MOLLER/PREX Detector Development

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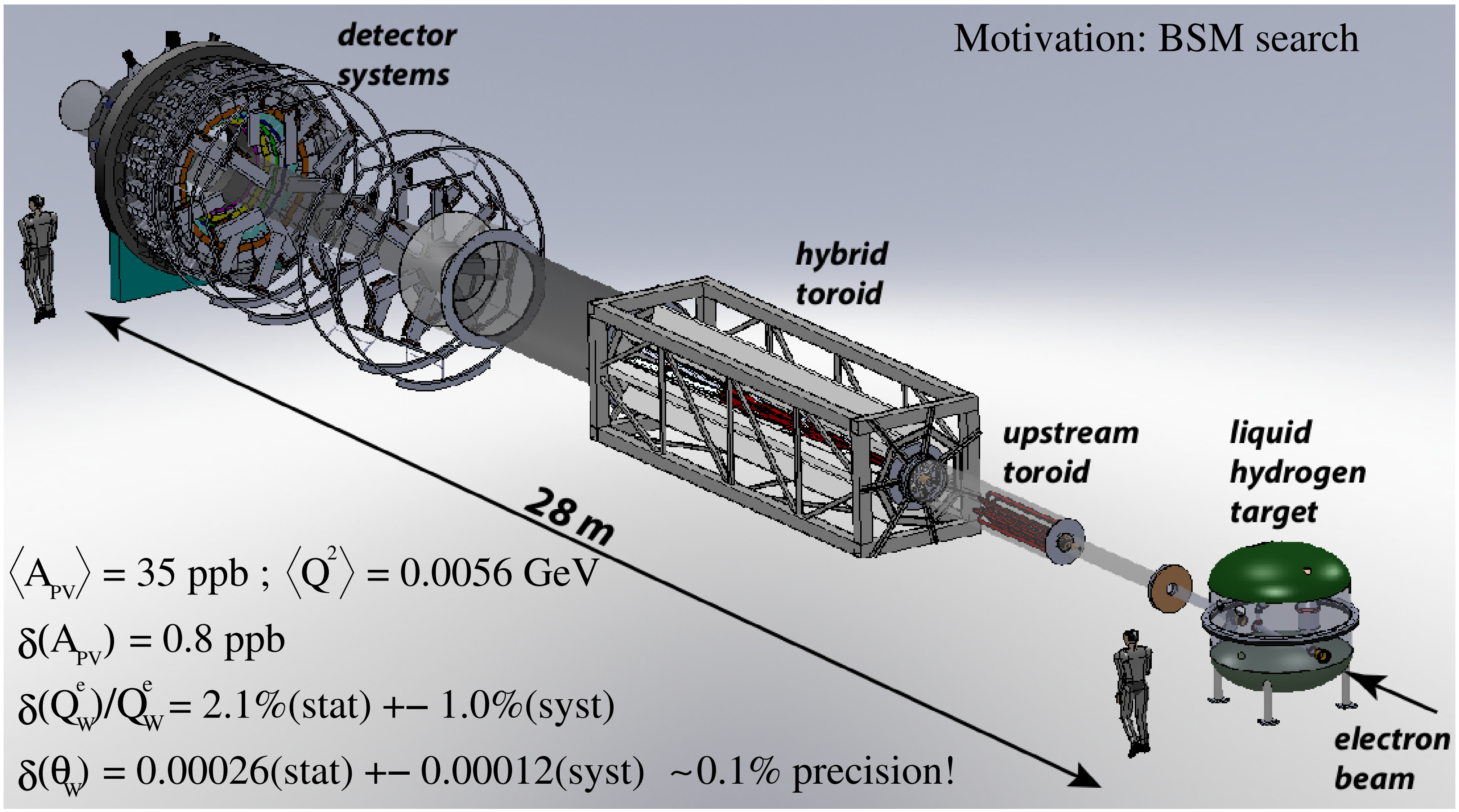
Introduction: Integrating detectors for PVeS

- PVES expts measure tiny asymmetries and require large statistical samples—need high luminosity and deadtime-less signal integration
- Over time, high intensity physics frontier pushes to smaller asymmetries thus requiring higher intensities...
- PVeS integrating detectors must meet the challenge of increasing demands on radiation hardness and performance
- We are currently pursueing the use of high-purity thin quartz (Cherenkov medium) coupled to air-core light guide and pmt
- This talk gives current conceptual designs and prototype test results for MOLLER and PREX-II/CREX quartz detectors
- The new Jefferson Lab Hall A luminosity monitor will also be discussed briefly (time permitting)

MOLLER target, spectrometer, and detectors (Hall A, Jefferson Lab)



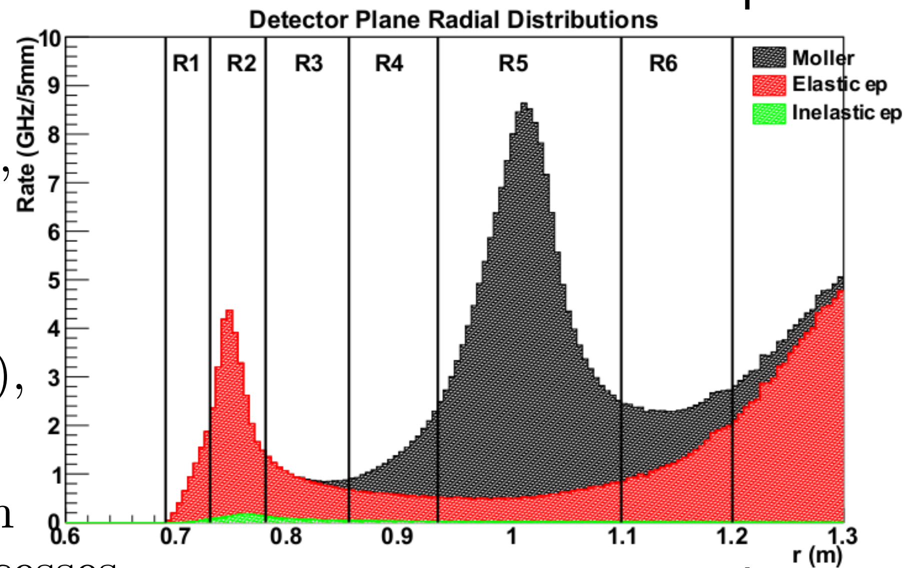
MOLLER Integrating Detector Group

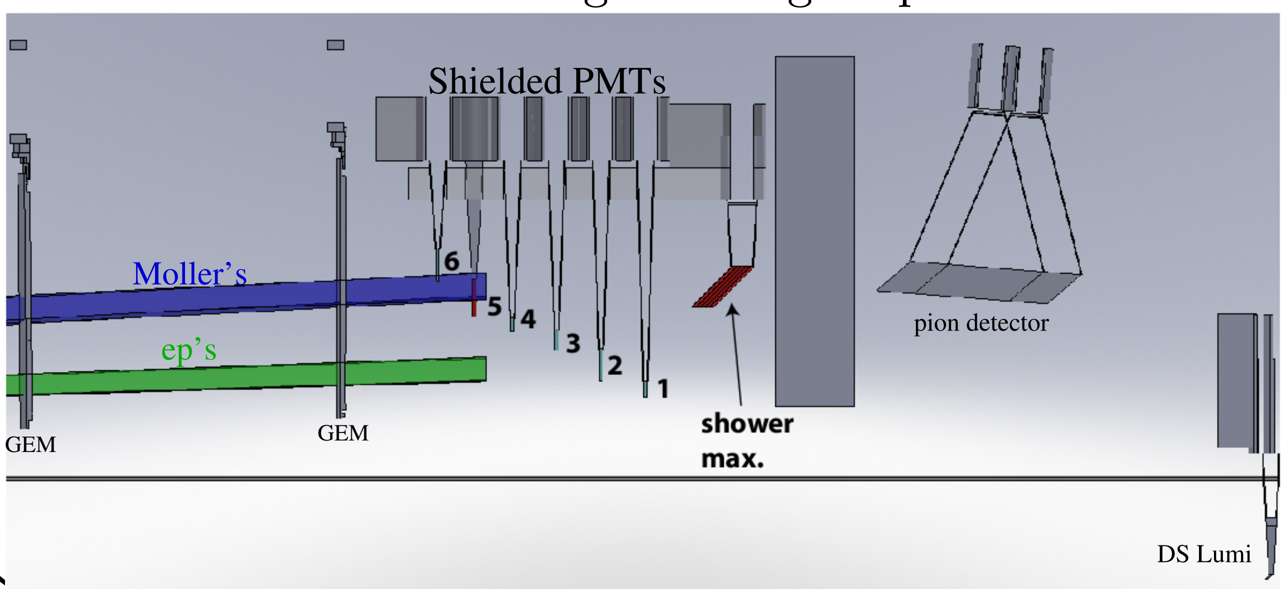
Who is involved in detector work (likely incomplete):

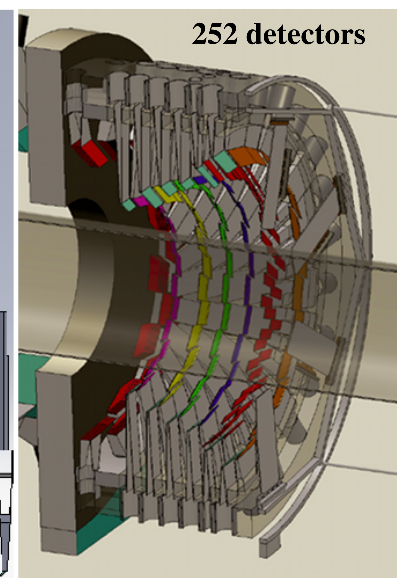
- U. Manitoba: M. Gericke, J. Mammei, Jie Pan, S. Rahman
- SBU: K. Kumar, S. Riordan, Tyler Kunz (?), Yuxiang Zhao
- ISU: D. McNulty
- U. Mainz: F. Mass, S. Baunack, K. Gerz, D. Becker, T. Jennewein
- U. Syracuse: P. Souder
- JLab: R. Michaels (DAQ / electronics)
- Ohio U.: P. King (DAQ / electronics)
- W&M: D. Armstrong, W. Deconinck

MOLLER Integrating Detector Layout and Rates

- Spectrometer separates signal from bkgd and radially focuses at detector plane
- Rates for 11 GeV/75 μA (80% pol.) beam, 1.5m liquid hydrogen target. See fig. $\longrightarrow$
- Six radial rings, 28 phi segments per ring*
- Ring 5 intercepts Moller peak (~150 GHz), Ring 2 intercepts bkgd "ep" peaks
- 250 quartz tiles: allow full characterization and deconvolution of bkgd and signal processes

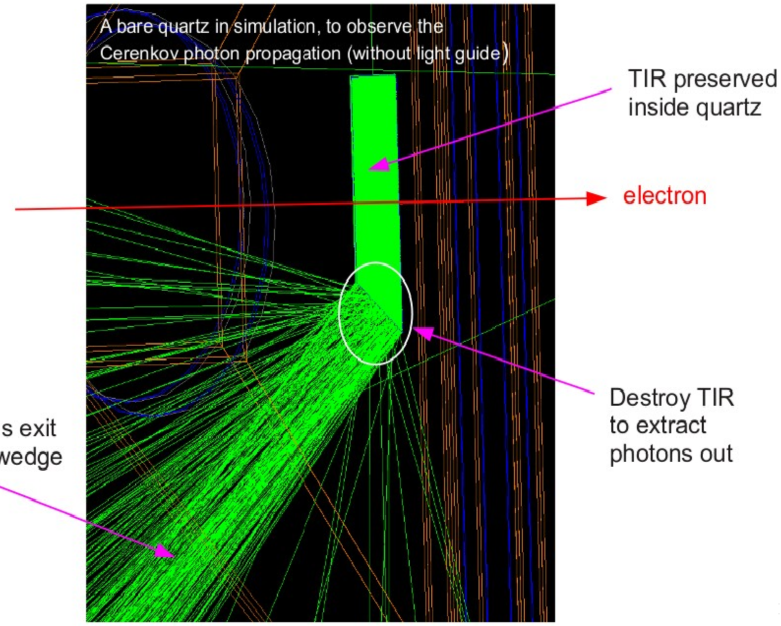


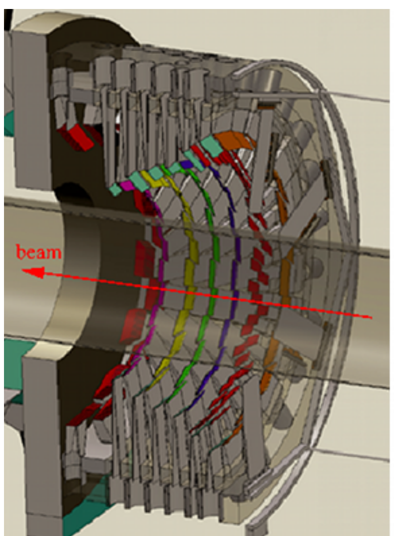


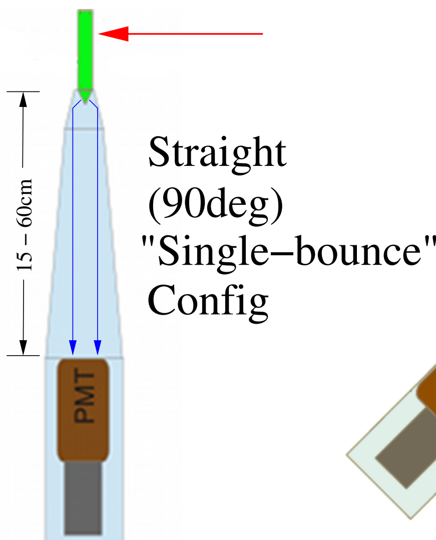


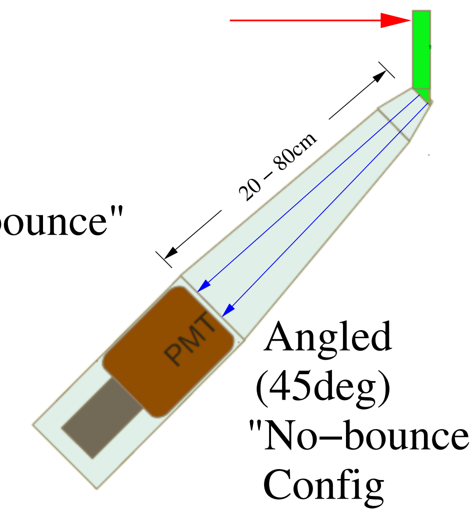
MOLLER Prototype Detector Development

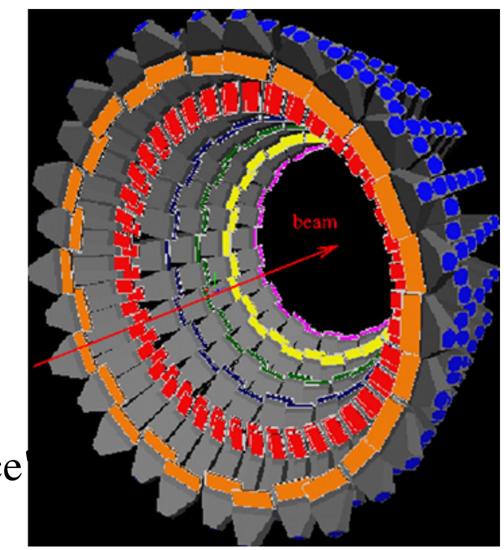
- Two quartz-lightguide configurations under consideration: Straight and Angled
- Spectrosil 2000 quartz (15mm thick), Miro Silver 4270 lightguide, 3 inch PMT
- Lightguide lengths range from 15 to 80 cm
- Prototypes for all six rings tested
- Benchmarked optical G4 Monte Carlo







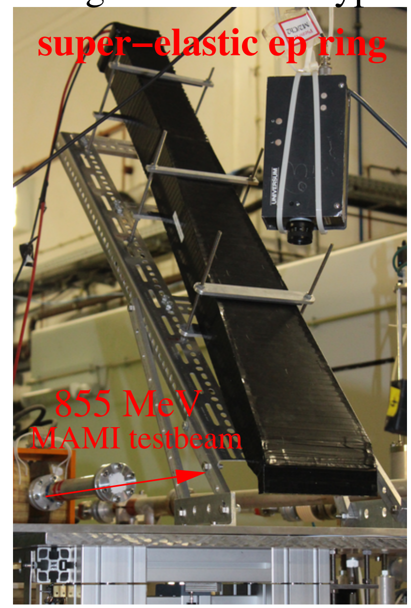




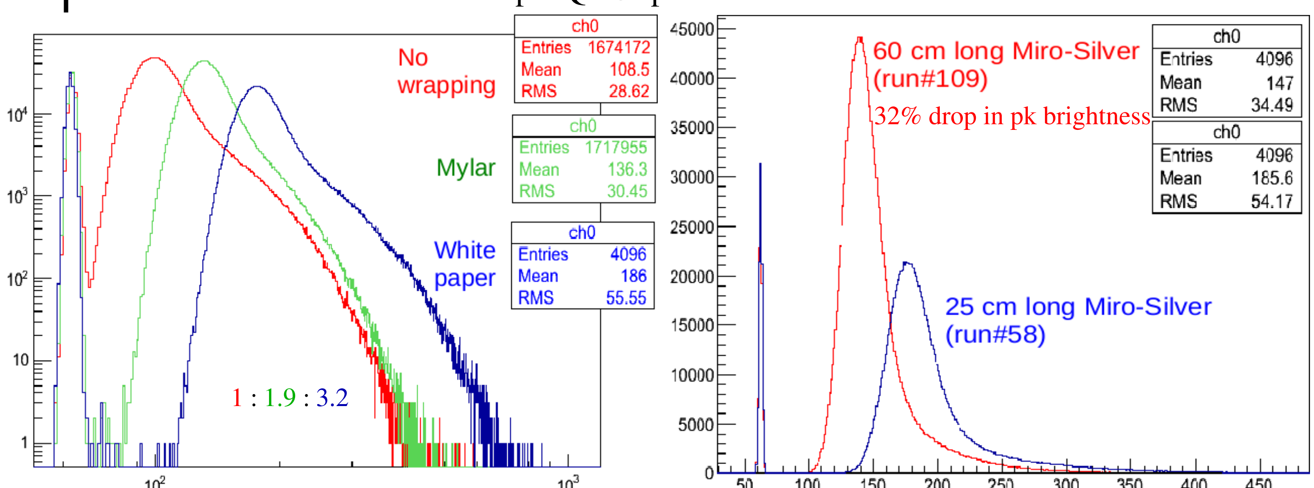
MOLLER Prototype Detector Beam Tests

- Several beam tests conducted since fall 2013 at MAMI with the P2 collaboration
- What's been studied: Pk # of PE's and Resolution
  - –Different quartz polishes and thicknesses
  - –Different quartz wrappings: Al. mylar, Tyvek,...
  - –Different LG materials: UVS, MIRO-silver, ...
  - –Beam - quartz position and angle scans
  - –Scintillation/Cherenkov bkgds from air in LG
  - –Angled vs. Straight configurations

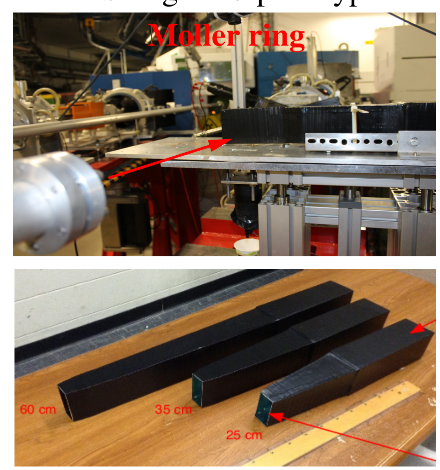
Angled R1 Prototype



Example QDC spectra from beam studies



Straight R5 prototype



Recent Testbeam Results

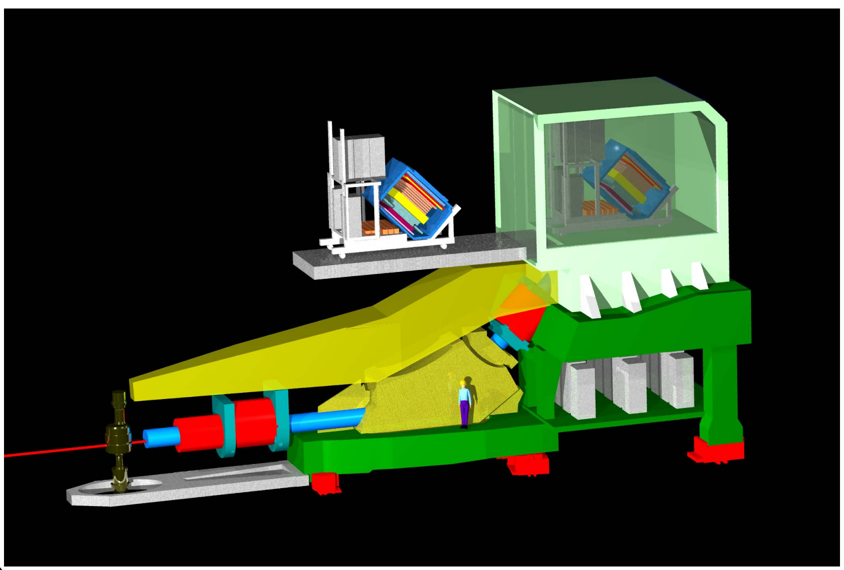
Detector Ring	Moller	Moller	Super-elastic	Super-elastic
Config	Angled	Straight	Angled	Straight
LG length (cm)	35	25	80	56
Mean (PE's)	32.9	24.2	20.6	16.2
RMS (PE's)	8.45	8.04	8.94	8.3
Res. (%)	25.7	33.2	43.4	51.2
Excess Noise (%)	3.2	5.4	9.0	12.4

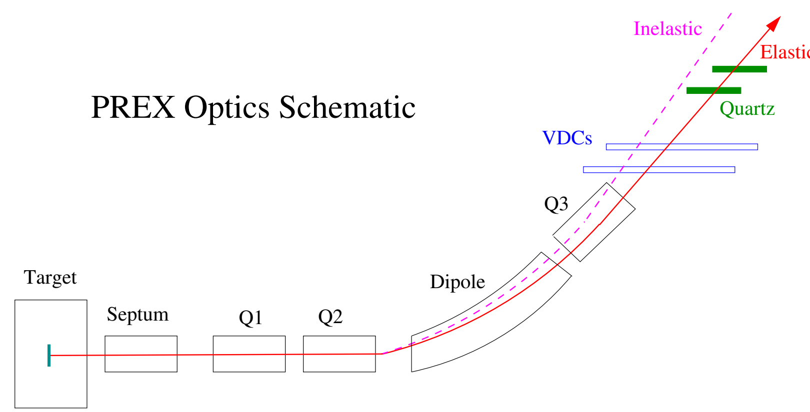
$$\text{Excess noise} \equiv \sqrt{1+\left(\frac{\sigma}{<n>}\right)^2}-1$$

- "Angled" configuration gives better results (a bit surprising)
- Note: "Straight" config quartz not double bevelled and its LG funnel not optimized for these results. Will repeat test at MAMI next June.

PREX/CREX Experimental Setup in Hall A (Spectrometer & Detectors)

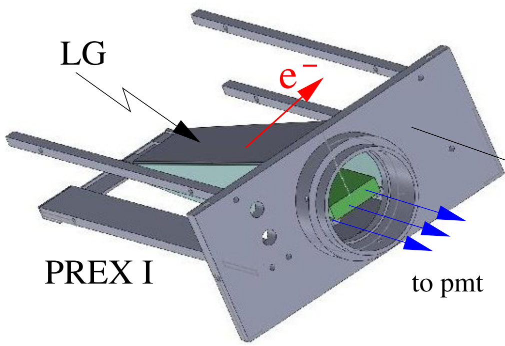
- PREX: $\langle A_{PV} \rangle = 0.6\text{ppm}$, $\delta(A_{PV}) = 3\%$ $\Longrightarrow R_n^{Pb} \sim 1\%$
  $\longrightarrow$ 1 GeV beam, $\theta_e = 5^o$, $Q^2 \approx 0.009$ GeV, 10% X_o ^{208}Pb tgt
- CREX: $\langle A_{PV} \rangle = 2\text{ppm}$, $\delta(A_{PV}) = 2.4\%$ $\Longrightarrow R_n^{Ca} \sim 0.6\%$
  $\longrightarrow$ 2.2 GeV beam, $\theta_e = 4^o$, $Q^2 \approx 0.022$ GeV, 6% X_o ^{48}Ca tgt
- Scattered electrons transported to detector plane quartz; HRS separates elastic and inelastic events — Only elastic events detected

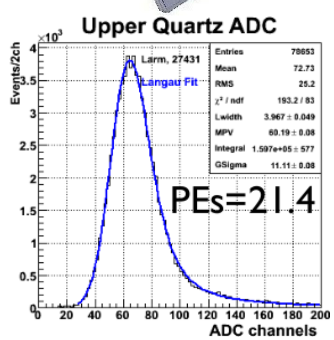




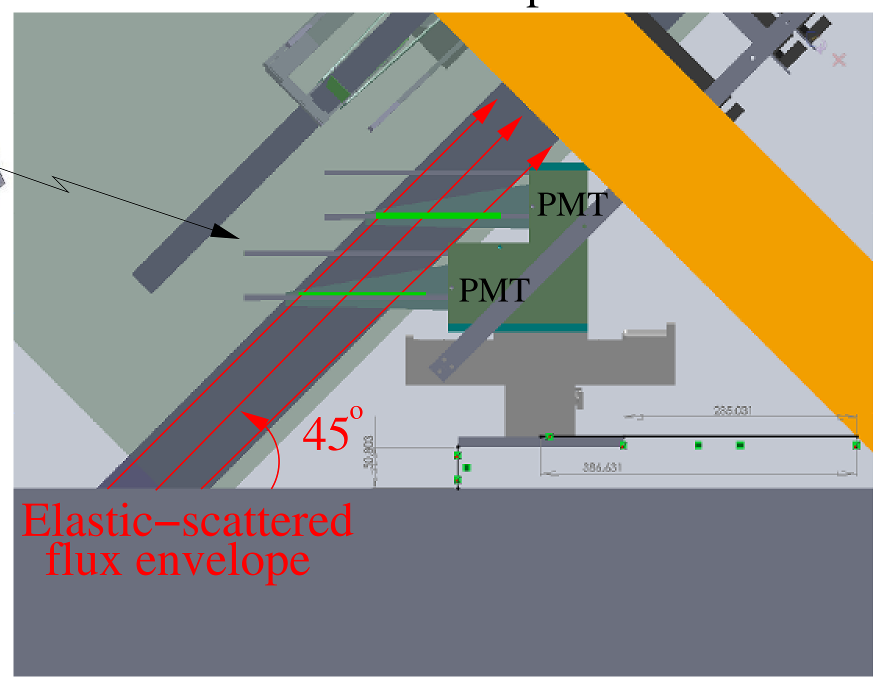
Detector designs: PREX I (ran in spring 2010)

- Conservative design with modest light output per electron
- Used Spectrosil 2000 quartz, UVS LGs, and 2 inch pmts
- 45^{o} incident electrons $\Rightarrow$ only get $\sim$half the Cherenkov light cone
- Focal plane elastic-env. footprint (at quartz) is small $\sim$3 by 12 cm^2
- Quartz bar dimensions: 15cm long $\times$ 3.5cm wide $\times$ 6(10)mm thick
- Overall performance: $\sim$20 PEs/e^- with 30% relative width





HRS focal plane

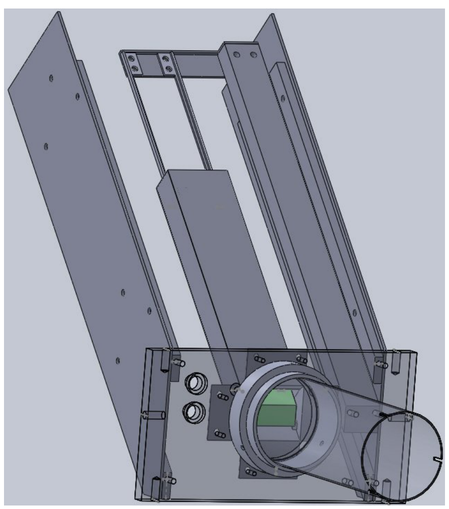


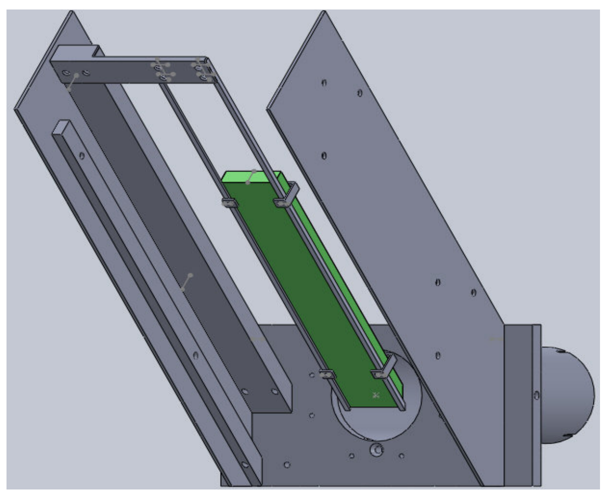
Detector design: PREX II & CREX

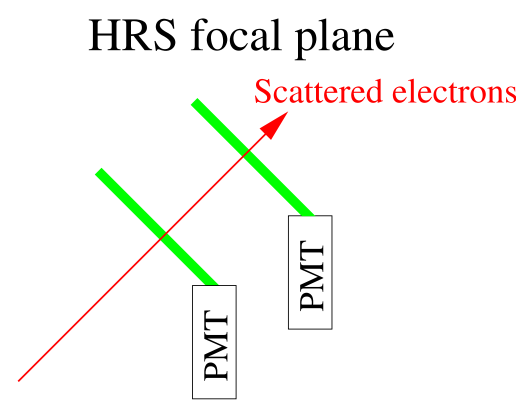
- More aggressive design – maximizes light output per electron
- PREX II will run at same kinematics as PREX I ⇒ FP dists same
- CREX kinematics are different ... FP simulations underway
- Major design change: electrons enter quartz at normal incidence
- Quartz - PMT separation is 0cm (instead of 7.7cm for PREX I)

→Quartz bars are longer...so can use quartz TIR as the light guide

- 45^{o} angle between scattered flux and pmt – reduces Landau tail
- Overall performance: ∼60 PEs/e^{-} with 15% relative width

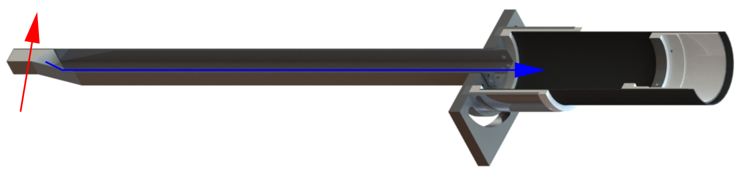


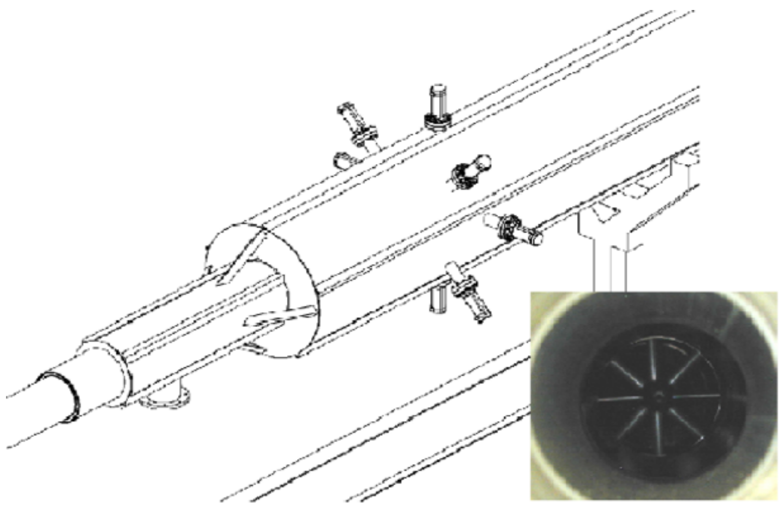




New (re-designed) Hall A Luminosity Monitor

- 8 quartz Cherenkov detectors with air-core light guides placed symmetrically around beam line 7.5m downstream of target
- Uses 3.3cm long × 2.0cm wide × 1.3cm thick quartz placed 5.5 cm from beamline center ⇒ 0.5° polar angle acceptance
- 40cm Miro-silver 4270 LG, 2 inch PMT with unity gain base





Summary

- MOLLER integrating detector baseline design and performance specs nearly complete
- Plans for MAMI test beam run in June 2016 — should decide on angled or straight config
- General findings:
  - –Miro-silver 4270 LG gives best performance
  - –Minimum quartz thickness for Moller ring is 15mm
  - –Standard optical polish from vendor is good enough
  - –Wrapping quartz in Al. mylar ∼doubled light output
- New PREX II and CREX detector designs give 3x better performance as compared to PREX I
- New Hall A Lumi detectors built this fall; installing next week and plans for beam tests in December

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