Shower-max Design Status and Plans

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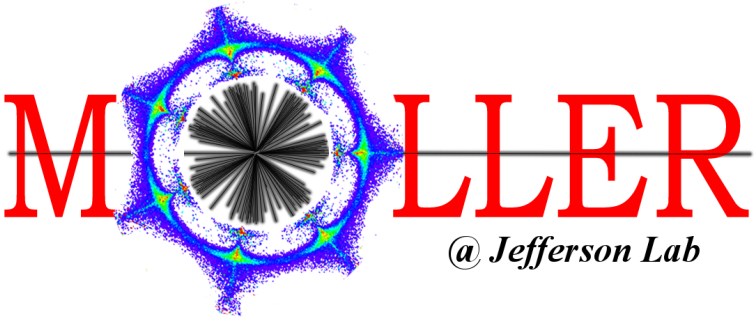
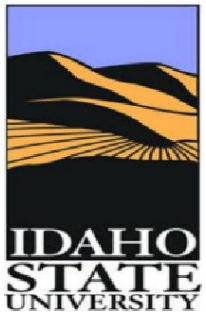
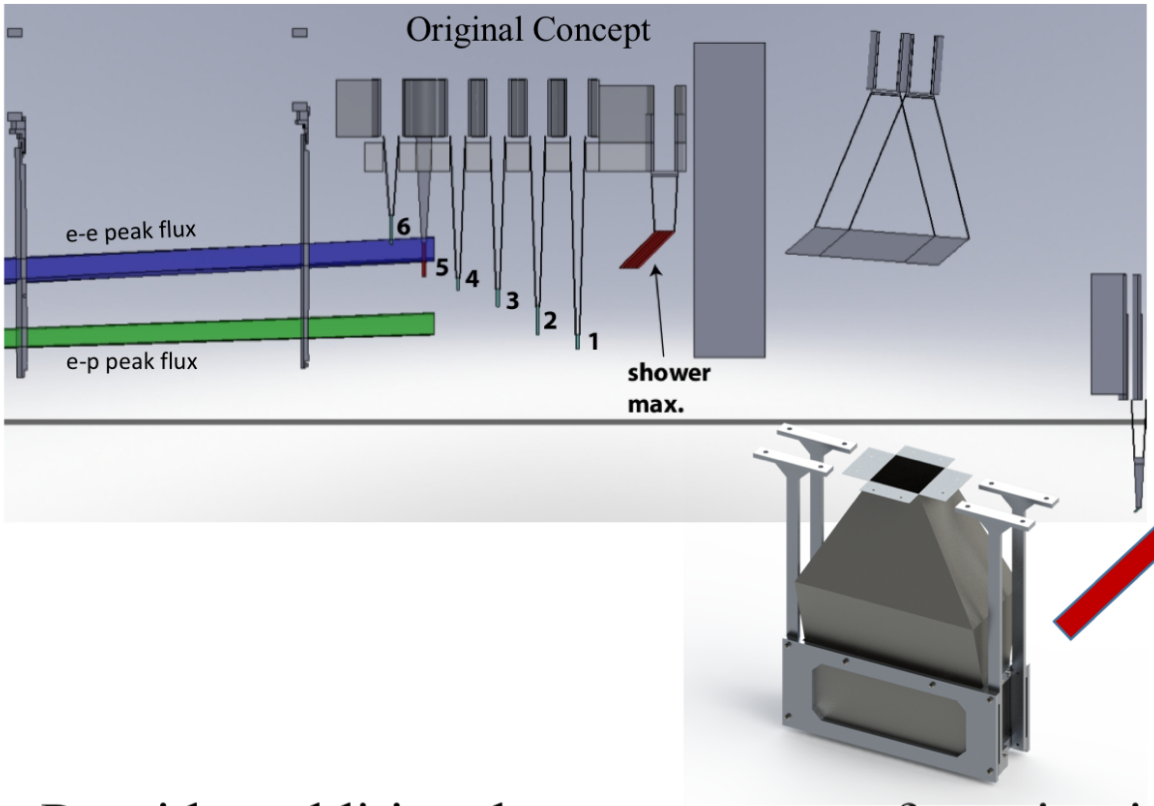
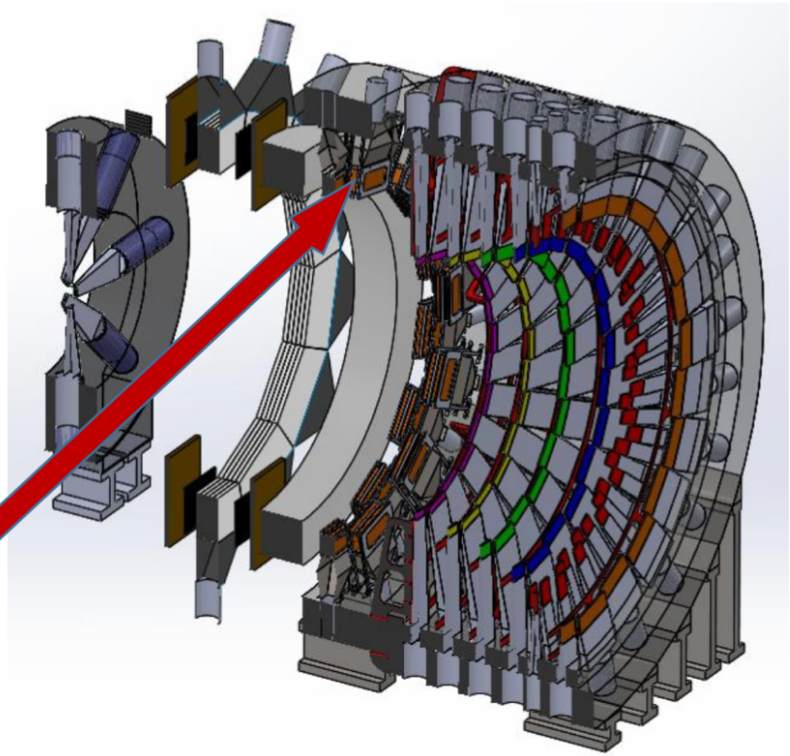




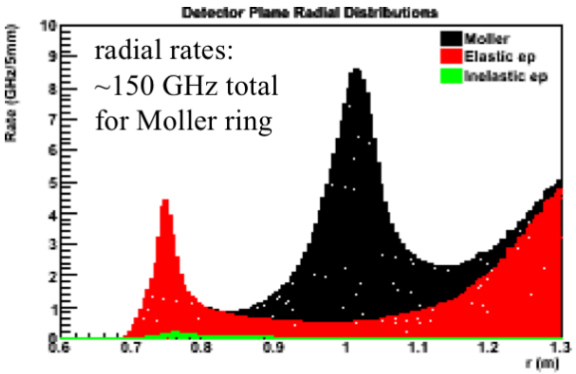
Motivation & Requirements

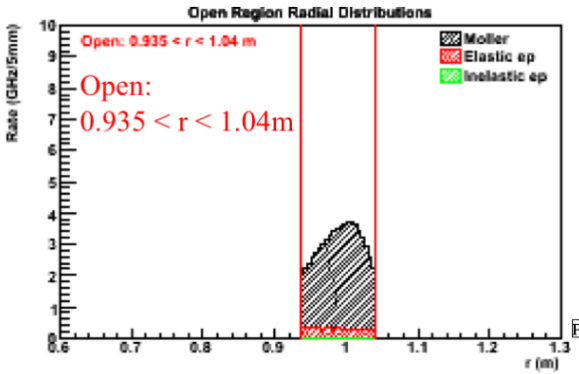


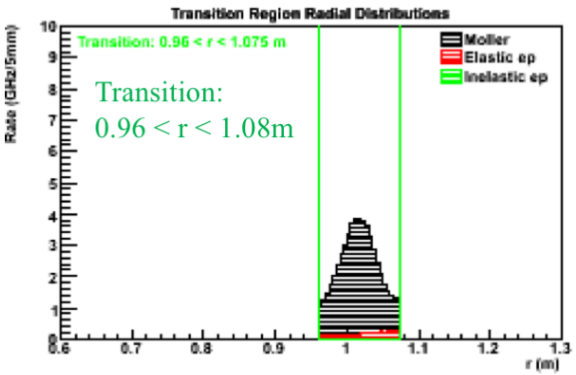


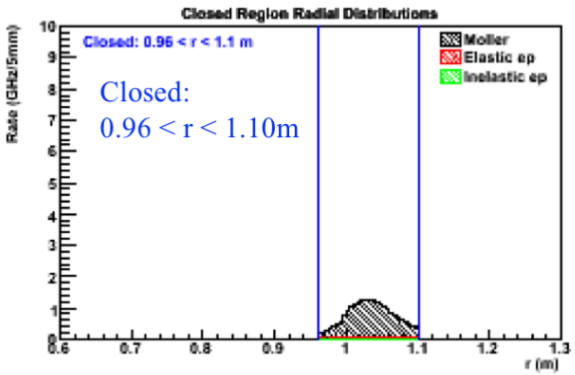
- Provides additional measurement of e-e ring integrated flux
- Weights flux by energy $\Longrightarrow$ less sensitive to low energy and hadronic backgrounds
- Will also operate in tracking mode to give additional handle on background (pion) identification – gives MIP signal
- Should have good resolution over full energy range ($\frac{\sigma}{\langle n \rangle} \lesssim 25\%$), long term stability and be radiation hard

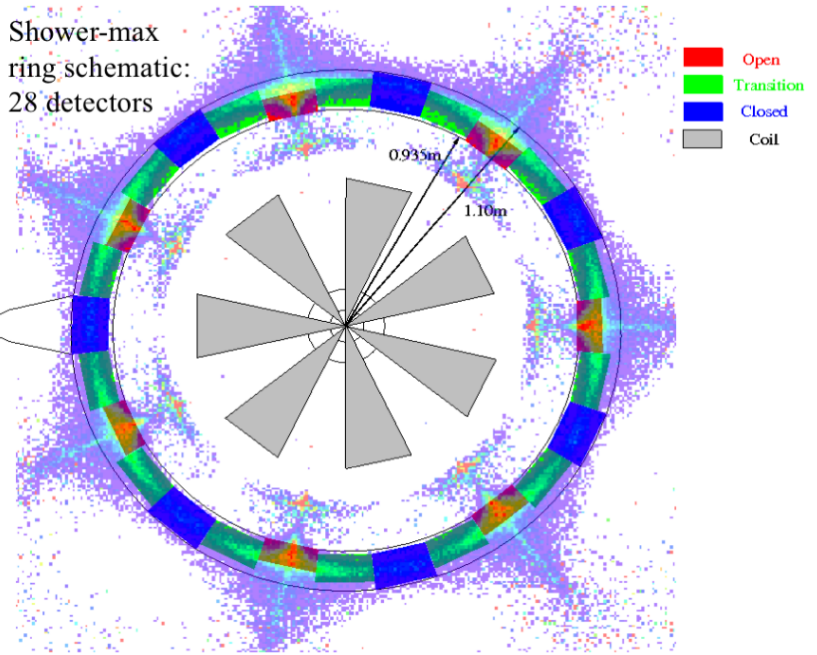
Shower-max phi-segmentation, rates and energies

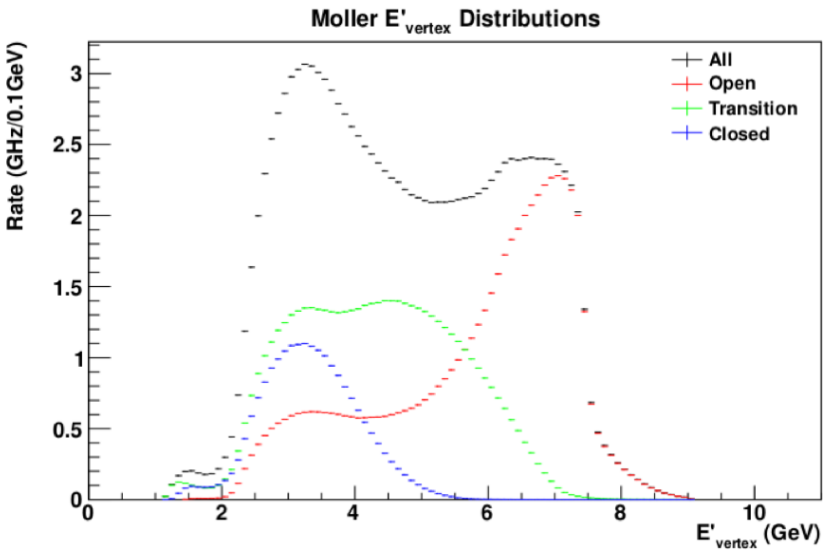








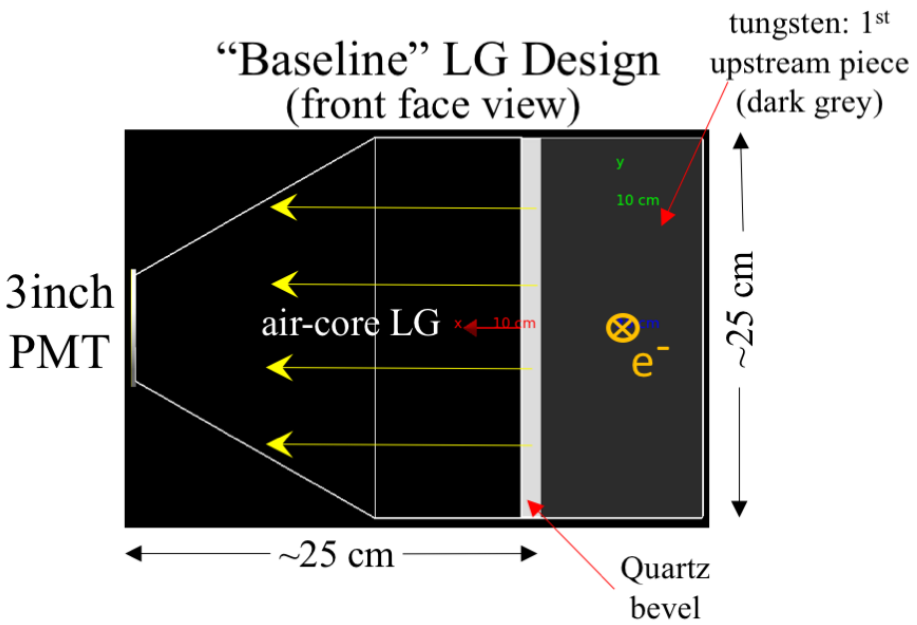


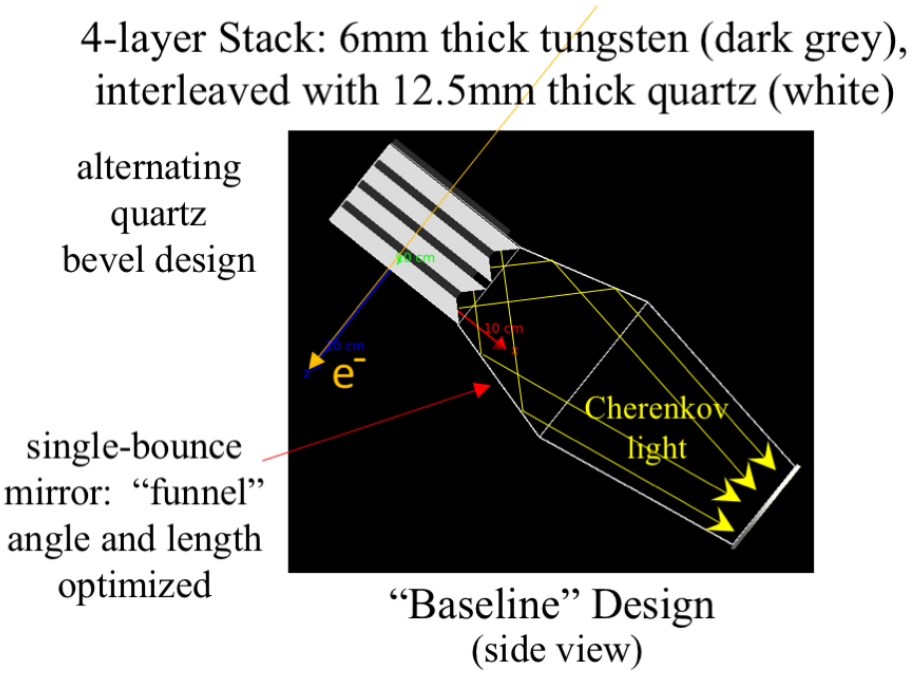


- Large range of rates and energies for different phi-region detectors:
  - Open ~9 GHz/det; 2 - 9 GeV, peak at 7 GeV…
  - Closed ~3.5 GHz/det; 2 - 5 GeV, peak at ~3 GeV
  - Transition ~4.5 GHz/det; 2 - 7 GeV, 3 – 5 GeV plateau

Baseline Shower-max Design: 4-layer Stack

- Detector concept uses a layered "stack" of tungsten and fused silica (quartz) to induce EM showering and produce Cherenkov light
- "Baseline" design developed using GEANT4 optical MC simulation:
  - Current design uses a 4-layer stack with 6mm tungsten and 12.5mm quartz pieces
  - Cherenkov light directed to 3inch PMT using air-core, aluminum light guide



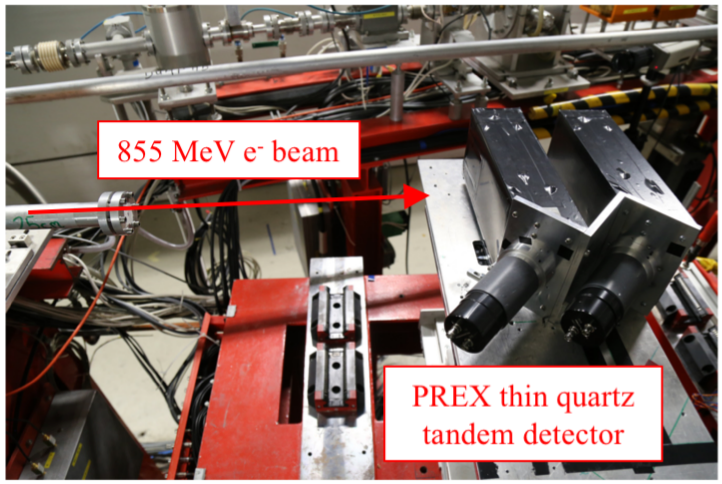


Materials (all rad-hard):

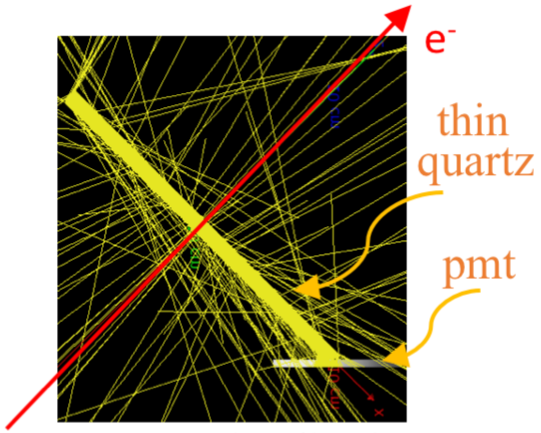
- Tungsten is high purity (99.95%) and quartz is optically polished Spectrosil 2000
- Light guides are aluminum specular reflectors (Miro-silver 27, Anolux, or al. mylar, …)
- Total radiation length: 6.8 X_0 tungsten + 0.4 X_0 quartz = 7.2 X_0

Monte Carlo tuning and Shower-max Simulations

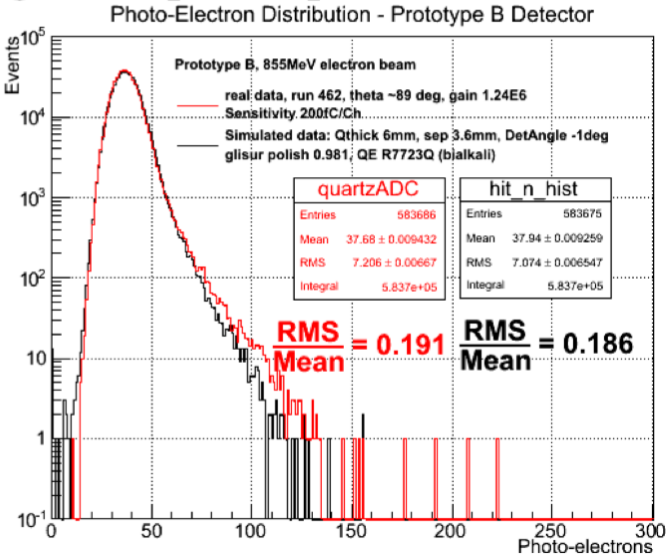
- Quartz optical G4 properties benchmarked at MAMI: Glisur ground polish parameter ~0.981



MAMI testbeam with PREX detector



G4 event visualization for PREX detector

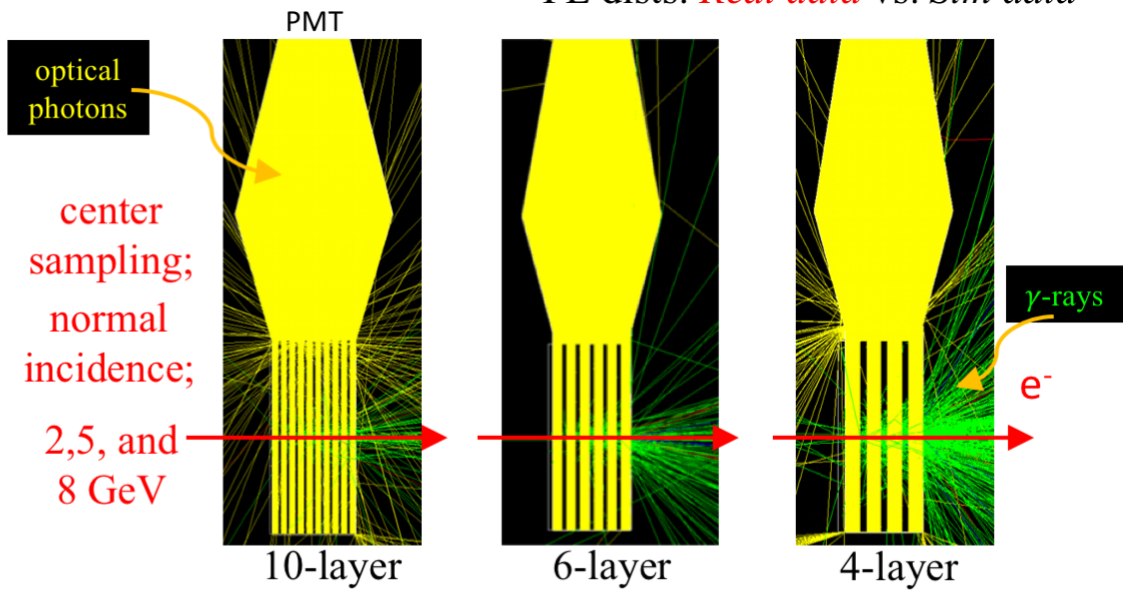


PE dists: *Real data* vs. *Sim data*

- Stack configuration MC study:
  - ❖ Stack thicknesses all same (7.2 X_0)
  - ❖ 2, 5, and 8 GeV incident electrons
  - ❖ PE dists generated using tuned polish parameter and 60% LG reflectivity

Conclusion:

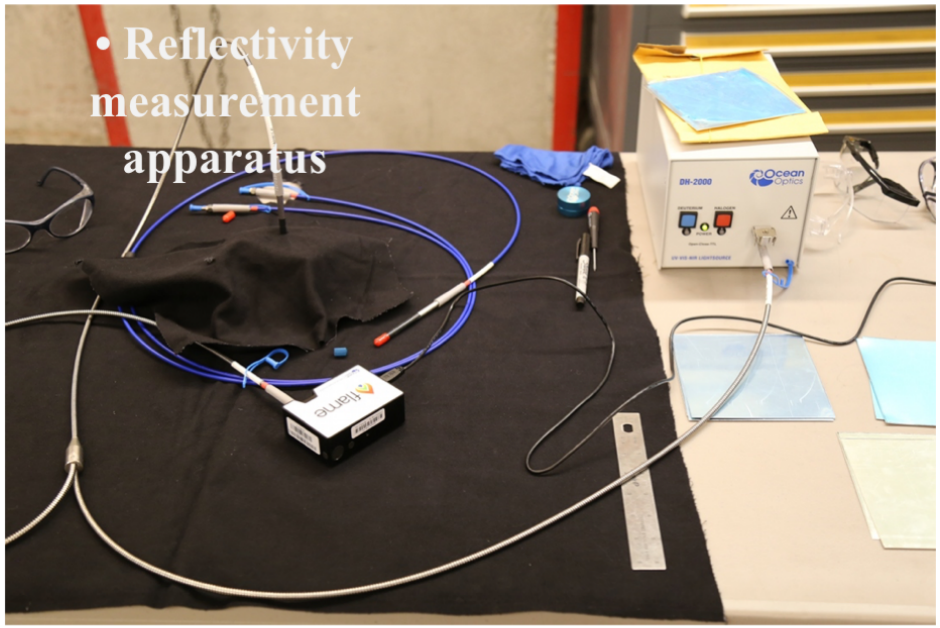
4-layer gives comparable performance to 10-layer (and is much cheaper to build)



Shower-max event visualizations

Light guide reflectivity measurements

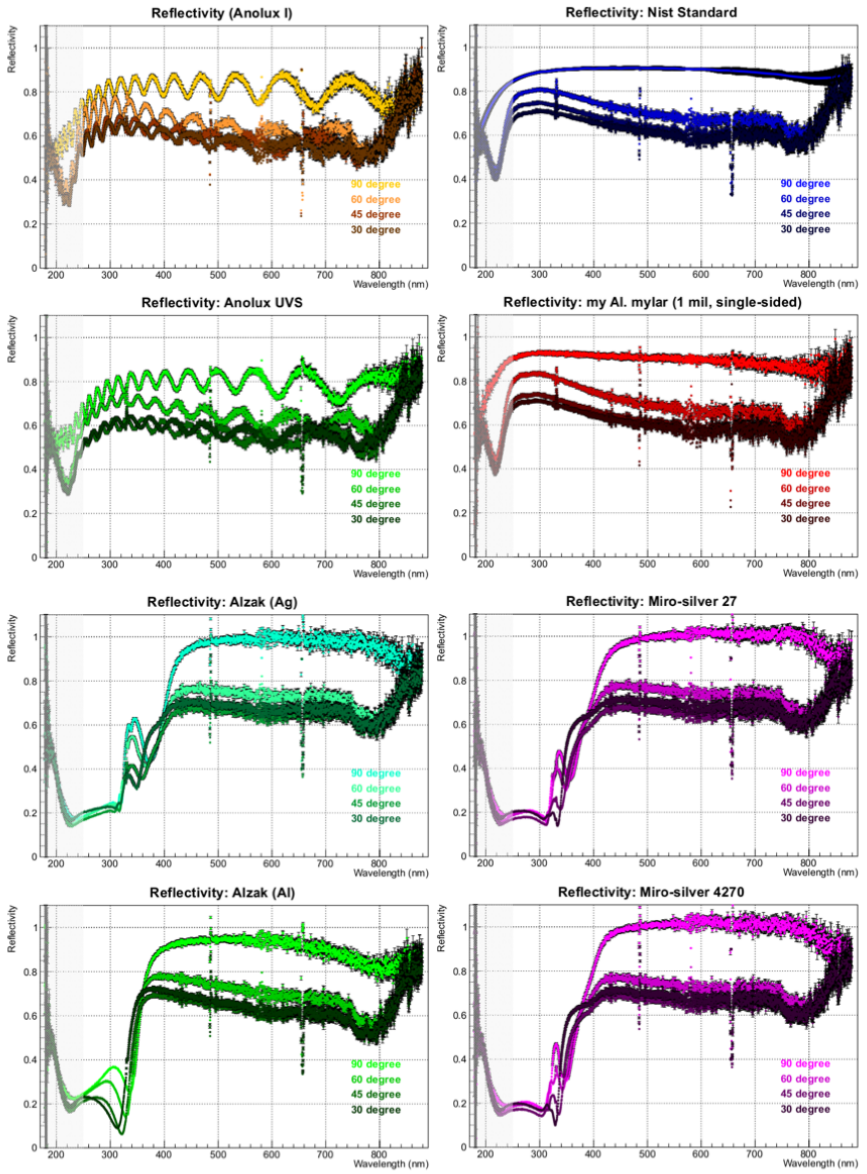
- Measuring light guide (LG) reflectivity as function of angle (10 – 90°) and λ (200 – 800nm); ongoing



- Light source: Ocean Optics DH2000: 200 - 800nm, 25W Deuterium bulb
- Spectrometer: Ocean Optics USB Flame, enhanced sensitivity, UV-VIS grating
- NIST specular calibration standard

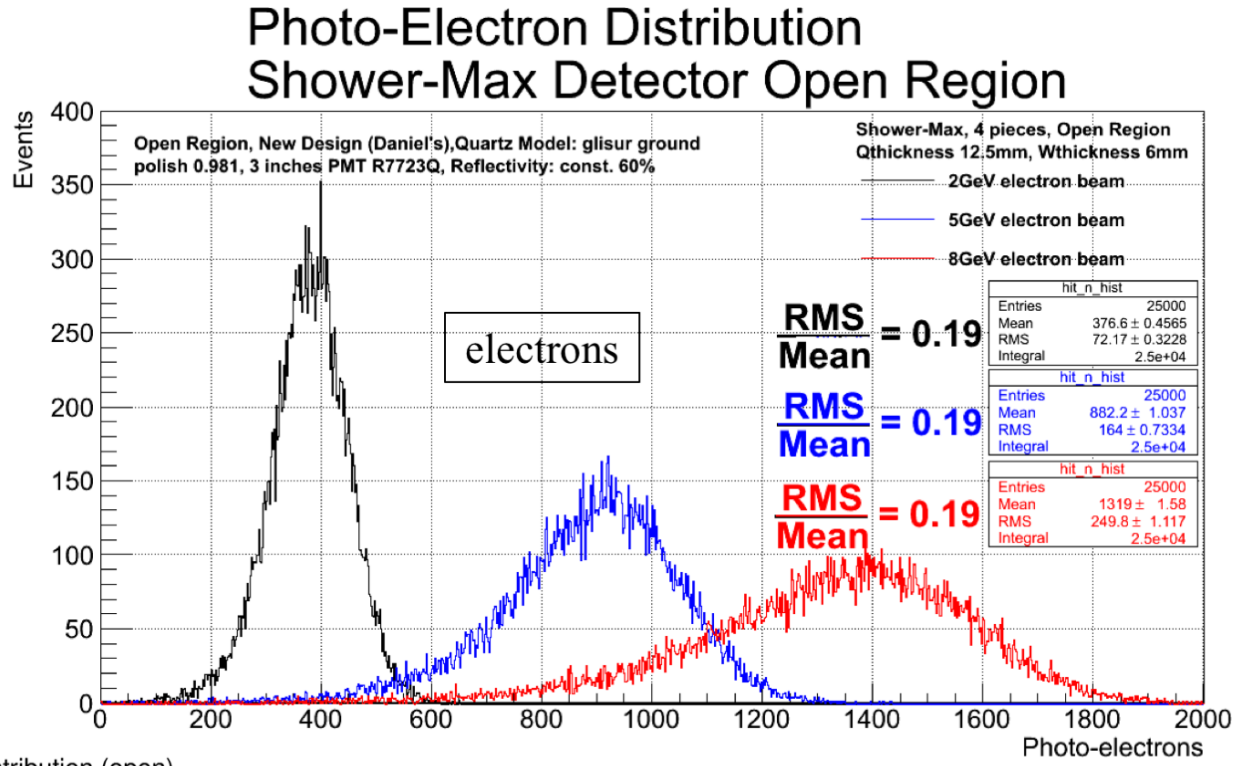
Light guide materials tested:

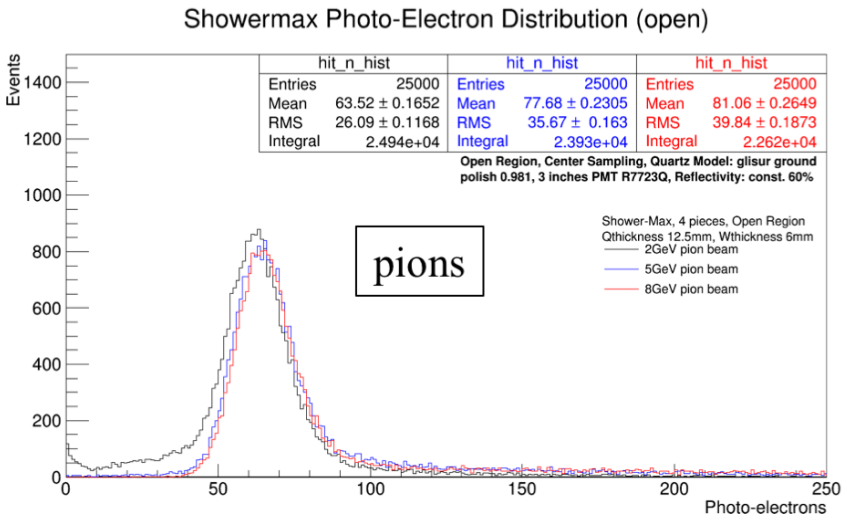
Miro-silver 4270	Miro-silver 27
Anolux I and UVS	Alzak-Al and Alzak-Ag
Miro 2000Ag (diffuse)	1 mil, single-sided aluminized mylar



Reflectivity vs. λ for various materials at diff. angles

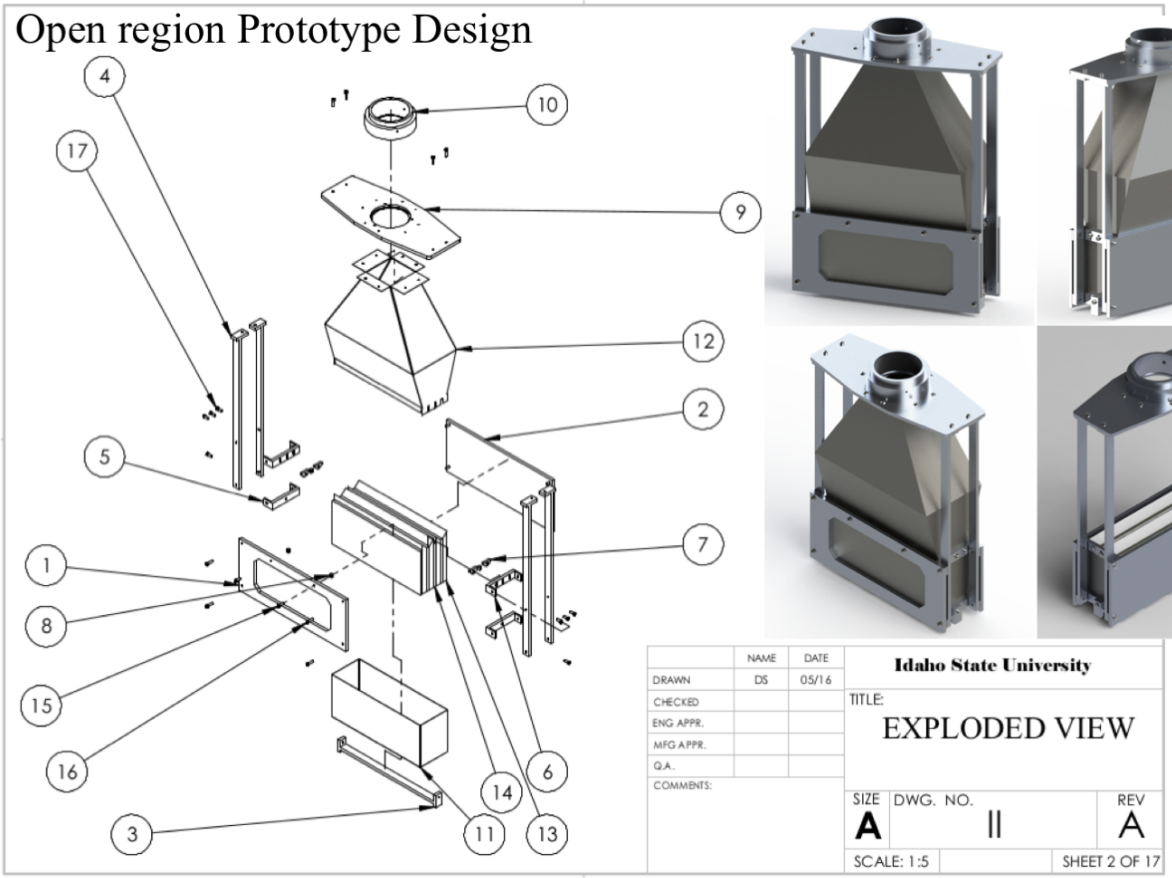
4-layer baseline PE Dists for 2, 5, and 8 GeV

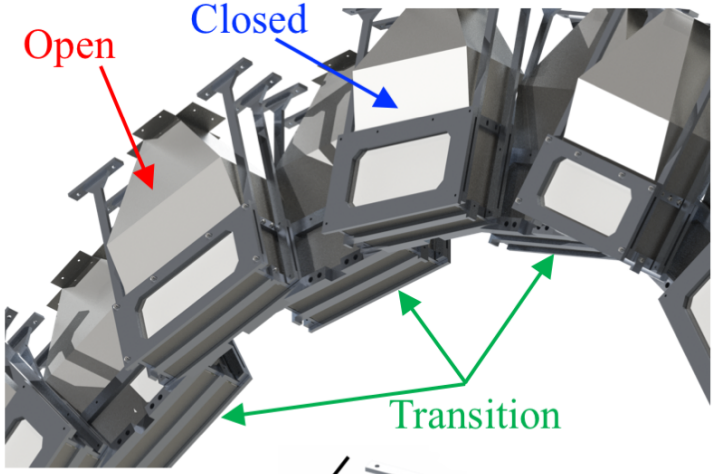


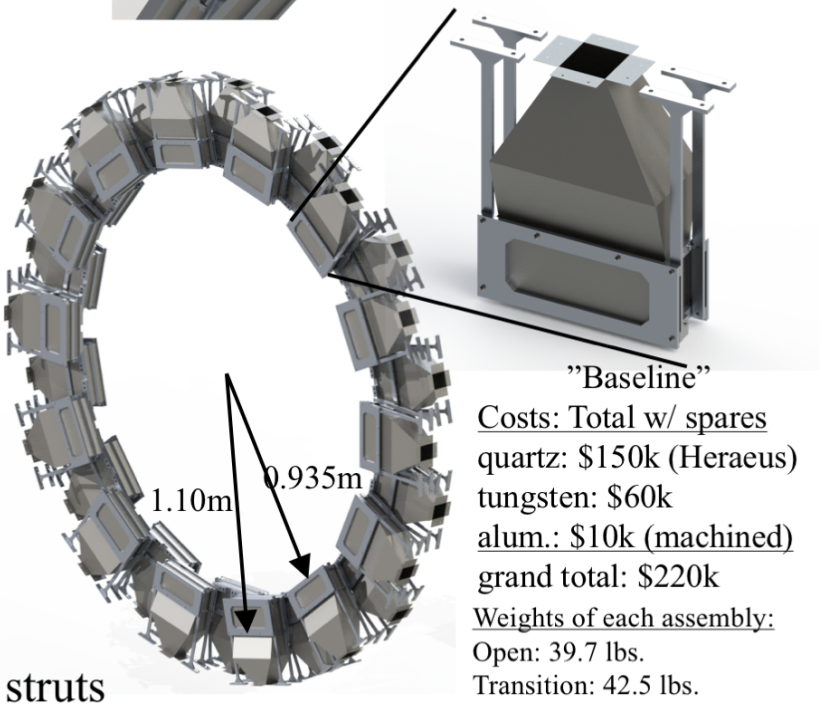


- Healthy ~65 peak-PE MIP signal for pion tagging during tracking mode operation

Prototype build/test plans and ring concept







- Engineered shop drawings and Prototype CADs in hand
- Will finalize prototype Stack designs this winter, construct in spring/summer and test using 8 GeV electron testbeam at SLAC
- Shower-max ring design concept: staggered in $\hat{z}$ with reinforced struts and brackets. 28 detectors in ring: 7 Open, 7 Closed, and 14 Transition

Costs: Total w/ spares
quartz: $150k (Heraeus)
tungsten: $60k
alum.: $10k (machined)
grand total: $220k

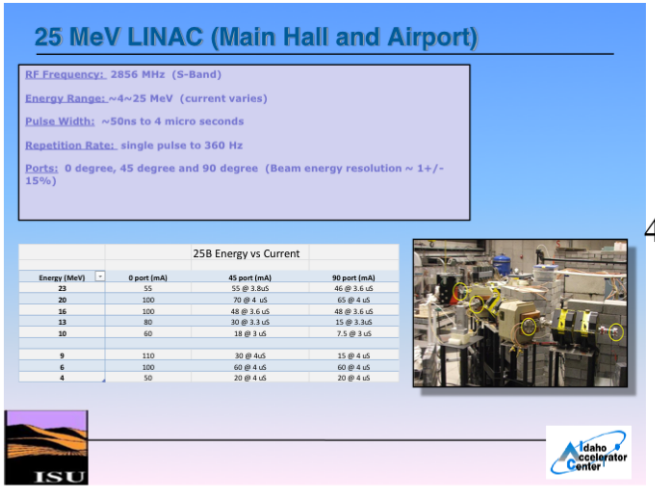
Weights of each assembly:
Open: 39.7 lbs.
Transition: 42.5 lbs.
Closed: 50.8 lbs.
ring weight: 1230 lbs.

Summary and future work

- MOLLER Shower-max baseline detector design developed
  - Meets requirement criteria: good res. and constructed with rad-hard materials to help ensure longterm stability
  - Continue design improvements; phi-dependent Stack configs
- G4 Monte Carlo work ongoing:
  - Continue to study/optimize Stack configurations
  - Study det. res. uniformity over entire face; edge effects
  - Incorporate LG reflectivity lookup tables; using 60%
  - Sample realistic e^- energy, position, and angle
  - Evaluate detector response to soft (photon) bkgds
- Plans and pre-R&D funds in place to build prototype and test at SLAC next year

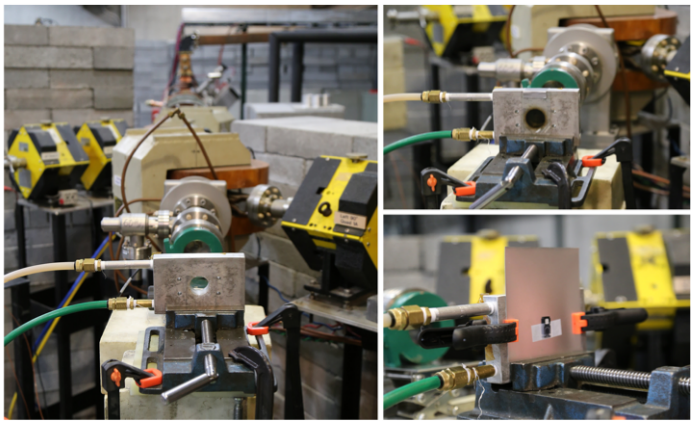
Backup Slides

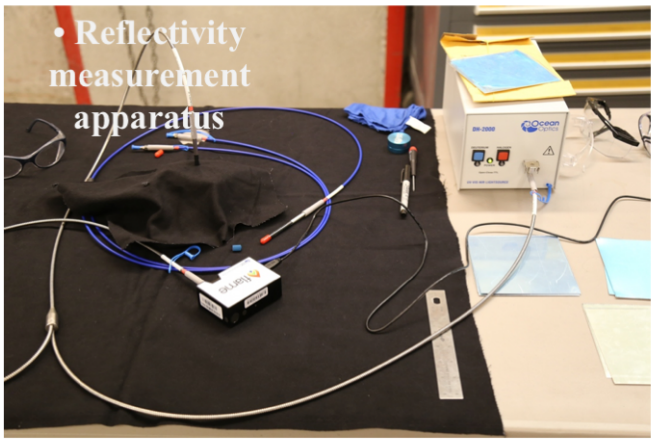
LG reflectivity radiation hardness study



- Used 8 MeV e⁻ beam, 65 - 110mA I_{peak}, 4μs pulse width at 250 Hz, 310 – 880 W

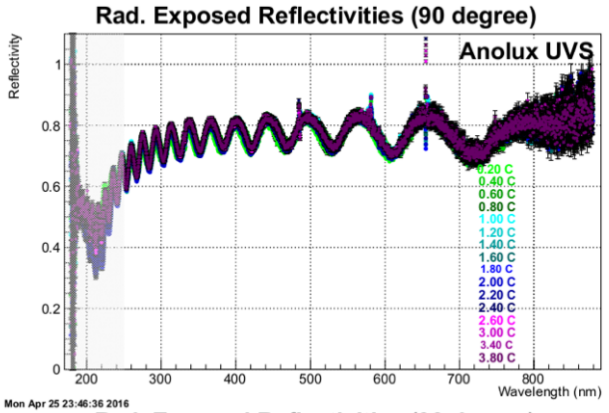
- Water-cooled (15° C) aluminum brick w/ 1.5 cm radius hole (for beam) – more than adequate cooling.

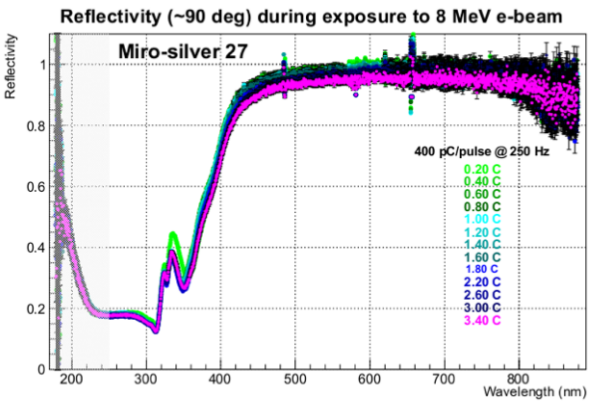


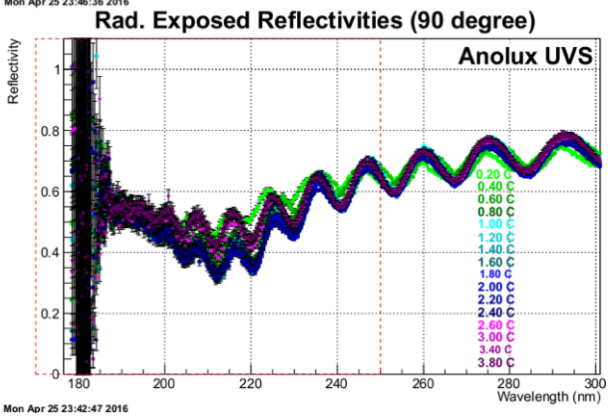


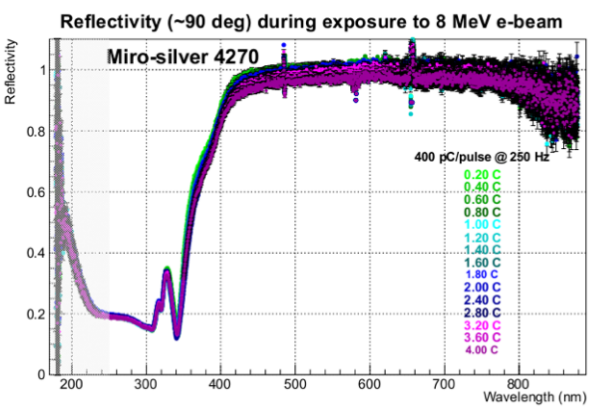
Irradiated several light guide material samples over a 3 day period from Mar 22 - 24, 2016:

Miro-silver 4270
Anolux UVS
Miro 2000Ag (diffuse)
Miro-silver 27 (from Michael)
Alzak-Al and Alzak-Ag (from KK)
1 mil, single-sided aluminized mylar

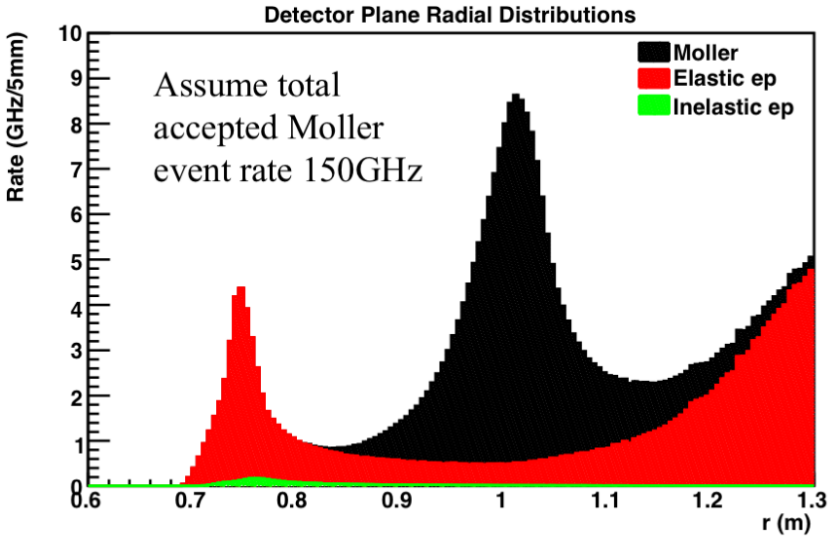


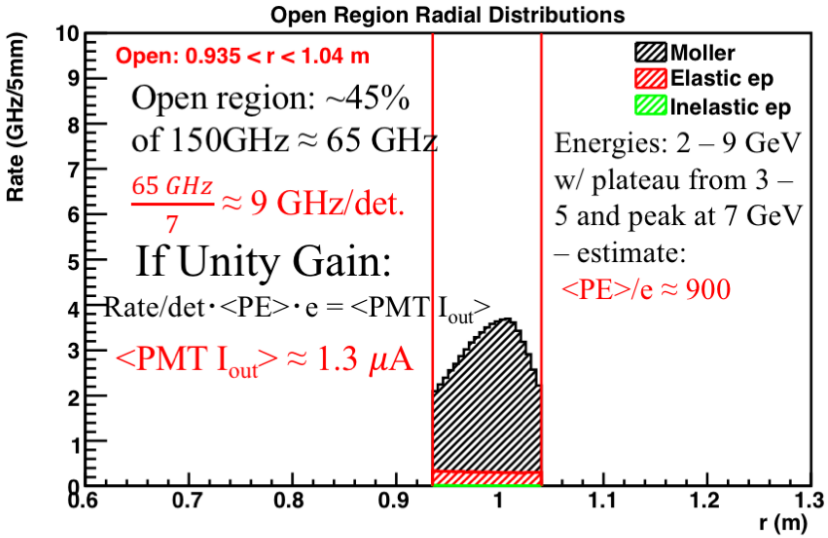


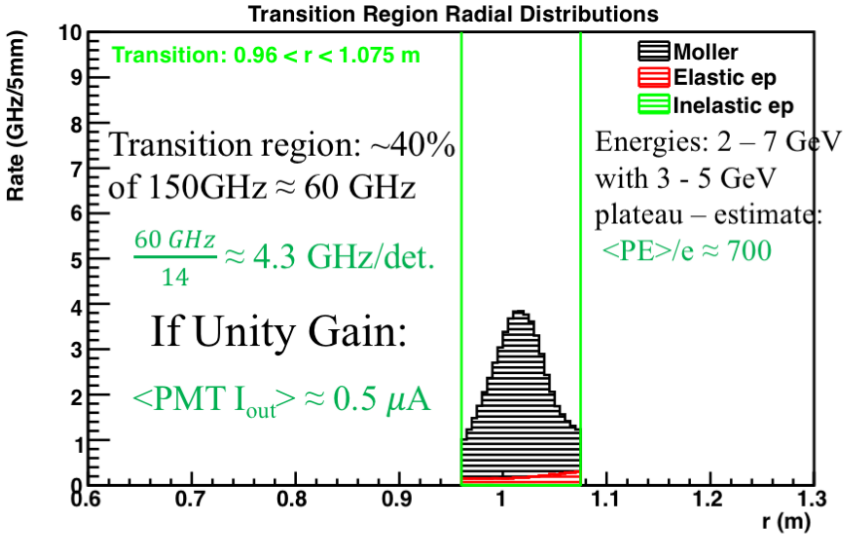


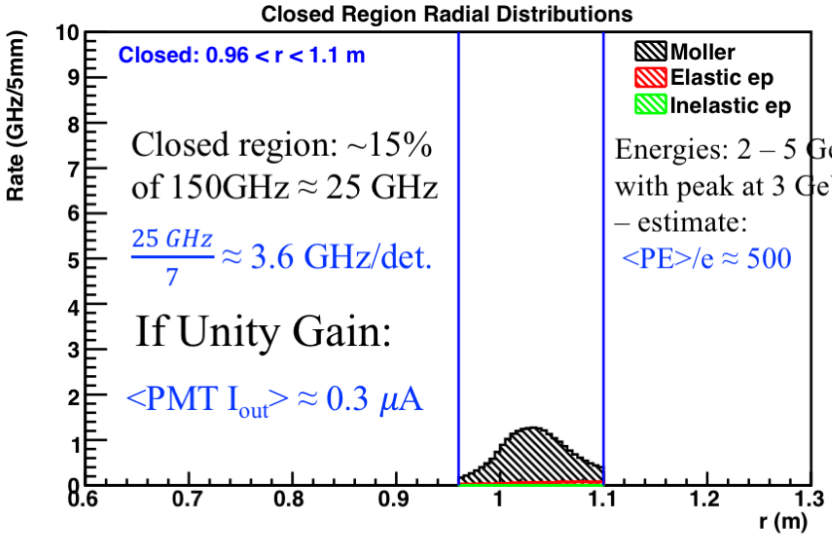


Unity Gain operation with Baseline design?





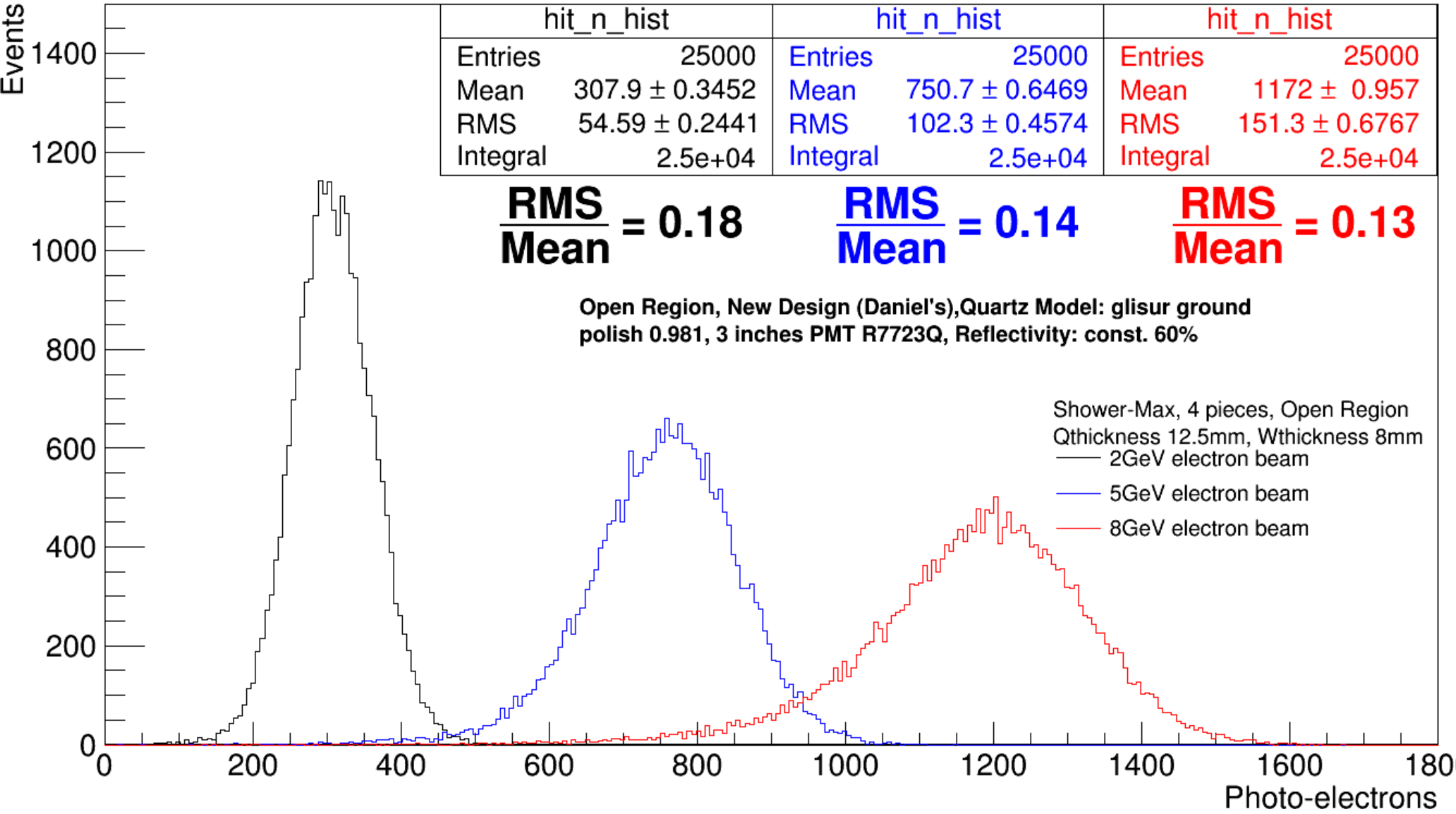




- Could be possible to use conventional 3" pmts with electronic switching between unity gain base (integrating mode) and high gain base (counting mode)

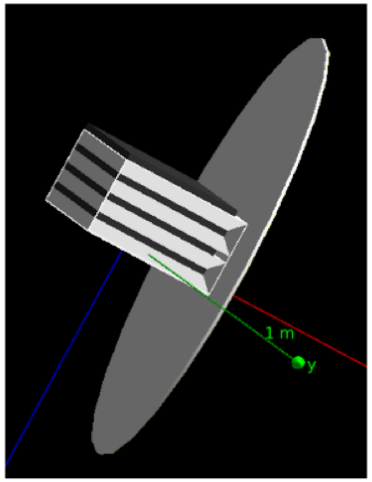
New results from W thickness optimization study

PE Distribution: Showermax Open - 8mm W

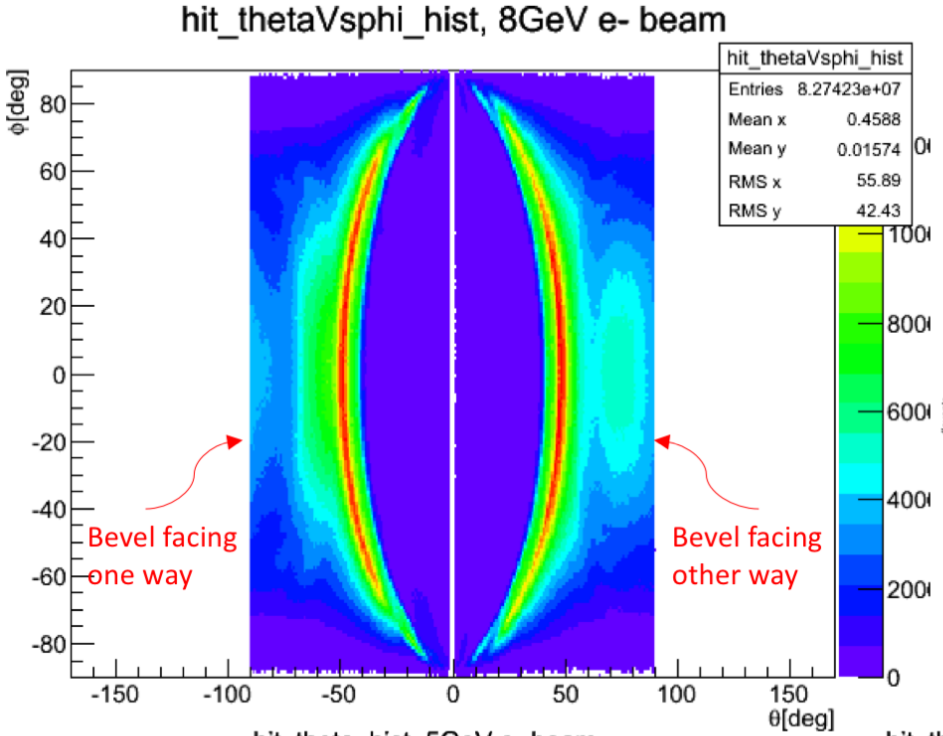


Optimal funnel-mirror angle and length study

Light exit angle study for optimizing funnel mirror



12.5mm quartz, 6mm tungsten, n = 4 layers

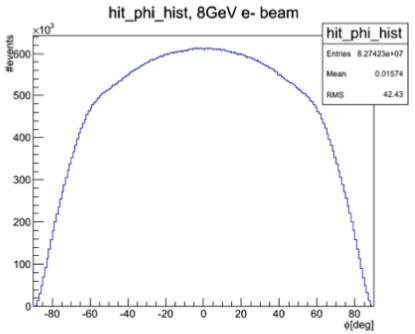


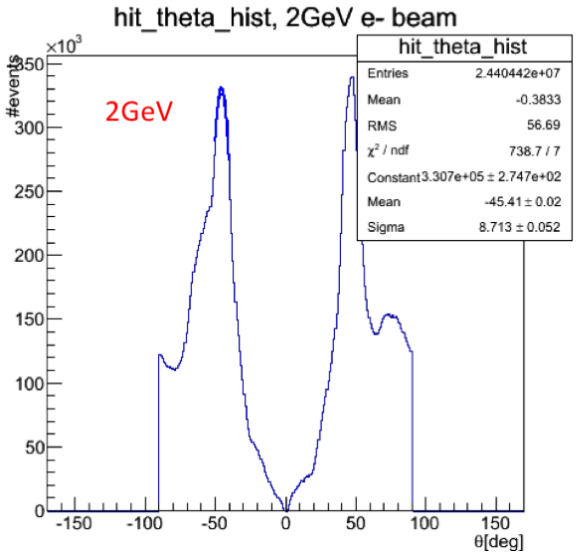
Results:

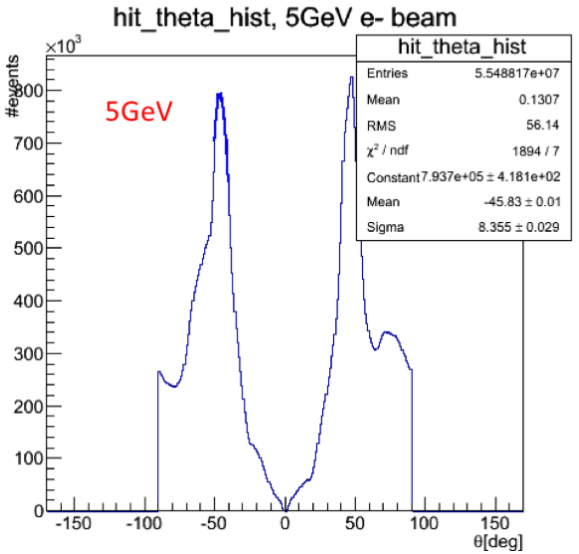
2GeV → $\theta_{peak} = 45.4^{o}$

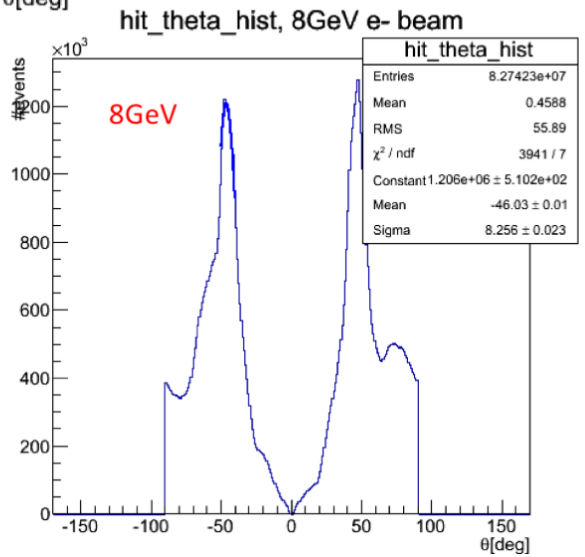
5GeV → $\theta_{peak} = 45.8^{o}$

8GeV → $\theta_{peak} = 46.0^{o}$



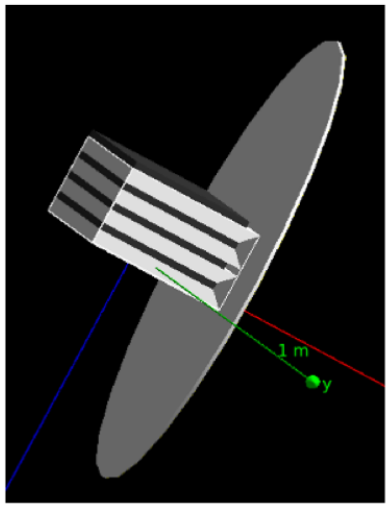




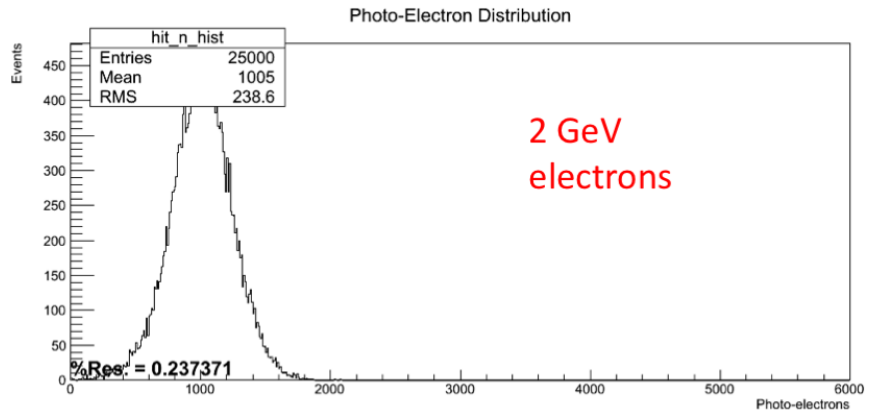


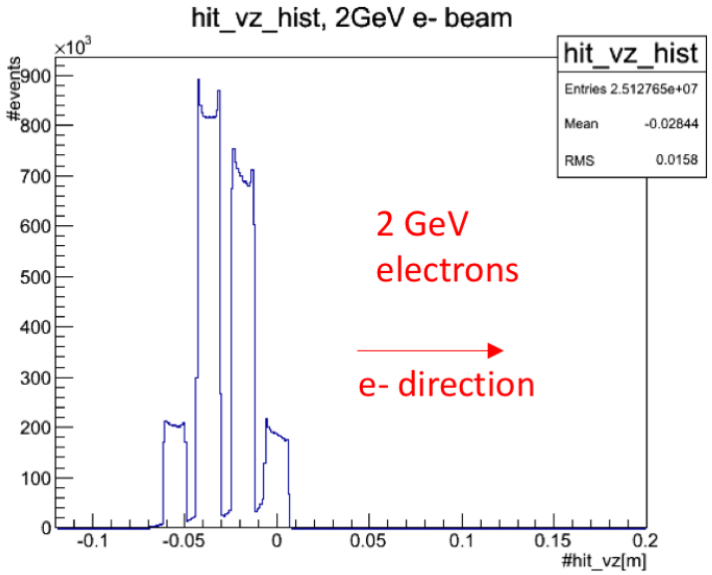
Which layers give the most light?

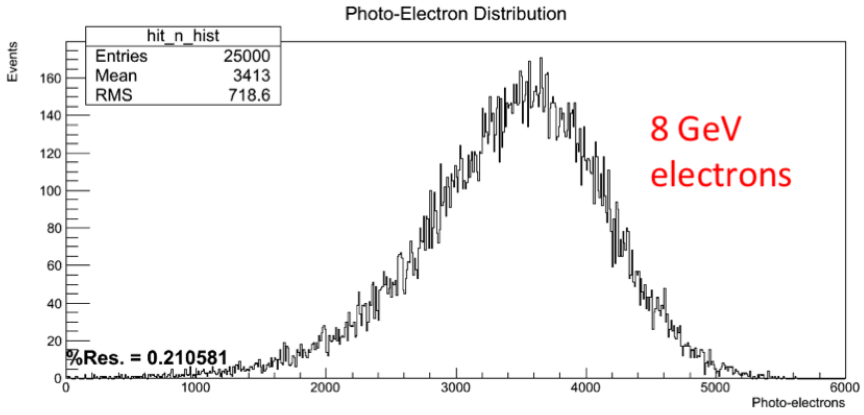
Light exit study for optimizing No. of layers

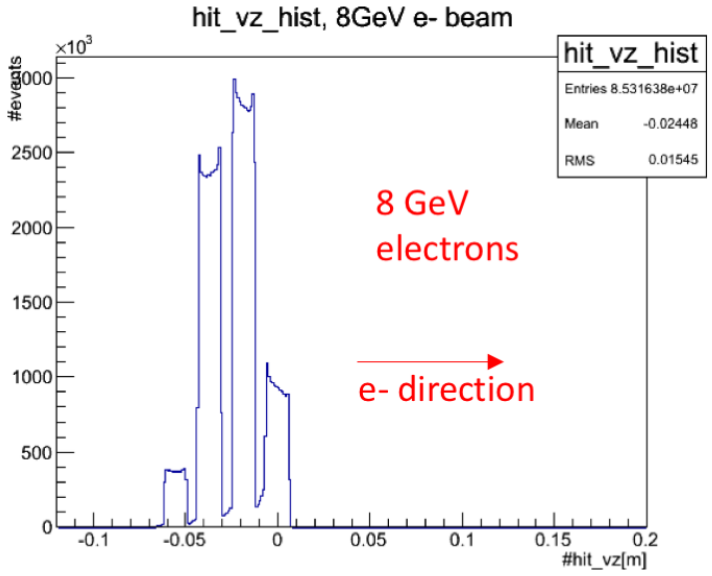


12.5mm quartz, 6mm tungsten, n = 4 layers





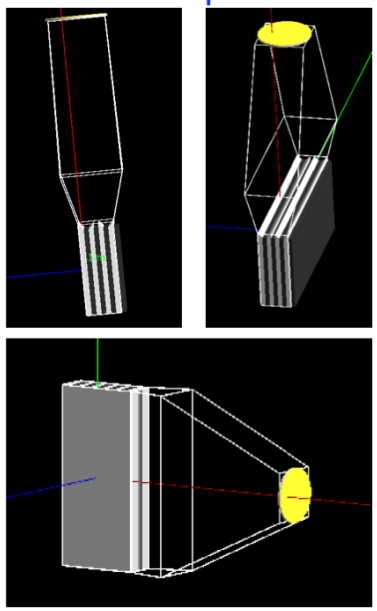




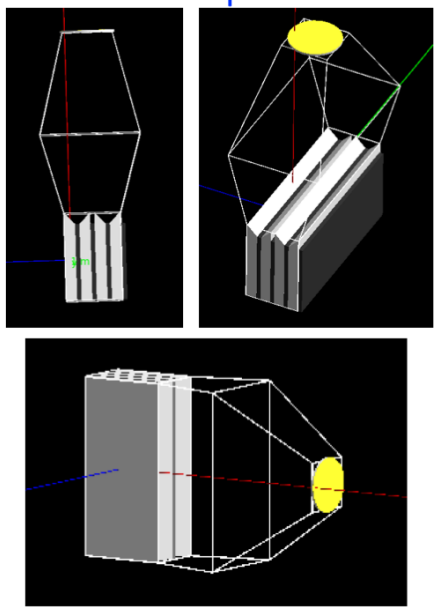
Optimization study (8 GeV):

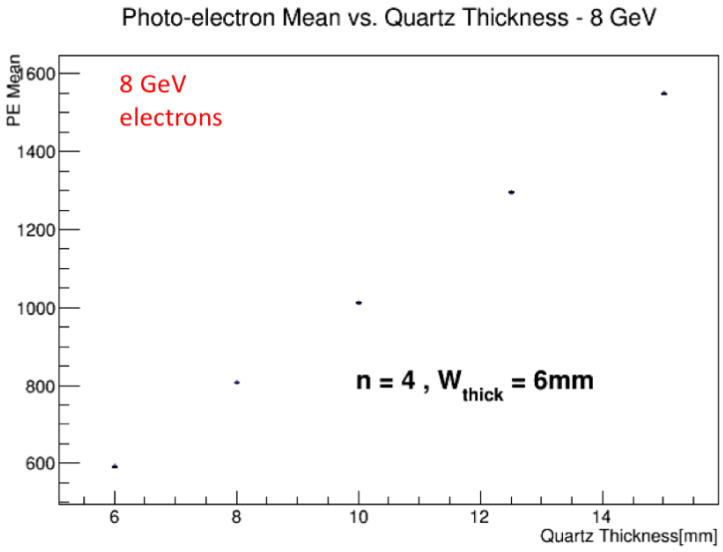
6mm thick tungsten, variable quartz thickness

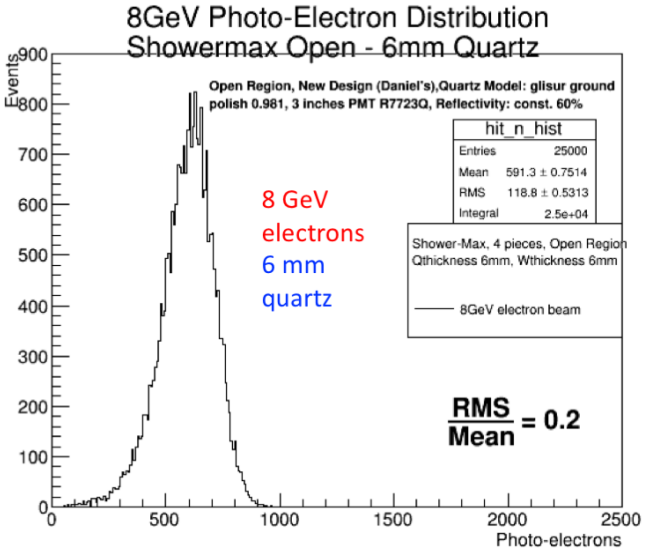
6mm quartz

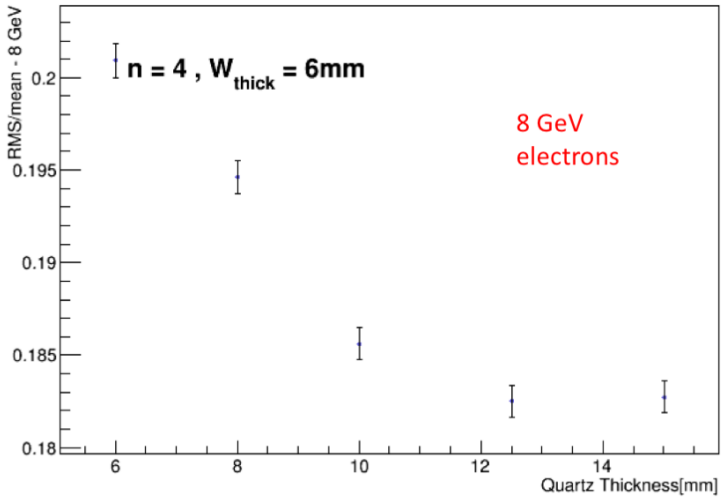


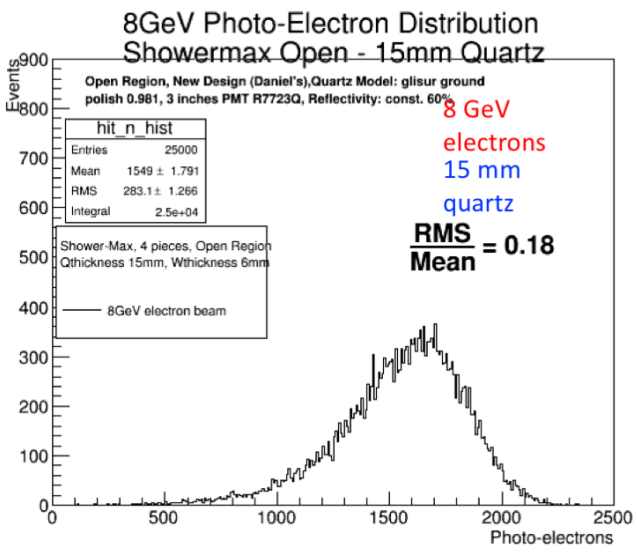
15mm quartz











Optimization study1 (2 GeV):

6mm thick tungsten, variable quartz thickness

6mm quartz

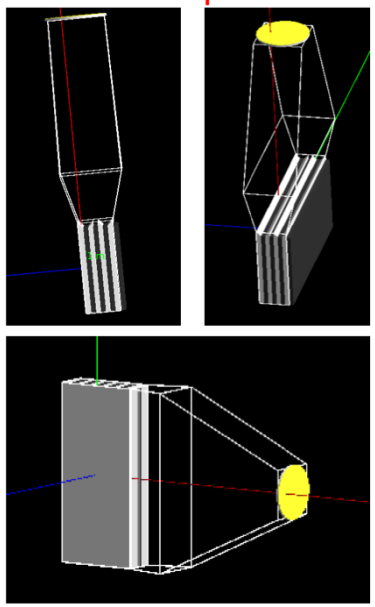
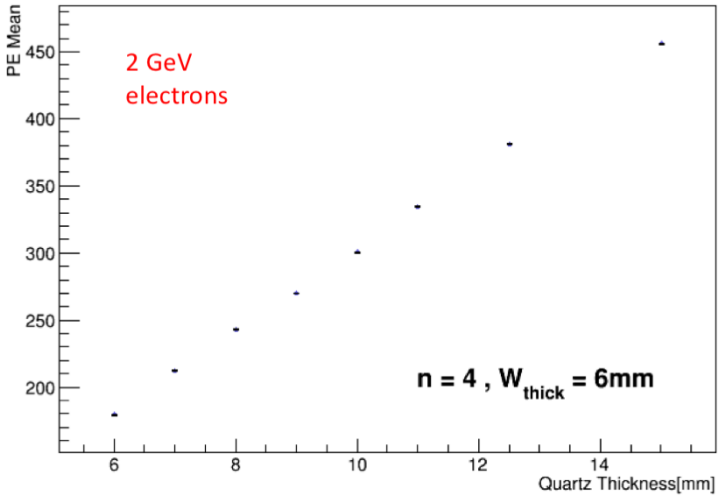


Photo-electron Mean vs. Quartz Thickness - 2 GeV



15mm quartz

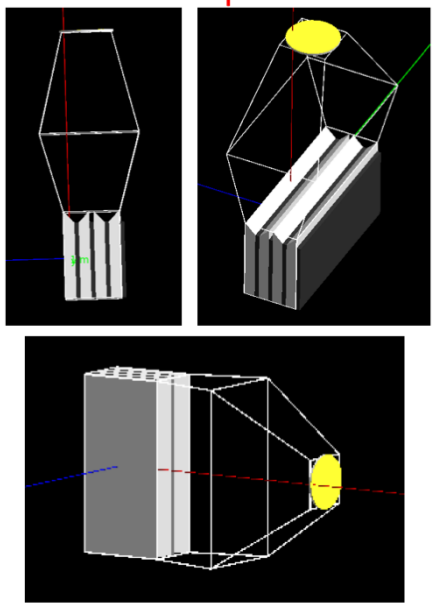
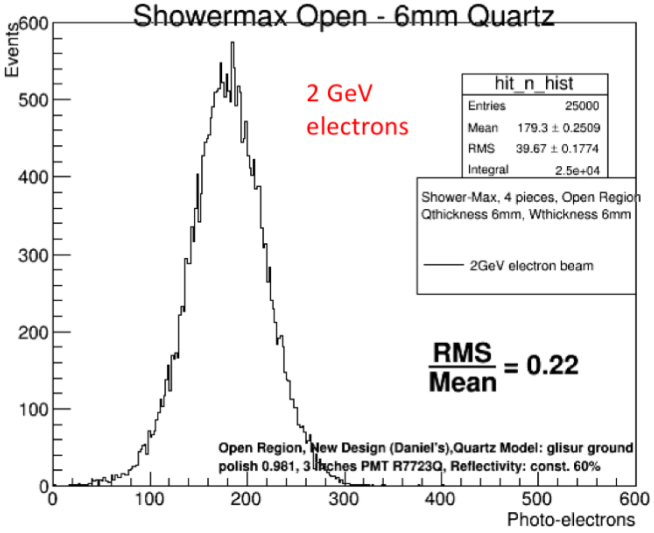


Photo-Electron Distribution
Showermax Open - 6mm Quartz



RMS/mean vs. quartz thickness

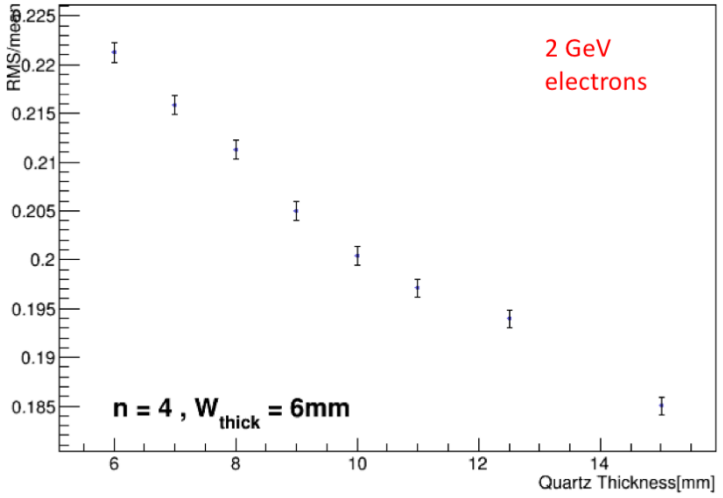
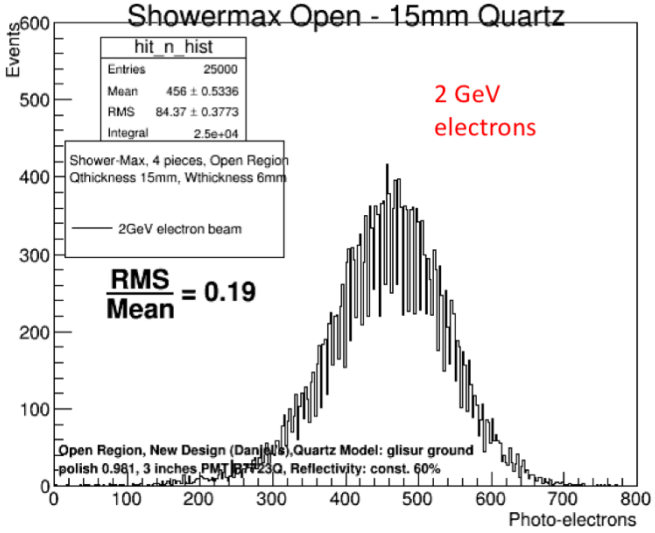


Photo-Electron Distribution
Showermax Open - 15mm Quartz



Optimization study1 (5 GeV):

6mm thick tungsten, variable quartz thickness

6mm quartz

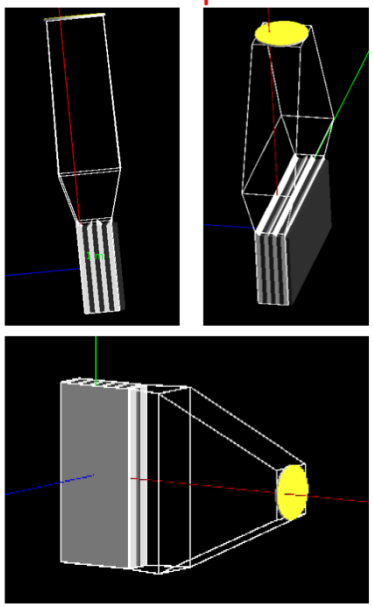
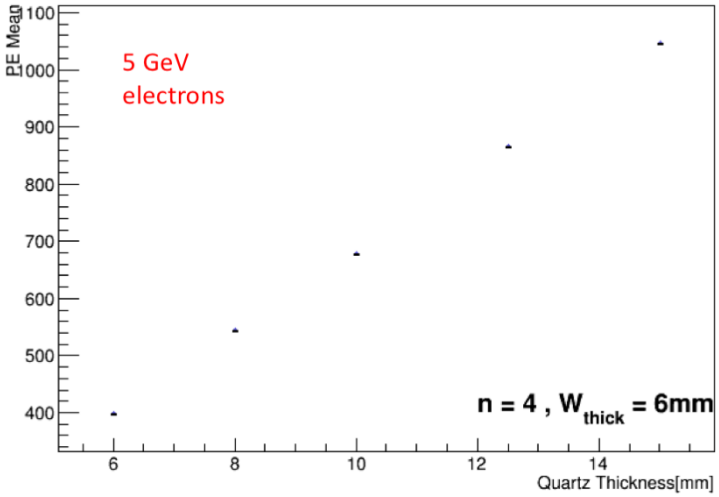
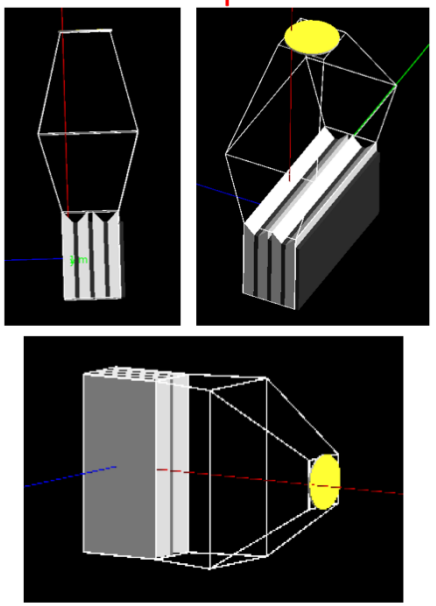


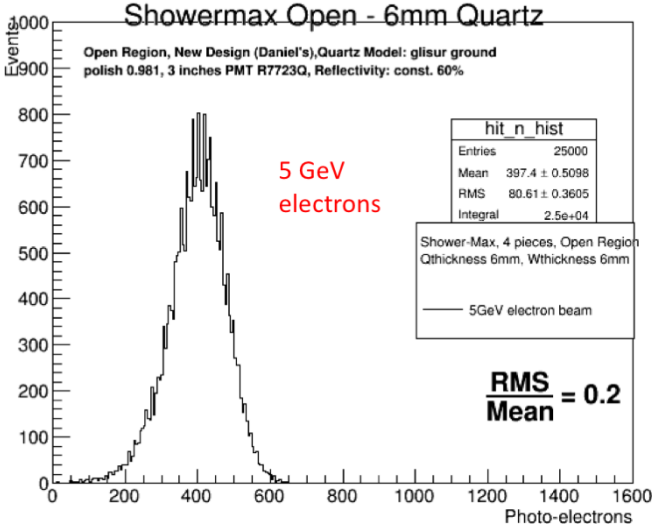
Photo-electron Mean vs. Quartz Thickness - 5 GeV



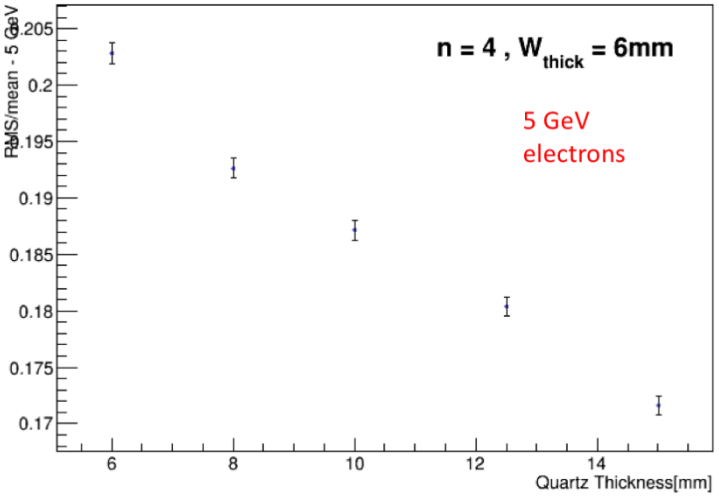
15mm quartz



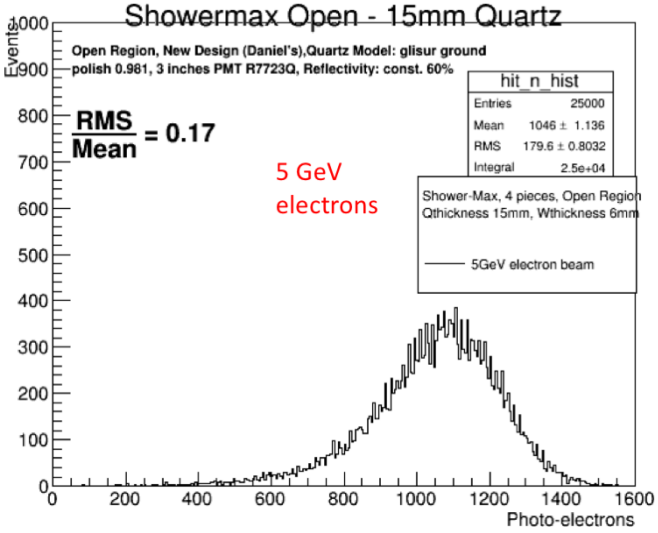
5 GeV Photo-Electron Distribution
Showermax Open - 6mm Quartz



RMS/mean vs. quartz thickness

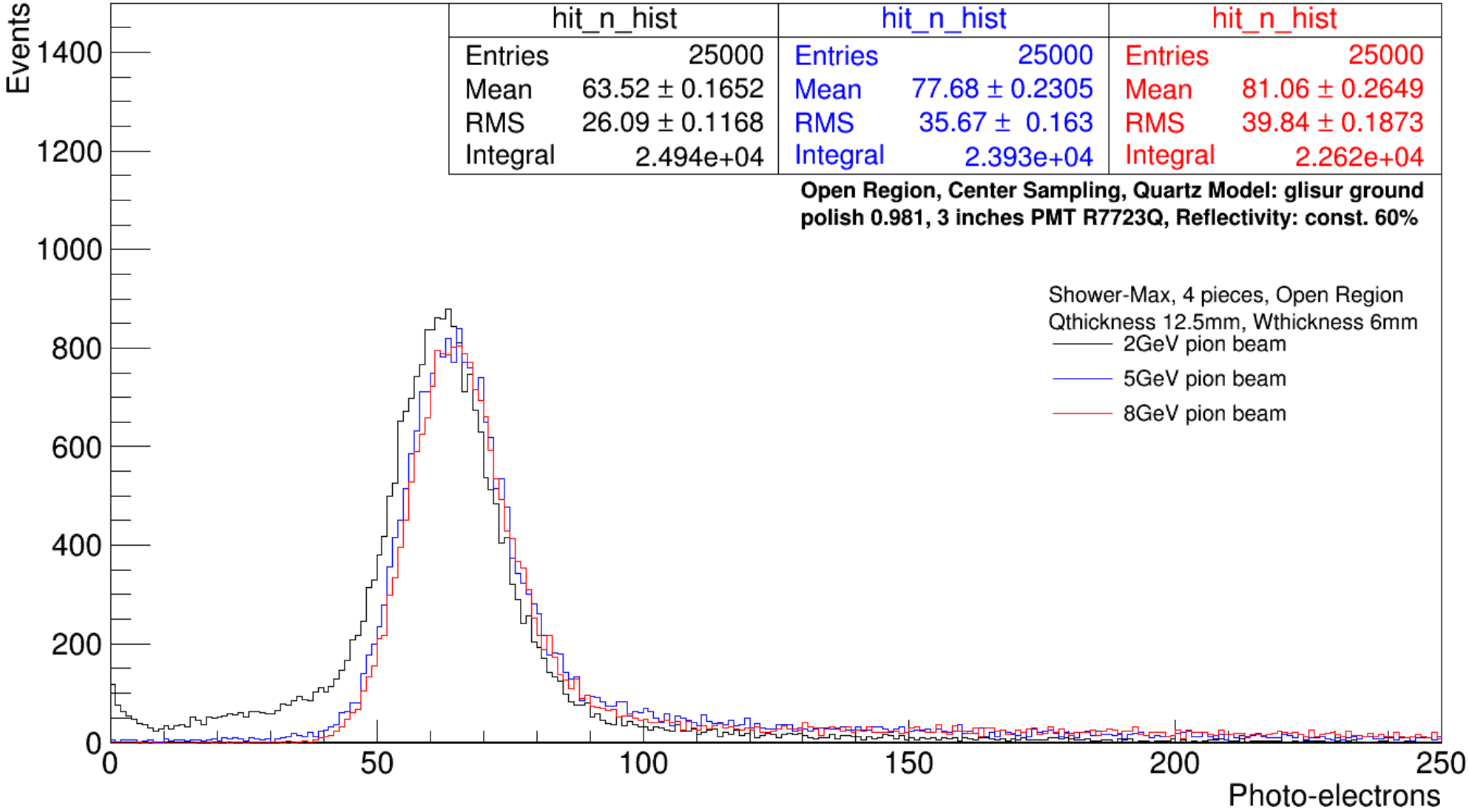


5 GeV Photo-Electron Distribution
Showermax Open - 15mm Quartz

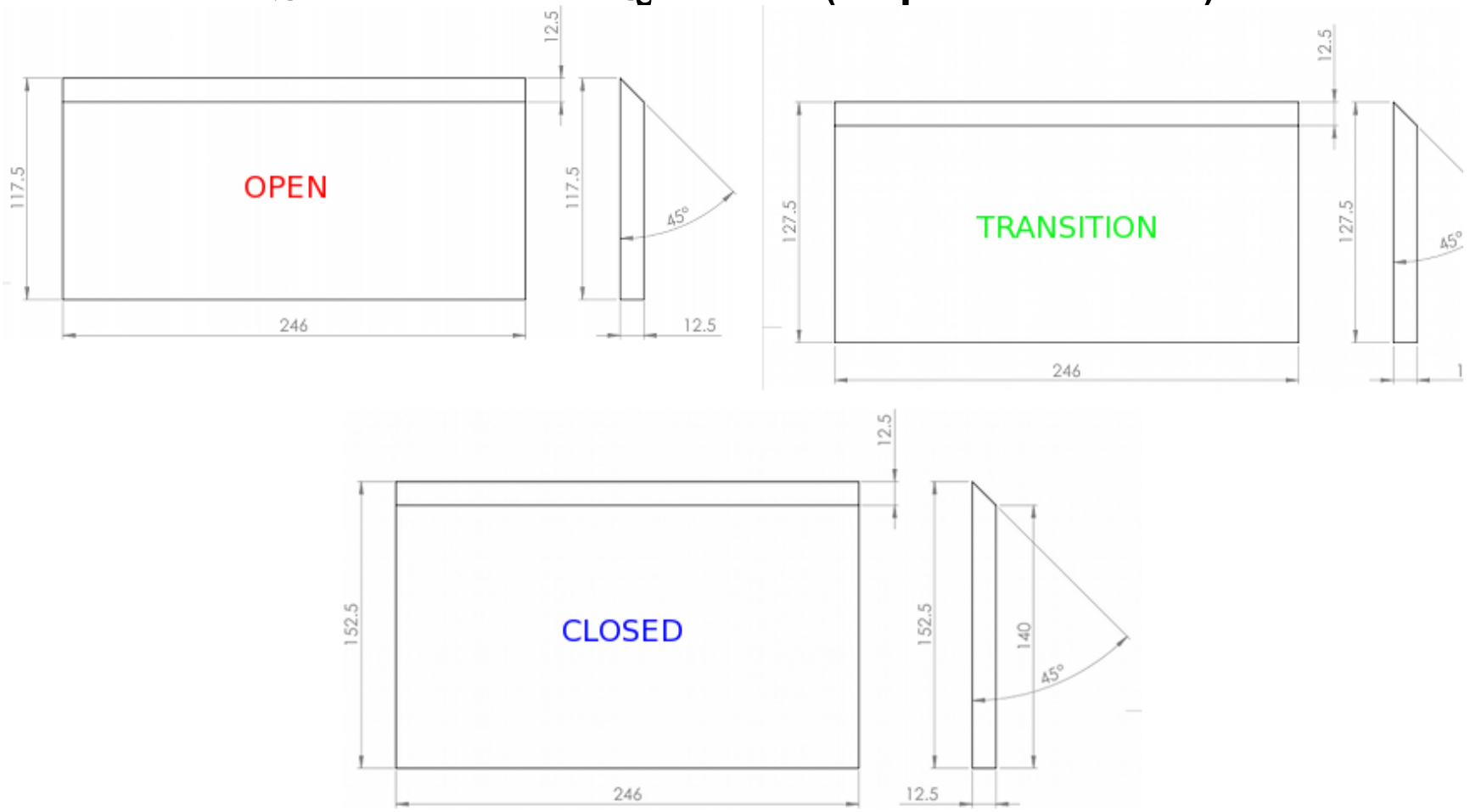


Baseline design PE Distributions for Pions

Showermax Photo-Electron Distribution (open)

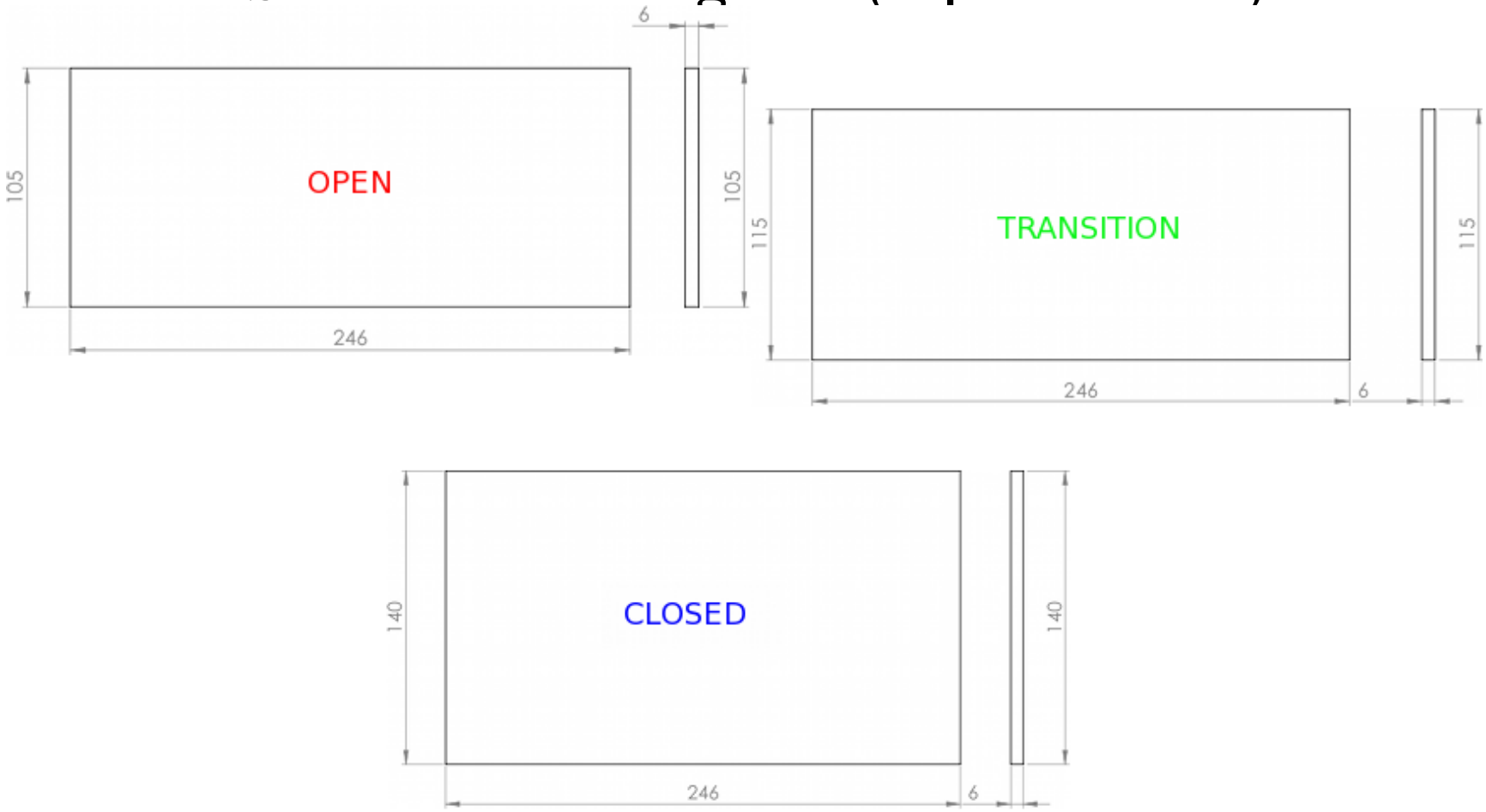


Showermax Quartz (4 piece stack)



Spectrosil 2000: One 45 degree polished face, all surfaces polished to 20 Angstroms or better, no small edge/corner bevels. Heraeus quote: ~$1100 per piece. $150k total.

Showermax Tungsten (4 piece stack)



99.95% purity; ±0.005" tolerances. Received quote from company "Marketech": OPEN–$484/piece ($13.6k), CLOSED–$647/piece ($18.1k) TRANSITION–$511/piece ($28.6k); total tungsten cost is $60.2k.

Prototype stack support structure and LG

(CAD and renders by Daniel)