The Case for the Dual Readout Calorimetry for SiD

Adam Para, December 4, 2007

Disclaimers

- We are not in a position, at the present time, to make the case anywhere solid enough for the LOI
- We may be in a position to start outlining how the case can be constructed
- We should assemble a list of questions and issues which would have to be addressed in the ideal case
- We may not be able to address all the issues at the required depth: we may have to limit the scope. Or seek more collaborators. Or, likely, both.
- Very critical approach is necessary at this stage to understand the credibility of the possible case

Elements of the case

- Physics of the dual readout calorimeter. Expected energy resolution for single particles and jets.
- Implementation of the calorimeter with homogeneous 'optical' medium with scintillation and Cherenkov readout
- Segmentation of the calorimeter: electromagnetic and hadronic sections
- Photodetectors and readout electronics
- Light collection, uniformity and efficiency
- Calibration and monitoring, systematics and the constant term
- □ Construction of a calorimeter, engineering issues
- Dual readout crystals and glasses: are there any? Can they be engineered? Large scale production and cost issues
- □ R&D program necessary to make a real case

Physics of Dual Readout Calorimetry

- How well do we understand the physics basis of the Cherenkov compensation?
- How much model-dependent (i.e. MC-modeling-dependent) the ultimate resolution is?
- How does the compensation/resolution depend on the material composition (A/Z)?
- How does it depend on the optical properties of the medium (index of refraction)
- How does the resolution depend on the total thickness of the calorimeter?
- What to do if one cannot afford 'thick enough' calorimeter? Physics of tail catcher/tagger? Ultimate limit to the energy resolution?

- Tail catching/tagging for single particles and for jets? What fraction of jets (inefficiency) one would need to reject to maintain very good energy resolution? (Resolution vs efficiency, non-gaussian tails, etc..)
- Jet vs single particle energy resolution. Jet composition dependence?
- Correction for the effect of magnetic field: jet mass reconstruction. Relation to the calorimeter granularity.
- Global vs local compensation: in a segmented calorimeter what is the optimal prescription for the compnesation?
- Measurement of spatial properties of EM showers: longitudinal segmentation of the EM section. Direction resolution. Twoparticle separation.

Intriguing Option: Recovery of the (part of) Binding Energy

- □ Idea of neutron binding energy recovery
- Gadolinium-loaded glass as a tool for the recovery/measurement of the 'missing' energy?
- Does it really work? What is the realistic timescale for the thermalization of neutrons?
- Can one produce a scintillating glass to thermalize neutrons on a microsecond-range scale?
- Depth/containment dependence of a neutronrecovery calorimeter

Dual Readout Calorimeter

- □ Cherenkov light yield: transmission as a function of wavelength
- Scintillation light yield, scintillation time constant and wavelength
- Cherenkov/scintillation separation
- Energy resolution as a function of light yield/collection efficiency. Limits for a possible Cherenkov/scintillation confusion.
- Optimal geometry/segmentation. EM section and hadronic section
- Projective vs 'regular' cell geometry
- □ Hermeticity issues: cracks and dead spots.
- Total number of channels: issues of response uniformity and calibration

PFA with Dual Readout and Vice Versa

- Motivation: high density, small size of hadronic showers as seen with Cherenkov light (quantify!)
- Performance of the 'traditional' PFA with the Cherenkov calorimetry. Dependence of the cell size
- Use of PFA to address the longitudinal leakage (problem primarily related to high momentum particles. Can one reduce the problem by selective replacement of the calorimetric information by momentum measurement?)

Light Collection and Phototransducers

- Uniformity and efficiency of light collection for different size and shapes crystals
- Optical isolation, wrapping, surface treatment of crystals (see extensive studies for CMS, BaBar)
- Direct coupling vs wavelength fiber light collection
- Photodetectors in the magnetic field: Avalanche Photodiodes? SiPM's? Depending on the direct/fiber readout?
- Front-end readout electronics: single channel vs multichannel+signal collection ASICs
- Heat dissipation
- Bias voltage distribution, signals collection, cables

Calibration and Monitoring

- Requirements for the response uniformity within a single cell and between different cells
- Absolute energy calibration
- Monitoring of the detector response using data
- Calibration/monitoring system
- (possibly) Temperature monitoring or regulation (ulikely)

Detector Construction and Engineering Issues

- □ Need a real engineer to take a critical look.
- Maintain good energy resolution with realistic material budget: supports, etc..
- Construction of ~100 ton calorimeter out of 'loose' pieces
- Servicing requirements: space technology vs 'fix-it' approach. Redundancy vs servicing requirements.
- Mechanical requirements on crystal properties

Crystals

- What crystals can be used for the dual readout? Doped PbWO4? CdWO4? Doped PbF2? CsI? Other?
- Are we constrained by the present catalog of crystals, or can one engineer crystals according to requirements?
- What is the timescale for the proof-of-principle? What is the timescale/perspective for massive (~100 ton production)?
- □ Cost, cost, cost. It is determined by a combination of:
 - □ Raw (purified) materials
 - □ Energy cost (→melting temperature !!)
 - Crucible intial investment/wear
- □ Cost dependence on size/shape of crystals
- Cost dependence on uniformity specifications

- Novel materials? (crystal fibers?)
- Realistic crystal R&D programs and possible timescales
- Manufacturers, production techniques and large scale production capabilities:
 - □ Shanghai Institute of Ceramics
 - 🗆 Saint-Gobain
 - Borogoditsk
 - Novosibirsk
 - Czochralski vs Bridgeman methods
- Crystals quality control
- Crystal Clear Collaboration and possible cooperation

R&D, Near Term

- Identify possible materials suitable for dual redaout. Produce samples.
- Develop characterization procedure (use some of the existing facilities)
- Demonstrate the performance of the separated functions EM calorimeter in the test beam (not necessarily with dual readout)
- Investigate light collection/uniformity with different light collection schemes
- Construct dual readout hadron test calorimeter and evaluate its performance in a test beam
- Study the issues of large scale production, identify cost drivers, optimize the detector design accordingly