Forward RICH detector for the PANDA experiment

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Talk outline

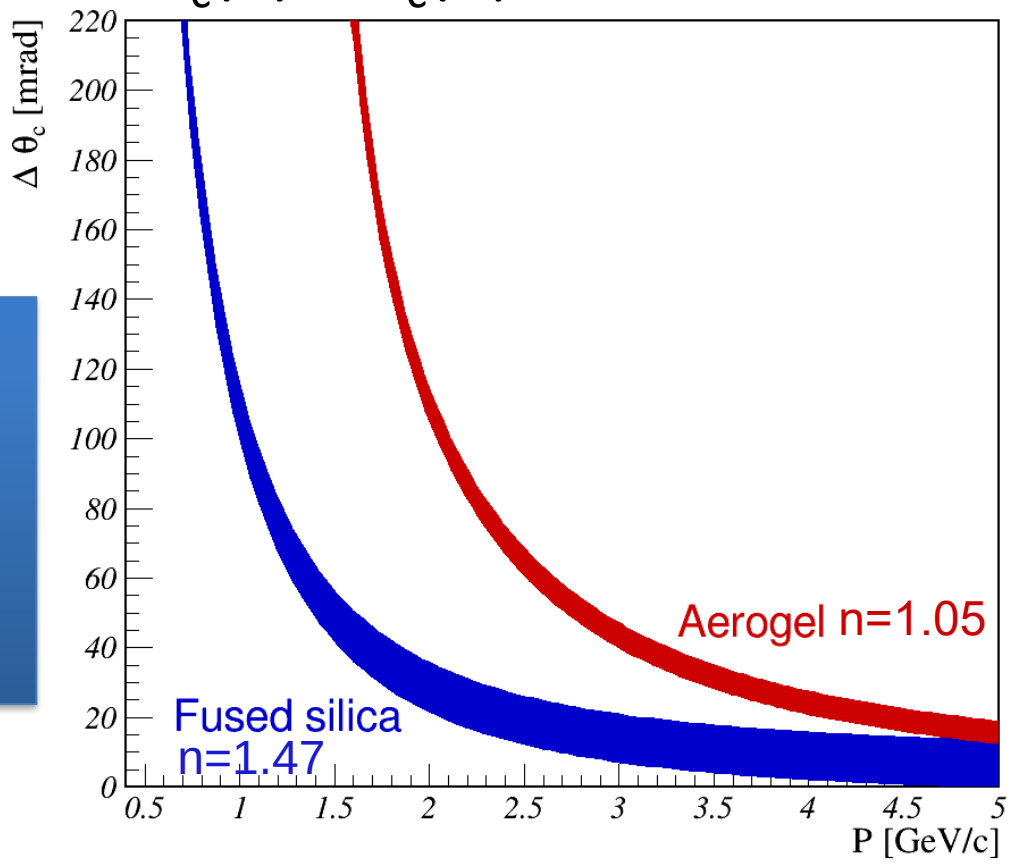
- Focusing Aerogel RICH concept
- PANDA Forward RICH design
- MC simulated performance
- Optical measurements
- Test beam 2019 results
- Conclusion & outlook

Quartz vs Aerogel as Cherenkov Radiator in a RICH detector

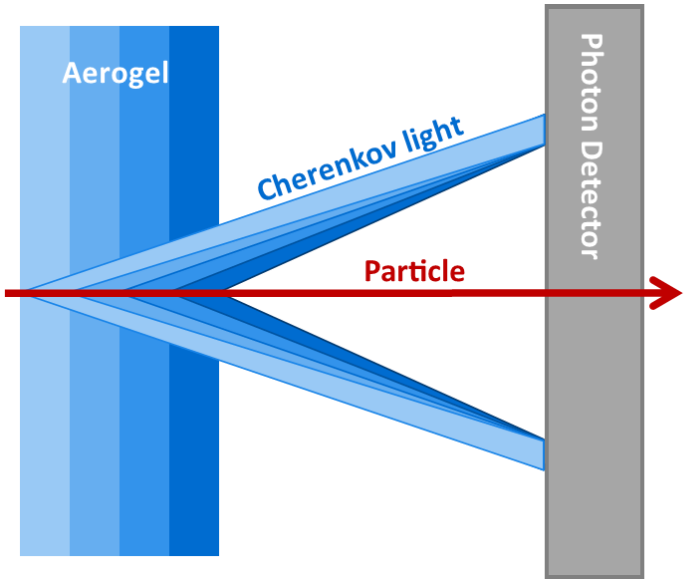
Band width correspond to the chromatic dispersion of refractive index in the 350-700 nm wavelength range

Aerogel has much larger Cherenkov angle difference and less chromatic dispersion than Fused silica → **Higher momentum PID coverage**

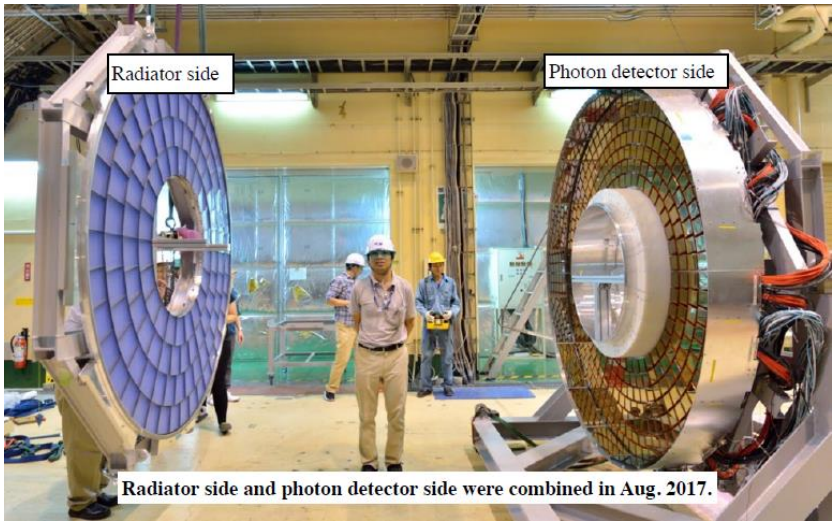
$\theta_c(K) - \theta_c(\pi)$ vs momentum



Focusing Aerogel RICH (FARICH) idea



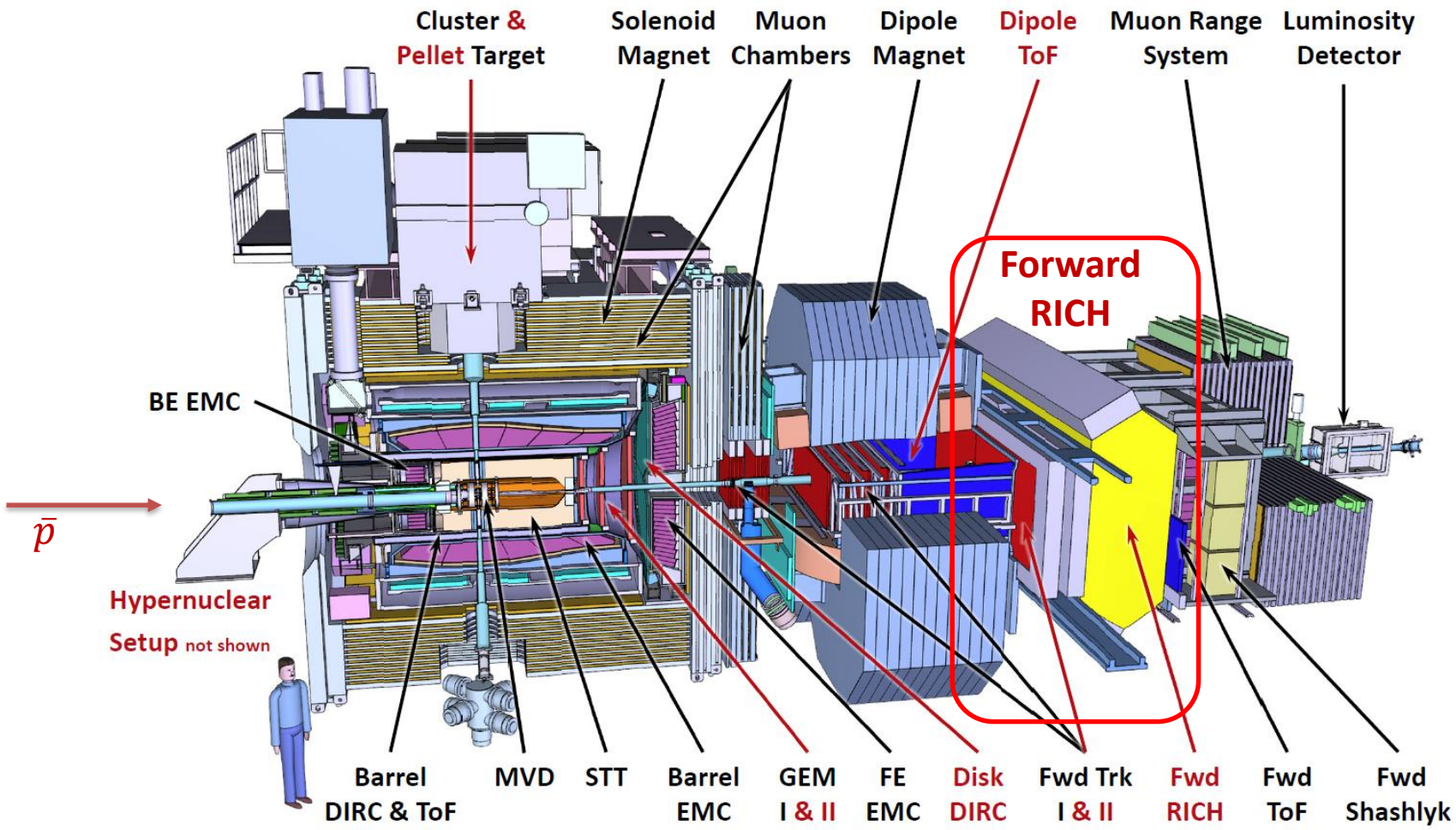
First real-life application in Belle2 ARICH



T.Iijima et al., NIM A548 (2005) 383
A.Yu.Barnyakov et al., NIM A553 (2005) 70

PANDA Detector

Day-1 & Full setups

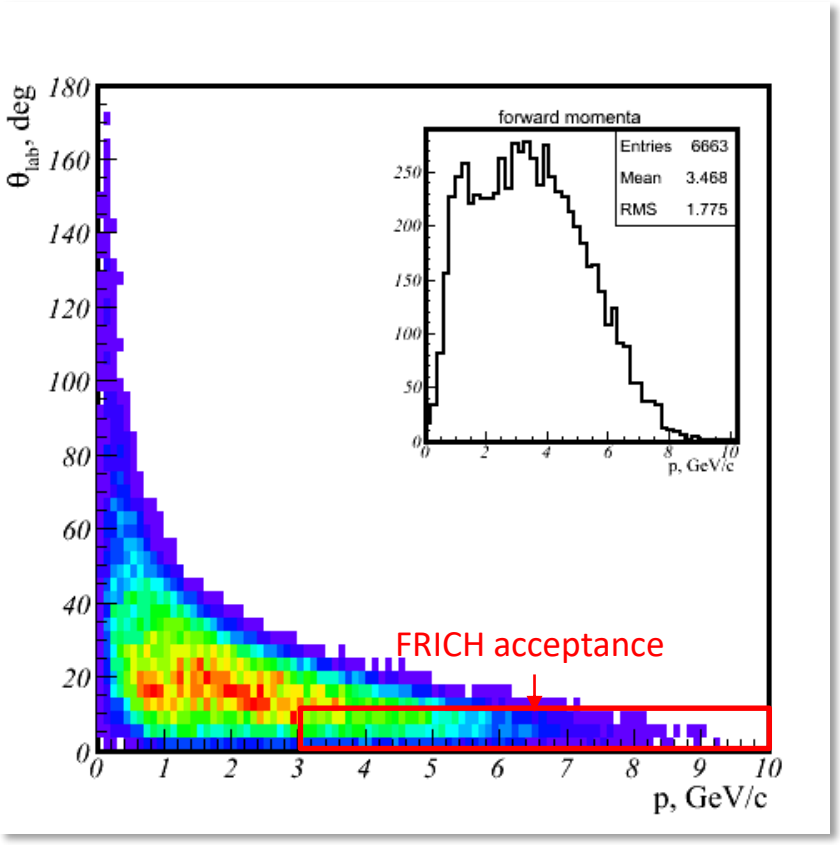


Parameters of the PANDA Forward RICH

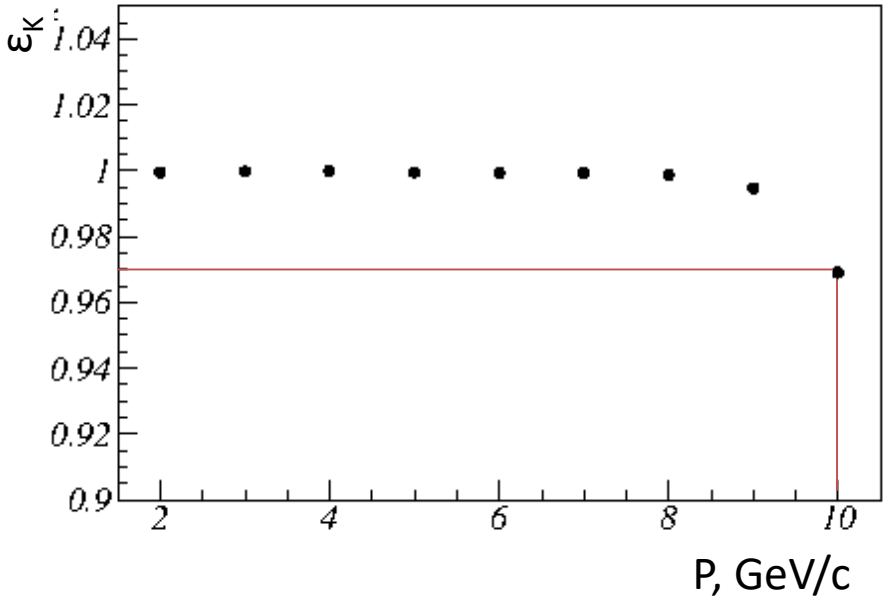
- **Purpose:** Charged PID in the Forward Spectrometer
- **Acceptance:** $|\theta_X| < 10°$, $|\theta_Y| < 5°$
- **Dimensions:** 3m (X) x 1m (Y) x 0.8m (Z)
- **Expected material budget:** $\leq 10\%\ X_0$
- **Expected PID performance:**
  - 3 s.d. π/K separation: $P = 2 \div 10$ GeV/c
  - 3 s.d. μ/π separation: $P = 0.5 \div 2$ GeV/c (complementing the Muon System)
- **Physics cases:** processes with high charged hadrons multiplicity in the final states for high beam momenta

Forward RICH PID MC performance

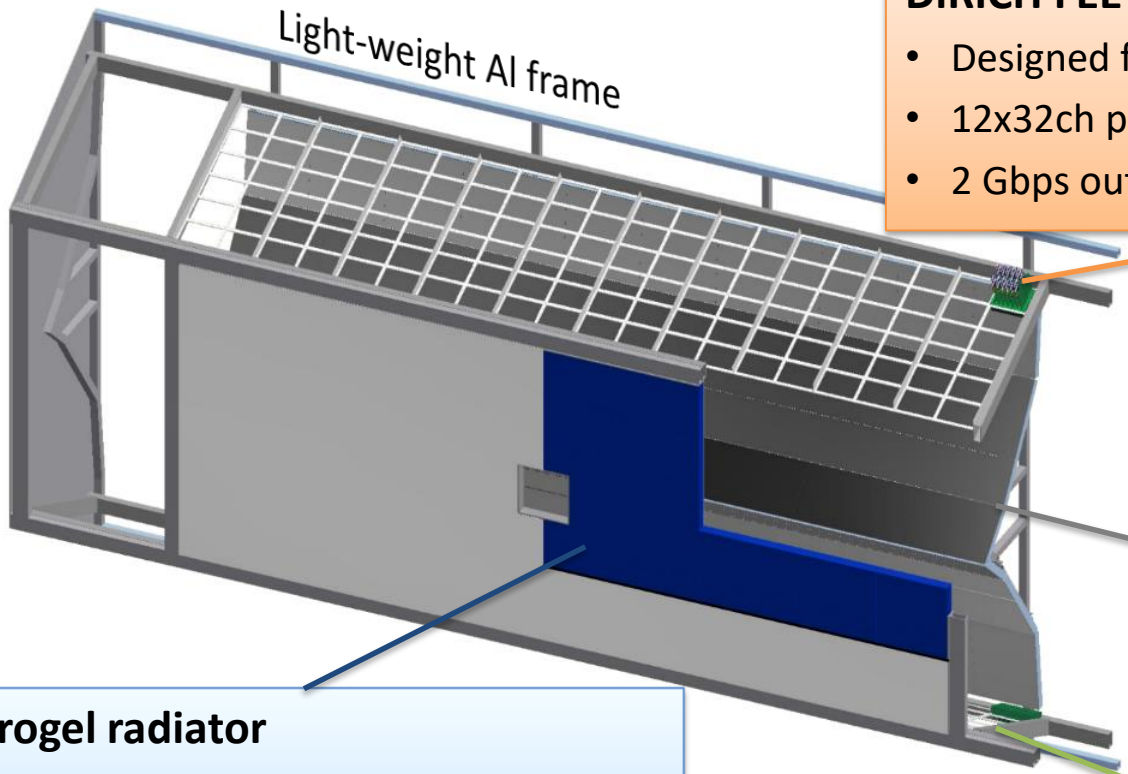
π, K from $p\bar{p} \rightarrow D^0 \bar{D}^{*0} \eta$ at $P_{\bar{p}} = 15$ GeV/c



K identification efficiency at
1% π misidentification rate



PANDA Forward RICH



DiRICH FEE (GSI)

- Designed for H12700 readout
- 12x32ch preamp+disc+TDC
- 2 Gbps output link

Mirrors

- Flat
- 2 mm float glass
- Al+SiO_2 coating

Aerogel radiator

- Focusing 2- or 3-layer aerogel
- n≈1.05
- 3 x 1 m^2 area
- 40 mm thickness

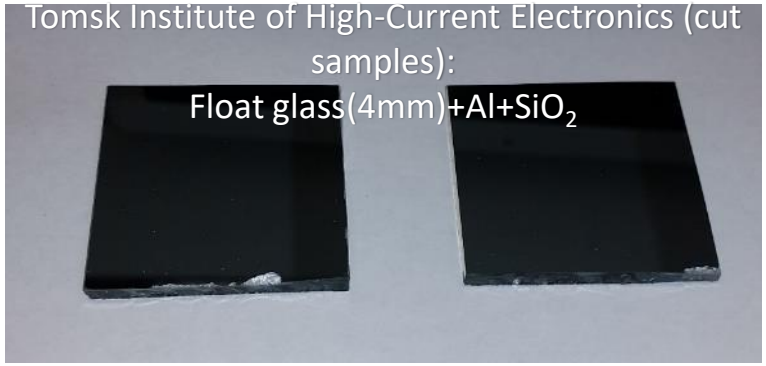
Photon Detector

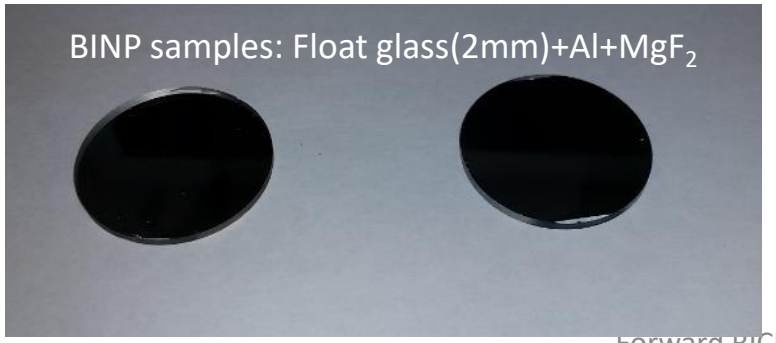
H12700 MaPMTs (Hamamatsu), 1400 pcs

- flat panel
- 87% active/total area ratio
- 8x8 anode pixels of 6mm size

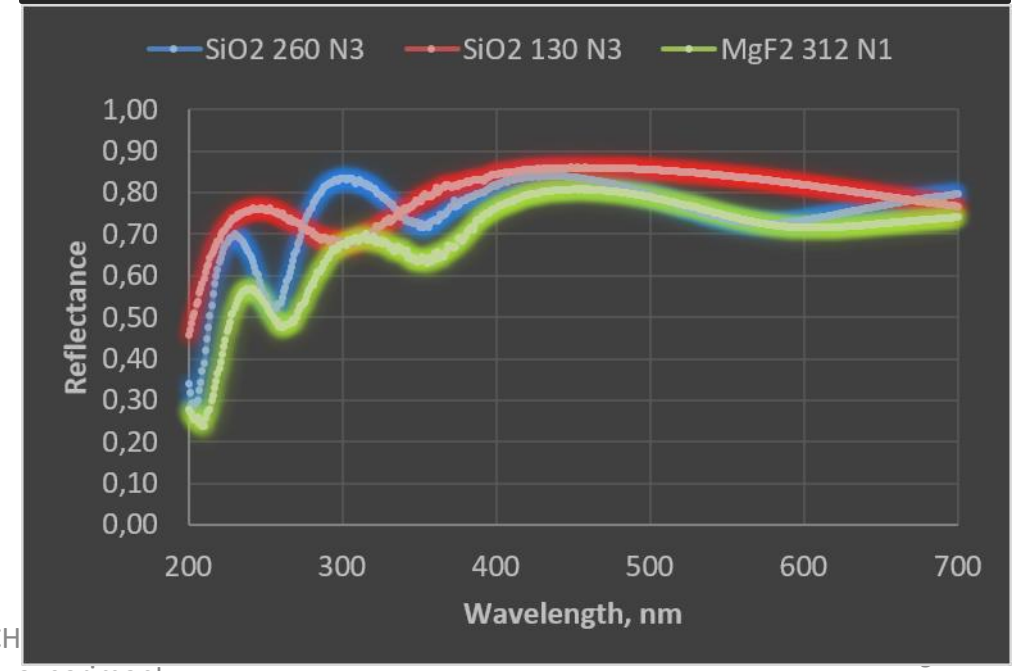
Mirror study

- Main option chosen after review of technologies: float glass with Al & SiO_2 coating. Pieces of 300x420 mm^2 can be produced in Tomsk
- A few µm flatness – quite good
- Reflectance is measured for several samples as a function of wavelength and angle of incidence





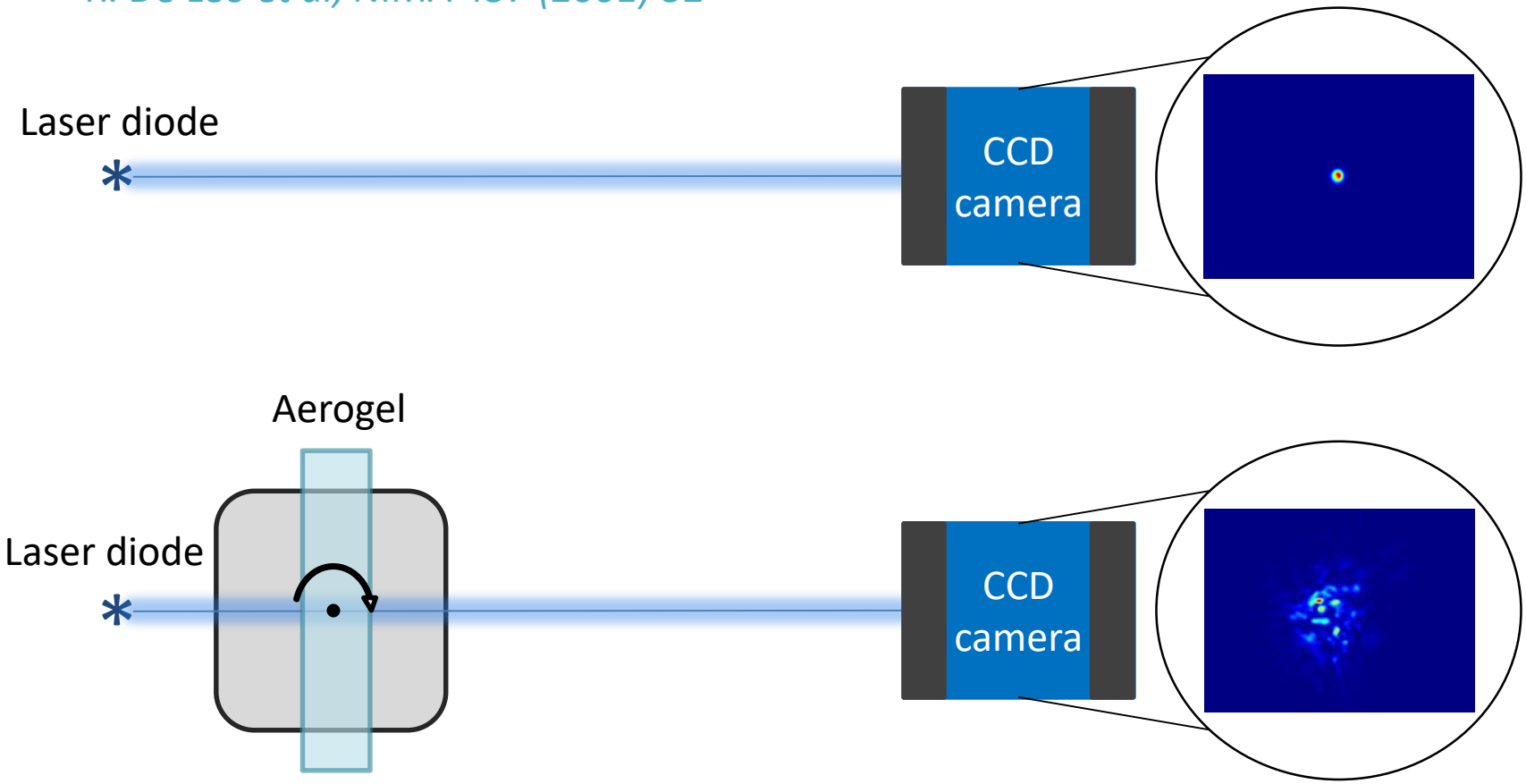
Absolute mirror reflectance measured with a monochromator and a specialized adapter



Light forward scattering in aerogel (1)

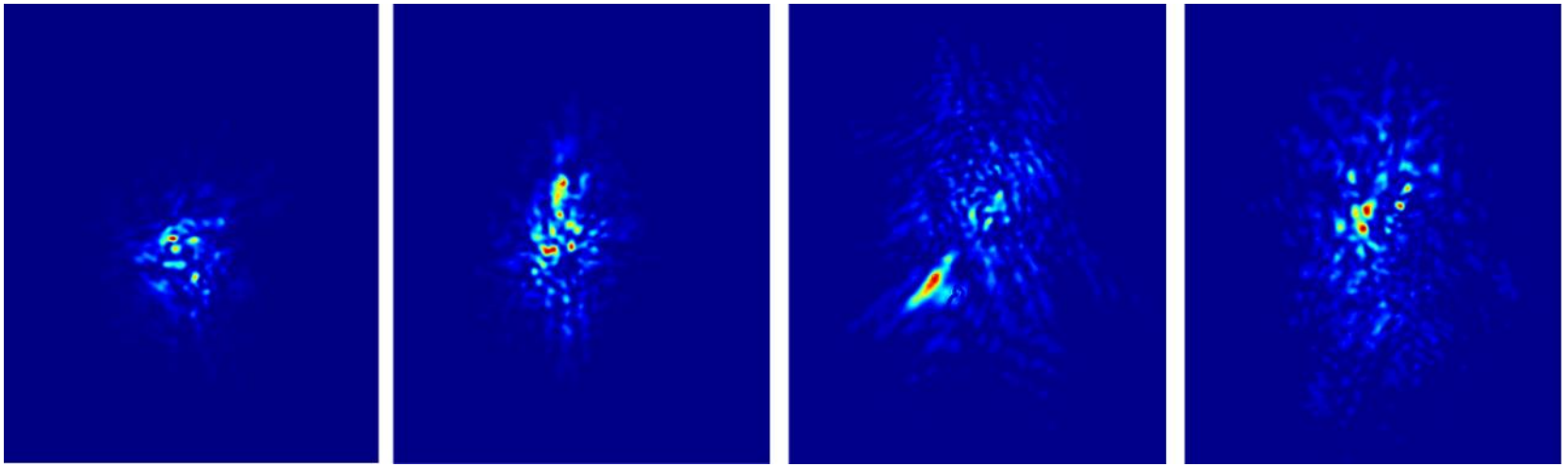
Forward scattering is known to contribute to the Cherenkov angle resolution in an aerogel RICH

R. De Leo et al, NIMA 457 (2001) 52



Light forward scattering in aerogel (2)

Images of the laser beam scattered in aerogel for different path lengths

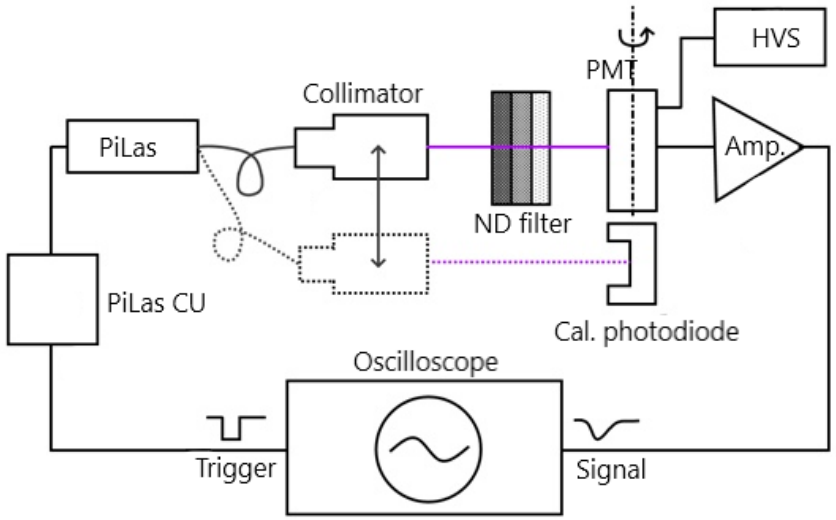


No significant dependence of the RMS scattering angle on the wavelength is found

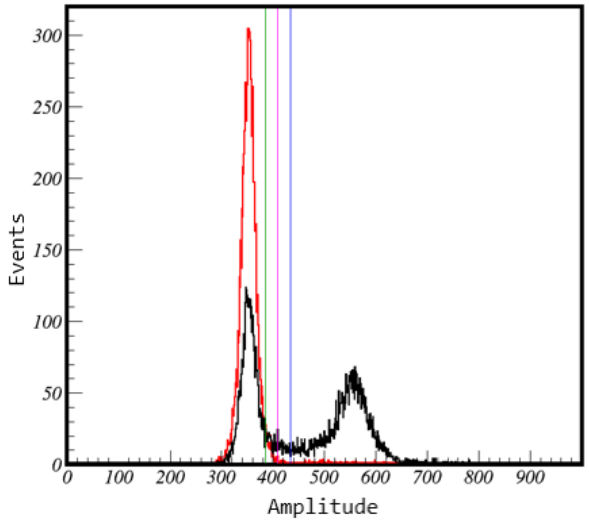
FS $\theta_{rms} \approx 1$mrad

to be compared with Forward RICH single photon resolution of 5mrad – **negligible**

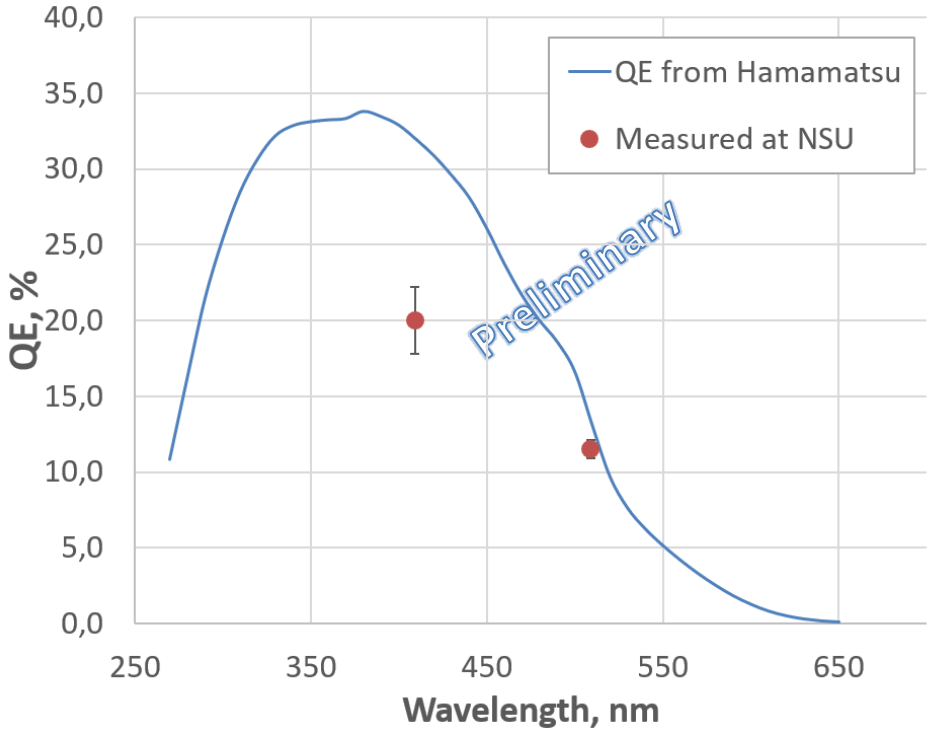
Absolute QE of MaPMT H12700



Charge amplitude spectrum

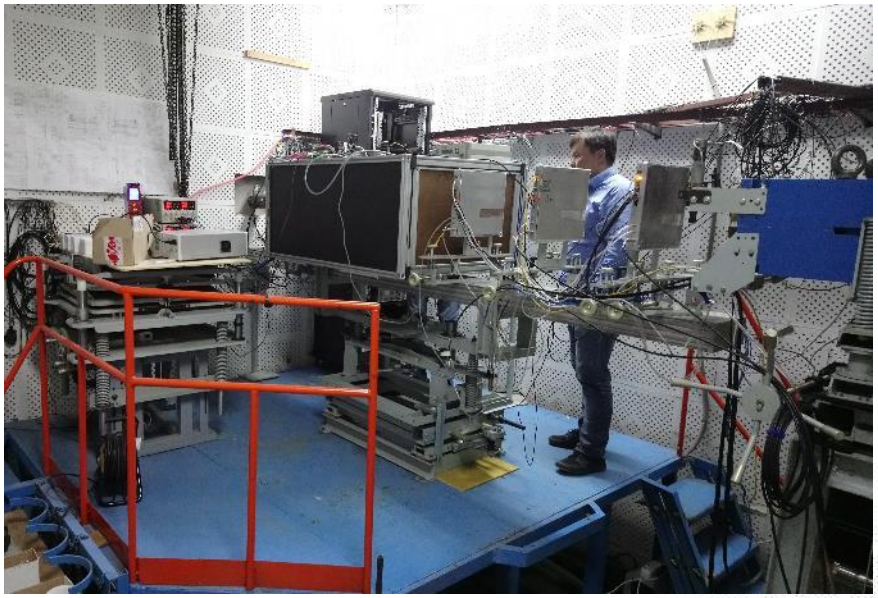


$$\mathrm{QE} = \frac{N_{\mathrm{p.e.}}}{N_\gamma} \qquad N_{\mathrm{p.e.}} = -\ln \frac{N_0^{signal}}{N_0^{noise}}$$



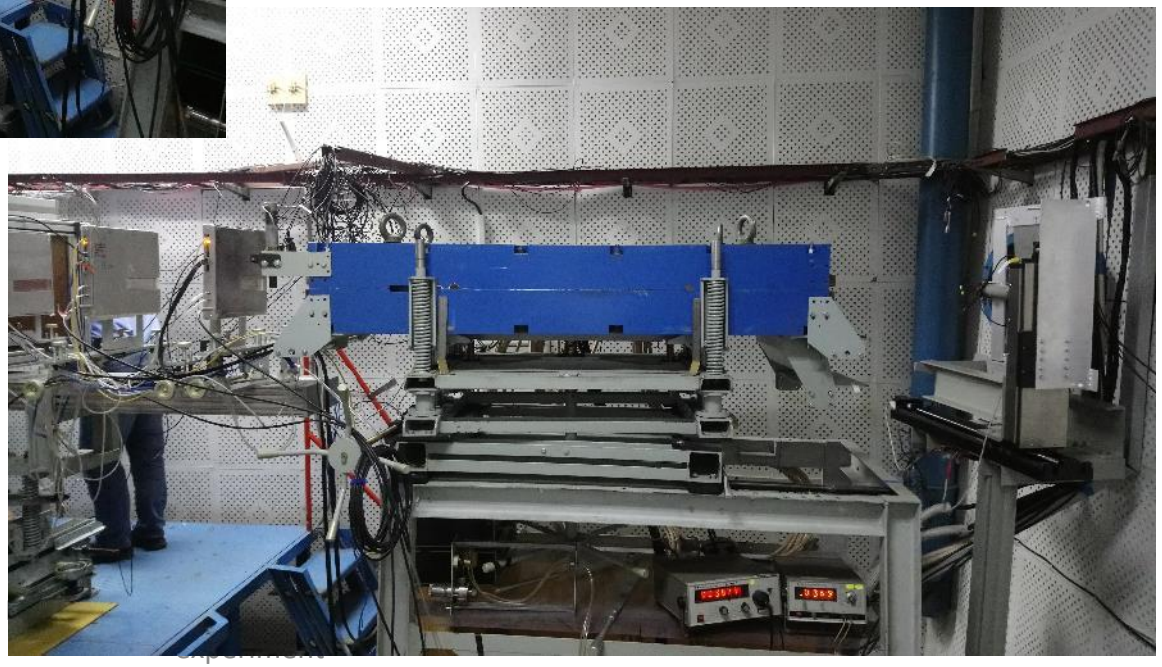
MaPMT DQE is to be measured as function of wavelength and position

Test beam in June 2019

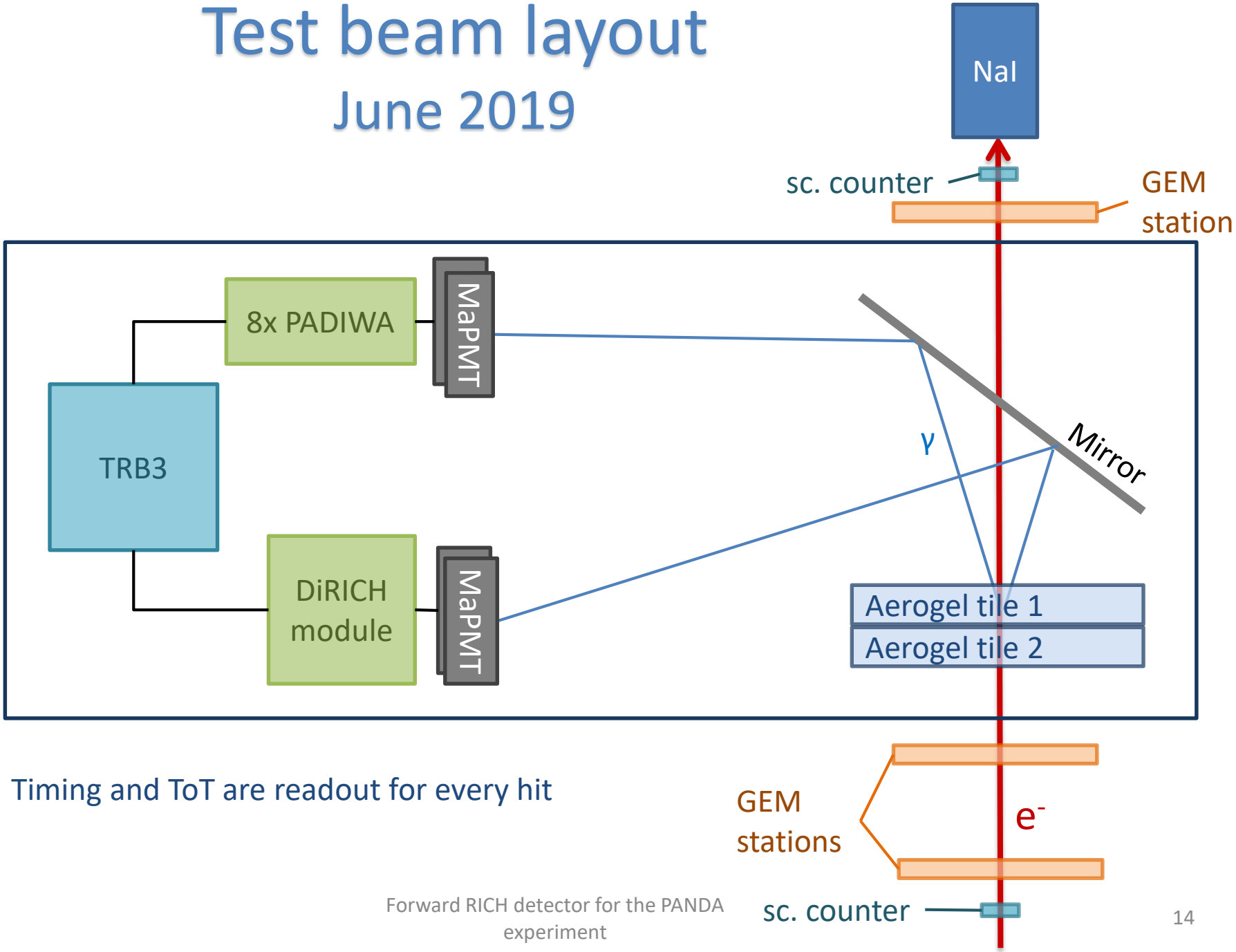


Electron and gamma test beam facility at the BINP VEPP-4M accelerator

- 3 GeV electrons
- 3 scintillation counters in coincidence for triggering
- 3 GEM with strip readout tracker stations with 70-200 μm resolution
- NaI calorimeter



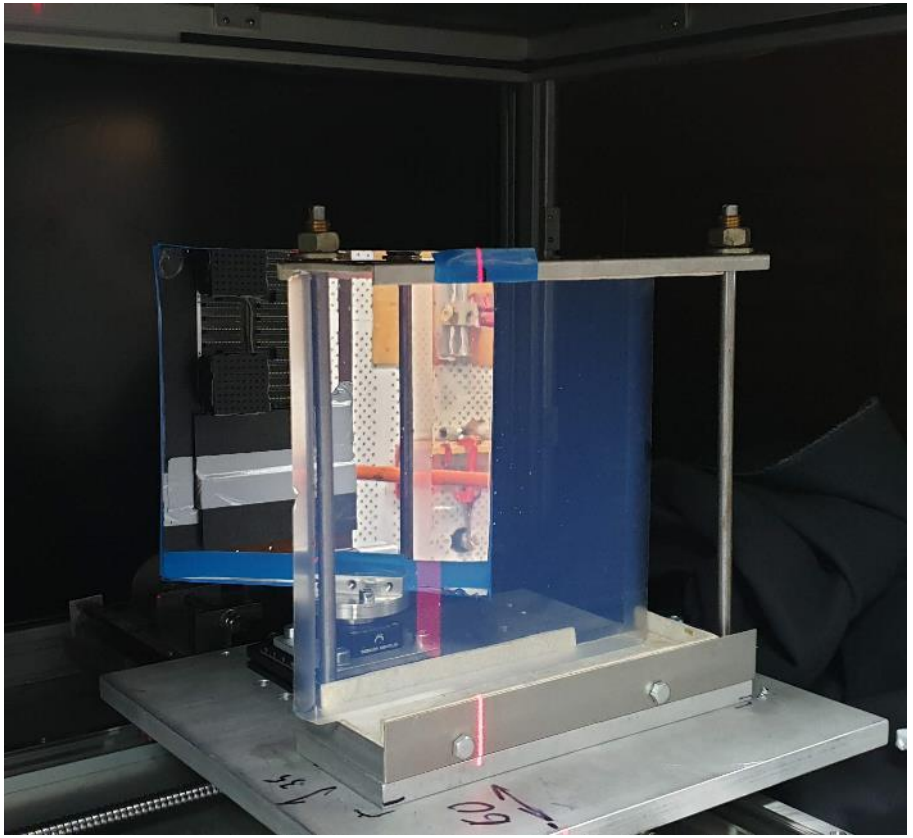
Test beam layout
June 2019



Timing and ToT are readout for every hit

Forward RICH prototype
June 2019

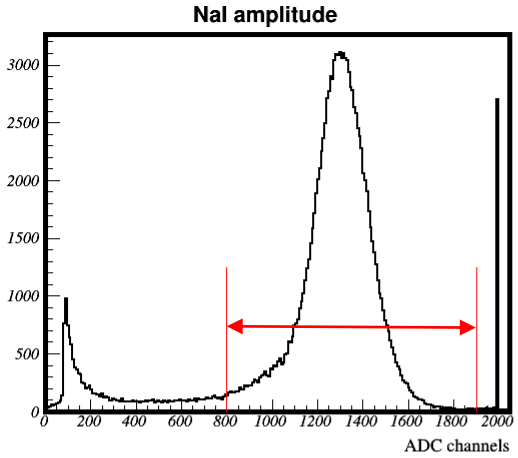
4 MaPMTs readout in half by PADIWA (128 ch) and DiRICH (128 ch)

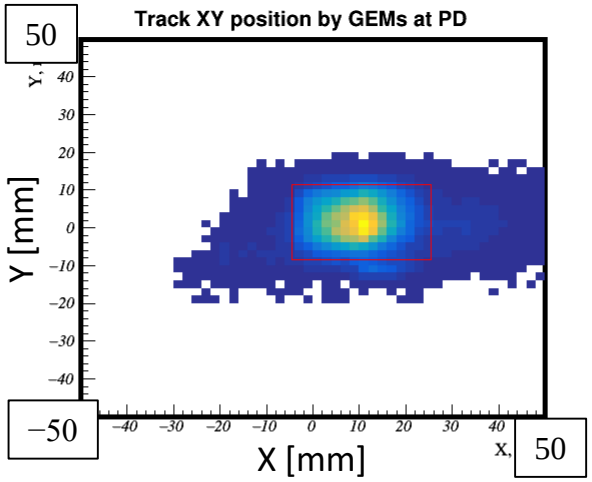


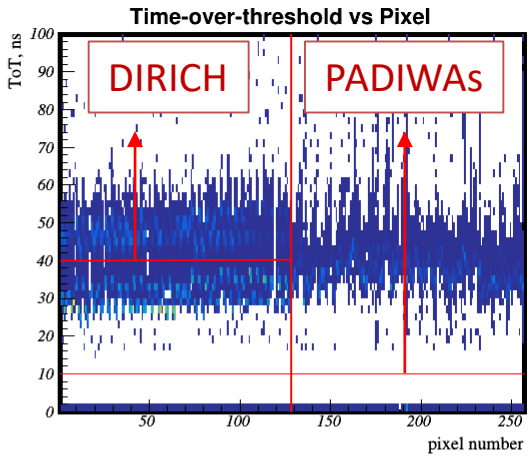
Aerogel sample with a flat mirror installed at 45° w.r.t. the PD and aerogel.

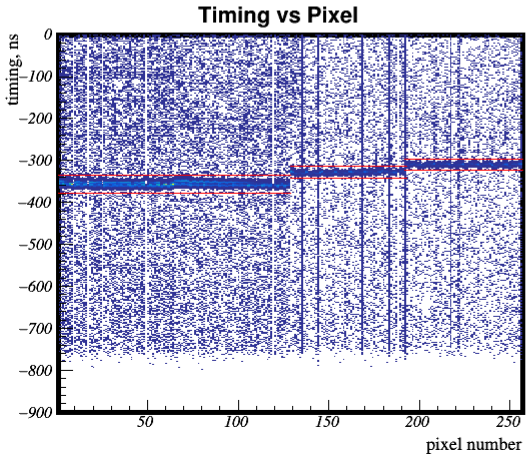
Event and hit selection

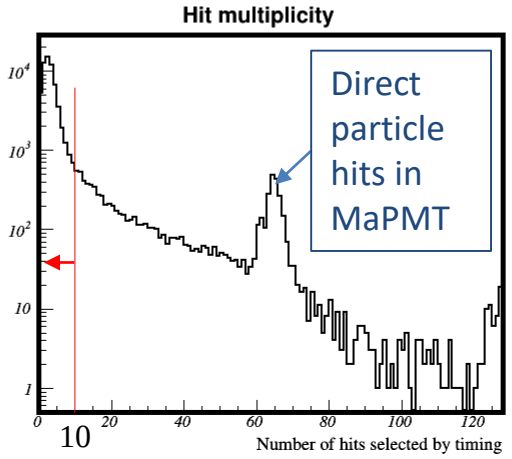
June 2019

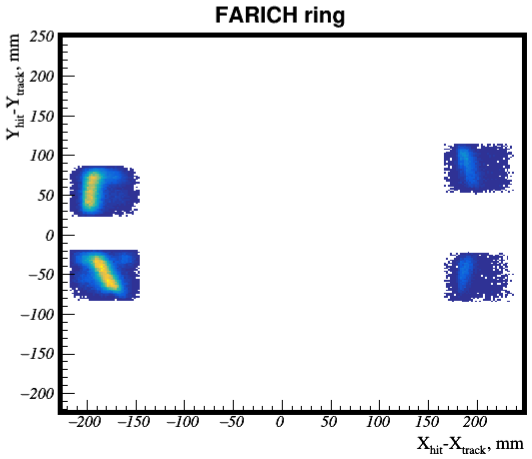






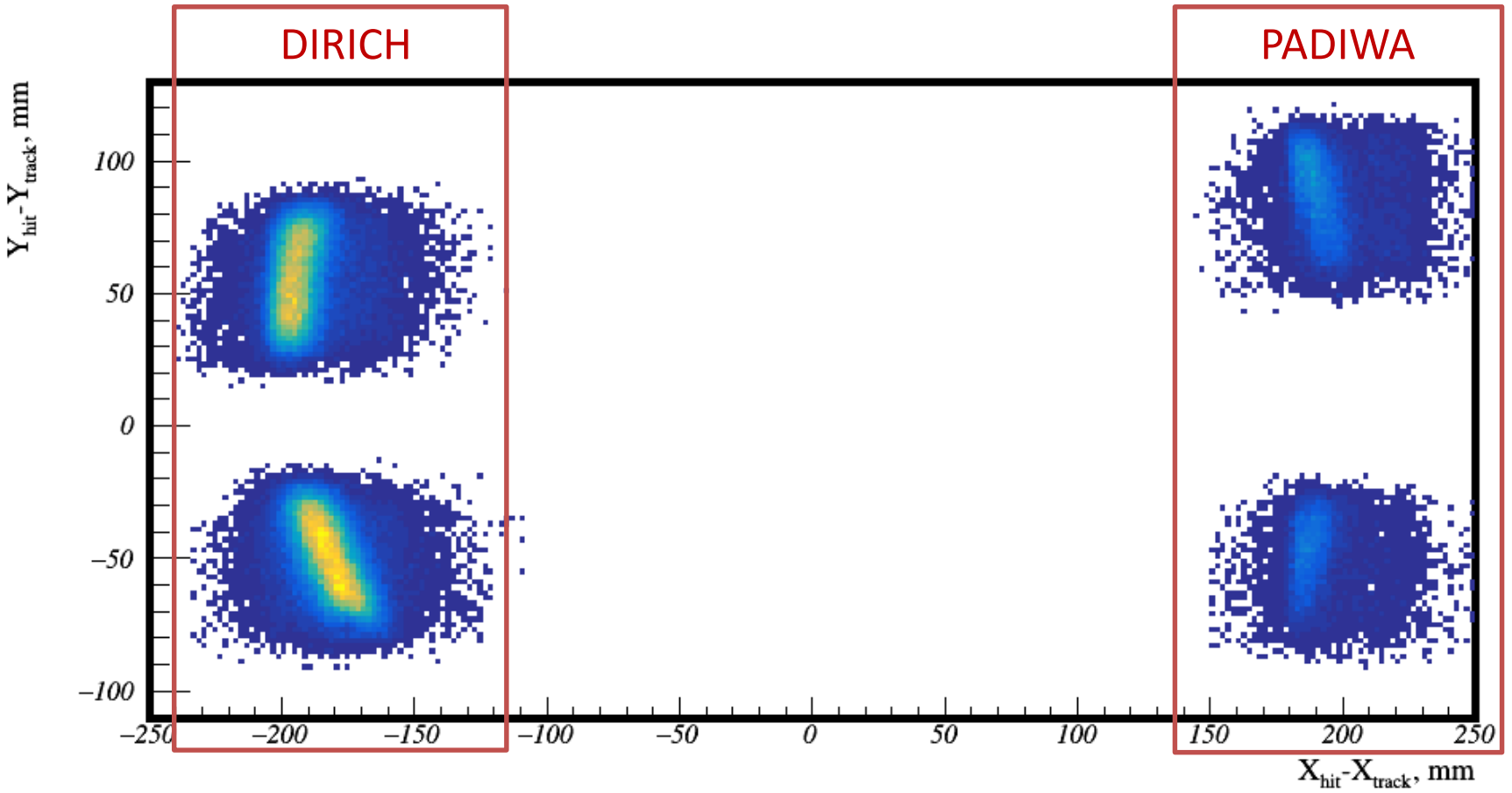






Track adjusted hit map – Cherenkov ring

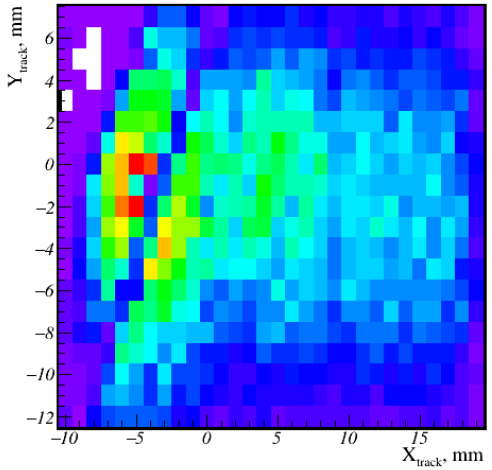
June 2019



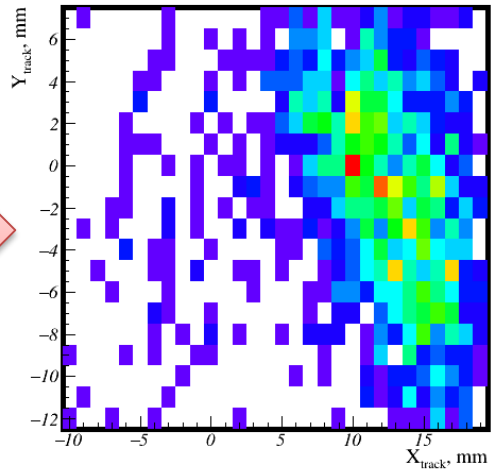
Evaluation of the F-RICH prototype performance

Track position XY distribution

All tracks

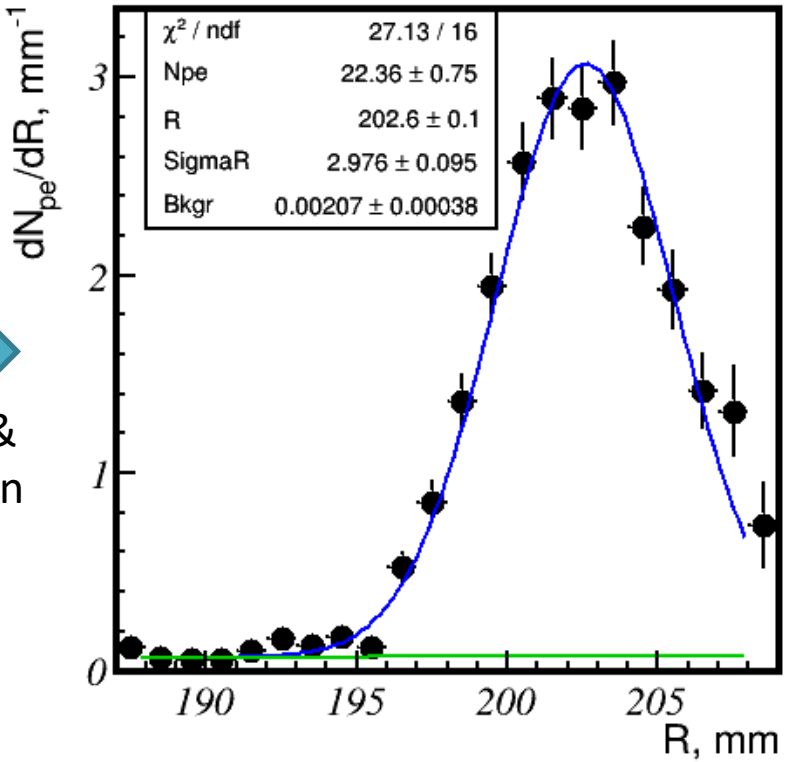


Tracks with pixel #20 hit



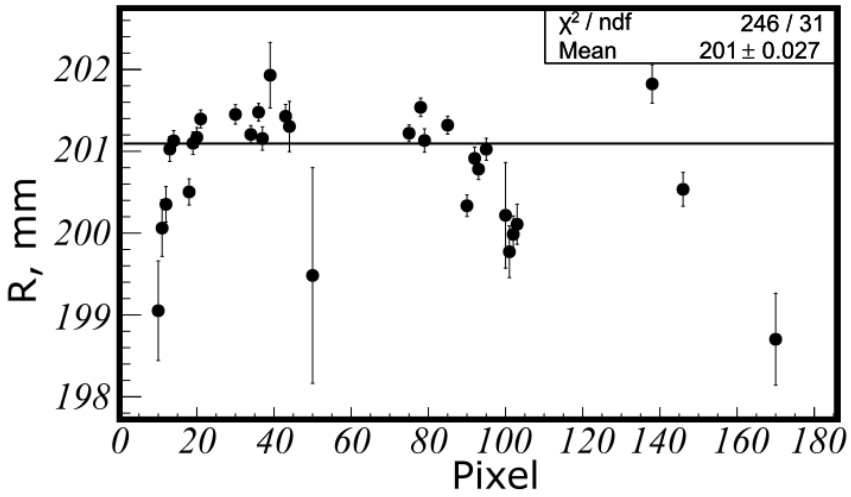
division & projection on R

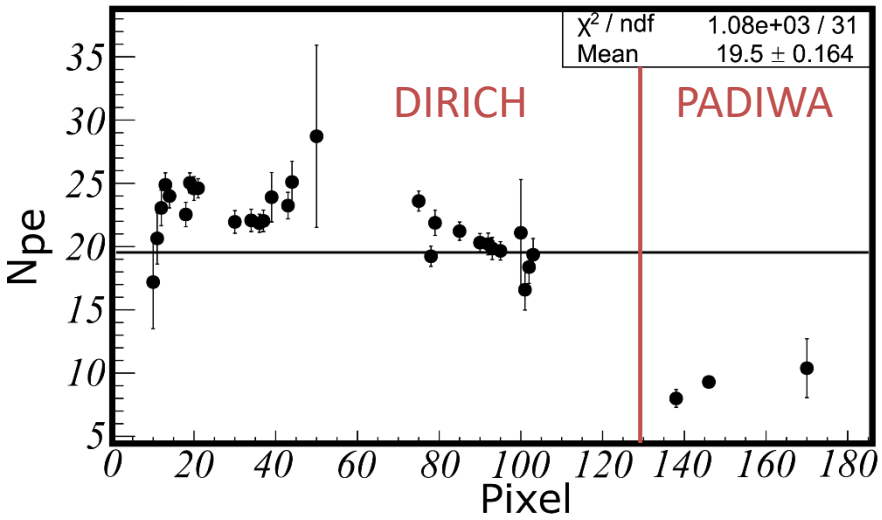
Photoelectron density distribution on radius for pixel #20 fitted by gaussian + linear background

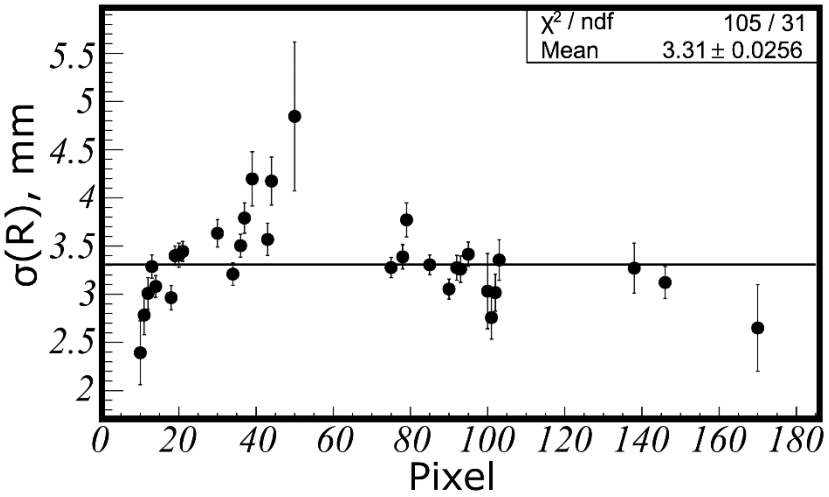


Test beam 2019 results (1)

Radiator configuration
1-st layer: n=1.0526, t=2cm
2-nd layer: n=1.0500, t=2cm







Test beam 2019 results (2)

Performance averaged on the DiRICH channels only

Radiator	Parameter	Test beam 2019	Calculation
Stack of 2 layers 2 cm, n=1.0526 + 2 cm, n=1.0500	N_{pe}	22	39
	R, mm	201	199
	σ_{1pe}(R), mm	3.31	3.08

1.8 times less

$\sqrt{3.3^2 - 3.1^2} \cong 1$ mm

Effects in the calculation: aerogel chromaticity, Rayleigh scattering, radiator thickness, pixel size, 80% efficiency factor (reflectance, light loss at aerogel surface).

Effects left out of the calculation: tracking resolution, multiple scattering, anode charge sharing, aerogel inhomogeneity, FEE efficiency, non-gaussian shape of dN_{pe}/dR.

Estimation of the π/K separation power at P=10 GeV/c:

$$S = \frac{R_\pi - R_K}{\sigma_{1pe}}\sqrt{N_{pe}} = \frac{198.6-196.2}{3.3}\sqrt{22} = 3.4$$

That is enough for reliable PID for PANDA's highest particle momentum

Conclusion and outlook

- PANDA Forward RICH design is described.
- Different mirror samples were studied. Tomsk mirrors are chosen.
- Preliminary measurement of the absolute QE for H12700 showed . To be studied in more detail and negotiated with the producer.
- Light forward scattering in aerogel is studied. Effect is negligible for the PANDA FRICH
- Results of the test beam in 2019 are presented. Single photon radius resolution agrees quite well with the calculation. Discrepancy in the photoelectrons is observed (probably due to low DQE).