Particle identification with the RICH detector

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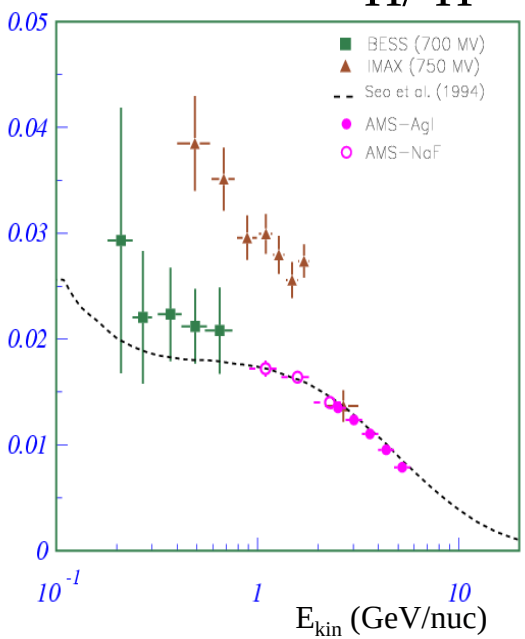
Outline

- Physics with the RICH detector
- Mass separation
- Monte Carlo samples
- Data analysis
  - Preliminary cuts
  - Pre-selection of events
  - RICH selection
  - Acceptance vs. energy
  - Mass resolution
- Conclusions

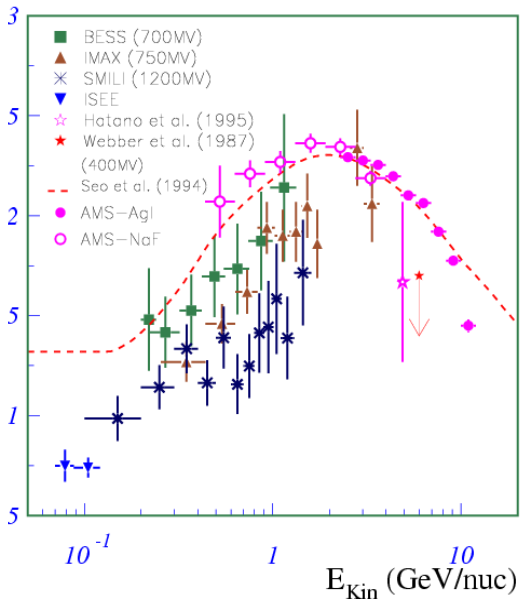
Physics with the RICH detector

- One of the main physics goals of AMS is the isotopic mass separation: $^{2}H/^{1}H$, $^{3}He/^{4}He$, $^{10}Be/^{9}Be$.
- It relies on an good β measurement (TOF, RICH) and momentum measurement (Silicon Tracker)

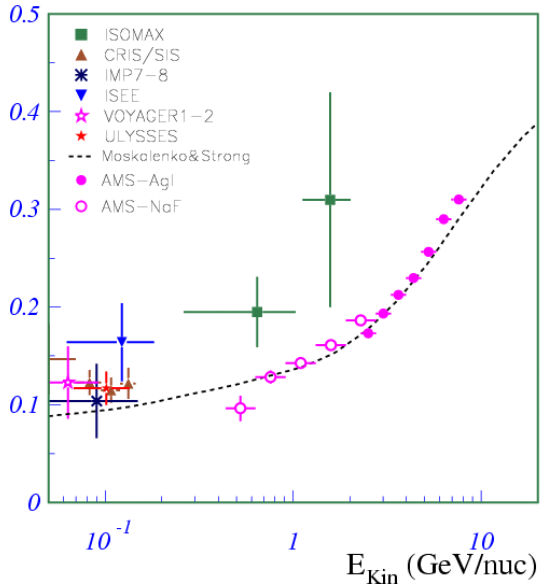
$^{2}H/^{1}H$



$^{3}He/^{4}He$



$^{10}Be/^{9}Be$

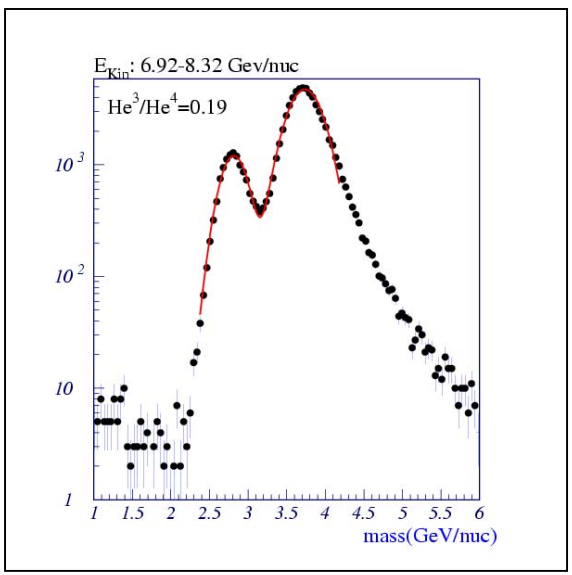


Mass separation: how it looks ...

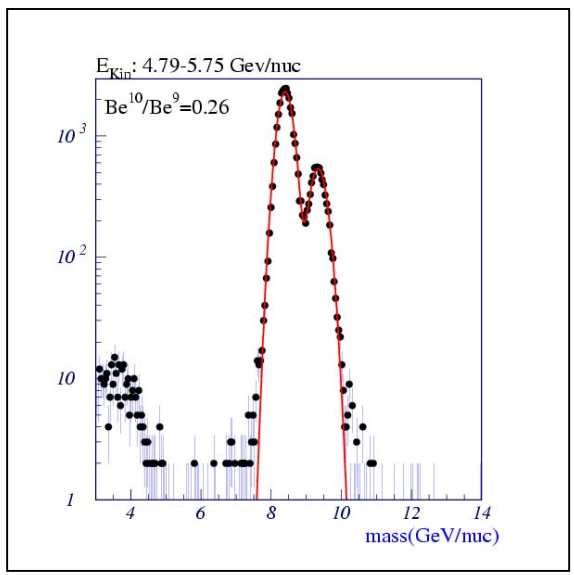
$$\frac{\Delta m}{m} = \frac{\Delta p}{p} \oplus \gamma^2 \frac{\Delta \beta}{\beta}$$

Aerogel

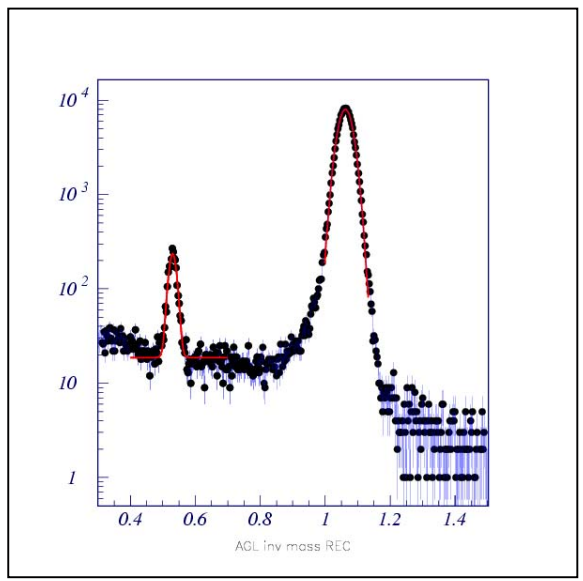
^{3}He, ^{4}He



^{10}Be, ^{9}Be



^{2}H, ^{1}H



AMS full simulation

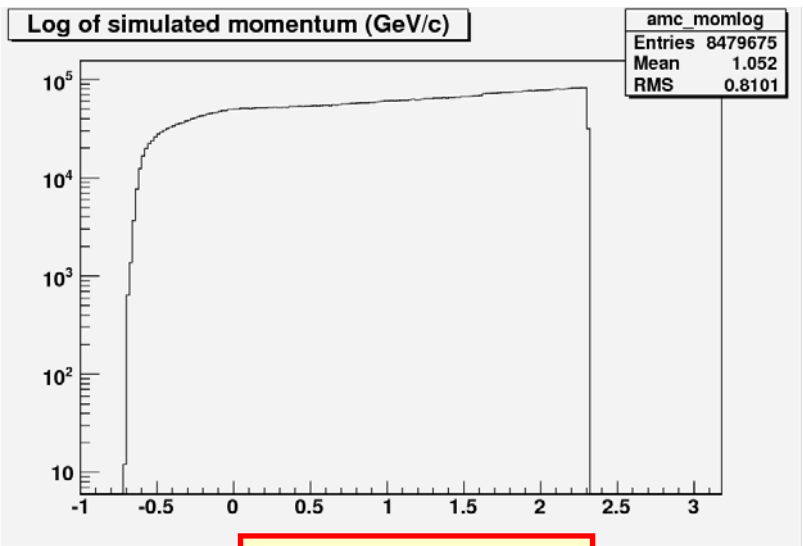
- The purpose of this preliminary study is to evaluate the capability of mass isotopic separation with AMS
  - Full AMS simulation used
  - Preliminary analysis: ongoing studies...

Analysis procedure

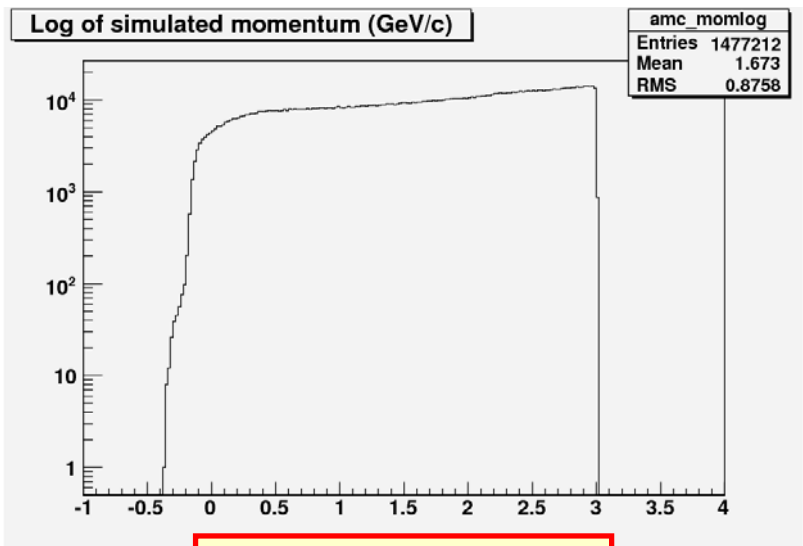
- Establish a set of wide pre-selection cuts
- RICH specific cuts
- Evaluate mass separation capability
- Future: TOF cuts

D/p separation: Monte Carlo samples

- Two separate samples: protons and deuterons
- Particles from 3.9 m cube, top plane
- p = 0.5-10 GeV/c/nucleon (log spectrum)
- Statistics after trigger (level 1):
  - *protons: 8.5 x 10^6 events*
  - *deuterons: 1.5 x 10^6 events*



proton sample



deuteron sample

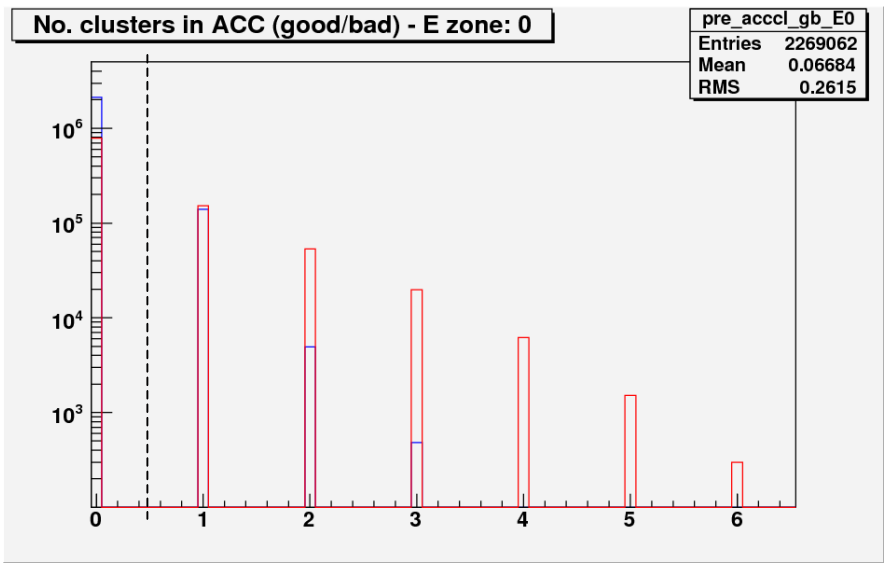
Pre-selection cuts: overview

- Preliminary selection:
  - Exactly one particle detected in event
  - Track exists

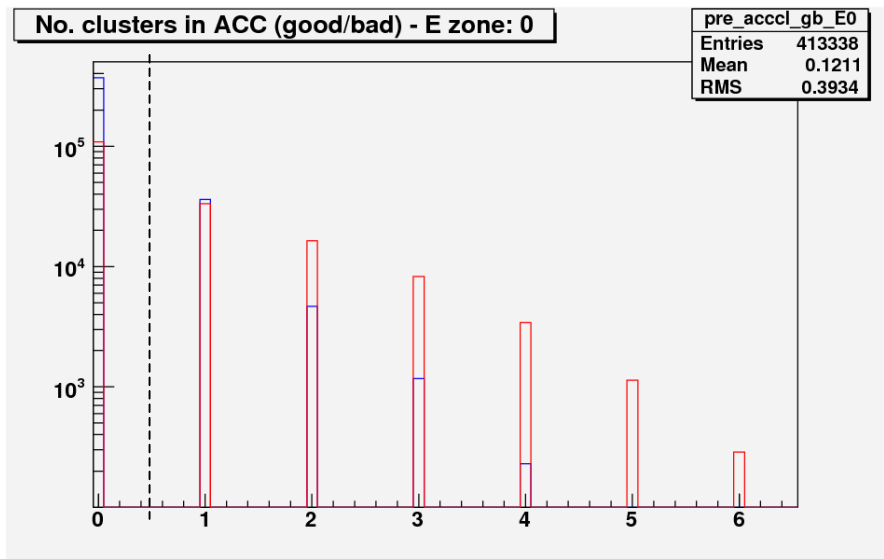
- Number of clusters in ACC
- Number of planes used in ToF
- Number of planes in Tracker
- ToF β measurement
- Rigidity cross-check
- Rigidity χ^2

Pre-selection cuts: ACC clusters

- Number of clusters in ACC = 0
  - Only possible cut: bad events dominate from $n_{clust} = 1$



protons, all energies



deuterons, all energies

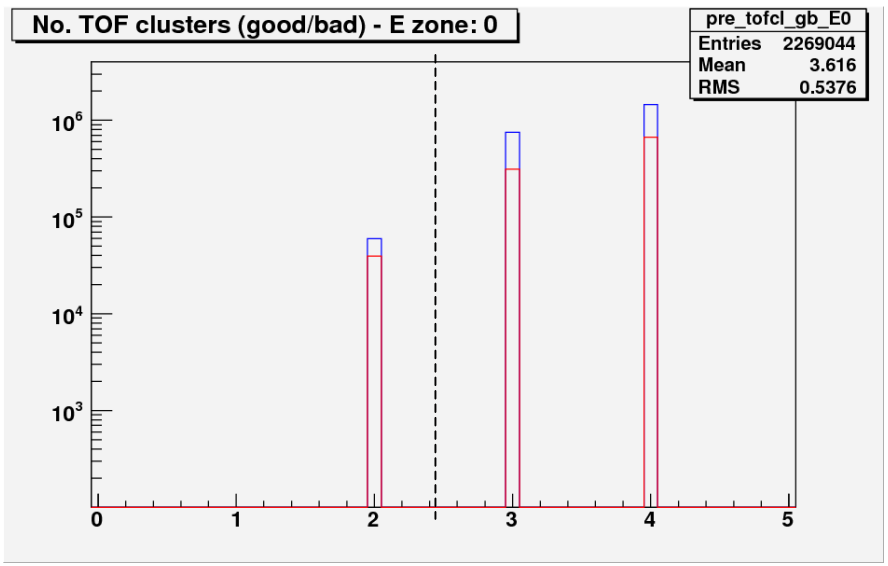
blue: good

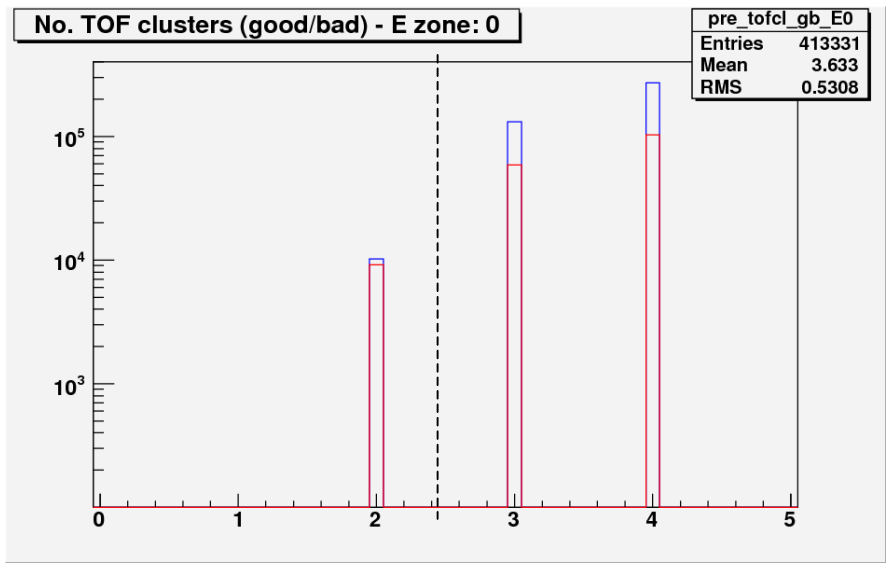
red: bad

good means <3% error in rigidity

Pre-selection cuts: ToF planes

- Minimum of 3 ToF planes used for β measurement
  - *Events with 2 planes have clearly lower quality*
  - *No significant difference between 3 and 4 planes*





protons, all energies

deuterons, all energies

blue: good

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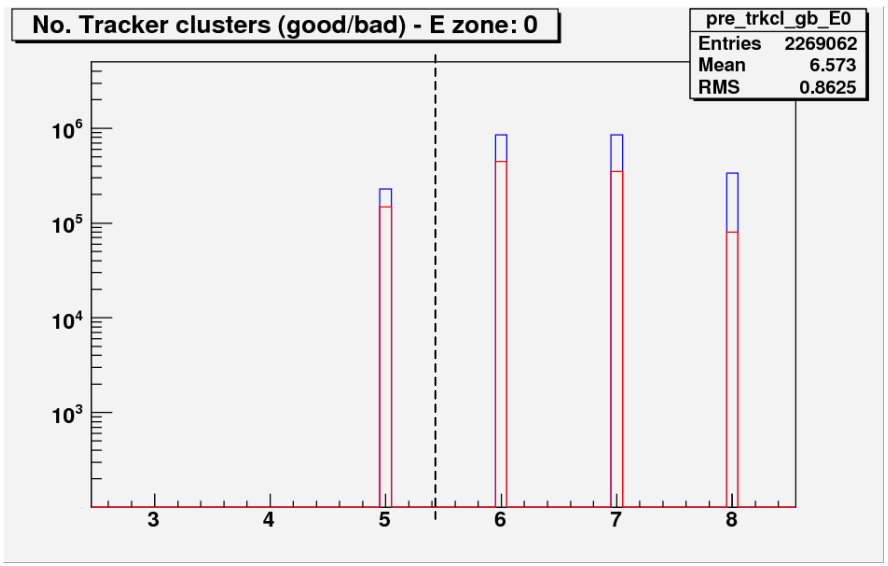
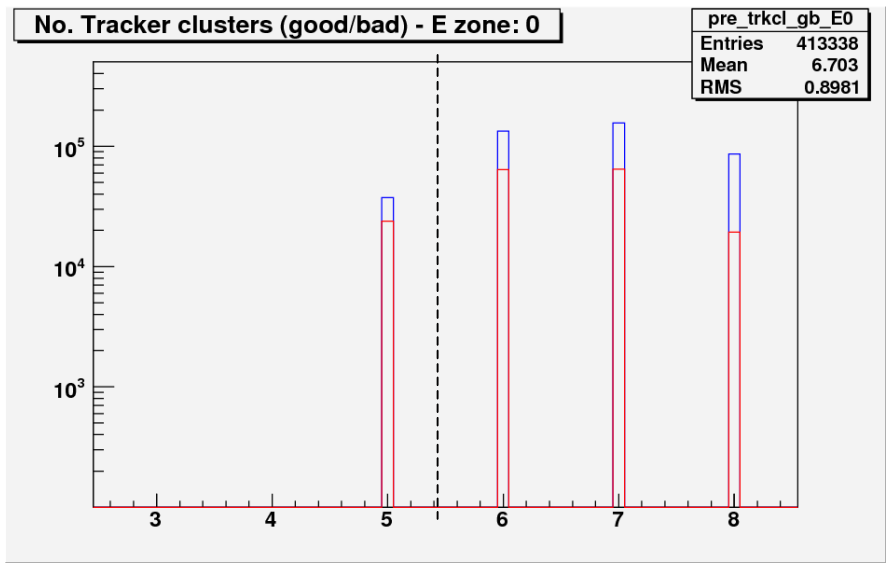
good means <3% error in rigidity

Pre-selection cuts: Tracker planes

- Minimum of 6 Tracker planes used for rigidity measurement
  - *Greater fraction of bad events with only 5 planes*





protons, all energies

deuterons, all energies

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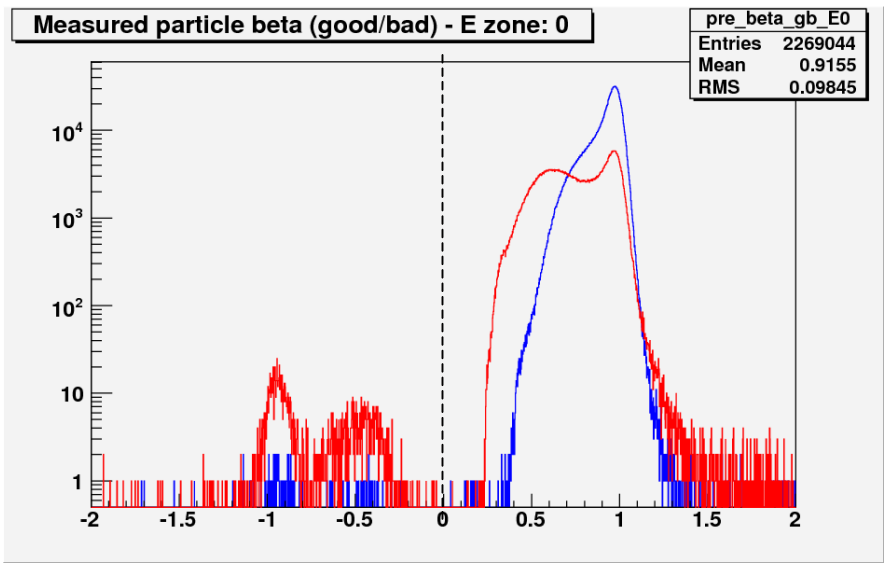
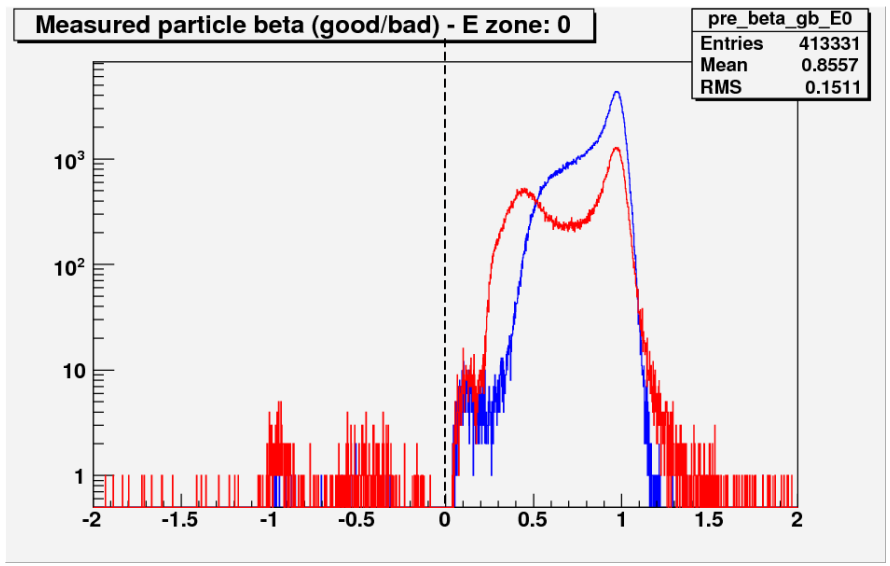
good means <3% error in rigidity

Pre-selection cuts: ToF β measurement

- β was measured with a positive value
- Only a few bad events are excluded with this cut



protons, all energies



deuterons, all energies

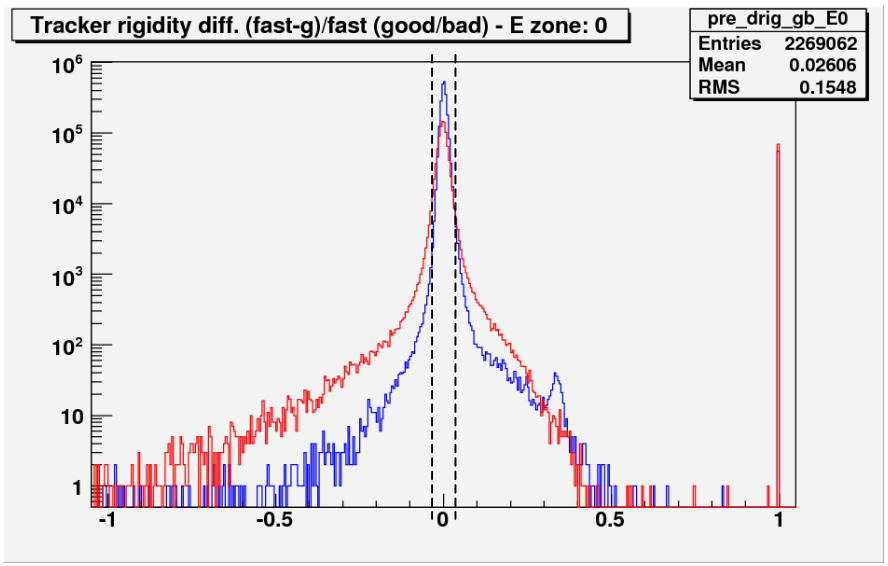
blue: good

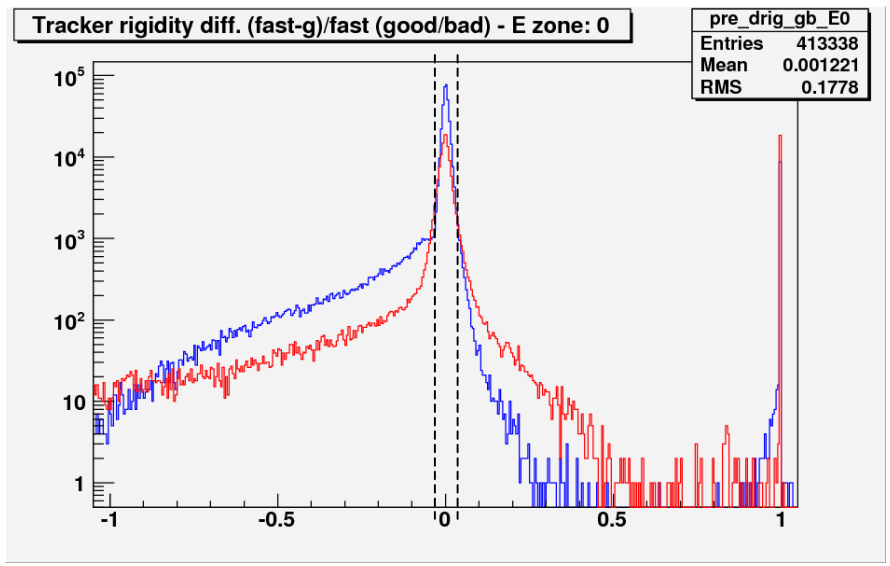
red: bad

good means <3% error in rigidity

Pre-selection cuts: rigidity

- Compatibility in rigidity measurements: "fast" measurement and "geane" measurement differ by less than 3 percent
- More significant tails in deuteron sample





protons, all energies

blue: good

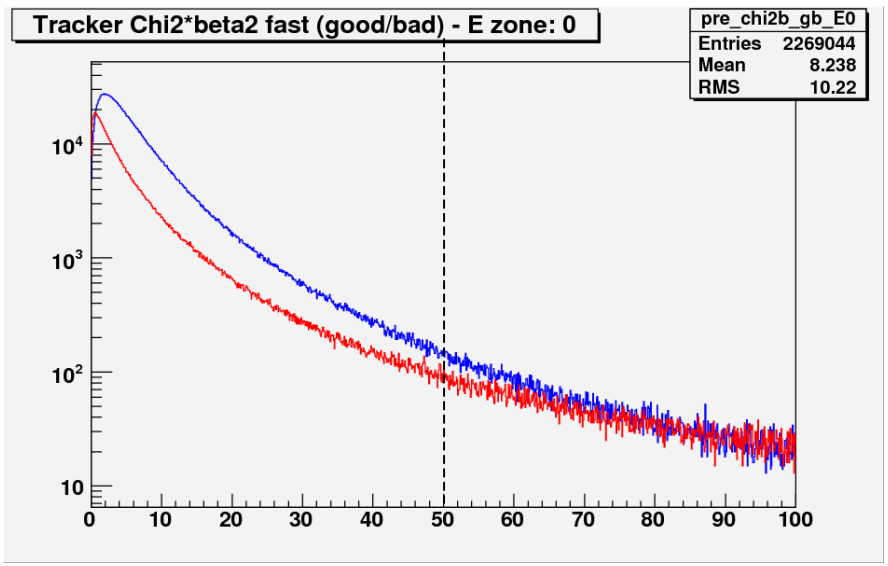
red: bad

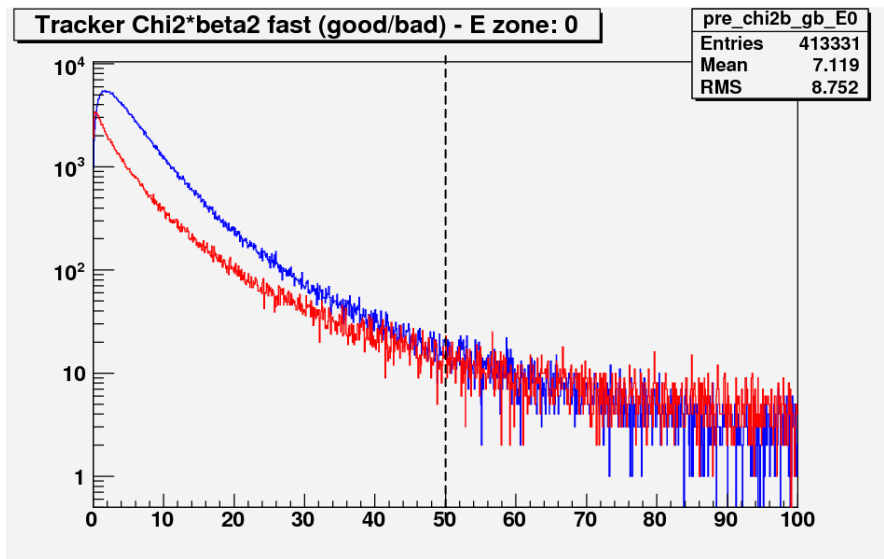
deuterons, all energies

good means <3% error in rigidity

Pre-selection cuts: rigidity χ^2

- $\chi^2 < 50$ for fast rigidity reconstruction
  - Conservative cut: deuteron sample has high fraction of bad events in the χ^2 = 30-50 region





protons, all energies

blue: good

red: bad

deuterons, all energies

good means <3% error in rigidity

Pre-selection cuts: summary

- Preliminary selection:
  - Exactly one particle detected in event
  - Track exists

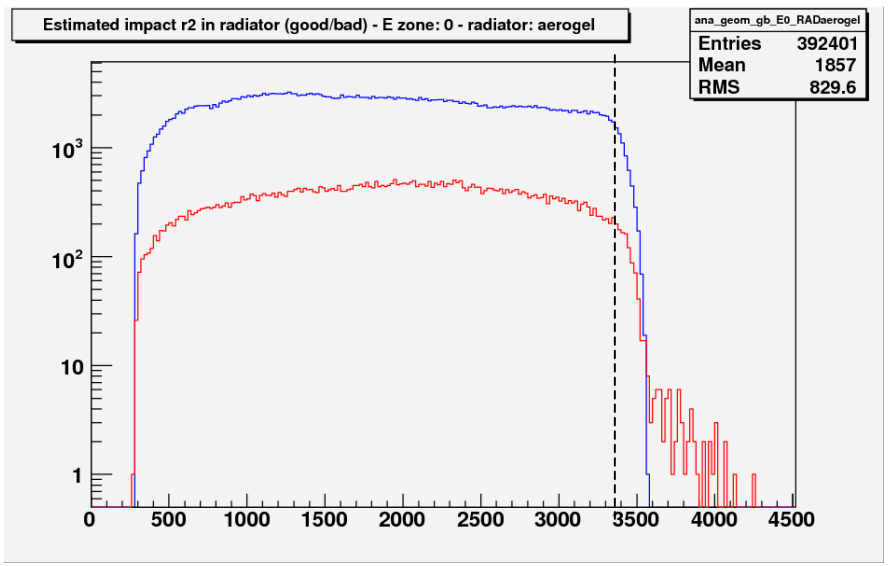
- Number of clusters in ACC = 0
- Number of planes used in ToF ≥ 3
- Number of planes in Tracker ≥ 6
- ToF β measurement > 0
- Rigidity cross-check diff. < 3%
- Rigidity $\chi^2 < 50$

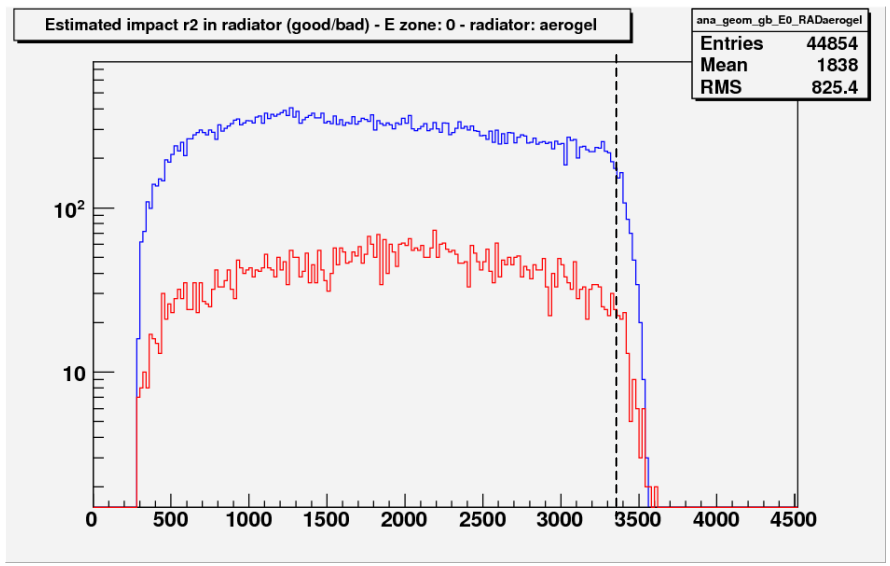
RICH selection cuts: overview

- Geometrical acceptance
- Number of hits
- Ring probability
- Ring signal
- RICH-ToF β consistency
- RICH β cross-check

RICH selection cuts: geom. acceptance

- Particle impact on radiator occurs at r < 58 cm
  - Point given by track extrapolation
  - Only relevant for aerogel (NaF is central square, r_{max} = 24 cm)





protons in aerogel, all energies

blue: good

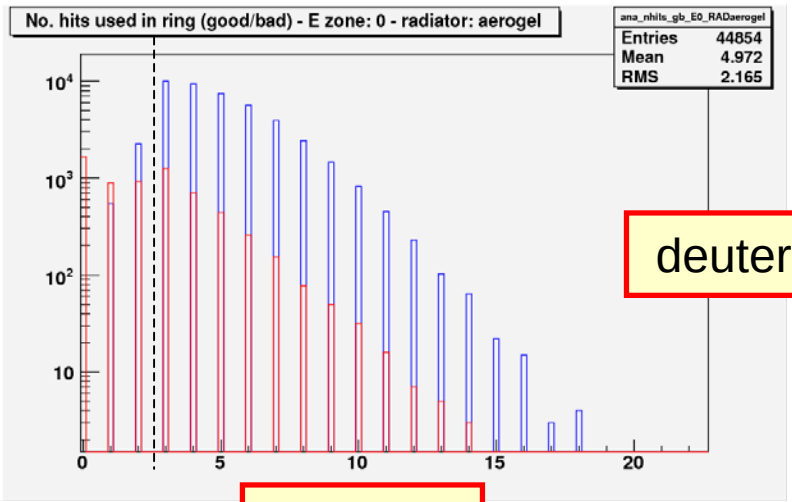
red: bad

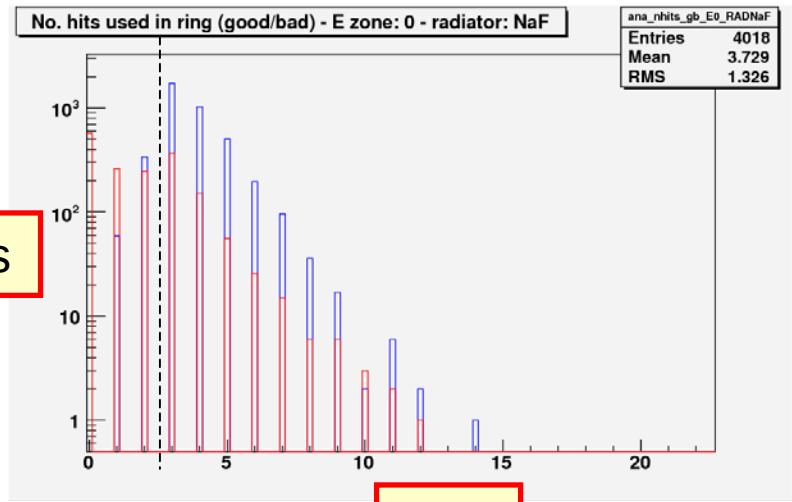
deuterons in aerogel, all energies

good means β error <1% (NaF), 0.5% (aerogel)

RICH selection cuts: number of hits

- At least 3 hits used in RICH ring reconstruction

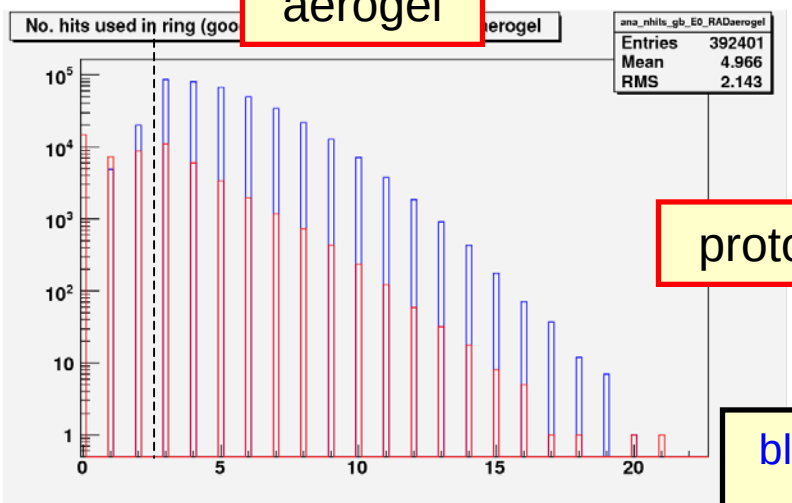


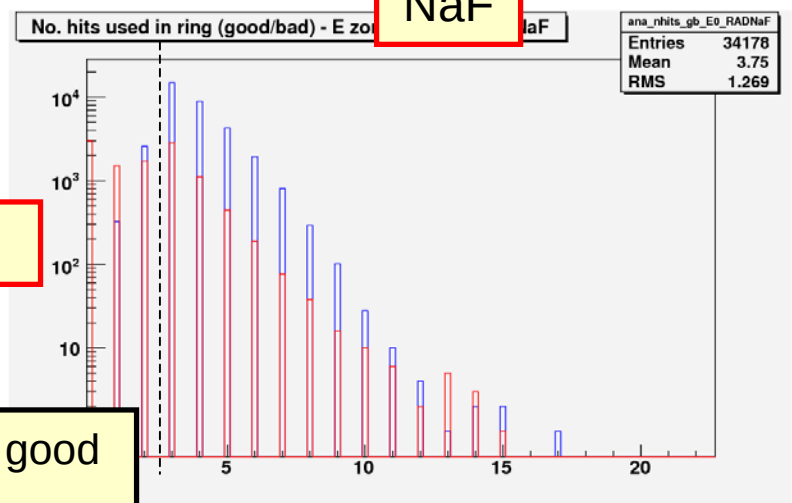


deuterons

aerogel

NaF





protons

blue: good

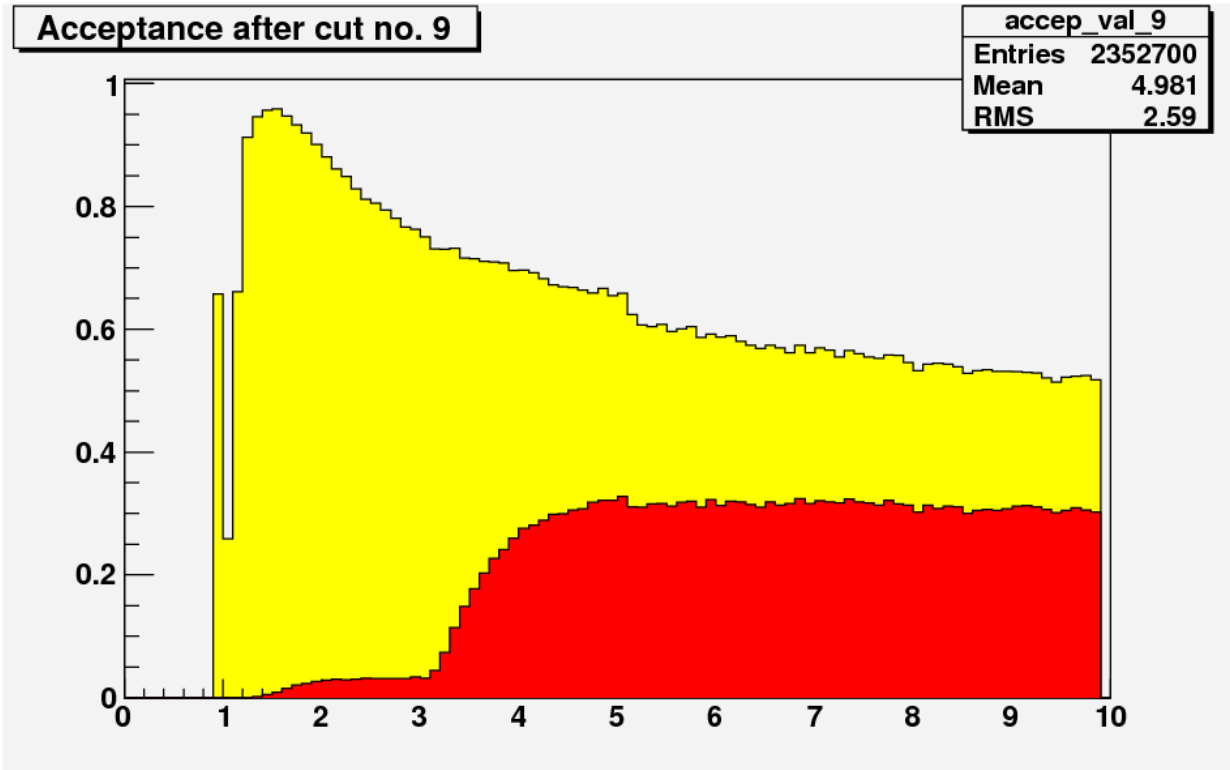
red: bad

plots show all energies combined

good means β error <1% (NaF), 0.5% (aerogel)

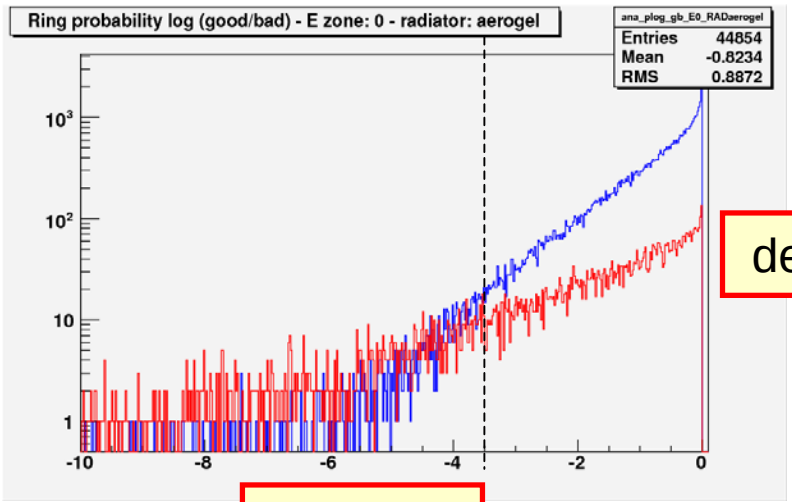
RICH acceptance

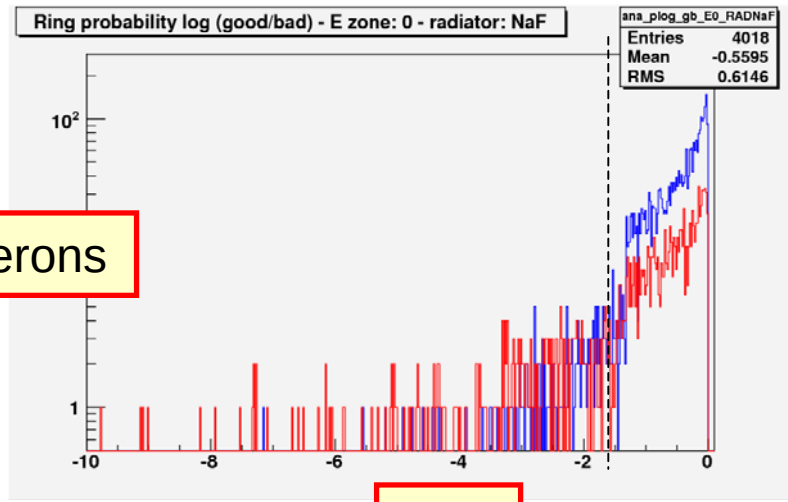
- Fiducial radiator region (58 cm)
- Cerenkov ring required



RICH selection cuts: ring probability

- Ring probability is: > 0.20 (NaF); > 0.03 (aerogel)

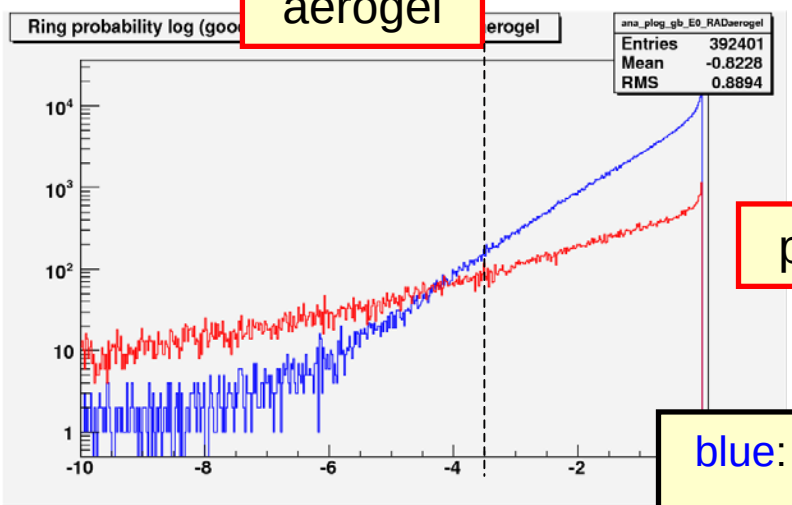


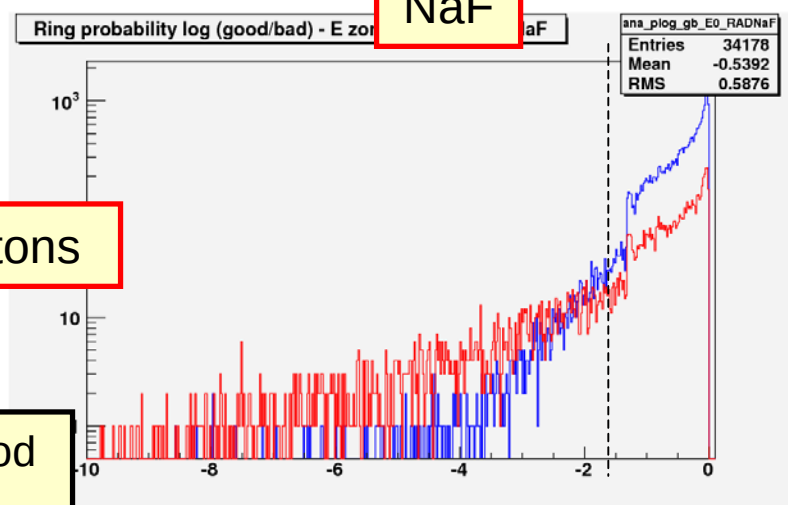


deuterons

aerogel

NaF





protons

blue: good

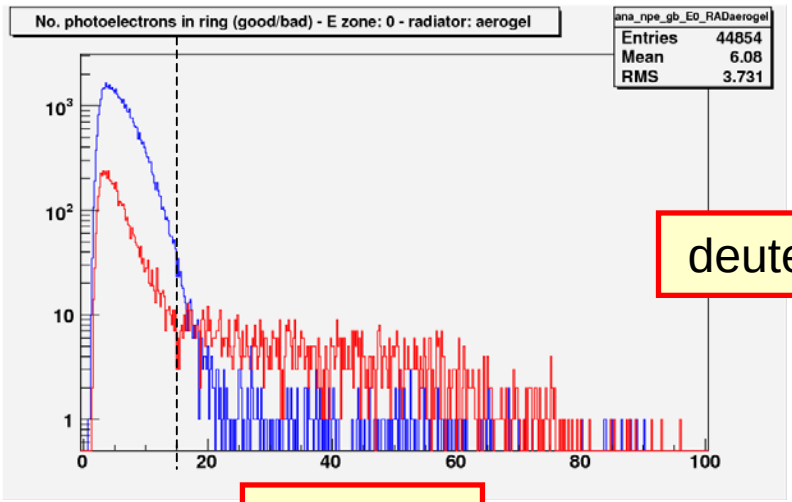
red: bad

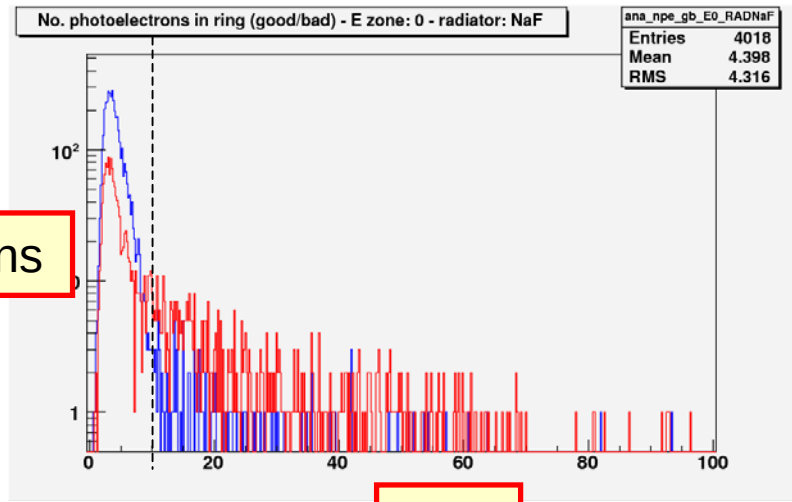
plots show all energies combined

good means β error <1% (NaF), 0.5% (aerogel)

RICH selection cuts: ring signal

- Total ring signal < 10 p.e. (NaF); < 15 p.e. (aerogel)

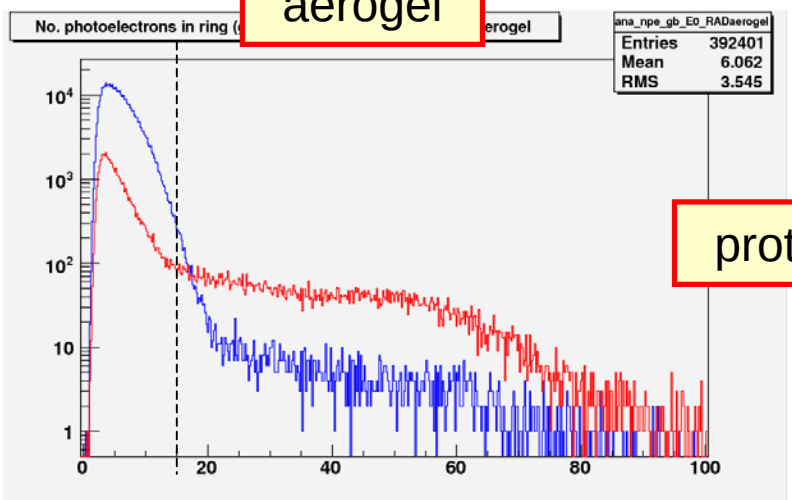


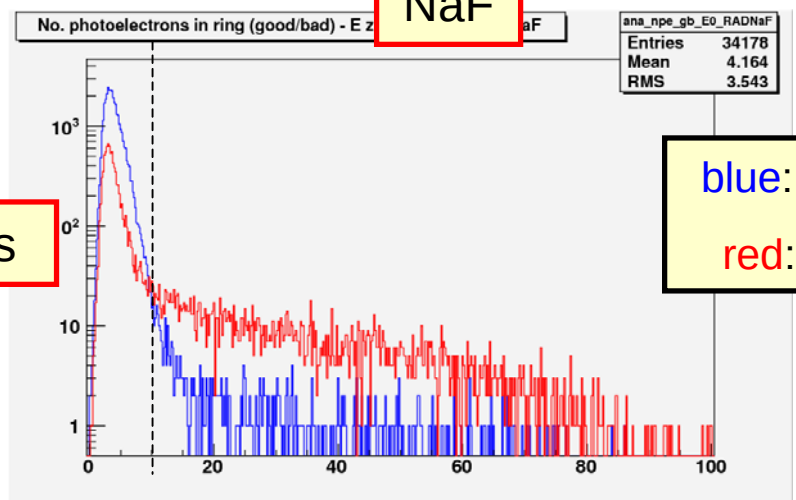


deuterons

aerogel

NaF





protons

blue: good

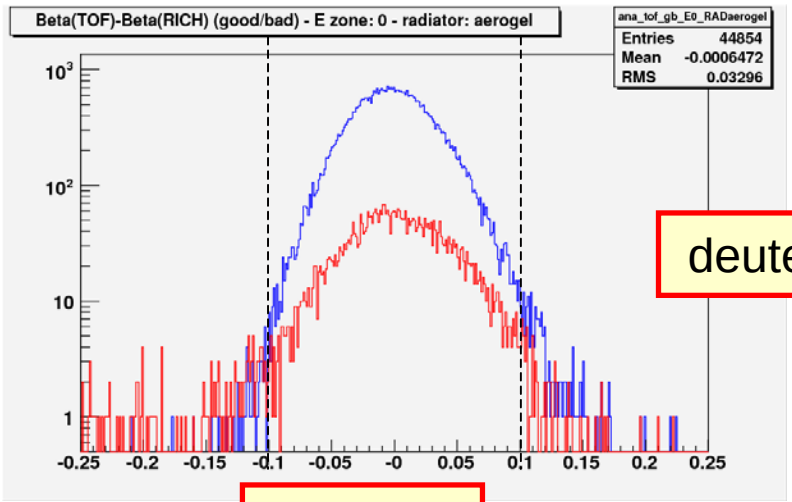
red: bad

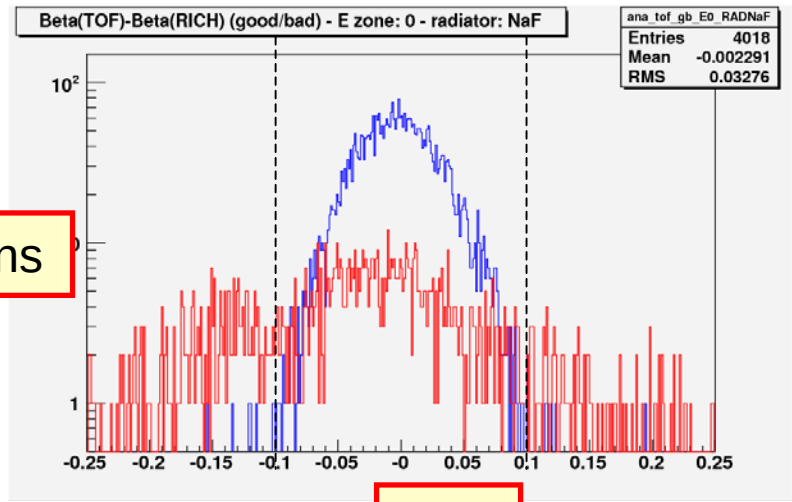
plots show all energies combined

good means β error <1% (NaF), 0.5% (aerogel)

RICH selection cuts: TOF β ckeck

- Compatibility in β: TOF-RICH difference < 10 percent

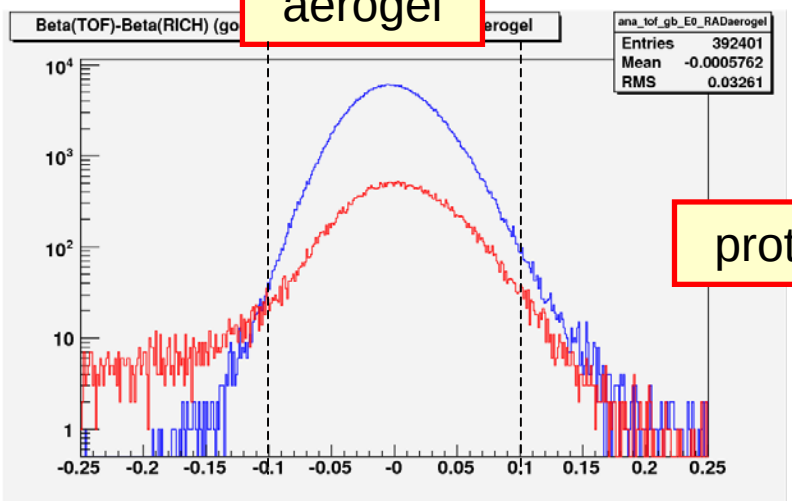


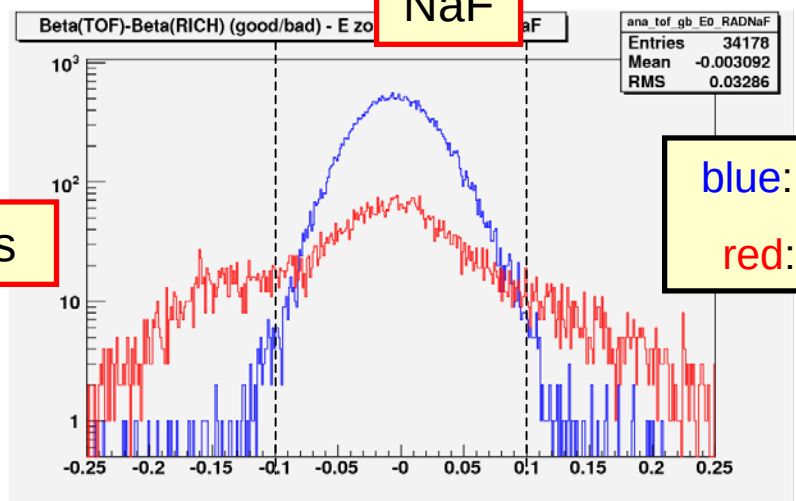


deuterons

aerogel

NaF





protons

blue: good

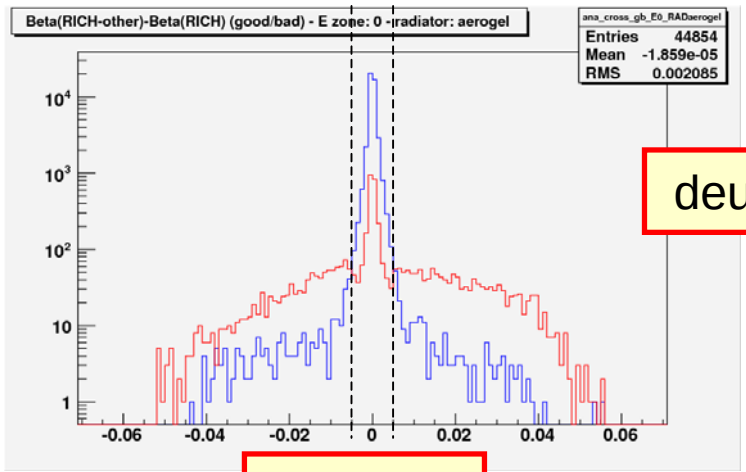
red: bad

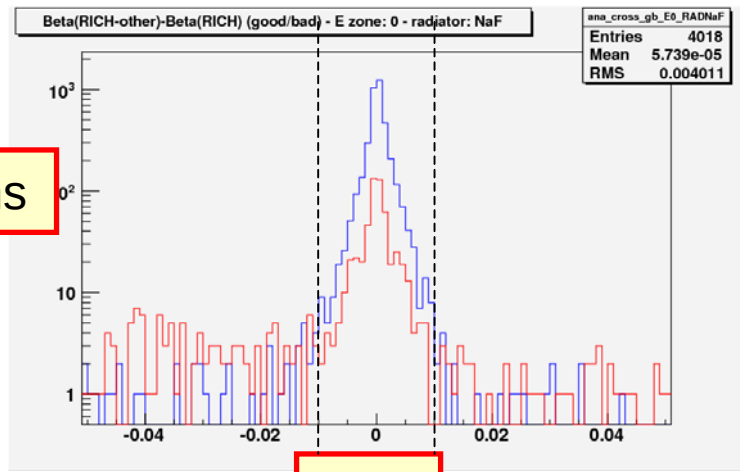
plots show all energies combined

good means β error <1% (NaF), 0.5% (aerogel)

RICH selection cuts: β cross-check

- Compatibility in RICH β: results two different methods differ by < 1 percent (NaF), < 0.5 percent (aerogel)

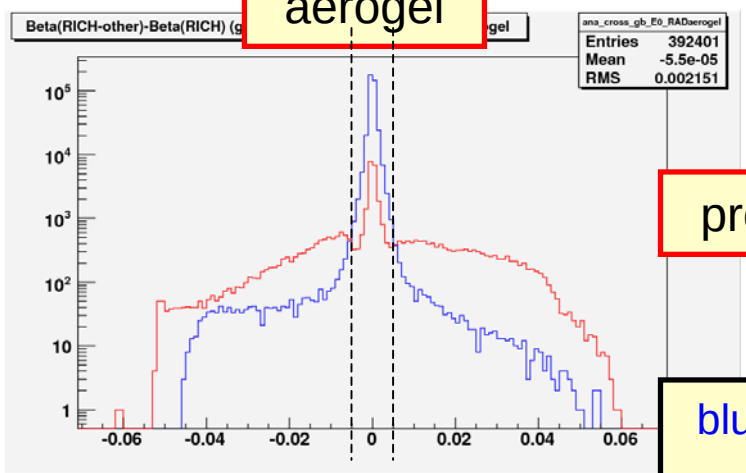


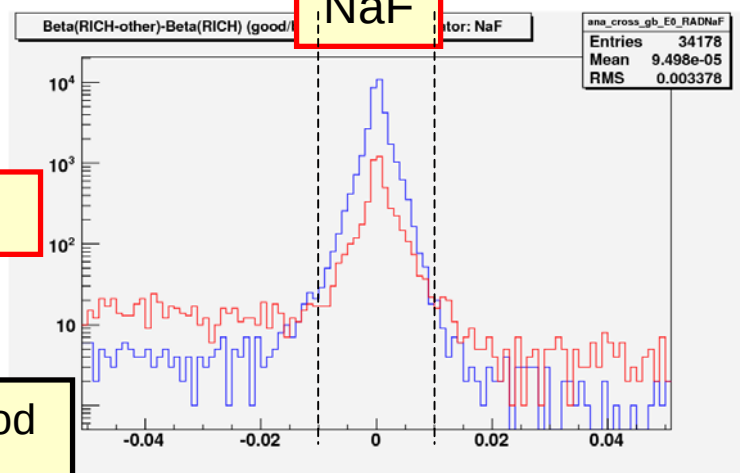


deuterons

aerogel

NaF





protons

blue: good

red: bad

plots show all energies combined

good means β error <1% (NaF), 0.5% (aerogel)

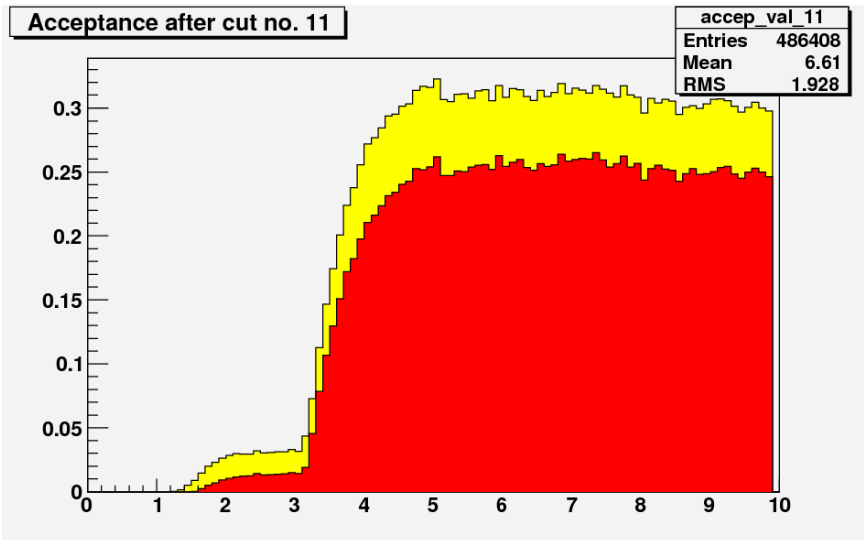
RICH selection cuts: summary

- Geometrical acceptance = 0
- Number of hits $\geq$ 3
- Ring probability $\geq$ 0.20 (NaF), $\geq$ 0.03 (aerogel)
- Ring signal < 10 p.e. (NaF), < 15 p.e. (aerogel)
- RICH-ToF β consistency diff. < 10%
- RICH β cross-check diff. < 1% (NaF), 0.5% (aerogel)

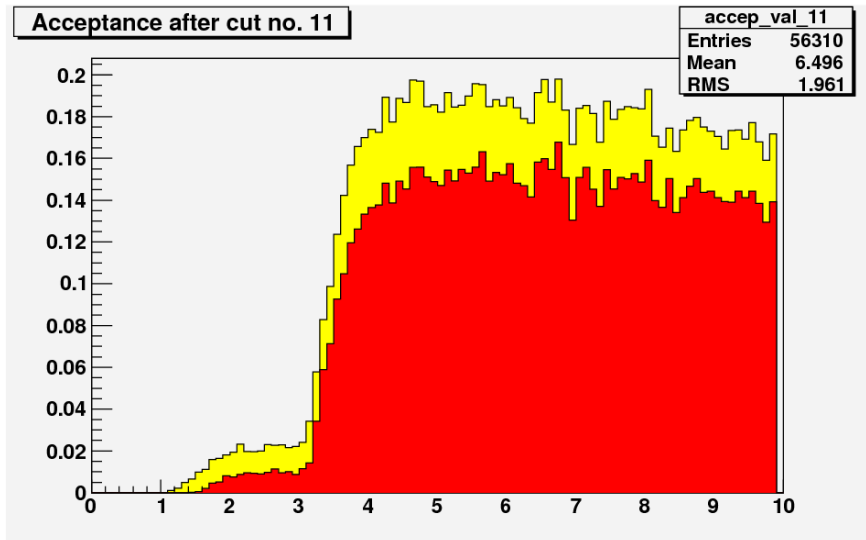
RICH selection cuts: acceptance

yellow: minimal set of cuts

red: full selection cuts



protons



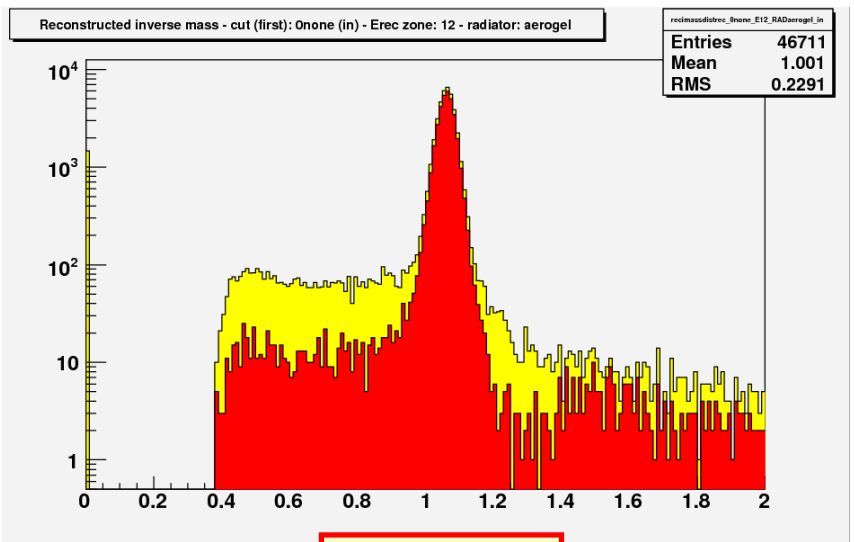
deuterons

Mass reconstruction: results (aerogel)

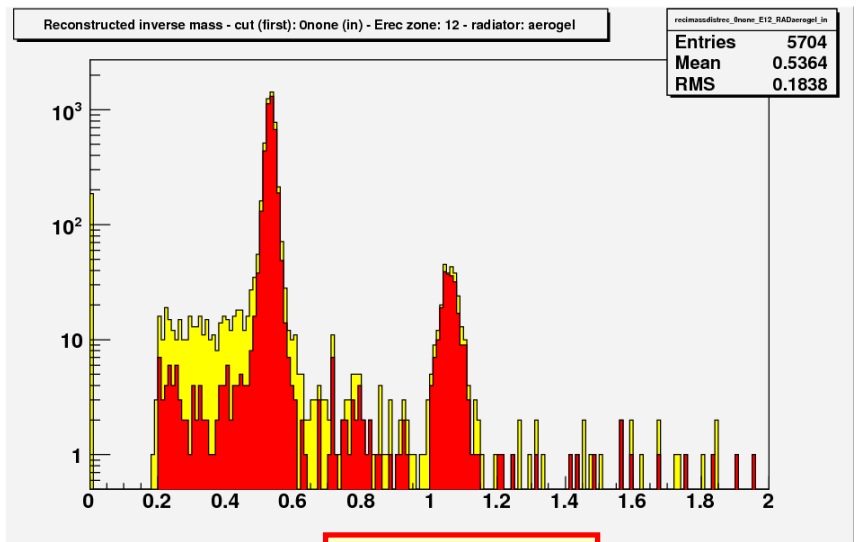
- Distributions in inverse mass
  - Significant improvement after RICH cuts (red vs. yellow)
  - Deuteron results show small proton peak (fragmentation?)

aerogel events

E_{kin} = 2.75-3.31 GeV/nuc



protons



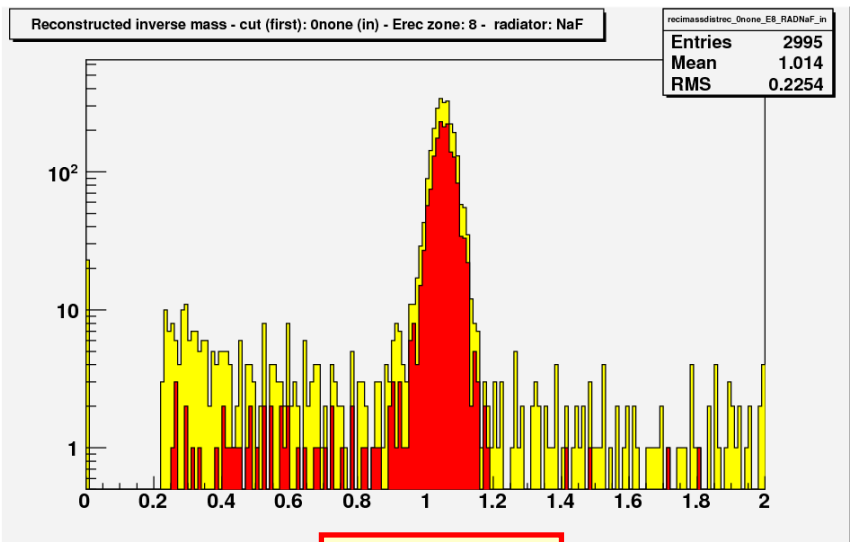
deuterons

Mass reconstruction: results (NaF)

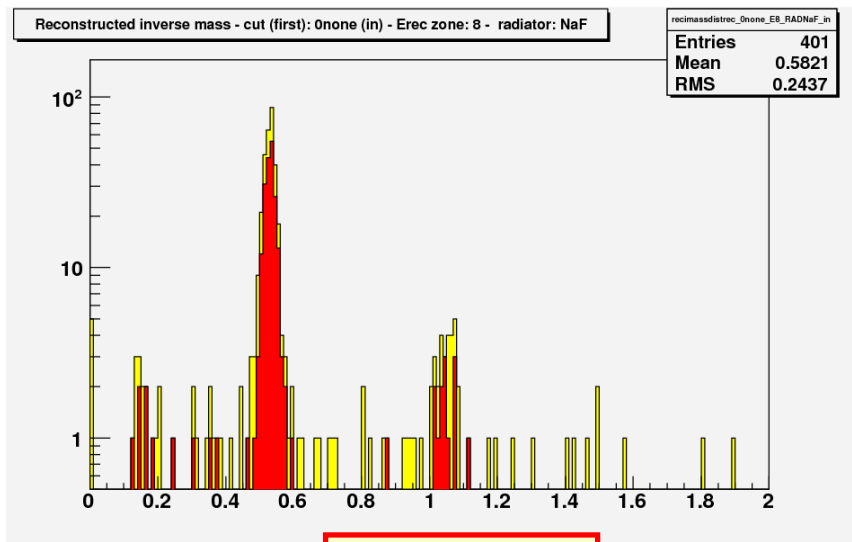
- Distributions in inverse mass
  - Again,significant improvement after RICH cuts
  - Quality of mass separation is similar to aerogel
  - Larger statistics needed for better study

NaF events

E_{kin} = 1.32-1.58 GeV/nuc



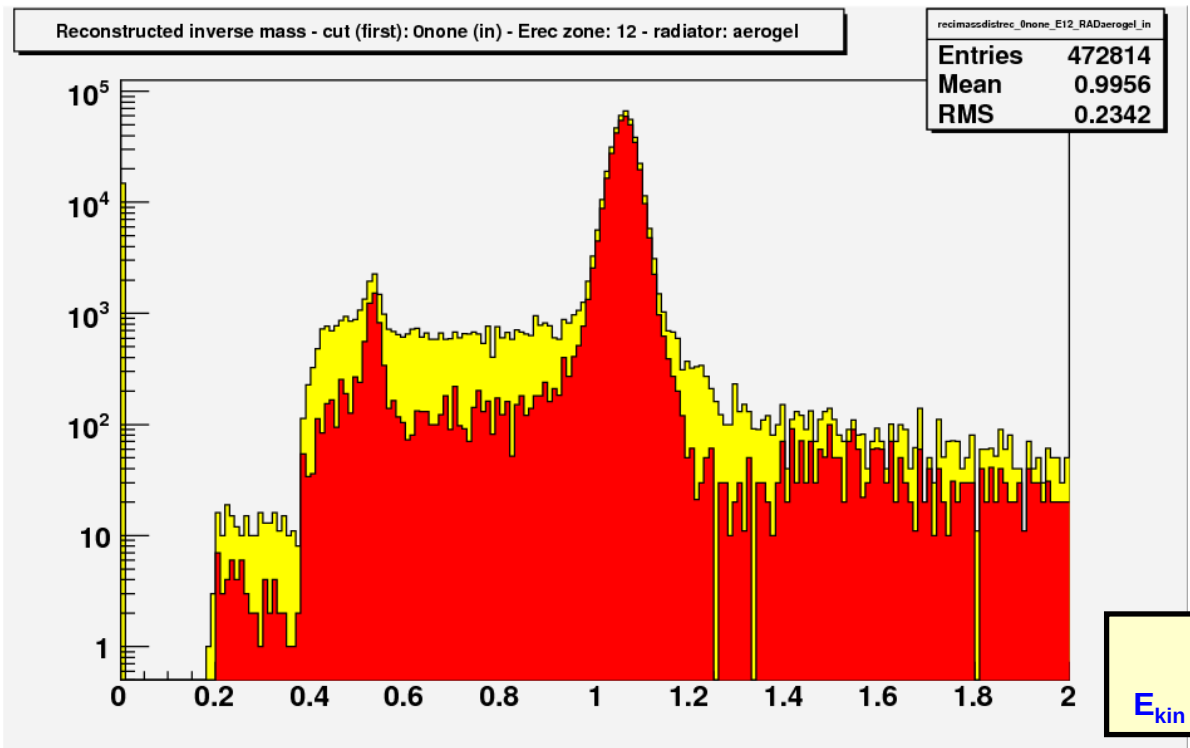
protons



deuterons

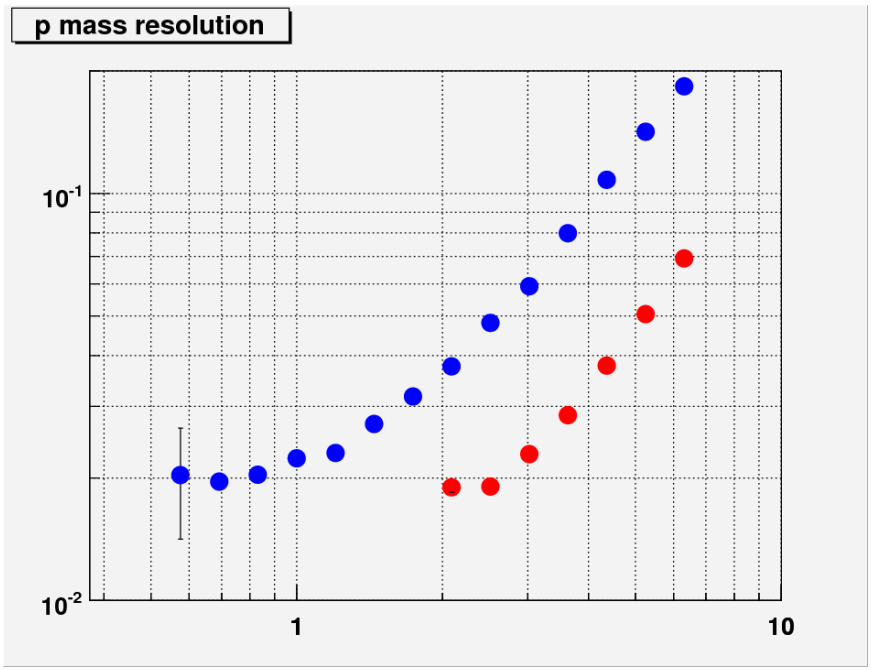
Mass reconstruction: D/p separation

- Combined D/p spectrum (aerogel sample):
  - (10 x proton) + deuteron ⇒ D/p ~ 2% (approximate ratio in CR)
  - Real proton sample 10 times bigger would have smaller statistical fluctuation
  - Deuteron peak is ~ 10 times above background

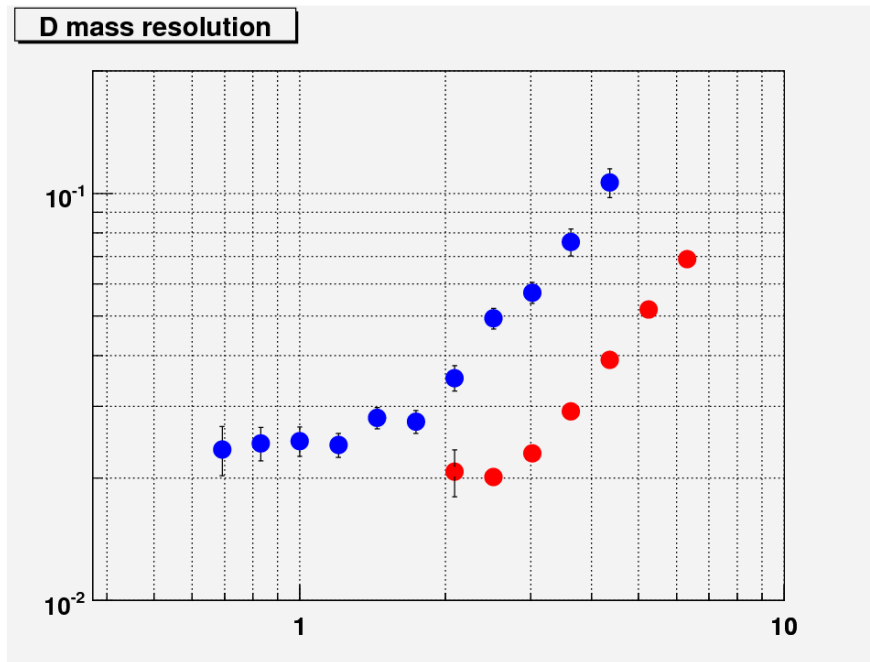


Mass resolution

- Results for protons and deuterons are consistent
- Best resolution ~2% at lower energies (< 1 GeV/n for NaF, 2-3 GeV/n for aerogel)



protons



deuterons

Conclusions (preliminary)

- The AMS RICH provides an effective way to do mass separation at energies of a few GeV/nucleon:
  - D/p separation is feasible
  - reconstruction limited by non-gaussian proton background, not by mass resolution (unlike He, Be)
  - cross-checks between detectors are useful
  - cross-check between two different methods improves quality of RICH β measurement
- Near future work
  - Higher statistics needed (especially in NaF events)
  - Analysis of other MC samples to expand proton tail data
  - Further background reduction adjustments: improvement in current cuts, possible new cuts
  - Usage of the ToF detector to improve results at lower energies
  - Study of other isotopes