FARICH simulation in SPD

Artem Ivanov
JINR, Dubna

XXXI Annual International Seminar

Nonlinear Phenomena in Complex Systems
Minsk, Belarus,

June 24-28, 2024

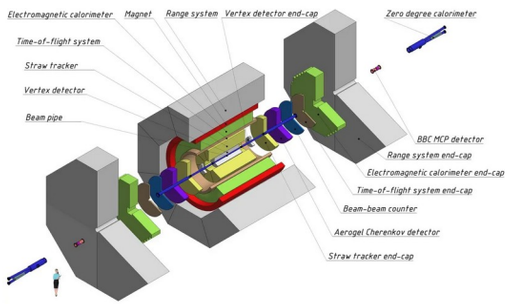
NICA – Nuclotron-based Ion Collider fAcility

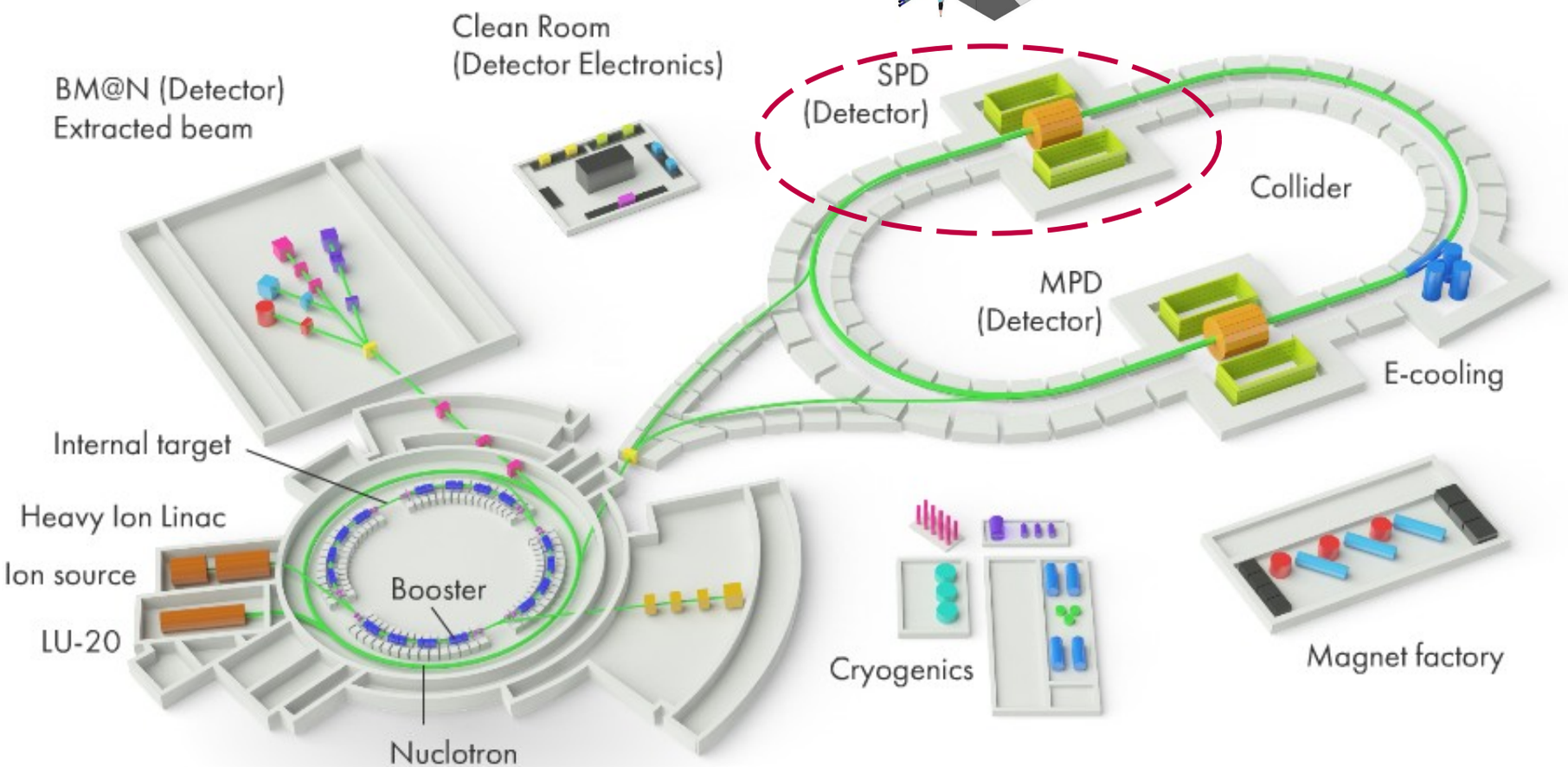
Polarized beams

$p^{\uparrow}\, p^{\uparrow}\, at\, \sqrt{s} \leq 27\, GeV$
$N^{\uparrow}\, N^{\uparrow}\, at\, \sqrt{s} \leq 13.5\, GeV$
$p^{\uparrow}\, N^{\uparrow}\, at\, \sqrt{s} \leq 19\, GeV$

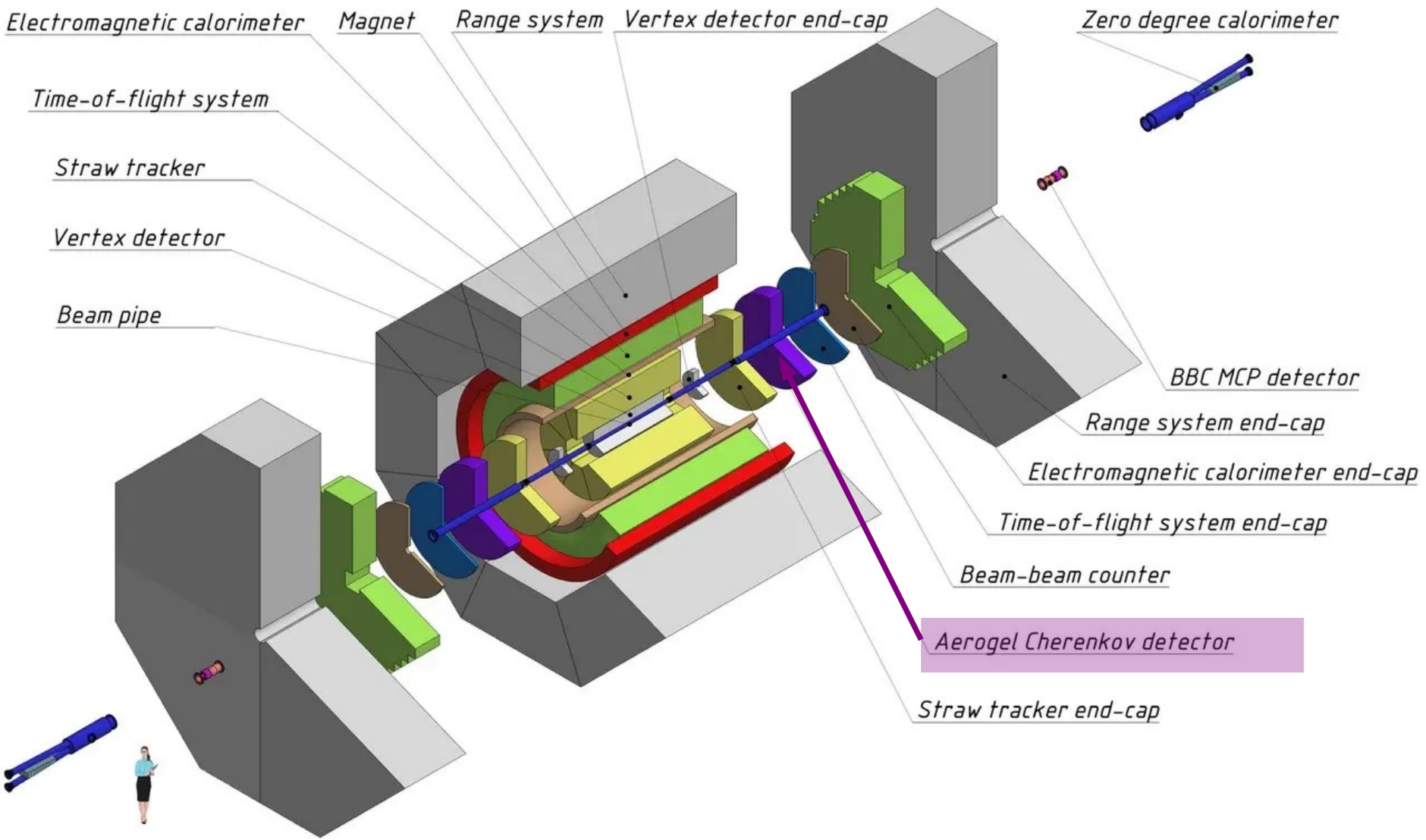
longitudinal and transverse polarization (UU, LL, TT, UT, LT) > 70%

Spin Physics Detector



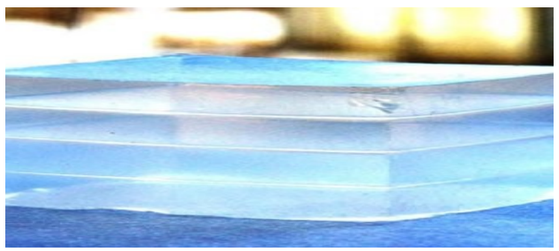


Focusing Aerogel RICH detector in SPD

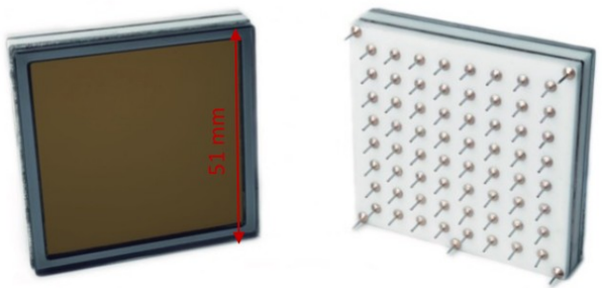


FARICH detector: basic principles

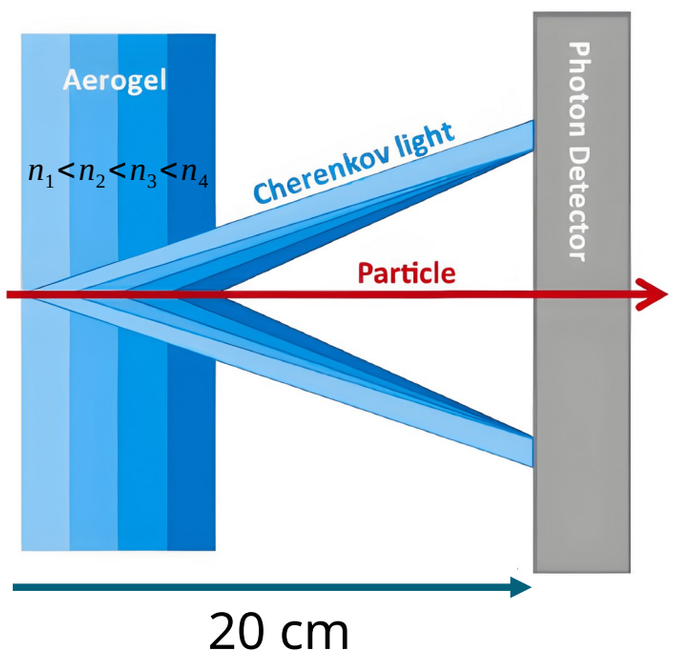
aerogel



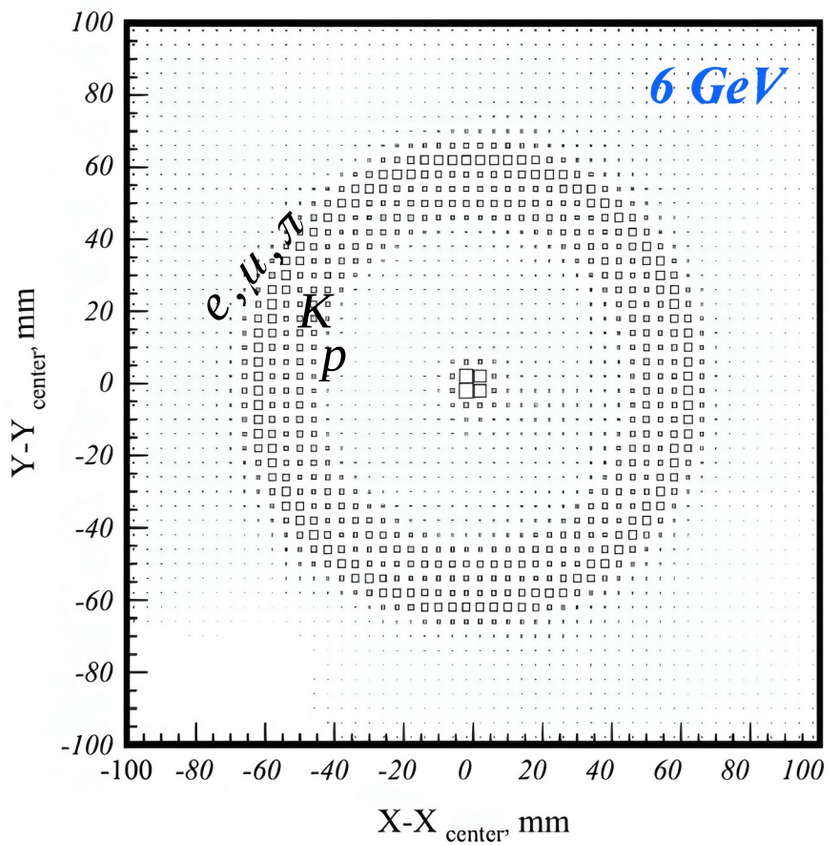
MCP PMTs N6021 from NNVT



Principle of detector operation



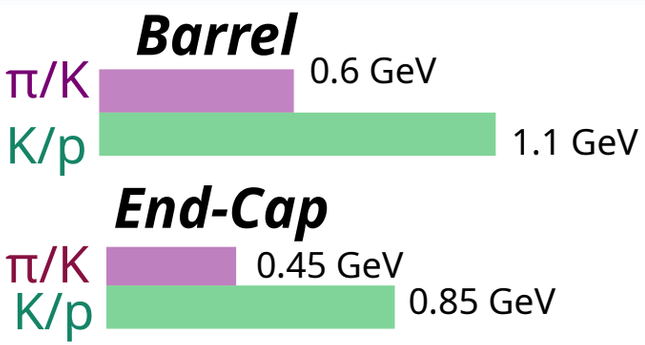
Accumulated *xy* distribution of hits



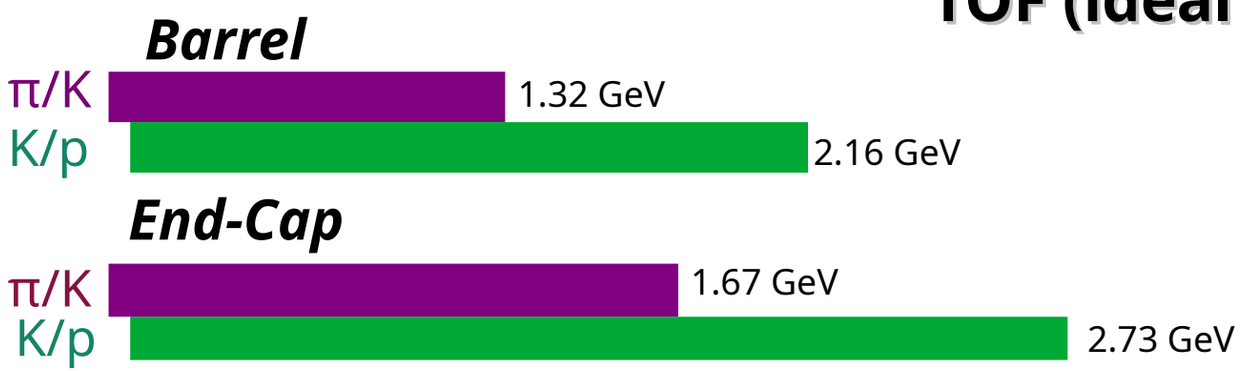
This work was carried out under the supervision of A.Yu. Barnyakov from the Budker Institute of Nuclear Physics, Novosibirsk.

Particle ID in SPD

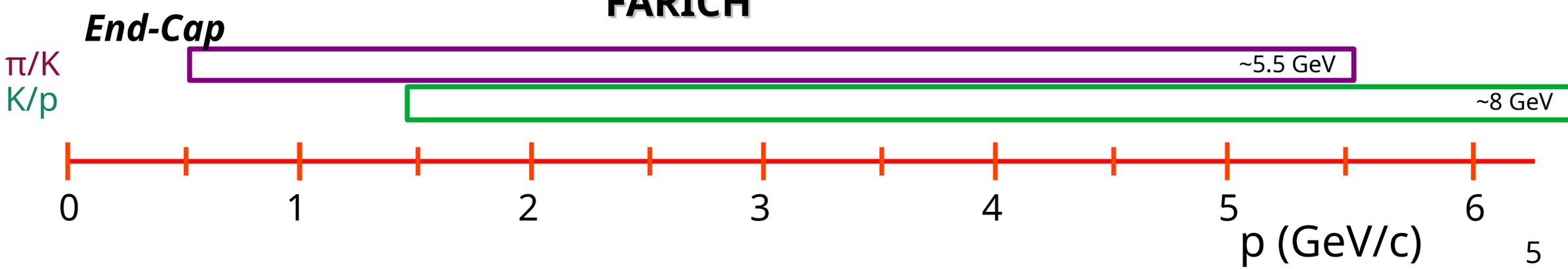
Straw tracker



TOF (ideal case without T0)

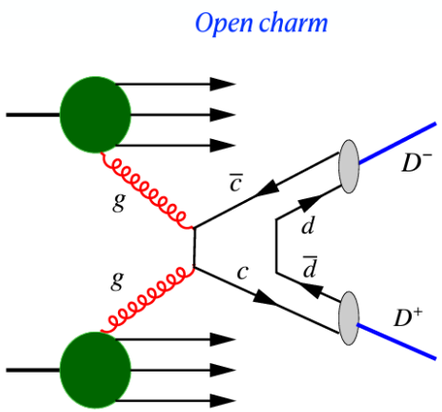


FARICH

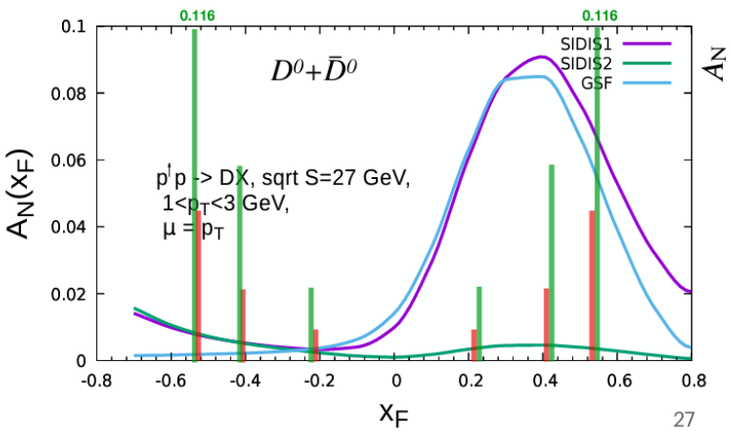


Why we need FARICH?

Gluon TMD: Open charm ($D^{0,\pm}$) production



$$D^0 \rightarrow K^- \pi^+$$
$$D^+ \rightarrow K^- \pi^+ \pi^+$$

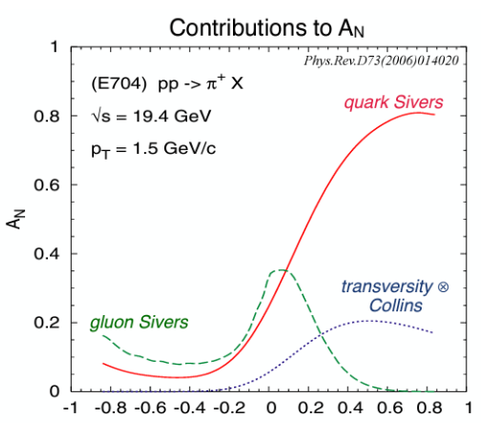


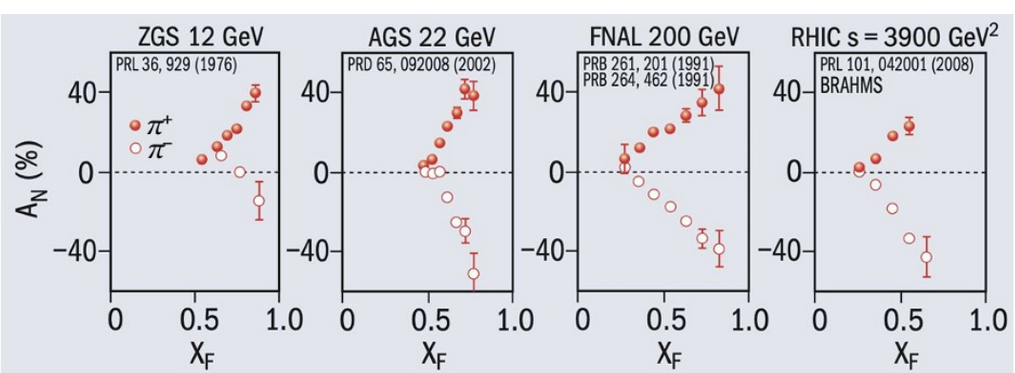
27

"*Possible studies at the first stage of the NICA collider operation with polarized* and unpolarized proton and deuteron beams" Phys. Part. Nucl. 52 (2021) 6, 1044-1119

"*On the physics potential to study the gluon content of proton and deuteron at NICA* SPD" Prog. Part. Nucl. Phys. 119 (2021), 103858

Quark TMD: Light hadron π,K,p production





$x_F = 2p_L/\sqrt{s}$

CERN Courier, June 2009

at leading order "twist 2"

Quark / Nucleon	U	L	T
U	number density		Boer-Mulders
L		helicity	worm-gear L
T	Sivers	Kotzinian-Mulders worm-gear T	transversity, pretzelosity

spin of the nucleon — spin of the quark — k_T

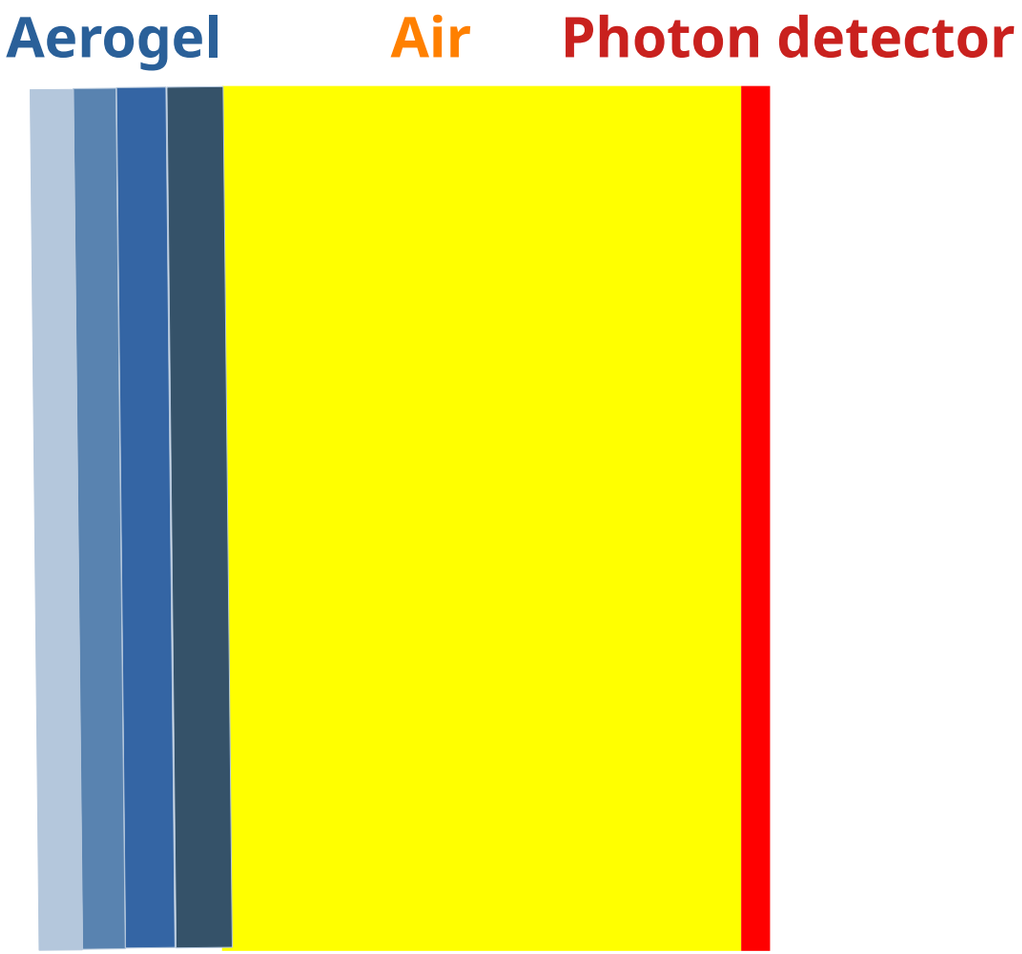
FARICH in SpdRoot

1) Description of geometry/material

2) Setting of optical properties in Geant4

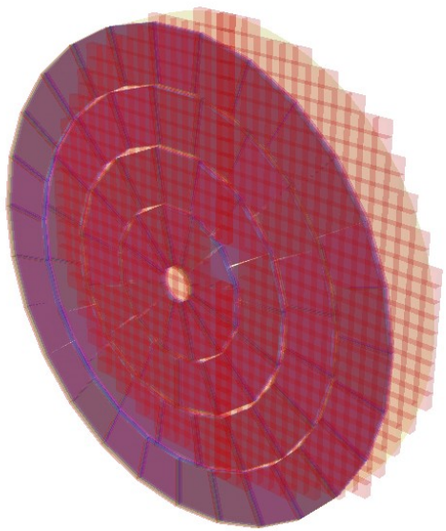
3) FARICH reconstruction

FARICH in SpdRoot: geometry

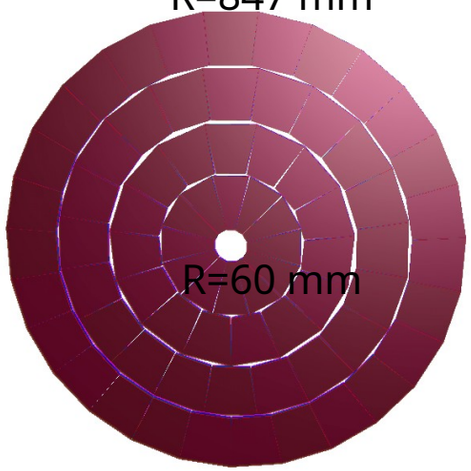


FARICH in SpdRoot: geometry

FARICH detector



Aerogel

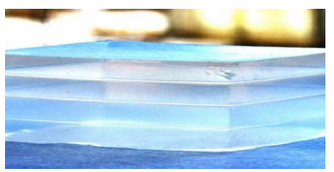


Material:

$Si\,0_2$ – 97 %

$H_2 0$ – 0.03 %

$density = \frac{(n^2-1)}{0.438}, [cm^3/g]$

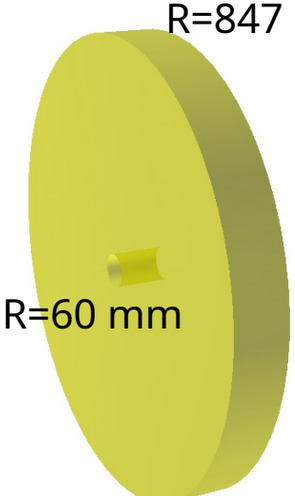


n(400)=1.0370, L=7.00 mm
n(400)=1.0410, L=10.00 mm
n(400)=1.0430, L=9.00 mm
n(400)=1.0470, L=10.00 mm

R=36 mm

Air

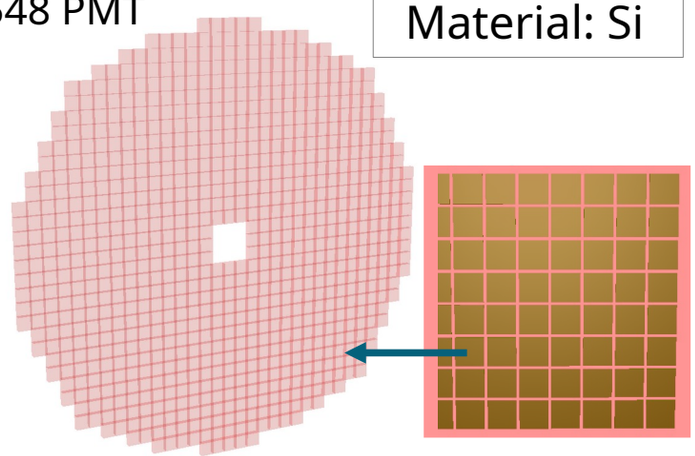
Material: Air



Photon detector

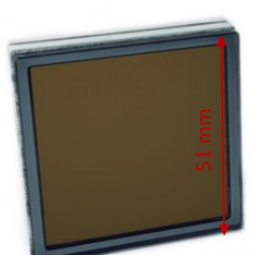
548 PMT

Material: Si



MCP PMTs N6021 from NNVT

- 8×8 pixels with size 5.8×5.8 mm²
- Lateral size 51×51 mm²
- Thickness = 1.7 mm



FARICH in SpdRoot

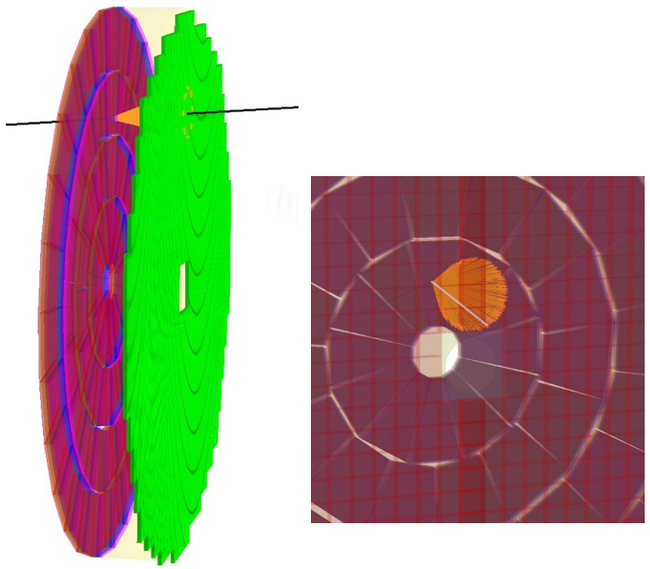
1) Description of geometry/material

2) Setting of optical properties in Geant4

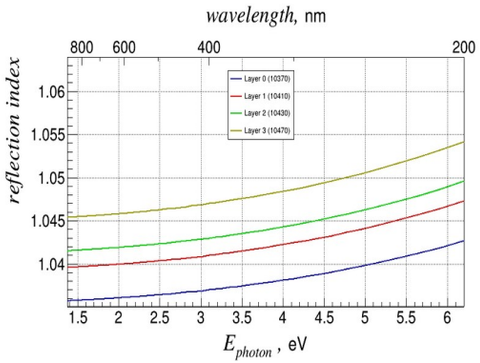
3) FARICH reconstruction

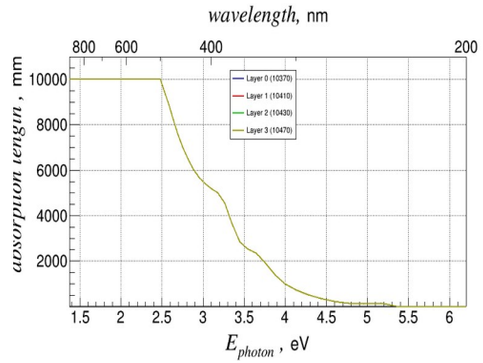
FARICH in SpdRoot: optical properties

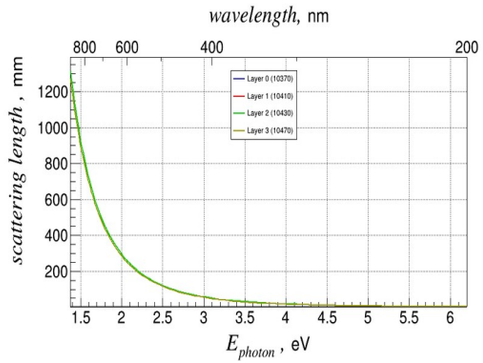
FARICH detector



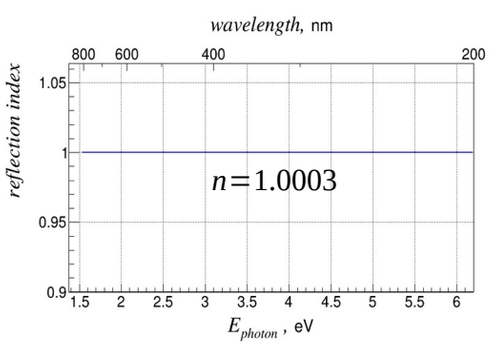
Aerogel

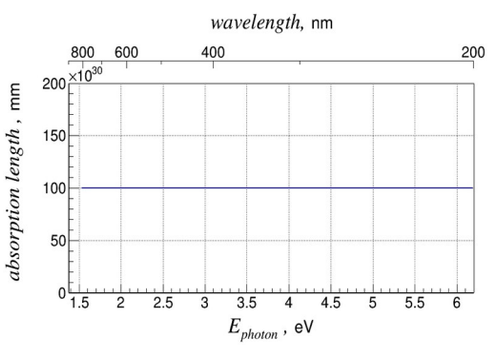




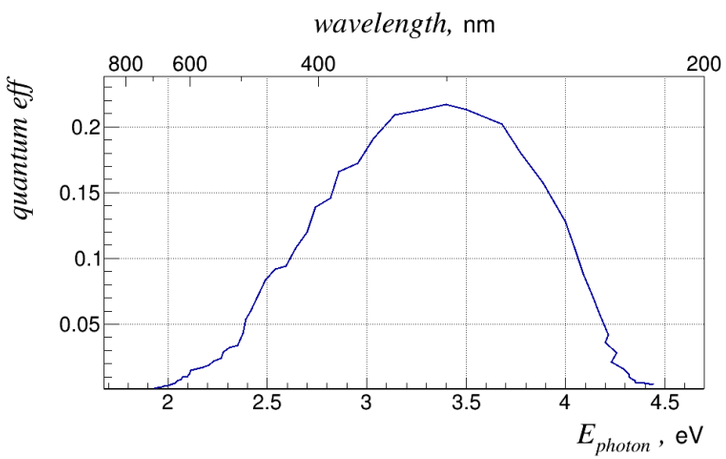


Air





Photon detector



FARICH in SpdRoot

1) Description of geometry/material

2) Setting of optical properties in Geant4

3) FARICH reconstruction

FARICH reconstruction

1) Reconstruction by ellipse

2) Reconstruction by dependence θ_c vs φ_c

3) Reconstruction using Likelihoods

4) Reconstruction using ML

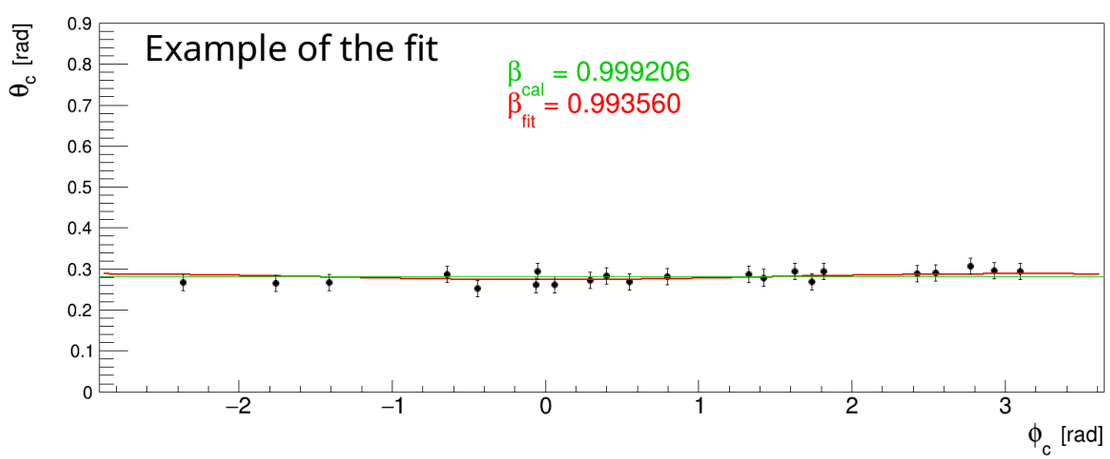
FARICH reconstruction: by dependence θ_c vs φ_c

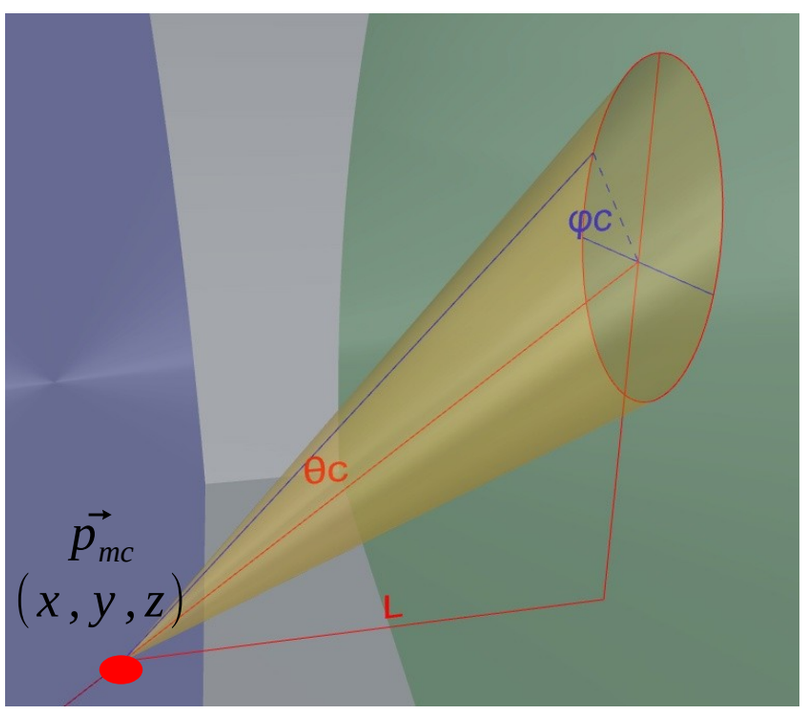
The simulation of FARICH was done at the SpdRoot framework for sets of particles: electrons, muons, pions, kaons, and protons. Momentum range is from p_{th} to 8 GeV. Currently, only Cherenkov photons from the ring are being studied.

The dependence of polar angle of Cherenkov photons θ_C on azimuth angle φ_c are used for reconstruction

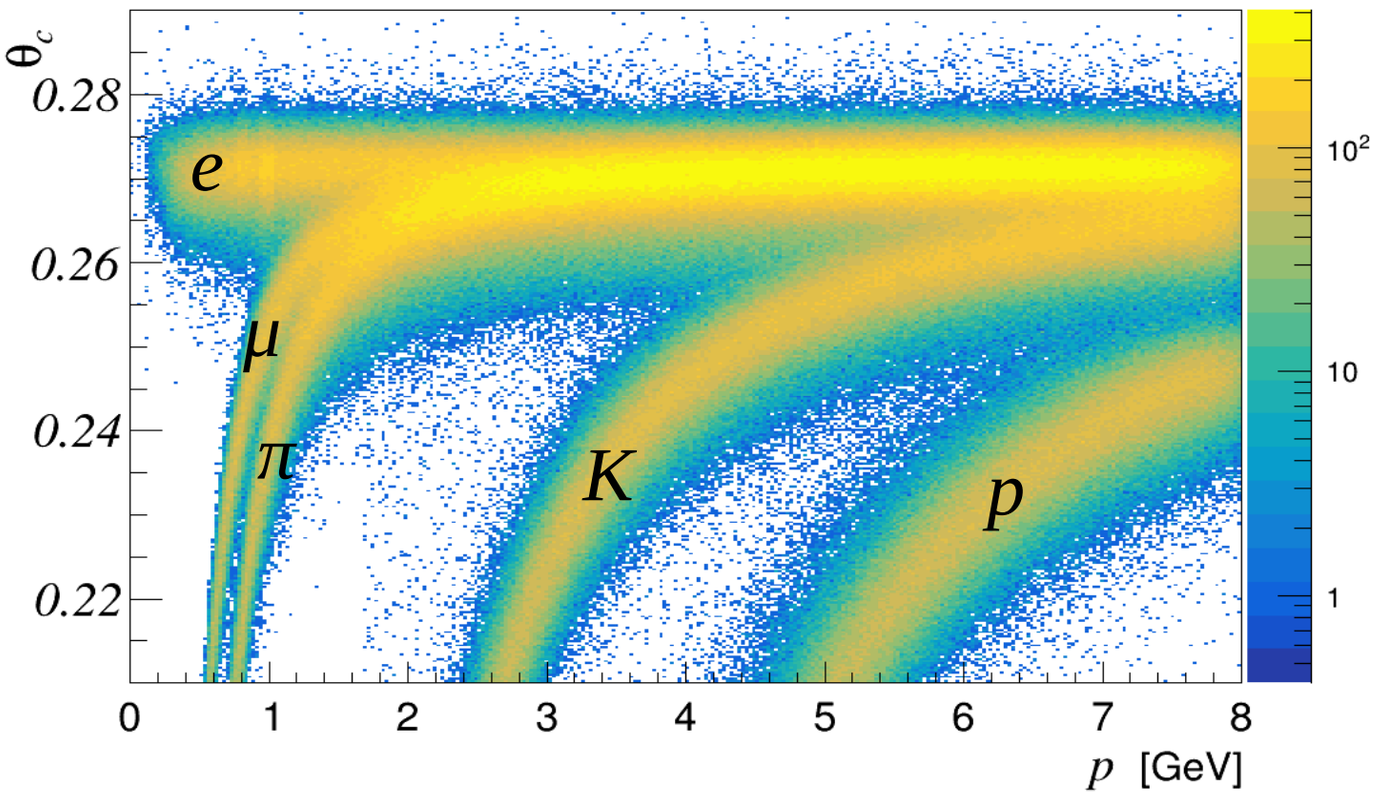
$$\theta_c(\varphi_c|\beta,n,\theta_t) = \arccos\left(\frac{1}{n\beta}\right) + \arccos\left(n\left(1-(\vec{n}_0\vec{n}_\gamma)^2\right) + (\vec{n}_0\vec{n}_\gamma)\sqrt{1-n^2\left(1-(\vec{n}_0\vec{n}_\gamma)^2\right)}\right)$$

- n average value refraction index of radiator
- $(\vec{n}_0\vec{n}_\gamma) = \cos\theta_t/(n\beta) + \cos\varphi_c \sin\theta_t\sqrt{1-1/(n\beta)^2}$
- $\vec{n}_0$ and $\vec{n}_\gamma$ vectors of the radiator and Cherenkov cone normal, respectively

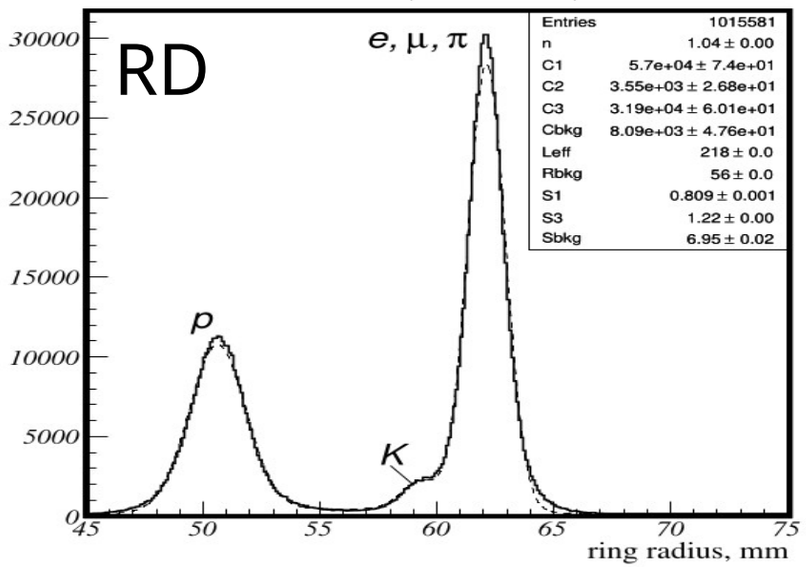




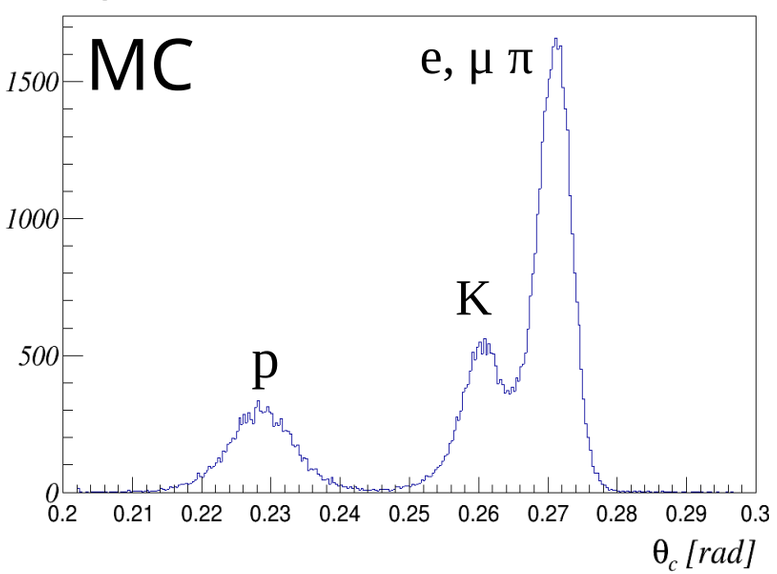
FARICH reconstruction: θ_c vs p_{rc}



Nucl. Instrum. Meth. A, 732:352–356, 2013



particles momentum 6 GeV/c



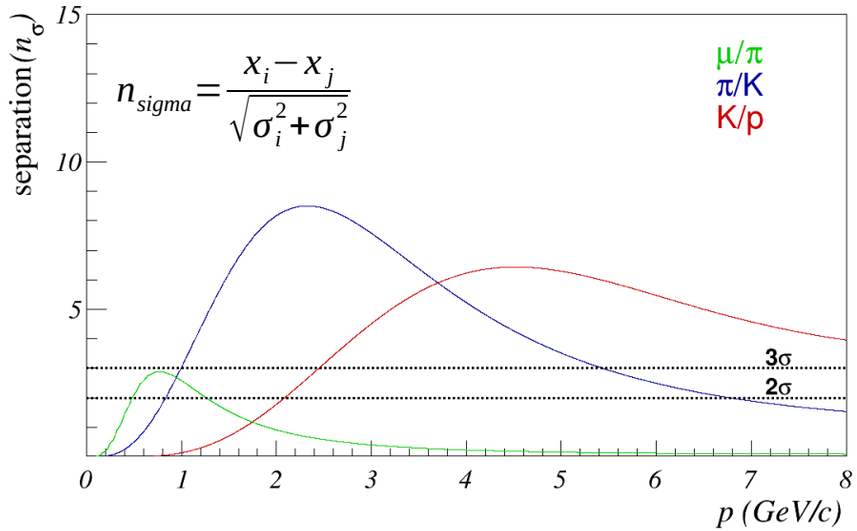
Conclusion

The detector is expected to perform separation at 3-sigma level

- π/K separation - from 0.6 to 5.5 GeV/c
- K/p separation - from 1.6 to 8.5 GeV/c

at 2-sigma level

- μ/π separation - from 0.48 to 1.25 GeV/c



Thank you for your attention