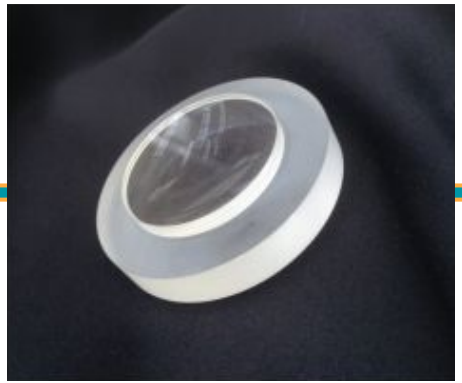
Studies of prototype 3-component lens in CERN test beam and on a test bench at ODU



Lee Allison[1], T. Cao[2], R. Dzhygadlo[3], T. Horn[4], C. Hyde[1], Y. Ilieva[2], G. Kalicy[1], P. Nadel-Turonski[5], K. Park[1], K. Peters[3], C. Schwarz[3], J. Schwiening[3], J. Stevens[5], W. Xi[5], and C. Zorn[5].

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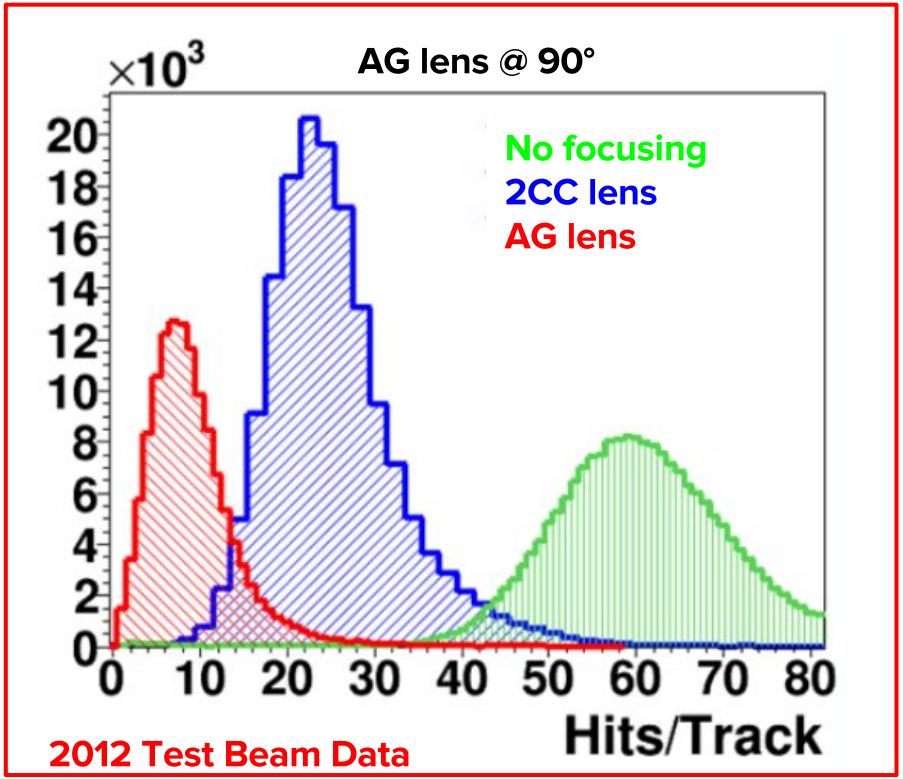
4) The Catholic University of America, Washington, DC 20064
5) Thomas Jefferson National Accelerator Facility, Newport News, VA 23606

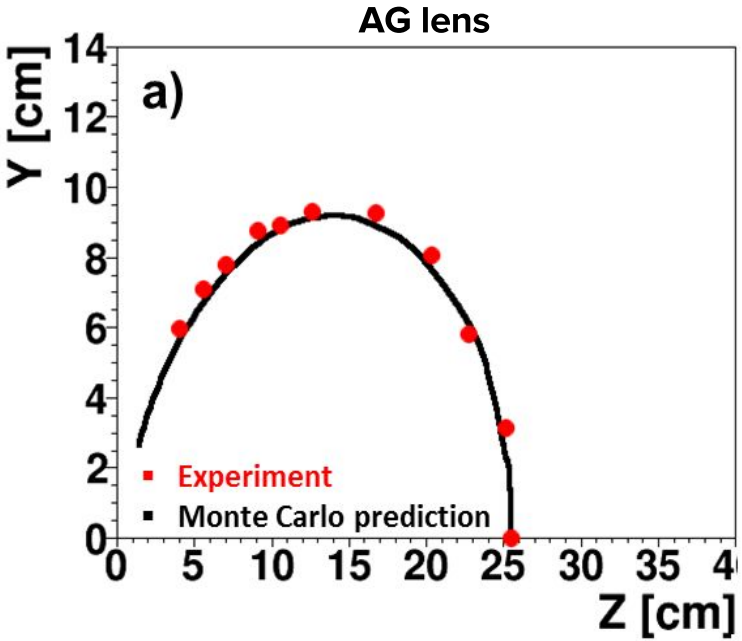
Challenges of standard focusing lenses

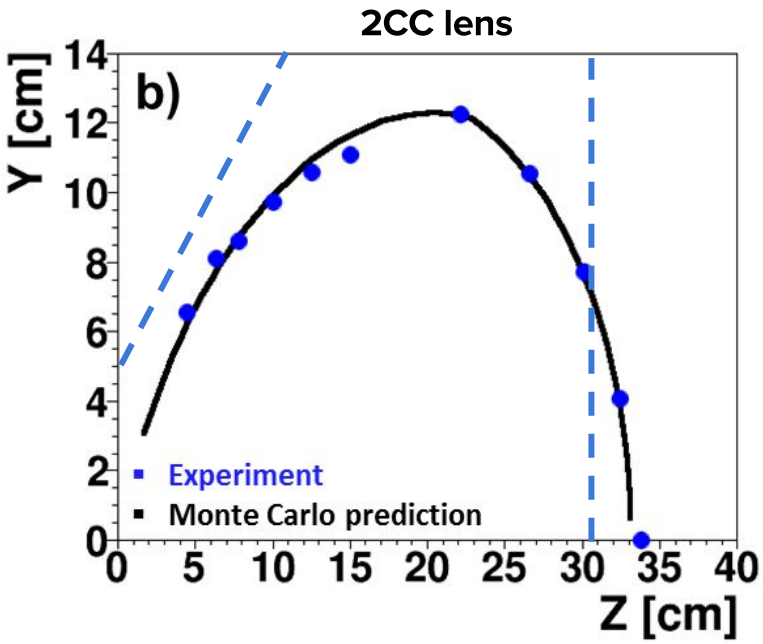
- The standard air gap (**AG**) lens has very low photon yield at angles close to perpendicular
- A 2-component cylindrical (**2CC**) lens that was coupled directly to the expansion volume solved this photon loss problem



Challenges of standard focusing lenses

Both AG lens and 2CC lens fail to focus steeply angled photons onto the photo-detector plane

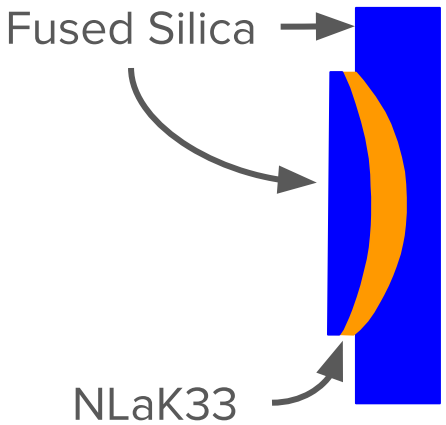


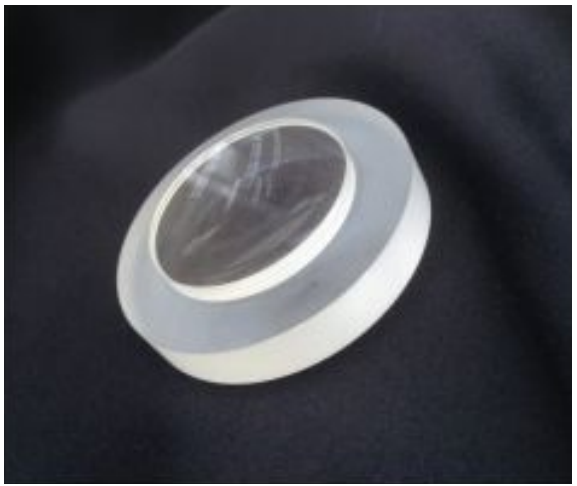


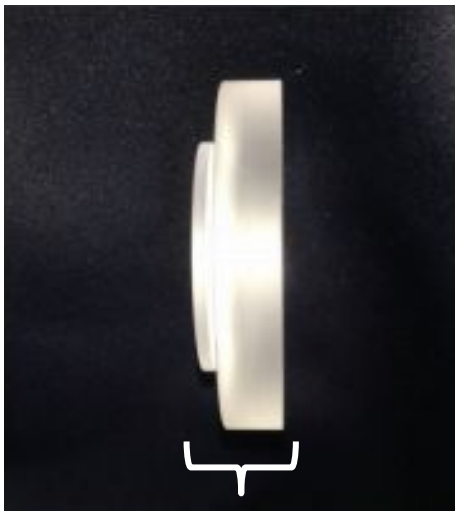
Prototype 3-component spherical (3CS) lens

Radii can be changed to modify the shape and position of the focal plane

Prototype built with radii of 47mm and 29mm

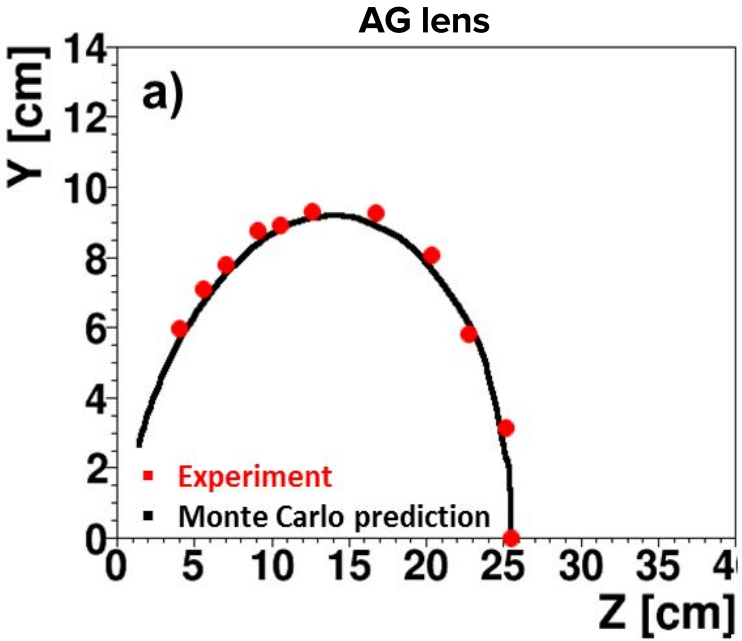


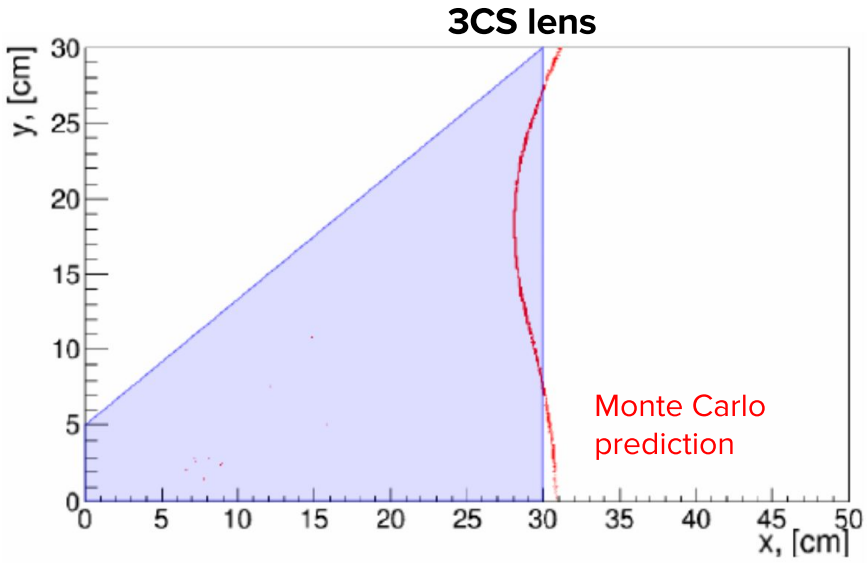




Advantages of a 3CS lens

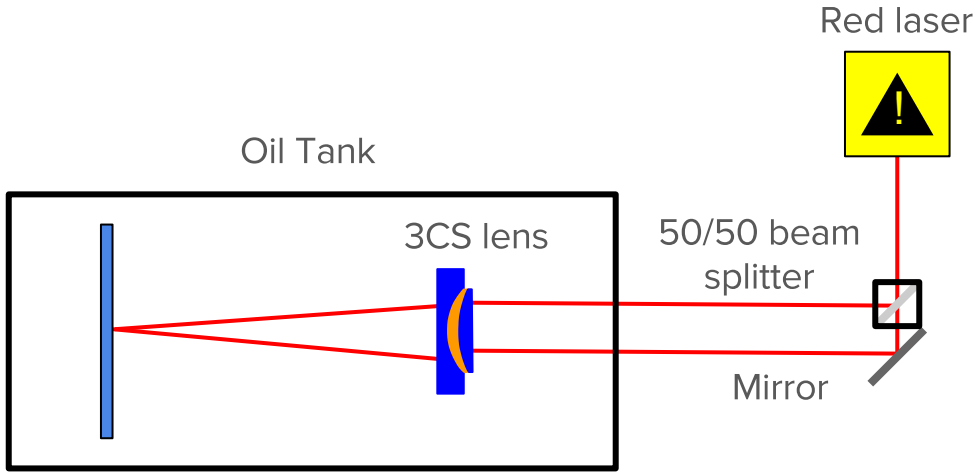
Simulation shows that the focal plane of a 3-component spherical (**3CS**) lens can contour more closely to the detector plane





Testing 3CS lens

- Measurements on test benches
  - Mapping focal plane at ODU
  - Radiation hardness testing at JLab
- Measurements in test beam
  - Evaluating performance with PANDA barrel DIRC prototype at CERN

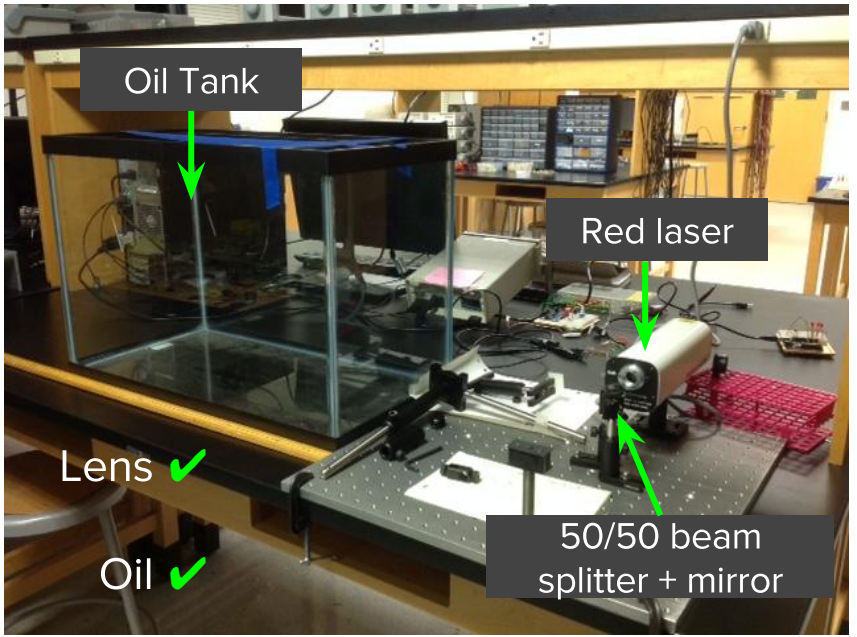


Using mineral oil that matches refractive index of lens

Testing 3CS lens

- Measurements on test benches
  - Mapping focal plane at ODU
  - Radiation hardness testing at JLab
- Measurements in test beam
  - Evaluating performance with PANDA barrel DIRC prototype at CERN

Laser setup at ODU



Testing 3CS lens

- Measurements on test benches
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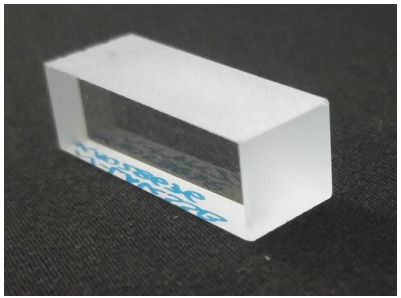
3CS lens

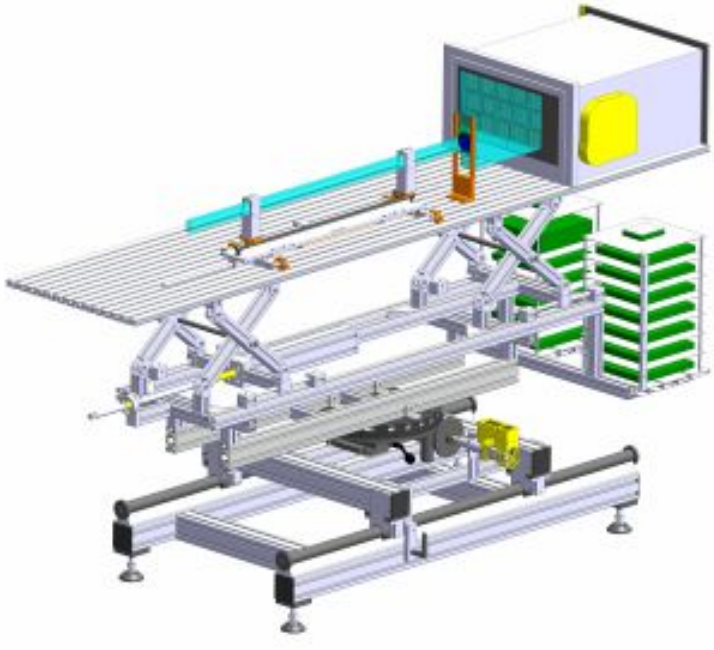
pure NLaK33



Irradiating pure NLaK33 material and 3CS lens with anti-reflective coating with Co-60 in steps, measuring radiation damage with monochromator

Testing 3CS lens

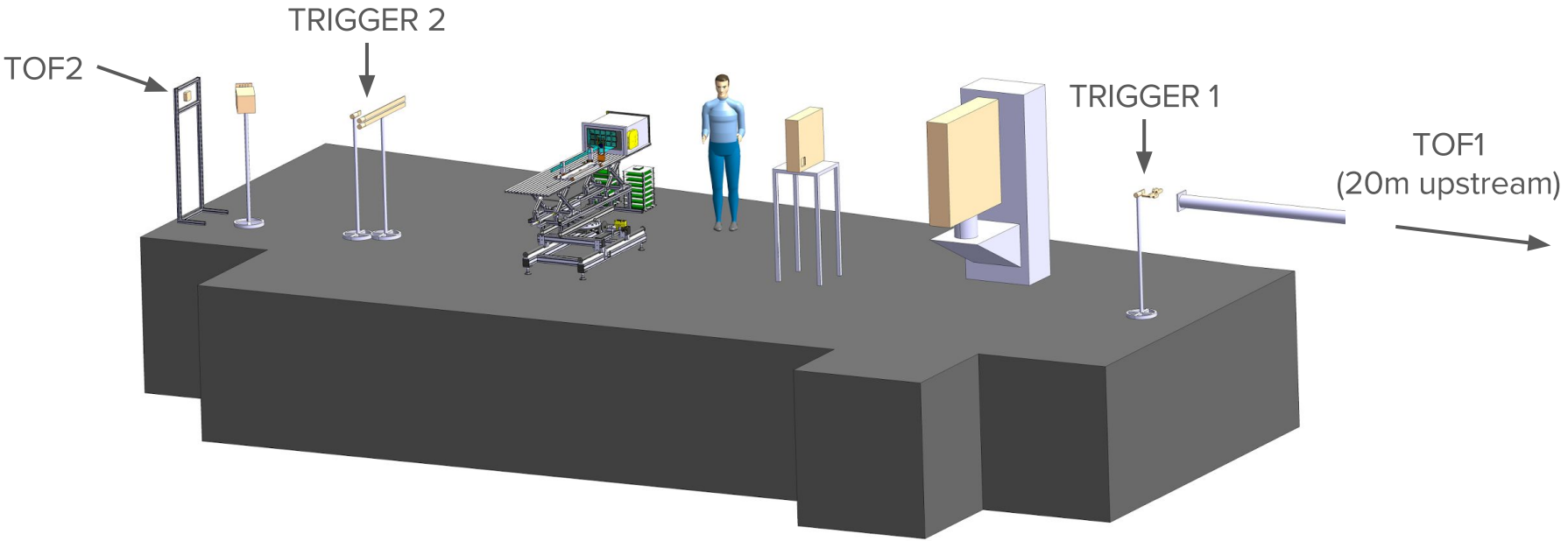
- Measurements on test benches
  - Mapping focal plane at ODU
  - Radiation hardness testing at JLab
- Measurements in test beam
  - Evaluating performance with PANDA barrel DIRC prototype at CERN



Setup can be rotated and translated with respect to the beam

Event Selection

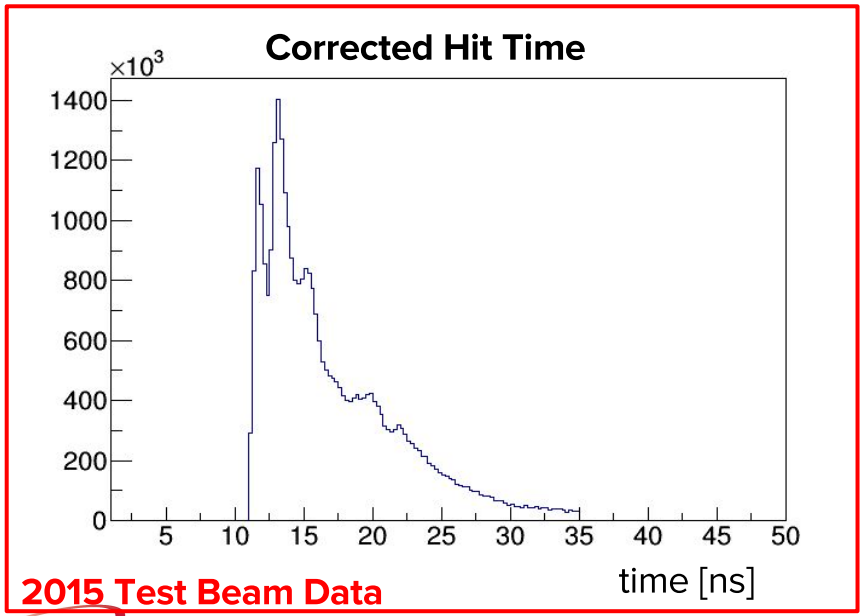
Coincidence required between TOF1, TRIGGER1, TOF2, and TRIGGER2

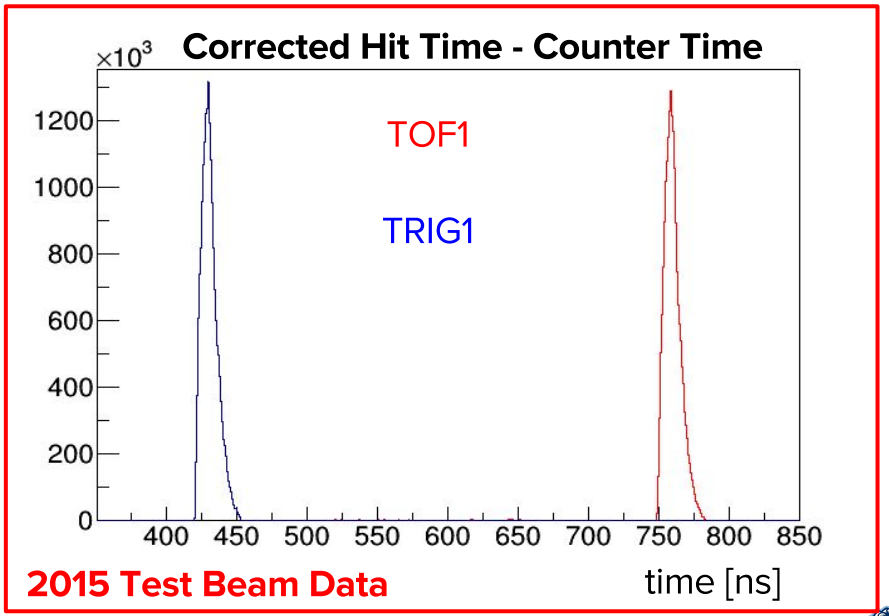


Hit Selection

Cut on lead time of MCP pixel based on bar angle

Cut around peaks in (MCP lead time) - (counter time) to ensure good relative timing

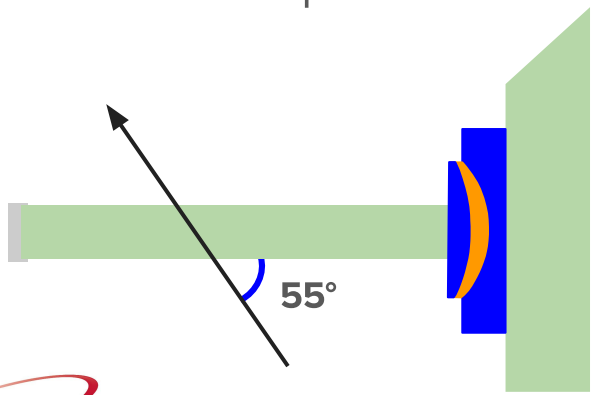




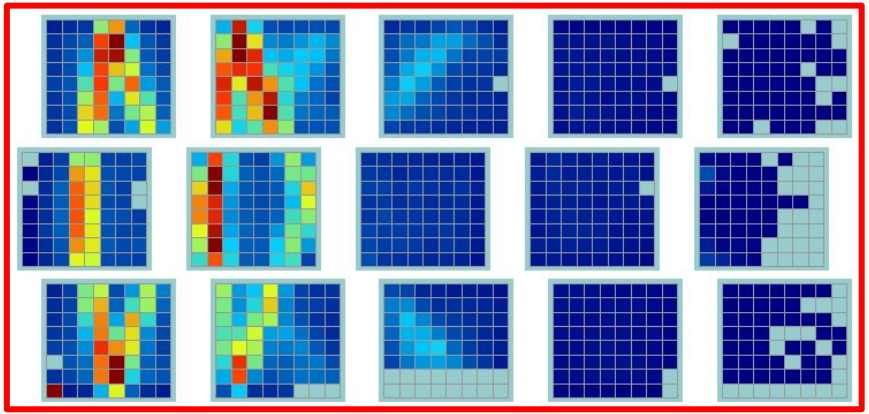
Test Beam Sample Occupancy

Beam/bar conditions:

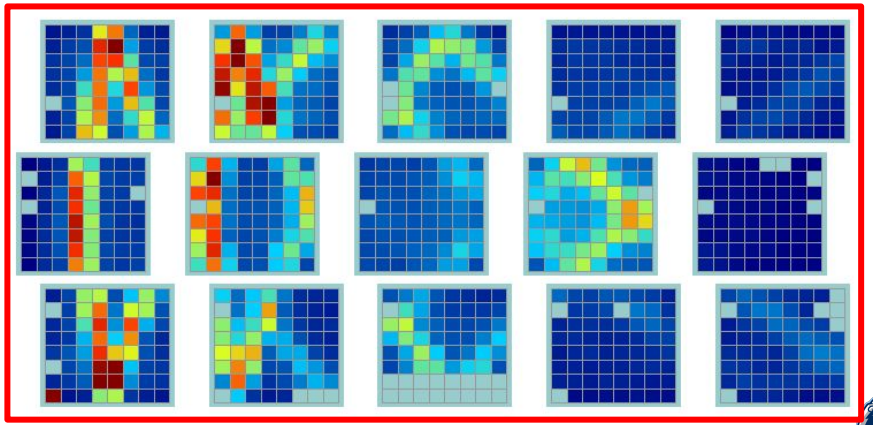
- 55° bar rotation
- 7 GeV/c beam momentum
- Selected protons



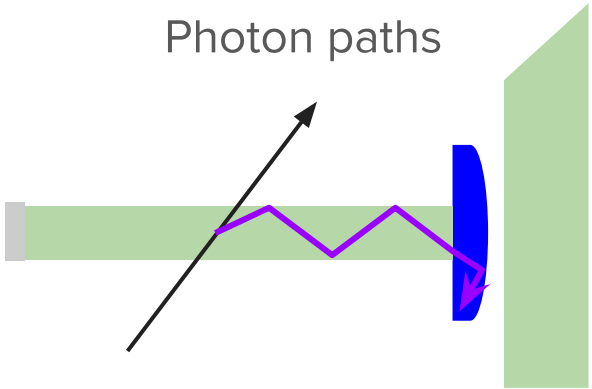
AG lens



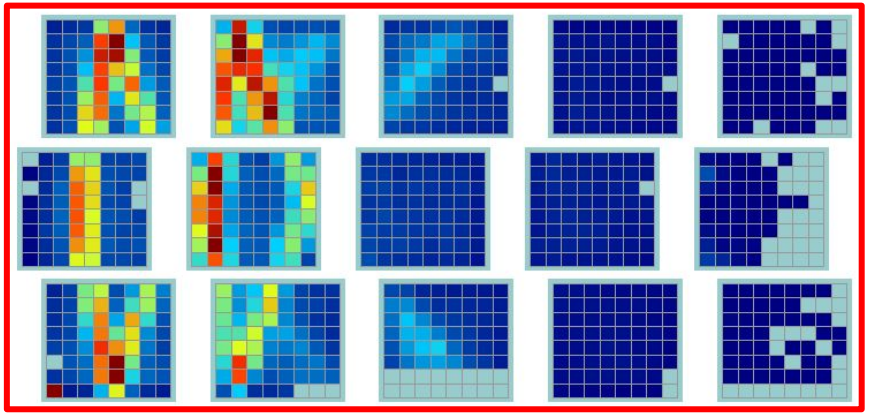
3CS lens

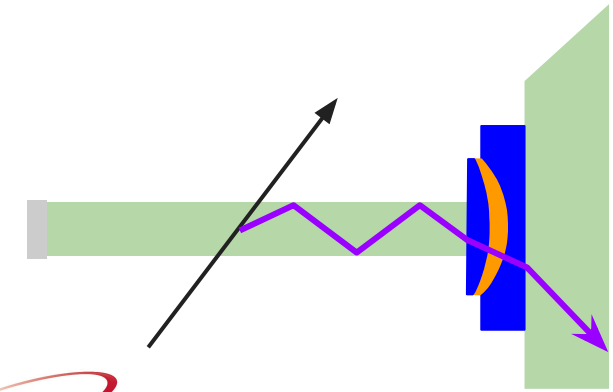


Test Beam Sample Occupancy

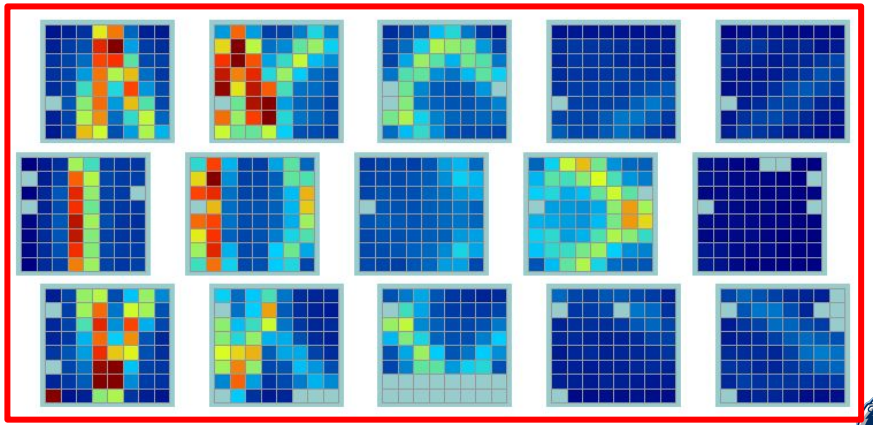


AG lens

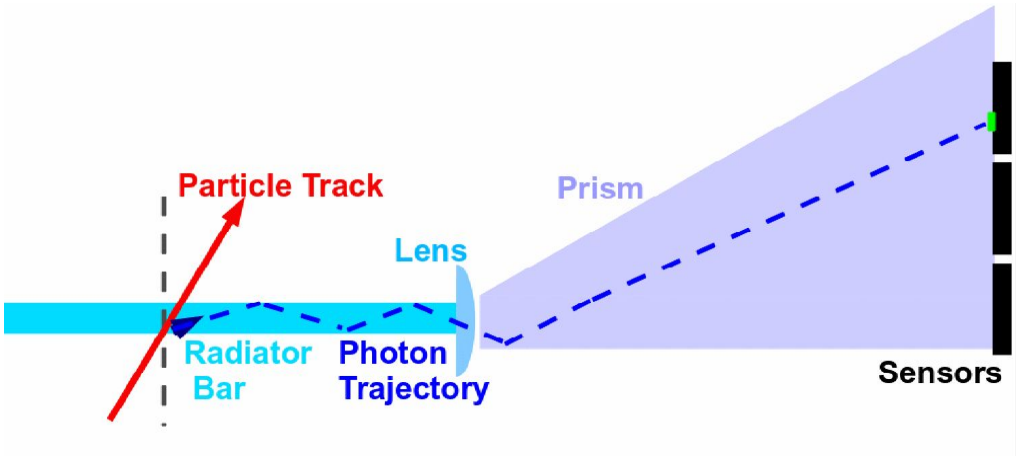




3CS lens

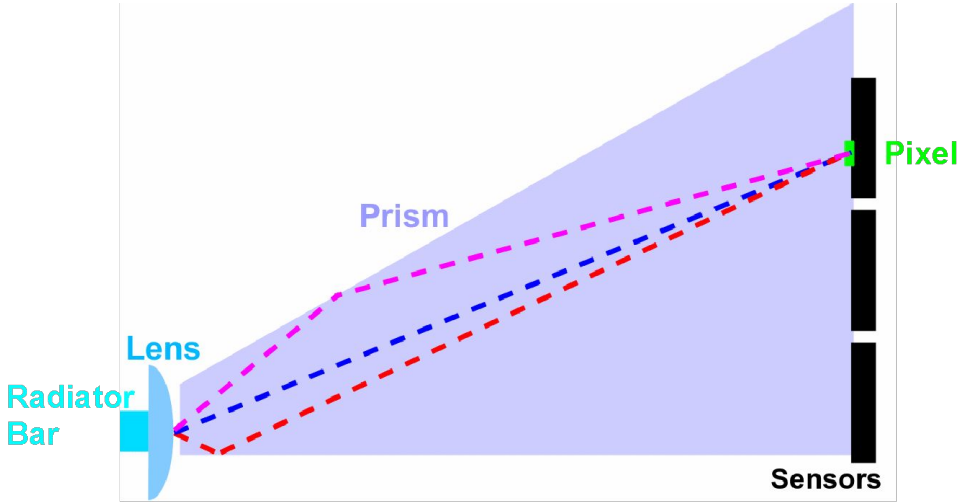


Geometric Reconstruction Method



- Pixel position + bar location define photon direction at the bar end
  - Stored in look-up table
  - Used with particle track to reconstruct angle
- Path from bar to pixel is not unique
  - Generates combinatorial background in Θ_C
- Cut on difference between measured and expected time

Geometric Reconstruction Method



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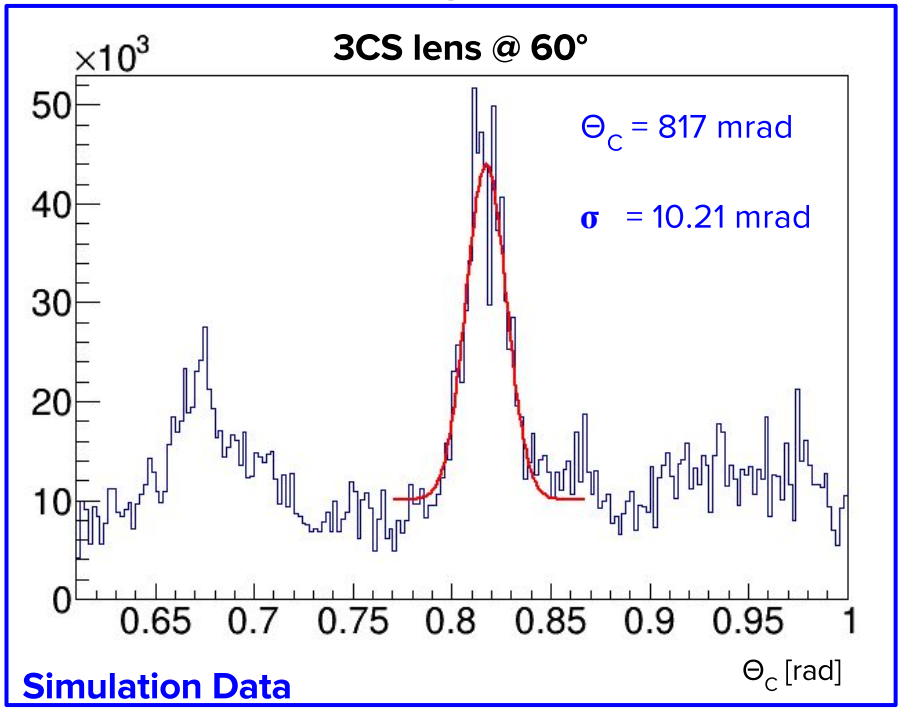
Geometric Reconstruction Method

Gaussian fit with constant background



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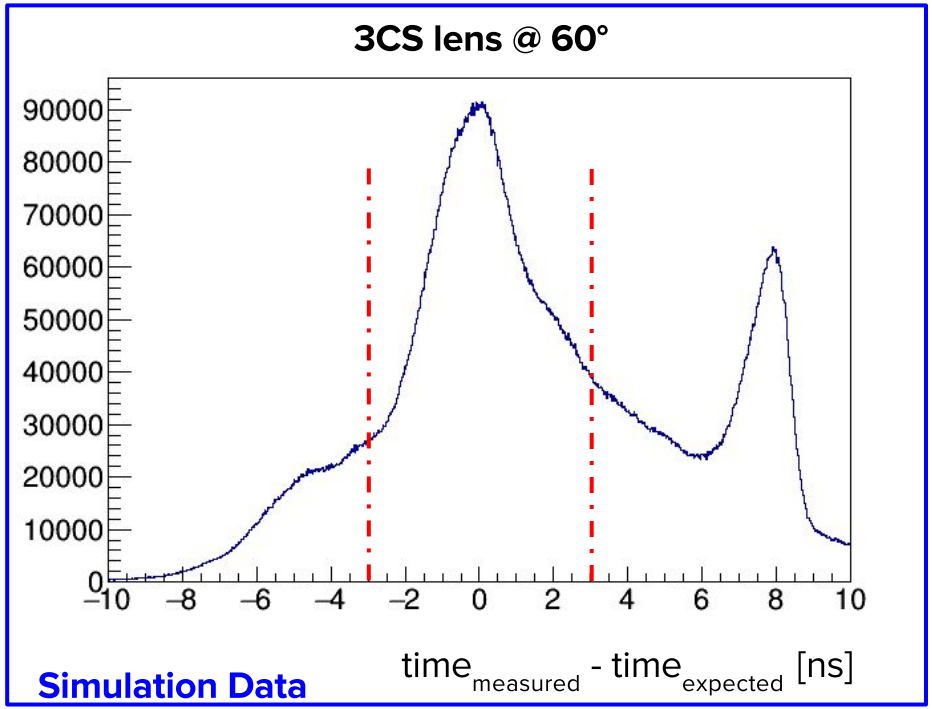
Geometric Reconstruction Method



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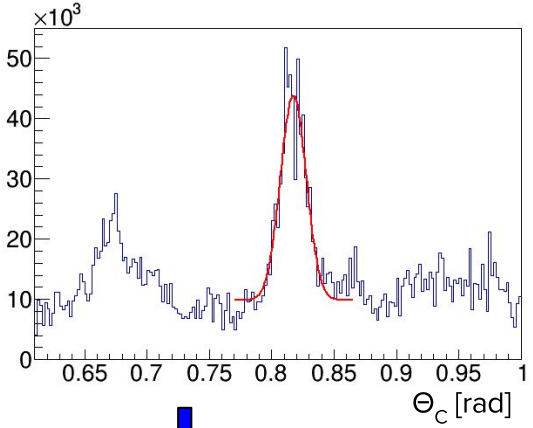
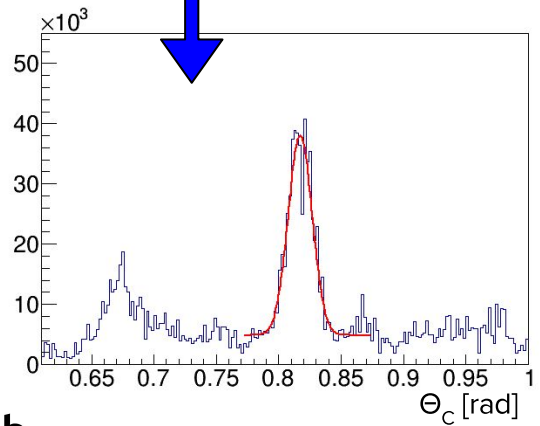


Θ_C = 817 mrad

σ = 10.21 mrad



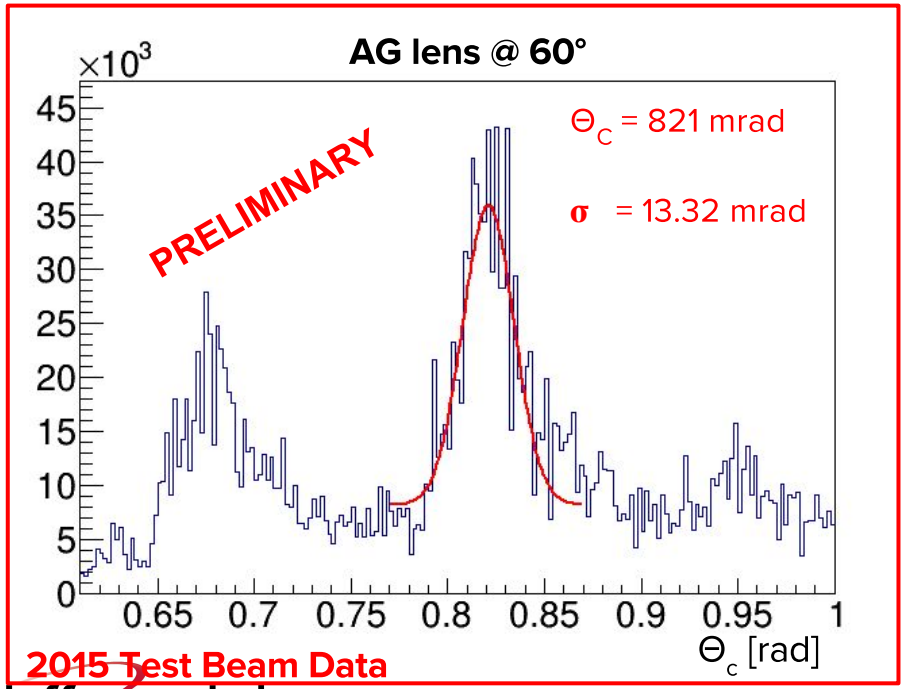
Θ_C = 817 mrad

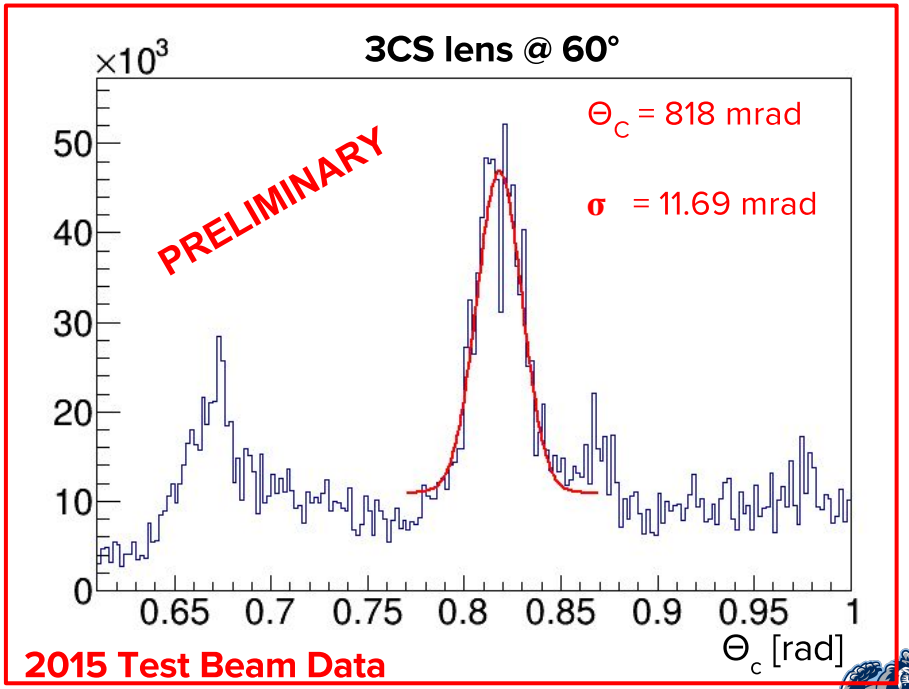
σ = 9.83 mrad

- Pixel position + bar location define photon direction at the bar end
  - Stored in look-up table
  - Used with particle track to reconstruct angle
- Path from bar to pixel is not unique
  - Generates combinatorial background in Θ_C
- Cut on difference between measured and expected time

Reconstructed Θ_c Resolution

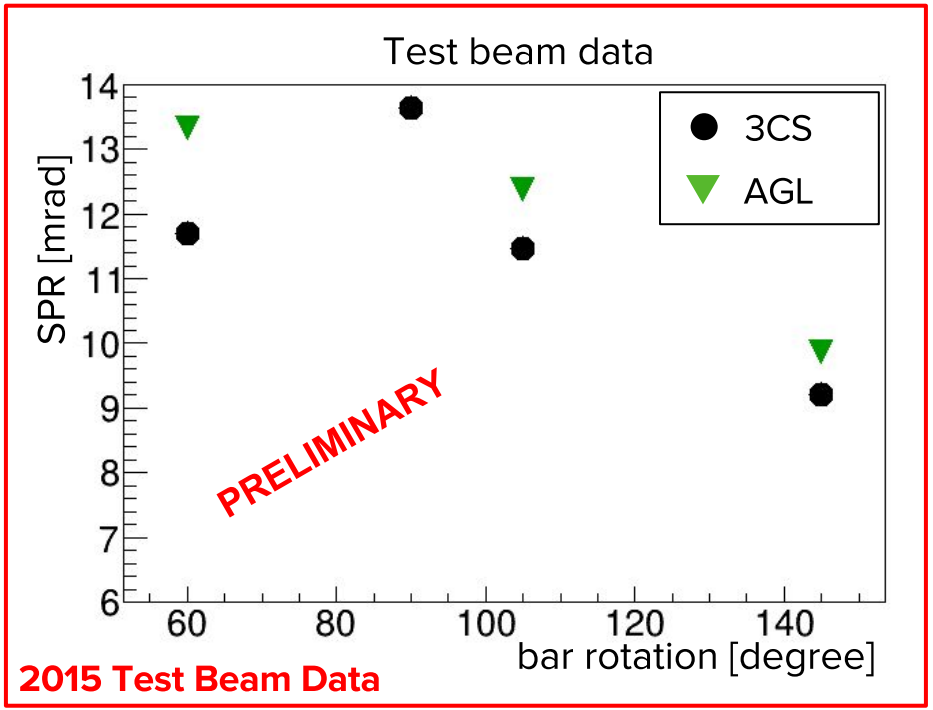
For 7 GeV/c protons, expected $\Theta_c \cong 816$ mrad



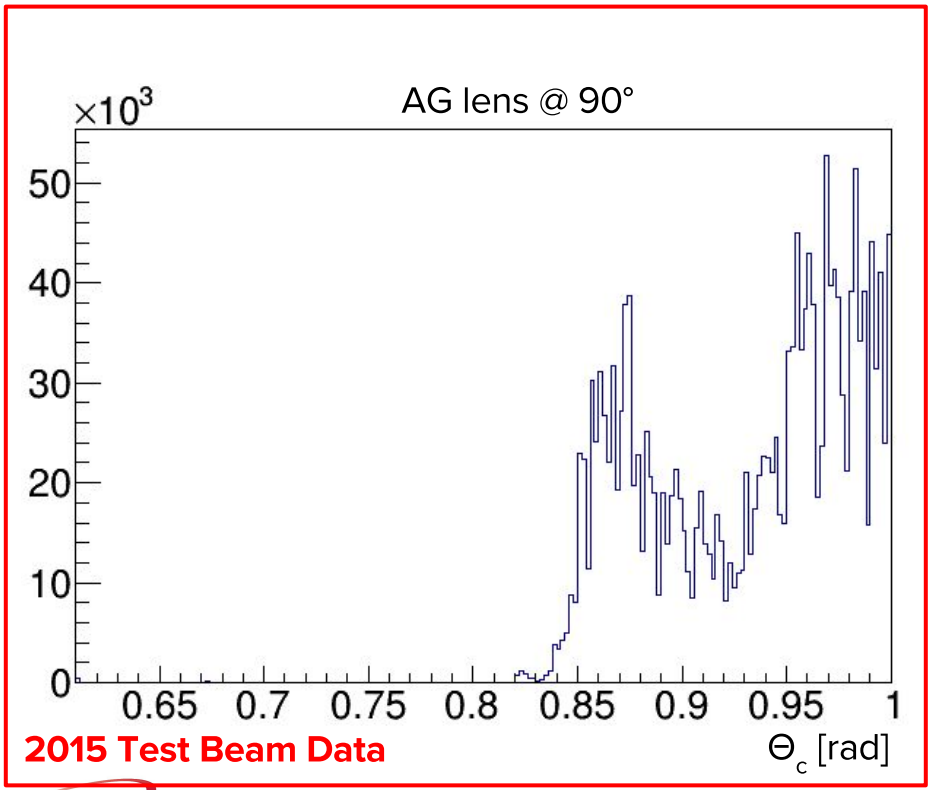


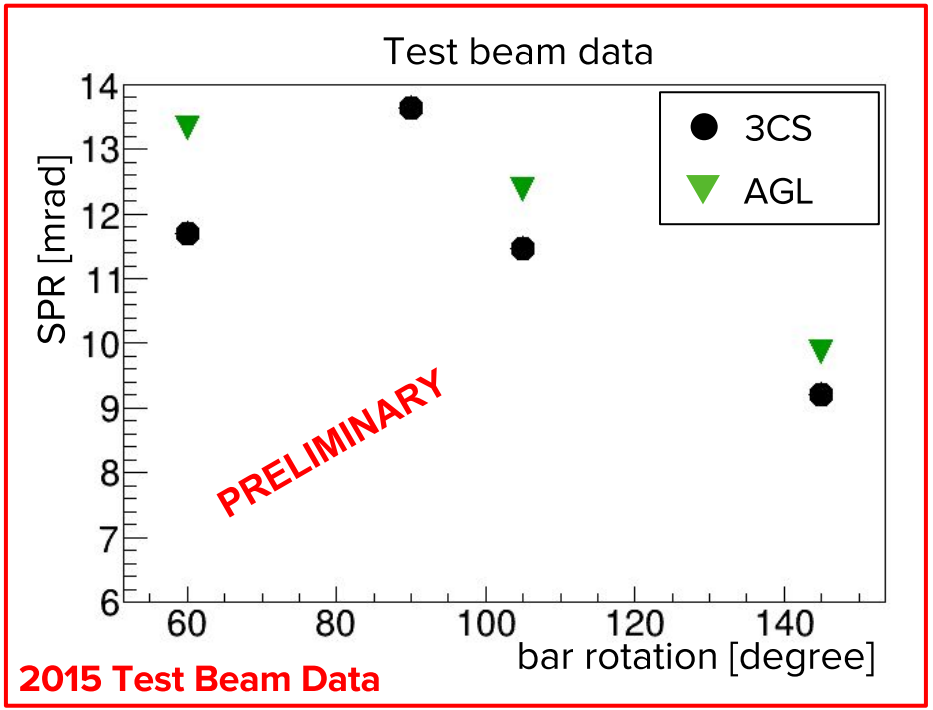
Reconstructed Θ_c Resolution

- Good resolution with 3CS lens even at 90° where AGL is not reconstructable



Reconstructed Θ_c Resolution

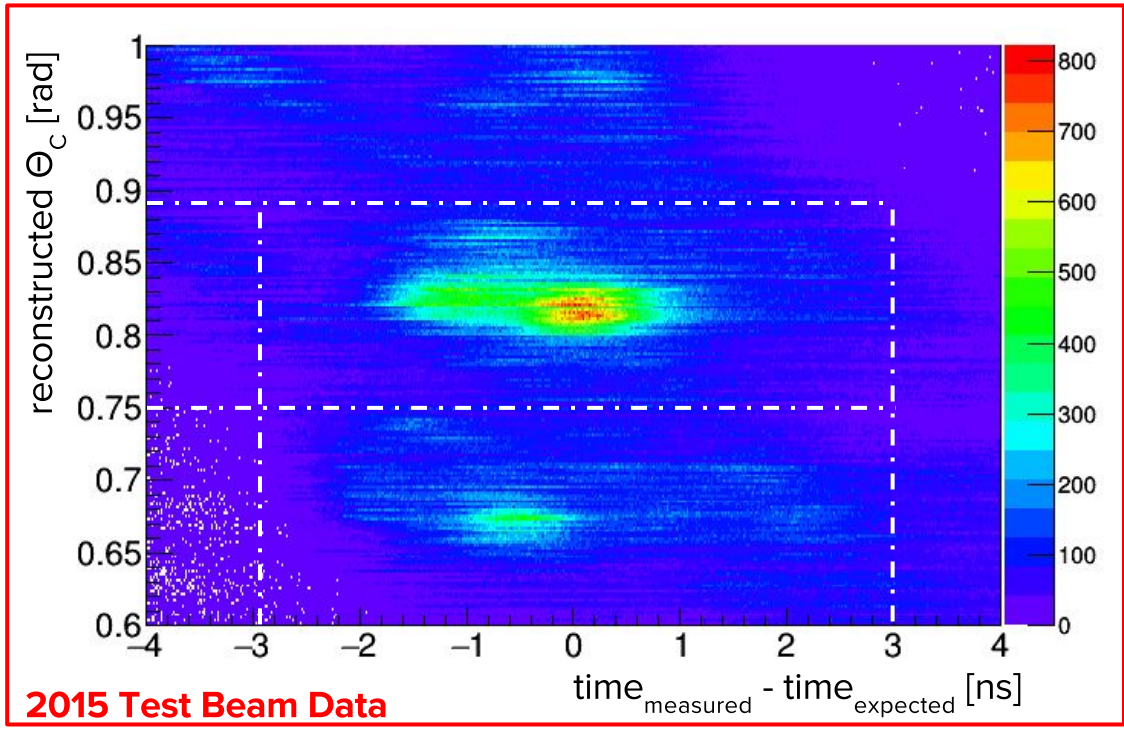




Ambiguity Subtraction for Photon Yield

Cutting on reconstructed Θ_C and ($time_{measured}$ - $time_{expected}$) can reduce background from various contributions

- Delta electrons
- Scattered photons
- Contributions from electronics



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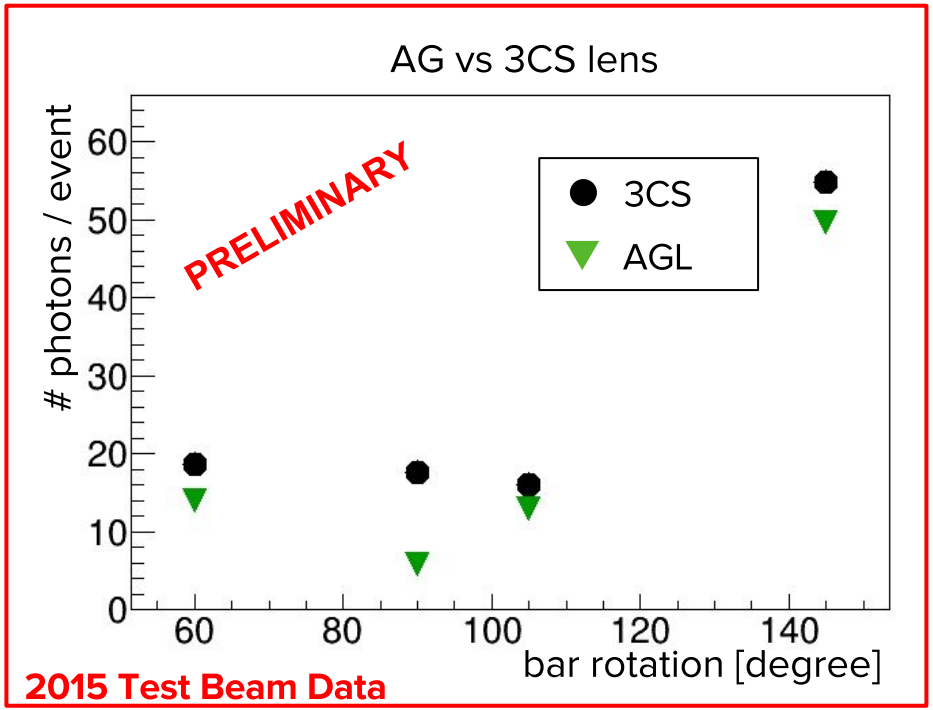
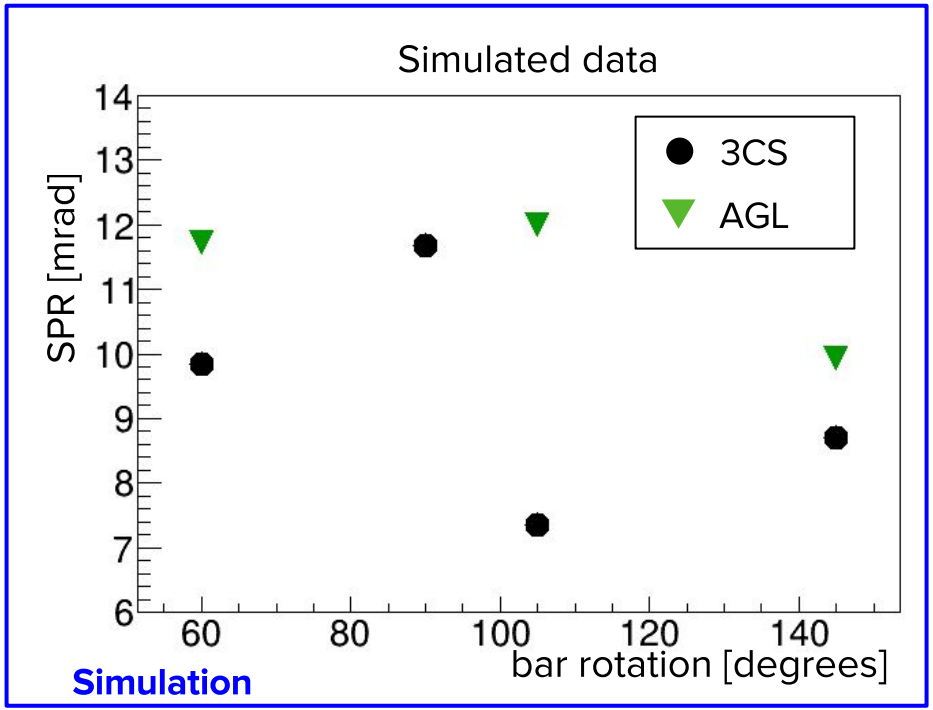


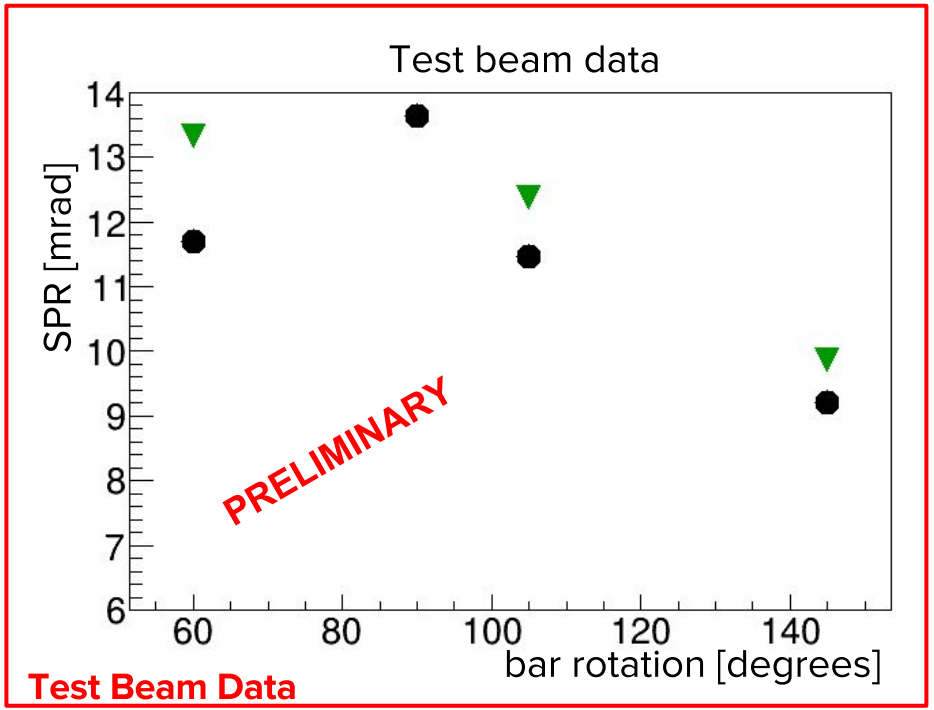
Summary

- Simulation for focal plane of 3CS lens suggests better focusing for steeper angled photons and a more customizable focal plane shape
  - Measurement to confirm shape of prototype's focal plane to be conducted at ODU
- Radiation hardness of NLaK33 material will be measured at JLab
- Preliminary analysis of 2015 test beam data suggests better resolution and photon yield compared to AG lens

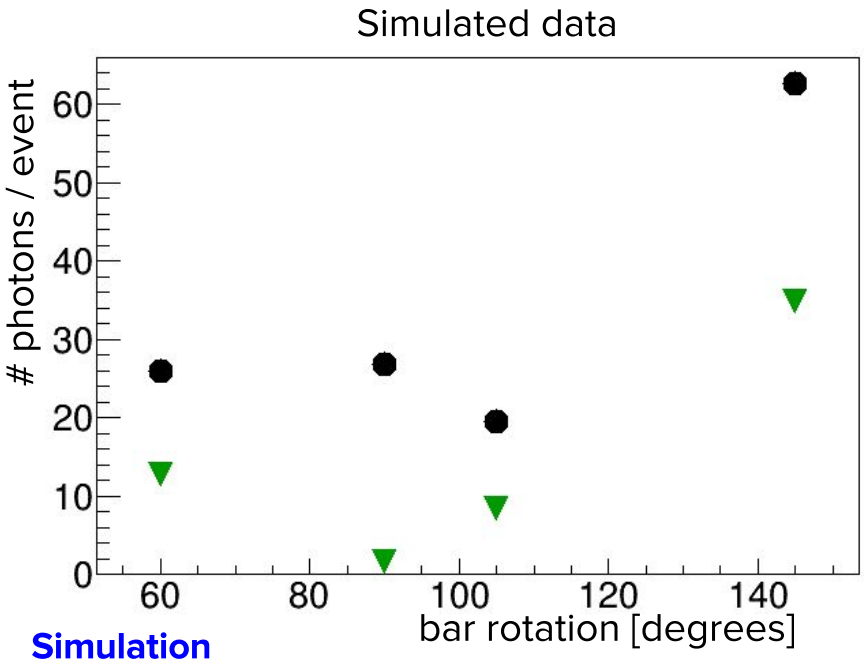
Backup Slides

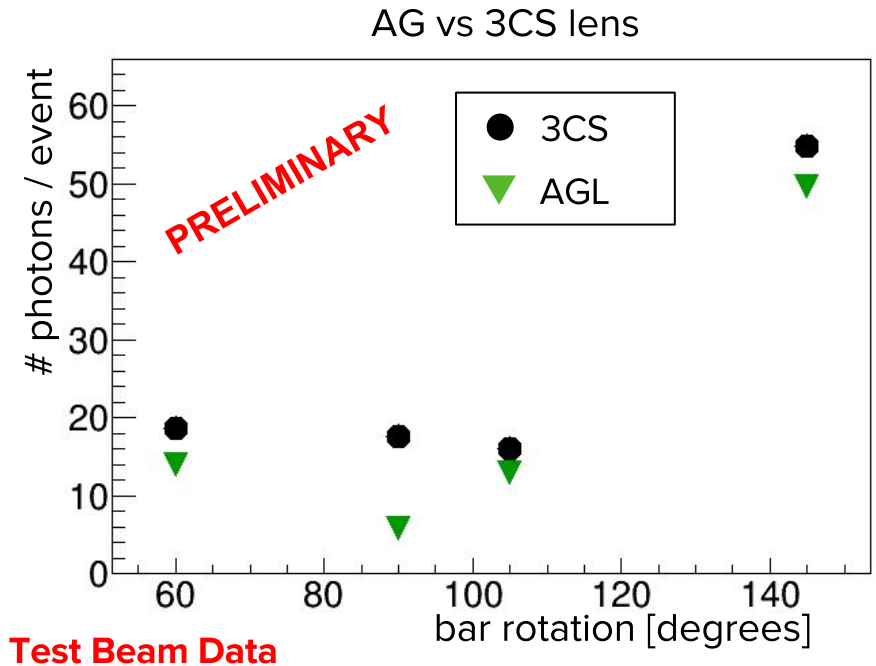
Reconstructed Θ_c Resolution

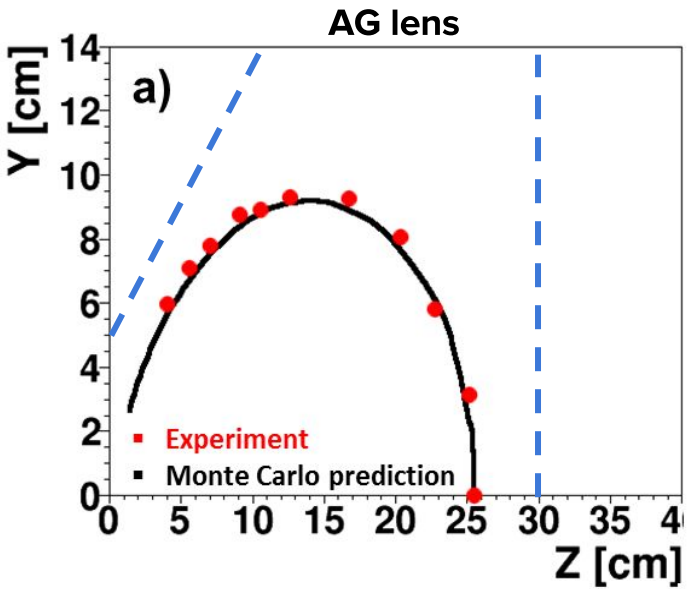


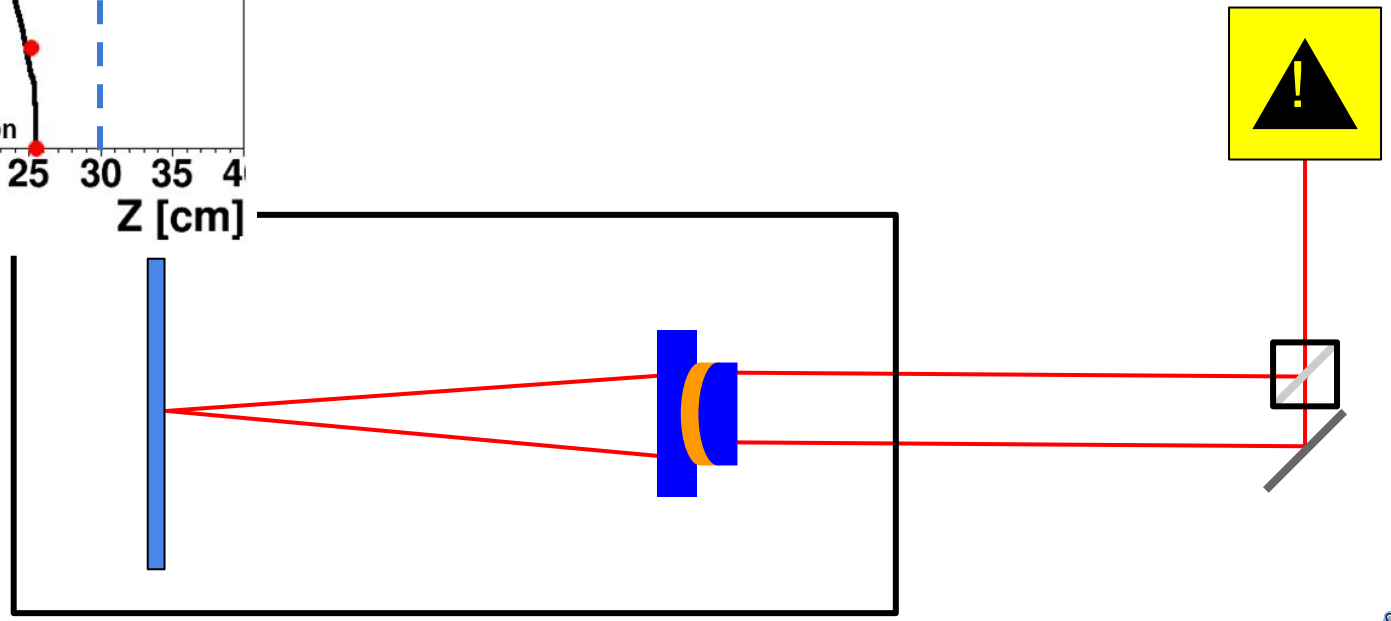


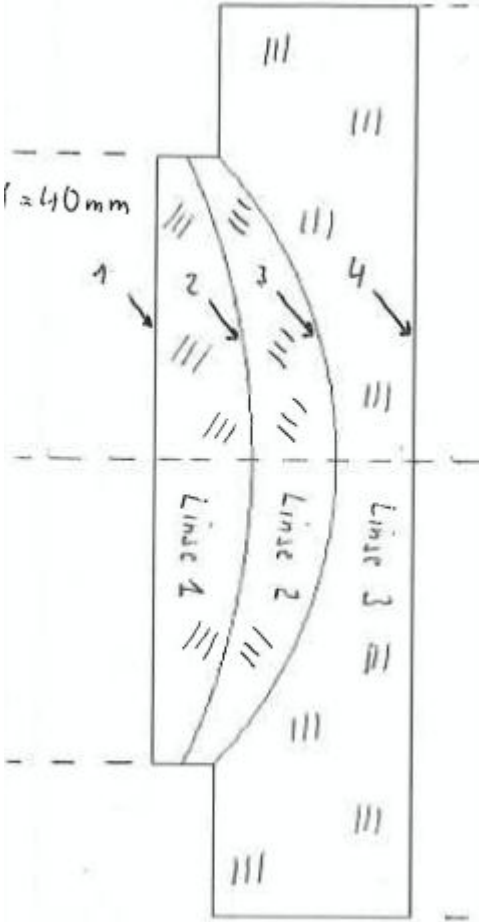
Photon Yield Comparison

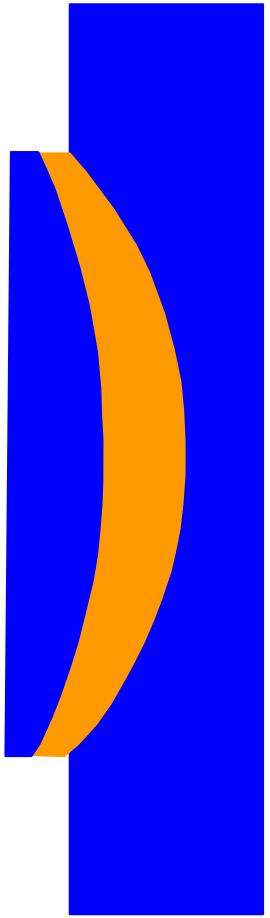


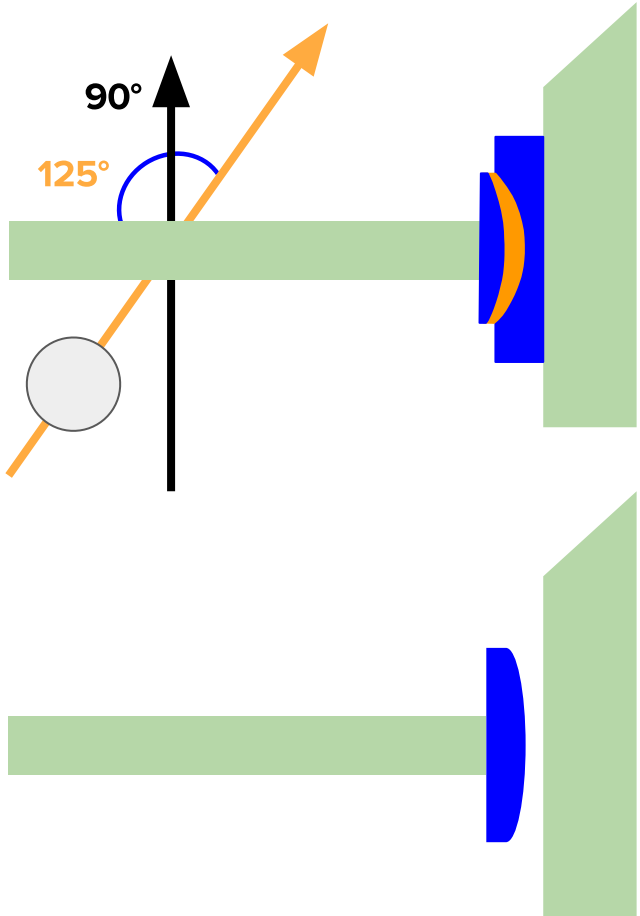



AG lens
a)
Y [cm]
Z [cm]
Experiment
Monte Carlo prediction




r = 40 mm
1
2
3
4
Line 1
Line 2
Line 3




90°
125°