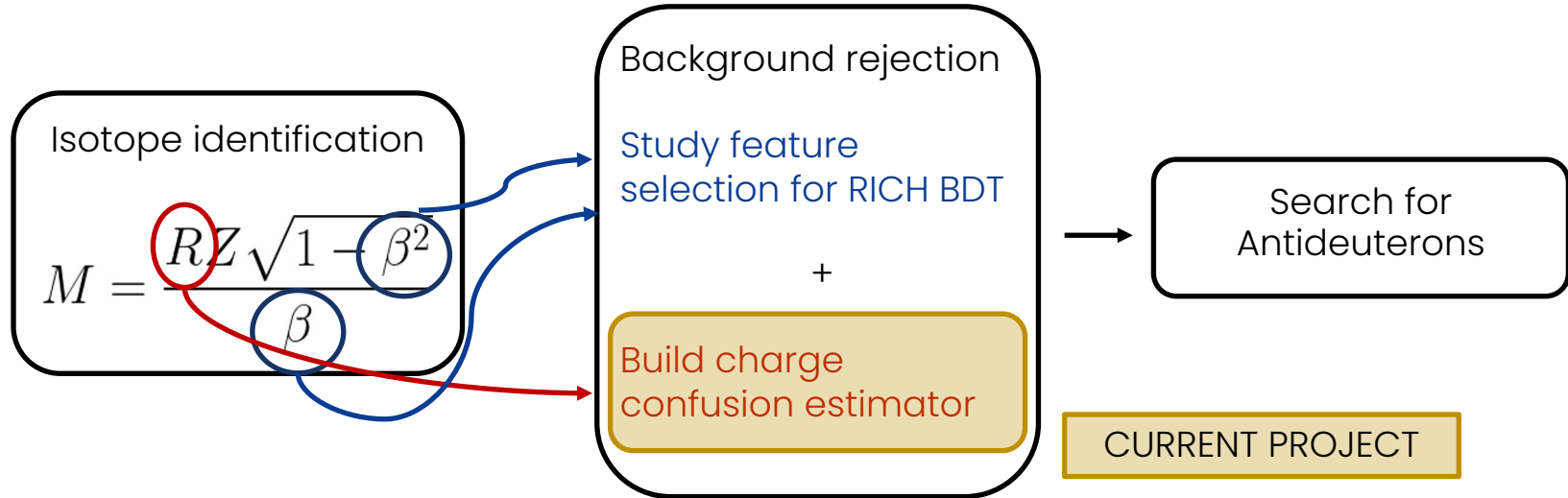


Antimatter search status

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23/04/24

Antideuteron identification



Charge confusion – Project overview

Aim:

build a charge confusion estimator (BDT trained on MonteCarlo events) to reject background composed by events whose rigidity sign is misreconstructed.

Steps:

1. Event selection
2. Background and signal choice
3. Feature selection
4. Train and test charge confusion estimator

Event selection

Purpose:

- get rid of background events not due to charge confusion
 - maintain a statistically significant sample of background events to train the BDT
- Start by applying **antiproton-like selection** on **MC proton events**

MC used:

v1.0.0/Pr.B1236/pr.pl1.05100.6_02

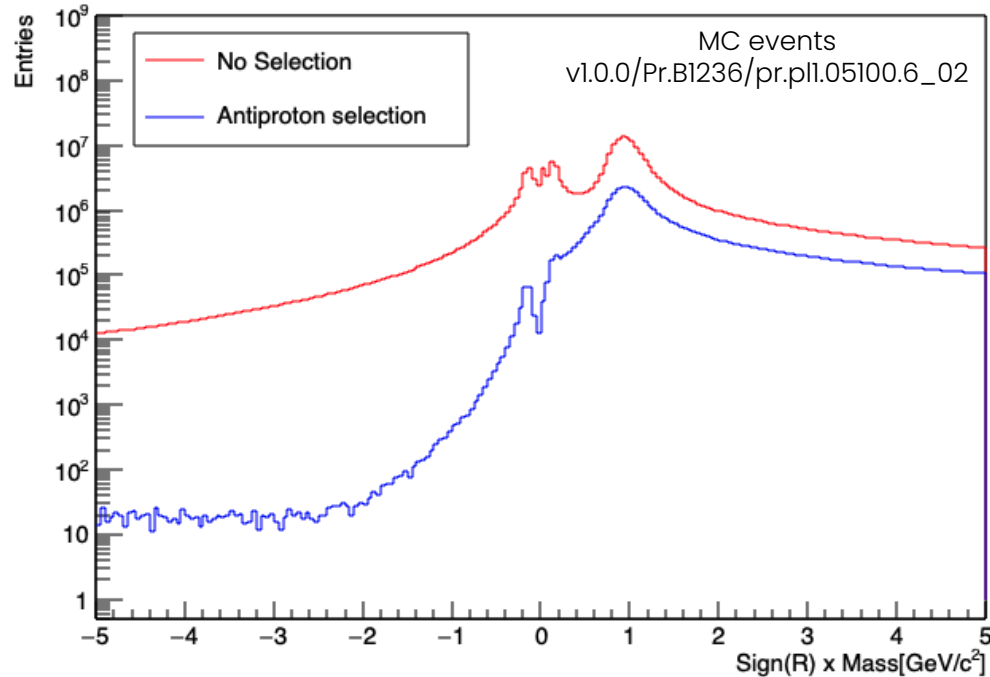
Antiproton-like selection

Z=1	Z=1 TOF	$0.5 < q_{tof} < 1.5$	
	Z=1 Tracker	$0.5 < q_{inntr} < 1.5$	
	God TOF Z	$q_{up} < 1.5 \ \&\& \ q_{dw} < 2.0$	
TOF	Good TOF NCluster	$N_{BetaCluster} == 4$	
	Good TOF chisq	$chisq_{tn} < 10 \ \&\& \ chisq_{cn} < 10$	
	Has Downgoing Track	$Beta_{tof} > 0.5$	
	Good Inner tracker chisq	$chisq_{InnerX_GBL} < 10 \ \&\& \ chisq_{InnerY_GBL} < 10$	
TRACKER	Single track	$n_{trtrack} == 1$	
	Tracker pattern	$L2 \ \&\& \ (L3 \ \ L4) \ \&\& \ (L5 \ \ L6) \ \&\& \ (L7 \ \ L8)$	
	XY Hits	At least 3 XY hits	
	Energy deposition	Less than 2.5 MeV deposited in Inner tracker (LayerEDep)	
	Enough TRD hits	$N_{HitsOnTrack} > 10$	
	TRD	Likelihood e/p	Likelihood e/p > 0.8
		Likelihood p/He	Likelihood p/He < 0.3

Mass distribution before and after selection

Events in total
 $6.2 \cdot 10^8$ events

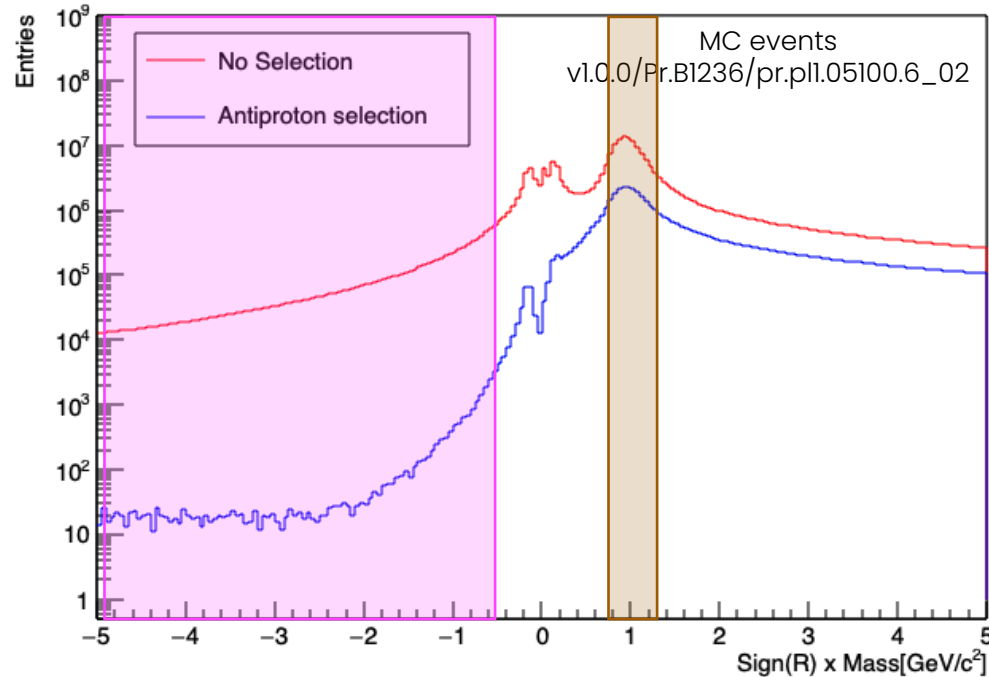
Events passing antiproton
selection
 $8.5 \cdot 10^7$ events



Background and signal samples

Signal Sample: events in mass proton range

Background sample: after the event selection almost all the events with $R < 0$ are charge confused protons



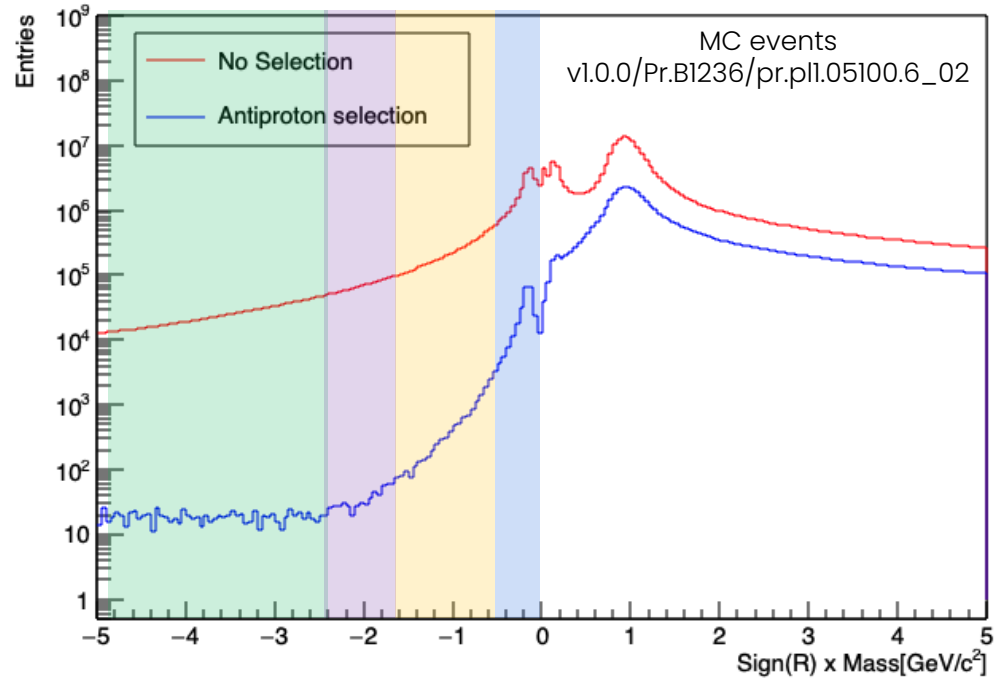
Background events

Light particles

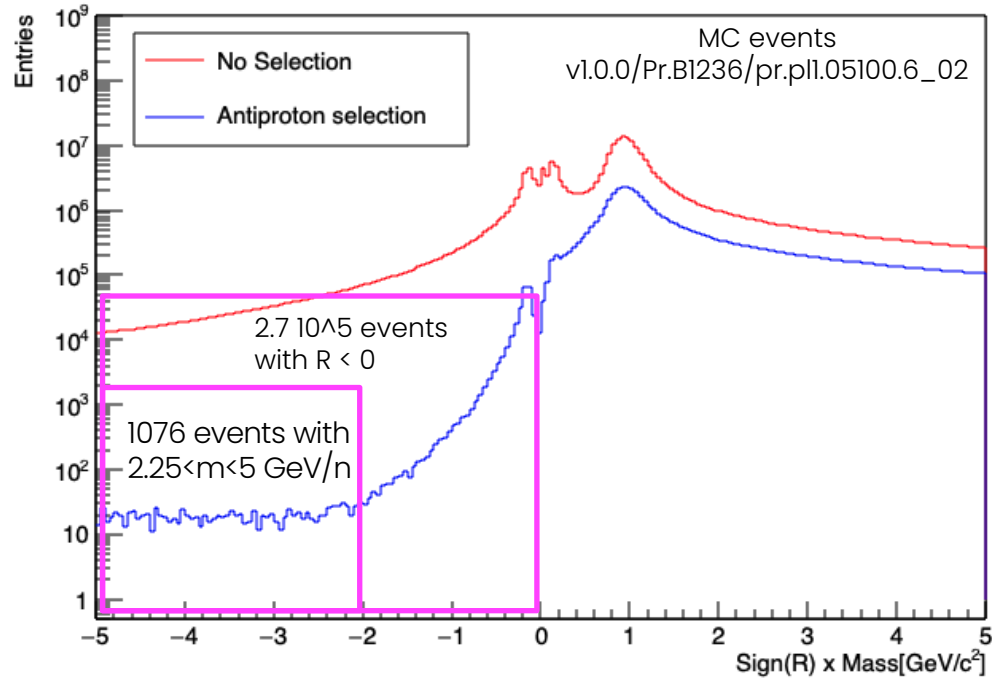
$p \rightarrow p\bar{b}$

$p \rightarrow d\bar{b}$

High mass tail



Background events



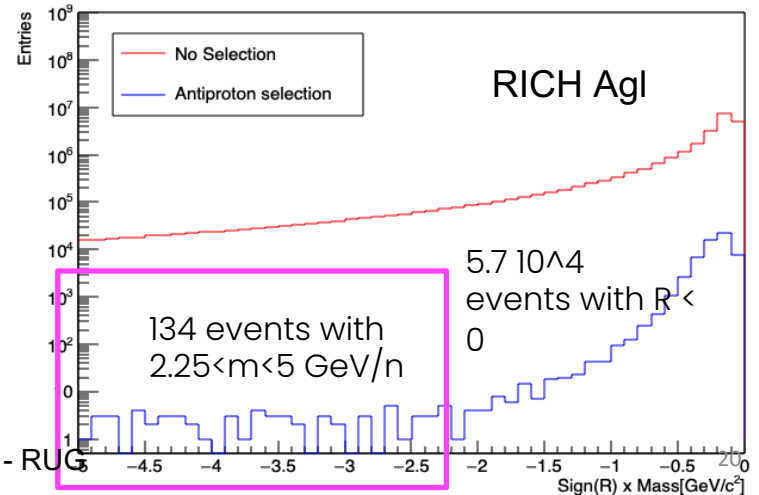
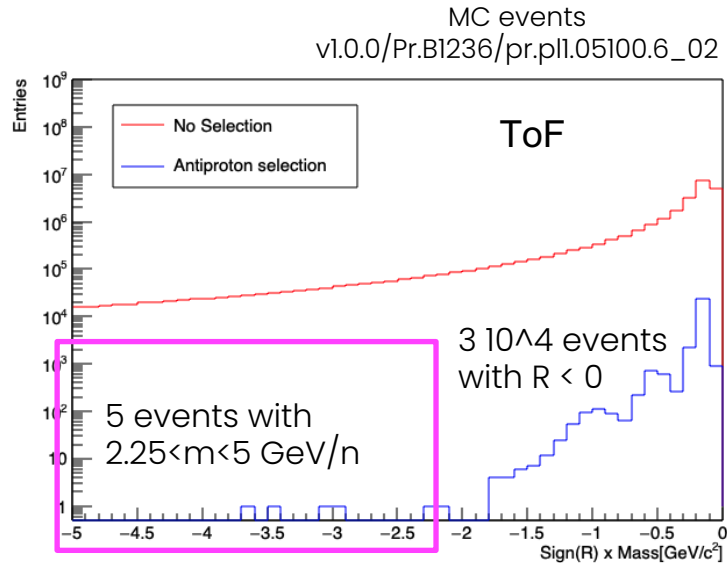
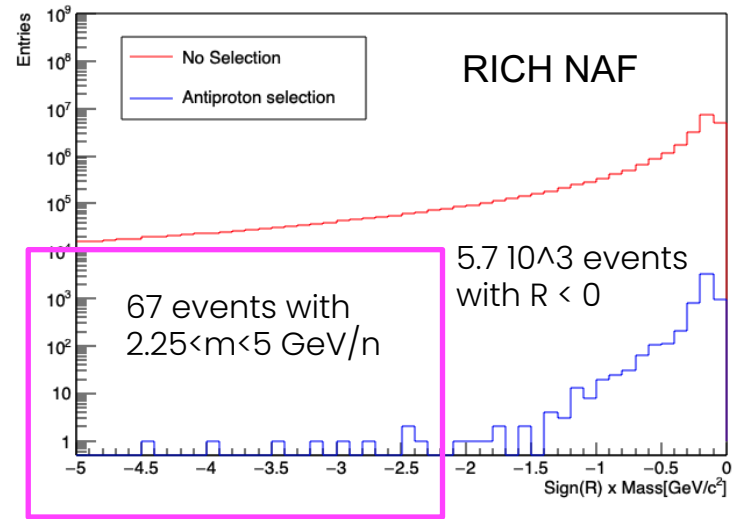
Beta requirement RICH & TOF

TOF	
Good AGL beta	$\text{beta_tof} < 0.9$
RICH NAF	
Track in NAF	Track in NAF
NAF beta above threshold	$\text{Beta} > 0.75 \quad \text{beta} < 0.99$
RICH AGL	
Track in AGL	Track in AGL
AGL beta above threshold	$\text{Beta_rich} > 0.96 \quad \text{beta_rich} < 0.997$

Other cuts on RICH from pbar selection have not been implemented for now because too restrictive

Mass distributions

RICH & TOF



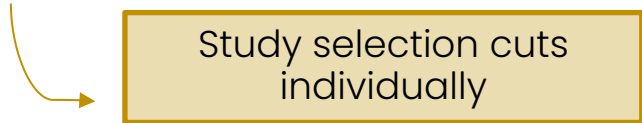
Solutions

Enough events with $R < 0$ for the background sample

- Change the background sample definition
- Consider (almost) all the events with $R < 0$ part of the background sample for the training of the BDT

Not enough events in the high mass tail

- Change the selection
- Release some of the cuts

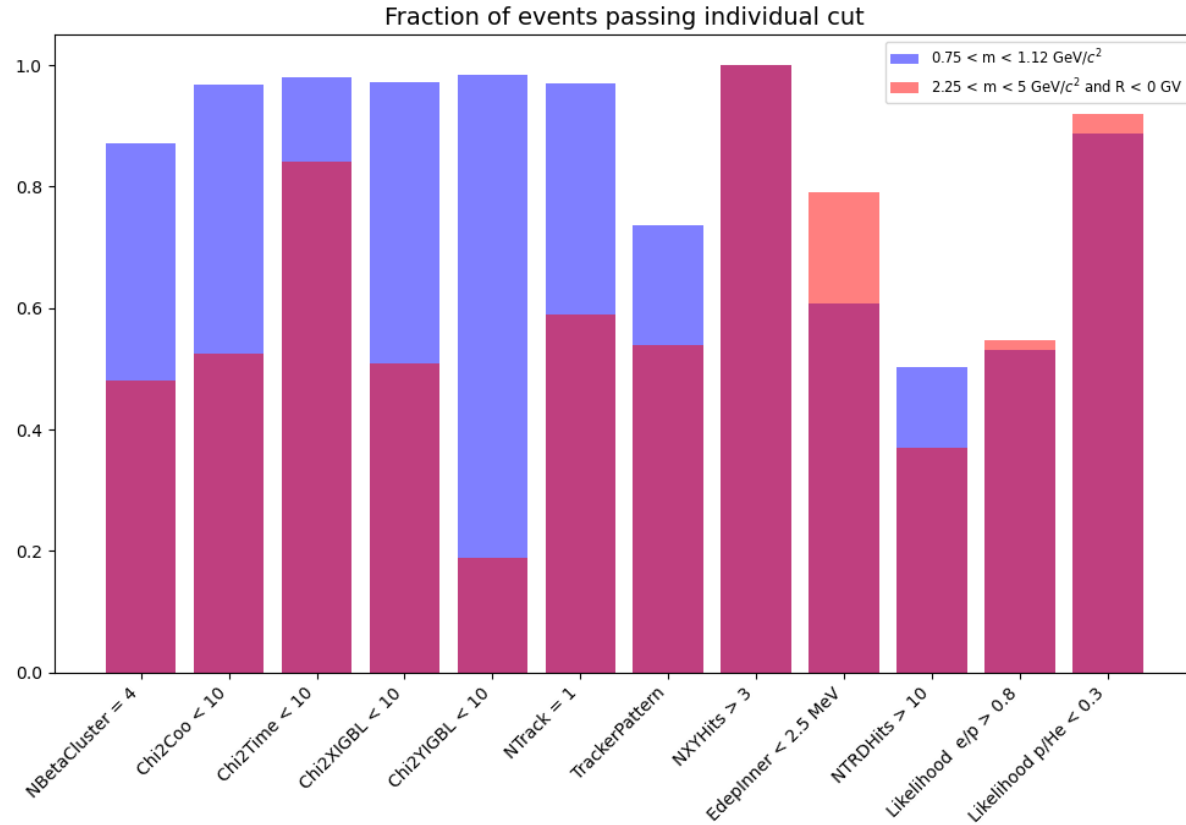


Study selection cuts individually

Selection cut study

Fraction of events passing each cut of the antiproton-like selection on top of the Z1 selection, for the negative tail (red) and the signal mass region (blue)

$$F_{passed} = \frac{N_{passed}(Z1+SingleCut)}{N_{passed} Z1}$$



Releasing some cuts

Option A: Maintain just the cuts related to the Tracker (and to the rigidity quality)

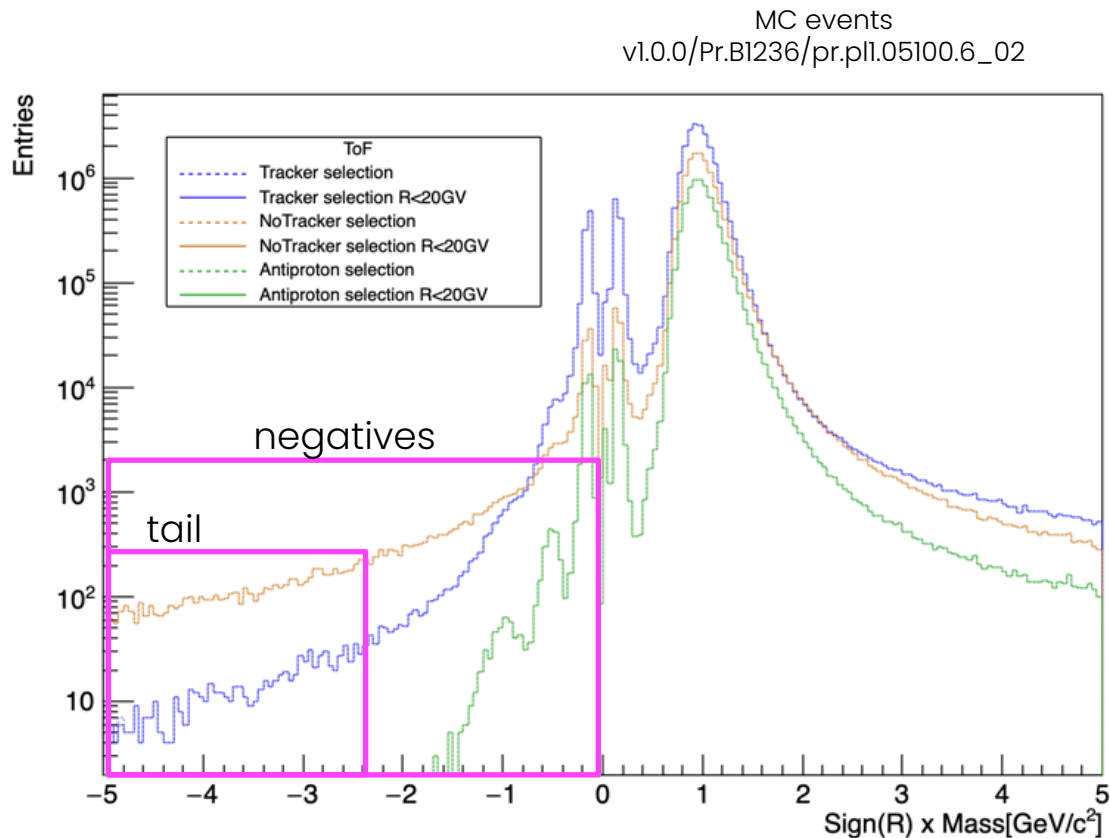
→ Tracker selection

Option B: Releasing all the cuts related to the Tracker (and to the rigidity quality)

→ No Tracker selection

+ Cut $R > 20$ GV since the general analysis aims at isotope identification

Background events - ToF

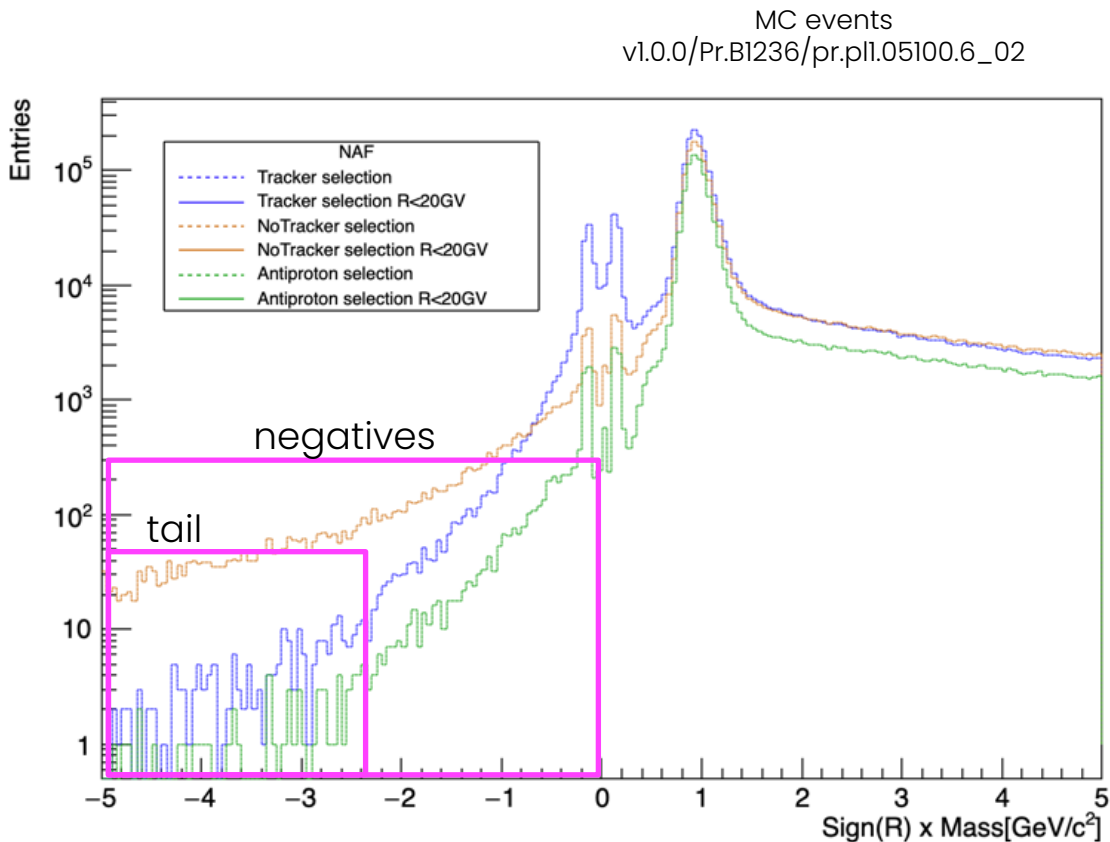


Number of events

ToF		Total	Negatives	Tail
Tracker selection	All R	2.4e7	1.05e6	869
	R<20 GV	2.4e7	1.05e6	868
NoTracker Selection	All R	1.3e7	1.3e5	6579
	R<20 GV	1.3e7	1.3e5	6579
Antiproton Selection	All R	7.0e6	29972	5
	R<20 GV	7.0e6	29972	5

- ToF beta requirements automatically select events with R<20GV.
- Enough events in tail for the new selections

Background events - NAF

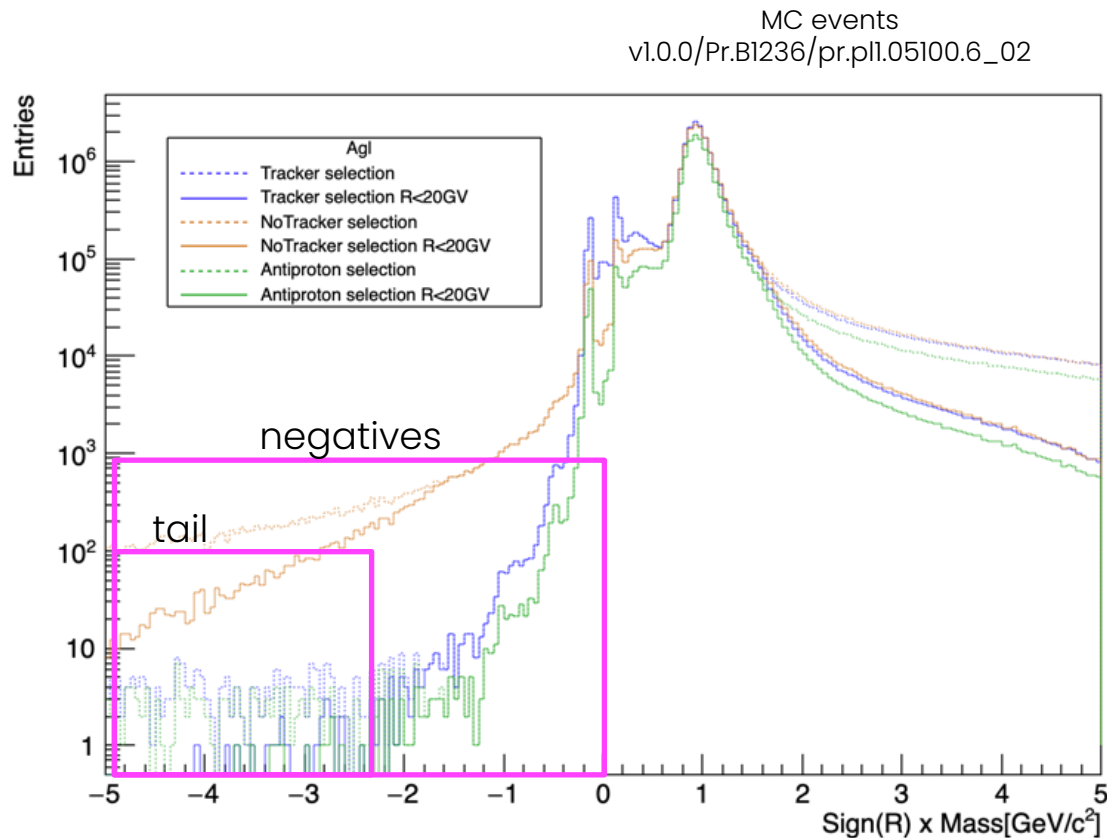


Number of events

	NAF	Total	Negatives	Tail
Tracker selection	All R	1.8e6	108474	244
	R < 20 GV	1.8e6	108474	244
NoTracker Selection	All R	1.4e6	3.0e4	2553
	R < 20 GV	1.4e6	3.0e4	2553
Antiproton Selection	All R	929381	7132	67
	R < 20 GV	929381	7132	67

- NAF beta requirements automatically select events with $R < 20 \text{ GV}$.
- Fewer events in tail for Tracker selection

Background events - Agl

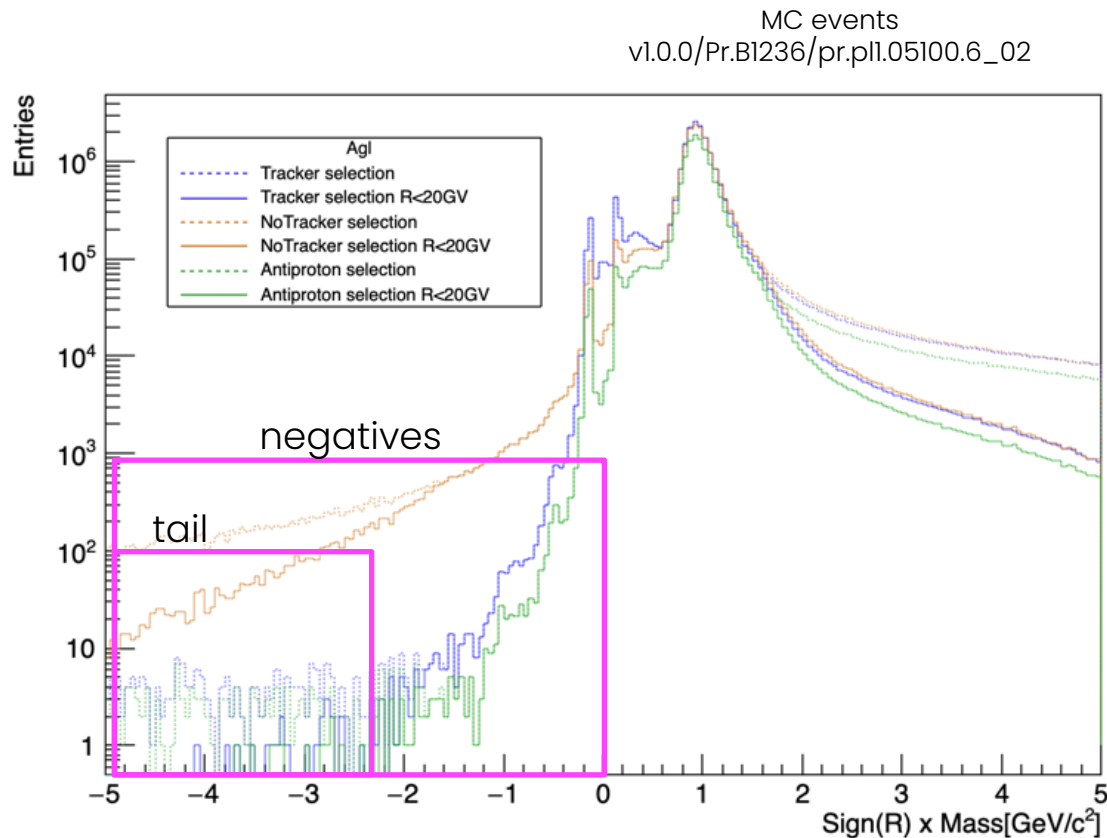


Number of events

	AgI	Total	Negatives	Tail
Tracker selection	All R	2.0e7	566169	205
	R<20 GV	1.9e7	565970	26
NoTracker Selection	All R	1.9e7	2.54e5	9586
	R<20 GV	1.8e7	2.46e5	3337
Antiproton Selection	All R	1.4e7	87385	134
	R<20 GV	1.3e7	87250	14

- AgI beta requirements do not select only events with R<20GV.
- Fewer events in tail for Tracker selection

Background events - AgI



NoTracker selection:

- Enough events in the tail to create background sample
- maximises the number of events in the tails while rejecting events in other mass ranges almost as the antiproton-like selection

Conclusion

Aim : building a charge confusion BDT estimator for antideuteron searches based on MC events.

- ✓ Identified the signal and background sample to train the estimator
- ✓ Antiproton selection does not provide a statistically significant sample in ToF/NaF and Aerogel sample
- ✓ Presented possible strategies to obtain a statistically significant background sample to train the BDT
- ✓ Releasing Tracker cuts provides the best selection for our analysis

FUTURE

- Upgrade NAIA to v1.1.0 and use [Pr.B1236/pr.pllphpsa.0550.4_00/](#)
- Apply selection to data
- Data/MC features comparison
- Train BDT on MC (and Data)

BACK UP

MC used

→ v1.0.0/Pr.B1236/pr.pll.05100.6_02

- 4515 files
- total size 3 Tb
- generated rigidity 05 - 100 GV
- Events generated on a square with sides 4m long
- All events that trigger AMS detectors are saved (not just the ones passing through L1)

Selection

Selection inspired from AMS02 p-bar paper [PRL 091103 (2016)] (main differences in red):

TOF β with estimated with 4 clusters, $\chi^2_{\tau} < 10$

Good association between TOF and Tracker track ($\chi^2_c < 10$)

$Q_{\text{UTOF}} < 1.5$, $Q_{\text{LTOF}} < 2.0$

Tracker track with 1 Y hit per layer: **L2** & (L3|L4) & (L5|L6) & (L7|L8)

Tracker track with 1 at least 3 XY hits

Tracker track with $\chi^2_Y < 10$, $\chi^2_X < 10$

TRD with at least 10 hits

Likelihood He/p < 0.3

Likelihood e/p > 0.8

N. Tracker Tracks = 1

X+Y Energy Dep. in all Inner Tracker < 2.5 MeV

N. TRD Tracks = 1

N. TRD Segments < 8

No use of RICH veto

RICH Selection:

Kolmogorov test prob > 0.01

Number of PMTs > 2

Coll. p.e./Tot p.e. > 0.5

Number of exp. p.e. > 2 (1 for NaF)

Exclude bad tiles

Good radiator fiducial area

$(\beta_{\text{TOF}} - \beta_{\text{RICH}})/\beta_{\text{RICH}} < 0.1$

Additional cuts (tight sel.):

1 TRD Track

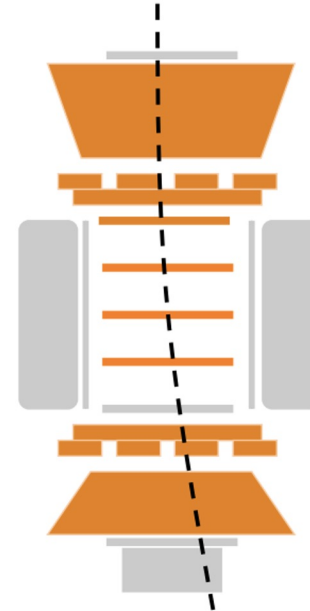
Tracker N. Hits Y $> 4,5,6$

Tracker N. Hits XY > 3

TOF cluster in time ≤ 4

$Q_{\text{UTOF}} < 1.5$, $Q_{\text{LTOF}} < 1.5$

Standard orbital cuts also included



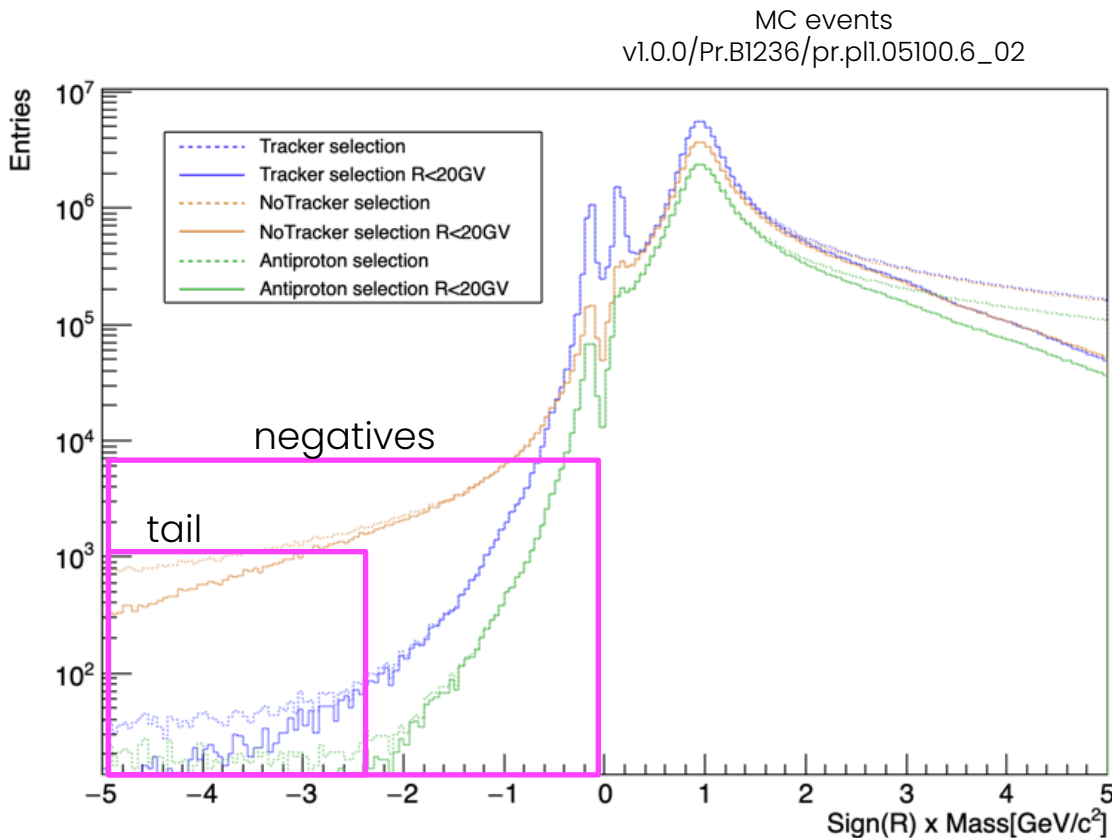
Tracker selection

Z=1	Z=1 TOF	$0.5 < q_{tof} < 1.5$
	Z=1 Tracker	$0.5 < q_{inotr} < 1.5$
TOF	God TOF Z	$q_{up} < 1.5 \ \&\& \ q_{dw} < 2.0$
	Has Downgoing Track	$Beta_{tof} > 0.5$
	Good Inner tracker chisq	$chisq_{InnerX_GBL} < 10 \ \&\& \ chisq_{InnerY_GBL} < 10$
	Single track	$n_{trtrack} == 1$
	Tracker pattern	$L2 \ \&\& \ (L3 \ \ L4) \ \&\& \ (L5 \ \ L6) \ \&\& \ (L7 \ \ L8)$
TRACKER	XY Hits	At least 3 XY hits
	Energy deposition	Less than 2.5 MeV deposited in Inner tracker (LayerEDep)

No Tracker selection

Z=1	Z=1 TOF	$0.5 < q_{tof} < 1.5$
	Z=1 Tracker	$0.5 < q_{in} < 1.5$
	God TOF Z	$q_{up} < 1.5 \ \&\& \ q_{dw} < 2.0$
TOF	Good TOF NCluster	$N_{BetaCluster} == 4$
	Good TOF chisq	$chisq_{tn} < 10 \ \&\& \ chisq_{cn} < 10$
	Has Downgoing Track	$Beta_{tof} > 0.5$
TRD	Enough TRD hits	$N_{HitsOnTrack} > 10$
	Likelihood e/p	Likelihood e/p > 0.8
	Likelihood p/He	Likelihood p/He < 0.3

Background events – no beta requirements



Number of events

NO BETA REQ		Total	Negatives	Tail
Tracker selection	All R	8.8e7	3.11253 e6	2732
	R<20 GV	8.2e7	3.11117 e6	1663
NoTracker Selection	All R	6.7e7	9.2e5	6.3e4
	R<20 GV	6.1e7	9.0e5	4.4e4
Antiproton Selection	All R	4.5e7	271069	1076
	R<20 GV	4.1e7	271045	359

Sanity checks

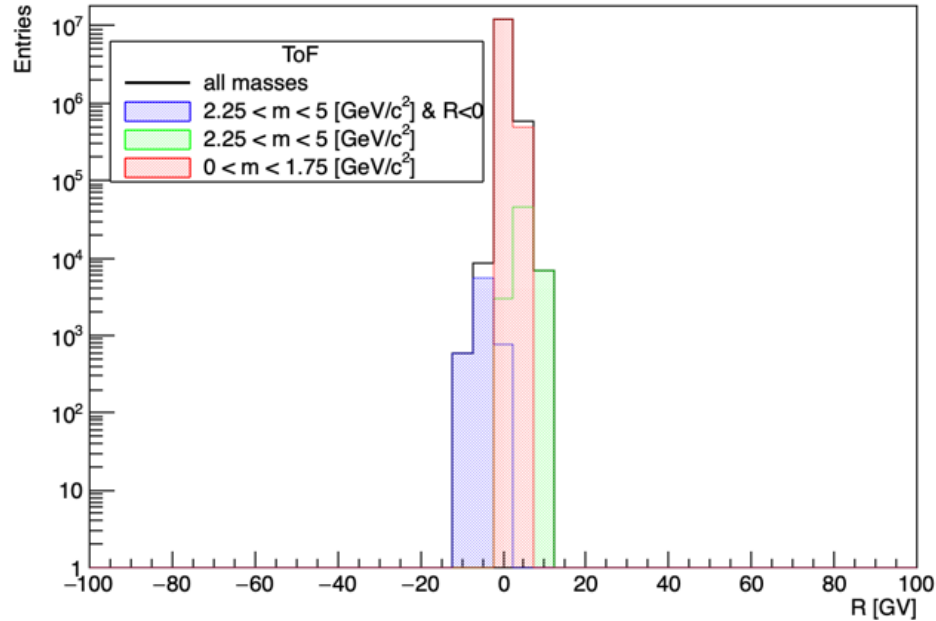
Check that:

- ToF and NAF beta requirements automatically select events with $R < 20 \text{GV}$
- The cut on the rigidity ($R < 20 \text{GV}$) almost doesn't impact the central mass range of the distribution (roughly from 0. to $1.75 \text{ GeV}/c^2$)

→ Plot Rigidity distributions

Rigidity distributions NoTracker Sel – ToF

MC events
v1.0.0/Pr.B1236/pr.pl1.05100.6_02



Rigidity distributions NoTracker Sel -Rich

MC events
v1.0.0/Pr.B1236/pr.pl1.05100.6_02

