Development of Aerogel Cherenkov Counters at Novosibirsk

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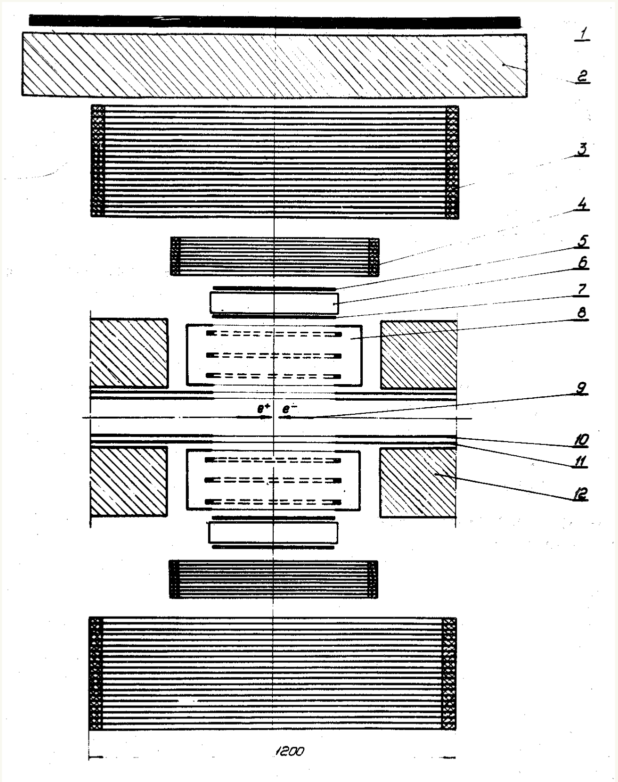
- VEPP-2, MD-1 Cherenkov detectors
- Aerogel
- ASHIPH method
  - KEDR ASHIPH system
  - Test beam results
  - Long-term stability of the counters
  - SND ASHIPH system
- Aerogel counter for bunch length measurement
- Aerogel RICH
  - LHCb RICH
  - RICH for Super BaBar
- Conclusion

VEPP-2-1970 detector*

- 1970, VEPP-2, 2E=1.18-1.34 GeV, L=13 nb^{-1}



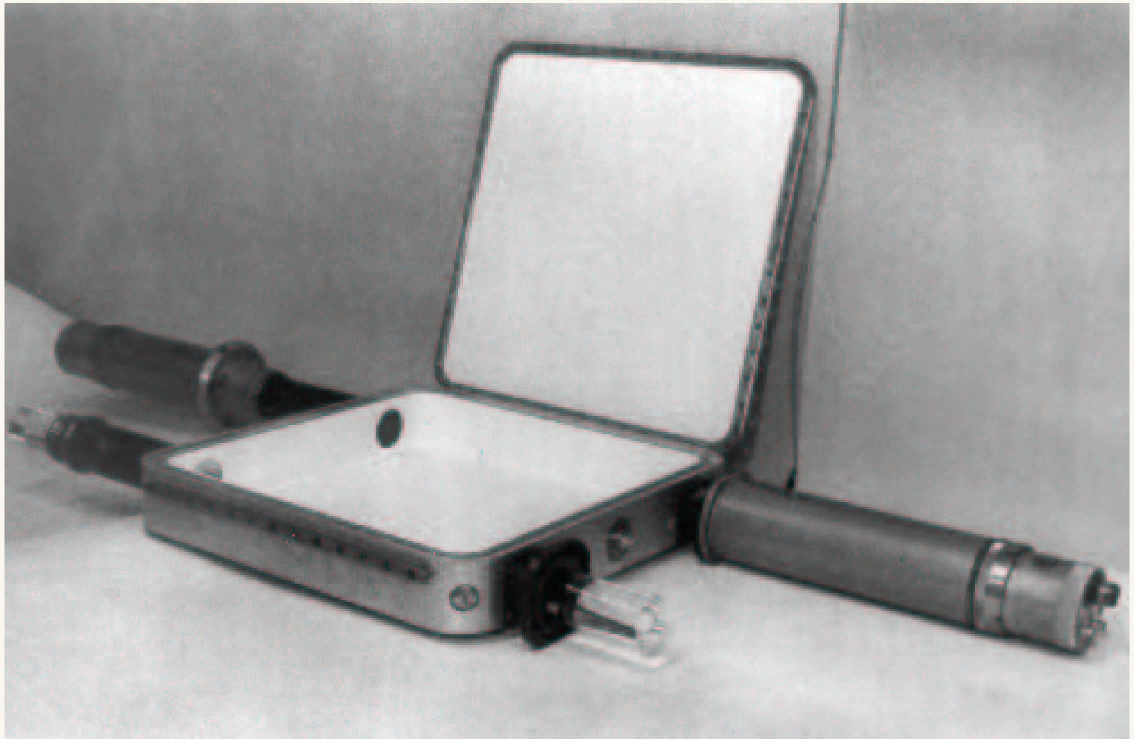
5 – water Cherenkov counters

- $0.13 \times 4\pi$ of solid angle, 2 counters
- $40 \times 40 \times 7$ cm^3
- 4 PMT $\oslash$ 5 cm

π-K Separation

E, GeV	0.59	0.67
π-efficiency,%	99.1	99.3
K-misident.,%	1	7

* A.Onuchin, S.Serednìakov, Instr. and Exp.Tech. 1972 №6, 52



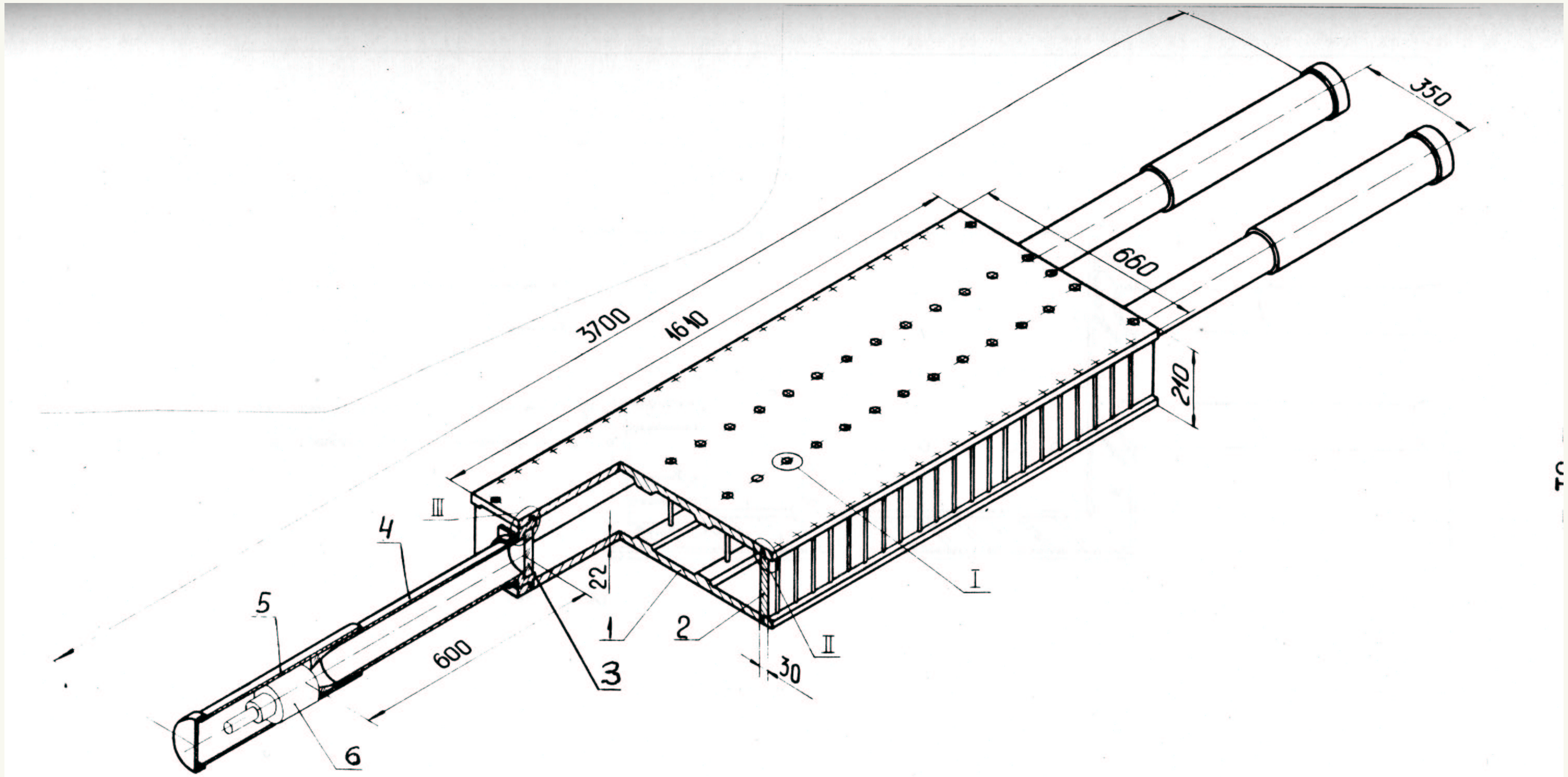
Two discoveries in the experiment:

- $e^+e^- \rightarrow$ hadrons (*a hint to light quarks*), Rochester conference, Kiev 1970:
  1.18 - 1.34 GeV - Novosibirsk
  1.6 - 2.0 GeV - Frascatti
  L.M.Kurdadze et al., Phys Lett. 42B (1972) 515
- $e^+e^- \rightarrow \pi^+\pi^-, K^+K^-$ Form-factors of π and K exceeded theoretical predictions (later ρ', ω', ϕ'-mesons were discovered). *V.E.Balakin et al., Phys Lett. 41B (1972) 205*

These results stimulated construction of VEPP-2M, DORIS, SPEAR, CESR, VEPP-4 and other e$^+$e$^-$ colliders.

MD-1 detector*

- 1980-1985, VEPP-4, 2E=7.2-10.5 GeV, L=30 pb^{-1}



Gas threshold counters

* S.E. Baru et al., Phys. Rep. 267 (1996) 72

- $0.6 \times 4\pi$ of solid angle, 8 counters
- n=1.02 γ_{th}=5 ethelen, 25 bar
- $160 \times 60 \times 17$ cm^3
- 4 PMT $\oslash$ 15 cm

π-K Separation at P=2.0 GeV/c

Number of PMT fired	$\geq$1	$\geq$2
π-efficiency,%	95	70
K-misident.,%	7	0.5

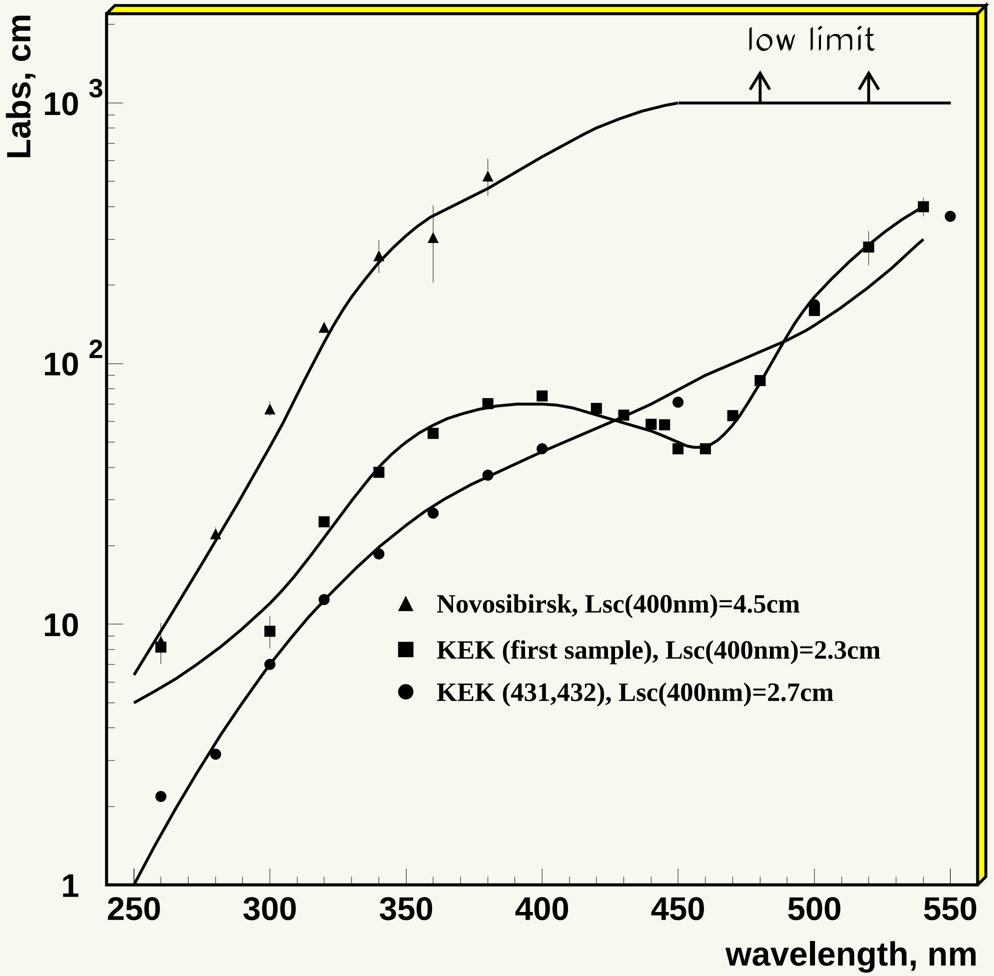
Aerogel

Why we use aerogel?

	n	P_π, MeV/c	P_K, MeV/c
quartz	1.458	131.5	465.3
water	1.33	159.2	563.0
C_6F_{14} (liq.)	1.27	178.3	630.6
C_5F_{12} (gas)	1.0018	2325	8225

- $\rho = 0.003 \div 0.3(1.)\ \mathrm{g/cm^3}$
- $\boxed{n = 1 + 0.21\rho} \Rightarrow 1.0006 \div 1.06(1.2)$

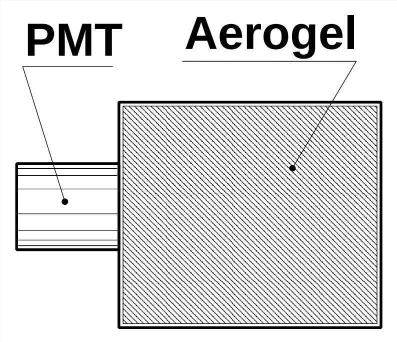
- porous SiO_2 (quartz) , d< λ
- strong Rayleigh scattering ($L_{sc} \sim \lambda^4$, $L_{sc} \ll L_{abs}$)
- $n = \sqrt{1 + \alpha\rho}$, $\alpha = 0.438$ (λ = 400 nm)



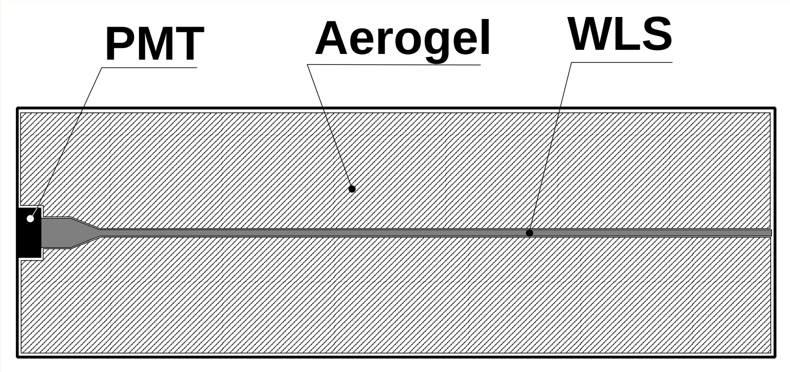
ASHIPH method*

- Aerogel
  - $\mathbf{L_{sc} \approx 1 \div 5\ cm}$
  - $\mathbf{L_{abs} \approx 1 \div 10\ m}$

- Direct Light Collection



- ASHIPH



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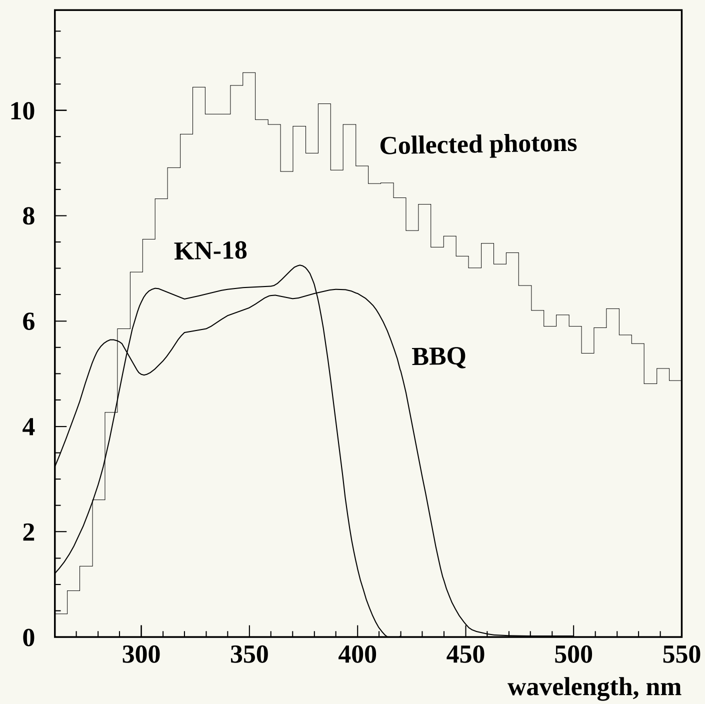
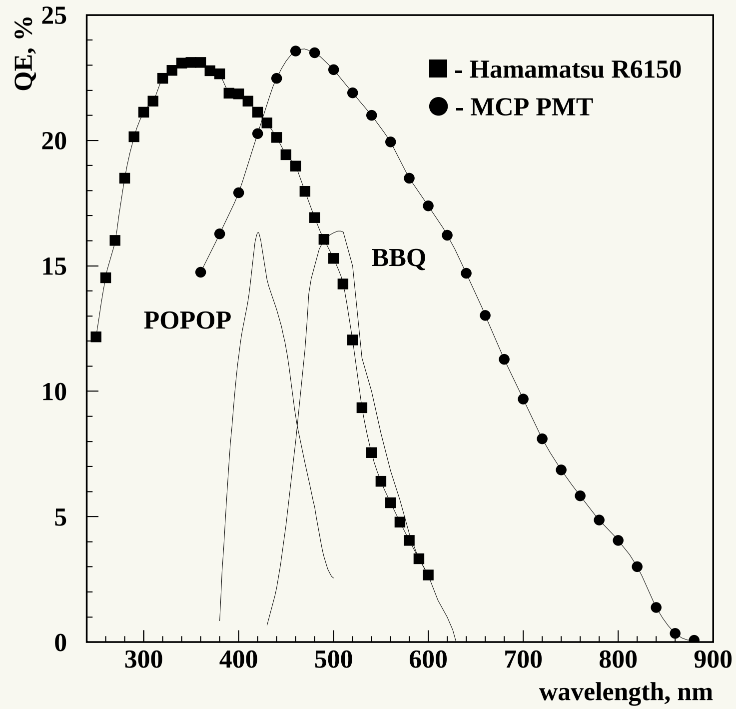
* ASHIPH – Aerogel, wavelength SHifter, PHototube

A.Onuchin et. al., NIMA 315(1992)517



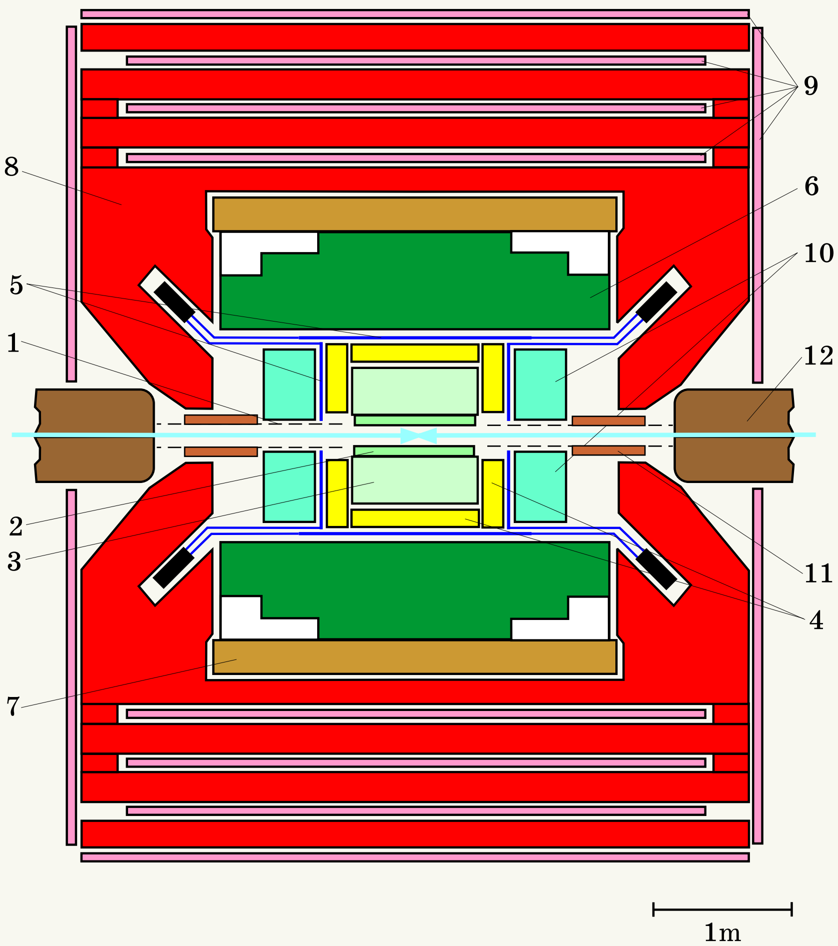


BBQ and POPOP(KN-18) absorption spectrums and spectrum of collected Cherenkov light

BBQ and POPOP emission spectrums and QE of Hamamatsu PMT and MCP PMT

- Advantage – Number of PMTs, Photocathode area
- Disadvantage – WLS

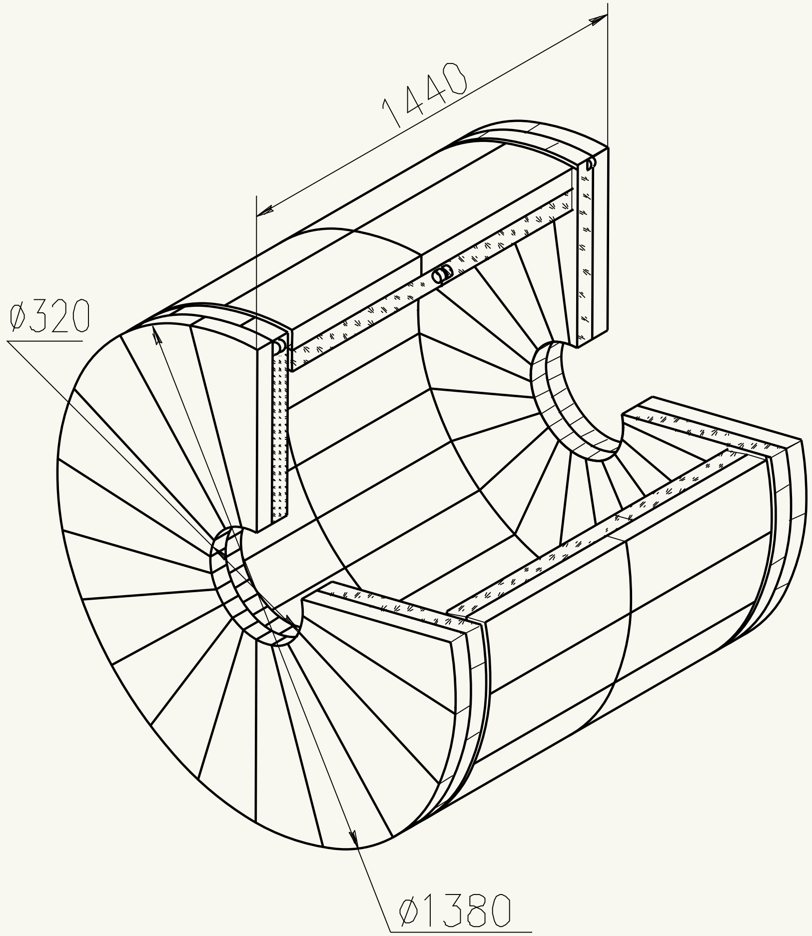
Detector KEDR



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

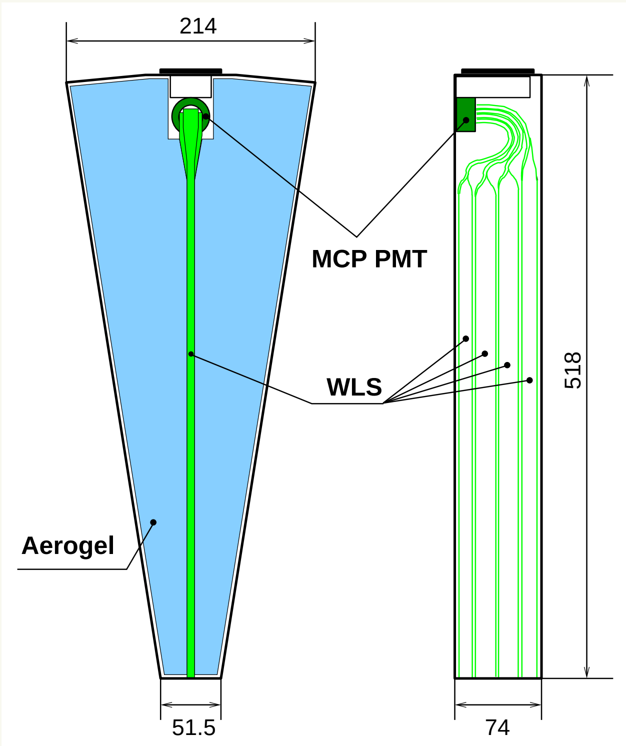
Charged tracking:	Vertex Detector (VD)
	Drift chamber (CDC)
Number of layers	42(CDC)+6(VD)
Magnetic field	1.8 T
Momentum resolution	$\sigma_p/p = \sqrt{A^2p^2(\mathrm{GeV}) + B^2}$
	$A = 0.3$ %
	$B = 0.3$ %
Calorimetry:	LKr Barrel, CsI endcap
Energy resolution	1 GeV $\to$ 2.5%
	0.1 GeV $\to$ 6% (LKr), 3%(CsI)
Angular resolution	1 GeV $\to$ 4(LKr), 9(CsI) mrad
	0.1 GeV $\to$ 4(LKr), 18(CsI) mrad
Identification:	TOF, dE/dx,
	Aerogel counters
π/K-separation	up to 1.5 GeV ($\geq 3\sigma$)

KEDR ASHIPH system

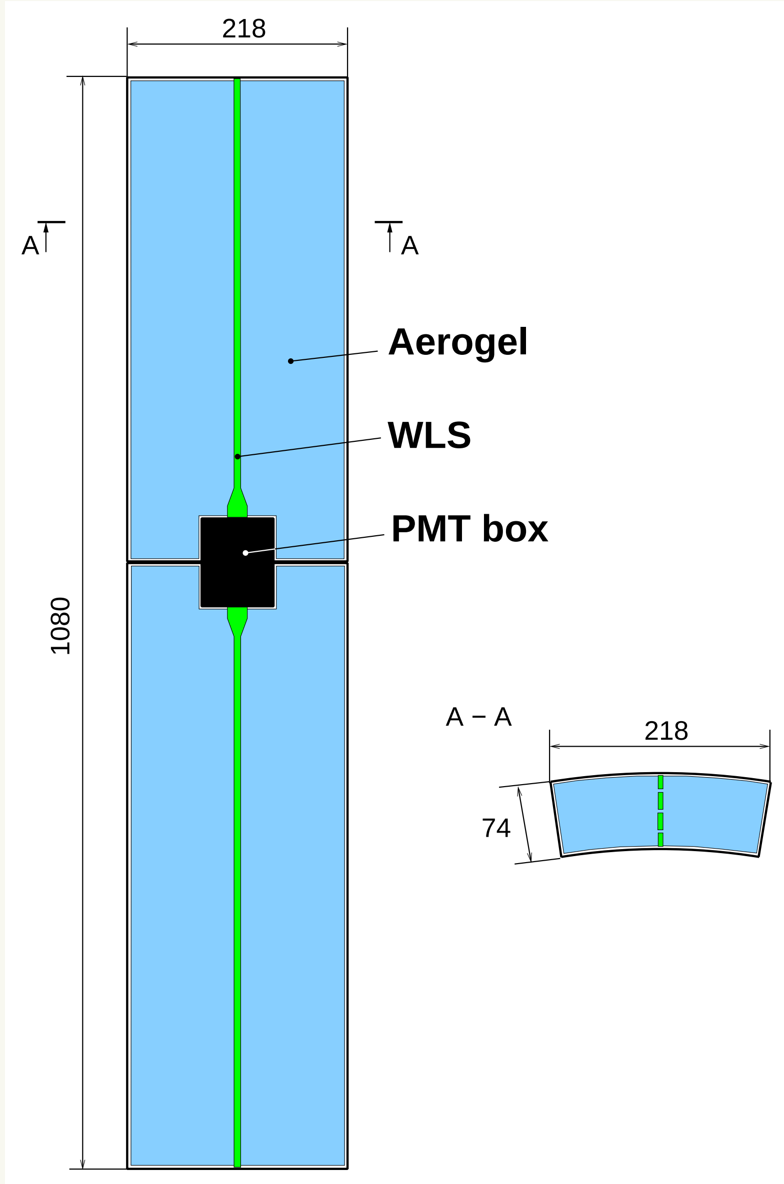


- **n = 1.05**
  (π/K separation from 0.6 to 1.5 GeV/c)
- **160 counters in two layers**
- **160 MCP PMTs**
- **1000 liters of aerogel**

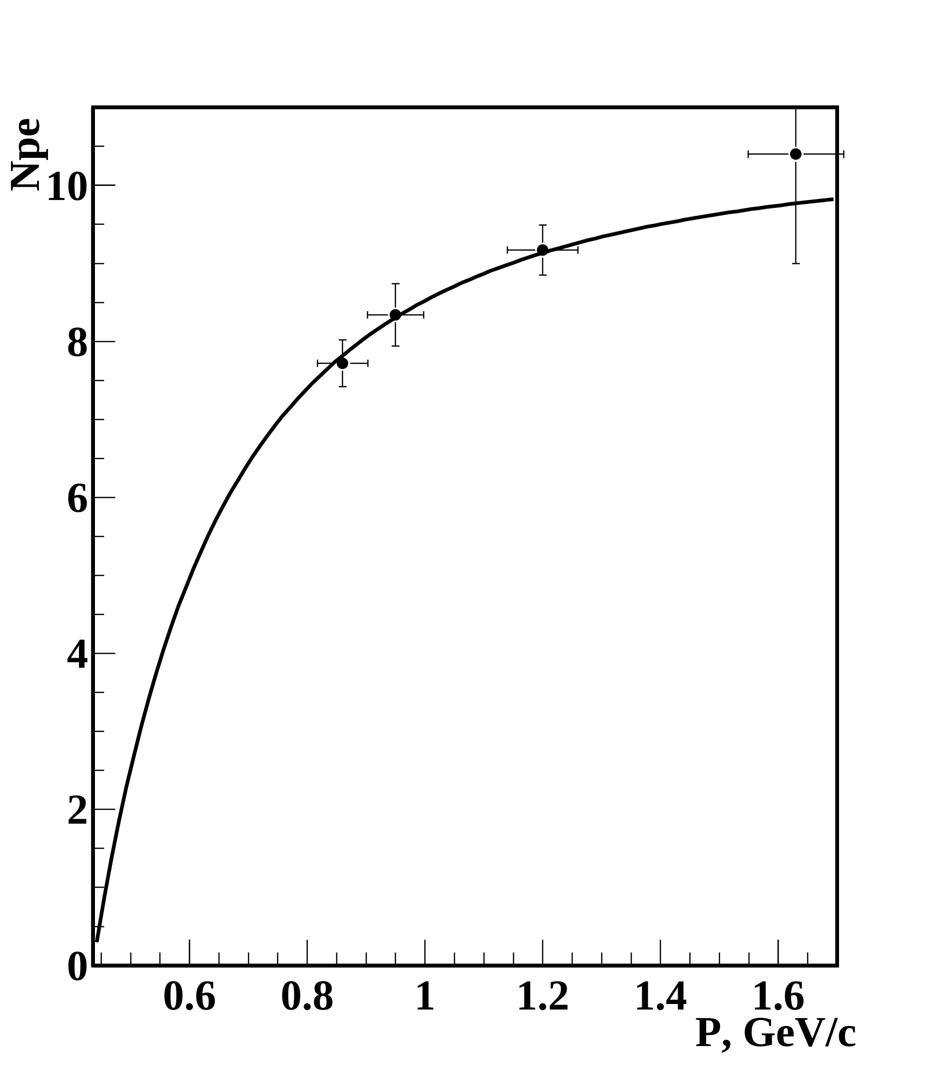
Endcap counter



Barrel counter



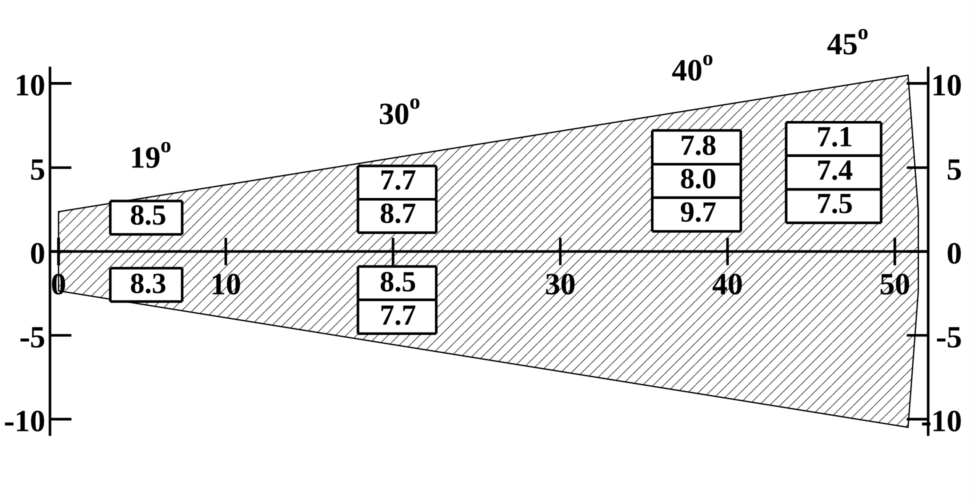
Number of photoelectrons from pions



- $N_{pe,(\beta\to1)}$ =10.6

Heterogeneity of light collection

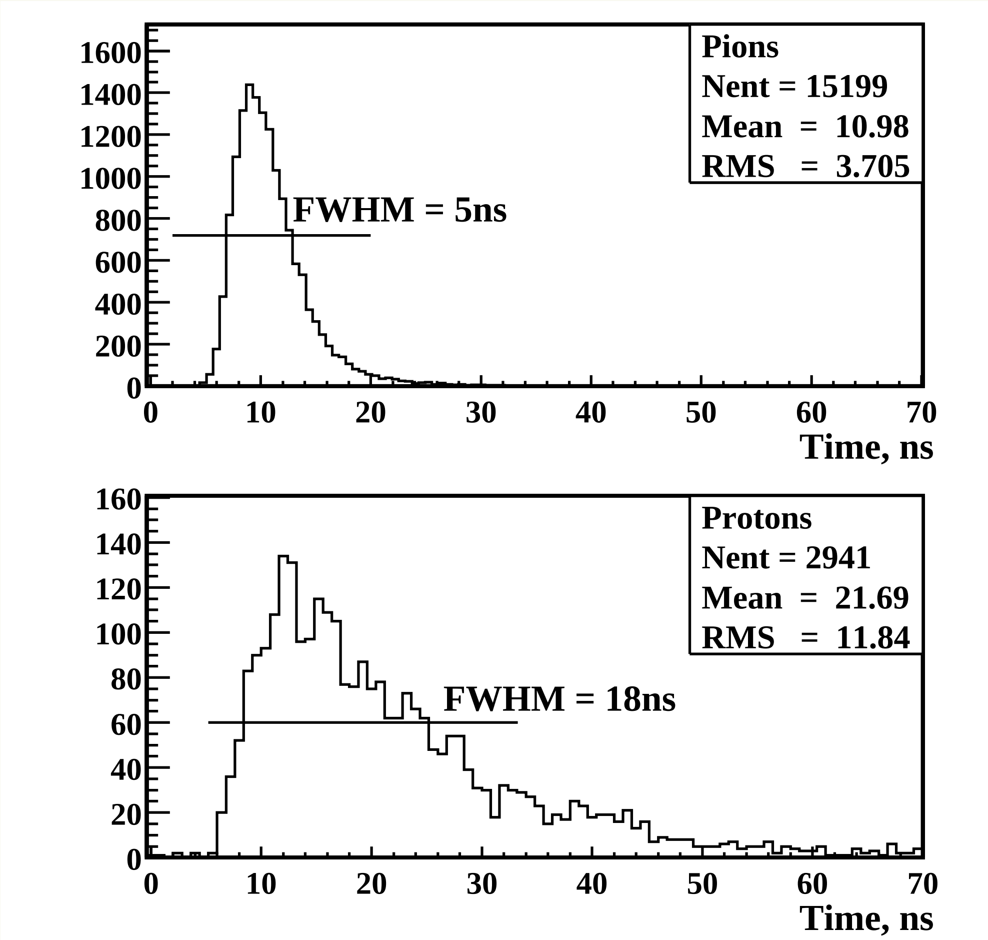
Pions, P = 0.86 GeV/c



- $N_{pe} = 7.1 \div 9.7$
- variation $\pm 15\%$

Time resolution

P = 0.86 GeV/c



Pions

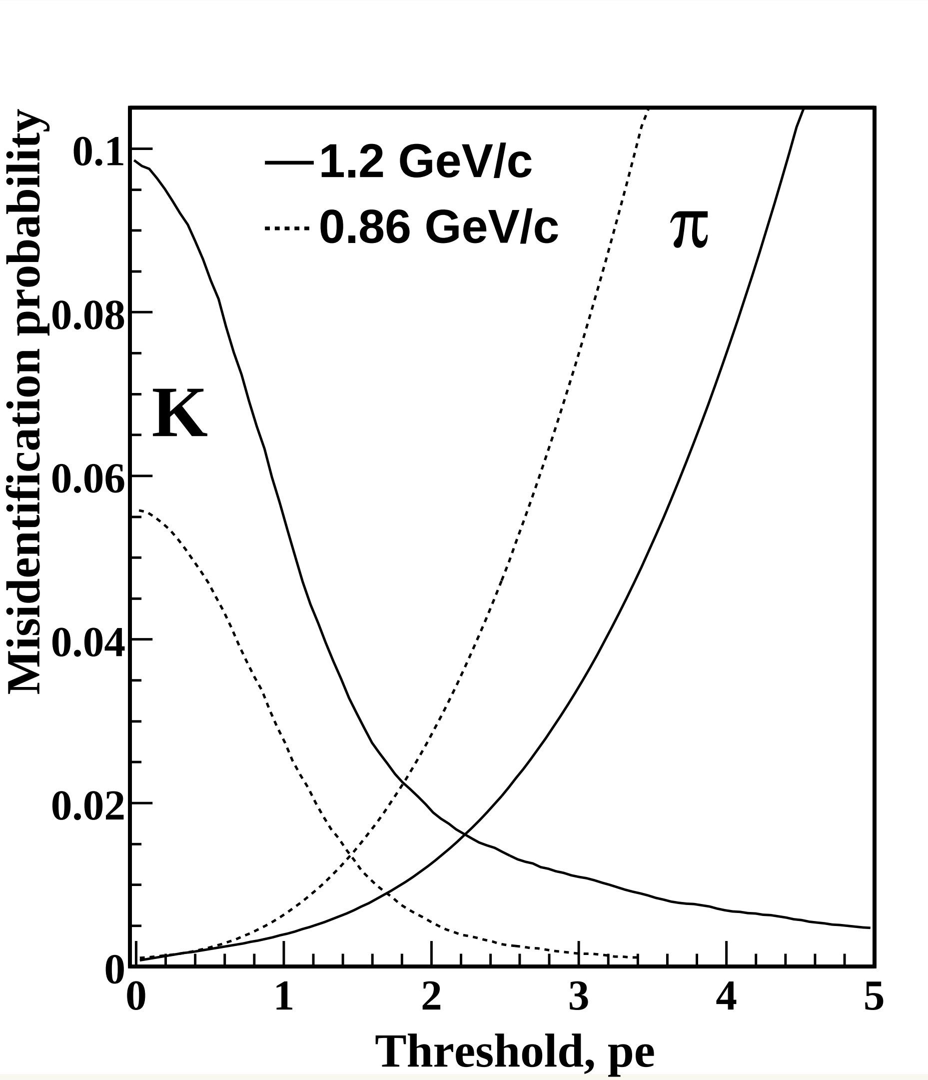
- $N_{pe} = 7.7$
- $\sigma_\tau = FWHM/2.36 \sim 2ns$

Kaons

- $N_{pe}(>0) = 1$
- $\sigma_\tau = FWHM/2.36 \sim 8ns$

BBQ decay time $\sim$ 15 ns

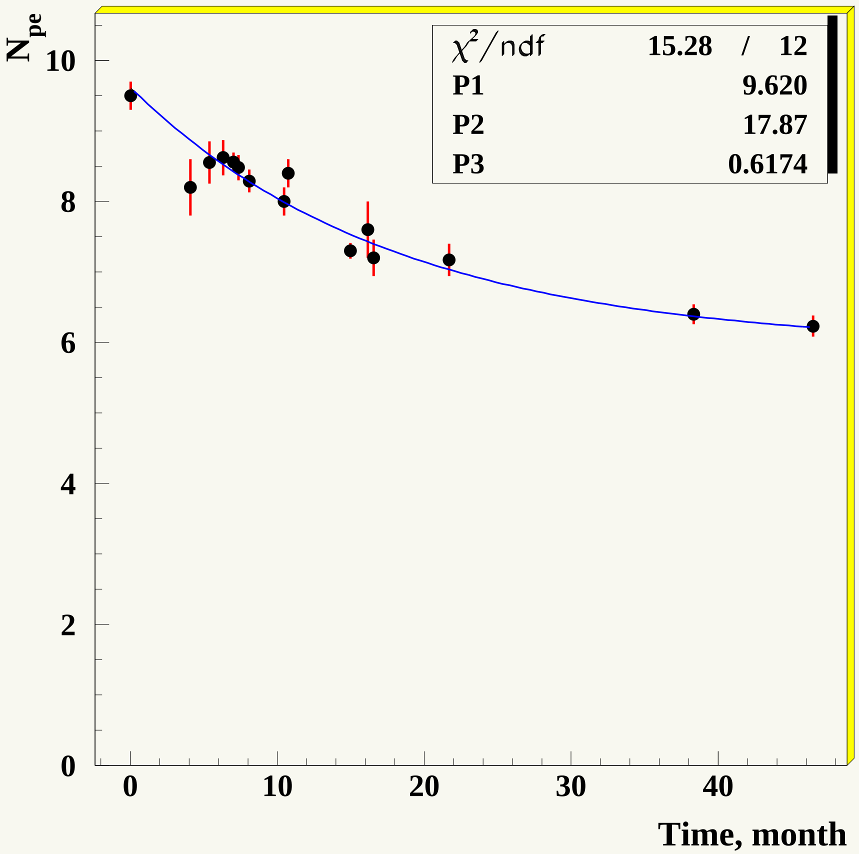
Misidentification probability



- threshold 0.05pe
- P = 1.2 GeV/c
  - **1300** — pion suppression
  - 90% — kaon detection efficiency
  - 4.5σ — π/K separation
- P = 0.86 GeV/c
  - **900** — pion suppression
  - 94% — kaon detection efficiency
  - 4.7σ — π/K separation

Long-term stability of the counters

Time dependence of amplitude

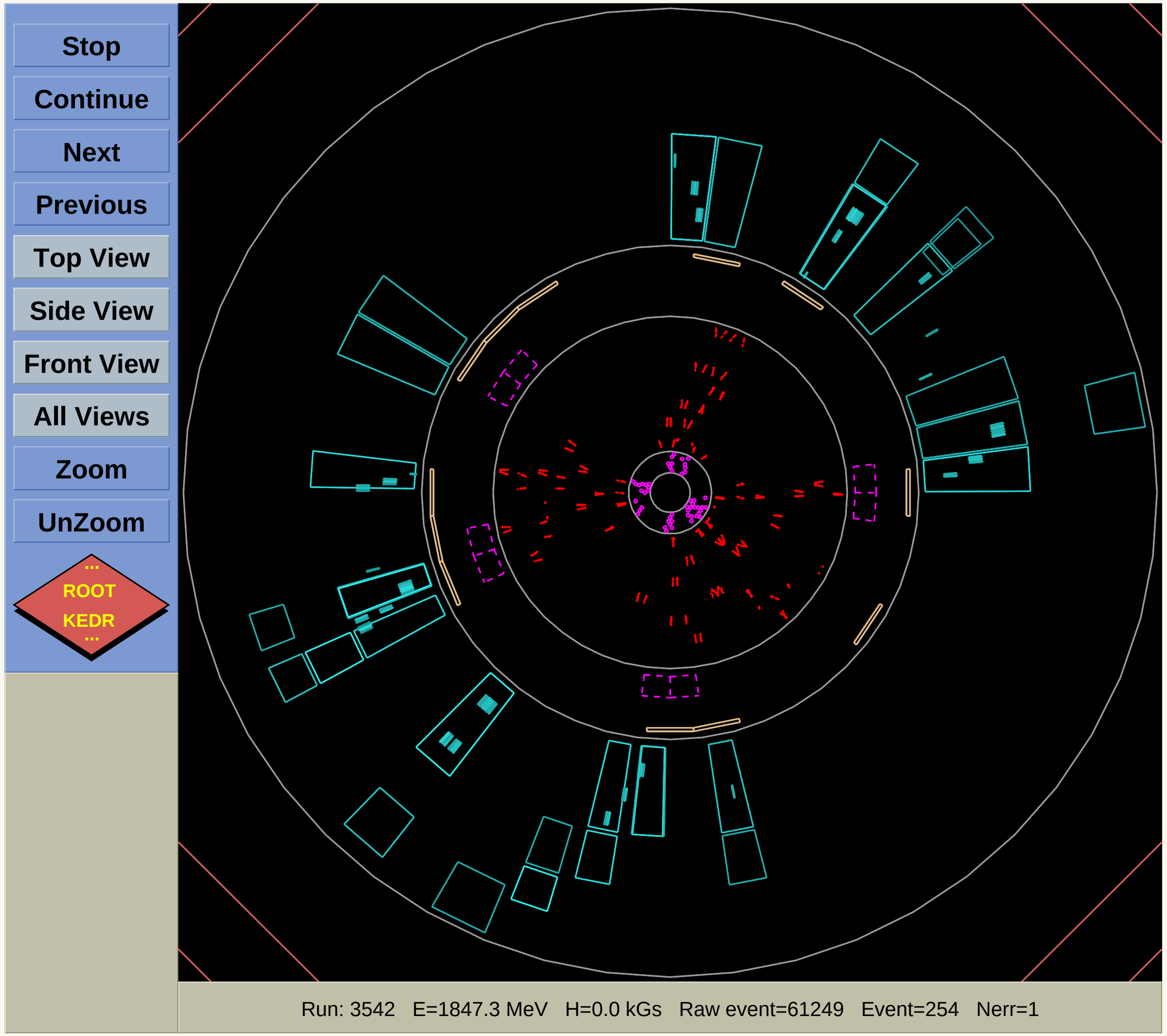


Aerogel is hygroscopic with high porosity

$$N_{pe} = P1 \cdot ((1 - P3) \cdot \exp(-\frac{t}{P2}) + P3)$$

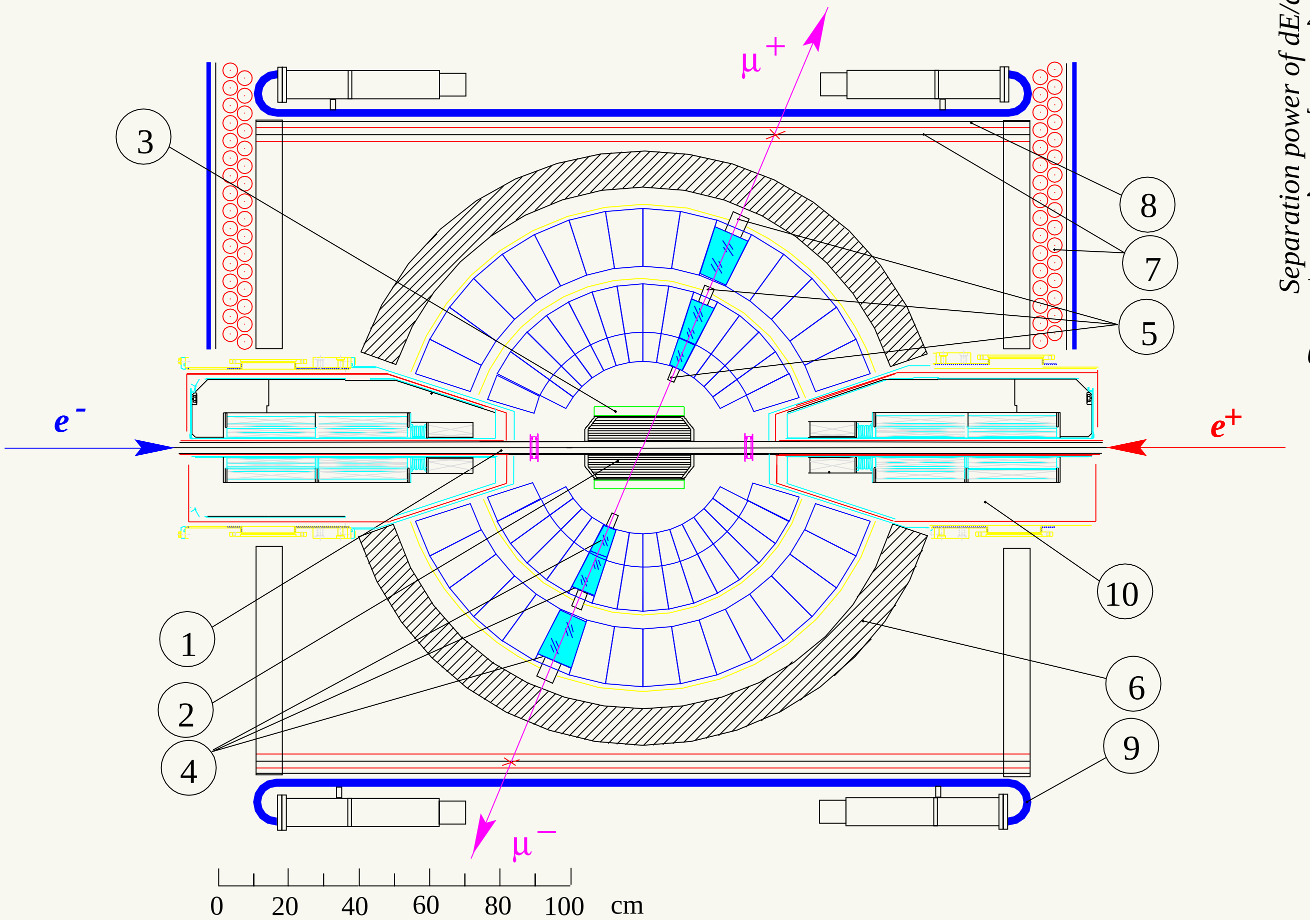
- P1, P2, P3 are free parameters of the fit
- $P(\chi^2) = 0.22$

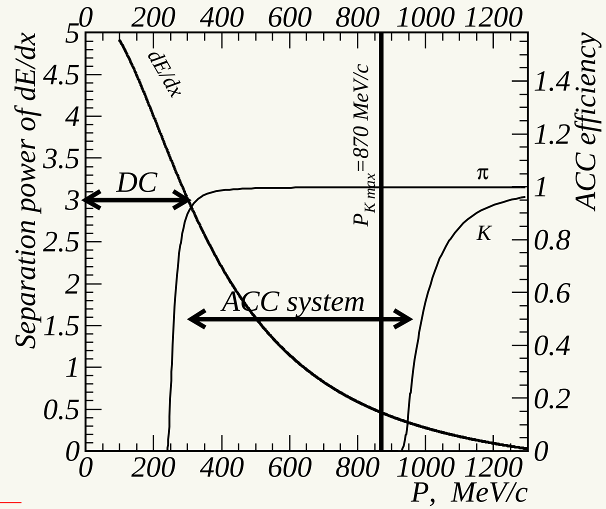
Status



The first layer of the ASHIPH system is installed into the KEDR detector and working in the experiment.

Development of ASHIPH system for the SND detector*

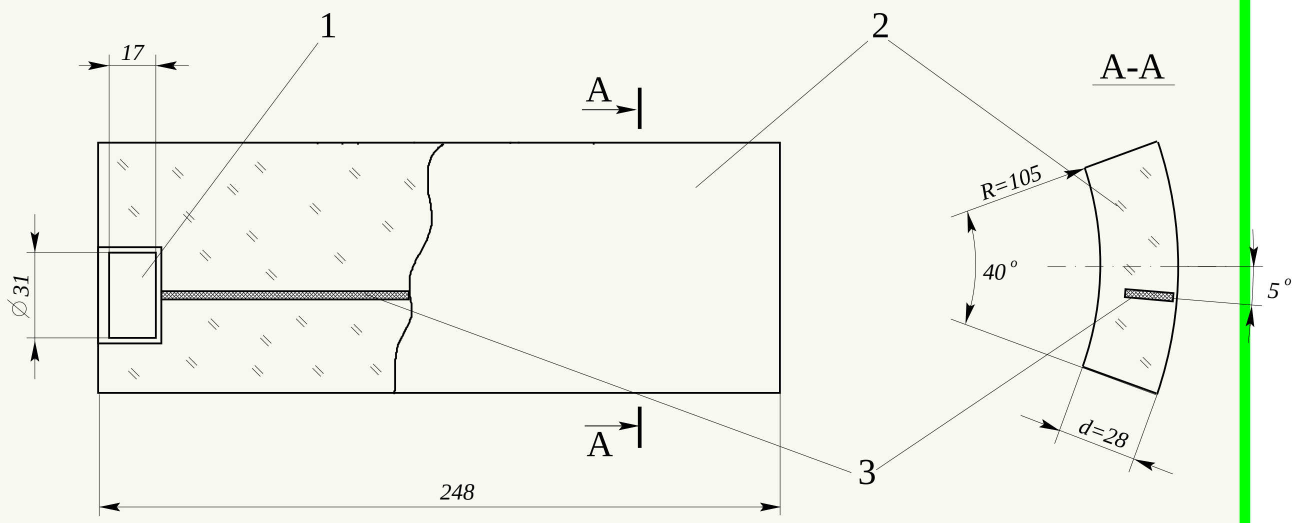




- **VEPP-2000 collider,** $E = 2 \times 1000$ **MeV**
- $\mathbf{n = 1.13}$, $\gamma_{th} = 2.1$ **(π/K separation** $400 \div 900$ **MeV/c)**

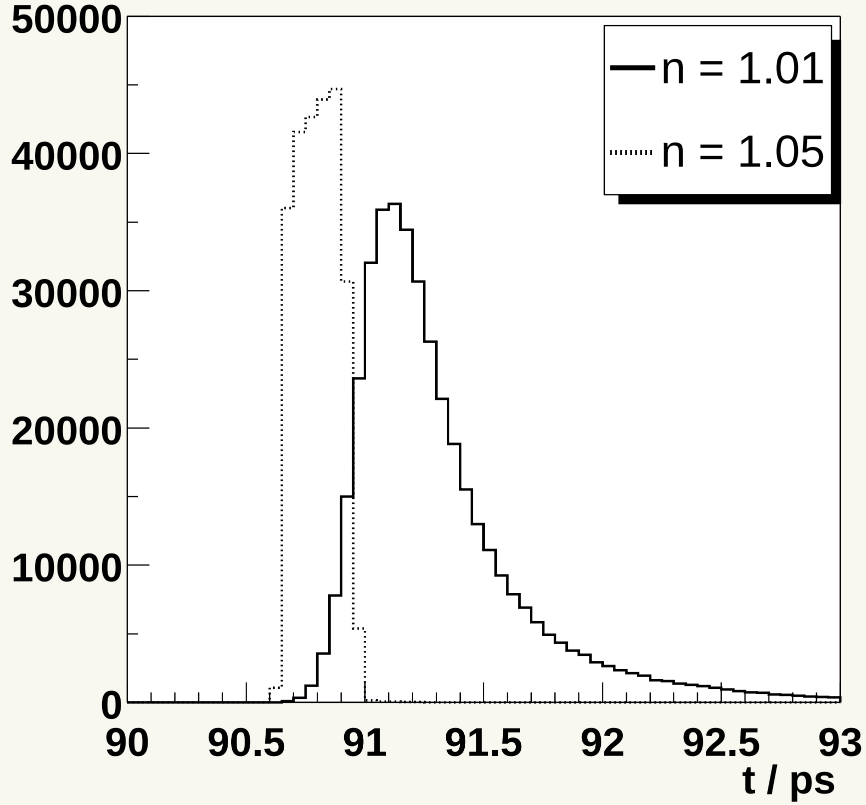
* K.I.Beloborodov et. al., NIM A494(2002)487

- $0.6 \times 4\pi$, **9 counters**
- **25×9×2.5 cm^3 , 1 MCP PMT ⊘ 1.8 cm**
- **6 liters of aerogel**
- **Npe=7 (Monte Carlo calculations)**
- **Amount of material – 8% X_0**



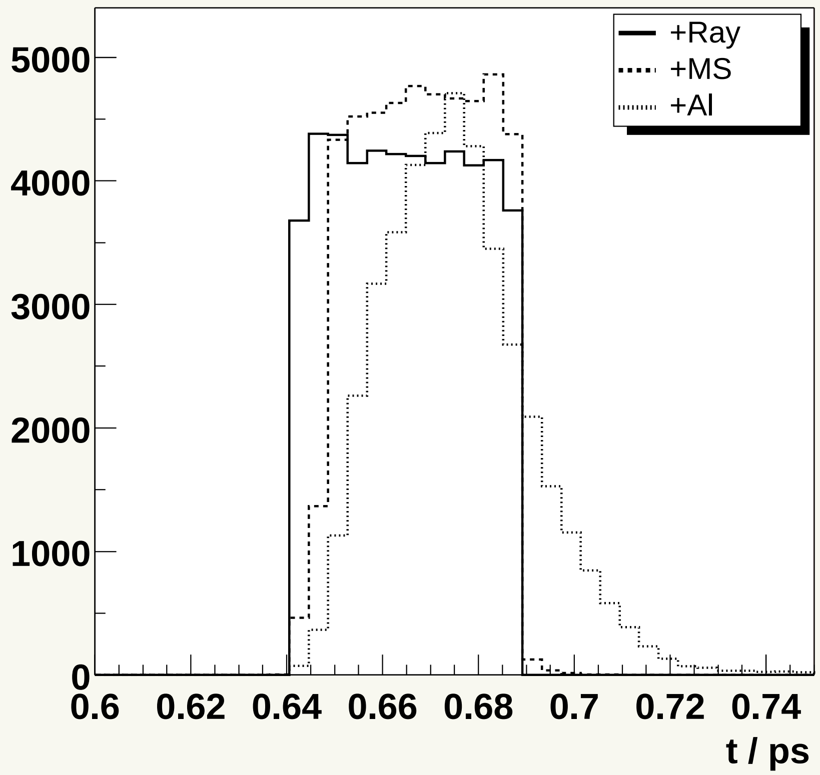
Aerogel for bunch length measurements

- Beam diagnostic for photo injector test facility at DESY Zeuthen (PITZ)
- 4-5 MeV electrons
- Better than widely used optical transition radiation because of larger number of photons and directivity



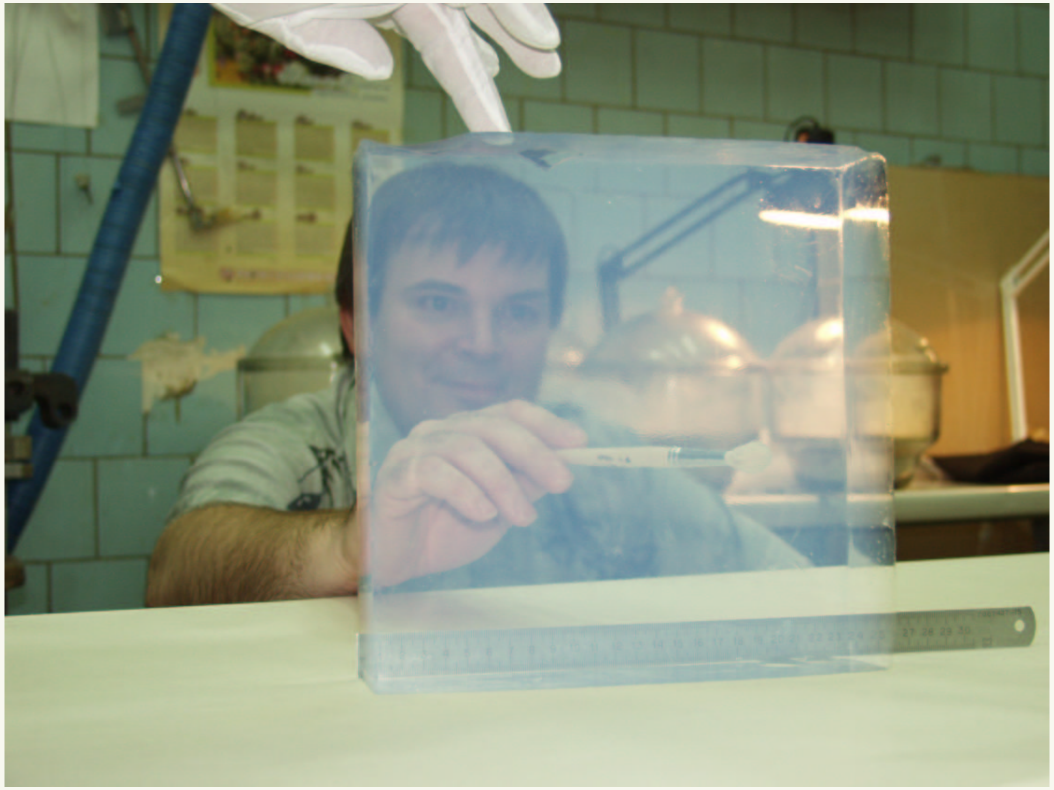
- **high photon intensities** $RMS = 0.1$ **ps**
- **thin aerogel radiators** $RMS = 0.02$ **ps**

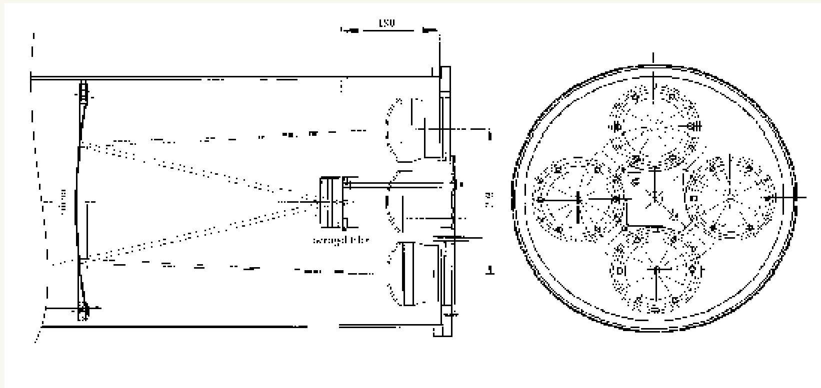
	n=1.01	n=1.03	n=1.05	n=1.01
l, mm	20	2	1	1
Cherenkov	0.14	0.092	0.086	0.014
+Rayleigh	0.60	0.104	0.090	0.014
+MS	0.80	0.094	0.084	0.012
+Al	0.58	0.110	0.091	0.017
				$\Longrightarrow$



Aerogel RICH for LHCb

Prototype beam test

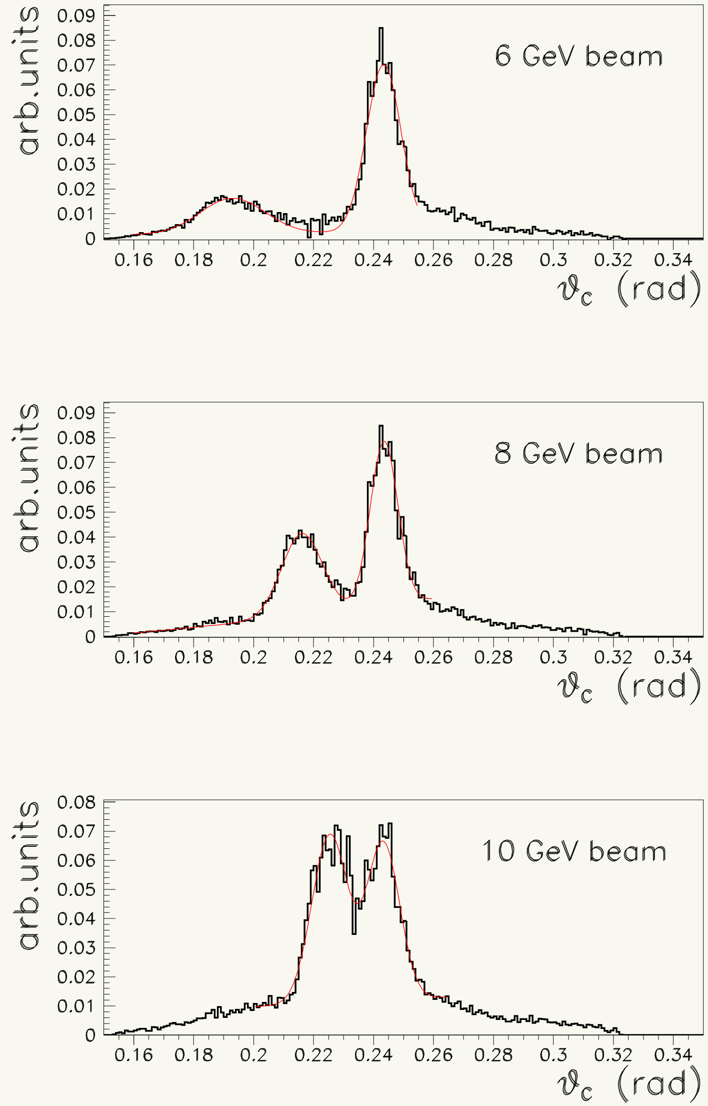




- Aerogel, Novosibirsk
  - n=1.03
  - Lsc = 45 mm (at 400 nm)
  - block dimensions $100 \times 100 \times 40$ mm

New block $200 \times 200 \times 50$ mm

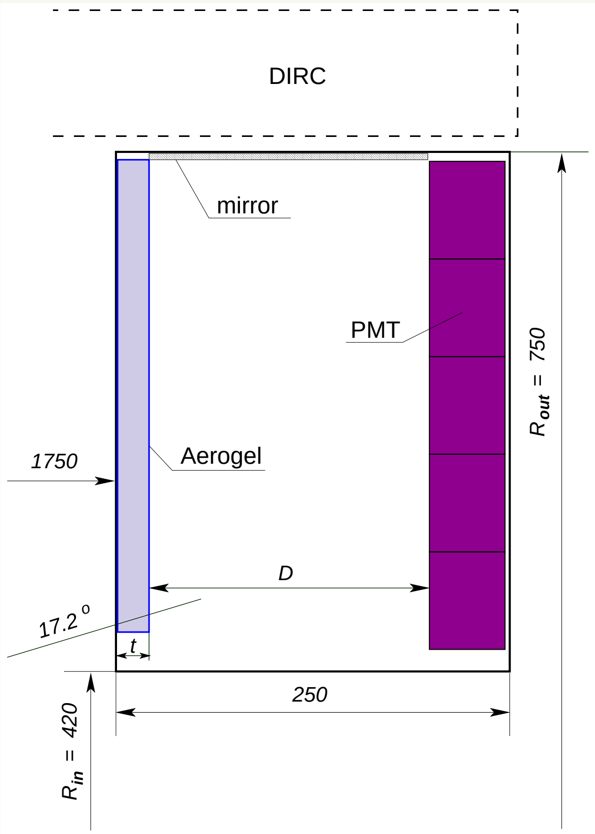
Pion/proton separation in aerogel RICH



- σ_θ for single photoelectron:
  - Experiment: 5.0 mrad
  - Monte Carlo: 3.1 mrad
- Number of photoelectrons: 10

P, GeV/c	σ_p	σ_π	$N_\sigma(p/\pi)$	$N_\sigma(K/\pi)$
6	7.8	2.9	17.1	4.7
8	4.1	2.8	9.9	2.9
10	3.0	2.3	7.8	1.6

Project of Aerogel Endcap RICH for SuperBaBar



π-K Separation

P, GeV/c	4	5
π-K separation,σ	4.5	3

- Aerogel, Novosibirsk
  - n=1.07
  - thickness 20 mm
- PMT, Burle Co.
  - Bialkali photocathode QEmax=24%
  - 6×6mm pads, 8×8
  - active/total area – 0.67
  - Photoelectron collection efficiency – 0.7
- Resolution at 4 GeV/c
  - aerogel thickness: 9.2mrad
  - PMT pixel: 7.5mrad
  - chromaticity: 5.6mrad
- Number of photoelectrons: 17

Conclusion