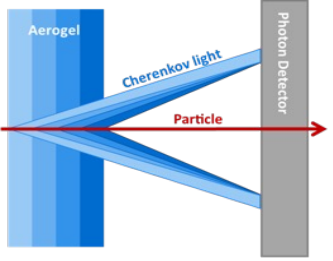
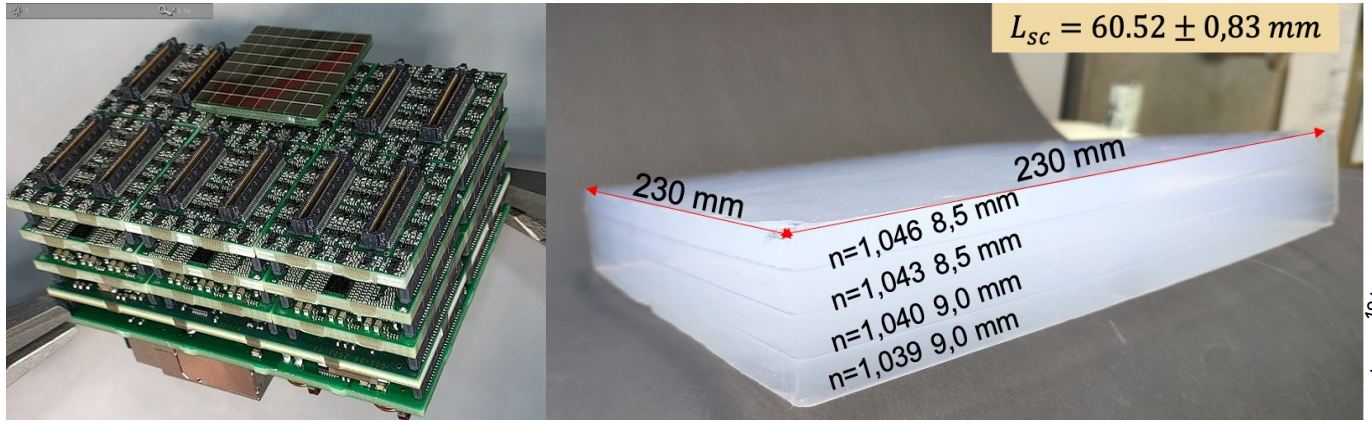


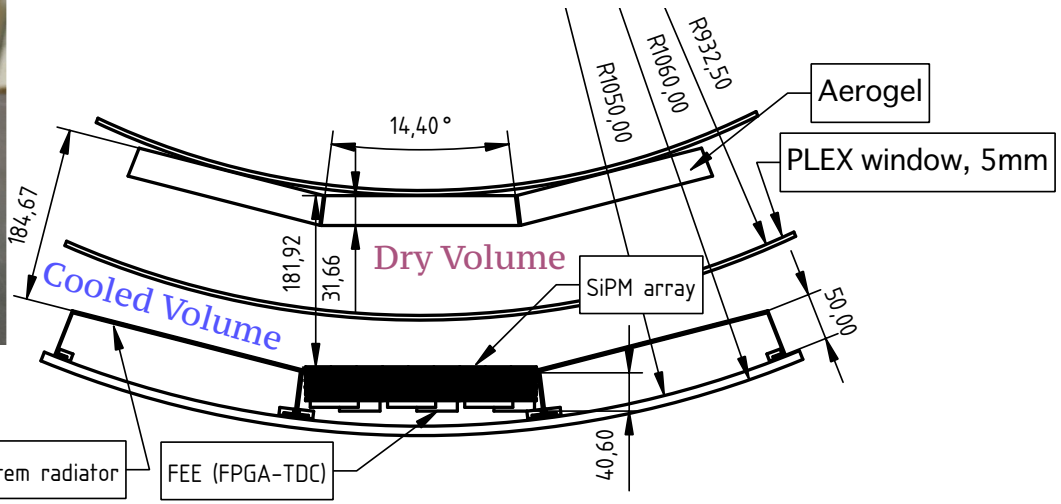
FARICH construction optimization for the Super C-Tau factory

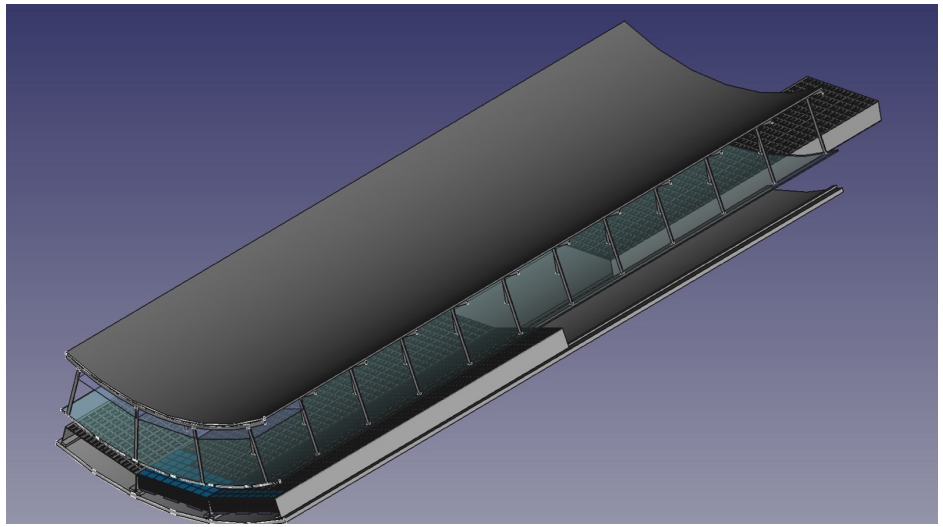
A. Barnyakov

The International Workshop on Future Tau Charm Facilities,
Sun Yat-Sen University, Guangzhou 2024

Barrel part of the FARICH system for the SCTF







- 275 aerogel tiles 200x202x35 in barrel part
- only SiPM will operate in magnetic field
- effective cooling system is required

- We have to separate dry volume with aerogel and cooled down volume with SiPM+FEE by transparent window (i.e. plexiglass)
- Position and thickness of the window is an option for optimisation

Cherenkov Rings from Plex and Aerogel

- Only particles with $P_t \geq 150$ MeV/c will reach the barrel part of the system due to magnetic field B=1T

- Optimal distance from PLEX and PD foreseen is about 50 mm

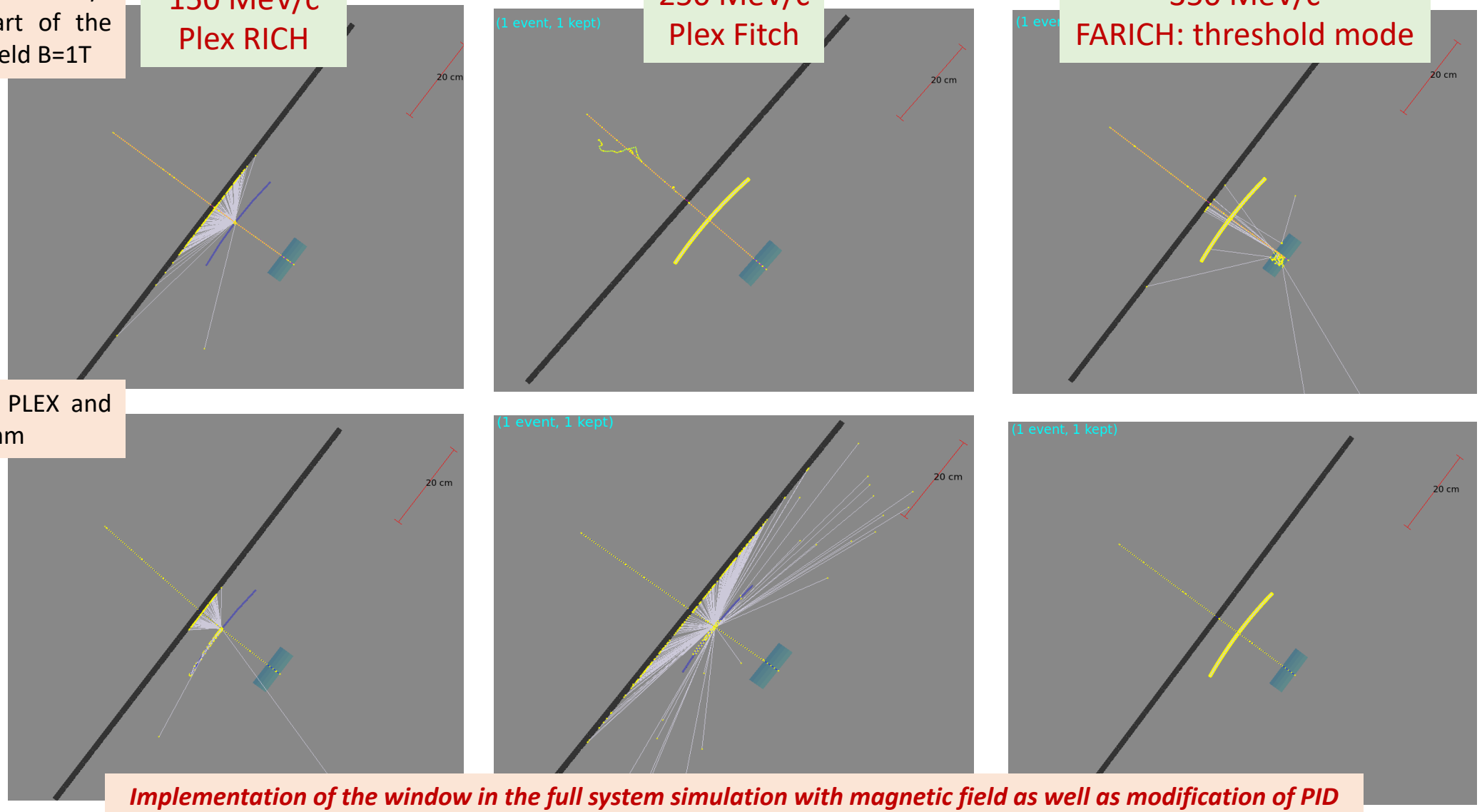
150 MeV/c
Plex RICH

250 MeV/c
Plex Fitch

350 MeV/c
FARICH: threshold mode

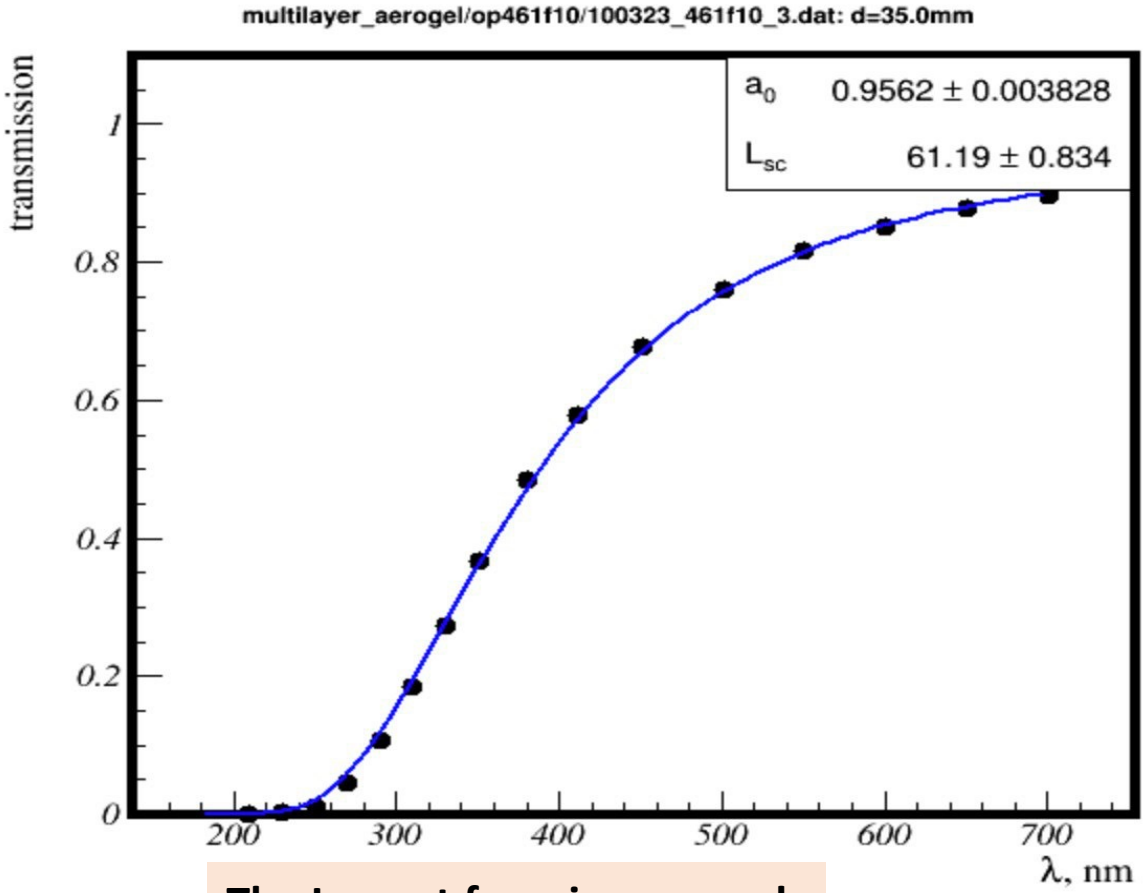
μ-meson

π-meson



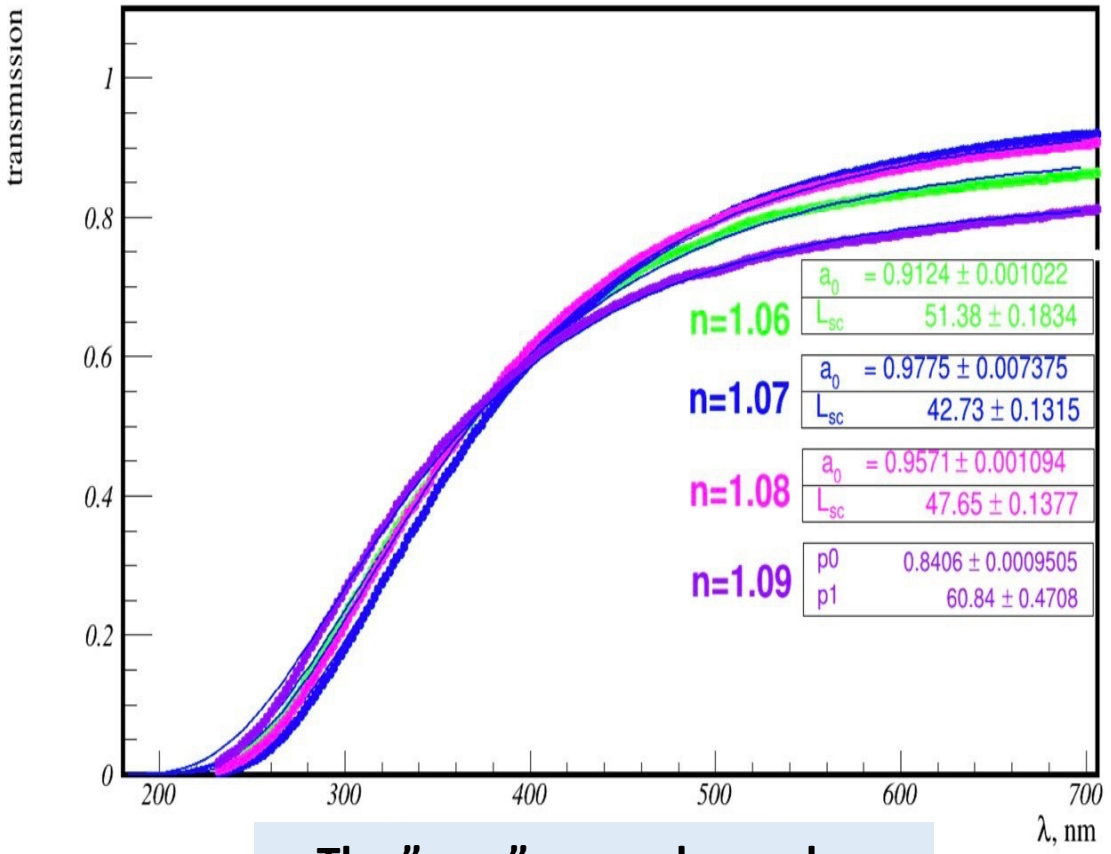
Implementation of the window in the full system simulation with magnetic field as well as modification of PID reconstruction algorithms are required to estimate pros and cons!

Highly transparent aerogels with n>1.05



The Largest focusing aerogel:

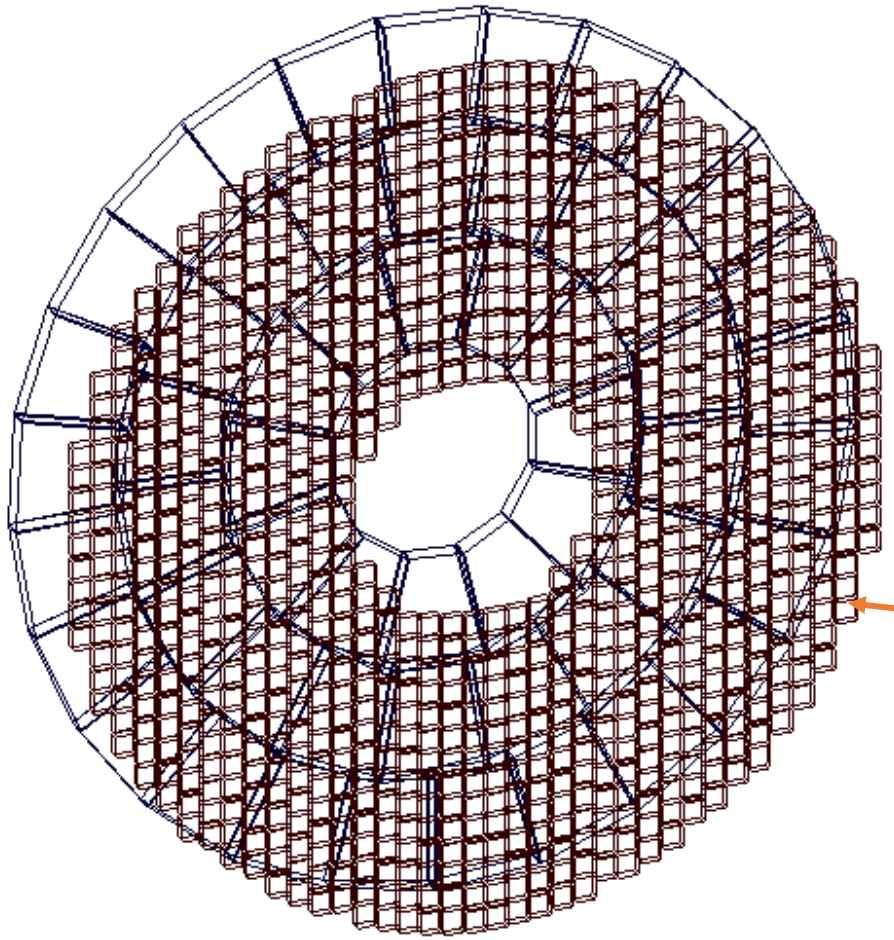
- n_{max}=1.05
- 4 layers
- 230x230x35 mm



The "new" aerogel samples
with different refractive indexes:
from n=1.06 to 1.09
(thickness ~ 22 mm)

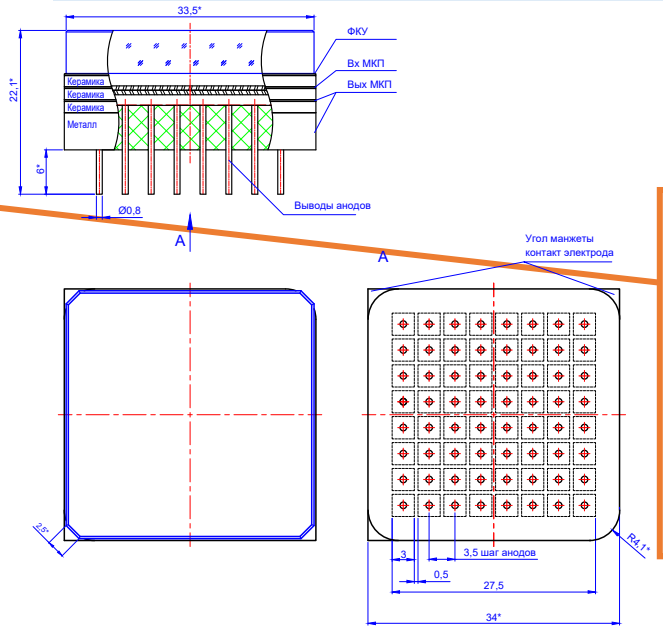
FARICH based on 4-layer aerogel with **n_{max}=1.08** will provide μ/π–separation from **250 MeV/c!!!**

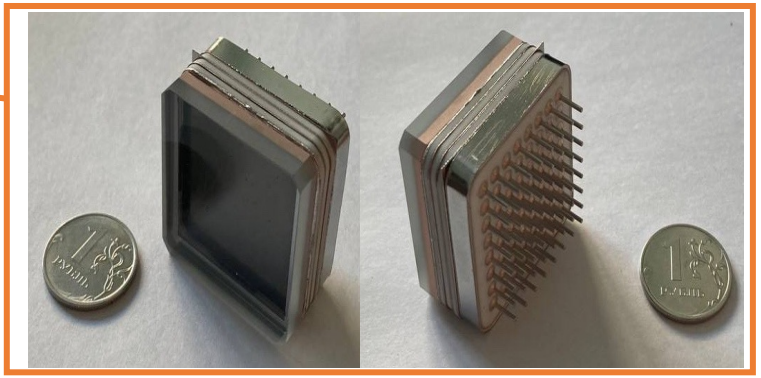
Endcap parts of the FARICH system



The first square MCP PMT produced in Russia:

- Construction and design is developed
- All technological processes are developed and realized
- All details and components are produced in Russia
- First samples for test will be available until the end of 2024



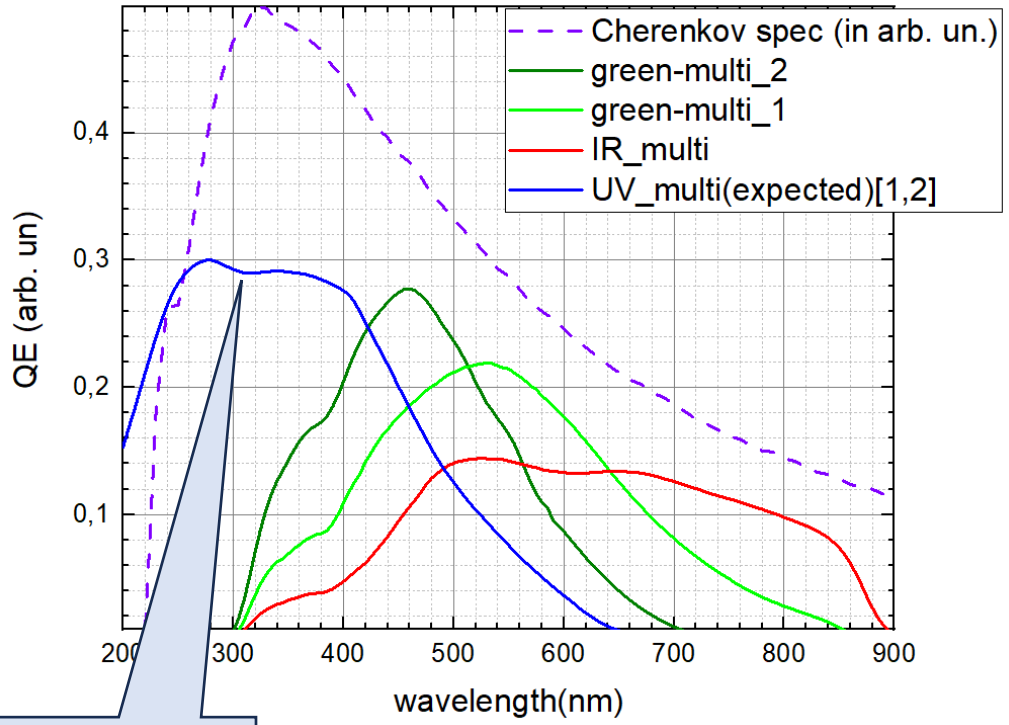


- 2x55 trapezoidal aerogel tiles in end caps:
- 2x1000 MCP PMTs 34x34mm^2 from “Ekran FEP”
- MCP PMTs can operate without cooling

The first fully asembled and vacume sealed prototype

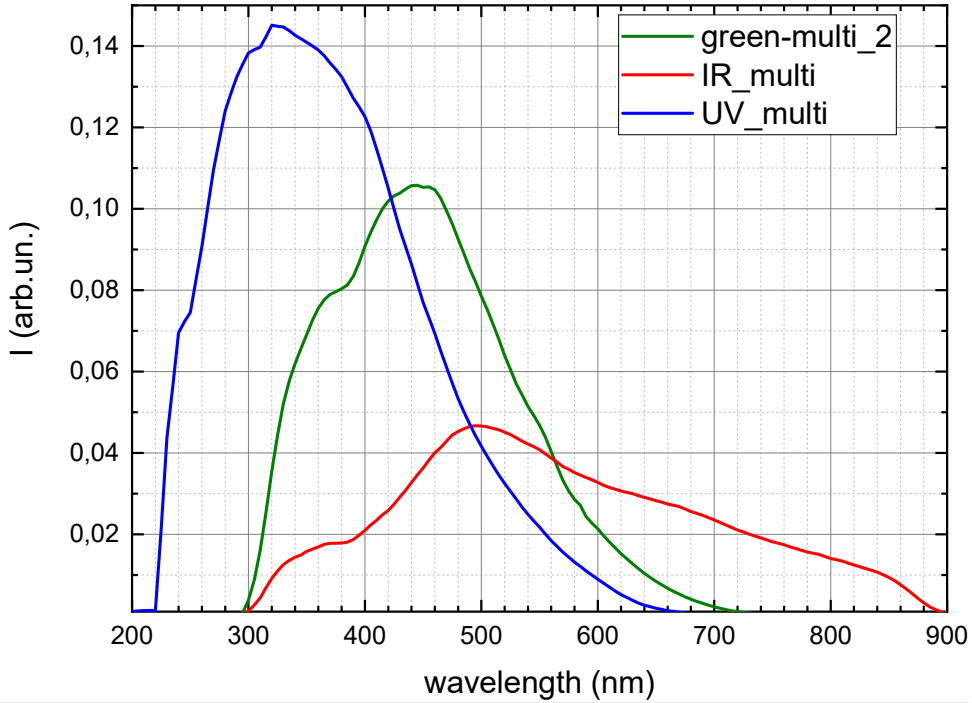
Photocathode options for “Ekran FEP” MCP PMTs

Multi-alkali PCs options and Cherenkov spectrum



It is planed to use Quartz to enhence PDE in UV region

Product of Ch. Sp. by QE of Multi-alkali PCs



The advantages of use **“UV_multi” PC (Quartz)** are expected as following:

– **factor of 1.5** more detcted Cherenkov photonsin in comparison with standard “green-multi2” PC

– **factor of 2** in comparison with standard “IR_multi” PC

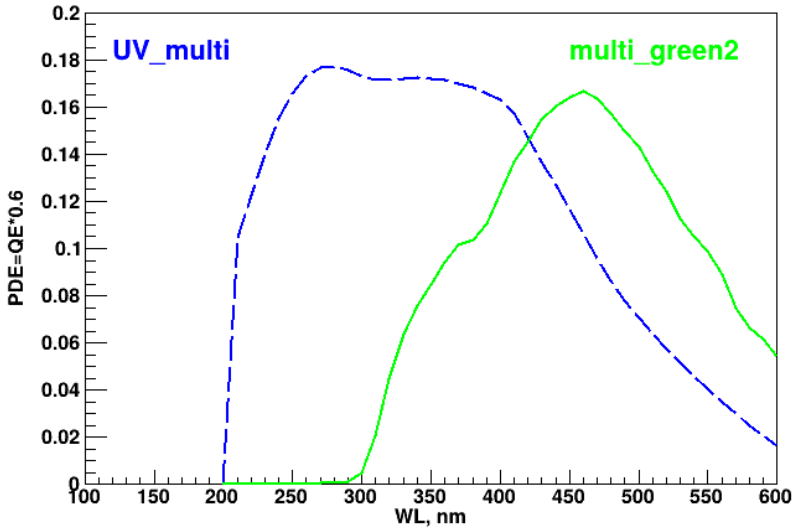
“UV_multi” QE based on data from papers:

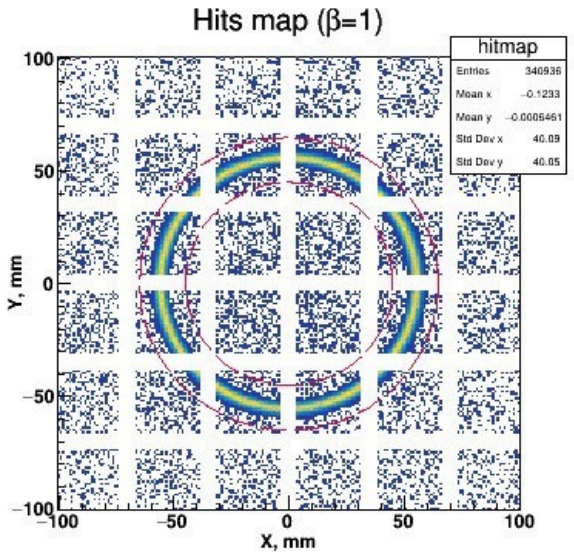
1. Orlov, D. A., et al., High quantum efficiency S-20 photocathodes in photon counting detectors. Journal of Instrumentation, 2016 11(04), C04015–C04015

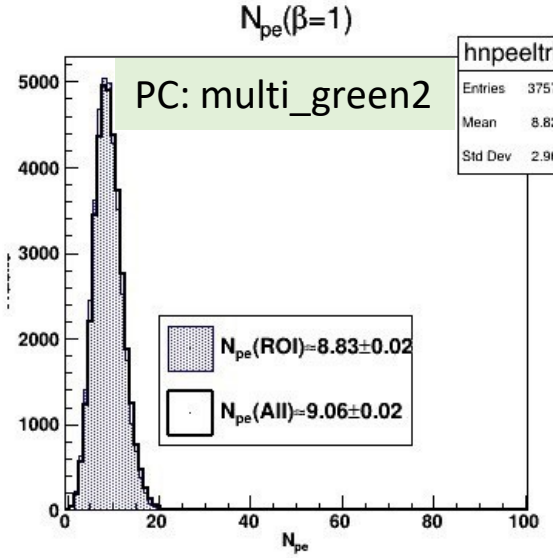
2. Milnes, J., et al., UV photocathodes for space detectors. Proceedings Volume 12181, Space Telescopes and Instrumentation 2022: Ultraviolet to Gamma Ray, 121813B (2022).

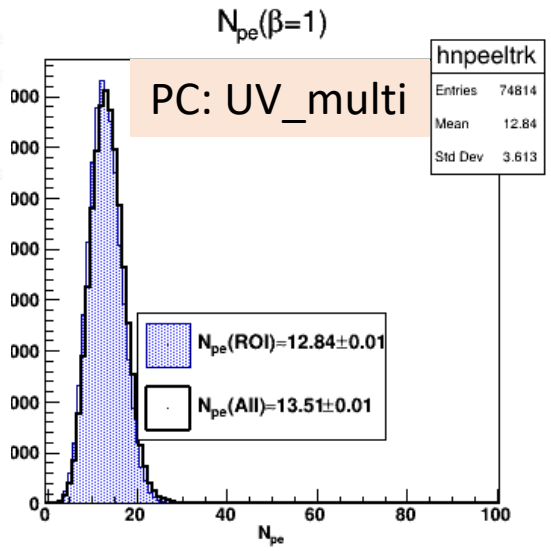
FARICH prototype based on MCP-PMT (Ekran FEP)

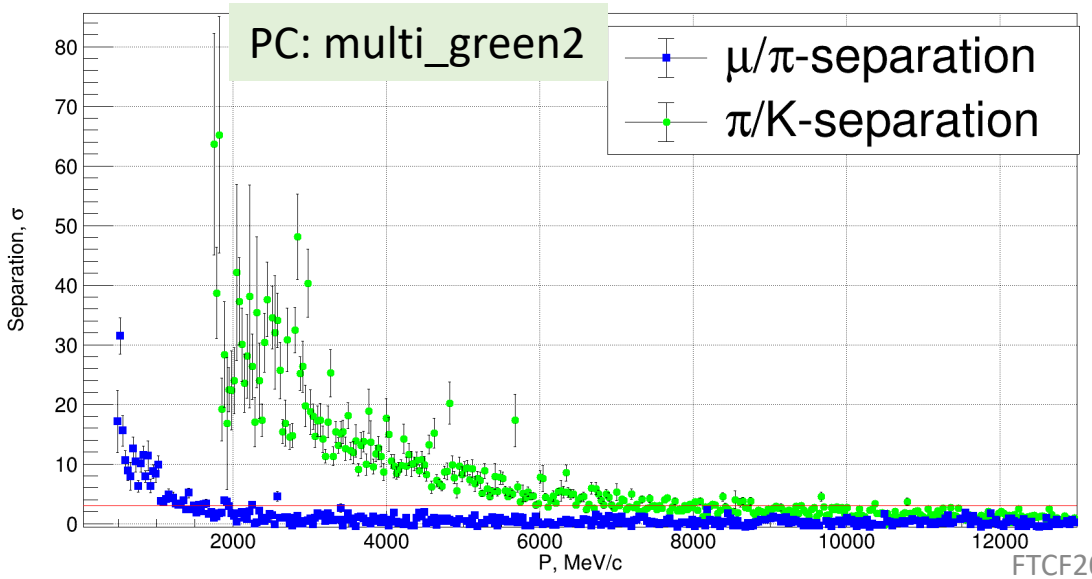
(expected performances: Geant4 simulation results)

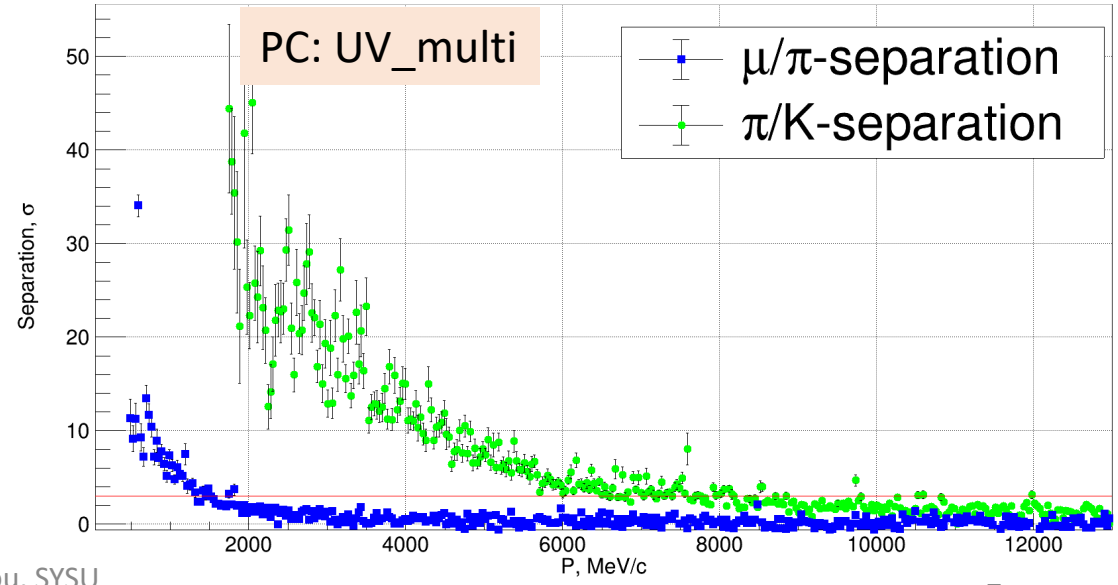












On ToF based on MCP PMTs for PID at P≤0.3GeV/c

- Quartz entrance window with 4 mm thick at MCP PMTs from Ekran FEP able to produce about 40 Cherenkov ph.e/track from μ– and π–mesons with P≥150 MeV/c
- Achievable $\sigma_t \approx {}^{30}/_{\sqrt{40}} \approx 5ps$
- IF

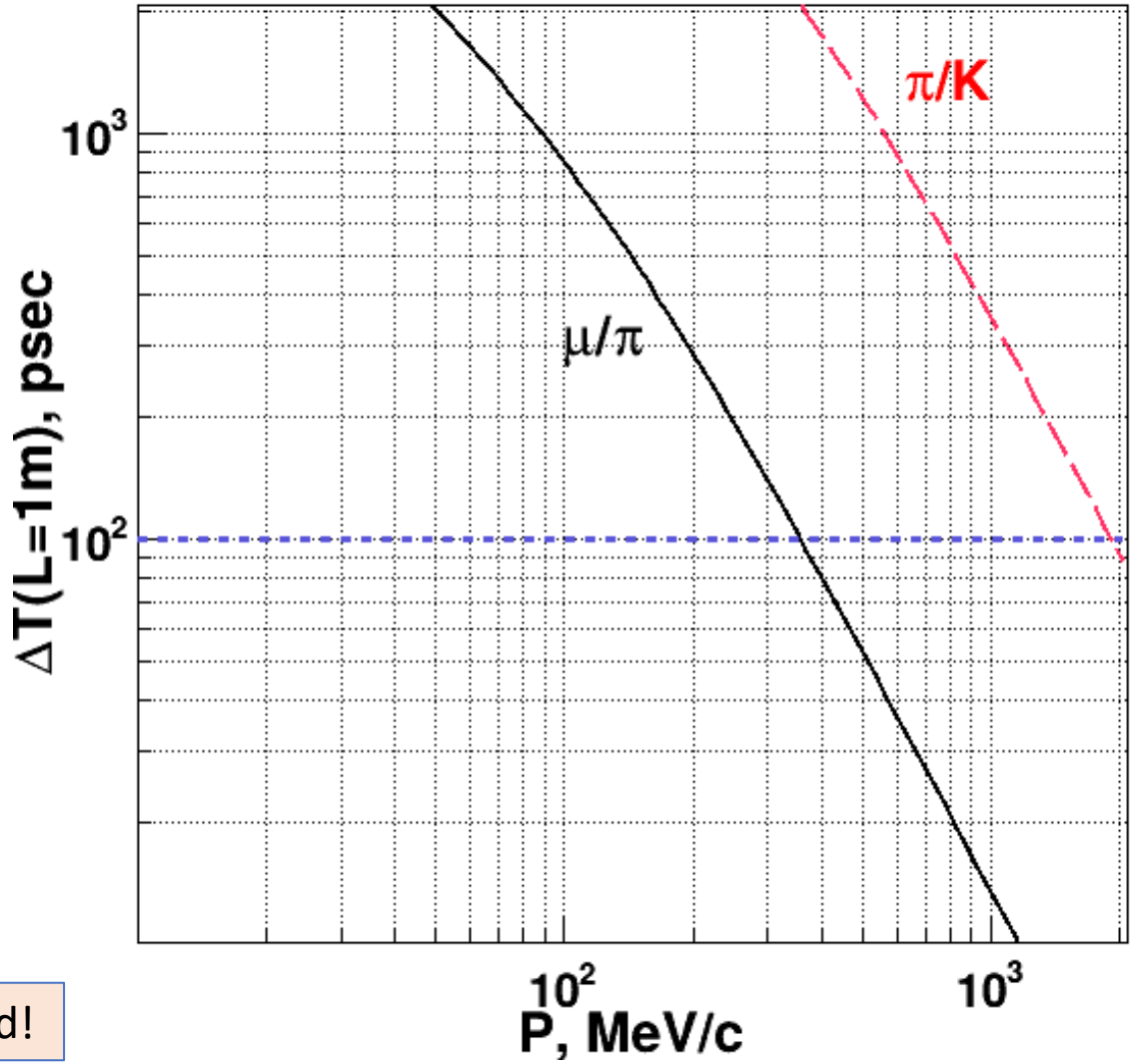
$$\sigma_{ToF} = \sqrt{\sigma_t^2 + \sigma_{elec}^2 + \sigma_{bunch}^2} = 30ps$$

THEN reliable particle separation by means of ToF technique could be achieved at the distance L=1m

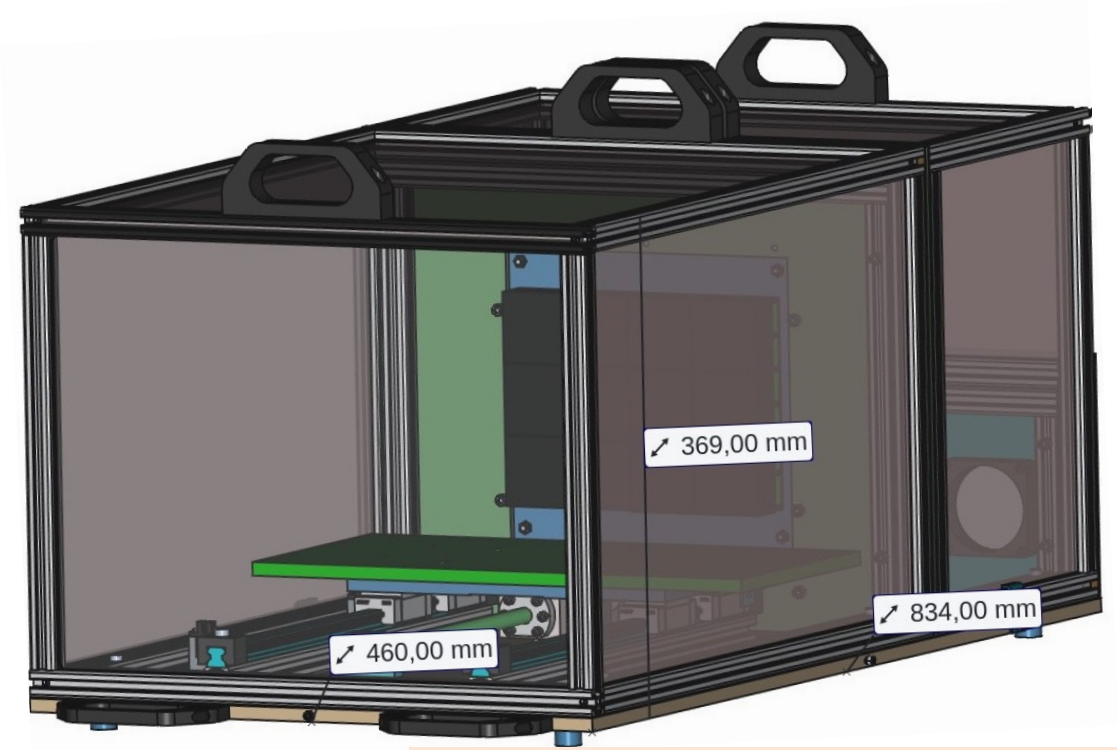
  - up to 300 MeV/c for μ/π
  - up to 2000 MeV/c for π/K

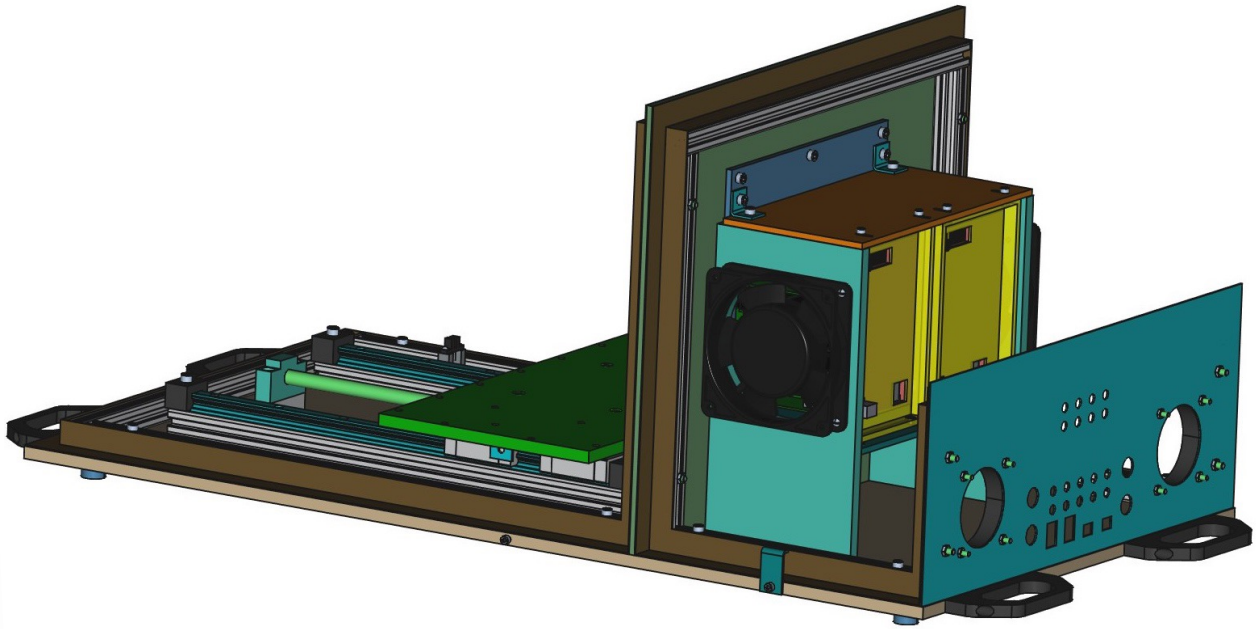
$$\Delta t = \frac{L}{c}\left(\sqrt{1+\left(\frac{m_2 c^2}{pc}\right)^2} - \sqrt{1+\left(\frac{m_1 c^2}{pc}\right)^2}\right)$$

Very specific and dedicated electronics are required!



The compact FARICH prototype with full ring detection

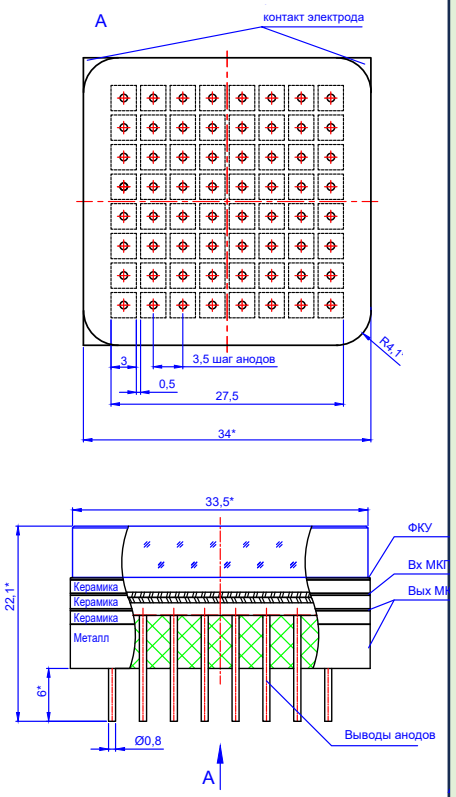


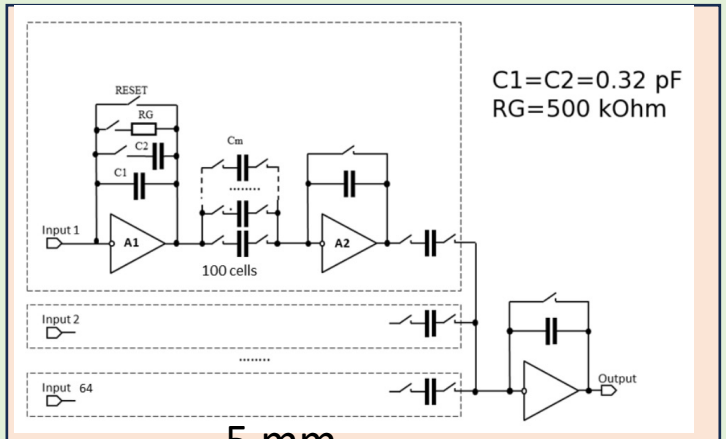


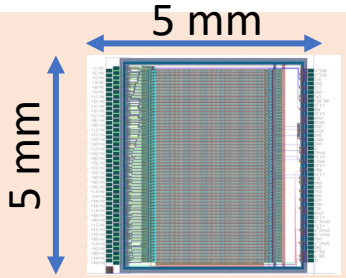
FARICH compact prototype based on MCP PMT:

- Tech. draws are ready
- Materials, components and equipment are purchased
- Production was started at the BINP
- Readout system (based on DiRICH+TRB3 boards from GSI) is ready
- 4-layer focusing aerogel is ready
- The prototype will be able operate with N6021 (NNVT) and “Ekran FEP” MCP PMTs

FEE concept based on BINP made components







DMXG64 ASIC:

- 64 channels with 100 analogue memory cells each
- peration freq. – 10MHz
- Input signals $\leq 2\times10^{6}e^{-}$
- ENC – 2700÷3200 e^{-}

High-speed ADC:

- Rate ≥10 MSPS
- Channels 1 or 2
- i.e. ADS4145 (14-bit, 125 MSPS)
- …

FPGA

PC

- ONE ASIC / MCP PMT 8x8 pxs
- ONE ADC / 64 pixels MCP PMT
- $T_{r/o}$≤6.4 µsec to read out 64 pixels

It is good enough for prototype!
For real DAQ optimisation is needed

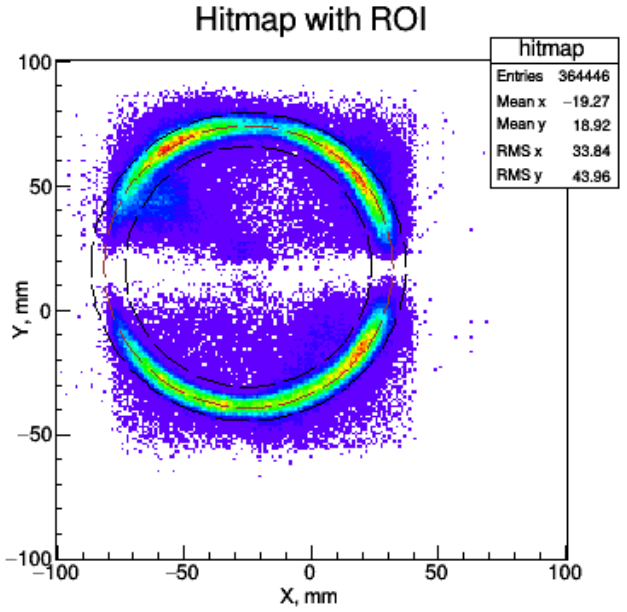
*V. Aulchenko et al 2017 JINST **12** C05004*

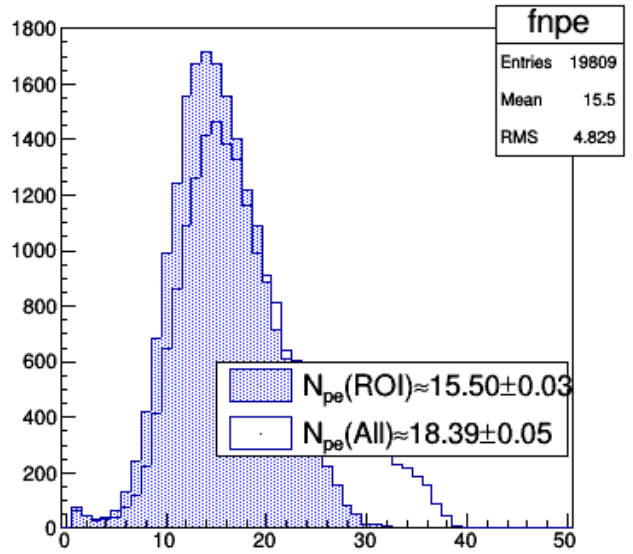
Summary

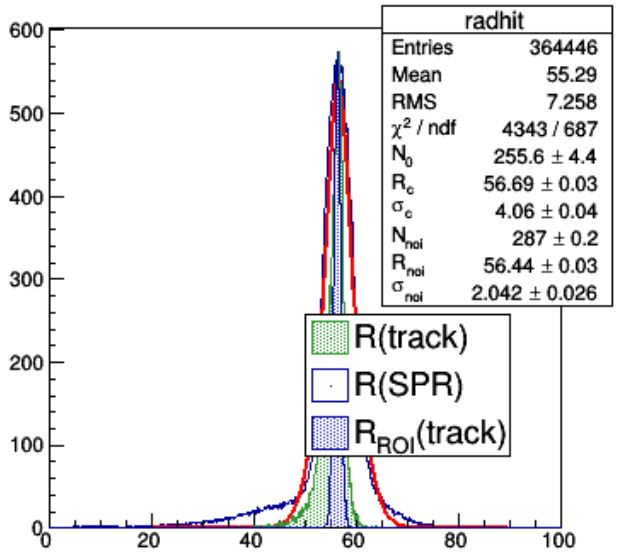
- The optimisation of barrel part of the FARICH system is ongoing with help of GENT4 simulation:
  - Plexiglass window is able to provide π/K–separation below the thershold of the FARICH detector based on multilayer aerogel with n_{max}=1.07
  - Investigation of possibilities to produce highly transparent aerogels (L_{sc}(400nm)≥40mm) with n≥1.07 has been started
- Development of square MCP PMTs with 8x8 pixels and 3x3mm size has been started in Novosibirsk:
  - Optimisation of the Multi-alkali Photocathode options is ongoing
  - The first sample for real tests are expected until the end of 2024
  - It shown with GEANT4 simulation that FARICH based on MCP PMTs designed by Ekran FEP will be able to provide:
    - π/K–separation up to 6 GeV/c
    - μ/π–separation up to 1.5 GeV/c
- Optimisation of the FARICH prototype was started:
  - Compact prototype for easy transportation to the mixed hadron beamlines (IHEP, JINR etc.) was designed and now is under production at the BINP's workshop

Recent beam test results

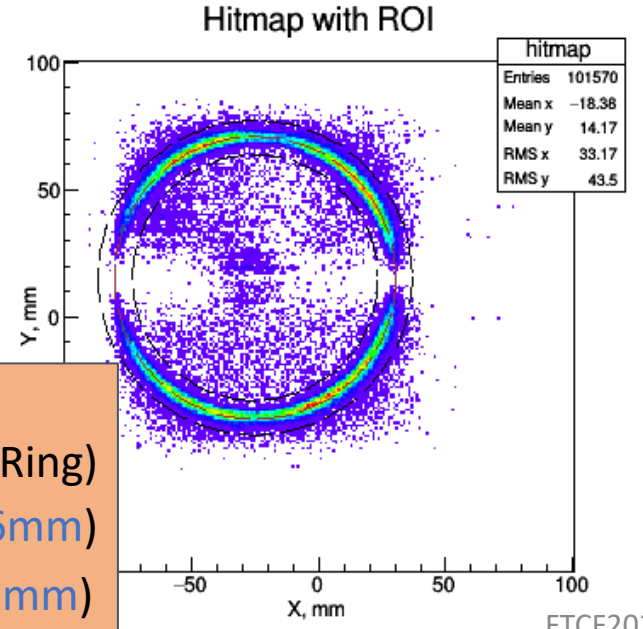
Pixel 6x6 mm
Geom.Eff. ~ 80%

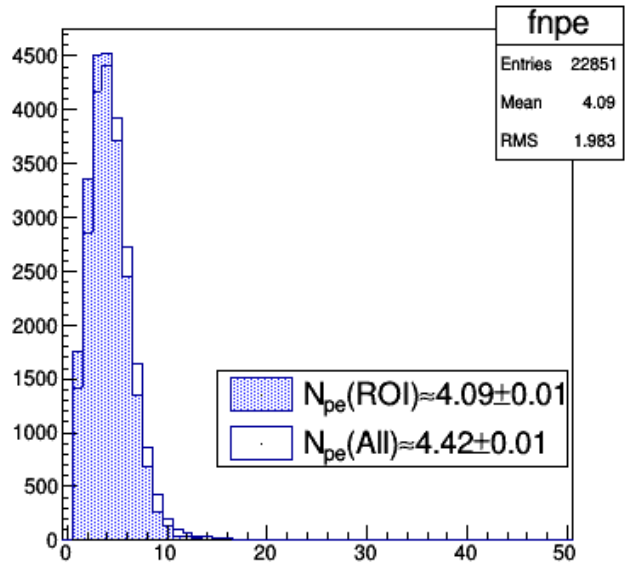


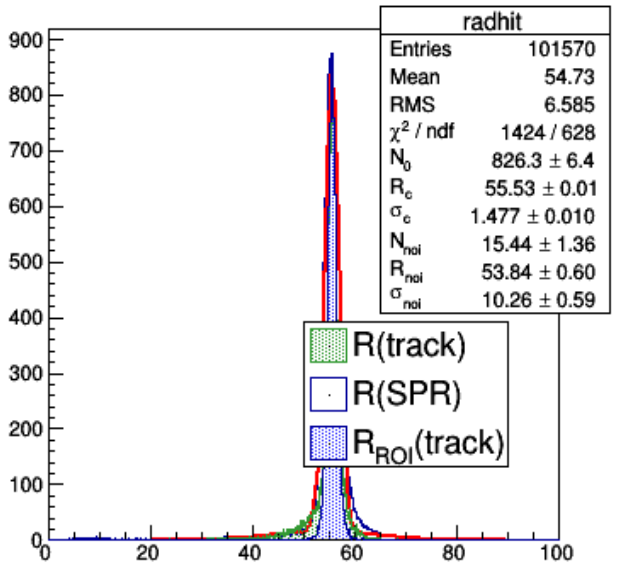




Pixel 3x3 mm
Geom.Eff. ~ 20%







Main results:

- N_{pe} ≈ 16 (~ 0.8 of Ring)
- σ_θ^{1pe} ≈ 13.5 $mrad$ (■ 6mm)
- σ_θ^{1pe} ≈ 7.5 $mrad$ (■ 3mm)