Aerogel radiators for RICH detectors

A.Yu.Barnyakov, M.Yu.Barnyakov, V.S.Bobrovnikov, A.R.Buzykaev, A.F.Danilyuk, S.A.Kononov, E.A.Kravchenko, I.A.Kuyanov, I.V.Ovtin, A.P.Onuchin

Budker Institute of Nuclear Physics, Novosibirsk, Russia

Boreskov Institute of Catalysis, Novosibirsk, Russia

Outline:

- Main properties of aerogel
- Novosibirsk aerogel applications
- FARICH
- Summary

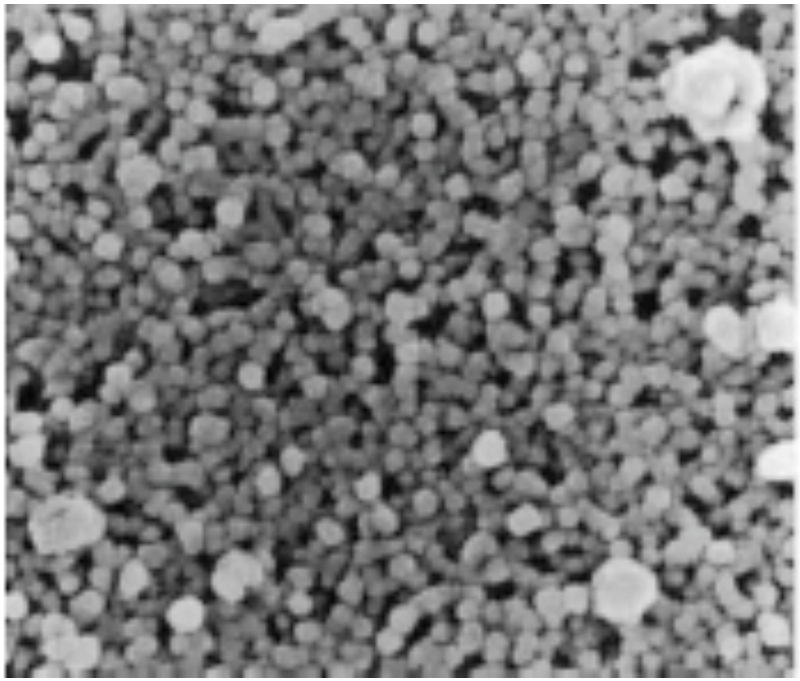
Aerogel in Novosibirsk

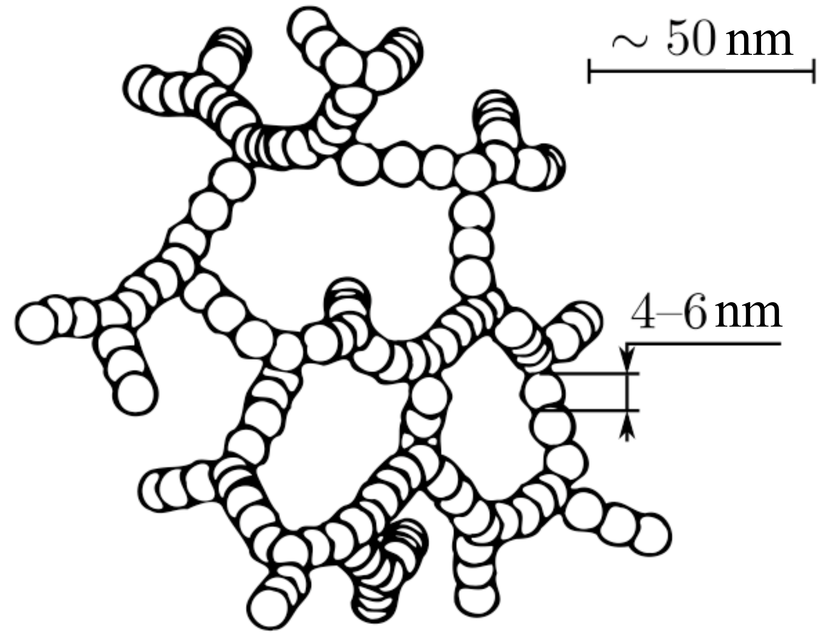
works on aerogel in Novosibirsk have started in 1986 by collaboration of the Budker Institute of Nuclear Physics and the Boreskov Institute of Catalysis for the development of threshold Cherenkov counters for the KEDR experiment

www.inp.nsk.su

www.catalysis.ru

Refractive index





$SiO_2 + H_2O(1\div5\%)$

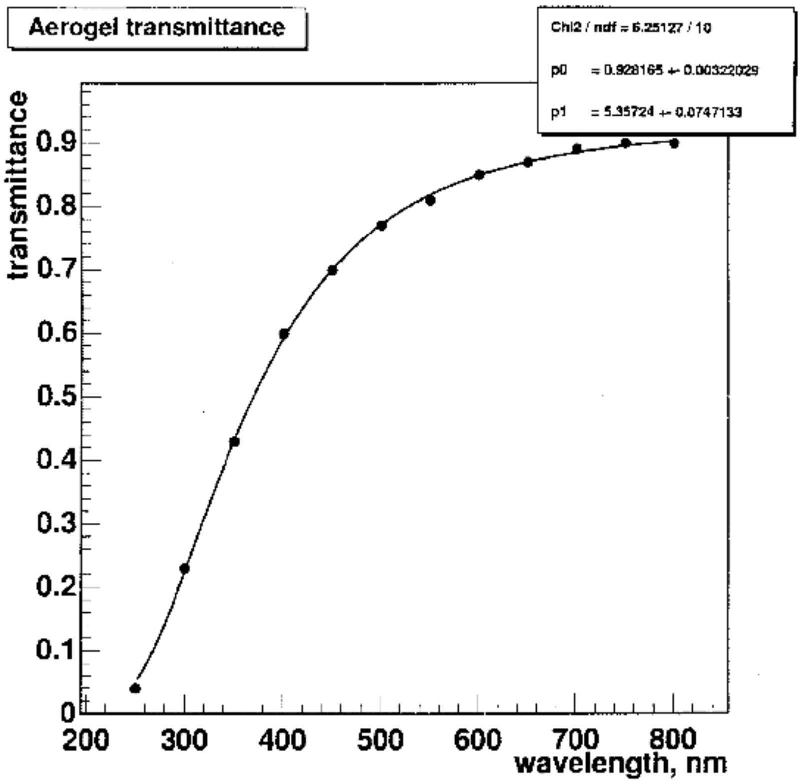
$$n^2 = 1 + 0.438\cdot\rho$$

n=1.006…1.070 – synthesis
n=1.070…1.130 – sintering

Light scattering

Rayleigh scattering on aerogel structure elements

Transmittance: $$T = \frac{I}{I_0} = A \cdot \exp \frac{-d}{L_{sc} \cdot (\lambda/400)^4} = A \cdot \exp \frac{-C \cdot d}{\lambda^4}$$

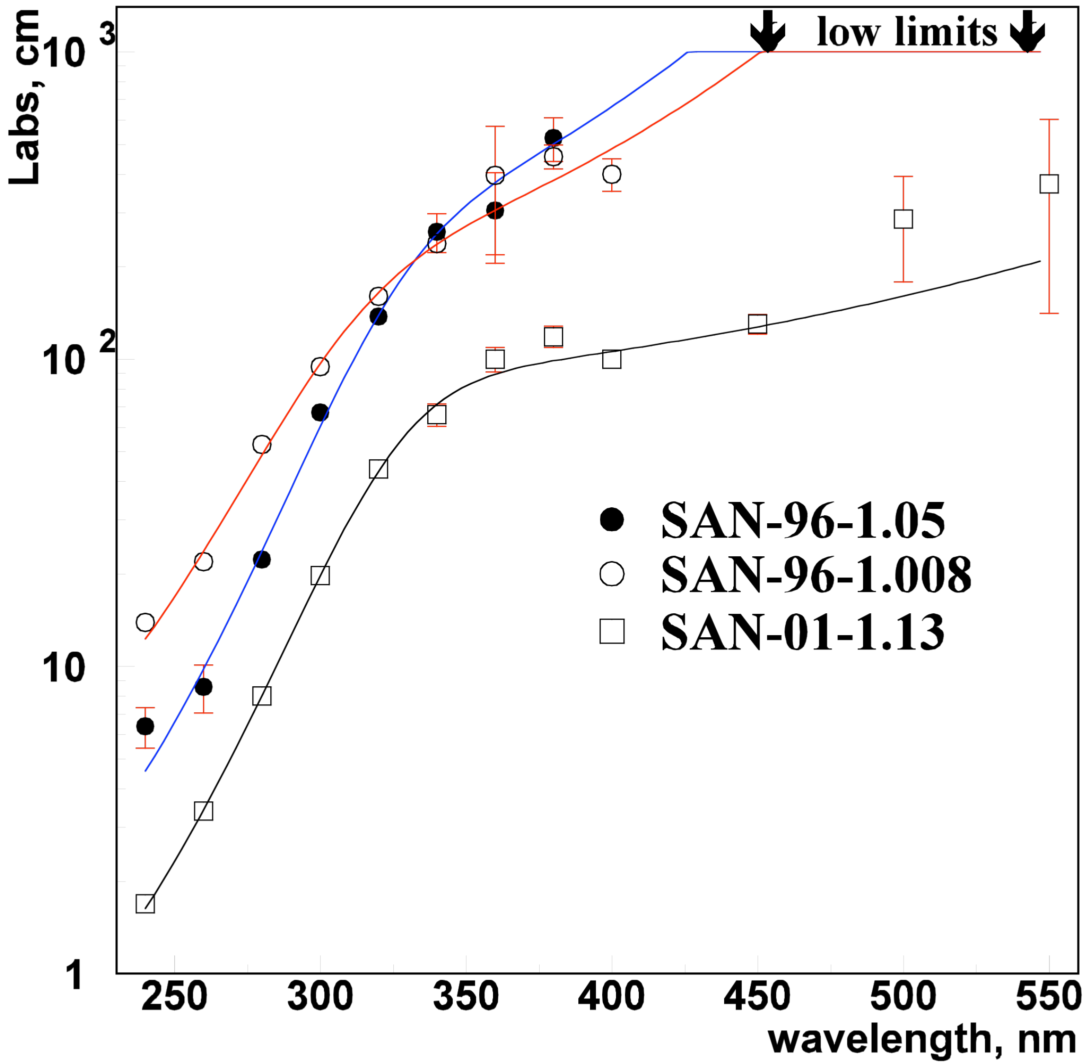


L_{sc} – scattering length at λ=400nm
> 4.5 cm

C – clarity (0.4^4 / L_{sc})
< 0.0057 μm^4/cm

A – surface scattering coefficient
~0.95 for untouched surface
~0.70 for one polished surface

Light absorption



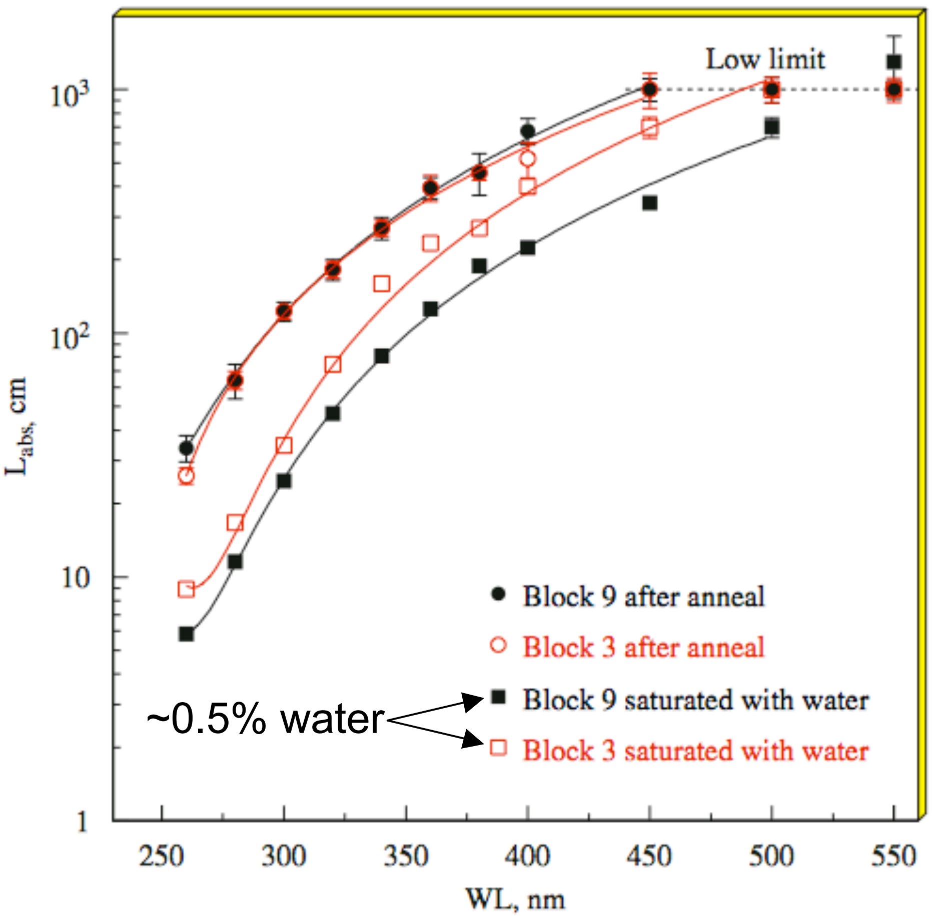
Light is absorbed by impurities (Fe, Co, Cu, Mn, etc.)

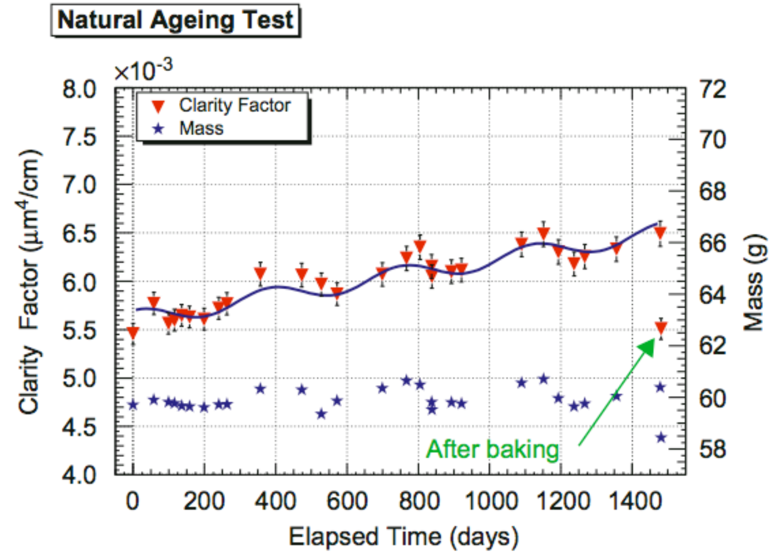
Contamination is determined by raw material quality and production technology.

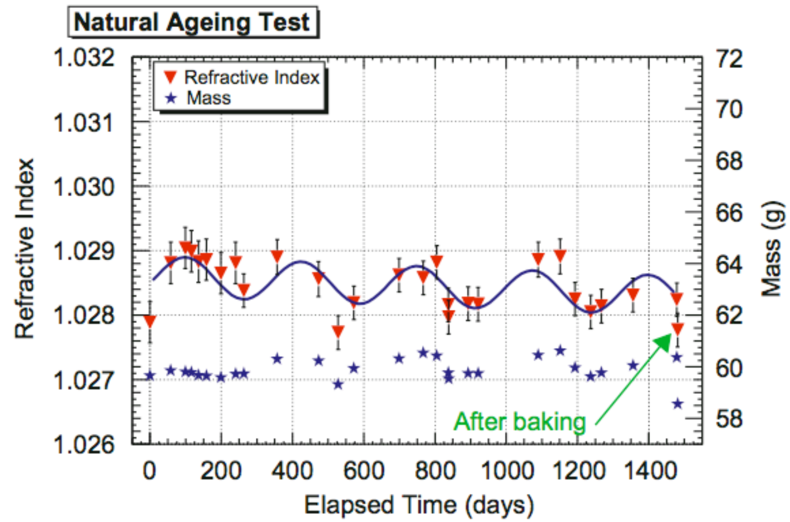
Metal concentration < 10^{-7}

Water adsorption

1 cm^3 $\Rightarrow$ S_{inner} ~ 100 m^2





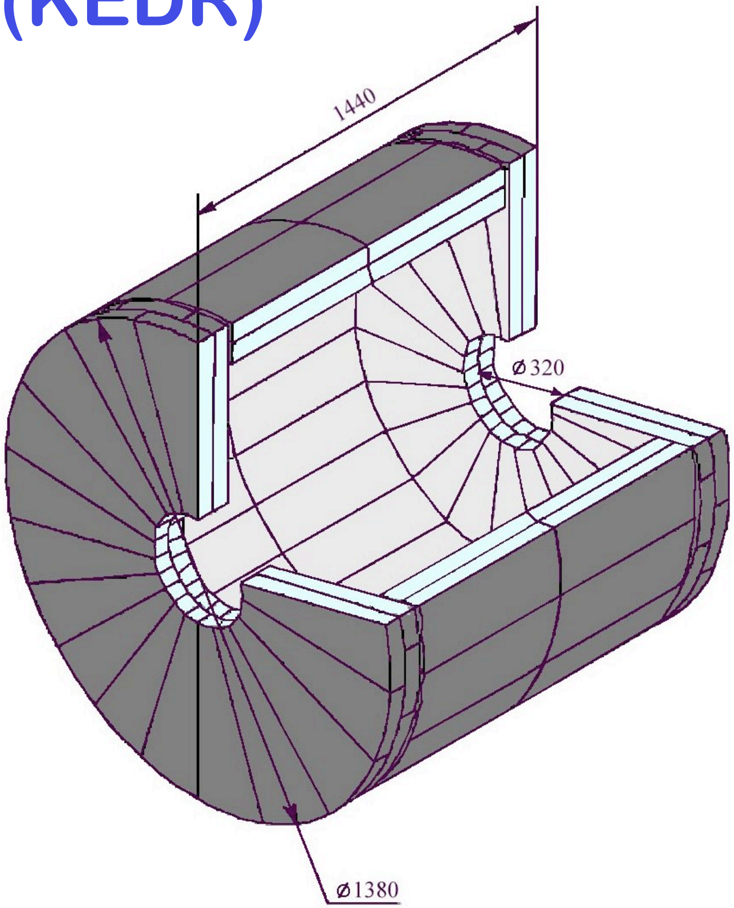


A.Yu.Barnyakov et al., NIM A598 (2009) 166

D.L.Perego, NIM A595 (2008) 224

Applications (KEDR)

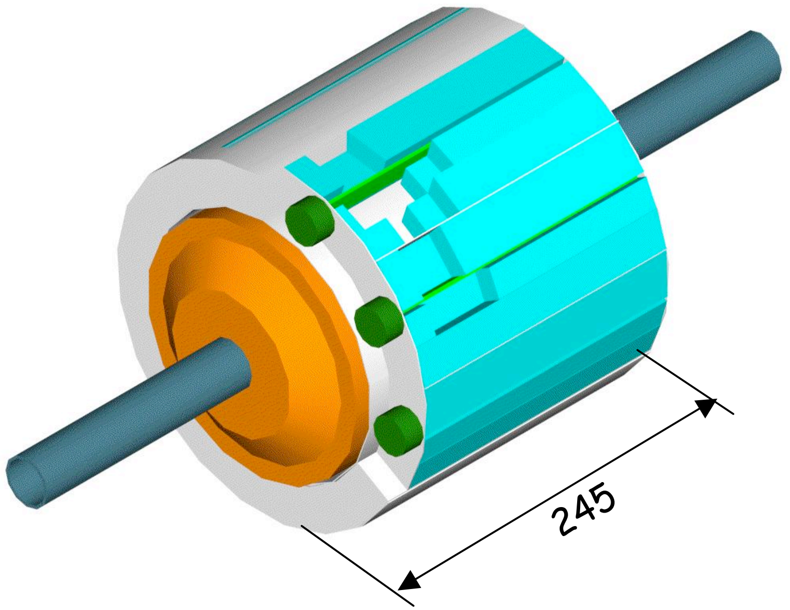
Experiment	n
Threshold counters	
KEDR@VEPP-4M	1.05
SND@VEPP-2000	1.13
DIRAC-II@CERN-PS	1.008
RICH detectors	
LHCb	1.03
AMS-02	1.05



- π/K separation from 0.6 to 1.5 GeV/c
- 1000 liters of aerogel in 160 counters
- WLS and MCP PMT for light detection

Applications (SND)

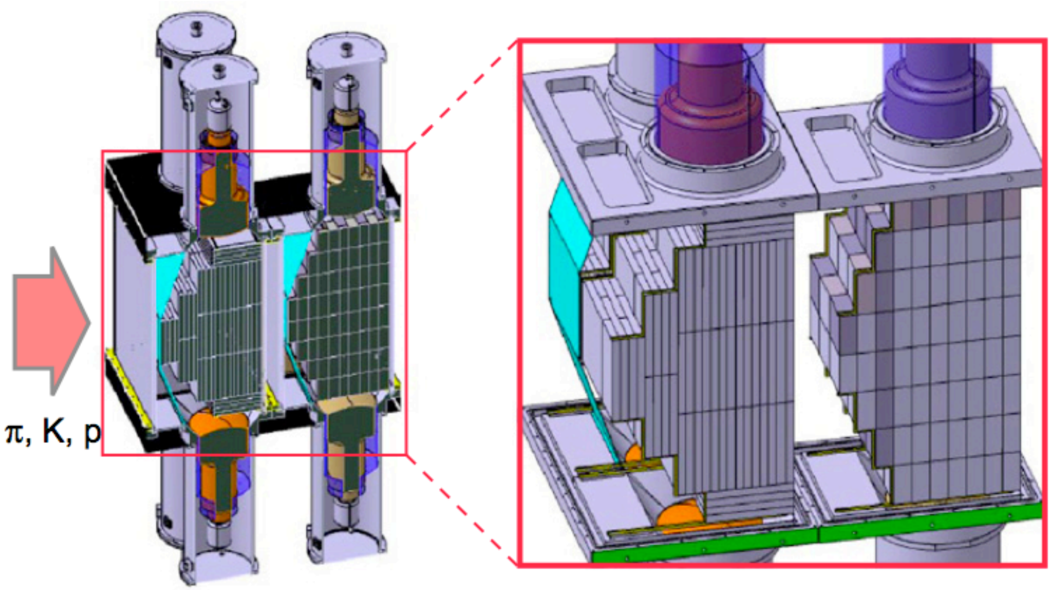
Experiment	n
Threshold counters	
KEDR@VEPP-4M	1.05
SND@VEPP-2000	1.13
DIRAC-II@CERN-PS	1.008
RICH detectors	
LHCb	1.03
AMS-02	1.05



- π/K separation from 300 to 870 MeV/c
- Aerogel of n=1.13 (V~6 liters)
- 9 counters with WLS and MCP PMT

Applications (DIRAC-II)

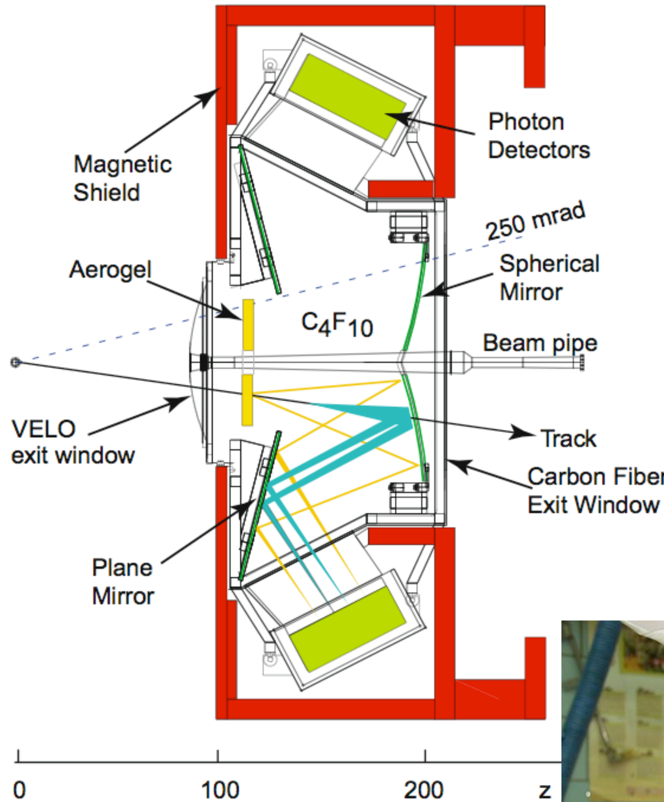
Experiment	n
Threshold counters	
KEDR@VEPP-4M	1.05
SND@VEPP-2000	1.13
DIRAC-II@CERN-PS	1.008
RICH detectors	
LHCb	1.03
AMS-02	1.05

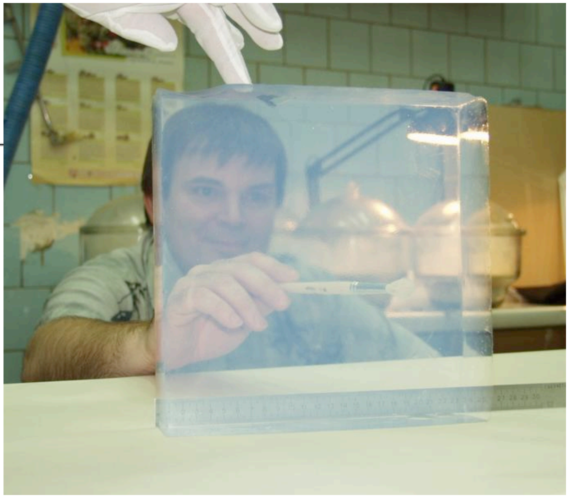


- Very light aerogel with n=1.008
- π/K separation from 5.5 to 8.0 GeV/c
- One of three counters (V~12 liters)

Applications (LHCb)

Experiment	n
Threshold counters	
KEDR@VEPP-4M	1.05
SND@VEPP-2000	1.13
DIRAC-II@CERN-PS	1.008
RICH detectors	
LHCb	1.03
AMS-02	1.05

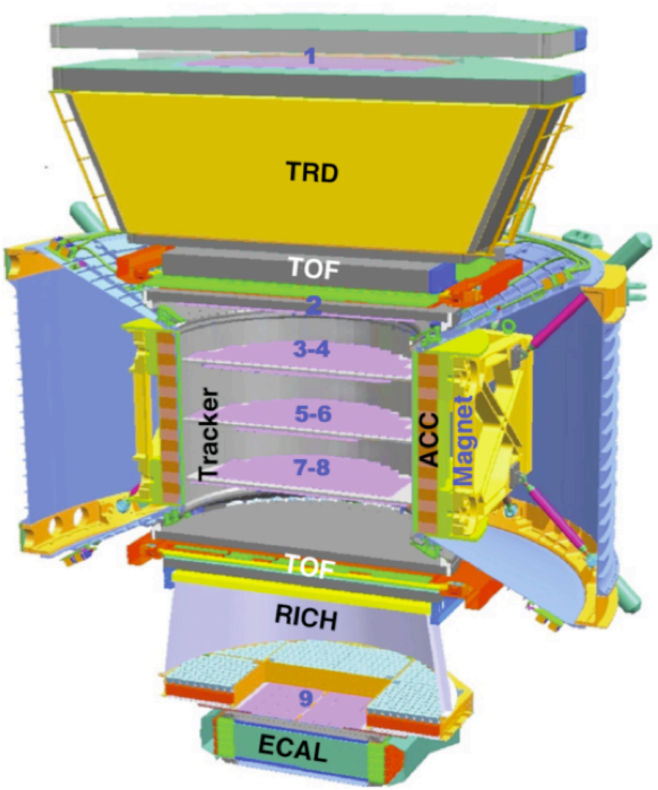




- π/K separation up to 10 GeV/c
- Aerogel block size up to 20x20x5 cm^3
- S ~ 0.5 m^2

Applications (AMS-02)

Experiment	n
Threshold counters	
KEDR@VEPP-4M	1.05
SND@VEPP-2000	1.13
DIRAC-II@CERN-PS	1.008
RICH detectors	
LHCb	1.03
AMS-02	1.05

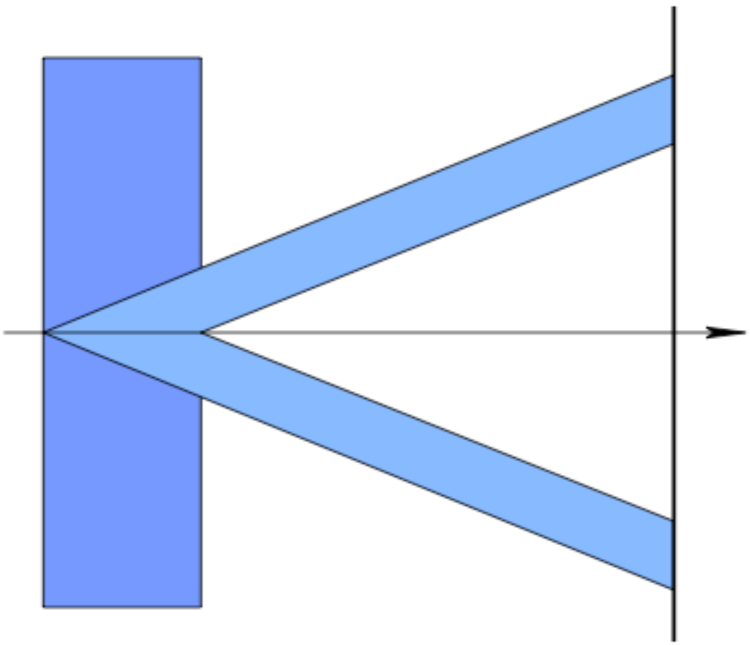


- Velocity and charge measurement
- Thickness tolerance ±0.2 mm
- S ~ 1 m^2

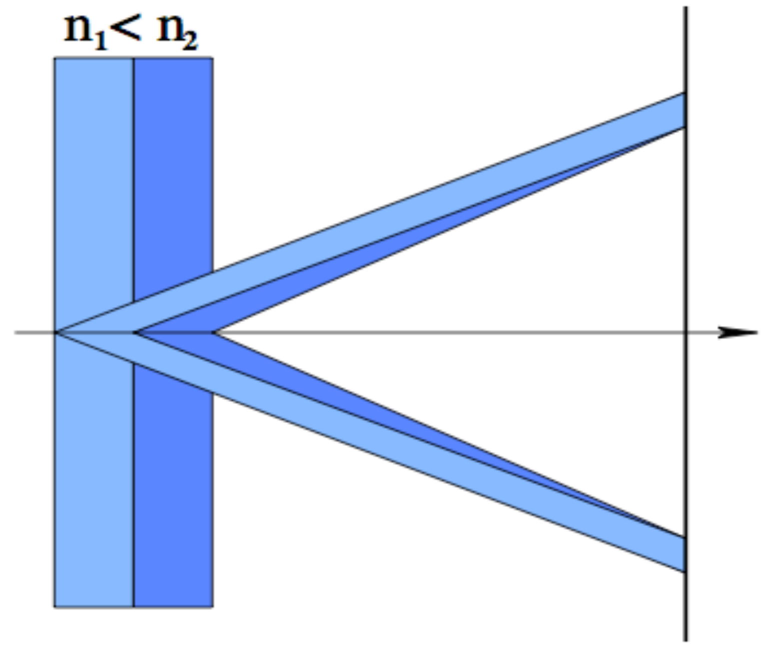
FARICH concept

Using of multilayer radiator to reduce thickness contribution into the Cherenkov angle resolution

Single layer aerogel



Multilayer aerogel

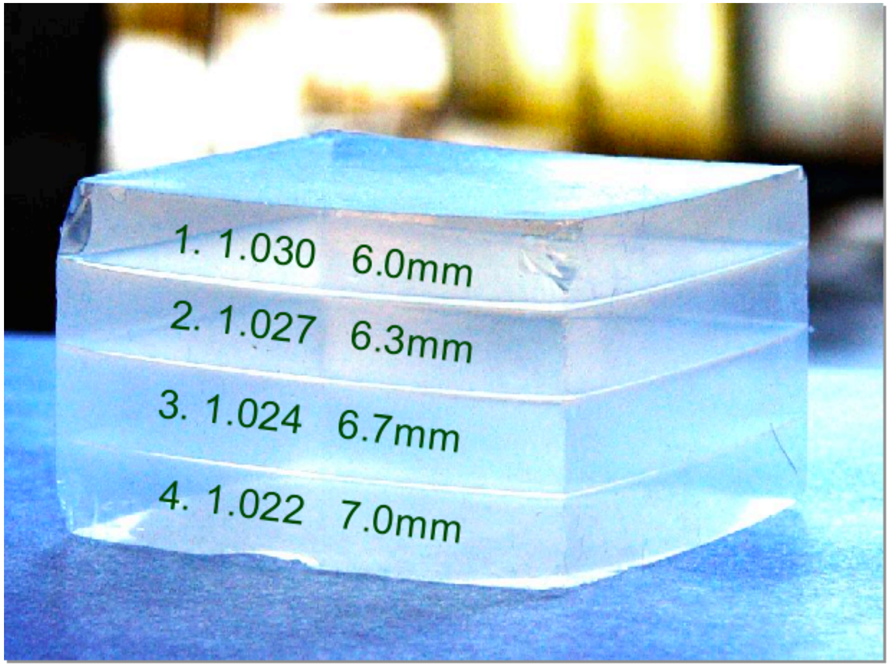


Focusing Aerogel RICH – FARICH

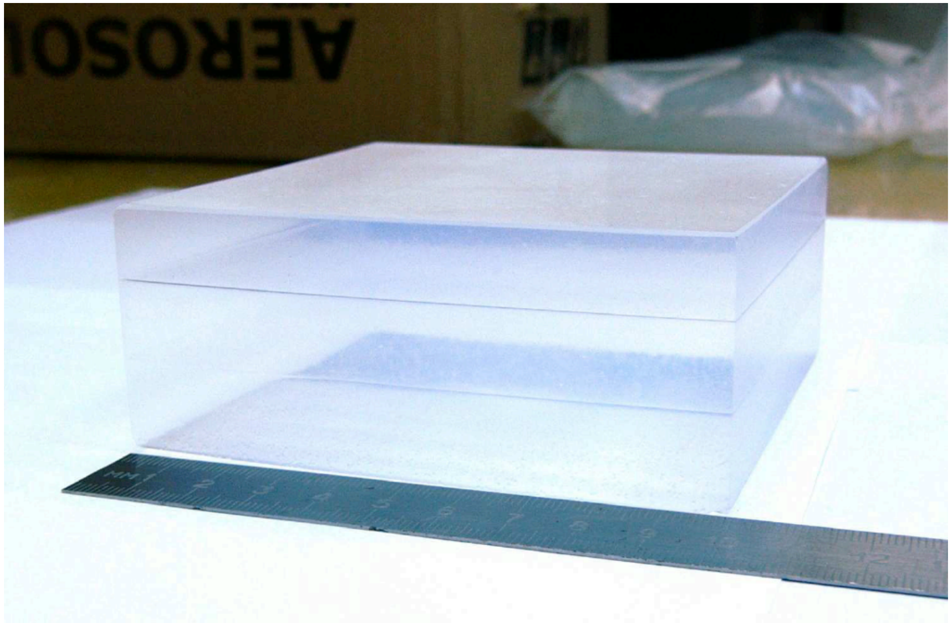
T.Iijima et al., NIM A548 (2005) 383
A.Yu.Barnyakov et al., NIM A553 (2005) 70

Multilayer focusing aerogel

produced since 2004



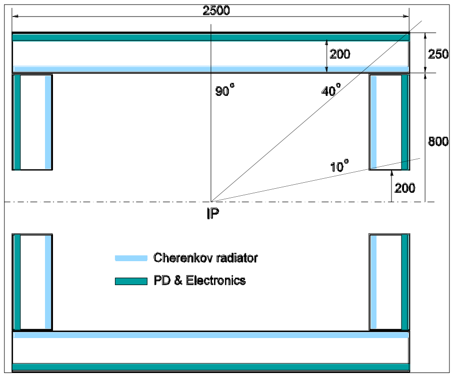
First 4-layer aerogel



3-layer aerogel 10×10×4 cm^3

Monolithic aerogel tile allows one to avoid additional light scattering on the borders between layers.

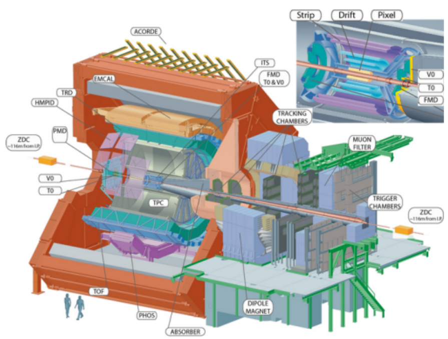
FARICH proposals



FARICH for Super Charm-Tau Factory

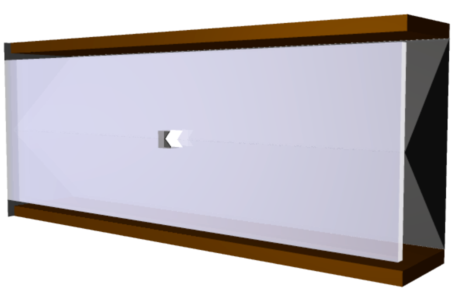
(http://ctd.inp.nsk.su)

PID: μ/π up to 1.7 GeV/c
21 m^2 detector area (SiPMs)
~1 M channels



FARICH for ALICE HMPID upgrade

PID: π/K up to 10 GeV/c, K/p up to 15 GeV/c
3 m^2 detector area (SiPMs)

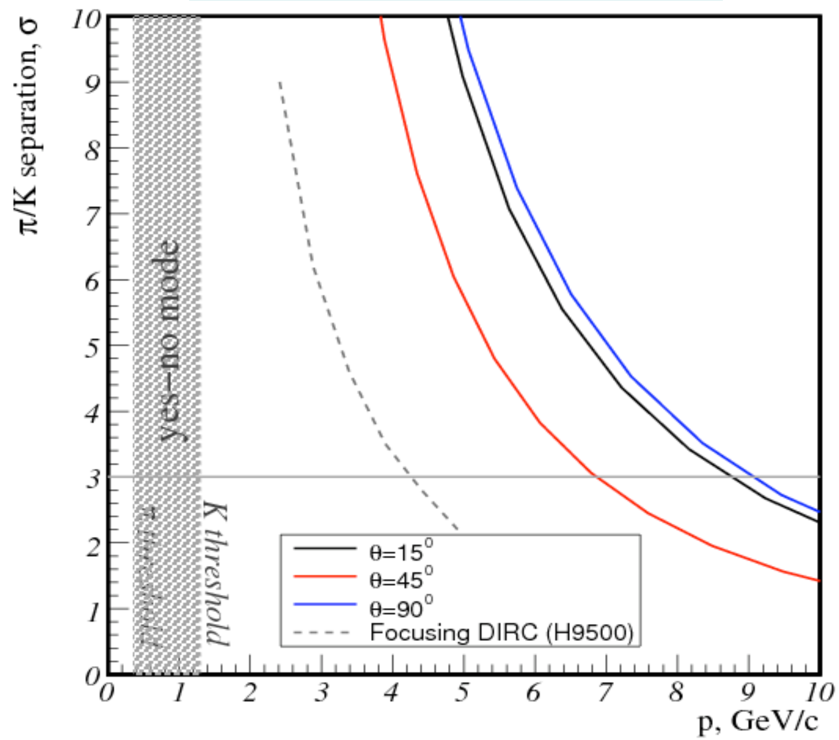


Forward Spectrometer RICH for PANDA

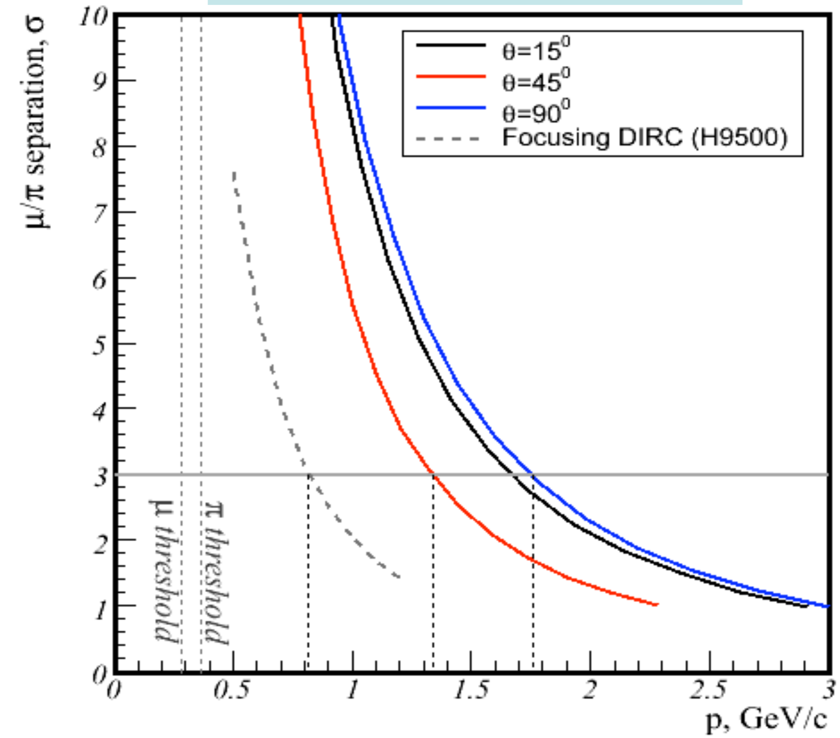
PID: π/K/p up to 10 GeV/c
3 m^2 detector area (MaPMTs or SiPMs)

FARICH simulation for Super c-τ factory

π/K-separation

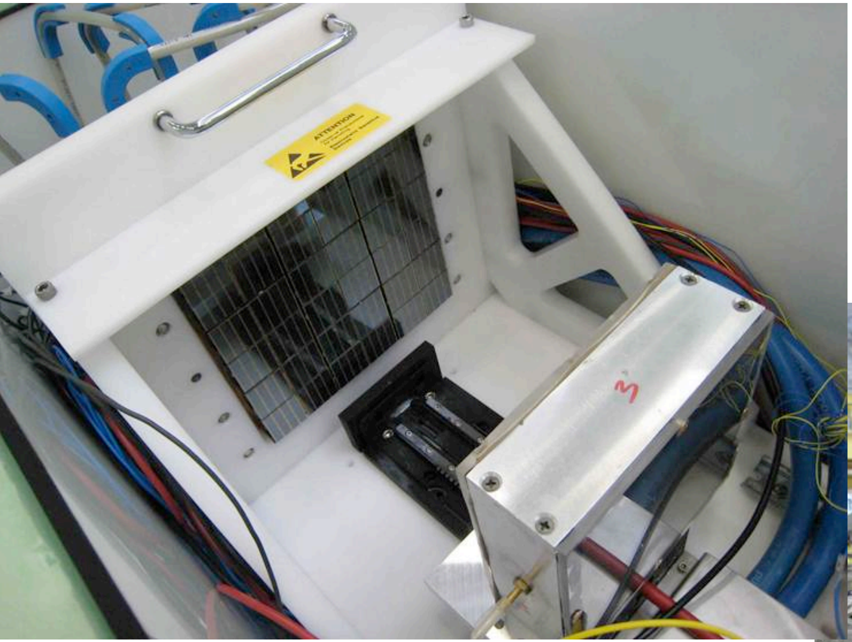


μ/π-separation



- 4-layer aerogel with n_{max}=1.07
- Hamamatsu MPPC 50μm sell, 4 mm pitch
- expansion volume 20 cm

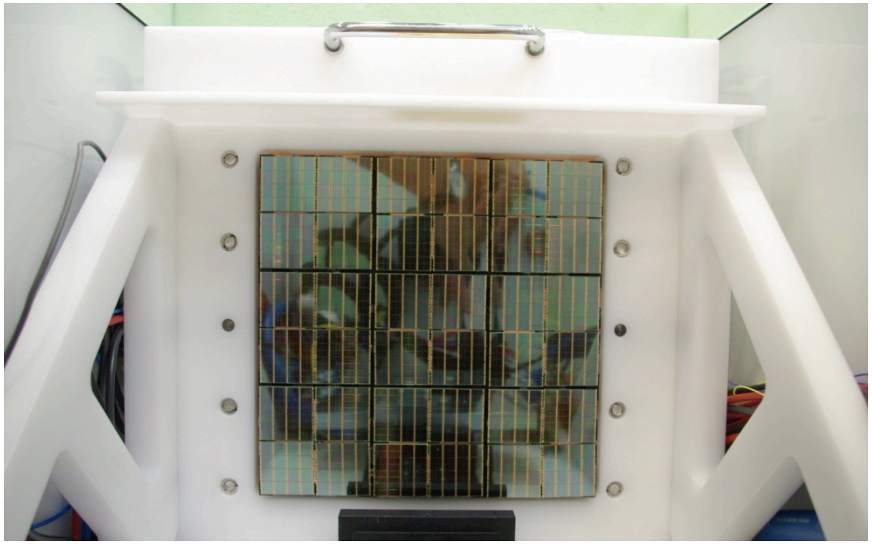
Beam test of FARICH with PDPC



FARICH prototype with Digital Photon Counter (dSiPM) was tested at CERN PS T10 beam channel in June 2012

Prototype was designed and built by Philips Digital Photon Counting (Aachen, Germany)

Beam test of FARICH with PDPC

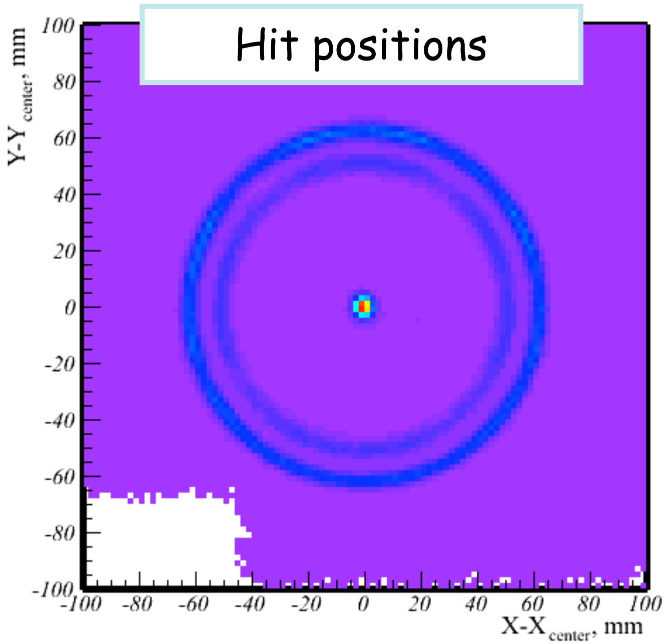


4-layer aerogel
- n_{max} = 1.046
- Thickness 37.5 mm
- Focal distance 200 mm

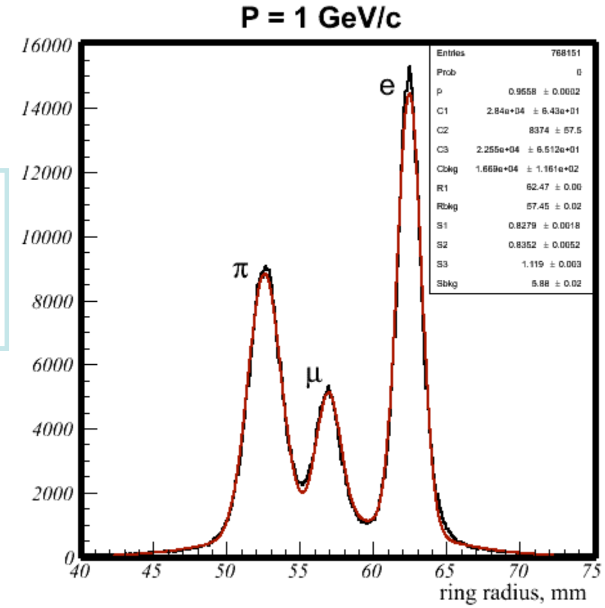
DPC matrix 20x20 cm^2
- Sensors: DPC3200-22-44
- 3x3 modules = 6x6 tiles = 24x24 dies = 48x48 pixels
- 576 time channels
- 2304 amplitude (position) channels
- Operation at –40°C to reduce dark counts

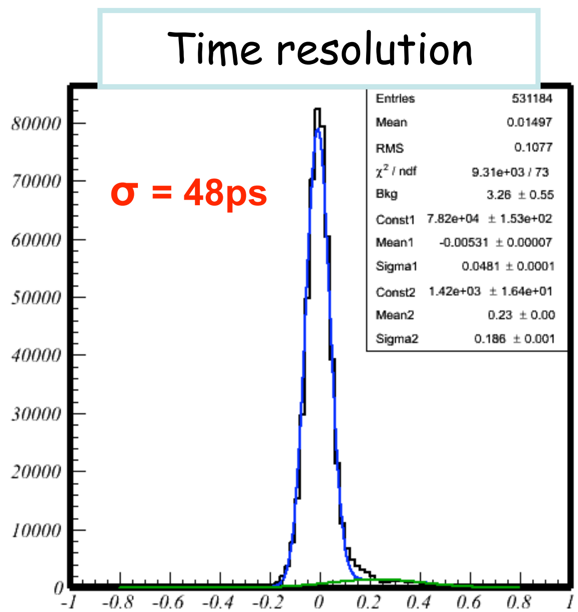
Test conditions
- Positive polarity: e^+, μ^+, π^+, K^+, p
- Momentum: 1–6 GeV/c
- Trigger: a pair of sc. counters 1.5x1.5 cm^2 in coincidence separated by ~3 m
- No external tracking, particle ID, precise timing

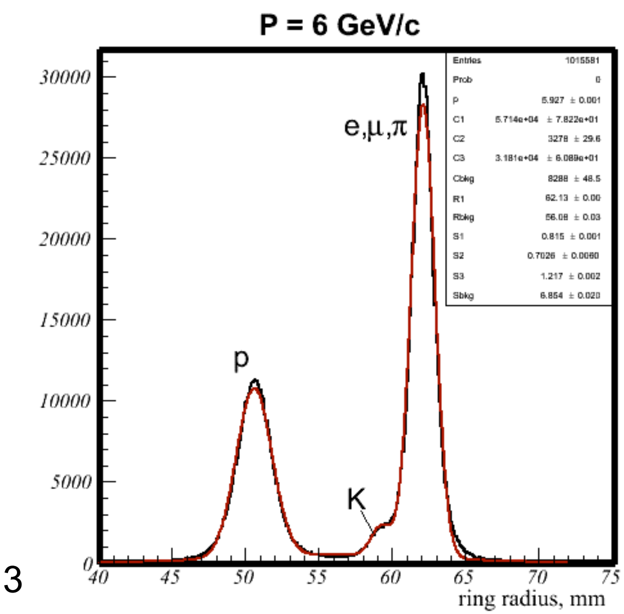
Beam test results



Ring radius distributions for 1 and 6 GeV/c :

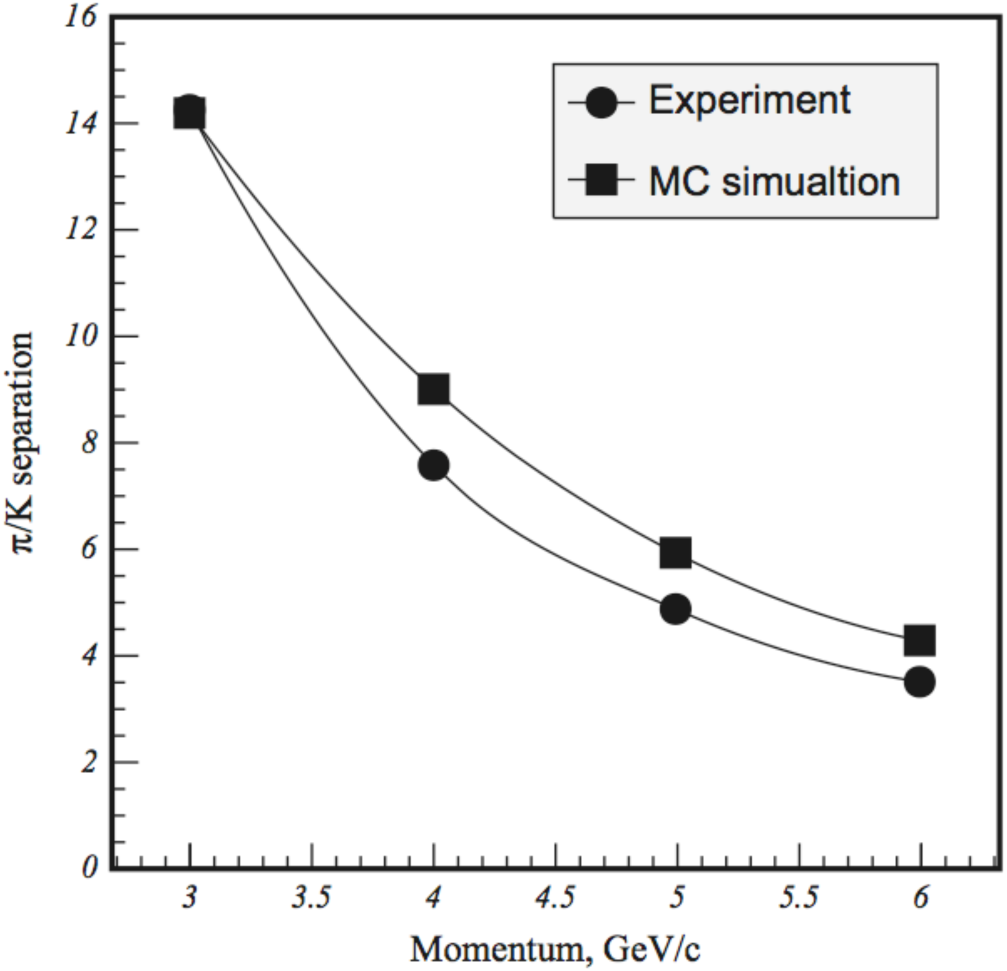






Beam test results

$$S(\pi/K) = \frac{R_\pi - R_K}{\sigma_\pi}$$



Separation:

- π/K: 7.6σ at P=4 GeV/c
- μ/π: 5.3σ at P=1 GeV/c

About 2 times better than SuperB FDIRC and Belle II ARICH

A.Yu. Barnyakov, et al., NIM A (in press)
http://dx.doi.org/10.1016/j.nima.2013.07.068

Summary

- Aerogel is an attractive material for application in Cherenkov detectors:

  $n = 1.006...1.13$, $L_{sc}^{(400nm)} > 4.5$ cm, $L_{abs}^{(400nm)} \sim 5$ m

- Aerogel is successfully used in a number of HEP experiments

- FARICH detector based on multilayer focusing aerogel provides excellent PID:

  π/K: 7.6σ @4 GeV/c; μ/π: 5.3σ @1 GeV/c