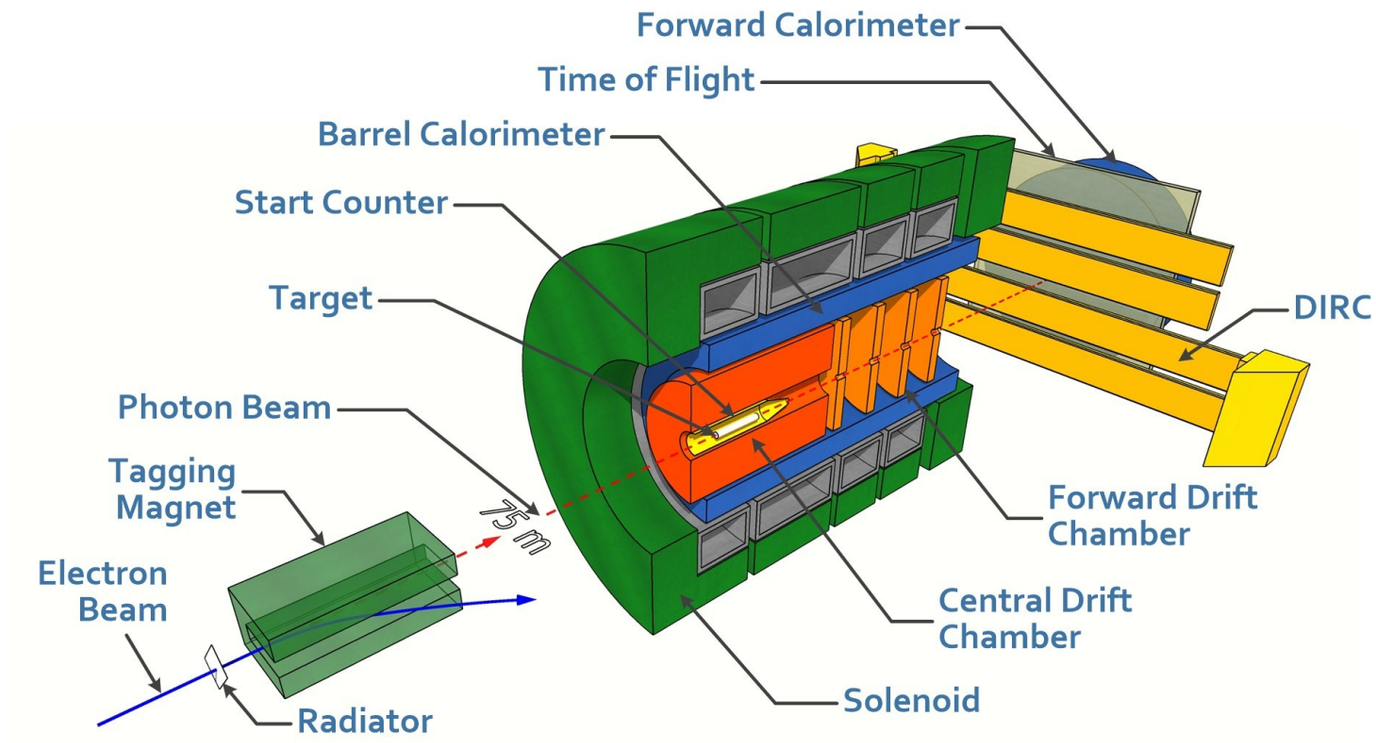
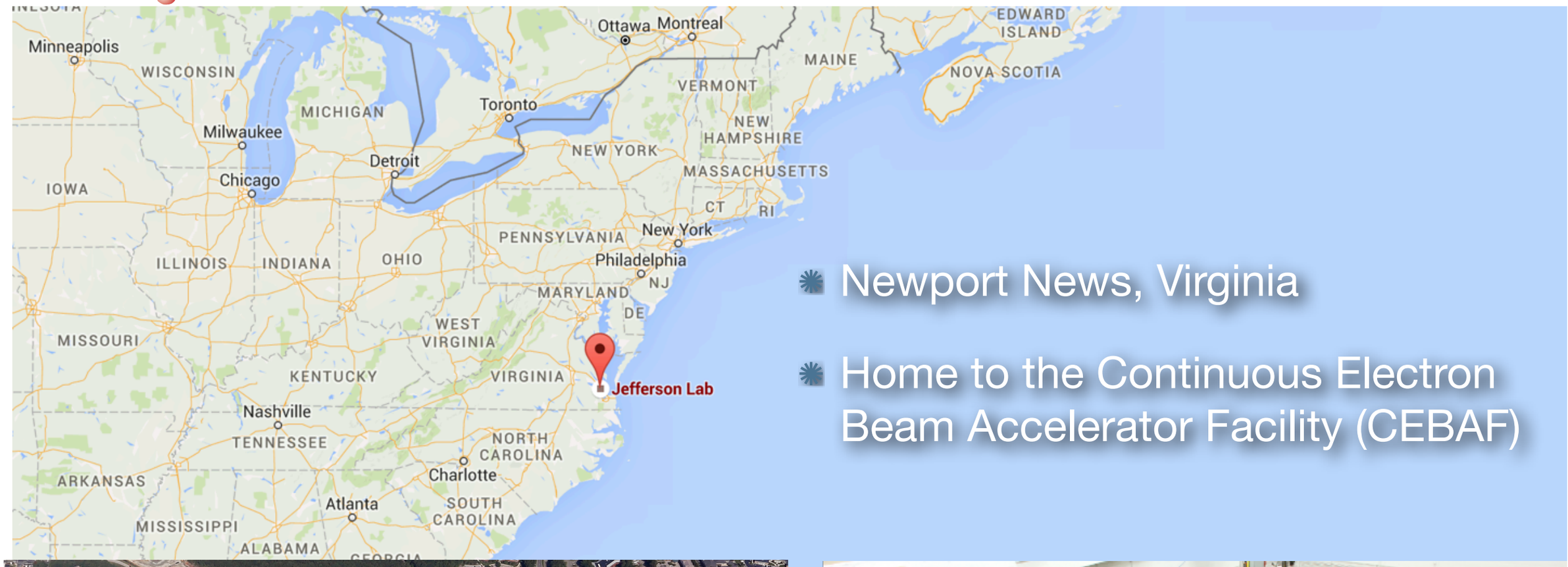


Status and Initial Performance of the GlueX DIRC

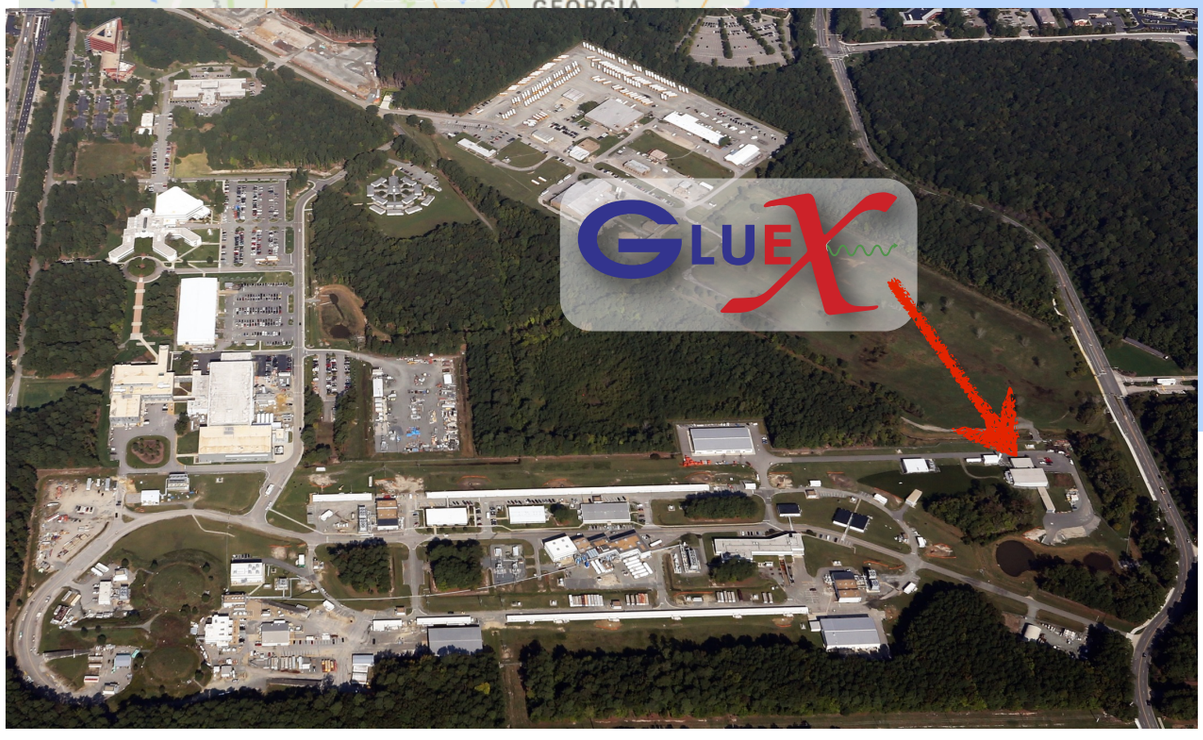
Justin Stevens

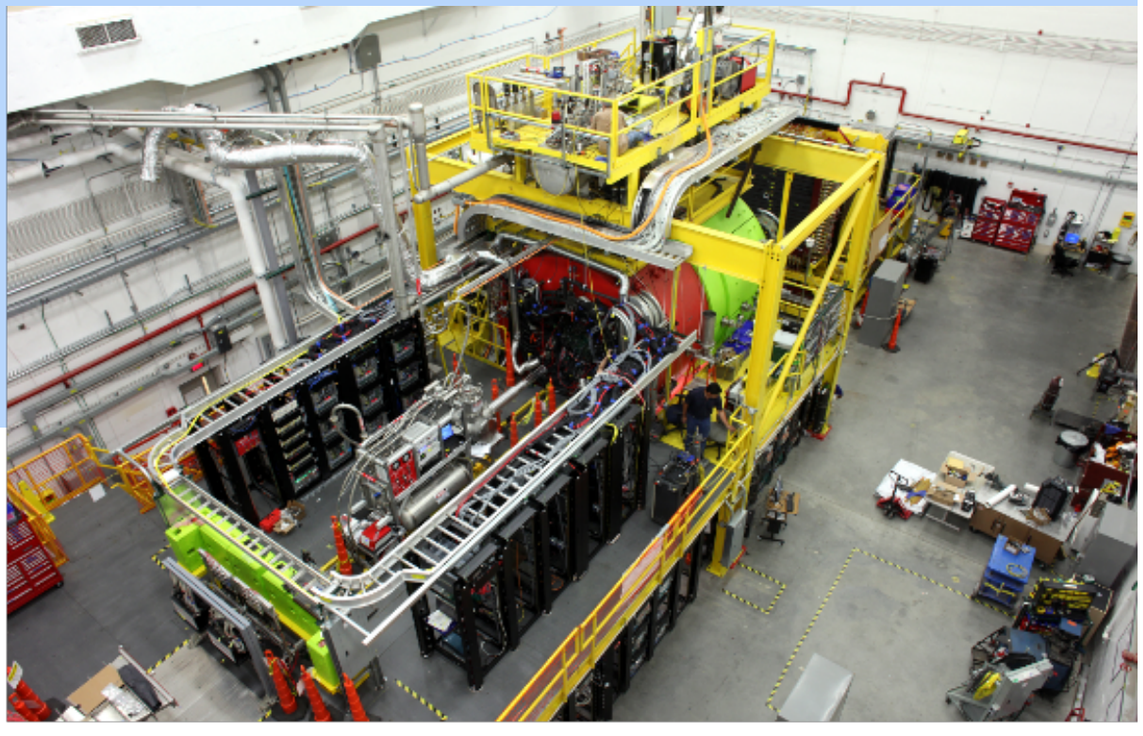
William & Mary
Chartered 1693

Jefferson Lab (JLab)



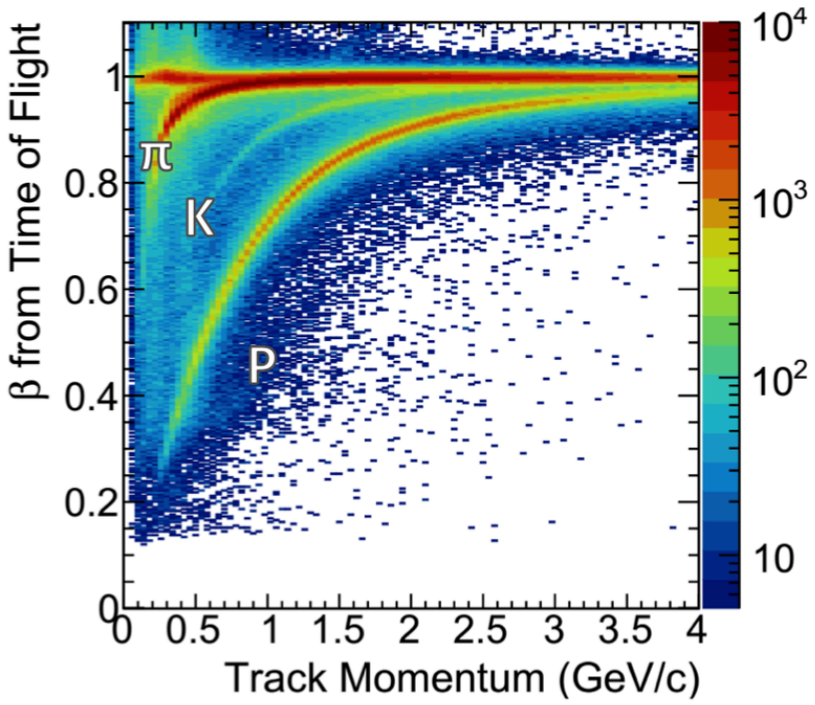
- Newport News, Virginia
- Home to the Continuous Electron Beam Accelerator Facility (CEBAF)

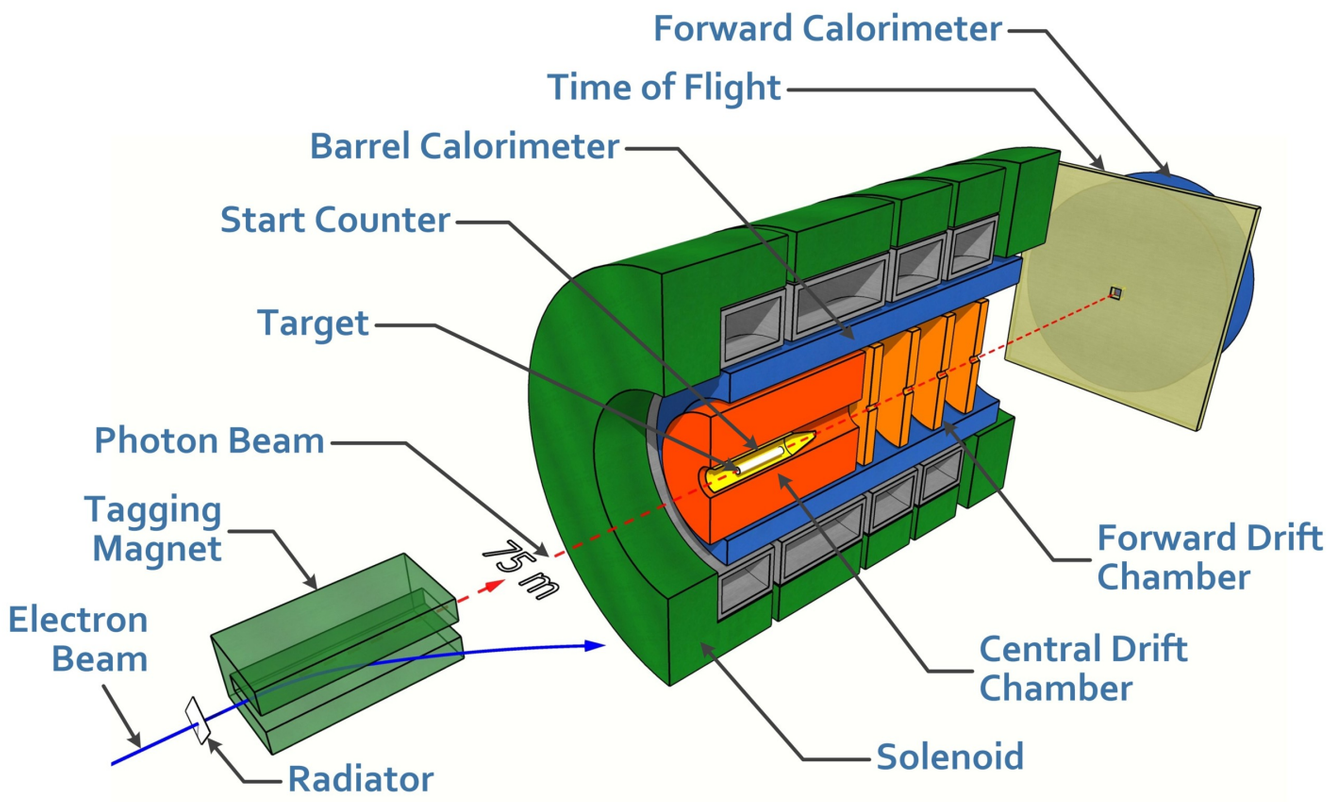




GlueX at JLab

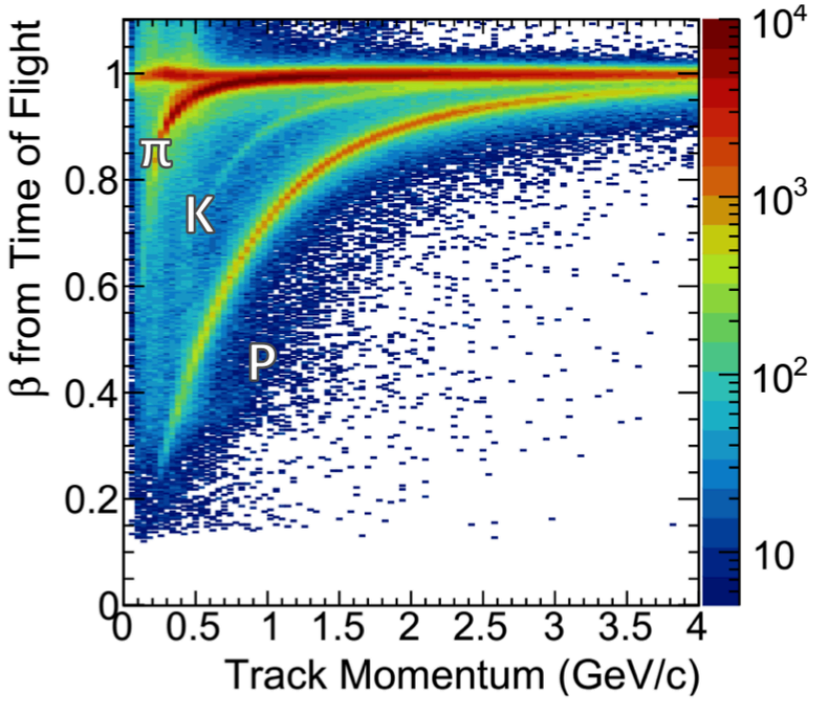
- Designed for light quark meson spectroscopy: 9 GeV linearly-polarized photon beam on LH_2 target
- GlueX-I: π/K separation up to ~2 GeV provided by time-of-flight

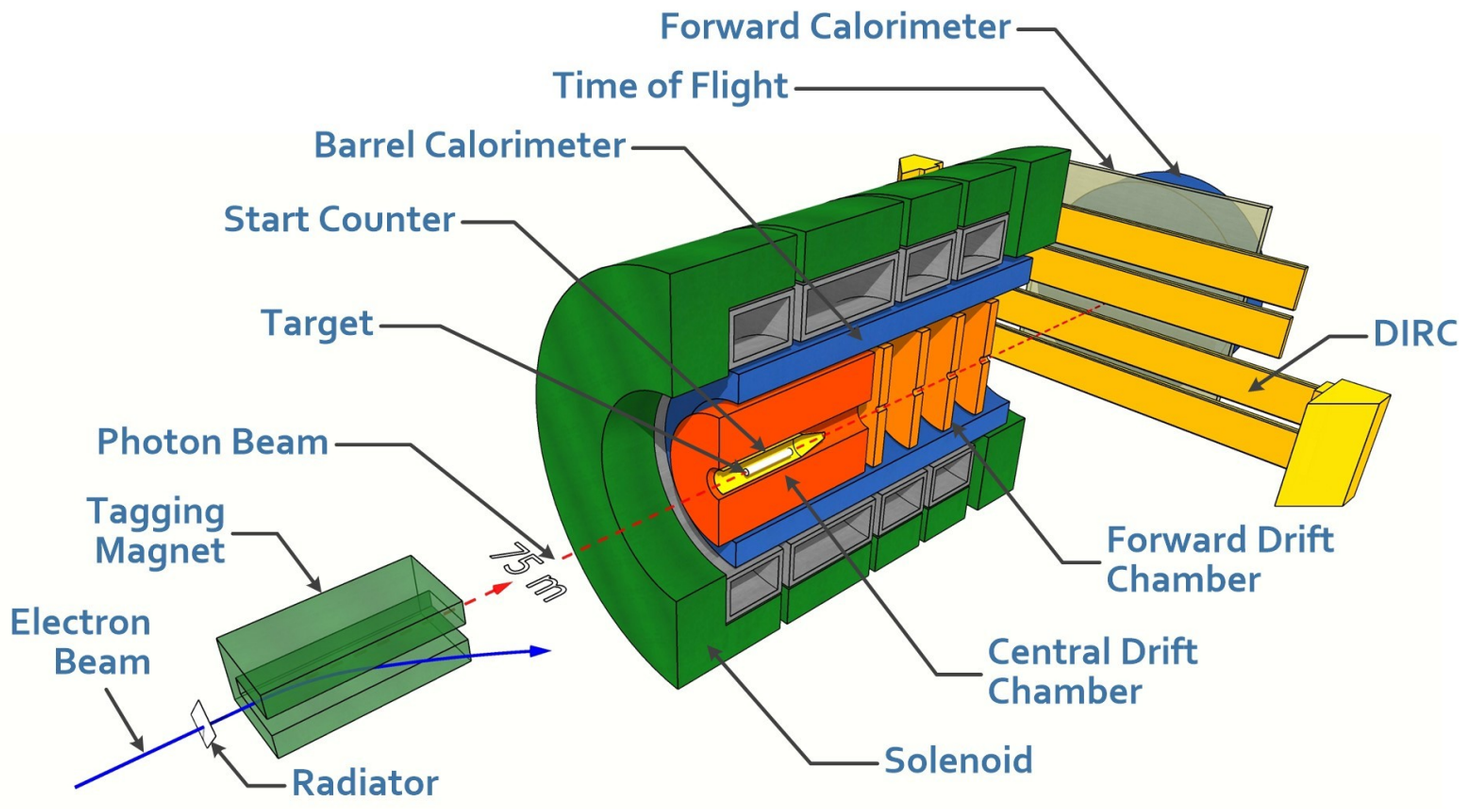




GlueX at JLab

- Designed for light quark meson spectroscopy: 9 GeV linearly-polarized photon beam on LH_2 target
- GlueX-I: π/K separation up to ~2 GeV provided by time-of-flight
- GlueX-II: high luminosity with DIRC PID with 3σ up to 3.7 GeV

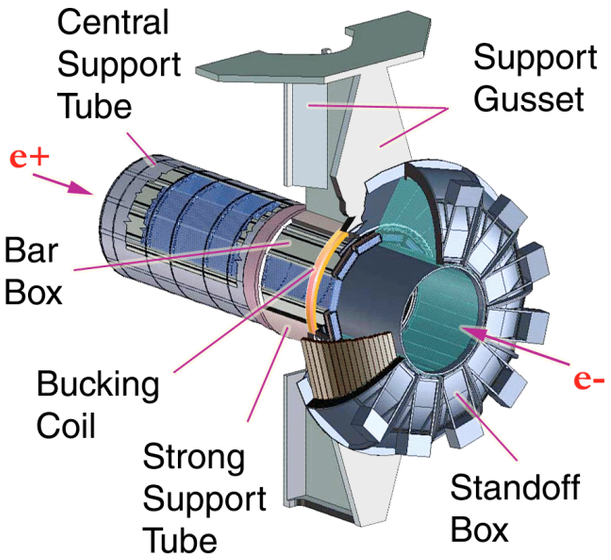




Recycling DIRC bar boxes

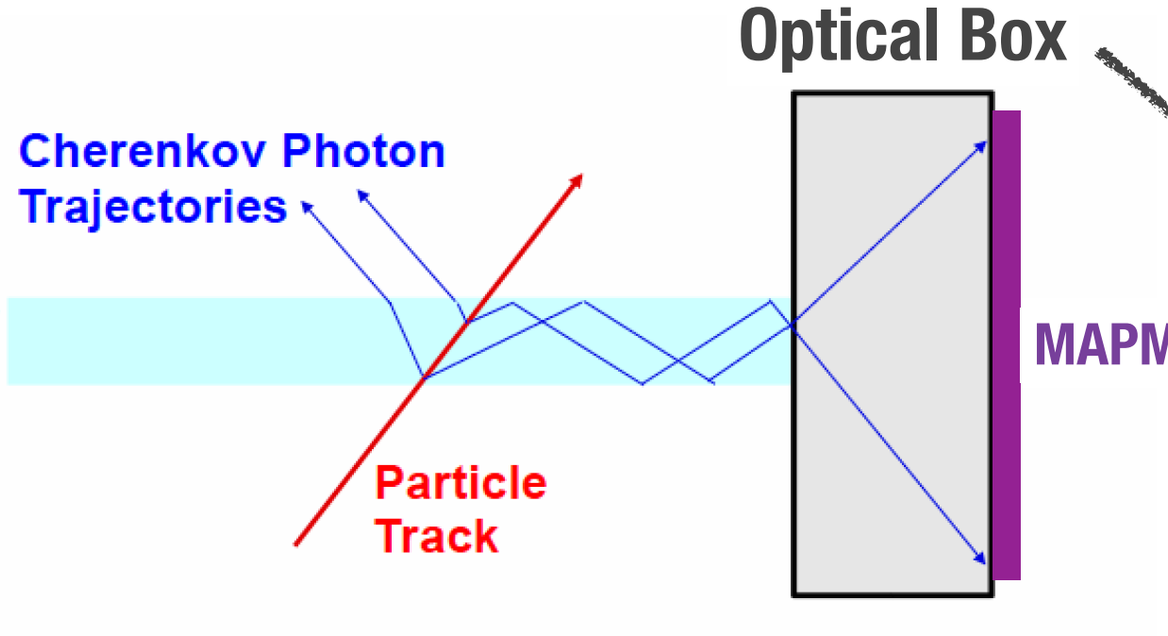
RECYCLE

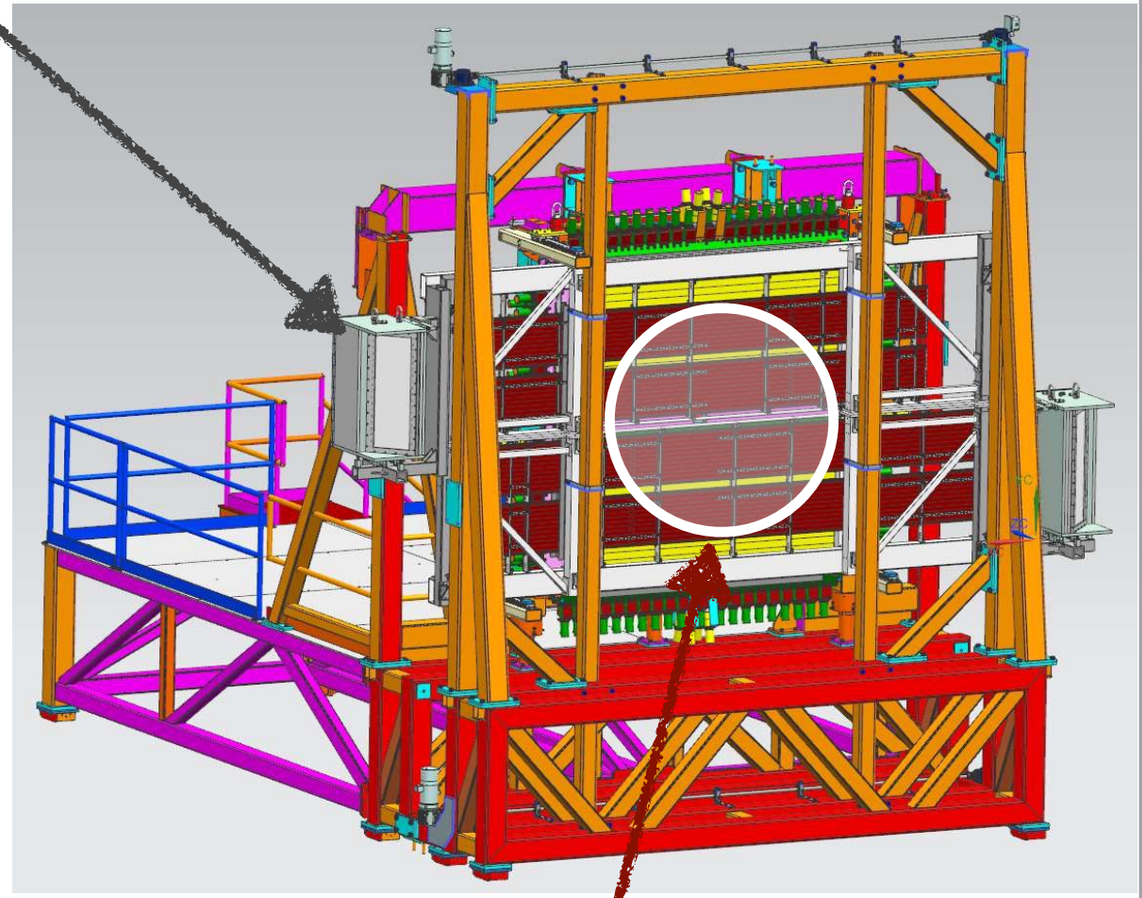
Transported 1/3 of BaBar DIRC radiators to JLab



Cameras, accelerometers, etc. provided real time feedback to trail car

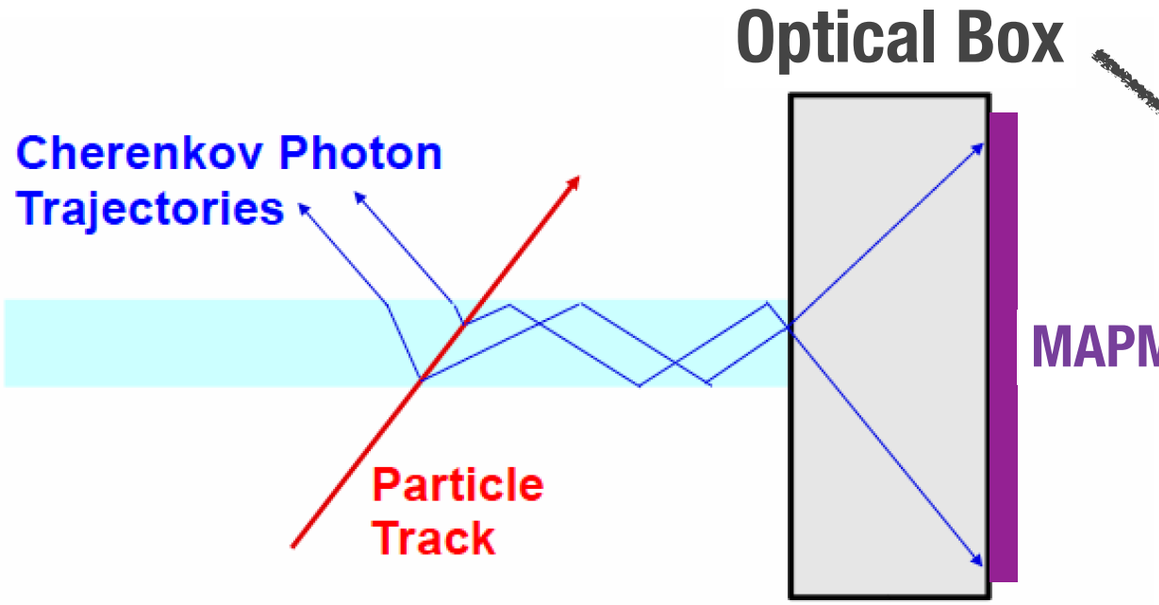
GlueX DIRC

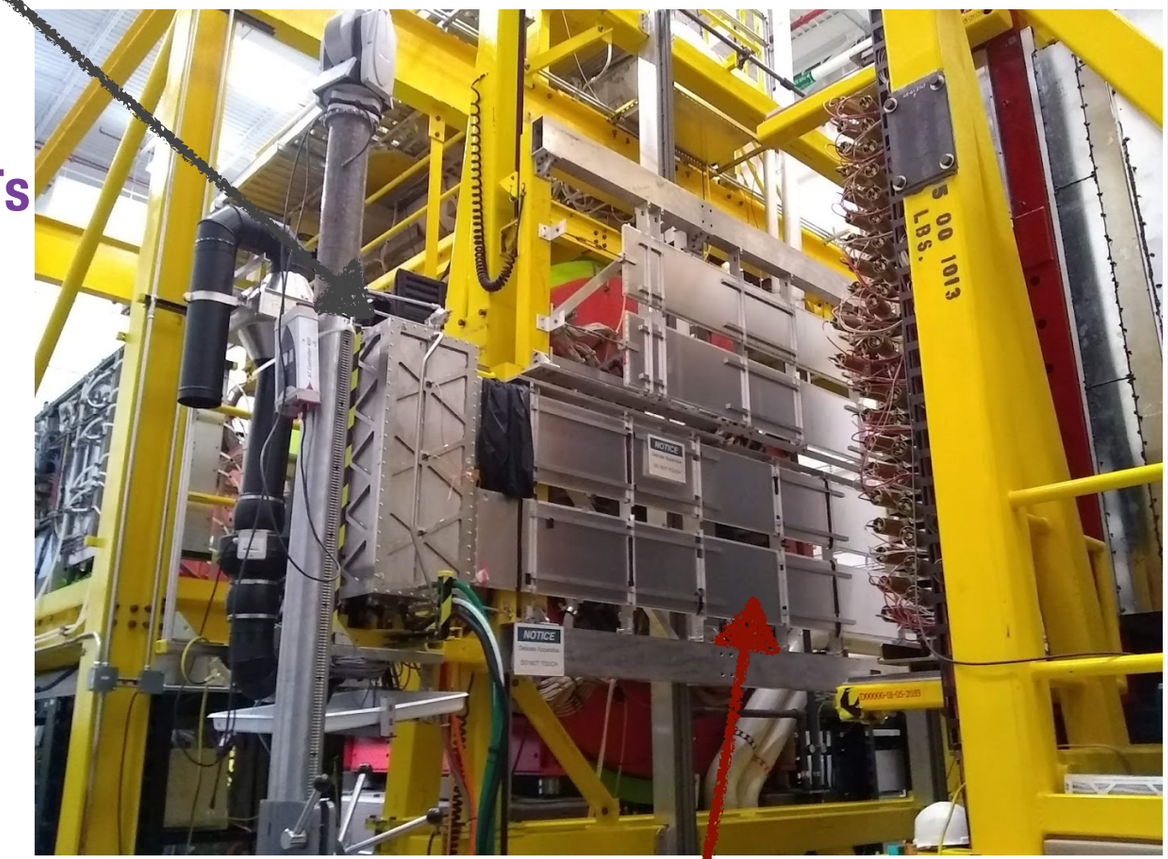




48 fused silica radiator bars installed, covering 2<θ<11°

GlueX DIRC



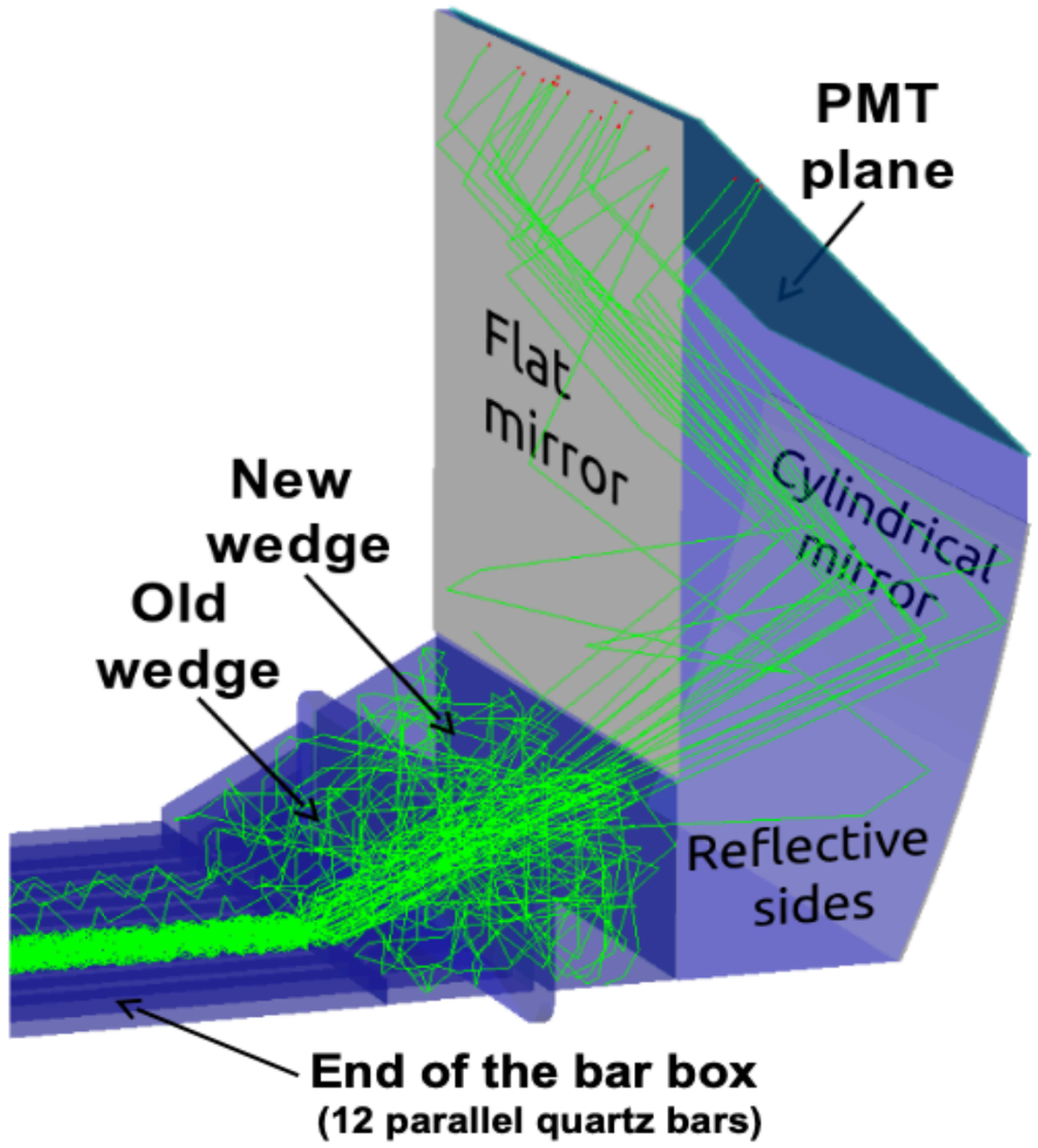


48 fused silica radiator bars installed, covering 2<θ<11°

Optical box design

- Design based on SLAC FDIRC prototype
  - Replace fused silica block from FDIRC prototype with mirrors contained in water
  - Replace of cylindrical mirror with 3-segment flat mirror
- Similar coupling of bar boxes to water volume as used at BaBar

RICH2016: Dey, Ratcliff and Va'vra
NIMA 876 (2017) 141



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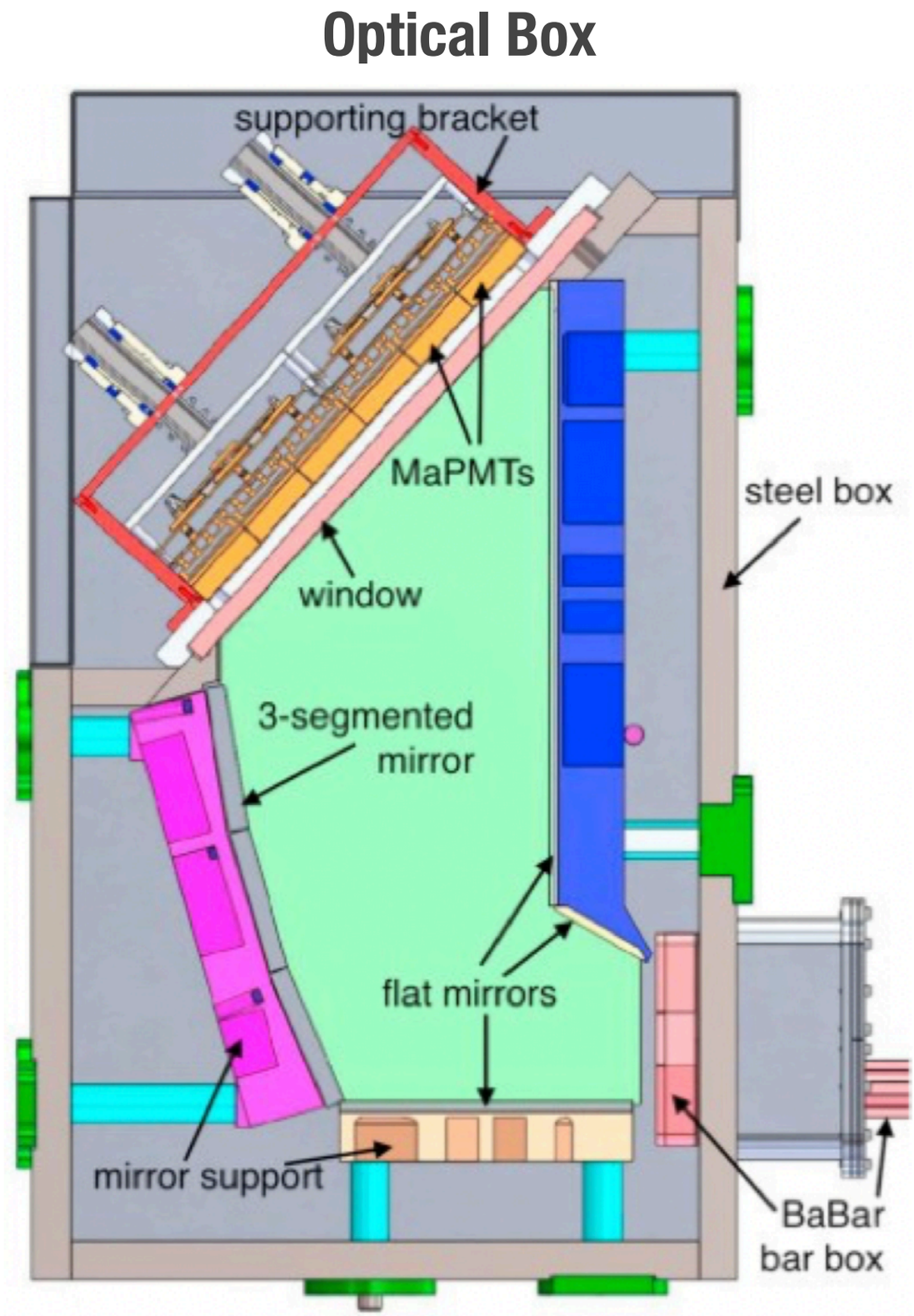
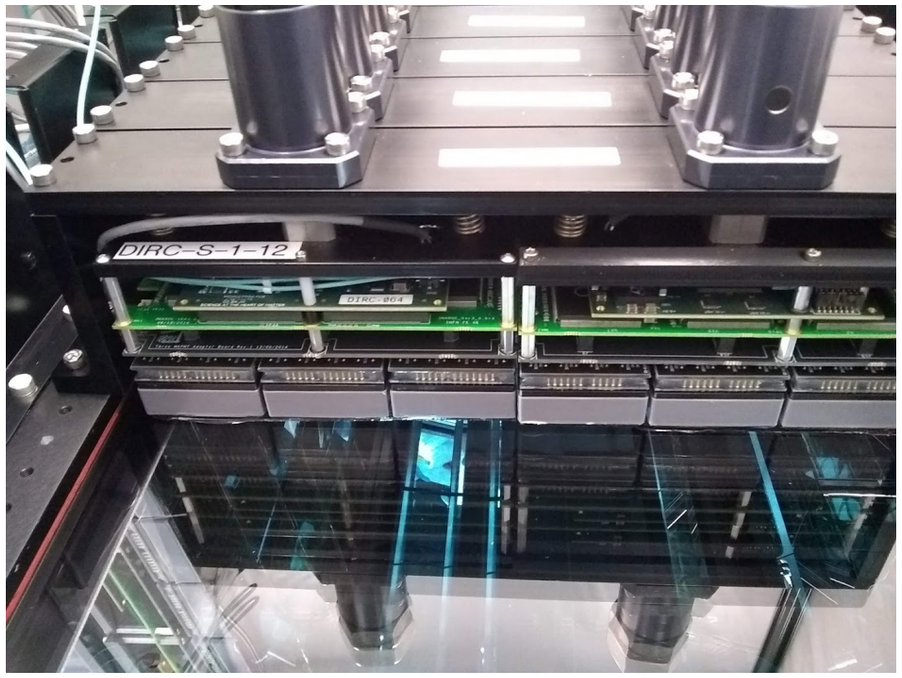
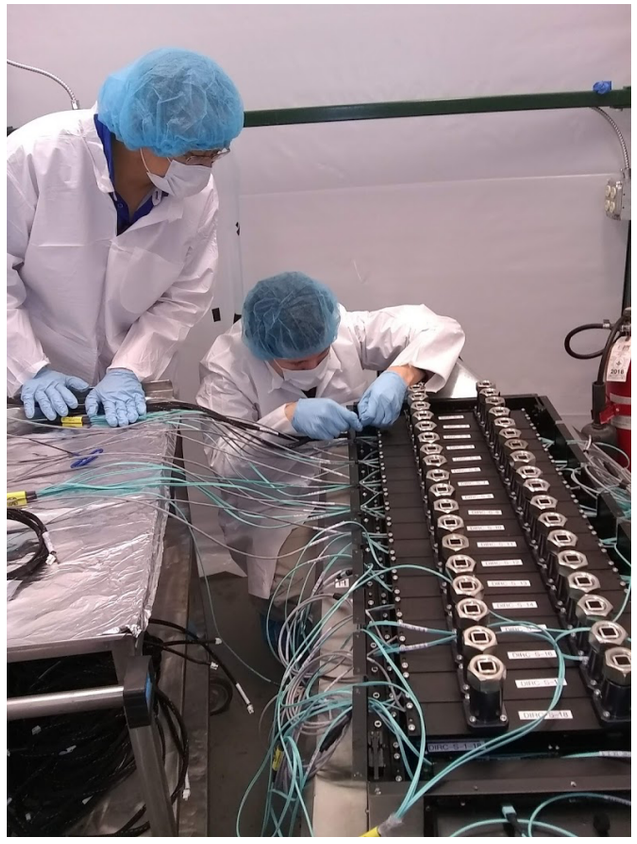
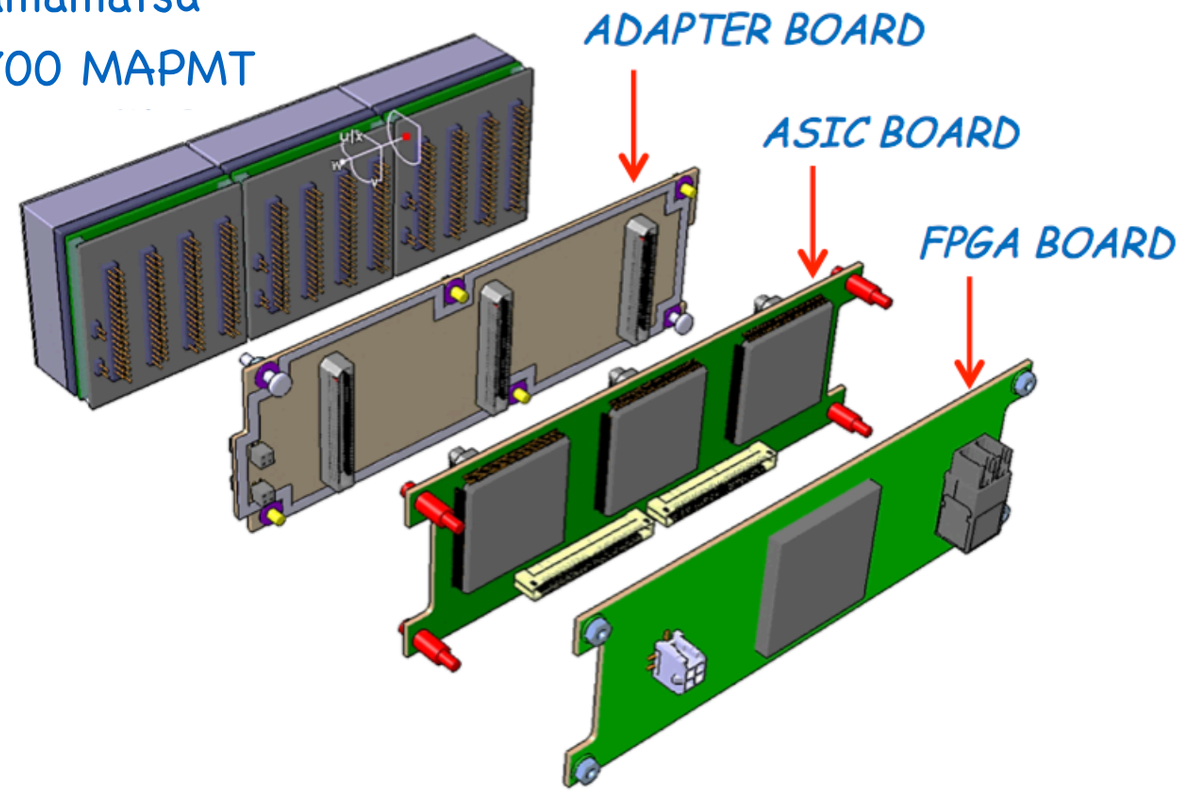


Photosensors and readout



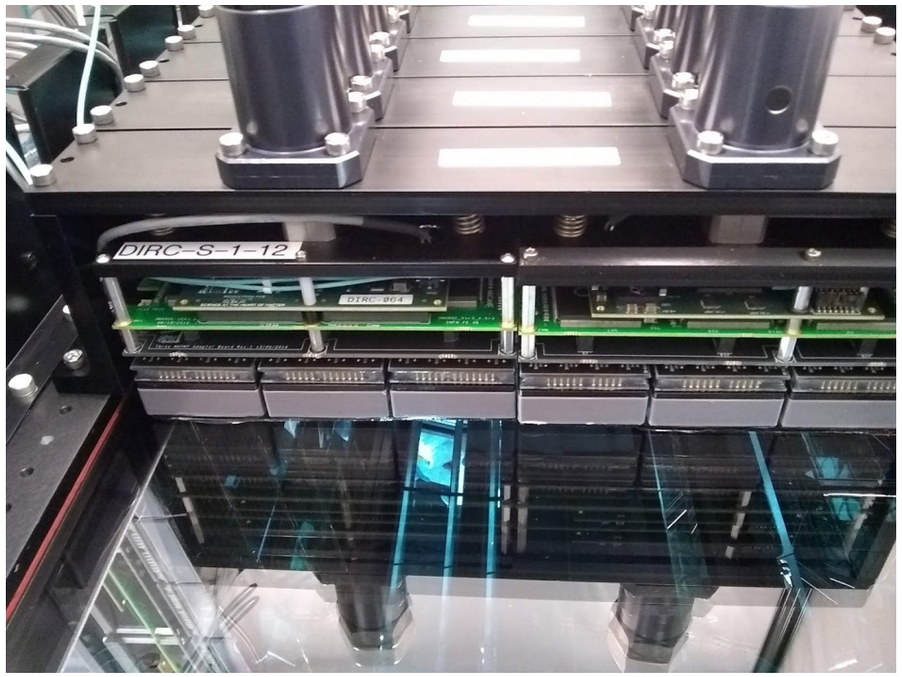


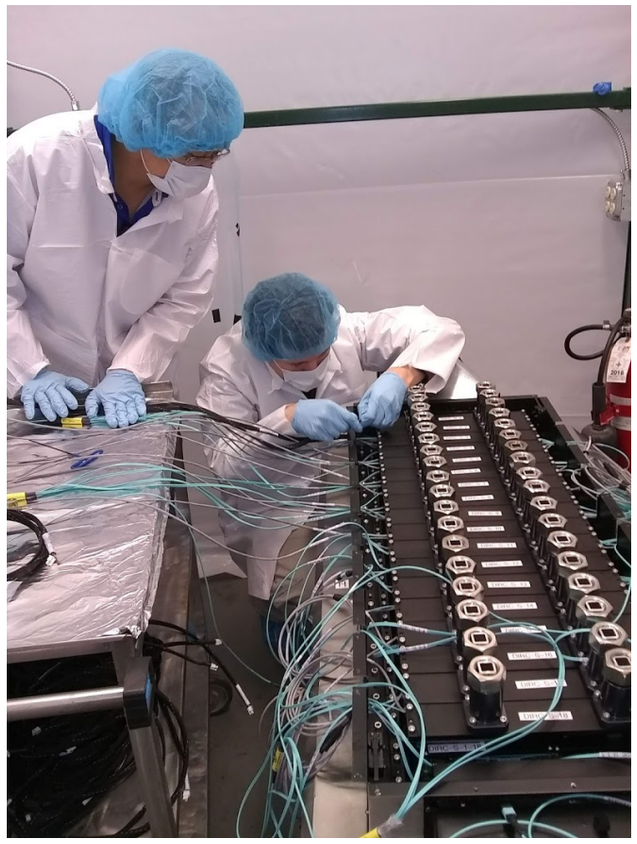
Hamamatsu
H12700 MAPMT



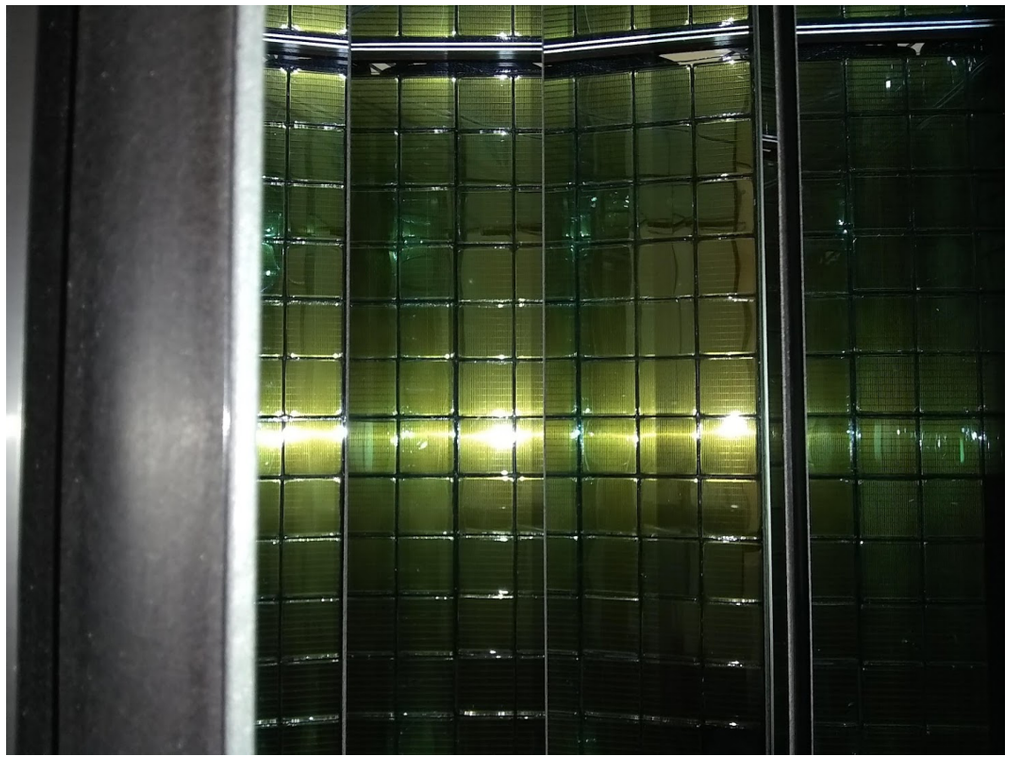
- Small magnetic field and limited timing resolution requirements to other DIRCs
- MAPMTs coupled to quartz window by optical cookies (a la Belle II)
- Utilized CLAS12 RICH readout with very similar requirements (see Marco's talk)

Photosensors and readout





Cherenkov Photon's Perspective

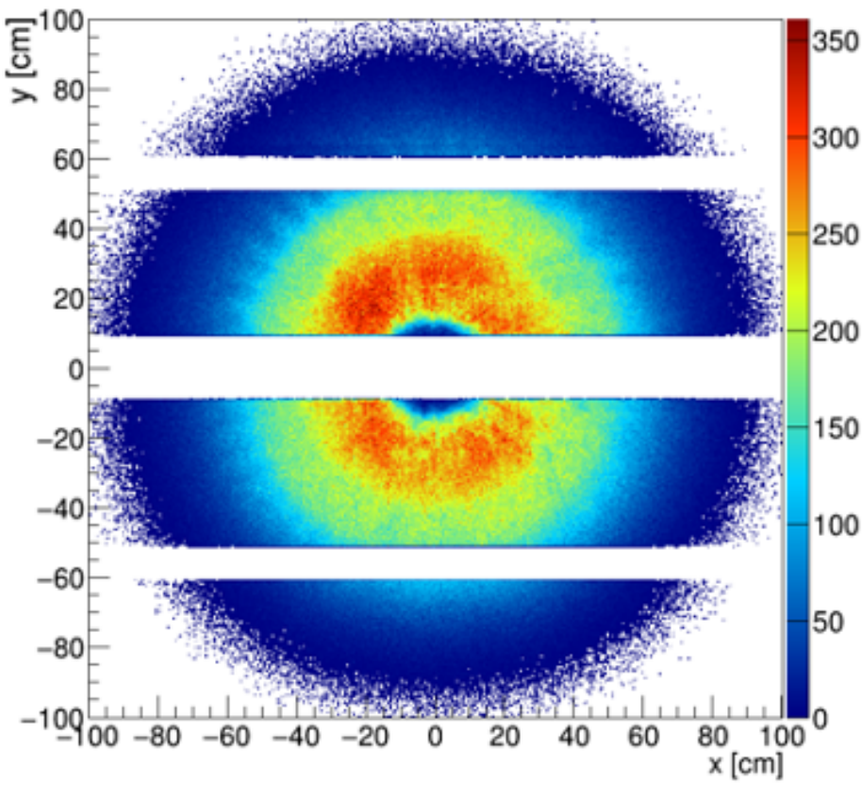


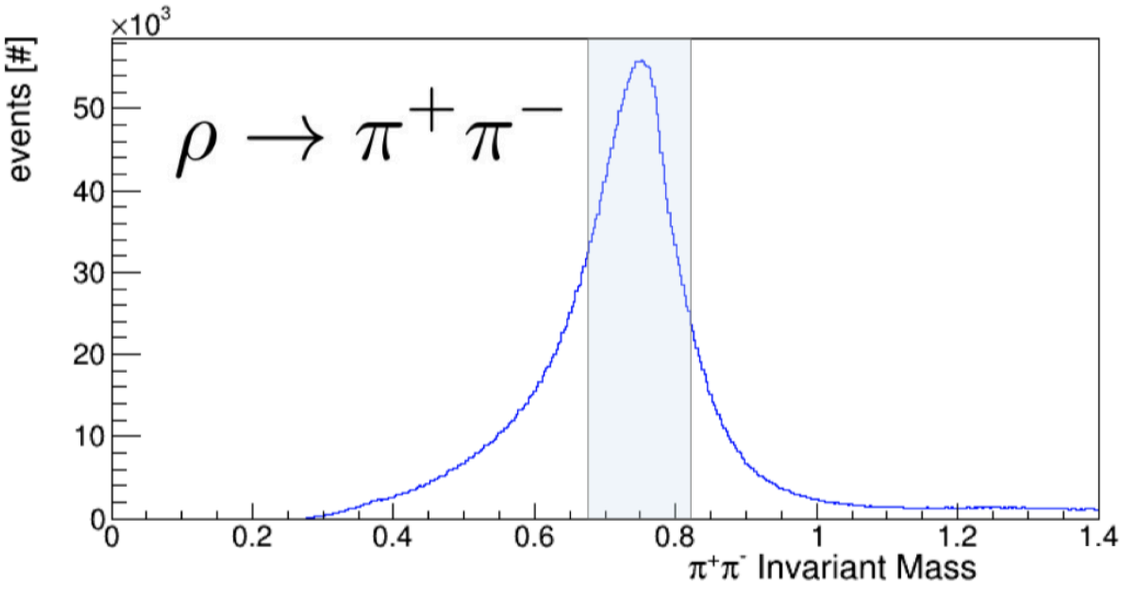
- Small magnetic field and limited timing resolution requirements to other DIRCs
- MAPMTs coupled to quartz window by optical cookies (a la Belle II)
- Utilized CLAS12 RICH readout with very similar requirements (see Marco's talk)

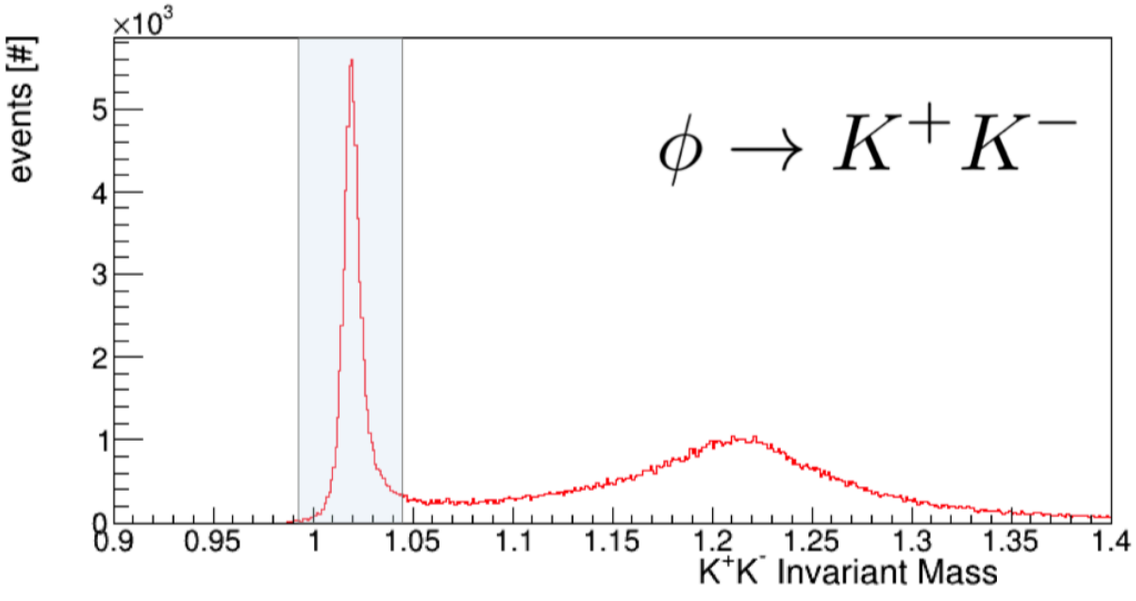
Timeline and performance evaluation

- 2018-2019: following GlueX-I, installation and commissioning
- 2020: GlueX-II production running for 6 months (COVID interruption), collected $\mathscr{L} \sim 0.35\ fb^{-1}$
- GlueX-II samples of exclusive ρ and ϕ photoproduction provide pure samples of $\pi^{\pm}$ and $K^{\pm}$ tracks for PID studies

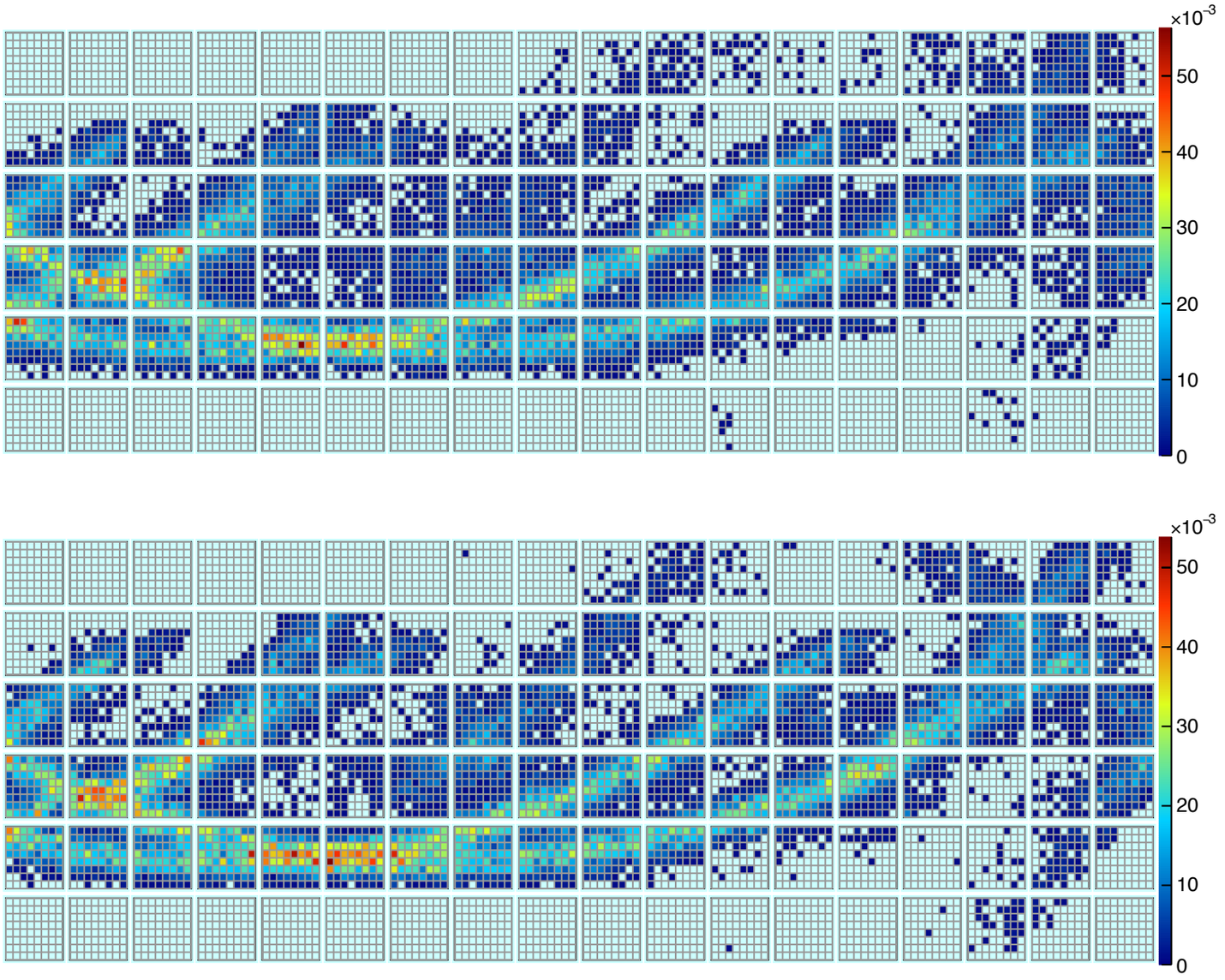
Track hit locations on DIRC plane







Photon hit patterns: **pions**

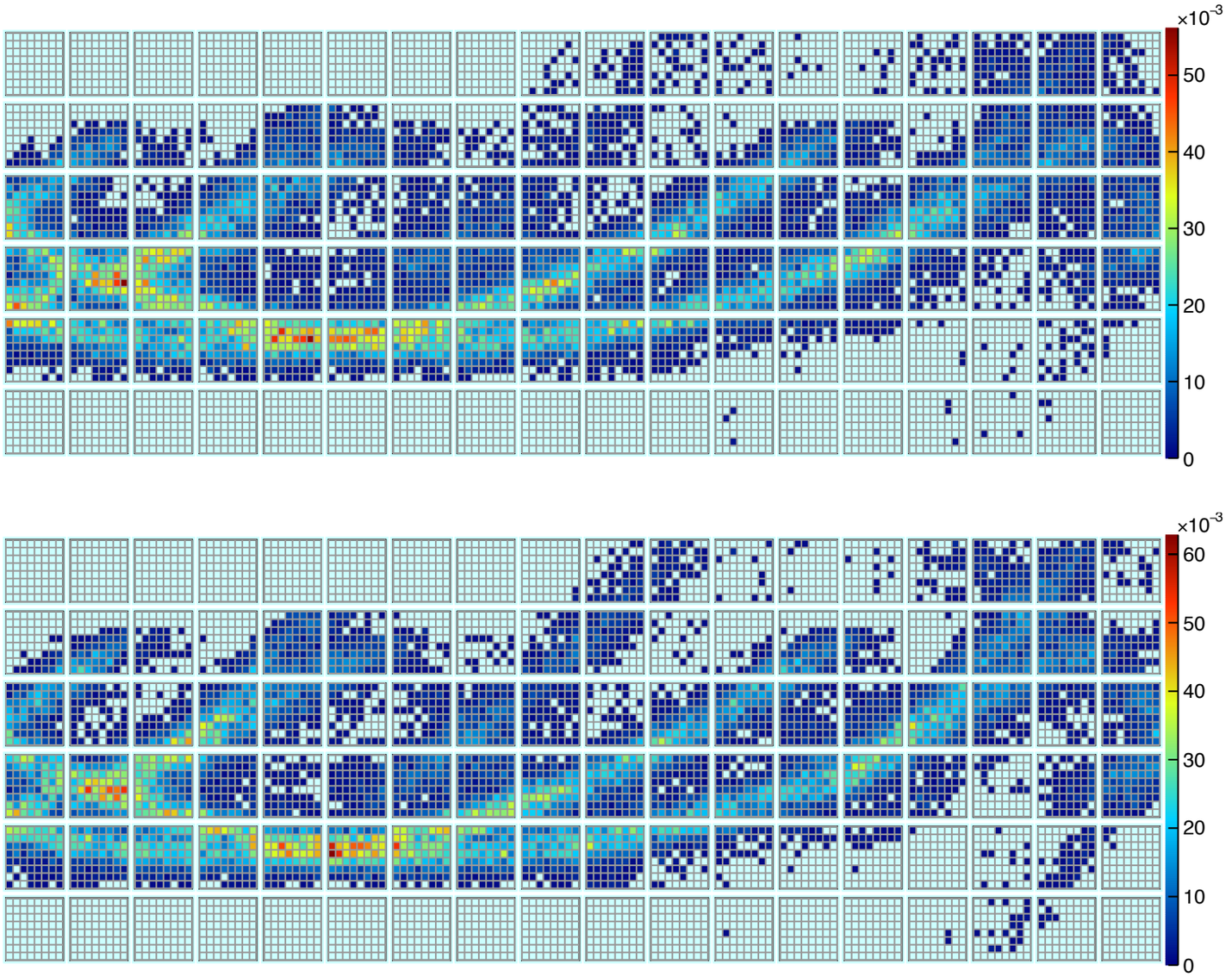


GlueX-II Data

Geant4 Simulation

- Hit patterns from 1000 identified pion tracks with p = 3.5 GeV/c
- Good agreement between beam data and simulations

Photon hit patterns: **kaons**



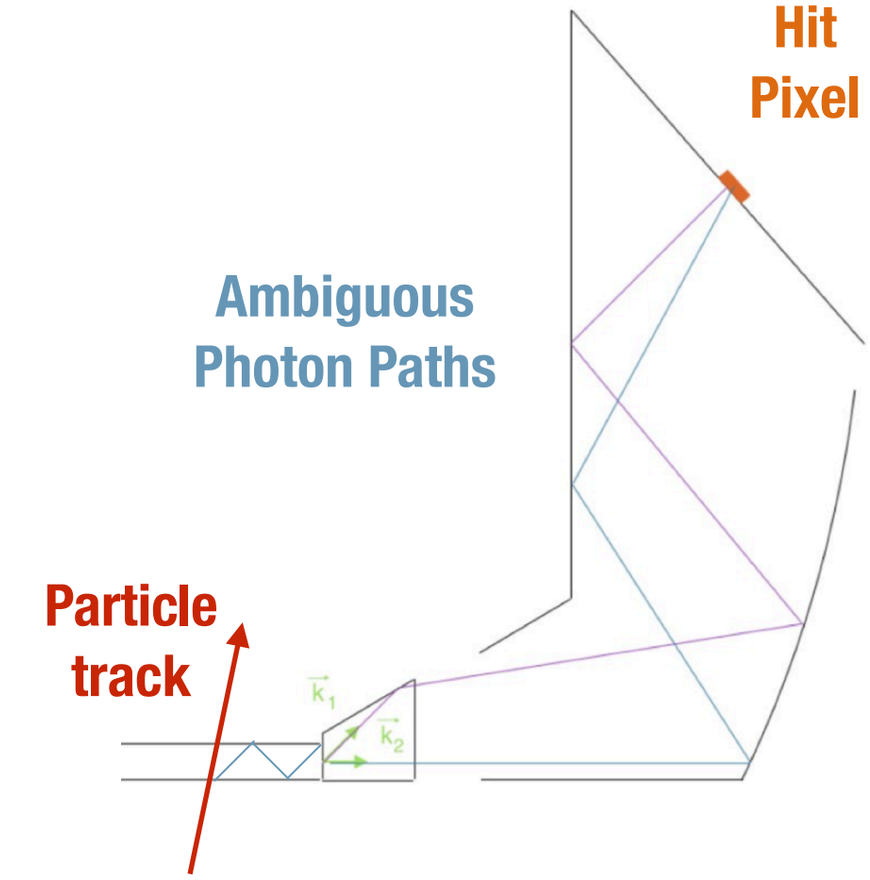
GlueX-II Data

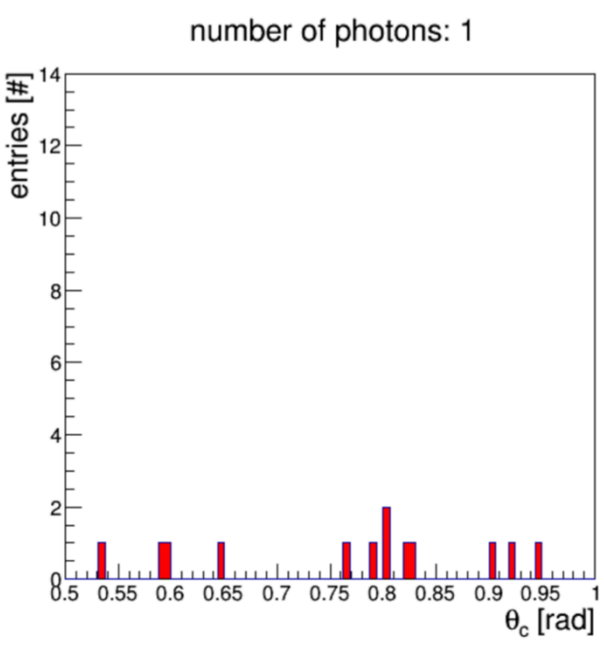
Geant4 Simulation

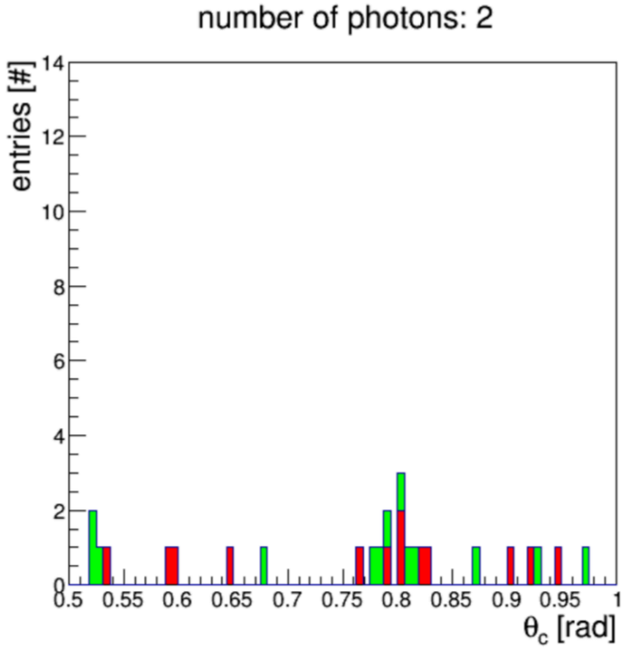
- Hit patterns from 1000 identified kaons tracks with p = 3.5 GeV/c
- Good agreement between beam data and simulations

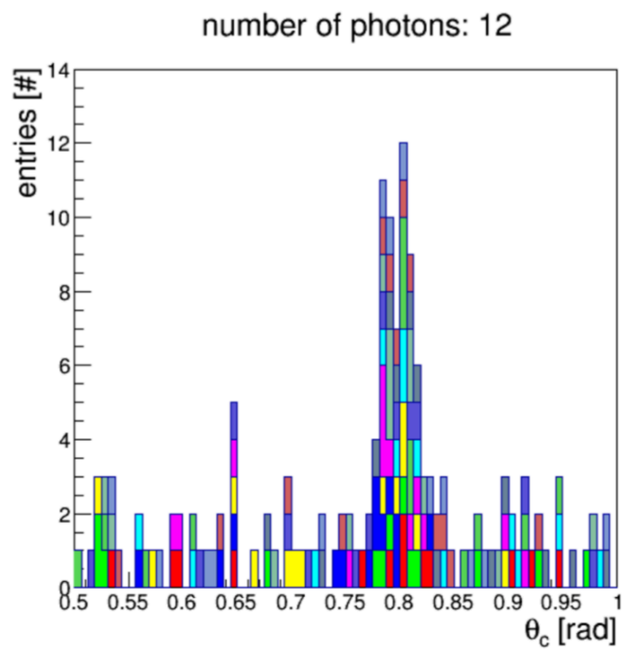
Geometric reconstruction

- Adapted from PANDA Barrel DIRC reconstruction (see Roman's talk next)
- Each detected photon has multiple ambiguous paths with different Cherenkov angles, computed using look up tables
- Compute likelihood for π and K mass hypothesis over all detected photons



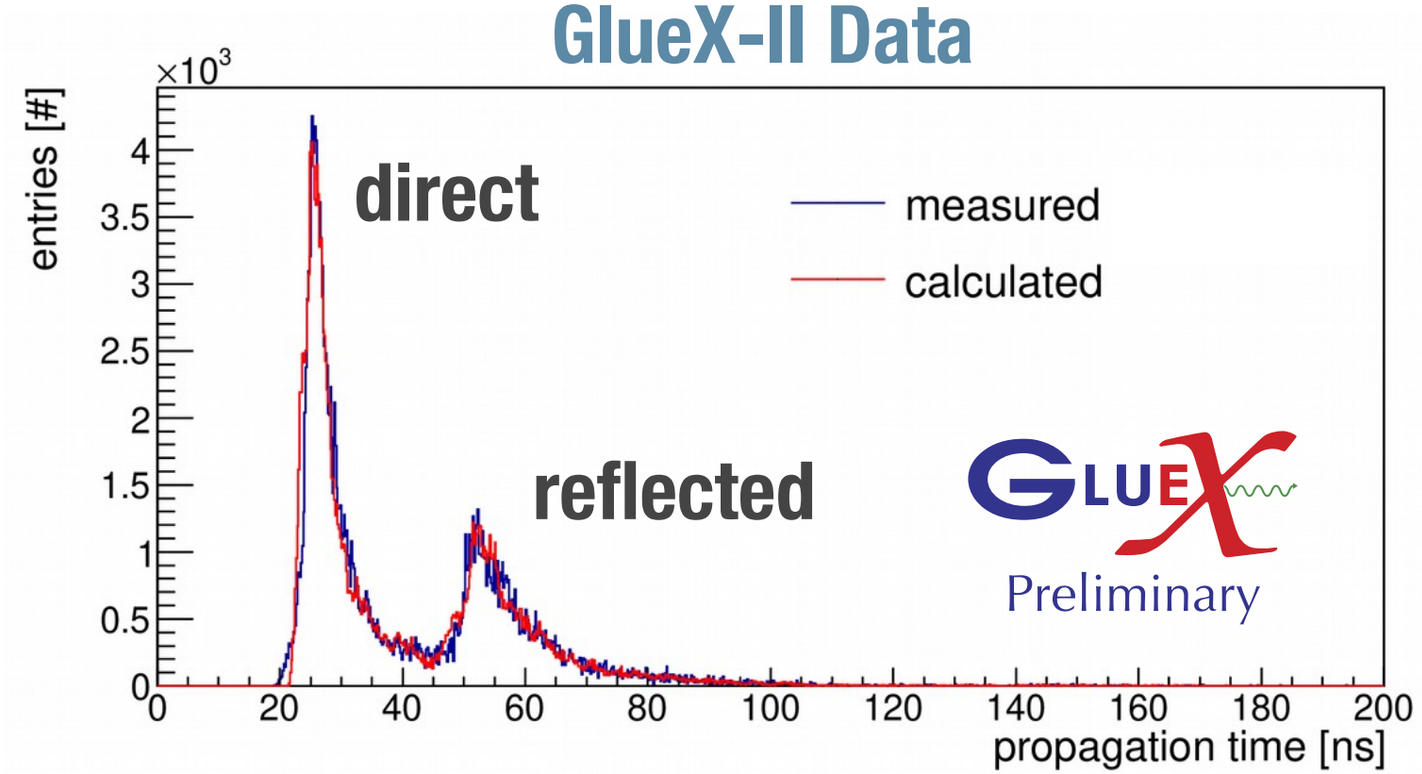


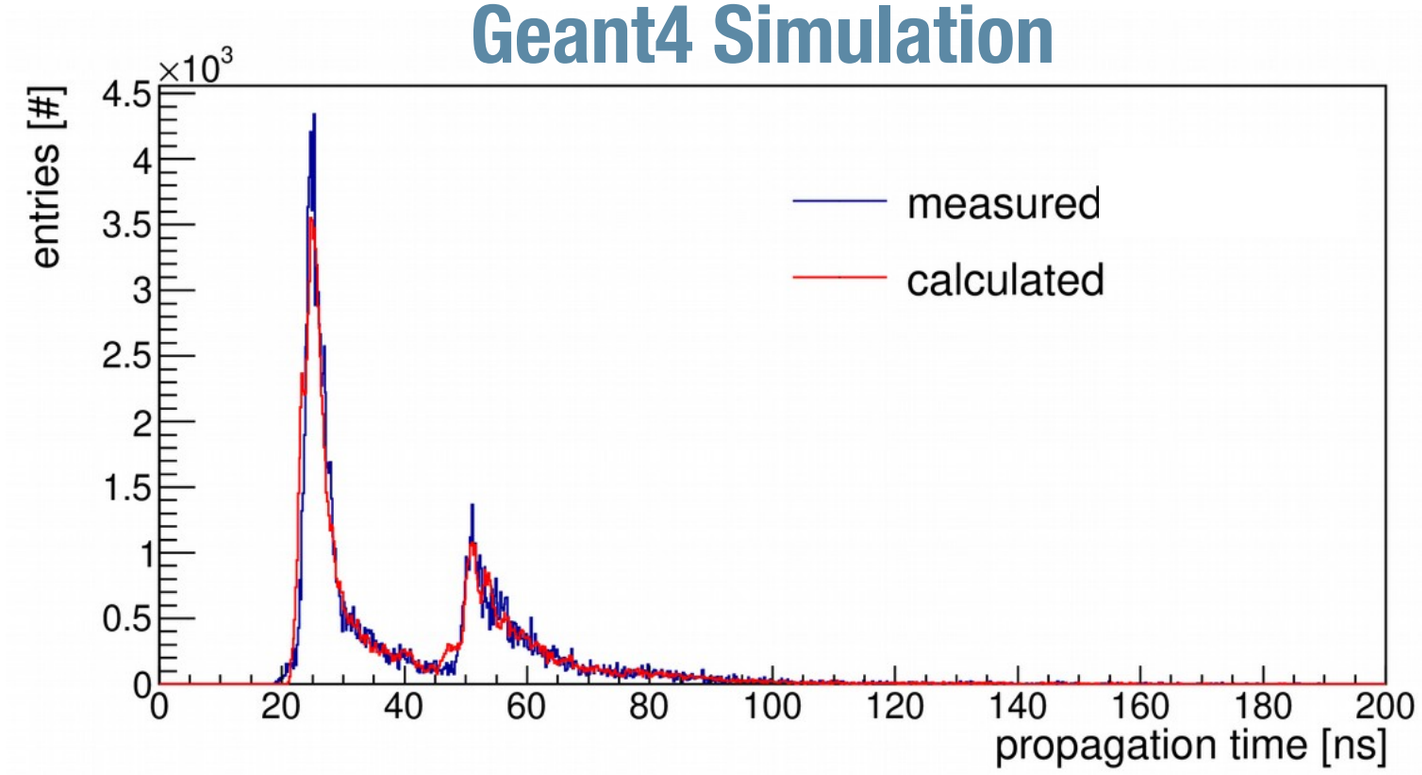




Photon Propagation Time

Propagation time: direct and reflected photons separable, reasonable data/MC agreement





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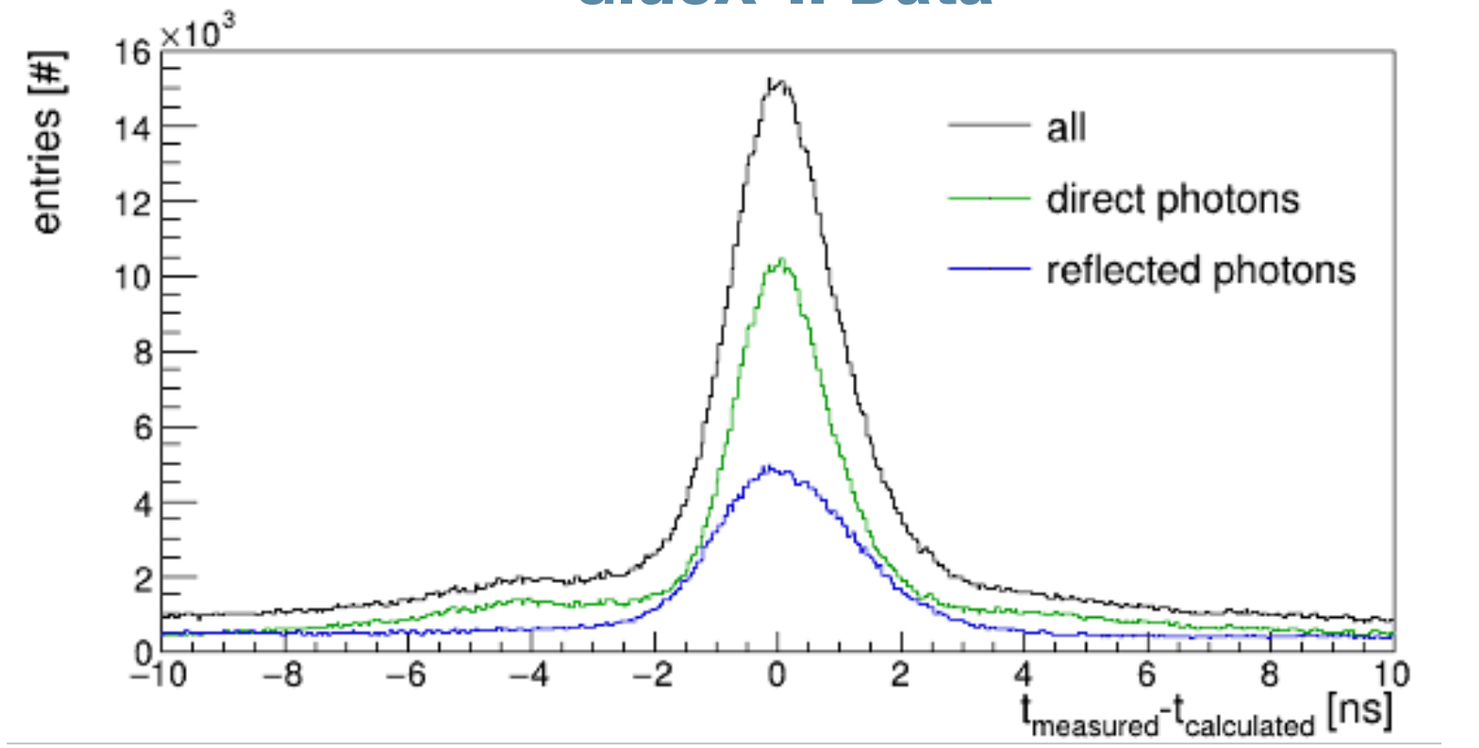
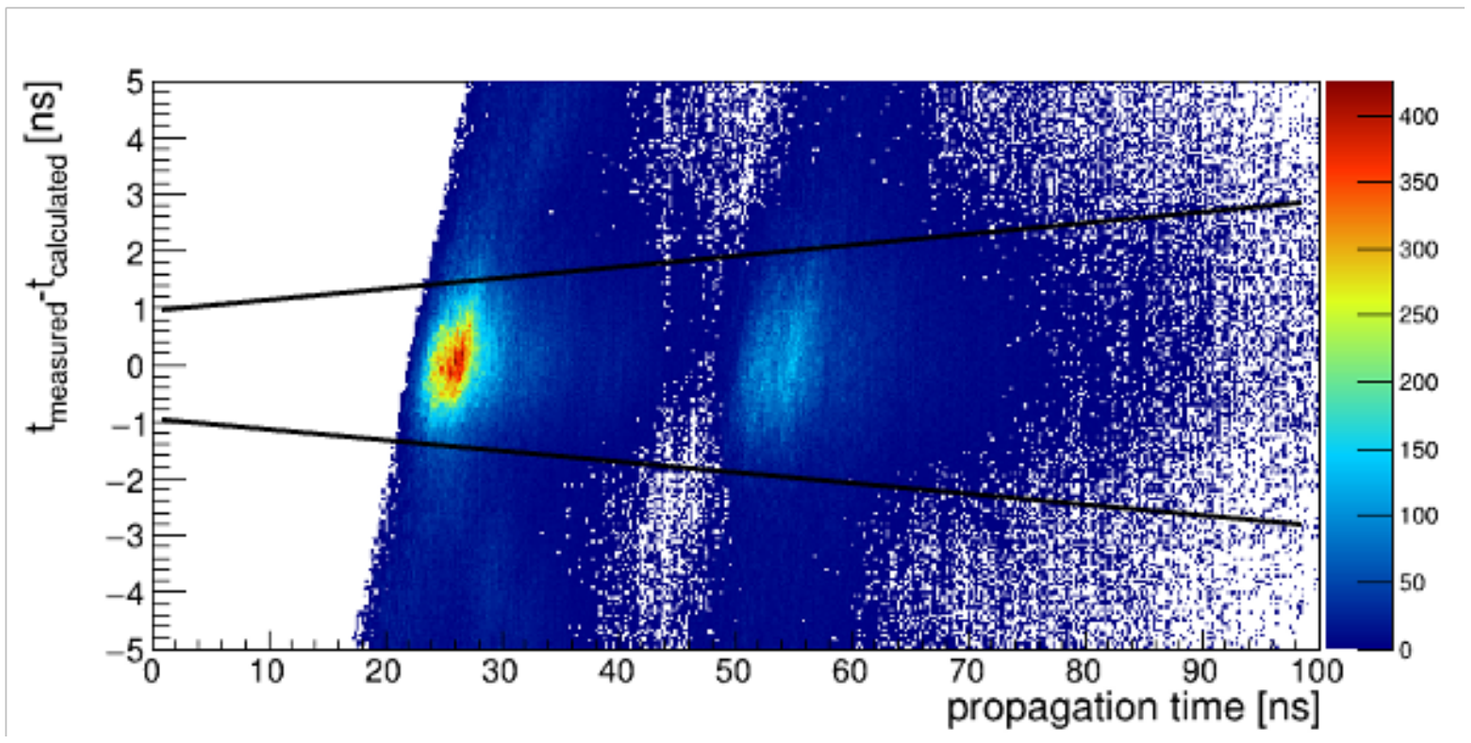
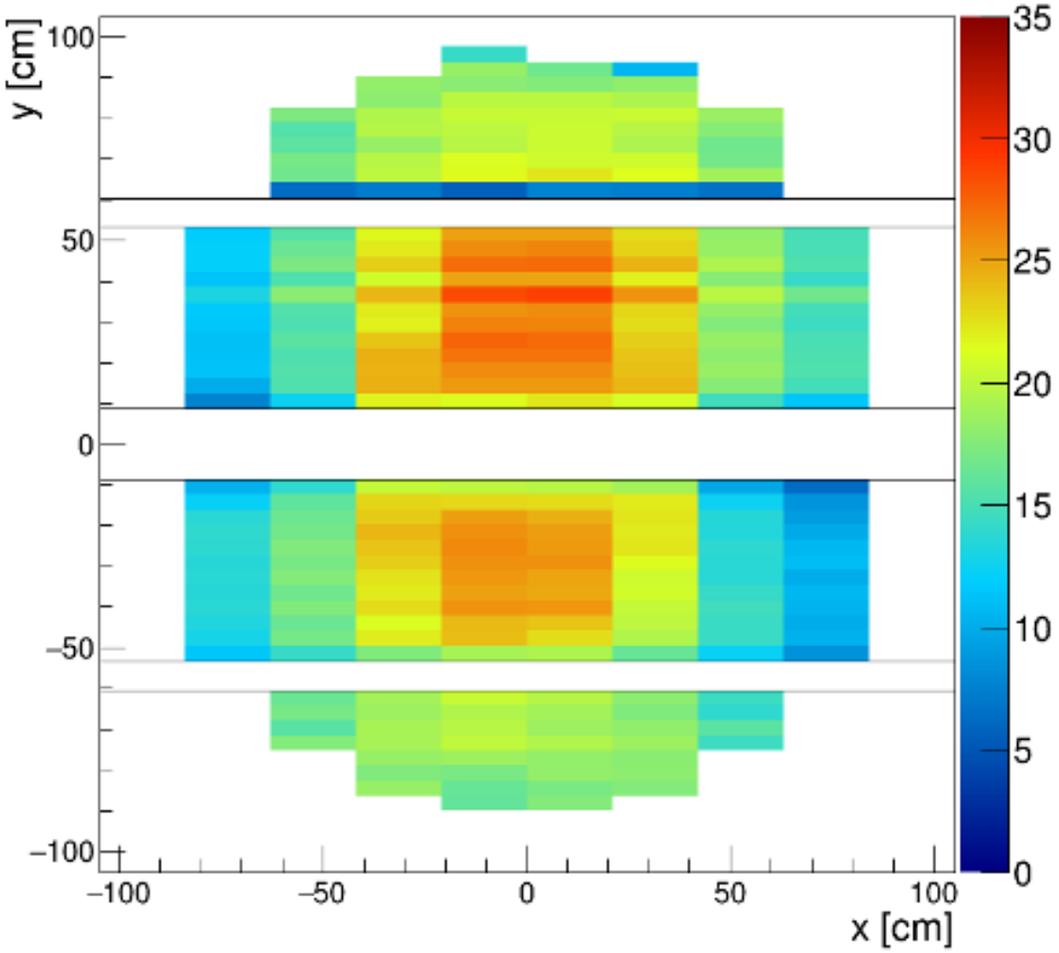


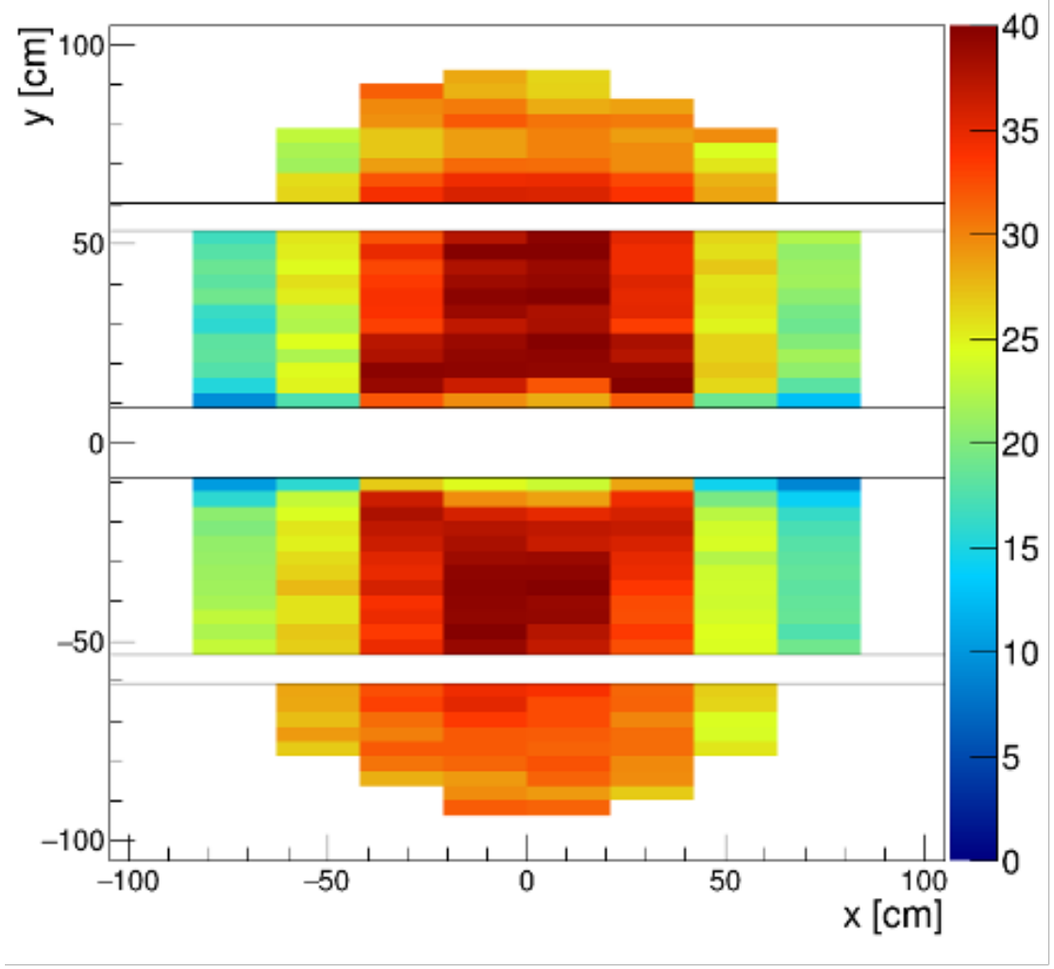


Photon Yield

GlueX-II Data



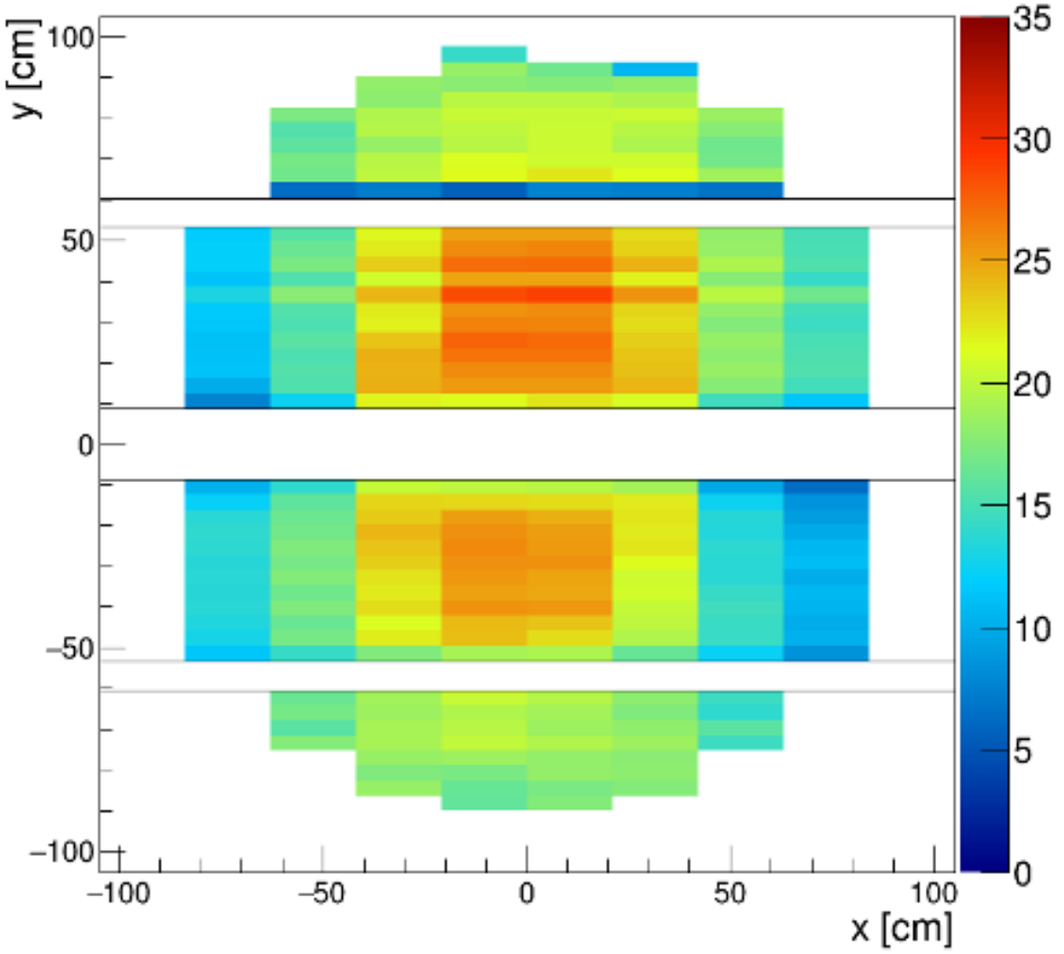
Geant4 Simulation



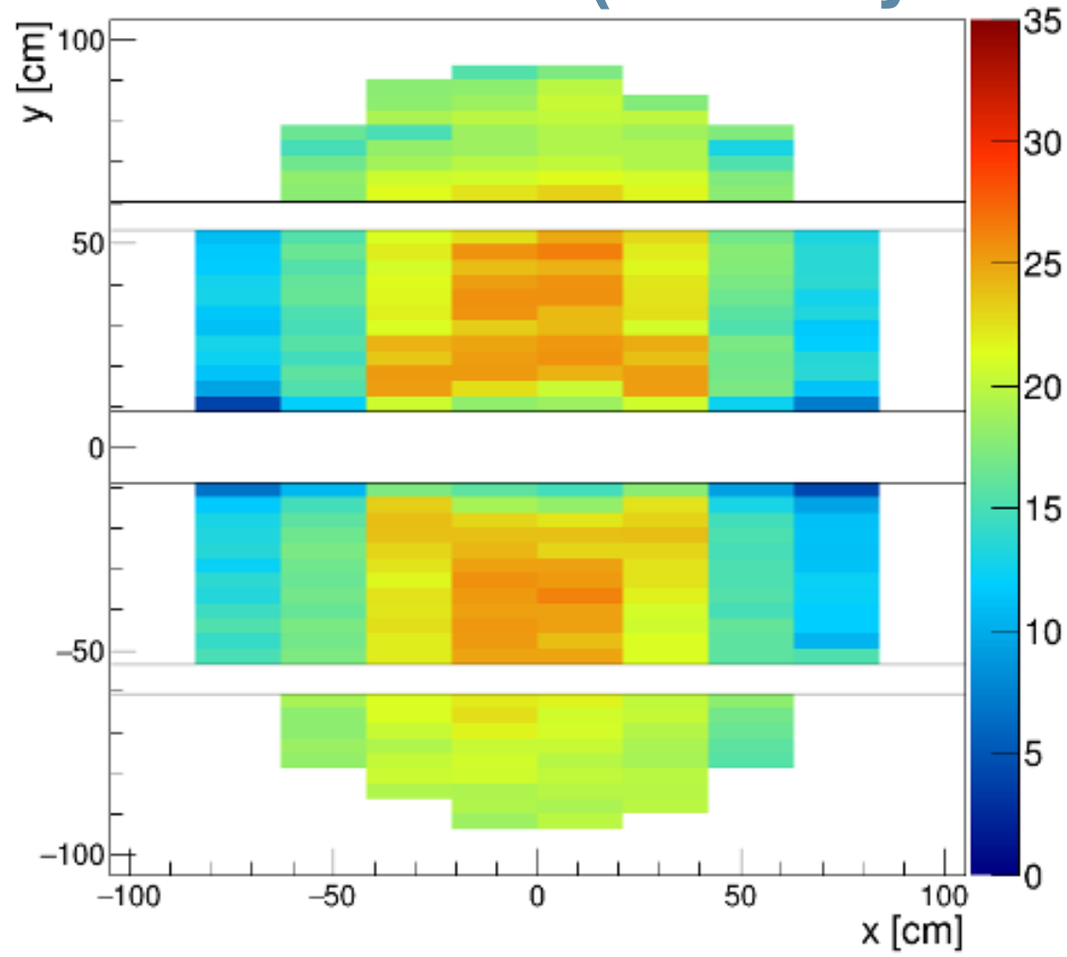
- Simulation overestimates yield by 36%, scaled for performance studies
- Observed mirror degradation during production running in 2020, mirrors replaced with borosilicate protective layer for improved water seal

Photon Yield

GlueX-II Data



Geant4 Simulation (scaled by 36%)



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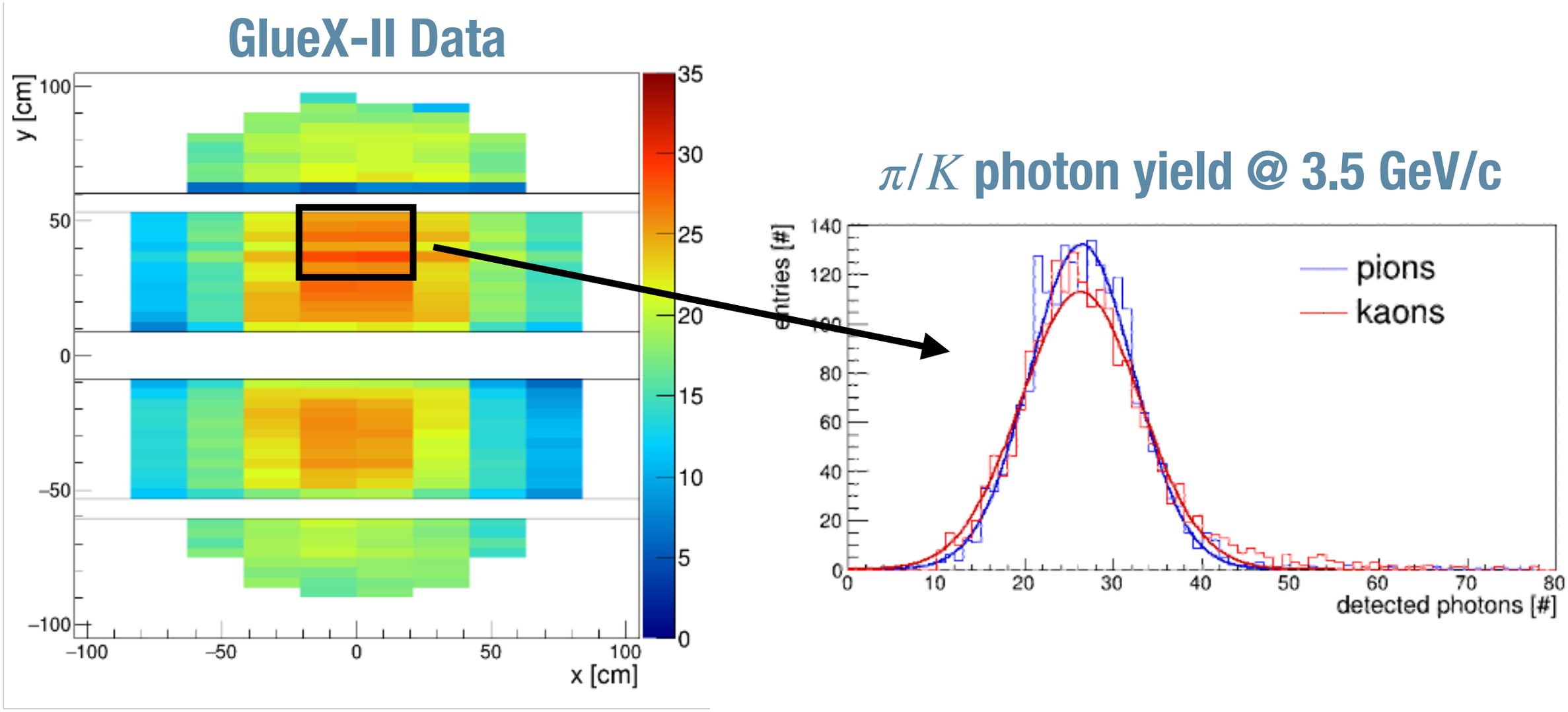

- Simulation overestimates yield by 36%, scaled for performance studies
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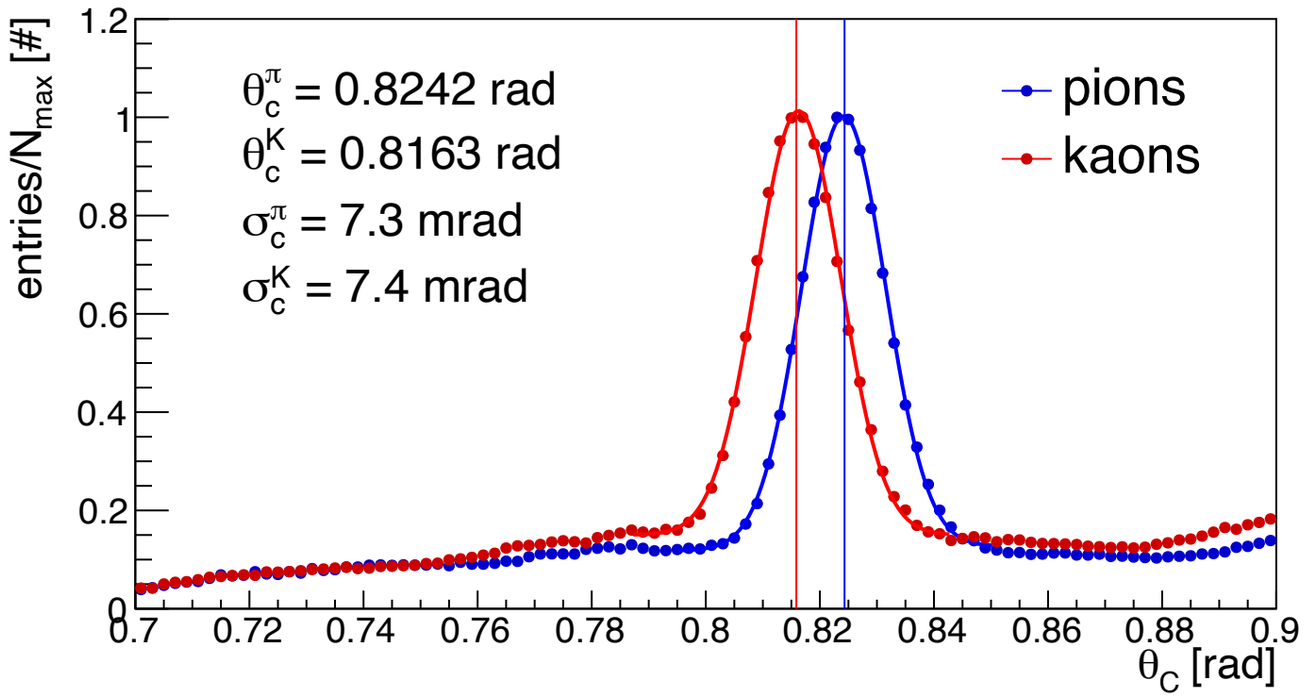
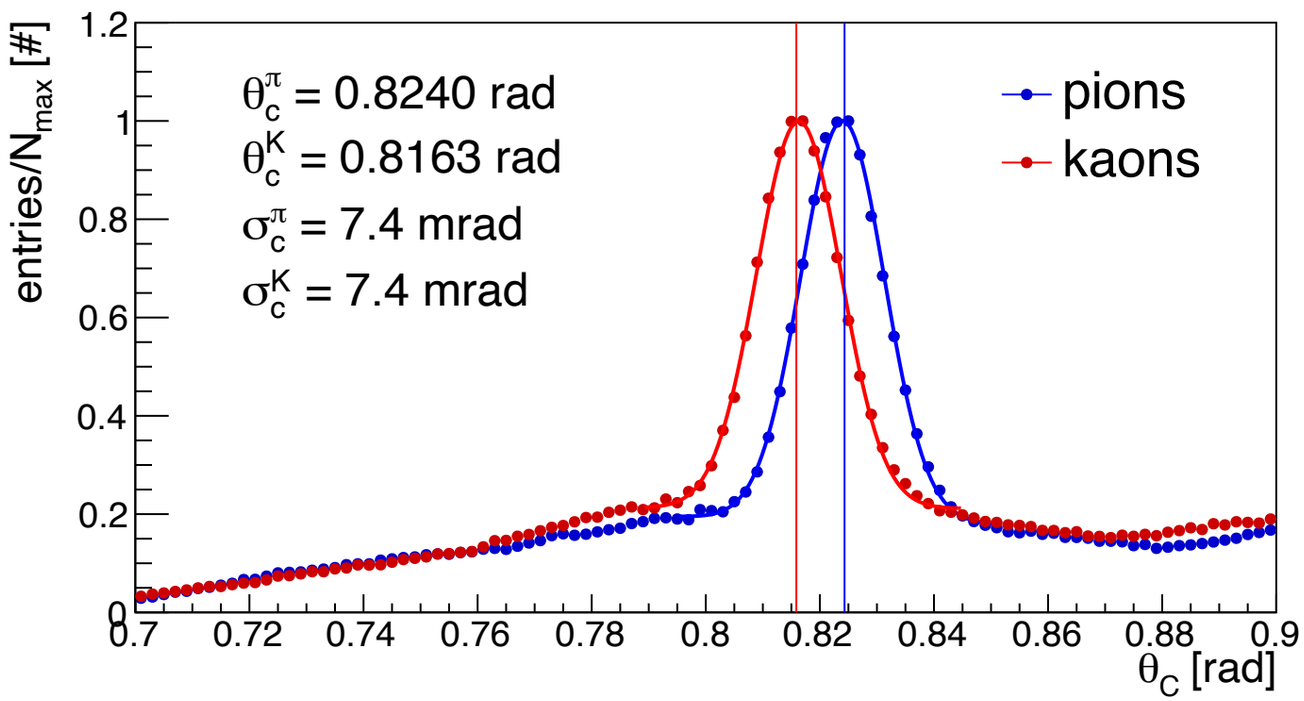
Single photon resolution

Single Photon Resolution: example at 3.5 GeV/c, in good agreement with expectations from simulation

GlueX-II Data



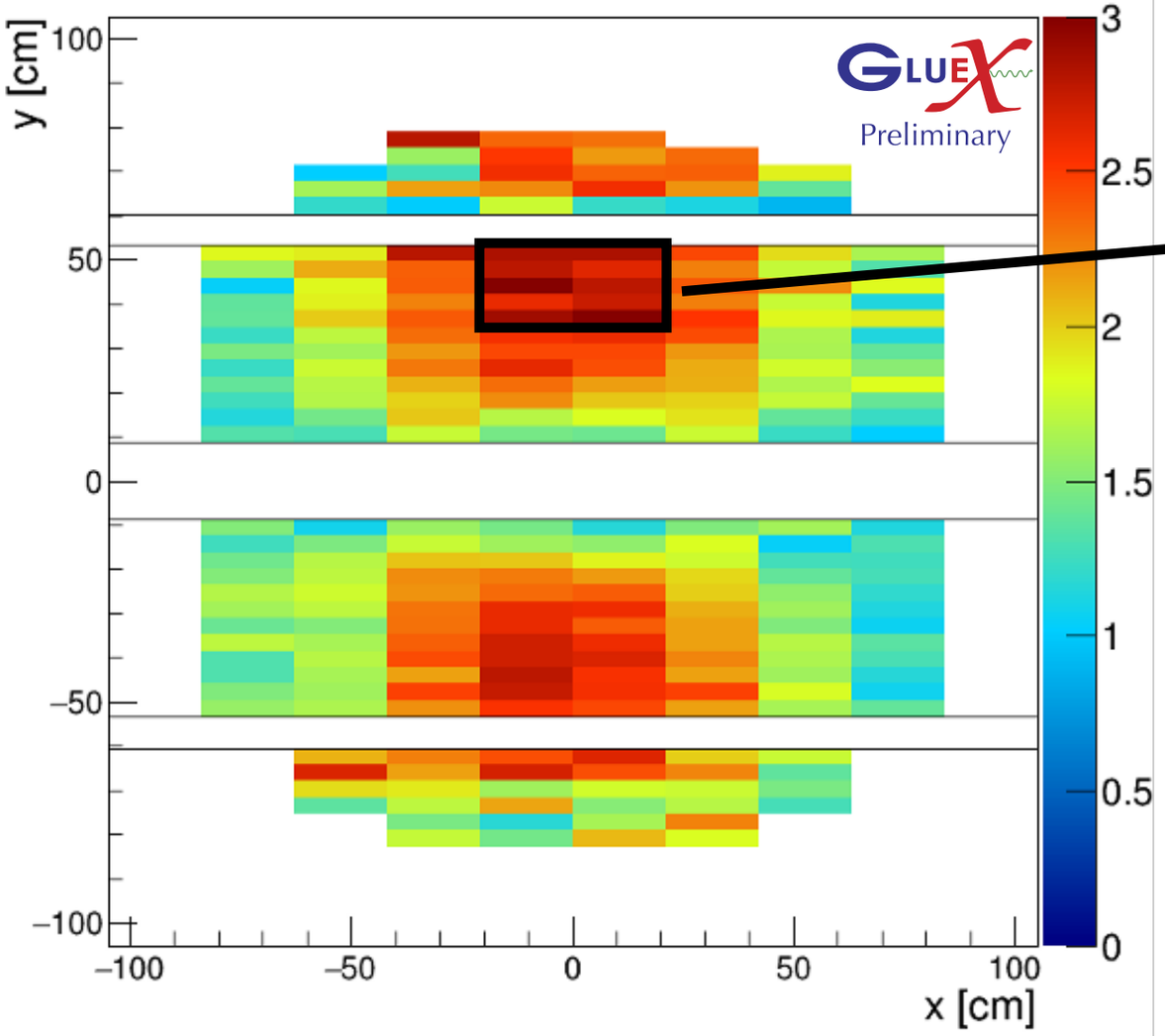
Geant4 Simulation

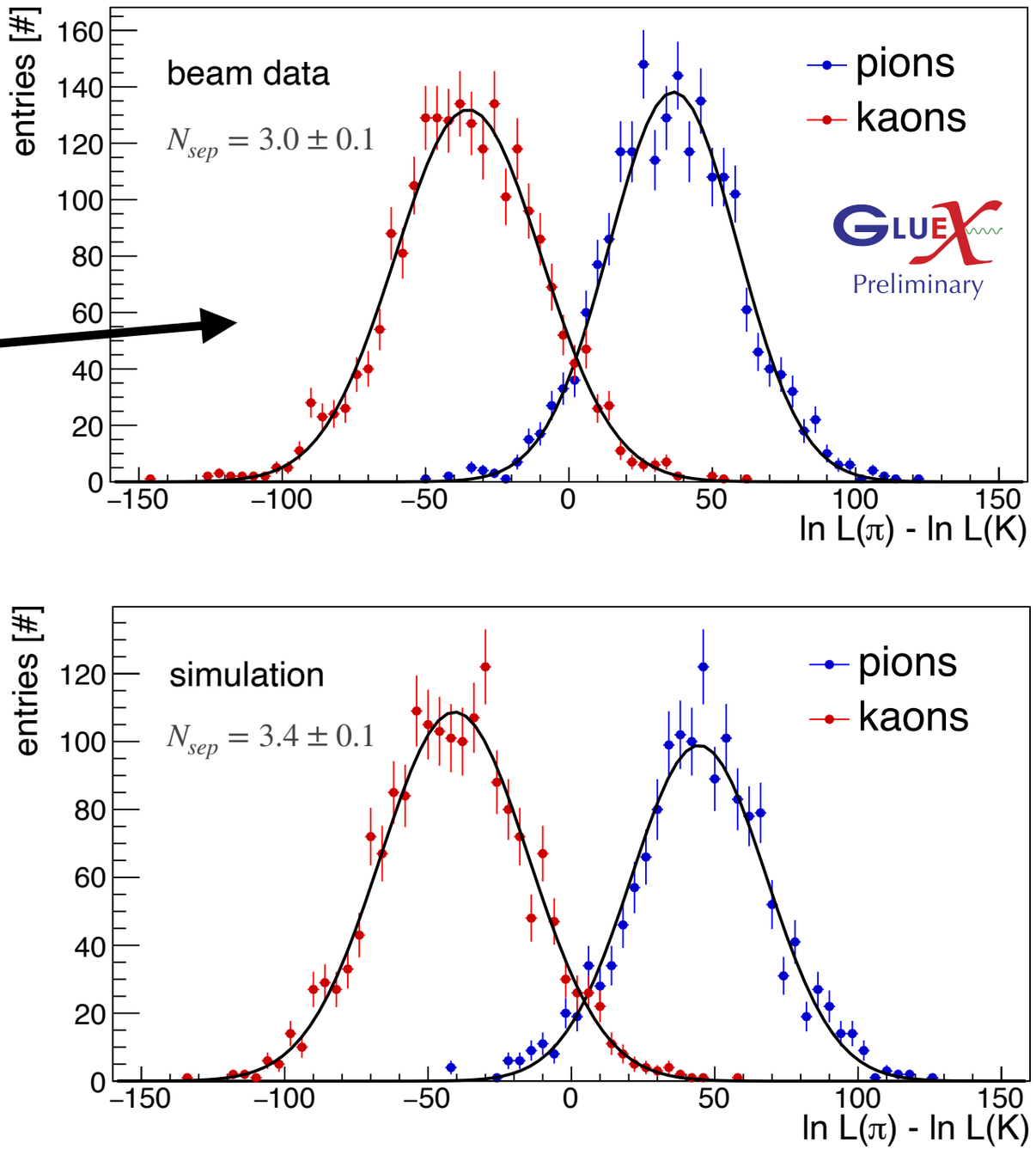


Separation power

$$N_{sep} = \frac{|\mu_\pi - \mu_k|}{0.5(\sigma_\pi + \sigma_k)}$$

π/K separation power @ 3.5 GeV/c

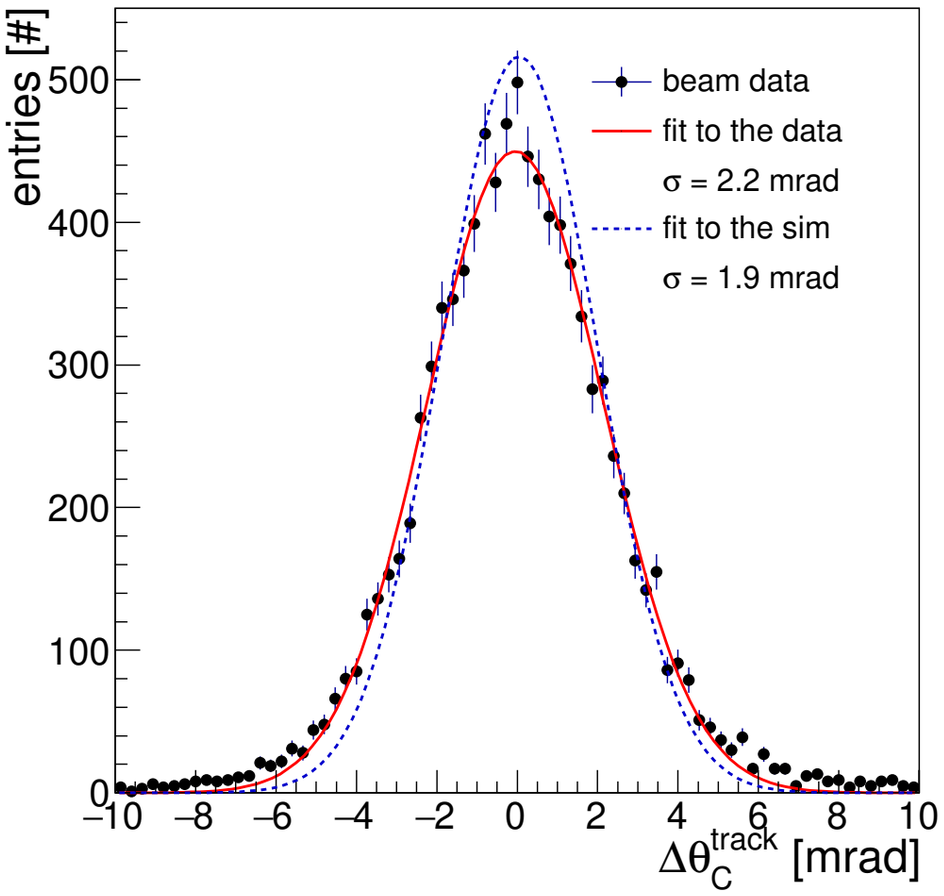




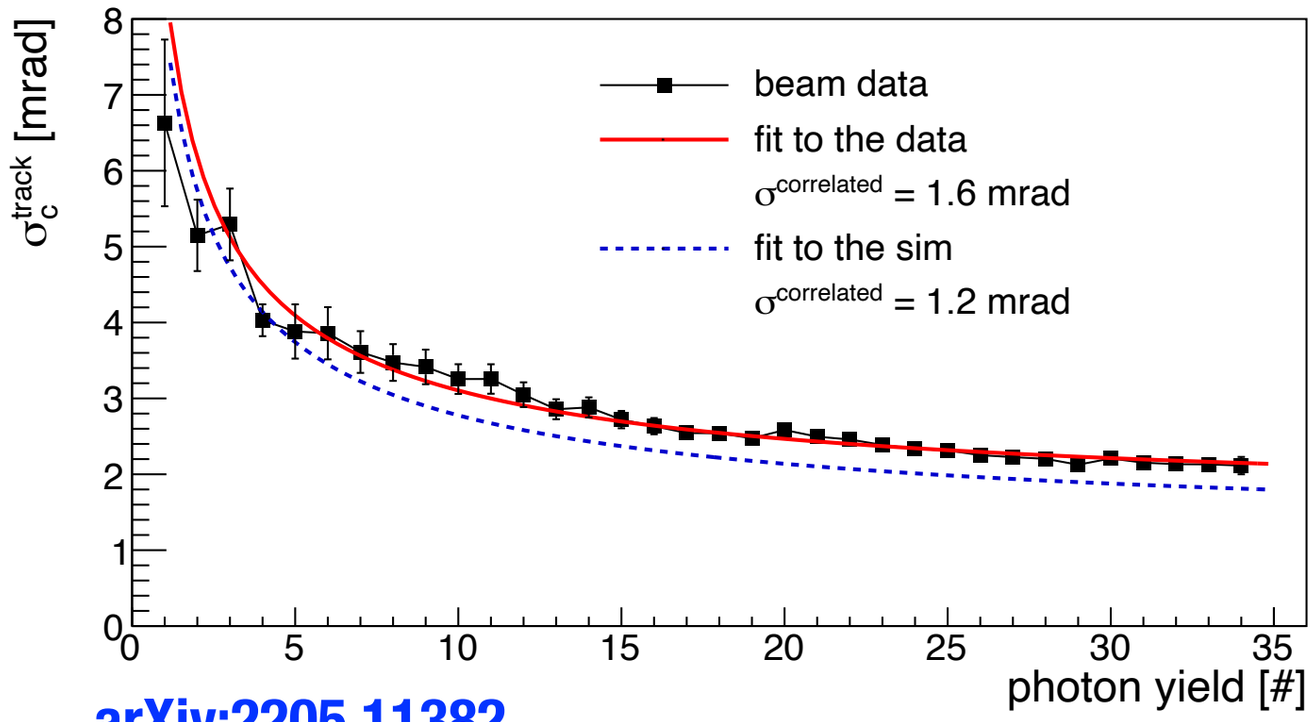
arXiv:2205.11382

Cherenkov Track Resolution

π track resolution @ 3.5 GeV/c



$$\sigma_C^{track} = \sqrt{\left(\frac{\sigma_C^{photon}}{\sqrt{N_{photons}}}\right)^2 + \left(\sigma^{correlated}\right)^2}$$

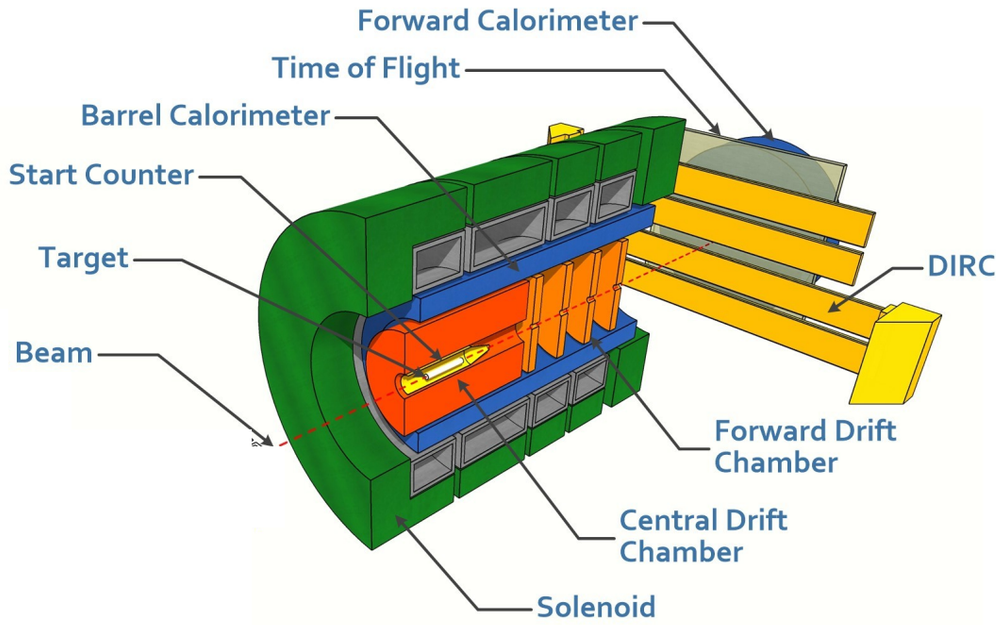


arXiv:2205.11382

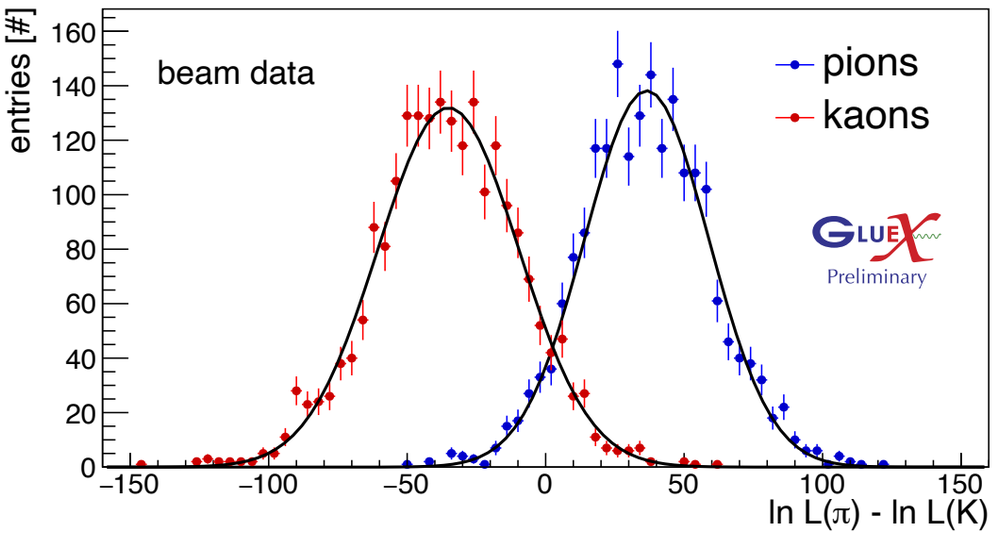
- Resolution for each track to separate per-photon and correlated contributions
- With 2.2 mrad resolution, expect 3.8σ π/K separation at 3.5 GeV/c, but so far only 3.0σ achieved: non-guassian tails contribute to reducing performance
- Simulation predicts 1.2 mrad for correlated term, improvements are possible

Summary

- The high-intensity phase of GlueX is well underway
- Successful DIRC installation and commissioning completed; first production data in 2020



- Initial performance evaluation: 3σ π/K separation at 3.5 GeV/c with significant correlated term
- Production running expected in 2023 before year-long shutdown to install $PbWO_4$ calorimeter



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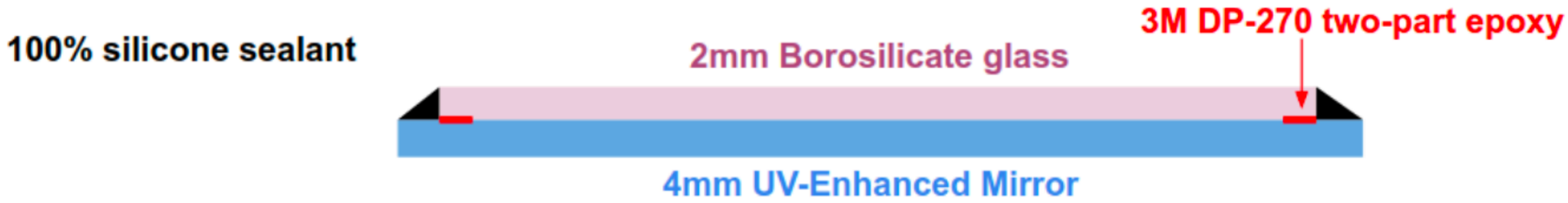
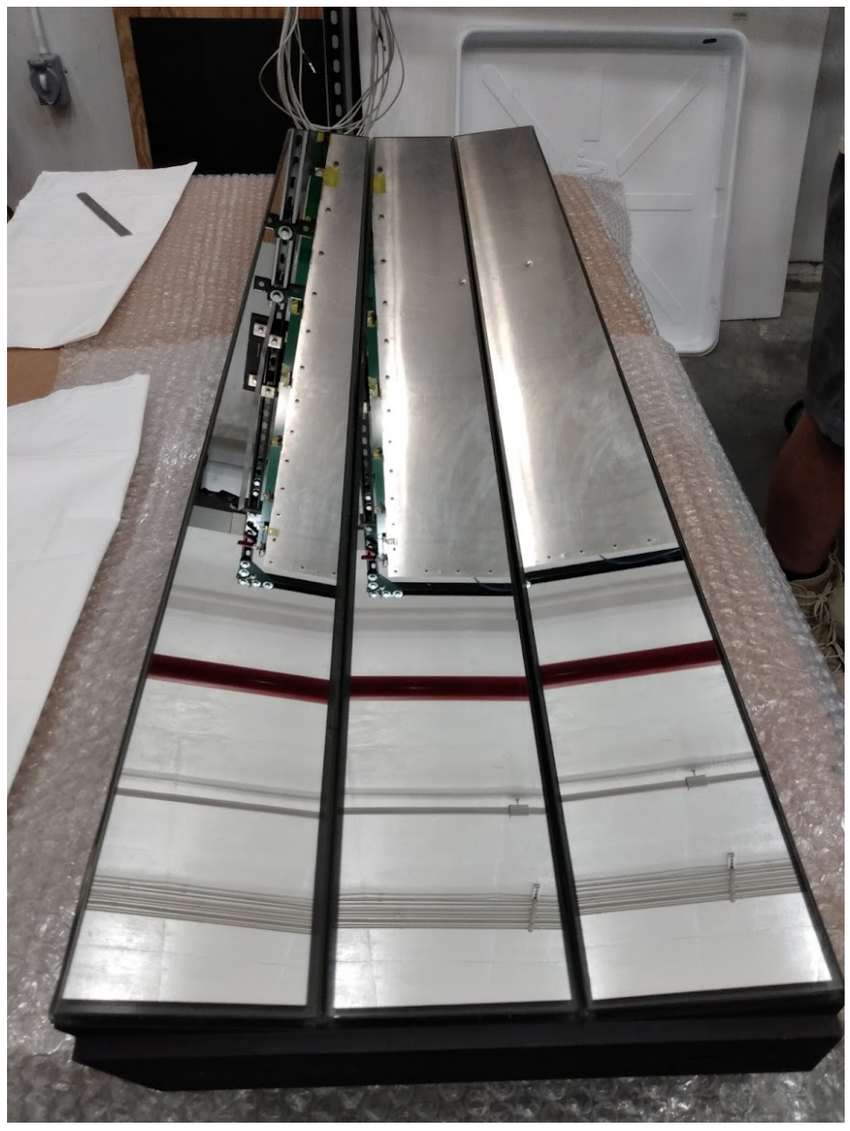
Backup

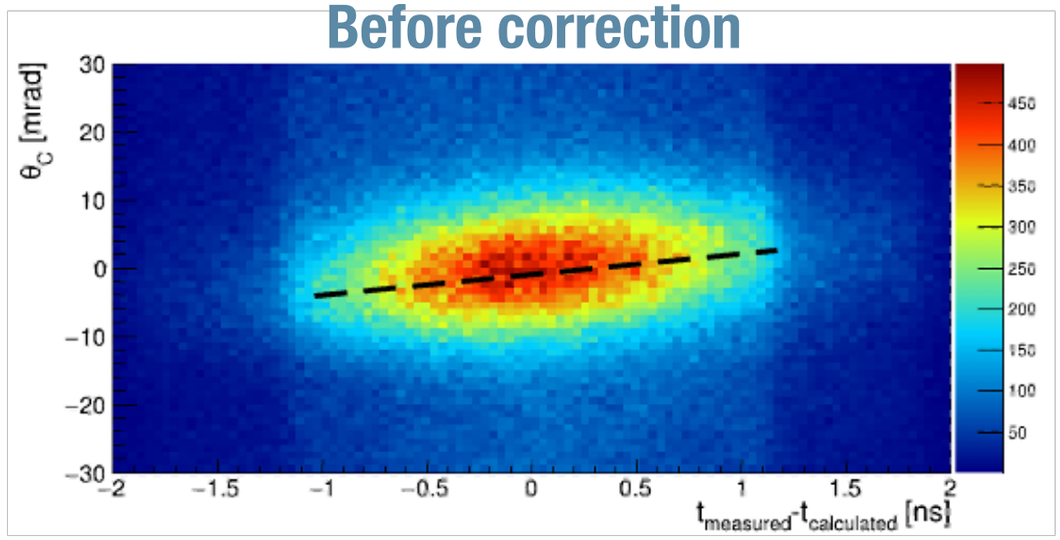
Mirror water protection

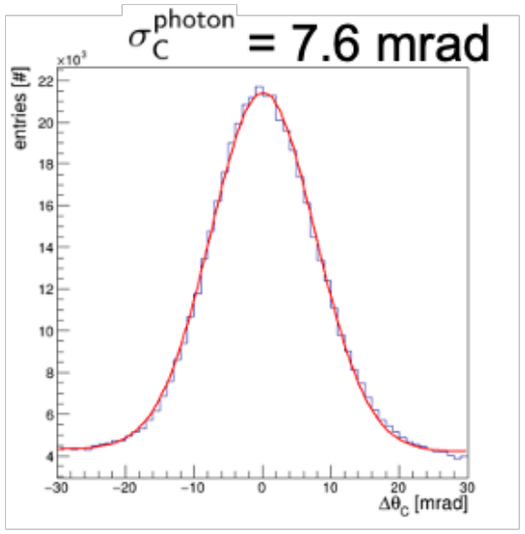


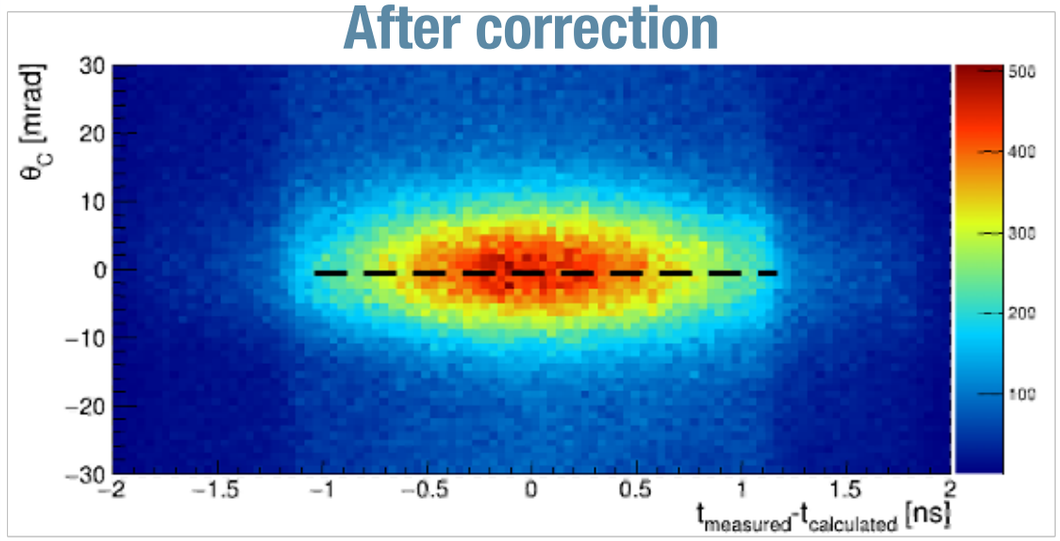


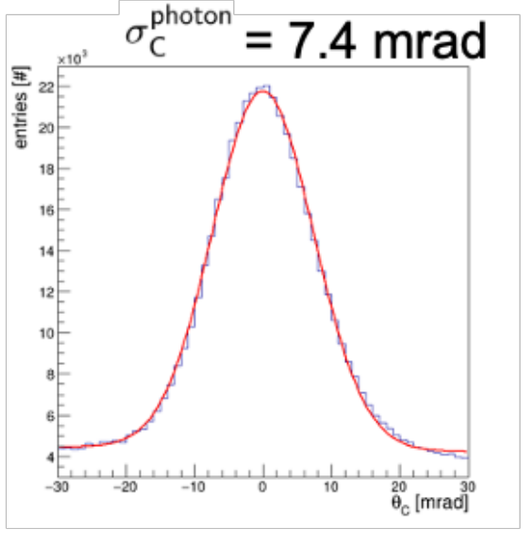
- Borosilicate bonding improved with etched mirror surface
- Silicone seal improved for redundant protection from water

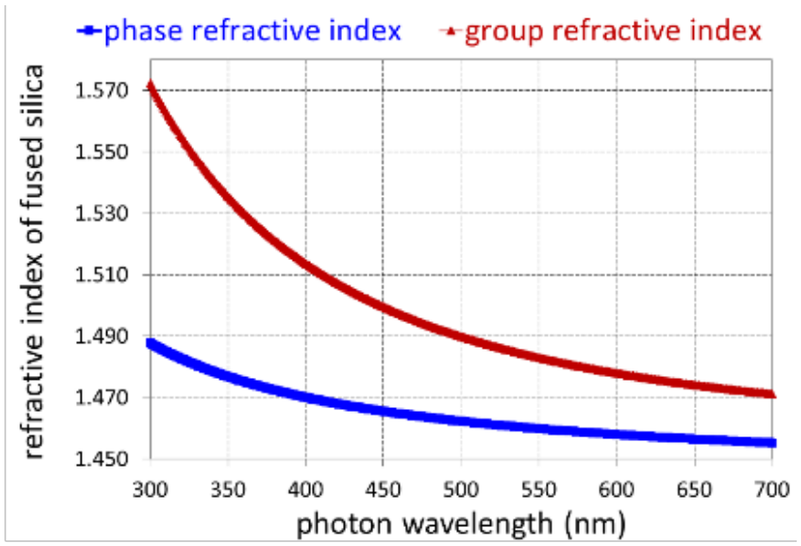
Chromatic correction





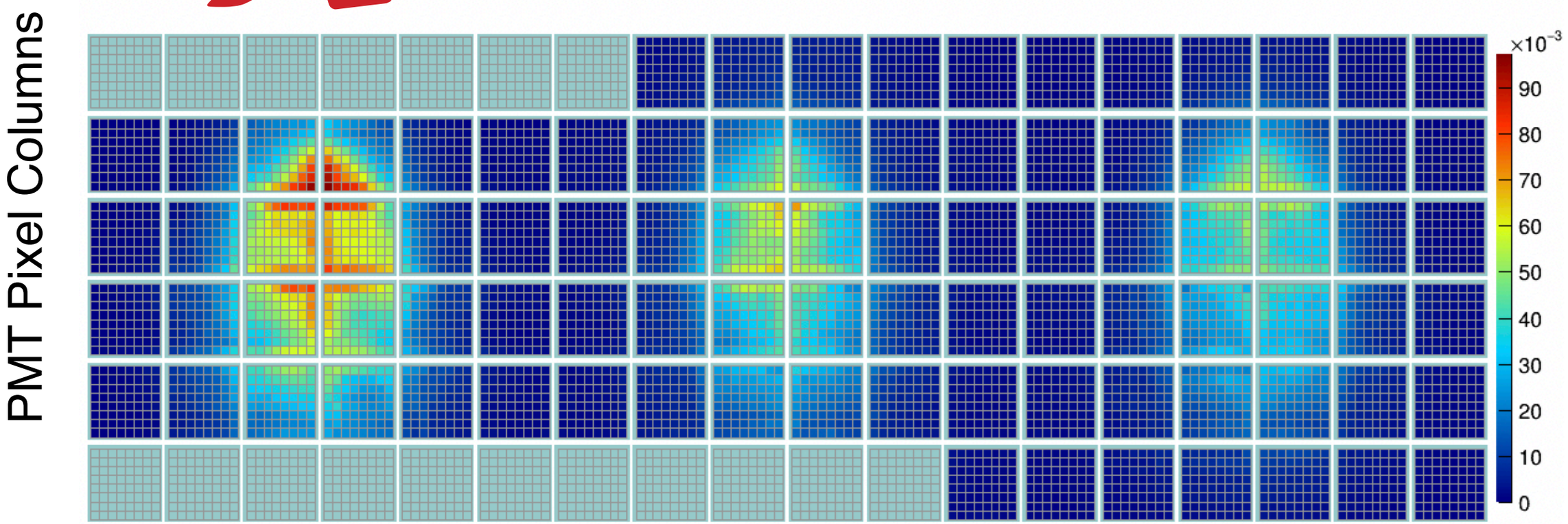




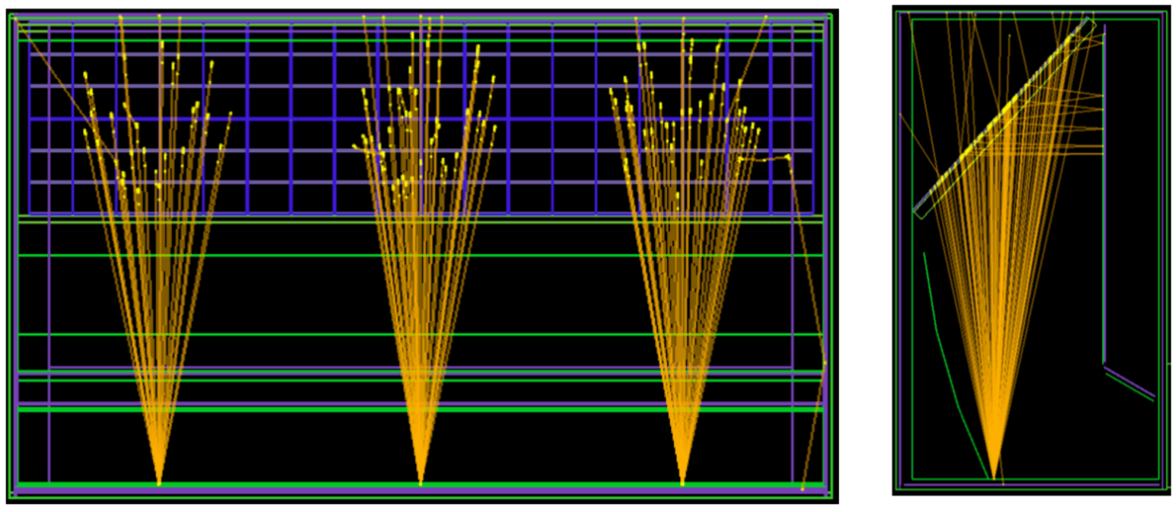


- Refractive index dependence on wavelength corrected by photon propagation time with limited ~1 ns resolution
- Improvement of single photon resolution after correction

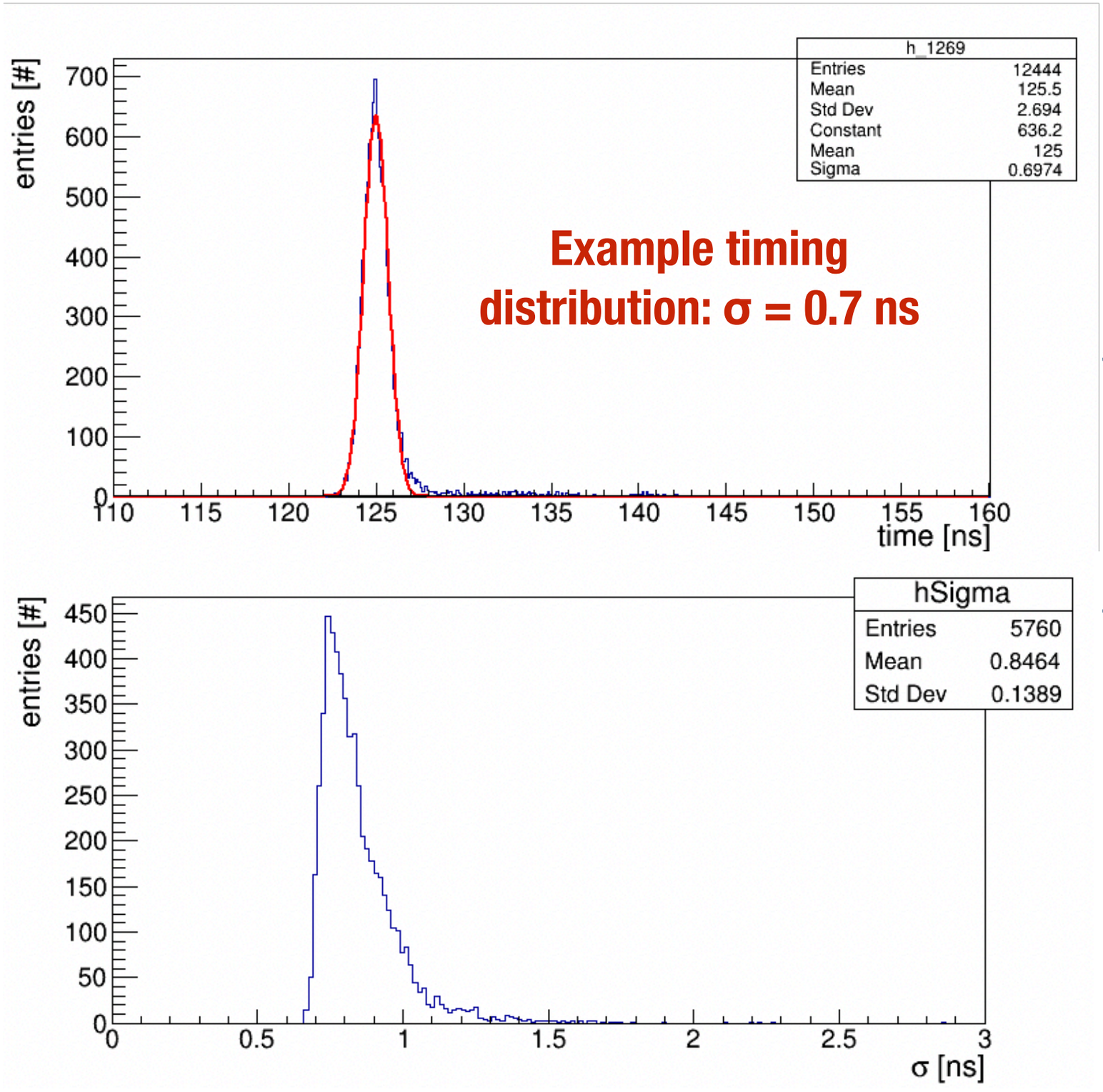
DIRC calibration system



- 405 nm LED pulser with 840 ps rise time, split over 3 fibers with 25° opening angle to cover the full MAPMT array
- Run in parallel with physics trigger for continuous monitoring



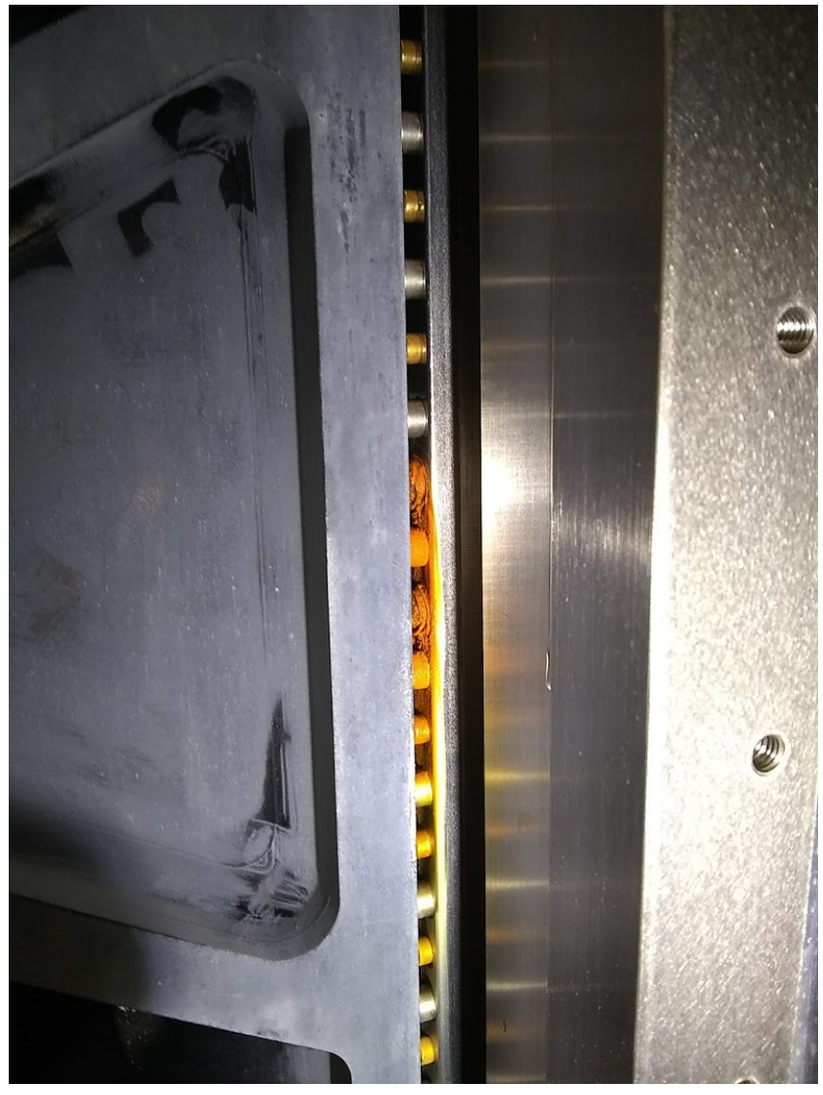
DIRC calibration system



- Per-pixel timing offsets calibrated with LED system
- Resolution < 1 ns is sufficient for geometric LUT reconstruction

Commissioning aftermath

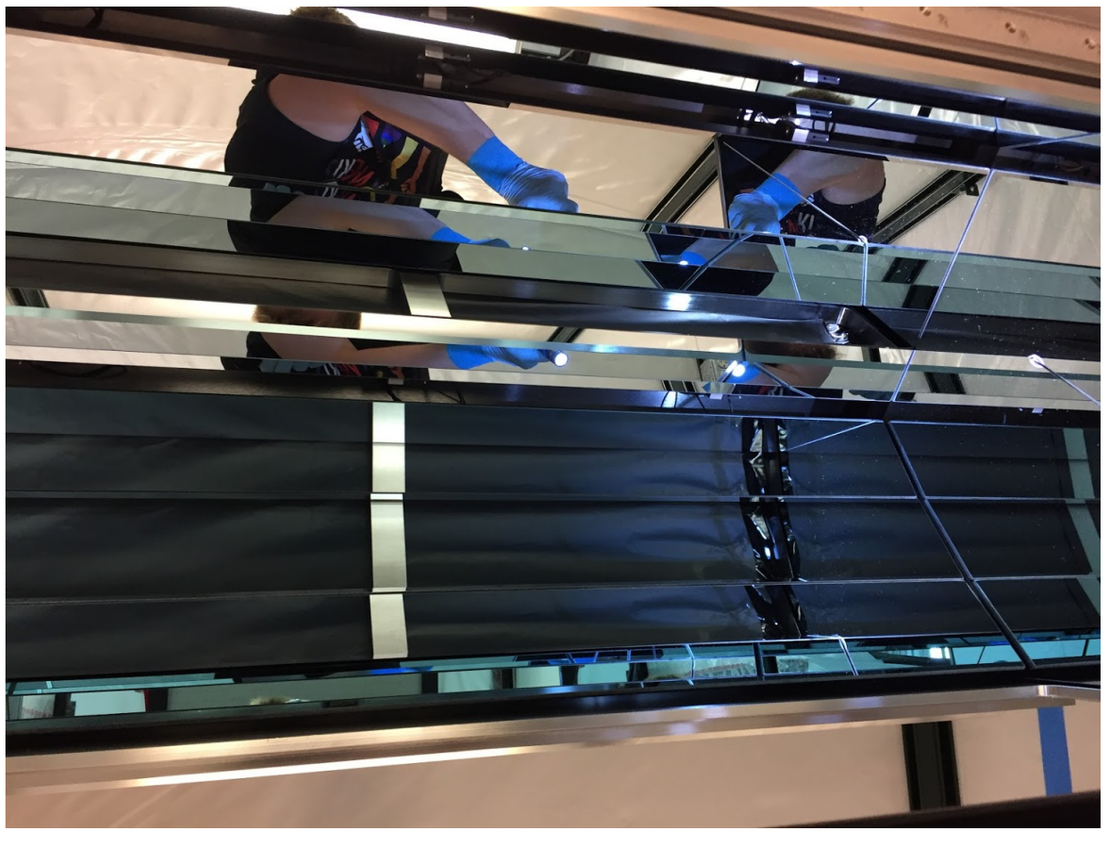
- After the commissioning run we learned some lessons:
  - Corrosion found from non-stainless components mistakenly used in assembly
  - **Solution:** all removed



Commissioning aftermath

- After the commissioning run we learned some lessons:
  - First surface mirrors reacted with the water
  - **Solution:** seal reflective surface from water using thin borosilicate glass

Initial mirror quality



Residue on mirrors after commissioning

Commissioning aftermath

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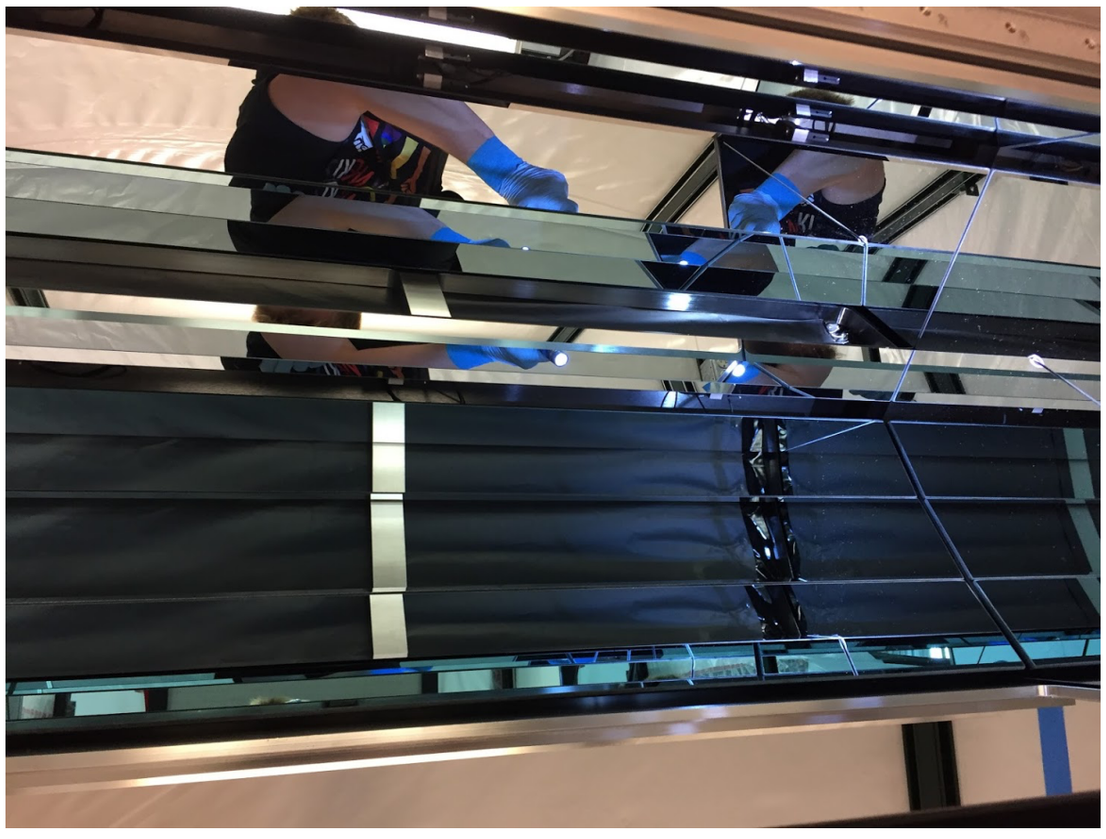
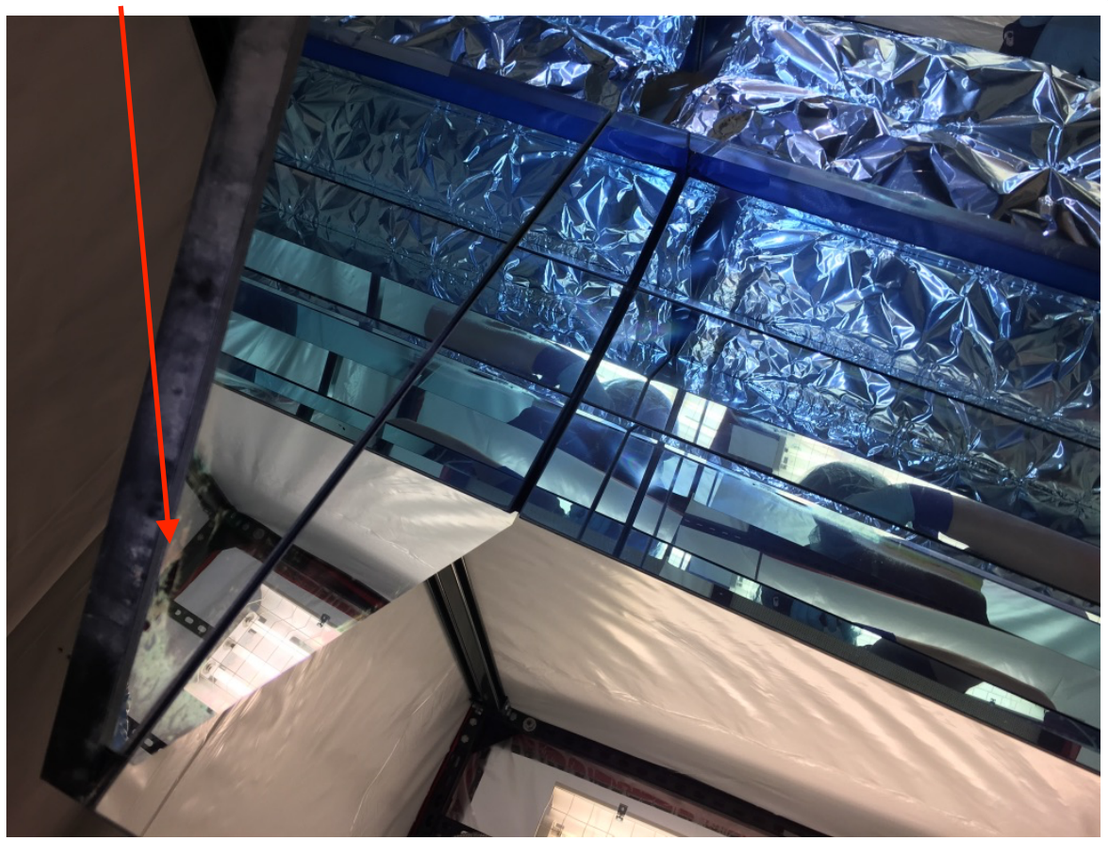
  - First surface mirrors reacted with the water
  - **Solution:** seal reflective surface from water using thin borosilicate glass

Initial mirror quality



Some residue remains after cleaning



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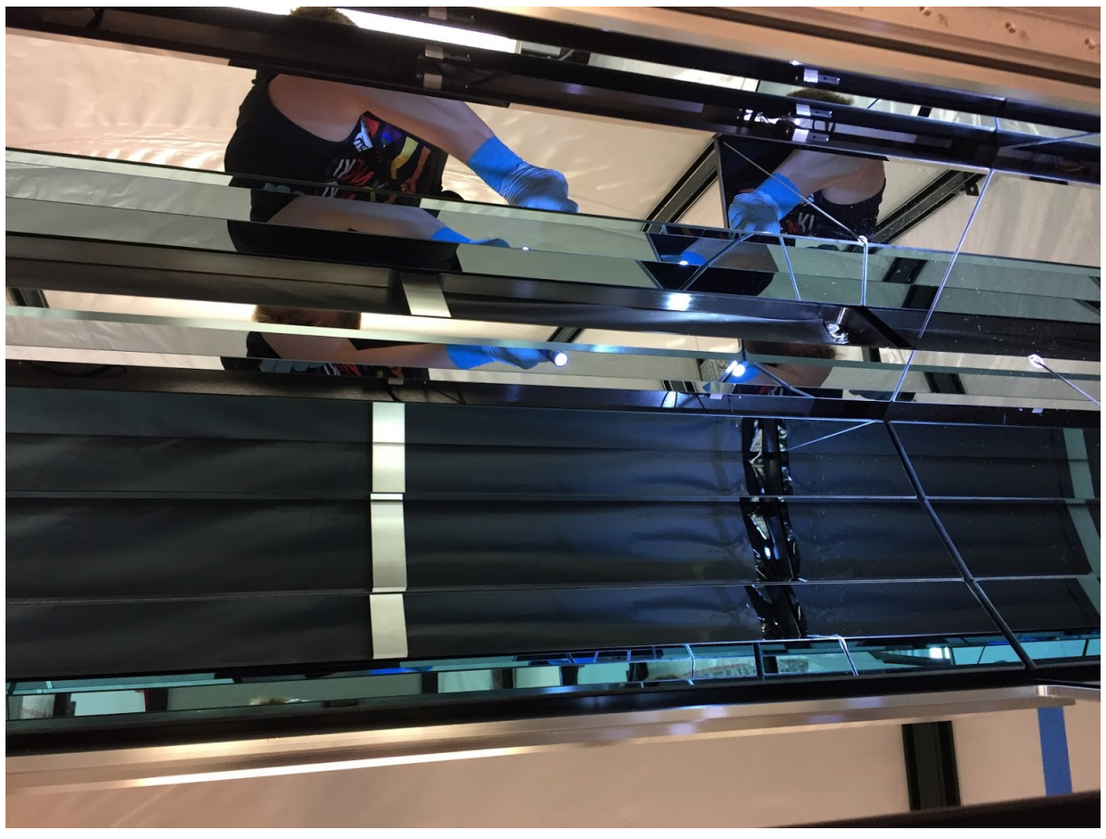

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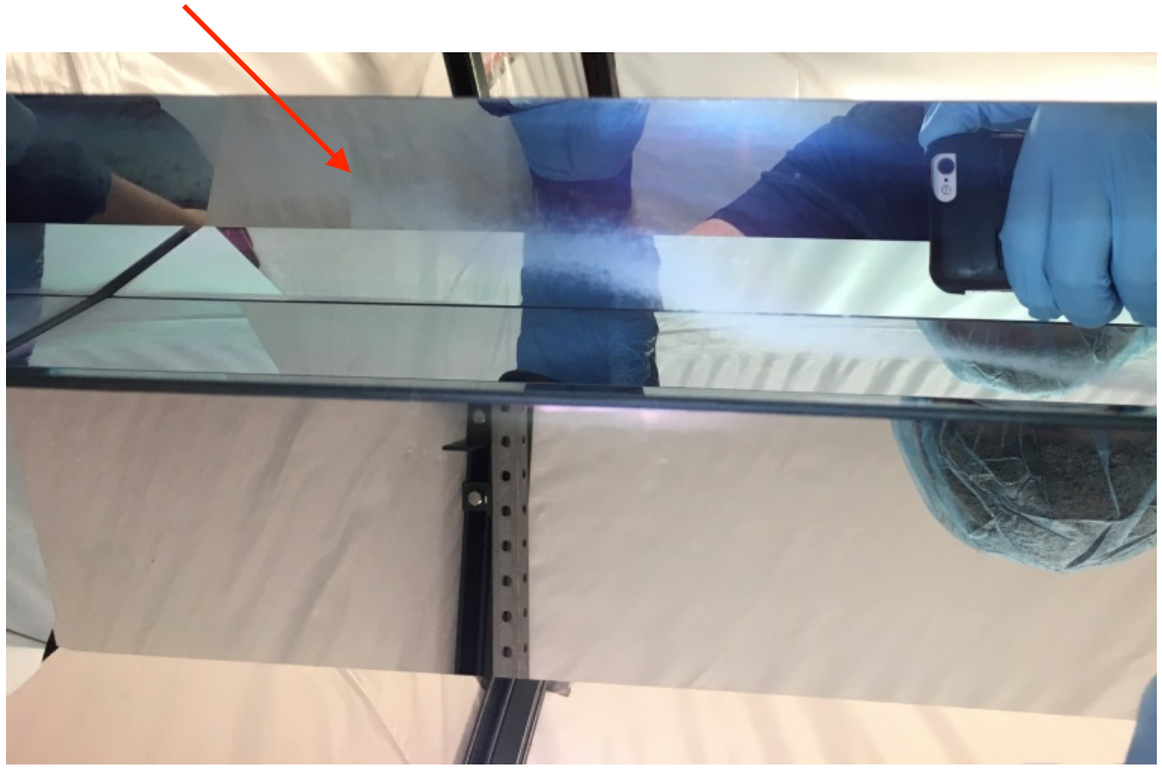
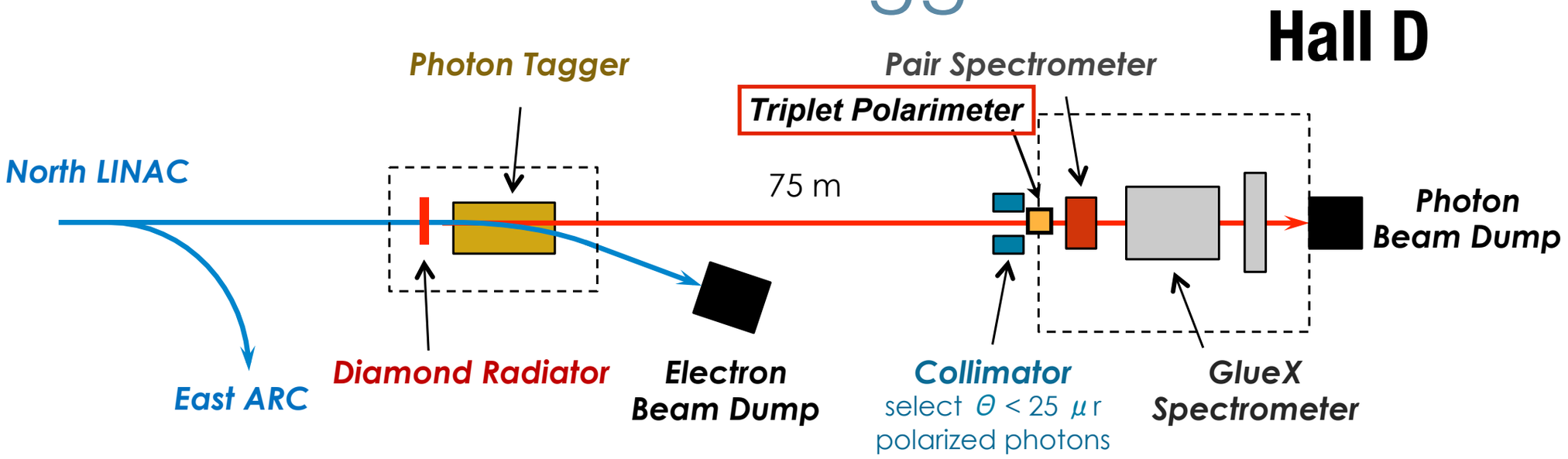
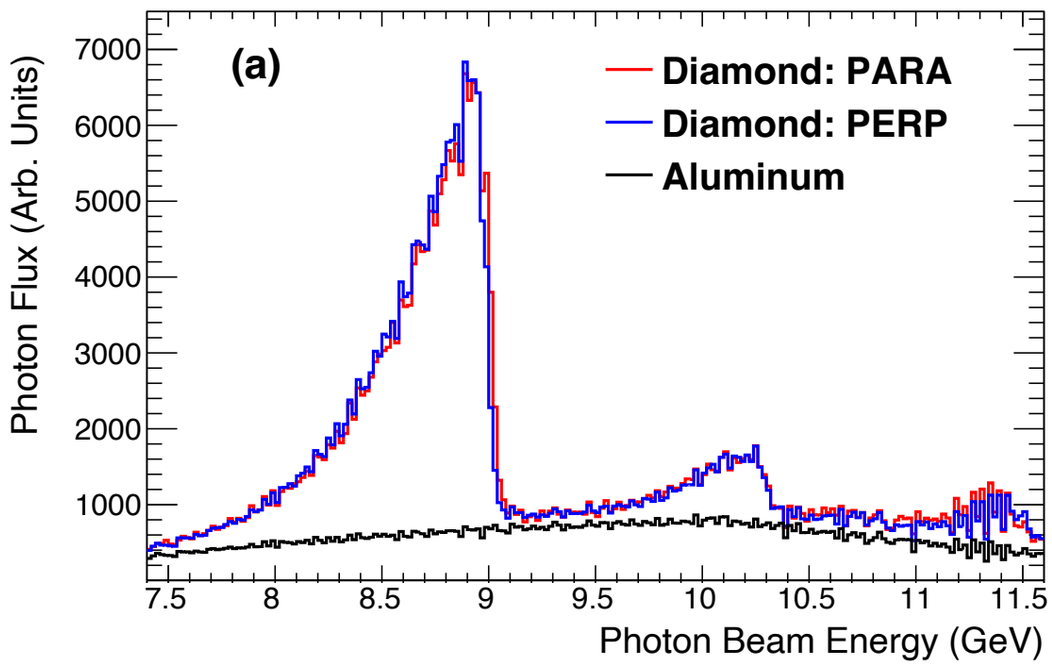


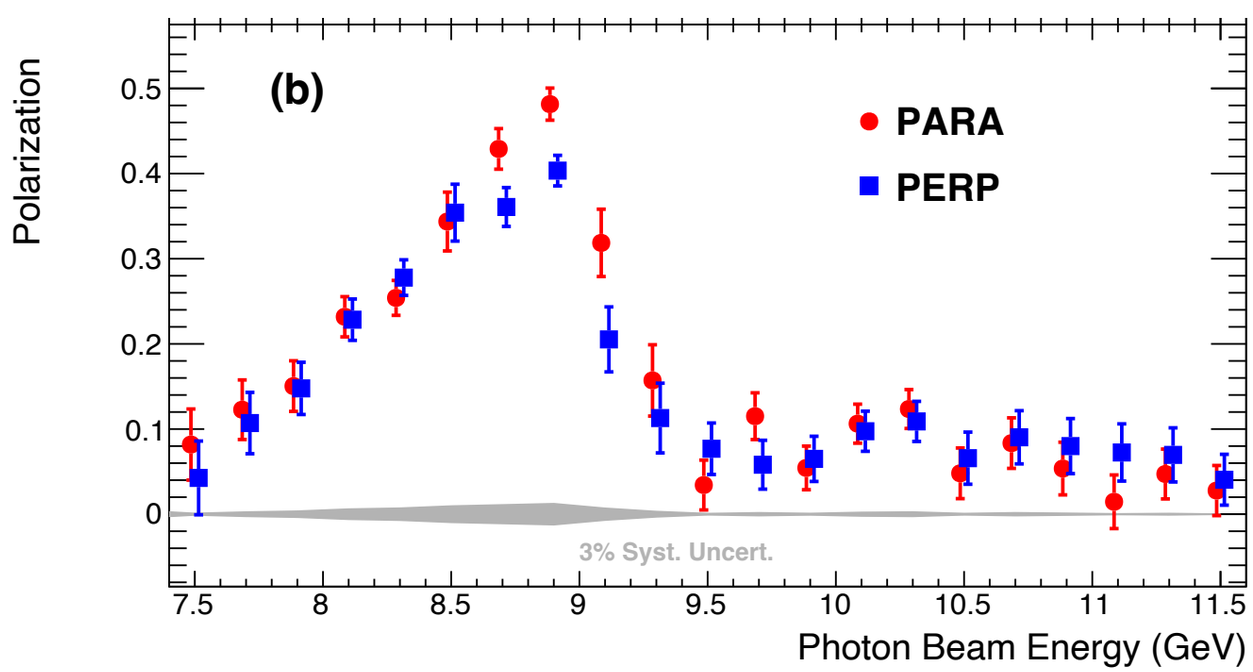
Photon Beam and Tagger



Measured Flux



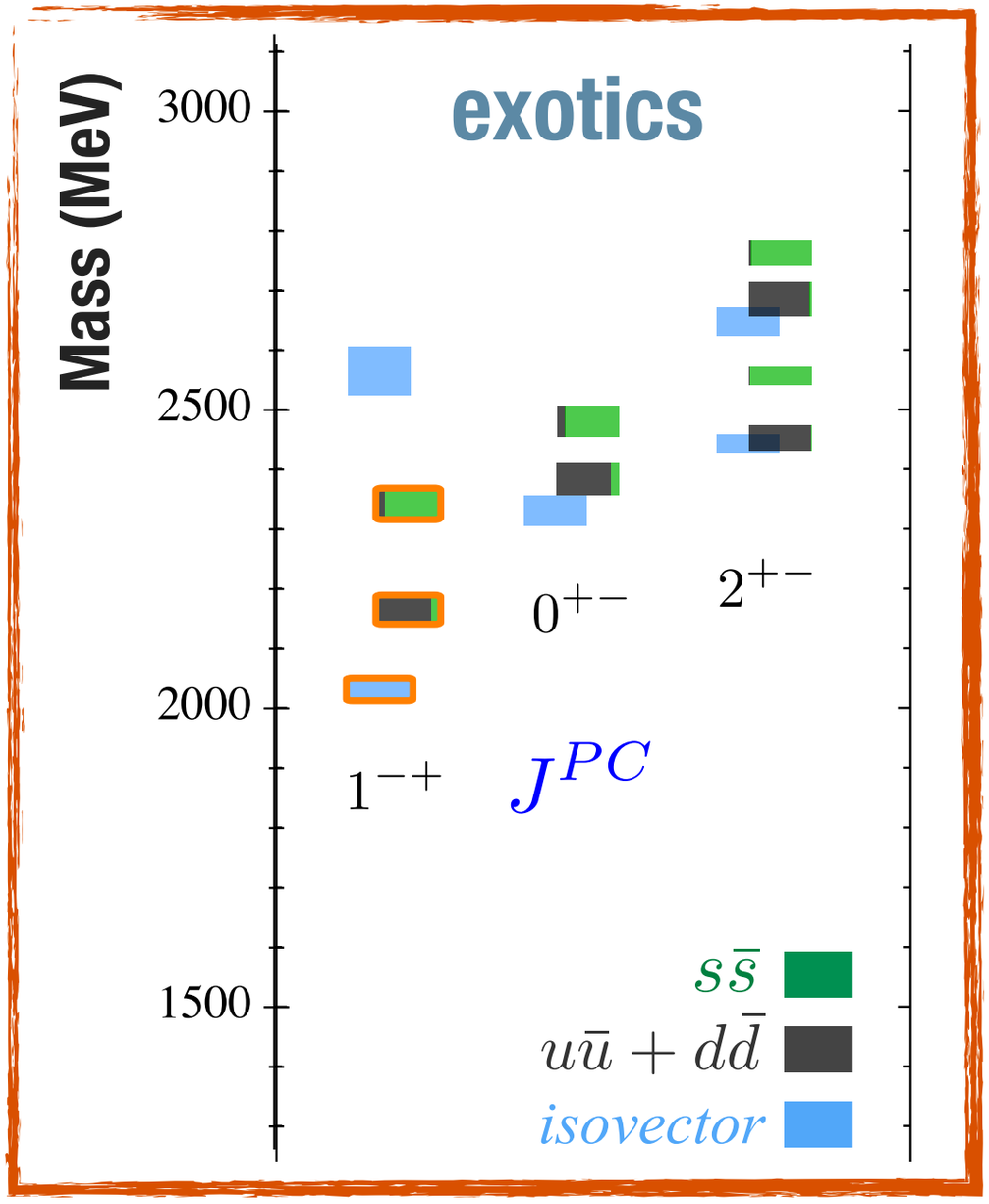
Measured Polarization



Filter on production mechanism

Strangeness program

- Lattice predicts **strange** and **light** quark content for mesons
- Search for a **pattern** of hybrid states in many final states
- Requires clean identification of charged pions and kaons



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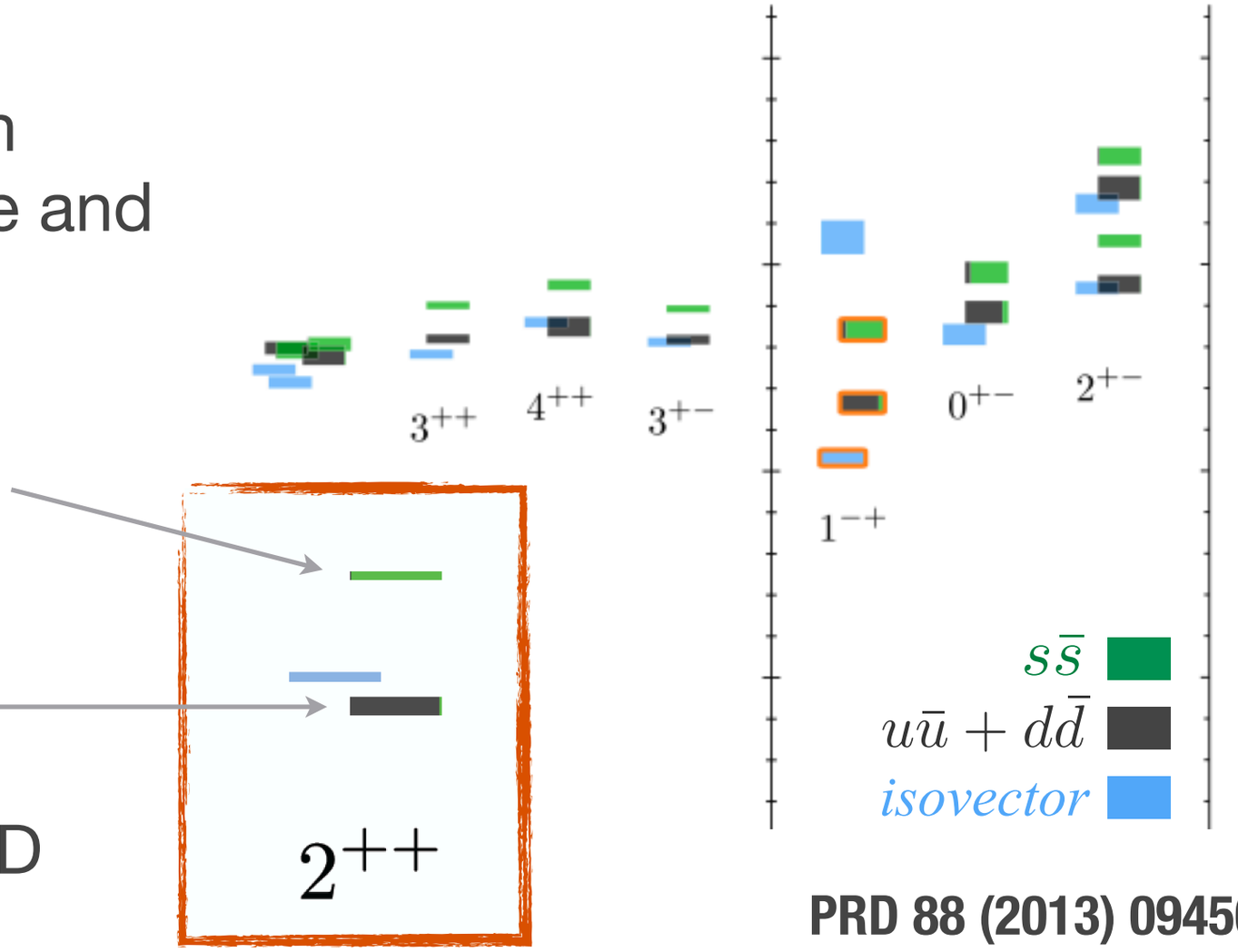
	Final States
π_1	$\omega\pi\pi$, 3π , 5π, $\eta 3\pi$, $\eta'\pi$
η_1	4π, $\eta 4\pi$, $\eta\eta\pi\pi$
η_1'	$KK\pi\pi$, $KK\pi$, $KK\omega$

Strangeness program: decay patterns

- Experimentally infer quark flavor composition through branching ratios to strange and non-strange decays

$$\frac{\mathcal{B}(f_2'(1525) \to \pi\pi)}{\mathcal{B}(f_2'(1525) \to KK)} \approx 0.009$$

$$\frac{\mathcal{B}(f_2(1270) \to \pi\pi)}{\mathcal{B}(f_2(1270) \to KK)} \approx 20$$



- Consistent with lattice QCD mixing angle for 2^{++}, and predictions for hybrids

- Need capability to detect strange and non-strange to infer hybrid flavor content

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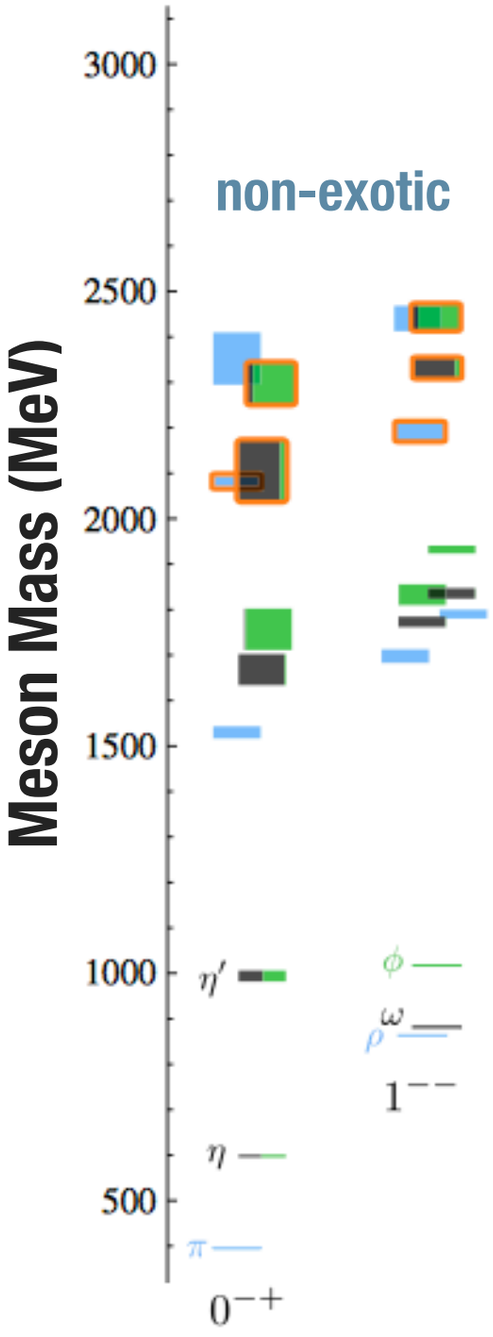
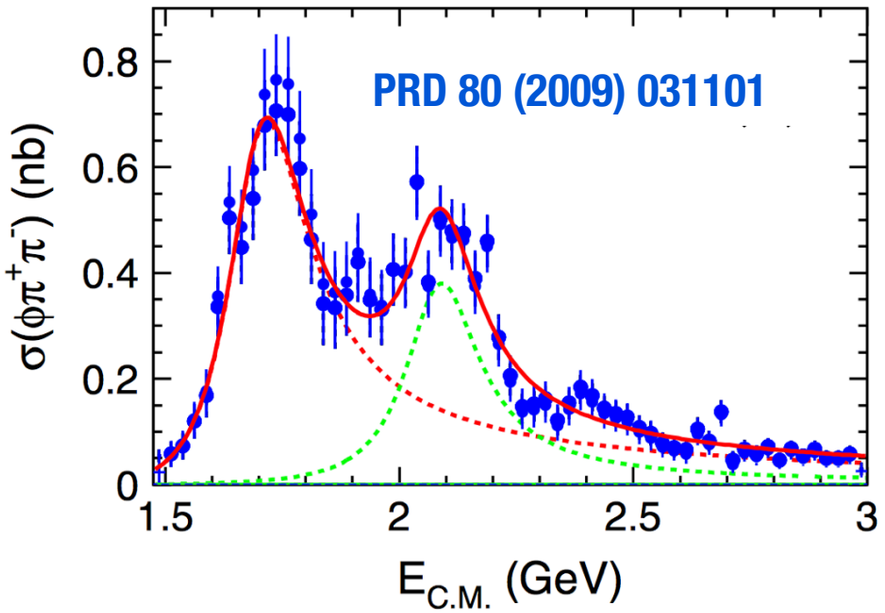
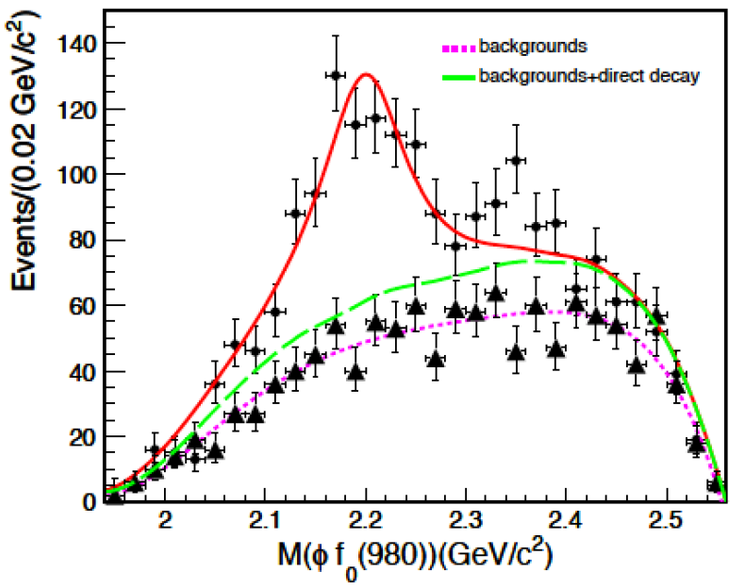
Strangeness program: Y(2175)



Belle: $e^+e^- \to \phi\pi^+\pi^-(\gamma)$



BES III: $J/\psi \to \eta\phi\pi^+\pi^-$



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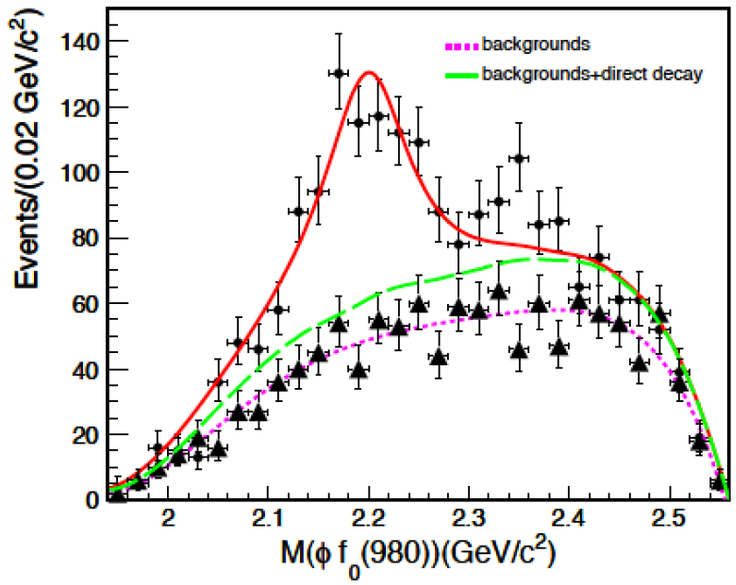
- Y(2175) $J^{PC}=1^{--}$ state observed by 3 experiments
- Decay pattern similar to Y(4260) in charmonium

$$Y(2175) \to \phi\pi^+\pi^- \qquad Y(4260) \to J/\psi\pi^+\pi^-$$

- Is there evidence for such strangeonium states in photoproduction?

Expected DIRC performance

BES III: $J/\psi \to \eta\phi\pi^+\pi^-$



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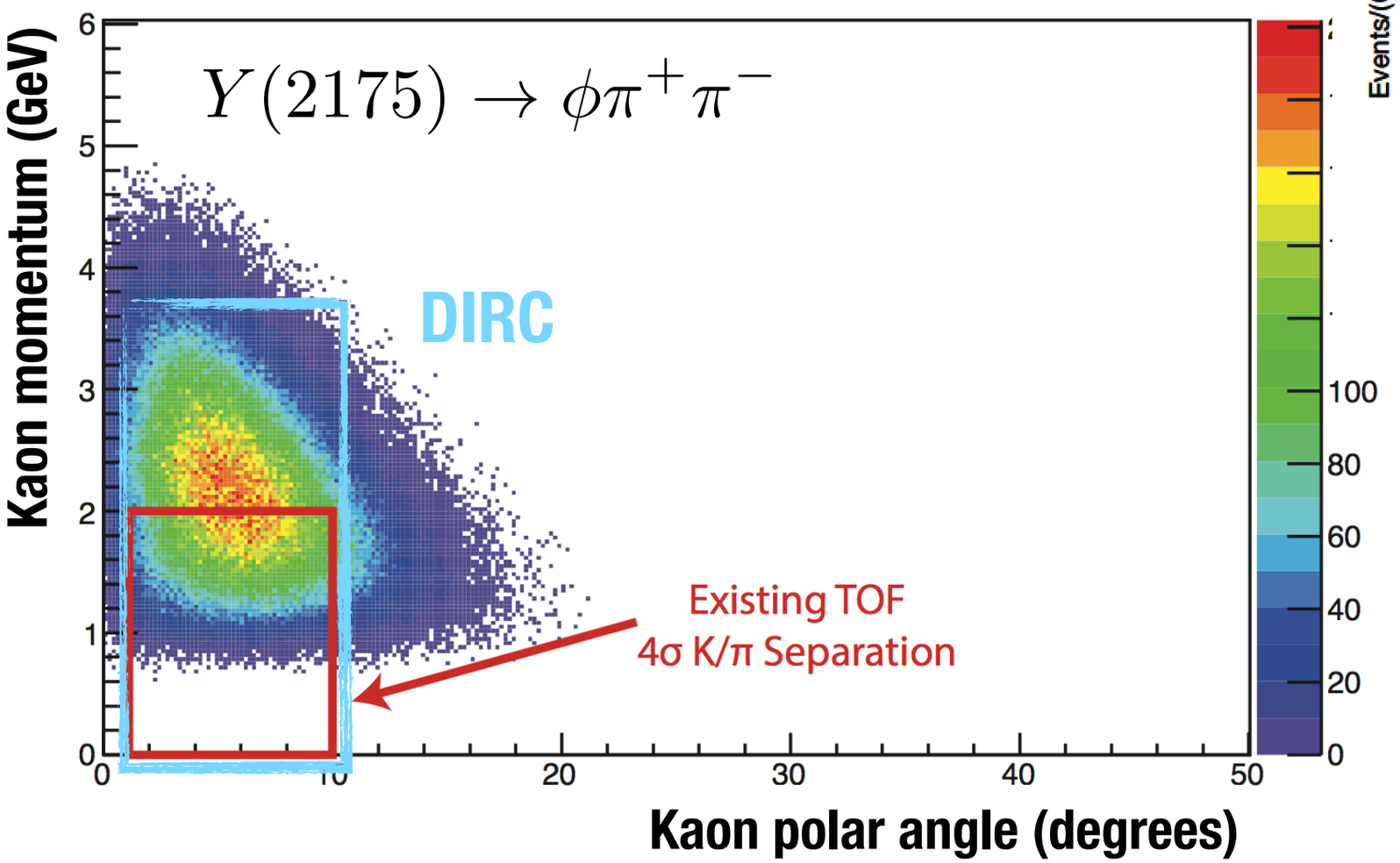
GlueX Simulation



- Significantly extends reach in search for exotic hadrons (hybrid, multi-quark, etc.) containing strange quarks