Particle identification by Cherenkov imaging techniques in the experiment ePIC at EIC

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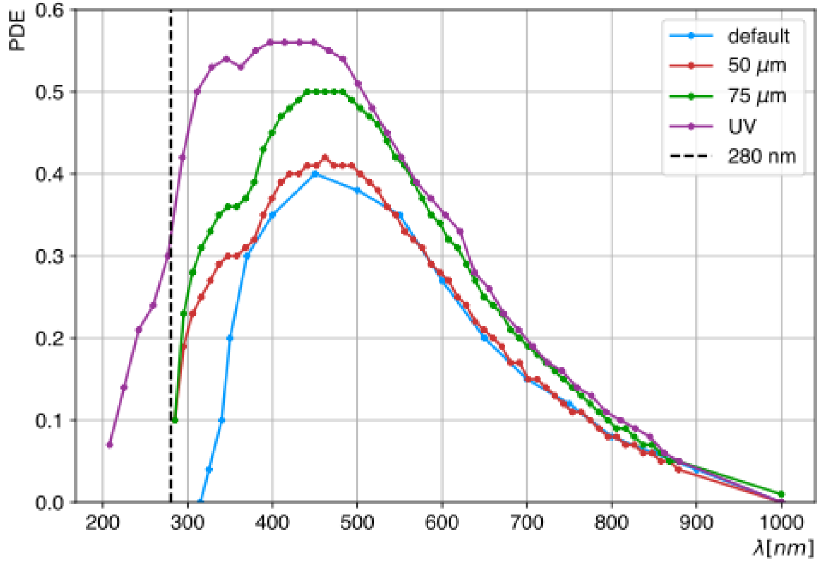
dRICH performance with different SiPMs parameters

- The dRICH geometry kept constant

- Different SiPMs PDE curves were tested
  - **Default**: Hamamatsu S13361-3050AE-08 (50 µm pixel, epoxy window)
  - **50 µm, 75 µm:** Hamamatsu S13360 series Silicon window
  - **UV** PDE extended down to ~200 nm
    Novel device (less extensively tested)



PDE curves for different SiPMs

- At 280 nm 50% of the aerogel photons are absorbed by the acrylic filter which separates the two radiators

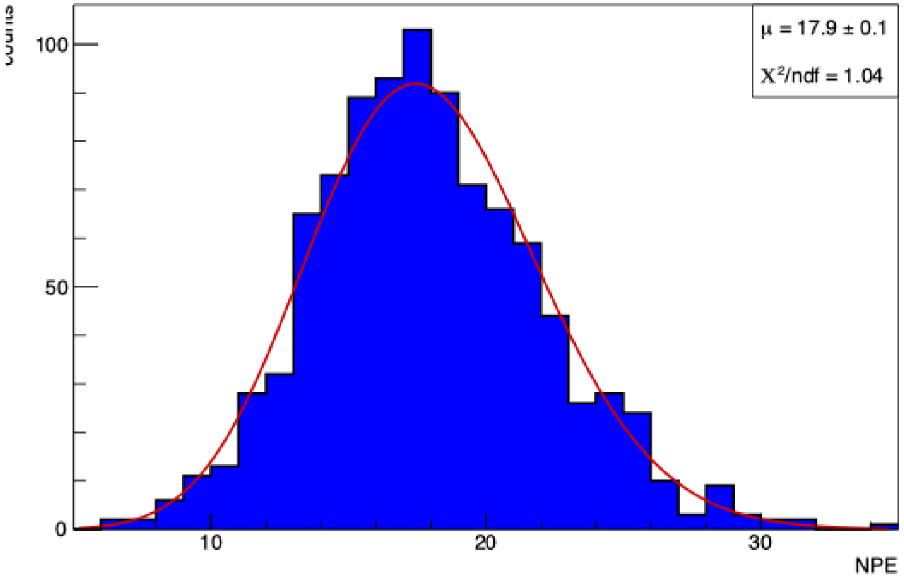
SiPMs parameters - simualtions

- 1k single-particle events per (p, η, Φ)
- Monochromatic momentum bins
  - ($\Delta p = 0.1$ GeV/c)
- Pseudorapidity bins:
  - [2.0–2.5]
  - [2.5–3.0]
  - [3.0–3.5]
- Uniform in azimuthal angle
  - $\Phi \in [0, 2\pi]$

- Pions / Kaons

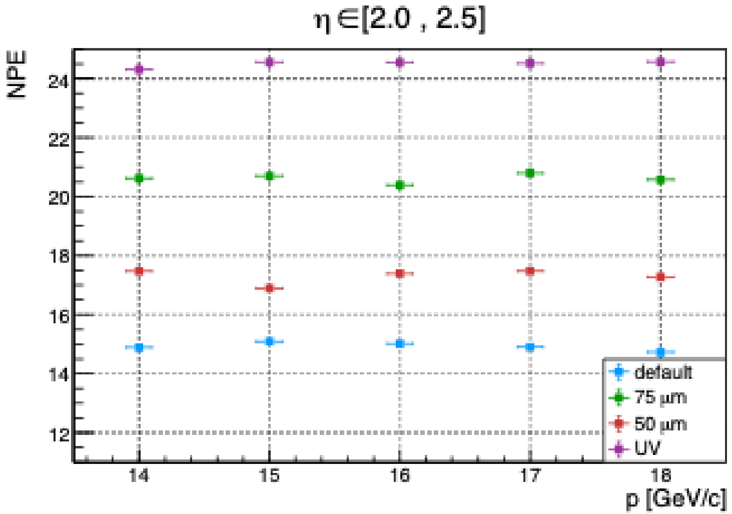
SiPMs parameters - Aerogel

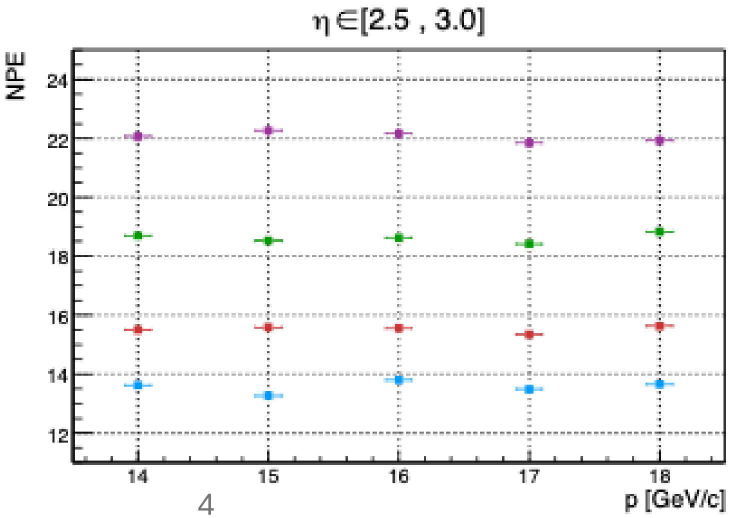
- Larger PDEs → increased photon detection
- Simulation results compatible with analytic calculations

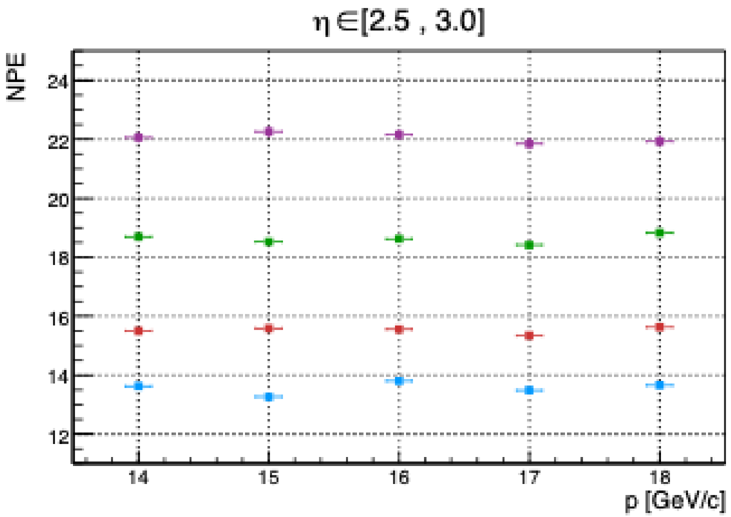


- Poisson distribution for 1000 π^+ at 15 GeV/c

NPE in the mean of the number of reconstructed hits

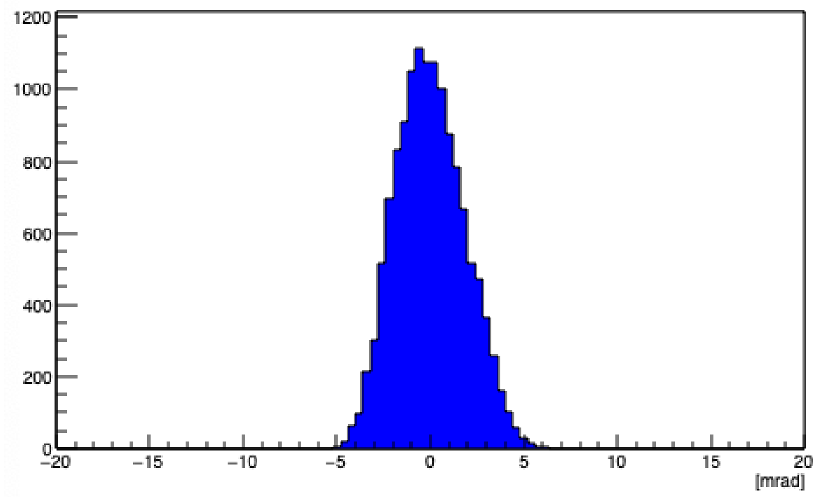






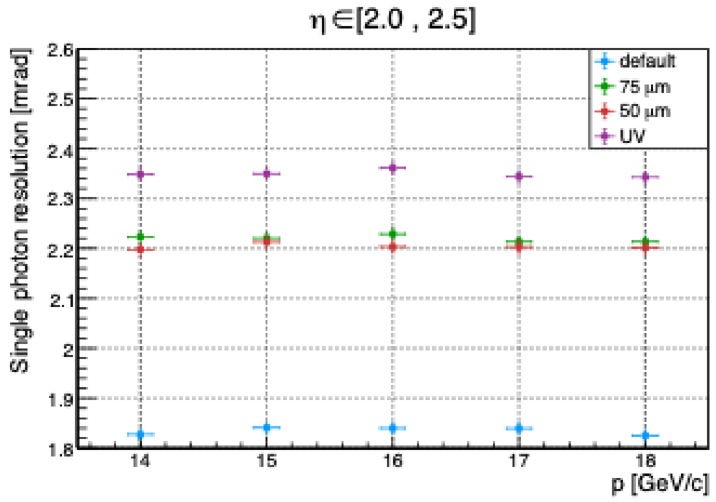
SiPMs parameters - Aerogel

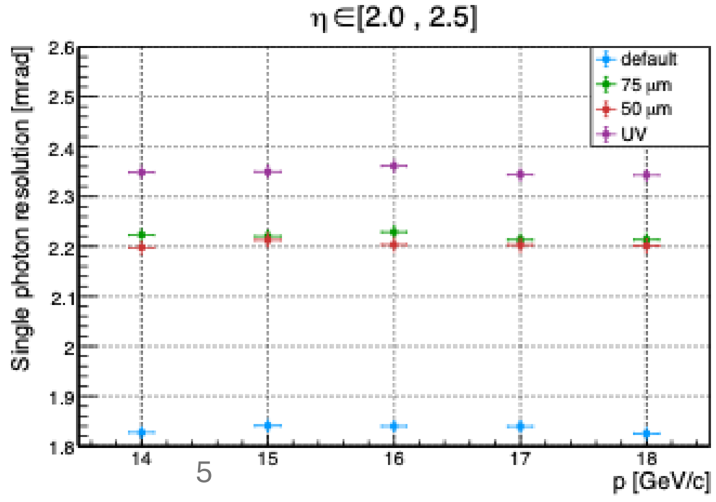
- Rayleigh scattering worsens Single Photon Resolution
  - Important for UV photons
- 50 μm and 75 μm SiPMs show similar SPR due to their detection range

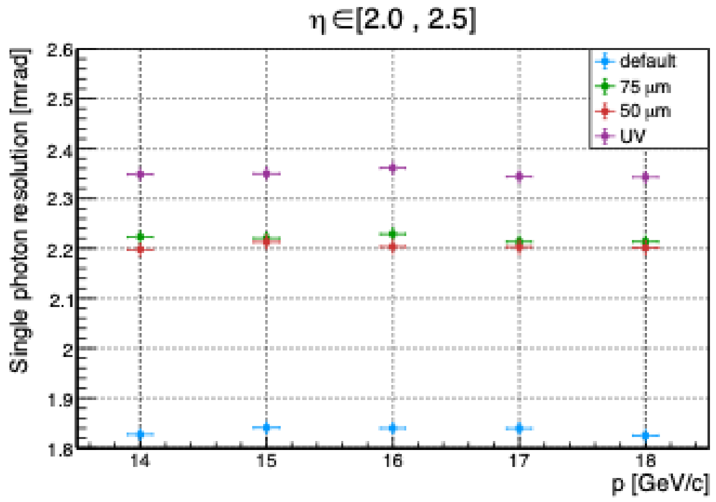


Single photon angle for 1000 π^+ at 15 GeV/c

Single Photon Resolution (SPR) σ_θ is the standard deviation of the single photon reconstructed angle distribution

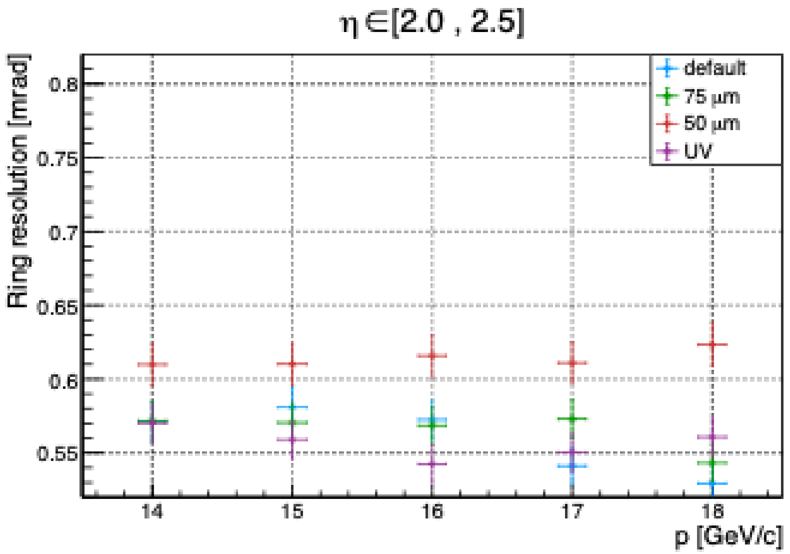


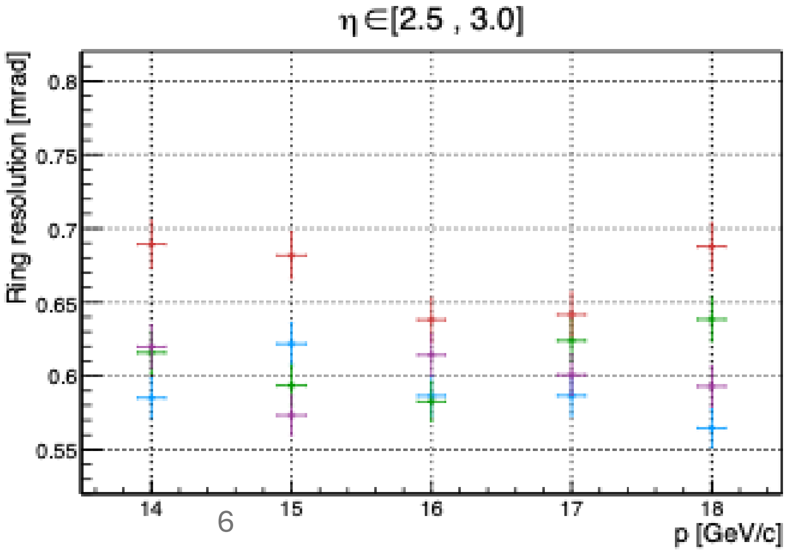


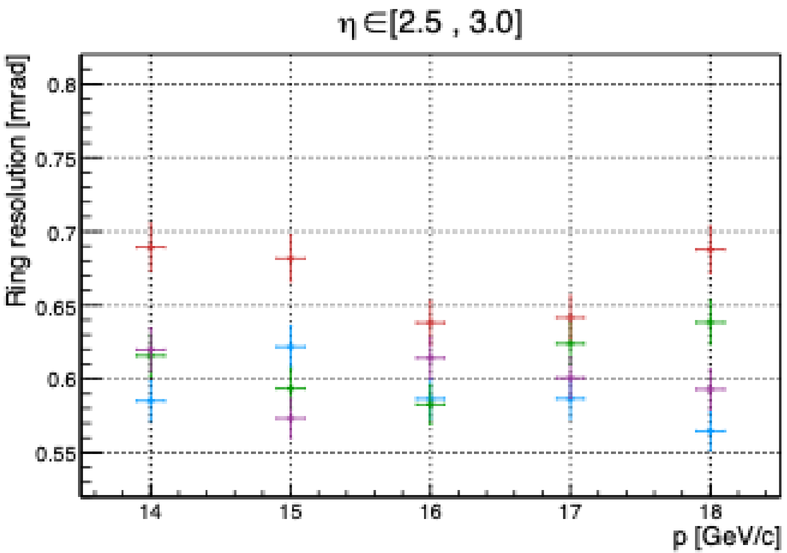


SiPMs parameters - Aerogel

- Ring resolution is defined as the standard deviation of the track Cherenkov angle distribution
- Ring resolution is $\sigma_{ring} = \frac{\sigma_{\theta}}{\sqrt{NPE}} + C$







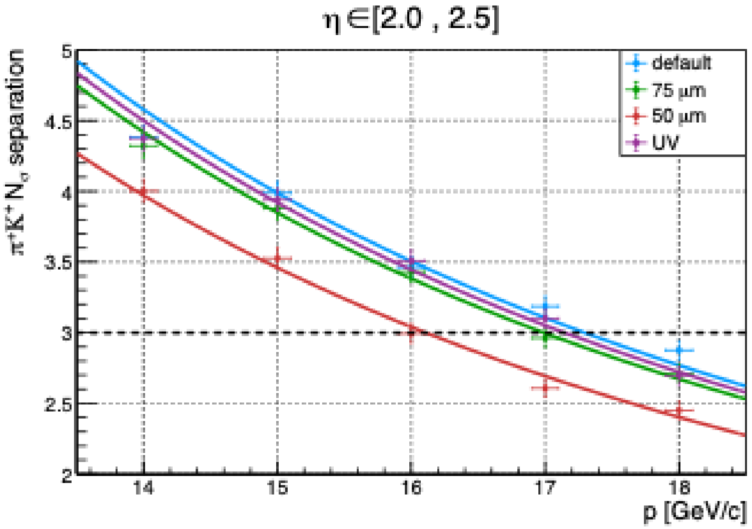
SiPMs parameters - Aerogel

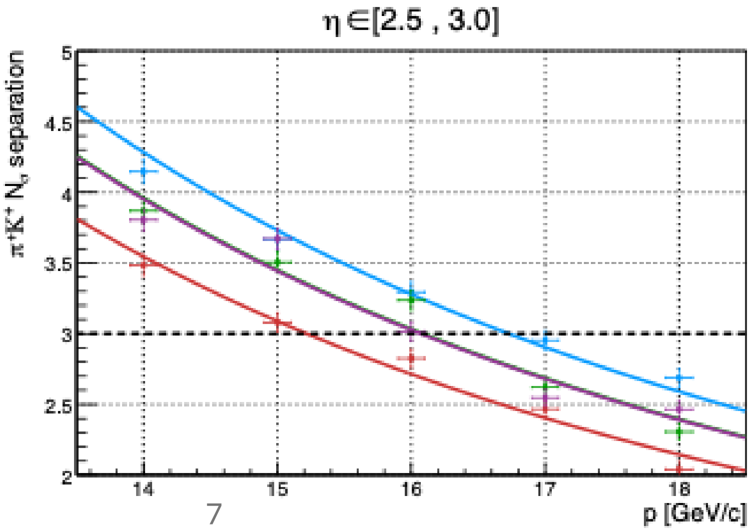
- Default SiPMs present the performance
  - Extend the detection range into the UV spectrum does not help
  - It can help when noise is taken into account

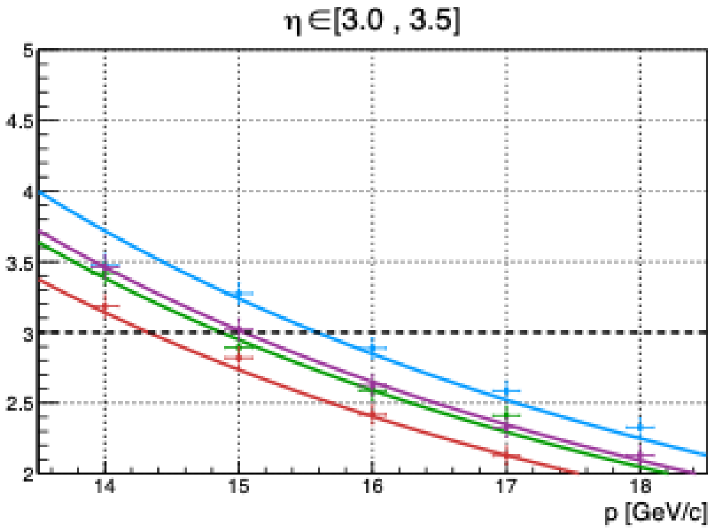
$$\sigma = \frac{\sigma_k + \sigma_\pi}{2}$$

$$N_\sigma = \frac{<\theta_k> - <\theta_\pi>}{\sigma}$$

Fit function $y = [0] \cdot x^{-2}$





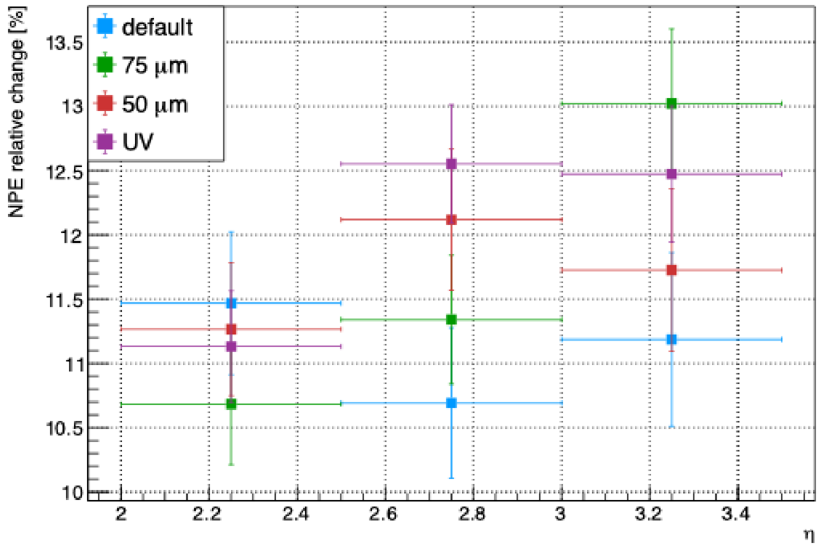


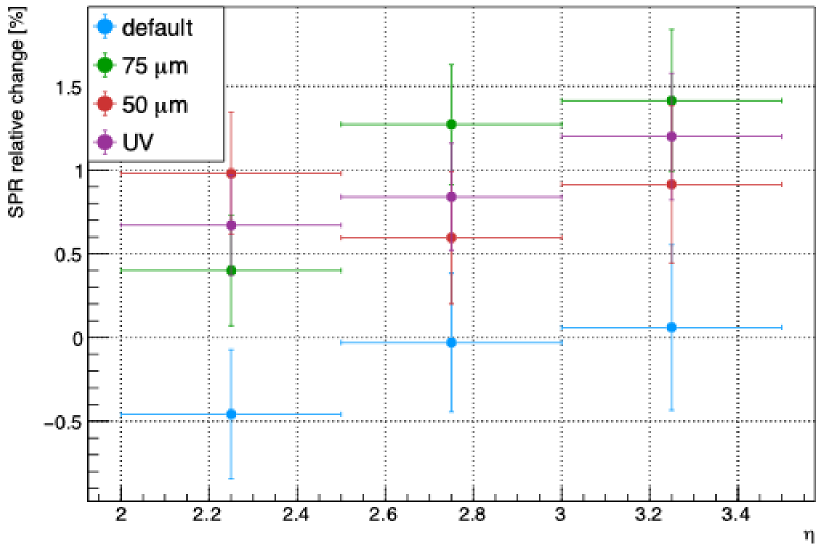
SiPMs parameters - filter

Between the two radiator am acylic filter prevents any contamination of the aerogel by the gas.

How much does it impact the performances?

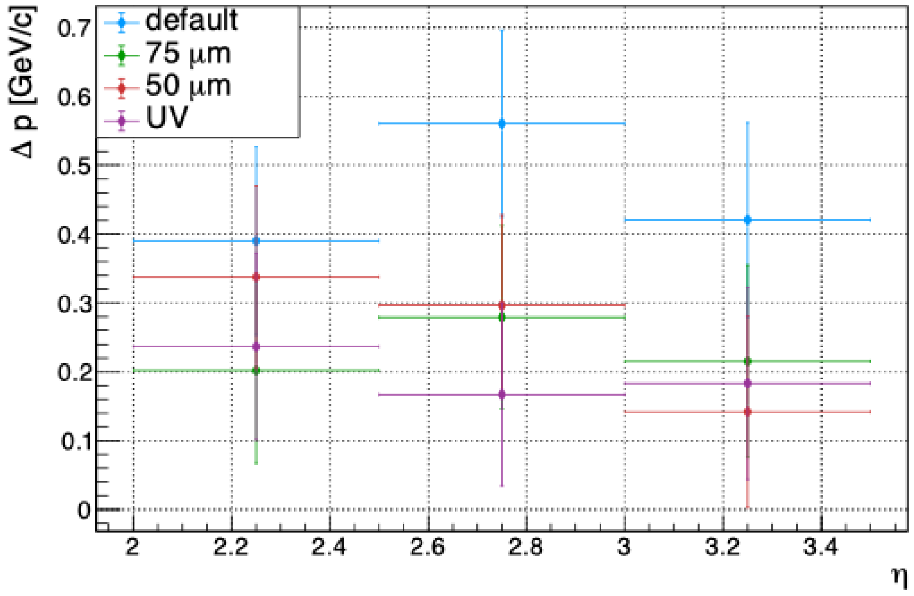
- NPE are reduce for all the SiPMs (due to the double reflection)
- SPR does not change for the default SiPM because it is not sensible to photons under 280nm
- X relative change $= \frac{X_{wo} - X_{w/}}{X_{w/}}$

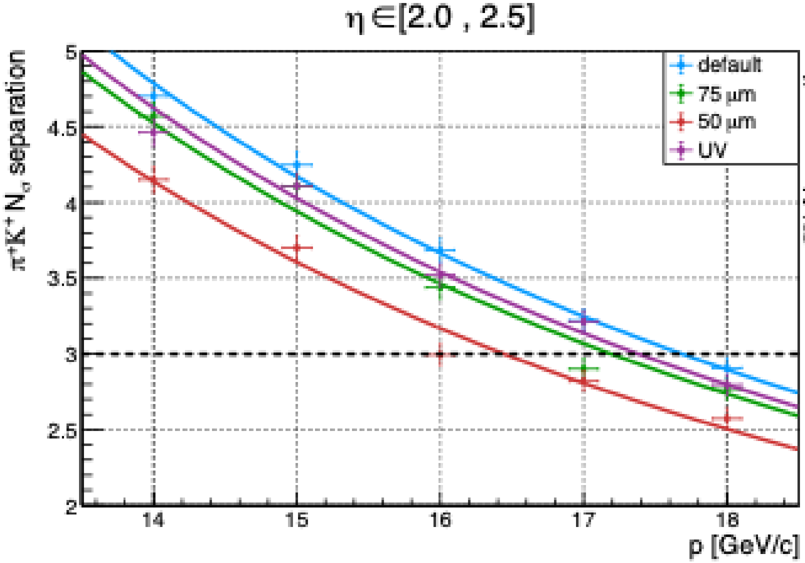


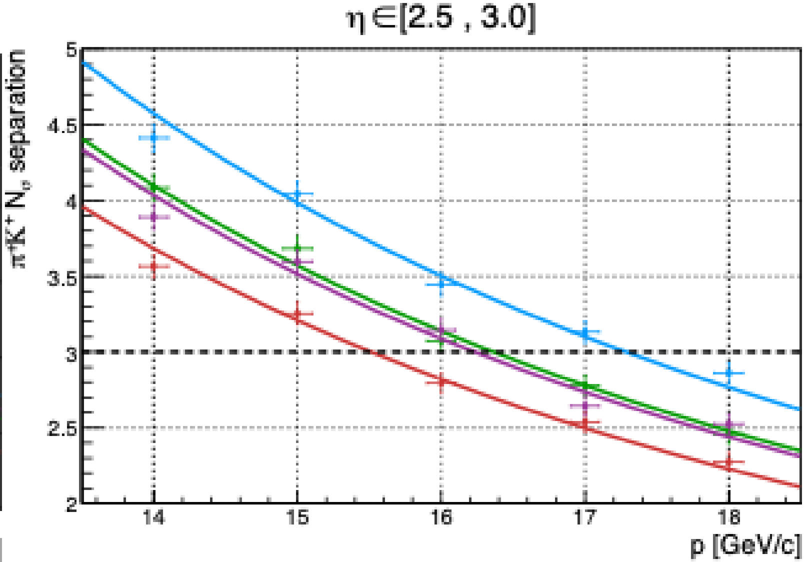


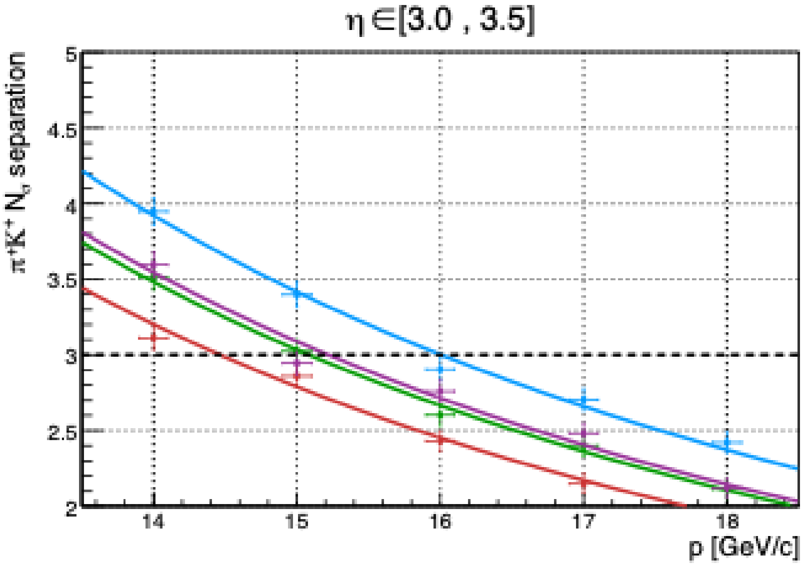
SiPMs parameters - filter

- Right: loss in 3σ π-k separation
  - Default suffer the most
- Bottom: N_σ π-k separation curve wo filter
  - Default sistematically better than the others
- $\Delta p = p_{3\sigma,wo} - p_{3\sigma,w}$





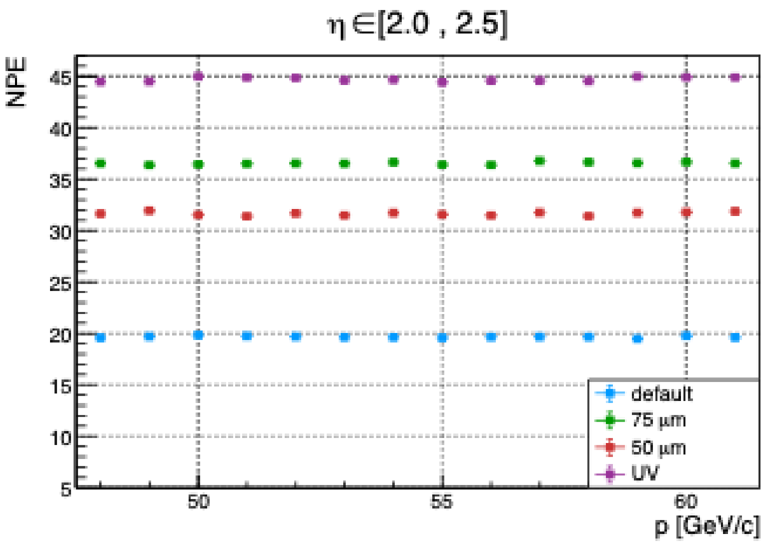


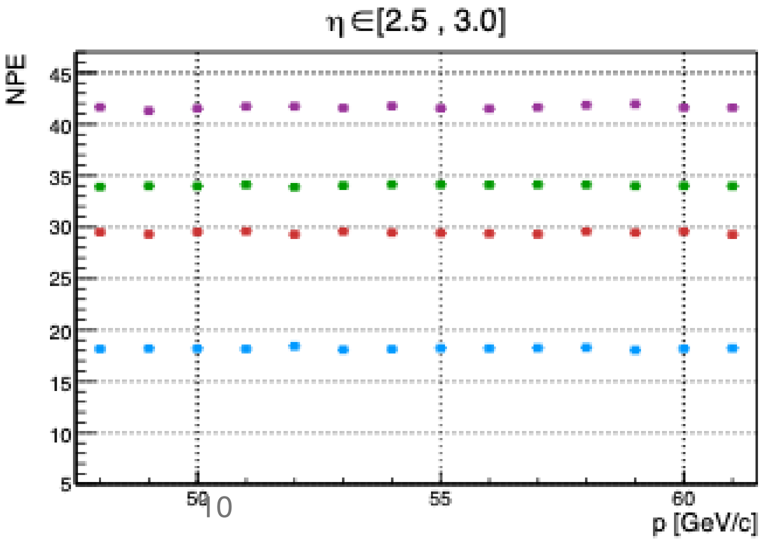


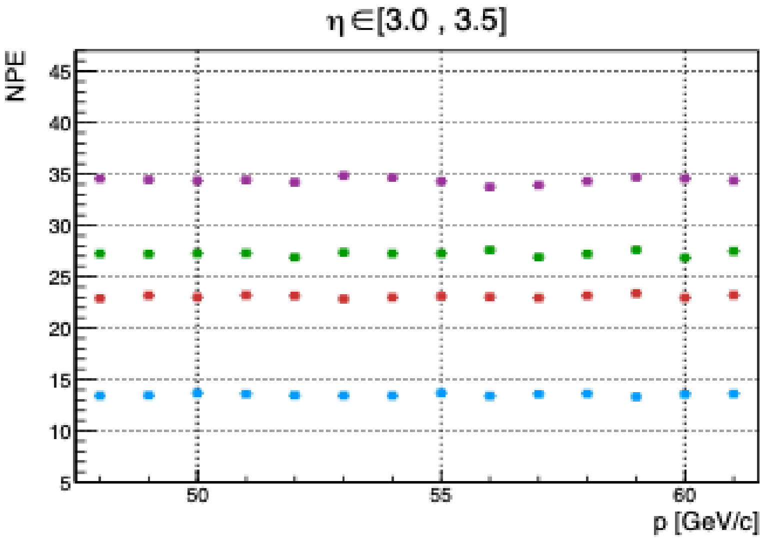
SiPMs parameters - Gas

The same was repeated for the gas radiator

- increment in the number of photons
- small increase in SPR (rayleigh scattering negligiable)

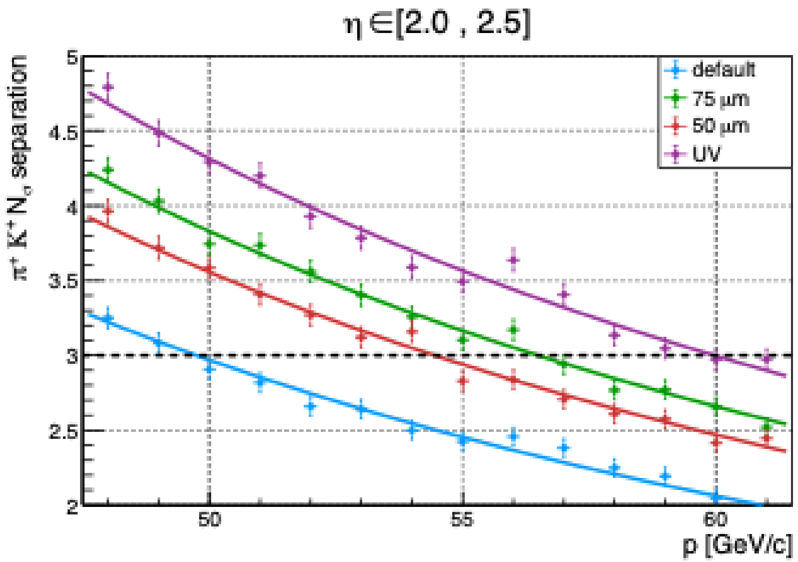


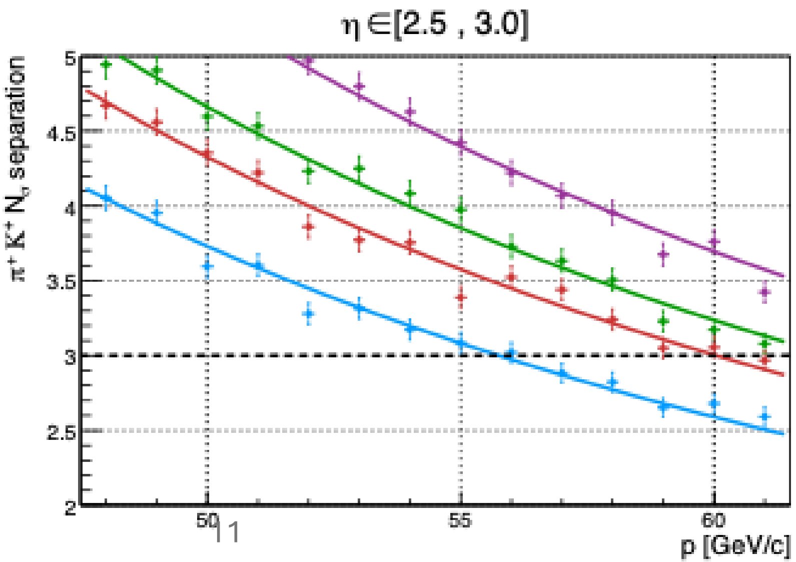


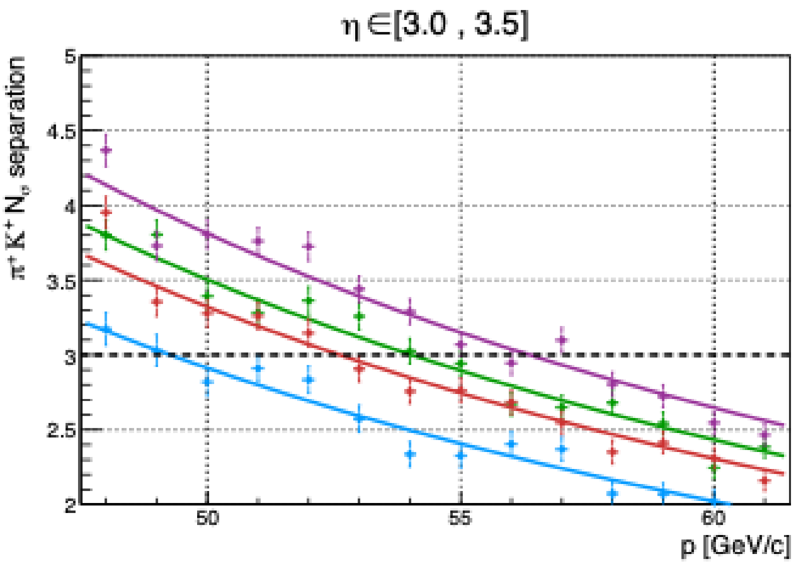


SiPMs parameters - Gas

- Real improvement in performances
  - 3.5σ in $\eta \in [2.5, 3.0]$ with 75μm
  - 3σ with 75μm separation up to 55 GeV/c







SiPMs parameters - Conclusions

- Aerogel performances, with filter, don’t change substancially with different SiPMs

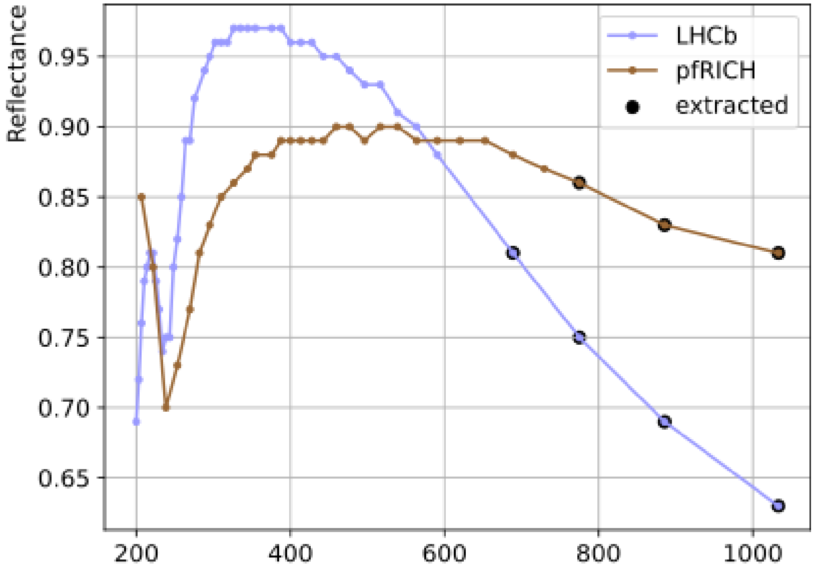
- The impact of the filters was studied

- Gas performance improve significantly with higher PDE SiPMs

dRICH performance with different mirrors

Different reflectance curves were tested

- Default configuration: ref=0.90
- One of the **LHCb** mirrors
- One **pfRICH** mirror prototype



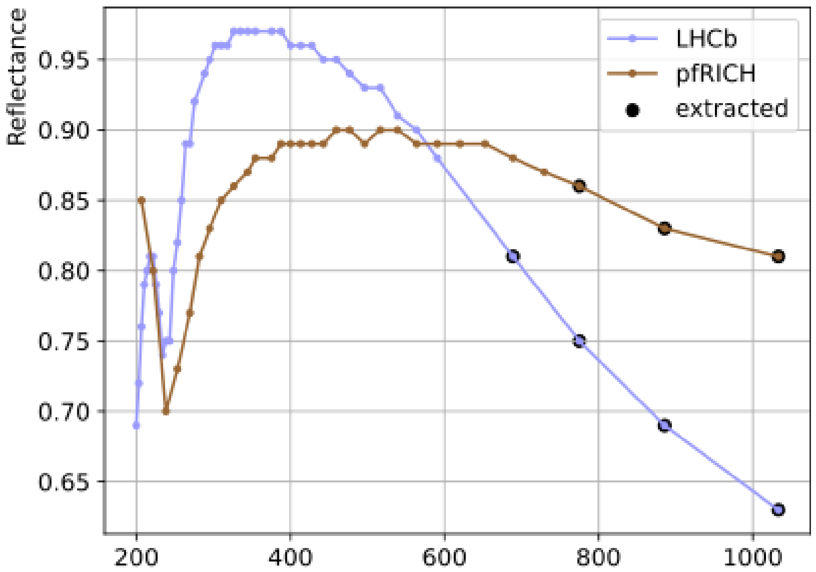
reflectance curves for different SiPMs

Mirror parameters - pfRICH

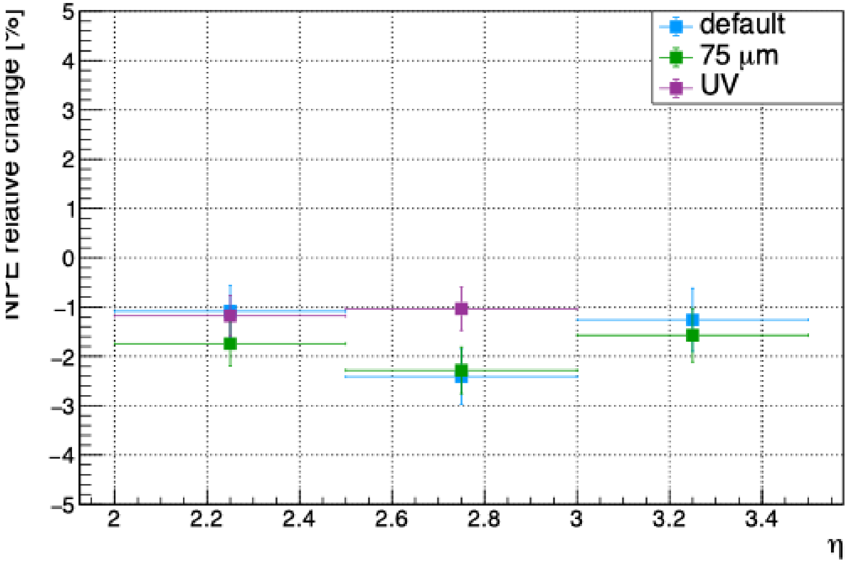
Loss in NPE at the percent level

- Bigger in gas because of the drop under 300nm
- In aerogel these photons are absorbed by the filter

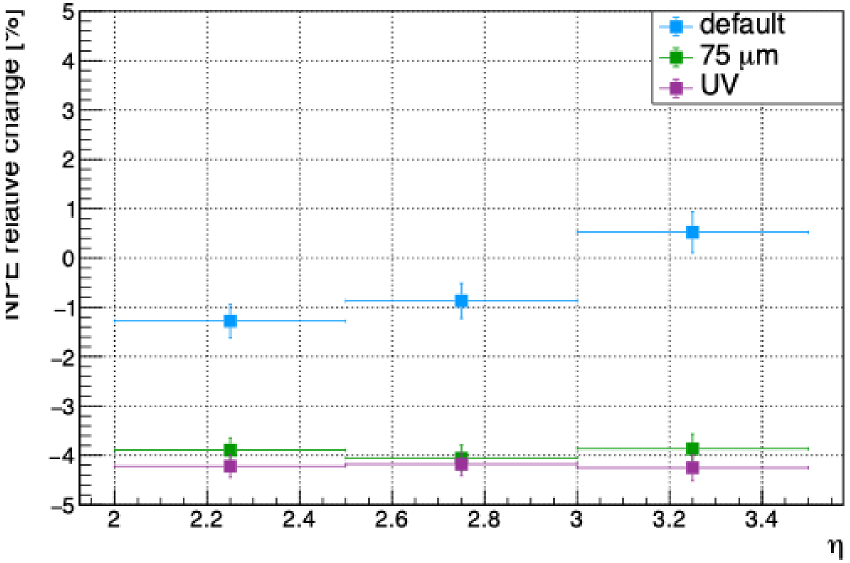
- X relative change $= \dfrac{X_{\mathrm{pfRICH}} - X_{0.9}}{X_{0.9}}$



Aerogel



Gas

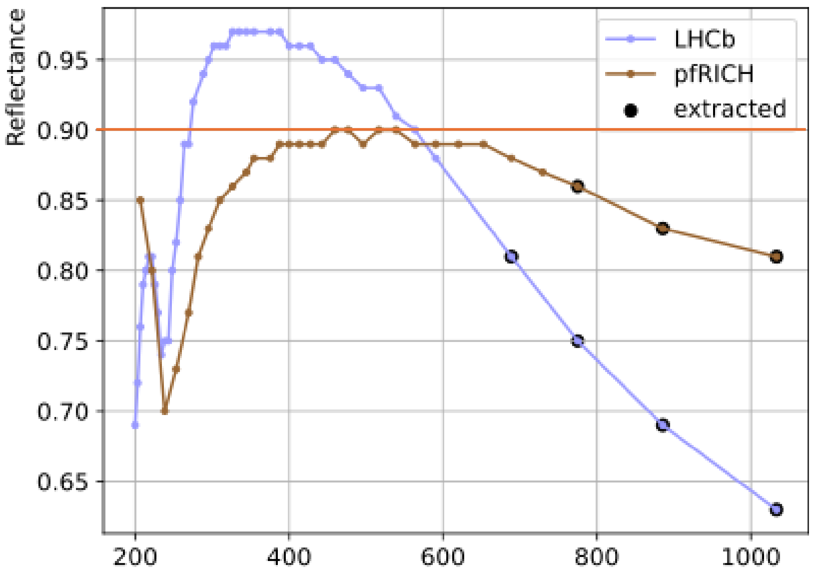


Mirror parameters - LHCb

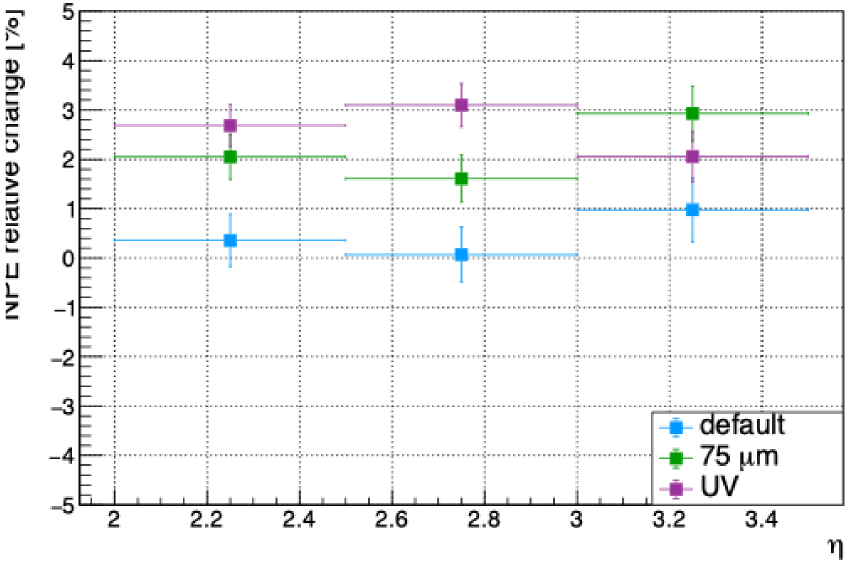
Improvement in NPE at the percent level

Lower for the gas

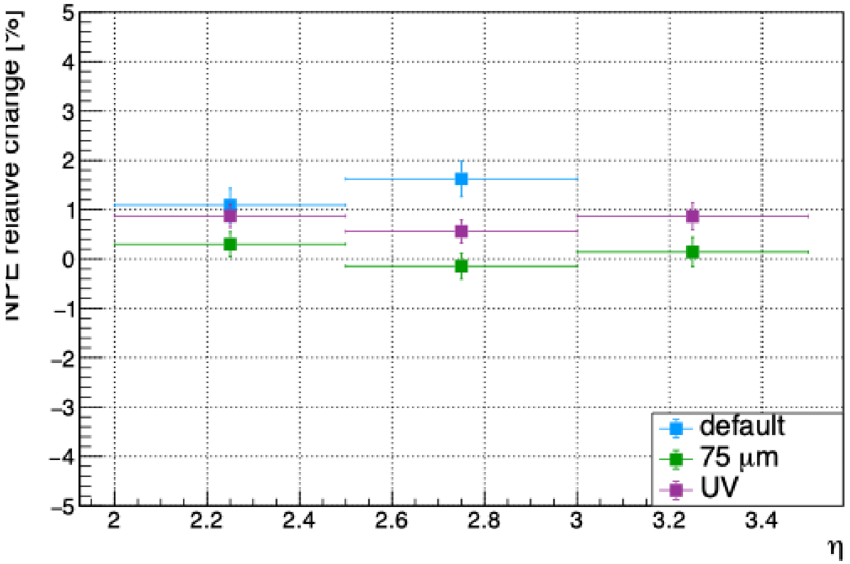
- gain in 300nm – 600nm
- Loss under 300nm
- For the aerogel the photons under 300nm are absorbed in the filter



Aerogel



Gas

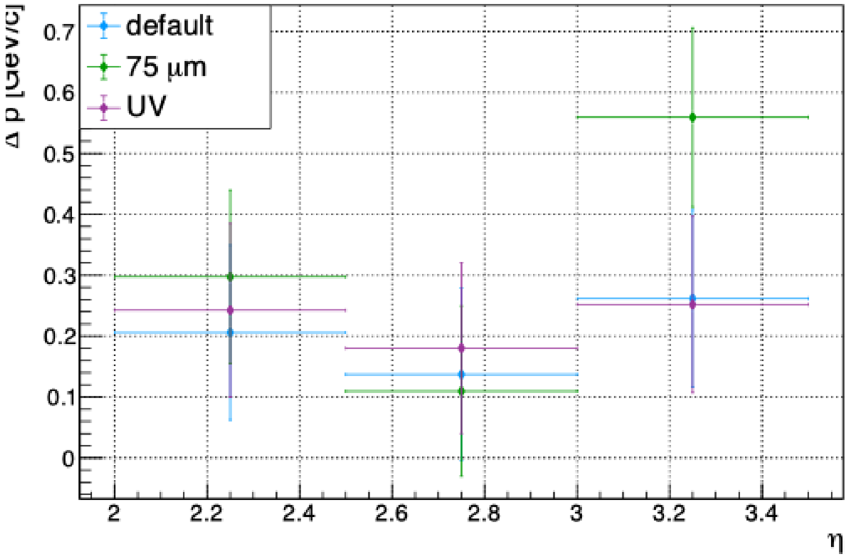


Mirror parameters - LHCb

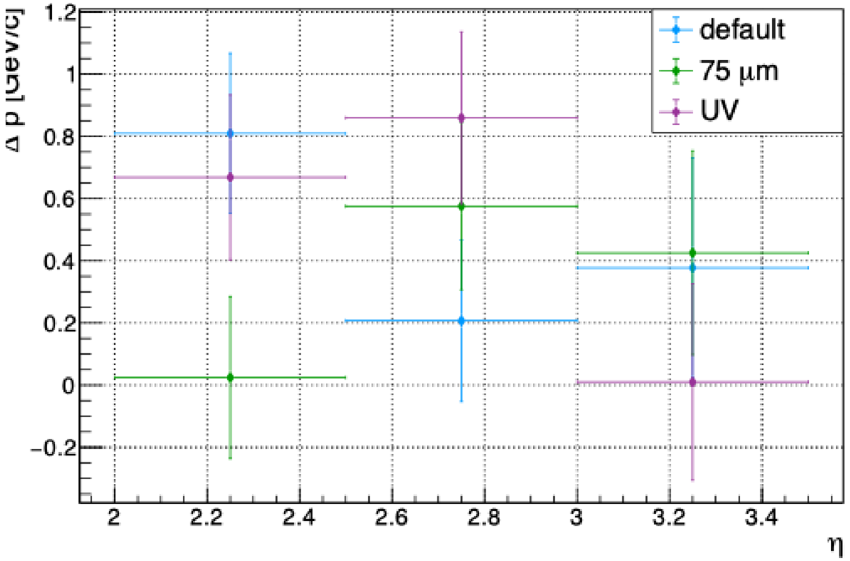
Difference in 3σ upper limit is of the order of hundreds of MeV/c

$$\Delta p = p_{3\sigma,\mathrm{LHCb}} - p_{3\sigma,0.9}$$

Aerogel



Gas



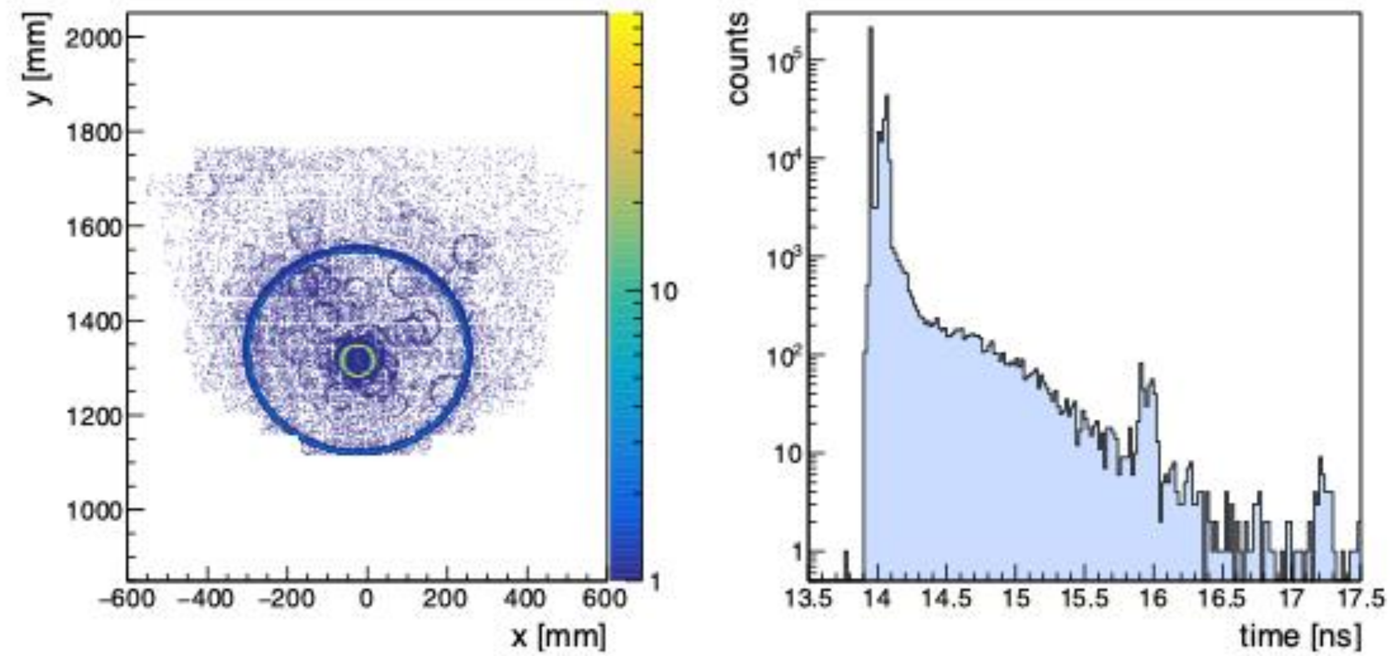
mirror parameters - Conclusions

- Ref 0.9 is a reasonable approximation of the mirror parameters

dRICH time response

Objective: study the time distribution of the dRICH

Hitmap and time distribution is a specific case

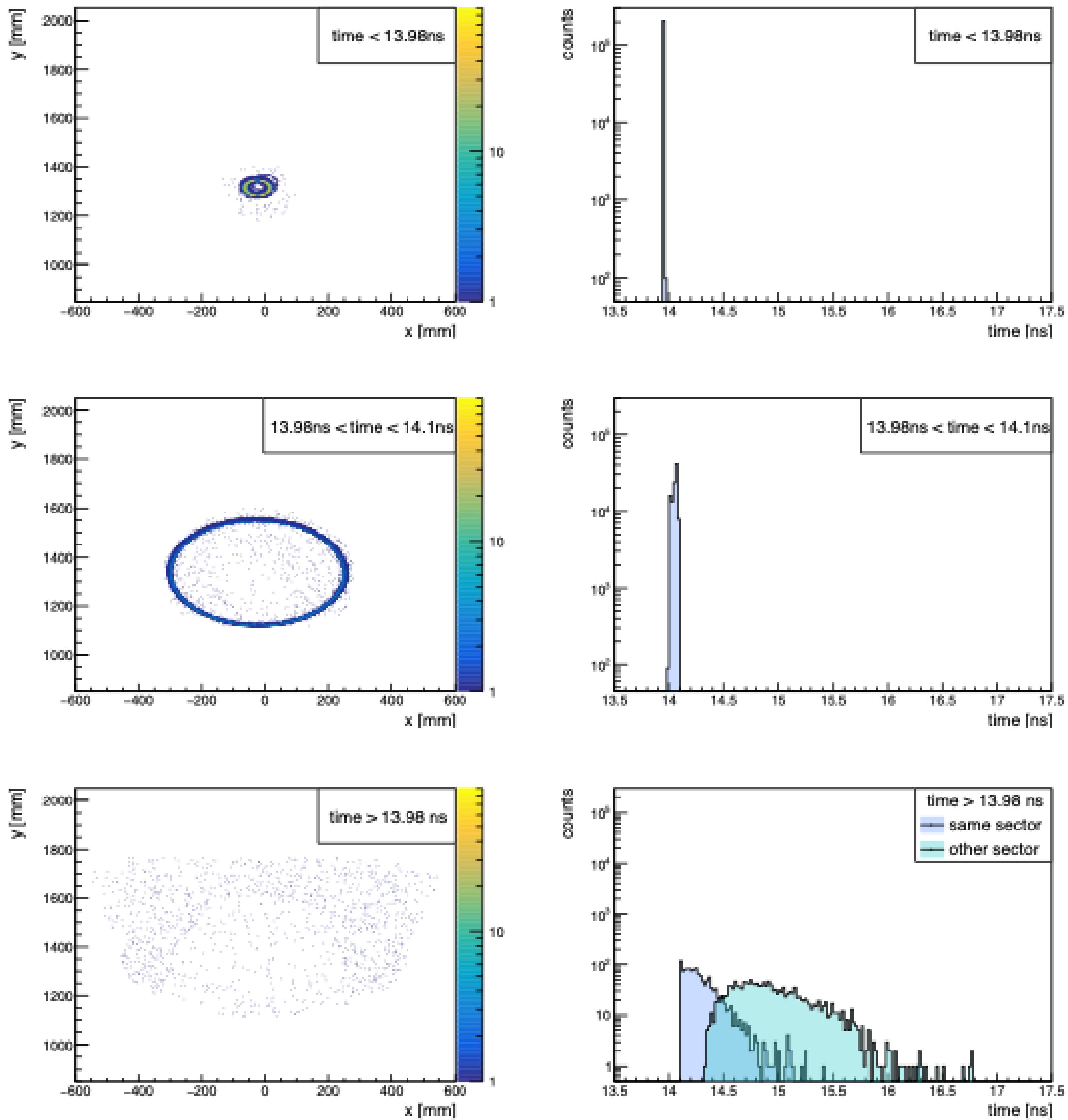


Pions, 11GeV/c, η=2.0, fixed Φ

dRICH time response

Filtering in time three components are identified

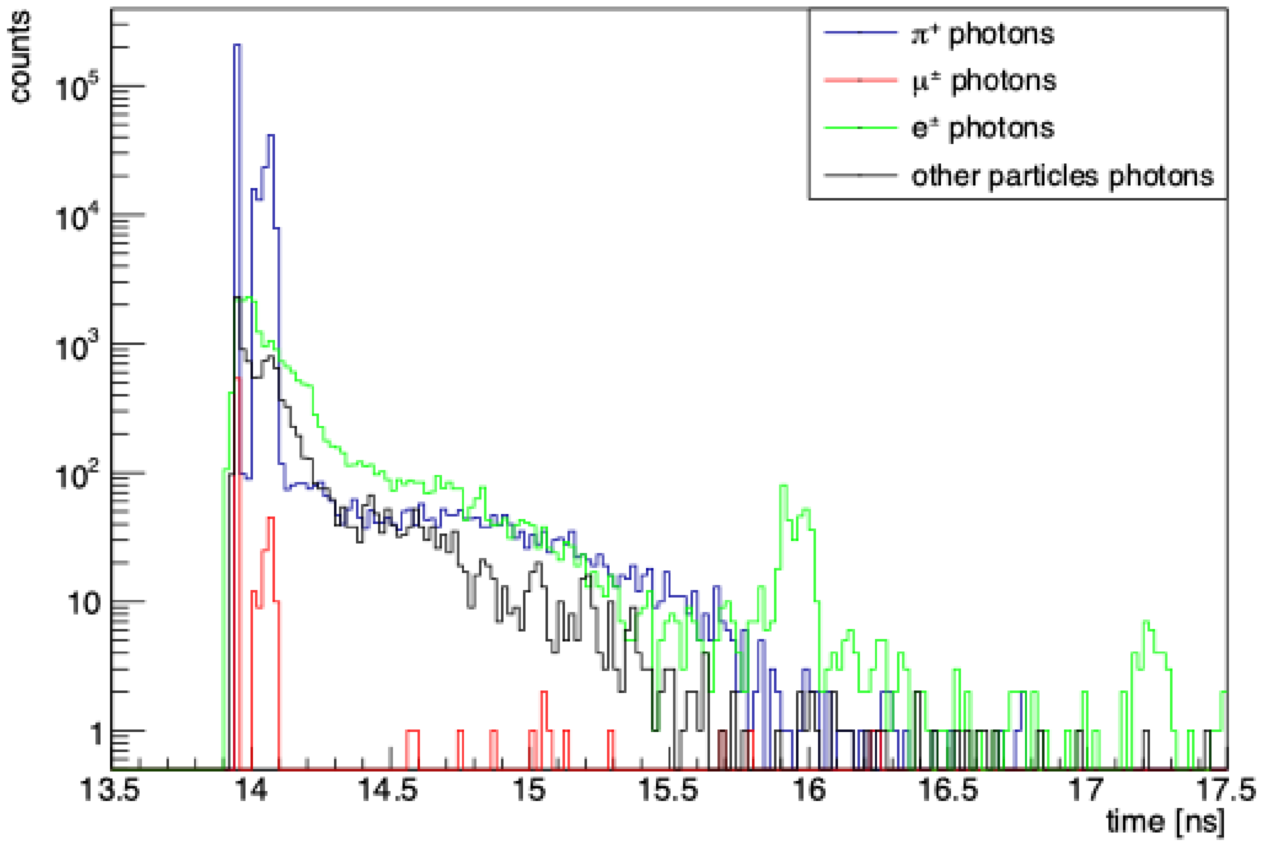
- Gas ring
  - First peak, photons emitted in gas travel less
- Aerogel ring
  - Second peak
- Scattered photons
  - Tail at longer times
  - The photons which goes to other sectors even longer times

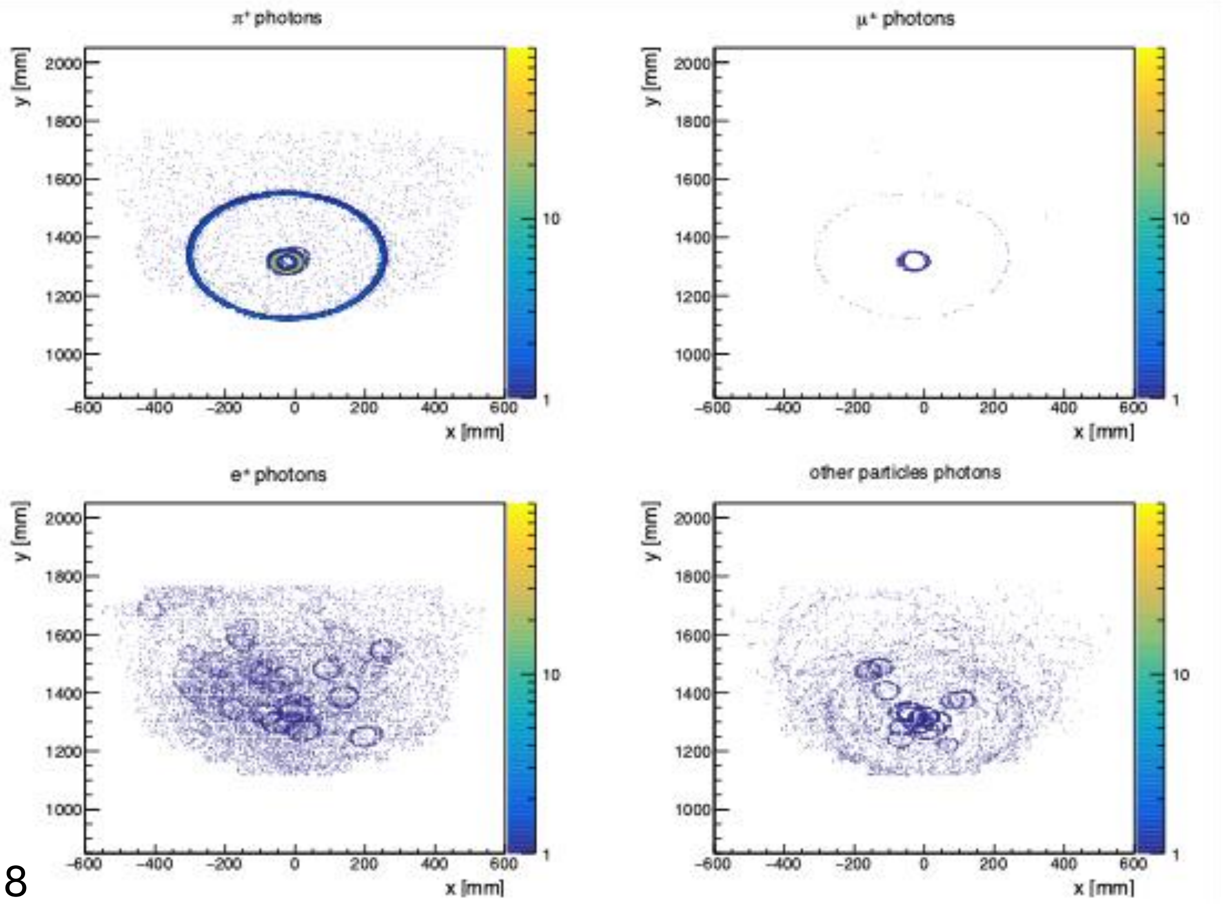


dRICH time response

Using MC information

- Most of the photons are emitted by pions
- Large background from electrons
- Other particles are there



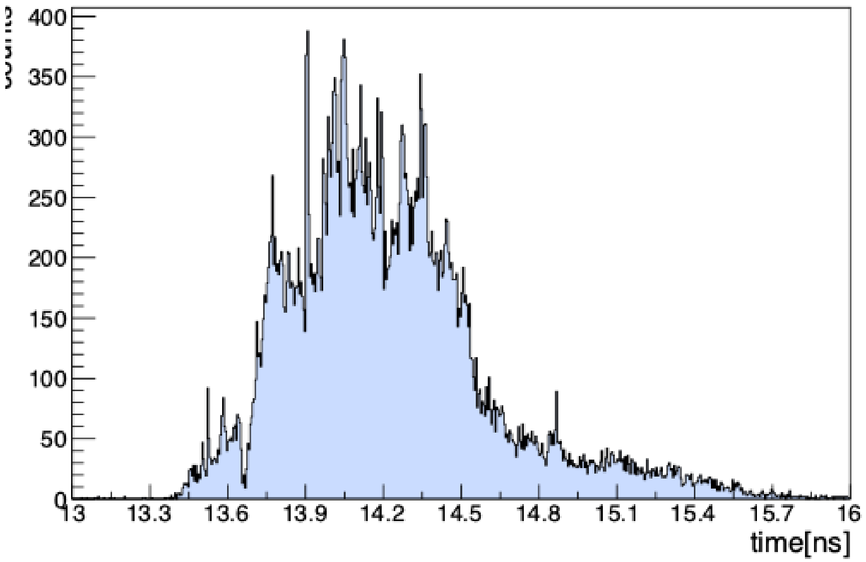


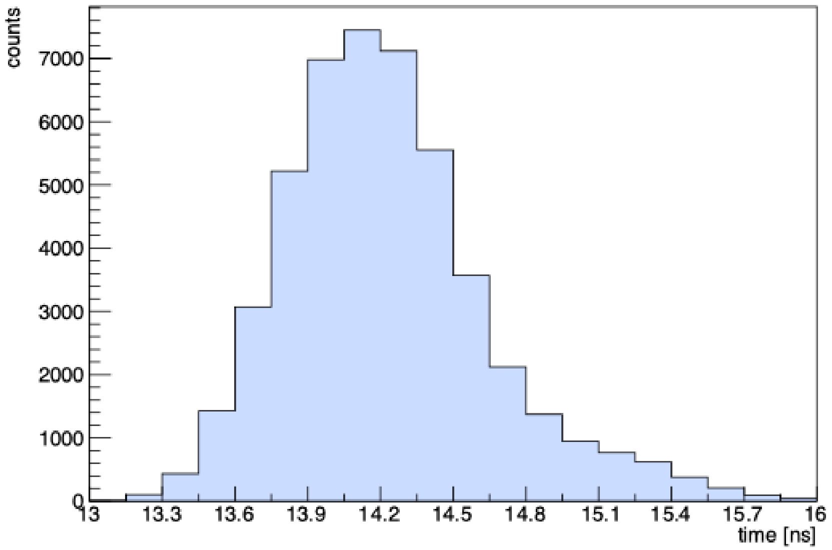
dRICH time response

Time window to collect a whole event: 3ns

p – e^- collsision

- Pythia8
- Convoluted with gaussian σ = 150ps



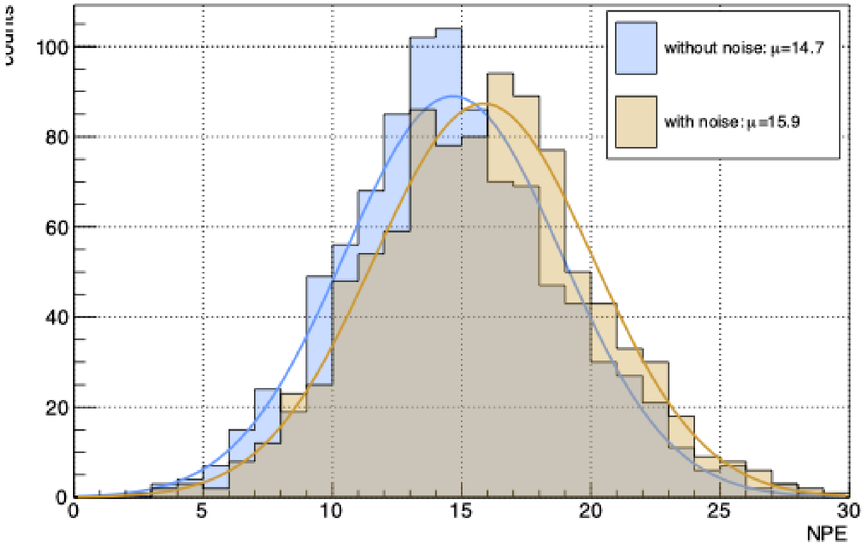


dRICH time response - DCR

We can estimate the impact of Dark count rates of the SiPMs in the dRICH

- Maximum DCR expected 300kHz / (event*pixel)
- Important for the aerogel performances

  It is bigger and less populted

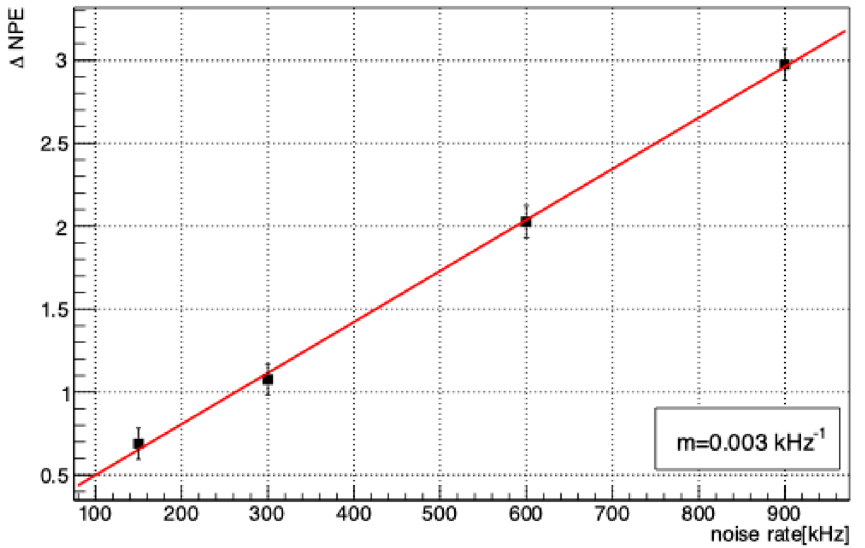


Pions at 15GeV/c, $\eta = 2.0$, all Φ

- Dark count hits are digitized and added at the recontruction level
  - Uniform on the detector surface
  - $\Delta NPE = (NPE_{w/\ noise} - NPE_{wo\ noise})$

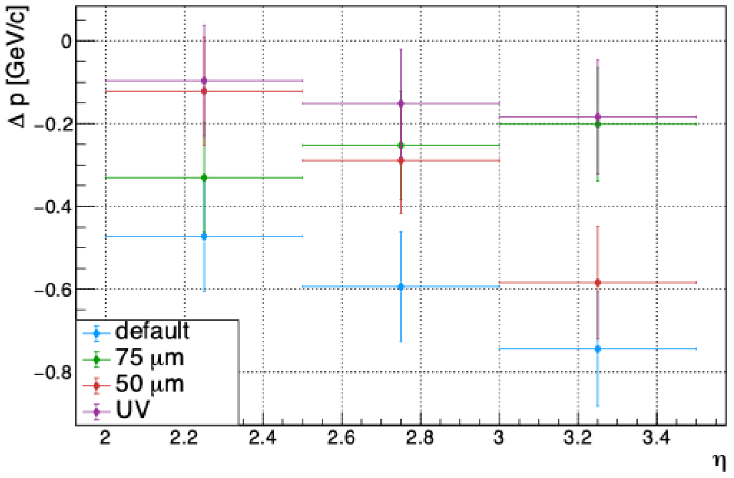
    Matches expectations

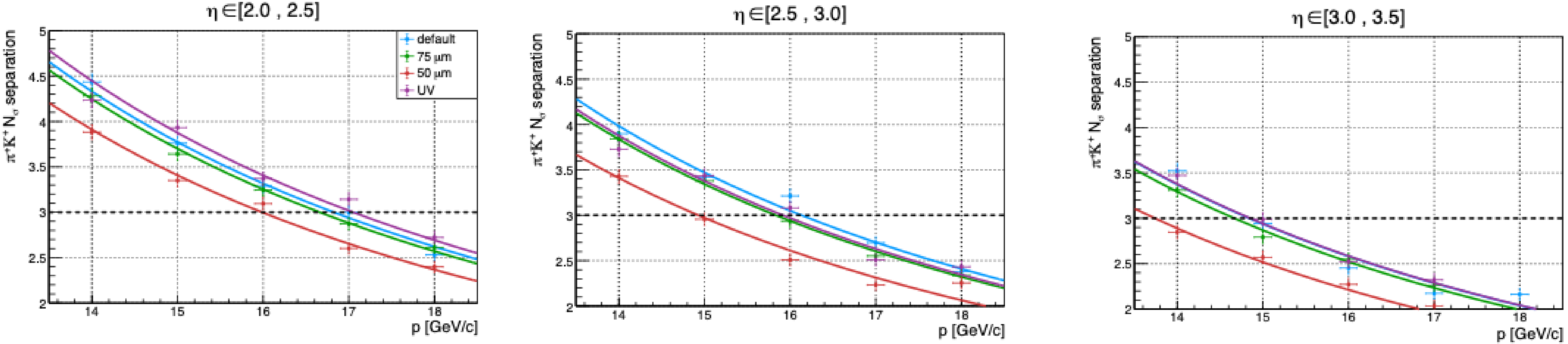
    Linear with DCR



dRICH time response - impact of noise

- Right: loss in 3σ π-k separation
    - UV and 75μm SiPMs are robust
    - Default suffer the most because of lower NPE
- Bottom: N_σ π-k separation curve with noise
    - 50μm is the less performative for our scopes
    - 75μm and UV compatible with the default SiPMs





dRICH time response - conclusions

- dRICH time response understood
- time windows per event needed: 3ns
- Impact of dark count rate estimated and resulted tollerable

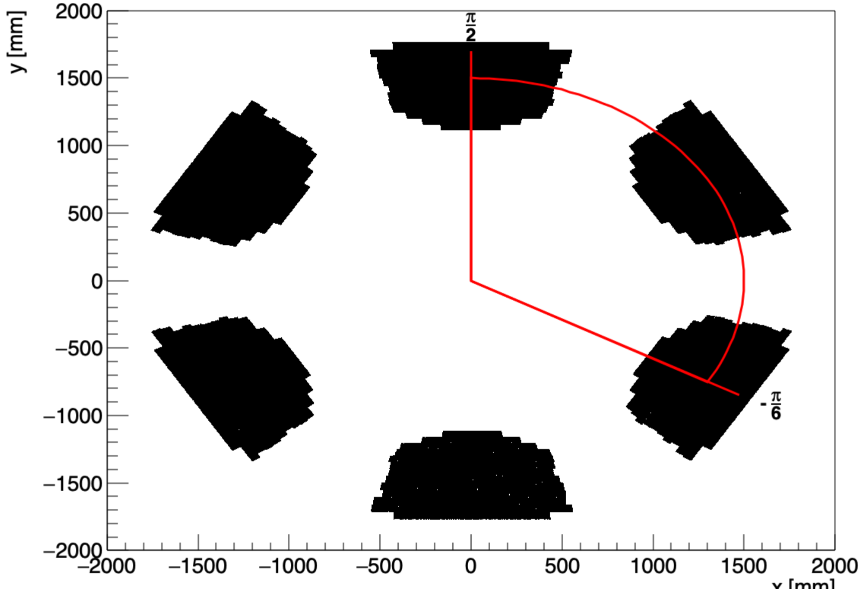
dRICH lower limit

Objective : determine the effective lower limit for PID of the dRICH

- At which momentum we detect enough photons to positivly identify a pion?

- It depends on geometry
  - Pions lunched over $(\Phi, \eta) \in \left[-\frac{\pi}{6}, \frac{\pi}{2}\right] \mathrm{x} \left[1.9, 3.3\right]$

- Physical threshold p ~ 0.6 GeV/c, (NPE=0)
  - Momentum range studied $p \in [0.8, 2.5]$ GeV/c

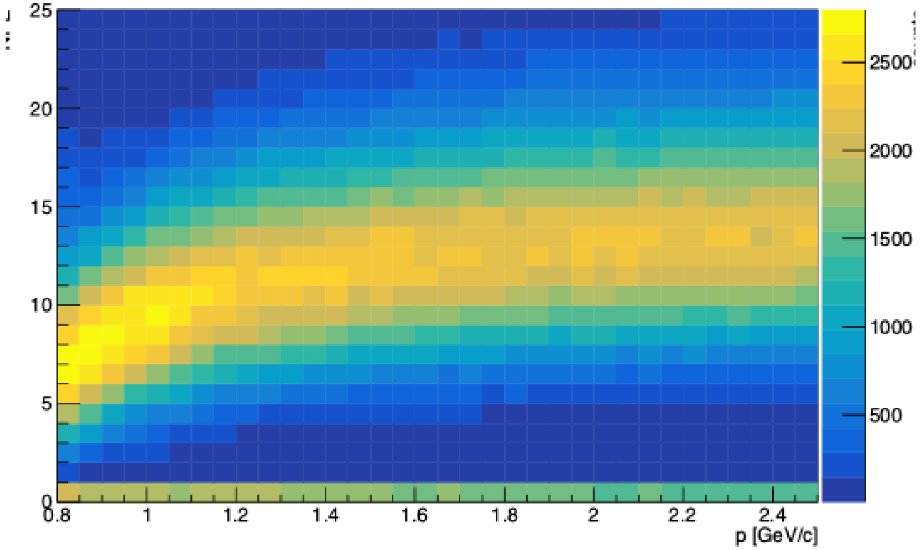


dRICH lower limit

Frank Tamm curve at low momentum

5% - 10% of the events have 0 reconstructed photons

- IRT2 requires at least 5 photons to reconstruct a track
- Some events are not reconstructed (efficiency of the algorithms)



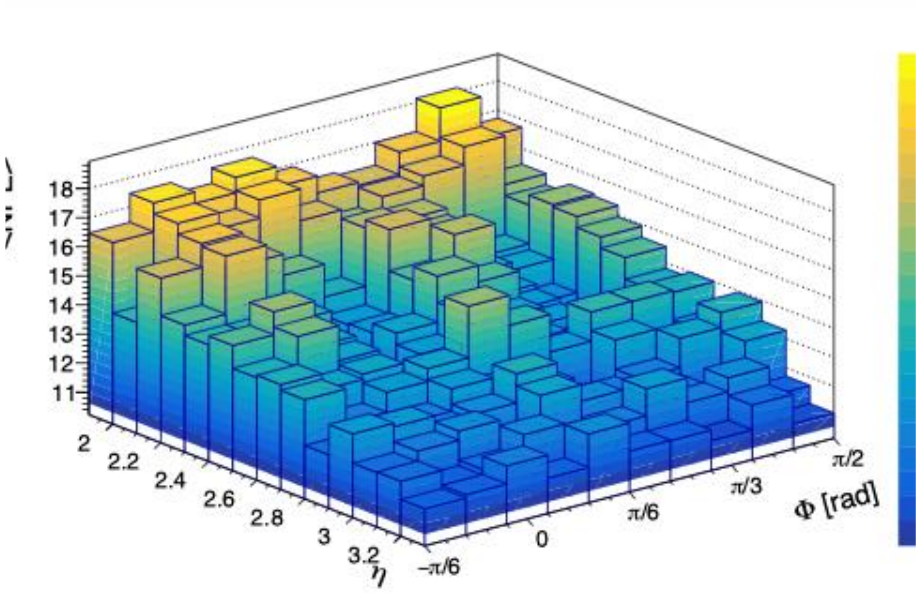
dRICH lower limit

NPE shows the geometric effects

- Peaks and valley along Φ
  - Less detected photons for trajectory between two petals
- Decrease along η
  - Part of the ring is lost

    (beam pipe and sensor acceptance)

Pions at 1.5 GeV/c



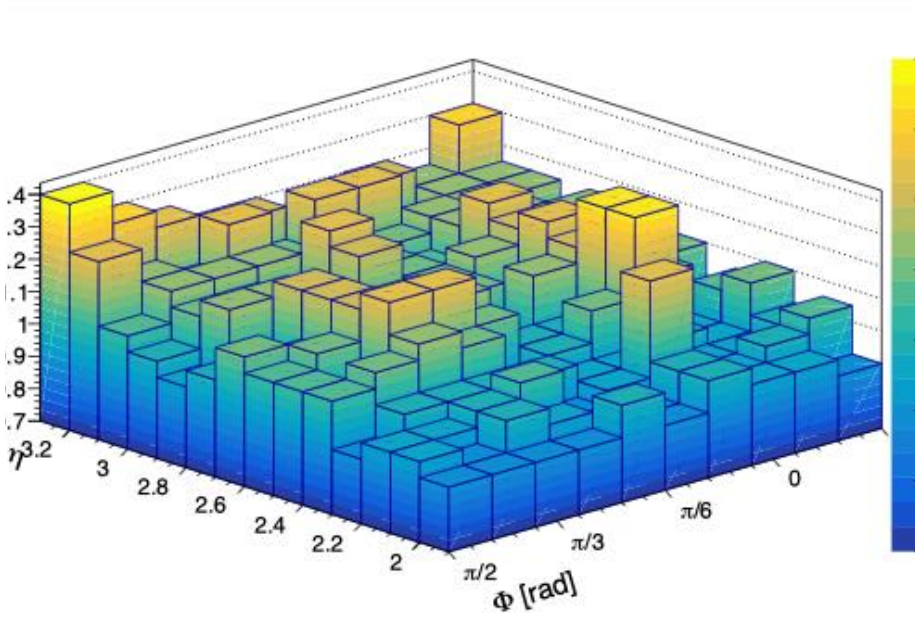
dRICH lower limit

Two threshold were studied

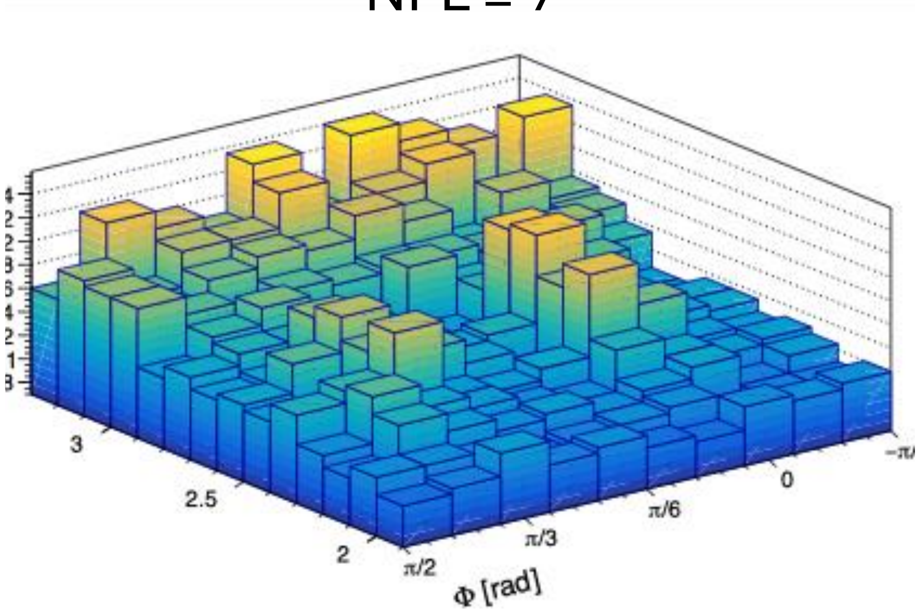
- 90% of events have reconstructed NPE ≥ 5
  - Lower limit up to ~1.3 GeV/c
- 90% of events have reconstructed NPE ≥ 7
  - Lower limit up to >2 GeV/c

- The geometrical effect is clearly visible

NPE ≥ 5



NPE ≥ 7



dRICH lowert limit - conclusions

This first study requires completion considering the background

Already without background effective PID has lower limit well above the physical threshold