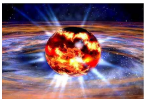


# Thin Quartz Detector R&D and PMT Linearity Studies

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Idaho State University  
*mcnulty@jlab.org*

Thanks to: Carlos Bula, Brady Lowe, Will Gorman

April 11, 2014



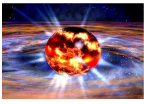
## Ongoing Work at ISU for CREX, PREX and MOLLER

### Quartz detector development

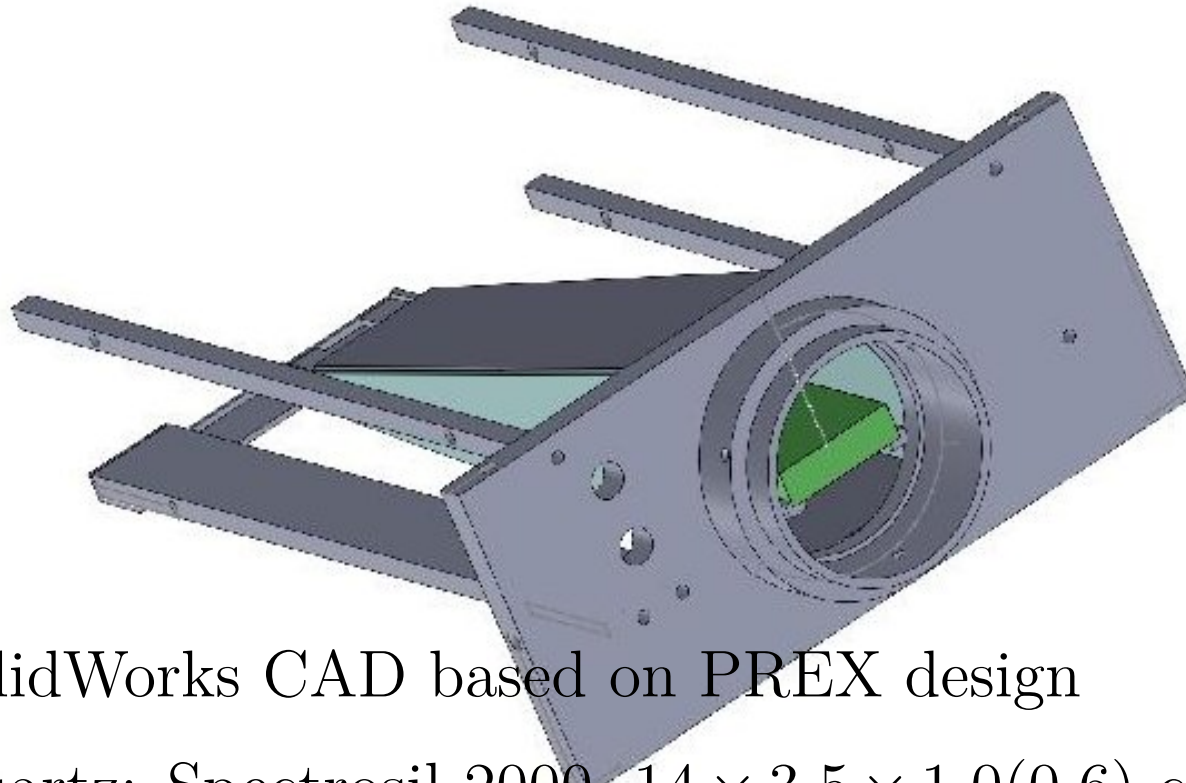
- Cosmic tests
  - Constructed baseline prototype detector
  - Constructed cosmic/beam test stand
  - Established counting DAQ (VME/CODA 2.6)
- G4 optical Monte Carlo
  - Using qsim framework developed by Seamus
  - Modeled precise geometry of cosmic test setup
  - Continuing to develop and refine.

### PMT Linearity Studies

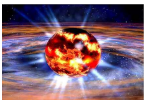
- Test apparatus constructed (based on Luis' setup)
- Use for pmt gain measurements
- Still working on Integrating DAQ



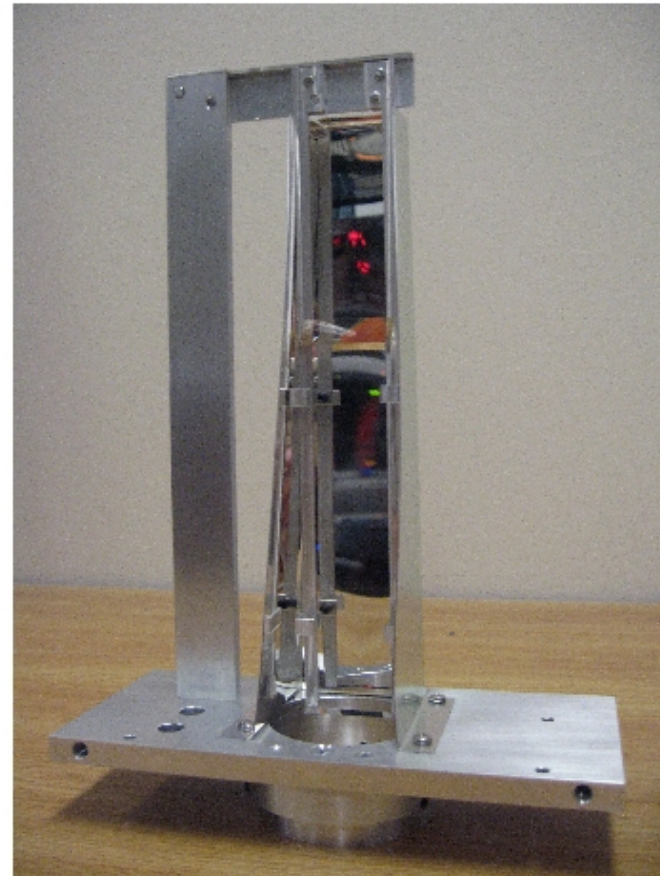
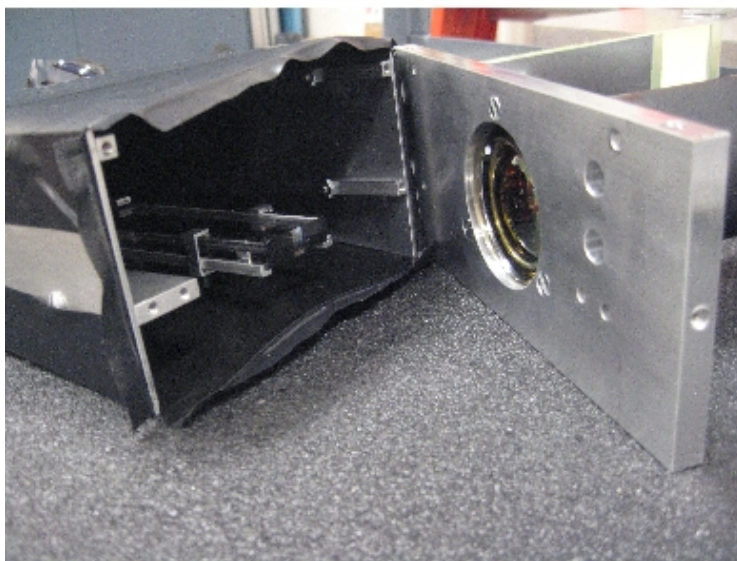
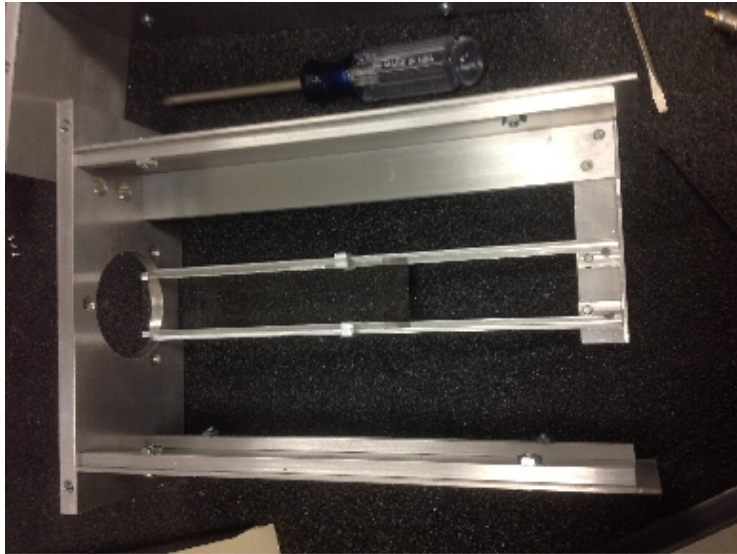
## Baseline prototype Quartz Detector

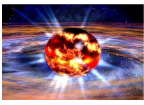


- SolidWorks CAD based on PREX design
- Quartz: Spectrosil 2000,  $14 \times 3.5 \times 1.0(0.6) \text{ cm}^3$ ,  $45^\circ$  bevel on one end, optical polish all sides
- Light guide: Anolux Miro-silver 4270AG, ...

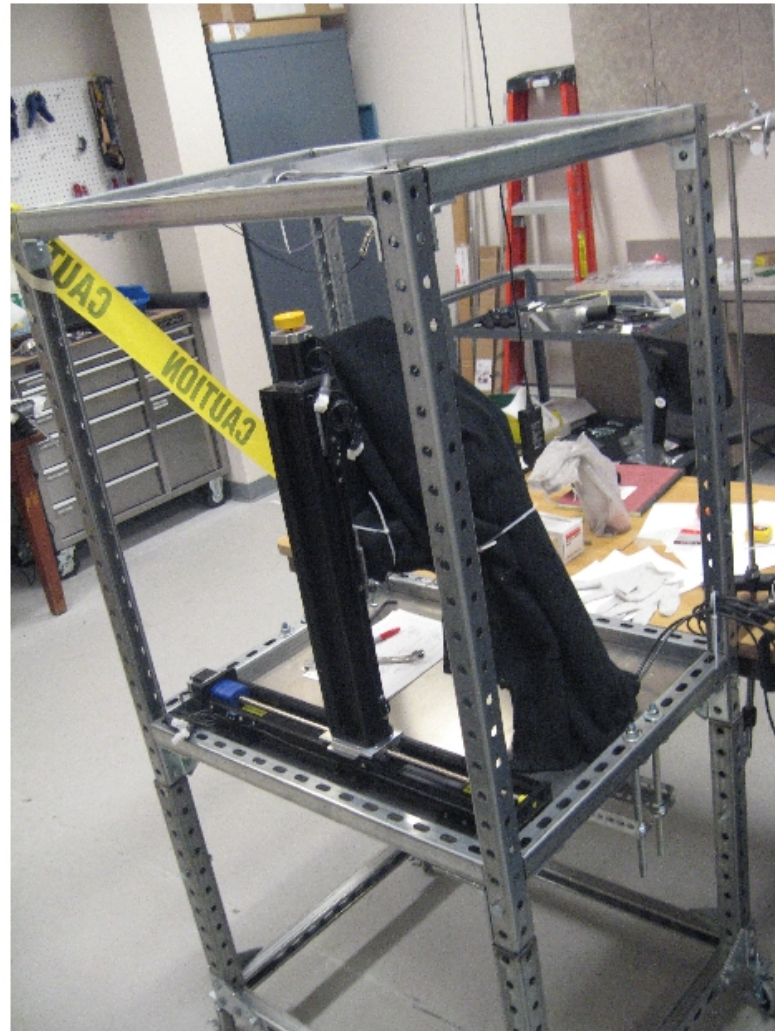
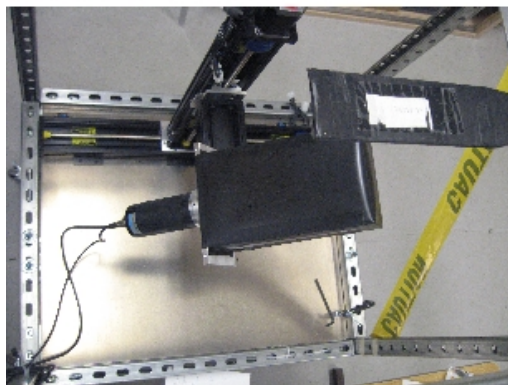
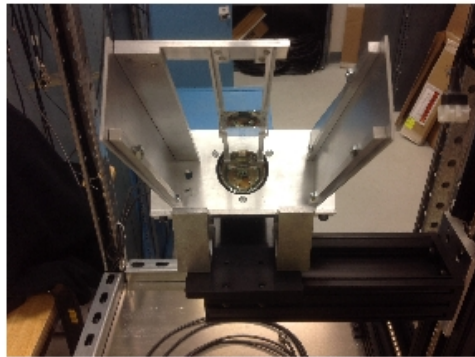


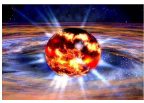
## Baseline prototype Quartz Detector



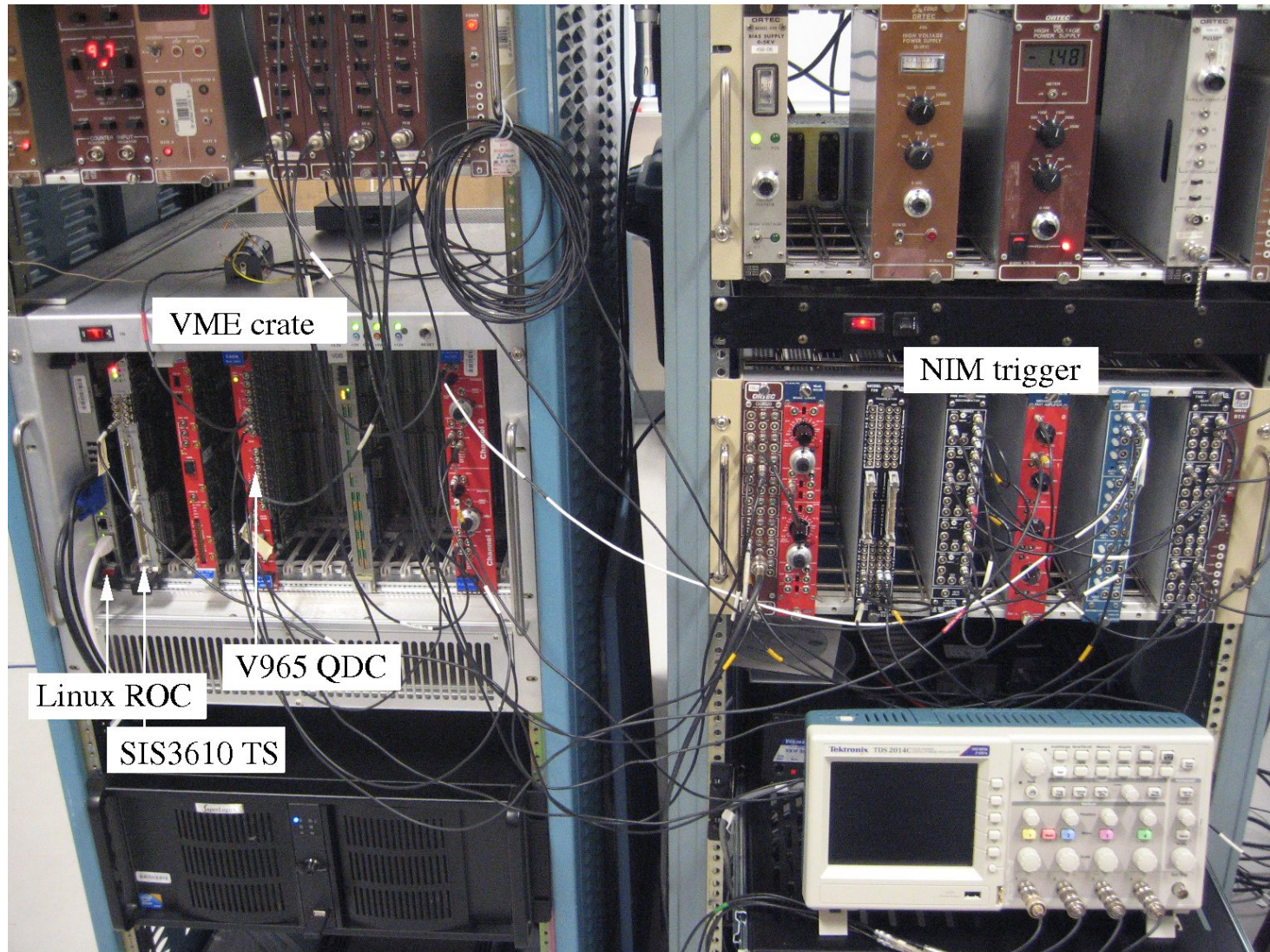


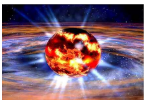
## Cosmic/Beam Test Stand





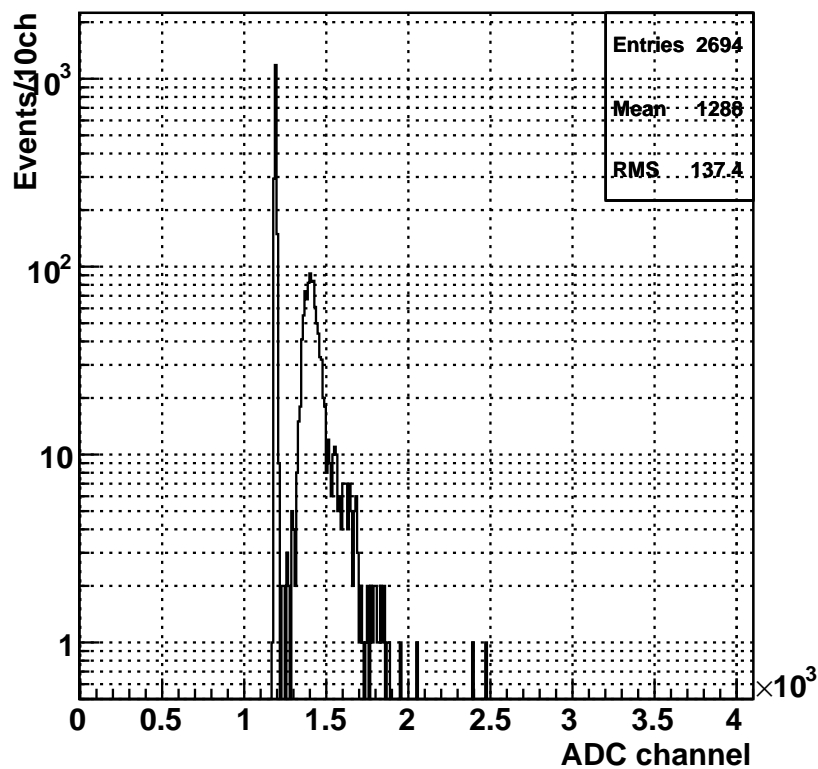
# Counting DAQ



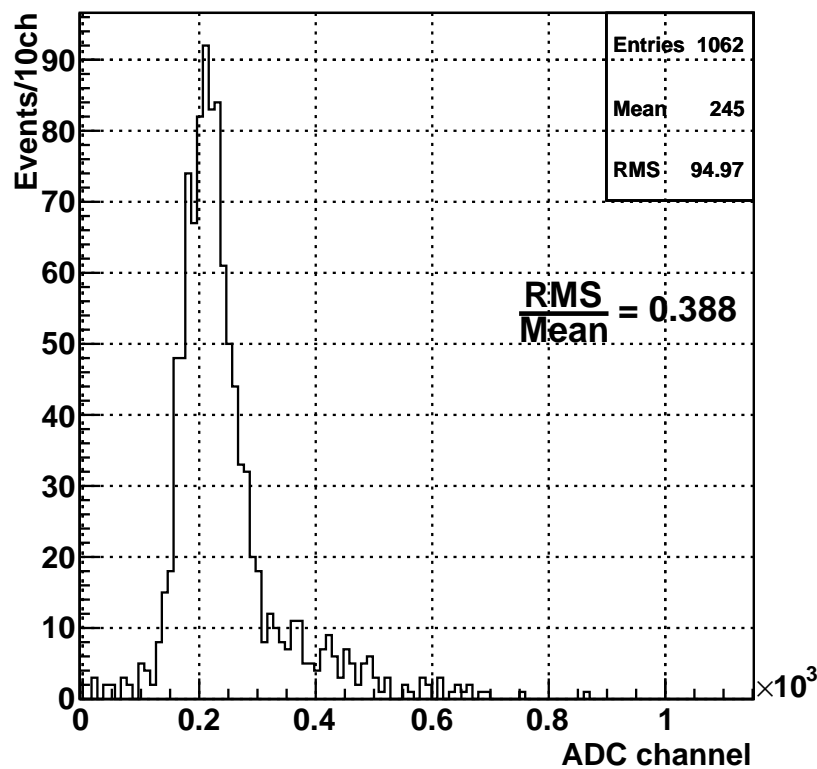


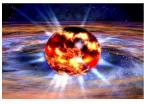
# Initial Cosmic Test Results

Raw Quartz Proto-1 ADC, run 243



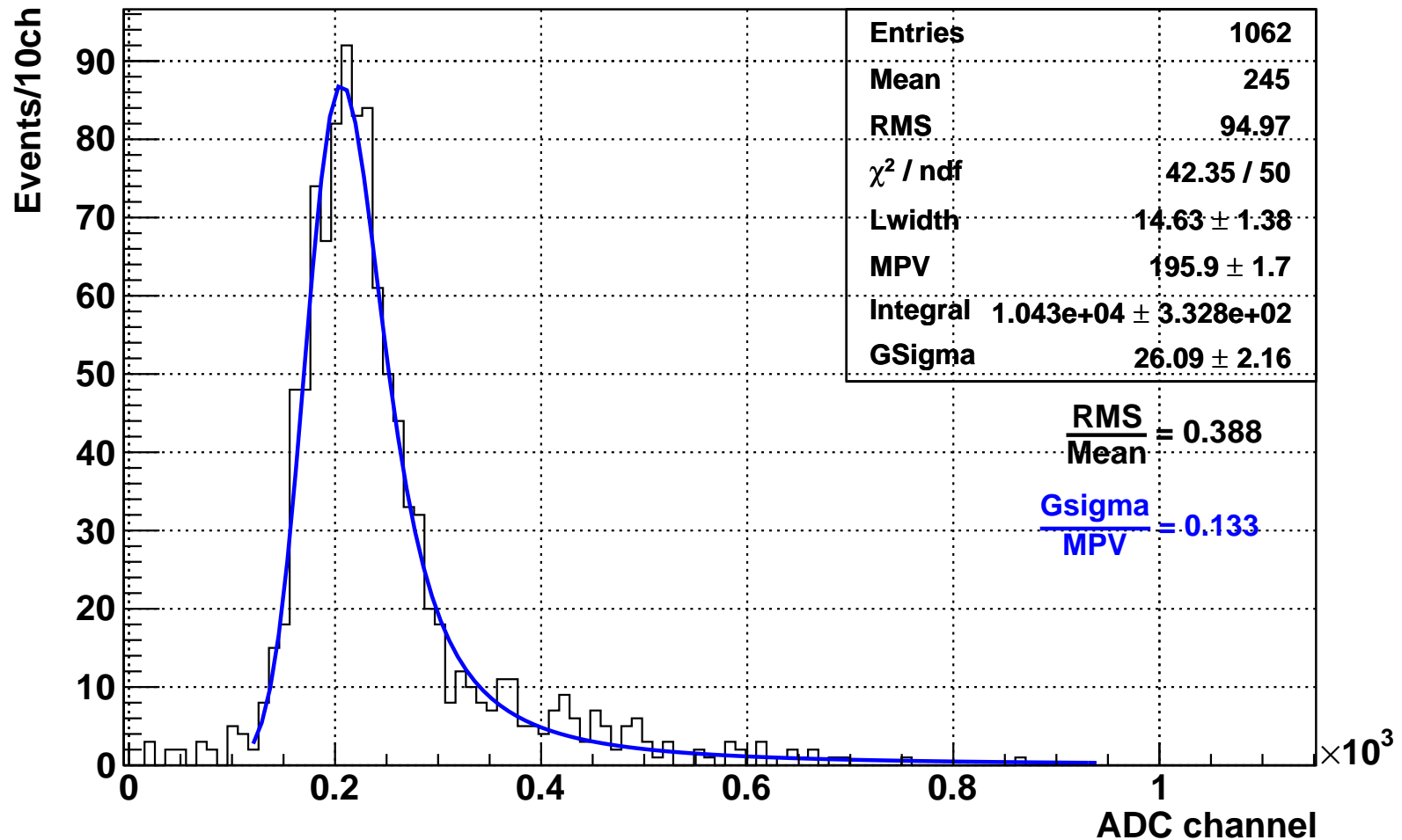
Ped-corrected Quartz Proto-1 ADC, run 243



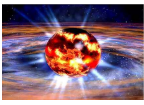


# Initial Cosmic Test Results

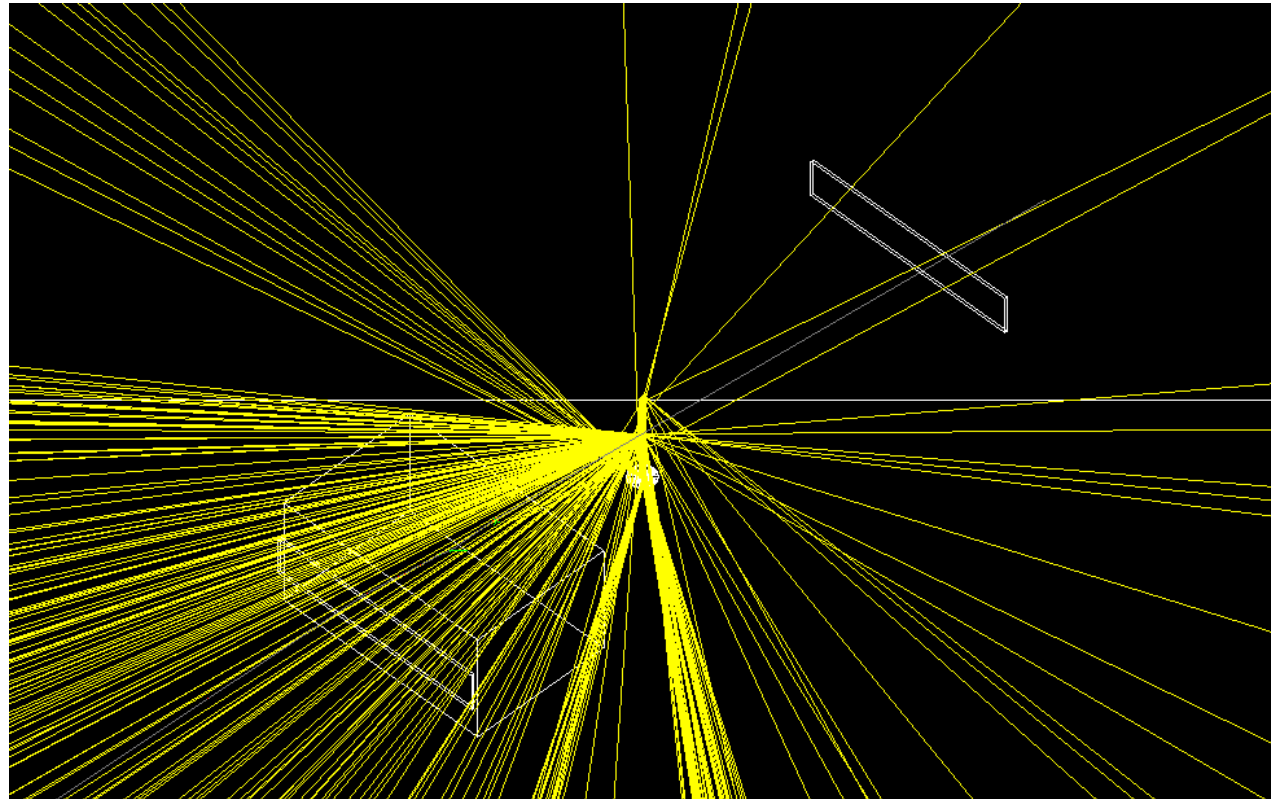
## Quartz Proto-1 ADC LanGau Fit, run 243



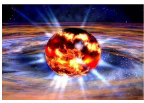




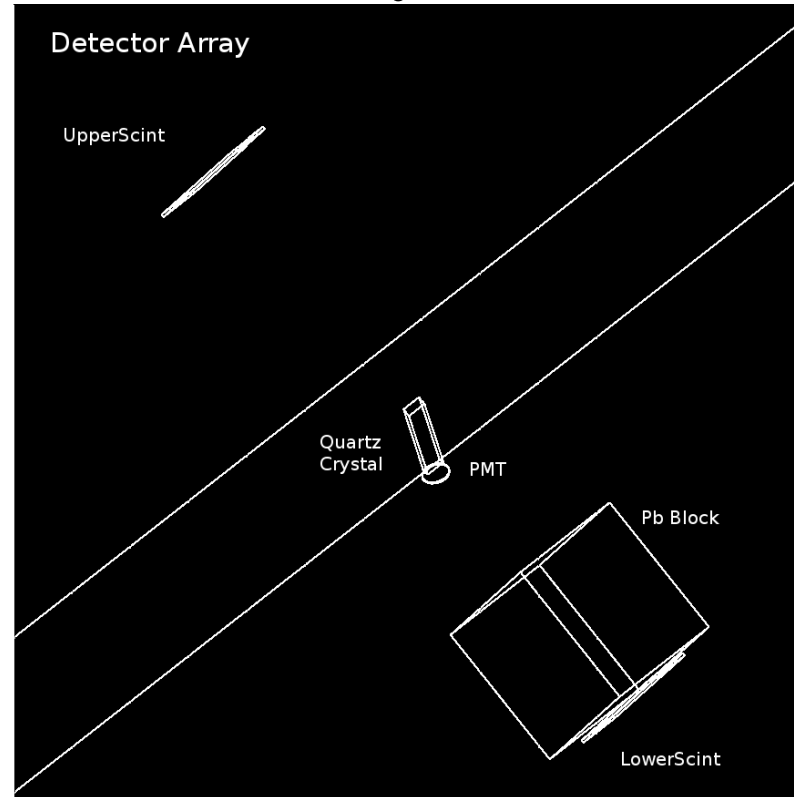
## G4 Optical Simulation: qsim



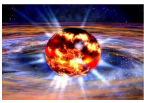
- qsim framework developed by Seamus
- Geometry adapted to ISU cosmic test setup
- Additional realistic features implemented: muon angle smearing, PMT QE, scintillator coinc. trigger



## qsim Geometry: Cosmic Tests

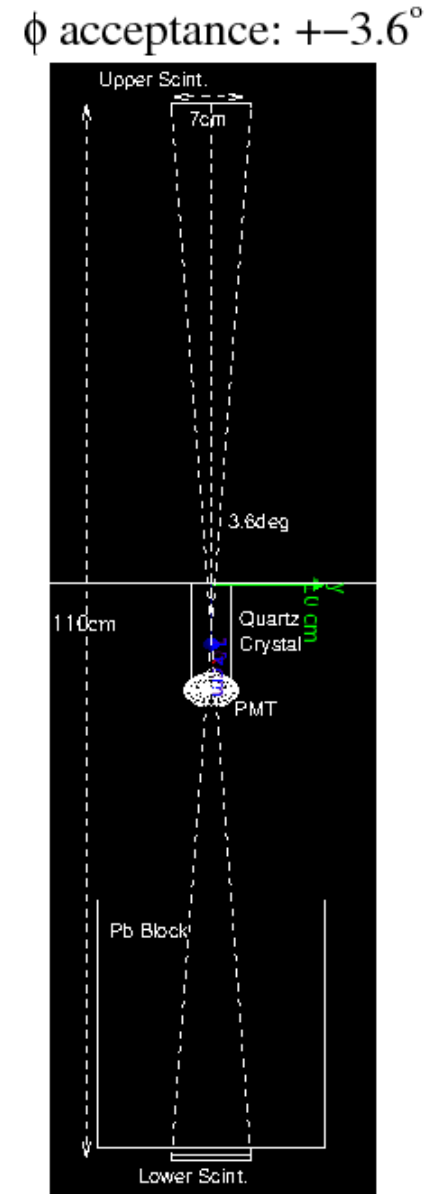
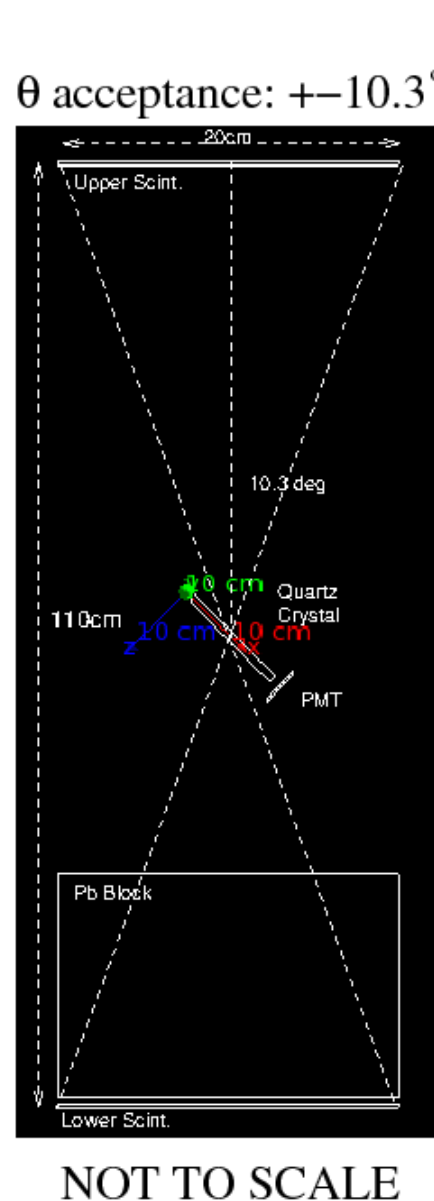


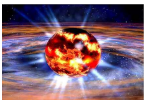
- Two scintillators: each  $20 \text{ cm} \times 7 \text{ cm}$ , separated by  $110 \text{ cm}$
- bare PREX detector: quartz bar,  $5 \text{ mm}$  from  $2 \text{ in}$  PMT, angled at  $45^\circ$  wrt scintillators
- 8 inches of Pb installed just above lower scintillator



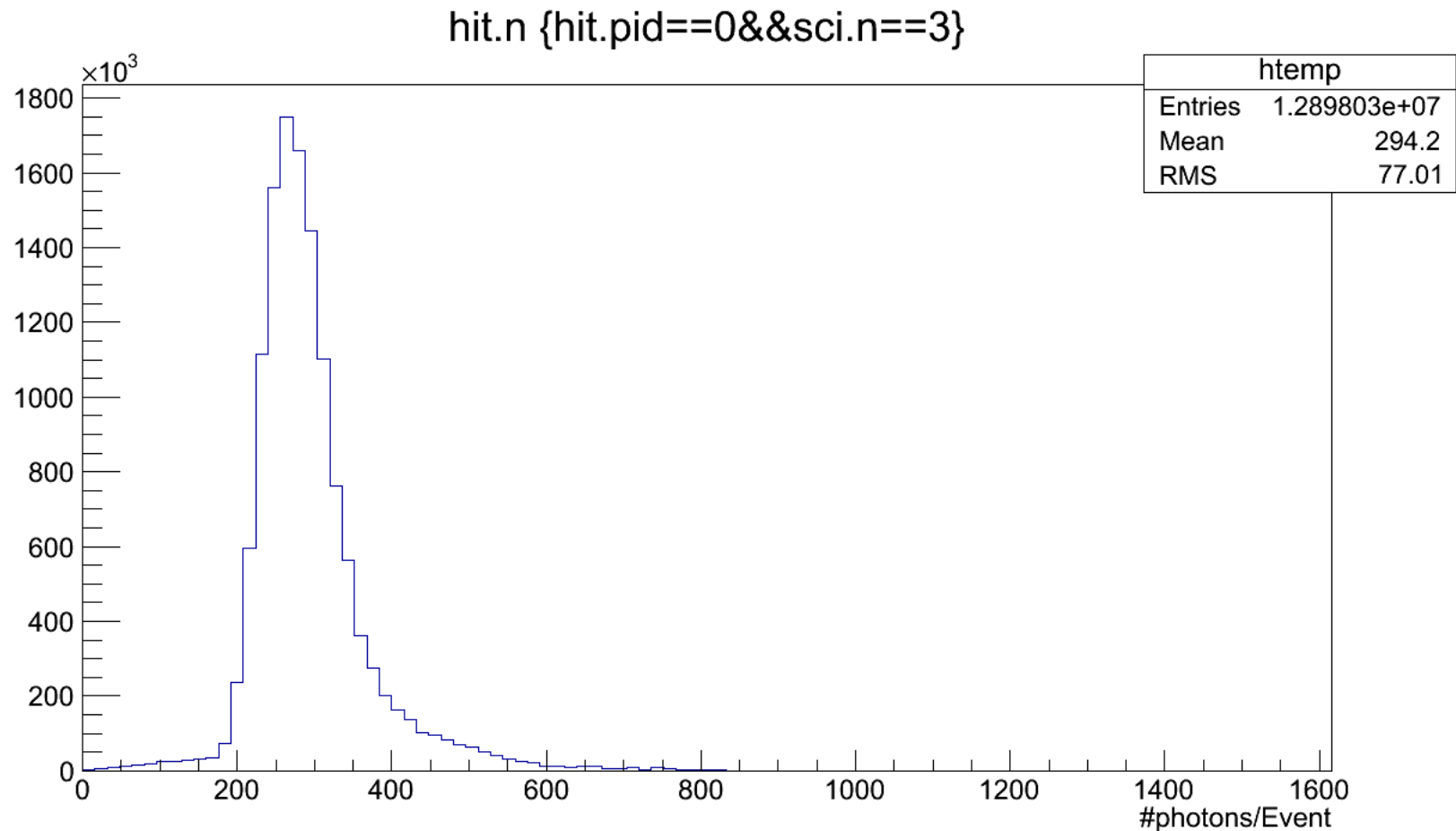
# qsim Beam Source: Cosmic Tests

- $\mu^-$  beam Energy: 800 MeV
- Angles:
  - $\theta : \{34.7^\circ, 55.3^\circ\}$
  - $\phi : \{-3.6^\circ, 3.6^\circ\}$
  - Uniformly sampled
- Positions:
  - Uniformly sampled over scintillator area



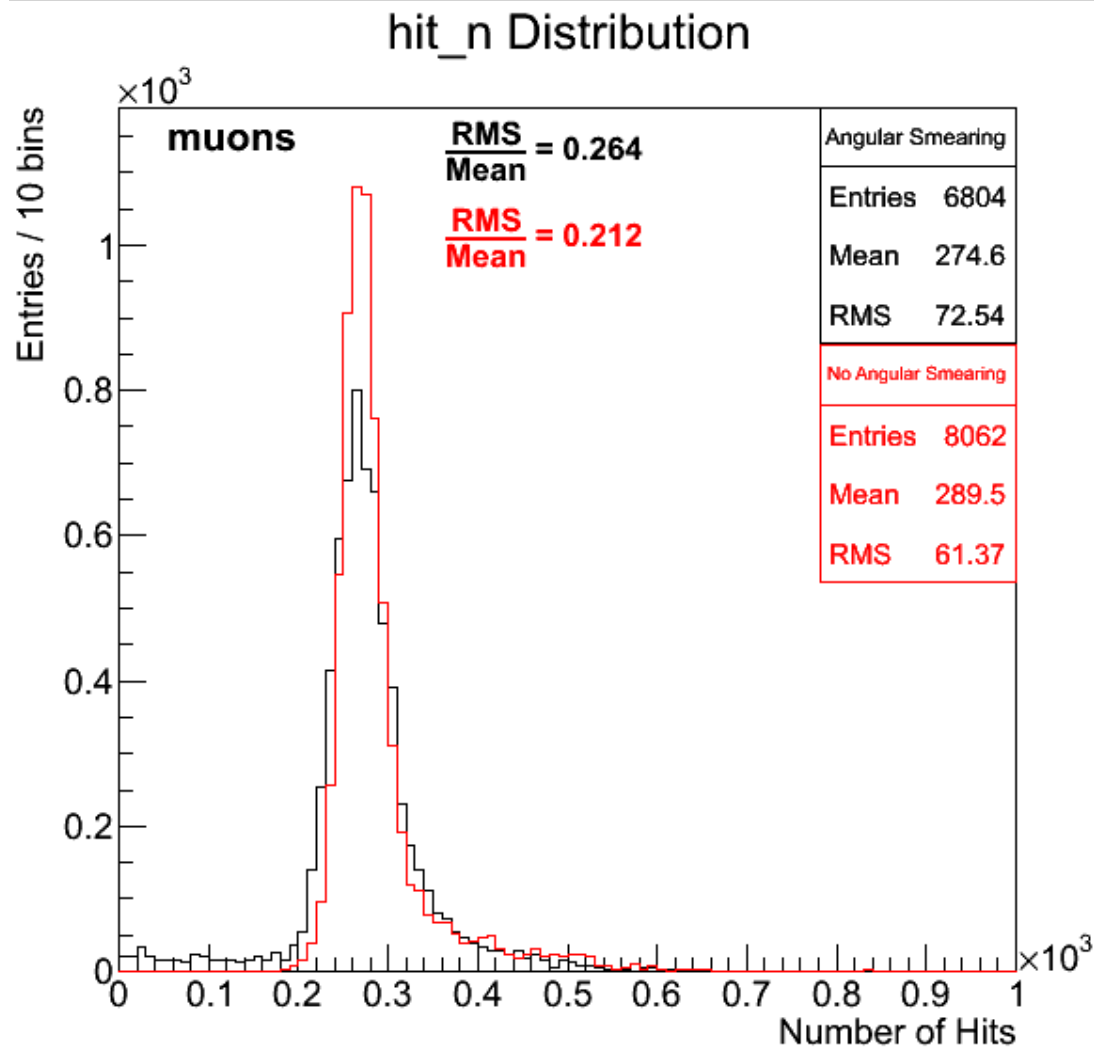


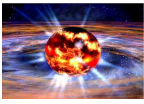
# Distribution of Photons/Muon Hitting PMT





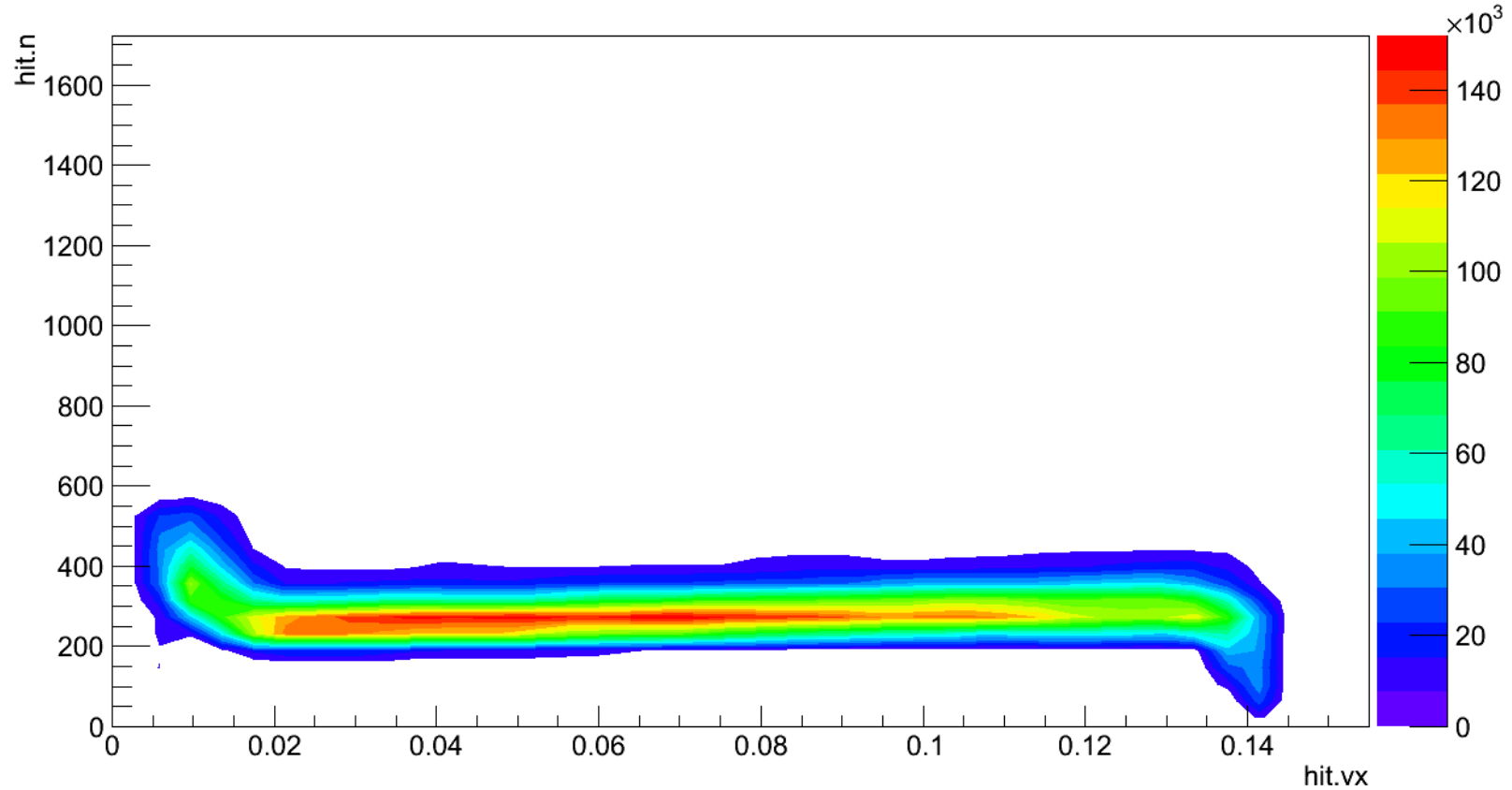
# Comparison with and without Angle Smearing

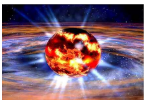




# Photon Distribution versus creation x\_vertex

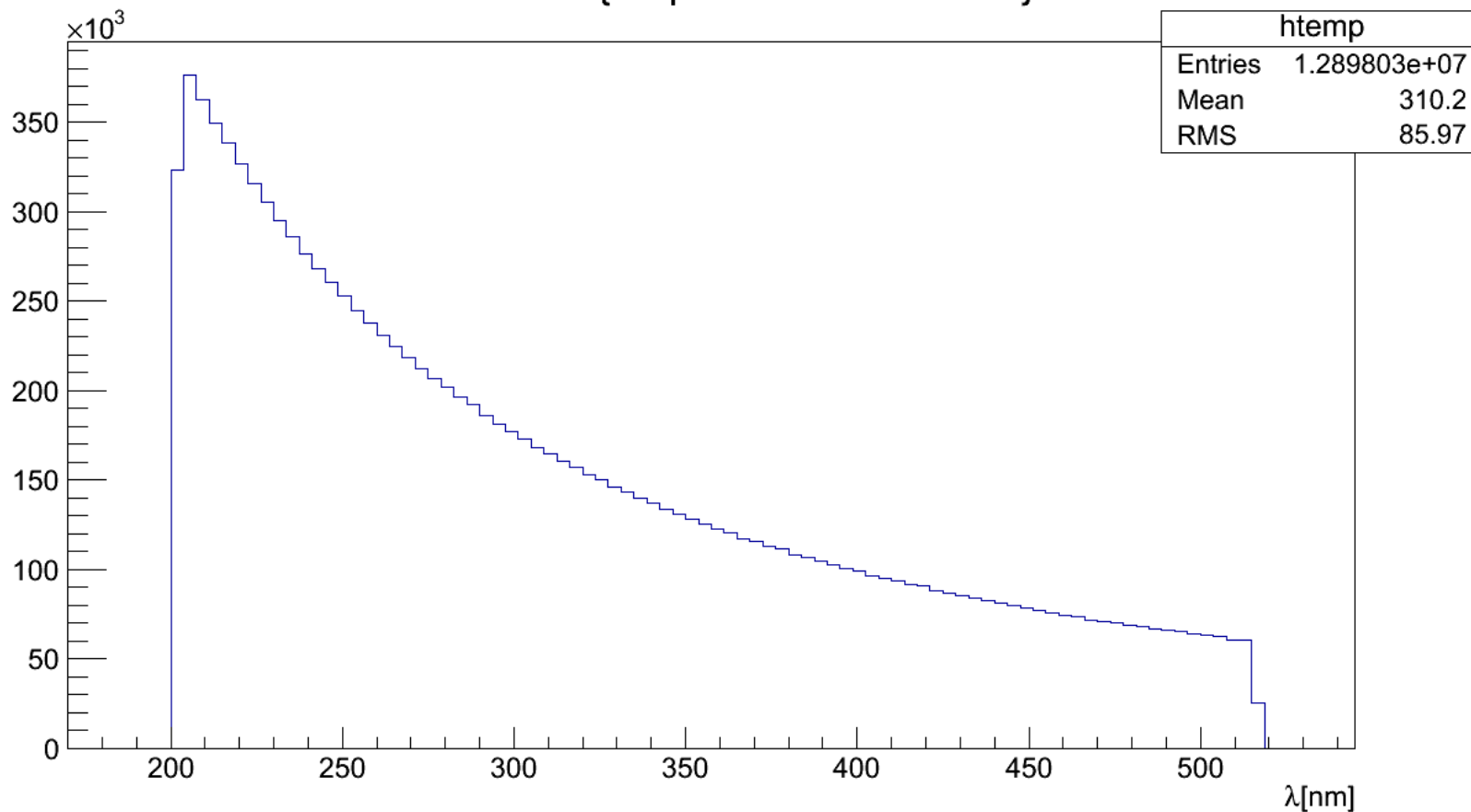
hit.n:hit.vx {hit.pid==0&&sci.n==3}

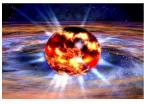




# Photon wavelengths

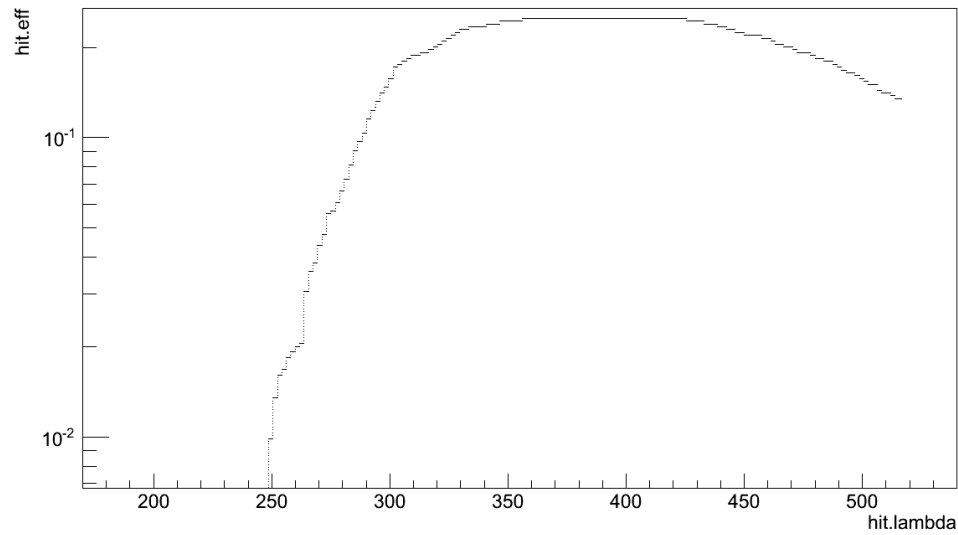
hit.lambda {hit.pid==0&&sci.n==3}



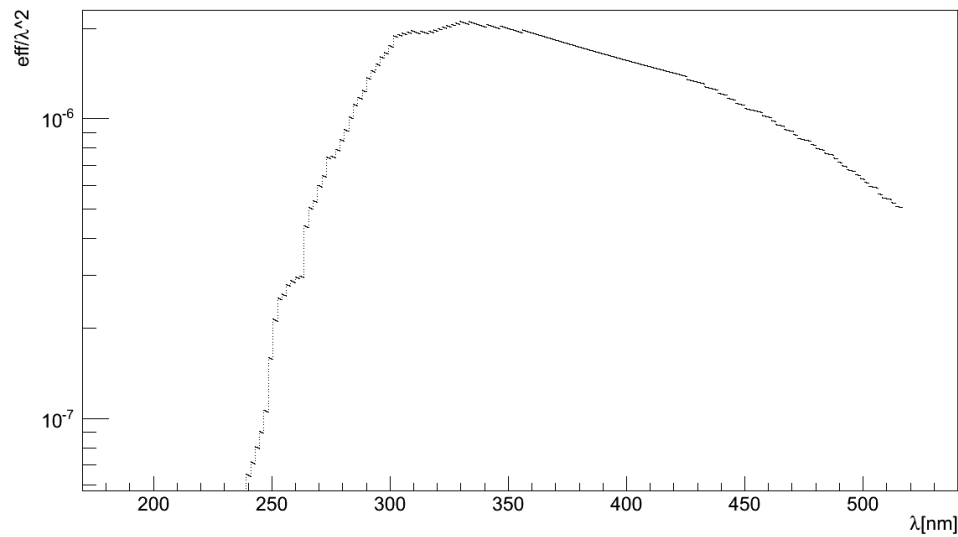


# PMT QE (Hamamatsu R7723Q)

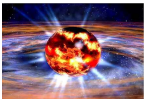
hit.eff:hit.lambda {hit.pid==0&&sci.n==3}



hit.eff/(hit.lambda\*hit.lambda):hit.lambda {sci.n==3&&hit.pid==0}

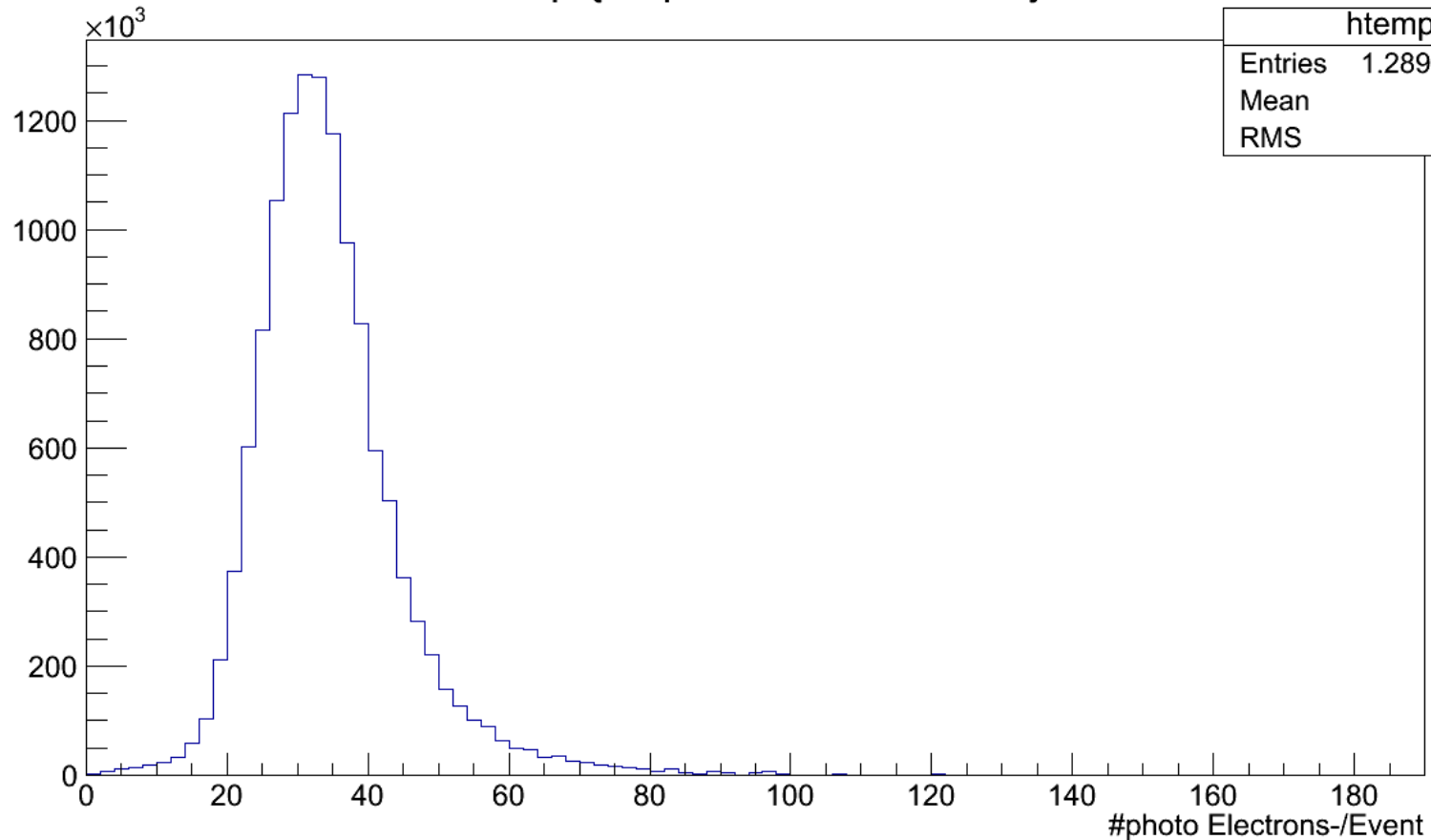






# Photo Electrons per Muon

hit.ep {hit.pid==0&&sci.n==3}

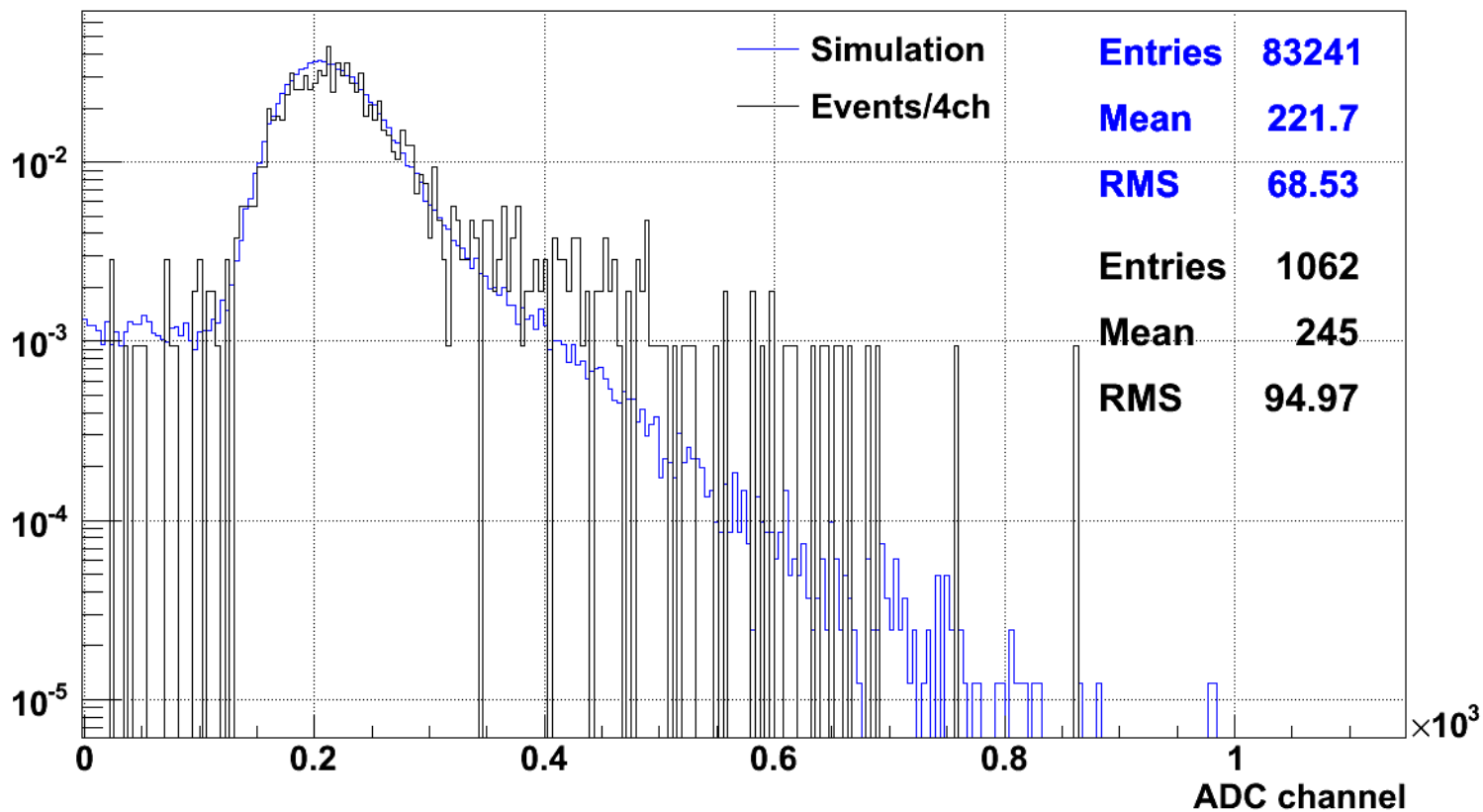


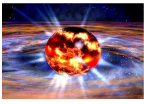
htemp	
Entries	1.289803e+07
Mean	33.84
RMS	10.42



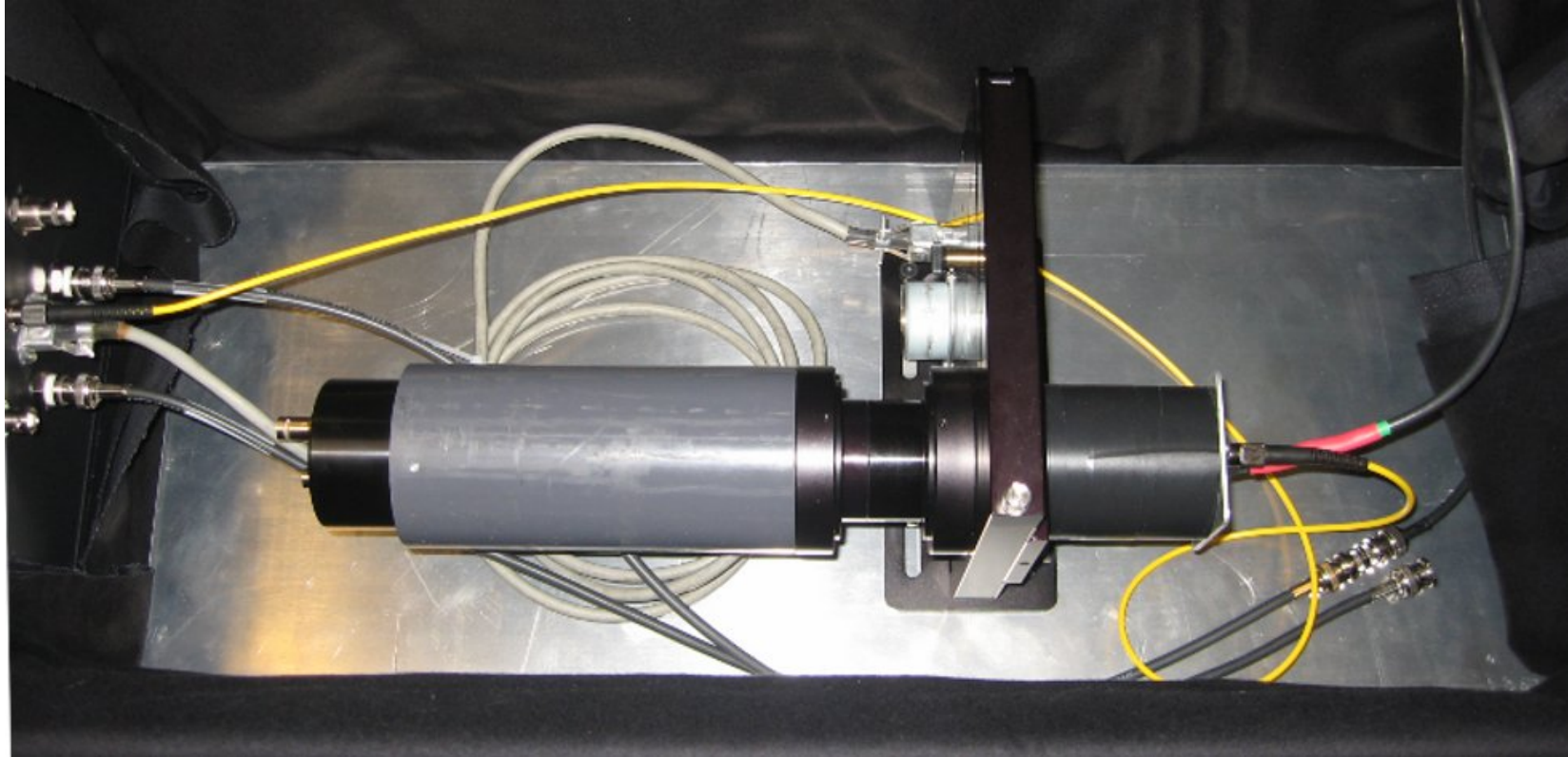
# Comparison between Simulation and Experiment

Normalized Ped subtracted preliminary prototype Quartz ADC, run 243 & Simulation

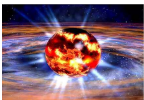




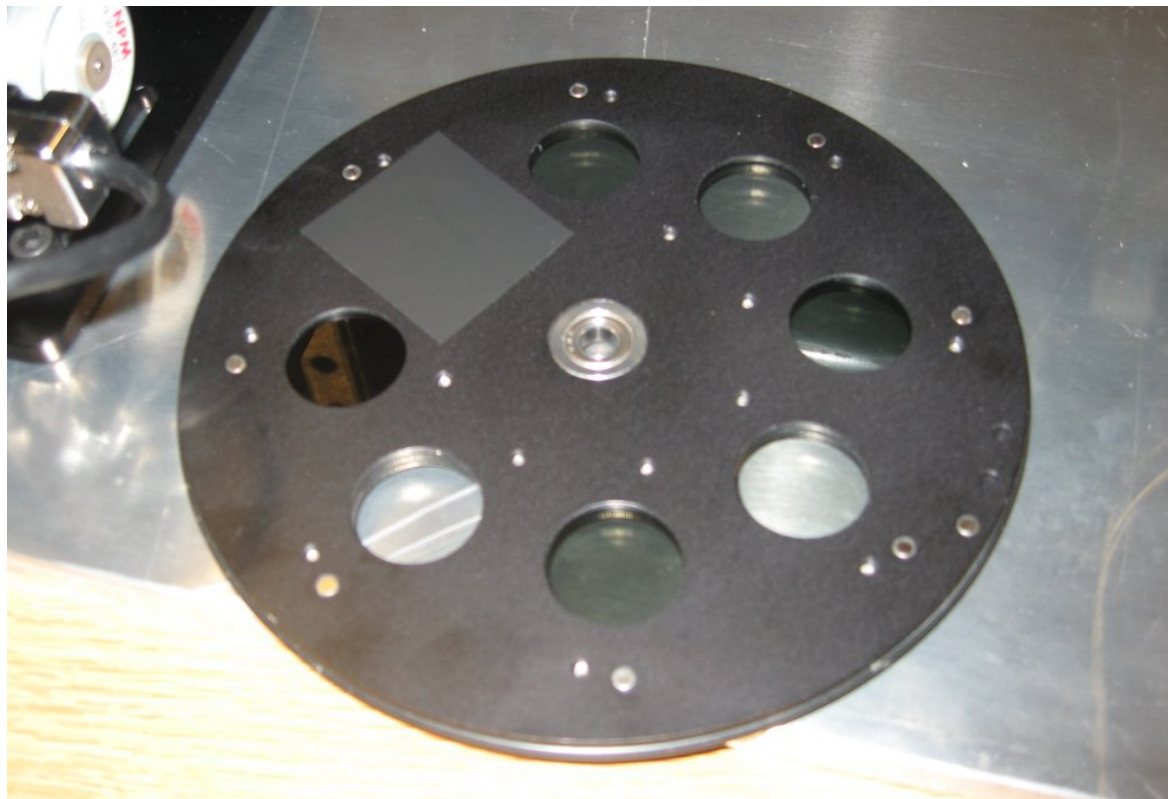
## PMT Linearity Test Setup



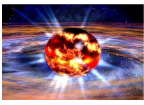
- Two LEDs (one steady, one flashing) → filter wheel → diffuser → pmt (mimics Luis' setup)
- Integrating DAQ using Qweak ADC (work in progress, need HAPPEX timer board)



## Filter Wheel

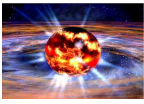


- Edmunds Intelligent Filter Wheel; computer controlled
- Absorptive ND filters: 400 - 700 nm
- Eight transmission settings (%): 100, 79, 63, 50, 40, 25, 10, 0



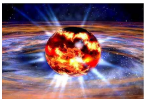
## PMT Linearity Box and Integrating DAQ





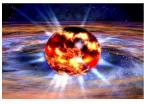
## Strategy of PMT Linearity Studies

- Use apparatus to map out pmt gain over large range of HV. In progress, no results yet.
- Will use this to calibrate PE's from quartz tests...Can then use estimated  $e^-$  flux combined with PE's/ $e^-$  to estimate anticipated pmt anode currents during PREX II and CREX.
- The LED light level is then adjusted to yield those anticipated anode currents.
- For various HV's, asymmetries are measured for each filter setting and the degree of non-linearity is extracted from fits to the data.



## Summary and Plans

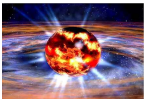
- Much progress made over the past year.
- Quartz detector cosmic tests are in full swing.
- Optical simulation comparisons with real data are promising...continuing to incorporate more realistic conditions: Correct beam energy with smearing, optical properties of mirrors, more surrounding material, ...
- Upcoming cosmic measurements to help further vet simulation: Examine different quartz thicknesses and distances from pmt window.
- 2nd Prototype design in progress (similar to the UMass det3.
- Planning for Late summer/early fall quartz detector beamtest at ISU using 12MeV electron beam.



## Issues

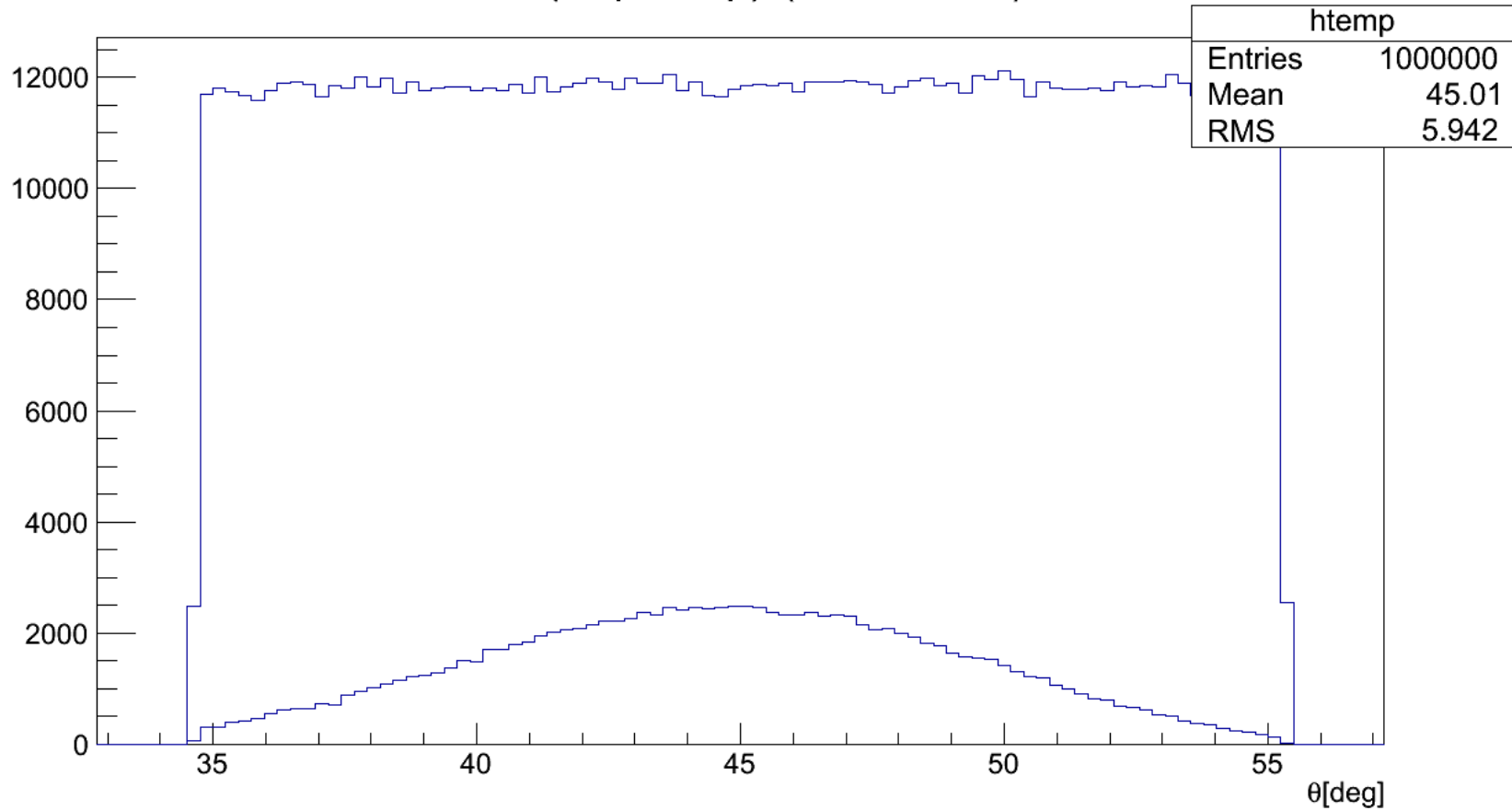
- Before finalizing CREX detector design, need optimized HRS tune to determine dispersive and transverse dimensions of quartz.
- Need to get integrating daq working. HAPPEX timing board loan would help. (Thanks Bob)

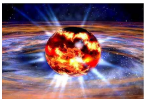




# qsim Theta: Generated and Accepted

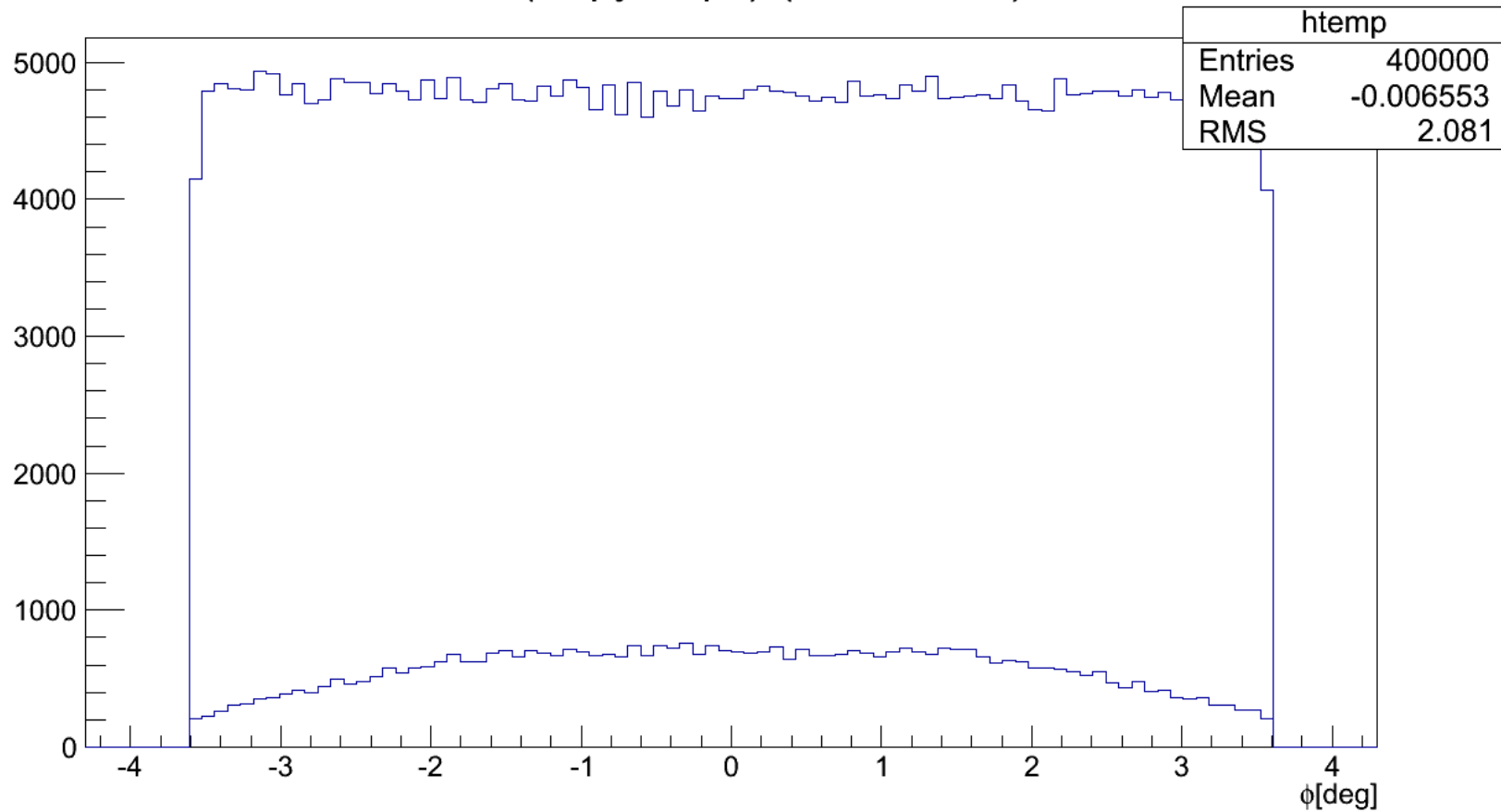
$$\text{acos}(\text{ev.pz}/\text{ev.p}) * (180/3.1416)$$

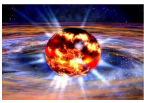




# qsim Phi: Generated and Accepted

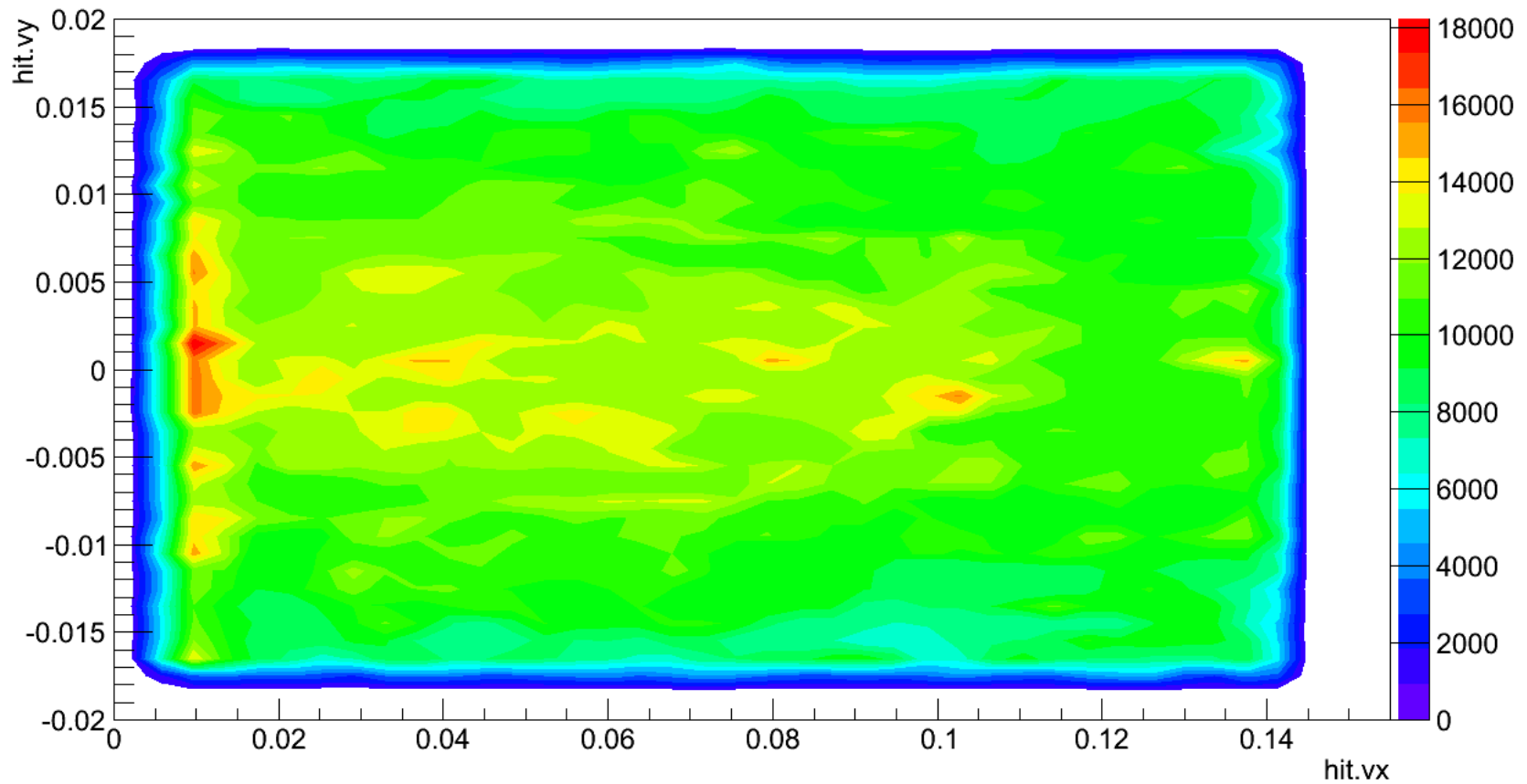
$$\text{atan}(\text{ev.py}/\text{ev.px}) * (180/3.1416)$$

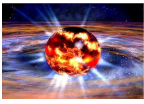




# Photon $y_{\text{vertex}}$ versus $x_{\text{vertex}}$

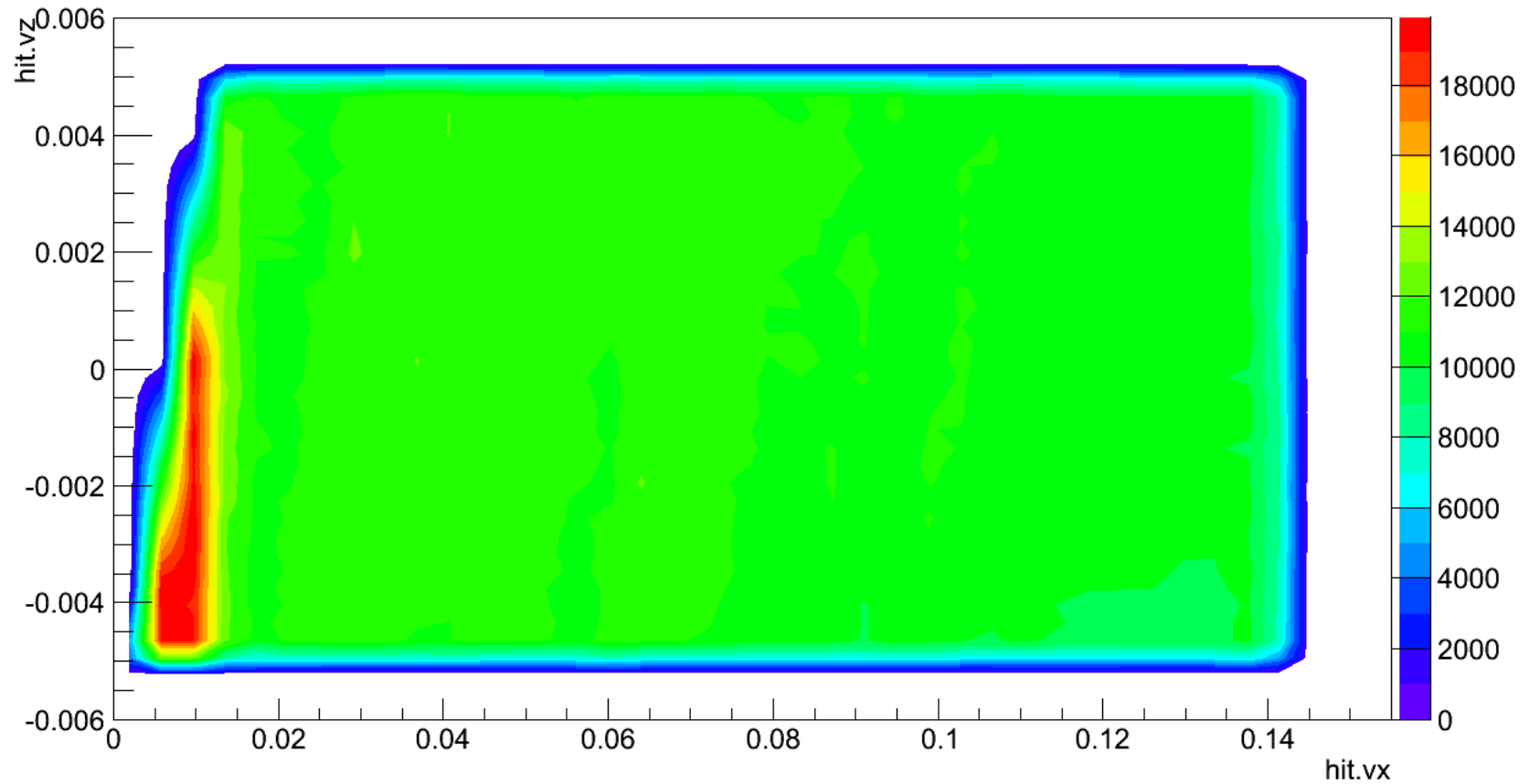
hit.vy:hit.vx {hit.pid==0&&sci.n==3}

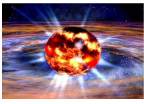




# Photon z\_vertex versus x\_vertex

hit.vz:hit.vx {hit.pid==0&&sci.n==3}





# Photon z\_vertex versus y\_vertex

hit.vz:hit.vy {hit.pid==0&&sci.n==3}

