FARICH system: prototyping and simulation progress report

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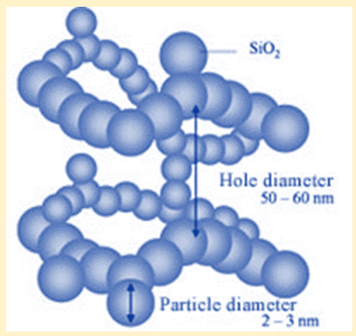
What is Aerogel?

Silica aerogel was first produced by S.S. Kistler in 1931. It is made of silica (SiO_2) nanospheres composing amorphous 3D structure.

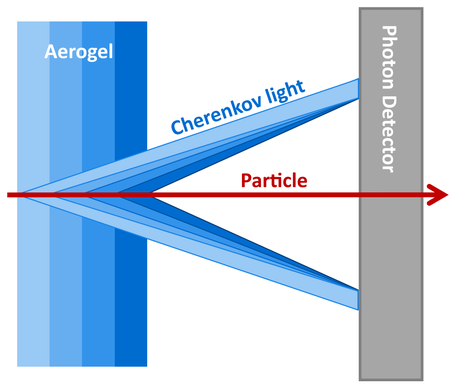
Refractive index of the aerogel for visible light is intermediate between silica (n≈1.5) and air (n≈1.0003): n = 1.006 — 1.20 and directly related to the aerogel density: $n^2 = 1+\alpha\rho$, where $\alpha = 0.44$ cm^3/g (for Novosibirsk aerogels).

Aerogel has a distinctive blueish color due to the Rayleigh scattering. Typical scattering length for modern aerogels is 5 cm at λ=400 nm.

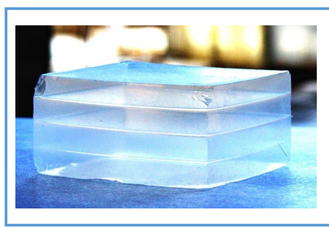
Aerogel is widely used as Cherenkov radiation medium in Particle Physics experiments, for example: TASSO@DESY, KEDR@BINP, SND@BINP, AMS-02@ISS, BELLE-2@KEK, CLAS12@JLAB.



Focusing Aerogel Ring Imaging Cherenkov detector (FARICH)



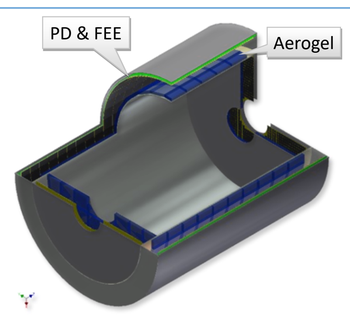
Cherenkov light in FARICH is focused on the Photon Detector using specially arranged several layers of aerogel.



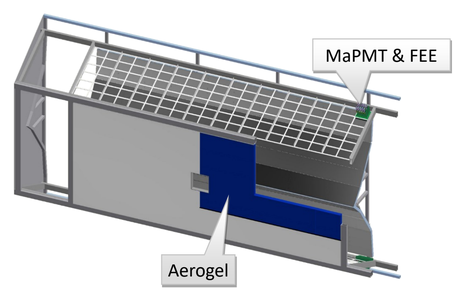
Sample of multilayer aerogel produced by Boreskov Institute of Catalysis in 2004

A.Yu.Barnyakov et al., NIM A553 (2005) 70

This concept found its first application in the Aergel RICH subdetector of BELLE-II. There are proposals to employ FARICH at the Super Charm-Tau Factory in Novosibirsk and in PANDA detector at FAIR.

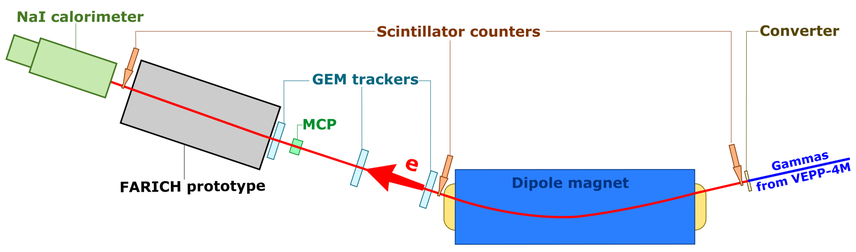


FARICH subdetector for SCTF
- 4-layer aerogel with n ≤ 1.05
- ~20 m^2 of detector area
- 3x3 mm^2 silicon photomultipliers (MPPC, SensL, etc)
- ~ 2M electronic channels
- μ/π separation up to 1.5 GeV/c momentum

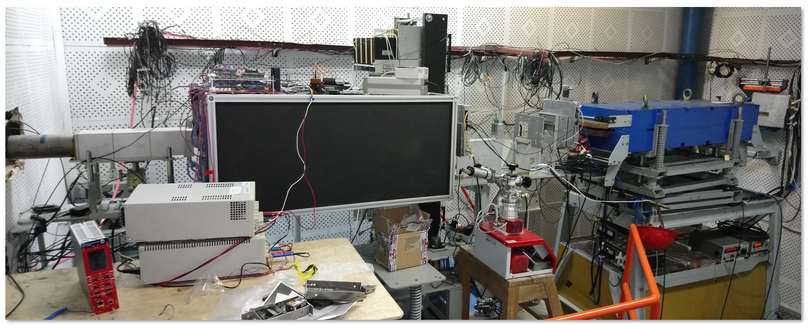


Forward RICH subdetector for PANDA
- 2- or 3-layer aerogel with n ≈ 1.05
- 3m^2 of aerogel area
- MaPMT H12700 for photon detection
- ~ 92k electronic channels
- π/K separation for 2-10 GeV/c momentum
- μ/π separation for 0.5-2 GeV/c momentum

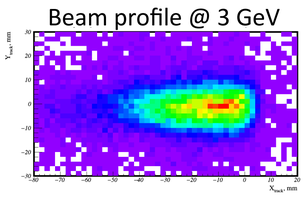
Electron Test Beam Facility at VEPP-4 (BINP)



Electron beam parameters	
Energy range	0.1—3.5 GeV
Average intensity	100 e^-/s
Energy spread @ 3 GeV	2.6%
GEM tracker resolution	≈ 100 μm

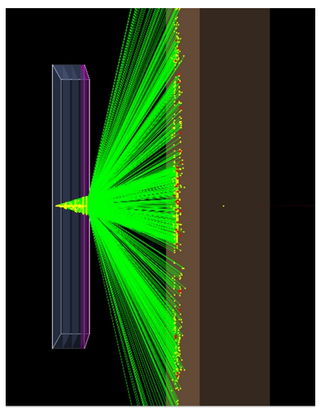


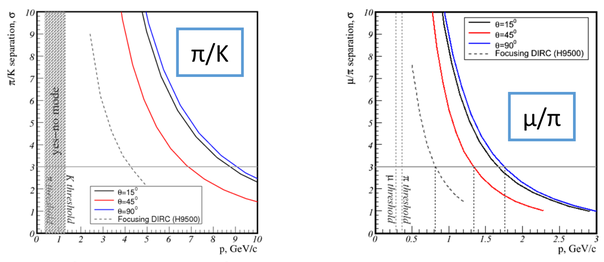
Beam profile @ 3 GeV



G.N. Abramov et al JINST 9 (2014) C08022

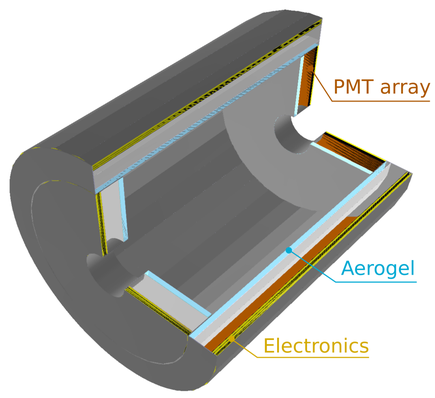
FARICH standalone simulation in Geant4





- Simple geometry description
- Possibility to simulate aerogels and other media
- Different photon detectors
- Quickly evaluate PID power for various configurations

FARICH simulation in the Aurora framework



- Full geometry description was implemented
- Material budget was estimated to be 14% X_0 at normal incidence

To do:
- Full simulation including Cherenkov emission and optical processes
- Parameterized fast simulation along with other subdetectors for physics production simulation

For more details about Aurora simulation see talk of Andrey Sukharev on Tuesday, December 4.

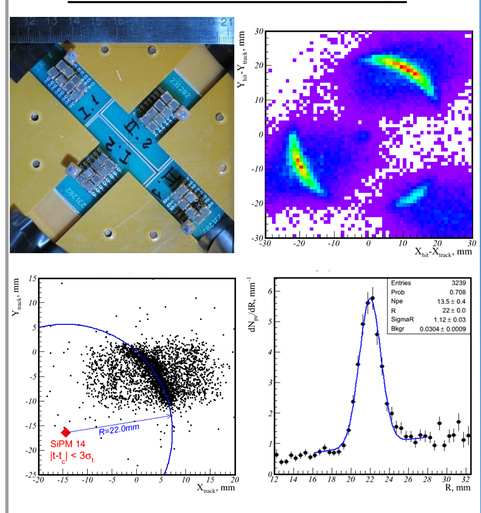
FARICH prototyping

FARICH prototype #1 (2011)

32 MRS APDs 2.1x2.1 mm^2

Custom amplifier-discriminator boards, CAEN TDC V1190B

BINP electron test beam in 2011



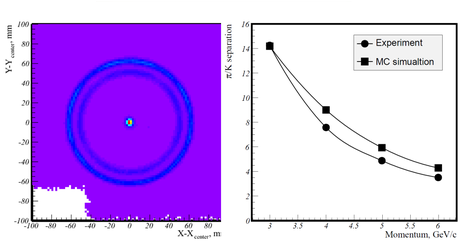
Focusing effect of Novosibirsk aerogel was demonstrated

SCTF CDR2 English (2018) p.66 [https://ctd.inp.nsk.su]

FARICH-PDPC prototype (2012)

20x20 cm^2 of digital SiPM DPC

CERN PS/T10 hadron mixed beam in 2012



Particle separation power was measured:

π/K - 7.6σ for 4 GeV/c

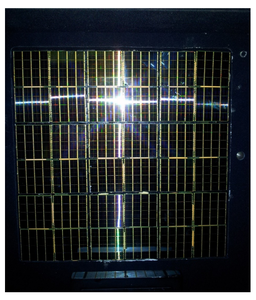
μ/π - 5.3σ for 1 GeV/c

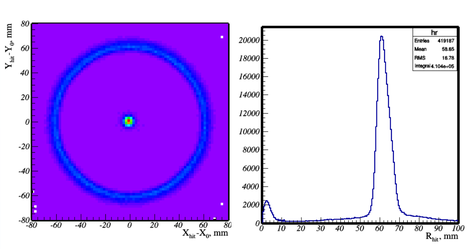
A.Yu. Barnyakov et al., NIM A732 (2013) 352

FARICH-PDPC upgraded prototype (2013)

20x20 cm^2 of digital SiPM DPC

BINP electron test beam in 2013-2016





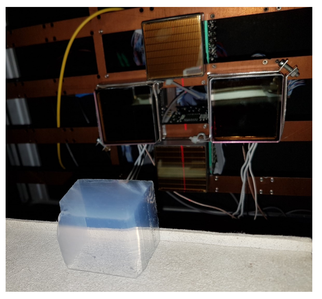
Characteristics of different aerogel samples were studied

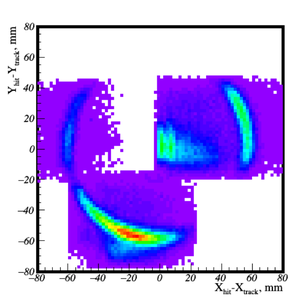
A.Yu. Barnyakov et al., NIM A766 (2014) 88

FARICH-MaPMT prototype (2018)

8x8 anodes MaPMTs + MCP PMTs with PADIWA+TRB3 readout

BINP electron test beam in 2018





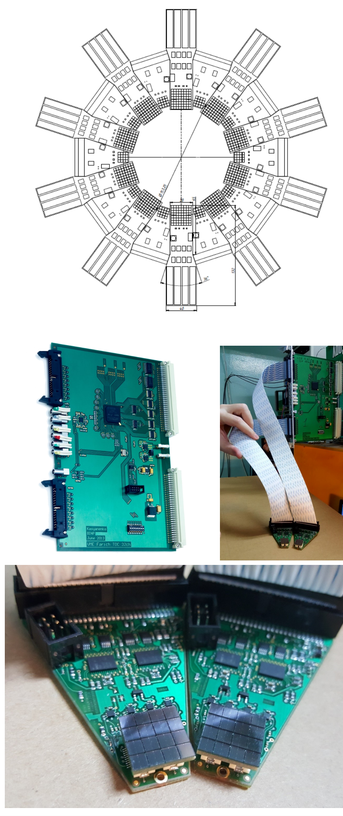
Measure single photon resolution for different pixel size and different aerogel samples

To be published

Next FARICH prototype (2019+)

10 of 8x8 + 10 of 4x4 SiPM arrays

ASIC NINO2+FPGA TDC on Altera Cyclon III



Conclusion

- Novosibirsk group has started FARICH R&D in 2004
- Since 2011 we built and tested three FARICH prototypes on particle beams
- Now we are working on a full-ring FARICH prototype for Super Charm-Tau Factory
- Description FARICH for SCTF in the Aurora simulation framework is in progress