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ELEMENTARY PARTICLE PHYSICS

Progress Report
July, 1993 – January, 1994

Joseph M. Izen
Department of Physics
University of Texas at Dallas

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Beijing Spectrometer (BES) Run History and Plans.

The BES 1993 run was devoted to D_s at $\sqrt{s} = 4.03$ GeV. The year began inauspiciously with a vacuum leak in the beam pipe near the interaction region. Once this problem was corrected, 7 pb^{-1} were collected between the Chinese New Year and the summer shutdown. BEPC operation resumed during the fall for a synchrotron light run. During December, 1993, BES recorded more than a million $\psi(3685)$ hadronic decays. The D_s running resumed at the start of January, 1994. The detector is operating reliably and typically collects $150 \text{ nb}^{-1}/\text{day}$ at $\sqrt{s} = 4.03$ GeV.

BES Physics Topics

Last year, BES published a tau lepton mass measurement $m_\tau = 1776.9_{-0.5}^{+0.4} \pm 0.2 \text{ MeV}$ using $\tau^+ \tau^-$ events identified by their $e\mu$ + missing energy topology. This result is being improved by using combinations of additional τ decay channels ($\tau \rightarrow e\nu\bar{\nu}$, $\tau \rightarrow \mu\nu\bar{\nu}$, $\tau \rightarrow \pi\nu$, and $\tau \rightarrow \rho\nu$) to reduce the statistical error to the level of the systematic error. Many $\psi(3685)$ measurements are underway, including a study of the suppression of the decay $\psi(3685) \rightarrow \rho\pi$, and the branching fraction $\text{Br}(\psi(3685) \rightarrow \tau^+ \tau^-)$. Various J/ψ studies (spin-parity analysis of hadronic final states, radiative decays including $J/\psi \rightarrow \gamma \chi(2200), \dots$) are continuing. The UTD group is investigating physics derived from $\sqrt{s} = 4.03$ GeV data. Interesting topics include D_s production, absolute D_s branching fractions (hadronic, leptonic, and inclusive semileptonic), D^*D and D^*D^* production, absolute D hadronic branching fractions, D^* branching fractions, and placing an upper limit on the ν_τ mass.

UTD BES Personnel

The UTD group has doubled in the past year. In January, 1994, Dr. XinChou Lou joined UTD from CERN and Indiana University where he is leading OPAL's B_s lifetime, $B_s^0 \bar{B}_s^0$ oscillation, and Λ_b mass measurements. He will return to CERN this summer with CERN and UTD support to complete these measurements. Dr. Lou's BES interests are leptonic and semileptonic D_s decays. Dr. Lou was hired as part of UTD's participation in the Rocky Mountain Consortium for High Energy Physics (RMCHEP). Consortium support from the Texas National Research Laboratory Commission ends on March 31, 1994, and it is not anticipated that RMCHEP will be able to honor the remaining four years of its obligation to UTD which includes half of Dr. Lou's salary. UTD is committed to supporting Dr. Lou should RMCHEP not find new sources of funding.

Three new Ph.D. students, John Standifird, Ira Blum, and Byung-Kyu Kim have joined the existing contingent of Bruce Lowery, Pat Gratton, and Jeff Campbell. Currently, Lowery, Gratton, and Byung-Kyu are supported with research assistantships (RA's) by this grant. Standifird and Blum are supported with teaching assistantships by the physics department. Campbell is an electrical engineer at Texas Instruments and does not require support. This summer, all five full-time students will be supported as RA's. The status of each student follows:

Name: Bruce Lowery

Thesis: D_s Production and Hadronic Branching Fractions

Status: Lowery expects to complete his Ph.D. in August, 1994.

Name: Patrick Gratton
 Thesis: The Mass of the Tau Neutrino
 Status: Gratton's Ph.D. proposal was approved by his committee in November, 1993.

Name: Jeffrey Campbell
 Thesis: The D_s Inclusive Semileptonic Branching Fraction
 Status: Campbell will present his Ph.D. qualifying exam/proposal during the Spring, 1993 semester.

Name: John Standifird
 Thesis: D_s Leptonic Branching Fractions
 Status: Standifird switched to high energy physics in September, 1993. He passed his qualifying examination while working for his previous advisor. Standifird will present a seminar on his new research topic to his committee during the Spring, 1994 semester.

Name: Ira Blum
 Thesis: Absolute Branching Fraction Scale of the D^0 Meson
 Status: Blum is a second year graduate student who joined BES in September, 1993. He plans to present his Ph.D. qualifying exam/proposal during August, 1994.

Name: Byung-Kyu Kim
 Thesis: not yet specified
 Status: Kim is a first year Ph.D. student. He is working on the calibration of the BES electromagnetic calorimeter. He is considering several D_s and D Ph.D. topics.

UTD Physics Analysis of 4.03 GeV Data

UTD is playing a leading role in the D_s analysis, and Joe Izen is coordinating the D_s and D analysis efforts for the U.S. side with Li Weiguo and Zhang Changchun in Beijing. The selection of hadronic data summary tapes (DST) is the first analysis step after the data has been reconstructed. Since early 1993, Bruce Lowery has produced the hadronic DST which have been used by all American collaborators. Bruce's strategy of simple visible energy and event vertex cuts inspired the collaboration-wide selection which is presently in use. The current routine was written by Hu Xiaoqing with feedback from Bruce Lowery and Joe Izen.

The next common feature of most analyses is kaon identification. Organizing efforts are underway in the U.S. and Beijing to standardize π/K separation (time of flight and dE/dx systems) and $K_s^0 \rightarrow \pi^+\pi^-$ reconstruction by the end of January, 1994. Since this work is occurring at many sites (UTD, Cal. Tech, SLAC, and IHEP), email and BESnews, a collaboration-wide electronic bulletin board using the Internet and international DECNET link to China is essential. UTD is directly involved in the K_s^0 studies.

The next step is the selection of 'single-tag' samples of reconstructed D_s hadronic decays. During July, 1993, UTD performed an independent single-tag analysis for the U.S. side to determine the D_s production cross section, and UTD helped prepare the D_s

analysis results shown by IHEP Director Zheng Zhipeng's at the Cornell Lepton Photon conference. The single-tags are the starting point for work on D_s leptonic decay, D_s semileptonic decay, and D_s absolute hadronic branching fraction analyses (double-tags). Currently, Bruce Lowery has reconstructed the largest sample of hadronic D_s decays in the collaboration using the $\phi\pi^+$, $\bar{K}^{*0}K^+$, and $\bar{K}_s^0 K^+$ final states (see Appendix I). Bruce will visit IHEP during April or May at IHEP's request to produce a standard set of single-tags events for the collaboration.

The two highest priority D_s topics are double-tags for absolute branching fractions and leptonic decays. Bruce Lowery is working on the double-tag analysis. Kinematic fitting will be important since the mass resolution for a fully reconstructed $e^+e^- \rightarrow D_s^+ D_s^-$ event can be improved by a 5-C fit. If there are narrow resonances among the D_s daughters, additional constraints may be applied. Currently Bruce is testing Mark III's Telesis kinematic fitting package which was ported to the BES environment at IHEP.

Leptonic D_s decays at BES are seen in two channels. The mode with the cleanest signature is $D_s^+ \rightarrow \mu^+ \nu_\mu$, however the branching ratio for this channel is expected to only be around 0.3%. A conventional analysis requires a single tag plus an identified muon and missing energy/momentum with zero missing mass. John Standifird is also exploring whether 'weak single-tags' may be used to improve the tagging efficiency. Weak single-tagging strategies increase the tagging efficiency by relaxing particle ID requirements, and even attempt to work when a small part of the D_s tag is not detected by BES.

The second leptonic channel is $D_s^+ \rightarrow \tau^+ \nu_\mu$ with either $\tau^+ \rightarrow e^+ \nu_e \bar{\nu}_\tau$ or $\tau^+ \rightarrow \mu^+ \nu_\mu \bar{\nu}_\tau$ subsequent decay. Each final state should have a combined branching fraction of around 0.5%. Kinematic constraints are lost due to the second neutrino in the final state, so lepton identification is crucial. The UTD electron subgroup (Campbell, Gratton, Standifird – the students with thesis topics using electrons, plus Kim who is the shower counter calibration expert) is optimizing electron identification. They are studying how to best make use of shower shape information, and are comparing neural net and confidence level methods. Jeff Campbell has pioneered the use of neural nets in BES. Training samples of electrons are being used from radiative Bhabha events, and hadrons from J/ψ and tau scan data.

Nonstrange D signals provide a useful monitor of data quality and are interesting in their own right. The D 's are produced copiously at $\sqrt{s} = 4.03$ GeV via $D^* \bar{D}$ and $D^* \bar{D}^*$ events (see Appendix II). BES has verified that direct $D\bar{D}$ production is small at this energy. The momentum resolution for the monochromatic $\bar{D}$'s produced in $D^* \bar{D}$ events is similar to that of D_s but much easier to directly measure. Ira Blum is using $D^{*0} \bar{D}^0$ and $D^{*0} \bar{D}^{*0}$ events to measure D^0 absolute branching fractions. A double-tag analysis is possible because the D^{*0} decays either to $D^0 \gamma$ or $D^0 \pi^0$. Ira has identified a few $K\pi$ vs. $K\pi$ double tags and is expanding his analysis to include additional D^0 decay modes.

Finally, UTD hosted the monthly BES collaboration meeting in October, 1993, and UTD will again host a BES meeting in April, 1994.

BES Software and Data Processing

UTD and Colorado State University (CSU) have set up parallel HP735/Unix machines and we have ported BES software to the HP. Modern debugging tools on the HP's have helped correct long-standing 'array out-of-bounds' problems which have an unpredictable

affect. Pat Gratton has provided the Unix scripts for controlling the linking and execution of BES jobs and for maintaining BES object libraries. Pat and John Standifird have written the HP lexical converters that translate BES code between the HP and other BES computing platforms. The HP/Unix environment has proven so stable that it has become the principle platform for data reconstruction in the U.S. Data reconstruction is being coordinated by Joe Izen. UTD has set up production libraries at UTD, CSU and recently on SSC's PDSF HP/Unix corral. In December, BES was officially approved to reconstruct data on PDSF although the lab is still wrestling with how to accommodate non-SSC users. When running at PDSF, we can process approximately 6 GB of BES data per day, and we are limited by the speed of our internet link to SSC lab for ftp transfers. UTD and CSU can each process 2-3 GB per day. We have just completed the reconstruction of the 7 pb^{-1} 1993 D_s data and have begun the reprocessing of the 3 pb^{-1} 1992 D_s data. Tapes with 1994 D_s data will begin arriving shortly as the run progresses and these will be given the highest priority. BES generates around 2 GB of data per day, so we should be able to catch up on older data sets and monte carlo production while process the latest data.

The U.S. side will be able to monitor the data quality this year on a daily basis. Joe Izen has benchmarked the transfer rate of the international DECNET link, and 25% of its capacity will be used to transfer one run (~200 MB) per day to SLAC. The UTD students set up a monitoring job which has been ported to VM by Alan Breakstone of Hawaii who will be checking the output once a day.

UTD Computing Upgrade

The UTD High Energy Lab's Unix computing system consists of a HP735 running at 99 MHz, three SCSI hard drives totaling 7.5 GBs, an Exabyte drive mounted in a 10 tape stacker, three X-terminals. Additional seats are provided by two Macintosh computers and the console of a Sparcstation IPC. The system has been heavily loaded with the following tasks:

- 1) Processing BES raw data for the BES collaboration.
- 2) Producing DST tapes to be dispatched to other BES institutes.
- 3) Running analysis and calibration jobs.
- 4) Generation of Monte Carlo simulated events.
- 5) Interactive fitting and graphical displays for physics analysis.
- 6) Storage of DST data and Ntuples.

Eight BES physicists rely on this installation and it is overloaded. For example, DST data is often removed in order to provide staging space for data reconstruction, and monte carlo jobs have to be carefully coordinated with data processing to avoid conflicts CPU and/or disk space conflicts. Occasionally, we run out of terminals. We also have some evidence that BES jobs are I/O limited by the speed of our fast (not wide) SCSI II bus. As the UTD group grows and as larger BES data sets accumulate, our computing needs will increase.

We plan to upgrade the current system to a level at which we will have sufficient CPU power and disk capacity to ensure that we can fulfill our commitment to BES, and the output of physics results for the next year. The outline of the upgrade follows:

- 1) Add two HP735 or HP735 equivalent Unix stations
- 2) Expanding the disk capacity to 25 GBs using fast-wide disks which are now becoming available.
- 3) Add four additional X-terminals.
- 4) A local network (FDDI or fast ethernet) to all the CPUs.
- 5) Port software developed by OPAL to coordinate job execution, output dispatch and data management, to create a farm-like computing environment.

The proposed upgrade will enhance the overall capacity of our computing and is crucial to our physics output in the coming year. The estimated cost will be \$89,690 and will be paid from Lou's start-up money contributed by the University of Texas at Dallas. With the additional load of *b* Factory computing which will be starting this year, and the anticipated 1995 BEPC and BES upgrades, we anticipate that we will shortly saturate our local capacity by the end of 1994. With a local network in place the system will be configured for future expansion.

PEP II *b* Factory (Babar)

The medium to long term plans of the UTD HEP group have changed with the cancellation of the Superconducting Super Collider and SDC. We are becoming involved with the PEP II *b* Factory project which is well suited to the group's experience with e^+e^- colliders. Most likely, UTD will become involved with the computing and physics simulation efforts, and our CsI work for the Tau Charm Factory may lead to participation in the design of Babar's electromagnetic calorimeter. The collaboration is still in the process of defining itself, and we will continue to attend Babar workshops/collaboration meetings.

Budget Justification

Senior Personnel: Two months of summer salary are requested for Izen. Lou will be supported by CERN during the summer.

Ph.D. Students: Spring, 1994: Three RA's. Summer, 1994: Five RA's. Fall and Spring 1995: Four RA's.

Domestic Travel: Based on 21 domestic trips of \$600 each. Travel is mainly to monthly BES collaboration meetings at SLAC or a collaborating BES university, and to PEP II *b* Factory meetings. During the summer, Dr. Izen and the five RA's plan to visit the Colorado State group. As a consequence, the lower, off campus indirect cost rate will apply to summer salaries, benefits, and travel.

Computer hardware/software maintenance and repairs: Required as initial one year warranties expire.

UTD

BES 北京譜儀

Beijing Spectrometer: Spring 92 data

Beam Constrained Mass

Beam Constrained Mass

Beam Constrained Mass

Beam Constrained Mass

UTD

BES 北京譜儀

Beijing Spectrometer: Spring 92 Data

Momentum

Invariant Mass

Invariant Mass

Invariant Mass

Publications of J.M. Izen, 1993 - Present

- 1 **A Measurement of the Charged Multiplicity of $Z^0 \rightarrow b\bar{b}$ Events.**
(SLD Collaboration) K. Abe, *et al.*, SLAC-PUB-6372, October 1993. 18pp.
Submitted to Physical Review Letters
- 2 **A Measurement of α_s From Jet Rates at the Z^0 Resonance.**
(SLD Collaboration) K. Abe, *et al.*, SLAC-PUB-6133, July 1993. 18pp.
Submitted to Physical Review Letters.
- 3 **First Measurement of the Left-Right Asymmetry in Z Boson Production**
(SLD Collaboration) R.D. Elia, *et al.*, Modern Physics Letters A8, 2237 (1993)
- 4 **First Measurement of the Left-Right Asymmetry in Z Boson Production by e^+e^- Collisions.**
(SLD Collaboration) K. Abe, *et al.*, Physical Review Letters 70, 2515 (1993).

Invited Talks and Colloquia Presented by J.M. Izen, 1993 - Present

- 1 **Measurement of the Mass of the Tau Lepton**
Physics Colloquium, University of North Texas, April 19, 1993, 1993.
- 2 **Measurement of the Mass of the Tau Lepton**
Physics Colloquium, Case Western Reserve University, January 21, 1993.

Publications of X.C. Lou, 1993 - Present

- 1 **Measurements of Neutral B Meson Oscillation at LEP**
X.C. Lou, Proceeding of *Particle Physics Before the Year 2000*, Jan. 17 -22, 1994, Aspen, U.S.A.
- 2 **Measurement of the B_s^0 Lifetime**
(OPAL Collaboration) P.D. Acton, *et al.*, Physics Letters 312B (1993) 501.
- 3 **Prospects for $B_s^0\bar{B}_s^0$ Oscillation Measurement at LEP**
X.C. Lou, Proceeding of *B Physics at Hadron Colliders*, June 21 - July 2, 1993, Snowmass, U.S.A.
- 4 **A Measurement of the Average Lifetime of b -flavoured Baryons**
(OPAL Collaboration) R. Akers, *et al.*, Physics Letters 316B (1993).
- 5 **The OPAL Silicon Microvertex Detector**
P.P. Allport, *et al.*, Nuclear Instruments and Methods A324 (1993) 34.
- 6 **Search for Massive, Unstable Photinos That Violate R Parity.**
(OPAL Collaboration) P.D. Acton, *et al.*, Physics Letters 313B, 333(1993).
- 7 **The Forward-Backward Asymmetry of $e^+e^- \rightarrow b\bar{b}$ and $e^+e^- \rightarrow c\bar{c}$ Using Leptons in Hadronic Z^0 Decays.**
(OPAL Collaboration) P.D. Acton, *et al.*, Zeitschrift Für Physik C 60, 19 (1993).

Reprints / removed

- 8 **Search for Anomalous Production of High Mass Photon Pairs in e^+e^- Collisions at LEP**
(OPAL Collaboration) P.D. Acton, *et al.*, Physics Letters 311 B, 391(1993) .
- 9 **Measurement of the Mass of the Z Boson and the Energy Calibration of LEP**
LEP Experiments, Physics Letters 307 B (1993) 187.
- 10 **A Determination of $\alpha_s(M_Z)$ at LEP using Resummed QCD Calculations**
(OPAL Collaboration) P.D. Acton, *et al.*, Zeitschrift Für Physik C 59, 1 (1993).
- 11 **Measurement of the B^0 and B^+ Lifetimes**
(OPAL Collaboration) P.D. Acton, *et al.*, Physics Letters 307 B 247 (1993).
- 12 **Measurement of $\Gamma(Z^0 \rightarrow B\bar{B}) / \Gamma(Z^0 \rightarrow \text{Hadrons})$ Using Leptons.**
(OPAL Collaboration) P.D. Acton, *et al.*, Zeitschrift Für Physik C 58, 523 (1993).
- 13 **Measurement of the Tau Lifetime**
(OPAL Collaboration) P.D. Acton, *et al.*, Zeitschrift Für Physik C 59, 183 (1993).
- 14 **Precision Measurement of the Neutral Current for Hadron and Lepton Production at LEP**
(OPAL Collaboration) P.D. Acton, *et al.*, Zeitschrift Für Physik C 58, 219 (1993).
- 15 **Evidence For Chain-like Production of Strange Baryon Pairs In Jets.**
(OPAL Collaboration) P.D. Acton, *et al.*, Physics Letters 305 B, 415 (1993).
- 16 **A Study of Difference Between Quark and Gluon Jets using Vertex Tagging of Quark Jets**
(OPAL Collaboration) P.D. Acton, *et al.*, Zeitschrift Für Physik C 58, 387 (1993).
- 17 **QCD Coherence Studies using Two Particle Azimuthal Correlations**
(OPAL Collaboration) P.D. Acton, *et al.*, Zeitschrift Für Physik C 58, 207 (1993).
- 18 **Studies of Strong and Electroweak Interactions using Final State Photon Emission in Hadronic Z^0 Decays,**
(OPAL Collaboration) P.D. Acton *et al.*, Zeitschrift Für Physik C 58, 405 (1993).
- 19 **A Study of Electric Charge Distribution of Quark and Gluon Jets in Hadronic Z^0 Decays**
(OPAL Collaboration) P.D. Acton, *et al.*, Physics Letters 302 B, 523 (1993).
- 20 **A Measurement of $K^{*\pm}(892)$ Production in Hadronic Z^0 Decays**
(OPAL Collaboration) P.D. Acton, *et al.*, Physics Letters 305 B, 407 (1993).
- 21 **A Study of $K_S^0 K_S^0$ Bose-Einstein Correlation in Hadronic Z^0 Decays**
(OPAL Collaboration) P.D. Acton, *et al.*, Physics Letters 298 B, 456 (1993).

Talks and Colloquia Presented by X.C. Lou, 1993 - Present

- 1 **Measurements of Neutral B Meson Oscillation at LEP**
X.C. Lou, Proceeding of *Particle Physics Before the Year 2000*, Jan. 17 -22, 1994, Aspen, Colorado.
- 2 **dE/dx Particle Identification using the OPAL Jet Chamber**
Invited Talk at *B Physics at Hadron Colliders*, June 21 - July 2, 1993, Snowmass, Colorado
- 3 **Measurement of Neutral B Meson Mixing at LEP**
Invited Talk at *B Physics at Hadron Colliders*, June 21 - July 2, 1993, Snowmass, Colorado
- 4 **What Do We know about the B_s Meson?**
Physics Colloquium, University of Texas at Dallas, April, 1993.

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