SEARCHING FOR ANTIDEUTERONS

STATUS OF THE DBAR ANALYSIS STARTING IN BOLOGNA

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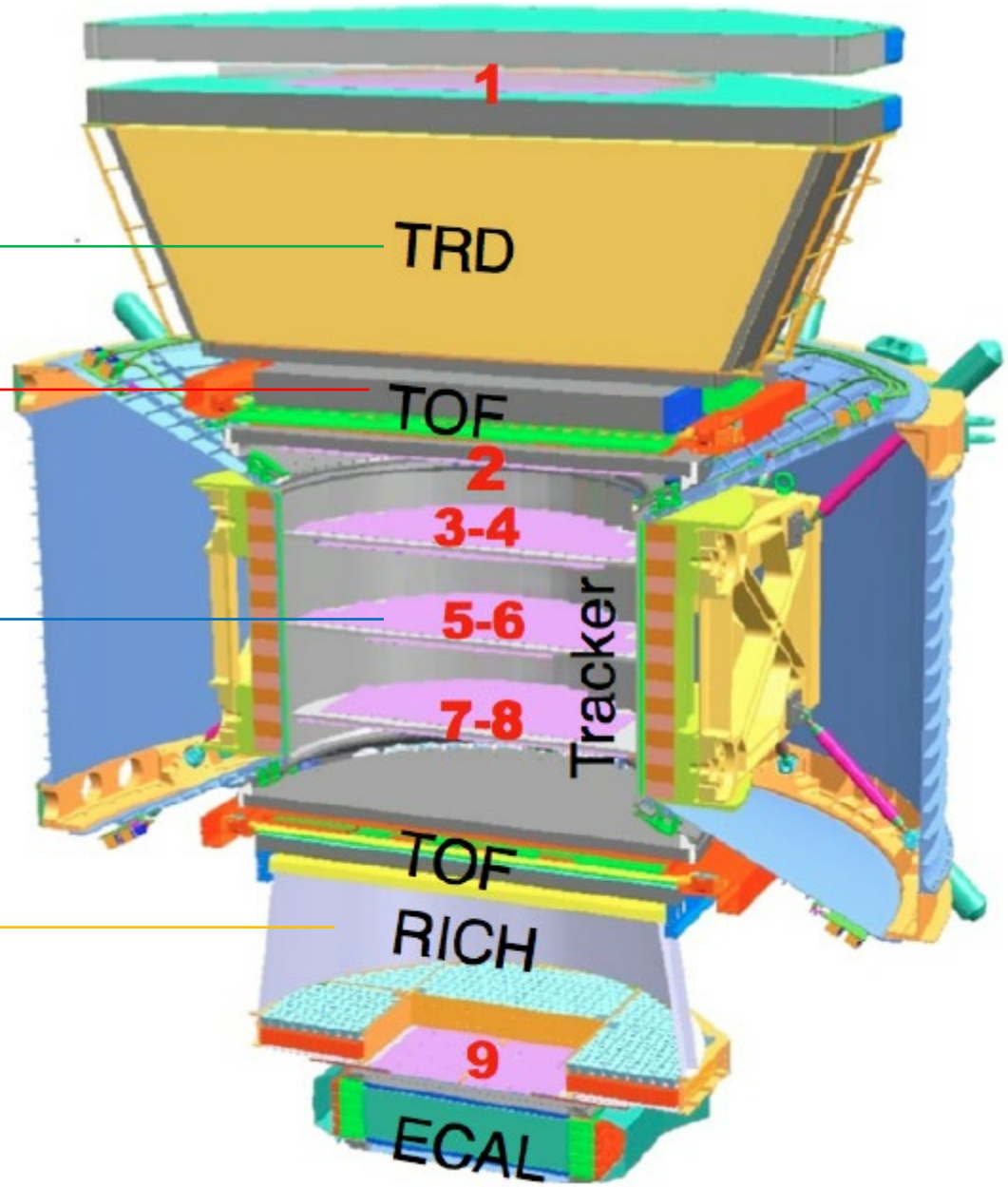
To search for antideuterons in the AMS-02 data are needed:

TRD to identify particle produced in the interaction with the detector

TOF for the beta and charge reconstruction reconstruction

Inner Tracker (IT) for the rigidity and charge reconstruction

RICH NaF & RICH aerogel for the beta reconstruction



SKIMMING

Each event is judged according to a skimming selection:

- IsPhysicsTrigger

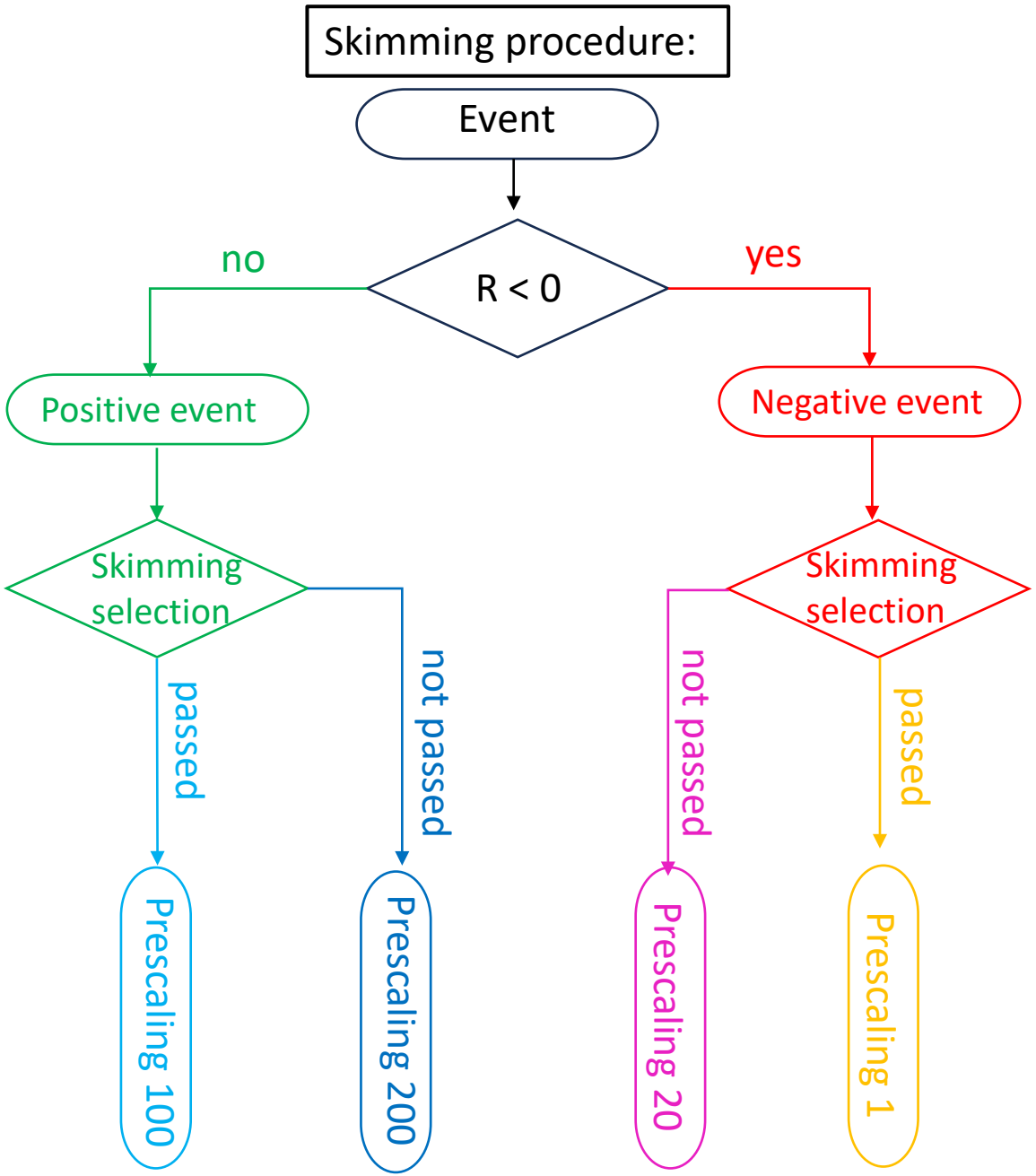
- TOF: N° Beta-Clusters = 4
- TOF: $\chi^2_{coo} < 4$

- IT: PatternY L2 && (L3 || L4) && (L5 || L6) && (L7 || L8)
- IT: $\chi^2_Y < 10$
- IT: $\frac{\sigma_Z}{Z} < 0.1$

- TRD (Z < 1.5): N° Hits OnTrack > 10

The events are stored according to different prescaling factor (1 event on X events is stored) if they positives or negatives and if they pass or don't pass the selection.

If the skimming selection is looser than the standard selection used in the analysis, all the events are prescaled by a factor of 1 (negatives) and 100 (positives). These two factors represent a "**skimming resolution**" (a sort of background limit in the plots).



SKIMMING

A new skimming has been done.

Around **114000 ntuples** in */storage/gpfs_ams/ams/groups/AMS-Italy/ntuples/v1.1.0/ISS.B1236/pass8/* have been skimmed (from *1305853512.root* to *1452417893.root*).

Each ntupla is around **4 GB** and a total storage of **450 TB** is estimated.

Each skimmed ntupla is around **100 MB** and a total storage of **8 TB** is obtained -> Expected **20 TB** for the complete production.

The skimming has reduced the storage of a factor around **55**. (Can I proceed for the complete production skimming? Are the CNAF storage problem solved?)

MASS SAMPLE DEFINITION

16 samples in mass in the TOF, NaF and agl analysis ranges have been defined using:

- Rigidity -> GBL (InnerTracker)
- Charge -> InnerTracker
- 0.3 < β < 0.9 (TOF); 0.75 < β < 0.99 (NaF); 0.95 < β < 1 (agl)

MASS SAMPLES have been used to discriminate between "bad (too high or too low mass)" and "good (correct mass)" events:

$$\frac{\sigma_m}{m} = \frac{\Delta R}{R} \oplus \frac{1}{(1-\beta^2)}\frac{\Delta\beta}{\beta}$$

Assuming: $\frac{\Delta R}{R} \cong 0.1$ for R < 100 GeV

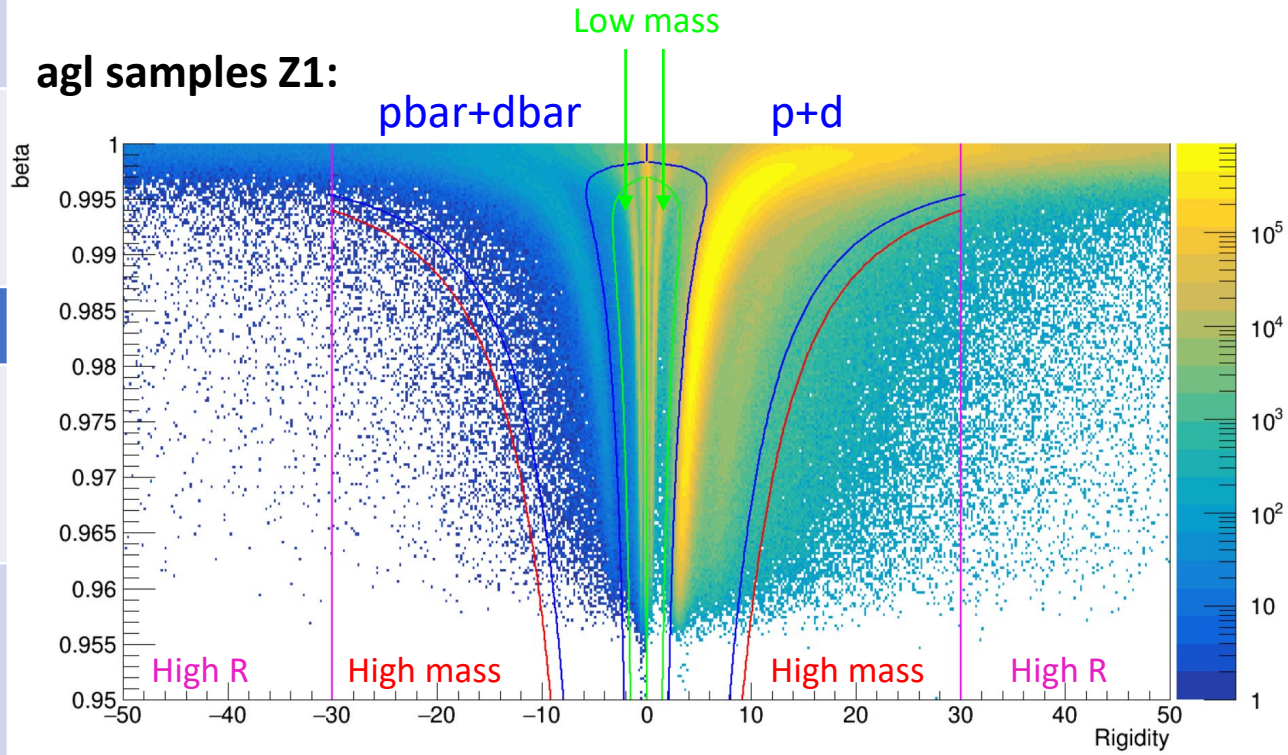
$\Delta\beta \cong 0.04$ at β = 1 and Z=1 (TOF)

$\Delta\beta \cong 0.004$ at β = 1 and Z=1 (NaF)

$\Delta\beta \cong 0.001$ at β = 1 and Z=1 (agl)

	POSITIVES
Z = 1	Low mass Z=+1: m < mp $(1 - 5\sigma_m)$ & R < 30 GV p+d: mp $(1 - 3\sigma_m)$ < m < md$(1 + 3\sigma_m)$ & R < 30 GV High mass Z=+1: m > md $(1 + 5\sigma_m)$ & R < 30 GV High Rigidity Z=+1: R > 30 GV
Z = 2	Low mass Z=+2: m < m3he $(1 - 5\sigma_m)$ & R < 30 GV He: m3he $(1 - 3\sigma_m)$ < m < m4he $(1 + 3\sigma_m)$ & R < 30 GV High mass Z=+2: m > m4he $(1 + 5\sigma_m)$ & R < 30 GV High Rigidity Z=+2: R > 30 GV
	NEGATIVES
Z=-1	Low mass Z=-1: m < mp $(1 - 5\sigma_m)$ & R > -30 GV pbar+dbar: mp $(1 - 3\sigma_m)$ < m < md $(1 + 3\sigma_m)$ & R > -30 GV High mass Z=-1: m > md $(1 + 5\sigma_m)$ & R > -30 GV High Rigidity Z=-1: R < -30 GV
Z=-2	Low mass Z=-2: m < m3he $(1 - 5\sigma_m)$ & R > -30 GV Hebar: m3he $(1 - 3\sigma_m)$ < m < m4he $(1 + 3\sigma_m)$ & R > -30 GV High mass Z=-2: m > m4he $(1 + 5\sigma_m)$ & R > -30 GV High Rigidity Z=-2: R < -30 GV

agl samples Z1:



FIRST LEVEL STANDARD SELECTION

The first level selection is defined by basic cuts that allow to use the various detectors for the reconstruction of the event.

FIRST LEVEL

TOF:

- Nhits TOF = 4
- $\chi^2_{Coo} < 4$

TRD:

- Nhits (OnTrack) > 10

RICH (NaF and agl ranges):

- HasRICHdata
- RingGeomTest
- KolmogorovProb > 0.01
- NHitsUsed > 2
- NRingPMTs > 2

Inner Tracker (L2 to L8):

- PATTERN Y L2 & (L3 || L4) & (L5 || L6) & (L7 || L8)
- $\chi^2_Y < 10$
- $\frac{\sigma_Z}{Z} < 0.1$

- Physics trigger ON

SECOND LEVEL STANDARD SELECTION

The second level selection has been defined on top of the first level selection as a range-focused selection to clean the samples in the various analysis ranges. All the variables have been assumed to be **independent** between each other and have been looked with a procedure defined in the next slides.

FIRST LEVEL

TOF:
- Nhits TOF = 4
- $\chi^2_{Coo} < 4$

TRD:
- Nhits (OnTrack) > 10

RICH (NaF and agl ranges):
- HasRICHdata
- RingGeomTest
- KolmogorovProb > 0.01
- NHitsUsed > 2
- NRingPMTs > 2

Inner Tracker (L2 to L8):
- PATTERN Y L2 & (L3 || L4) & (L5 || L6) & (L7 || L8)
- $\chi^2_Y < 10$
- $\frac{\sigma_Z}{Z} < 0.1$

- Physics trigger ON

SECOND LEVEL

TOF range:
- $\frac{|Z_{utof} - Z_{ltof}|}{Z_{utof}} < 0.2$ (for Z = 1)
- $\frac{|Z_{utof} - Z_{ltof}|}{Z_{utof}} < 0.1$ (for Z = 2)

RICH (NaF):
- *TOF-RICH Beta Asymmetry < 0.1*

RICH(agl)
- PhotoElMeas/PhotoElExpected < 3 (Z = 1)
- 1.5 < PhotoElMeas/PhotoElExpected < 7 (Z = 2)

FINAL STANDARD SELECTION

Searching for antideuterons requires reaching the antiproton peak before. To fulfill this condition, *new variables* have been studied on top of the second level selection, assumed **independent** between each other.
The final selection obtained is:

TOF:
- Nhits TOF = 4
- $\chi^2_{Coo} < 4$
- *NTotalClusters (OnTime + OffTime – BetaClusters) < 2*

TRD:
- Nhits (OnTrack) > 10
- *LikelihoodRatio e/p > 0.8 (for Z = 1)*
- *LikelihoodRatio p/He < 0.3 (for Z=1)*
- *LikelihoodRatio p/He > 0.3 (for Z=2)*

Inner Tracker (L2 to L8):
- PATTERN Y L2 & (L3 || L4) & (L5 || L6) & (L7 || L8)
- $\chi^2_Y < 10$
- $\frac{\sigma_Z}{Z} < 0.1$
- *NHitsXY > 3 && NHitsY > 5*

- Physics trigger ON

All-Ranges selection

Range-focused selection

TOF (TOF range):
- $\frac{|Z_{utof} - Z_{ltof}|}{Z_{utof}} < 0.2$ (for Z = 1)
- $\frac{|Z_{utof} - Z_{ltof}|}{Z_{utof}} < 0.1$ (for Z = 2)

RICH (NaF and agl range):
- HasRICHdata
- RingGeomTest
- KolmogorovProb > 0.01
- NHitsUsed > 2
- NRingPMTs > 2

RICH (NaF range):
- *TOF-RICH Beta Asymmetry < 0.1*

RICH(agl range)
- PhotoElMeas/PhotoElExpected < 3 (Z = 1)
- 1.5 < PhotoElMeas/PhotoElExpected < 7 (Z = 2)

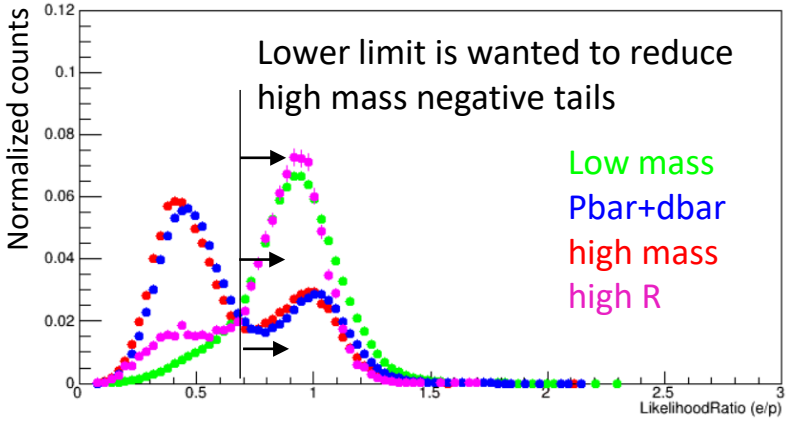
LOOK-UP VARIABLES PROCEDURE

1. To define the selection described before some variable distributions **(assumed independent)** have been looked in the different mass samples, identifying the ones with a high discrimination power.

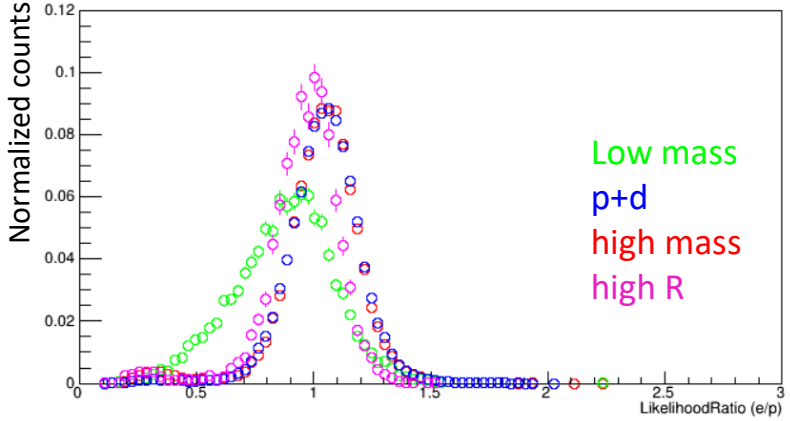
agl range: 0.97 < β < 0.98
TRD LikelihoodRatio e/p

Example:

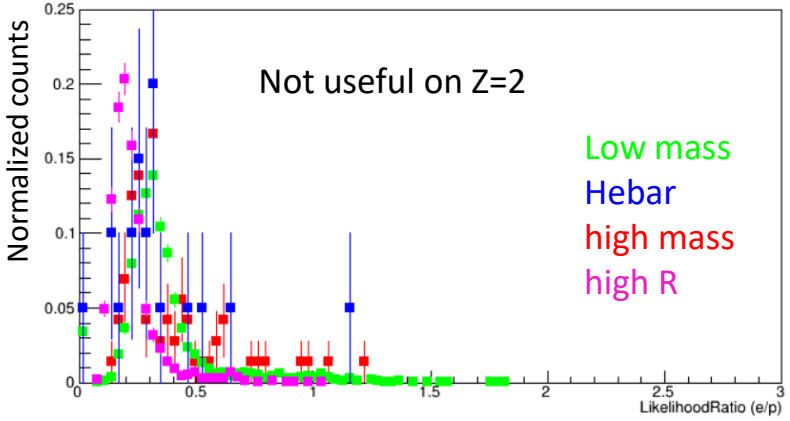
Z = -1



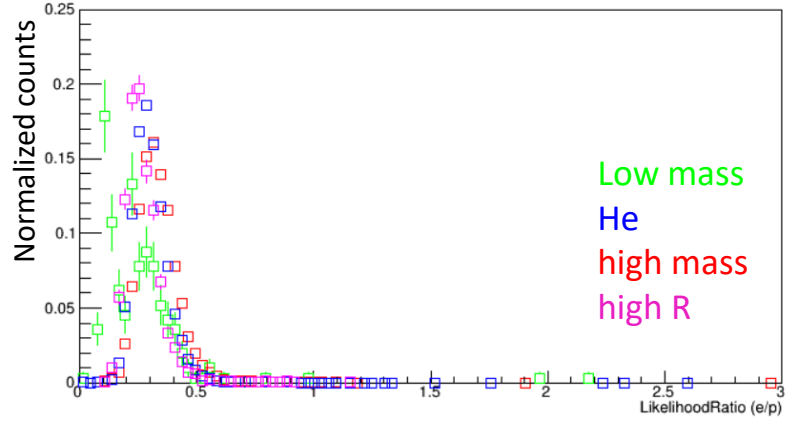
Z = +1



Z = -2



Z = +2



Cut applied (second level selection):

TOF:

- Nhits TOF = 4
- $\chi^2_{Coo} < 4$

RICH:

- HasRICHdata
- RingGeomTest
- NHitsUsed > 2
- NRingPMTs > 2
- RICH(agl range)
- PhotoElMeas/PhotoElExpected < 3 (Z = 1)
- 1.5 < PhotoElMeas/PhotoElExpected < 7 (Z = 2)

TRD:

- Nhits (OnTrack) > 10 (for Z = 1)

Inner Tracker (L2 to L8):

- PATTERN Y L2 & (L3 || L4) & (L5 || L6) & (L7 || L8)
- $\chi^2_Y < 10$
- $\frac{\sigma_Z}{Z} < 0.1$

- Physics trigger ON

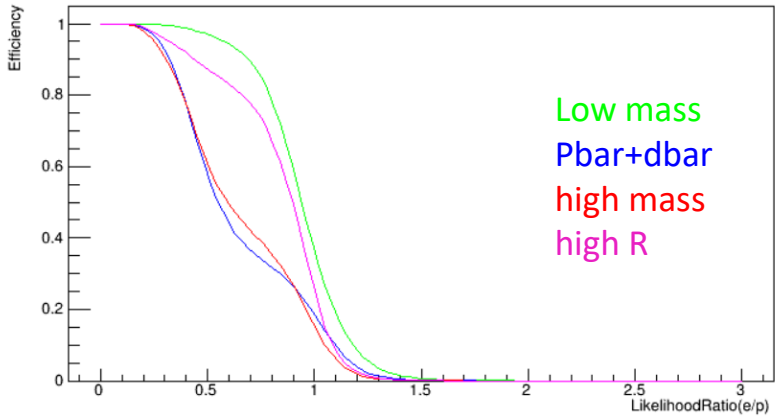
STANDARD SELECTION DEFINITION

2. The interested variable has been treated as a cut variable and the x-axis values are the cut values used as an upper or lower limit. The efficiencies and the rejections have been calculated as a function of the cut value.

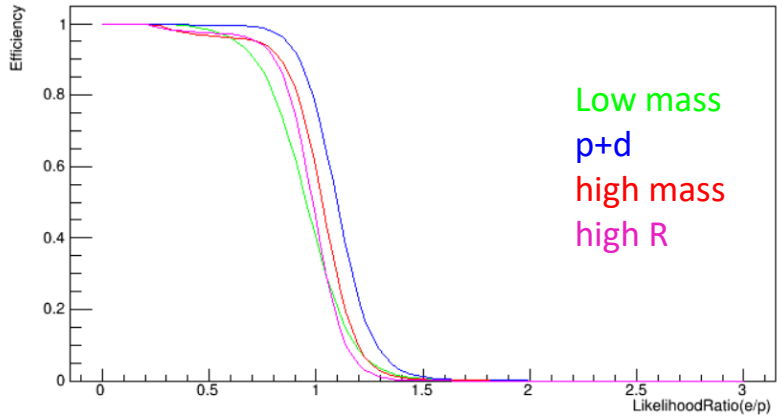
Example:

agl range: 0.97 < β < 0.98
TRD LikelihoodRatio e/p

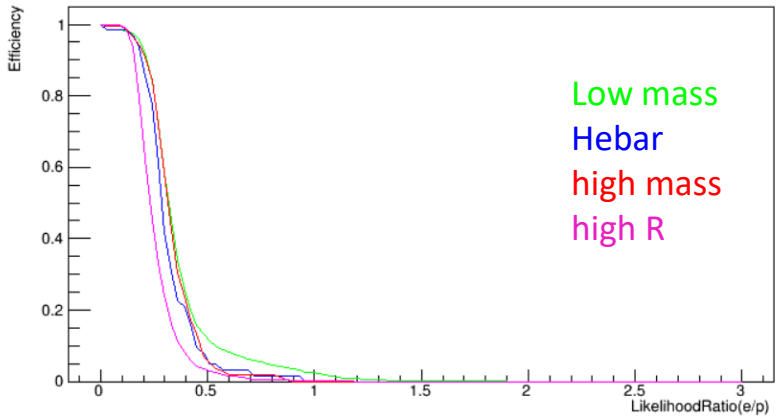
Z = -1



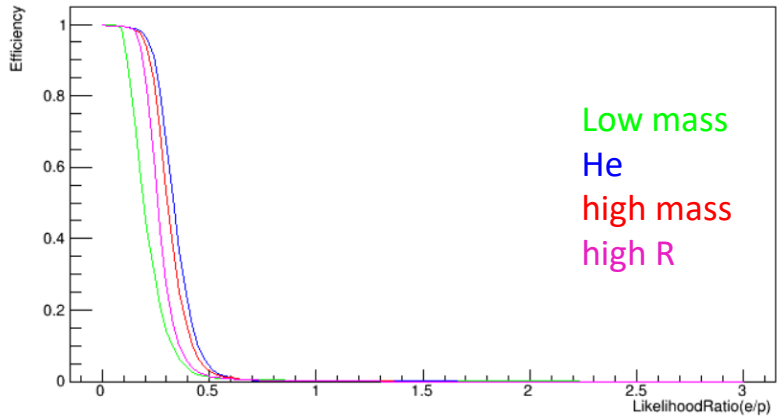
Z = +1



Z = -2



Z = +2



Lower limit cut:

$$efficiency = \frac{\#events\ (variable > x)}{\#total\ events}$$

Upper limit cut:

$$efficiency = \frac{\#events\ (variable < x)}{\#total\ events}$$

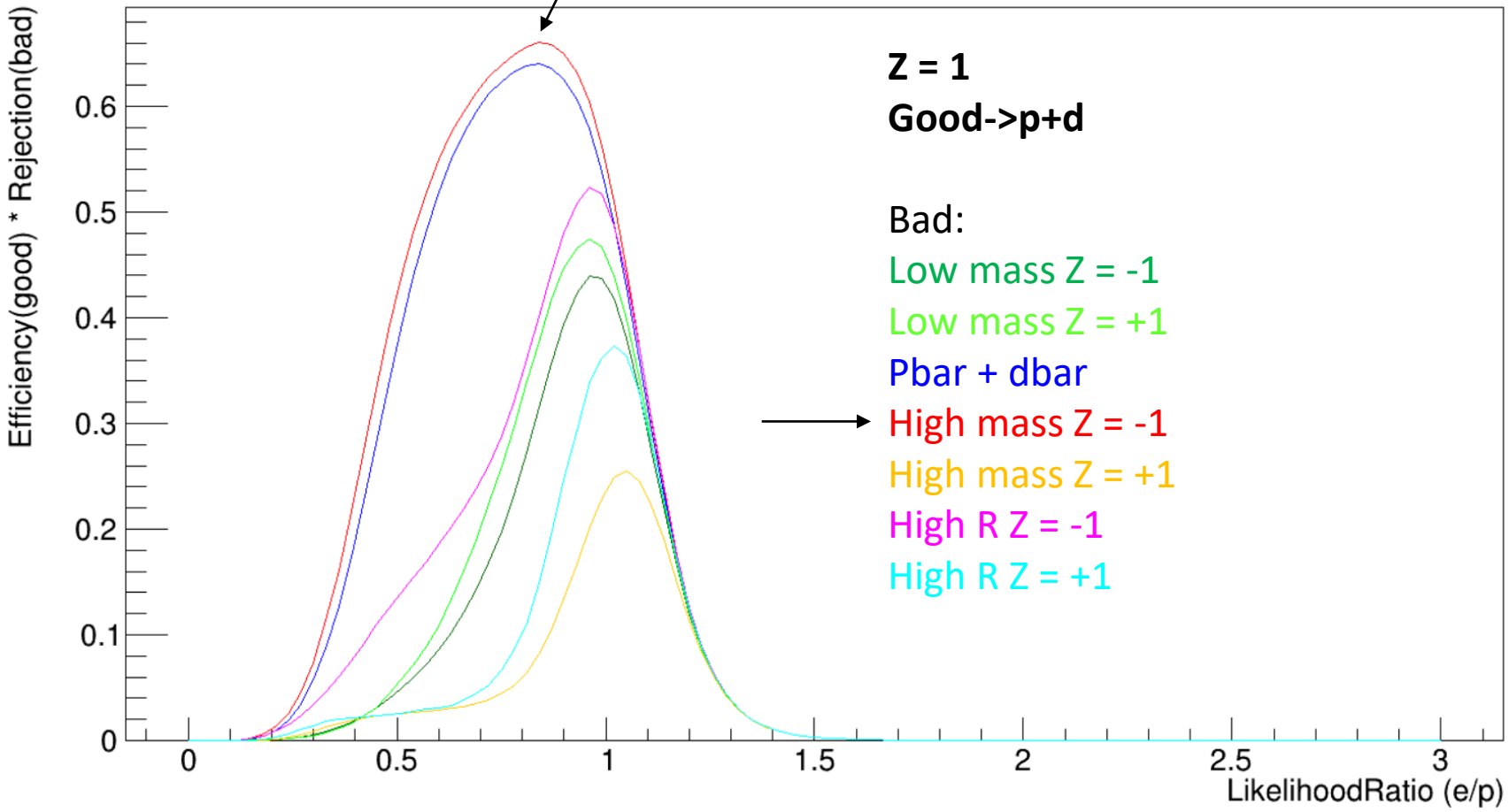
$$rejection = 1 - efficiency$$

STANDARD SELECTION DEFINITION

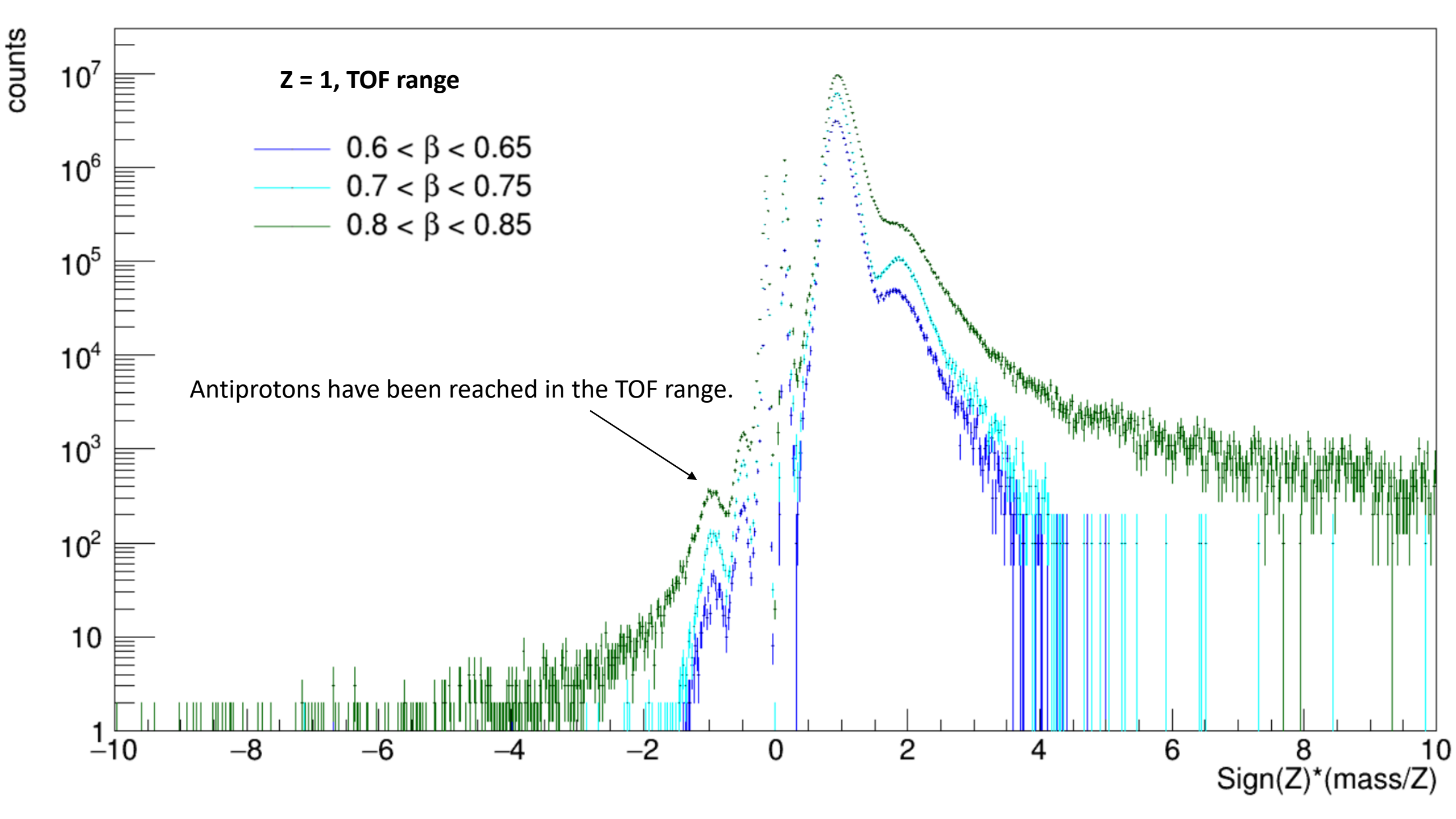
3. The cut value for the selection has been chosen as the value that maximize the rejection of a bad sample times the efficiency of a good sample (protons for Z=1 and heliums for Z=2)

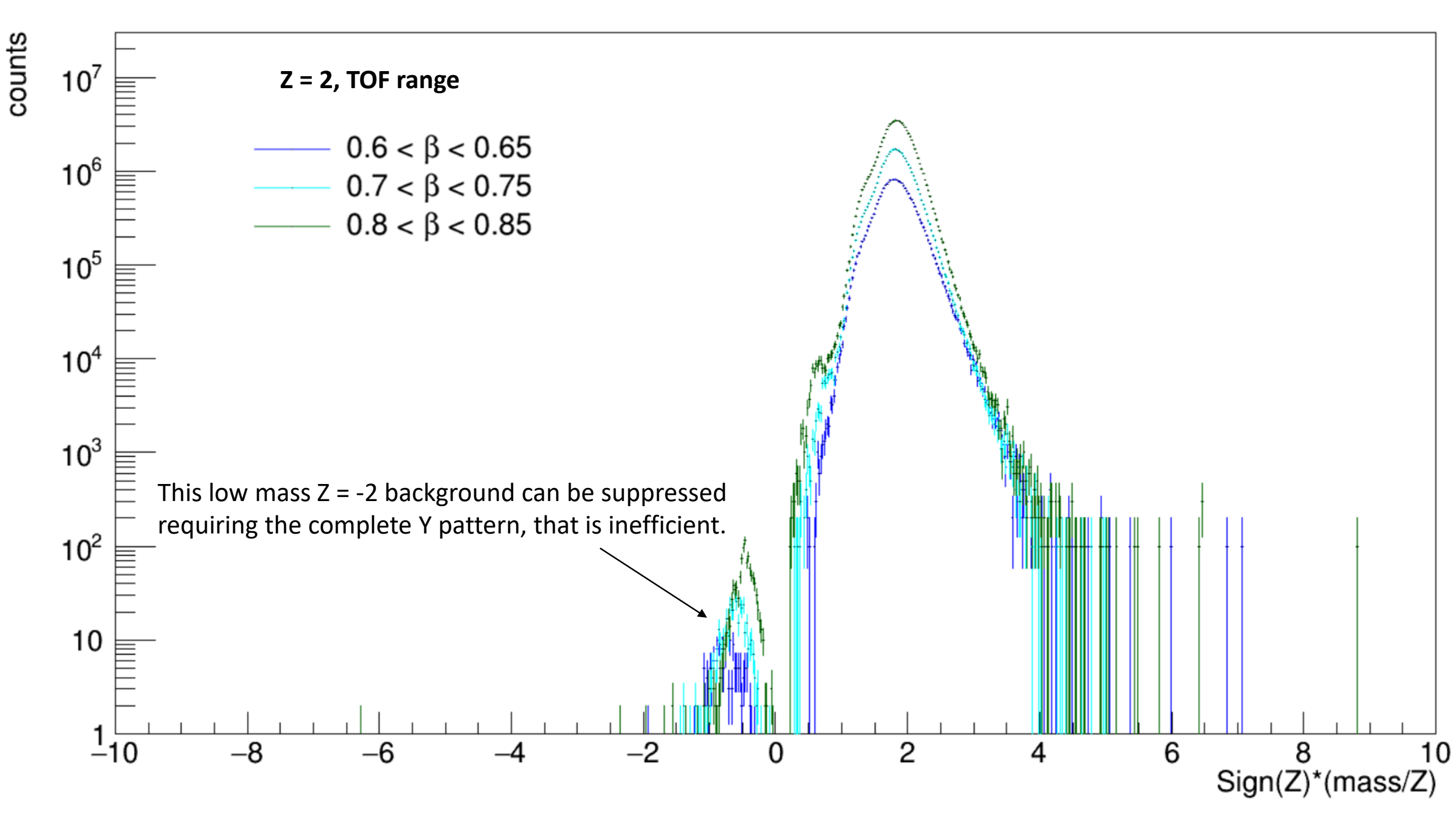
Example:

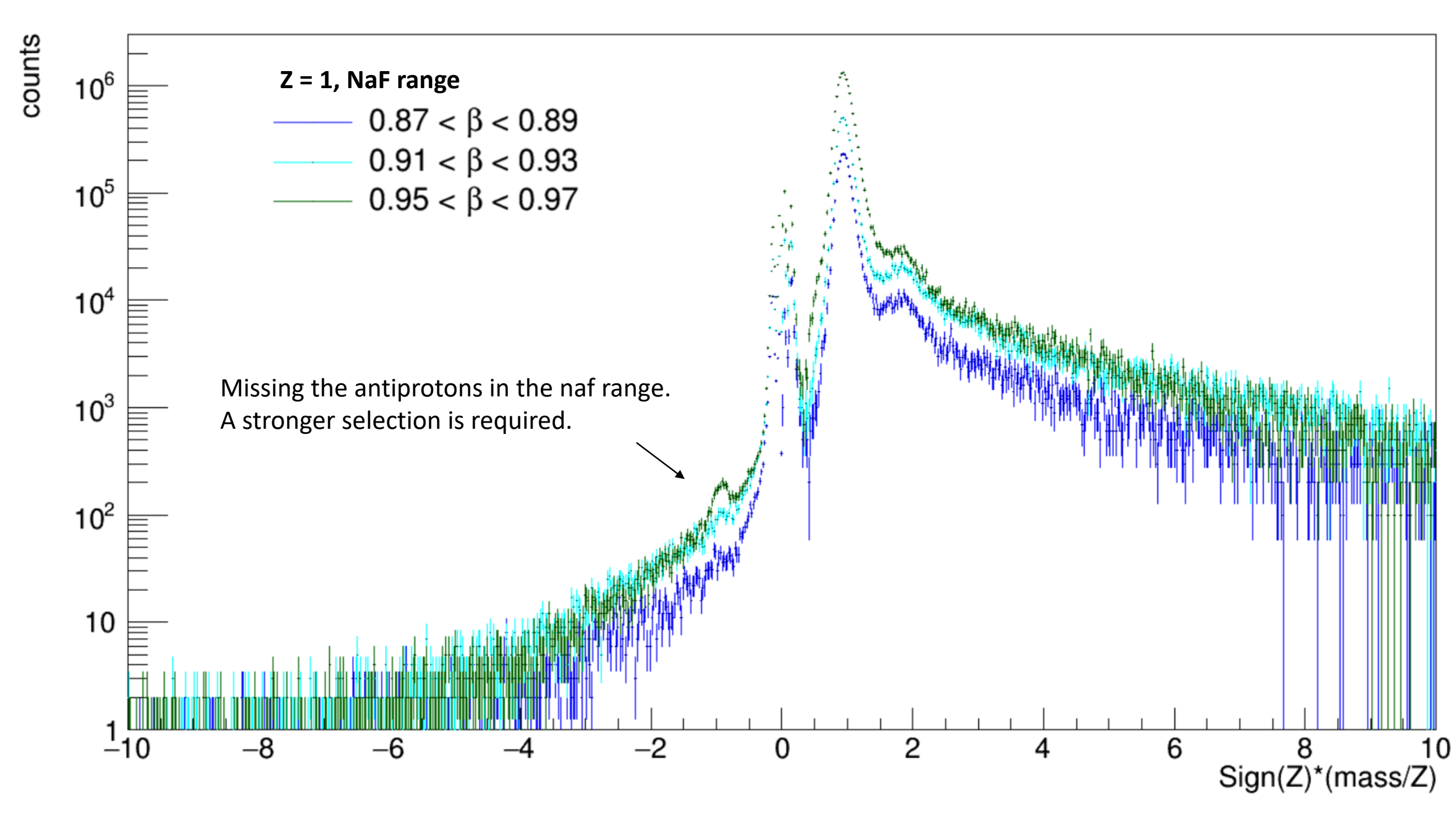
Z = 1 agl cut value: LikelihoodRatio(e/p) > 0.8

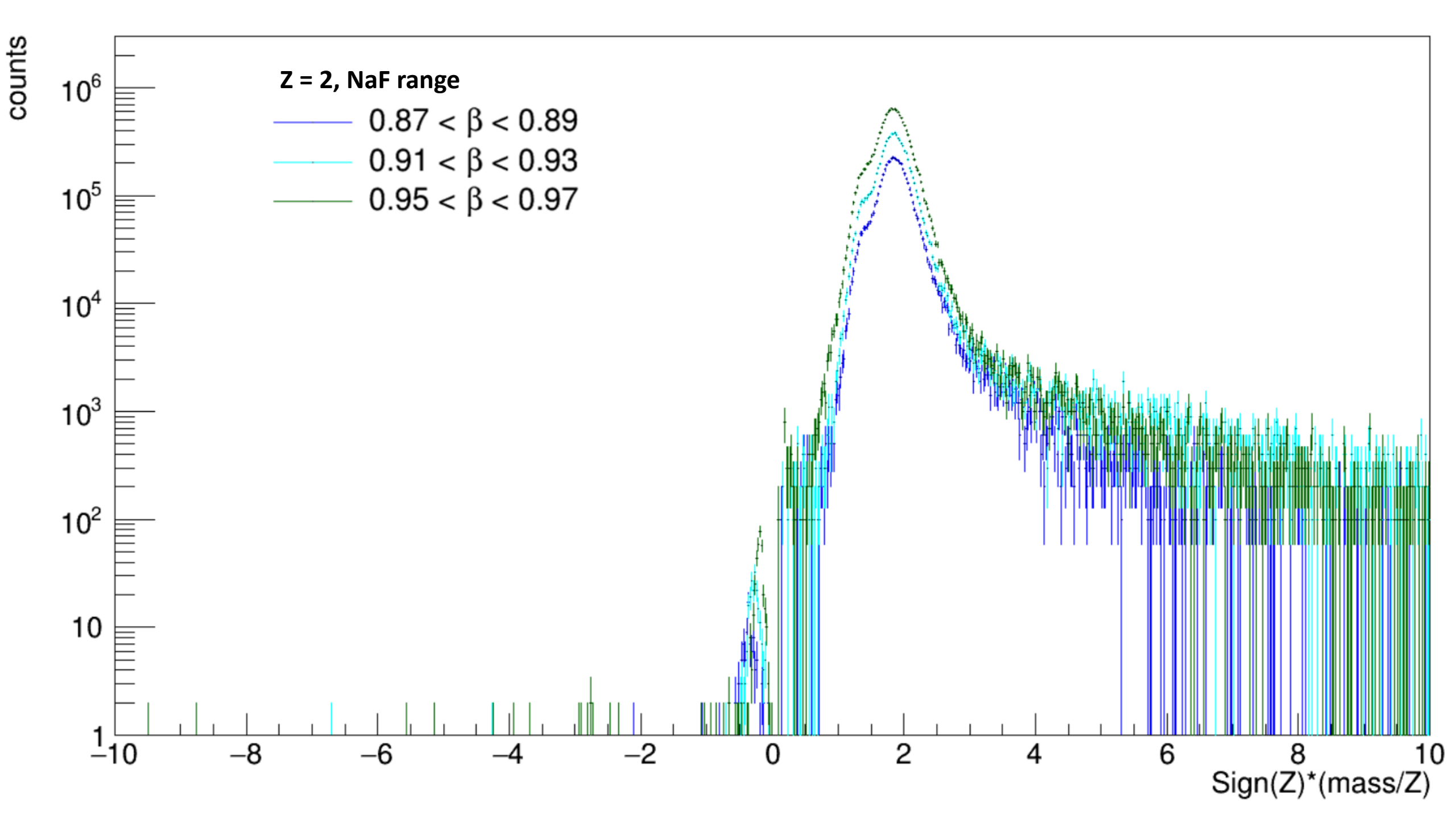


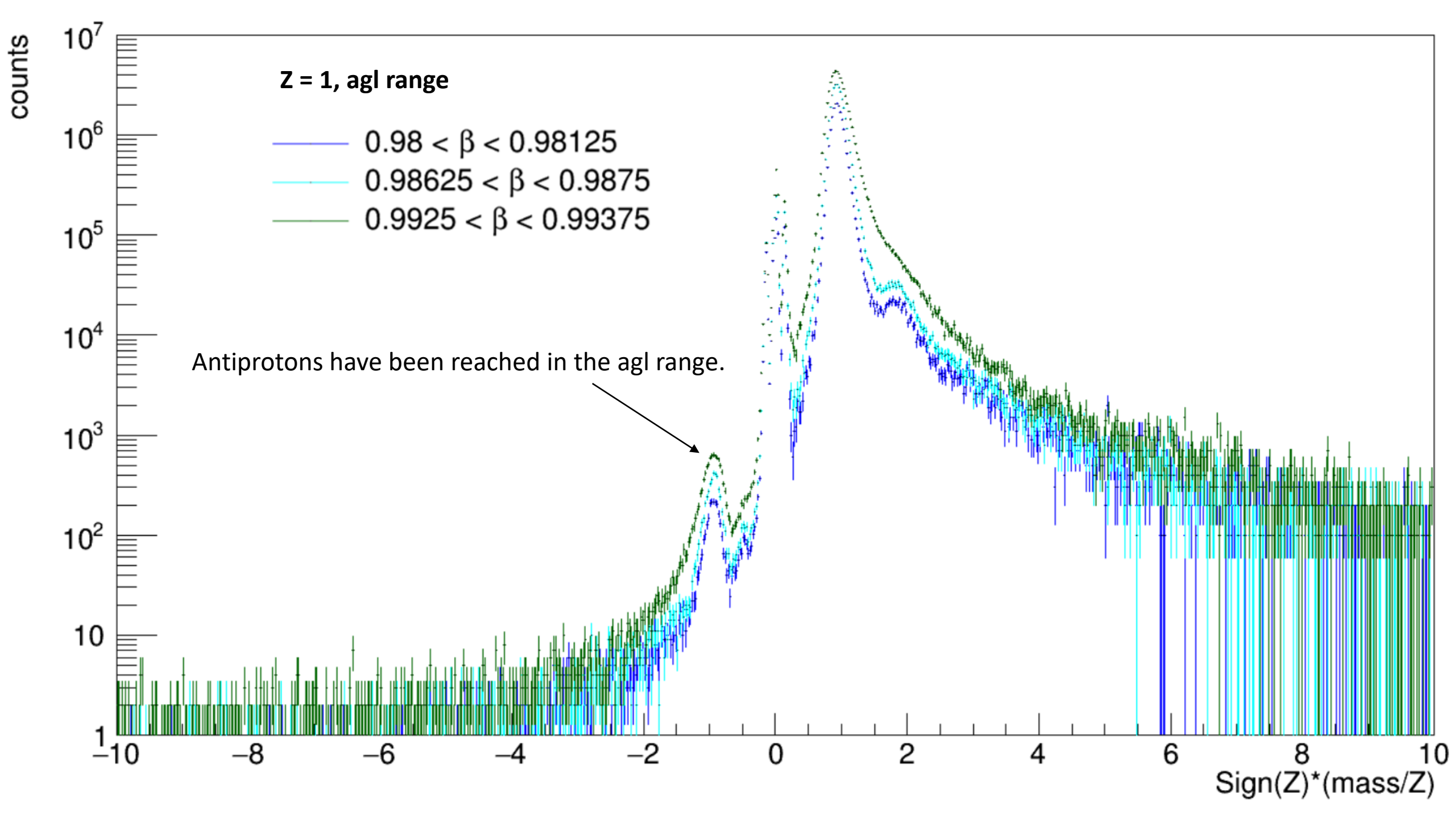
agl range: $0.97 < \beta < 0.98$
TRD LikelihoodRatio e/p

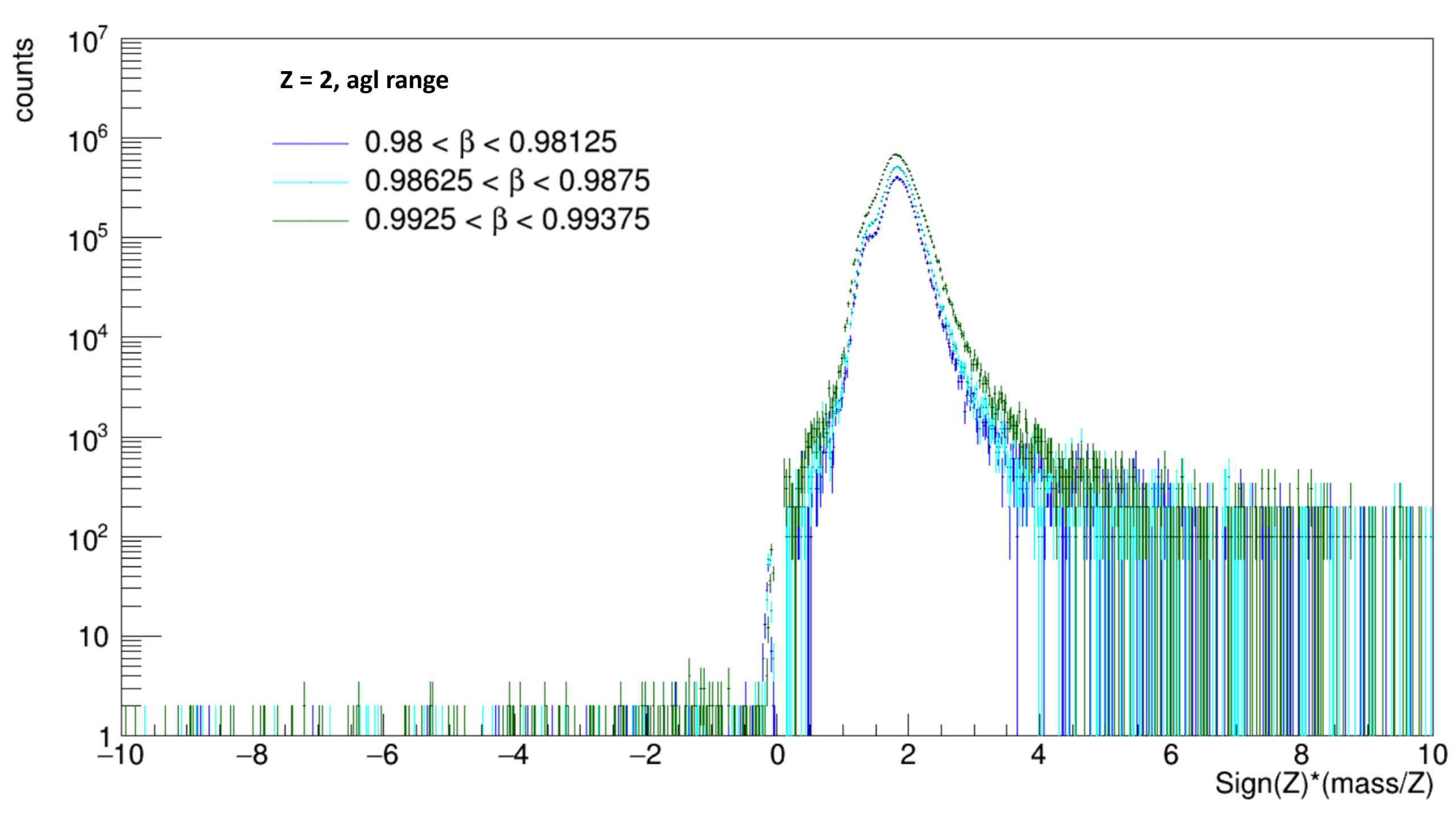

counts
Z = 1, TOF range
0.6 < β < 0.65
0.7 < β < 0.75
0.8 < β < 0.85
Antiprotons have been reached in the TOF range.
Sign(Z)*(mass/Z)


counts
Z = 2, TOF range
0.6 < β < 0.65
0.7 < β < 0.75
0.8 < β < 0.85
This low mass Z = -2 background can be suppressed
requiring the complete Y pattern, that is inefficient.
Sign(Z)*(mass/Z)


counts
Z = 1, NaF range
0.87 < β < 0.89
0.91 < β < 0.93
0.95 < β < 0.97
Missing the antiprotons in the naf range.
A stronger selection is required.
Sign(Z)*(mass/Z)


counts
Z = 2, NaF range
0.87 < β < 0.89
0.91 < β < 0.93
0.95 < β < 0.97
10^6
10^5
10^4
10^3
10^2
10
1
−10
−8
−6
−4
−2
0
2
4
6
8
10
Sign(Z)*(mass/Z)


counts
10^7
10^6
10^5
10^4
10^3
10^2
10
1
Z = 1, agl range
0.98 < β < 0.98125
0.98625 < β < 0.9875
0.9925 < β < 0.99375
Antiprotons have been reached in the agl range.
–10
–8
–6
–4
–2
0
2
4
6
8
10
Sign(Z)*(mass/Z)


Z = 2, agl range
0.98 < β < 0.98125
0.98625 < β < 0.9875
0.9925 < β < 0.99375
counts
Sign(Z)*(mass/Z)
10^7
10^6
10^5
10^4
10^3
10^2
10
1
−10
−8
−6
−4
−2
0
2
4
6
8
10

MONTECARLO PROCESSING IN PROGRESS

Started to process the MonteCarlo:

1. Helium MC L1 Focused
/storage/gpfs_ams/ams/groups/AMS-Italy/ntuples/v1.1.0/He.B1236/he4.pl1.l1.24000.6_02/

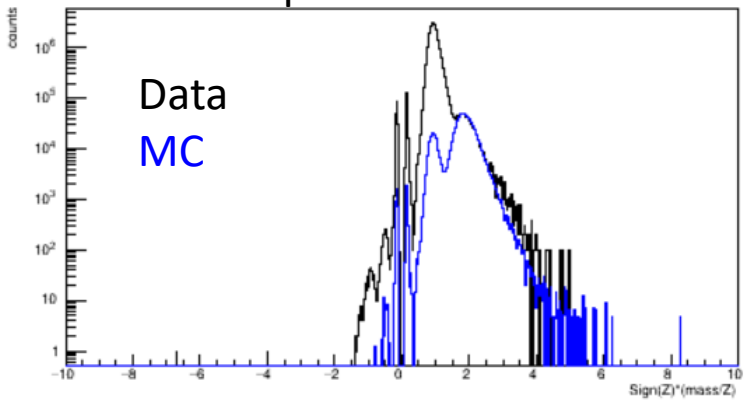
2. Deuteron MC
/storage/gpfs_ams/ams/groups/AMS-Italy/ntuples/v1.1.0/D.B1236/d.pl1.05200/

SOON:

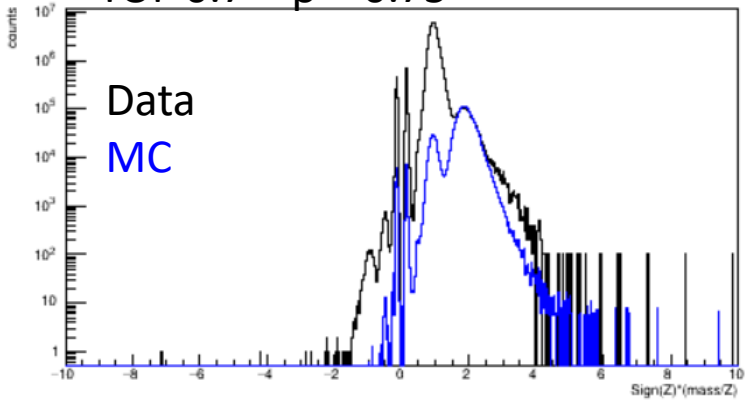
- Proton MC (and pbar)
/storage/gpfs_ams/ams/groups/AMS-Italy/ntuples/v1.1.0/Pr.B1236/pr.pl1phpsa.0550.4_00/

Deuteron MC

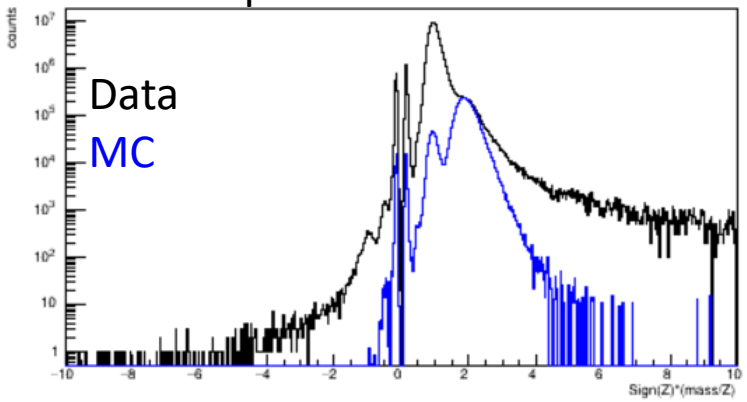
TOF 0.6 < β < 0.65



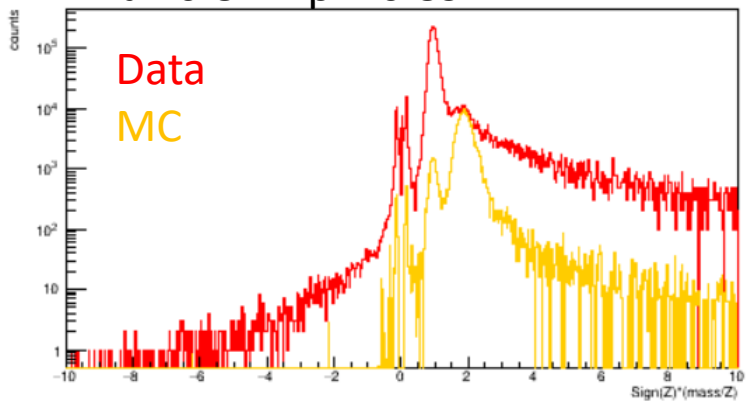
TOF 0.7 < β < 0.75



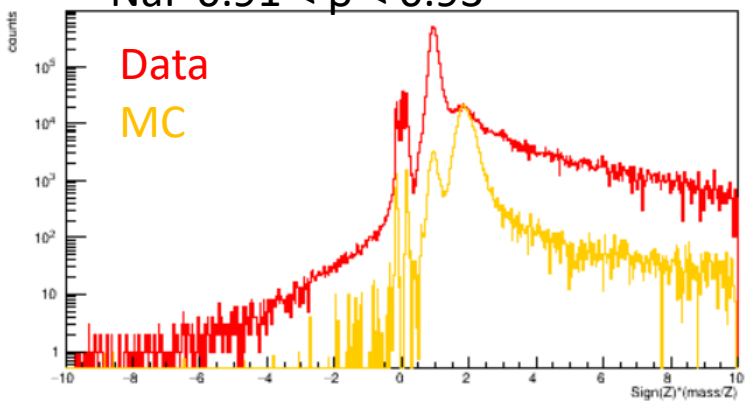
TOF 0.8 < β < 0.85



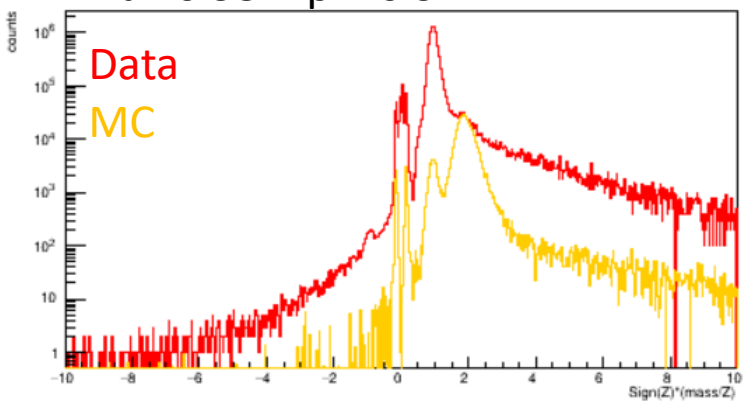
NaF 0.87 < β < 0.89



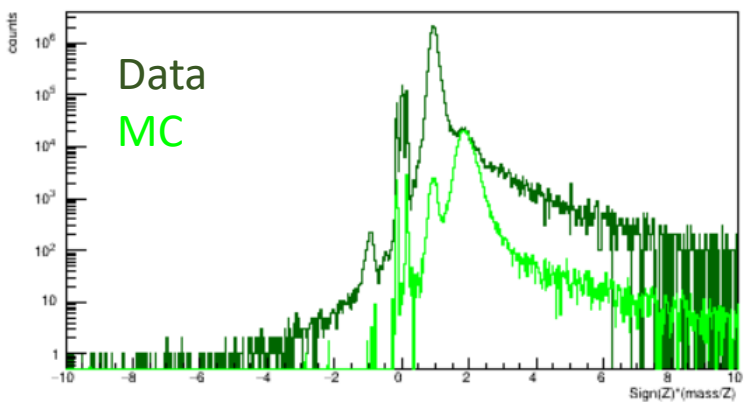
NaF 0.91 < β < 0.93



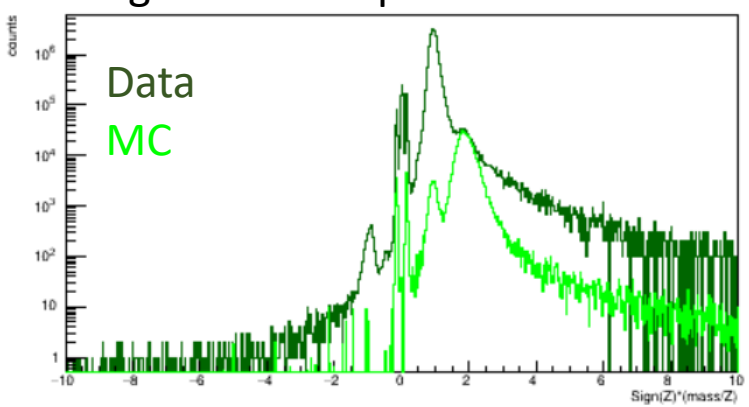
NaF 0.95 < β < 0.97



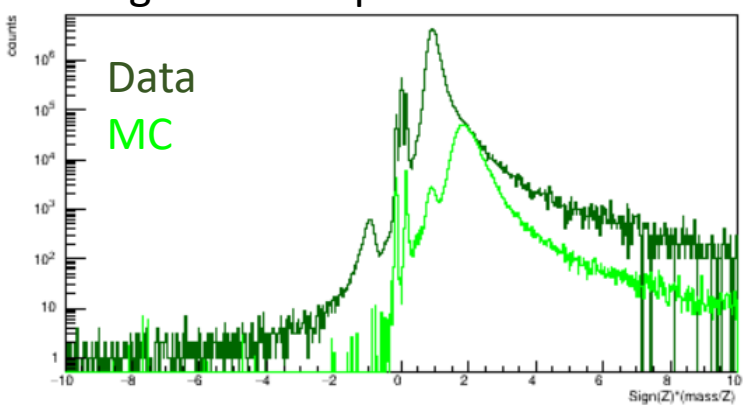
agl 0.98 < β < 0.98125



agl 0.98625 < β < 0.9875

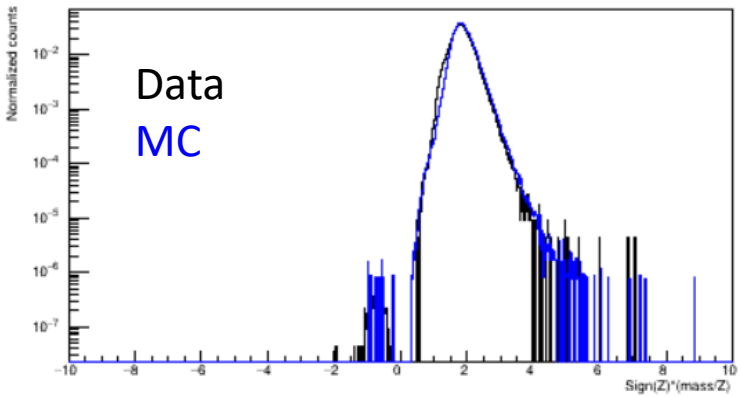


agl 0.9925 < β < 0.99375

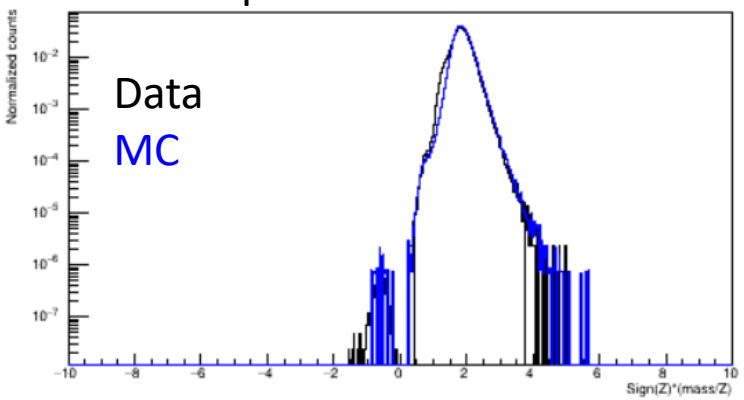


He4 MC (L1 – Focused)

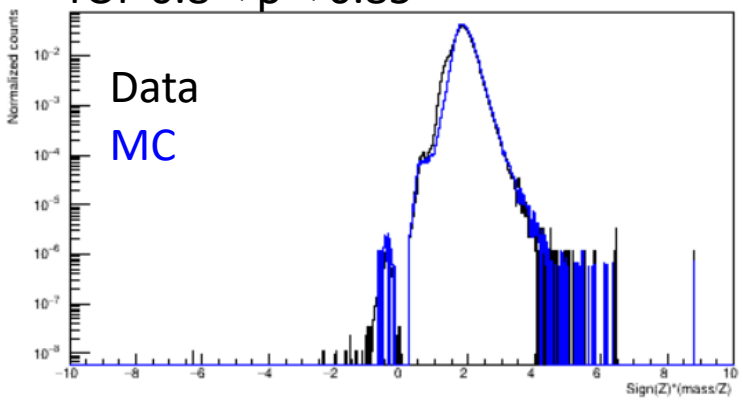
TOF 0.6 < β < 0.65



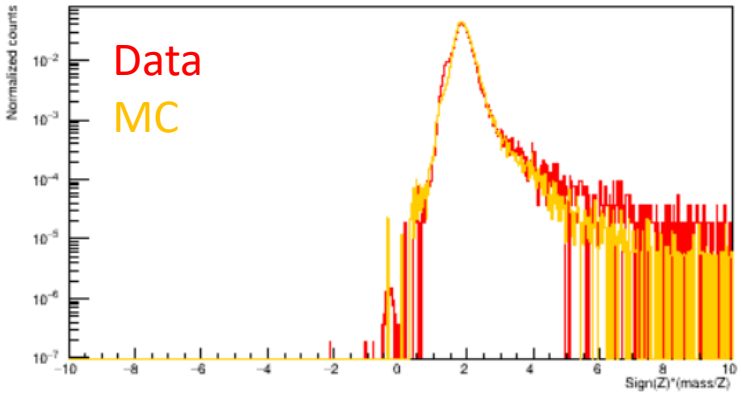
TOF 0.7 < β < 0.75



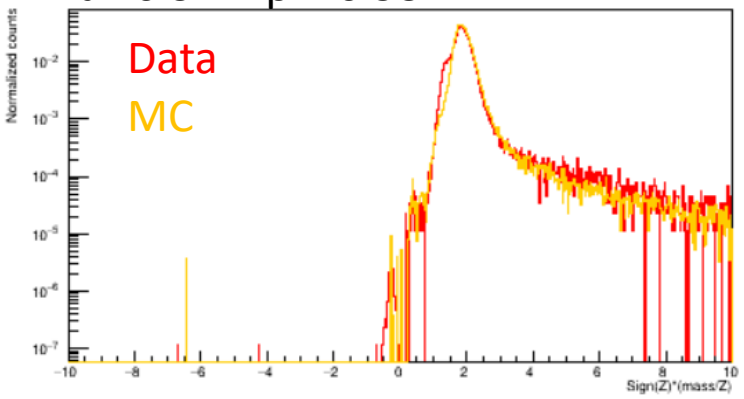
TOF 0.8 < β < 0.85



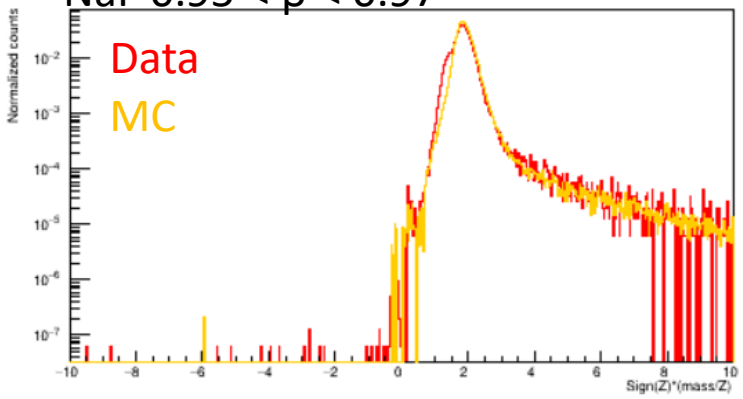
NaF 0.87 < β < 0.89



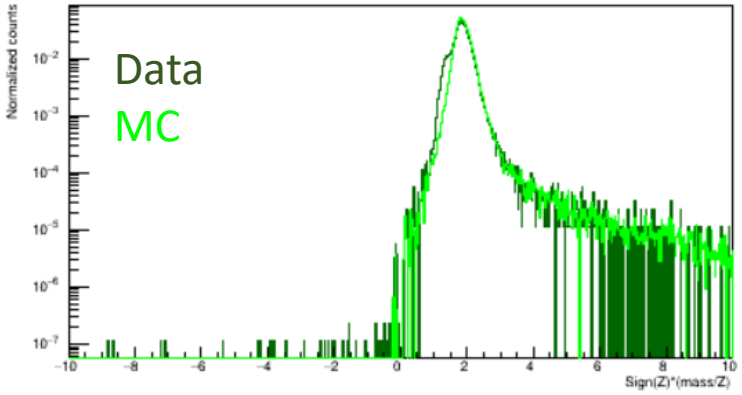
NaF 0.91 < β < 0.93



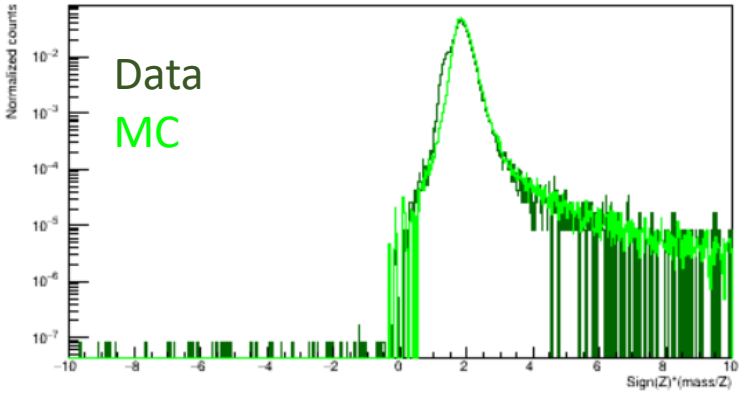
NaF 0.95 < β < 0.97



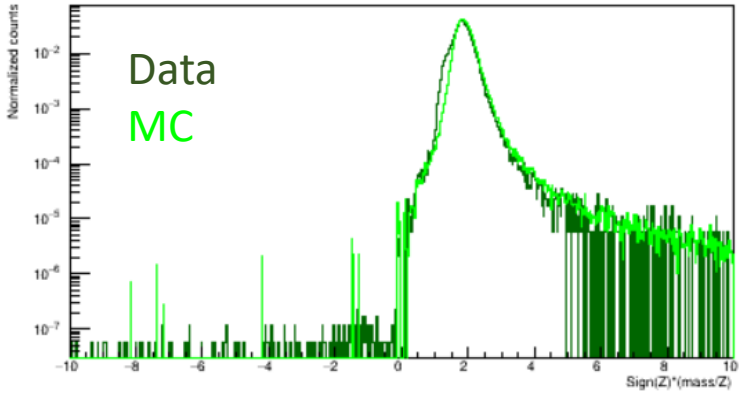
agl 0.98 < β < 0.98125



agl 0.98625 < β < 0.9875



agl 0.9925 < β < 0.99375



SUMMARIZING:

A low mass background for Z = 2 may be caused by wrong rigidity reconstruction:

- The complete pattern can suppress it a lot but is still inefficient on good events.
- The variable Jian Tian used in his work can be useful to reject this kind of background (thanks Jian).

In the NaF range, wrong beta reconstruction is dominating and the samples (Z = 1 especially) are still bad:

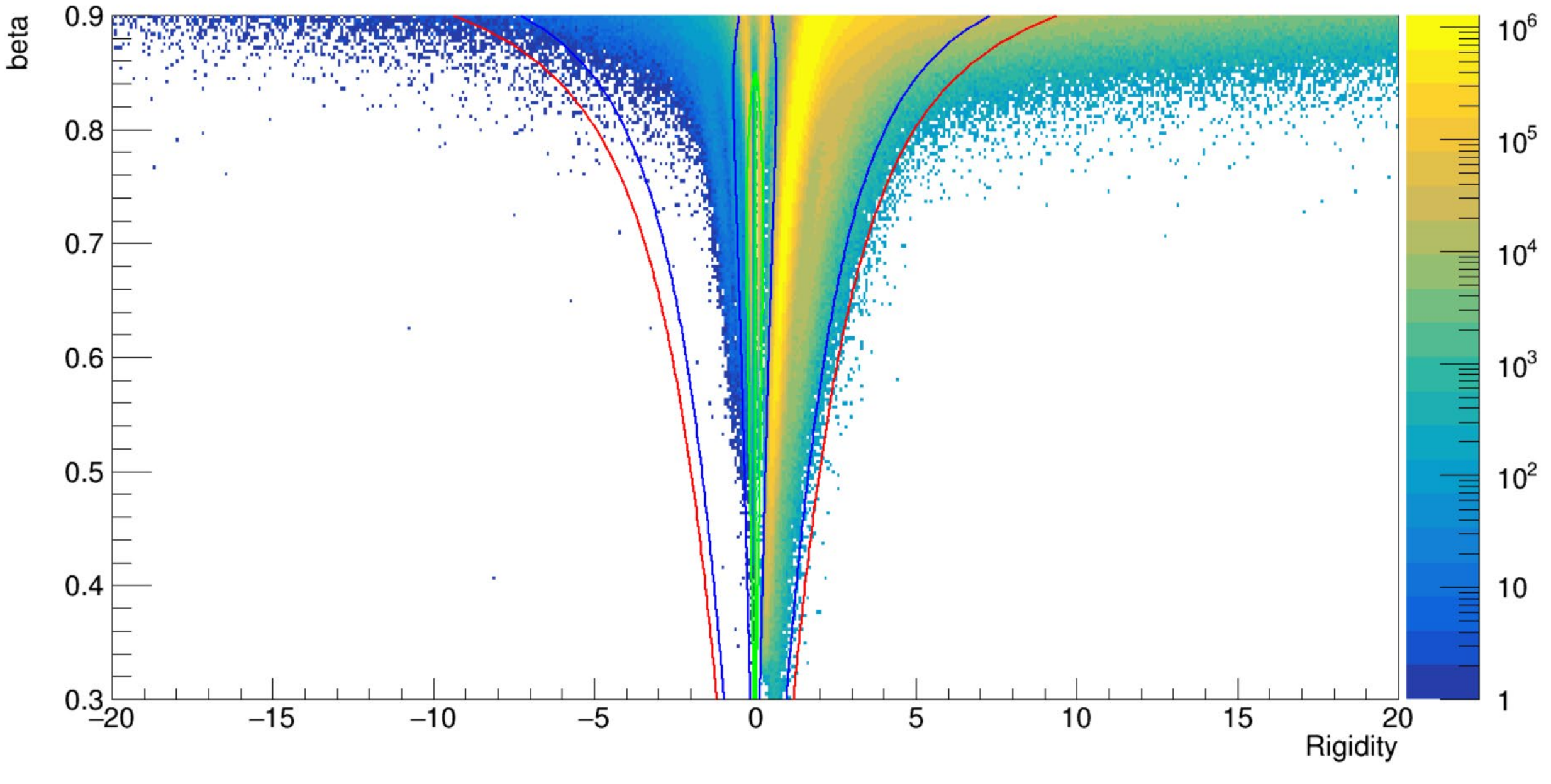
- $\beta = 1$ hypotheses variables, β clustering, LIP-CIEMAT β compatibility and IT-RICH charge consistency (thanks to Francesco Dimiccoli and Francesca Giovacchini for the suggestions).
- Further work is needed!

In the TOF and agl range the antiproton peak has been clearly reached. Maybe Neural Networks can be the next step.

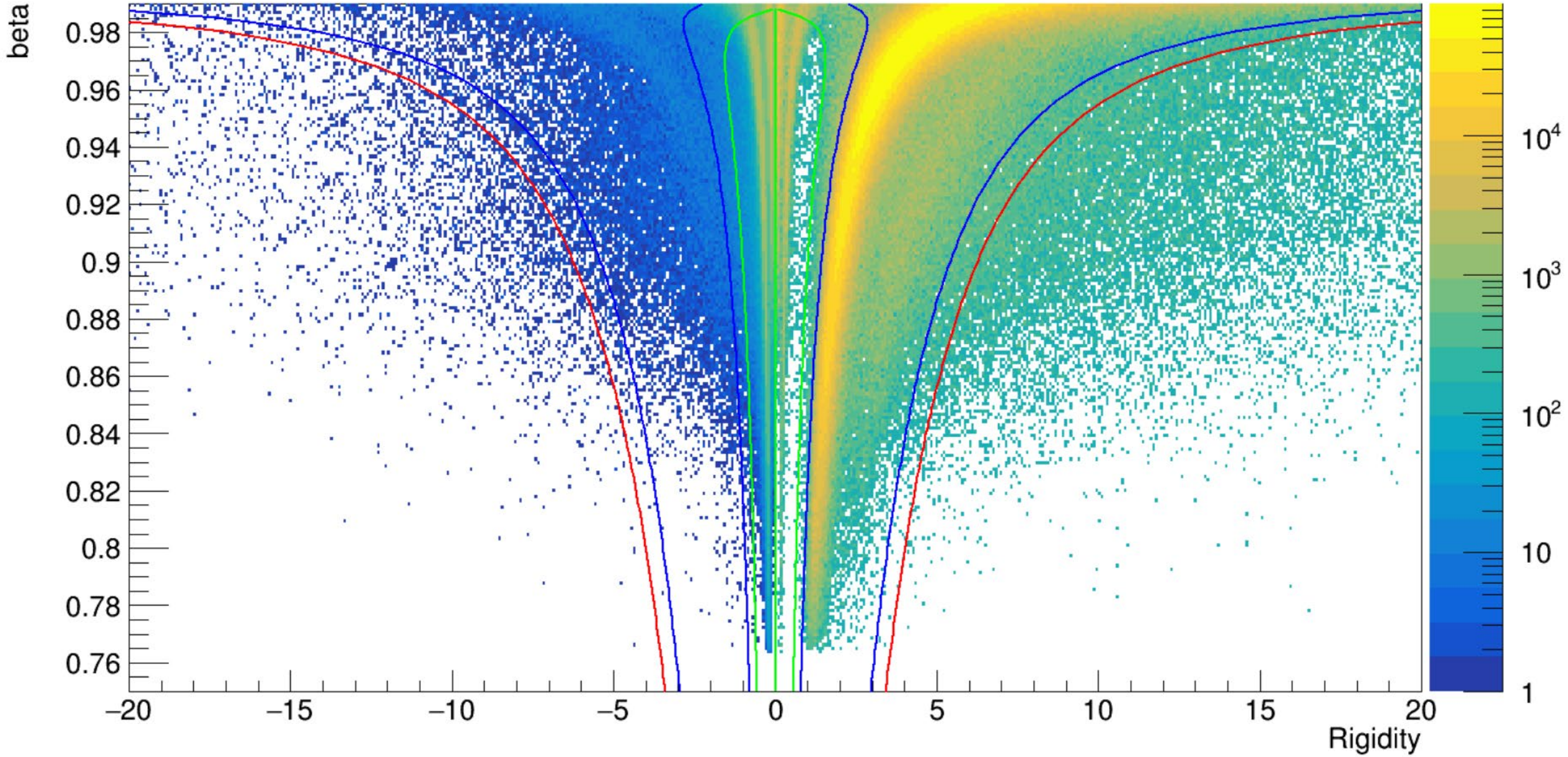
The MC processing of Helium 4 and Deuterium is at the beginning. The normalization doesn't agree with data (need to be solved). However it's possible to look at the general distributions and at the single variables. If there is agreement between data and MC, those may be used for Machine Learning.

BACKUP

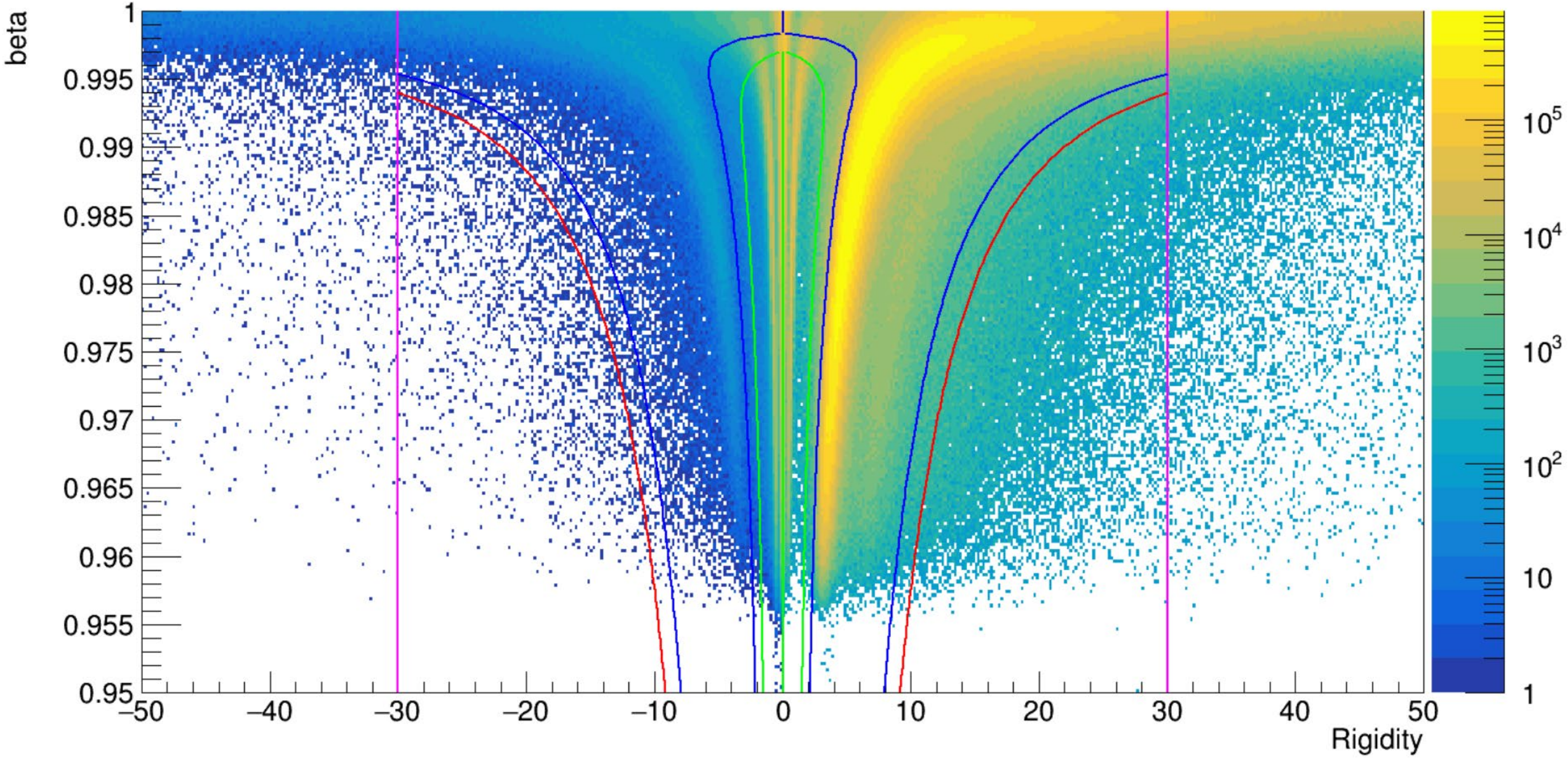
TOF RANGE Z1


beta
0.9
0.8
0.7
0.6
0.5
0.4
0.3
−20
−15
−10
−5
0
5
10
15
20
Rigidity
10^6
10^5
10^4
10^3
10^2
10
1

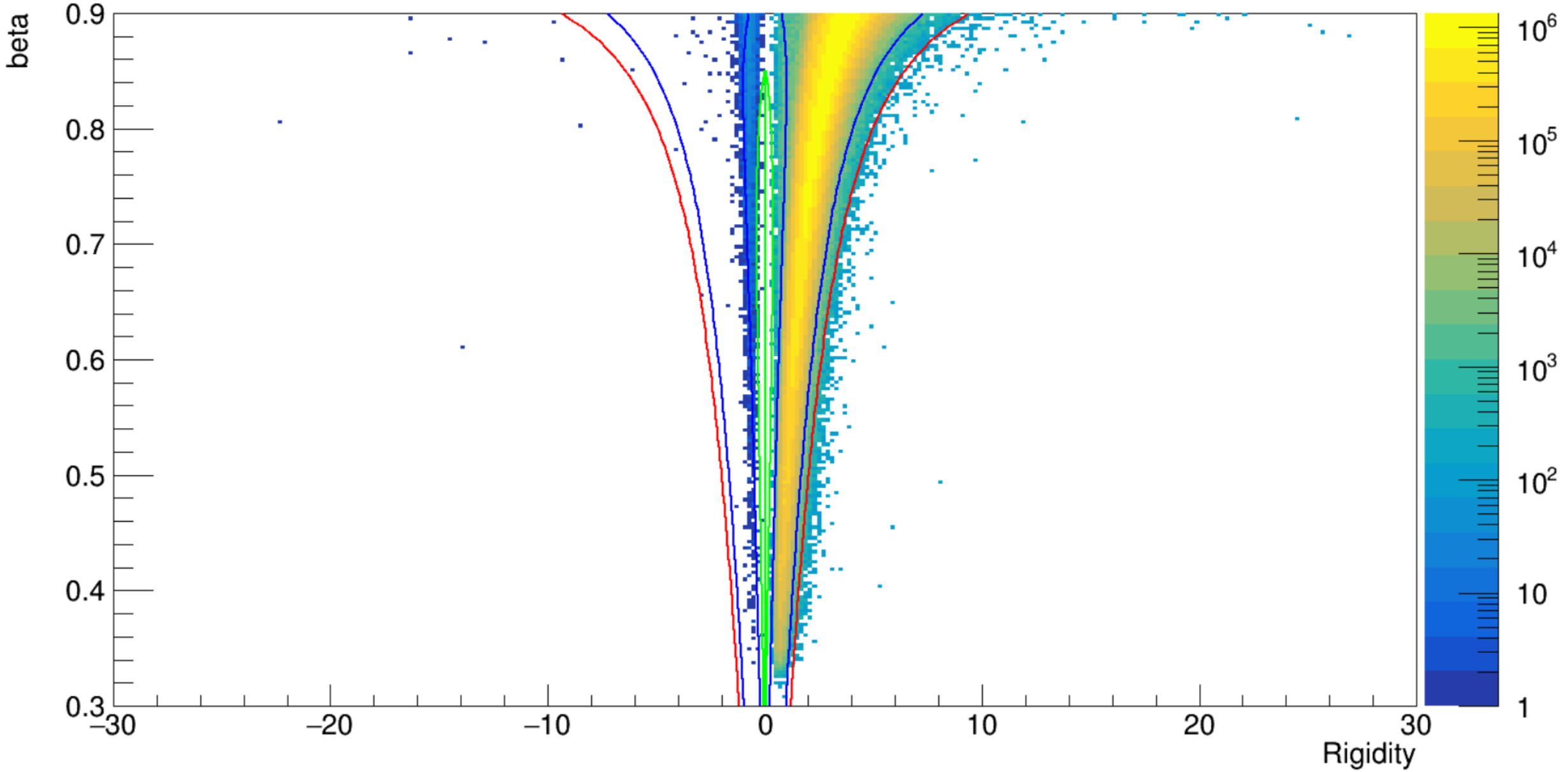
NAF RANGE Z1


beta
0.98
0.96
0.94
0.92
0.9
0.88
0.86
0.84
0.82
0.8
0.78
0.76
−20
−15
−10
−5
0
5
10
15
20
Rigidity
10^4
10^3
10^2
10
1

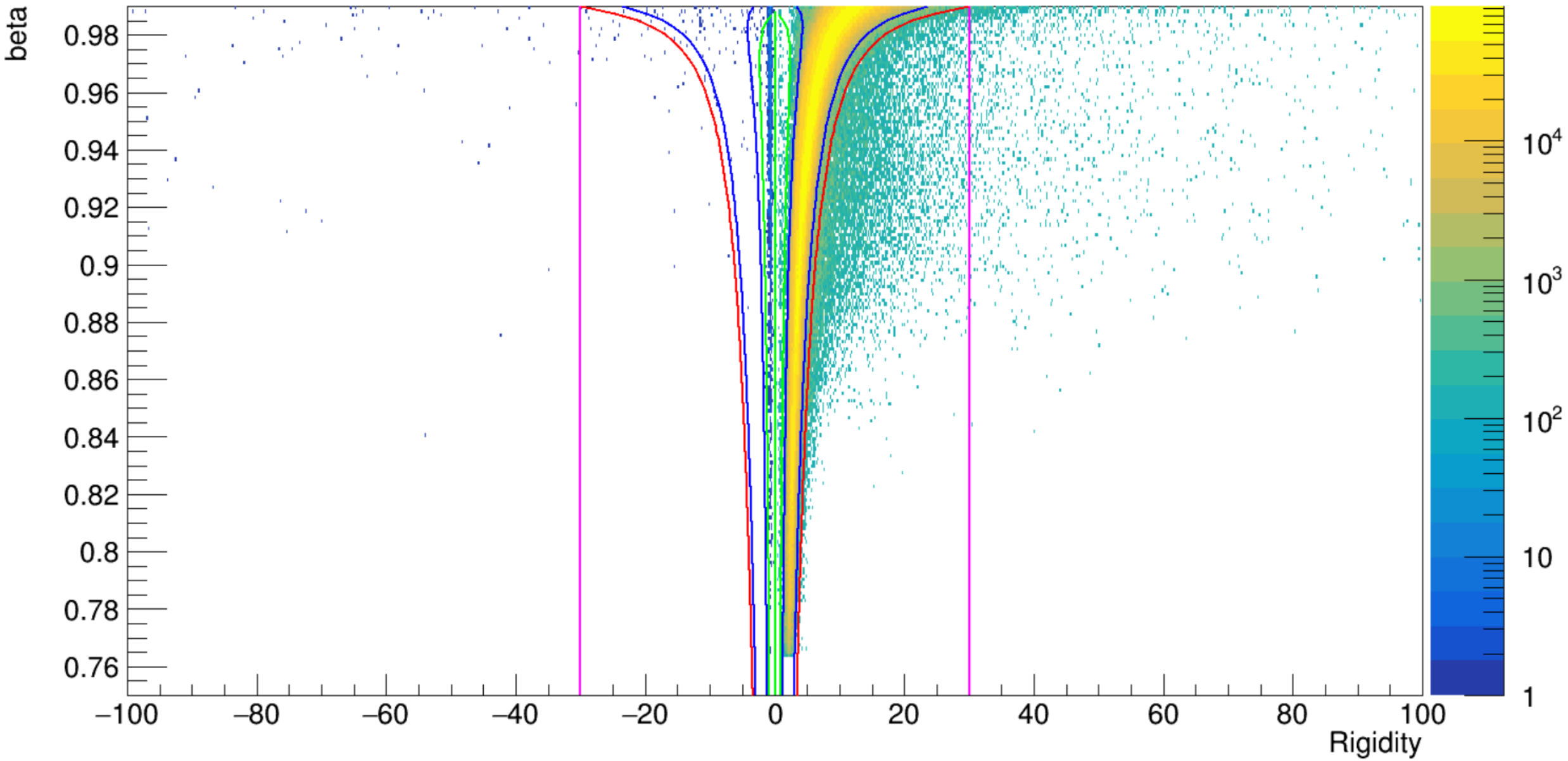
AGL RANGE Z1


beta
1
0.995
0.99
0.985
0.98
0.975
0.97
0.965
0.96
0.955
0.95
−50
−40
−30
−20
−10
0
10
20
30
40
50
Rigidity
10^5
10^4
10^3
10^2
10
1

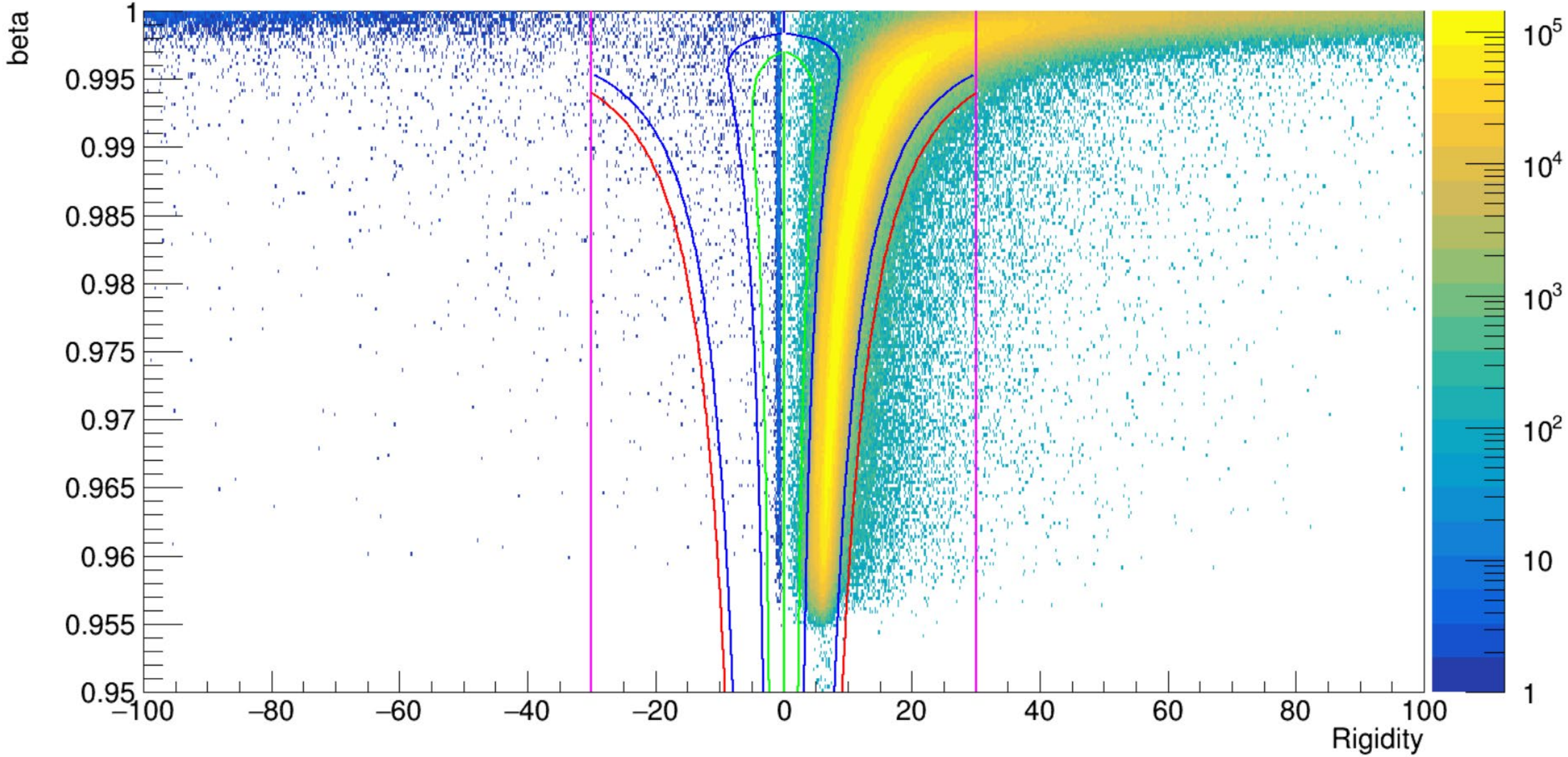
TOF RANGE Z2

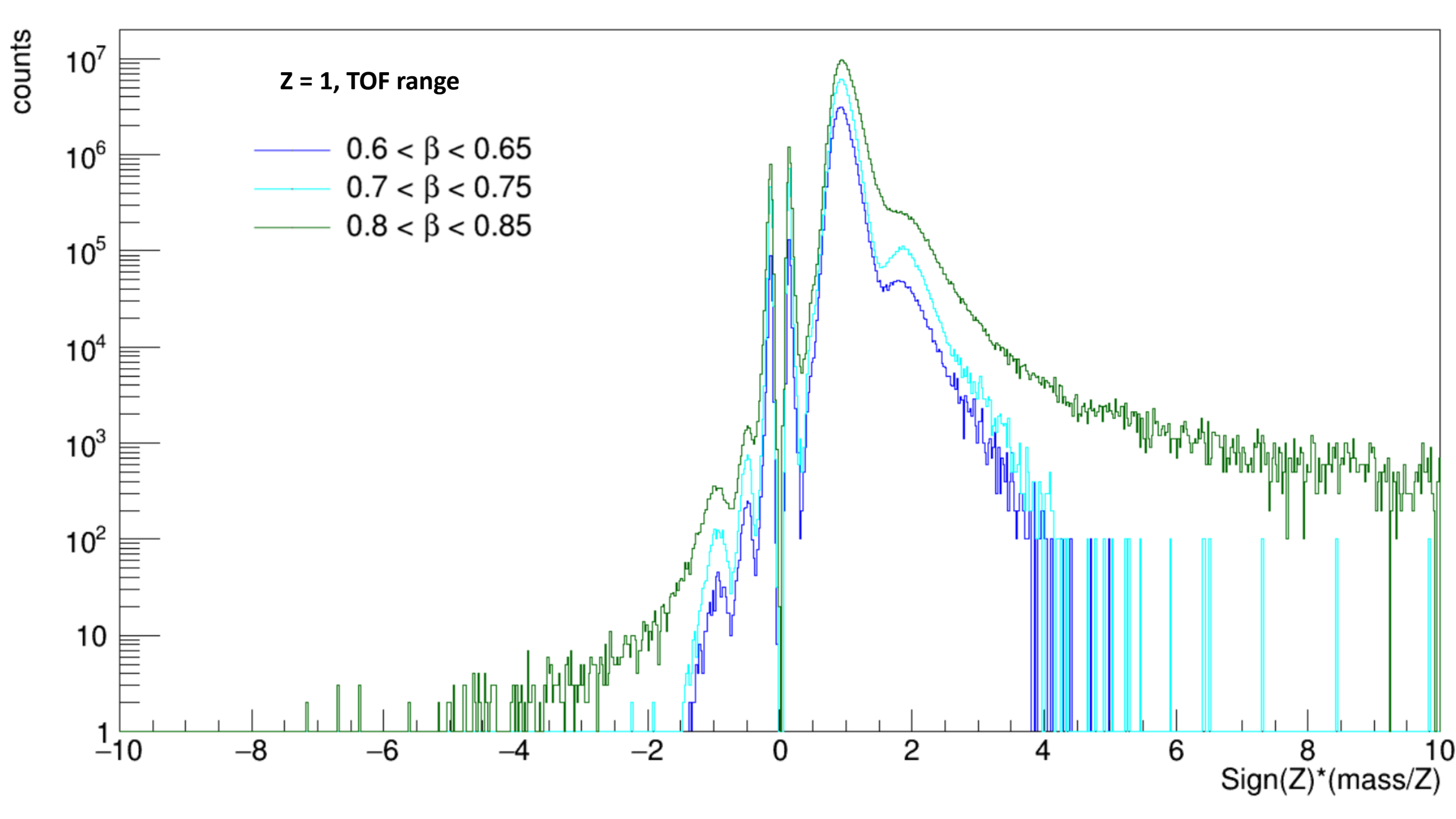

beta
0.9
0.8
0.7
0.6
0.5
0.4
0.3
−30
−20
−10
0
10
20
30
Rigidity
10^6
10^5
10^4
10^3
10^2
10
1

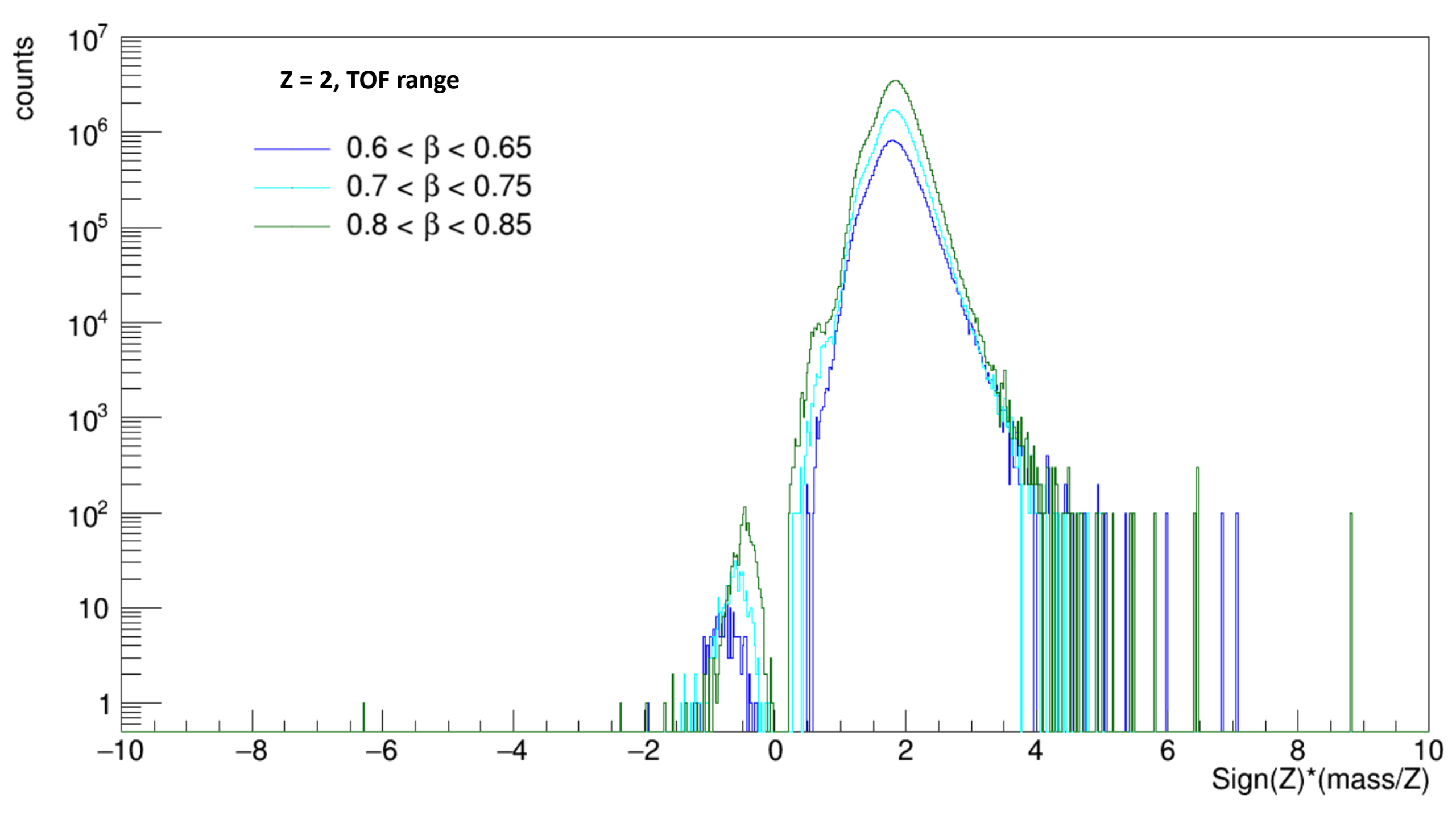
NAF RANGE Z2

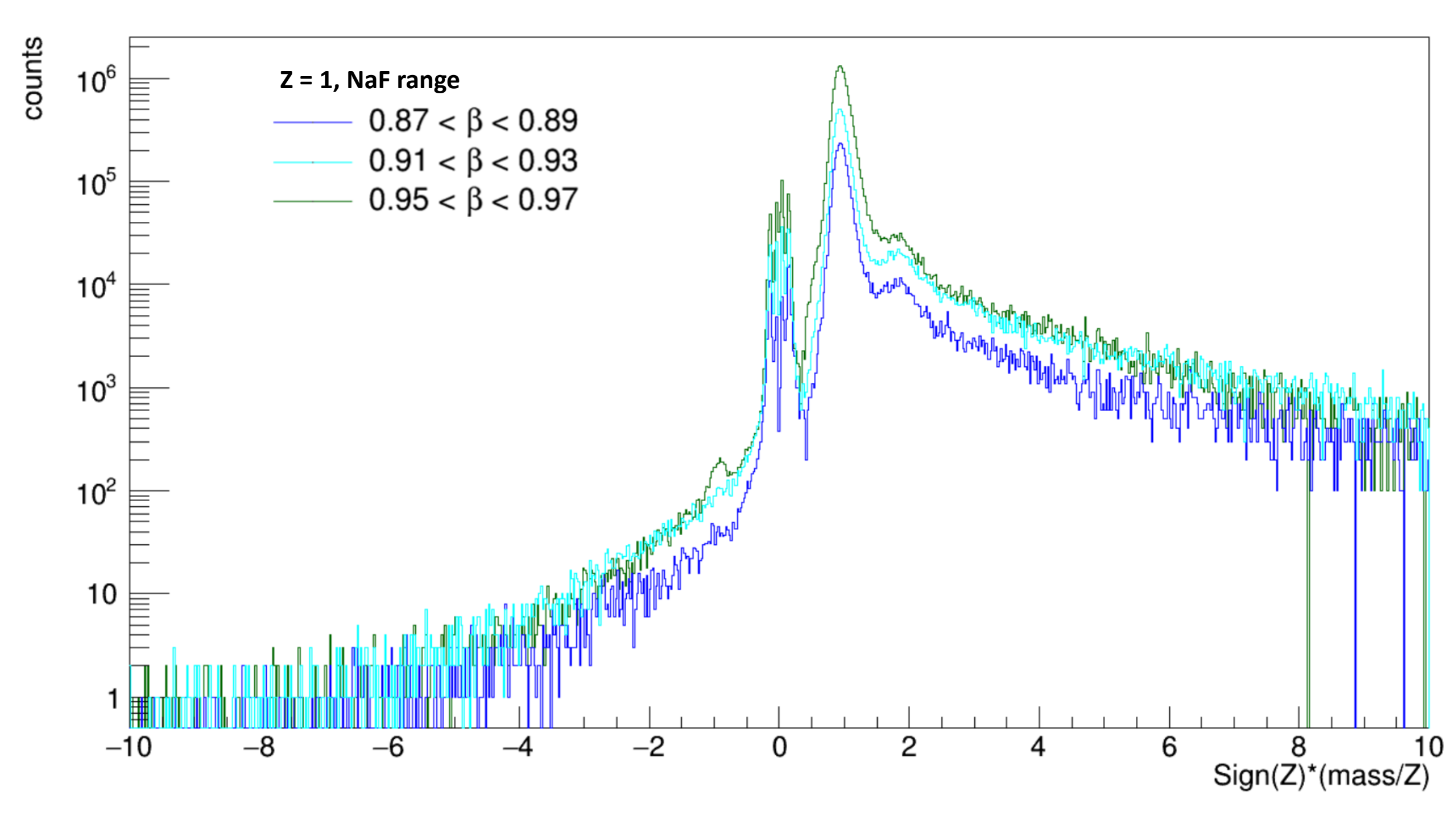

beta
0.98
0.96
0.94
0.92
0.9
0.88
0.86
0.84
0.82
0.8
0.78
0.76
−100
−80
−60
−40
−20
0
20
40
60
80
100
Rigidity
10^4
10^3
10^2
10
1

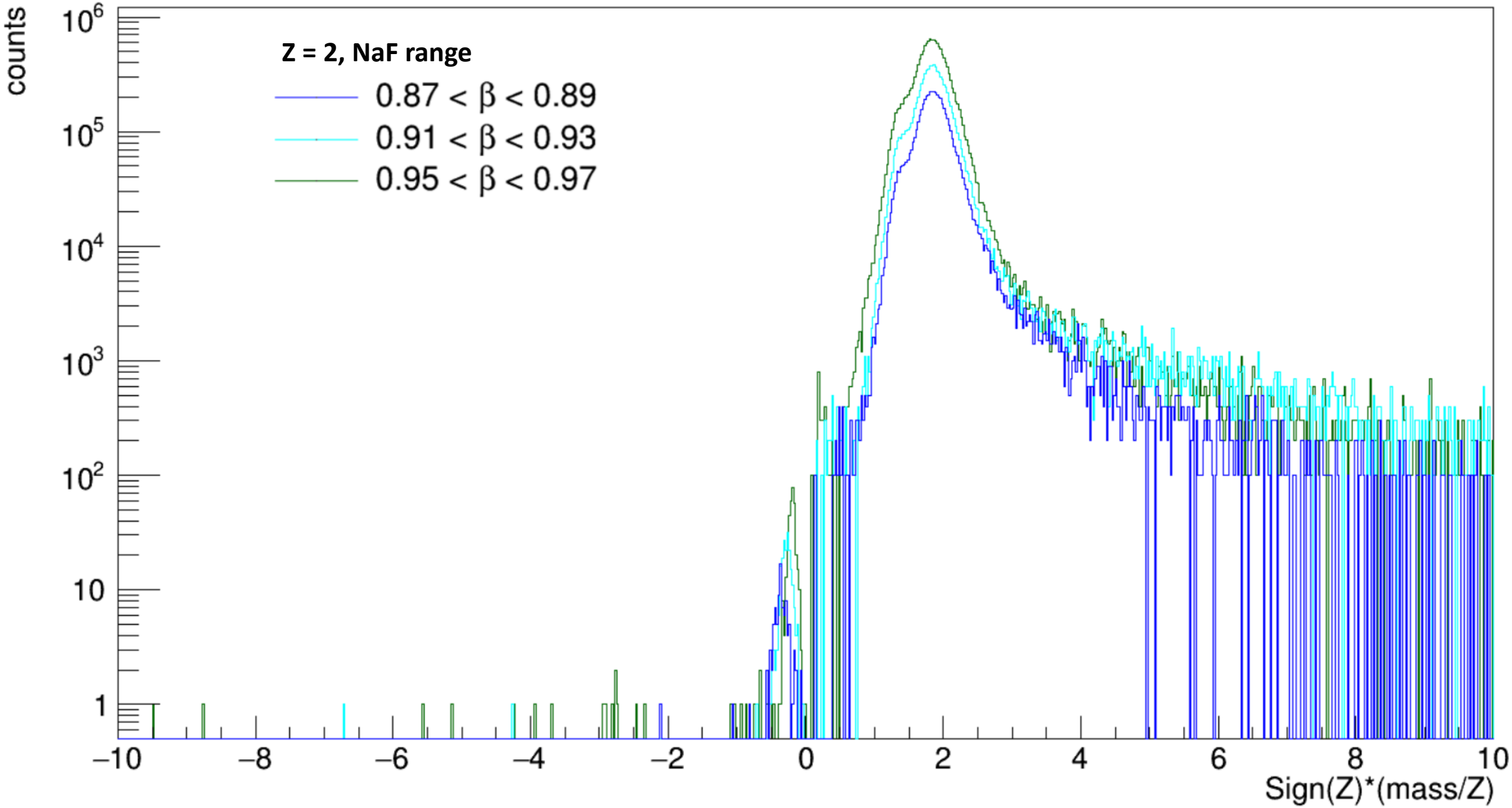
AGL RANGE Z2

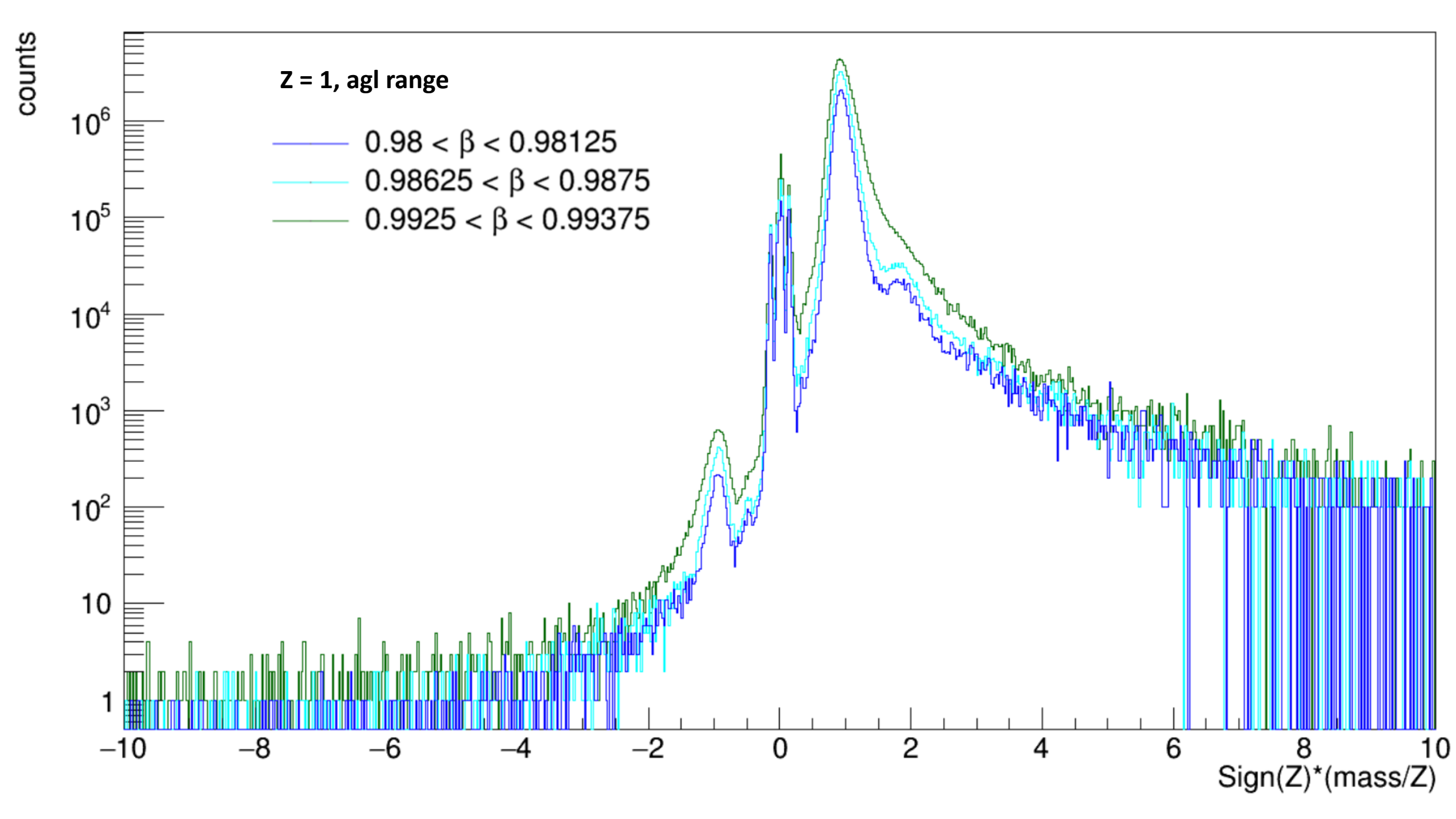

beta
1
0.995
0.99
0.985
0.98
0.975
0.97
0.965
0.96
0.955
0.95
−100
−80
−60
−40
−20
0
20
40
60
80
100
Rigidity
10^5
10^4
10^3
10^2
10
1

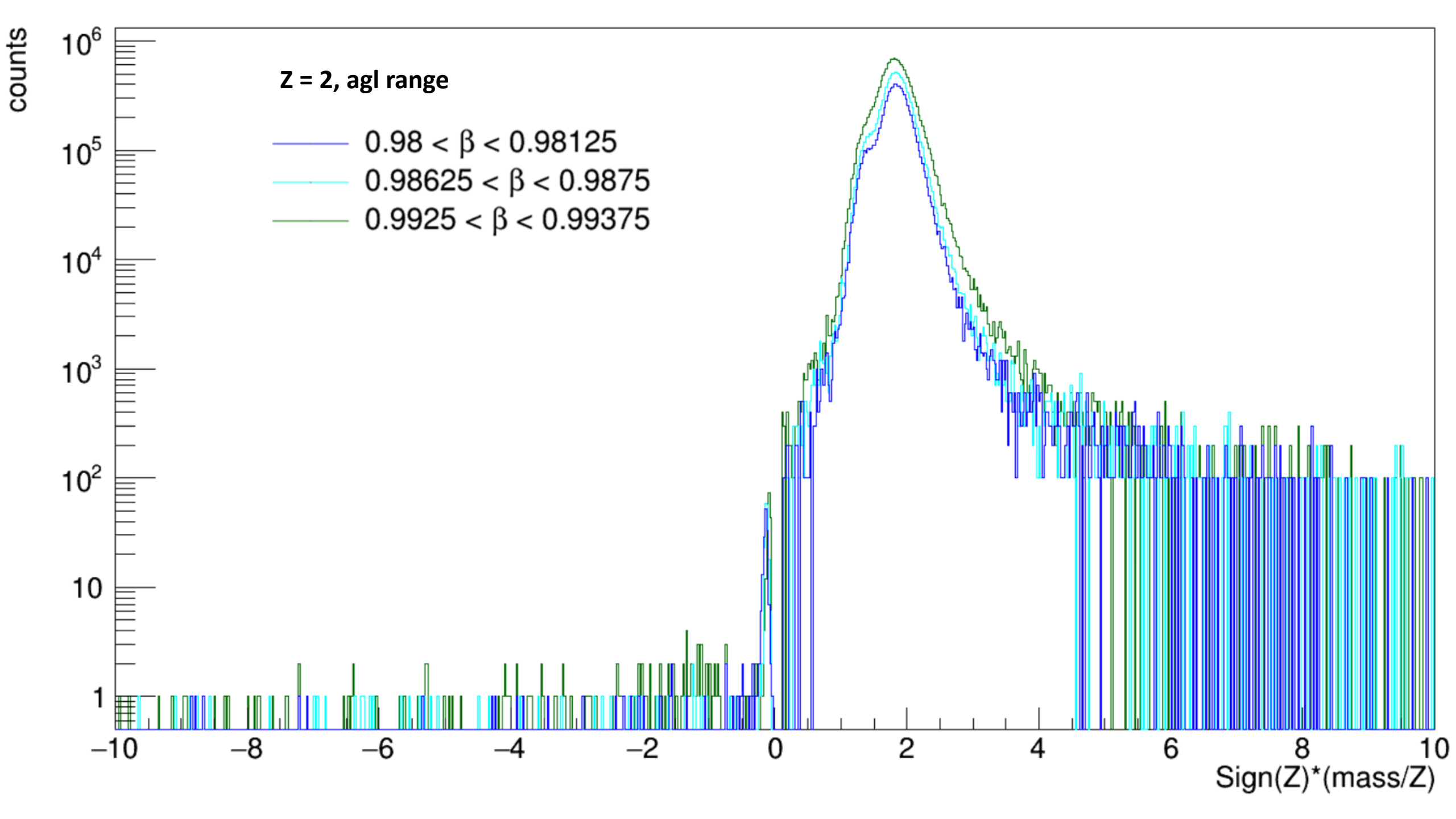

counts
Z = 1, TOF range
0.6 < β < 0.65
0.7 < β < 0.75
0.8 < β < 0.85
10^7
10^6
10^5
10^4
10^3
10^2
10
1
−10
−8
−6
−4
−2
0
2
4
6
8
10
Sign(Z)*(mass/Z)


Z = 2, TOF range
0.6 < β < 0.65
0.7 < β < 0.75
0.8 < β < 0.85
counts
10^7
10^6
10^5
10^4
10^3
10^2
10
1
−10
−8
−6
−4
−2
0
2
4
6
8
10
Sign(Z)*(mass/Z)


counts
Z = 1, NaF range
0.87 < β < 0.89
0.91 < β < 0.93
0.95 < β < 0.97
10^6
10^5
10^4
10^3
10^2
10
1
−10
−8
−6
−4
−2
0
2
4
6
8
10
Sign(Z)*(mass/Z)


counts
10^6
10^5
10^4
10^3
10^2
10
1
Z = 2, NaF range
0.87 < β < 0.89
0.91 < β < 0.93
0.95 < β < 0.97
−10
−8
−6
−4
−2
0
2
4
6
8
10
Sign(Z)*(mass/Z)

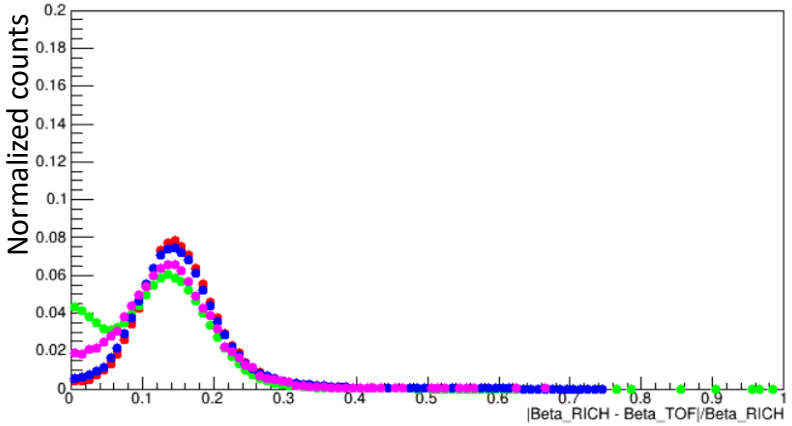

Z = 1, agl range
0.98 < β < 0.98125
0.98625 < β < 0.9875
0.9925 < β < 0.99375
counts
10^6
10^5
10^4
10^3
10^2
10
1
−10
−8
−6
−4
−2
0
2
4
6
8
10
Sign(Z)*(mass/Z)


counts
10^6
10^5
10^4
10^3
10^2
10
1
Z = 2, agl range
0.98 < β < 0.98125
0.98625 < β < 0.9875
0.9925 < β < 0.99375
−10
−8
−6
−4
−2
0
2
4
6
8
10
Sign(Z)*(mass/Z)

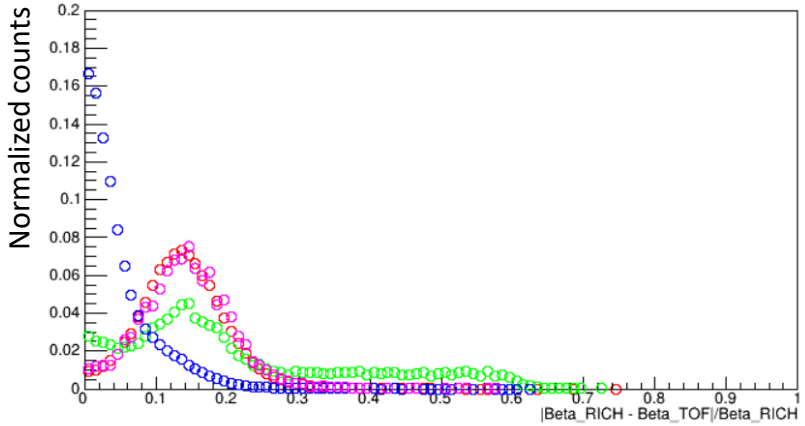
STANDARD SELECTION DEFINITION

NaF range: 0.846 < β < 0.894
TOF-RICH β asymmetry

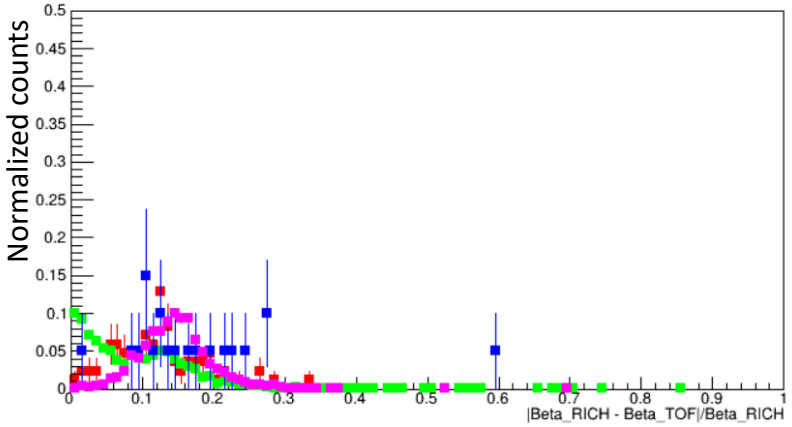
Z = -1



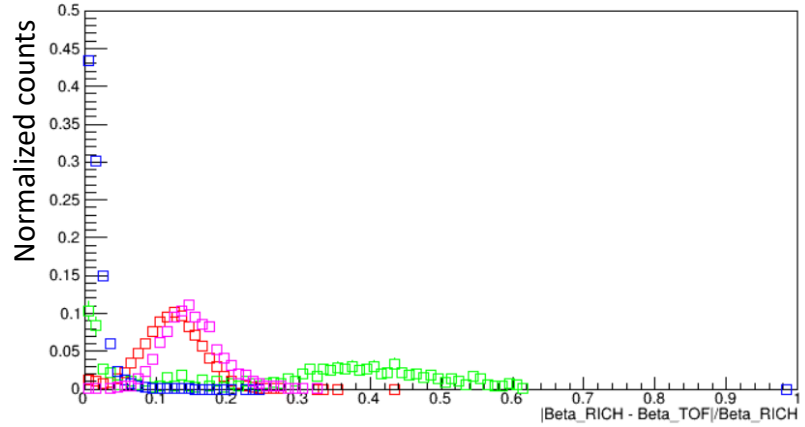
Z = +1



Z = -2



Z = +2



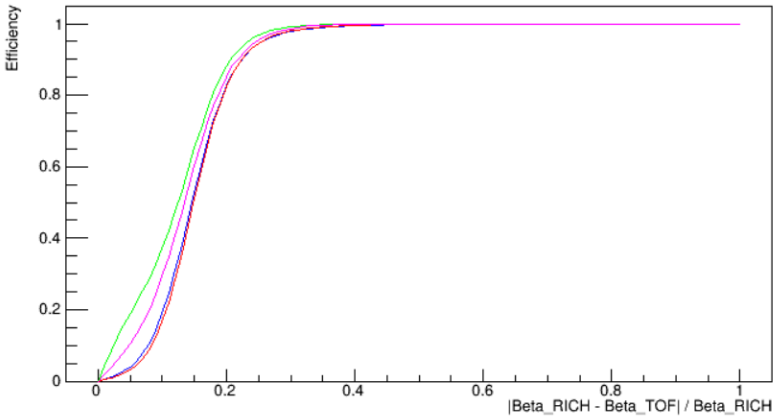
To define a standard selection:

1. some variable distributions **(assumed independent)** have been looked for the different mass samples, identifying the ones with a high discrimination power
2. Using the interested variable as a cut variable, the efficiencies and the rejections have been calculated as a function of the cut value
3. The cut value has been chosen as the value that maximize the rejection of a bad sample times the efficiency of a good sample (protons for Z=1 and helium for Z=2)

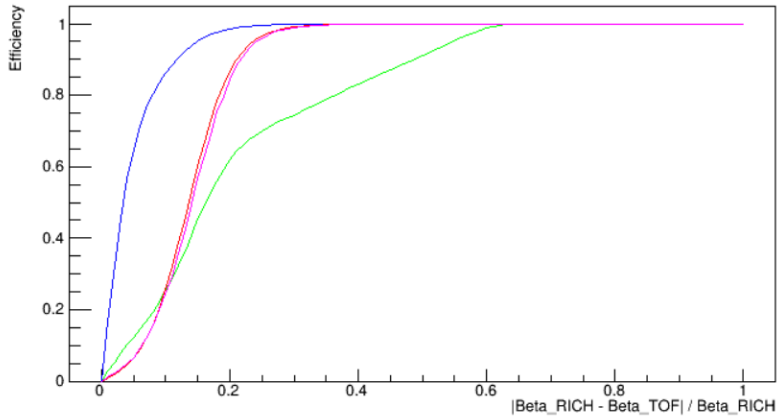
STANDARD SELECTION DEFINITION

NaF range: $0.846 < \beta < 0.894$
TOF-RICH β asymmetry

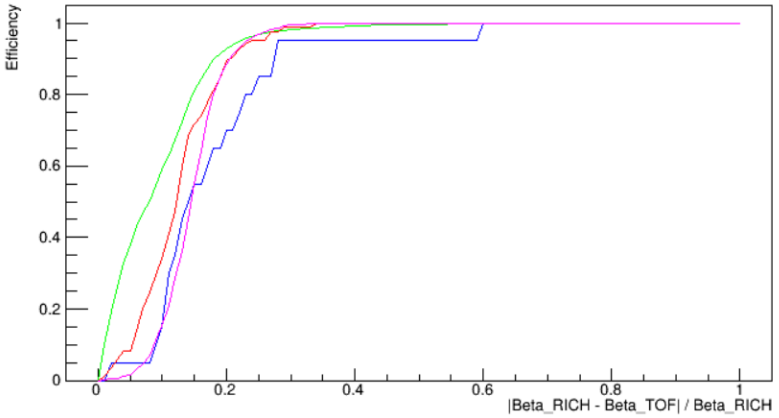
Z = -1



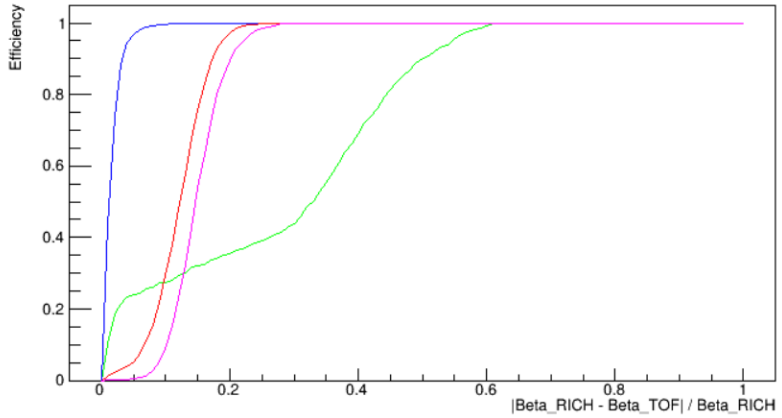
Z = +1



Z = -2



Z = +2



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1. some variable distributions (**assumed independent**) have been looked for the different mass samples, identifying the ones with a high discrimination power

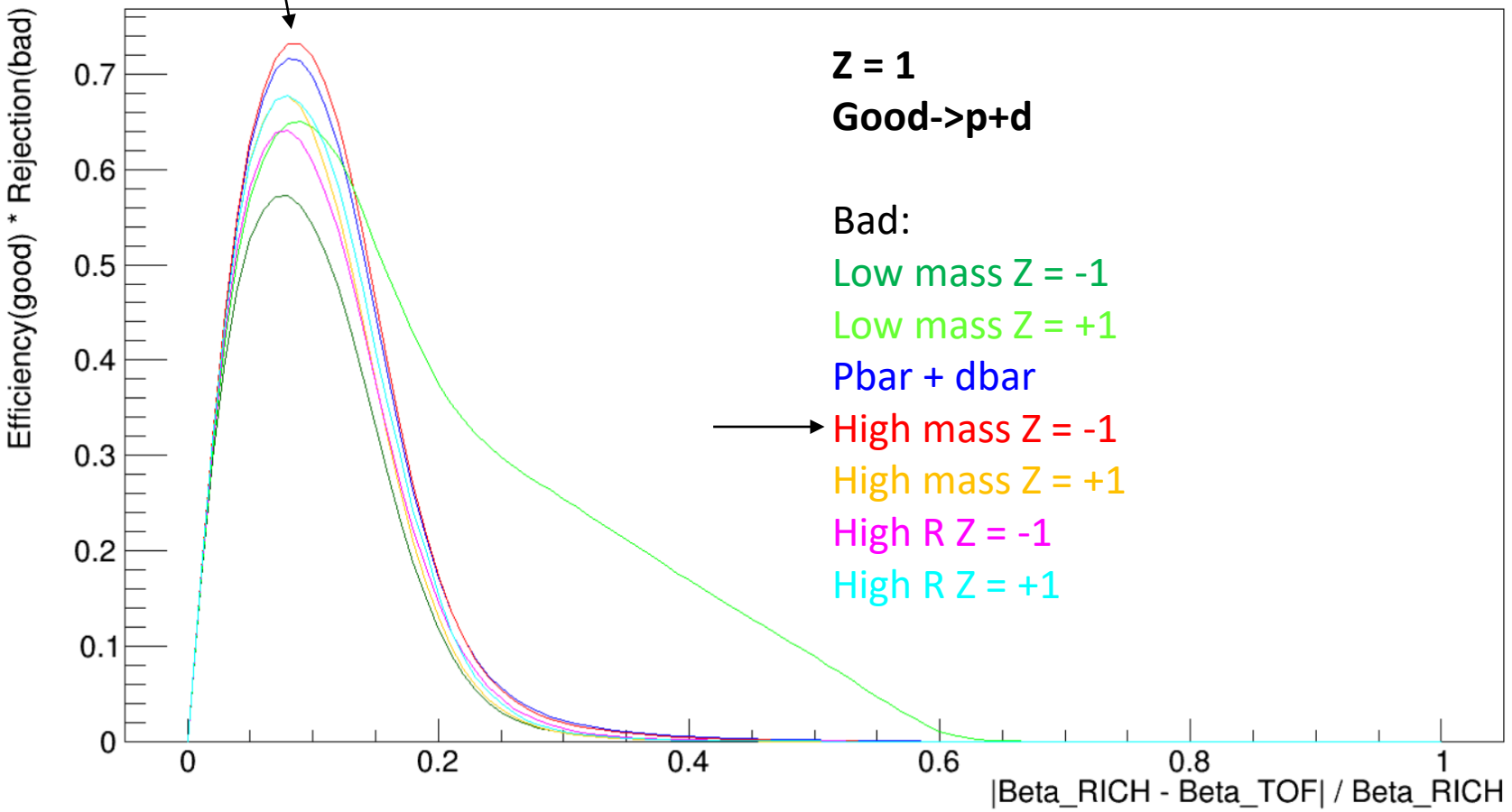
2. Using the interested variable as a cut variable, the efficiencies and the rejections have been calculated as a function of the cut value

3. The cut value has been chosen as the value that maximize the rejection of a bad sample times the efficiency of a good sample (protons for Z=1 and helium for Z=2)

STANDARD SELECTION DEFINITION

Z = 1 NaF cutvalue: 0.1

NaF range: 0.846 < β < 0.894
TOF-RICH β asymmetry



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3. The cut value has been chosen as the value that maximize the rejection of a bad sample times the efficiency of a good sample (protons for Z=1 and helium for Z=2)