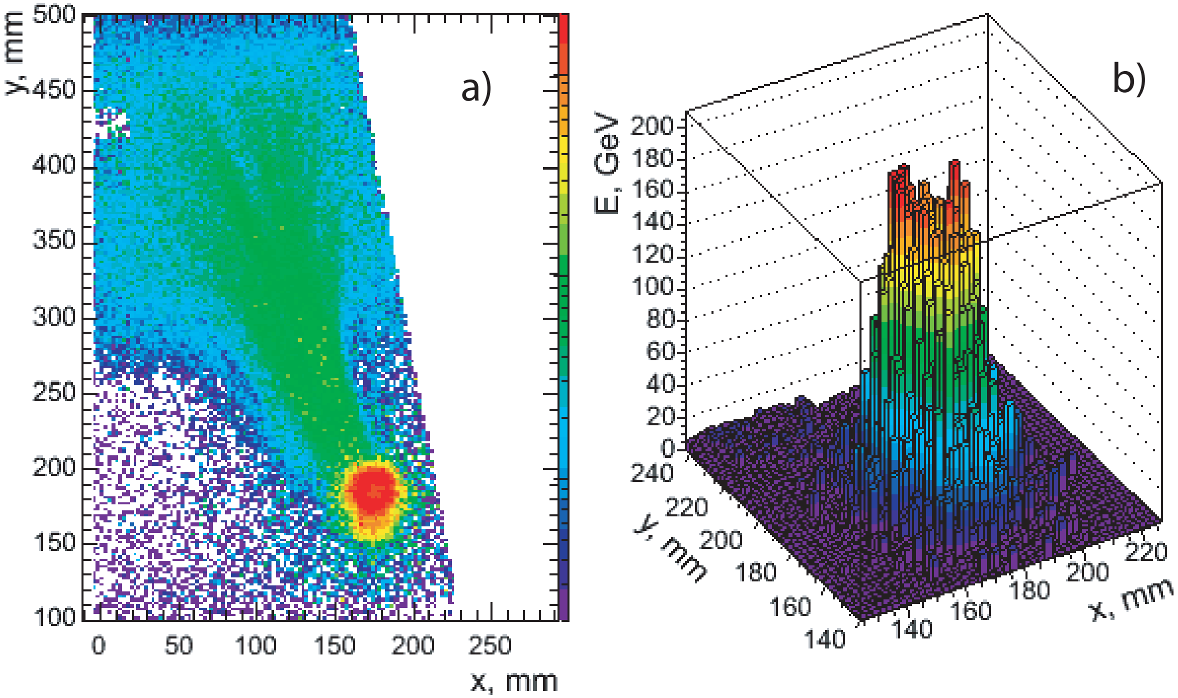
An AntiCherenkov Photomultiplier

Nural Akchurin, Jordan Damgov, Sung-Won Lee and Efe Yazgan
Texas Tech University

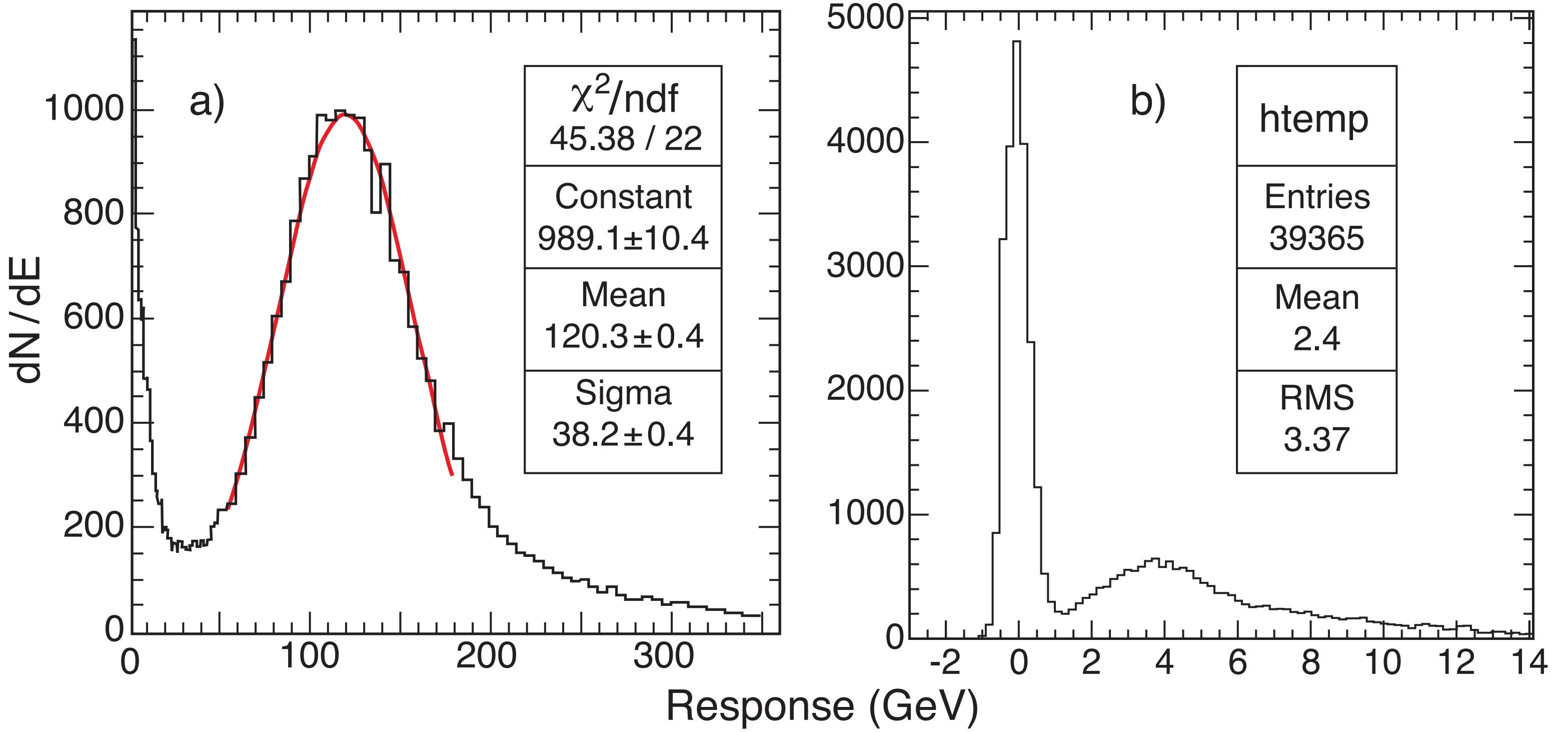
Problem?



"Hot spots" have been observed in many detectors, especially in calorimeters, for when the signal strength due to instrumentation exceeds that of the desired signal. This becomes a concern when the light yield of a calorimeter is low (a few *pe* per GeV) and there is no redundancy in the system to veto these events

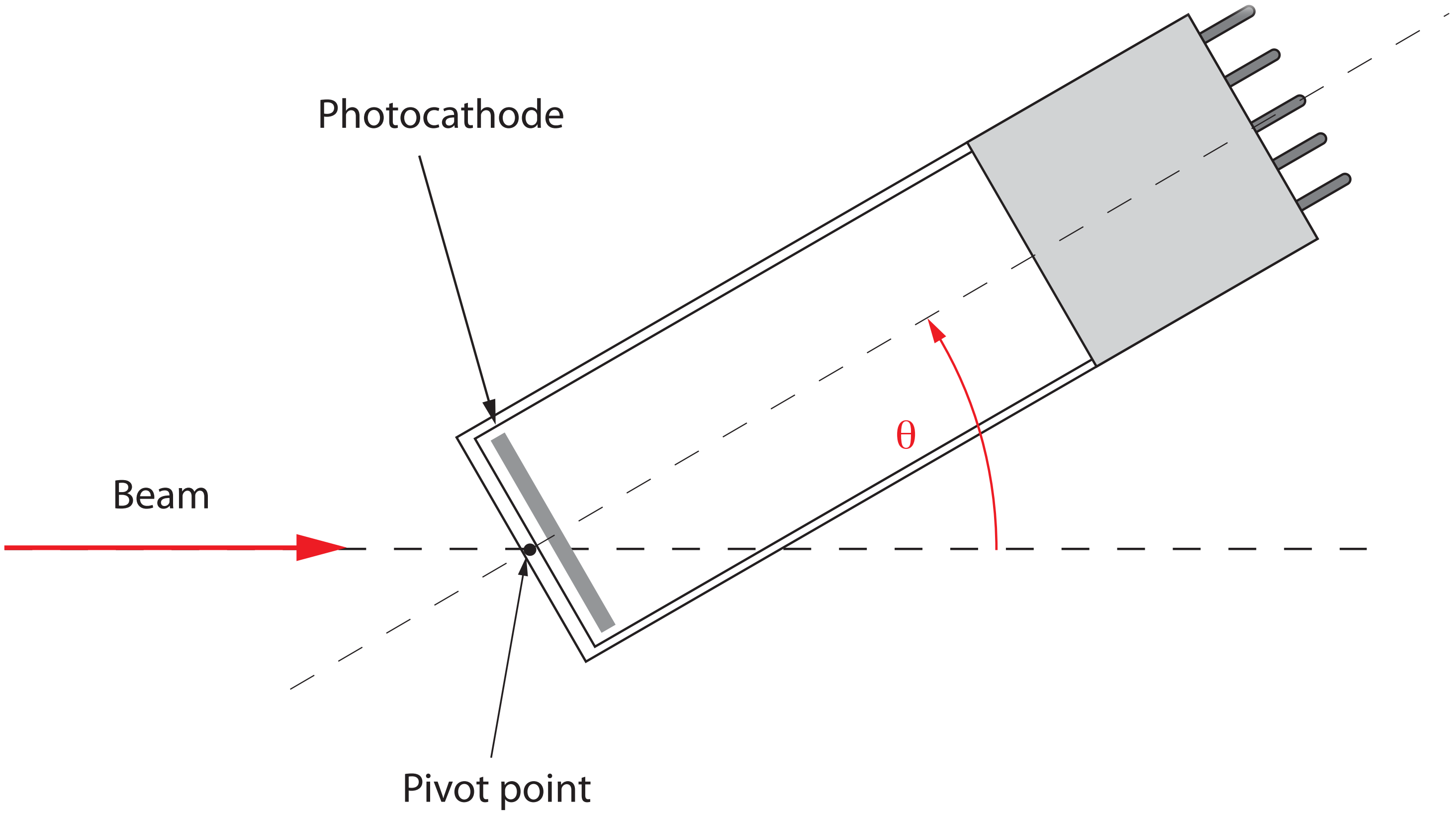
Problem ?

S. Abdullin *et al*, EPJC, **53**, 139-166 (2008)



- Test beam data show that a through-going muon generates ~30 *pe* in a PMT window (R7525), equivalent to ~120 GeV signal in this particular case, due to the Cherenkov light produced in the window.
- The average plano-concave window thickness is ~6 mm for R7525.
- The following studies show that we can effectively suppress this effect by altering the window+photocathode interface.

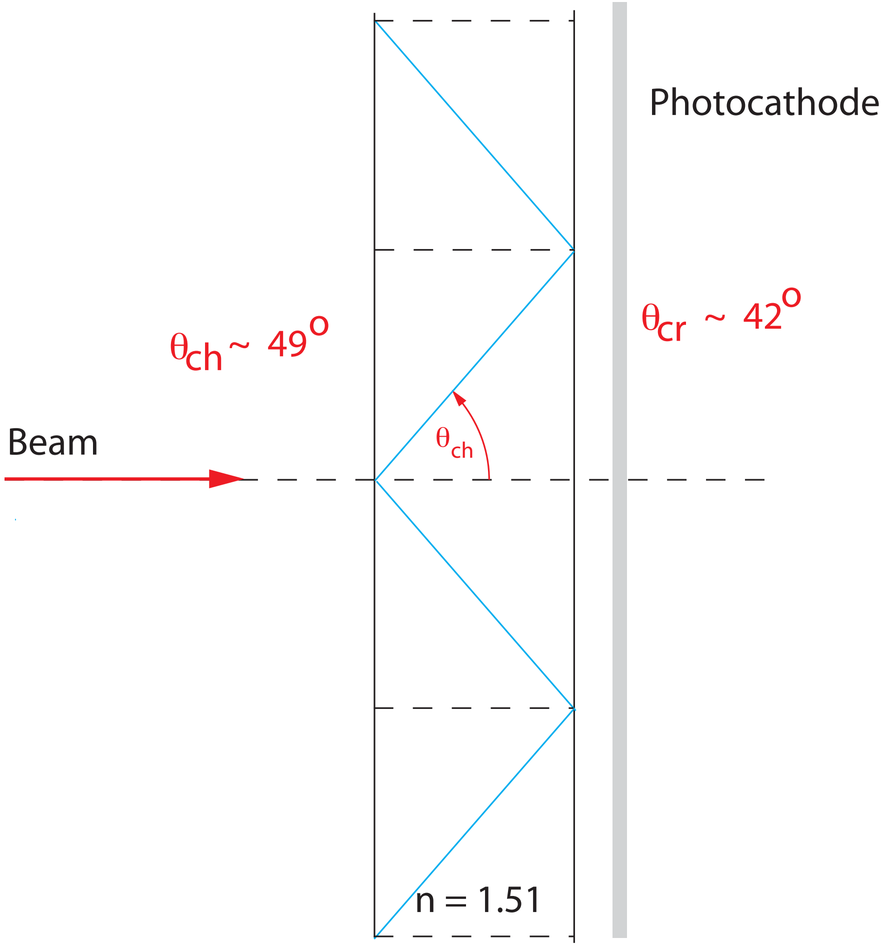
Idea



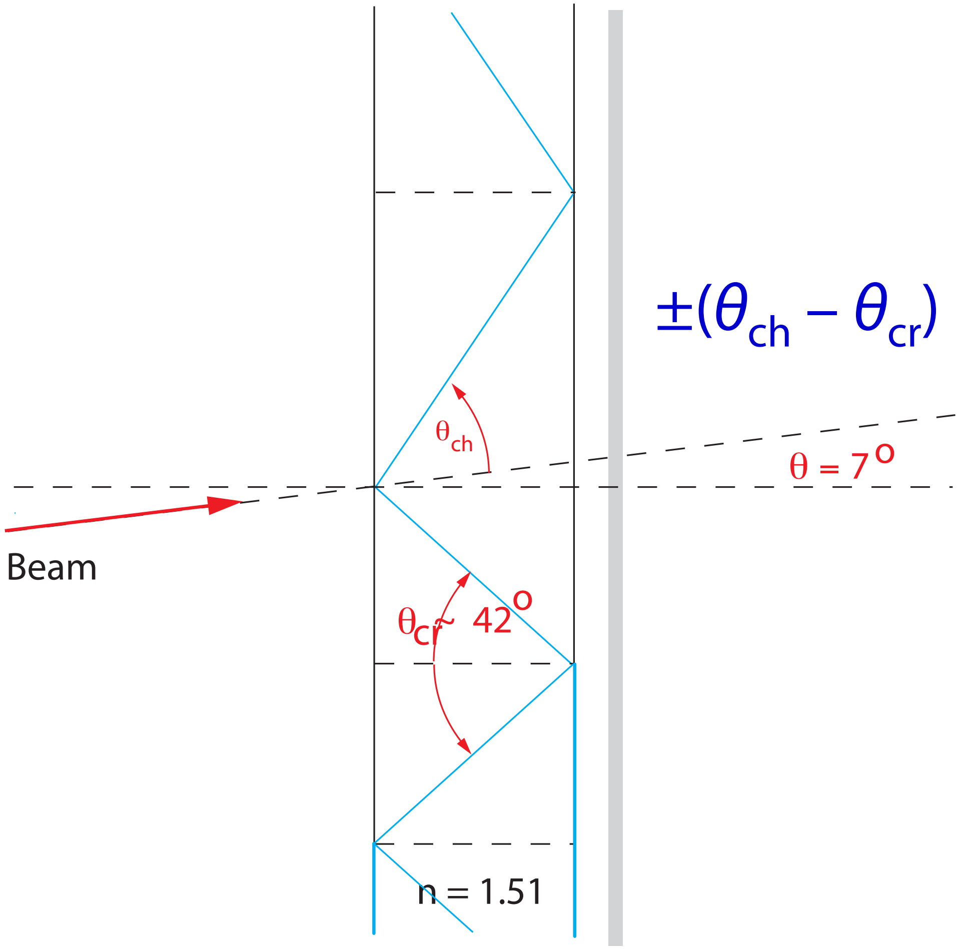
If the photocathode is separated from the window inside the PMT and deposited on a thin mica disk, then the *pe* emission will cease while the Cherenkov light is trapped in the glass

The critical measurement is the response of the PMT to relativistic charged particles as a function of the incidence angle, *θ*. We investigate this response under different conditions for future applications in calorimetry

Capturing Cherenkov Light - I

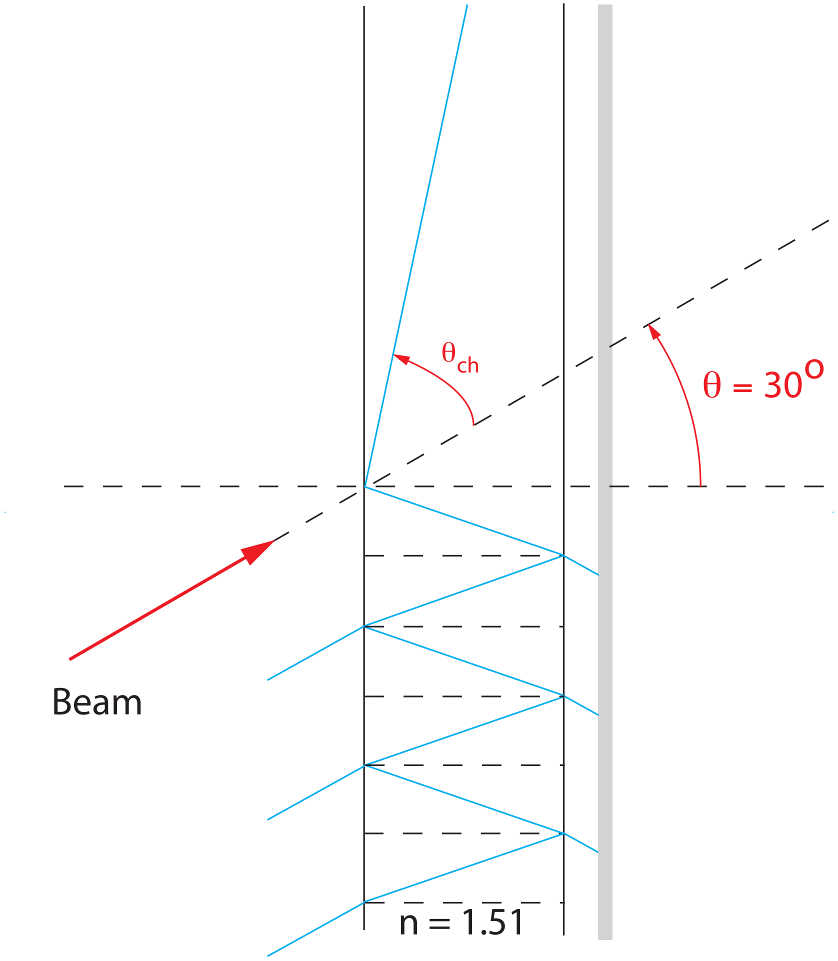


Case #1(0°)

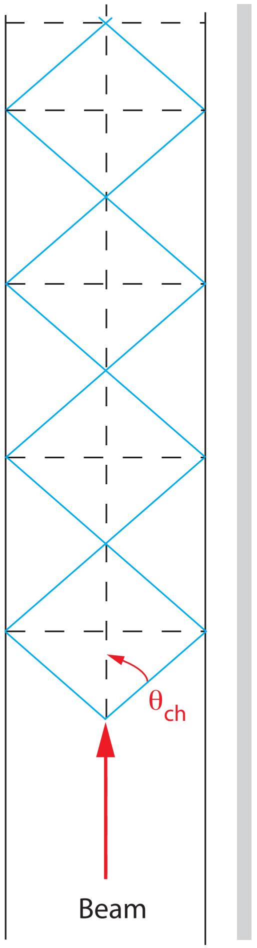


Case #2 (7°)

Capturing Cherenkov Light - II



Case #3 (30°)



Case #4 (90°)

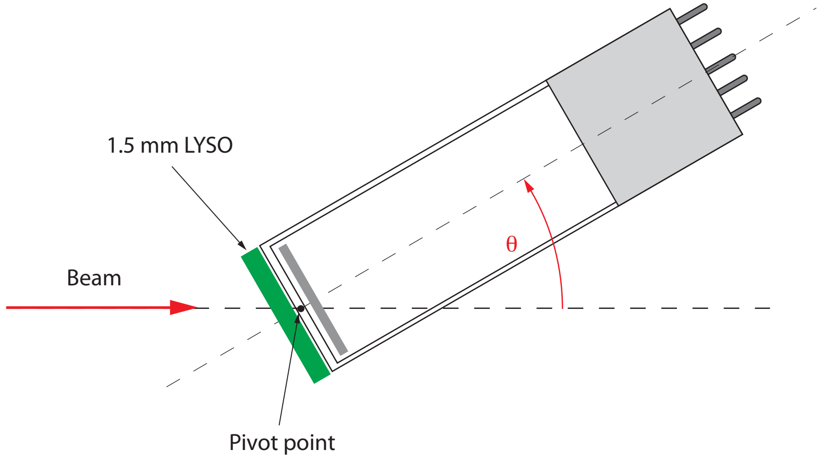
Nural.Akchurin@ttu.edu 6 July 2011

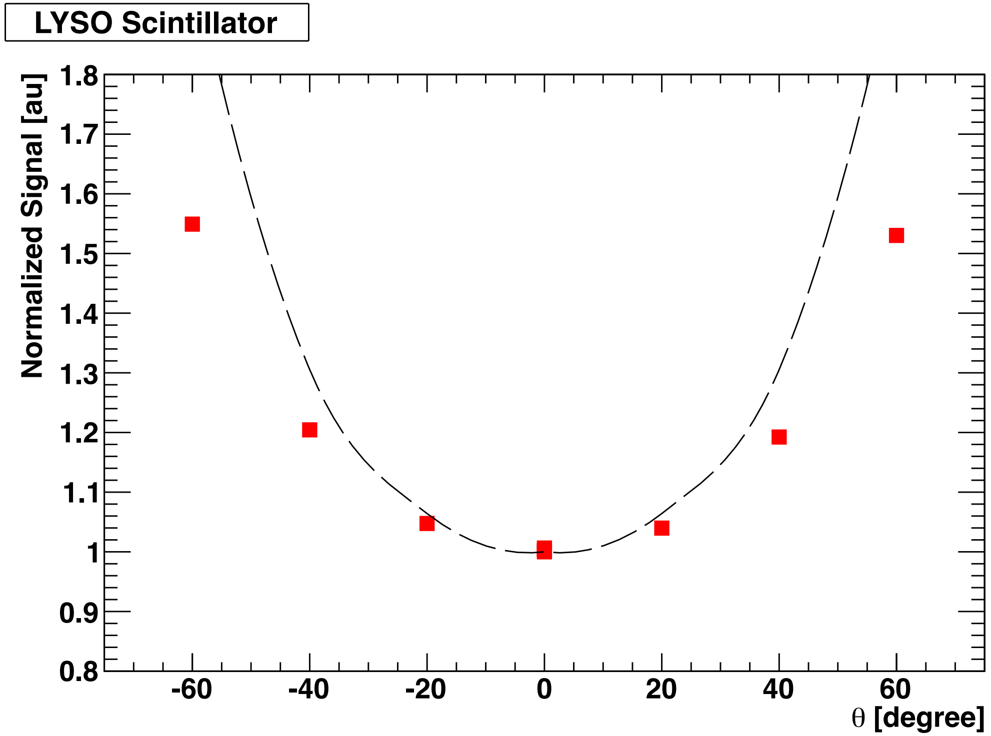
AntiCherenkov PMT (ET 865) Prototype

ET 865	**Typical**
Photocathode	Bialkali
Active diameter	23 mm
QE at peak	20 %
Luminous sensitivity	50 µA/lm
Dynodes	LF 8 stages
Dynode material	SbCs
Max anode sensitivity	50 A/lm
HV for max an. sens.	1200 V
Gain at nominal an.sens.	2×10^5
Dark current at max an. sens.	0.25 nA
-5% nonlinearity (A)	10 mA
Single *pe* peak/valley	1.8

Nural.Akchurin@ttu.edu 6 July 2011

Angular Scan with 1.5 mm Thick Scintillator

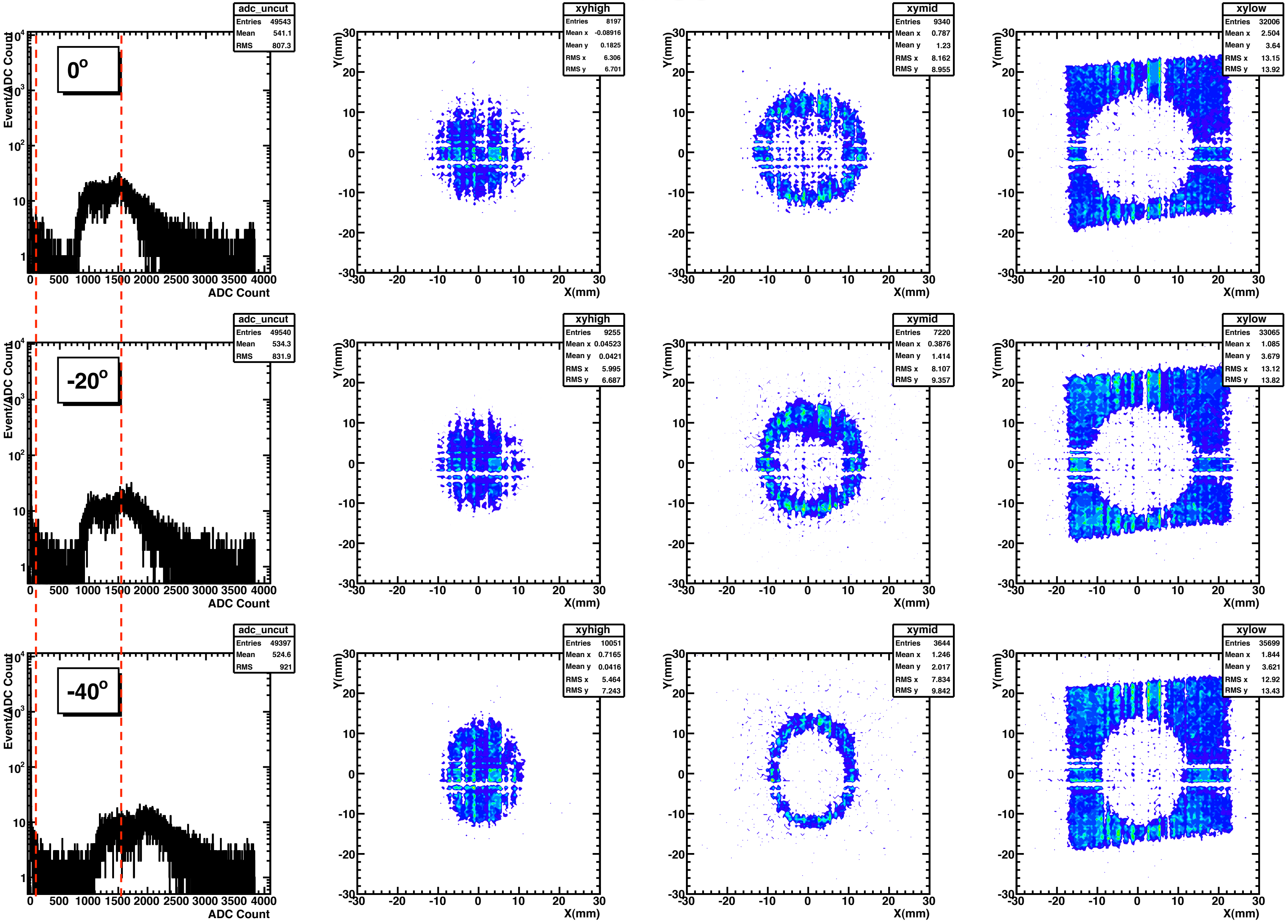




- As a test, a 1.5-mm-thick LYSO scintillator disk is mounted on the AntiCherenkov PMT (1-1/8" dia.) and rotated around the pivot point. 180 GeV/*c* μ^+ beam is used and the impact point of the particles is measured by a beam chamber.
- PMT is operated at -1100 V and $g \sim 10^5$.

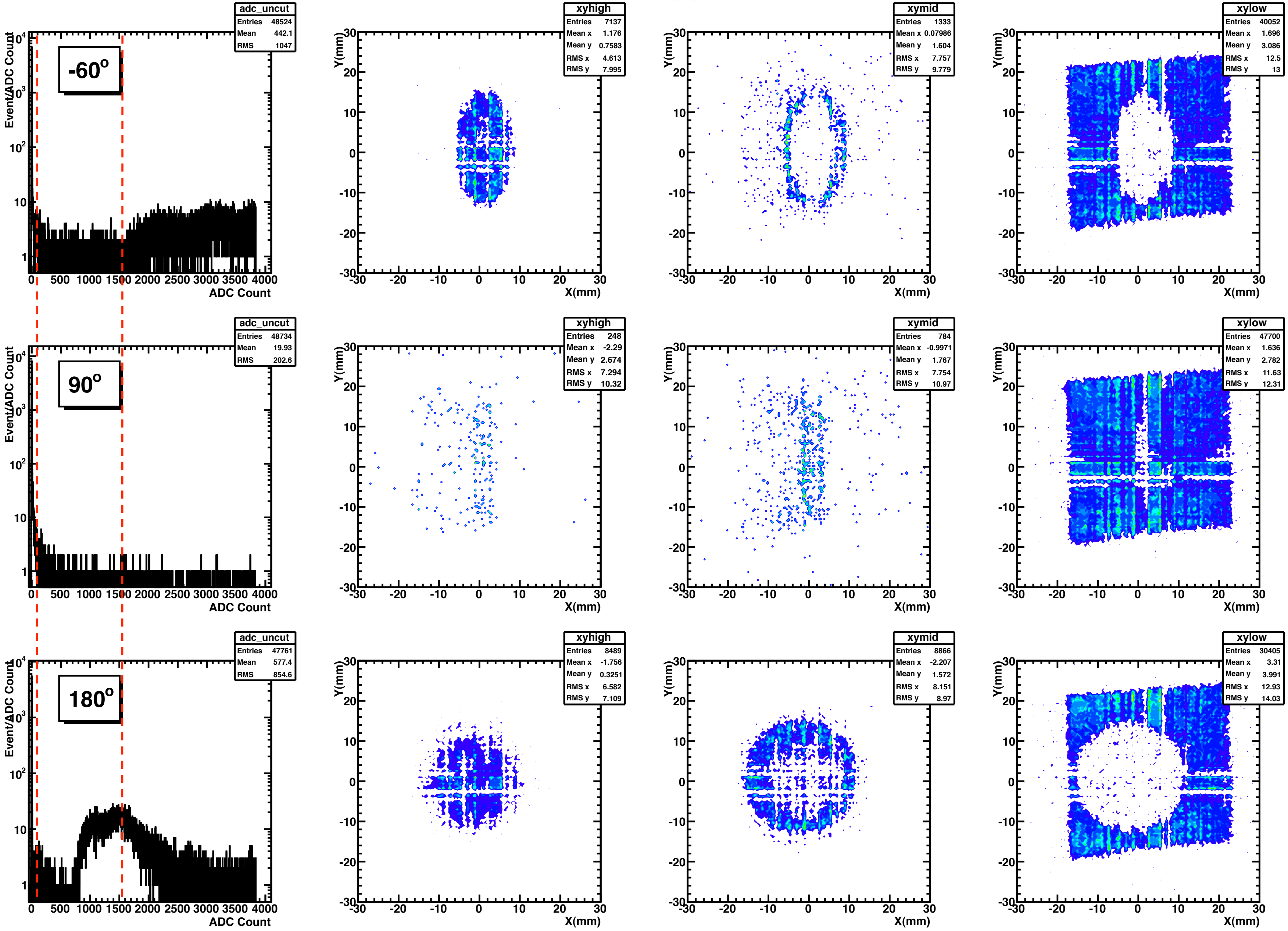
Nural.Akchurin@ttu.edu 6 July 2011

Profiles - I

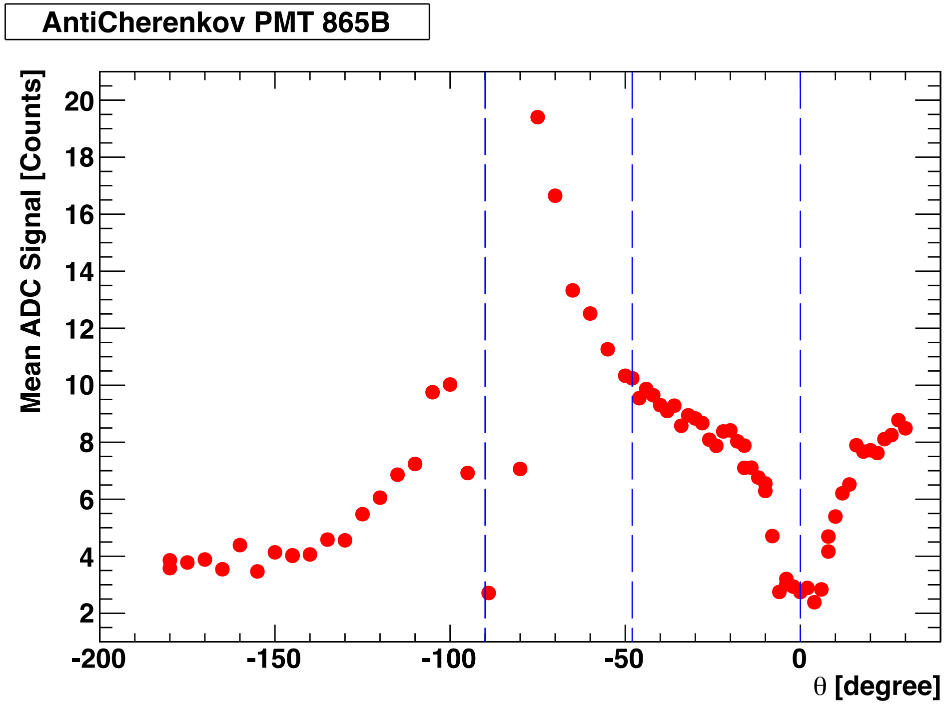


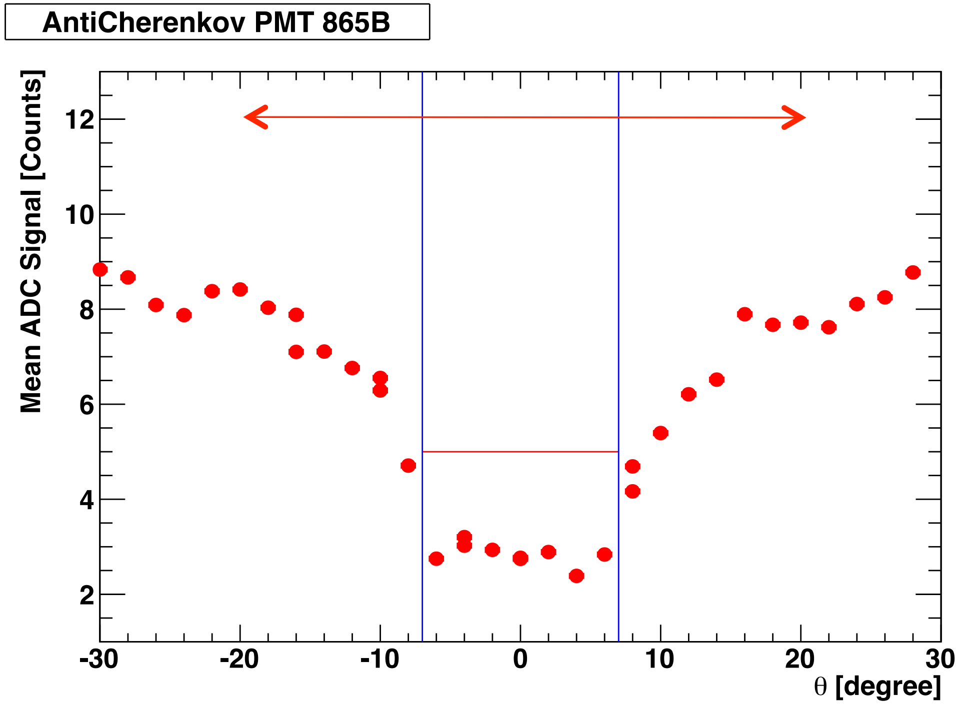
Nural.Akchurin@ttu.edu 6 July 2011

Profiles - II


-60°
90°
180°
adc_uncut
Entries 48524
Mean 442.1
RMS 1047
adc_uncut
Entries 48734
Mean 19.93
RMS 202.6
adc_uncut
Entries 47761
Mean 577.4
RMS 854.6
Event/ΔADC Count
ADC Count
xyhigh
Entries 7137
Mean x 1.176
Mean y 0.7583
RMS x 4.613
RMS y 7.995
xymid
Entries 1333
Mean x 0.07986
Mean y 1.604
RMS x 7.757
RMS y 9.779
xylow
Entries 40052
Mean x 1.696
Mean y 3.086
RMS x 12.5
RMS y 13
xyhigh
Entries 248
Mean x -2.29
Mean y 2.674
RMS x 7.294
RMS y 10.32
xymid
Entries 784
Mean x -0.9971
Mean y 1.767
RMS x 7.754
RMS y 10.97
xylow
Entries 47700
Mean x 1.636
Mean y 2.782
RMS x 11.63
RMS y 12.31
xyhigh
Entries 8489
Mean x -1.756
Mean y 0.3251
RMS x 6.582
RMS y 7.109
xymid
Entries 8866
Mean x -2.207
Mean y 1.572
RMS x 8.151
RMS y 8.97
xylow
Entries 30405
Mean x 3.31
Mean y 3.991
RMS x 12.93
RMS y 14.03
Y(mm)
X(mm)

Angular Scan with Bare AntiCherenkov PMT



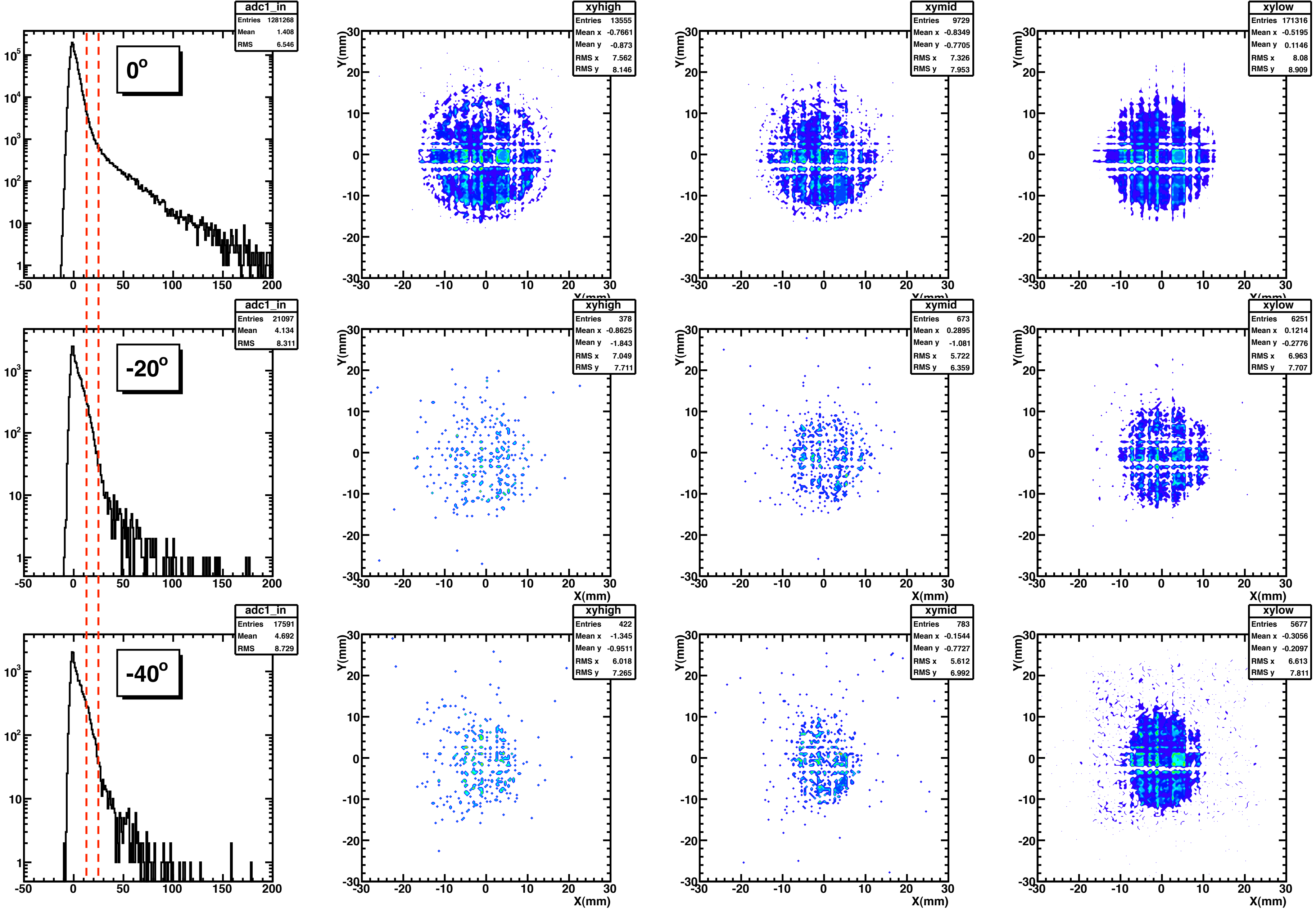


The angular scan of the bare PMT is carried out with 180 GeV/c μ^+ beam. A beam spot of 10 mm diameter is selected. Around zero, $\pm(\theta_{ch} - \theta_{cr}) = \pm 7^o$, and 90^o, the Cherenkov light is trapped in the window glass.

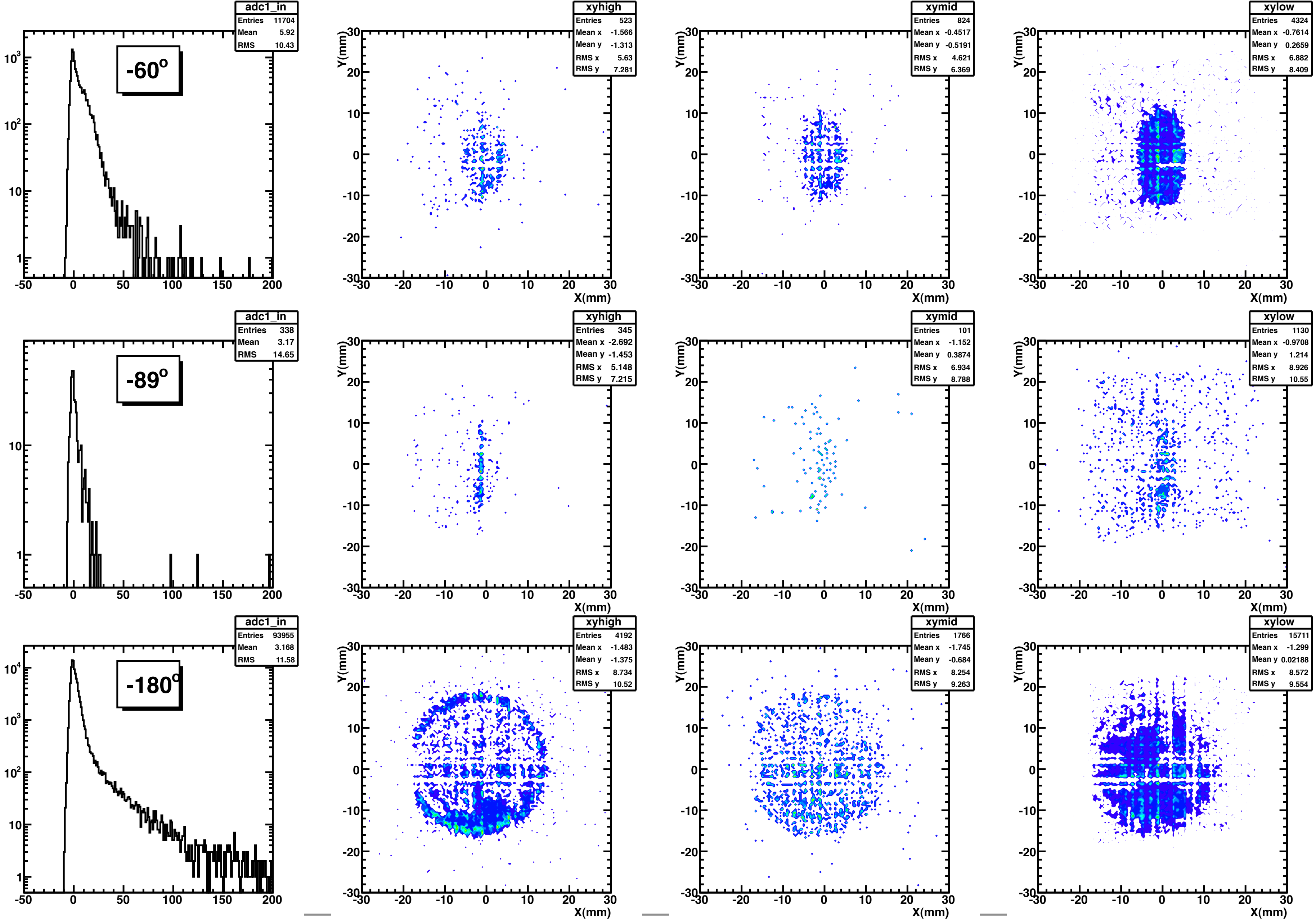
The effectiveness is maintained up to large angles (~40^o). At larger angles ($90^o < \theta < \theta_{ch}$), the signal amplitude is $\propto 1/\cos(\theta)$.

The signal is suppressed at ~90^o and ~180^o for the same reasons.

Signal Profiles ($r = 15$ mm) - I

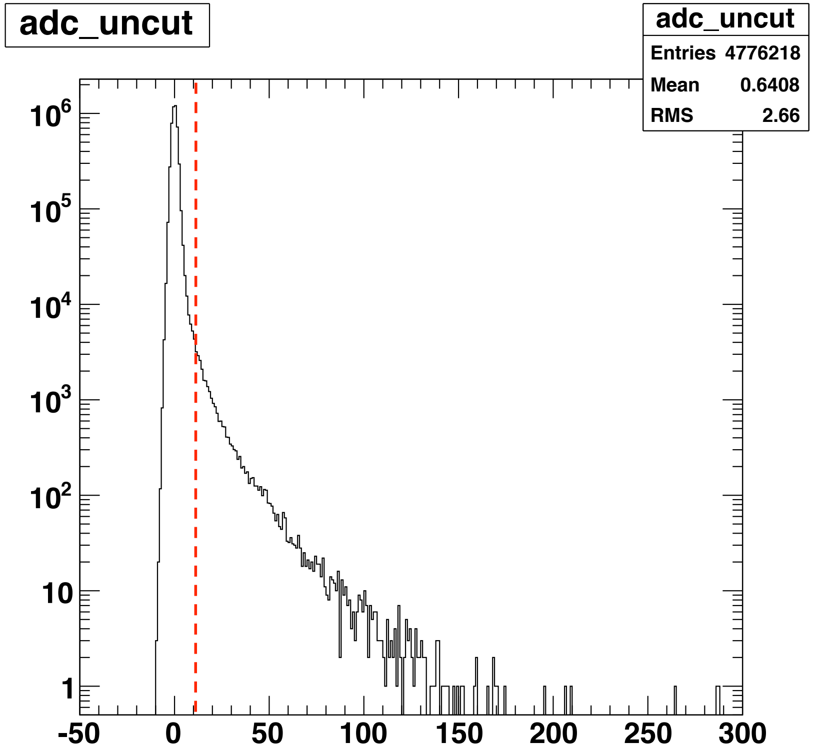


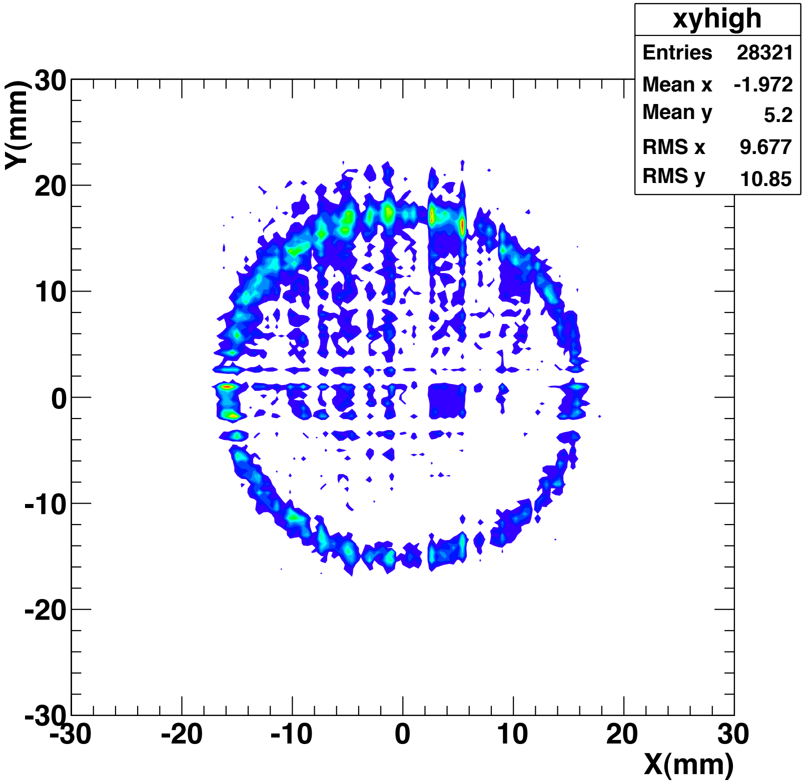
Signal Profiles (r = 15 mm) - II



Nural.Akchurin@ttu.edu 6 July 2011

PMT Edge Effect

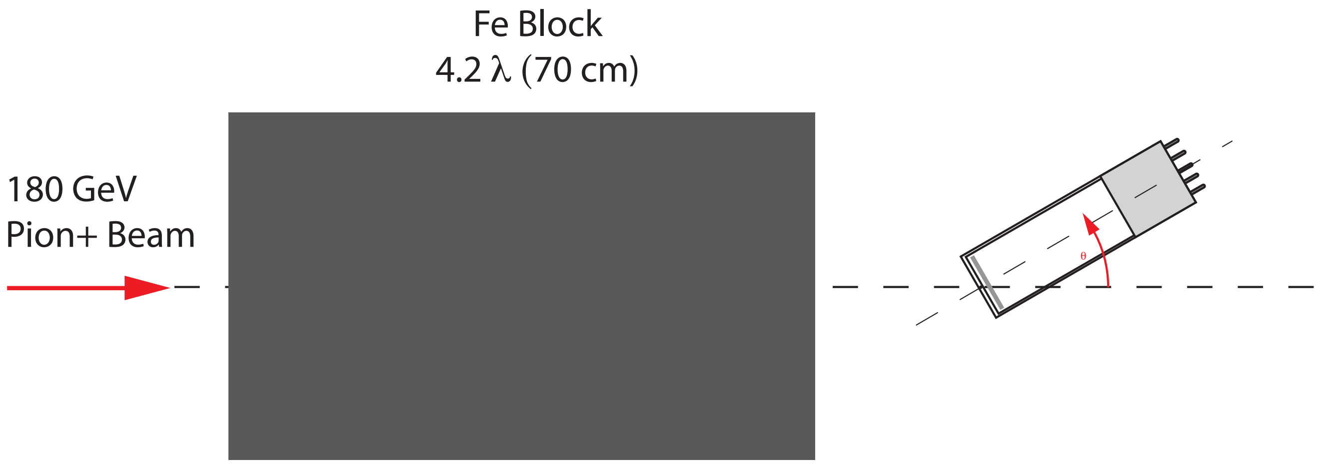




The largest contribution to the tail of the spectrum comes from the PMT rim when probed by muons. The central photocathode disk works as intended. The Cherenkov radiation from the disk ~negligible.

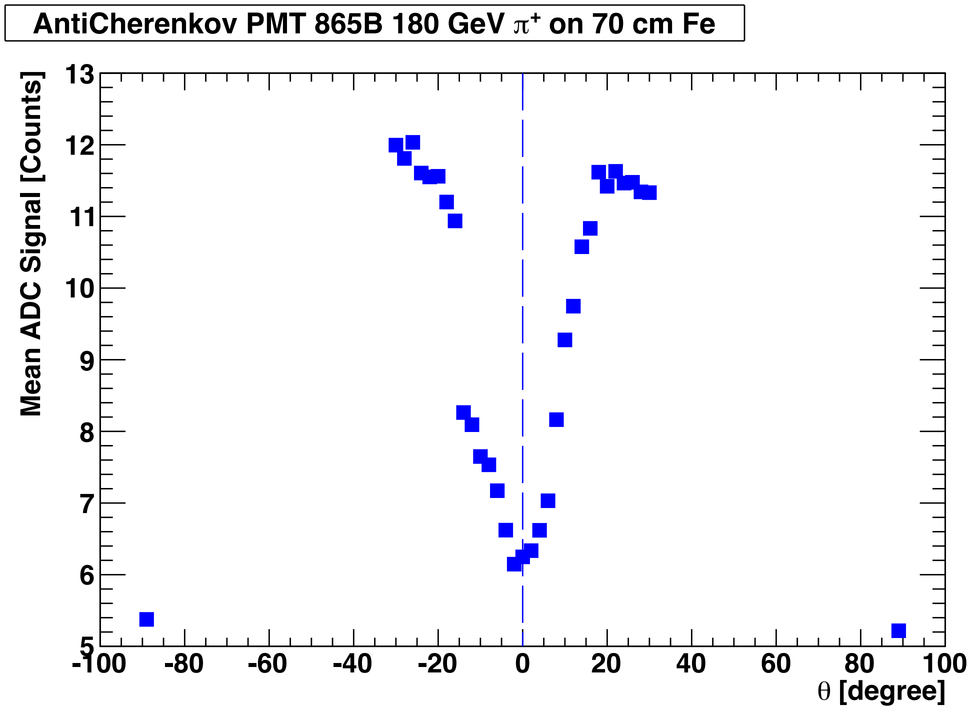
Nural.Akchurin@ttu.edu 6 July 2011

AntiCherenkov PMT behind a Calorimeter Absorber

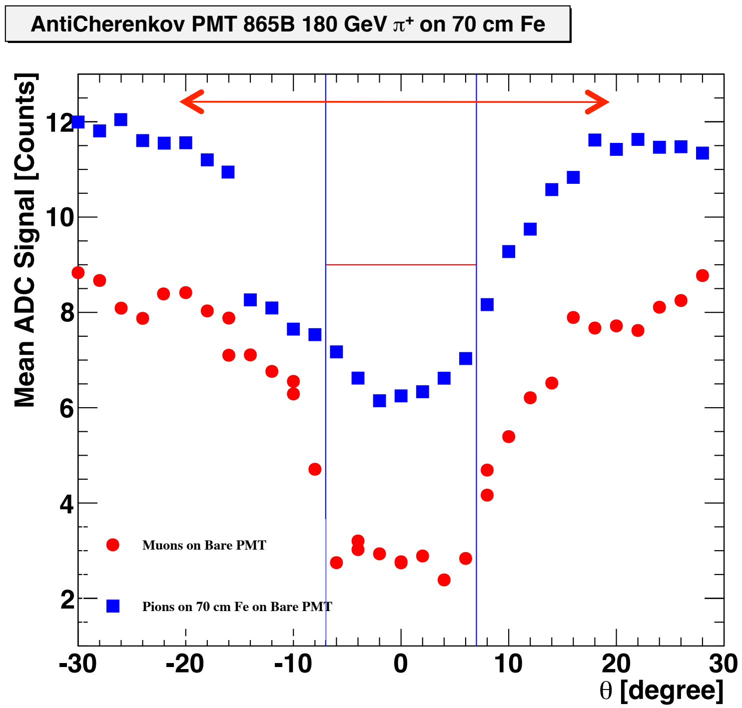


Fe Block
4.2 λ (70 cm)

180 GeV
Pion+ Beam



AntiCherenkov PMT 865B 180 GeV π^+ on 70 cm Fe



AntiCherenkov PMT 865B 180 GeV π^+ on 70 cm Fe

Nural.Akchurin@ttu.edu 6 July 2011

Conclusions

AntiCherenkov PMT is effective suppressing signal due to the Cherenkov radiation produced in the window by relativistic charged particles

The most effective zone is around 0° incidence angle $\pm(\theta_{ch} - \theta_{cr})$. It is uniquely determined by the refractive index (*n*) of window glass ($n \sim 1.51$ and $\theta_{ch} - \theta_{cr} = 7^{o}$ in our case)

Larger *n* values will increase this region, *e.g.* sapphire will give ±14°

It may be possible to "shape" the window to further increase the effective zone

AntiCherenkov PMTs are ideally suited for use behind calorimeters (late developing showers, punch-though muons *etc.*)

Newer high QE photocathodes will further enhance the capabilities of this PMT and compensate for the additional refractive surfaces (2) introduced by the displacement of the photocoathode

Thanks go to Walter Kononenko, Andy Cormack, Paul Davisson, Larry Ludlum, Ron McAlpine who have paved the road way before us