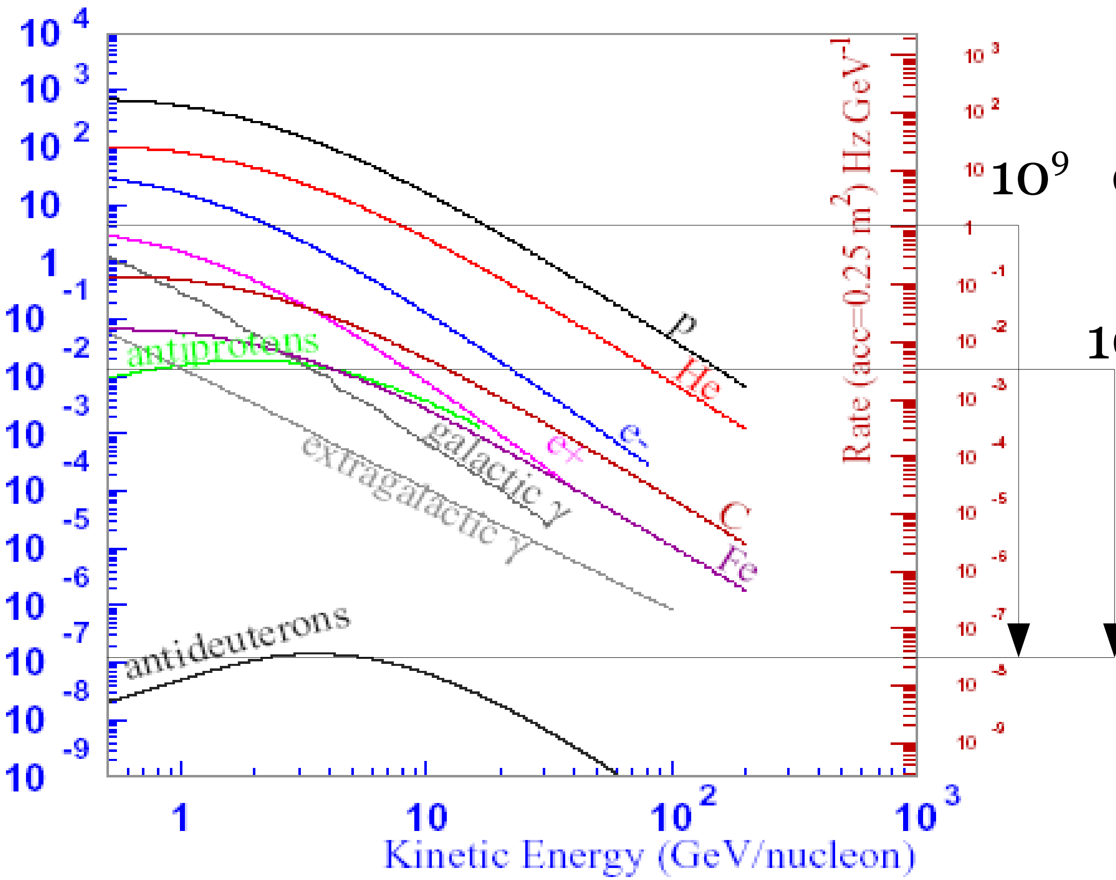
About the possibility of observation of antideuterons in AMS02

Mariusz Sapinski, INFN Roma1

CERN, April 26, 2006

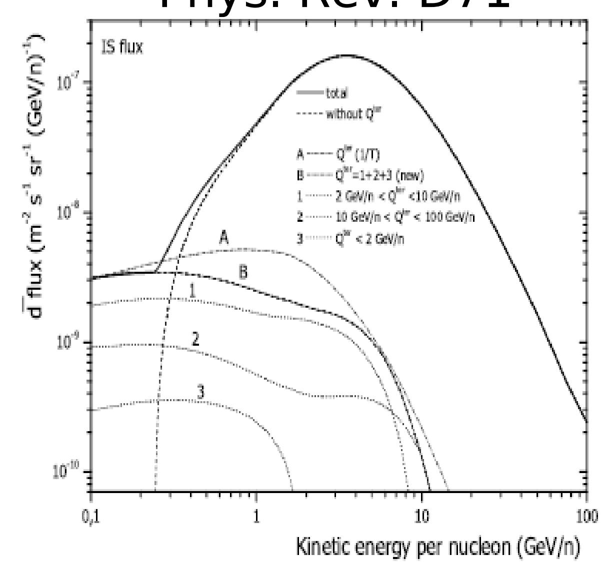
Goals



10^9 electrons

10^6 antiprotons

Phys. Rev. D71



Protons > 10^{11}, but charge confusion for low momenta gives 10^8 and the rest is like antiprotons, so we are safe.

Outlook

1. MC statistics
2. Preselection and acceptance
3. Tuning cuts on momentum reconstruction
4. Cuts on velocity reconstruction in TOF and RICH
5. Momentum and velocity recalibration
6. use of TRD to reject electrons
7. Antideuteron, antiproton and electron fluxes on orbit
8. AMS sensitivity

MC statistics

1. mailny CERN-generated events were used
   (0.5-10 (20) GeV/c, generated from the plane above AMS)

2. electrons: $8*10^6$ (no more MC at CERN (2005A) and this is rather not enough)

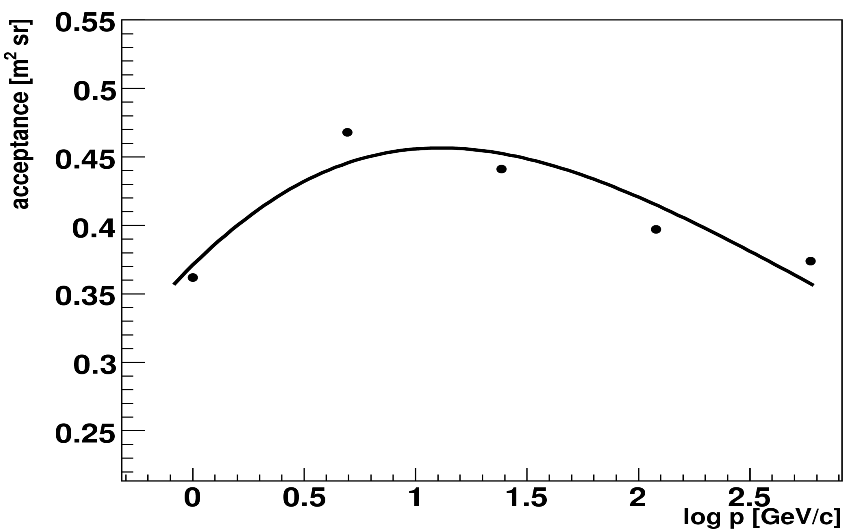
3. antiprotons: 10^6

4. antideuterons: $5*10^5$

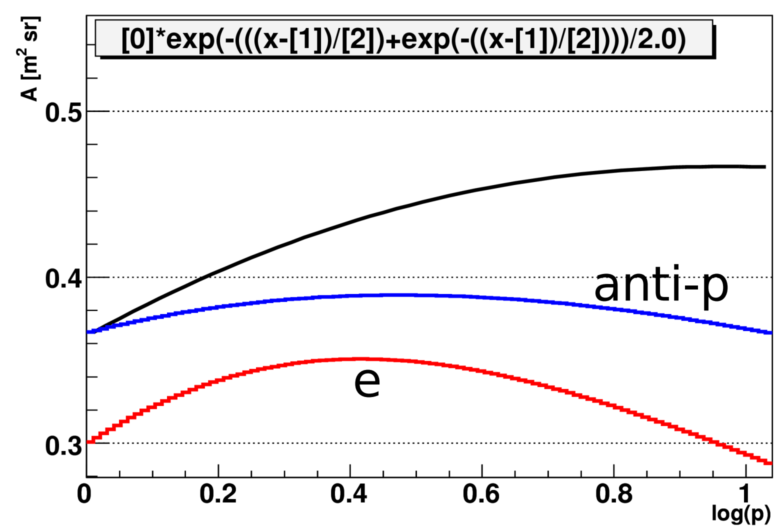
5. for acceptances: antiprotons, antideuterons and electrons with p=1,2,4,8 and 16 GeV/c were used

Antideuteron acceptance

Preselection cuts: events with no activity in anticoincidence counters, with one AMS-Particle with tracks in TRK and TRD, with Beta measurement with |Z|=1.
Acceptance calculated separately for electrons and antiprotons.



events generated on the top plane



Acceptance formula:

$$\mathrm{Acc}(p) = p_0 \exp \frac{\frac{-x-p_1}{p_2} + \exp\left(\frac{-x-p_1}{p_2}\right)}{2}$$

p_0=0.77
p_1=0.97
p_2=1.14 m^2 sr

Cut on number of hits used in track

- $N_{\text{hits on track}} > 5$
- It does not improve momentum resolution

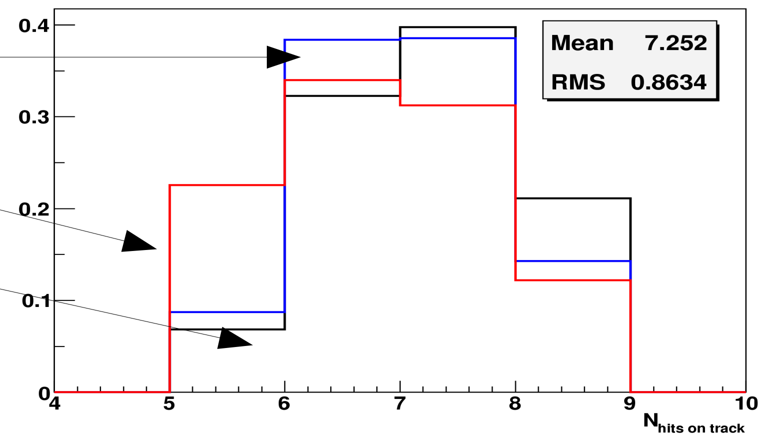
- 5 hits: 6.6% (and 21% of electr
- 6 hits: 32.8%
- 7 hits: 40.2 %
- 8 hits: 20.4 %

- But helps to reject electrons and antiprotons paying low price in efficiency

antiprotons

electrons

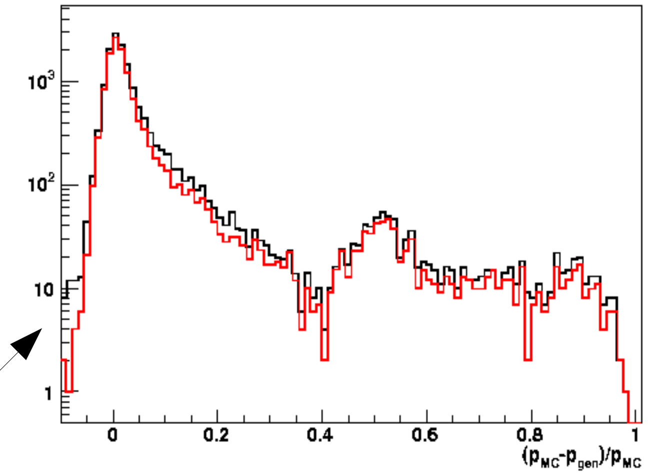
antideuterons



chi² cut

- chi2/ndf < 3.0: 86%

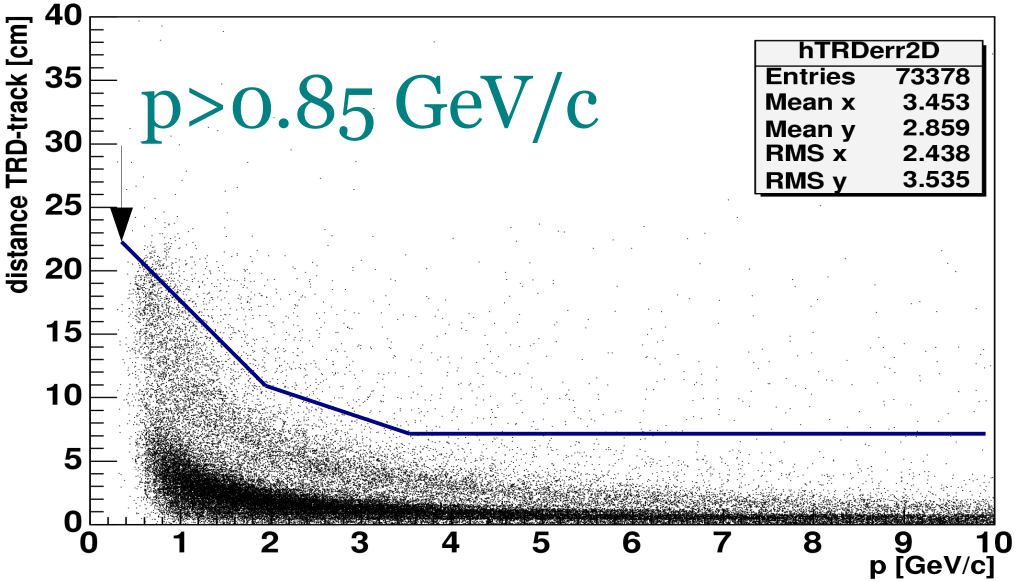
chosen value because efficiency grows slower after chi2/ndf = 3



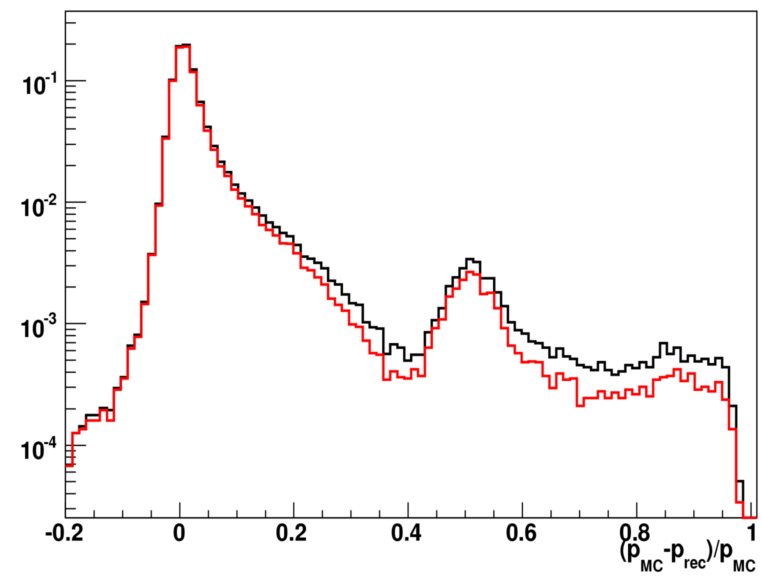
Rejects events with overestimated momentum – helps to reject antiproton background

Distance between TRD track and extrapolation of Particle track

Idea: low momentum particles might loose significant fraction of energy with soft scattering in TRD – reject those which loose the most by cutting the ones which changed direction of motion (TRD vs TRK estimation).



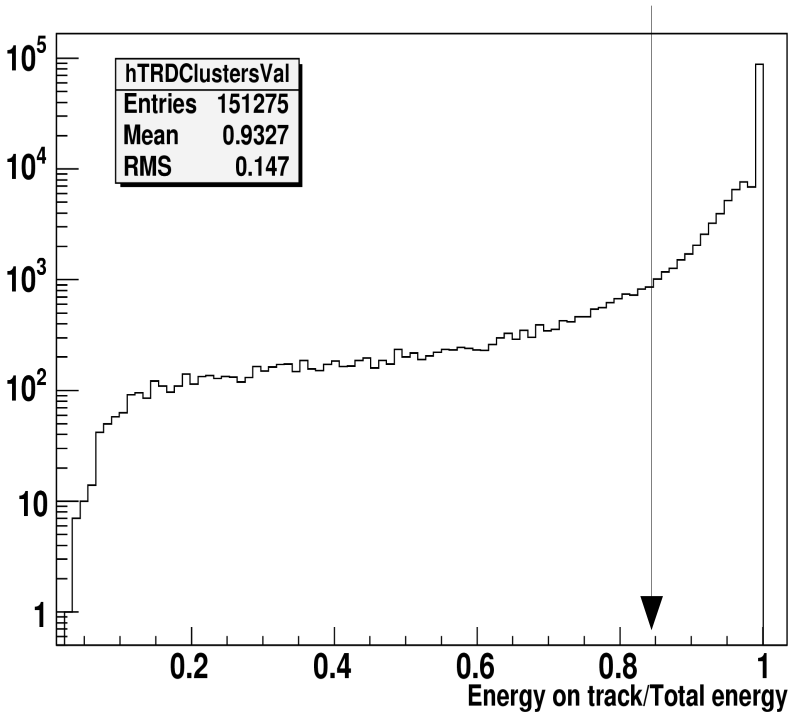
momentum-dependent cut because low-momentum antideuterons are important



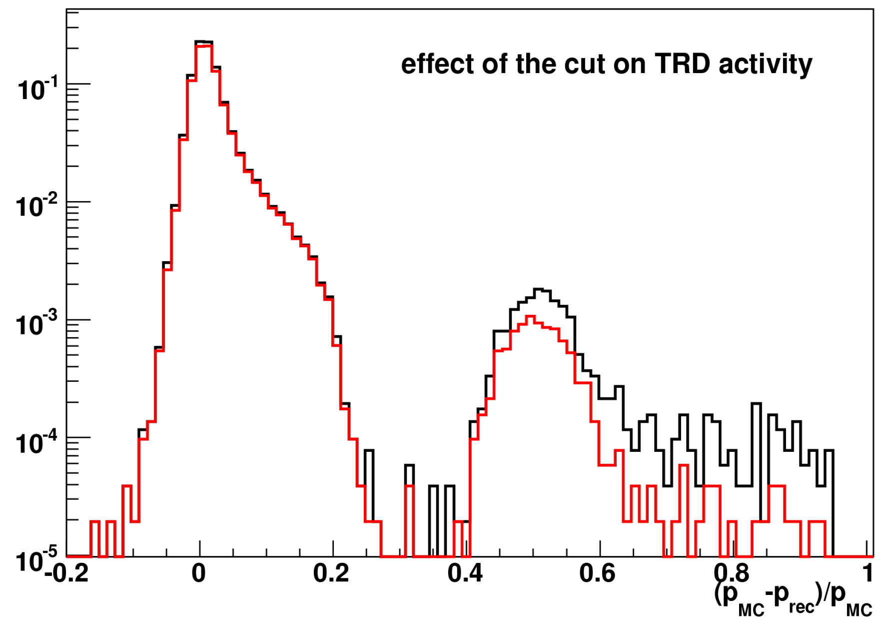
efficiency=0.94

Cut on activity in TRD

Idea: events with too much energy off TRD track should be rejected as the ones where particle interacts strongly in TRD.

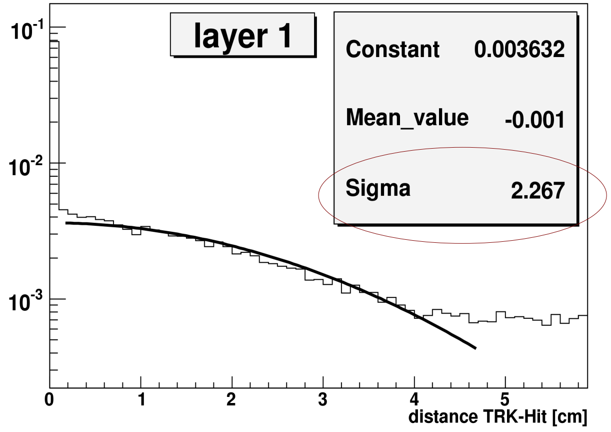


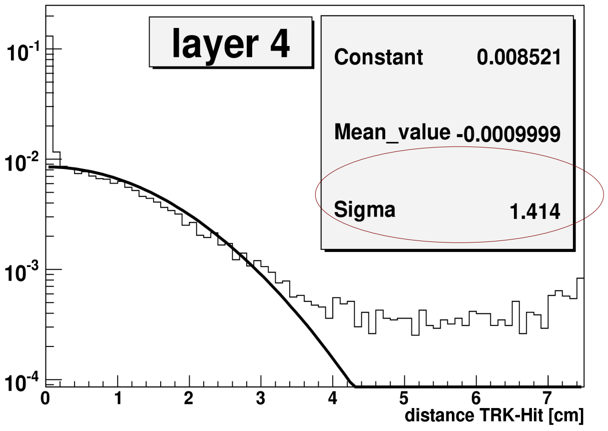
efficiency=0.92

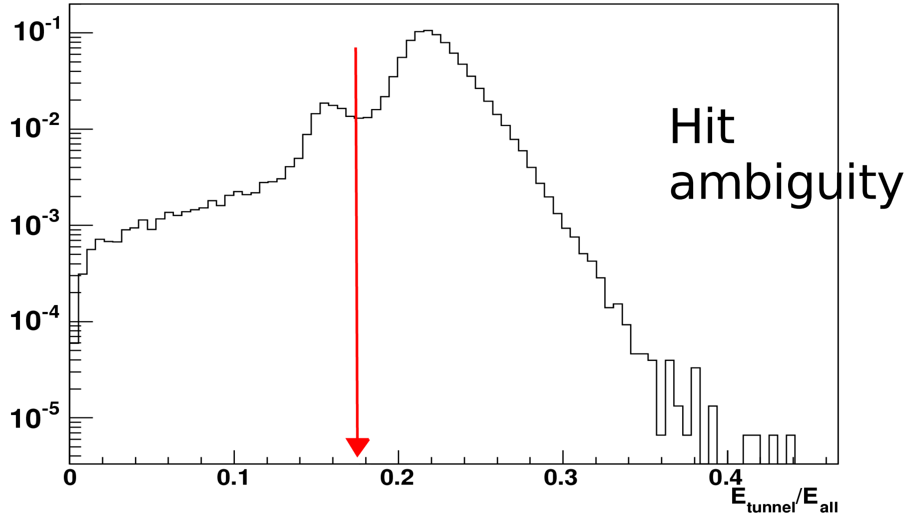


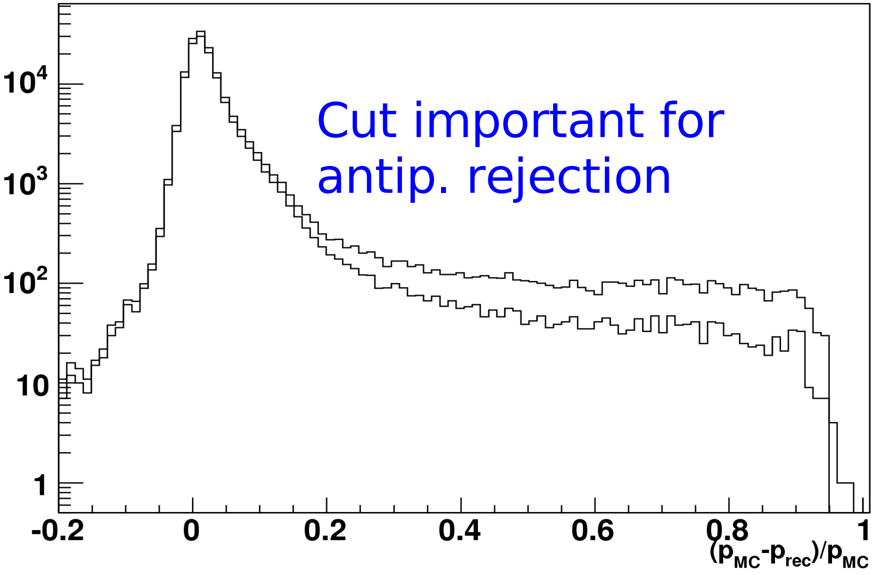
Energy in TRK tunnel

Ratio of energy in a tunnel around the track divided by energy of all clusters in the tracker. Due to clusters ambiguity it is not close to one. The diameter of the tunnel in every layer is chosen to be 2.5σ.





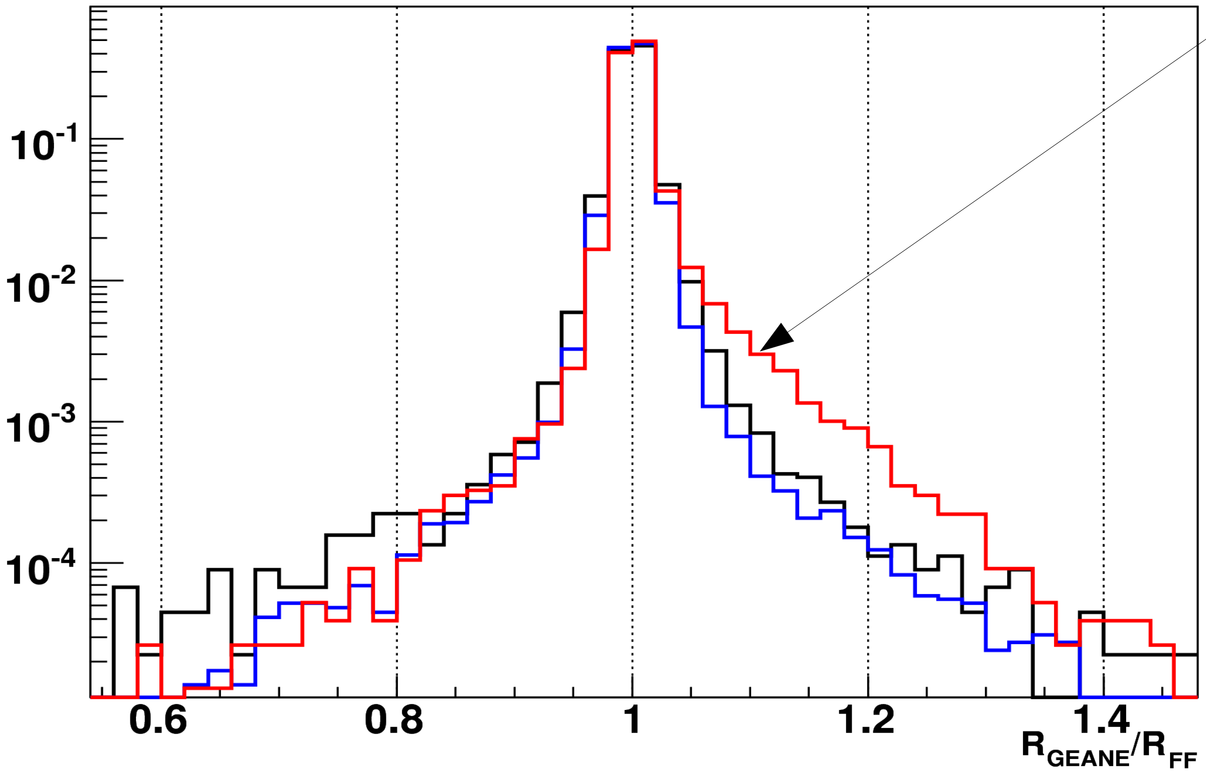




Geane/FastFit rigidity

We need a very precise measurement of momentum, so we ask to have the same momentum measurements from two independent algorithms.

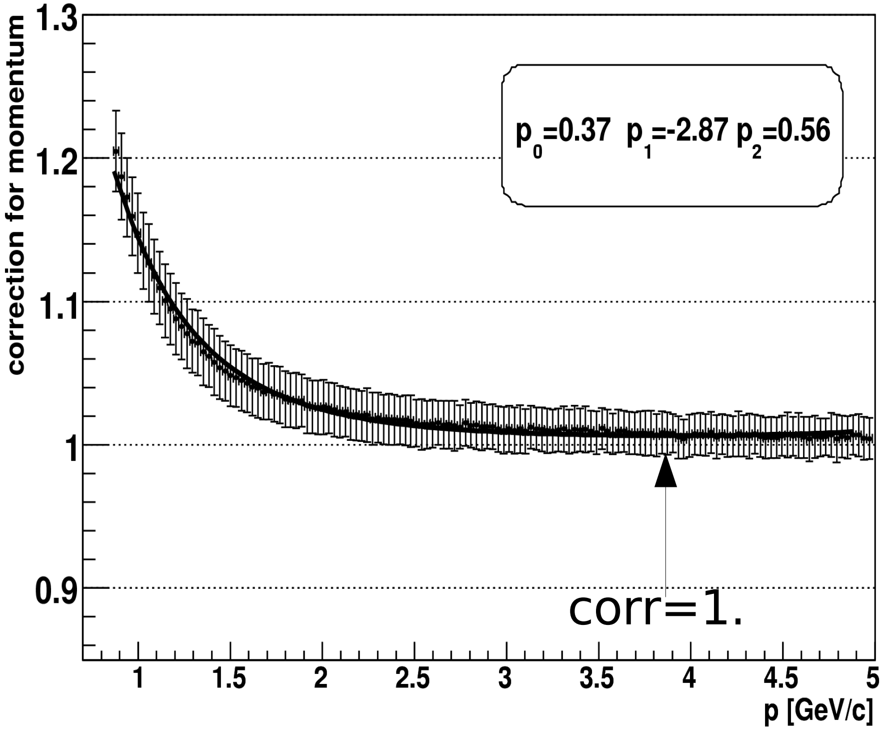
$$0.97 < R_{GEANE}/R_{FF} < 1.03$$



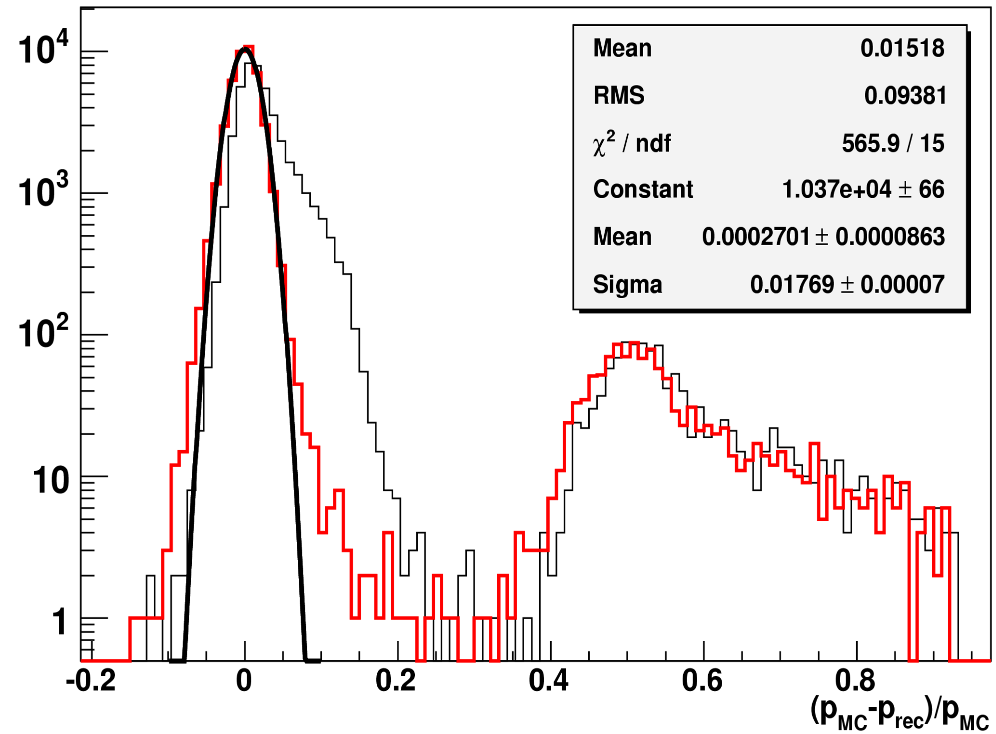
electrons

Efficiency
antideuterons = 0.95

Momentum recalibration



$$\mathrm{corr}(p) = 1 + \exp(p_0 p^2 + p_1 + p_2)$$



Recalibration is not unfolding, it is due to physical processes (multiple scattering) in TRD mainly. It might be important for low momentum particles (TOF branch of analysis).

Velocity measurement

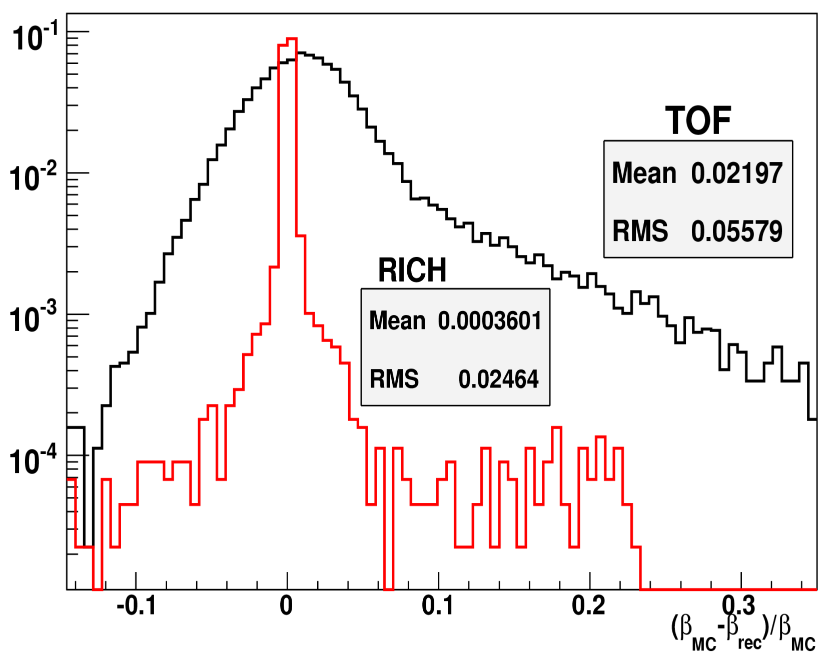
Two possibilities: RICH and TOF

if RICH is accessible and passes cuts, we take RICH
otherwise we take TOF

optimization cuts:

TOF – strong cut $\beta < 0.90$ or lower (0.9 allows to “glue” TOF and RICH branches of analysis)

RICH – cuts suggested by Carlos Delgado + cuts cleaning sample from events interacting in the upstream detectors



26% of events have a RICH Ring

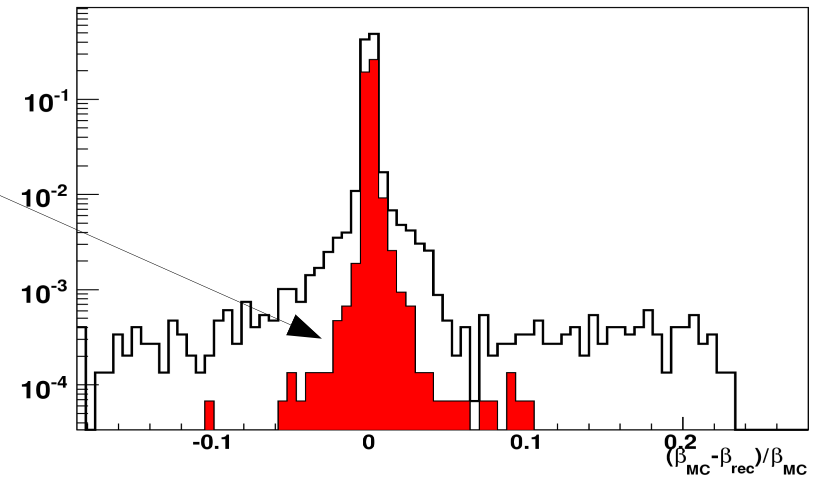
A comparison of beta reconstruction if TOF and in RICH:
TOF has large tail with under-estimated beta while for RICH we must deal with overestimated beta

Optimization on RICH beta

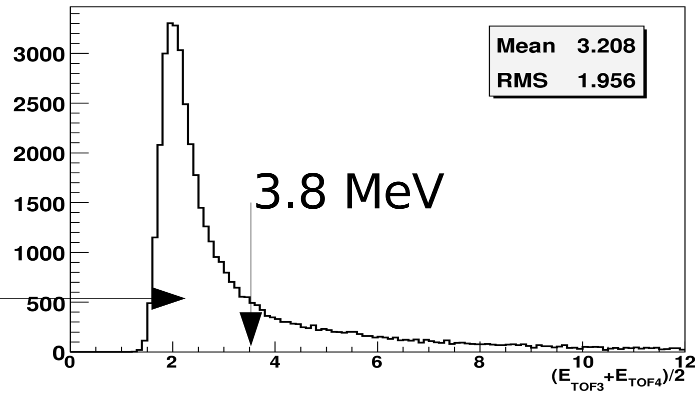
All cuts on RICH together

efficiency=0.841

Carlos Delgado proposition:
1. ring without overlapping particle
2. Z=1 - compatible ring
3. good-shape ring (probability)
4. only one particle crossing the plane with PMTs



Additional cuts:
1. particle entrance point to RICH r<55-60 cm
1. number of reconstructed rings < 3
2. extra TOF cluster not in layers 3/4
3. cut on energy deposit in layers 3/4



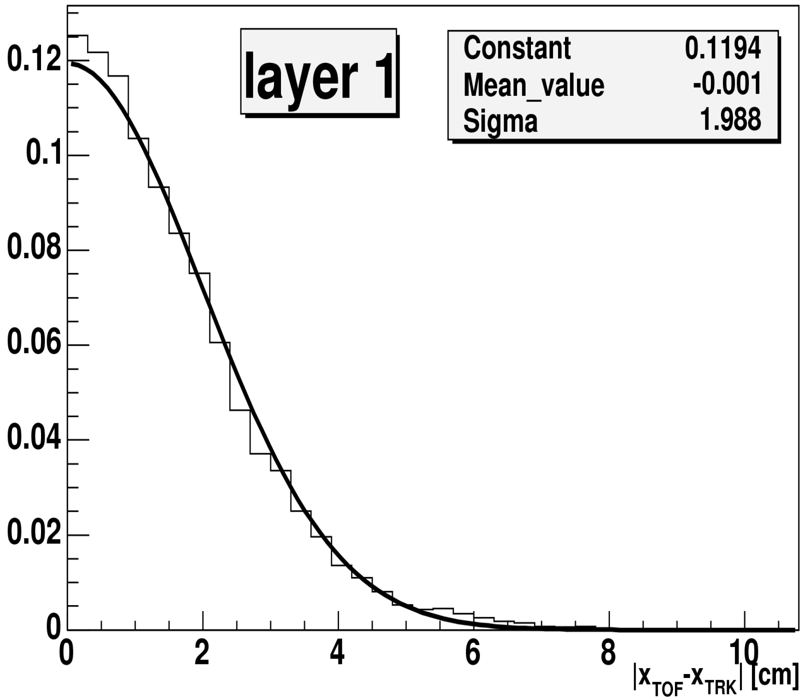
effic=0.75

Optimization on TOF beta

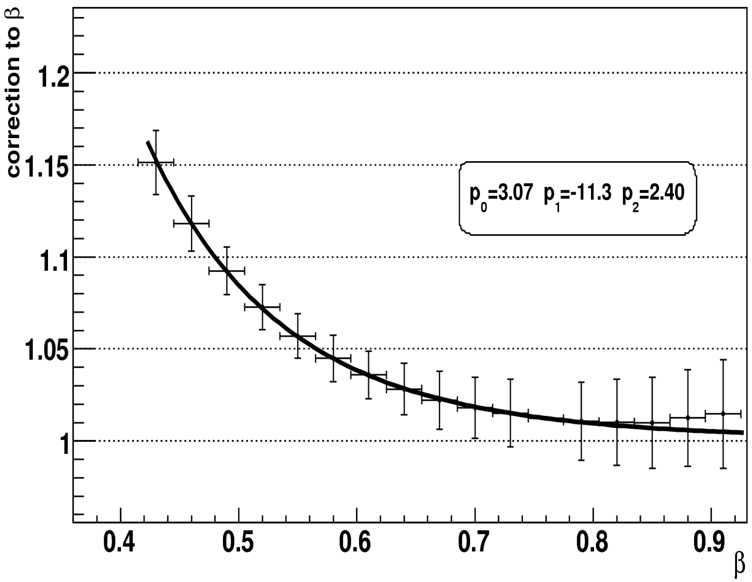
1. TOF planes used for beta reconstruction = 4 ; efficiency= 0.75
2. extra TOF clusters < 2 ; efficiency=0.96
   (one extra cluster allowed because it can be low-energy cluster in TOF layer 1,2)
3. beta < 0.9 (0.87)
4. distance between TOF clusters and TRK extrapolation (2.5 sigma) efficiency=0.88

beta< 0.9 gives about:
2 antideuteron events
150 antiproton events

beta<0.87 gives about:
1 antideutron event
100 antiproton events



Velocity recalibration (in TOF)

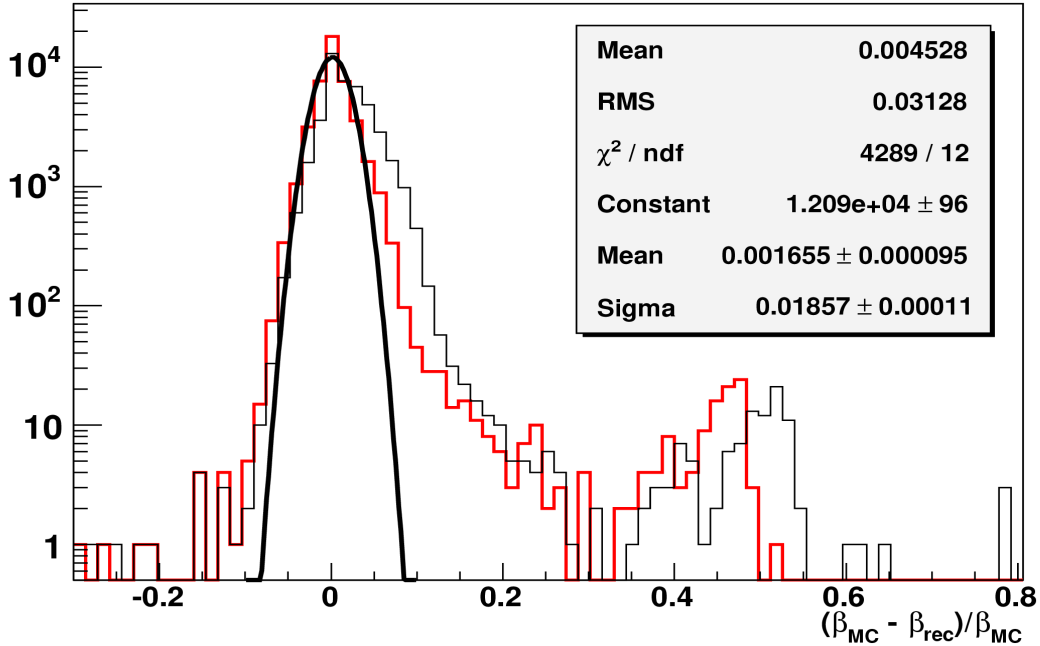


For the same reasons as momentum the velocity in TOF should be recalibrated.

$$\mathrm{corr}(\beta) = 1 + \exp(p_0\beta^2 + p_1\beta + p_2)$$

Beta bins correspond to TOF resolution

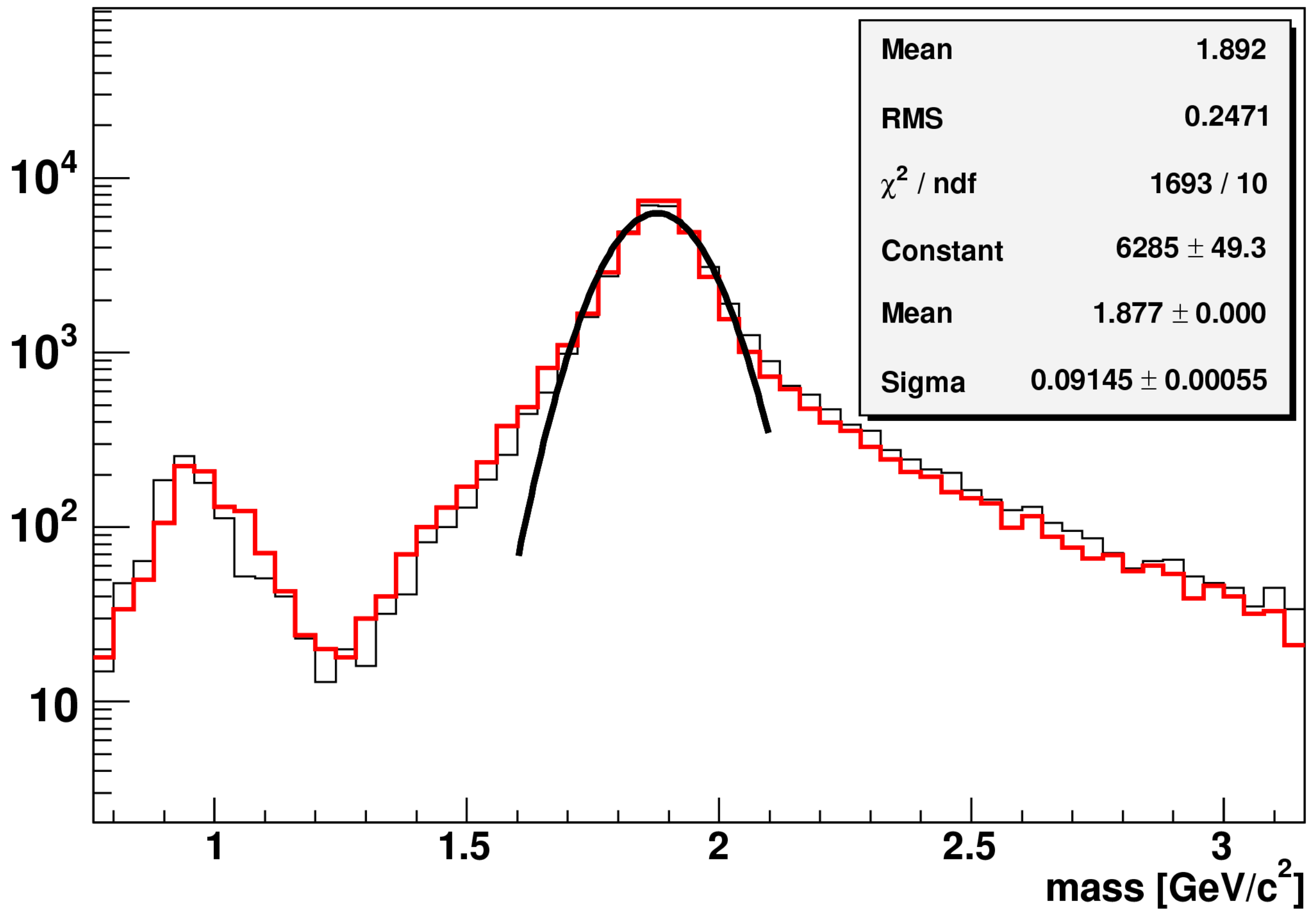
Recalibration with use of deuterons



Effect of the recalibration on mass reconstruction

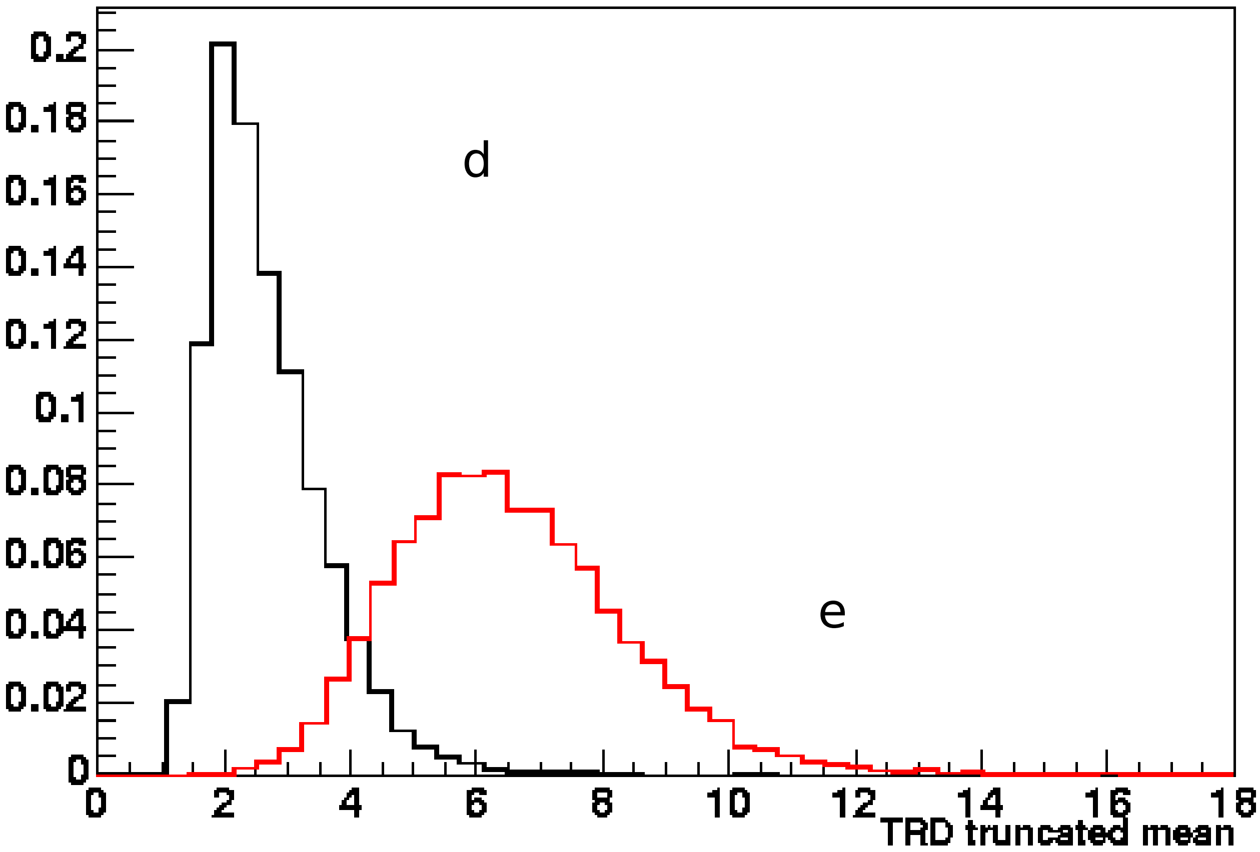
$$m = \frac{p}{\beta}\sqrt{1-\beta^2}$$

Recalibration of momentum and velocity compensates.



No effect on mass resolution, a slight ship of proton peak into higher values. But anyway it is important procedure for low momentum antideuterons.

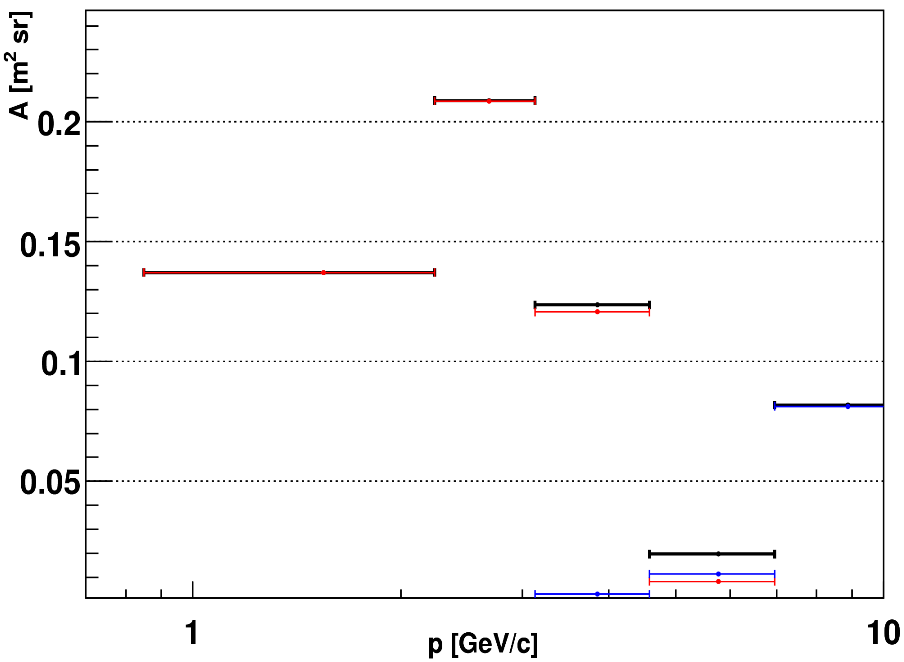
Electron rejection: truncated mean energy



Momentum-dependent cut:
0.85-2 GeV/c: 4.7 MeV
2-3 GeV/c : 4.1 MeV
3-5 GeV/c : 3.3 MeV
> 5 GeV/c : 3.1 MeV

efficiency:
antideuteron - 87%
electron - 4%
(with respect to preselection)

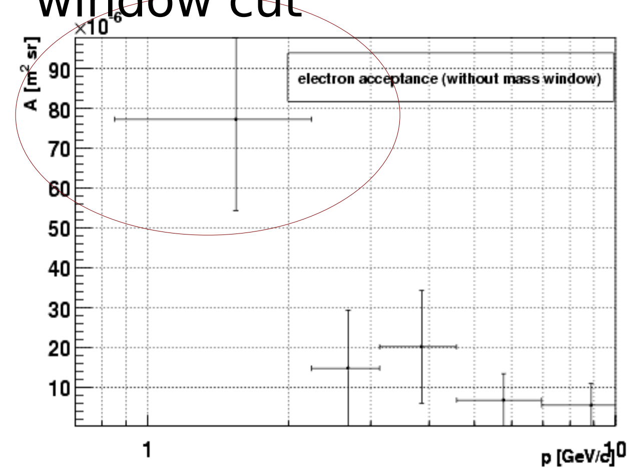
Final acceptance and efficiencies

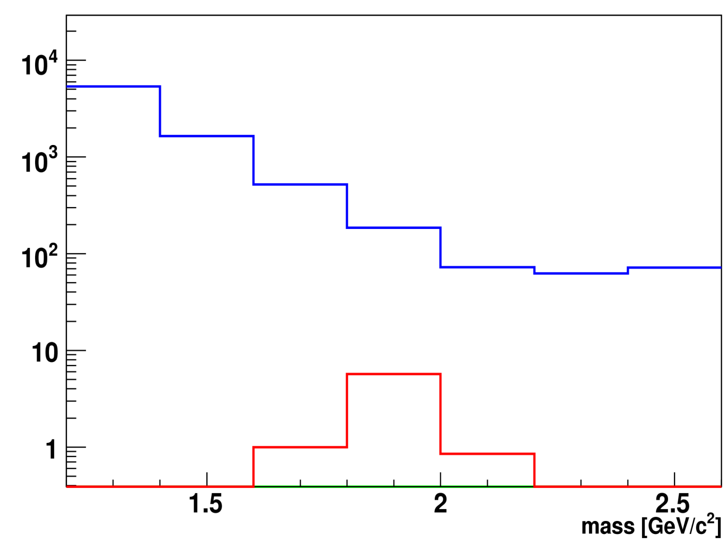


TOF RICH

$\beta = 0.9$ corresponds to $p = 3.8$ GeV/c

This momentum is disfavored by mass window cut





Fluxes on orbit

The geomagentic cutoff for deuterons is:

1. about 6 GeV/c for equatorial region (0<Theta<0.3)
2. about 4 GeV/c for 0.6<Theta<0.7
3. about 0.8 GeV/c for 0.9<Theta<1.0 (Quasi-polar region)

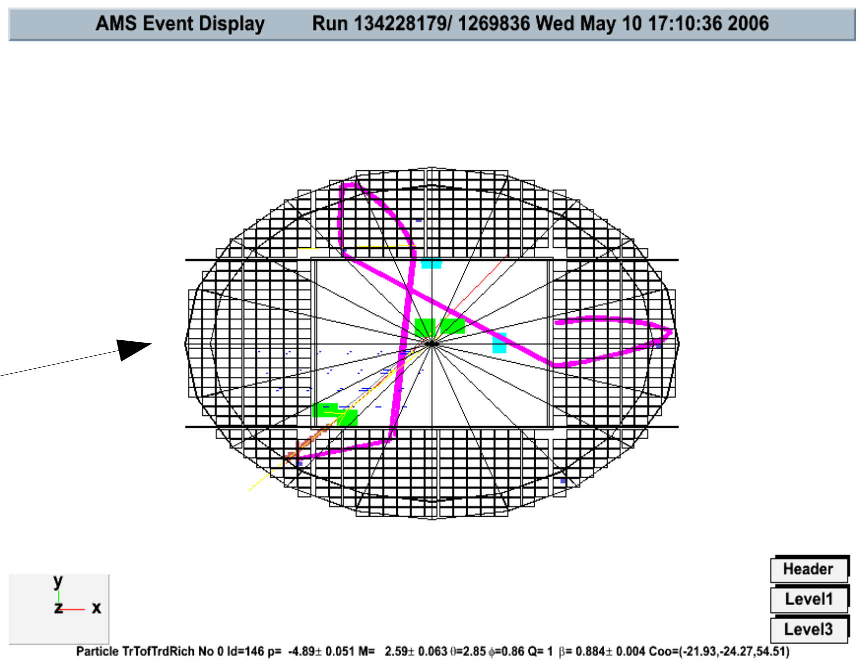
The fluxes in this analysis are taken from BESS measurements (antiprotons), AMS-01 (electrons). Geomagnetic cutoff is included in a approximative way (no flux below the cutoff).
Calculation is done in 5 momentum ranges defined by:
0.85, 2.24, 3.13, 4.58, 6.96,10.8

Numbers of events

$$N=\sum N_i=\sum(\Phi_i A_i \epsilon_i t\, f_g)\, where\ A-acceptance,\ t=3\ years,\ f_g-correction\ for\ geomagnetic\ cutoff$$

Antideuterons: (secondary)	8 (6)	in RICH: 5 (5)
electrons:	< 1000	in RICH: < 100 (lack of stat)
antiprotons:	1000 ± 400 (600)	in RICH: 150 ± 50 (140)

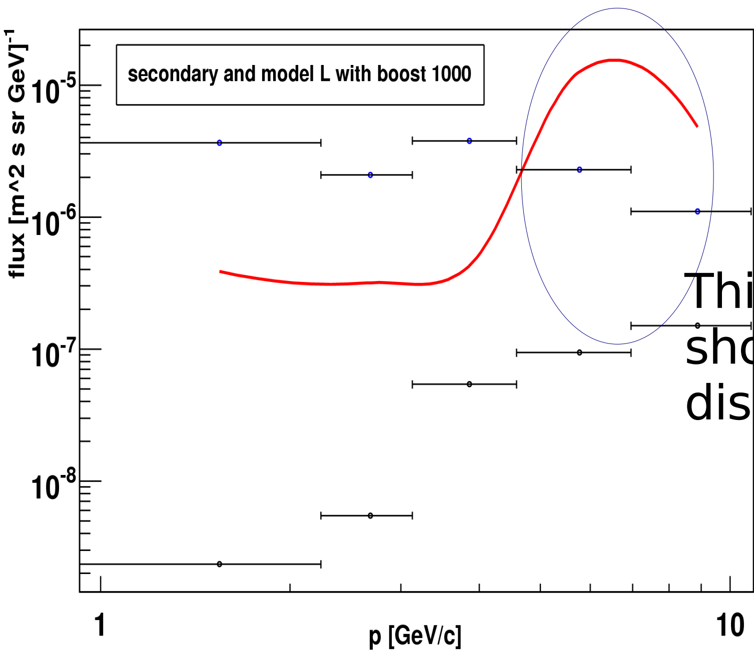
Antiprotons are a subject of further amelioration, there are events which have problems with reconstruction in RICH, for example:



Sensitivity

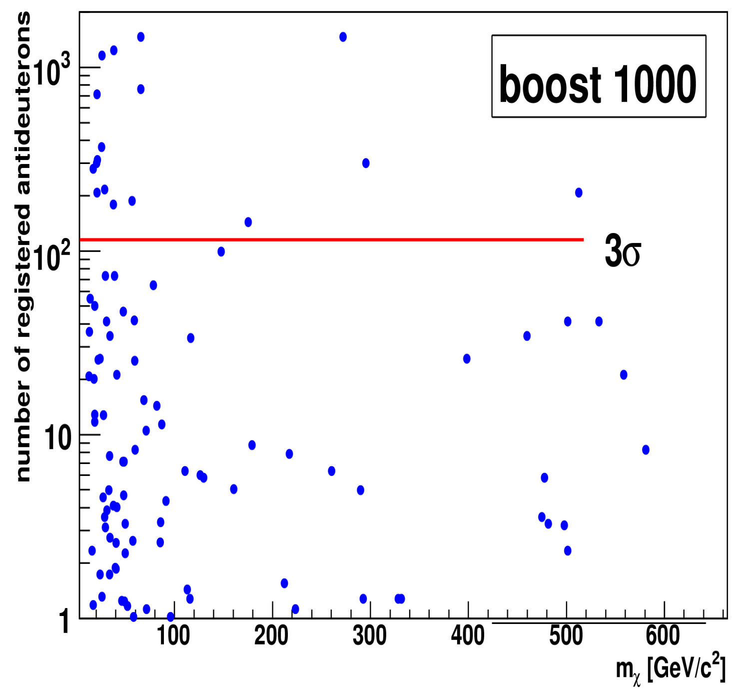
Sensitivity:
$$\mathrm{Sens} = max(3\frac{\sqrt{B}}{A\epsilon t}, \frac{5}{A\epsilon t})$$

model L: m_0=300, $m_{1/2}$ = 450, A_0=0, sign(μ)=1, tgβ=50



This bump should disappear

Simple Sugra wild scan (500 models), DarkSusy 4.1,
m_0: 50-3000 $m_{1/2}$: 50-1600
A_0 : 0.1 – 2000 tgβ: 2 - 60



Model L detectable: 200 deuterons registered (45 in RICH)

Choice of cut on beta

We will not be able to see secondary antideuterons with low momentum.
Q: how much flux from neutralino annihilation should be higher than secondary flux to have S/sq(B) = 3?

Let's assume first bin of momentum only.

$$S = \Phi_{sec} A \epsilon t \qquad S_{dm} = \Phi_{dm} A \epsilon t \qquad B = \Phi_B A_B \epsilon_B t$$

$$\frac{S_{dm}}{\sqrt{B}} = 3 \qquad therefore \qquad \frac{\Phi_{dm}}{\Phi_{sec}} = \frac{S_{dm}}{S} = \frac{3\sqrt{B}}{S}$$

$$if\ \beta < 0.9 \qquad \frac{\Phi_{dm}}{\Phi_{sec}} = 17 \qquad\qquad if\ \beta < 0.87 \qquad \frac{\Phi_{dm}}{\Phi_{sec}} = 30$$

Conclusions

1. there are 8 expected antideuterons from spallation processes and 5 of them will be in RICH channel

these antideuterons probably will not be visible due to antiproton background (there is still a hope for RICH)

2. electron background is below 1000 events (100 in RICH) – we need much more statistics to estimate it better, but there is room for extra/more efficient cuts

3. antiproton background in TOF is about 450 and in RICH 150 events. In addition many of these events have badly reconstructed rings in RICH so it is a reducible backgoround. Also further reduction in TOF possible with stronger cut on β, but this cut should be tuned to get the best sensitivity.

4. antideuterons from neutralino annihilation will not be visible unless there is a large boost factor (> 100).