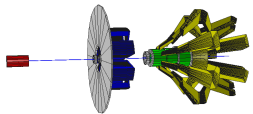# Shower Max Detector Plans for MOLLER

Dustin McNulty
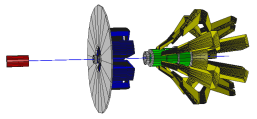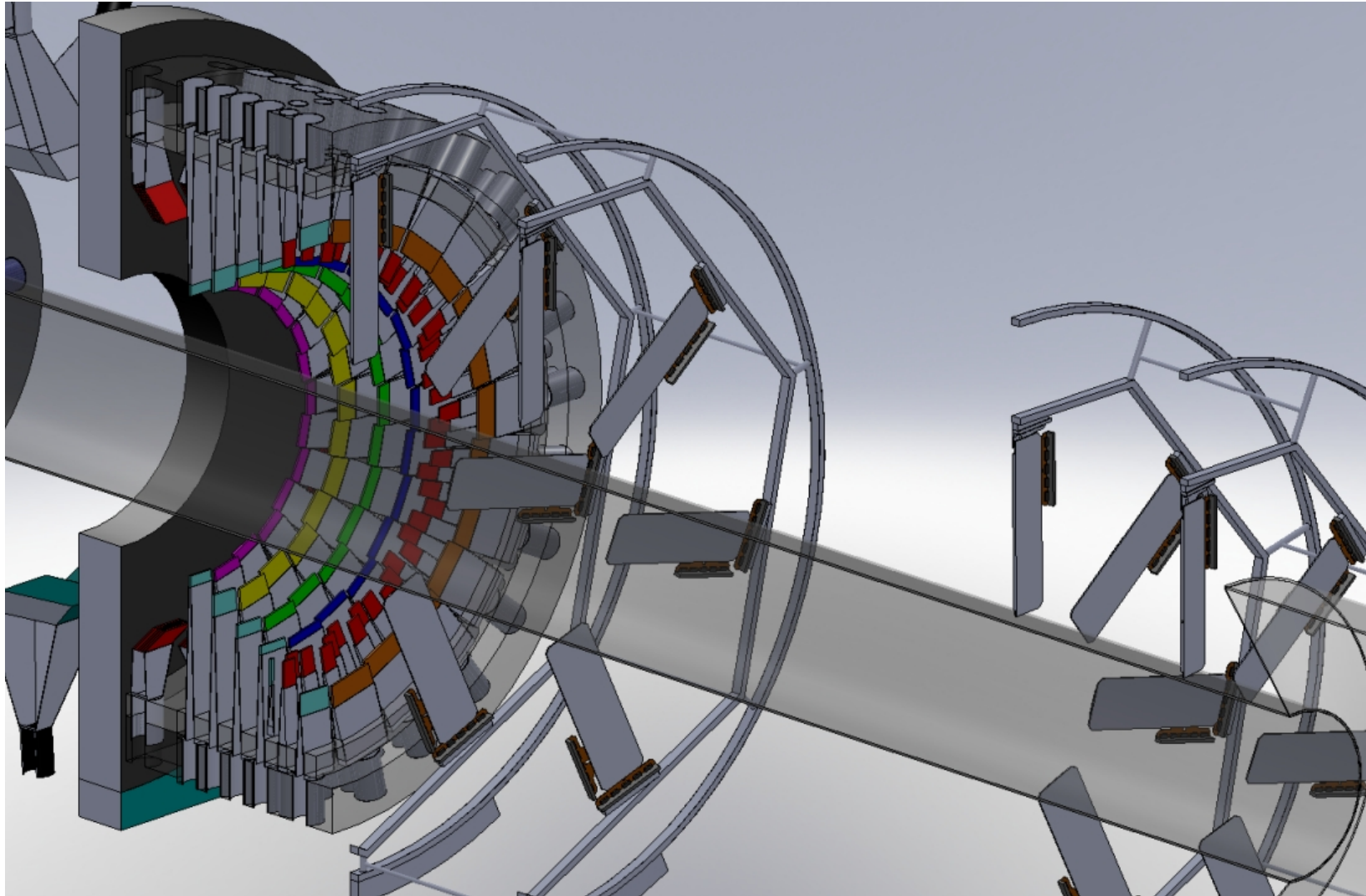Idaho State University
mcnulty@jlab.org
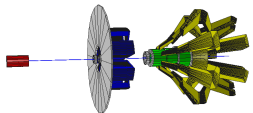
May 8, 2014

MOLLER Shower Max Detector

Outline

- Conceptual Design and Motivation

- Review 2008 prototype "stack"
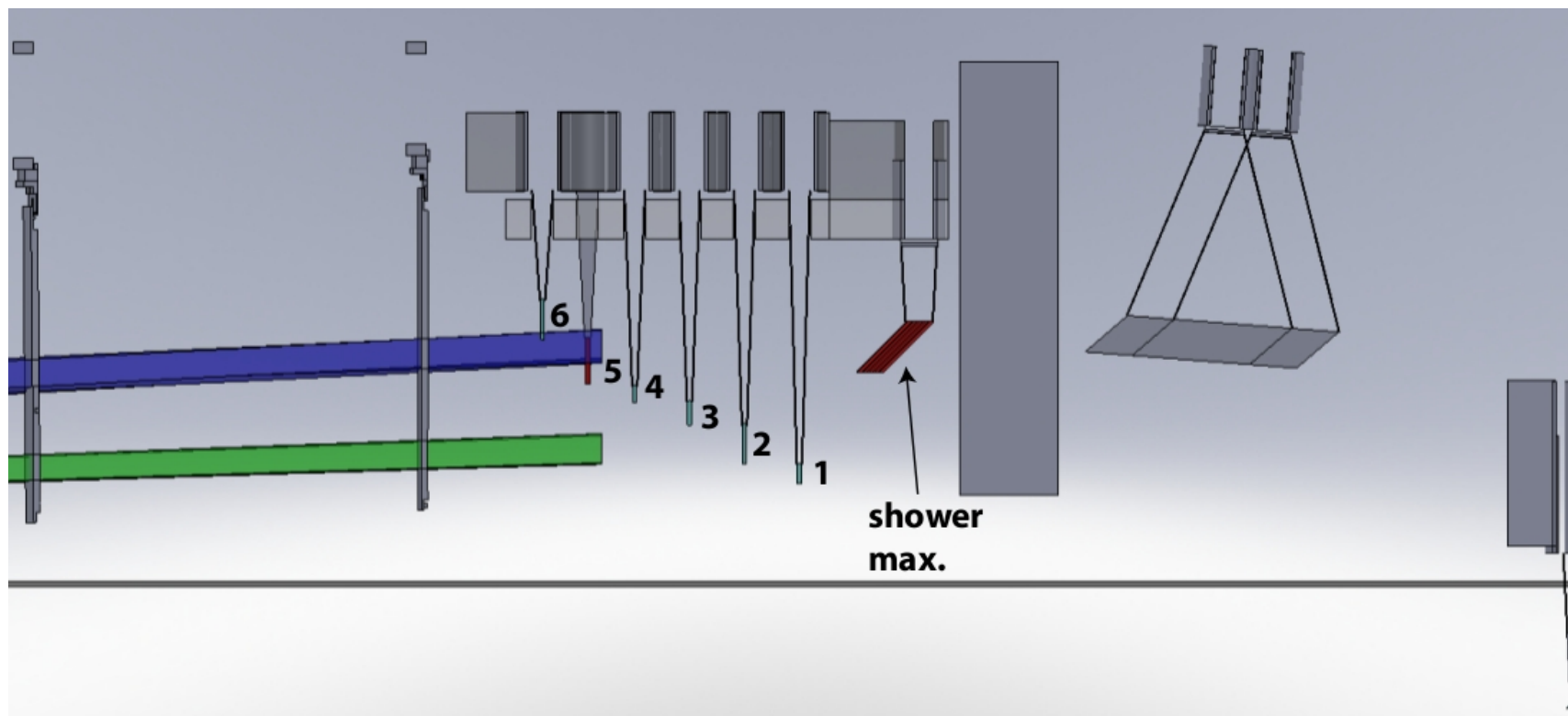   - Design
    - Monte Carlo
    - Beam tests and results

- Plans

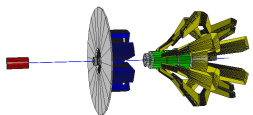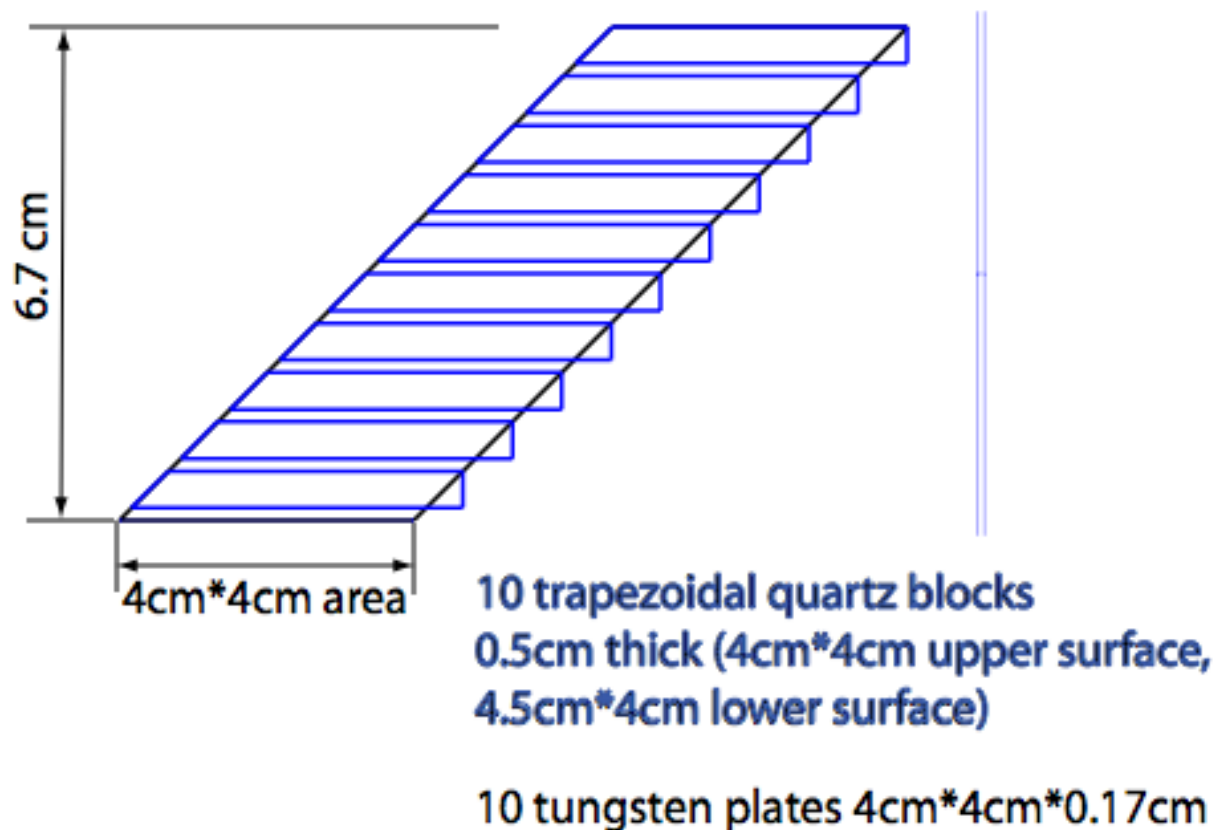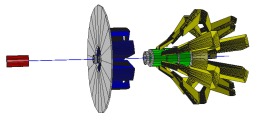# Detector Ring Design Concept

Motivation

- Provides additional measurement of e-e ring flux

- Weights flux by energy–less sensitive to low energy bkgds

2008 Shower Max

Detector concept

6.7 cm

4cm*4cm area

10 trapezoidal quartz blocks
0.5cm thick (4cm*4cm upper surface,
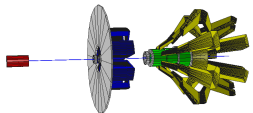**4.5cm*4cm lower surface)**

10 tungsten plates 4cm*4cm*0.17cm

Slide from Piotr

2008 Shower Max Detector Schematic
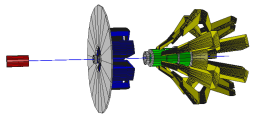
Alzak mirror tube

PMT

stack

Al mirror
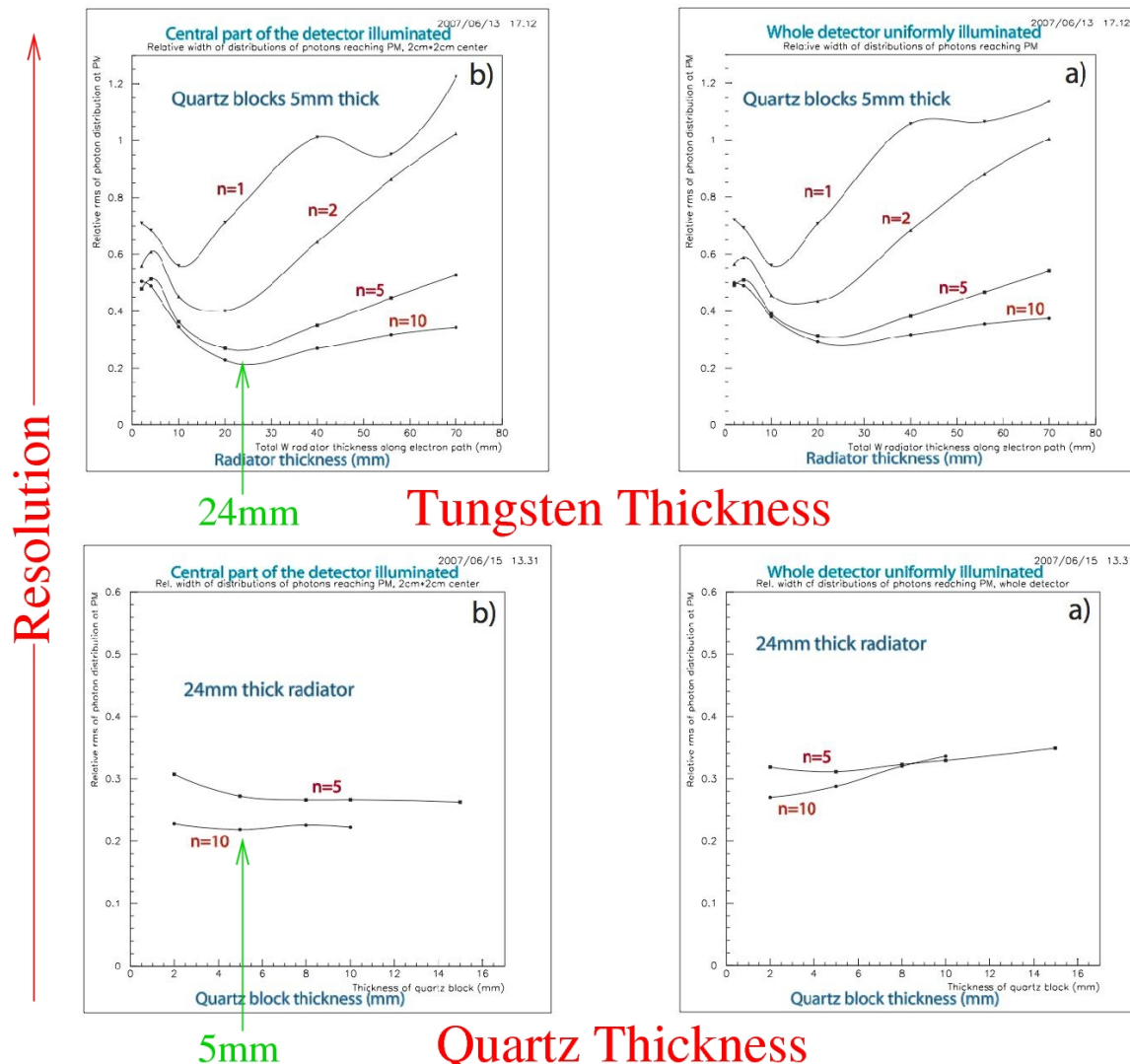
PVC
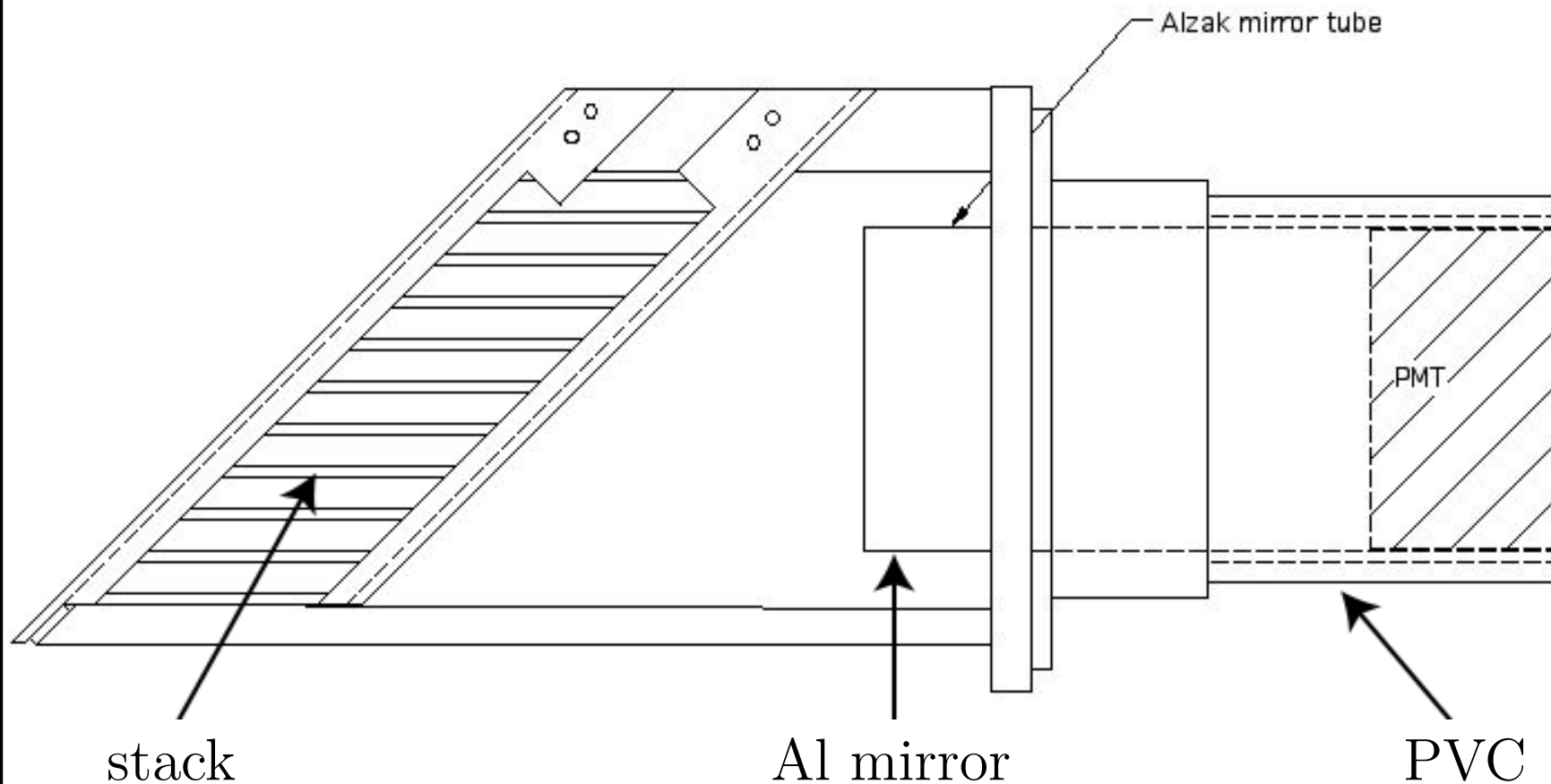
Schematic from Piotr
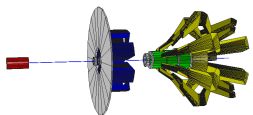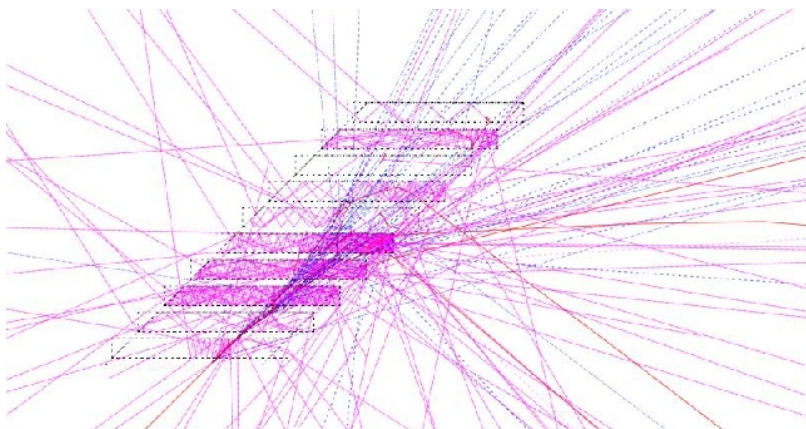
2008 Shower Max Detector Frame
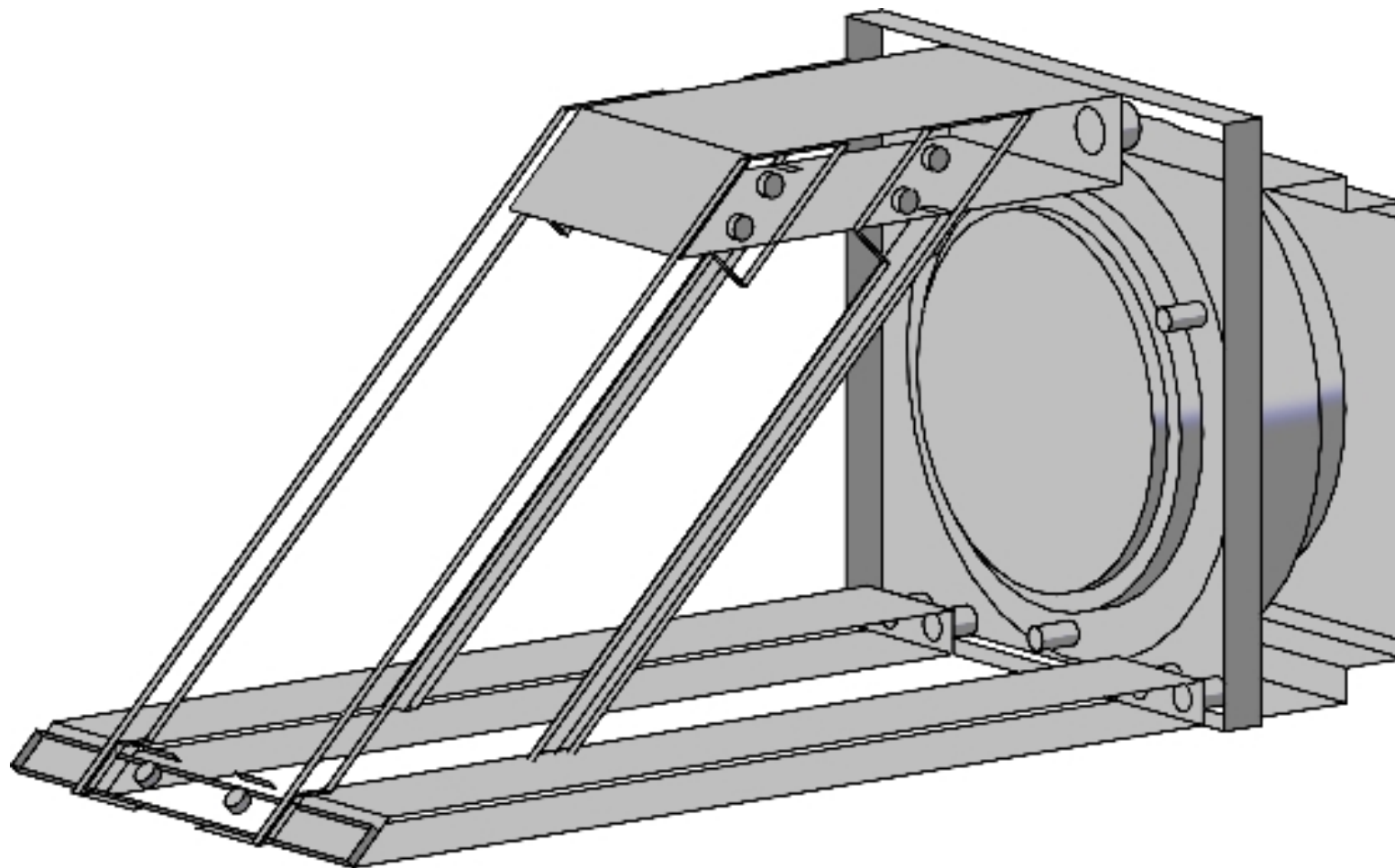
from Piotr

Piotr's MC: Tungsten and Quartz thickness study (for ~900MeV electrons)

Piotr's Simulations (Stray Electrons)

Number of Electrons
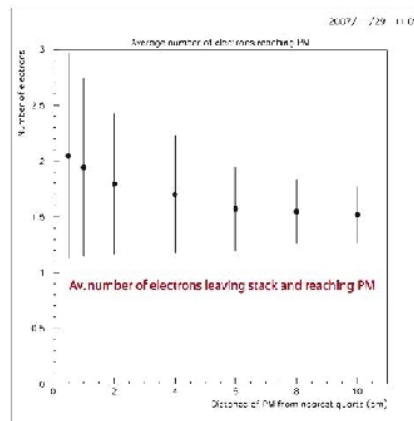
Number of Photons
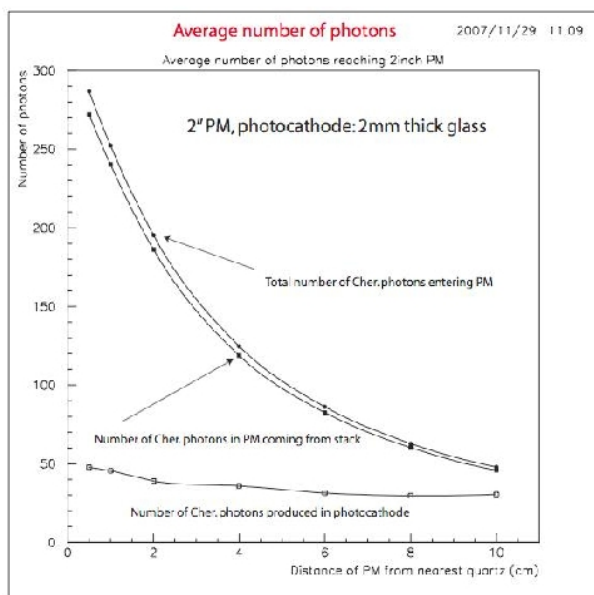
Resolution
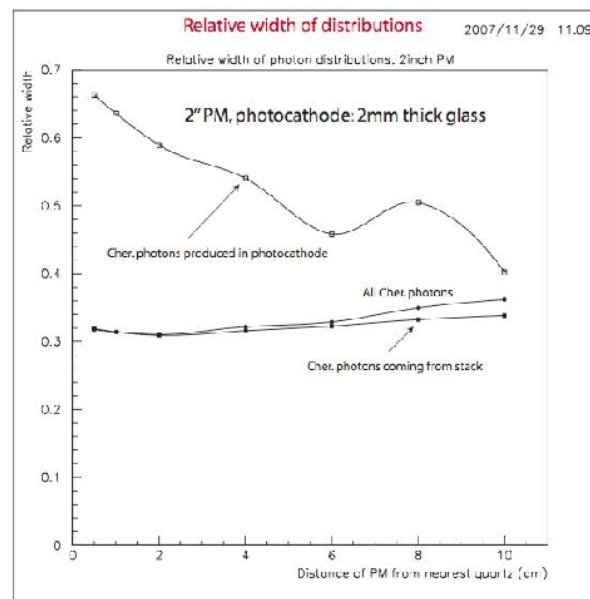
PMT distance from the nearest quartz

Jan2008 Testbeam Setup and Conditions

- Thin and Stack dets rigidly mounted along 45° angle; installed above rHRS focal plane (between VDC's and S1 scint. plane)

- $E_{beam} = 956$ MeV, 5 - 50μA, 100mg/cm^2 Ta target

- rHRS at 19°, using VDC's and s0 trigger (removable)

- Counting rates $\sim$10 Hz/μA
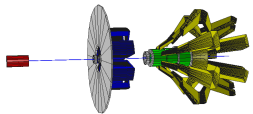
Jan2008 Testbeam Setup Alignment

PREx Detector Jan2008 Beamtest
Schematic Layout
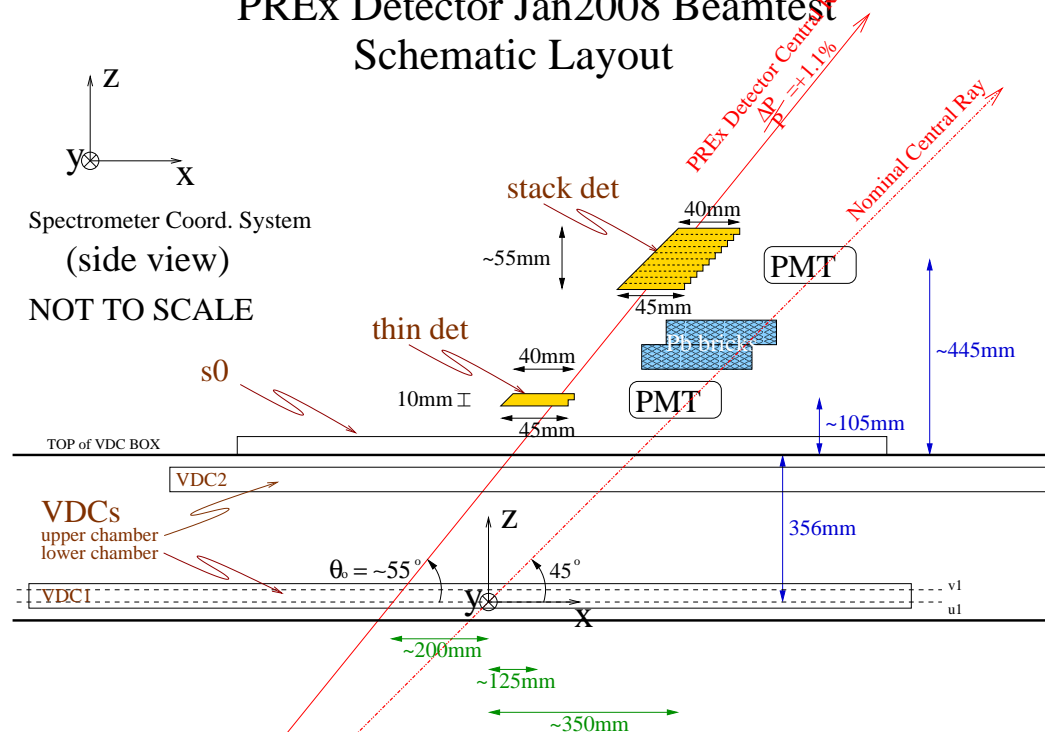
- Small detector footprint made FP alignment non-trivial
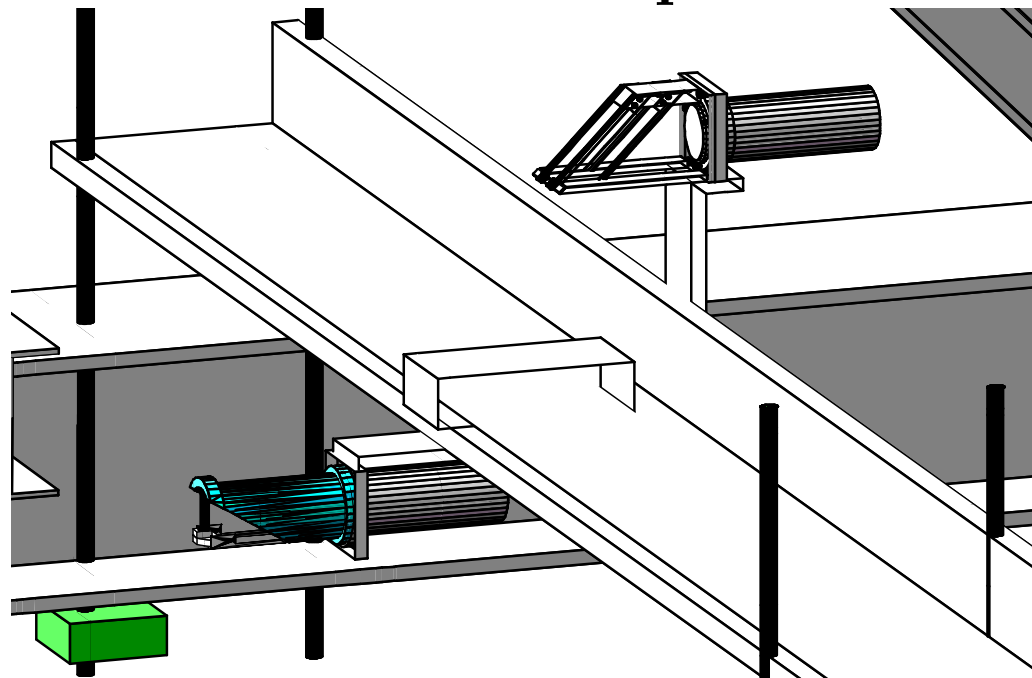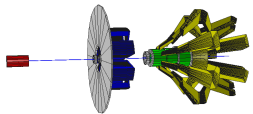
- Further complicated by space constraints from s1 scint. plane; creating the need for a $\Delta P/P$ shift of $+1.1\%$ from nominal

- This shifted central ray from 45° to 55°

- Q3 defocused (10% field increase) for further improvement

Jan2008 Testbeam Setup Alignment

X

y   z

Spectrometer Coord. System

(top view)

NOT TO SCALE

Nominal
Central Ray
φ = 0.0

PREx Detector Central Ray
φ = −0.5°

PMT

stack det

~90mm

thin det

40mm

X   45mm

y   z

s0

TOP of VDC BOX
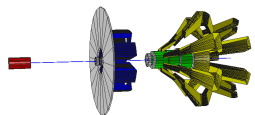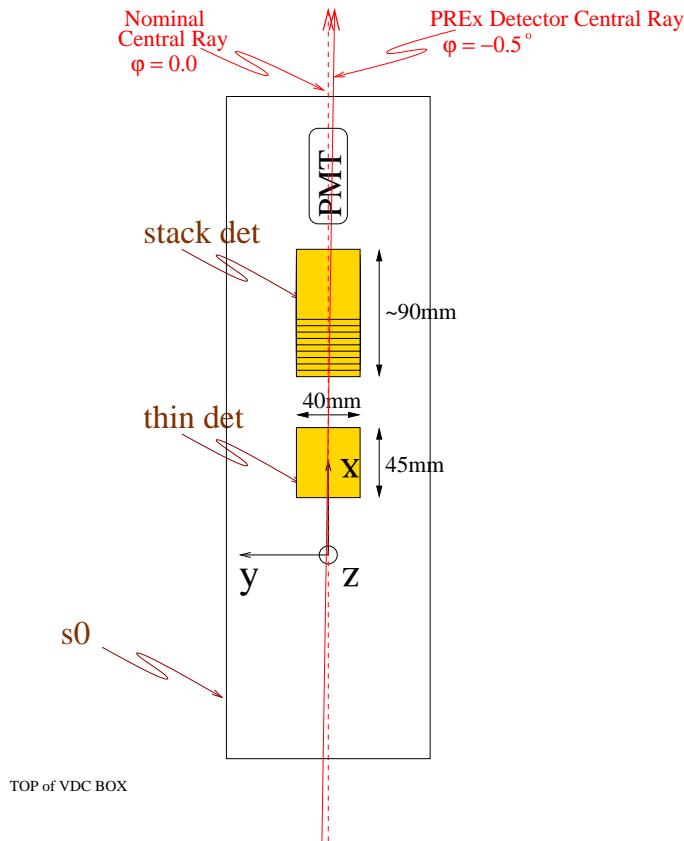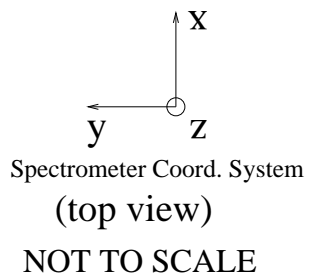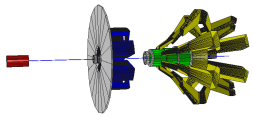
Jan2008 Testbeam Run conditions Sumary

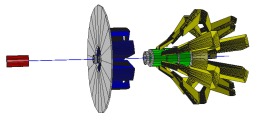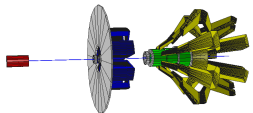| Run	Beam E (GeV)	rHRS angle	Targ	I_{beam} (μA)	Q3 Tweak	s0	Thin Det	ADC Change
3512[a]	2.77	19°	Pb	60	Before	IN	10mm	Before
3661[b]	0.956	19°	C	5	Before	IN	10mm	Before
3676	0.956	19°	Ta	50	Before	IN	10mm	Before
3681	0.956	19°	Ta	50	After	IN	10mm	After
3686	0.956	19°	Ta	50	After	IN	10mm	Before
3704	0.956	19°	Ta	8	After	OUT	10mm	After
3705	0.956	19°	Ta	8	After	OUT	5mm	After
3720	0.956	12.5°	Ta	5	After	OUT	5mm	After

[a] This run occurred during the Lead target stress-tests at 3-pass.

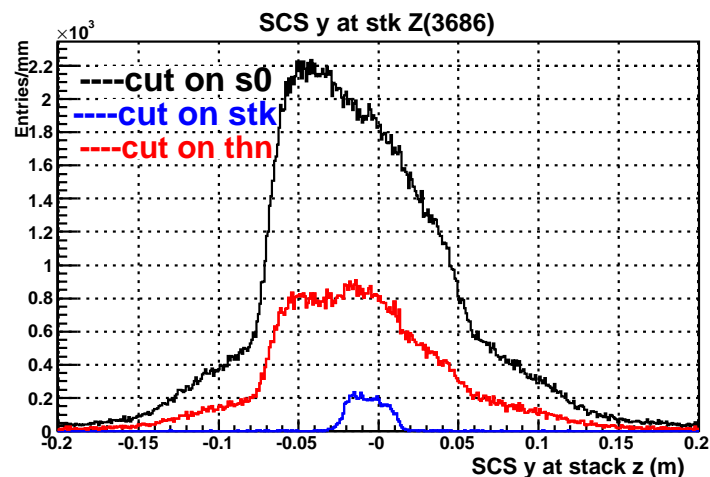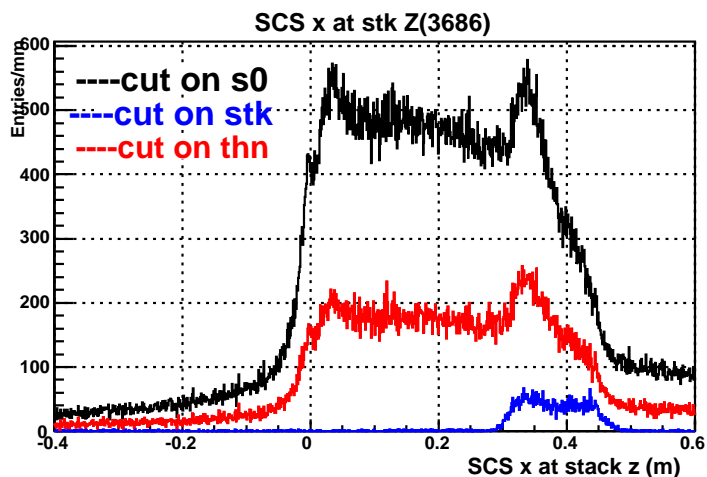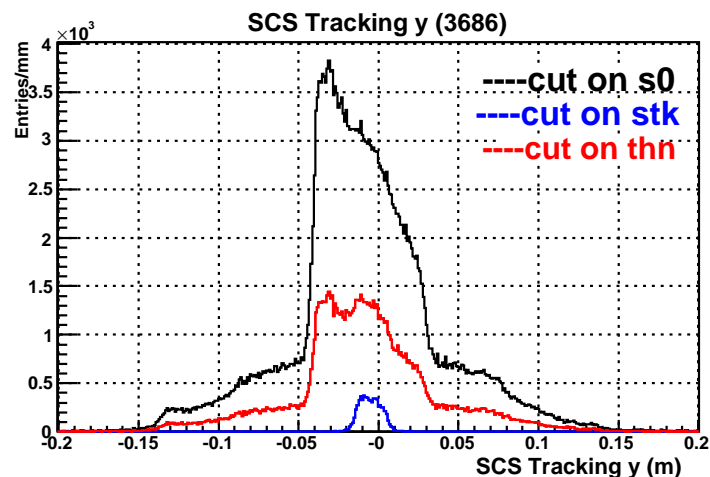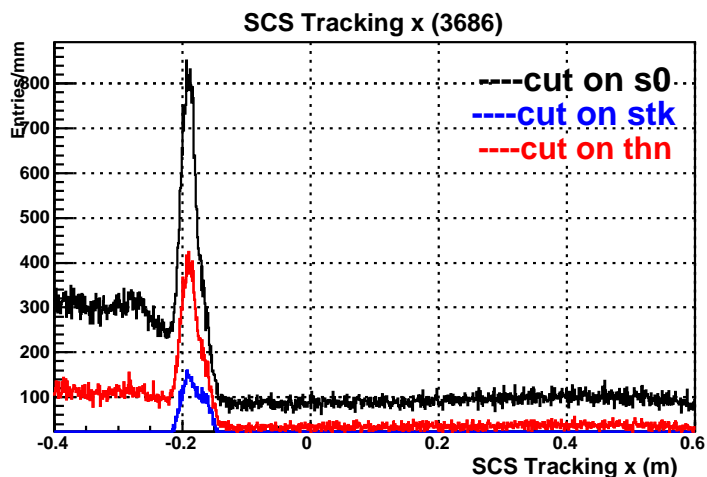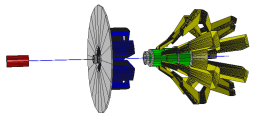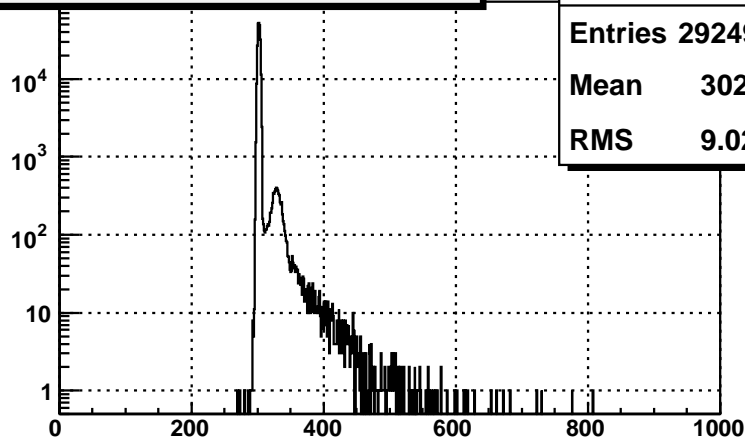[b] This run occurred before rHRS $\Delta P/P$ change to $= +1.1$ % (969 MeV).

Jan2008 Testbeam θ and ϕ Spectra
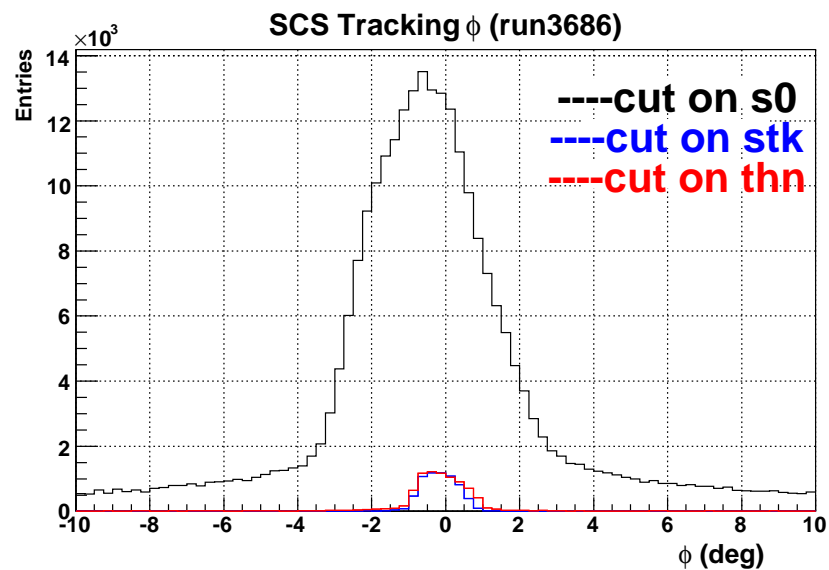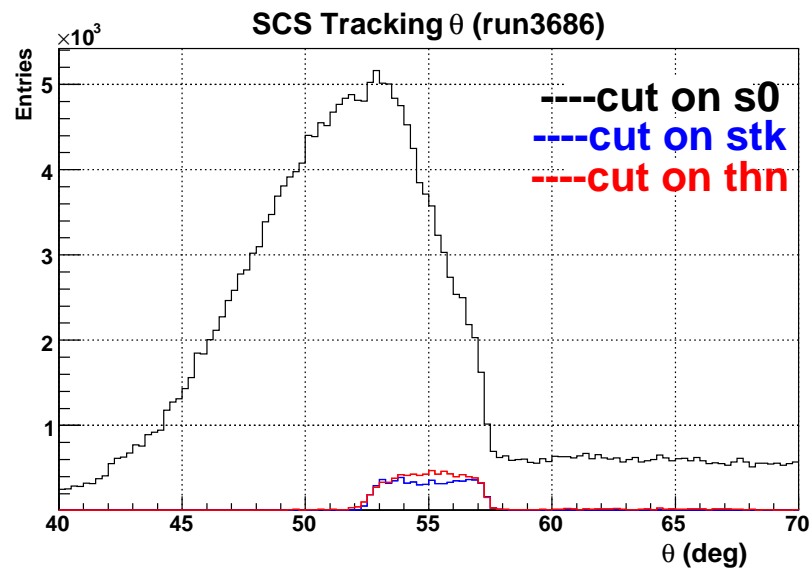
Jan2008 Testbeam x and y Spectra

Jan2008 Testbeam Pulse Height Dists

Thin Det (Raw, 3686, trig s0)
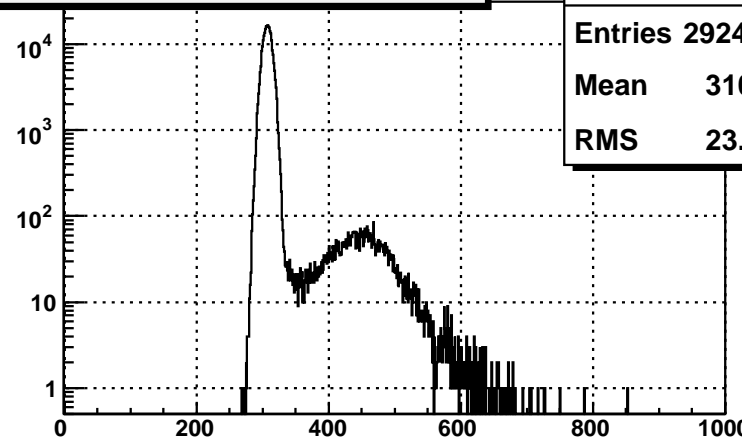
hthin_raw	
Entries	292492
Mean	302.8
RMS	9.023

Stack Det (Raw, 3686, trig s0)

hstk_raw	
Entries	292492
Mean	310.6
RMS	23.95

Thin Det (ped sub, 3686, trig s0)
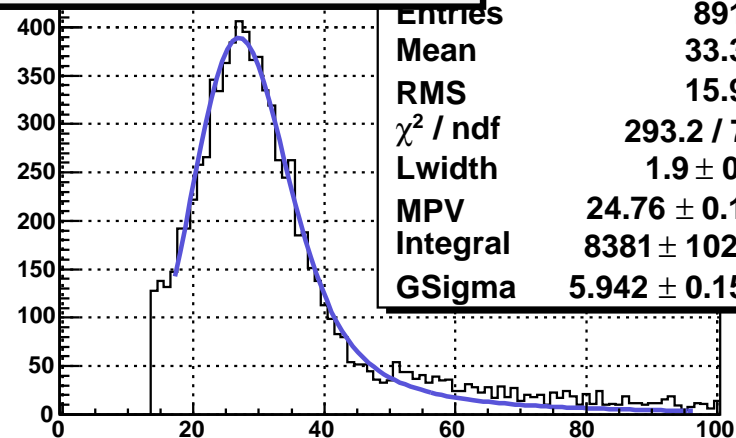
hthin	
Entries	8915
Mean	33.36
RMS	15.95
χ^2 / ndf	293.2 / 76
Lwidth	1.9 ± 0.0
MPV	24.76 ± 0.13
Integral	8381 ± 102.2
GSigma	5.942 ± 0.152

Stack Det (ped sub, 3686, trig s0)
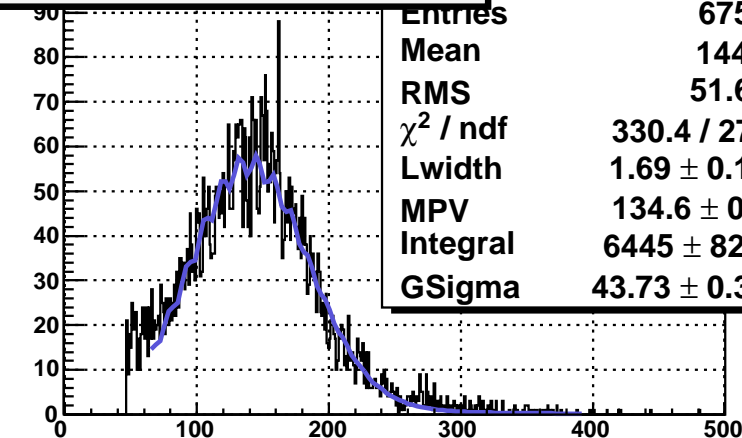
hstk	
Entries	6758
Mean	144.1
RMS	51.65
χ^2 / ndf	330.4 / 272
Lwidth	1.69 ± 0.13
MPV	134.6 ± 0.3
Integral	6445 ± 82.8
GSigma	43.73 ± 0.36

- Stack performance: $51.7/144 = 0.358$ (raw)

Jan2008 Testbeam Pulse Height Dists

Thin Det (Raw, 3676, trig stk)

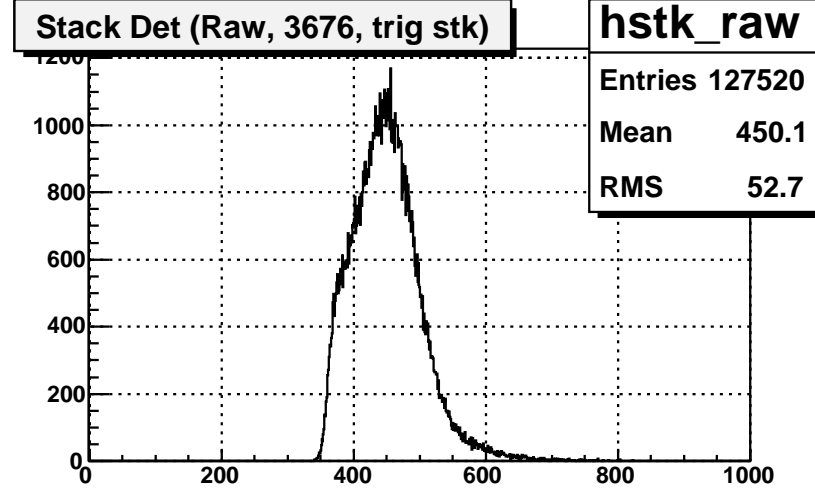| hthin_raw	
Entries	127520
Mean	319.6
RMS	16.51

Stack Det (Raw, 3676, trig stk)

hstk_raw	
Entries	127520
Mean	450.1
RMS	52.7

Thin Det (ped sub, 3676, trig stk)

hthin	
Entries	88614
Mean	26.58
RMS	11.28
χ^2 / ndf	142.2 / 66
Lwidth	1.114 ± 0.018
MPV	23.85 ± 0.04
Integral	$8.384\mathrm{e}{+04} \pm 301$
GSigma	5.908 ± 0.040

Stack Det (ped sub, 3676, trig stk)

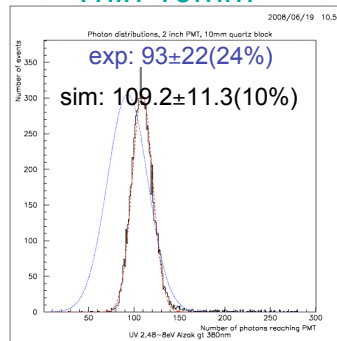| hstk	
Entries	127520
Mean	143.8
RMS	52.4
χ^2 / ndf	975.7 / 343
Lwidth	2.464 ± 0.055
MPV	131.3 ± 0.3
Integral	$1.271\mathrm{e}{+05} \pm 475$
GSigma	46.08 ± 0.23

January 2008 PREx detectors tests, comparison with simulations

Thin 5mm

exp: 50±17(34%)

sim: 56.8±7.7(14%)

Thin 10mm

exp: 93±22(24%)

sim: 109.2±11.3(10%)

Stack

exp: 434±152(35%)

sim: 538.3±140.5(26%)
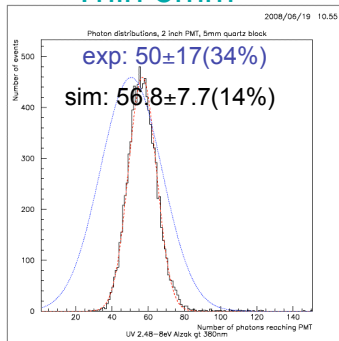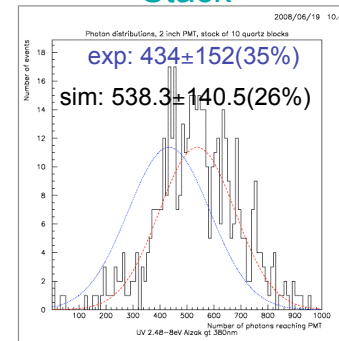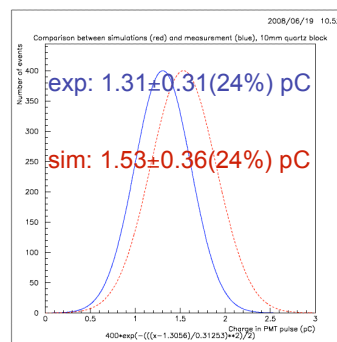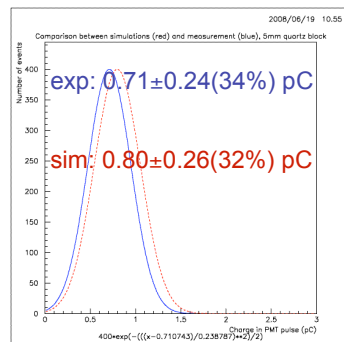
Number of Cherenkov photons reaching PM
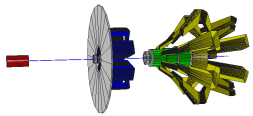
$N_{PE}=0.2N_{ph}$ (<QE>=0.2)

In panels below widths of gaussian fits to the simulated N_{ph} distributions (red lines) are corrected for the PMT resolution according to the formula (for the used PMTs measured value of the δq is 0.23):

$$\delta Q_e = \sqrt{(\delta N_{ph})^2 + \frac{1 - \overline{QE} + (\delta q)^2}{N_{PE}}}$$

exp: 0.71±0.24(34%) pC

sim: 0.80±0.26(32%) pC

exp: 1.31±0.31(24%) pC

sim: 1.53±0.36(24%) pC

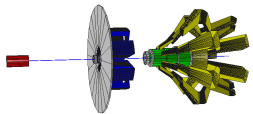exp: 7.74±2.71(35%) pC

sim: 9.61±2.68(28%) pC
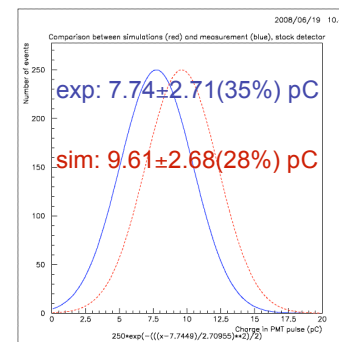
PM output charge (pC)

Slide from Piotr

2008 Testbeam Summary

- Results for stack detector were lack-luster: 35% relative width
    - Why?

    - Because energy too low?

    - Or some other reasons? ...det alignment, e^- trajectories,...

- Results do not agree with simulations...Why?

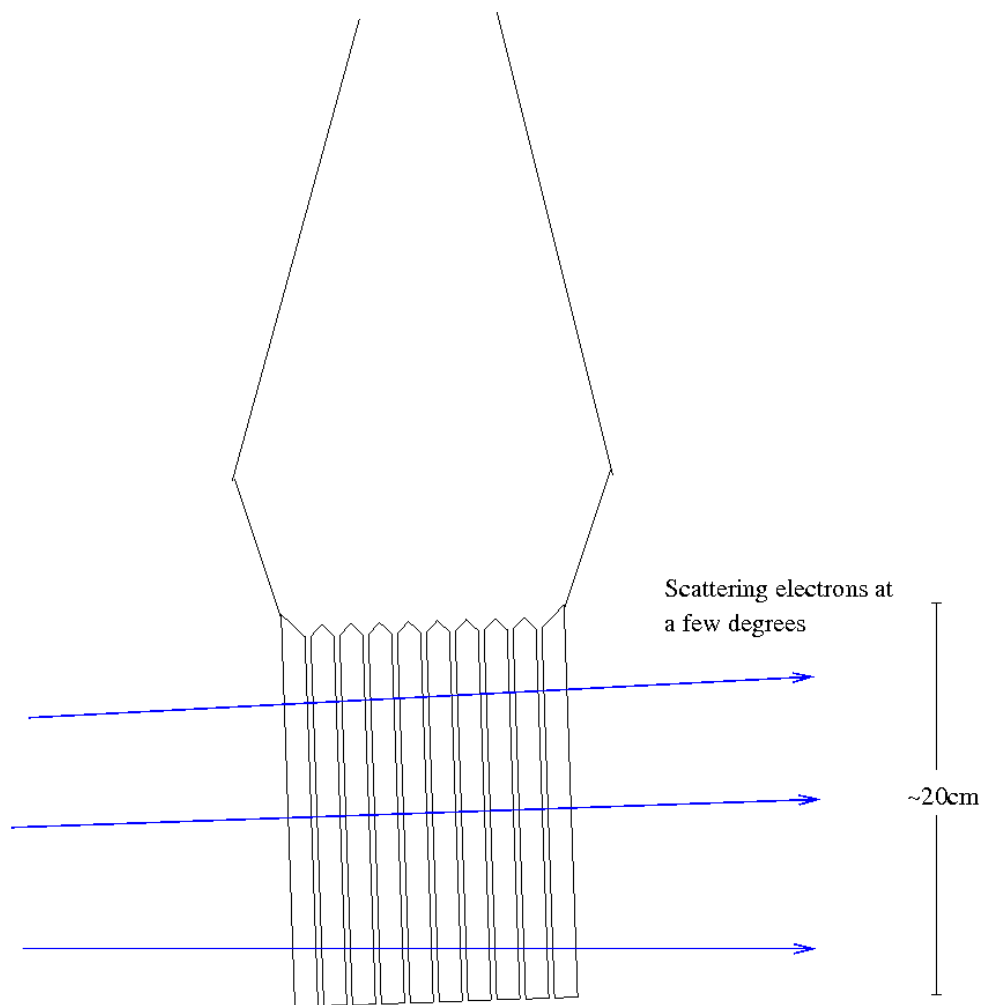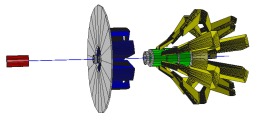- Would further analysis and/or simulation refinement help here?

Plans for MOLLER Shower Max

- Start with 2008 stack experience

    - Apply benchmarked "qsim" optical MC to the stack
    - Try to reproduce Piotr's simulation results
    - Study dependence on numbers and thicknesses of W and Quartz, distance from pmt, and beam energy

- Modify stack/LG/pmt geomerty for MOLLER; repeat studies

- Other considerations/questions for MOLLER:

    - 90° LG versus 135° (or 45°) LG
    - Frame support struct: space constraints, ϕ segmentation, staggered to eliminate gaps or use trapezoidal quartz?
    - What is optimal design for 2 - 8 GeV electrons
    - Need to worry about sensitivity to pions
    - Stray electrons, spashback,...What else?
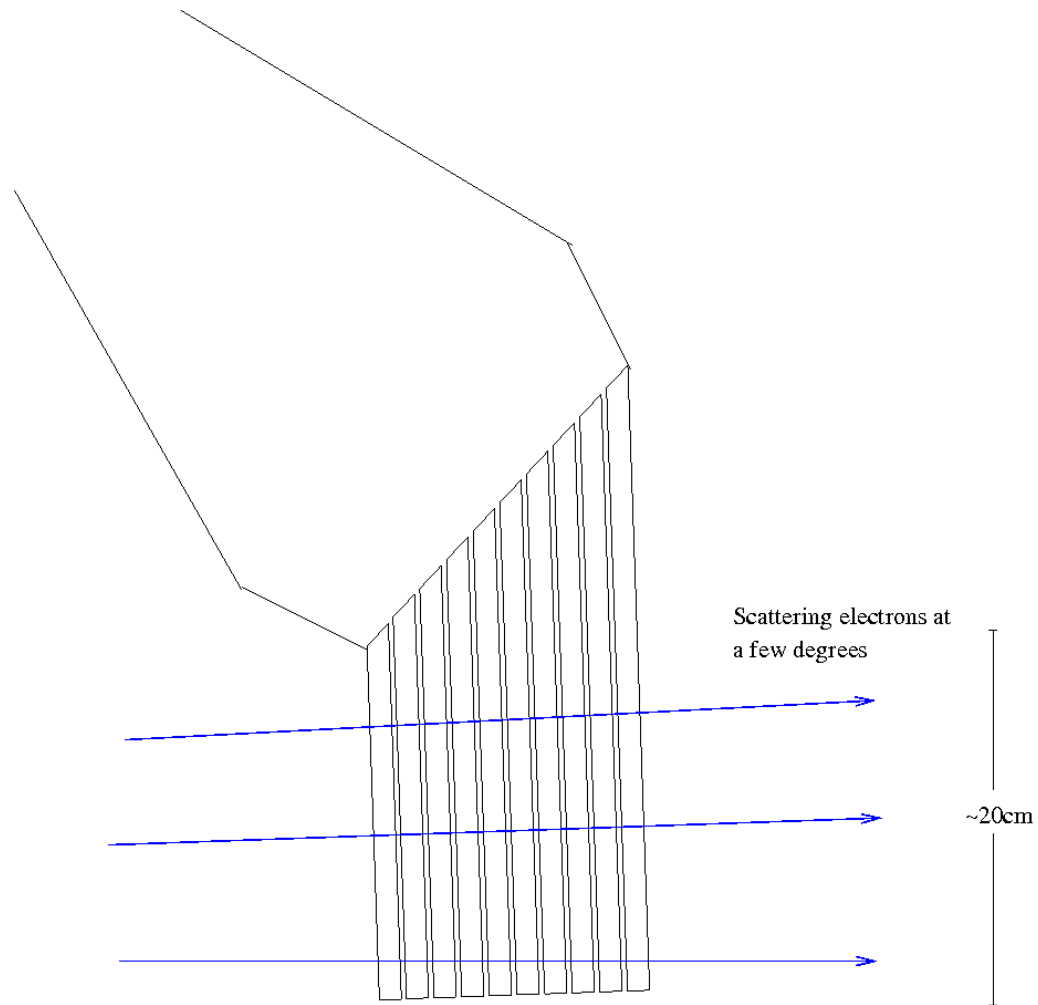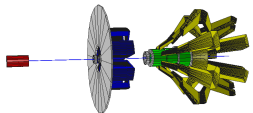
- Build protype and test with beam (at SLAC?)
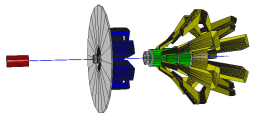
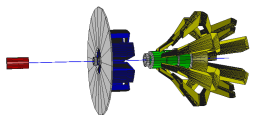# Crude Design based on Peiqing's work and PREx/Mainz testbeam experience

Scattering electrons at
a few degrees

~20cm

Another Crude Design...but has problems

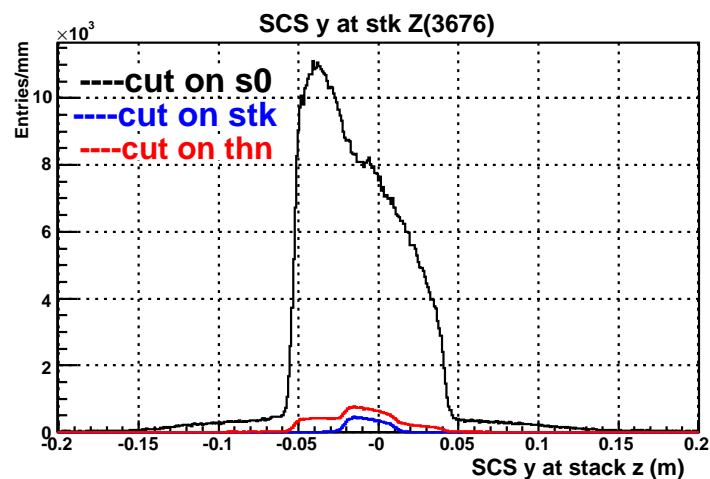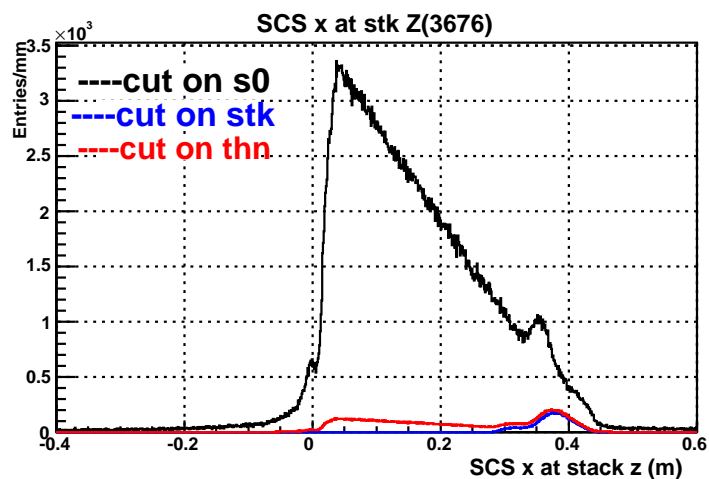Scattering electrons at
a few degrees

~20cm

Extra Slides

θ and ϕ Spectra (Before Q3 change)

SCS Tracking θ (run3676)

----cut on s0
----cut on stk
----cut on thn

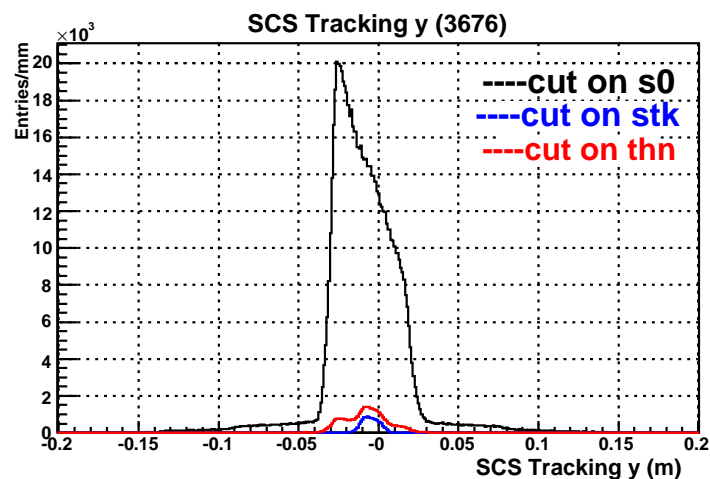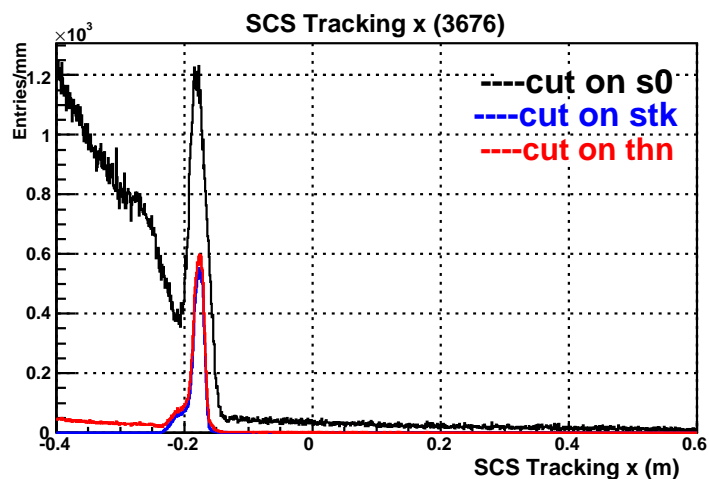θ (deg)

SCS Tracking ϕ (run3676)

----cut on s0
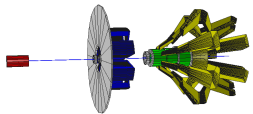----cut on stk
----cut on thn

ϕ (deg)
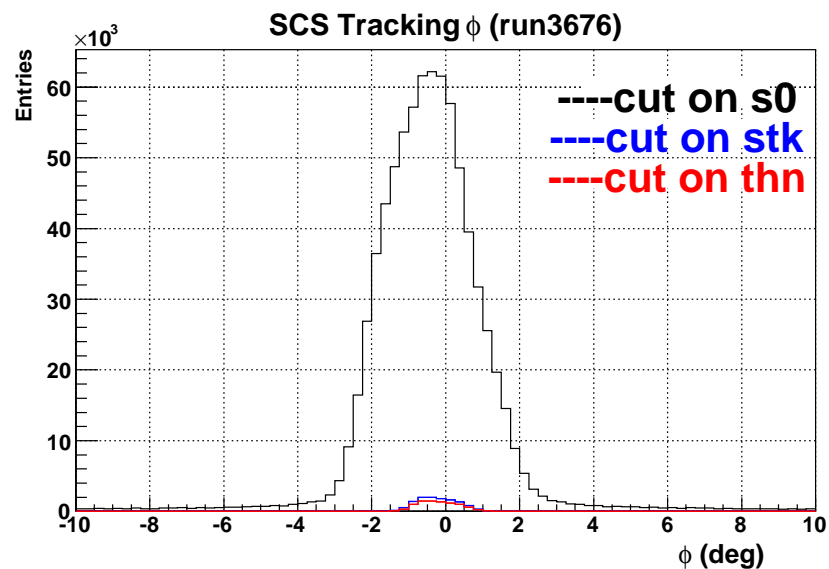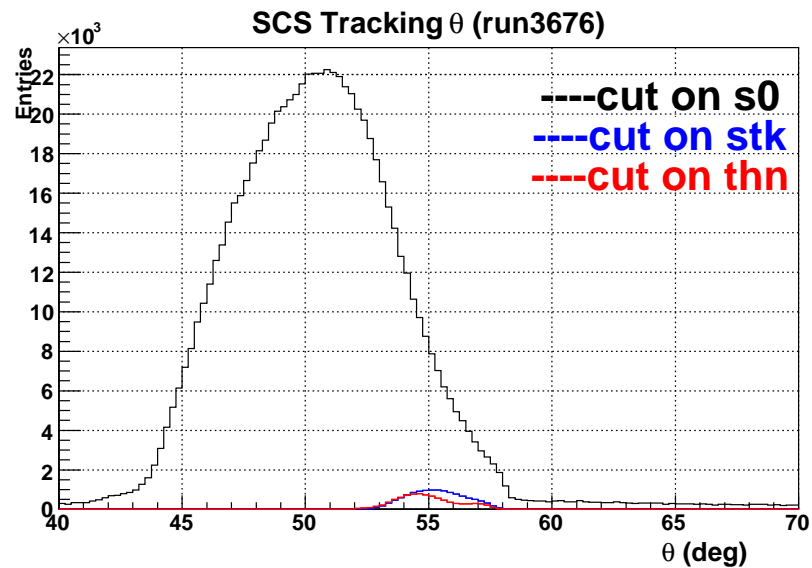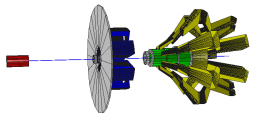
x and y Spectra (Before Q3 change)

Sim. and Exp. (ISU thin quartz cosmic tests)

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