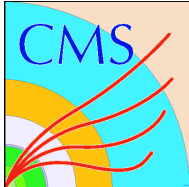


“Summary of HE Upgrade Studies”

Yasar Onel

HE Upgrade R&D Group:

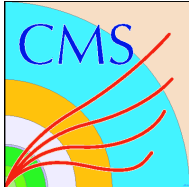
Iowa, Fairfield, Fermilab, Mississippi, Notre Dame, Trieste



Outline



- **0th Phase of R&D**
 - Show that Quartz is Radiation Hard
- **1st Phase of R&D**
 - Cherenkov Light Collection from Quartz Plate
 - Tests of WLS fiber Embedded Quartz Plate Calorimeter
- **2nd Phase of R&D**
 - Light enhancement tools: ZnO, PTP
 - Tests of PTP Deposited Quartz Plate Calorimeter
- **3rd Phase of R&D**
 - Alternative readout options: SiPMT, APD
 - Radiation Hard WLS Fiber options
- Final Upgrade Proposal



Zeroth Phase of R&D



- We tested various quartz types under electron, proton, neutron, and gamma radiation.

Electron Irradiation Tests:

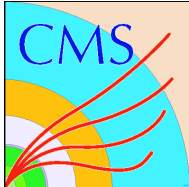
Dumanoglu *et al.* “Radiation-hardness studies of high OH content quartz fibres irradiated with 500 MeV electrons” **Nucl. Instr. Meth. A 490 (2002) 444-455**

Proton Irradiation Tests:

Cankocak *et al.* “Radiation-hardness measurements of high OH content quartz fibres irradiated with 24 GeV protons up to 1.25 Grad” **Nuclear Instruments and Methods in Physics Research A 585 (2008) 20–27**

Neutron and Gamma Irradiation Tests:

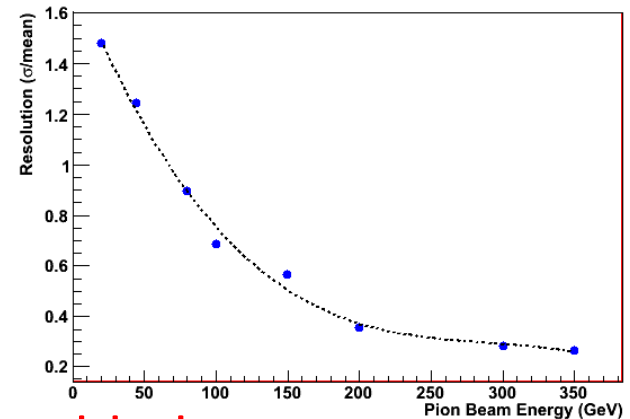
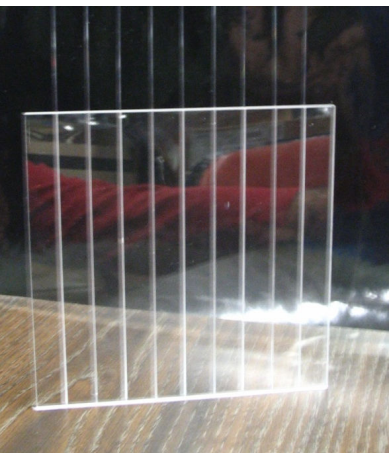
Bruecken *et al.* “Radiation Damage in Quartz Fibers Exposed to Energetic Neutrons”
CMS Internal Note 2006/014



First Phase of the R&D



We showed that Cherenkov light collection inside the quartz is feasible with UV absorbing WLS fibers.

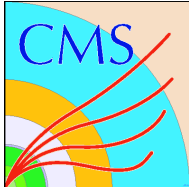


We built and tested “WLS Fiber Embedded Quartz Plate Calorimeter”



F. Duru *et al.* “CMS Hadronic EndCap Calorimeter Upgrade Studies for SLHC - Cerenkov Light Collection from Quartz Plates” , **IEEE Transactions on Nuclear Science**, Vol 55, Issue 2, 734-740, Apr 2008.

U. Akgun *et al.*, "Quartz Plate Calorimeter as SLHC Upgrade to CMS Hadronic Endcap Calorimeters", XIII International Conference on Calorimetry in High Energy Physics, CALOR 2008, Pavia, Italy, May 2008, Published in **J.Phys.Conf.Ser.160:012015, 2009** and **CMS-CR-2008-056**

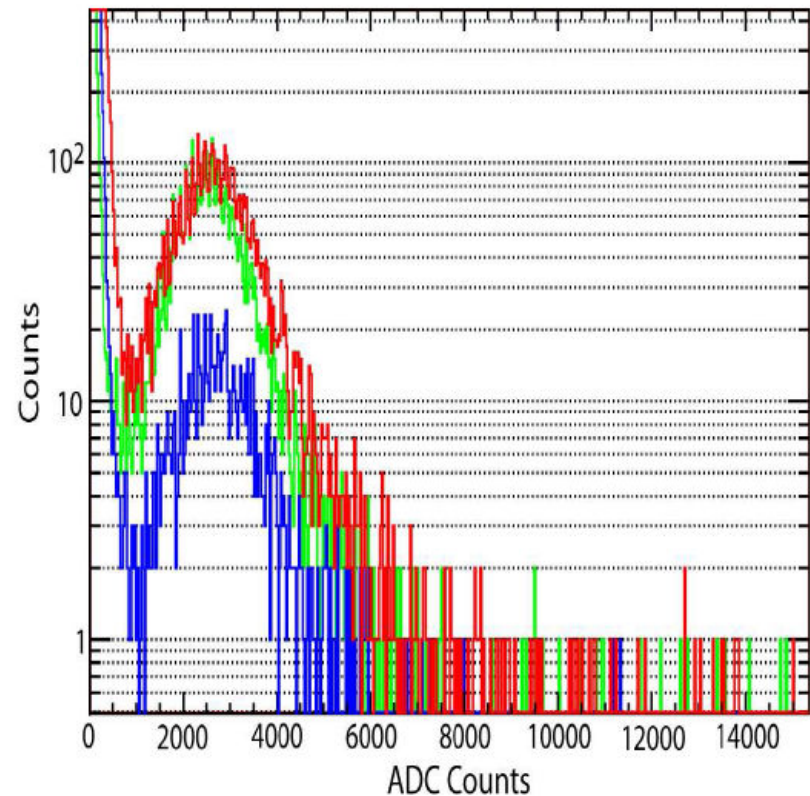
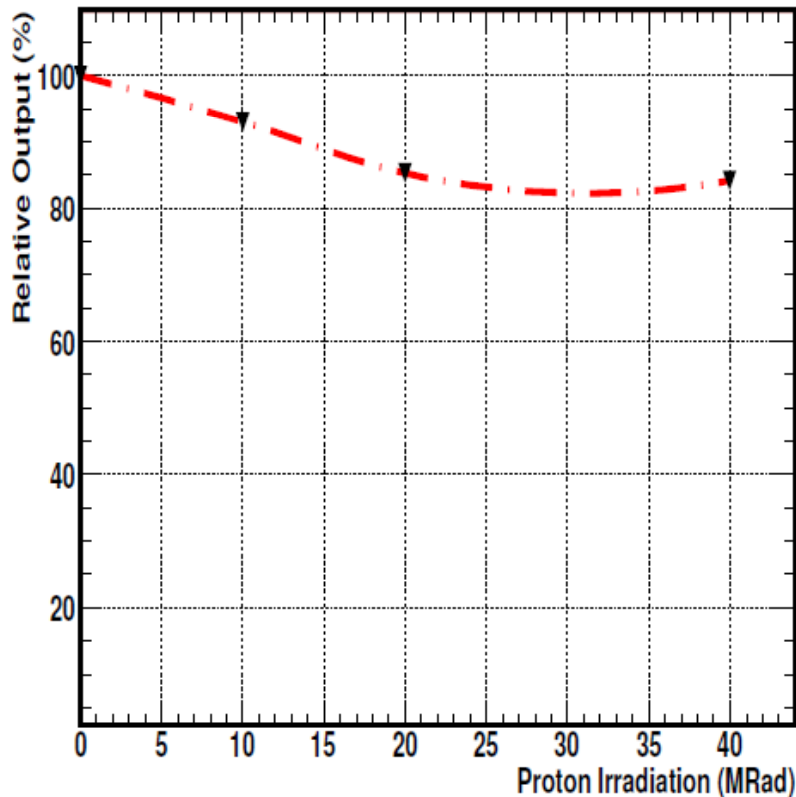


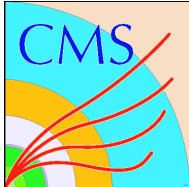
Second Phase of the R&D



We showed that radiation hard light enhancement tools (pTp, and ZnO) can be used with quartz.

U. Akgun *et al.*, "P-Terphenyl Deposited Quartz Plate Calorimeter Prototype", IEEE Nuclear Science Symposium Conference, Dresden, Germany, 19-25 October 2008



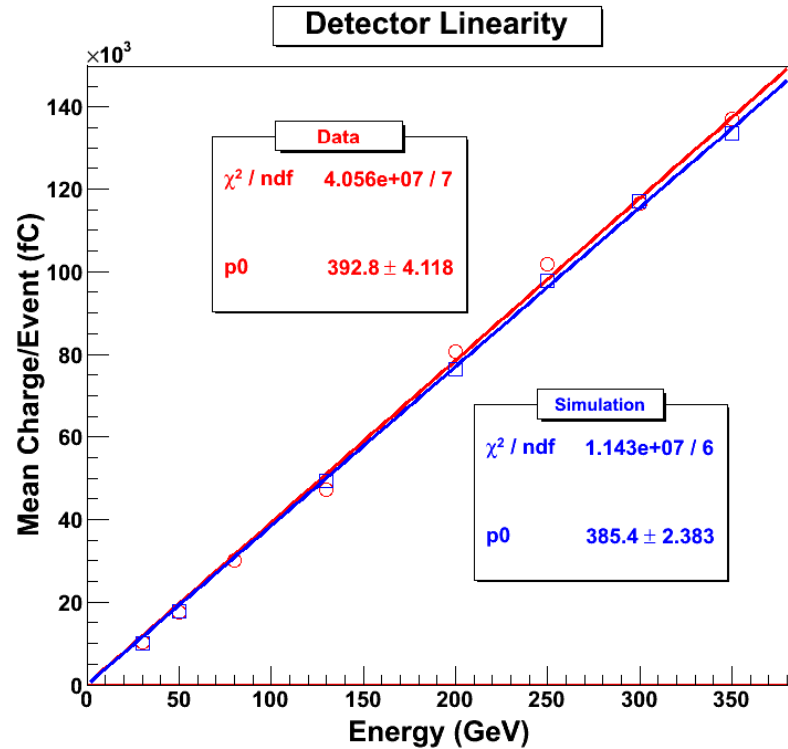
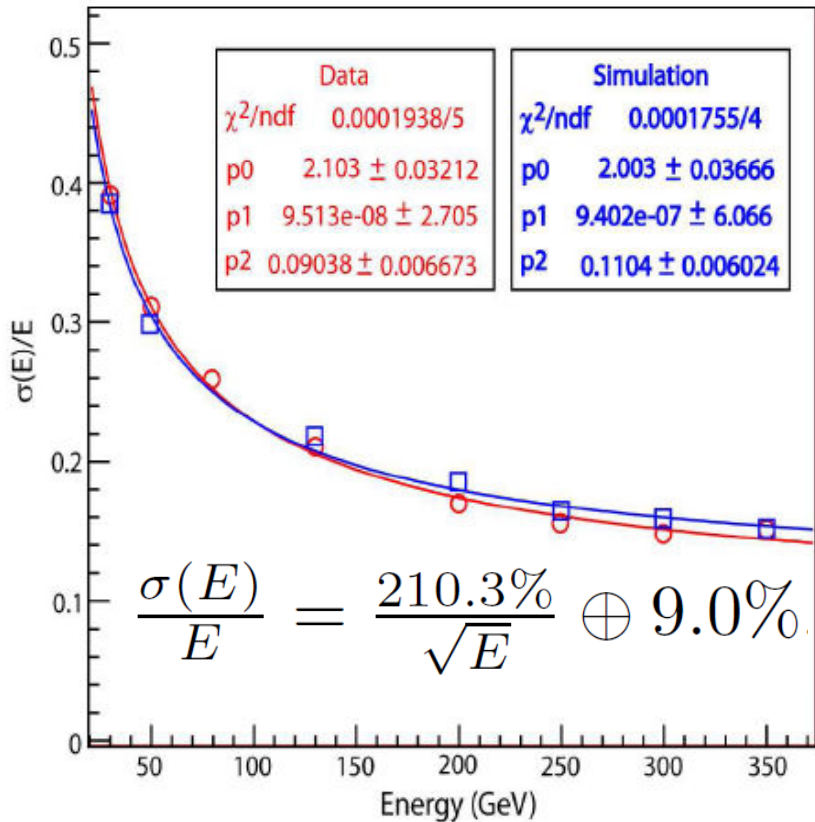


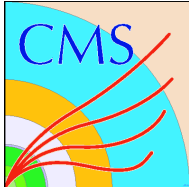
Second Phase of the R&D (HAD)



We built and tested "PTP Deposited Quartz Plate Calorimeter"

U. Akgun *et al.* "CMS Hadronic Calorimeter Upgrade Studies - P-Terphenyl Deposited Quartz Plate Calorimeter Prototype ", APS 2009, Denver, CO, USA, May 2009

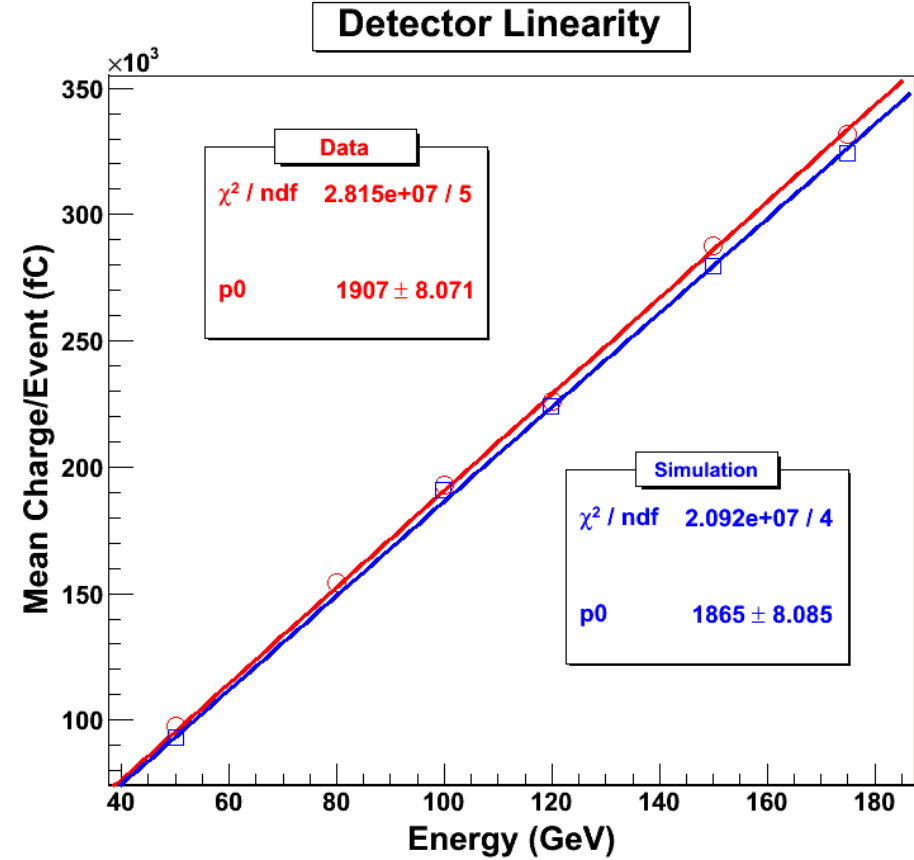
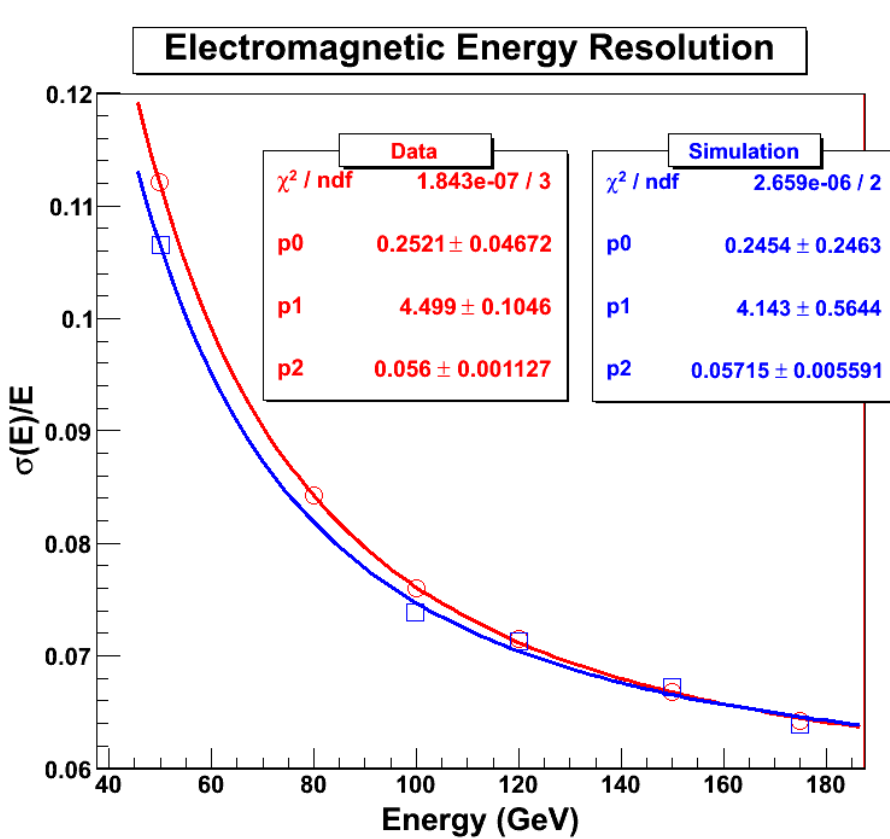




Second Phase of R&D (EM)



We also run pTp calorimeter in EM mode (with 2 cm absorber thickness). We can Use combination as radiation hard **CMS Endcap Calorimeter (EE + HE)**.

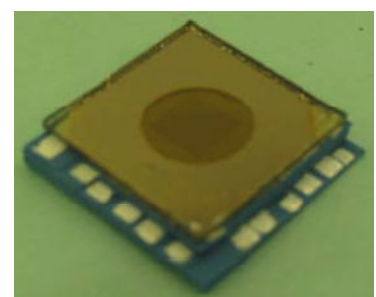
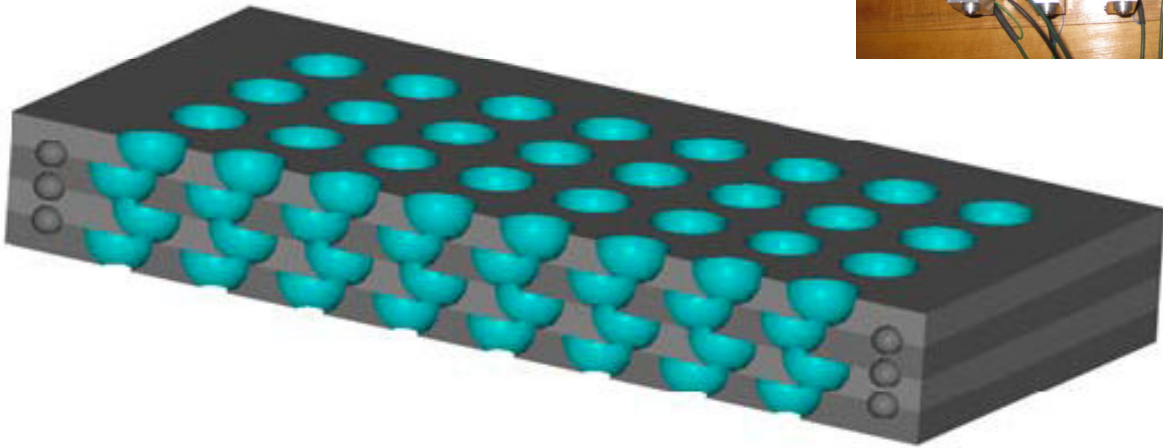
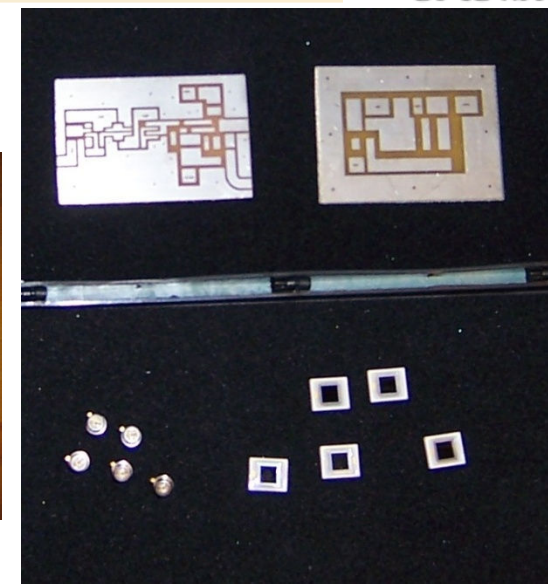


$$\frac{25.2\%}{\sqrt{E}} \oplus \frac{4.5\%}{E} \oplus 5.6\%$$

Third Phase of the R&D

We constructed and tested alternative readout options from pTp deposited quartz plates:
APD, SiPMT, PIN diode.

They are not very effective and most importantly, the APD and SiPMTs are not radiation hard.



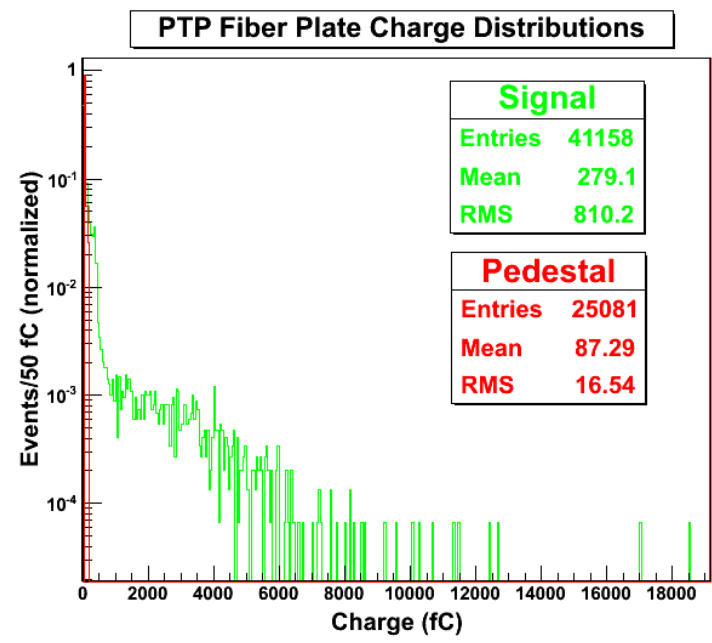
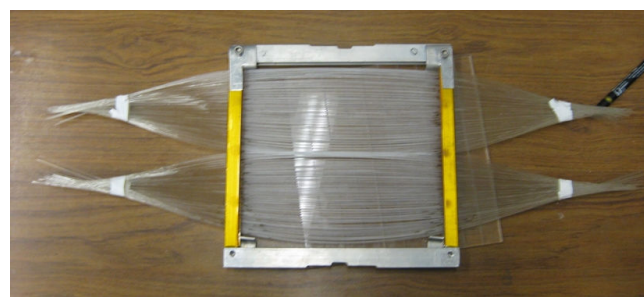
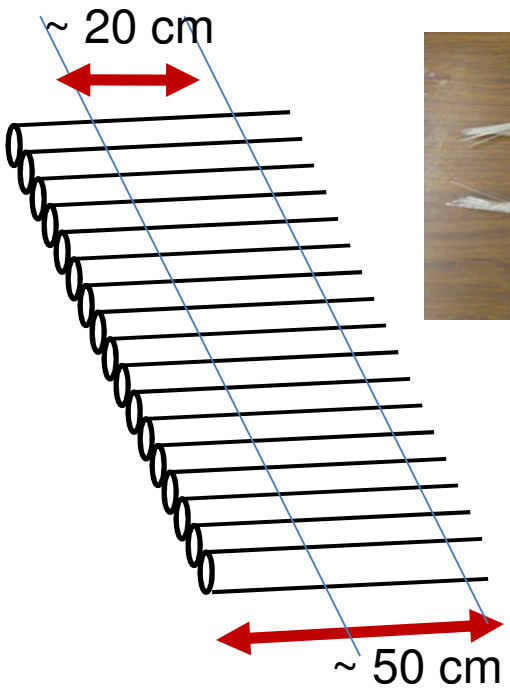
Our solution for alternative readout is “Microchannel PMT”

Fast response time, high gain, small size, robust construction, power efficiency, wide bandwidth, **radiation hardness**, and low cost.

Third Phase of the R&D

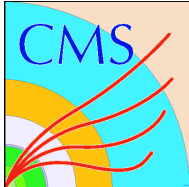
We Develop Radiation Hard Wavelength Shifting Fibers: Quartz fibers with PTP/ZnO covered core.

We built a radiation hard WLS fiber prototype. We deposited pTp on the stripped region, on both face. Then the whole ribbon will be sandwiched between quartz plates.



The red line show the pedestal. With a very simple prototype we collected substantial signal.

We prepared a “homemade” rad-hard WLS fiber. We stripped the plastic cladding from QP fibers for “middle 20 cm” portion of 60 cm fibers. This unit was tested with 80 GeV electron shower.



Final Plan



- We have two “viable” options for HE Upgrade:
 - Will read signal from PTP deposited plate, directly.
 - This will require radiation hard detector: multi channel PMT.
 - The current technology of APD and SiPMT is NOT enough.
 - Will use WLS fibers
 - This requires rad-hard WLS fiber, which DOES not exist.
 - We built a primitive prototype with PTP, it is promising. Need R&D on PTP, ZnO deposition on quartz fibers. Sapphire fiber is another option.