Moller Detector Simulation Update

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Several scattered subtopics will be discussed:

- light guide geometry
- shape of PMT window
- shower-max detector and pre-rad optimization
- detector design parameters
- auxiliary components (shutter & LED)
- prototyping
- summary

Recall: Status and To-do's at Collaboration Meeting

Status:

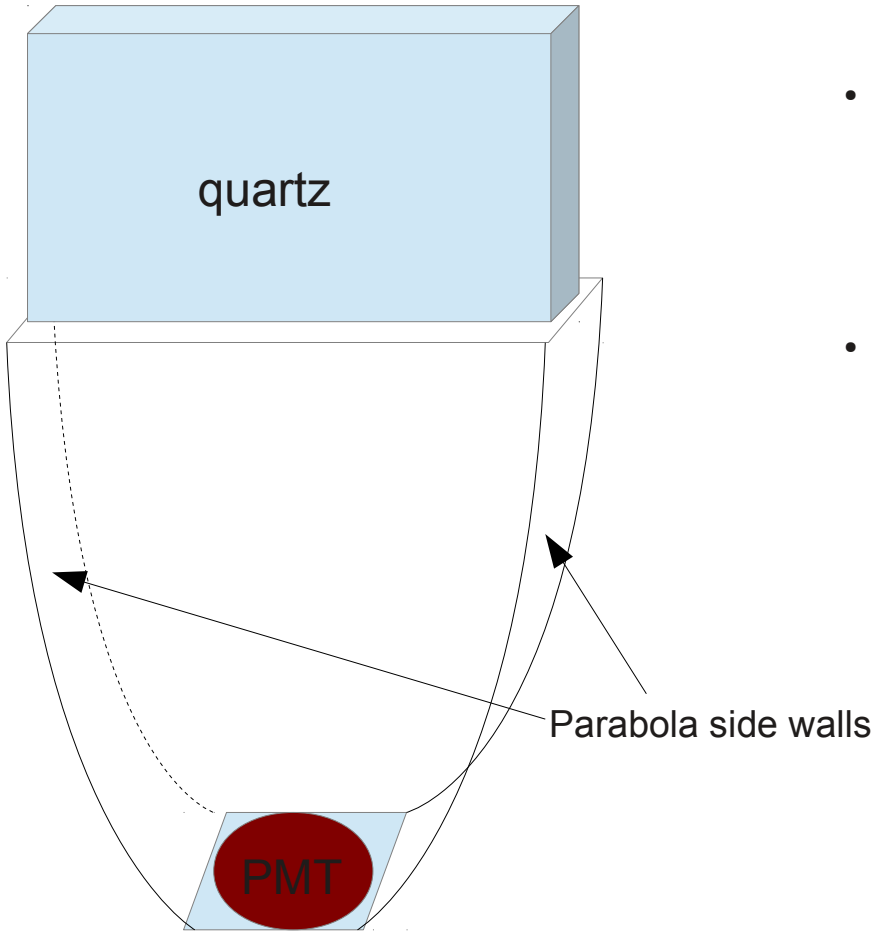
- Developed a detector simulation package
- Implemented detector array in the simulation
- Completed the first iteration of detector design optimization.

To-do's

updates on these two items in the following slides

- Start the next iterations of optimization to tweak the design
- Implement the shower-max detector ring
- Study background and cross-talk
- Integrate the detector array into main Moller simulation package

Light Guide Geometry: Using Winston Cone?



- During the collaboration meeting, it was proposed to test the idea of using Winston cone for the light guide to maximize collection of incoming rays within limited field of view.
- We have a round PMT vs. a long and thin rectangular quartz. It is not possible to make a Winston cone with a parabola of revolution. Only a 2D version of the Winston cone (side walls with a parabola outline, see the figure) can be considered.
- I am going to abandon this idea because:
  - a simple test in simulation shown that it was not very helpful in boosting #PE;
  - it is difficult to build.

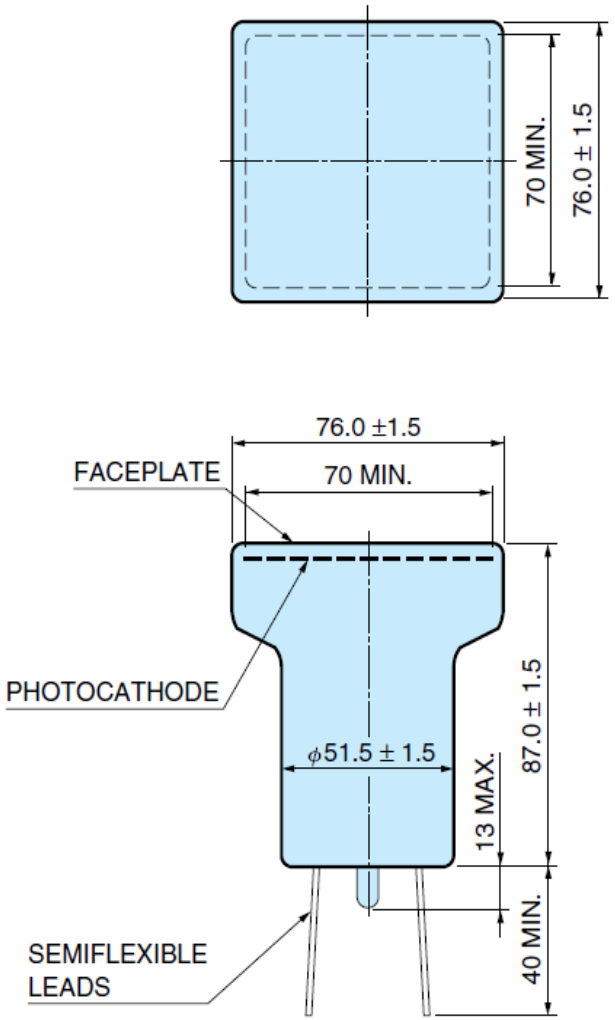
However, the shapes of light guide and the end-cap gave us a hint:

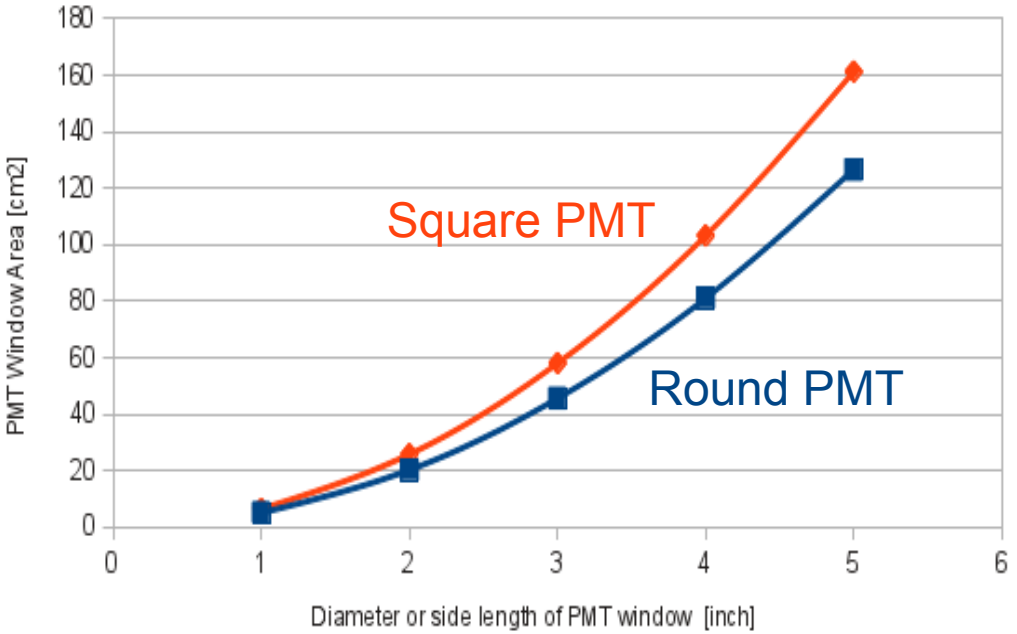
Could we use square PMT to increase light collection area hence #PE yield?

(see next slide)

Square PMT

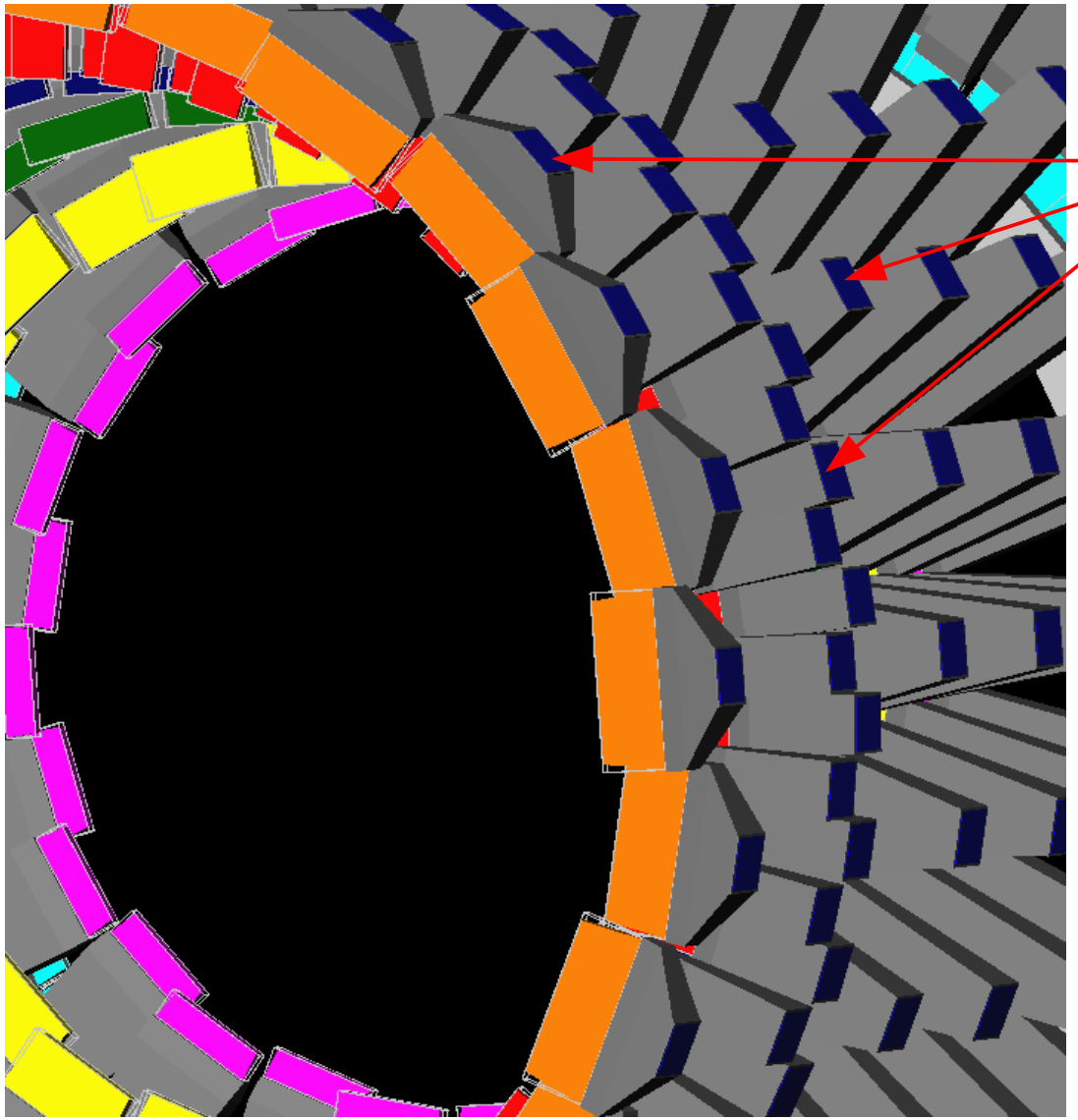
An example of square window PMT:
“HAMAMATSU PHOTONICS R6237-01”, 3 inch, head-on, square window (for geometry reference only)





For 3 inch PMTs, square PMT has ~20% larger window area

Implementation of square PMT in simulation:



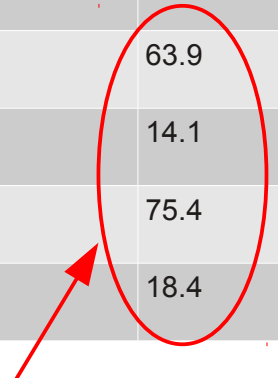
3 inch square PMTs

(they will not cause additional space constrains comparing with the corresponding round window PMTs)

Simulation Test for Square PMT (3 x 3 inch)

- Using detector model 10
- Comparing #PE for round and square PMTs with varying quartz thickness

Detector Configuration		#PE yield & RMS					
PMT (3 inch)	Quartz thickness	Ring 0 super-elastic	Ring 1 e-p	Ring 2 e-p tail	Ring 3 e-p tail inelastic	Ring 4 e-e	Ring 5 e-e tail
Round	1.0 cm	12.8	12.1	12.8	13.4	30.3	24.2
		4.5	3.5	3.8	4.1	7.3	7.0
Round	1.25 cm	24.2	24.5	22.7	22.5	52.3	40.4
		6.2	5.9	6.01	6.0	10.6	8.5
Square	1.25 cm	26.6	27.5	24.6	24.2	62.7	45.5
		7.9	7.1	6.6	6.5	14.8	10.5
Round	1.5 cm	27.2	30.2	27.0	27.2	63.9	47.6
		7.2	7.8	7.4	6.1	14.1	8.7
Square	1.5 cm	32.9	34.3	30.0	29.9	75.4	52.9
		8.9	9.1	7.6	6.2	18.4	10.2



~15% improvement on #PE yield

Square Window PMT

Square window PMT:

- has larger effective light collection area (~20% more) than round PMT (3”),
- matches the light-guide shape,
- increases #PE yield by ~10 – 15% from simulation.

Feasibility and technical details need to be studied, such as:

- cathode, window material
- dynode material and configuration
- gain, linearity, stability, dark current, noise
- cost if custom design and fabrication are needed

Shower-max Detectors

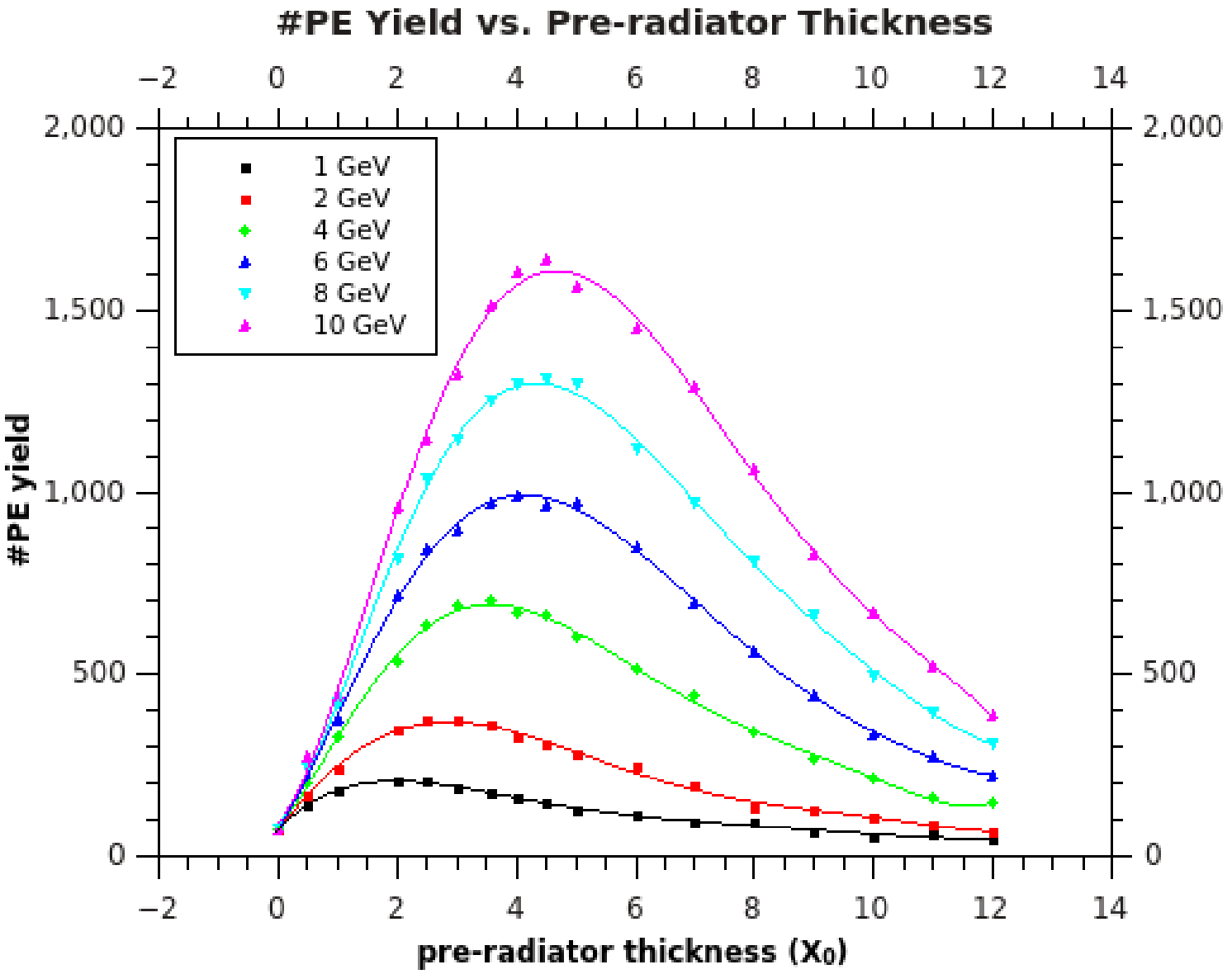
Implementation:

- Duplicate e-e ring
- adding pre-radiator in front of quartz
- Located downstream of other detector rings

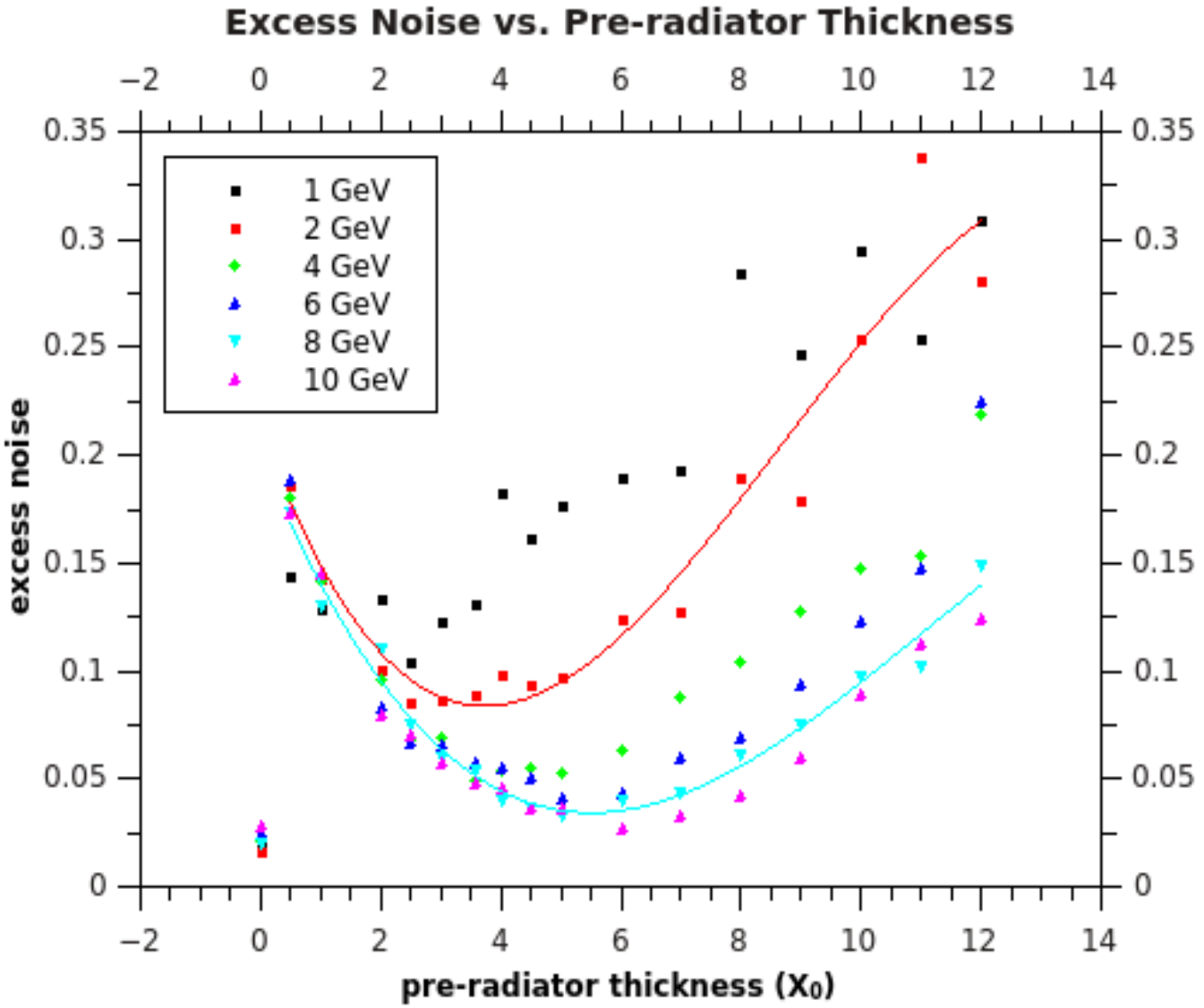
Optimization:

- Varying the thickness of pre-radiator from 0 up to 12 X_0
  (X_0 = 0.5612 cm for lead, 0.3503 cm for tungsten)
- Varying the beam energy from 1 GeV to 10 GeV to cover the experimental beam energy range
- Observing the trends of "#PE vs thickness" and "excess noise vs thickness"
- Finding out the optimized pre-rad thickness, with which the #PE can be maximized and the excess noise can be minimized.

Intensive study since shower & optical photon simulation demand significant computing time!



For 2 – 8 GeV electron beam, #PE is maximized when pre-radiator thickness is 2 - 5 X_0.



Large shower fluctuation for low energy beam (~ 1-2 GeV)

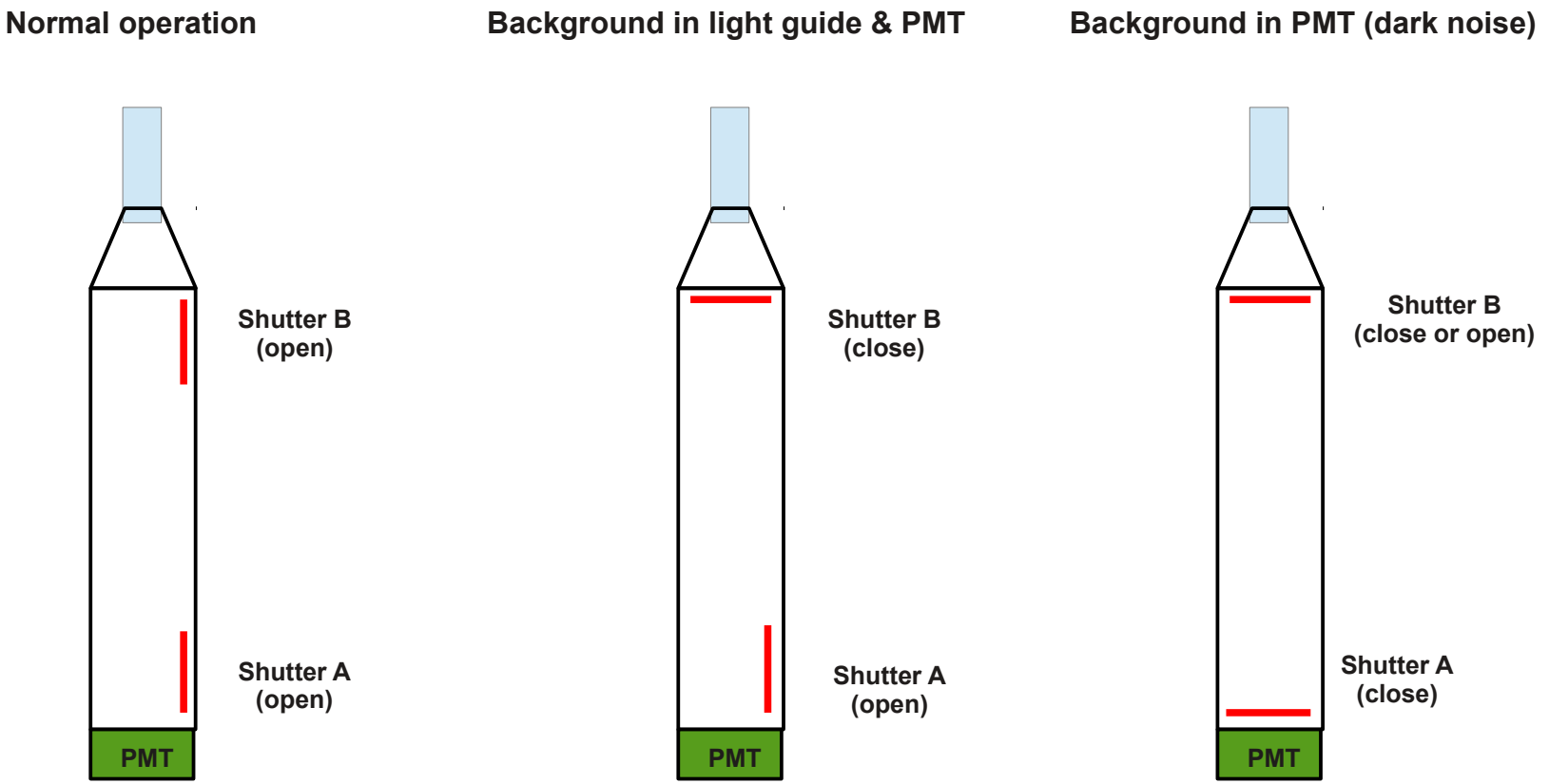
For 2 – 8 GeV electron beam, excess noise is minimized when pre-radiator thickness is ~ $4X_0$.

Detector Parameters for Design/Prototyping Reference

Ring# Detector	0 super elastic	1 e-p elastic	2 e-p tail	3 e-p tail/inelastic	4 e-e	5 e-e tail	6 shower-max
Radial position of quartz geometry centre (cm)	65.6	73.1	81.1	86.0	94.0	105.0	94.0
Top width of quartz (cm) (width of inner radius side)	14.6	15.8	18.0	19.4	7.1	22.9	7.1
Bottom width of quartz (cm) (width of outer radius side)	15.8	18.0	19.4	20.3	8.0	25.2	8.0
Height of quartz (cm)	5.0	10.0	6.0	4.0	12.0	10.0	12.0
Thickness of quartz (cm)	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Quantity of quartz	28	28	28	28	84	28	84
Reflector length (cm)	3.5	3.5	3.5	3.5	3.5	3.5	3.5
Reflector opening angle (deg)	19.0	19.0	19.0	19.0	19.0	19.0	19.0
Light guide length (cm) (exclude reflector section)	48.5	38.5	32.5	28.5	16.5	6.5	16.5
Pre-radiator thickness (cm) (4 radiation length)	-	-	-	-	-	-	2.25 (Pb) 1.4 (W)

Double Shutters for Background Measurement

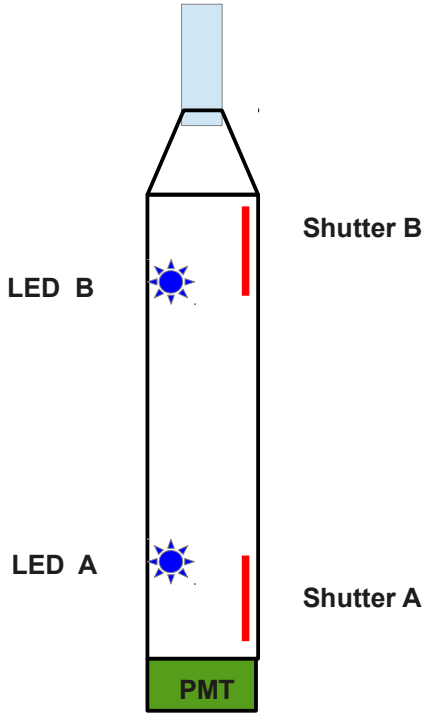
- Propose to add double-shutter system to light guide
- One is at PMT side (shutter A), another is at quartz side (shutter B)
- Allow us to evaluate background



Concept of Double-shutter System

Diagnostic/Calibration LEDs

- Propose to add diagnostic/calibration LEDs to light guide
- Two LEDs are mounted on side wall of light guide
- Operating in continuous mode or pulse mode
- Useful in checking electronics chain, measuring linearity and gain, calibrating SPE, and so on.



Concept of LED System

Detector Prototyping

- Detector prototyping should be started to benchmark MC.
- A test bench (dark box, required electronics and DAQ) and a decent machine shop are available at U. of Manitoba.
- Materials, components & labour:

  - quartz, Alazk, PMT&base
  - cutting & polishing quartz

- Vendor, cost and resource allocation?

Summary of Status and To-do's

- Work done after collaboration meeting
  - **Performed the 2nd iteration of the detector optimization and verified the results of the 1st iteration study**
  - **Tested and confirmed that the square window PMT can effectively increase #PE**
  - **Implemented the Shower-max detector and conducted intensive pre-radiator studies**
- Summary for detector optimization
  - **Detector model 10 with square window PMT are preferable**
  - **Quartz: trapezoid shape when looking in beam direction, with two 45 deg cuts at the outer radius (light guide) side, thickness: 1.5 cm, no tilting w.r.t. light guide**
  - **Light guide: Alazk tube with a reflector section, no tilting w.r.t. beam axis, rectangular cross-section at quartz side and square cross-section at PMT side, reflector length: 3.5 cm, opening angle 19 deg**
  - **PMT: 3”x3” square quartz window**
  - **Shower-max detectors: duplicate e-e detectors with pre-radiator (thickness: ~4X_0)**
  - **Light yield & excess noise: ~75 PE, excess noise ~3% (e-e detector)**
    ~200 -1500 PE, excess noise ~ 5 -10% (shower-max detector)
- Asking for suggestions
  - **Adding auxiliary components: shutters for measuring background, LEDs for test, diagnostic and calibration**
  - **Design with an option of installing pre-radiators for all detectors**

- To-do's

  Start to work on integrating the detector array into main Moller simulation package

  When done, study background/cross-talk with simulated beam in the "Moller" environment

  Would like to start prototyping ASAP to benchmark Monte Carlo

Implementation of detector ring in main Moller simulation

(https://jlabsvn.jlab.org/svnroot/moller12gev/mollersim/branches/peiqing_mollersim_gdml/)