# Thin Quartz Cherenkov Detector R&D

## (for PREX, CREX, and MOLLER)

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# Quartz Cherenkov Detector Development

- Optical Monte Carlo Simulation
  - –Using GEANT4, C++ based
  - –Model precise geometry of detector concepts
  - –Model precise geometry of Cosmic or Testbeam setup
  - –Use real data to benchmark (or vet) sim. results
  - –Once benchmarked, use to further optimize detector design
- Prototyping – SolidWorks CAD $\longrightarrow$ Machine Shop
- Cosmic-ray tests at ISU
  - –Constructed cosmic test stand
  - –Established counting Data Acquisition System (DAQ)
- Testbeam at Mainz, Germany
  - –Take prototypes to the Mainzer Microtron (MAMI)
  - –MAMI electron testbeam: 855 MeV, 1 - 10 kHz
  - –Runs in Oct 2013, June 2015, and June 2016 (anticipated)

# Student Research Assistants

- Present Students:
  - –PhD candidate Carlos Bula(2012)
  - –Undergraduates (2015): Max Sturgeon, Chase Juneau
    Daniel Sluder

- Past Undergraduate RAs:

–Kevin Rhine(2014) – Grad. 2015. Grad. stud. ISU Math

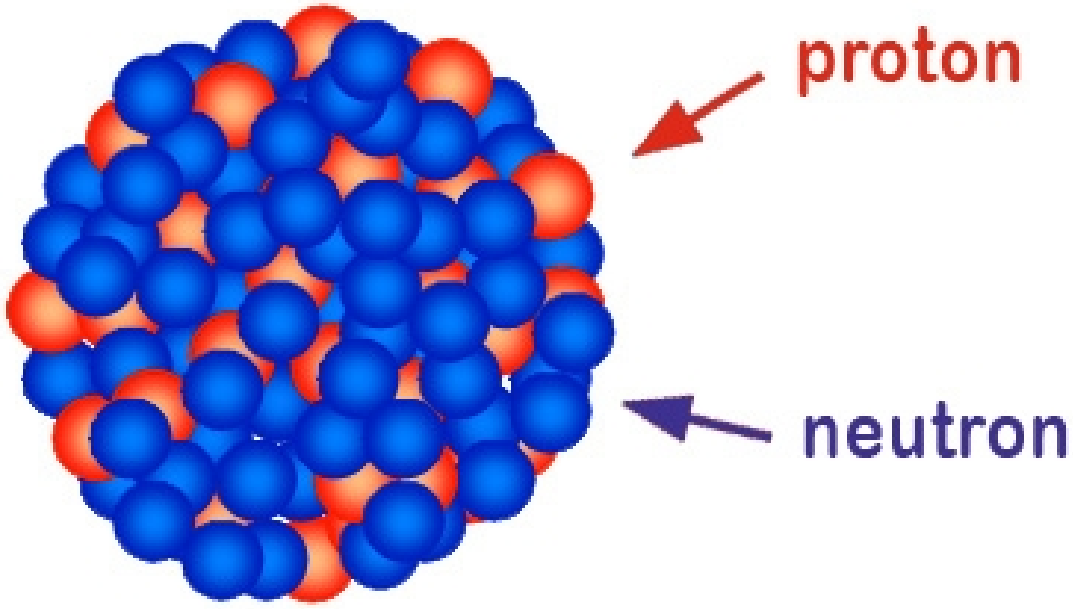
–Brady Lowe(2013) – Grad. 2015

–Blake French(2015) – Grad. 2015. Job at Micron

–Dayah Chrisman(2014) – Grad. 2015. Grad. Stud. MSU

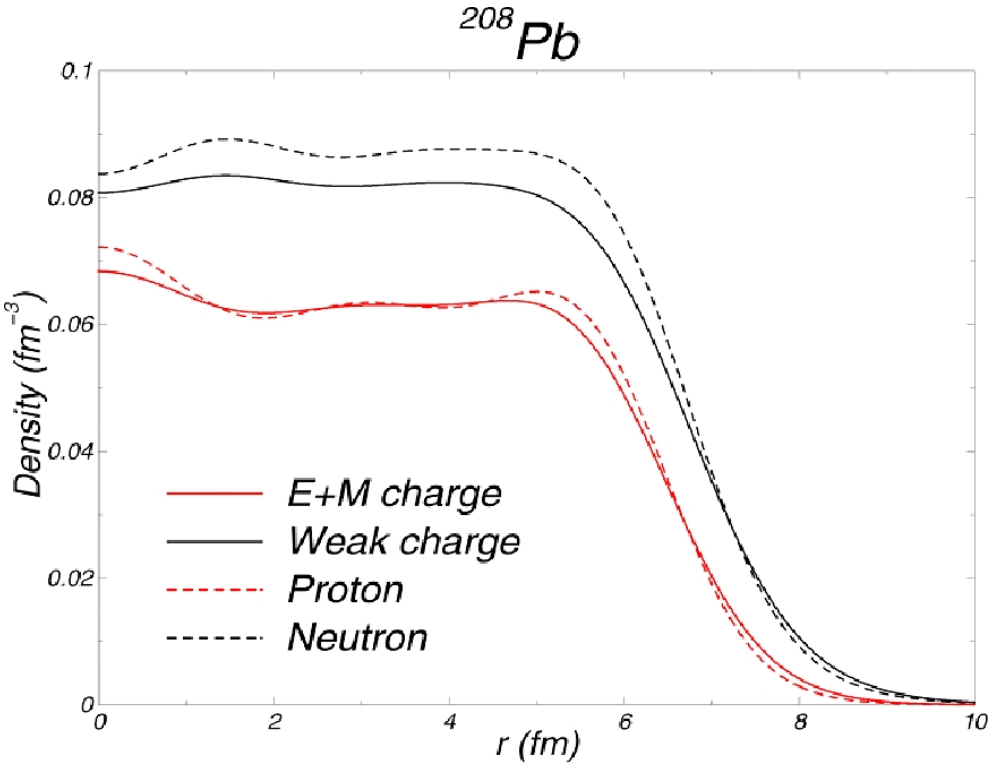
–Will Gorman(2013) – Grad. 2014. Grad. Stud. U. of Rochester

## What is the size of a $^{208}$Pb nucleus (82p+126n)?



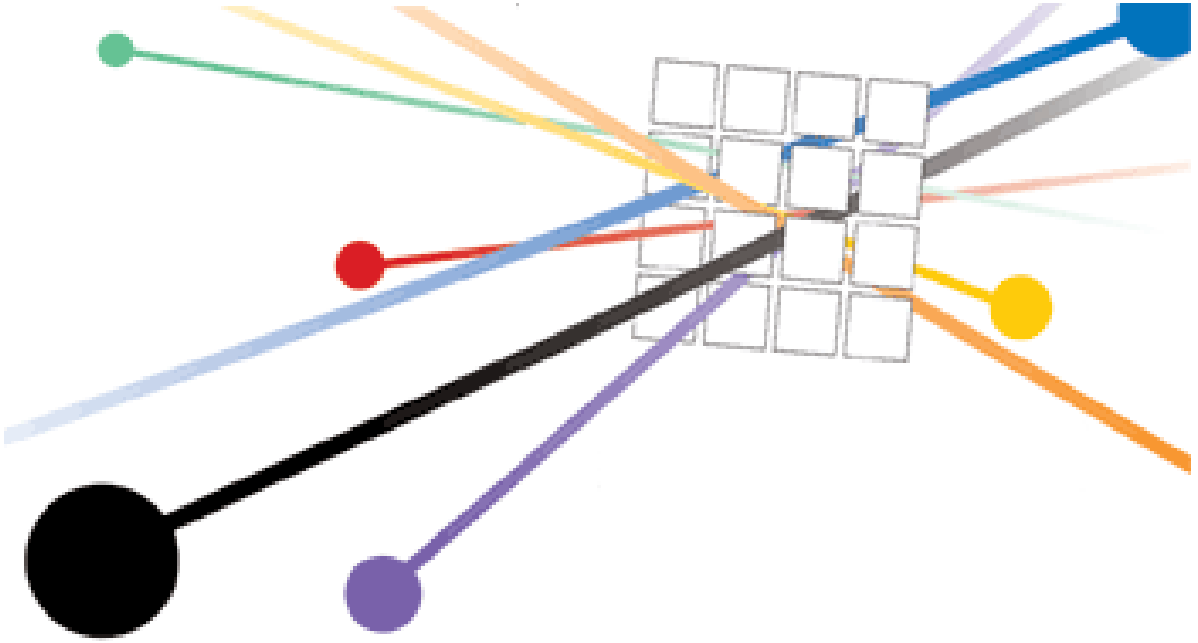

- What do we mean by size? The mass radius, the charge radius?
- PREx (Pb Radius Experiment) addresses this question in a unique way: Uses a "Weak" nuclear force probe to measure how much neutrons stick out past protons (The Neutron "skin")
- CREx (Calcium Radius Experiment) performs same measurement but on $^{48}$Ca nucleus

# Mass versus EM Charge Radii of $^{208}$Pb



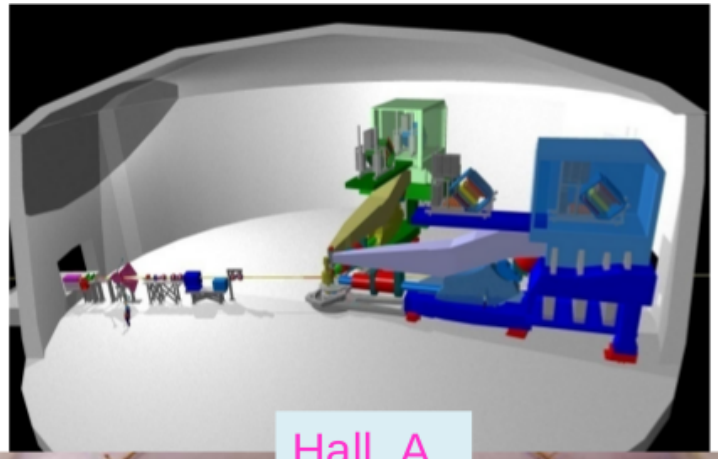

- Electromagnetism: Force mediated by $\gamma$ exchange; Protons have EM charge "+e" while neutrons have 0...
- Weak Nuclear: Force mediated by $Z^0$ and $W^{\pm}$; **Neutrons have 12 times more Weak charge than protons**

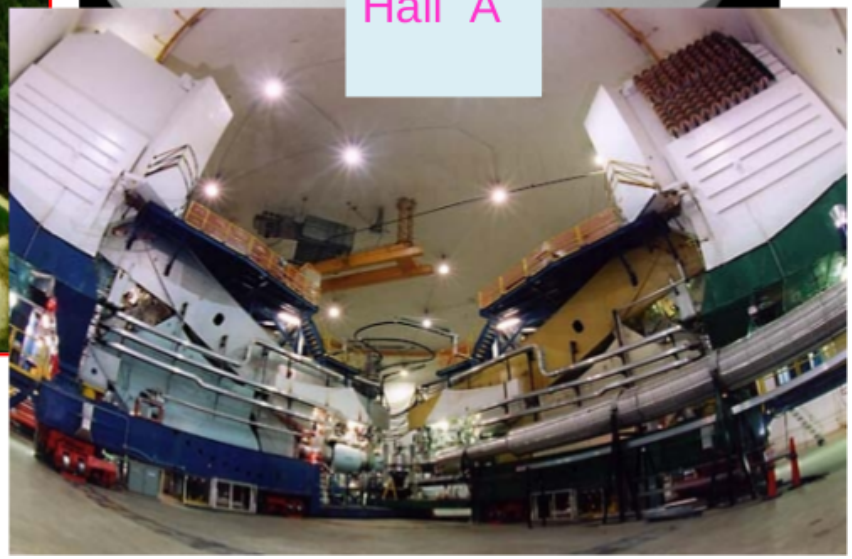
# Is there Physics Beyond the Standard Model?



- Indirect search or high-intensity frontier (PVeS expts.) complements direct search or high-energy frontier (CERN LHS expts.)
- The MOLLER experiment leverages the extreme precision of Electroweak Theory to search (indirectly) for the presence of new physical interactions that are so "weak" they have yet to be observed.

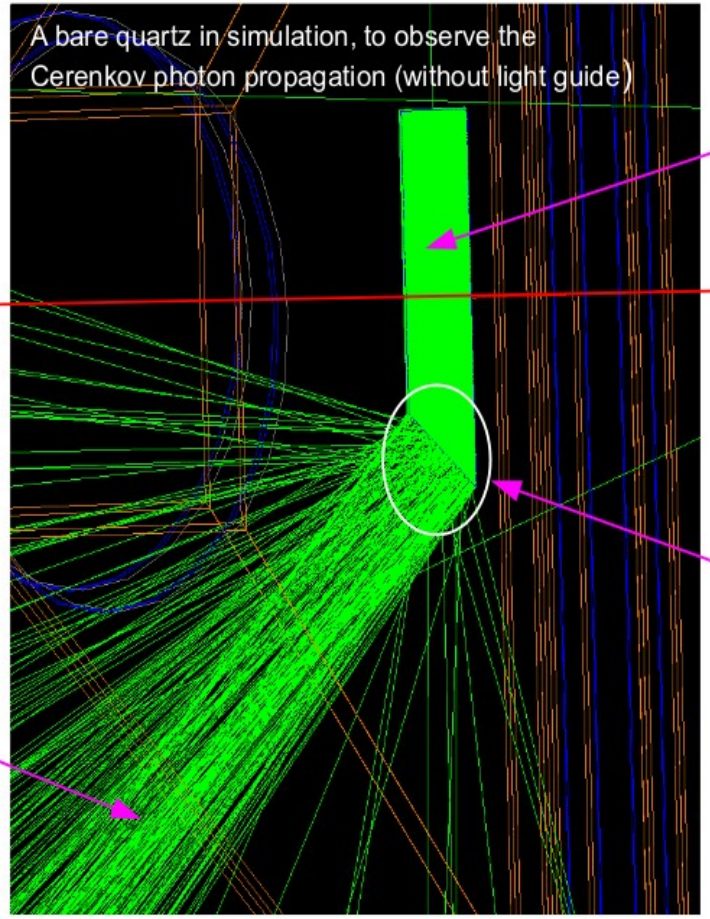
# Jefferson Lab Hall A (Newport News, Virginia)



# Cherenkov Production in Quartz

## Light Propagation without Light Guide

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## Quartz Detector Design/Construction Projects Ongoing at ISU

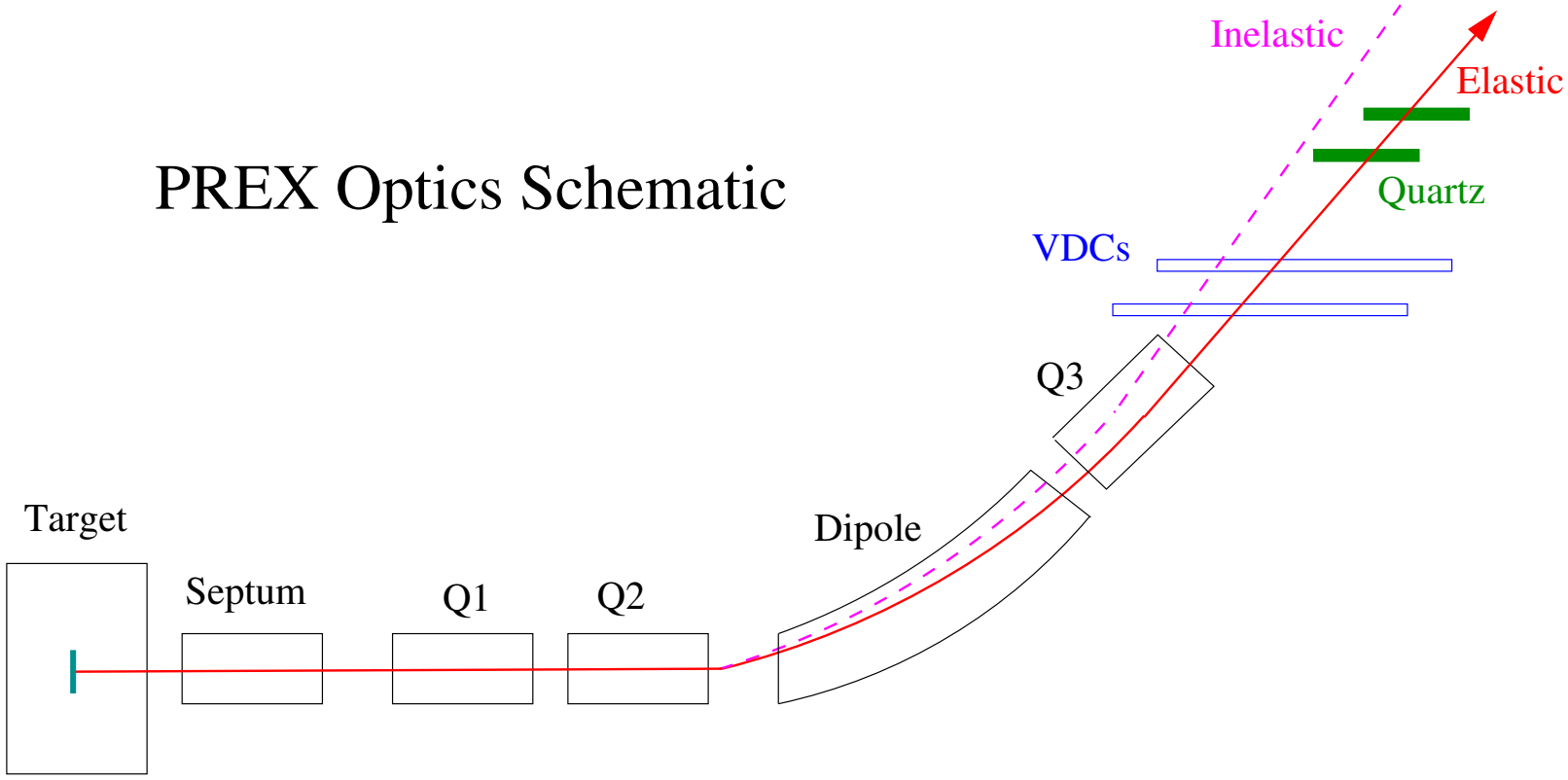
- PREX II/CREX Main Detectors
- Hall A Luminosity Monitors (Lumis)
- MOLLER Shower Max Detectors
- MOLLER Small Angle Lumis

### Other Detector R&D-supporting Projects

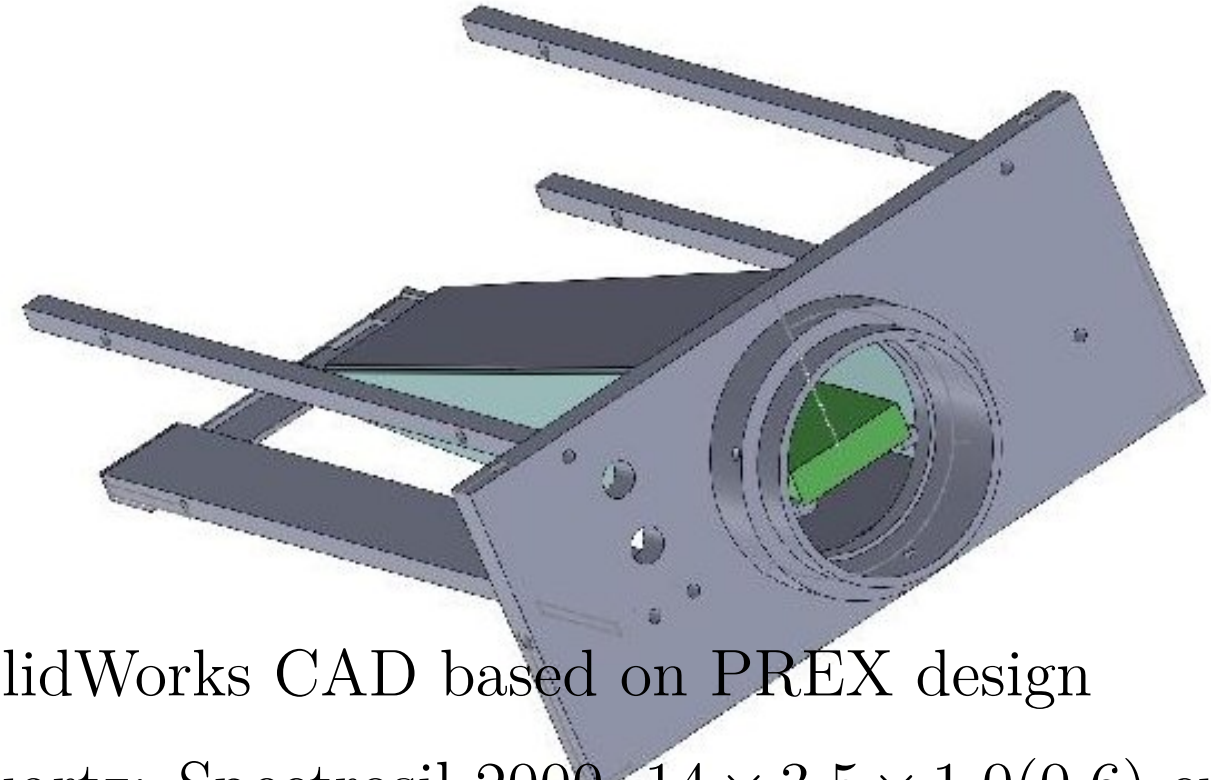
- Monte Carlo benchmarking; Cosmic Tests; Beam Tests
- PMT gain measurements
- PMT linearity measurements
- Meas. Reflectivity($\lambda$) at various angles off aluminum light guide
- Meas. Absorbance($\lambda$) in Spectrosil 2000 quartz

# PREX/CREX Main Detectors

## PREX Optics Schematic

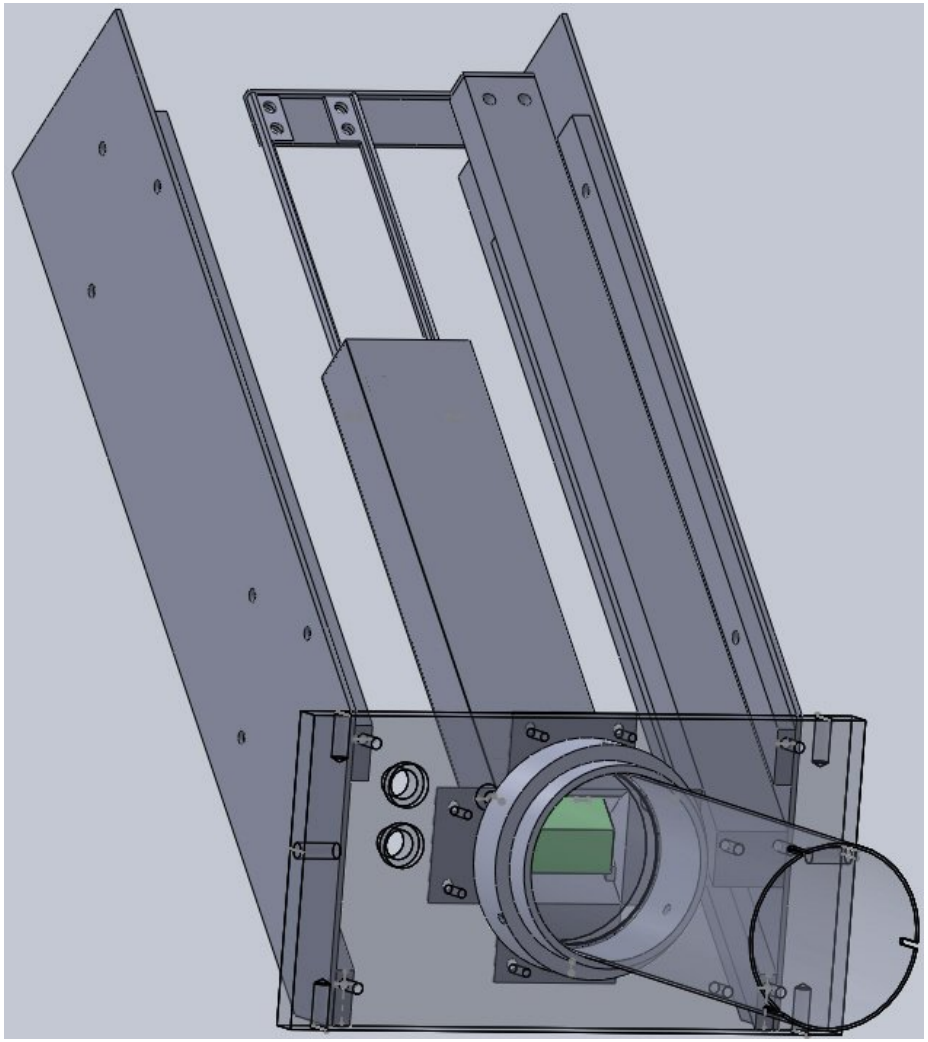


# Baseline prototype (PREX I) Detector



- SolidWorks CAD based on PREX design
- Quartz: Spectrosil 2000, $14 \times 3.5 \times 1.0(0.6)$ cm$^3$, 45$^o$ bevel on one end, optical polish all sides
- Light guide: Anolux Miro-silver 4270AG, ...

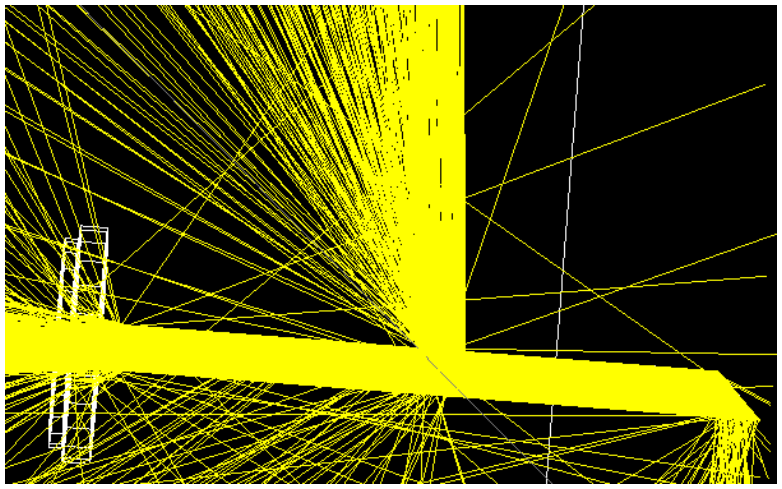
# New Detector Prototype (PREX II/CREX)



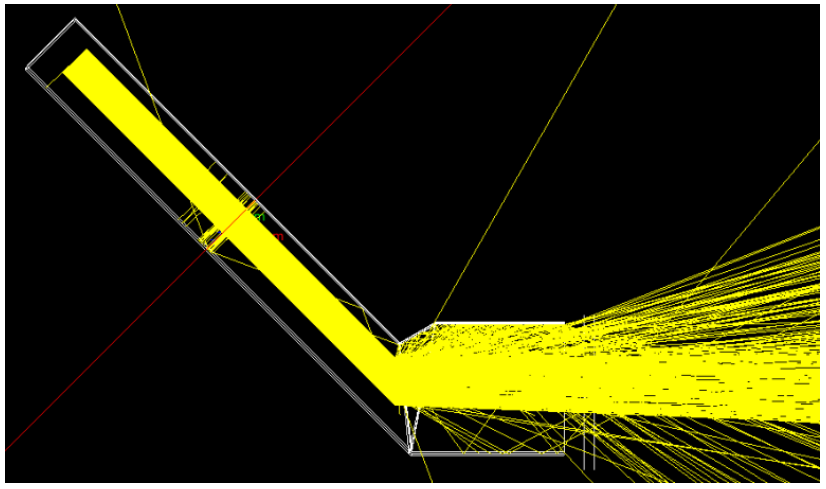
- Designed by Brady Lowe using SolidWorks

## Essential Differences b/t New and Old Designs

- Old design gives up back-half of Cherenkov cone, whereas new design does not.
- Old design poses $\sqrt{2}$ times more material than new design which results in larger Landau tail for old design.
- New design's light output is much more sensitive to incident angle than old design

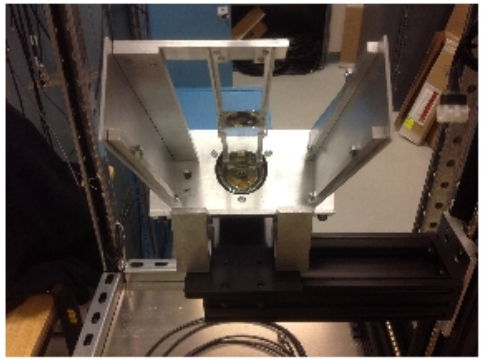


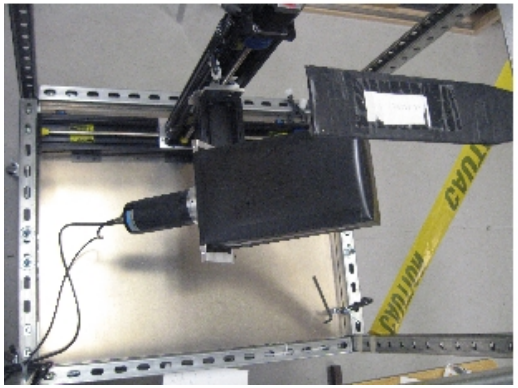
Old Design

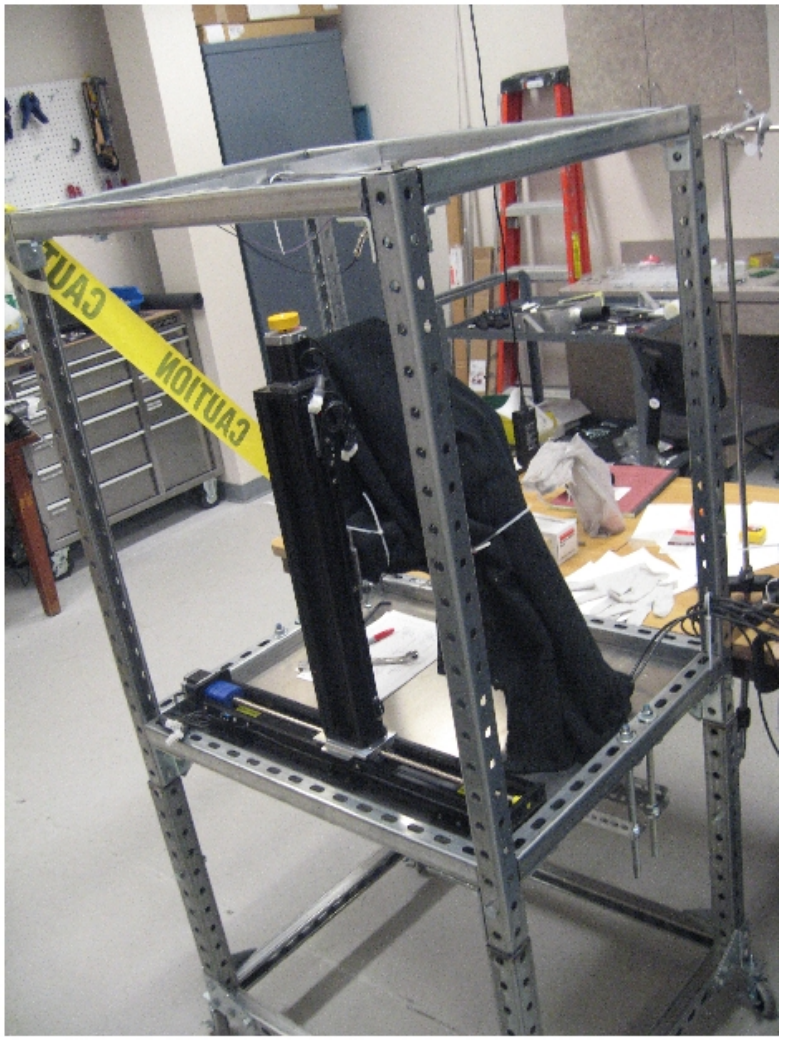


New Design

# Cosmic/Beam Test Stand

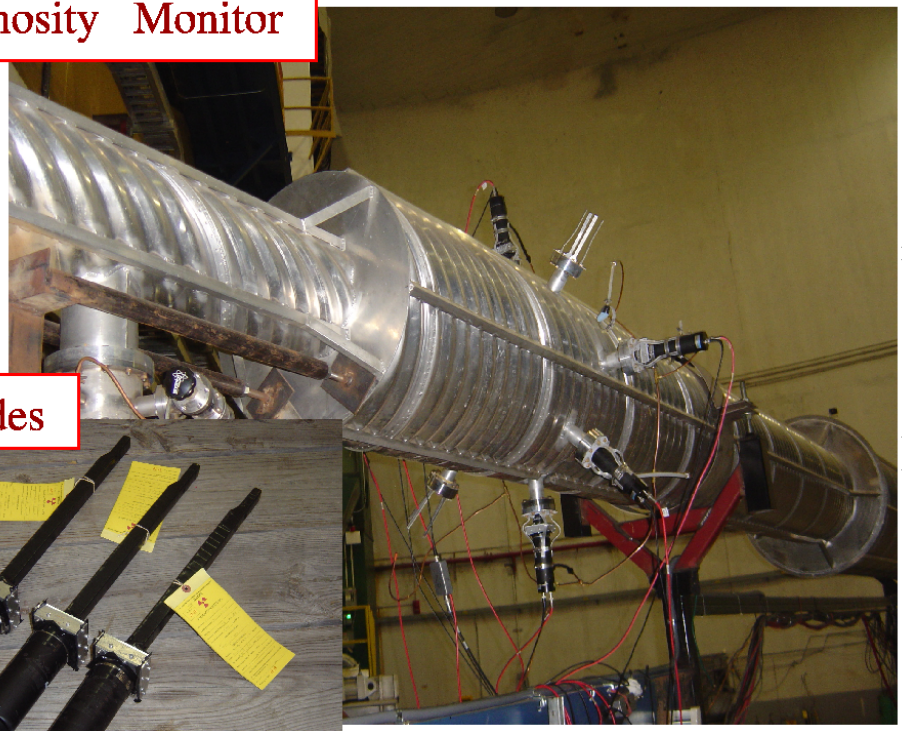




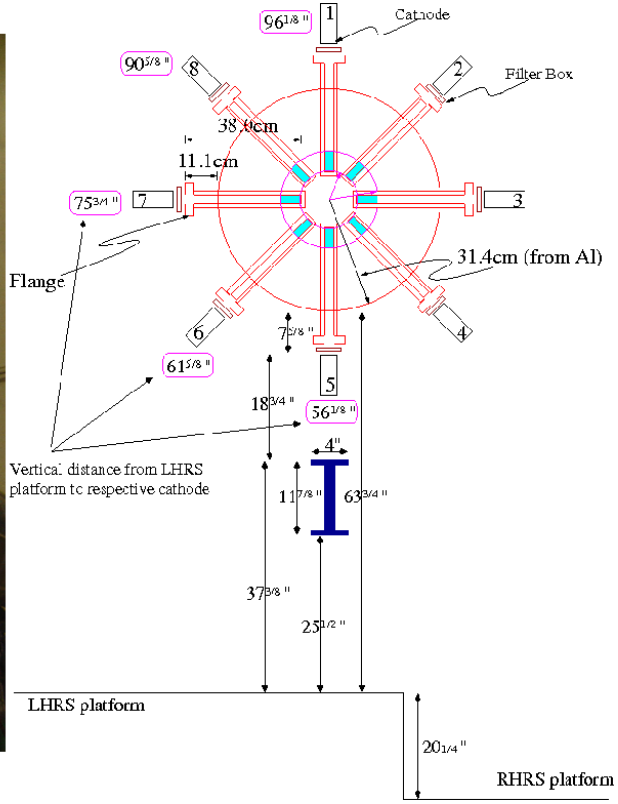


# Hall A Luminosity Monitor

Luminosity Monitor

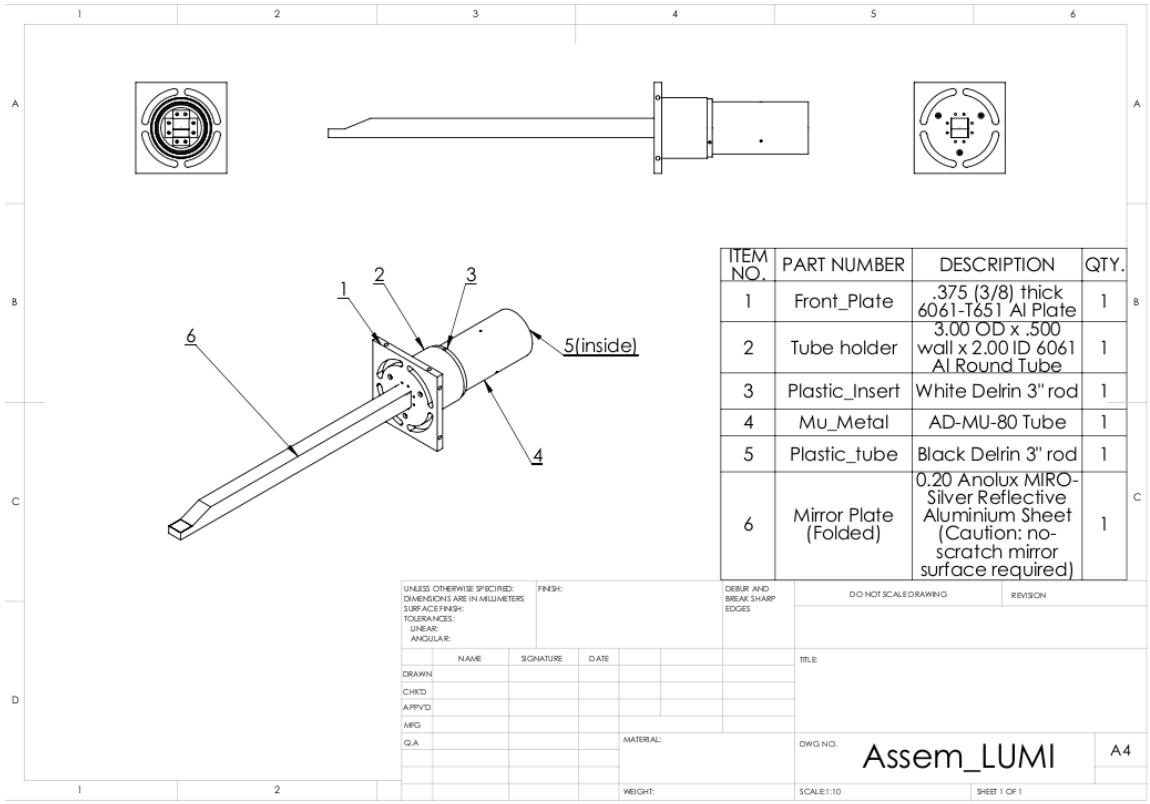


Upgrades




- 8 quartz Cherenkov detectors with air-core light guides placed symmetrically around beam line 7.5m downstream of target (∼0.5 deg polar angle acceptance)

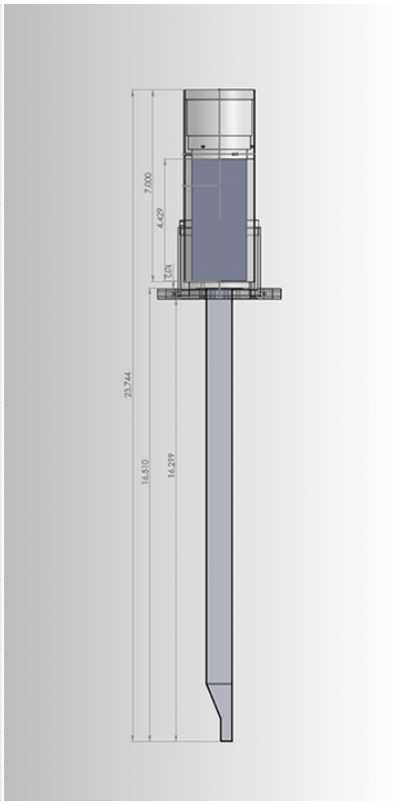
# New Hall A Luminosity Monitor




| ITEM NO. | PART NUMBER | DESCRIPTION | QTY. |
|---|---|---|---|
| 1 | Front_Plate | .375 (3/8) thick 6061-T651 Al Plate | 1 |
| 2 | Tube holder | 3.00 OD x .500 wall x 2.00 ID 6061 Al Round Tube | 1 |
| 3 | Plastic_Insert | White Delrin 3" rod | 1 |
| 4 | Mu_Metal | AD-MU-80 Tube | 1 |
| 5 | Plastic_tube | Black Delrin 3" rod | 1 |
| 6 | Mirror Plate (Folded) | 0.20 Anolux MIRO-Silver Reflective Aluminium Sheet (Caution: no-scratch mirror surface required) | 1 |

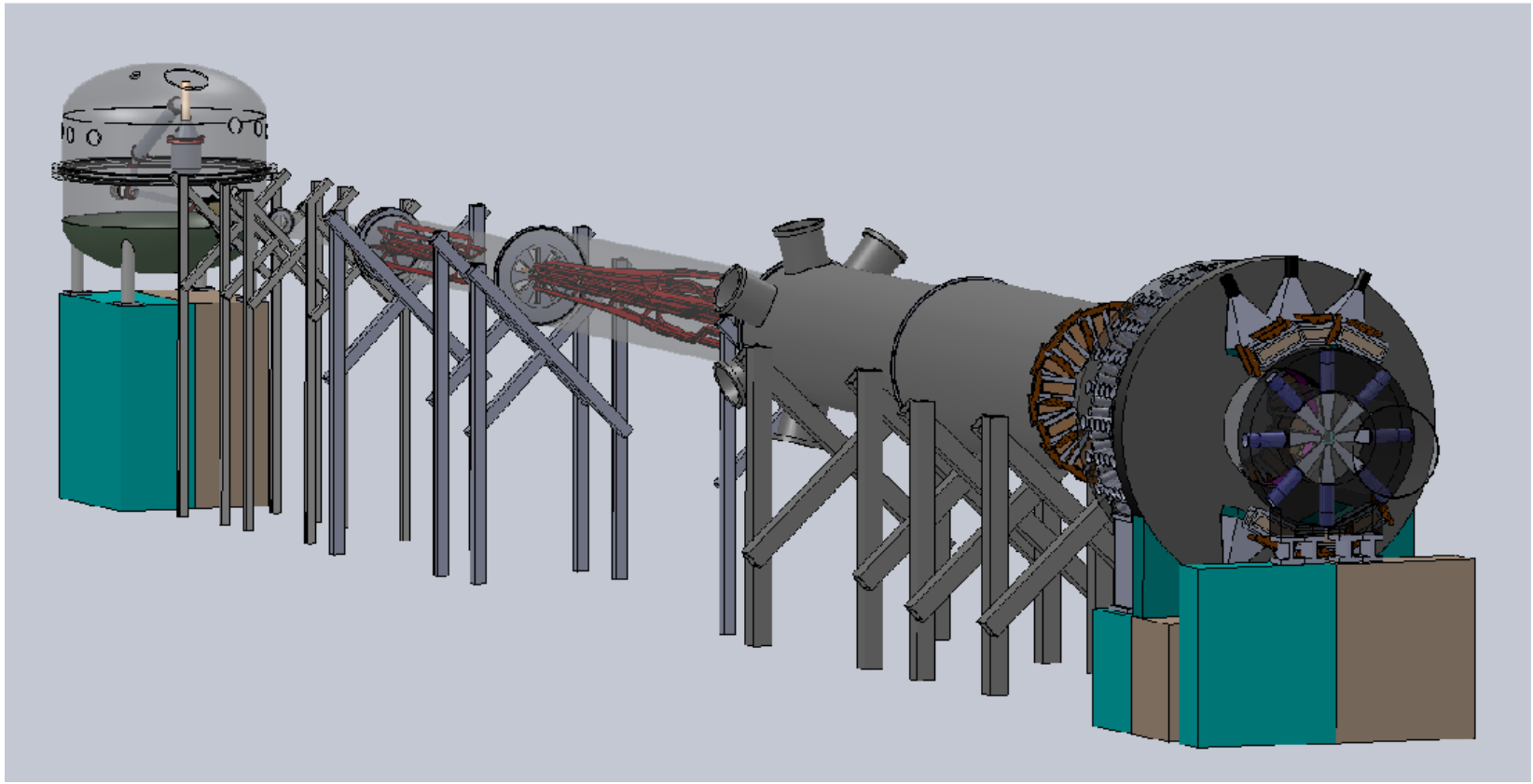
Assem_LUMI

A4



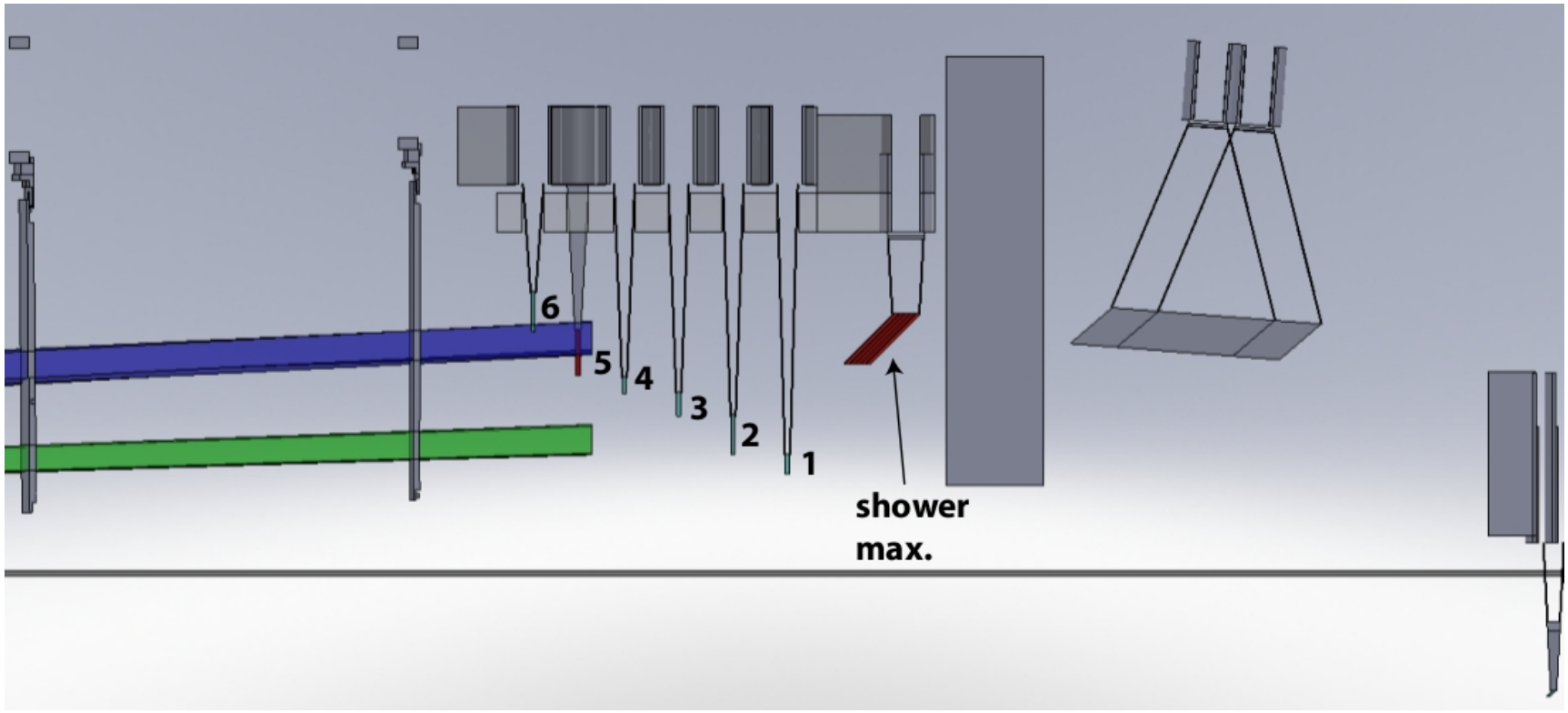
- CAD drawings (Carlos), Lightguide design (Kevin Rhine), lightguide folding (Max Sturgeon). In the process of building and installing 8 new Lumis in Hall A this fall.

# MOLLER Experiment at Jlab Hall A



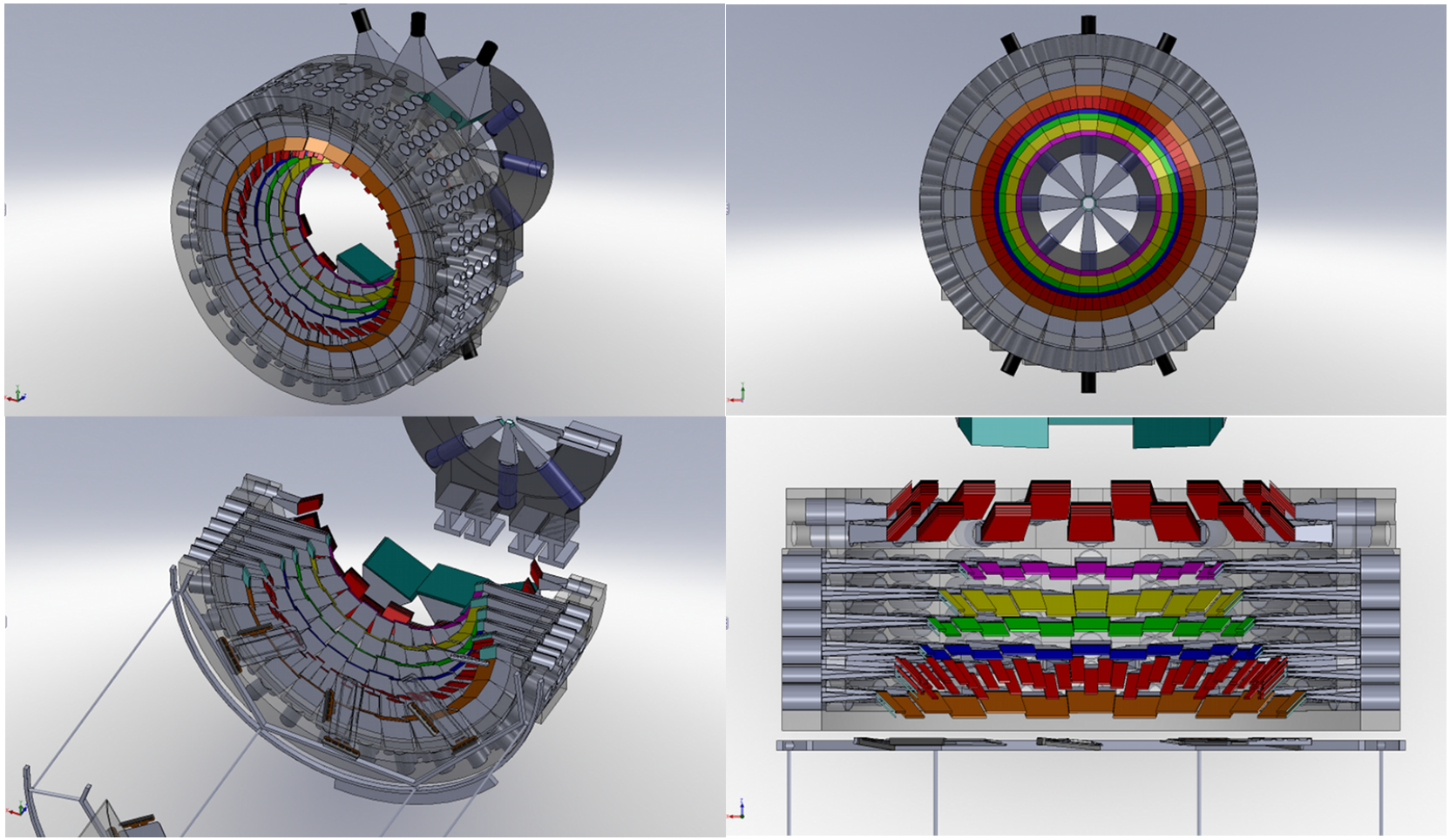
- Long/skinny spectrometer. 28 meters between target and main detector rings

# Showermax Detector

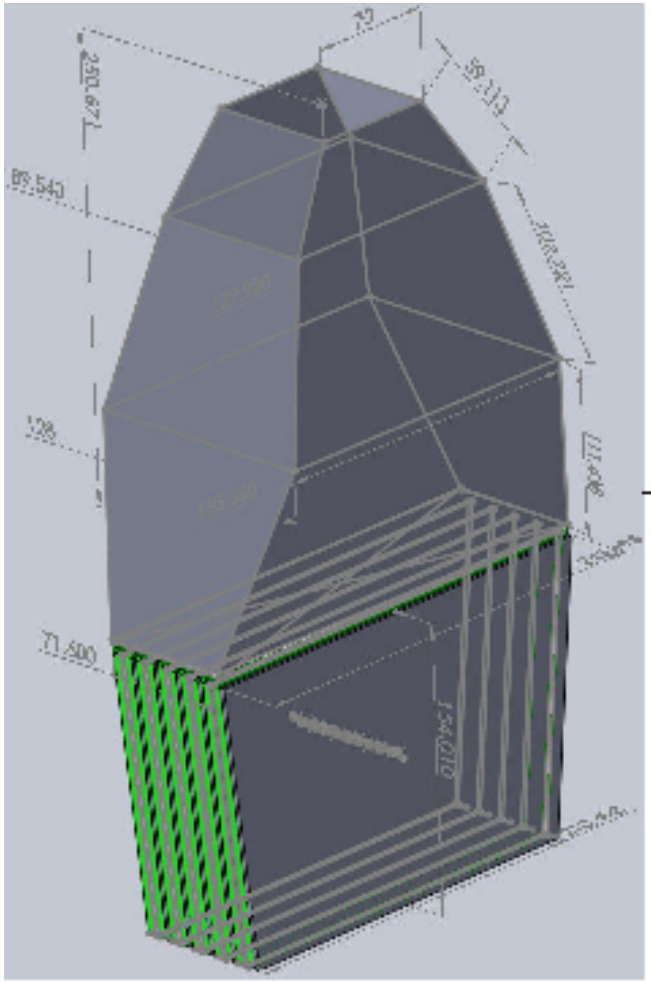


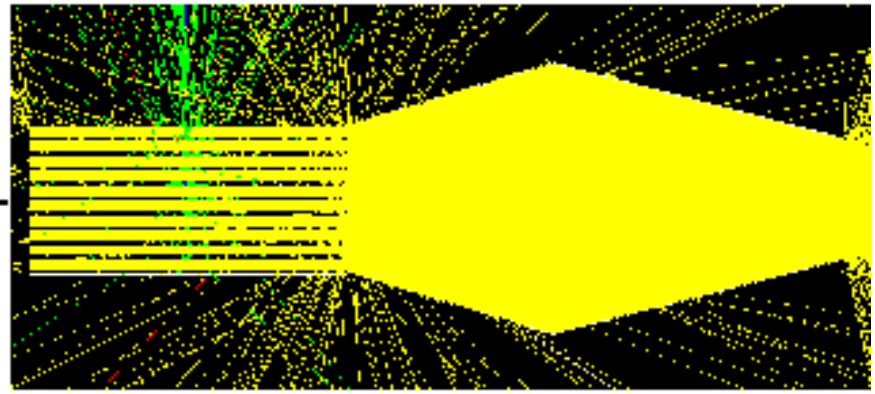

- Provides additional measurement of e-e ring flux
- Weights flux by energy $\Longrightarrow$ less sensitive to low energy/low light bkgds

# MOLLER Quartz Detector Ring Assemblies



# Shower Max Baseline Prototype (Jan2015)





10 pieces of quartz (5mm thick)
10 pieces of W (2.4mm thick)
$0.41 + 6.8 = 7.2\ X_0$
Using 3" PMT

## Summary and Plans

- Final PREX II/CREX detector test beam next June in Mainz, Germany. Design is near final
- New Hall A Lumis built/installed/tested this Fall at JLab
- Continued benchmarking of GEANT 4 Optical Monte Carlo
- Finalize baseline Shower Max design and start prototyping – test with 8GeV SLAC testbeam next year
- Establish PMT Linearity test bench and integrating DAQ
- I'm always on the lookout for a talented student to hire, so email me for a lab tour if you're interested: mcnudust@isu.edu

More info can be found at http://www.isu.edu/∼mcnudust