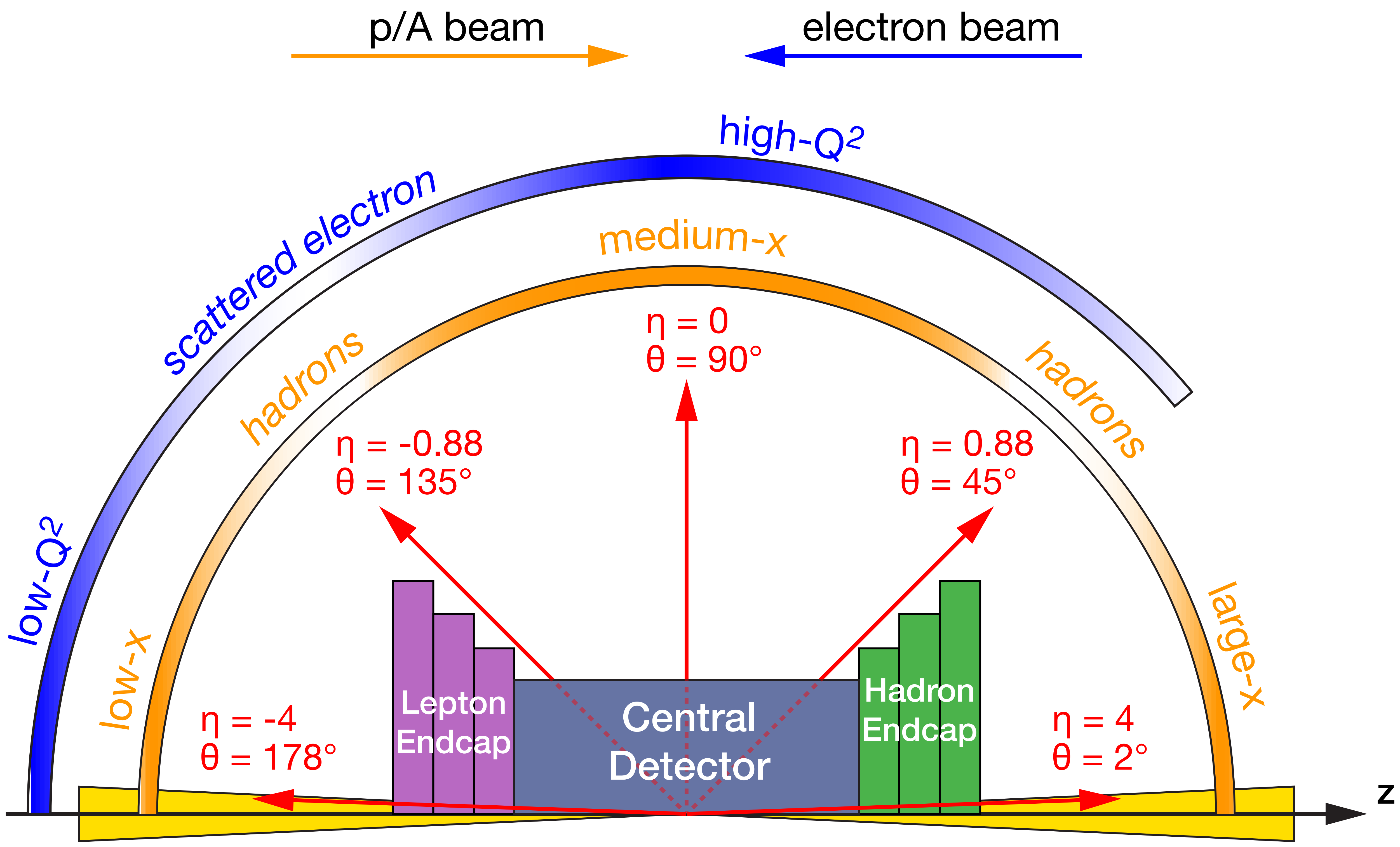
ePIC Backward RICH

Prakhar Garg

YR Requirements for PID in backward direction



η	Nomenclature			π/K/p PID	
				p-Range (GeV/c)	Separation
-6.9 — -5.8	↓ p/A	Auxiliary Detectors	low-Q² tagger		
…					
-4.5 — -4.0			Instrumentation to separate charged particles from γ		
-4.0 — -3.5					
-3.5 — -3.0			Backwards Detectors	≤ 7 GeV/c	
-3.0 — -2.5					
-2.5 — -2.0					
-2.0 — -1.5					
-1.5 — -1.0					
-1.0 — -0.5					

Yellow report requirement: 3 sigma pion/K separation up to 7 GeV/c

<u>ePIC new requirement: provide ~20 ps timing reference for ePIC ToF detectors</u>

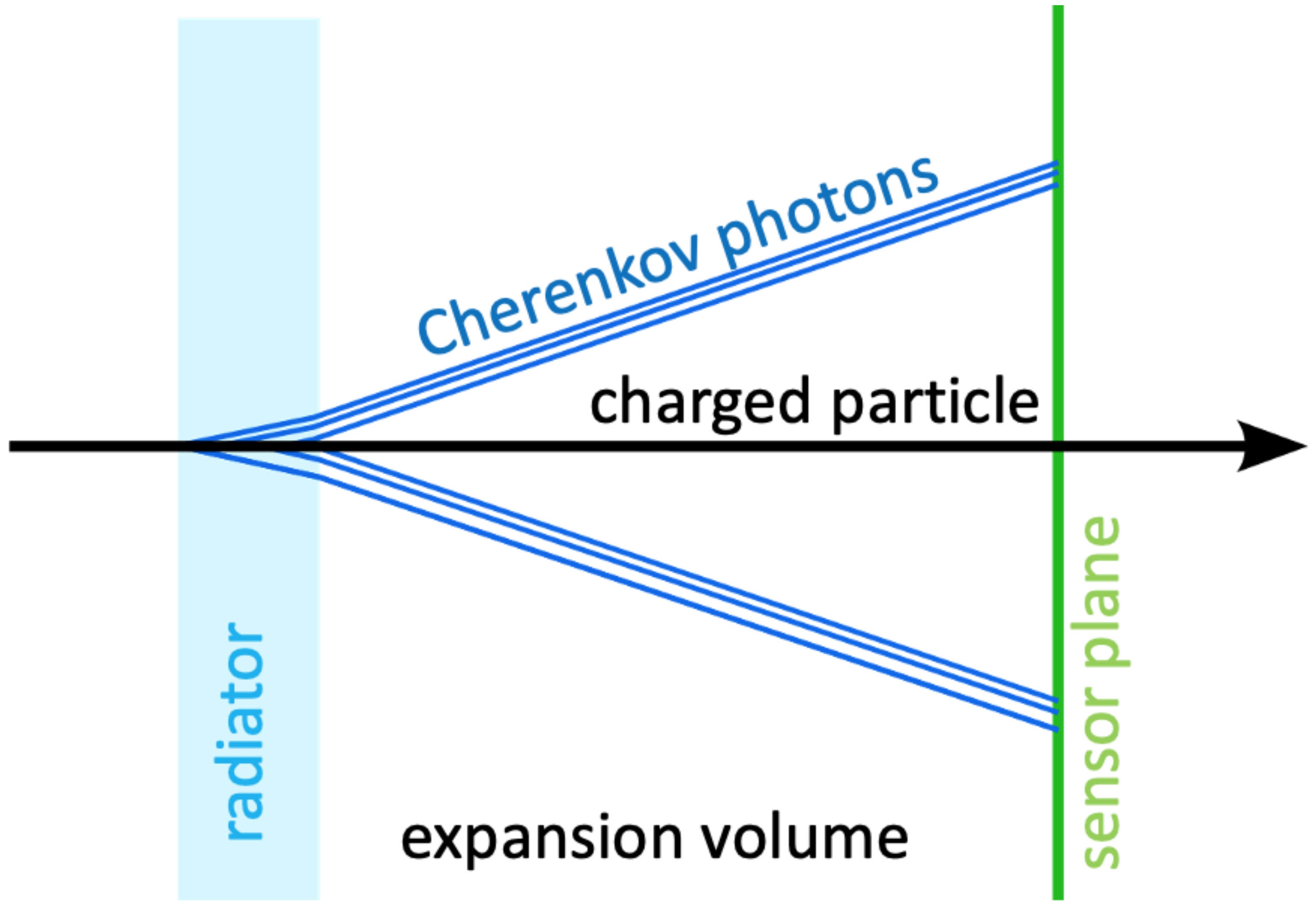
The Devil is in the details

- Tolerable material budget (Living in Harmony With Neighbors)
- Large acceptance
- Uniform performance
- Reconstruct scattered electrons
- High electron purity down to low p
- Magnetic Field Susceptibility
- Cooling
- Support structure
- Long term stability
- Cost
- Rate Capability
- Radiation Hardness
- Mechanical stability

…………………………. And what not

pfRICH in general

- Large proximity gap
- Thin aerogel radiator
- High enough spatial resolution in the photosensor matrix
- Weak n(λ) dependency in the photosensor effective quantum efficiency (QE) range
- Sufficient number of detected photons per track



p = m$\gamma\beta$ E = mγ velocity(β) measurement yields

Direct measurement:

➡Record signal time at multiple locations, calculate v.

➡"Fast" detector = low transit time spread (most easily achieved at small transit time)

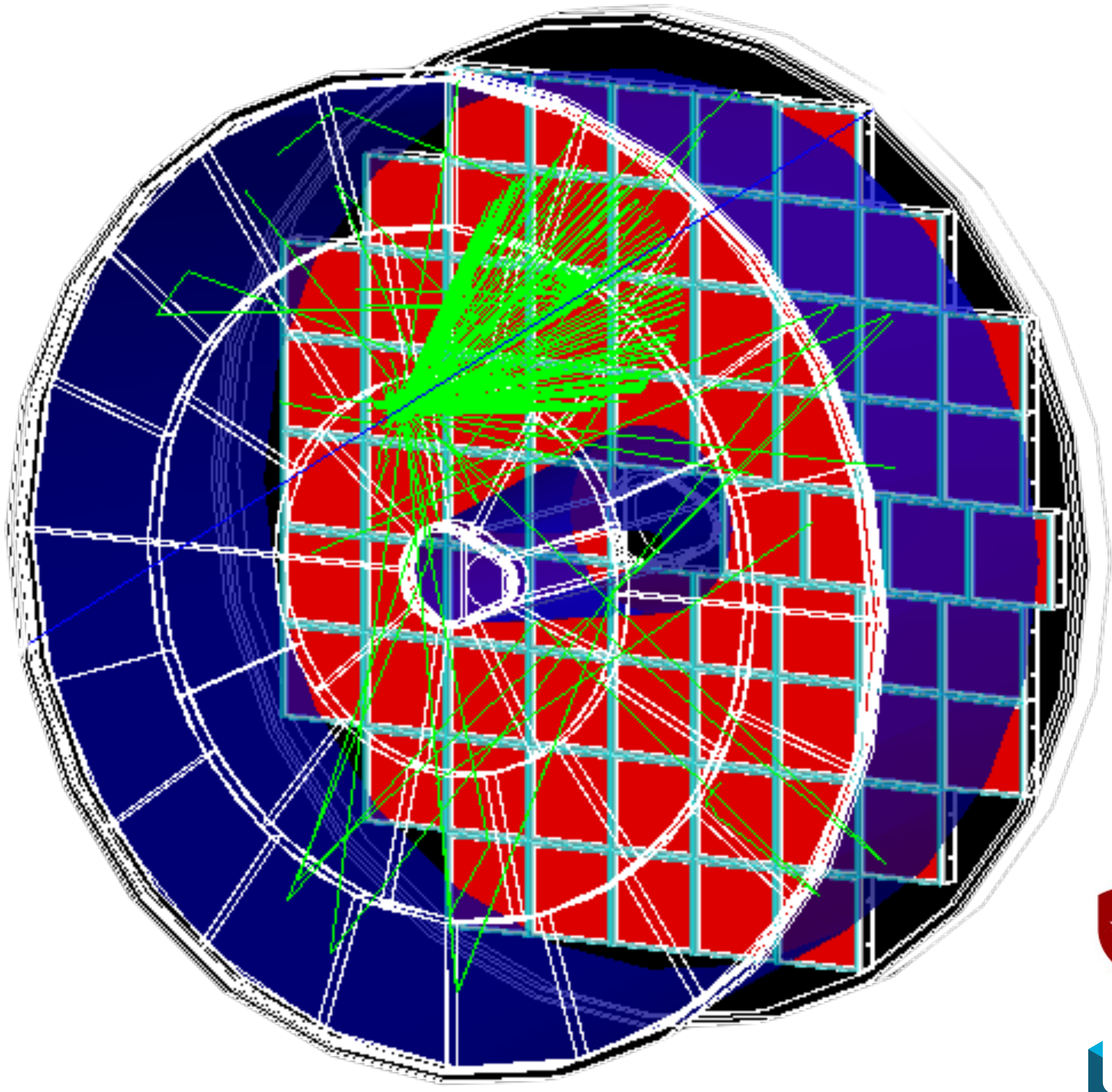
Velocity-dependent interaction(s) with detector:

❖ Specific Ionization ($\frac{dE}{dx}$)

❖ Cherenkov Radiation: $cos\theta_c = 1/n\beta$
θ_c measured wrt. track direction.

From Tom's talk yesterday

ePIC pfRICH: Overview



ePIC pfRICH:

- ❑ A classical proximity focusing RICH
- ❑ Pseudorapidity coverage: $-3.5 < \eta < -1.5$
- ❑ Uniform performance in the whole $\{\eta,\phi\}$ range
- ❑ π/K separation: above 3σ up to ~ 9.0 GeV/c
- ❑ t_0 reference with a ~100% geometric efficiency

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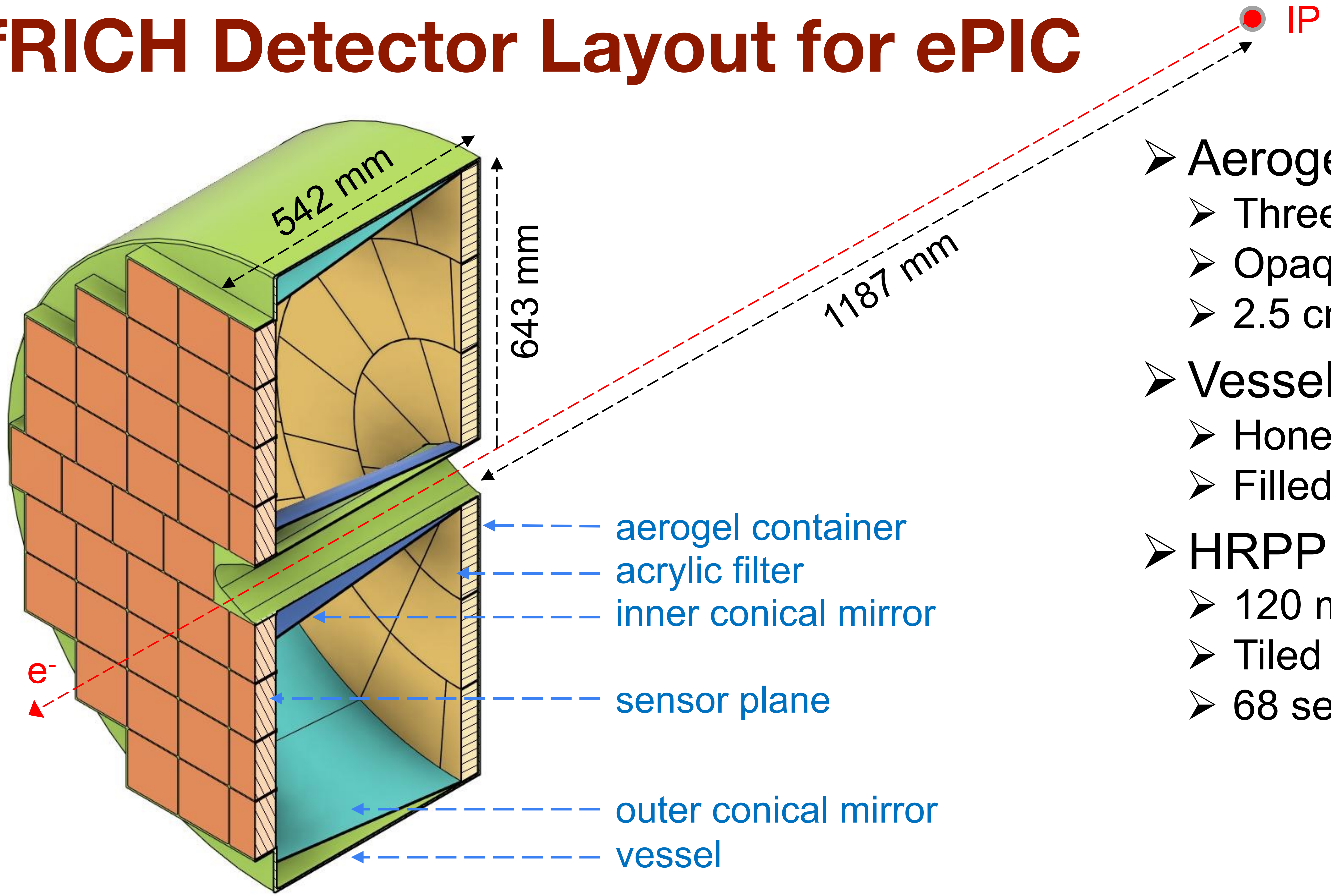
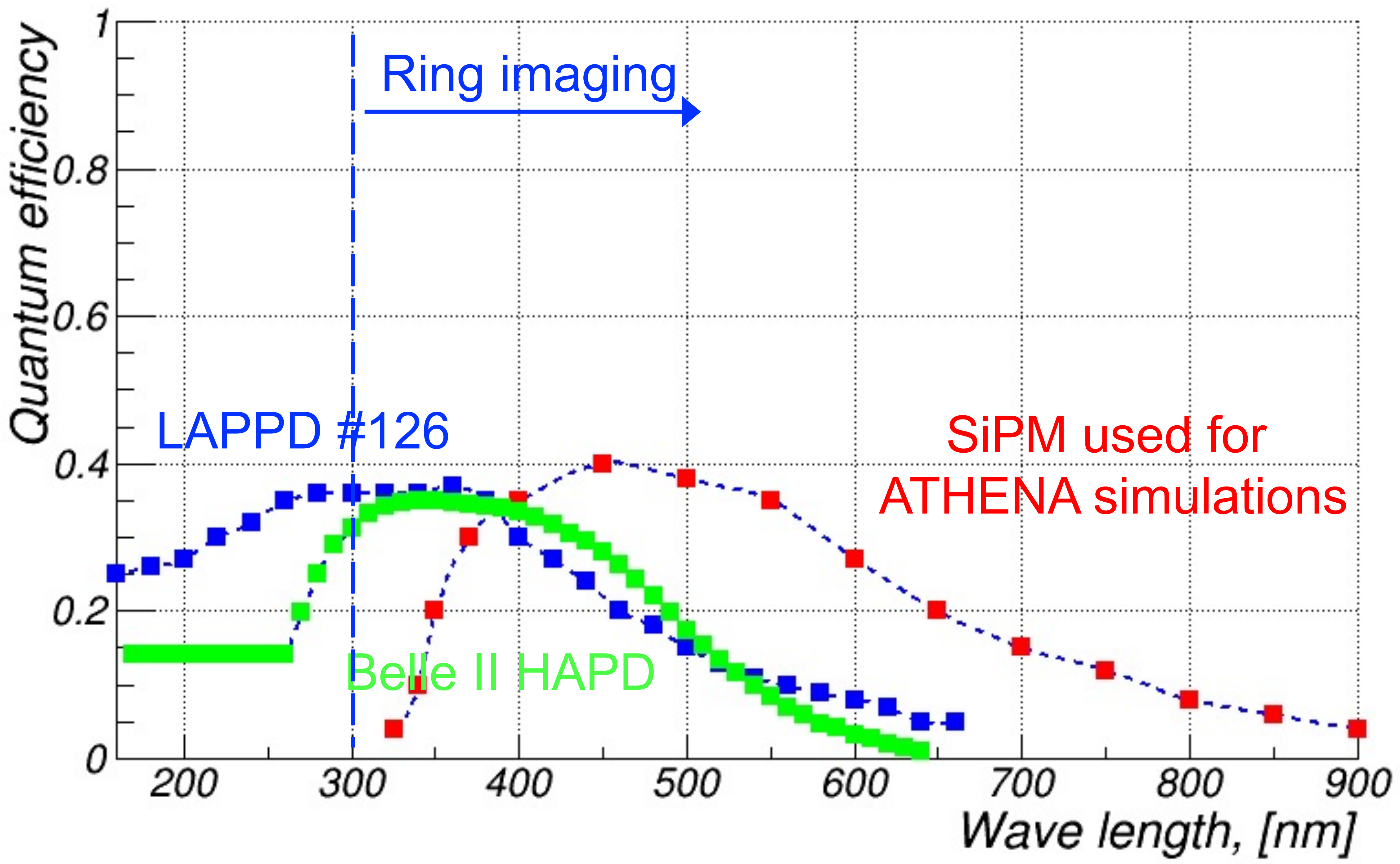
pfRICH Detector Layout for ePIC



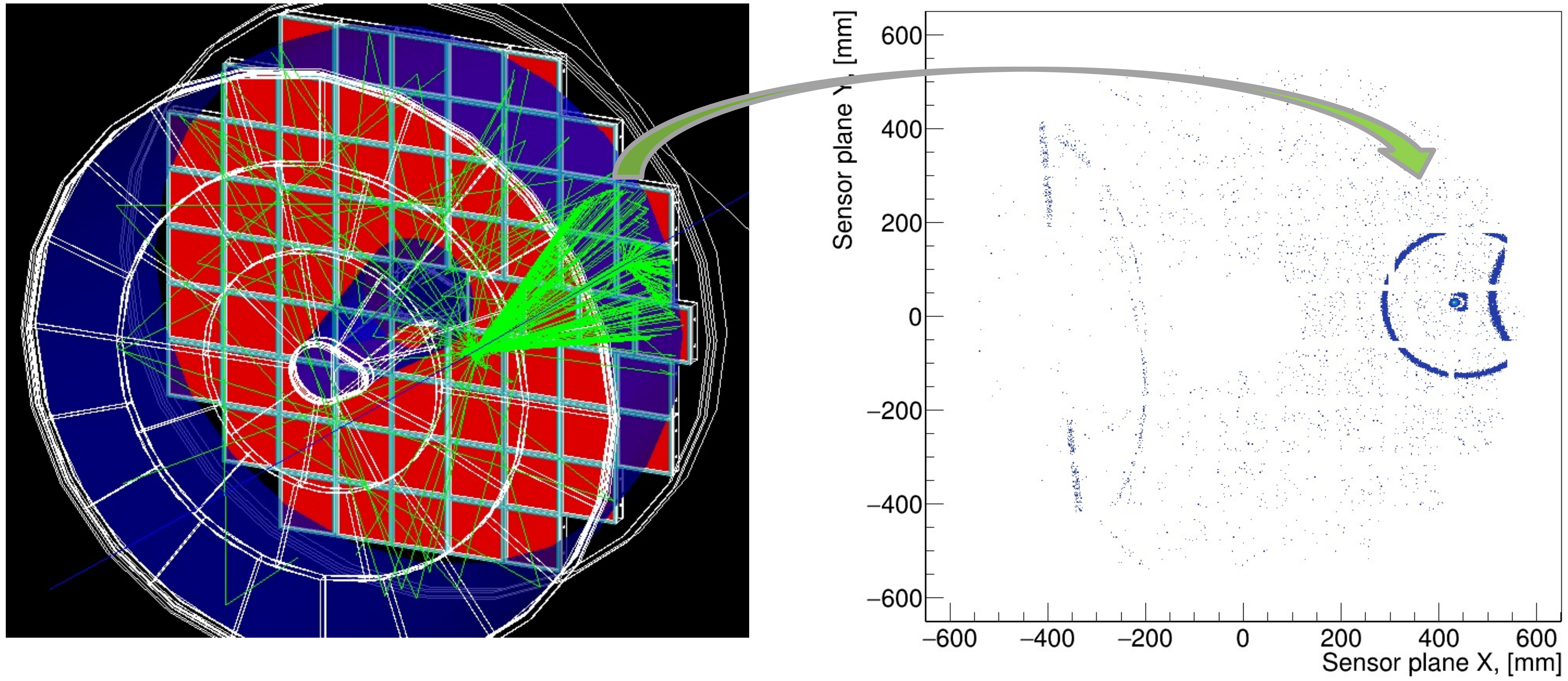
- Aerogel
  - Three radial bands
  - Opaque dividers
  - 2.5 cm thick, 42 tiles total
- Vessel
  - Honeycomb carbon fiber sandwich
  - Filled with nitrogen
- HRPPD photosensors
  - 120 mm size
  - Tiled with a 1.5mm gap
  - 68 sensors total

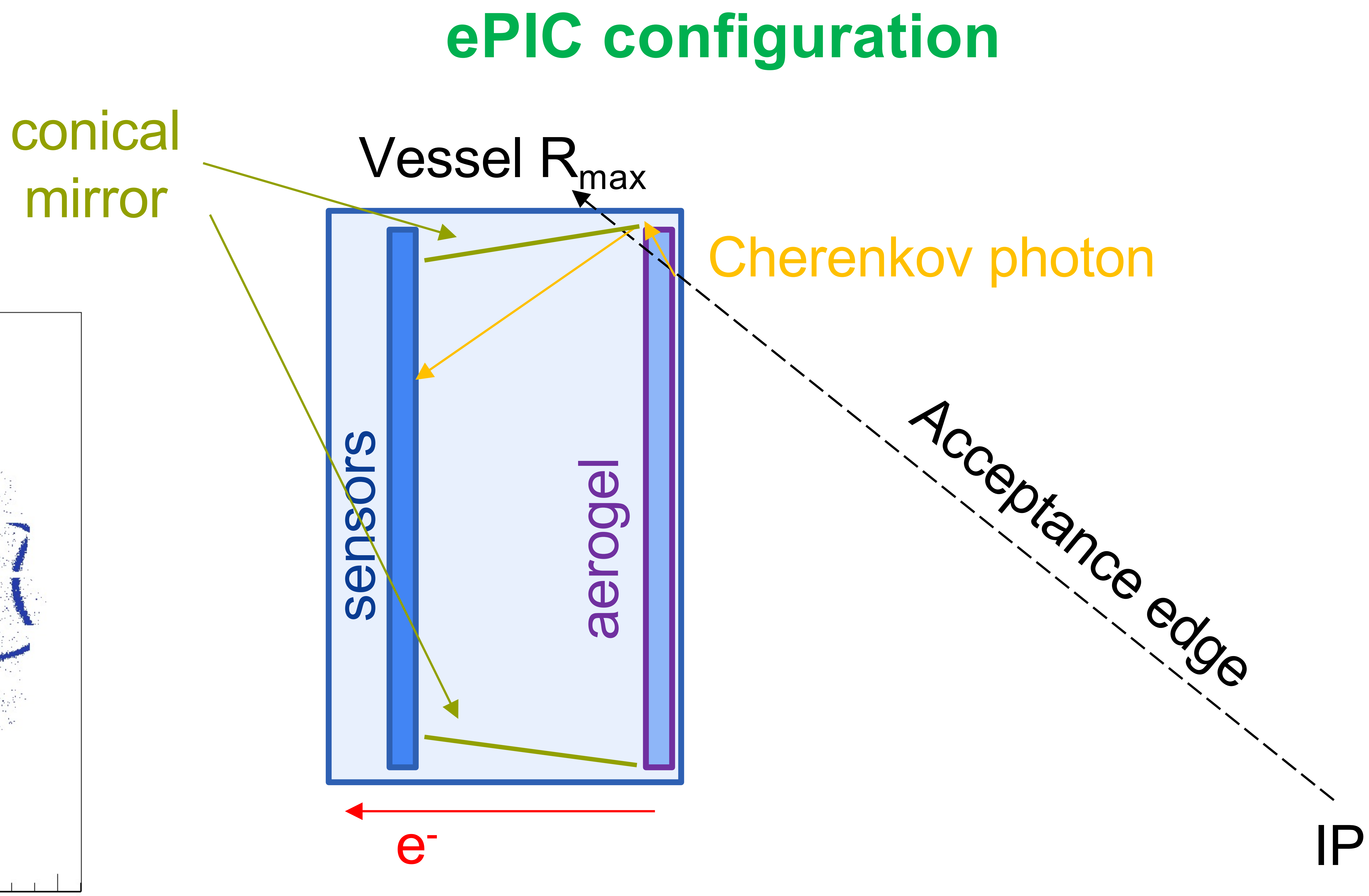
Aerogel Selection

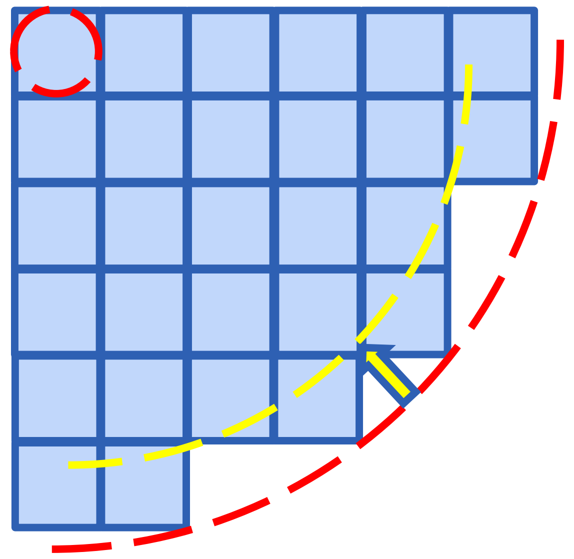
- HRPPD PDE is expected to be substantially smaller than of the SiPMs
  - And peak value shifted to the UV range, where it cannot be used for ring imaging
- Therefore working with <n> ~ 1.020 does not look feasible (<N_{pe}> too small)
- **Consider using n ~ 1.040 … 1.050**
  - 300 nm acrylic filter cutoff for imaging
  - <N_{pe}> ~ 11-12
  - *For ToF still make use of the UV range for abundant Cherenkov light produced in the window*
  - Natural choice for simulations: Belle II n ~ 1.045
  - Natural hardware reference: Chiba University aerogel recently produced for J-PARC (n = 1.040)



Mirrors to improve acceptance

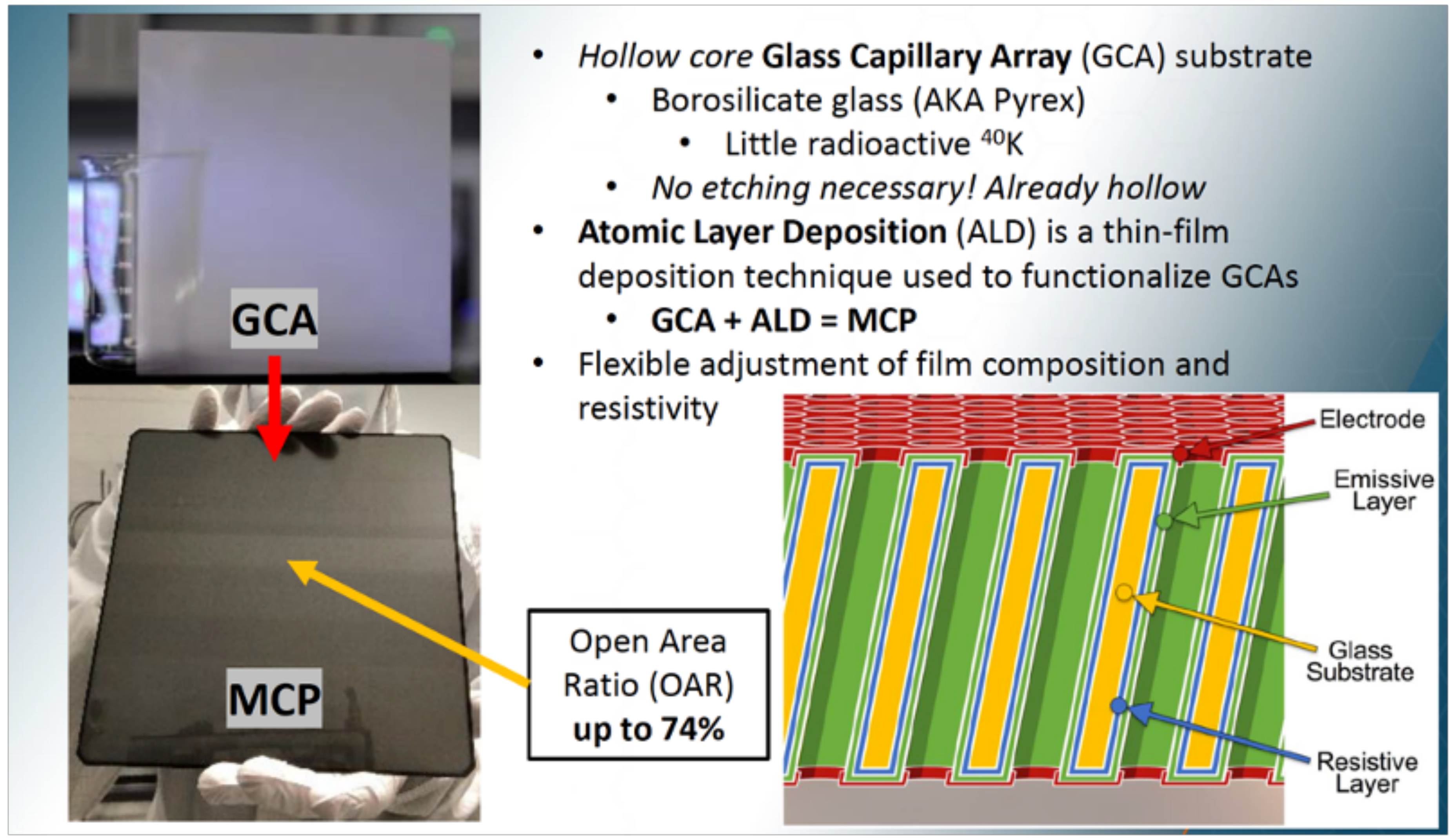


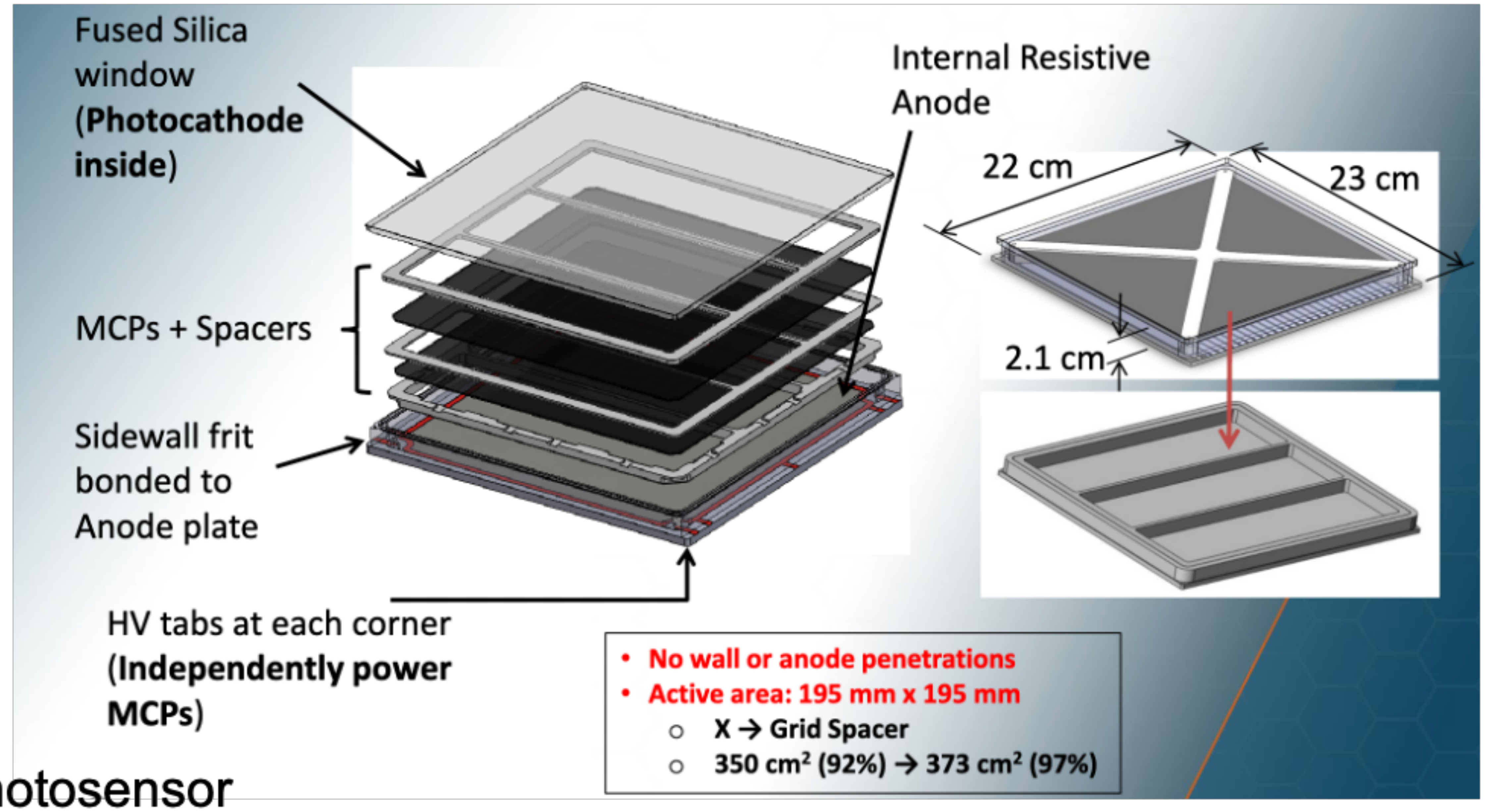




- Use side wall mirrors to increase η acceptance
  - Achieve $-3.5 < \eta < -1.5$ coverage
  - Make mirrors *conical* to avoid inefficiency on the sensor plane

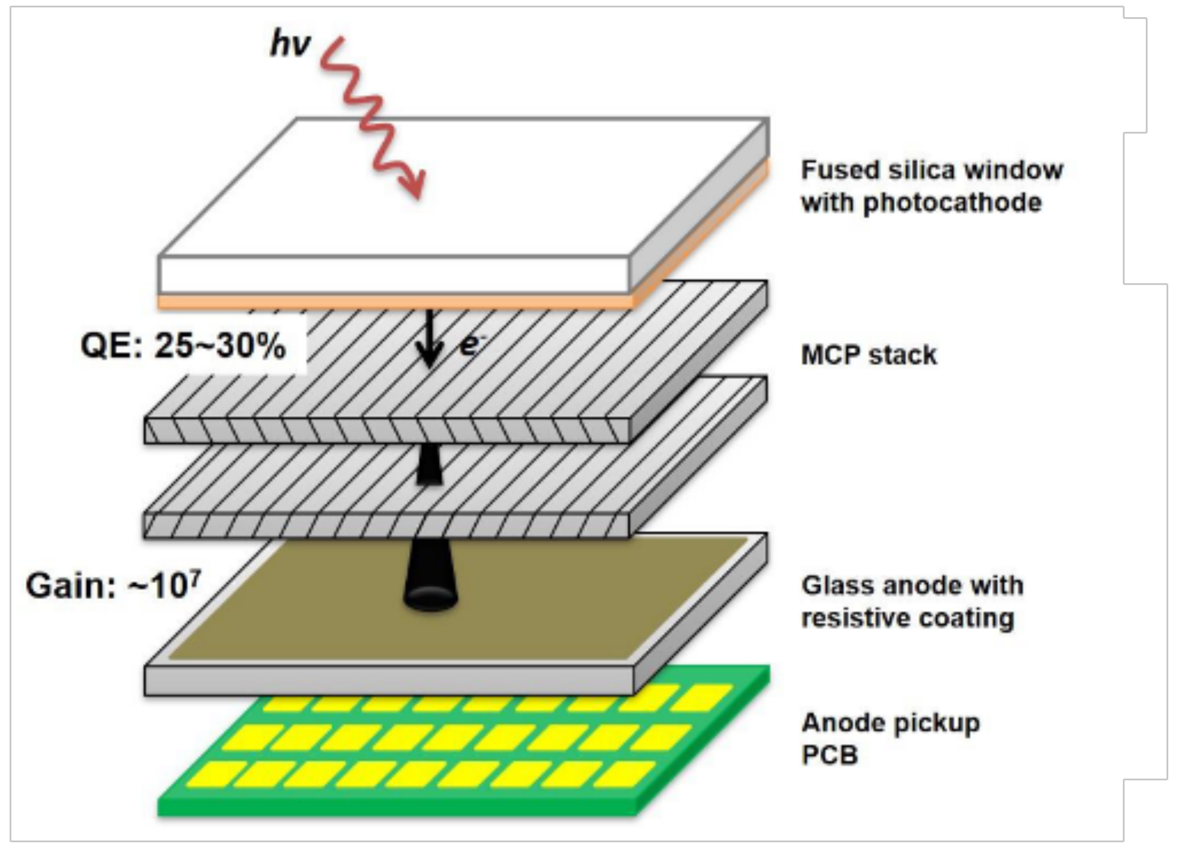
LAPPDs / HRPPDs by Incom Inc.





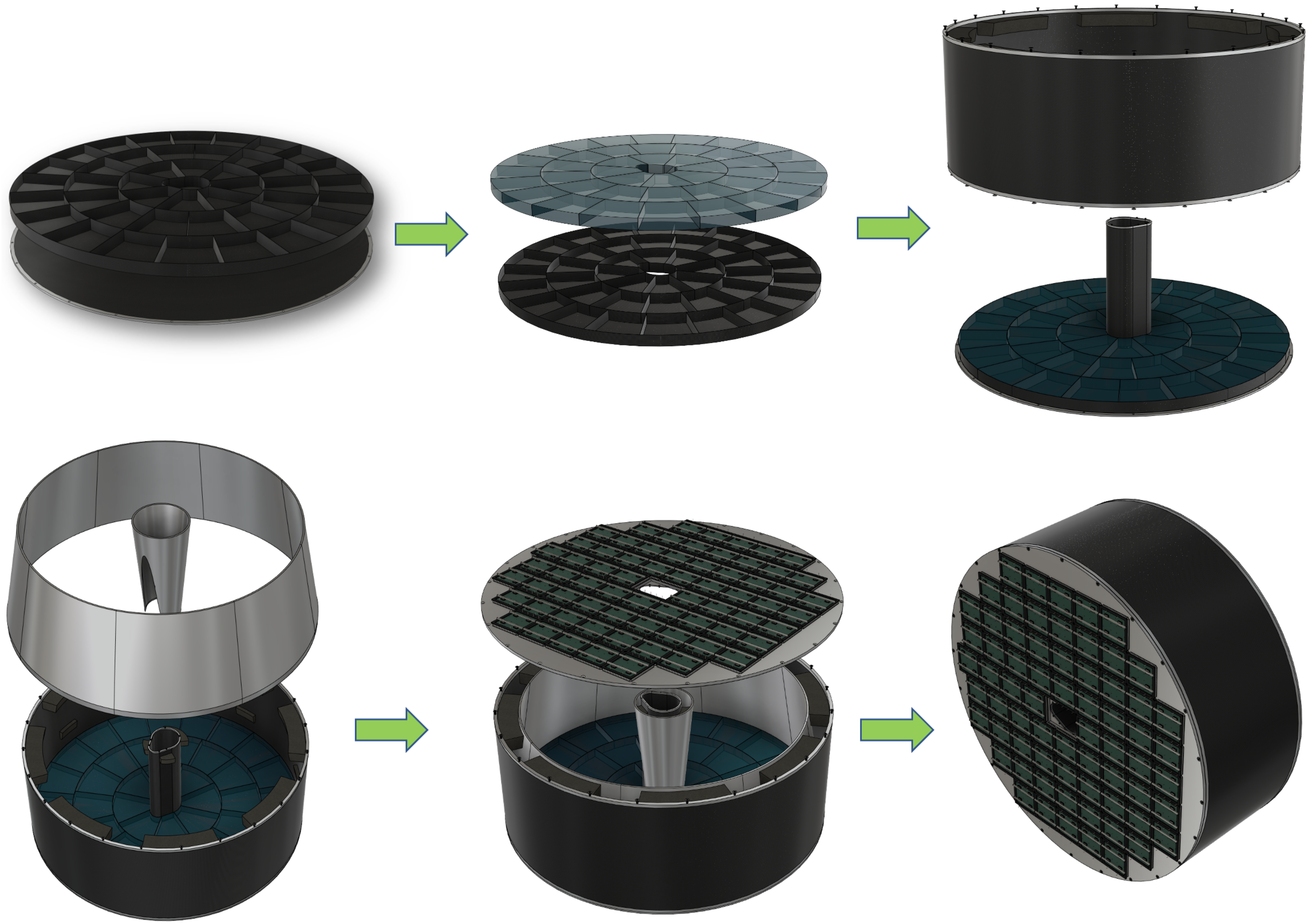
- An affordable large area (finely pixelated) vacuum photosensor
- 10x10 cm^2 or 20x20 cm^2 active area
- DC- (Gen I) or capacitively (Gen II) coupled species
- DC-coupled strips or 2D pixellation
- Expected to be (very) cost efficient in mass production
- High enough quantum efficiency and uniform high gain up to ~10^7
- Sub-mm spatial resolution for finely pixelated tiles
- Single-photon timing resolution on a ~50ps level or higher

Gen II variety



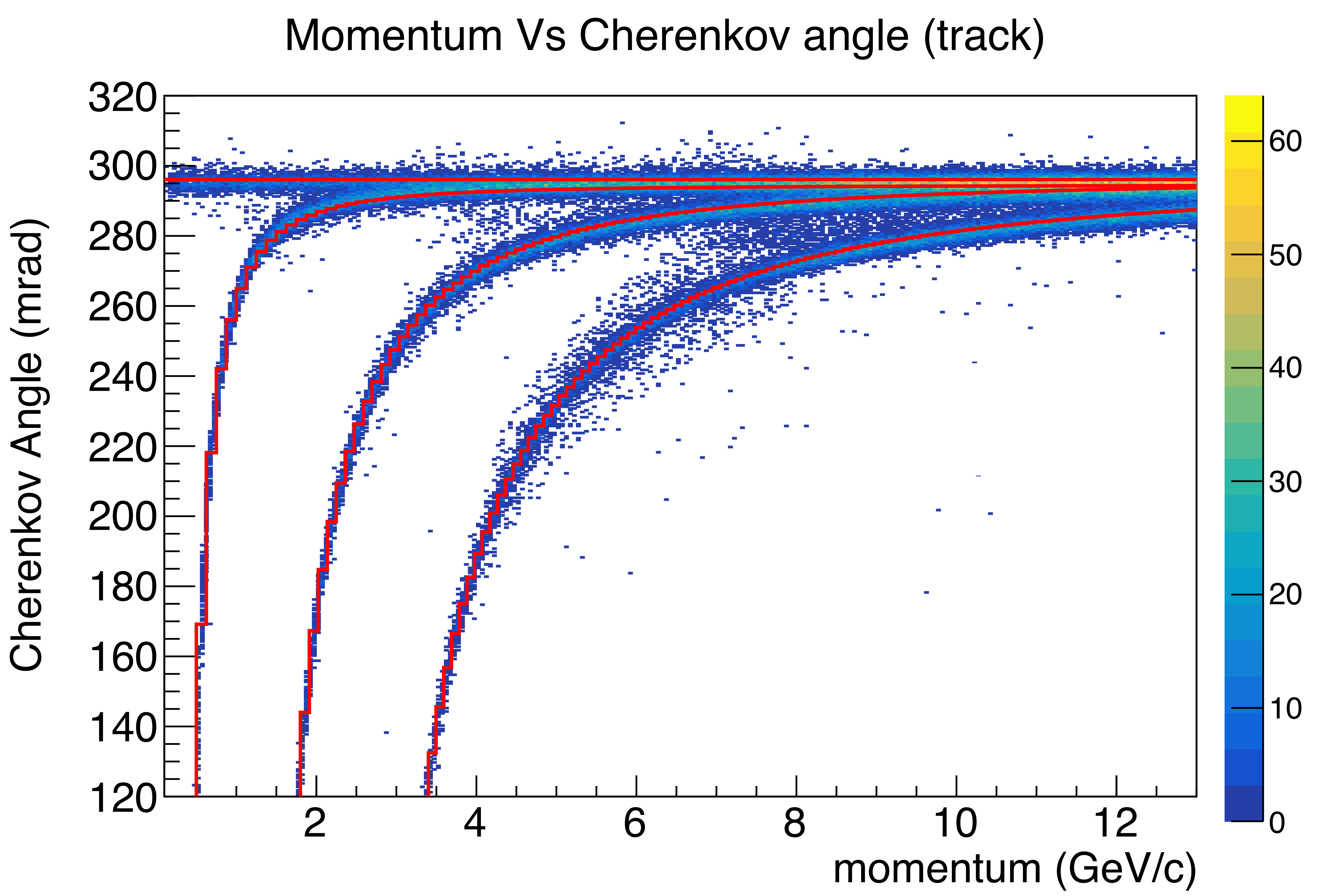
Next talk on PhotoSensors

Vessel Design and Assembly



Simulated Performance

Performance of Separation Power



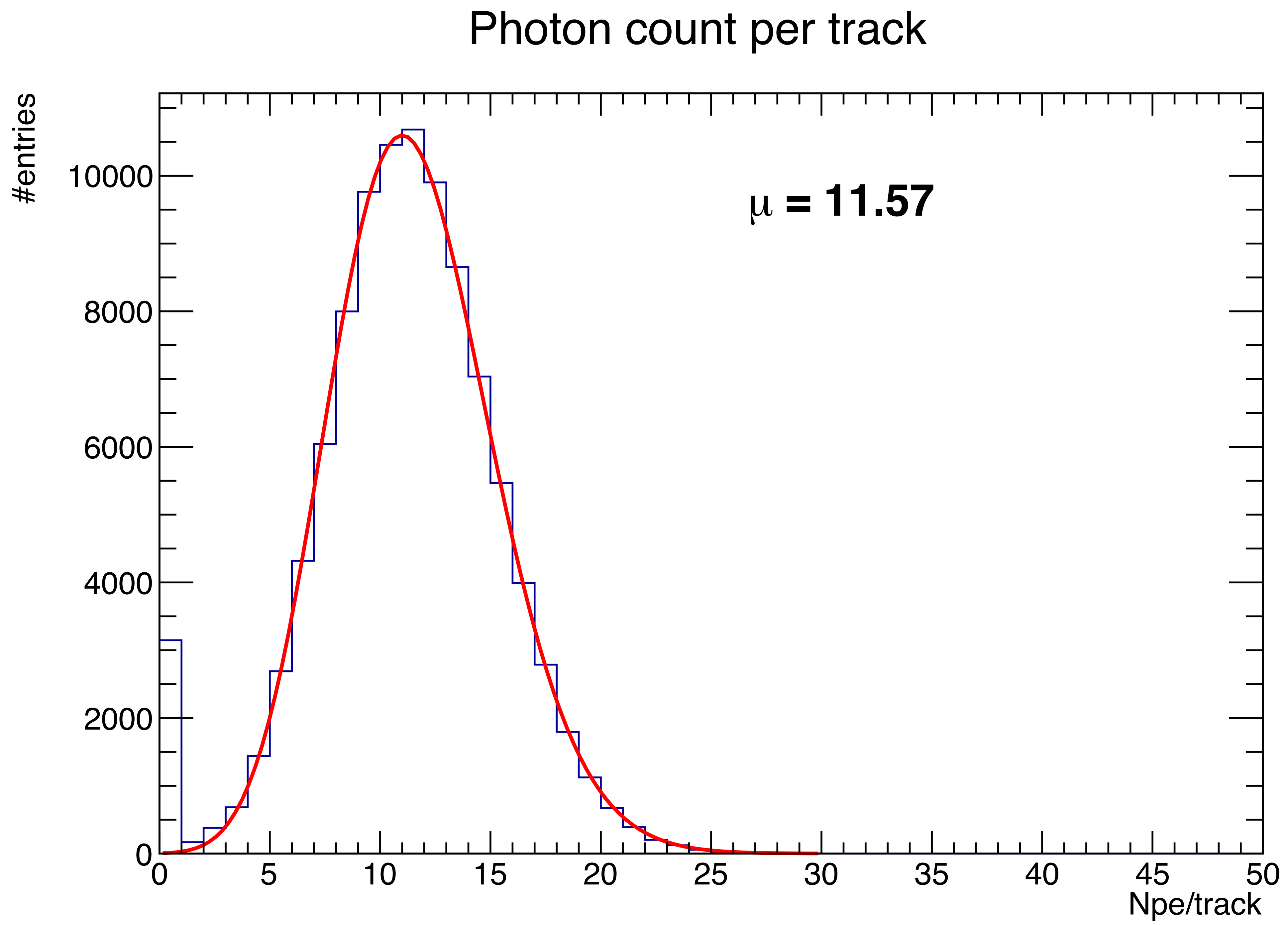
(a) Reconstructed Cherenkov angle for particles as a function of particle momentum

Expected performance with at least 3σ Separation

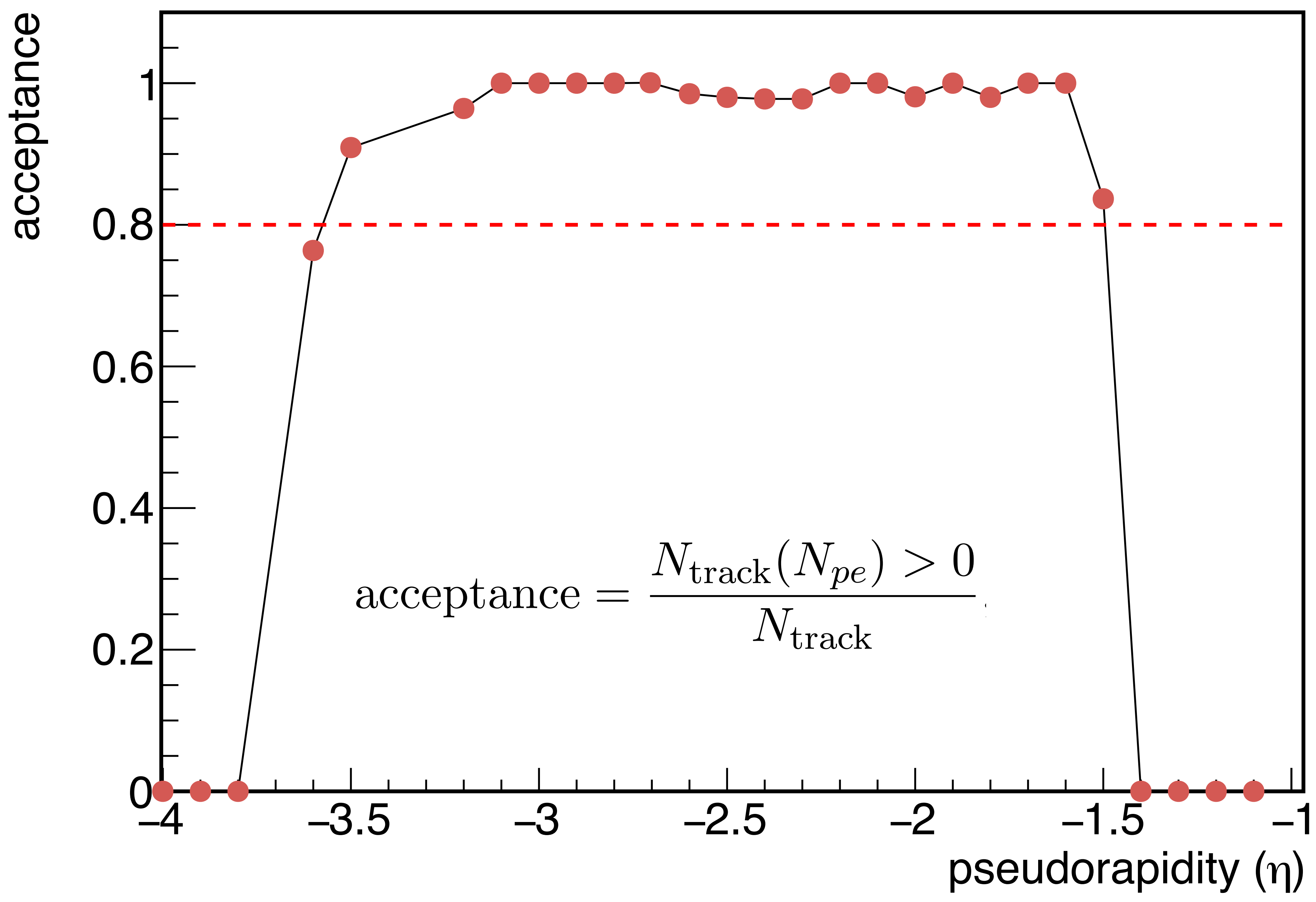
(No tof info, only angle)

competing particle species	separation range (GeV/c)
e *vs* π/K/p	$\sim$0.2 $\div$ $\sim$2.5
K *vs* π/p	$\sim$ 2.0 $\div$ $\sim$9.0

Acceptance and Number of detected photons



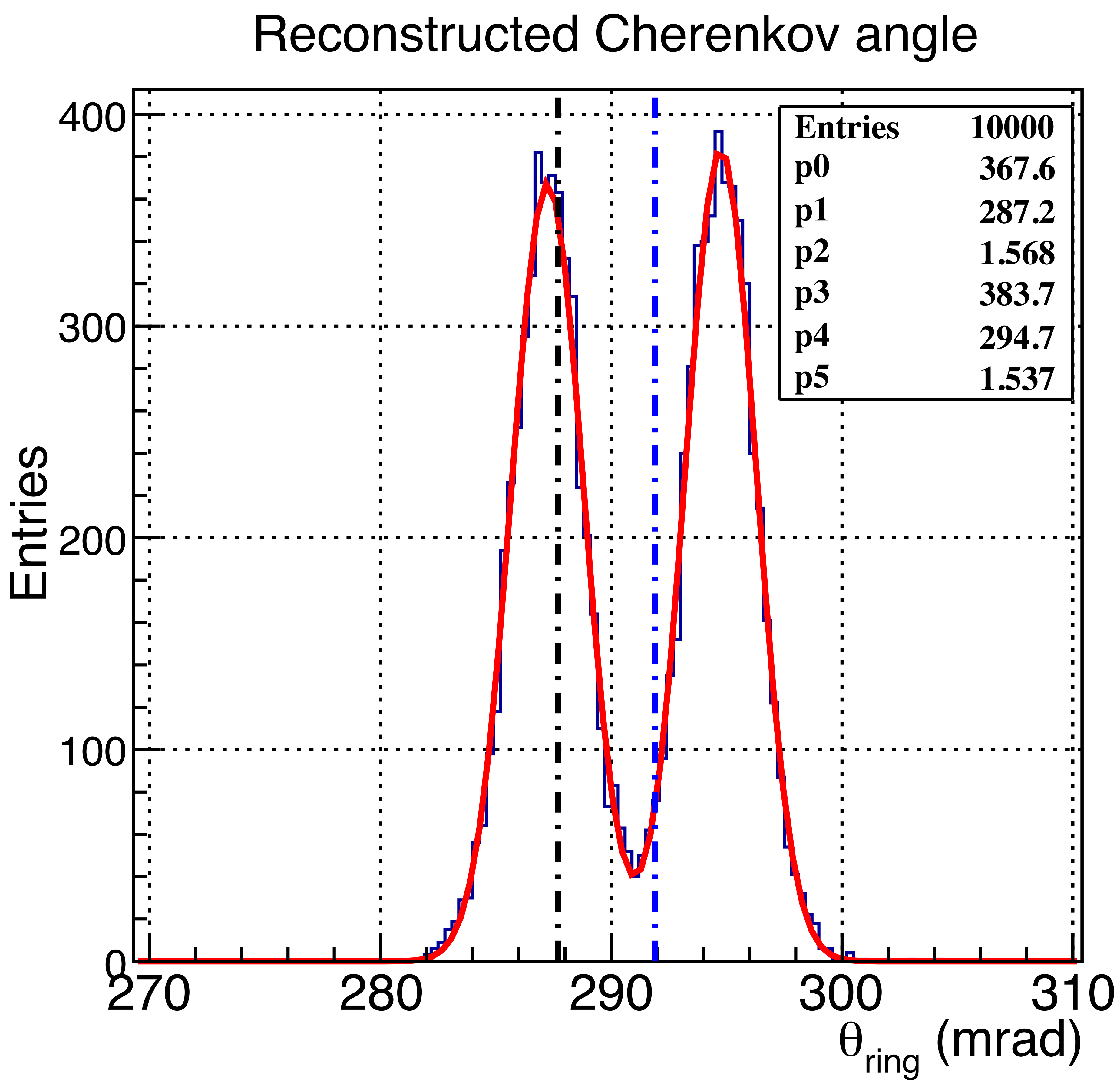
Number of photons detected for 7 GeV/c pion at -2.0 pseudo-rapidity

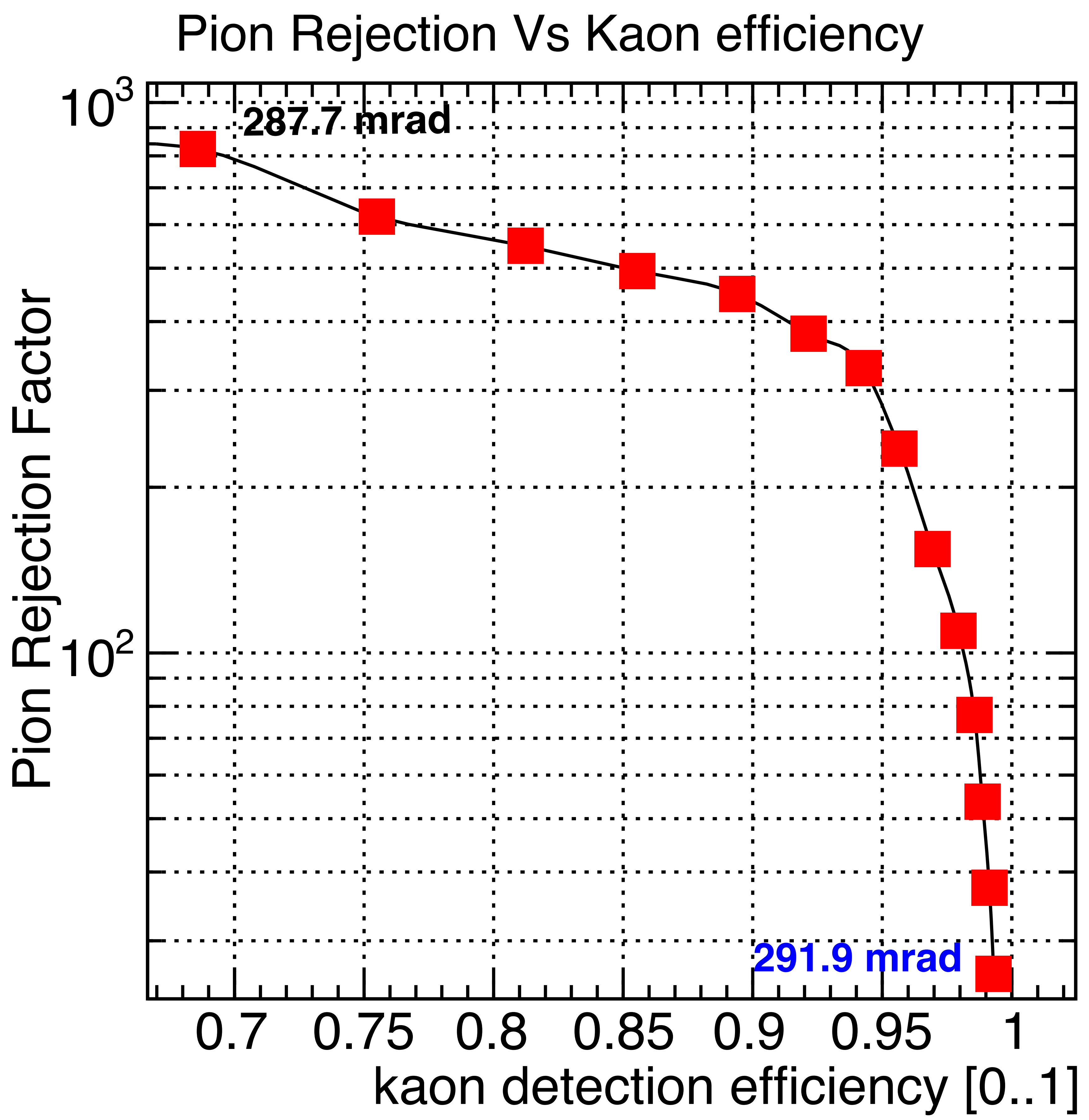


pfRICH acceptance as a function of pseudo-rapidity. Apart from the acceptance boundary areas, a constant value greater than 95% is achieved.

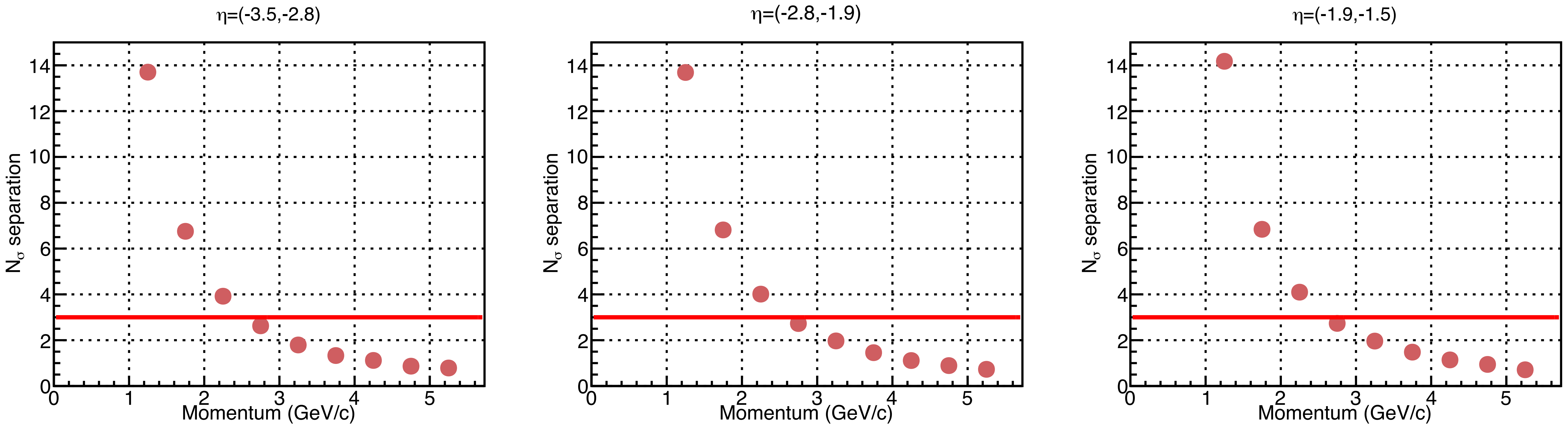
(finite primary vertex distribution width of σ ~ 10 cm along the beam line at the IP)

K detection efficiency and pion rejection close to saturation angles

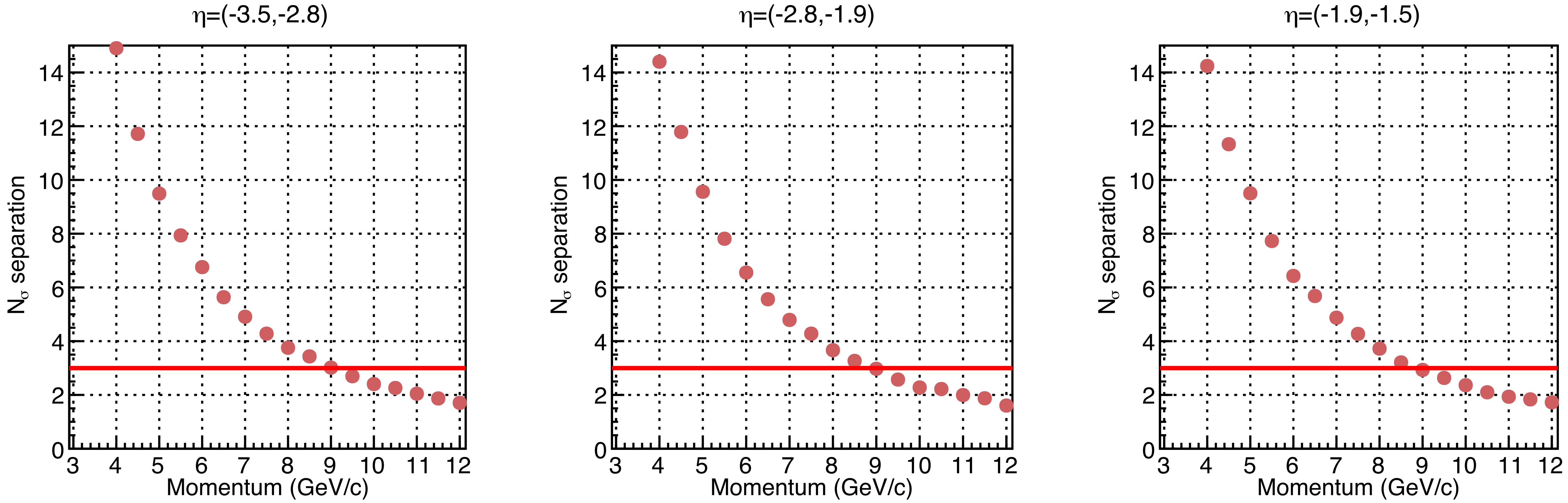




e-π and π/K Separation Power



(a) N_σ separation between the electron an pion hypotheses as a function of momentum for different bins of pseudo-rapidity.



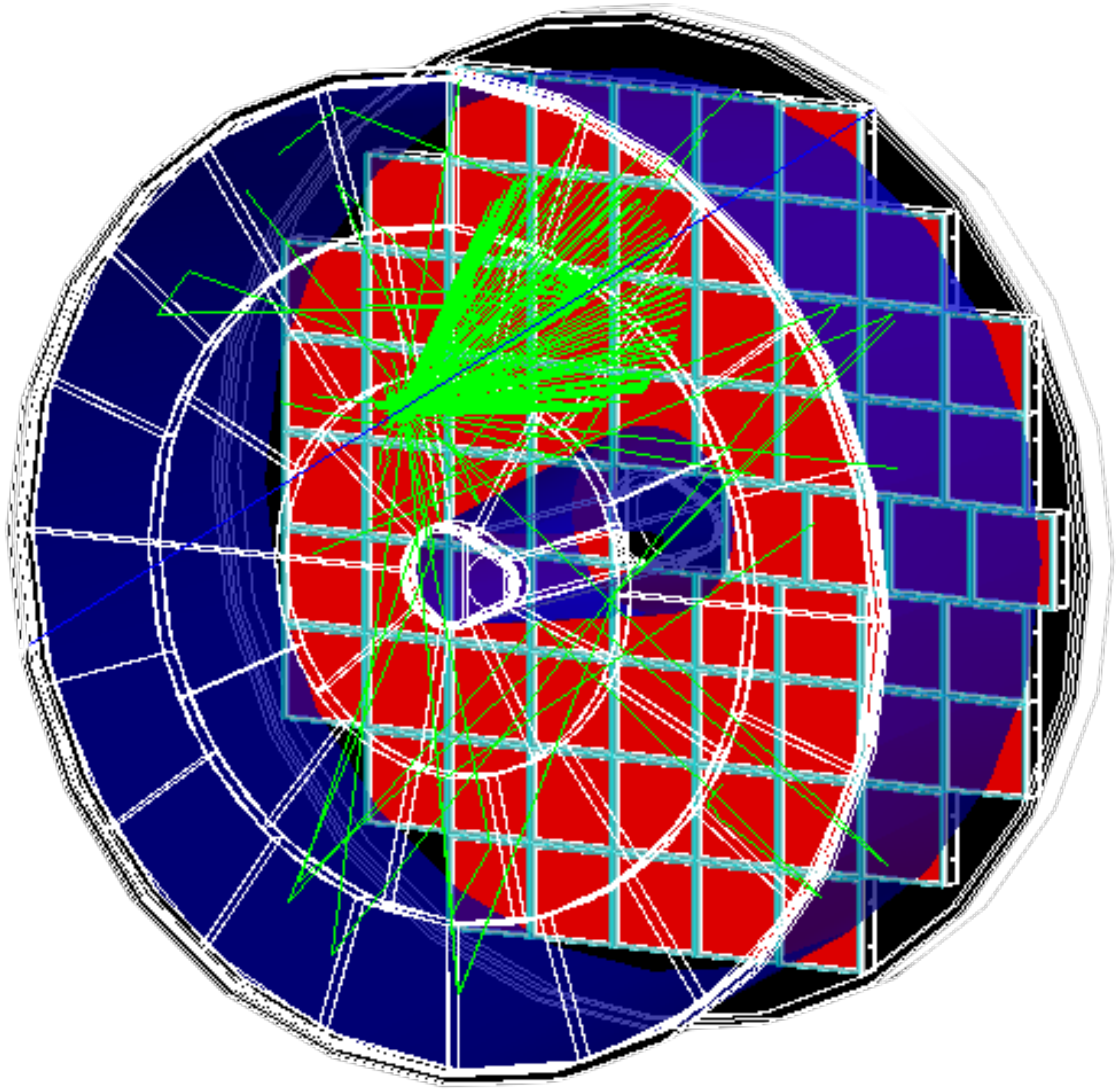
(b) N_σ separation between the pion and kaon hypotheses as a function of momentum for different bins of pseudo-rapidity.

$$N_\sigma = \frac{\theta_e - \theta\pi}{(\sigma_e + \sigma_\pi)/2}$$

competing particle species	separation range (GeV/c)
e *vs* π/K/p K *vs* π/p	$\sim$0.2 ÷ $\sim$2.5 $\sim$ 2.0 ÷ $\sim$9.0

Lots of details can be found in pfRICH CDR

The current version can be found on the ePIC Wiki
https://wiki.bnl.gov/EPIC/index.php?title=PfRICH_info



A Proximity-Focusing RICH for the ePIC Experiment
– Conceptual Design Report –
(Draft 1.1)

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Complementary vs. Overlap in the context of IP8

- Dual aerogel configuration
- HERMES and LHCb like with a combination with focusing mirrors?
- Use different Photosensor as it suits (MCP-PMT or SiPM …)
- Some heavy gases in the expansion volume to have threshold mode

And many more

Summary

Having only one method to cover wide range of p for PID is difficult

pfRICH has additional → **Cherenkov angle**

→ **Time-of-flight (low p)**

+ t_0

Of course for IP8, the Magnet and integration will guide the design

pfRICH as a concept is a well tested detector by other experiments