Cherenkov Detector with a Focussing Aerogel Radiator

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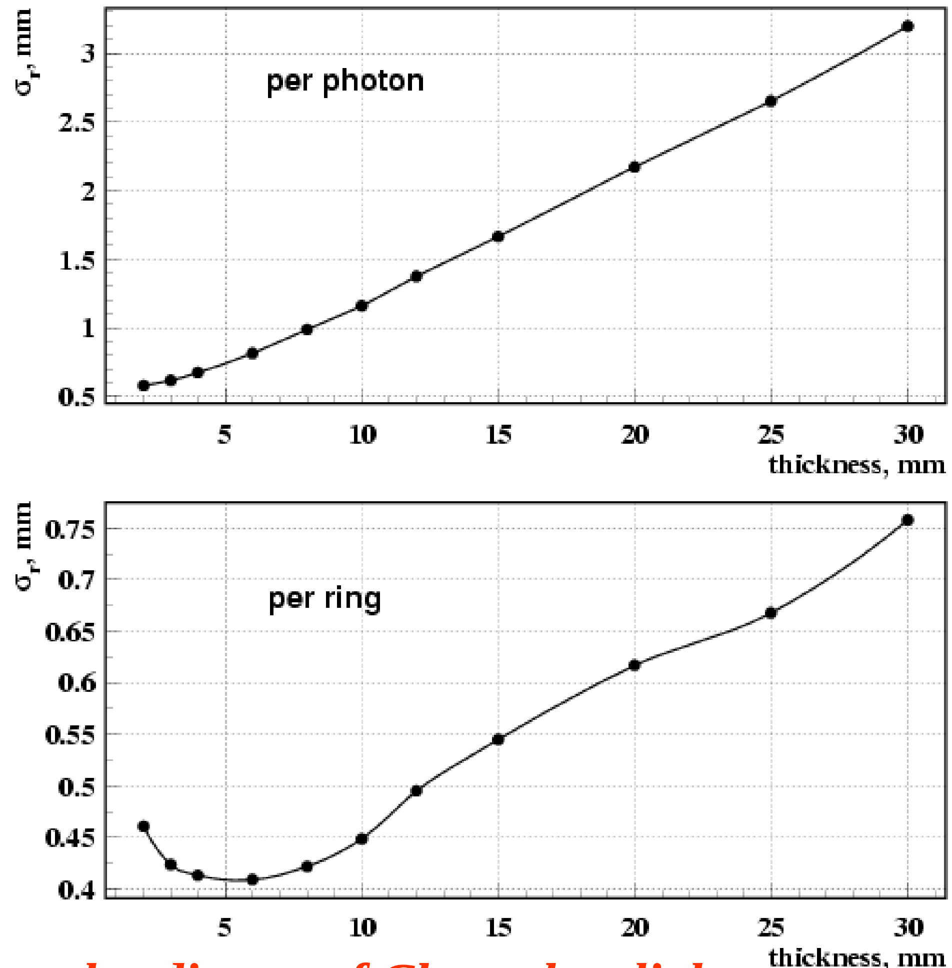
In proximity focusing RICH detectors thickness of the radiator is one of the main parameters effecting the accuracy of particle velocity measurement

With thickness increase:

- we increase the number of detected photons in the Cherenkov ring ⇨ make better the accuracy of Cherenkov angle measurement
- we increase the width of Cherenkov ring ⇨ make worse the accuracy of Cherenkov angle measurement

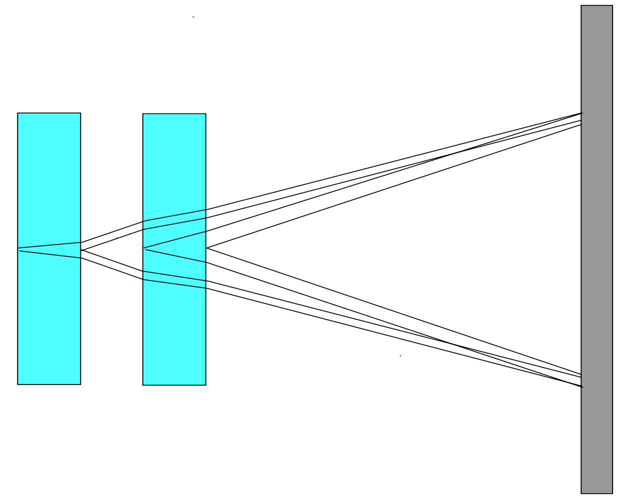


Possible solution – to use several radiators of Cherenkov light

The idea of the method:

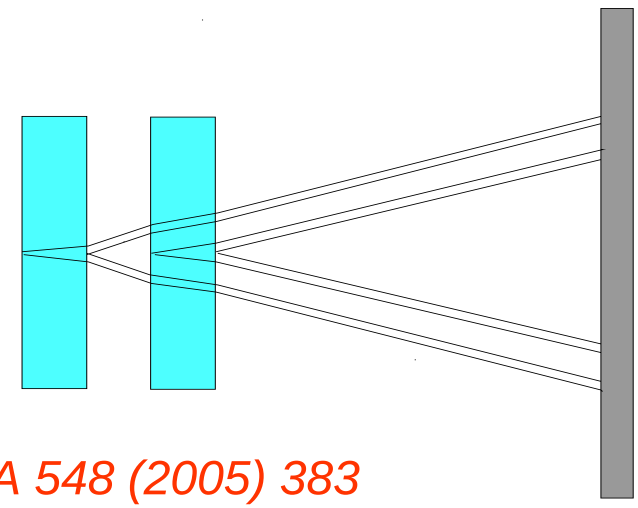
- Single ring,

  thickness of the layers and indices of refraction are adjusted in such a way that rings from the layers superimpose



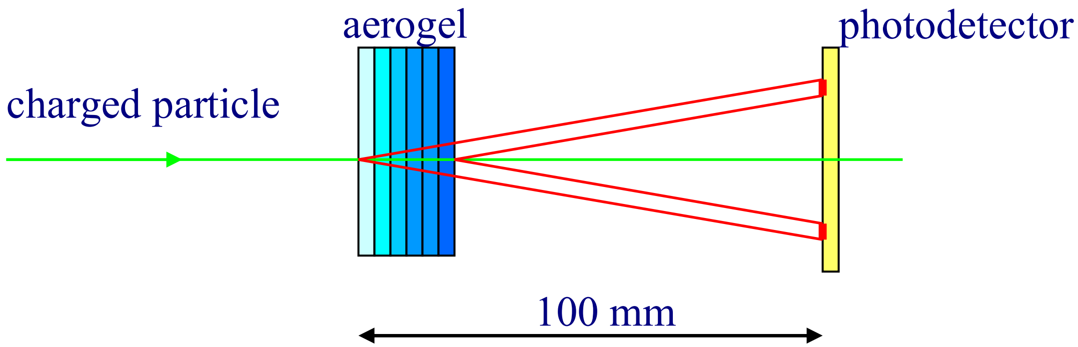
- Multi ring,

  thickness of the layers and indices of refraction are adjusted in such a way that rings from the layers are separated



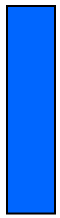
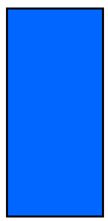
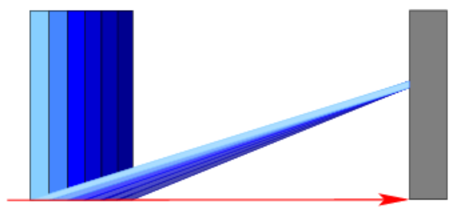
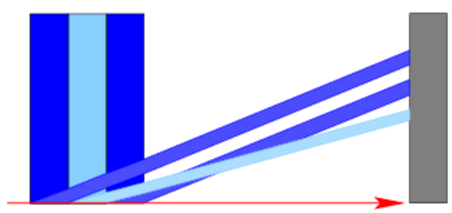
The idea is first published by Belle aerogel group in NIMA 548 (2005) 383

MONTE CARLO SIMULATION (GEANT4)



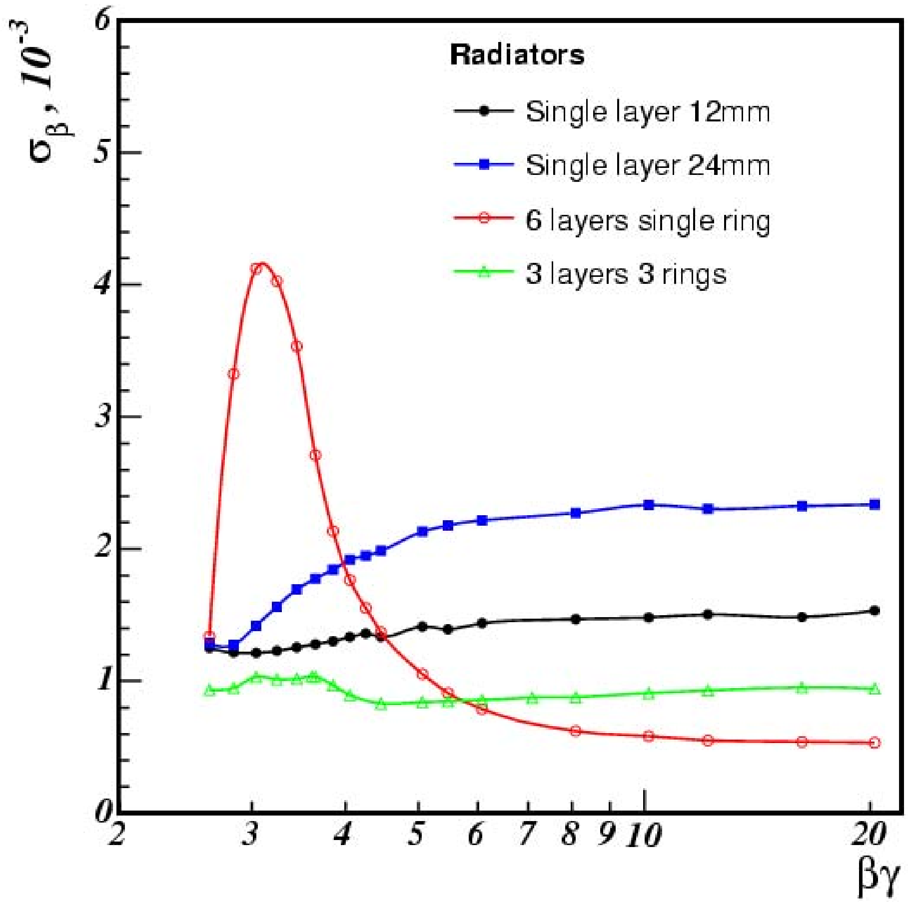
LIGHT PROCESSES:	PHOTODETECTOR:
generation scattering refraction reflection absorption	MCP type with bialkali cathode borosilicate window (Burle) QEmax - 24% active area – 70% photoelectron collection –70% pixel size – less than chromatic aberration
aerogel scattering length Lsc = 40 mm at 400 nm	

SIMULATION: FOUR RADIATORS AT NORMAL AND AT 30º BEAM INCIDENCE

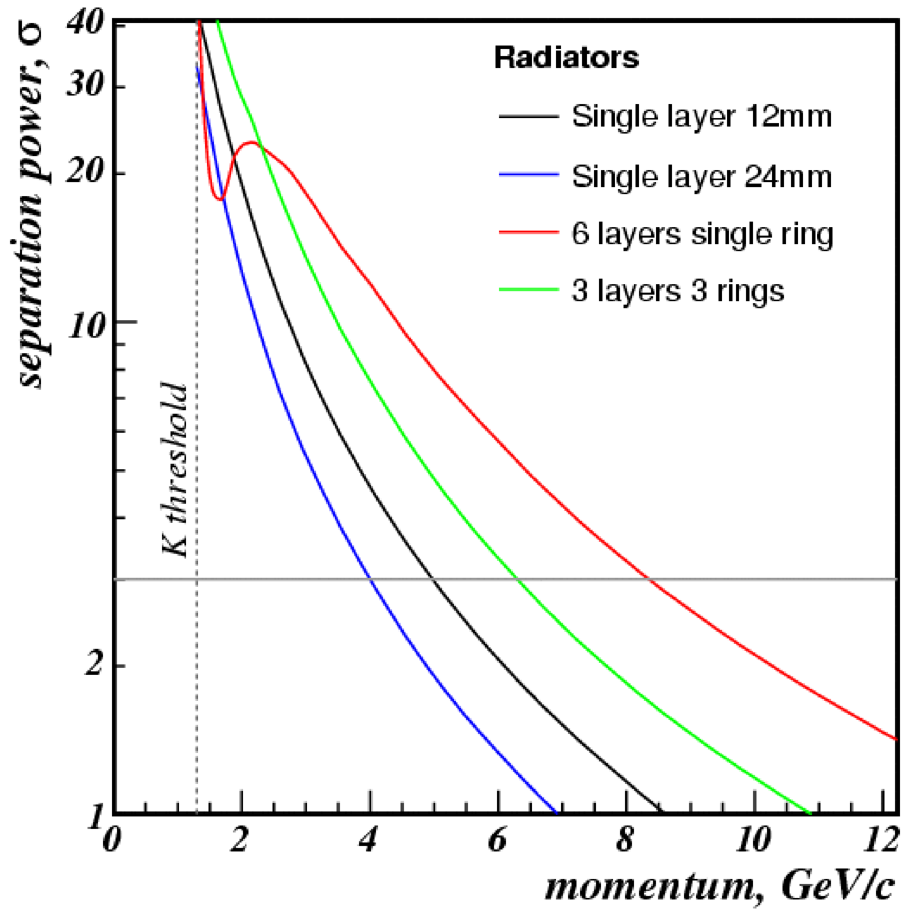
		Total thickness, mm	Layer thickness, mm	index
Single layer		12	12	1.070
Single layer		24	24	1.070
6 layers single ring		26.9	4.02 4.19 4.38 4.57 4.78 5.00	1.070 1.064 1.059 1.054 1.050 1.046
3 layers 3 rings		30	10 10 10	1.070 1.037 1.070

Normal particle incidence

β resolution per track

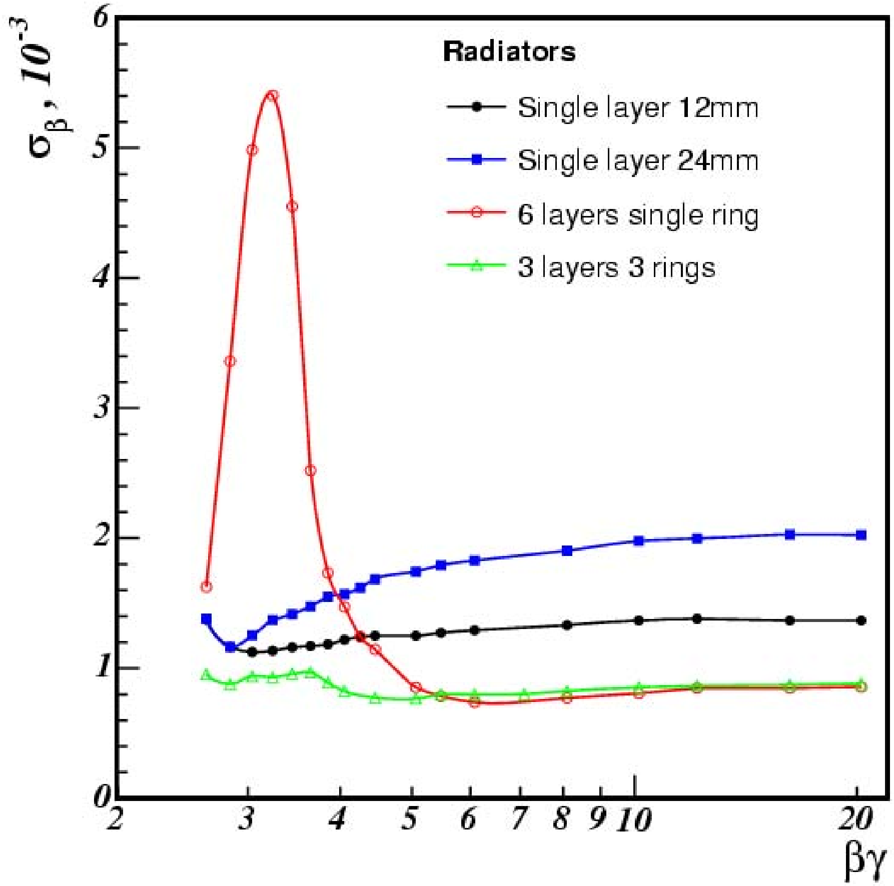


π/K separation

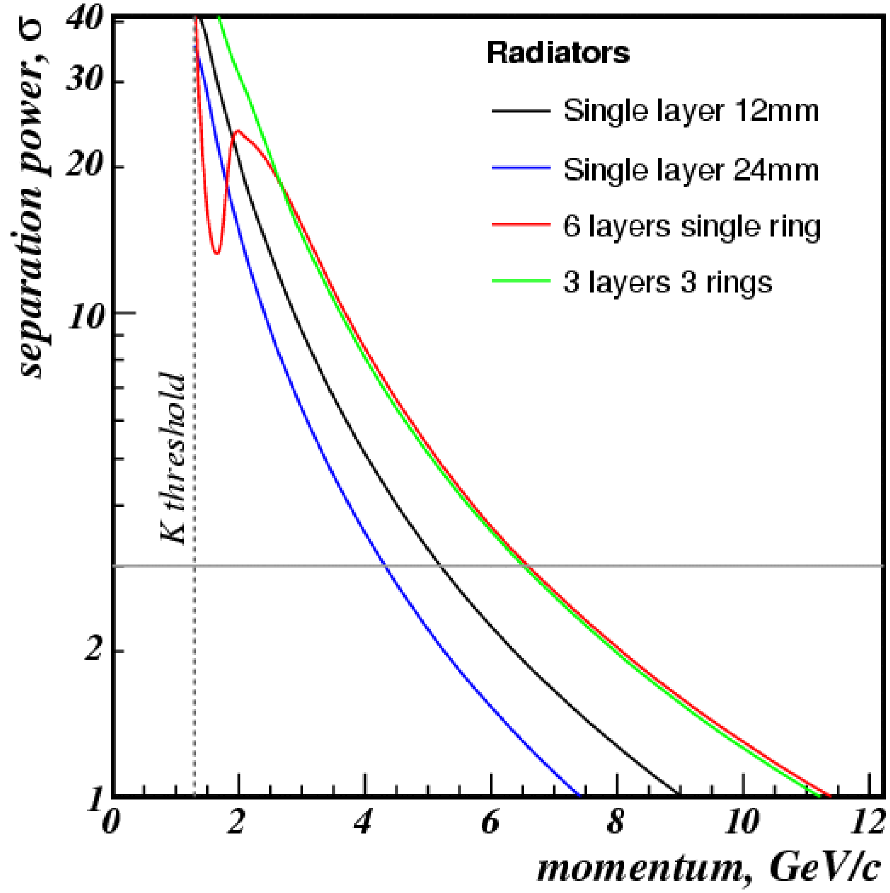


30° degree particle incidence

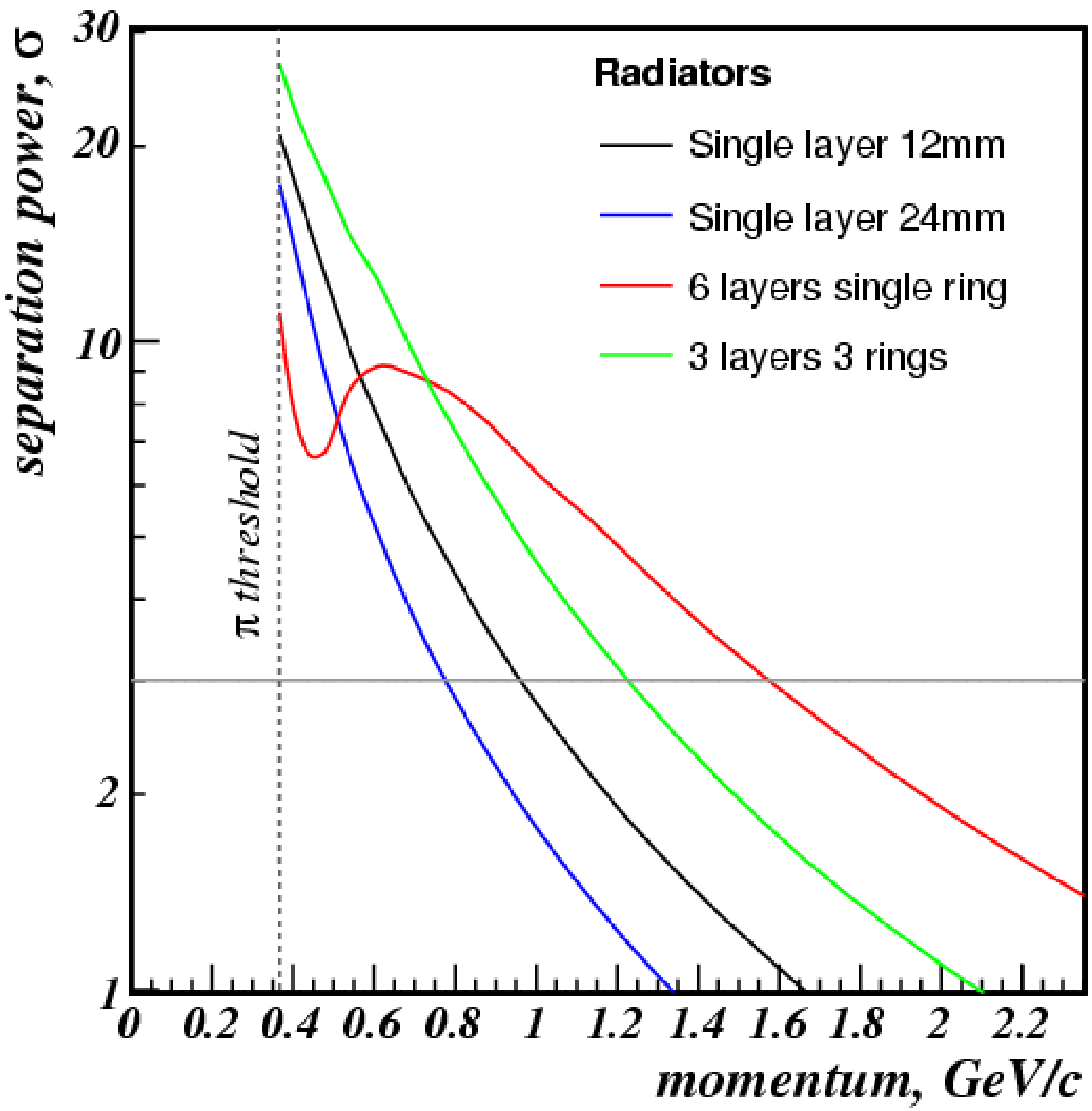
β resolution per track



π/K separation



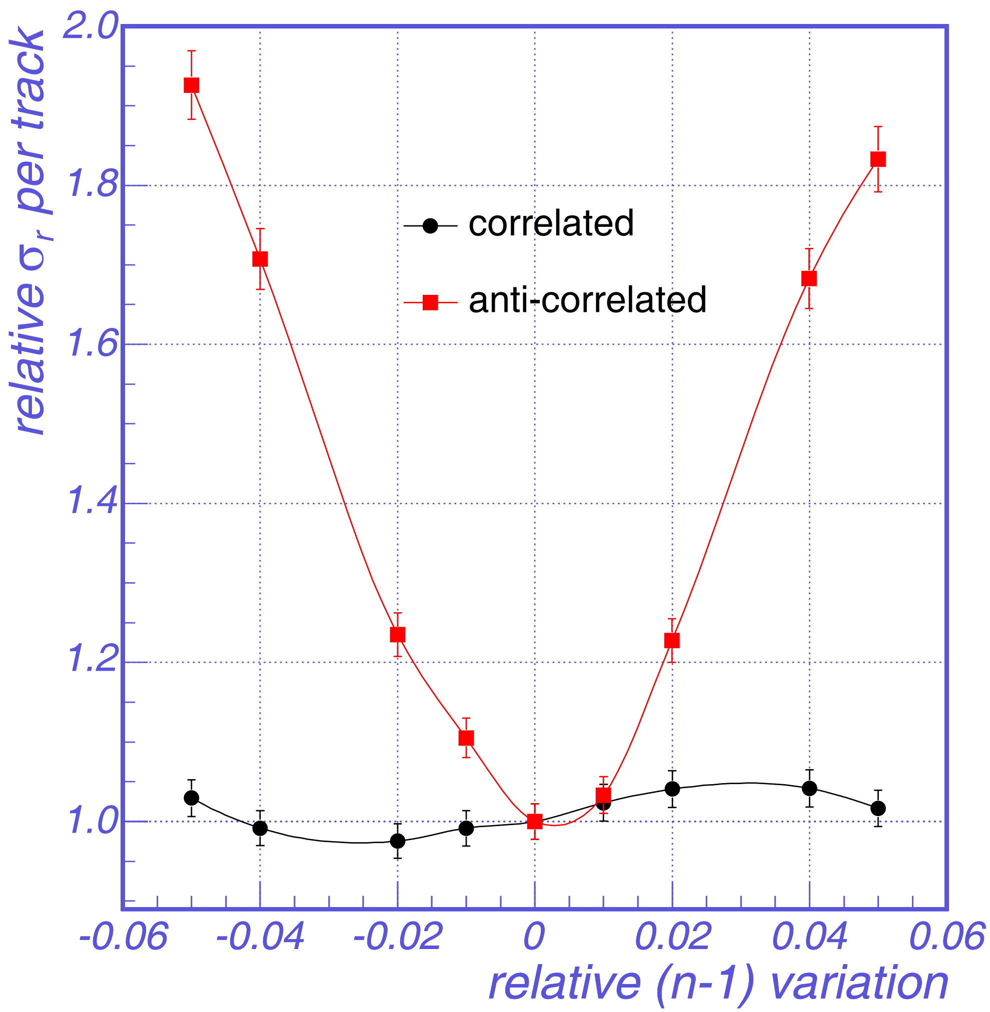
μ/π SEPARATIONS AT NORMAL INCIDENCE



Technical requirements on multilayer aerogel, single ring (index of refraction)

Accuracy on the refractive index in the layers

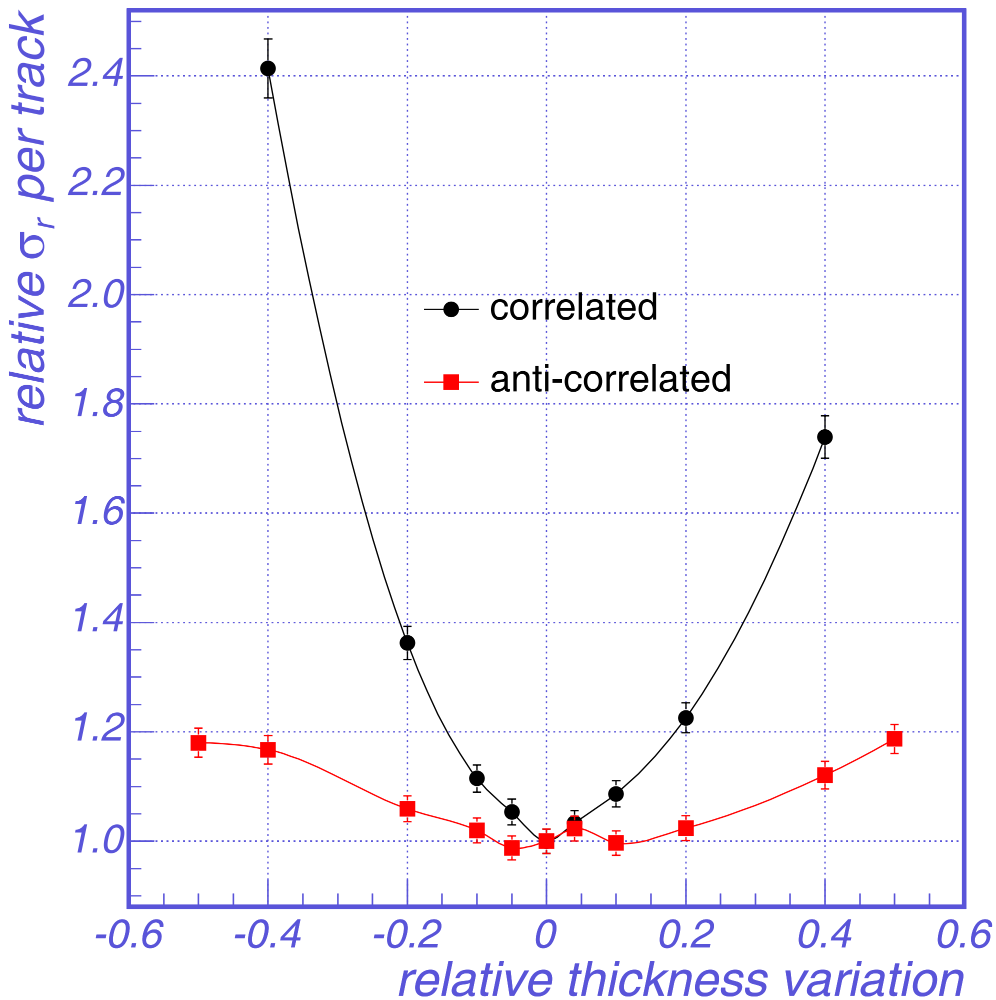
- 6-layer option
- 2 cases –
  - "correlated" (all layers change equally)
  - "anti-correlated" (half of the layers increase, other decrease)



Technical requirements on multilayer aerogel, single ring (layer thickness)

Accuracy on the thickness of the layers

- 2 cases –
  - "correlated" (all layers change equally)
  - "anti-correlated" (half of the layers increase, other decrease)

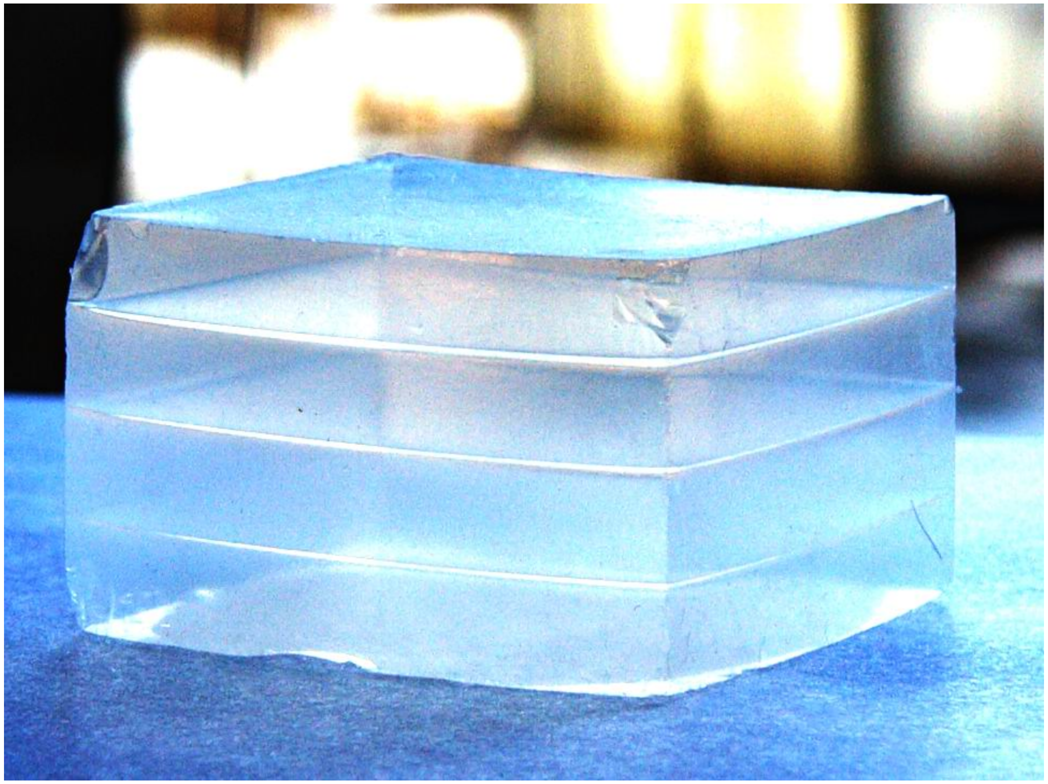


FOCUSING FOUR-LAYERED AEROGEL TILE

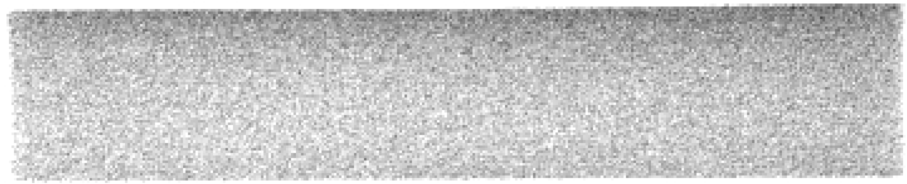
Produced in May 2004

	thickness mm	index designed	index measured
Layer1	6.0	1.030	1.0297+- 0.0003
Layer2	6.3	1.027	1.0268+-0.0005
Layer3	6.7	1.024	1.0234+-0.0003
Layer4	7.0	1.022	1.0213+-0.0003

Lsc = 44 mm
at 400 nm (!)

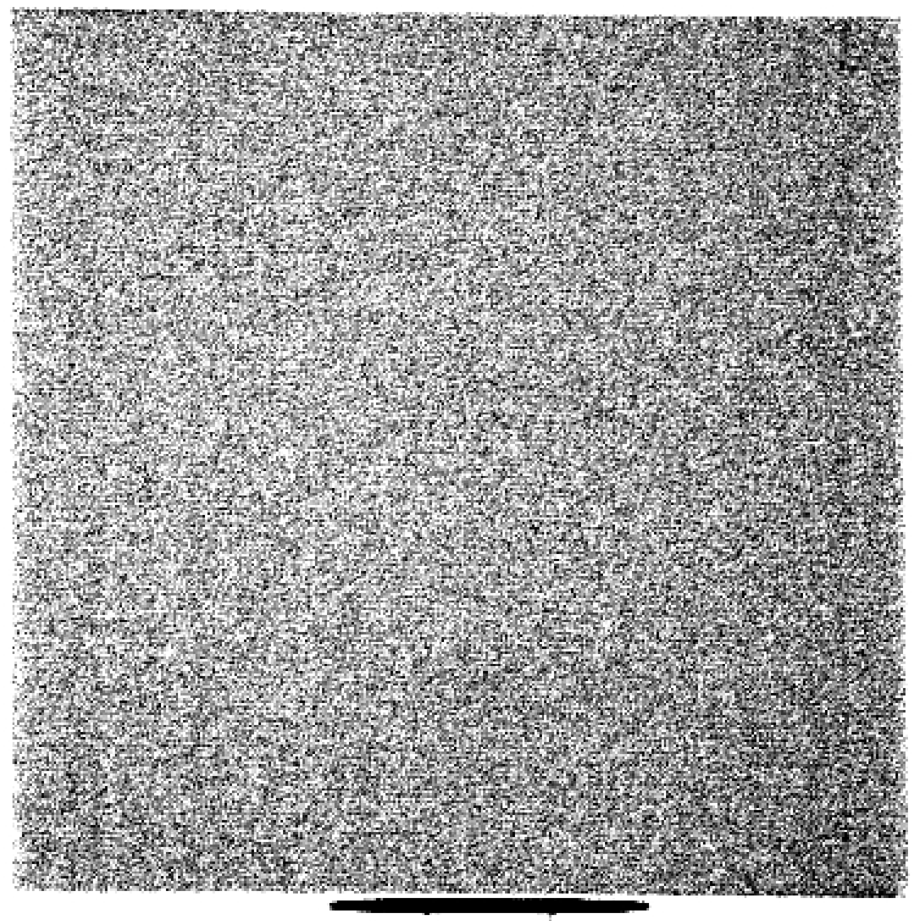


Digital X-ray measurements of aerogel density variations



To measure variations of the refractive index we suggest new method:

- The origin of refractive index variations are density variations
- $$n = \sqrt{1 + \alpha\rho}$$
- 123x123x25 mm aerogel block



Digital X-ray detector was used

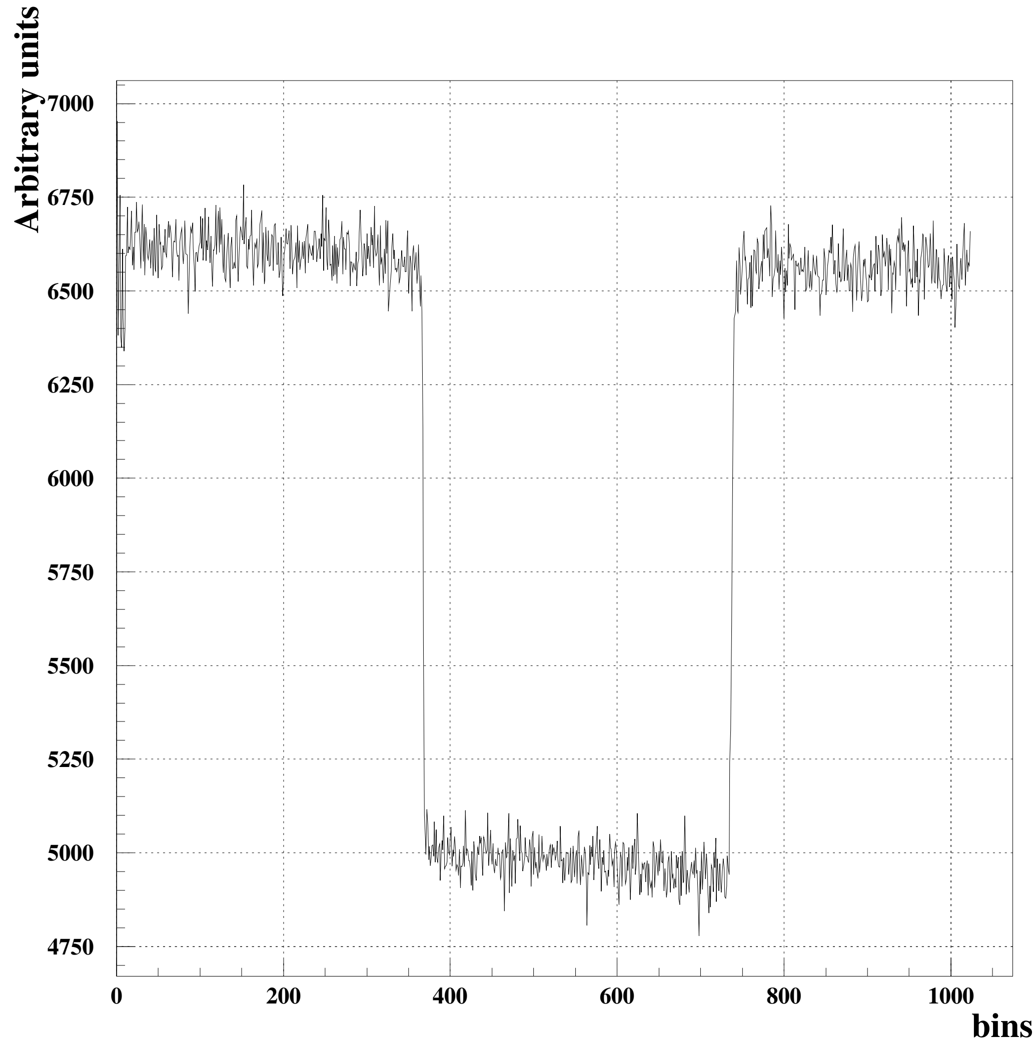
- scanning system
- good signal/noise ratio
- 0.4 mm resolution

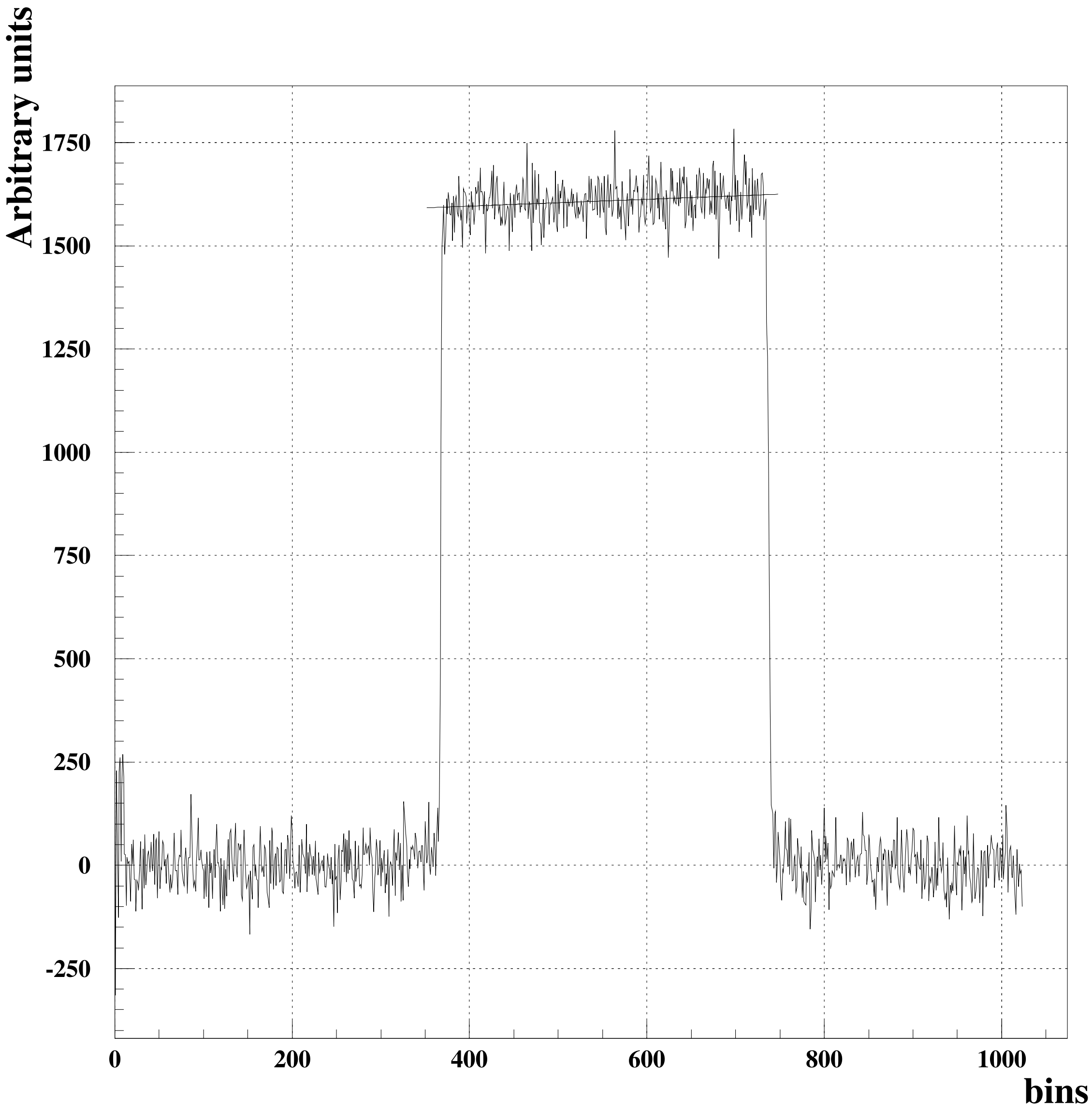
"The new effective detector for digital scanning radiography" NIMA513(2003)57-60

Raw image profile (middle of the block)

Several corrections were applied:

- background subtraction
- angle correction
- thickness correction





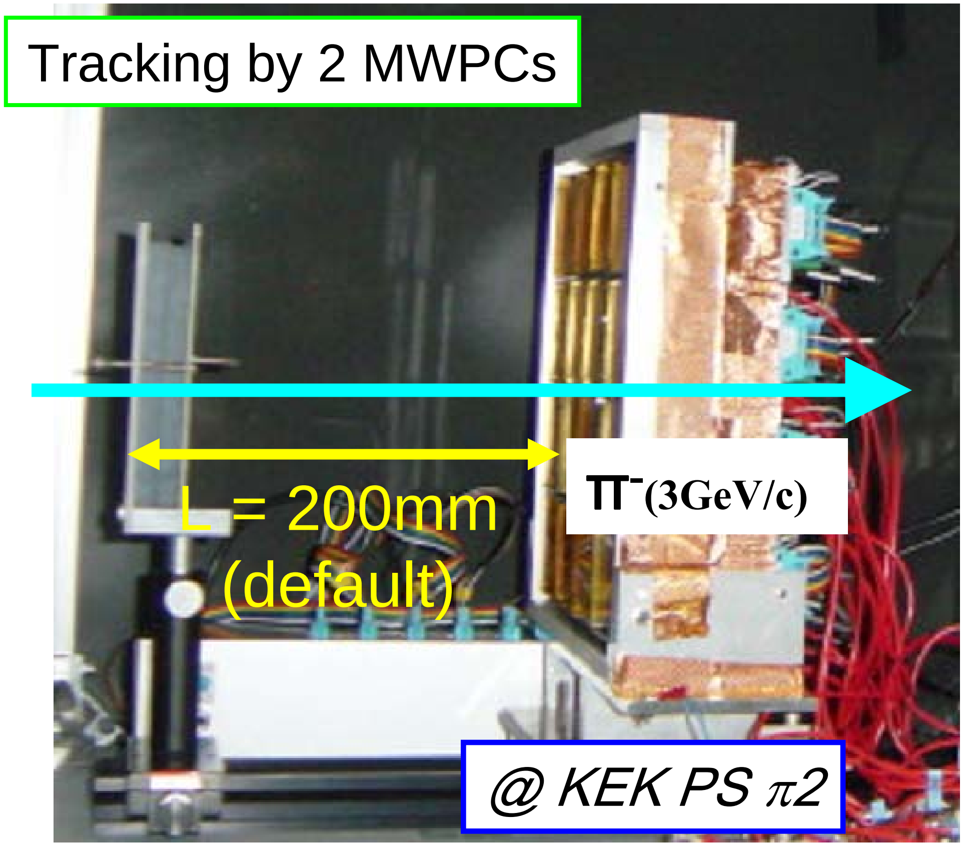
The slope in aerogel density was observed

$(\rho_{max} - \rho_{min})/\rho = 1.8\%$

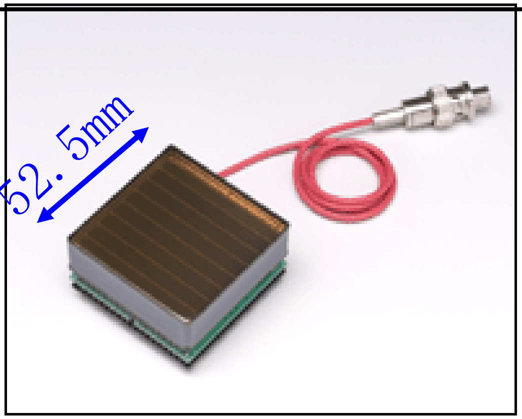
More work to be done!

Beam test measurements

Beam test setup



H8500 [Flat panel PMT]



- Gain : 2×10^6 @1100V
- Pixel size : 5.8mm
- Total ch : 64ch

Photon detector
Flat panel PMT : 4x4 array
(Total ch : 1024ch)

Aerogel samples

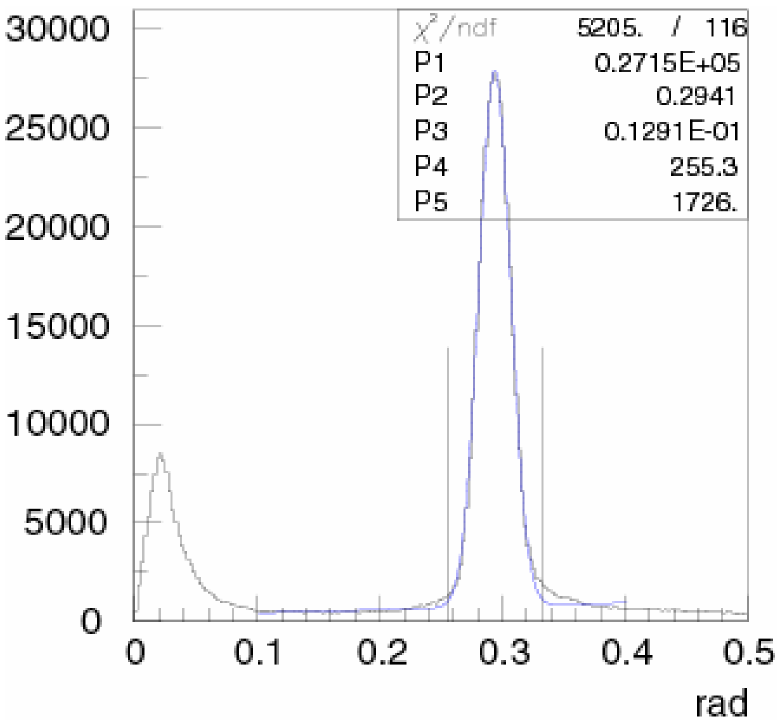
- Index → refractive index measured by laser @405nm
- d → thickness of aerogel
- Lsc → measured scattering length @400nm

	index	d (mm)	Lsc (mm)
4-layer	1.0473 1.0447 1.0421 1.0416	6.0 6.0 6.0 6.9	34.9
2-layer	1.0486 1.0409	14 14	30.55

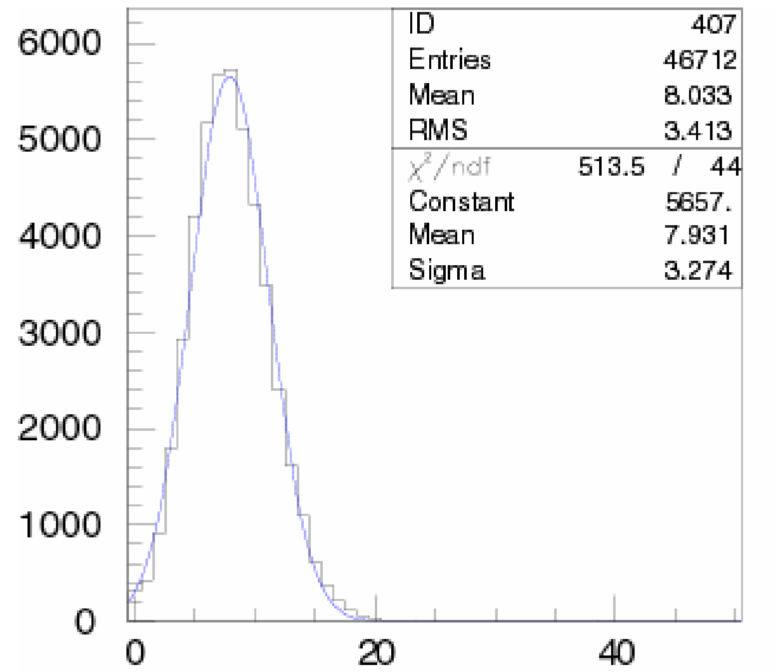
	index	d (mm)	Lsc (mm)
Single layer with longitudinal variation	1.0532 1.0525 1.0517 1.0510 1.0513 1.0510 1.0509 1.0506 1.0505	19.5	~45

4-layer focusing

Cherenkov angle distribution



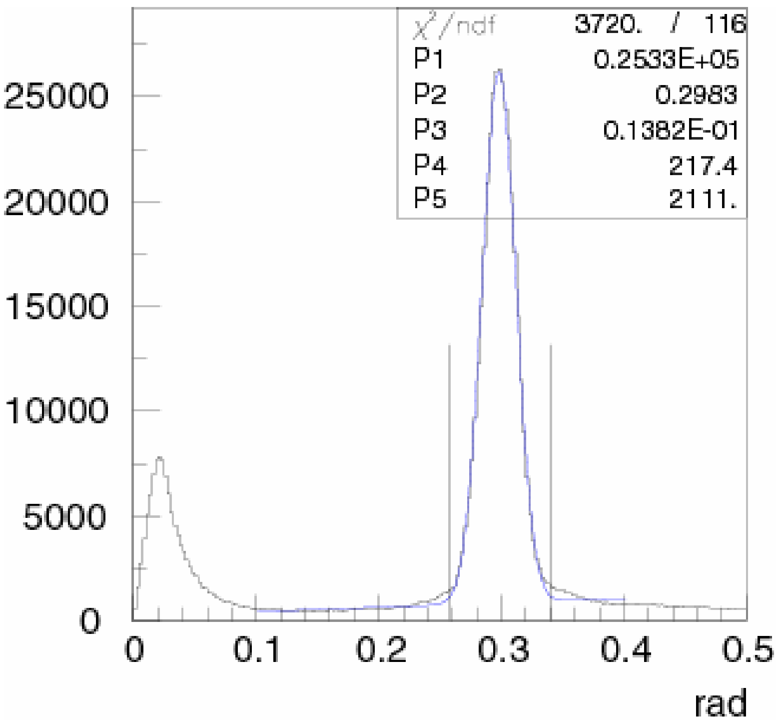
Number of hits



	θc	σθ	Npe	Nbg	S/N
4-layer focusing	0.2941 rad	12.9 mrad	7.4	0.5	14.9

2-layer focusing

Cherenkov angle distribution



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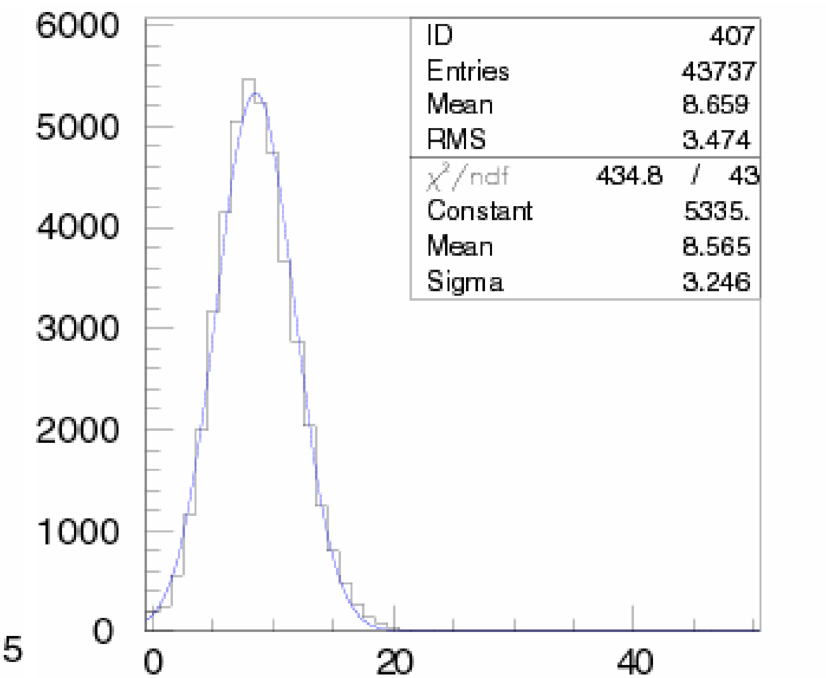
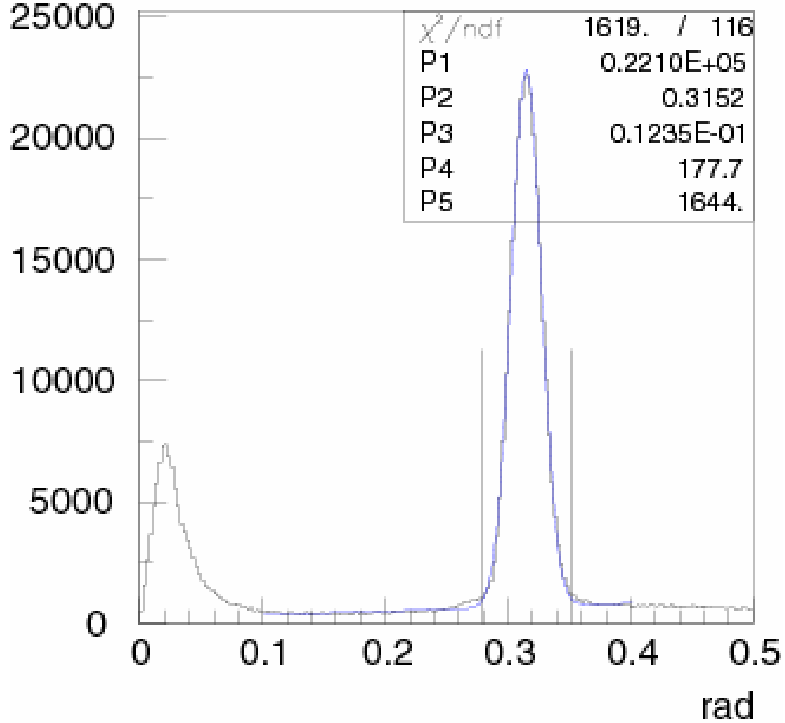


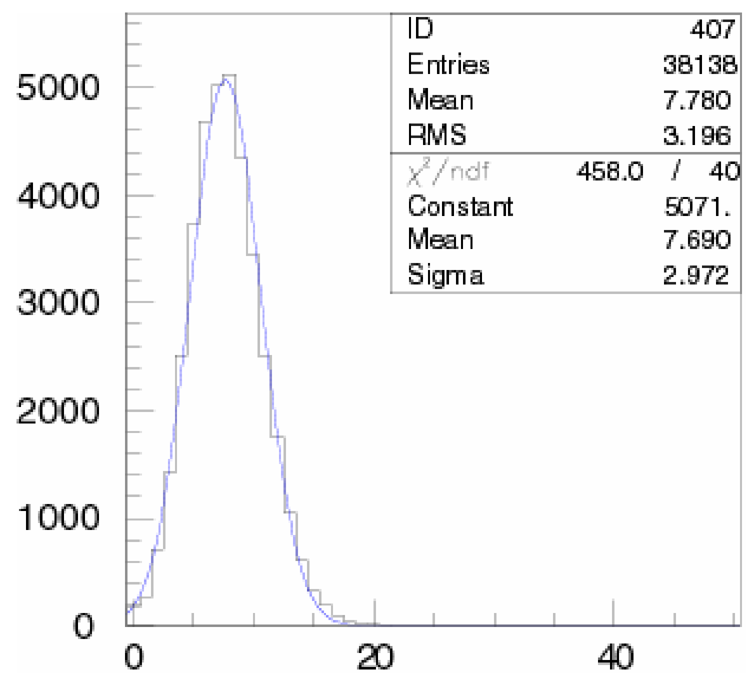
	θc	σθ	Npe	Nbg	S/N
2-layer focusing	0.2983 rad	13.8 mrad	7.9	0.6	12.5

Single layer with variation, focusing at 200 mm

Cherenkov angle distribution



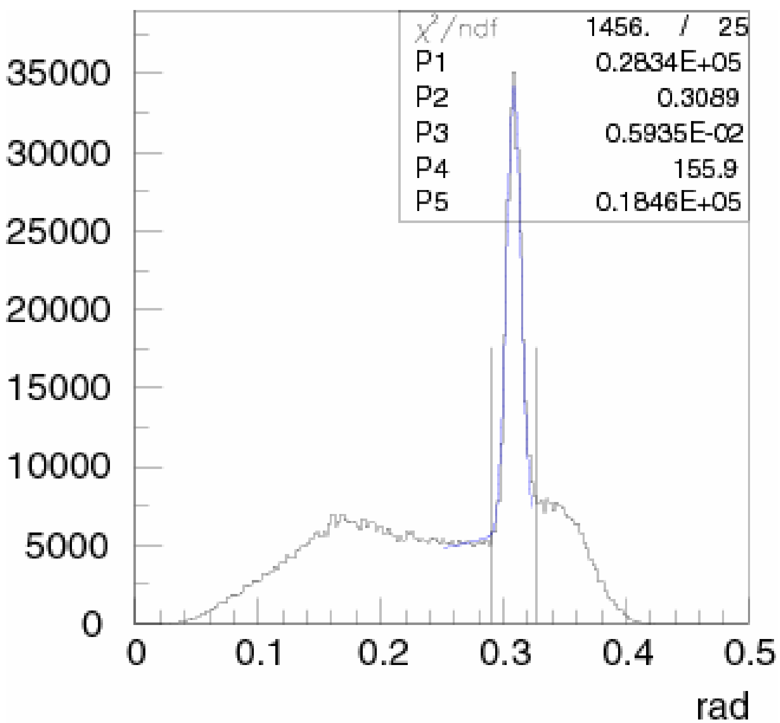
Number of hits



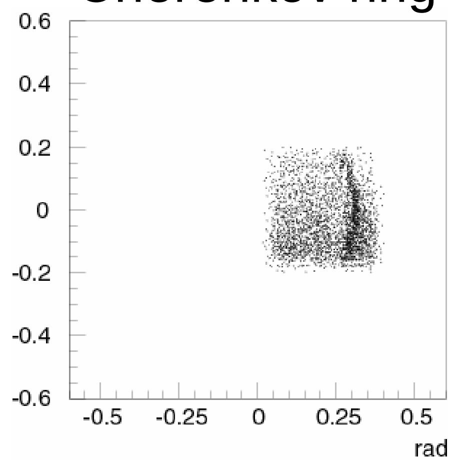
	θc	σθ	Npe	Nbg	S/N
Single, L=200 mm	0.3152 rad	12.4 mrad	7.2	0.5	13.3

Single layer with variation, focusing at 600 mm

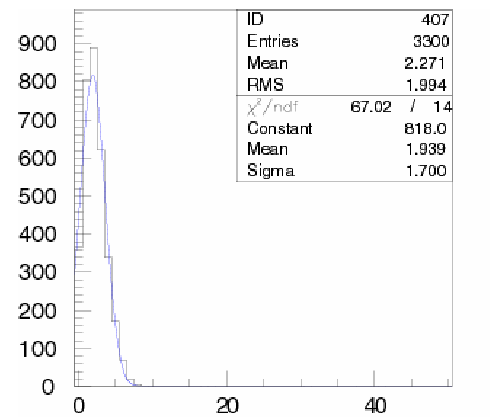
Cherenkov angle distribution



Cherenkov ring



Number of hits



More information in the poster presentation of Yoshinobu Kozakai "Study of Proximity Focusing RICH with an Aerogel Radiator"

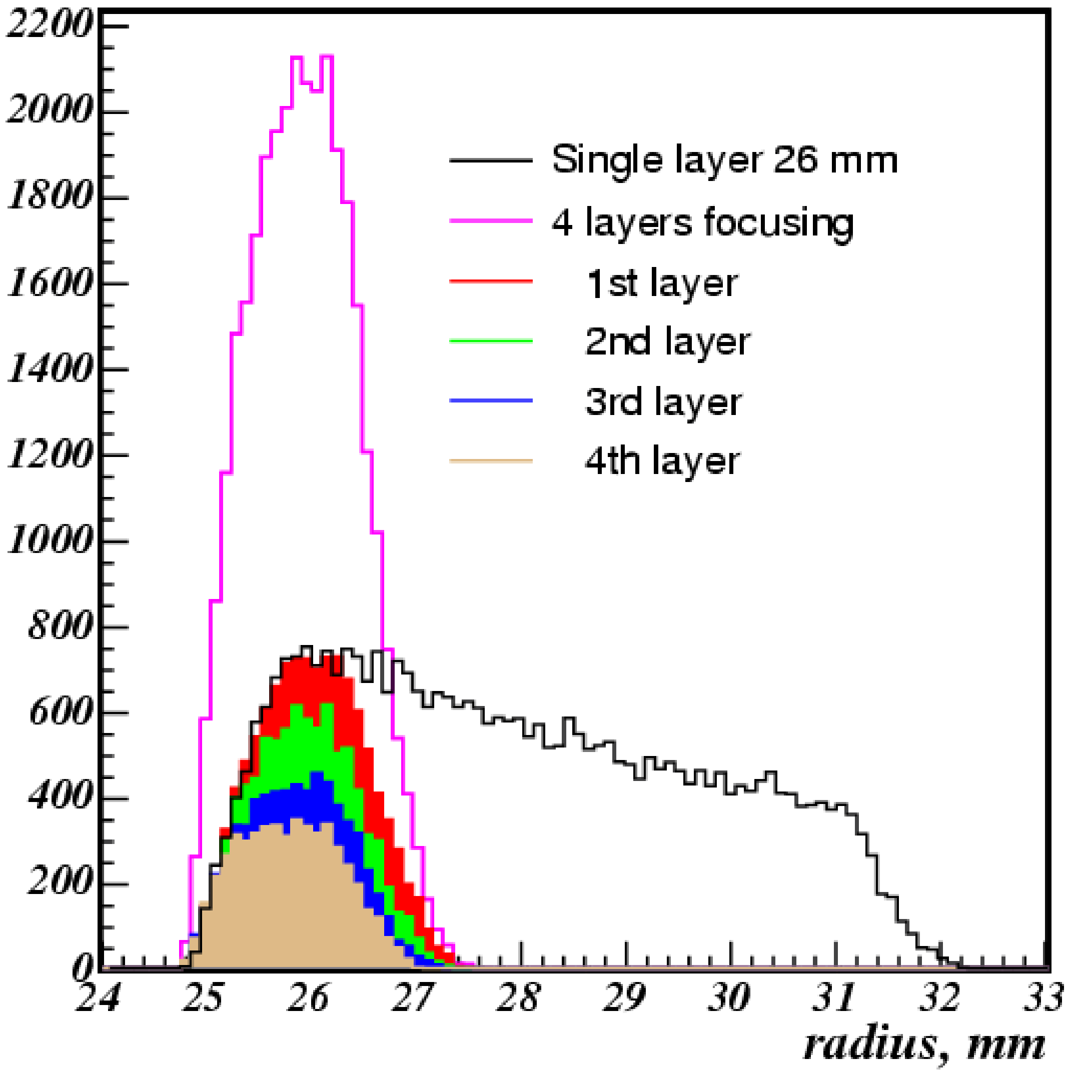
	θc	σθ	Npe	Nbg	S/N
Single, L=600 mm	0.3089 rad	**5.9** mrad	1.3	0.6	2.0

Conclusions

- The development of focusing aerogel RICH is in progress:
  - technical requirements on parameters of multi-layer aerogel for single ring option have been investigated
  - the new method of refractive index variation characterization was suggested and tested
  - several samples of multilayer aerogel were produced
  - test measurements have been done with 2-layer, 4-layer samples and with sample having longitudinal variation on π-meson beam at KEK, data analysis is in progress

Additional slides:

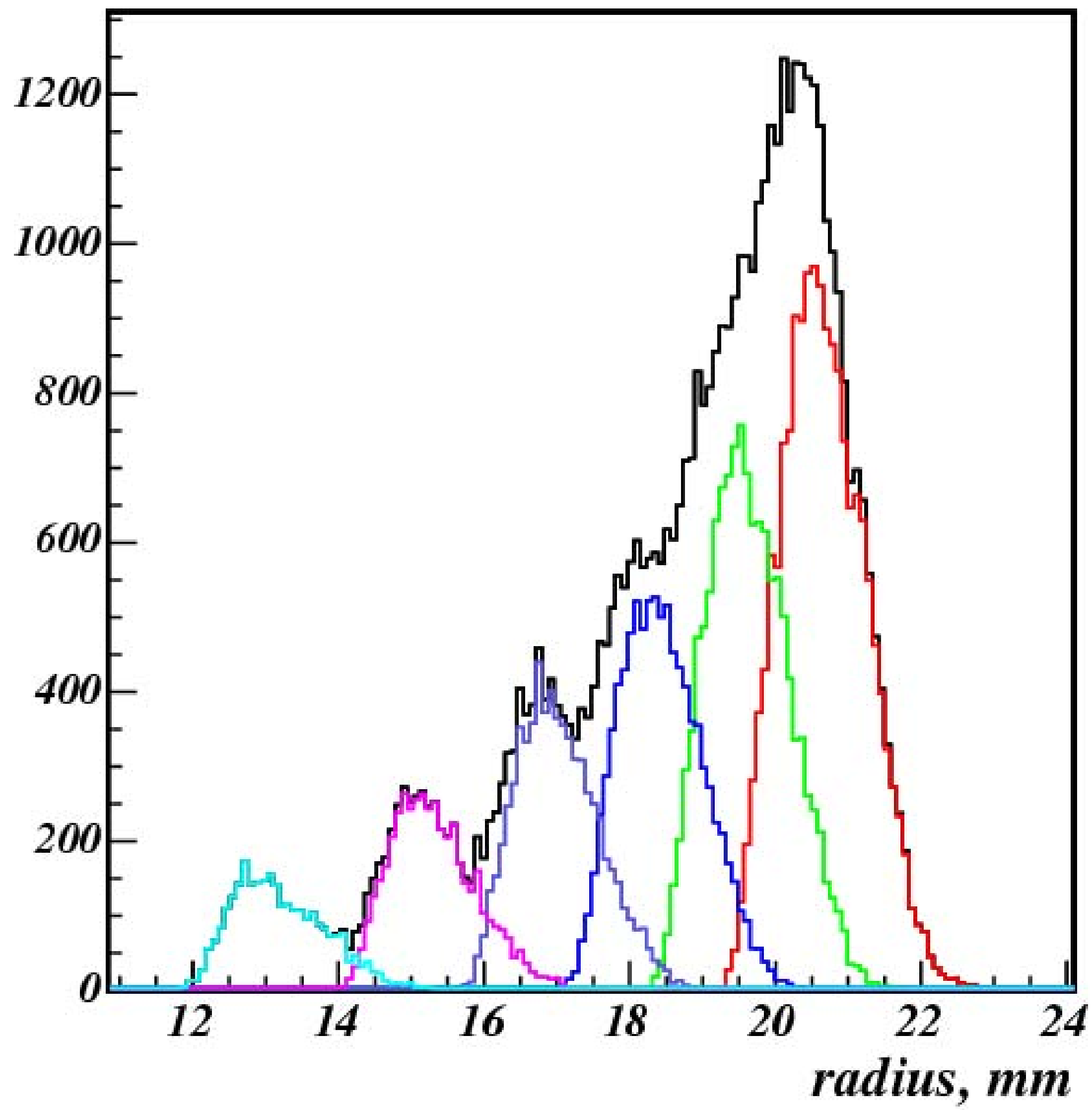
CHERENKOV PHOTON DISTRIBUTIONS FOR SINGLE LAYER AND FOUR- LAYERED FOCUSING AEROGELS OF EQUAL THICKNESS



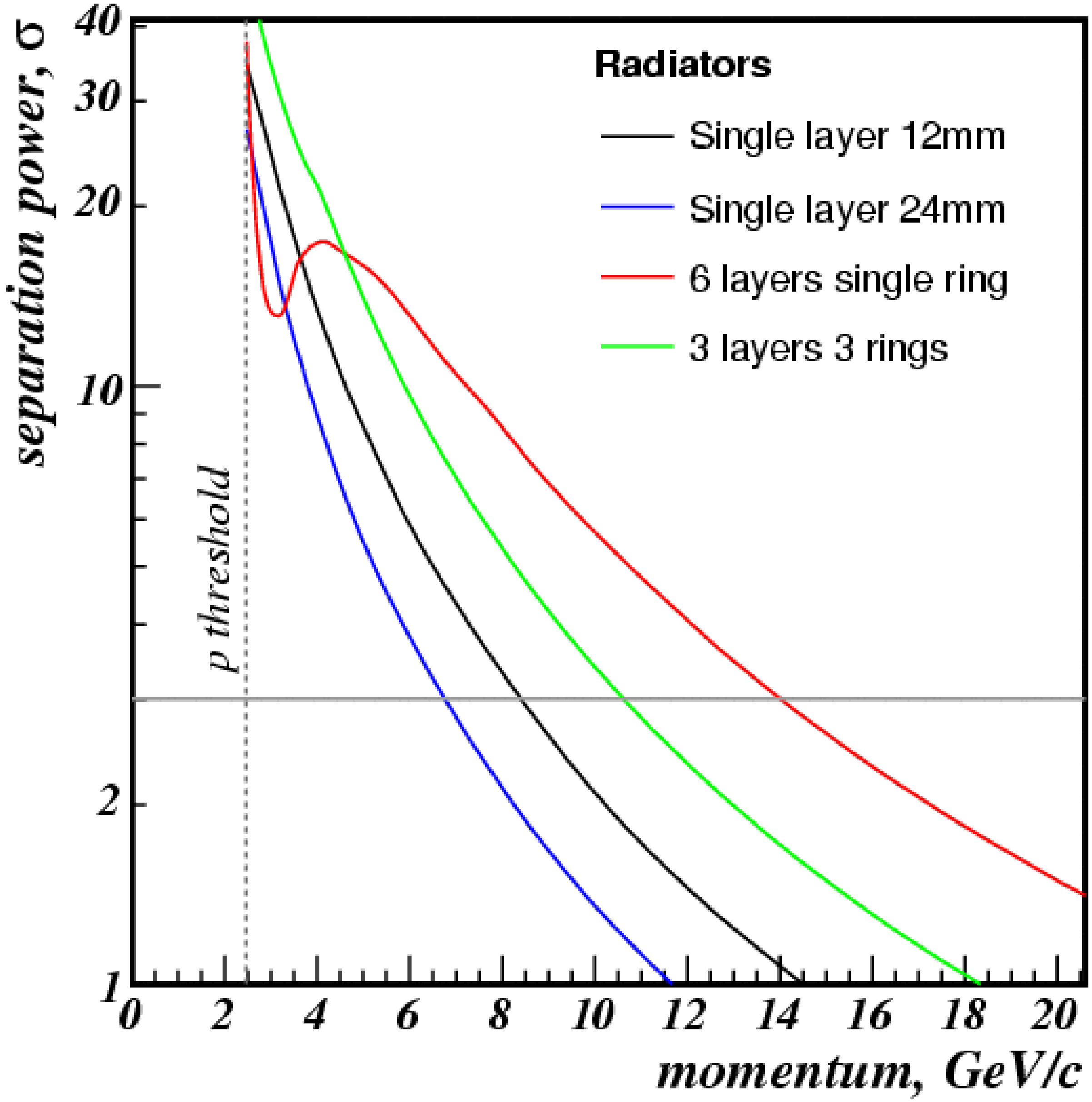
PHOTON DISTRIBUTIONS

Single layer	<r> =28.0	σ=1.80
4-layered	<r> =26.2	σ=0.51
	Δr	σ
Layer1	0.056	0.51
Layer2	-0.004	0.51
Layer3	-0.033	0.50
Layer4	-0.071	0.49

MOMENTUM ABERRATION ON 6-LAYERED SINGLE RING AEROGEL RADIATOR (1.8 GeV/c kaons)



K/p SEPARATIONS AT NORMAL INCIDENCE



Technical requirements on multilayer aerogel, single ring (longitudinal density variations)

Accuracy on the density variations along the track

- case sensitive
  - negative – variation in the layer from low values to high (continuous focusing)
  - positive – variation from high values to low

Technical requirements on multi ring aerogel are more simple!