Update

1- Signal MC (inclusive tau)
2- Control channels

Sample size

5.0 M **dedicated signal MC**
$B^+ \rightarrow K^+ \tau^- (\rightarrow \text{generic}) \mu^+$
$B^- \rightarrow \text{generic}$

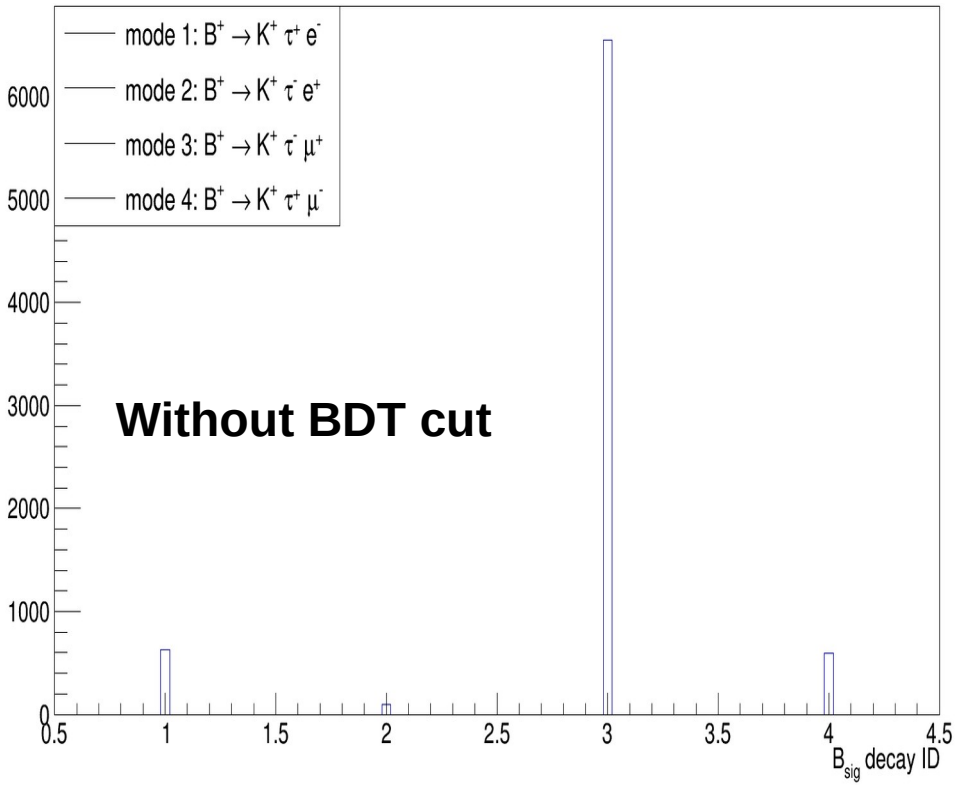
03 streams of generic MC normalized to Belle luminosity.

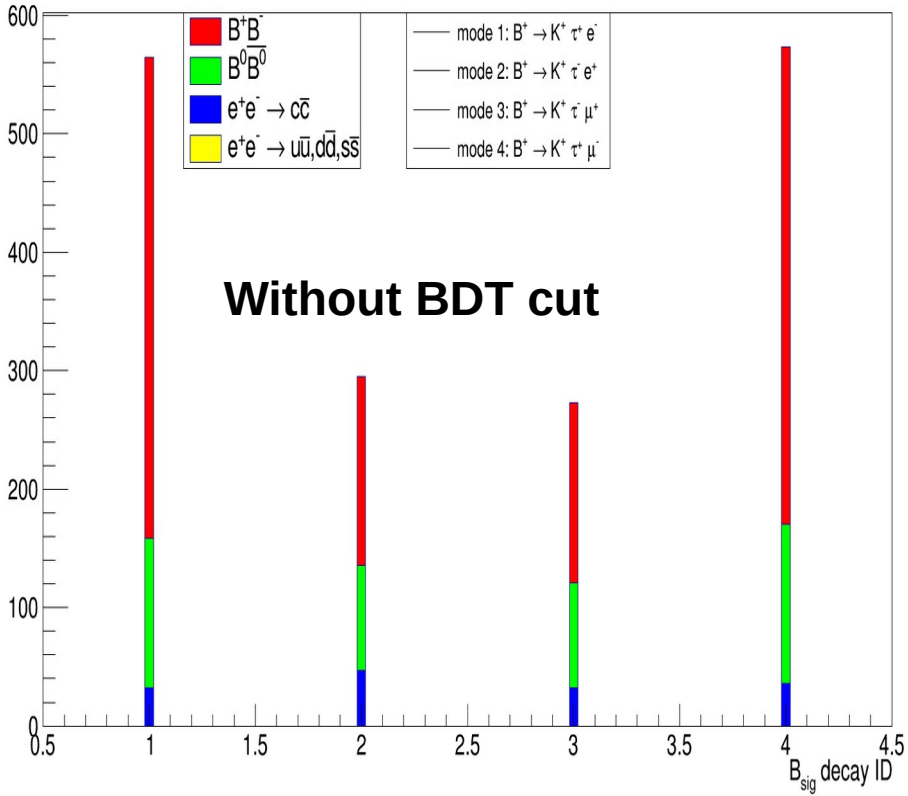
Basf2 release: light-2409-toyger

30/10/2024

Signal decay modes

- Added all the possible signal decay modes.

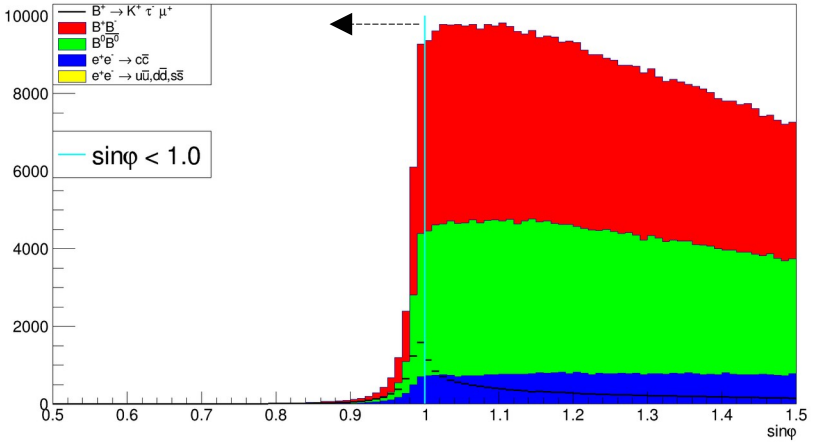


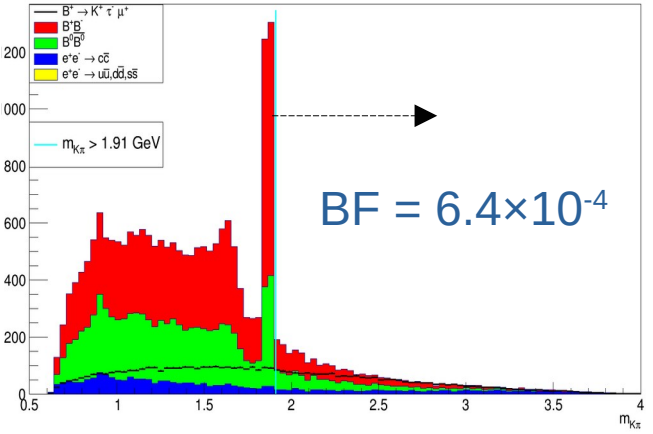


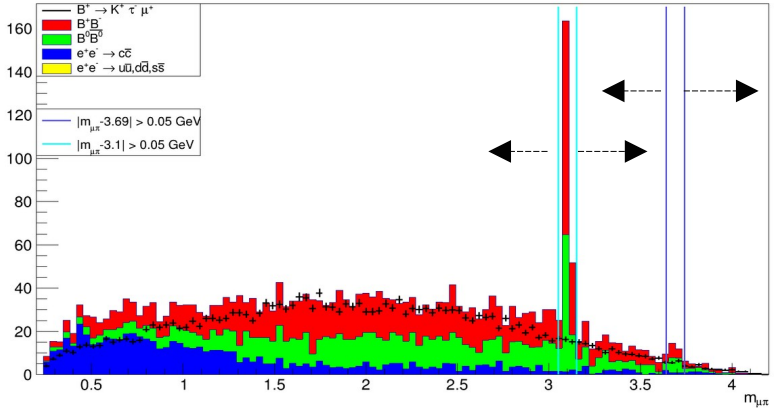
Signal side veto selections

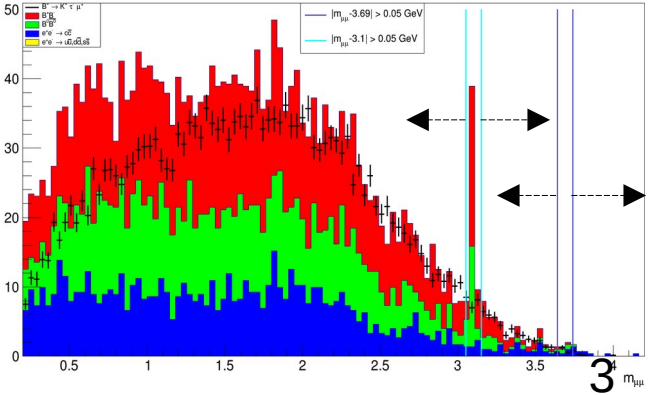
- Following veto selections are imposed on the signal side.

$\sin\varphi < 1$
$m_{K\pi}$>1.91 GeV
$\lvert m_{\mu\pi}-3.1\rvert>0.05$& $\lvert m_{\mu\pi}-3.69\rvert>0.05$GeV
$\lvert m_{\mu\mu}-3.1\rvert>0.05$& $\lvert m_{\mu\mu}-3.69\rvert>0.05$ GeV



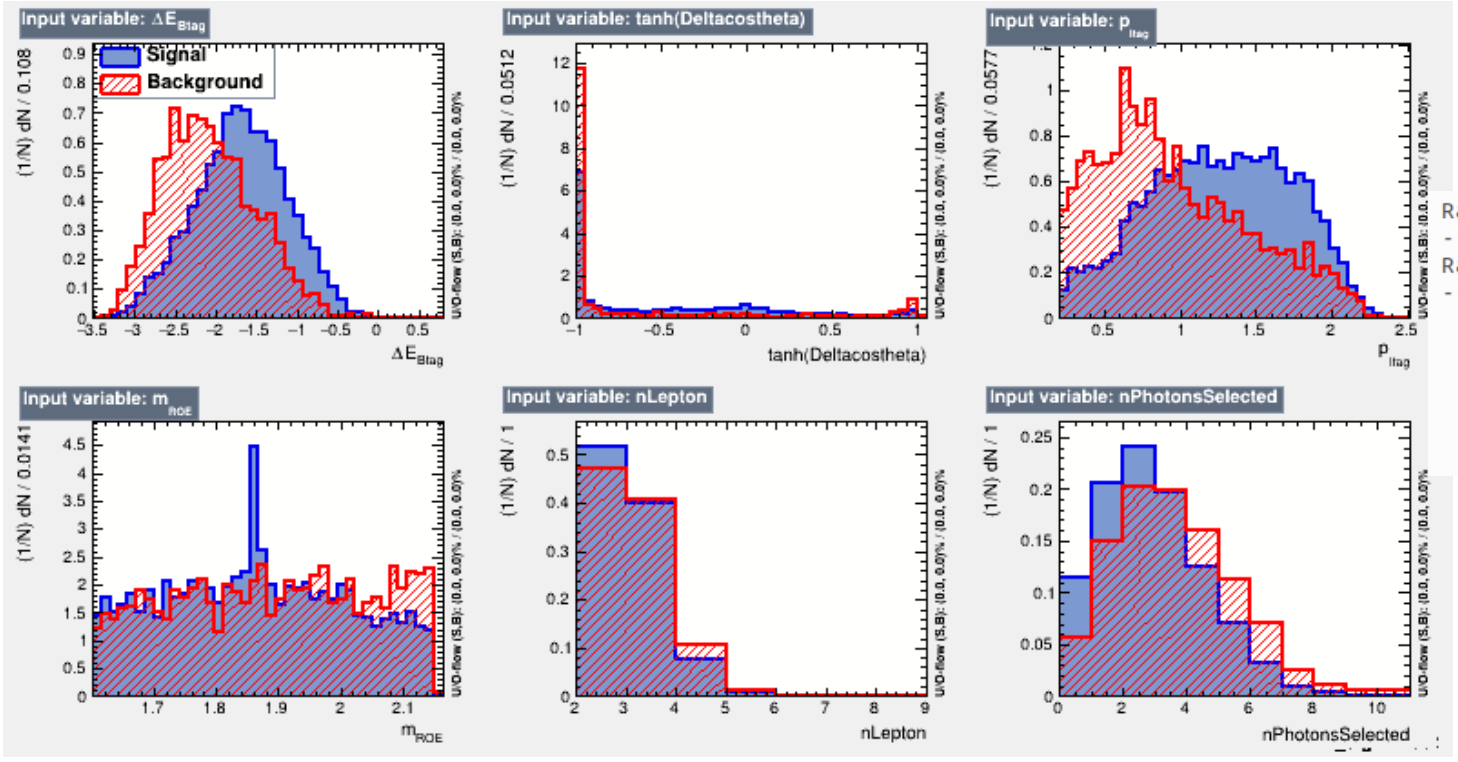






BDT training

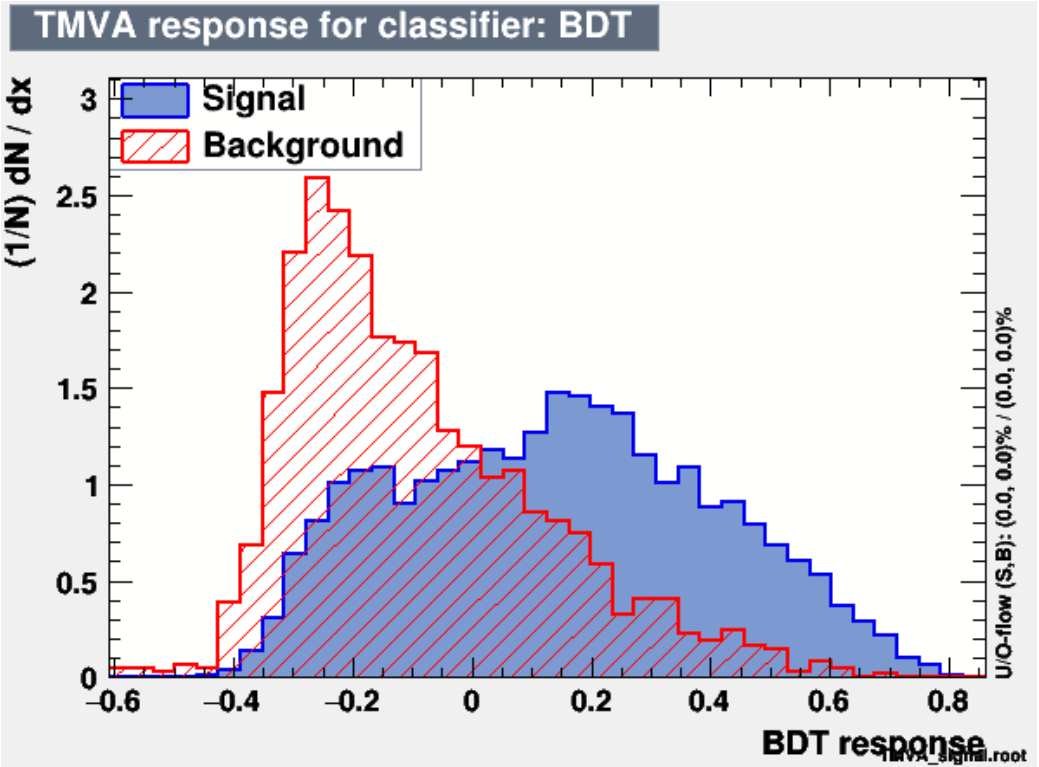
Input variables = {ΔE_{Btag}, $\Delta\cos\theta$, p_{ltag} , m_{ROE}, nLepton, nPhotons}

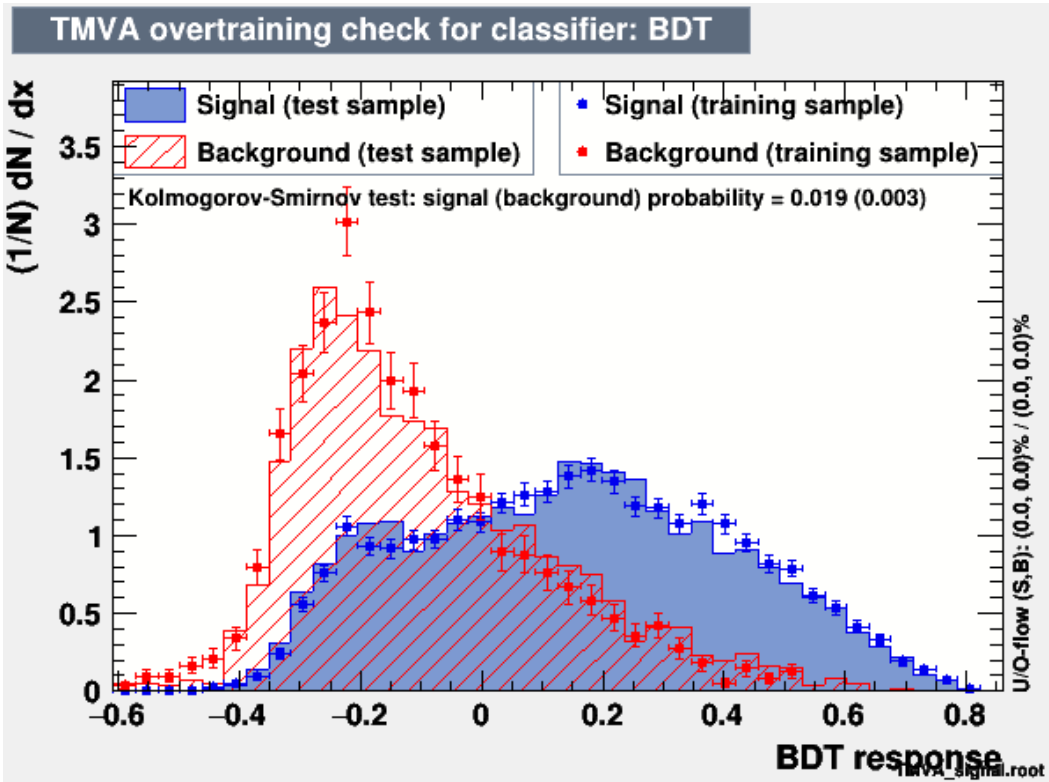



```
Ranking result (top variable is best ranked)
-------------------------------------------------------
Rank : Variable            : Variable Importance
-------------------------------------------------------
   1 : #DeltaE_{Btag}      : 2.682e-01
   2 : tanh(Deltacostheta) : 2.028e-01
   3 : m_{ROE}             : 1.670e-01
   4 : p_{ltag}            : 1.545e-01
   5 : nPhotonsSelected    : 1.303e-01
   6 : nLepton             : 7.719e-02
```

Loose selections for BDT = [1.6<m_{ROE}<2.6, 0.2<p_{ltag}<2.5, ΔE_{Btag}<1.0] GeV

BDT response





Punzi figure of merit

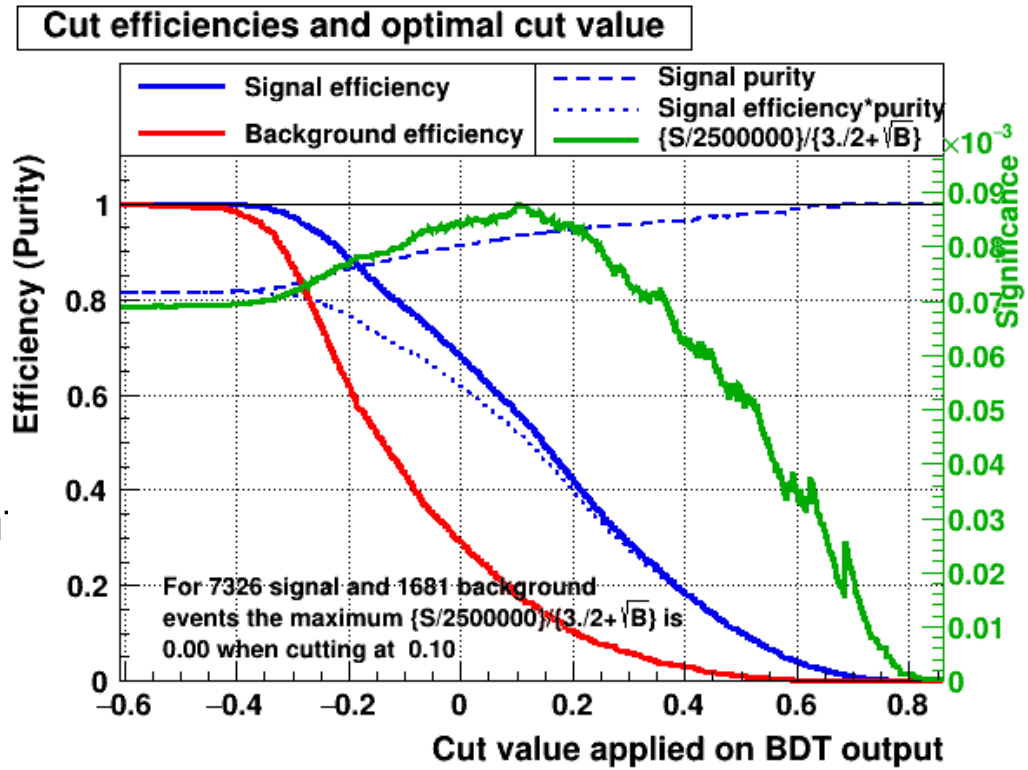
- Punzi figure of merit.

$$FOM_{Punzi} = \frac{\epsilon(t)}{\frac{\alpha}{2} + \sqrt{B(t)}}$$

ε(t) = signal efficiency

α = desired significance

B(t) = remaining background even



Optimal cut BDT > 0.10

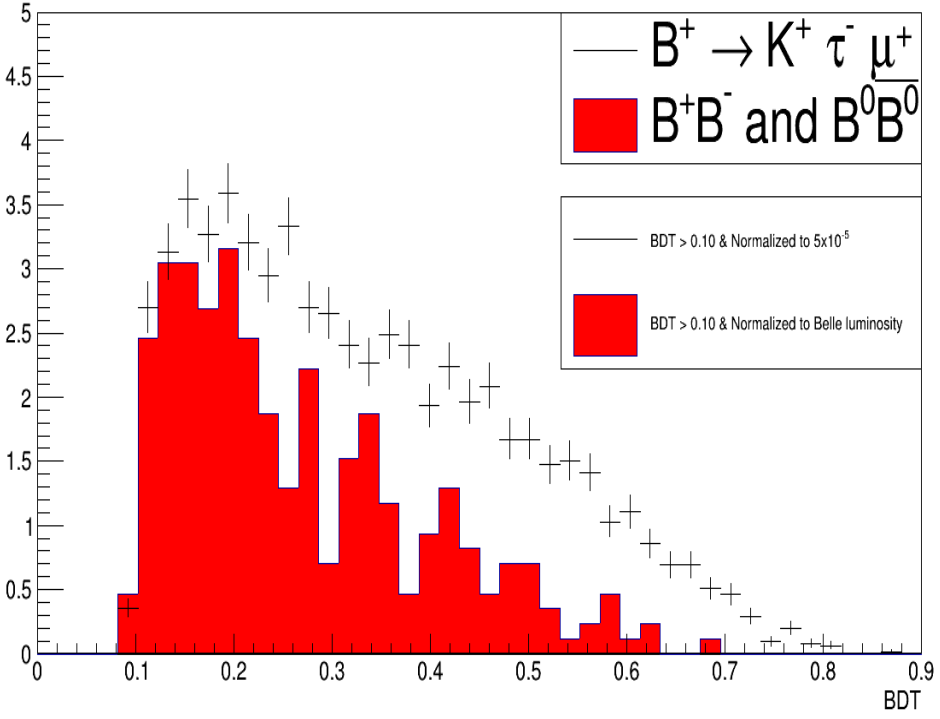
Classifier	Input N_{sig}	Input N_{bg}	Optimal cut	FOM_{Punzi}	Final N_{sig}	Final N_{bg}	Signal eff.	Bg eff.
BDT	7326	1681	0.1041	8.8×10^{-5}	4070	290	0.5556	0.1725

BDT response after optimal cut

- Signal is normalized to the BF of 5×10^{-5}.

  N_{sig} = 63
  N_{bg} = 35

- Using ΔE_{Btag} in the input variables, we have **much better S/B**.

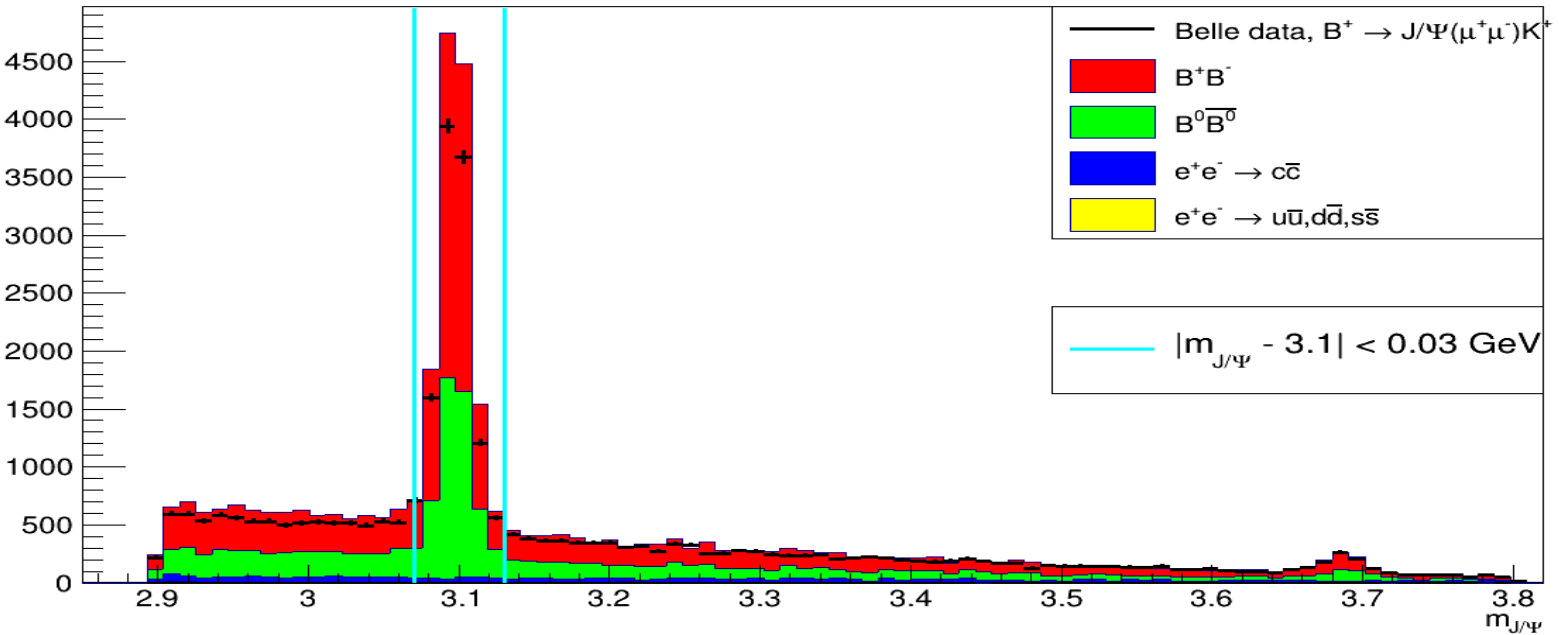


Control mode study

- Now, I have a script, which can **simultaneously** reconstruct the following **two control modes**

  1- $B^+ \rightarrow J/\psi(\mu^+\mu^-)\ K^+$

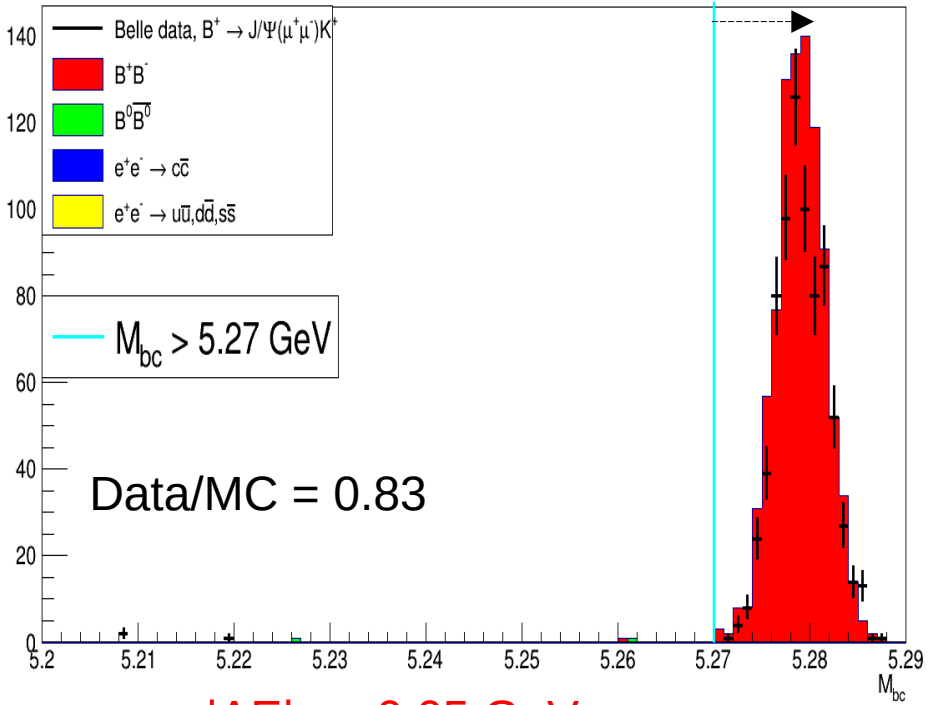
  2- $B^+ \rightarrow \psi(2S)(\mu^+\mu^-)\ K^+$



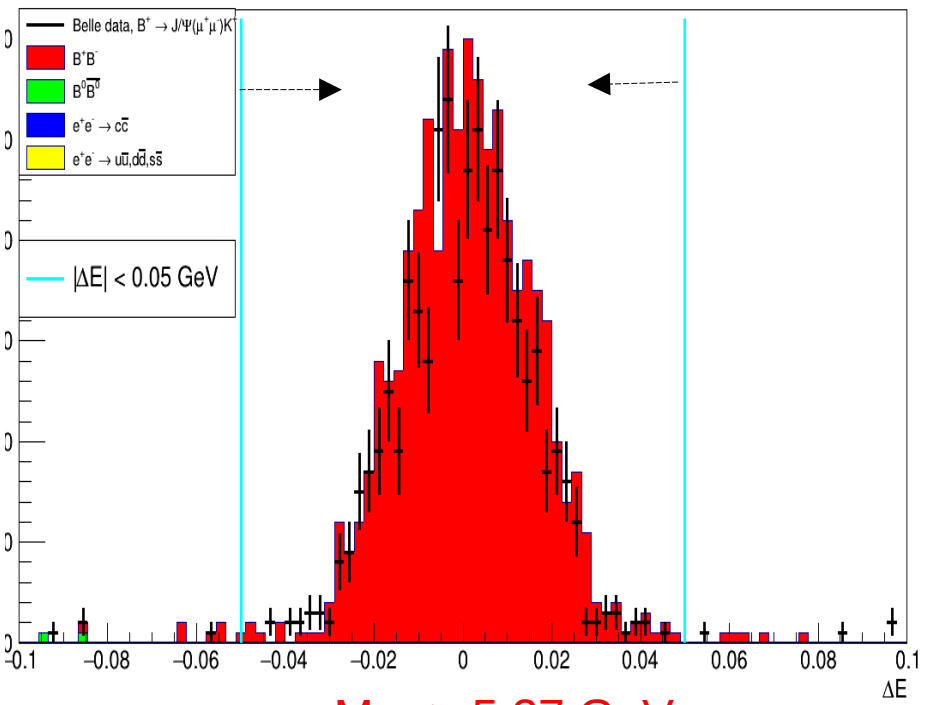
Selections for $B^+ \rightarrow J/\psi(\mu^+\mu^-)\, K^+$

-Additional variables (M_{bc} and ΔE) to use alongside other signal variables.

-Full Belle dataset
-01 Stream of generic MC

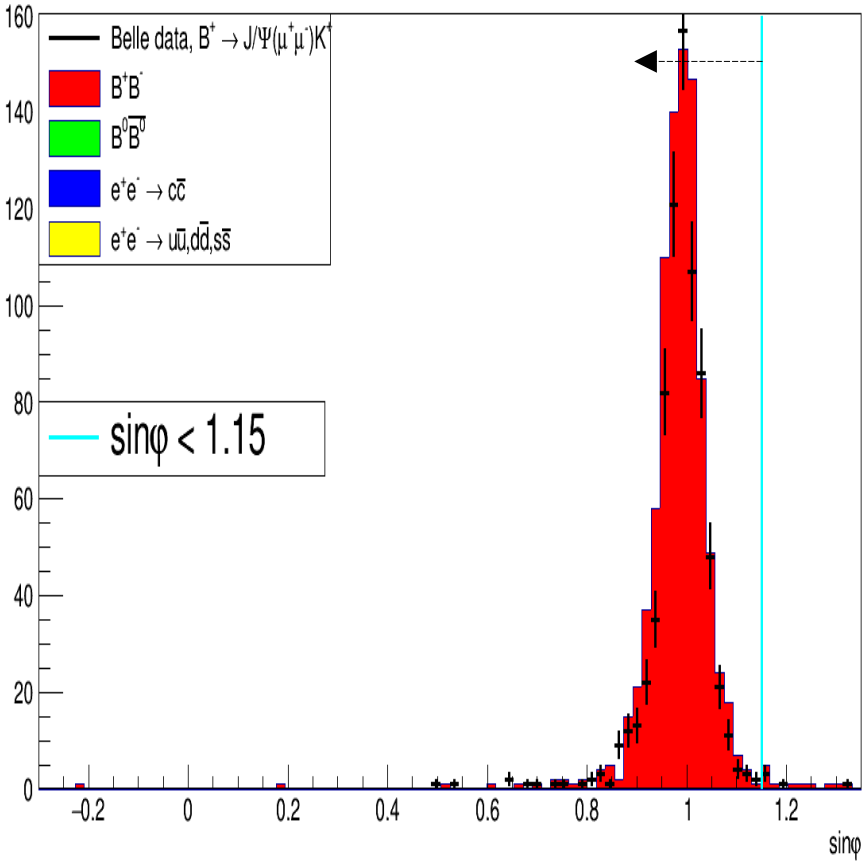


|ΔE| < 0.05 GeV

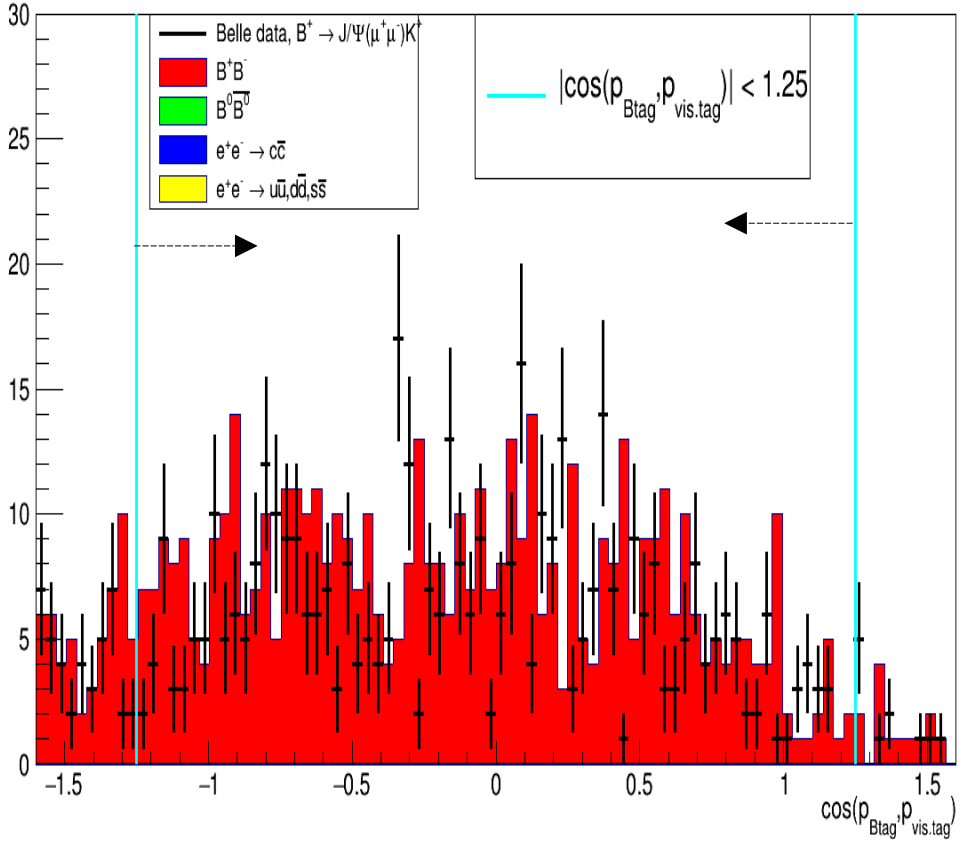


M_{bc} > 5.27 GeV

Selections for $B^+ \rightarrow J/\psi(\mu^+\mu^-)\, K^+$

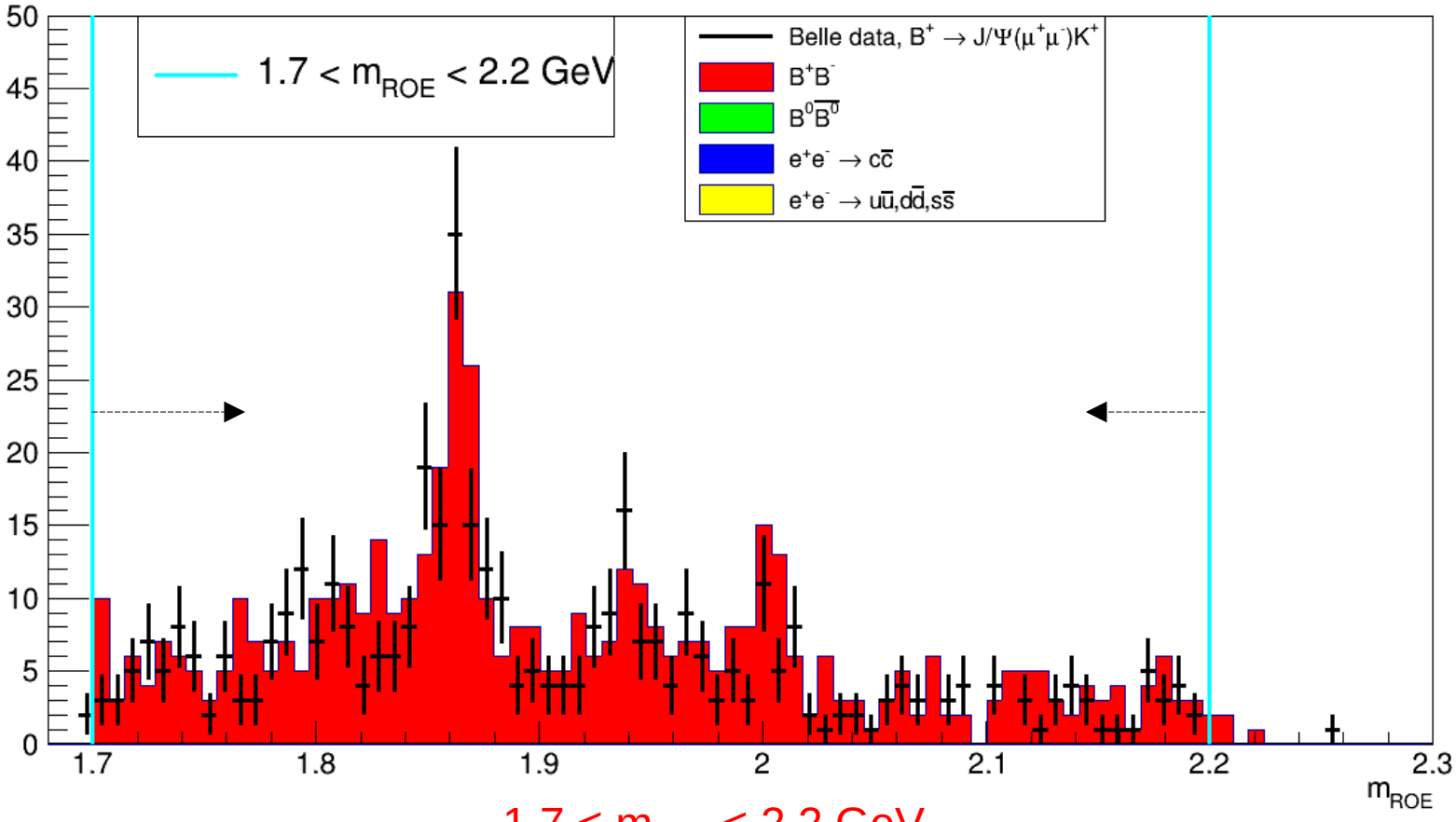


Sinφ < 1.15



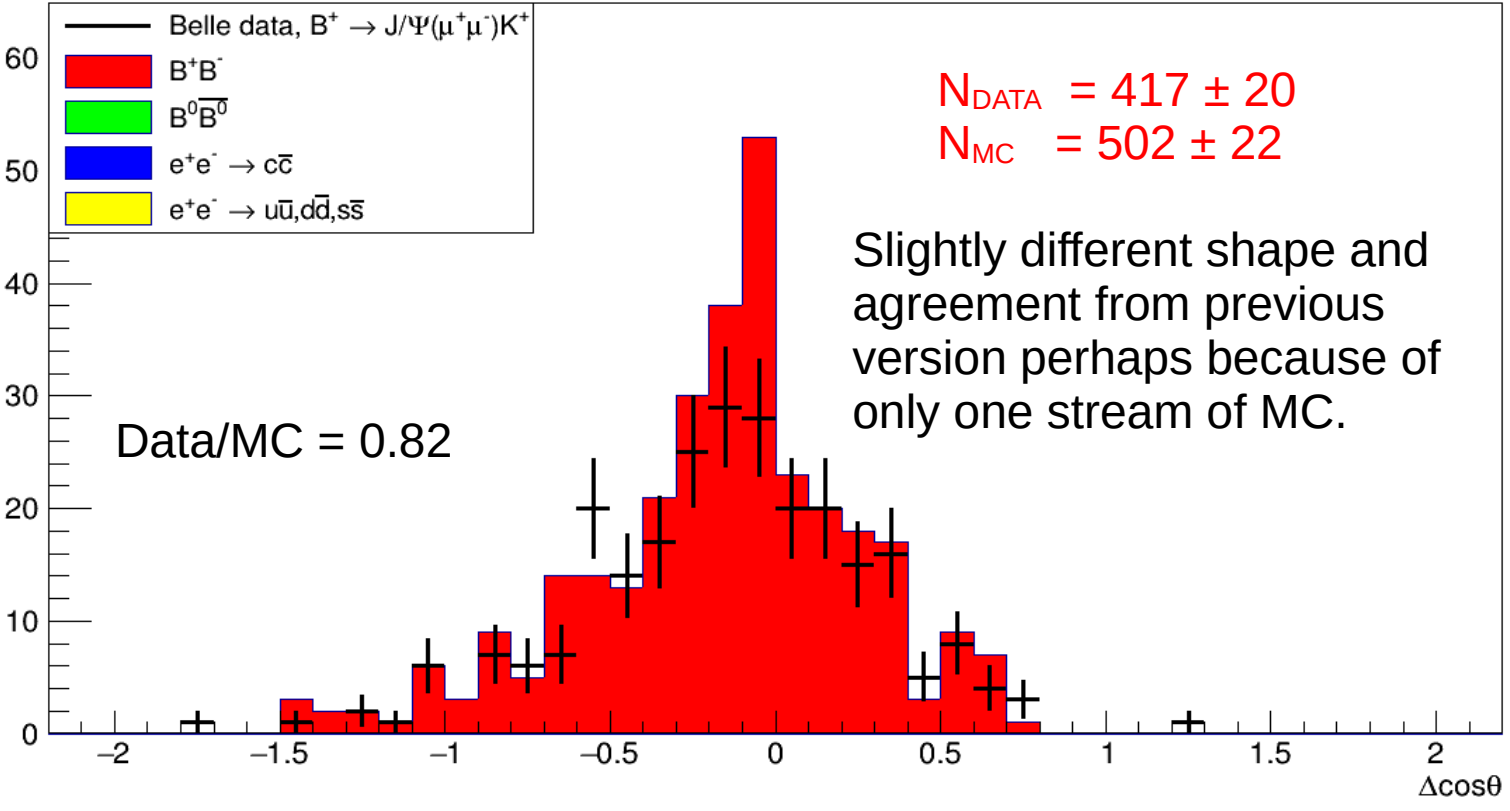
$|\cos(p_{Btag}, p_{vis.tag})| < 1.25$

Selections for $B^+ \to J/\psi(\mu^+\mu^-)\, K^+$



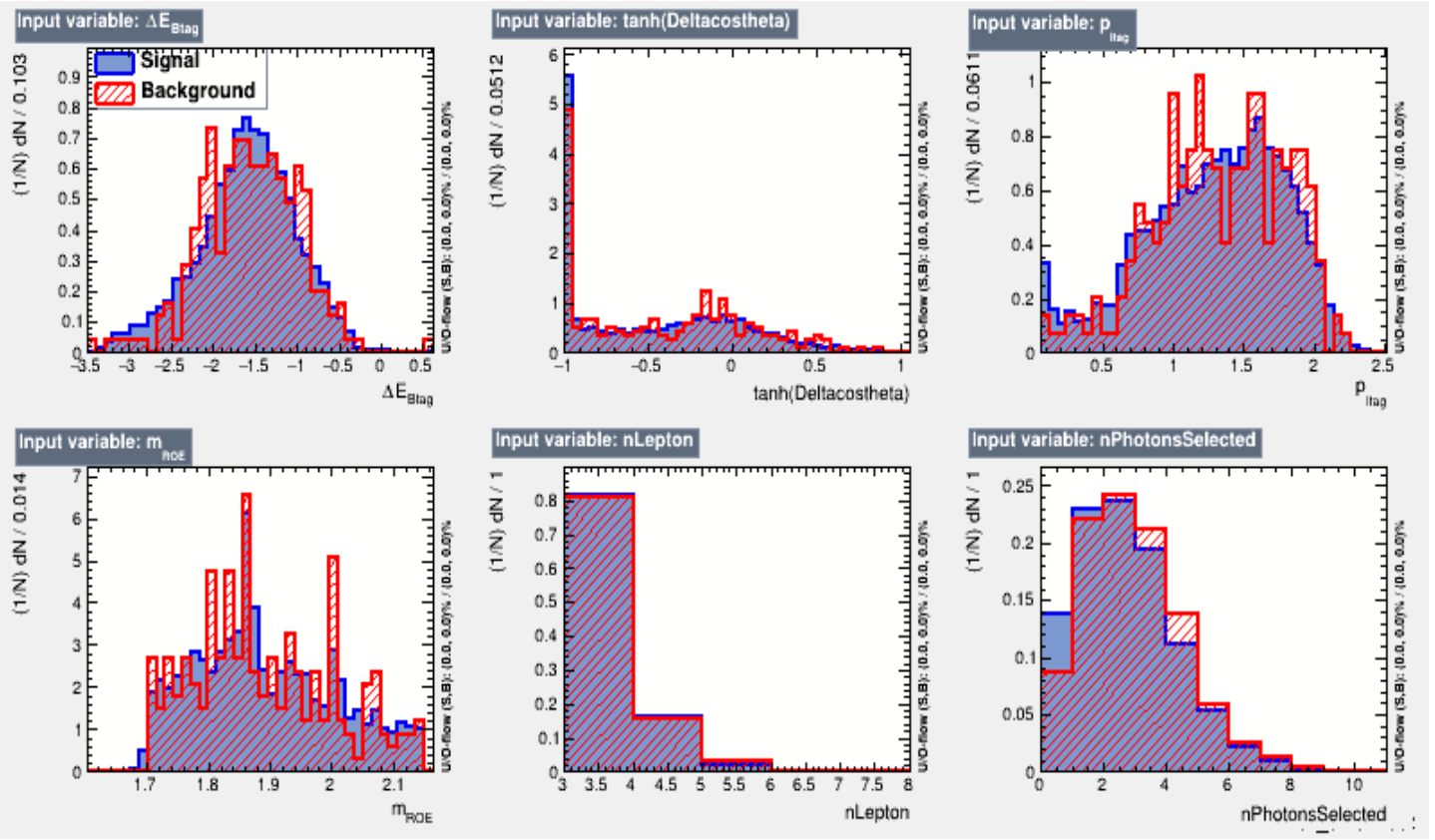
$1.7 < m_{ROE} < 2.2$ GeV

$\Delta\cos\theta$ for $B^+ \rightarrow J/\psi(\mu^+\mu^-)\, K^+$

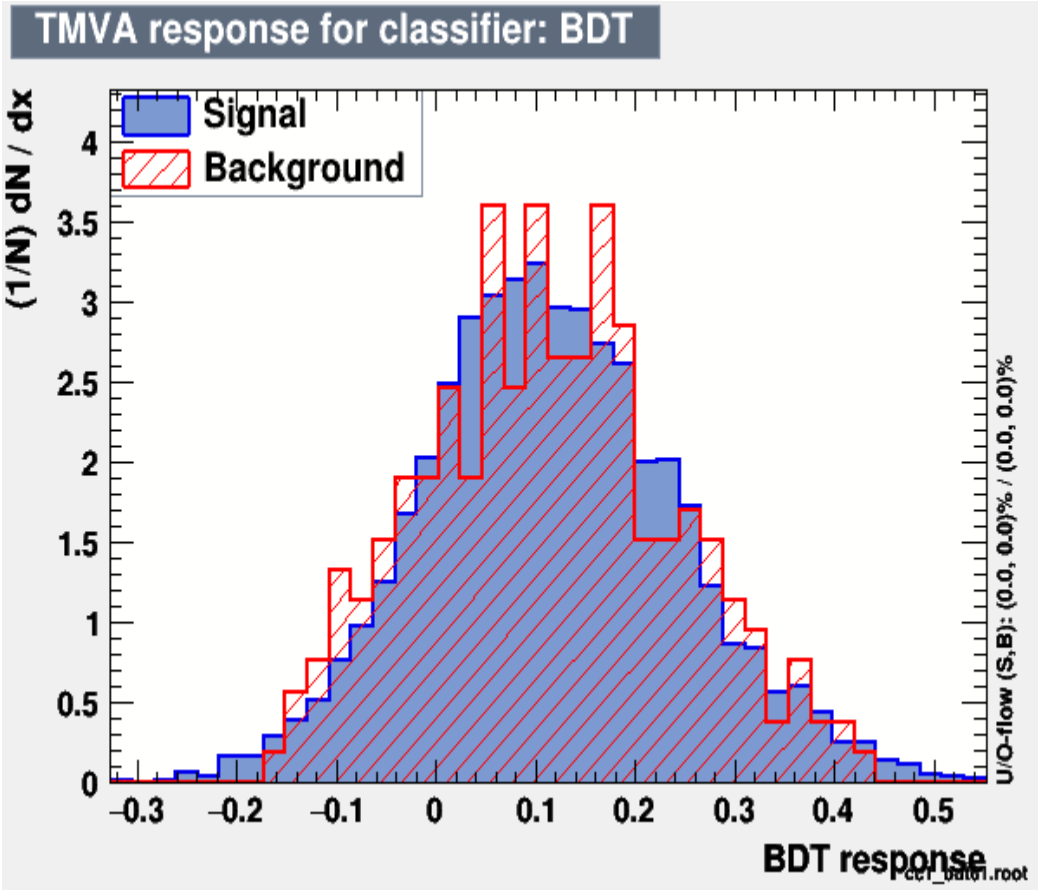


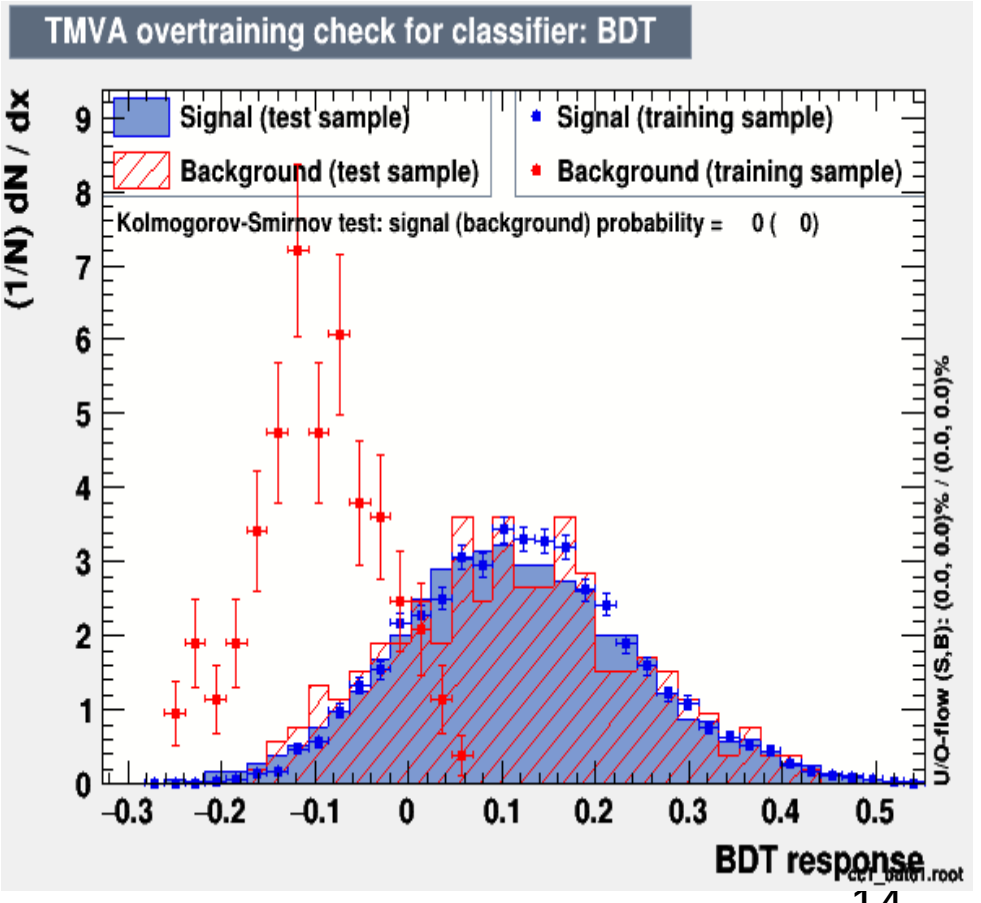
BDT analysis for $B^+ \rightarrow J/\psi(\mu^+\mu^-)\ K^+$

1 M dedicated signal sample
1 Stream of generic MC

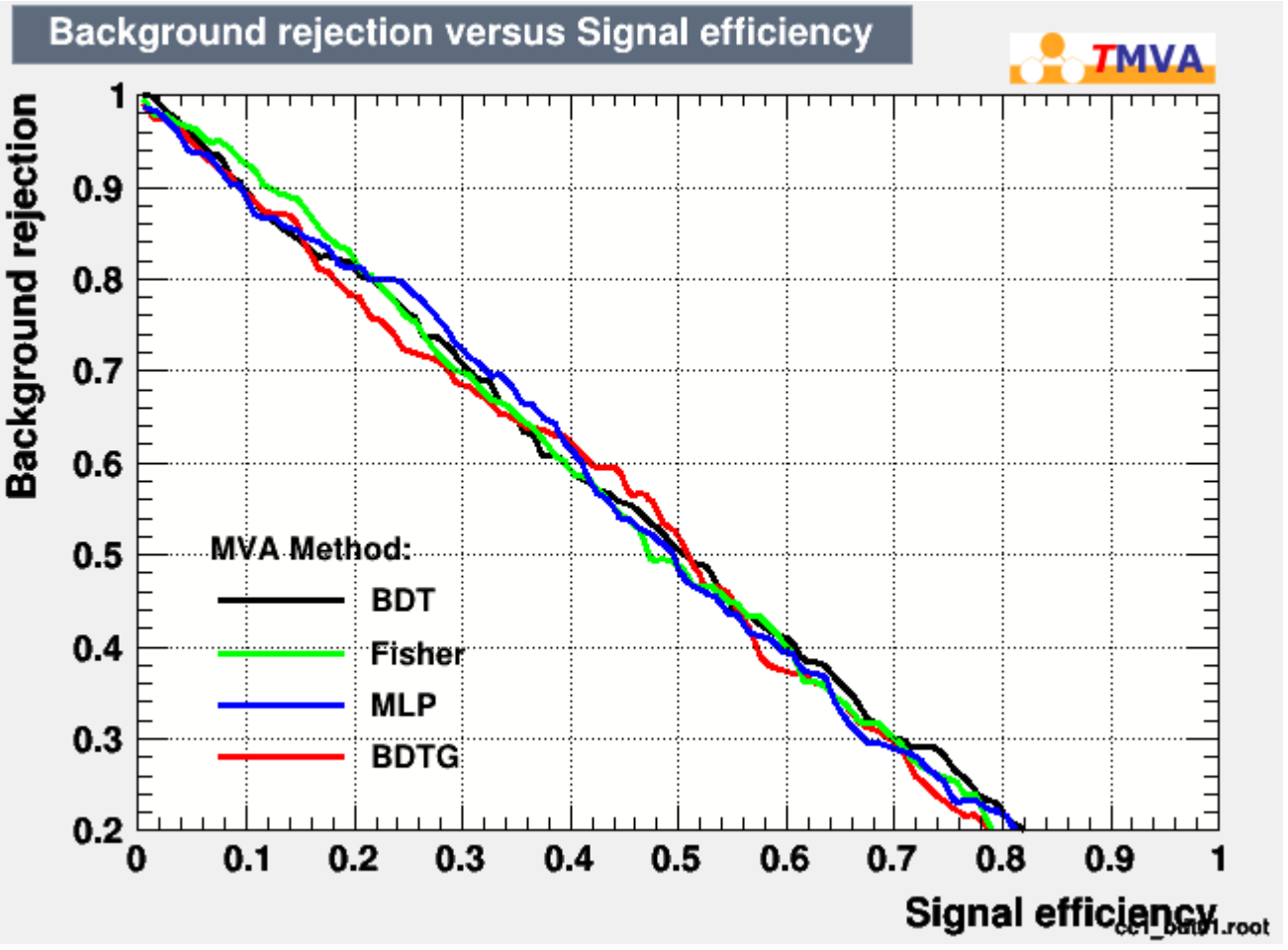


BDT analysis for $B^+ \rightarrow J/\psi(\mu^+\mu^-)\ K^+$





BDT analysis for $B^+ \rightarrow J/\psi(\mu^+\mu^-)\ K^+$



Need to understand more about the BDT analysis for $B^+ \rightarrow J/\psi(\mu^+\mu^-)\ K^+$

Control mode $B^+ \rightarrow \overline{D}^0(K^+\pi^-)\pi^+$

- To further check our results, we are using the following decay as our second control channel mode.

$$B^+ \rightarrow \overline{D}^0\ \pi^+ \qquad (BF = 4.61\times10^{-3})$$

$$\overline{D}^0 \rightarrow K^+\pi^- \qquad (BF = 3.947\ \%)$$

- Topology of this decay is also similar to our signal decay.

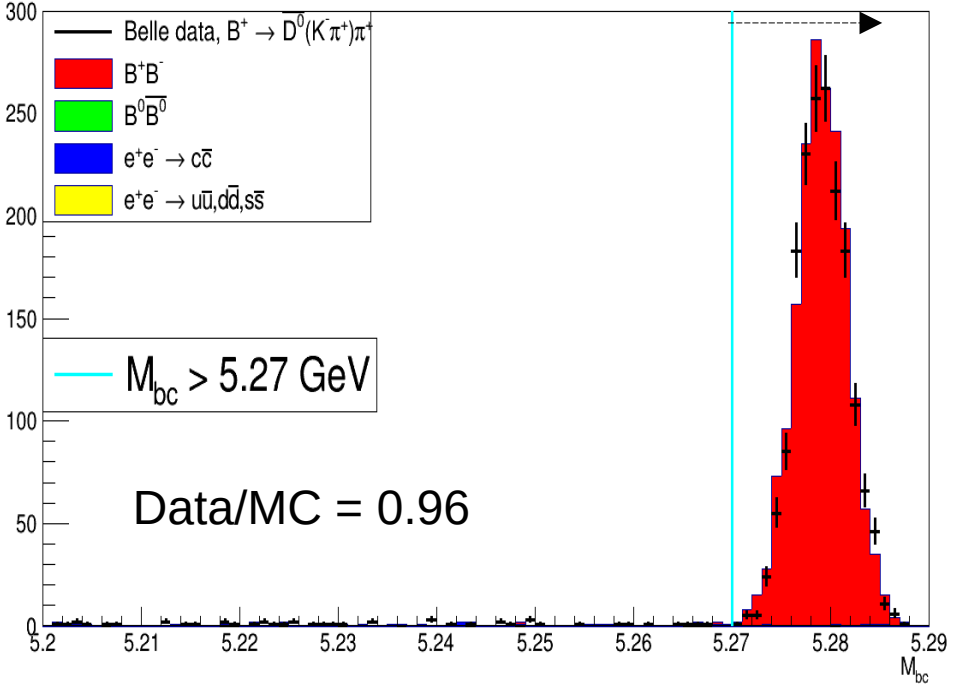
- We assume that π^- is missing, so that it can replicate our signal decay reconstruction.

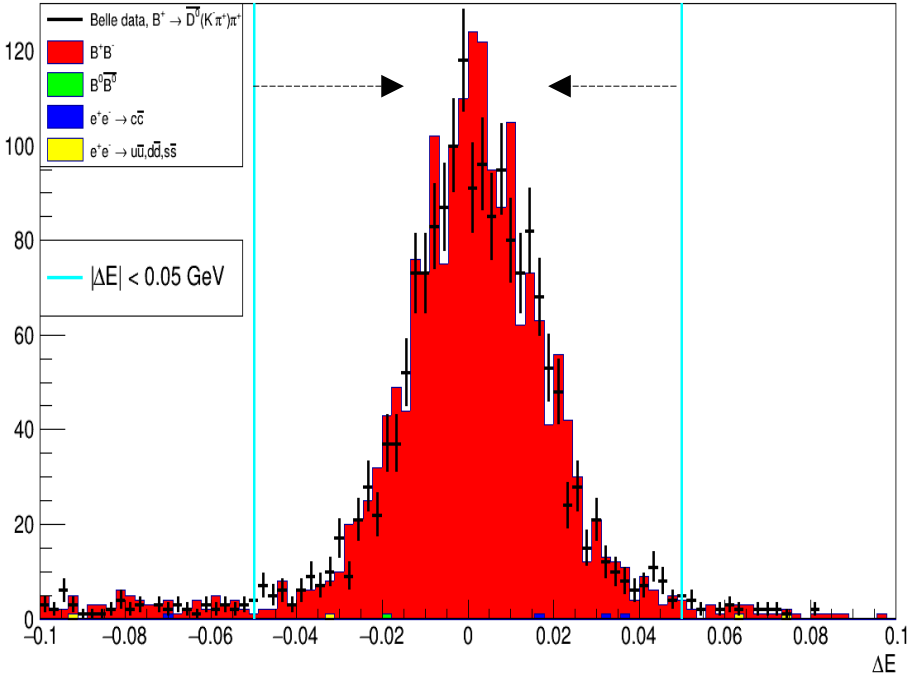
- We have performed the initial checks on the dedicated MC.

- We have also checked it on the Belle data set.

Selections for $B^+ \to \overline{D}^0(K^+\pi^-)\pi^+$

-Full Belle dataset
-1 Stream of generic MC

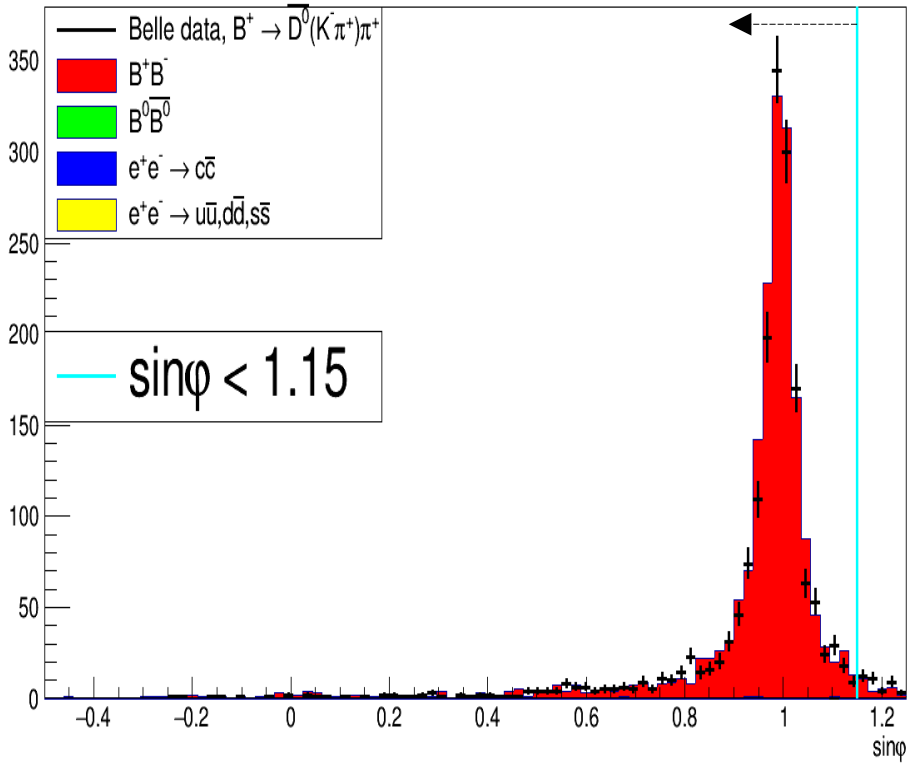




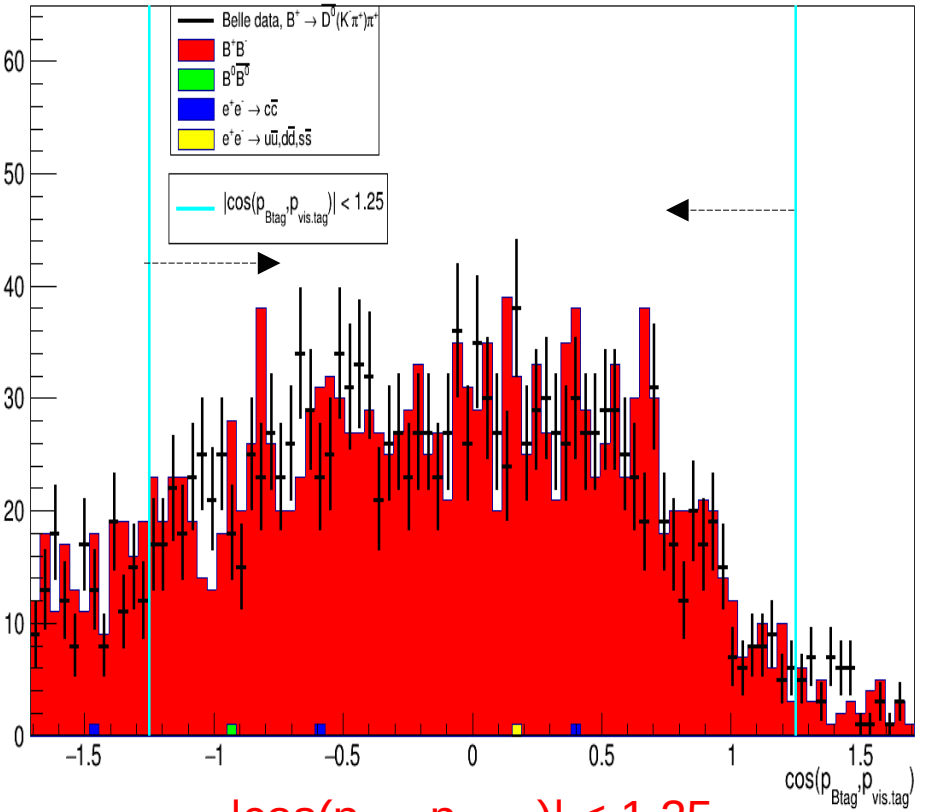
$|\Delta E| < 0.05$ GeV

$M_{bc} > 5.27$ GeV

Selections for $B^+ \to \overline{D}^0(K^+\pi^-)\pi^+$

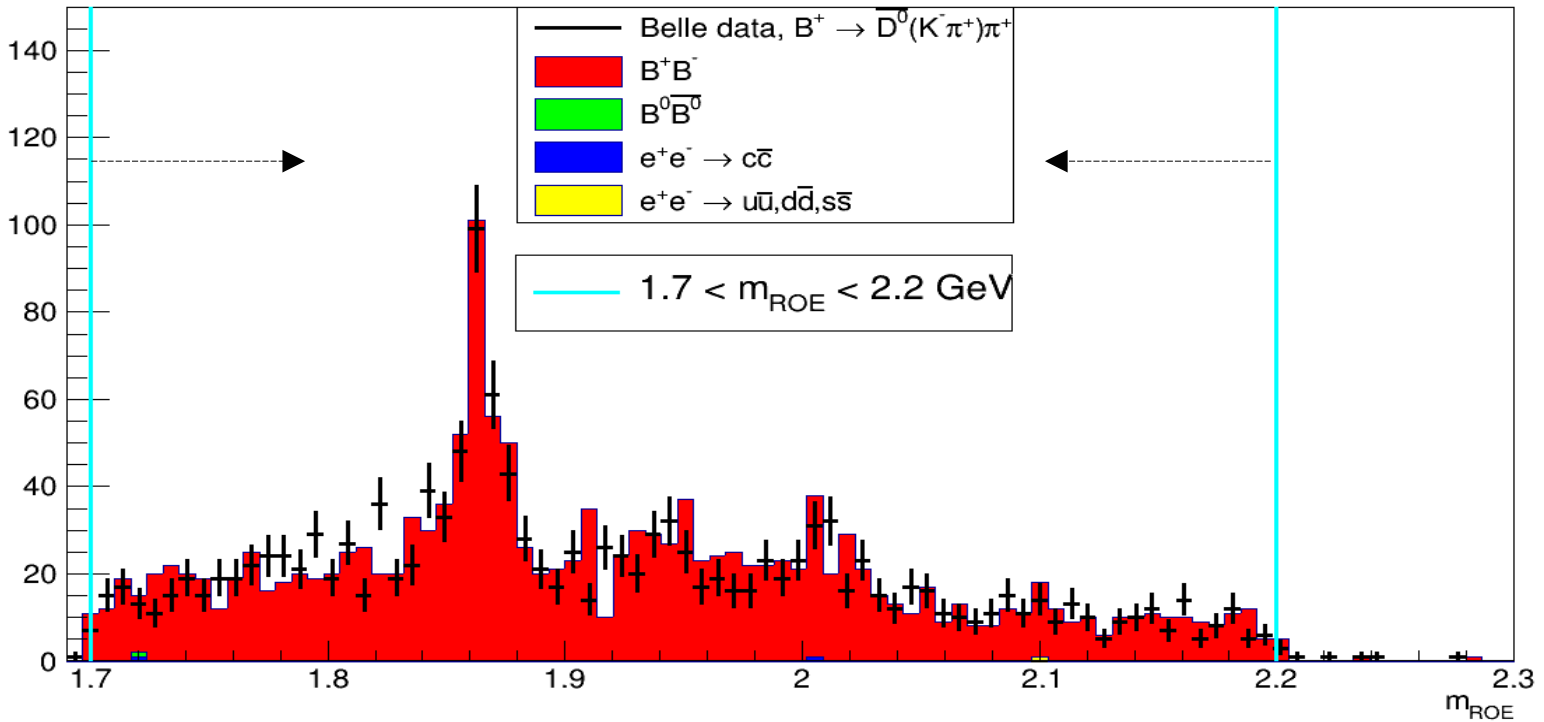


Sinφ < 1.15



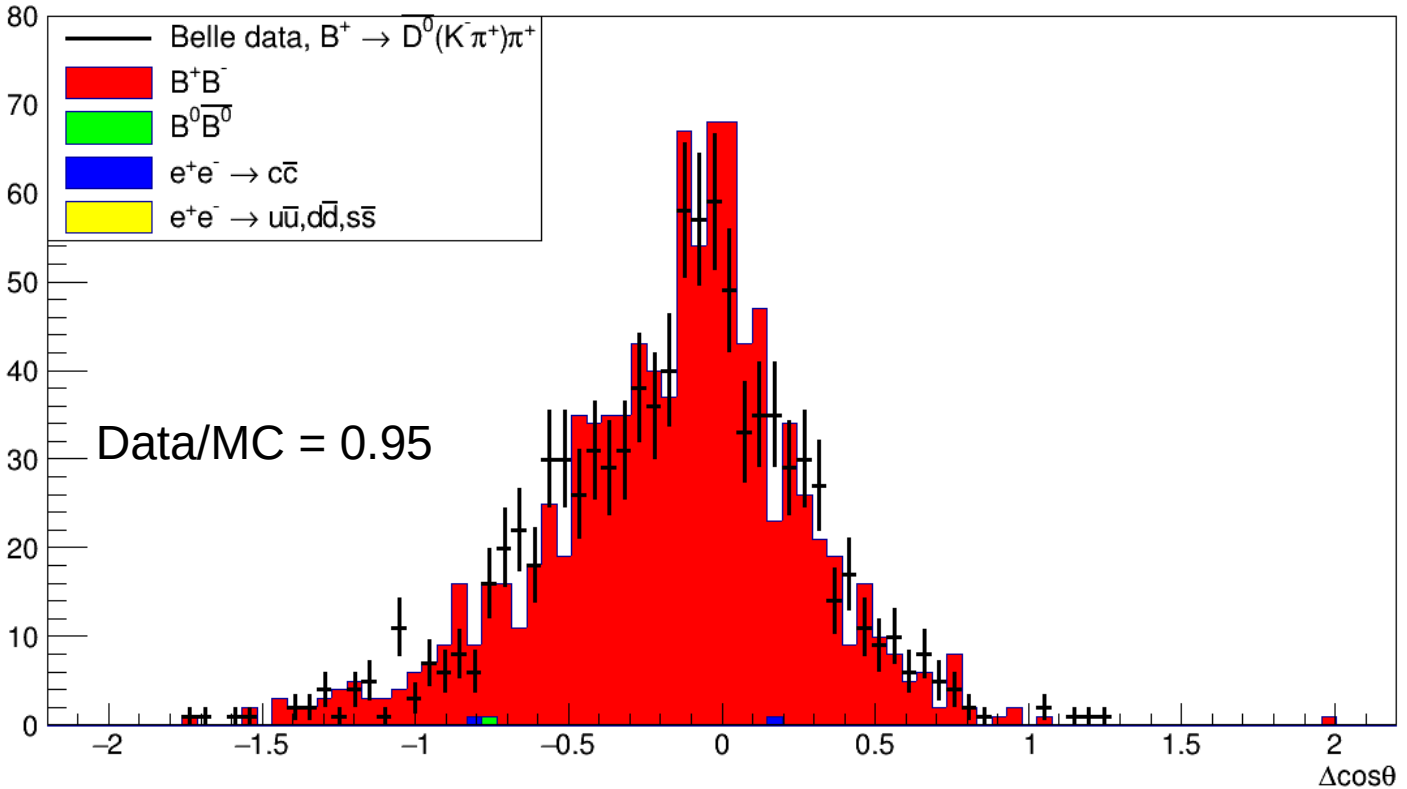
$|\cos(p_{Btag},p_{vis.tag})| < 1.25$

Selections for $B^+ \to \overline{D}^0(K^+\pi^-)\pi^+$



$1.7 < m_{ROE} < 2.2$ GeV

$\Delta\cos\theta$ for $B^+ \to \overline{D}^0(K^+\pi^-)\pi^+$



N_{DATA} = 1493 ± 39
N_{MC} = 1555 ± 39

Reasonable agreement of shape between data and MC.

BDT for $B^+ \to \overline{D}^0(K^+\pi^-)\pi^+$

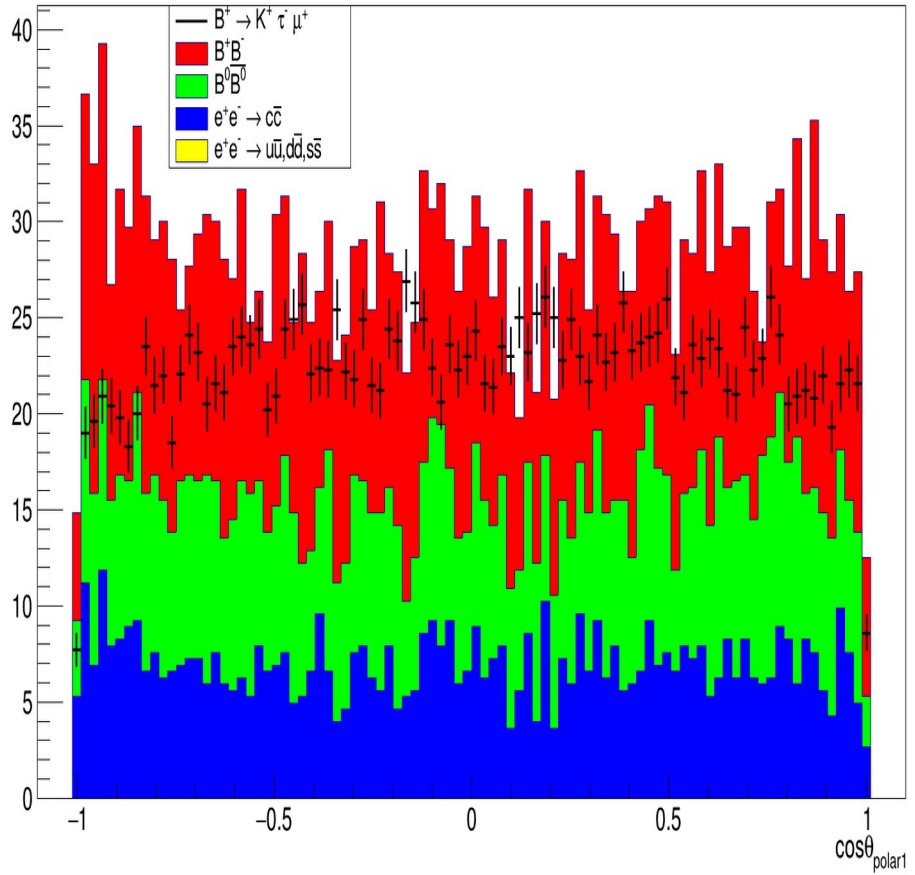
Not started yet

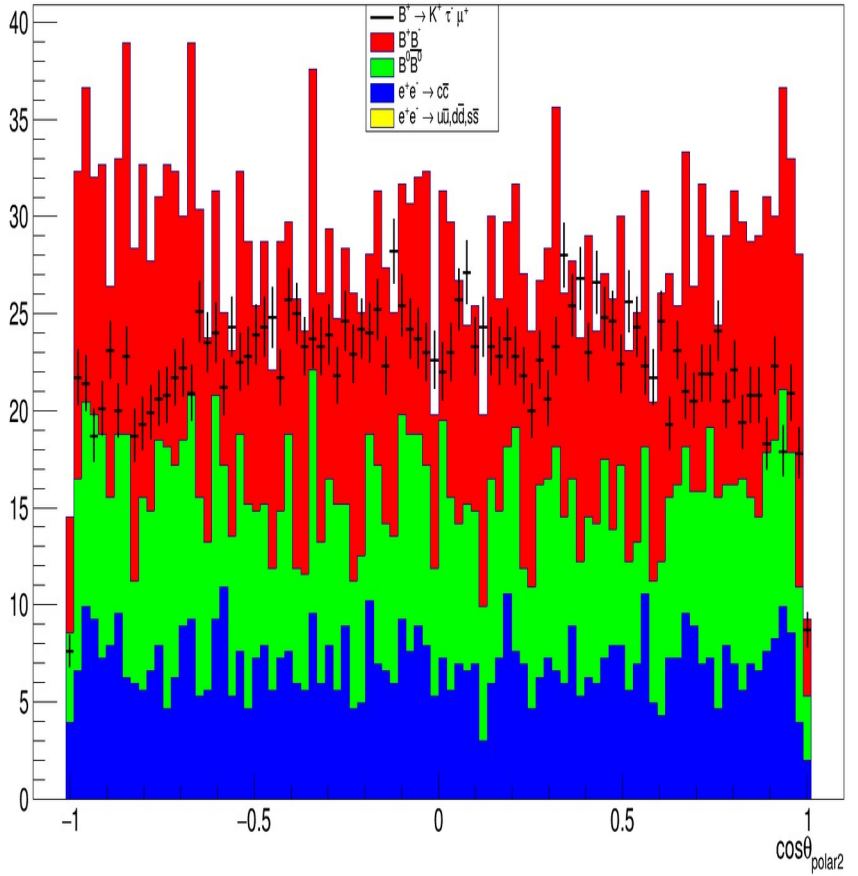
Summary

- All the four signals modes are included now.
- S/B is better now for signal after including ΔE_{Btag} in the input variables.
- Need to understand how to use BDT on the control samples.

Backup

Polar angles

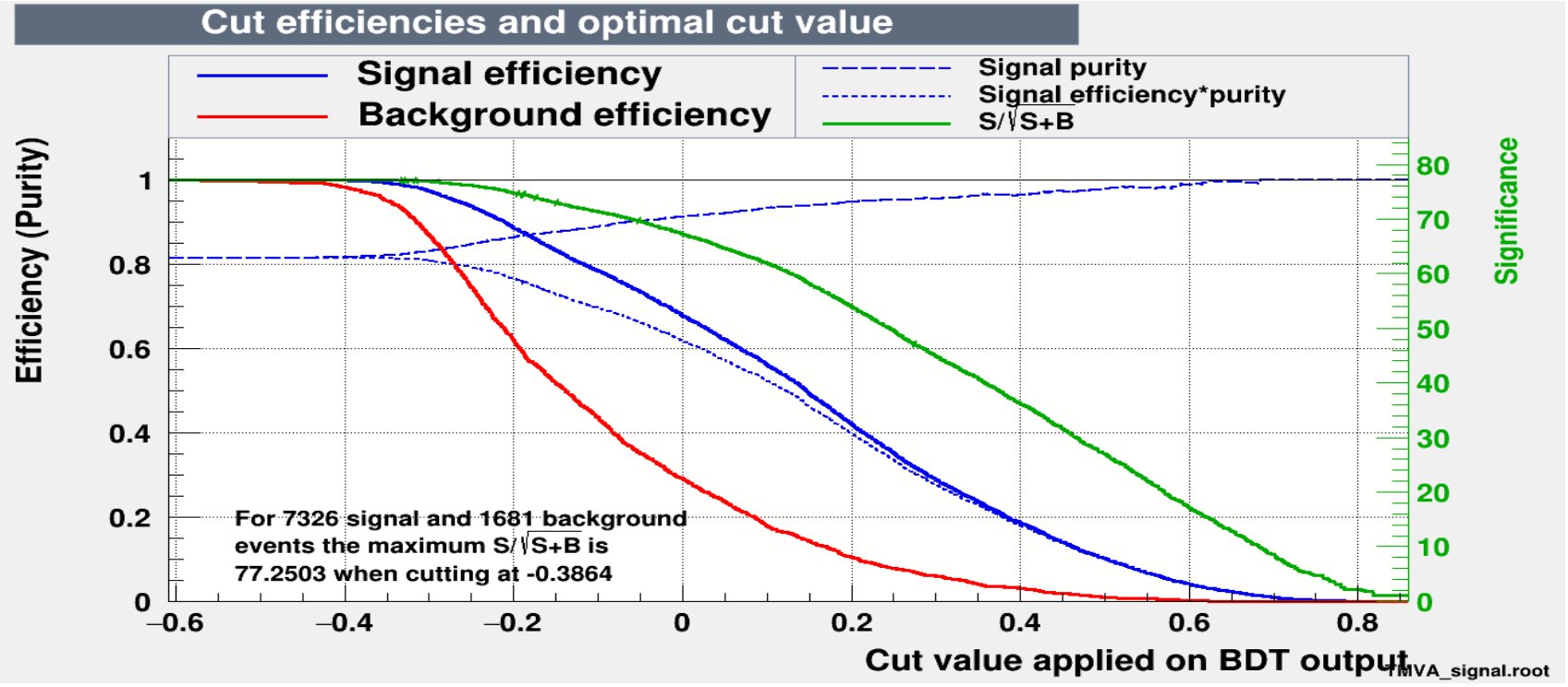




Punzi figure of merit

Classifier	(#signal,	#backgr.)	Optimal-cut	(S/2500000)/(3./2+sqrt(B))	NSig	NBkg	EffSig	EffBkg
BDT:	(7326,	1681)	0.1041	8.78604e-05	4070	290	0.5556	0.1725
BDTG:	(7326,	1681)	0.1816	8.38754e-05	4524	403	0.6175	0.2397
Fisher:	(7326,	1681)	-0.0506	7.98266e-05	5465	670	0.746	0.3986
MLP:	(7326,	1681)	0.5842	8.71967e-05	4293	331	0.586	0.1969

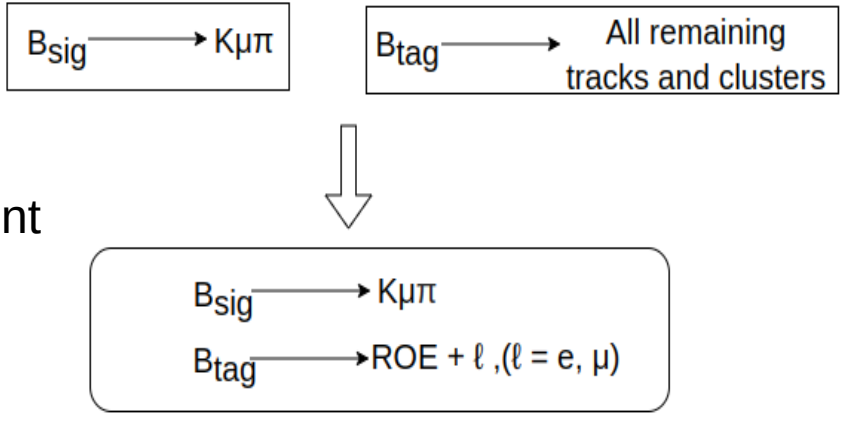
Figure of Merit



Classifier	(#signal, #backgr.)	Optimal-cut	S/sqrt(S+B)	NSig	NBkg	EffSig	EffBkg
BDT:	(7326, 1681)	-0.3864	77.2503	7307	1640	0.9974	0.9756
BDTG:	(7326, 1681)	-0.8996	77.21	7326	1677	1	0.9976
Fisher:	(7326, 1681)	-0.6159	77.2212	7323	1670	0.9996	0.9935
MLP:	(7326, 1681)	0.0729	77.2322	7322	1666	0.9995	0.9911

Reconstruction methodology

- We are using B2BII module for this analysis.



- We are right now working only on Belle environment and Belle II will be added later.

- We reconstruct B_{sig} by combining K,π and μ tracks.

$$B^+ \rightarrow K^+ \tau^-(\rightarrow \pi^- \nu_\tau)\mu^+$$

$$B^- \rightarrow X \ell^- \nu_\ell$$

- By combining B_{sig} and B_{tag}, we form an Y(4S) candidate.

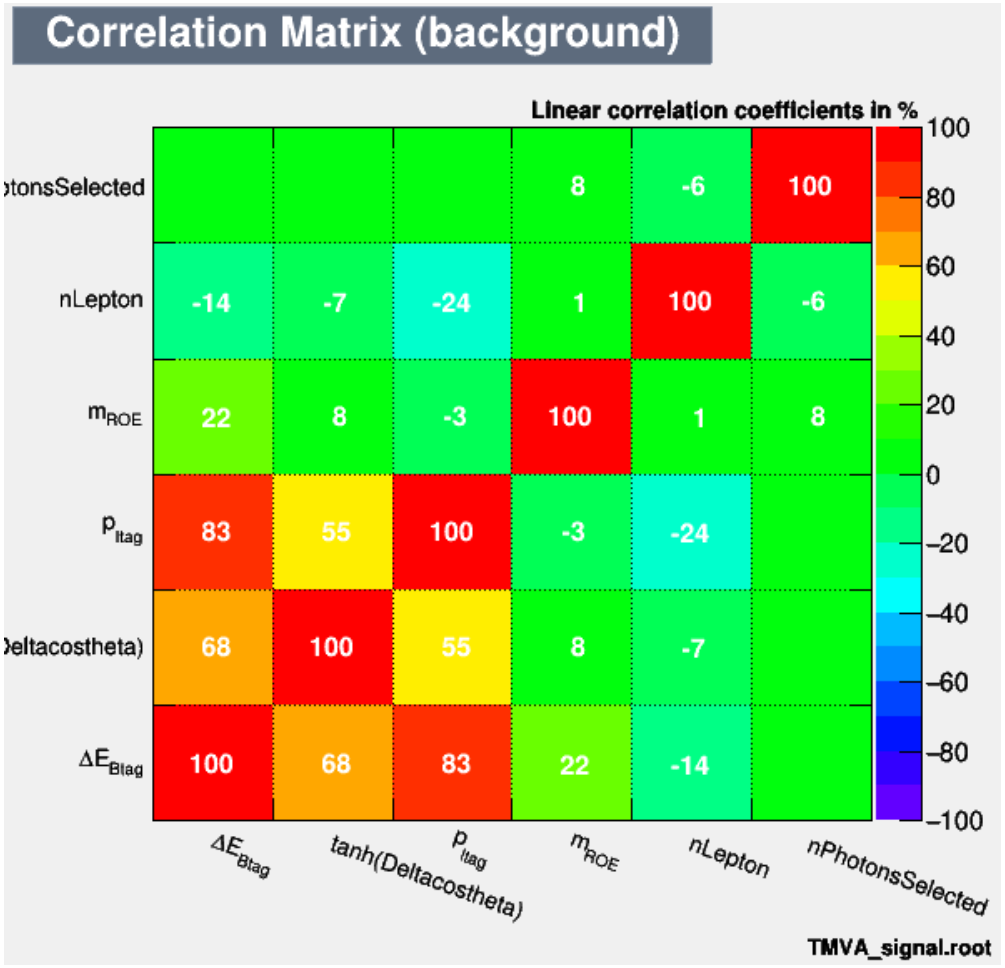
Particles selection

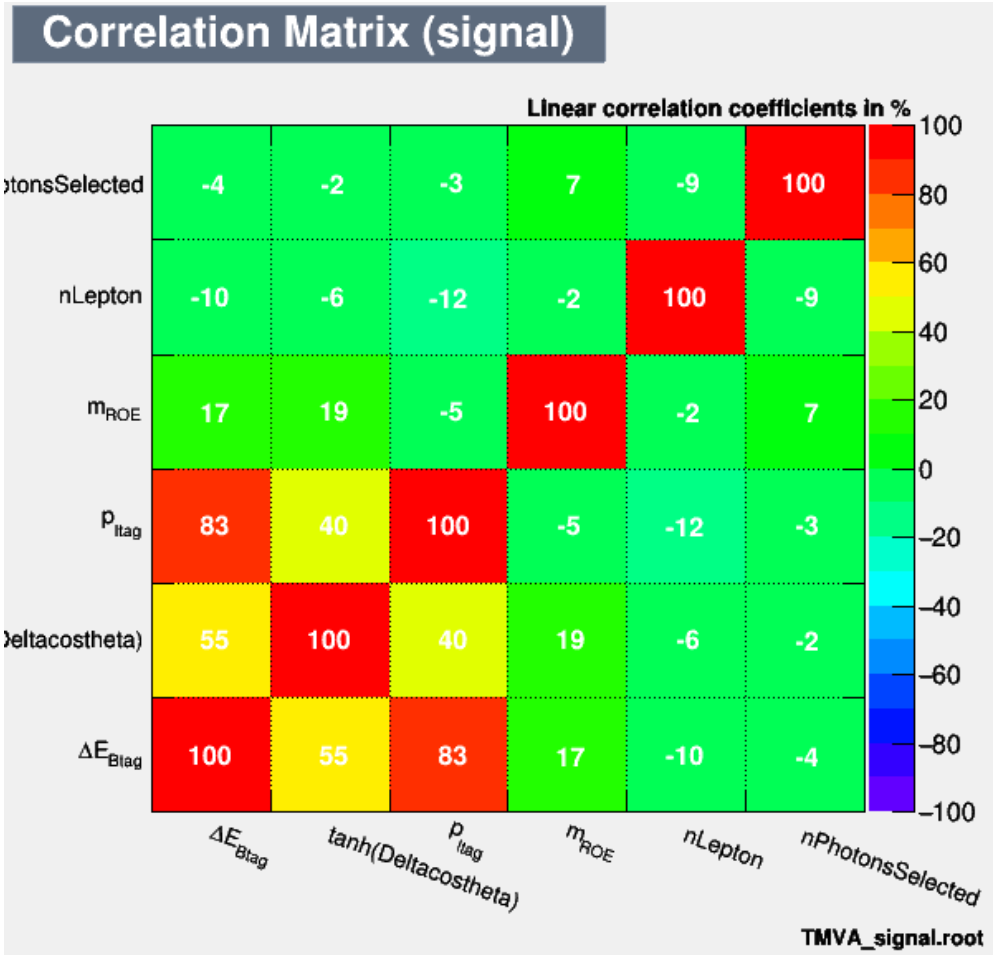
- **e^- selection:** $d_0 < 1$ cm, $|z_0| < 4$ cm, p > 0.05 GeV, eIDBelle >0.6, muIDBelle <0.98, atcPIDBelle(3,0) <0.98
- **μ^- selection:** $d_0 < 1$ cm, $|z_0| < 4$ cm, p > 0.05 GeV, muIDBelle >0.6, eIDBelle <0.98, atcPIDBelle(3,1) <0.98
- **K^- selection:** $d_0 < 1$ cm, $|z_0| < 4$ cm, p > 0.05 GeV, muIDBelle <0.98, eIDBelle <0.98, atcPIDBelle(3,2) >0.6
- **π^+ selection:** $d_0 < 1$ cm, $|z_0| < 4$ cm, p > 0.05 GeV, atcPIDBelle(3,2) <0.6
- **π^0 selection:** $0.08 < m_{\pi 0} < 0.18$ GeV
- **Photons selection:** goodBelleGamma==1 and pybdt_bb>0.3 and pybdt_fp>0.3

For ROE only

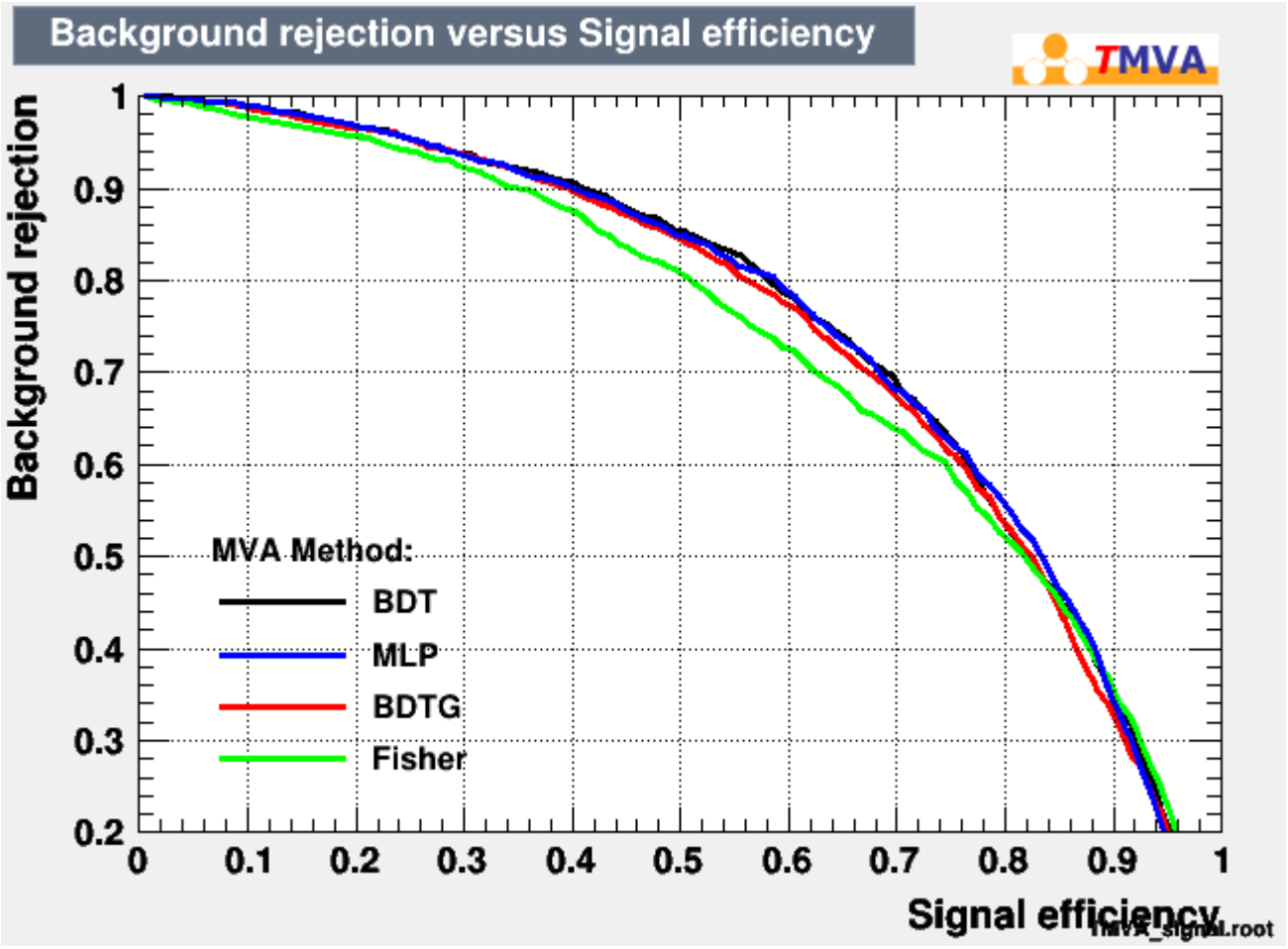
MVA Photon cuts

Correlation matrices





ROC



DataSet Name:	MVA Method:	ROC-integ
dataset	BDT	: 0.756
dataset	MLP	: 0.756
dataset	BDTG	: 0.748
dataset	Fisher	: 0.732