Studies for Low-Noise Integrating Detectors

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Thanks to: Carlos Bula, Brady Lowe, Kevin Rhine

December 16, 2014

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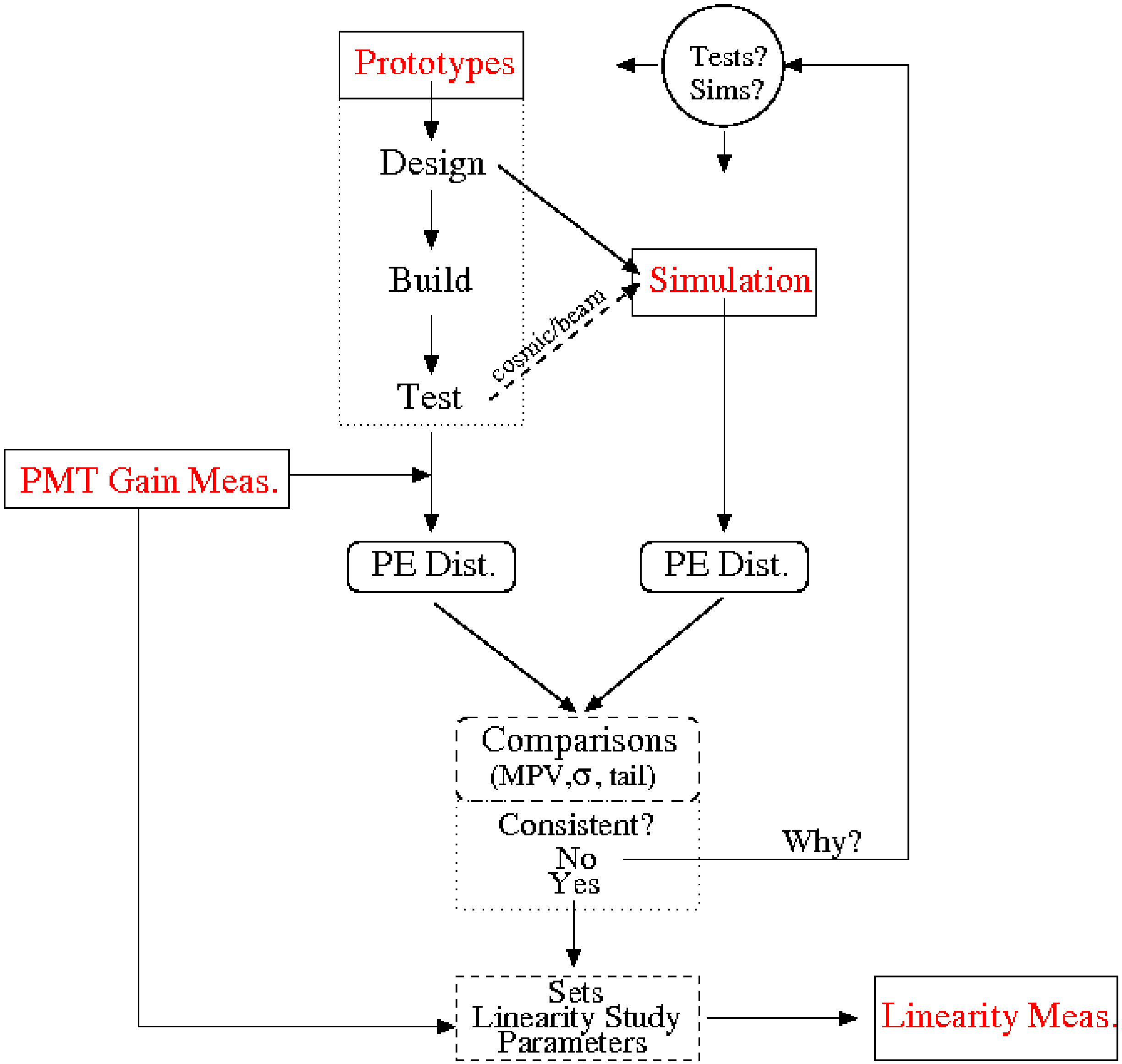
Outline

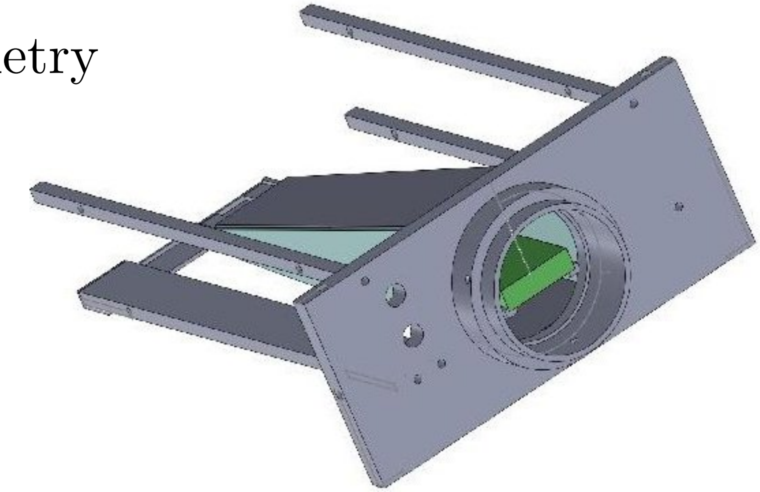
- Intro/Strategy
- Prototype Development
- Simulation Studies
- PMT Gain Measurements
- Path to Linearity Measurements
- Prel. Cosmic Test results
- Summary

Detector Development Strategy

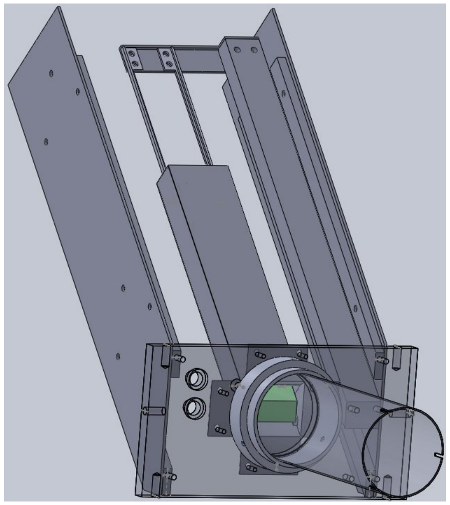


Prototype Development

- Design A: PREX I style geometry
  - Quartz in line with PMT

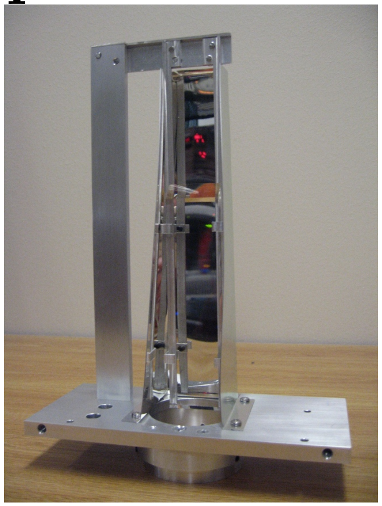


- Design B: based on UMASS design3
  - Quartz and PMT at 45 deg.



Prototype Development

- Design A: PREX I style geometry
  - Quartz in line with PMT
  - Constructed



- Design B: based on UMASS design3
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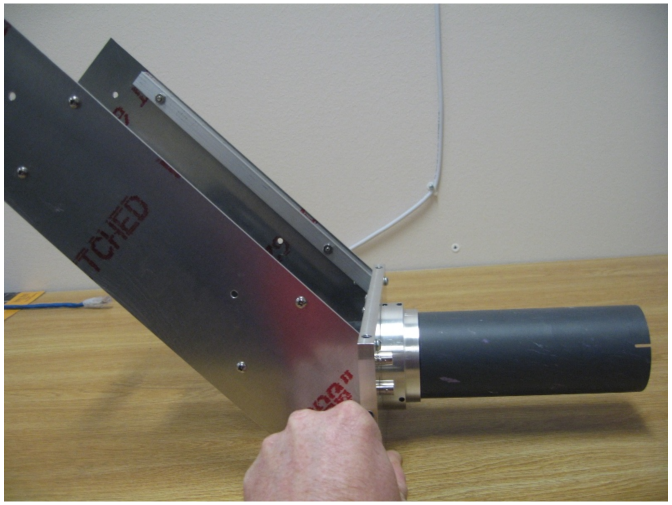
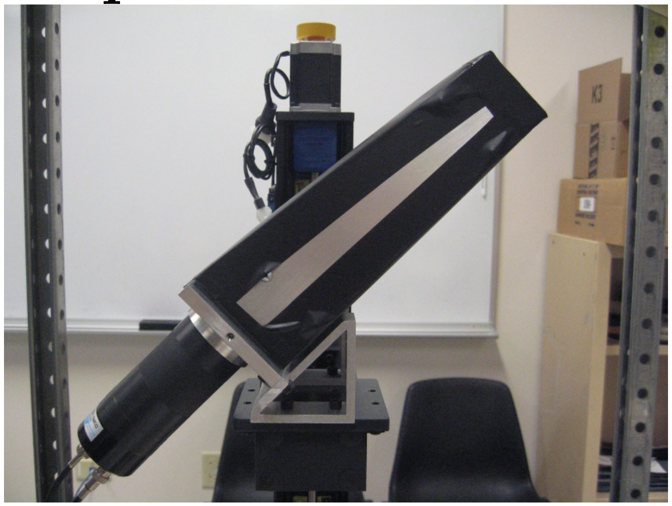
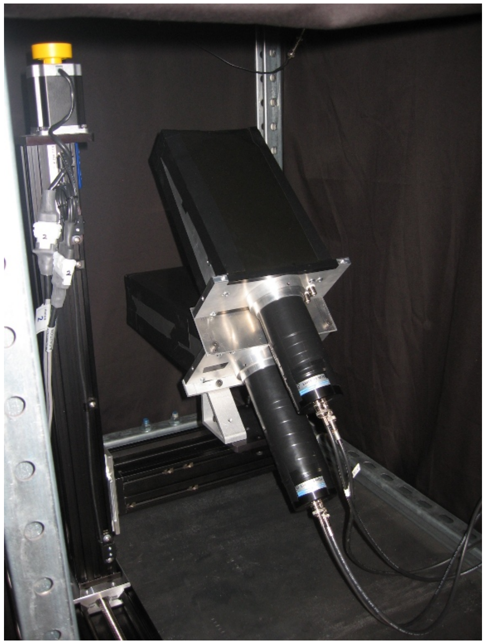


Prototype Development

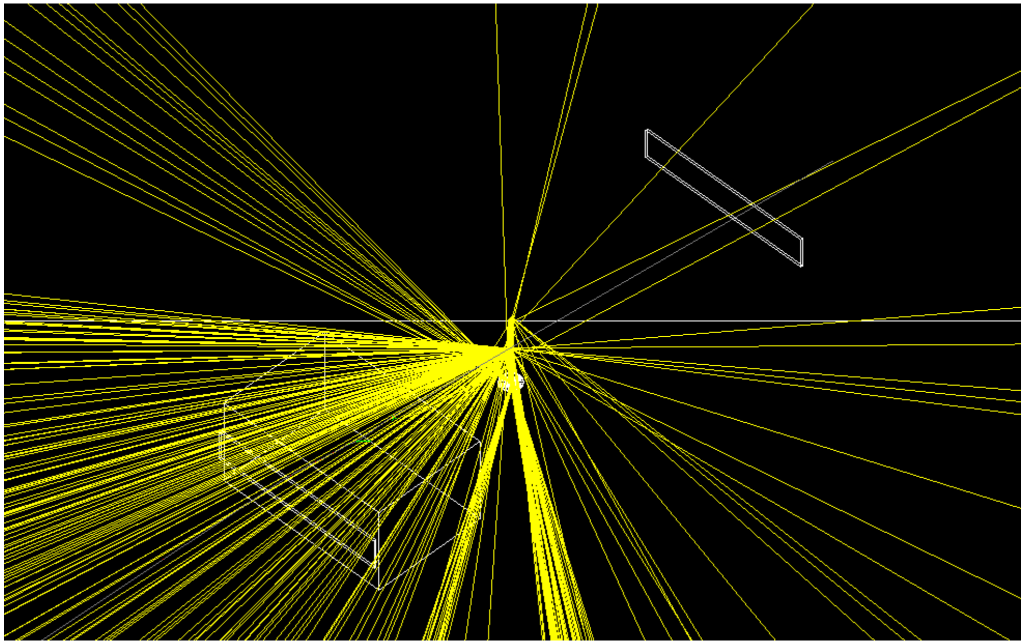
- Design A: PREX I style geometry
  - Quartz in line with PMT
  - Constructed
  - Preliminary cosmic tests completed



- Design B: based on UMASS design3
  - Quartz and PMT at 45 deg.
  - Constructed
  - Ready for cosmic tests



Simulation Development



- Using "qsim" G4 framework developed by Seamus
- Geometry adapted to ISU cosmic test setup
- Additional realistic features implemented:

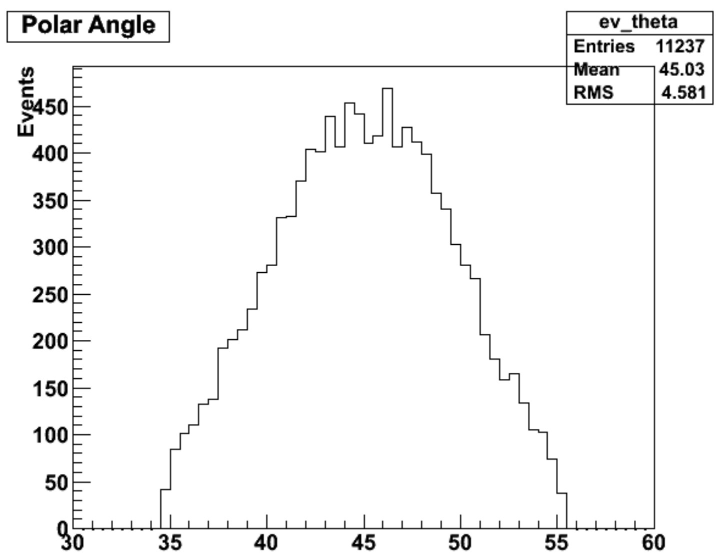
–Muon beam smearing: energy, angles, position

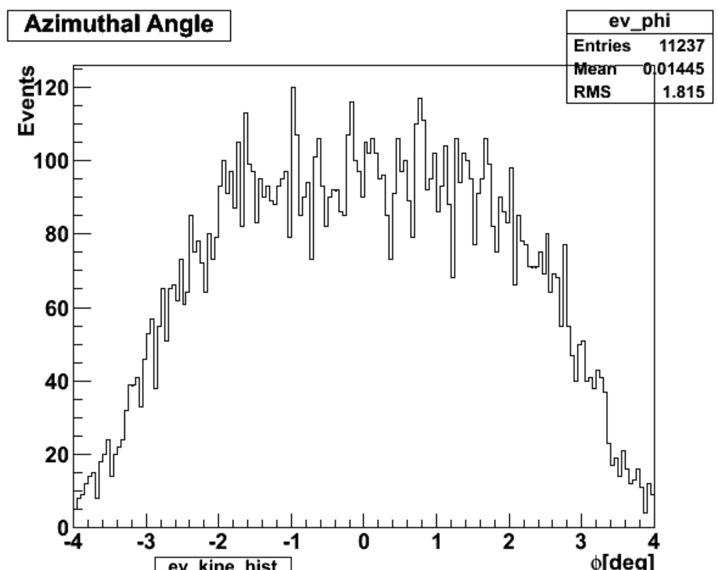
–PMT QE sampling

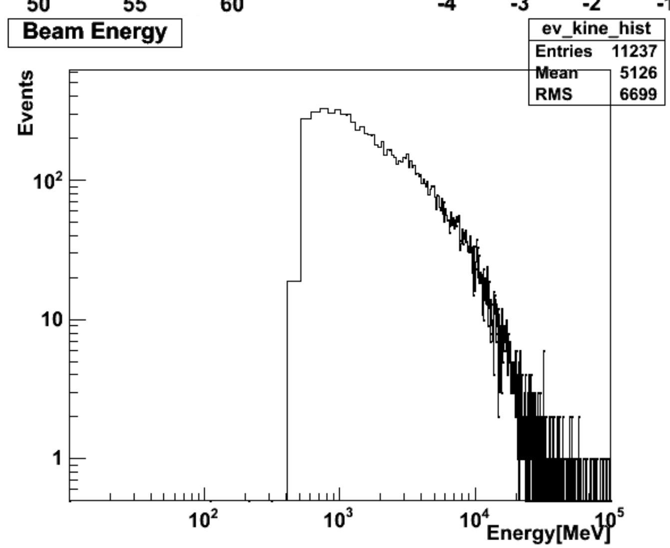
–Simulated coinc. trigger

Cosmic Beam Source

- Uniform sampling of θ and ϕ with cosmic-ray energy profile

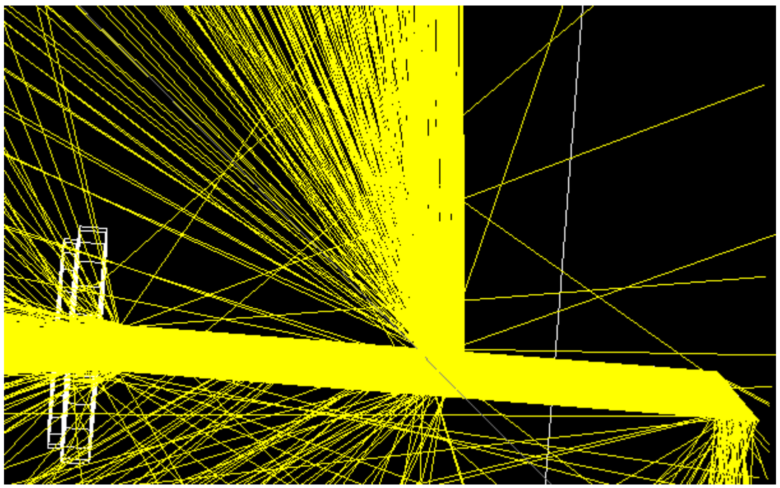


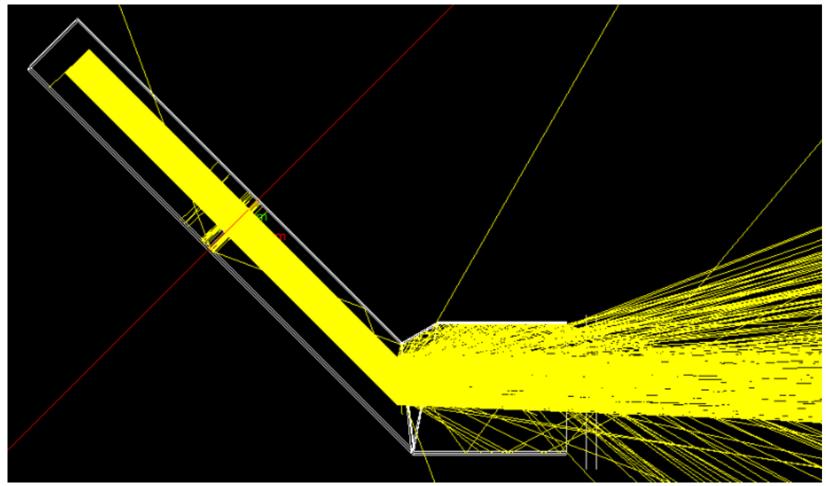




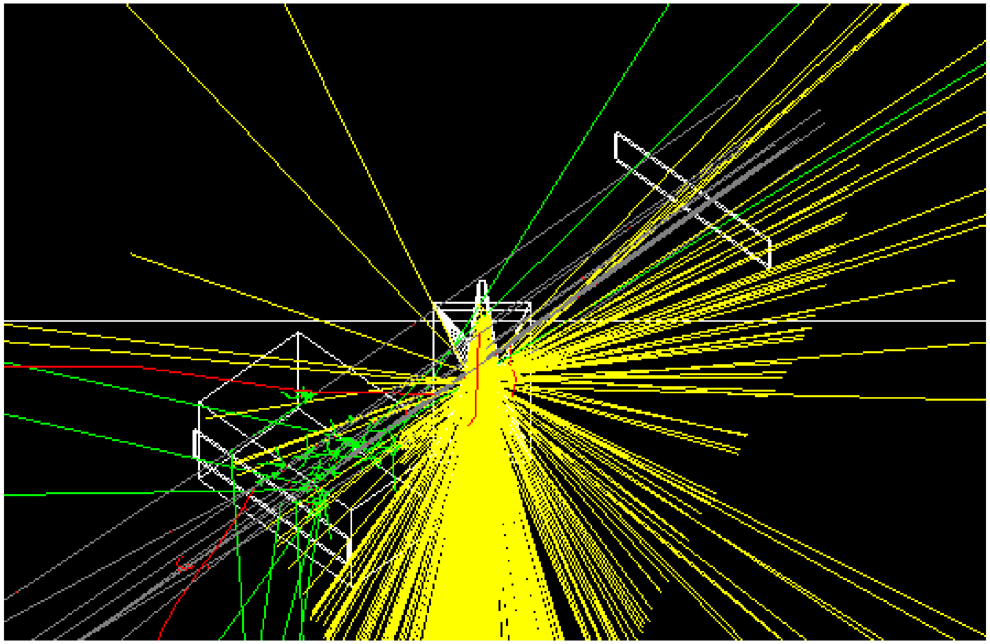
Essential Differences between Designs A and B

- Design A gives up back-half of Cerenkov cone, whereas design B does not.
- Design A poses $\sqrt{2}$ times more material than Design B – which results in larger Landau tail for design A.





Simulation Studies



- Produce PE dists. for various test configs. of designs A and B:
  - –Different distances between quartz and pmt
  - –Incident beam angle dependence
  - –With and without lightguides
  - –Inclusion of aluminum frame supports for quartz & pmt

Simulation Study Findings

- As quartz is pushed closer to pmt, mean goes up and resolution gets better (light collection fluctuations go down)

  –Used design A with lightguide and 10mm quartz

  –Measured photons reaching pmt per muon for 0, 2, and 4 cm separations between end of quartz and pmt

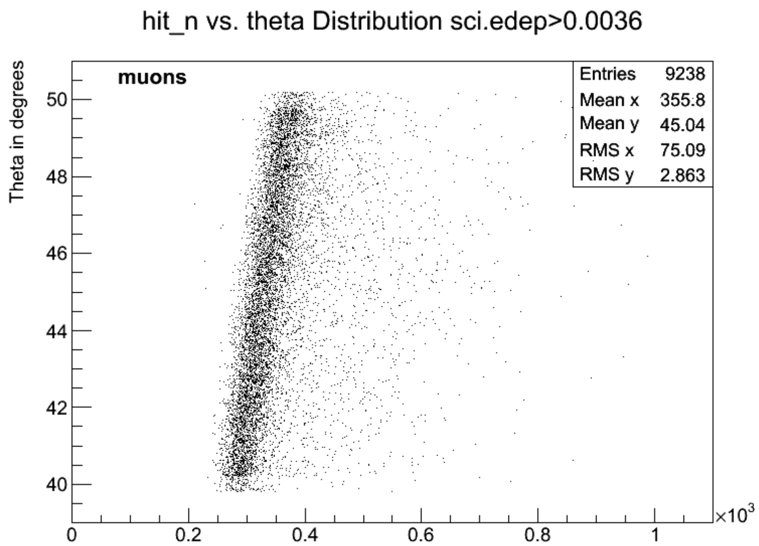
  –Results:

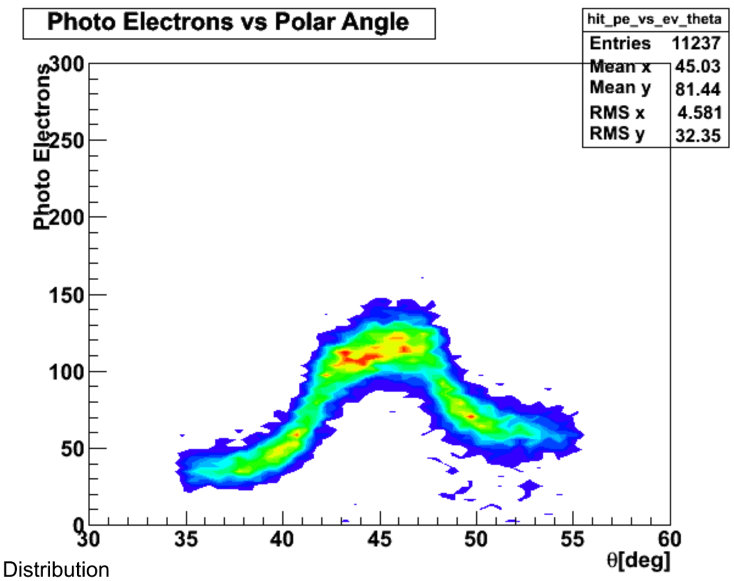
Separation (cm)	Mean (γ's/μ)	Resolution (%)
0	469	26.8
2	410	29.3
4	365	31.5

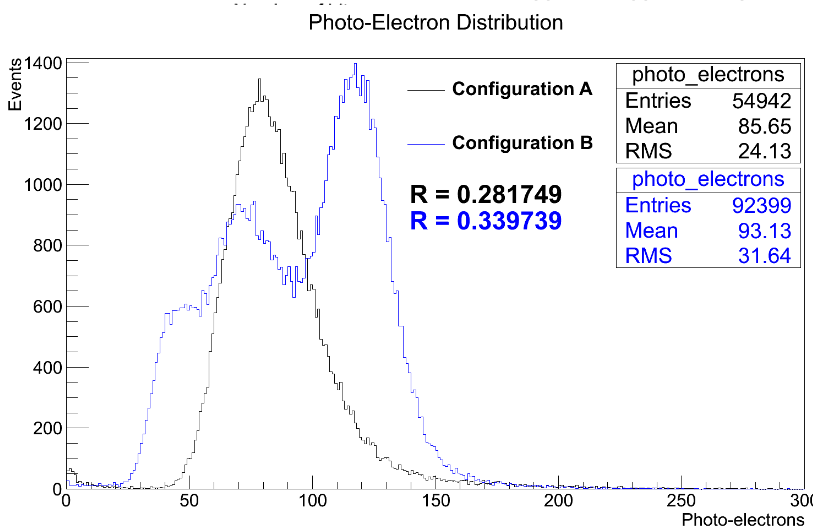
Table 1: Shows number of photons reaching pmt decreases at rate of $\sim$25 γ's/cm and resolution worsens by $\sim$1%/cm as quartz is moved away from pmt.

Simulation Study Findings

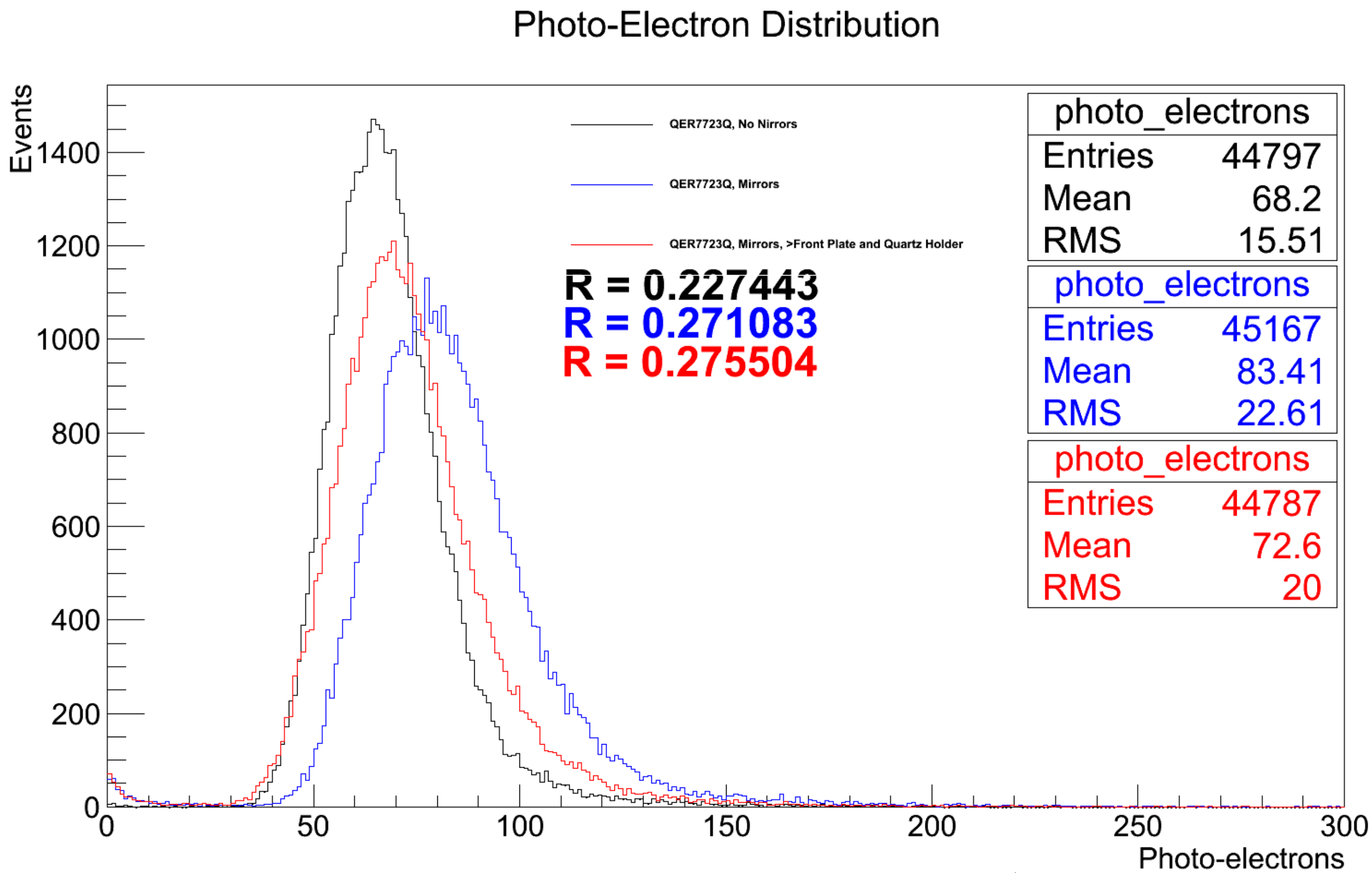
- Design A less sensitive to incident angle than design B.







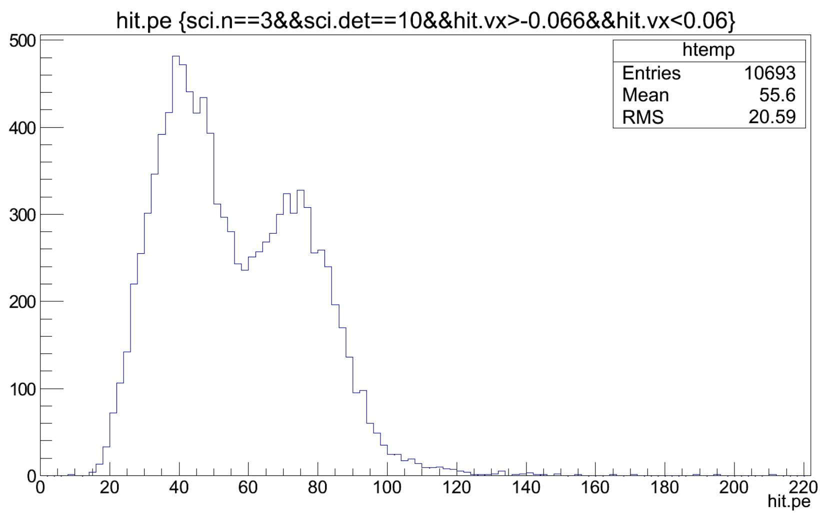
Simulation Study Findings (Design A)

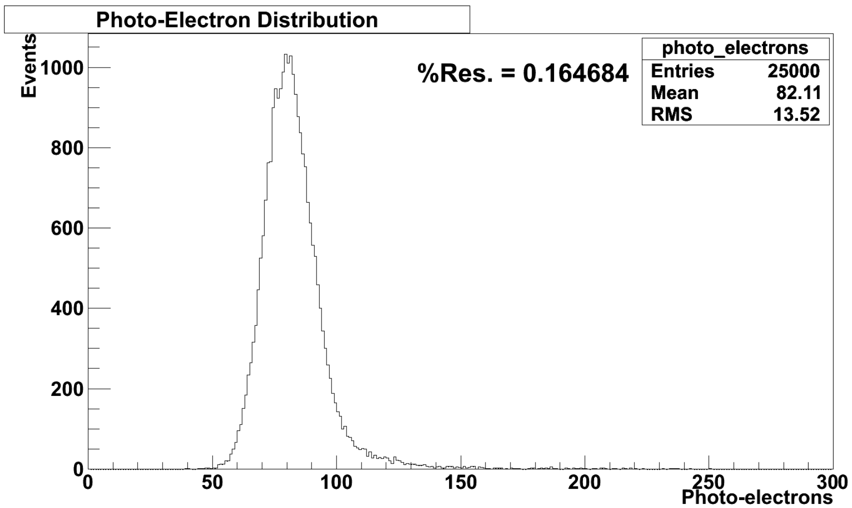


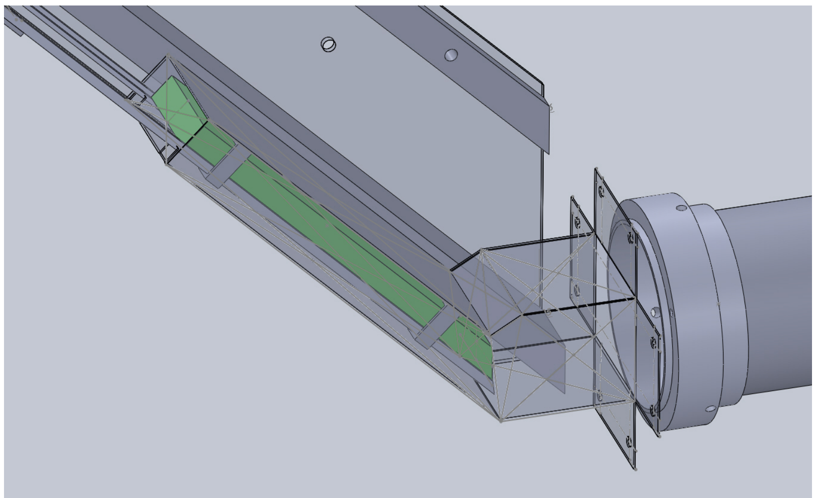
- Plot shows effect on PE dists for design A with:
  - –no lightguide (best resolution)
  - –with lightguide (brightest signal)
  - –with lightguide, quartz holders, front plate (most realistic?)

Simulation Study Findings (Design B)

- Cosmic beam vs perfect e^- beam (with LG and 55mm sep.)

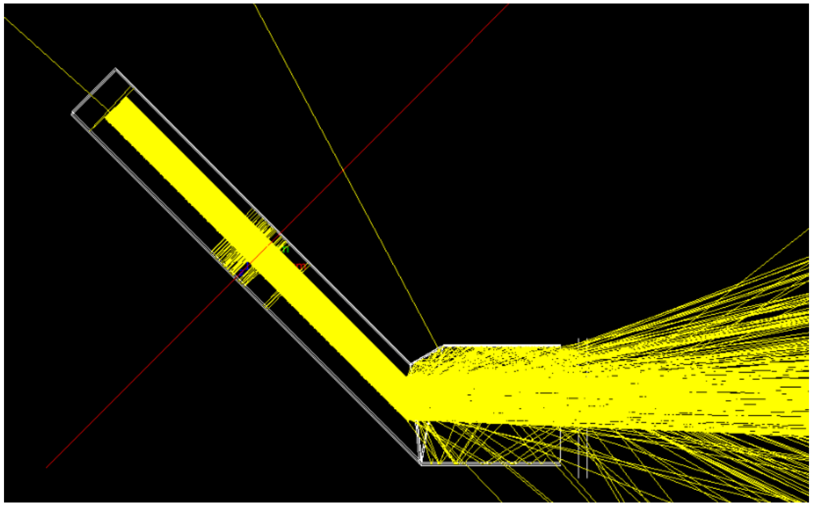


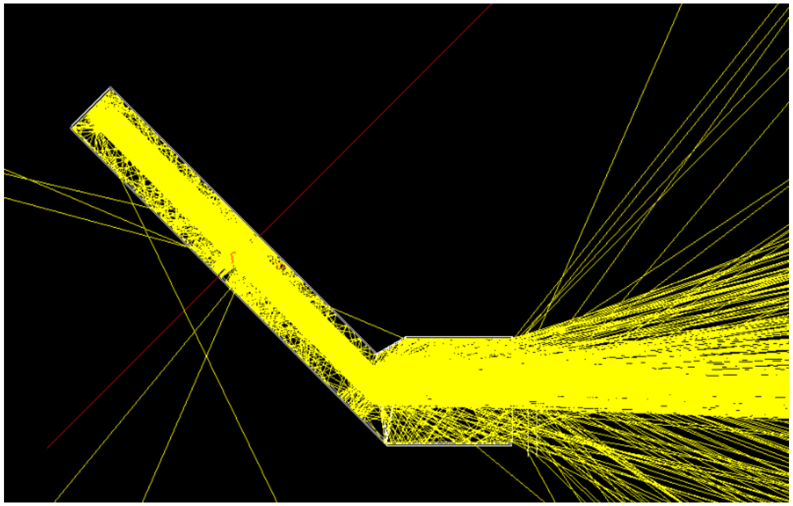


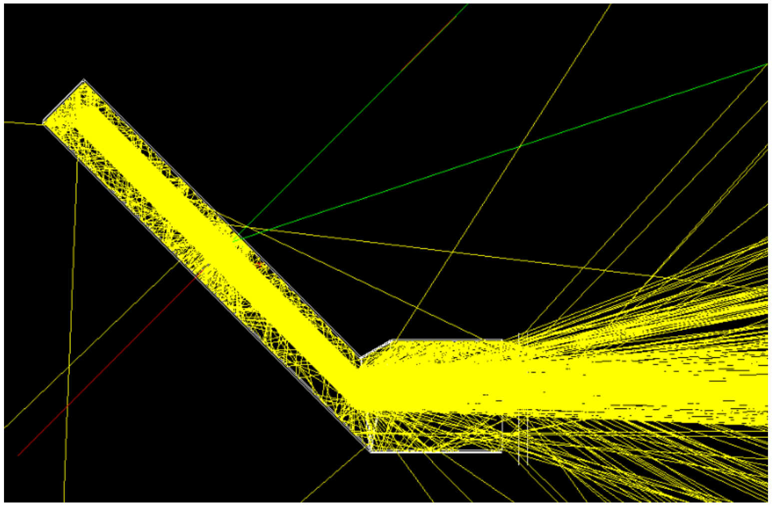


Simulation Study Findings (Design B)

- Sample event visualizations with lightguide

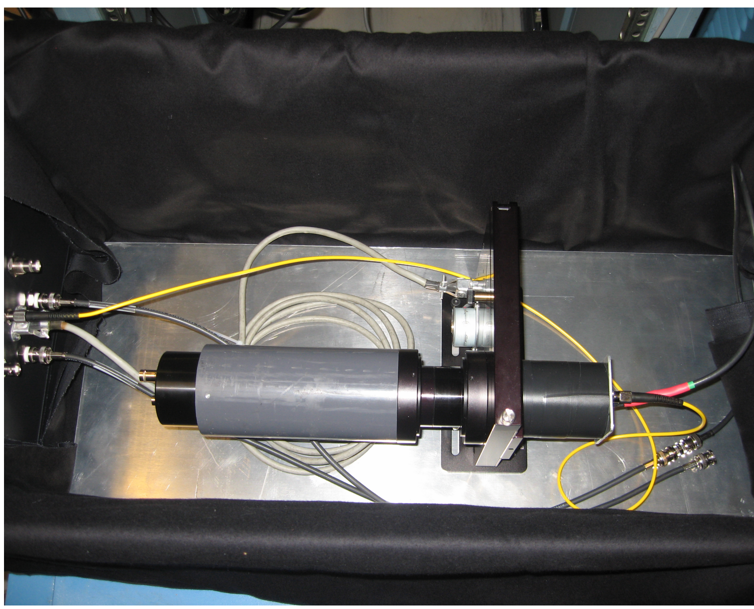


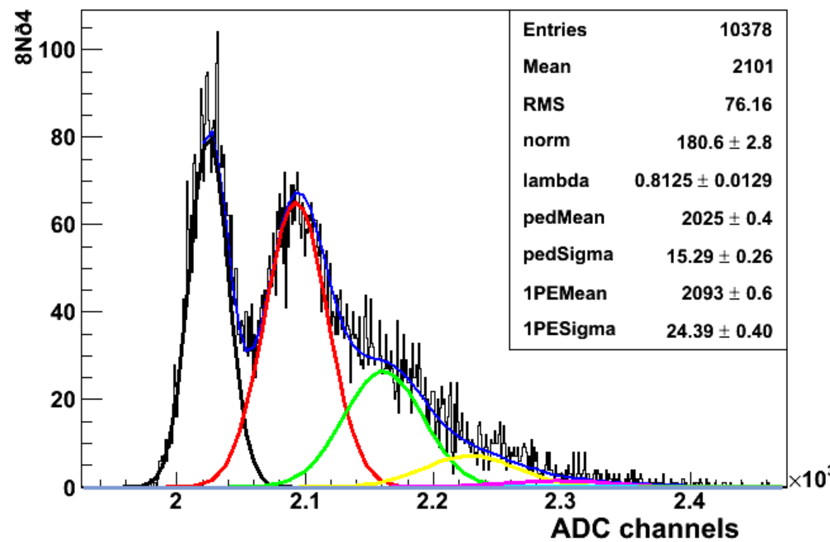




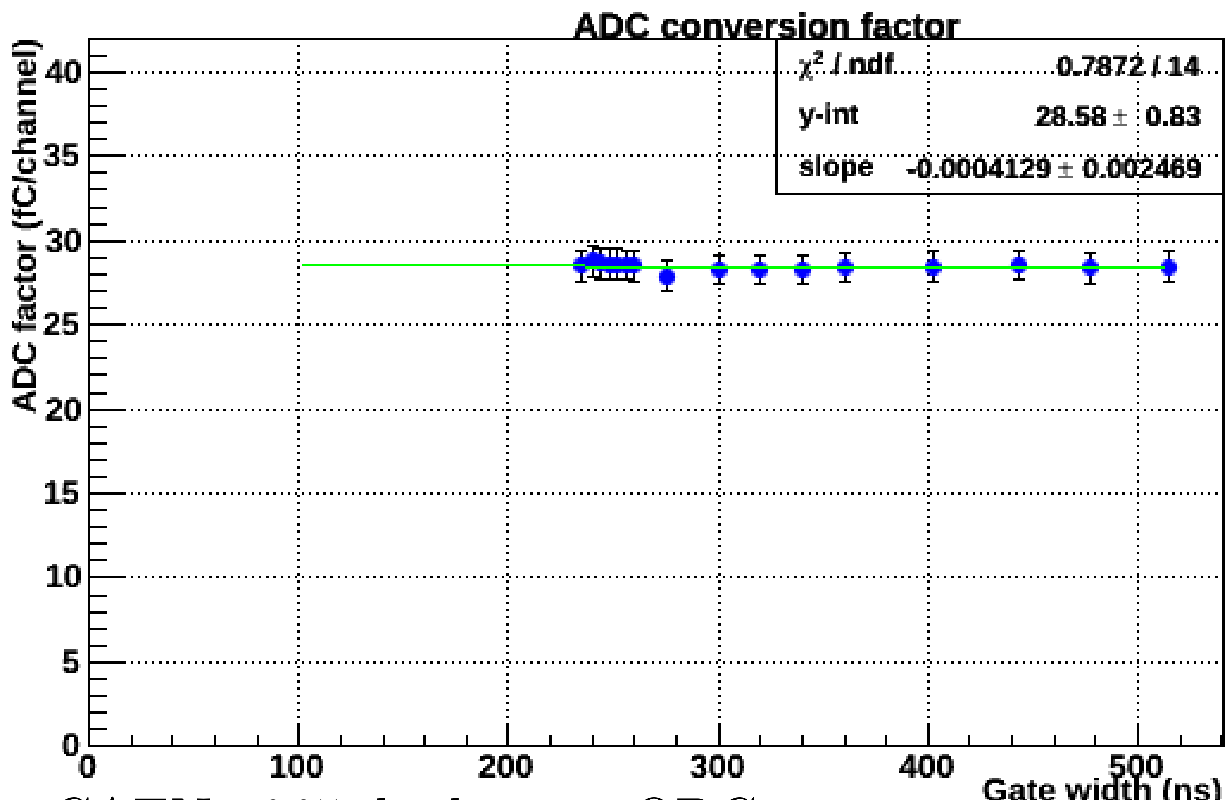
PMT Gain Measurements

- ADC charge sensitivity calibrated
- Gains measured using linearity apparatus with CAEN LED driver, ND filter wheel, and CAEN fast amplifier
- PE peaks extracted using multi-Poisson fit algorithm
- Purchased 4 new R7723Q pmts (with Mod. base); also have two pmts on loan from Jlab





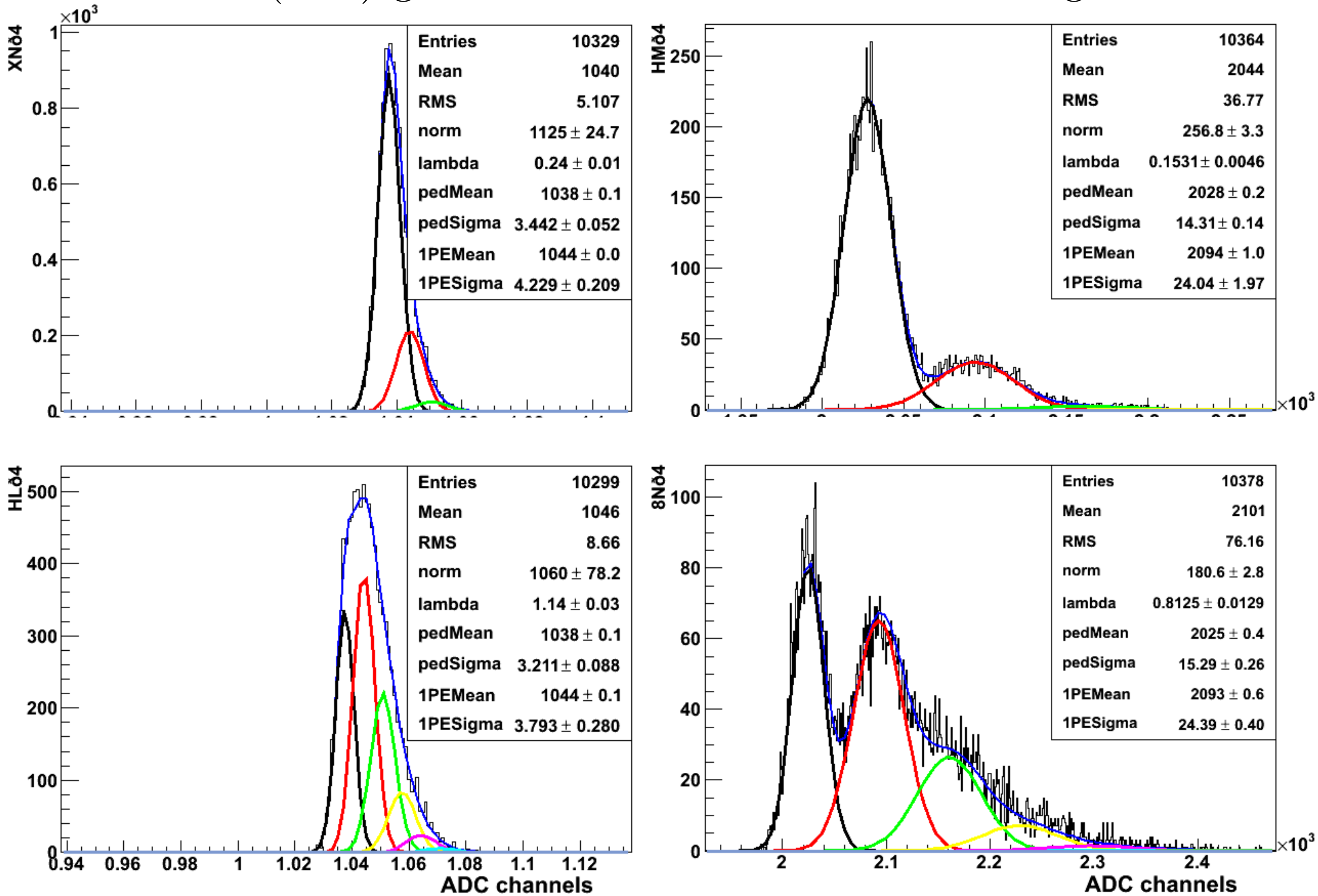
PMT Gain Measurements (ADC Charge Sensitivity)



- Using CAEN v965 dual range QDC
- Spec. gives 25 and 200 fC/ch sensitivities
- We found ∼28.6 and ∼230 fC/ch with about ∼3% uncertainty

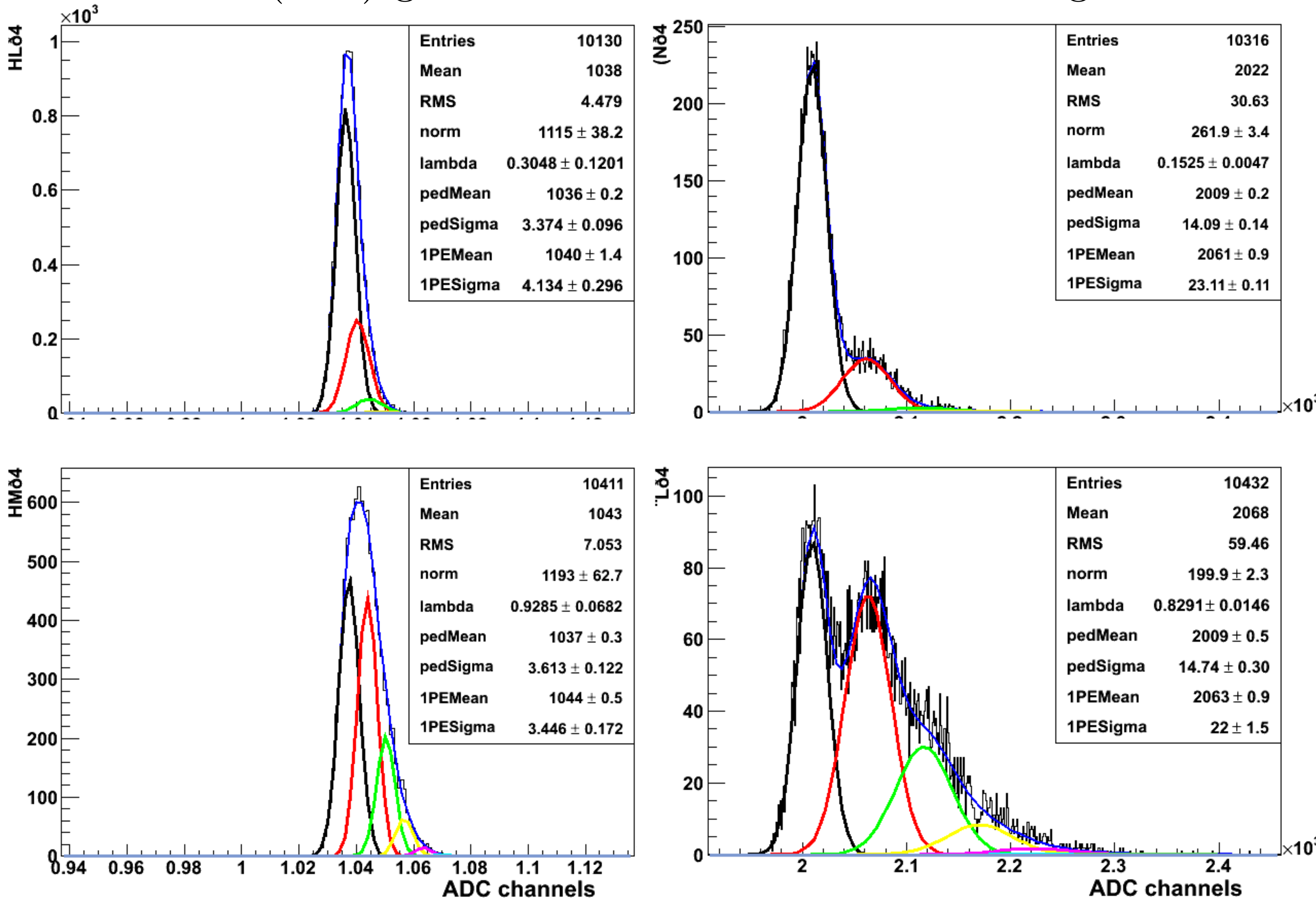
PMT Gain Measurements

- PMT 1 (new) gain at -2000 V for two different light levels:



PMT Gain Measurements

- PMT 2 (new) gain at -2000 V for two different light levels:



PMT Gain Measurements

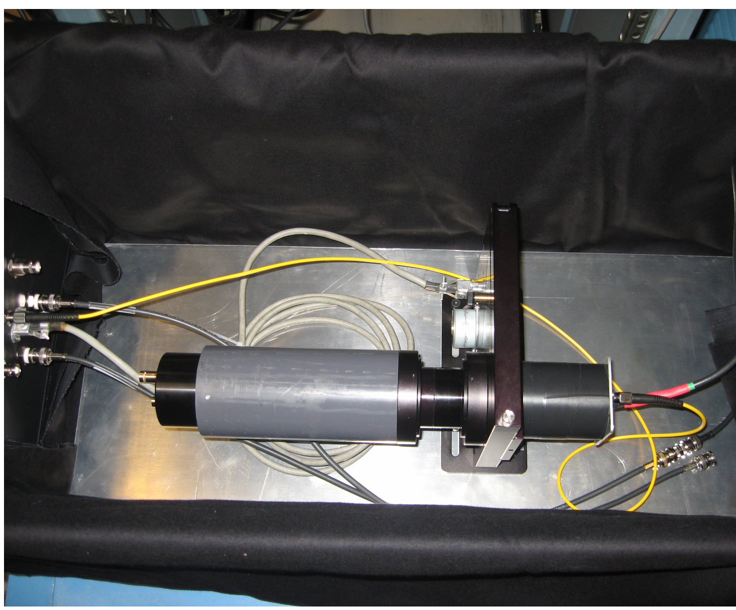
RUN	LED amplitude	PMT	Amp	Gain ($\times 10^6$)
1410	4,50	1	No	1.33
1412	5,50	1	No	1.16
1417	4,50	1	Yes	1.23
1419	5,50	1	Yes	1.25
1424	4,50	2	No	0.75
1426	5,50	2	No	1.16
1431	4,50	2	Yes	0.96
1433	5,50	2	Yes	0.99

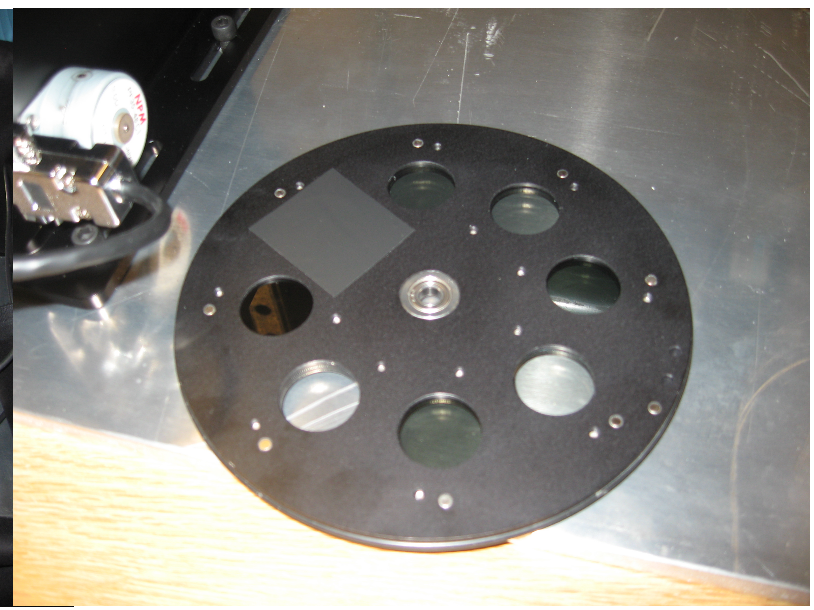
Table 2: Table of gain measurements at -2000 V. Uncertainty is about 10% right now and is dominated by uncertainty in 10x amp. Gains measured without amplifier are somewhat sensitive to fitting.

Path to Linearity Measurements

- Test apparatus constructed (based on Luis' setup):
  –Two LEDs (one steady, one flashing) ⟶ filter wheel ⟶ diffuser ⟶ pmt

  –Integrating DAQ using Qweak ADC: have HAPPEX timer and ported drivers for linuxROC, NEED help porting drivers for Qweak ADC!!!– Paul King volunteered to help

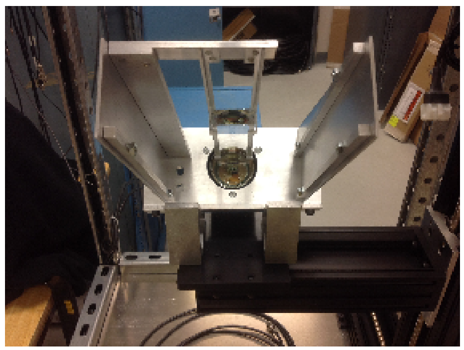


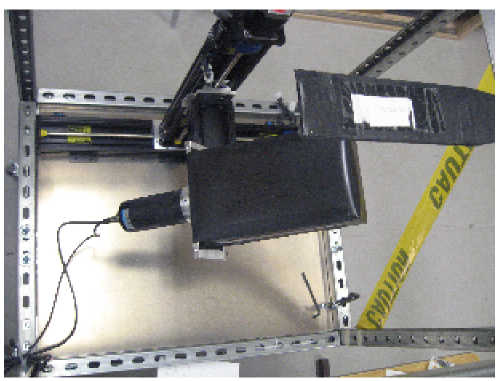


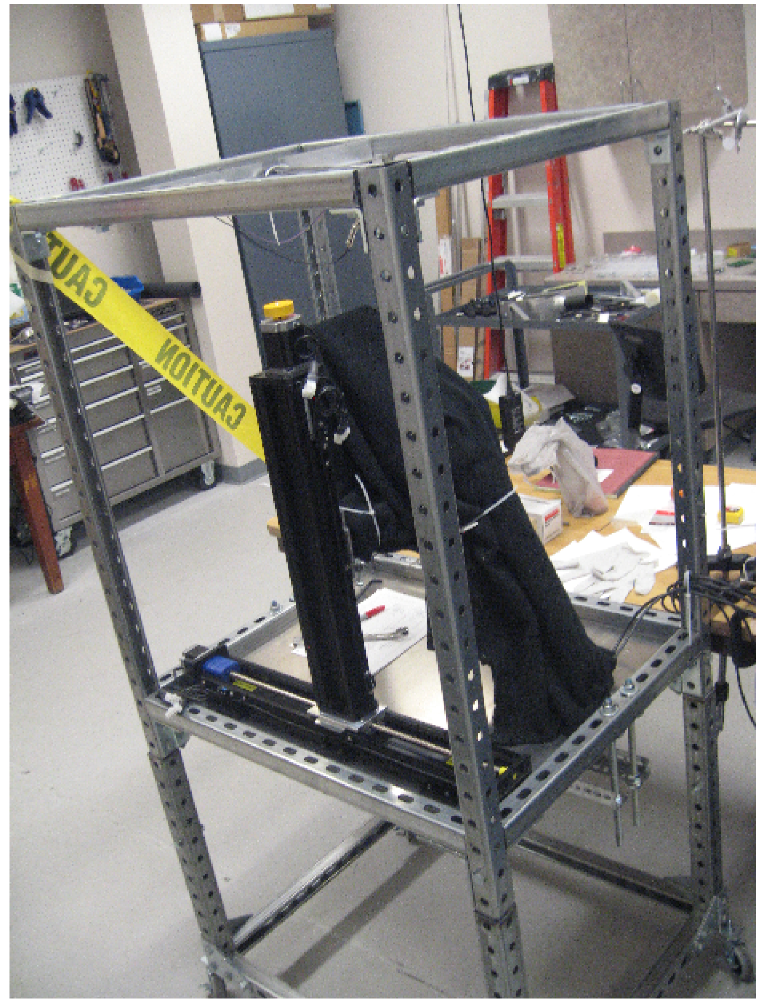
Linearity Study Strategy

- Using apparatus to map out pmt gains over large range of HV
- Will use these gains to calibrate PE's from real data tests. Can then use estimated e^- flux combined with PE's/e^- to estimate anticipated pmt anode currents during PREX II and CREX
- LED light level is then adjusted to yield those anticipated PE rates
- For various HV's, LED asymmetries are measured for each filter setting and the degree of non-linearity is extracted from fits to the data.
- Choose HV setting that gives best linearity while utilizing ~full range of 18-bit ADCs

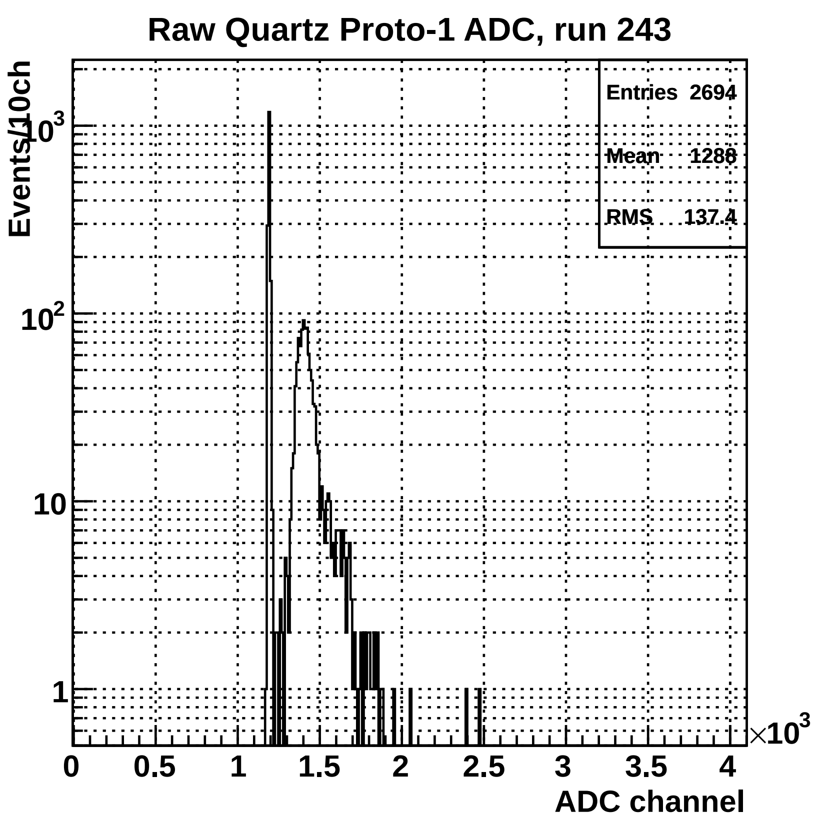
Cosmic Stand: Design A Tests

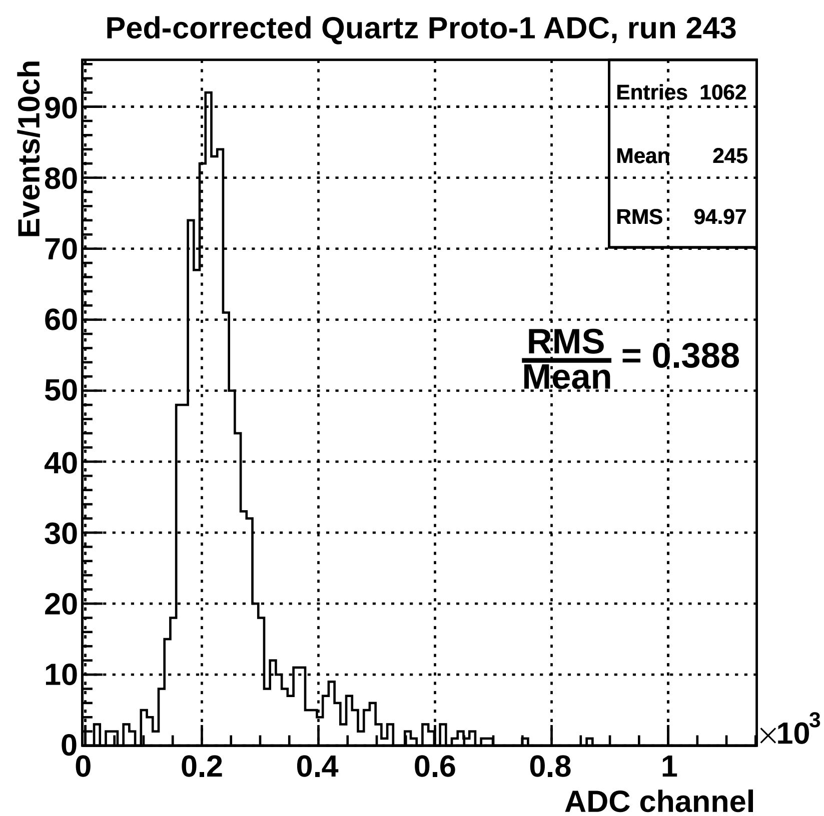






Initial Cosmic Test Results: Design A
10mm quartz, 5mm separation, -1800V, Anolux miro-silver LG





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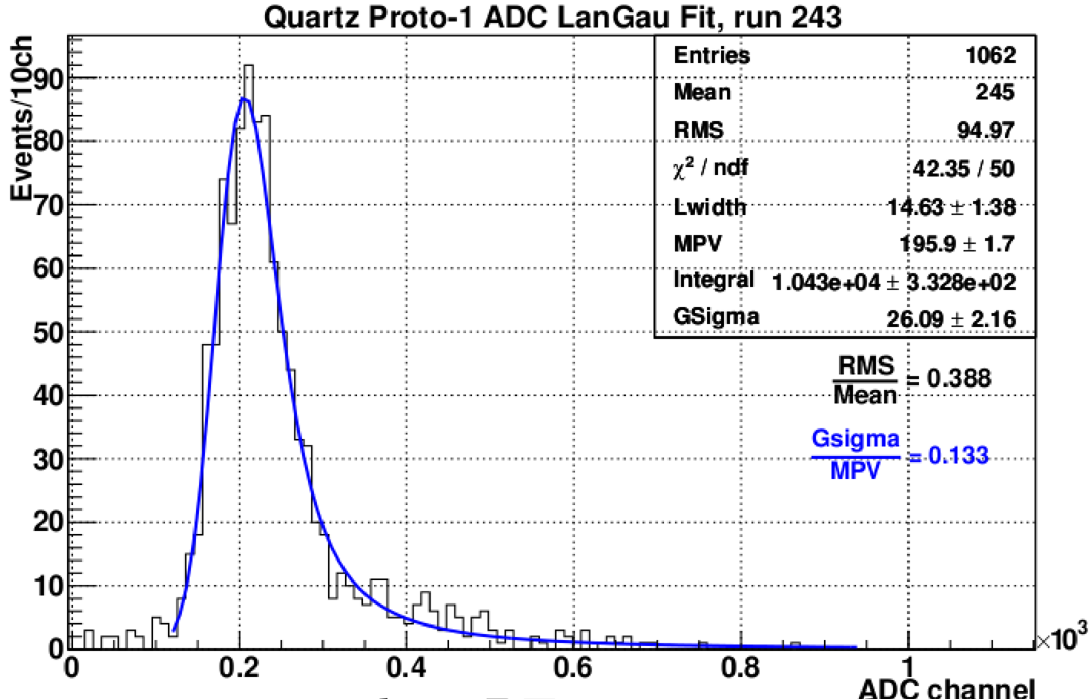
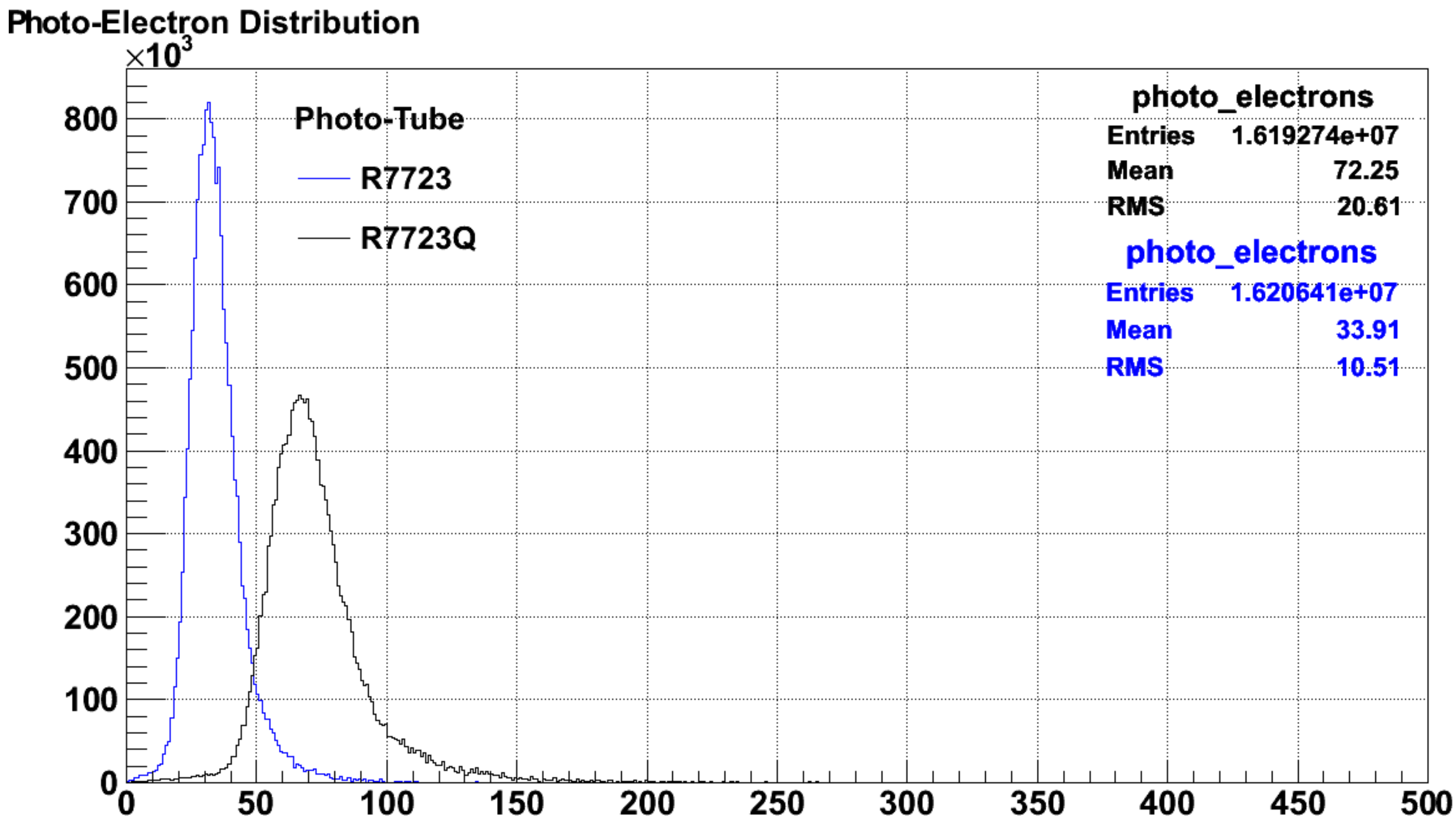


- LanGau parameters isolate PE statistics, where:

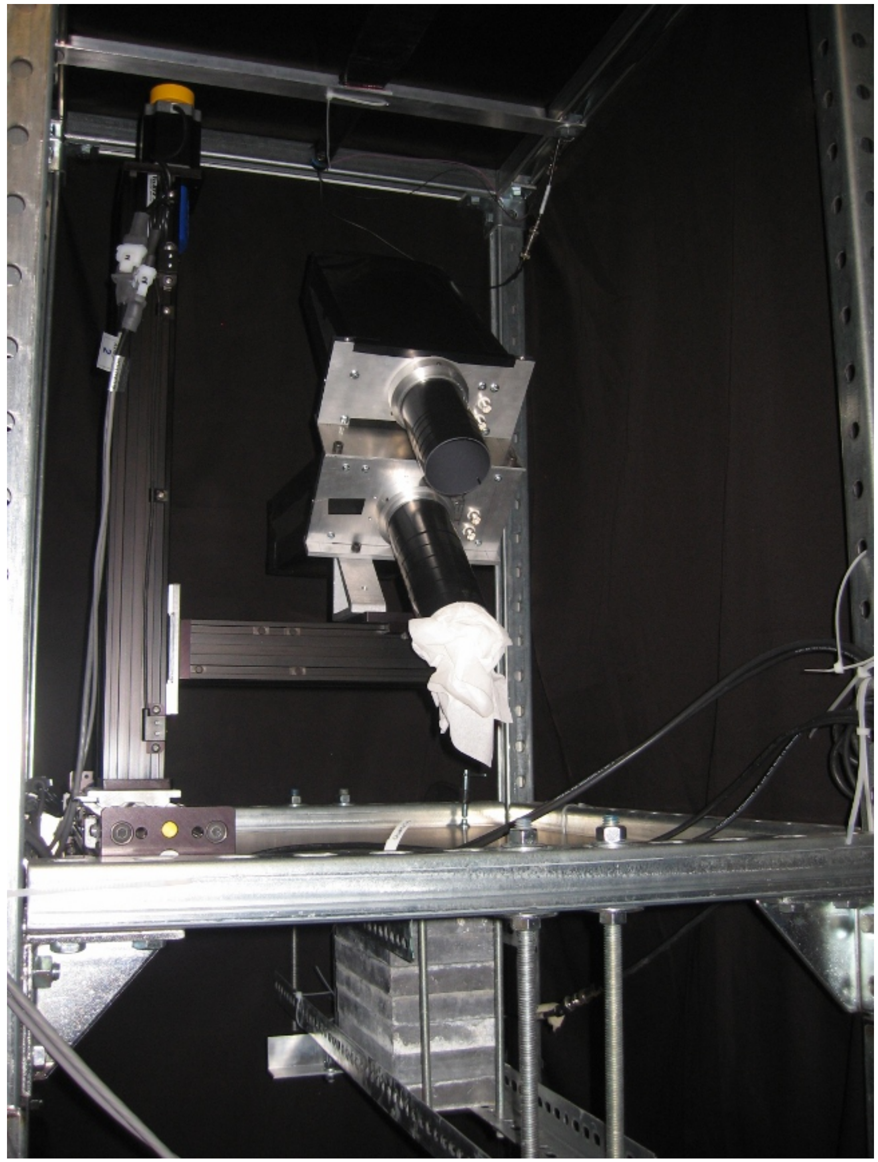
$$\text{peak PEs} = \left(\frac{MPV}{Gsigma}\right)^2 + 1 = 57.5$$

- Used jlab pmt1 at -1800 V (note: "selected" low gain tube)
- Preliminary gain measurements of this tube are 7.5×10^5 at -2000 V and 6.1×10^5 at -1800 V (data to come)
- Calculated peak PEs $= \frac{MPV \cdot Q_{sensitivity}}{e \cdot pmtGain} = \frac{196 \cdot 28.6}{e \cdot 6.1 \times 10^5} = 57.4$

Simulated PE distribution: Design A



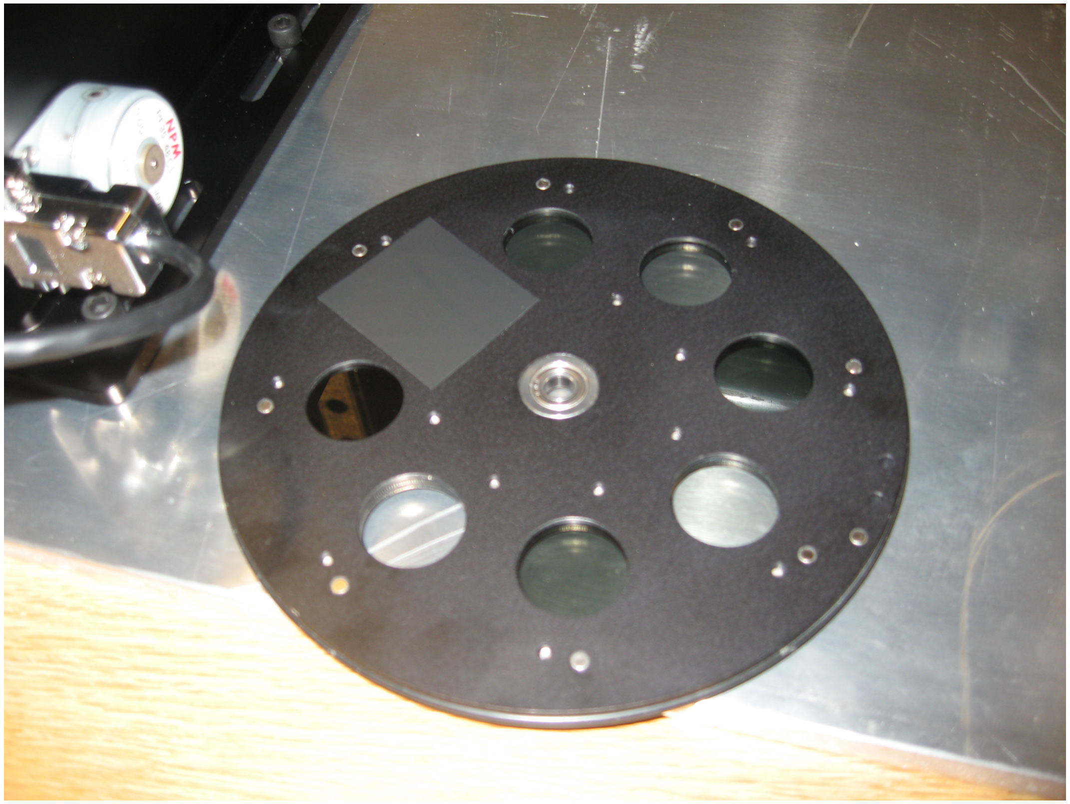
Cosmic Stand: Design B Tests (Coming soon)



Summary and Plans

- Two prototypes constructed including new 45deg design
- Optical simulations are mature and producing pulse height distributions that compare well with real data
- Simulation studies show that:
  –Minimize quartz - pmt separation (best of both worlds!)
  –Design B more sensitive to incident angle (sweet spot limited to 45 ± 3 degrees)
  –If have enough light, then don't want or need a lightguide
- Purchased 4 new R7723Q pmts and have started mapping-out gain vs. HV
- Linearity Studies: Getting closer to an integrating DAQ using Qweak ADC and linuxROC (Paul King to help port drivers)
- First "full-circle" PE comparison between real (LanGau and gain method) and simulated data almost too good...story to be continued
- Cosmic data for design B coming by the end of the month

Filter Wheel



- Edmunds Intelligent Filter Wheel; computer controlled
- Absorptive ND filters: 400 - 700 nm
- Eight transmission settings (%): 100, 79, 63, 50, 40, 25, 10, 0

PMT Linearity Box and Integrating DAQ