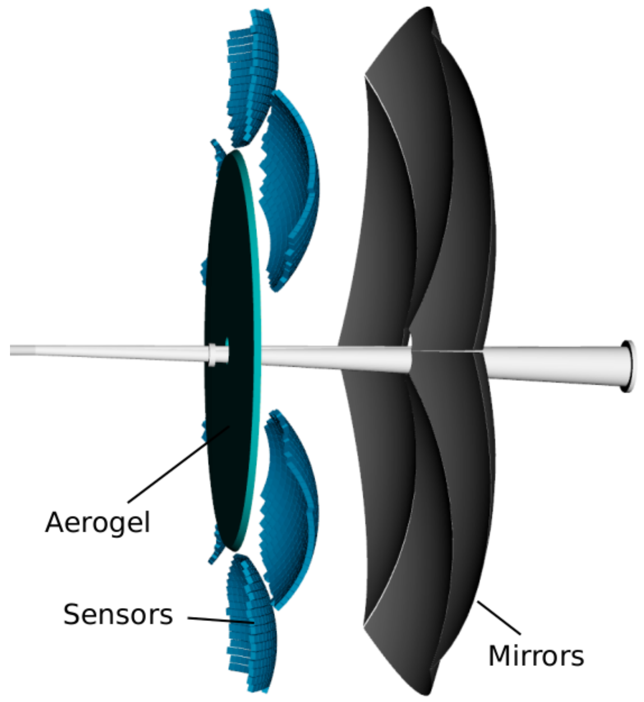
PID Systems: Key Plots and Other Items

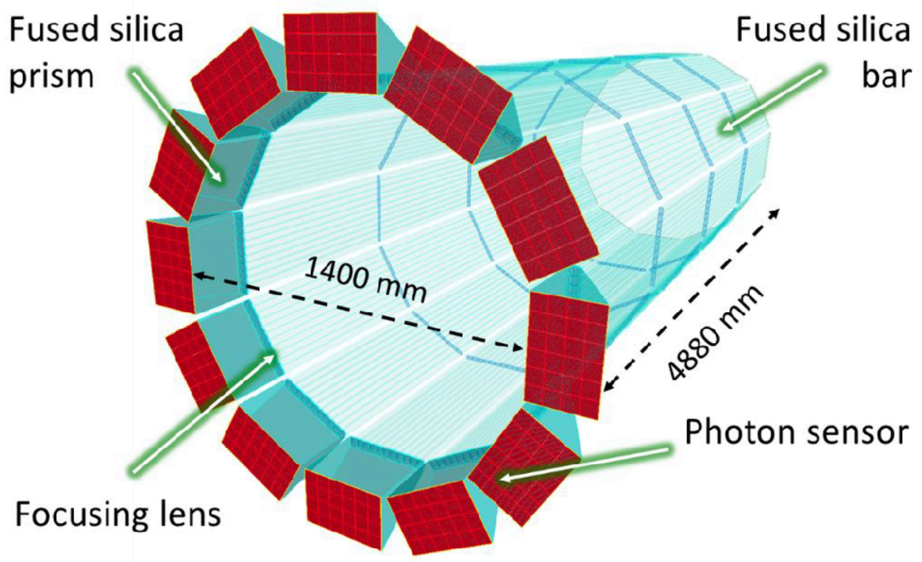
Thomas Ullrich on behalf of the PID DSCs

TIC Meeting

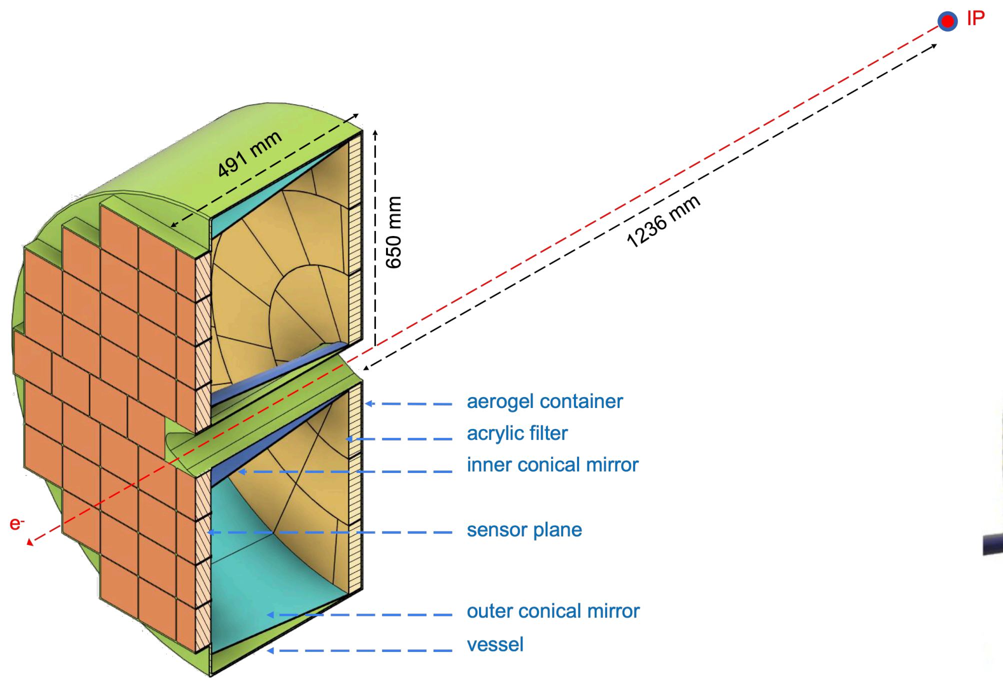
April 22, 2024



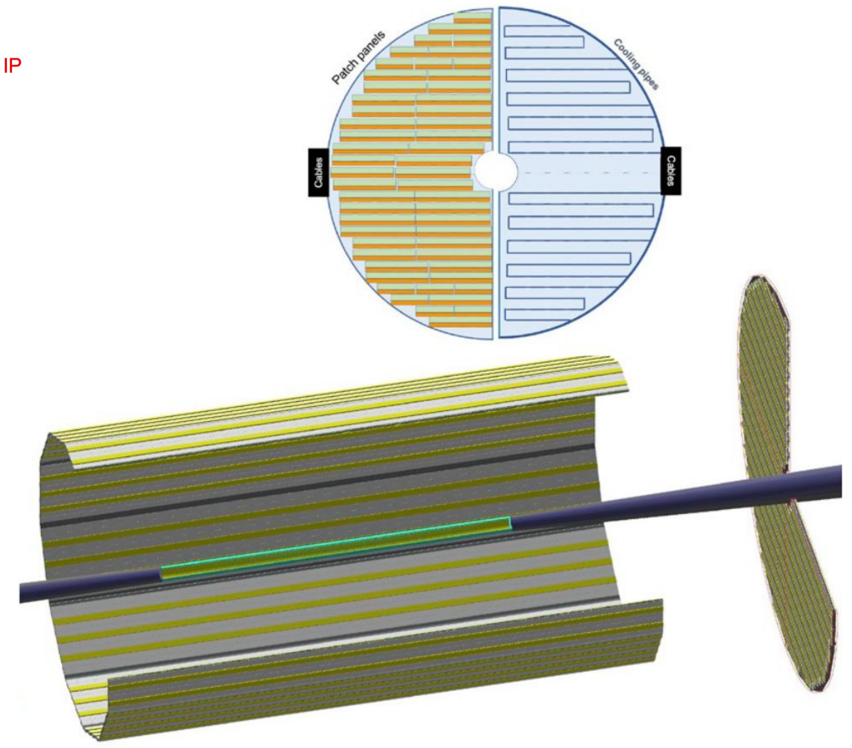
dRICH



hpDIRC



pfRICH



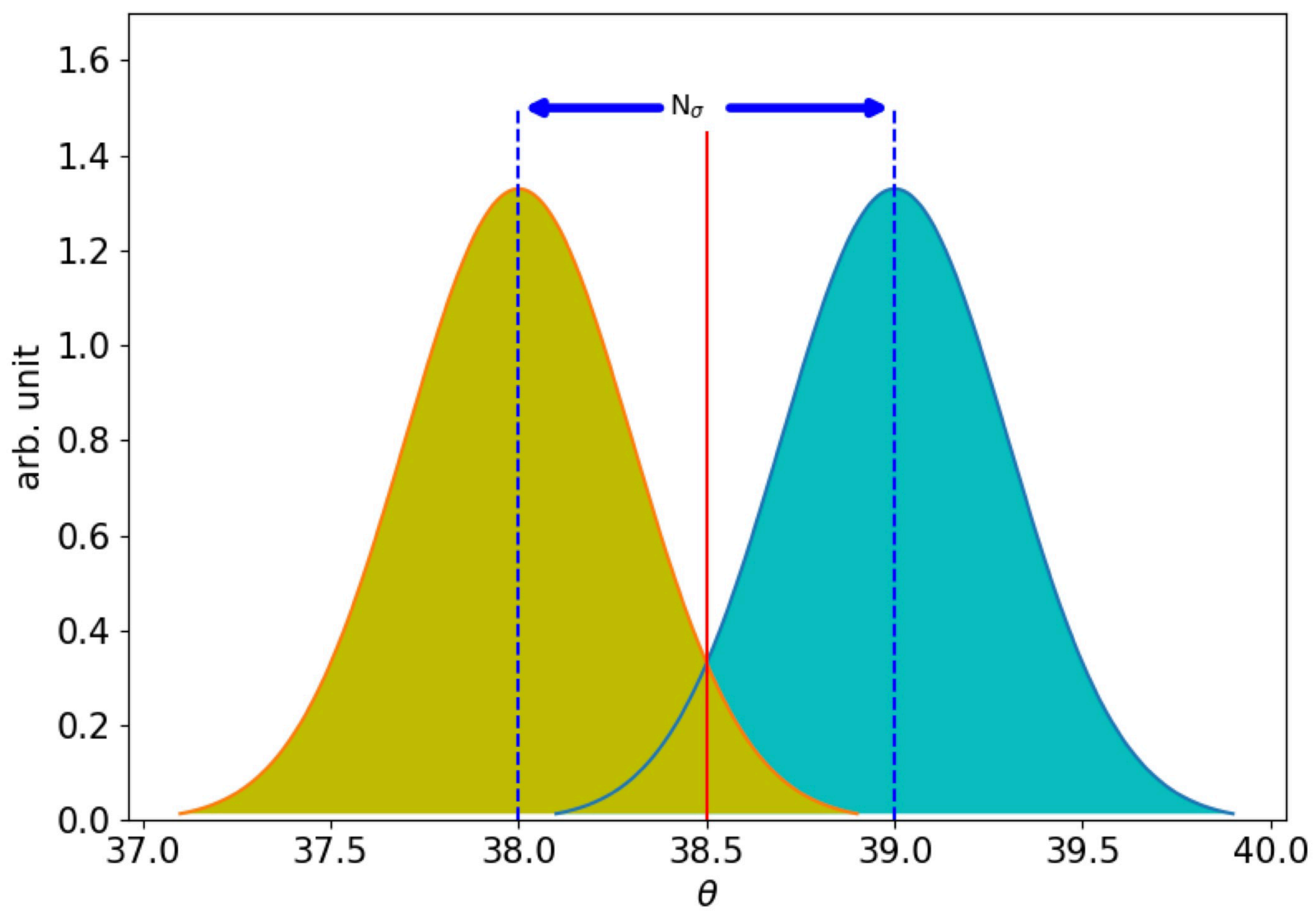
ToF

Brookhaven National Laboratory

Upfront - Reflection on a Definition

Say we look at the π, K separation power. We typically think of this in terms of $n\sigma$. But how is this defined?

- All PID groups use the difference between the two Gaussians, divided by the average Gaussian σ to define the separation power

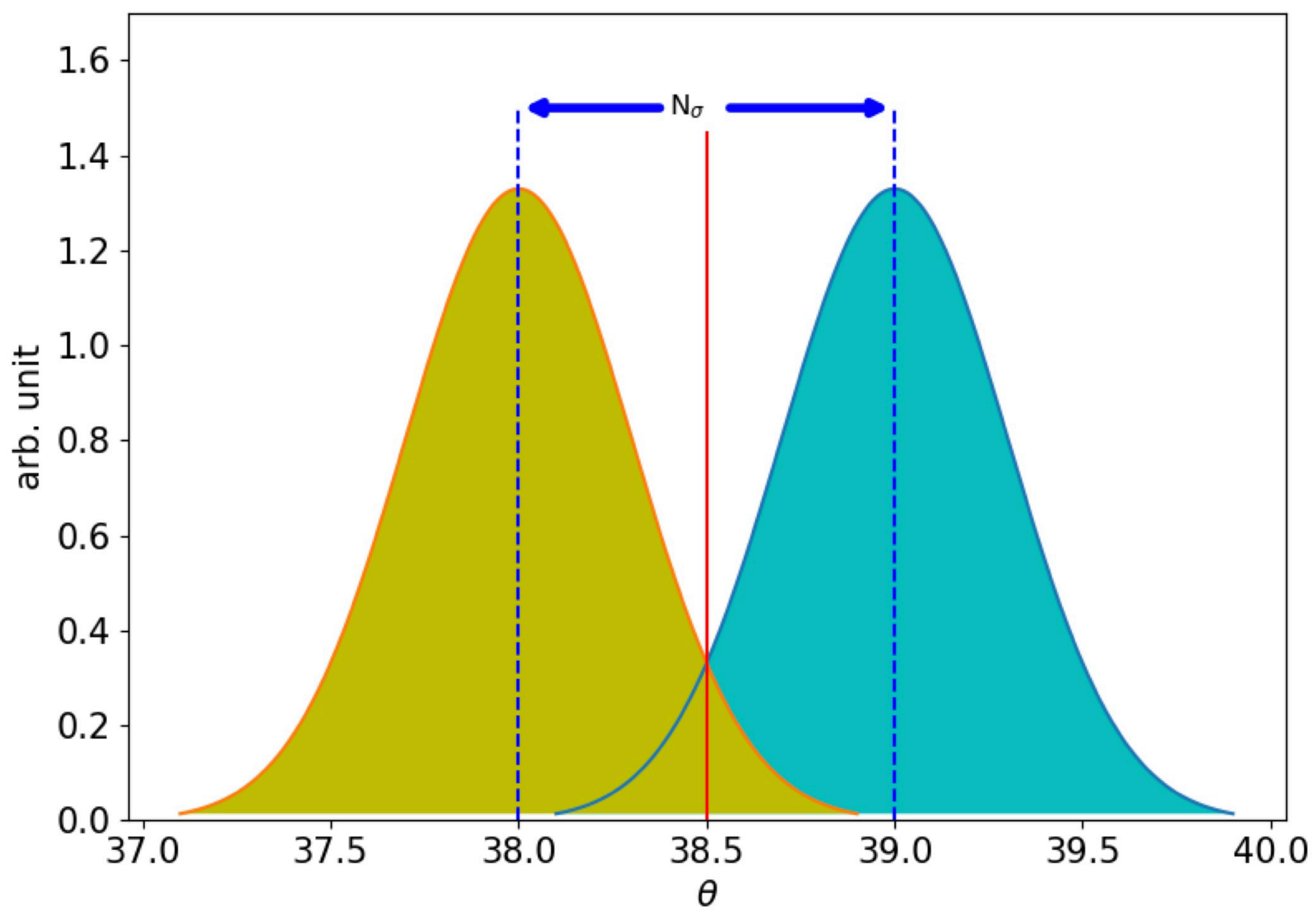


$$n\sigma = \frac{\theta_C^{\pi} - \theta_C^{K}}{(\sigma_\theta^{\pi} + \sigma_\theta^{K})/2}$$

Upfront - Reflection on a Definition

Say we look at the π, K separation power. We typically think of this in terms of $n\sigma$. But how is this defined?

- All PID groups use the difference between the two Gaussians, divided by the average Gaussian σ to define the separation power
- However
  - this $n\sigma$ is not the quantity people are used to in statistics. The true $n\sigma$ is always smaller than the $n\sigma$ obtained from the definition we are using. We are a bit overselling our performance. In short when we say 3σ, this is not the 99.73% one is used to.
  - Difference $\approx \sqrt{2}$, so 3σ is really ~2σ or 95.45%
  - This is not ePIC specific but common for PID systems
  - Question was raised: Should we change this for TDR?
  - On the other hand, PID systems too complex to be reflected by just one number: better migrate at some point into describing our detector performance in terms of efficiency / rejection factors



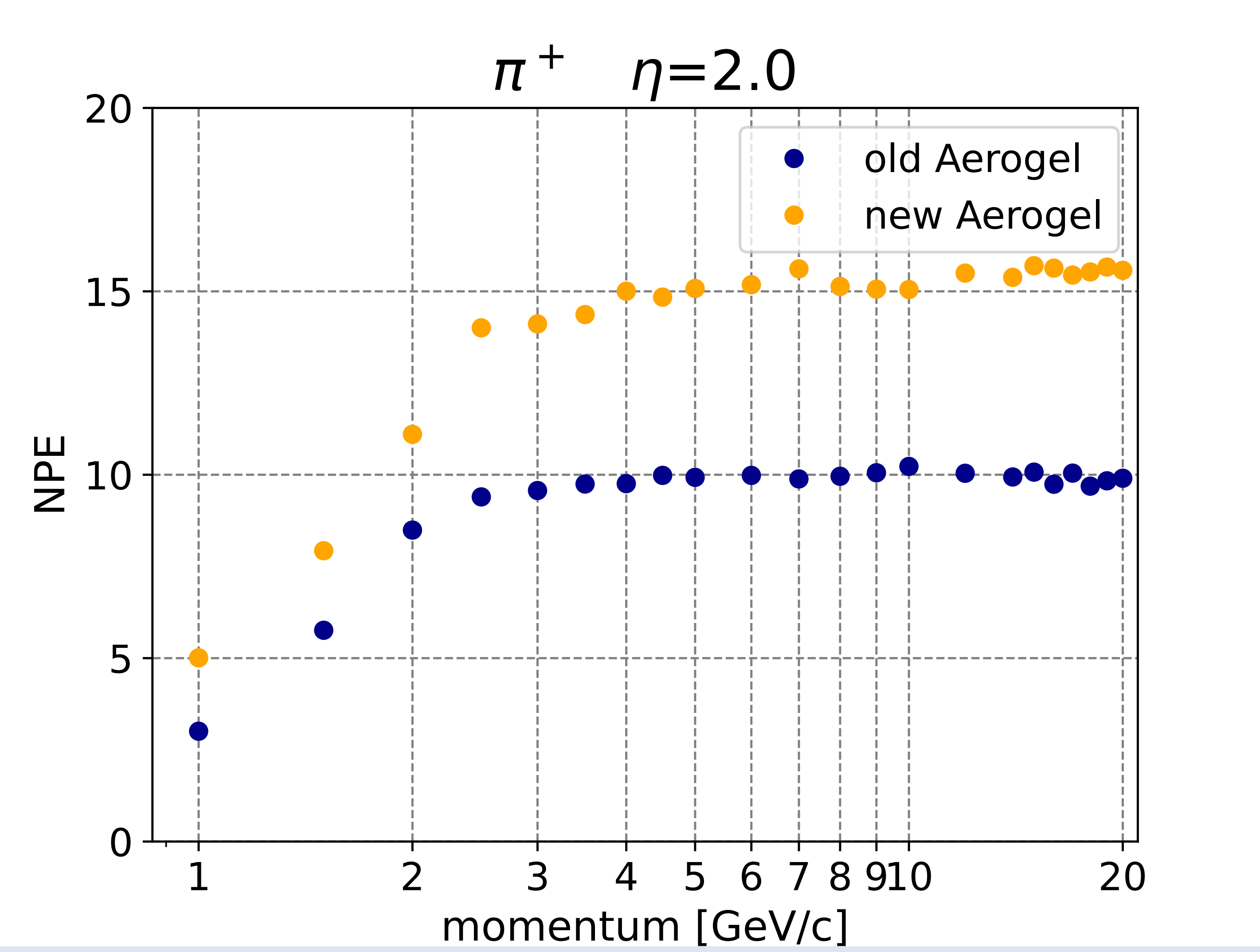
$$n\sigma = \frac{\theta_C^\pi - \theta_C^K}{(\sigma_\theta^\pi + \sigma_\theta^K)/2}$$

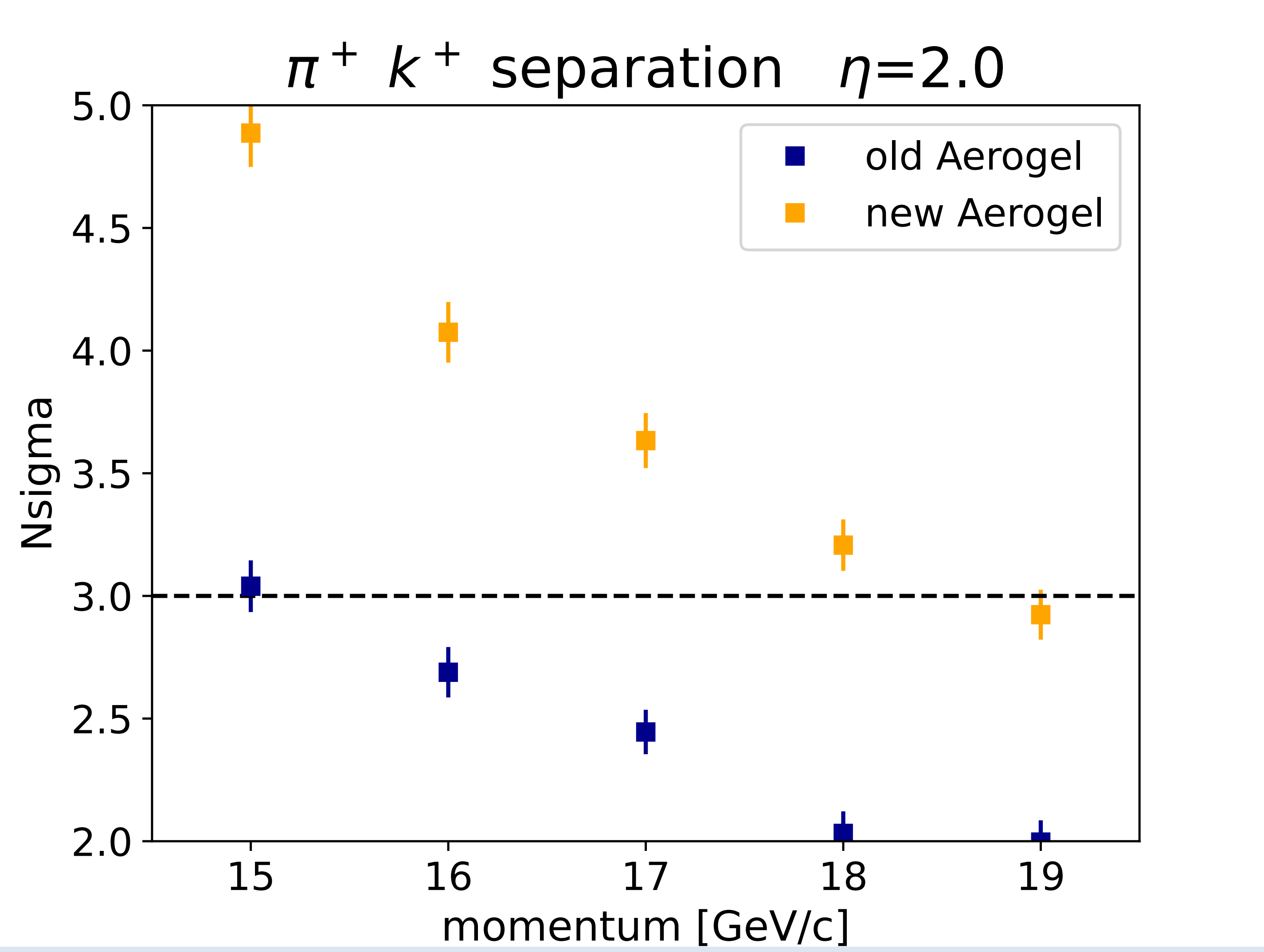
$$n\sigma = \frac{\theta_C^\pi - \theta_C^K}{\sqrt{(\sigma_\theta^\pi)^2 + (\sigma_\theta^K)^2}}$$

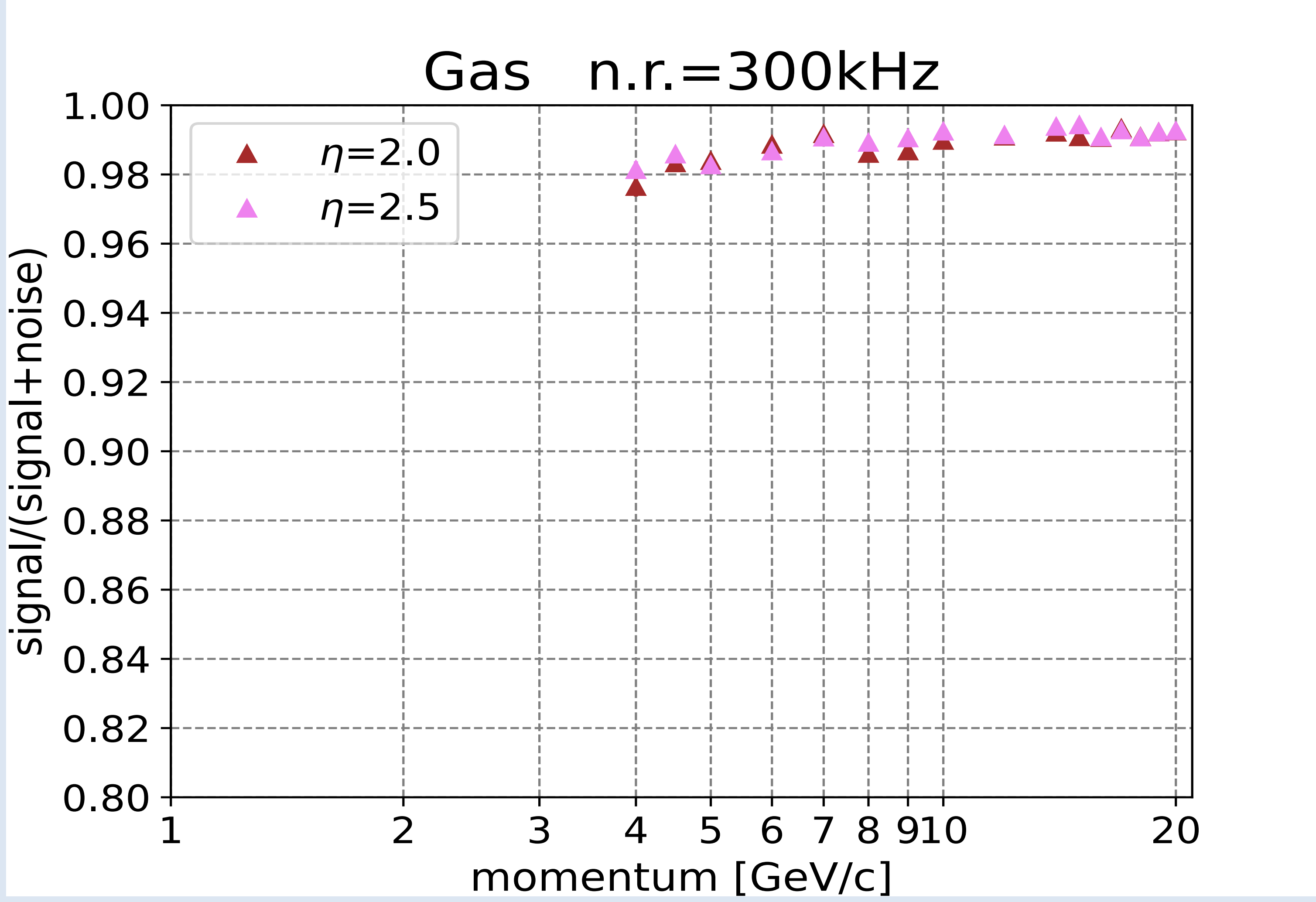
d*RICH*

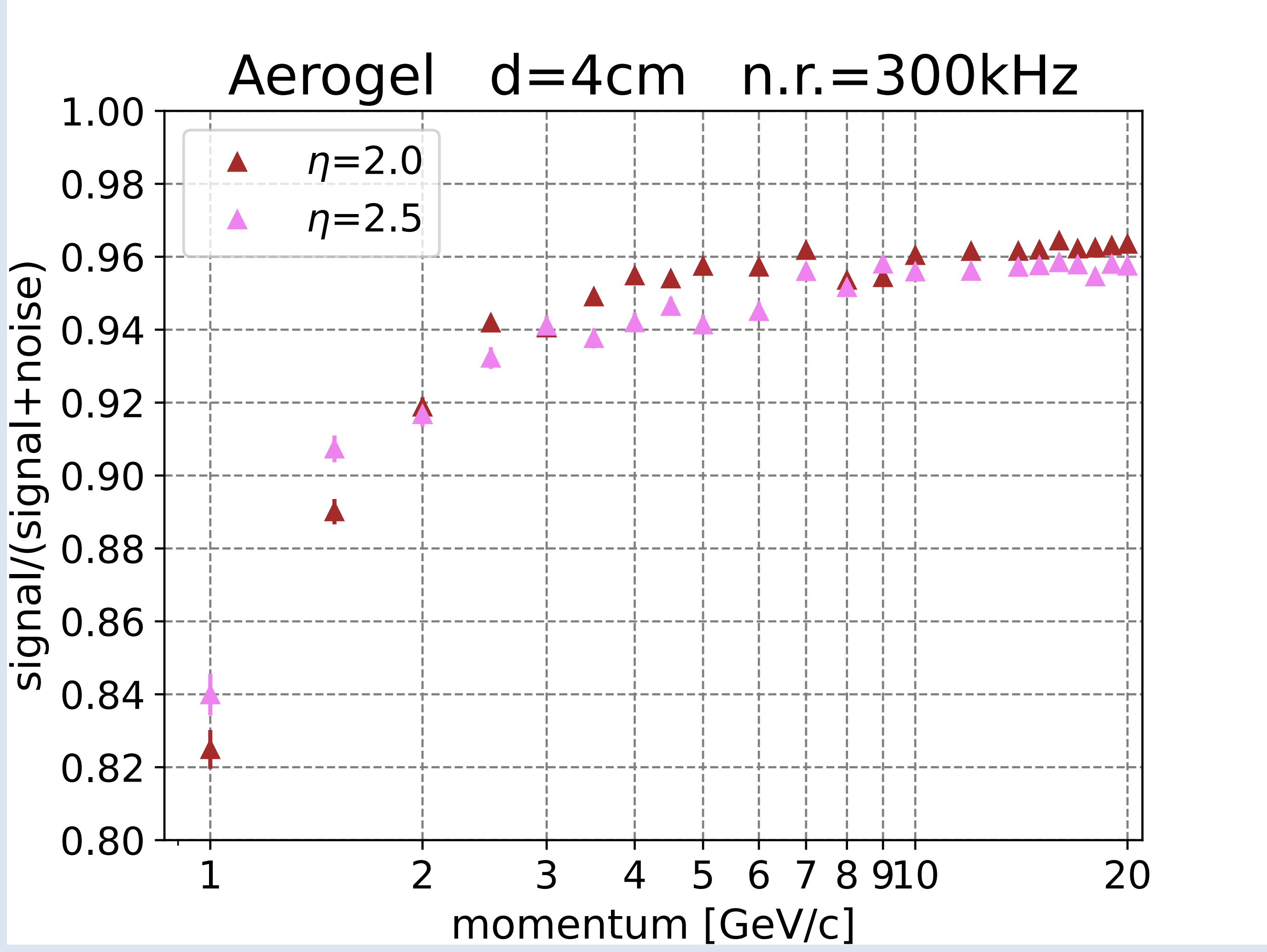
dRICH - Current Efforts

- Optimization study ongoing for aerogel refractive index
- Study of “worse case” DCR background impact on resolution
- LUTs will be refined while the full epIC simulation/ analysis chain is commissioned



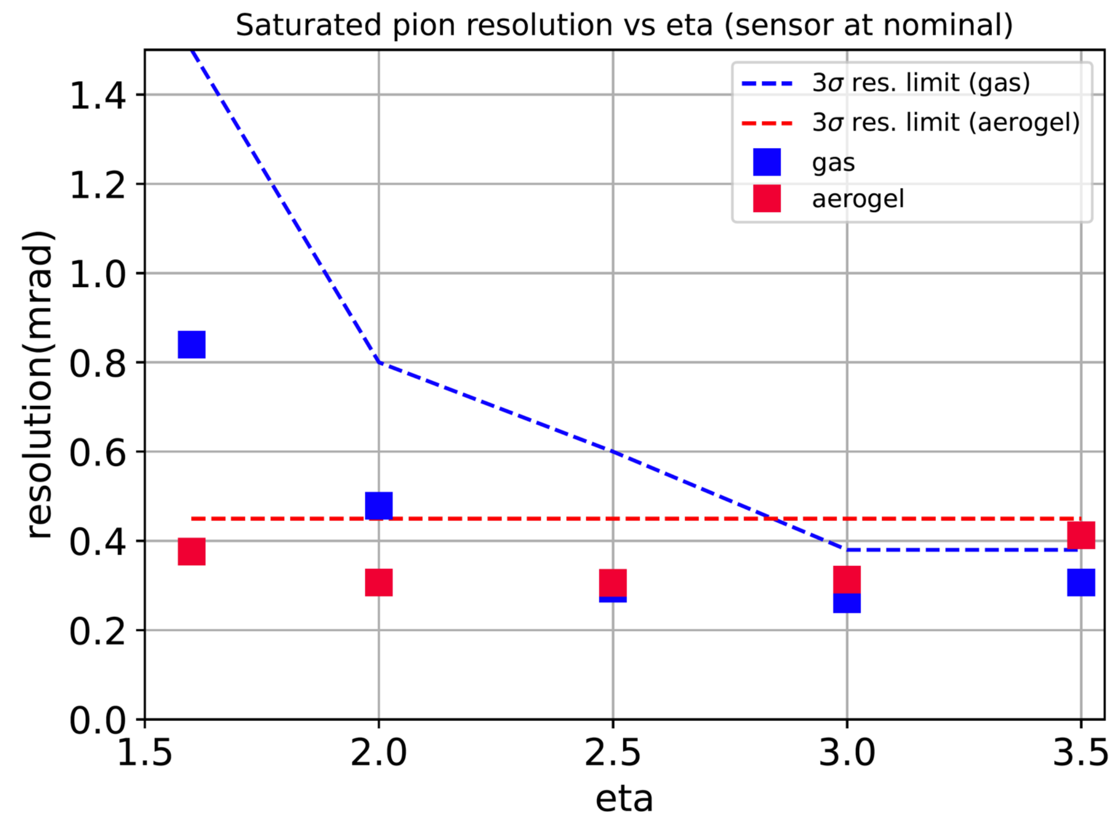


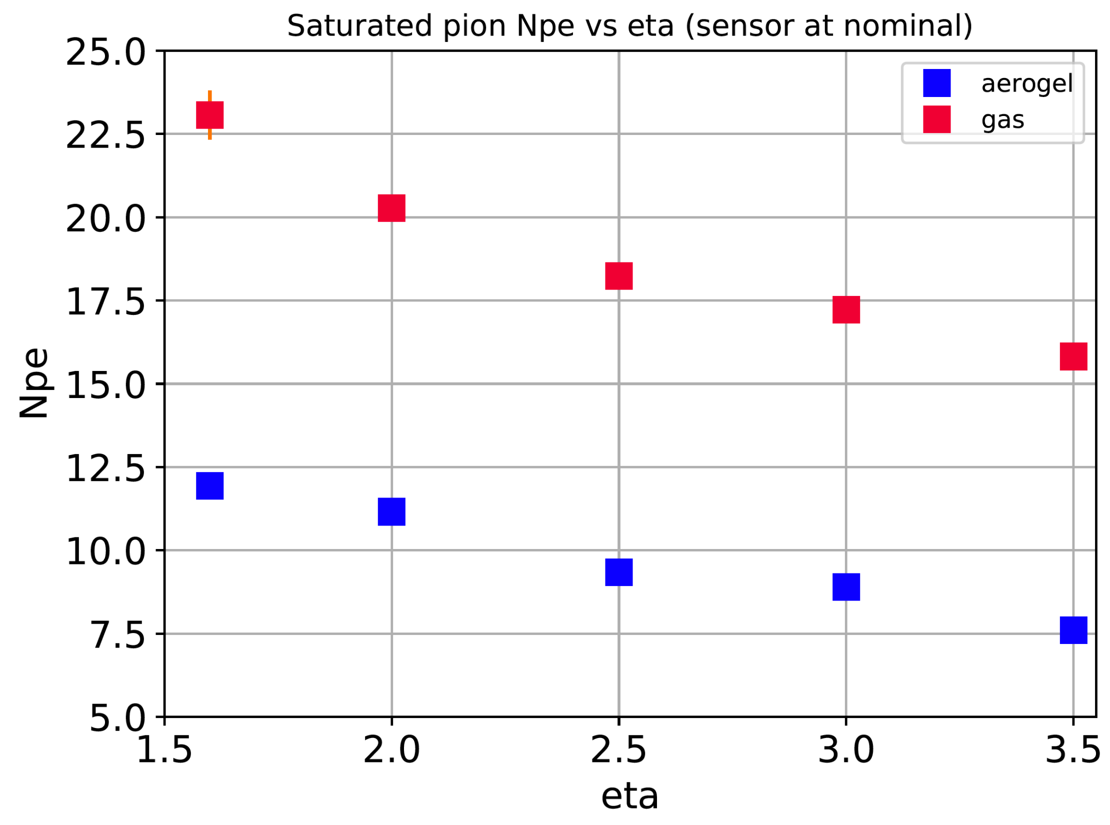




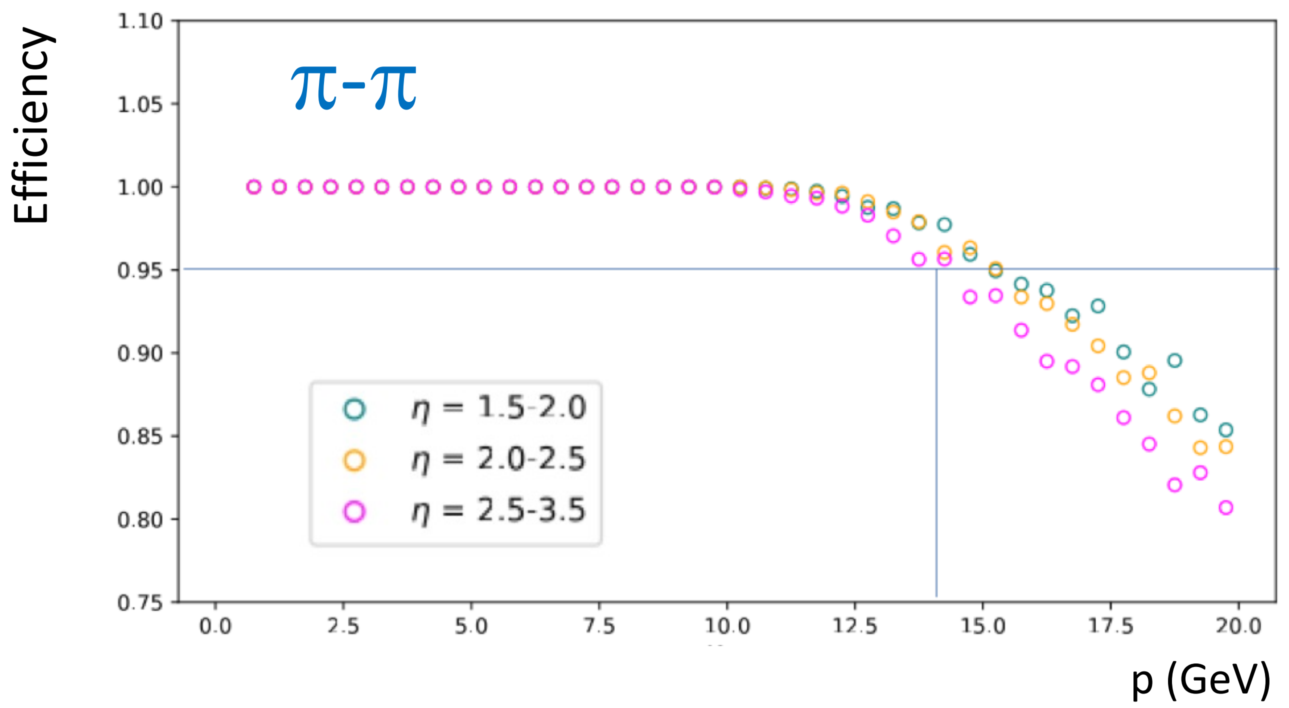
dRICH - Key Plots

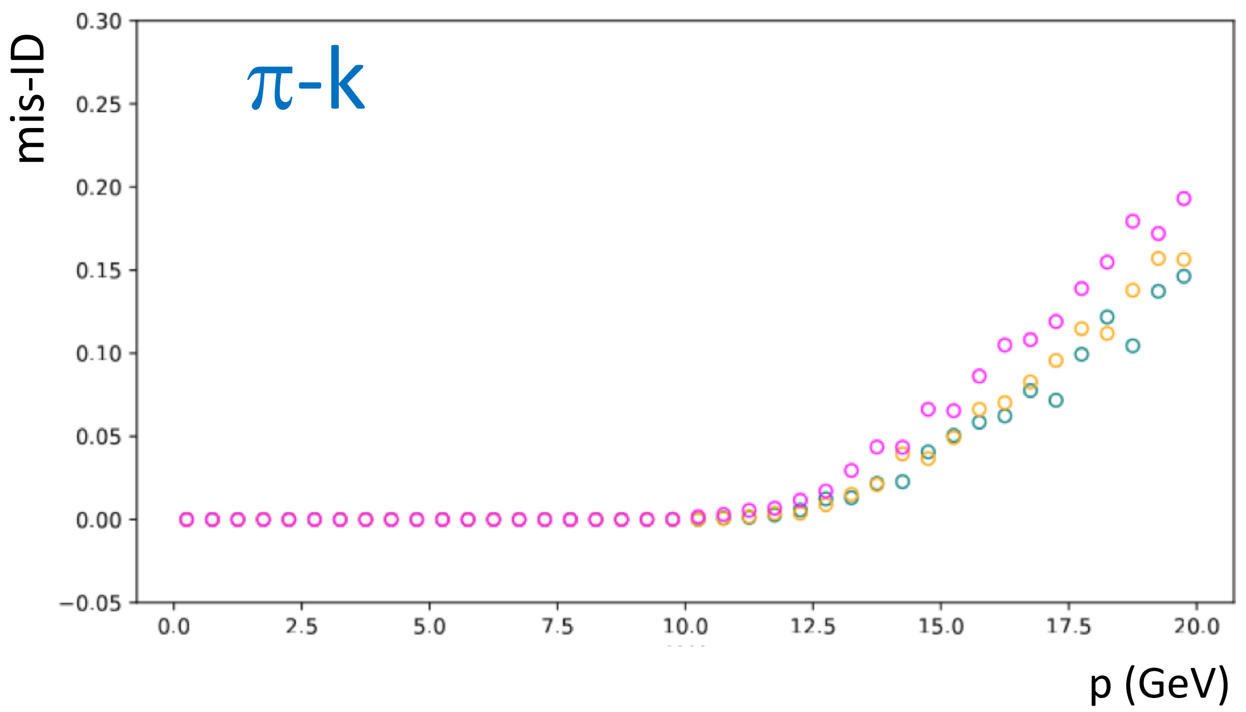
- Not fully defined yet
- Clear candidates:
  - 3σ separation in the wanted momentum range
  - # of photons
  - Efficiencies
  - Misidentification (purity)
  - Separate for gas/aerogel and combined for p/K/p,e
  - Many plots need to find way to present in fewer



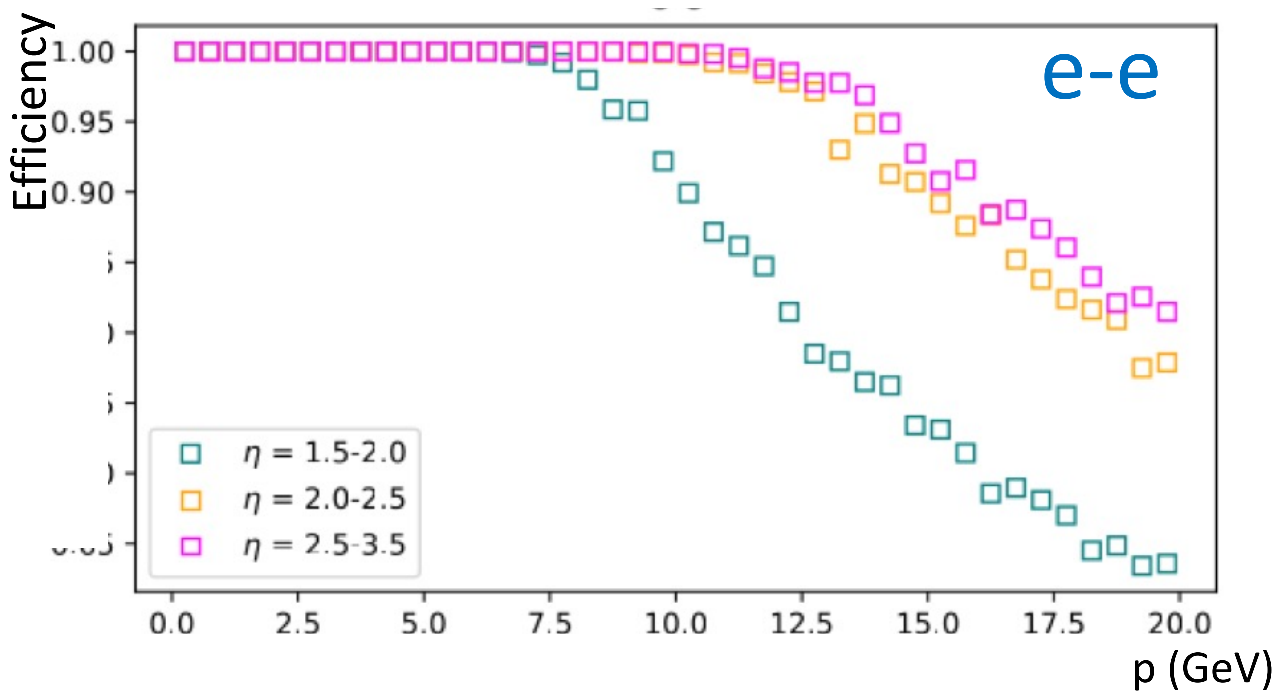


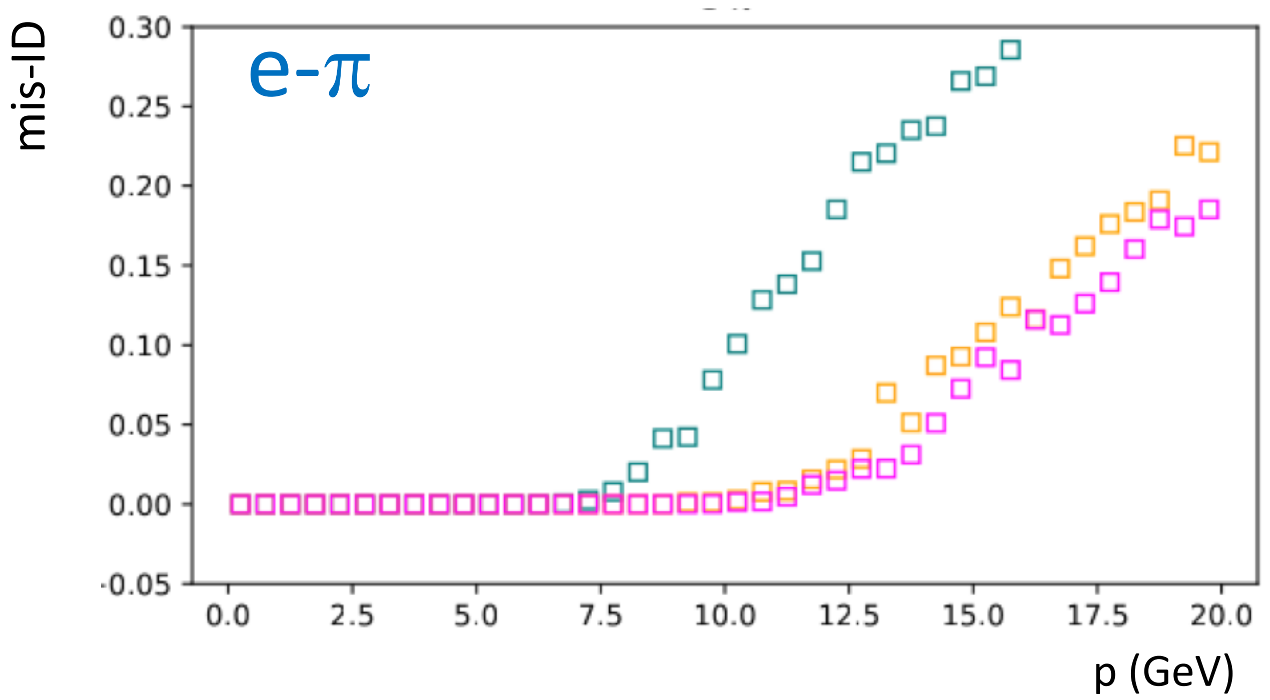
Aerogel





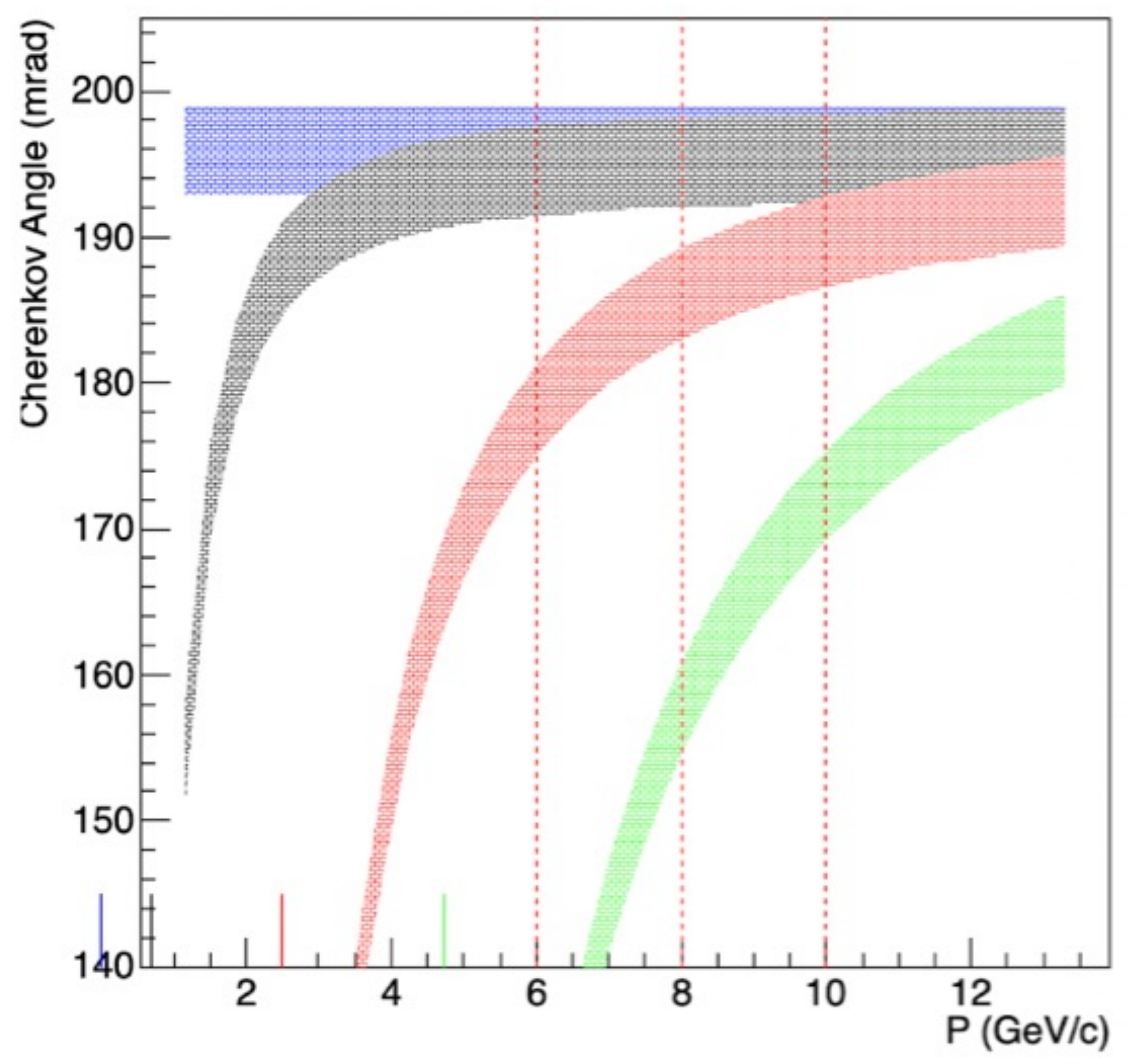
Gas

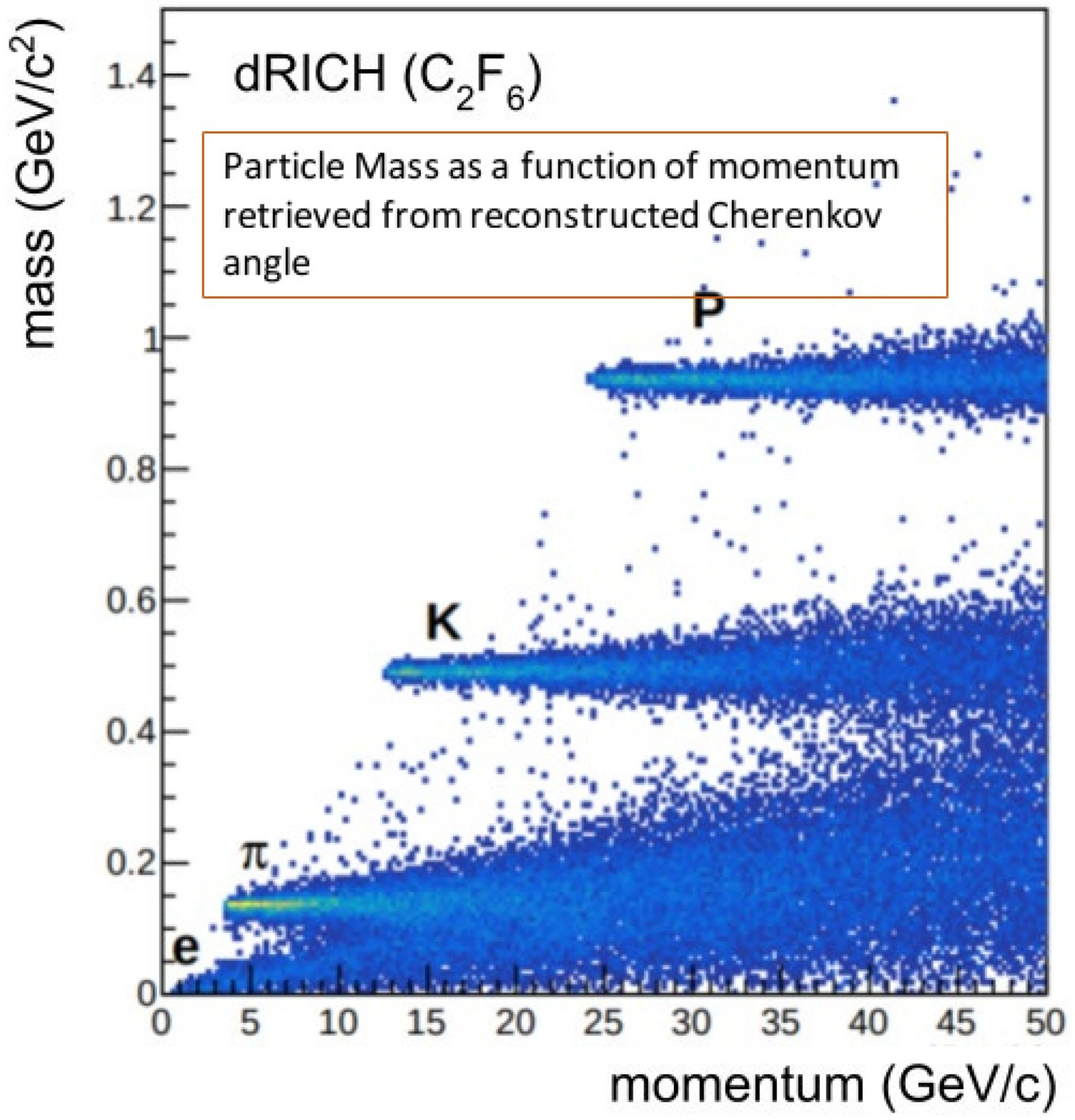


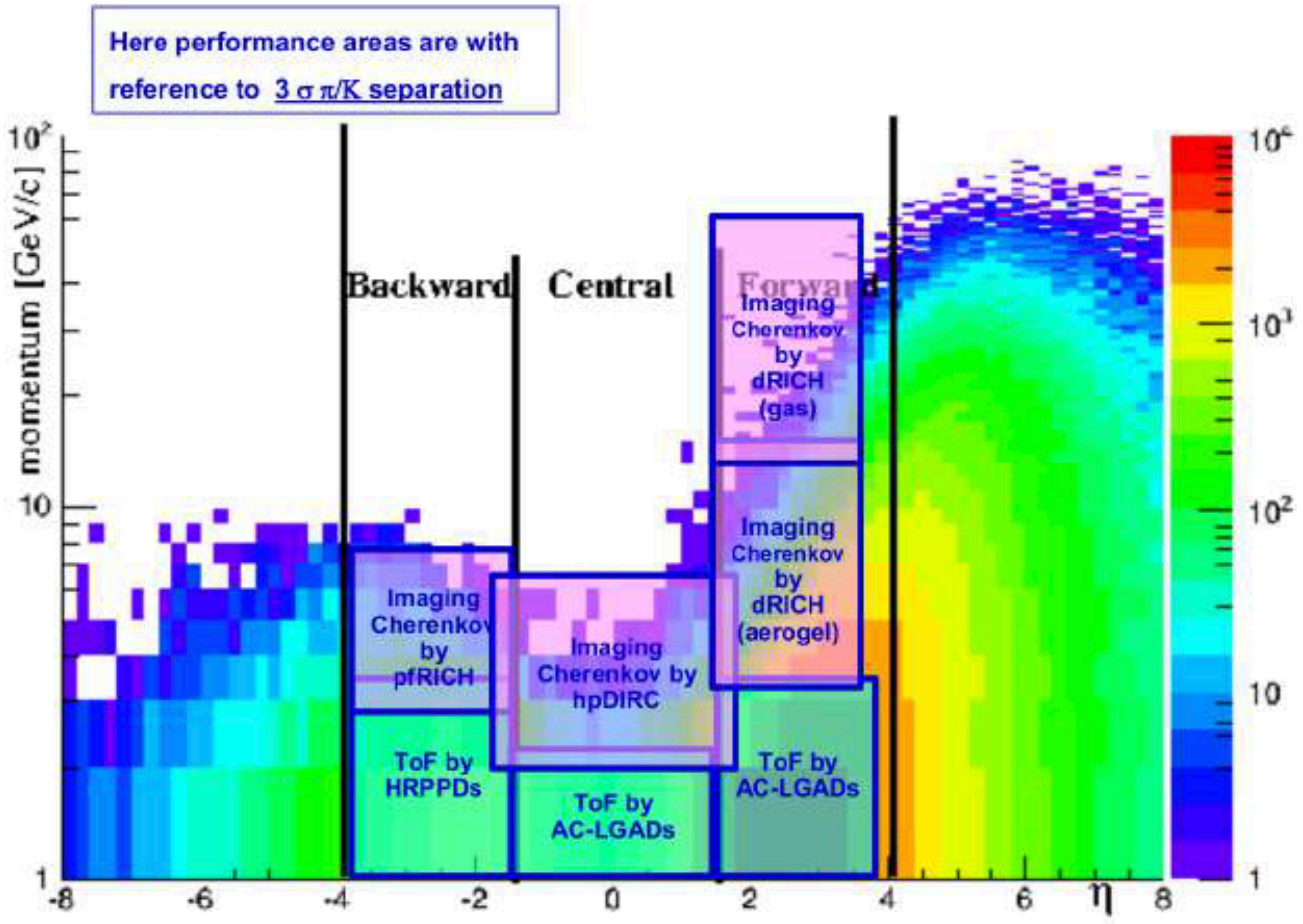


dRICH - Blockbuster Plots

- Always look our for plots that are
  - Impressive
  - Simple to understand
  - Iconic







- This is a popular plot depicting all ePIC PID
- It could be a blockbuster but there's an issue with the dRICH/gas
- Needs work
  - More statistics?
  - Indicate region of physics importance (topic)

pf*RICH*

pfRICH - TDR Planning

- Have a solid base in the existing CDR
  - Much needs to be updated to reflect progress in last year
  - Several new sections will need to be planned / written
  - We may need to condense existing sections to fit within allotted space
- Intention is to start early
  - CDR effort was a bit of a slow burn and then a frantic final couple of weeks
  - avoid this unnecessary stress
- Planning meetings ongoing

Reminder: Proposed TDR Structure

FOR EACH SUBSYSTEM

- Requirements
  - From **physics**
  - **Radiation hardness**
  - Expected **data rates**
- Justification
  - Device **concept and justification** for the technological choice
  - **Description**
    - General device description
    - Sensors
    - FEE (for rates with reference to a global table in electronics/DAQ section)
    - Other components (f.i.: radiators in calorimetry and in Cherenkov devices, …)
  - **Performance** from available input (lab studies, test beam, prototyping, simulation studies)
- Implementation
  - **Services** (cooling, gas system, sensor power supply, FEE power supply, …)
  - Subdetector **mechanics and integration**
  - **Calibration, alignment and monitoring** strategy and tools
  - **Status and remaining design effort**
    - R&D up to here (and missing, if any); E&D status and outlook
    - Other work needed for design completion
    - Status of maturity (with reference to next slide)
  - **ES&H** (Environmental, Safety & Health) aspects and **QA** (Quality Assessment) planning
  - **Construction and assembly planning**
  - **Collaborators** (=Institutions) and their role, resources and workforce
  - **Risks and mitigation strategy**

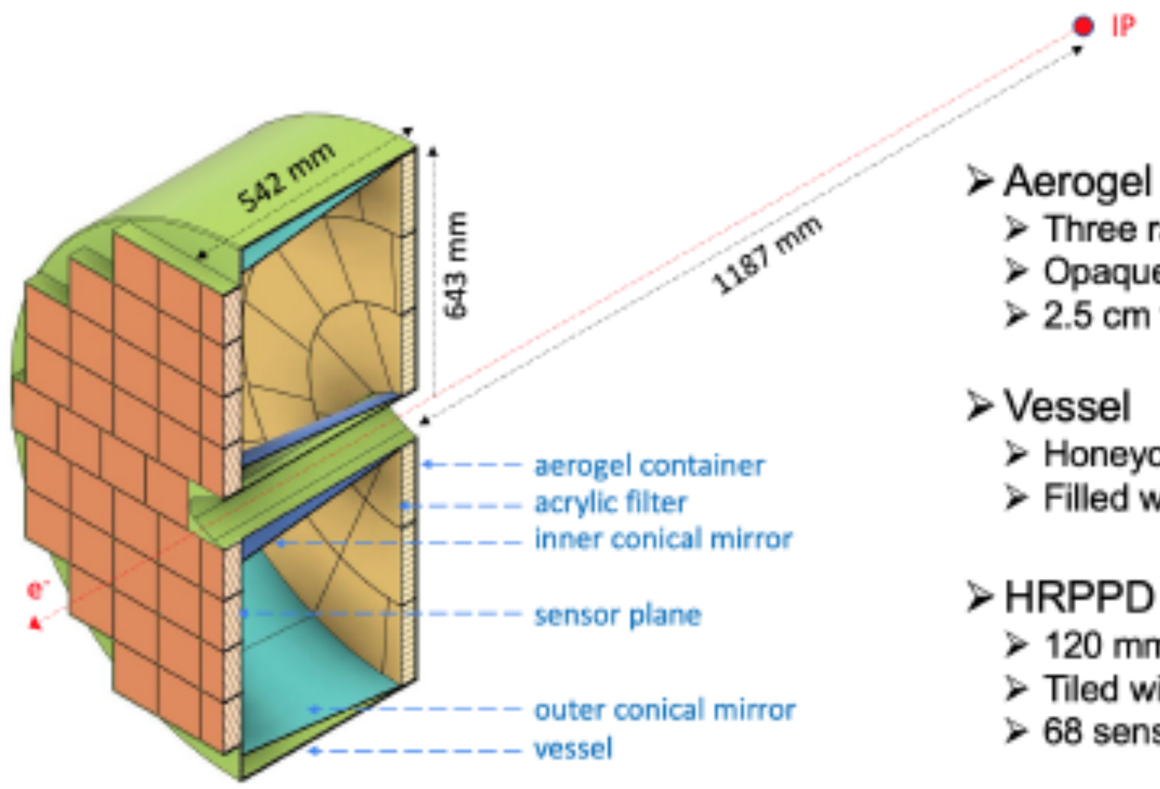
pfRICH - TDR, Mapping, Responsibilities, and Plots

Requirements

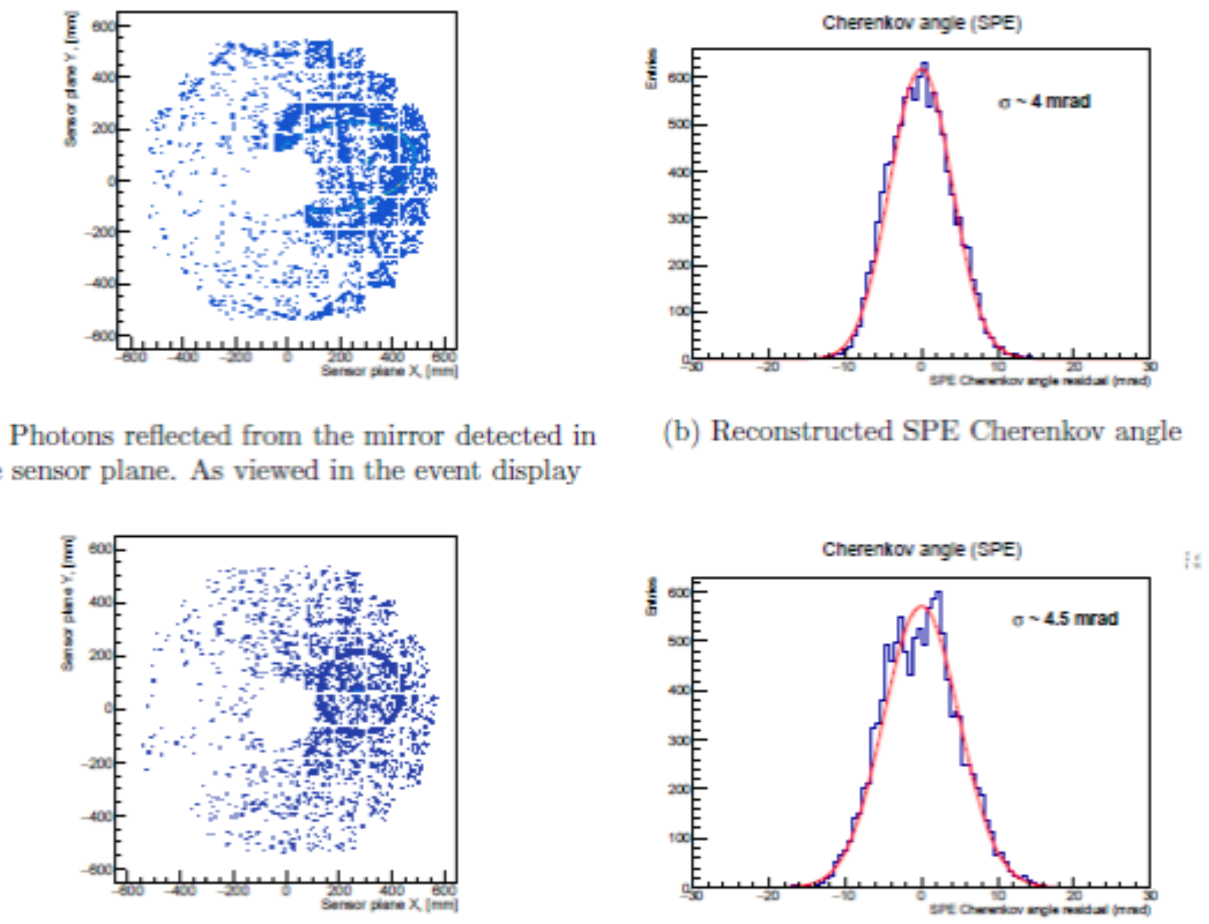
- From Physics (Kong, Brian, Thomas)
- Radiation Hardness (Alex J., Alexander)
  - No corresponding CDR section
- Expected Data Rates (?)
  - No corresponding CDR section

Justification

- Device concept and justification for the technological choice (Alexander)
- Description
  - General device description (Alex E., Charles, Bill)
  - Sensors (Alexander, Brian)
  - FEE (Alexander, Jeff?)
  - Other components (Alexander, Bill)
- Performance from available input (lab studies, test beam, prototyping, simu studies) (All)
  - Mirror test results
  - Aerogel characterization results
  - HRPPD test results



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



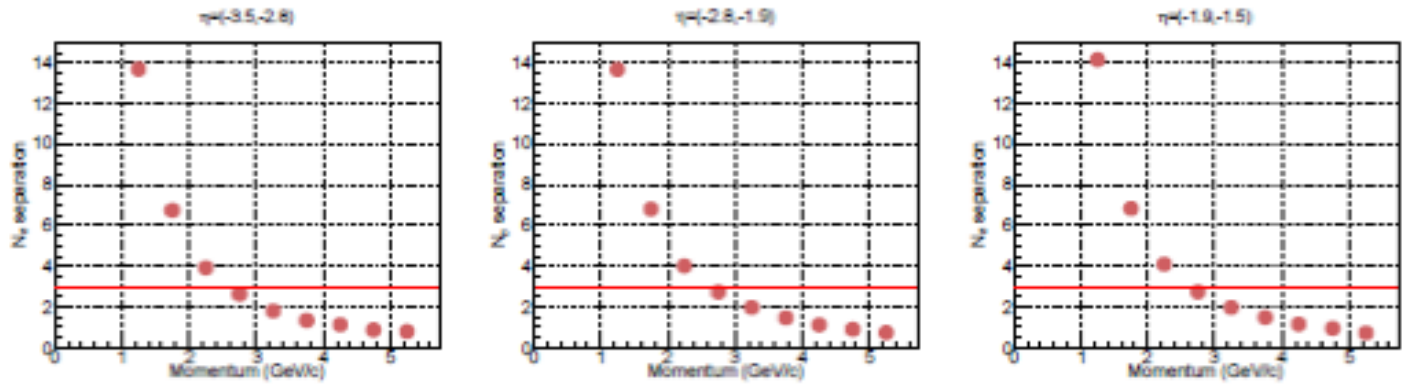
(a) Photons reflected from the mirror detected in the sensor plane. As viewed in the event display

(b) Reconstructed SPE Cherenkov angle

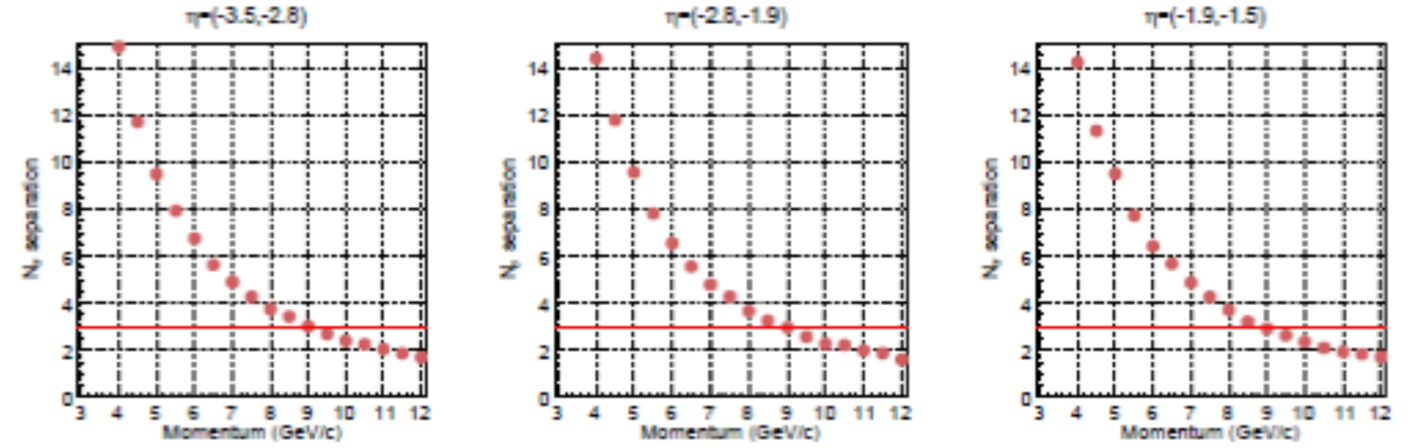
(c) Photons coming directly from the aerogel detected in the sensor plane. As viewed in the event display

(d) Reconstructed SPE Cherenkov angle

Figure 4.11: N_σ separation



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

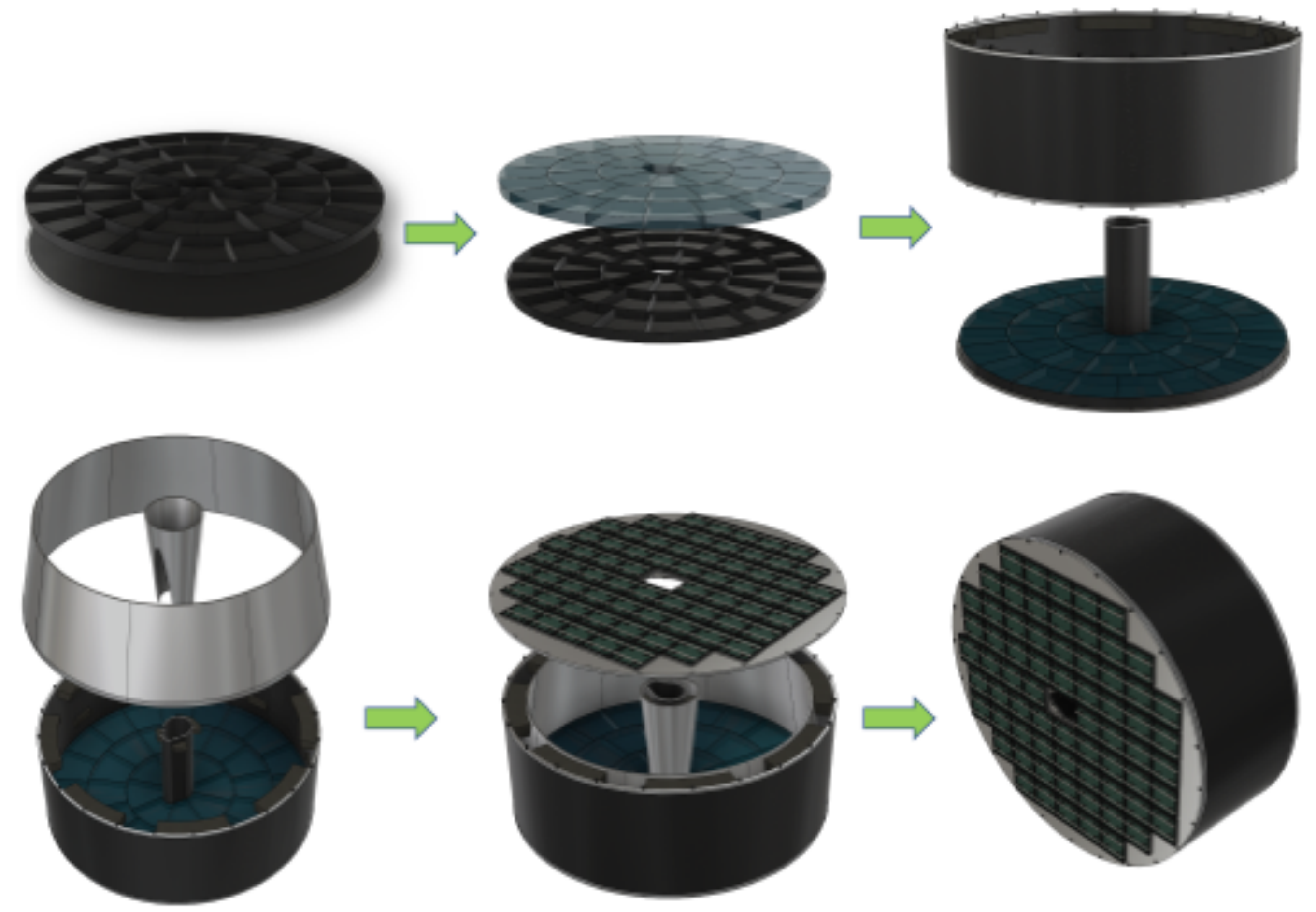


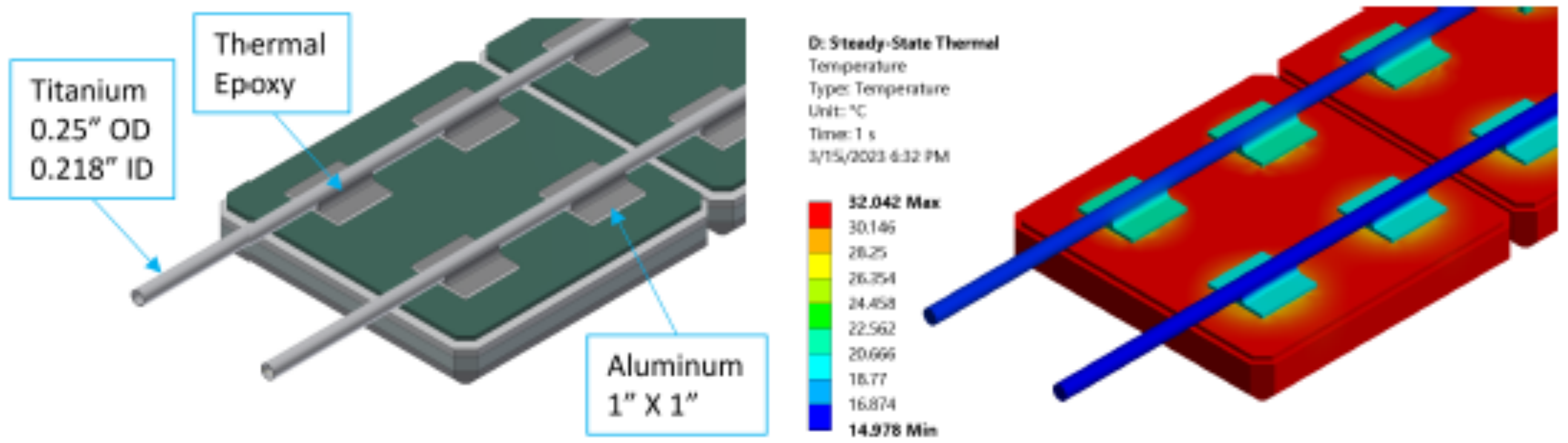
(b) N_σ separation between the pion and kaon hypotheses as a function of momentum for different bins of pseudo-rapidity.

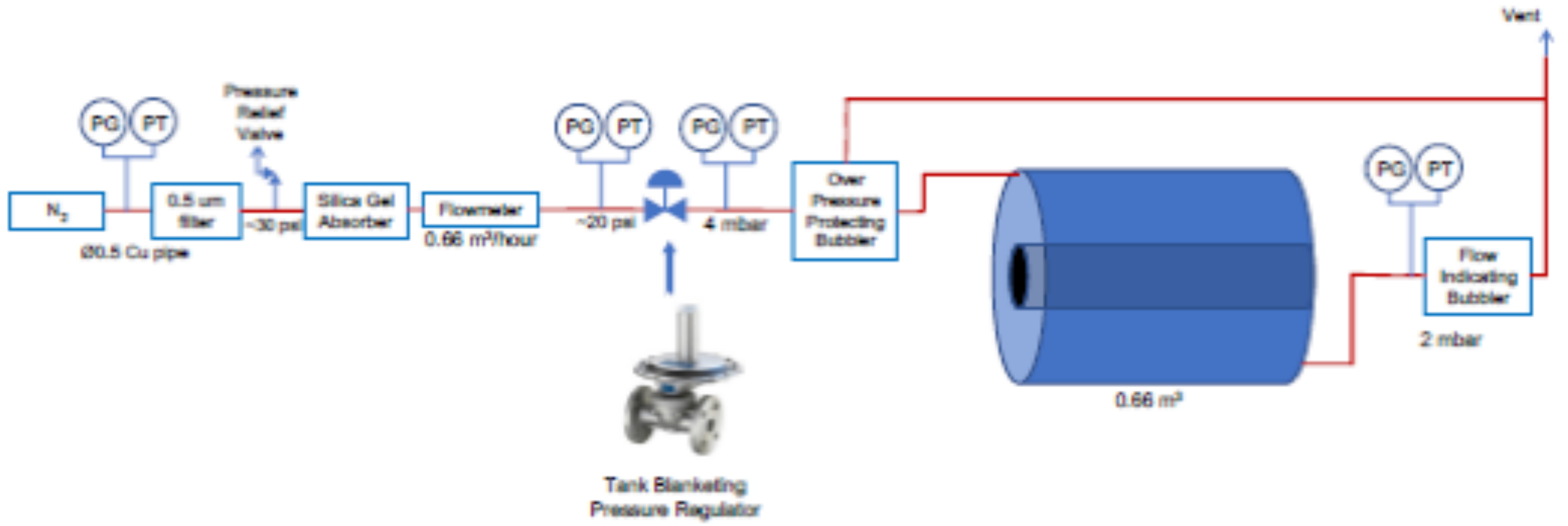
pfRICH - TDR, Mapping, Responsibilities, and Plots

Implementation

- Services (cooling, gas, power, etc) (Alexander, Alex E.)
- Subdetector mechanics and integration (Alex E., Andy, Charles, Kong)
- Calibration, alignment and monitoring (Alex E., Bill)
  - No CDR section – proposals for in situ testing?
  - Alignment strategies?
- Status and remaining design effort (Alexander, Thomas)
  - R&D up to here (and missing) E&D status
  - Other work needed for design completion
  - Status of maturity
- ES&H aspects and QA (?)
- Construction planning (Charles, Kong, Andy)
- Collaboration summary (Alexander, Thomas)
- Risks and mitigation strategy (?)



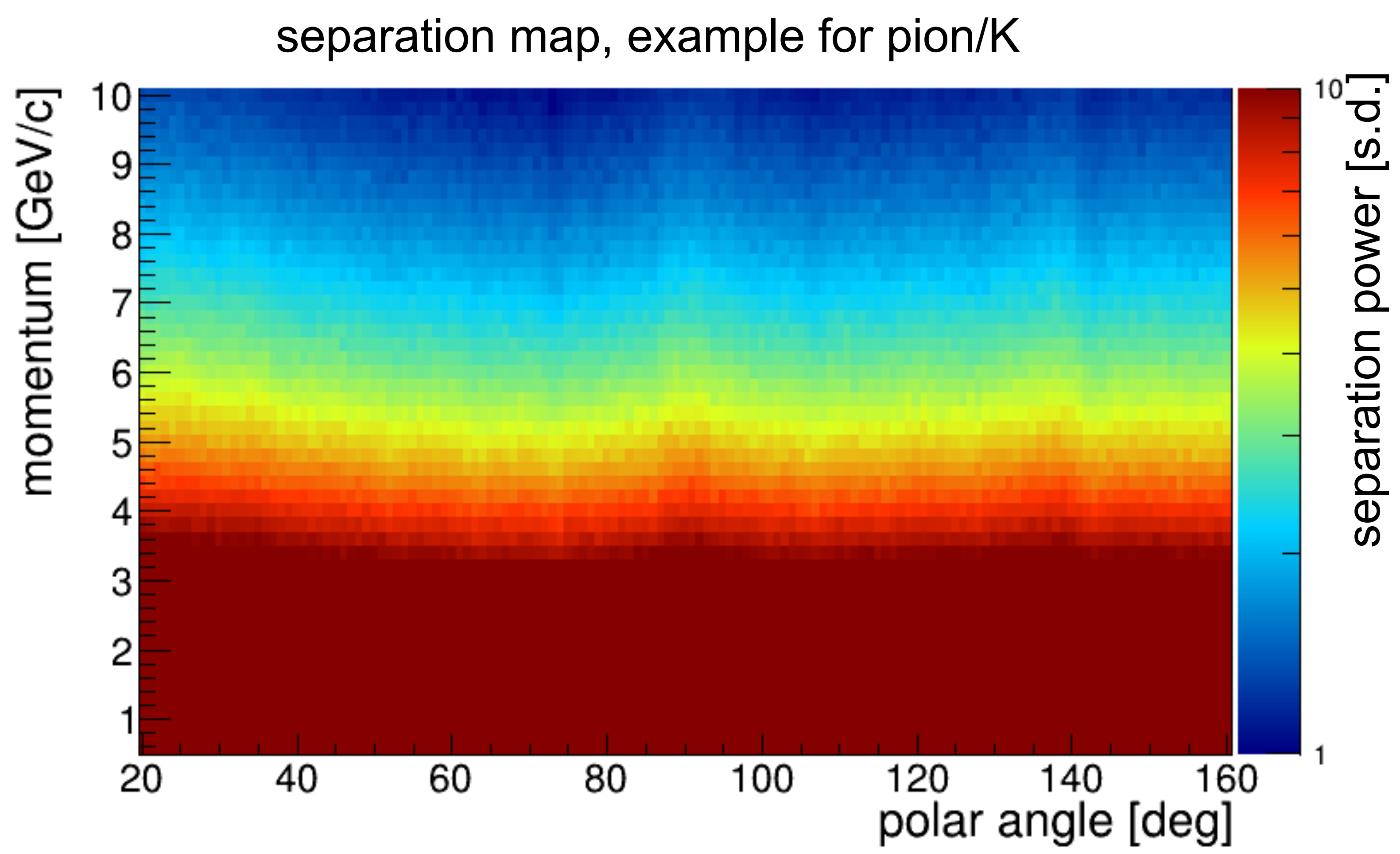


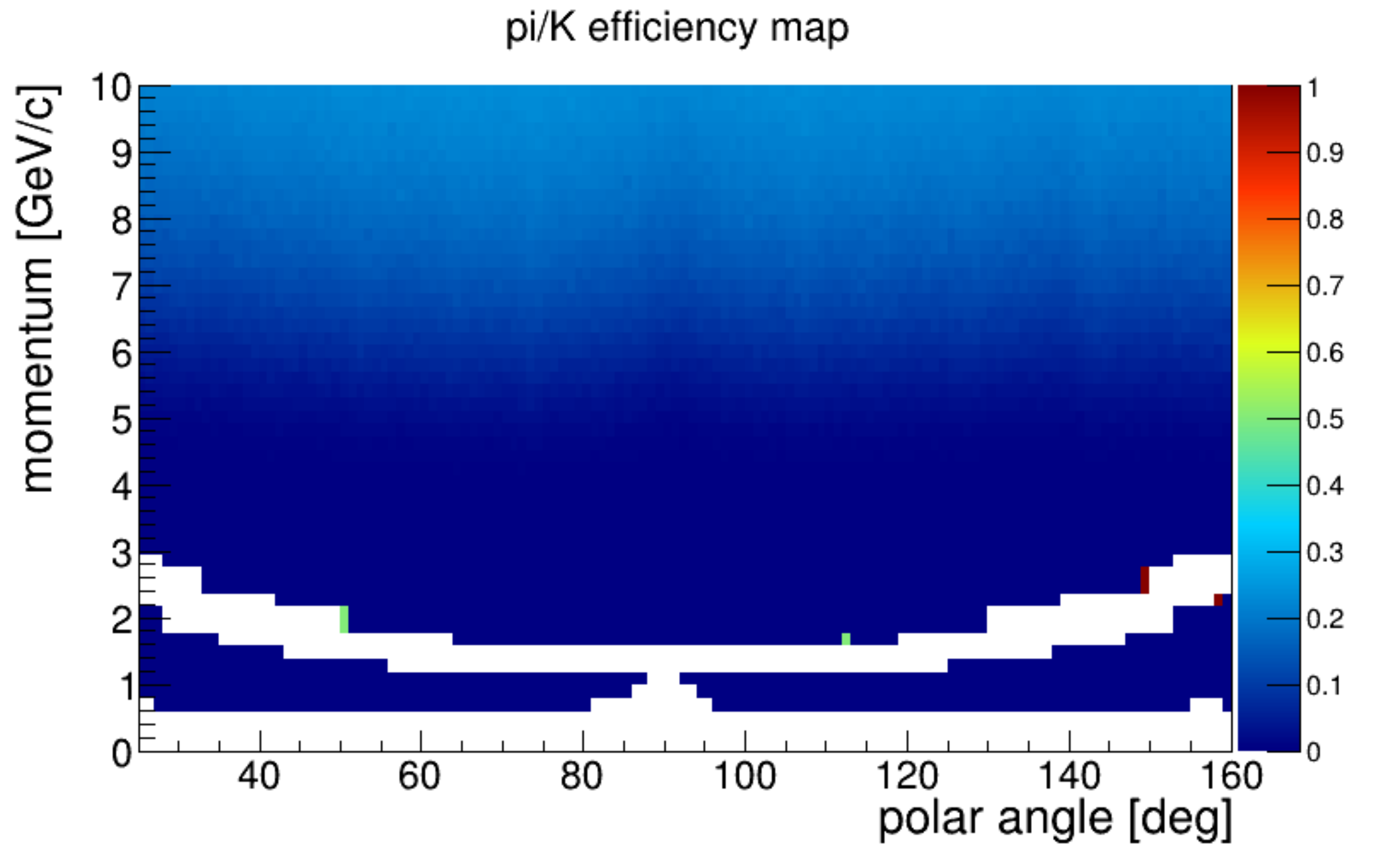


hp*DIRC*

hpDIRC - Studies Towards TDR

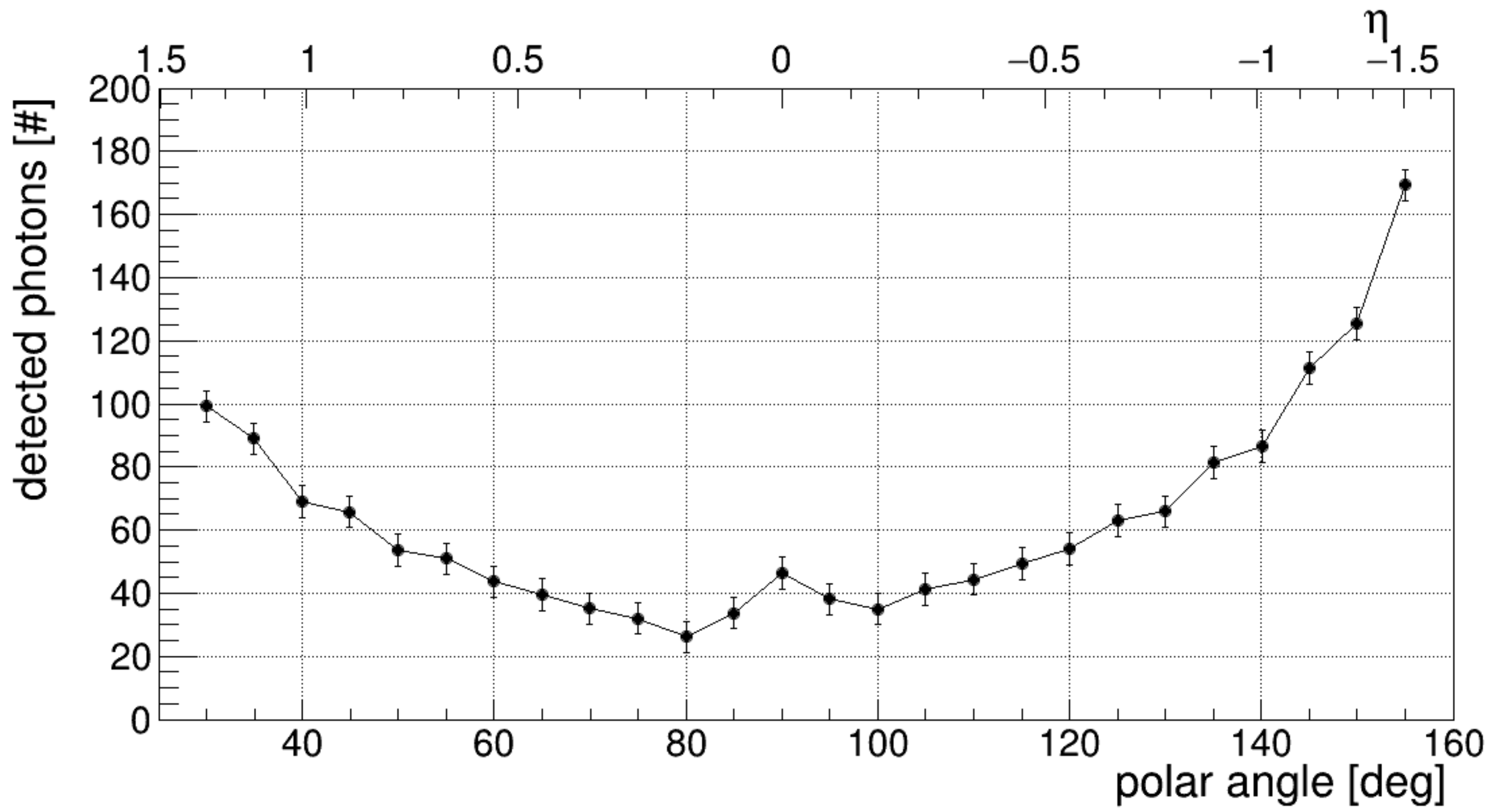
- hpDIRC performance studies were done with full standalone Geant4 simulation and reconstruction yielding wide range of plots
- Recently provided hpDIRC LUTs include threshold mode, impact of ePIC magnetic field, Yellow Report tracking resolution assumptions (tracking resolution map can be easily integrated once available)
- Pythia event generator was integrated enabling to do performance studies with physics events and multiple tracks in hpDIRC/module/single bar in single event
- Results can be easily adjusted to agreed format and representation
- Still in preparation for TDR:
  - Evaluation of backgrounds from other detectors and accelerator
  - Evaluation of track rate per event and its impact on photosensors



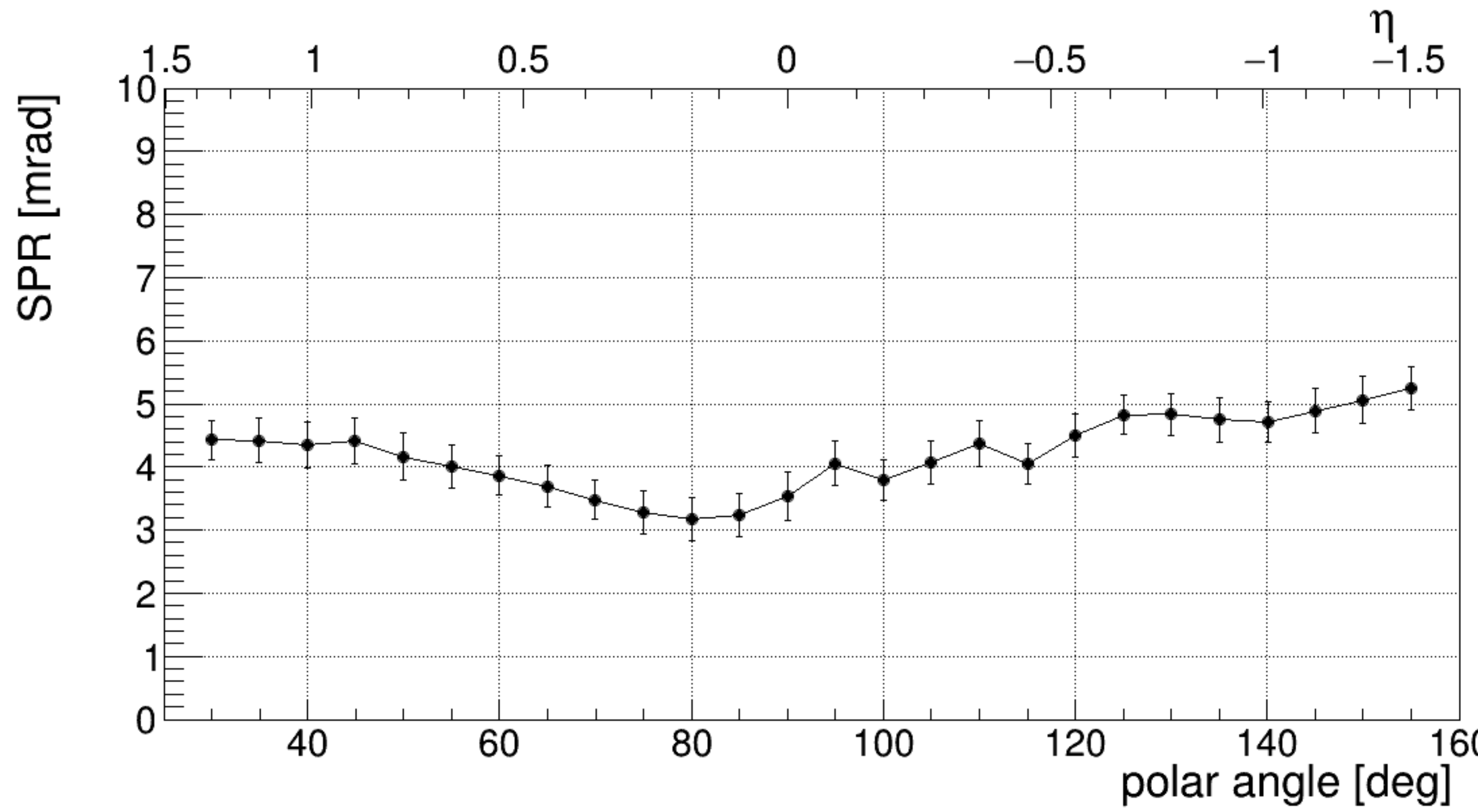


hpDIRC - Sample of Performance Plots

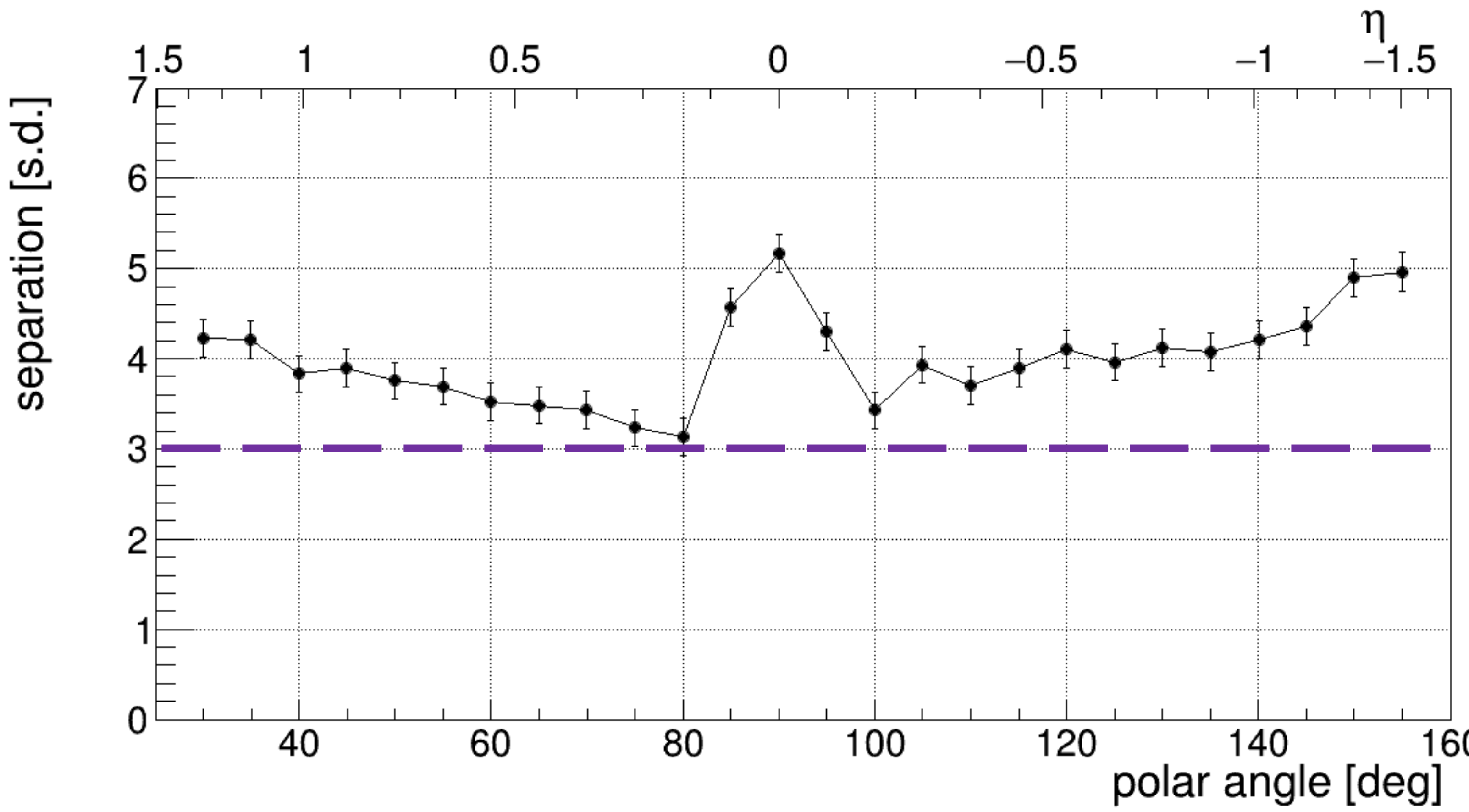
Photon yield per particle



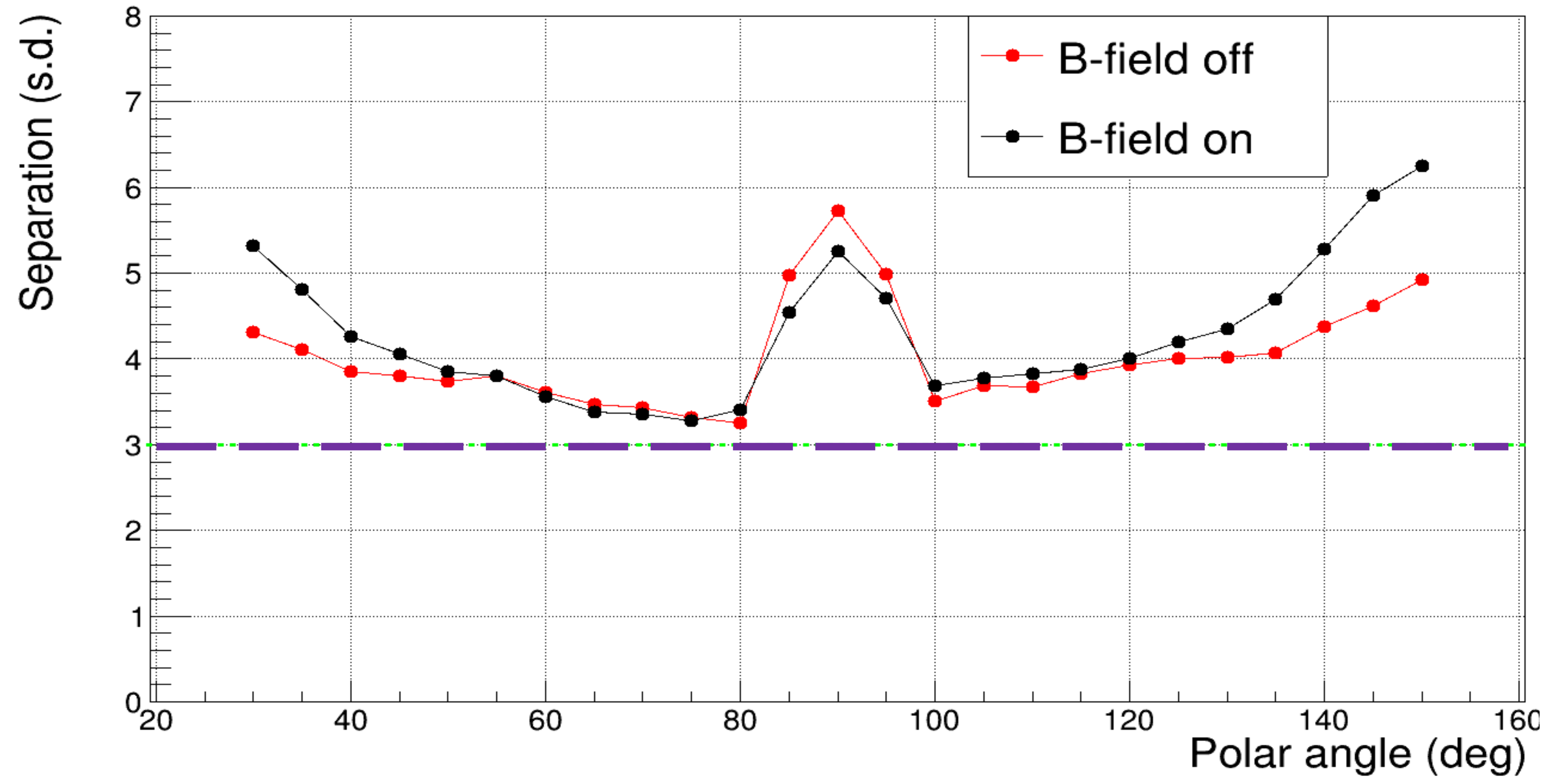
Cherenkov angle resolution per photon (SPR)



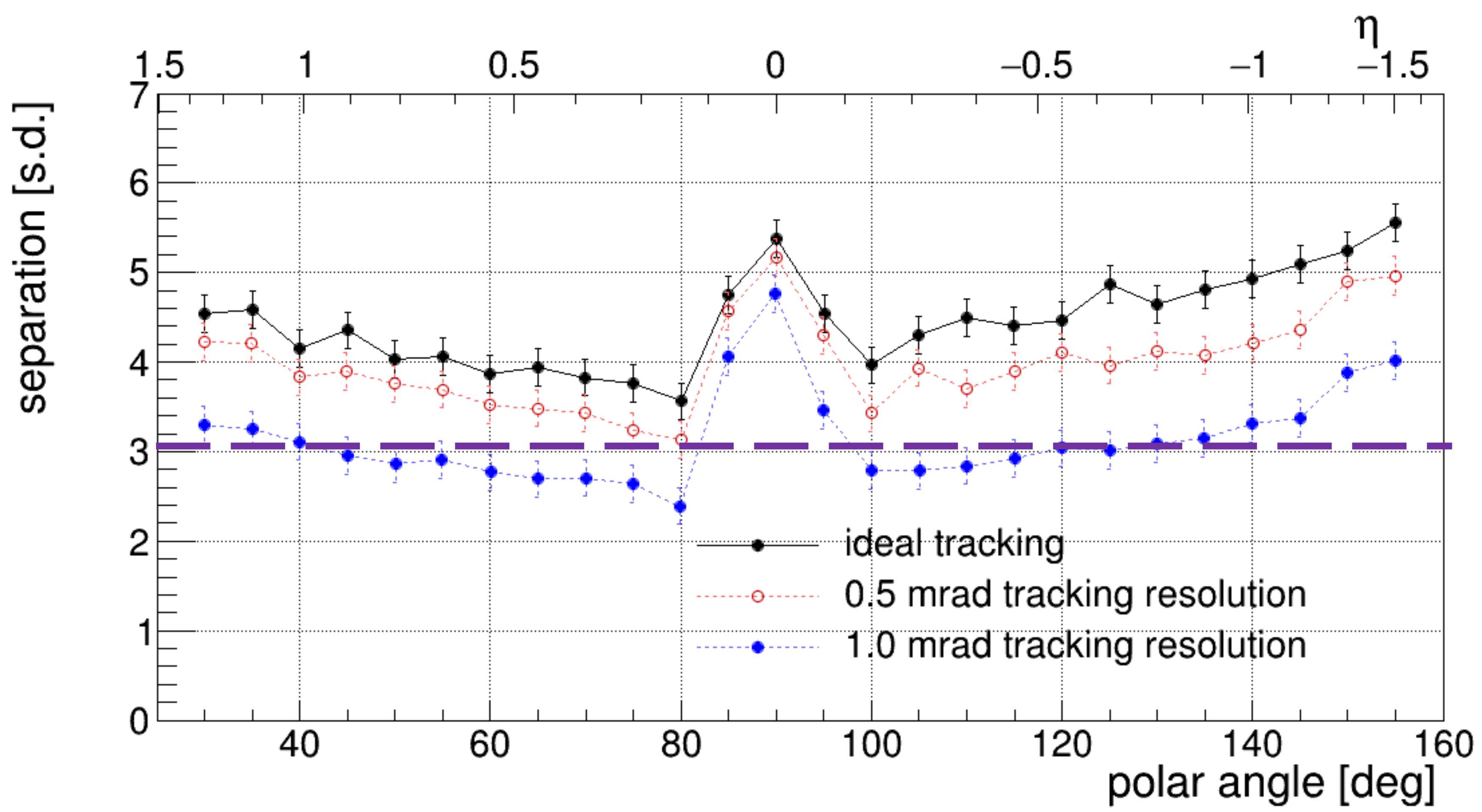
π/K separation power at 6 GeV/c



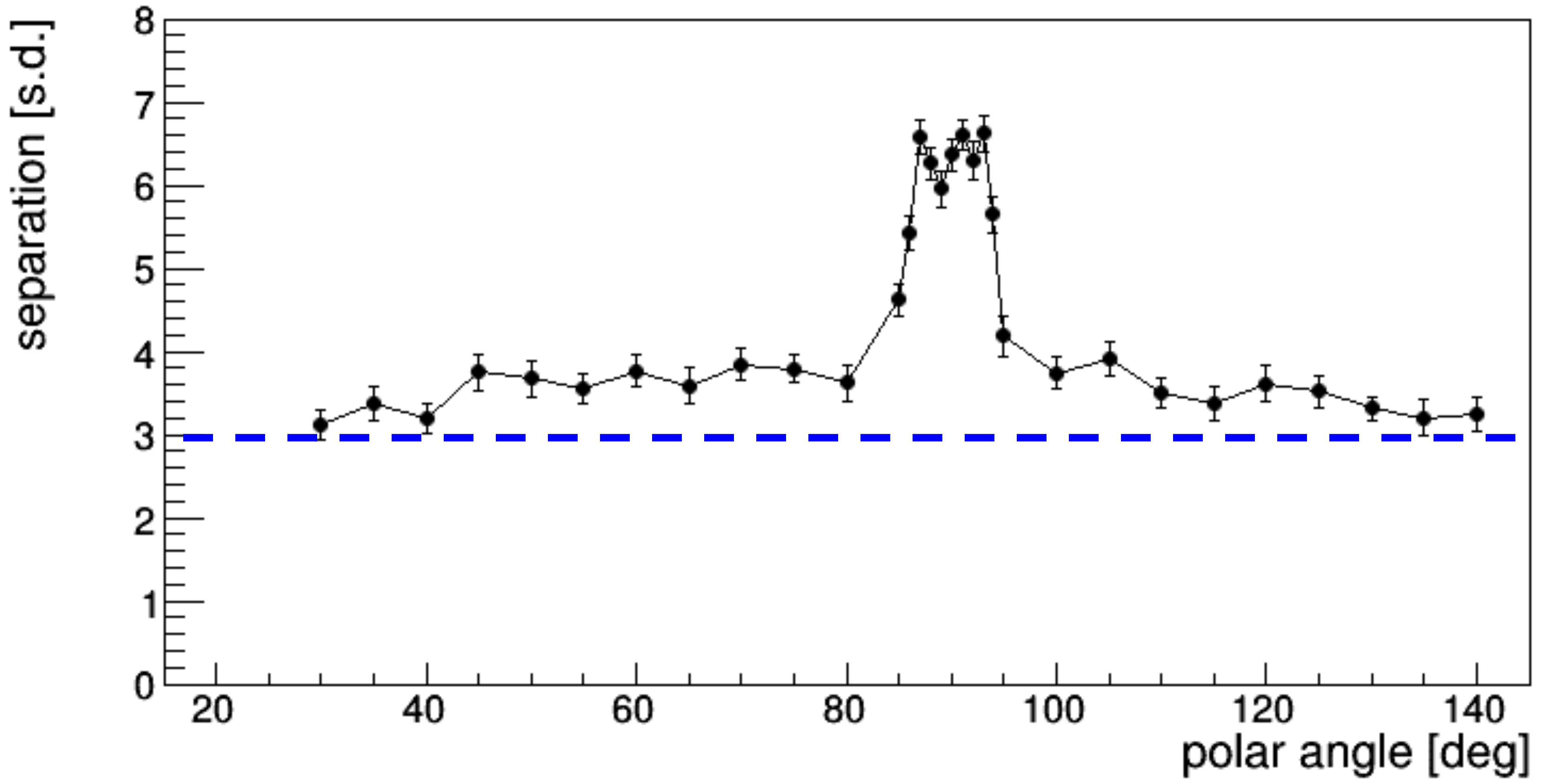
π/K separation power at 6 GeV/c with B field



Impact of Tracking resolution



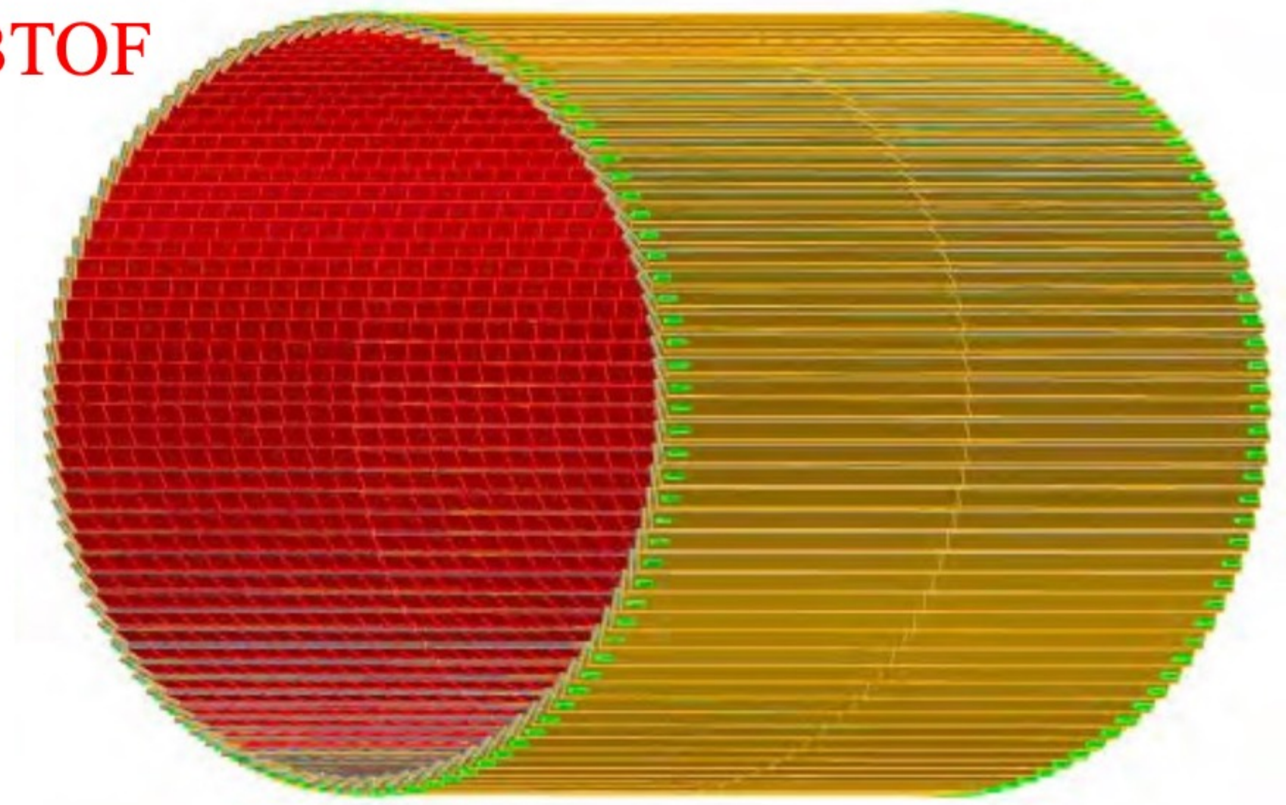
e/π separation at 1.2 GeV/c
without MS mitigation

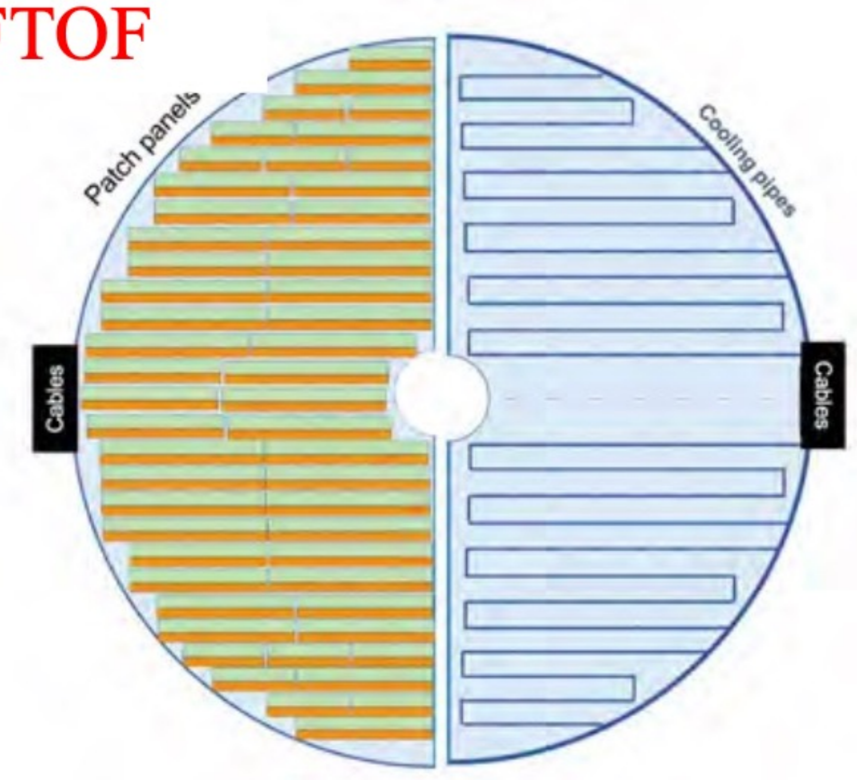


ToF

ToF - Key Elements for TDR

Detector configurations and Key requirements

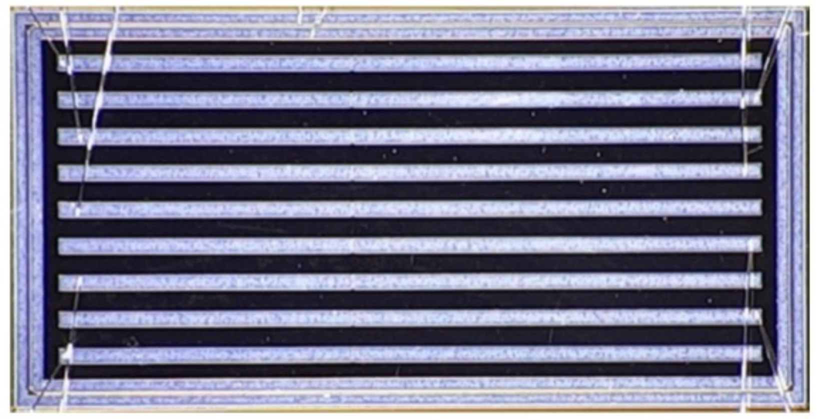


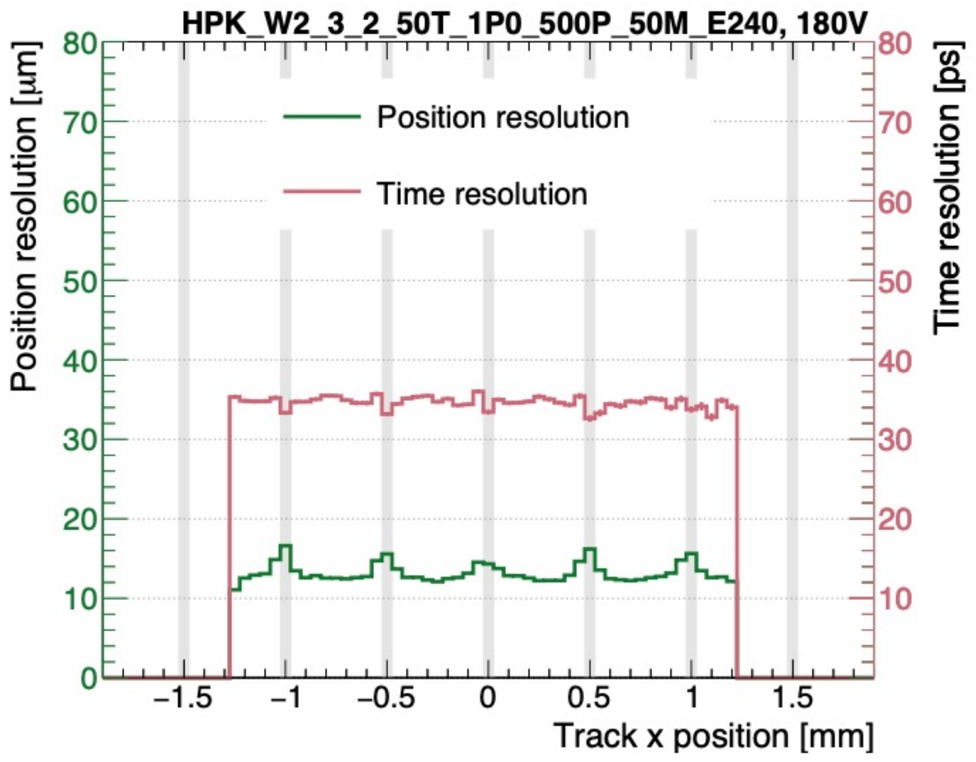


	Area (m^2)	Channel size (mm^2)	# of Channels	Timing Resolution	Spatial resolution	Material budget
Barrel TOF	10	0.5*10	2.4M	35 ps	30 μm in $r \cdot \varphi$	0.01 X_0
Forward TOF	1.4	0.5*0.5	5.6M	25 ps	30 μm in x and y	0.05 X_0
B0 tracker	0.07	0.5*0.5	0.28M	30 ps	20 μm in x and y	0.05 X_0
RPs/OMD	0.14/0.08	0.5*0.5	0.56M/0.32M	30 ps	140 μm in x and y	no strict req.
Lumi Tracker						

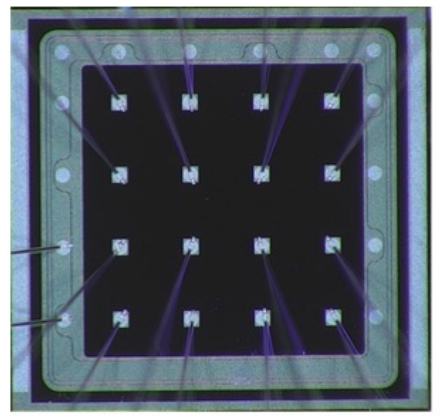
Position and timing resolutions

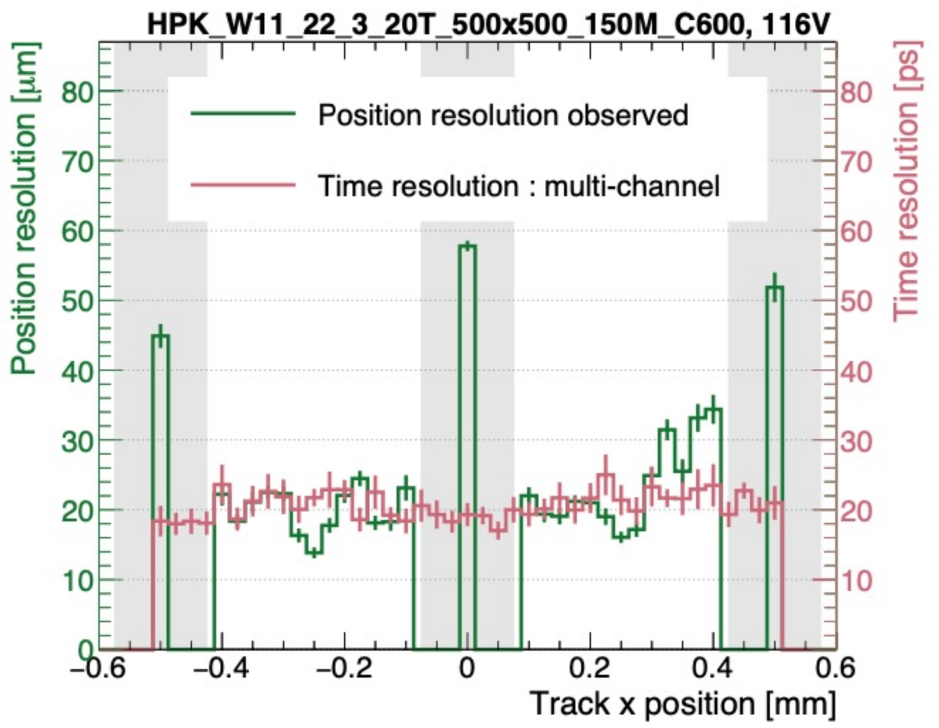
HPK Strip Sensor (4.5x10 mm^2)





HPK Pixel Sensor (2x2 mm^2)

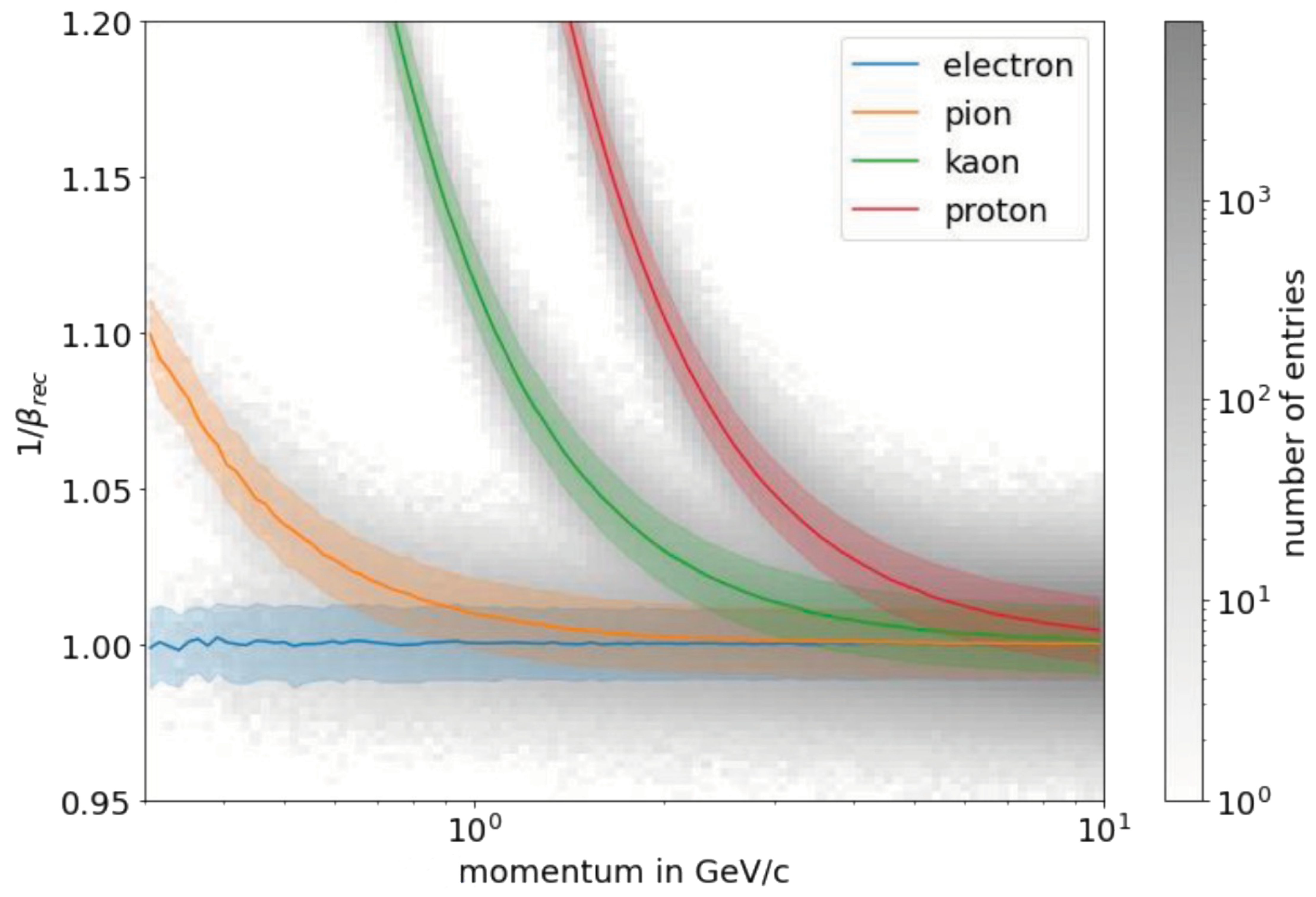


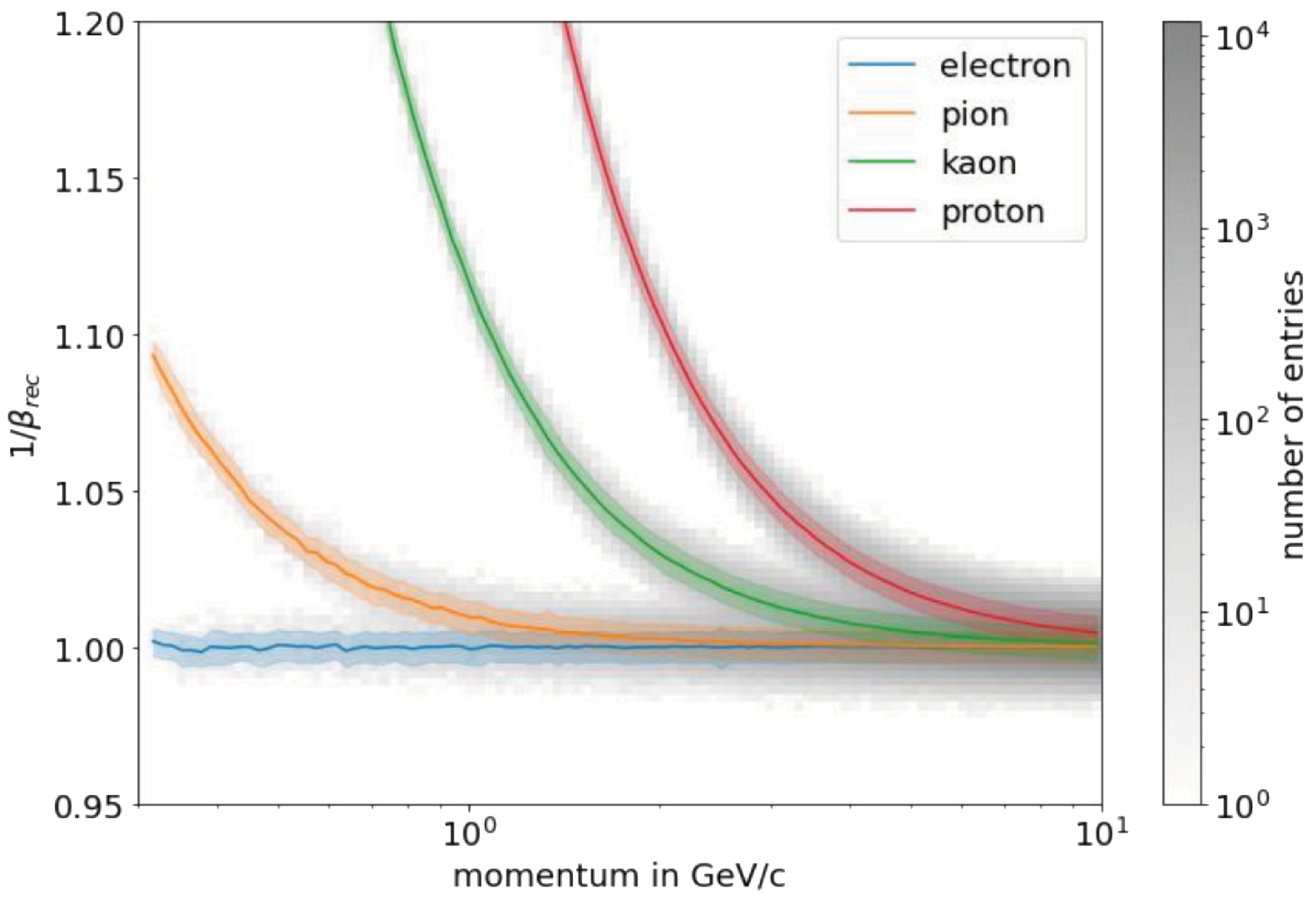


ToF - Key Plots on ToF Performance

- Barrel Region
  - e/π up to 0.5 GeV/c
  - π/K up to 1.9 GeV/c
  - K/p up to 3.1 GeV/c

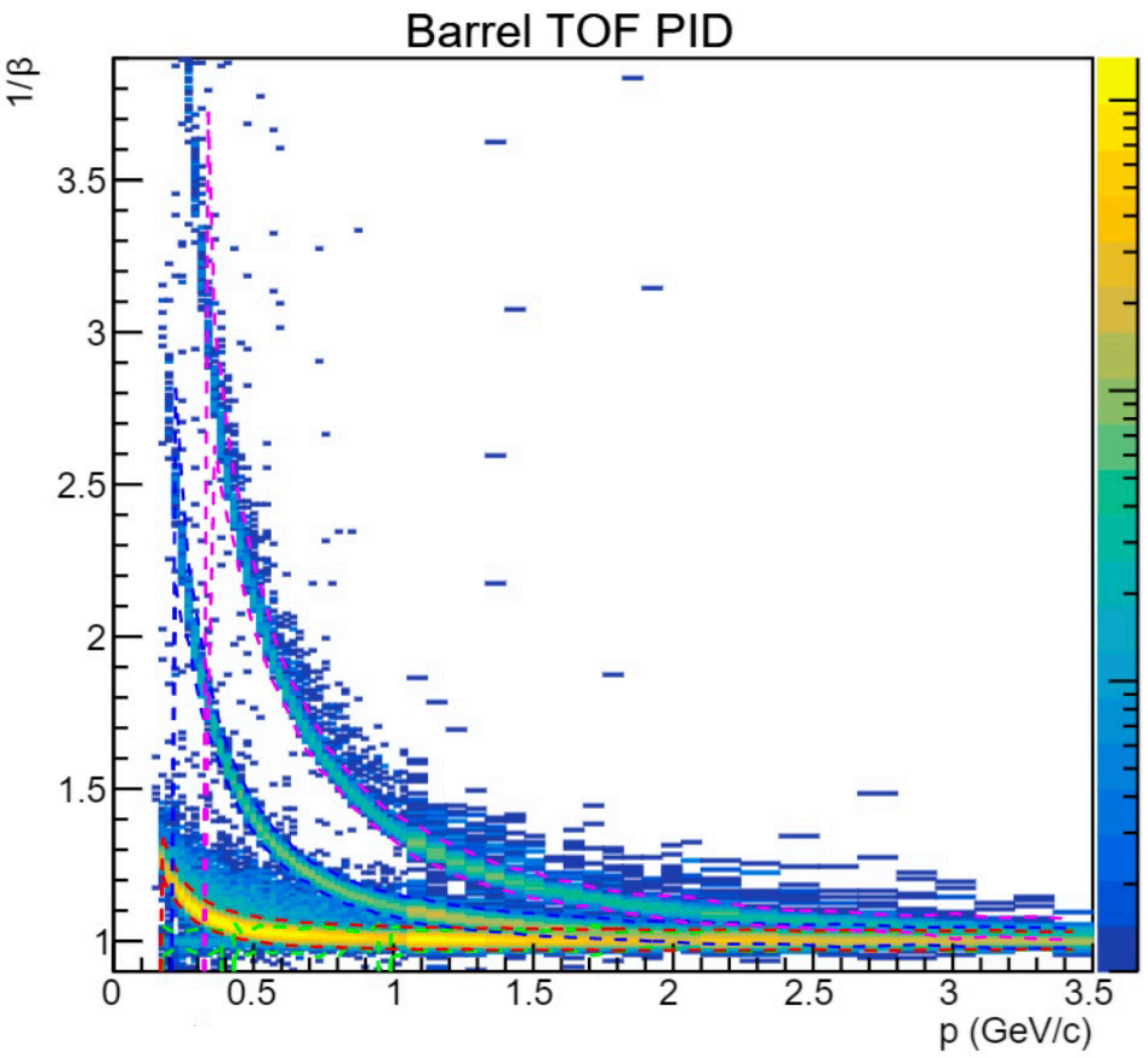
- Endcap Region
  - e/π up to 0.8 GeV/c
  - π/K up to 2.7 GeV/c
  - K/p up to 4.6 GeV/c



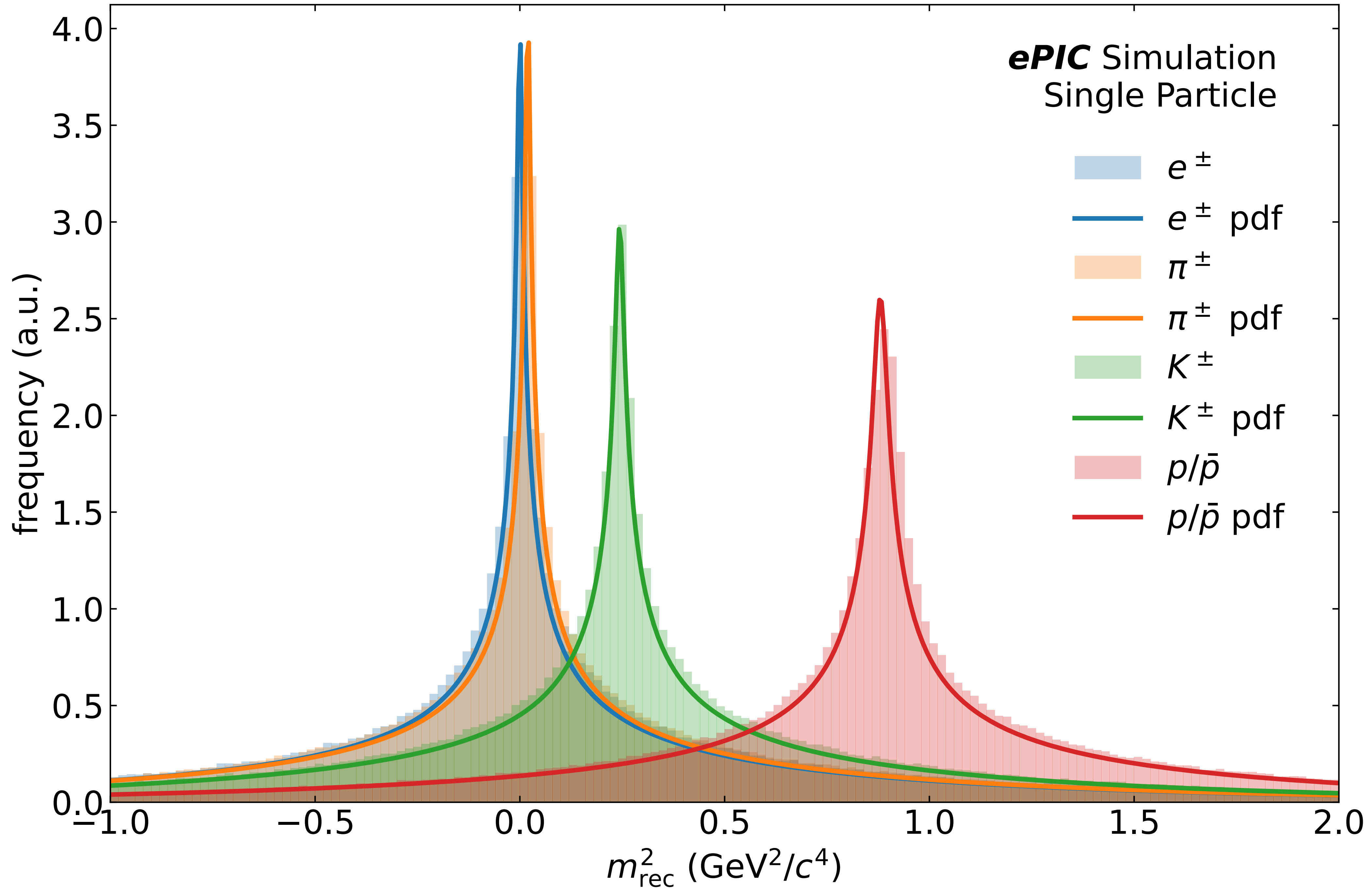


ToF - PYTHIA DIS Simulations

- PYTHIA DIS event without beam background



- PYTHIA DIS event with beam background and full reconstruction



Summary

Take Away Message

- Even if not completely defined for all DSCs the key plots are in principle straight forward
- Some groups are further than others but so far all are plowing forward
- In some case we have to find means to reduce the number of plots w/o complicating them (especially for dRICH, the reason is the “d”)
- My take: Each DSC need one (1!) iconic plot that summarizes their performance in a simple but impressive fashion
- We need also one plot that combines all 4 PID systems highlighting what makes ePIC special