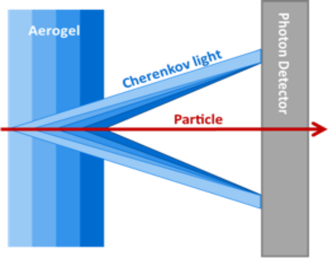
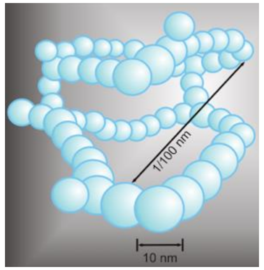




Методика ФАРИЧ: статус разработок и перспективы

А.Ю. Барняков

от имени ``Аэрогелевой группы ИЯФ СО РАН”

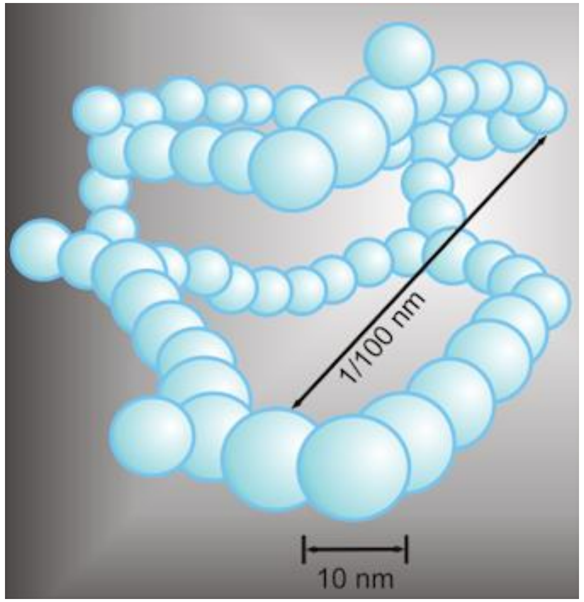
- Аэрогель
- ФАРИЧ для СЦТФ
- ФАРИЧ для эксперимента SPD@NICA
- ФАРИЧ для π/K разделения выше 20 ГэВ/c

Физика частиц при средних и высоких энергиях
НИЦ Курчатовский институт – ИФВЭ (г. Протвино)
2-5.06.2026г.

Aerogel is a classical nanomaterial

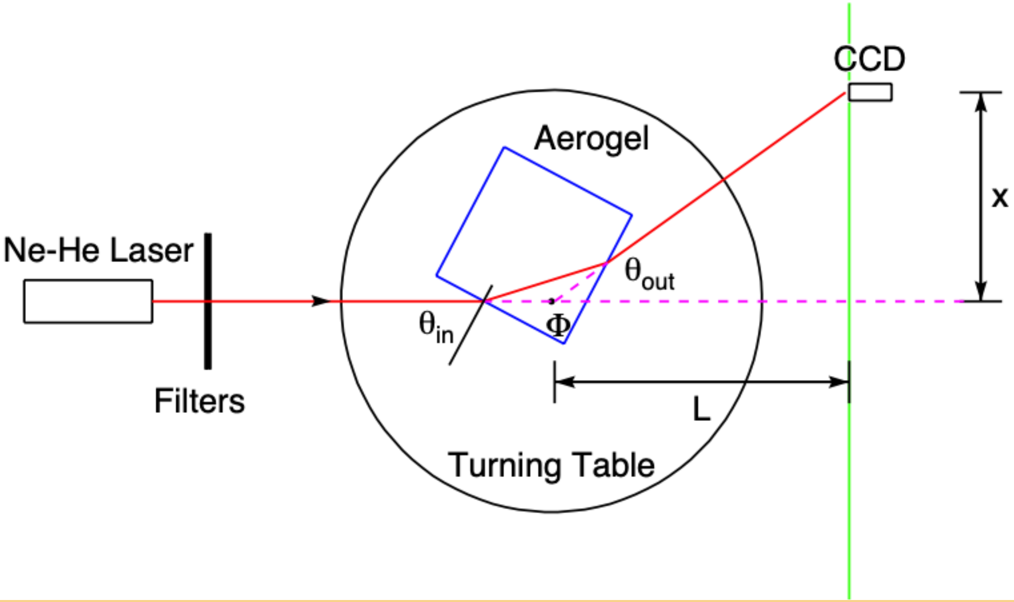
•Aerogel was first synthesized by Samuel Stephens Kistler in 1931

•S.S.Kistler, "*Coherent Expanded Aerogels and Jellies*", Nature, 1931,vol. 127, p. 741



Aerogel – is a porous material with pore dimension less than visible light wavelength.
It is a classical **nanomaterial**.The most interesting for physics experiments are silicon dioxide based aerogels, although aerogels based on metal oxides, carbon, gelatin and other substanses are widely used in various other applications.

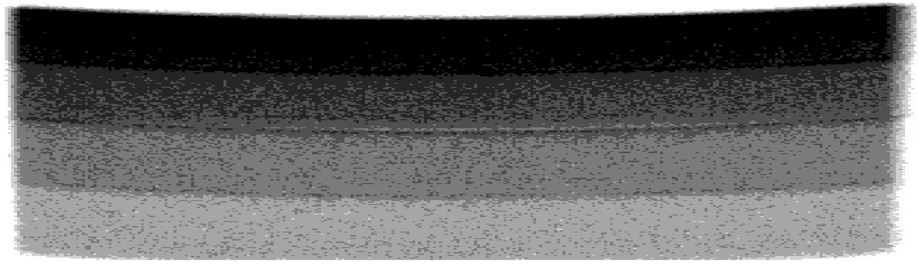
Main aerogel params for FARICH: Refractive index



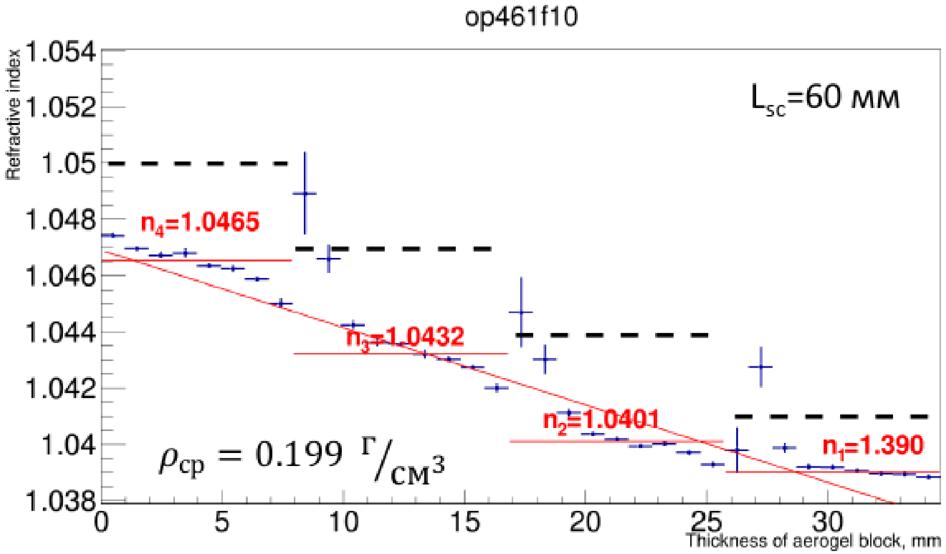
Impirical relation is used for fast determination of n:

$$n^2 = 1 + 0.438 \cdot \rho \left[{}^{g}/_{cm^3}\right]$$

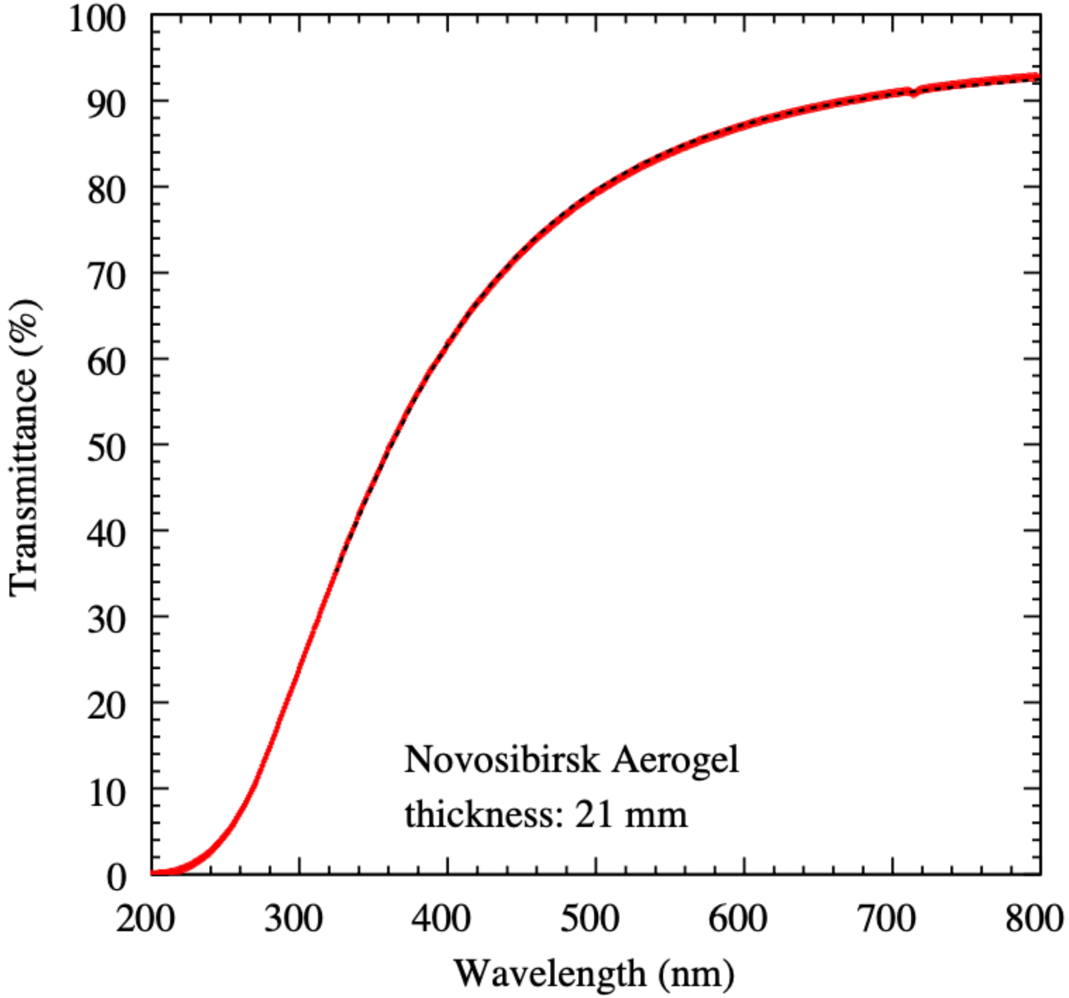
Impirical equation is in good agreement with theoretical dependence Lorentz-Lorentz formula evaluated for gas mixtures.



- Refractive index profile is measured with help of didgital X-ray setup at the BINP.
- Normalized on averaged refractive index calculated through bulk densety



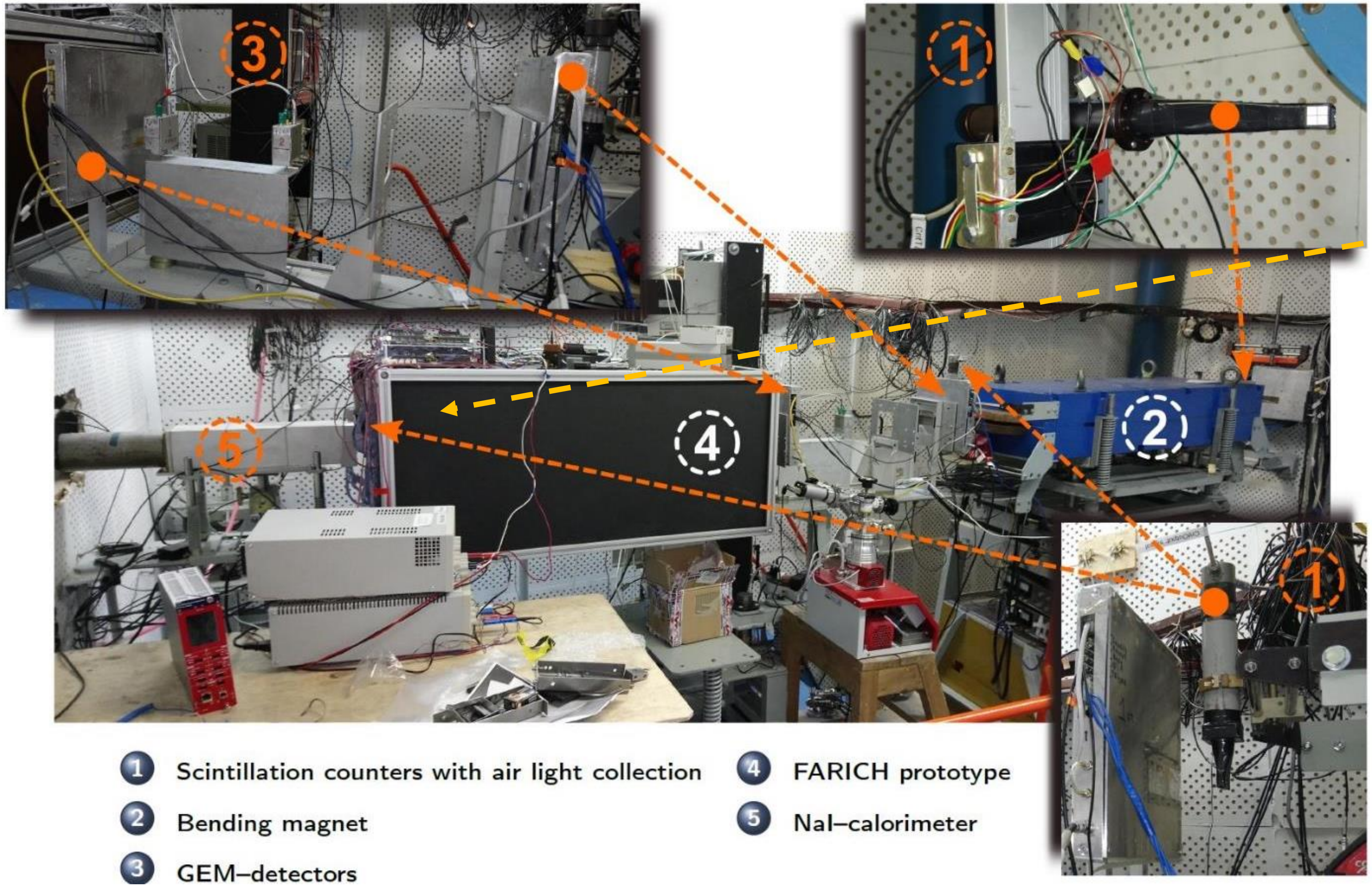
Main aerogel params for FARICH: transperancy and Rayleigh light scattering



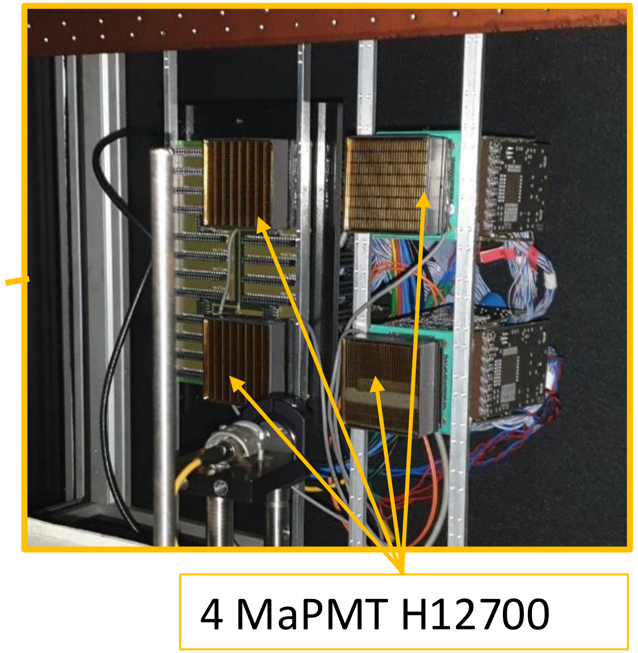
- Hunt formula to fit the transmittance (T) usually are used in two variations:
- $T(\lambda) = \frac{I}{I_0} = A_0 e^{-\left(\frac{d}{L_{sc}^{400} \times \left[\frac{\lambda}{400}\right]^4}\right)}$
- or
- $T(\lambda) = \frac{I}{I_0} = A_0 e^{-\left(C \cdot d / \lambda^4\right)}$
- where d – aerogel thickness, L_{sc}^{400}– light scattering length at 400 nm and C – so called clarity, A_0 – coefficient responsible for light absorption and scattering at the surface of aerogel samples.

BINP beam test facility

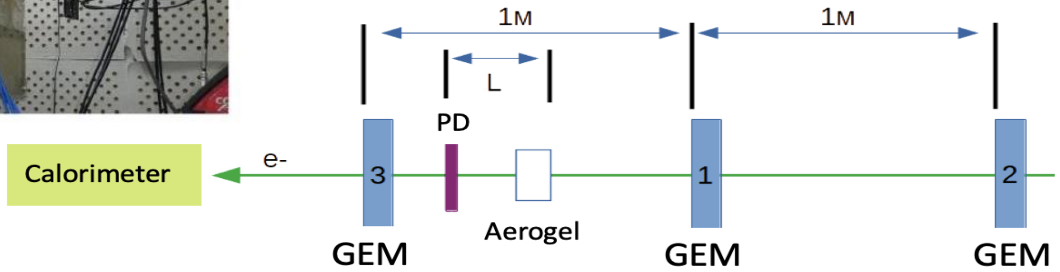
Example disposition of equipment in experimental hall (15/03/2018)



1 Scintillation counters with air light collection
2 Bending magnet
3 GEM–detectors
4 FARICH prototype
5 NaI–calorimeter

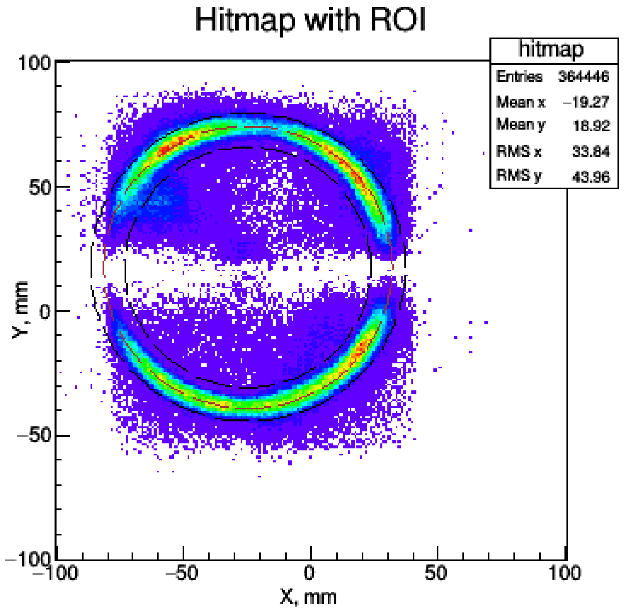


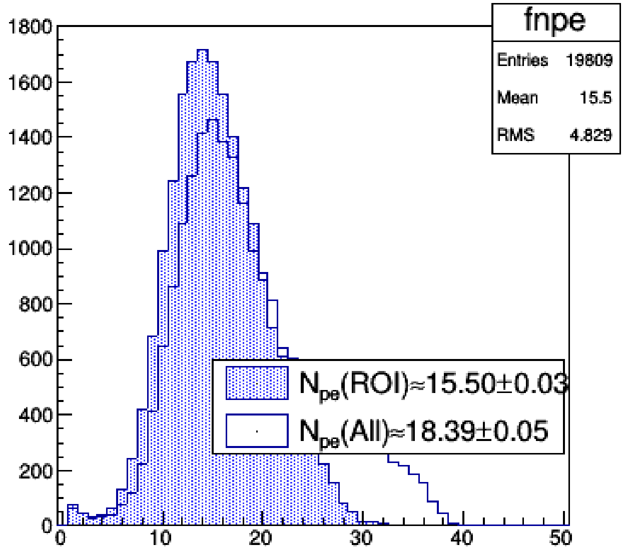
*G N Abramov et al 2014 JINST **9** C08022*

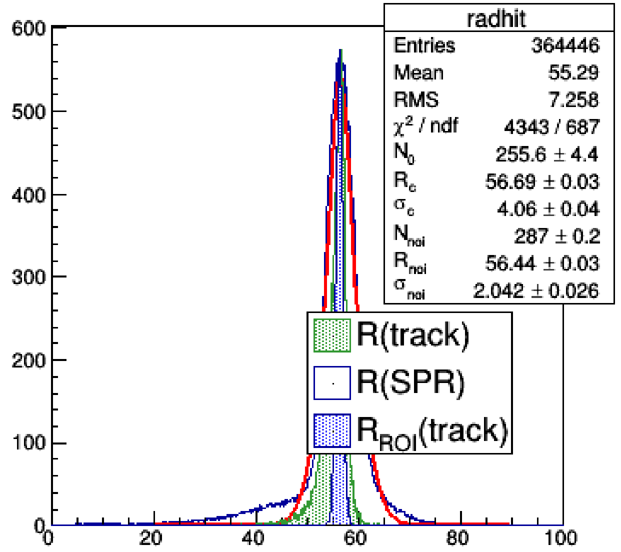


Beam test results with 4-layer aerogel n_{max}=1.046

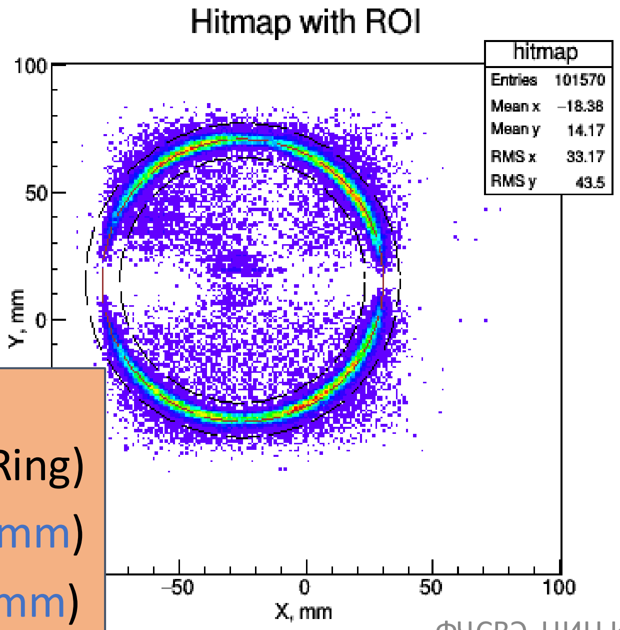
Pixel 6x6 mm
Geom.Eff. ~ 80%

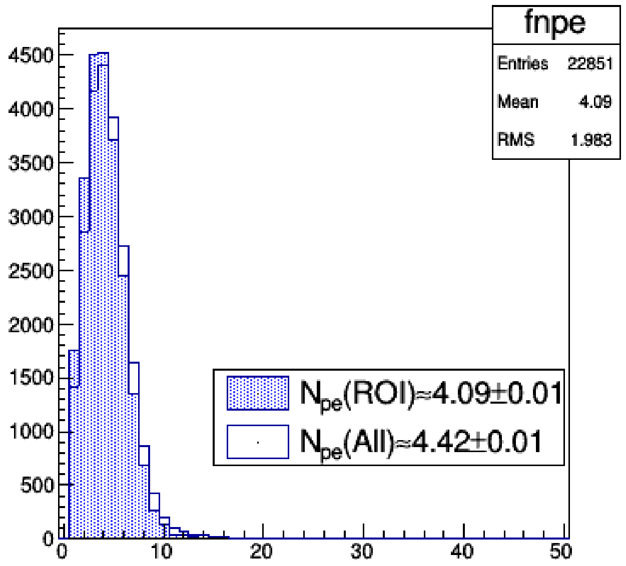


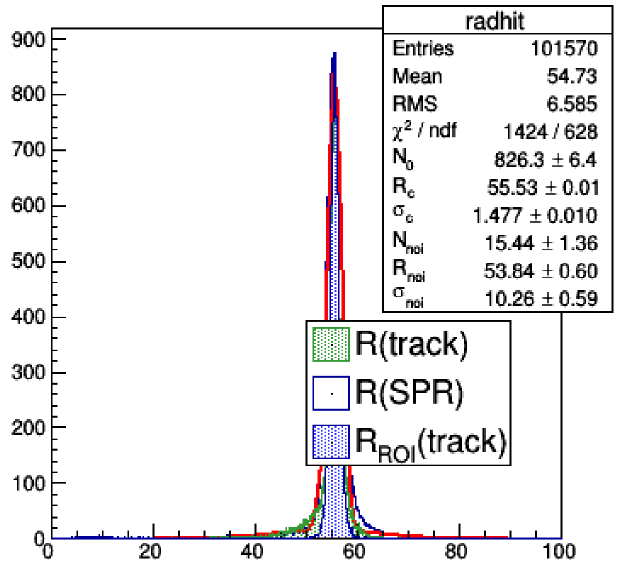




Pixel 3x3 mm
Geom.Eff. ~ 20%



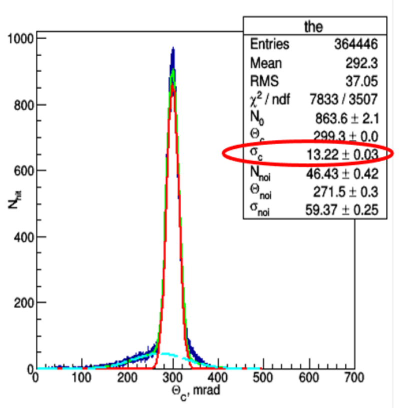


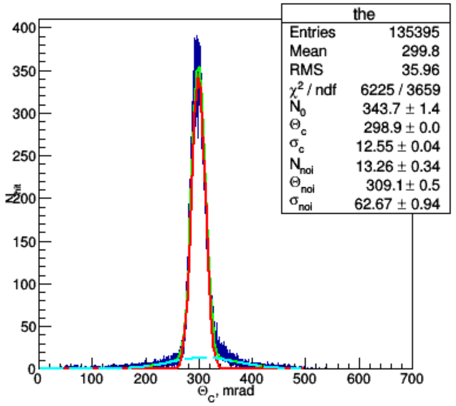


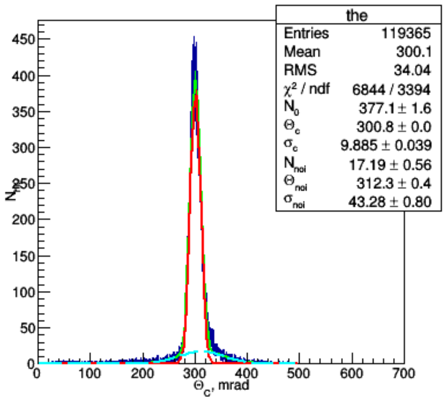
Main results:

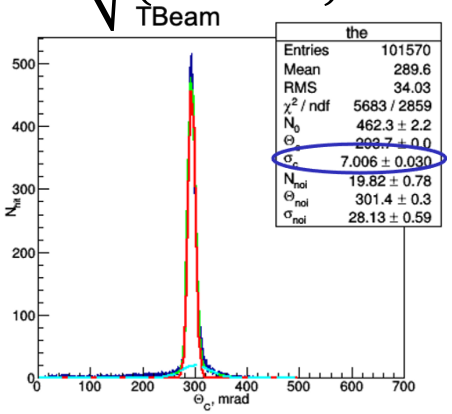
- $N_{pe} \approx 16$ (~ 0.8 of Ring)
- $\sigma_\theta^{1pe} \approx 13.5\ mrad$ (■ 6mm)
- $\sigma_\theta^{1pe} \approx 7.0\ mrad$ (■ 3mm)

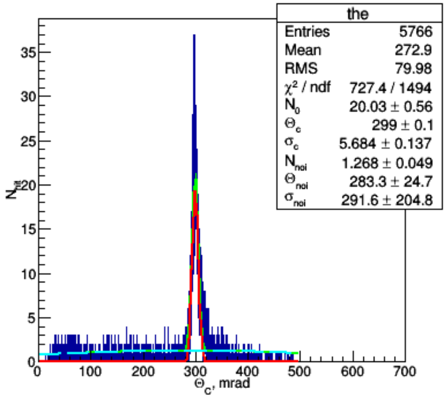
Approach with masks: $\sigma_{\theta_C}^{1pe} = \sqrt{\frac{\Delta_{pix}^2}{\left(\sqrt{12}\cdot L\cdot n\right)^2} + \sigma_{aer}^2 + \sigma_{trk}^2}$



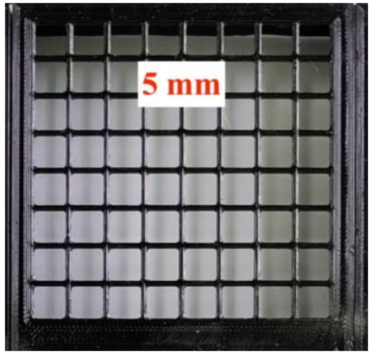


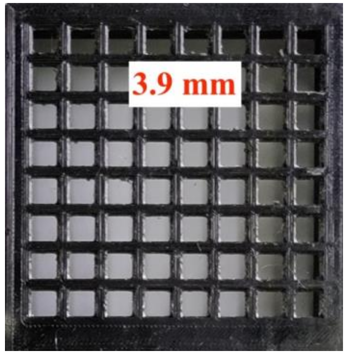


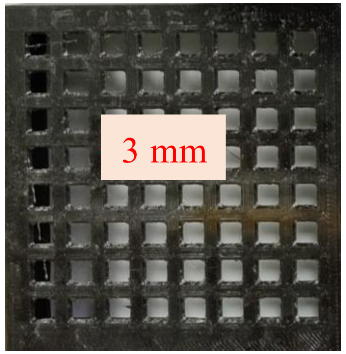




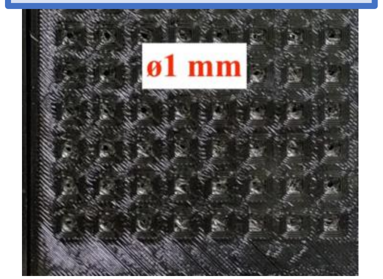
No mask:
$6 \times 6\ mm$





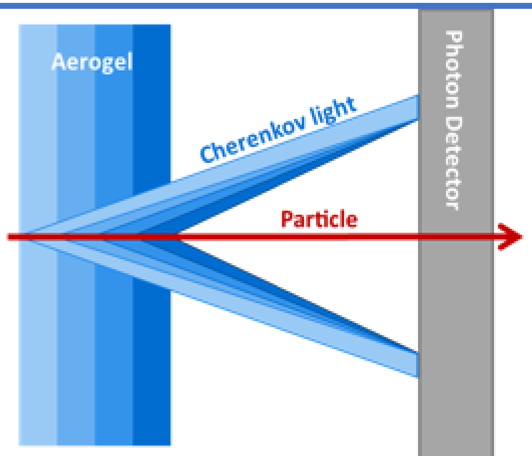


$\sigma_{aer} \approx 5.6$ mrad

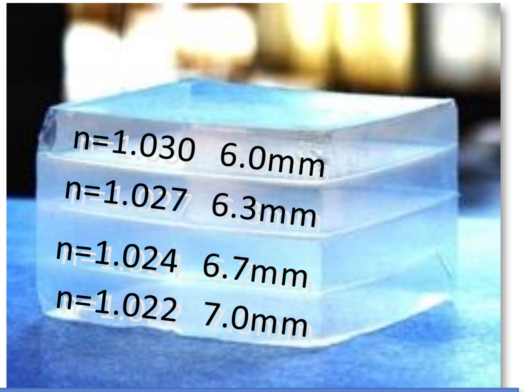


04/23: L≈200 mm	12/23: L≈180 mm	12/23: L≈180 mm	04/23: L≈200 mm	12/23: L≈180 mm
Geom.Eff. ~ 80%	Geom.Eff. ~ 56%	Geom.Eff. ~ 36%	Geom.Eff. ~ 20%	Geom.Eff. ~ 2%
$N_{pe} \approx 16$	$N_{pe} \approx 12$	$N_{pe} \approx 8$	$N_{pe} \approx 4$	$N_{pe} \approx 1$
π/K: – 5.5 GeV/c	6 GeV/c	6.5 GeV/c	8.0 GeV/c	8.5 GeV/c
μ/π: – 1.2 GeV/c	1.4 GeV/c	1.5 GeV/c	1.6 GeV/c	1.7 GeV/c

FARICH technique milestones



The first 4-layer monolithic sample

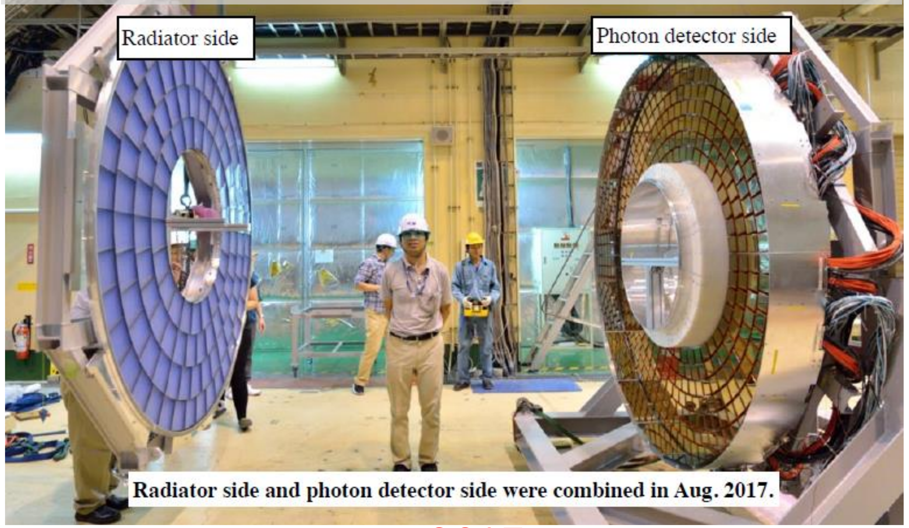


Increase N_{pe} due thickness increase without $\sigma_{\Theta c}$ degradation

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

2004÷2005

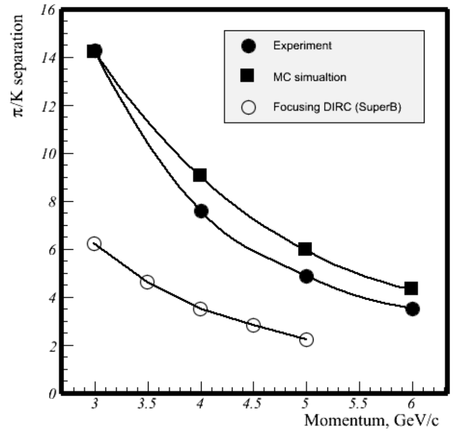
The Belle II (ARICH) is the first application of the method

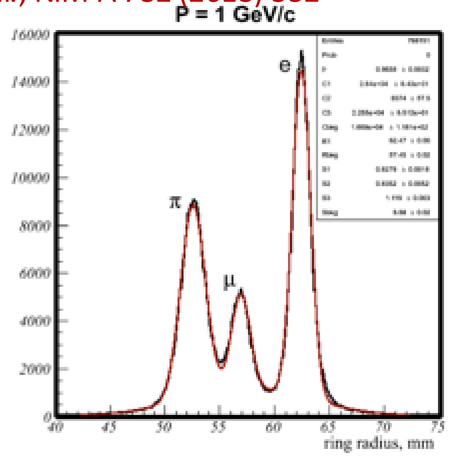


2017

Excellent PID capability were shown at CERN beam test in 2012

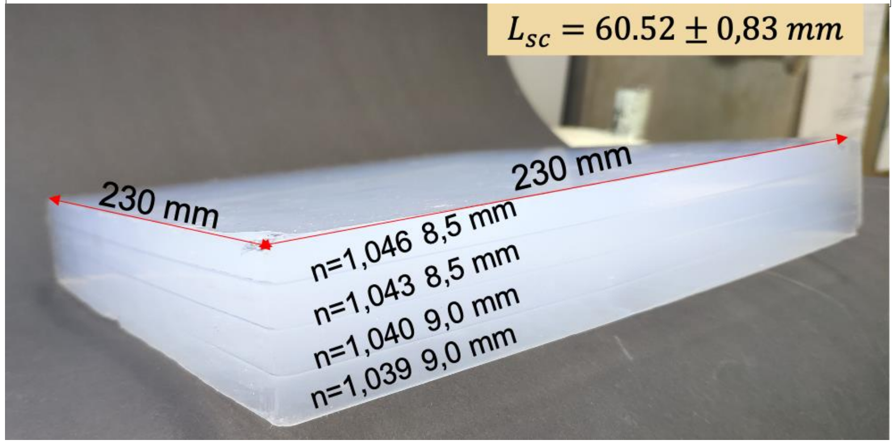
A.Yu. Barnyakov, et al., NIM A 732 (2013) 352





Two 4-layer focusing aerogel blocks
230x230x35 mm

$L_{sc} = 60.52 \pm 0{,}83\ mm$

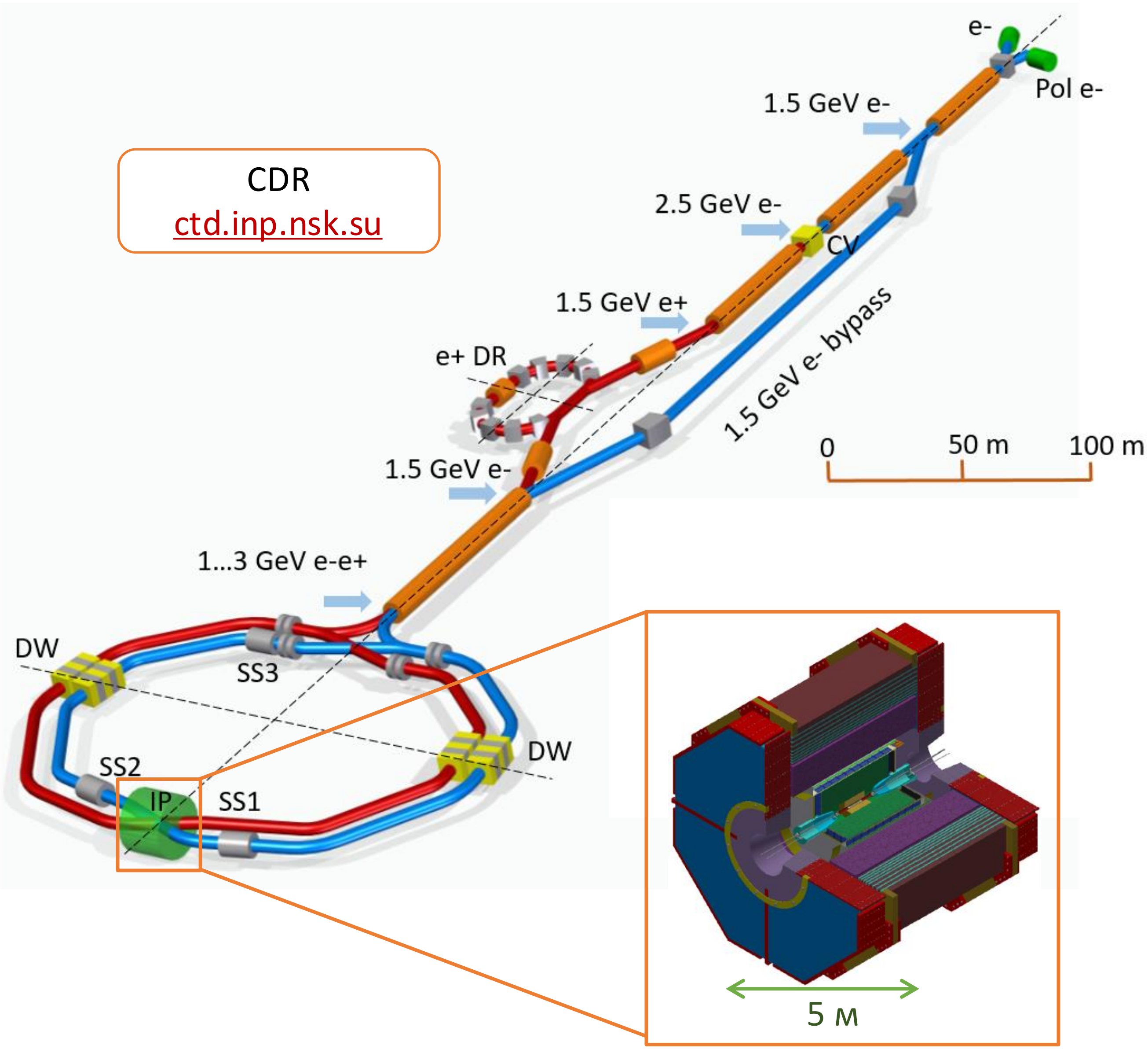


2022÷2023

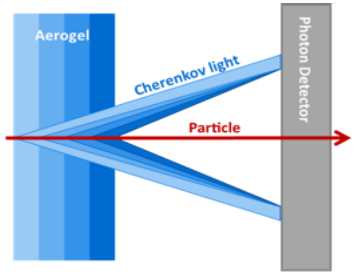
The SCT experiment

- Super charm-tau factory is e+e− collider, dedicated to precision study of properties of charm-quark, τ-lepton, study of strong interactions, search of BSM physics
  - Beam energy from 1.5 (1.0) to 3.5 GeV
  - Luminosity $\mathcal{L} = 10^{35}\ \mathrm{cm}^{-2}\mathrm{s}^{-1}$ @ 2 GeV
  - Longitudinal polarization of the e^- beams
- Experiments will be conducted using state-of- the-art general purpose detector
  - Tracking (including low p_t)
  - Calorimetry (high resolution, fast, π^0/γ sep.)
  - PID system:
    - π/K – separation up to 3.5 GeV/c
    - μ/π – separation up to 1.5 GeV/c

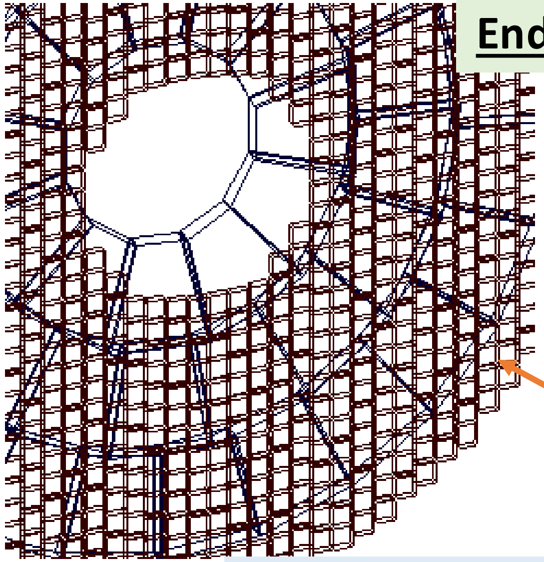
CDR
ctd.inp.nsk.su



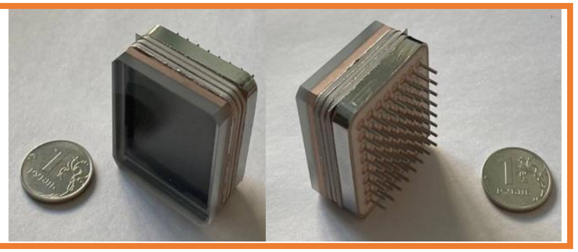
FARICH system for the SCTF project



Endcap part Sketchs & key elements



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

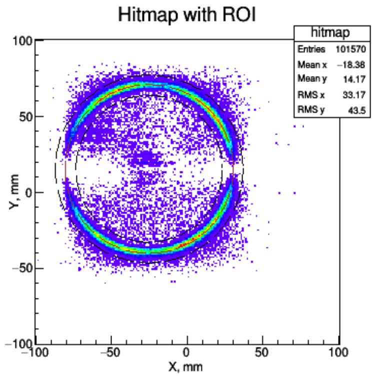


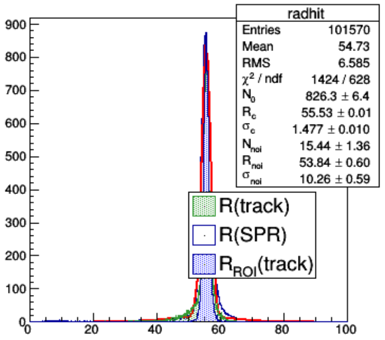
The first square MCP PMT produced in Russia

All details and components are produced in Russia

- 33×33 mm^2 total area
- 27×27 mm^2 sensitive area
- 8×8 pixels with 3×3 mm size

Measured angle resolution

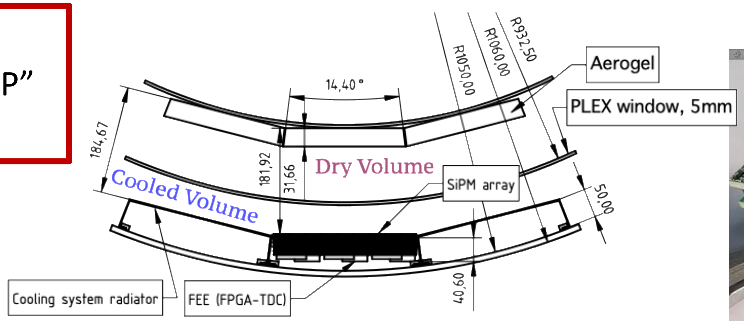


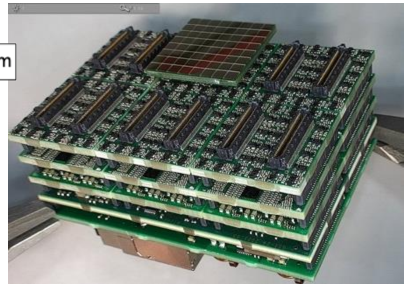


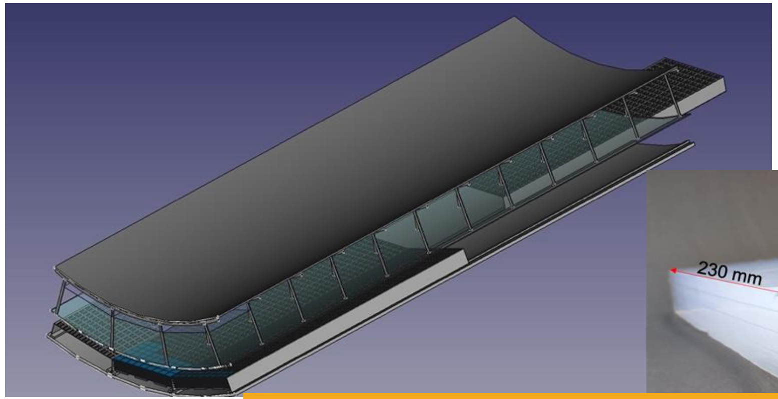
Single PE resolution 7.5 mrad was measured

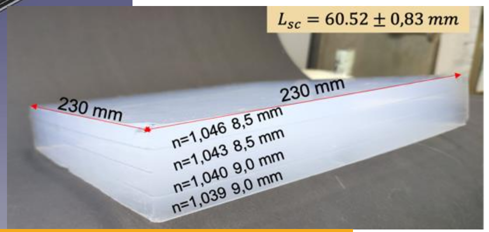
It corresponds to:

- Exccelent π/K–separation in whole operation momentum range
- Reliable μ/π–separation up to 1.5 GeV/c







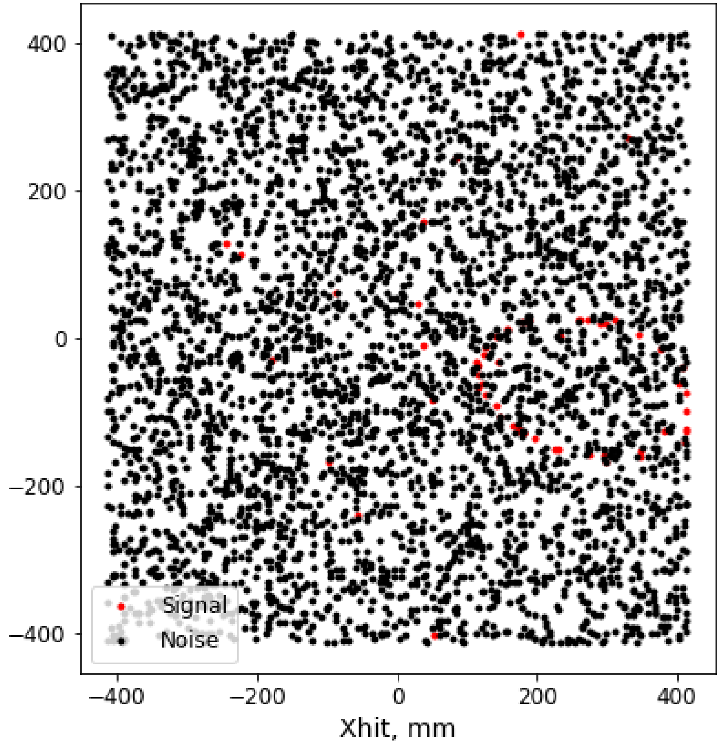


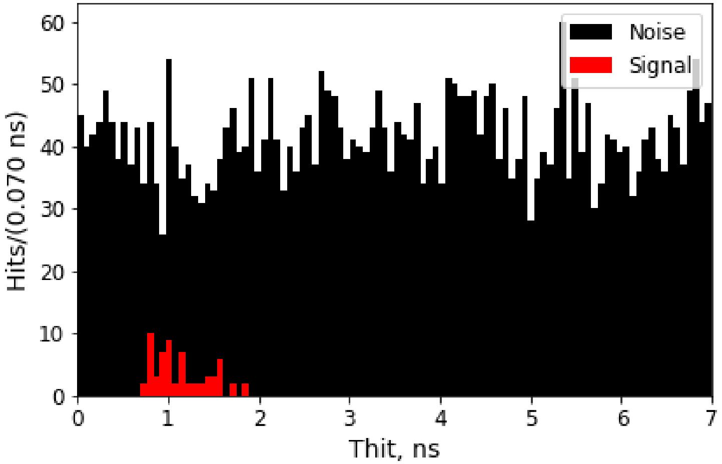
Barrel part Sketchs & key elements

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

Several R&Ds on reconstruction of events in the FARICH

Single FARICH event in with DCR ~ 10^6 cps/mm^2.





- **<u>LPI group</u>** developed classical approach so called “slider box”

  – X,Y-scan of the PD area is performed with fixed geometry box to search its position when the maximal number of hits are inside the box

  – The scan on time axis is also performed to find the time gate with maximal number of hits

  – It was shown that such method works very well until the DCR~10^5cps/mm^2

  Bulletin of the Lebedev Physics Institute, 2023, Vol. 50, No. 12, pp. 534–539.

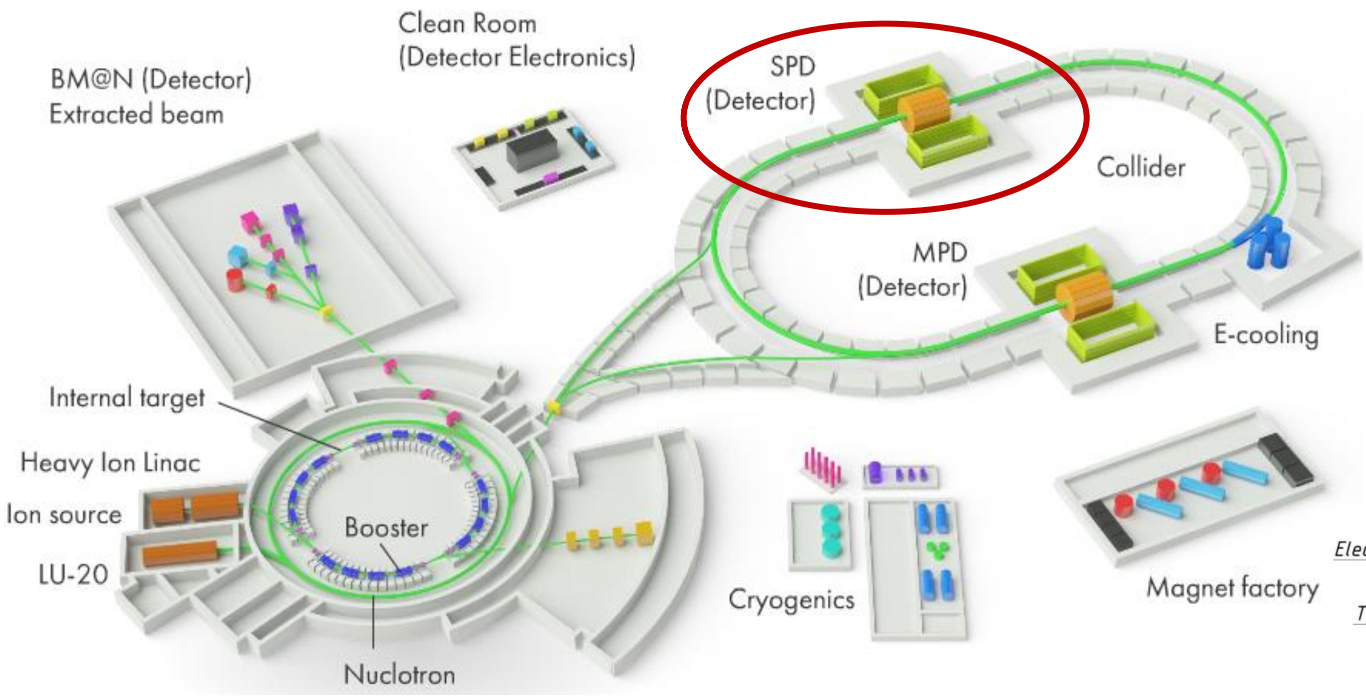
- **<u>HSE group</u>** developed reconstructions algoritms based on ML aproaches

  – It was shown that CNN could help to suppress nose pile-up suficiently without degradation of events reconstruction efficiency up to DCR~10^5cps/mm^2.

  – ML based algorithms are working in case of DCR~10^6cps/mm^2, however with some less reconstruction efficiency.

  Physics of Atomic Nuclei, 2023, Vol. 86, No. 5, pp. 864–868.

SPD@NICA



https://nica.jinr.ru/complex.php

Nuclotron based Ion Colliding fAcility

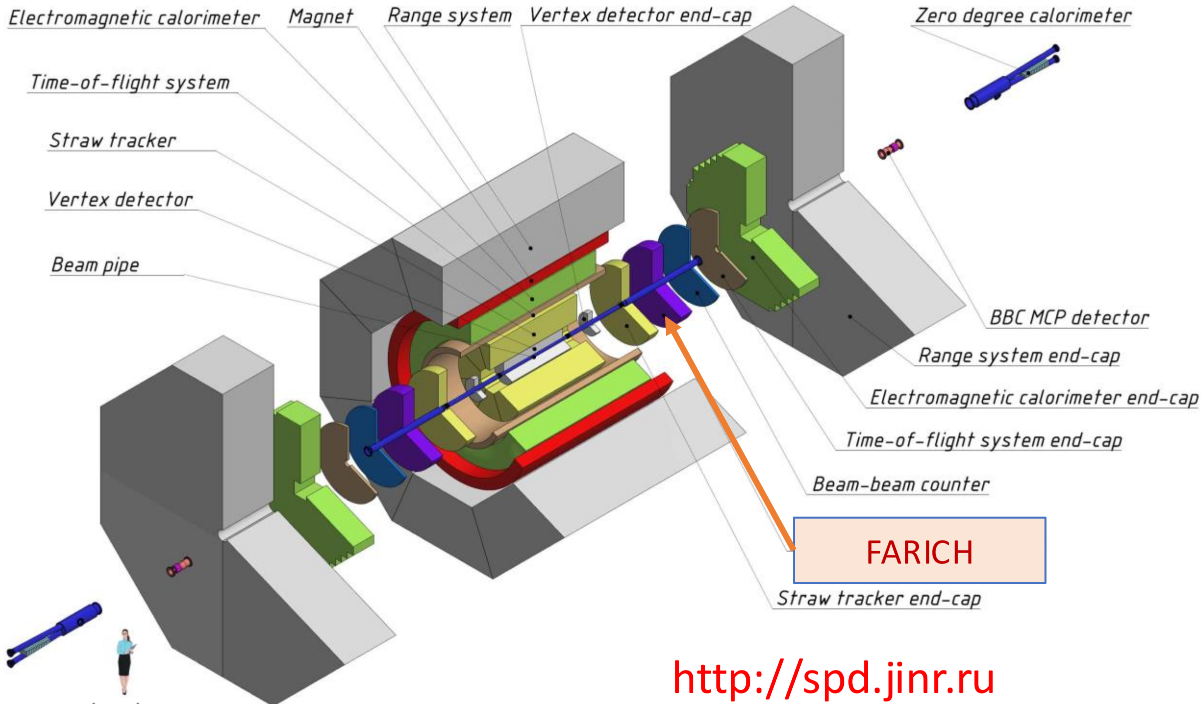
for fundamental nuclear interaction study

Spin Physics Detector

to investigate nucleon and light nuclei (p & d) spin structure with help of colliding beams at the energies up to 27 GeV.

– Polarized p and d

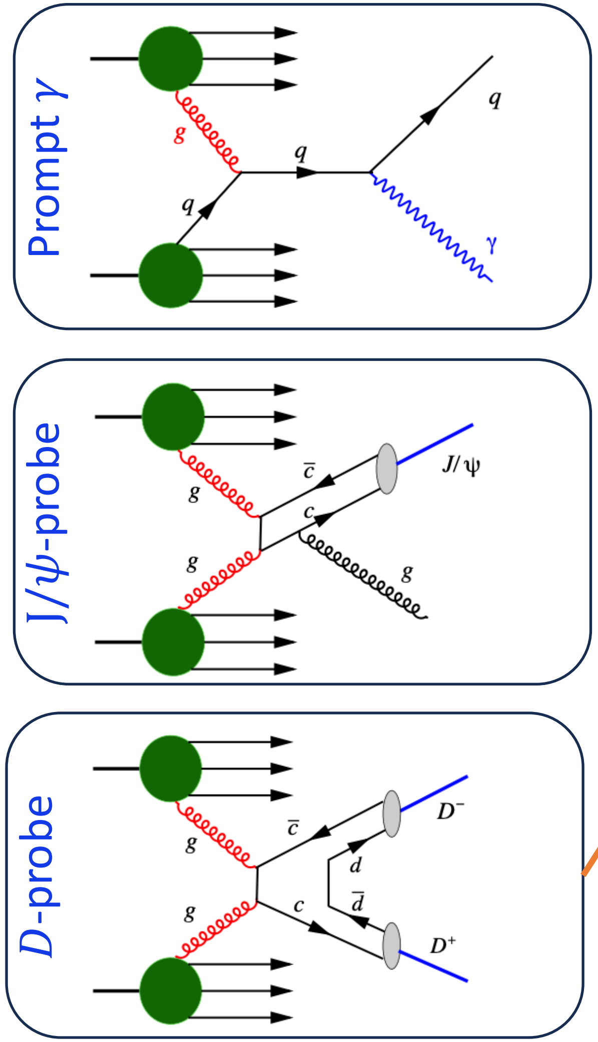
– $L = 10^{32} cm^{-2} s^{-1}$

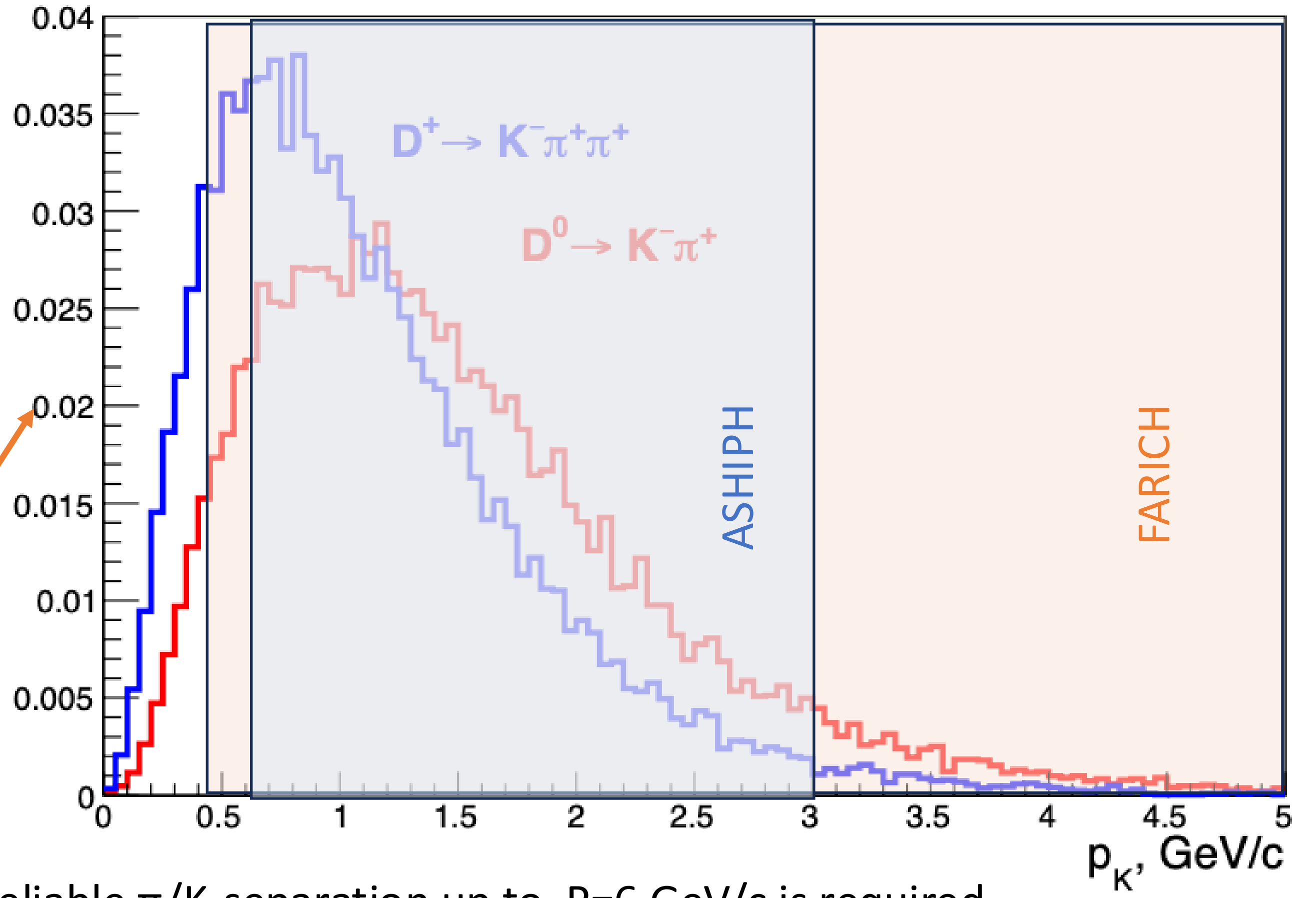


http://spd.jinr.ru

PID system: requirements

Three major probes for Gloun TMD investigations are considered:

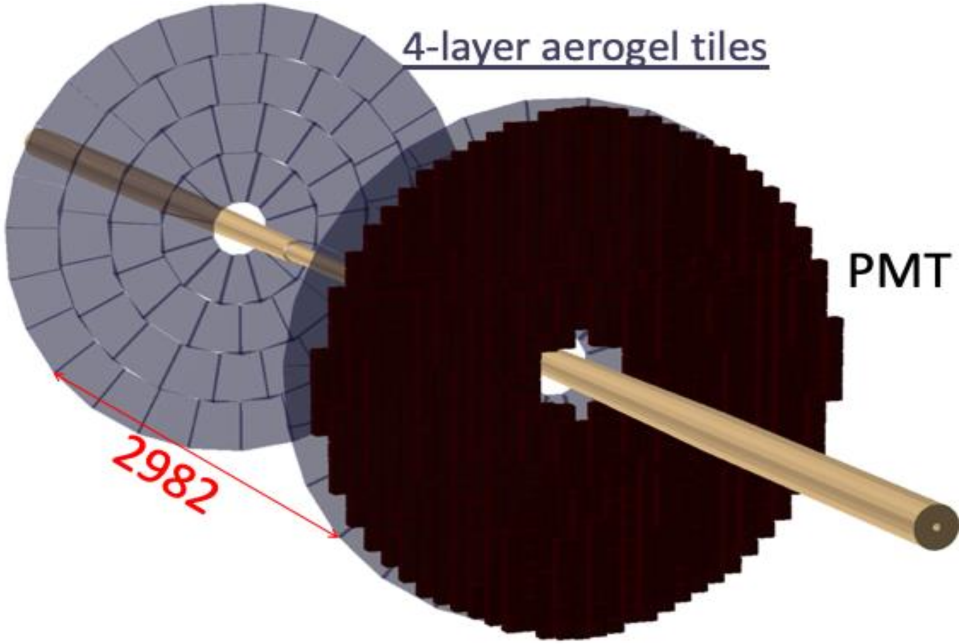


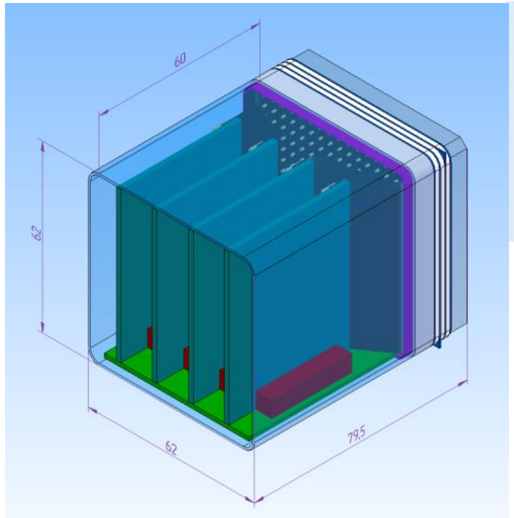


- The reliable π/K-separation up to P=6 GeV/c is required
- RICH based on radiator with n≤1.05 (aerogel) + focusing are needed

to provide $\sigma_C \sim 2.5\ mrad/track$ and π/K-separation ≥ 3 σ @ 6 GeV/c

FARICH system for the SPD-NICA





Rectangular MCP PMT with active area 50x50mm

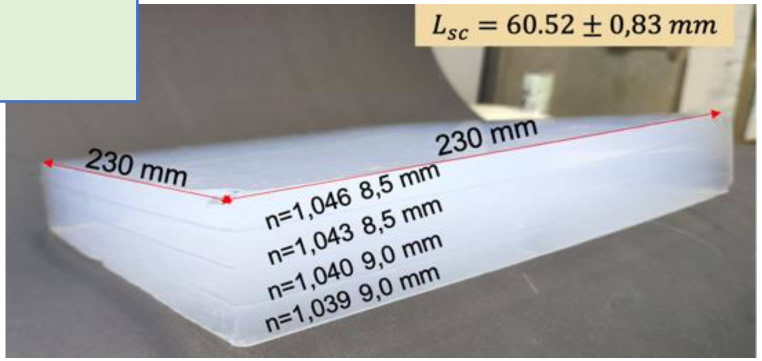
- Construction and design are under development in Novosibirsk by BINP and Ekran FEP in close cooperation
- All details and components will be produced in Russia

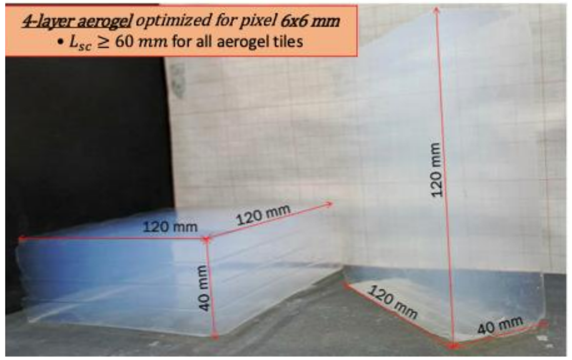
Goal parameters:

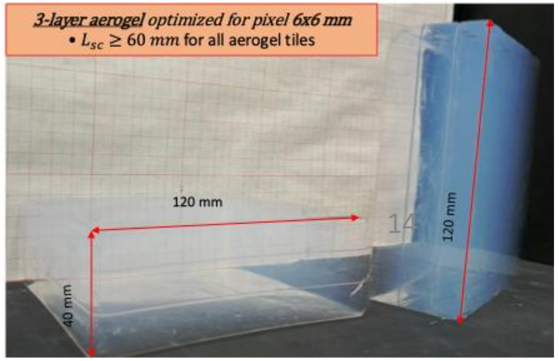
- 62× 62 mm^2 total area
- 50× 50 mm^2 sensitive area
- 16× 16 pixels with 3×3 mm size
- Multi-alkali PCs extended in blue region
- Fused silica input window
- Gain ≥5·10^5

Aerogel:
- 2 end-caps × 74 tiles (4 form-factors)
- 4 or 3-layer focusing aerogel (n_{max}≤1.05)
- Focal distance ~20 cm

Position-sensitive MCP-PMT:
- 2 × 508 PMTs ~60×60 mm^2

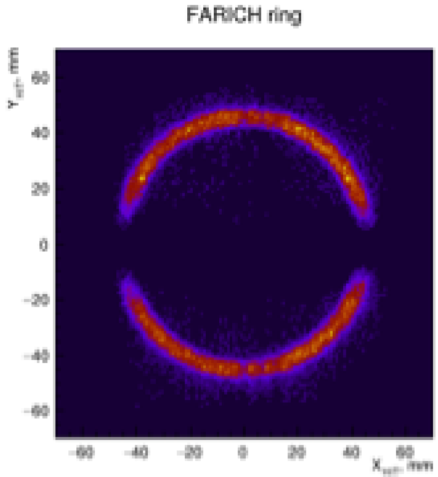


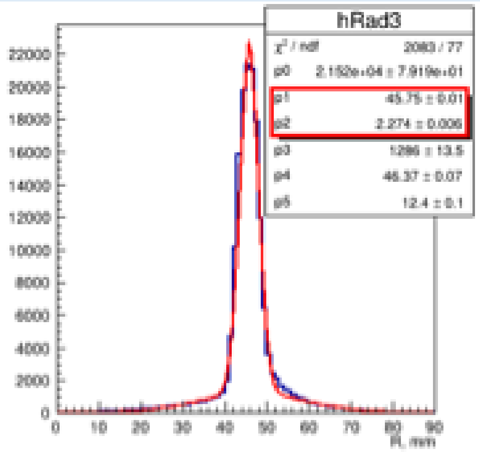


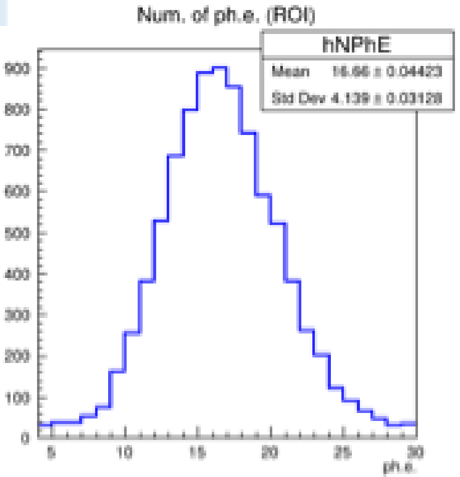


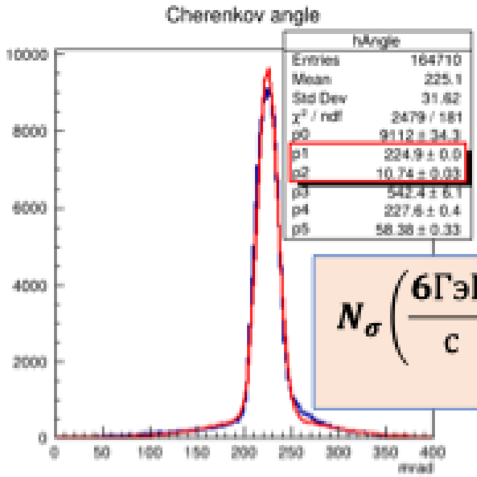
Beam test results with relativistic electrons: June 2025

4-layer, n_{max}=1.04, t=40 mm





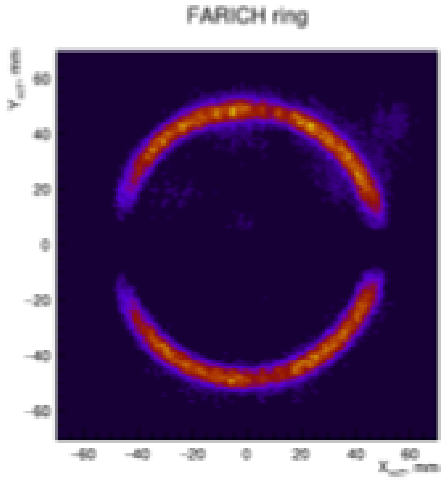


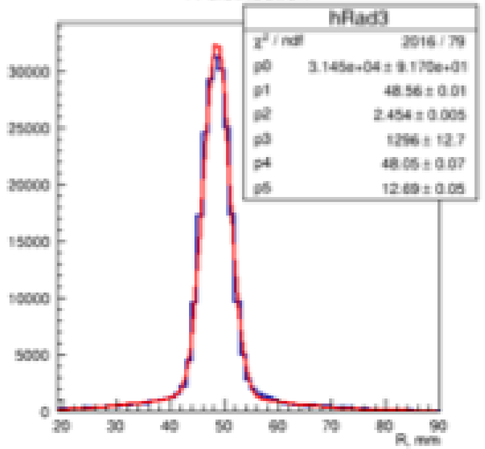


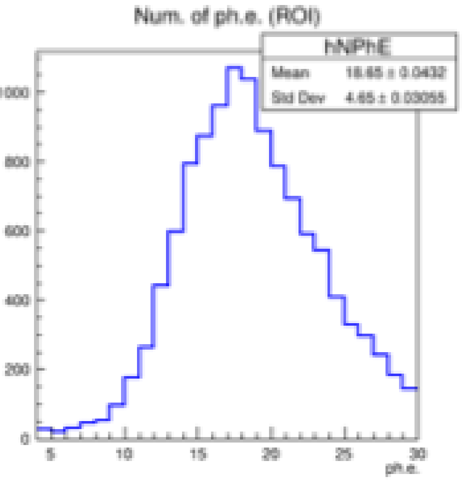
$$\sigma_{1pe} \approx 10.7\ mrad$$

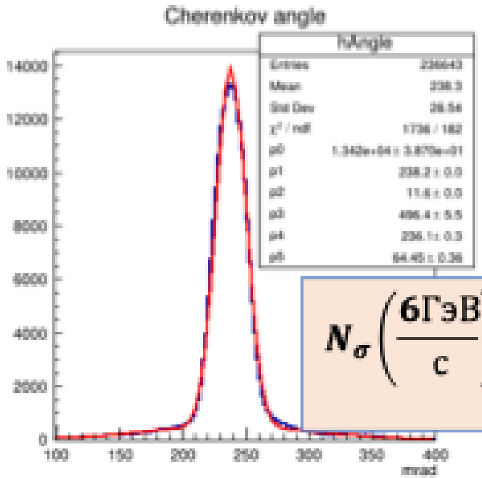
$$N_\sigma\left(\frac{6\text{ГэВ}}{c}\right) \approx \frac{11\ mrad}{10.7mrad\Big/\sqrt{N_{pe}}} \approx 4.2$$

3-layer, n_{max}=1.04, t=40 мм







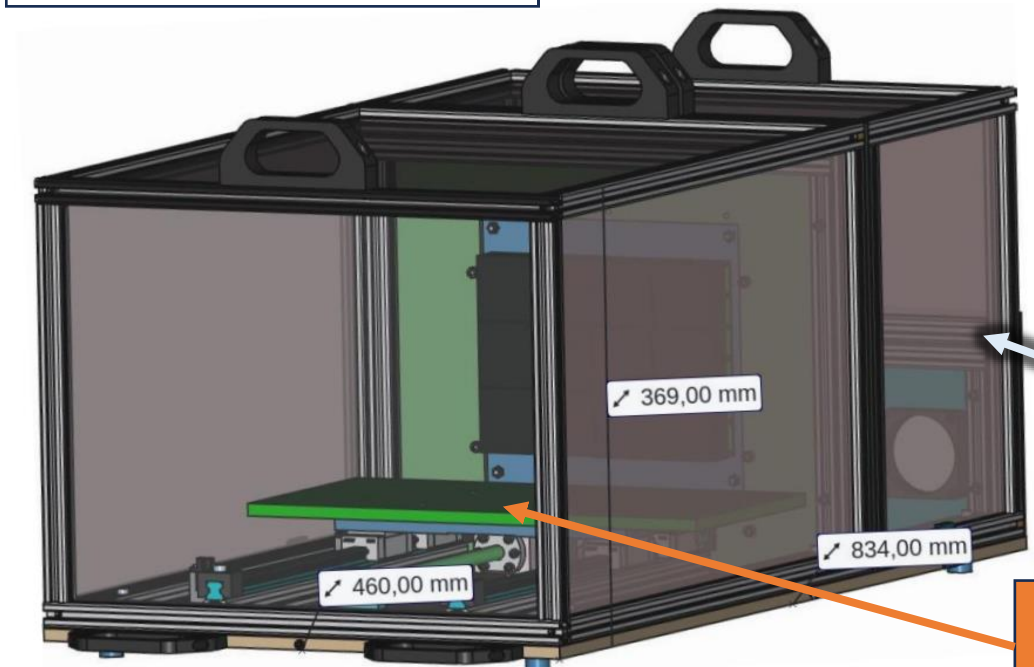


$$\sigma_{1pe} \approx 11.6\ mrad$$

$$N_\sigma\left(\frac{6\text{ГэВ}}{c}\right) \approx \frac{11\ mrad}{11.6mrad\Big/\sqrt{N_{pe}}} \approx 4.1$$

Новый прототип ДЧК

3D модель прототипа

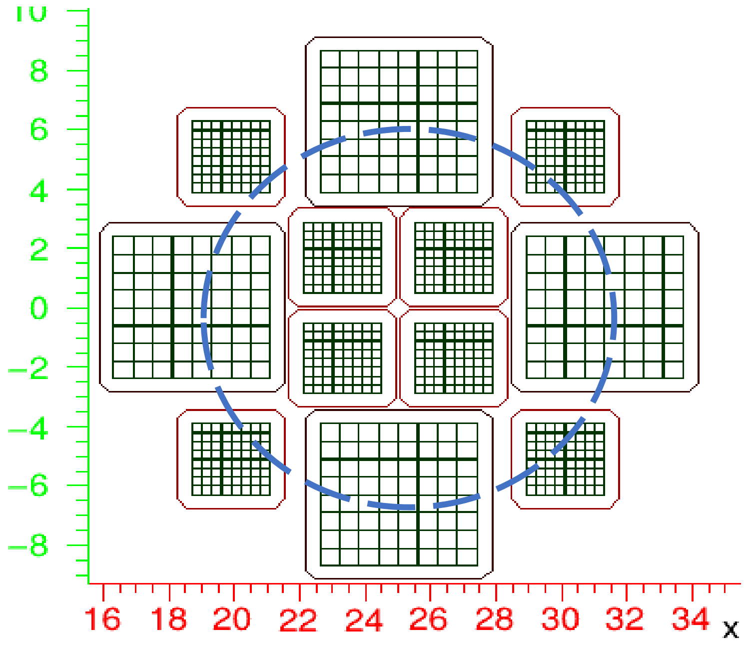


Отсек под электронику

Подвижный стол под радиатор

Прототип во время сборки

ФЭУ Hamamatsu H12700

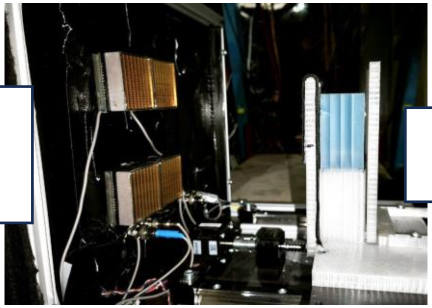


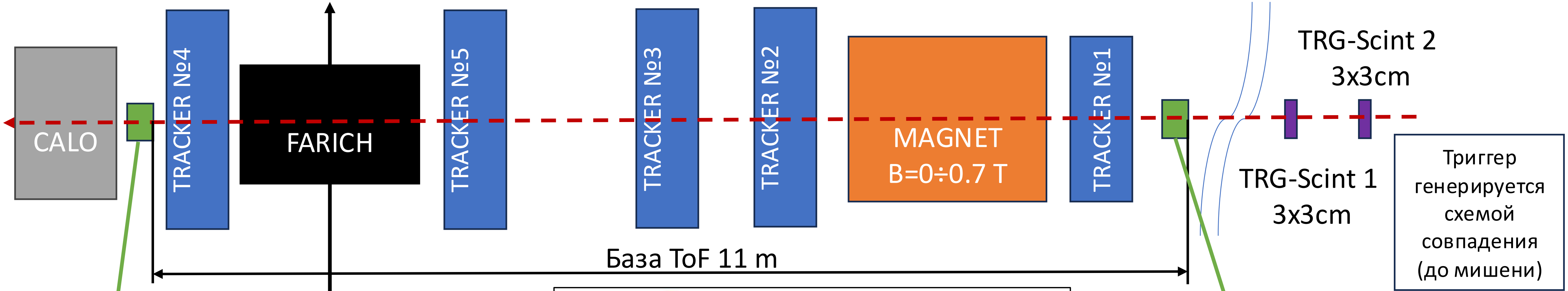
Модернизация ФД прототипа 2026

- Текущая версия прототипа может считывать до 12 ФЭУ H12700 (Hamamatsu) при помощи FEE DiRICH (GSI)
- В 2026 году планируем добавить к 4-ем ФЭУ H12700 8 ФЭУ с МКП от «Экран ФЭП»
- В 2027 году оснастить 9-ю фоторегистрирующими модулями на основ КЧФЭУ с МКП и DMXG64

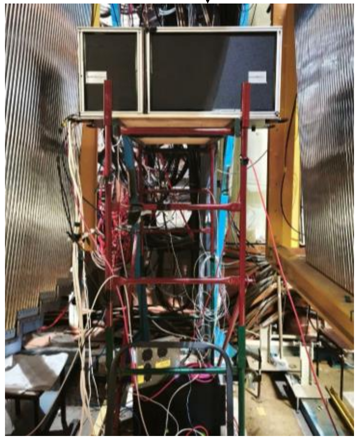
Испытания прототипа на адроном пучке на базе СПАСЧАРМ@У-70 (ИФВЭ, г. Протвино)

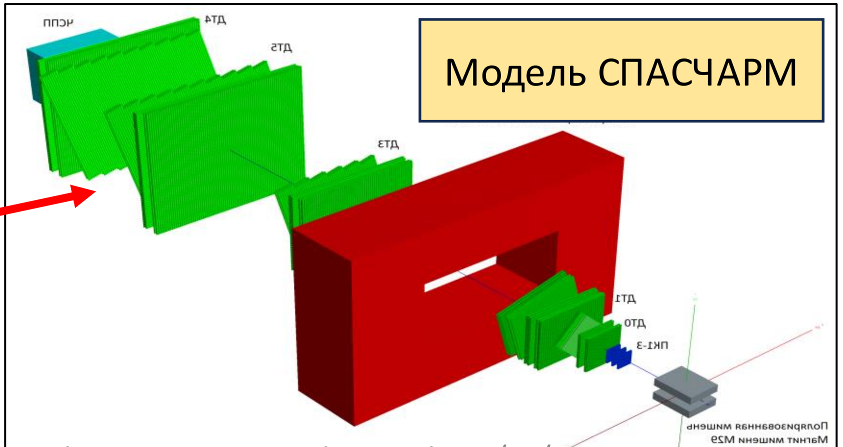
- **Основная частица** – протоны;
- **Вторичные** рождаются в Al-мишени
- **Импульсы** 1.5≤P≤10 GeV/c

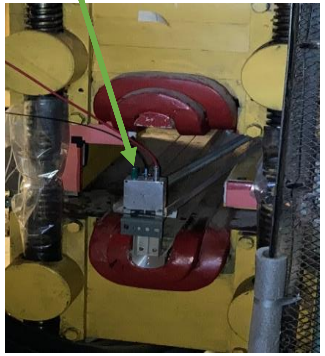




MCP-PMT
ToF2 ø18mm

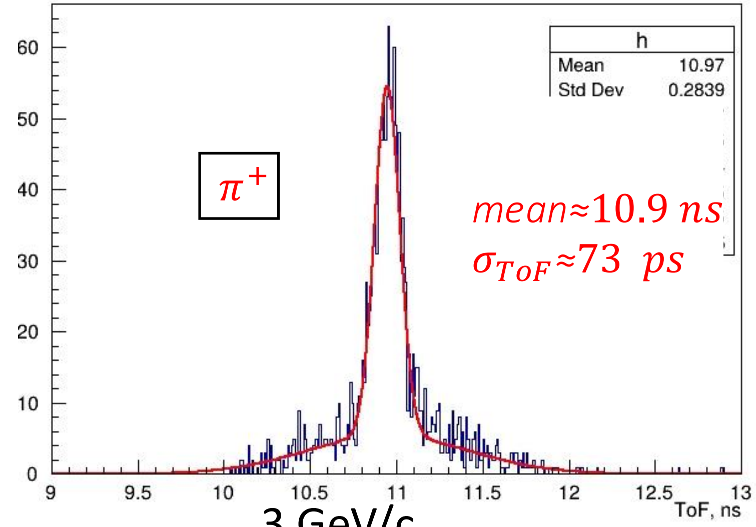




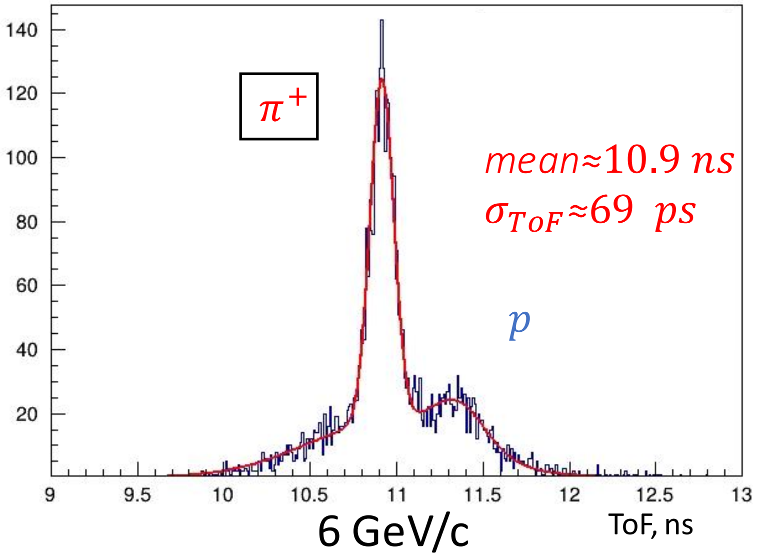


MCP-PMT
ToF1 ø18mm

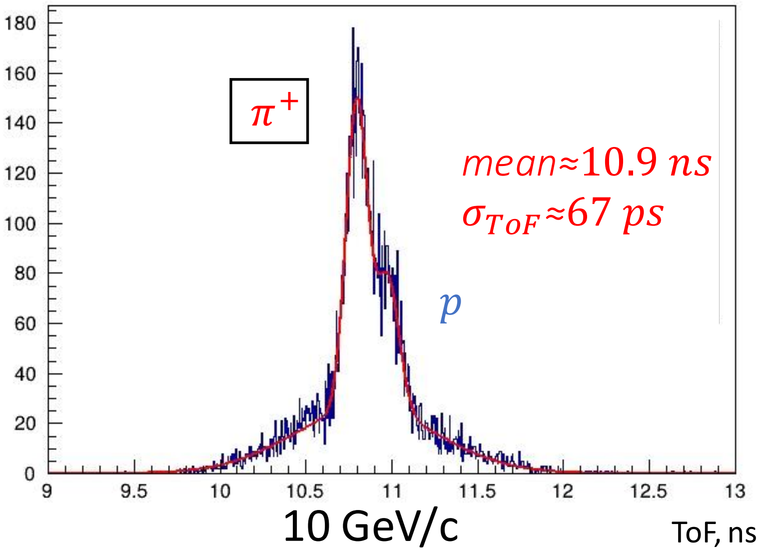
Предварительные результаты: TOF



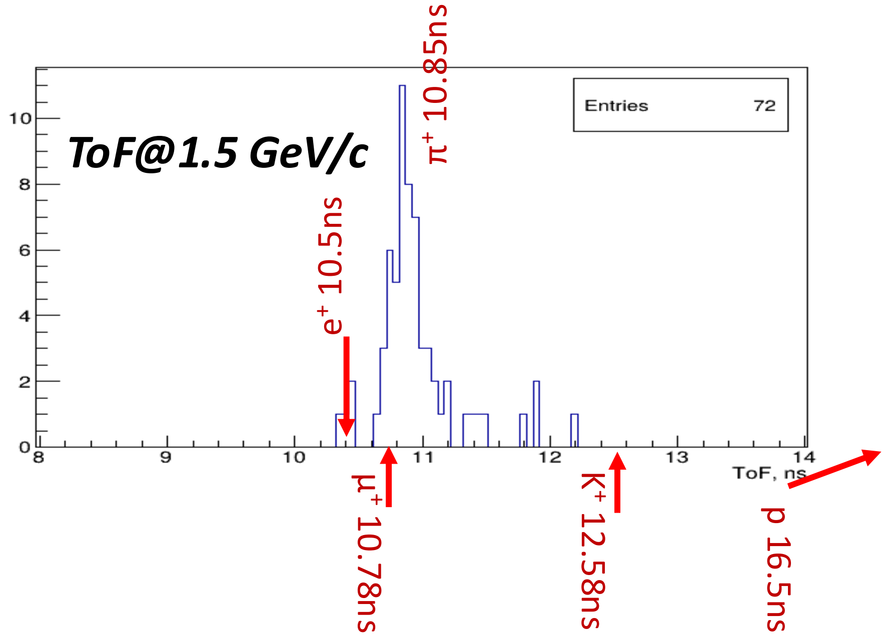
3 GeV/c



6 GeV/c



10 GeV/c



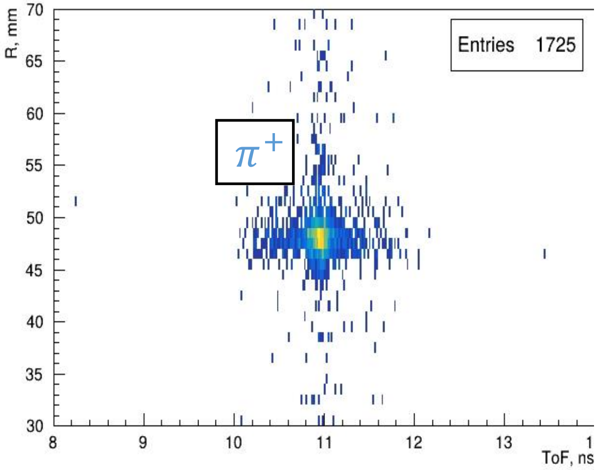
- σ_{ToF} по экспериментальным данным ~70 ps
- Состав пучка π+(~75%), p (~20%), K^+?, e^+?
- Ниже P=3 ГэВ/с протонов нет

Предварительные результаты: R_c и N_{pe}

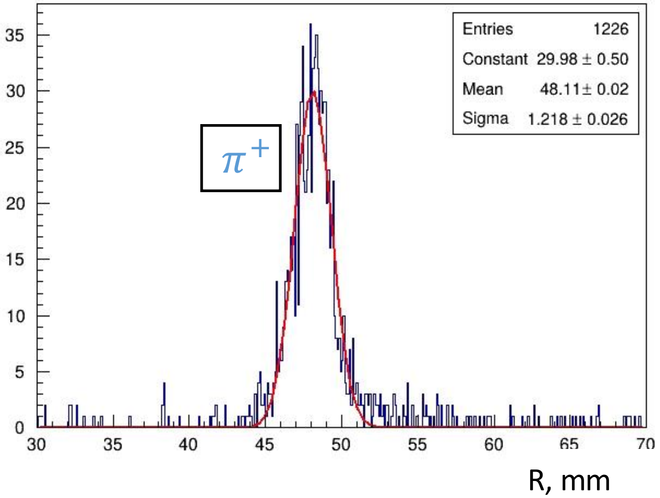
Без привлечения трековой системы (пока!)

3 GeV/c:

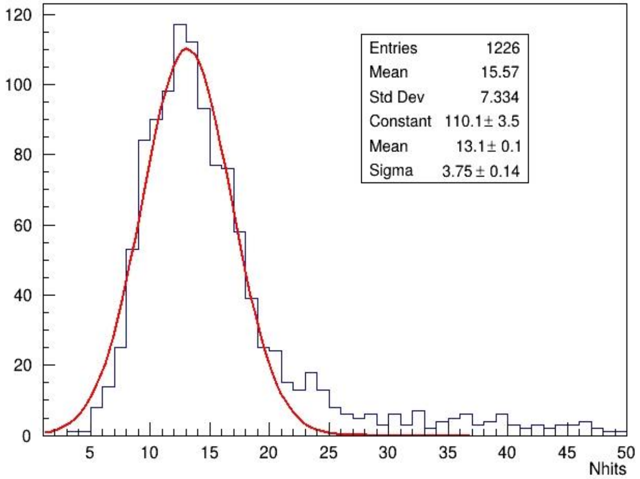
R vs ToF



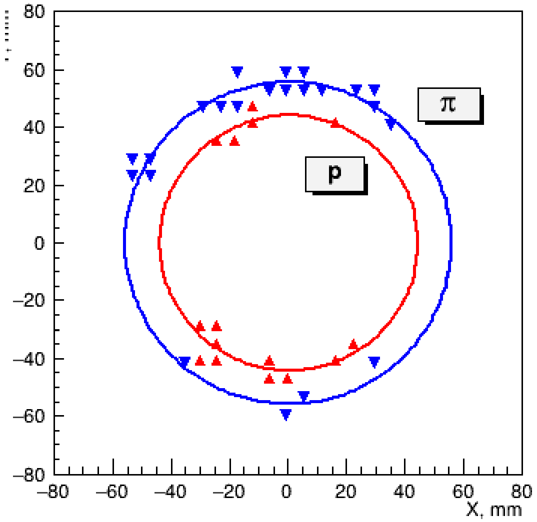
Распределение радиусов.
Time cut && ToF cut



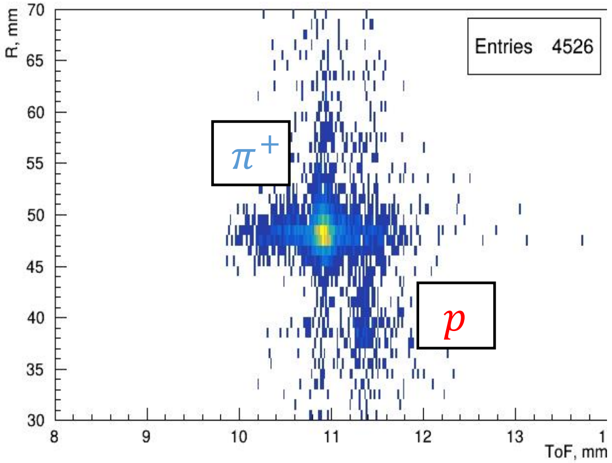
Распределение фотоэлектронов

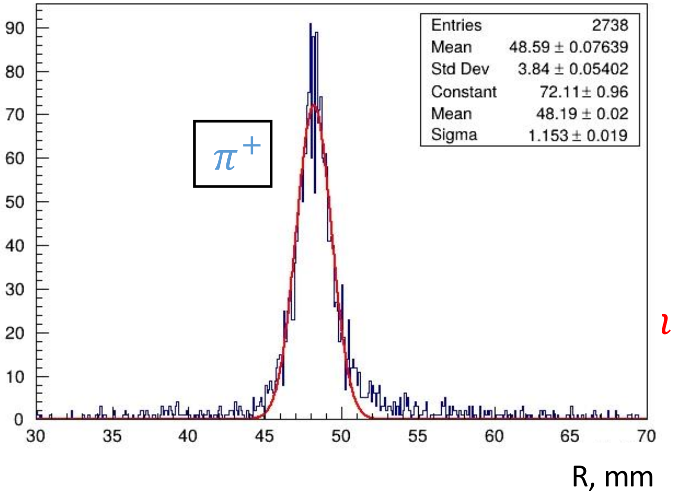


Сравнение кольца пиона и протона@6 GeV/c

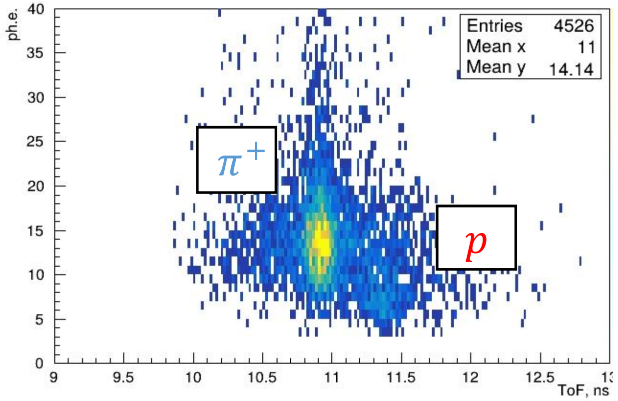


6 GeV/c:



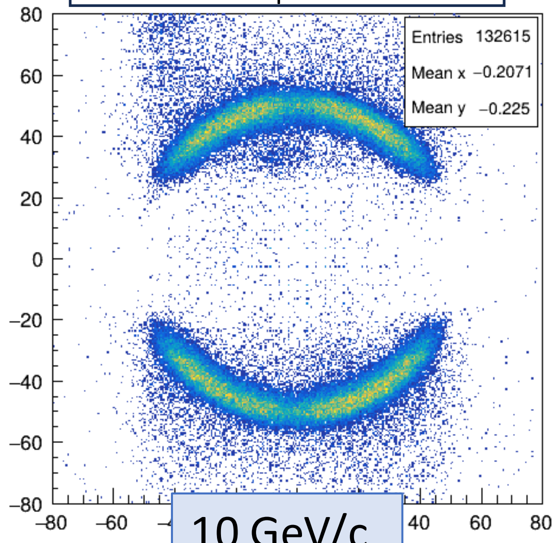


Распределение фотоэлектронов
vs ToF



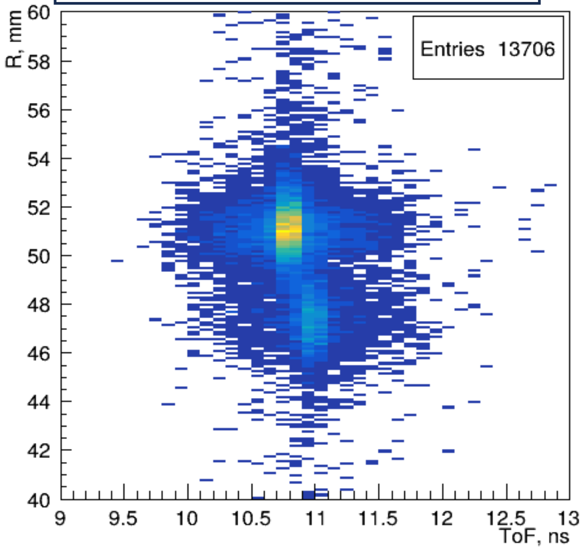
Предварительные результаты: оценка *π/K разделения*

Картина наложения колец. Y vs X

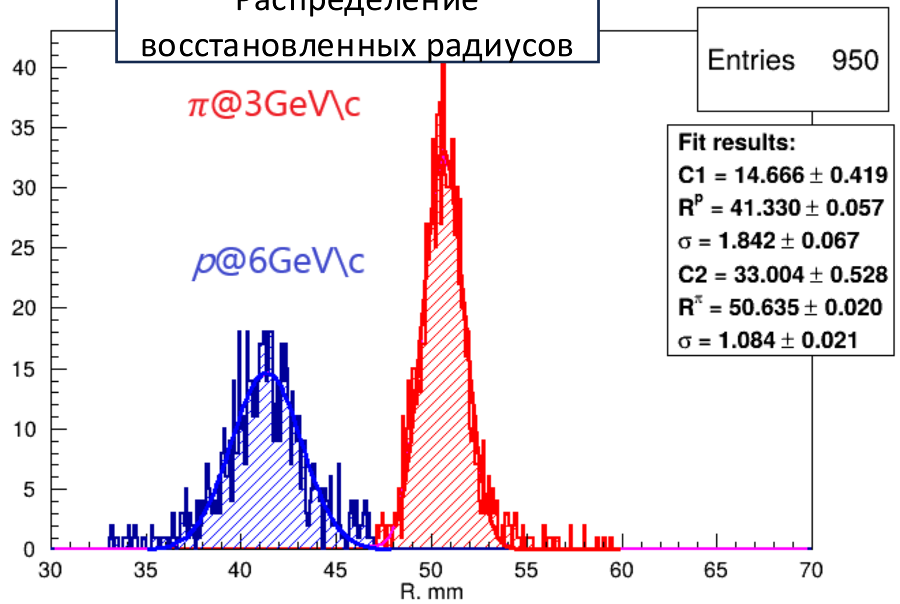


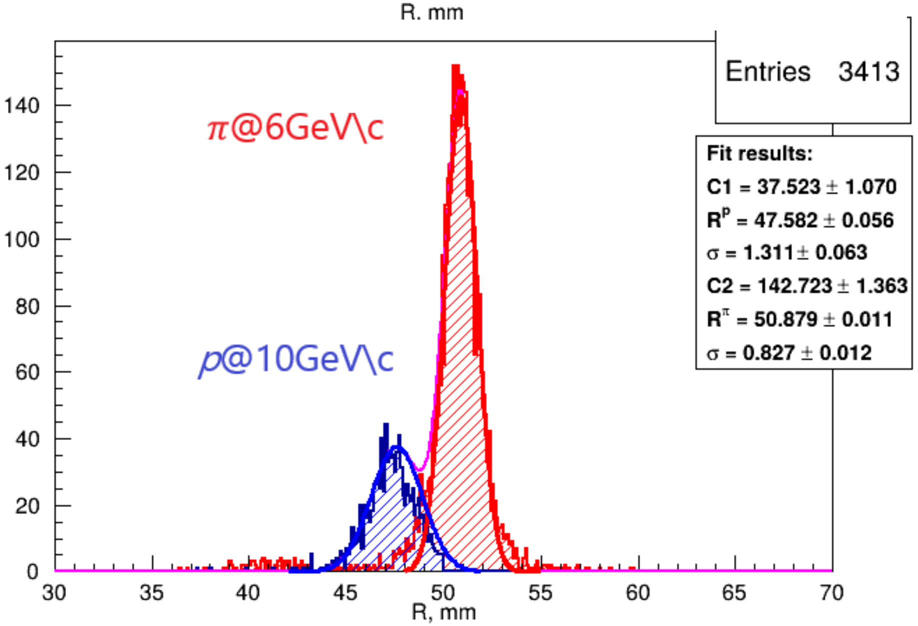
10 GeV/c

R [mm] vs ToF [ns]



Распределение восстановленных радиусов





$$N_{\sigma} = \frac{(R^{\pi} - R^{p})}{0.5(\sigma^{\pi}_{R_{track}} + \sigma^{p}_{R_{track}})}$$

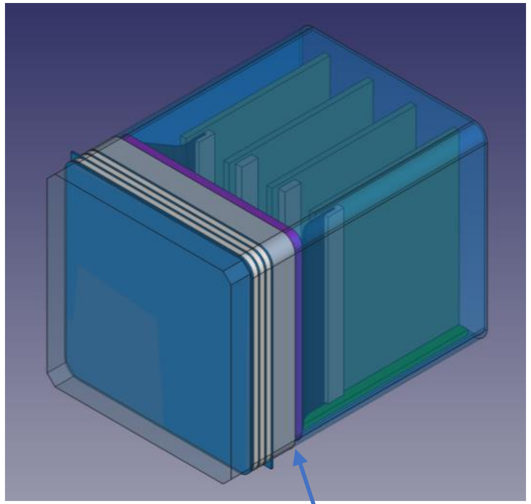
π/K ~ 6.4σ @ 3 GeV/c

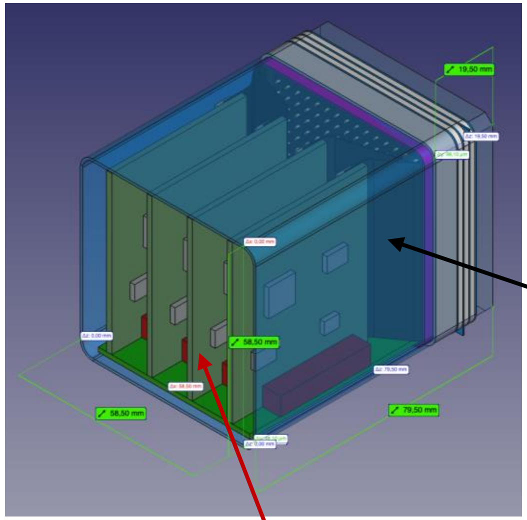
π/K ~ 3.1σ @ 5.4 GeV/c

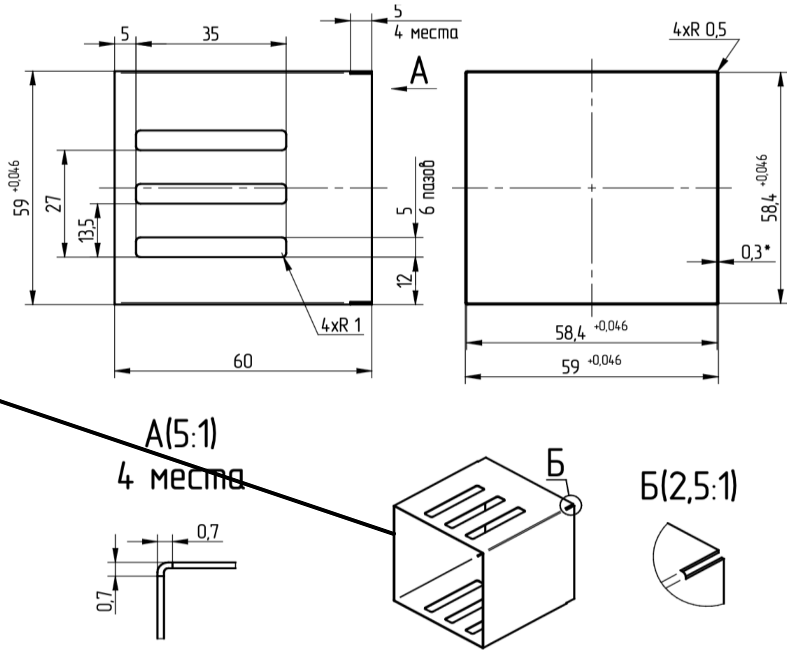
- Аэрогель: 3-слоя; t_{tot}=40 мм; n_{max}=1.04
- пиксель 6x6 мм; 60% кольца
- нет трековой информации

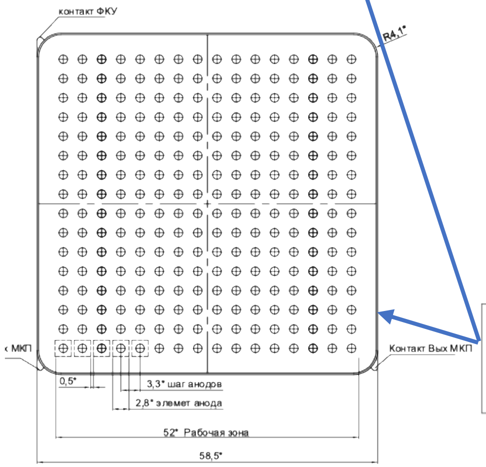
Результат может быть лучше!!!

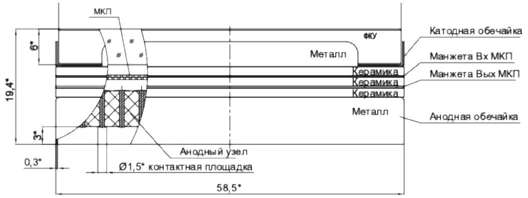
Concept of the photon detection module

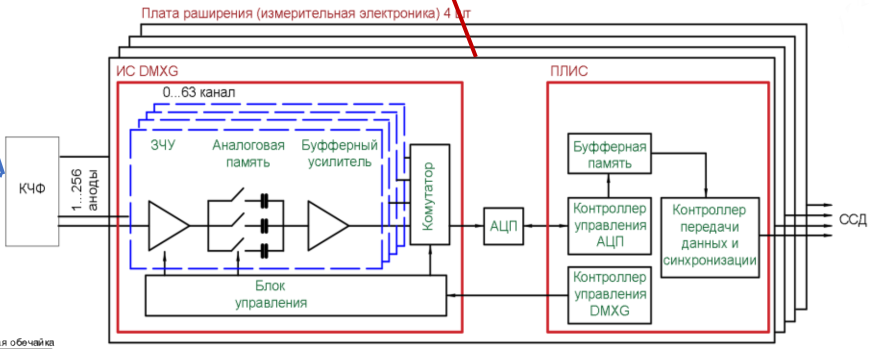








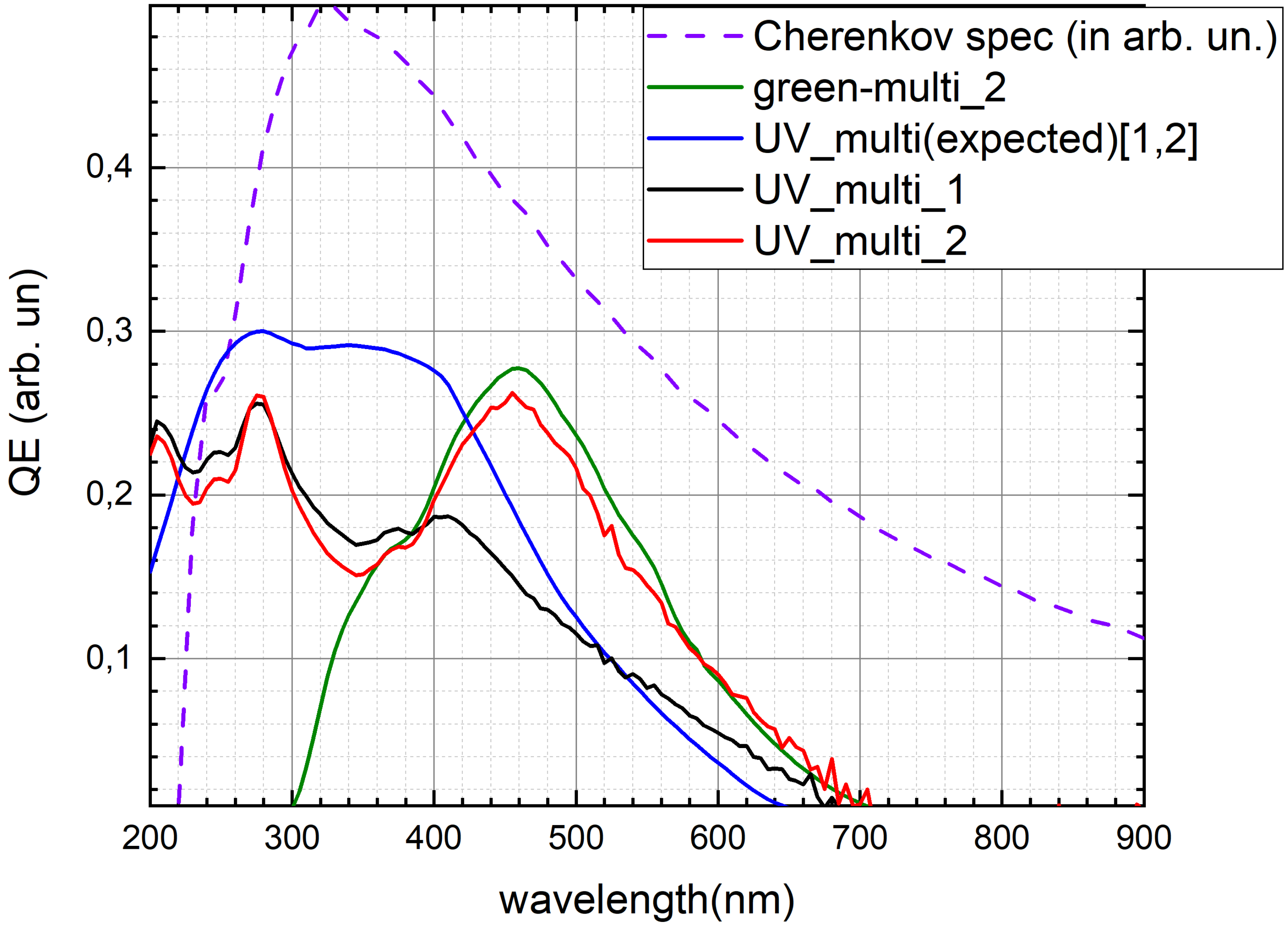




Current design concept:

- Square position-sensitive MCP PMT with 256 anode pads 2.8x2.8 mm each
- 4 readout PCB with 1 ASIC DMXG64 each are reading out through C-Link protocol (USB-3.0 or Eth. plugs)
- Flexible PCBs are used to connect MCP PMT and FEE
- Backend board placed HV-divider and HV-plugins
- CFRP shield has ventilation holes and could be a construction element of the large system
- The estimated mass of the module is 200g (MCP PMT)+ 200g (FEE)

Photocathode optimisation

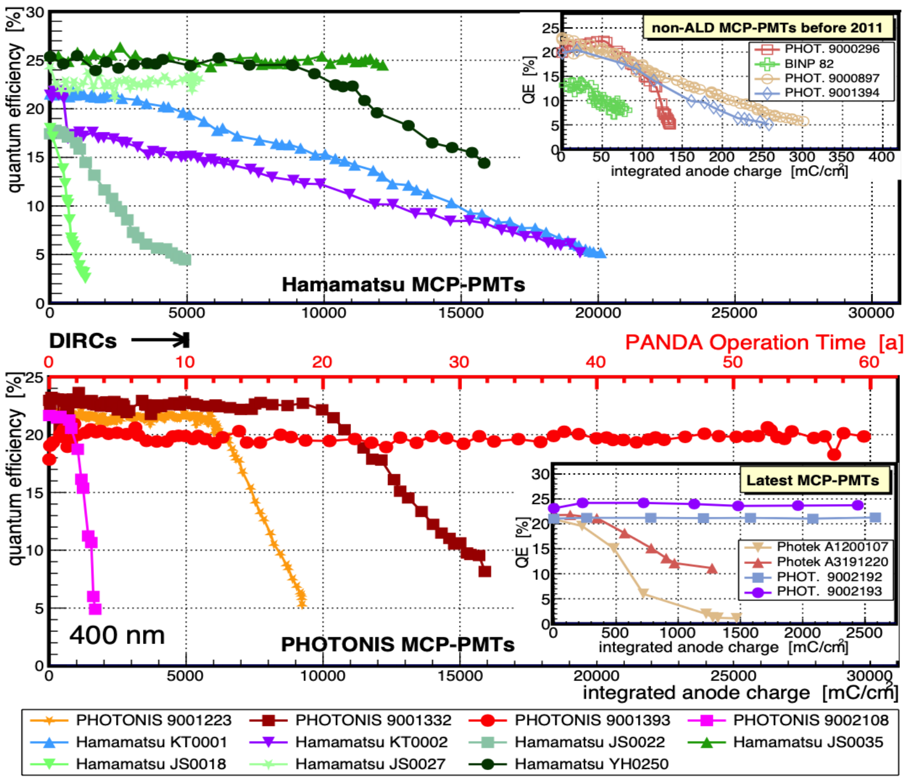


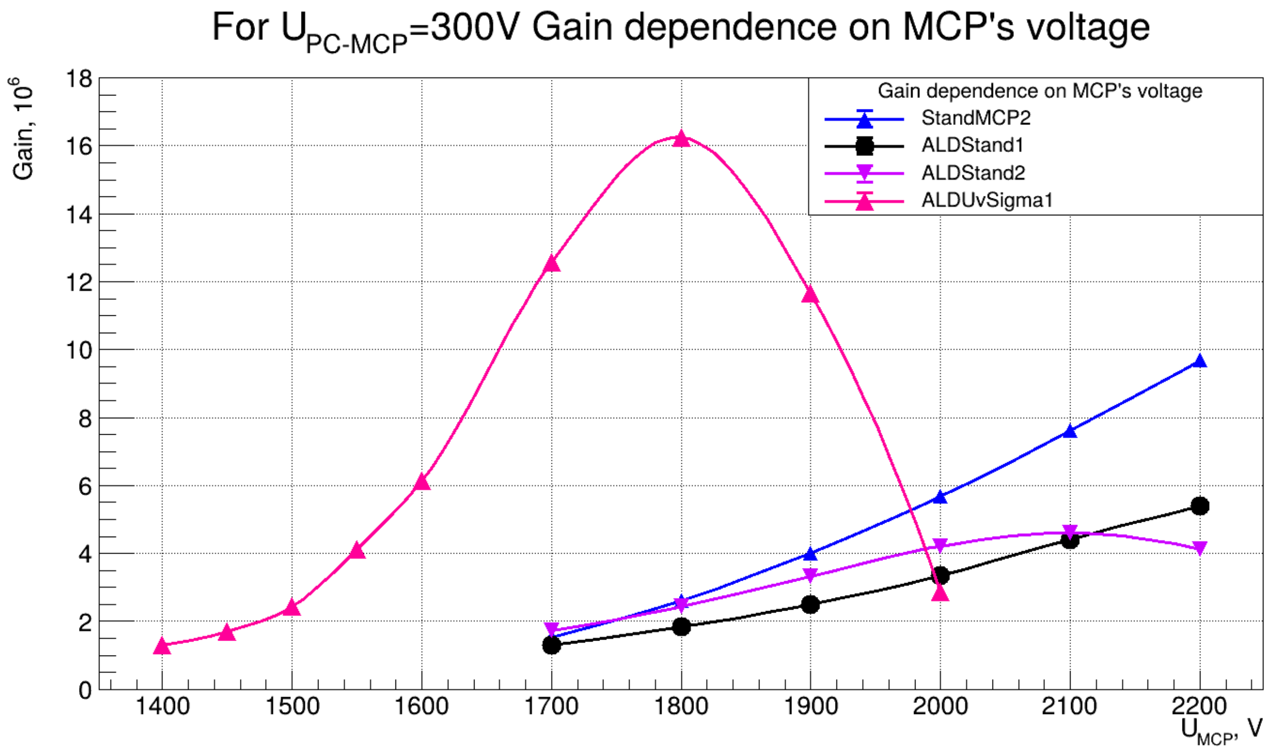
- Use of the multi-alkali PCs deposited on fused quartz input window with extended sensitivity in UV-region allows us to increase light collection by of 1.5 times
- UV-multi-alkali PC deposited on fusedis quartz is a base option for the MCP PMT based photon detection modules
- Bi-alkali PCs are also considered as an alternative option

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).

MCP with ALD: PC lifetime, Gain and CE

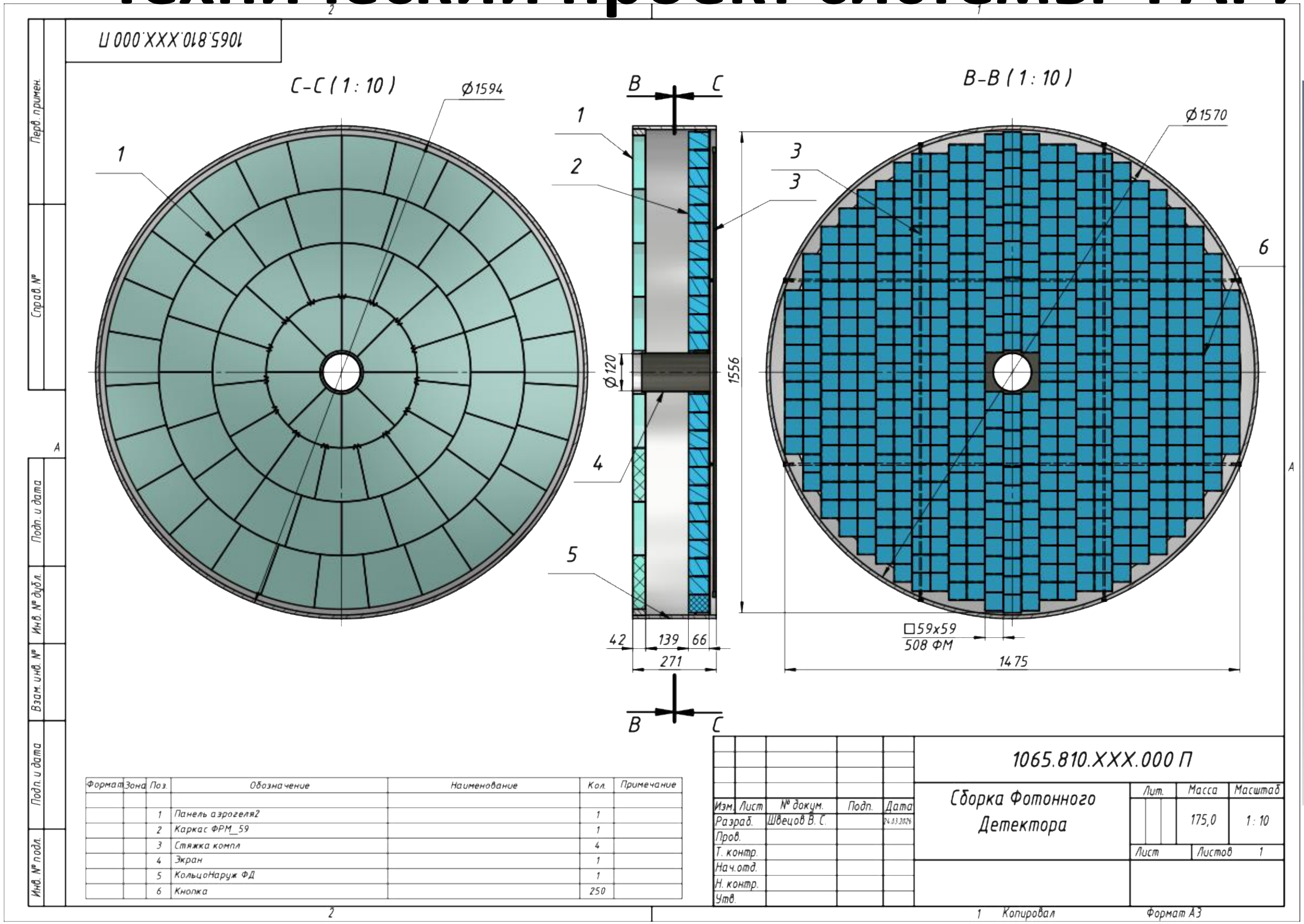


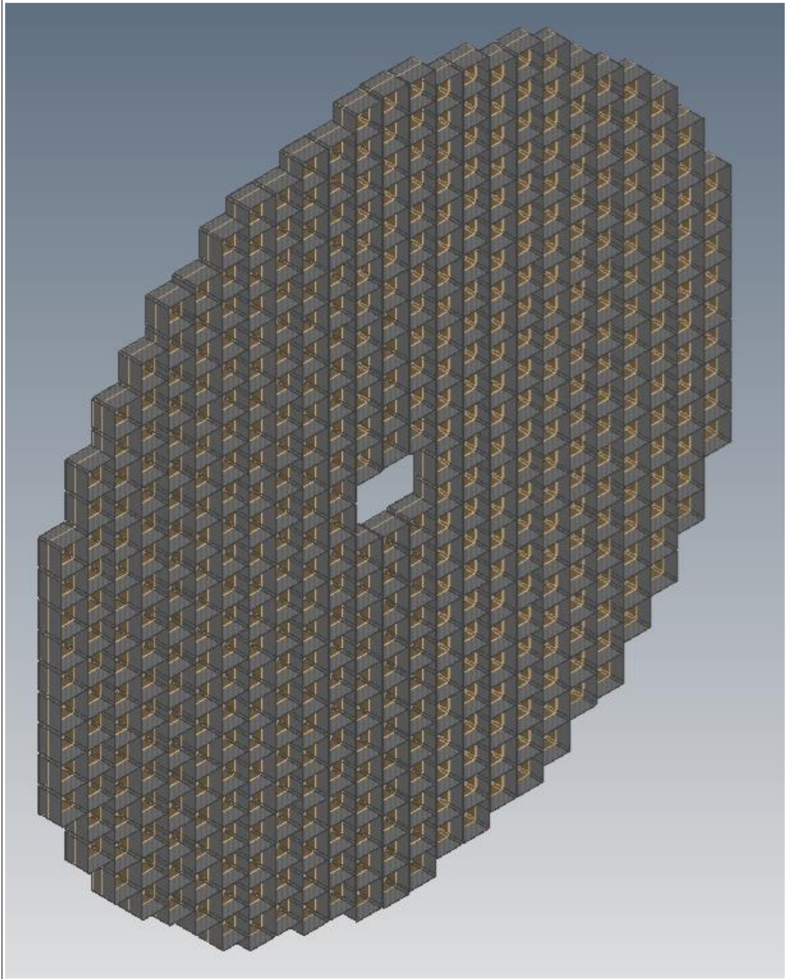


- It is known, that ALD coating is able significantly improve the PC's lifetime in colliding beam experimental conditions
- Also it is increase the gain and allows us to operate at lower voltges
- We expect to get PE collection effeciency >60% by use ALD coating at the entrance of the first MCP

- According to our very preliminary results of relative measurements, the PE collection efficiency increased by 25% for MCPs with ALD coating at the entrance plane in comparison with standard one
- Further optimisations of the ALD coating and MCP bulk resestivity are foreseen

Технический проект системы ФАРИЧ-SPD: ver.1.0





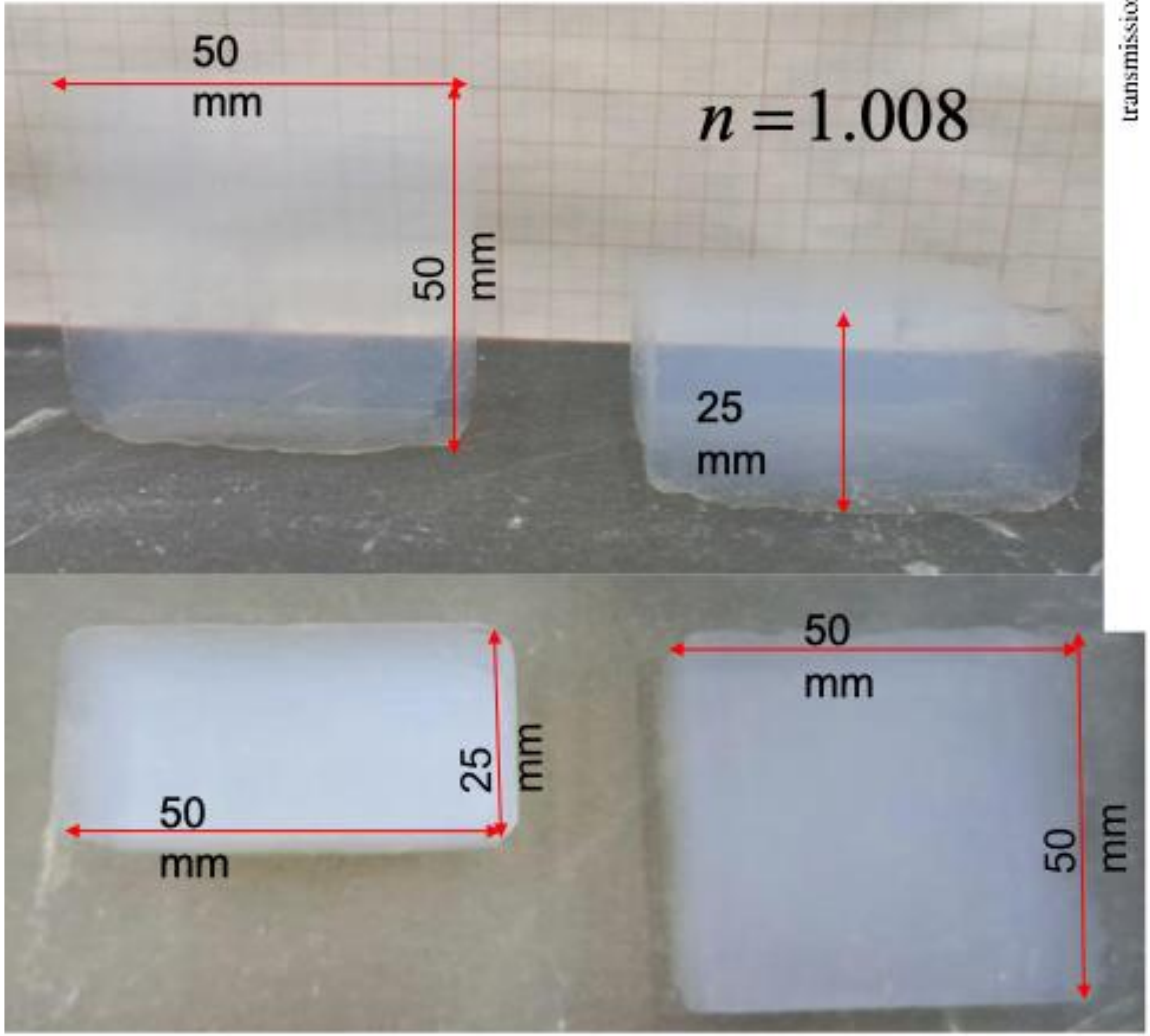
Motivations for π/K–separation above 20 GeV/c

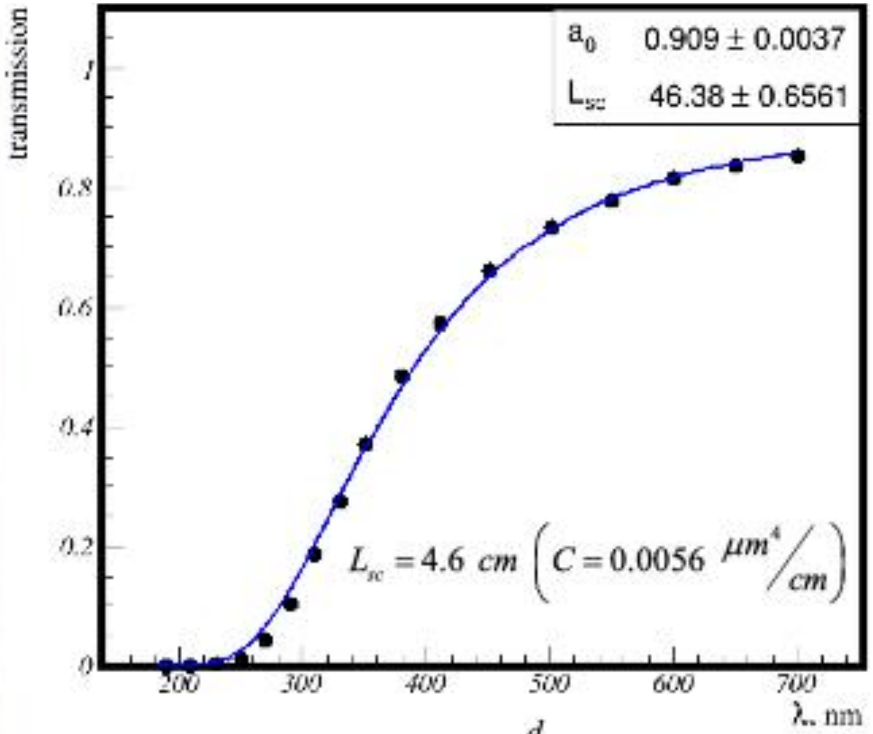
- Future e^+e^- H-factories such like FCCee (CERN) and CEPC (China) have extensive physics programe at Z-pole $(\sqrt{s} = 91.2\ GeV)$.
- Expected 4×10^{12} Z-bozons $\left(\int Ldt \approx 100ab^{-1}\right)$ will provide extensive statistic of $b\bar{b}$, $c\bar{c}$ and $\tau^+\tau^-$ for precise flavor physics investigations. *[arXiv:2412.19743v2 [hep-ex] 31 Dec 2024]*
- π/K– separation is needed not only to supress combinatorial background and to separate similar topology of final states like:

$B^0_{(s)} \to \pi^+\pi^-, B^0_{(s)} \to K^+K^-, B^0_{(s)} \to K^\pm\pi^\mp$ and so on.

- Baseline option of the CEPC detector is able to provide π/K– separation at the level of 2σ up to 20 GeV/c by combining ${}^{dE}/_{dx}$ and ToF techniques. *[Y.Zhu et al., NIM A 1047 (2023) 167835]*
- π/K–separation at the level $\geq 3\sigma$ in wider momentum range is highly desirable for such experiments.

Aerogel with n=1.008 (Novosibirsk)





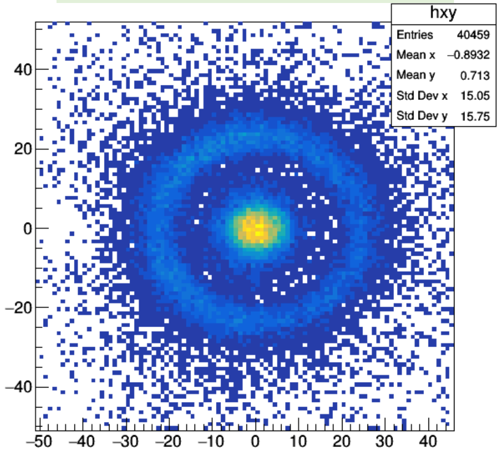
$$T = \frac{I}{I_0} = a_0 \cdot e^{-\frac{d}{L_{sc}\cdot\left(\lambda/400\right)^4}} = a_0 \cdot e^{-\frac{C\cdot d}{\lambda^4}}$$

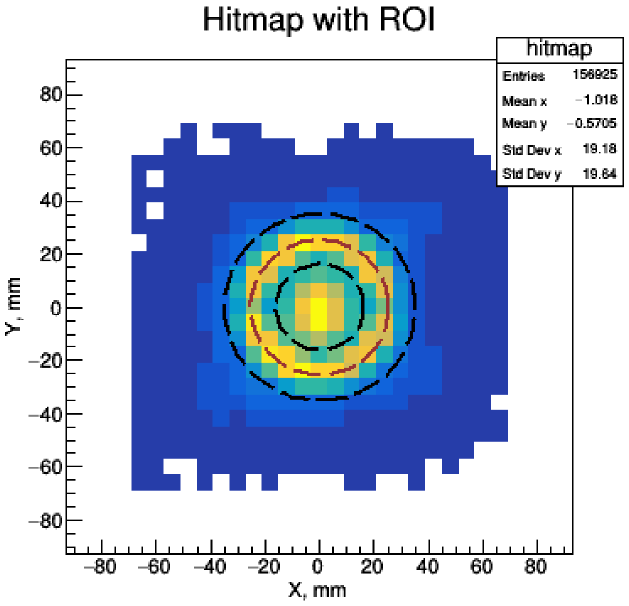
d – thickness of a sample,
λ – wavelength in nanometers,
Lsc – scattering length at 400 nm,
a_0 – surface scattering coefficient,
C – clarity coefficient

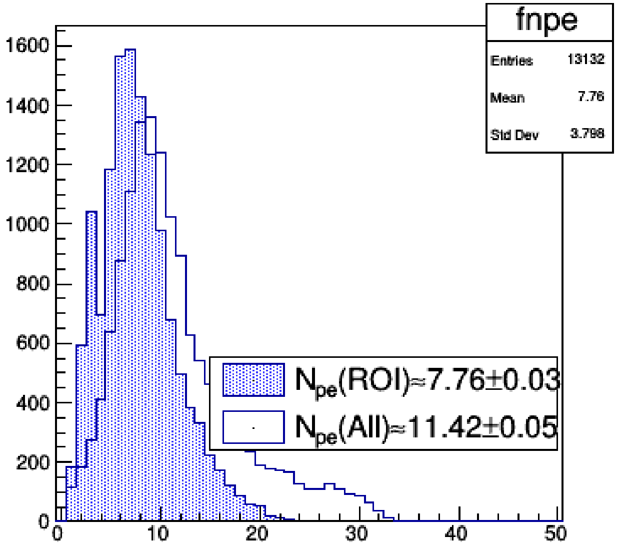
RICH based on aerogel n=1.008: some beam test results

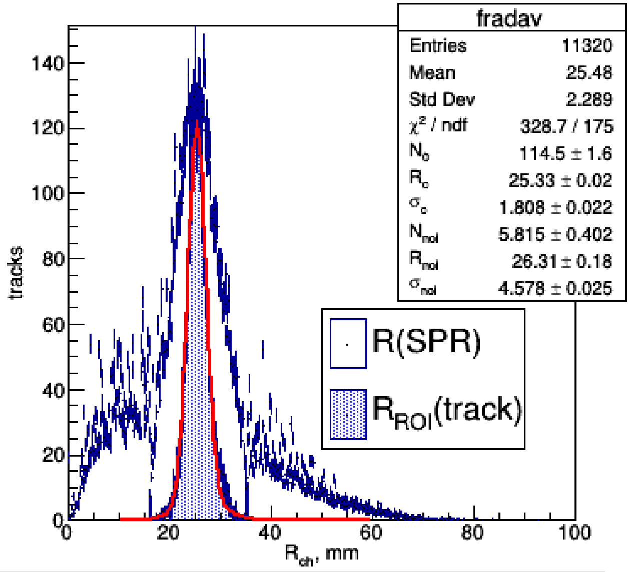
Tbeam e⁻@2.5GeV

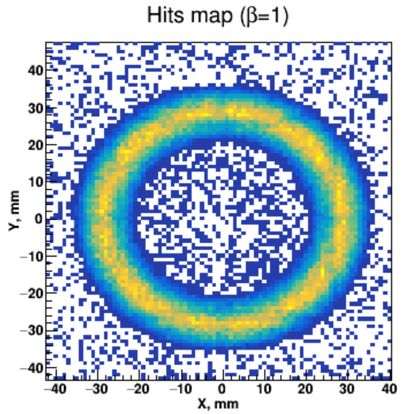
- t_{aer}=25+25=50 mm
- L_F=200 mm











Geant4 sim.:

- t_{aer}=60 mm
- L_F=250 mm

TBeam results reconstructed w/o track information:

- MaPMT H12700 with QE(400nm) ≈ 20%
- Pixel 6x6 mm
- Aerogel:
  - stack of 3 tiles 25+25+25=75 mm
  - refractive index n≈1.008
- L_F=235 mm

OUTPUT:

- SiPM based photon detector with PDE(400nm)=45÷50% will alow us to detect ***10÷20 ph.e.*** for relativistic tracks
- RICH based on aerogel with n=1.008 and pixel 3x3mm is able to provide π/K-separtion at P=10 GeV/c
- ***Proximity focusing system and PD with $\sigma_x \leq 1\,mm$ is required to reach π/K-separation above 20 GeV/c***

G4sim conditions

8-layers aerogel n_{max}=1.008 (2 tiles)

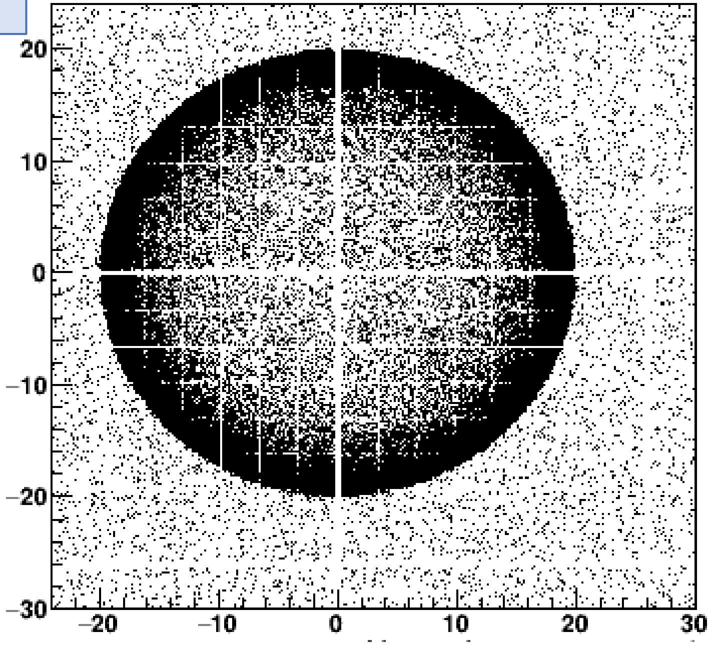
1) 1.0055, t = 8.24
2) 1.0058, t = 8.02
3) 1.0061, t = 7.80
4) 1.0064, t = 7.59

5) 1.0068, t = 7.38
6) 1.0072, t = 7.18
7) 1.0076, t = 6.99
8) 1.0080, t = 6.80

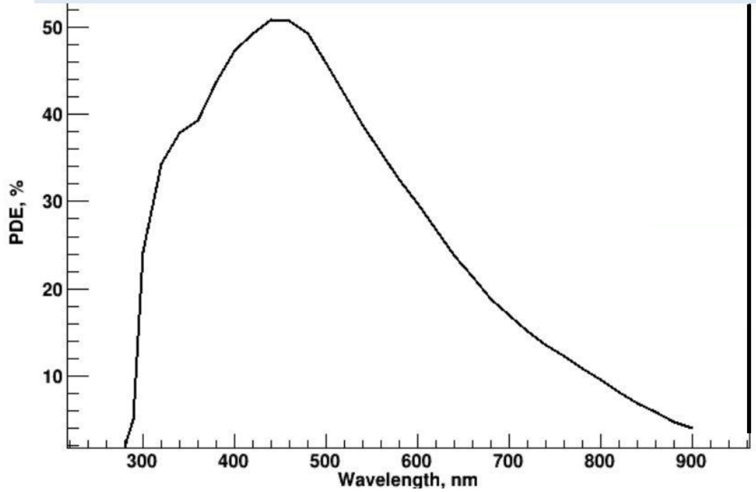
Focal distance is 300 mm

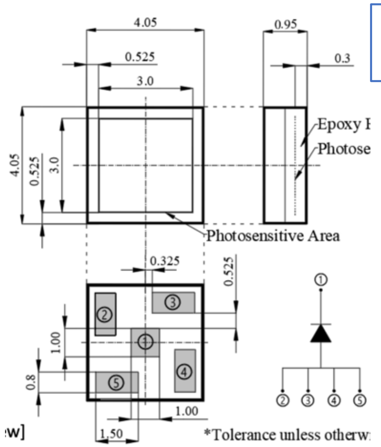
- L_{abs} is taken from *NIMA494 (2002) 491–494*
- $L_{sc}(\lambda)=L_{sc}(400nm)\cdot\left(\frac{\lambda}{400}\right)^4$
- $n(\lambda) = \sqrt{1 + a_0 \cdot \frac{\lambda^2}{\lambda^2-\lambda_0{}^2} \cdot \frac{(n(400)^2-1)}{a_0 \cdot \frac{400^2}{400^2-\lambda_0{}^2}}}$, where

λ_0=83.22 nm and a_0=0.05639 is taken from *Eur. Phys. J. C 52, 759–764 (2007))*



PDE for MPPC-S14160 (Hamamatsu)





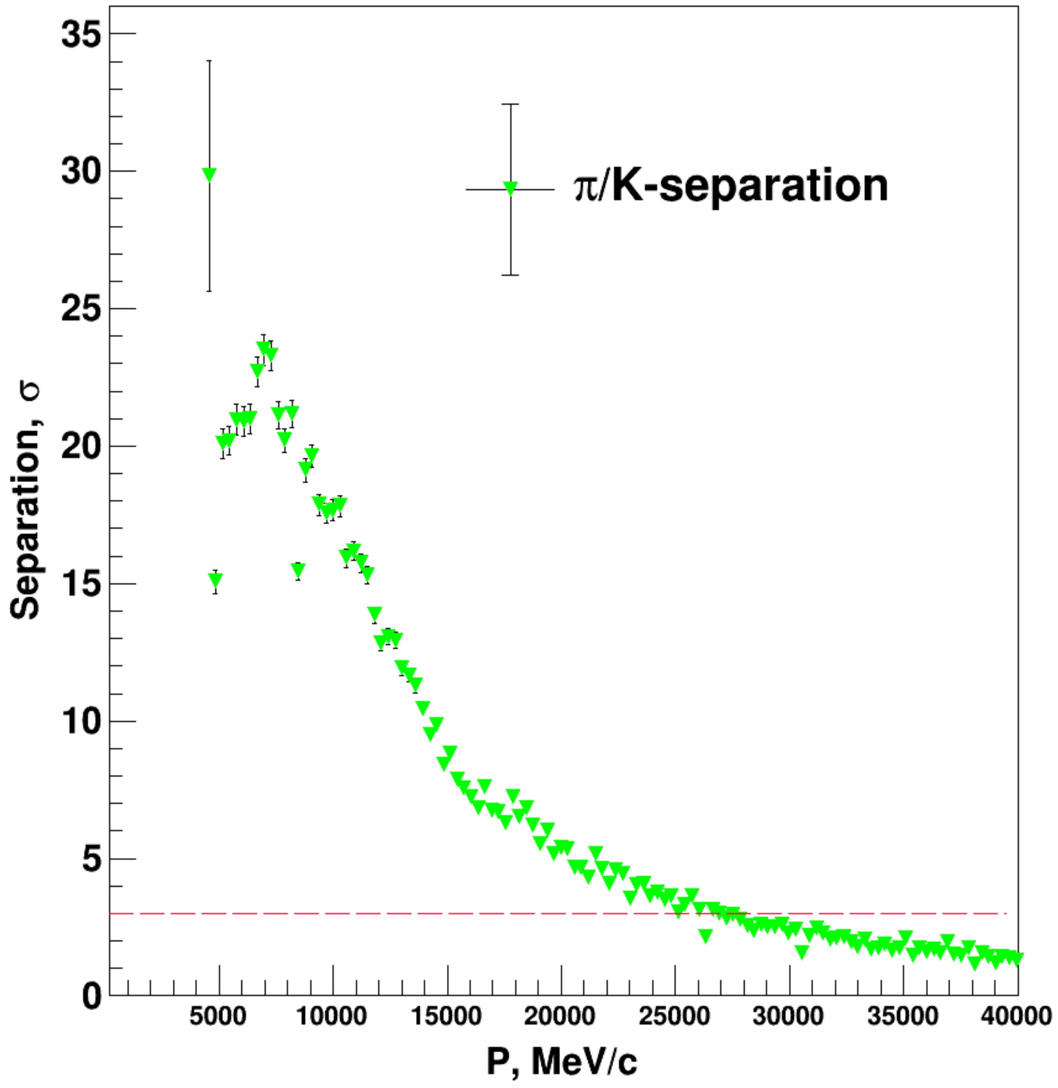
SiPM PSS15 11-3030 from NDL (China)

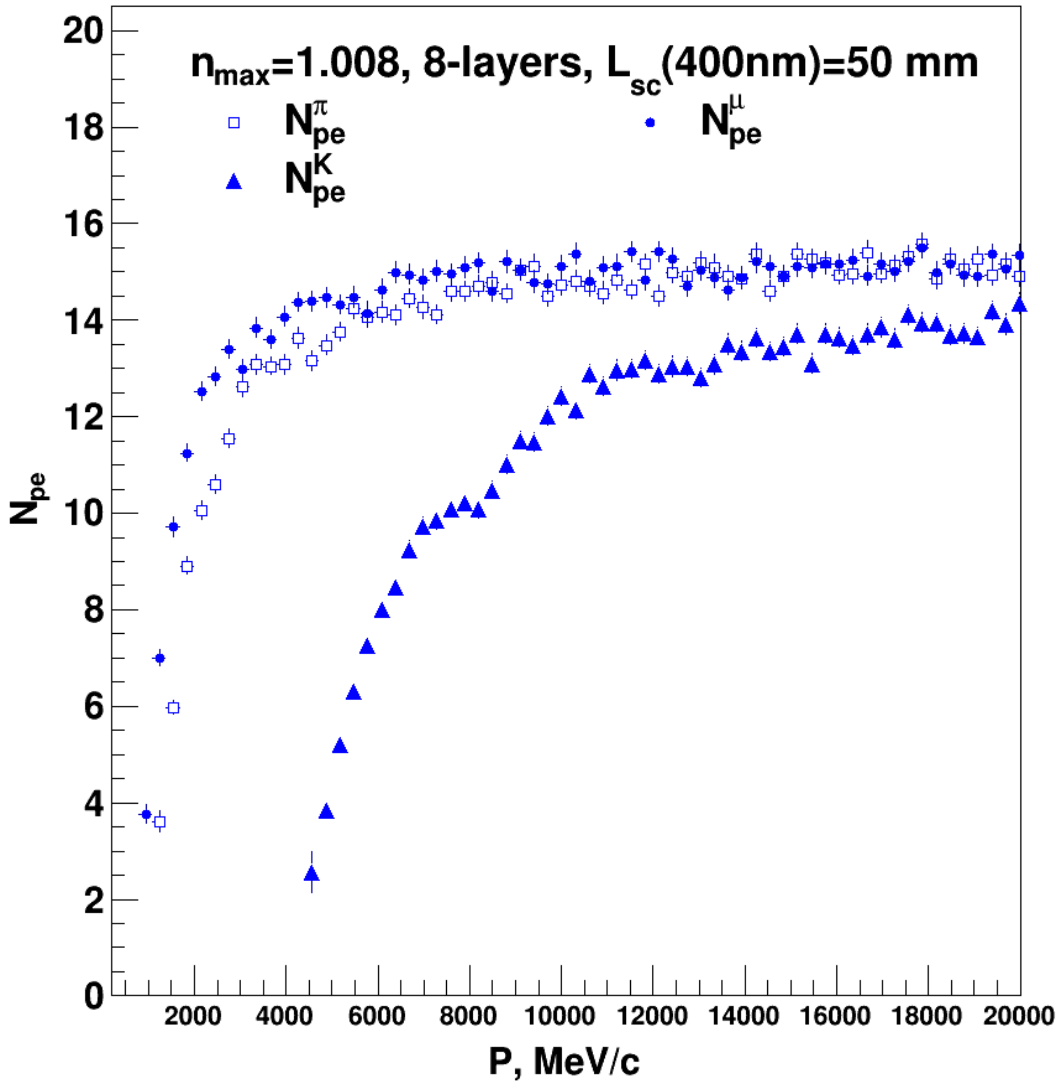
$$x_c = \frac{L}{2} \cdot k \cdot \frac{(Q_2+Q_3)-(Q_1+Q_4)}{(Q_1+Q_2+Q_3+Q_4)}$$

$$y_c = \frac{L}{2} \cdot k \cdot \frac{(Q_3+Q_4)-(Q_1+Q_2)}{(Q_1+Q_2+Q_3+Q_4)}$$

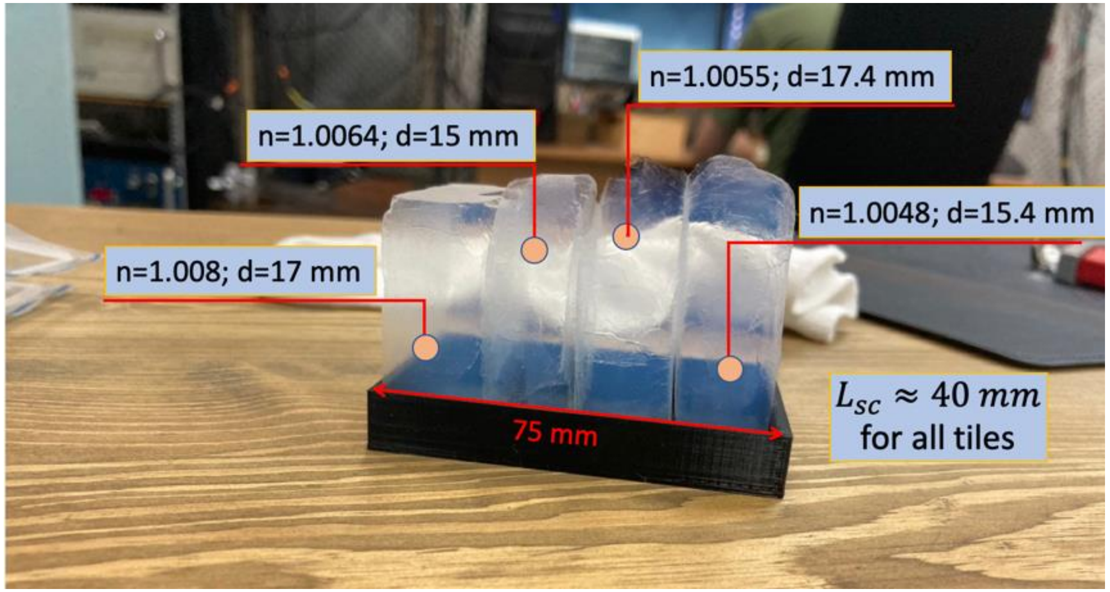
Exact hit positions from G4sim are smeared by Gaussian with $\sigma_x = 200\mu m$

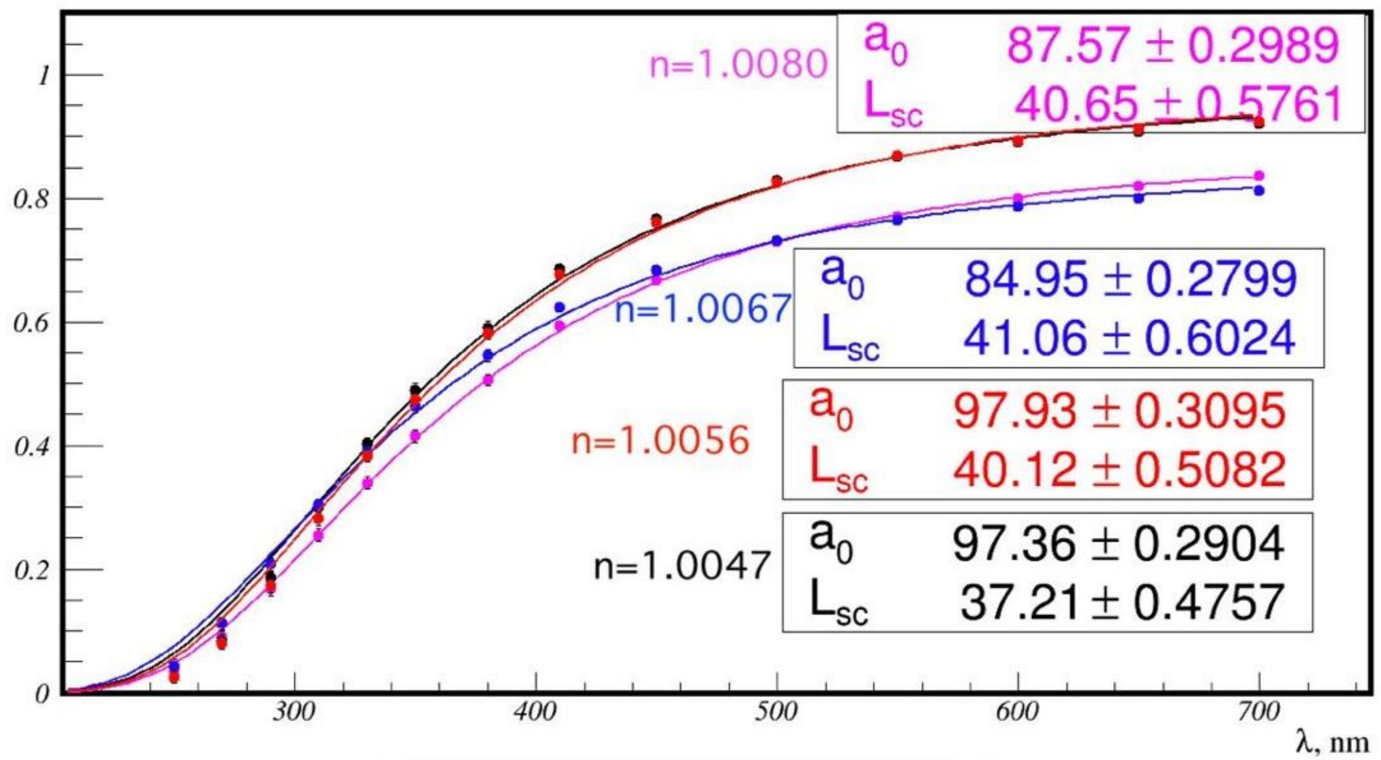
π/K–separation in 20÷30 GeV/c region: G4sim results





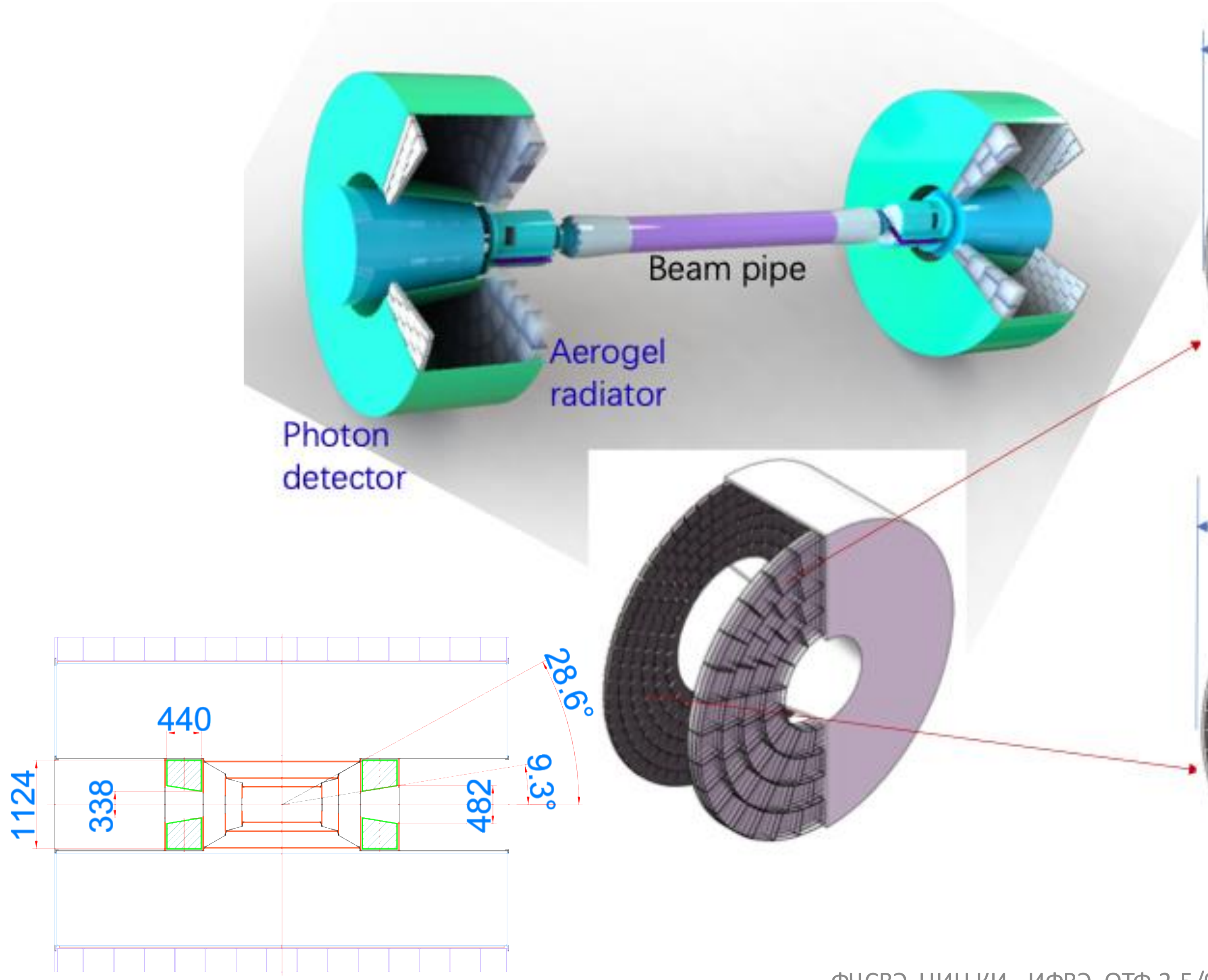
Some practical results of 2025

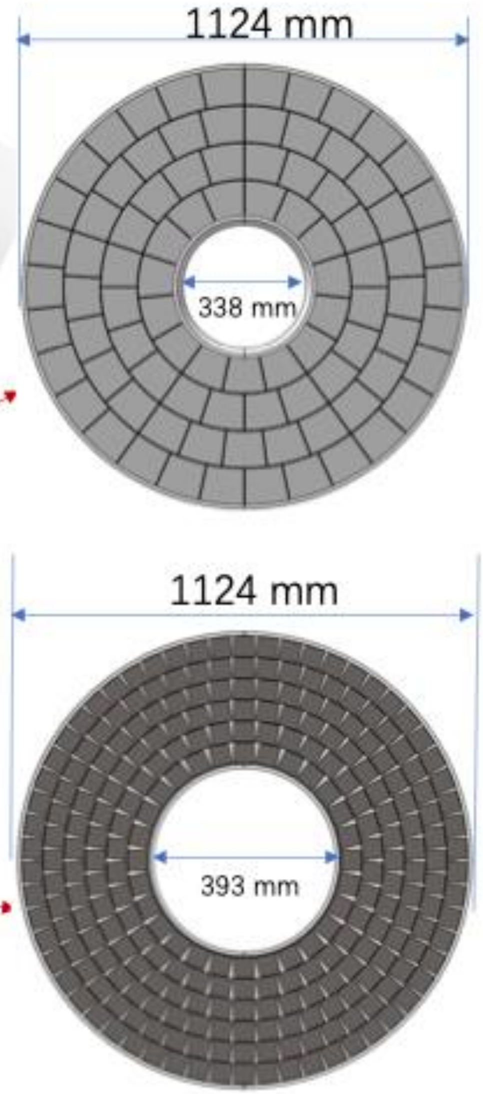




In 2025 for the first time ultra-light SiO_2 aerogels with high transperancy were produced in Novosibirsk!
Next step is produce multilayer aerogel samples with n≤1.008 and total thickness 30÷40 mm

FARICH for CEPC project sketch





From Jian Wang, mechanical group

Aerogel radiator :
- 90 aerogel tiles in 4 layers
- each tile of ~10 cm x 10 cm

Photon detector:
- 258 PMTs(sensor module) in 6 layers
- each PMT(sensor module) of ~5 cm x 5 cm

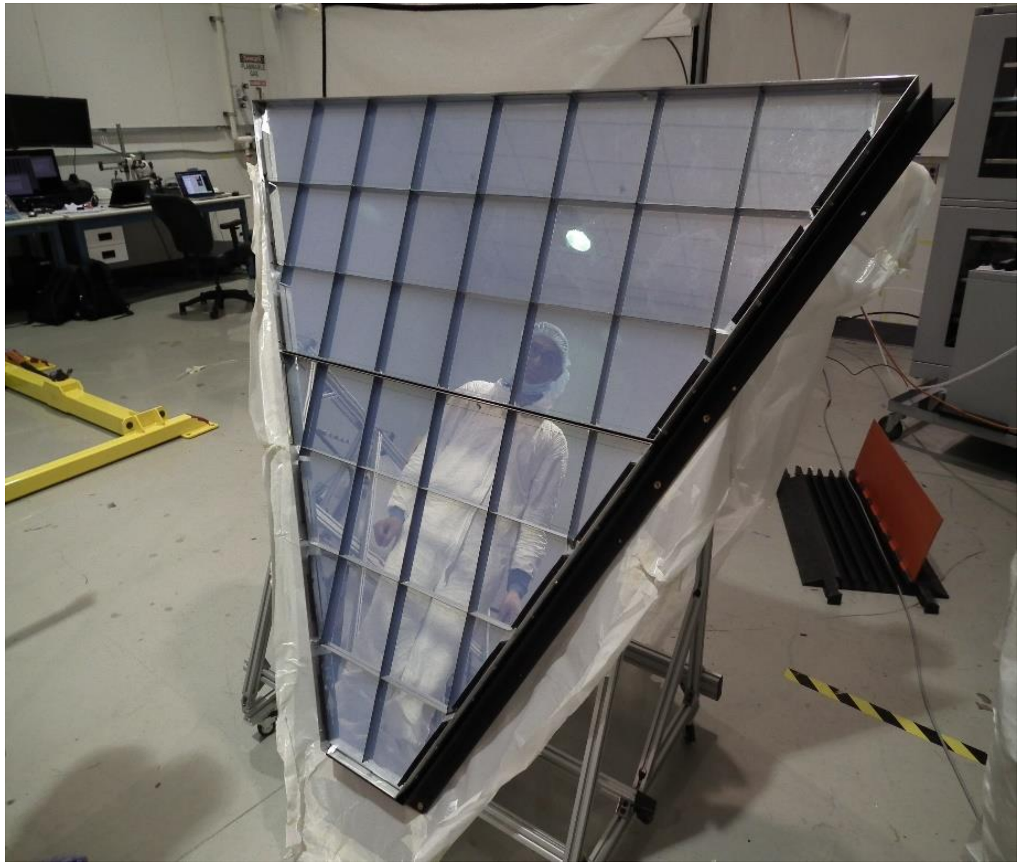
Заключение

- Разработка системы идентификации для Российского проекта Супер С-Тау фабрики сыграла определяющую роль в развитии методики ФАРИЧ
- Сегодня активно ведется разработка системы ФАРИЧ для эксперимента SPD@NICA:
  - Разрабатывается координатно-чувствительный фотоприемник
  - Идет оптимизация аэрогелевого радиатора и технологии его производства
  - Прорабатывается конструкция системы, ПО для моделирования и реконструкции, концепция FEE и DAQ
- Показано, что на основе методики ФАРИЧ с аэрогелями $n \leq 1.008$ можно разрабатывать системы идентификации для π/K разделения в области импульсов 20÷30 ГэВ/c

BACK UP SLIDES

History of aerogel radiators in Novosibirsk

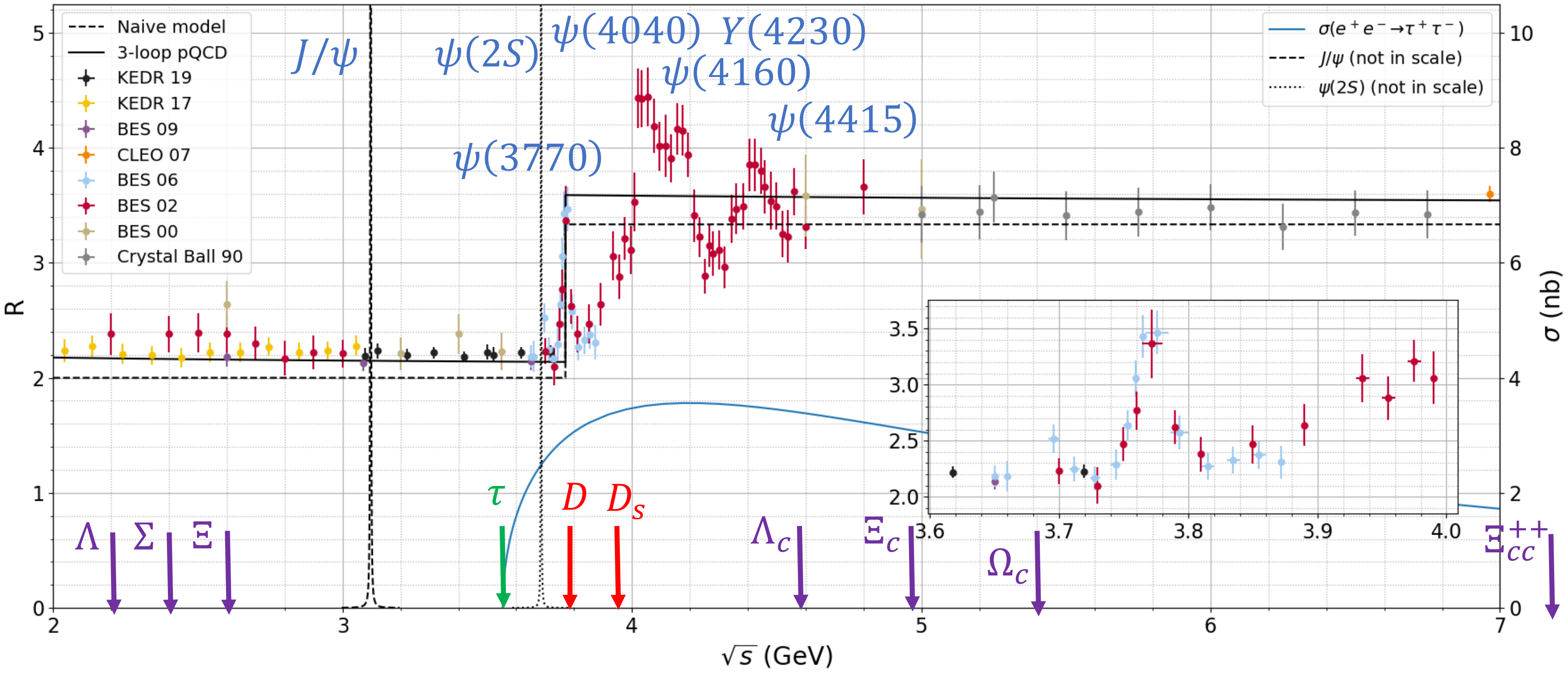
- **KEDR ASHIPH** system (VEPP-4M – BINP):
  - π/K-separation in the momentum range 0,6÷1,5 GeV/c.
  - Aerogel $n = 1{,}05$ (V~1000 L).
- **SND ASHIPH** system (VEPP-2000 – BINP):
  - π/K-separation in the momentum range 300÷870 MeV/c.
  - Aerogel $n = 1{,}13$ (V~9 L).
- **DIRAC-II** (PS – CERN):
  - π/K-separation in the momentum range 5,5÷8,0 GeV/c.
  - Aerogel $n = 1{,}008$ (V~9 L).
- **AMS-02** aerogel RICH (ISS):
  - Search for antimatter, study of cosmic rays.
  - Aerogel $n = 1{,}05$ (S~1 m^2).
- **LHCb** aerogel RICH (LHC – CERN):
  - π/K-separation in the momentum range 5,5÷8,0 GeV/c.
  - Aerogel $n = 1{,}03$ (S~0,5 m^2), aerogel tile 20x20x5 $см^3$.
- **CLAS-12** aerogel RICH (J-Lab):
  - π/K- & K/p-separation at level 4σ with several momentum GeV/c.
  - Aerogel $n = 1{,}05$ (S~6 m^2), aerogel tile 20x20x2-3 $см^3$.



The SCT energy range

$$R \equiv \frac{\sigma(e^+e^- \to \text{hadrons})}{\sigma_0(e^+e^- \to \mu^+\mu^-)}$$

Threshold production of nonrelativistic particles provides best conditions for their comprehensive study



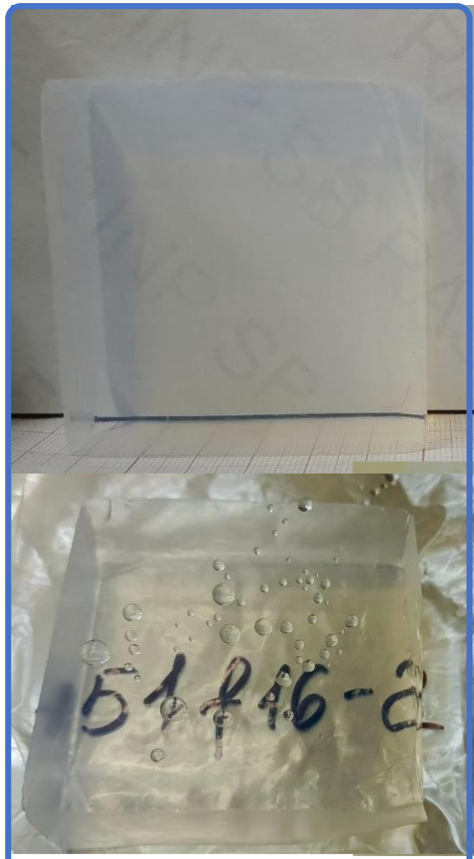
$\mathcal{L} = 10^{35}\ \text{cm}^{-2}s^{-1}$

A one-year dataset

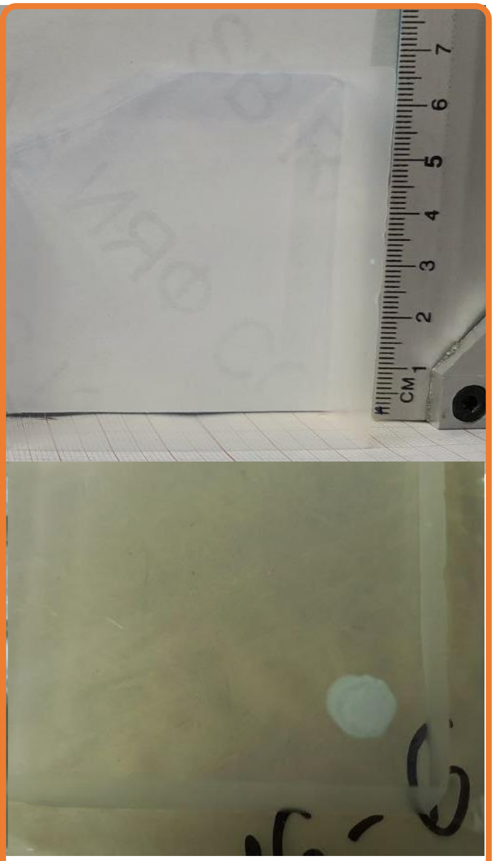
$2E$, GeV	Events recorded
3.1	$10^{12}\ J/\psi$
3.69	$10^{11}\ \psi(2S)$
3.77	$10^{9}\ D\bar{D}$
4.17	$10^{8}\ D_s\bar{D}_s$
3.55 ÷ 4.3	$10^{10}\ \tau\ \tau$
4.65	$10^{8}\ \Lambda_c^+\Lambda_c^-$

The first experience with hydrophobization #1

- Production of thick hydrophobic tiles is limitted by large time of fabrication because the clarification processes have to be done at low temperatures (below 175˚C)
- The main idea is to produce thick multilayer aerogels with standard Novosibirsk’s procedure when optical clarification is obtained due to burning of the most organic additions in aerogel and after that make hydrophobization in the vapors of the **H**exa**M**ethyl**DiS**ilasane ($[(CH_3)_3Si]_2NH$)

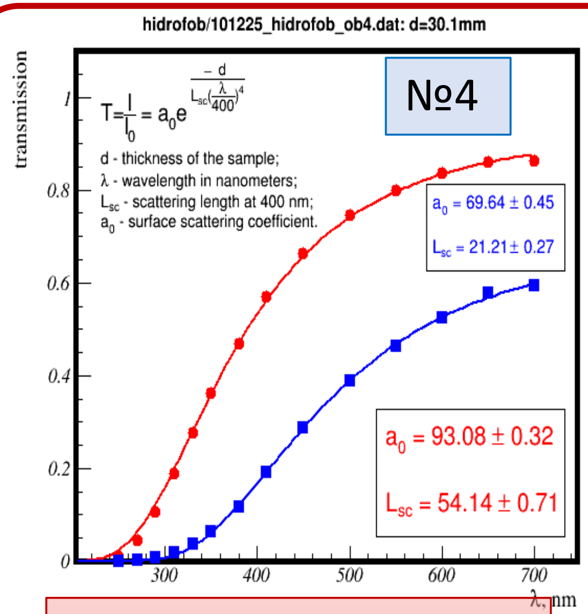


Hydrophobic

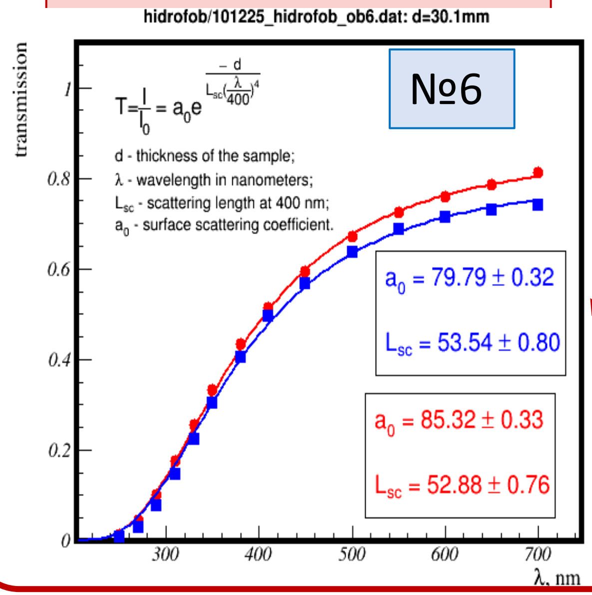


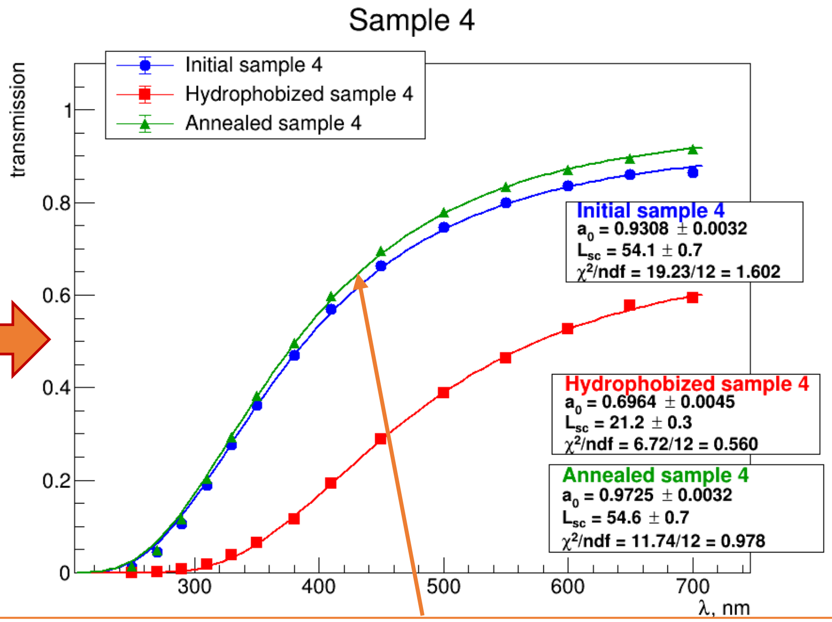
Hydrophilic

The first hydrophobization experience #2



HMDS – 5% (3 samples)





- It was shown, it is possible totally restore optical transparency of hydrophobic aerogels with help of annealing (5 hours at 500˚C)

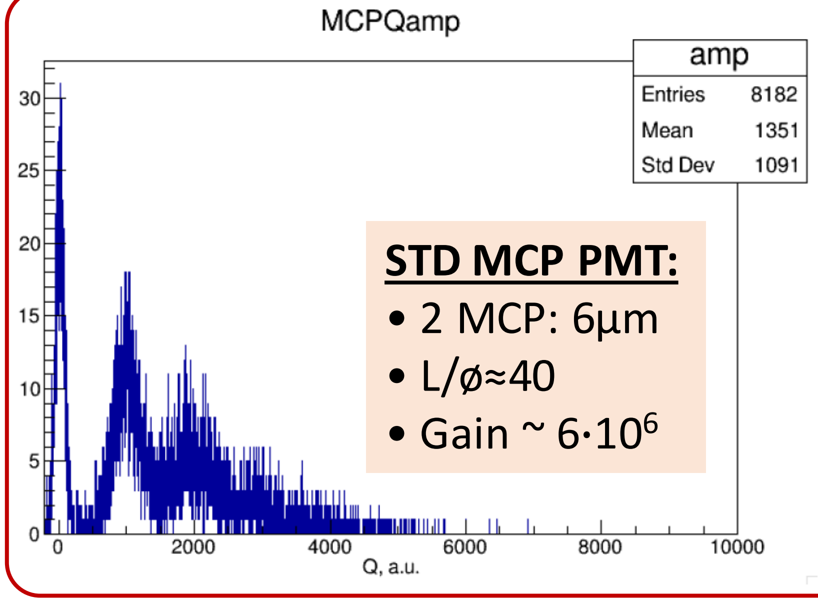
- Hydrophilic aerogel (left) totally destroid in contact with water, while after hydrophobization it can be tooled by water-jet cutting machine

- Influence of hydrophobisation on aerogel transparency has not been studied well yet

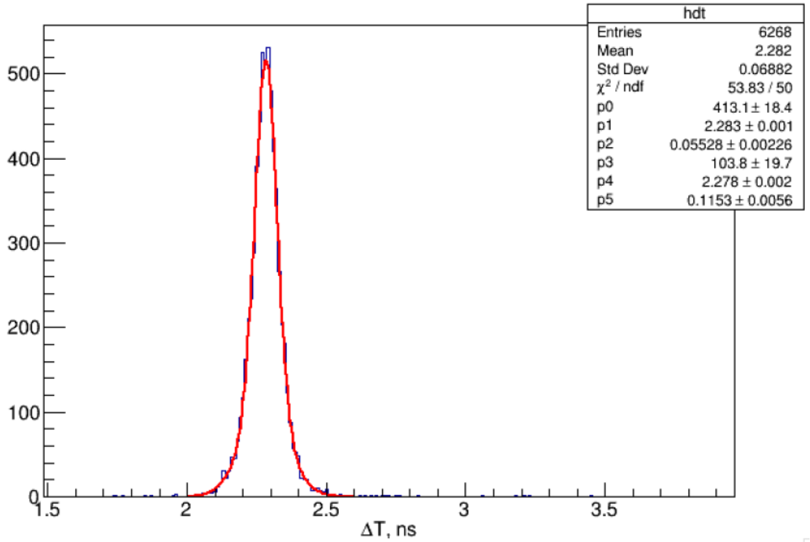
The first practical output:

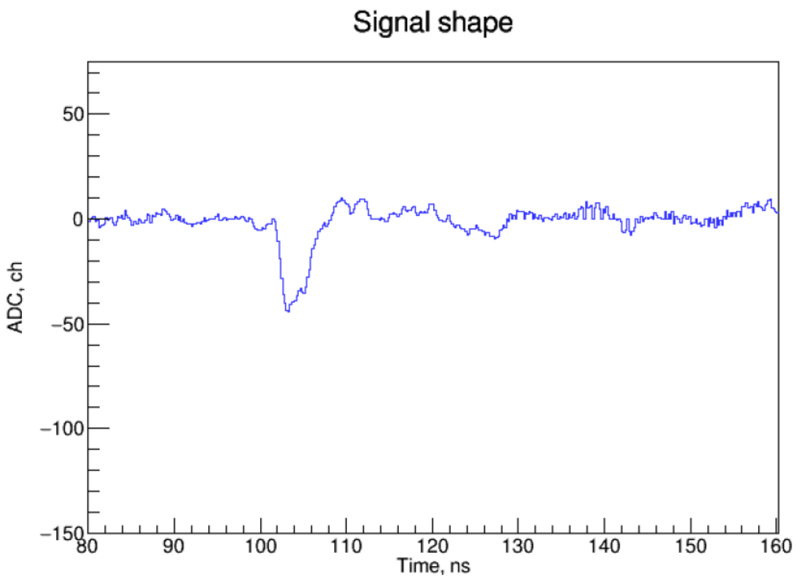
We can produce aerogels as we need (highly transperant, thick and so on), then make tooling after hydrophobization and restore its tranparency before the assembling the detector.

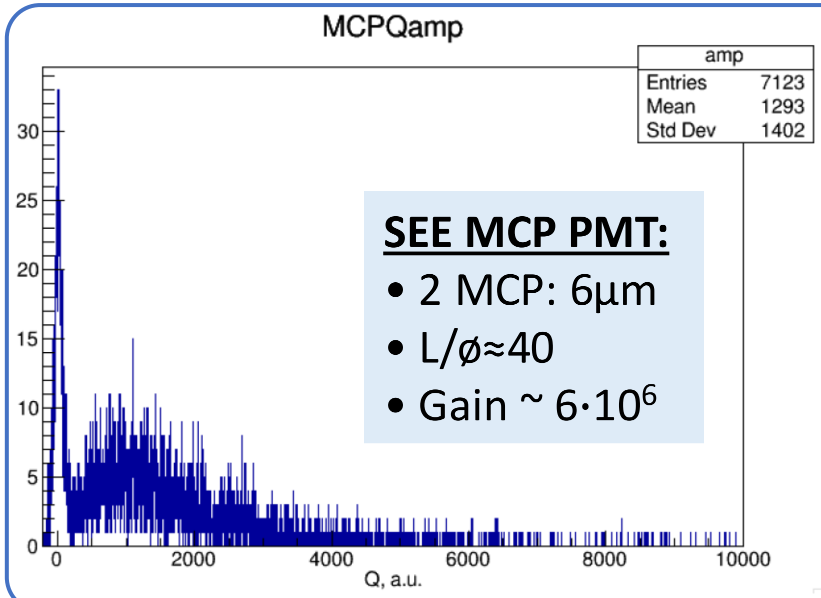
MCP optimisation with ALD #2: SPE & TTS



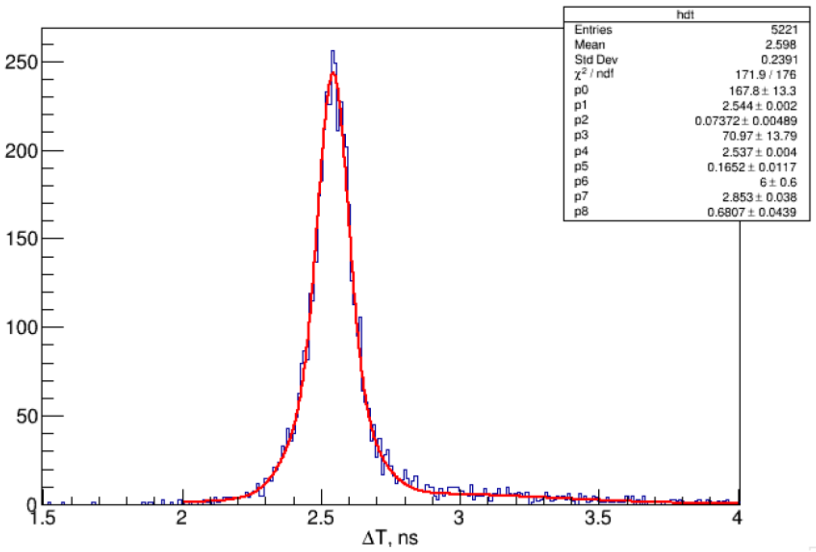
STD MCP PMT:
- 2 MCP: 6μm
- L/ø≈40
- Gain ~ $6 \cdot 10^6$

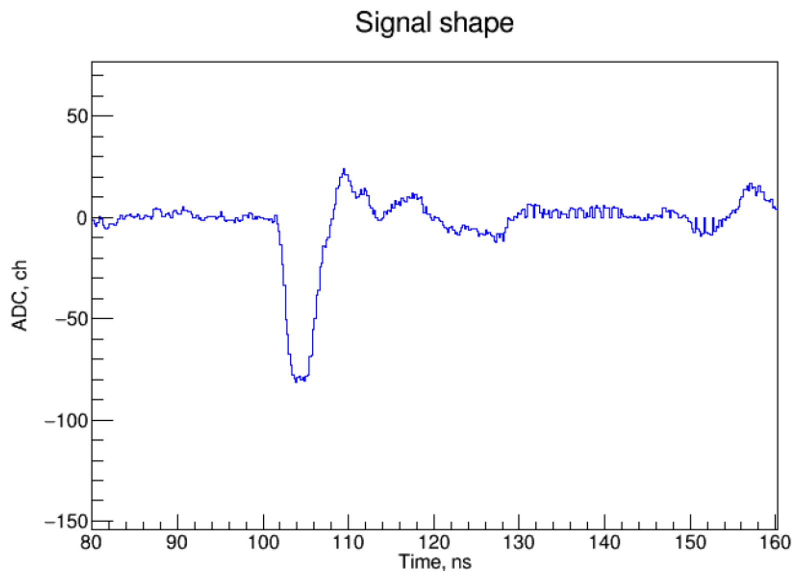




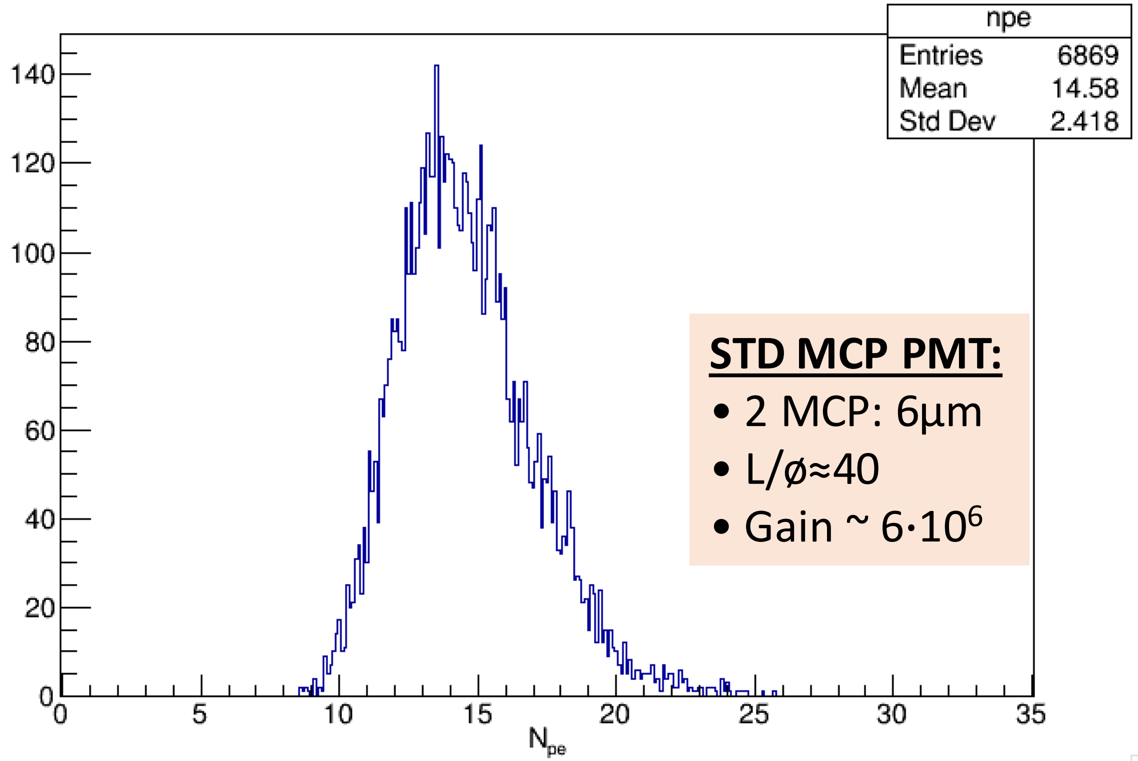


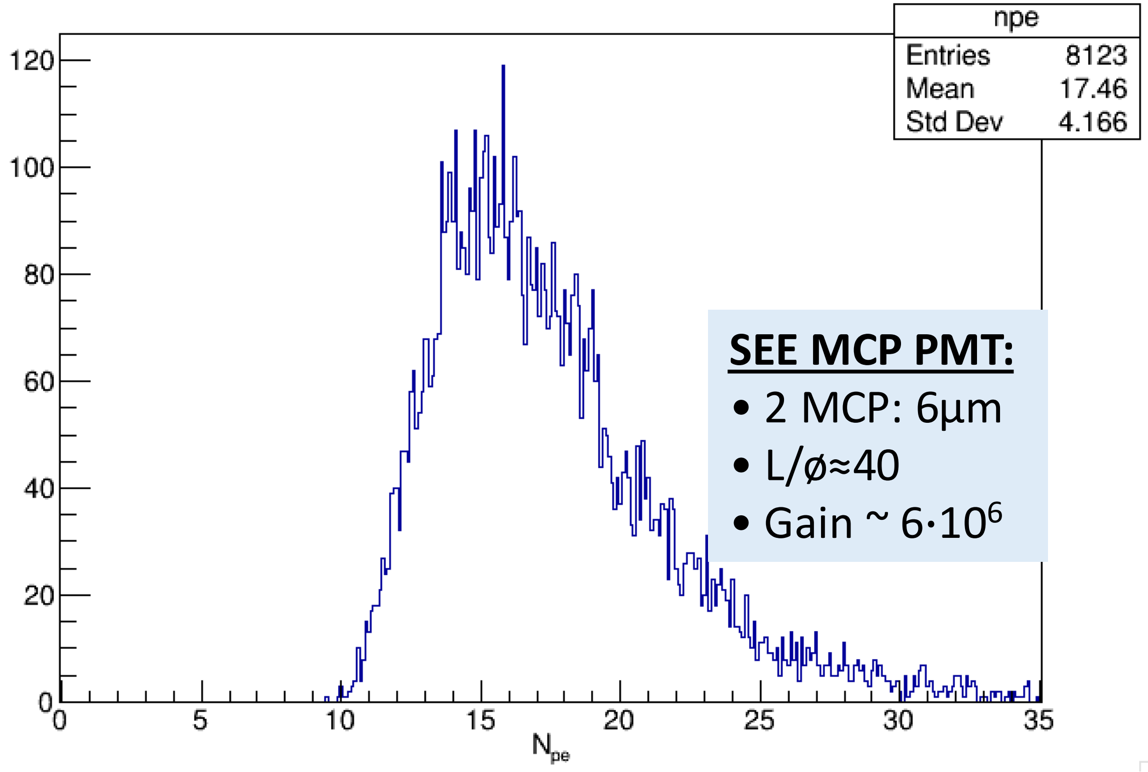
SEE MCP PMT:
- 2 MCP: 6μm
- L/ø≈40
- Gain ~ $6 \cdot 10^6$





MCP optimisation with ALD #3: PE Collection Eff.





$$\boldsymbol{CE(SEE)}\big/\boldsymbol{CE(STD)} = \frac{N_{pe}(SEE)\big/QE(SEE)}{N_{pe}(STD)\big/QE(STD)} = \frac{17.46\big/19.65}{14.58\big/20.49} \approx \mathbf{1.25}$$

Practical output:

- SEE MCP Gain ~ 1÷15·10^6
- CE(SEE)≈1.25·CE(STD)
- TTS(SEE) worse than TTS(STD)

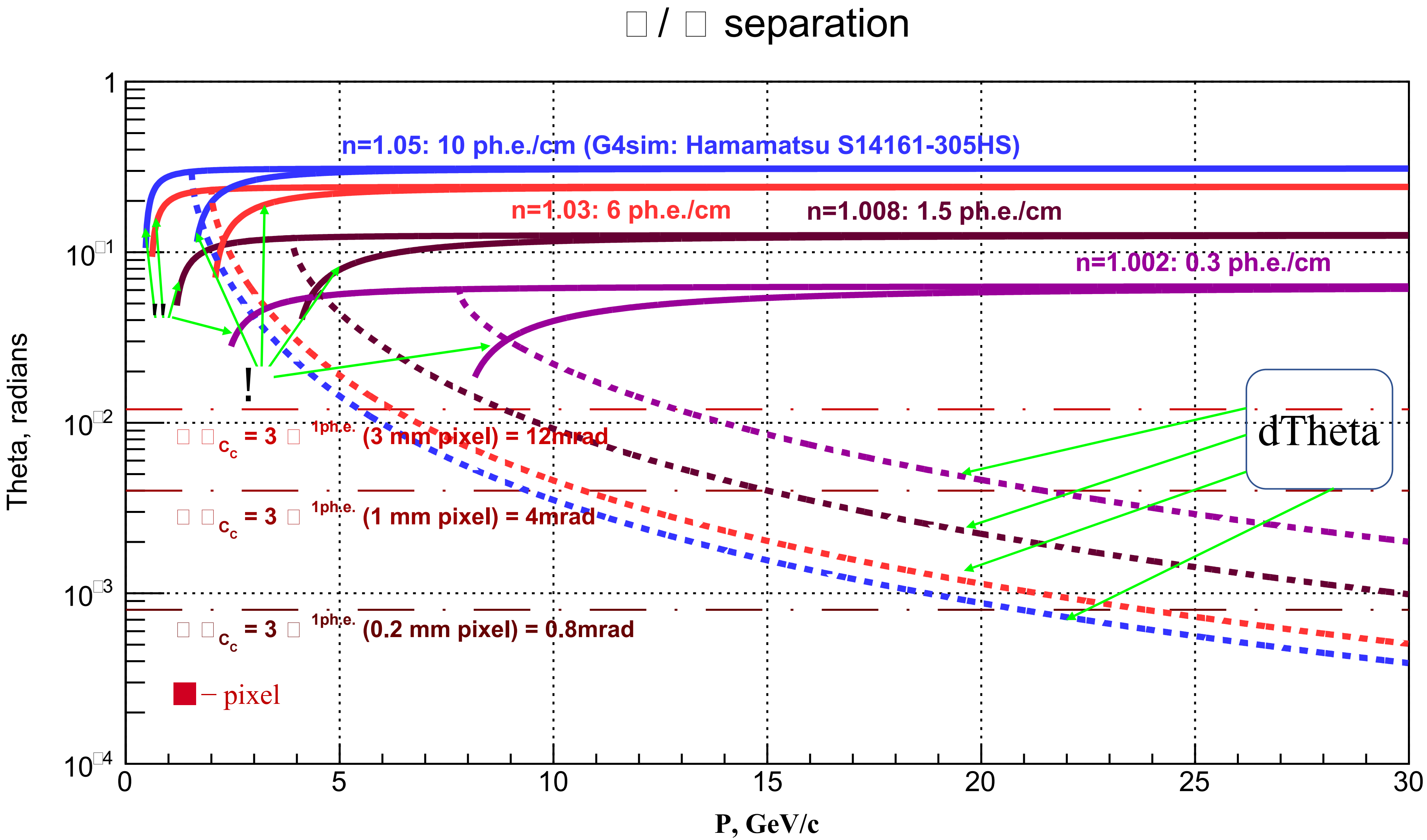
Further R&D and optimization is needed.

Набранные данные:

Date	aerogels	P, GeV/c	Number, events	Comments
12.03.2026	460f5 4-layer SCTF	5	425k	n_{max}=1.046, t=35 mm, 230x230 mm^2
13.03.2026	467_8 3-layer SPD	5	400k	n_{max}=1.040, t=40 mm, 100x100 mm^2
	467_1 4-layer SPD	5	340k	n_{max}=1.040, t=40 mm, 100x100 mm^2
	467f10_1 4-layer SCTF	5	230k	n_{max}=1.046, t=35 mm, 200x60 mm^2
	467f10_1 4-layer SCTF	3	600k	n_{max}=1.046, t=35 mm, 200x60 mm^2
14.03.2026	467_1 4-layer SPD	3	600k	n_{max}=1.040, t=40 mm, 100x100 mm^2
	467_8 3-layer SPD	3	600k	n_{max}=1.040, t=40 mm, 100x100 mm^2
	460f5 4-layer SCTF	3	200k	n_{max}=1.046, t=35 mm, 230x230 mm^2
	460f5 4-layer SCTF	1,5	50k	n_{max}=1.046, t=35 mm, 230x230 mm^2
15.03.2026	460f5 4-layer SCTF	6	1M	n_{max}=1.046, t=35 mm, 230x230 mm^2
	467_8 3-layer SPD	6	600k	n_{max}=1.040, t=40 mm, 100x100 mm^2
	467_1 4-layer SPD	6	600k	n_{max}=1.040, t=40 mm, 100x100 mm^2
	467_1 4-layer SPD	10	600k	n_{max}=1.040, t=40 mm, 100x100 mm^2
	460f5 4-layer SCTF	10	600k	n_{max}=1.046, t=35 mm, 230x230 mm^2
	467_8 3-layer SPD	10	600k	n_{max}=1.040, t=40 mm, 100x100 mm^2

Тестировались 3- и 4-слойные радиаторы для SPD, а также радиатор для C-Tau.

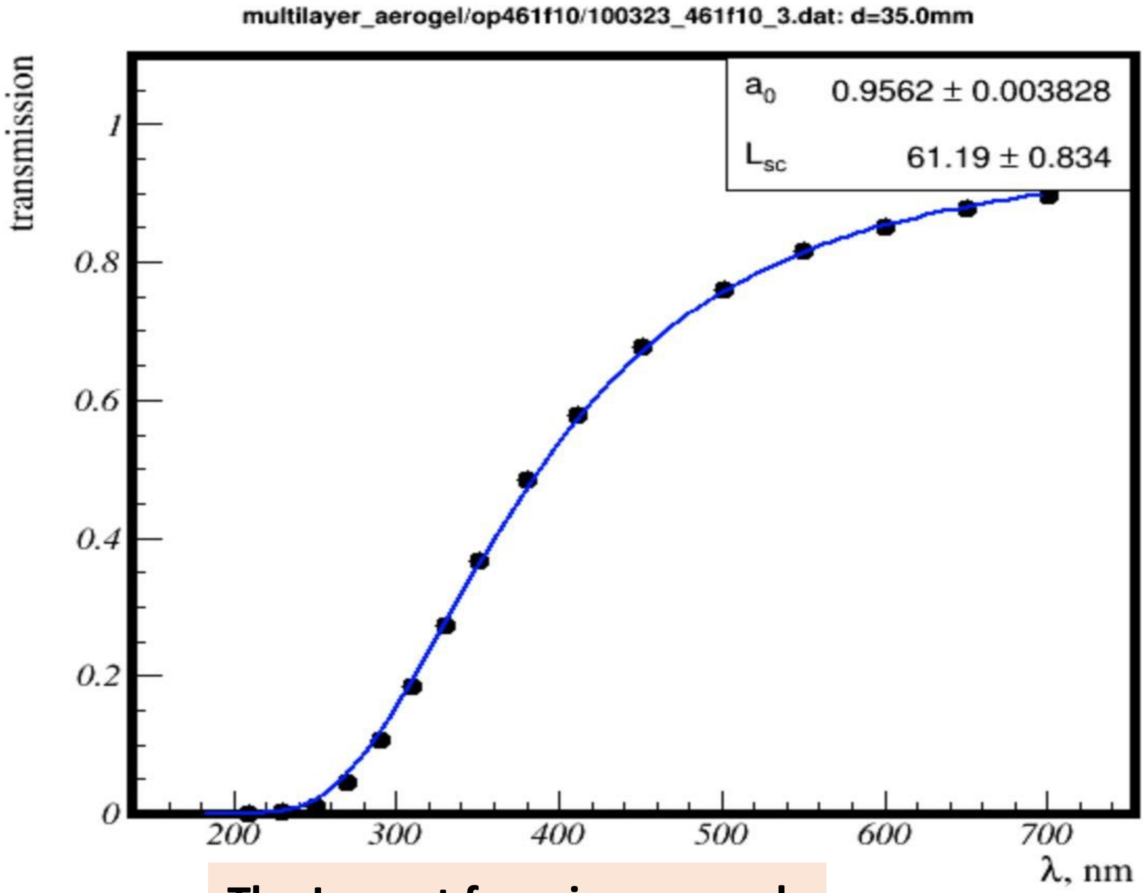
RICH detectors capability for π/K–separation

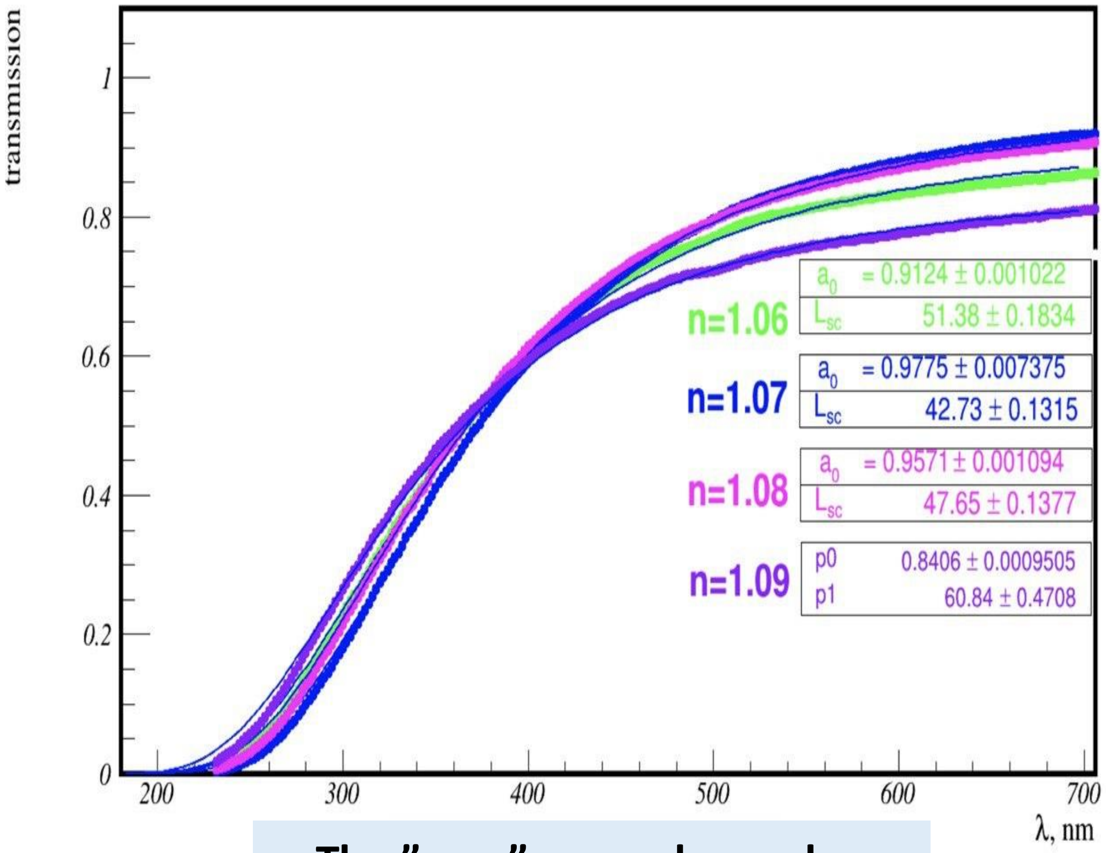


- At least 5 hits have to be detected to reconstruct Cherenkov ring.
- Thickness of Cherenkov radiator should be:
  - ≥1 cm for n=1.05 (aerogel)
  - ≥4 cm for n=1.008 (aerogel)
  - ≥15 cm for n=1.002 (C_5F_{12})
- Some focusing system is needed to provide impact from thickness at the level of few mrads for base 200÷300 mm!!!

- $\sigma_C^{tr} = {}^1/_{\sqrt{N_{pe}}} \cdot \sqrt{\left(\frac{\Delta_{pix} \cdot \cos\theta_C}{L \cdot \sqrt{12}}\right)^2 + \left(\frac{\sigma_n}{n \cdot \tan\theta_C}\right)^2 + \left(\frac{t \cdot \sin\theta_C}{L \cdot \sqrt{12}}\right)^2 + \sigma_{tr}^2} \sim \sqrt{t}$
- $N_{pe}(\beta = 1) \sim 500 \cdot \frac{n^2 - 1}{n^2} \cdot t \cdot QE$

Highly transparent aerogels with n>1.05





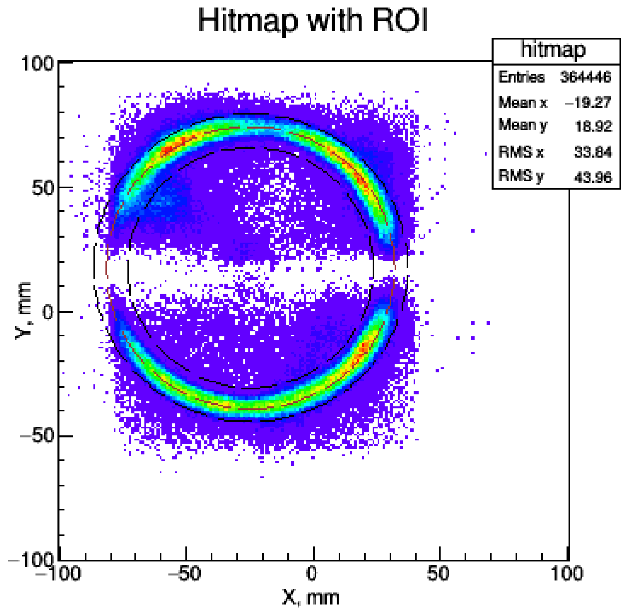
The Largest focusing aerogel:
- n_{max}=1.05
- 4 layers
- 230x230x35 mm

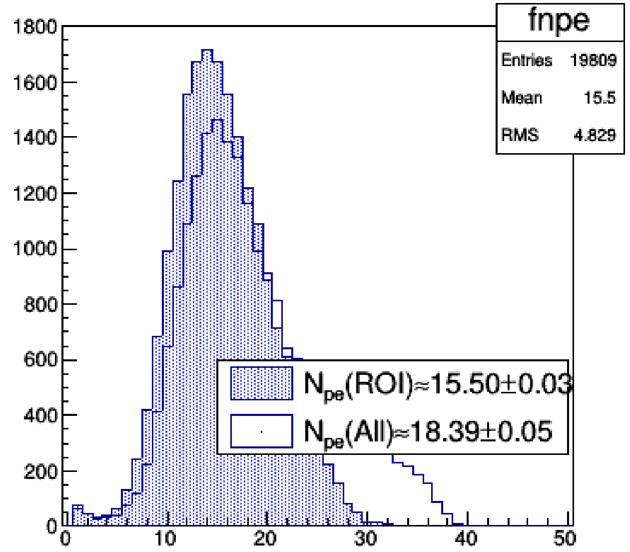
The "new" aerogel samples
with different refractive indexes:
from n=1.06 to 1.09
(thickness ~ 22 mm)

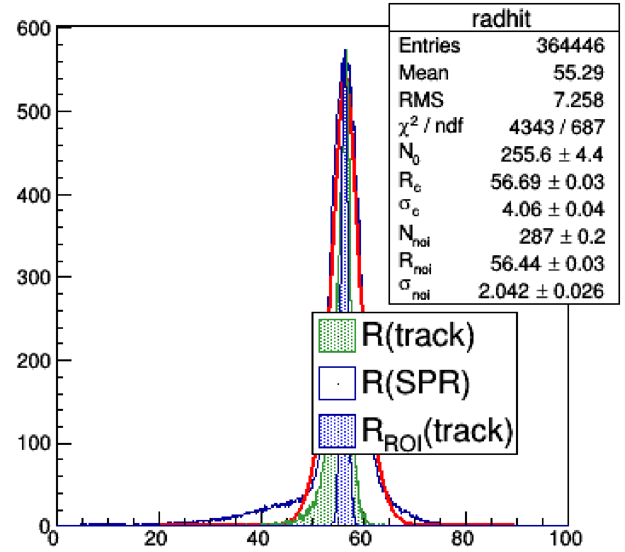
FARICH based on 4-layer aerogel with **n_{max}=1.08** will provide μ/π–separation from **250 MeV/c!!!**

Recent beam test results

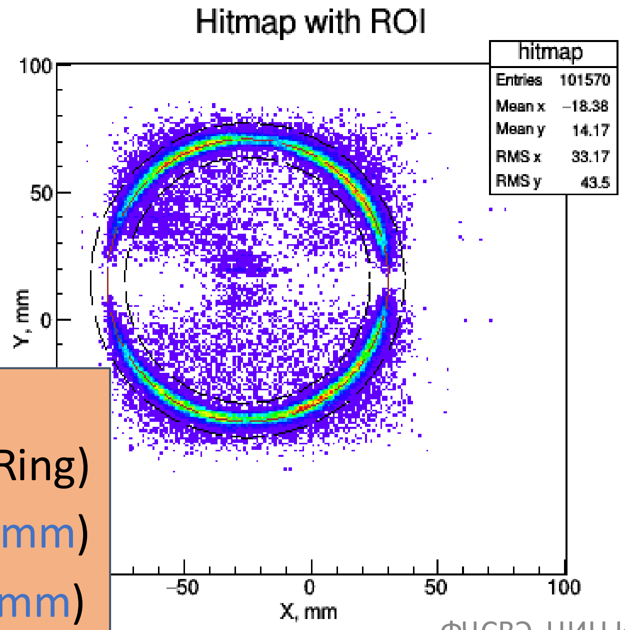
Pixel 6x6 mm
Geom.Eff. ~ 80%

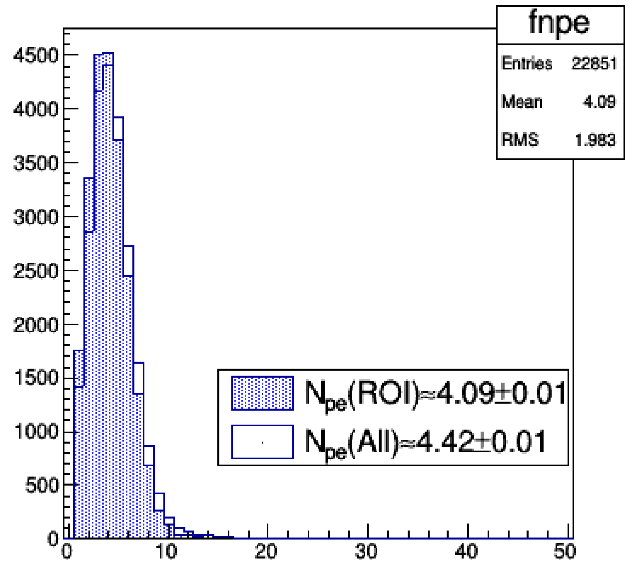


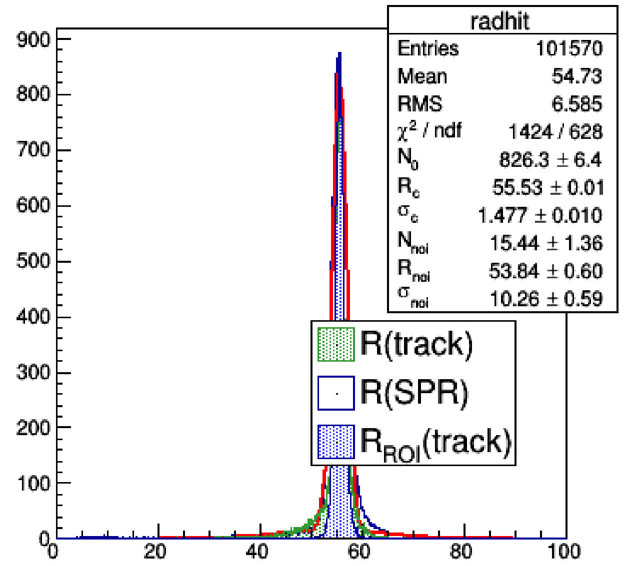




Pixel 3x3 mm
Geom.Eff. ~ 20%







Main results:

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