Università degli Studi di Milano Bicocca

Variation of Refractive Index inside an Aerogel Block

Davide Perego

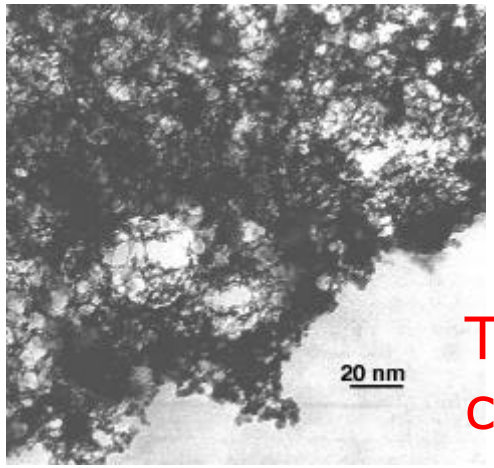
RICH MEETING - CERN - April 21st 2004

Introduction

The Refractive Index of aerogel and its density are related by the following relation:

$$n(l) = 1 + k(l)r$$

k=0.21
@ λ=632 nm



Local inhomogeneities (occurring during production) lead to variations of the Refractive Index within monoliths

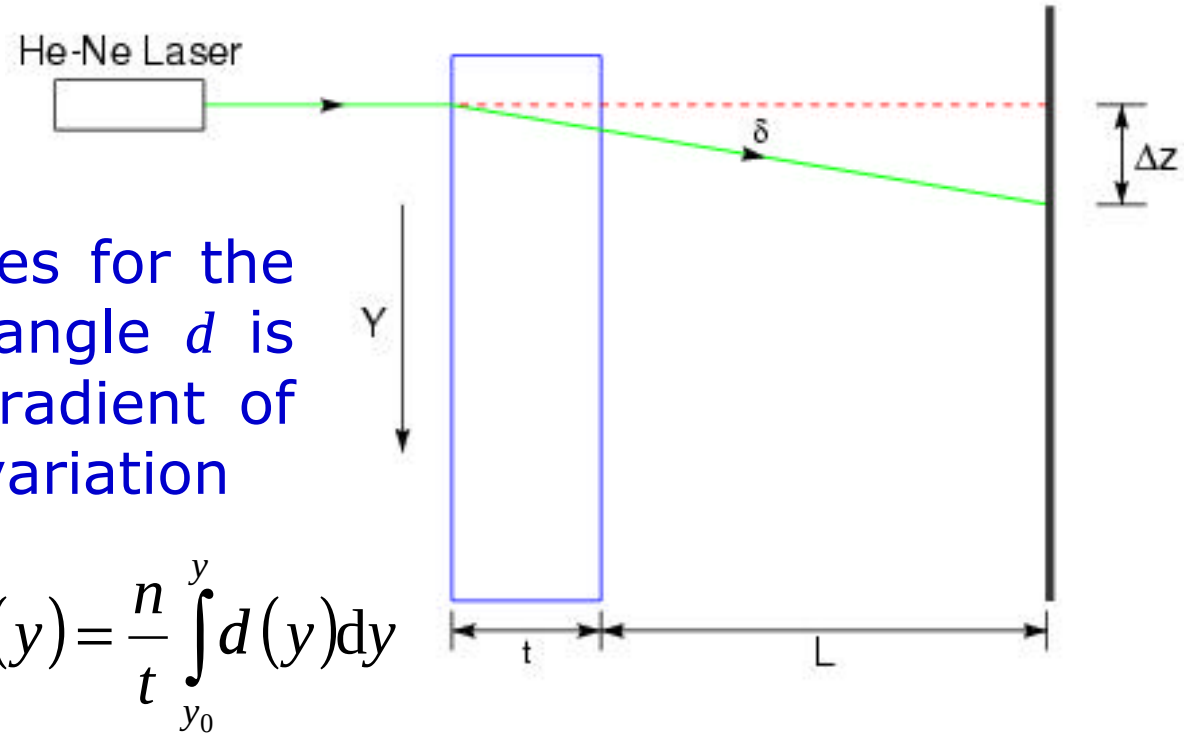
These variations can give non-negligible contribution to the q_C measurement accuracy

Δn_{max} allowed for LHCb RICH1 aerogel tiles is $\sim 3 \cdot 10^{-4}$, corresponding to Δq_C 1.17 mrad

How such variations can be evaluated? Two methods available: (I) Laser Beam Deflection and (II) APACHE

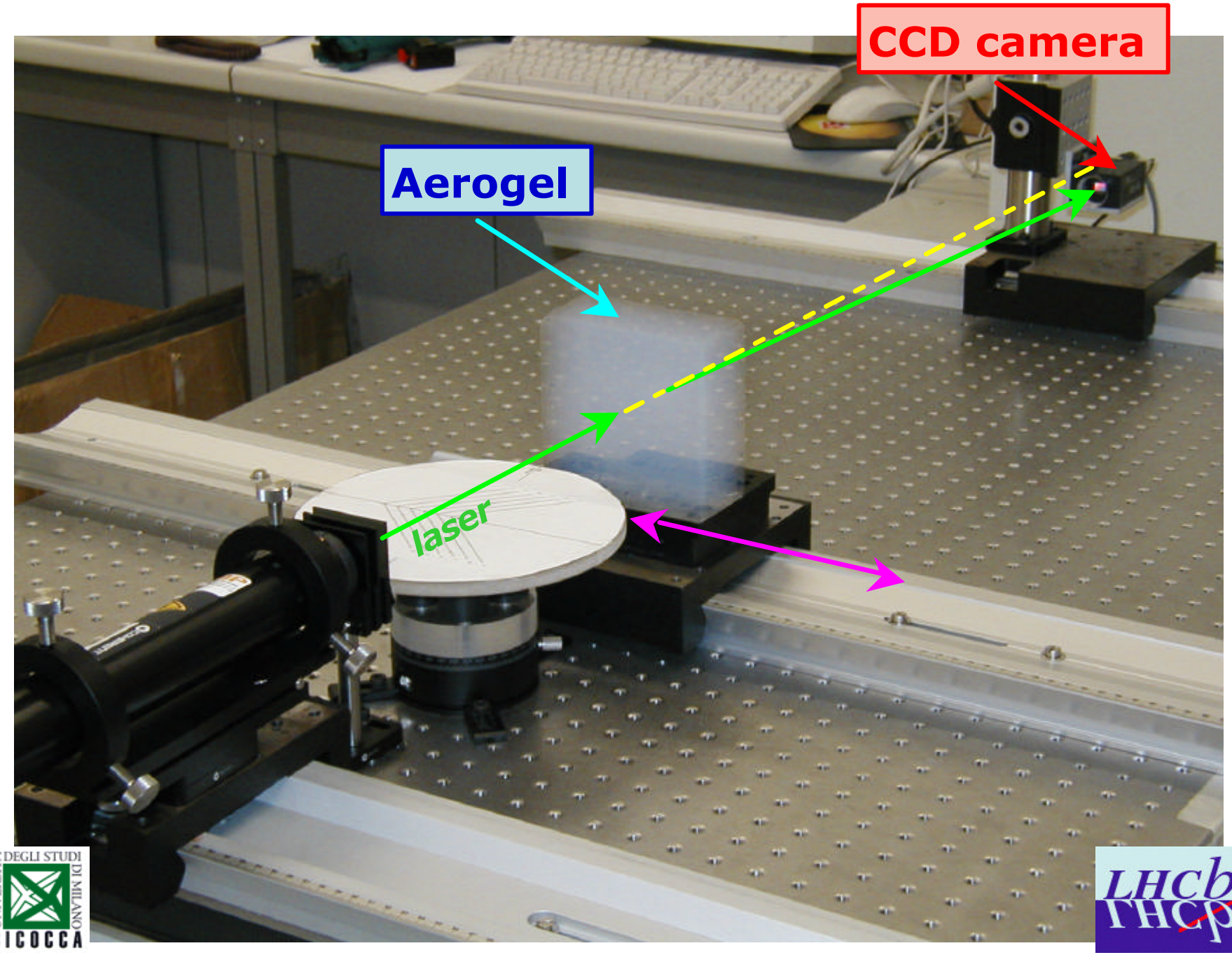
Laser Beam Method

Local variations of the Refractive Index in a uniformly transparent medium are gradient indexes which affect the propagation of laser rays



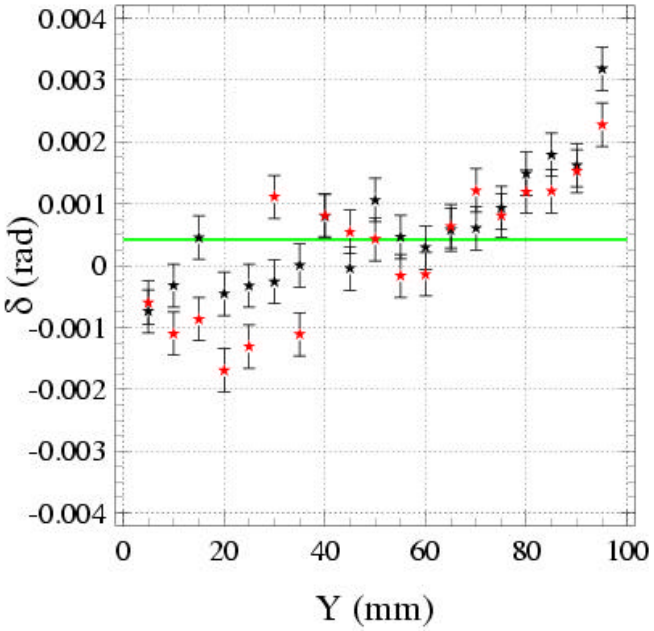
Assuming parallel faces for the block, the deviation angle *d* is proportional to the gradient of the Refractive Index variation

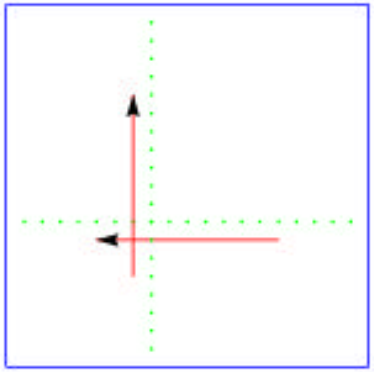
$$\frac{dn}{dy} \approx \frac{n \cdot d(y)}{t \cdot L} \Rightarrow \Delta n(y) = \frac{n}{t} \int_{y_0}^{y} d(y)\,dy$$


CCD camera
Aerogel
laser

Laser Beam Method

Measurements performed with a 100×100×42 mm^3 block & with L=75.8 cm



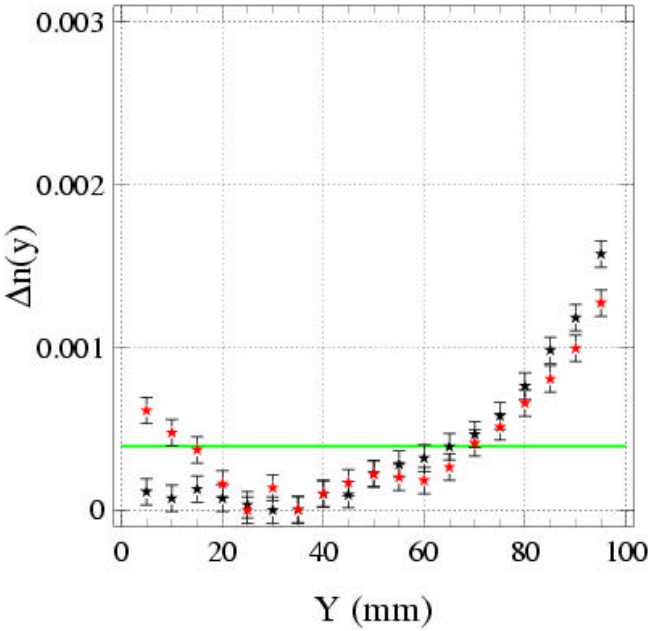


n 1.031

λ=543.5 nm

σ_δ~0.35 mrad

$\sigma_{\Delta n}$~0.8·10^{-4}



σ_n 4.6·10^{-4} which means σ_q 1.8 mrad

APACHE

Why not using a particle beam to characterize Aerogel tiles?

500 MeV electron beam at the **BTF** Beam Test Facility (**DA**Φ**NE** LNF-Frascati)

+

photographic film in a "*proximity focusing*" configuration…

APACHE

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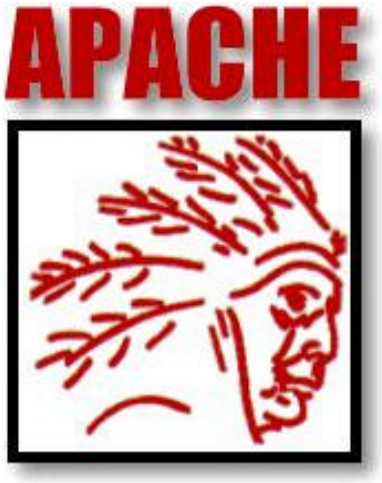

APACHE

Aerogel Photographic Analysis by CHerenkov Emission

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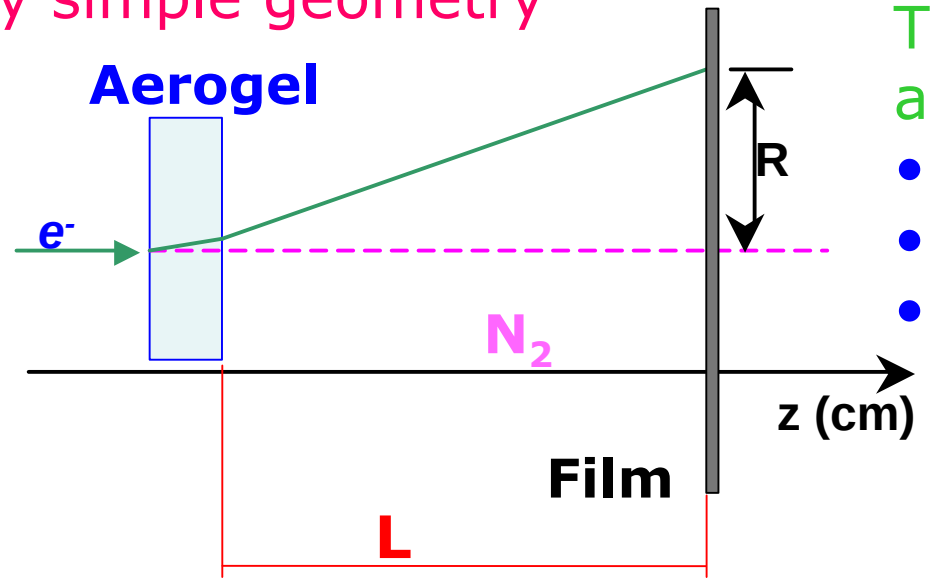
LHCb

APACHE

Very simple geometry



The radius of the ring, R, is a function of:

- Refractive Index n=n(λ)
- aerogel thickness t
- aerogel-film distance L

The dimensions of the photographic film define the maximum R

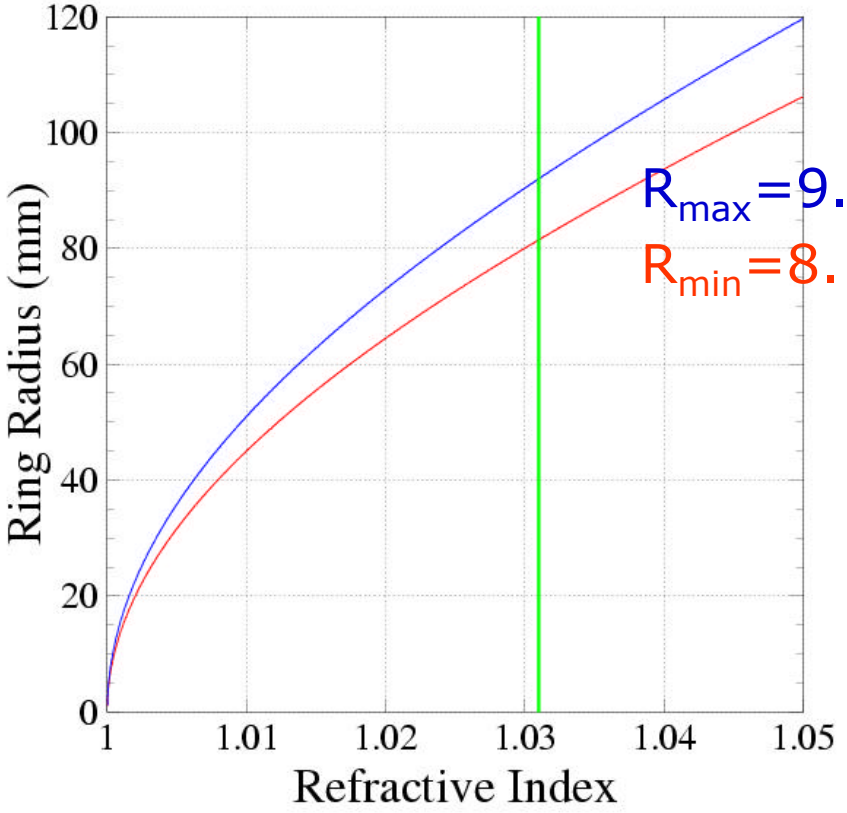
8″×10″ Kodak TRI-X B/W
8″×10″ Kodak EKTACHROME
(wavelength range: 300÷600 nm)

L 30.0 cm

n~1.031 with
λ=543.5 nm

APACHE

Assuming a simplified scenario without scattering, chromatic dispersion, absorption effects, etc



R_{max}=9.19 cm

R_{min}=8.14 cm

Parameters

n=1.031

β=1

t=4.2 cm

d=31.4 cm

$$R_{\min} = L\tan\left[\arcsin\left[n\sin\left(\arccos\left(\frac{1}{nb}\right)\right)\right]\right]$$

$$R_{\max} = R_{\min} + t\tan\left[\arccos\left(\frac{1}{nb}\right)\right]$$

APACHE

Geant 4

Beam & Geometry

520 MeV e^- Beam

L=31.4 cm

Beam spot size

$\sigma_x=\sigma_y=4.0$ mm

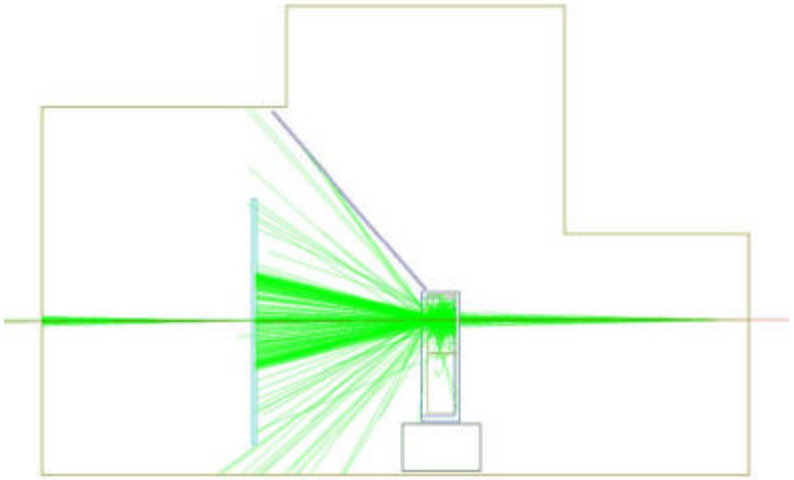
Aerogel

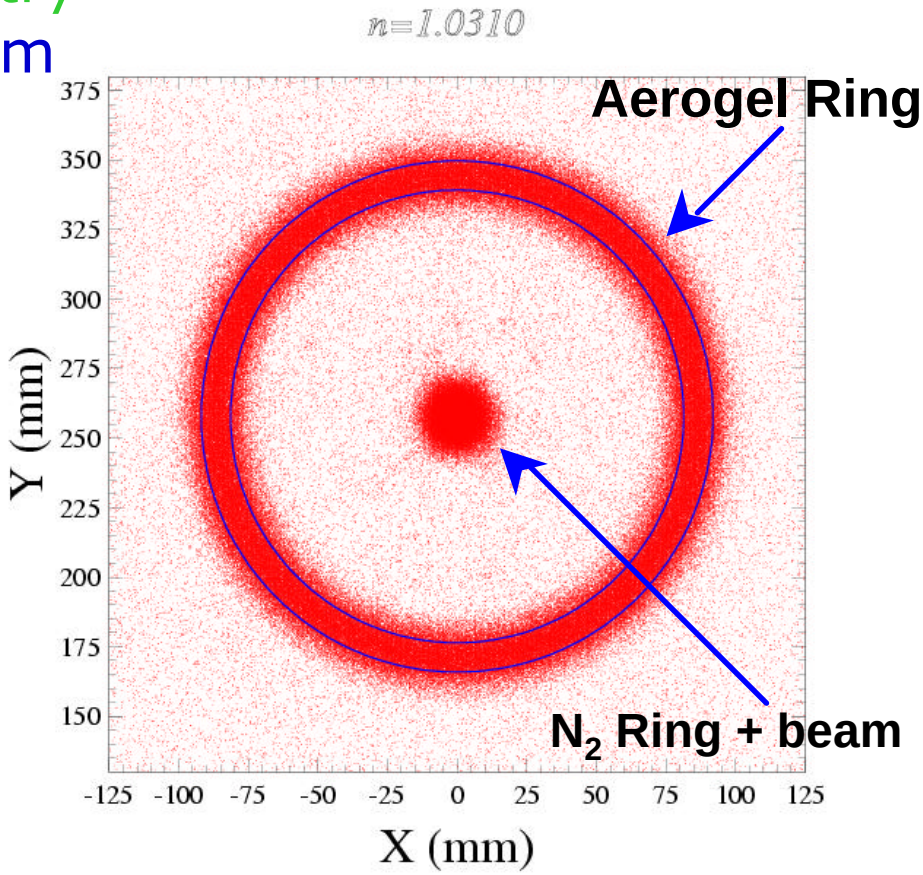
n=1.031

t=4.2 cm

A=95.58%

C=0.0060 $\mu m^4/cm$





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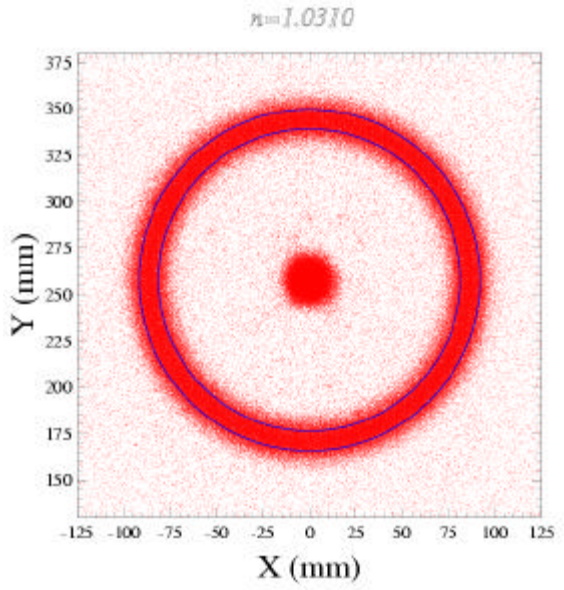
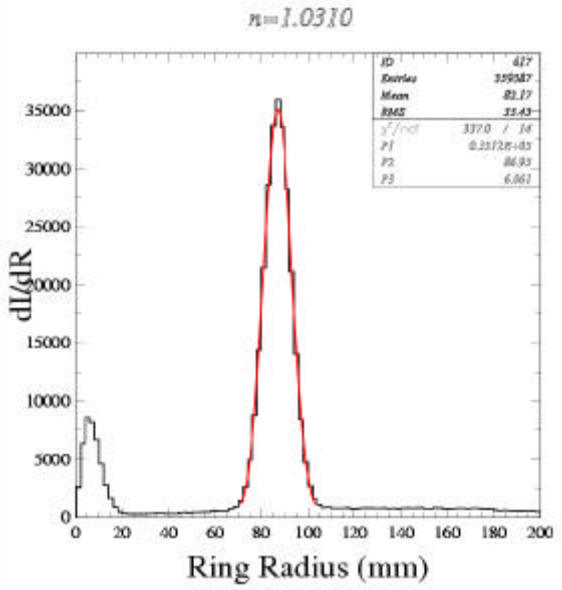
Procedure for the analysis of the films:

- digitization with a (8bit) scanner
- subtraction of background
- search of the center of gravity, then integration
- comparison of the positions of peaks for different input n





Geant 4

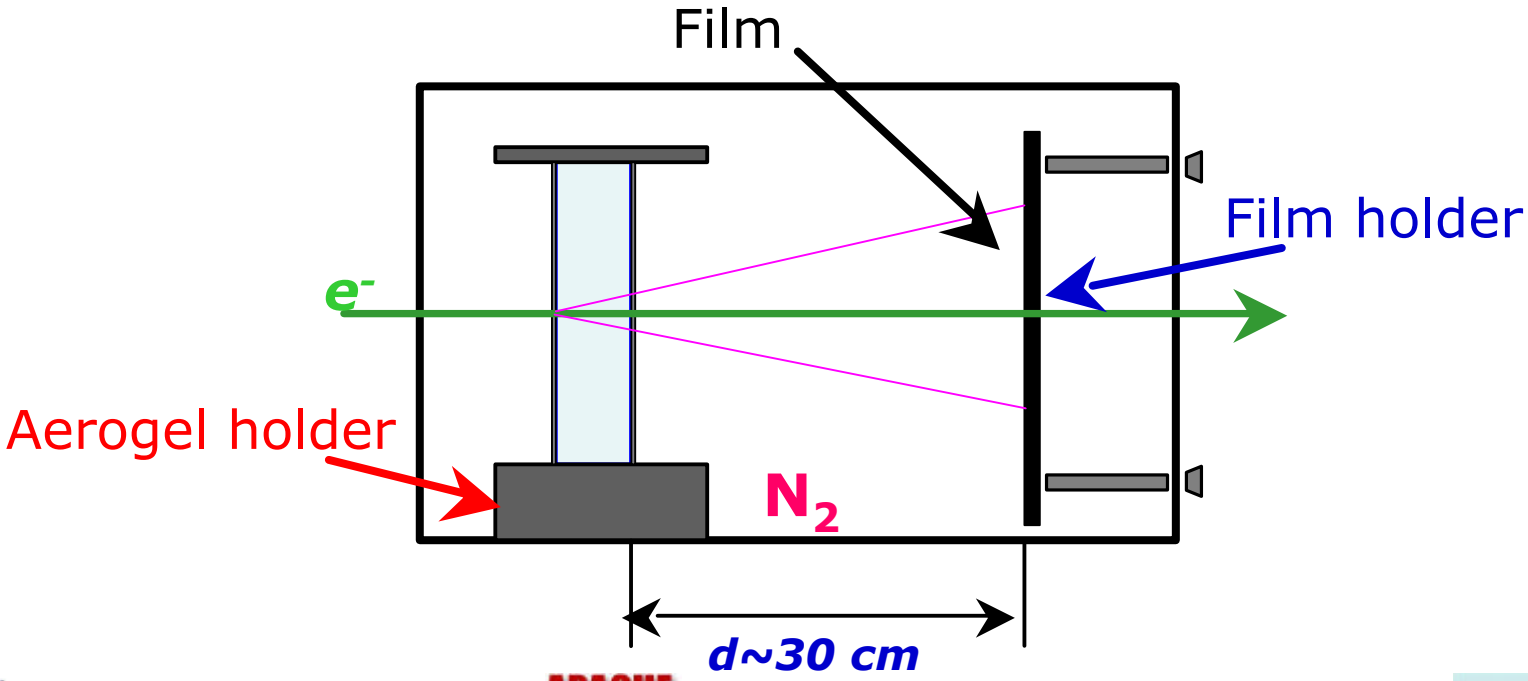
n	R (mm)
1.0307	86.55±0.01
1.0310	86.95±0.01
1.0313	87.41±0.01

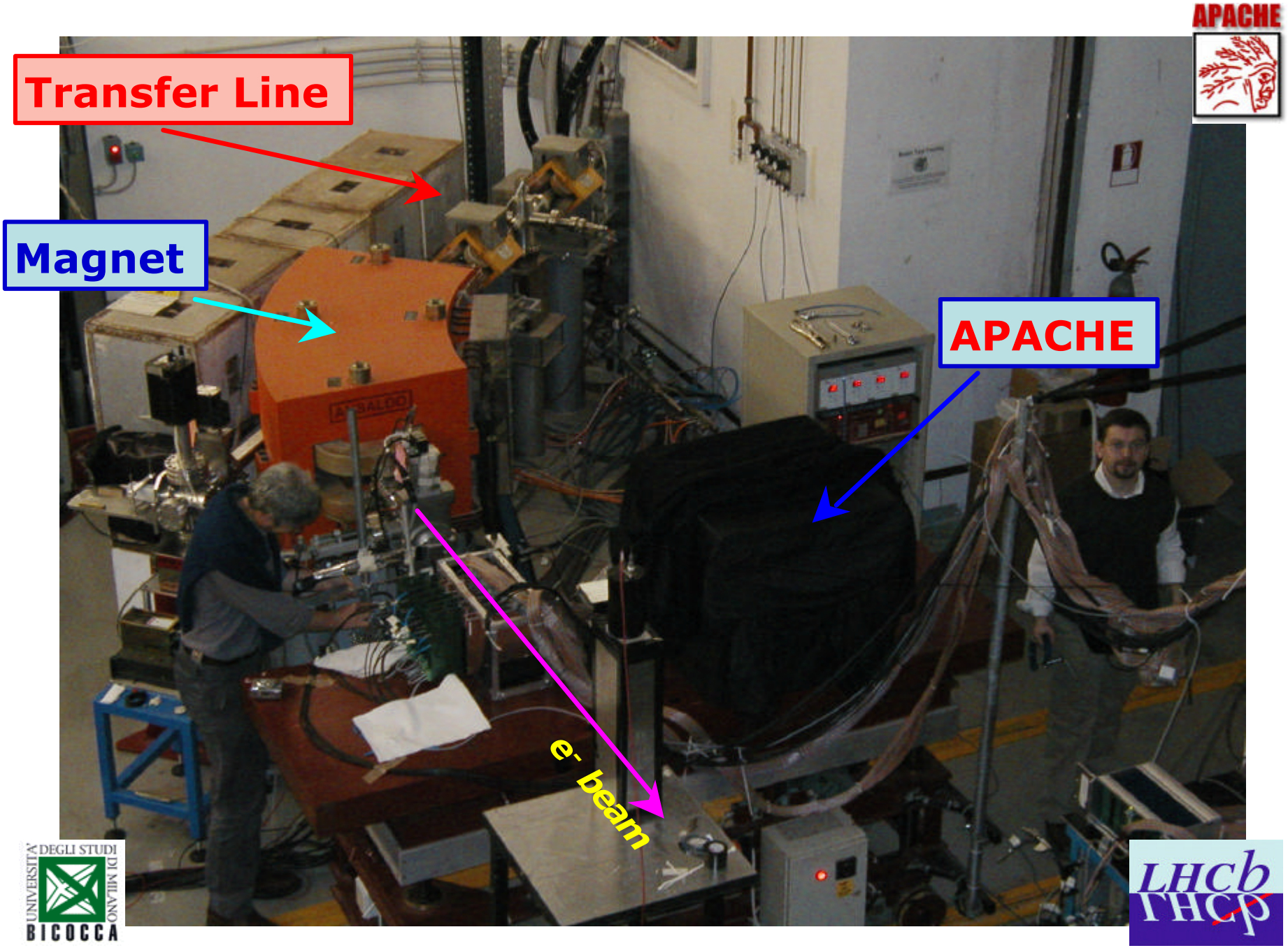
Resolution for $3 \cdot 10^{-4}$ ~0.25 mm

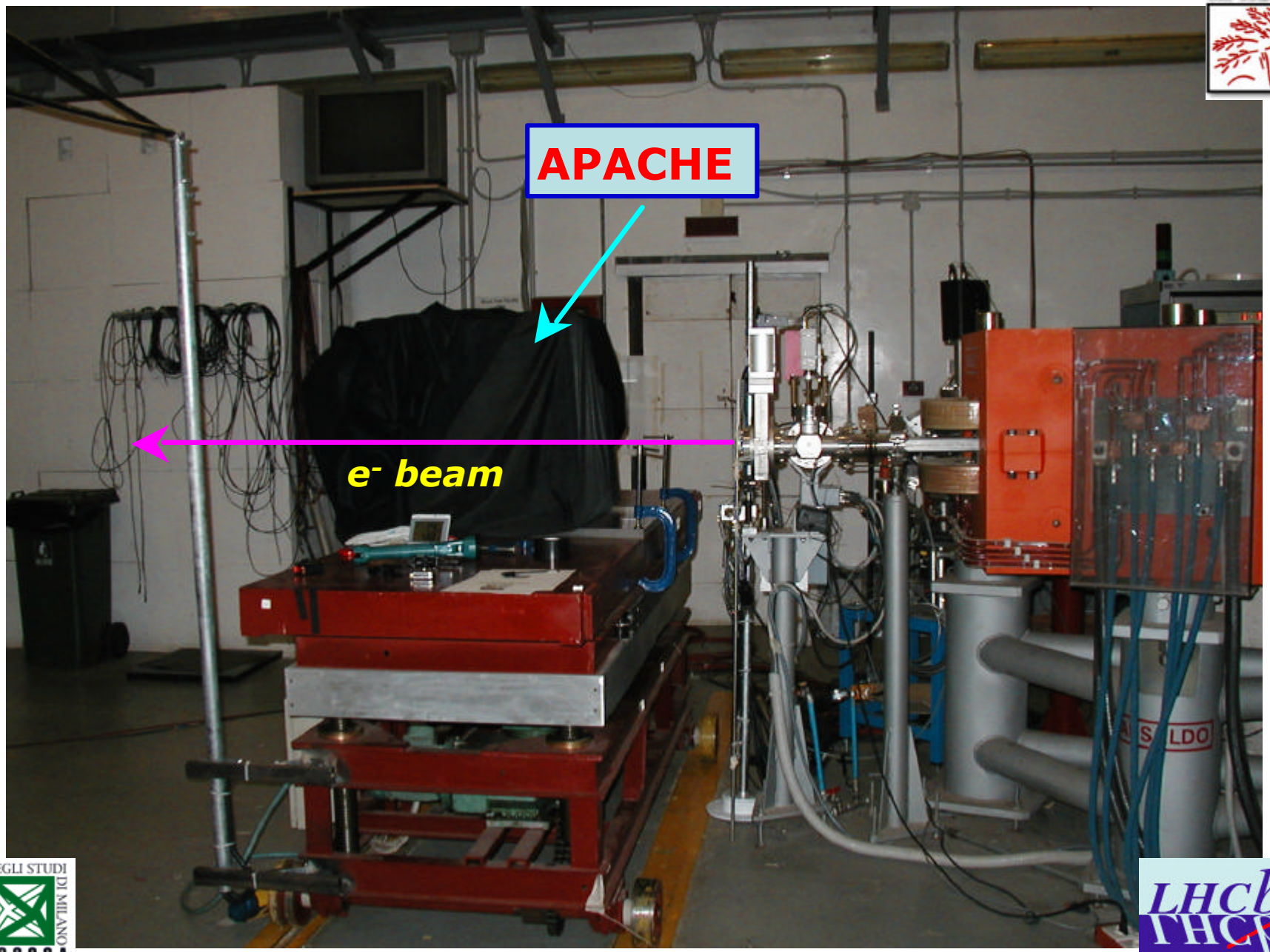
APACHE

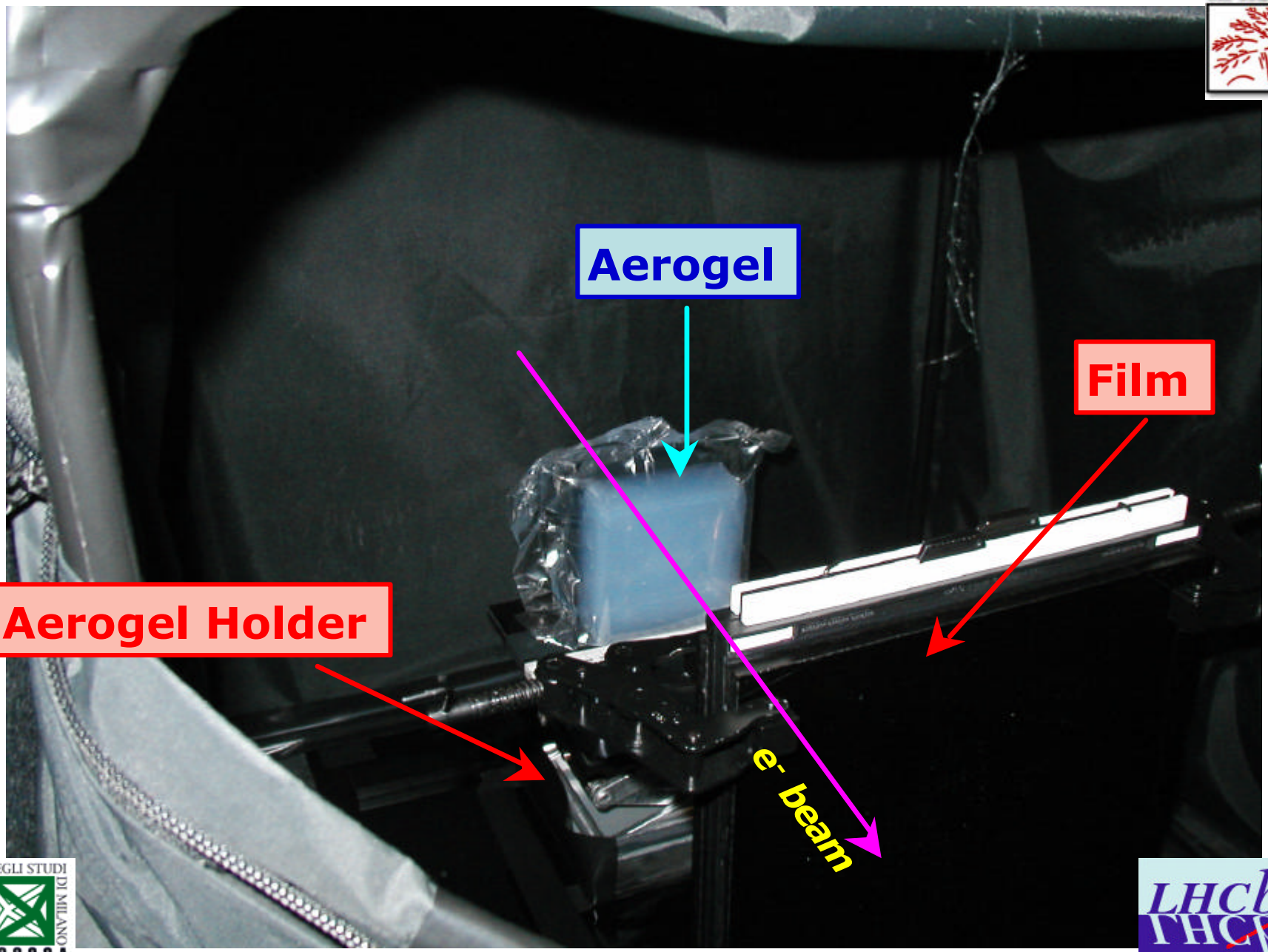
Experimental Setup:

- portable dark room, ~60×60×60 cm^3
- variable height aerogel holder
- N_2 flux inside the dark room
- 0.1 mm D263 filter downstream the aerogel (UV photons)



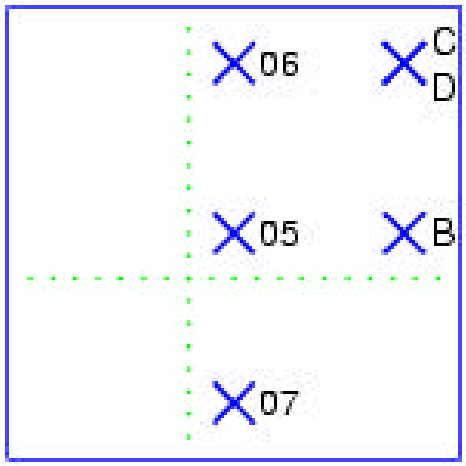

Transfer Line
Magnet
APACHE
e- beam


APACHE
e- beam


Aerogel
Film
Aerogel Holder
e- beam

APACHE

- data taking: March 2004 @ BTF, LNF-Frascati
- ~10^{10} electrons/run
- scan on different entrance points
- 0.1 mm D263 filter used for run D (compare to run C)
- films processed by a professional PhotoLab in Frascati
- digitization for the analysis



e^-

V. Kandinsky,
Einige Kreise (1926)

see the processed films...

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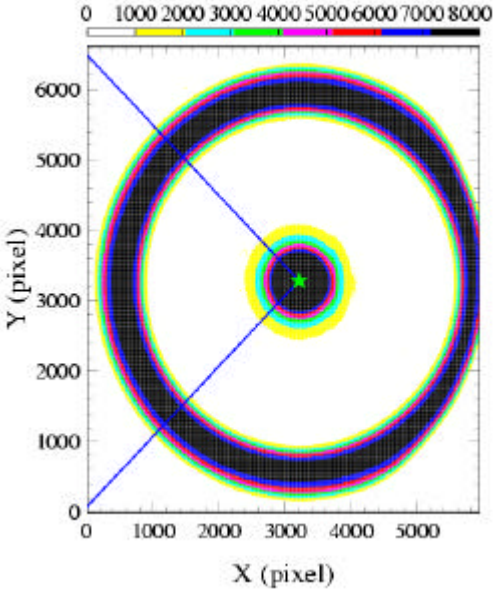
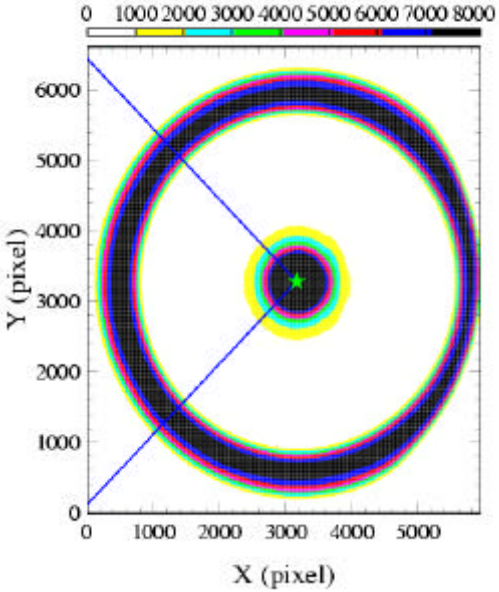
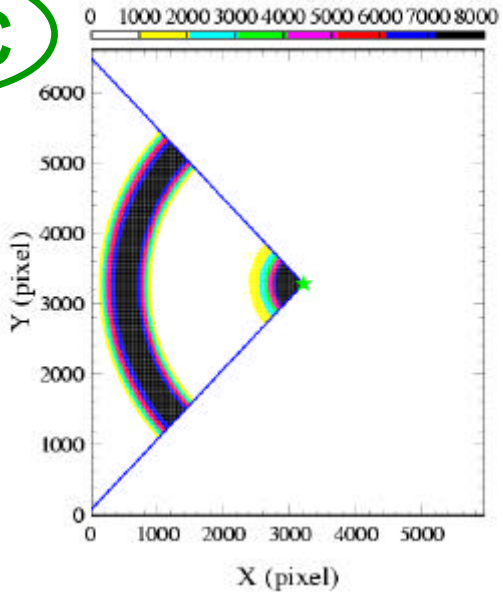
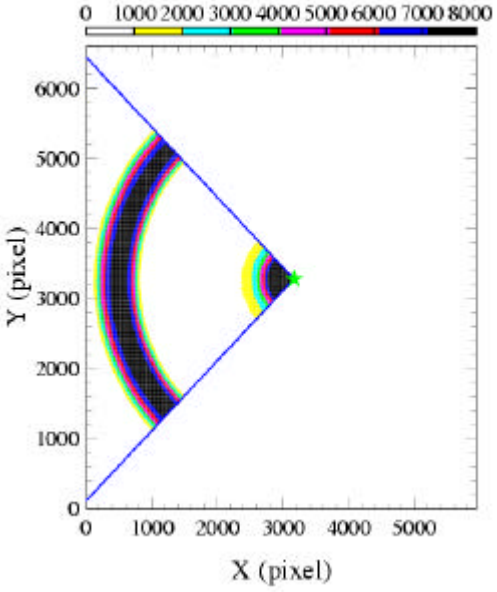




Run C





Run D

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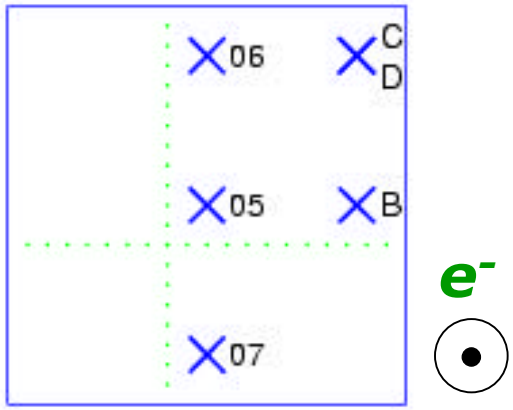
There is not yet an analytical description of the shape of the distributions (i.e. how to parametrize the film efficiency, etc)

Preliminary results available with the following methods:

- Gaussian fit restricted to the rising and falling edges of the distributions around the peak
- Center of gravity of the distribution's peaks
- Radius corresponding to the maximum of the differential distributions

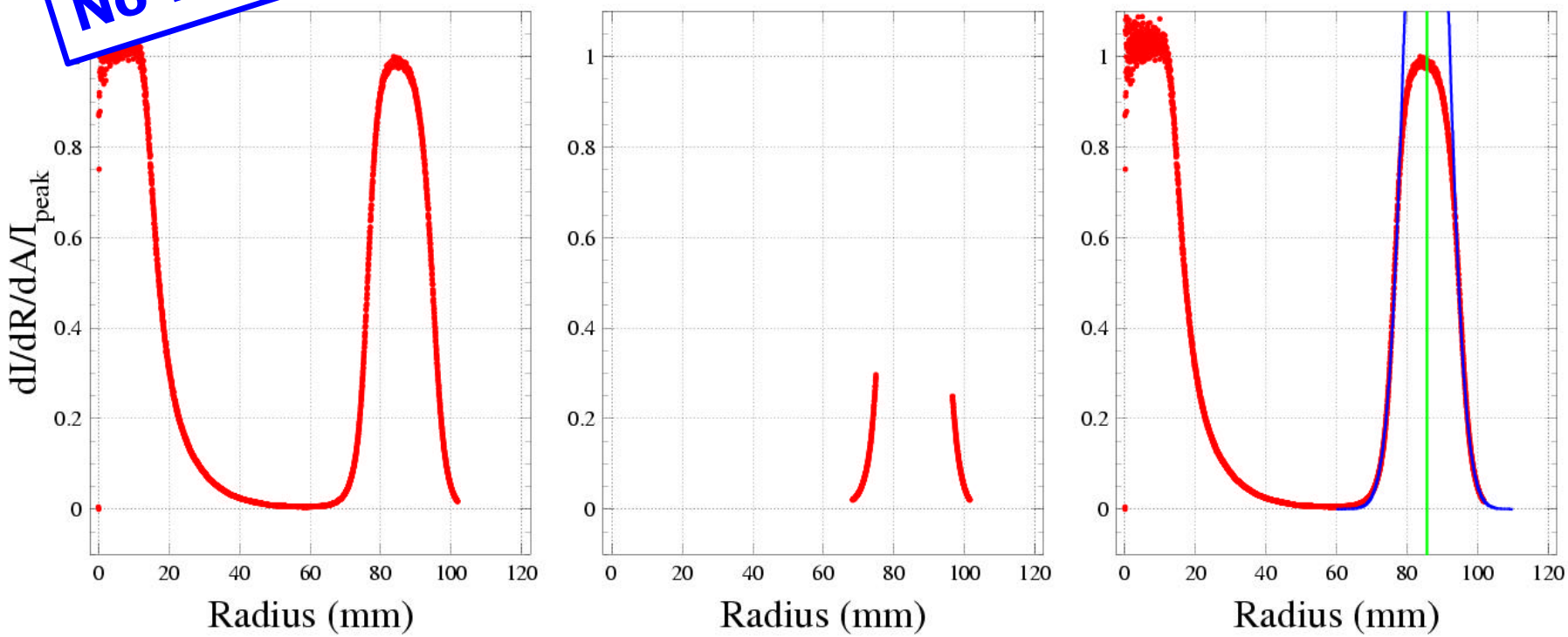


Run	R_1 (mm)	R_2 (mm)	R_3 (mm)
5	85.9±0.1	86.0±0.1	85.2±0.8
6	85.5±0.1	85.0±0.1	84.4±0.3
7	85.3±0.1	84.9±0.1	82.3±0.5
B	85.5±0.1	85.2±0.1	84.7±0.3
C	85.6±0.1	85.3±0.1	84.4±0.3
D	85.6±0.1	85.4±0.1	84.4±0.3

APACHE

No filter

Run: C

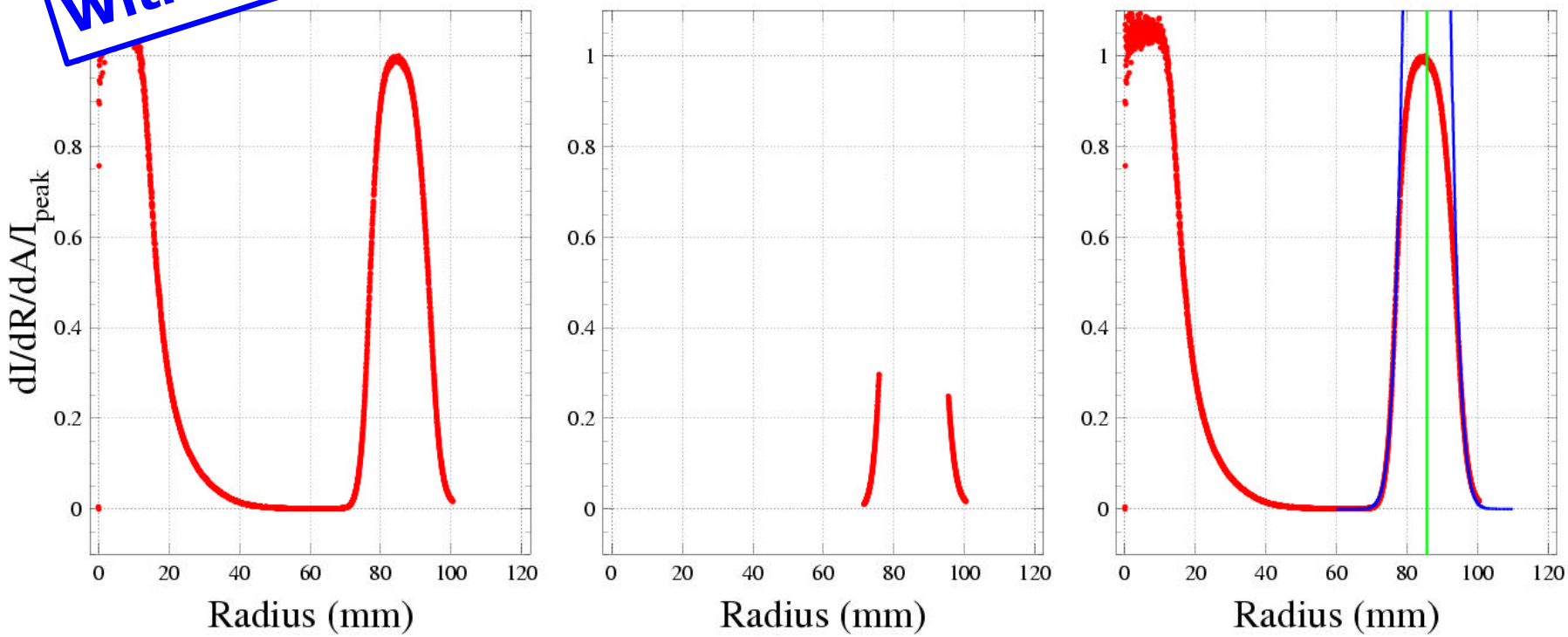


Run No.	R_1 (mm)	R_2 (mm)	R_3 (mm)
C	85.6±0.1	85.3±0.1	84.4±0.3
D	85.6±0.1	85.4±0.1	84.4±0.3

APACHE

With filter

Run: D



Run No.	R_1 (mm)	R_2 (mm)	R_3 (mm)
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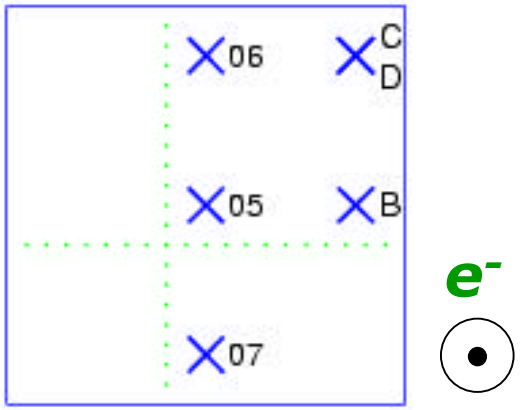
D	85.6±0.1	85.4±0.1	84.4±0.3

APACHE

Preliminary Results



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D	85.6±0.1	85.4±0.1	84.4±0.3

correpsonding to

? R_{max}	0.6±0.1	1.1±0.1	2.9±0.9
? n_{max} (10^{-4})	3.9±0.7	7.2±0.7	18.9±5.9

The difference between the position of the peaks is assumed to be independent of the detailed shape of distributions

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APACHE

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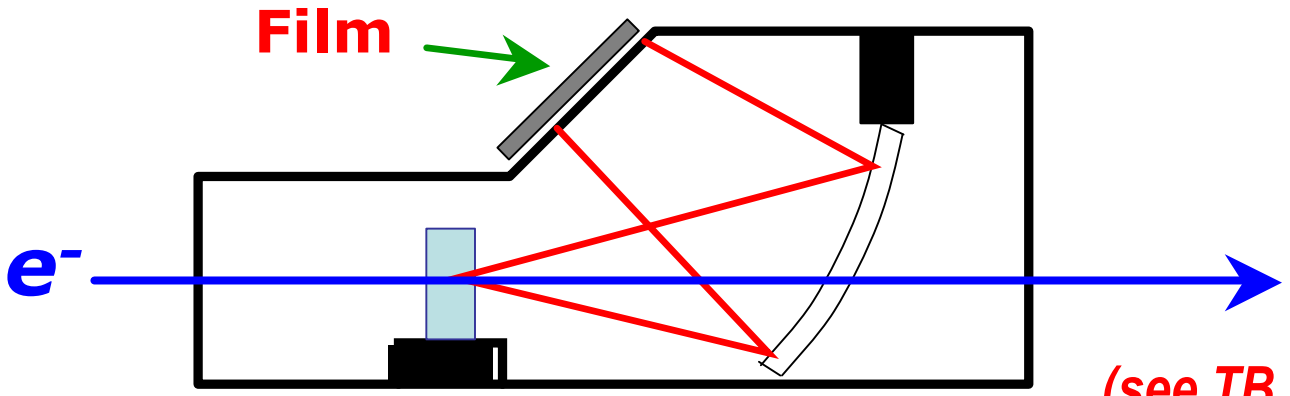
LHCb

APACHE

Possible improvements for APACHE:

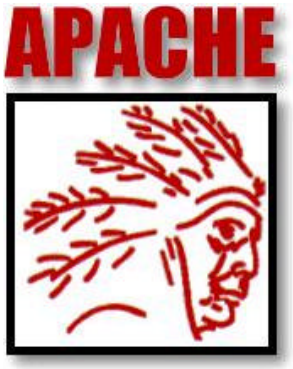
- use of a spherical mirror tilted wrt the beam axis
  - photographic film in a RICH configuration
  - distorsions of the ring due to the spherical aberration
  - no aerogel thickness effects
- separation of the different chromatic components by the use of filters



(see TB 2003 Vessel)

Summary

- local inhomogeneities of the density lead to variations of n
- the maximum Δn allowed for LHCb aerogel tiles is $\sim 3 \cdot 10^{-4}$
- two methods are presented to evaluate those variations:
  - ✓ Laser Beam Deflection
  - ✓ APACHE
- the results from the two methods agree with each other within the experimental resolution
- the APACHE method is very promising and artistic too!



Special thanks to Giovanni Mazzitelli
&
the Beam Test Facility (LNF Frascati)

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LHCb