$B_s^0 \to \mu^+\mu^-$ Cross Check Analysis

Purdue, Pisa

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Abstract

The aim of this analysis note is to provide supporting material for the cross check analysis for the search for $B_s^0 \to \mu^+\mu^-$ and $B^0 \to \mu^+\mu^-$ decays. It follows closely the documentation provided in [**?**] and includes direct comparison to the results in that note.

Contents

Official MC datasets
BsToMuMu_BsFilter_8TeV-pythia6-evtgen/Summer12_DR53X-PU_S10_START53_V7A-v1/AODSIM
Data /MuOnia/Run2012A-13Jul2012-v1/AOD /MuOnia/Run2012A-recover-06Aug2012-v1/AOD /MuOnia/Run2012B-13Jul2012-v1/AOD /MuOnia/Run2012C-24Aug2012-v1/AOD /MuOnia/Run2012C-PromptReco-v2/AOD /MuOnia/Run2012C-EcalRecover_11Dec2012-v1/AOD /MuOnia/Run2012D-PromptReco-v1/AOD

1 Introduction

Goals and how the note is organized.

2 Datasets

The datasets used are shown in table **??**.

The events are selected using the same triggers as described in the reference [**?**].

The analysis is based on a boosted decision tree (BDT) algorithm to select $B_s^0 \to \mu^+\mu^-$ events from the background. A preselection is applied to the data and MC samples to reduce the size and remove outliers that might confuse the BDT training. The signal is taken from the $B_s^0 \to \mu^+\mu^-$ MC sample, while the background is taken from the sidebands in the data sample.
Despite the availability of the full 2012 dataset, in order to allow a direct comparison with the results in [**?**] this study is limited to runs <= 203002. The dataset is split in three different categories according the remainder of "event number%3".

3 Selection

3.1 pre-selection

The same preselection as in [**?**] is used.

3.2 muon identification

The muons are chosen to pass global muon prompt tight selection (GM_PT). [to be updated]

3.3 variable distributions

The distributions of the variables used for the BDT training are shown in Figures 1 and 2.

	0		1		2	
rank	variable	separation	variable	separation	variable	separation
1	alpha	6.010e-01	alpha	6.102e-01	alpha	6.091e-01
2	fls3d	4.903e-01	fls3d	4.938e-01	fls3d	4.851e-01
3	docatrk	4.135e-01	docatrk	4.255e-01	docatrk	4.205e-01
4	pvips	3.792e-01	pvips	3.669e-01	pvips	3.888e-01
5	m1iso	3.352e-01	m1iso	3.369e-01	m1iso	3.341e-01
6	m2iso	3.012e-01	m2iso	2.907e-01	m2iso	3.048e-01
7	iso	2.827e-01	iso	2.741e-01	iso	2.770e-01
8	chi2/dof	1.165e-01	chi2/dof	1.205e-01	chi2/dof	1.213e-01
9	eta	7.956e-03	eta	5.700e-03	eta	5.443e-03

Table 1: Variable ranking for events of the three different event samples in the barrel before training.

	0		1		2	
rank	variable	separation	variable	separation	variable	separation
1	alpha	6.279e-01	alpha	6.334e-01	alpha	6.344e-01
2	fls3d	5.114e-01	fls3d	5.405e-01	fls3d	5.209e-01
3	closetrk	4.916e-01	closetrk	5.235e-01	closetrk	4.987e-01
4	pvips	3.545e-01	pvips	3.460e-01	pvips	3.666e-01
5	iso	2.377e-01	iso	2.541e-01	m1iso	2.468e-01
6	m1iso	2.361e-01	m1iso	2.473e-01	iso	2.282e-01
7	m2iso	2.136e-01	m2iso	2.334e-01	m2iso	2.182e-01
8	chi2/dof	1.246e-01	chi2/dof	1.152e-01	chi2/dof	1.416e-01
9	pt	6.623e-02	pt	8.460e-02	pt	8.087e-02
10	eta	1.029e-02	eta	7.767e-03	eta	9.411e-03

Table 2: Variable ranking for events of the three different event samples in the endcaps before training.

3.4 variable ranking and correlations

Tables **??** and **??** show the ranking of variables before the BDT training.

4 Boosted Decision Tree

The inclusive samples are split in three different subsamples according to the rule $index = eventNumber\%3$. These samples are then used as follows:

- events of type 0: analyzed by BDT0, trained on type-1 events, tested on type-2 events
- events of type 1: analyzed by BDT1, trained on type-2 events, tested on type-0 events
- events of type 2: analyzed by BDT2, trained on type-0 events, tested on type-1 events

for the training and testing.

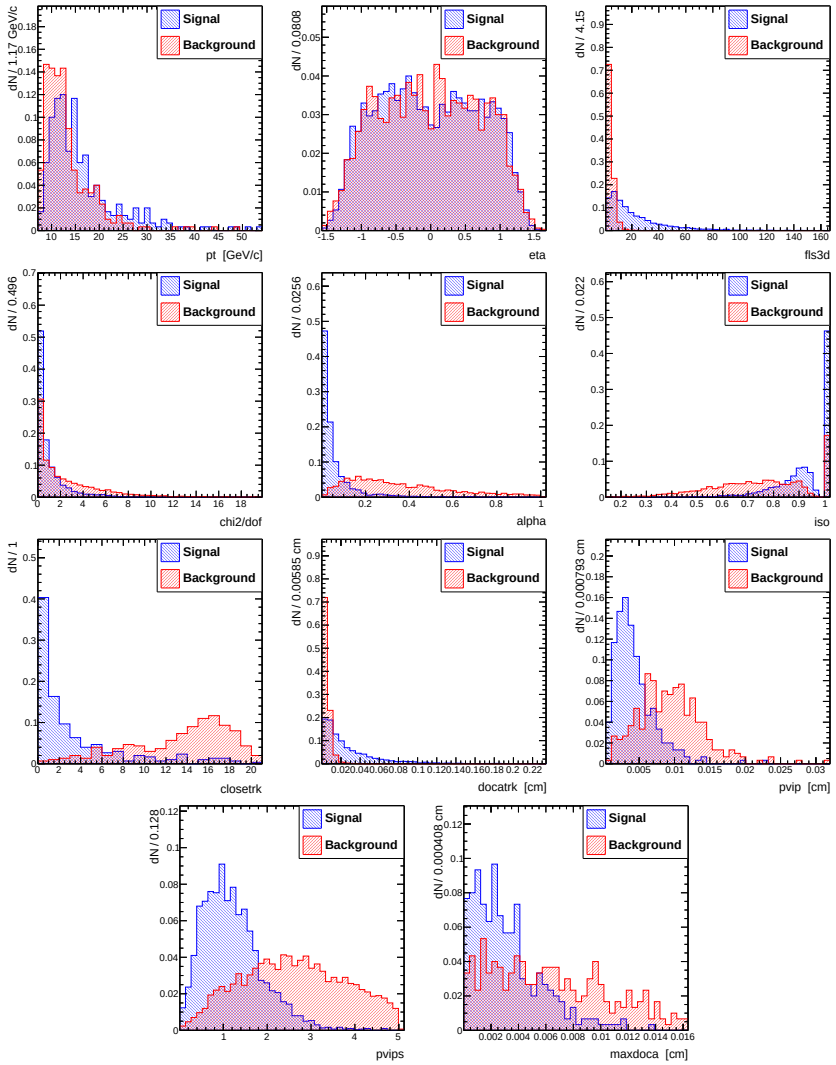

Figure 1: Standard TMVA plot of the input variables for the barrel BDT for signal (blue) and background (red). The background is extracted from data dimuon sidebands.

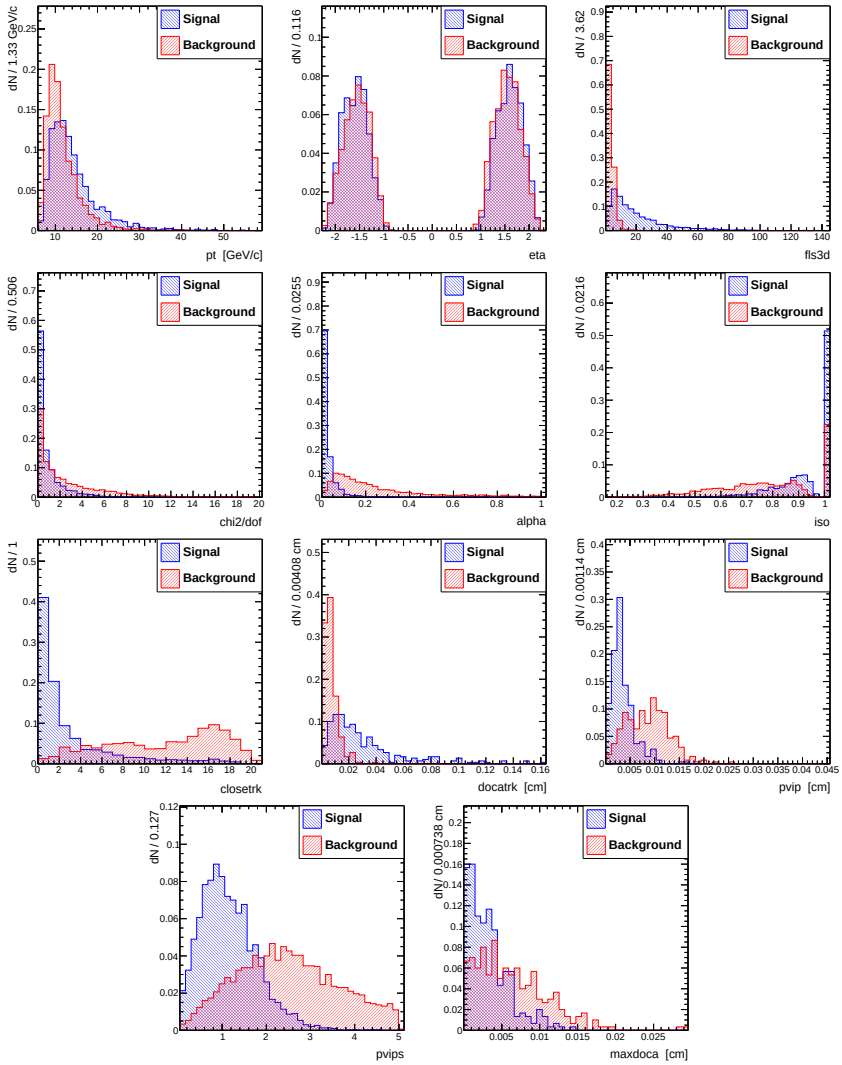

Figure 2: Standard TMVA plot of the input variables for the endcaps BDT for signal (blue) and background (red). The background is extracted from data dimuon sidebands.

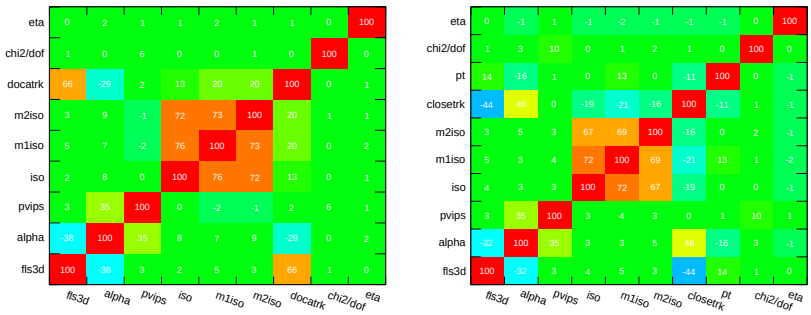

Figure 3: Correlation matrix for signal events in the barrel (left) and the endcap (right).

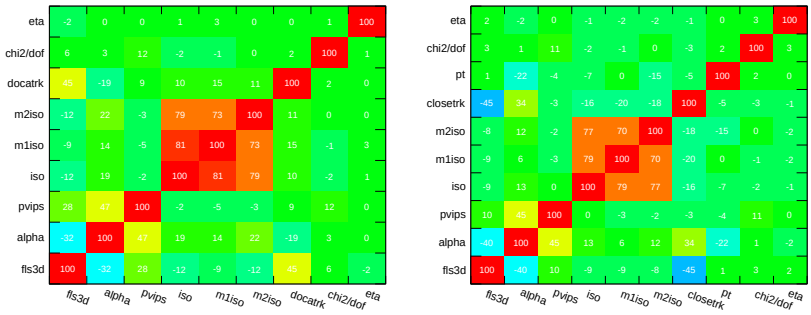

Figure 4: Correlation matrix for background events in the barrel (left) and the endcap (right).

	0		1		2	
rank	variable	separation	variable	separation	variable	separation
Ranking	(top	is	(top	is	(top	is
Rank	Variable	Variable	Variable	Variable	Variable	Variable
1	pvips	1.564e-01	alpha	1.608e-01	alpha	1.577e-01
2	alpha	1.428e-01	pvips	1.406e-01	pvips	1.541e-01
3	fls3d	1.416e-01	chi2dof	1.252e-01	fls3d	1.372e-01
4	m2iso	1.185e-01	fls3d	1.216e-01	m2iso	1.187e-01
5	chi2dof	1.066e-01	m1iso	1.155e-01	m1iso	1.108e-01
6	m1iso	1.019e-01	iso	9.576e-02	docatrk	1.047e-01
7	docatrk	9.052e-02	m2iso	9.354e-02	chi2dof	8.586e-02
8	eta	7.312e-02	eta	7.607e-02	iso	6.847e-02
9	iso	6.851e-02	docatrk	7.090e-02	eta	6.243e-02

Table 3: Variable ranking for events of the three different event samples in the barrel after BDT training.

	0		1		2	
rank	variable	separation	variable	separation	variable	separation
Ranking	(top	is	(top	is	(top	is
Rank	Variable	Variable	Variable	Variable	Variable	Variable
1	alpha	1.608e-01	alpha	1.600e-01	pvips	1.514e-01
2	fls3d	1.383e-01	pvips	1.403e-01	alpha	1.380e-01
3	pvips	1.380e-01	fls3d	1.151e-01	fls3d	1.144e-01
4	iso	1.114e-01	m2iso	1.109e-01	chi2dof	1.135e-01
5	closetrk	9.159e-02	m1iso	1.081e-01	m2iso	1.105e-01
6	m2iso	8.764e-02	iso	9.380e-02	m1iso	8.947e-02
7	chi2dof	7.560e-02	closetrk	9.190e-02	closetrk	7.862e-02
8	eta	7.451e-02	chi2dof	7.353e-02	pt	7.390e-02
9	m1iso	7.284e-02	eta	5.964e-02	eta	6.659e-02
10	pt	4.927e-02	pt	4.667e-02	iso	6.354e-02

Table 4: Variable ranking for events of the three different event samples in the endcaps after BDT training.

Sample	Type 0	Type 1	Type 2
Signal barrel	5872	6060	5774
Signal endcaps	3447	3384	3222
Background barrel	16352	16315	16435
Background endcaps	10668	10644	10647

Table 5: Number of events per type for signal and background events in the barrel and endcap.

Tables **??** and **??** show the ranking of variables before the BDT training.

Tables **??** shows the number of candidates in each of the subsamples. The events are after all preselections including muon-id (tight muon).

Figure 5 shows control plots for the BDT training.

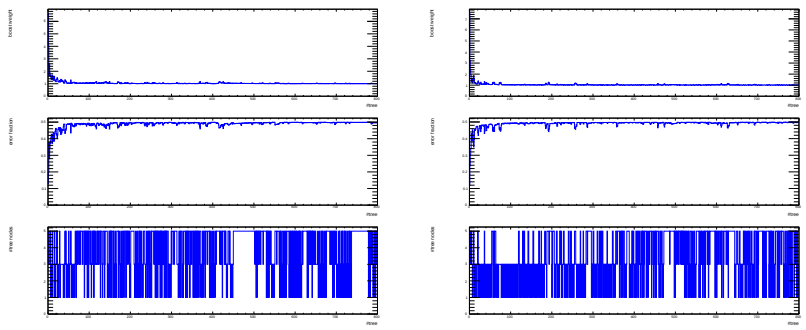

Figure 5: TMVA BDT charaterization plots for the barrel (left) and the endcap (right). Shown versus the tree number is the boost weight (top) and the event misclassification rate (middle), and the number of nodes before pruning (bottom).

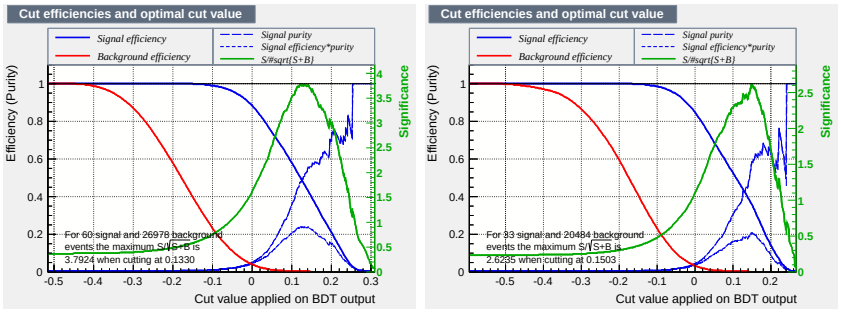

Figure 6: Optimal BDT cut value for barrel (left) and endcaps (right). WARNING: This plot is taken from the training on the full sample.

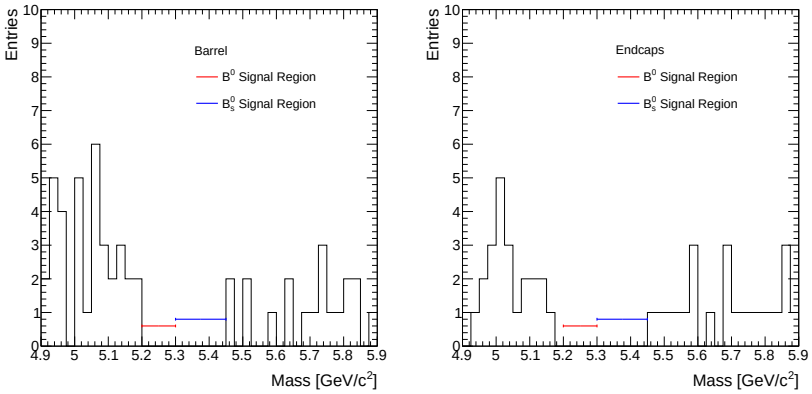

Figure 7: Blinded invariant mass distribution for all candidates passing the BDT selection for barrel (left) and endcaps (right).

Figures 6 show the optimal value of the BDT cut for the estimated numbers of signal and background events.

Figures 7 show the blinded invariant mass distribution after applying the BDT selection.

Figures 8, 9, show variable distributions after the application of the BDT selection.

In figure **??** the standard control plots of TMVA with a linear scale are shown that check against overtraining of the BDT in the barrel and the endcap.

Figures **??** and **??** show the output of the BDT application on different samples for data and $B_s^0 \to \mu^+\mu^-$ simulation.

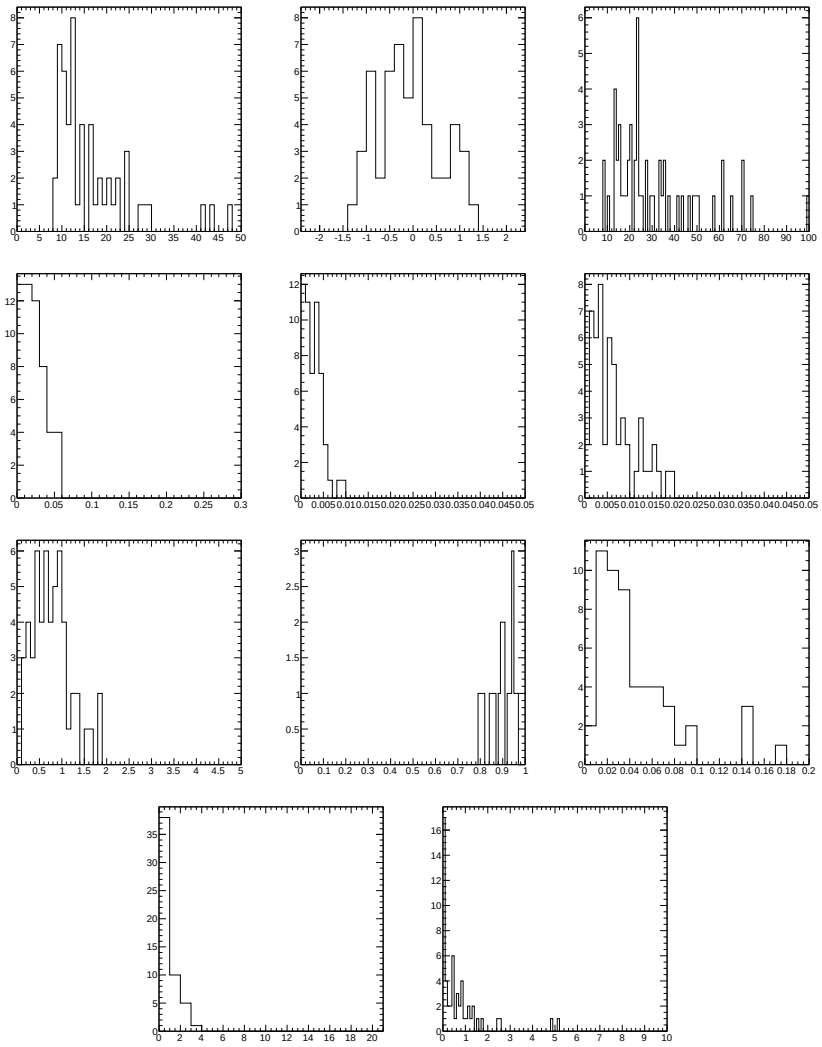

Figure 8: Variable distributions for the barrel after BDT cuts on blinded data.

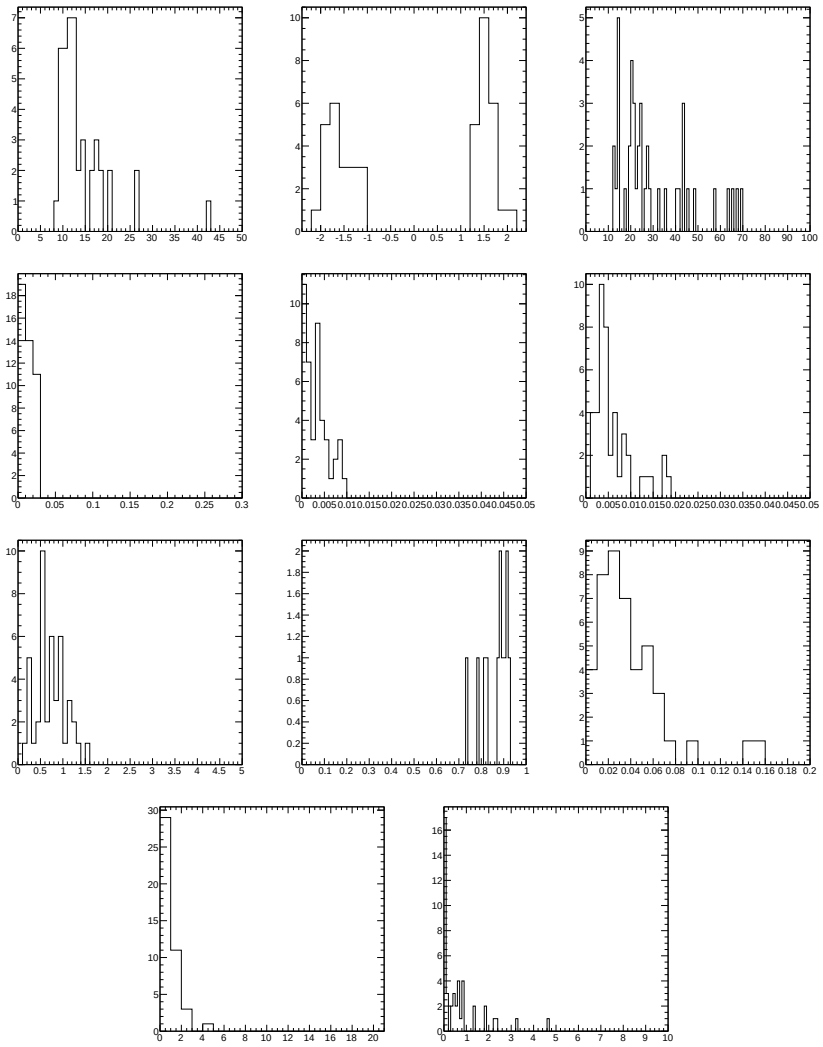

Figure 9: Variable distributions for the endcaps after BDT cuts on blinded data.

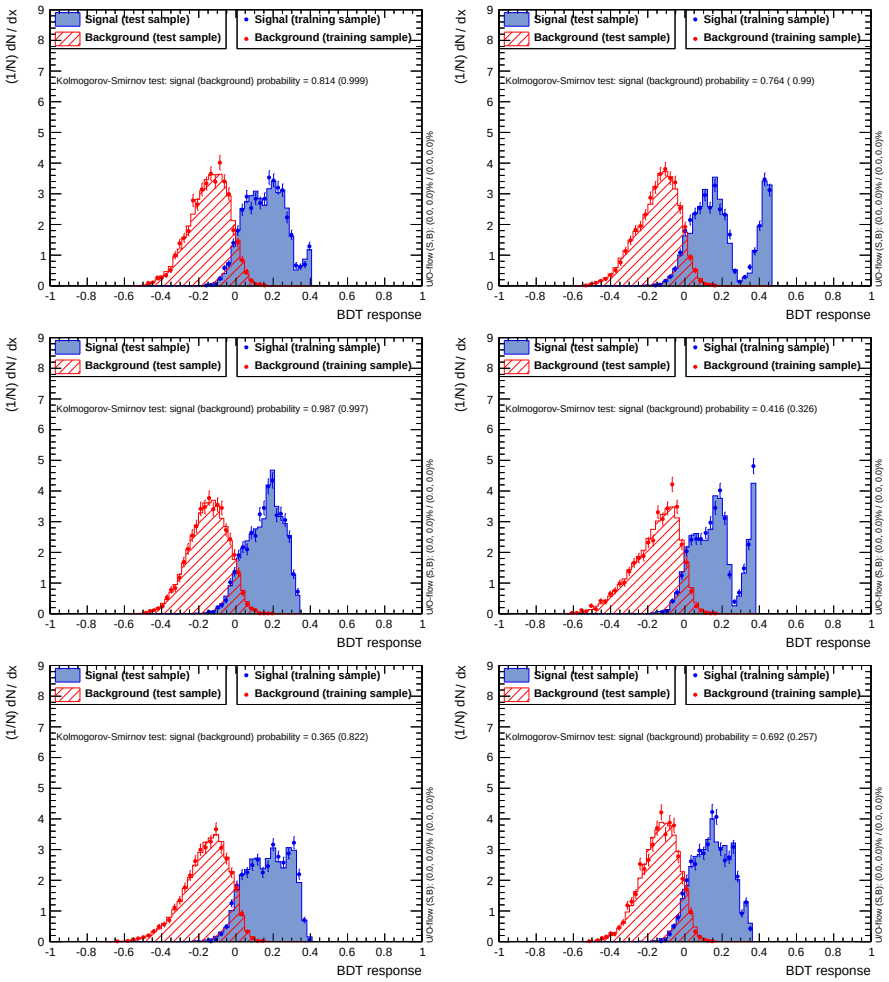

Figure 10: TMVA overtraining control plot for the barrel(left) and the end-cap(right), for events of type 0...2 from the top to the bottom.

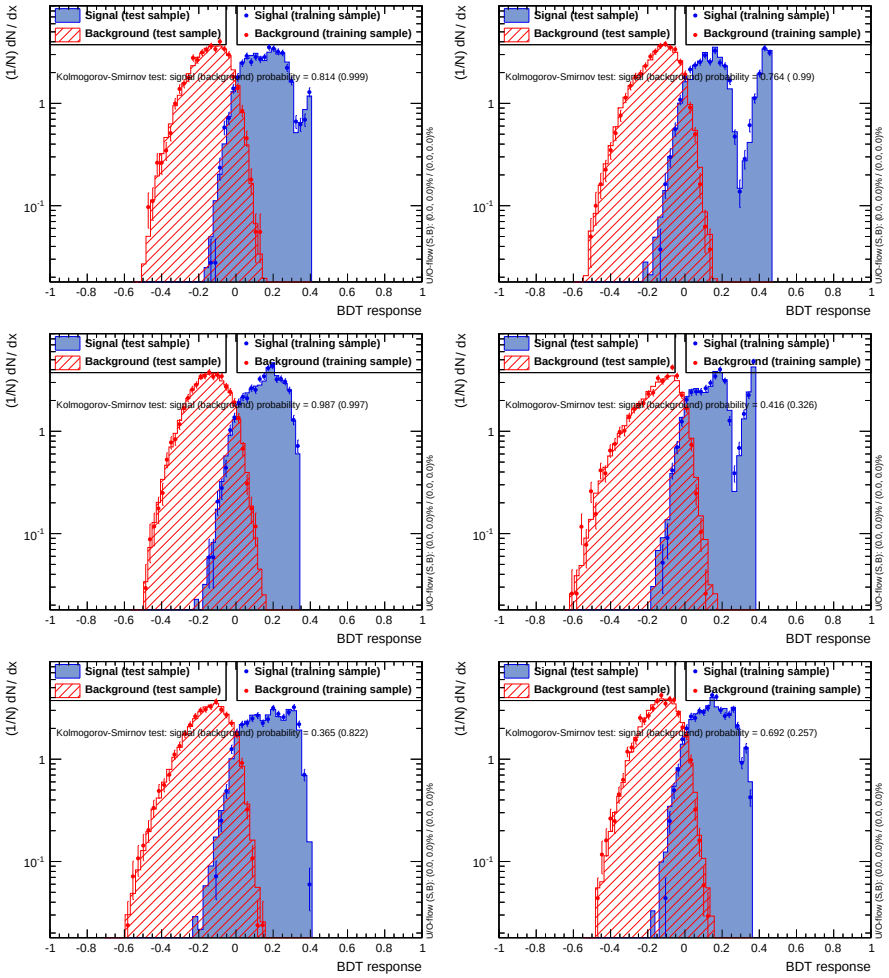

Figure 11: TMVA overtraining control plot for the barrel(left) and the end-cap(right), for events of type 0...2 from the top to the bottom. This Figure shows on a logarithmic scale.

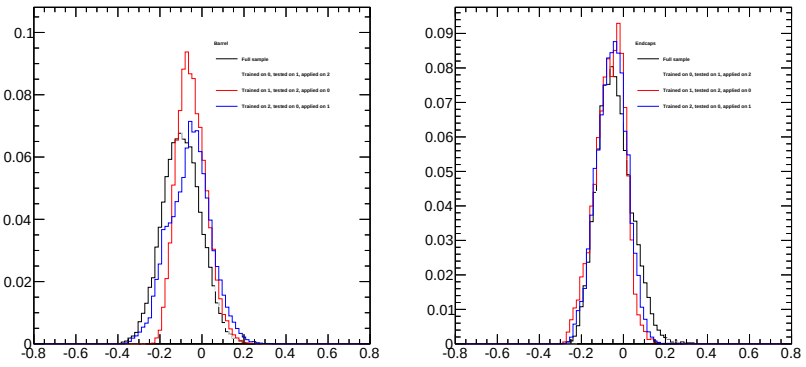

Figure 12: BDT output distribution for the application on data for different control samples and the full sample for (left) and endcaps (right).

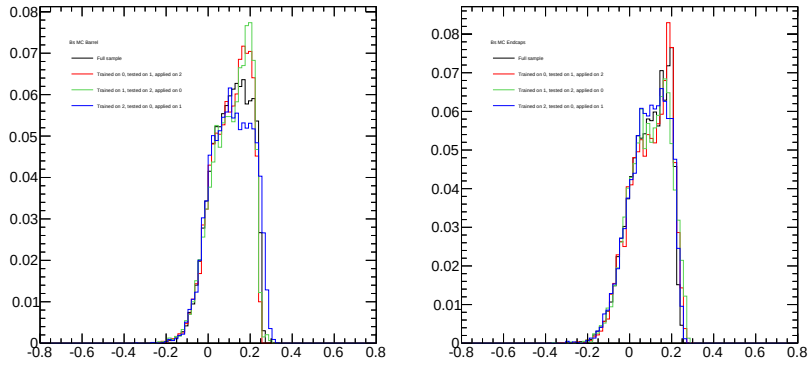

Figure 13: BDT output distribution for the application on $B_s^0 \to \mu^+\mu^-$ signal MC different control samples and the full sample for (left) and endcaps (right).

variable	min	max
pt	5.99	121.05
eta	-1.25	1.37
fls3d	16.97	81.03
alpha	0.00	0.13
maxdoca	0.00	0.03
pvip	-0.00	0.07
pvips	0.21	1.57
iso	0.77	1.25
docatrk	0.00	0.10
closetrk	-0.17	2.94
chi2dof	-0.04	7.25

Table 6: Rectangular cut values, optimized for the BARREL, corresponding to a signal efficiency of 0.3.

variable	min	max
pt	10.19	88.56
eta	-2.01	2.24
fls3d	11.86	117.63
alpha	0.00	0.18
maxdoca	-0.00	0.03
pvip	-0.00	0.02
pvips	0.21	2.10
iso	0.48	1.08
docatrk	0.02	0.27
closetrk	-0.16	15.51
chi2dof	-0.04	3.46

Table 7: Rectangular cut values, optimized for the ENDCAPS, corresponding to a signal efficiency of 0.3.

5 Cut and count analysis

The same varibale set as used for MVA training is employed. The Simulating Annealing method in TMVA is used.

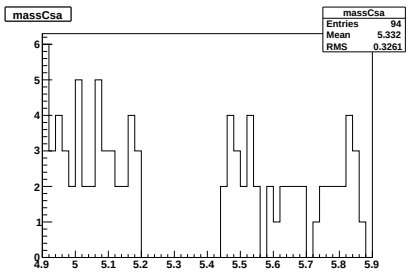

Figure 14: Blinded cut results for barrel (left) and endcaps (right), after optimization.

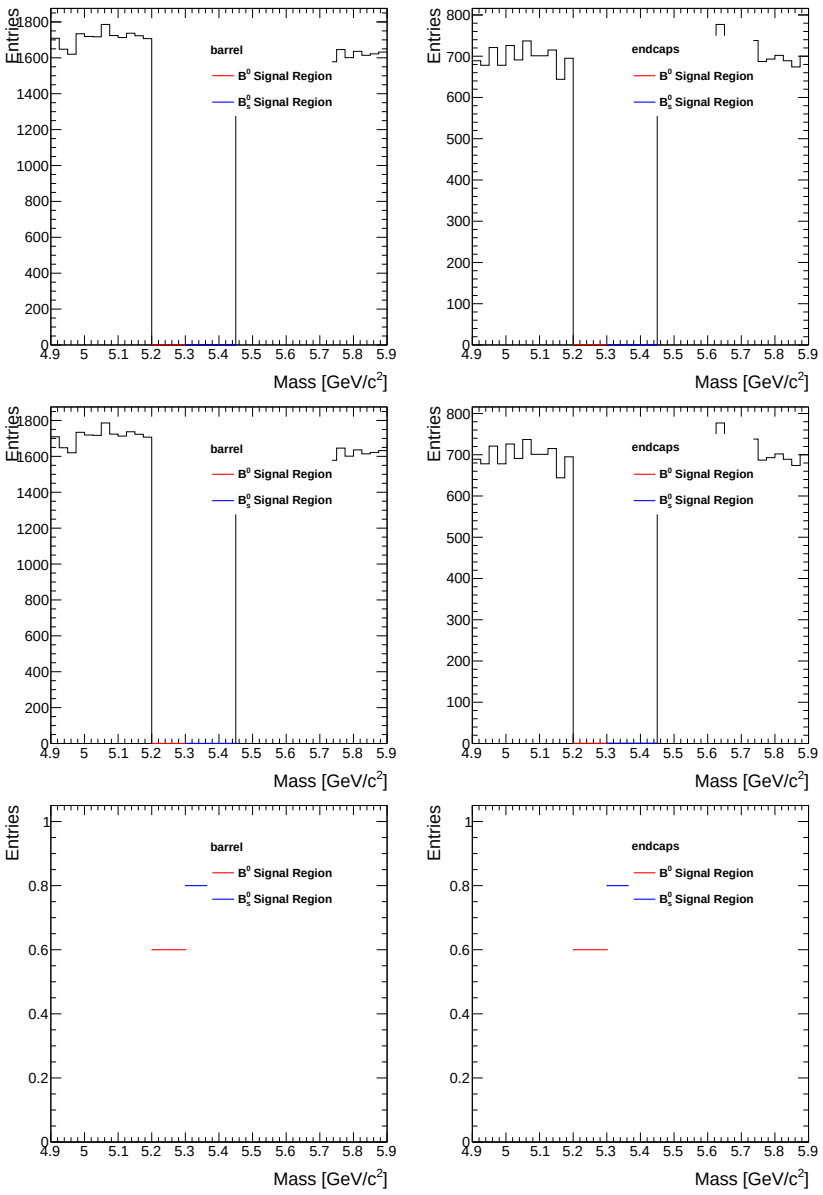

Figure 15: mass plots: barrel (left) and edncaps (right); BDT (top), MLP (middle), Cuts (bottom).

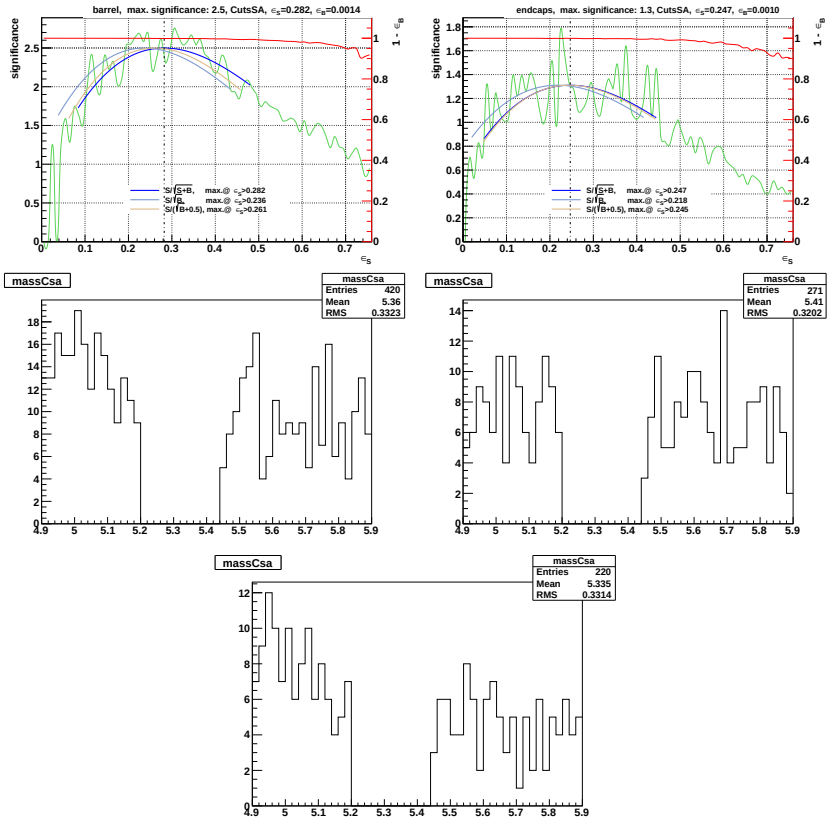

Figure 16: cut 'n count

6 Normalization channel

6.1 datasets

6.2 selection

6.3 BDT

6.4 yields

7 Full dataset

8 Selection

8.1 datasets

8.2 muon identification

8.3 variable distributions, correlations, ranking

8.4 TMVA training

8.4.1 MLP

8.4.2 BDT

8.5 Normalization channel

8.5.1 MLP

8.5.2 BDT

8.6 Limits

9 Summary

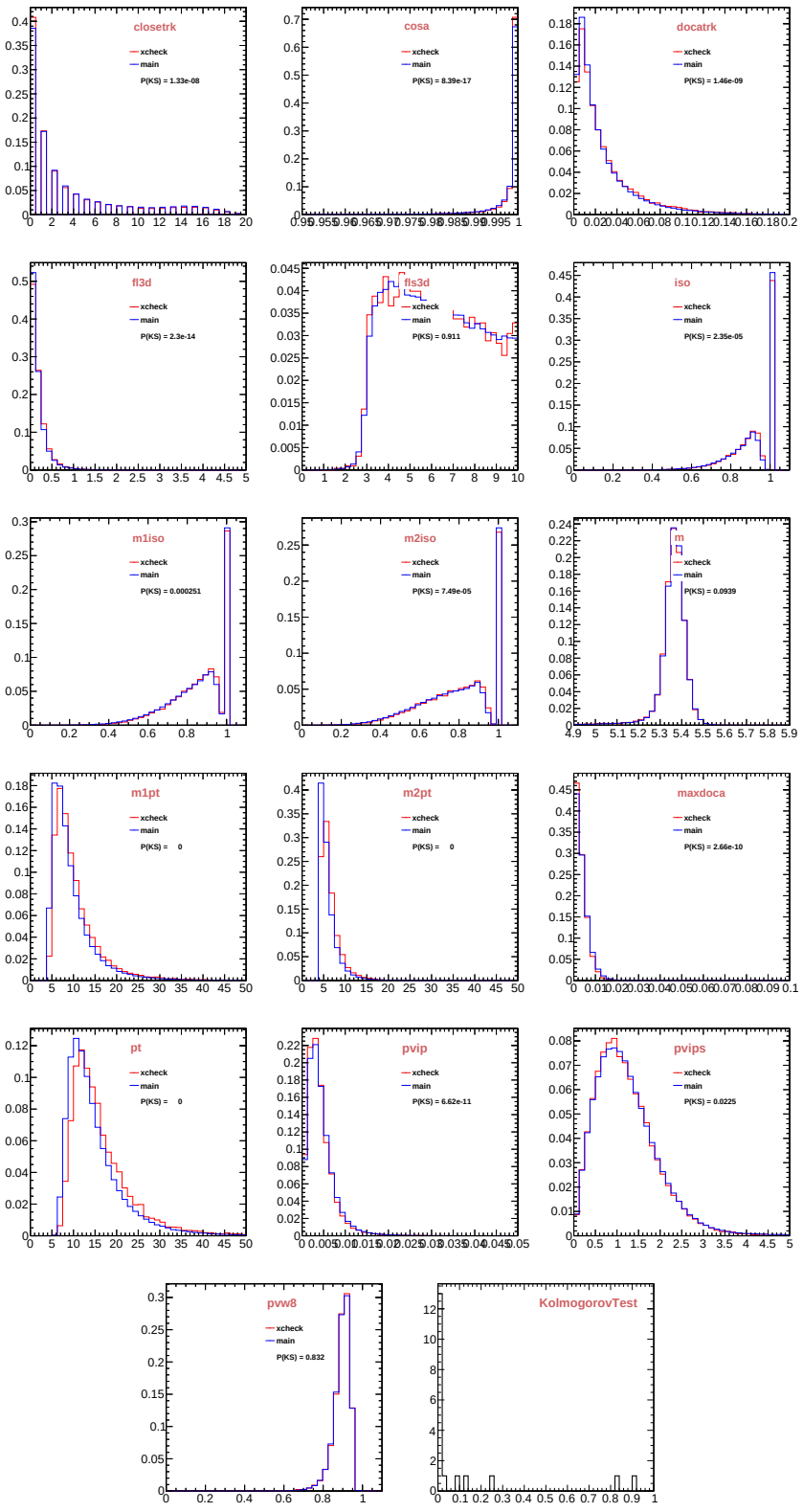

Figure 17: Variable comparisons between the main analysis and the cross-check analysis. Part I: MC barrel.

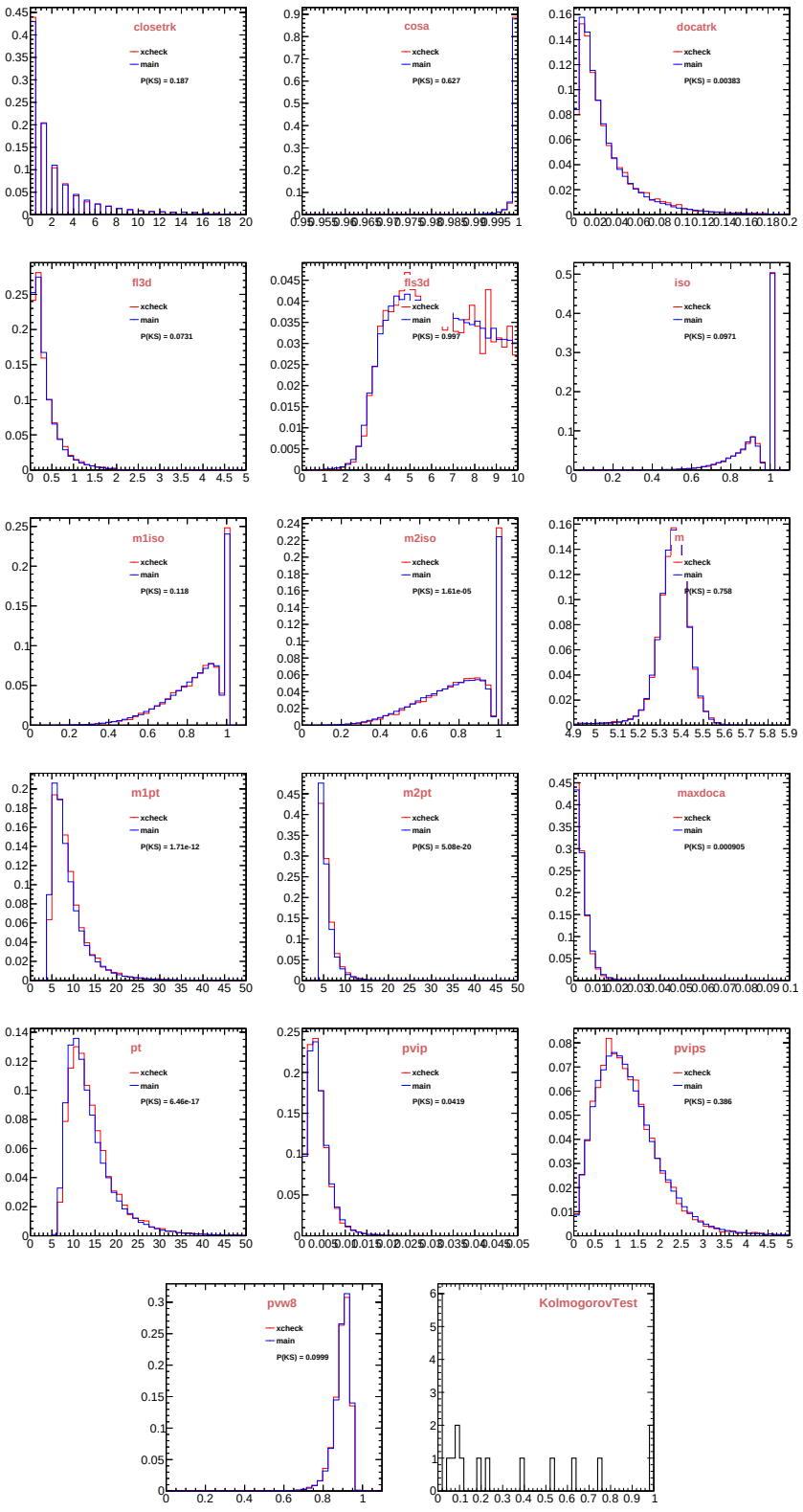

Figure 18: Variable comparisons between the main analysis and the cross-check analysis. Part II: MC endcaps.

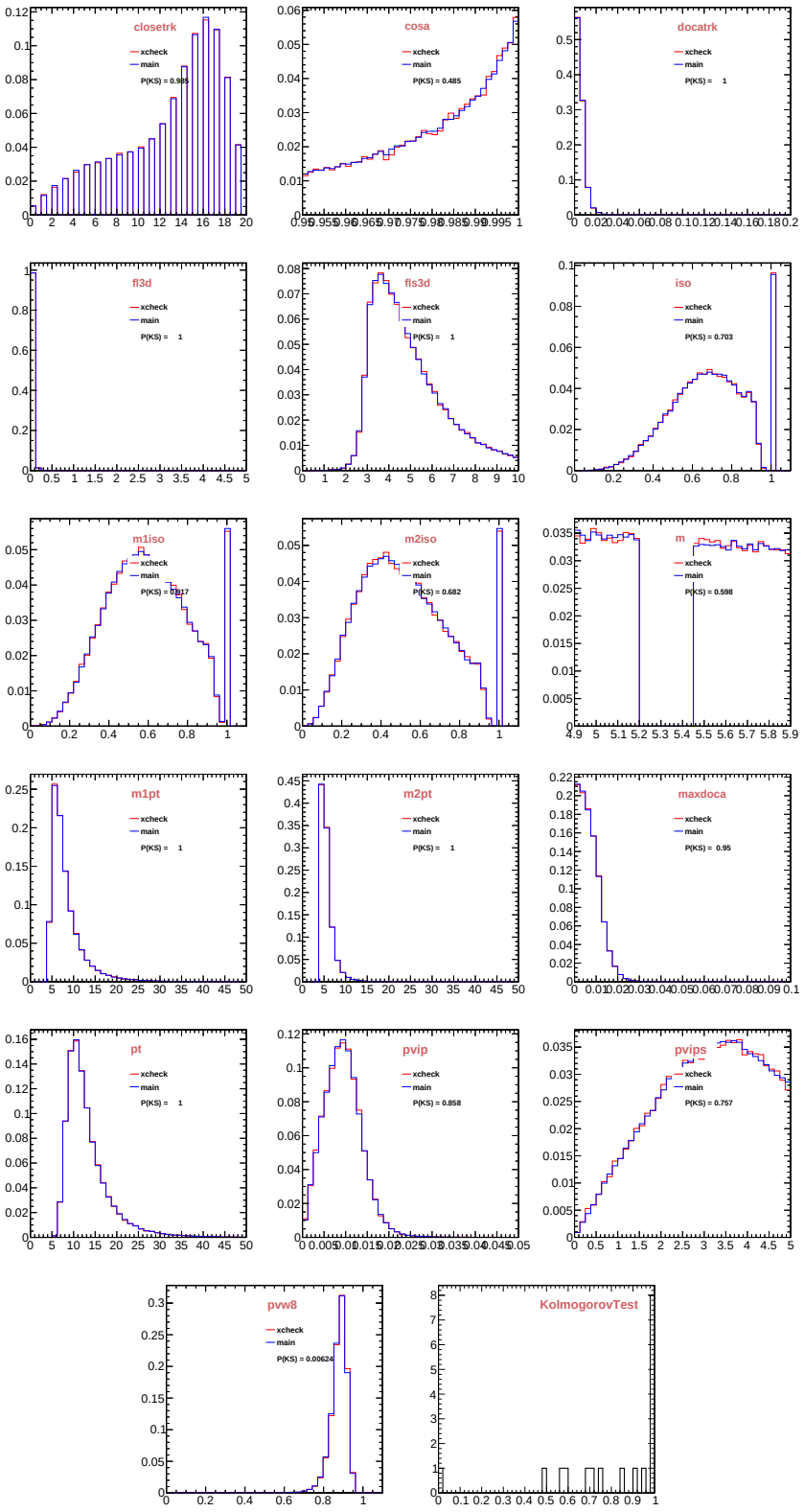

Figure 19: Variable comparisons between the main analysis and the cross-check analysis. Part III: Data barrel.

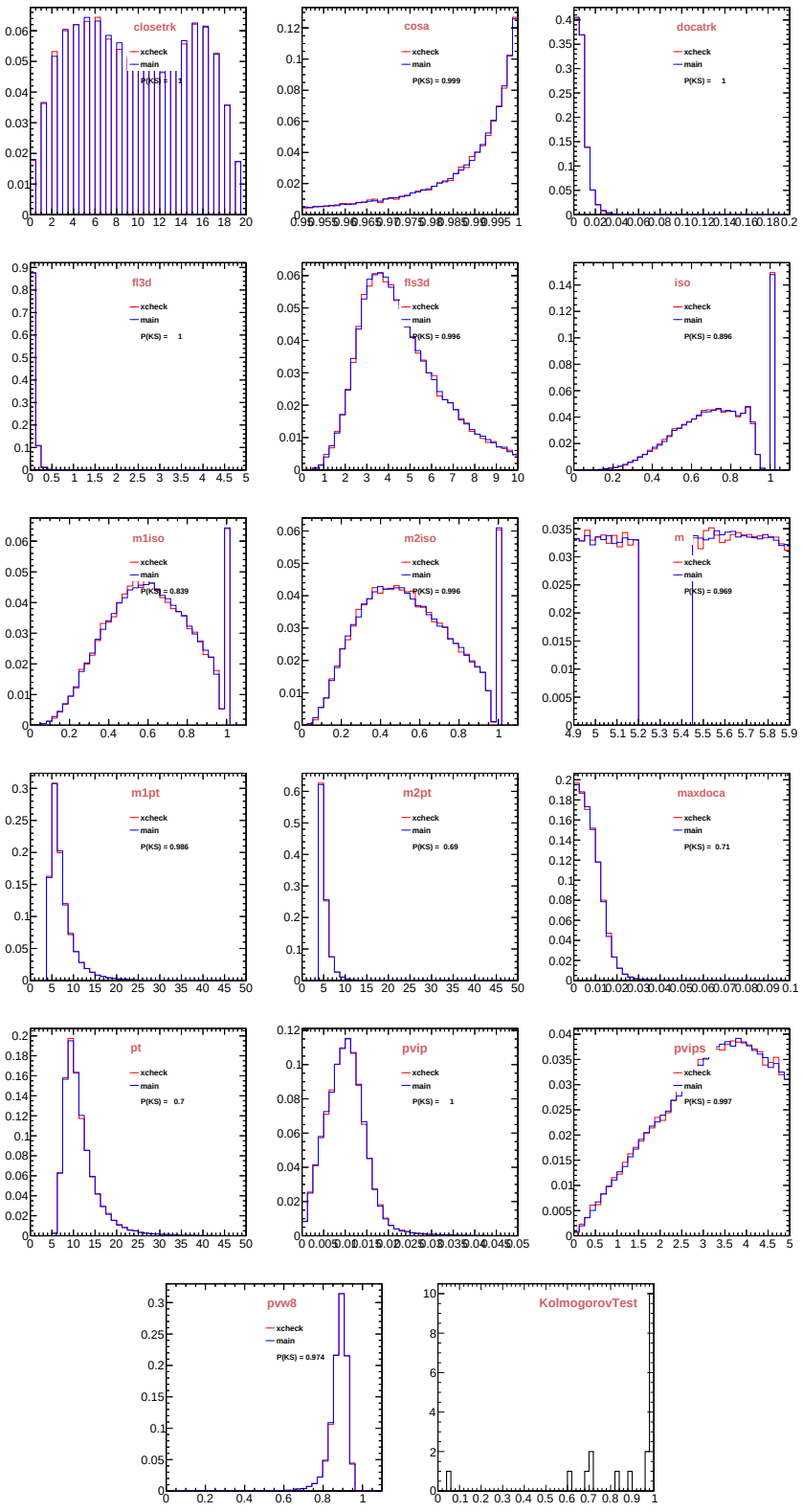

Figure 20: Variable comparisons between the main analysis and the cross-check analysis. Part IV: Data endcaps.