Development of particle identification systems based on aerogel at BINP

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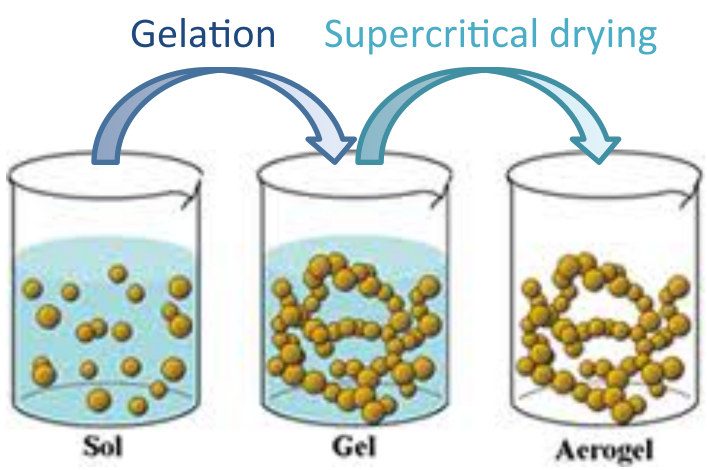
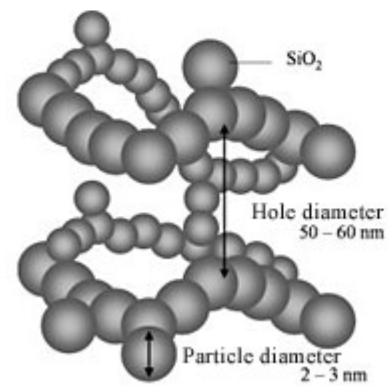
Outline:

- Aerogel
- Threshold counters
  - ASHIPH method
  - The ASHIPH system of the KEDR detector
  - The ASHIPH system of the SND detector
- RICH detectors
  - AMS-02
  - CLAS-12 (J-Lab)
- Projects
  - FRICH for PANDA detector
  - FARICH for Super CTF
- Summary

Silica aerogel

- Silica aerogel was first produced in 1931 by Samuel S. Kistler
- Lightest solids. Close the nature's gap in refractive index between gases @ STP ($n-1 \lesssim 10^{-3}$) and liquids/solids ($n \gtrsim 1.3$).
- 3D network of SiO_2 nanometer sized pellets and 50-100 nm pores
- Now produced by sol-gel method out of silicon alkoxide $Si(OR)_4$





Production of aerogel in Novosibirsk

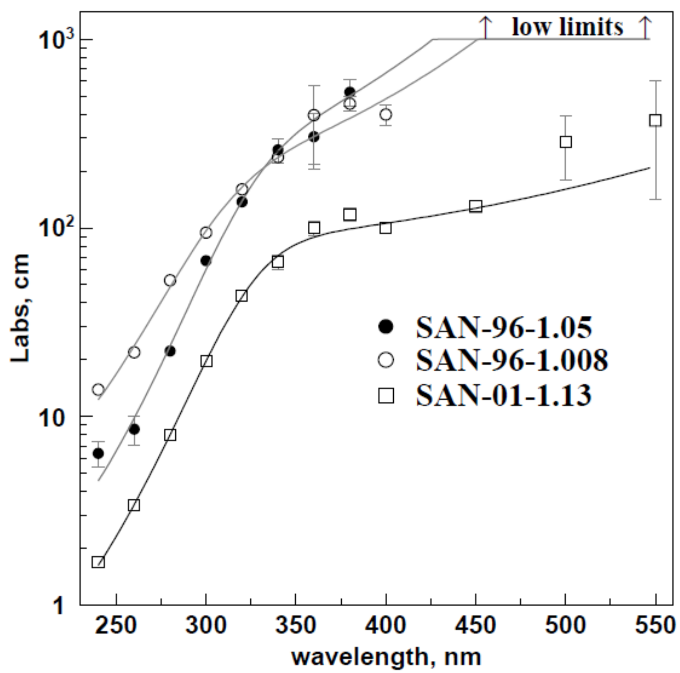
- Started in 1986 by the Boreskov Institute of Catalysis SB RAS in cooperation with the Budker Institute of Nuclear Physics SB RAS
- Hydrophilic
- Refraction indices 1.006 – 1.08 (1.08-1.13 produced by sintering)
- Block dimensions up to 200x200x50 mm^3 (n=1.03) & 200x200x30 mm^3 (n=1.05)
- Inner surface 800 m^2/g
- Remarkable optical quality has been achieved:

  L_{abs} (400nm) = 5 – 7 m

  L_{sc} (400nm) = 4 – 6 cm

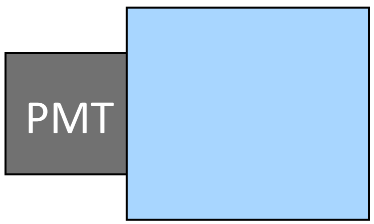
  (Clarity = 0.0043 – 0.0064 $\mu m^4/cm$)

Absorption length vs λ



Threshold Cherenkov counters

Direct light collection

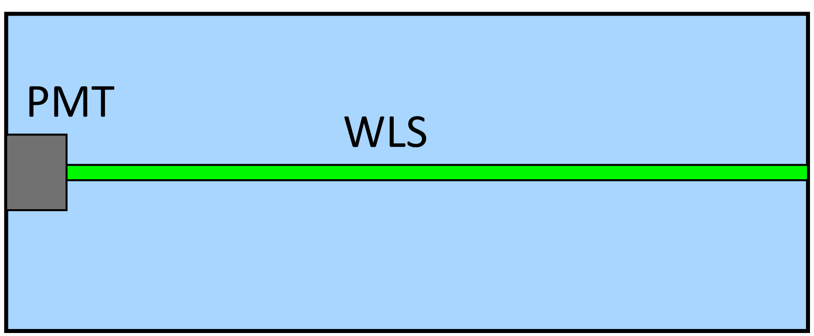


Pros: Simplicity

Cons: Counter size limited → large PMT number&area → high total cost

ASHIPH – Aerogel-SHIfter-PHotomultiplier

Suggested by A.Onuchin et al. for PID of the KEDR detector [NIM A315 (1992) 517]



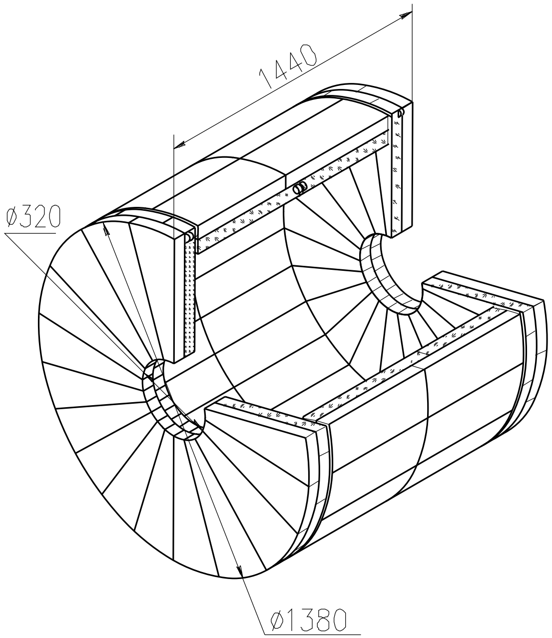
Pros:

- Large light collection area
- Small PMT (up to 10x smaller p.c. area in comparison with direct LC)
- Low cost

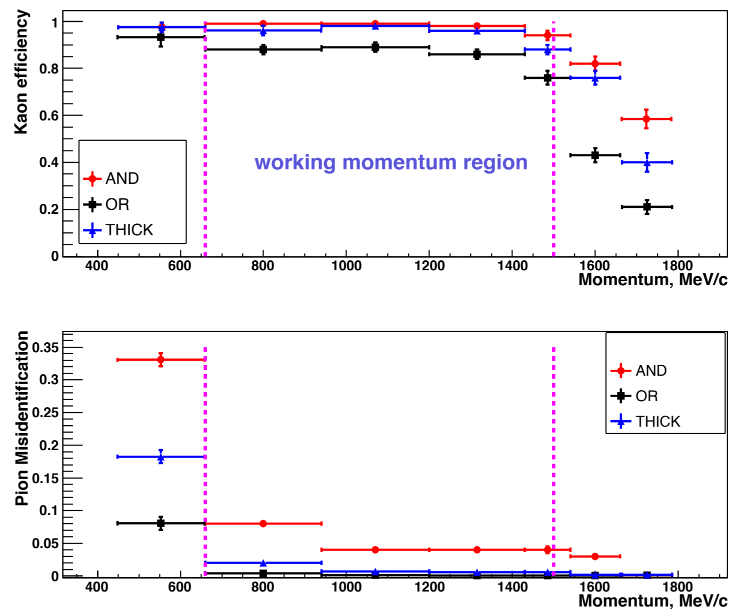
Cons:

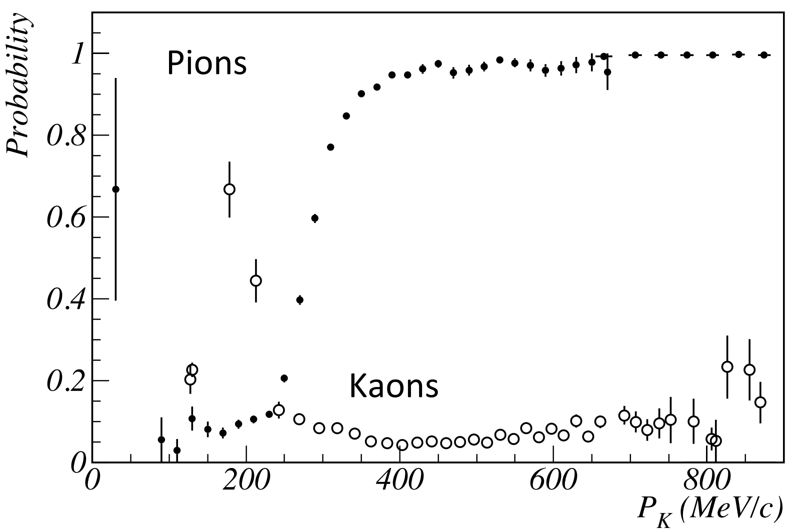
- Particle acceptance loss due to WLS

Aerogel Cherenkov ASHIPH counters

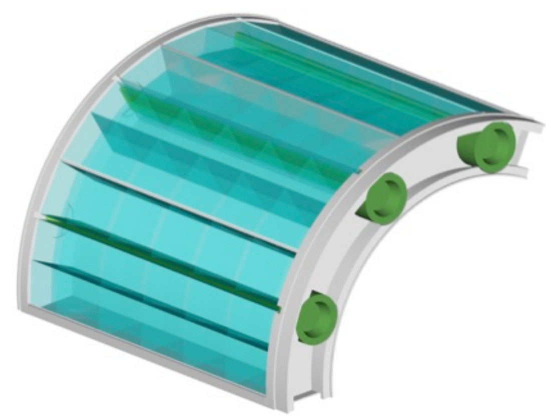


KEDR:
- 160 counters (2 layers)
- n=1.05 (1000l)
- WLS (BBQ)
- MCP PMT øPC=18 mm
- 0.97x4π
- 24% X_0



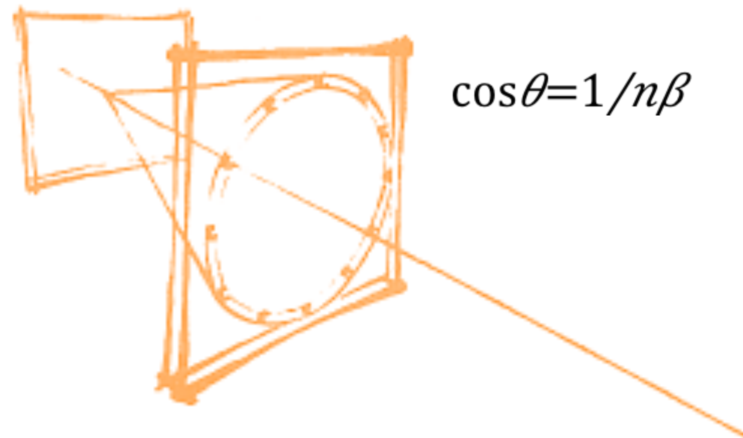


SND:
- 9 counters (1 layer)
- n=1.13 (9l)
- WLS (BBQ)
- Thickness ~ 30 mm
- MCP PMT øPC=18 mm
- 0.6x4π



Ring Imaging Cherenkov detectors with aerogel radiators

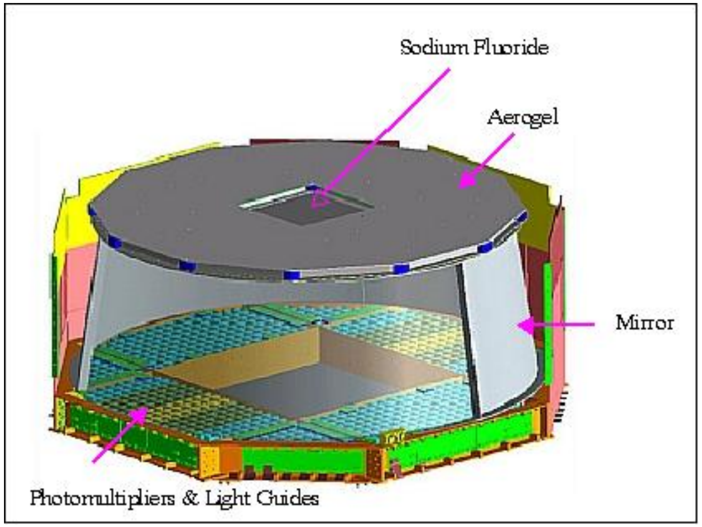
- If the Cherenkov radiation angle is measured, the precision in the determination (identification) of particle masses will be higher than in threshold counters.
- In the 1980s and 1990s, a whole series of RICH detectors were constructed:
- CRID, SLD detector, SLAC(C6F14 n=1.277, C5F12/N2 n=1.0017)
- RICH, Delphi detector, CERN, (C5F12|C6F14, C4F10)
- RICH, CLEOIII detector, Cornell, (LiF, n=1.50)
- DIRC, детектор BaBar, SLAC, США (SiO2, n=1.47)
- Main problem – they do not provide pion-kaon identification in the range of momenta 4—10 GeV/*c*
- **Material with n=1.03-1.05 is needed. Aerogel!**

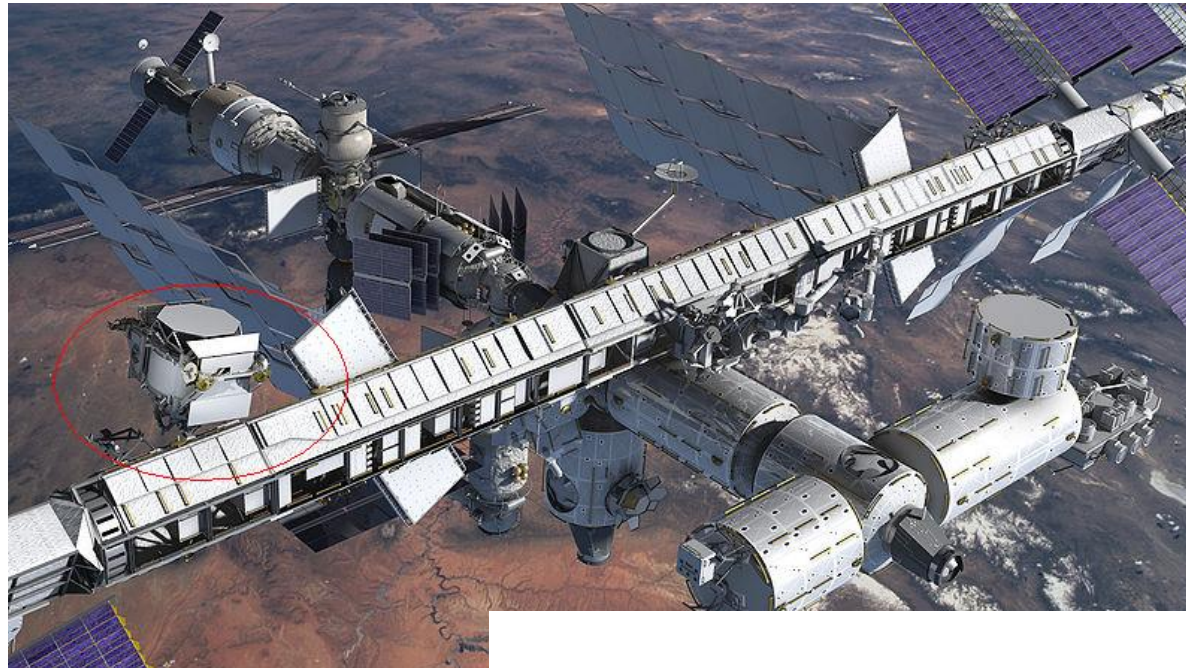


$$\cos\theta = 1/n\beta$$

- A.Roberts, Nucl. Instrum. and Methods 9(1960)55
- J.Seguinot and T.Ypsilantis, Nucl. Instrum. and Methods 142(1977)377

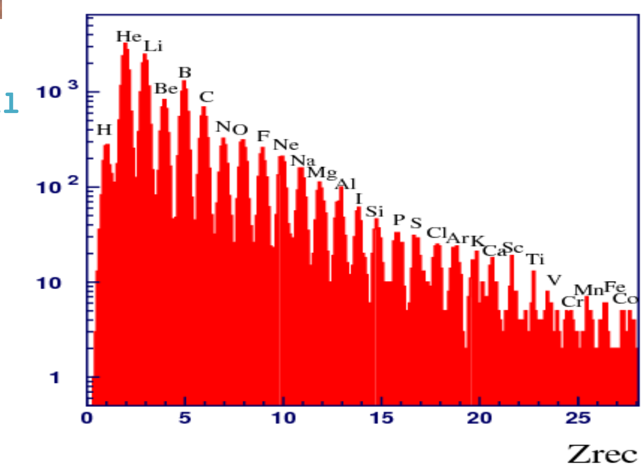
Aerogel RICH of AMS-02 at ISS





- Antimatter search
- Dark matter
- Cosmic rays
- Strangelets search
- …

M=8.5T, V=54m³, S=1m², B=1.26kGs
TOF, TRD, RICH, Si Tracker, eCal

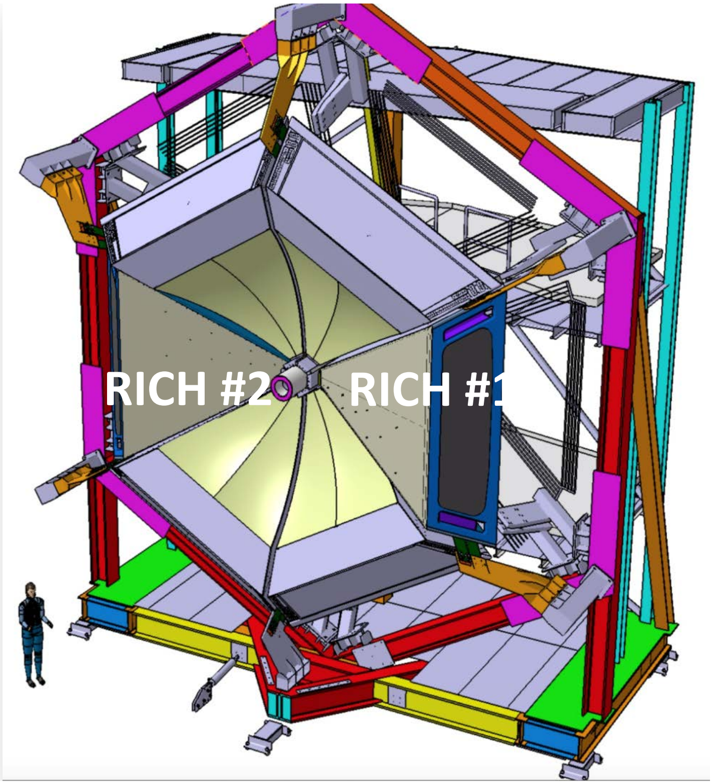


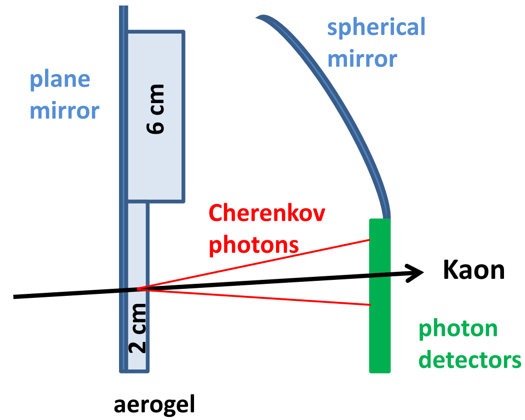
Measurement of Z of the nucleon, $N_{pe} \sim Z^2$

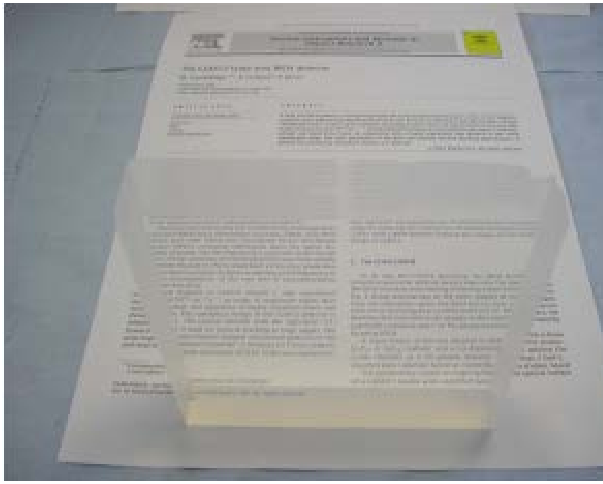
BIC/BINP production, n=1.05

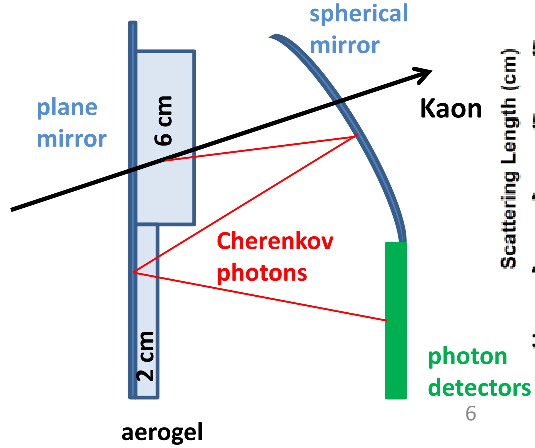
It has working at ISS since 2011

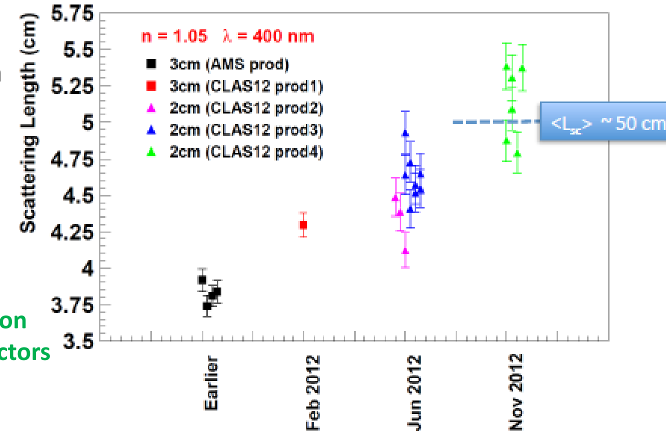
RICH detector for the CLAS12











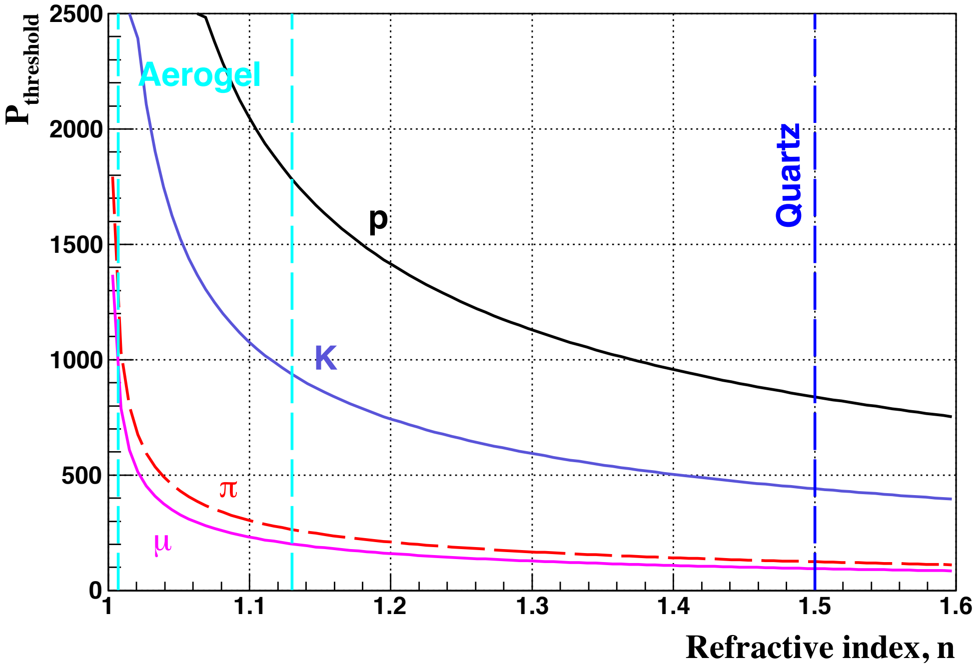
- **K/π** and **K/p** separation at **>4σ** level in **few GeV/c** region;
- **The RICH will replace the existing LTC detectors;**
- **Installation in CLAS12 by September 2017;**

RICH 2016, September 9th 2016, Bled: talks by M.Marazita, M.Contralbrigo, E.Kravchenko

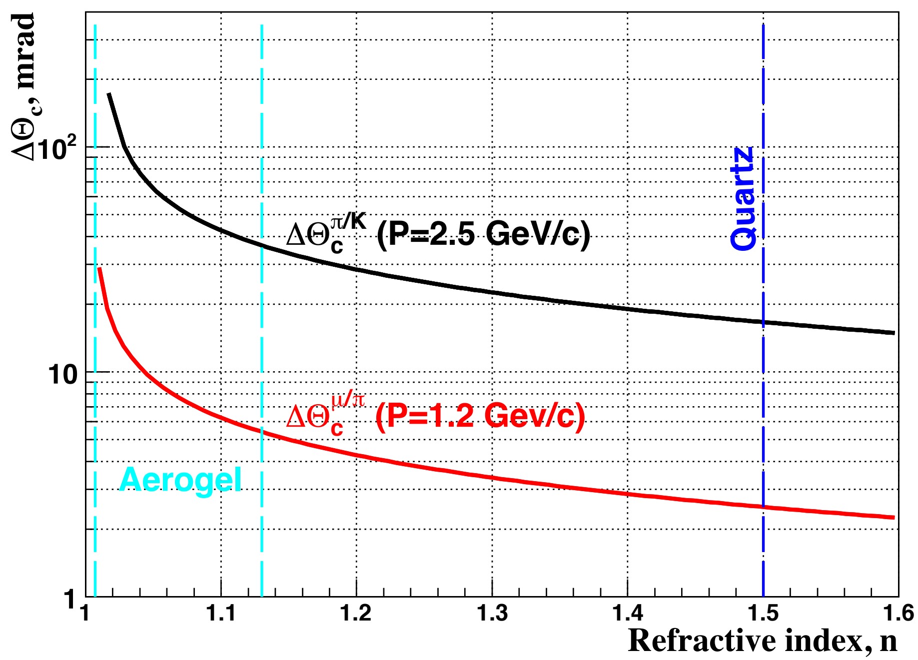
Focusing Aerogel RICH for PID system

(Motivation)

Dependence of Cherenkov threshold momentum on refractive index



Dependence of $\Delta\Theta_c$ on refractive index



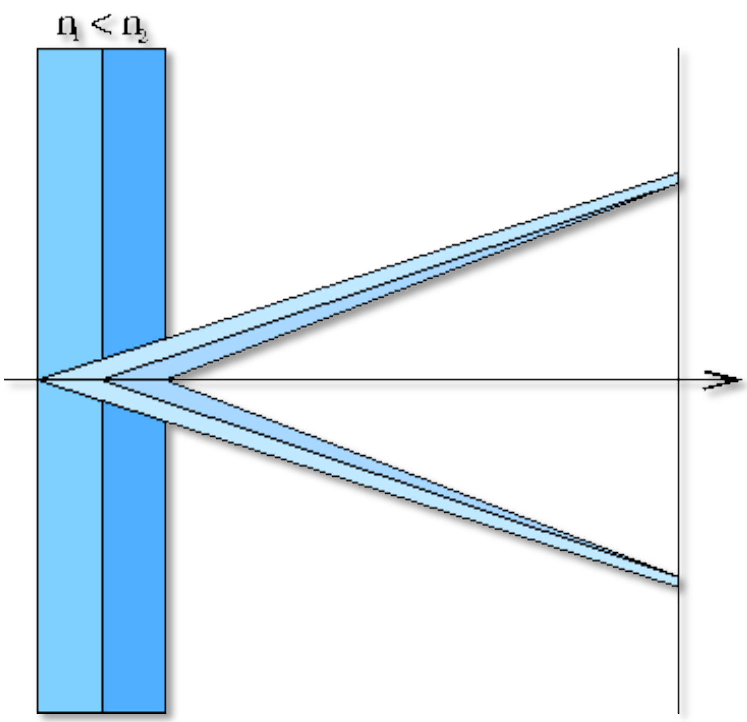
Aerogel threshold counters could be used for reliable K/π separation.

For reliable μ/π separation we need aerogel RICH with $\sigma_{track}(\Theta_c) < 2.5$ mrad

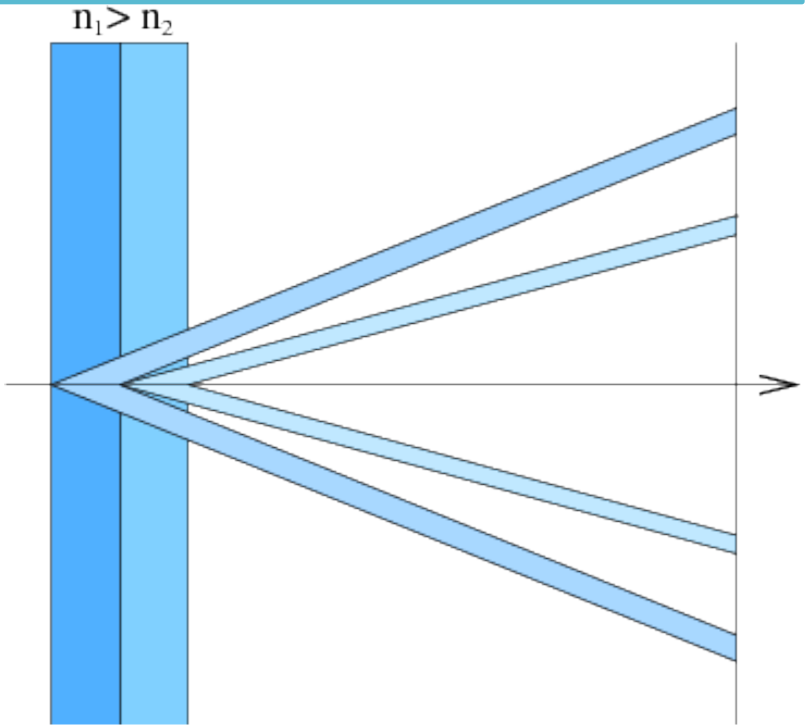
Focusing Aerogel RICH – FARICH
(Concept)

Focusing aerogel improves proximity focusing design by reducing the contribution of radiator thickness into the Cherenkov angle resolution

Single ring option



Multi-ring option



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

Single ring option: two approaches

Two blocks	Two layer block

Two blocks

- Aerogel RICH for Belle-II:
  - n_1=1.045, n_2=1.055
  - Thickness – 20 + 20 mm
  - Distance – 200 mm
- HAPD with 5x5 mm pixel
- σ_Θ=15.8 mrad and N_{pe}=8.6

$\sigma_\Theta(track) = \sigma_\Theta/\sqrt{N_{pe}} \approx 5.4$ mrad

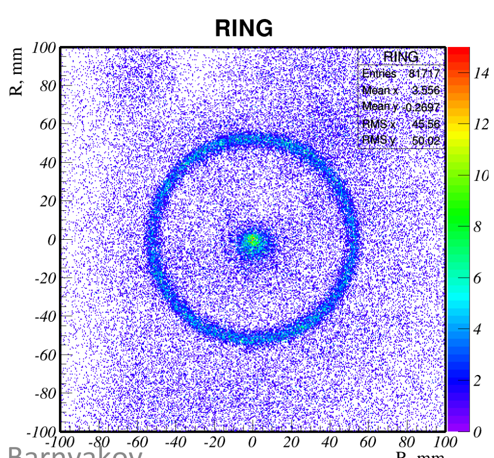
S.Nishida et al., NIM A 766 (2014) 28

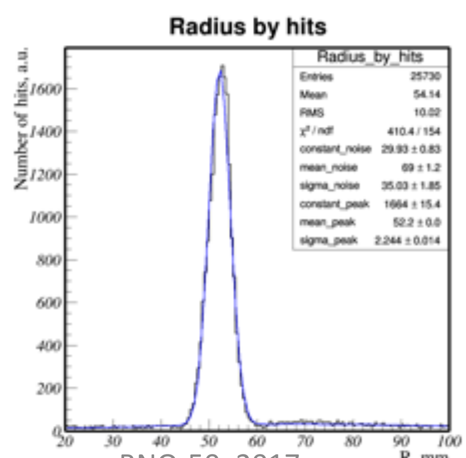
Two layer block

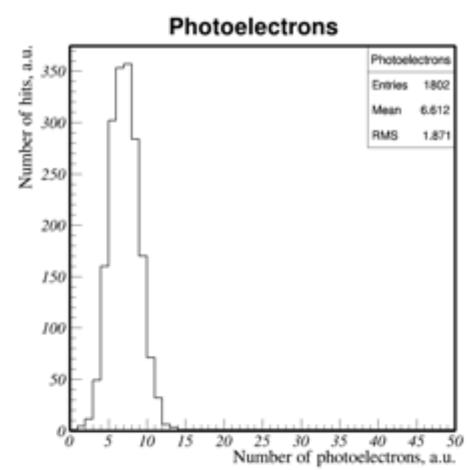
- Aerogel from BINP&BIC:
  - n_1=1.045, n_2=1.053
  - Thickness – 15 + 15 mm
  - Distance – 200 mm
- Philips DPC3200 – 4x4 mm pixel
- σ_Θ=11.2 mrad and N_{pe}=6.6

$\sigma_\Theta(track) = \sigma_\Theta/\sqrt{N_{pe}} \approx 4.4$ mrad

Preliminary results of BINP testbeam 2016



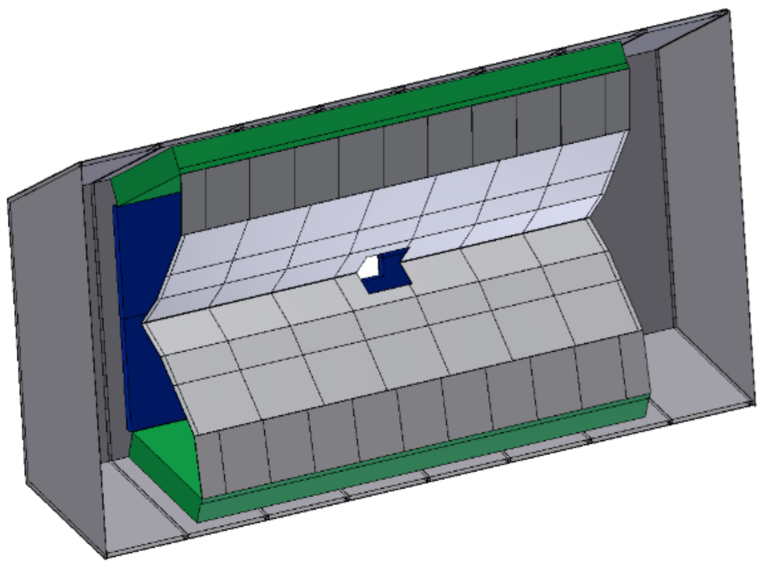


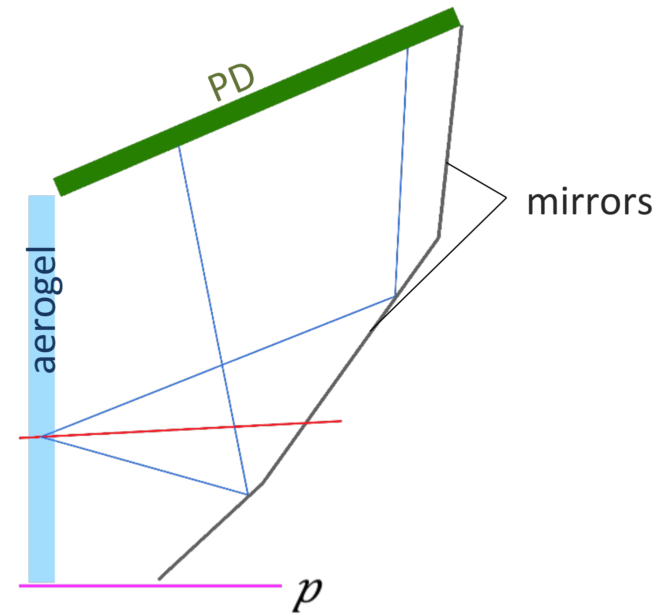


Forward Spectrometer RICH for PANDA

(BINP, BIC)

PANDA Forward RICH





Particle ID: π/K/p up to 10 GeV/c
3m² detector area (MaPMTs or SiPMs)

Radiator

- Focusing 2- or 3-layer aerogel
- 40 mm thick

Mirrors

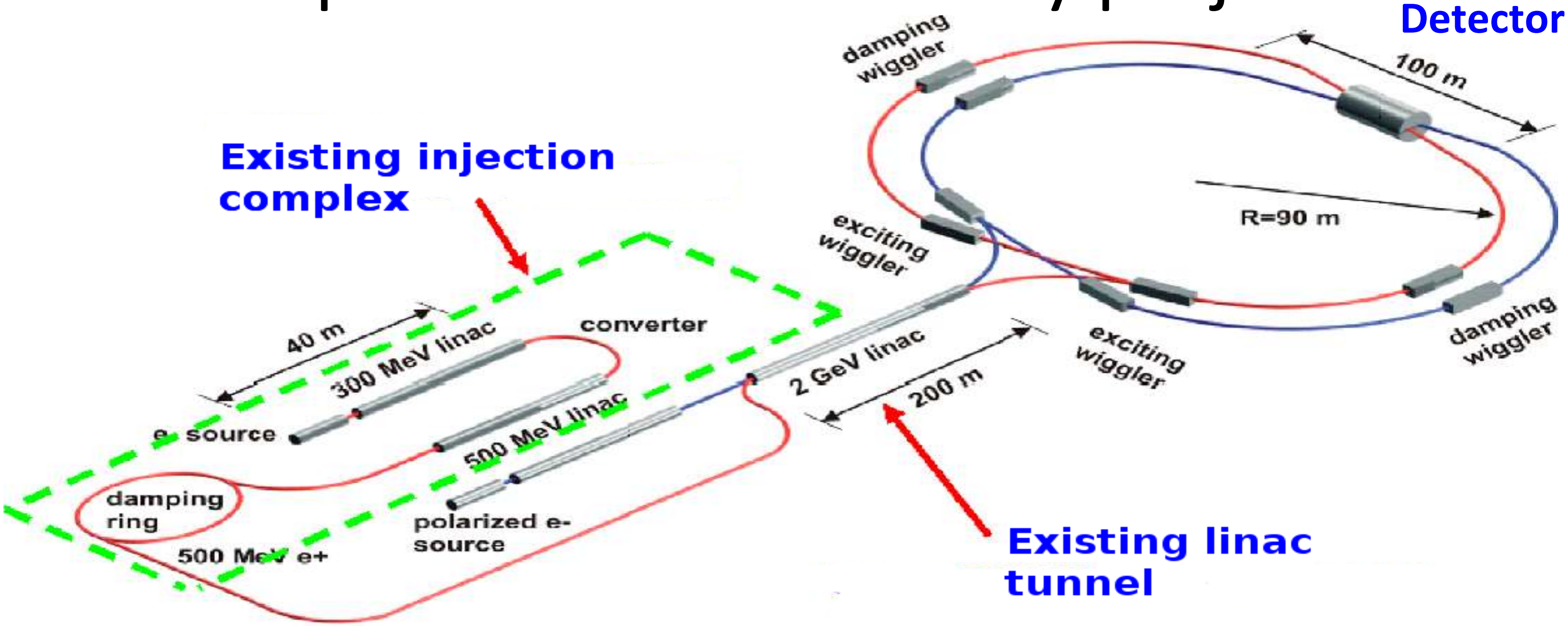
- Flat segments
- Float glass substrate 2 mm thick
- Al+SiO_2 coating, R≥90%

Photon Detector

Hamamatsu H12700 MaPMT

- flat panel,
- 8x8 anode pixels of 6mm size
- 87% active area ratio
- Bialkali photocathode
- Gain: $1.5 \cdot 10^6$

Super Charm-Tau Factory project



Factory outline:

- Double ring Symmetric e^+e^- collider with Crab Waist scheme
- $E_{c.m.} = 2 \div 5$ GeV
- $L = 10^{35}$ $cm^{-2}s^{-1}$
  (100 times more than existing c-τ factories)
- Longitudinal polarization of e^- - beams in IP

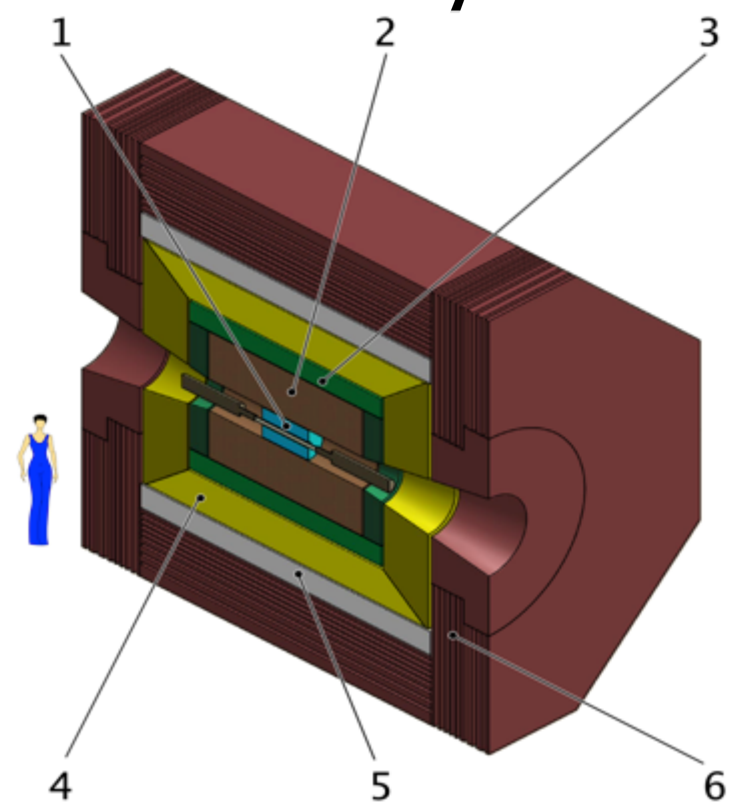
Detector for Super CT-factory

Physical program:

- Rare decays of D mesons, τ lepton;
- $D^0\check{D}^0$ oscillations;
- Searches for lepton-flavor-violating decays of τ (for instance τ → μγ);
- …

Detector requirements

- An excellent momentum resolution for charged particles and a good energy resolution for photons;
- K/π separation higher than 3σ;
  μ/π separation up to 1.5 GeV/c;
- DAQ system, which is able to read events at a rate of 300÷400kHz with 30kB event length;
- …

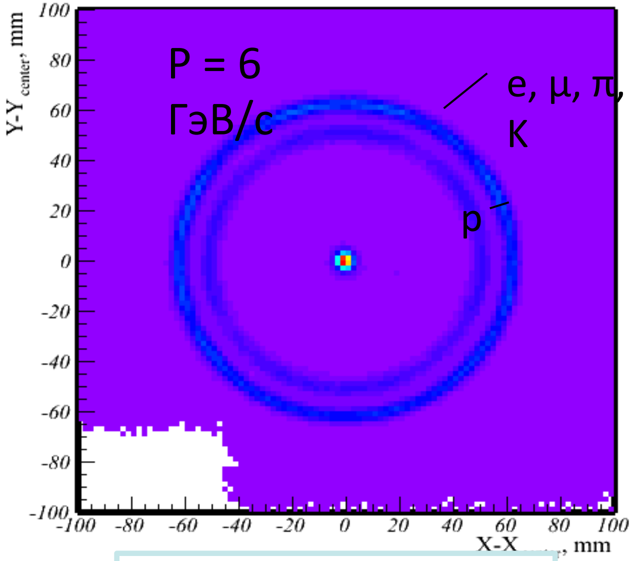


- 1 – Vertex Detector
- 2 – Drift Chamber
- 3 – PID => FARICH
- 4 – EMC
- 5 – Superconducting Solenoid
- 6 – IFR

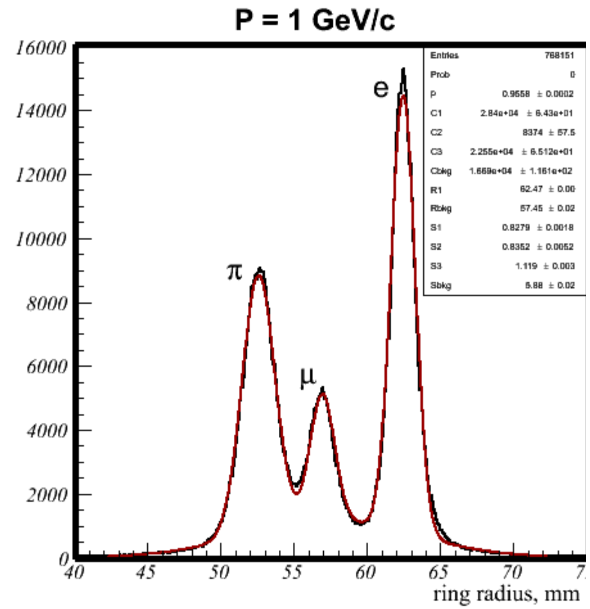
See CTF CDR (https://ctd.inp.nsk.su/docs/ScTau_CDR_en/CDR_en_ScTau.pdf)

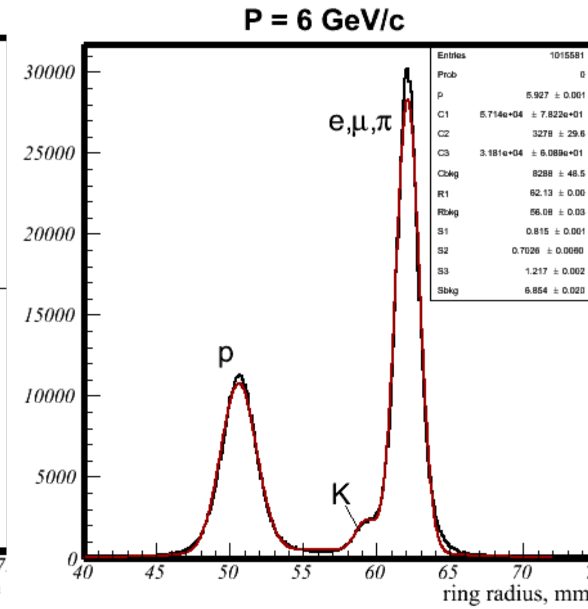
Beam test results at CERN PS T10, June 2012

Hit positions

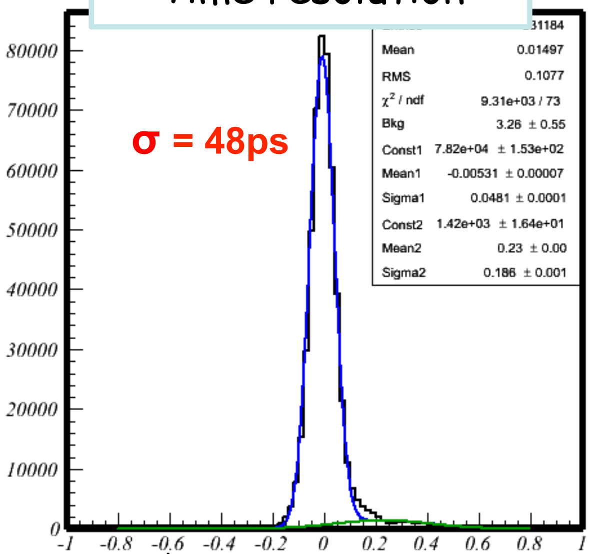


Ring radius distributions





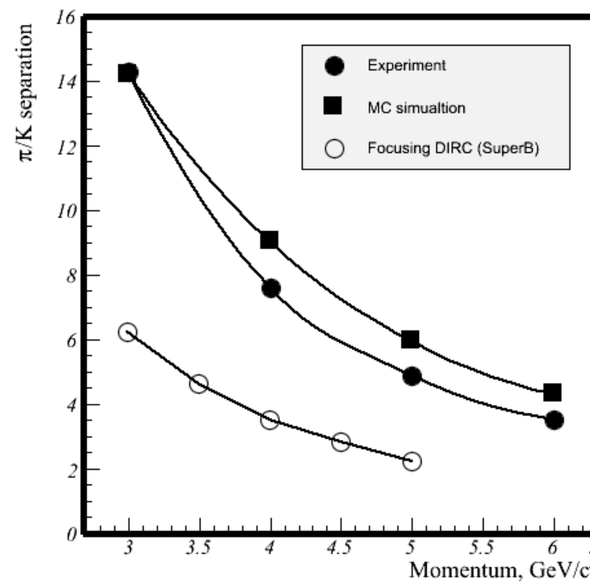
Time resolution



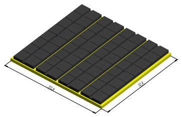
$$S(\pi/K) = \frac{R_\pi - R_K}{\sigma_\pi}$$

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

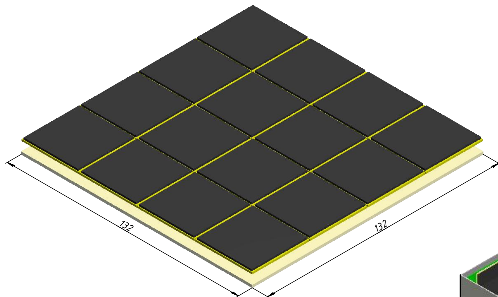
A.Yu. Barnyakov, et al., NIM A 732 (2013) 352



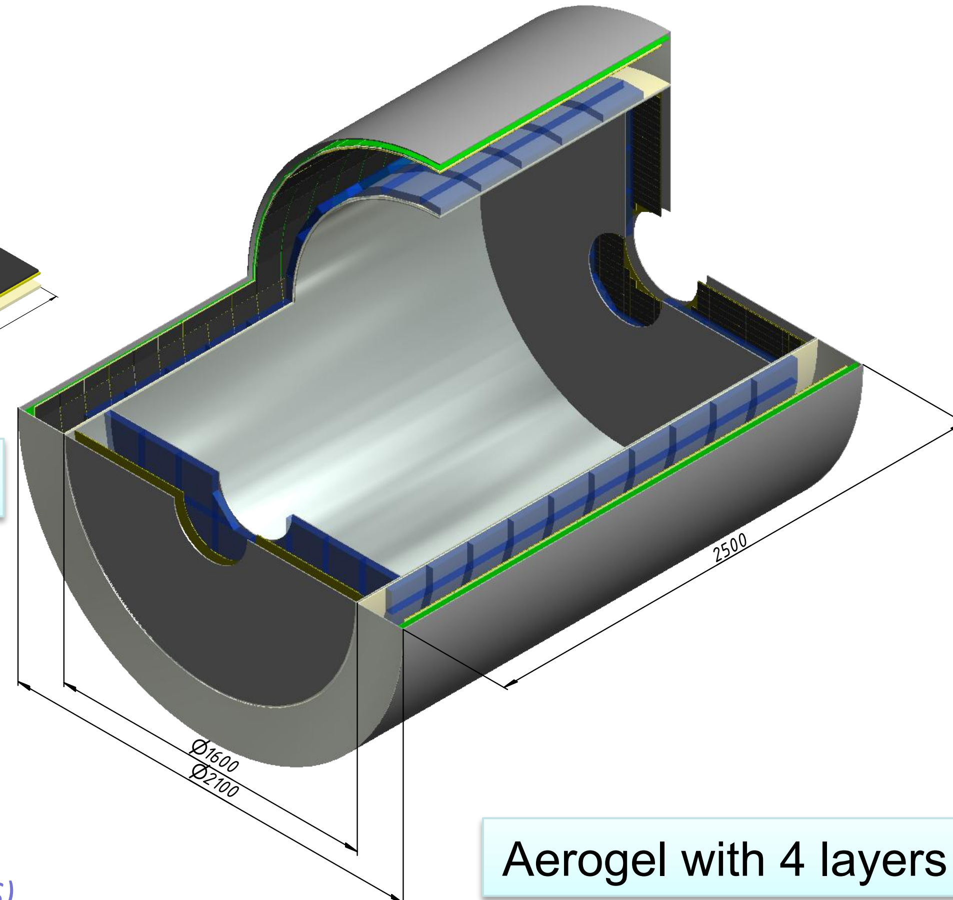
FARICH system



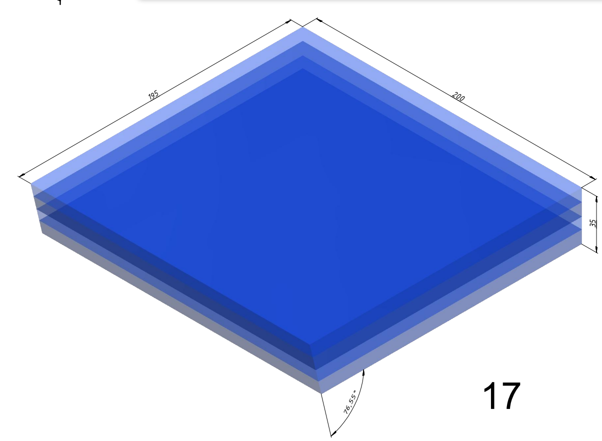
Tile with 64 pixels



Module with 16 tiles



Aerogel with 4 layers



Main parameters

- Focusing aerogel radiator, n_{max}=1.07, 4 layers
- Photon detector:~3x3mm^2, pitch 4 mm

DPC (Philips), MPPC (Hamamatsu), NUV-HD (FBK-IRIS), Array-C (SensL)

- Area of the photon detector: 20 m^2
- Area of the radiator: 14 m^2
- ~10^6 channels

Summary

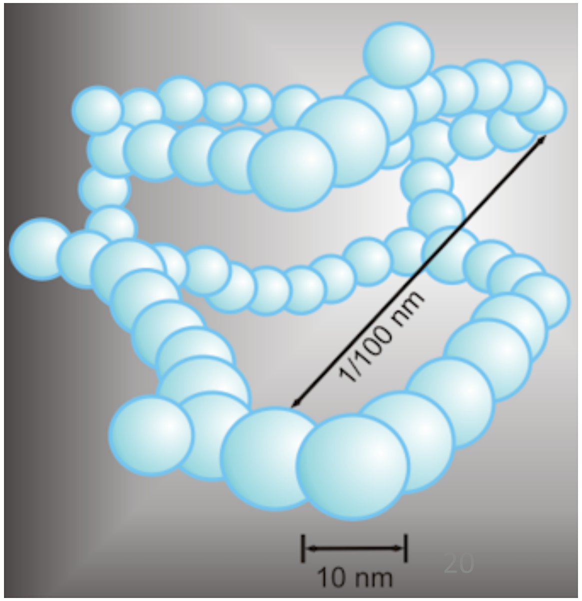
- Development of aerogel Cherenkov counters for HEP experiments have been carrying out in Novosibirsk since 1986 by BINP and BIC in close cooperation.
- The ASHIPH method for threshold Cherenkov counters was developed. Good π/K-separation was achieved in ASHIPH system of the KEDR detector and the SND dtector.
- Aerogel radiators for RICH detector of the AMS02 experiment were produced in Novosibirsk. Experimental number of photoelectrons and Cherenkov angle resolution are in good agreement with MC simulation. The AMS02 experiment has been operating since 2010 at ISS.
- Production of aerogel radiators with 200x200 transvers dimensions and high transparency for RICH of CLAS12 project is organized in Novosibirsk.
- Two projects of FARICH detectors for PANDA experiment and SCTF experiment are under development now.

Addendum

What it is -- Aerogel?(1)

•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 widespread are silicon dioxide aerogel, although aerogels based on metal oxides, carbon, gelatin and others.

What it is -- Aerogel?(2)

- Production method:
- Synthesis of the alcogel:
- $Si(OR)_4 + 2H_2O \Rightarrow SiO_2 + 4HOR$
- alkoxide water silica alcohol
- Supercritical drying in the autoclave to remove alcohol P_{max}=100 atm, T_{max}= 260°C
  - methanol -- P_{cr}=81 atm, T_{cr}=230°C
  - isopropanol -- P_{cr}=53 atm, T_{cr}=235°C
  - carbon dioxide -- P_{cr}=73 atm, T_{cr}=31°C

- Aerogel parameters:
- Density 0.003 до 1.0 g/cm^3 *(fused silica ρ=2.2* g/cm^3 *)*
- Refractive index
- $n \approx 1 + 0.2 \cdot \rho[g/cm^3] \Rightarrow$
- (n = 1.0006 ÷ 1.2)
- Porosity 99.8%
- Inner surface 800 m^2/g

Era of high transparency aerogel

L.W.Hrubesh, T.M. Tillotson, J.F. Poco "*Characterization of ultralow-density silica aerogels made from a condensed silica precursor*", MRS Proc. 180(1990)315

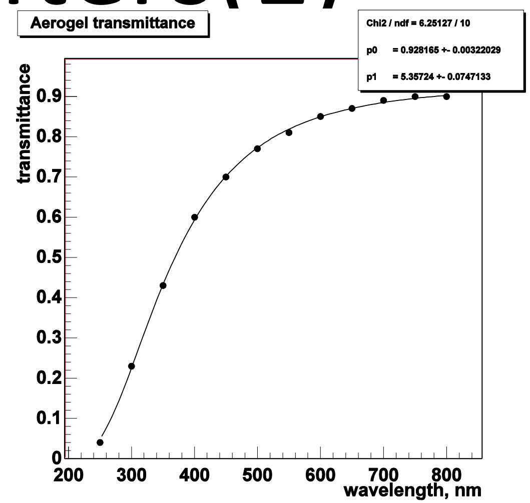
- One-step technology
- Direct alcogel synthesis
- $Si(OR)_4 + 2H_2O \Rightarrow SiO_2 + 4HOR$
- alkoxide water silica alcohol
- $L_{sc}(400) \sim 20$ mm

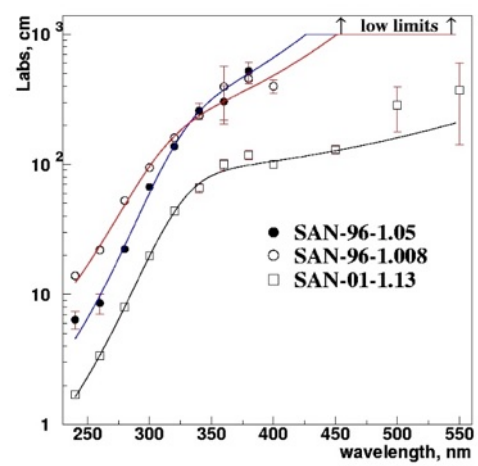
- Two-step technology
- A mixture of oligomers preparation
- $Si_kO_l(OR)_m(OH)_n \Rightarrow SiO_2$+alcohol
- $L_{sc}(400) > 35$ mm

Two-step technology was implemented at BIC in 1992

Aerogel threshold counters with wavelength shifters(1)

- At λ=400 nm
  - L_{sc}~ 40 mm, L_{abs}~ 4-5 m
- At λ=300 nm
  - L_{sc}~12 mm, L_{abs}~ 0.5-1 m
  - –But!
    - $dN/d\lambda \sim 1/\lambda^2$
    - At ~300 nm Number of Cherenkov photons is 3 times larger than at ~400 nm
  - –The idea is to absorb Cherenkov photons at short wavelengths and re-emit at large where aerogel transparency is better.



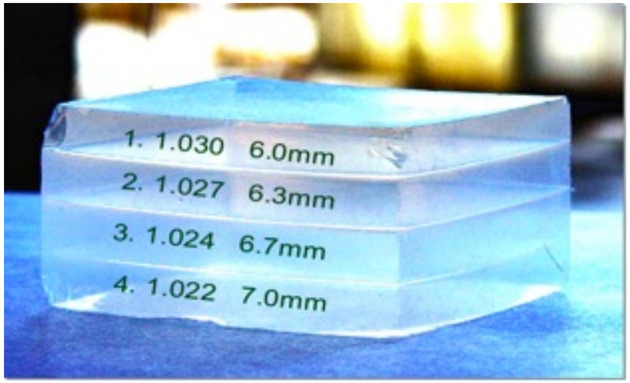


Status of aerogel production in Novosibirsk

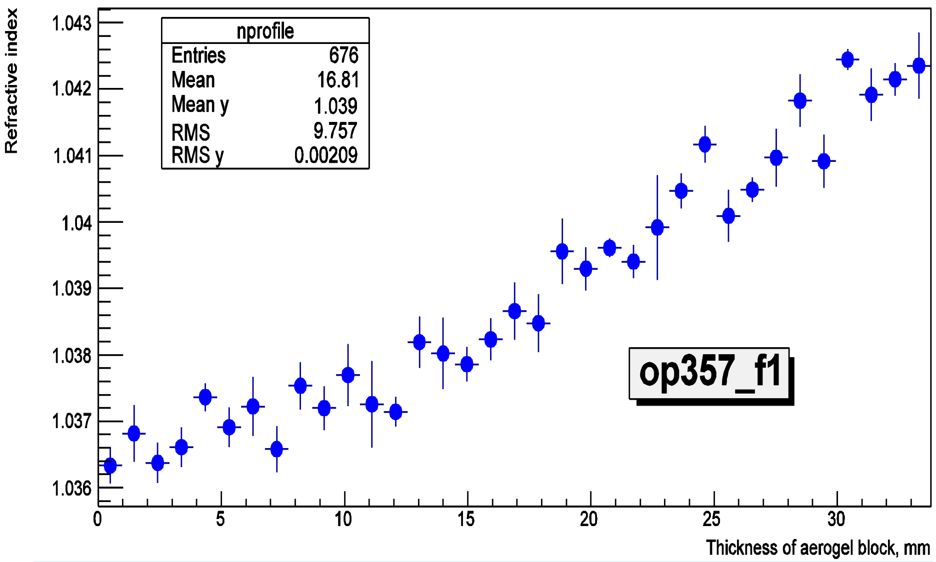
- Aerogel production in Novosibirsk was started in1986.
- $n=1.006 \div 1.13$; $L_{sc}(400nm) \geq 43$ mm.
- In 2004 first 4-layer tile was produced
- 2,3,4-layer blocks with $n_{max}=1.05$ 100x100x30 mm were produced in recent years.
- Tiles with n=1.05 and 200x200x30 mm are produced for J-Lab CLAS12 experiment. Total amount is 6 m^2.
- In 2012 development of aerogel production with continuous designed profile of density gradient was started.

The aims:

- Regular production of 3,4-layer tiles with $n_{max}=1.07$ and 200x200x35 mm.
- Development of "gradient" aerogel production.

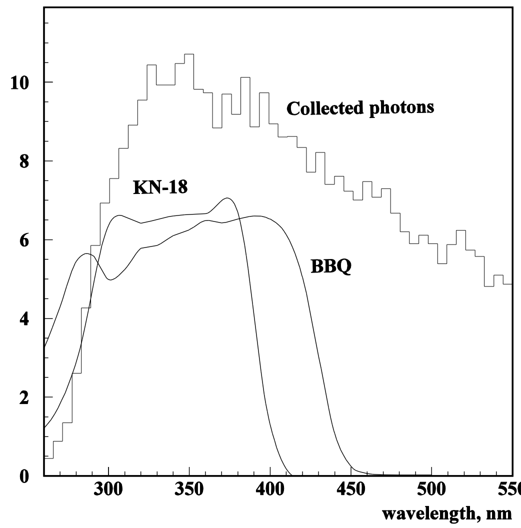


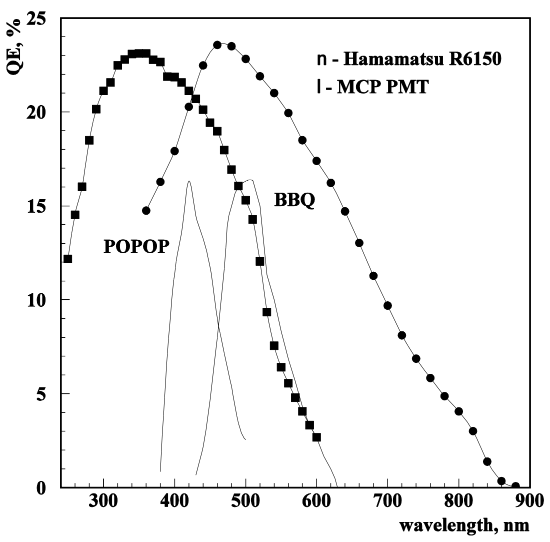
A.Yu.Barnyakov et al., NIM A553 (2005) 70



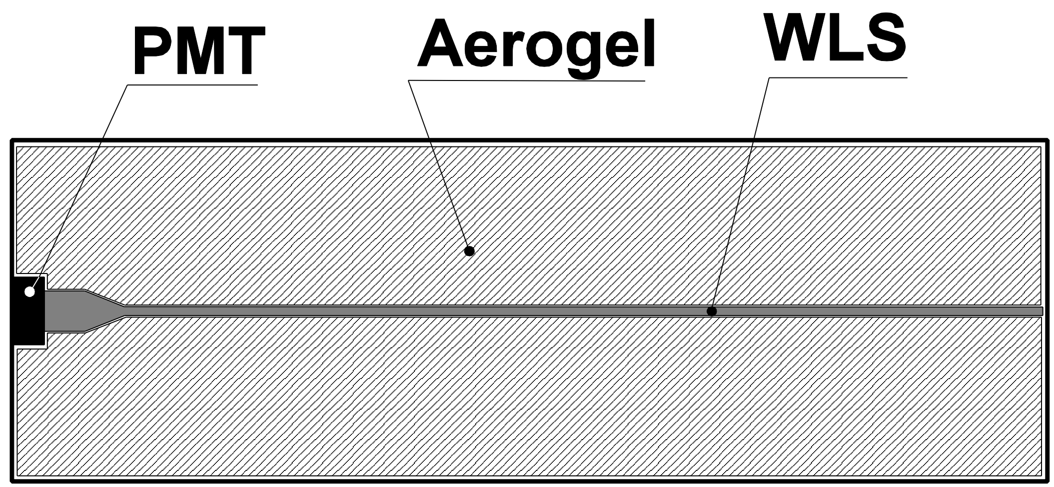
A.Yu.Barnyakov et al., NIM A766 (2014) 88
A.Yu.Barnyakov et al., NIM A766 (2014) 235

ASHIPH detectors





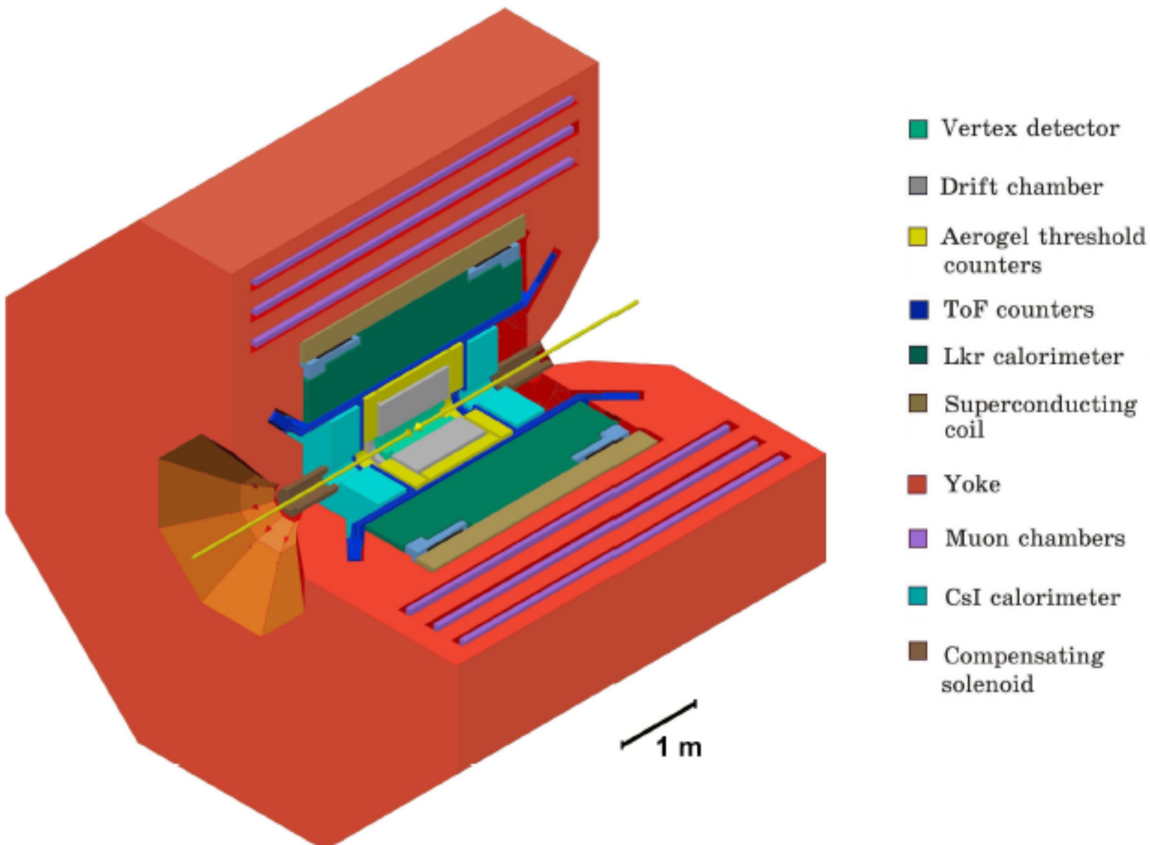
Aerogel SHIfter and PHotomultiplier



PMMA light guide doped with BBQ dye
is used as wavelength shifter

Suggested at BINP. A.Onuchin et.al. NIM A315(1992)517

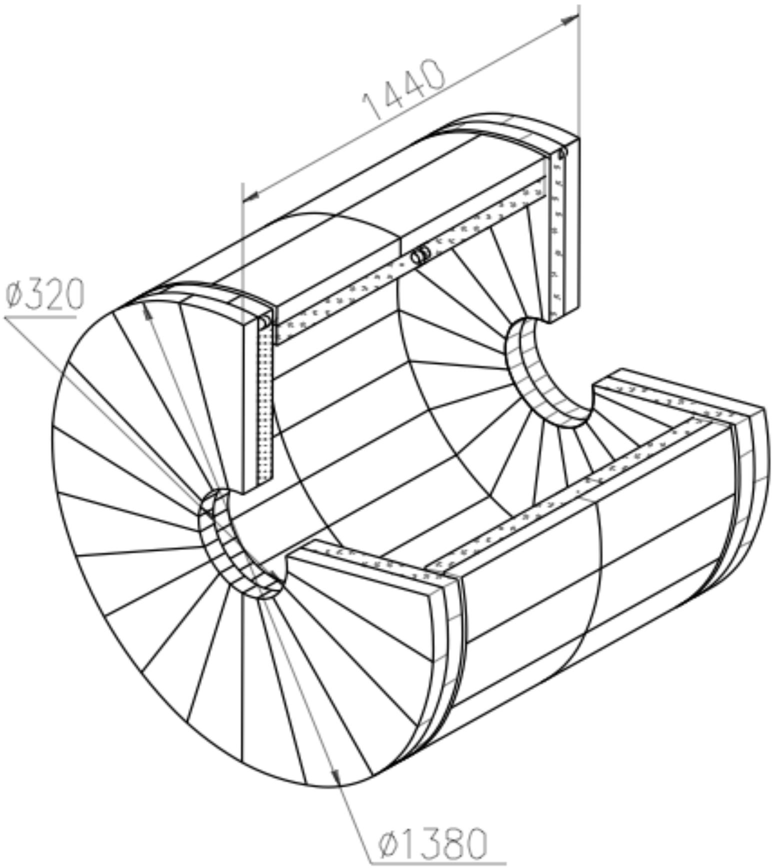
KEDR experiment at VEPP-4M



VEPP-4M
- Symmetric e^+e^- collider
- $E_{c.m.}$ = 2–10 GeV
- L = (1÷80) x 10^{30} $cm^{-2}s^{-1}$
- Precise energy calibration:
  RD: (5÷15)x10^{-6}
  CBS: 3x10^{-5}

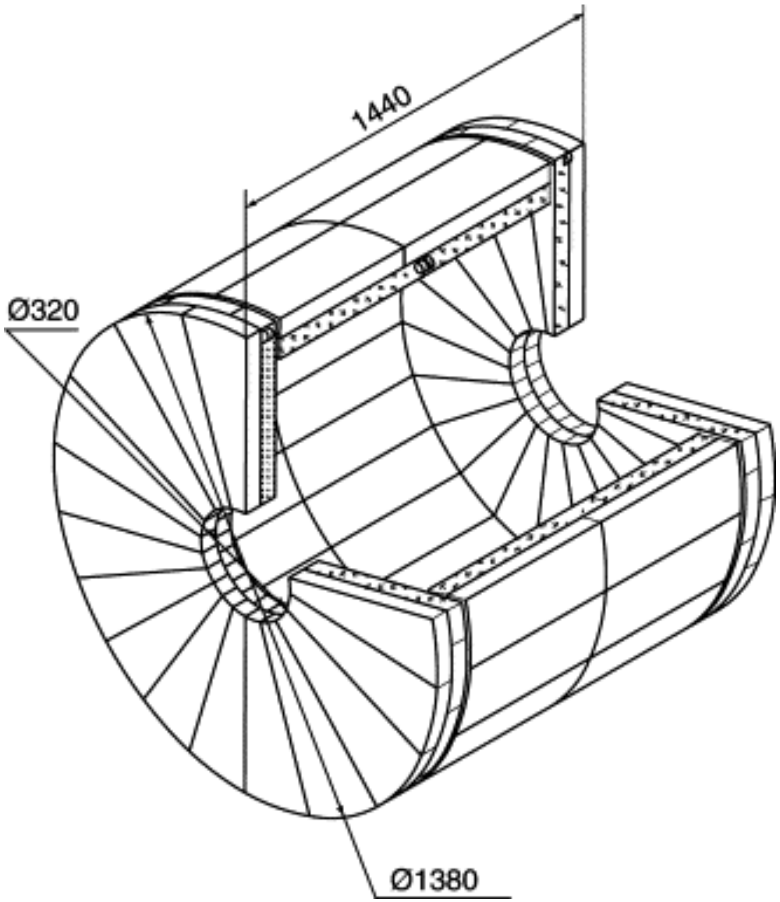
Physics program
- Precise particle mass measurements: *J/ψ, ψ*(2S), *ψ*(3770), *τ* lepton, *D* mesons, *Υ* mesons
- Measurements of *ψ* and *Υ* mesons lepton width
- R measurement in 2-10 GeV c.m. energy range
- γγ→*hadrons* and other 2γ processes
- Branching fractions measurements in charm and bottom quark systems (above 10^{-4})

KEDR ASHIPH system(1)



- 160 counters in 2 layers
- Solid angle 96% of 4π
- n=1.05, V_{Σ}=1000 l, high transparency SAN-96 aerogel
- π/K- separation in the momentum range 0.6÷1.5 GeV/*c*
- 160 MCP PMTs, photocathode diameter ø18mm, able to work in the magnetic field up to 2 T
- Fully installed in the detector in 2013. Now in operation.

KEDR ASHIPH system

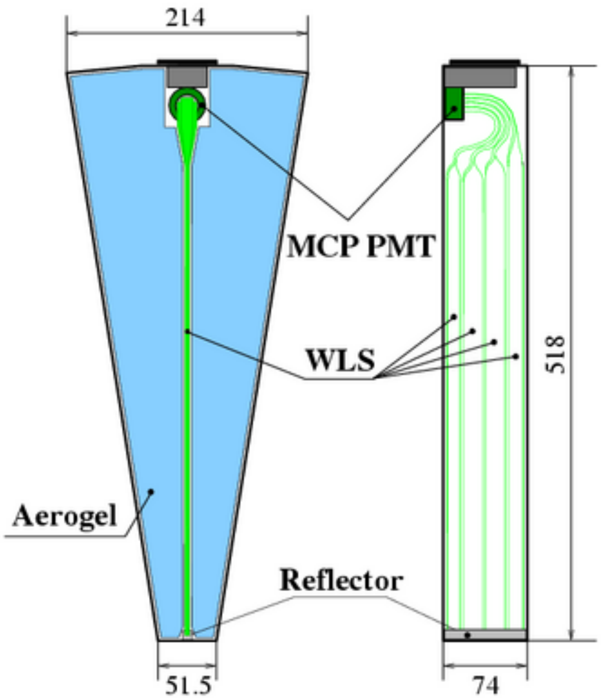


- n=1.05
- π/K separation:
  0.6 – 1.5 GeV/c
- 160 counters in 2 layers
- 160 MCP PMTs
- works in magnetic field up to 1.5T
- 1000 liters of aerogel
- 24% X_0 for 2 layers

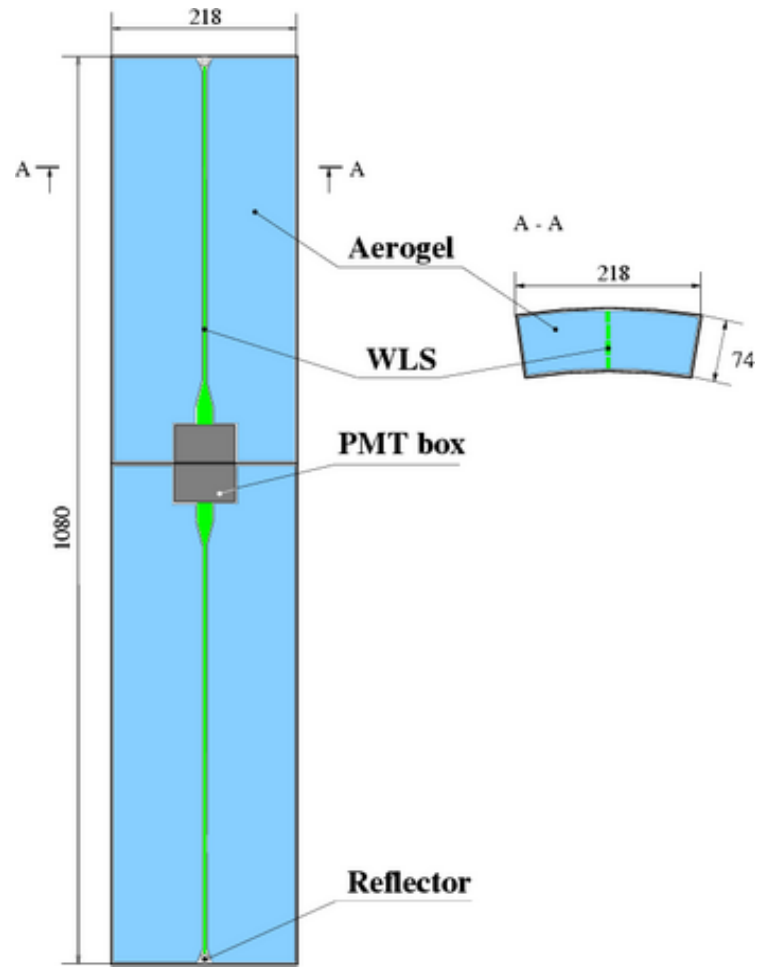
Beam test in Dubna (2000) A.Yu.Barnyakov et al., NIM A494 (2002) 424	
$N_{pe} \approx 10$ at saturation	
P=0.86 GeV/c	P=1.2 GeV/c
pion rejection 900:1 kaon efficiency 0.94 π/K separation 4.7 σ	pion rejection 1300:1 kaon efficiency 0.90 π/K separation 4.5 σ

KEDR ASHIPH counters

End-cap counter

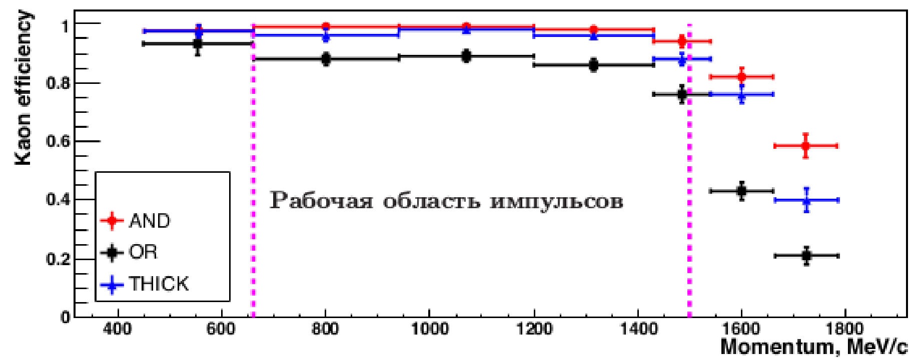


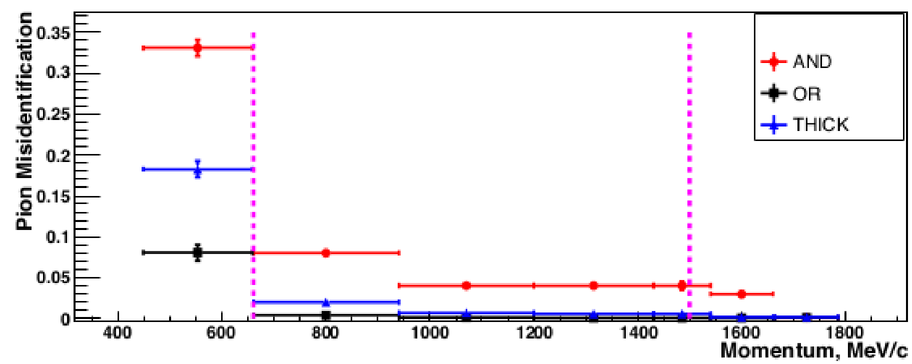
Barrel counter



KEDR ASHIPH system(2)

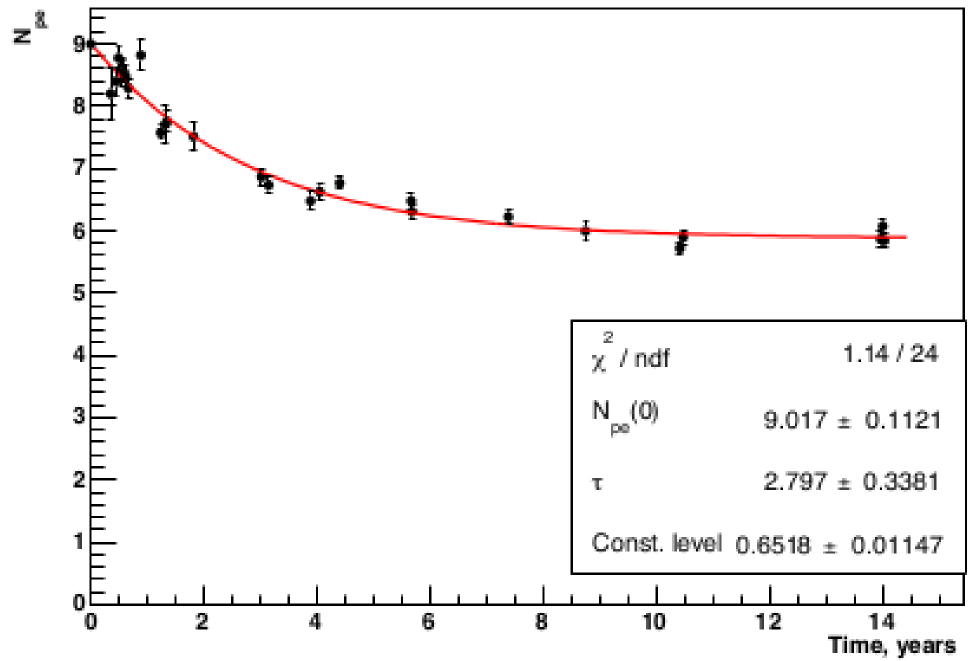
- Npe = 6.4±0.2 – layer 1
- Npe = 5.0±0.2 – layer 2
- Npe = 10.9±0.2 – sum of the signals in 2 layers (80%)
- π/K separation at 1.2GeV/*c* is 4.3σ



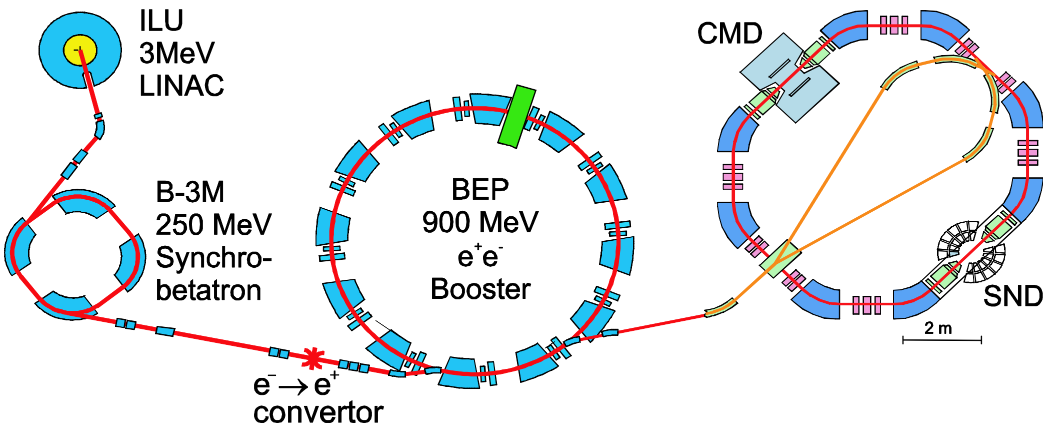


ASHIPH long term stability

•A prototype of the endcap ASHIPH counter are under operation since 2000. From time to time it is tested in Cosmic Ray Telescope (CRT). Its signal degradation now has stabilized at the level of 60% from initial value.



SND at VEPP-2000



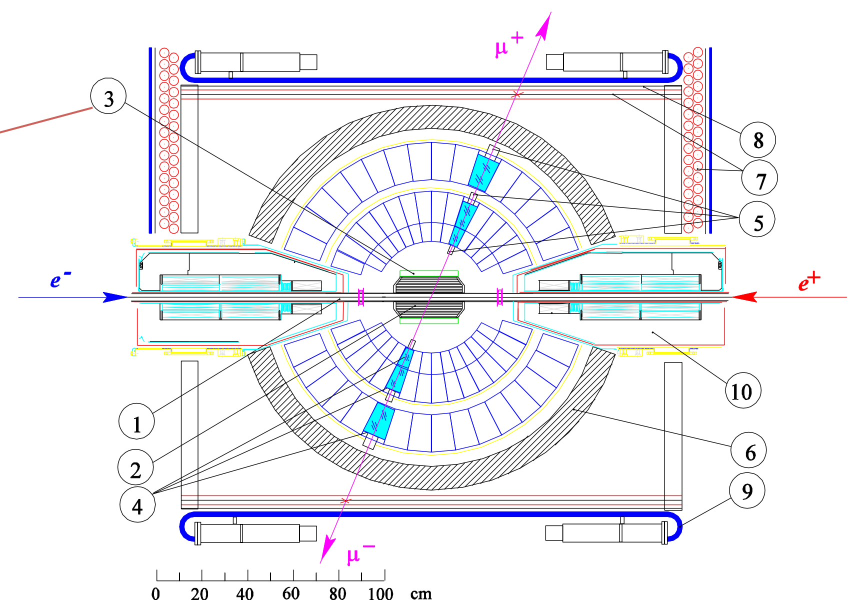
Symmetric e⁺e⁻ collider with round beams

$2E_{max}$=2000 MeV

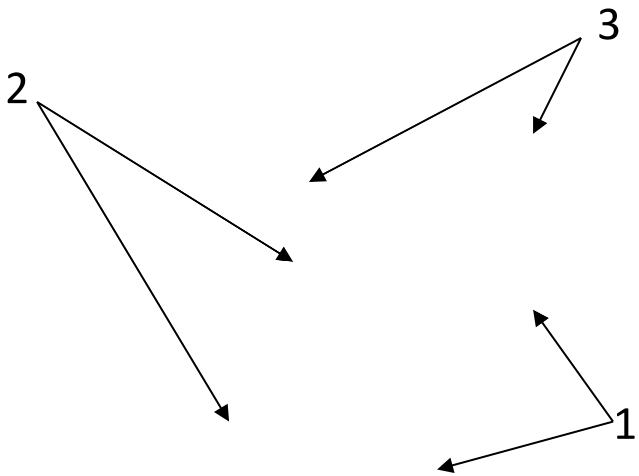
$L=10^{31}cm^{-2}s^{-1}$ at E=510 MeV

$L=10^{32}cm^{-2}s^{-1}$ at E=1000 MeV

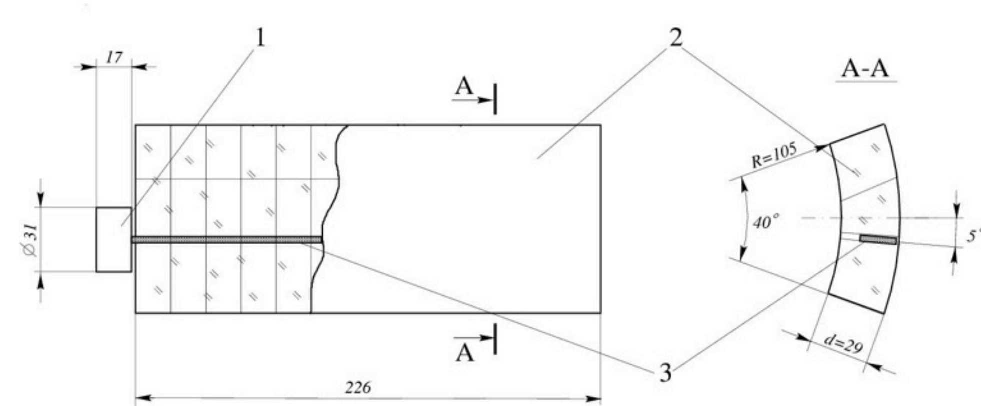
1. VEPP-2000 beam pipe
2. Tracking system
3. Aerogel Cherenkov counters
4. NaI(Tl) crystals } EMC
5. Vacuum phototriodes } EMC
6. Fe absorber
7. } Muon system
8. } Muon system
9. } Muon system
10. VEPP-2000 s.c. focusing solenoids



Aerogel Cherenkov counters for SND



1 - PMT, 2 – aerogel, 3 - WLS



Counter Design

- Scheme: ASHIPH
- WLS position: displaced by ~5° from counter center
- Aerogel thickness: ~30 mm

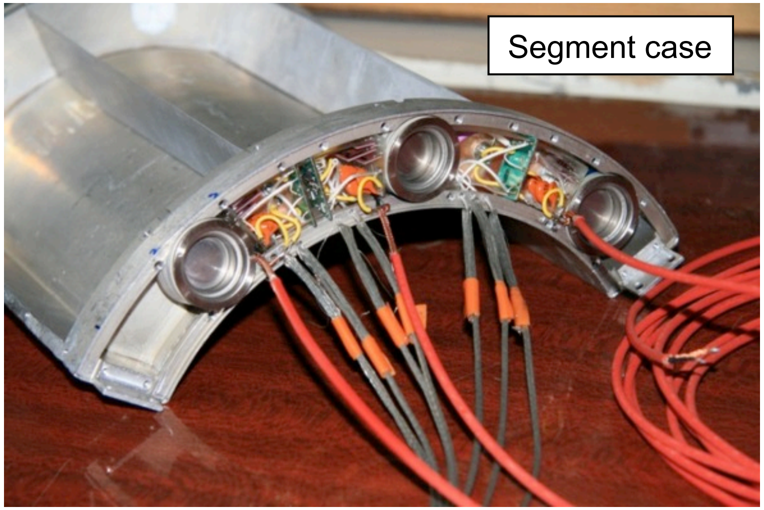
Outline

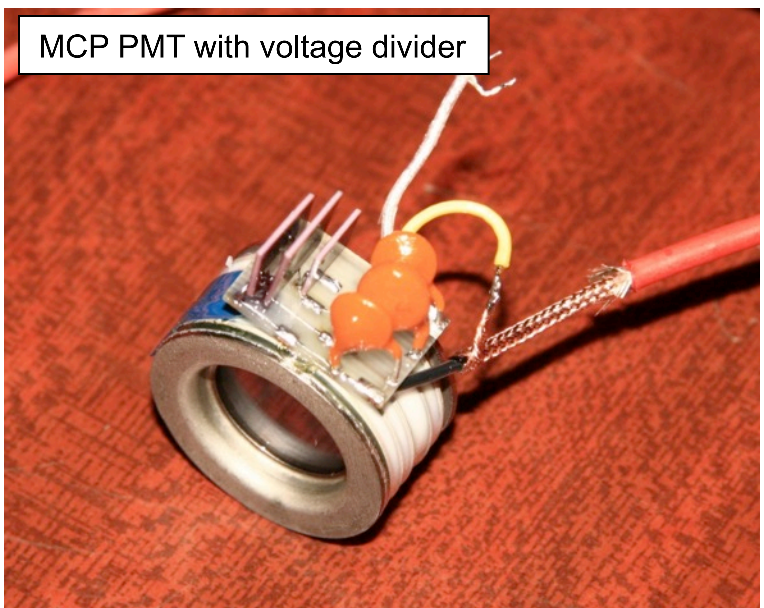
- π/K separation from 300 to 870 MeV/c
- Cylindrical shape: R=105÷141 mm
- Case material: 1mm of Al
- 3 segments of 3 counters in each
- Solid angle: ~60% of 4π
- Thickness: 0.09 X_o

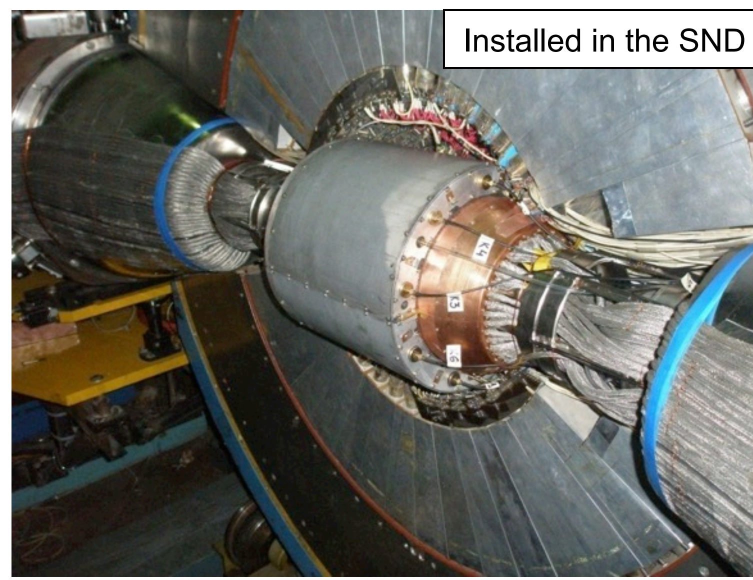
Aerogel parameters

- Refraction index: **n=1.13±0.01**
- Density: ρ=0.65 g/cm^3
- L_{sc}=19 mm at λ=400 nm
- L_{abs}=100 cm at λ=400 nm

SND counters assembling & installation







Альфа Магнитный Спектрометр (AMS-02)

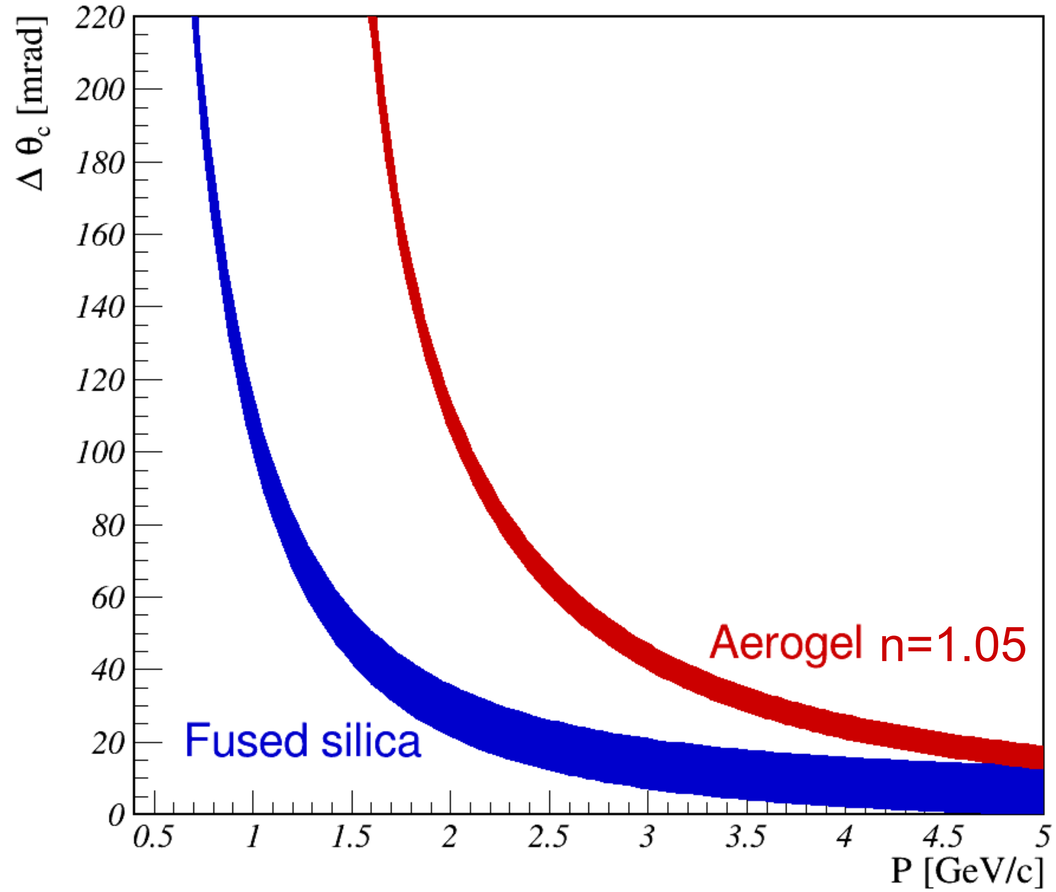
Задачи:

- Антивещество
- Темная материя
- Состав космических лучей
- Поиск странглетов

- Работает на МКС с 2011 года
- M = 8.5 тон, V = 54 м^3, S = 1 м^2
- Магнитное поле – 1.26 кГс
- TOF, TRD, Si Tracker, RICH, Ecal

Quartz vs Aerogel radiators

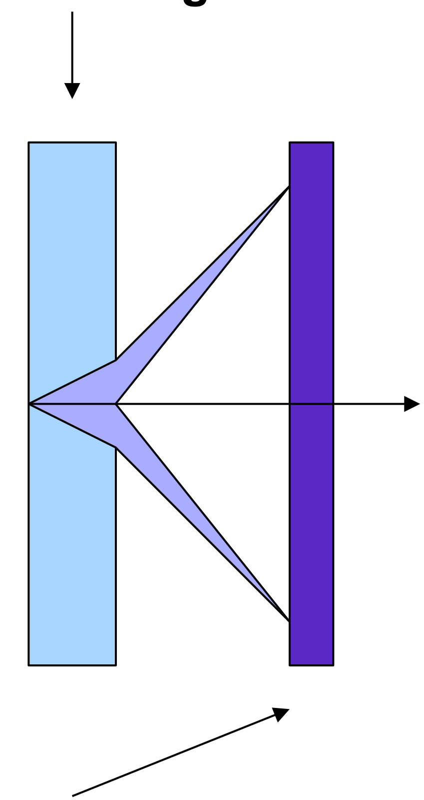
Difference in Cherenkov angle θ_c for π and K
Bands – chromatic dispersion in 350-700 nm



FARICH perspectives

For the proximity focusing RICH detectors there are 3 main contributions to the resolution: $\sigma_{\Theta}^2 = \sigma_{chr}^2 + \sigma_{geom}^2 + \sigma_{phot}^2$

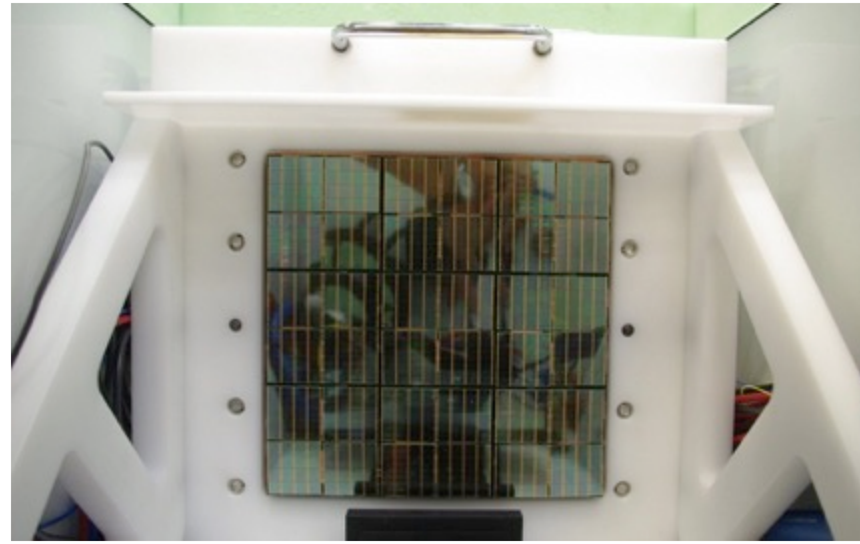
- Suggested technilogy of gradient aerogel tile production could give us radiators with $\sigma_{geom} << \sigma_{chr}$
- Philips Digital Photon Counting are working on the next version of the sensor which could read out the time and micro-cell number(instead of the number of fired cells)of the hit, $\sigma_{phot} \approx 20\ \mu m << \sigma_{chr}$
- **Could we build RICH with $\sigma_{\Theta}^2 \approx \sigma_{chr}^2$?**



Beam test of FARICH at CERN PS T10, June 2012

4-layer aerogel

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



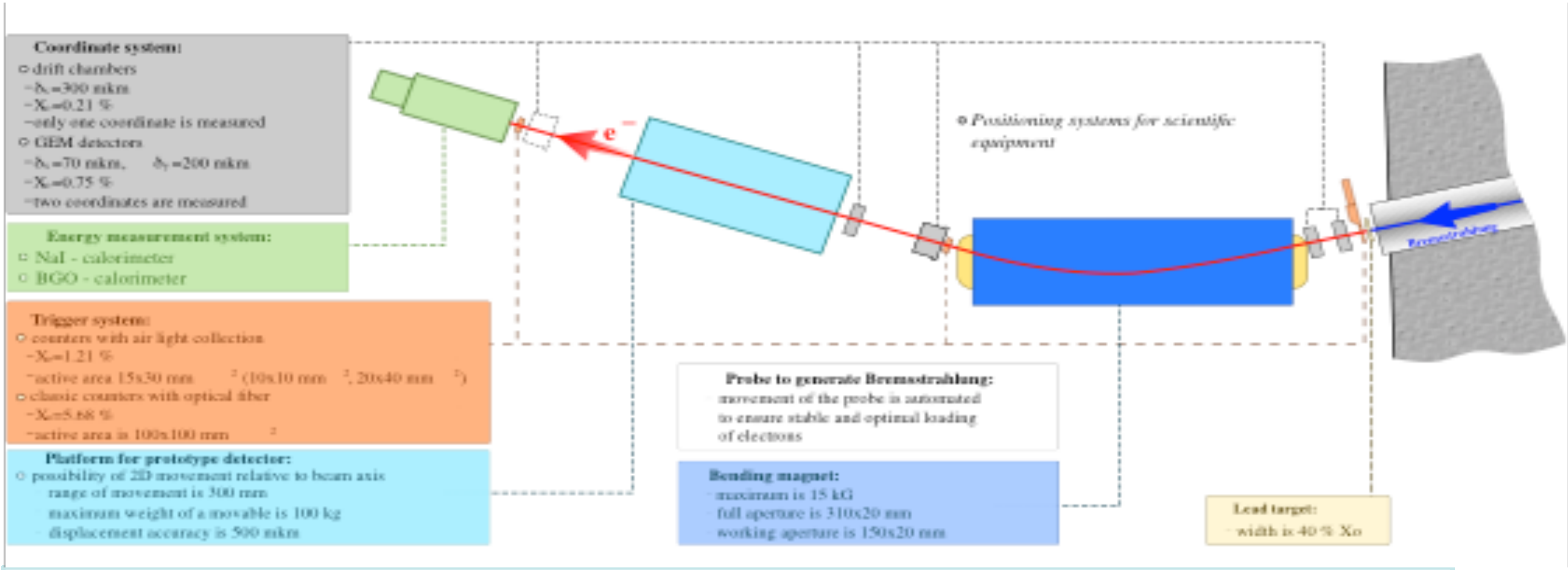
Test conditions

- 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

DPC matrix 20x20 cm^2

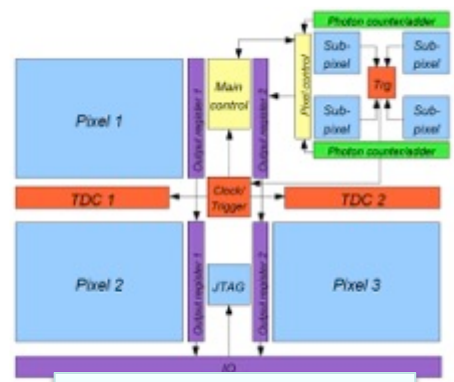
- Sensors: DPC3200-22-44
- 3x3 modules = 6x6 tiles =
  24x24 dies = 48x48 pixels
- 576 time channels
- 2304 amplitude (position) channels
- Operation at –40°C to reduce
  dark counts

Test beam facilities at BINP



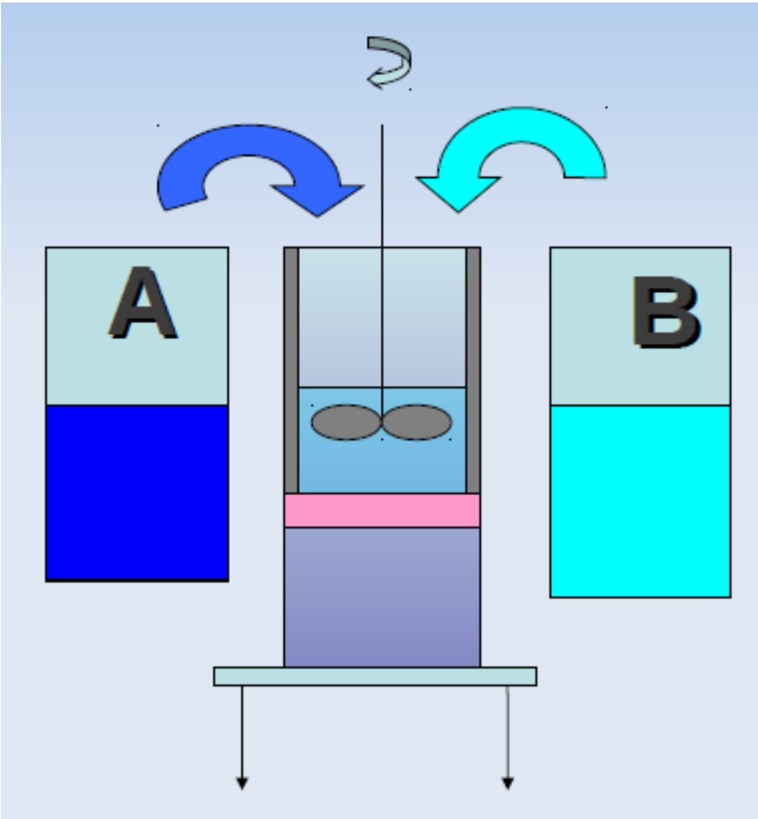
See V.S. Bobrovnikov et al., 2014 *JINST* **9** C08022 and G.N.Abramov et al., 2016 JINST 11 P03004

- **Philips DPC matrix 20x20 cm^2**
- Sensors: DPC3200-22-44
- 3x3 modules = 6x6 tiles =24x24 dies = 48x48 pixels
- 576 time channels
- 2304 amplitude (position) channels
- Size of pixel could be changed from 3x3 mm^2 to 50x50 μm^2
- Operation at –40°C to reduce dark counts



Die Architecture

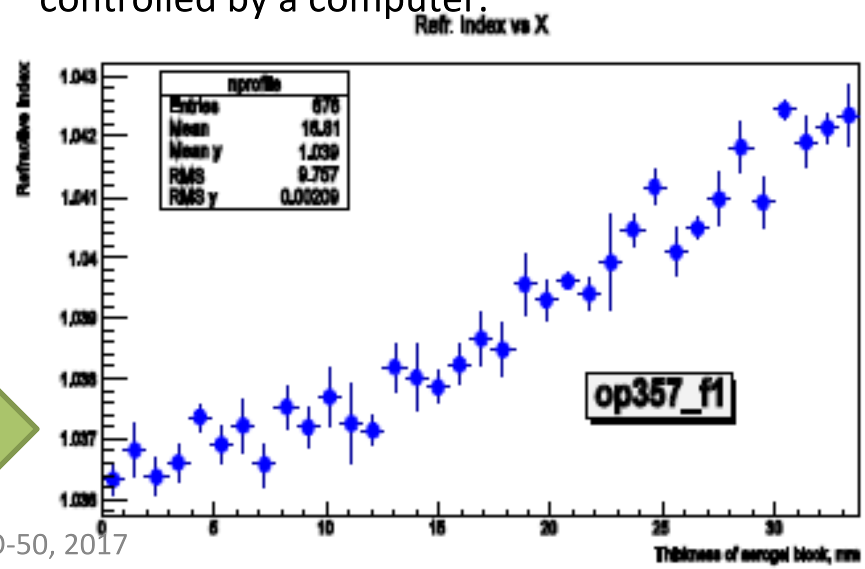
Continuous density gradient aerogel



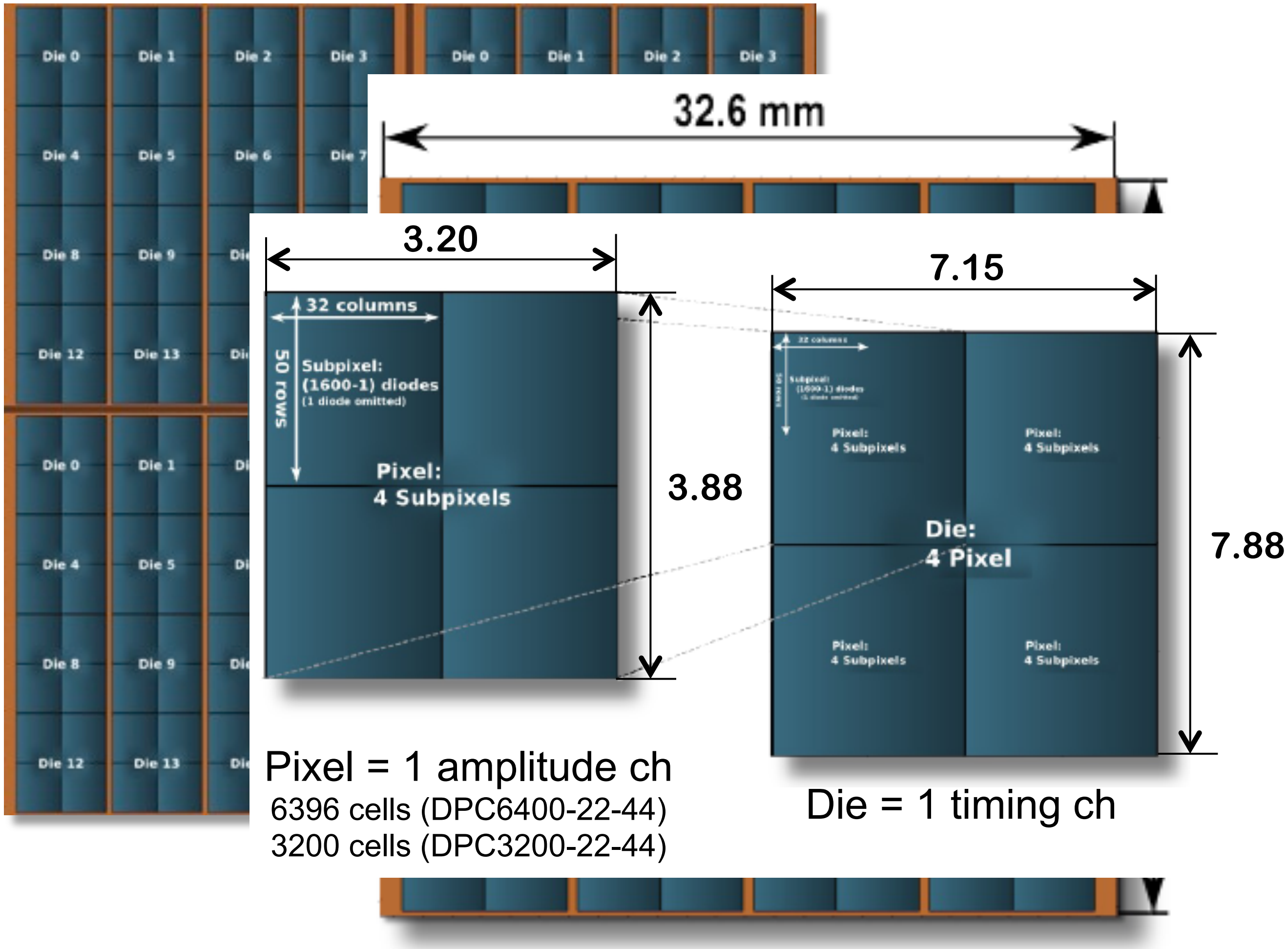
To produce aerogel tiles with designed profile of gradient we modernized the method suggested by [S.M. Jones "A method for producing gradient density aerogel", J Sol-Gel Sci Technol. 44 (2007) 255]

- We mix two pre-prepared mixtures with different content of TEOS fed by peristaltic pumps from vessels A and B.
- The mixture with designed concentration of TEOS seeps through the filter to the mould where gelation takes place.
- The mould is positioned on the vertically moving table. The peristaltic pumps and moving table are controlled by a computer.

Refractive index profile along thickness



DPC hierarchy in PDPC-FARICH

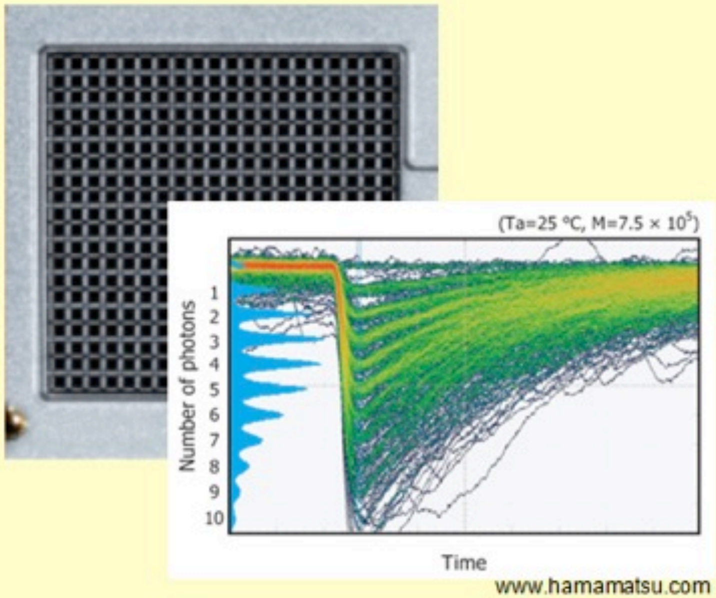


Pixel-in-module packing density ≈70%

DPC: Front-end Digitization by Integration of SPAD & CMOS Electronics

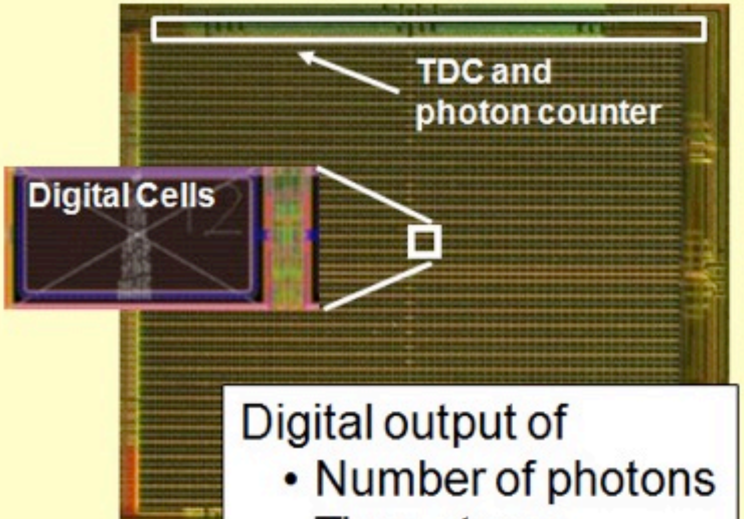
Philips Digital Photon Counting (PDPC)

analog SiPM



Summing all cell outputs leads to an analog output signal and limited performance

Digital Photon Counter (DPC)



Digital output of

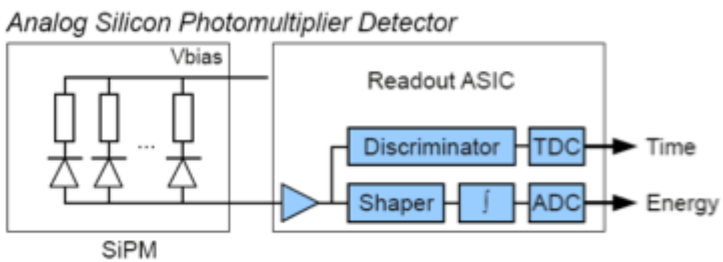
- Number of photons
- Time-stamp

Integrated readout electronics is the key element to superior detector performance

T. Frach, G. Prescher, C. Degenhardt, B. Zwaans, IEEE NSS/MIC (2010) pp.1722-1727
C. Degenhardt, T. Frach, B. Zwaans, R. de Gruyter, IEEE NSS/MIC (2010) pp.1954-1956

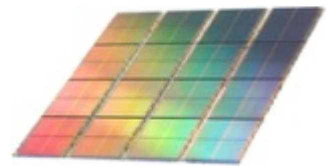
DPC: Front-end Digitization by Integration of SPAD & CMOS Electronics

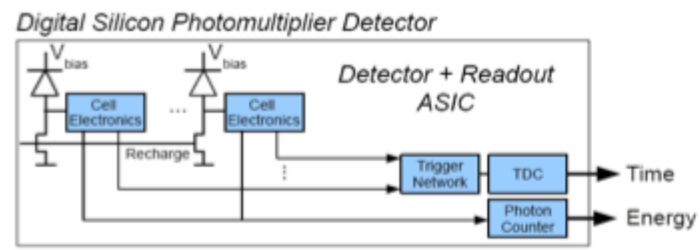
Analog SiPM



- discrete, limited integration
- analog signals to be digitized
- dedicated ASIC needed
- difficult to scale

Digital SiPM

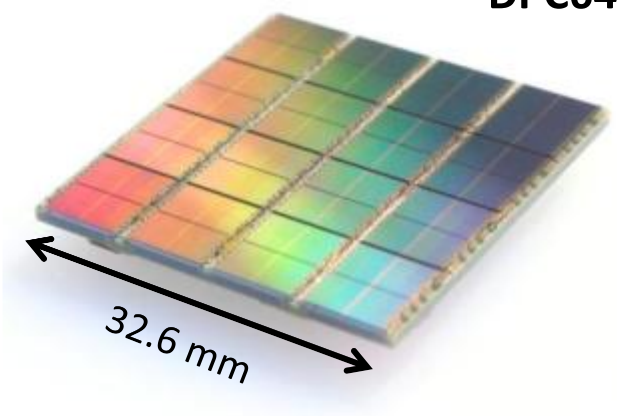




- fully integrated
- fully digital signals
- no ASIC needed
- fully scalable

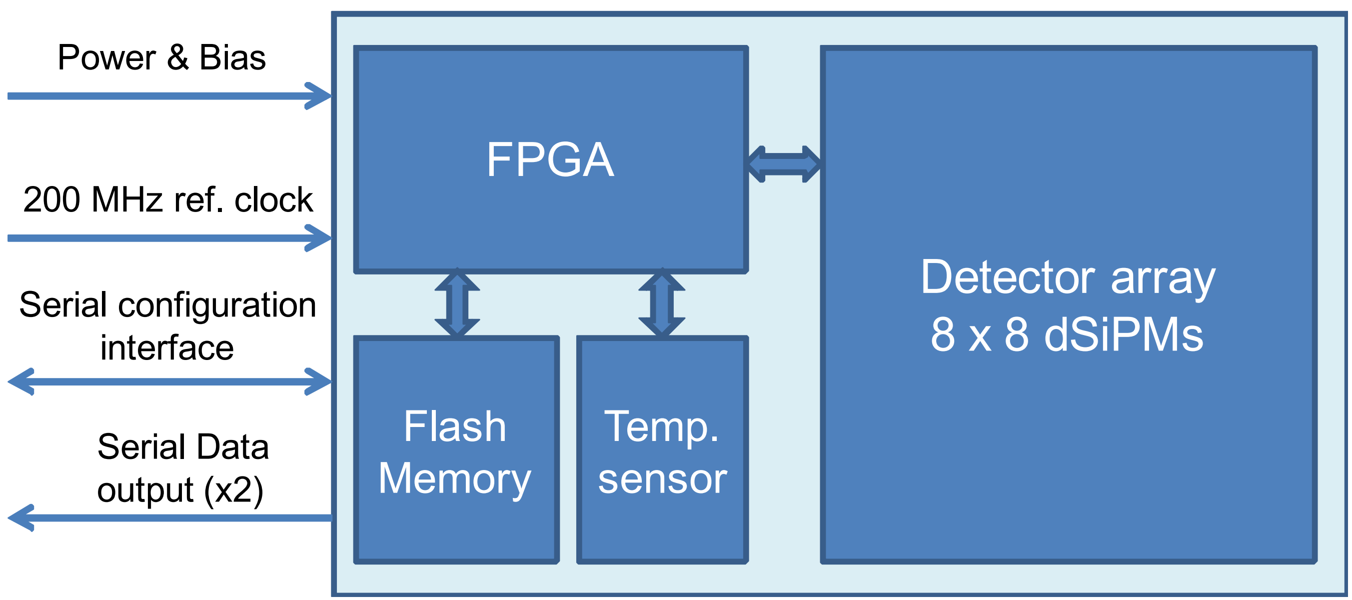
DPC tile – PCB with densely packed 4x4 sensors (8x8 pixels)

DPC3200-22-44 – 3200 cells/pixel
DPC6400-22-44 – 6396 cells/pixel

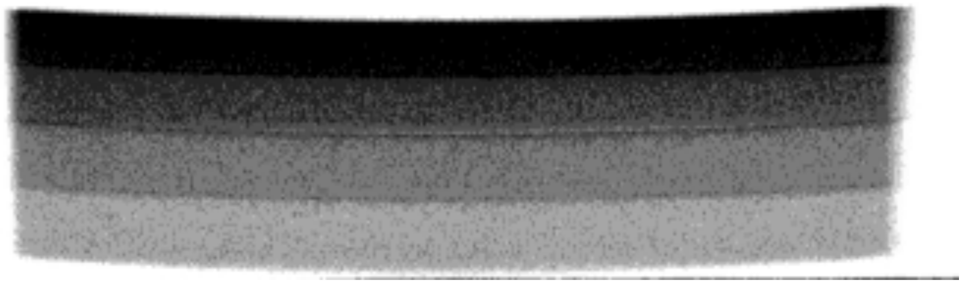


FPGA
- Clock distribution
- Data collection/concentration
- TDC linearization
- Saturation correction
- Skew correction

Flash
- FPGA firmware
- Configuration
- Inhibit memory maps



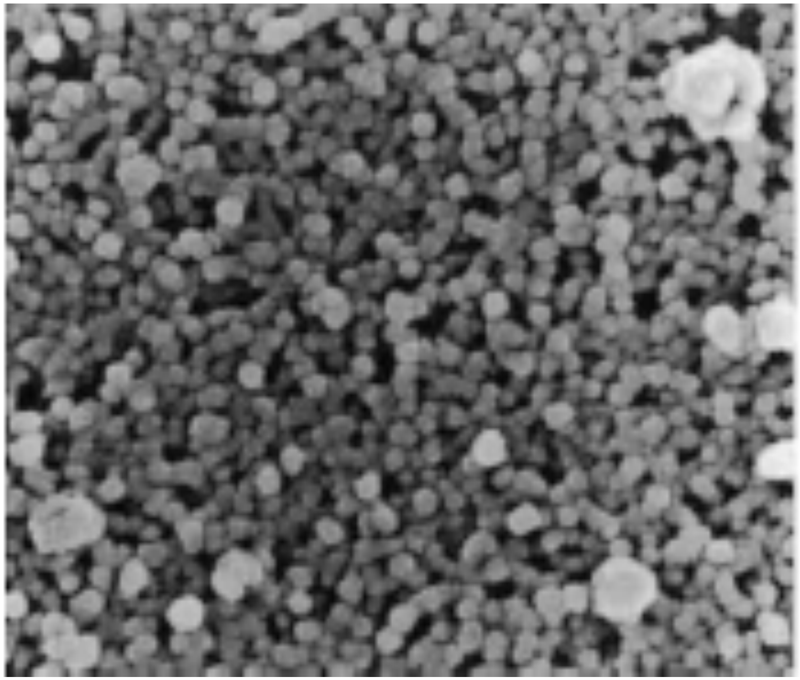
Aerogel study with digital X-ray setup

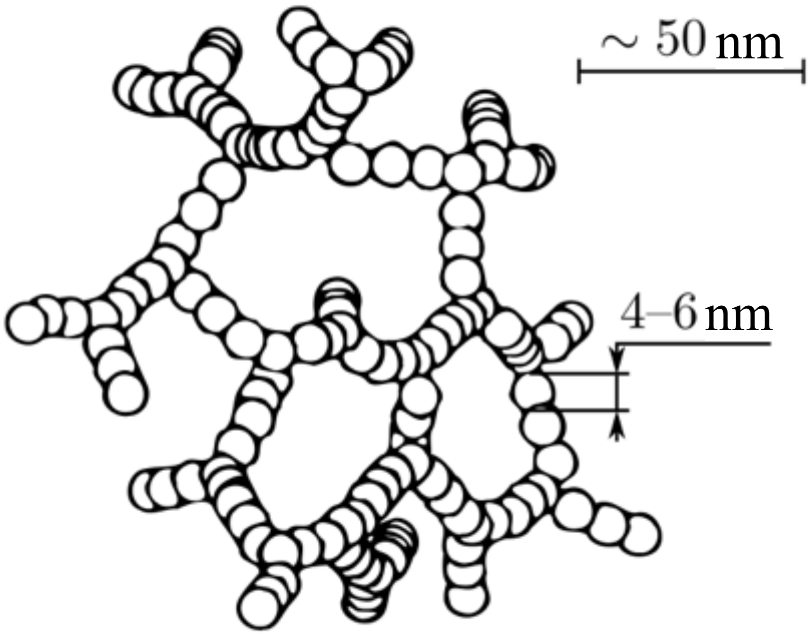


	n	h, mm
Layer 1	**1.050**	**6.2**
Layer 2	**1.041**	**7.0**
Layer 3	**1.035**	**7.7**
Layer 4	**1.030**	**9.7**

- $100x100x31\ mm^3$
- Lsc(400nm)=43 mm
- $n^2=1+0.438*\rho$

Refractive index





$SiO_2 + H_2O(1 \div 5\%)$

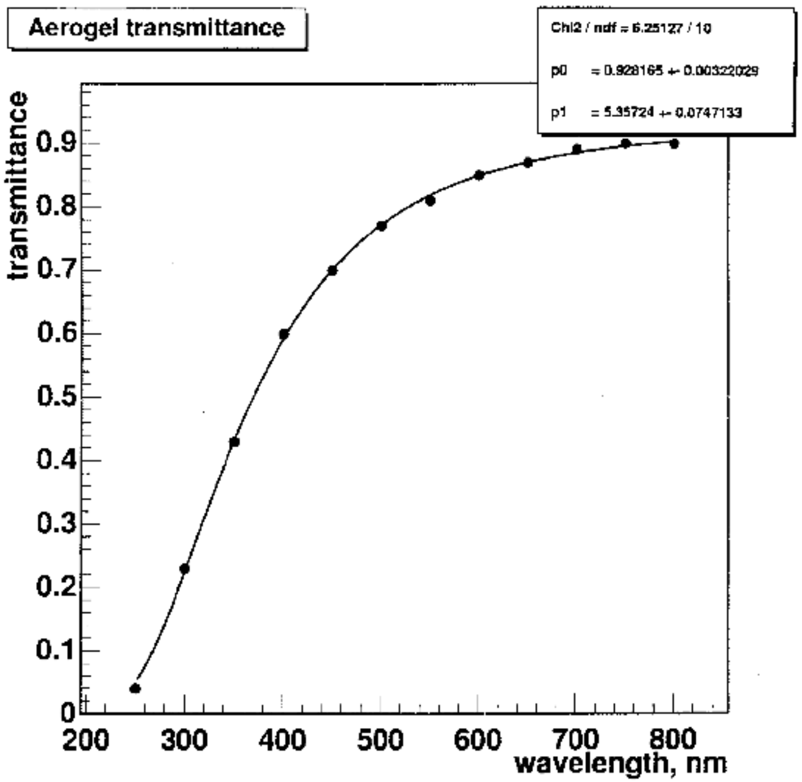
$$n^2 = 1 + 0.438 \cdot \rho$$

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

Light scattering

Rayleigh scattering on aerogel structure elements

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

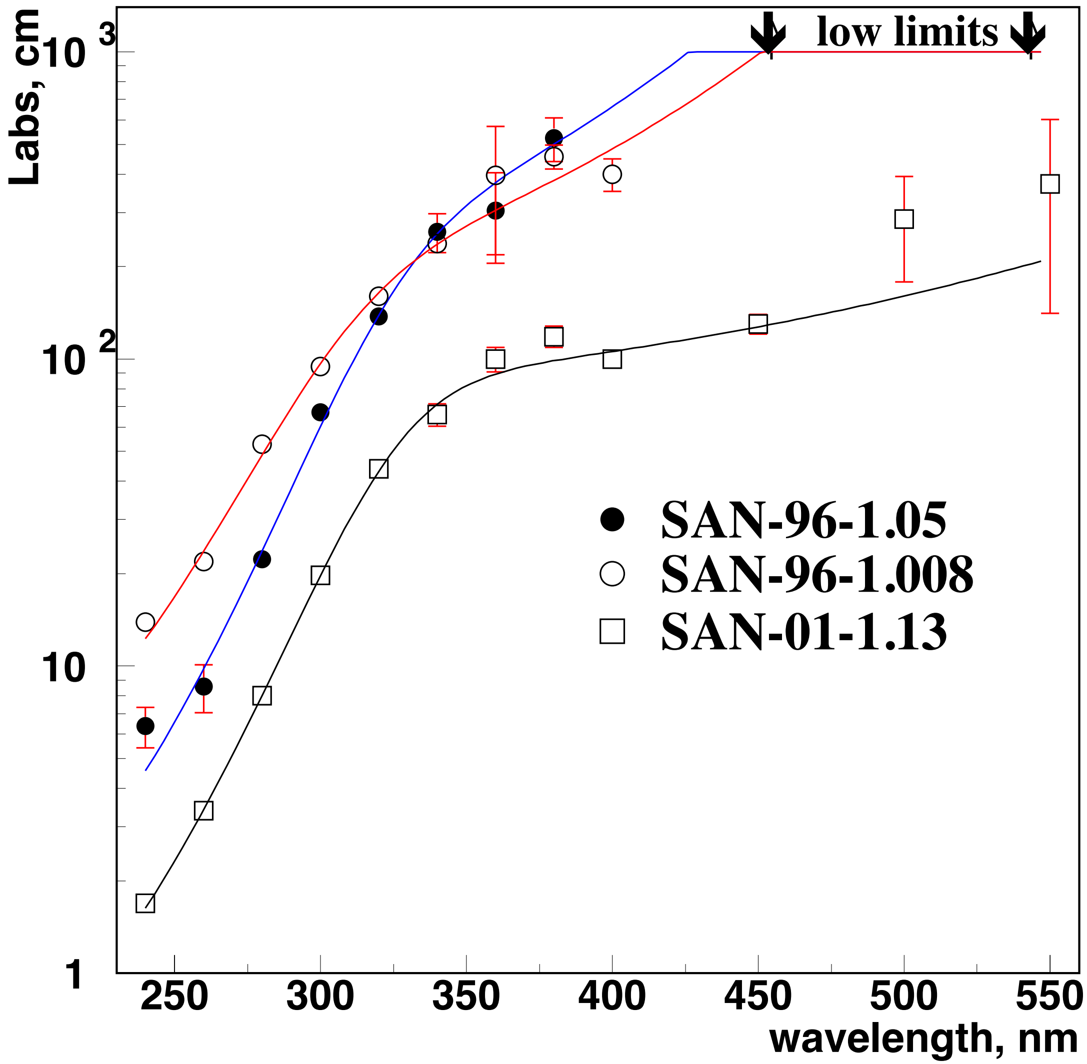


A – surface scattering coefficient
~0.95 for intrinsic surface
~0.70 for polished surface

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

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

Light absorption

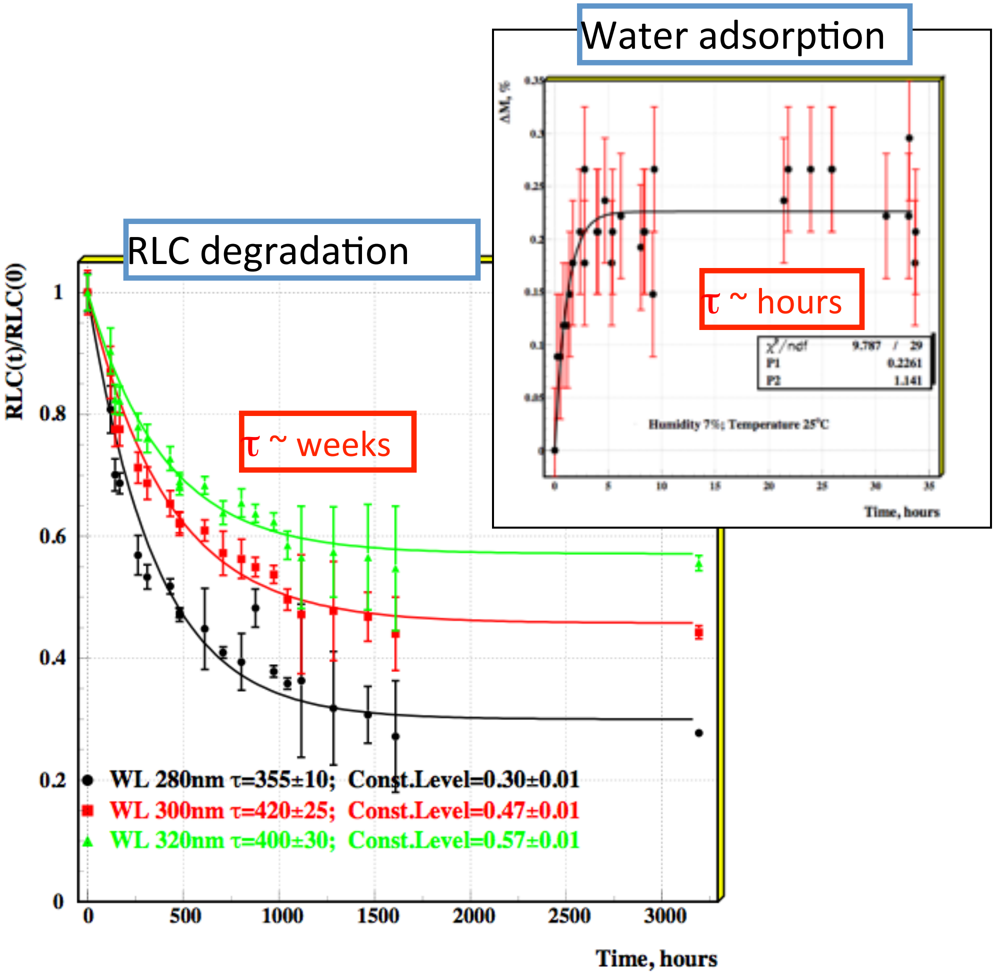


Light is absorbed by impurities.

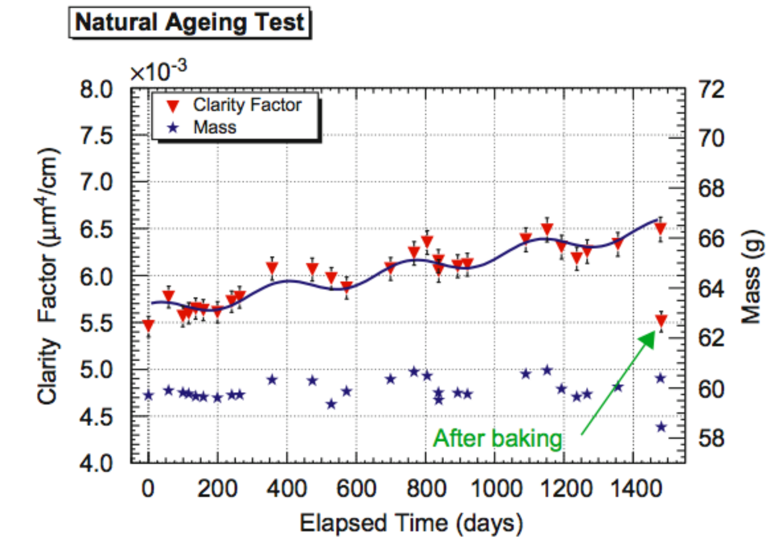
Contamination of metals (Fe, Co, Cu, Mn, etc.) is determined by raw material quality and synthesis technology.

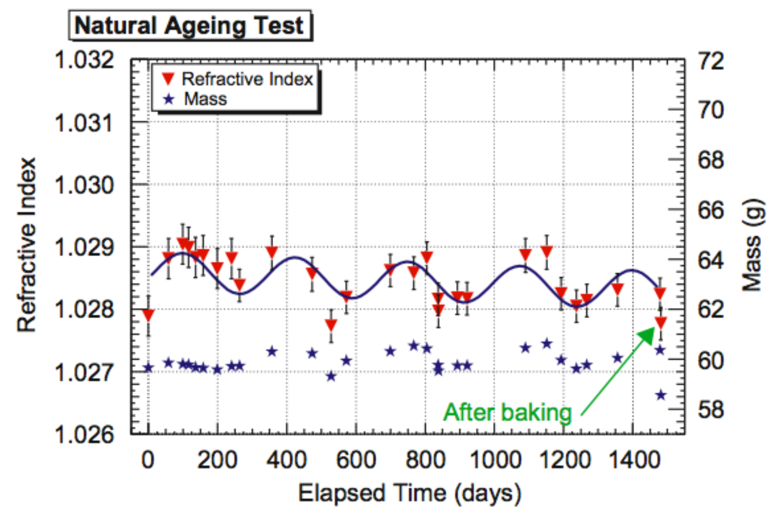
Water adsorption

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



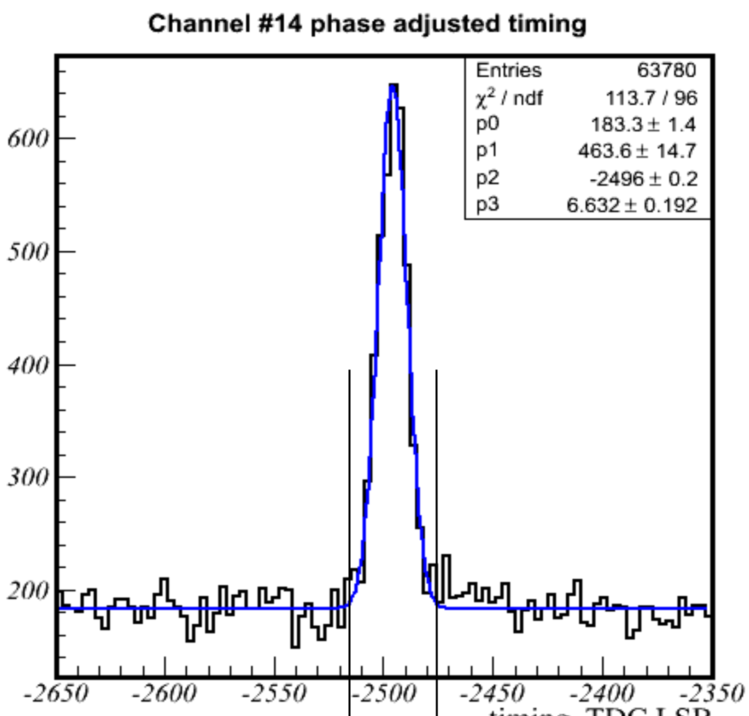
A.Yu.Barnyakov et al., NIM A598 (2009) 166

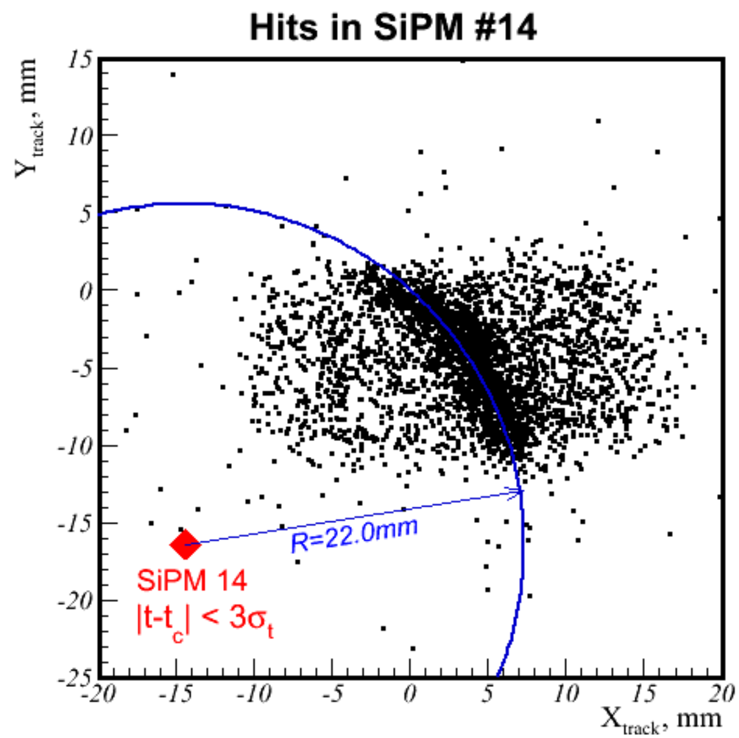




D.L.Perego, NIM A595 (2008) 224

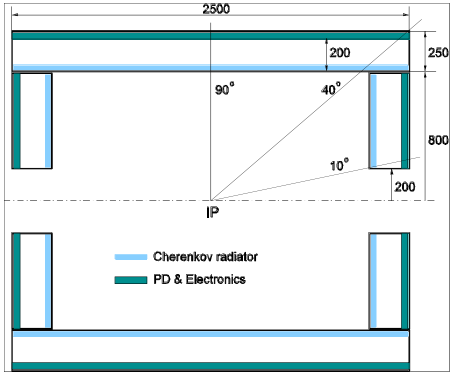
Event selection





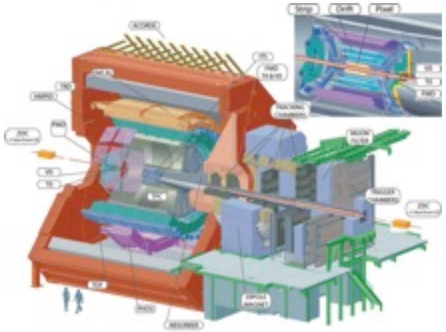
- **We select events with |t-t$_{ch}$|<3σ$_t$**

FARICH proposals



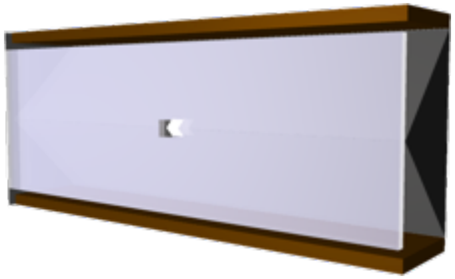
FARICH for Super Charm-Tau Factory (Novosibirsk)

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