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Selection of the GEM Electromagnetic Calorimeter Technology: Decision Memorandum

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Abstract:

The GEM Collaboration has selected a sampling liquid krypton calorimeter as the preferred electromagnetic calorimeter technology for inclusion in the GEM Technical Design Report. This choice reflects the goal of the GEM Collaboration to construct a major detector for the SSC which emphasizes the physics discovery potential of gammas, electrons, and muon final states. We intend to exploit the maximum capability of the liquid krypton technique towards our goal of constructing a calorimeter with precise energy resolution and one which is robust against backgrounds.

DECISION MEMORANDUM

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ELECTROMAGNETIC CALORIMETER TECHNOLOGY

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SUMMARY

The GEM collaboration has selected a sampling liquid krypton calorimeter as the preferred electromagnetic calorimeter technology for inclusion in the GEM Technical Design Report. This choice reflects the goal of the GEM collaboration to construct a major detector for the SSC which emphasizes the physics discovery potential of gamma, electron, and muon final states. We intend to exploit the maximum capability of the liquid krypton technique towards our goal of constructing a calorimeter with precise energy resolution and one which is robust against backgrounds.

CONTEXT OF THE DECISION

At the submission of the GEM Letter of Intent in December 1991, we identified two possible technological options for the GEM electromagnetic calorimeter: a noble liquid (argon or krypton) sampling calorimeter with an integrated hadronic unit as one option, and a BaF2 total absorption calorimeter followed by a scintillating fiber hadronic section as the other.

Both techniques were viewed as attractive possibilities to reach the GEM design goals, but each presented challenges. The noble liquid technique was considered an engineering challenge to make the complicated structure and with consequences for system integration. At the same time, the minimum required stochastic resolution for the accordion technique had not been demonstrated. The BaF2 approach raised questions about the ability to control systematic effects at the level needed to assure a sufficiently small constant term in the energy resolution. In addition, crystals of sufficient radiation hardness had not been produced, and it was unclear whether this would be possible within the time constraints necessary for GEM

We determined that the choice between these two options involved many unknowns and to facilitate the decision a focused program of R&D and Engineering should be undertaken. In this regard, we concentrated our engineering resources on the important engineering problems of making the Liquid Argon/Krypton projective accordion structure, including for the end cap calorimeter. We also undertook to convene a panel of experts on crystals to advise us on the feasibility of making sufficiently radiation hard crystals and to help us formulate an optimal R&D program to that end.

On our request the Physics Research Division of SSCL appointed a BaF2 Expert panel selected from the worldwide community of experts on materials science, crystal growth and processing, radiation damage and instrumentation. The panel was charged to advise the Laboratory and the GEM collaboration on the feasibility of obtaining crystals which met all GEM performance and manufacturing requirements on a suitable time scale for consideration in the GEM design. The panel met in December, 1991, a subgroup visited the crystal manufacturers in China, and the panel met a second time in January, 1992. In their report, they concluded that they had not uncovered any fundamental limitations in making crystals to GEM specifications, and they outlined a research and development program within our budget constraints aimed at determining whether the GEM design specifications could be met before the calorimeter decision was scheduled to be made in August 1992.

The GEM Collaboration Meeting at Tucson served as the forum for reviewing and adopting the first GEM design baseline. A principal milestone in this process was adoption of a calorimeter baseline for physics, engineering and cost/schedule studies prior to the July 1992 SSC Program Advisory Committee review. As this baseline evolved during the spring, it was determined that within the noble liquid option, we should adopt liquid krypton to pursue our goal of precise resolution. It was also determined that a hybrid configuration, combining a liquid krypton electromagnetic calorimeter with a scintillating fiber hadron calorimeter had potential advantages and merited consideration, as well as an integrated electromagnetic/hadronic system.

Aided by the BaF2 expert panel report, and studies of the noble liquid option performance, the collaboration identified a set of quantitative performance goals that each technology should seek to verify by measurement prior to consideration by GEM of the final technology choice. A vigorous R&D program aimed at these verifications has been carried out on both technologies. In addition, a set of important questions that required simulation work or other study was asked of both groups.

For both techniques, impressive progress has been made in physics simulations of calorimeter performance, conceptual engineering, beam tests, and studies of fabrication. The BaF2 expert panel reconvened in early August to evaluate progress in the development of radiation hard crystals. They reviewed the substantial progress that had been made in understanding the origin of radiation damage in BaF2 crystals. They also reviewed the status and prospects for manufacturing radiation hard crystals in China. Their conclusions were optimistic about the long term prospects of developing radiation hard crystals with BaF2, but concluded that making crystals to GEM specifications and time frame had not been demonstrated. They suggested that an alternative of mitigating the radiation damage with *in situ* light annealing should be pursued.

During August some progress was made in China on new crystal production and much new information was obtained on light annealing damaged crystals. In particular, promising data showed that much of the damage could be removed, even with light at long wavelengths. This interesting new information was presented to a subgroup of the BaF2 panel, convened by the proponents, on Aug 31 - Sept 1. They were impressed with the prospects and concluded that this could solve the radiation hardness problems. This information and the report of this subpanel were presented to the collaboration and were thoroughly considered in the making the decision.

A panel was also formed by the collaboration to evaluate progress on the engineering issues for the Liquid Krypton/Argon option. The panel confirmed that the major concerns had been addressed in the conceptual design and uncovered no 'show stoppers' with respect to Engineering issues.

A prototype liquid Krypton/Argon module was tested at BNL and the stochastic term was measured to be below 7%/sqrt(E). These tests also confirmed the further improvements in resolution for Krypton filling.

THE DECISION PROCESS

During the week August 30-September 4, GEM held several meetings to facilitate making a selection between the two candidate electromagnetic calorimeter technologies. The calorimeter subgroup met and reviewed all of the work to date, in an open meeting where anyone in the collaboration could make a presentation. The GEM physics subgroup held a meeting to discuss and rank the importance of technical features (e.g. resolution, speed, spatial and pointing abilities, etc.) from the standpoint of physics considerations.

The GEM Collaboration Council met and heard summary presentations on the status of the noble liquid option, the barium fluoride option, and a technical comparison of the two systems prepared by Barry Barish, a GEM spokesman, and Yuri Kamyshkov, the chair of the calorimeter subgroup. This session included considerable discussion of the technical issues.

Finally, the GEM Executive Committee met on September 3 and 4 to consider the large body of information provided by the system proponents and the calorimeter subgroup, and to discuss the decision and to provide advice to the spokesmen. Several members of GEM, including the proponents of the competing technologies and spokesmen for the BaF2 subpanel and Liquid Krypton Engineering Review were invited to make brief statements to the Executive Committee. The Committee then discussed the decision.

THE DECISION

The decision we reached, supported without dissent by the Executive Committee, is that the liquid krypton technology offers the best overall opportunity for GEM to construct a superior electromagnetic calorimeter.

This conclusion is based on the GEM goal to obtain precision resolution and took into account recent progress and expectations for continued progress. We concluded that BaF2 and Liquid Krypton both have the possibility to obtain the required resolution in the region of Higgs-->gamma+gamma, and while the BaF_2 will have better resolution at low energies, liquid krypton should have better resolution at the higher energies, which we feel are important on very general grounds for a very high energy collider. The added spatial and pointing abilities of liquid krypton will make it more robust against backgrounds and at high luminosities. Integral to this decision is the assumption that vigorous development and optimization of the liquid krypton technique will continue, and that no compromises will be made in our performance goals. For this reason, the decision explicitly excludes substituting a liquid argon filling where liquid krypton offers better performance, and assumes a vigorous effort will be undertaken to incorporate better spatial and pointing ability. We believe that this decision will lead to considerable improvement in the overall GEM detector performance and will help us to address the background rejection improvement issues pointed out by the PAC.

Finally, our decision leaves open the single remaining system choice, namely that between an integrated liquid krypton electromagnetic and hadronic calorimeter vs. a hybrid liquid krypton electromagnetic calorimeter surrounded by a scintillating fiber hadronic module. We have taken this decision under advisement and are soliciting additional information and advice with the aim of making this choice by October 1992.