Status of the Forward RICH development in Novosibirsk

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Cherenkov-PID session, PANDA LIII. CM

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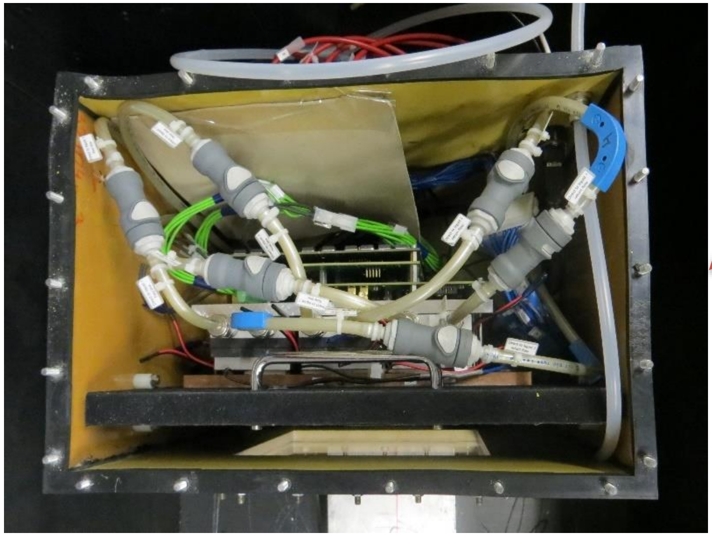
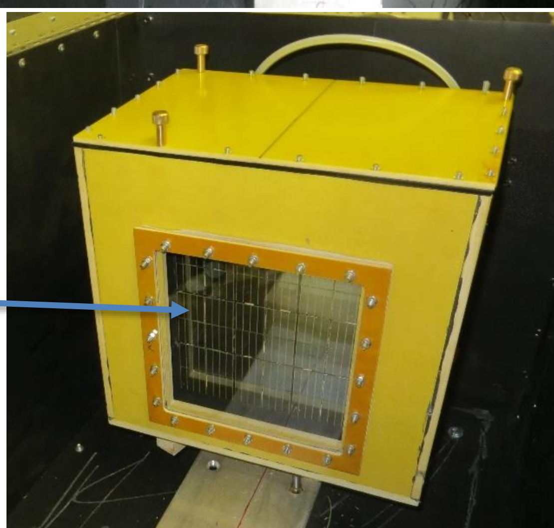
Upgrade of PDPC-FARICH prototype

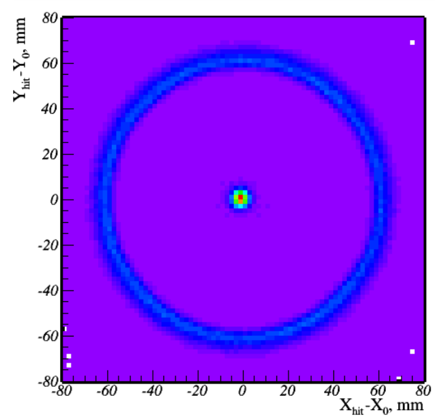


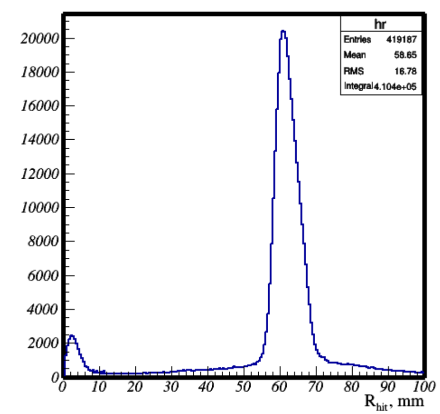
- Cold box for DPC photon detector. Aerogel is placed outside at room temperature and can be easily exchanged
- Extend aerogel-PD distance to ~500 mm
- Dark envelop box with moving stage for aerogel and mirror (under construction)



PMMA window

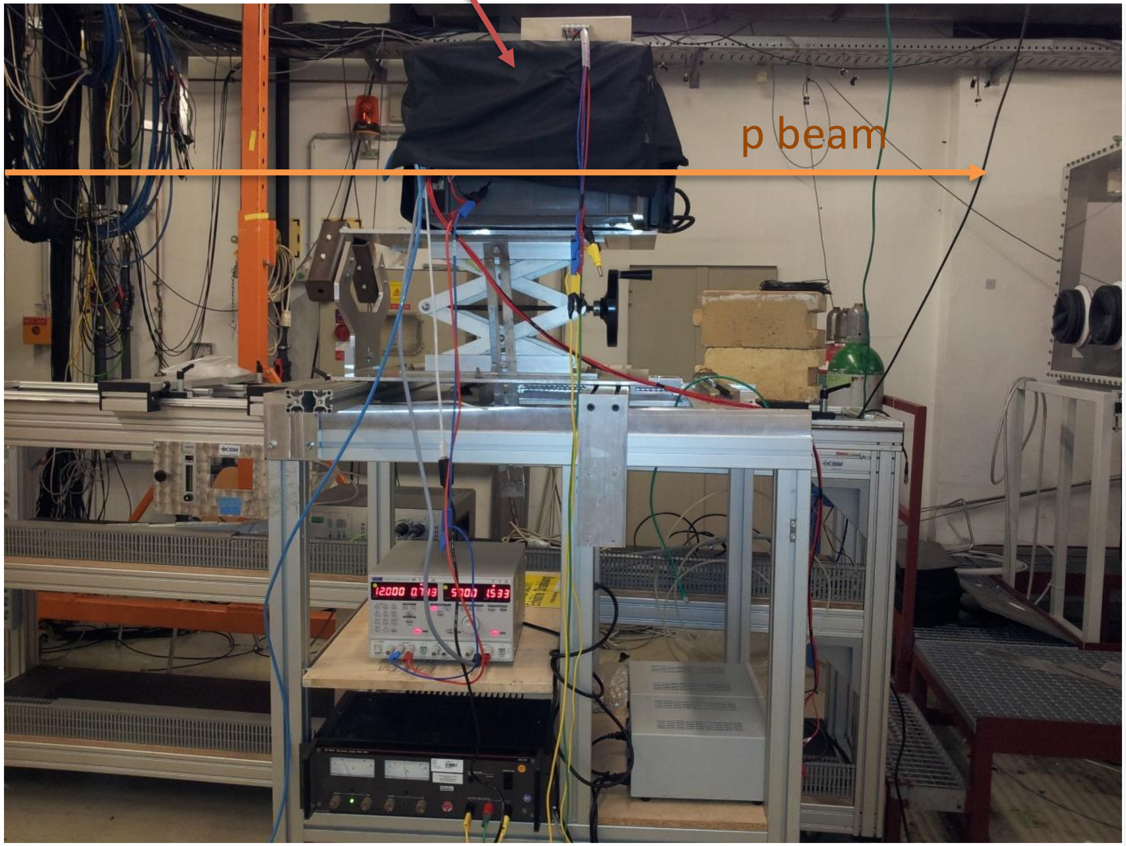
Test of upgraded DPC detector with e^- beam in March 2015





Proton irradiation of DPC at COSY August 1-4, 2014

Box with 2 DPC
3200-22-44 tiles

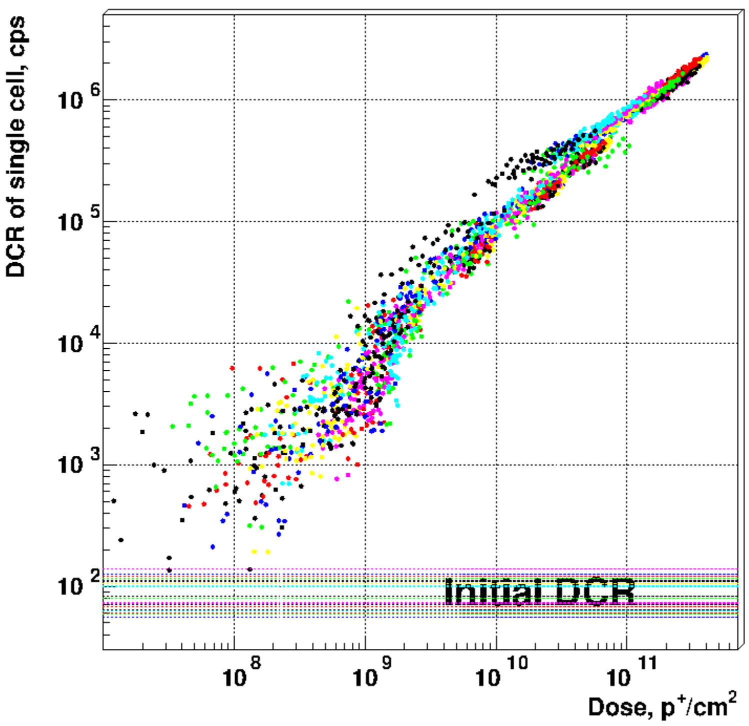


- Protons with P=800 MeV/c (T=295 MeV)
- Maximum fluence ~$4 \cdot 10^{11}$ p/cm^2 accumulated in 9 steps
- Tiles irradiated at -18°C
- DCR scan of cells was done in beam stops
- Total dose is measured by ionization chamber provided by COSY team
- Beam profile was determined by data

Poster by M. Barnyakov on Pisa2015 conference

Dark count rate vs fluence

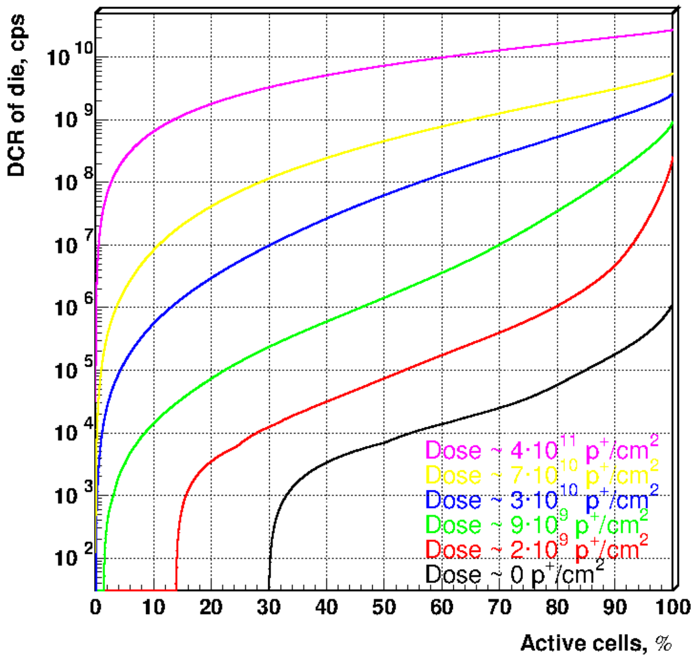
Single cell DCR averaged over one subpixel (32x25 cells). Different colors for different dies.



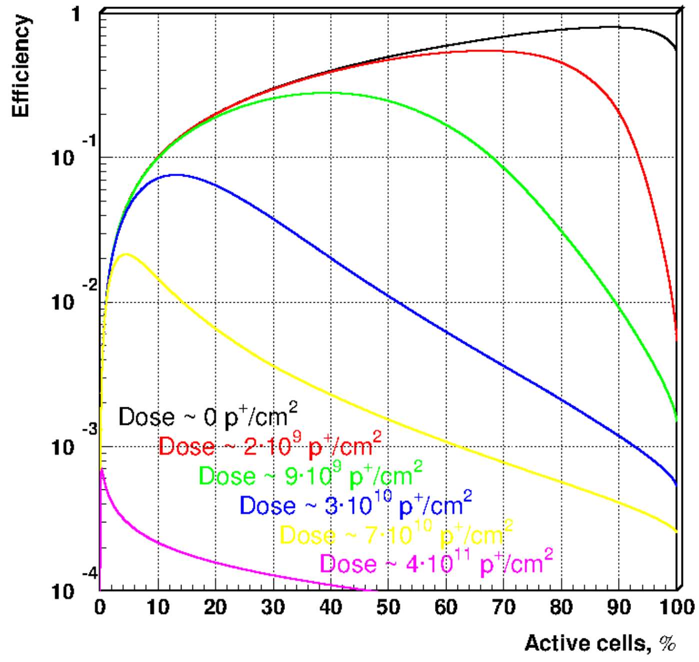
- Maximum fluence of protons (T=295 MeV) is ~$4x10^{11}cm^{-2}$.
- NIEL scaled fluence of 1MeV neutrons is ~$3x10^{11}cm^{-2}$ (80% of proton fluence).

Leveraging DPC cell inhibit function to keep up efficiency

DCR of a die as a function of active cells fraction for different proton fluences.

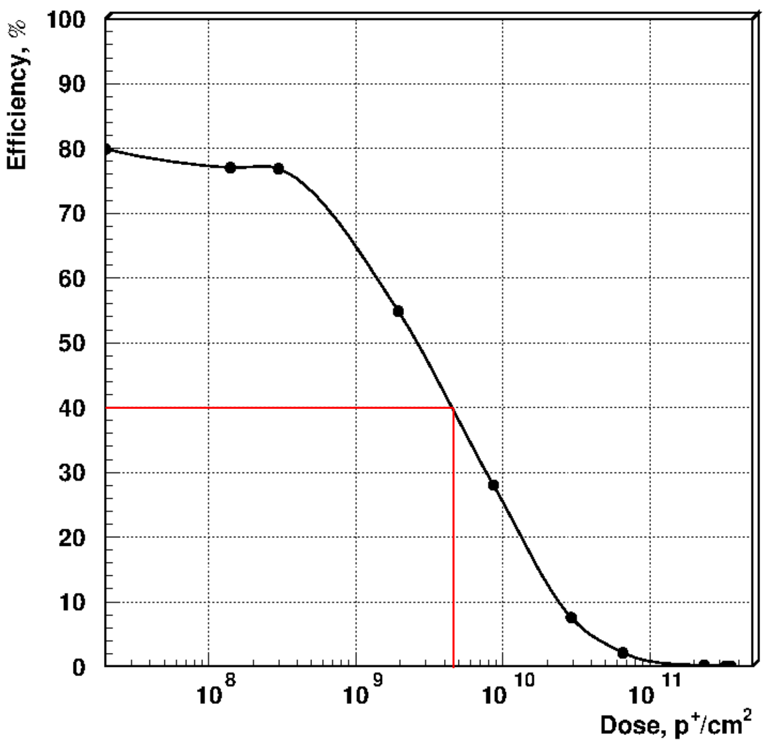


Relative photon detection efficiency as a function of active cell fraction taking into account dead time.



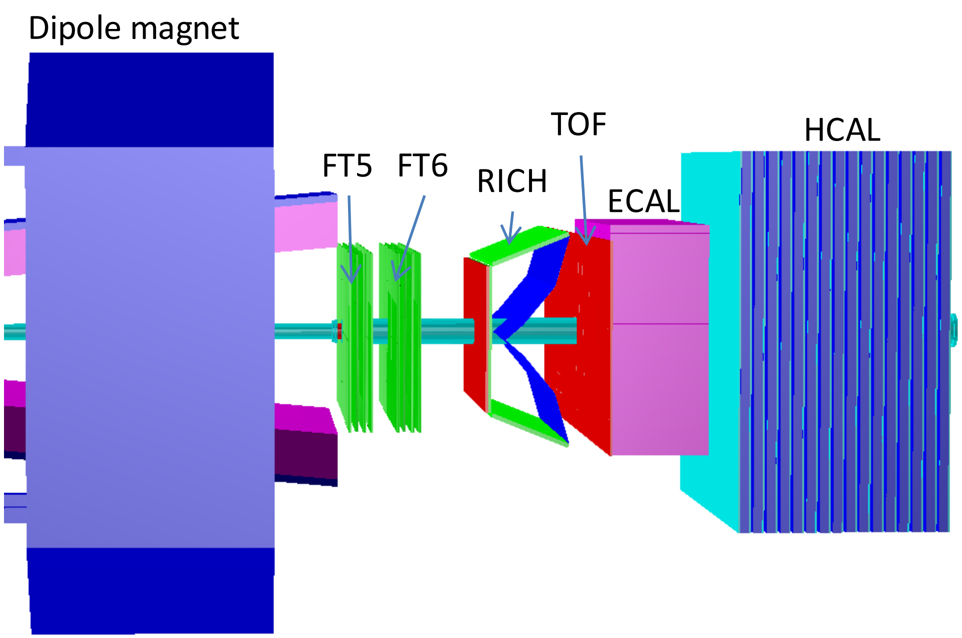
Optimal efficiency is a tradeoff between the fraction of active cells and DCR-induced dead time. The dead time for the current chip design is 720 ns.

DPC optimal efficiency vs proton fluence



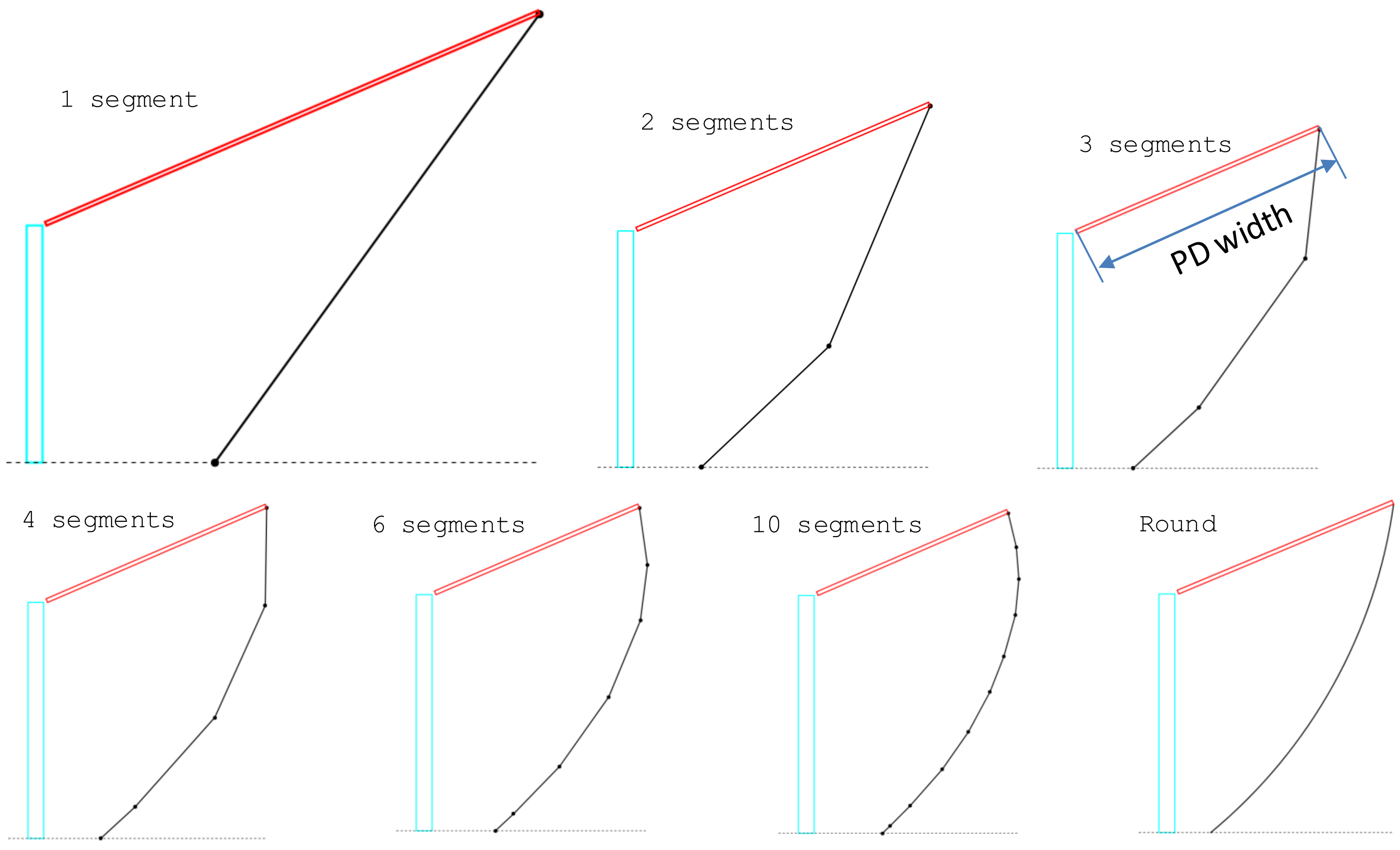
- 2 times efficiency drop at ~$4 \cdot 10^9$ n_{1MeV}/cm^2
- According to preliminary PANDAroot simulation the FRICH photon detector will accumulate ~$3 \cdot 10^{-5}$ n_{1MeV}/cm^2 per $\bar{p}p$ interaction at 10 GeV/c beam momentum.
- Assuming $2 \cdot 10^6$ s^{-1} beam-target interactions for HR mode and $2 \cdot 10^7$ s/effective year DPC at PANDA will accumulate $1.2 \cdot 10^9$ n_{1MeV}/cm^2/year.
- DPC will survive ~4 years at HR mode (preliminarily)

Forward RICH in PANDAroot



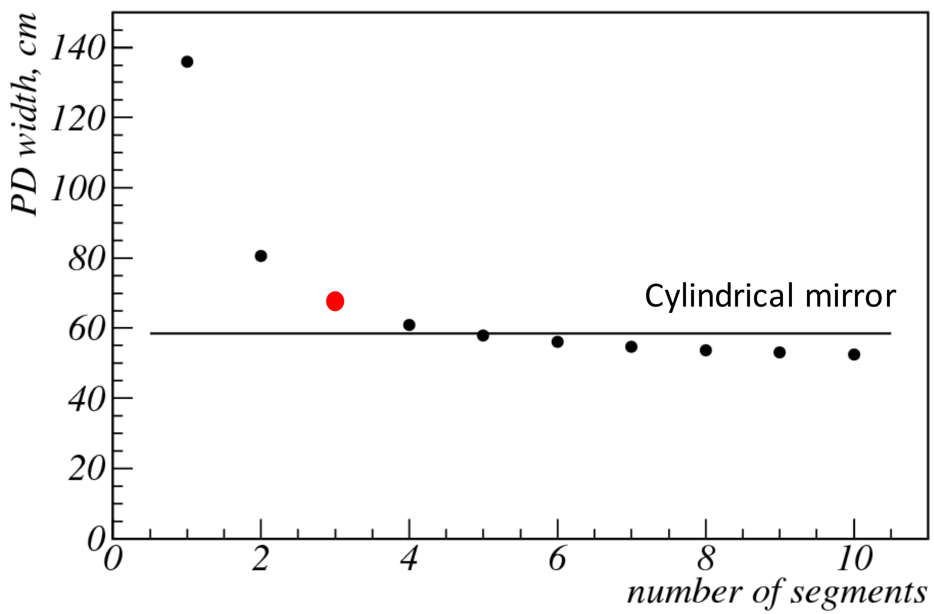
π/K-separation	up to ~10 GeV/c
Radiator	Focusing aerogel
Refractive indices	~1.05
Radiator thickness	4 cm
Placement	Between FT5 and FT6 (no place for FRICH in the current version)
Vertical angle	±5°
Horizontal angle	±10°

Optimizing mirror configuration



Acceptance for Cherenkov photons is maximized, photon detector area is minimized. Mirror is curved in 1D.

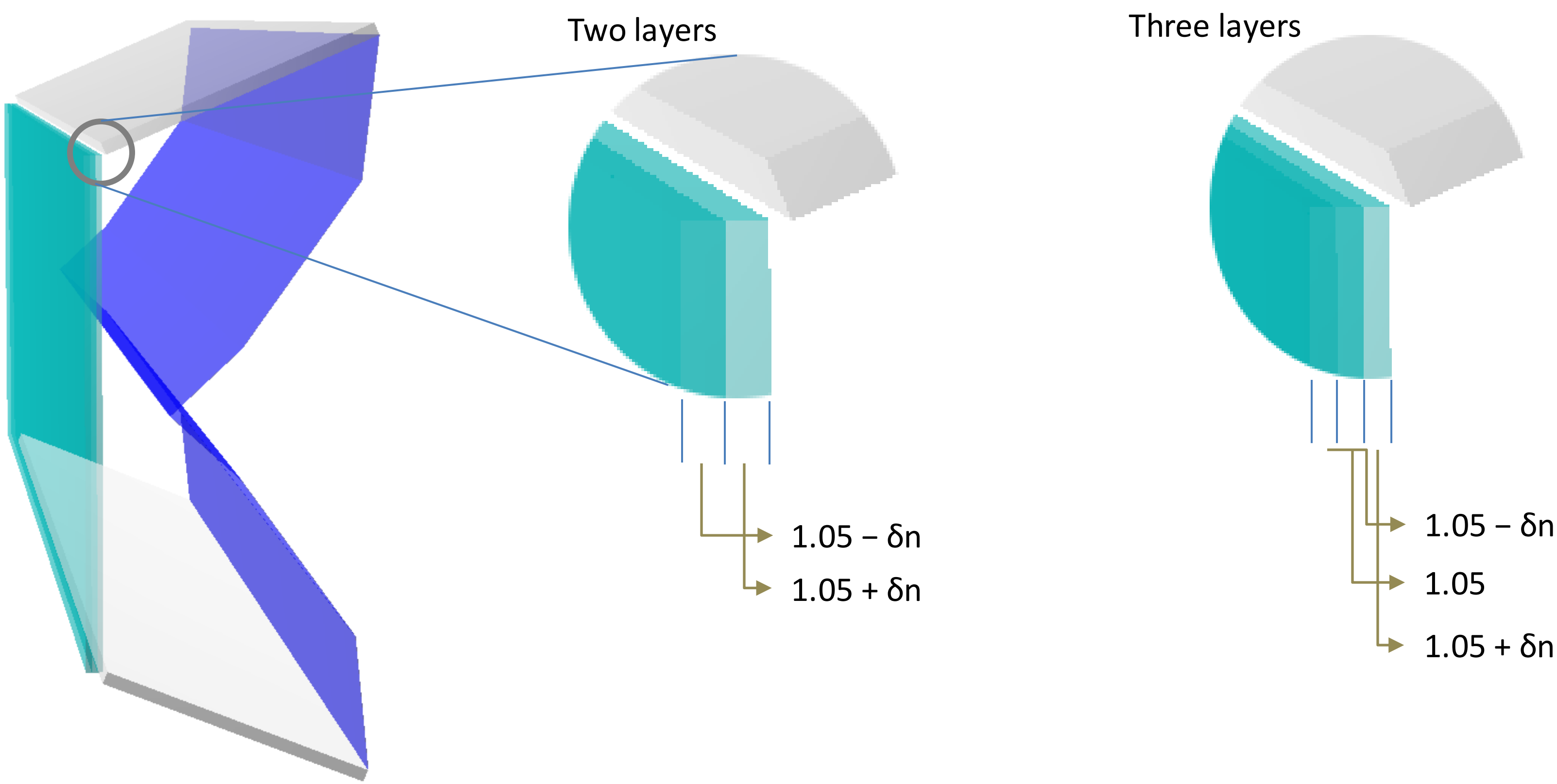
Optimal photon detector width



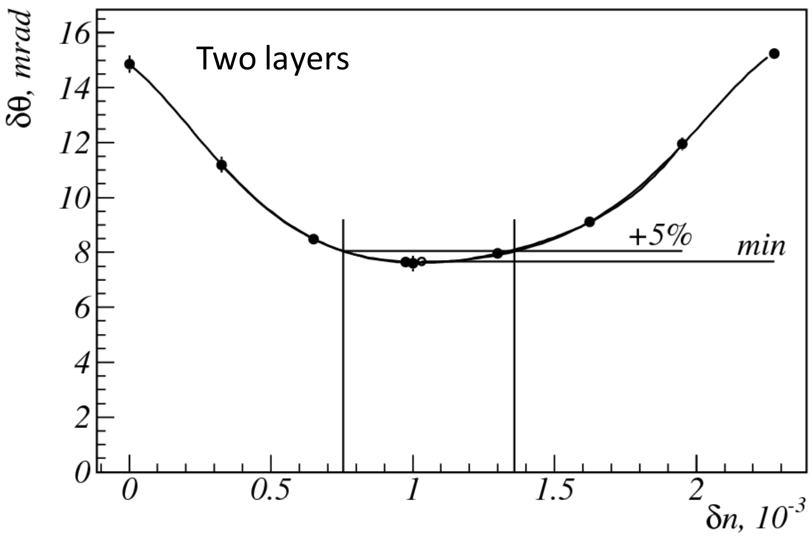
3 flat-segment vs cylindrical mirror

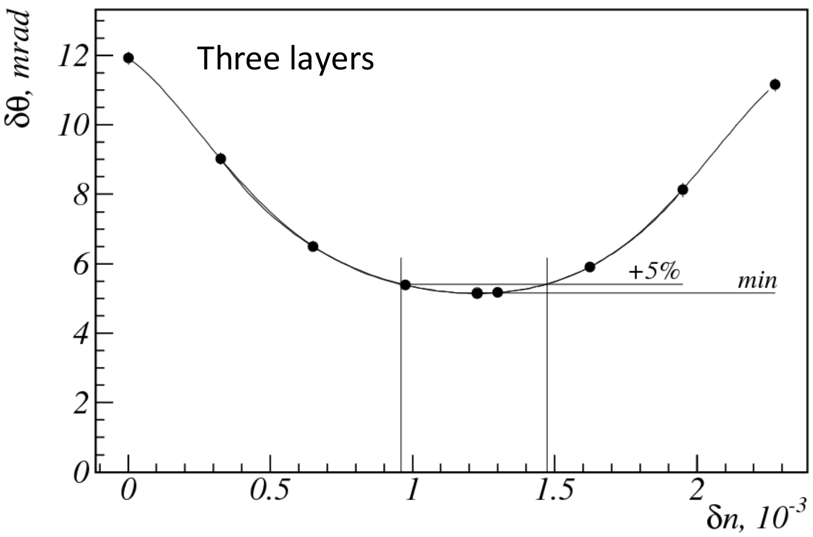
	3 flat segments	cylindrical
PD width, cm	67.5	58.5
Mirror focusing	no	yes
Aerogel focusing	yes	no
Combinatorial background	yes	no
Cherenkov "ring" shape on PD	elliptical	complicated
Number of part	3	1

Multi-layer aerogel optimization



Multi-layer aerogel: optimal refractive index spread



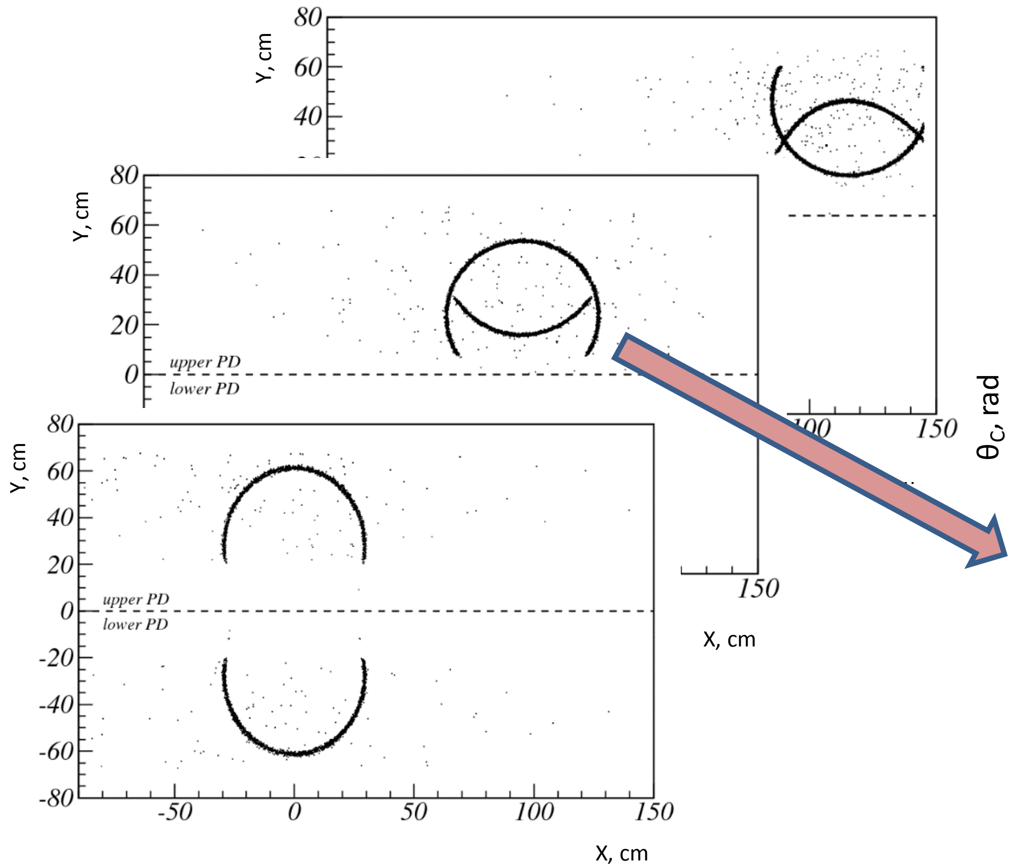


$n = 1.05$
$\delta n_{opt} = 1.03 \cdot 10^{-3}$
$\delta n_{min} = 0.76 \cdot 10^{-3}$
$\delta n_{max} = 1.36 \cdot 10^{-3}$

$n = 1.05$
$\delta n_{opt} = 1.23 \cdot 10^{-3}$
$\delta n_{min} = 0.96 \cdot 10^{-3}$
$\delta n_{max} = 1.47 \cdot 10^{-3}$

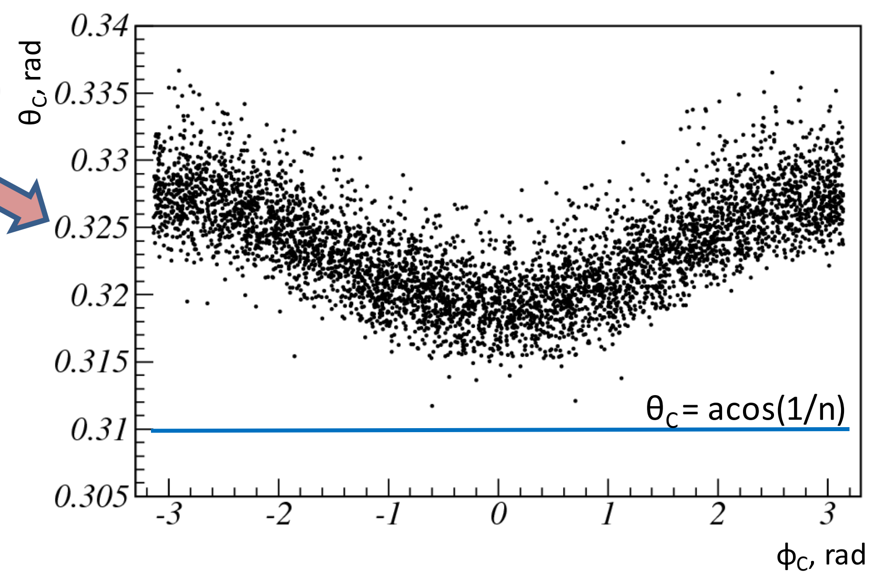
Three segments mirror and three layer aerogel are used further on

Events simulation and reconstruction

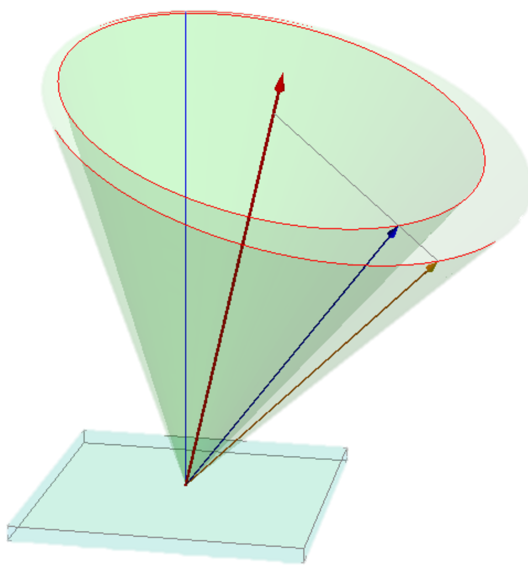


Possible reconstruction methods:

- on photon detector surface (x-y pattern recognition) – to do
- tracing hits back to reconstruct Cherenkov angles (θ_c, φ_c)

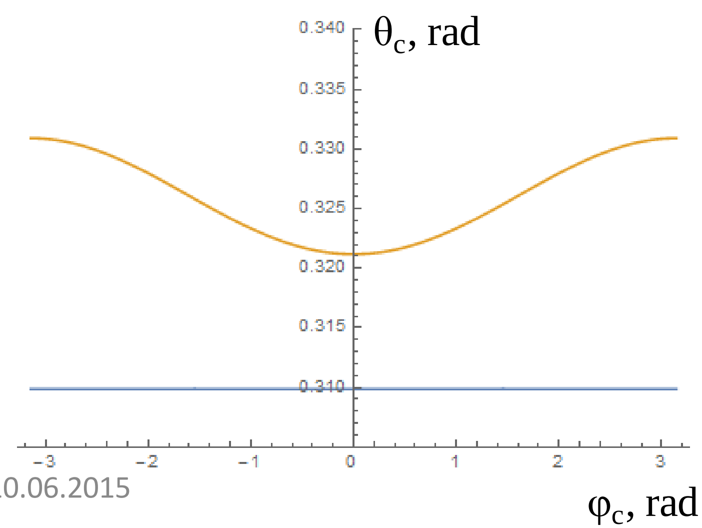


Reconstructing Cherenkov photon direction angles

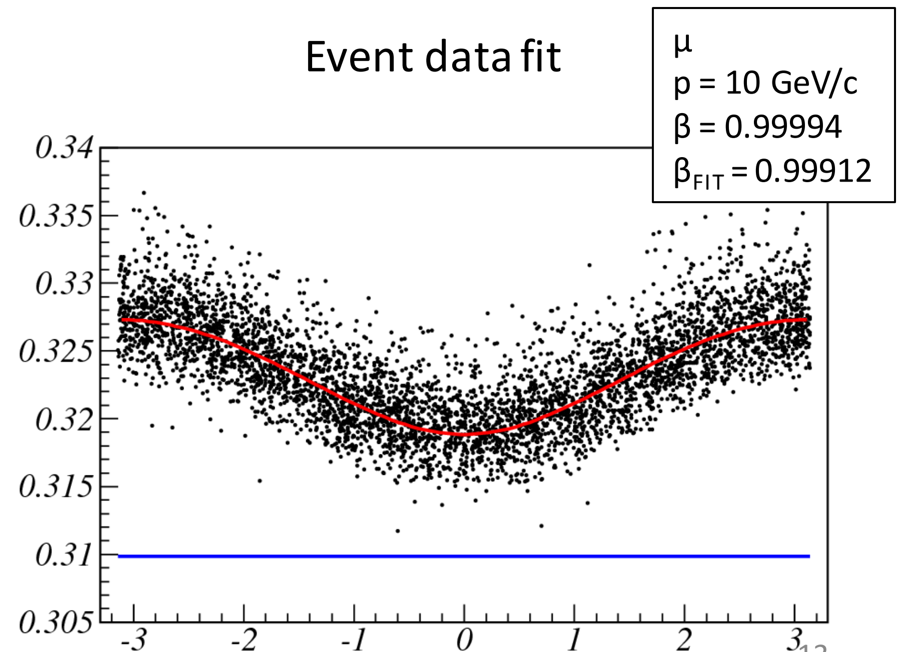


$\theta_c = f(\varphi_c; \beta, n, \alpha)$

- φ_c – azimuthal angle
- β – velocity of the charge particle
- n – refraction index of the aerogel
- α – polar angle of the charge particle



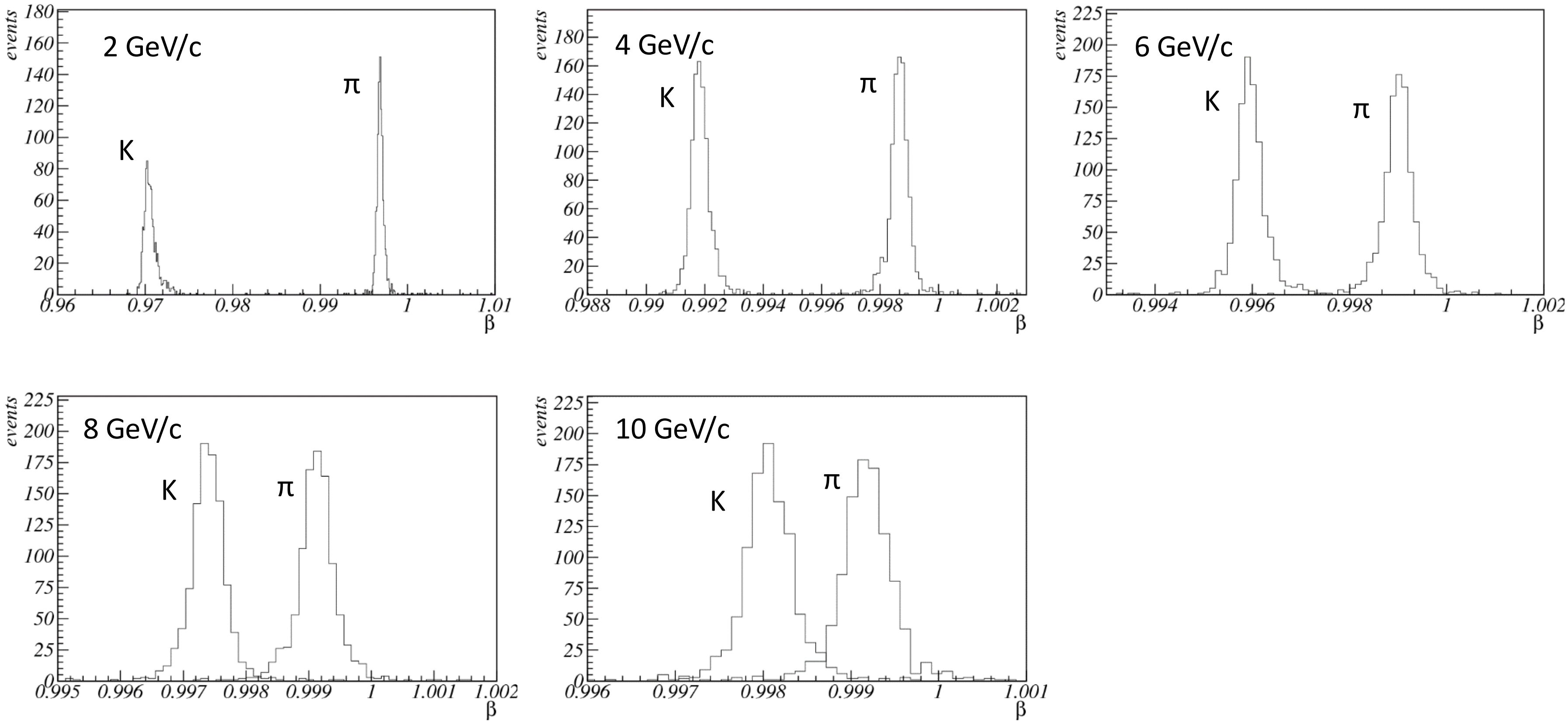
Event data fit



Simulated effects

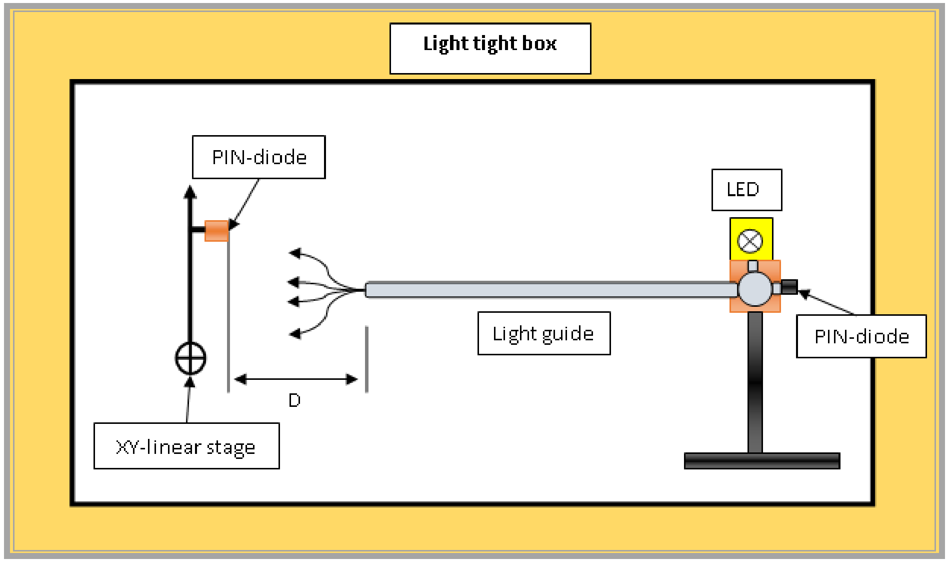
1. Simulation
   - ✓ Geometry description
     - RICH position
     - Aerogel (size, number of layers, refraction index)
     - Mirror geometry (round, flat)
   - ✓ Materials properties for Cherenkov photons
2. Digitization
   - ✓ Pixelization
   - ✓ Quantum efficiency of photodetector
   - ✓ Photon detector noise
   - ✓ Dead time of photodetector
   - ✓ Photodetector time resolution
   - ✓ Crosstalks (to do)
3. Reconstruction (simple mode)
   - ✓ Hit preselection
   - ✓ Fit θ(ϕ) dependence
4. PID (to do)
   - ✓ Probability calculation
   - ✓ PID selector implementation

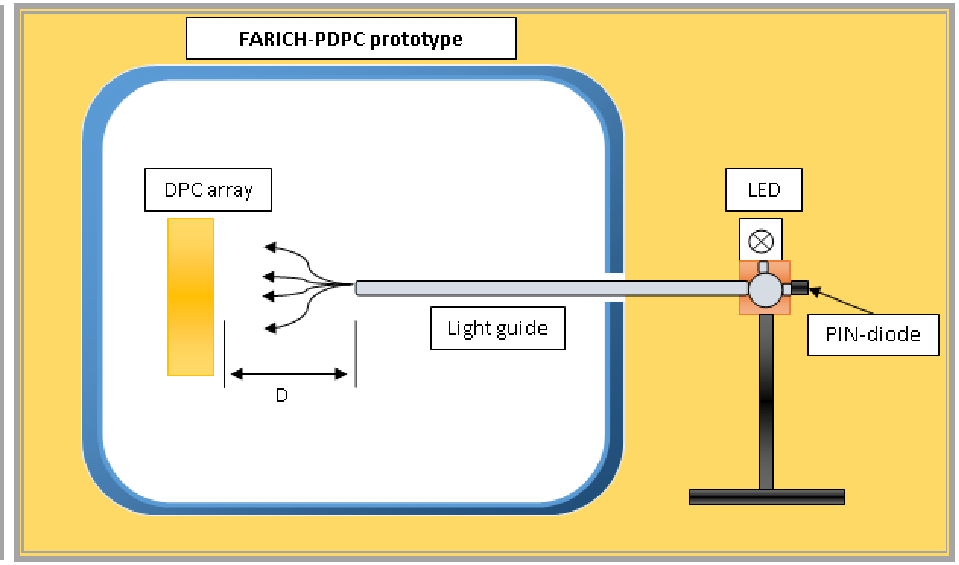
π/K-separation: first result



DPC PDE measurement

Measurement scheme



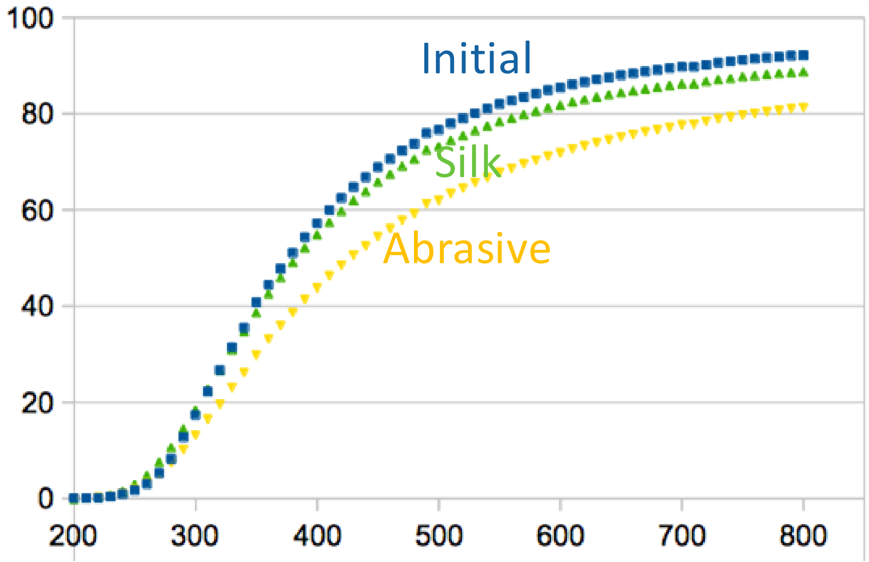


Scanning setup to calibrate wide-angle light source intensity

As PDPC-FARICH prototype is being refurbished we decided to switch to measurements with PDPC M-TEK instead. Now cooling system for M-TEK is set up. Calibrated Newport SiPD 918D-UV-OD3R will be used for absolute calibration.

Aerogel polishing

Transmittance (%) as function of wavelength



Fit transmittance by

$$T(\lambda) = A \exp\left(-\frac{t}{L_{sc}(\lambda/400\text{nm})^4} - \frac{M}{(\lambda/400\text{nm})^2}\right)$$

	Initial	Abrasive	Silk
A	94.9±0.8	91.2±1.7	92.4±1.2
L_{sc}	51.3±0.9	56.8±2.2	50.3±1.5
M	0.01±0.01	0.36±0.03	0.05±0.02

Optical smooth surfaces after polishing will allow us to

- construct focusing radiator of separate aerogel layers to increase production yield,
- improve light output from cut tile sides.

H12700 MaPMT

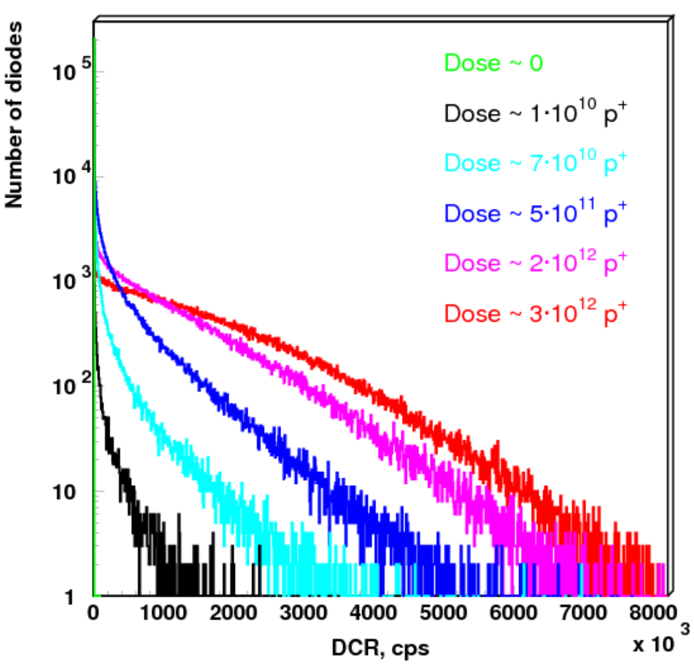
- Two H12700 are bought
- Purchase of PADIWAs and TRBv3 from GSI is in progress
- Adapter board for PADIWA should be designed

Project status

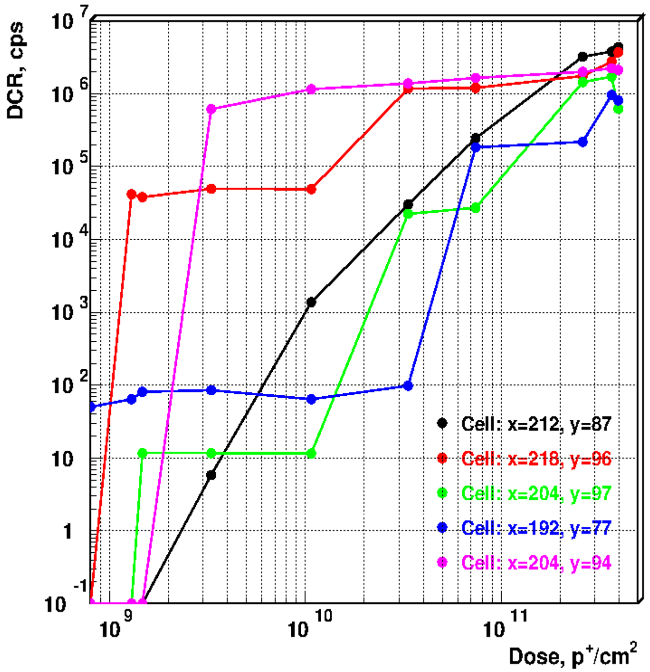
- DPC detector of PDPC-FARICH prototype was upgraded. Dark box with moving stage for aerogel is under construction.
- DPC radiation study is almost finalized.
- Full PANDAroot simulation of FRICH is under development. First results on PID performance of FRICH are obtained.
- Aerogel polishing technique is developed.
- DPC PDE measurement is in progress
- FRICH-DPC prototype is being constructed
- Study of MaPMT H12700 will be started this year

Effect of irradiation on cell DCR

DCR distribution of cells for several total doses



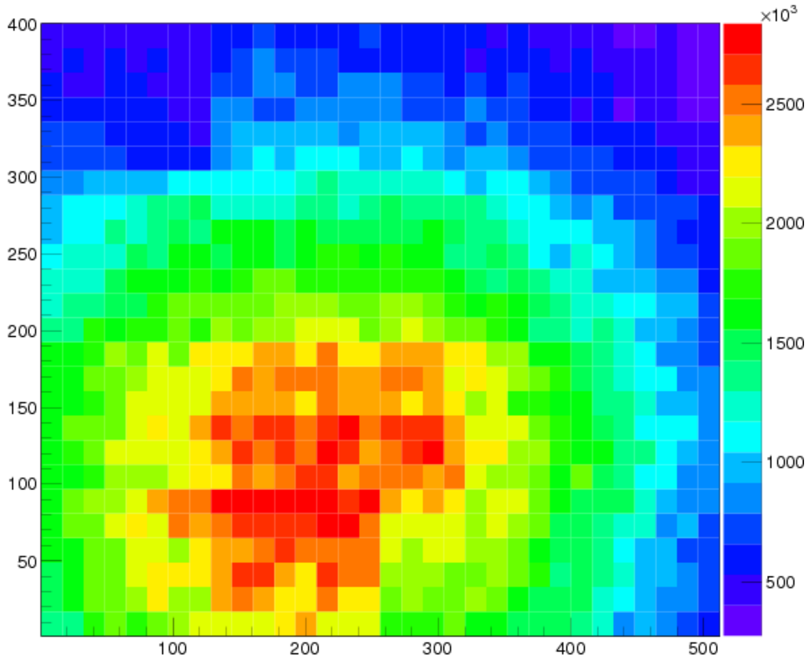
Change of DCR for 5 cells vs fluence



With the dose accumulation the number of noisy cells increases rather than DCR of each cell. ⇒ Cell damage caused by single interaction of protons with Si lattice.

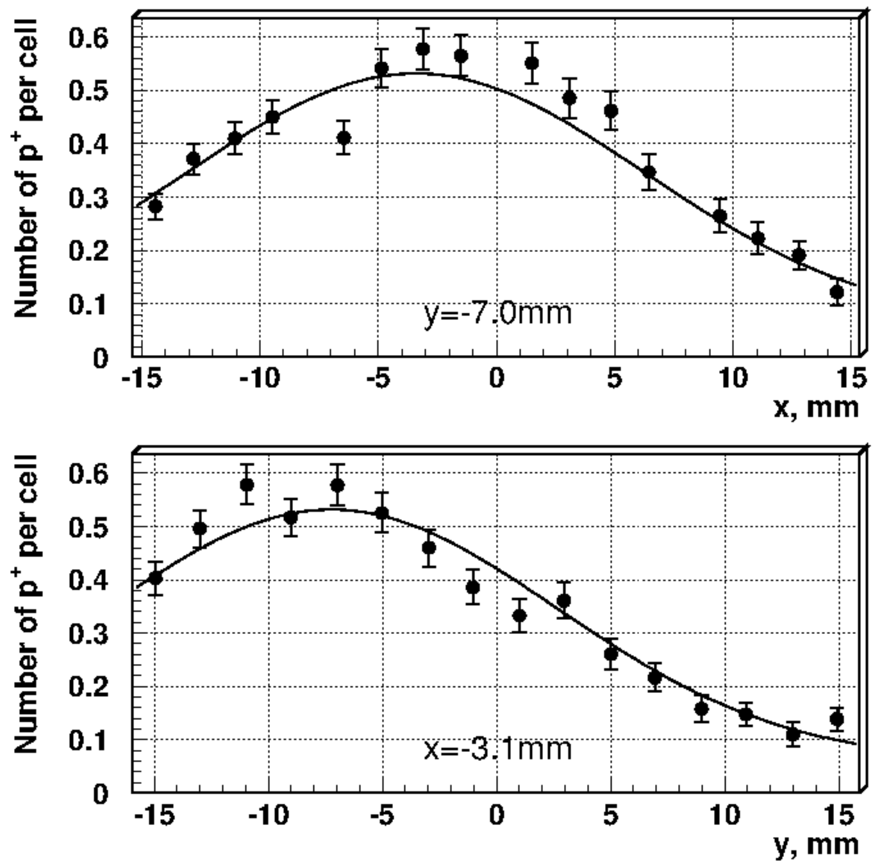
Beam profile and fluence evaluation

Dark count rate map after final dose



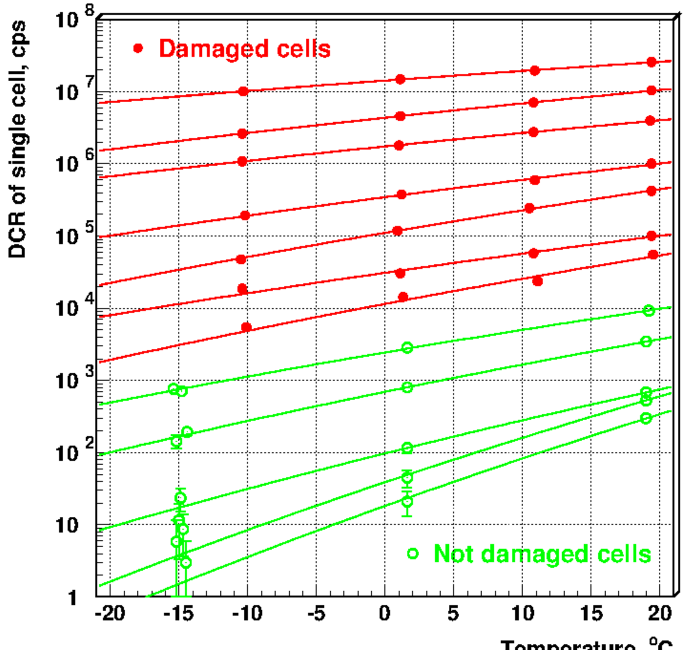
Gaussian fit of beam profile

evaluated from the fraction of damaged cells per subpixel (32x25 cells)



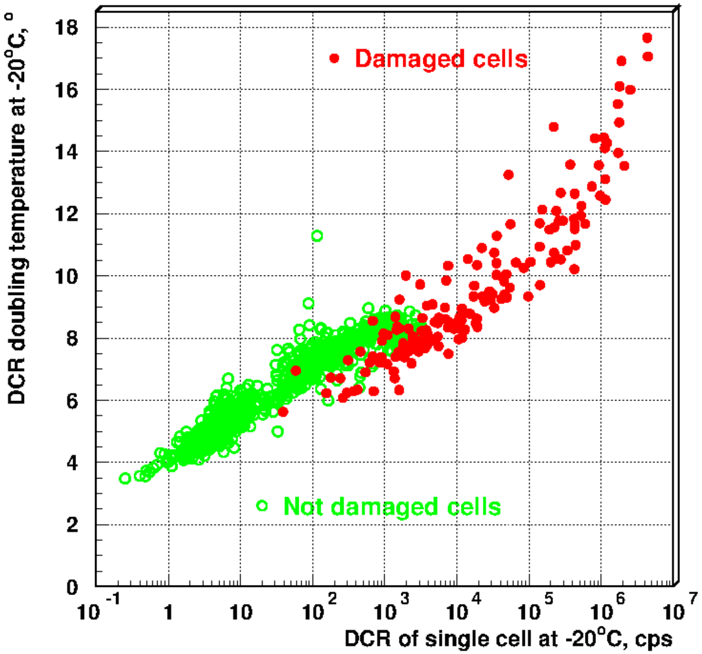
DCR vs temperature

DCR vs temperature fit

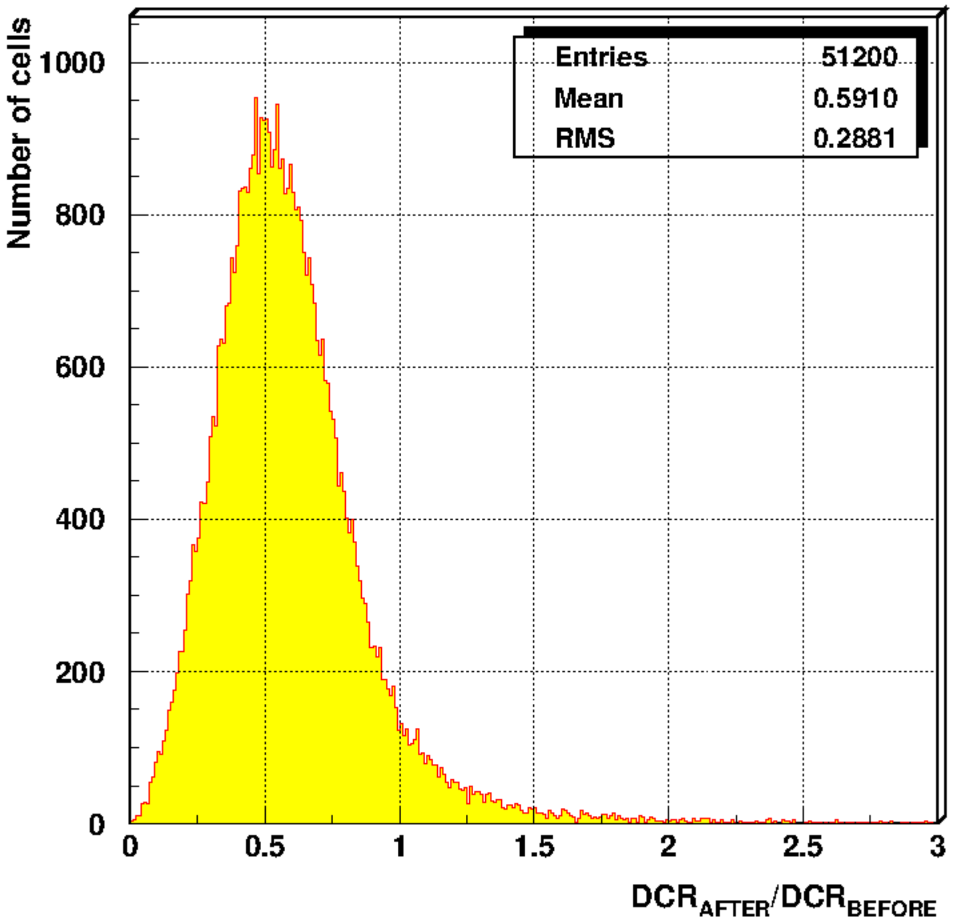


Richardson's law fit: $AT^2 \exp(-{}^{\alpha}/_{T})$

Temperature difference that doubles DCR

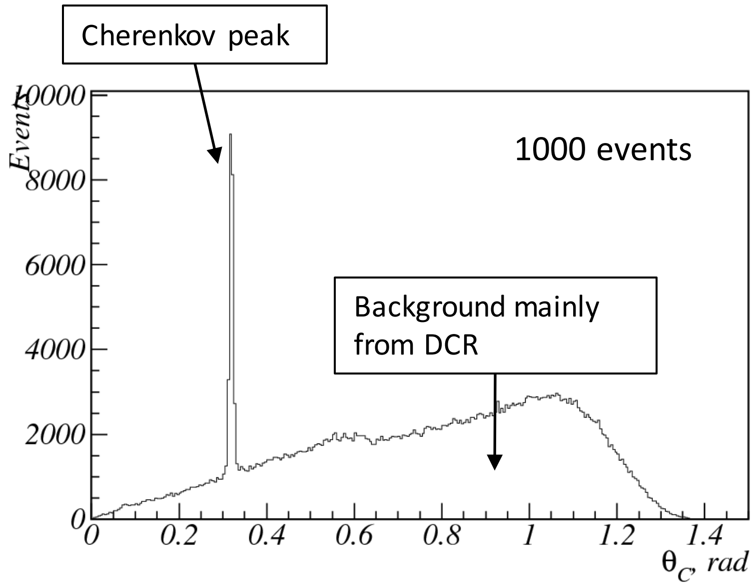


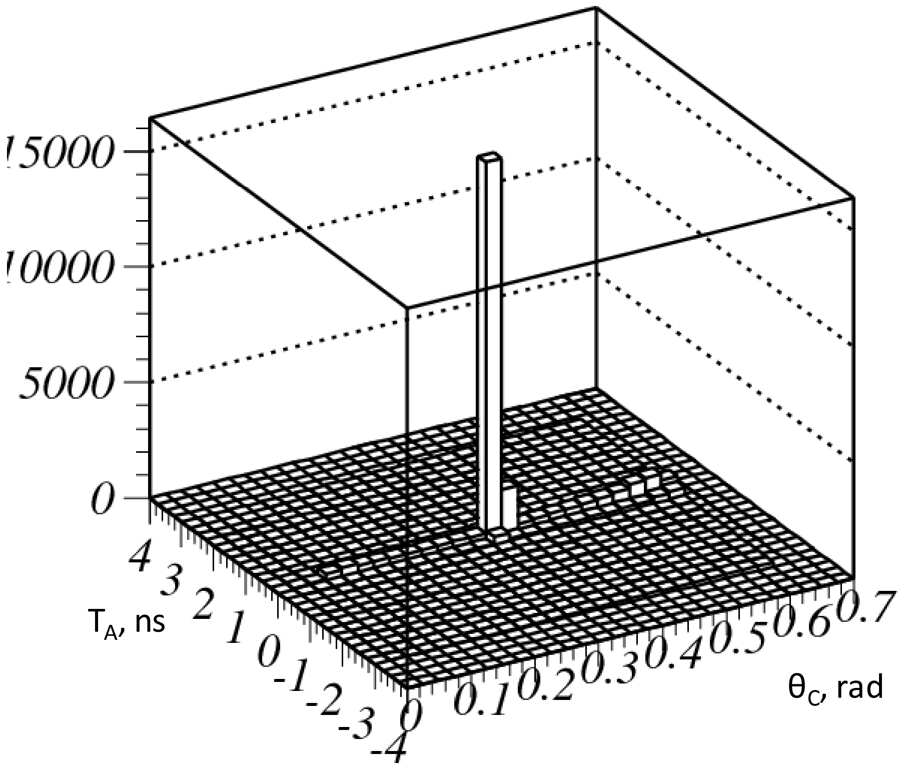
Effect of annealing



7.5 hours at +45°C ⇒ 1.7 times DCR decrease

Hit selection for fit





Hits distribution in time and θ_C