The GlueX DIRC Detector

- Design of the GlueX DIRC
- Simulation and expected performance
- Installation plans

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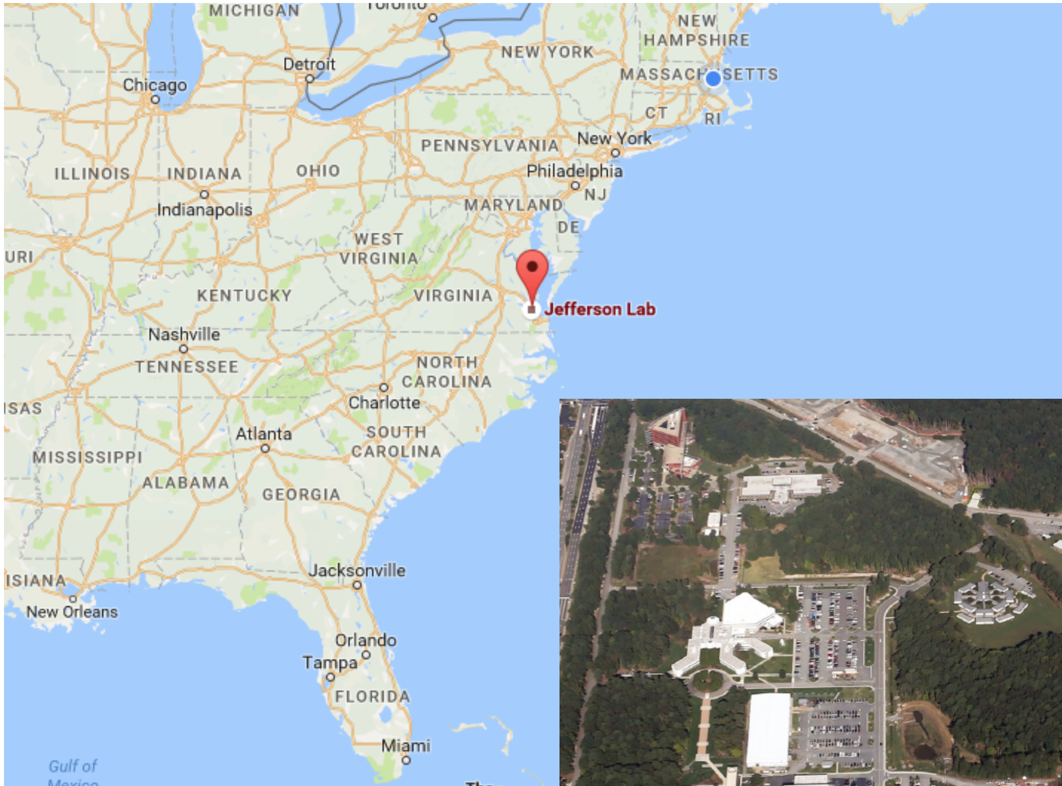
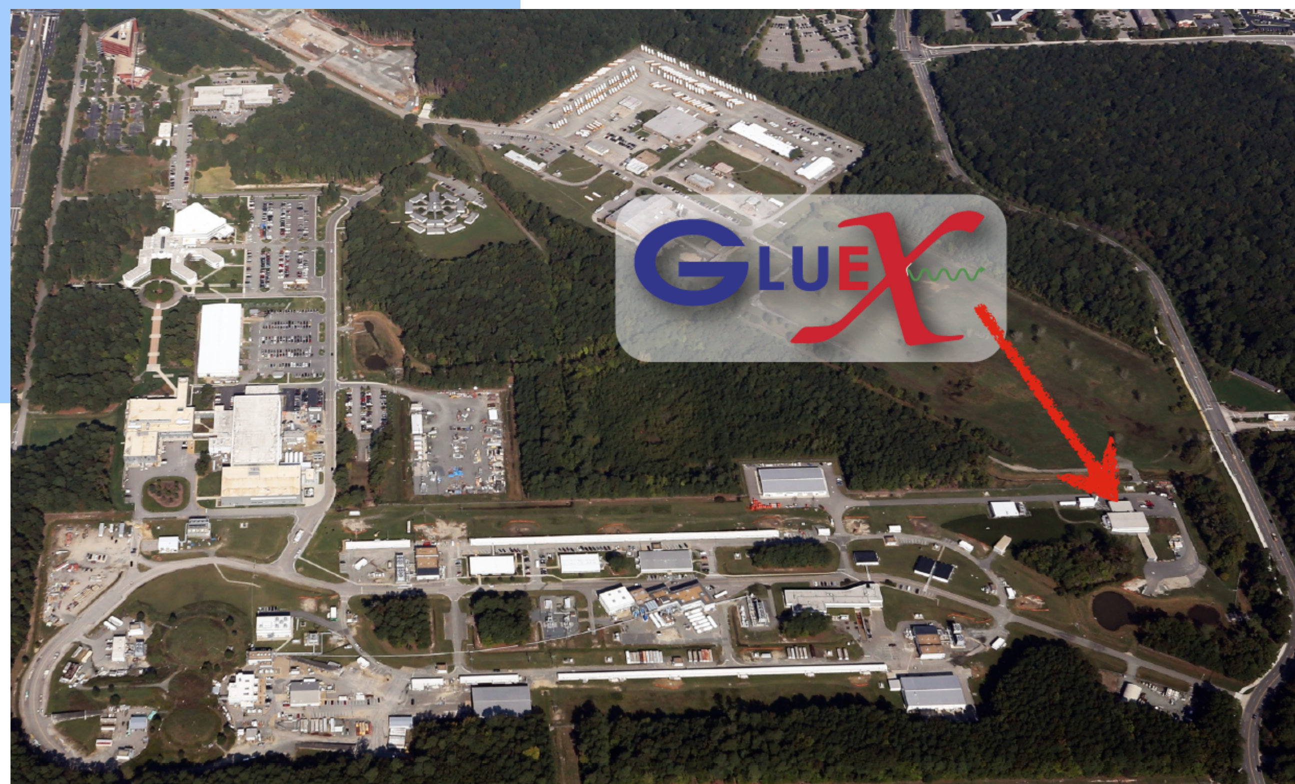


Newport News, Virginia



Continuous Electron Beam Accelerator Facility (CEBAF) 12 GeV

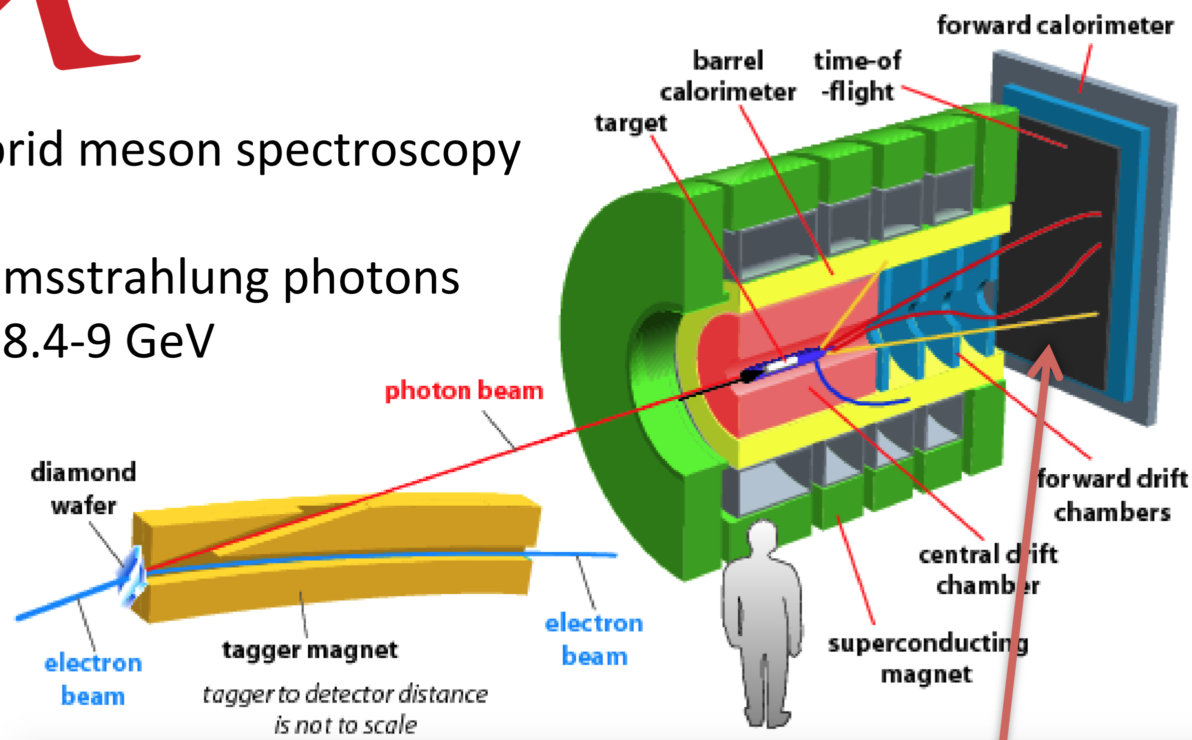
GlueX at JLab

Designed for light quark hybrid meson spectroscopy

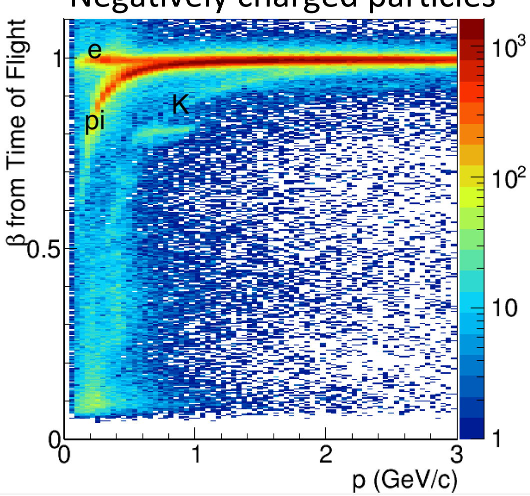
Beam: linearly polarized bremsstrahlung photons
10^8 γ/s in coherent peak E_γ=8.4-9 GeV

Target: liquid hydrogen

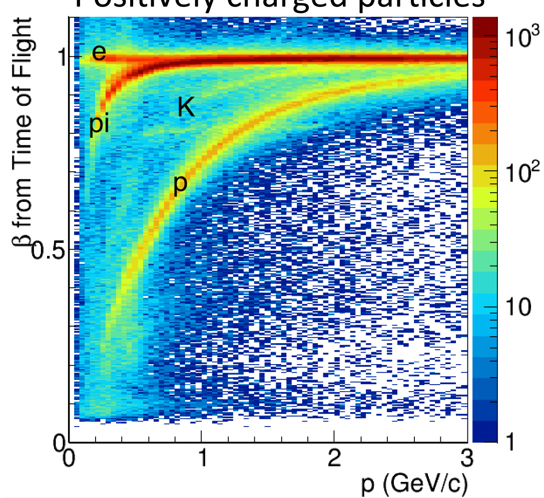
TOF provides baseline π/K separation up to 2 GeV/c



Negatively charged particles



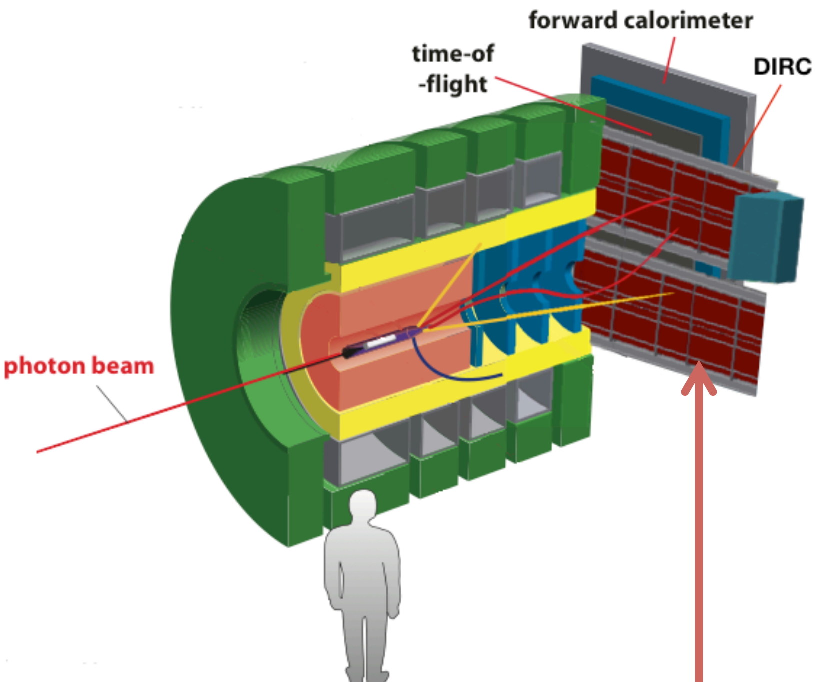
Positively charged particles



Place for the DIRC

PID goal:
K/π separation up to 4 GeV/c

GlueX DIRC design

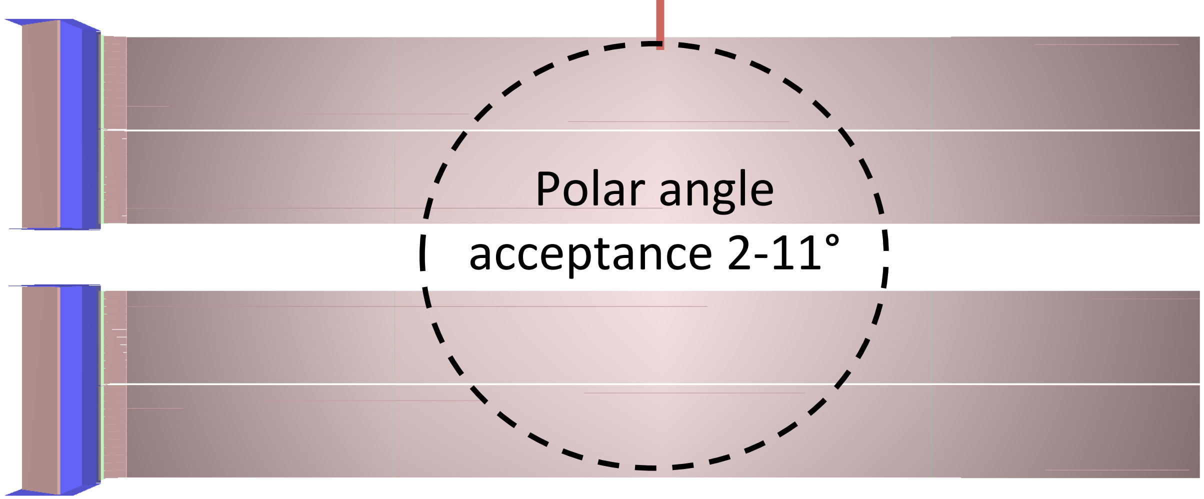


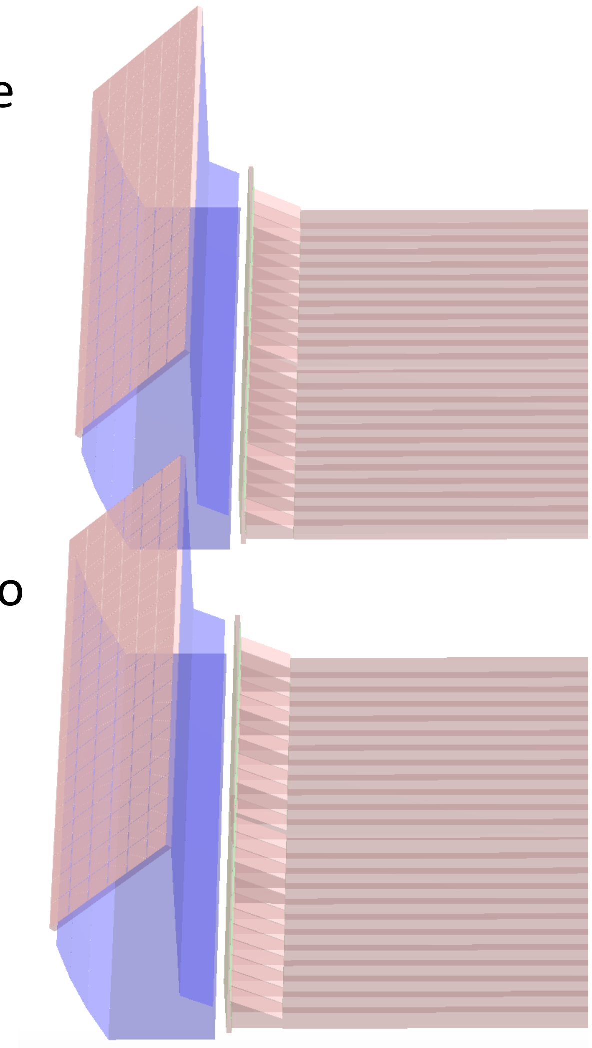
Forward wall made of four **unaltered** BaBar DIRC

bar boxes

Two separate photon cameras

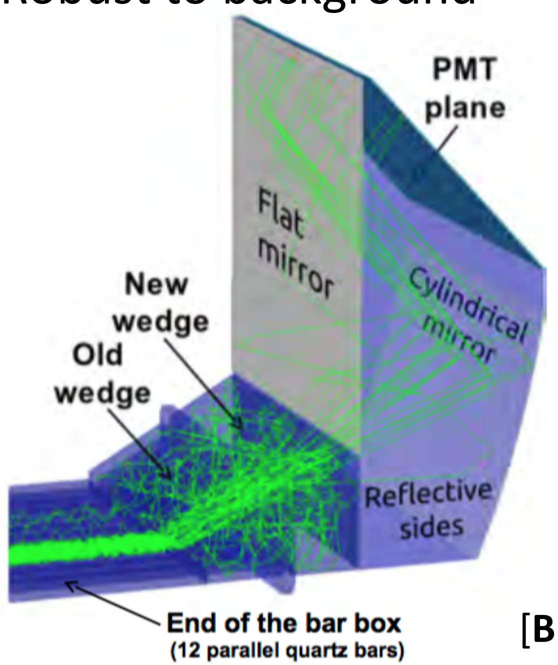
each couples to two BaBar bar boxes





FDIRC for SuperB

- Based on BABAR DIRC
- Barrel shape
- BaBar bar boxes + new **compact** photon camera:
  - Modular design
  - Fewer photosensors (pixel size 6 mm²)
  - Robust to background

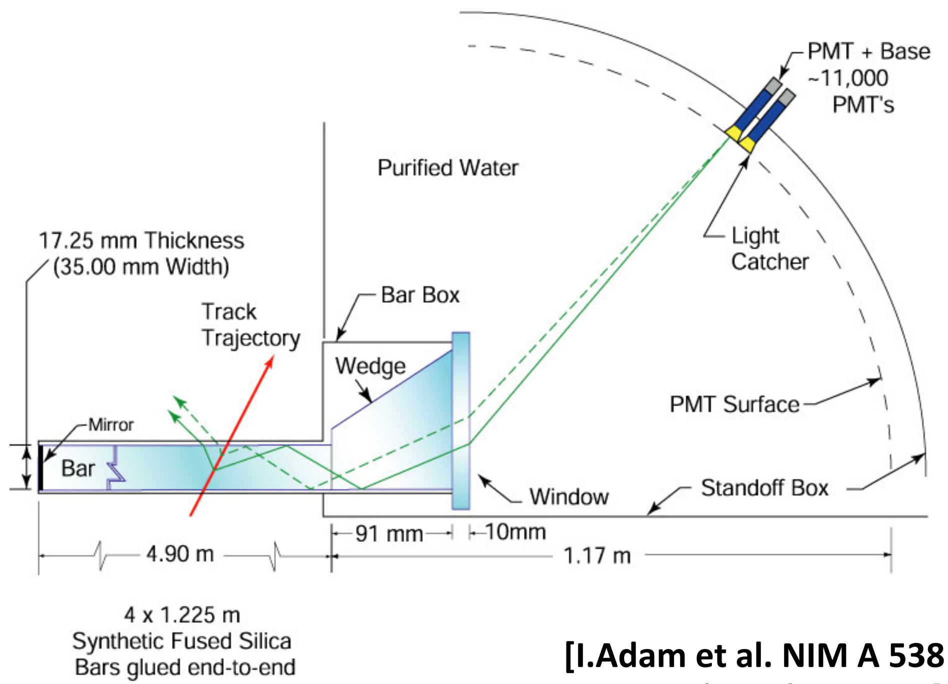


[B.Dey et al. 1410.0075]

BABAR DIRC (1999-2008)

Barrel shape

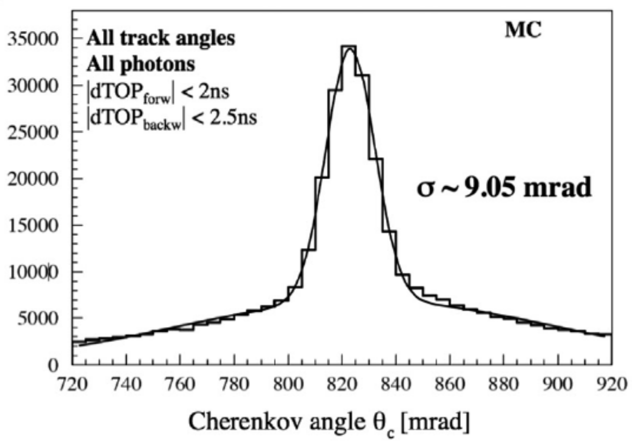
Large optical box: 6000 liters of water, 1.2 m deep, 11 000 PMTs, ø = 3 cm

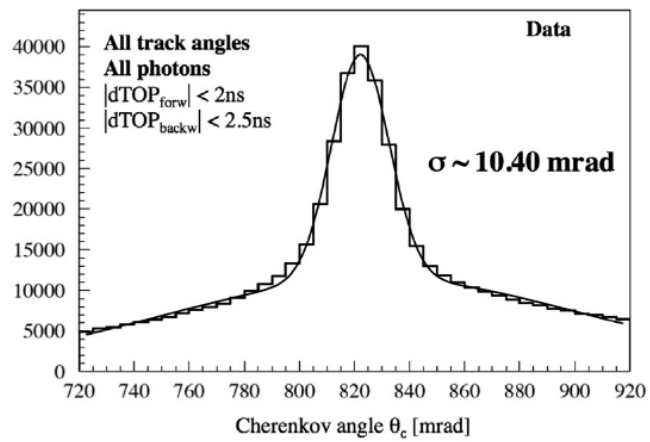


[I.Adam et al. NIM A 538 (2005) 281-357]

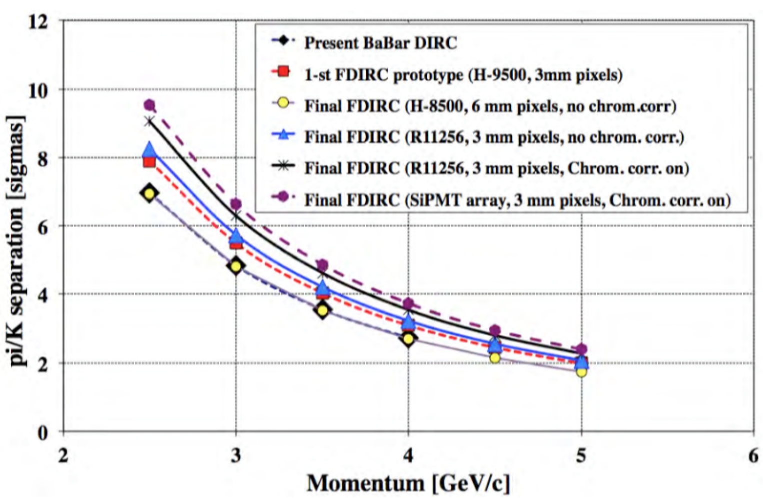
FDIRC for SuperB

- Prototype was built and tested
- GlueX DIRC inspired by FDIRC prototype





GlueX DIRC resolution for TDR was estimated based on these results



GlueX DIRC photon camera

Based on SLAC FDIRC prototype

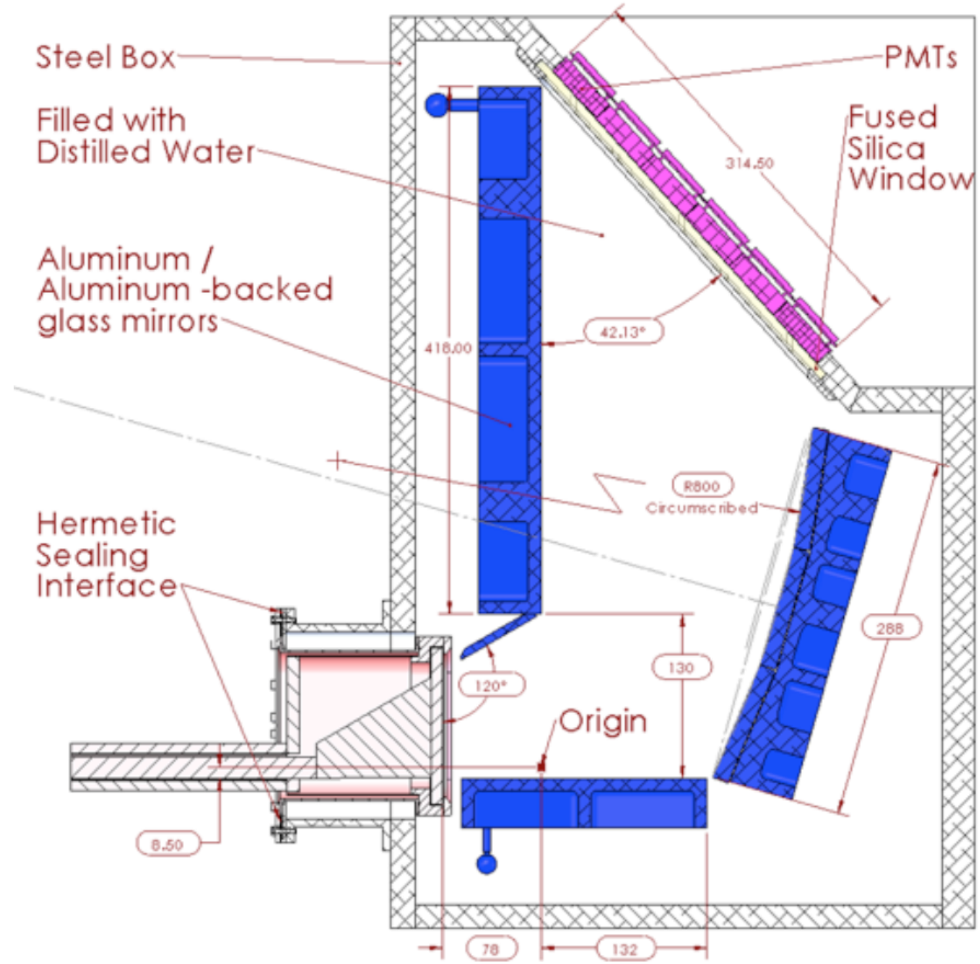
<u>Modifications:</u>

Replace FDIRC fused silica block with mirrors contained in distilled water

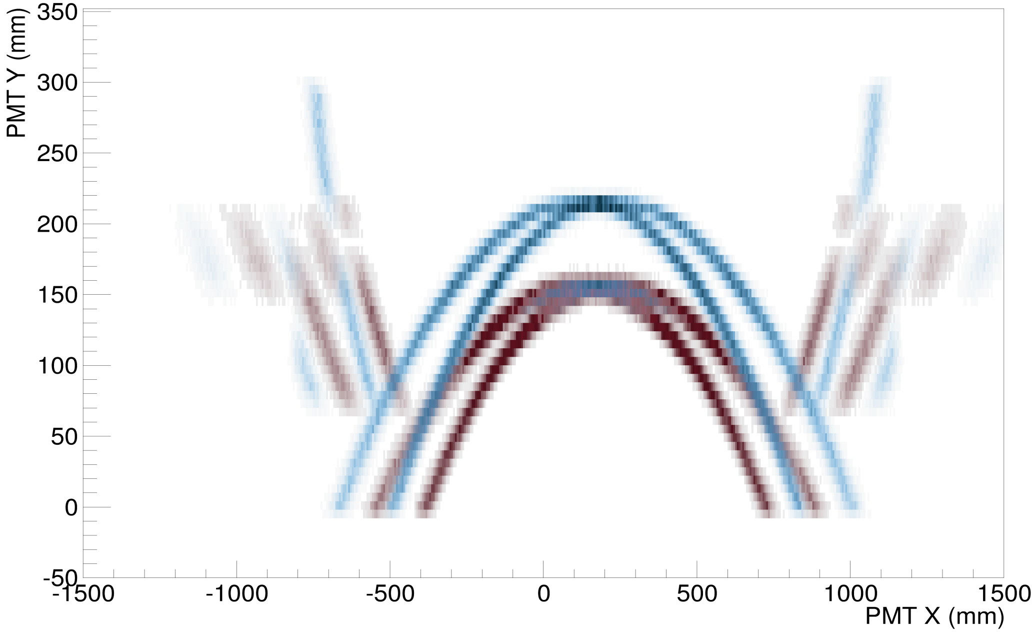
Optical box is attached to 2 bar boxes

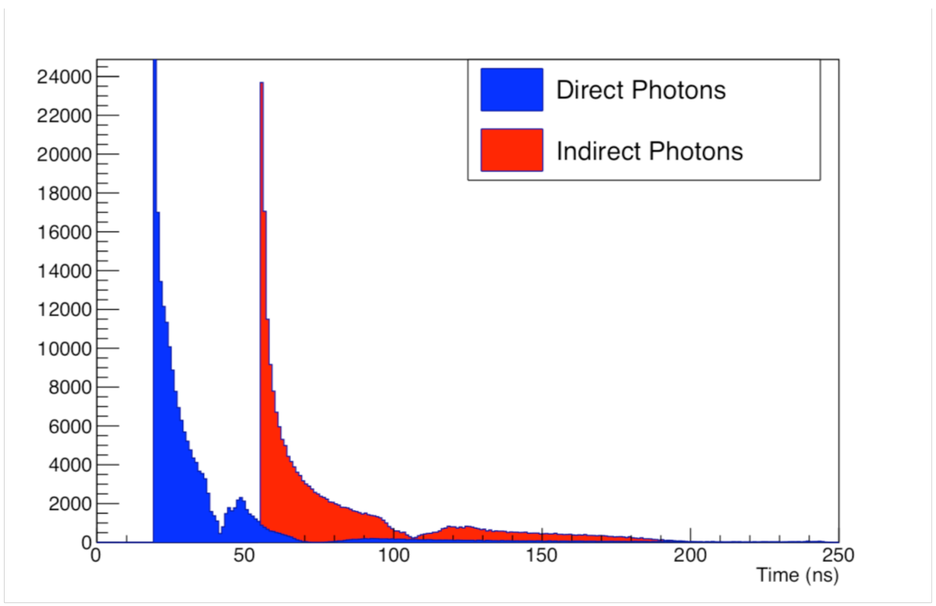
Optical coupling between photosensors and the box window

Replace the cylindrical mirror by 3 flat mirror segments



GlueX DIRC hit pattern





conic section with reflections

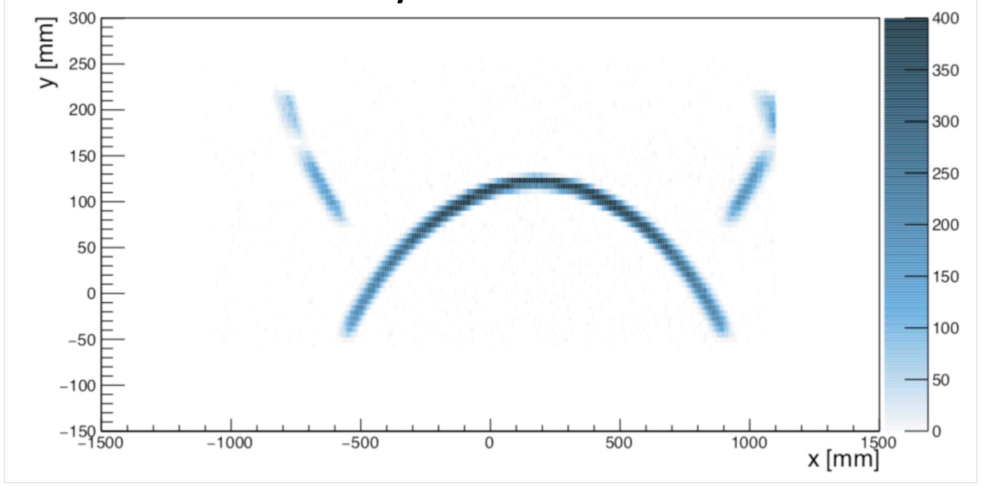
in the coordinate space some parts overlap, but timing helps to separate those photons

Blue – propagated straight to the readout end of the radiator

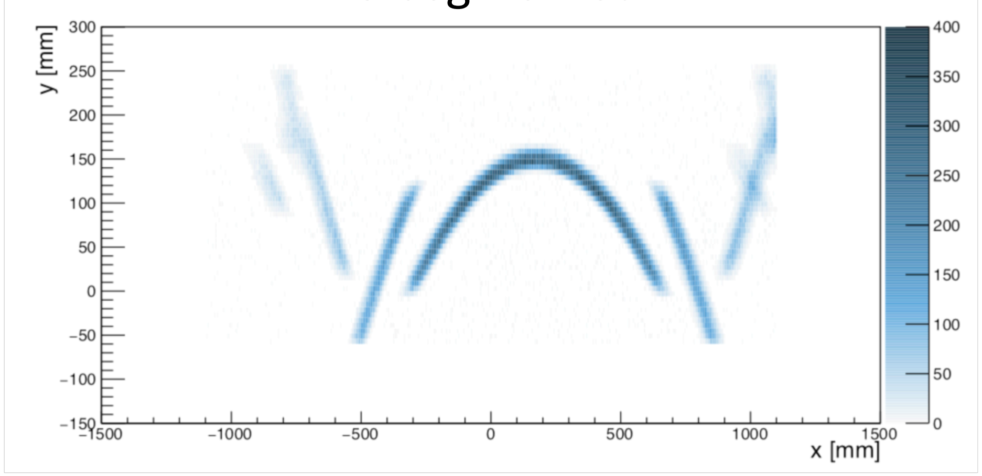
Red – first went to the mirror at the end of the radiator

"Focusing" mirror

cylindrical



3-segmented



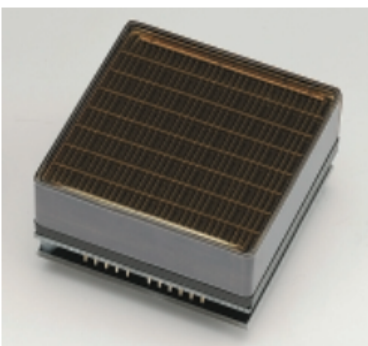
Cylindrical mirrors are complicated and expensive to build

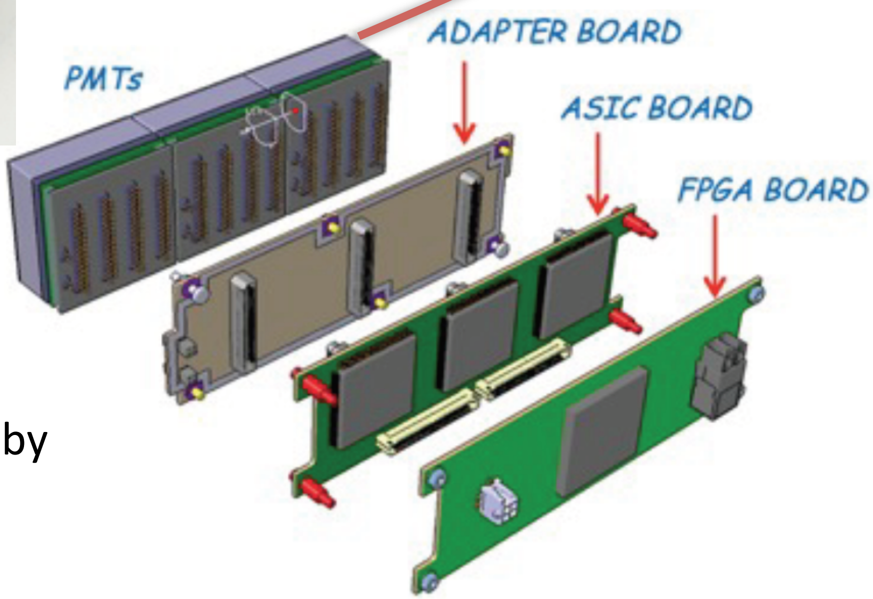
Cherenkov angle resolution is effectively the same for both designs (for GlueX angular acceptance)

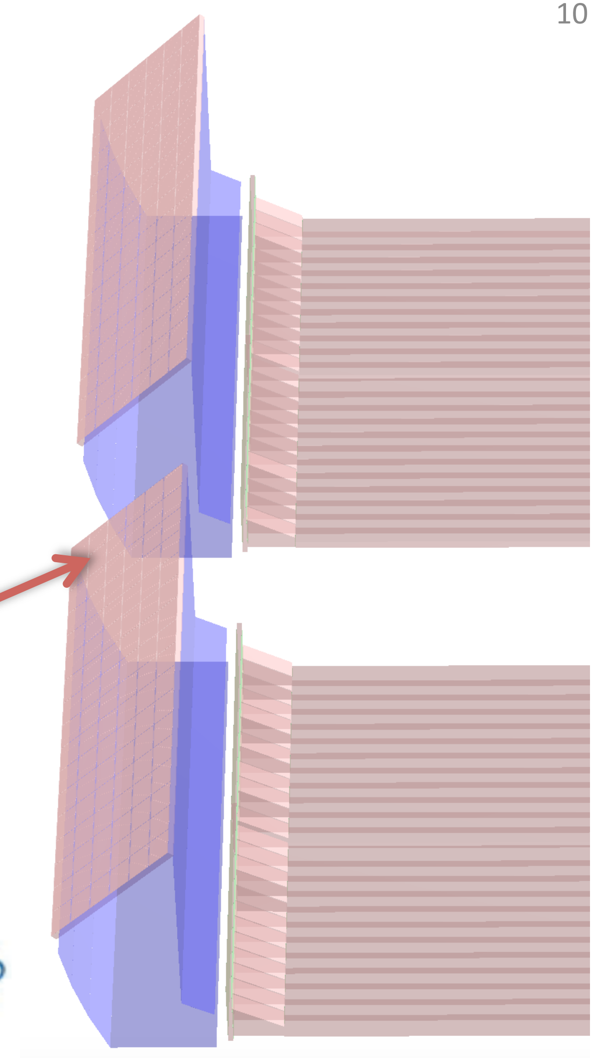
Readout

<ins>Photosensors</ins>: 216 Hamamatsu H12700 MaPMTs (~14k channels)

<ins>Electronics</ins>: we use boards developed for CLAS12 RICH in HallB (JLab)
They are compatible with generic JLab DAQ systems







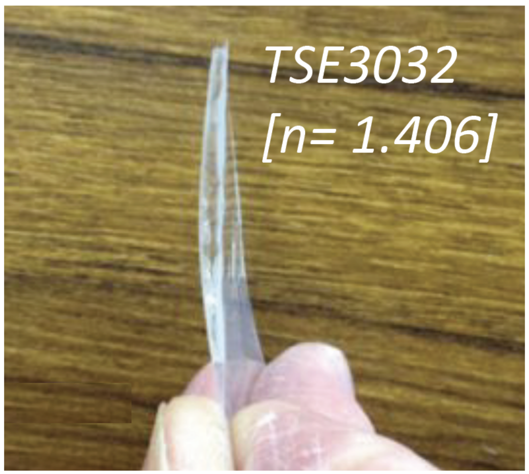
Timing resolution ~1 ns

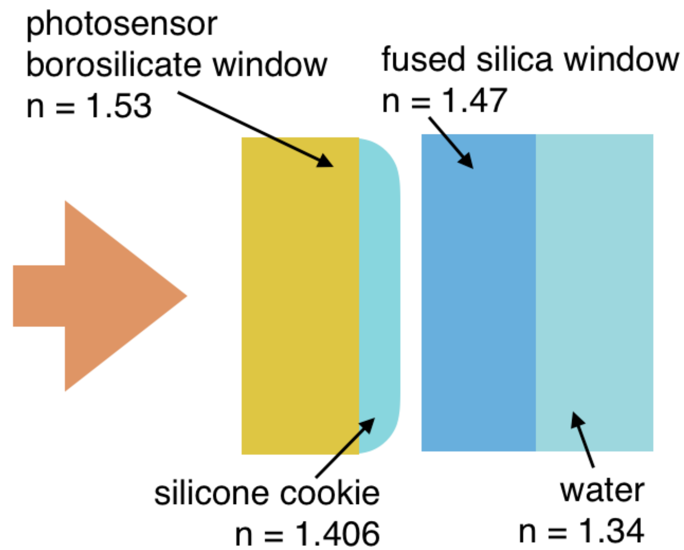
See the next talk by M. Mirazita

Optical coupling of PMTs

FDIRC prototype used direct coupling, which effectively implied an air gap

Belle II TOP is using silicone cookies





Photon loss between the optical box and the PMT (compared to the ideal case):

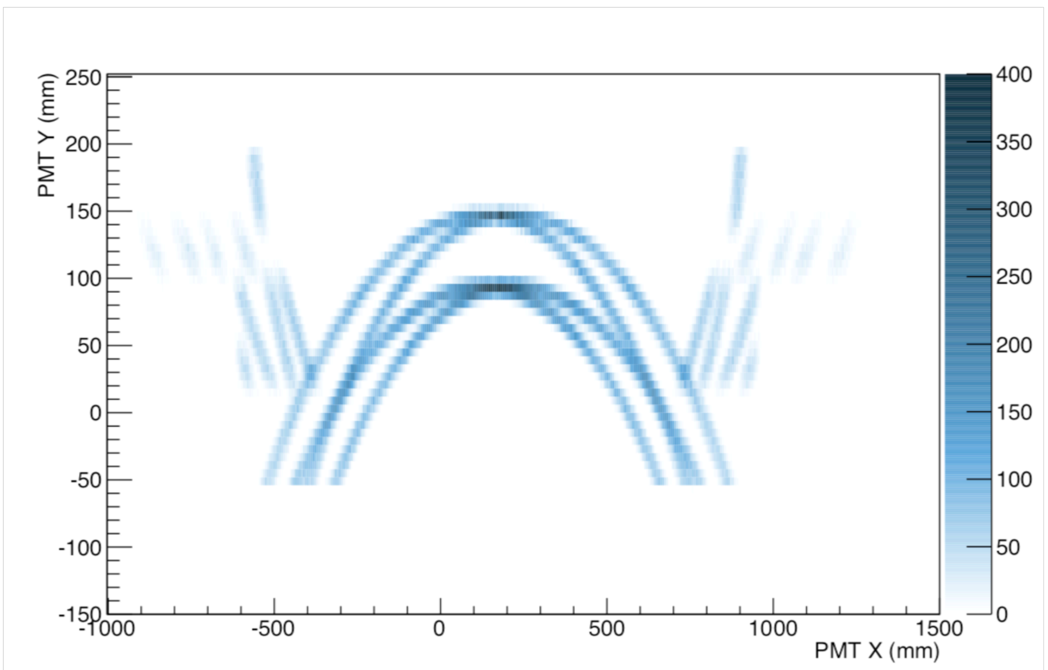
- Up to 25 % in case of air gap
- 2-4 % in case of cookie

GlueX DIRC plans to use silicone cookies – molding/testing in progress

Simulation

1. FastDIRC [J.Hardin, M. Williams 1608.01180]

- Analytical fast Monte Carlo and reconstruction algorithm for DIRC detectors
- More than 10 000 times faster than Geant-based simulation
- Includes reconstruction based on look-up tables (LUT), kernel density estimation (KDE)
- KDE-based reconstruction is 1000 slower than LUT-based, but provides better resolution

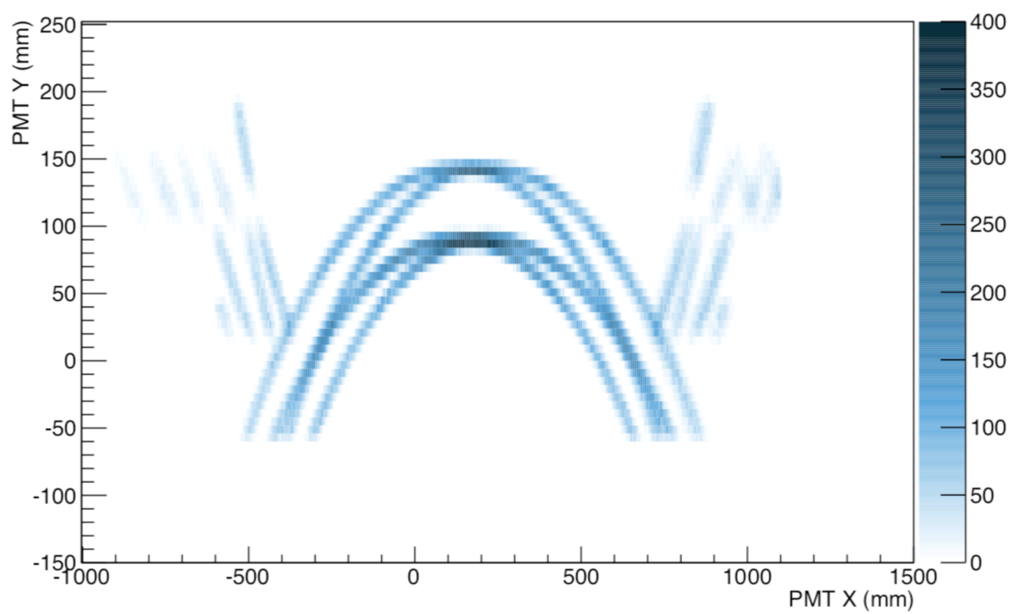


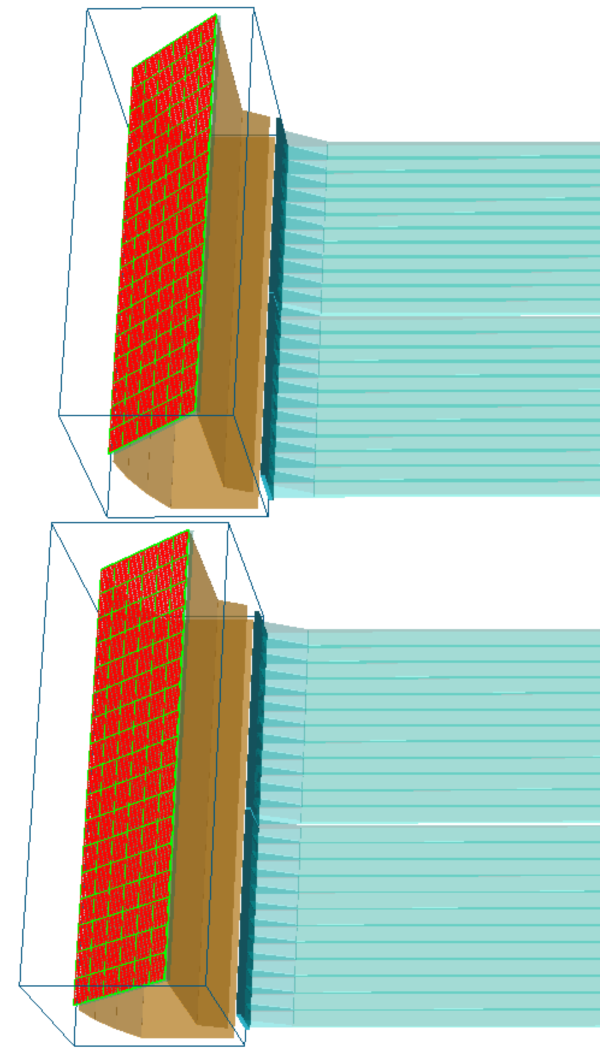
Simulation

2. Geant4-based standalone simulation

- Used for PANDA Barrel DIRC, EIC DIRC
- Includes reconstruction based on look-up tables (LUT), time-based imaging

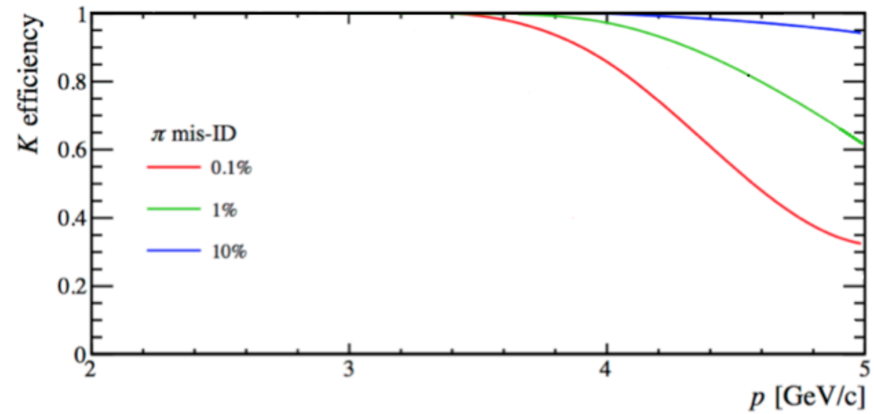
Work ongoing to incorporate the standalone simulation into the GlueX framework





Expected performance

Access to very high purity event selections (99%), which were not possible without DIRC



Conservative estimate of performance:

Design goal (based on SuperB):
$\sigma_{\theta c} \leq 2.5$ mrad
N_γ: 20 – 30 photons/track

* for tracks with θ=4°, averaged over ϕ

$$\sigma_{\theta c}^2 = \sigma_{corr}^2 + \frac{\sigma_\gamma^2}{N_\gamma}$$

$\sigma_{corr} = 0.5$ mrad, tracking and multiple scattering

$\sigma_\gamma = 7.3$ mrad, Single photon Cherenkov angle resolution *

$$\sigma_\gamma = \sqrt{\sigma_{\text{int}}^2 + \sigma_{pix}^2 + \sigma_{kal}^2 + \sigma_{ch}^2}$$

$\sigma_{\text{int}} = 3$ mrad, bar imperfection

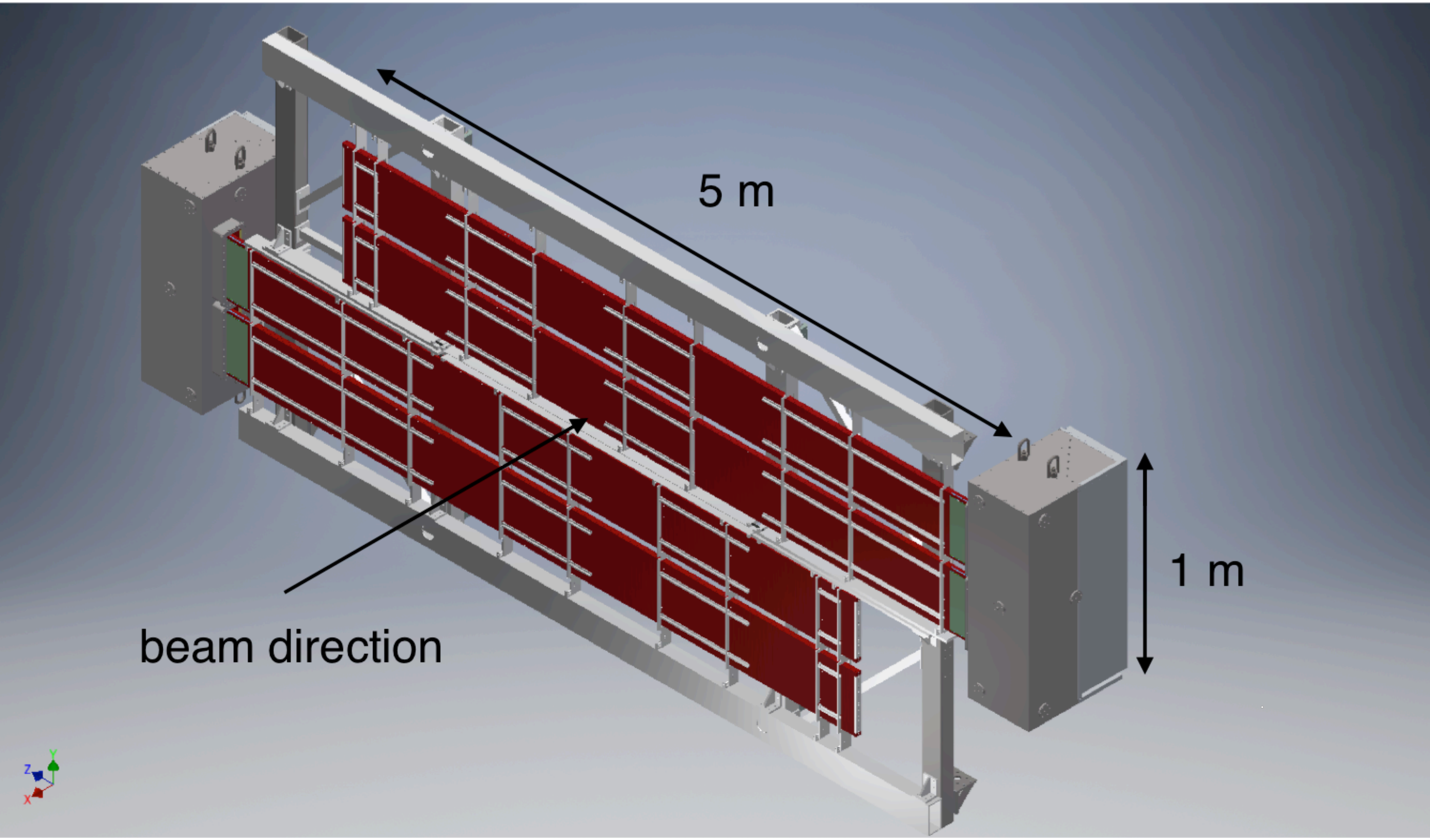
$\sigma_{pix} = 2.7$ mrad, pixel size

$\sigma_{kal} = 4.3$ mrad, kaleidoscopic effect *

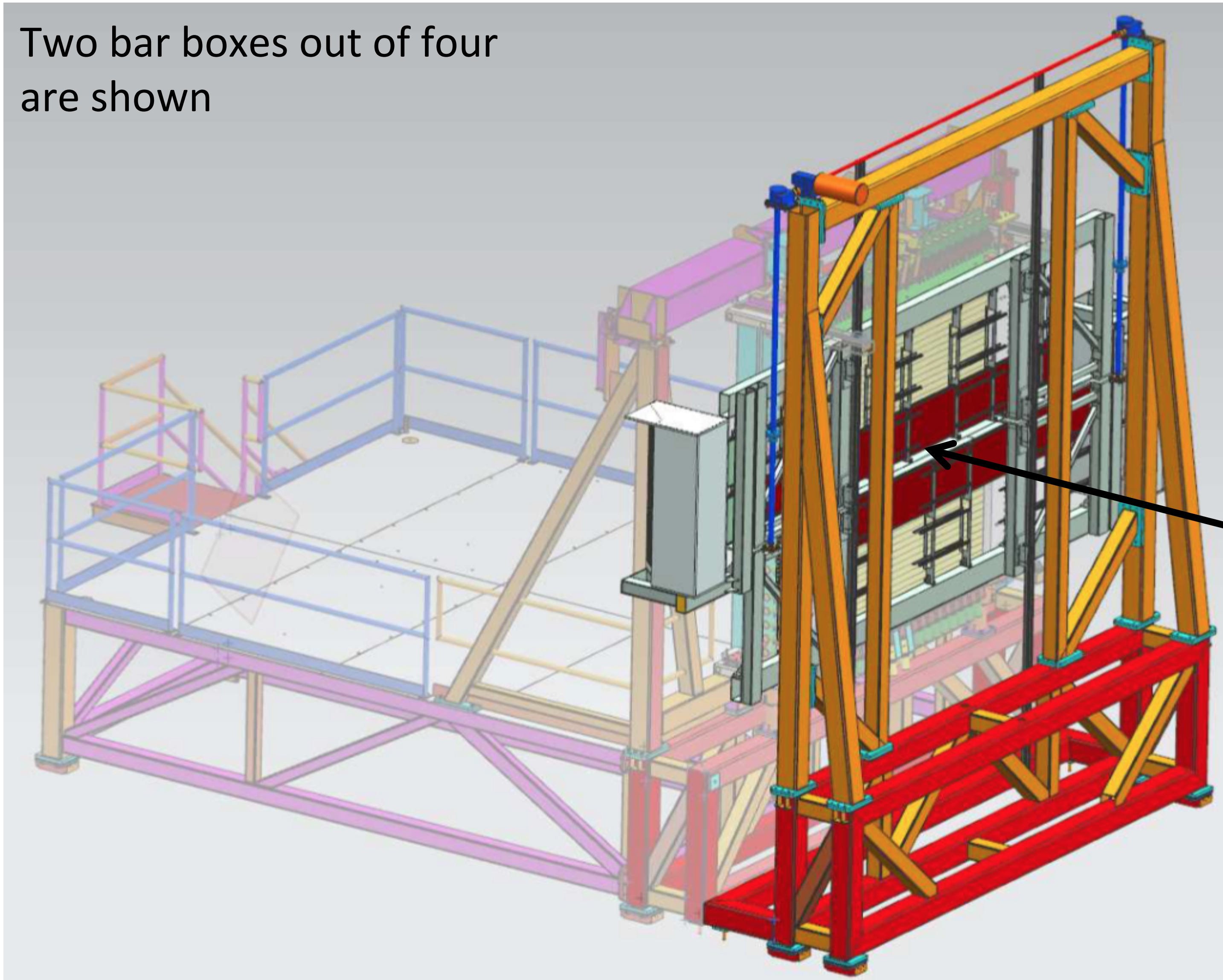
$\sigma_{ch} = 4.3$ mrad, chromatic effect *

Better photon yield, more accurate tracking resolution will improve the DIRC performance, and the DIRC's impact on the GlueX physics program should be even larger than previously expected

Support structure

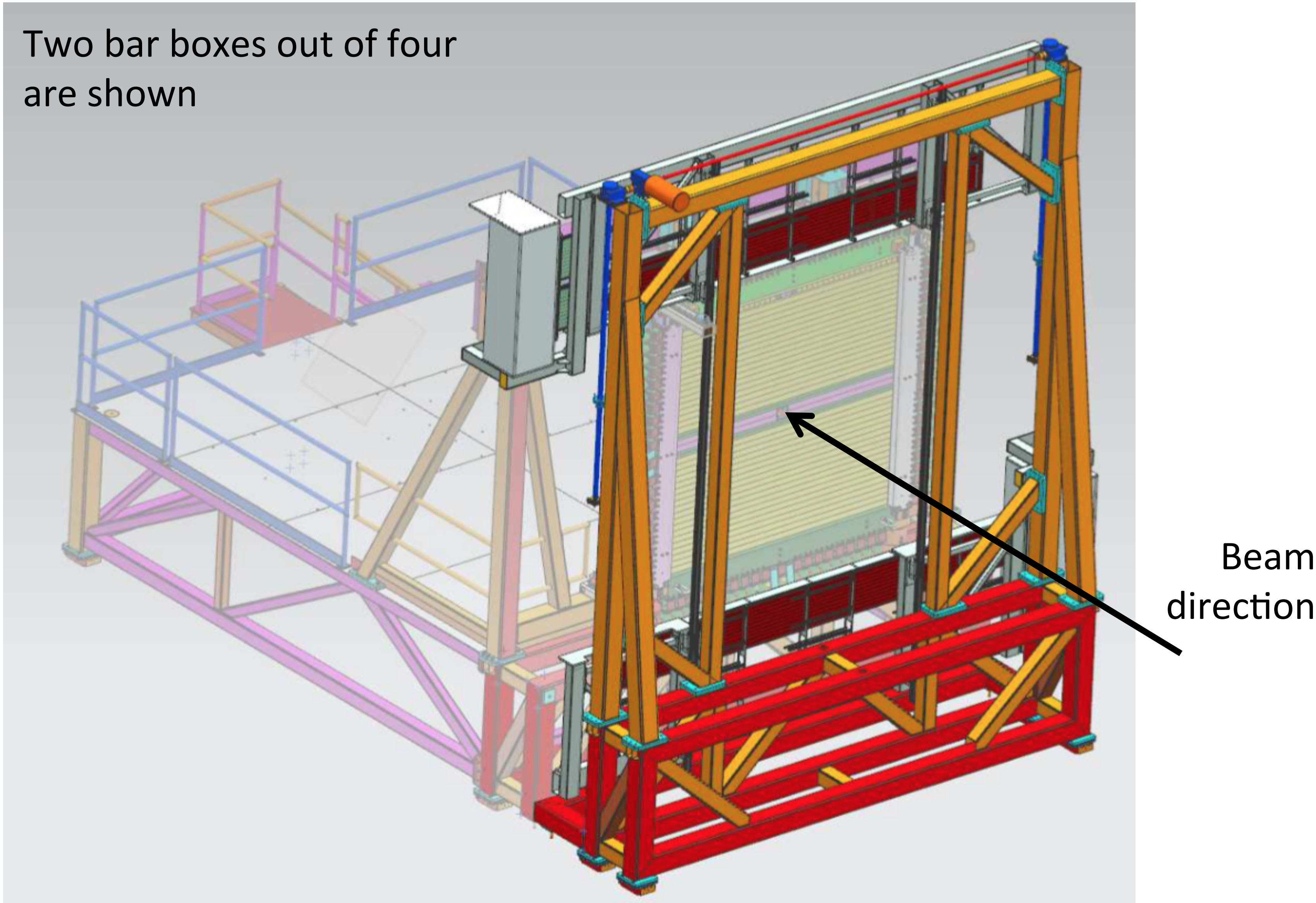


Support structure



Beam
direction

Support structure



DIRC Timeline

- 2014
  - SLAC approved reuse of the four BaBar DIRC bar boxes in GlueX
- 2015
  - Technical Design Review and approval of TDR
- 2016
  - Engineering review is planned for September
  - Beginning of fabrication of support structure and optical box
- 2017
  - Transport of BaBar boxes from SLAC to Jlab
  - Install and begin commissioning one optical box with attached two bar boxes
- 2018
  - Install and commission complete detector
  - Begin GlueX strangeness program

[DIRC TDR: http://argus.phys.uregina.ca/gluex/DocDB/0028/002809/003/dirc_tdr.pdf]

Transport of bar boxes

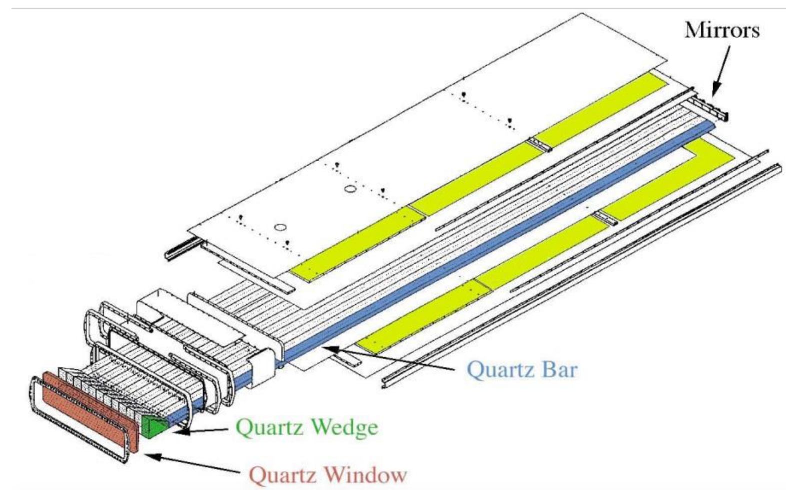
- 17 years old (support buttons might be damaged)
- Were exposed to radiation
- Were not designed for transportation
- Fragile (especially glue joints)

Value of the bar boxes is priceless!

Transportation plan:

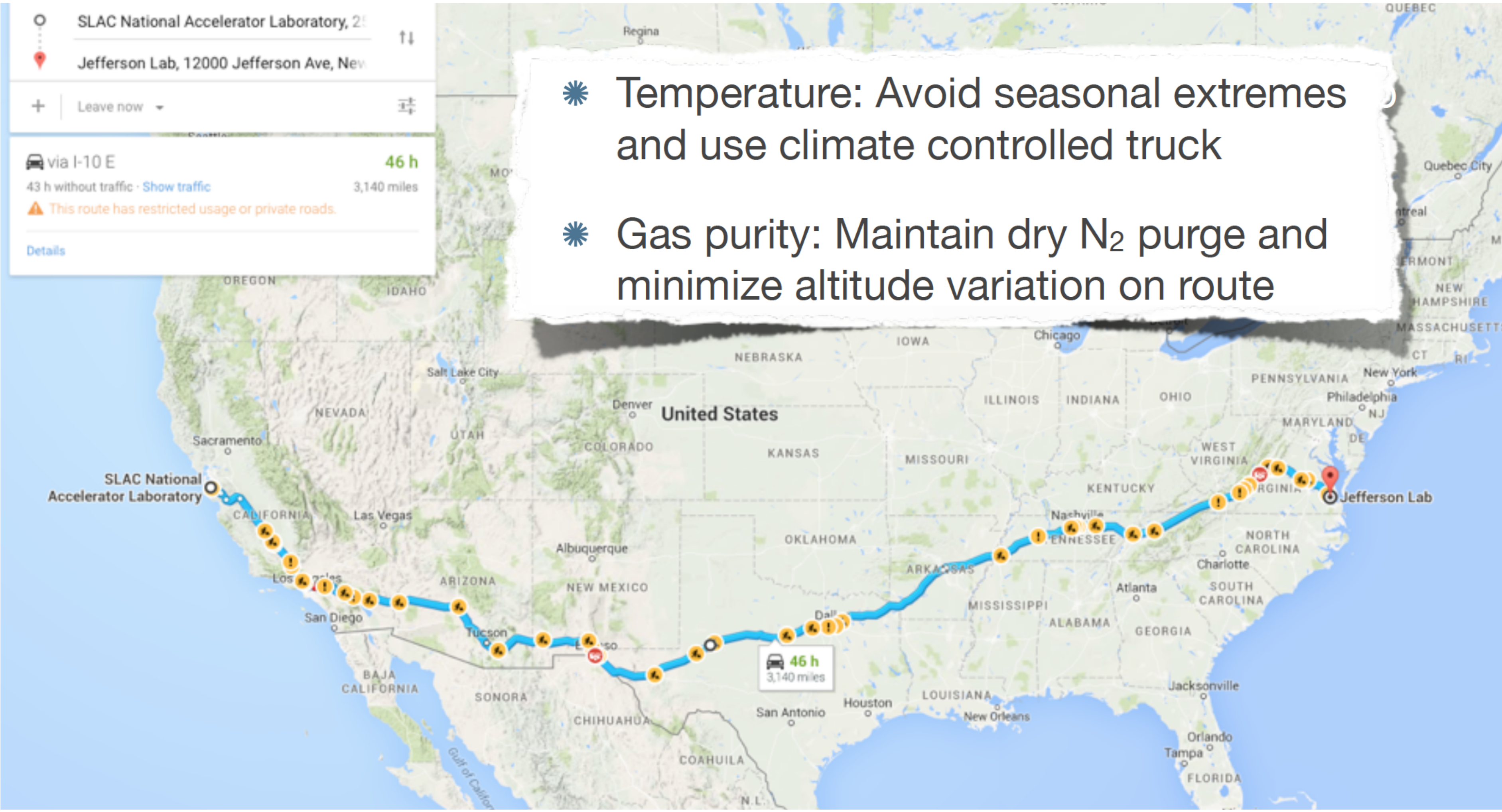
1. Preparation: shipping crate with accelerometers (design acceleration: 3g transversal, 1.5 g longitudinal), climate controlled truck, accompanying person with technical expertise
2. Test ride with a mock bar box near SLAC
3. Transportation of one bar box, inspection on the way and upon arrival in Jlab, storage in HallD, N_2 purge
4. Second trip to bring the other three bar boxes

BABAR DIRC radiator bars ready to be moved into the bar box (pic taken in 1999)



Transport of bar boxes

* Temperature: Avoid seasonal extremes and use climate controlled truck
* Gas purity: Maintain dry N_2 purge and minimize altitude variation on route



Summary

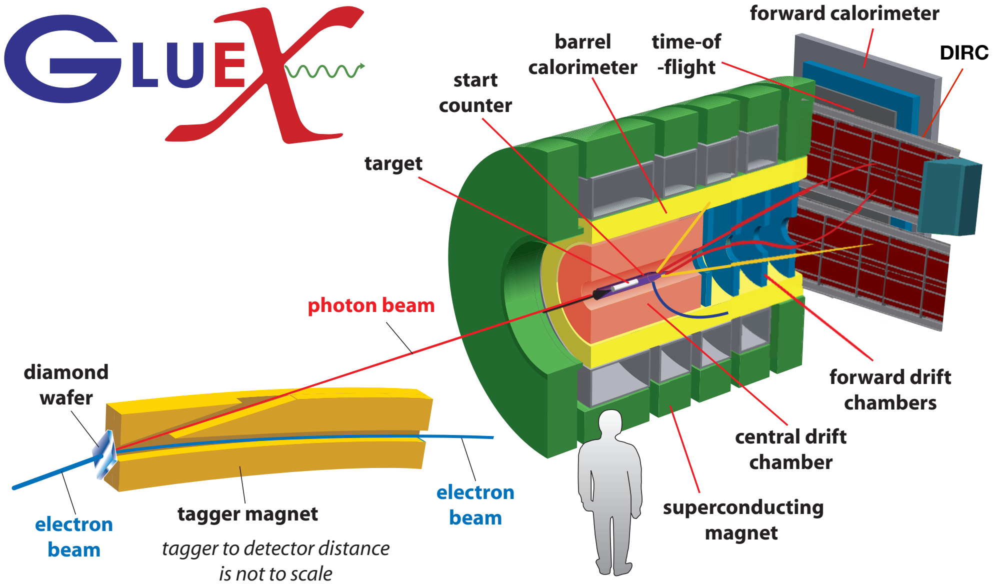
GlueX DIRC will reuse 4 BaBar bar boxes, optical box inspired by FDIRC, electronics based on CLAS12 RICH

Performance of the GlueX DIRC is being studied in detail in simulations

Upgrade of the PID system with DIRC doubles the momentum range, where K can be separated from π to ≤4 GeV/c

Construction is starting now

DIRC will expand the GlueX physics program to strange mesons!



Backup

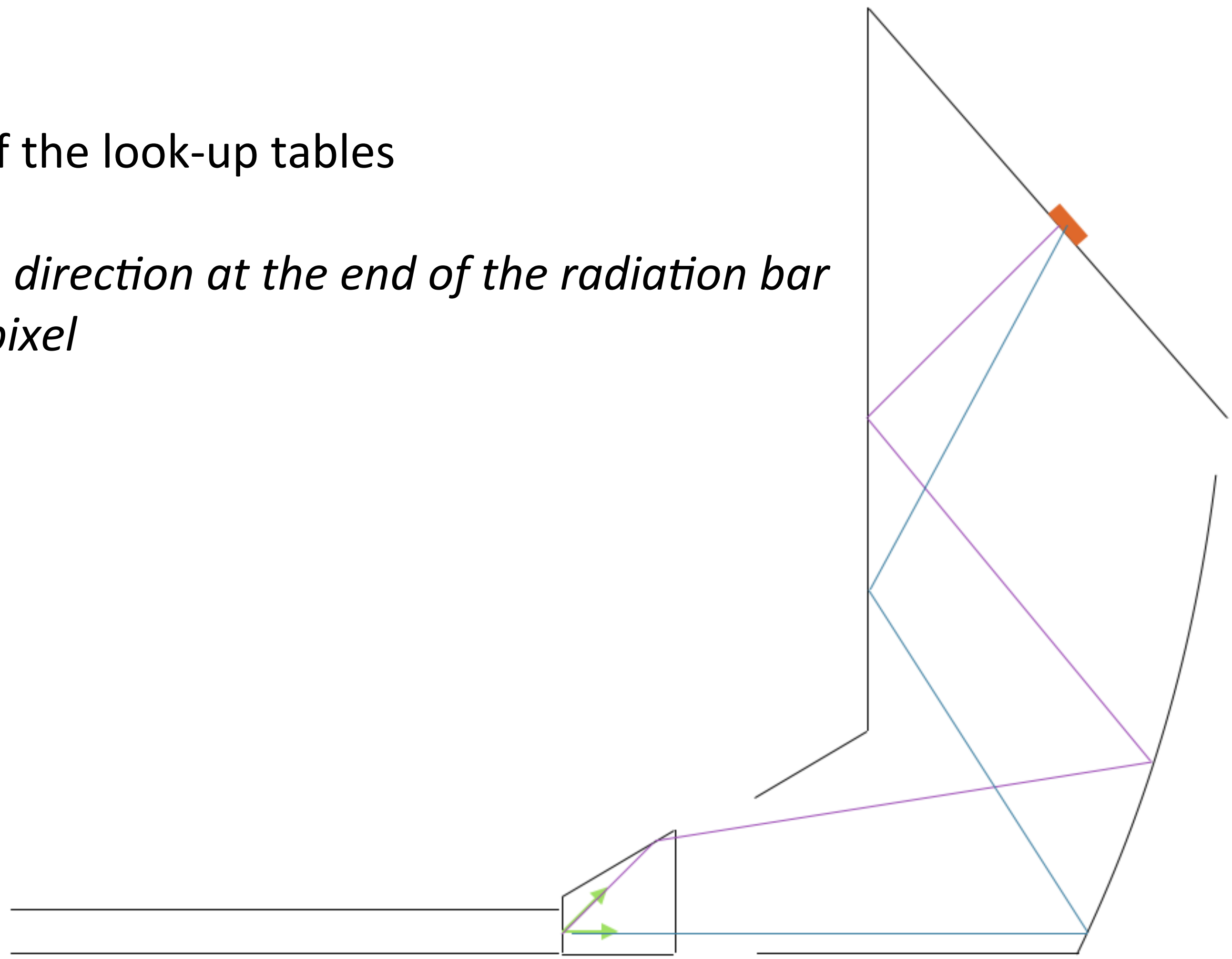
LUT reconstruction

Used for BABAR DIRC

Two stages:

1. creation of the look-up tables

Store photon direction at the end of the radiation bar for each hit pixel



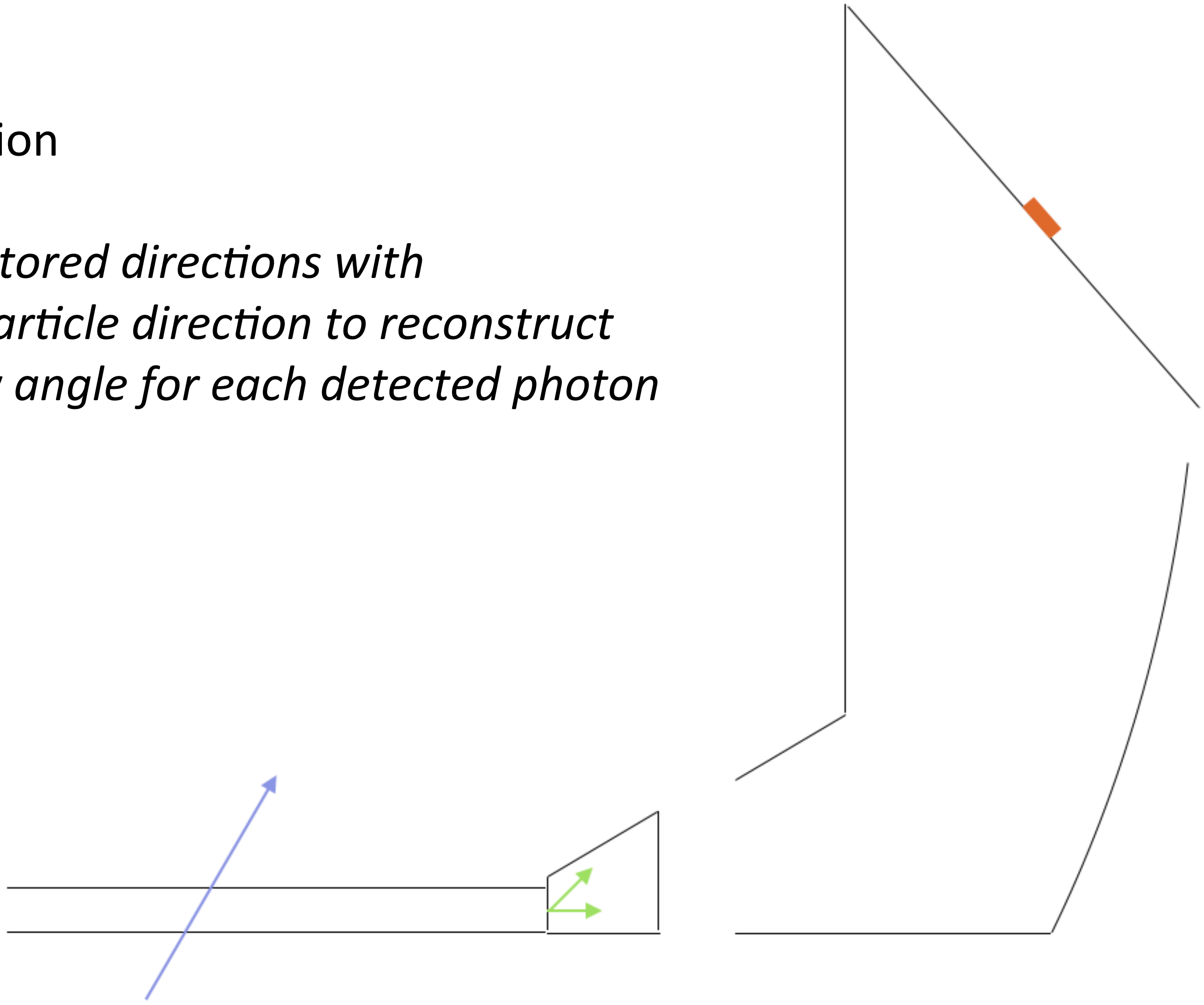
LUT reconstruction

Used for BABAR DIRC

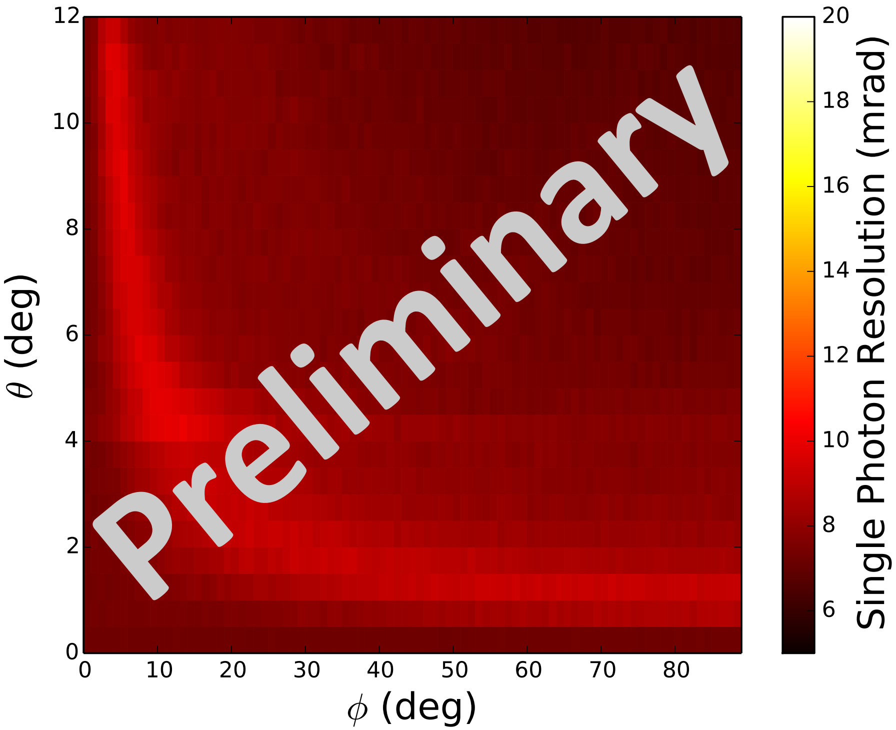
Two stages:

2. reconstruction

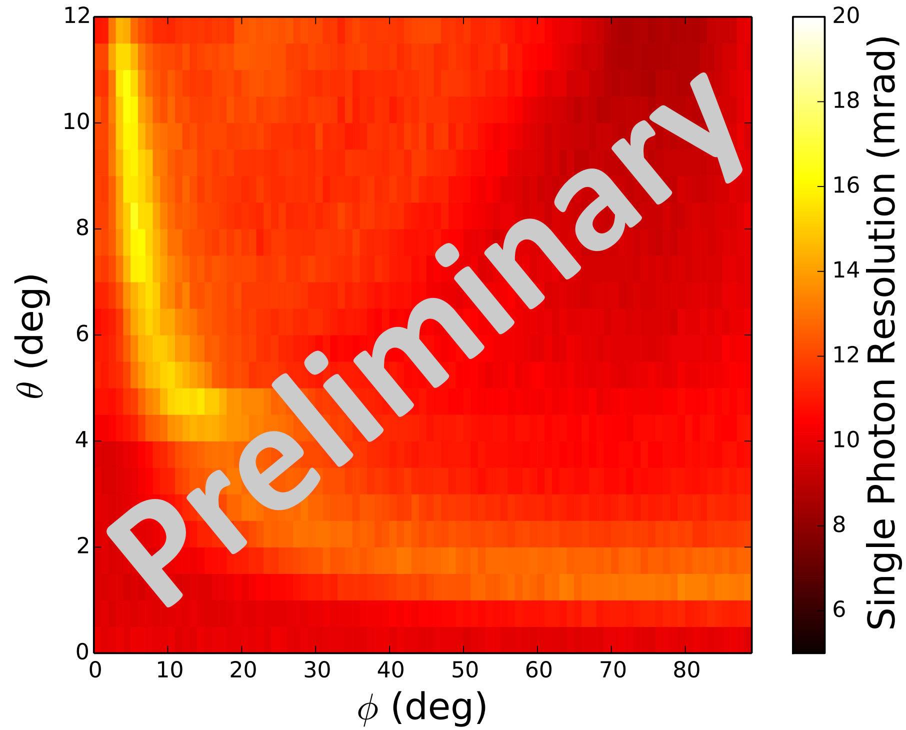
Combine the stored directions with the charged particle direction to reconstruct the Cherenkov angle for each detected photon



Single Photon Resolution

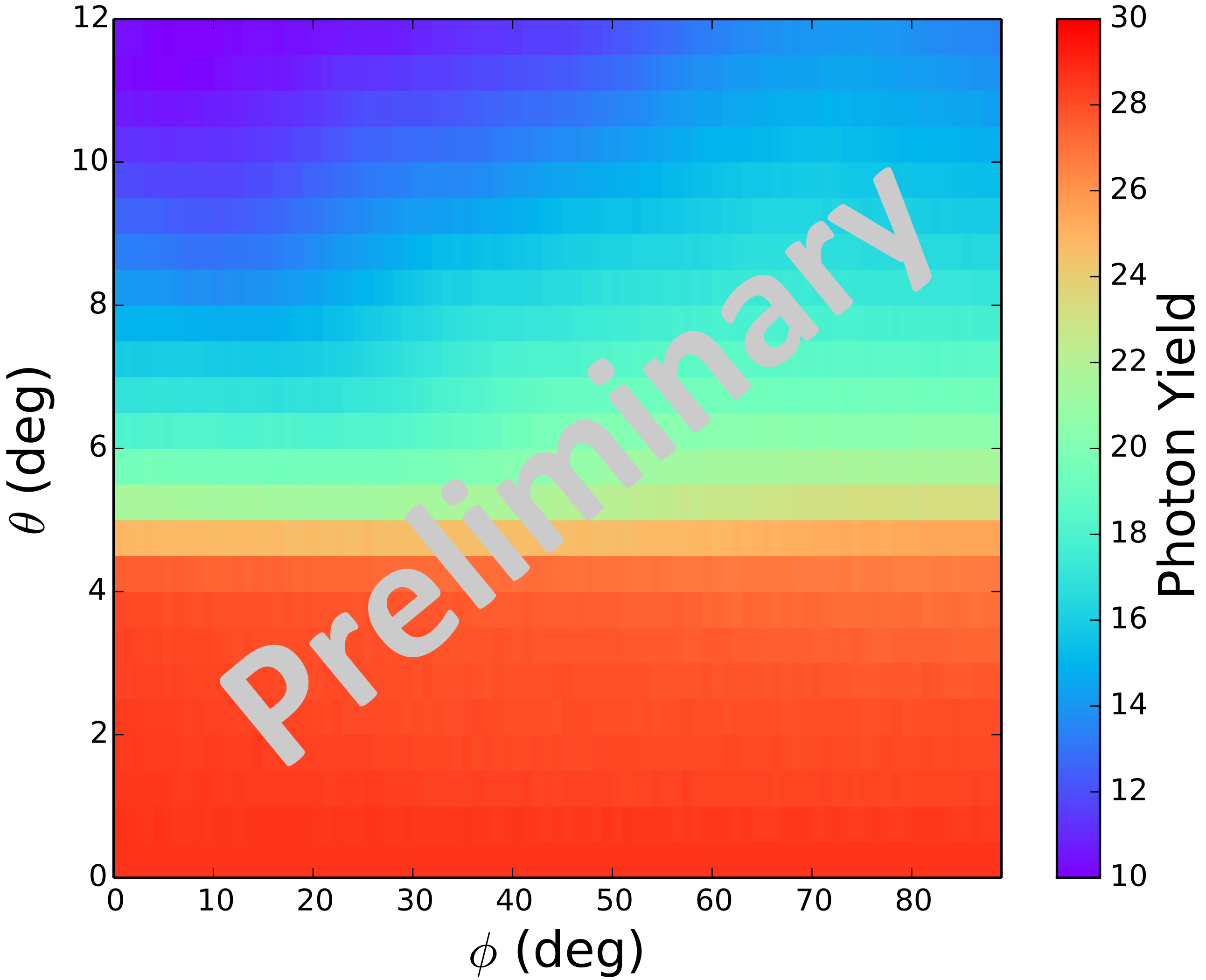


Using KDE method



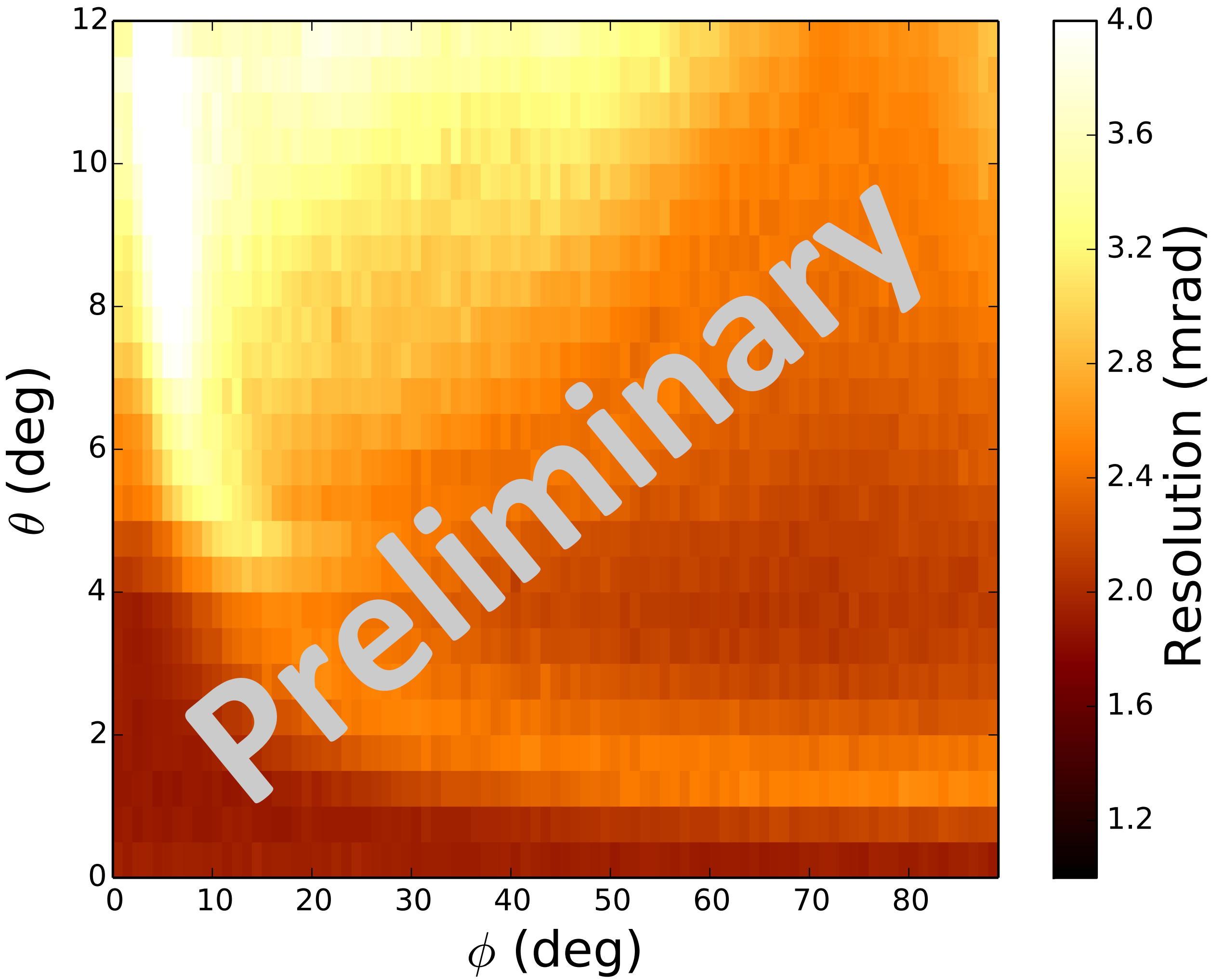
Using LUT method

Number of Detected Photons

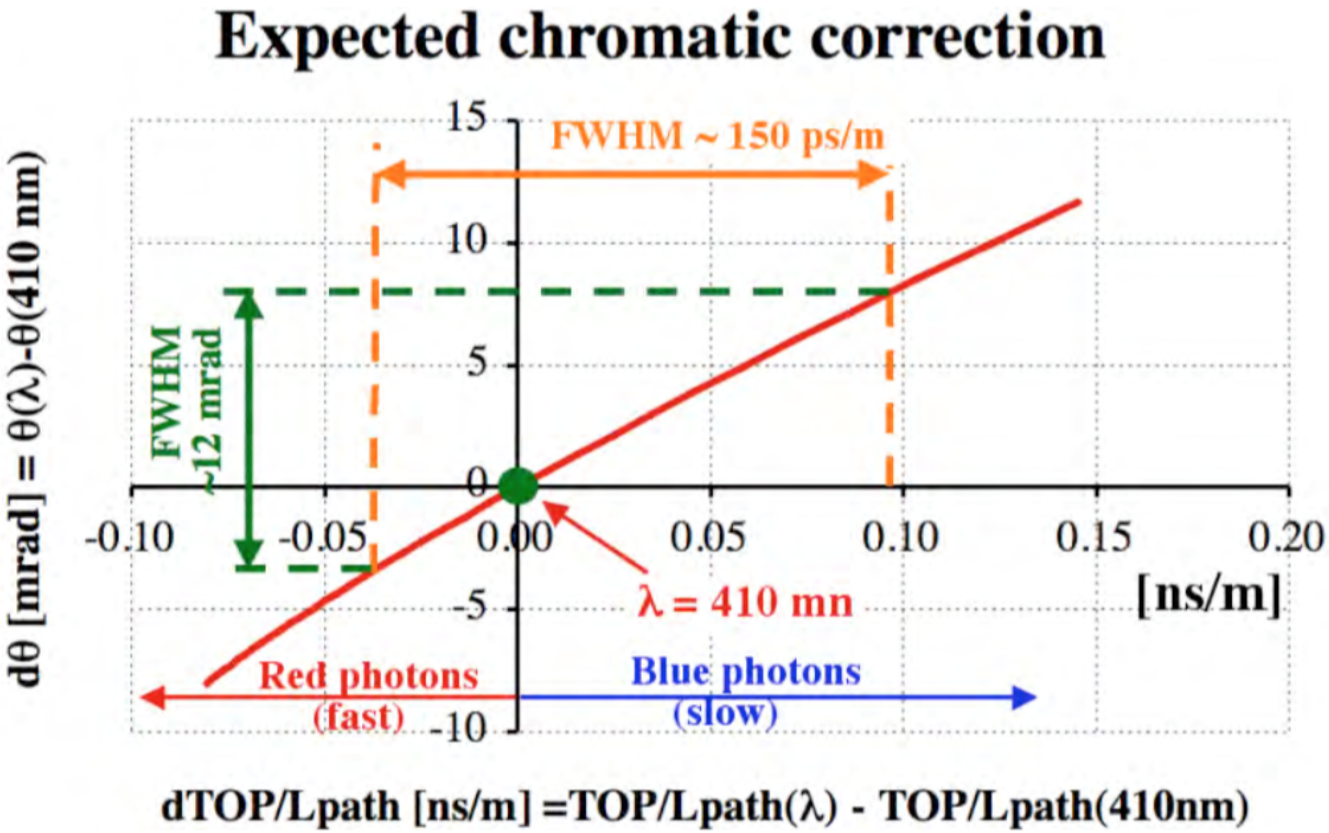


Resolution

Cherenkov angle resolution per track obtained using LUT method (no chromatic correction)



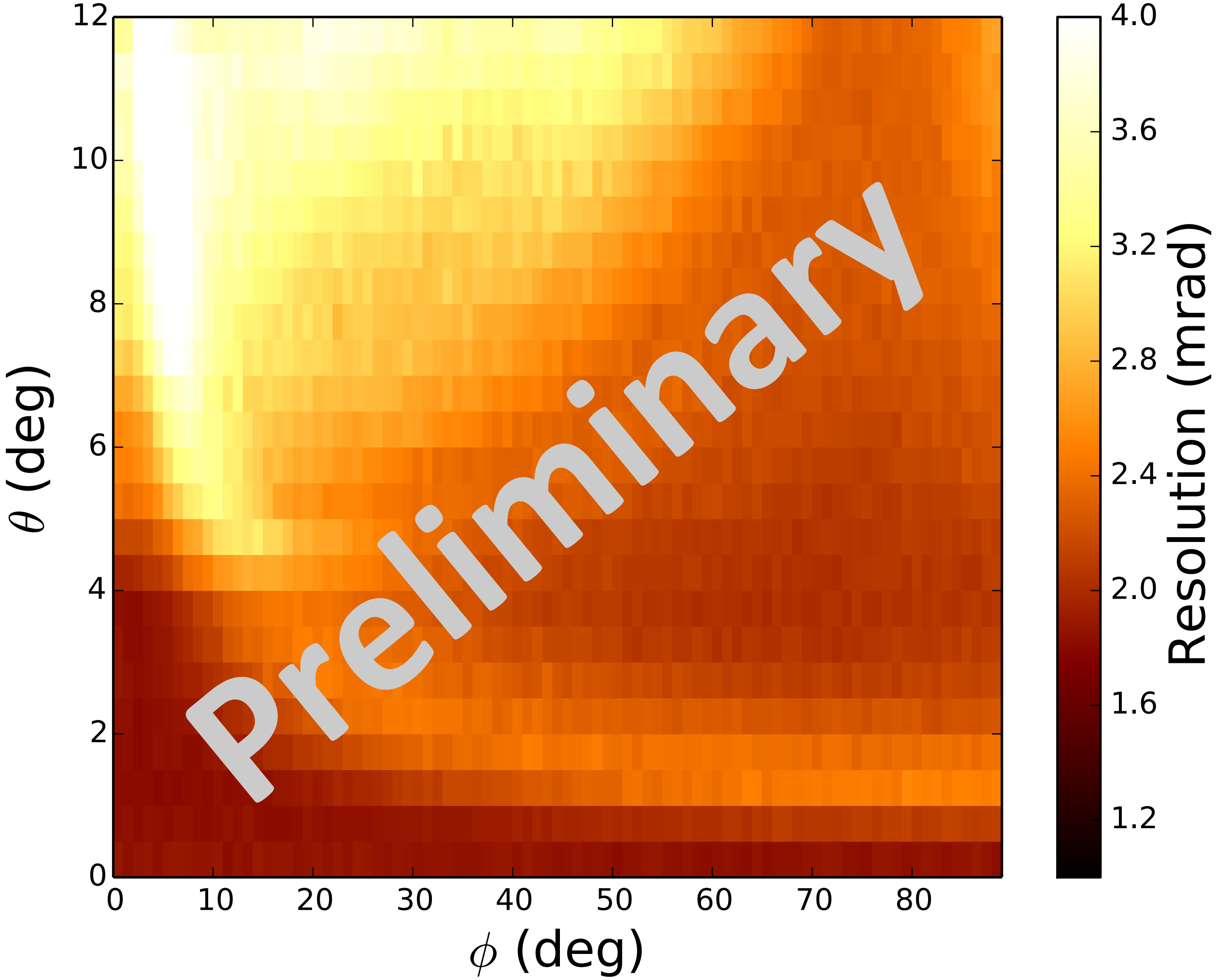
Chromatic correction



$$\theta_C^{corr} = \theta_C - slope \cdot (dTOP / L_{path})$$

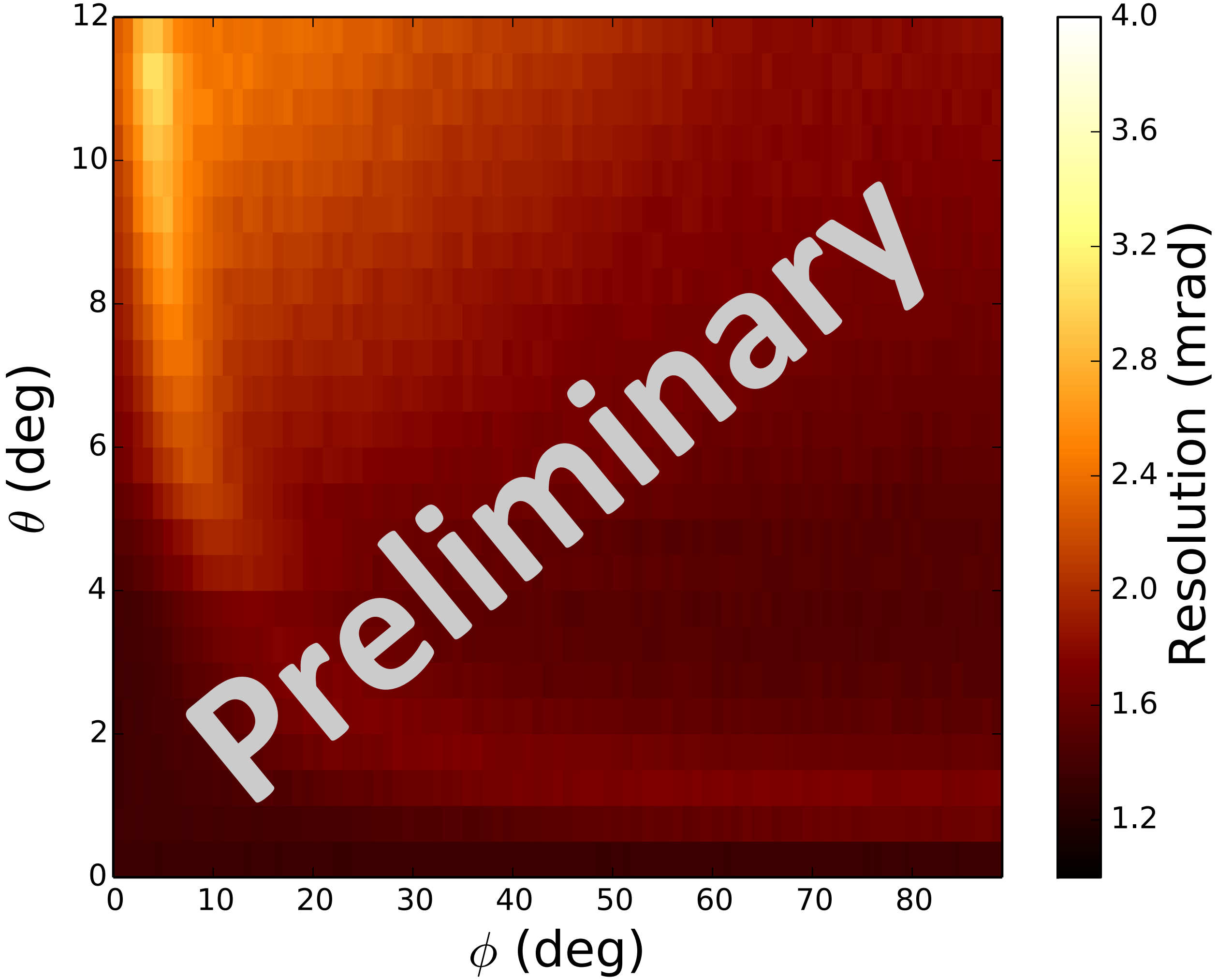
Resolution

Cherenkov angle resolution per track obtained using LUT method (chromatic correction applied)



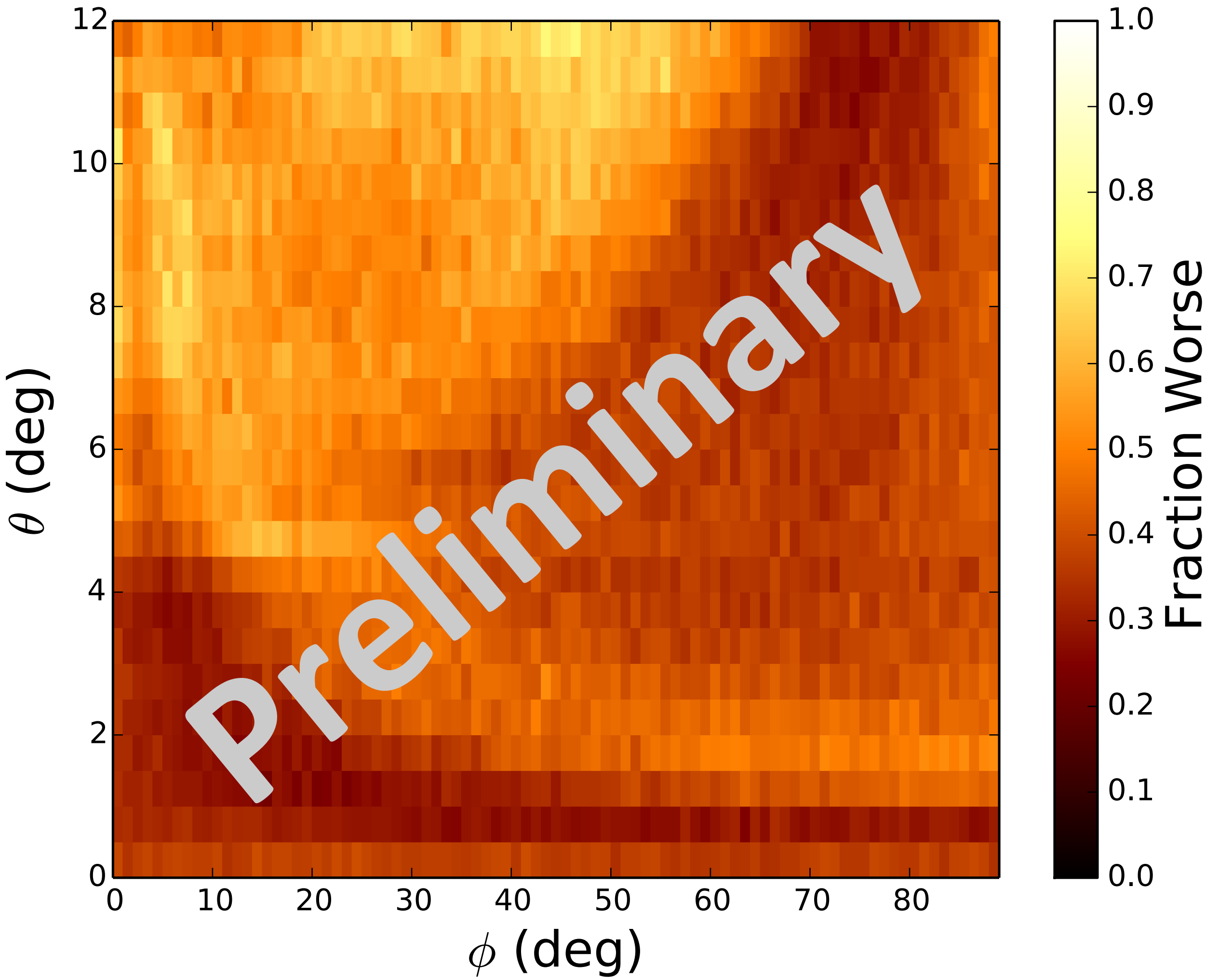
Resolution

Cherenkov angle resolution per track obtained using KDE method



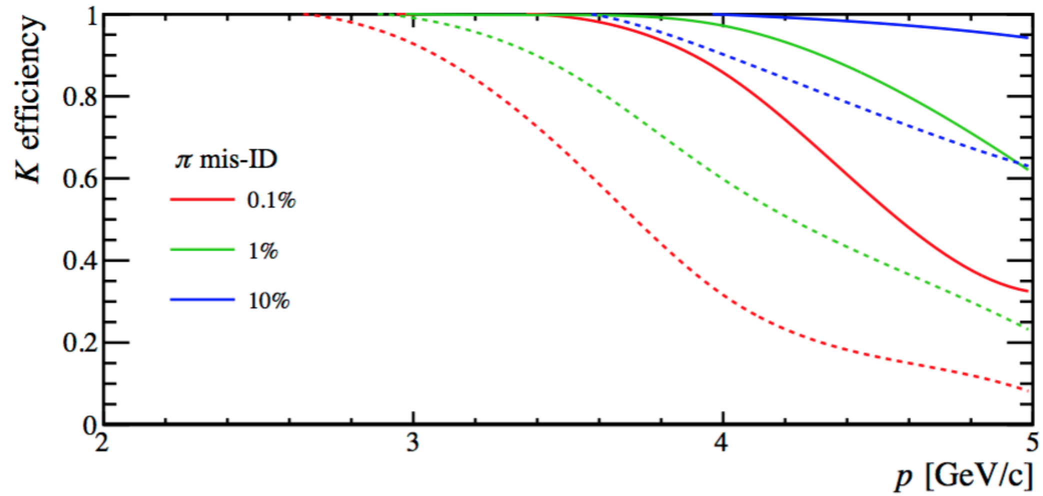
Resolution

Relative gain in the Cherenkov angle resolution per track using KDE-method versus LUT-based method (chromatic correction applied)



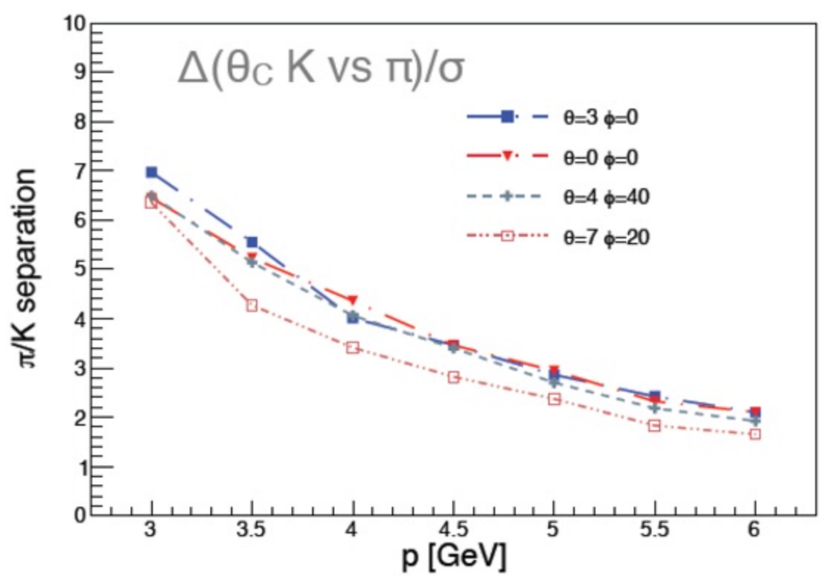
$$\frac{\sigma_{LUT}(\theta_C) - \sigma_{KDE}(\theta_C)}{\sigma_{KDE}(\theta_C)}$$

K efficiency



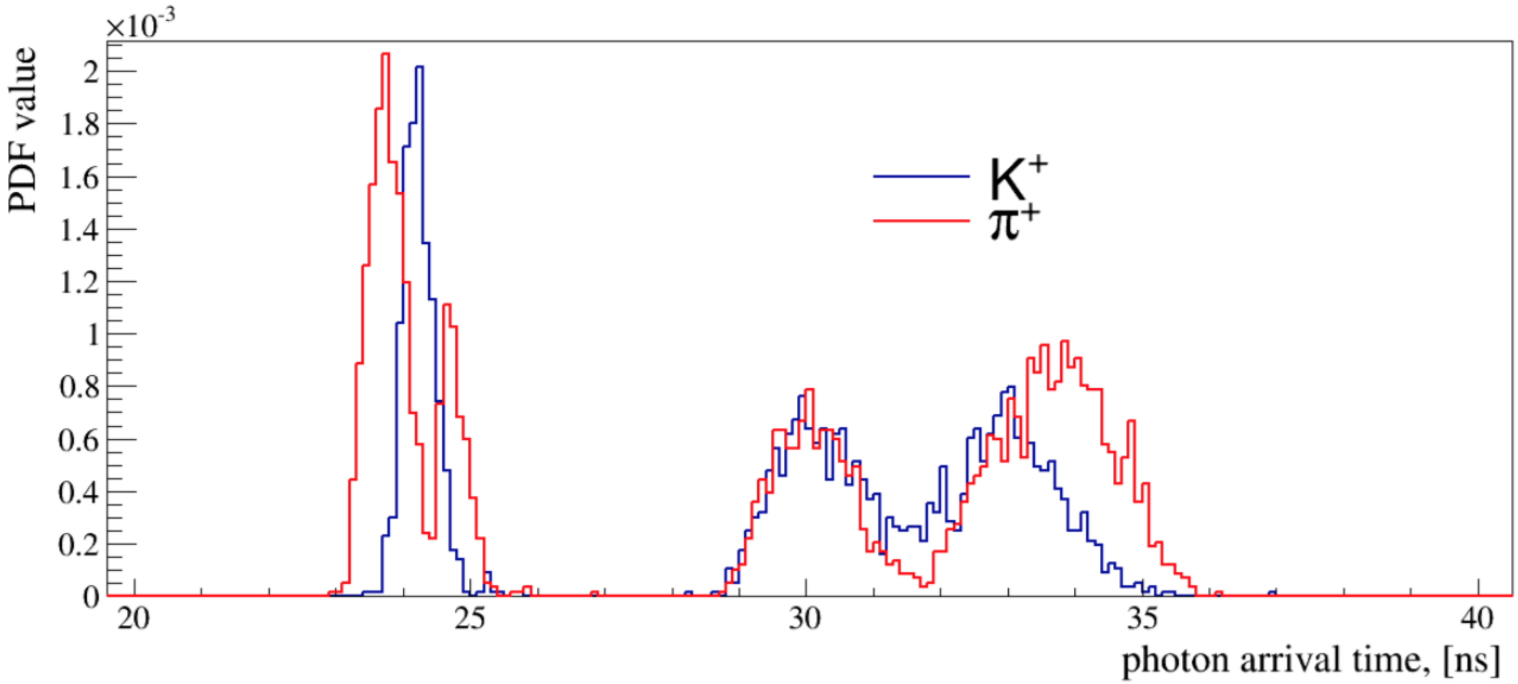
Solid lines – current design. Dashed lines show the initial estimate. Main upgrades:

- H12700
- Tracking error estimates



Time-based imaging

For each pixel the full simulation is used to record the arrival time of photons from e, μ, π, K, p (including MCP-PMT signals from charge sharing and dark noise) and stored in an array of histograms, which are normalized to produce probability density functions (PDF).



Time-based imaging

For a given track the observed photon arrival time for each pixel with a hit is compared to the histogram array to calculate the time-based likelihood for the photons to originate from a given particle species. Combining this likelihood with the Poissonian PDF of the number of observed photons creates the full likelihood. Example of the log likelihood difference between kaon and pion mass hypothesis for 1000 π^+ and K^+ tracks with momentum p_{track} = 3 GeV/c at a polar angle θ_{track} = 22° for a geometry with one wide plate per bar box and a prism type expansion volume.