RICH with focusing aerogel

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Budker Institute of Nuclear Physics

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History

Aerogel RICH

- **1977** — first successful demonstration of the Ring Imaging CHerenkov counter;
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  Aerogel RICH for HERMES and LHC*b* experiments were proposed
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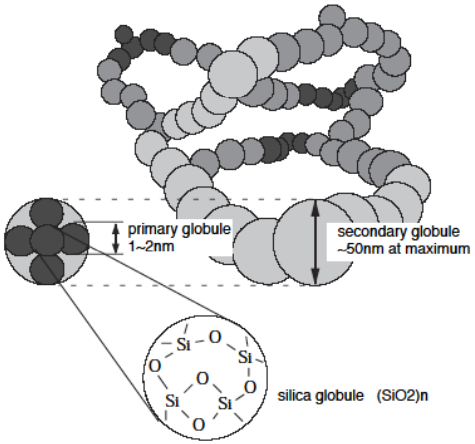
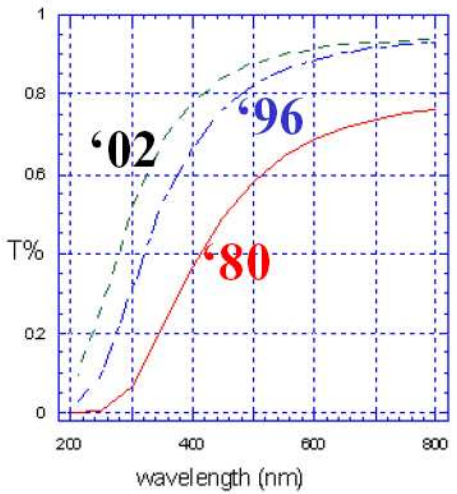


producer	year	$L_{\rm sc}(0.4\mu{\rm m})$
Novosibirsk	'02	5 cm
Matsushita	'96	2.3 cm
Airglass	'80	1 cm



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- **1998** — HERMES RICH with a dual gaseous and aerogel radiator.
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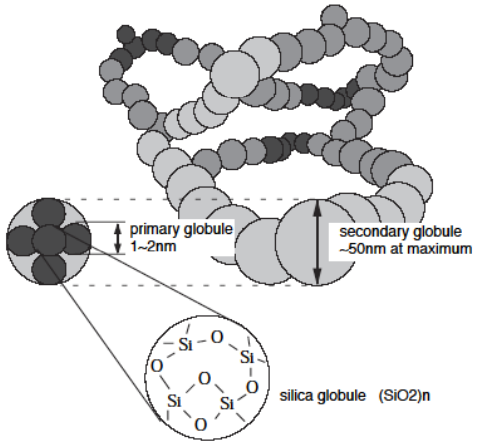

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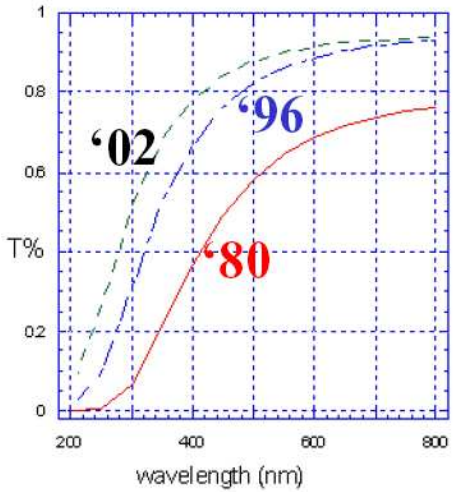

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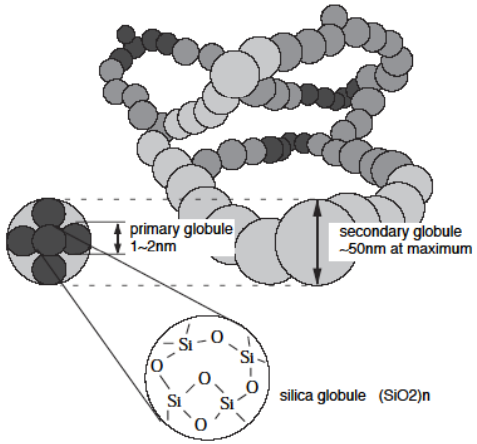
- **1998** — HERMES RICH with a dual gaseous and aerogel radiator.
  D. Ryckbosch, NIMA433 (1999) 98;
- **2003–2004** — idea of a multilayer 'focusing' radiator came up.
  P.Križan, talk at SuperB wokshop in Hawaii, Jan 2004
  A.Yu.Barnyakov et al., NIMA553 (2005) 70



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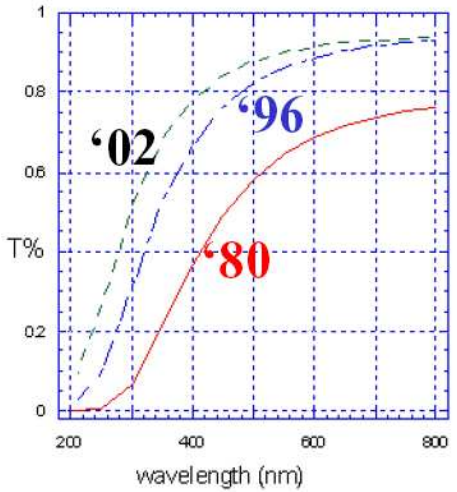

Novosibirsk experience

Works at Novosibirsk (BINP & BIC)

- **1986** — beginning of aerogel development in Novosibirsk by collaboration of *Budker INP* and *Boreskov Institute of Catalysis*.
  Since then a substantial progress in aerogel transparency have been achieved:
  $L_{sc} \approx 5$ cm, $L_{abs} \approx 5$–7 m @ 400 nm, n=1.006–1.13.
  Production:
  KEDR (VEPP4-M) — 2000l of n=1.05,
  SND (VEPP-2000) — a few litres of high density aerogel of n=1.13,
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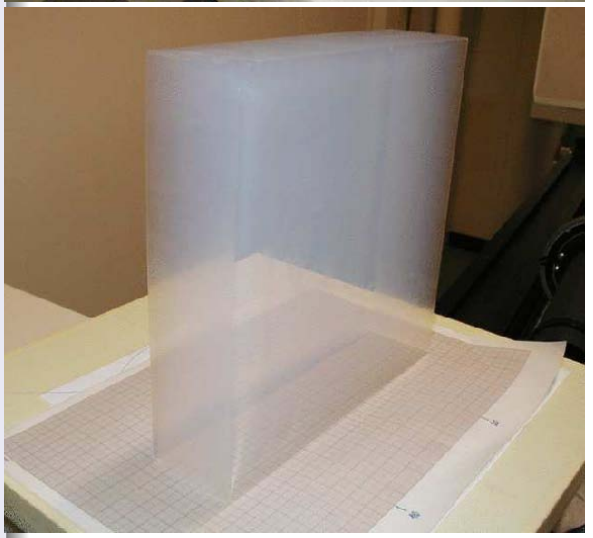
- **2002** — started works towards aerogel RICH.
  LHC-b RICH: 20l, n=1.03, record breaking dimension $200 \times 200 \times 50$ mm^3,
  AMS RICH: 60l, n=1.05, dimension $115 \times 115 \times 25$ mm^3.



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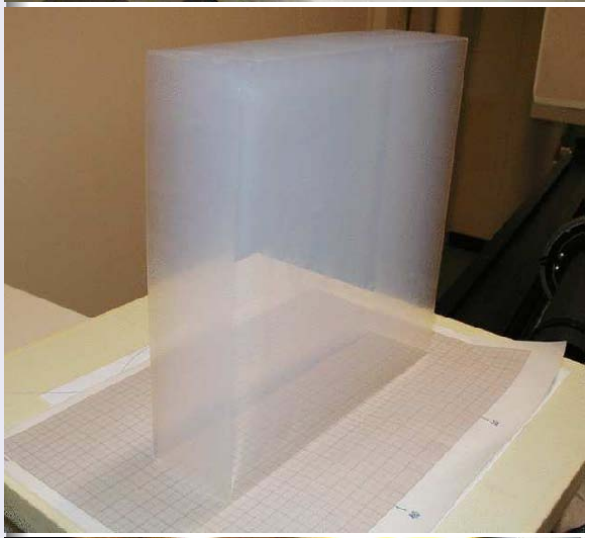
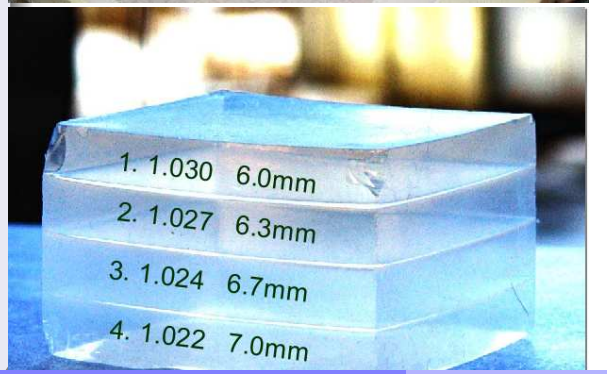
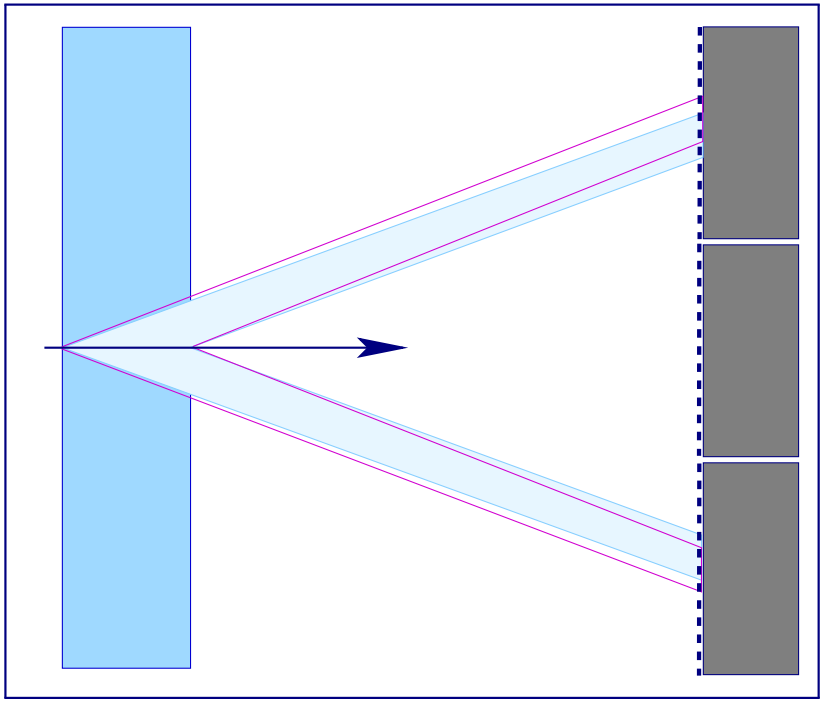
- **2004** — multilayer focusing aerogel was proposed. 4-layer aerogel tile was produced for the first time. Toy simulation program using Geant4 has been developed.



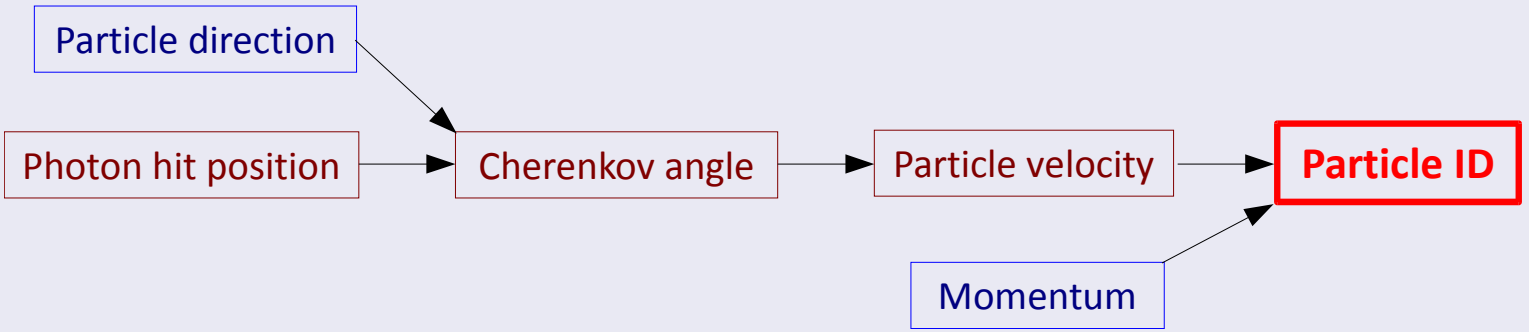


Proximity focusing RICH



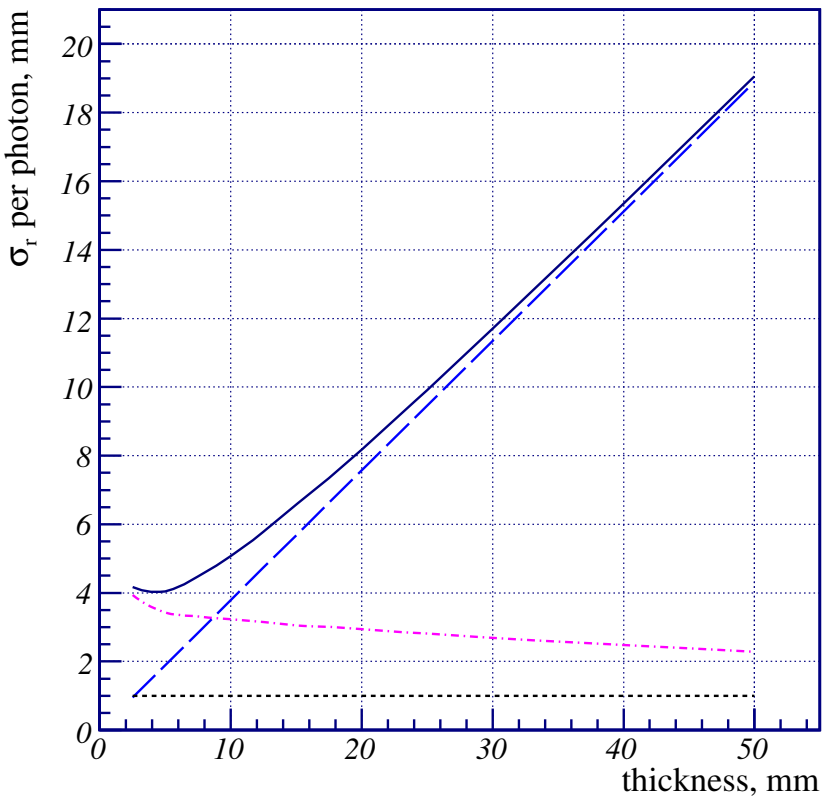
$$\sigma_{1\mathrm{ph}} = \sigma_{\mathrm{chrom}} \oplus \sigma_{\mathrm{thick}} \oplus \sigma_{\mathrm{pixel}}$$

Reconstruction flow

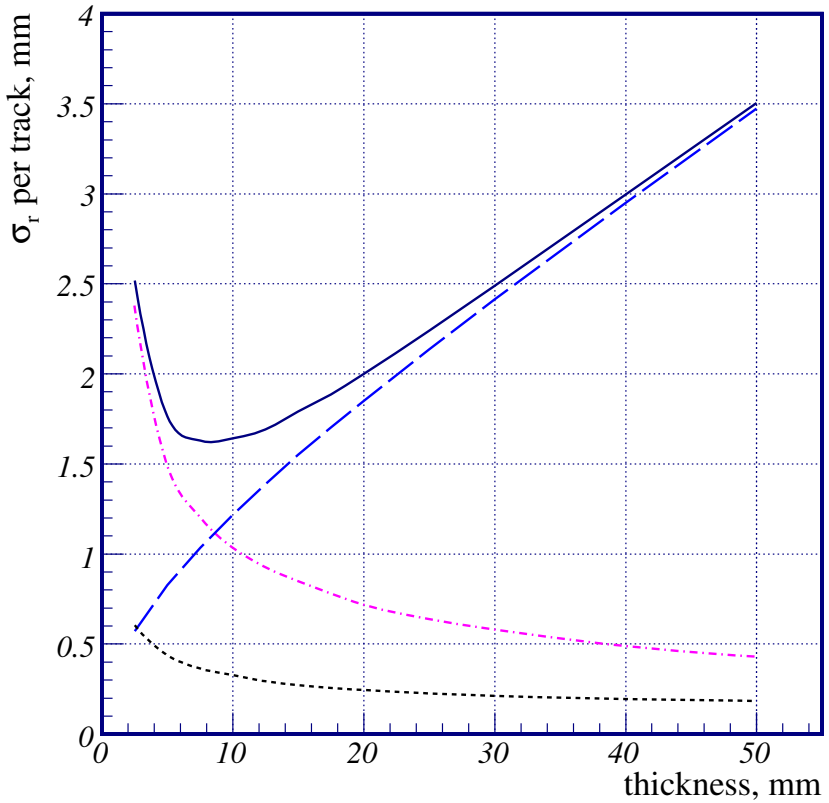


Contributions to resolution

$$\sigma_{\text{track}} = \frac{\sigma_{1\text{ph}}}{\sqrt{N}}$$

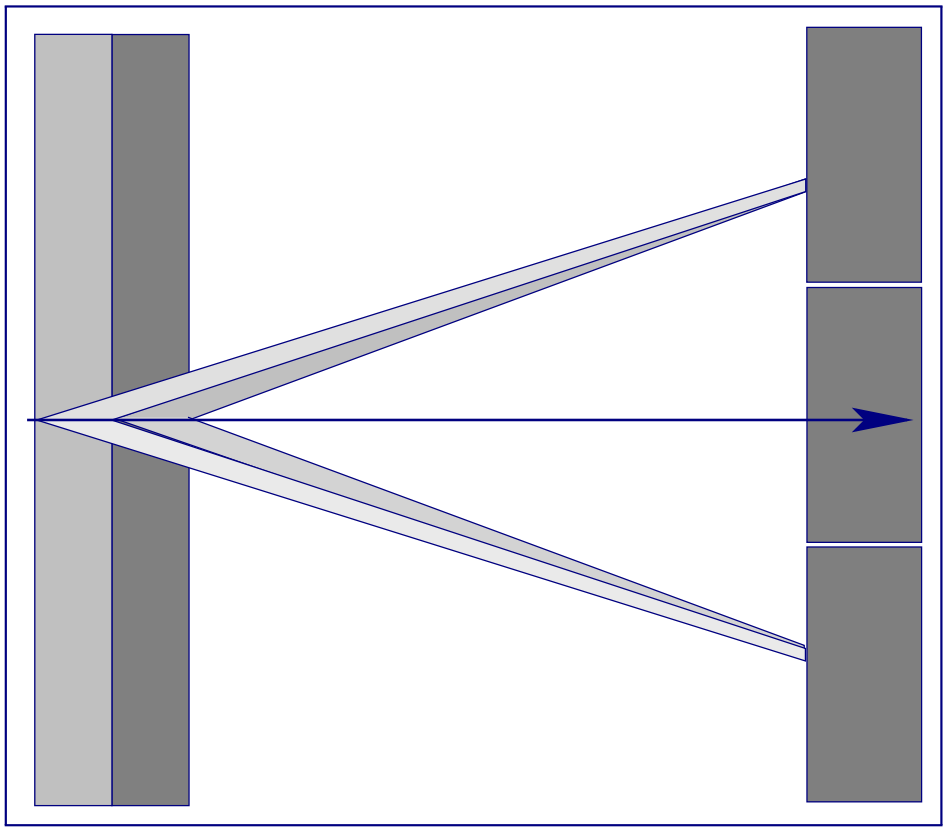


Radius error by photon.

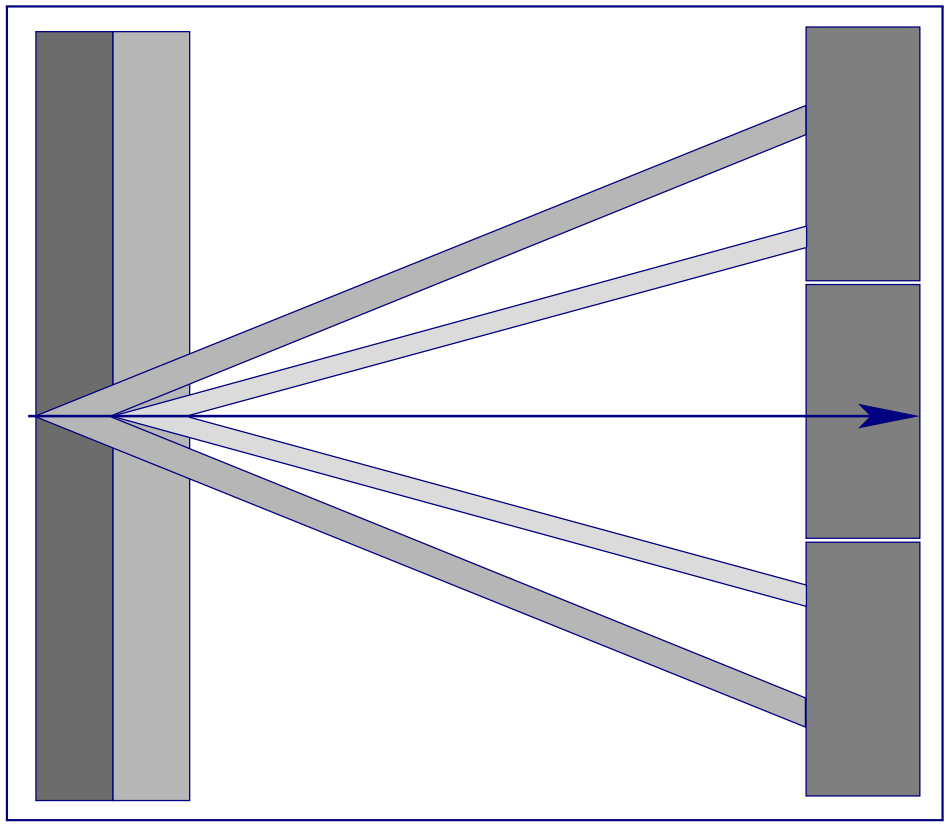


Radius error by track.

FARICH concept

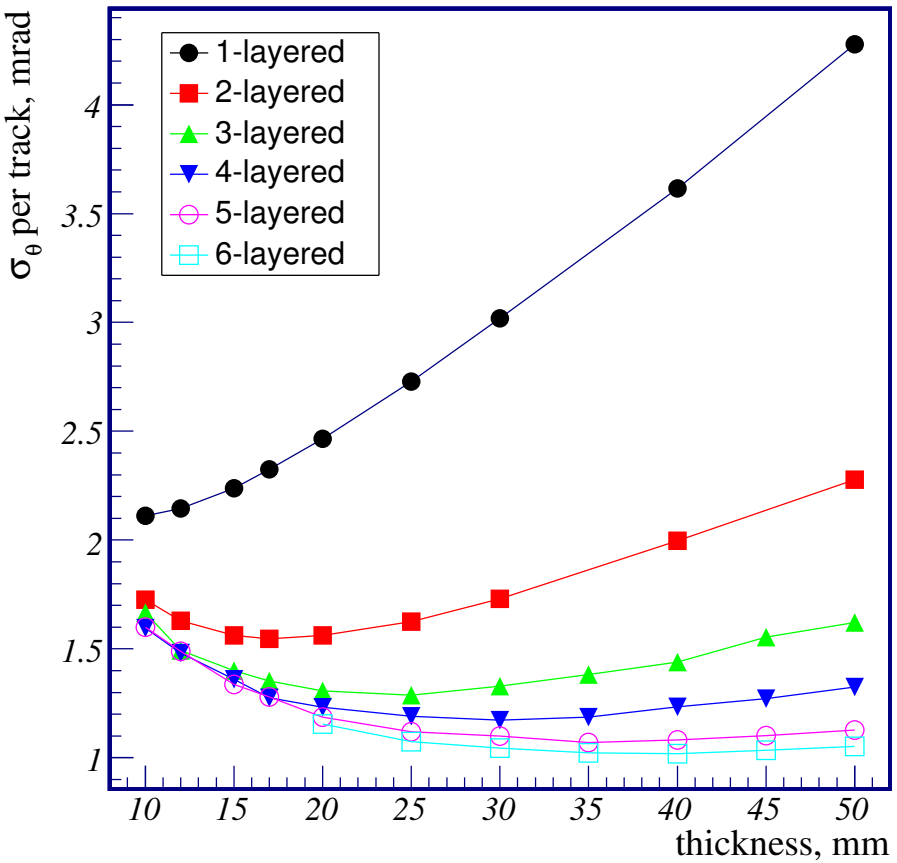


Single ring (focusing)



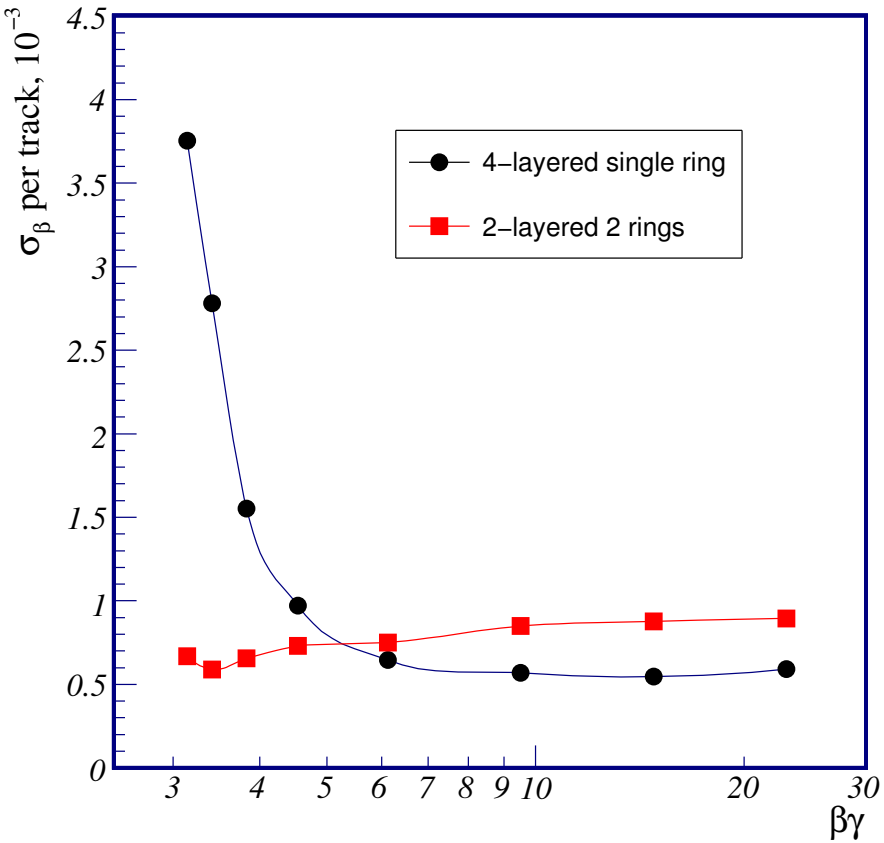
Multi-ring (defocusing)

Thickness optimization



Cherenkov angle measurement error as function of thickness.

Particle velocity resolution



β measurement error as funciton of $\beta\gamma$ for single ring and multi-ring FARICH.

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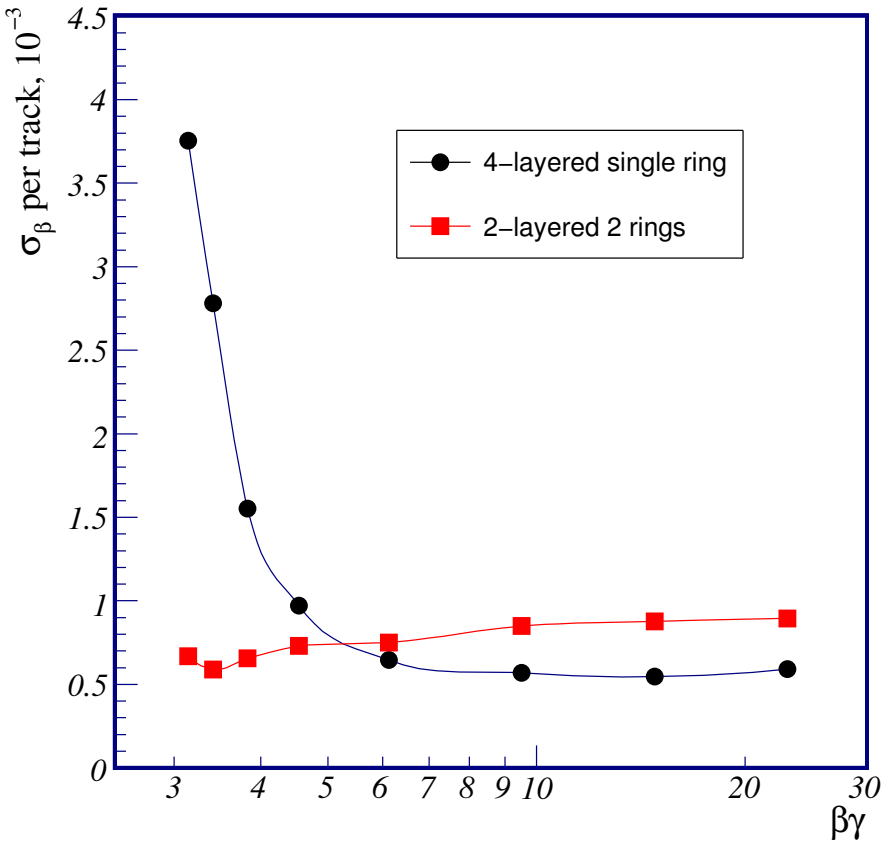

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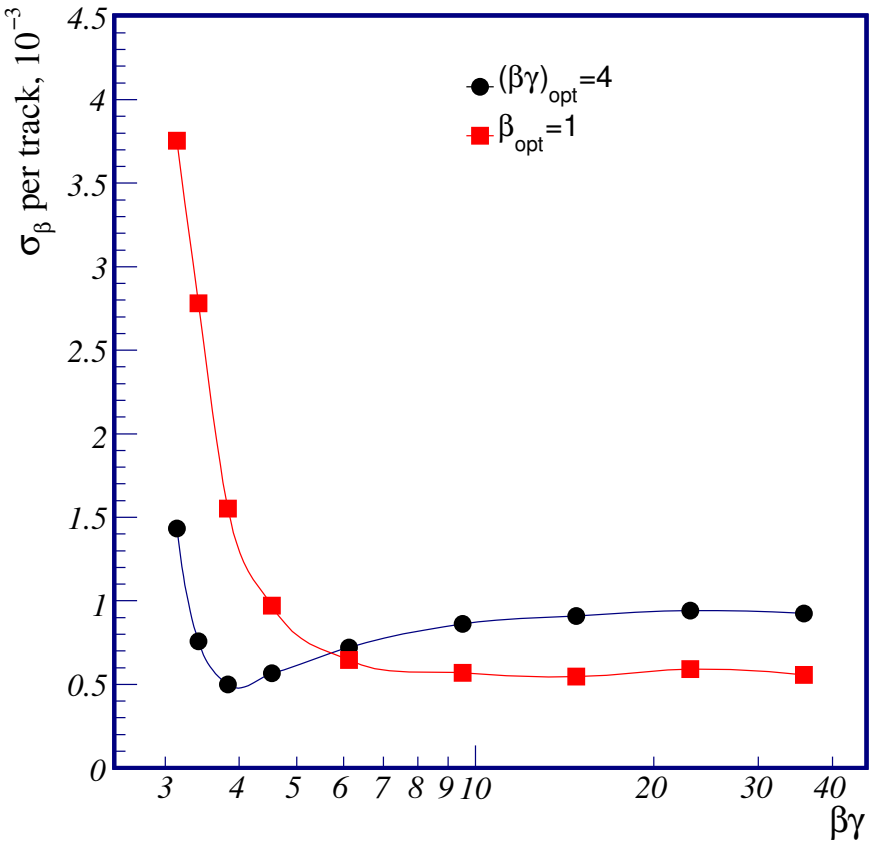
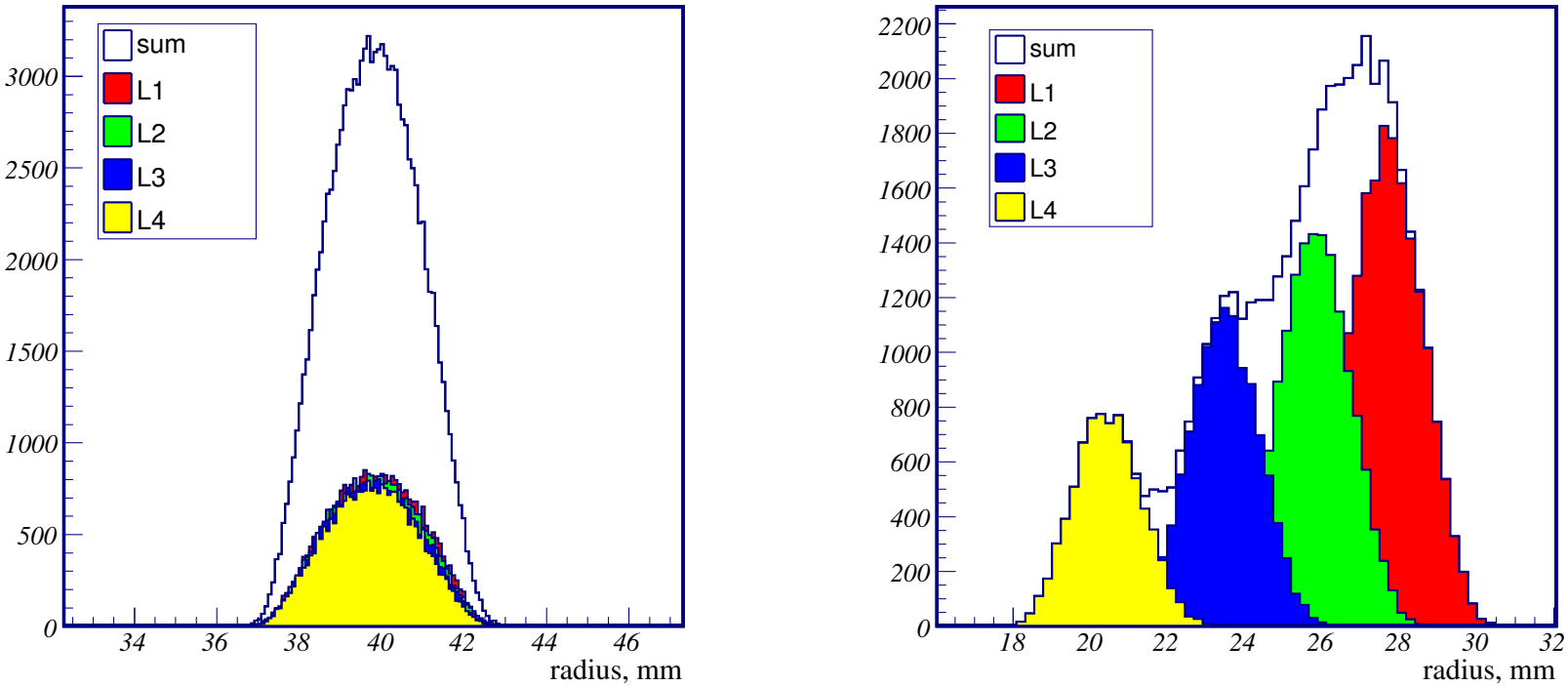


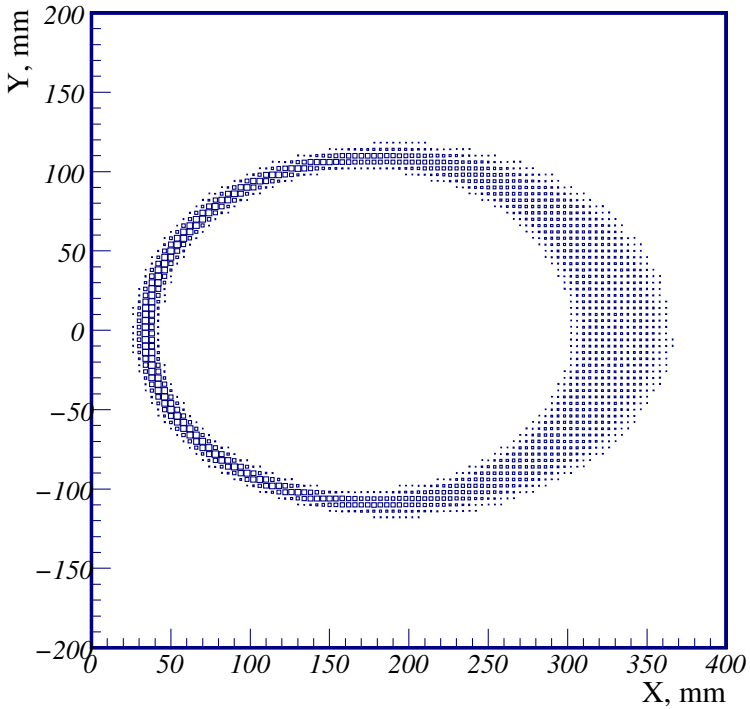
β measurement error as funciton of $\beta\gamma$ for radiators focusing at $\beta \sim 1$ and $\beta\gamma = 4$.

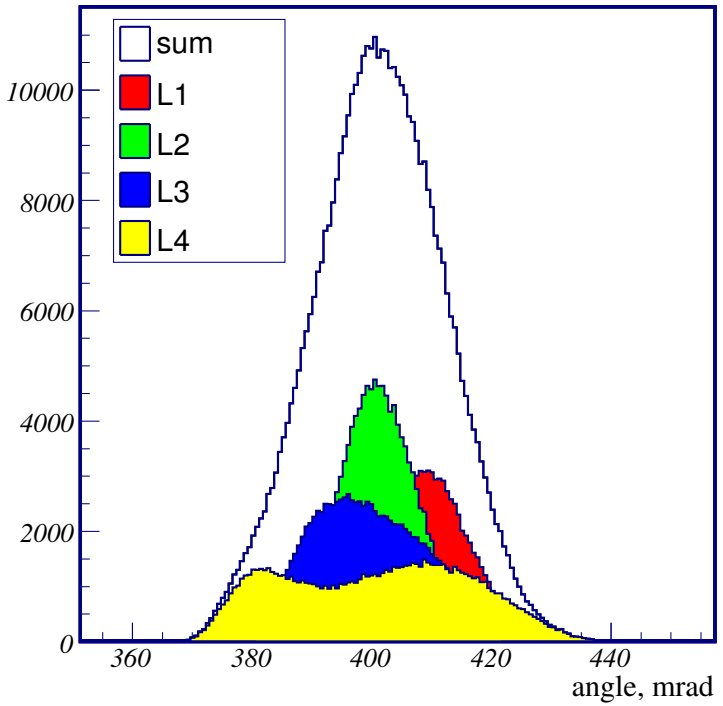
Focusing deterioration at different momenta



Photon radius distribution for π at P=5 GeV/c (left) and P=0.53 GeV/c (right) in 4-layer aerogel optimized at $\beta = 1$.

Focusing deterioration for inclined particles



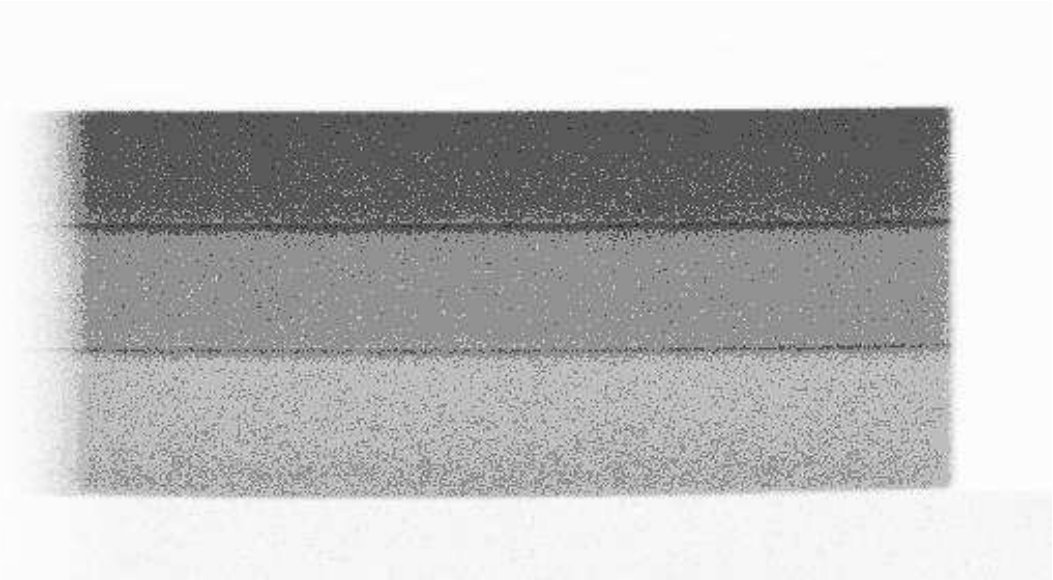


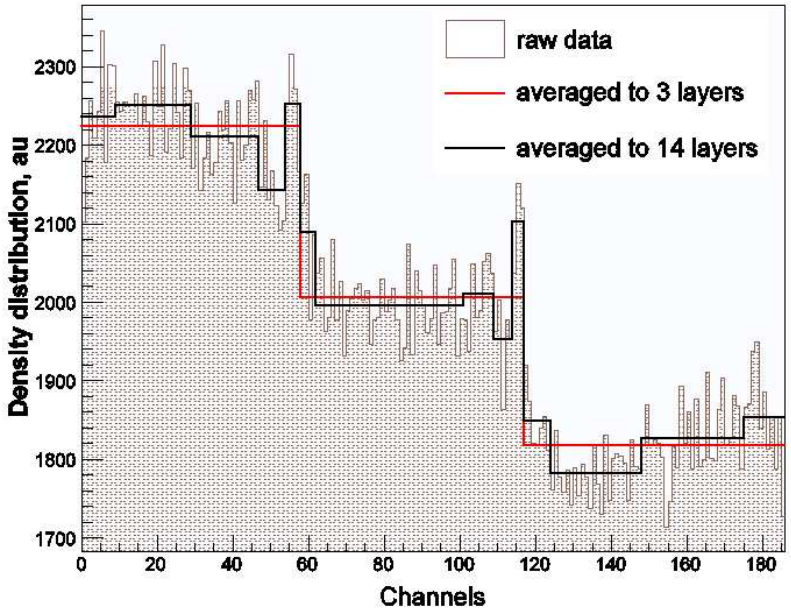
Distribution of photons by position (left) and by θ_c (right) for relativistic π with 30^o incident angle in 4-layer aerogel.

FARICH validation

3-layer aerogel $100 \times 100 \times 41$ *mm,* $L_{\mathrm{sc}} = 45$ *mm (400 nm), focusing at 20 cm for* π *@ 4 GeV/*c*.*

X-ray scan of aerogel density



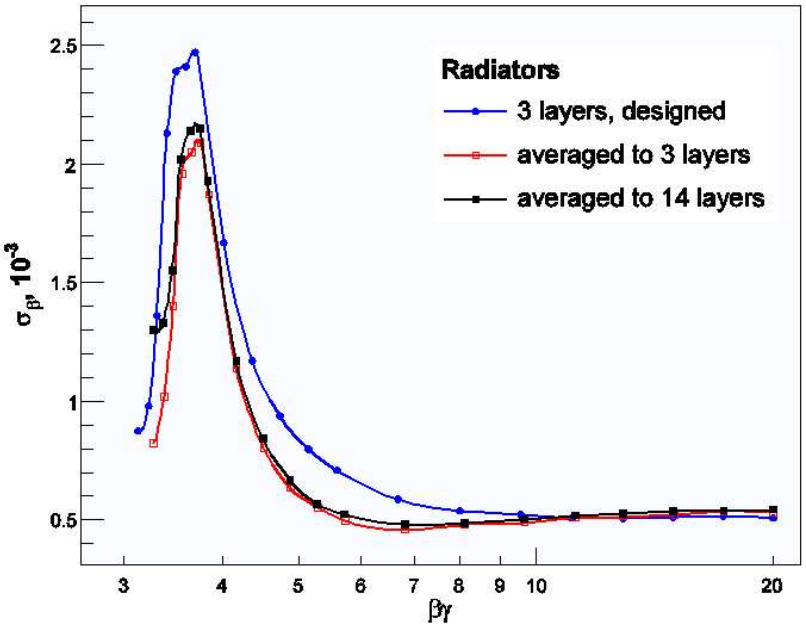


#	designed		measured		optimal
	t, mm	n	t, mm	n	n
1	12.5	1.050	12.6	1.046	1.046
2	13.3	1.044	13.2	1.041	1.040
3	14.2	1.039	15.2	1.037	1.035

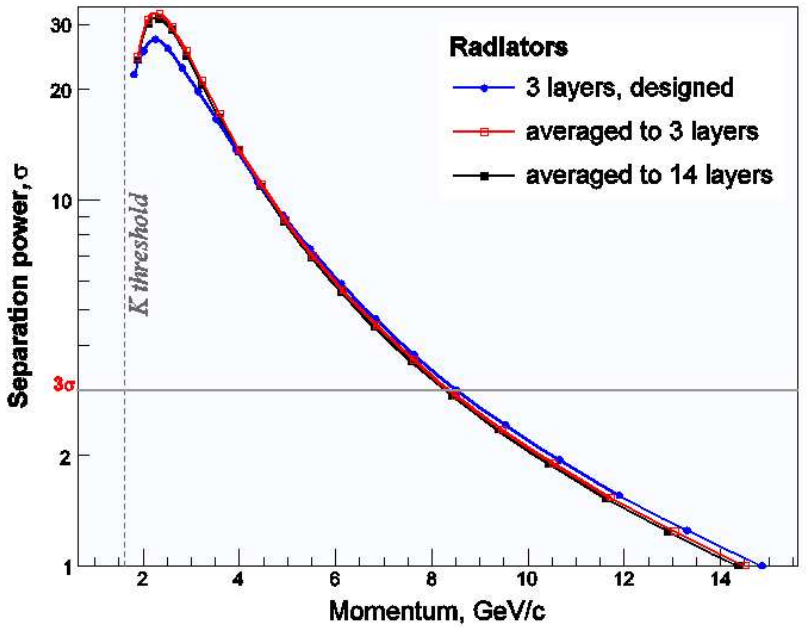
Simulation parameters:

- Distance between PMT and aerogel — 200 mm
- 3 options:
  1. designed
  2. approximation by 3 layers
  3. approximation by 14 layers

Comparison of ideal and real aerogels with simulation



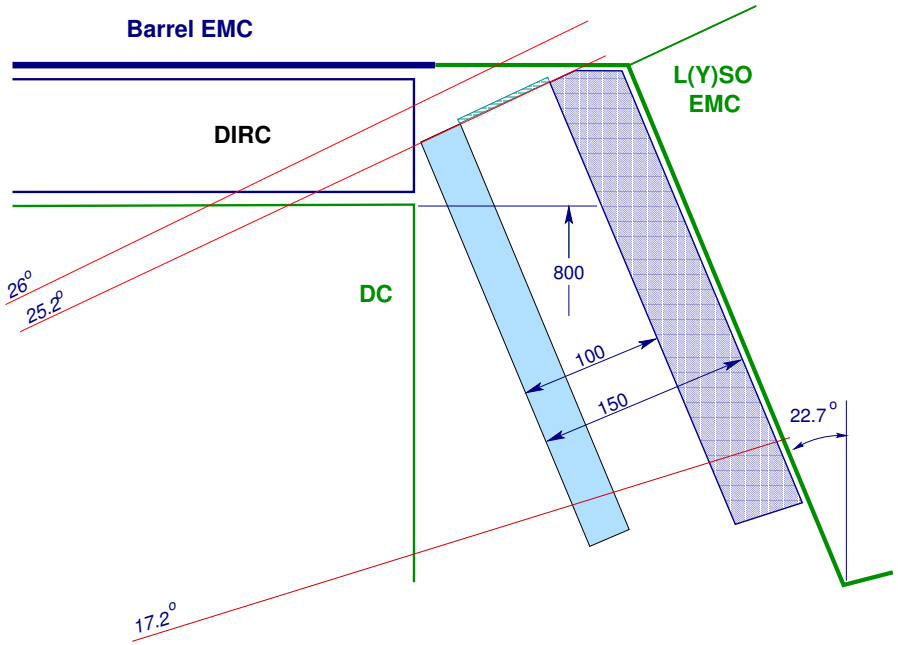
Velocity resolution as function of $\beta\gamma$.



π/K-separation ($\geq 3\sigma$ up to 8 GeV/c

$N_{pe} = 14$

SuperB FARICH project



FARICH sideview.

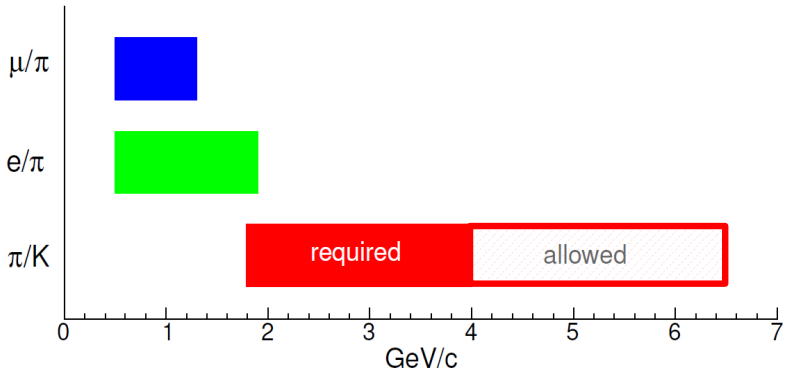
Photon detector

- MRS APD (CPTA, Moscow) or Burle/Photonis MCP PMT;
- Pixel size 1–2 mm;
- Packing efficiency $\approx$ 50%;
- SiPM: PDE=**40%** @ 600 , MCP PMT: QE=24% @ 400 nm;
- Gain $10^5 - 10^6$;
- Time resolution $\sim$ 100 ps
- Number of channels $\sim 10^5$;

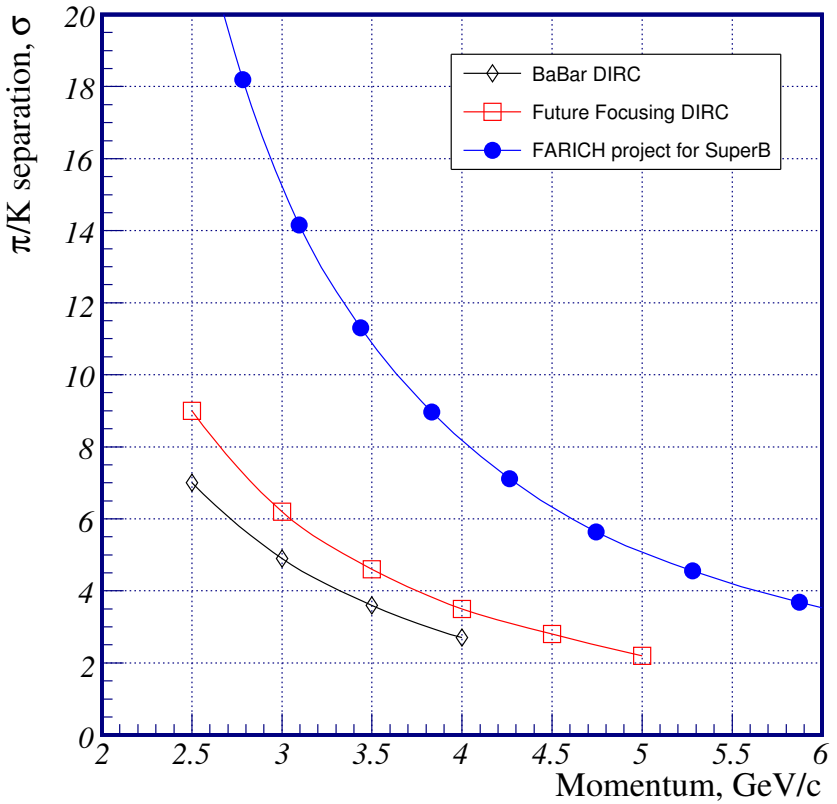
Aerogel

- **4**-layer focusing aerogel, 35 mm thickness
- n_1 =**1.07**
- L_{sc} = 5 cm @ 400 nm

PID at SuperB



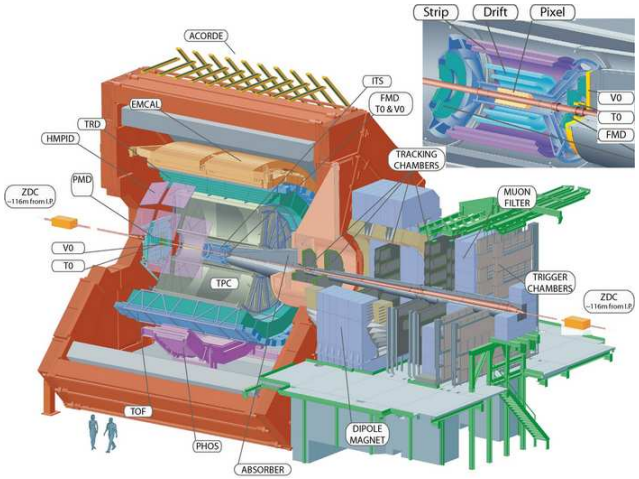
SuperB FARICH 3σ momentum range

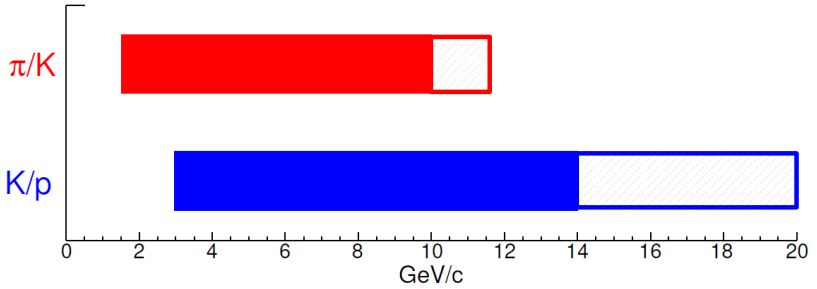


Perfomance comparison of the present and future focusing DIRCs with the FARICH project.

DIRC data: talk of J.Schwiening "Status of the Focusing DIRC" at RICH'07

FARICH for ALICE HMPID upgrade (project)





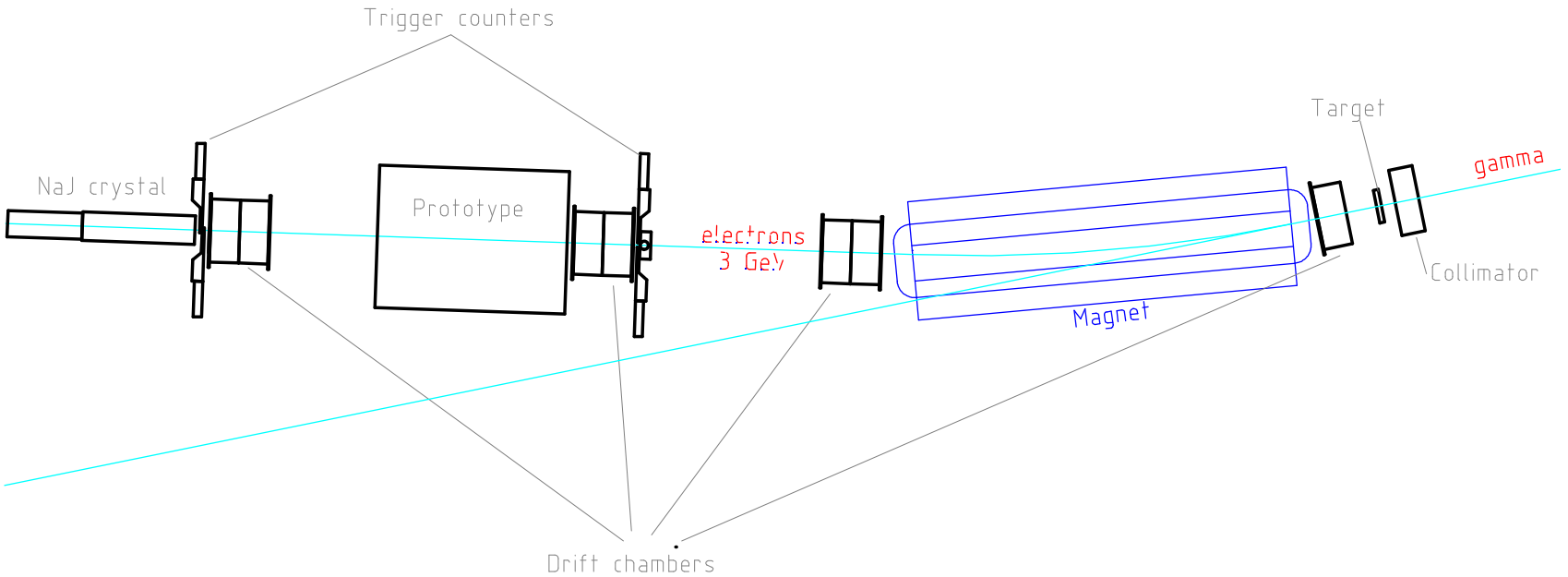
Current parameters

- Expansion gap of 500 mm,
- CPTA MRS APD with ⌀ 1 mm,
- Winston cone of ⌀ 3 mm to improve light collection,
- Aerogel of 2-3 layers with $n_1 = 1.05$.

Working momentum range of FARICH for ALICE:
solid — required, open — possible.

Objectives

- Measure the velocity resolution of FARICH and compare with calculations,
- Look for other contributions to resolution,
- Development of the SuperB FARICH prototype,
- R&D of other detectors



Test beam construction at VEPP-4M

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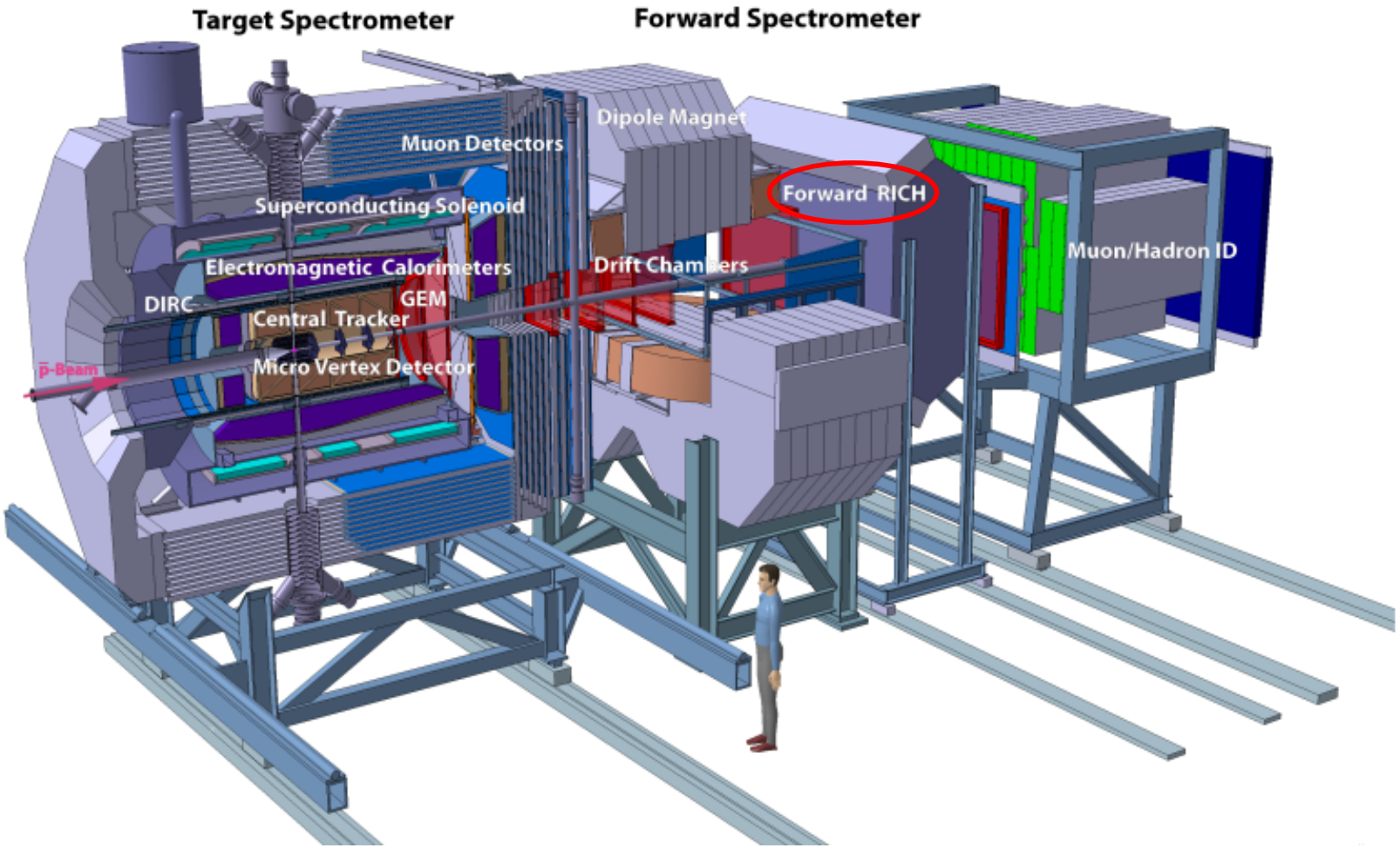
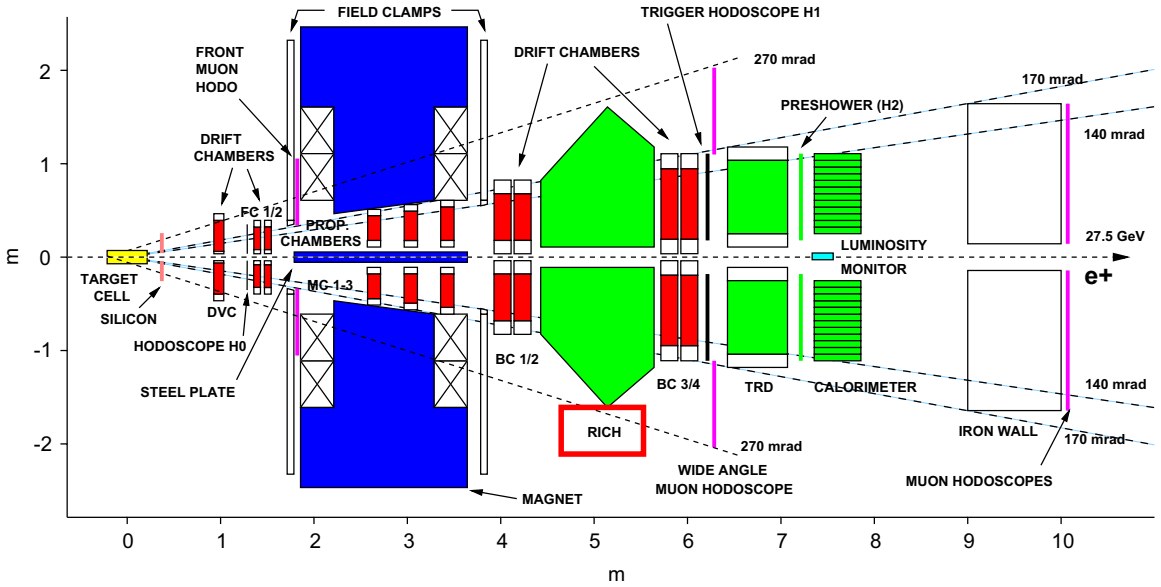
Forward Spectrometer RICH for PANDA



Artistic view of the $\overline{P}$ANDA Detector

Re-use of the HERMES RICH (option)



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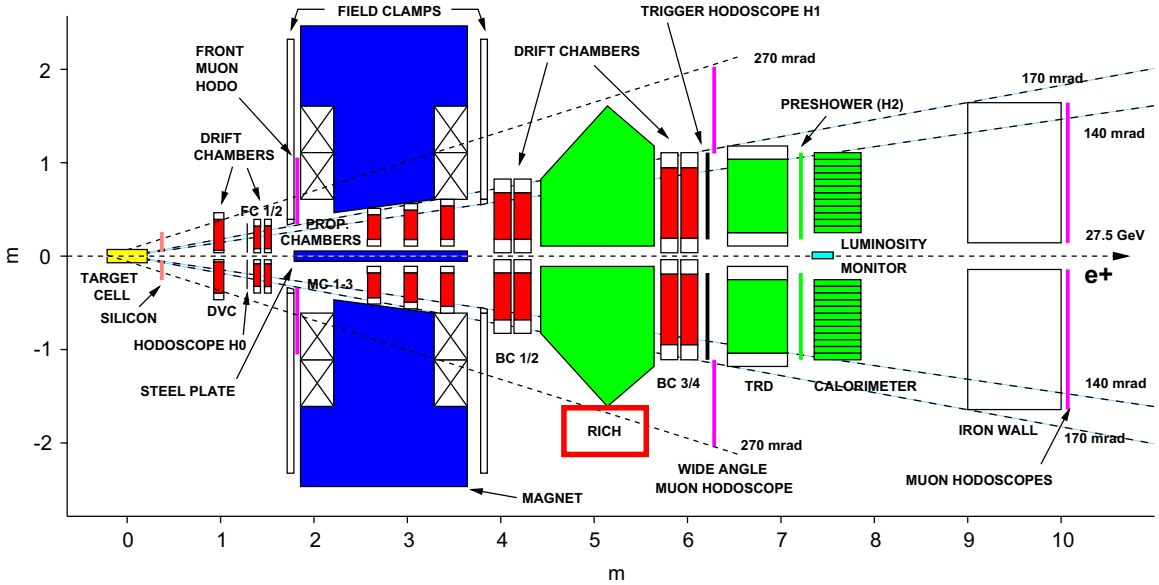

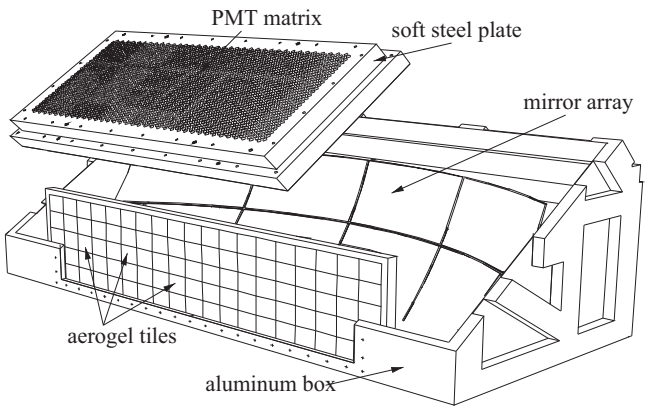

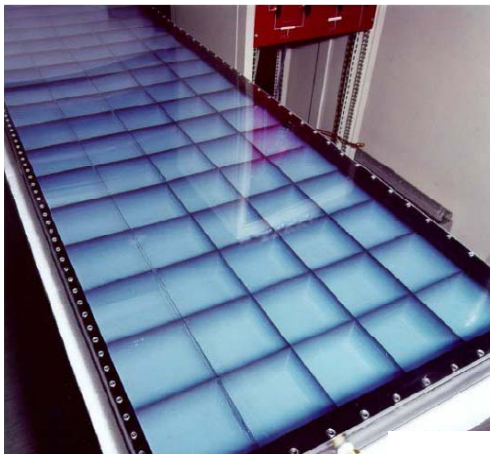

My calendar plan

Сроки выполнения	Содержание работ	Форма отчетности
Дата подписания – 30 июня 2009 года	Предварительное исследование, часть 1. Выявить условия, при которых необходим ForwardRICH детектор, оценить выигрыш в эффективности при наличии идентификации частиц с большими импульсами в переднем спектрометре, выработать требование на максимальный импульс разделения частиц.	Аннотационный отчет
1 июля 2009 года – 30 сентября 2009 года	Предварительное исследование, часть 2. Выработать возможные конфигурации ForwardRICH детектора, рассмотреть различные варианты фотонного детектора и компоновки всего детектора.	Аннотационный отчет
1 октября 2009 года – 10 января 2010 года	Разработка программы моделирования. Разработка программы для предварительного моделирования разных вариантов детектора в Geant4: описание геометрии, создание алгоритма реконструкции скорости частиц.	Аннотационный отчет
11 января 2010 года – 30 марта 2010 года	Оптимизация детектора. С помощью моделирования исследовать разные варианты детектора. Оптимизировать аэрогелевый черенковский радиатор и пространственное разрешение фотонного детектора. Выработать предложение по устройству базового варианта детектора.	Аннотационный отчет и финальный отчет

Conclusion

- Aerogel produced in Novosibirsk by BINP&BIC has excelent transparency and well fit RICH applications. A wide range of dimensions (up to $20 \times 20 \times 5$ cm^3) and refractive indices (1.006–1.13) is available. Aerogel for LHCb and AMS RICHes has been produced and shipped.

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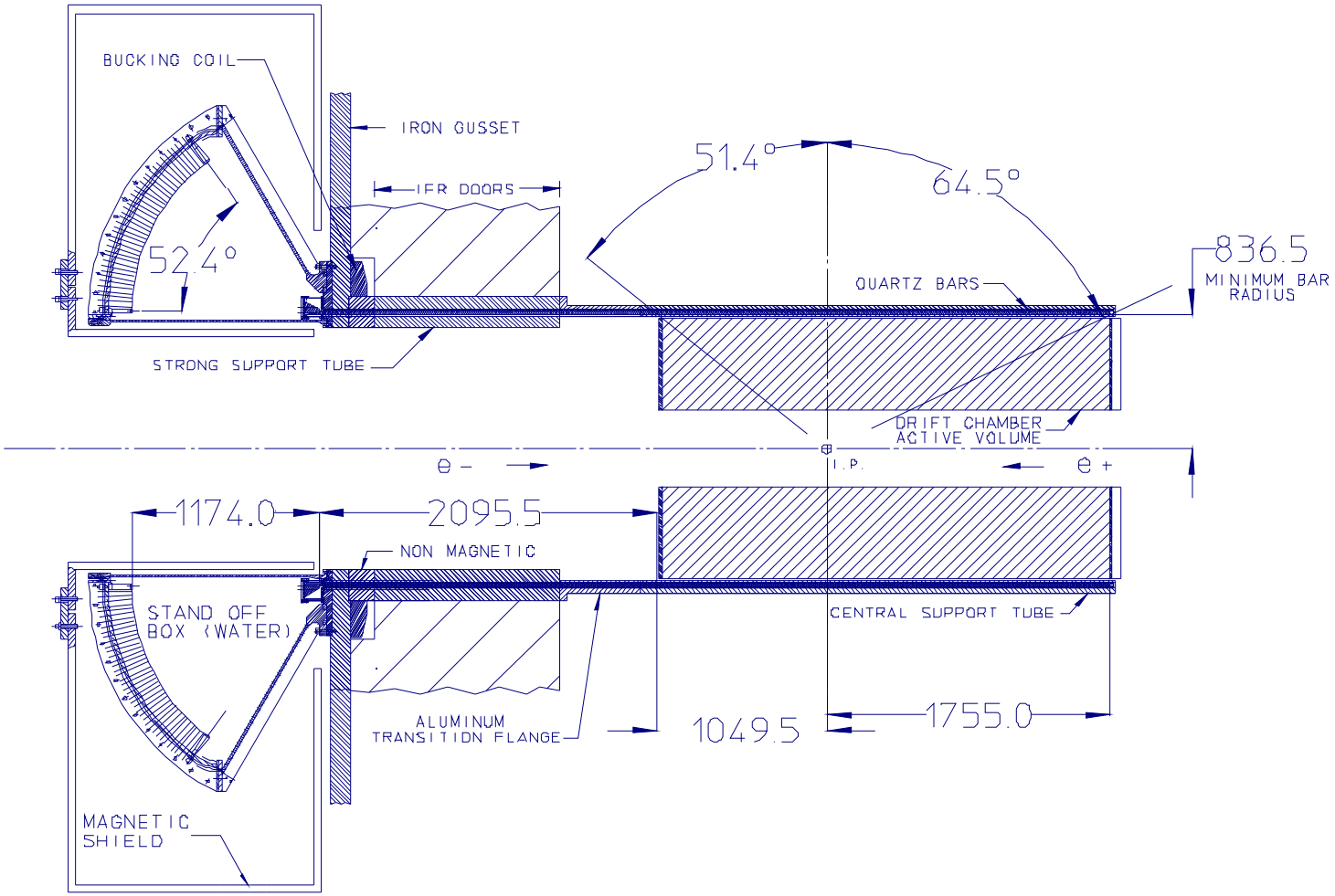
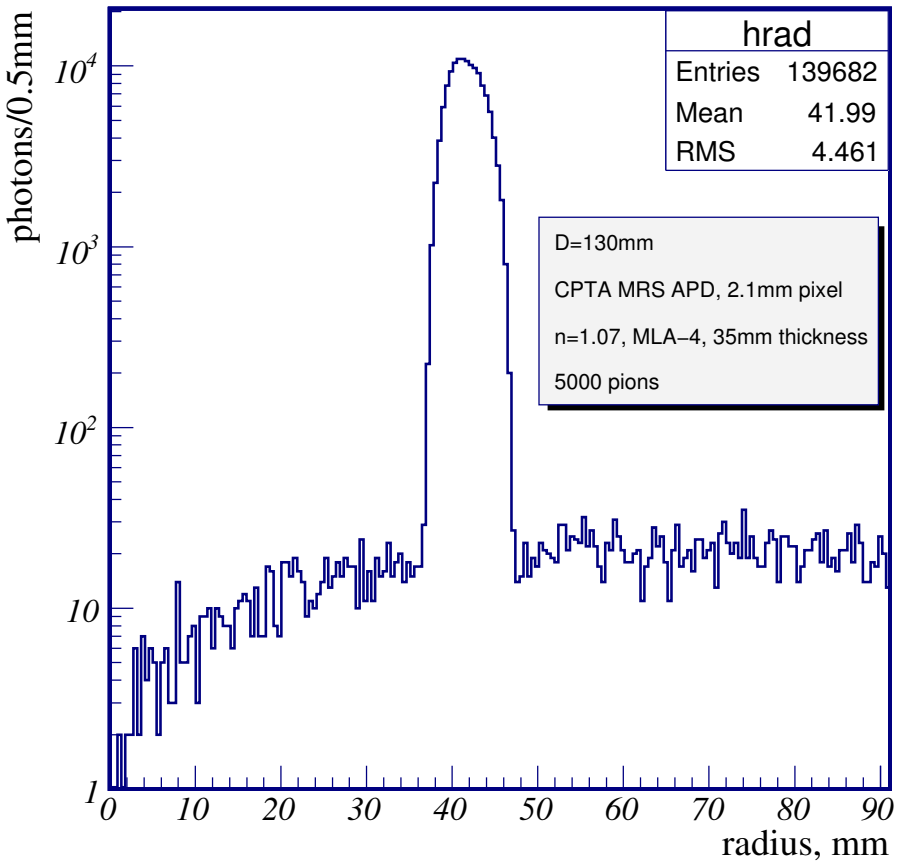
- The electron test beam in BINP to be set up by Fall 2009.
- Application of FARICH for the PANDA FS is reasonable.

Backups


BUCKING COIL
IRON GUSSET
IFR DOORS
52.4°
51.4°
64.5°
836.5
MINIMUM BAR RADIUS
QUARTZ BARS
STRONG SUPPORT TUBE
DRIFT CHAMBER ACTIVE VOLUME
e −
I.P.
e +
1174.0
2095.5
NON MAGNETIC
STAND OFF BOX (WATER)
CENTRAL SUPPORT TUBE
ALUMINUM TRANSITION FLANGE
1049.5
1755.0
MAGNETIC SHIELD

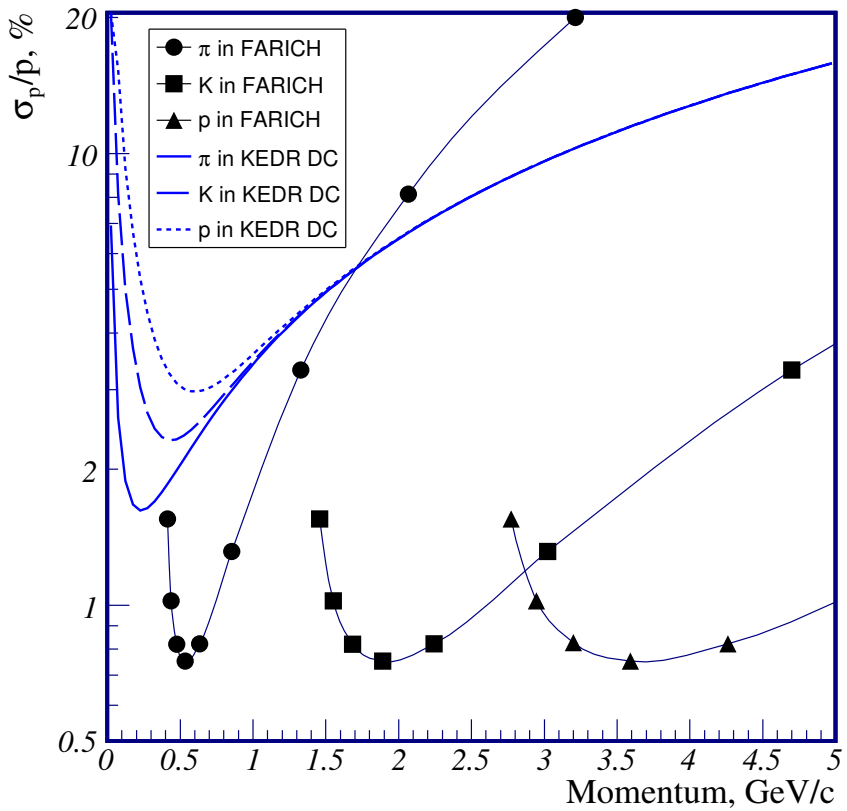
BaBar DIRC



Background from particle interactions.

Momentum precision enhancement with FARICH

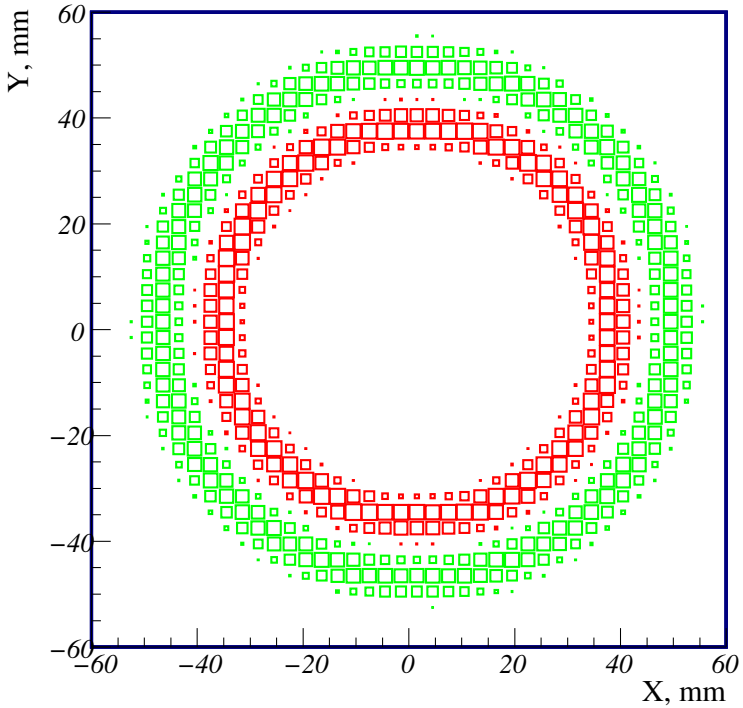
$$\frac{\sigma_p}{p} = \gamma^2 \frac{\sigma_\beta}{\beta}$$

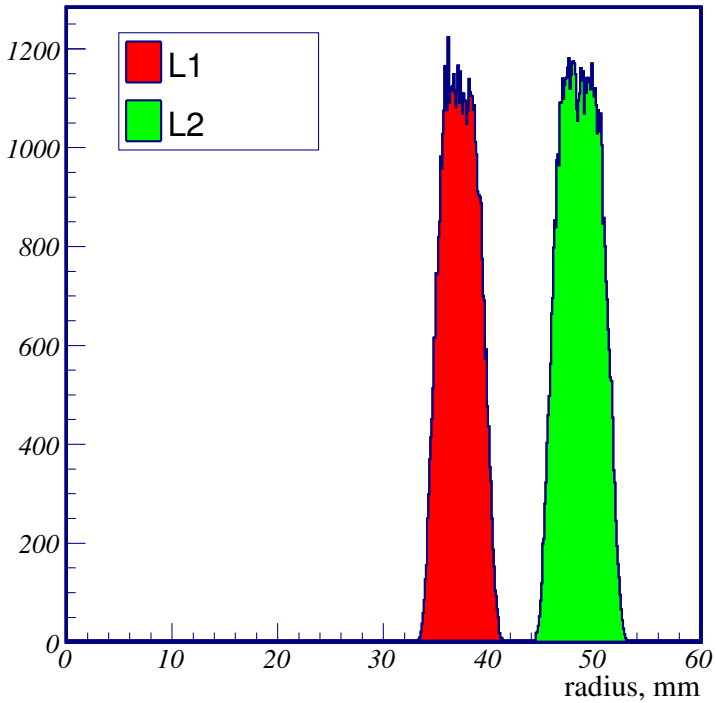


Momentum resolution for FARICH and KEDR DC for particle angle $\theta = 30^\circ$ *from beam direction.*

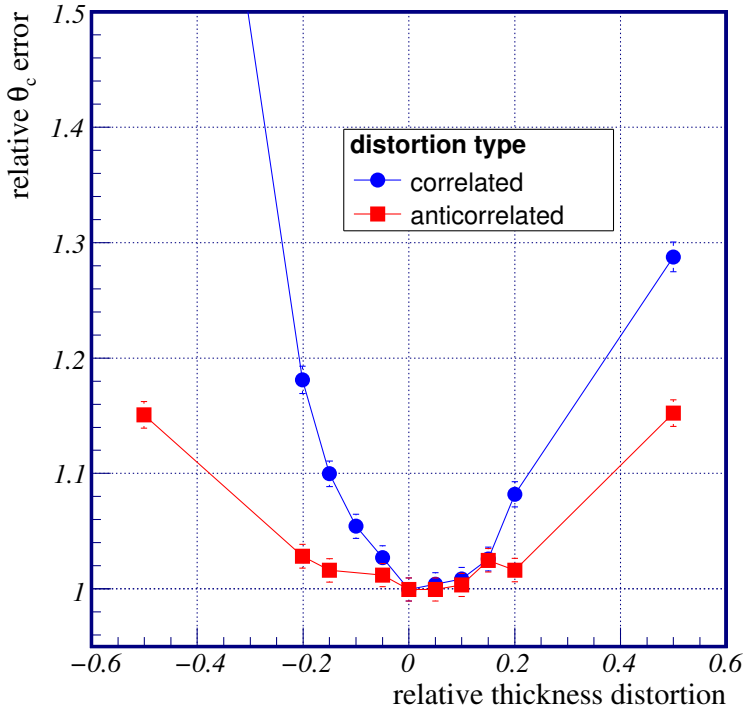
FARICH ($D = 200$ mm, GaAs pc., 4-layer aerogel)

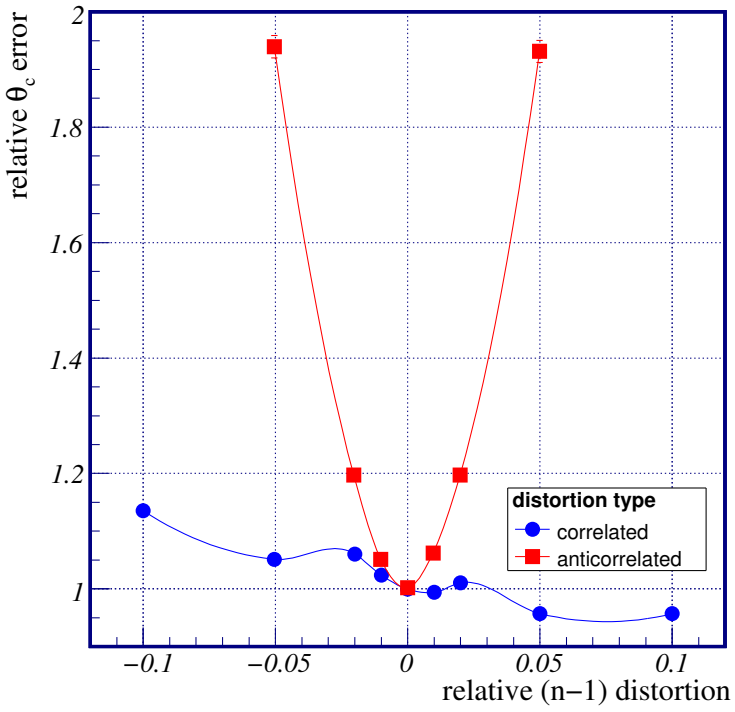
Two ring FARICH.





Position distribution of photons.

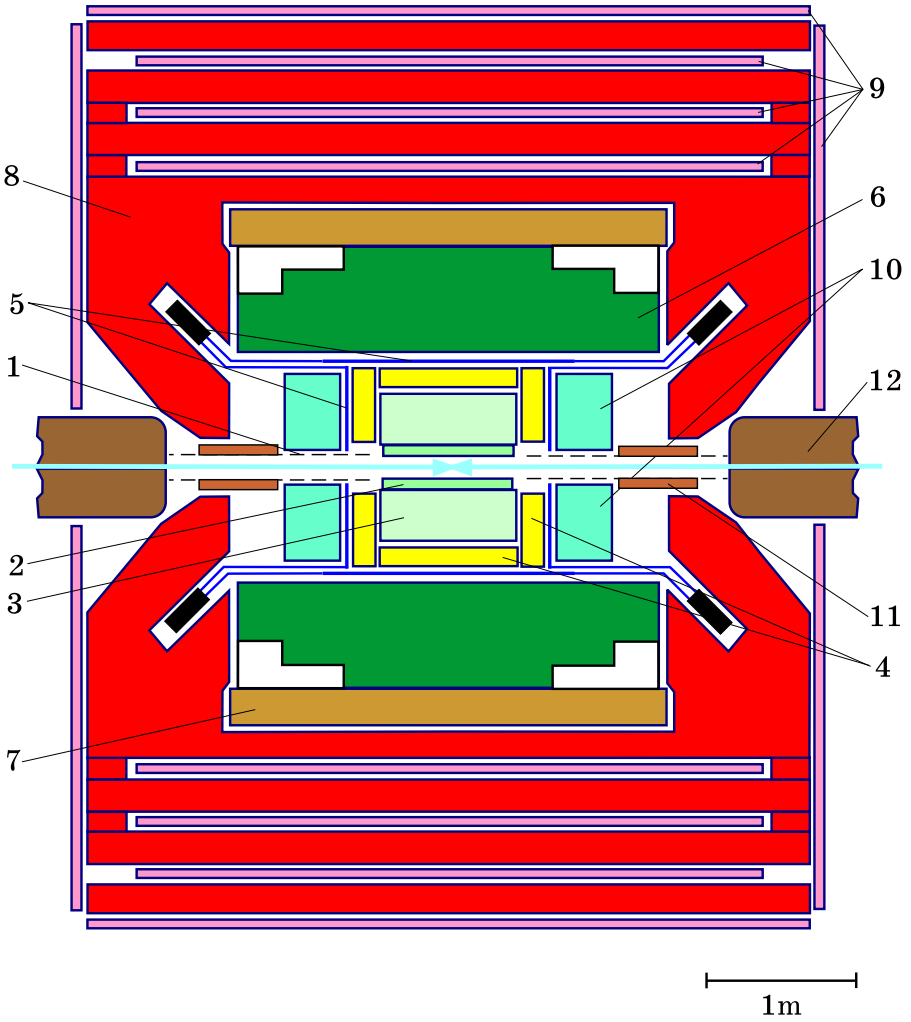




Relative change in resolution of SuperB FARICH for layers' thicknesses (left) and refractive indices (right) mismatch.

Berrel ATC of the KEDR detector before installation.

Detector KEDR



1 - Beam pipe
2 - Vertex detector
3 - Drift chamber
4 - Aerogel threshold counters
5 - ToF counters
6 - Lkr calorimeter
7 - Superconducting coil
8 - Yoke
9 - Muon chambers
10 - CsI calorimeter
11 - Compensating solenoid
12 - Quadrupole

Simulation with Geant4

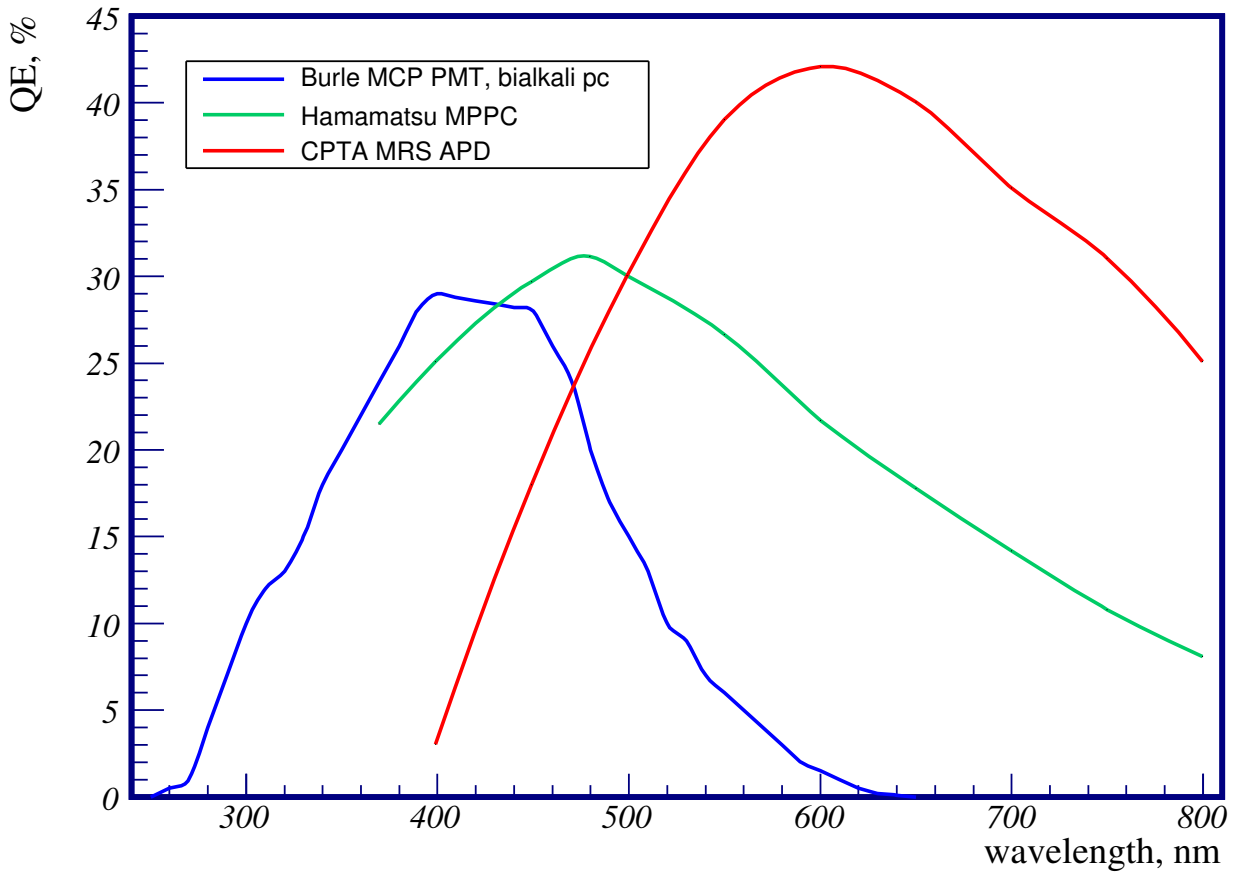
The processes defined:

- for charged particles: Cherenkov emission, multiple scattering, magnetic field;
- for optical photons: Fresnel refraction and reflection, Rayleigh scattering g, bulk absorption.

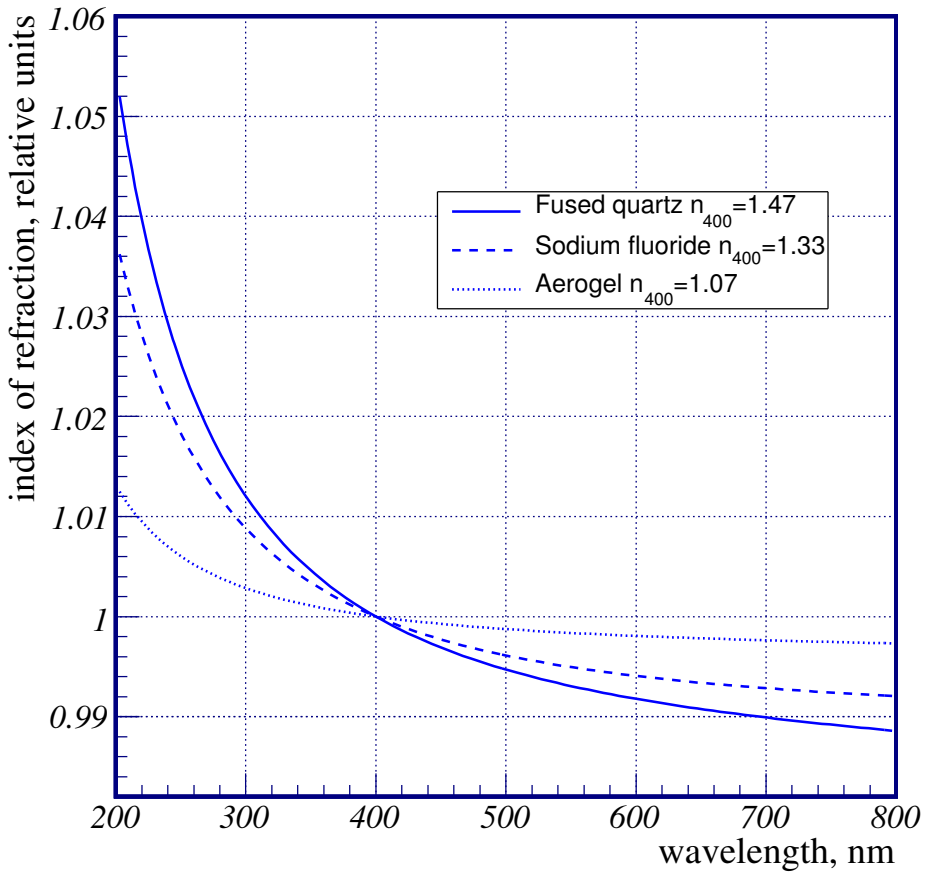
Model:

- Dispersion of aerogel index of refraction is obtained by scaling quartz index proportionally to density;
- No scattering on aerogel-air boundary;
- Scattered photons are discarded in the simulation;
- Exact knowledge of particle position and direction is assumed.

Quantum efficiency



Chromaticity



Relative refractive index of fused silica, NaF and aerogel ($n = 1.07$) as function of wavelength.