Thoughts on Crystals, Glasses, Calorimetry R&D

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Hadron Energy Resolution

- The principal problem(s):
  - very large fraction of the primary hadron is converted into 'potential' energy necessary to extract nucleons from the nuclei (binding energy). This energy does not show up as kinetic energy of the showering particles
  - Fluctuations of the energy observed in the calorimeter are dominated by fluctuations of the binding energy losses (caused by the fluctuations in the actual numbers of nuclei broken in a given shower)
  - Any significant improvement of the hadron energy is possible only by correcting on the event-by-event basis for the binding energy losses

High Resolution Compensating Calorimeters: Possible Configurations

- Total absorption, dual readout calorimeter
  - Scintillation/Cherenkov light collection and separation from a single volume
  - Correction for the binding energy losses by EM fraction (Cherenkov/scintillation ratio)
- Total absorption scintillating calorimeter
  - Correction for the binding energy losses by detection of nuclear de-excitation following the neutron re-absorption
- Dual readout sampling calorimeter
  - Separate detection volumes ➔ sampling fluctuations
  - Correction for bonding energy losses by EM fraction (Cherenkov/scintillation ratio)

Overall Calorimeter Geometry

- High density (>6 g/cm^3)
- Combined function: Hadron/EM calorimeter
- Several depth segments in the ‘EM’ section to allow for silicon layers for the determination of spatial characteristics of the showers (position, direction, two-particle separation)
- Transverse segmentation TBD, but likely somewhere in 5×5 cm^2 range
- Segmentation in the hadronic section determined by practical considerations (for the total absorption calorimeters) or by the optimization of the energy resolution (in the sampling calorimeter case)
- A reality check: SiD calorimeter (as an example) == 80 m^3(6-7λ). Take 5×5×10 cm^3 cells = 2.5×10^{-4} cm^3 ➔ 320K readout channels

Problems Common to All Designs

- Light collection from a plate/cube/detecting volume
  - Coupling efficiency. What fraction of the emitted light is detected ? As a function of wavelength?
    - Wrapping, groves, optical coupling?
    - Fiber/direct readout?
    - ➢ Need systematic studies, cosmic test stand? (NIU? Pisa? Fermilab?)
- Photodetectors. SiPM's? are APD's an option for direct coupling??
- Mechanical design (structural design of the calorimeter)
  - Cables (power in/signal out)
  - Power dissipation
  - ➢ Engineering studies probably premature at this point

Total Absorption, Dual Readout

- Scintillator/Cherenkov radiator:
  - PbWO4?
  - PbF2 doped with scintillator?
  - Scintillating glass transparent for Cherenkov?
  - Need samples, need to demonstrate experimentally scintillation/Cherenkov light separation using timing and/or wavelength (Shanghai/Pisa/Fermilab/Seattle)
  - Is the Cherenkov/scintillation separation possible with the WLS fiber readout? (need slow scintillation ~1μsec)
- Photodetector for Cherenkov light, if direct coupling?
- Detector optimization: scintillating glass likely to be cheaper than the ‘dual’ medium.
  - What volume needs to have dual readout?? (George’s Geant 3 simulation?)

Total Absorption, Scintillation Only

- Gadolinium loaded scintillating glass
  - Demonstrate experimentally the detection of photon cascades from the neutron capture
  - Test beam prototype 30×30×50 cm^3 (18 10×10×25 cm^3 blocks), look for the late component of the hadron shower.
  - Compare temporal distribution of the signal of the hadron cascade with the ‘normal’ scintillating glass
  - Neutron reflector?

Spatial Measurements in the EM section

- Longitudinally segmented ‘optical’ calorimeter allows for decoupling of the energy measurement function for the spatial measurements function.
- Demonstrate the position/angle resolution and two/more tracks separation with a test beam prototype with 2? 3? layers of silicon pixel detectors (CALICE? SLAC/Oregon/Brookhaven?)