ECAL for GEp5

B. Wojtsekhowski

Electron Calorimeter for GEP

Performance Requirements

- Function: Detect 4 to 5 GeV Electrons
- Energy resolution: σ/E at least 10% for 3.5 GeV
- Spatial resolution: 6-8 mm
  (2 mm with upstream coordinate detector)
- Full luminosity: 26-29 degrees, 8×10^{38} Hz/cm^2
- Trigger: Overlapping segments correlated with the proton
  Trigger at threshold > 75% of elastic peak

PMT dark current induced TR

a) Emissivity of glass and a heater

100% = Emissivity + Transmisivity + Reflectivity

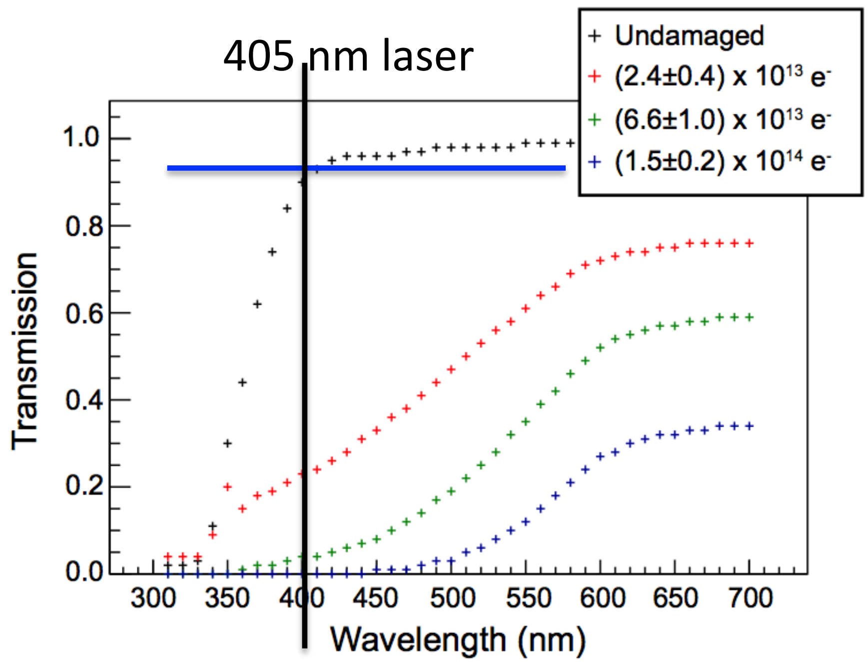


Figure 5: Transmission coefficient of 4 cm of lead glass as a function of wavelength for various amounts of radiation. Estimated errors are 2% (10%) for wavelengths above (below) 380 nm.

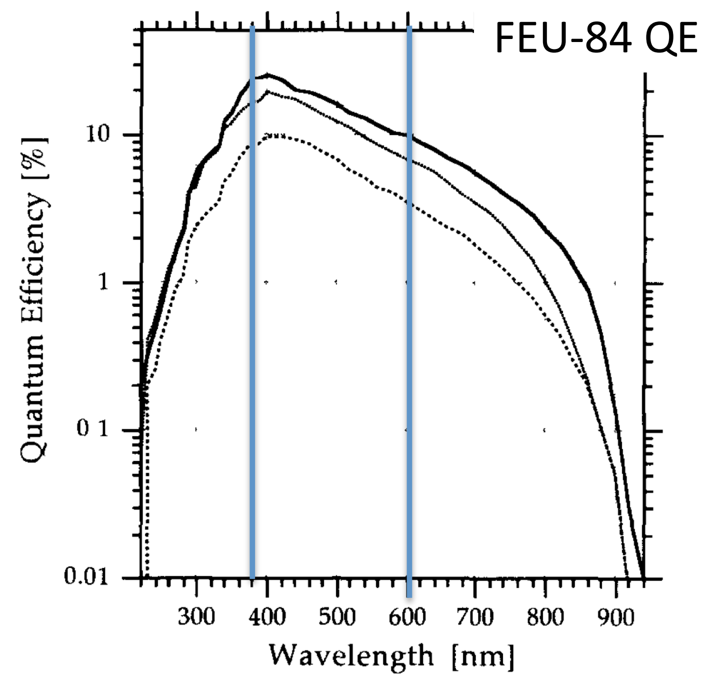
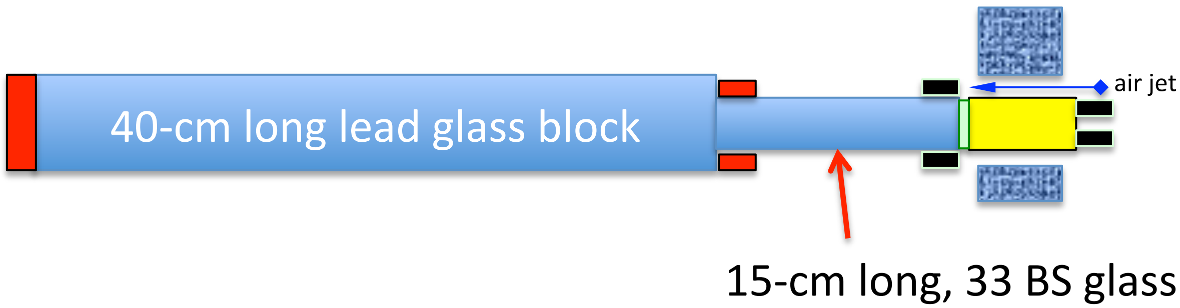
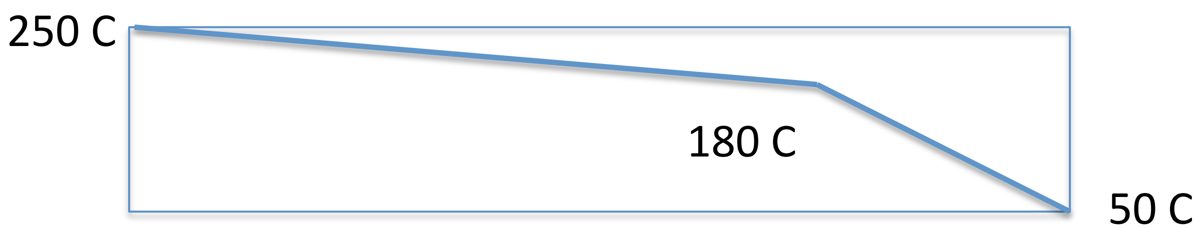


Fig. 4. The absolute quantum efficiency of three FEU-84-3 phototubes as measured by Hamamatsu Inc. using a calibrated source. Three tubes were selected, using the method described in the text, as having relatively high, medium and low relative quantum efficiencies.

The high temperature ECal

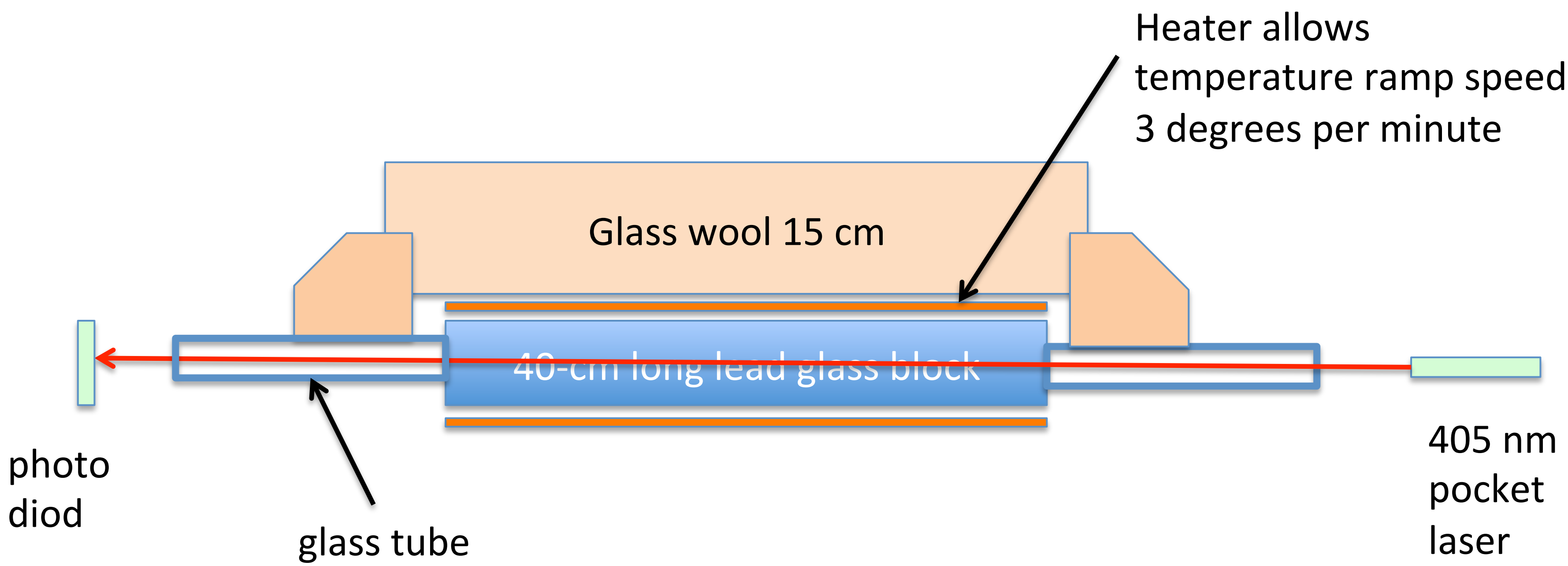




Temperature profile

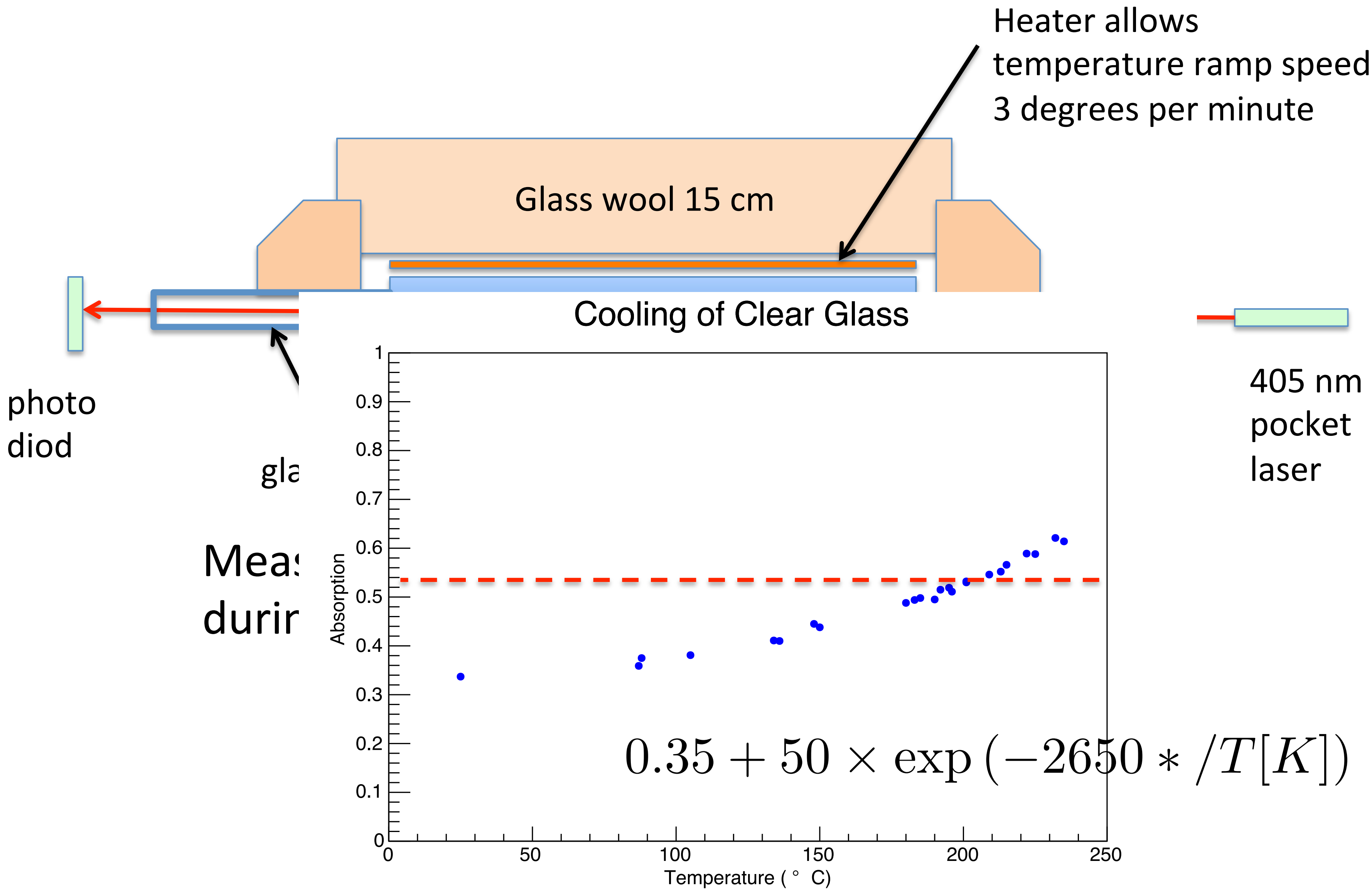
Power: 0.008x7x130/15 = 0.6 W heat leak through the light guide

The annealing experiment



Measurement of the transparency at 405 nm during the thermal annealing process

The annealing experiment



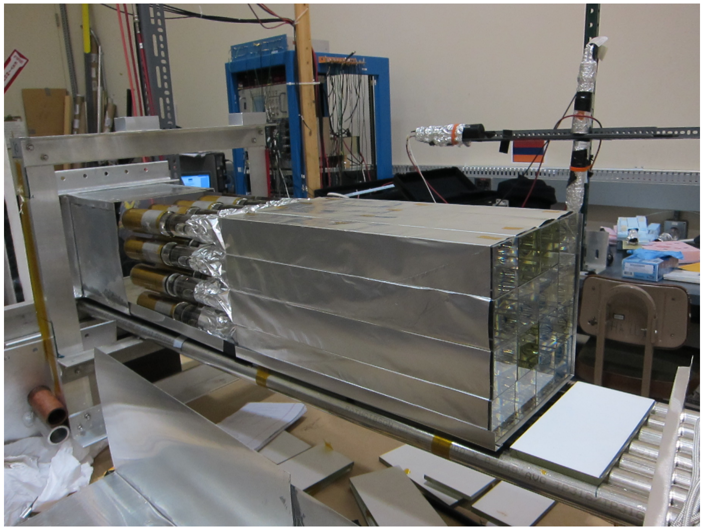
Electron Calorimeter for GEP

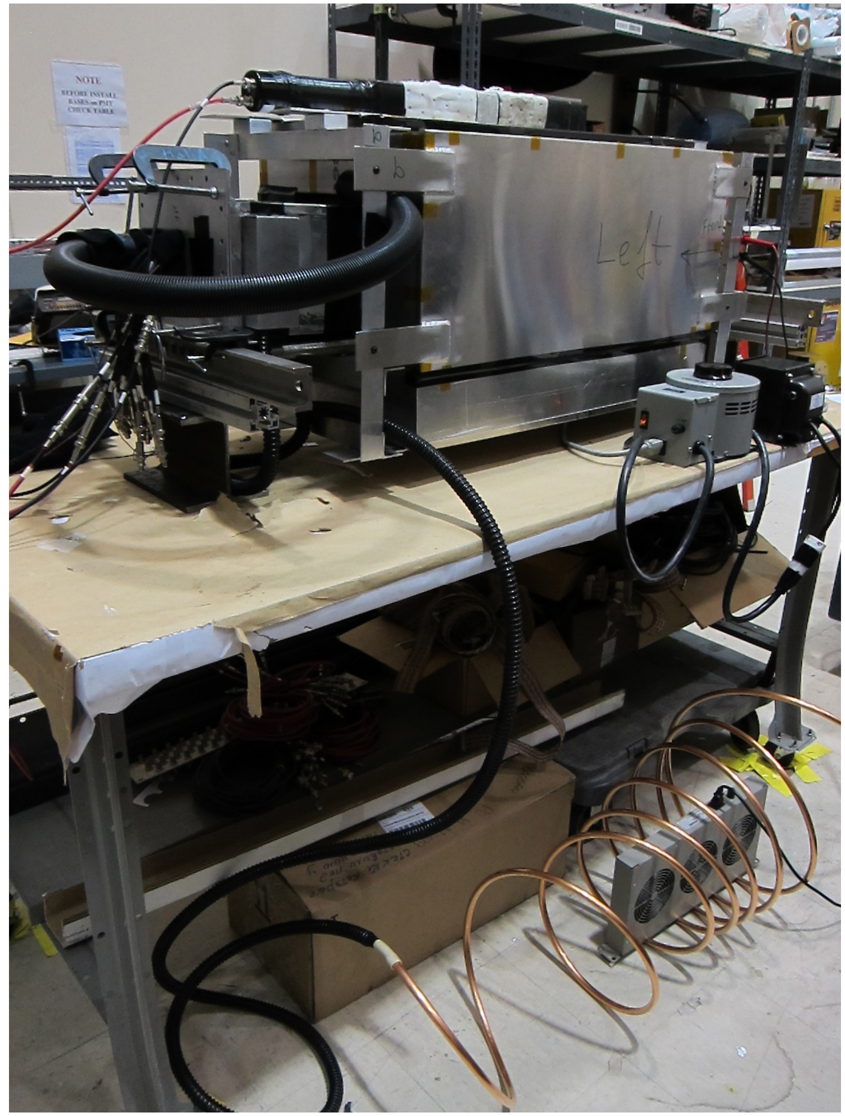
The idea of continuous thermal annealing of the ECal is an example of innovative thinking that, if it tests out successfully, will make a significant improvement in the ECal operation. There is concern about operating PMTs at an elevated temperature, however. Implementation of the ECAL annealing scheme on the scale of the full detector assembly will no doubt take some further development; a several detector element test assembly operated and monitored in a beam/radiation environment may be the best way to confirm viability of the approach, including mechanical, temperature and readout stability issues.

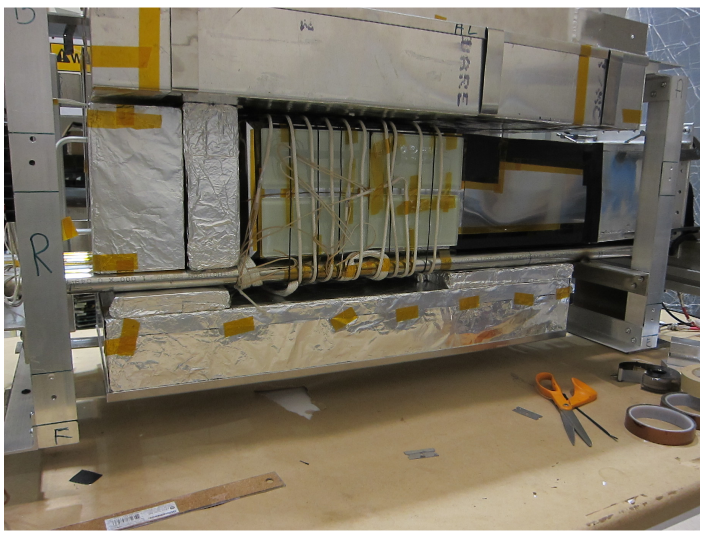
SBS review 2014

Recommendations:

- The collaboration should test the continuous thermal annealing in a realistic radiation environment with constant monitoring of the detector response, before finalizing the design of the detector.







How large is the large radiation dose?

Radiation damage monitor

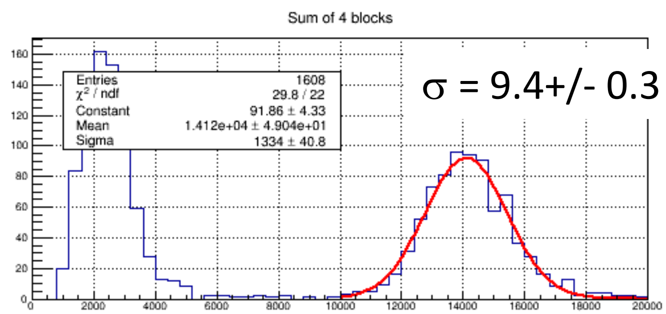
Could be estimated to be at least 30 kRad in 6 hours

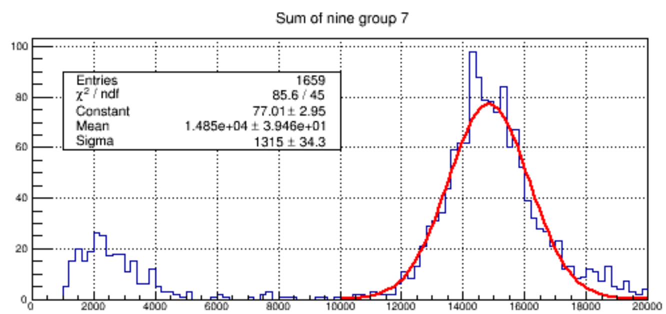
~ 10 times of GEP projected dose rate

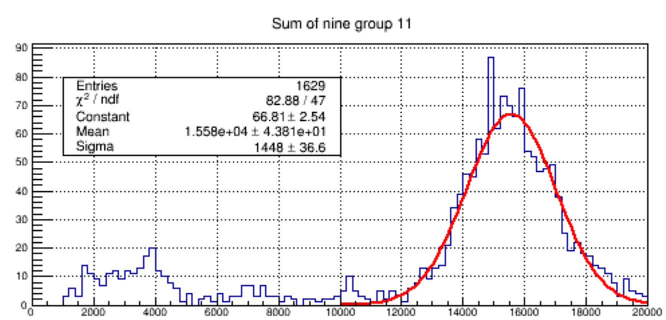
Calibration with 1.6 GeV electrons

Before the large radiation dose

for run 755 at 6 uA

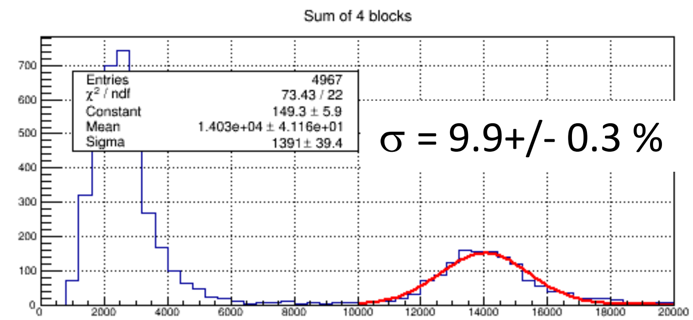


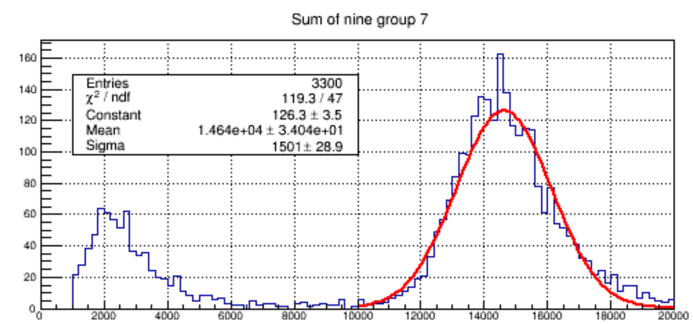


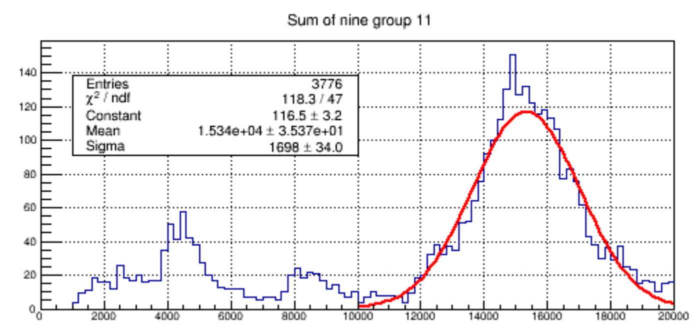


After the large radiation dose

' run 772 at 6 uA







Electron Calorimeter for GEP

- The scheme for the continuous ECAL annealing uses a temperature profile along the length of the lead glass blocks, ~ 250 degree C at the entrance with a “hockey stick” drop to 50 degrees C at the readout end where an air jet cools the phototube on an extended light guide.
- A test comprising a 16-bar ECAL prototype for continuous annealing of radiation damage was carried out in May 2015; measurement of the resolution of the bars before and after a large radiation dose indicated a slightly elevated average sigma but acceptable and within errors; an associated average gain factor compensation was observed to be ~ 25%.
- A dynamical model of the radiation damage and annealing has been developed with parameters determined from a series of bench tests using damaged cells under heat treatment annealing; included in the model is some increase in absorption arising from the heating of the lead glass bars themselves.
- The fabrication of an ECAL C200 frame is ongoing as the next stage of testing in order to understand the heating and mechanical issues associated with a large array of ECAL blocks (~ 10% of final ECAL array). The finite element analysis program COMSOL has been found useful to evaluate the thermal and mechanical issues of the design
- A sequence of milestones was presented for further testing and design of the final ECAL frame and oven; a goal of lead glass installation starting January 15, 2017 and cosmic ray tests finished and detector ready for installation January 15, 2018.

Electron Calorimeter for GEP

- The ECal design has changed from the original proposal. The change in design has caused a considerable delay of the possible start of the SBS proton form factor physics program.
- While the 16 bar prototype test was a significant proof-of-principle for in-beam heat annealing, it appears not to be scalable. A validated model will be critical for design of the full scale equipment. The available observations should be used to further tune and refine the model, an effort that so far appears not to have been done.
- Judging from the presentations so far, implementation of an ECAL annealing scheme on the scale of the full detector assembly will take some further R&D which poses some risk. The C200 prototype test appears to be a reasonable next step in order to understand what is required to construct the full ECAL array with continuous heat annealing.

SBS review 2015

Recommendations:

- The team should provide to DOE a report on the annealing tests by Feb 16, 2016. This report should use the beam test data to validate the heat annealing model, and use the model to predict performance under expected operating conditions.

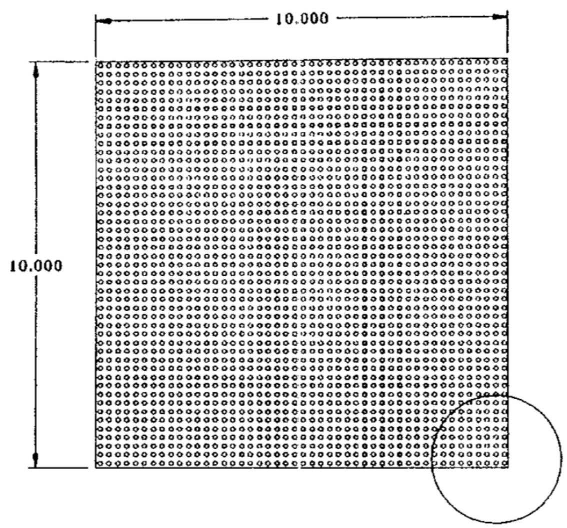
About possibility to reuse the E864 calorimeter

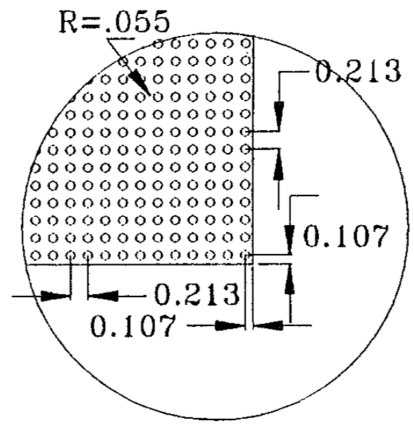
B. Wojtsekhowski

----- Original Message -----
From: "Hank Crawford" <hjcrawford@lbl.gov>
To: "Bogdan Wojtsekhowski" <bogdanw@jlab.org>
Sent: Wednesday, November 18, 2015 10:28:02 AM
Subject: ECal

Hi Bogdan - We are writing a NIM article on the E864 calorimeter that we modified for our Drell Yan experiment. It is a SpaCal using BCF-12 scintillating fibers for readout. These fibers are rad hard to at least 2.5 MRad, implying more than 5000 hours of operation at SBS if I take Mark's number of 0.5kRad/hr as the dose. That gives >200 days of operation, sufficient for the FF program at least. Our electromagnetic resolution is nearly equivalent to PbGlass for energies for 5-25 GeV electrons. We have 416 cells 10cm x 10cm that we pixelize to 3.3cm x 3.3cm pixels to accommodate 1" PMT readout to achieve this resolution. I am including here the original E864 NIM for your reference. Are you interested in any portion of this for SBS? - thanks - hank

The E864 lead-scintillating fiber hadronic calorimeter, NIM (1998)





for hadrons $dE/E \sim 0.34/E^{0.5}$

Time resolution ~ 0.40 ns

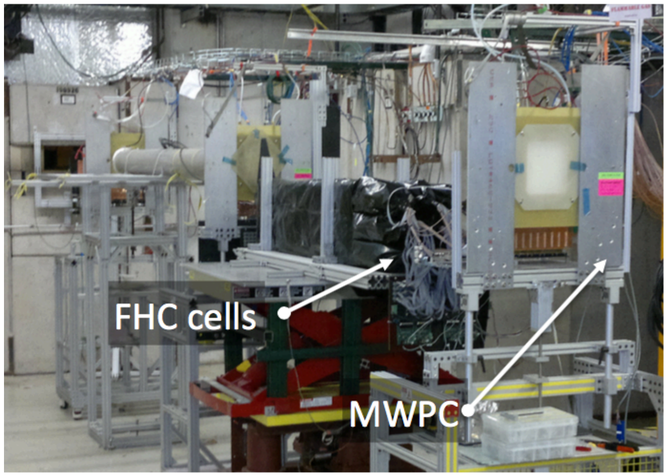
135 ph.e. per 1 GeV (proton)
250 ph.e. per 1 GeV (electron)

rad. length X0 ~ 0.8 cm

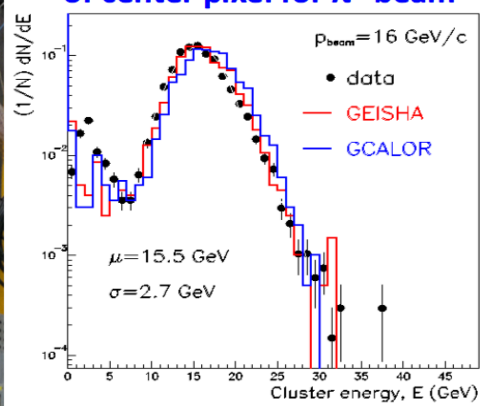
Scint/Pb ~ 0.25 in volume

The E864 in STAR experiment

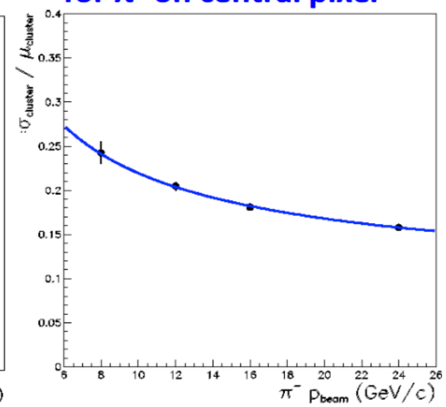
Results from Fermilab Test Beam Facility-T1064



Cluster energy distribution of center pixel for π⁻ beam

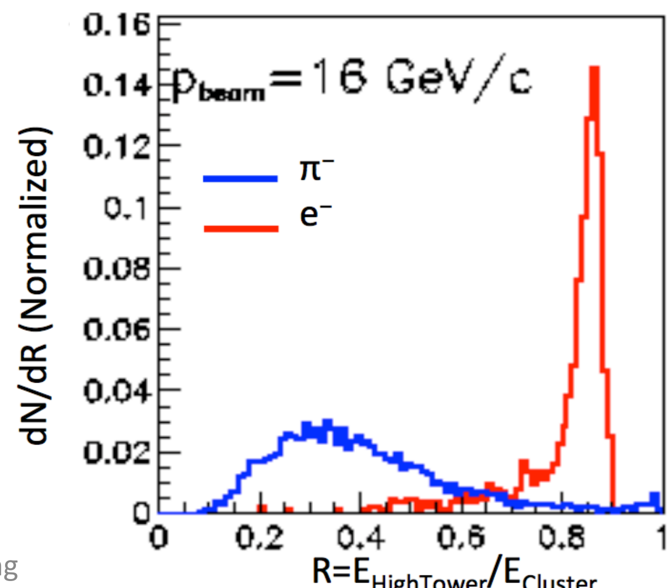


Cluster energy resolution for π⁻ on central pixel



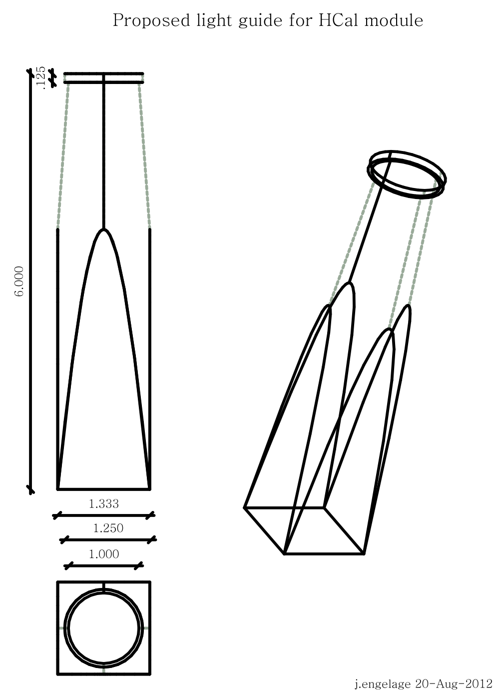
- 1 GeV (π,*K*,*p*) to 120 GeV *p* (resolution <3%)
- Cerenkov Detector (Particle Identification)
- MWPC Tracking System (Beam profile, trigger)

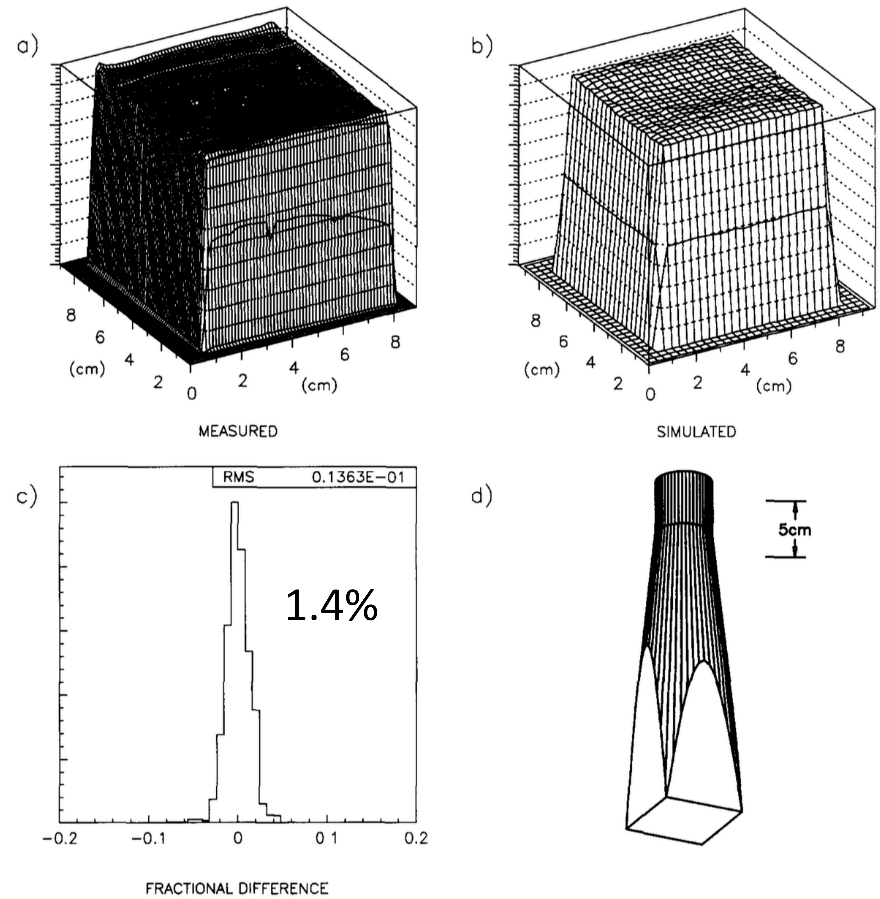
- 3×3 Cells (9×9 pixel) were used
- Studied shower shapes of e^- & π^- at beam momenta : 8, 12, 16, 24 GeV/c
- Simulations shows **good** agreement with data
- **Shows clean separation between e^- & π^- shower shapes**



http://ppd.fnal.gov/ftbf/

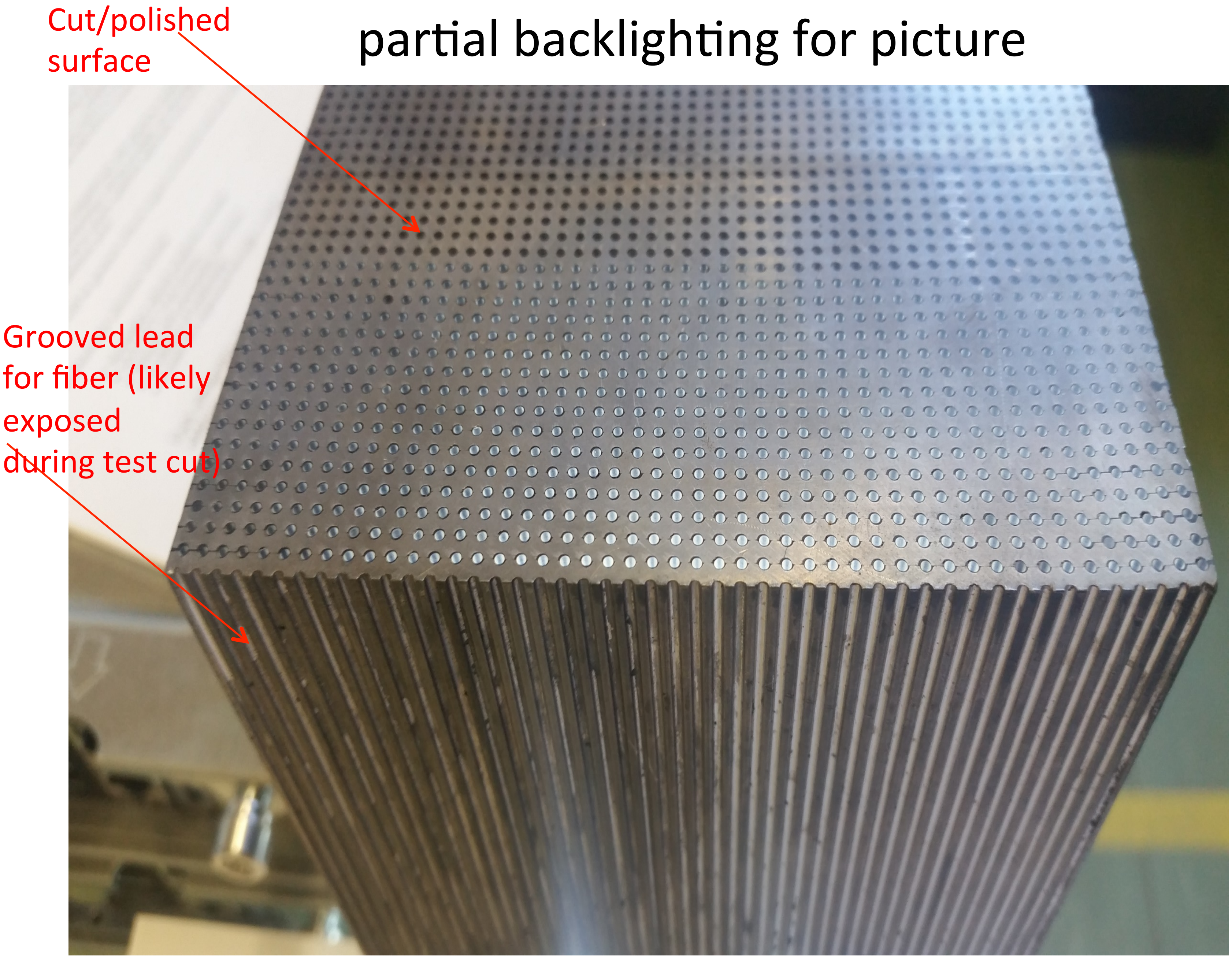
The light guide





Calorimeter cell test cut

partial backlighting for picture



Cost and plans

- Scheme: 5cm x 5cm => 1600 channels = 4 m^2
- Cost of the light guide construction: $6+3 material, $3-10 machining, $10 polishing: ~$25*2000 = $50,000
- Cost of accurate cut (for optical gluing) $6,000-10,000
- Complete construction of a 4x4 prototype for the test on cosmic and HRS by mid March
- Document on ECAL cost is under preparation

Profile