Study of HF pmt high tail signal

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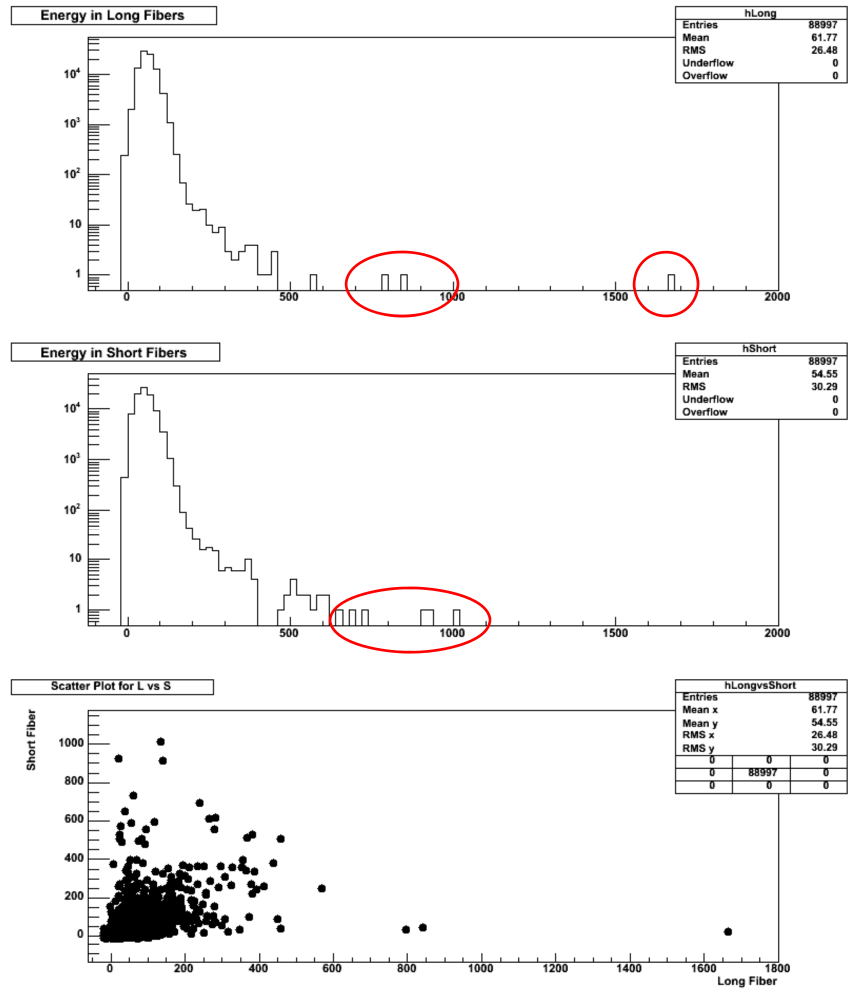
- Princeton: Valeri Halyo, Adam Hunt

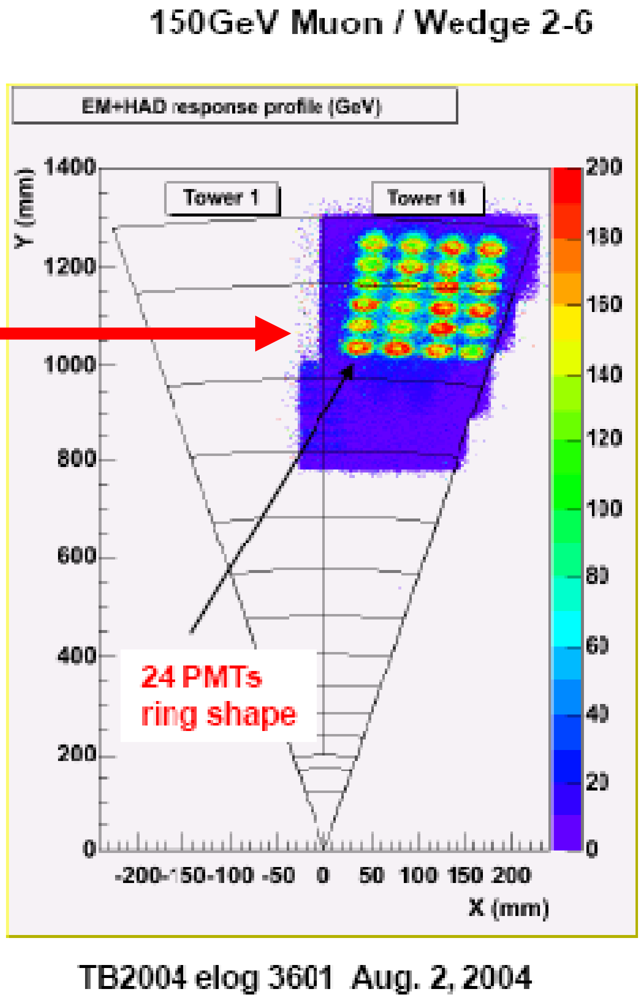
- Thanks to Ren Yuan Zhu for getting the crystals BGO , LYSO (Shanghai Institute of Ceramics)

TB04 analysis from 2005

- 100 GeV pions from TB04
- While analyzing TB04 data during the summer of 2005, abnormally high energy events were seen in several pion runs.

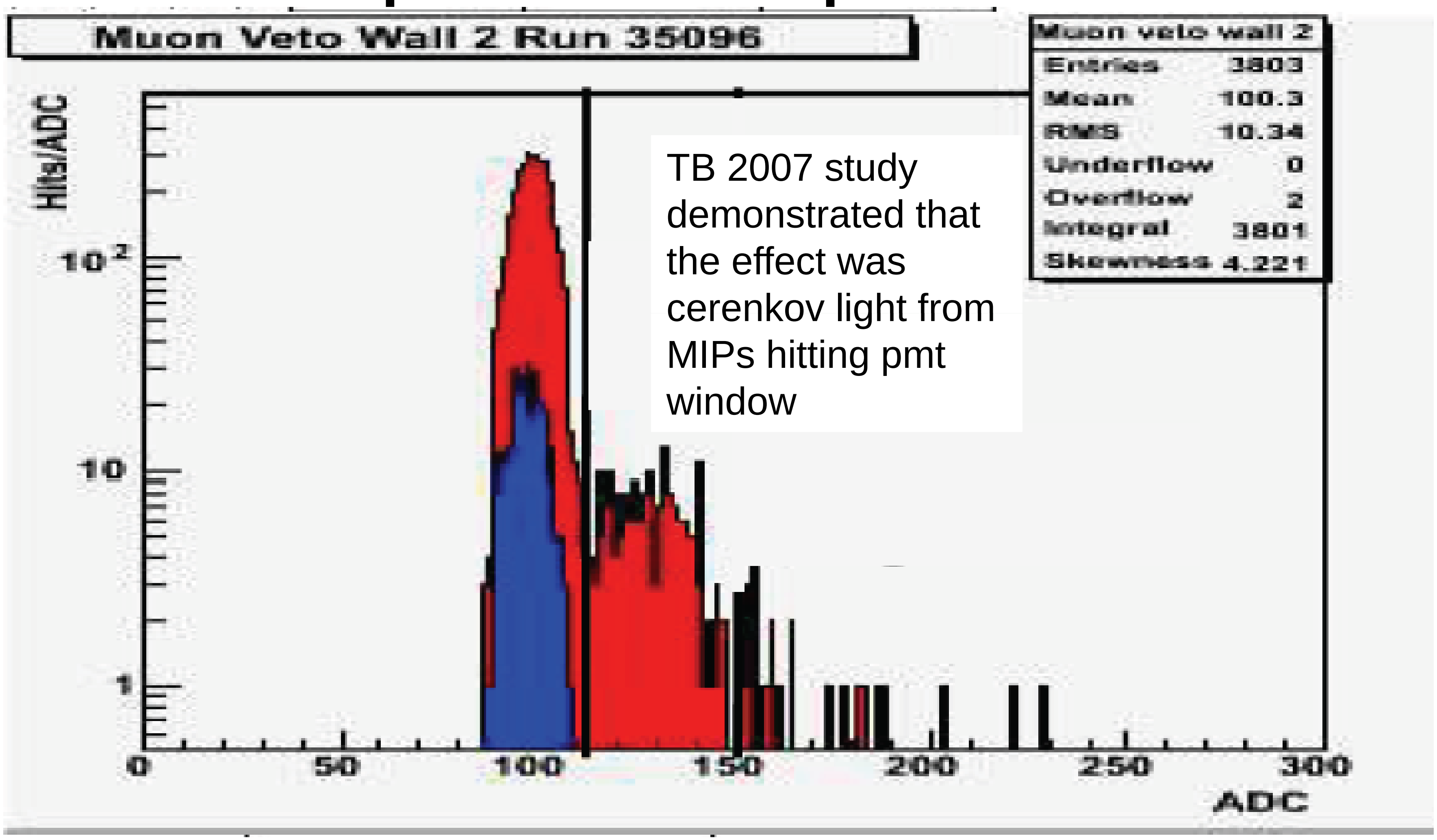


Abnormal Events

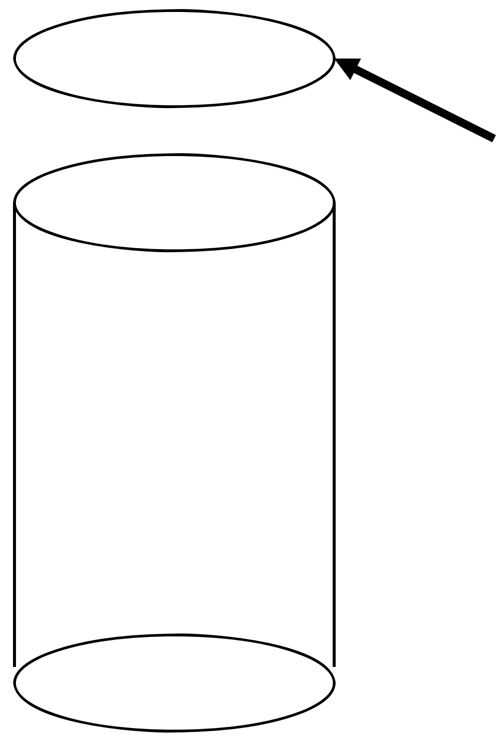


- These events are most likely to be from Cerenkov radiation from particles directly hitting the PMT window.
  - peak of muon signal ~ 200 GeV
- The glass window is plano-convex.
  - 1mm thick in center
  - 6.1mm thick at the edges
- These events were also seen in TB07 by Freeman et. al.

HP pmt noise problem



FNAL Test Beam



Thin disk of “scintillator” that is transparent to blue/UV light. Make it have slow response (100ns or so).

Then can cut MIP-in-pmt events.

Will attempt to test at FNAL

Scint crystal properties

- UV transparent
- Fast response time ~50-100 ns
- Rad hard
- Low index refraction
- Low n-capture cross section
- Cheap?

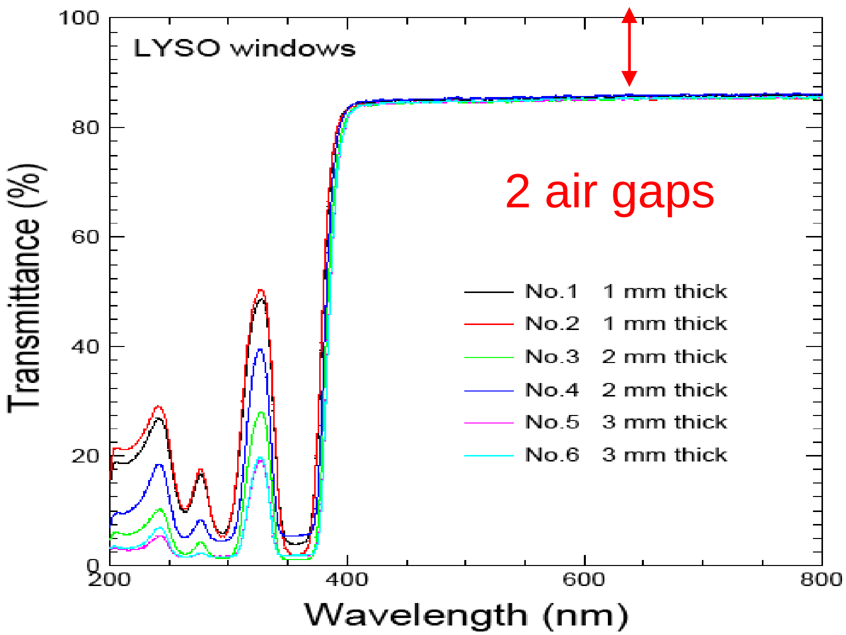
Scintillating Crystals

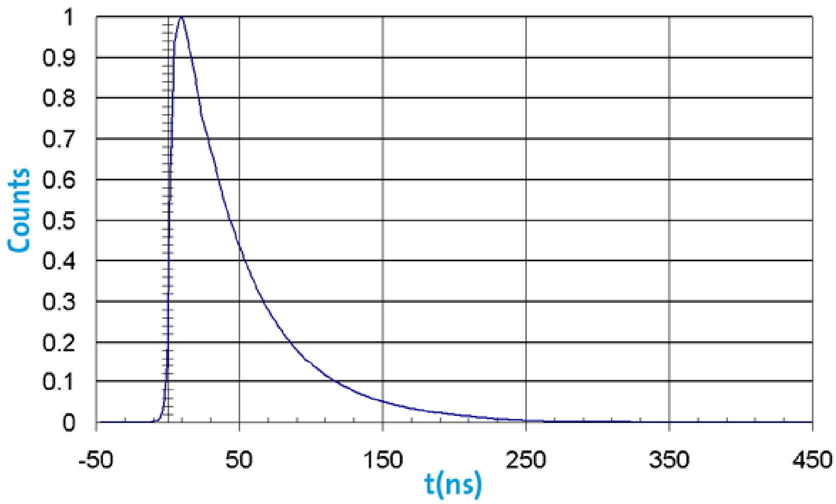
Characteristics

Crystal scintillators	GSO	BGO	LSO	YSO	YAP	CWO	NaI:Tl
Density (g/cm^3)	6.71	7.13	7.4	4.45	5.55	7.9	3.67
Radiation length (cm)	1.38	1.11	1.14	2.75	2.67	1.06	2.6
Decay constant (ns)	30 - 60	300	40	40	28	5000	230
Light yield (relative)	20	7 - 12	40 - 75	30 - 45	40	30 - 40	100
Peak emission λ_{em} (nm)	430	480	420	420	347	480	415
Index of refraction (at λ_{em})	1.85	2.15	1.82	1.8	1.94	2.25	1.85
Radiation hardness (gray)	10^6	10^{2-3}	10^5	10^4	10^4	10^3	10
Hygroscopicity	no	no	no	no	no	no	Strong
Melting point (°C)	1950	1050	2050	1980	1850	1300	651

LYSO

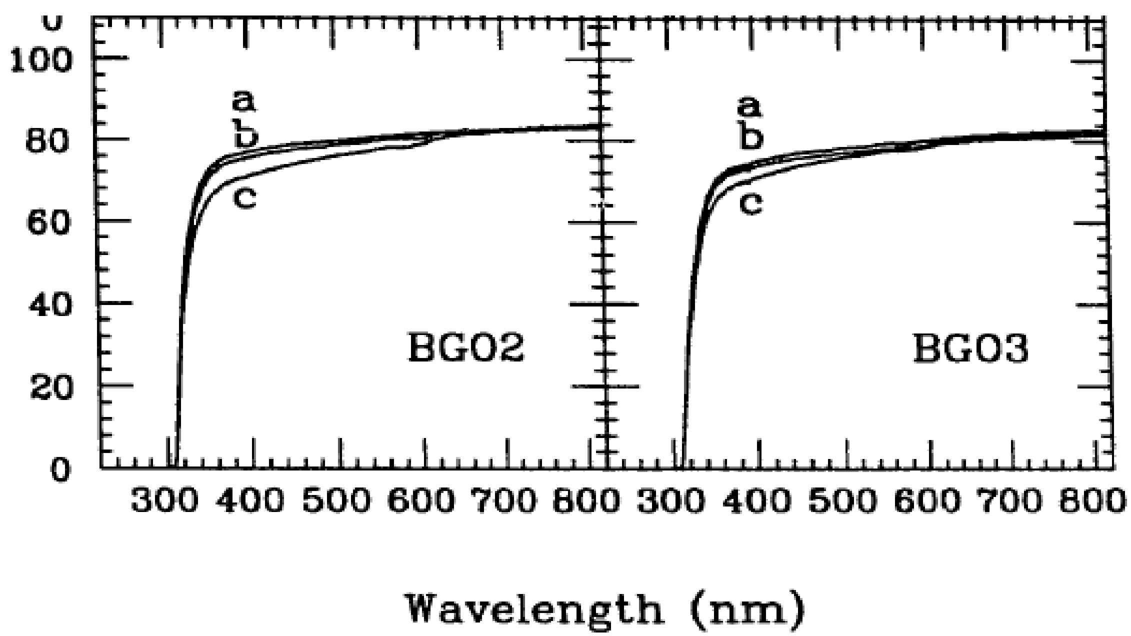
Lutetium Yttrium orthosilicate : Cerium $Lu_9Y(SiO_5)_5:Ce$





With proper optical coupling, 10% light loss

BGO



Before and after 2.5kRad rad dose

Li-glass

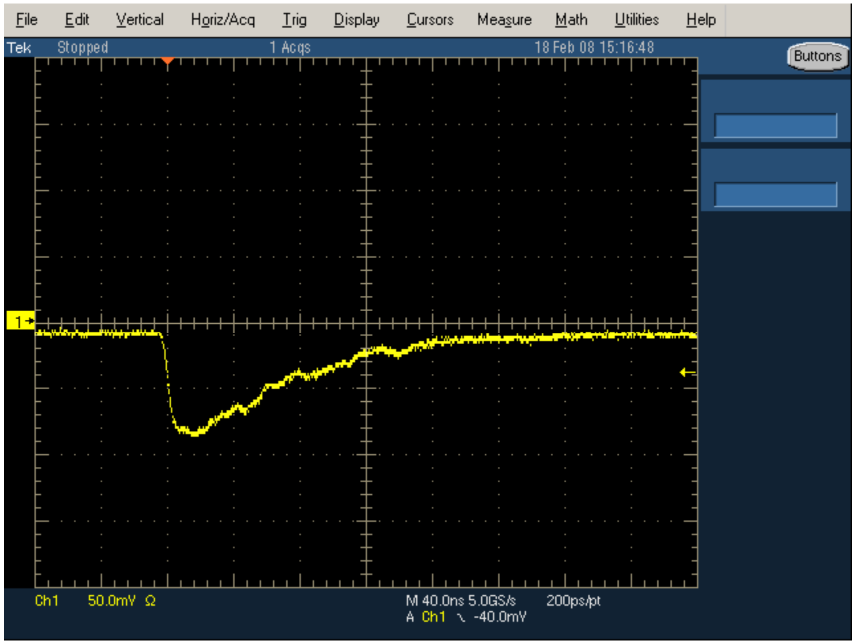
	GS1/2/3	GS10/20/30	KG1/2/3
Density (g/ml)	2.66	2.50	2.42
Refractive Index n_{4047}	1.58	1.55	1.566
Glass Transition Tg (°C)	620	499	464
Softening Point Ts (°C)	650	522	490
Strain Point Tsr (°C)	350	410	461
Coefficient of linear expansion	7×10^{-6}	9.23×10^{-6}	100×10^{-6}
Wavelength of maximum emission (nm)	395	395	395
Relative light pulse height per unit energy input	100(1)	85	60
Light output relative to anthracene	22-34%(2)	20-30%(2)	20%
Decay time (ns)	50 - 70	50 - 70	50 - 70

Neutron capture

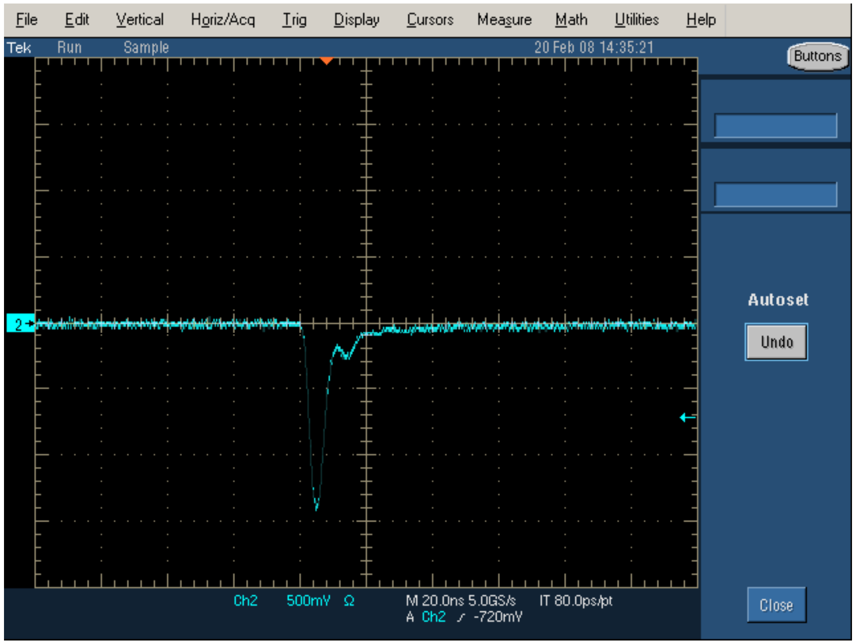
- Thermal neutron capture cross section:
  - 0.01 Fluorine
  - 0.03b Bismuth
  - 0.17b lead
  - 0.3b Hydrogen;
  - 0.6b Cerium
  - 2.2b Germanium
  - 18b Tungsten
  - 35b Yttrium;
  - 70b Lithium
  - 84b Lutetium;
  - 767b Boron (boro-silicate glass)
  - 49,000b Gadolinium
- Borosilicate glass ~ 10% boron; LYSO ~ 100% Lu → 1mm glass = 1mm LYSO for neutron capture. But LYSO active!
- BGO would be better in this regard

Waveform LYSO, Cerenkov

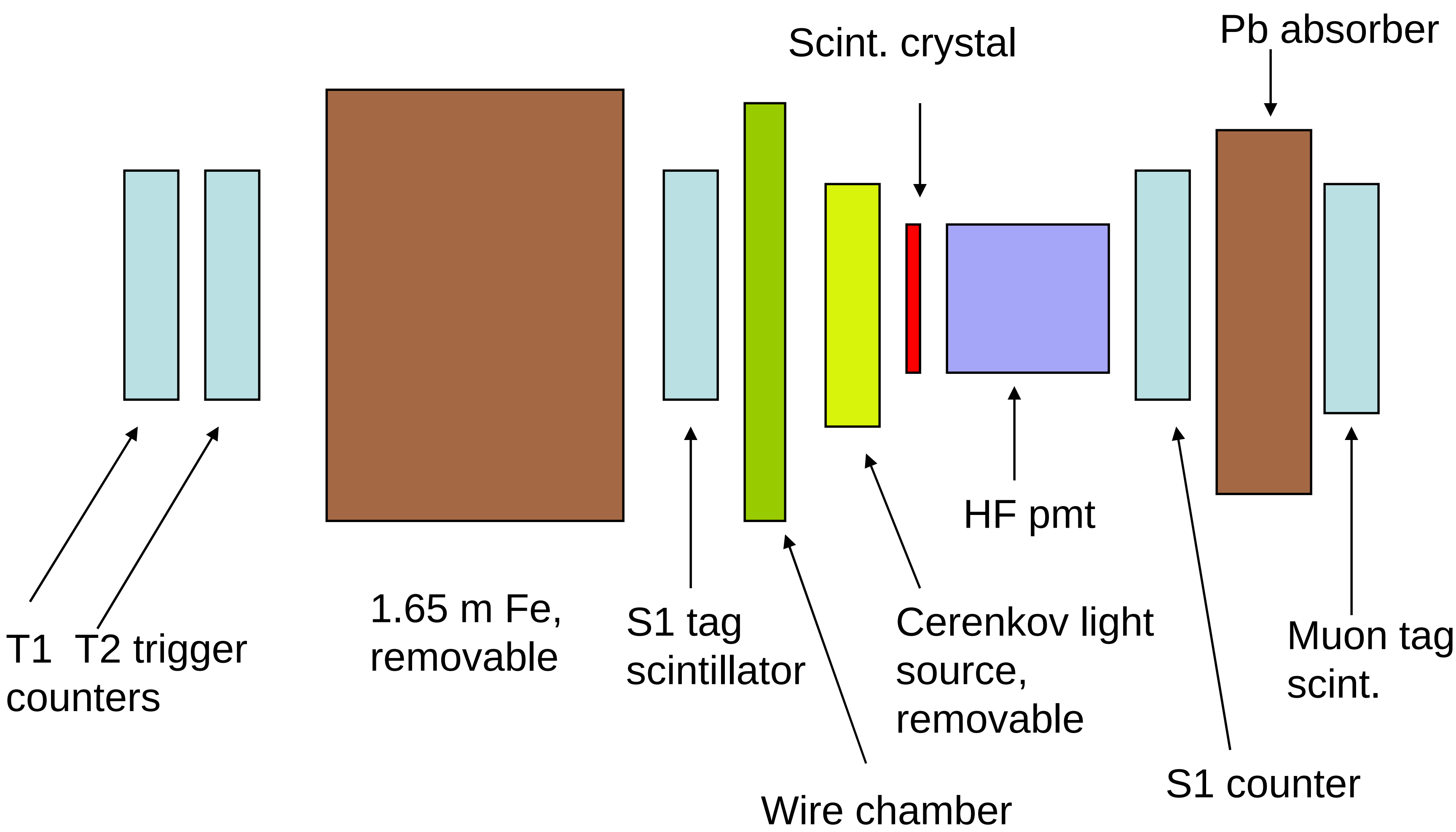
LYSO 40ns/div



Cerenkov light 20 ns/div



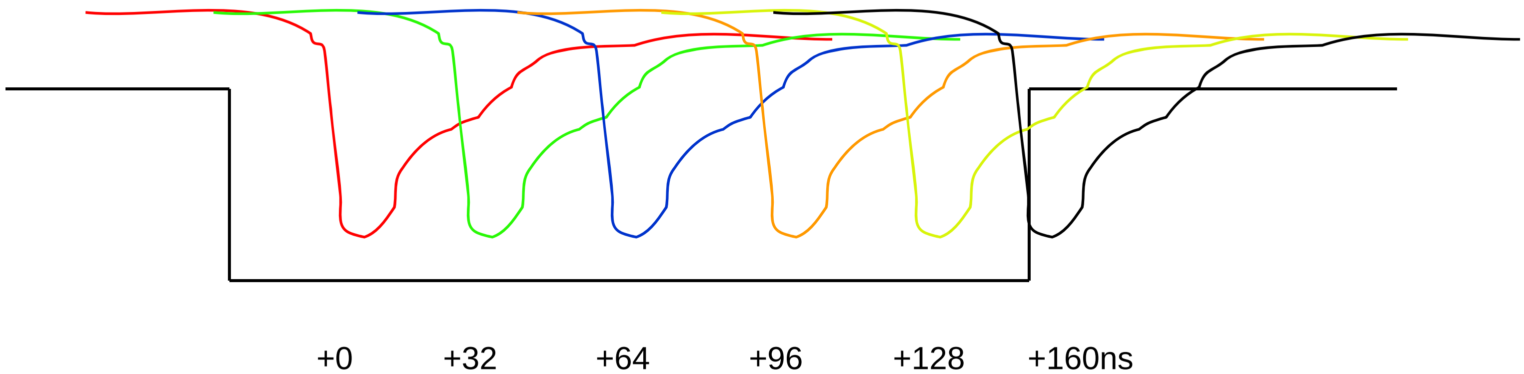
FNAL Testbeam 3/18/08



Readout

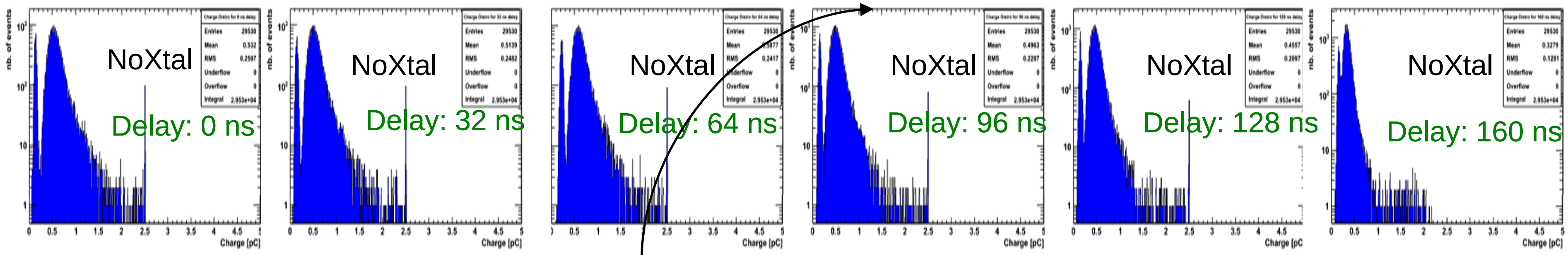
- No flash ADC so..
- Use 6 channels of 2249, 215ns gate. Set edge of undelayed pmt signal at ~50ns from leading edge of gate.
- Signals delayed by 0,32,64, 96,128,160 ns
- Observe decrease in signal as it falls outside gate

Signal delayed in ADC Gate



Nb. of Events vs. Charge (pC)

Beam: 120 GeV proton without HF Absorber (~30k)



Single hit requirement.

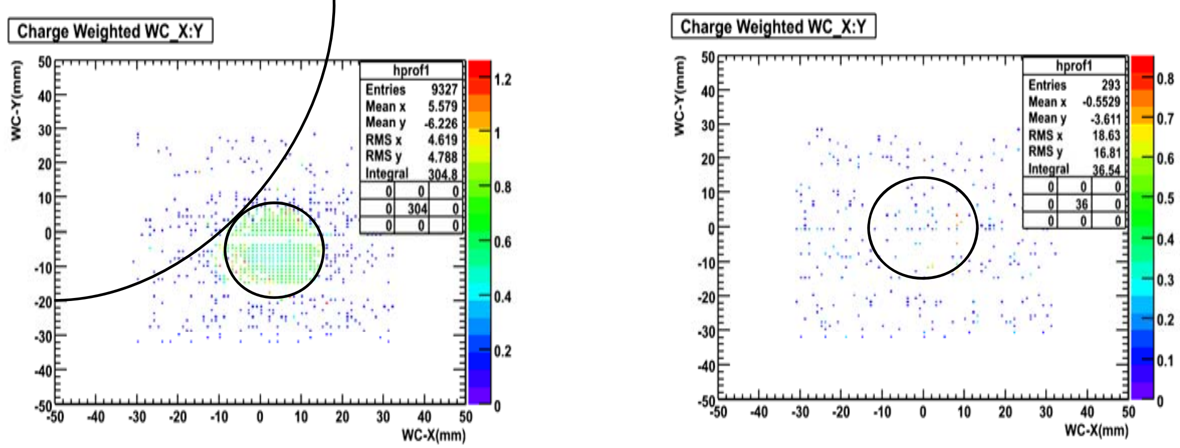
No muon id tag.

w/ block:

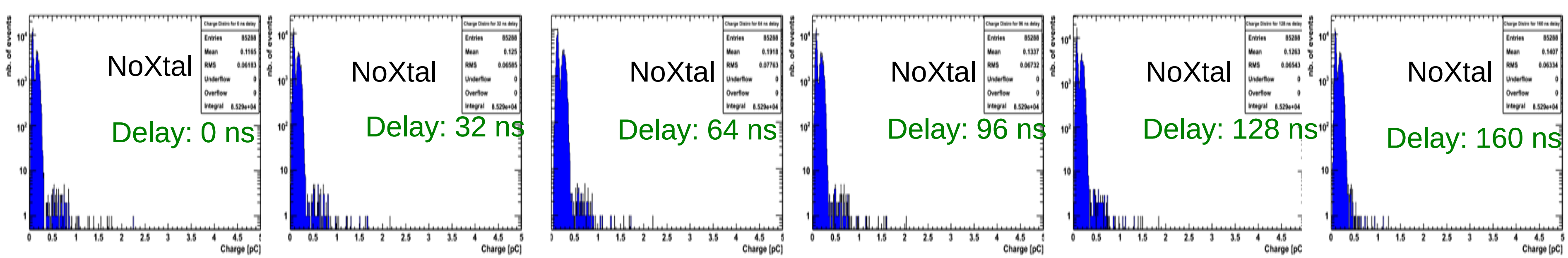
0.3% (293/85288)

w/o block:

31.6% (9327/2953)



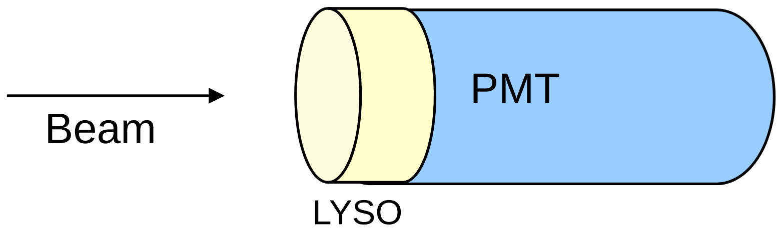
Beam: 120 GeV proton with HF Absorber (~85k)

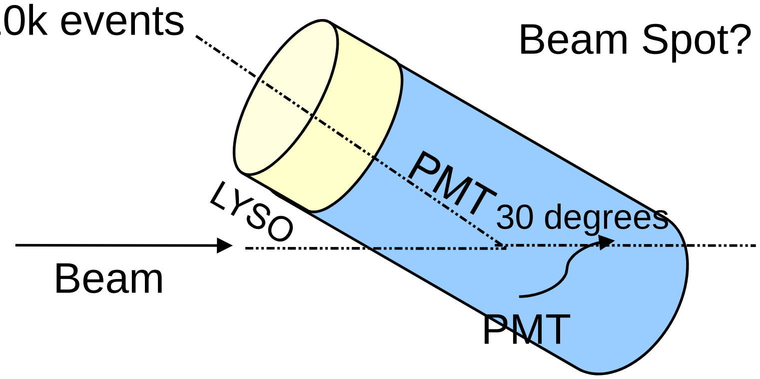


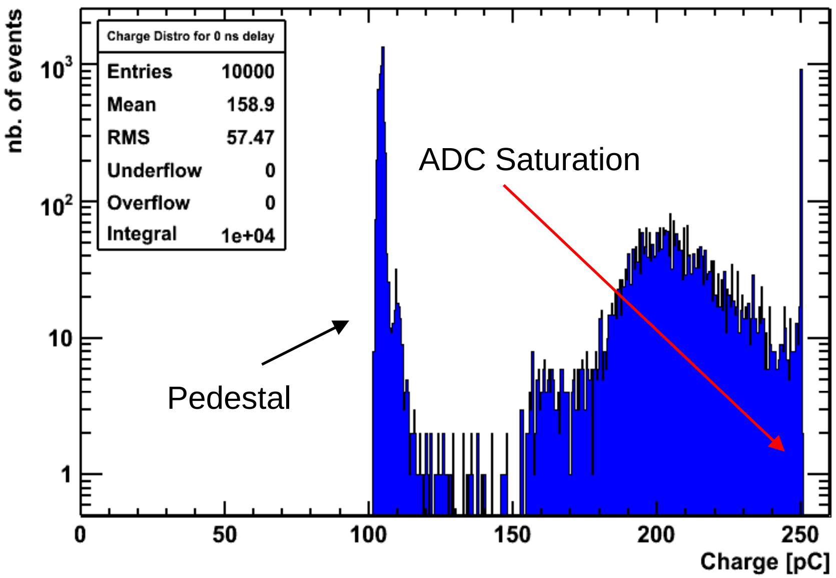
Angle Study

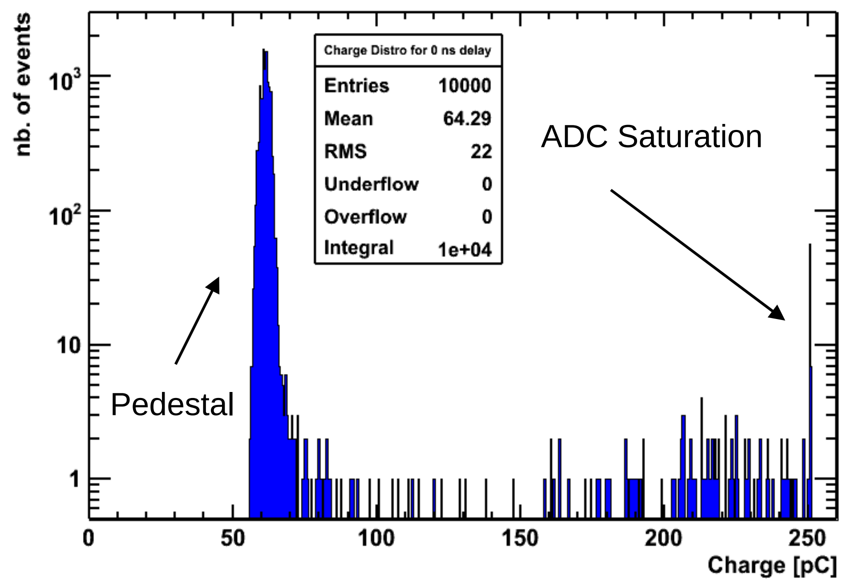
Beam: 16 GeV proton without HF Absorber

Histograms have 10k events



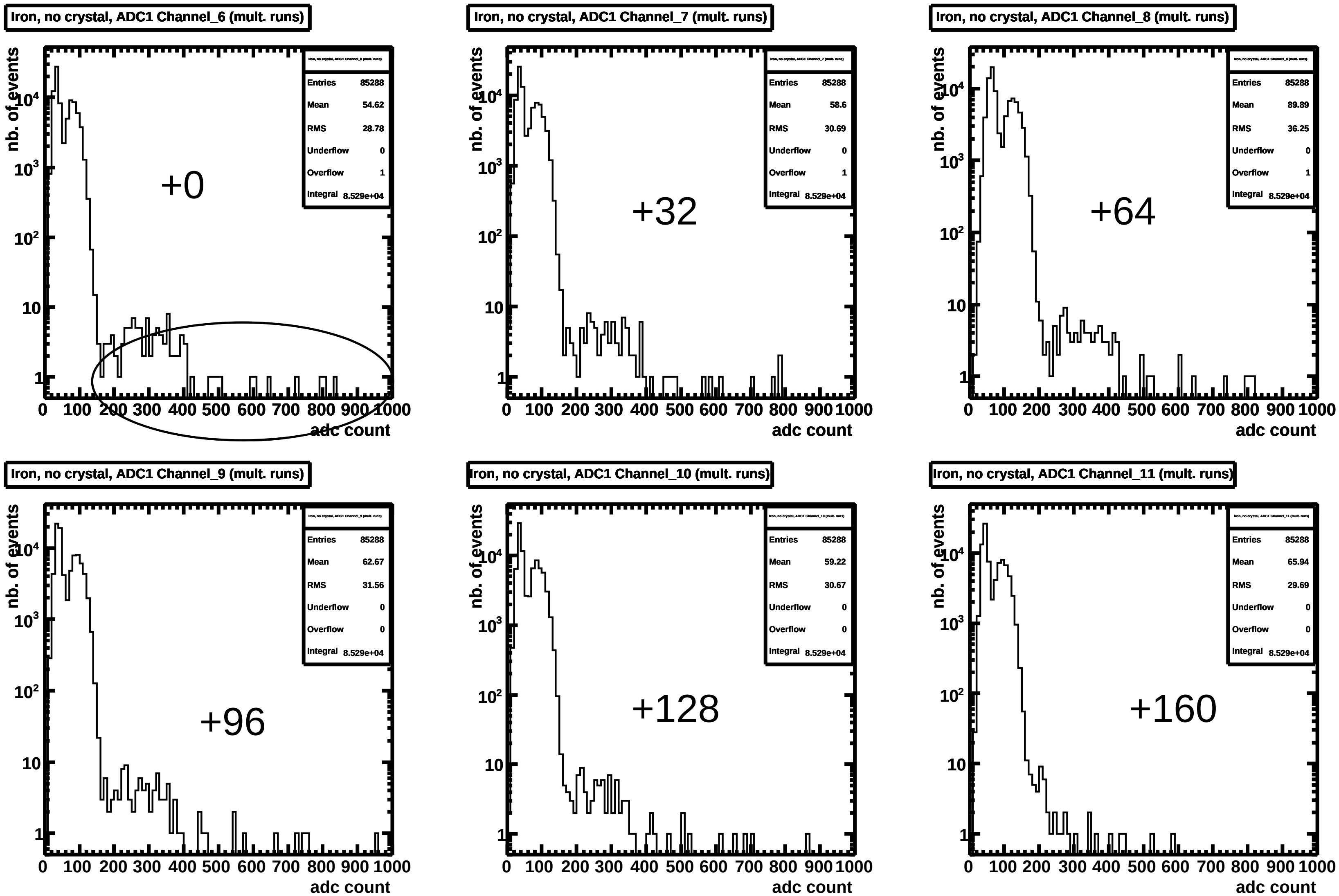






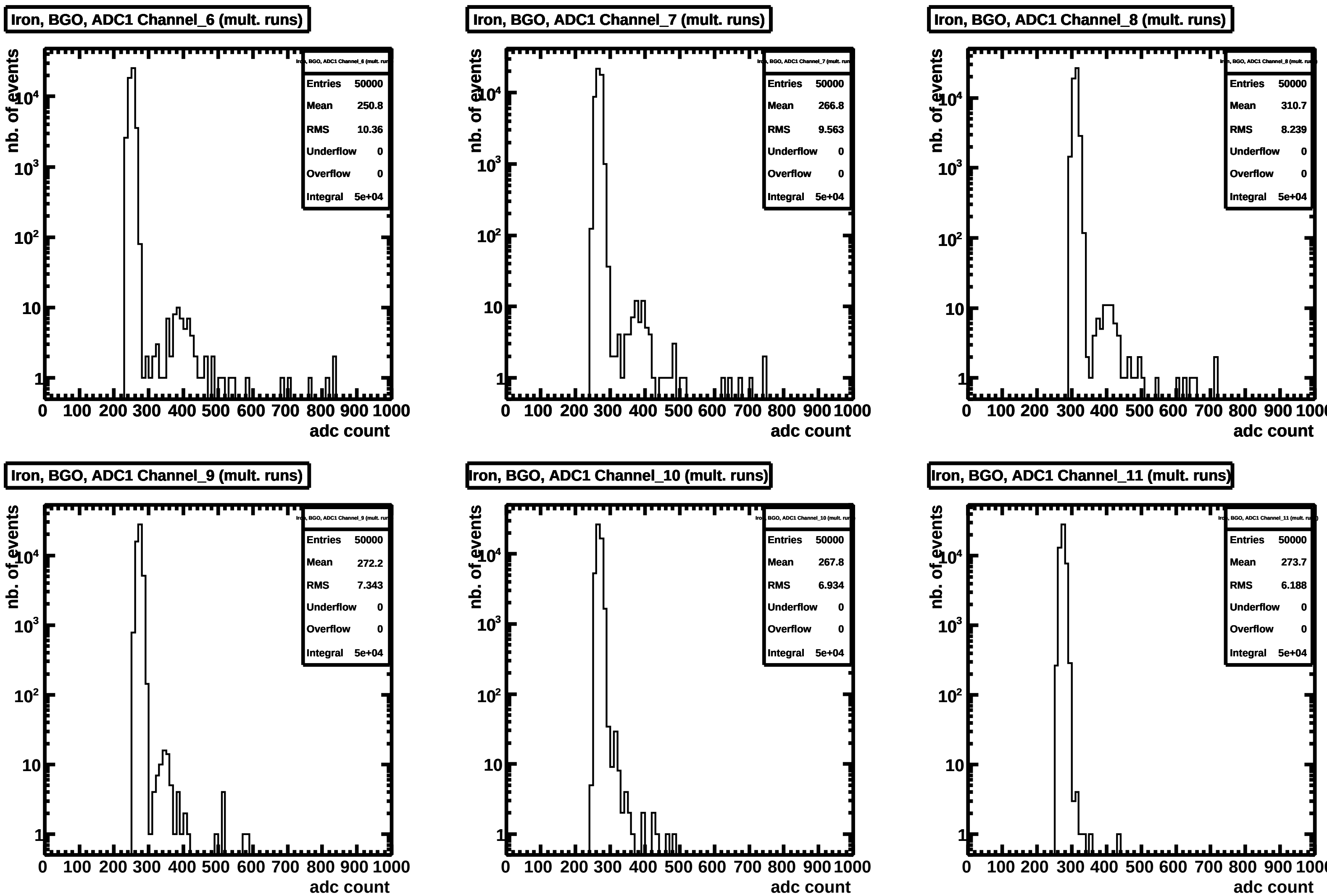
n.b. this is what you expect for good signal separation

Fe, No Crystal



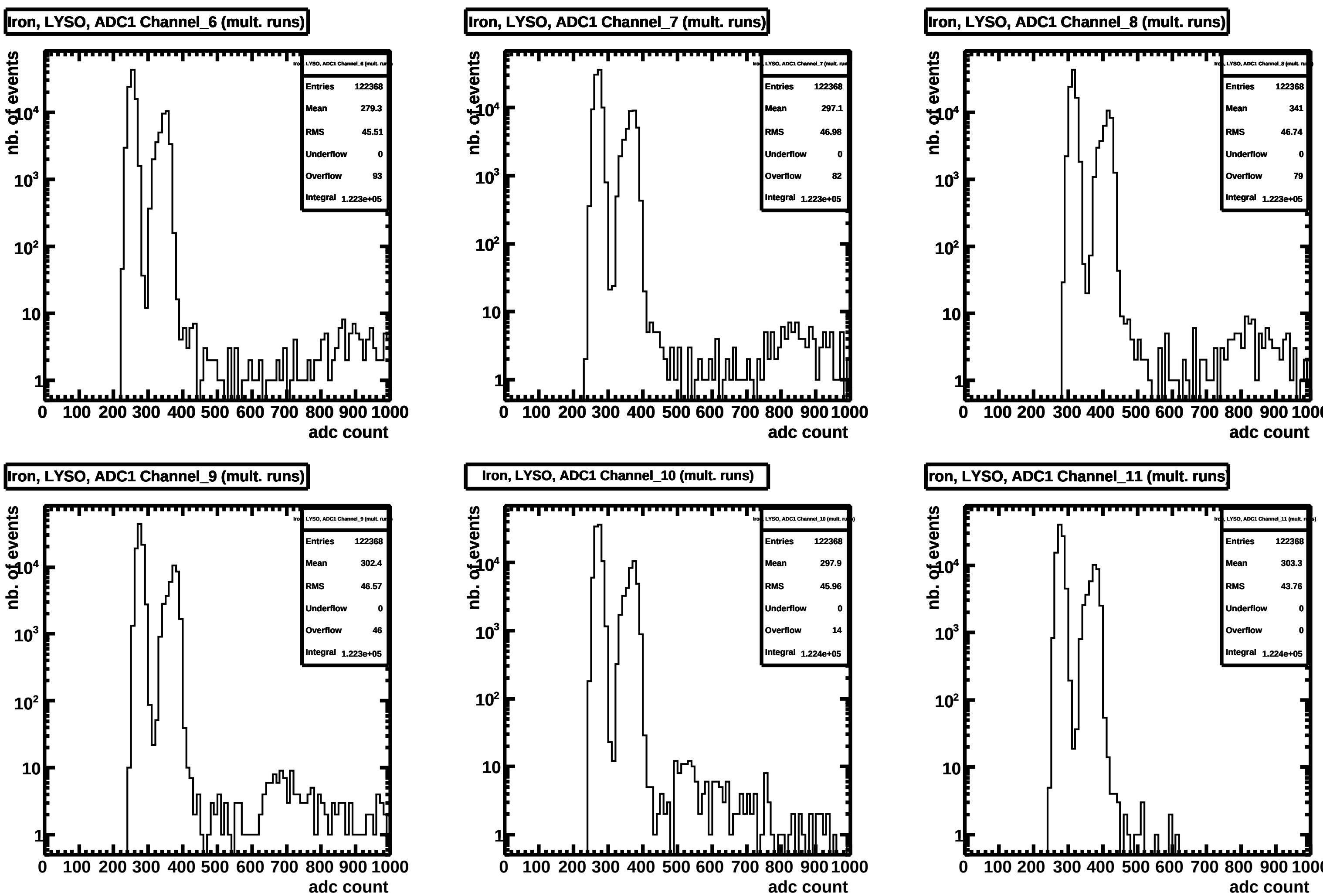
n.b. external gain = 100X, bad peds

Fe, BGO Crystal



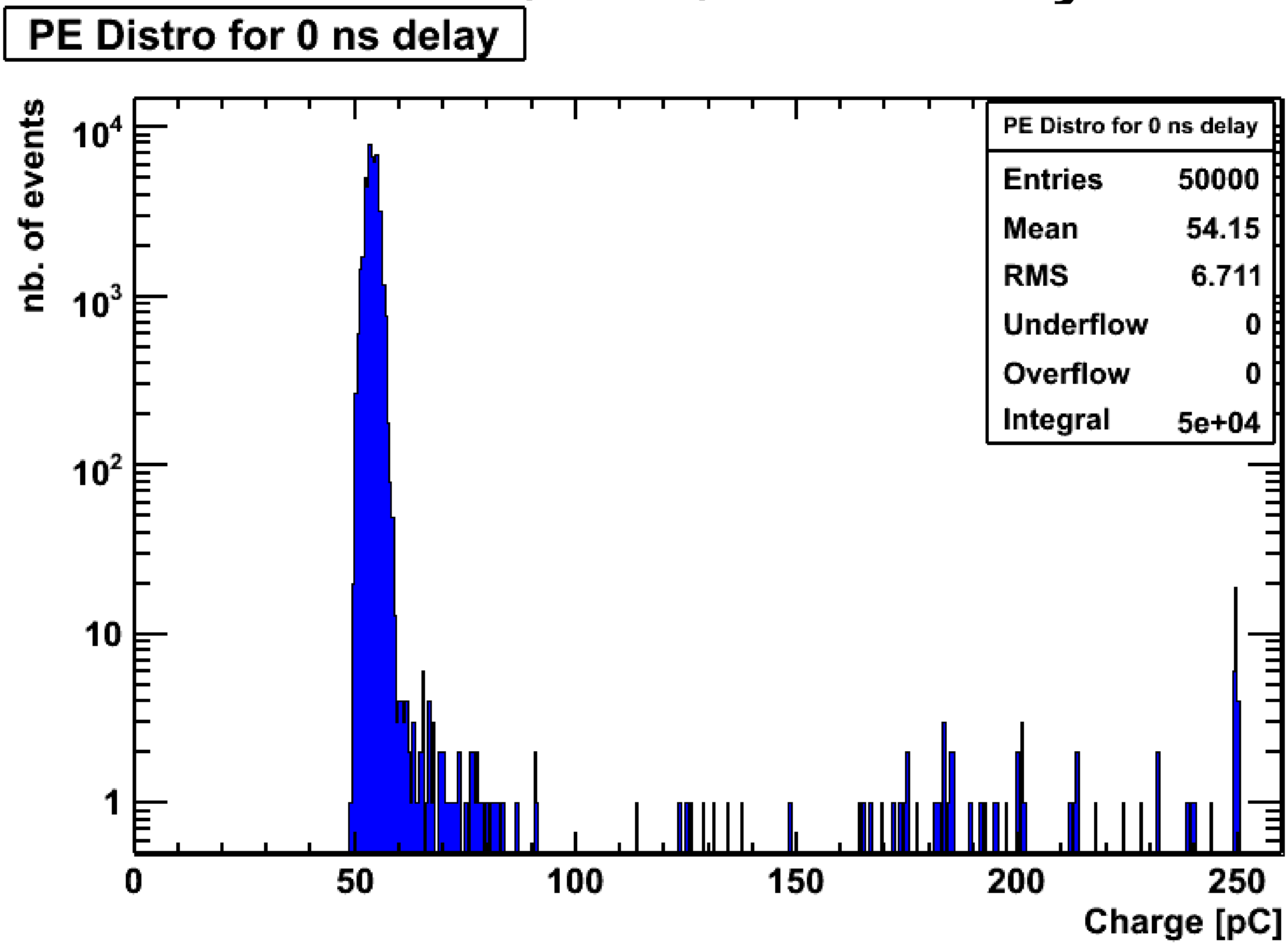
n.b. external gain = 10X

Fe, LYSO Crystal

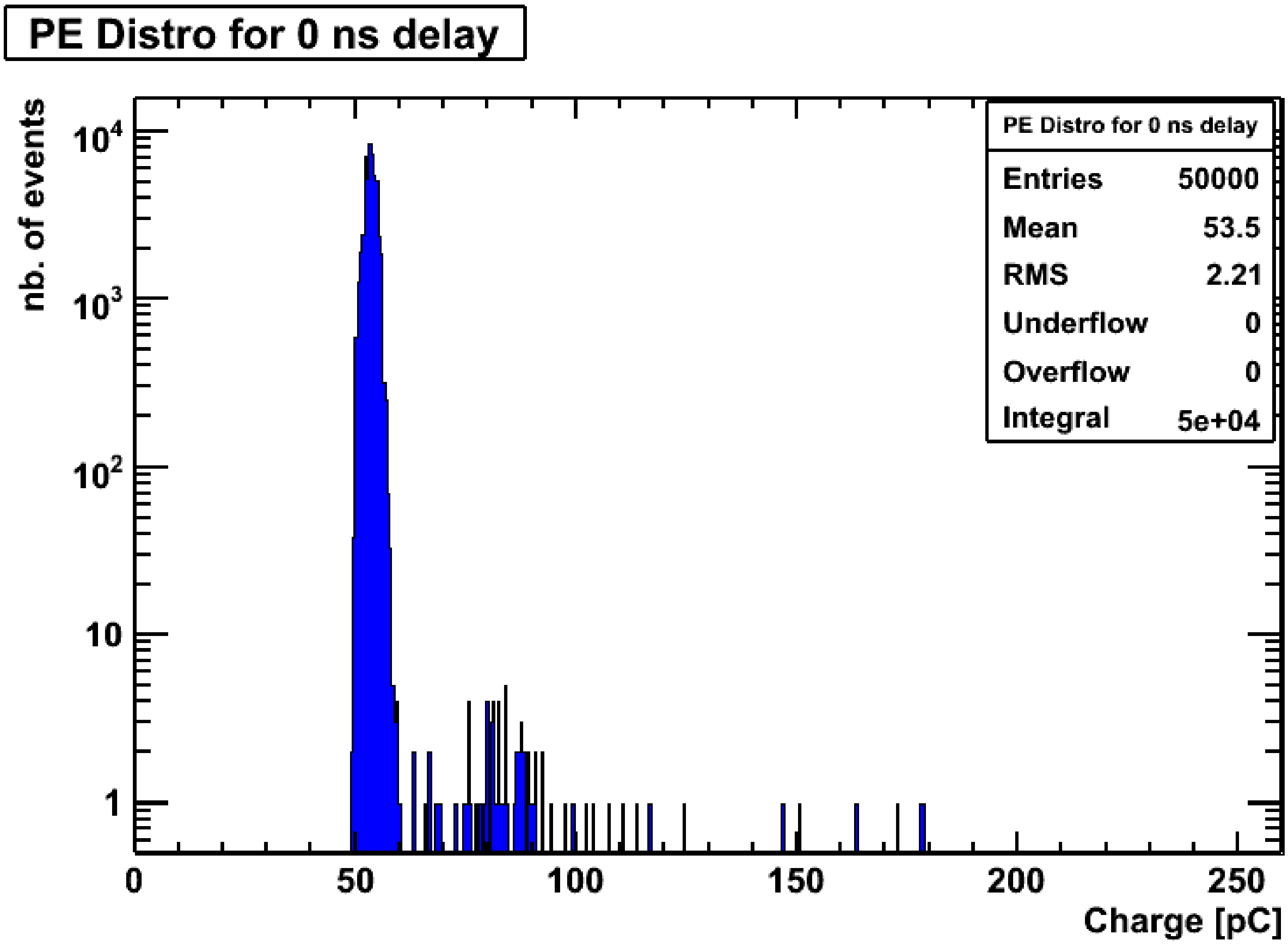


n.b. external gain = 1X. Also note pedestal (= ADC gate?) problem

LYSO, FE, no delay



BGO, FE, no delay

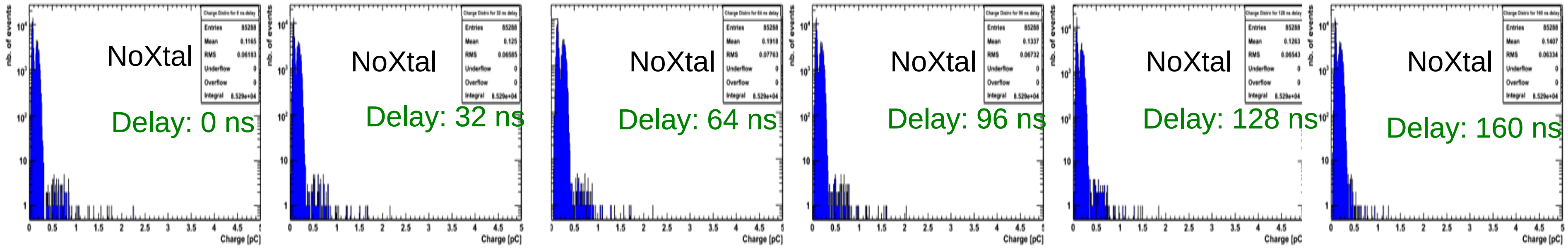


Conclusions

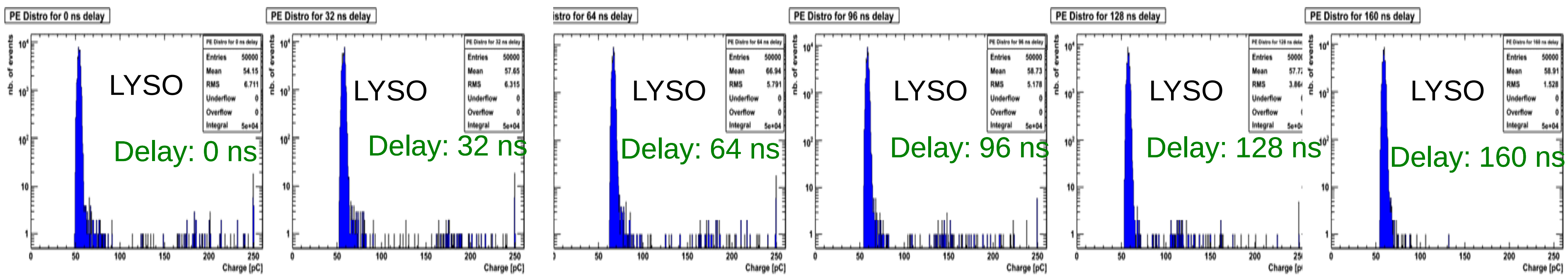
- Tail is due to cerenkov light in window
- Can tag by use of scint disk ~100% efficient
- LYSO 1mm too thick, at least 10X too much light. Looking at 0.1mm
  - (cost 0.1mm = $35, 0.15mm = $23, 0.2mm =$18 , SIC)
  - Maybe reduce the cerium content to reduce light yield
- BGO Looks good (except for long time constant)
- Other possibilities like Li-glass
- Will need to get prototypes and bench test
- Will propose to instrument some channels for summer LHC run. 1 ROBOX?

Nb. of Events vs. Charge (pC)

Beam: 120 GeV proton with HF Absorber, No crystal



Beam: 120 GeV proton with HF Absorber, LYSO crystal (50k)



Beam: 120 GeV proton with HF Absorber, BGO crystal (50k)