Cal Progress Report and Proposal – Part 1

Calorimeter Consortium

– Contact Persons: H.Z. Huang huang@physics.ucla.edu
C. Woody woody@bnl.gov

S.Boose, E. Kistenev, J.Haggerty, C.Pinkenberg, S. Stoll, and C. Woody
(PHENIX Group, Physics Department)
E. Aschenauer and S. Fazio
(Spin and EIC Group, Physics Department)
Y. Fisyak
(STAR Group, Physics Department)
Brookhaven National Laboratory
W. Jacobs, G. Visser and S. Wissink
Indiana University
S. Heppelmann
Pennsylvania State University
C. Gagliardi and M. Mondal
Texas A&M University
L. Dunkelberger, H. Z. Huang, G. Igo, K. Landry, Y. Pan, S. Trentalange and O. Tsai
University of California at Los Angeles
Y. Zhang, H. Chen, C. Li and Z. Tang
University of Science and Technology of China

Calorimeter-Related R&D Projects

RD1 – UCLA/IU/TAMU/PSU/BNL

W-powder scintillating fiber SPACAL Design

sPHENIX – BNL

W plate scintillating fiber sPHENIX design

Crystal – USTC

BSO crystals

Monte Carlo Simulations – BNL

Physics and Detector System simulations

Calorimeter Requirements (Woody, June 2013)

- Endcap EMCAL at $\eta < 0$ (electron going direction)
  - Needs to be high resolution (~ 1-2 %/$\sqrt{E}$) in order to measure electron energy well (solenoid field does not provide good momentum resolution in forward/backward directions)
  - Best choice is scintillating crystals
    - PWO (similar to PANDA)
    - LSO/LYSO (excellent resolution but very expensive)
    - BSO (under development by this group)
- Barrel EM calorimeter
  - Need ~ 12%/$\sqrt{E}$ when combined with tracking
  - Want to be compact (short X_0 and small R_M) in order to fit inside solenoid
  - Best achieved with tungsten absorber with scintillating fiber readout
    - STAR design – tungsten powder epoxy with embedded scintillating fibers
    - sPHENIX design – tungsten metal plates with layers of scintillating fibers in between
- Forward EM calorimeter
  - Assumed to be similar to barrel design
- Forward and backward HCALs
  - Need ~ 50-100%/$\sqrt{E}$ for single particles
  - sPHENIX HCAL (steel/scintillating tile with WLS fiber readout)
  - STAR forward HCAL (Pb/scintillator plates similar to ZEUS design)

RD1 – Progress Report and Proposal
UCLA/IU/TAMU/PSU/BNL
Oleg Tsai et al.

- Technology development for W powder Sc. Fibers calorimeters construction;
- Plan for FNAL beam test of EM prototypes in Feb-Mar 2014;
- Characterization of SiPM sensors;
- Proposal for next year and funding request.

Improve and Standardize Construction Technique towards mass production at industrial facility

1. Entire superblock consisted of four towers was constructed at once (instead of being glued from two sub-assemblies in 2012). That significantly reduced amount of work and at the same time improved homogeneity of detector.
2. New less viscous epoxy (longer pot life, faster injection) was used to build prototypes in 2013.
3. New screens to hold fibers have improved hole pattern close to edges (to minimize amount of post machining of superblocks after gluing).

More refinements will still be pursued in the future; no major impact is expected

Development non-projective barrel EMC Construction:

Technical Goals: completely hermetic, compact EM barrel calorimeter. Inner radius ~1 meter. Non-projective. Simple construction technique (shared with forward instrumentation). Good energy resolution ~ 10%/√(E).

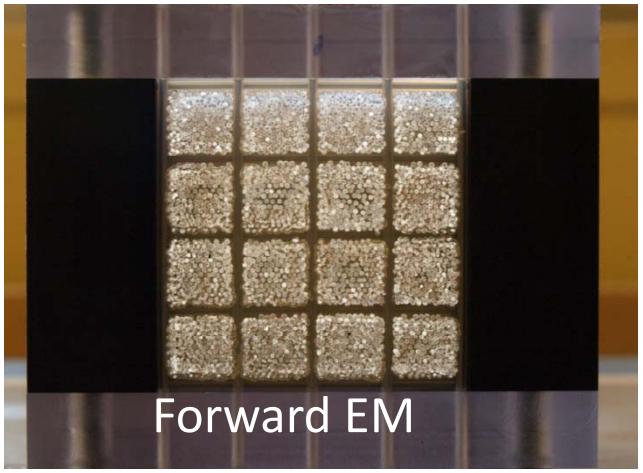
Geometry: wedge-shape in phi and non-projective in eta

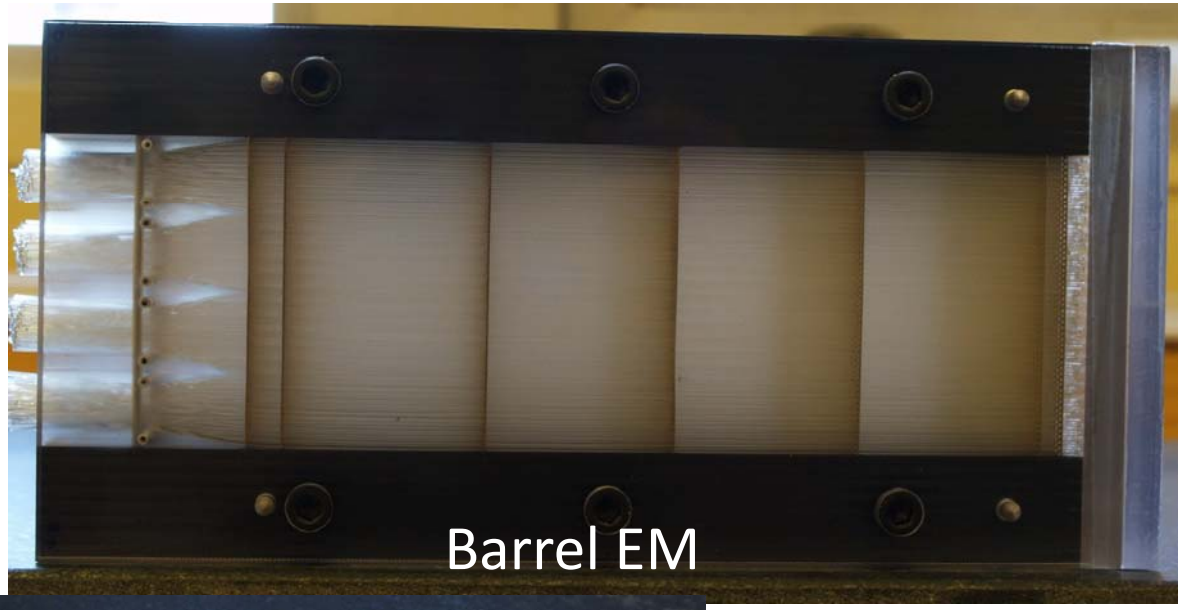
Results to date:

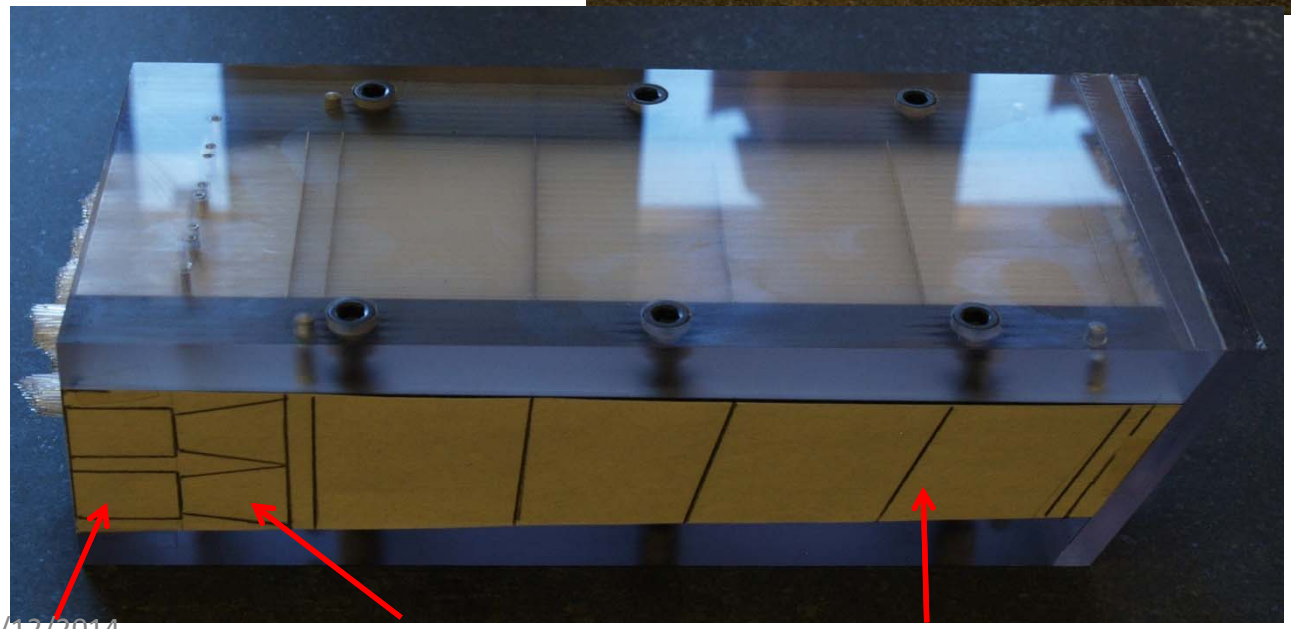
- Desired taper of towers was achieved with just two types of meshes which were progressively inclined.
- Two different types of light collection schemes were prototyped.
- The size of a single building block for now was restricted to two towers (same size as for non-projective prototype in 2012).
- At the end construction of the barrel EM prototype was as simple as non-projective.
- Homogeneity is as good as for non-projective version (<1%).
- Future developments mostly depends on results of the test run (light yield, energy resolution).
- Further improvements: electro polishing of all meshes to smooth edges of the holes (done mechanically this year), change scintillation fibers to S type.

We Built a prototype to be tested in Feb-Mar 2014 at FNAL

Construction pictures of prototypes with the first light collection scheme.

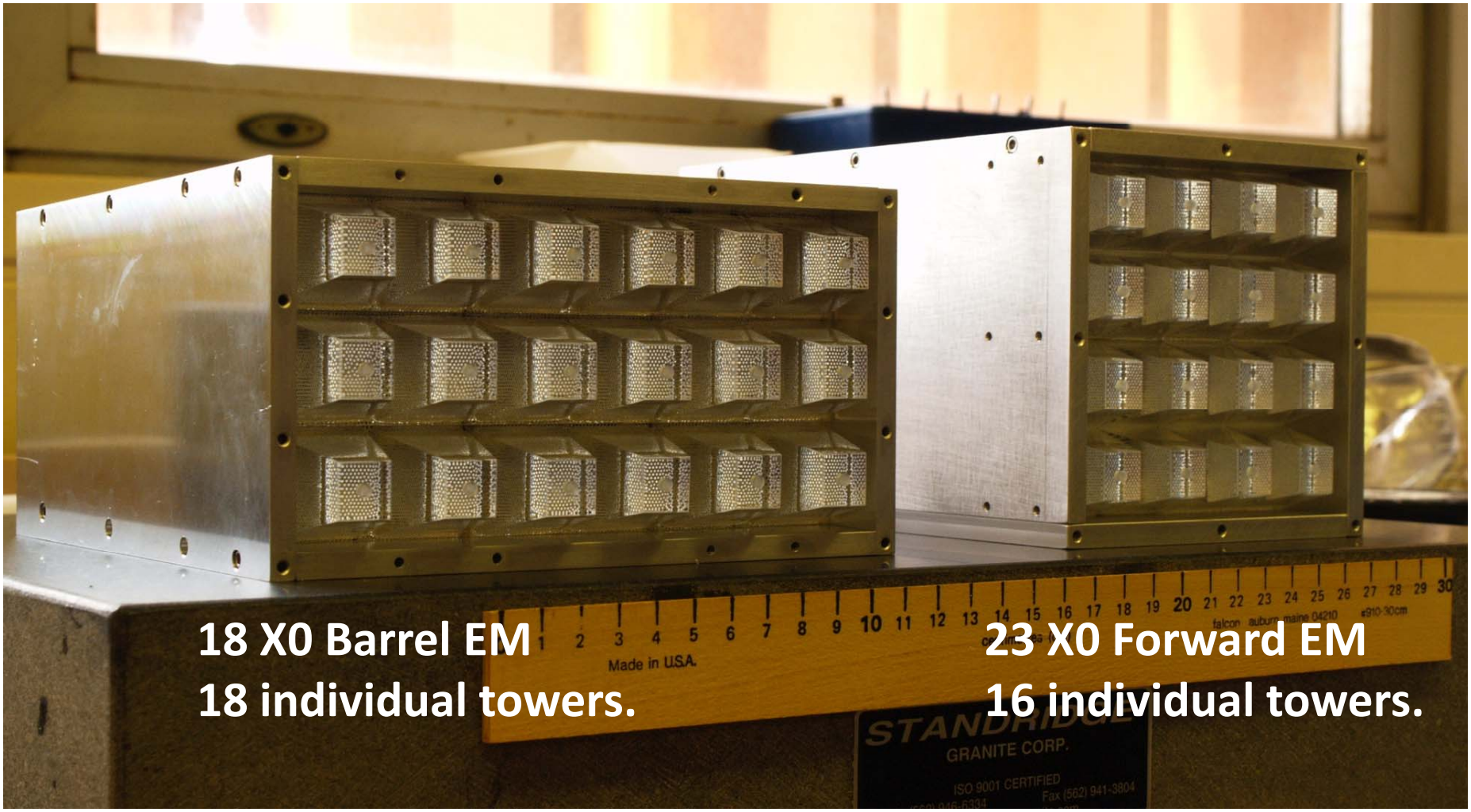






First light collection scheme was consisted of four independent light guides per tower. It was later dropped in favor of a single tapered light guide.

Two EM prototypes prepared for the test run at FNAL.

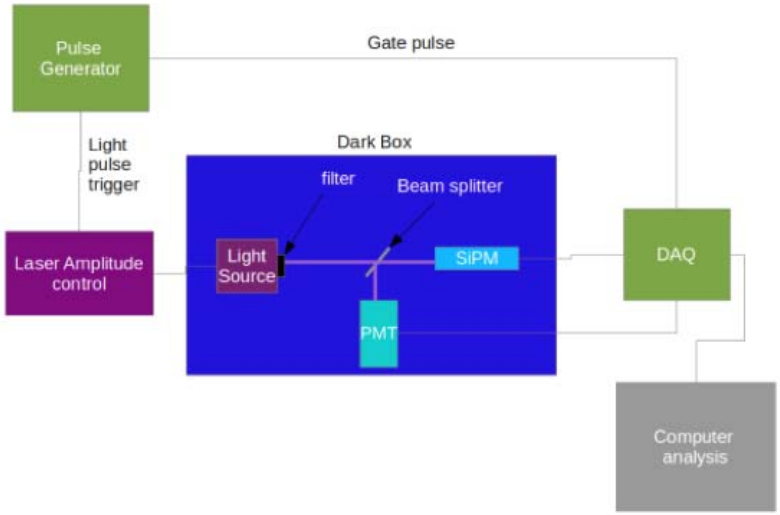


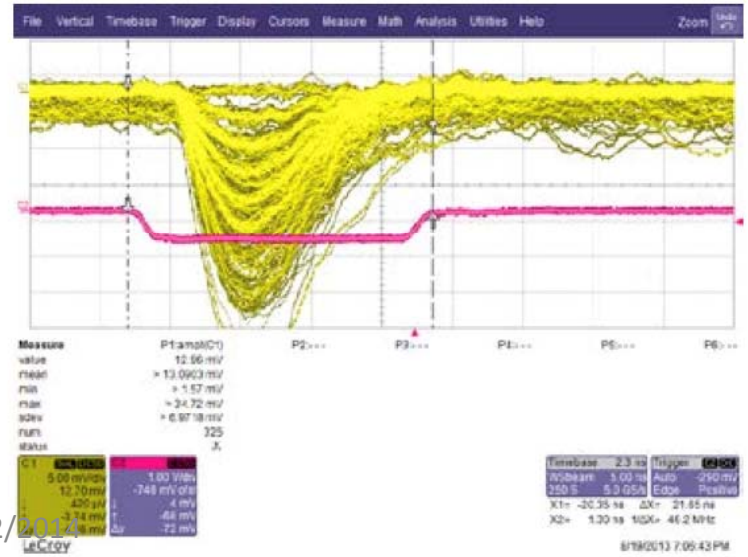
For the test run at FNAL we decided to proceed with a single trapezoidal light guide/mixer per tower.

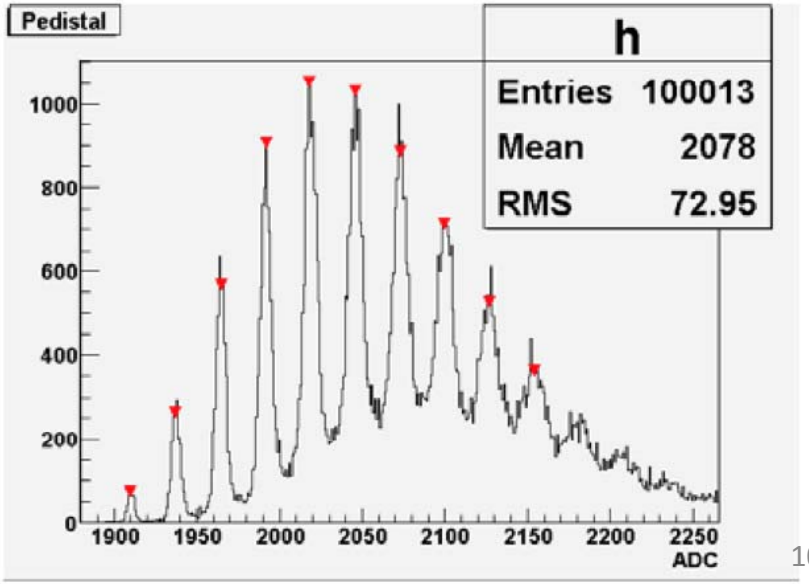
Characterization of SiPMs

- **We built a test stand at UCLA that allows us to measure almost all parameters of the MPPCs as a function of bias voltage and temperature.**
- **These measurements and data analysis were carried out by summer undergraduate students from RPI and UCLA.**
- **For the test run at FNAL we decided to group MPPCs with equal gain at same bias for EM sections. For HCAL we have better front end electronics and such grouping is not required.**
- **Optimization of bias voltage setting for MPPCs is not possible without results from the test run. This task left for summer 2014 (once test run data will be analyzed).**
- **Systematic studies of performance of MPPCs at different temperatures need more efforts (time consuming tests), only basic parameters were measured so far for a few sensors.**
- **In 2014 we want to continue these studies. We also want to compare new sensors from HPK, KETEK, and SENSL. This will be done first in the lab and later in conditions close to a real experiment.**

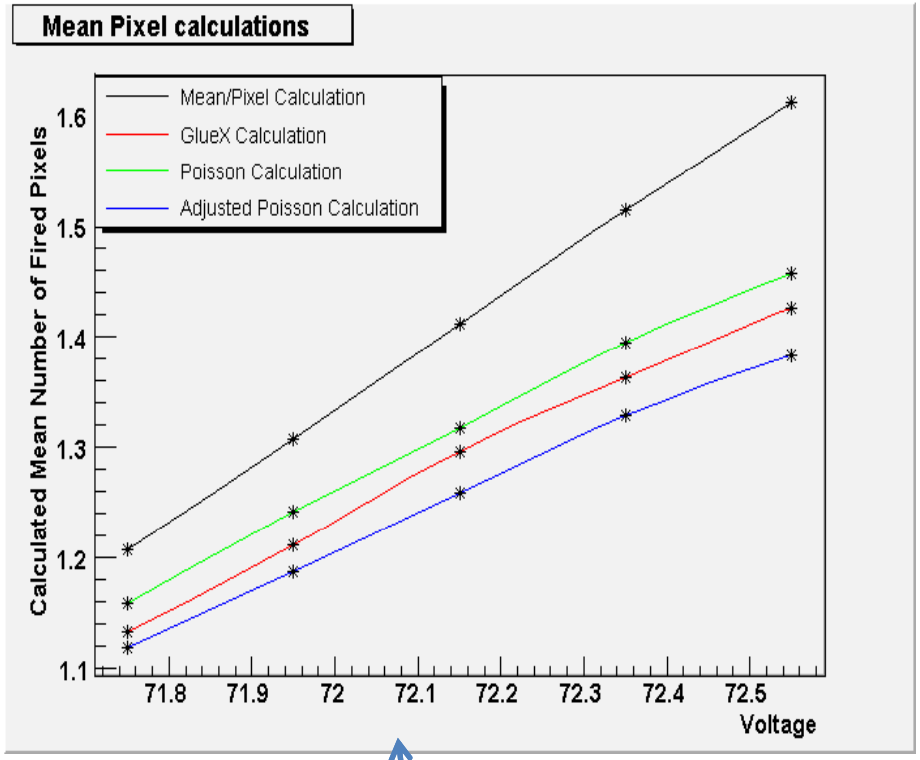
Characterization of Hamamatsu S1093-025p MPPCs.

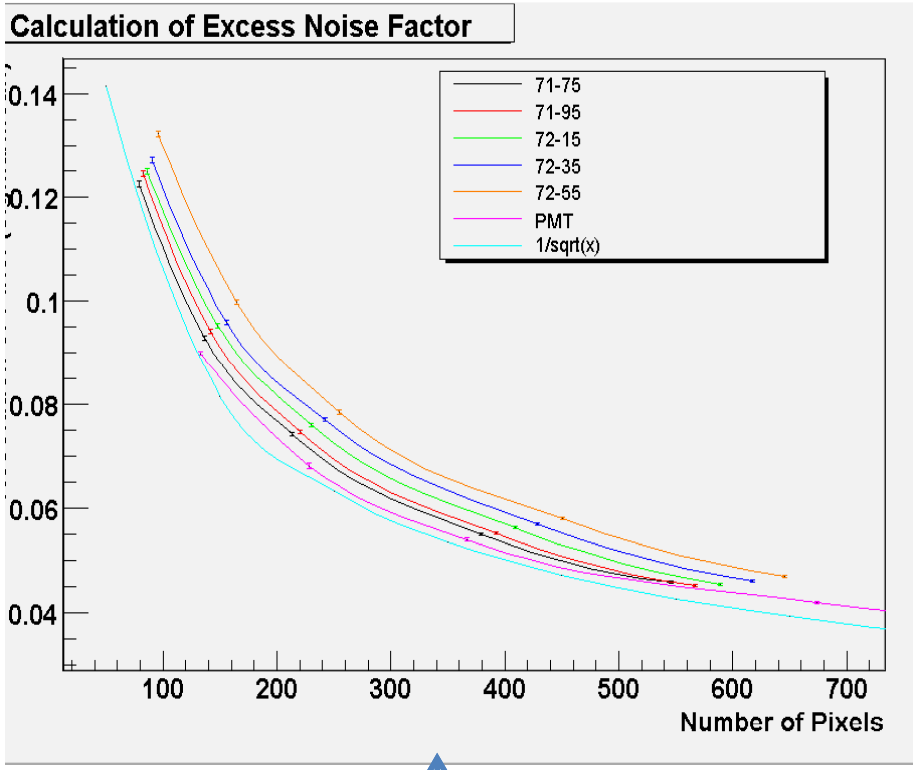






SiPM Operation Characteristics





PDE strongly depends on overvoltage (P(0) – probability to trigger avalanche).

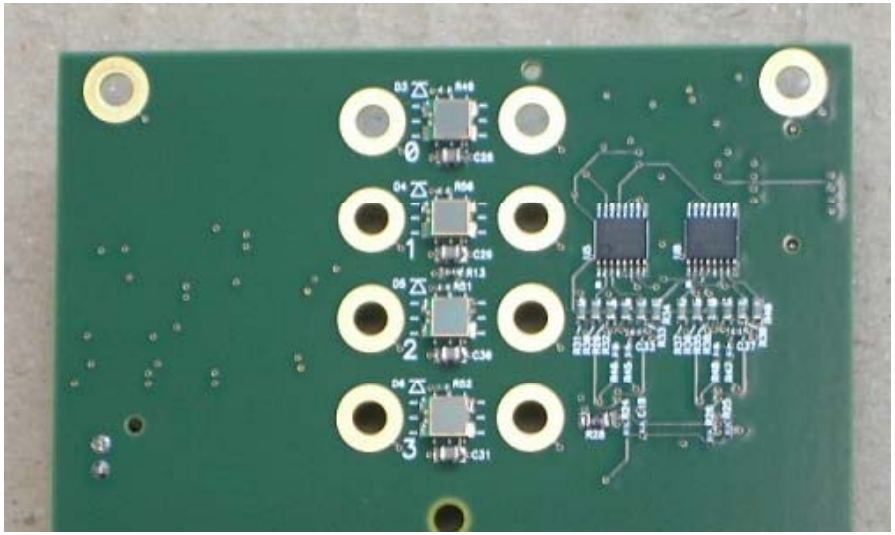
Excess noise factor is also depends on overvoltage.

Measured light yield at the test run will allow to optimize overvoltage (PDE vs ENF), Then other factors like dark noise, after pulses etc. should be taken into account.

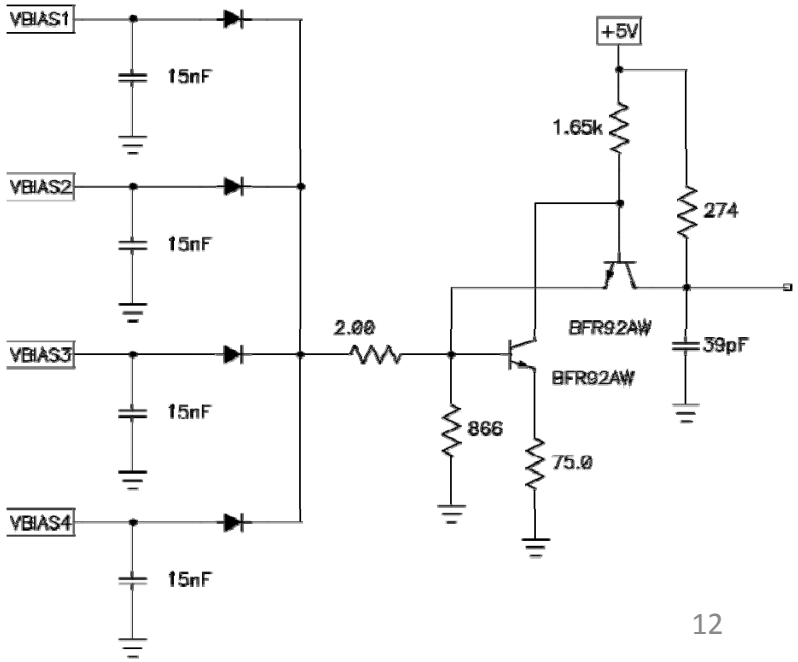
Integrated SiPM front-end electronics module development (IU, Gerard Visser)

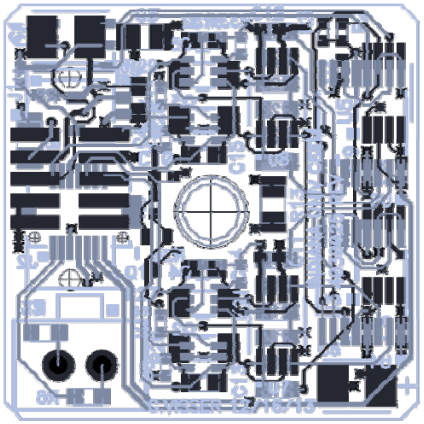
Goal: A compact, low-mass, integrated module including several SiPM chips, bias voltage regulator with temperature compensation, fast low noise preamplifier, cable driver, and a simple multi-drop controls interface.

- 4 SiPM's for UCLA EMCAL tower
- use two copies of circuit in a different mechanical arrangement for UCLA HCAL tower (8 SiPM's), externally summed outputs
- novel low input impedance preamplifier rapidly collects signal charge from ganged SiPM's, and potentially improves linearity



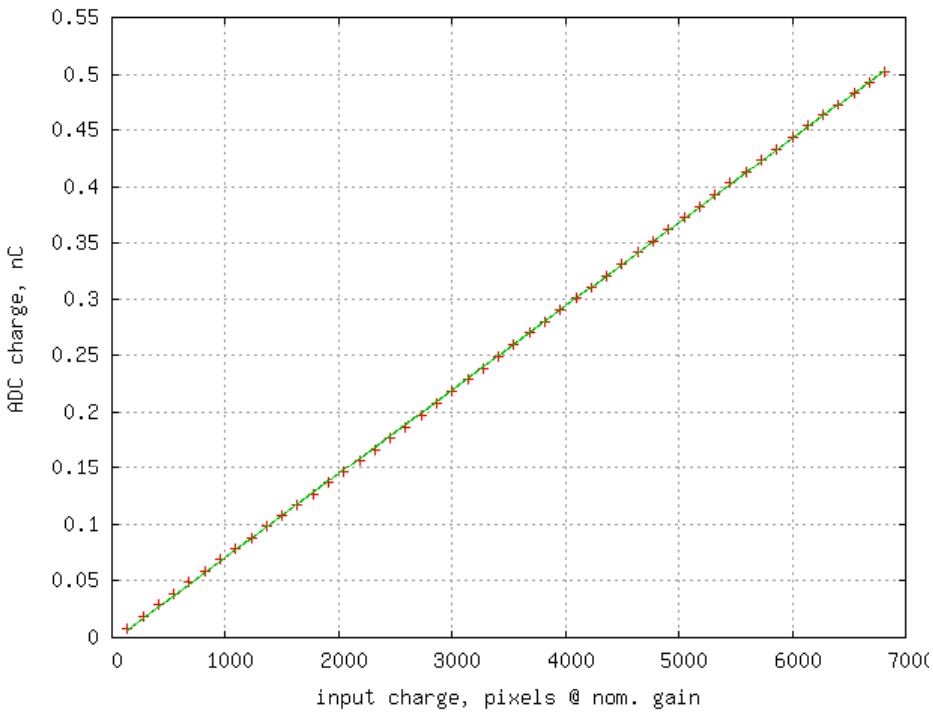
HCAL (half board)

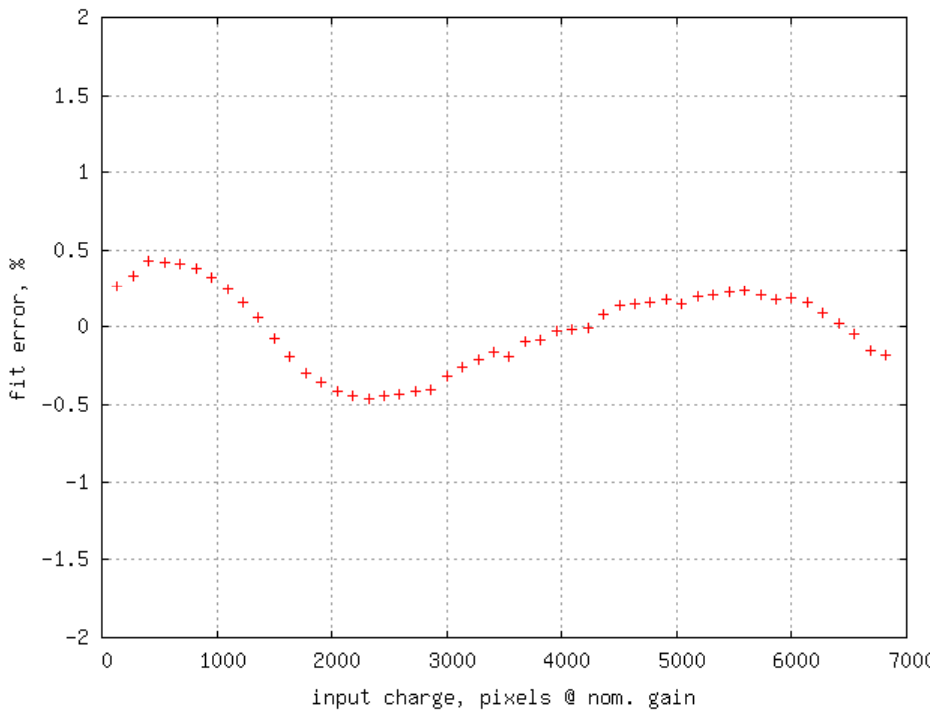




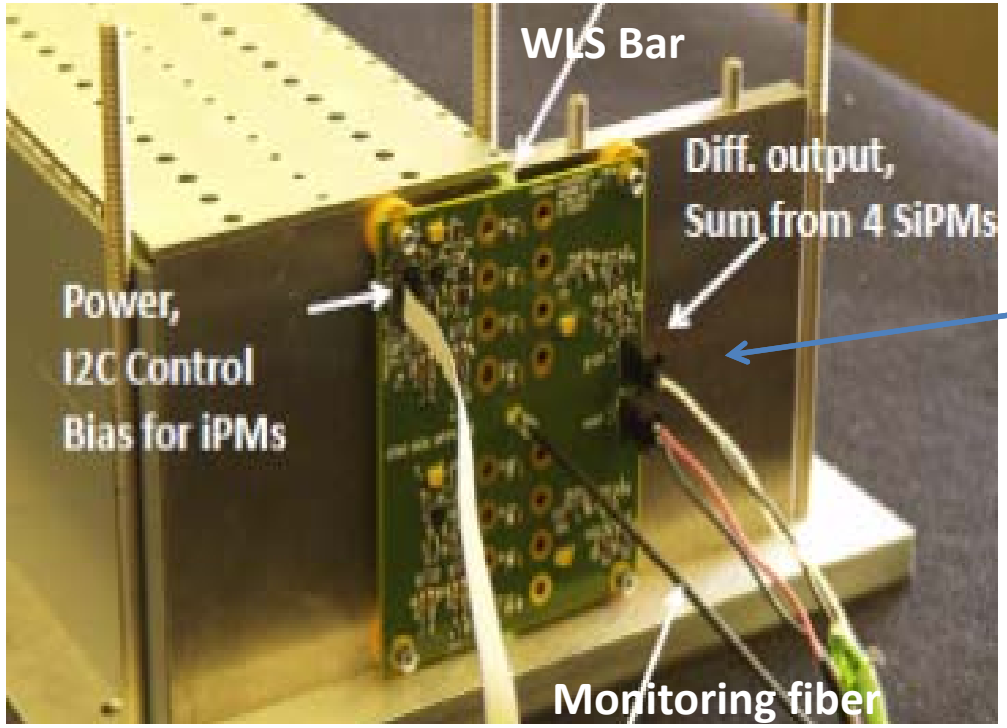
EMCAL board A – 24 mm square

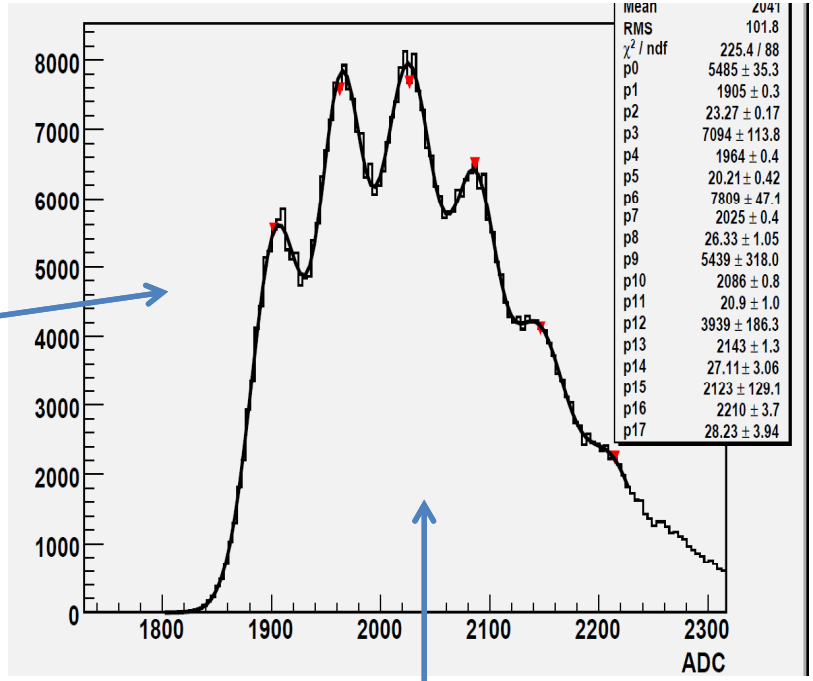
Preamplifier linearity from charge pulser. 1200 pF “SiPM” capacitance is installed. Linearity better than 0.5% to >6000 pixels nominal signal.

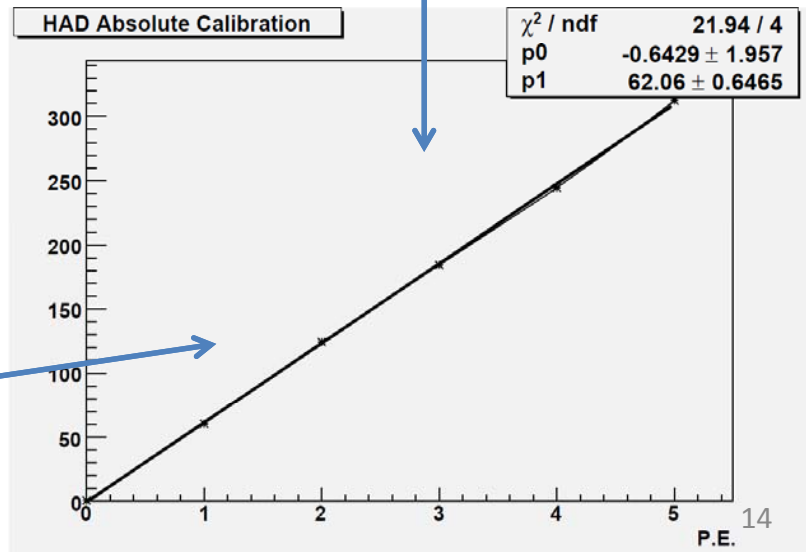




HAD Calorimeter Readout for STAR FCS (8 sensors per tower)







FEE board was developed by IUCF.
Independent control of bias and T compensation for every sensor.

Response to low level of light allows 1% level of monitoring.

Gain is stable within 1% in T range 18 -28 C.

Estimate neutron background in STAR Detector Hall

Table 1. The measured He^3C rate (C_0), the estimated from the He^3C rate neutron flux for $E_{kin} < 250meV$ (RC) using the counter sensitivity (100±10 counts/(Hz/cm^2)) and its efficiencies in the kinematical range (87%), simulated (MC) thermal neutron flux (Hz/cm^2), and ratio RC to MC for the different He^3C locations in WAH. All numbers are normalized per 1 MHz of pp inelastic collisions at $\sqrt{s} = 500$ GeV.

Location	C_0 (kHz)	RC (Hz/cm^2)	MC(Hz/cm^2)	ratio
South	1.18	13.6 ± 1.4	34.7 ± 5.9	0.39 ± 0.08
West	9.15	105.2 ± 10.5	124.1 ± 11.1	0.85 ± 0.11
East	12.14	139.5 ± 13.9	105.3 ± 10.3	1.33 ± 0.18
North	2.34	26.9 ± 2.6	39.9 ± 6.3	0.67 ± 0.13
Bottom	0.66	7.6 ± 0.8	23.9 ± 4.9	0.32 ± 0.07
FarAway	0.63	7.2 ± 0.7	7.0 ± 2.6	1.03 ± 0.40

In future (RHIC, Run 15) we want to use West Side of STAR to study performance of SiPMs from different vendors under realistic experimental conditions (funding request 2014).

RD1 Team -- Proposed Plan for 2014:

(FNAL Beam Test Run 2/26-3/18, Previously funded)

- Iterate readout scheme for EM sections after analyzing data from the test run at FNAL;
- Plan an joint EIC calorimeter consortium test run at SLAC during fall 2014;
- Systematic comparison of SiPMs from different vendors;
- Study performance of SiPMs from different vendors under experimental conditions at RHIC during Run 15;
- Finalize construction technique for non-projective sampling calorimeters utilizing W powder and standardize the procedure for mass production.

Synergetic Activities

Regular meetings for people involved in
Calo R&D, Tracking R&D and Simulations
(Elke et al ….);

Close cooperation on SiPM readout design (IU-BNL);

Excellent interactions between BNL-UCLA on
W-fiber construction technology and agreed
to combine the best technology from all efforts
for the final design of the EIC calo;

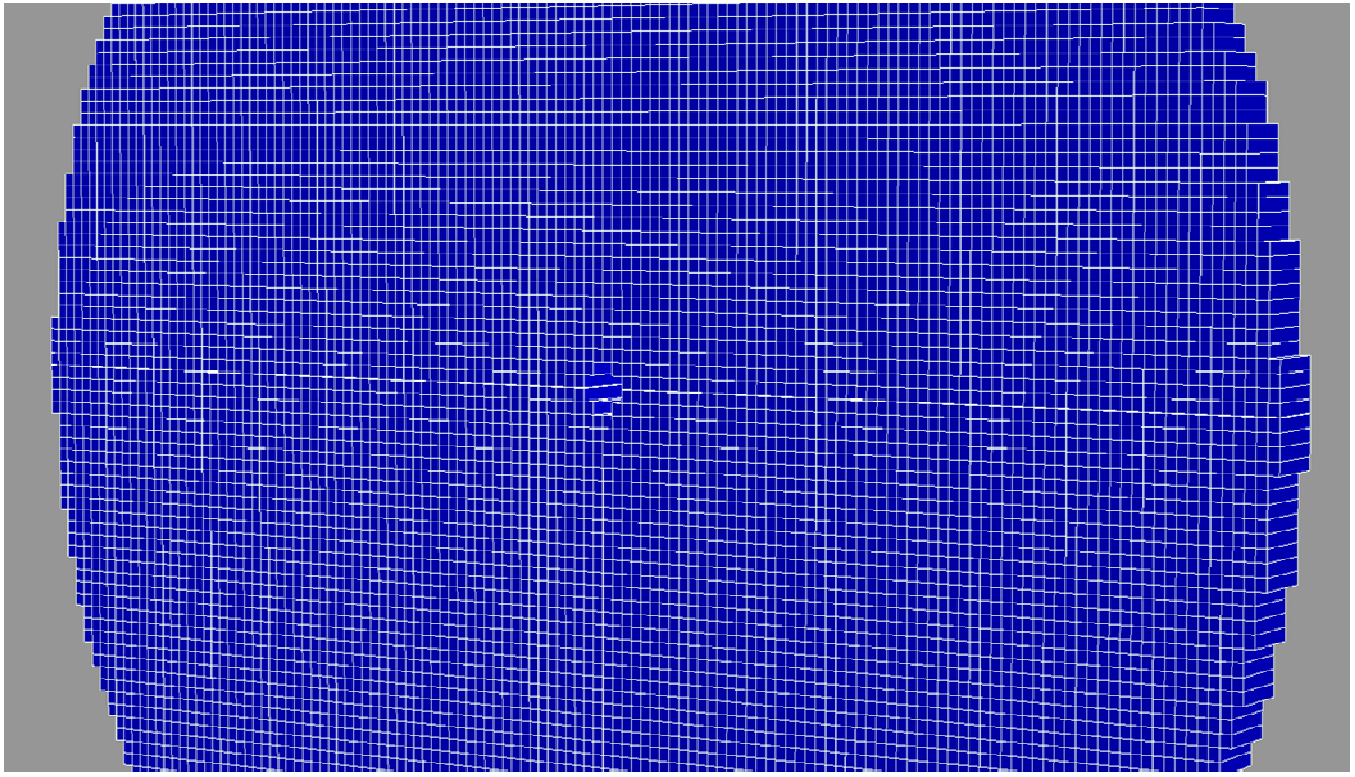
Share experience/knowledge about FNAL test ;

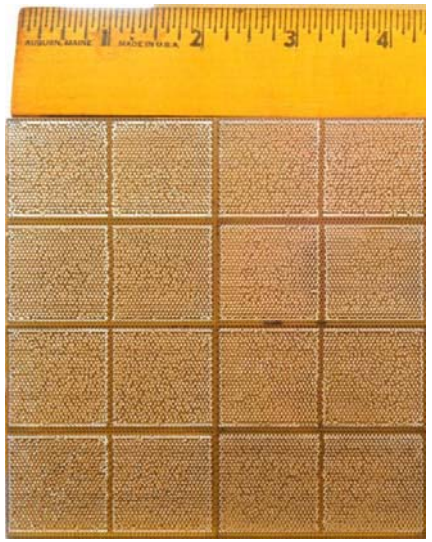
Plan an joint beam test at SLAC in the fall 2014 .

To do: interacting with groups from other community
and recruit more groups to be involved.

STAR EMC Design in EIC Detector MC

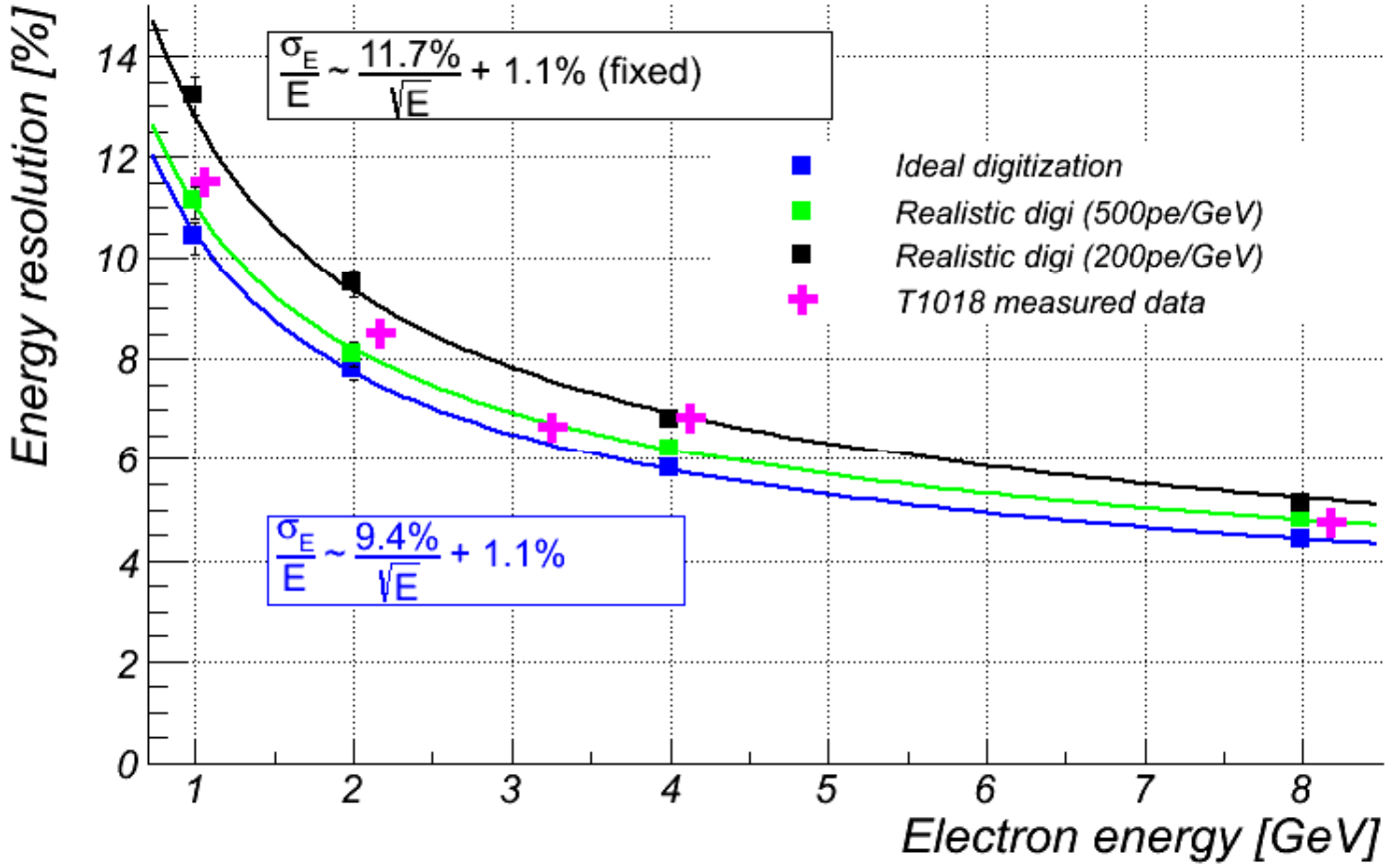
A. Kiselev





- STAR EM calorimeter upgrade building blocks (tungsten powder scintillating fiber sampling technology)
- 1mm fibers; sampling fraction for EM showers ~2.6%
- +2500mm from the IP; non-projective geometry

FEMC energy resolution study



-> good agreement with original MC studies and measured data

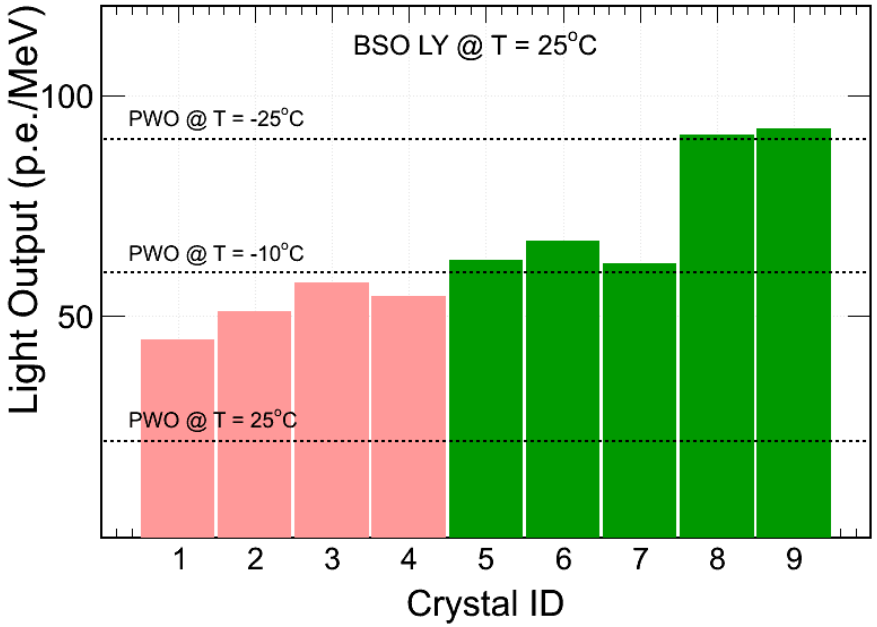
Crystal Calorimeter R&D Report

Yifei Zhang et al, USTC

Crystals from SICCAS

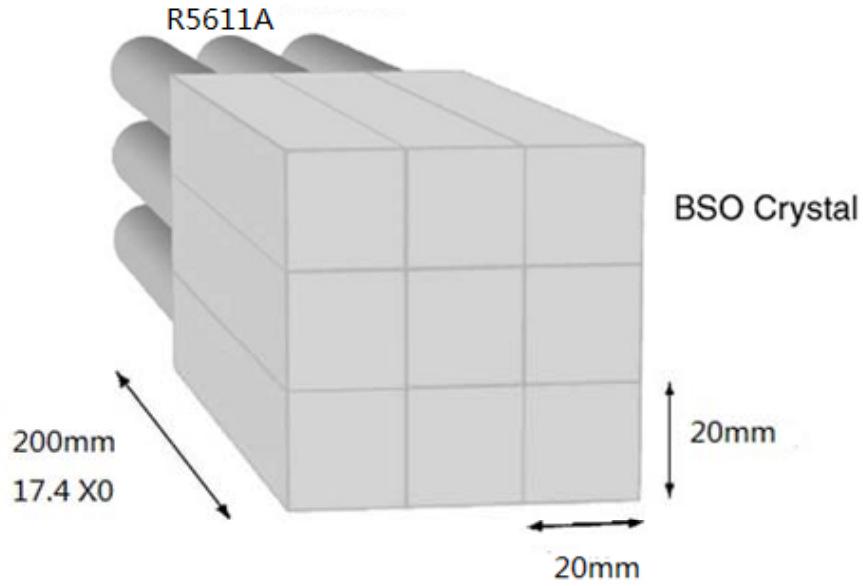
The 9 BSO crystals from SICCAS last year have been tested in USTC and CalTech (#5 and #9 for radiation test).

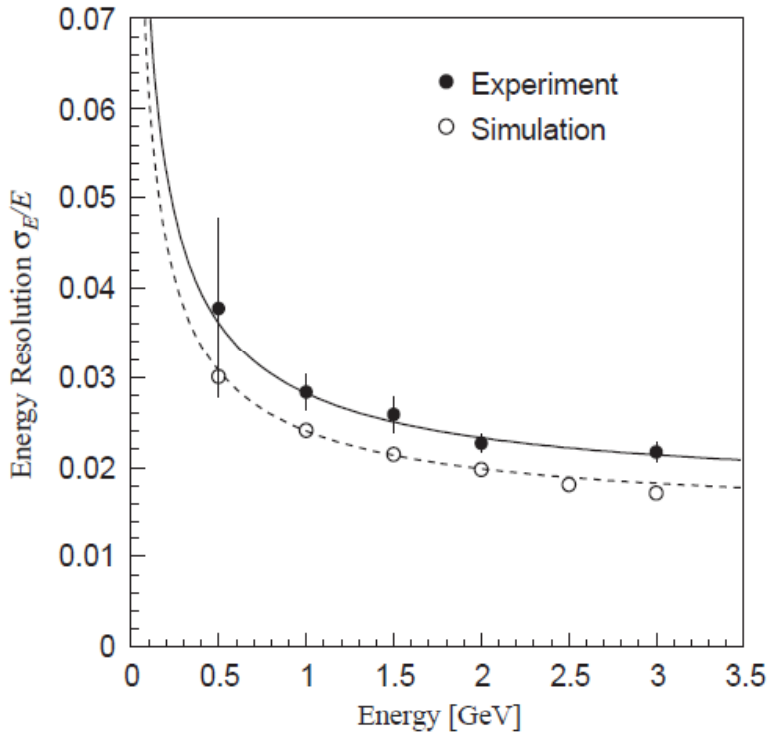
The two crystals #8 and #9 reach the LO of PWO under T=-25°C and with very good uniformity.
The production technique is maturing, now SICCAS can maintain the quality as #9.



Plan to participate in the SLAC beam test

Geant Simulations

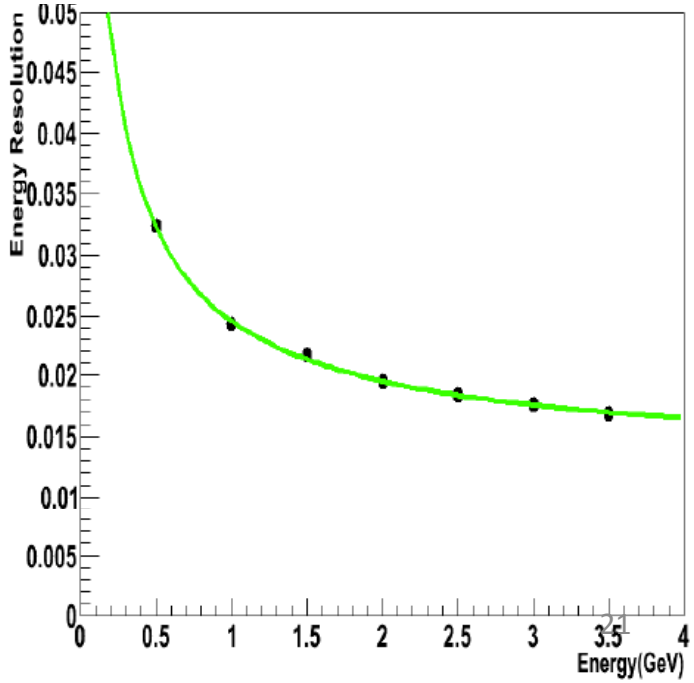




2-3 GeV electron -> 2-3% energy resolution.

Our result is consistent with
H. Shimizu, et al., NIM A550 (2005) 258.

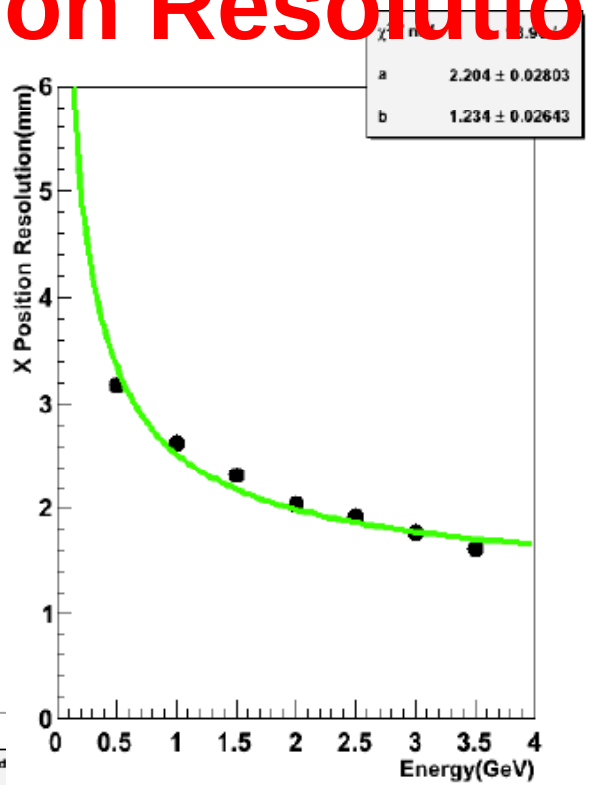
$$\frac{\sigma_E}{E} = (0.021 \pm \frac{0.000098}{\sqrt{E}})^2 + (0.013 \pm 0.000081)^2$$

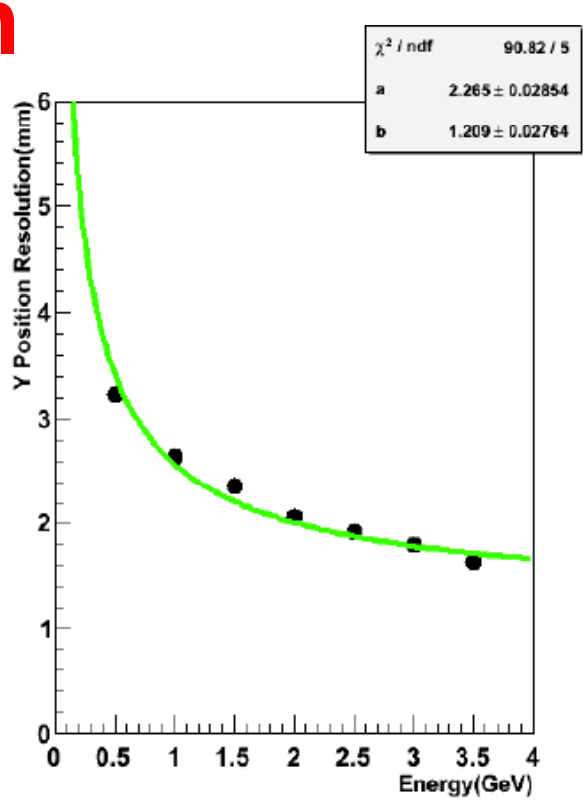


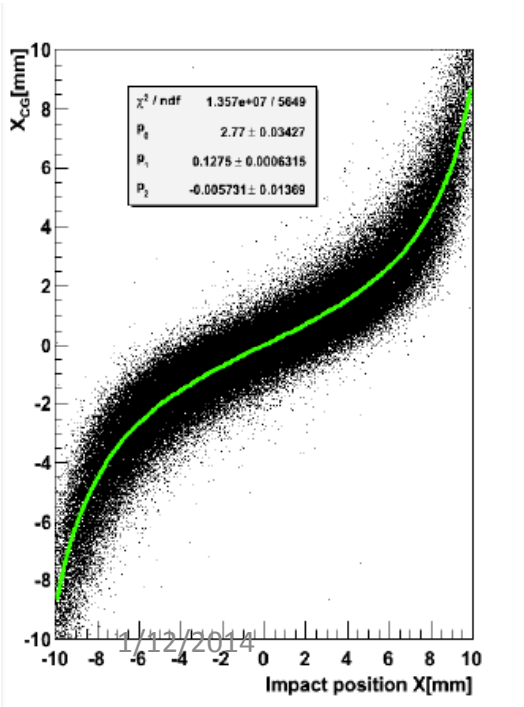
Position Resolution

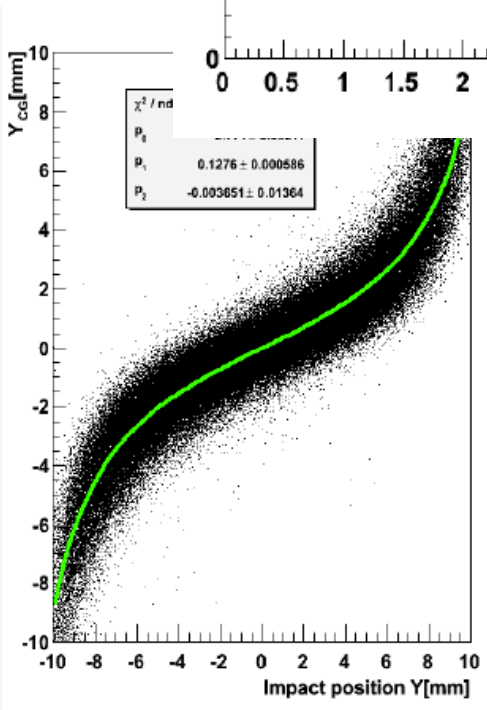
Center-of-gravity method was used

$$X_{CG} = \frac{\sum_{i=1}^{9} E_i x_i}{\sum_{i=1}^{9} E_i}$$









The position resolution is better than 5mm for incident electron energy > 0.5 GeV and is better than 2mm for energy > 3 GeV.

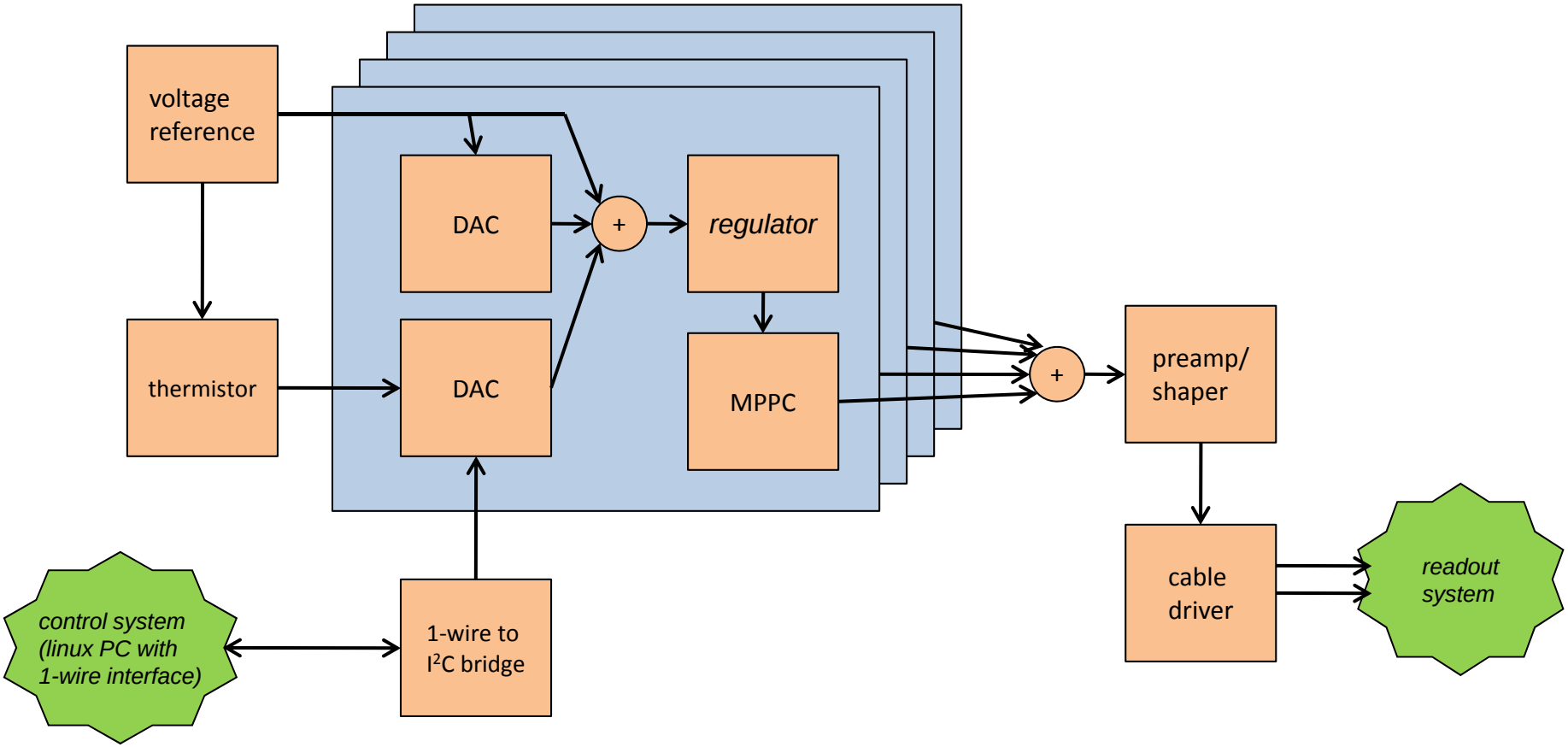
Need Beam Test Results !

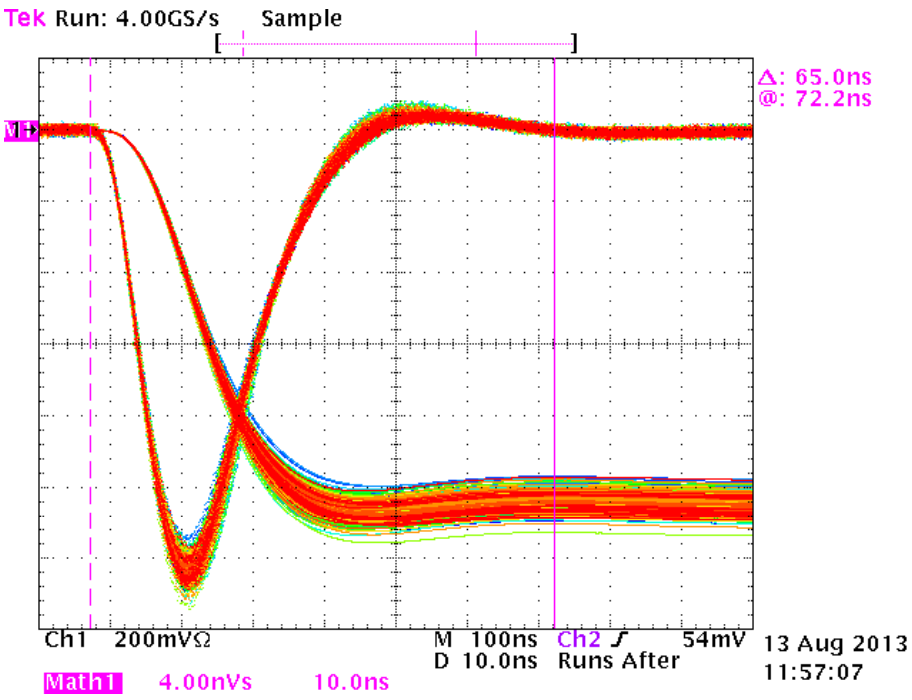
The End

RD1 collaboration, Budget Request for 2014

Sensors (HPK, SENSL, KETEK)	$15k
Materials and Supplies	$10k
Machine and Electronics Shop	$10k
Upgrades for optical system and additional neutron counter.	$15k
Undergrad students labor (includes 26% overhead)	$12.6k
Electronics Engineer (includes 56% overhead)	$27.3k
Travel for test beam, EIC meetings and Recruit new groups for mass production (includes 26% overhead)	$25.2k
Total direct cost	$97.5k
Total indirect cost	$17.6k
Total	$115.1k

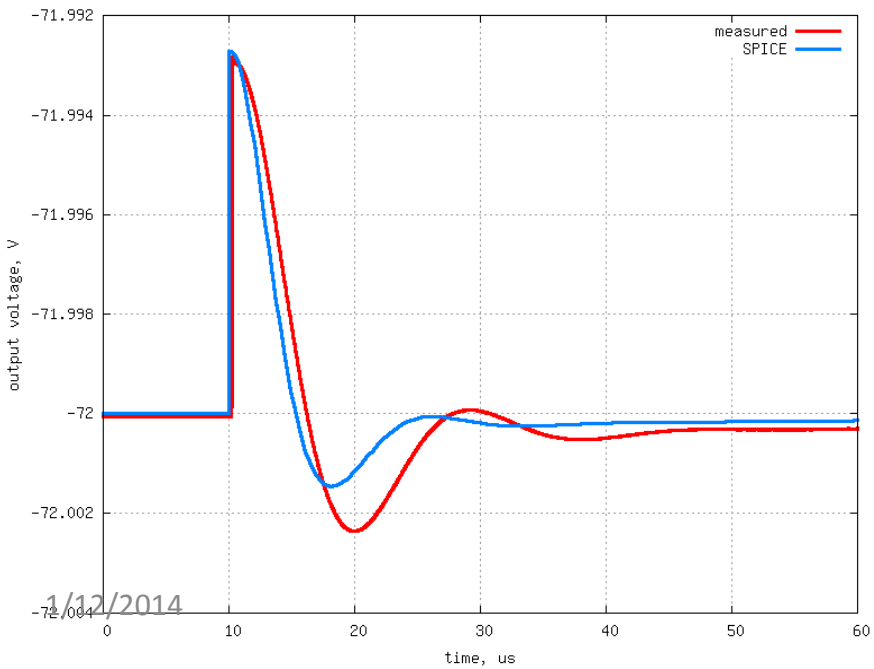
FEE block diagram





Preamplifier output with four ganged SiPM

This figure showss the pulse and its integral with a 65 ns integration gate such as may be used for e-RHIC (10 ns reset, 75 ns period).



Bias voltage regulator transient response to +110 pC load

(≈2500 pixel signal load)