Superconducting Super Collider Laboratory

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October 1991

APPROVED FOR RELEASE OR
PUBLICATION - O.R. PATENT GROUP
BY...*ES*.....DATE *4/3/95*.

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*Operated by the Universities Research Association, Inc., for the U.S. Department of Energy under Contract No. DE-AC35-89ER40486.

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Muon Systems

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Abstract

The designs of both the GEM and SDC muon systems and the technological choices are reviewed. In particular, the chamber options for the detectors are discussed.

Introduction

The development of a muon system for an experiment at the SSCL requires an understanding of the physics objectives for a particular system and how those goals translate into specific requirements for such a system. These requirements are established by the final off-line measurement accuracy needed to provide the necessary resolution for the experiment. It is the trigger requirements which generally determine the on-line placement accuracy that the system components have to achieve. Finally, it is an understanding of backgrounds and the operating environment which sets the operational requirements of the system.

Having established these conditions, one must proceed to systematically develop all parts of a muon system. For muon chambers, this means choice of gas and basic unit cell, choice of chamber size and construction method, as well as the structural system that holds the chambers. For trigger systems, it means choice of technology to provide fast timing to associate the muons with a particular beam crossing and a mechanism to provide an approximate momentum for the trigger track. Triggering is generally done in stages to provide an approximate rate reduction factor of 10^4 in level one and an additional reduction factor of 10 to 100 in level two.

In this paper we will review the GEM and SDC muon systems to understand motivation for the SSCL Subsystem R&D program. Then we will discuss the specific R&D results from the subsystem progress reports #200¹, #207², and #218^{3,4}.

GEM Muon System

The goal for the GEM muon system is a precision momentum measurement outside the calorimeter with high precision tracking chambers in a large magnetic field. The sagitta method for momentum determination is used. Measuring muons outside the calorimeter means the detector will be robust at the highest luminosities. The expected precision of the GEM muon system is 5% at $\eta=0$ and $P_\mu=0.5$ TeV. One possible implementation of the GEM muon system is shown in Figure 1.

Level 1 triggering in GEM is accomplished by requiring that the ϕ difference in track position in the outer two superlayers of the muon system be smaller than a predetermined threshold. Level 2 is then given by calculating the change in slope of the track measured in the outer two muon superlayers. Successful triggers will have a difference below another preset threshold. This is shown in Figure 2.

SDC Muon System

The SDC muon system provides muon identification, a trigger, and augments the central tracker momentum measurement. In the forward direction it provides the primary momentum measurement. Momentum is calculated by measuring the bend in an iron toroid. Figure 3 shows the SDC muon system. Figure 4 shows the expected resolution for muon measurement.

For the SDC muon trigger a road and timing pulse is created by the coincidence of a pair of scintillation counters. Wires (θ measuring) in alternate layers of drift tubes are projective to the interaction point. The time difference between signals arriving at the wires is a measure of the bend in the toroidal magnet. These signals arriving sufficiently close in time, coincident with a scintillator, make a Level 1 trigger. The timing diagram for this trigger is shown in Figure 5.

Chamber Gas and Electrostatic Cell Studies

The requirements for a choice of an electrostatic cell design or a choice of chamber gas is based on several considerations. One wants a gas that is insensitive to the variations in the electrostatic field, ambient pressure, and variations in composition (including impurities). If we have large drift distances, we would like it to have a small longitudinal diffusion but high drift velocity. If the chamber is used in a magnetic field, we would like a small Lorentz angle. Proper cell operation implies that the gas should cause minimal chamber ageing and not be prone to sparking. The large volume of the proposed muon systems implies that the gas should be safe (nonflammable and nontoxic) and affordable both in initial and operating costs.

Systematic studies of various gases to find the optimal combination of gases given the specific requirements of the various systems have been made by all groups. Some typical results (from the MIT group¹) are shown in figures 6 and 7. Of course it is the behavior of the gas in combination with the electrostatic fields in the chamber and the surrounding magnetic field that determines the quality of the measurement. An example of such a convolution is shown in Figure 8. The arrival time (in 50 nsec steps) of ionization along various field lines is shown by the *'s and o's.

In most cases the groups reported satisfactory solutions to the problem of finding the correct combination of chamber gas and electrostatic cell design. It does not appear that the optimum solution for SSC running has been found in all cases and these studies will continue.

Chamber Studies

The requirements for muon chambers are:

1. They must have reasonably good resolution. This is required to provide good momentum measurements to several hundred GeV transverse momentum.
2. They must have good track pair resolution so that delta rays accompanying muons can be resolved.
3. They must be capable of having a single wire span a distance of up to 9 m.
4. There should be a minimum of dead space within a layer so that level triggers are as robust as possible.
5. They must be easily industrialized. That is, they must be capable of being built at sites with relatively unskilled labor but with good quality control.
6. They must be relatively inexpensive.

The proposed technologies for the GEM system are:

1. For the central region $0 < \eta < 1.3$ the choice is between Pressurized Drift Tubes (PDT) and Limited Streamer Drift Tubes (LSDT). PDT achieve their accuracy by capturing the wires in precision plates, as is shown in Figure 9.
2. In the endcap region $1.3 < \eta < 2.5$ Cathode Strip Chambers (CSC) are the technology of choice. The advantage here is that only the cathodes have to be accurately positioned to achieve the required resolution. The backup technology for this region is LSDT.
3. The timing information is provided by Resistive Plate Chambers, essentially a self-quenching spark chamber which uses a resistive glass for electrodes. An illustration of this chamber is shown in Figure 10.

The chamber cell technological choice for SDC is either a single wire cell or a 3-wire jet cell. For the single wire extruded tube one can have a simple round or octagonal tube or more complex tube with field shaping as shown in Figure 8. An example of this is the SSCL/Washington design for a stack of round cells made from Aluminum extrusions, shown in Figure 11. The version shown in the figure contains field shaping electrodes. The wire position is maintained by capture of the tube endcap in a precision milled endplate.

Figure Captions

- 1) Elevation view of one possible implementation of the GEM muon system.
- 2) Level 1 and Level 2 muon trigger definition for GEM.
- 3) Cross section view of the SDC muon system. The barrel and forward (FT) toroids are shown. Tracking chambers are BW - barrel tracking, IW - intermediate tracking, and FW - forward tracking.
- 4) Expected resolution for the SDC muon system including a central tracker resolution of $.25 (\text{TeV}/c)^{-1}$ up to $\eta = 1.7$.
- 5) Timing diagram for SDC muon Level 1 trigger.
- 6) Velocity and Lorentz angle for various combinations of Argon and CO_2 .
- 7) Velocity and Lorentz angle for various combinations of CF_4 and Isobutane.
- 8) Drift time calculation for ionization in cell with field shaping. *'s and o's indicate arrival time in 50 nsec ticks of ionization produced in the cell. The gas is Argon (90%), CF_4 (5%), and CH_4 (5%).
- 9) Pressurized Drift Tube End Plug Assembly. (GEM)
- 10) Restive Plate Chambers. (GEM)
- 11) SSCL/Washington design for a stack of round cells made from aluminum extrusions and containing field shaping electrodes. The wire position is maintained by capture of the tube endcap in a precision milled endplate. (SDC)

¹ Progress on the Research and Development Program to Continue the Development of Precision Instrumentation for the Study of Muons in the TeV Region. Charles Stark Draper Laboratories, Harvard University, John Hopkins University, Lawrence Livermore Laboratory, Massachusetts Institute of Technology, Princeton University, Purdue University. Contact: Samuel C.C. Ting, M.I.T.

² Muon Subsystem R&D 1991 Progress Report. Argonne National Laboratory, University of Colorado, University of Illinois, University of Maryland, University of Michigan, University of Minnesota, Rochester University, University of Washington, and University of Wisconsin. Contact: K. Heller, U. of Minn. and S. Errede, U. of Ill.

³ Toroidal Spectrometer Group - Progress Report. Joint Institute for Nuclear Research at Dubna, University of Houston, LeCroy Corporation, Louisiana State University, Massachusetts Institute of Technology. Contact: Louis S. Osborne, M.I.T.

⁴ Progress Report on Streamer Chamber - Drift Chamber R&D. University of Houston. Contact: R. Weinstein, U of Houston.

ELEVATION OF PDT MUON SYSTEM

Figure 1 Elevation view of one possible implementation of the GEM muon system.

DPHI AND RAYS TRIGGERS

DPHI IS A VALID TRIGGER IF THERE IS A COINCIDENCE BETWEEN PADS
PHI3(i) AND ONE OF PHI2(1 +/- thr)

WHERE thr = 0,1,2,3,....

RAYS IS A VALID TRIGGER IF CALCULATED ANGLE BETWEEN
RAY2 AND RAY3 IS SMALLER THAN A GIVEN THRESHOLD

Figure 2 Level 1 and Level 2 muon trigger definition for GEM.

SDC Muon System

Figure 3 Cross section view of the SDC muon system. The barrel and forward (FT) toroids are shown. Tracking chambers are BW - barrel tracking, FW - intermediate tracking, and FW - forward tracking.

Muon momentum resolution as a function of pseudorapidity for various values of transverse momentum. A resolution of $0.25 \text{ (TeV/c)}^{-1}$ from Table 1 is used to characterize the central tracking performance.

Figure 4 Expected resolution for the SDC muon system including a central tracker resolution of $.25 \text{ (TeV/c)}^{-1}$ up to $\eta=1.7$.

SDC MUON TRIGGER

Figure 5 Timing diagram for SDC muon Level 1 trigger.

Figure 6 Velocity and Lorentz angle for various combinations of Argon and CO₂.

Figure 7 Velocity and Lorentz angle for various combinations of CF_4 and Isobutane.

Figure 8 Drift time calculation for ionization in cell with field shaping. *'s and o's indicate arrival time in 50 nsec ticks of ionization produced in the cell. The gas is Argon (90%), CF₄ (5%), and CH₄ (5%).

Pressurized Drift Tube End Plug Assembly Concept (REV3, one piece Insulator)

F. Nimblett 20 Sept 91
Draper Laboratory

Figure 9 Pressurized Drift Tube End Plug Assembly. (GEM)

Resistive Plate Chambers

Ar/150/Freon = 60/38/2

* R&D project for a new version of large gap parallel plate counters (GLASS)

Figure 10 Resistive Plate Chambers. (GEM)

Figure 11 SSCL/Washington design for a stack of round cells made from aluminum extrusions and containing field shaping electrodes. The wire position is maintained by capture of the tube endcap in a precision milled endplate. (SDC)