Particle identification with the RICH detector: further results

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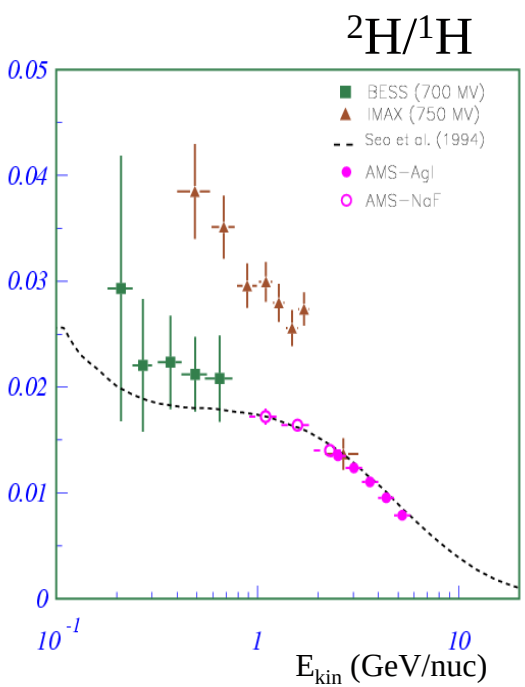
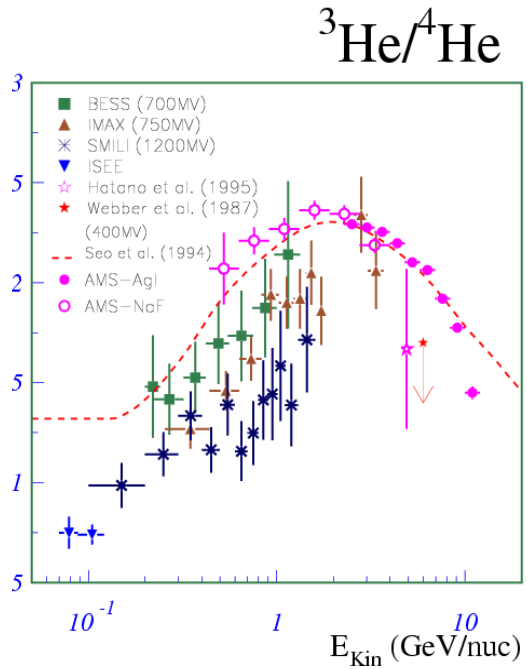
Outline

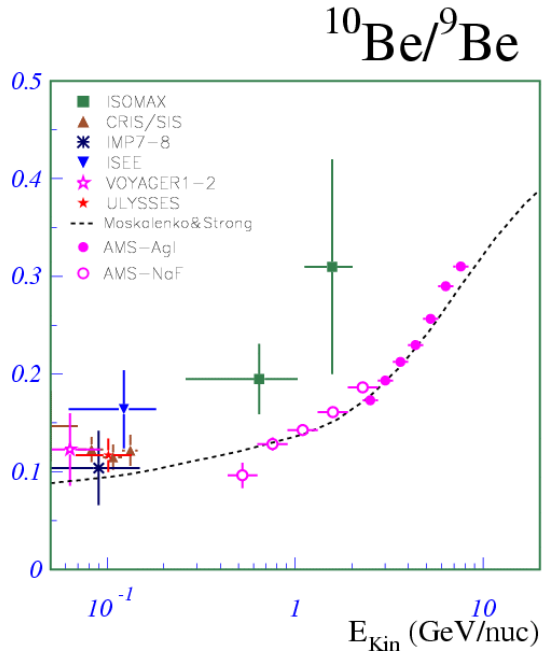
- Mass separation
- Monte Carlo samples
- Data analysis
  - Pre-selection cuts
  - RICH selection cuts
  - Geometrical acceptance
  - Mass reconstruction
  - Mass resolution
  - Rejection factor
  - Signal/background
- Conclusions

Mass separation

- 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)





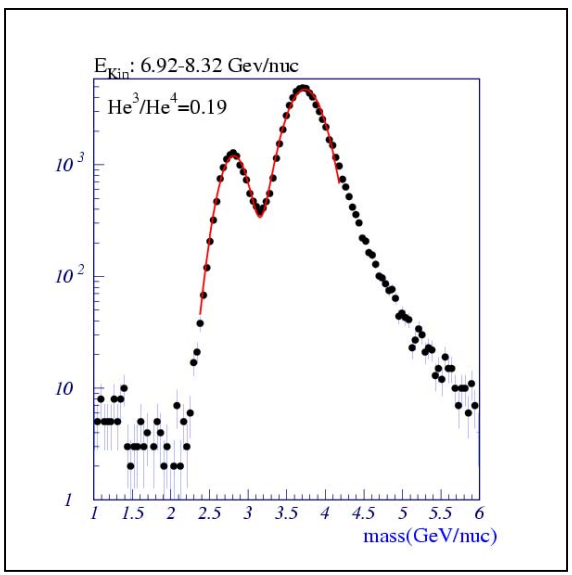


Mass separation: standalone studies

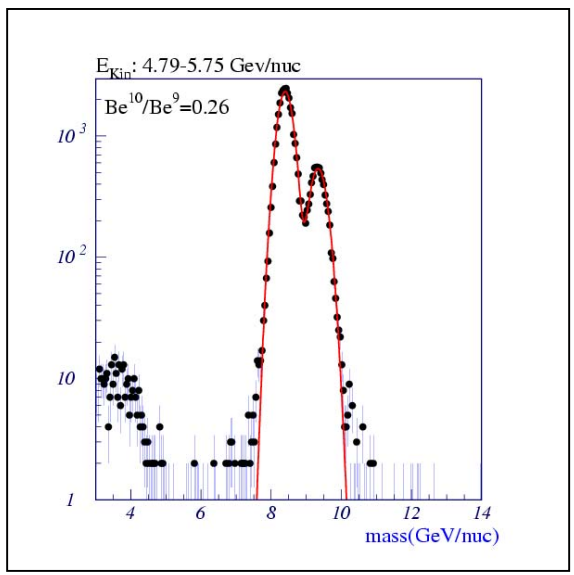
$$\frac{\Delta m}{m} = \frac{\Delta p}{p} \oplus \gamma^2 \frac{\Delta \beta}{\beta}$$

Aerogel

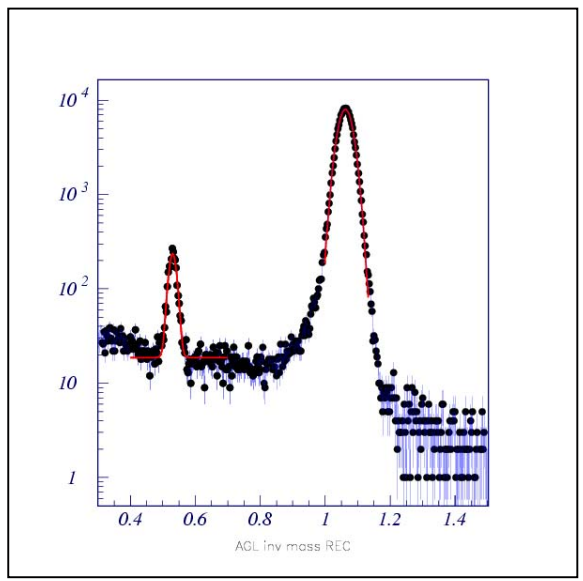
^{3}He, ^{4}He



^{10}Be, ^{9}Be



^{2}H, ^{1}H



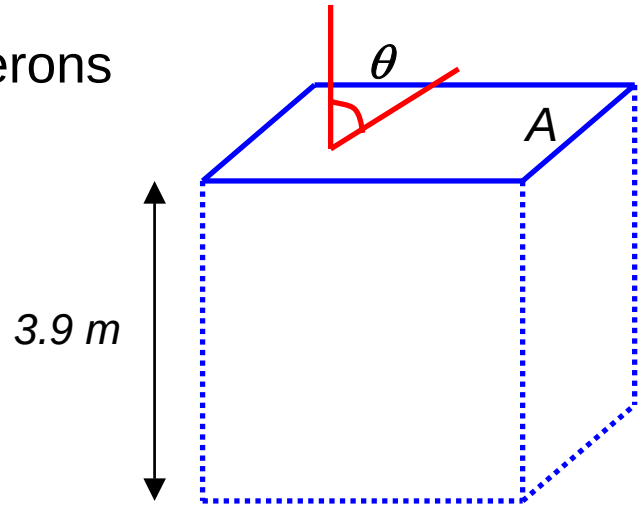
AMS full simulation

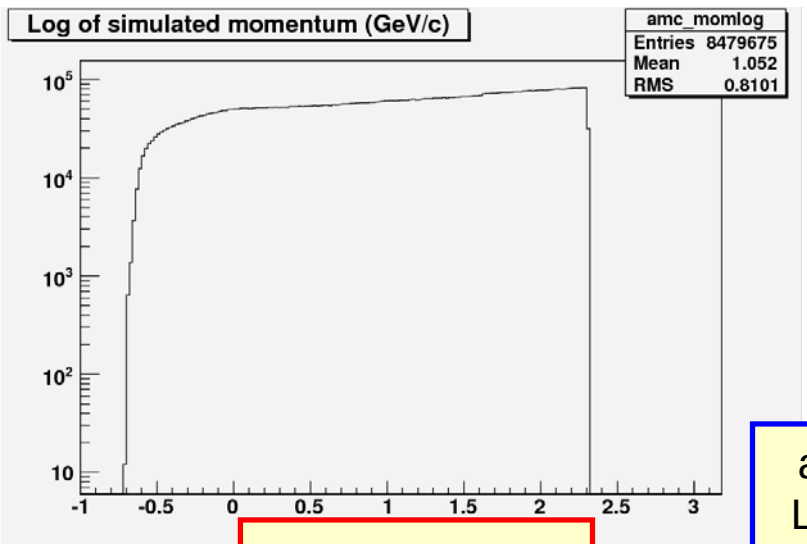
- The purpose of this preliminary study is to evaluate the capability of mass separation with AMS
  - Full AMS simulation used
  - Preliminary analysis: ongoing study

- Procedure:
  - Establish a set of wide pre-selection cuts
  - Study and optimize RICH specific cuts
  - Evaluate mass separation capability
  - D/p case used

D/p separation: Monte Carlo samples

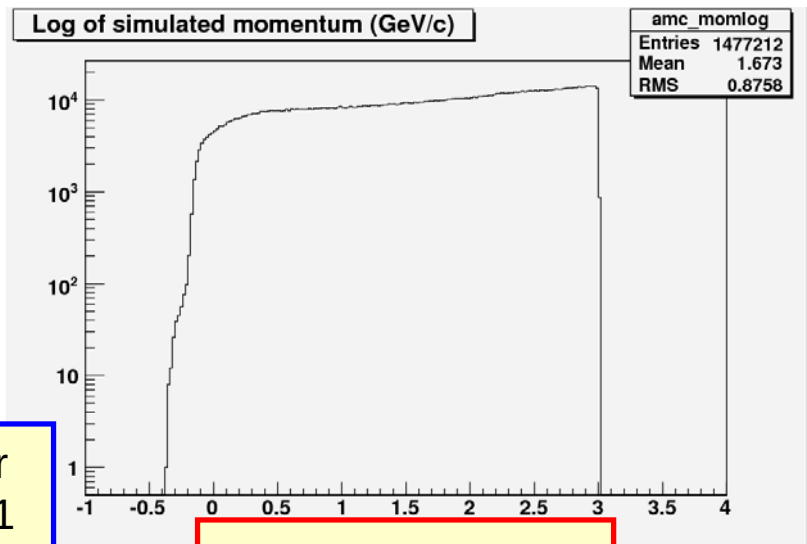
- Two separate samples: protons and deuterons
- Particles from 3.9 m cube, top plane
  - *acceptance = π A = 47.78 m^2.sr*
- Momentum range (log spectrum):
  - *protons: p = 0.5-10 GeV/c/nucleon*
  - *deuterons: p = 0.25-10 GeV/c/nucleon*





proton sample

after LVL1 trigger

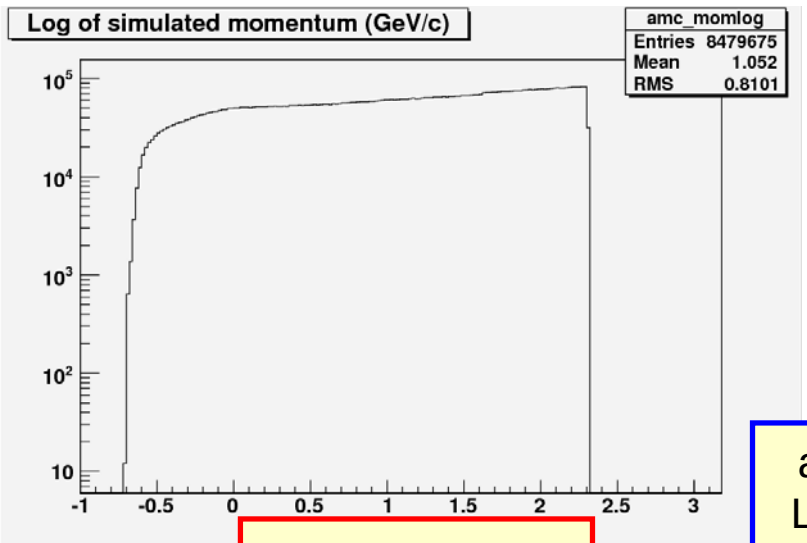


deuteron sample

D/p separation: Monte Carlo samples

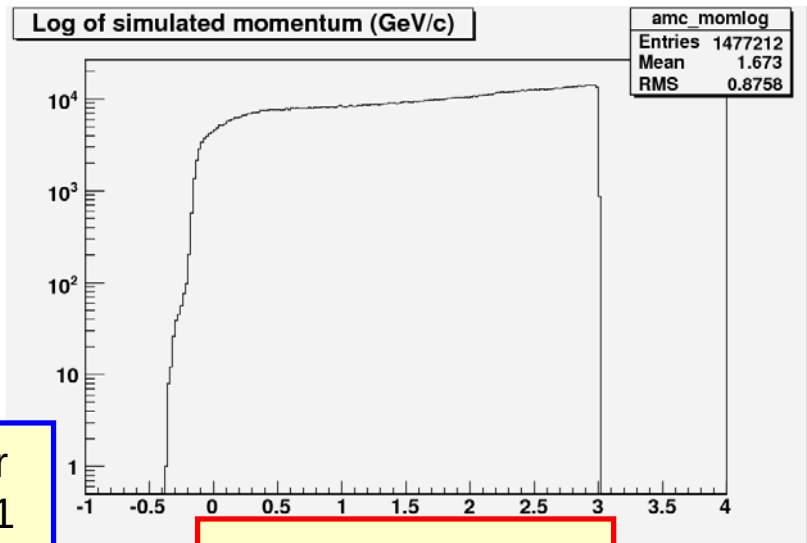
- Simulated statistics
  - *protons: 3.1 x 10^8 events*
  - *deuterons: 5.6 x 10^7 events*

- Statistics crossing AMS, including LVL1 trigger:
  - *protons: 8.5 x 10^6 events (2.75%)*
  - *deuterons: 1.5 x 10^6 events (2.65%)*



proton sample

after LVL1 trigger



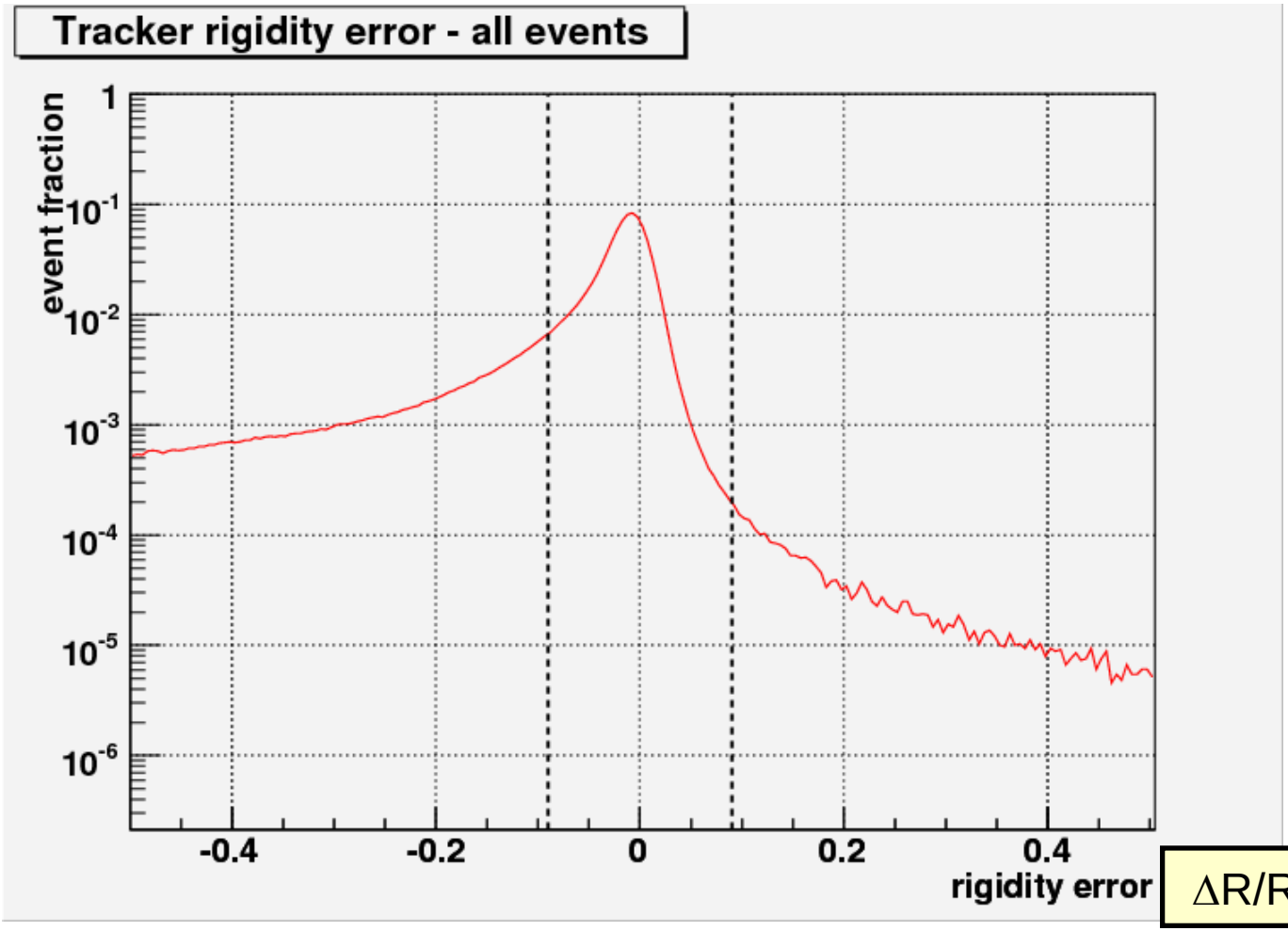
deuteron sample

Pre-selection cuts: overview

- Event:
  - One particle
  - Track exists
- ACC:
  - Number of clusters
- TRD:
  - Number of tracks
- ToF:
  - Number of planes used
  - β measurement
  - Z measurement
  - Number of extra clusters
- Tracker:
  - Number of planes used
  - Rigidity cross-check
  - Half-rigidity cross-check
  - Z measurement

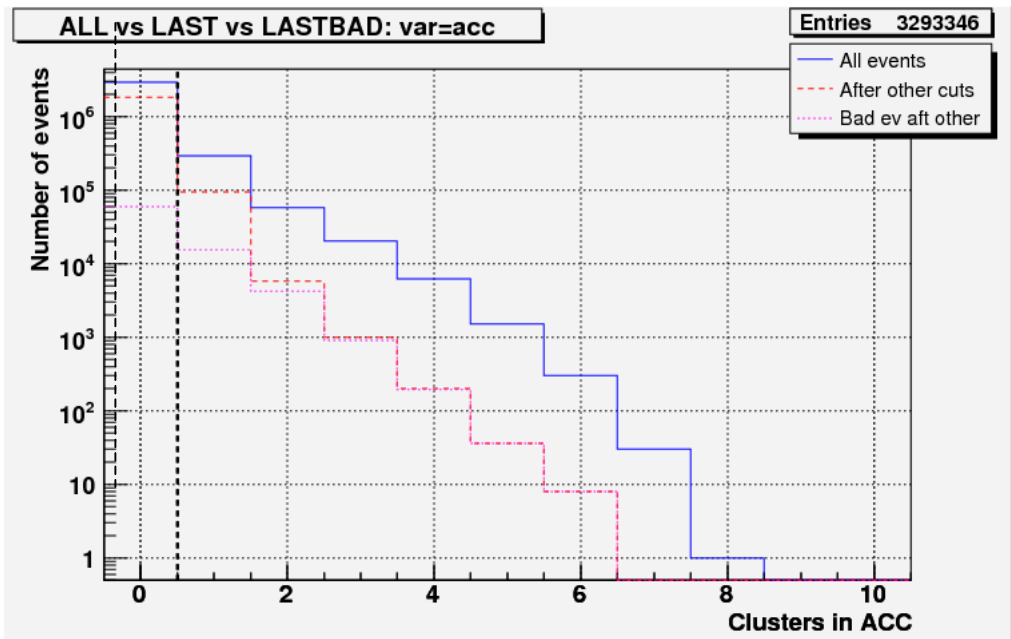
Pre-selection cuts: bad events

- Events labeled as "bad" if they have error in rigidity > 9%

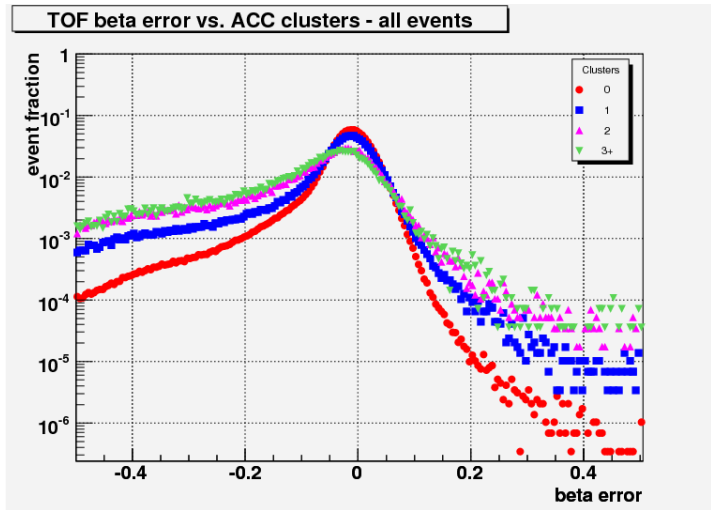


Pre-selection cuts: ACC clusters

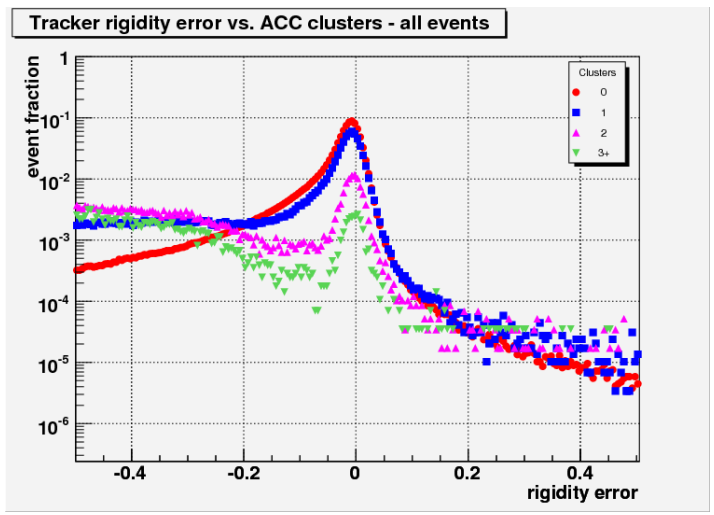
- Number of clusters in ACC = 0
  - Events with clusters clearly have lower quality



protons, all energies

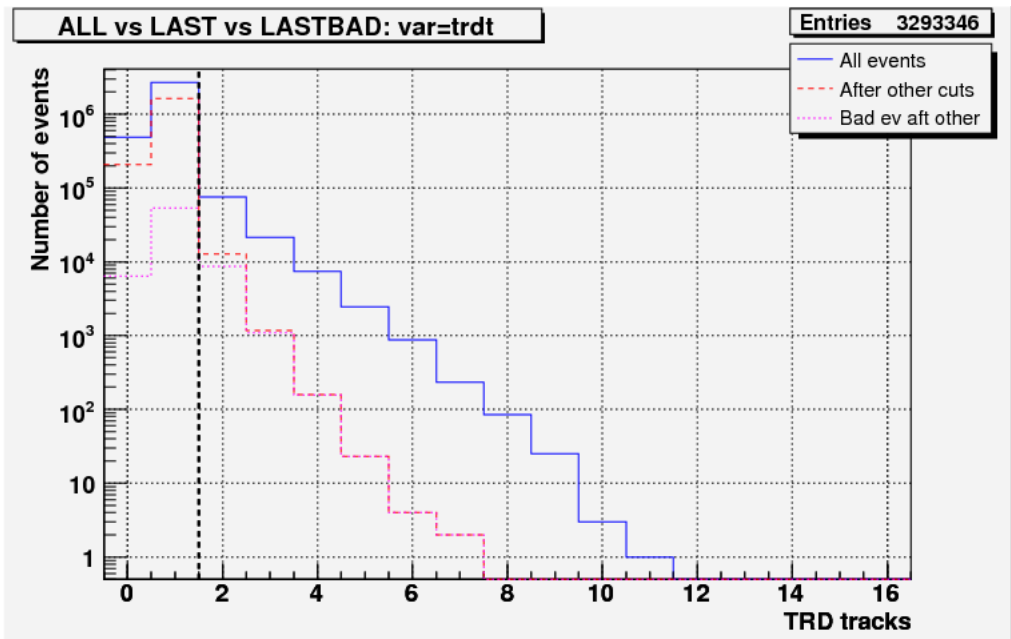


Red: 0, Blue: 1, Magenta: 2, Green: 3+

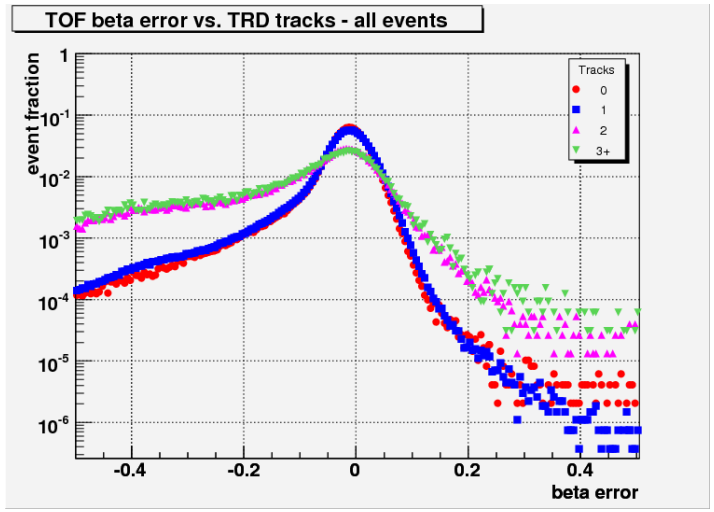


Pre-selection cuts: TRD tracks

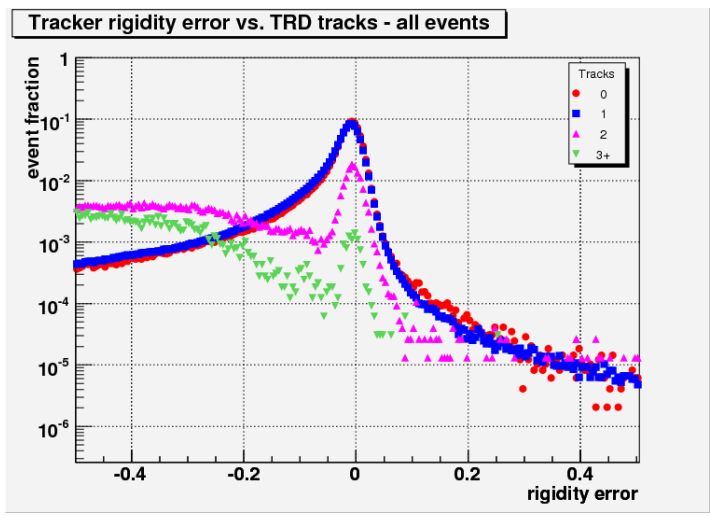
- Number of TRD tracks = 0 or 1
  - Clear transition in reconstruction quality for events with more than one track



protons, all energies

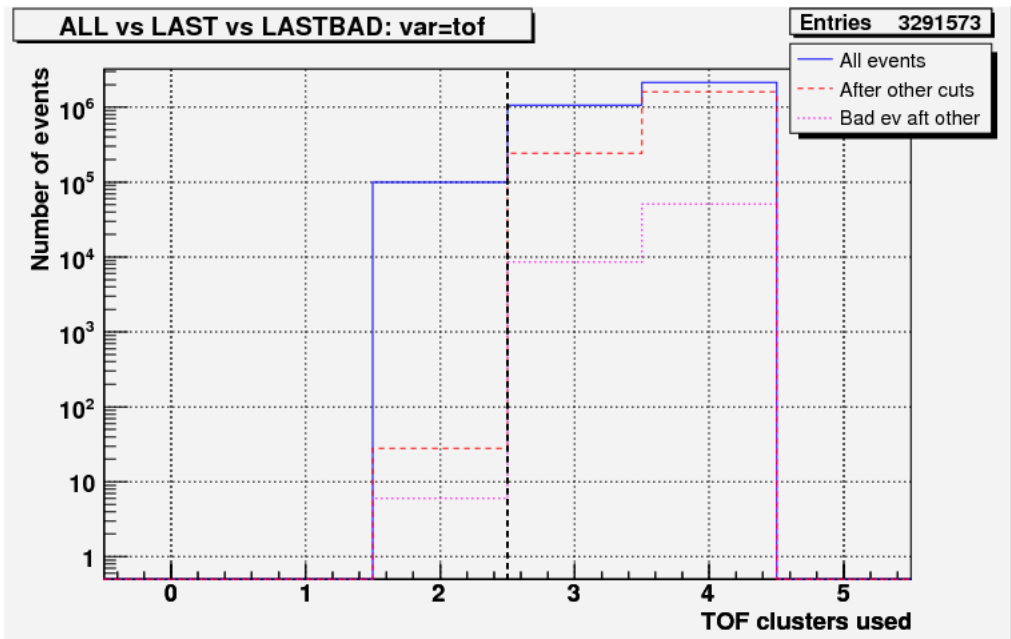


Red: 0, Blue: 1, Magenta: 2, Green: 3+

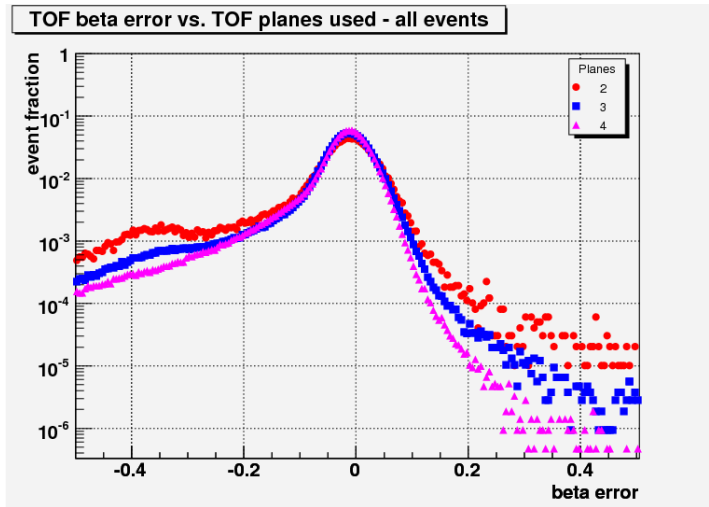


Pre-selection cuts: ToF planes

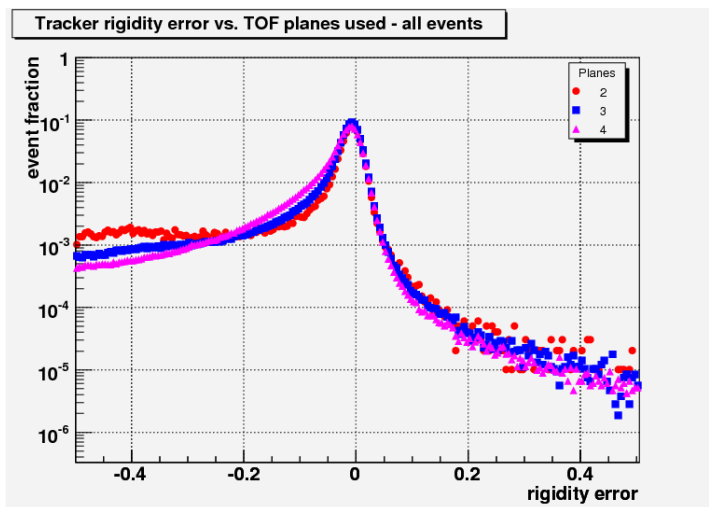
- Minimum of 3 ToF planes used for β measurement
  - Quality increases with no. planes
  - Events with 3 planes must be kept since they are a high fraction



protons, all energies

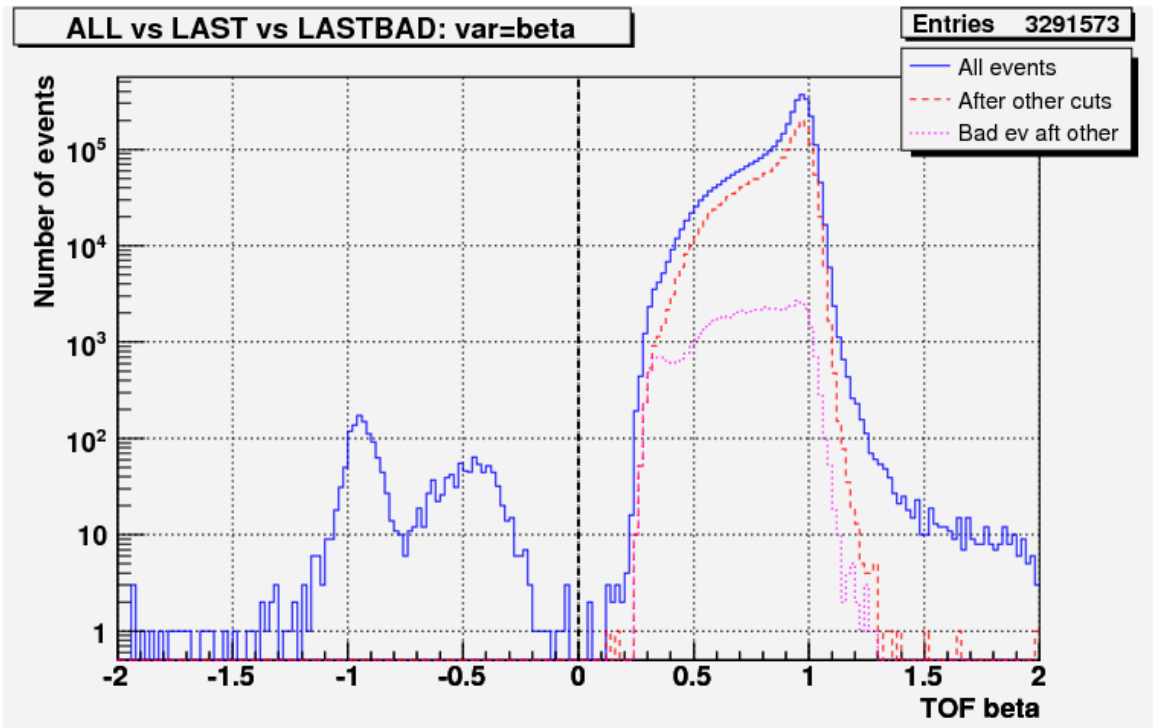


Red: 2, Blue: 3, Magenta: 4



Pre-selection cuts: ToF β measurement

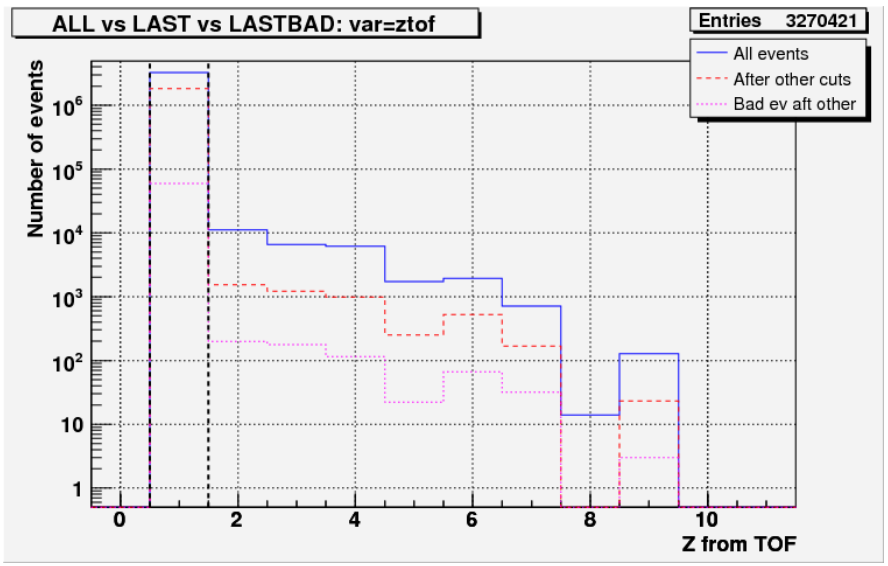
- ToF β measurement should give a positive value (i. e. downgoing particle)
  - Currently redundant: other pre-cuts already exclude events with negative β

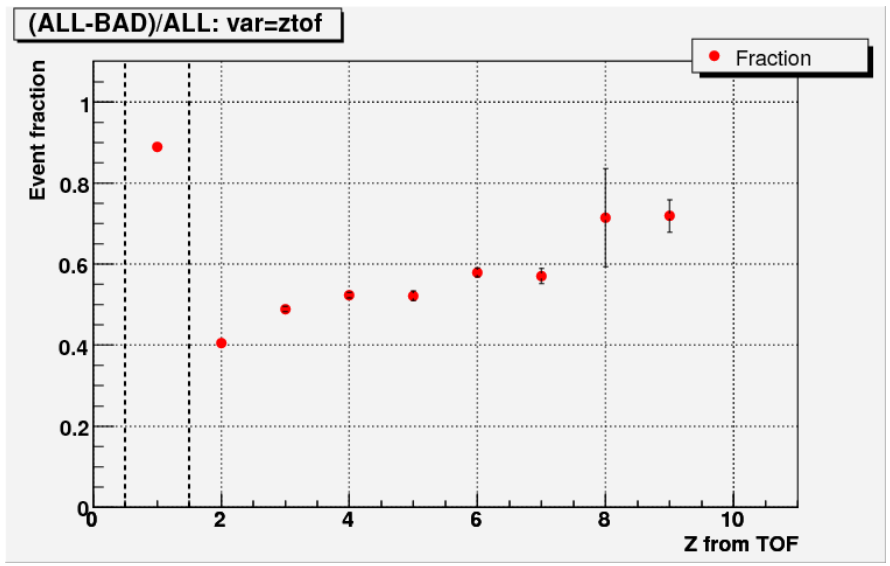


protons, all energies

Pre-selection cuts: ToF Z measurement

- Z = 1 required
  - Experimental conditions will require clear Z identification
  - Events with Z > 1 have a high fraction of bad rigidity reconstructions (defined as having rigidity error > 9%)

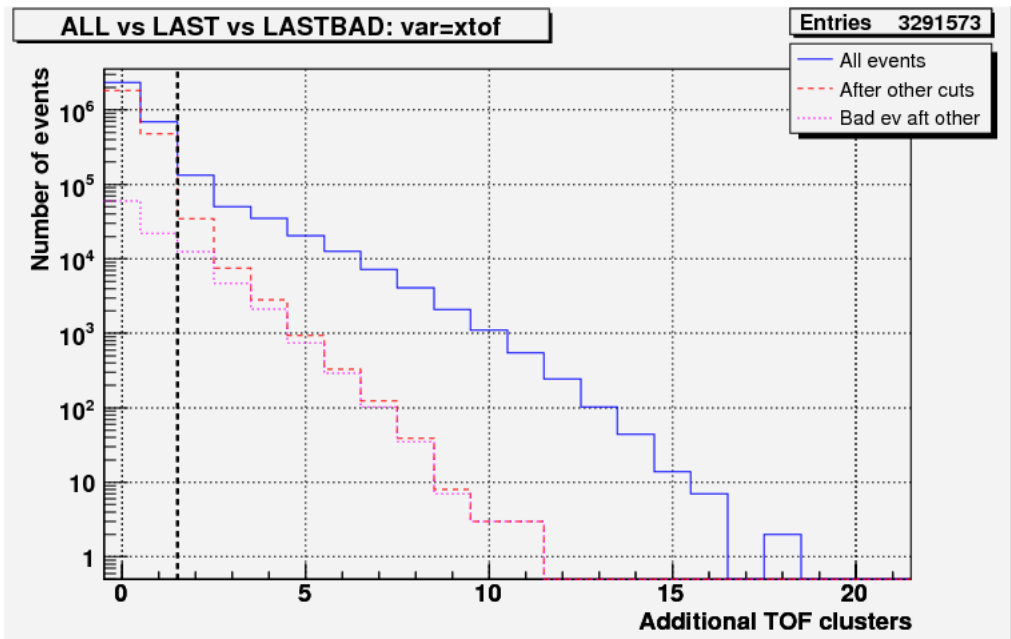




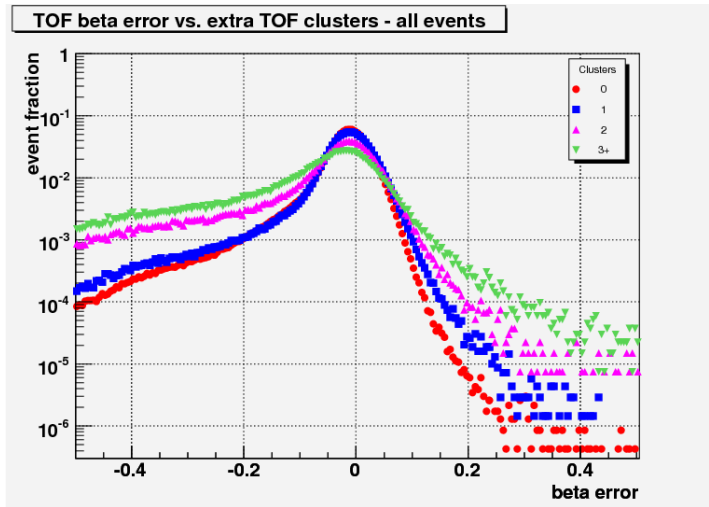
protons, all energies

Pre-selection cuts: ToF extra clusters

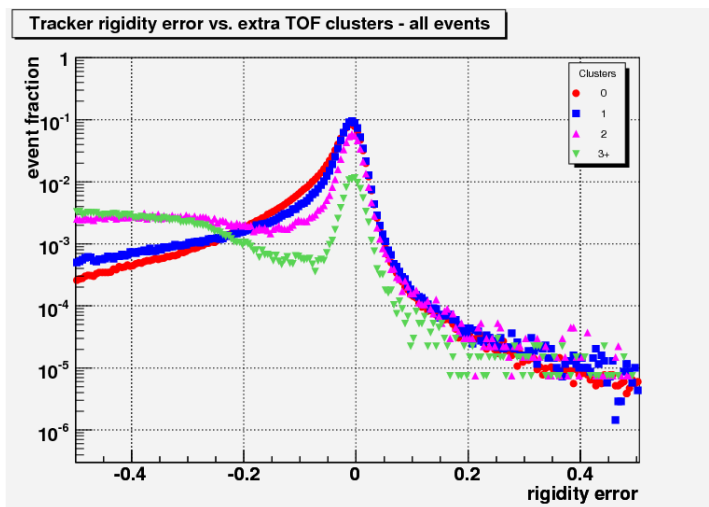
- Number of extra ToF clusters = 0 or 1
  - Clear transition in reconstruction quality for events with more than one extra cluster



protons, all energies

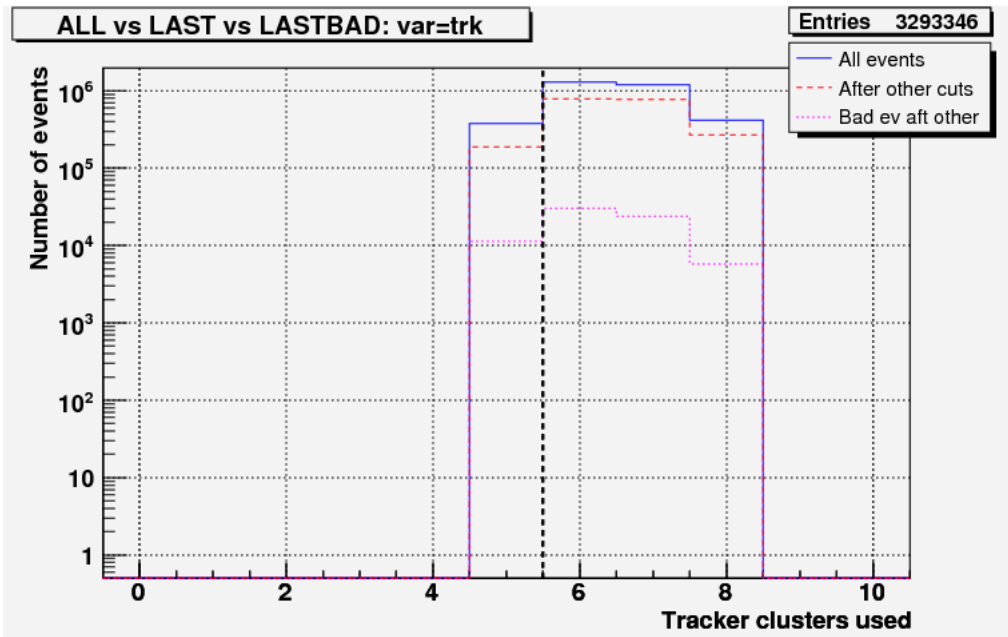


Red: 0, Blue: 1, Magenta: 2, Green: 3+

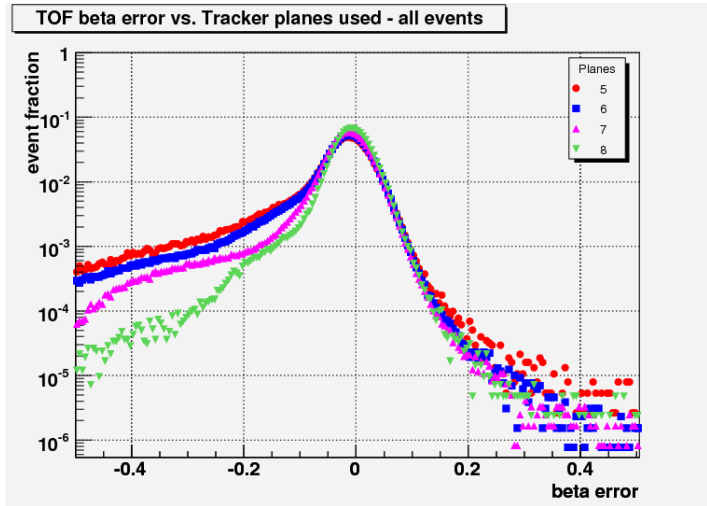


Pre-selection cuts: Tracker planes

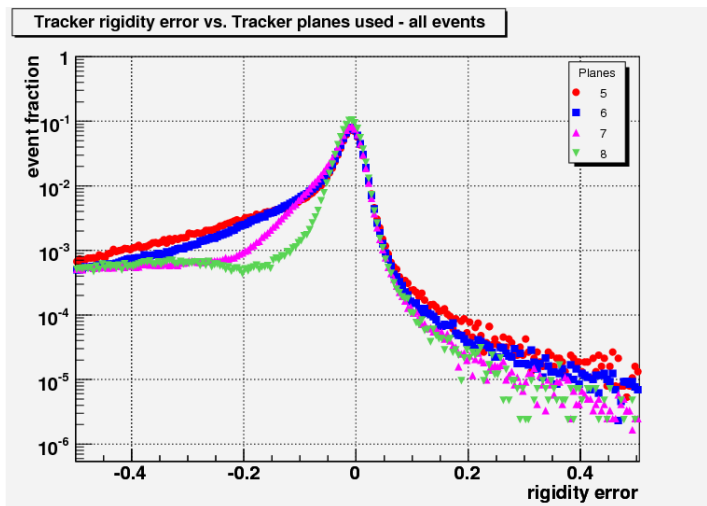
- Minimum of 6 Tracker planes used for rigidity measurement
  - Quality increases with no. planes
  - Events with 6 planes must be kept since they are a high fraction



protons, all energies

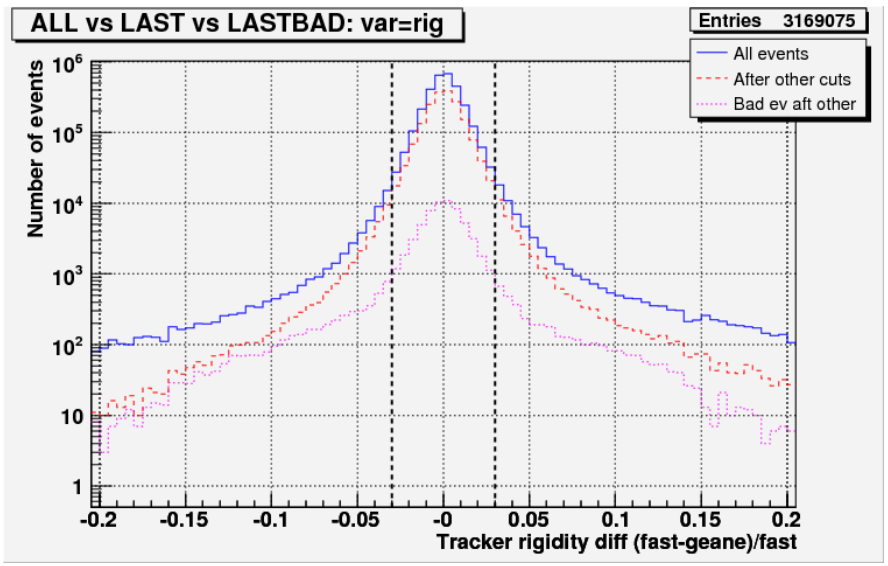


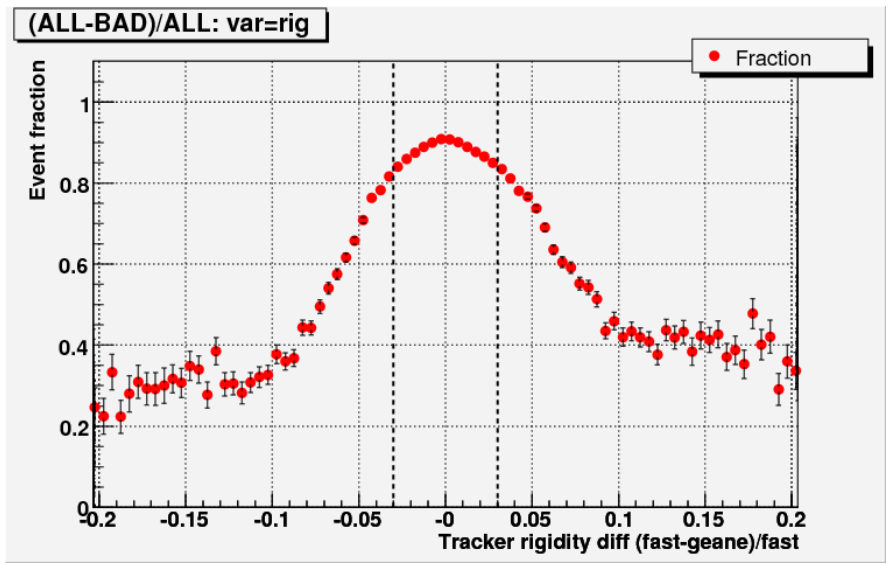
Red: 5, Blue: 6, Magenta: 7, Green: 8



Pre-selection cuts: Tracker rigidity

- Compatibility in rigidity measurements: both "fast" and "geane" measurements exist and they differ by less than 3 percent
  - Cut is at over 3σ (peak standard deviation is 0.9%)

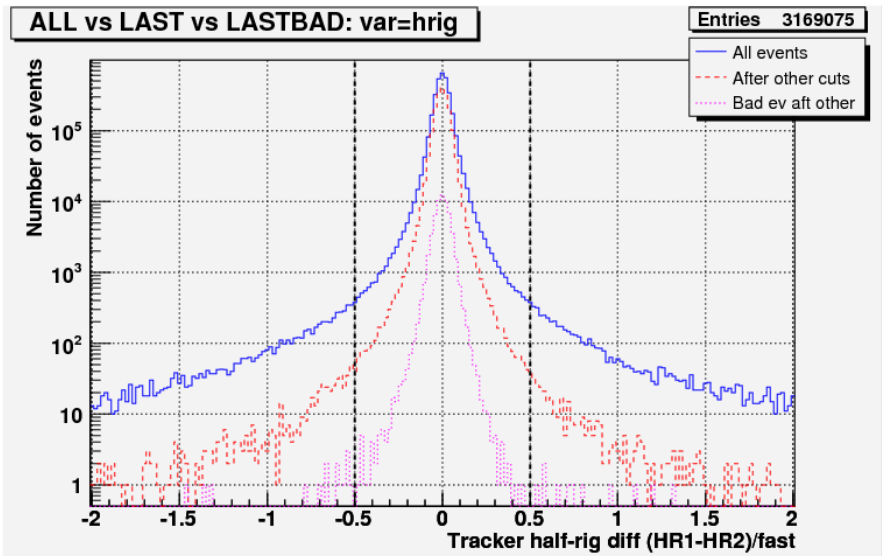


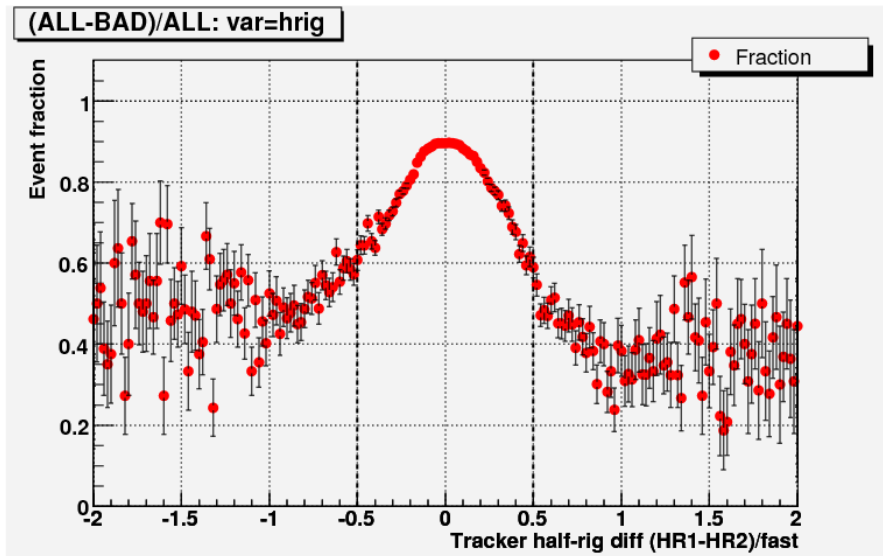


protons, all energies

Pre-selection cuts: Tracker half-rigidity

- Compatibility in half-rigidity measurements: both rigidities from 1st and 2nd half exist and differ by less than 50% of global rigidity measurement

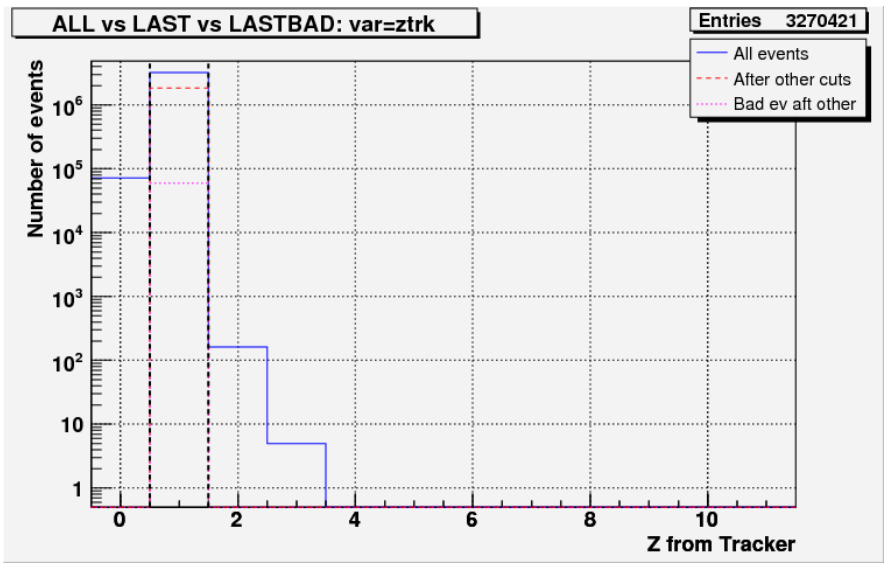


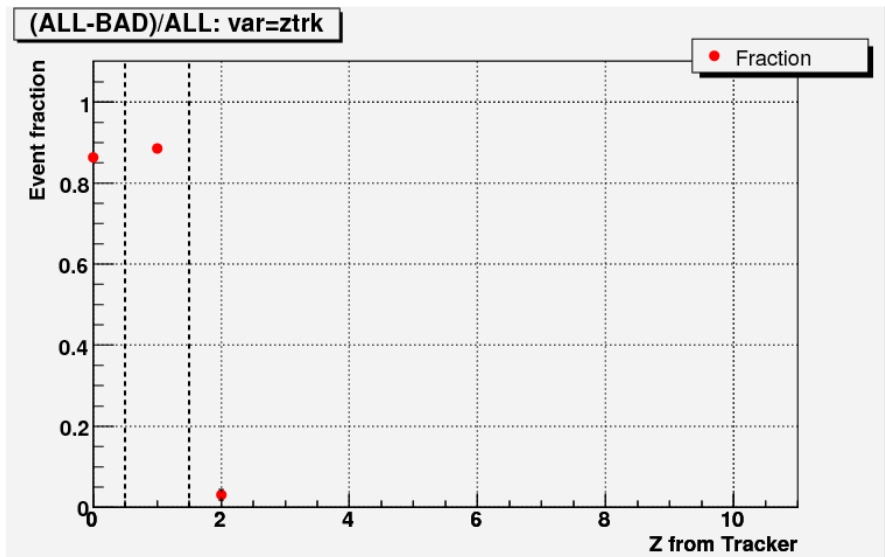


protons, all energies

Pre-selection cuts: Tracker Z

- Z = 1 required
  - Best charge estimate, only very small fraction of events has $Z \neq 1$
  - Currently redundant after all other pre-cuts





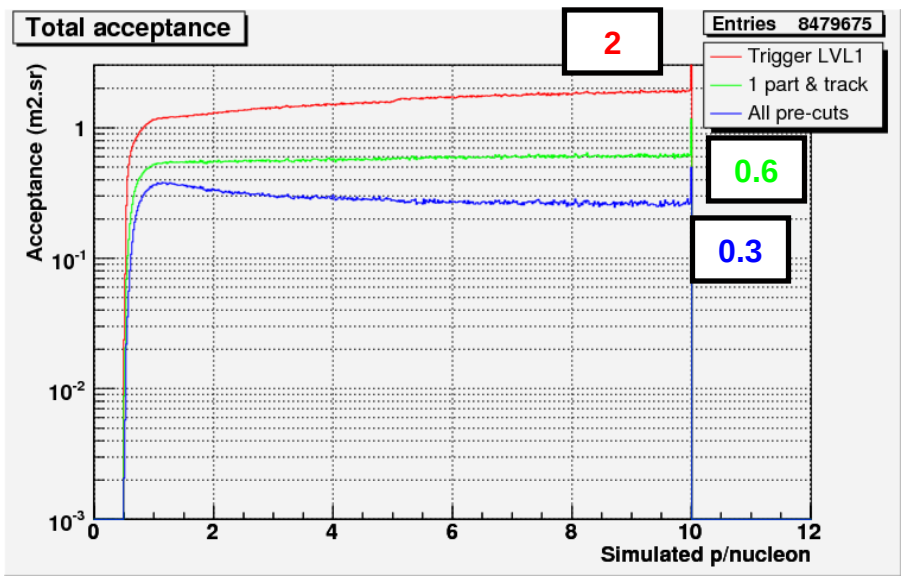
protons, all energies

Pre-selection cuts: summary

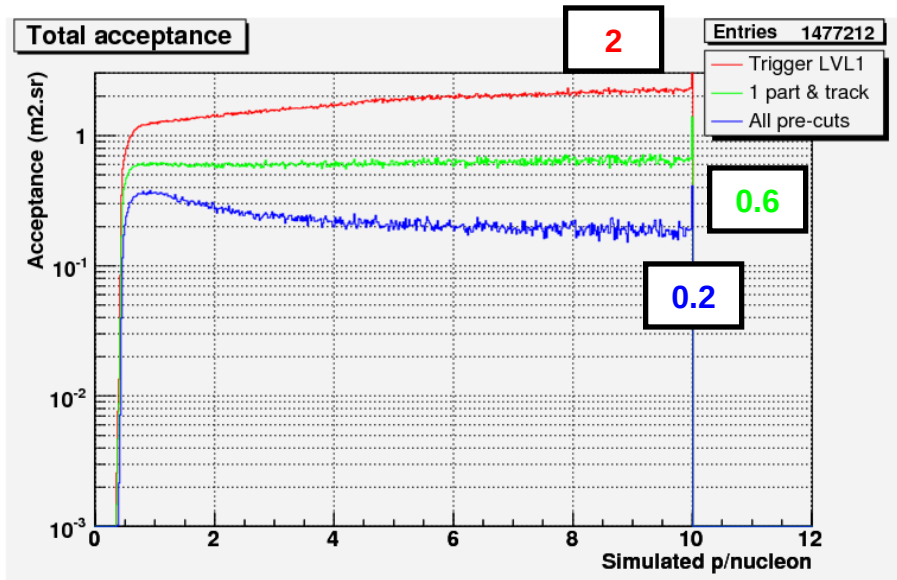
- Event:
  - One particle
  - Track exists
- ACC:
  - Number of clusters = 0
- TRD:
  - Number of tracks ≤ 1
- ToF:
  - Number of planes used ≥ 3
  - β measurement > 0
  - Z measurement = 1
  - Number of extra clusters ≤ 1
- Tracker:
  - Number of planes used ≥ 6
  - Rigidity cross-check diff < 3%
  - Half-rigidity cross-check diff < 50%
  - Z measurement = 1

Geometrical acceptance

- After pre-cuts:



protons



deuterons

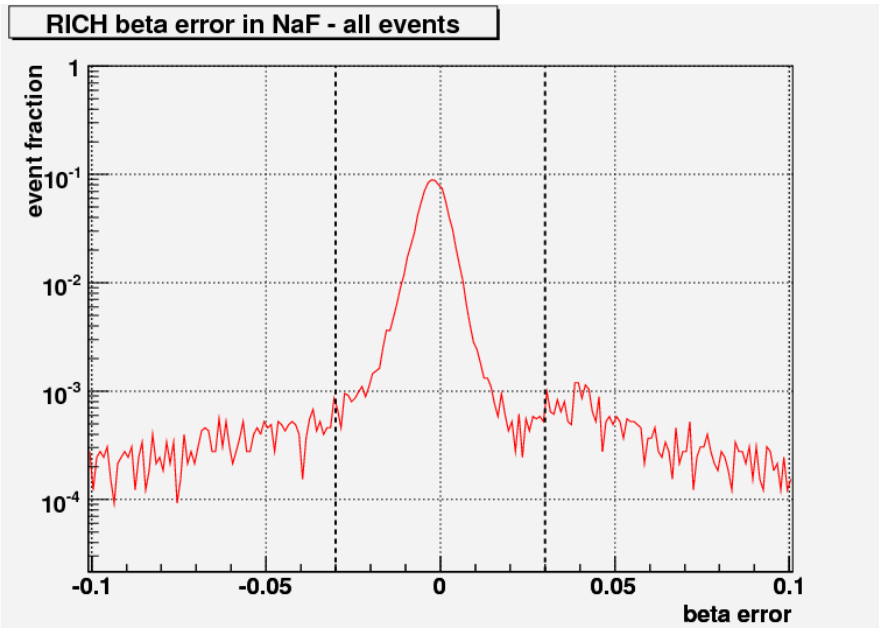
RICH selection cuts: overview

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

RICH selection cuts: bad events

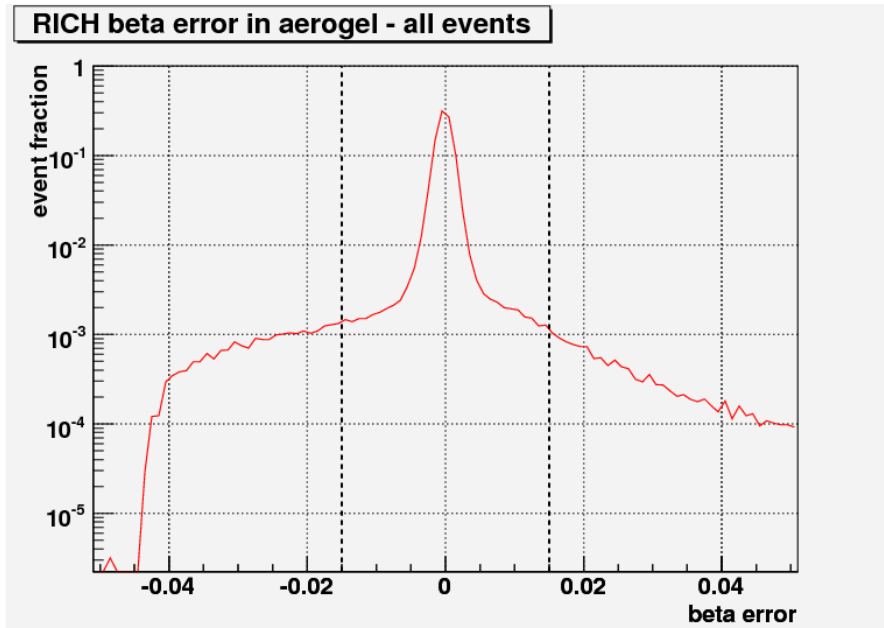
- Events labeled as "bad" if they have error in RICH β:
  - > 3% (NaF)
  - > 1.5% (aerogel)

NaF



Δβ/β

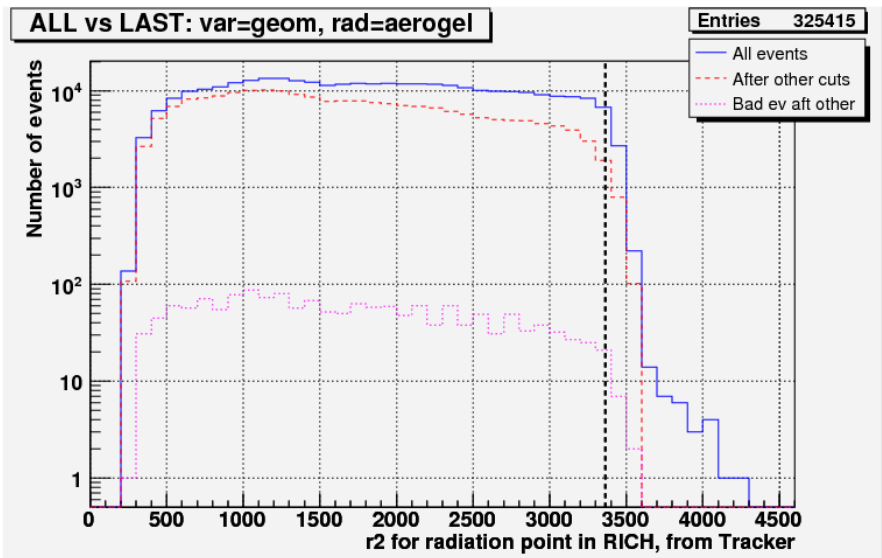
aerogel

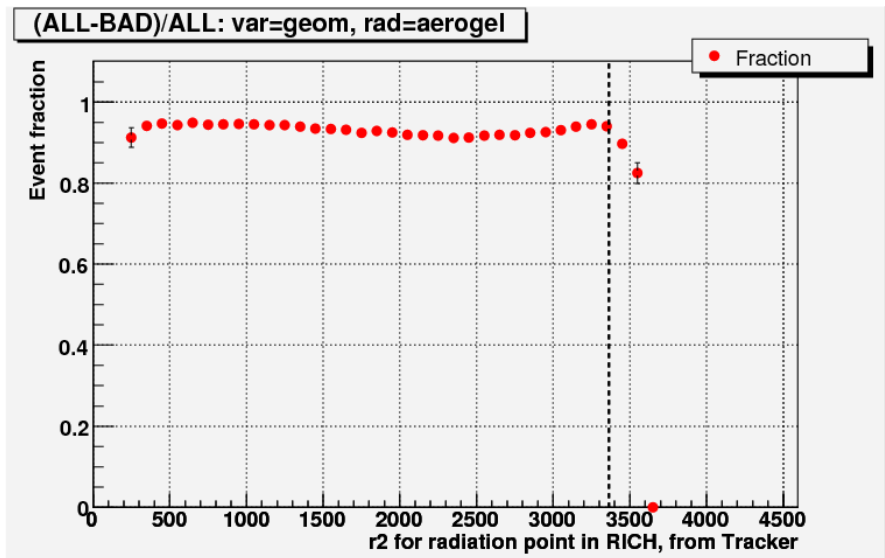


Δβ/β

RICH selection cuts: geom. acceptance

- Particle impact on radiator occurs at r < 58 cm
  - Point given by track extrapolation
  - Goal is to exclude events at the edge of the matrix (r_{mirror} = 60 cm)
  - Only relevant for aerogel (NaF is central square, r_{max} = 24 cm)
  - Fraction of bad events does not change significantly with radius
    - *bad event selection: RICH β error >1.5% (aerogel), >3% (NaF)*

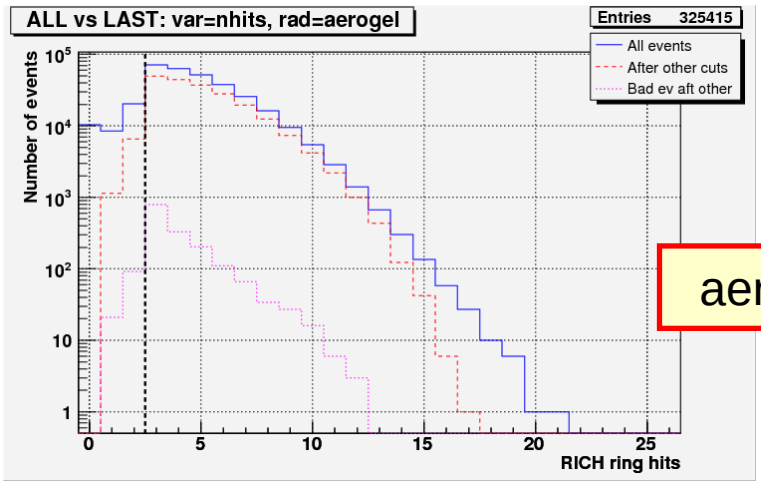


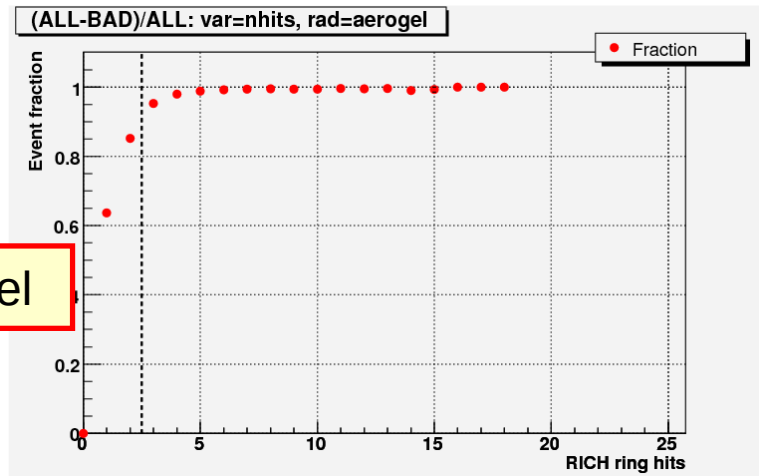


protons in aerogel, all energies

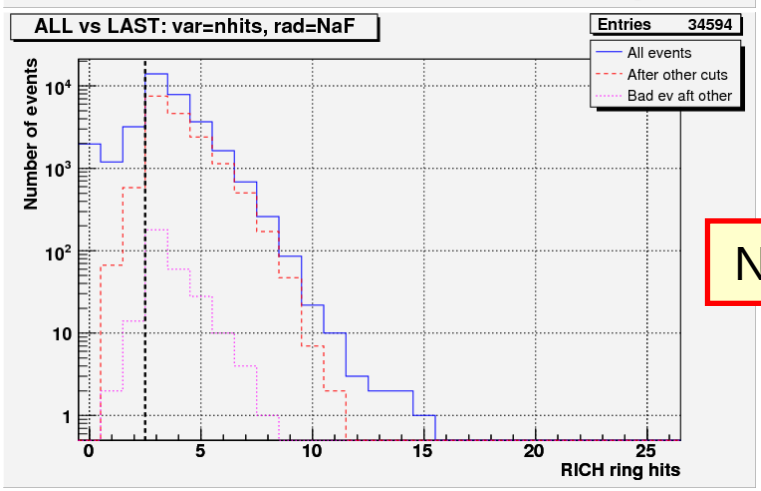
RICH selection cuts: number of hits

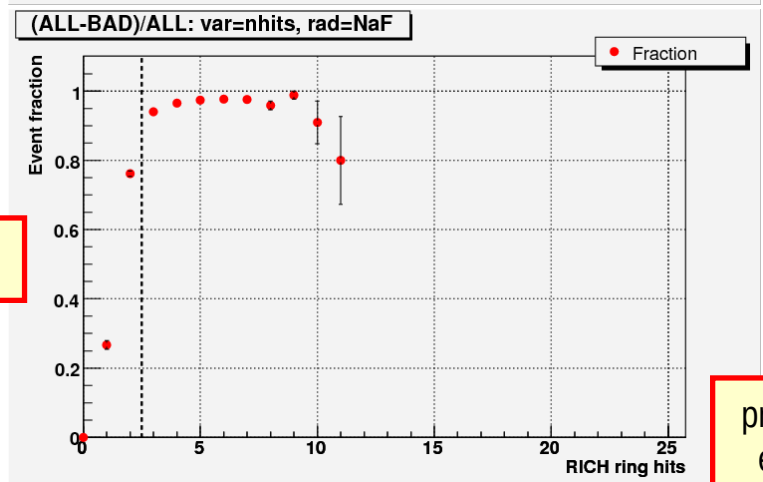
- At least 3 hits used in RICH ring LIP reconstruction
  - RICH data with less than 3 hits in CIEMAT reconstruction were not saved in simulation files





aerogel



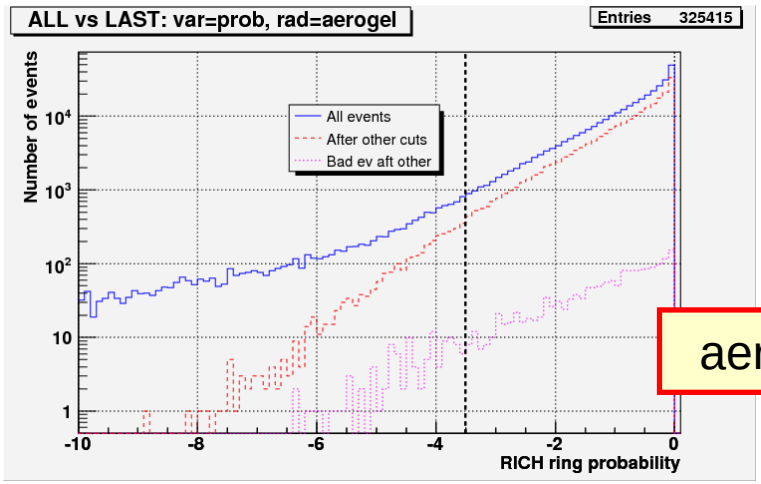


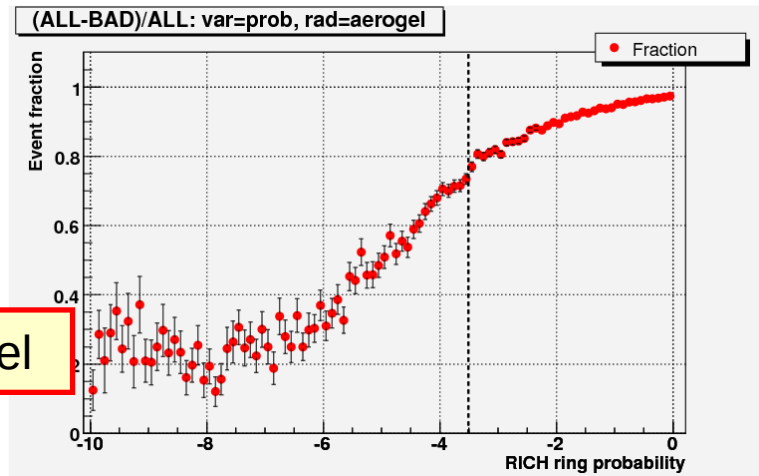
NaF

protons, all energies

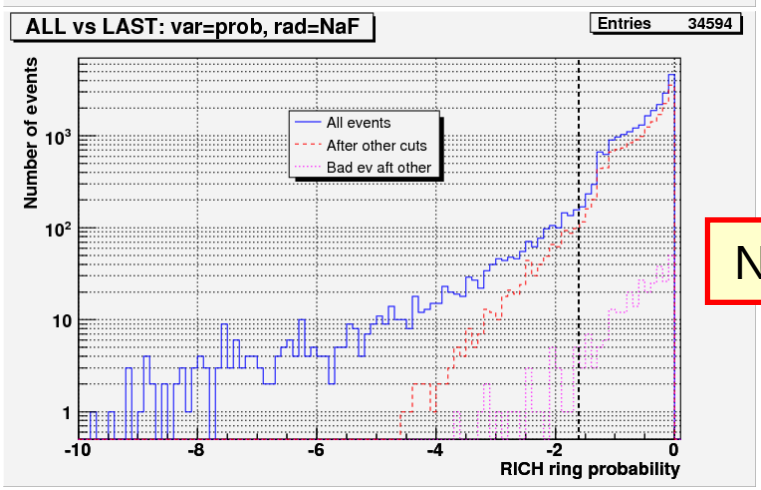
RICH selection cuts: ring probability

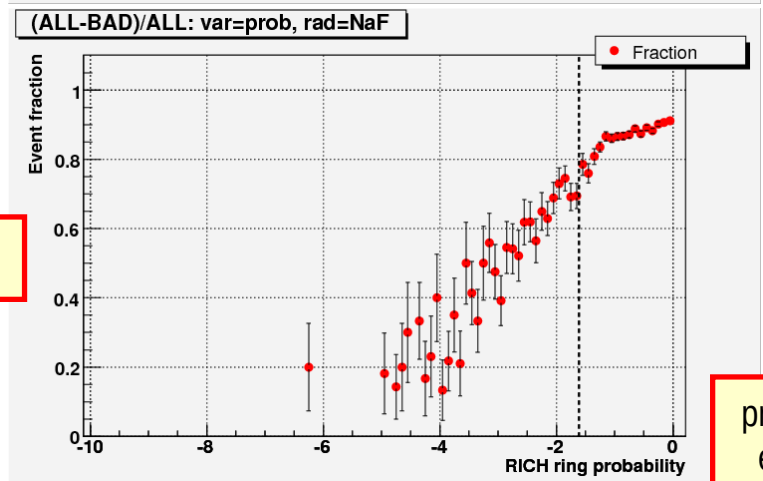
- Ring probability is:
  - > 0.20 (NaF); > 0.03 (aerogel)





aerogel



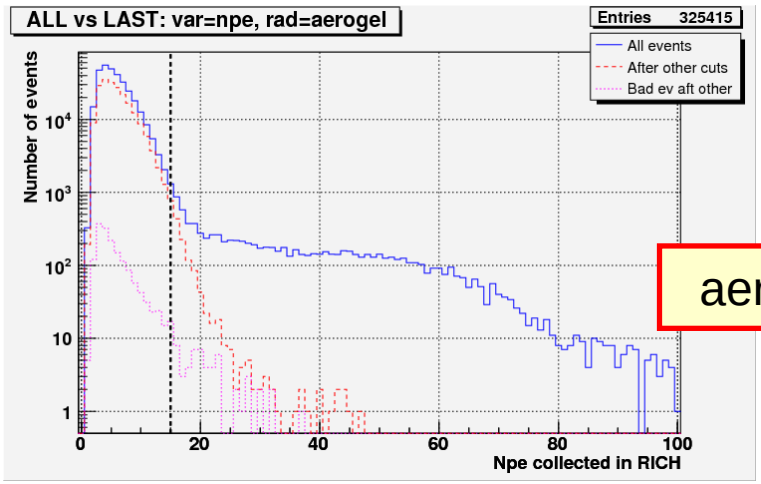


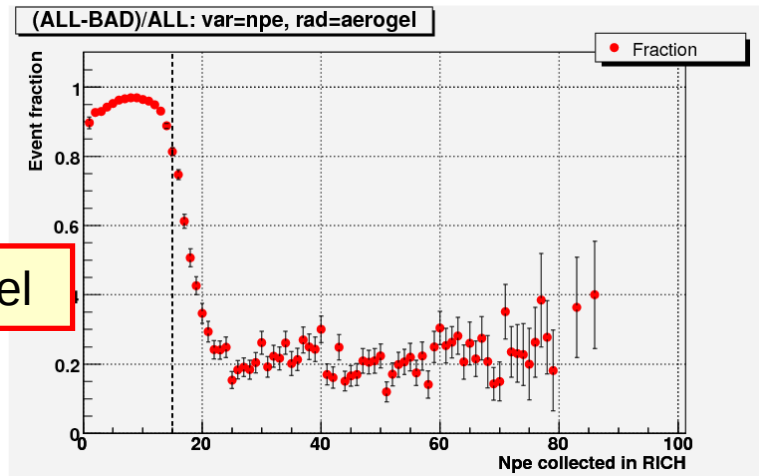
NaF

protons, all energies

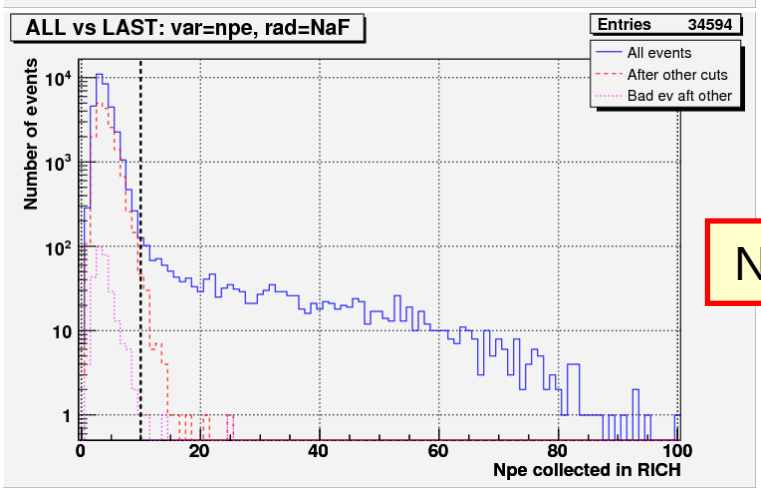
RICH selection cuts: ring signal

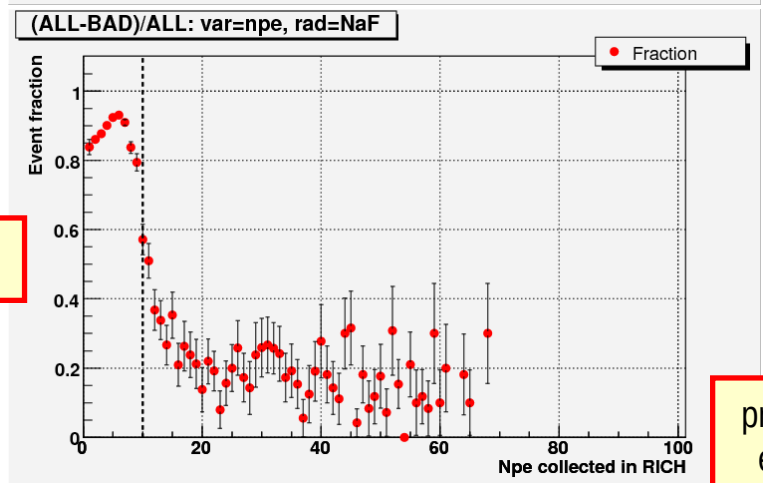
- Total ring signal is:
  - < 10 p.e. (NaF); < 15 p.e. (aerogel)





aerogel



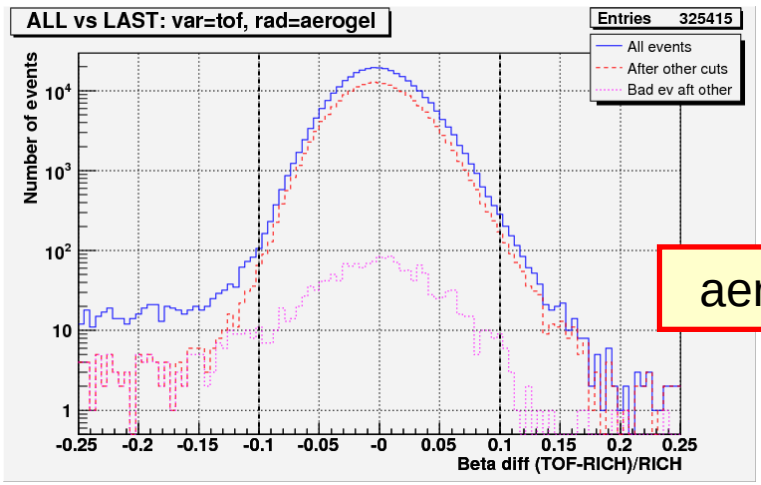


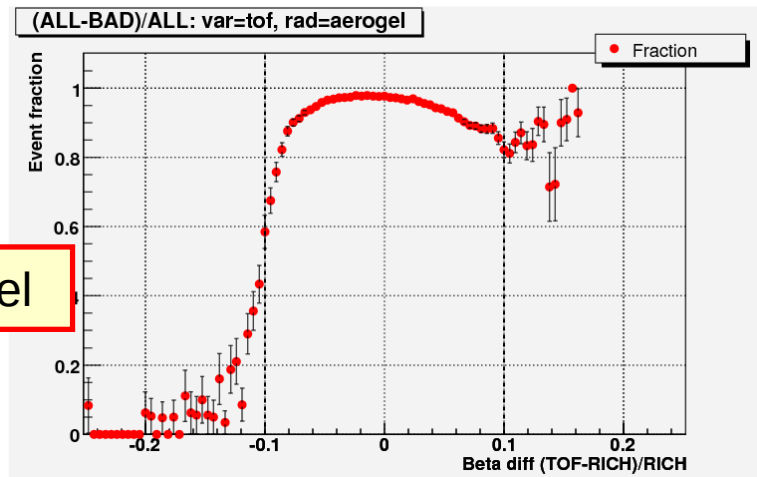
NaF

protons, all energies

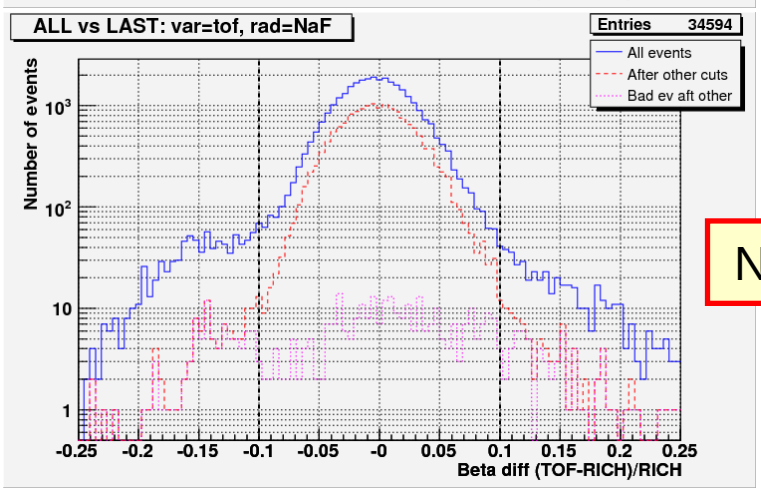
RICH selection cuts: ToF β check

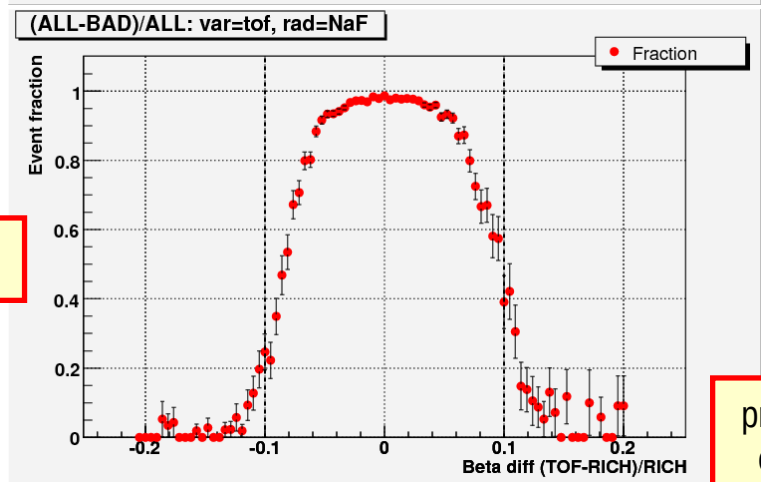
- Compatibility in β measurements:
  - ToF-RICH difference < 10%





aerogel



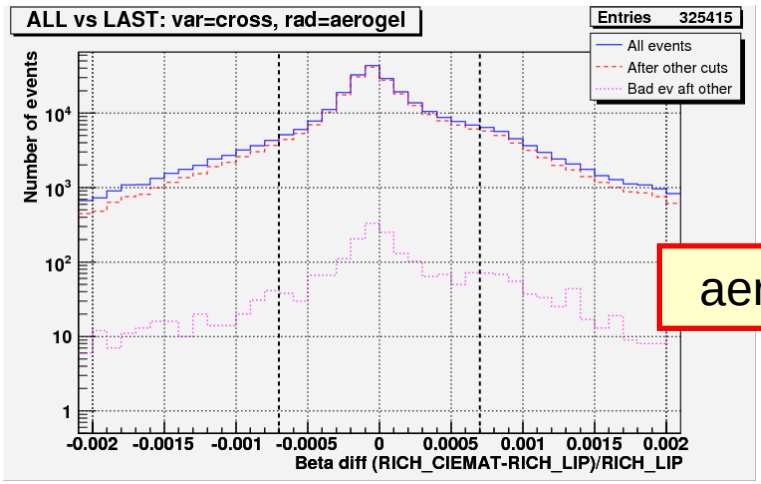


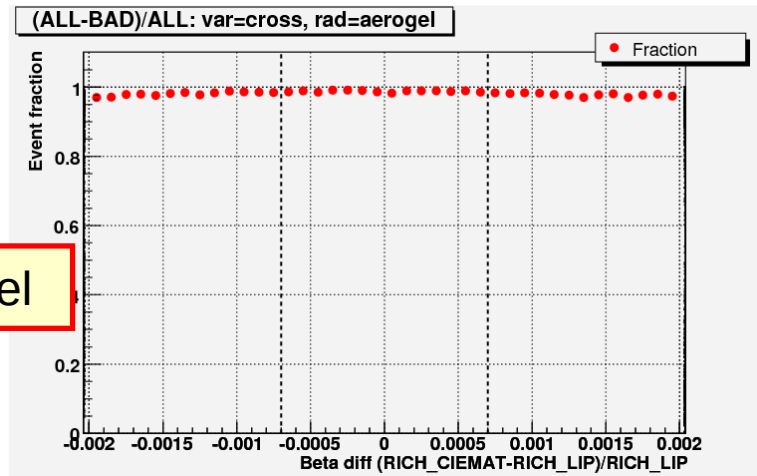
NaF

protons, all energies

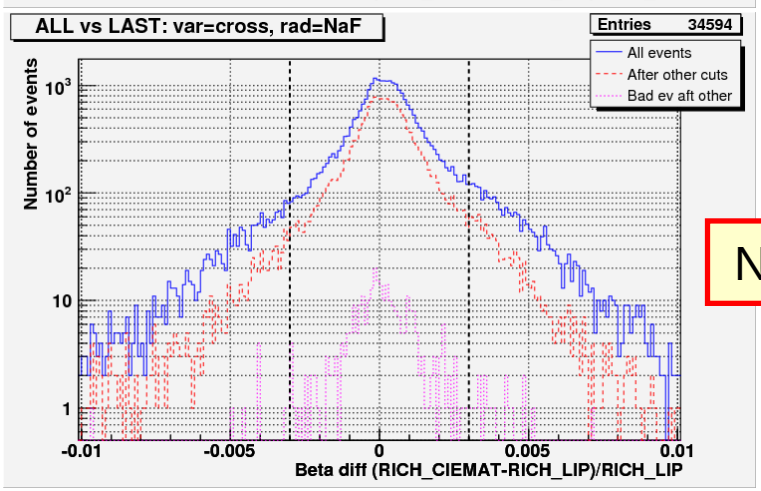
RICH selection cuts: β cross-check

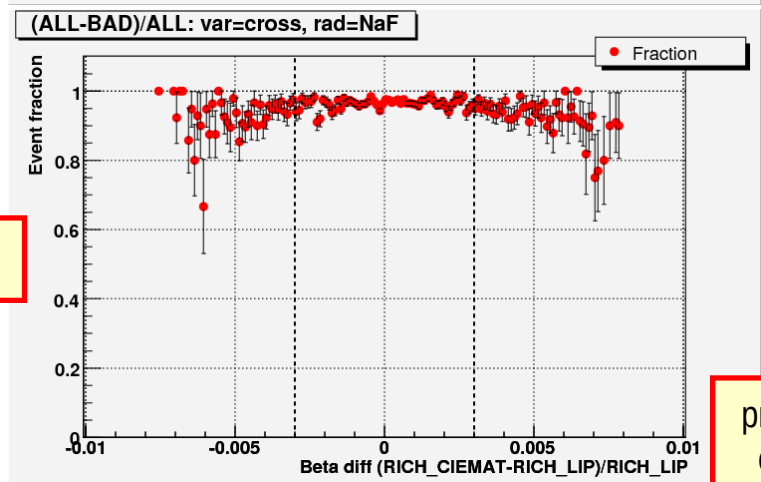
- CIEMAT & LIP β measurements differ by:
  - < 0.3% (NaF), < 0.07% (aerogel)
  - limits are > 3 peak σ in both cases





aerogel



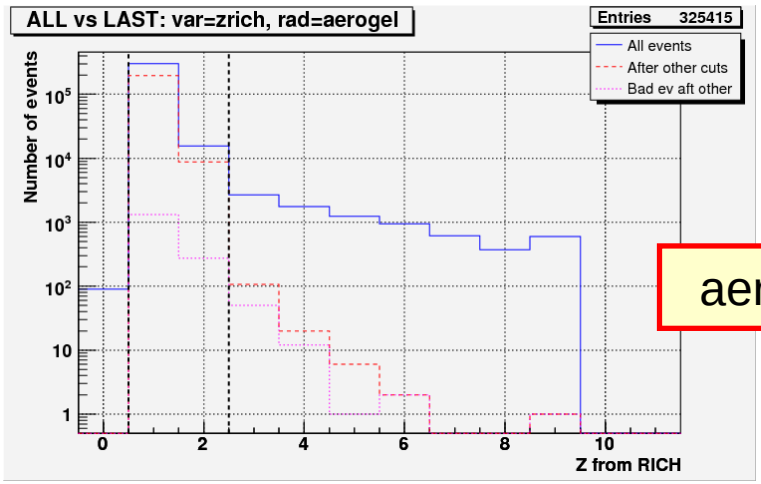


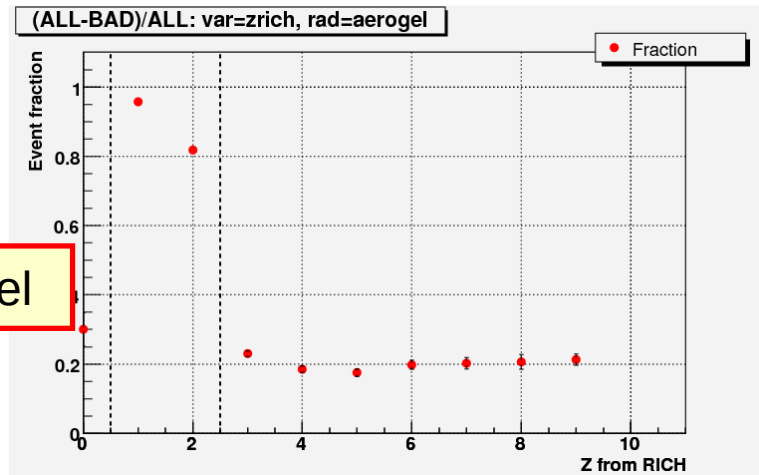
NaF

protons, all energies

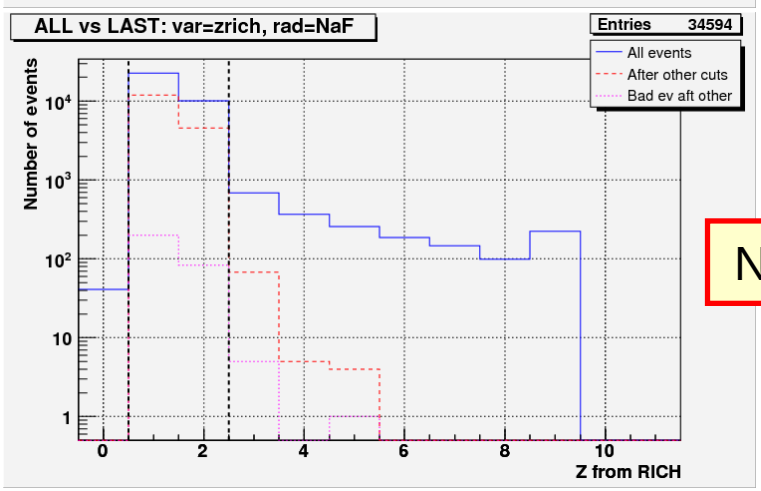
RICH selection cuts: Z measurement

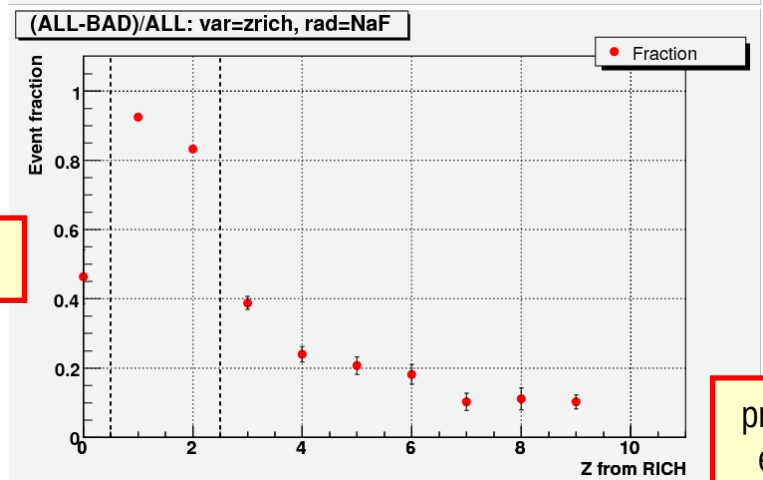
- Z = 1 or 2 accepted
  - Z = 2 tolerated due to large fluctuations in ring signal
  - Pre-cuts already selected Z = 1 in Tracker & ToF





aerogel





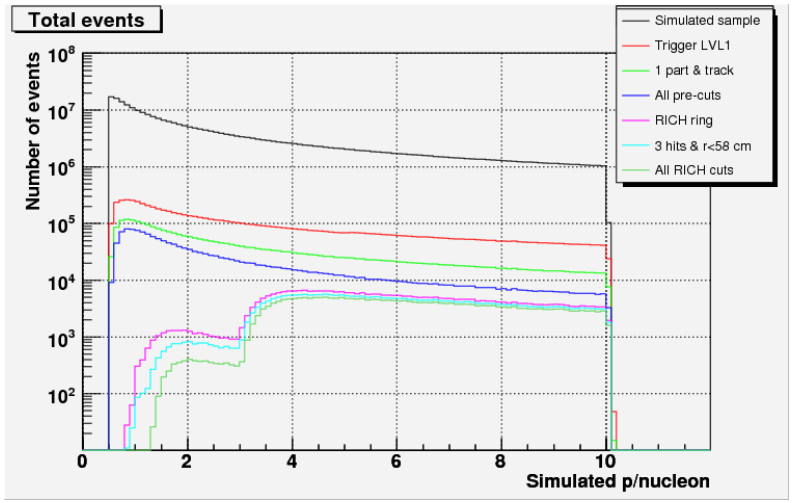
NaF

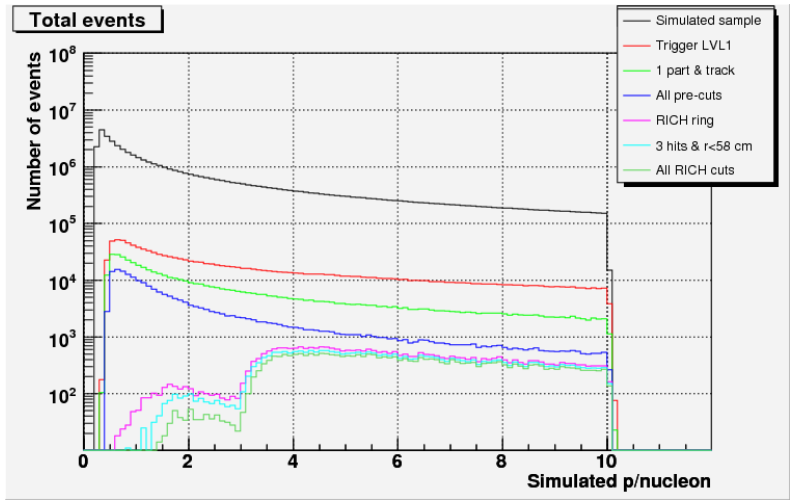
protons, all energies

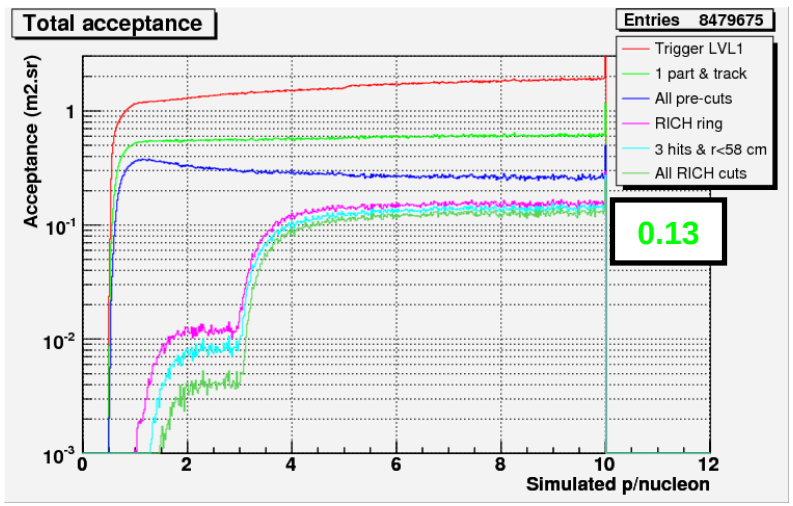
RICH selection cuts: summary

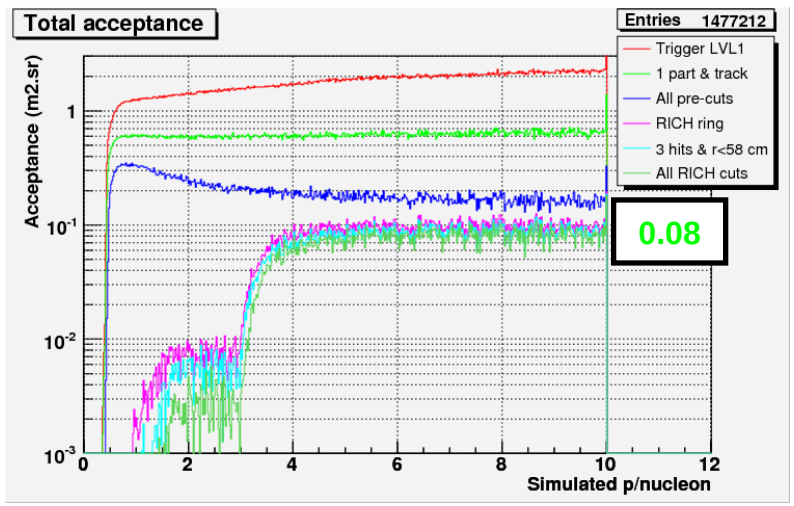
- Ring exists
- Geometrical acceptance $r_{imp} < 58$ cm
- Number of hits ≥ 3
- Ring probability ≥ 0.20 (NaF), ≥ 0.03 (aerogel)
- Ring signal < 10 p.e. (NaF), < 15 p.e. (aerogel)
- RICH-ToF β consistency diff. $< 10\%$
- RICH β cross-check diff. $< 0.3\%$ (NaF), 0.07% (agl)
- Z measurement $= 1$ or 2

Geometrical acceptance







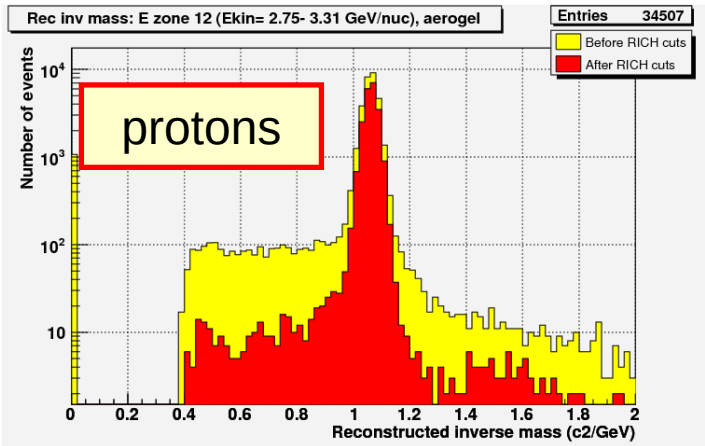


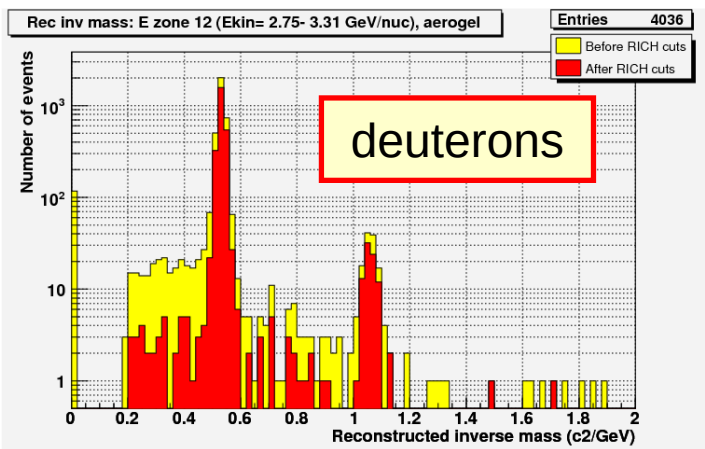
protons

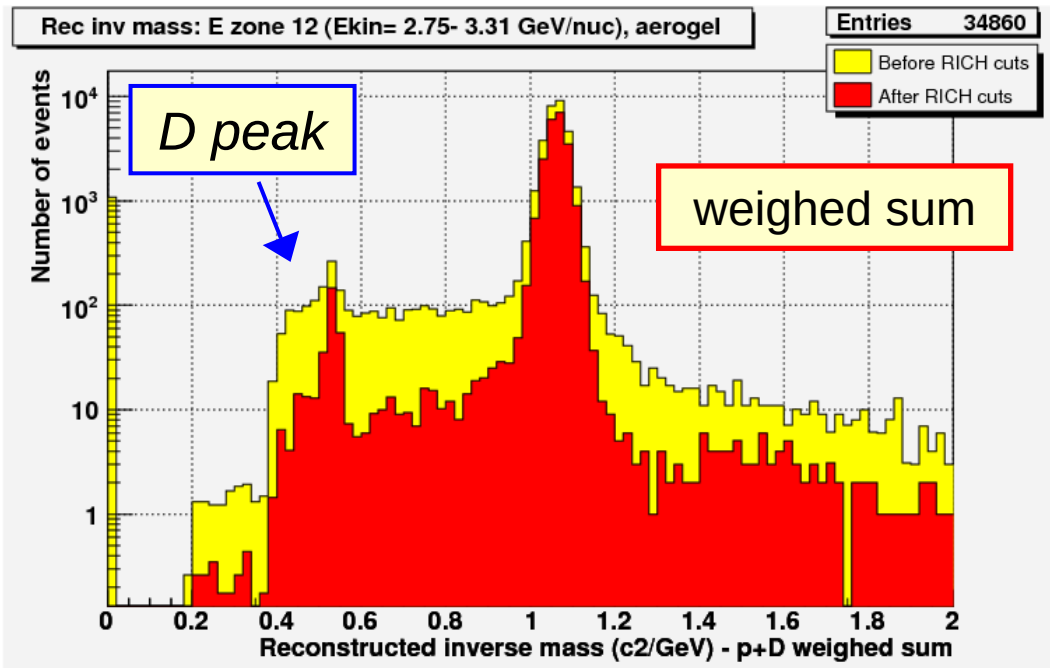
deuterons

Mass reconstruction: results (aerogel)

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





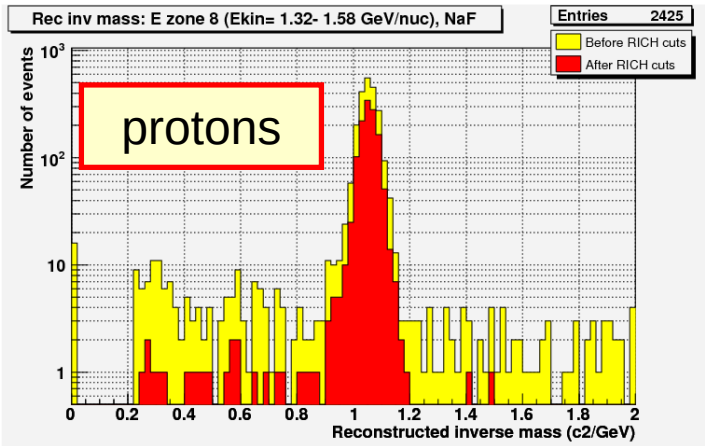


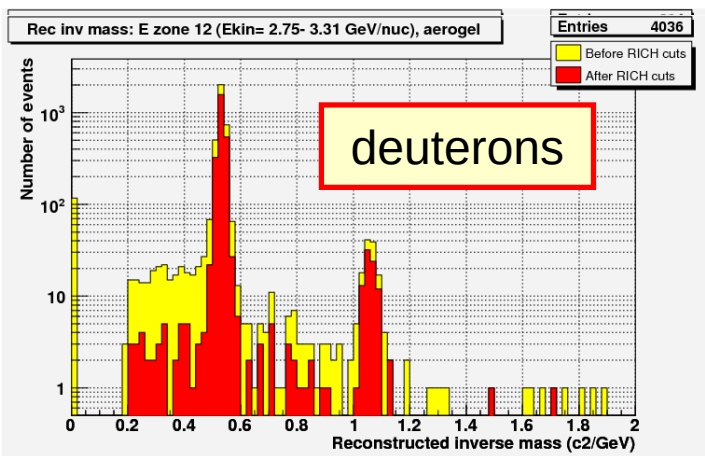
aerogel events

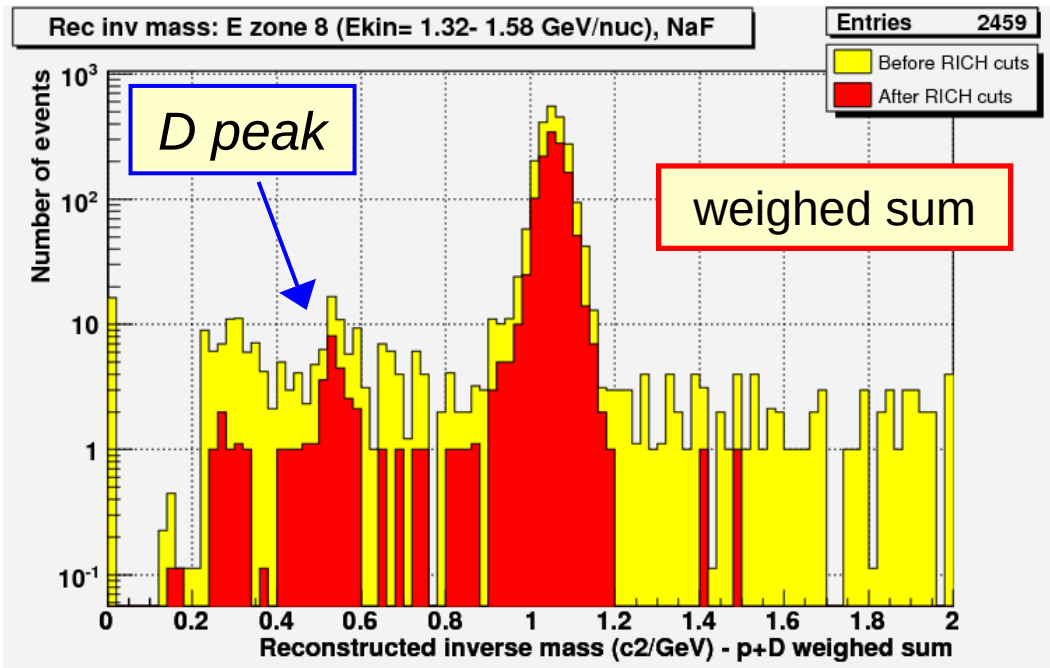
E_{kin} = 2.75-3.31 GeV/nuc

Mass reconstruction: results (NaF)

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





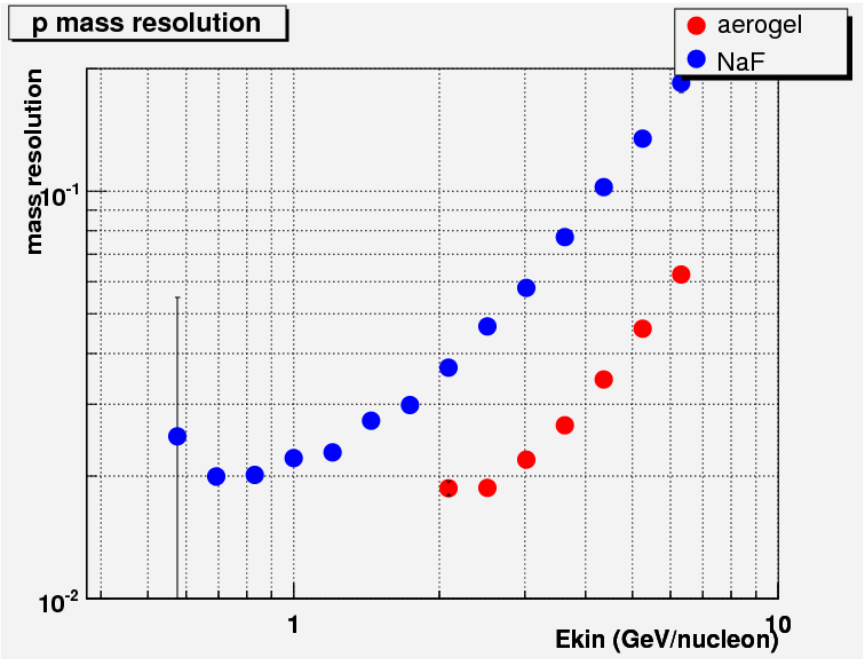


NaF events

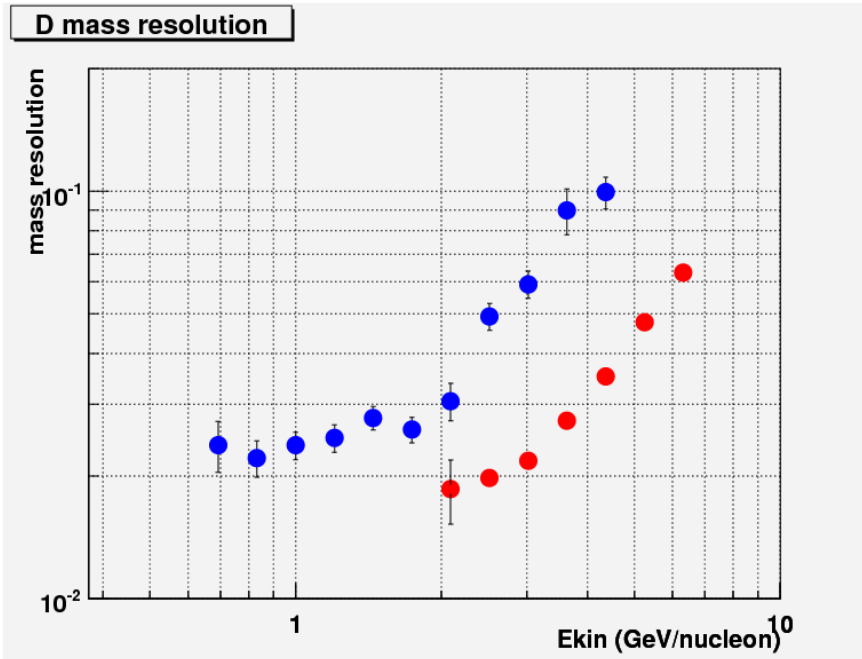
E_{kin} = 1.32-1.58 GeV/nuc

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)



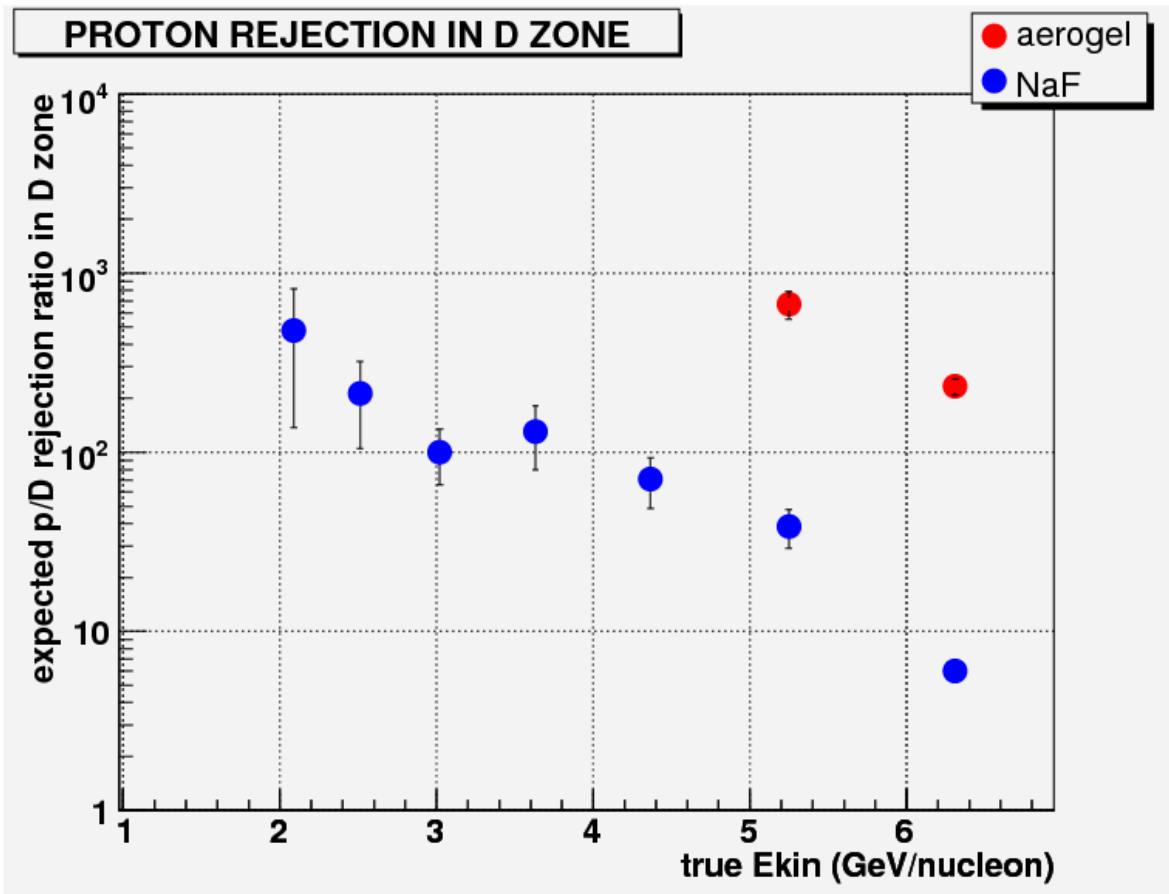
protons



deuterons

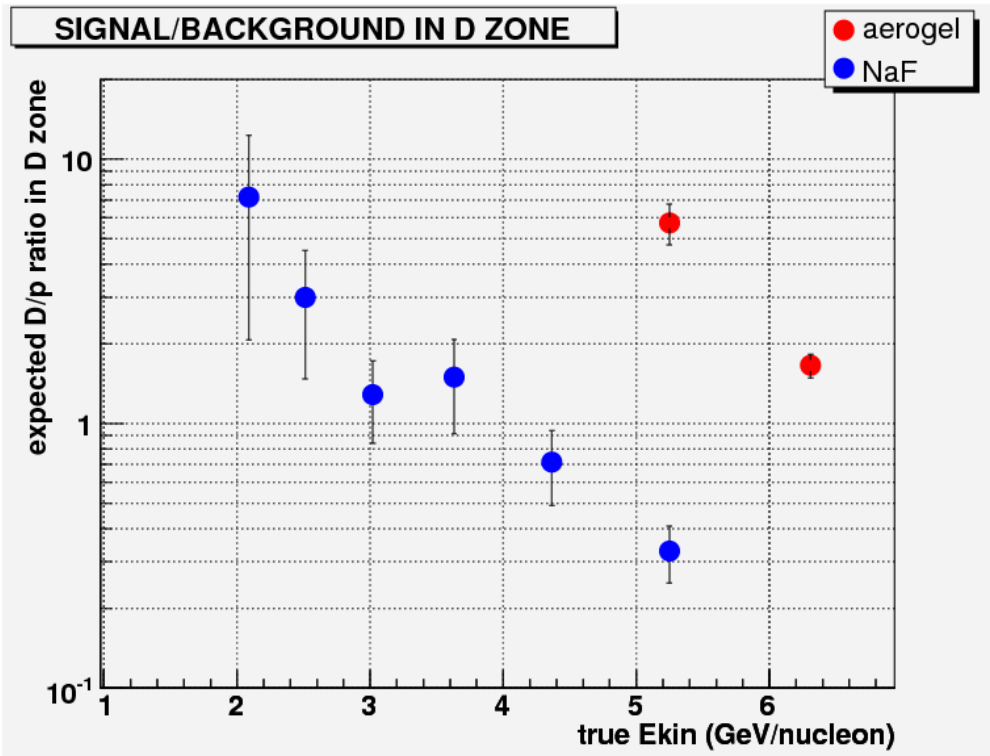
Rejection factor

- For the same *real* (not reconstructed) energy, protons are 10^2-10^3 times less likely than deuterons to fall on deuteron mass region ($m_D \pm 3\sigma$)
- Values cannot be obtained for energies close to radiation threshold



Signal/background

- Signal/background ratio is given by: **S/B = D/p |$_{cosmic}$ x 1/rej**
- Relative D/p abundances (from Seo et al., 1994) give sgn/bkg ~ 1-10
- Proton noise comes from events with higher energy, meaning that the exponential decay of cosmic ray spectrum will make experimental signal/background ratios higher than those shown here
- Full simulation confirms RICH simulation: ***D/p separation is feasible***



Conclusions (preliminary)

- The AMS RICH provides an effective way to do mass separation at energies of a few GeV/nucleon:
  - Results from RICH standalone simulation confirmed
  - 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

Near future

- Refinements in pre-cuts:
  - Tracker: rigidity χ^2, number of (near) extra clusters, Z measurement probability
  - ToF: Z measurement probability
  - Other...
- Refinements in selection cuts:
  - 4 hits in ring instead of 3
  - Ring acceptance
  - N_{pe} per hit
  - Exclusion of events with $Z_{RICH} = 2$
  - Z_{RICH} measurement probability
  - Other...
- Analysis of other MC samples to expand proton tail data (needed for detailed estimation of background)
- Higher statistics (especially for NaF events)
- Usage of the ToF detector to improve results at lower energies
- Study of other isotopes