

Investigation of Cherenkov light scattering and refraction on aerogel surface

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Outline

- Motivation
- Light scattering on the polished aerogel surface
- Impact of cracks in aerogel on the accuracy of Cherenkov angle measurement
- Conclusions

Beam test with PDPC FARICH prototype at CERN (2012)



- 4-layer aerogel
- $n_{\max} = 1.046$
- thickness 37.5 mm
- focal distance 200 mm
- hermetic box with acrylic glass window was used to prevent moisture condensation on aerogel tile

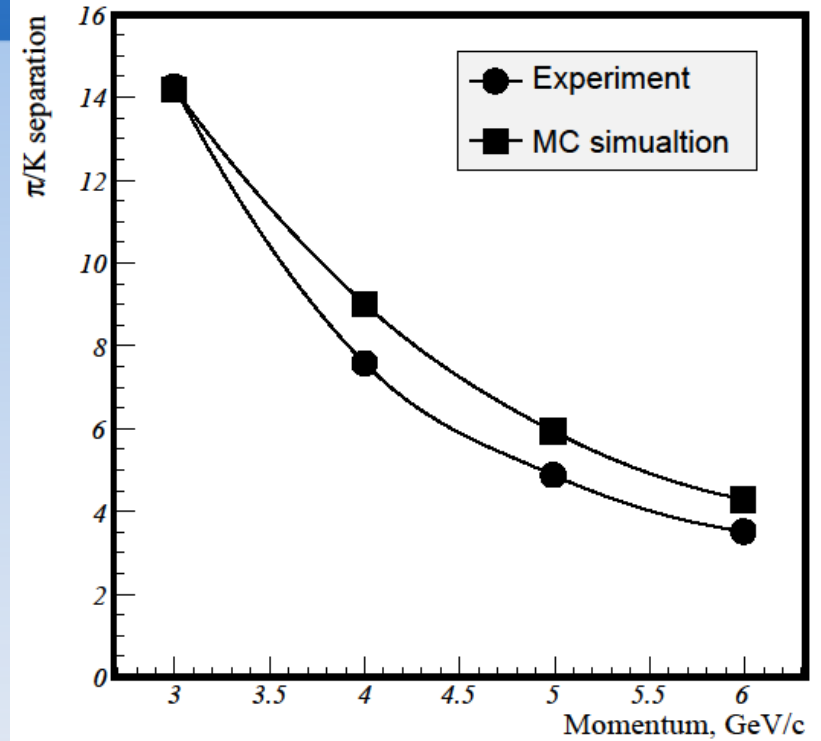
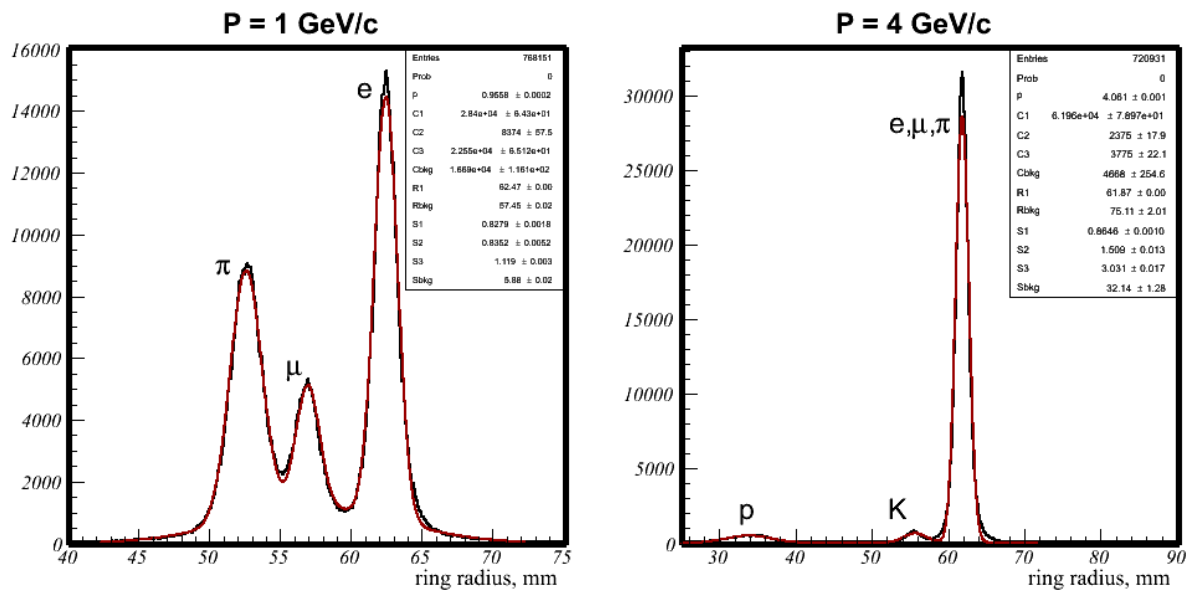
Photon matrix $20 \times 20 \text{ cm}^2$

- Sensors DPC3200-22
- 3200 micro-cells in pixel,
- 3x3 modules = 6x6 tiles = 24x24 dies = 48x48 pixels
- 576 time channels
- 2304 amplitude (position) channels
- Pixel dimension $3.2 \times 3.9 \text{ mm}^2$
- to detect single photons detector was cooled to $-40^\circ \text{ Celsius}$



Beam test results: particle identification

Cherenkov rings radius distribution



μ/π : **5.3 σ** @ 1 GeV/c
 π/K : **7.6 σ** @ 4 GeV/c
 π/K : **3.5 σ** @ 6 GeV/c

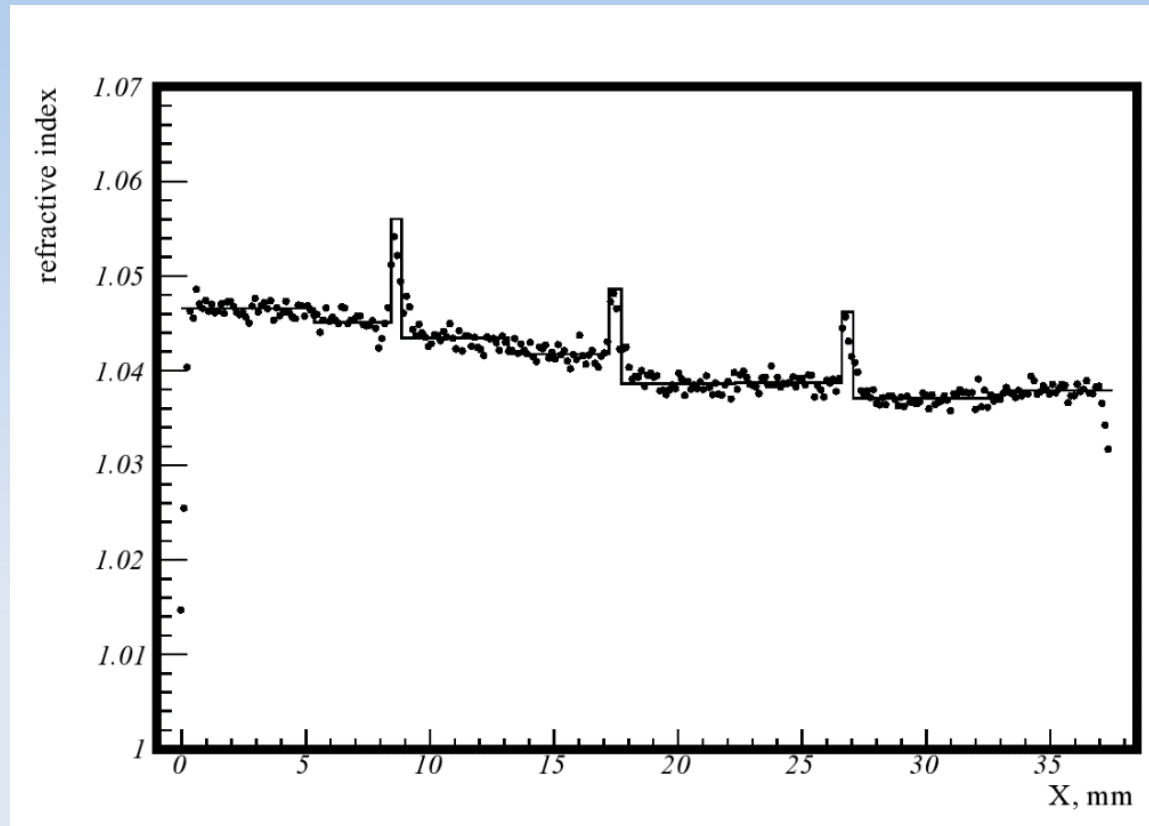
▣ **2.6 times less than in initial MC simulation**

A.Yu. Barnyakov, et al., Nuclear Instruments & Methods in Physics Research A 732(2013)352-356

Why we were 2.6 times worse than expected?

X-ray scan of the density within thickness of the tile

- N_{pe} was 1.6 times less than expected
- Strong effect of uncontrolled refractive index variations



What we could do?

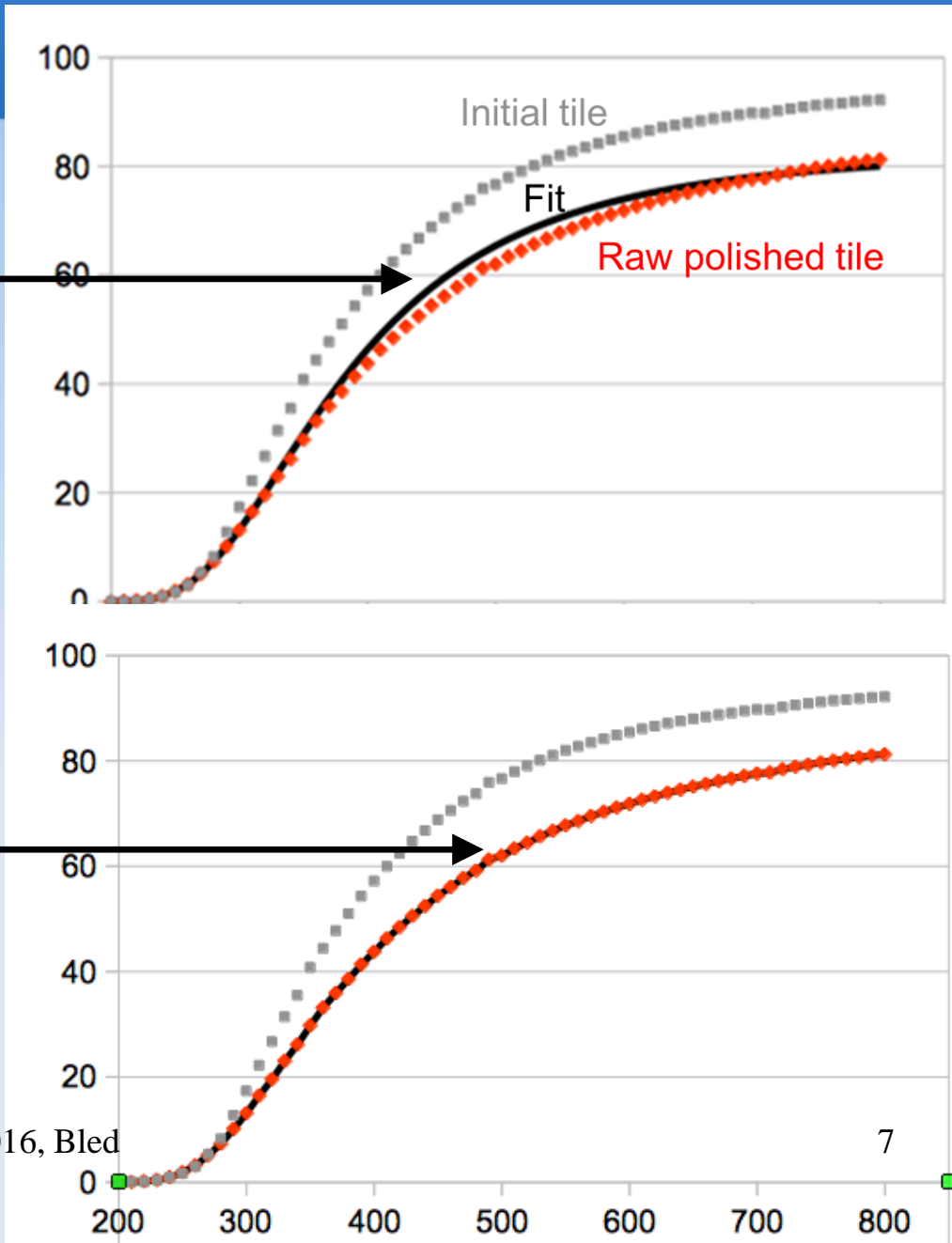
- **Make step back**
- **Separate tiles (5-8 mm thickness)**
 - **How to make thin tiles?**
 - **What to do with 1-10% light loss at each air gap?**
 - **Can we polish aerogel?**
 - **How can we characterize quality of polishing?**

Light scattering on the polished aerogel surface (1)

$$\frac{I}{I_0} = A \cdot \exp\left(-\left(\frac{t}{L_{sc}} \left(\frac{\lambda}{400}\right)^4\right)\right)$$

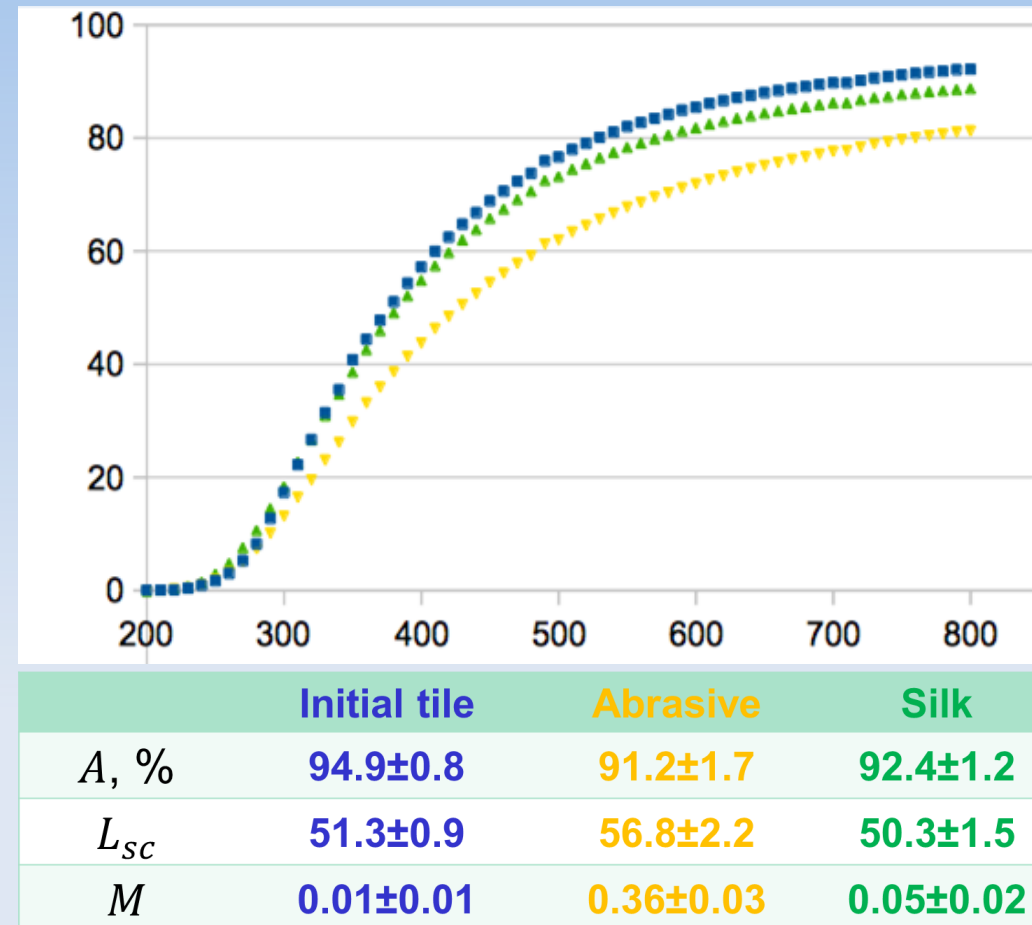
	A, %	Lsc, mm
Initial tile	94.85±0.4	51.3±1.5
Raw polished tile	91.15±0.9	56.8±1.7

$$\frac{I}{I_0} = A \cdot \exp\left(-\left(\frac{t}{L_{sc}} \left(\frac{\lambda}{400}\right)^4\right) - \frac{M}{\left(\frac{\lambda}{400}\right)^2}\right)$$

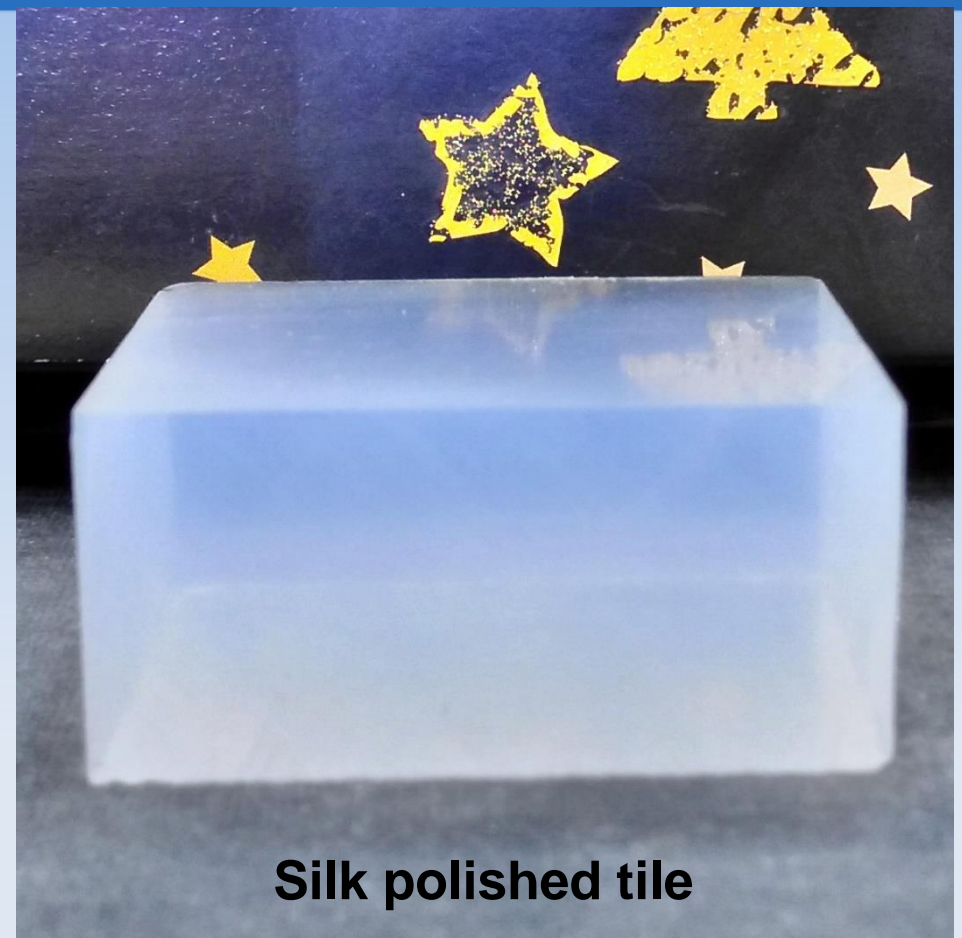
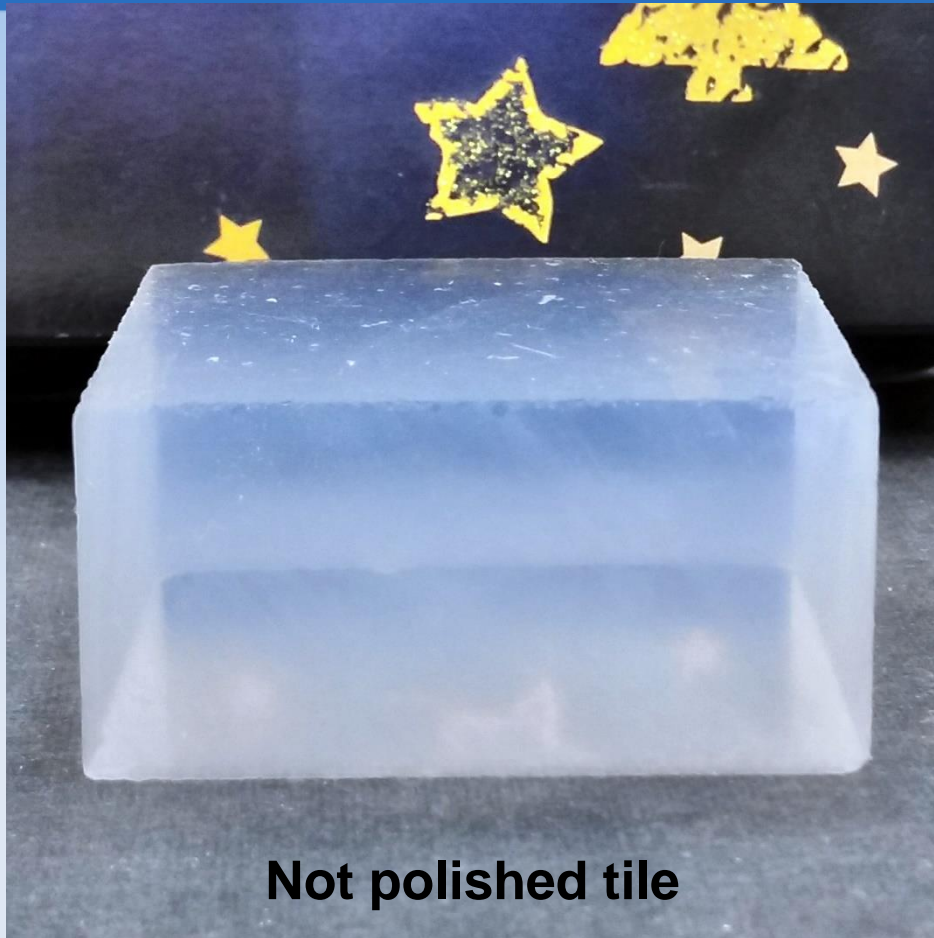


Light scattering on the polished aerogel surface (2)

- Best result we got using natural silk for polishing
 - Almost optical quality
- Only ~5% loss of light



Light scattering on the polished aerogel surface (3)



But!

Test beam measurements with polished tile(1)

- Electron beam with 3 GeV/c momentum at VEPP-4M
- Sensors DPC3200-22
- 3200 micro-cells in pixel,
- 20x20 cm = 3x3 modules = 6x6 tiles = 24x24 dies = 48x48 pixels
 - = 576 time channels
 - = 2304 amplitude (position) channels
 - = Pixel dimension 3.2x3.9 mm²
- to detect single photons detector was cooled to -40° Celsius



Test beam measurements with polished tile(2)

3 tiles where tested:

- Polished with silk
- Polished with abrasive paper
- Normal tile

Each tile was tested when Cherenkov photons come through 'clean' and 'polished' surface.

	R,mm	σR ,mm	Npe
clean	69.33±0.05	1.18±0.03	13.3±0.1
silk	69.01±0.05	1.83±0.06 +55%	12.7±0.1
clean	69.78±0.05	1.22±0.03	12.6±0.1
abrasive	68.01±0.05	2.67±0.09 +119%	12.0±0.1
clean	70.95±0.05	1.08±0.04	13.3±0.1
bottom	71.27±0.05	1.39±0.06 +29%	13.3±0.1

We see strong degradation of Cherenkov angle resolution due to small angle scattering at polished surface

Impact of cracks in aerogel on the Cherenkov angle resolution(1)

What will happen when a crack appears inside of aerogel tile?



Impact of cracks in aerogel to the Cherenkov angle resolution(2)

Refraction

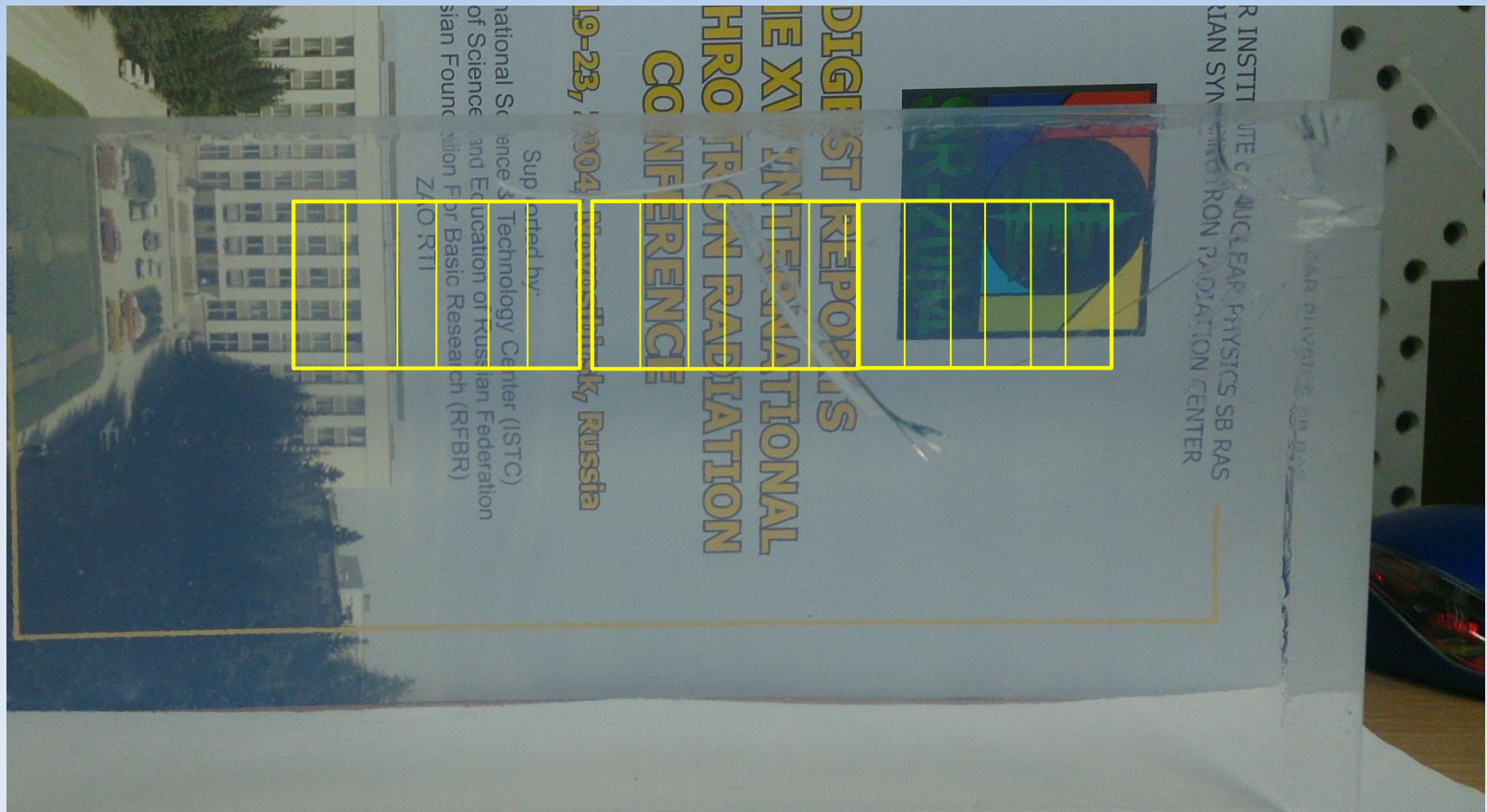
- Crack is a **thin** air gap inside aerogel.
 - Radius of curvature of the crack is much-much larger than gap.
 - We can assume that this is a parallel gap.
- In addition $\sin(\Theta_{agl}) * 1.05 = \sin(\Theta_{air})$
 - Light deviation from the initial direction after the crack should be very small.

Reflection

- Fresnel reflection at normal incidence is $(n-1)^2/(n+1)^2 \sim 0.0025/4 \sim 0.0006$
 - Loss of photons on the crack is negligible
- The angle of total internal reflection is large. $\Theta_{tir} = 72^\circ$
 - Probability of total internal reflection is small.

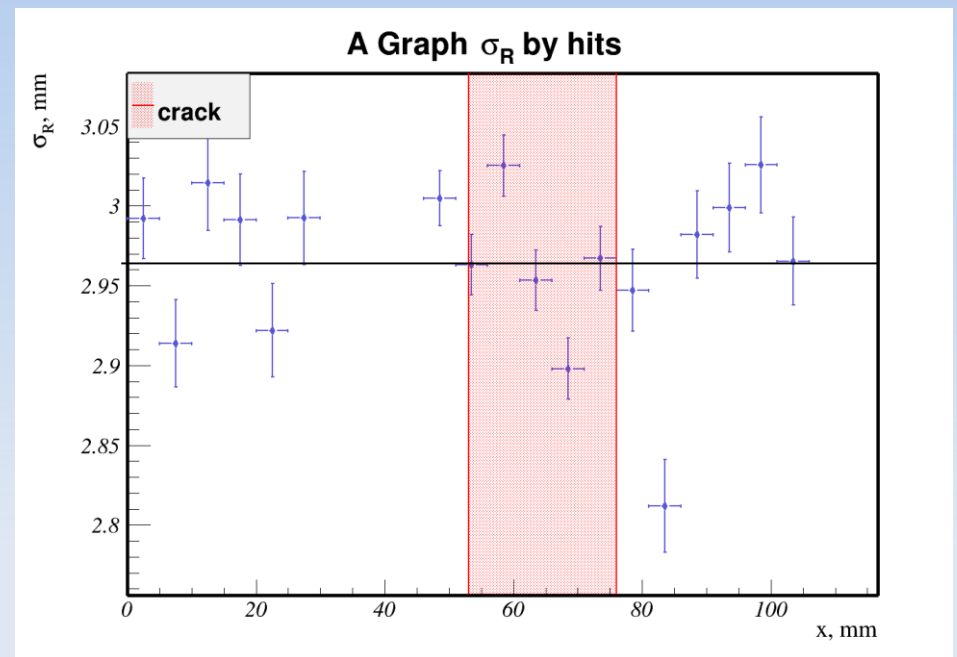
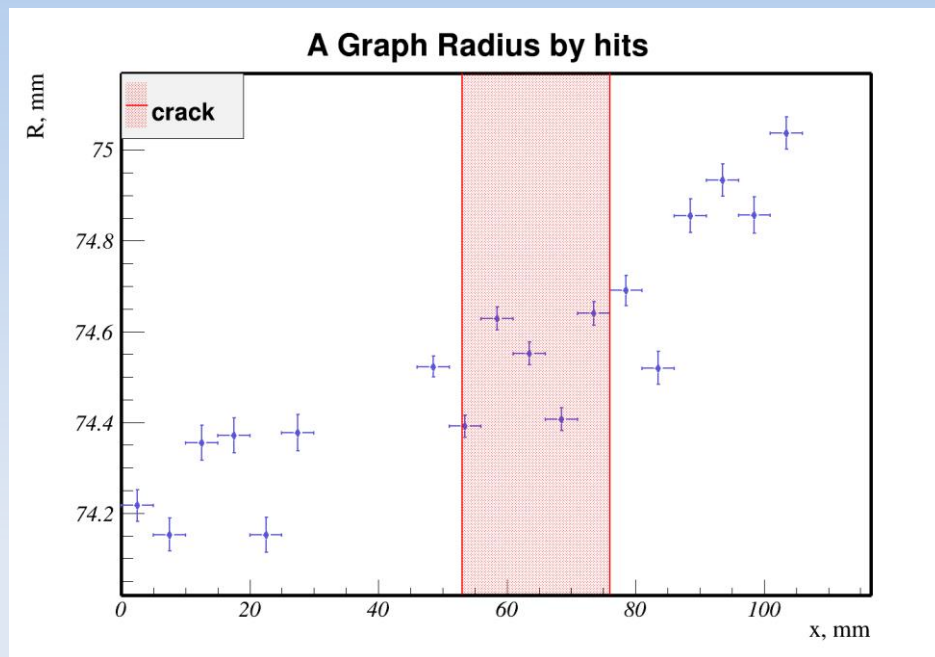
Test beam experiment with cracked aerogel tile(1)

- 3 GeV/c electrons
- 18 points, 5x20 mm each
- $n=1.05$
- 3 cm thickness aerogel tile



Test beam experiment with cracked aerogel tile(2)

Preliminary results



We do not see Cherenkov angle resolution degradation in the crack area of the tile

Conclusions

- **Previously found method of aerogel polishing with silk can not be used. We see a strong effect of small angle scattering at polished surface.**
- **Non destroying crack in aerogel tile does not influence on the accuracy of Cherenkov angle measurement at that area.**