Study of Various Photomultiplier Tubes for Window Events: Upgrade R&D for CMS Hadron Forward Calorimeters

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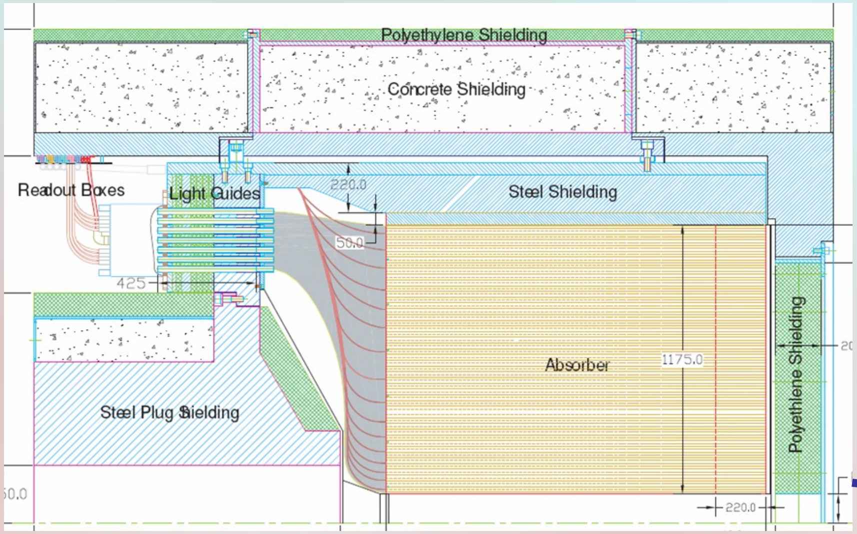
On Behalf of CMS HCAL Collaboration

Calor2010, Beijing

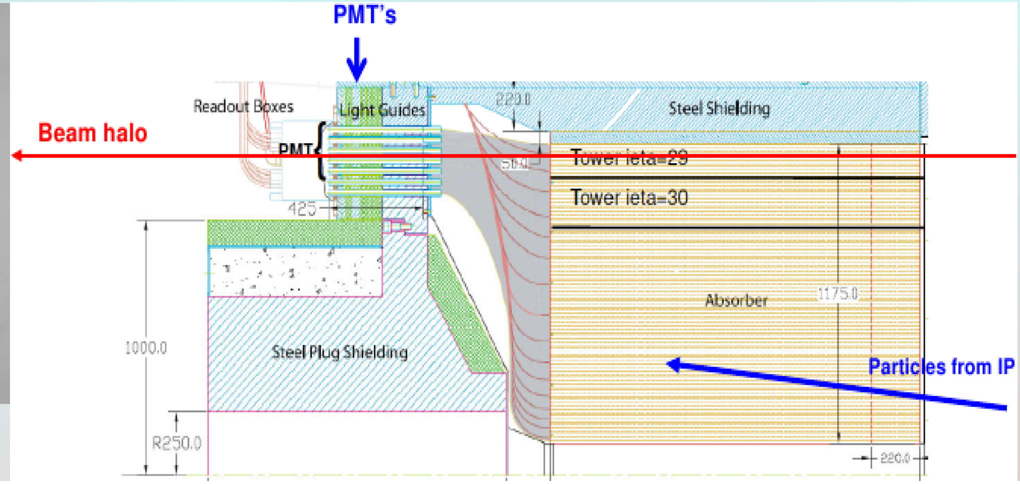
CMS Hadron Forward (HF) Calorimeters

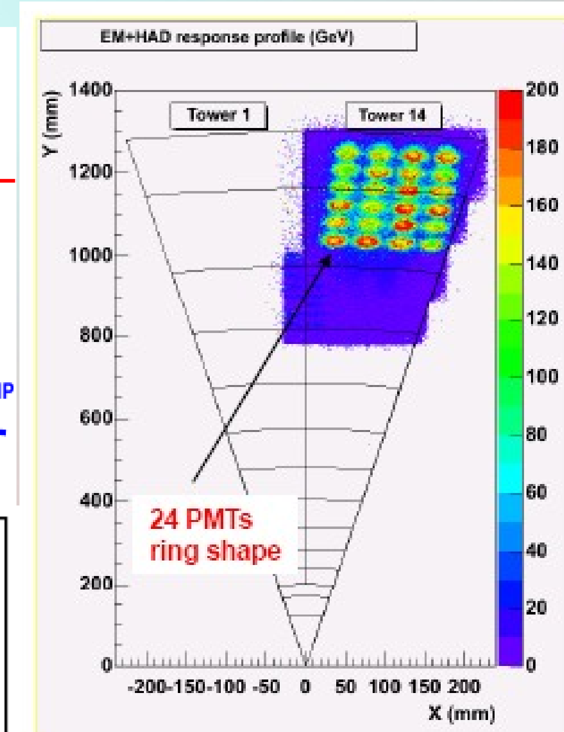


Interaction point
(~11m this way)

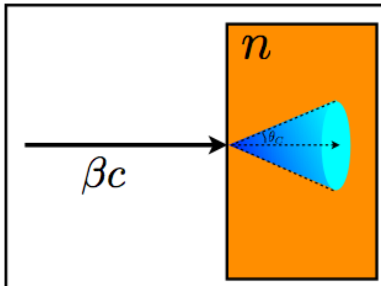
- The Hadron Forward (HF) Calorimeter is a part of HCAL.
- One on each end of CMS, covering 3<η<5 (0.77°-5.7°).
- Composed of quartz fibers embedded in a 1.65 meter steel absorber.
  - Two lengths of fiber
- Readout boxes containing PMTs sit behind it at 3< η<3.2.

Motivation for An Upgrade R&D





S. Abdullin et. al.,
Eur. Phys. J. C 53, 139, 2008



$$\frac{d^2N}{dEdx} \approx 370 \sin^2\theta_C \quad \mathrm{eV}^{-1}\mathrm{cm}^{-1}$$

$$\theta_C = cos^{-1}\left(\frac{1}{\beta n}\right)$$ = 48.087° for n=1.5 and β = 0.998

N~20 * ε_Q p.e. /(mm*eV)

- Cerenkov radiation from particles directly hitting the PMT window create abnormally large signals.

- The glass window is plano-convex: ~ 2 mm thick at the center, ~ 6 mm thick at the edges.

Search for new PMTs to identify window hits and eliminate this effect keeping the abnormal signal at a low level and PMT performance at a better scale.

PMT Information (Manufacturer Hamamatsu)

PMT Type	PMT Type Number	Photocathode	Quantum Efficiency (max. %)	Typical Gain	Window Area (mm^2) app.
Four Anode PMT	R7600U-100-M4	Super Bialkali	35	1.3×10^6	324 (square)
Four Anode PMT	R7600U-200-M4	Ultra Bialkali	43	1.3×10^6	324 (square)
Four Anode PMT	R8900U-100-M4	Super Bialkali	35	1.0×10^6	324 (square)
Single Anode PMT	R7600U-100	Super Bialkali	35	1.0×10^6	324 (square)
Single Anode PMT	R7600U-200	Ultra Bialkali	43	1.0×10^6	324 (square)
miniPMT	R9880U-110	Super Bialkali	40	2.0×10^6	50 (round)
HFPMT	R7525	Bialkali	25	5.0×10^5	490 (round)

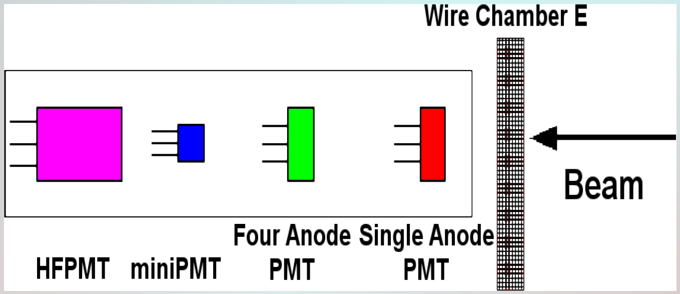
Window: ~2 mm thick at the center, ~6 mm thick at the edges.

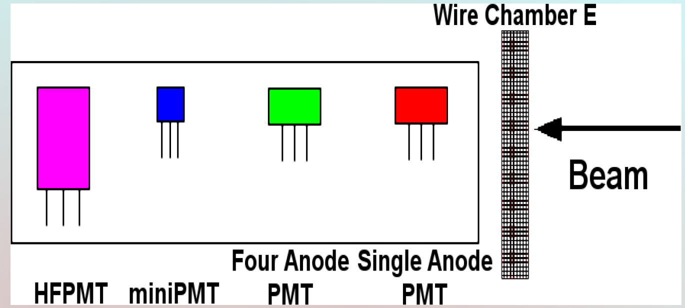
Window: < 1 mm thick

Window: < 0.5 mm thick

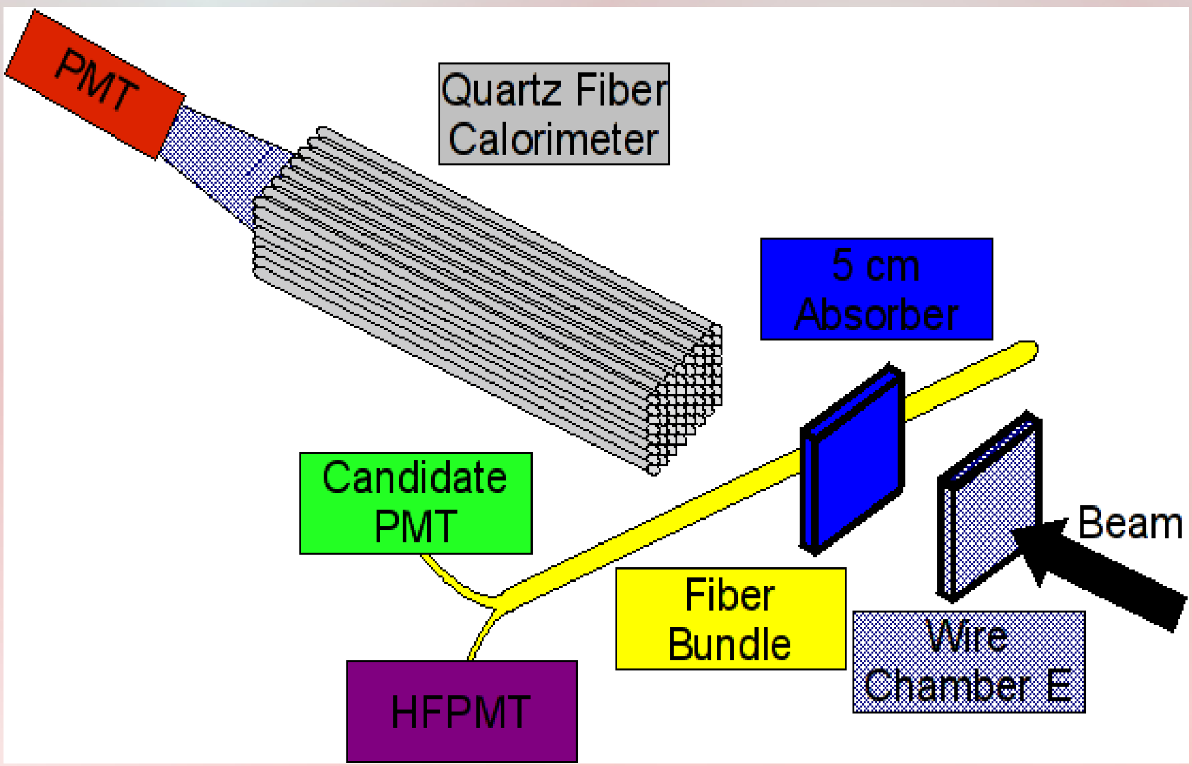
Window: < 1 mm thick

Beam Tests
(CERN H2 Beamline – Summer09)





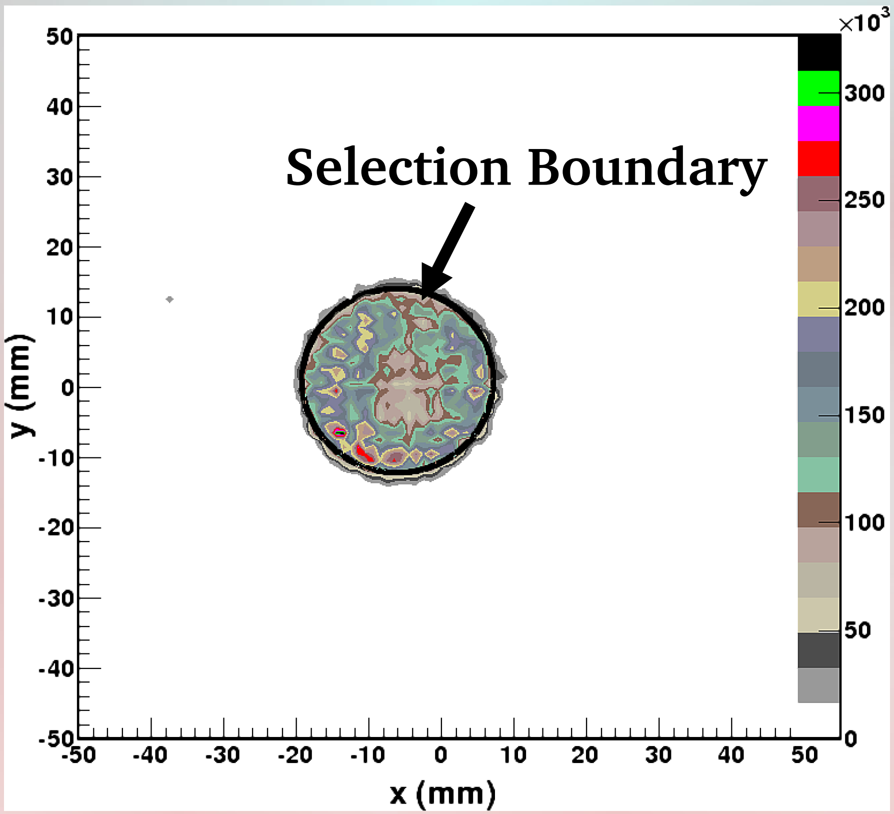
150 GeV/c
Muon Beam

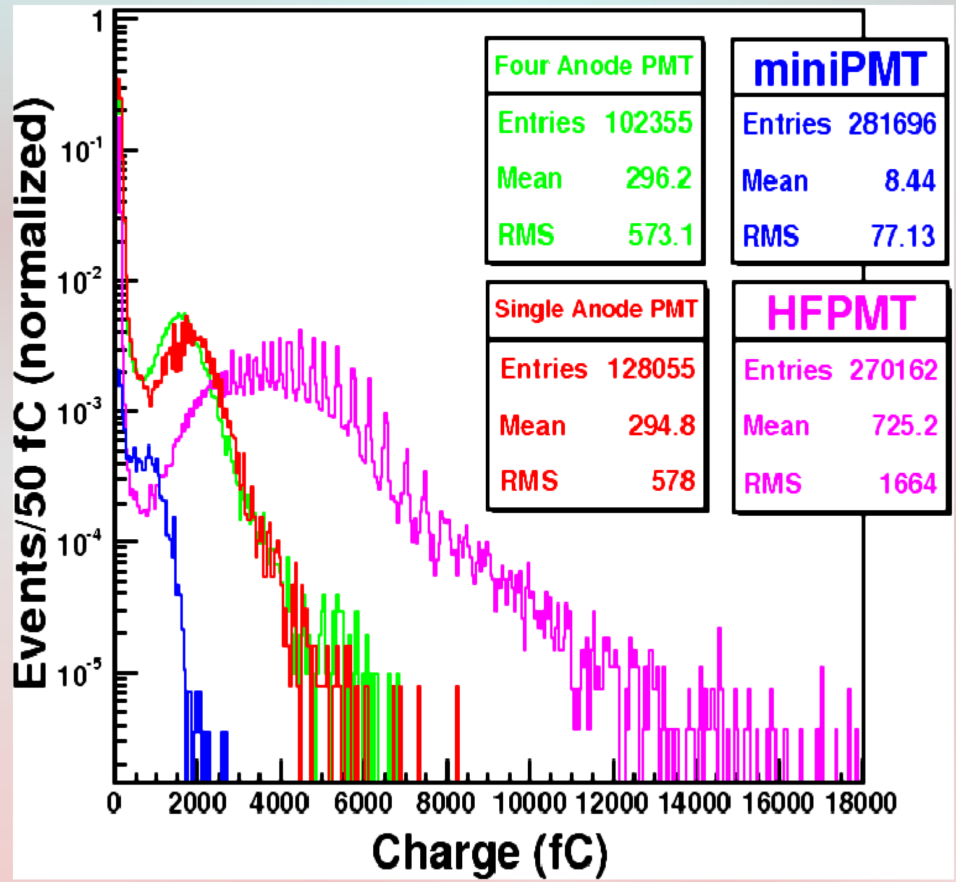


<u>Trigger</u>
Coincidence of two scintillation counters:
4 cm x 4 cm
14 cm x 14 cm

80 GeV/c
Electron Beam

Muon Interactions with PMT Windows (Front Incidence)

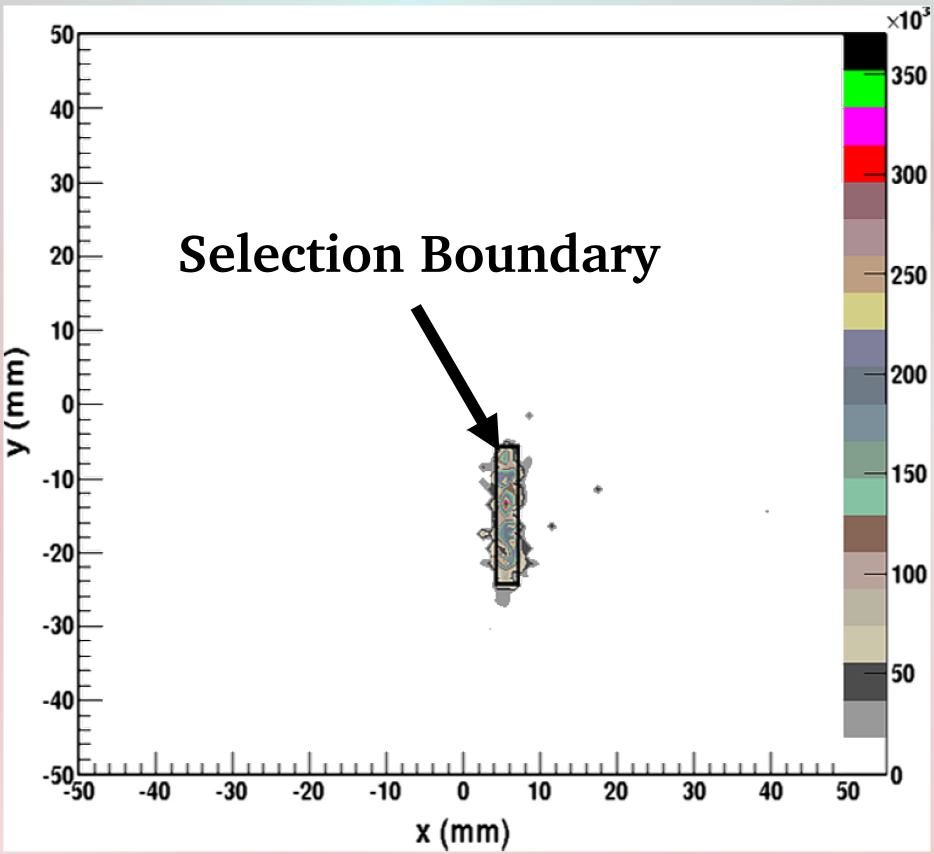


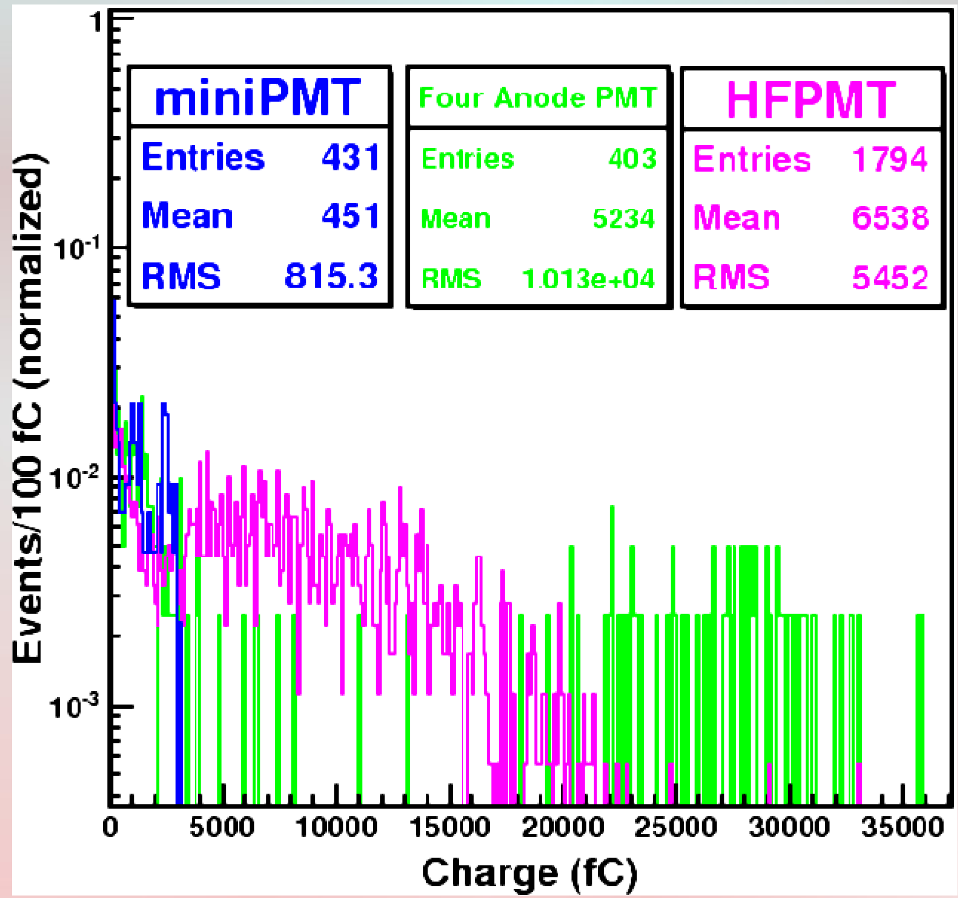


PMT Window Event Rates:

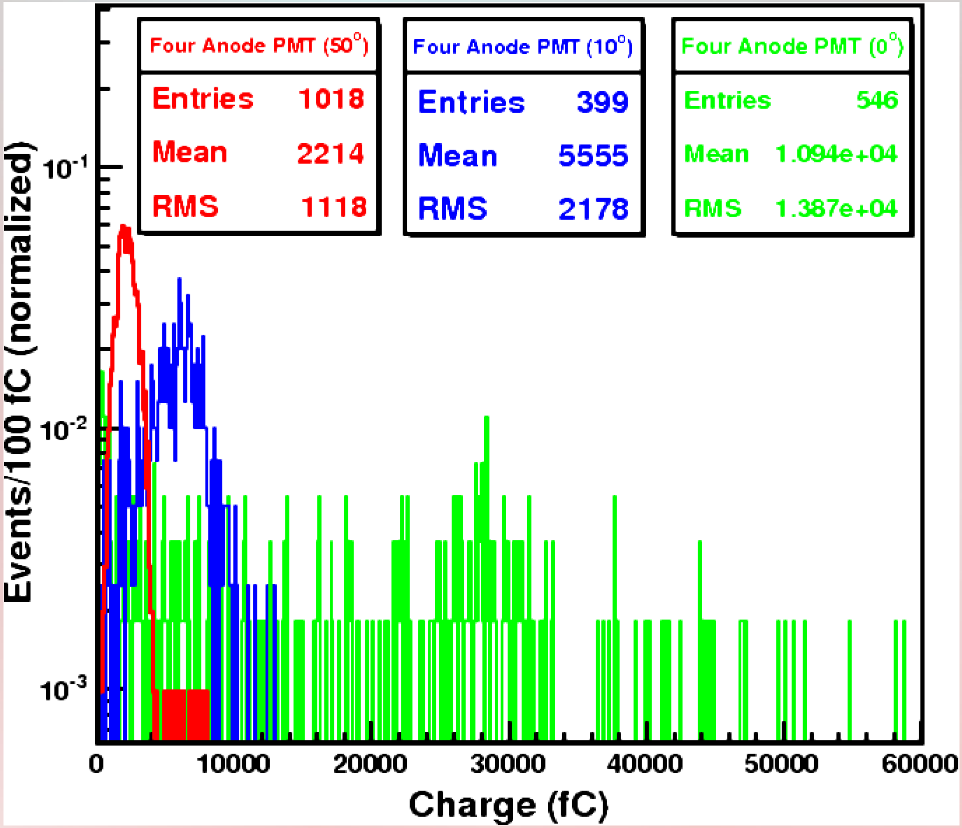
HFPMT 90% Four Anode PMT 69% Single Anode PMT 64% miniPMT 51%

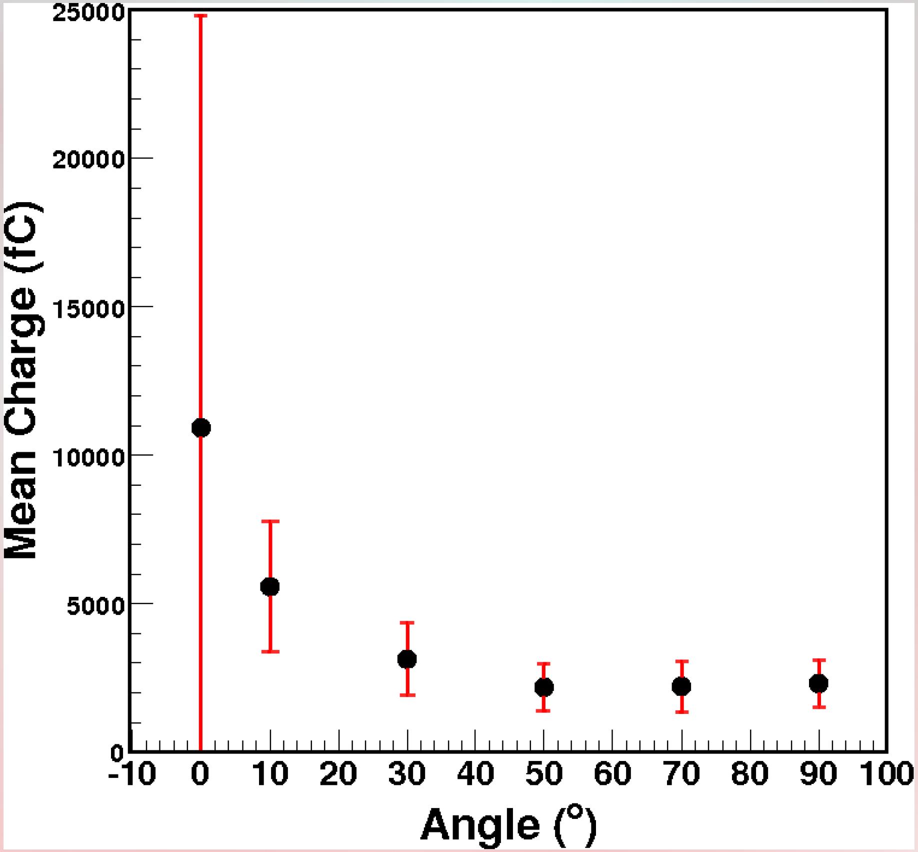
Muon Interactions with PMT Windows (Side Incidence)



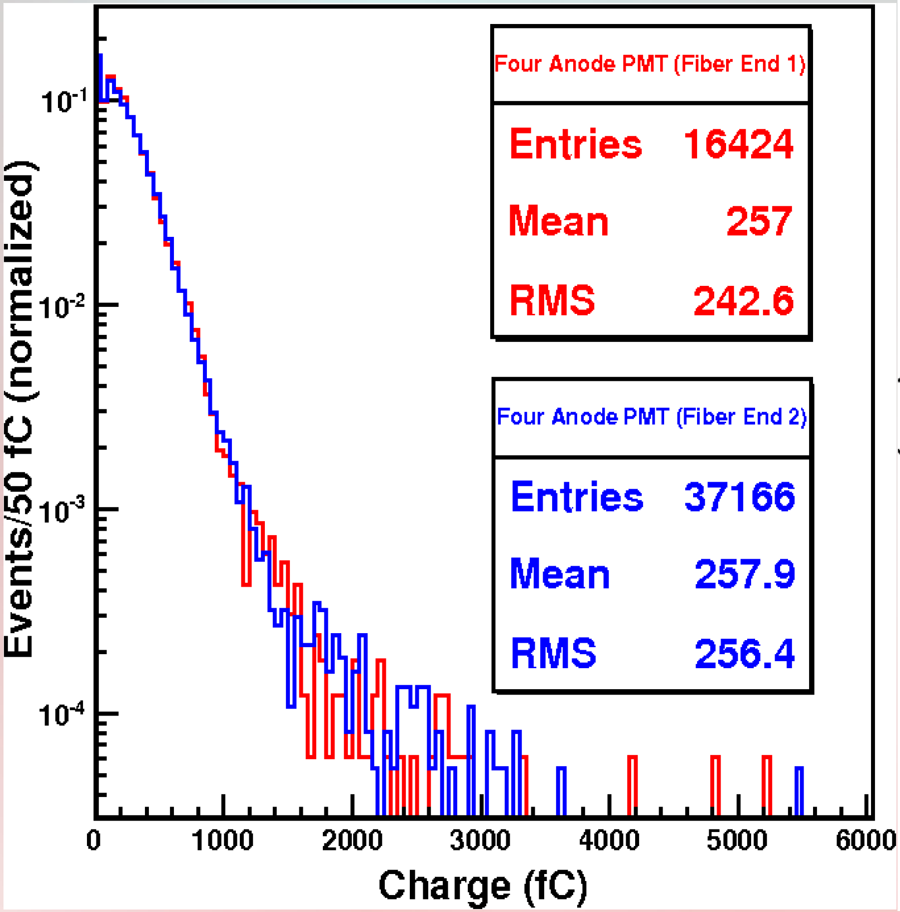


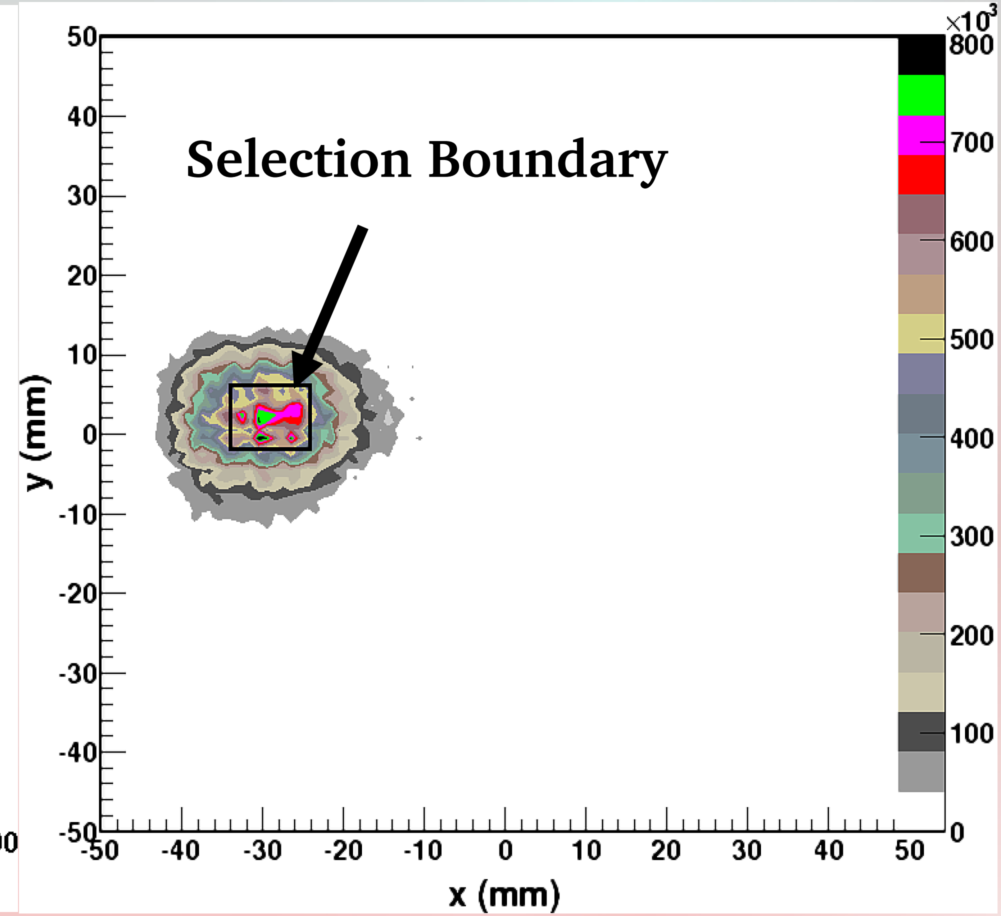
Muon Interactions with PMT Windows (Incidence At Different Angles)



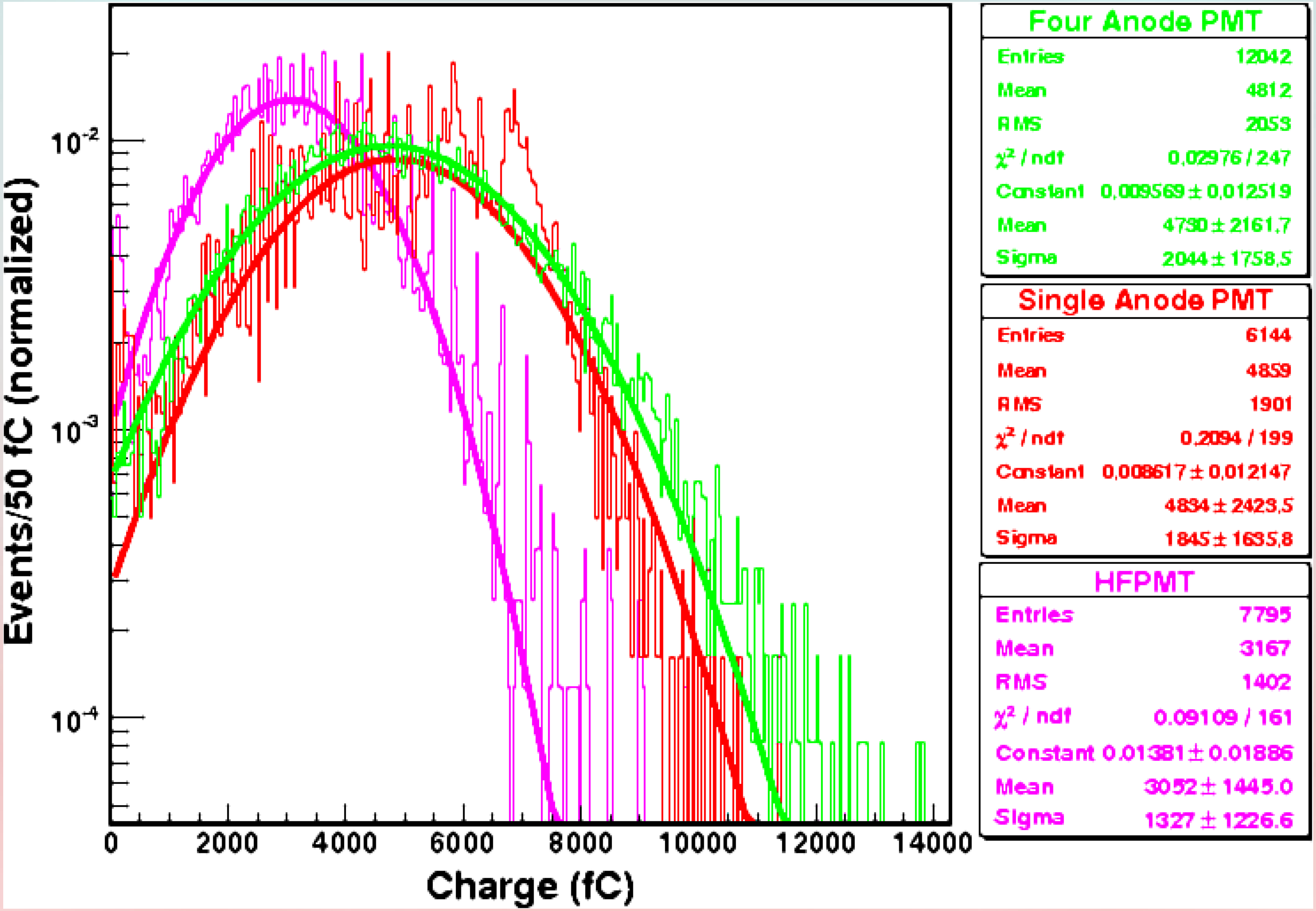


Čerenkov Response of PMTs (Tests with The Fiber Bundle)

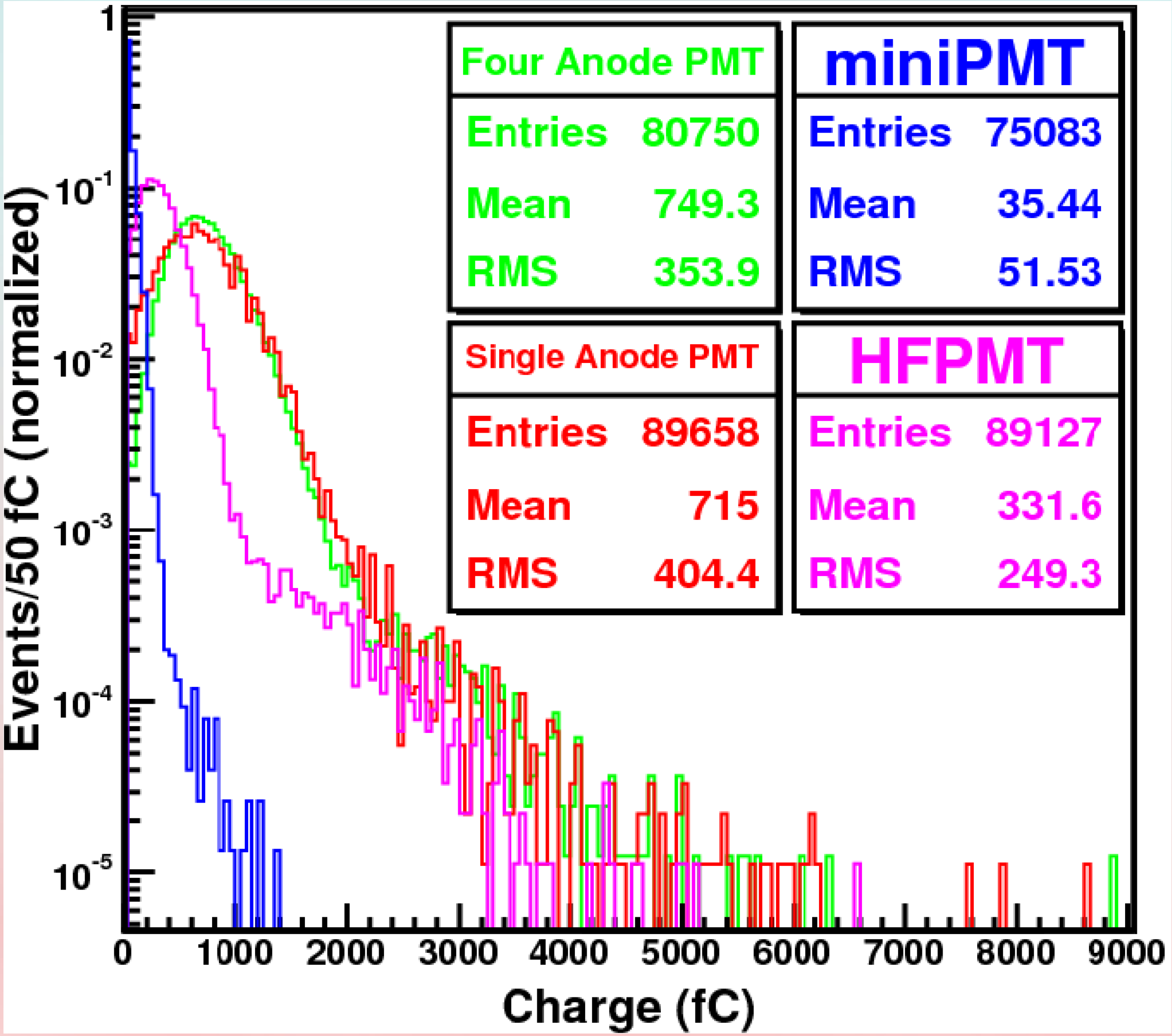




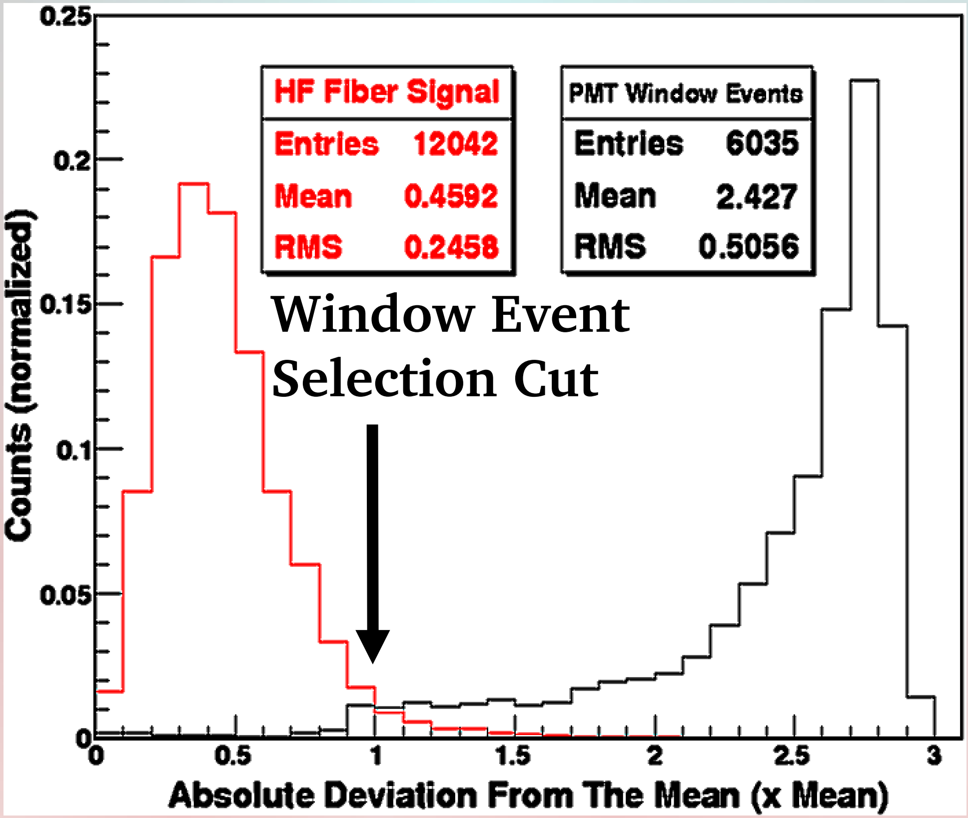
Čerenkov Response of PMTs (Tests with The Fiber Bundle)



Čerenkov Response of PMTs
(Tests with The Quartz Fiber Calorimeter)



PMT Window Event Selection and Signal Recovery with Four Anode PMT



0. Identify PMT window events

1. Order signal magnitudes from four quadrants: S1>S2>S3>S4.

2. If S1/S2>20, then single quadrant hit:
Signal=(4/3)*(S2+S3+S4)

3. Remaining <20% events are multiple quadrant hits:

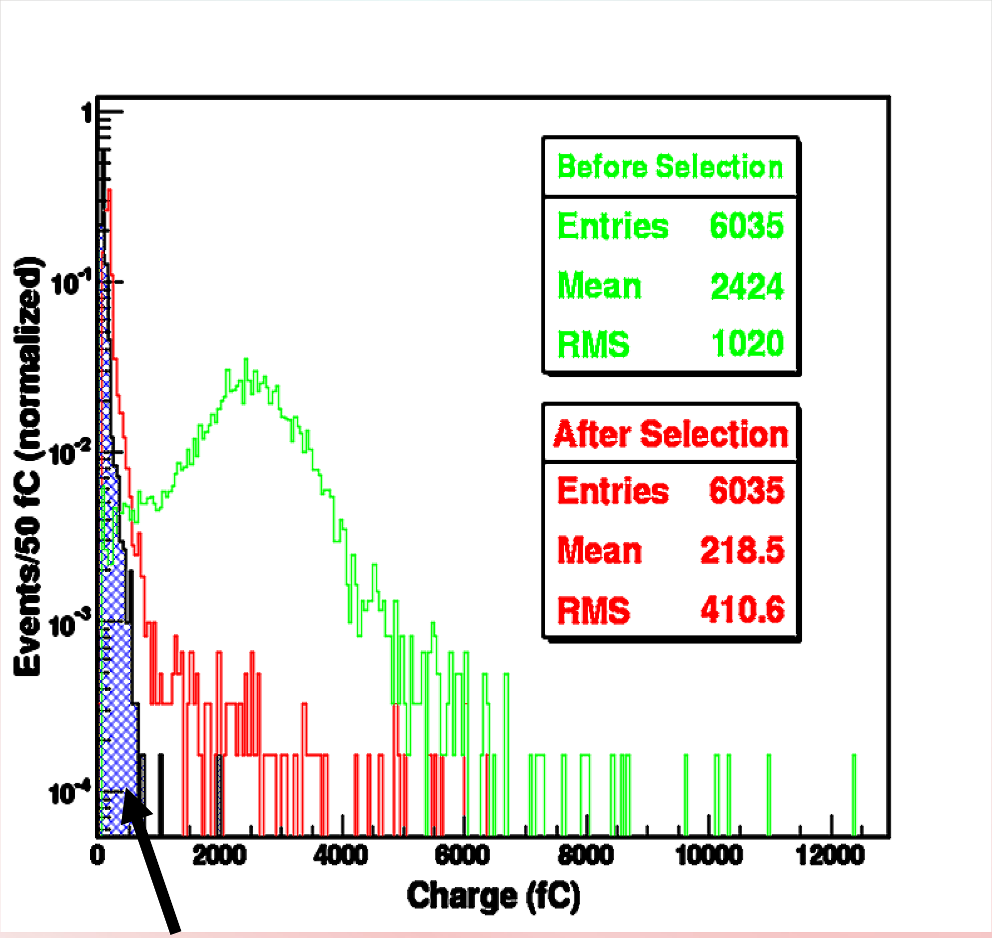
3. a. If S2>0.8*(S2+S3+S4), then double quadrant hit:
Signal=2*(S3+S4)

3. b. Remaining ~5% are triple quadrant hits:
Signal=4*S4

3. c. Remaining ~2.5% is irreducible.

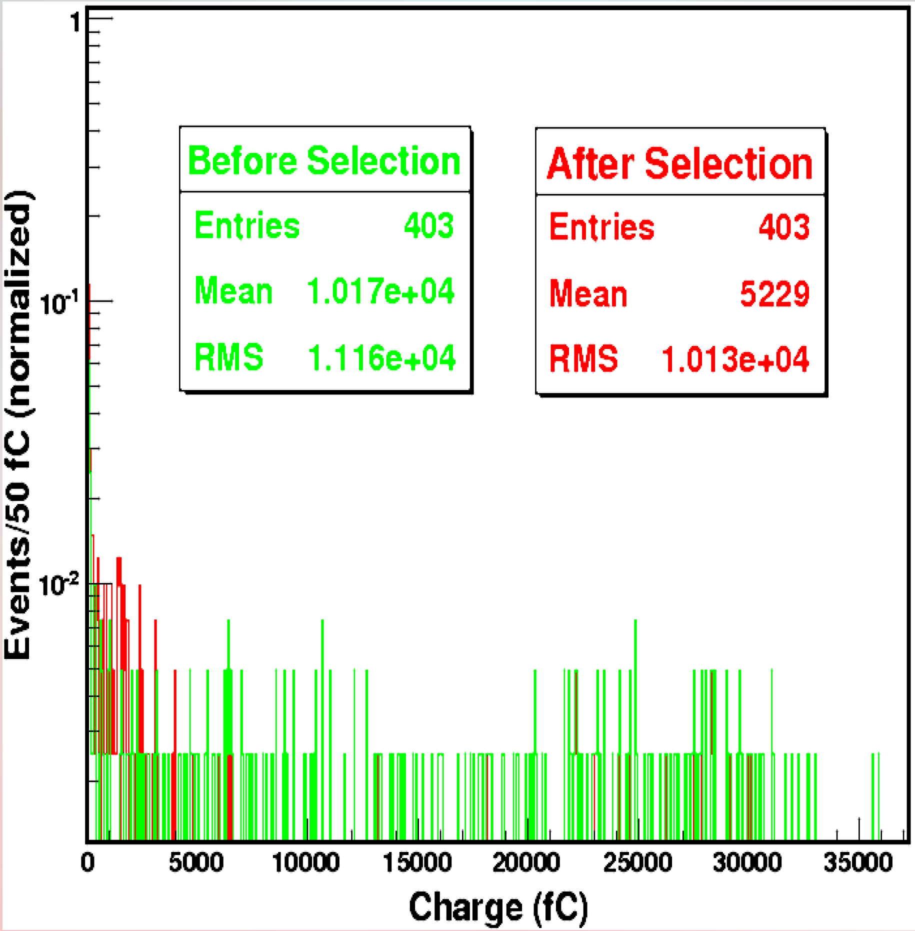
PMT Window Event Selection and Signal Recovery with Four Anode PMT

Front Muon Incidence on PMT Window



Pedestal

Side Muon Incidence on PMT Window

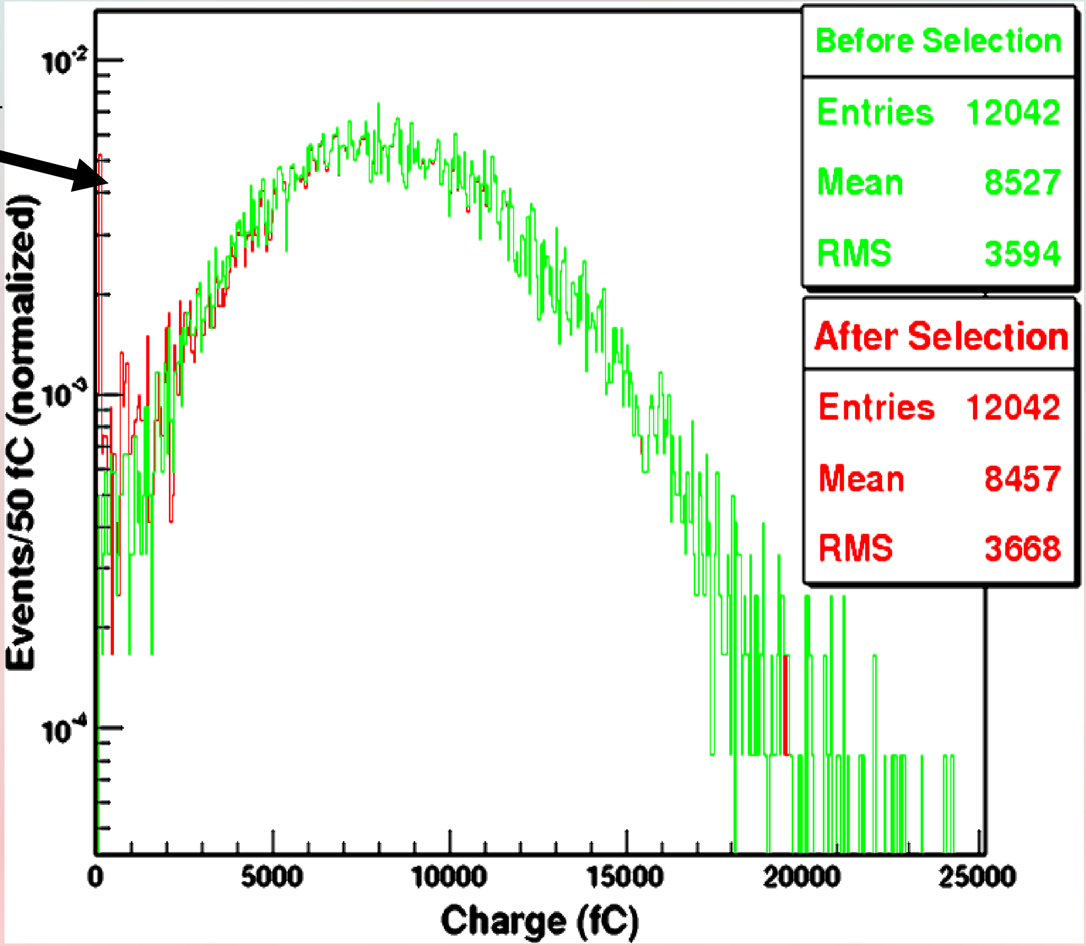


PMT Window Event Selection and Signal Recovery with Four Anode PMT

Fiber Bundle PMTs

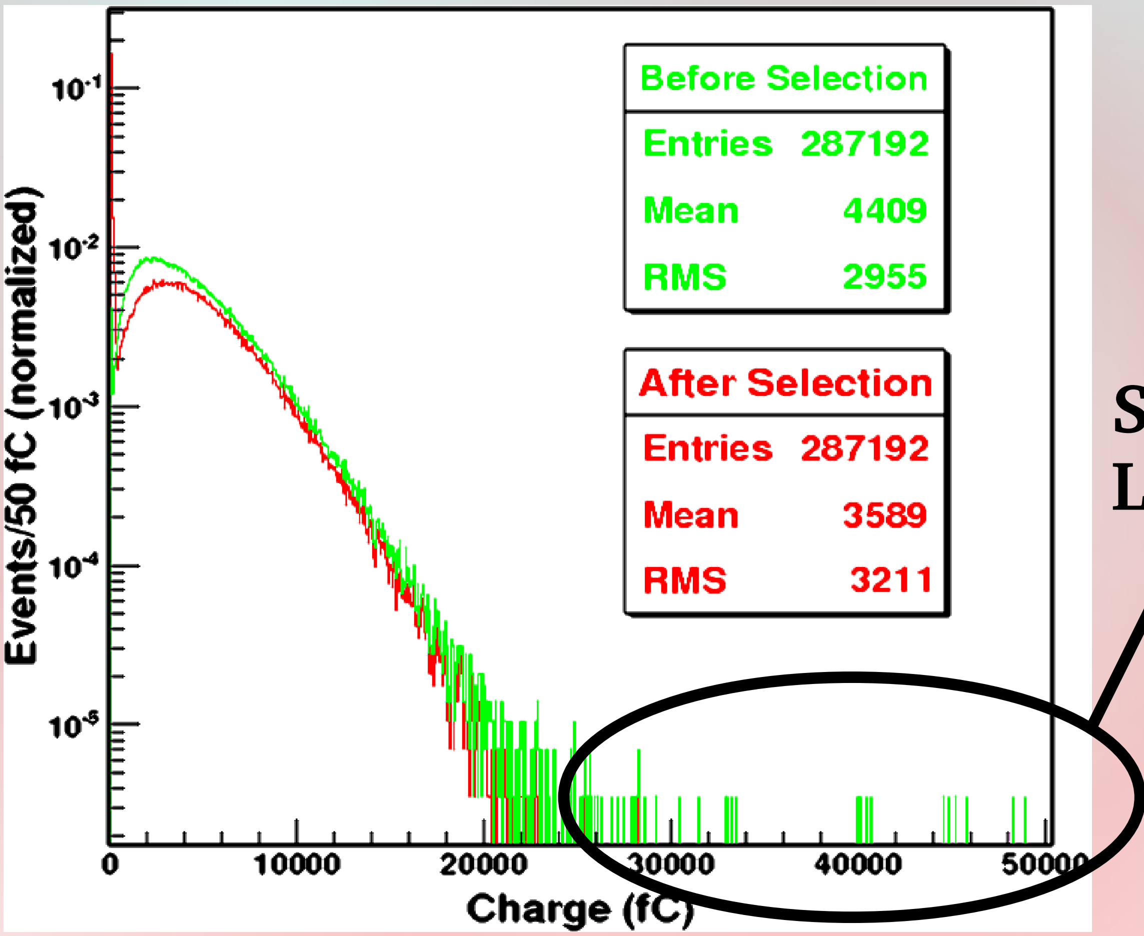
Algorithm should have no effect on the signal!!!

<2.5% misidentification



PMT Window Event Selection and Signal Recovery with Four Anode PMT

Fiber Bundle PMTs with the PMTs in the Beamline!!!



Success!!!
Large tail is gone!!!

Conclusions

Candidate PMTs offer reduced rate and lower response to muon incidence on PMT windows at any angle of incidence when compared to HFPMT.

Single and four anode PMTs have a Čerenkov response that is ~1.5 (for super bialkali photocathodes) - 2 (ultra bialkali photocathodes) times higher than the HFPMT response. The resolution is also improved.

A simple and efficient algorithm for identifying PMT window events with four anode PMT and recovering the signal utilizing the remaining useful information is developed. The algorithm is ~97% efficient in events with direct muon incidence on PMT windows as well as identifying rare window event occurrences coincident with real signal.

Presented results are published in CMS DN-2009/011, CMS DN-2009/012, CMS NOTE-2010/003 and submitted to JINST.