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Abstract

During the past three years, the Brandeis experimental particle physics group was comprised of four faculty (Bensinger, Blocker, Sciolla, and Wellenstein), one research scientist, one post doc, and ten graduate students. The group focused on the ATLAS experiment at LHC. In 2011, the LHC delivered 5 fb^{-1} of pp colliding beam data at a center-of-mass energy of 7 TeV. In 2012, the center-of-mass energy was increased to 8 TeV, and 20 fb^{-1} were delivered.

The Brandeis group focused on two aspects of the ATLAS experiment – the muon detection system and physics analysis.

Since data taking began at the LHC in 2009, our group actively worked on ATLAS physics analysis, with an emphasis on exploiting the new energy regime of the LHC to search for indications of physics beyond the Standard Model. The topics investigated were $Z' \rightarrow \ell\ell$, $\text{Higgs} \rightarrow ZZ^* \rightarrow 4\ell$, lepton flavor violation, muon compositeness, left-right symmetric theories, and a search for $\text{Higgs} \rightarrow ee$.

The Brandeis group has for many years been a leader in the endcap muon system, making important contributions to every aspect of its design and production. During the past three years, the group continued to work on commissioning the muon detector and alignment system, development of alignment software, and installation of remaining chambers.

1 Introduction

1.1 Overview

During last three years, the focus of the Brandeis experimental high energy group was the ATLAS experiment at the LHC. This included a very active physics analysis program primarily concentrating on searches for new physics beyond the Standard Model (SM), namely, $Z' \rightarrow \ell\ell$, vector boson fusion production of Higgs decaying to four leptons, lepton flavor violation in the modes $\tilde{\nu}$ or $Z' \rightarrow e\mu$, $e\tau$, or $\mu\tau$ and in continuum production of $e\mu$ pairs, excited muons decaying as $\mu^* \rightarrow \mu\gamma$ or $\mu q\bar{q}$, left-right symmetric models, and a search for $\text{Higgs} \rightarrow ee$.

The Brandeis group has a long history of significant contributions to the design, construction, installation, and commissioning of the ATLAS endcap muon system, including the optical alignment system, detector integration, precision tooling for MDT chamber construction, installation of services, and construction of the small and big wheels. During the past three years, we had sole responsibility for operation and maintenance of the endcap alignment system. We actively participated in the installation of the remaining muon chambers during shutdowns of the LHC.

Building on our familiarity with the muon system, our group was active in commissioning of the MDT chambers and understanding their performance, including hit efficiencies, hit resolutions, track segment finding, and chamber alignment. We developed new techniques to better parameterize the momentum resolution of high transverse momentum muons – a study that is crucial to the $Z' \rightarrow \mu\mu$ and other analyses.

The group takes its service to the collaboration seriously. We held several leadership positions in US ATLAS, had numerous responsibilities on several ATLAS committees, reviewed papers, took shifts, and advised physics analysis groups on questions where we have particular expertise, such as alignment of the muon detector and its impact on momentum resolution.

The Brandeis group participated in ATLAS planning for a new small wheel upgrade in the endcap to handle anticipated luminosity increases.

1.2 Personnel

The Brandeis Experimental High Energy Physics Group has four faculty members – James Bensinger, Craig Blocker, Gabriella Sciolla, and Hermann Wellenstein. Professor Sciolla joined the Brandeis faculty in July 2011. Professors Bensinger, Blocker, and Sciolla concentrate on ATLAS. In recent years, Professor Wellenstein worked on the dark matter detector DMTPC, but in the past year returned to working on ATLAS on the new small wheel upgrade.

Christoph Amelung is an Associate Research Scientist stationed at CERN.

Rozmin Daya is a post doc stationed at CERN working with Sciolla. She joined the Brandeis ATLAS group in October 2011 after receiving her doctorate from Southern Methodist University.

During this reporting period, we had ten graduate students working on ATLAS – Scott Aefsky, Glenn Amundsen, Lou Bianchini, Laurel Coffey, Eric Fitzgerald, Serdar Gozpinar, Dan Pomeroy, Alessio Venturini, Stefano Zambito, and Keith Zengel. Scott completed his thesis in November 2011, Dan completed his thesis in July 2012, and Serdar completed his thesis in July 2012.

Kevan Hashemi is an electrical engineer who worked on ATLAS and DMTPC. Andrey Dushkin is a mechanical engineer who worked on ATLAS and DMTPC.

2 Physics Analyses

Discovery in July 2012 of a new boson in the search for the Higgs has perhaps opened the final chapter on the Standard Model. It is essential to determine the properties of this particle to establish whether it is a Standard Model Higgs or something else (such as a supersymmetric Higgs). In addition, the LHC has significant potential for discovery of particle physics beyond the Standard Model.

During the first three years of data taking at the LHC, we chose topics that were promising channels for discovery of new physics and where our expertise on the detector could make significant contributions, such as Higgs, Exotics and SUSY analyses involving high- p_T leptons and $H \rightarrow 4\ell$. Our interests range from high-profile analyses involving larger working groups (such as Higgs and Z') to novel analyses where there is less coverage and students can work on all aspects of the analysis.

2.1 Higgs $\rightarrow ZZ^{(*)} \rightarrow 4$ leptons (Sciolla, Zambito, Artoni)

After the discovery of a Higgs-like particle in Summer 2012, the focus of the ATLAS and CMS collaborations has become the determination of the properties of this particle. The measurement of the Higgs' mass, spin, parity, couplings, and branching ratios has become the top priority of the LHC physics program. The Brandeis group is very much involved in the measurement of the properties of the Higgs in the channel $H \rightarrow ZZ^{(*)} \rightarrow 4\ell$, a channel that allowed us to capitalize on our experience in the Muon Combined Performance group.

Our present activity in the Higgs $\rightarrow ZZ^{(*)}$ group focuses on the Vector-Boson Fusion (VBF) production mechanism and measurement of the Higgs couplings. In the Standard Model, the production cross section for the various Higgs production mechanisms can be precisely calculated as a function of the mass of the Higgs boson. For a Higgs mass of 125 GeV, the gluon-gluon fusion (ggF) mechanism has the highest cross-section, followed by vector boson fusion (VBF). The associated production (VH) of a Higgs boson with W or Z boson is further suppressed. Measuring the cross-section of the various production mechanisms determines the couplings of the Higgs candidate to fermions and bosons, which provides an important handle to test if the newly found resonance is indeed the SM Higgs boson.

The lower cross section of the VBF mechanism is compensated by the cleanliness of the final state due to its distinct topology. The presence of two additional energetic forward tagging jets introduces a number of kinematic variables that can be used to separate the signal from all backgrounds, including the otherwise irreducible Standard Model diboson (ZZ) background. Because of the favorable kinematics of the VBF process, the Higgs boson can be reconstructed in 4-lepton final states with very high purity (S/B $\sim$ 9:1).

In 2012, Zambito and Sciolla pioneered the VBF analysis in $H \rightarrow ZZ \rightarrow 4\ell$ in ATLAS. In the past two years, Brandeis has defined and implemented the entire analysis framework for the VBF analysis in $H \rightarrow 4\ell$, developed and optimized the selection criteria, estimated signal and background yields, and performed the necessary data-MC validation. The fast progress and the promising quality of our results attracted other groups to this analysis, including colleagues from Technion and Birmingham, with Brandeis leading the progress, especially after postdoc Artoni joined the group in March 2013.

Our VBF search focuses on events in which both tagging jets are reconstructed. To pass the VBF selection criteria, the tagging jets must be energetic, have large pseudo-rapidity separation, and form a large invariant mass. Figure 1 shows the distributions of separation in pseudo-rapidity and

Figure 1: Rapidity separation (left) and invariant mass (right) between the two tagging jets.

dijet invariant mass for Higgs bosons and the dominant SM background, ZZ .

ATLAS-CONF-2012-169 and ATLAS-CONF-2013-013 (Sciolla, Zambito) The first version of our VBF analysis was presented at the Council Meeting in December 2012 (ATLAS-CONF-2012-169) and then published as a conference note presented at the 2013 Moriond conference (ATLAS-CONF-2013-013). This was a cut-and-count analysis based on the entire 2011 and 2012 luminosity which led to the first observation of a VBF Higgs event in the $H \rightarrow 4\ell$ final state and to the first measurement of the Higgs couplings in the same channel.

The strategy we developed for this analysis was to divide the data sample in three different categories. A candidate was associated to the vector boson fusion category if at least two jets were found in the event and the two highest- p_T jets satisfy cuts on their separation in pseudo-rapidity ($|\Delta\eta| > 3.0$) and on their invariant mass ($m_{jj} > 350$ GeV). Otherwise, if an additional lepton was found in the event, the candidate was assigned to a category corresponding to associated production with a vector boson. If none of the above conditions were met, the candidate was assigned to the ggF category. From a fit of the yields in these categories, we extracted the signal strength for the coupling to fermions and vector bosons, obtaining $\mu_F = 1.8^{+0.8}_{-0.5}$ and $\mu_V = 1.2^{+3.8}_{-1.4}$.

Final Run-1 publication for $H \rightarrow 4\ell$ (Sciolla, Zambito, Artoni) A significant update of the analysis on the full Run-1 luminosity is in progress, and a journal publication is expected in Fall 2013. The main change with respect to the original (cut-based) analysis is that the new measurement is based on a multivariate approach. In the new analysis, the VBF rate is extracted from a fit to the 4-lepton invariant mass and the output of a Boosted Decision Tree (BDT) built to distinguish the Higgs bosons generated in VBF and ggF events using 6 kinematic variables. The Brandeis group has developed the BDT and the entire framework for the new categorization of the $H \rightarrow 4\ell$ analysis.

The 2013 publication will also include a new category, the hadronic VH, in which the Higgs bosons are produced in association with a heavy boson (W or Z) which is reconstructed in its hadronic decays. The signature of the hadronic VH category is similar to that of the VBF category (4 leptons and two jets), but the kinematics are different. The Brandeis group has developed the multivariate analysis that is used in ATLAS to identify the category enriched in hadronic VH, and performed the first evaluation of the improvements that this category will bring to the measurement of the

Higgs couplings.

The leadership of Brandeis in the measurement of VBF in the $H \rightarrow 4\ell$ channel has been recognized inside the ATLAS Higgs group. Members of our group were assigned several high-profile talks inside the collaboration, three talks at Higgs Workshops, and two conferences talks. In addition, postdoc Artoni has been selected as co-editor for the VBF/VH part of the 2013 publication.

The measurement of VBF and hadronic VH production of $H \rightarrow 4\ell$ in ATLAS based on the entire 2012 dataset will be the core of Zambito's Ph.D. thesis. His remarkable contribution to this analysis has gained him a lot of visibility in the $H \rightarrow 4\ell$ group (HSG2) already in 2012, when he became HSG2 representative to the LHC-wide task force that focuses on understanding the jet-related theory uncertainties.

2.2 $Z' \rightarrow l^+l^-$ (Sciolla, Daya, Zambito, Fitzgerald, Venturini)

The search for a heavy, narrow resonance decaying into a pair of opposite charged leptons is one of the most promising avenues to discover new physics beyond the Standard Model at the LHC. Such resonances, commonly referred to as Z' , are predicted in many extensions of the Standard Model.

Because most of these models predict a natural width for the Z' that is smaller than the detector resolution, the search strategy for $Z' \rightarrow \ell^+\ell^-$ is fairly model independent, although the limits on the cross-section as a function of mass have to be determined within a specific model. The analysis reconstructs the invariant mass of pairs of electrons and muons and looks for narrow peaks on top of the backgrounds expected from Standard Model processes. To reduce the backgrounds, each lepton is required to have a $p_T > 25$ GeV, to be well identified as a lepton, to point back to a common primary vertex, and to be isolated from other particles. The largest source of background in the $Z' \rightarrow \mu\mu$ channel is Drell-Yan production, with smaller contributions from W +jets, diboson, and $t\bar{t}$ events.

Our group started its activity in the dilepton Exotics group focusing on the dimuon channel in order to take full advantage of the experience on the ATLAS muon detector within the Brandeis group. Over the years, we have extended our contributions to the electron channels as well.

The Brandeis group became a leader in the flagship dilepton analysis, the search for Z'_{SSM} , when Sciolla joined Brandeis in summer 2011. Starting with the publication of the data collected at 7 TeV in 2011, this analysis allowed us to explore uncharted territory in the cross section versus $m_{Z'}$ space. The new data collected at 8 TeV in 2012 allowed us to further improve our reach, due to the increased center-of-mass energy and increased statistics. Over the past few years, Brandeis has made substantial contributions to six publications searching for Z' resonances. Since 2012 our postdoc, Rozmin Daya, has become the contact person for the entire dilepton working group. As such she is coordinating the activity of about 20 physicists working on 6 different measurements.

First 7 TeV article: Phys. Rev. Lett. 107 (2011) 272002 (Sciolla, Fitzgerald) In this article, based on 1 fb^{-1} of data collected in 2011, we were able to set a lower mass limit of 1.83 TeV on the SSM Z' boson and of 1.63 TeV on the Randall-Sundrum graviton with coupling $k/M_{Pl} = 0.1$. These results represented an important milestone for ATLAS because, for the first time, the LHC was able to improve on the Tevatron limits in these important searches for new physics. Our contribution to this publication focused on some aspects of the event selection and background estimates in the dimuon system. In addition, Sciolla served as an editor for the article and was given special dispensation by the Spokesperson to sign the Phys. Rev. Lett. article even

though she was not yet an ATLAS author at the time.

Final 7 TeV papers: ATLAS-CONF-2012-007 and JHEP 1211, 138 (2012) (Sciolla, Daya, Zambito, Fitzgerald) The analysis of the full 7 TeV dataset was first presented at the 2012 Moriond conference (ATLAS-CONF-2012-007). This analysis allowed us to improve the limits on the mass of the graviton and Z' boson both in the SSM and E_6 models. The combination of the dielectron and dimuon channels yielded a 95% C.L. limit of 2.21 TeV for the Z'_{SSM} and of 2.16 TeV for the graviton. The contribution of the Brandeis group to this article was extensive. Daya and Zambito took the lead on the dimuon channel of the Z' search both in the SSM and in the E_6 channels providing fundamental contributions in most aspects of the analysis, including the determination of the selection criteria, the study of the performance of the muon system and the determination of the limits on the Z'_{SSM} . Sciolla served as co-editor for the conference note.

Sciolla also served as an editor of a comprehensive journal article that included all of the dilepton results obtained within the ATLAS Exotics Working Group based on the 5 fb^{-1} collected in 2011. The article, which includes searches for Z' , Randall-Sundrum gravitons, Z^* bosons, technimesons, Kaluza-Klein Z/γ bosons, and bosons predicted by Torsion models, was published in JHEP in Summer 2012.

The Brandeis group was responsible for all Z' results in the dimuon final state, as well as for the combined dielectron+dimuon results (Zambito). Although this work is based on the same data already used in conference note ATLAS-CONF-2012-007, the analysis was significantly improved for the publication by the use of an improved Monte Carlo simulation and an in-depth study of the data-MC discrepancies (Daya). In addition, a new fitting technique was developed by Fitzgerald to estimate diboson and $t\bar{t}$ backgrounds at high invariant masses.

8 TeV Z' analyses: ATLAS-CONF-2012-129, ATLAS-CONF-2013-017, and PRD in preparation (Daya, Fitzgerald, Venturini) In 2012, postdoc Daya became the Analysis Contact for all of entire ATLAS Exotics dilepton analyses for 8 TeV data. In addition, Fitzgerald, who was resident at CERN for most of 2012, quickly became the leading student on the dimuon channel. In addition to his work on the optimization of the selection criteria for the analysis, the monitoring of the muon detector performance, and the fitting of the various backgrounds, Fitzgerald also took over from Daya the responsibility of producing the signal and background templates and from Zambito the responsibility of extracting the limits. Venturini contributed to the first round of the 2012 Z' analysis by expanding our contribution to the electron-positron channel under the direct supervision of Daya, who has substantial experience in electron identification from her Ph.D. work and previous analysis contributions to $H \rightarrow \gamma\gamma$ and $Z' \rightarrow e^+e^-$.

Under the leadership of Daya, the first 6 fb^{-1} recorded at $\sqrt{s} = 8 \text{ TeV}$ were analyzed in record time and presented at the 2012 Physics in Collision conference (**ATL-COM-PHYS-2012-846**). Thanks to the higher center-of-mass energy, the limit on the mass of the Z'_{SSM} obtained from the analysis of this small fraction of the 2012 data set (2.49 TeV) represents a considerable improvement over the previously published 7 TeV result.

The analysis of the full Run-1 dataset was presented at Moriond in March 2013 (**ATLAS-CONF-2013-017**). Figure 2 (left) shows the invariant mass distribution for the dimuon final state after final selection. Figure 2 (right) shows the 95% CL observed and expected exclusion limits on the product of the cross section times branching fraction for the combination of the electron and muon

Figure 2: Left: dimuon invariant mass distribution after final selection, compared with the stacked sum of all expected backgrounds, with two example Z'_{SSM} signals overlaid. Right: Expected and observed 95% CL limits on σB and expected σB for Z'_{SSM} production and the two E_6 -motivated Z' models with lowest and highest σB for the combination of the dielectron and dimuon channels. The thickness of the Z'_{SSM} theory curve represents the theoretical uncertainty and holds for the other theory curves.

channels. It also shows the theoretical cross section times branching fraction for the Z'_{SSM} and for the lowest and highest σB of E_6 -motivated Z' models. The 95% CL σB limit is used to set mass limits for each of the models considered. The combined observed mass limit for the Z'_{SSM} is 2.86 TeV.

Daya is continuing to lead the 8 TeV dilepton analysis and is coordinating the activities toward the publication of the final Run-1 results, expected by the end of Summer 2013. This work constitutes the core of Fitzgerald's Ph.D. thesis, which he will defend in Fall 2013.

2.3 Higgs $\rightarrow 4\ell$ (Amelung)

Amelung was a member of the Editorial Board of the $H \rightarrow 4\ell$ paper for Moriond, He concentrated on the proper interpretation/presentation of the spin/parity hypothesis testing results and the interpretation of Higgs mass and signal strength combined.

2.4 Searches for Lepton Flavor Violation

Neutrino oscillations show that lepton flavor is not a good symmetry of Nature. An obvious question is whether charged leptons also exhibit violation of lepton flavor conservation. Lepton flavor violation in the charged lepton sector induced by neutrinos is expected to be extremely small in the Standard Model. Observation of such a violation would be a signature of new physics. Many models of physics beyond the Standard Model naturally have lepton flavor violation.

During the past three years, we worked on several analyses searching for lepton flavor violation, namely, search for a heavy, narrow resonance decaying to an $e\mu$, $e\tau$, or $\mu\tau$ final state and a search for anomalous production of $e\mu$ pairs in continuum production.

2.4.1 $Z' \rightarrow e\mu$ (Blocker, Aefsky, Pomeroy)

The original analysis was a search for a heavy, narrow resonance decaying to $e\mu$ in 7-TeV ATLAS data. The resonance could either be a spin-0 particle modeled by an R-parity violating sneutrino $\tilde{\nu}$ (supersymmetric partner of a neutrino) or a spin-1 particle modeled by a Z' .

This analysis was the thesis of Scott Aefsky. Scott contributed to all the analysis and concentrated on the Z' model. No evidence of a signal was seen and two papers with limits on the mass and couplings were published – the first one based on 35 pb^{-1} [Phys. Rev. Lett. **106**, 251801 (2011)] and the second on 1 fb^{-1} [Eur. Jour. Phys. **C72**, 1809 (2011)]. The results from the 1-fb^{-1} were the basis of Scott’s thesis, which he completed in November 2011.

2.4.2 $e\mu$ Continuum Search (Blocker, Pomeroy, Aefsky)

It is possible that lepton flavor violation could occur in continuum production of leptons, for example, production of $e\mu$ pairs whose invariant mass does not form a resonance. One example would be the t-channel exchange of a new particle with lepton-flavor-violating couplings.

For his thesis, Dan Pomeroy did a search for such production modeled by the t-channel exchange of an R-parity violating stop squark $\tilde{t}$ (supersymmetric partner of the top quark). This was a novel search that had not previously been done at a hadron collider. Based on 2 fb^{-1} of 7-TeV ATLAS data, Dan found the rate of $e\mu$ production in the continuum to be consistent with Standard Model expectations and placed limits on the couplings as a function of the mass of the $\tilde{t}$. These results were published in Eur. Phys. J. **C72**, 2040 (2012). Dan defended his thesis in July 2012.

2.4.3 $Z' \rightarrow e\mu, e\tau$, or $\mu\tau$ (Coffey, Zengel, Blocker)

The search for a narrow resonance with lepton flavor violating decays was extended to $e\tau$ and $\mu\tau$ in addition to $e\mu$ final states using 5 fb^{-1} of 7-TeV ATLAS data.

The τ final states have additional challenges since taus decay quickly into a multitude of final states. ATLAS has developed effective algorithms for recognizing these decays. In addition, we developed a powerful technique for correcting the momentum of hadronic tau decays for the missing neutrino based on having only one tau in the event and on the taus having momenta large compared to their mass. In this case, the neutrino goes in nearly the same direction as the other tau-decay products and the missing E_t vector gives the transverse components of the neutrino momentum vector, allowing a full reconstruction of the neutrino momentum. This significantly improves the resolution of the $e\tau$ and $\mu\tau$ invariant masses for a potential signal. In addition, requiring the missing E_t vector and the transverse momentum vector of the tau to be in the same direction rejects much of the background.

No signal was detected in any of the three final states. Limits on couplings of a possible R-parity violating sneutrino were published in Phys. Lett. **B723**, 15 (2013). Figure 3 shows the limits on the cross section times branching ratio in the three modes.

Towards the end of this reporting period, work began on extending this analysis in all three modes to the 20 fb^{-1} of 8-TeV data that has been collected by ATLAS. For this analysis, the resonance will be modeled by both a spin-0 R-parity violating $\tilde{\nu}$ and a spin-1 Z' . The analysis of the $e\tau$ final state will form the basis of Laurel Coffey’s thesis, and the $\mu\tau$ final state will be Keith Zengel’s thesis.

2.5 Excited Muon Searches

In the history of physics, as smaller distances were probed, substructure was often discovered. It is possible that the particles in the Standard Model that we presently consider to be fundamental may be composite themselves. One consequence would be excited states of these particles. The Brandeis group has worked on searches for such excited states of muons, known as μ^* .

Figure 3: Limit on the cross section times branching ratio for the lepton flavor violating decay of an R-parity violating sneutrino in the $e\mu$ (left), $e\tau$ (middle), and $\mu\tau$ (right) modes.

2.5.1 $\mu^* \rightarrow \mu\gamma$ (Gozpinar, Blocker)

A search for production of $\mu\mu^*$ followed by $\mu^* \rightarrow \mu\gamma$ was the subject of Serdar Gozpinar's thesis. Serdar found no evidence for this production and set limits on the μ^* mass and the muon compositeness scale Λ . This work was combined with a search for excited electrons and published in Phys. Rev. D **85**, 072003 (2012).

2.5.2 $\mu^* \rightarrow \mu q\bar{q}$ (Amundsen, Blocker)

An excited muon could also decay via a contact interaction as $\mu^* \rightarrow \mu q\bar{q}$. Production of $\mu\mu^*$ followed by this decay would yield events the a pair of muons and a pair of jets.

This signature is the thesis of Glenn Amundsen. This mode could have a rate at least as large as $\mu^* \rightarrow \mu\gamma$ and so merits a separate search. In addition, there could be the decay $\mu^* \rightarrow \mu Z$. The subsequent decay $Z \rightarrow q\bar{q}$ would appear as a peak in the dijet mass spectrum in Glenn's analysis.

2.6 W_R , Z_R , and Heavy Neutrino (Bianchini, Blocker)

One of the puzzles in the Standard Model is why weak interactions are left handed. One possible answer is that at high energies weak interactions have both left- and right-handed interactions, as given in left-right symmetric theories. These theories predict a right-handed W_R , an additional neutral gauge boson Z_R , and heavy neutrinos.

Lou Bianchini is working on searches for evidence of left-right symmetric models for his thesis. He has been working with groups at Pittsburgh and Moscow on an analysis focussed on signals with a W_R and heavy neutrinos. This resulted in a paper based on 2 fb^{-1} of 7-TeV data [Eur. Phys. J. **C72**, 2056 (2012)]. Lou's thesis work is on a search for the Z_R .

3 ATLAS Detector reconstruction and calibration

3.1 Muon p_T studies (Sciolla, Fitzgerald, Zambito, Venturini)

Sciolla and her students are active members of the Muon Combined Performance (MCP) working group. This group constitutes the interface between the muon detector team and the analysis teams that use muons objects in all physics analyses in ATLAS.

The responsibility of Sciolla's team within the MCP working group is closely related to their physics interests in $Z' \rightarrow \mu\mu$ and $H \rightarrow 4\ell$. Their goal is to provide a reliable parameterization of

the muon's p_T resolution in a wide momentum region as well as the smearing parameters to apply to the simulation to improve the data-MC agreement.

In ATLAS, most muons used in physics analyses are separately reconstructed in the Inner Detector (ID) and the Muon Spectrometer (MS). Then, the two measurements are merged into a combined track. To fully understand the quality of the reconstruction of the combined tracks, we had to separately understand the output of the ID and the MS reconstruction. The Brandeis group performed extensive studies of the momentum resolutions reconstructed in both detectors.

Our studies on the Muon Spectrometer concluded that the parameterization currently used by the MCP group, which assumes a uniform parameterization of the p_T resolution over large regions of the MS, is not accurate enough. Our group is developing a novel parameterization that takes into account the amount of material crossed by the track in the detector.

The studies on the Inner Detector tracks have been completed and the work is being published in a Conference Note in collaboration with the ATLAS Tracking group. In this work, the ID momentum resolution is measured using a pure sample of muons produced in Z^0 decays.

The momentum resolution is parameterized as a function of the muon's transverse momentum p_T and pseudorapidity η . The function used to describe the momentum resolution is given by the product of two functions. The first, which describes the dependence in η of the resolution, is parameterized as a polynomial function with coefficients that are determined from Monte Carlo. The second, which describes the p_T dependence of the resolution, takes into account the effect of the multiple scattering in the ID and the ID's intrinsic resolution. The parameters of the second function are fitted separately in data and Monte Carlo using an unbinned maximum likelihood fit to the Z^0 mass. The fitting function used to describe the dimuon invariant mass in the fit is the convolution of a Gaussian, which describes the experimental resolution, with a function that accurately describes the Z^0 lineshape, including the Z^0 boson natural width, the photon radiation term, and the $\gamma - Z$ interference term. Corrections for final state radiation (FSR) are implemented prior to the fit. These corrections, extracted from the Monte Carlo, are applied to both data and simulation. The Z^0 intrinsic width and mass are fixed to the world averages, thus making the fit sensitive to a global p_T scale factor α , with $1/p_T \rightarrow 1/p_T(1 + \alpha)$.

The momentum resolution measured in the Monte Carlo is shown in figure 4(left) for the p_T interval $p_T=[47,55]$ GeV. The result of the 2D parameterization is also shown. The excellent agreement between the two distributions validates the method. This parameterization provides an excellent description in all regions of the ID for transverse momenta between 15 and 400 GeV.

Figure 4(right) shows the momentum resolution as a function of p_T fitted in data and Monte Carlo for $\eta=0.3$. The figure also shows the smearing function to add in quadrature to the Monte Carlo to provide a good description of the resolution in data.

We have performed extensive validation of the method and concluded that the Brandeis parameterization of the ID p_T resolution is accurate and stable in p_T , η , and ϕ . Our measurement of the momentum scale is compatible with that obtained in dedicated studies and has a sub-permill precision.

Our detailed parameterization of the p_T resolution for data and Monte Carlo also allowed us to produce a calibration of the errors on $1/p$ provided by the track fitter. The algorithm providing

Figure 4: Left: momentum resolution in $1/p_T$ as a function of pseudorapidity measured in the Monte Carlo in the p_T region $p_T=[47,55]$ GeV. The red dots show the measured resolution. The blue line shows the projection of the fit obtained using the 2D parameterization described in the text. Right: fractional p_T resolution for data (red line) and MC (blue line) as a function of p_T for $\eta=0.3$. The black line shows the smearing function that has to be added in quadrature to the MC resolution to reproduce the data.

such errors has detailed knowledge of each muon and takes into account the amount of material traversed by the track, the number of hits, and the χ^2 of the fit. This information is important to improve the resolution on the mass of the Higgs boson reconstructed in the 4-muons final state.

3.2 Muon MDT Chamber Performance Studies (Blocker)

Blocker studied the performance of the muon MDT chambers beginning with stand alone cosmic ray data from when endcap sectors were being constructed up to and including 2011 colliding beam data. These studies included hit efficiencies, segment finding efficiencies, hit resolutions, segment resolutions, timing, drift time distributions, and hit resolution and average residual versus drift time.

There was very good agreement between most of the distributions studied and the expectations from design and prototyping studies. The major difference was that the hit residual distributions had significantly larger non-Gaussian tails in the collision data than expected or than seen in the stand-alone cosmic ray studies. These tails appear dominantly on the short drift time side of the distribution and are probably due to delta rays.

Inclusion of delta rays on tracks degrades the momentum resolution of the muon spectrometer. For release 17 of the offline reconstruction software, the hit selection was tightened, which improved both the hit residual distributions and the momentum resolution.

4 MDT Alignment Validation and Optimization

During the period covered by this grant, the Brandeis group had sole responsibility for the maintenance and operation of the ATLAS endcap muon alignment system. We provided up-to-date alignment parameters for tracking programs and analysis of the alignment contribution to the

muon momentum resolution. These efforts have been instrumental in the recent discovery of and measurement of the mass of the Higgs boson in the four lepton decay channels.

4.1 Segment-Triplet Study (Amelung, Aefsky, Wiener)

We have completed our studies of the MDT chamber alignment using segment triplets. For this study they select triplets of segments associated to a track traversing the three layers of chambers in the endcaps. The sagitta of the track, inversely proportional to its momentum, is calculated as the distance of the middle segment from the straight line joining the inner and outer ones. In magnet-off runs and for a perfect alignment, one expects the sagitta distribution to be centered at zero and to have a width that is dominated by multiple scattering. In spring and fall 2011, about 11 million muon tracks were recorded in magnet-off runs.

Figure 5 (left) shows sagitta distributions obtained from this data. With this large dataset it was possible, for the first time, to cross-check the optical alignment at the level of individual towers, that is, triplets of chambers that can be traversed by a muon originating at the interaction point. Previous estimates of the alignment accuracy, derived from the consistency between redundant sensor measurements, had predicted a performance around $50\text{ }\mu\text{m}$. The track data are indeed found to be compatible with a $50\text{ }\mu\text{m}$ alignment accuracy for the EI-EM-EO region. (Only a few chambers of the EE wheels were installed at the time of the 2011 run, with an incomplete alignment system.) More toroid-off data are required in order to reduce the statistical error below $50\text{ }\mu\text{m}$ everywhere, and only then can a final assessment of the optical alignment quality be made.

To improve the optical alignment in those regions where it is not yet optimal, or will never be (for example, for chambers with damaged alignment sensors whose calibration is thus lost), we employed a method proposed by Amelung in 2005, which includes track information along with optical sensor data in the alignment fit. We believe that the combined track and optical system alignment approach provides the best possible ultimate alignment. This method has several advantages: (1) in the limit of very few tracks, it reproduces the optical-only result, and thus the fit result is stable even if no large track data samples are available; (2) in the limit of very many tracks, it improves on a tracks-only approach, because those degrees of freedom that tracks have only little sensitivity to will be well-constrained by optical sensor measurements, while those degrees of freedom to which tracks are highly sensitive will be dominated by track measurements; (3) in cases of inconsistent fits, that is, sensor measurements being incompatible with track measurements, the individual contributions of sensors and tracks to the overall fit χ^2 help to identify the origin of the problem. The current status of the alignment of muon chambers is shown in table 1.

ATLAS management finally approved a significant toroid-off run in 2012 (25M recorded events). Improvements were made in the analysis, such as optimizing event/track selection, event weighting in the fit, and including track back-extrapolation to the IP in the fit χ^2 calculation, that is, performing MS-ID alignment at the same time as MS-internal alignment. This resulted in an alignment (as of December 2012) that is near $40\text{ }\mu\text{m}$ sagitta accuracy in the majority of the well-alignable endcap regions (large sectors and all of the CSC region), but still somewhat worse (near $90\text{ }\mu\text{m}$) in small MDT sectors, which needs to be studied and understood. MS-ID alignment improved by a factor of 3, up to a point where systematic effects seen in the back-extrapolation to the IP have become the limiting factor for the MS-ID alignment.

Figure 5: Left: sagitta distributions in the EI-EM-EO region, before (black-hashed) and after (yellow) applying optical alignment corrections. The means of the distributions are compatible with zero within $\pm 50 \mu m$. Right: sagitta mean values in bins of the radial coordinate (local z) of the track at the EO wheel, for sectors 01 to 16 (bottom to top), from a combined sensors-and-tracks alignment. The yellow bands correspond to $\pm 100 \mu m$. The ensemble of mean values is compatible with zero within statistical errors ($\chi^2/ndf = 0.85$).

BA Large	BA Small	EC Large	EC Small	CSC Large	CSC Small	EE Large	EE Small
0.042	0.041	0.044	0.093	0.047	0.046	0.034	0.095

Table 1: Current alignment resolution (in mm) of the various regions of the ATLAS Muon System.

4.2 EE Chamber Installation (Bensinger, Amelung, Dushkin, Wiener, Coffey, Daya, Amundsen)

During the 2011/12 shutdown, 28 new MDT chambers were installed in ATLAS, together with alignment bars and sensors. Another 24 chambers were installed in the LS1 shutdown. These chambers form the EE wheel, providing a third measurement point along muon tracks in the region $1.0 < |\eta| < 1.4$. Before the shutdown, Wiener and Coffey prepared the chambers for installation by outfitting them with alignment sensors and testing the sensor readout system. During the shutdown, Amelung, Daya, and Amundsen worked in the ATLAS cavern, connecting the chambers to the ATLAS alignment sensor readout, and troubleshooting malfunctioning and damaged devices.

Amelung and Dushkin did the fine-positioning of chambers and bars, with help from the CERN survey group. Due to space and visibility constraints in the EE region of the detector, neither alignment sensor measurements nor survey data were alone sufficient to determine the required position adjustments, and so a combination of the two was used for positioning the chambers in a

carefully orchestrated sequence.

The installed EE chambers are now fully integrated into the alignment readout and reconstruction. This completes the muon system as originally designed. Thanks to our experience from the installation of other muon chamber wheels in the past, the process went very smoothly.

4.3 Alignment Hardware Maintenance (Bensinger, Amelung, Dushkin)

The optical alignment system continued to work very reliably. There are 6000 devices in the system, and at the currently observed failure rate of 0.1%/year, this corresponds to 6 failures per year. These items are repaired or replaced whenever access is available. We also do detailed analyses of failures and develop strategies to prevent them in the future.

4.4 Alignment Software Maintenance (Bensinger, Amelung, Hashemi)

ATLAS endcap alignment software comes in two parts, LWDAQ and ARAMyS. The LWDAQ (Long Wire DAQ) system reads out the sensors and analyzes the optical images. This part was written and is maintained by Hashemi. The alignment reconstruction software (ARAMyS) takes the output from the LWDAQ system and determines the exact location and shape of the muon chambers in the endcap system. This part was written and is maintained by Amelung.

In addition to maintaining the LWDAQ software for the endcap muon system, Hashemi also supports the many other software and hardware users. The ATLAS Barrel Alignment group uses our RASNIK (one type of alignment device in our system) analysis for their most difficult images. The NIKHEF laboratory uses our RASNIK analysis for their new high-precision split images. The ALICE, LHCb, and CMS experiments all use BCAM's (another alignment device) and the LWDAQ software. The CERN survey group uses BCAM's in various small test stands. Changes in operating system, expansion of the operating scripts, and new uses of existing instruments require enhancements and repair of the code.

4.5 Alignment of BEE Chambers (Wellenstein, Amelung, Dushkin)

Wellenstein developed the conceptional design for the alignment of the BEE chambers by monitoring them with respect to the already aligned EES and EIS chambers. This system, with improvements by Dushkin and Amelung, was implemented.

The layout was validated in simulations by Amelung. Amelung and Dushkin installed prototypes in one sector (C-16) and verified that sensors can be mounted and see their targets. Platforms and sensor parts were manufactured, platforms on A-side glued onto EIS2 and BEE, sensor assembled at Brandeis.

Wellenstein designed and successfully tested a straight-line alignment system by monitoring the light from a point source reflected by a wire (the straight line, after sag correction) with two orthogonal CCD cameras. A sub-micron precision was achieved.

4.6 Alignment Hardware Database (Blocker)

Blocker has continued responsibility for maintenance of and updating the alignment hardware database, which contains the identity, location, and calibration of every device (sources, sensors, bars, chambers, *etc.*) in the endcap optical alignment system. During 2012, the full EE chamber system was added to the database.

5 Leadership and Service

5.1 Muon System Responsibilities (Bensinger, Amelung)

Jim Bensinger is the US ATLAS M&O Muon Manager. As such, he oversees the operations of the endcap muon system, establishes priorities and milestones, and works with the various institutes in the ATLAS Endcap Muon System to determine responsibilities and budgets for their activities. This is done on an annual basis and coordinated with the ATLAS project office at BNL and the management of the ATLAS Muon Subsystem at CERN. In addition, he reports monthly to the DOE/NSF LHC Detector Operations Meeting on the progress and problems in the ATLAS muon system.

Bensinger is also the Level 3 Manager for the alignment system of the nSW upgrade.

Christoph Amelung is co-convenor of the Muon Alignment Group. The biweekly meetings of this group are the forum for discussing alignment issues among the experts working on optical alignment and/or on alignment using tracks. Amelung is also the co-convenor of the MATF group. This group was created shortly after the first LHC collisions in 2008, under the (now somewhat outdated) name of Muon Run Analysis Task Force, as a group of experts with the mandate to thoroughly analyze and optimize the reconstruction of muons in ATLAS. Activities have included the validation of the new alignment for the 2012 fast reprocessing, studies of track reconstruction performance (energy loss, B-field map, MDT calibration and alignment) using Z events, the discovery of MDT high-rate limitations at unexpectedly low rates, background studies, muon performance studies for the nSW, and realistic simulation of goodness-of-alignment ("smeared A-lines").

Amelung is also the ATLAS Muon Deputy Project Leader, assisting the Muon Project Leader (currently Ludovico Pontecorvo) in all aspects of the operation of the ATLAS Muon Subsystem.

During the "Higgs mass crisis," Amelung led (together with Ludo) the subgroup that revisited the muon standalone momentum measurement. He authored the chapter on muon standalone momentum measurement in the internal ATLAS note "Higgs mass measurements and uncertainties in 2011 and 2012 data."

5.2 Sciolla's leadership activity in ATLAS physics

US ATLAS Deputy Physics Advisor (2013–present)

Starting in January 2013, Sciolla became the US ATLAS Deputy Physics Advisor (DPA). This is a two year position at the end of which she will become the Physics Advisor. The goal of the US ATLAS Physics Advisors is to help the Operations Managers develop the strongest possible US ATLAS physics program.

In her role as DPA, during her sabbatical at CERN Sciolla led the CERN-based US ATLAS and CMS community to take a more central role in the 2013 Snowmass activities by starting the *Snowmass@CERN* group. This group of about 40 US physicists met weekly at CERN in Summer 2013 to discuss the Snowmass activities, get familiar with the tools available to perform physics studies, and to discuss the physics potential at future machines. The *Snowmass@CERN* activities inspired several Snowmass white papers as well as some ATLAS upgrade studies.

As DPA, Sciolla is also involved in several committees that have an impact on the US ATLAS

physics activity. An example is the Task Force on the future of the US ATLAS Tier 3 centers, that Sciolla co-chaired in 2013. This task force was convened by the US ATLAS Institutional Board in early 2013 to survey the current Tier 3 deployment and make recommendation about the evolution of Tier 3 centers in the next decade.

Editorial Board activity (2011–present)

Sciolla has been very active in the review of physics analyses in ATLAS since she joined in 2011.

In 2011 and 2012, she served as a member of the Editorial Board overseeing the Standard Model measurement of the W^+W^- ($W \rightarrow \ell\nu$) cross section. During her tenure on this Editorial Board, she reviewed and helped with three publications: the 2010 WW cross section (Phys. Rev. Lett. 107, 041802 (2011)); a conference note based on 1 fb^{-1} of 7 TeV data presented at the 2011 EPS conference; and the first limits on anomalous gauge couplings were recently submitted to Physics Letters B (CERN-PH-EP-2012-060).

In summer 2011, Sciolla has also served as a member of the ATLAS Analysis Review Team in charge of reviewing the progress of the W^+W^- analyses in the Higgs and Standard Model working groups. The members of this team met with the ATLAS physics management on a daily basis to review the soundness of the results and ensure that a coherent approach was used in the two analyses.

In 2012 Sciolla served on the Editorial Board overseeing a conference note documenting the performance of the ATLAS muon trigger in 2011. Since 2013 she is serving on a new the Editorial Board overseeing the search for Extra Dimensions in diphoton events based on the full 8 TeV dataset.

5.3 Blocker’s leadership positions

Blocker chaired a committee of the US ATLAS Institution Board (IB) that investigated issues of visitors. The primary issues were funding (particularly covering Category A/B funds), oversight, consistency with ATLAS requirements, and review of work. The committee gathered information on many cases and formulated a policy. The final report was presented to the US ATLAS IB on February 15, 2012, and the policy was adopted.

Blocker is a member of the Editorial Board for a search for a heavy resonance decaying to $t\bar{t}$. This work resulted in the conference note entitled “Search for $t\bar{t}$ resonances in the single lepton channel at 8 TeV” (ATLAS-CONF-2013-052). Late in this reporting period, Blocker joined an Editorial Board on an analysis of the decay parameters for $\Lambda_b \rightarrow J/\psi \Lambda^0$.

5.4 ATLAS Shifts

Over the past three years, the Brandeis group has done significantly more class 1 and class 3 shifts than required and somewhat less class 2 shifts. Daya helped correct this by contributing to detector operations during Run 1 as a class 1 and class 2 expert shifter.

6 ATLAS Upgrades

6.1 New Small Wheel (Bensinger, Wellenstein, Amelung, Blocker, Hashemi, Duskin)

Analysis of current data has shown that the current Small Wheel has two significant problems. First, the trigger is dominated by background events. The current endcap muon trigger is determined

using only Thin Gap Chambers (TGCs) in the middle layer of the endcap muon system. The L1MU20 trigger is dominated by junk events, with only 2% of the triggers reconstructing as muons with $P_t \geq 20$ GeV coming from the IP. This is primarily due to the poor momentum resolution of a single station trigger and the large numbers of secondary particles in the forward direction. A trigger plane with good angular resolution in the first station of the muon system will rectify this problem. Second, with the expected radiation levels in the small wheel region the tracking efficiency will suffer when the LHC reaches full energy and luminosity. For these reasons, ATLAS elected to build a new Small Wheel (nSW), with trigger capability, using a combination of the TGC and MicroMegas (MM) chambers. The nSW will be installed in ATLAS during the LS2 shutdown, currently planned for 2018.

The chambers for the nSW will have to be integrated into the existing endcap alignment system. To achieve this, engineering studies will be required to ensure that existing optical paths, which are necessary to link the nSW with the rest of the muon endcap, are preserved. In addition, we will need to work with each of the chamber technologies to insure that the chambers are constructed such that they can be precisely aligned. This will require that the features which insure the precision of the measurements are transferred to outside of the chamber with “hooks” that can be related to the alignment system. We will also have to design sensors that relate these “hooks” to the existing alignment system. As the alignment has to be extended to a smaller radius, we will have to develop new sensors that handle the higher radiation environment expected at the inner chambers in the nSW. To do this, the Brandeis alignment group will be involved with the chamber design and construction teams throughout the construction process. Brandeis is responsible for this effort, which is currently going through CD1 approval with DoE.

Amelung represented the alignment community in the weekly layout meetings and presented ideas for aligning nSW chambers in various meetings and discussions, leading to the layout presented in the nSW TDR. Amelung was co-editor of the TDR and author of the alignment chapter in the TDR.

The design of large-area MicroMegas planes (a single detector) was spearheaded by the CERN team. Brandeis joined the effort to develop methods to assemble mechanically precise planes and to assemble four of those into a precision multiplet, also called a quad. The precision needed, $20\text{ }\mu\text{m}$ in Z (in the plane of the anode strips) and $40\text{ }\mu\text{m}$ (perpendicular to the anode plane) was determined by using simulation by Amelung. In addition, alignment devices have to be attached to the quad with a similar precision.

Several design and assembly methods were proposed by Brandeis and were adopted, usually in an improved version, by other groups. Then Brandeis in turn adopted those improvements in its plans. A particular challenge is the alignment system where the lack of space makes it difficult to monitor the shape of the quads (the MDT internal alignment system) as well as the position of the quads (the MDT BCAM plus proximity sensor system). Brandeis proposed a schema where several lines of sources placed onto the outside of the quads is monitored by three or more BCAM lines (figure 6 top left). Saclay improved this system by proposing additional alignment bars (figure 6, bottom left), and Amelung found a working solution by optimal arrangement of the bars and BCAM lines (figure 6 right) for both large and small sectors. This design was proposed in the now approved TDR.

Brandeis is setting up an assembly table to build a small of $0.5\text{ m} \times 0.5\text{ m}$ quad to prove some of

Figure 6: Top left: The initial Brandeis proposal to combine the in-plane and quad alignment system (would not have worked). Bottom left shows the introduction of a second set of alignment beams by Saclay. Right: The presently approved design by Amelung in the TDR.

the methods it has proposed. It will largely follow the CERN design of making single planes but use a granite table and flat stiff-plate to assemble the parts in a single gluing step. Each part has a stiffener, a honey-comb structure, between the two FR4 boards. There are three different types to be assembled: the outside cathodes, the two back-to-back anodes and the back-to-back cathode in the middle. Wire-meshes are glued to the cathodes and the five parts are bolted together using precision bars between anodes and cathodes PCB.

One of the biggest challenges is to verify that the Z and Y precisions of $20\text{ }\mu\text{m}$ and $40\text{ }\mu\text{m}$, respectively, have been obtained. X-raying the quads (small mock-ups were used) to image all anodes was not successful, even if thicker copper cladding is used. It is possible to image the anode of a single plane but for a quad the multiple anodes, the meshes, and honey-comb structures make it impossible. We started work on an alternative method. Small spheres of tungsten are glued to the back side of all anodes and cathodes. With the thickness of the PCB at this location measured and the PCB with the sphere x-rayed, the position of each sphere with respect to the anode (Y and Z) or cathode (Y) is known.

This method is tedious and time consuming and can only be used at a few locations of a quad. It will, however, be useful to verify an assembly method and it should be used to survey the position of all alignment devices. The “cluttered” background in the x-ray image is due to multiple meshes and anodes (no honeycomb in x-ray corridors) and might make it difficult to determine the spheres to high precision.

The wire mesh chosen by CERN has $18\text{ }\mu\text{m}$ diameter wires, spaced by $72\text{ }\mu\text{m}$, and needs to be stretched to 10 N/cm . This can only be done on a commercial stretcher. As the mesh has to be glued to the cathode, the mesh either has to be shipped on a bulky transfer-frame or the cathode has to be assembled at the stretching facility. Stretching a mesh in the clean-room, directly on the assembly table would solve this problem. We have developed a table-top stretcher where the mesh under the claps is also stretched. This is shown in figure 7.

Figure 7: Top Left: In the conceptual design of the stretcher, the mesh is clamped between foam tape and hence allowed to stretch under the clamps as all clamps are pulled back and the mesh stretches. Bottom left: A mesh is stretched using string, pulleys and weights, verifying the method. Right: a CAD drawing of the $0.6 \text{ m} \times 0.6 \text{ m}$ stretcher, the clamps are pulled back by actuators each exerting 200 N, stretching the mesh uniformly to 10 N/cm. Finally, the cathode will be pushed under the assembly and the mesh will be glued to the brackets.

6.2 The Long Guide Tube (Amelung, Bensinger, Dushkin, Hashemi, Wiener, and Amundsen)

The Long Guide Tube (LGT) was designed for the installation of a new pixel layer (called the Insertable B Layer or IBL) to be installed inside the existing pixel detector. The LGT cannot be a simple object since this will not achieve the required sag control. A complex tool (active and pretensioned) is required to insure that, as the beam pipe is extracted and the load on the LGT changes, a control system changes tension rods to adjust to the new load configuration without the LGT changing its shape. The stringent requirements on the LGT are that over a 7.4 meter span it should not deviate from a straight line by more than a few millimeters. An additional requirement is that this activity be controlled remotely to reduce radiation exposure to the activated beam pipe.

Because of our experience with our active alignment bars, we were asked to design this tool. This includes the mechanical design of the IGT, the instrumentation to monitor the shape of the tube and the tension in the tensions rods, and a remote control system to control the operations of the tube and the extraction of the beam pipe.

The LGT was built and tested in the inner detector mock-up in building 180 at CERN. After extensive efforts with prototypes and development of control programs and fail safe devices, the device worked and exceeded the very stringent specifications. The results of the test at shown in figure 8. In spite of the successful test, other repairs needed by the pixel system dictated that the entire pixel system be removed and taken to a surface building and the IBL be inserted by a different method.

Figure 8: During repeated IBL insertion tests, the IST (outer cover of the IBL) was moved by steps of about 150mm and the gap between IST and three rings that represented a physical space of a B-layer was measured. Two red lines on the graphs represents the maximum gap of a 2.4mm between IST and a B-layer in any direction. Shown are graphs of the IST centerline runout in ZX and ZY planes.

7 DMTPC Experiment (Wellenstein)

Brandeis is a member of the DMTPC collaboration, which uses low-pressure gas TPCs to search for WIMP-nucleon elastic scattering in our galaxy Dark Matter halo. CF_4 gas is used to take advantage of the expected favorable WIMP-Fluorine spin-dependent cross section. The ionization electrons produced by the recoiling nucleus drift in the gas along a uniform electric field toward an amplification region created by a wire mesh and a copper anode where the large electric fields cause an avalanche process, during which one photon is produced for every three avalanche-electrons. This scintillation light is viewed through a vacuum port by a CCD camera. In CF_4 at a pressure of 75 Torr, a 50 keV fluorine recoil has an average range of about 1 mm, such that low diffusion in the TPC and sub-mm resolution of the read-out plane are needed to measure the range and direction of nuclear recoils from elastic scattering with dark matter. Electronic recoils from β and γ decay products from radioactive material inside the detector and from ambient x-rays make up the dominant background in dark matter direct detection experiments. To further improve the background rejection a charge readout system was investigated using the DMTPC detector in the surface laboratory at MIT. At a statistics-limited 90% CL, a γ and e rejection ratio of 6×10^{-6} was obtained for energies greater than 40 keV.

Brandeis designed, procured, built, and tested a station for monitoring the environment in the underground laboratory at WIPP.

The camera monitoring the dark-matter tracks in the amplification gap is the most important component of the DM-TPC. As CCD and CMOS chips are becoming larger in size, CCDs up to $50\text{ mm} \times 50\text{ mm}$ and CMOS chips up to $100\text{ mm} \times 100\text{ mm}$ are already available, and standard objectives are no longer suitable. Brandeis worked with optical design firms to commission a specialty lens, to optimize the light collection. This new lens and some existing lenses were tested at Brandeis in the optical set-up using point sources and small CCD cameras, developed for the ATLAS alignment system.

The photon collection efficiency from an isotropic point source (the tip of a fiber) positioned on the optical axis was measured by recording the flux, uniform over the lens area, with a small CCD placed in front of the lens. Then, using the same CCD, the total intensity of the (un-)focused image was recorded after the lens in position 2. This specially designed lens had an efficiency of $(1.0 \pm 0.1) \times 10^{-4}$ compared well to the design efficiency of 1.2×10^{-4} . Available commercial lenses have efficiencies of typically less than 4×10^{-5} . The relative illumination, that is, the reduction of efficiency as a function of angle, was measured by moving the fiber along the object plane and rotating it such that it always points towards the “pivot point” of the lens. The CCD was moved to record the full image. The result compared well with the curves provided by the company. The inset results showed the loss in efficiency is due to vignetting inside the lens as more and more of the rays are cut off.

Due to the intrinsic small acceptance angle of all objective lenses, the efficiencies cannot be much higher than 10^{-4} . Brandeis explored an optical system consisting of a fiber-optics plate, FOP, and a CMOS detector. The copper anode was replaced with a transparent and electrically conductive indium tin oxide, ITO, film mounted directly over the FOP, which is also the vacuum window. The light collection efficiency of the FOP-CMOS was expected to be about 10^{-2} , two orders of magnitude more efficient than CCD cameras. The test-chamber was constructed such that a CCD camera and the ITO-FOP-CMOS detector could be used simultaneously. Test results showed the new system to be a factor of two less efficient than expected. This is probably due to not fully understanding the efficiency of light collection of photons entering the FOP at large angle. This still leaves an improvement factor of 50, however as the FOP is also the vacuum window and must therefore be as large as the anode itself, using FOP-CMOS for DM-TPC is not feasible. However, there are other possible applications, where imaging the recoil traces is important. This work is still ongoing in collaboration with James Battat at Wellesley College.

Brandeis designed the vacuum vessel for the cubic meter Dark Matter Time Projection Chamber. It is a 68 inches long and 53 inches in diameter vessel with the option of either one or four CCD cameras at both ends. The design calls for two pairs of drift chambers, each pair with two drift regions of 0.25 m and a diameter of 1.15 m. The amplification gaps are back-to-back with a common 80% transparent mesh and are both imaged by either of the cameras at the domed end of the chamber. The total detection volume exceeds one cubic meter. Extensive FEA was used to chose all dimensions maintaining a safety factor of 2.5.

Appendix 1: Papers, ATLAS Notes, and Conference Talks

Below are the papers, ATLAS notes, and conference talks from the last three years with significant Brandeis contributions.

7.1 Papers with major Brandeis contribution

“Search for high-mass dilepton resonances in 21 fb⁻¹ of pp collisions at $\sqrt{s} = 8$ TeV with the ATLAS experiment,” ATLAS Collaboration, to be submitted to PRD.

“Measurements of Higgs boson production and couplings in diboson final states with the ATLAS detector at the LHC,” ATLAS Collaboration, arXiv: 1307.1427 [hep-ex] (submitted to Phys. Lett. B).

“Search for a heavy narrow resonance decaying to $e\mu$, $e\tau$, or $\mu\tau$ with the ATLAS detector in $\sqrt{s} = 7$ TeV pp collisions at the LHC,” ATLAS Collaboration, arXiv: 1212.1272 [hep-ex], Phys. Lett. **B723**, 15 (2013).

“Observation of a new particle in the search for the Standard Model Higgs boson with the ATLAS detector at the LHC,” ATLAS Collaboration, Phys. Lett. **B716**, 1 (2012).

“Search for the Standard Model Higgs boson in the decay channel $H \rightarrow ZZ^{(*)} \rightarrow 4\ell$ with 4.8 fb¹ of pp collision data at $\sqrt{s} = 7$ TeV with ATLAS”, ATLAS Collaboration, Phys. Lett. **B710**, 383 (2012).

“Search for high-mass resonances decaying to dilepton final states in pp collisions at $\sqrt{s} = 7$ TeV with the ATLAS detector,” ATLAS Collaboration, arXiv:1209.2535 [hep-ex] JHEP **1211**, 138 (2012).

“Search for heavy neutrinos and right-handed W bosons in events with two leptons and jets in pp collisions at $\sqrt{s} = 7$ TeV with the ATLAS detector,” ATLAS Collaboration, Eur. Phys. J. **C72**, 2056 (2012).

“Search for Lepton Flavor Violation in the $e\mu$ Continuum with the ATLAS Detector in $\sqrt{s} = 7$ TeV pp Collisions at the LHC,” ATLAS Collaboration, arXiv:1205.0725 [hep-ex], Eur. Phys. J. **C72**, 2040 (2012).

“Search for excited leptons in proton-proton collisions at $\sqrt{s} = 7$ TeV with the ATLAS detector,” ATLAS collaboration, arXiv:1201.3293v1 [hep-ex], Phys. Rev. D **85**, 072003 (2012).

“Search for the Standard Model Higgs boson in the decay channel $H \rightarrow ZZ^{(*)} \rightarrow 4\ell$ with the ATLAS detector,” ATLAS Collaboration, Phys. Lett. **B705**, 435 (2011).

“Search for a heavy particle decaying into an electron and a muon with the ATLAS detector in $\sqrt{s} = 7$ TeV pp collisions at the LHC,” ATLAS collaboration, Phys. Rev. Lett. **106**, 251801 (2011).

“Search for dilepton resonances in pp collisions at $\sqrt{s} = 7$ TeV with the ATLAS detector,” ATLAS Collaboration, arXiv:1108.1582, Phys. Rev. Letter **107**, 272022 (2011).

“Search for a heavy neutral particle decaying into an electron and a muon using 1 fb⁻¹ of ATLAS

data,” ATLAS collaboration, arXiv:1109:3089, Eur. Jour. Phys. **C72**, 1809 (2011).

“Alignment Systems in LHC General Purpose Detectors,” J. Bensinger and T. Rodrigo, Nucl. Instrum. Meth. A, doi:10.1016/j.nima.2011.04.058.

“First Dark Matter Search Results from a Surface Run of the 10-L DMTPC Directional Dark Matter Detector,” DMTPC Collaboration, arXiv:1006.2928v3 [hep-ex], Phys. Lett. **B695**, 124–129 (2011).

“DMTPC: Dark matter detection with directional sensitivity,” the DMTPC Collaboration, arXiv:1012.3912v1 [astro-ph.IM], to be published as part of conference proceedings for Identification of Dark Matter 2010, Montpellier, France.

“Commissioning of the ATLAS Muon Spectrometer with Cosmic Rays,” ATLAS Collaboration, Eur. Phys. J. **C70** 875–916 (2010).

“Background Rejection with the DMTPC Dark Matter Search Using Charge Signals,” DMTPC collaboration, submitted to NIM.

7.2 ATLAS Notes with Major Brandeis Contributions

“Updated results and measurements of properties of the new Higgs-like particle in the four lepton decay channel with the ATLAS detector. Spin and CP measurement,” ATL-COM-PHYS-2013-146.

“Four lepton decay channel with production mechanism specific signatures: study of the Higgs-like particle at 125 GeV and searches for additional resonances,” ATL-COM-PHYS-2013-145.

“Updated results and measurements of properties of the new Higgs-like particle in the four lepton decay channel with the ATLAS detector. Mass and signal strength measurement,” ATL-COM-PHYS-2013-144.

“Search for high-mass dilepton resonances in 20 fb⁻¹ of pp collisions at $\sqrt{s} = 8$ TeV with the ATLAS experiment,” ATL-COM-PHYS-2013-163, March 2013.

“Search for high-mass dilepton resonances in 20 fb⁻¹ of pp collisions at $\sqrt{s} = 8$ TeV with the ATLAS experiment,” ATLAS-CONF-2013-017, March 2013.

“Measurements of the properties of the Higgs-like boson in the four lepton decay channel with the ATLAS detector using 25 fb⁻¹ of pp collision data,” ATLAS-CONF-2013-013, March 6th, 2013.

“Combined coupling measurements of the Higgs-like boson with the ATLAS detector using up to 25 fb⁻¹ of proton-proton collision data,” ATLAS-CONF-2013-034, March 14th, 2013.

“Observation of a new particle in the search for the Standard Model Higgs boson in the $H \rightarrow ZZ \rightarrow 4\ell$ channel and measurements of its properties using 4.6 fb⁻¹ and 13.0 fb⁻¹ of proton-proton collisions at $\sqrt{s} = 7$ TeV and 8 TeV, respectively, recorded with the ATLAS detector,” ATL-COM-PHYS-2012-1547.

“Search for high-mass dilepton resonances in 6.1 fb⁻¹ of pp collisions at $\sqrt{s} = 8$ TeV: Supporting document,” ATL-COM-PHYS-2012-846, June 2012.

“Updated results and measurements of properties of the new Higgs-like particle in the four lepton decay channel with the ATLAS detector,” ATLAS-CONF-2012-169, December 13th, 2012.

“Search for high-mass dilepton resonances in 4.2 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$,” ICHEP 2012 conference note in preparation.

“Search for high-mass dilepton resonances with 5 fb^{-1} of pp collisions at $\sqrt{s} = 7 \text{ TeV}$ with the ATLAS experiment,” conference note ATLAS-CONF-2012-507.

“Search for high-mass dilepton resonances in 5 fb^{-1} of pp collisions at $\sqrt{s} = 7 \text{ TeV}$,” ATL-COM-PHYS-2012-111, September 2012.

“Search for excited leptons in pp collisions at $\sqrt{s} = 7 \text{ TeV}$ with the ATLAS detector,” analysis support note ATL-COM-PHYS-2011-1550.

“Search for excited leptons in 5 fb^{-1} of pp collisions at $\sqrt{s} = 7 \text{ TeV}$ with the ATLAS Experiment,” analysis support note ATL-COM-PHYS-2012-121.

“Observation of an excess of events in the search for the Standard Model Higgs boson in the channel $H \rightarrow ZZ^{(*)} \rightarrow 4\ell$ with the ATLAS detector,” ATLAS-CONF-2012-092, July 7th, 2012.

“Search for high-mass dilepton resonances in 6.1 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ with the ATLAS experiment,” ATLAS-CONF-2012-129, June 2012.

“Search for highmass dilepton resonances with 5 fb^{-1} of pp collisions at $\sqrt{s} = 7 \text{ TeV}$ with the ATLAS experiment,” conference note ATLAS-CONF-2012-007.

“Search for Lepton Flavor Violation in the $\mu\mu$ Continuum with the ATLAS detector in $\sqrt{s} = 7 \text{ TeV}$ pp collisions at the LHC,” EPJC paper support note, ATL-COM-PHYS-2011-1375.

“Search for a heavy neutral particle decaying into an electron and a muon pair using $L = 0.87 \text{ fb}^{-1}$ of ATLAS data,” EPS conference Note, ATLAS-CONF-2011-109.

“Search for a heavy neutral particle decaying into an electron and a muon pair using $L=0.87 \text{ fb}^{-1}$ of ATLAS data,” EPS support note ATL-COM-PHYS-2011-748.

“Measurement of the inclusive isolated prompt photon cross section in pp collisions at $\sqrt{s} = 7 \text{ TeV}$ with the ATLAS detector using 35 pb^{-1} ,” ATL-PHYS-INT-2011-075. September 2011.

“Search for a heavy particle decaying into an electron and a muon with the ATLAS detector in $\sqrt{s} = 7 \text{ TeV}$ pp collisions at the LHC,” 2010 Support Note ATL-COM-PHYS-2010-1061.

“Search for a heavy neutral particle decaying into an electron and a muon pair using $L=1.07 \text{ fb}^{-1}$ of ATLAS data,” 2011 support note ATL-COM-PHYS-2011-958.

“Search for high-mass dilepton resonances in pp collisions at $\sqrt{s} = 7 \text{ TeV}$,” ATL-COM-PHYS-2011-770, June 17, 2011, (2011 update for the EPS conference).

“MDT and CSC Alignment Studies using Track Segments”, S. Aefsky and Ch. Amelung, ATLAS note ATL-MUON-INT-2011-003.

7.3 Conference Talks

G. Artoni, “Higgs $\rightarrow$ ZZ in Atlas and CMS”, VI Italian workshop on p-p physics at the LHC, Genova, Italy, May 8–10, 2013.

S. Zambito, “Properties of the Higgs Boson in the 4 Lepton Decay Channel with the ATLAS Detector”, Higgs and beyond the Standard Model Physics 2013, Trieste (IT), Jun 24–28, 2013.

A. Venturini, S. Zambito, “ATLAS Muon System Performance & Detector Operation 2012”, LHCC2013, CERN, May 13, 2013.

S. Zambito, “Muon Performance: Status Report”, ATLAS $H \rightarrow ZZ^{(*)}$ Workshop, Rome (IT), Apr 16–19, 2013.

S. Zambito, “Higgs to four Leptons Searches Using the VBF Exclusive Mechanism”, ATLAS $H \rightarrow ZZ^{(*)}$ Workshop, Orsay (FR), Oct 10, 2012.

D. Pomeroy, “ATLAS R-Parity Violation SUSY Searches, International Conference on High Energy Physics (ICHEP 2012), Melbourne, Australia, July 4–11, 2012.

R. Daya, “Photon and photon+jet production measured with the ATLAS detector,” CIPANP 2012, May 29–June 3, 2012.

H. Wellenstein, “Status and Prospects of the DMTPC Directional Dark Matter Experiment,” PANIC2011, 19th Particles and Nuclei International Conference, July 24–29, 2011, MIT, Massachusetts.

S. Zambito, “Searches for New Physics at BaBar,” 24th Recontres de Blois (Particle Physics and Cosmology), May 27–June 1, 2012.

S. Zambito, “Study of the $\psi(2S) \rightarrow \pi^+\pi^-$ final state produced in e^+e^- collisions with Initial State Radiation (ISR) at BaBar,” Incontri di Fisica delle Alte Energie (IFAE 2012), Ferrara, Italy, April 11–13, 2012.

H. Wellenstein, “Rejection of Backgrounds in the DMTPC Dark Matter Search Using Charge Signals,” DPF2011: Division of Particles and Fields of the American Physical Society, August 9–13, 2011, Brown University, Rhode Island.

H. Wellenstein, “Status of the DMTPC Experiment,” CYGNUS2011, 3rd Workshop on directional detection of Dark Matter, June 7–10, 2011 Aussois, France.

H. Wellenstein, “DMTPC R&D,” CYGNUS2011, 3rd Workshop on directional detection of Dark Matter, June 7–10, 2011 Aussois, France.

H. Wellenstein, “Rejection of Backgrounds in the DMTPC Dark Matter Search Using Charge Signals,” TIPP2011: Technology and Instrumentation in Particle Physics 2011, June 9–14, 2011, Chicago, Illinois.

S. Aefsky, “Alignment of the ATLAS Muon Spectrometer,” TIPP 2011 (Technology and Instrumentation in Particle Physics), Chicago, IL, June 8–14, 2011.

D. Pomeroy, “Search for Lepton Flavor Violation in the $e\mu$ Continuum with the ATLAS Detector,” APS April Meeting, Atlanta, Georgia, March 31–April 3, 2012.

S. Gozpinar, “Search for Excited Muons with the ATLAS Experiment,” APS April Meeting, Atlanta, Georgia, March 31–April 3, 2012.

S. Aefsky, “Search for a Heavy Resonance Decaying into an $e\mu$ Pair at ATLAS,” APS April Meeting, Anaheim, CA, April 30–May 3, 2011.

C. Amelung, “The Alignment of the ATLAS Muon Spectrometer,” CERN detector seminar, CERN, Geneva, May 7, 2010.

C. Amelung, “The Alignment of the ATLAS Muon Spectrometer,” 3rd LHC Detector Alignment Workshop, CERN, Geneva, June 15–16, 2009.

7.4 Seminars and Colloquia

R. Daya, “CP and Spin and their effects on reconstruction of a Higgs decay,” SMU at CERN seminar and discussion session, July 11 2012.

R. Daya, “Search for high-mass dilepton resonances in Grand Unified Theories,” LPPC Seminar at Harvard University, November 9 2011.

R. Daya, “Search for the Standard Model Higgs boson,” Colloquium at Brandeis University, October 4 2011.

7.5 Talks at Major ATLAS Meetings

S. Zambito, “Muon Combined Performances in ATLAS, ongoing activities and future plans”, ATLAS Week (plenary talk), CERN, Feb 6, 2013.

S. Zambito, “Toy studies from real data using $Z \rightarrow \mu\mu$ events”, ATLAS Muon Week: Performance Session, CERN, Nov 12, 2012.

S. Zambito, “Approval to unblind the $H \rightarrow ZZ^{(*)} \rightarrow 4l$ analysis for HCP”, ATLAS Higgs Approval Meeting, CERN, Oct 15, 2012.

A. Venturini, “Inner Detector p_T resolution, Update Plots”, ATLAS Physics & Performance Week, May 21, 2013.

A. Venturini, “ID resolution studies: support note discussion”, ATLAS Physics & Performance Week, March 20, 2013.

R. Daya, “Recent ATLAS Exotics results,” ATLAS Physics Plenary, March 26 2013.

G. Sciolla, “Category-based analysis of $H \rightarrow ZZ(*) \rightarrow 4l$,” Higgs Approval Meeting, October 22 2012.

R. Daya, “Search for high-mass dilepton resonances,” ATLAS Physics Plenary, September 7 2012.

C. Amelung, “Endcap Alignment Status in 2012,” ATLAS Muon Week Performance Meeting, March 21, 2012.

C. Amelung and S. Aefsky, “Combined Alignment Using Optical Sensors and Collision Tracks,” ATLAS Muon Week Performance Meeting, November 16, 2011.

S. Aefsky, “ Z' in $e\mu$ Channel,” ATLAS Physics Workshop, Boston Univ., Aug. 15–17, 2011.

S. Gozpinar, “Search for Excited Muons with the ATLAS Experiment,” ATLAS Physics Workshop, Boston University, Aug. 15–17, 2011.

D. Pomeroy, “Search for Lepton Flavor Violation in $e\mu$ Continuum,” ATLAS Physics Workshop, Boston University, Aug. 15–17, 2011.

J. Bensinger, “New Small Wheel Overview,” Boston Univ., Boston MA, August 15, 2011.

C. Amelung, “Performance of the Muon Spectrometer Alignment,” ATLAS Muon Combined Performance Meeting during the ATLAS week, October 6, 2010.

C. Amelung, “Alignment Strategy for the Muon Spectrometer,” ATLAS Muon Week, July 9, 2010.

C. Amelung, “CSC Alignment with the Optical System,” ATLAS Muon Week, July 7, 2010.

J. Bensinger, “Preliminary Look at the Alignment of the New Small Wheel,” Upgrade Workshop, CERN, Geneva Switzerland, June 30, 2011.

J. Bensinger, “Comments on Mechanical Structures,” Upgrade Workshop, CERN, Geneva Switzerland, July 29, 2011.

Ch. Amelung, “A First Look at the Endcap Alignment in Runs 177986–178021,” ATLAS Muon Week Performance Meeting, April 13, 2011.

Ch. Amelung, “Alignment Upgrade Issues,” ATLAS Muon Week Upgrade Meeting, April 12, 2011.

Ch. Amelung, “Muon Spectrometer Alignment,” ATLAS Inner Detector Week Alignment Meeting, February 23, 2011.

Ch. Amelung, “Alignment Ideas for the BEE and BIS7/8 Chambers,” General Muon Upgrade Meeting, February 3, 2011.

J. Bensinger, “JD-Calorimeter Interface,” CERN, Geneva, Switzerland, February 1, 2011.

J. Bensinger, “Muon Subsystem WBS 3.5,” Brookhaven National Laboratory,” U.S. ATLAS Operations Program Manager’s Review,” January 27–28, 2011.

J. Bensinger, “Shape and Location of the JD,” Harvard University, Cambridge, MA, December 16, 2010.

Ch. Amelung, “A First Look at the CSC Alignment Using Run 167963,” ATLAS Muon Week, November 10, 2010.

C. Amelung, “Performance of the Muon Spectrometer,” ATLAS Overview Week, Copenhagen/Denmark, June 28, 2010.

7.6 Outreach Talks

G. Sciolla, “Dark Matter,” Women in Science Colloquium, Brandeis University, November 3, 2011.

C. Blocker, “Experimental Particle Physics,” Brandeis Summer Science Program (REU and MRSEC undergraduate students from across the country), July 29, 2011.

J. Bensinger, “Where We Stand – The Universe to Quarks,” Watertown High School, Watertown, MA, November 23, 2010.

J. Bensinger, “Brandeis at the Large Hadron Collider – The ATLAS Experiment,” Fall Fest, Brandeis University, October 16, 2010.

Appendix 2: Curriculum Vitae

B

James Bensinger

Physics Department, Brandeis University
415 South Street, Waltham, MA 02454

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Education

1970 Ph.D., University of Wisconsin
1963 B.S., Bucknell University

Professional Positions

1989- Present Brandeis University Professor, Brandeis University
1996-2000 Chair, Brandeis University Physics Department
1980-1989 Associate Professor, Brandeis University
1974-1980 Assistant Professor, Brandeis University
1973-1974 Research Associate, Brandeis University
1970-1973 Instructor/Assistant Professor, University of Pennsylvania

Selected Professional Activities

2010-present Project Manager for US Muon M&O Program
2010 Chair of Search Committee for the Upgrade R&D Manager
2011 US ATLAS Program/Deputy Recommendation Committee
2012 US ATLAS R&D ManagerSearch Committee

Experimental Collaborations

1994-present ATLAS Experiment, CERN
1989-1993 SDC Experiment, SSC
1981-1991 Collider Detector at Fermilab (CDF), Fermilab
1980-1981 Venus Detector at Tristan, KEK
1973-1980 Multiparticle Spectrometer (MPS), Brookhaven Laboratory

Undergraduates Supervised at CERN

A numbers of undergraduates have taken time out of there studies to to spend a year working on the construction and maintenance of the ATLAS detector.

2005-2006 Ben Kaplan
2005-2006 Matt Gardner
2006-2007 Benson Way
2007-2008 David Nash
2008-2009 Miles Ketchum
2009-2010 Kathryn Marable
2011-2012 Ben Wiener

Selected Publications

“Alignment Systems in LHC General Purpose Detectors,” J. Bensinger and T. Rodrigo, Nucl. Instrum. Meth. A, doi:10.1016/j.nima.2011.04.058.

“Studies of the performance of the ATLAS detector using cosmic-ray muons,” ATLAS Collaboration, Eur. Phys. J. C **71**, 1593 (2011) [arXiv:1011.6665 [physics.ins-det]].

“Commissioning of the ATLAS Muon Spectrometer with Cosmic Rays,” ATLAS Collaboration, Eur. Phys. J. C **70** 875-916 (2010).

“Commissioning of the ATLAS Muon Spectrometer with Cosmic Rays,” ATLAS Collaboration, Eur. Phys. J. C **70**, 875 (2010) [arXiv:1006.4384 [physics.ins-det]].

“Performance of the ATLAS Detector using First Collision Data,” ATLAS Collaboration, JHEP **1009**, 056 (2010) [arXiv:1005.5254 [hep-ex]].

Recent Talks

“The Long Guide Tube,” CERN, Geneva, Switzerland , February 12, 2010.

“First Look at BIS7, BIS8, BEE,” CERN, Geneva, Switzerland (by video), February 25, 2010.

“Long Guide Tube Status Report,” University of Geneva in Geneva, Switzerland, June 17, 2010.

“Shape and Location of the JD,” Harvard University, Cambridge, MA, December 16, 2010.

“Muon Subsystem WBS 3.5,” Brookhaven National Laboratory, “U.S. ATLAS Operations Program Managers Review,” January 27-28, 2011

“JD - Calorimeter Interface,” CERN, Geneva, Switzerland (by video), February 1, 2011.

“Preliminary Look at the Alignment of the New Small Wheel,” Upgrade Workshop, CERN, Geneva Switzerland, June 30, 2011.

“Comments on Mechanical Structures,” Upgrade Workshop, CERN, Geneva Switzerland, July 29, 2011.

“New Small Wheel Overview,” Boston University, Boston MA, August 15, 2011.

“Muon Subsystem - WBS 3.5,” U.S. ATLAS Operations Program Manager’s Review, Brookhaven National Laboratory, February 7, 2012.

“Alignment Issues for the New Small Wheel,” ATLAS Upgrade Workshop 2012, Stanford University, March 26, 2012.

“New Small Wheel Alignment,” New Small Wheel - US Muon Workshop, Brandies University, April 19, 2012.

Craig Blocker

Brandeis University
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blocker@brandeis.edu
(781)736-2879

Education

1980 Ph.D., University of California at Berkeley
1976 M.S., University of California at Berkeley
1974 B.S., University of Nebraska

Professional Positions

1991–present Professor, Brandeis University
2000–2003 Chair, Brandeis Physics Department
1991–1994 Senior Scientist, SSC Lab (on leave from Brandeis)
1985–1991 Associate Professor, Brandeis University
1982–1985 Assistant Professor, Harvard University
1980–1982 Research Associate, Harvard University

Awards and Honors

1974 Φ BK honor society

Selected Professional Activities

2004–2007 CDF representative to the Heavy Flavor Averaging Group (HFAG)

Experimental Collaborations

2005–present ATLAS at CERN
1982–2008 CDF at Fermilab
1991–1993 SDC at SSC
1980–1982 Mark II at PEP
1976–1980 Mark II at SPEAR

Postdoctoral Scholars Advised

W. David Dagenhart, 2001–2009, now with Fermilab Computing Division
Jodi Lamoureux, 1995–1999, now a scientist at Lawrence Berkeley Labs
John Cunningham, 1991–1995, now Professor of Physics at Loyola University
Phil Kesten, 1986–1990, now Assoc. Professor and Assoc. Provost at Santa Clara Univ.
Steve Behrends, 1986–1998, now scientist at Lincoln Labs

Students Advised

Glenn Amundsen, Lou Bianchini, Laurel Coffey,
and Keith Zengel, current Ph.D. students on ATLAS
Serdar Gozpinar, Ph.D. 2012, recent graduate, looking for post doc position
Dan Pomeroy, Ph.D. 2012, now with science policy group
Scott Aefsky, Ph.D. 2011, now in industry
David Clark, Ph.D. 2011, now in industry
Natasa Miladinovic, Ph.D. 2008, now a lecturer with University of Nebraska
Hongquan Niu, Ph.D. 2003, now a radiology physicist with hospital in Boston area
Mike Kirk, Ph.D. 2003, now a radiology physicist with hospital in Boston area
Steve Moulding, Ph.D. 1993, now working with financial company
Bob Mattingly, Ph.D. 1992, now in industry

Selected Publications

Search for Lepton Flavor Violation in the $e\mu$ Continuum with the ATLAS Detector in $\sqrt{s} = 7$ TeV pp Collisions at the LHC, ATLAS Collaboration, accepted by EPJC, May 2012.

Search for excited leptons in proton-proton collisions at $\sqrt{s} = 7$ TeV with the ATLAS detector, ATLAS collaboration, PRD **85**, 072003 (2012).

Search for a heavy particle decaying into an electron and a muon with the ATLAS detector in $\sqrt{s} = 7$ TeV pp collisions at the LHC, ATLAS collaboration, Phys. Rev. Lett. **106**, 215801 (2011).

Search for a heavy neutral particle decaying into an electron and a muon using 1 fb^{-1} of ATLAS data, ATLAS collaboration, Eur. Jour. Phys. **C72**, 1809 (2011).

Recent Conference Talks and Seminars/Colloquia

Experimental Particle Physics, Brandeis Summer Science Program, July 29, 2011.

Statistics, New England Particles Physics Student Retreat VII, Cape Cod, Massachusetts, August 11-15, 2009.

Analysis of M5/P2 Data, US ATLAS Software Workshop, University of Michigan, May 2008.

Tracking, New England Particles Physics Student Retreat VI, Cape Cod, Massachusetts, August 13-17, 2007.

Cosmic Ray Tracks in Pit Data, US ATLAS Software Workshop, Tufts University, May 24, 2007.

Endcap Chamber Alignment Using Cosmic Rays, US ATLAS Software Workshop, Brandeis University, December 7, 2006.

Physics at 14 TeV: an LHC Overview, Colloquium, Brandeis University, September 12, 2006.

First Run II B Physics Results From the Tevatron, FPCP 2003, Paris, France, June 3-6, 2003.

Gabriella Sciolla

Brandeis University
415 South Street, Waltham, MA 02454

sciolla@brandeis.edu
(781)736-2841

Education

- 1996 Ph.D., Torino University
- 1992 Laurea, Torino University, 110/110 cum laude and honorable mention

Professional Positions

- 2011–present Associate Professor, Brandeis University
- 2007–2011 Associate Professor, MIT
- 2003–2007 Assistant Professor, MIT
- 2002–2003 Pappalardo Fellow, MIT
- 2000–2002 Research Scientist, Laboratory for Nuclear Science, MIT
- 1996–2000 Research Associate, Stanford Linear Accelerator Center

Awards and Honors

- 2010 Buechner Undergraduate Advising Award, MIT
- 2007 Cecil and Ida Green Career Development Professorship, MIT
- 2006 Outstanding Faculty Mentor Award for Undergraduate Research, MIT
- 2005 Charles E. Reed Faculty Initiatives Fund, MIT
- 1992 Angelo Della Riccia Fellowship, Italy

Selected Professional Activities

- 2013–present US ATLAS Deputy Physics Advisor
- 2013 US ATLAS Tier 3 Task Force (Co-chair)
- 2010–present Fermilab Physics Advisory Committee (PAC), member
- 2011 DPF Task Force on Instrumentation in High Energy Physics, member
- 2003–2005 Executive Committee of the SLAC Users Organization (Chair 2003–04)
- 2003–2005 BABAR Speakers Bureau (Chair 2005–06)

Experimental Collaborations

- 2011–present ATLAS at CERN
- 2007–2011 DMTPC - Dark Matter Time Projection Chamber
- 1996–2008 BABAR at SLAC
- 1992–1996 DELPHI at CERN

Postdoctoral Scholars Advised

Rozmin Daya, 2011-present; Giacomo Artoni, 2013-present;
Stephen Sekula, 2004-2007, now Assistant Prof. at the Southern Methodist University;
James Battat, 2008-2010 (Pappalardo Fellow), now Assist. Prof. at Bryn Mawr University;
Denis Dujmic, 2007-2008, now Research Scientist at L3 Security and Detection Systems.

Students Advised

Eric Fitzgerald, Stefano Zambito, Alessio Venturini, current Ph.D. students on ATLAS.
Karsten Koenke, Ph.D. 2007, now Assistant Professor in Freiburg (Germany).
Minliang Zhao, Ph.D. 2008, now at Oracle (California).
Jeremy Lopez and Cosmin Deaconu, co-supervised with P. Fisher on DMTPC.

Selected Publications

Observation of a new particle in the search for the Standard Model Higgs boson with the ATLAS detector at the LHC, Phys. Lett. **B716**, 1 (2012).

Measurements of the properties of the Higgs-like boson in the four lepton decay channel with the ATLAS detector using 25 fb⁻¹ of pp collision data, ATLAS-CONF-2013-013.

Measurements of Higgs boson production and couplings in diboson final states with the ATLAS detector at the LHC, arXiv: 1307.1427 [hep-ex] (submitted to Phys. Lett. B).

Search for high-mass dilepton resonances in 20 fb⁻¹ of pp collisions at $\sqrt{s} = 8$ TeV with the ATLAS experiment, ATLAS-CONF-2013-017.

Search for high-mass dilepton resonances in 5 fb⁻¹ of pp collisions at $\sqrt{s} = 7$ TeV, ATLAS Collaboration, JHEP **1211**, 138 (2012).

Search for dilepton resonances in pp collisions at $\sqrt{s} = 7$ TeV with the ATLAS detector, ATLAS Collaboration, Phys. Rev. Lett. **107**, 272002 (2011).

Directional Detection of Dark Matter, G. Sciolla, Mod. Phys. Lett. A, Vol. 24, No. 23, 1793-1809 (2009), e-Print: arXiv:0811.2764 [astro-ph].

Observation of the 'head-tail' effect in nuclear recoils of low-energy neutrons, DMTPC Collaboration, Nucl. Instrum. Meth. A **584**, 327 (2008).

A measurement of CP asymmetry in $b \rightarrow s\gamma$ using a sum of exclusive final states, BaBar Collaboration, Phys. Rev. Lett. **101**, 171804 (2008), Minliang Zhao's Ph.D. thesis.

Branching fraction measurements of $B^+ \rightarrow \rho^+\gamma$, $B^0 \rightarrow \rho^0\gamma$, and $B^0 \rightarrow \omega\gamma$, BaBar Collaboration, Phys. Rev. Lett. **98**, 151802 (2007), Karsten Koenke's Ph.D. thesis.

Improved Measurement of Time-Dependent CP Violation in $B^0 \rightarrow c\bar{c}K^{0(*)}$ Decays, BaBar Collaboration, Phys. Rev. Lett. **94**, 161803 (2005).

Recent measurements of CP violation at the B factories, G. Sciolla, Mod. Phys. Lett. A, Vol. 18, No. 30, 20832098 (2003), [hep-ex/0307045].

Hermann Wellenstein

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415 South Street, Waltham, MA 02454

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(781)736-2841

Education

- 1971 Ph.D., University of Texas, Austin
- 1966 B.Sci., University of London
- 1962 GCE, North-West College of Technology, Dartford, England
- 1958 M.R.C., Adam Gymnasium Munich

Professional Positions

- 1978–present Associate Professor, Brandeis University
- 1973–1978 Assistant Professor, Brandeis University
- 1980–1982 Postdoctoral Fellow, Indiana University
- 2000 Visiting Professor, University of Munich
- 1998 Senior Research Fellow, Max Planck Institute, Munich
- 1988 Visiting Associate Professor, University of Texas
- 1980–1981 Maitre de Recherche Associe, Universite Paris-SUD
- 1976–1977 Professor Associe, Universite Paris-SUD
- 1972–1973 Visiting Professor, Universidade de Sao Paulo, Brasil

Selected Professional Activities

- 2002 Site Verification Committee, Muon System, ATLAS LHC

Experimental Collaborations

- 1993–present ATLAS at CERN
- 2007–present DMTPC - Dark Matter Time Projection Chamber
- 1990–1993 SDC at SSC
- 1988–2007 Neutrino Rest Mass Collaboration

Students Advised

Wolfgang Rueckner (PhD 1982)
Dilak Barlas (PhD 1984)

Selected Publications

First Dark Matter Search Results from a Surface Run of the 10-L DMTPC Directional Dark Matter Detector, DMTPC Collaboration, arXiv:1006.2928v3 [hep-ex], Phys. Lett. **B695**, 124-129 (2011).

DMTPC: Dark matter detection with directional sensitivity, DMTPC Collaboration, arXiv:1012.3912v1 [astro-ph.IM], to be published as part of conference proceedings for Identification of Dark Matter 2010, Montpellier, France.

Background Rejection with the DMTPC Dark Matter Search Using Charge Signals, DMTPC collaboration, submitted to NIM.

Observation of the “head–tail” effect in nuclear recoils of low–energy neutrons, DMTPC Collaboration, Nucl. Instrum. Meth. **A584**, 327-333 (2008).

Assembly of MDT Chambers, Atlas Internal Note, Muon No. 71-1999.

A New Positron Source with High Flux and Excellent Electron Optical Properties, with Manfred Fink, Scott Nguyen, Nucl. Instrum. and Meth. **B432**, 168-583 (2007).

Mapping the Large Area Straw Detectors of the COMPASS Experiment with X-rays, with Klaus Platzer, Wolfgang Dnnweber, Nicolas Dedek, Martin Faessler, Reiner Geyer, Christoph Ilgner, Vladimir Peshekhonov, IEEE Trans.Nucl.Sci., **52**, 793 (2005)

Proposal to Isolate the Origin of the 17 keV Kink in the β Spectrum, with S. Cook, S. Thomas, and M. Fink, Phys. Rev. D**46**, R6 (1992).

High Energy Electron Impact Spectrometer for Absolute Triple Differential Cross-Section, with A. L.-Bennani, A. Duguet and M. Lecas, Rev. Sci. Instr. **56**, 43 (1985).

Recent Conference Talks and Seminars/Colloquia

Rejection of Backgrounds in the DMTPC Dark Matter Search Using Charge Signals, DPF2011: Division of Particles and Fields of the American Physical Society, August 9-13, 2011, Brown University, Rhode Island.

Status and Prospects of the DMTPC Directional Dark Matter Experiment, PANIC2011, 19th Particles and Nuclei International Conference, July 24-29, 2011, MIT, Massachusetts.

Status of the DMTPC Experiment, CYGNUS2011, 3rd Workshop on directional detection of Dark Matter, June 7 - 10, 2011 Aussois, France.

DMTPC R&D, CYGNUS2011, 3rd Workshop on directional detection of Dark Matter, June 7 - 10, 2011 Aussois, France.

Rejection of Backgrounds in the DMTPC Dark Matter Search Using Charge Signals, TIPP2011: Technology and Instrumentation in Particle Physics 2011, June 9 - 14, 2011, Chicago, Illinois.

A new approach to directional detection of neutrons and dark matter, TIPP: Technology and Instruments in Particle Physics, Tokyo, March 2009.

The Neutrino Mass Experiment, NEXTEX, Neutrino Conference in Santa Fe, June 2006.

Neutrino Mass Experiment at The University of Texas at Austin, NEXTEX, Neutrino Tagung, Bad Honorf, Germany, 2006.

Christoph Amelung

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Education

- 1999   Doctoral degree in Physics (Dr. rer. nat.), Bonn University (Germany)
- 1996   Diploma in Physics (Dipl.-Phys.), Bonn University

Professional Positions

- 2008–present   Associate Research Scientist, Brandeis University
- 2002–2007   Research Staff, CERN
- 2000–2002   Research Fellow, CERN
- 1999–2000   Post-doctoral researcher, Bonn University

Selected Professional Activities

- 2012–present   Muon Analysis Task Force (Co-convenor)
- 2008–present   Muon Steering Group (Member)
- 2008–present   Muon Alignment Working Group (Co-convenor)

Experimental Collaborations

- 2000–present   ATLAS at CERN
- 1995–2000   ZEUS at DESY

Selected Publications

Commissioning of the ATLAS Muon Spectrometer with Cosmic Rays, ATLAS Collaboration, Eur. Phys. J. C DOI 10.1140/epjc/s10052-010-1415-2.

The Optical Alignment System of the ATLAS Muon Spectrometer Endcaps, S. Aefsky et al., 2008 JINST 3 P11005.

The ATLAS Experiment at the CERN Large Hadron Collider, ATLAS Collaboration, 2008 JINST 3 S08003.

Reference Bars for the Alignment of the ATLAS Muon Spectrometer, Ch. Amelung et al., Nuclear Instruments and Methods A 555 (2005) 36–47.

Measurement of the Proton Structure Function F_2 at Very Low Q^2 at HERA, ZEUS Collaboration, Phys. Lett. B 487 (2000) 53.

Recent Conference Talks and Seminars/Colloquia

The Alignment of the ATLAS Muon Spectrometer, CERN detector seminar, CERN, Geneva, May 7, 2010.

The Alignment of the ATLAS Muon Spectrometer, 3rd LHC Detector Alignment Workshop, CERN, Geneva, June 15–16, 2009.

First Results from the ATLAS Muon Spectrometer Optical Alignment System, 1st International Conference on Technology and Instrumentation in Particle Physics (TIPP 2009), Tsukuba, Japan, March 12–17, 2009.

ATLAS Muon Spectrometer – The Optical Alignment System of the Endcaps, 2nd LHC Detector Alignment Workshop, CERN, Geneva, June 25–26, 2007.

Status of Commissioning and Experimental Issues for Early Physics in ATLAS, Hadron Collider Physics Symposium (HCP 2007), La Biodola, Elba, Italy, May 20–26, 2007.

ARAMyS – Alignment Reconstruction Software for the ATLAS Muon Spectrometer, 10th Topical Seminar on Innovative Particle and Radiation Detectors (IPRD 2006), Siena, Italy, October 1–5, 2006.

For a full list of publications and talks see

<http://cern.ch/amelung/publications.html>

http://cern.ch/amelung/public_talks.html

http://cern.ch/amelung/internal_notes.html

http://cern.ch/amelung/internal_talks.html

Rozmin Daya

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Education

- 2011 Ph.D., Southern Methodist University
- 2006 B.A., Southern Methodist University

Professional Positions

- 2011–present Post-Doctoral Fellow, Brandeis University
- 2006–2011 PhD candidate, SMU

Awards and Honors

- 2008, 2011 Lightner-Sams Graduate Fellowship, SMU
- 2008 Young Researcher at the 58th Meeting of Nobel Laureates, Lindau, Germany

Selected Professional Activities

- 2012–present Contact Editor for Exotics Dilepton searches at ATLAS
- 2011 Co-editor of supporting documentation for ATLAS measurements of inclusive isolated prompt photon cross-section

Experimental Collaborations

- 2007–present ATLAS at CERN

Selected Publications and Reviewed Notes

Search for high-mass dilepton resonances in 21 fb⁻¹ of pp collisions at $\sqrt{s} = 8$ TeV with the ATLAS experiment, ATLAS Collaboration, to be submitted to PRD.

Search for high-mass dilepton resonances in 20 fb⁻¹ of pp collisions at $\sqrt{s} = 8$ TeV with the ATLAS experiment, ATLAS Collaboration, ATLAS-CONF-2013-017, March 2013.

Search for high-mass dilepton resonances in 6.1 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ with the ATLAS experiment, ATLAS Collaboration, ATLAS-CONF-2012-129, June 2012.

Search for high-mass resonances decaying to dilepton final states in pp collisions at a centre-of-energy of 7 TeV with the ATLAS experiment, ATLAS Collaboration, JHEP **1211**, 138 (2012).

Search for the Standard Model Higgs boson in the two photon decay channel with the ATLAS detector at the LHC, ATLAS Collaboration, Phys. Lett. B **705**, 452-470 (2011). Role: Measurement of background from electrons

Search for dilepton resonances in pp collisions at $\sqrt{s} = 7 \text{ TeV}$ with the ATLAS detector, ATLAS Collaboration, Phys. Rev. Lett. **107**, 272002 (2011).

Limits on the production of the Standard Model Higgs Boson in pp collisions at $\sqrt{s} = 7 \text{ TeV}$ with the ATLAS detector, ATLAS Collaboration, Eur. Phys. J. C **71**, 1728 (2011).

Search for high mass dilepton resonances in pp collisions at $\sqrt{s} = 7 \text{ TeV}$ with the ATLAS experiment, ATLAS Collaboration, Phys. Lett. B **700**, 163-180 (2011).

Measurement of the inclusive isolated prompt photon cross-section in pp collisions at $\sqrt{s} = 7 \text{ TeV}$ using 35 pb^{-1} of ATLAS data, ATLAS Collaboration, Phys. Lett. B **706**, 150-167 (2011).

Measurement of the inclusive isolated prompt photon cross section in pp collisions at $\sqrt{s} = 7 \text{ TeV}$ with the ATLAS detector, ATLAS Collaboration, Phys. Rev. Lett. D **83**, 052005 (2011).

Recent Conference Talks, Plenaries and Seminars/Colloquia

March 2013	<i>Recent ATLAS Exotics results</i> , ATLAS Physics Plenary
Sept 2012	<i>Search for high-mass dilepton resonances</i> , ATLAS Physics Plenary
July 11 2012	<i>CP, spin effects on reconstruction Higgs decay</i> , SMU@CERN seminar
June 3 2012	<i>Photon and photon+jet production measured with the ATLAS detector</i> , CIPANP 2012
Nov 9 2011	<i>Search for high-mass dilepton resonances</i> , LPPC Seminar, Harvard University
Oct 4 2011	<i>Search for the Standard Model Higgs boson</i> , Colloquim, Brandeis University
July 2011	<i>Search for the Higgs boson in the $H \rightarrow \gamma\gamma$ channel in ATLAS</i> , Higgs Hunting 2011
April 2011	<i>$Z' \rightarrow ee$ searches with ATLAS</i> , Southwest USATLAS Jamboree