FARICH system for Super c-τ Factory.

A. Barnyakov

Budker Institute of Nuclear Physics

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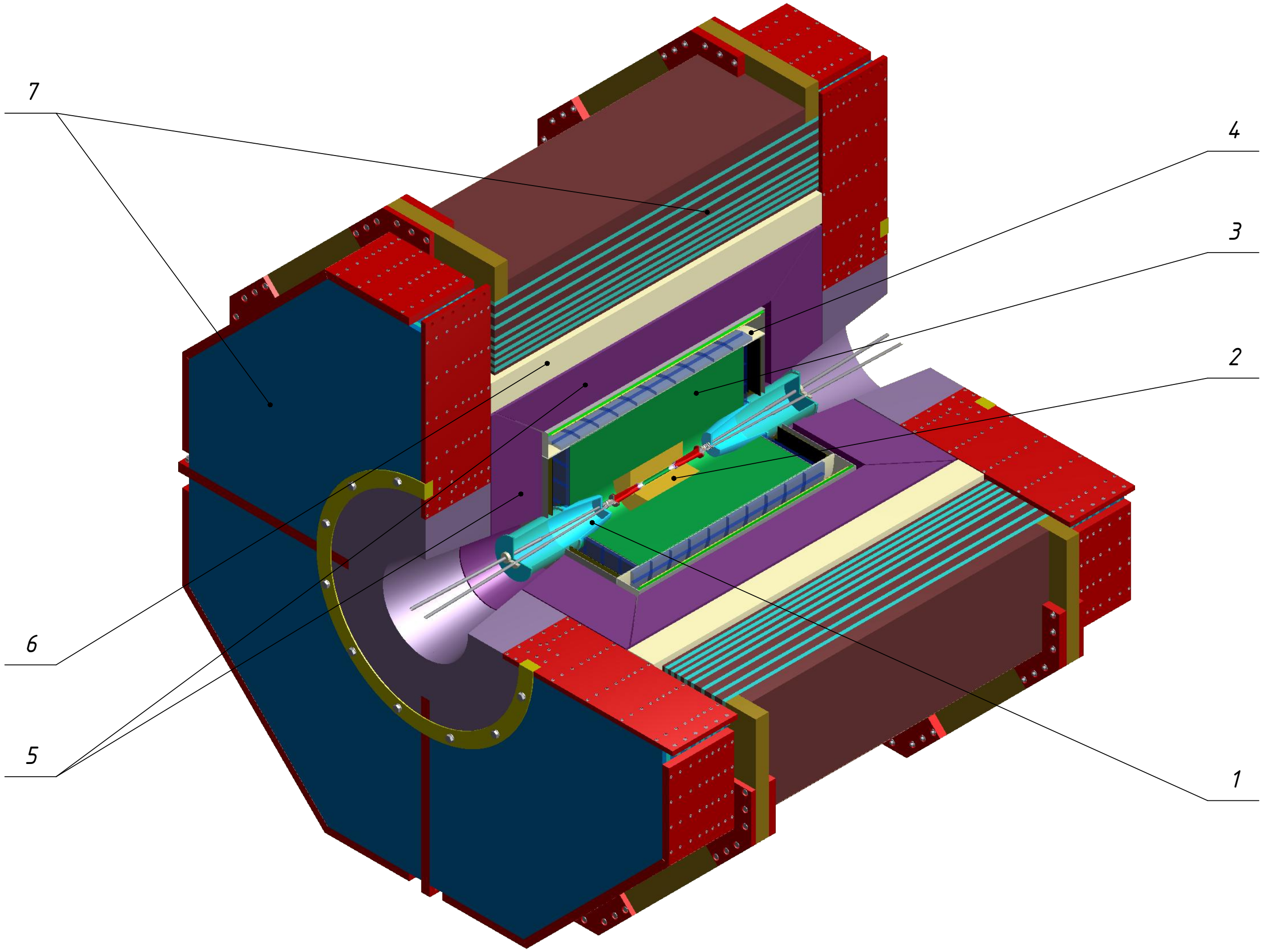
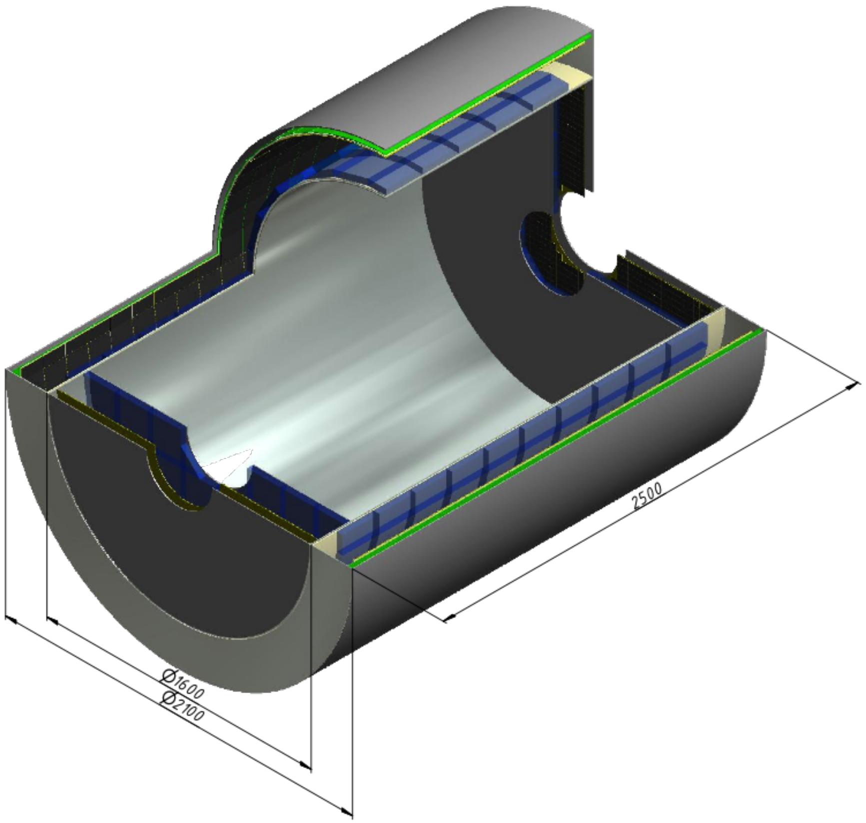


1. CVC
2. Inner tracker
3. Drift chamber
4. PID system
5. Calorimeter
6. SC coil (B∼1 T)
7. Yoke and MU system

PID system sketch and requirements



System sketch

Requirements

High PID quality

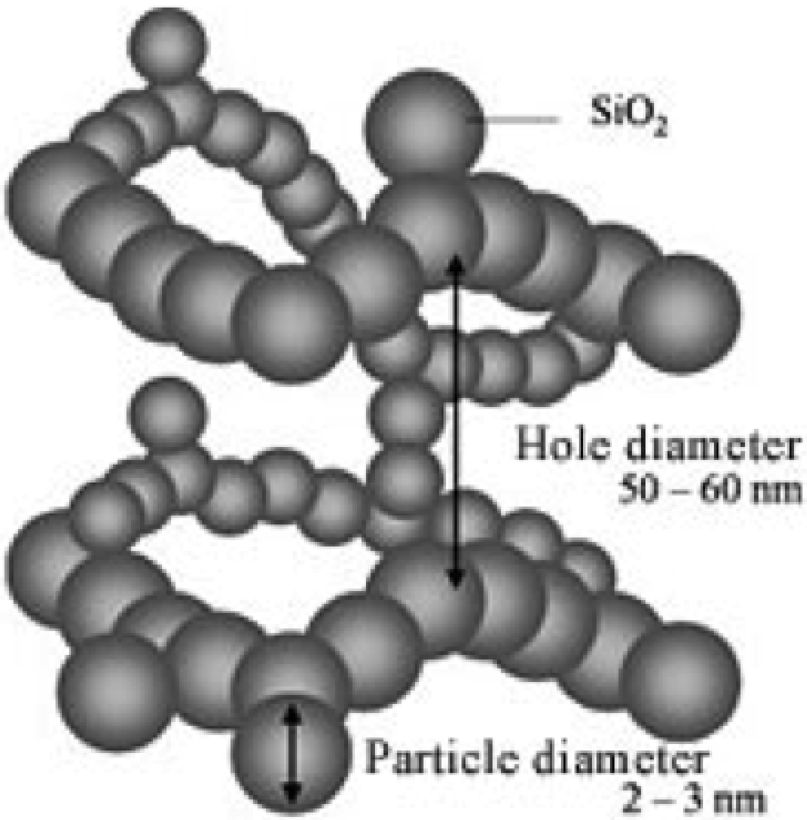
- π/K-separation from 0.6 to 2.5 GeV/c (i.e. for D-meson mixing study)
- μ/π-separation from 0.4 up to 1.5 GeV/c (rare τ-lepton decays i.e. $\tau \to \mu\gamma$)

Main aerogel properties:

- Refraction indices 1.006÷1.20;
- Inner surface 800 m^2/g;
- L_{abs}(400nm)=5÷7 m;
- L_{sc}(400nm)=4÷6 cm;

Aerogel production in Novosibirsk

- It started in 1986 (IC&BINP);
- Aerogel for threshold counters:
  - n=1.008 for DIRAC-II (PS–CERN);
  - n=1.05 for KEDR (VEPP-4M);
  - n=1.13 for SND (VEPP-2000).
- Aerogel for RICH counters:
  - n=1.03 for LHCb (LHC-CERN);
  - n=1.05 for AMS-02 (ISS) & CLAS-12 (J-Lab);
- Modern production activity:
  - Blocks dimensions 200×200×30(20) mm;
  - L_{sc} ⩾4.5 cm;
  - 2 m^2/year aerogel;
  - Multilayer (2÷6) monolithic samples have been producing since 2004.



Aerogel structure

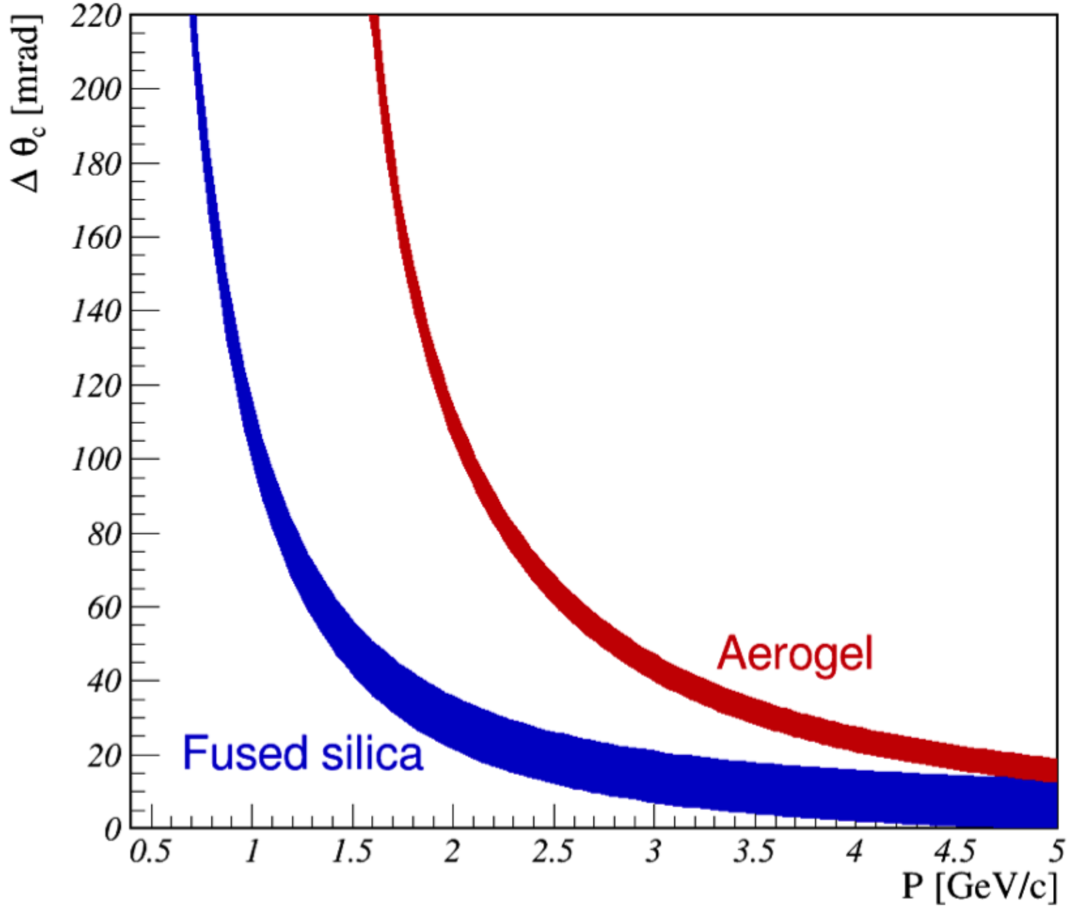
Aerogel & Quartz

Refractive index

$n \downarrow \rightarrow \Delta\Theta_c \uparrow$

Chromatic Dispersion (D_n)

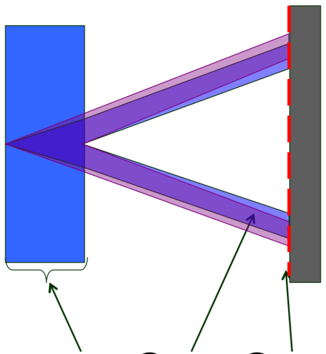
$D_n \downarrow \rightarrow \sigma(\Theta_c) \downarrow$



$\Delta\Theta_c$ for π and K.

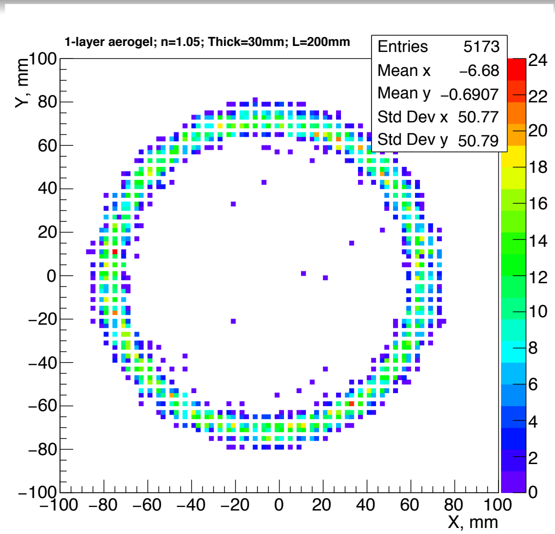
Bands correspond to chromatic dispersion in 350÷700 nm.

Lower refractive index lead to lower number of Cherenkov photons.
To increase N_{phot} without angle resolution degradation focusing is needed.
Proximity focusing approach with multilayer aerogel (FARICH) is suggested.

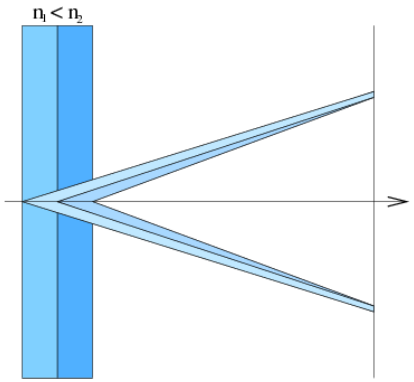


$$\sigma_{\theta,1\gamma} = \sigma_{ep} \oplus \sigma_{ch} \oplus \sigma_{px}$$

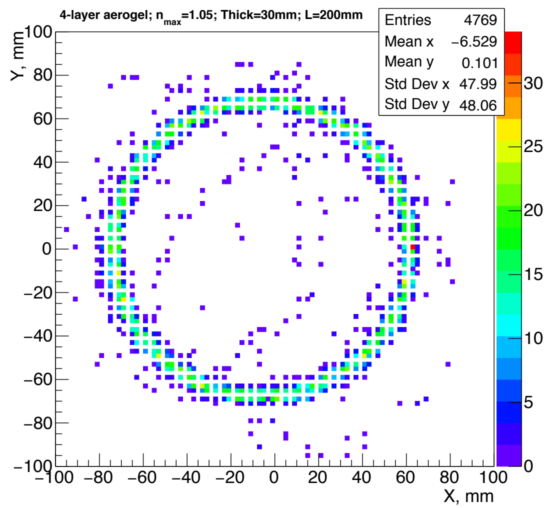
Proximity focusing single layer RICH



Simulation results: n=1.05, thickness 3 cm, L=20 cm, QE(MPPC, Hamamatsu), pixel 3×3 mm, pitch 3.2mm.

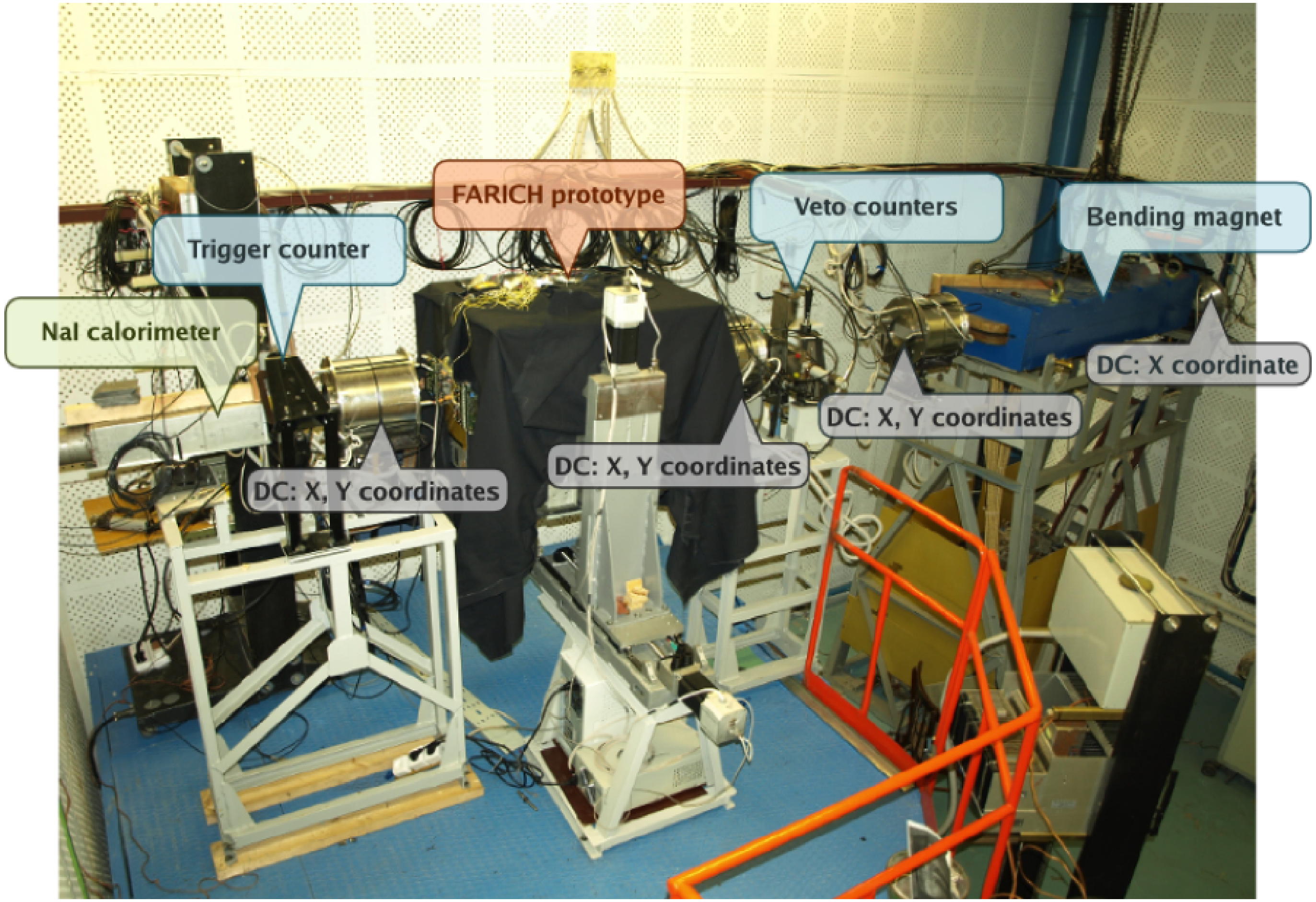


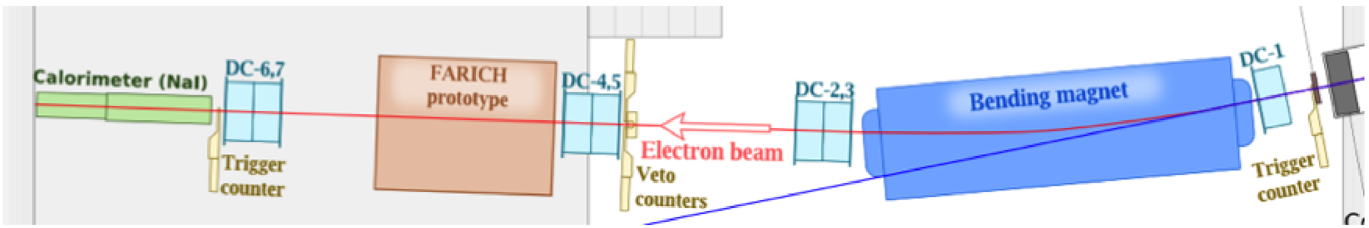
Proximity focusing multilayer RICH

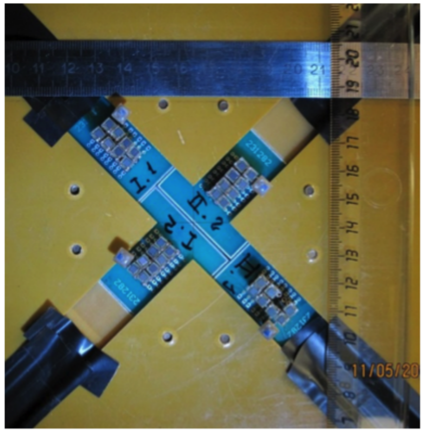


Simulation results: n_{max}=1.05, thickness 3 cm, L=20 cm, 4-layer aerogel.

Prototype with CPTA MRS APDs BINP e^- test beam in 2011







32 CPTA MRS APDs with active pixel size 2.1x2.1mm^2

4-layer aerogel focusing at 62 mm

n_1=1,050 t_1=6,2mm

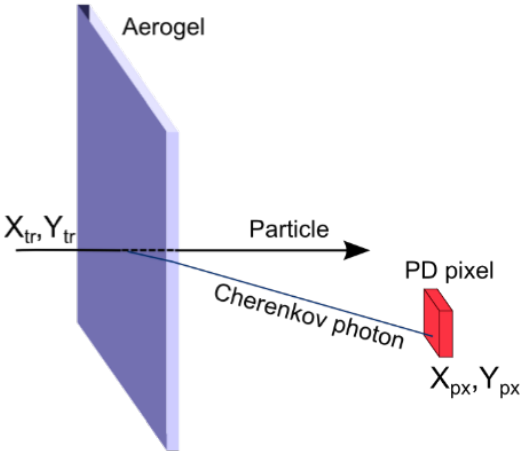
n_2=1,041 t_2=7,0mm

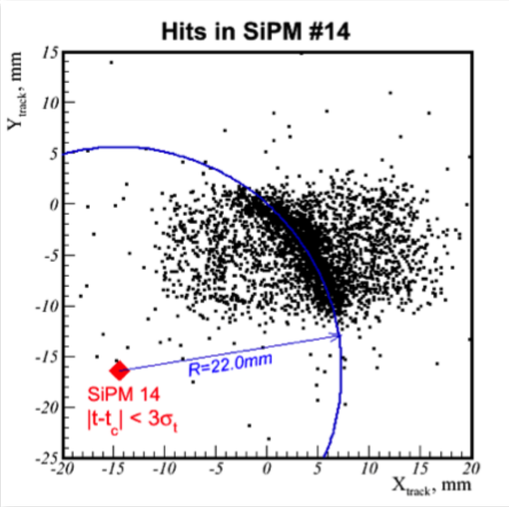
n_3=1,035 t_3=7,7mm

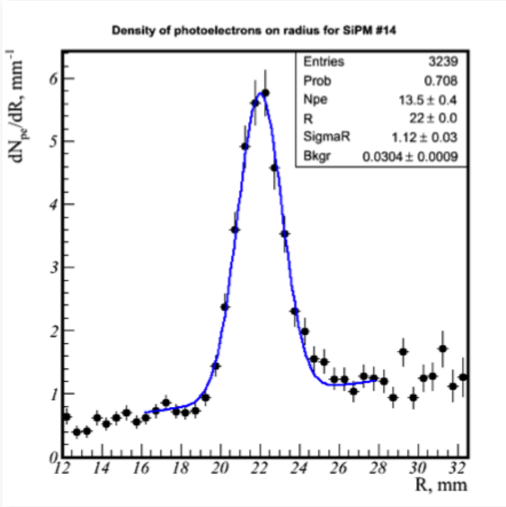
n_4=1,030 t_4=9,7mm

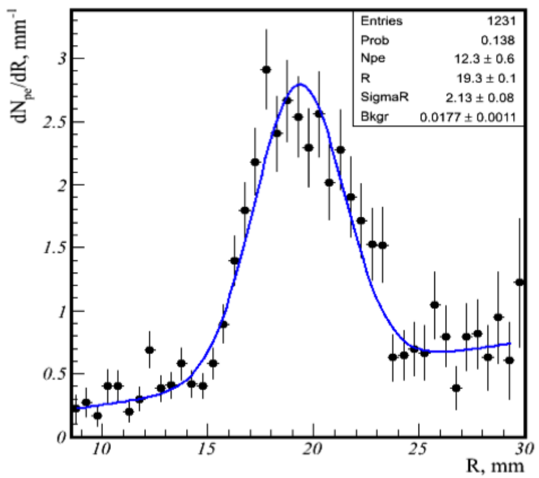
Size: 100x100x31mm^3

L_{sc}(400nm) = 43mm



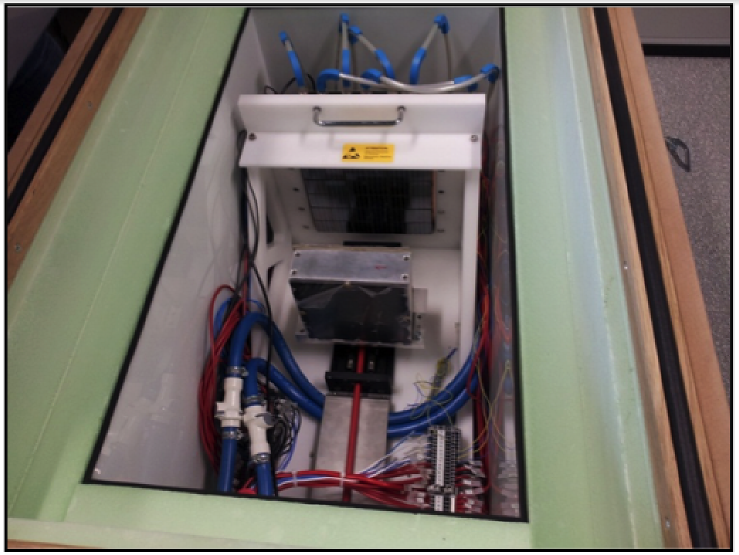






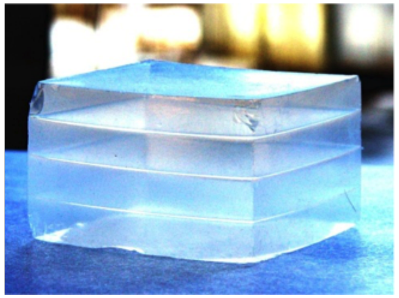
Main results

- Effect of focusing was demonstrated:
  - σ_R=1.1 mm for 4-layer aerogel t=30 mm;
  - σ_R=2.1 mm for 1-layer aerogel t=20 mm;



Beam test at CERN PS/T10 in 2012

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

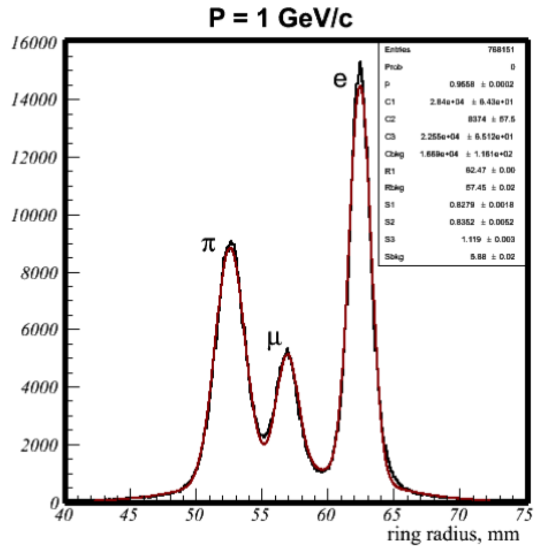


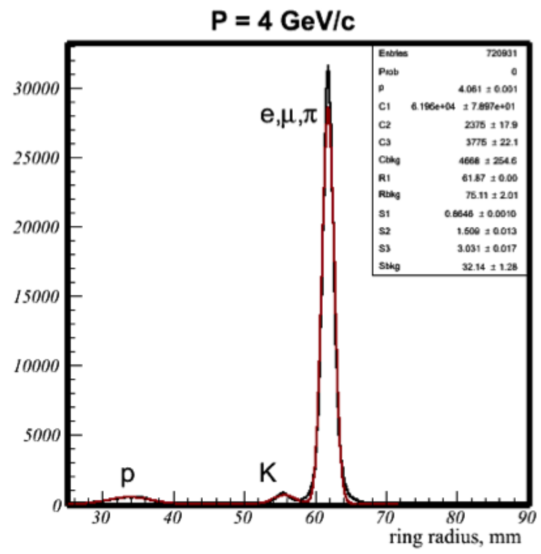
Aerogel

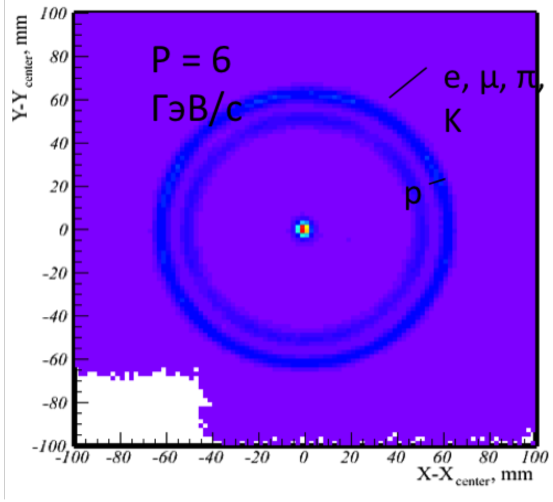
- 4-layer
- $n_{max} = 1.046$
- Thickness 37.5 mm
- Focal distance 200 mm

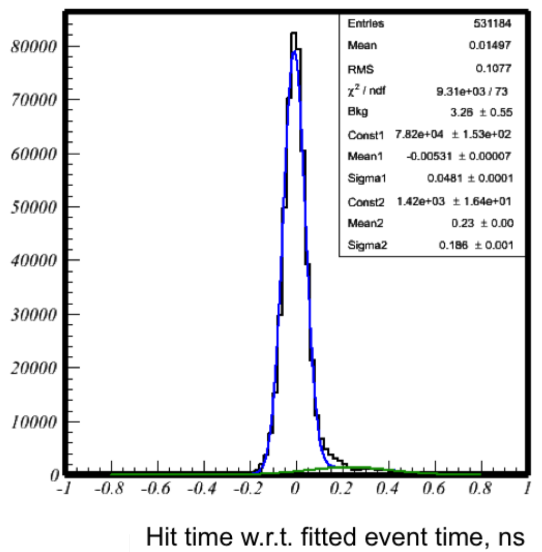
DPC matrix 20×20 cm

- Sensors: DPC3200-22-44
- 3×3 modules = 6×6 tiles = 24×24 dies = 48×48 pixels
- 576 time channels
- 2304 amplitude (position) channels
- Operation temperature is -40°C to suppress dark count rate
  - Dead time is 720 ns
  - DCR(+25°C)≈10 Mcps/sensor single photon detection is not feasible!
  - DCR(-40°C)≈100 kcps/sensor inefficiency is 7%

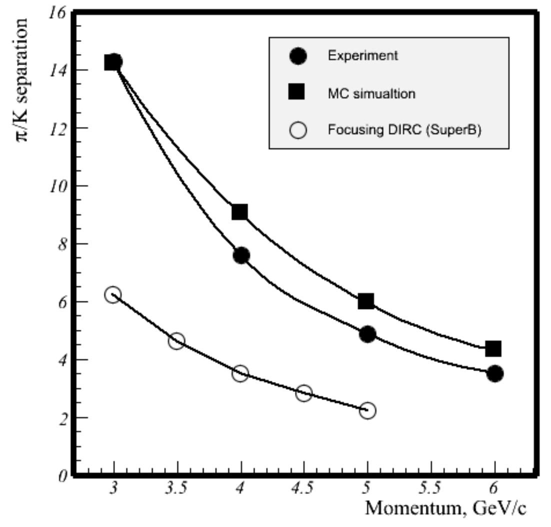






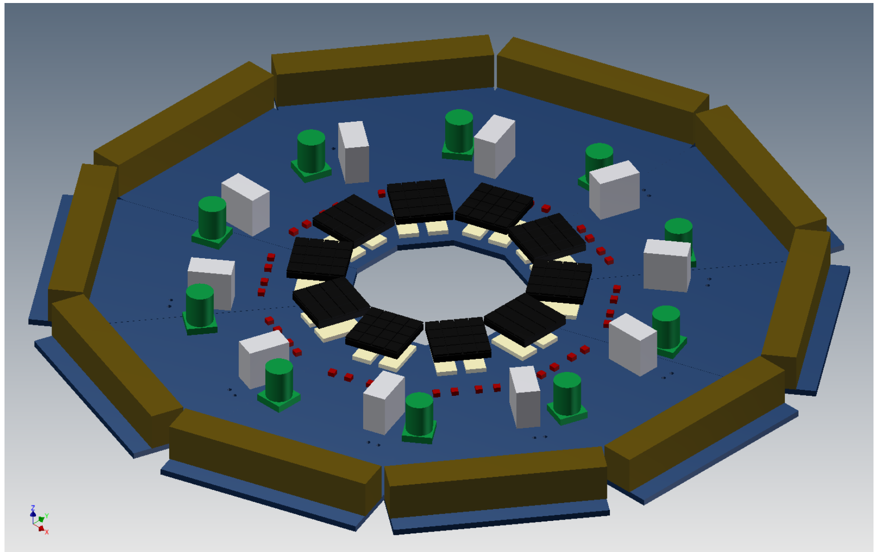


- $S(\pi/K) = \frac{R_\pi - R_K}{\sigma_{R_\pi}}$
  - π/K: 7.6σ at 4 GeV/c;
  - μ/π: 5.3σ at 1 GeV/c;
- N$_{pe}$=12;
- σ_t=48 ps for single photon;

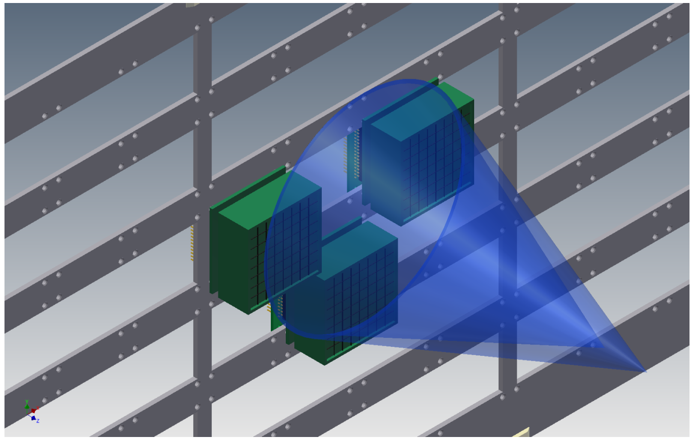


3^{rd} prototype generation to:

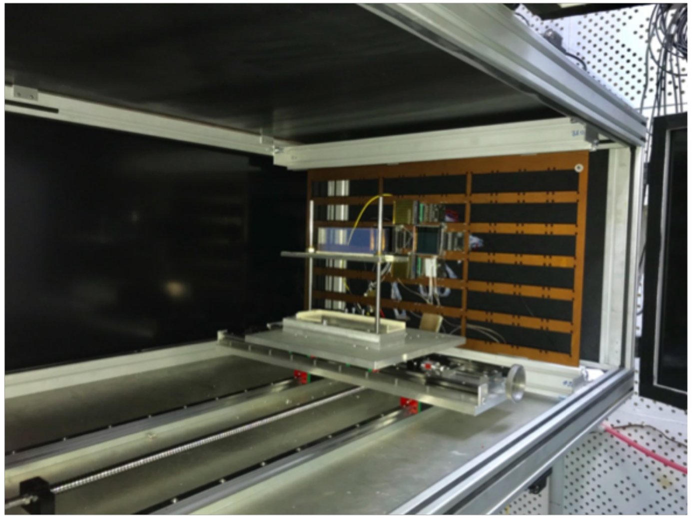
– Determine critical moments in focusing aerogel production;
– Define optimal photon detector type and producer for SCTF;
– Find solution for readout electronics.



10×16 pixel SiPM matrix.



3×64 anodes PMTs.



- SiPM matrix + Discr. + TDC
- SiPM matrix + ASIC (integrated Discr.& TDC)
- HAPD + readout electronics
- MCP PMT + readout electronics

Photon detectors

The general candidates is SiPMs:

– Analog SiPM:

Advantages:

- Magnetic field immunity
- High PDE
- Acceptable DCR at room temperature

Disadvantages

- Especial designed electronic is needed
- Low radiation hardness

– Digital SiPM

Advantages

- Magnetic field immunity
- Digitizing electronics is integrated
- Timing resolution ~ 50 ps

Disadvantages

- Lower PDE
- Low radiation hardness
- Operation at – 20÷40°C to reduce DCR

Photon detectors

Optional candidates:

- HAPDs:
  - Magnetic immunity to axial fields
  - Radiation hardness is enough for SuperB factories
  - Readout electronics is developed
- MCP PMTs
  - Magnetic immunity to axial fields
  - PE collection in 2 times smaller in magnetic field 1T&45°
  - Radiation hardness is enough for SuperB factories
  - Readout electronics is developed
- Possible solution:
  - MCP PMTs or HAPD – endcap part of the system
  - (D)SiPM – barrel part of the system

Summary

- Focusing effect was demonstrated with monolithic 4-layer aerogel in 2011.
- π/K-separation $\geqslant 4\sigma$ up to 6 GeV/c and μ/π-separation $\geqslant 5\sigma$ at 1 GeV/c were obtained with prototype based on 4-layer aerogel and 20×20 cm pixel matrix from DPC Philips in 2012.
- PID technique based on focusing aerogel now is used in Belle-II experiment.
- SiPM have good tolerance to magnetic fields but radiation tolerance could be not enough for SCTF.
- There several option of photon detectors with better radiation tolerance but they are able to work only in axial magnetic field
- We need to estimate radiation flux to make right chose of photon detectors.
- To optimize FARICH system construction and compare different option we are going to start simulation FARICH system response to the physics processes.