Development of a Velocity Reconstruction Algorithm for AMS RICH

results from Prototype data

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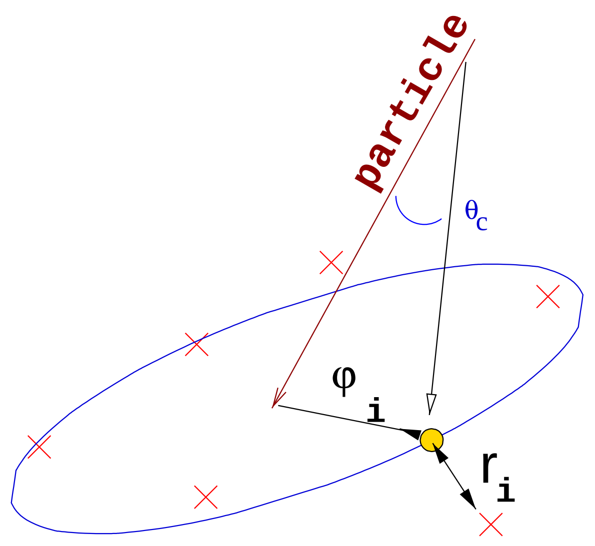
Summary

- The reconstruction method
- Results from RICH Flight setup (MC)
- Results from RICH prototype (Data .vs. MC)
- Future prospections and Conclusions

(θ_c) reconstruction: A pattern fit procedure

- ✔ The AMS Tracker provides the **particle direction (θ, ϕ)** and **impact point** at the RICH radiator
- ✔ The **photon pattern** at the PMT matrix plane is computed, leaving $\boldsymbol{\theta_c}$ as the *only free parameter* for fit
- ✔ The hits associated to the particle track are excluded
- ✔ The **maximization of a likelihood function** provides the **best θ_c angle**



$$P(\theta_c) = \prod_{i=1}^{nhits} P_i\{r_i(\varphi_i(\theta_c);\theta_c)\}$$

Range for θ_c search : $(2^\circ, 1.1 \times acos(\frac{1}{n}))$ where n is the nominal radiator refractive index

$r_i \equiv$ *closest distance to photon pattern*

$P_i \equiv$ *probability of a hit belonging to photon pattern*

θ_c reconstruction: probability function summary

- noisy hits distribution essentially flat
  PMT noise, scattering,...

$$P_{noise} = \frac{b}{R} \sim 10^{-3} \;\; cm^{-1}$$

$b \equiv$ photon background fraction

$R \equiv$ PMT matrix dimension

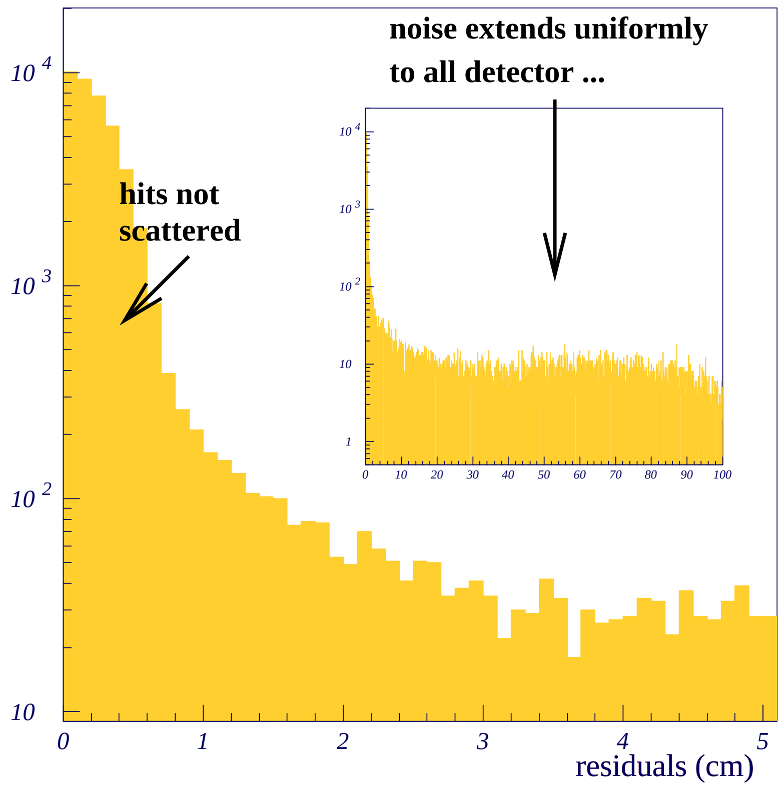
- pattern hits distribution essentially gaussian
  pixel size, radiator thickness, chromaticity,...

$$P_{signal}(r) = (1-b)\frac{1}{\sigma\sqrt{2\pi}}\exp^{-\frac{1}{2}\left(\frac{r}{\sigma}\right)^2}$$

$$\sigma \sim 0.5\ cm$$

- combined probability function

$$P_i(r_i) = (1-b)P_{signal}(r_i) + \frac{b}{R}$$



for FLIGHT SETUP (simulation)

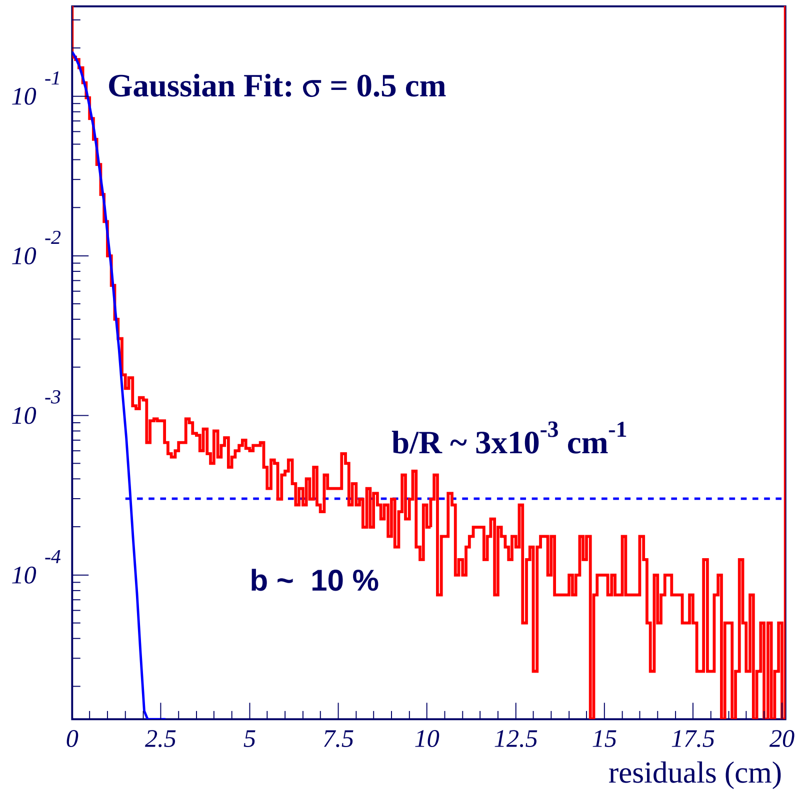
- Advantage of likelihood : **being insensitive to noise spread all over the RICH matrix**

θ_c reconstruction: probability function optimization

1 - Evaluate parameters $\boldsymbol{\sigma}$ and b from the residuals obtained by a standard reconstruction (residuals from simulation points out the values)

- $\boldsymbol{\sigma}$ parameter :
  fit Gaussian slice of residuals (with information about $\boldsymbol{\theta_C}$)
- b parameter :
  Geometrical effects modulate background residuals distribution .
  Assume flat distribution .

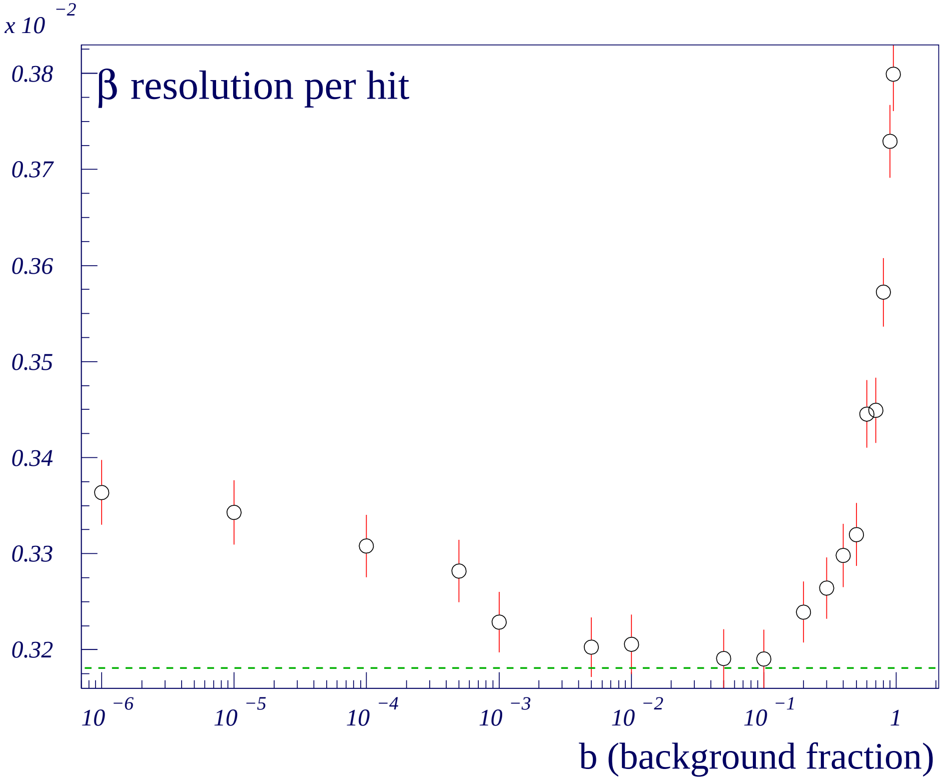
for PROTOTYPE (simulation)



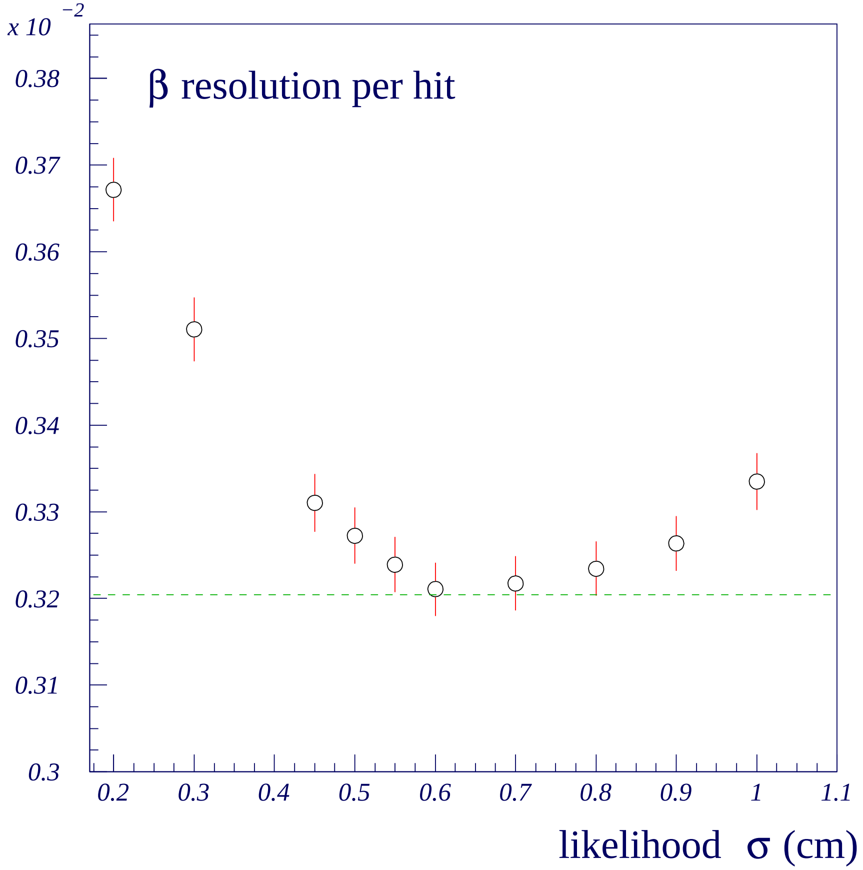
θ_c reconstruction: probability function optimization

2 - Test robustness of likelihood to choice of parameters

PROTOTYPE (with smearing on particle track)



σ like set to 0.5 cm

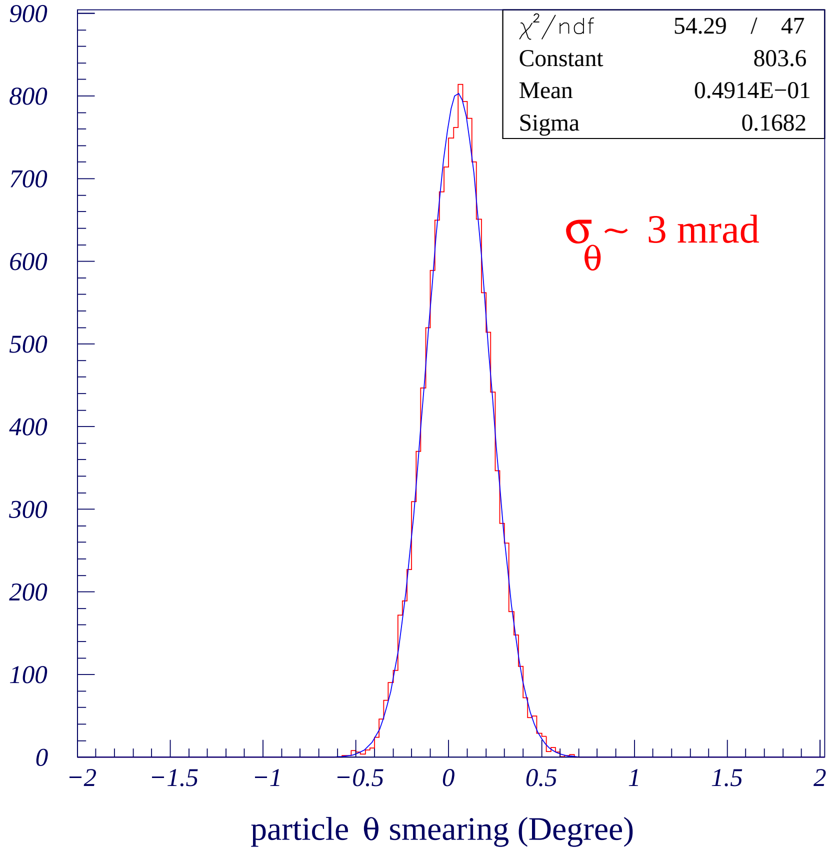


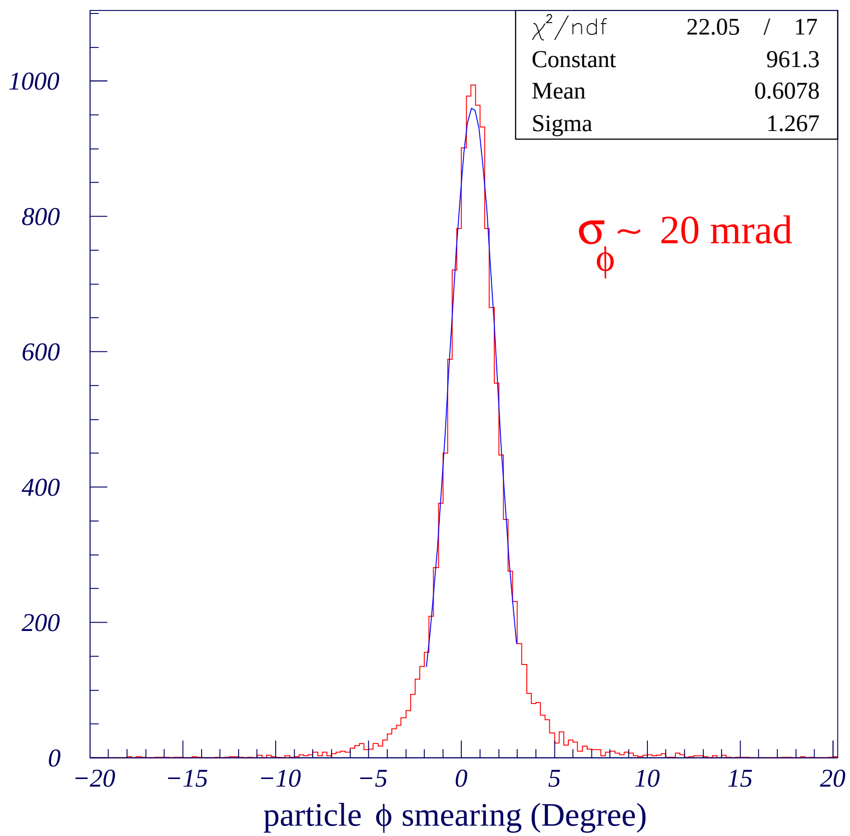
b like set to 0.1

good agreement with values estimated from residuals !

θ_c reconstruction: effect of track resolution on β resolution

Track resolution for particle direction $(\boldsymbol{\theta}, \boldsymbol{\phi})$ due to smearing (simulation)

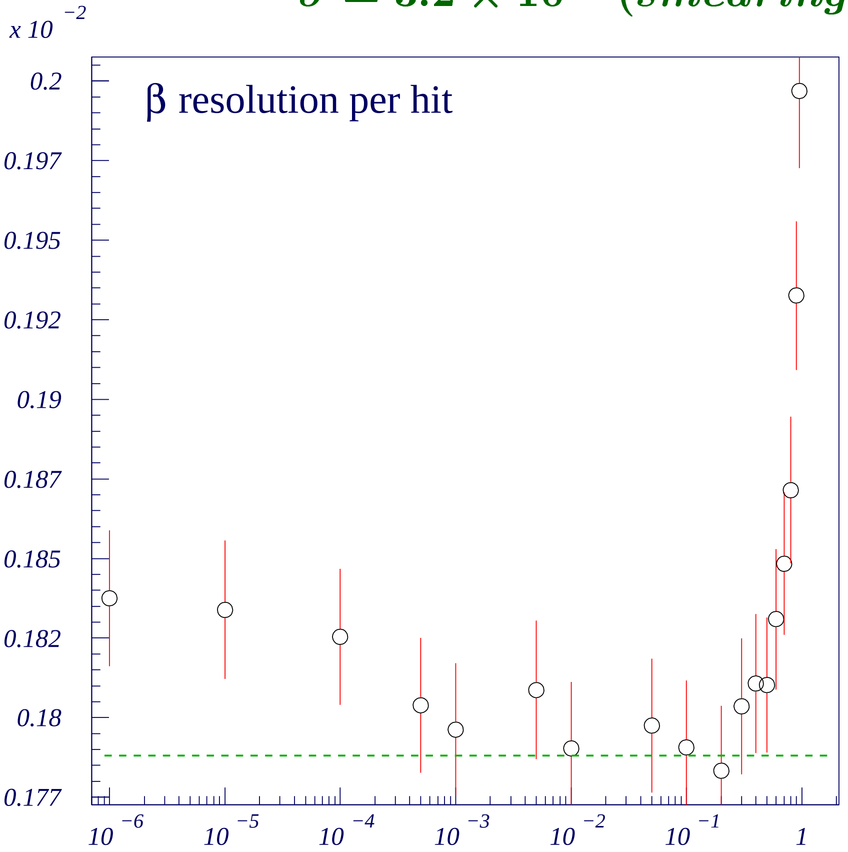




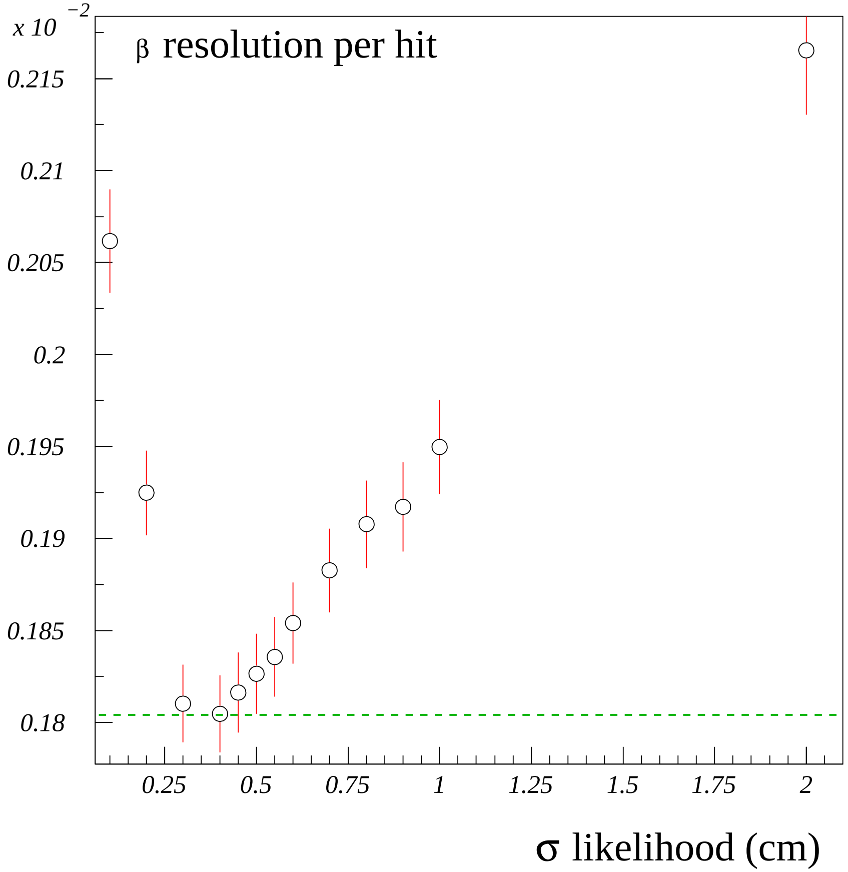
θ_c reconstruction: effect of track resolution on β resolution

Here there is no TRACK SMEARING ! β resolution increases 30 %

$$\sigma = 3.2 \times 10^{-3}(smearing\ ON) \rightarrow 1.8 \times 10^{-3}(smearing\ OFF)$$



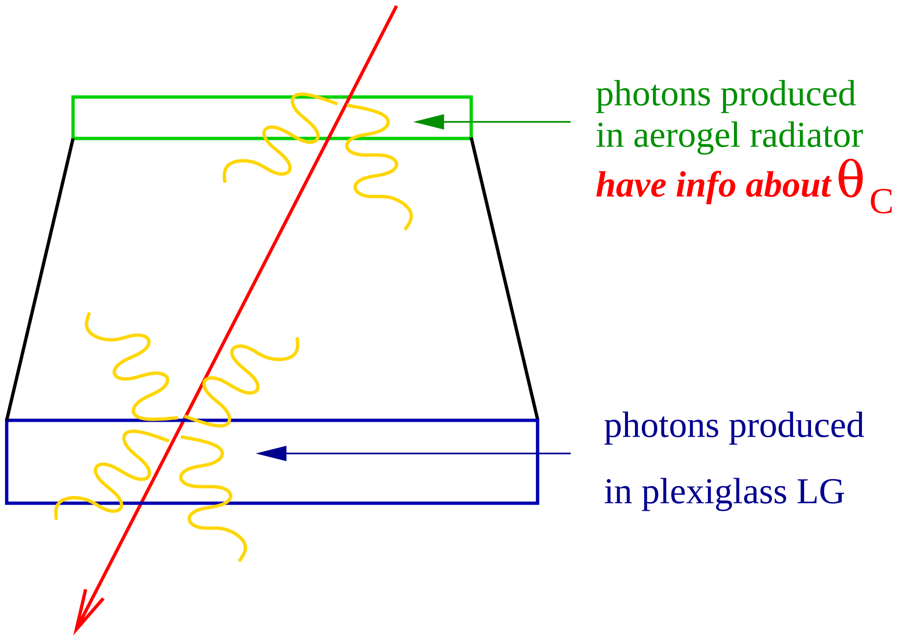
σ like set to 0.3 cm

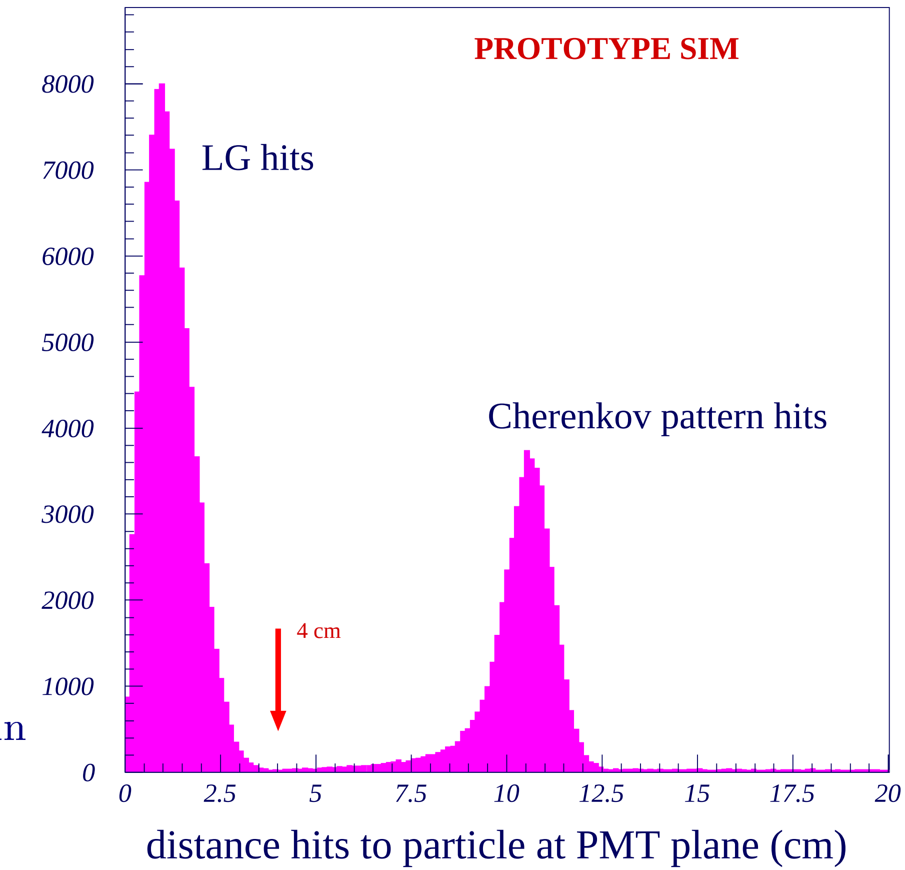


σ like set to 0.3 cm

Particle Cluster

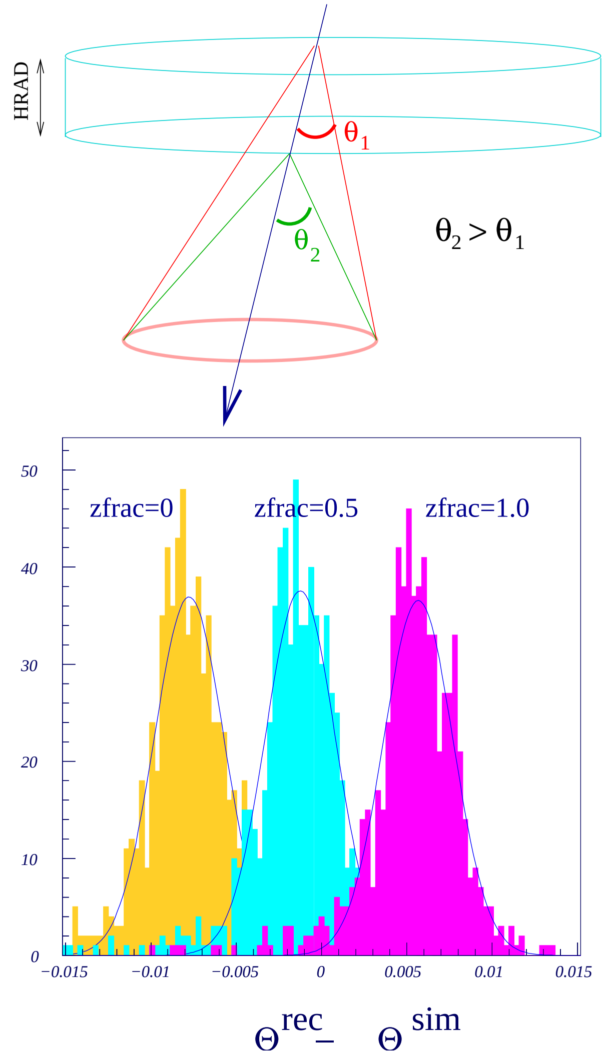
LG hits (hits produced by particle passage trough Light Guides) are excluded from fit

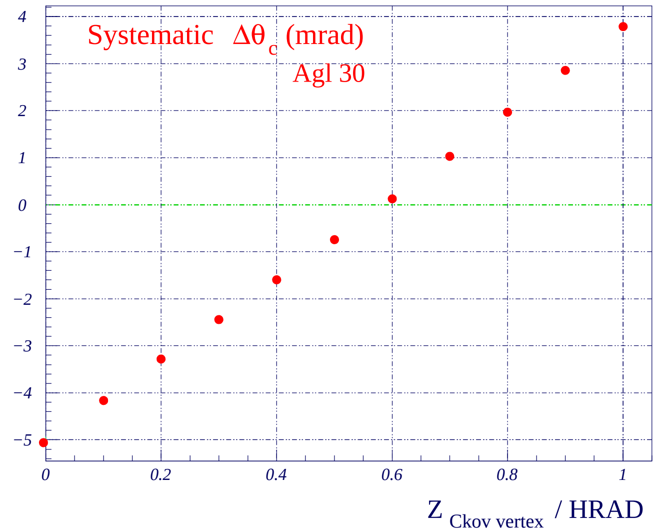


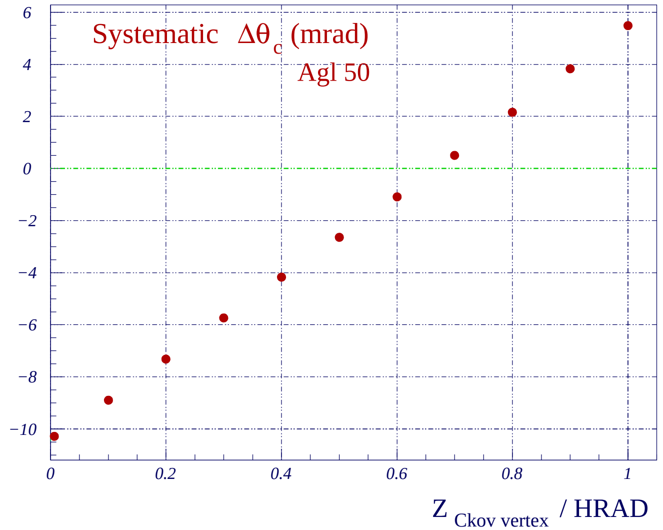


Use track extrapolation to exclude particle hits in a 4cm “window” $\Rightarrow$

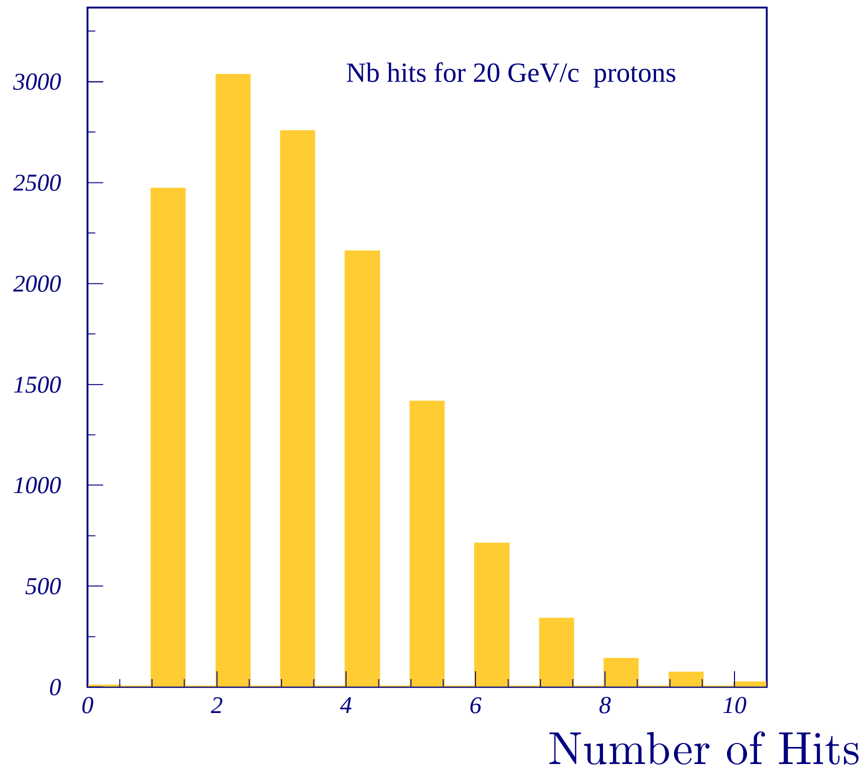
tunning of the mean photon emission point (bias on θ_c^{rec})

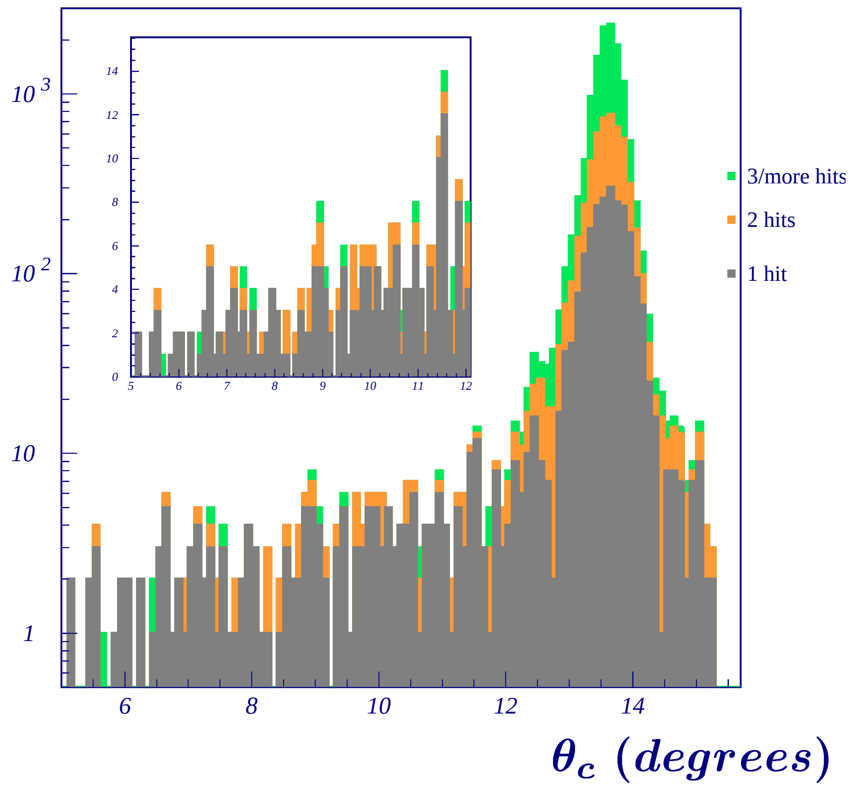






Results: the Number of hits





radiator: aerogel (n=1.030) 2cm thickness

☞window for hits counting around rec pattern: 3 σ

☞ large tails for events with $\leq$ **3** hits

So, keep only 3 hits reconstructions !

Cerenkov angle resolution

- The cerenkov angle:

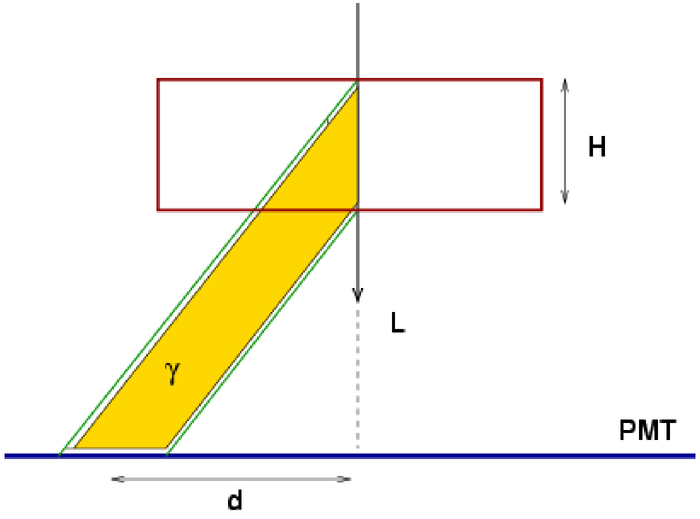
$$cos\theta_c = \frac{1}{\beta\ n}$$

- The particle velocity uncertainty (per hit):

$$\frac{\Delta\beta}{\beta} = \tan\theta_c\ \Delta\theta_c$$

- The cerenkov angle uncertainty:

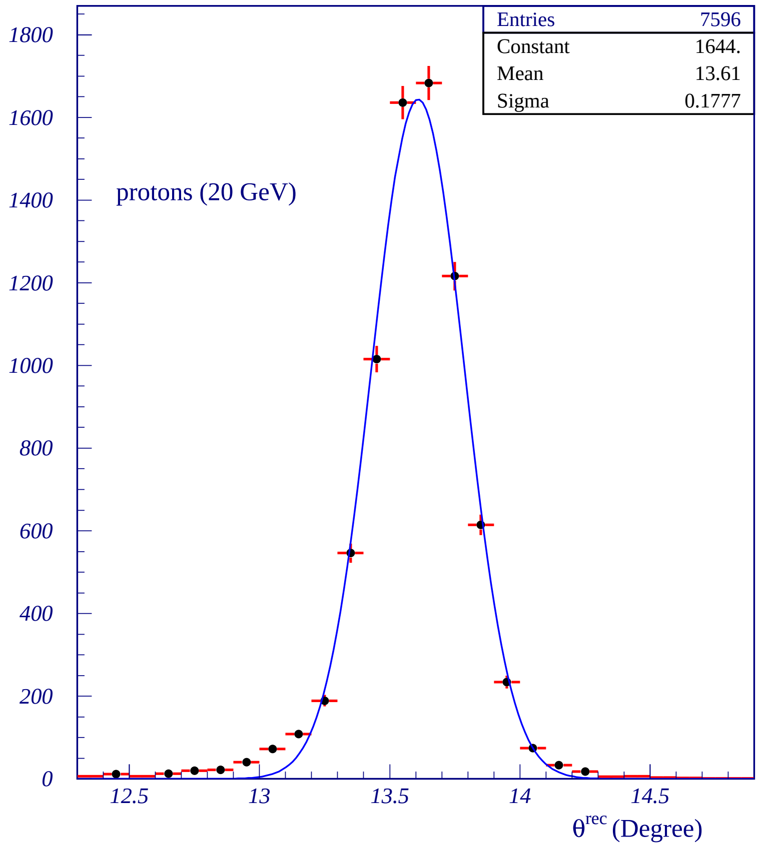
$$\Delta\theta_c \sim \cos^2\theta_c \frac{\Delta d}{L}$$

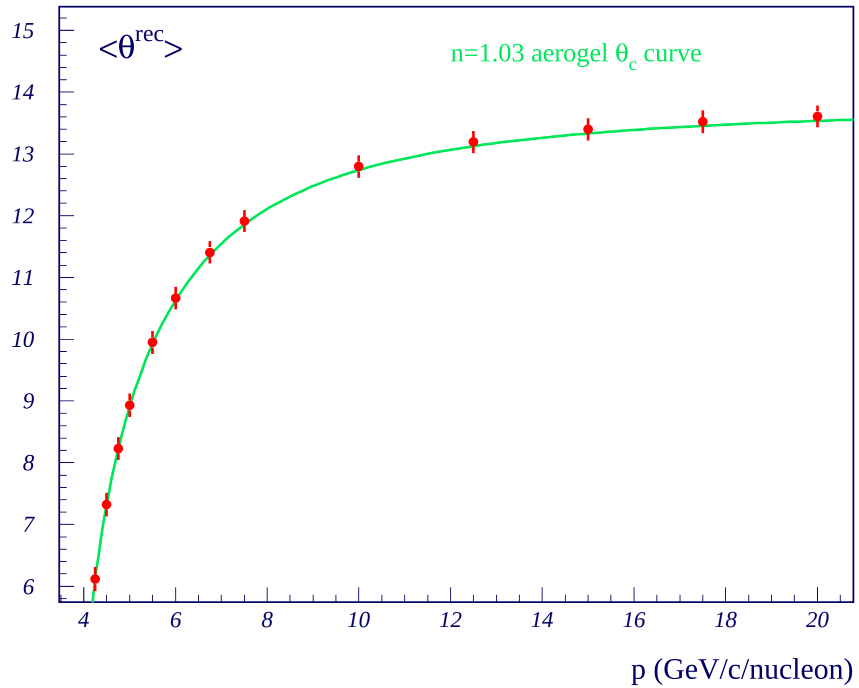


- the θ_c uncertainty deals with

❑ pixel size (granularity) $\sim 8.5mm$	$\Delta d \sim \frac{pixel}{\sqrt{12}}$	$\Rightarrow \Delta\theta_c \sim 5\ mrad$
❑ radiator thickness $2-3cm$	$\Delta d \sim \frac{H\ \tan\theta_c}{\sqrt{12}}$	$\Rightarrow \Delta\theta_c < 5\ mrad$
❑ chromaticity	$\Delta\theta_c \sim \frac{\Delta\ n}{\sqrt{2(n-1)}}$	$\Rightarrow \Delta\theta_c < 5\ mrad$

Cerenkov angle reconstrucion

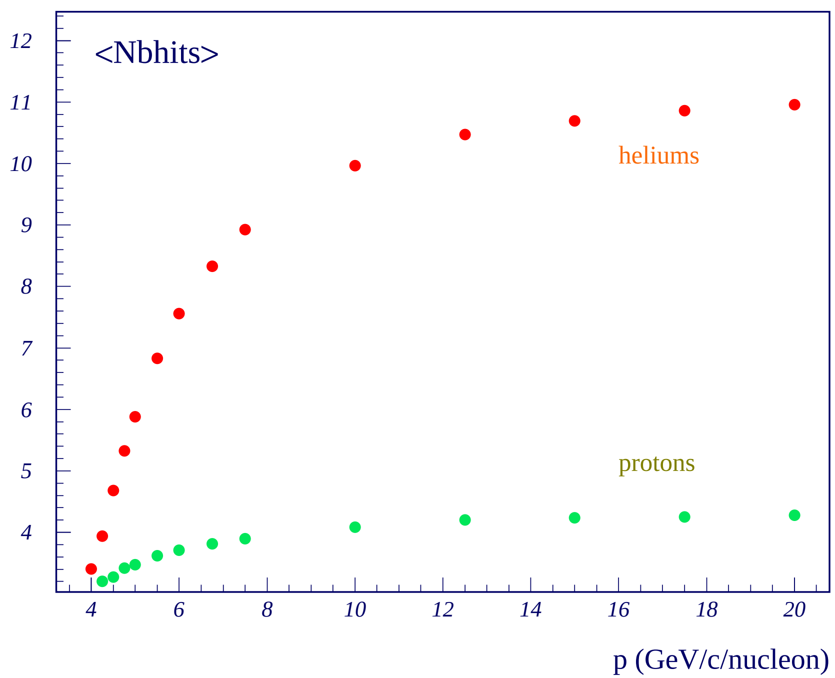


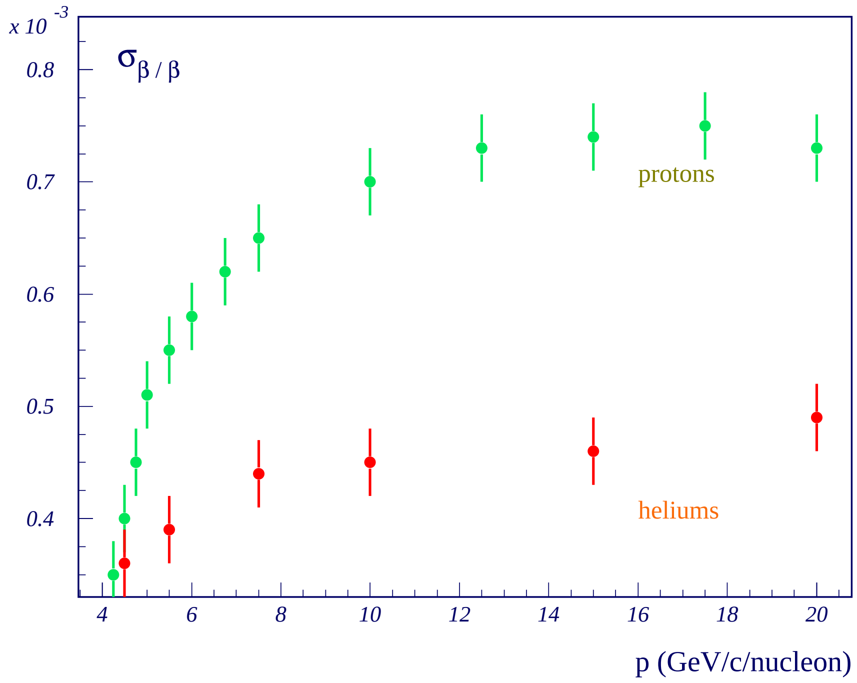


☞ Cerenkov angle reconstruction for events with at least 3 hits

☞ The reconstructed Cerenkov angle follows the expected law $\boldsymbol{cos\theta_c = \frac{1}{\beta n}}$ at all energies

Results : β resolution scaling





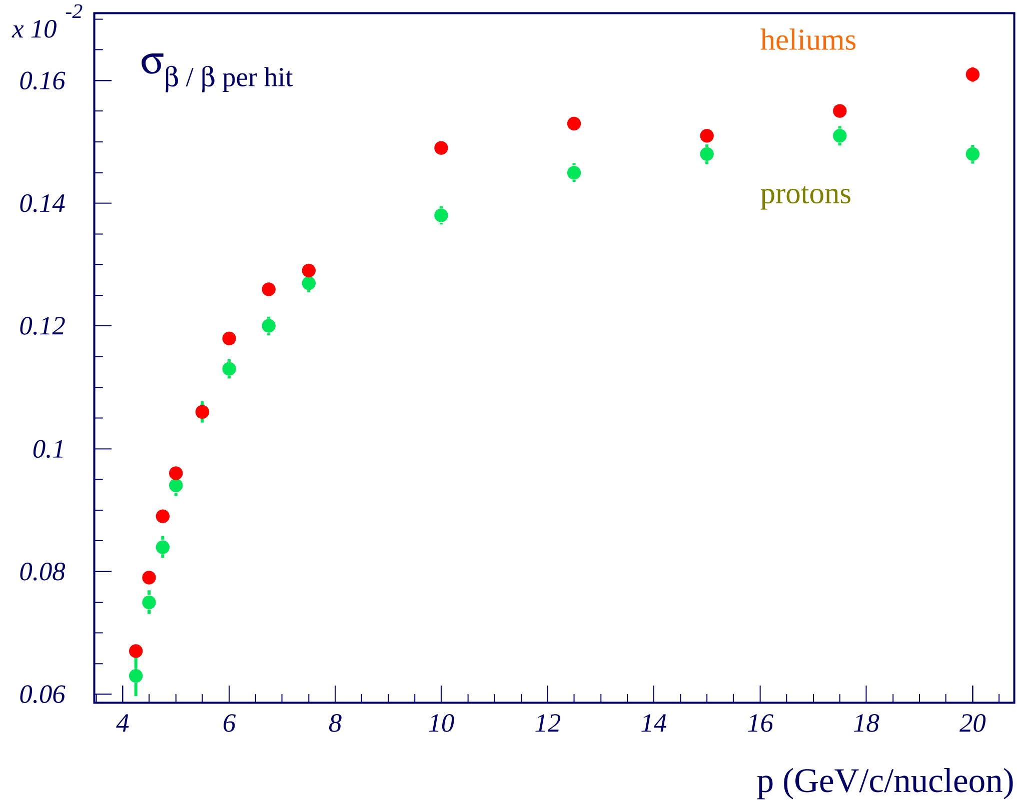
☞ the relative uncertainty on the velocity determination scales down with the number of hits

$$\frac{\Delta_\beta}{\beta} = \tan\theta_c \frac{\Delta_\theta}{\sqrt{N_{hits}}}$$

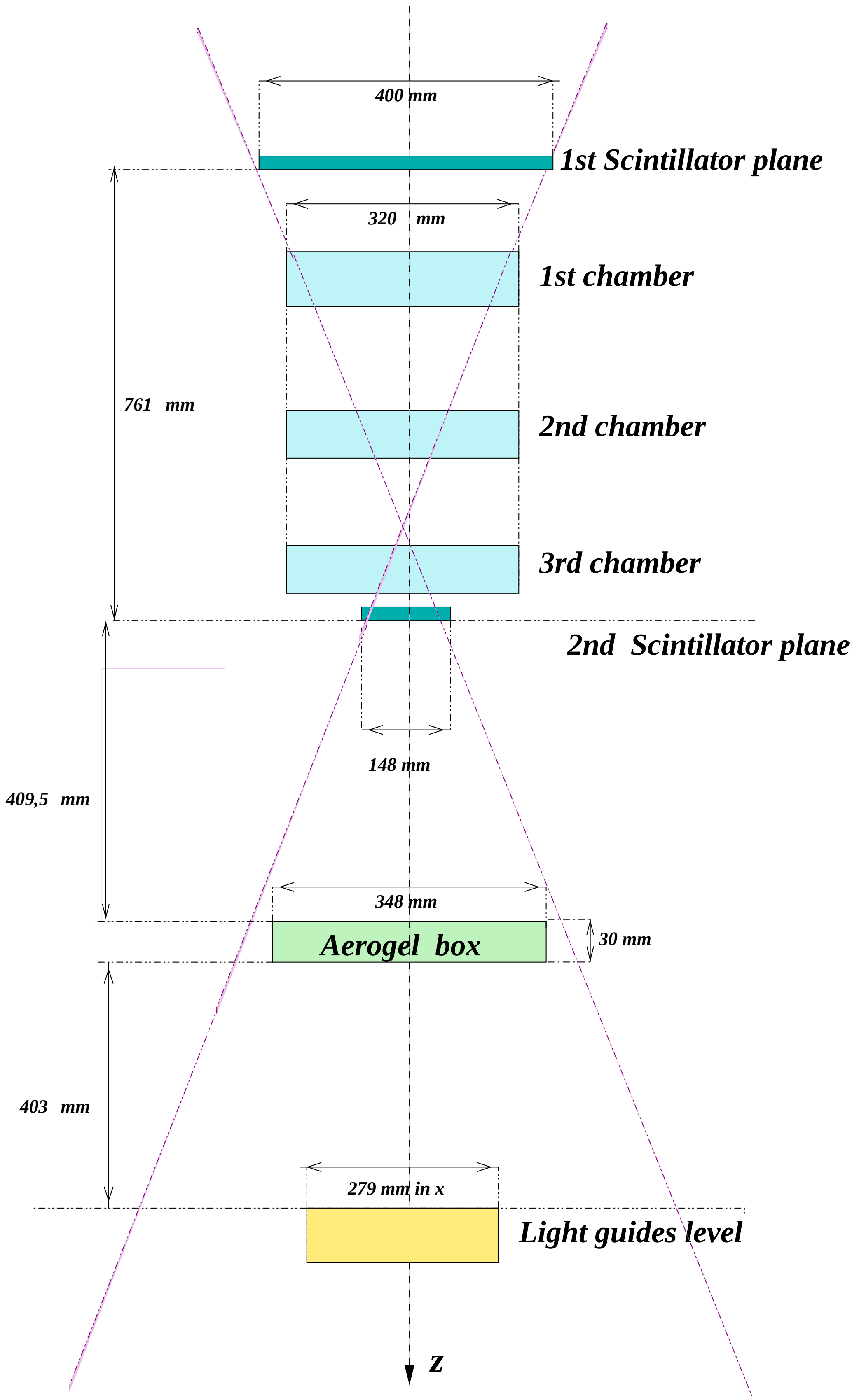
$\Delta\beta/\beta$: Resolution per hit

✔ It is possible to estimate the velocity resolution independently of the number of hits of every event

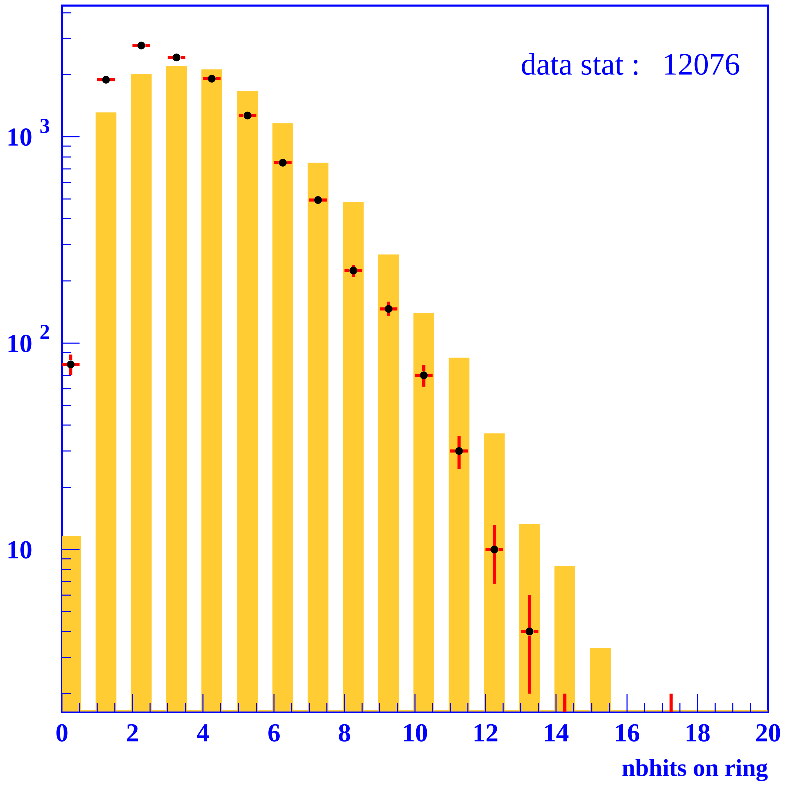
$$\left(\frac{\Delta\beta}{\beta}\right)_{hit} = \frac{\Delta\beta}{\beta} \times \sqrt{N_{hits}}$$



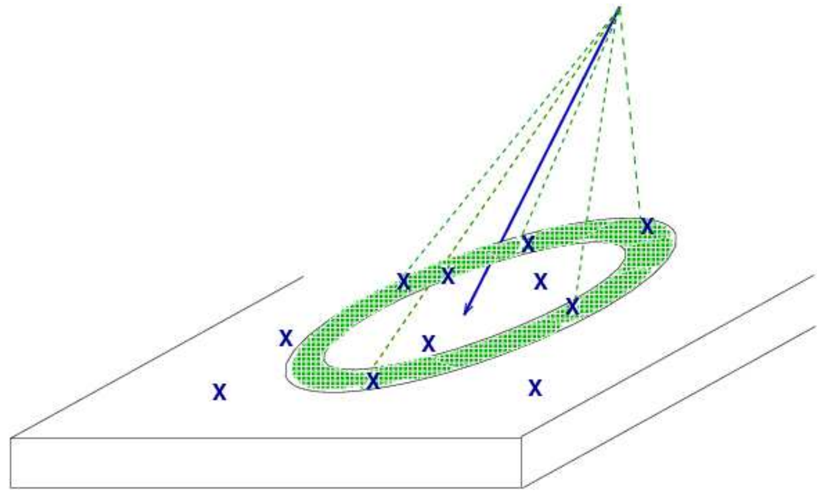
prototype setup for RUN 21



Prototype Data Analysis: Comparing DATA to MC

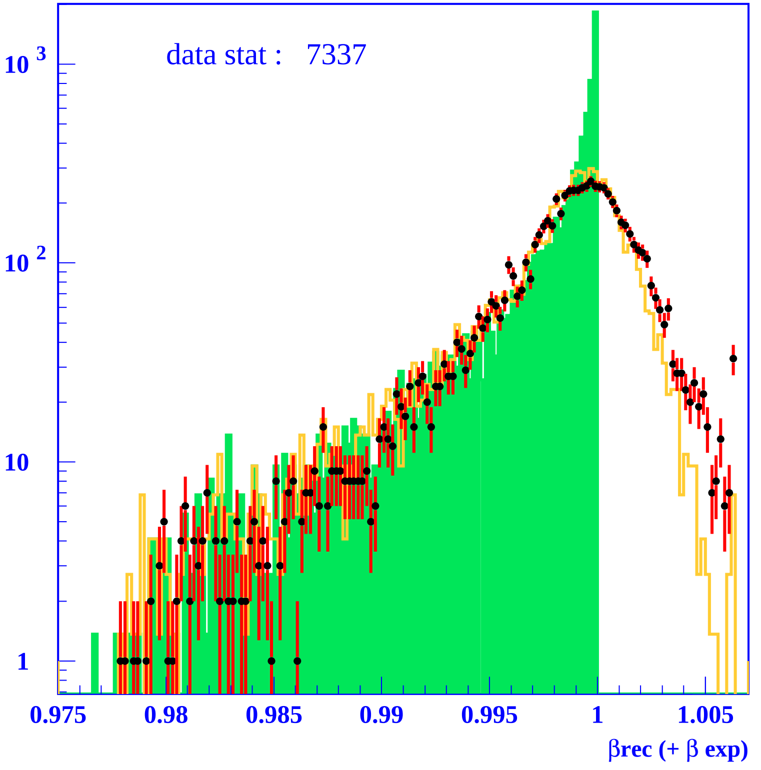


number of hits correlated with the photon pattern

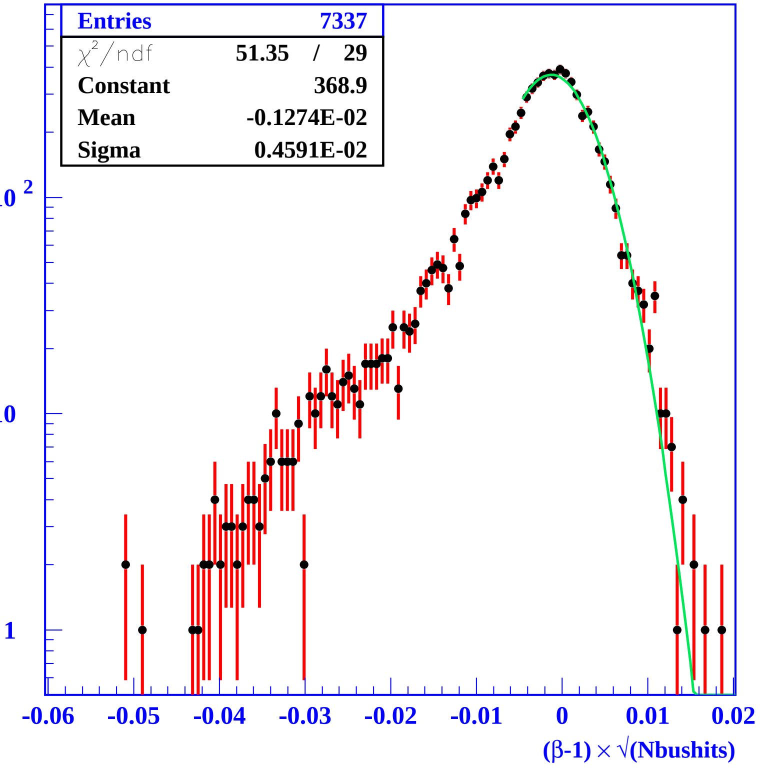


window defined by 3 sigma of rec pattern residuals distribution

Cosmic muons velocity spectrum



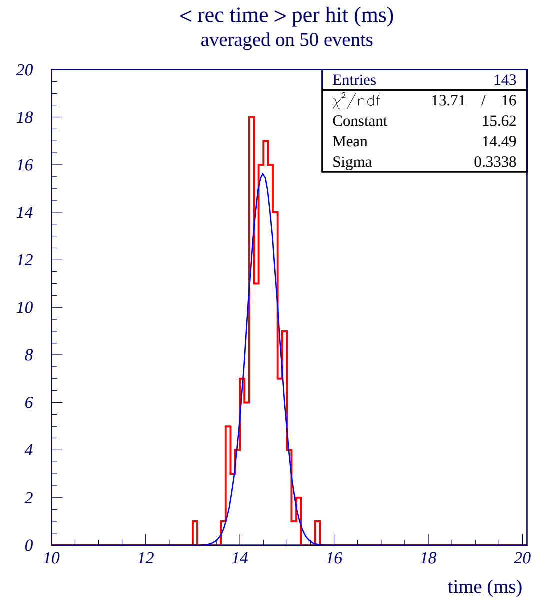
Measured β on data and simulation

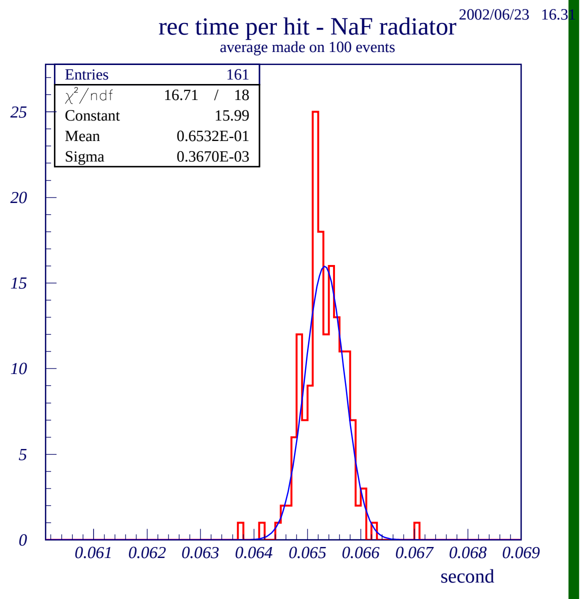


Velocity resolution from one hit

Conclusions and Future prospects

- A θ_C reconstruction based on a likelihood fitting technique has been developed, that works fine with 2 very different radiators; Aerogel(n=1.03) and NaF(n=1.33)
- Understand what is the better resolution achievable with likelihood approach
- solve some (very) few "pathological" events that give tails
- numerical improvements (in time computation) still possible

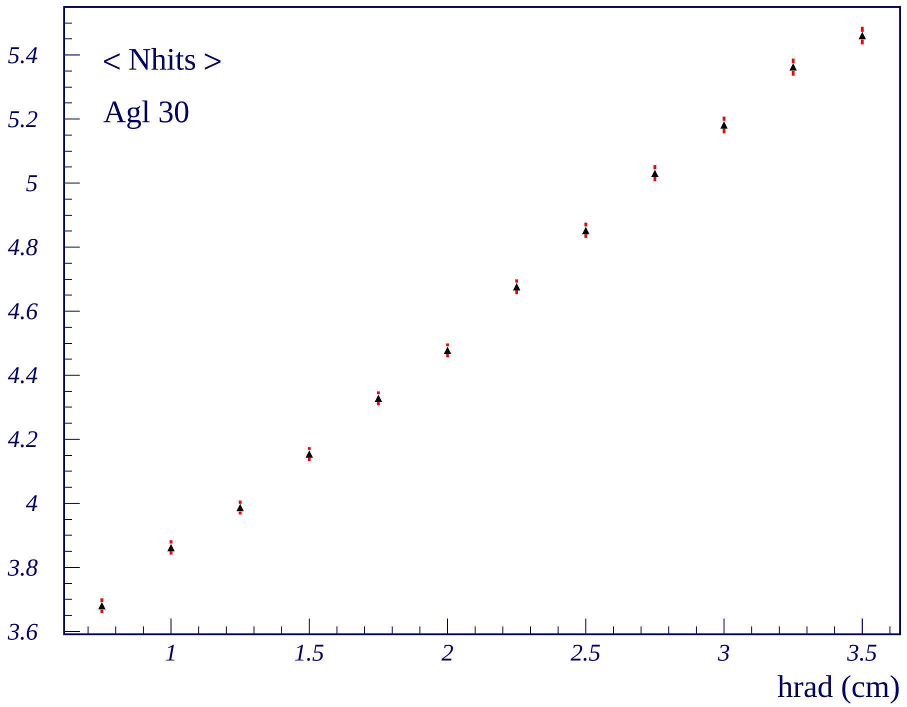


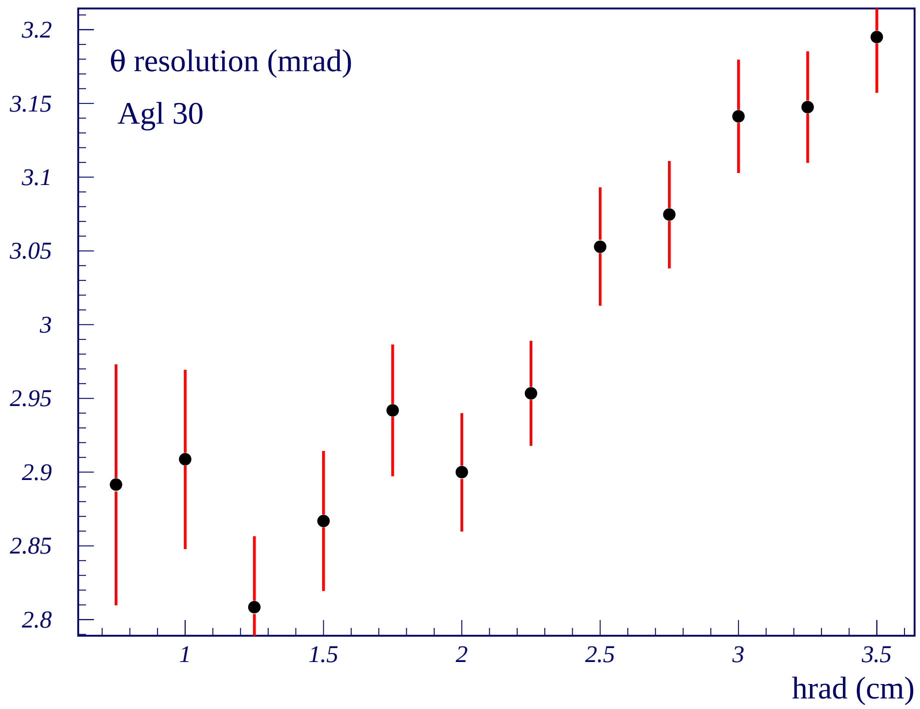


- Prototype Data (only RUN 21 for yet) has been analysed in a satisfactory way

Effect of radiator thickness

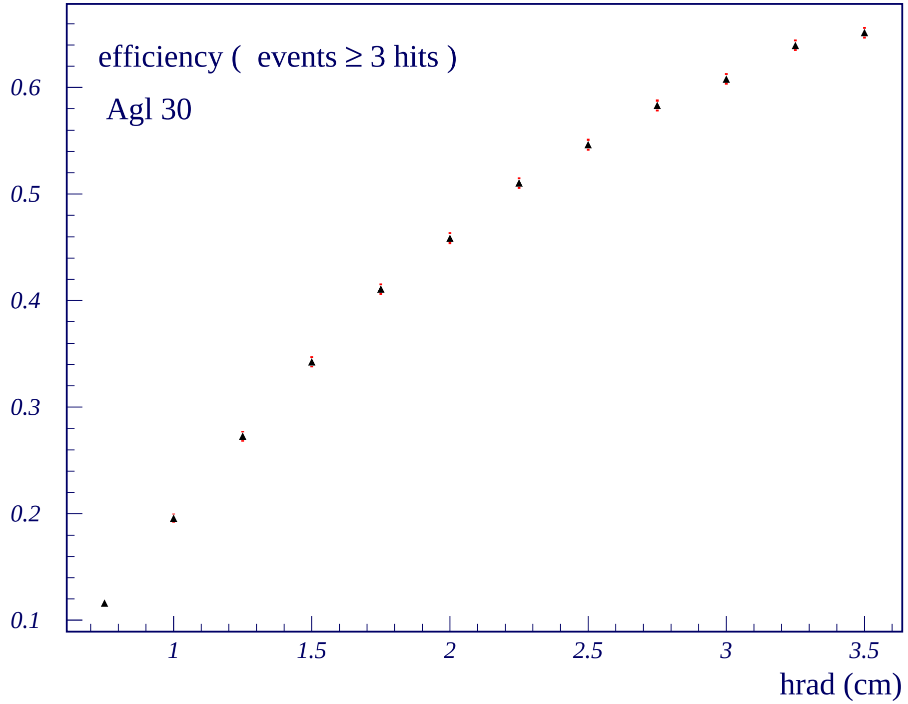
Despite increase of the pattern hits mean number, resolution has a slightly decreasing trend .





particles considered: Z=1, β=0.999

Effect of radiator thickness



particles considered : Z=1, β=0.999

In short :

- ☞ when radiator thickness goes from 2 to 3 cm, resolution decreases ∼ 5 % but reconstruction efficiency increases ∼ 40% due to increase of hits number (when refered to 2cm numbers).