A Double radiator configuration approach for the RICH detector

F. Barao

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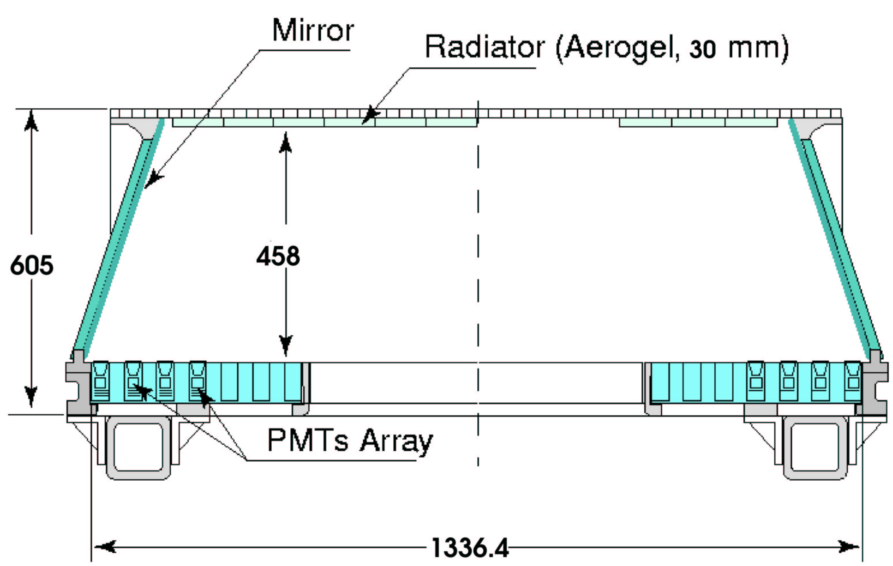
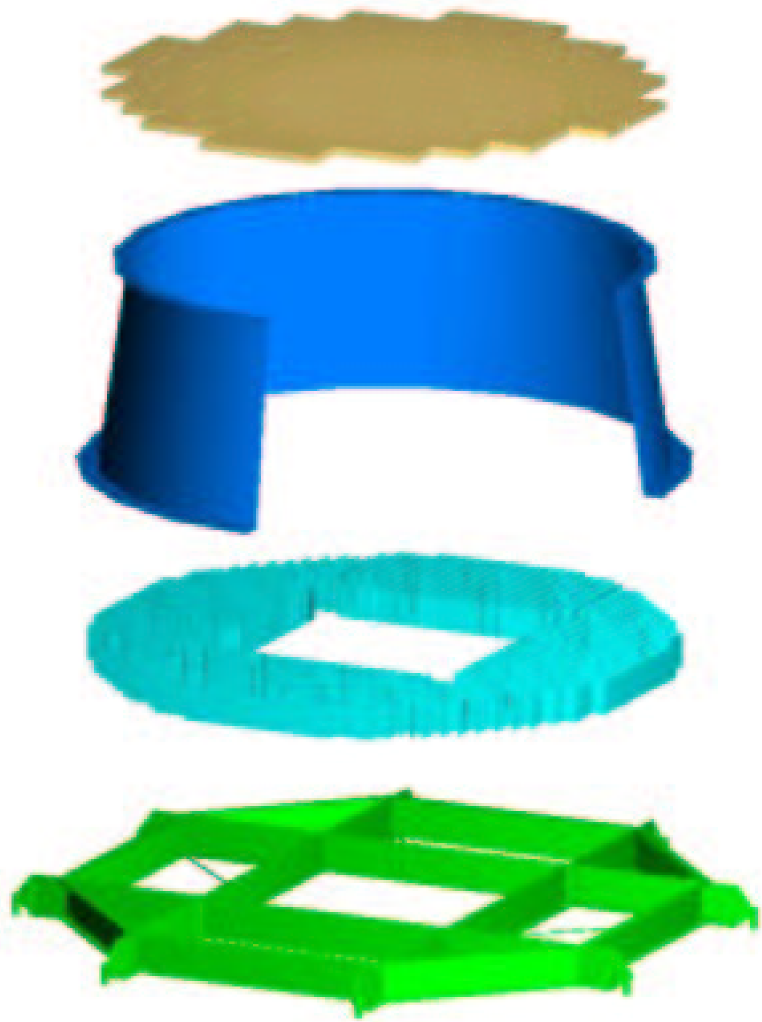
RICH detector

The Ring Imaging Cerenkov of AMS is a proximity focusing detector with a radiator on the top, a high reflectivity mirror and pixelized photomultiplier tubes.

- velocity measurement $\frac{\Delta\beta}{\beta} = 0.1\%$
- charge measurement
- redundancy on albedo rejection
- e/p separation



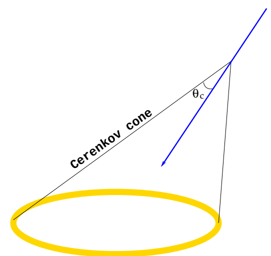


Cerenkov radiation

✔ Cerenkov radiation

a charged particle traveling in a medium with a velocity higher than the light speed radiates photons:

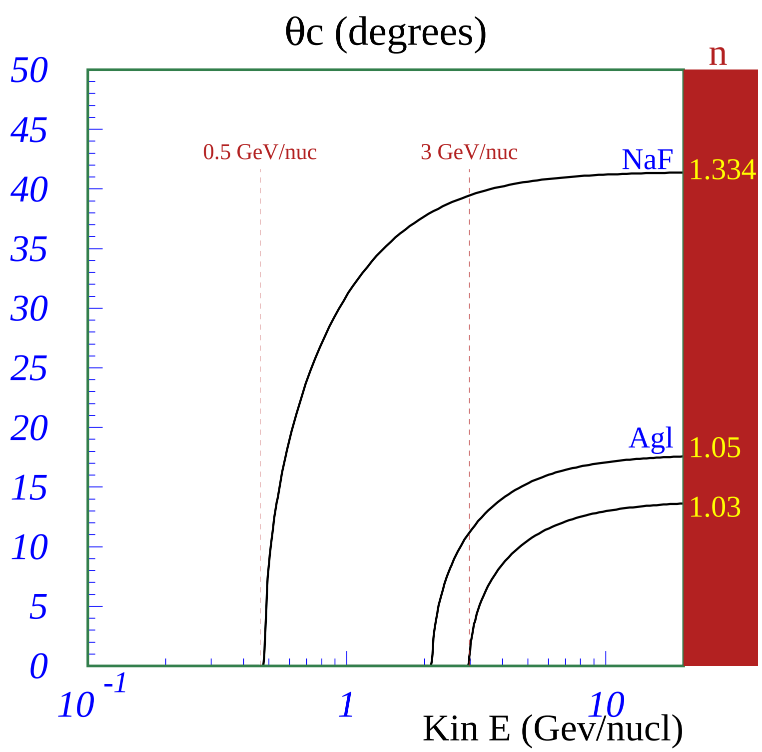
$$\cos\theta_c = \frac{1}{\beta n}$$

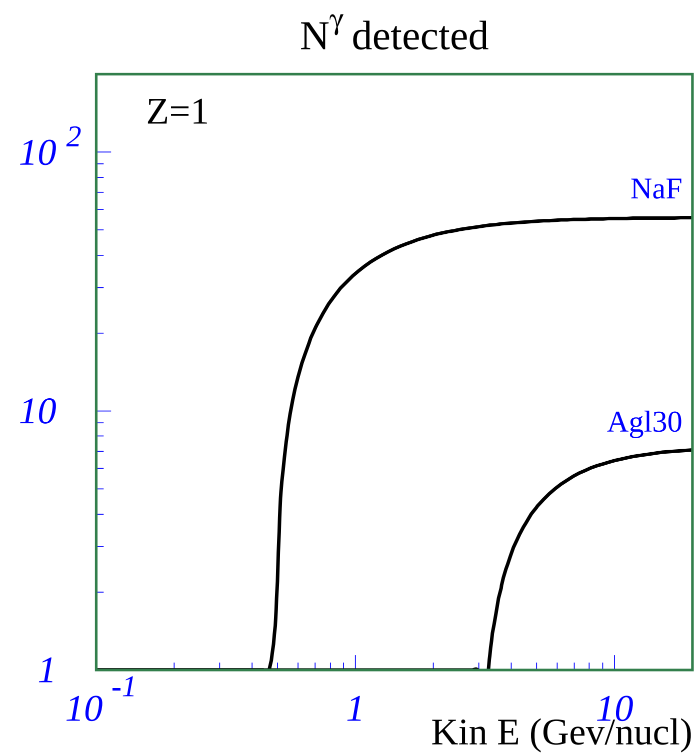


✔ Light Yield

the light yield increases with the radiator thickness (L), the charge (Z), the velocity (β) and refractive index (n):

$$n_{p.e} \propto Z^2\, L \left(1 - \frac{1}{\beta^2 n^2}\right) \int \varepsilon dE$$

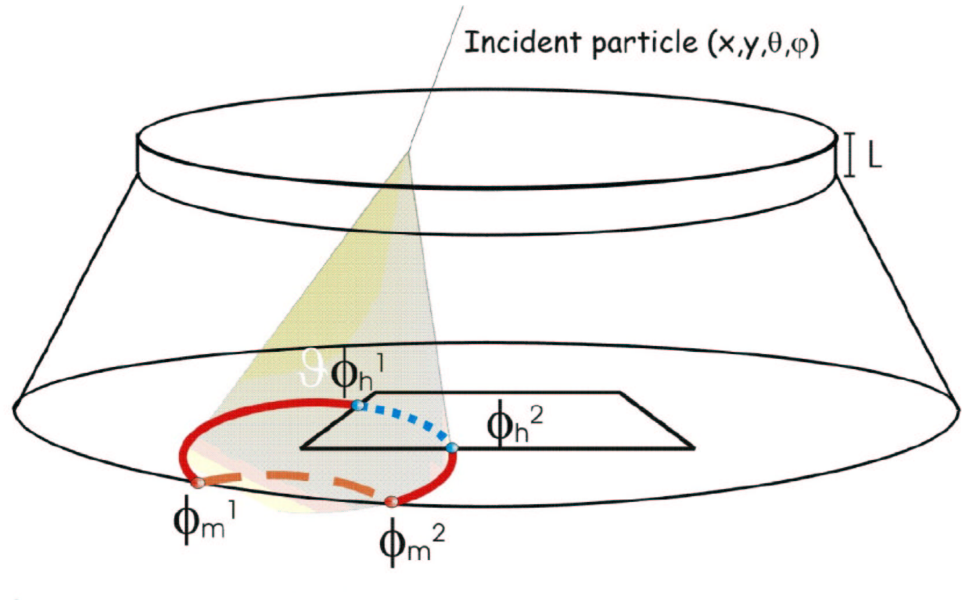




Fraction of visible photons

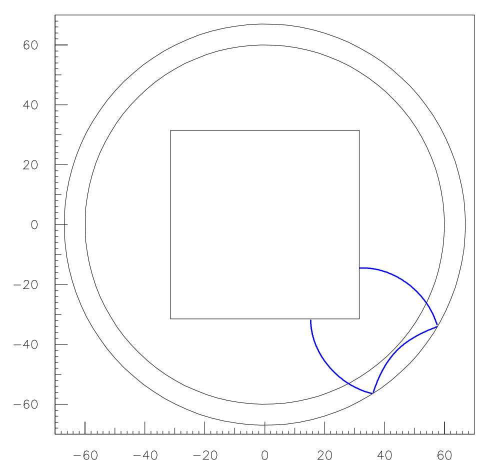
- ✔ photons are emitted with an opening angle θ_c and with an azimuthal angle φ ranging from $(0, \pi)$
- ✔ a fraction of these photons are *lost* due to *(geometrical acceptance)*:
  - ➪ escaping from radiator (lateral walls)
  - ➪ total reflecting medium transitions
  - ➪ falling into non-active readout area

    $\sim 63 \times 63$ *cm*

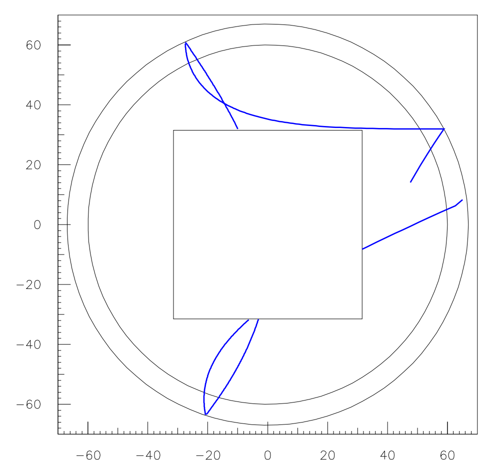


typical patterns

- ✔ for aerogel (n=1.030)
- ✔ for NaF (n=1.334)

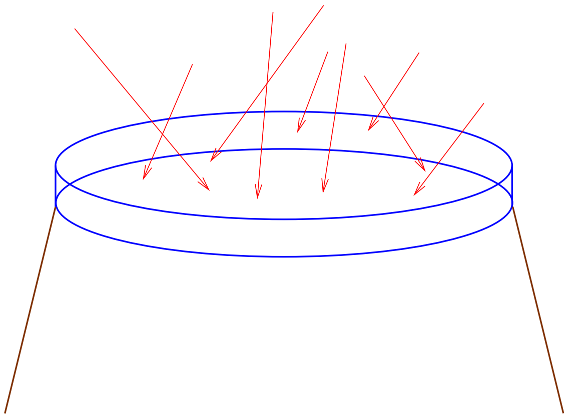


aerogel (n=1.030)

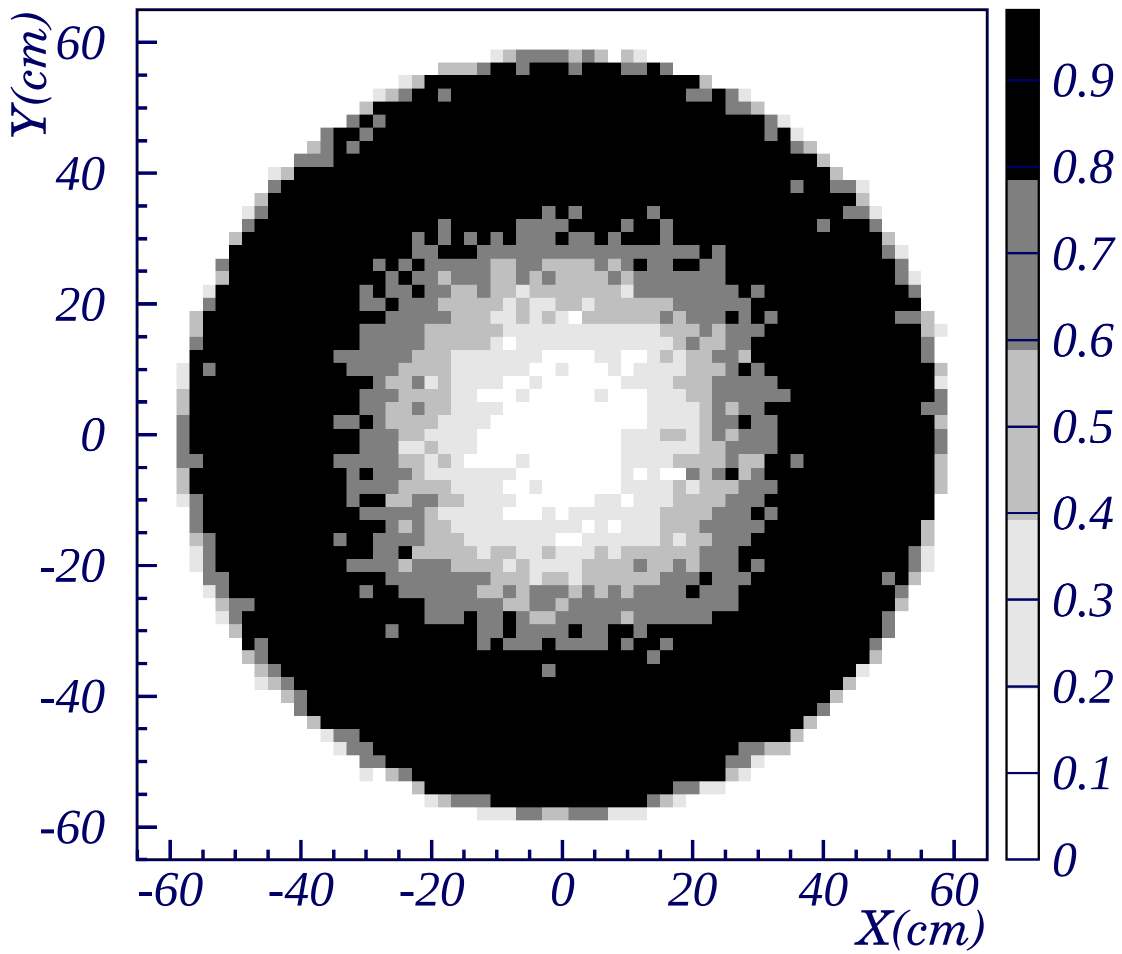


NaF

Event geometrical acceptances with Aerogel

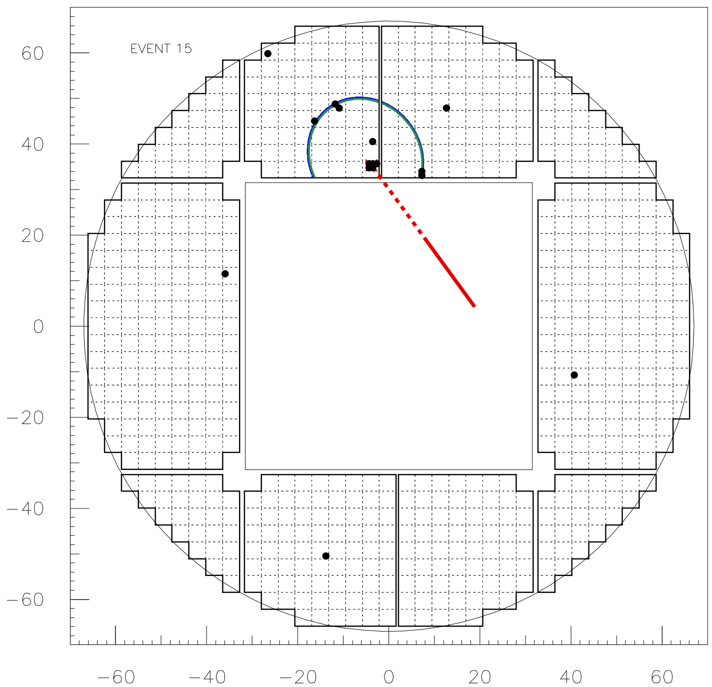


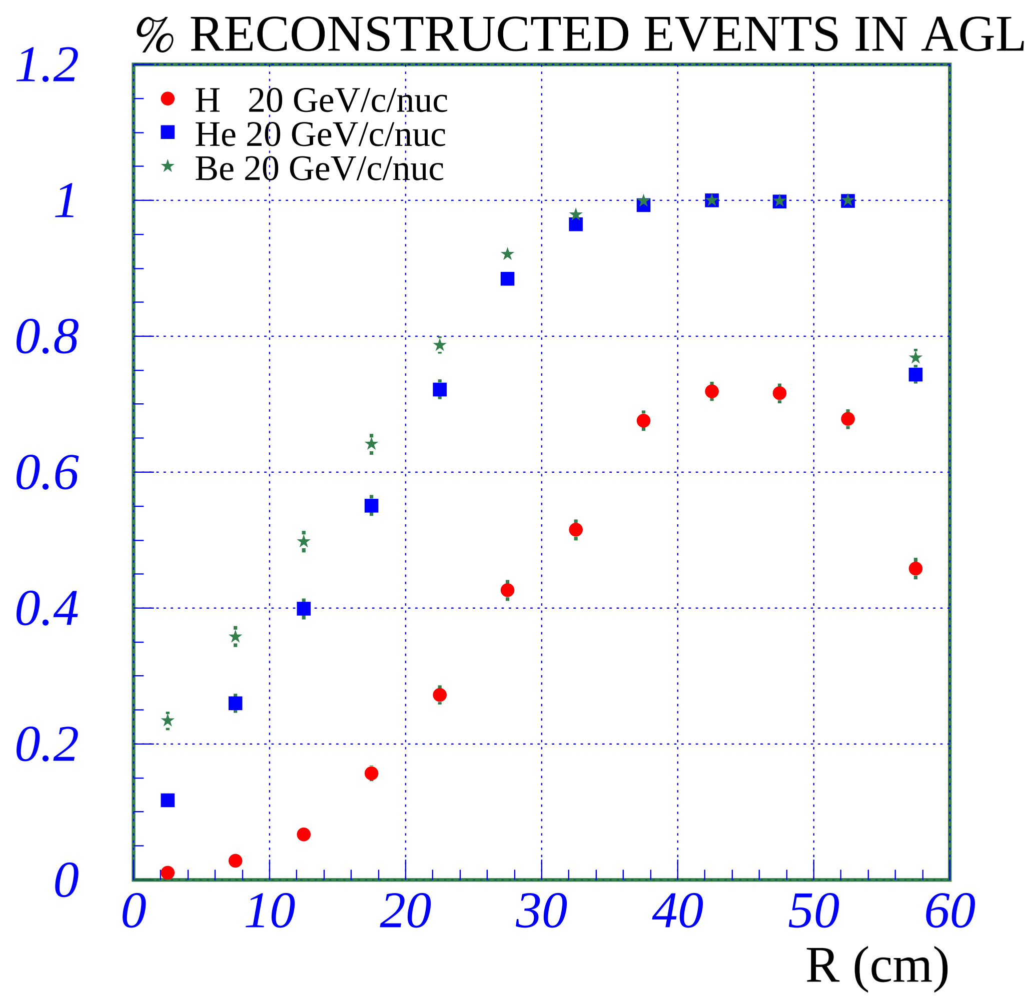
- particles are impinging within the AMS acceptance on top of aerogel radiator (n=1.03)
- the fraction of detected photons depends on:
  - particle impact point on the radiator
  - particle direction



Aerogel: event reconstruction efficiencies

- ✔ cerenkov angle is reconstructed for protons, heliums and berylliums
  - ➪ $\geq$ 3 hits required
- ✔ reconstruction efficiency drops as far as particles get closer to the radiator center
  - ➪ large fraction of photons lost on *hole*





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The Cerenkov signal and the θ_c resolution

Cerenkov signal depends on:

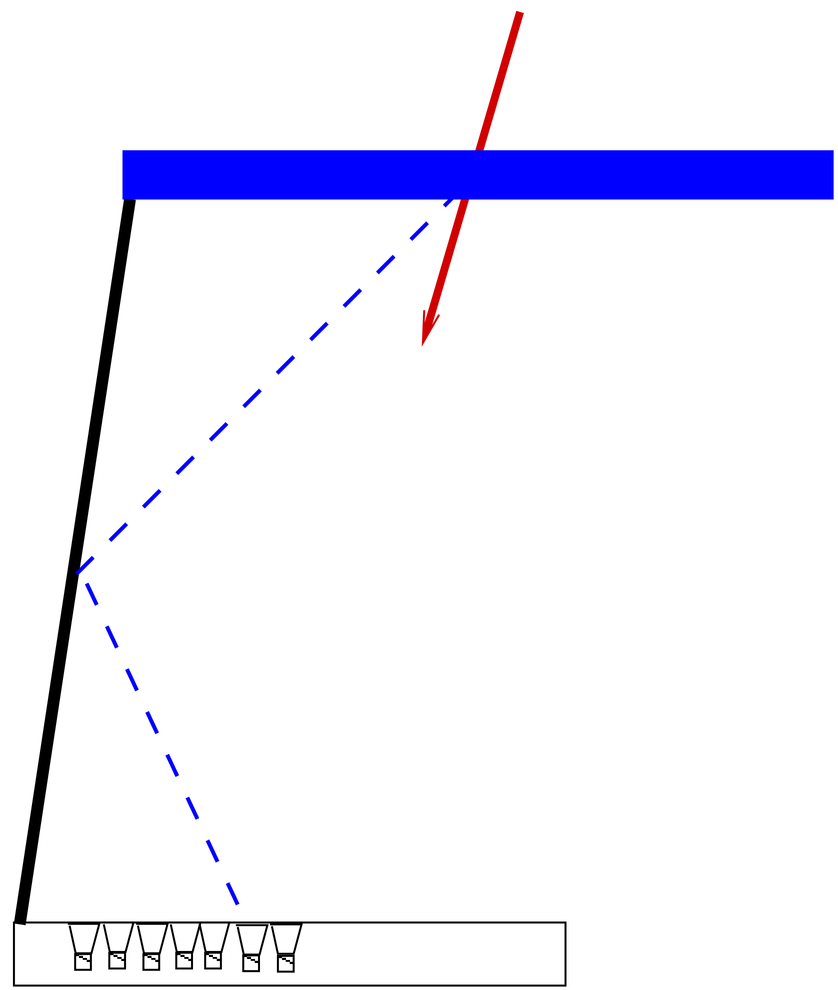
- radiator:
  - refractive index (n)
  - chromaticity
  - interactions (scattering, absorption)
- geometrical acceptance
- light guide
- pmt

Resolution:

$$\frac{\Delta\beta}{\beta} = \tan\theta_c \Delta\theta_c / \sqrt{N^{hits}}$$

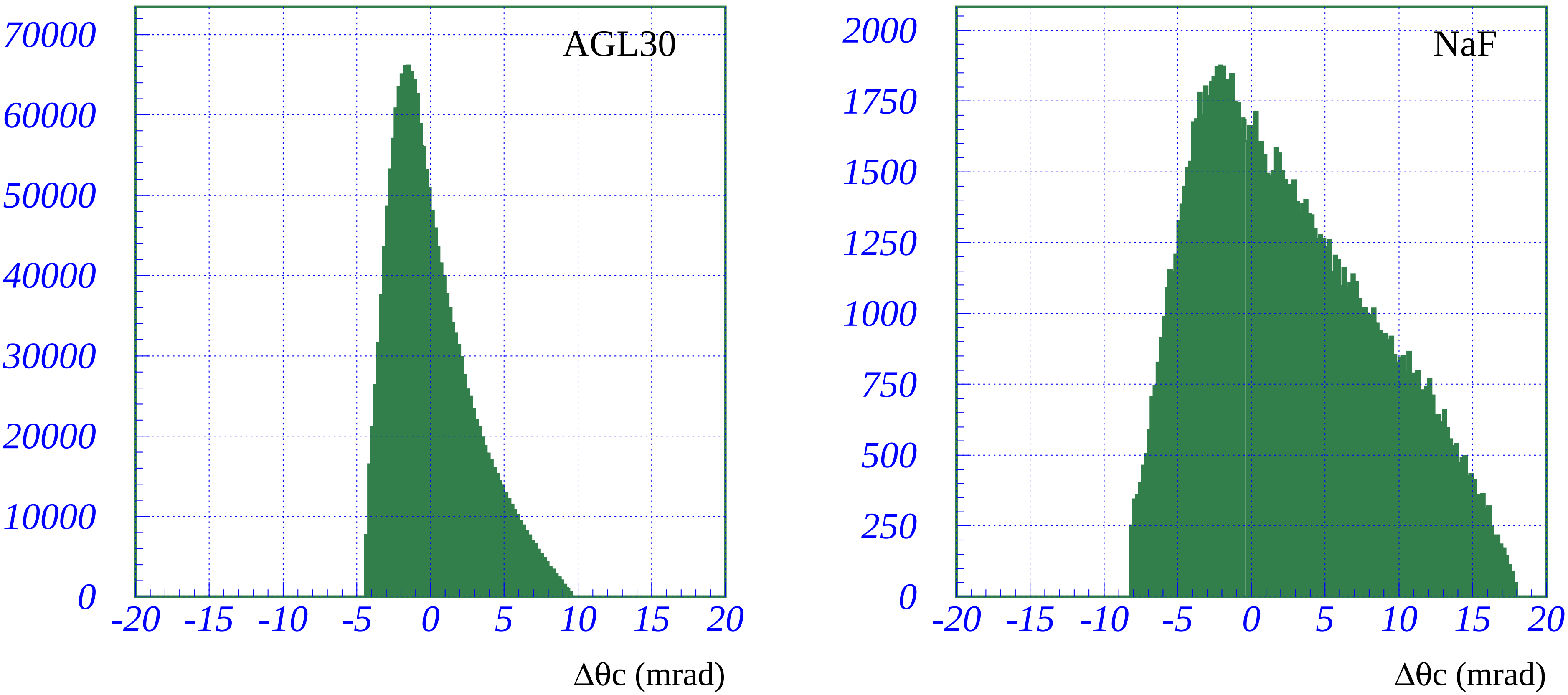
the θ_c uncertainty deals with:

- pixel size (8.5 mm)
- chromaticity
- radiator thickness

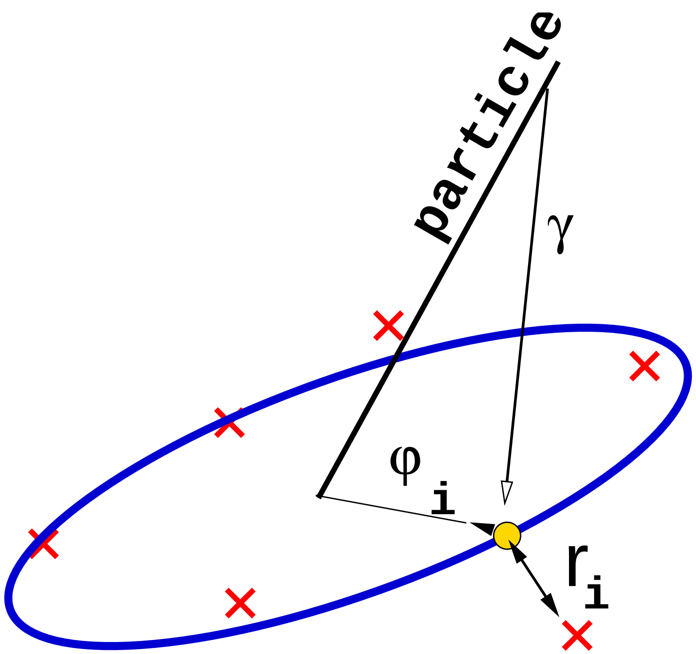


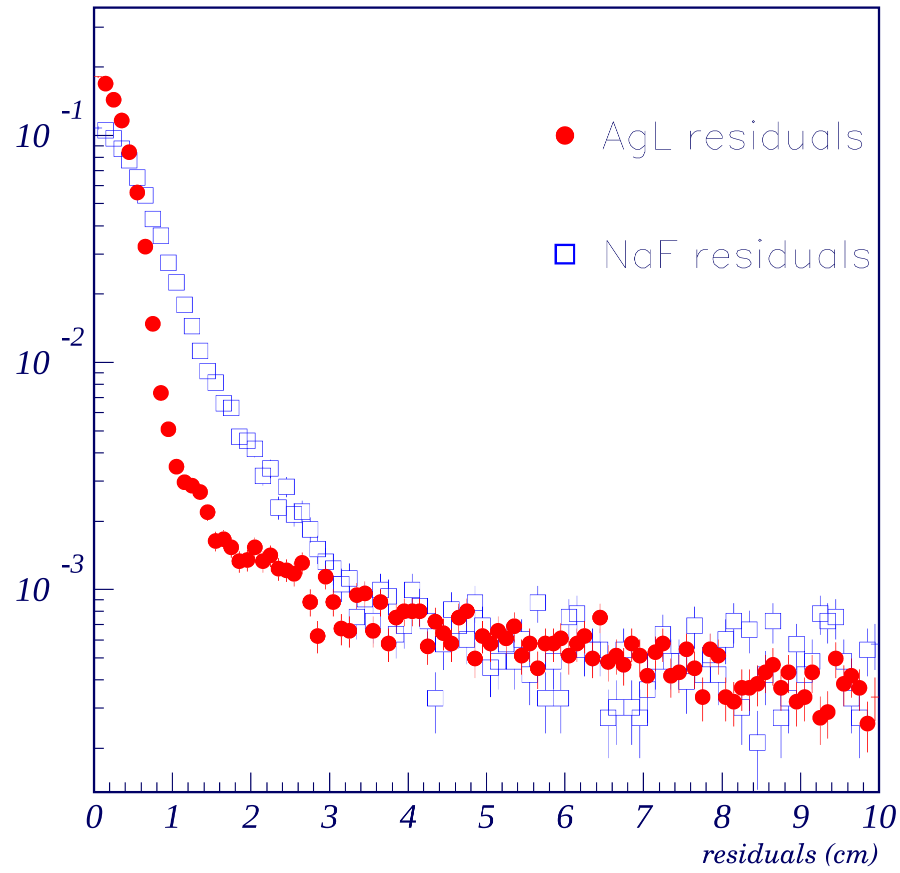
NaF.vs.Agl: chromaticity dispersion

$$cos\theta_c(\lambda) = \frac{1}{\beta\ n(\lambda)}$$



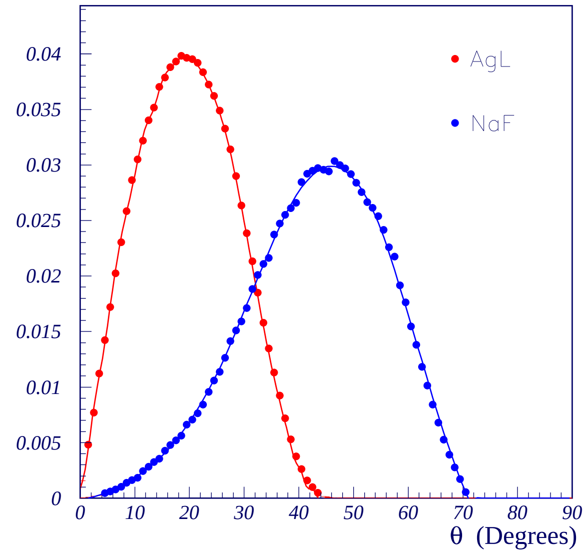
NaF.vs.Agl: hit residiuals

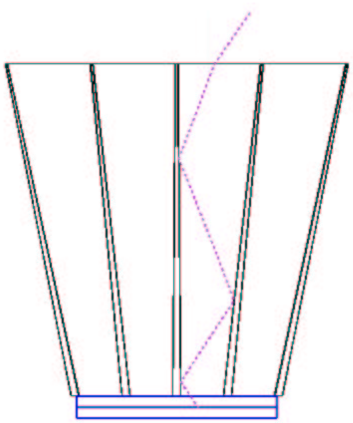


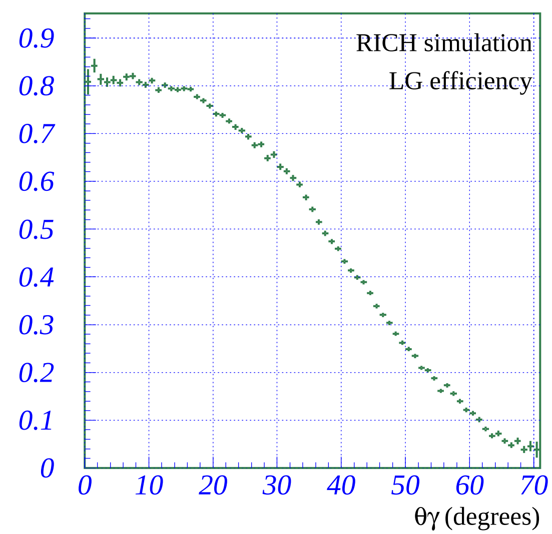


NaF.vs.Agl: Light Guide Efficiency

- The light guide efficiency depends on the photon entrance angle (θ_γ)
  - NaF radiated photons have larger entrance angles and therefore lower efficiencies

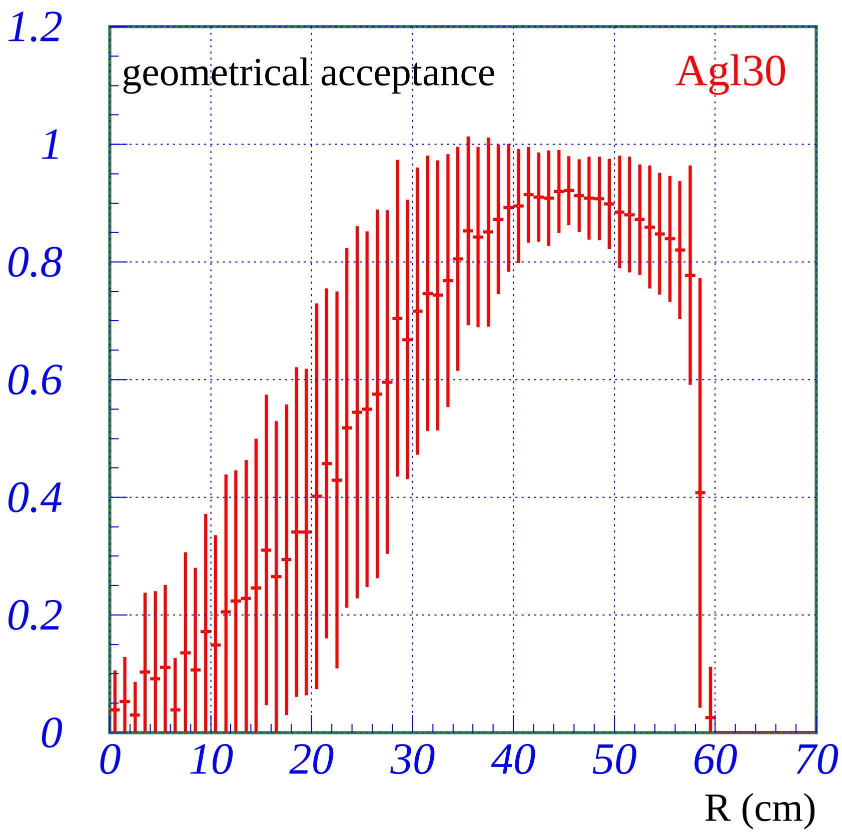


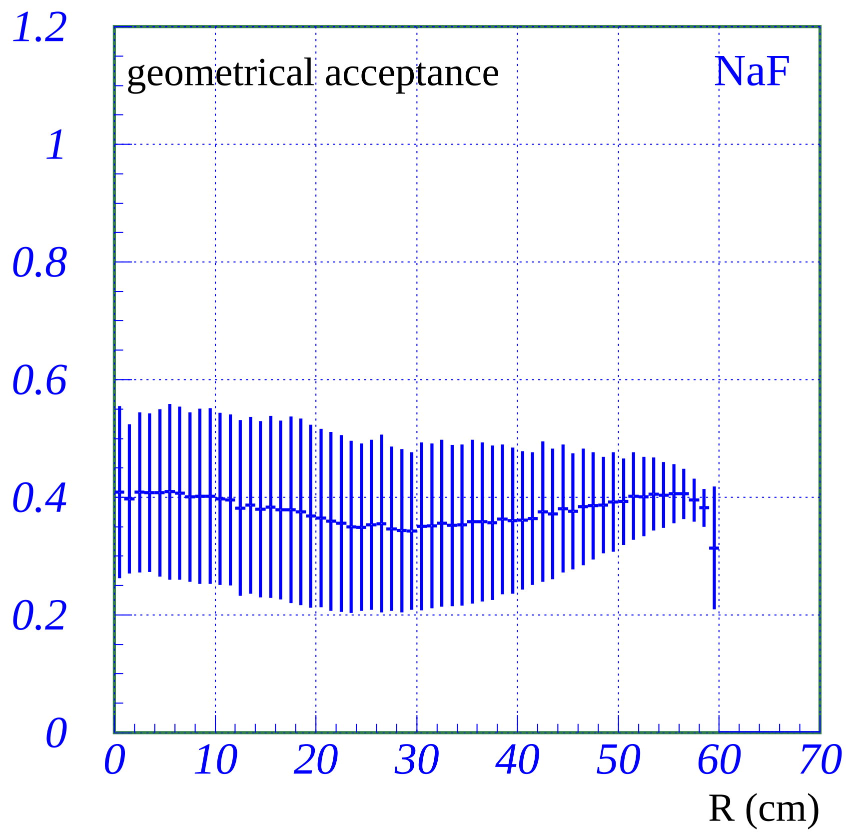




NaF.vs.Agl: geometrical acceptance

- Fraction of lost photons as function of the particle impact point distance to the radiator center
  - essentially due to the non-active region on PMT matrix



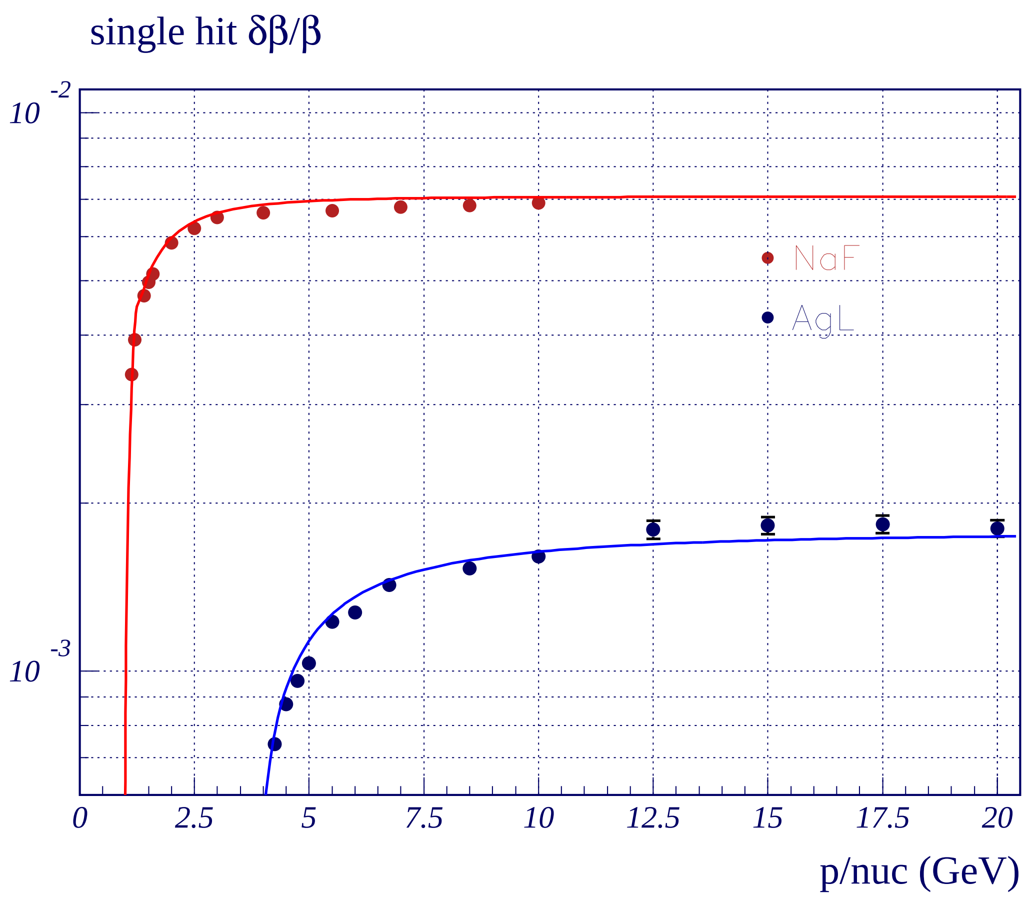


NaF.vs.Agl

Confronting Aerogel and Naf

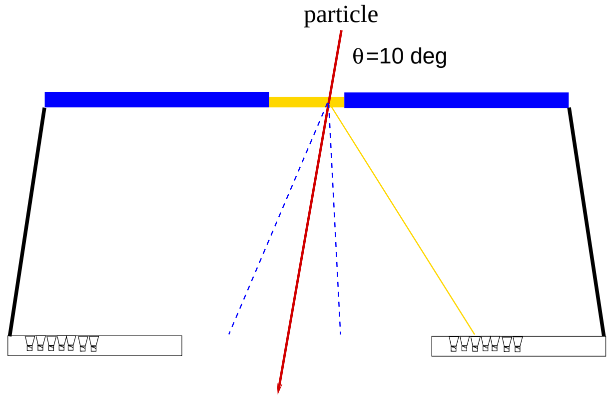
Effect on the number of cerenkov hits used on θ_c reconstruction	Agl	NaF
❑ nb of radiated photons (/cm)	↘	↗
❑ radiator chromaticity	↗	↘
❑ radiator interactions	↘	↗
❑ light guide efficiency	↗	↘
❑ geometrical acceptance ($R < 15 - 20\ cm$)	↘	↗
❑ geometrical acceptance ($R > 20\ cm$)	↗	↘

NaF.vs.Agl: resolutions

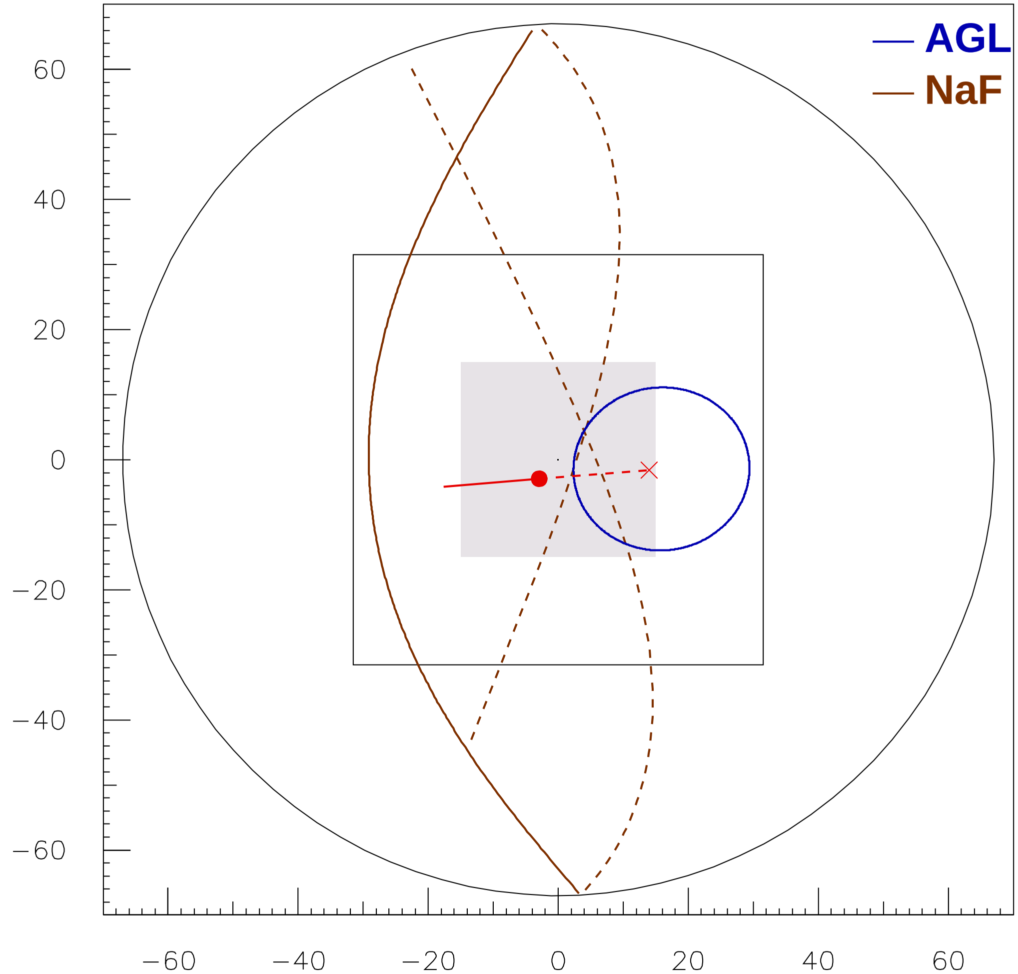


Solving the problem..

- A larger refractive index radiator in the central region

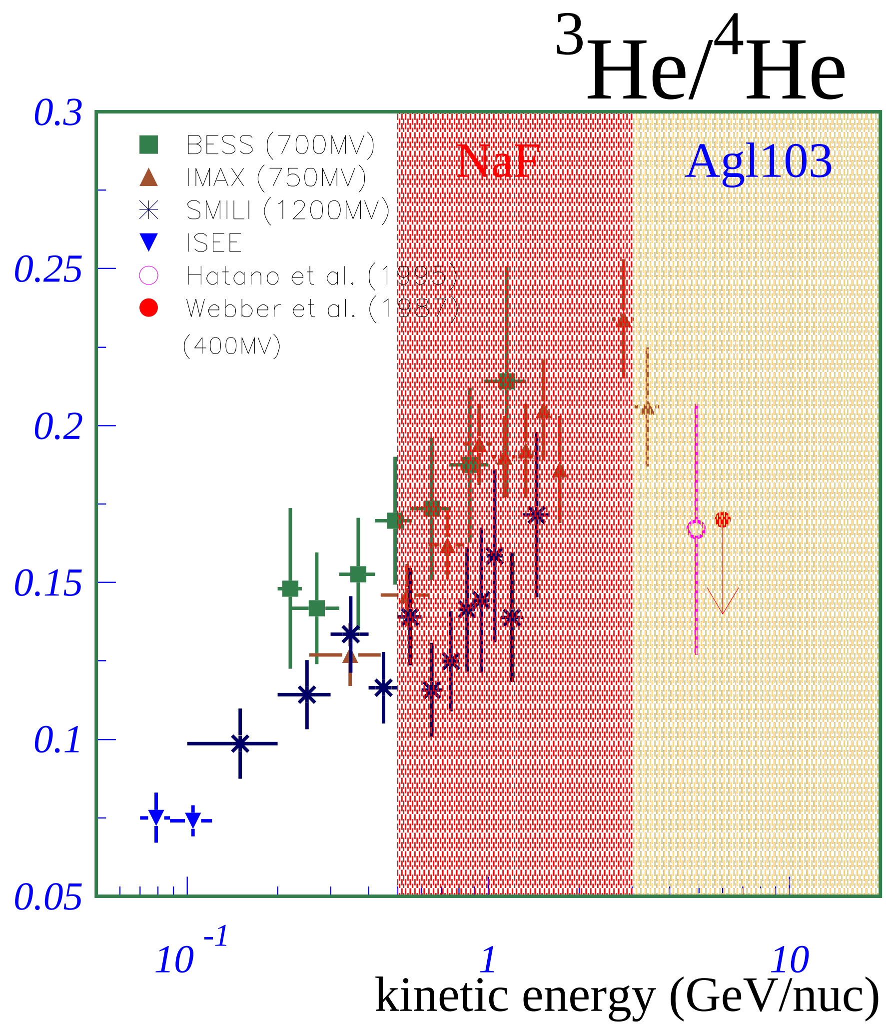


- photons emitted at larger cerenkov angles
- more photons detected in the active area



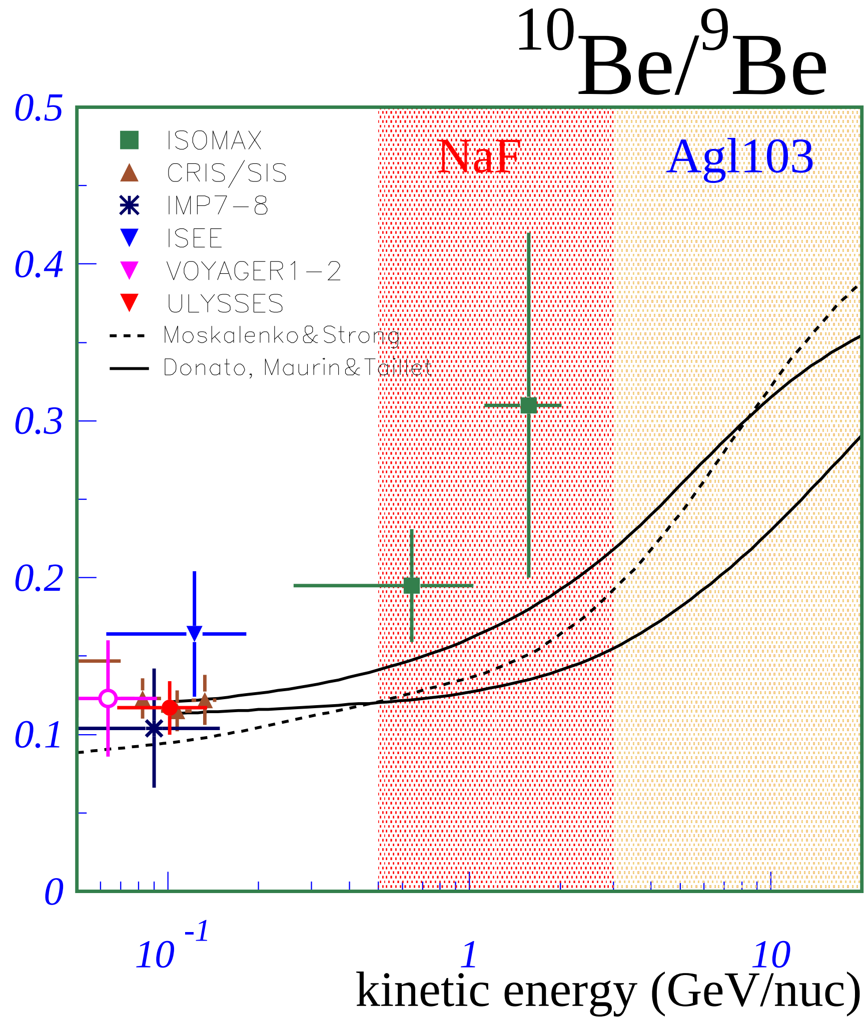
Physics arguments: helium isotopes

- The propagation history of the helium can be probed by measuring the isotopic ratio $^{3}He/^{4}He$
  - ^{3}He is essentially secondary and comes from the spallation of ^{4}He
- aerogel in AMS will provide isotopic ratios from $E_{kin} \simeq 3\ GeV/nuc$
- the integration of NaF in the Rich radiator will allow to measure isotopic ratios down to $E_{kin} \simeq 0.5\ GeV/nuc$



Physics arguments: beryllium

- Measurement of ratio $^{10}Be/^{9}Be$ give us information about confinement of cosmic rays in the Galactic volume and is sensitive to different propagation models
  - ☞ $t_{1/2}(^{10}Be) \sim 1.5 \times 10^{6}\ yrs$



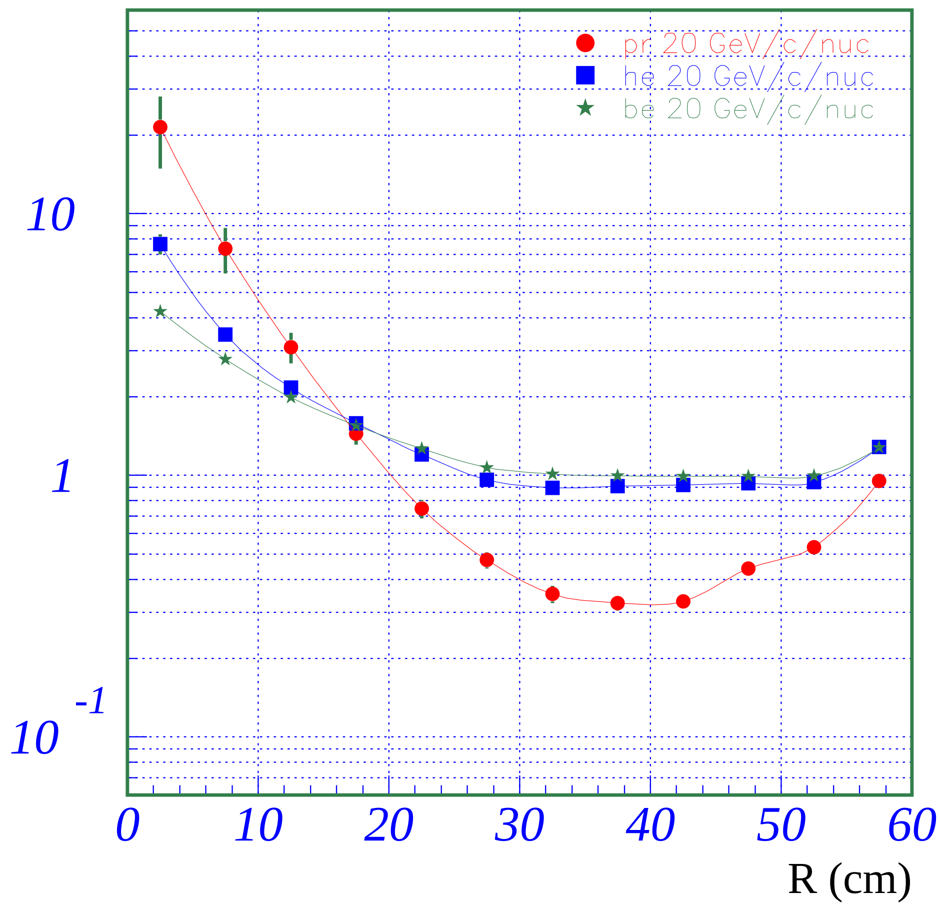
- aerogel in AMS will provide isotopic ratios from $E_{kin} \simeq 3\ GeV/nuc$
- the integration of NaF in the RICH radiator will allow to measure isotopic ratios down to $E_{kin} \simeq 0.5\ GeV/nuc$

Which size for NaF?

- A minimal number of 3 hits required on θ_c reconstruction
- The ratio of the events reconstructed on **NaF** and **Agl30** as function of the incident particle distance to the radiator center

$$\frac{\%\ Recevents(NaF)}{\%\ Recevents(Agl30)}$$

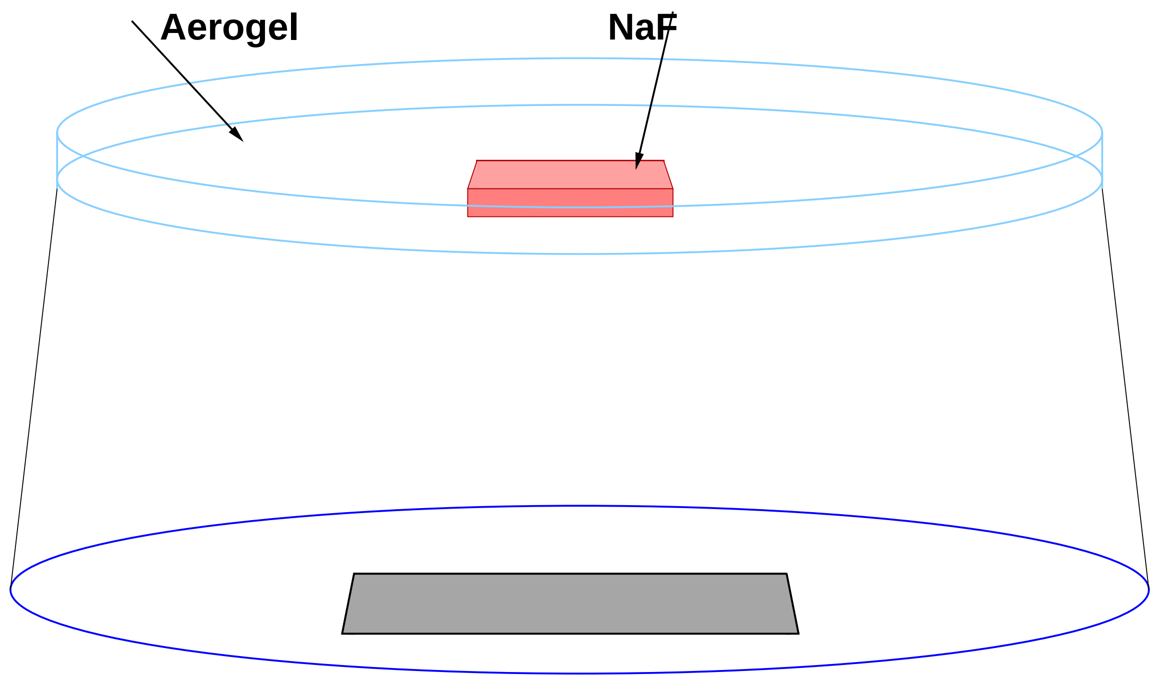
- NaF reconstruction is dominant for R lower than $\sim 20\ cm$



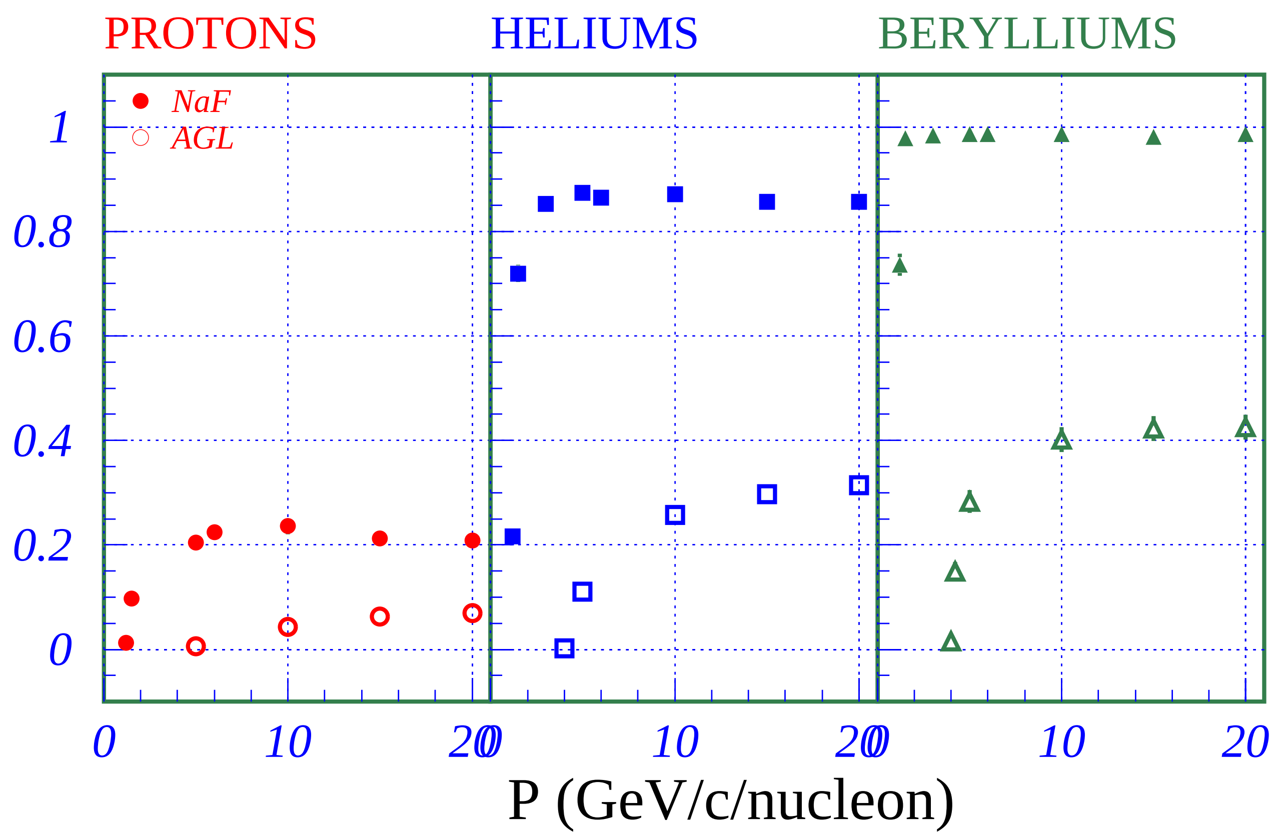
$\beta \sim 1$

Dual radiator configuration

- a square of sodium fluoride (NaF) with $\sim \mathbf{30 \times 30 \times 0.5}\ \boldsymbol{cm^3}$ placed in the center of of the RICH radiator
- it covers about 10% of the RICH acceptance
- an amount of matter correspon-ding to $\sim$ 4% of $\boldsymbol{X_0}$ *(aerogel is ∼3%)*
- important implications:
  - ✔ RICH acceptance increases which implies larger reconstruction efficiencies
  - ✔ kinetic energy range is extended down to values around $\mathbf{0.5}\ \boldsymbol{GeV/nuc}$



NaF.vs.Agl: reconstruction efficiency (30 cm square)

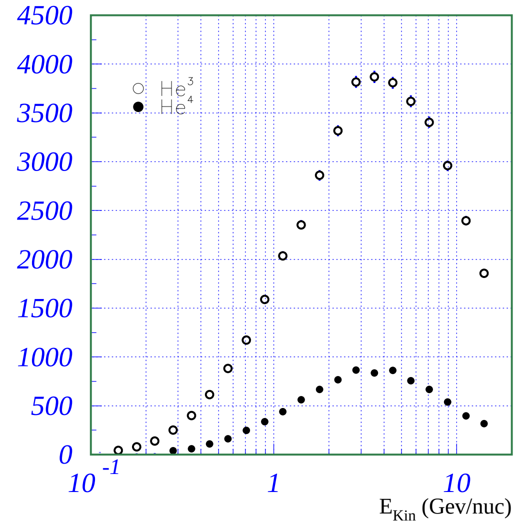


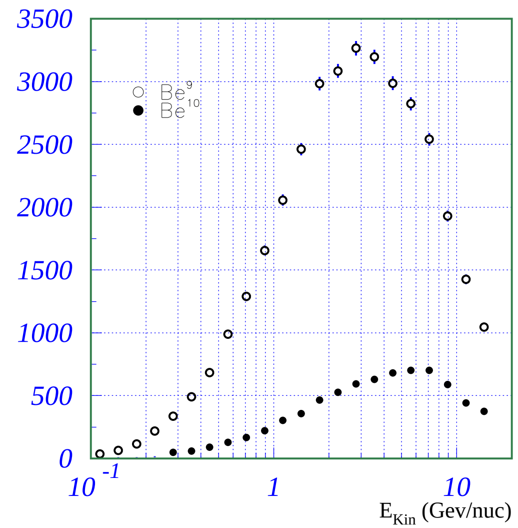
- The fraction of particles impinging on the NaF area (**30** cm square) and being reconstructed ($N_{hits} > 2$) depends strongly on the charge

NaF efficiency reaches 100% for Berylliums

Simulation of helium and beryllium nuclei

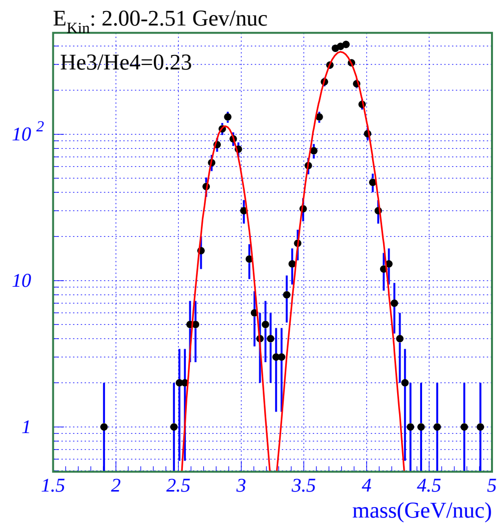
- A statistics of ${}^{3}\boldsymbol{He} \sim \mathbf{85 \times 10^3}$ and ${}^{4}\boldsymbol{He} \sim \mathbf{421 \times 10^3}$ nuclei, were simulated through the RICH
  6 hours of data taking
- A statistics of ${}^{10}\boldsymbol{Be} \sim \mathbf{75 \times 10^3}$ and ${}^{9}\boldsymbol{Be} \sim \mathbf{349 \times 10^3}$ nuclei, were simulated through the RICH
  6 months of data taking
- geomagnetic field taken into account
  modulation of the nuclei energy with the ISS location
- momentum uncertainty folded

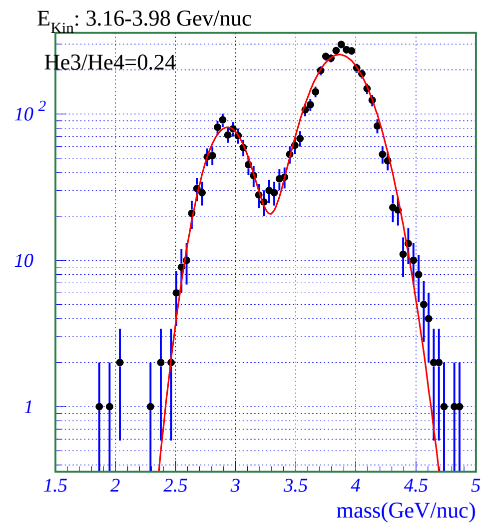




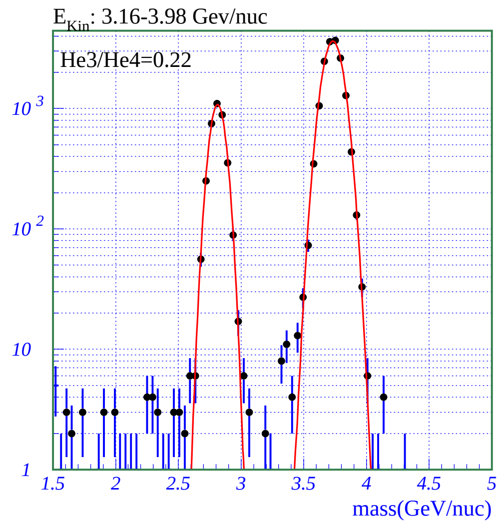
Helium isotopic separation

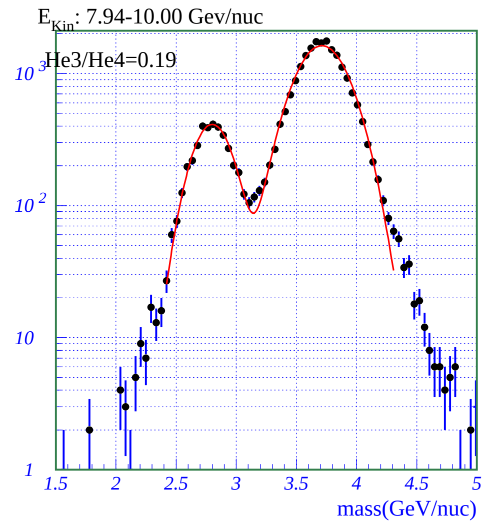
NaF



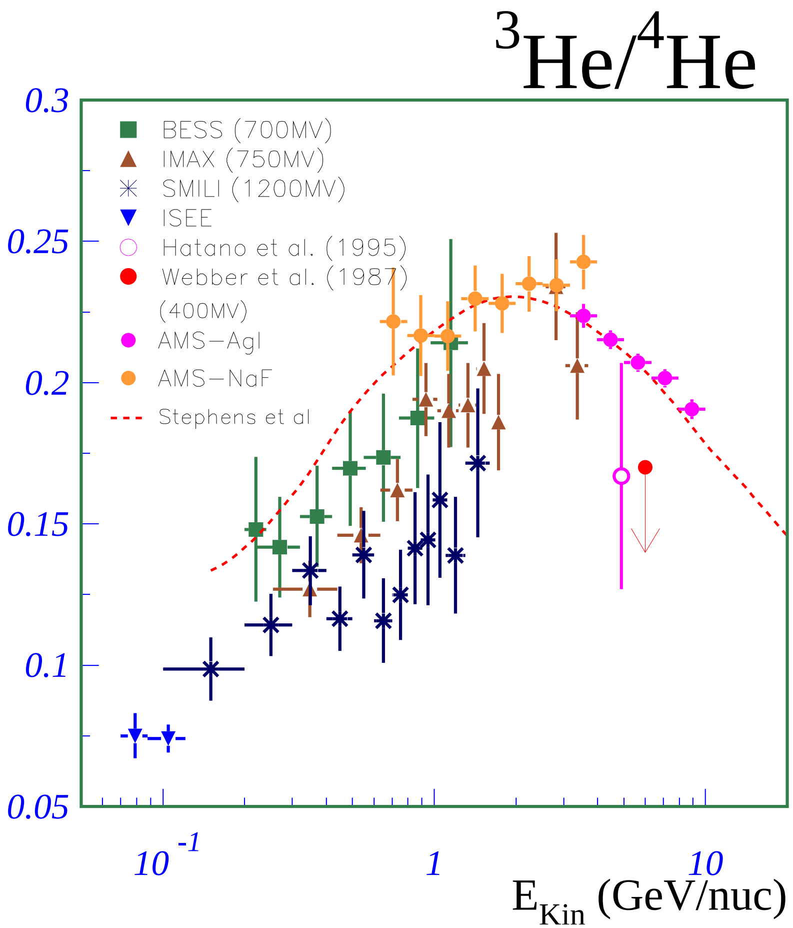


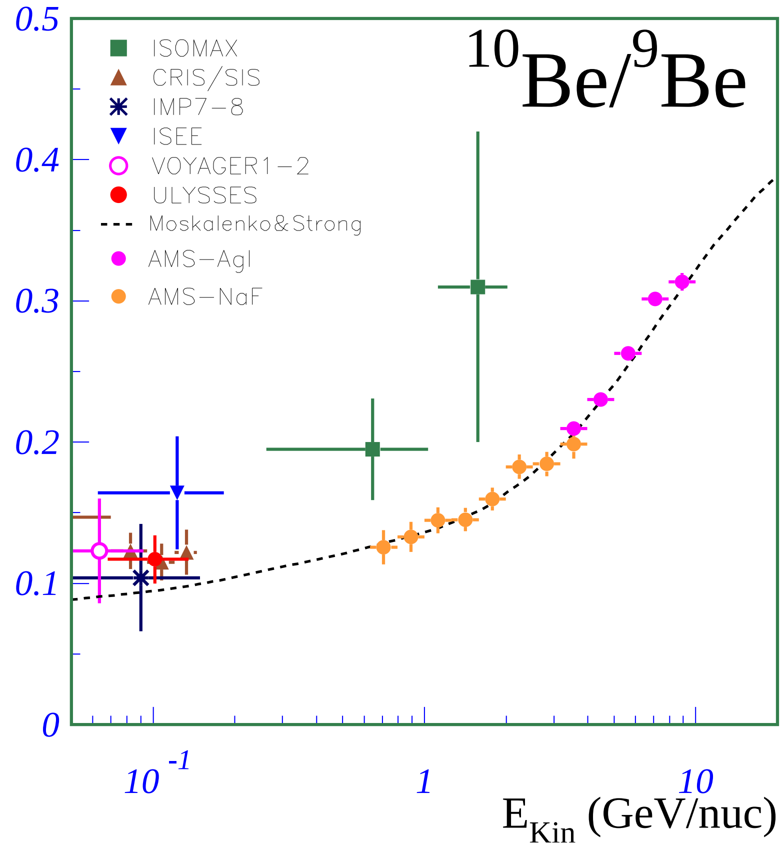
Agl30





Reconstructed isotopic ratios for He and Be





AMS data: 6 hours

AMS data: 6 months

Conclusions

- The possibility of having a mixed radiator configuration with both a large and a low refractive index radiators, was studied
- Aerogel radiator shows low event geometrical acceptances for particles impinging close to the radiator center
- The placement of a NaF radiator at the center of the radiator plane ($\mathbf{30 \times 30}\ \boldsymbol{cm^2}$) increases substantially the number of reconstructed events (Nhits>2), when compared with aerogel
- At last (but not at least) the introduction of a NaF radiator allows AMS to cover the complete spectrum of helium and beryllium isotopic measurements from $\mathbf{0.1}\ \boldsymbol{GeV/nuc}$ up to around $\mathbf{10}\ \boldsymbol{GeV/nuc}$