Forward Calorimetry Ideas

Ren-Yuan Zhu

California Institute of Technology

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Introduction

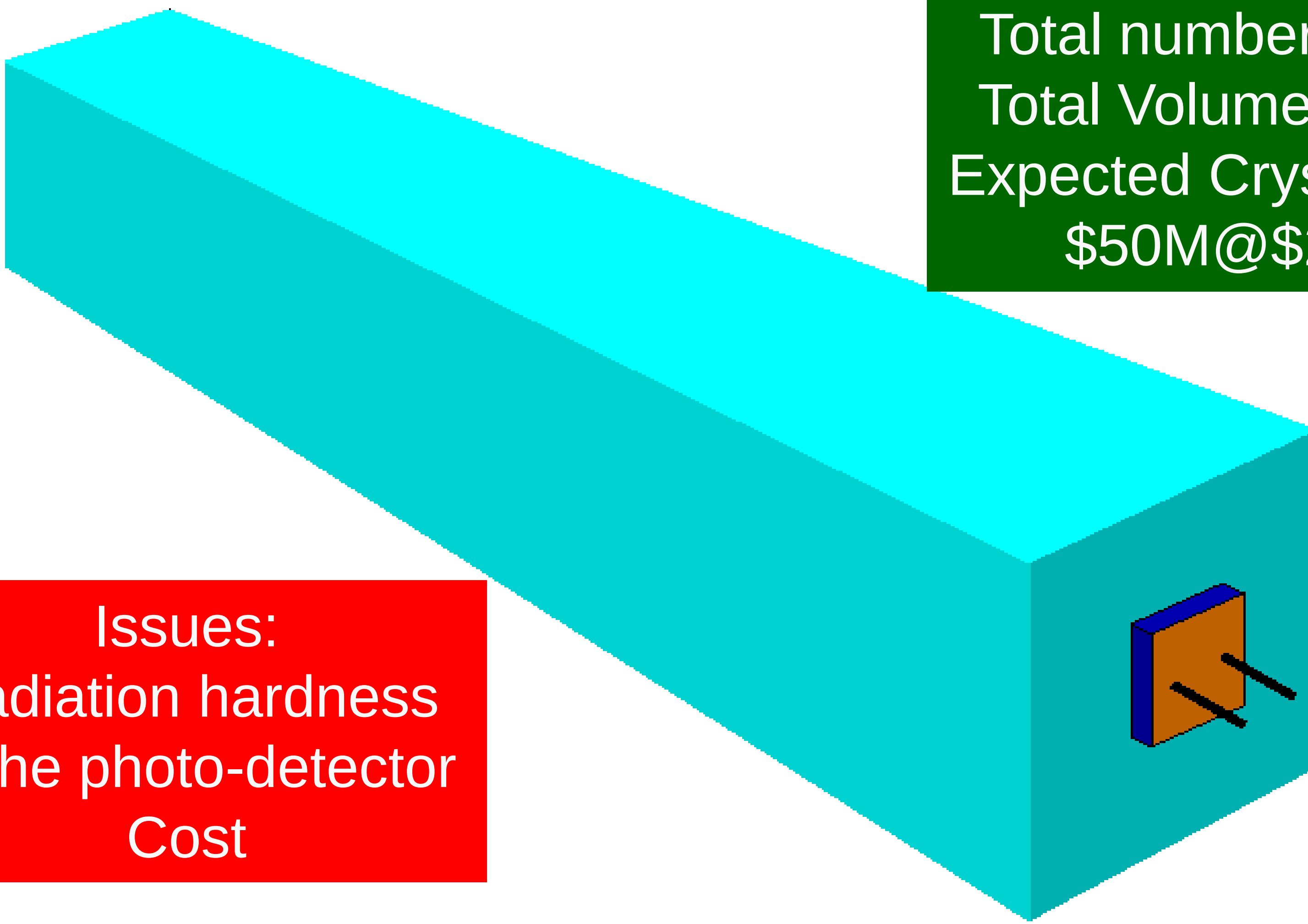
LSO/LYSO is a bright (200 times of PWO) and fast (40 ns) crystal scintillator. It has been widely used in medical industry. Its mechanical characteristics allows it to be used in various forms for different calorimeter designs.

Supported by DOE ADR and US CMS Upgrade Effort the Caltech group has been investigating this material for HEP applications since 2005. It was found that its radiation hardness is excellent against γ–ray and neutrons. Work by the ETH group also found that it is radiation hard against high energy protons. It thus is an excellent candidate material for the high luminosity LHC.

References: *IEEE Trans. Nucl. Sci.* NS-52 (2005) 3133-3140, *Nucl. Instrum. Meth.* A572 (2007) 218-224, *IEEE Trans. Nucl. Sci.* NS-54 (2007) 718-724, *IEEE Trans. Nucl. Sci.* NS-54 (2007) 1319-1326, *IEEE Trans. Nucl. Sci.* NS-55 (2008) 1759-1766 and *IEEE Trans. Nucl. Sci.* NS-55 (2008) 2425-2341, paper N69-8 @ NSS08, Dresden, paper N32-3, N32-4 and N32-5 @NSS09, Orlando.

An LYSO Endcap ECAL

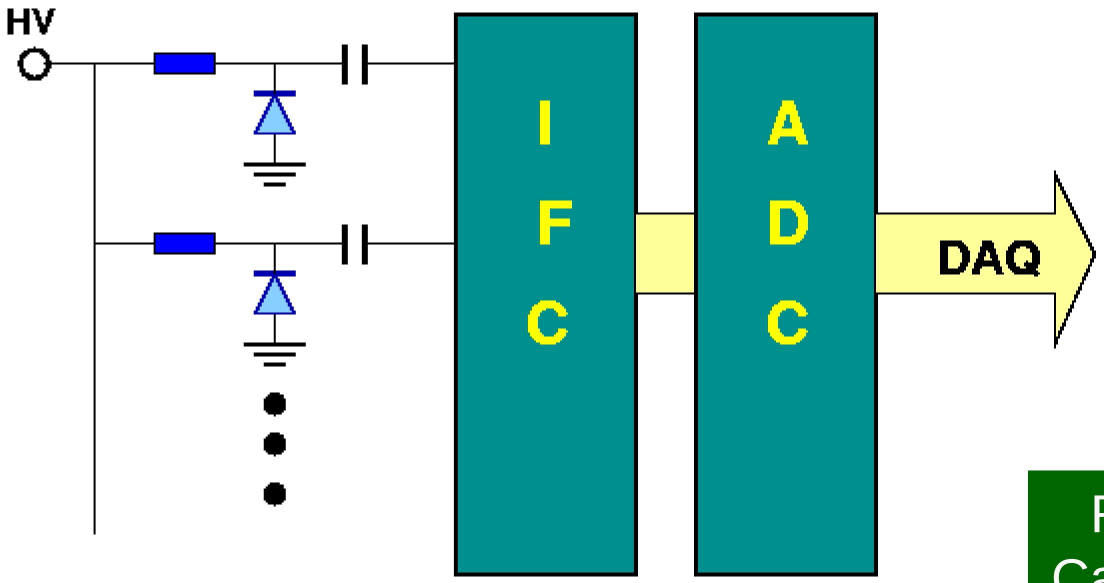
CMS ECAL endcap:
Single Crystal: 160 cm^3
Total number: 16,000
Total Volume: 2.5 m^3
Expected Crystal Cost:
$50M@$20/cc



Issues:
Radiation hardness
of the photo-detector
Cost

Ways to Handle the Neutron Induced Nuclear Counter Effect

Multiple independent readout channels are a good solution. The potential high cost may be minimized by an intelligent frontend chip (IFC) which reads out only uncontaminated signals.



R.Y. Zhu, talk in Calor 2010, Beijing

Advanced data analysis may also be implemented to reduce this effect.

Possible Applications in F. Cal.

A Joint Proposal by Caltech and ETH

i. LYSO/LSO could be used for a replacement preshower detector. Its material characteristics allow it to be machined into mm-sized crystals, as already done for PET applications.

ii. LYSO/LSO could be considered as a first sampling section to be added in front of part of the existing EE, once the ES is removed as planned. In fact, while PWO is expected to degrade, it will still continue giving some signal. Its energy resolution performance might be enhanced by introducing a LYSO/LSO first sampling layer, a few radiation lengths deep.

iii. This material has excellent radiation resistance. If an EE replacement is needed, as a most affordable option, CMS might want to consider constructing new, hybrid end-caps, where LYSO/LSO crystals are implemented in the highest-η region and a different kind of crystals is used in the lower-η region.

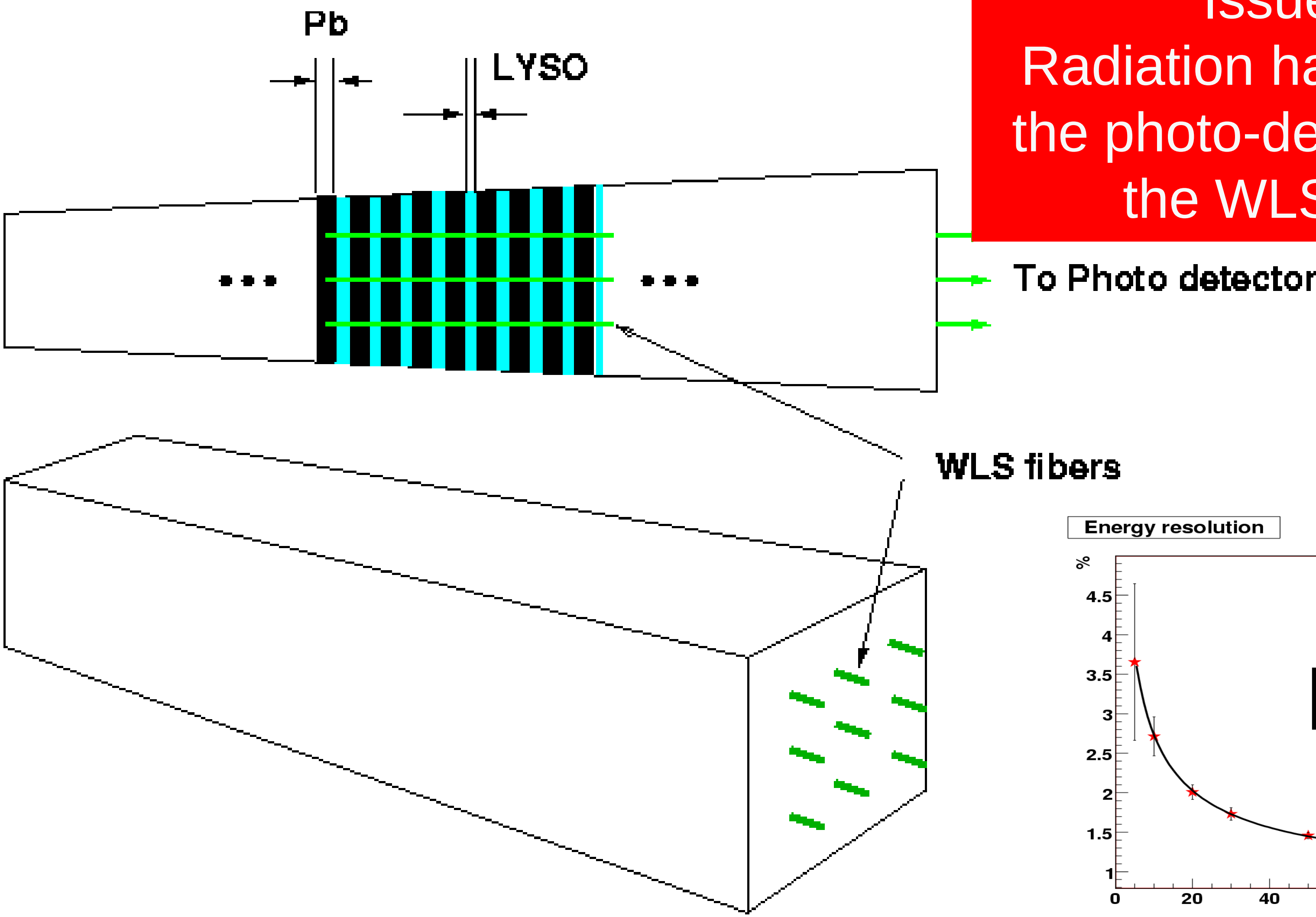
iv. LYSO/LSO has a superb light yield. A different option for EE replacement could be built e.g. as a sandwich calorimeter made out of $1X_0$ (3.5 mm) W-plates interleaved with thin LYSO slides, read out over an air gap and quartz fibers. This would allow for accommodating 25 X_0 in less than 15 cm depth.

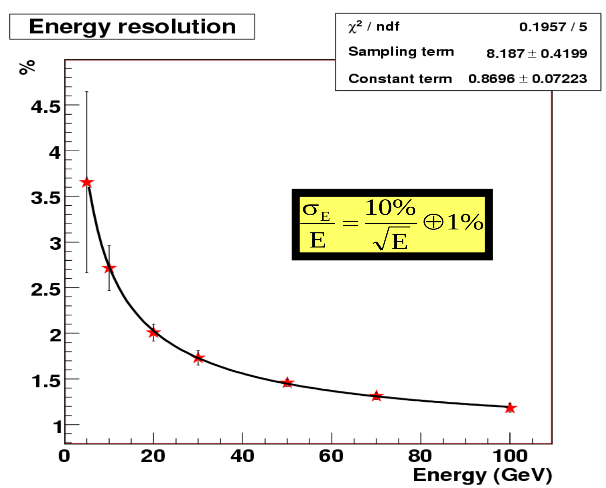
v. An HCAL application could be in form of a sandwich calorimeter with plates of graduated thickness and still-thin LYSO layers.

An LYSO Shashlic ECAL

Crystal volume may be reduced by a factor of >5 to <$10M

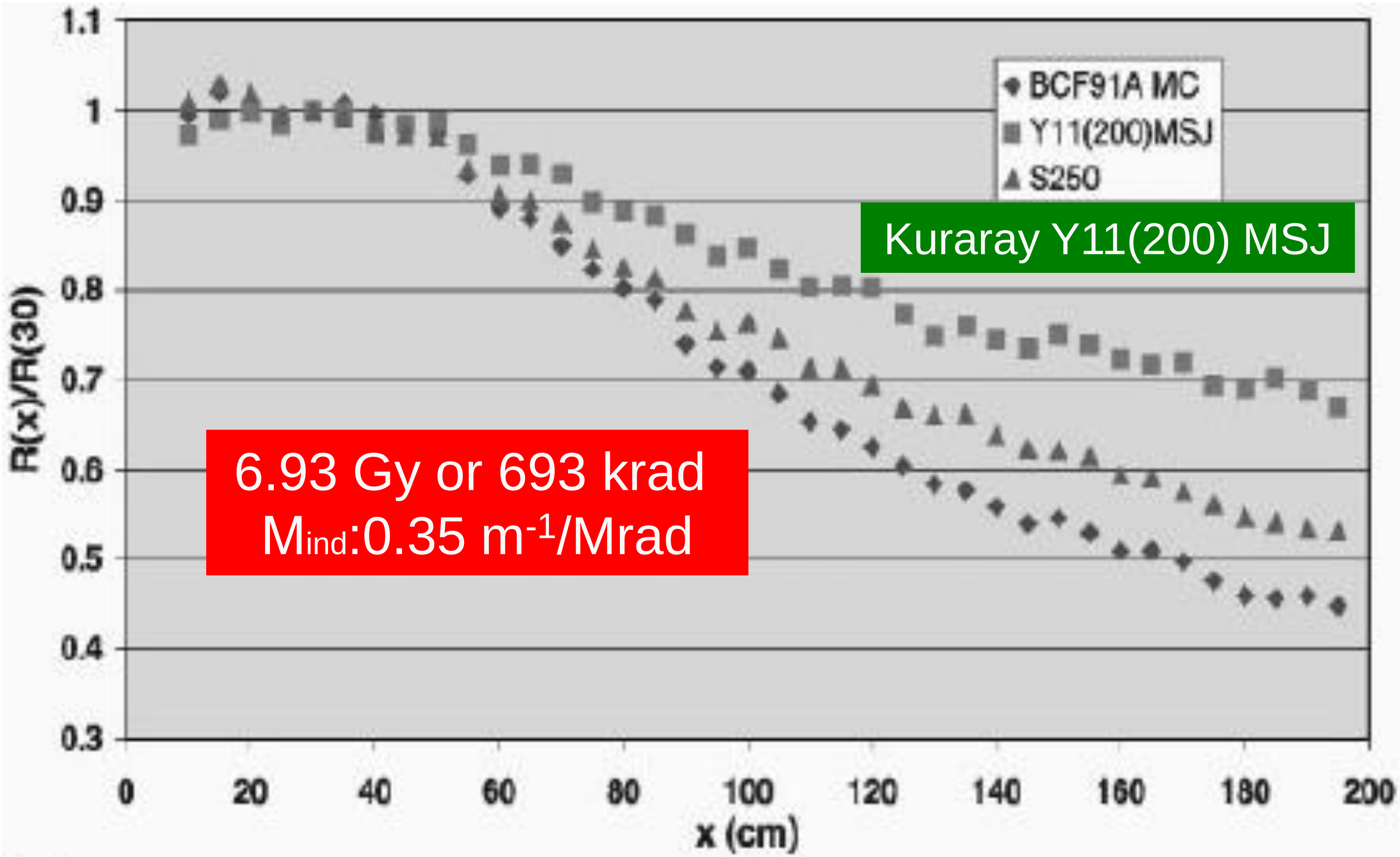
Issues:
Radiation hardness of the photo-detector and the WLS fiber





Radiation Hardness of WLS Fibers

M. David, A. Gomes, A. Maio, NIM A453 (2000) 255.



The HHCAL Detector Concept (I)

A Fermilab team (A. Para et al.) proposed a total absorption homogeneous HCAL detector concept (HHCAL) for the International Linear Collider to achieve good jet mass resolution, where both Cherenkov and scintillation lights are measured for good hadronic energy resolution.

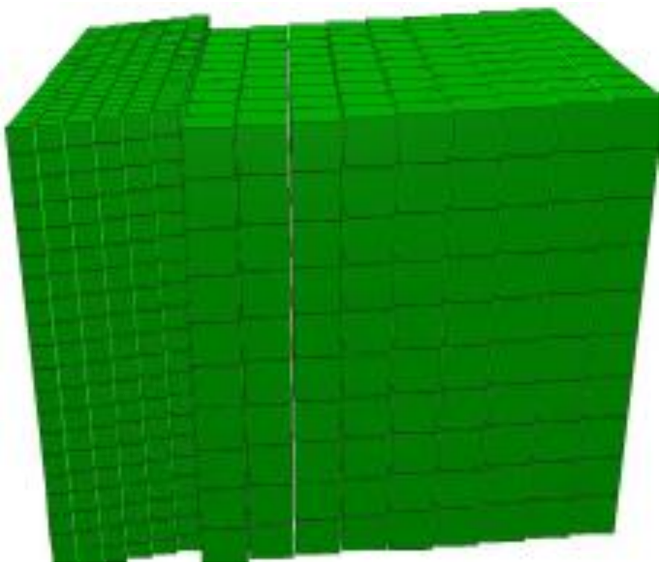
Requirements to Materials for HHCAL:

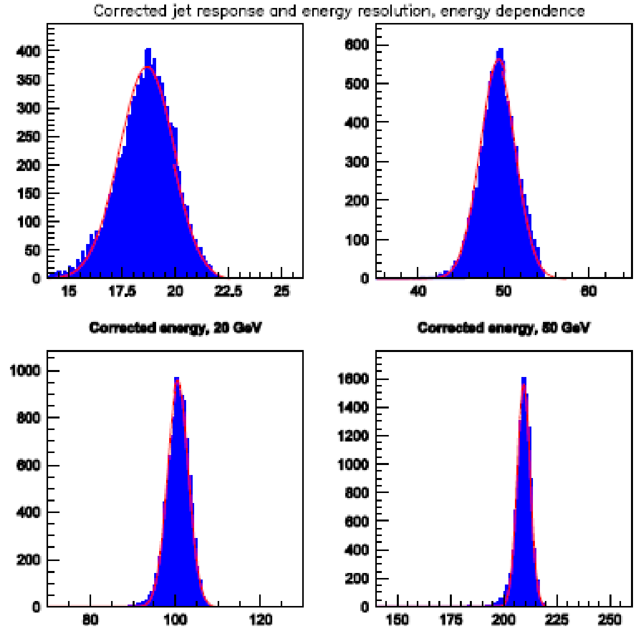
- **Short nuclear interaction length: ~ 20 cm.**
- **Good UV transmittance: UV cut-off < 350 nm.**
- **Some scintillation light, not necessarily bright and fast.**
- **Cost-effective material: < \$2/cc for 100 m^3 !**

Candidate materials: PbF_2, PbClF, BSO, glasses, ceramics

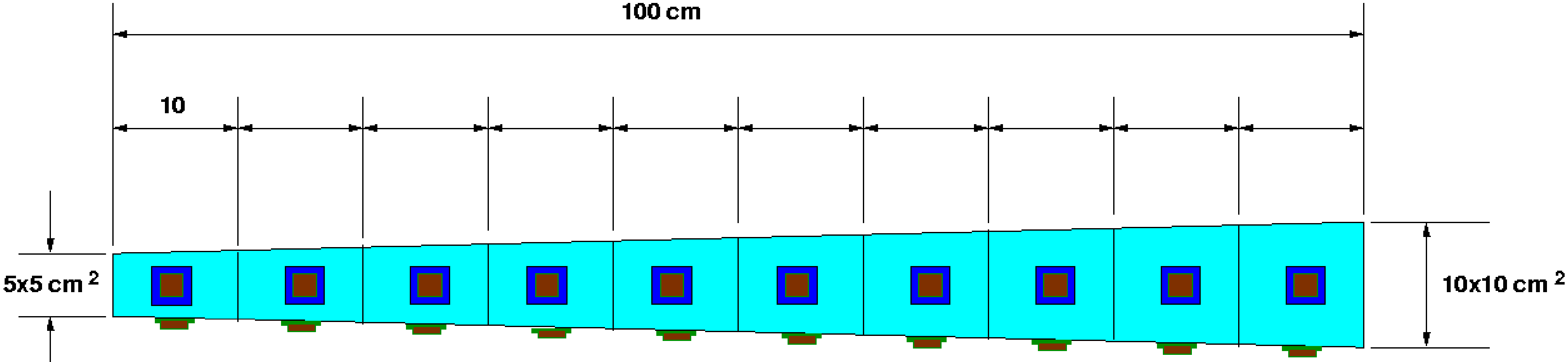
Radiation hardness of the material is not required at ILC/CLIC!

The HHCAL Detector Concept (II)





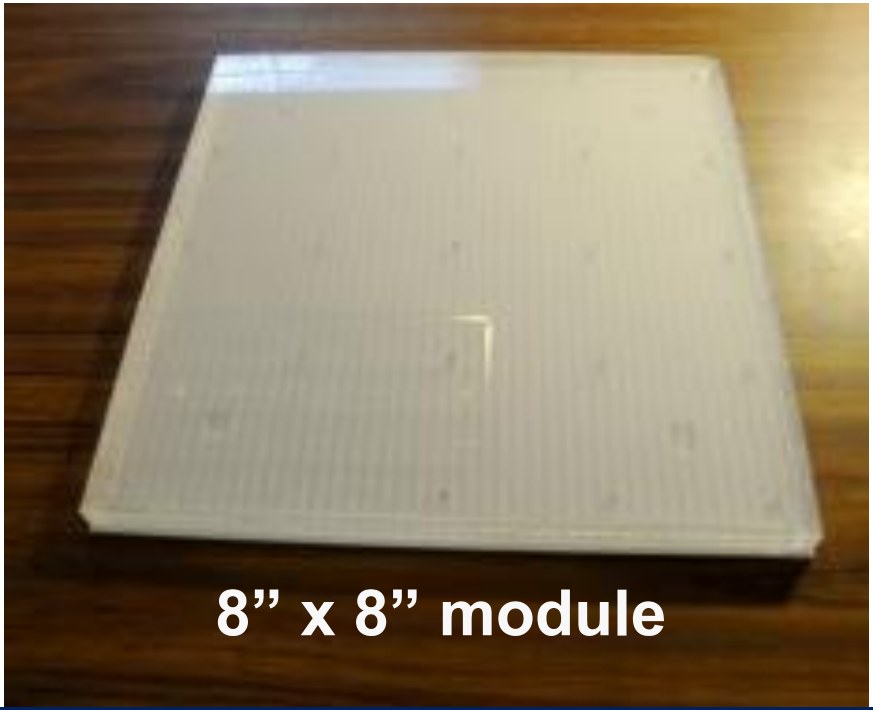
See H. Wenzel, talk in Calor2010: GEANT simulation shows jet energy resolution of better than 20%/√E after corrections.



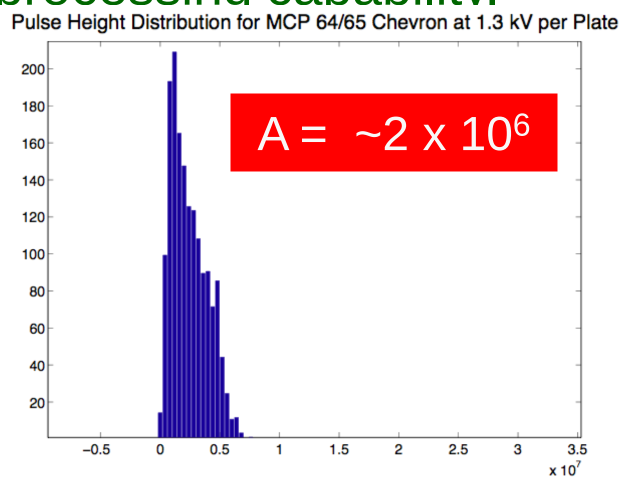
R.-Y. Zhu, ILCWS08, Chicago: a HHCAL cell with pointing geometry
Many structure details can be borrowed from the LHC calorimeters

Readout: Large Area Photo-Detector

H. Nicholson, talk at HEPAP, June 3, 2010



University of Chicago and ANL: large area, "flat panel" photo-detector using atomic layer deposition and relatively inexpensive channel blanks to generate a micro-channel plate gain stage with the readout consisting of transmission line traces on circuit board with custom ASIC processing capability.



Very good timing resolution (~10 psec); Good spatial resolution (~mm); High gain (~1 x 10^6); Less expensive than conventional photomultipliers of similar area; Thin and mechanically robust with relatively few electrical connections; Internal signal processing capability.