$B^0 \to \pi^0\pi^0$ first look towards LS1 data update

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BtoHadrons meeting
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Overview

BF and A_{CP} of $B^0 \to \pi^0\pi^0$ decays: important measurements unique to Belle II.

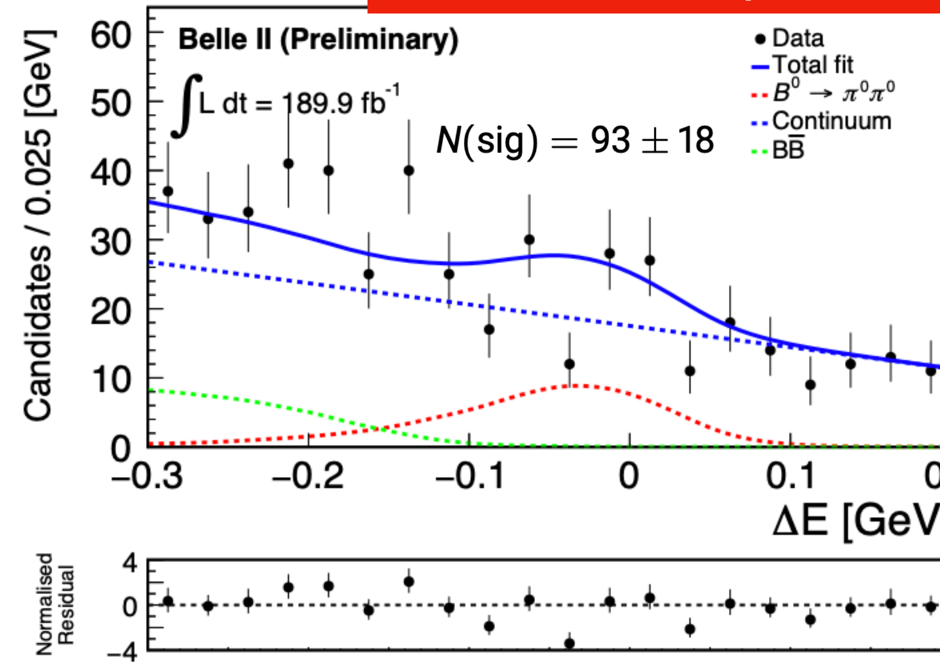
Status: 189.9 fb^{-1} analysis by Francis shown at ICHEP2022 and targeting PRD submission soon.

Start from Francis analysis, and try to improve for full LS1 data update.

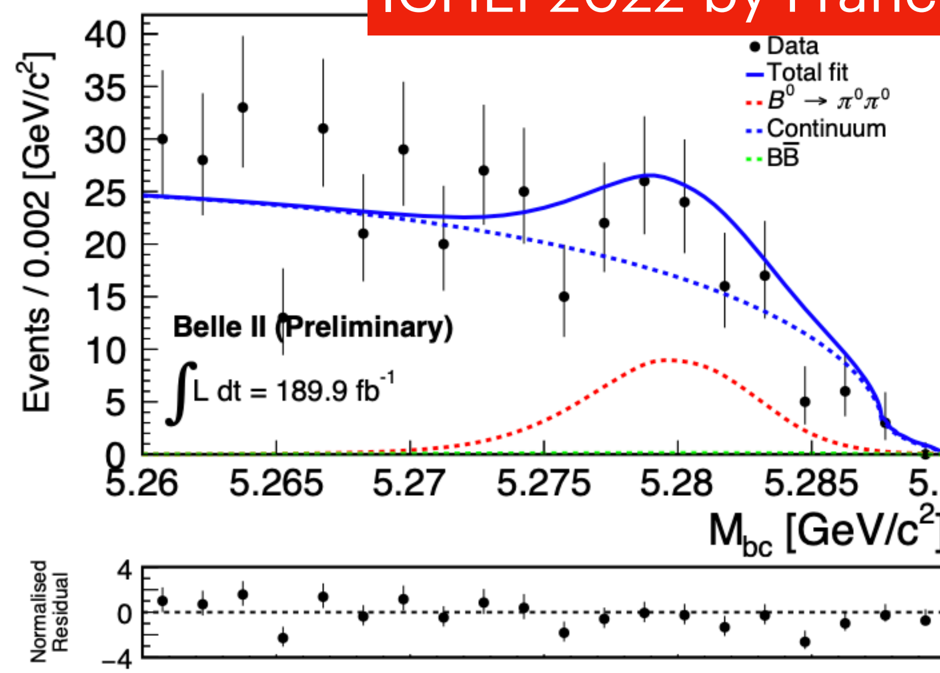
Today focus on selection:

- revisit photonMVA
- revisit CSBDT
- Introduce specific BDT trained against continuum ρ's

ICHEP2022 by Francis



ICHEP2022 by Francis



$\mathcal{A}^{CP} = -0.14 \pm 0.46$ (stat.) ± 0.07 (syst.)
$\mathcal{B} = (1.27 \pm 0.25$ (stat.) ± 0.17 (syst.)$) \cdot 10^{-6}$

Samples and selections

Samples

GenericMC: MC15ri

SignalMC: MC15 locally produced (600000 events)

Data: Proc13 chunk1+chunk2

Off-res data: Proc13 (c1+c2) +Prompt

For data use "all" (no hadron skim).

Base selections (from Francis analysis)

γ: E>0.03 GeV, |clusterTiming|<200, clusterNHits>1.5, 0.30<clusterθ<2.62 (very loose cuts)

π^0: daughterAngle < 0.4, |daughterDiffOfPhi| < 0.4, |cosHelicityAngleMomentum| < 0.99, p > 1.5 GeV/c, 0.115 < InvM < 0.150 GeV/c^2 (very loose cuts)

B^0: -0.3<ΔE<0.2 GeV, M_{bc}>5.26 GeV/c^2

Will be optimised, large improvements unlikely

NEW SINCE LAST TIME

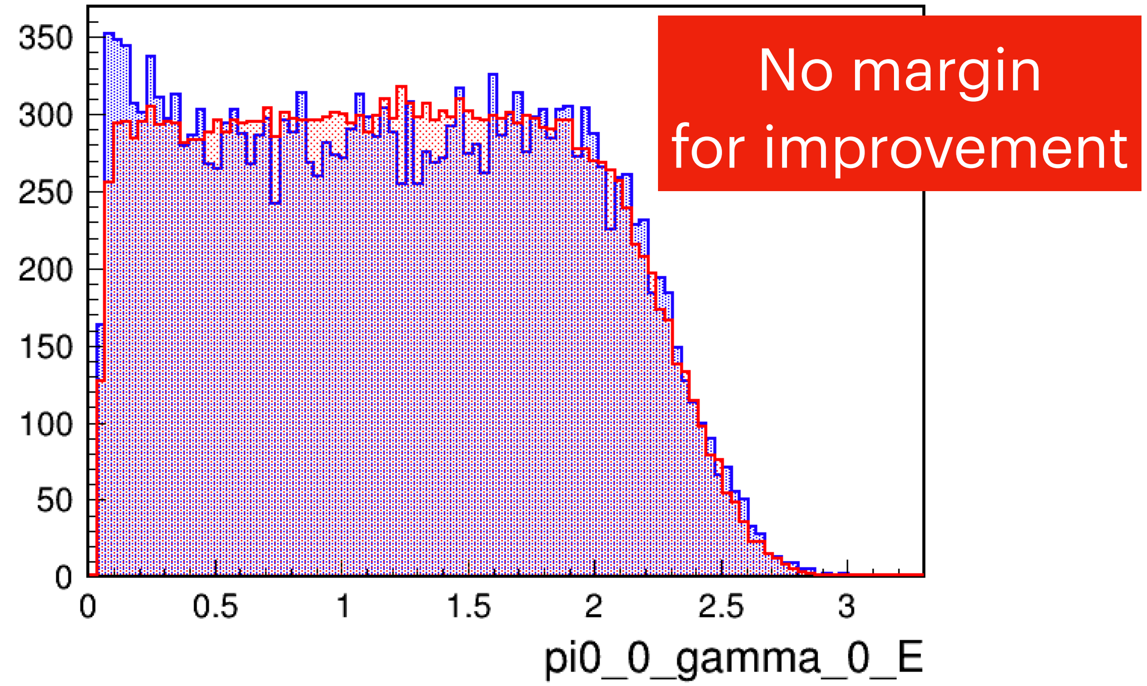
Can we improve γ and/or π^0 selections?

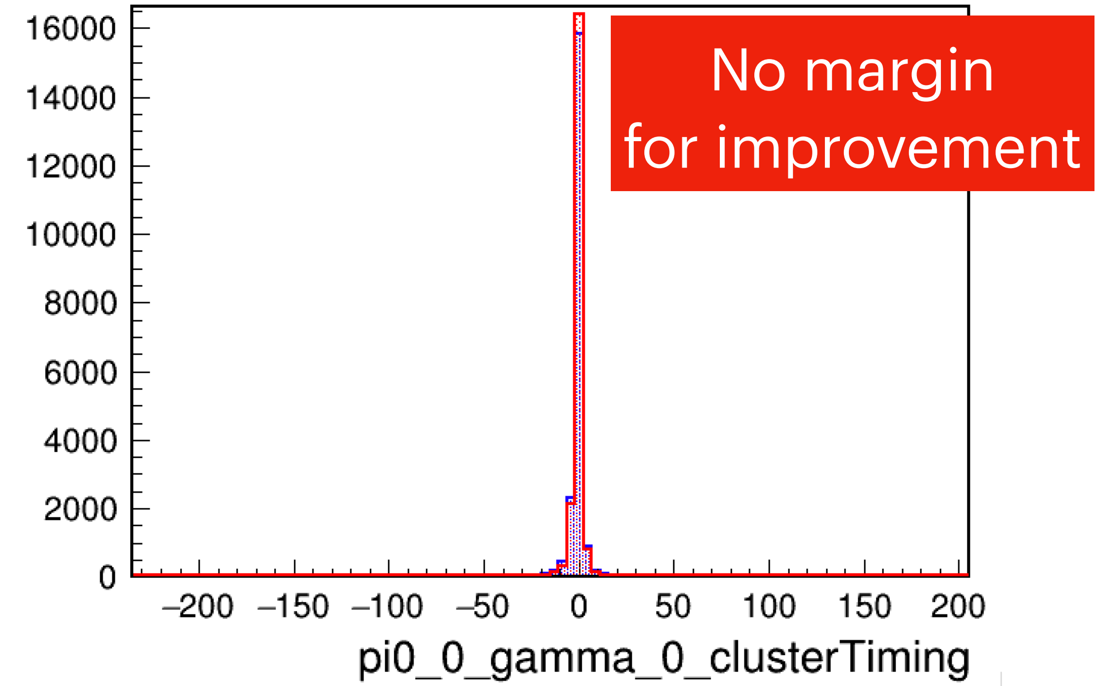
Apply all selections, CSMVA and photonMVA and check again distributions.

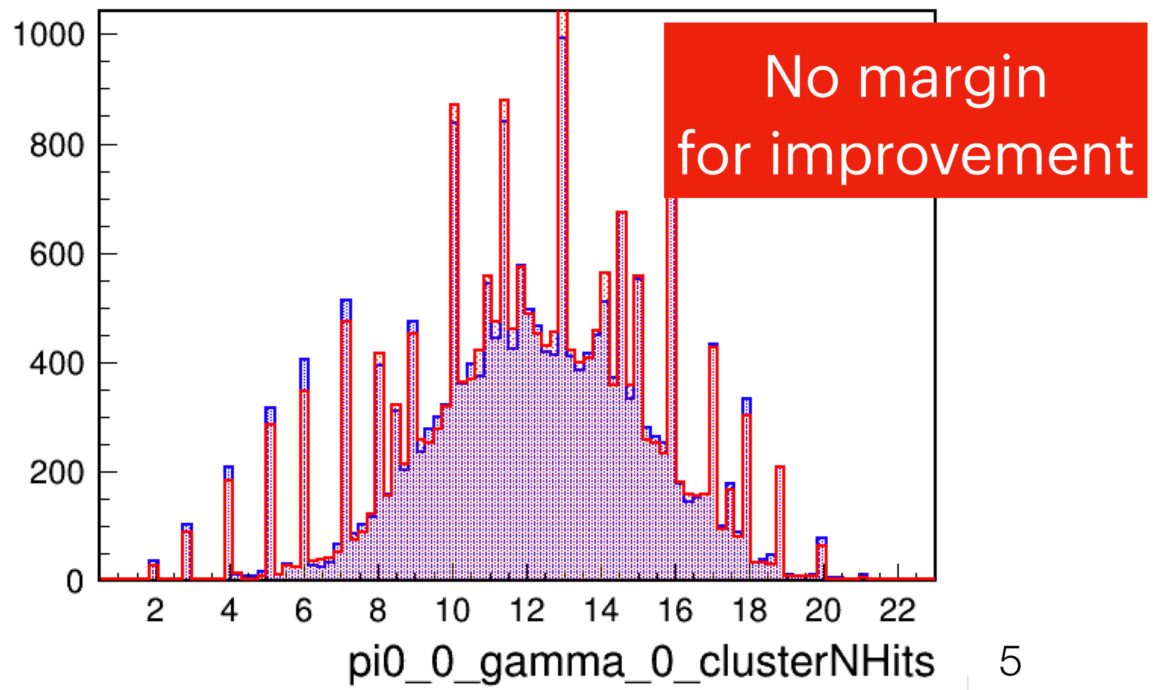
New possible γ selections?

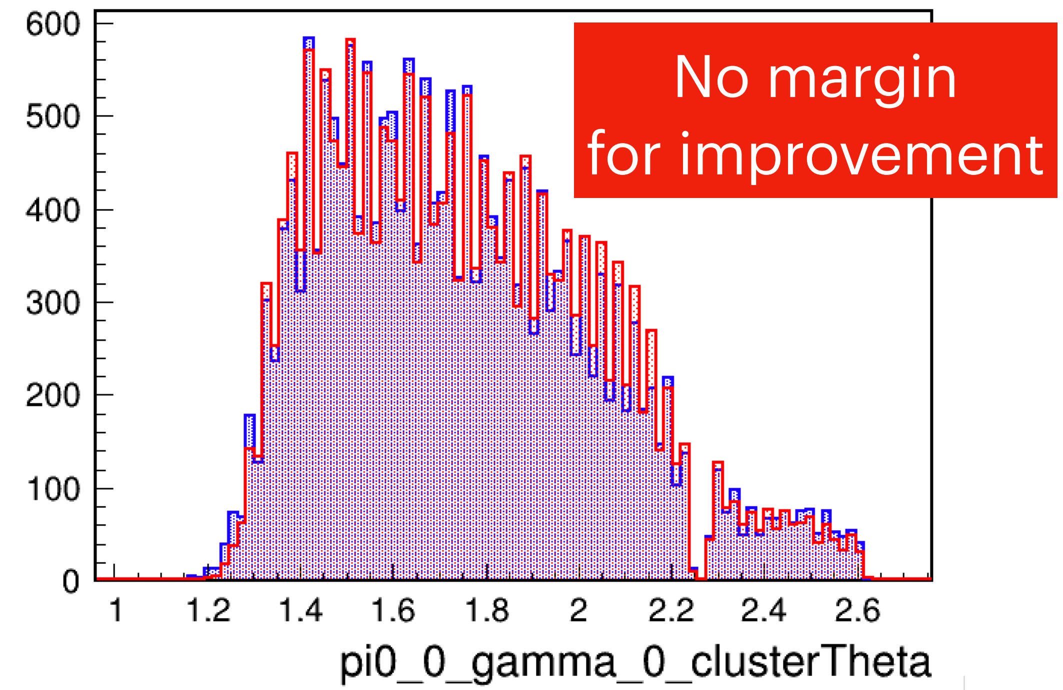
γ: E>0.03 GeV, |clusterTiming|<200, clusterNHits>1.5, 0.30<clusterθ<2.62

Note: **clusterTiming** is not well reproduced → very loose cut





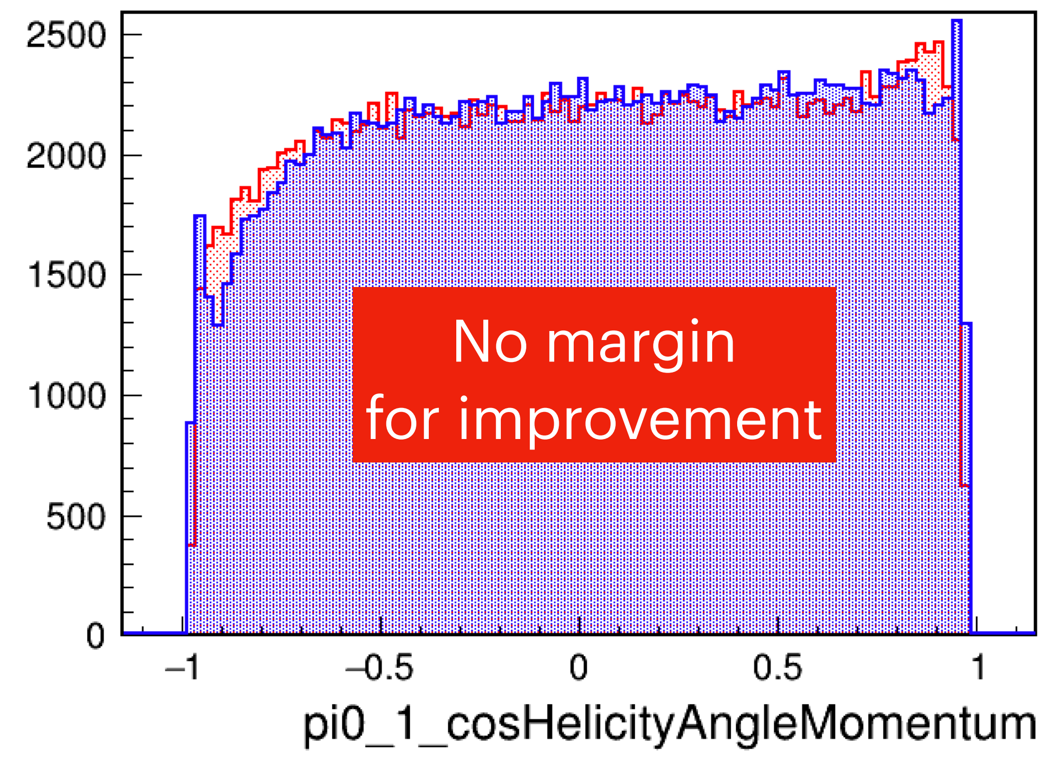


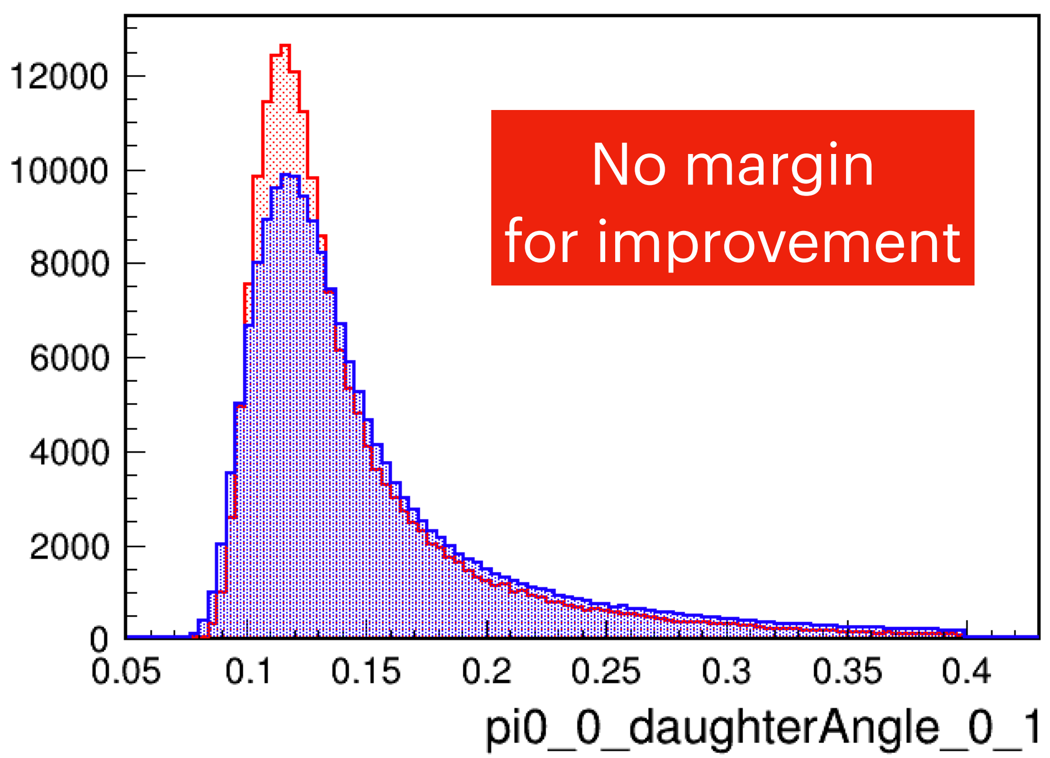


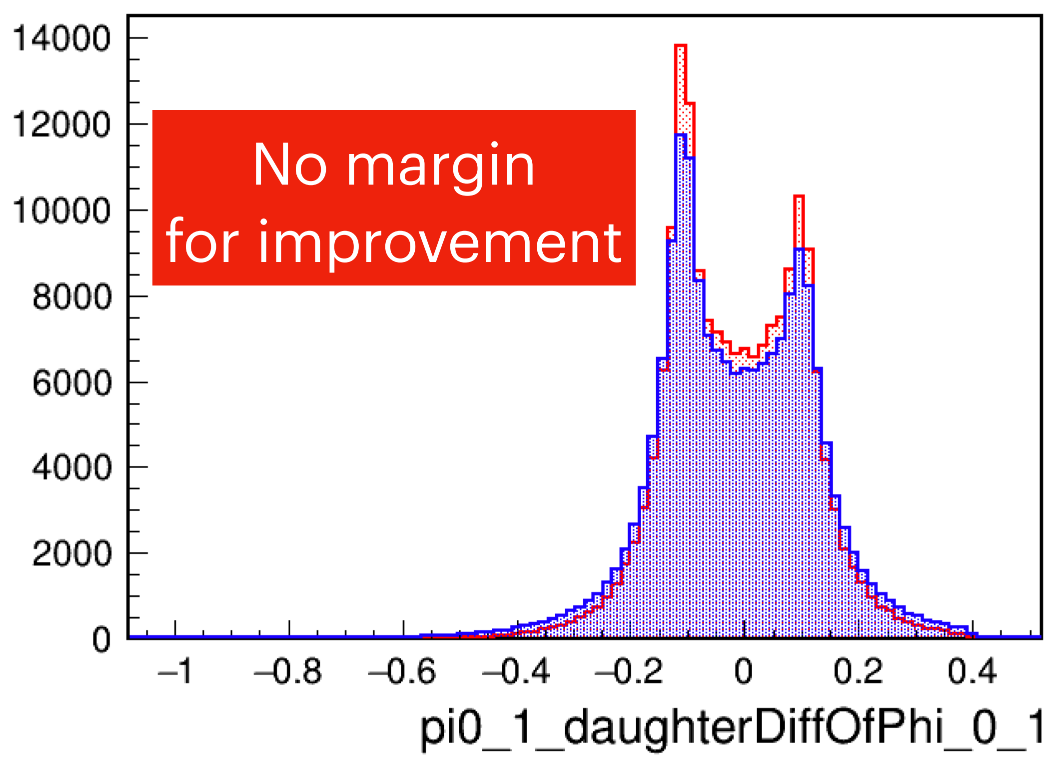
NEW SINCE LAST TIME

New possible π^0 selections?

π^0: daughterAngle < 0.4,
|daughterDiffOfPhi| < 0.4,
|cosHelicityAngleMomentum| < 0.99



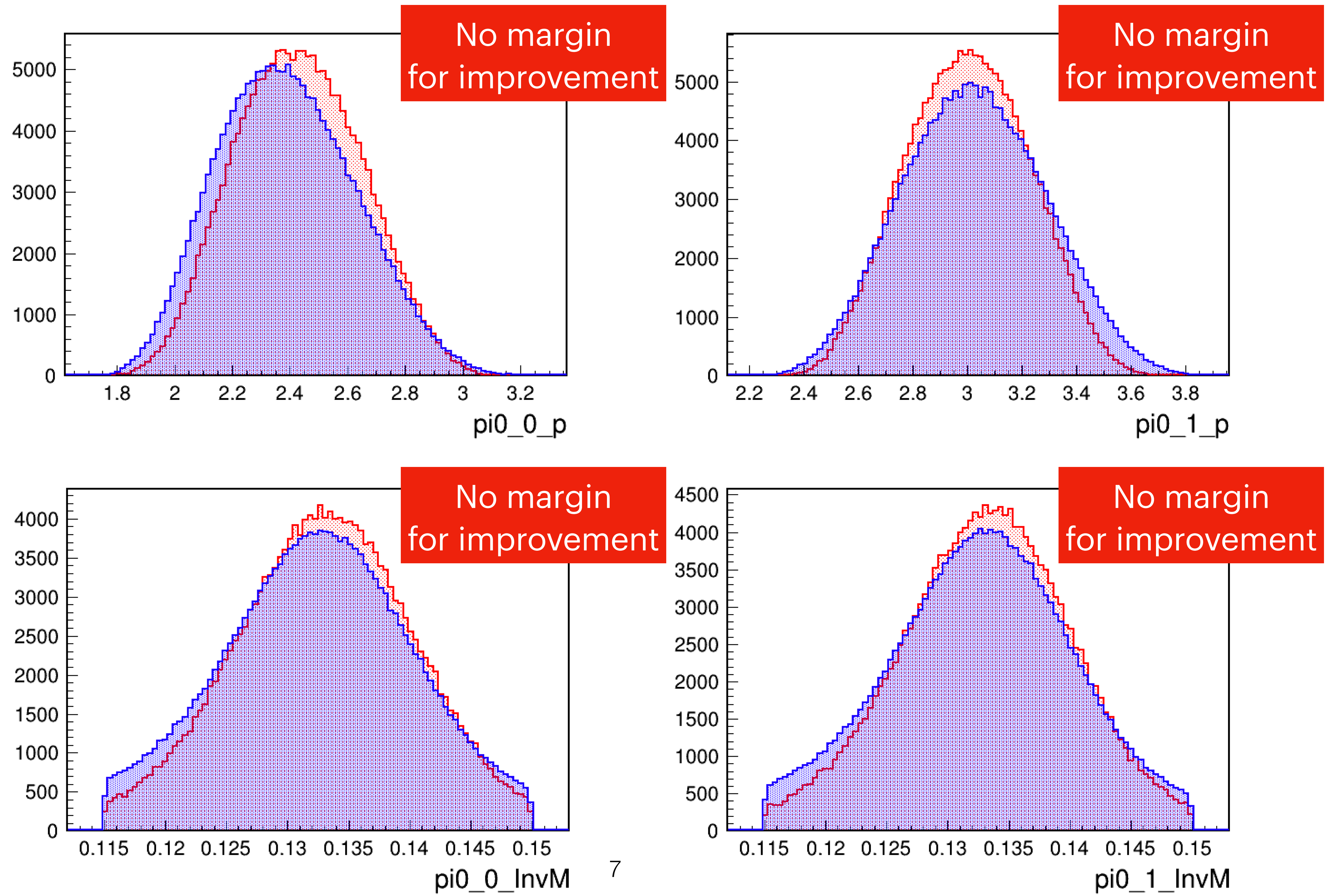




NEW SINCE LAST TIME

New possible π^0 selections?

$p > 1.5$ GeV/c, $0.115 < \mathrm{InvM} < 0.150$ GeV/c^2



Photon MVA

Photon MVA

Distinguish between signal photons and misreconstructed photons: beam backgrounds, energy releases from other particles...

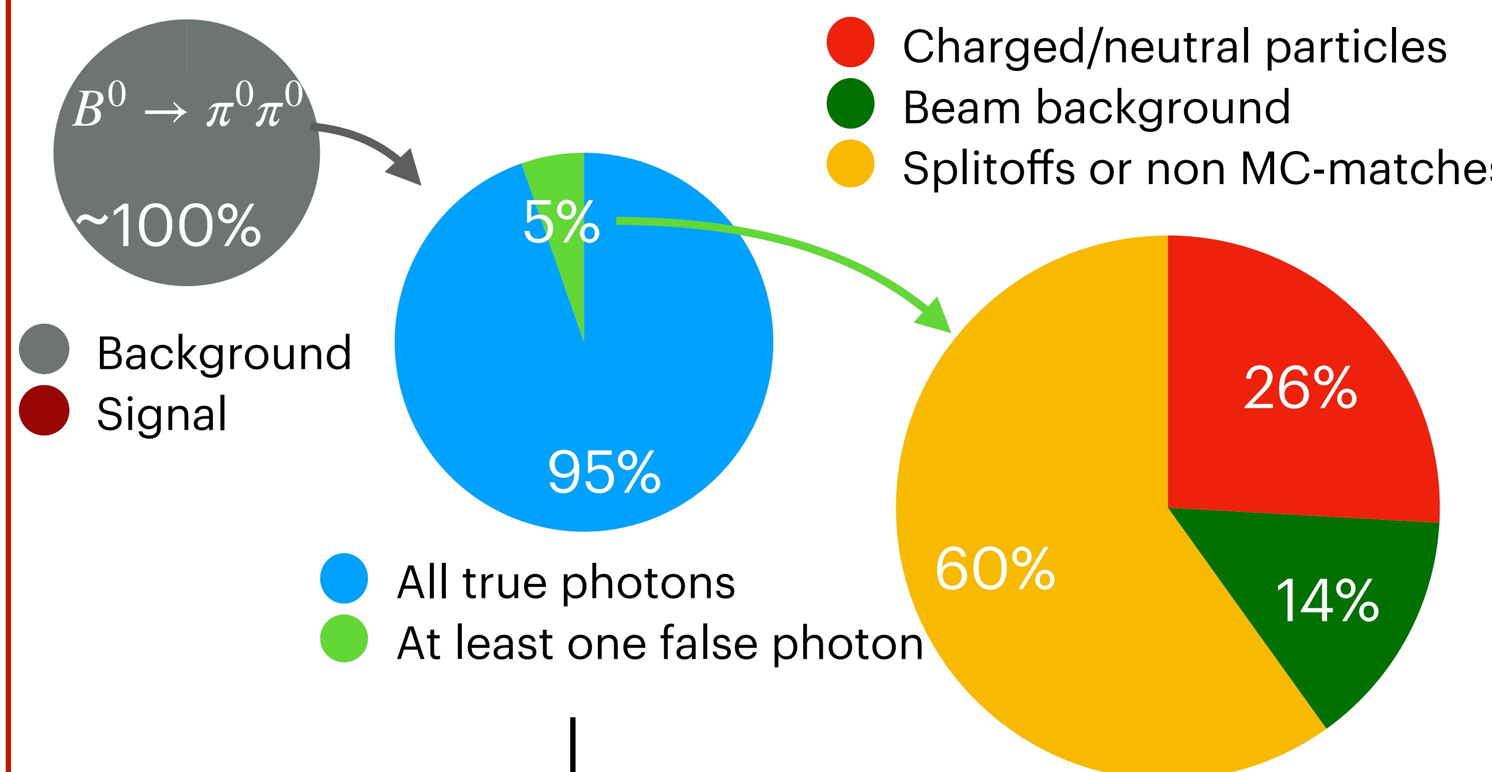
Combine highly-discriminant cluster- and photon-variables in a MVA.

Mis-rec photons have low energies, $B^0 \to \pi^0\pi^0$ photons have high-energy.

→ Specialise MVA on high-energy photons: apply π^0 selections before training.

MC15

Reconstruct $B^0 \to \pi^0\pi^0$ in genericMC. Apply γ and π^0 selections. Check composition of photons from the π^0's.



Few bkg photons because π^0 selections restrict to high-energy photons

Photon MVA: inputs validation

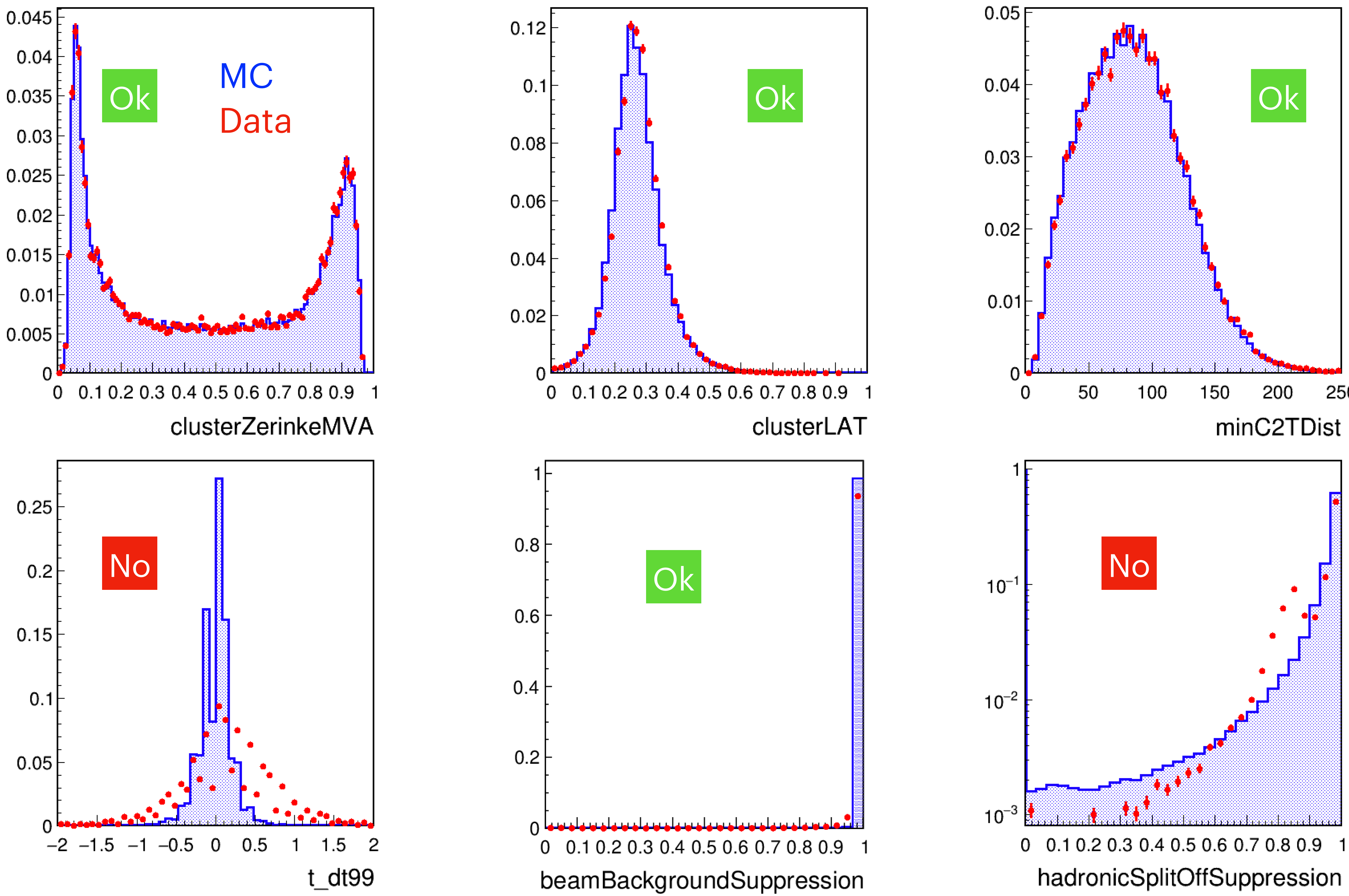
Ideally would need a sample of true photons and a sample of mis-rec photons in data (difficult).

Use inclusive sample of photons from $D^* \to D^0(K\pi\pi^0)\pi$ decays: reweigh momenta to mirror $B^0 \to \pi^0\pi^0$ signal kinematics.

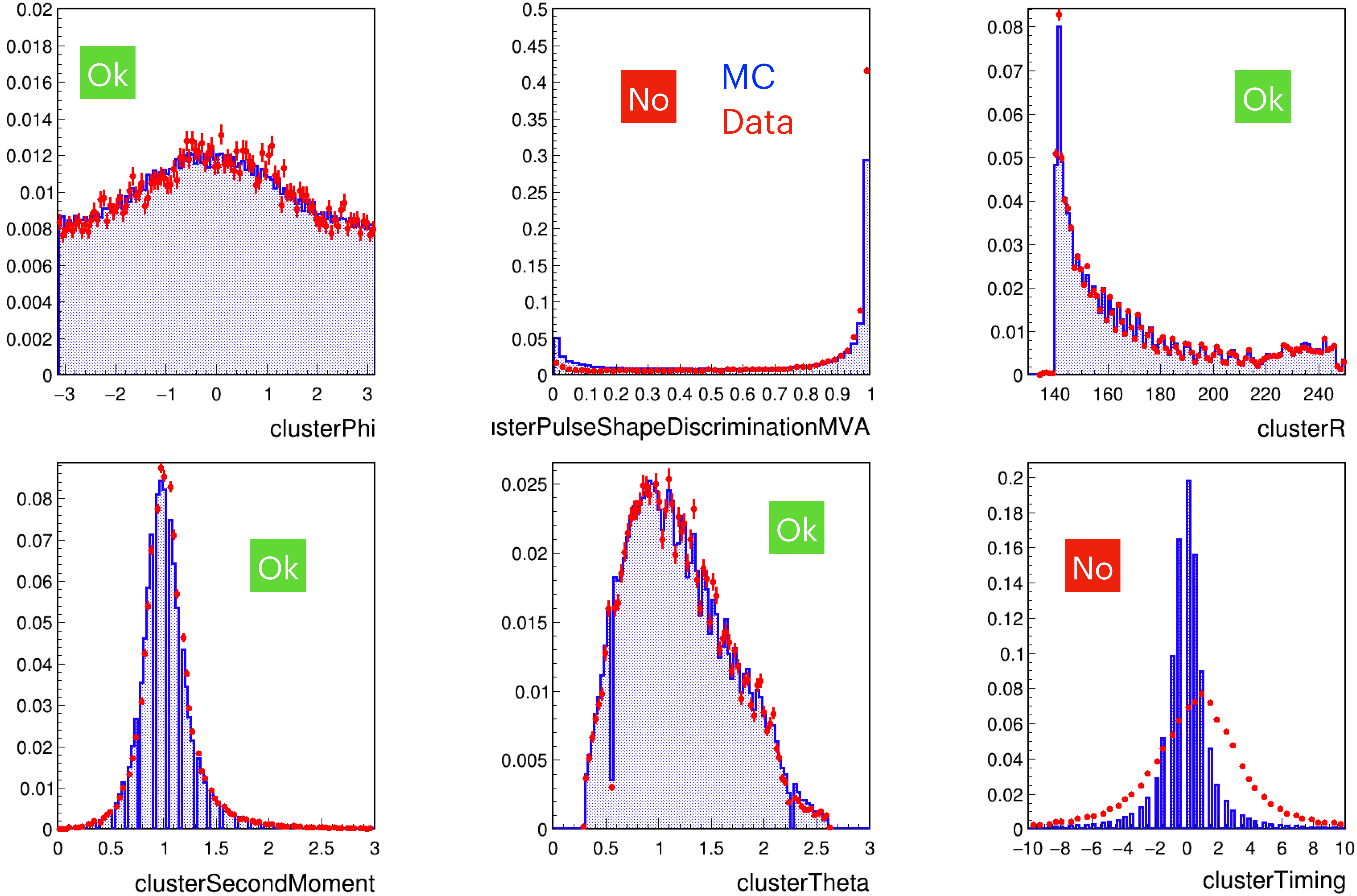
Sample is signal dominated → ~all true photons (as in $B^0 \to \pi^0\pi^0$).

Compare many and new possible ECL input variables using MC15ri (200 fb^{-1}) and Proc13c1(8 fb^{-1}).

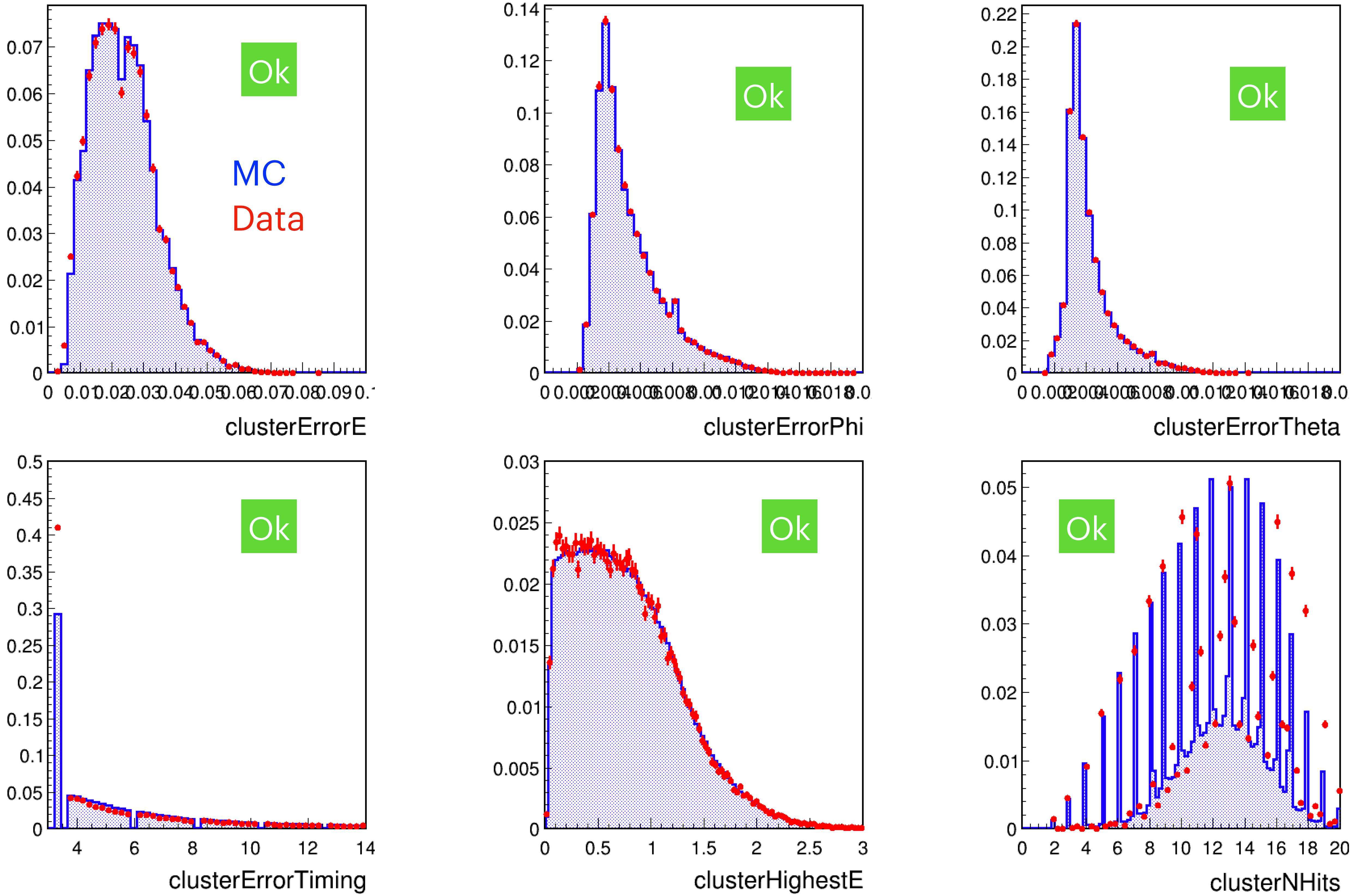
Photon MVA: inputs validation (rel-06)



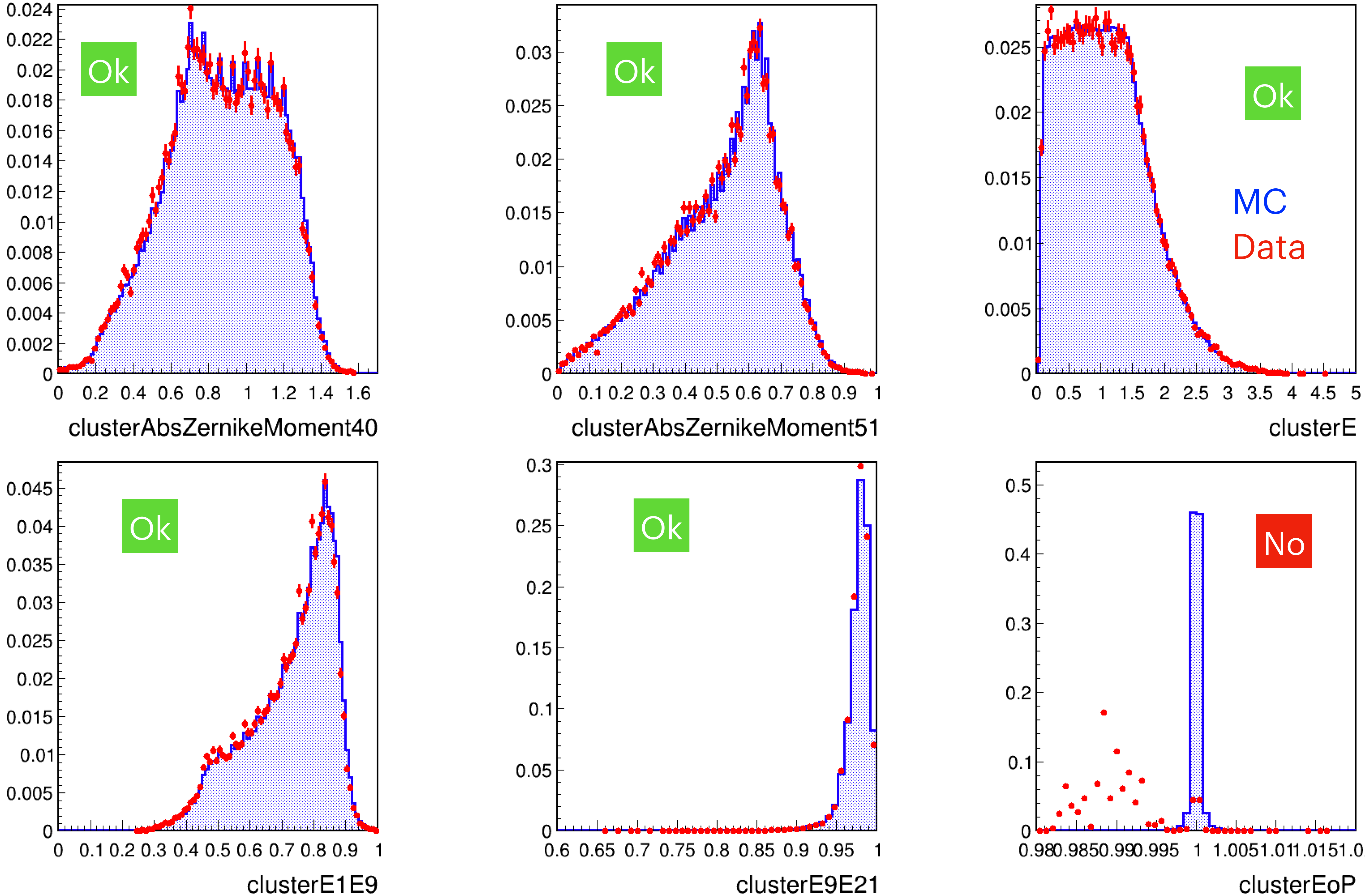
Photon MVA: inputs validation (rel-06)



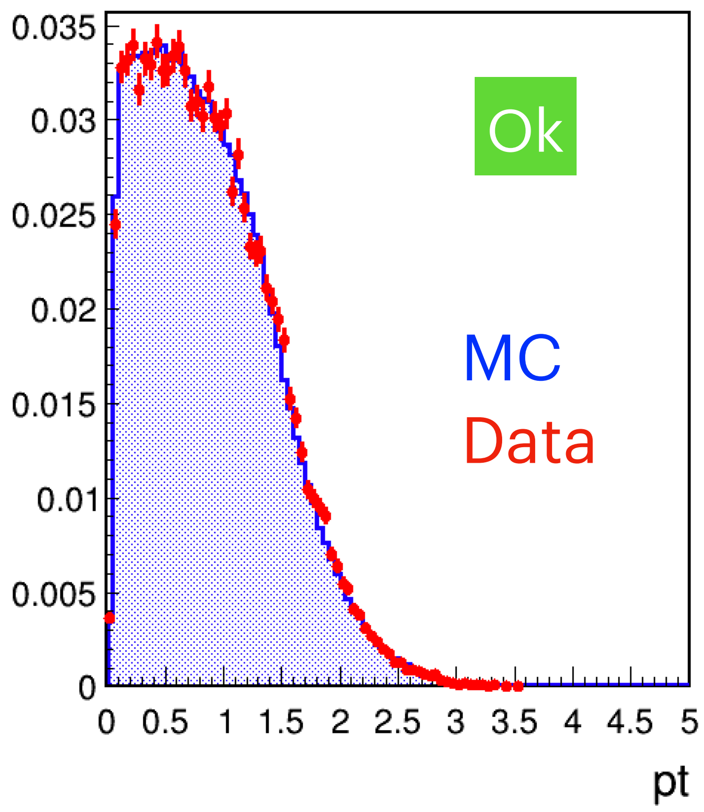
Photon MVA: inputs validation (rel-06)

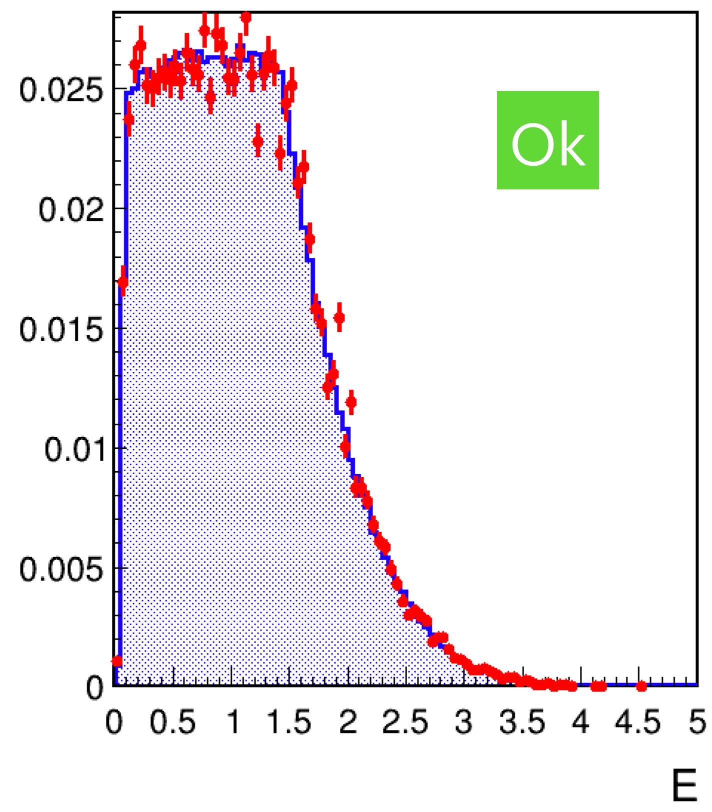


Photon MVA: inputs validation (rel-06)



Photon MVA: inputs validation (rel-06)



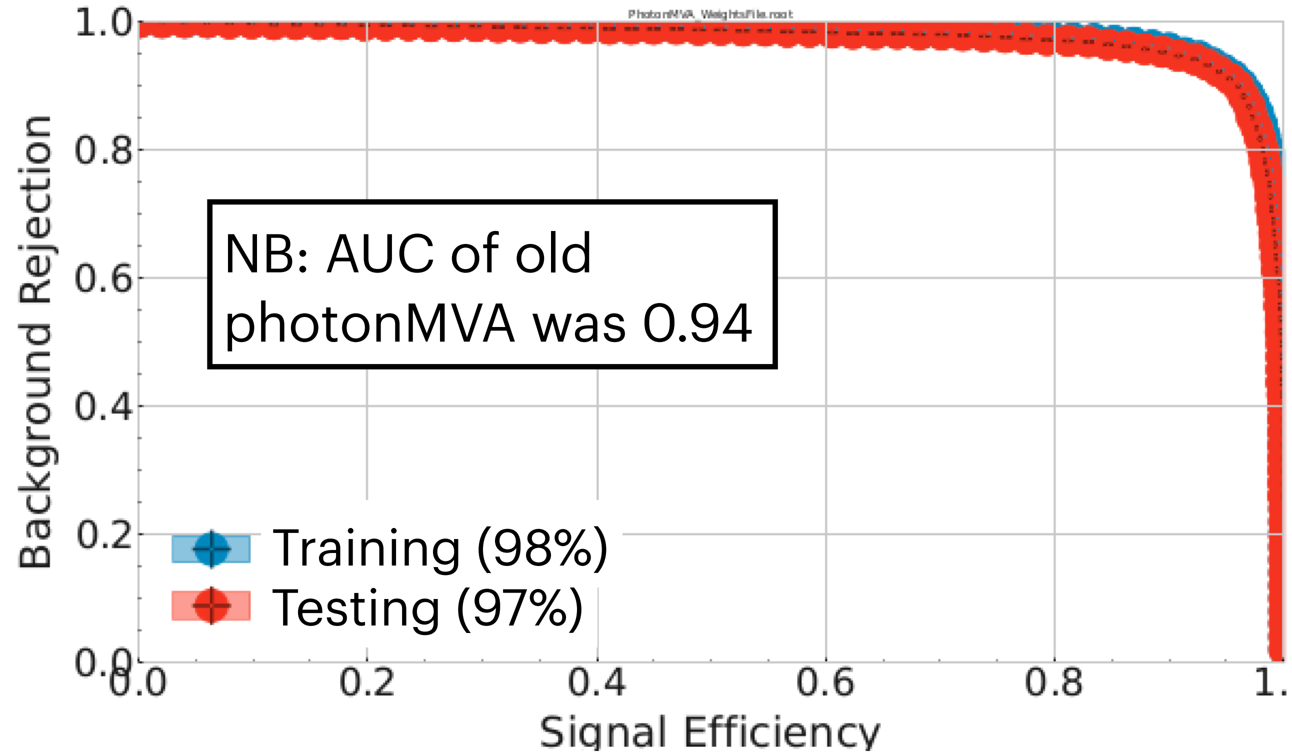


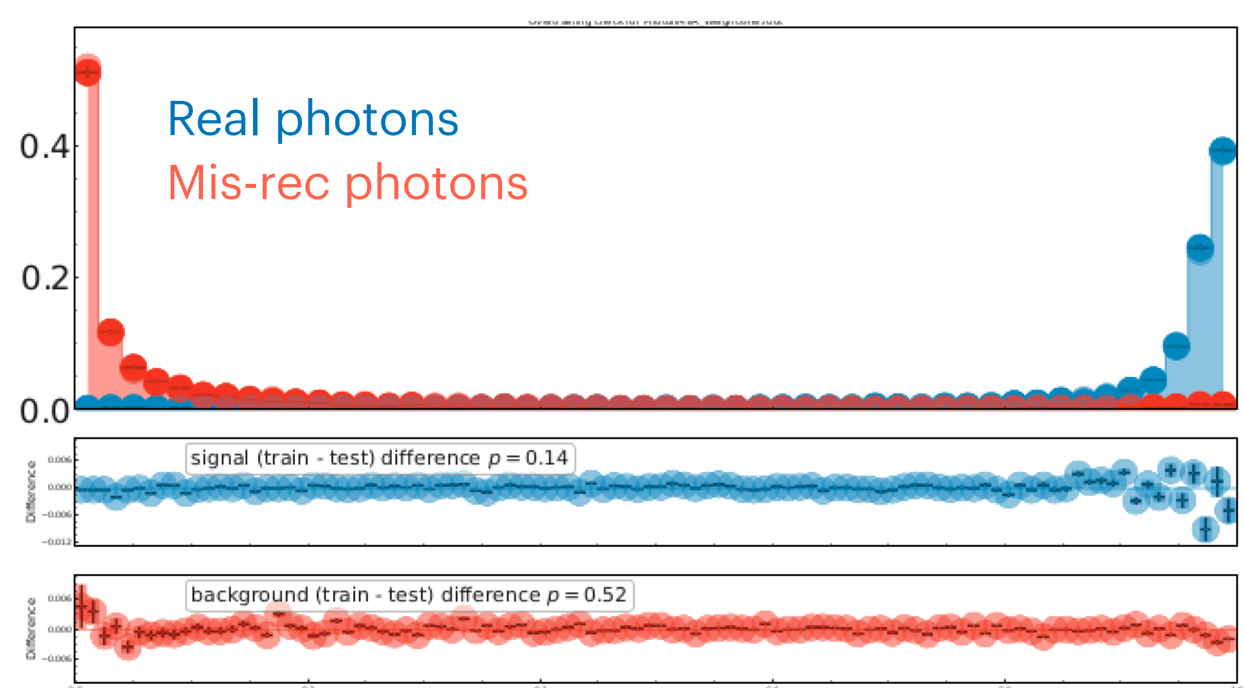
Photon MVA discrimination in release-06

Train on MC sample after applying all π^0 selections.

Inputs (after pruning)
pt
clusterE1E9
clusterErrorPhi NEW
clusterHighestE
clusterSecondMoment
clusterZernikeMVA
minC2TDist
clusterLAT NEW
clusterNHits NEW
clusterTheta NEW
beamBackgroundSuppression NEW

Dropped: clusterAbsZernikeMoment40, clusterAbsZernikeMoment51, E, clusterE9E21



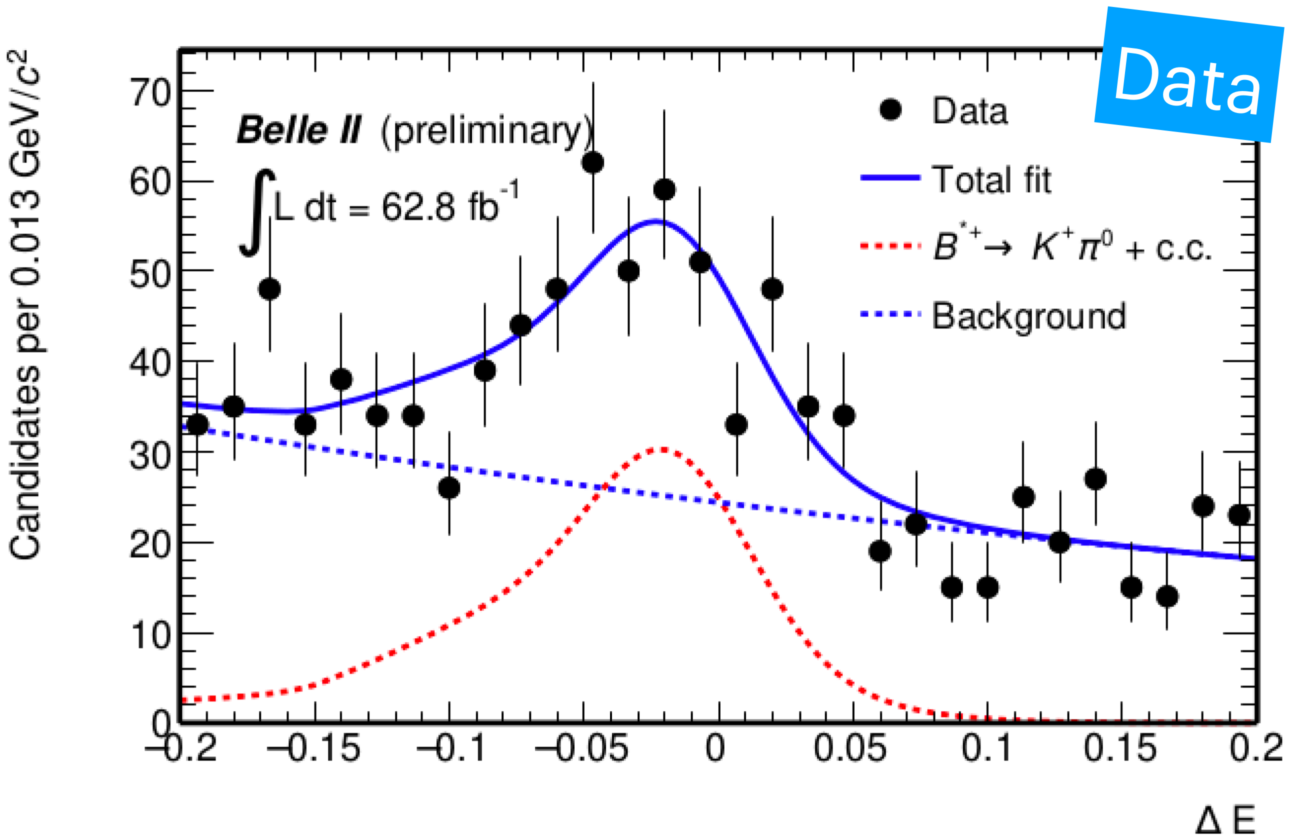


PhotonMVA output

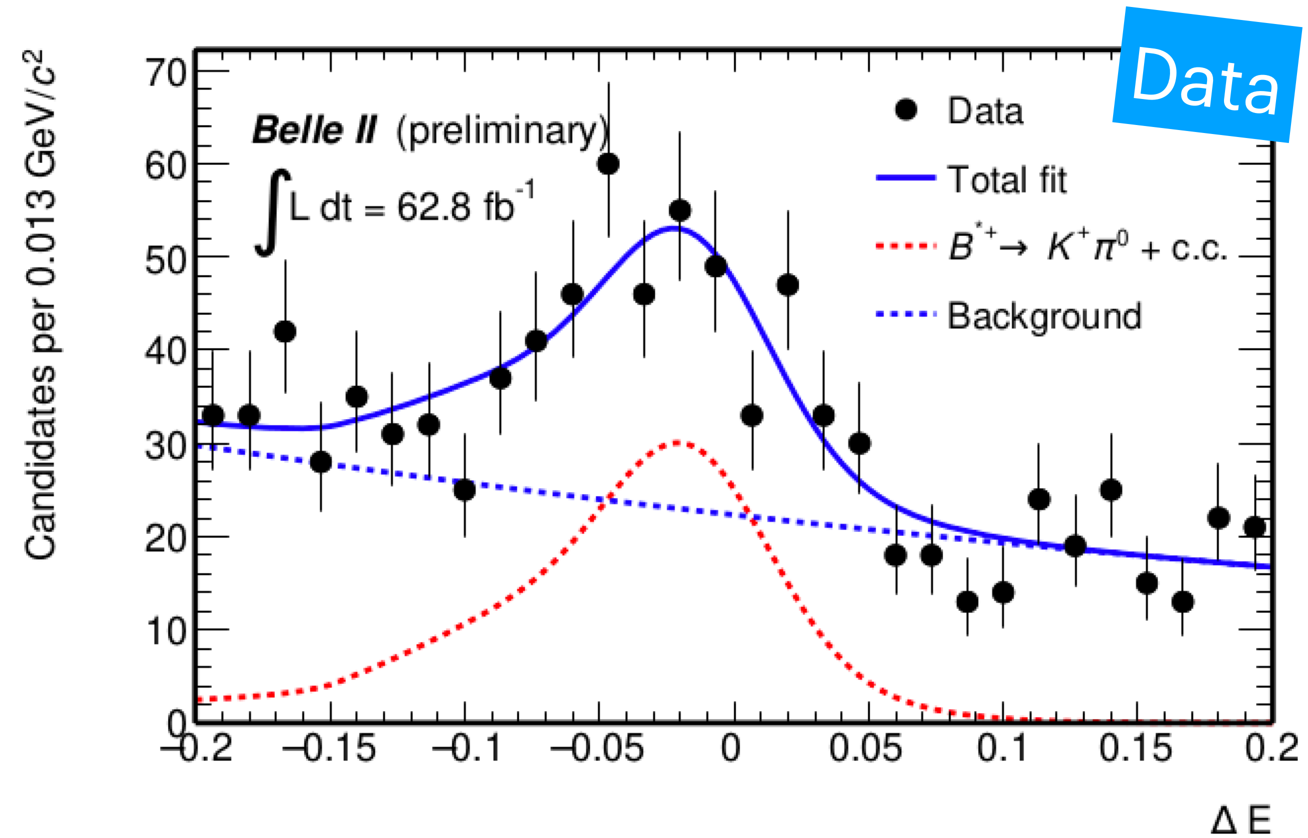
Photon MVA validation

Apply photonMVA to $B^+ \to K^+\pi^0$ proc13 sample (chunk1+chunk2 — 62fb^{-1}).

No photonMVA



PhotonMVA>0.2



Background: 740 ± 40
Signal: 260 ± 30

Background: 680 ± 40 (-8,5%)
Signal: 260 ± 30 (-0%)

Small statistics. Modest but positive impact.
Will repeat using 190 fb^{-1}.

Photon MVA comparison

Simulation

1

Look at photons: reconstruct $B^0 \to \pi^0\pi^0$ in genericMC and apply γ and π^0 selections. Consider as "signal" all real photons, and as "background" all misreconstructed photons. Use MC info to obtain photon signal efficiency and bkg rejection after photonMVA selection. For fixed ε_{sig} (=96%), compare bkg rejection.

Old bkg rejection: 67.4% $\longrightarrow$ My bkg rejection: 85.2%

Simulation

2

Look at B^0 candidates: reconstruct $B^0 \to \pi^0\pi^0$ candidates in genericMC and apply γ and π^0 selections. Consider as "signal" all signal $B^0 \to \pi^0\pi^0$ events, and everything else as "background". Use MC info to obtain signal efficiency and bkg rejection after photonMVA selection. For fixed ε_{sig} (=94.5%), compare bkg rejection.

Old bkg rejection: 14.8% $\longrightarrow$ My bkg rejection: 15.7%

Data

3

Check on data: reconstruct $D^{*+} \to D^0(K^-\pi^+\pi^0)\pi^+$ candidates in data and apply γ and π^0 selections. Reweigh using $p(\pi^0)$. Consider as "signal" all signal $D^{*+} \to D^0\pi^+$ events, and everything else as bkg. Obtain ε_{sig} and bkg rejection as $N_{\text{pass}}/(N_{\text{pass}} + N_{\text{not pass}})$ from fit. For fixed ε_{sig} (=96.6%), compare bkg rejection.

Old bkg rejection: 5.1±0.1% $\longrightarrow$ My bkg rejection: 9.4±0.1%

Photon MVA comparison

190 fb^{-1} analysis

- 10 ECL variables
- Inputs are validated using MC14 and Proc12.
- Validation on $D^{*+} \to D^0(K_S^0\pi^0)\pi^+$ with no reweighing.
- AUC = 0.94

This analysis

- 11 ECL variables including beamBackgroundSuppressionMVA.
- Apply π^0 selections prior to training.
- All inputs are validated using MC15 and Proc13.
- Validation on $D^* \to D^0(K\pi\pi^0)\pi$ reweighed using $p(\pi^0)$.
- AUC = 0.97

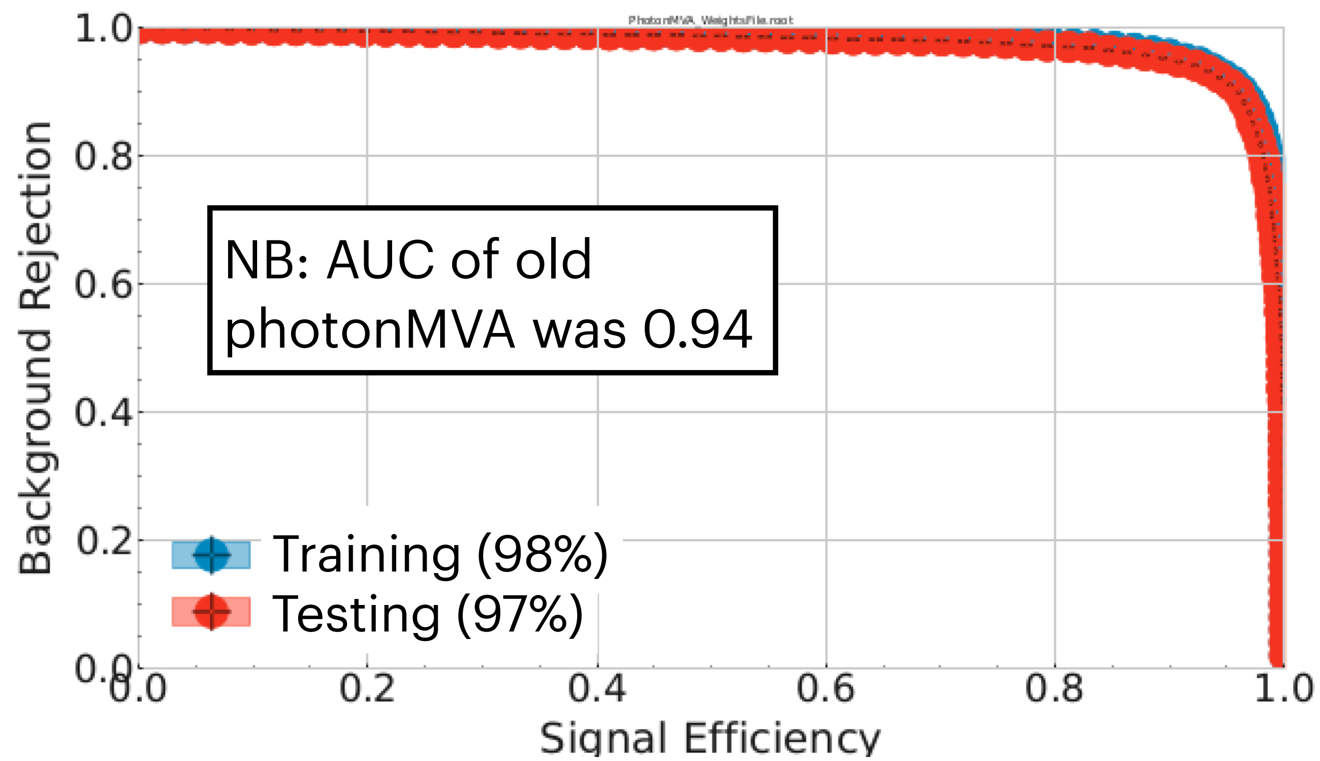
3% improvement in AUC. For given $\varepsilon_{\rm sig}$, bkg rejection is always modestly better.

NEW SINCE LAST TIME

Photon MVA discrimination in release-06

Train on MC sample after applying all π^0 selections.

Inputs (after pruning)
pt
clusterE1E9
clusterErrorPhi NEW
clusterHighestE
clusterSecondMoment
clusterZernikeMVA
minC2TDist
clusterLAT NEW
clusterNHits NEW
clusterTheta NEW
beamBackgroundSuppression NEW



This is a MVA with main inputs clusterTiming and PulseShapeDiscriminatorMVA, not well reproduced by MC.

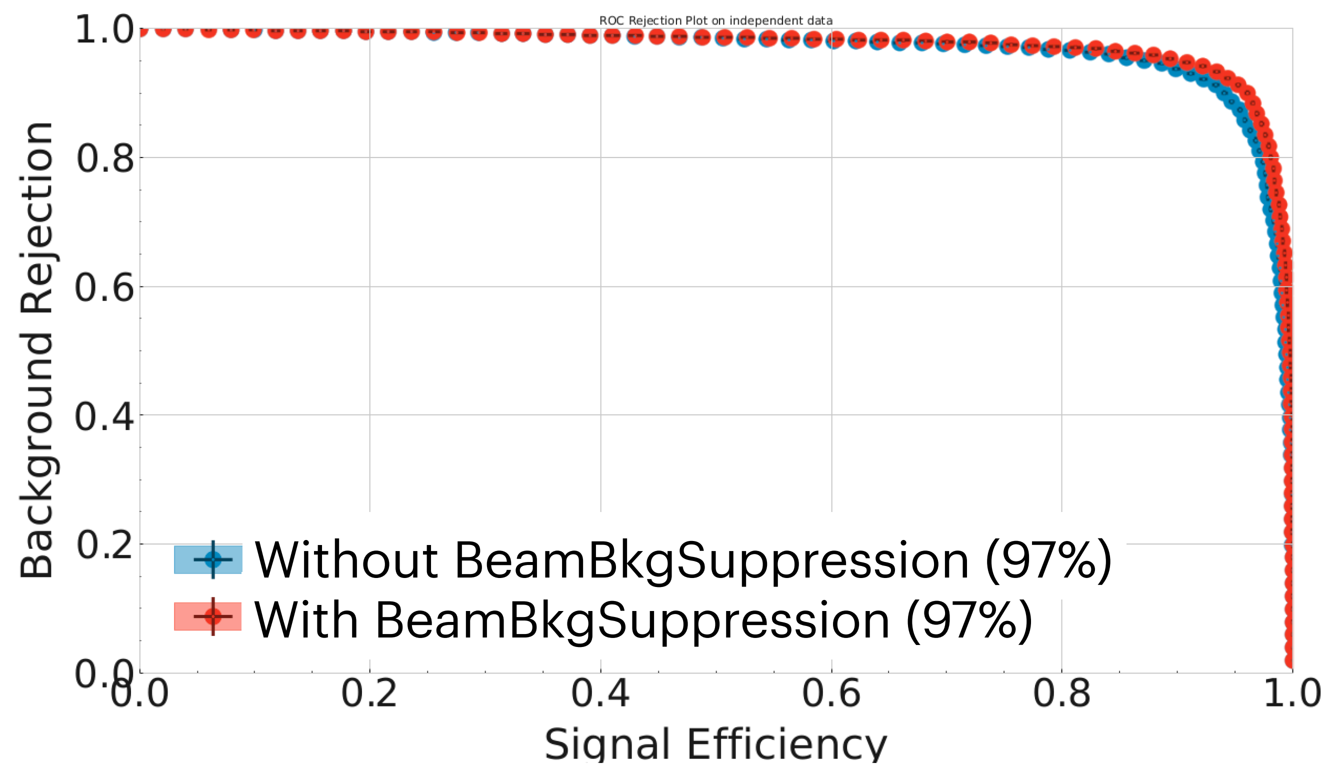
NEW SINCE LAST TIME

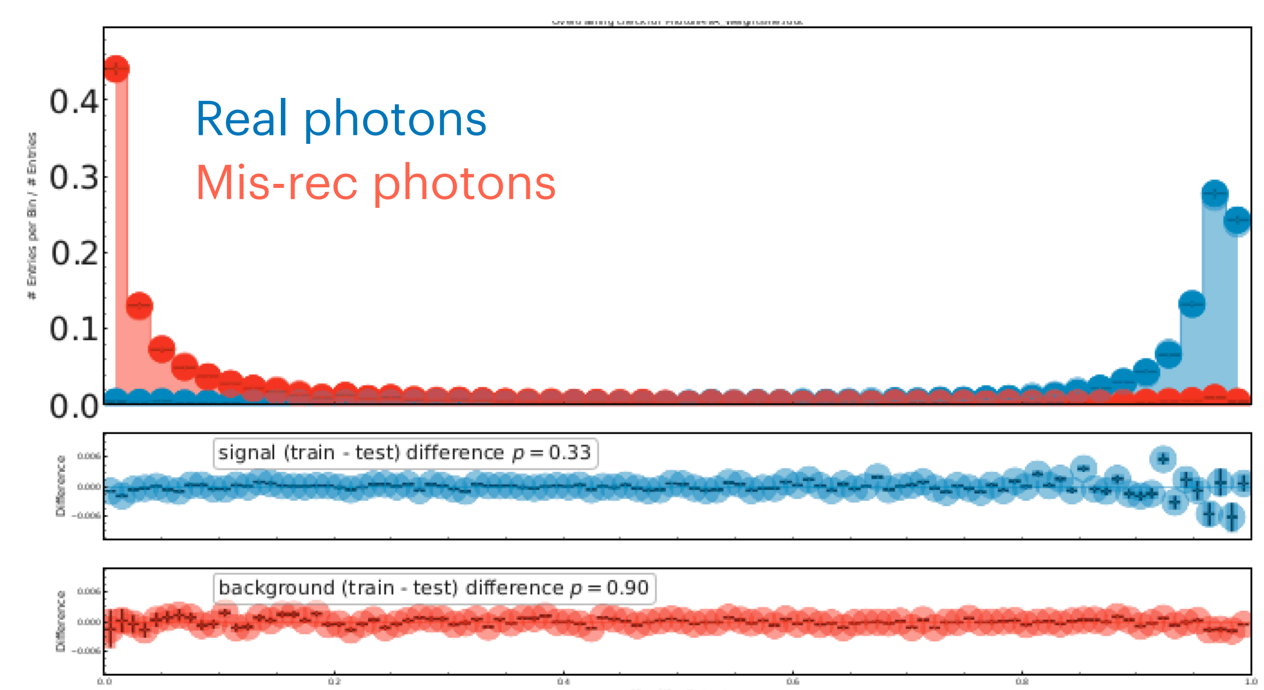
Remove beamBackgroundSuppression

Try removing beamBackgroundSuppression.

Inputs (after pruning)
pt
clusterE1E9
clusterErrorPhi NEW
clusterHighestE
clusterSecondMoment
clusterZernikeMVA
minC2TDist
clusterLAT NEW
clusterNHits NEW
clusterTheta NEW
~~beamBackgroundSuppression NEW~~

Dropped: clusterAbsZernikeMoment40, clusterAbsZernikeMoment51, E, clusterE9E21





PhotonMVA output

CSBDT

CSBDT

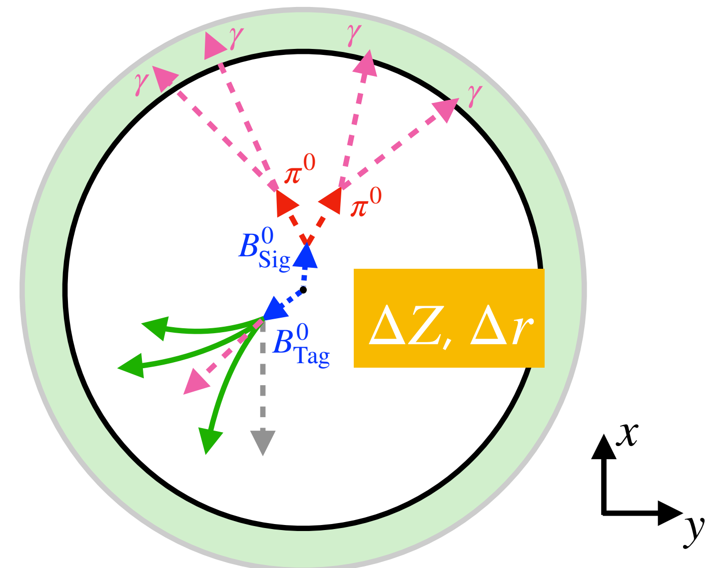
Develop continuum-suppression BDT.
Main difference wrt Francis analysis: include B_{Tag} variables, avoiding large correlations (<10% — was 5% in old analysis) and/or sculpting.

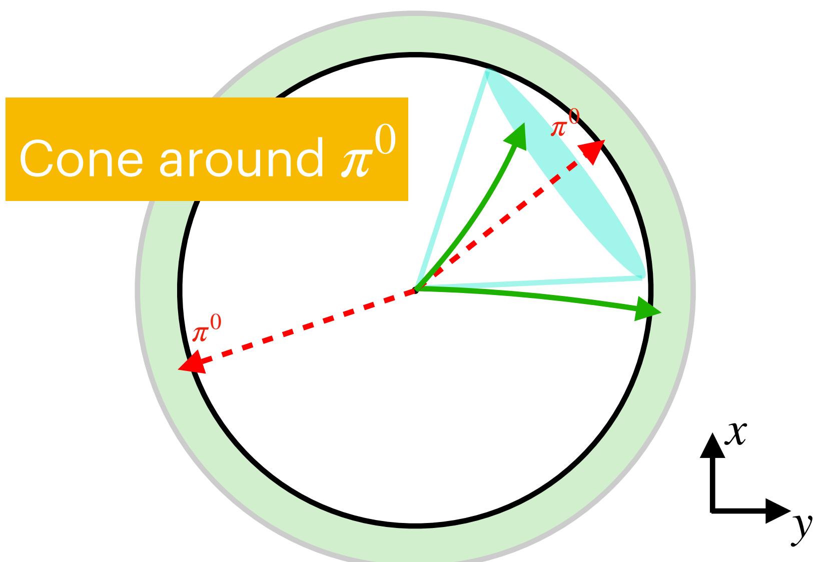
Check if B_{Tag} variables sculpts or introduces large correlations in flavour tagger.

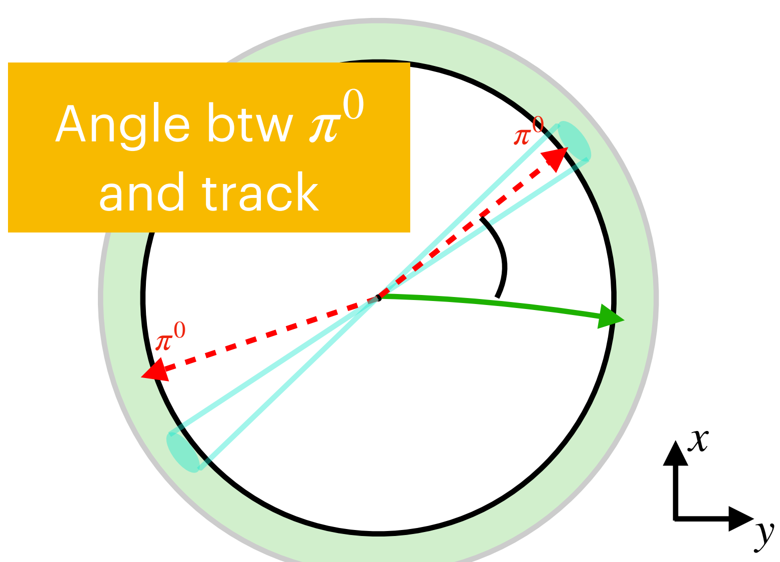
Start from Δr and ΔZ (distance of vertex from IP).

Note: 6.7% of the signal events don't have a B_{Tag} vertex → remove these events (bkg: -9.4%).

New possible inputs:



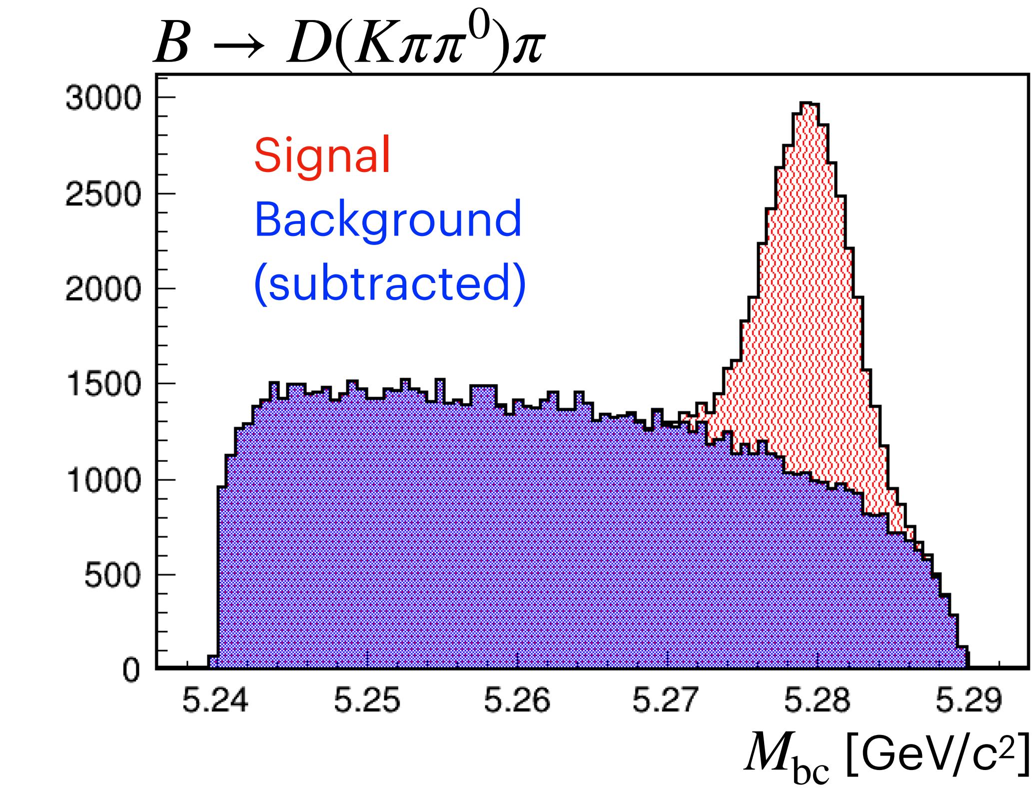




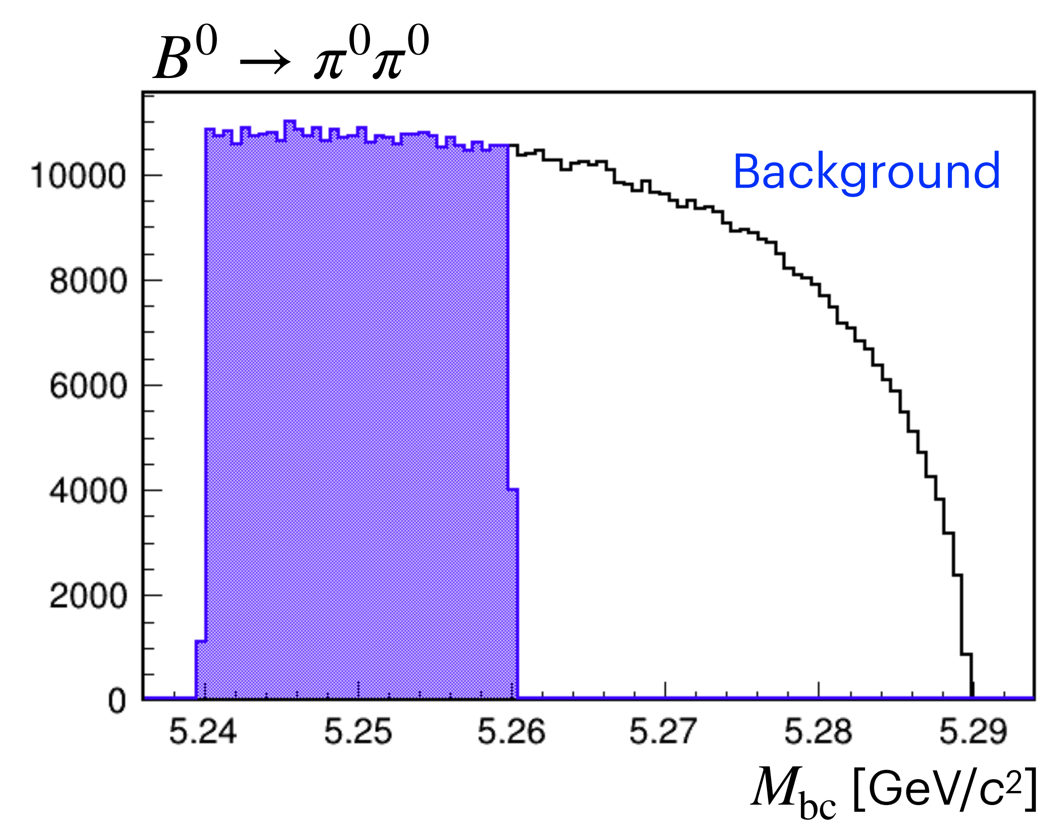
CSBDT: inputs validation

Validate **signal** distributions: compare $B \to D(K\pi\pi^0)\pi$ sideband-subtracted data and sideband-subtracted MC.

Do not use $B \to D(K\pi\pi^0)\pi$ for bkg because of the different compositions

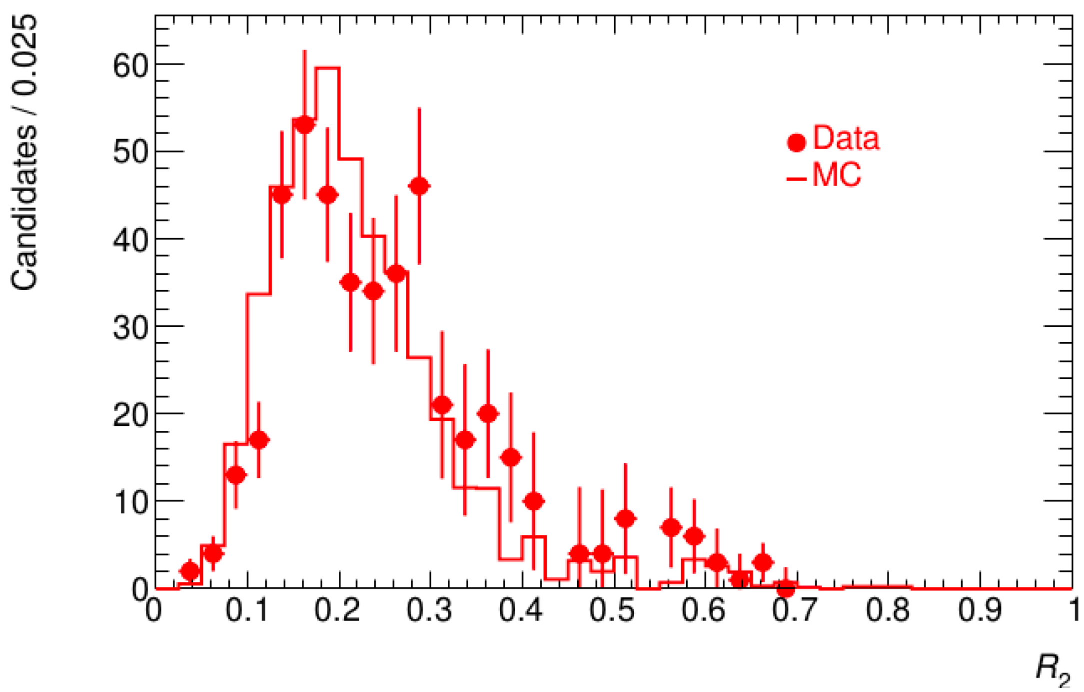


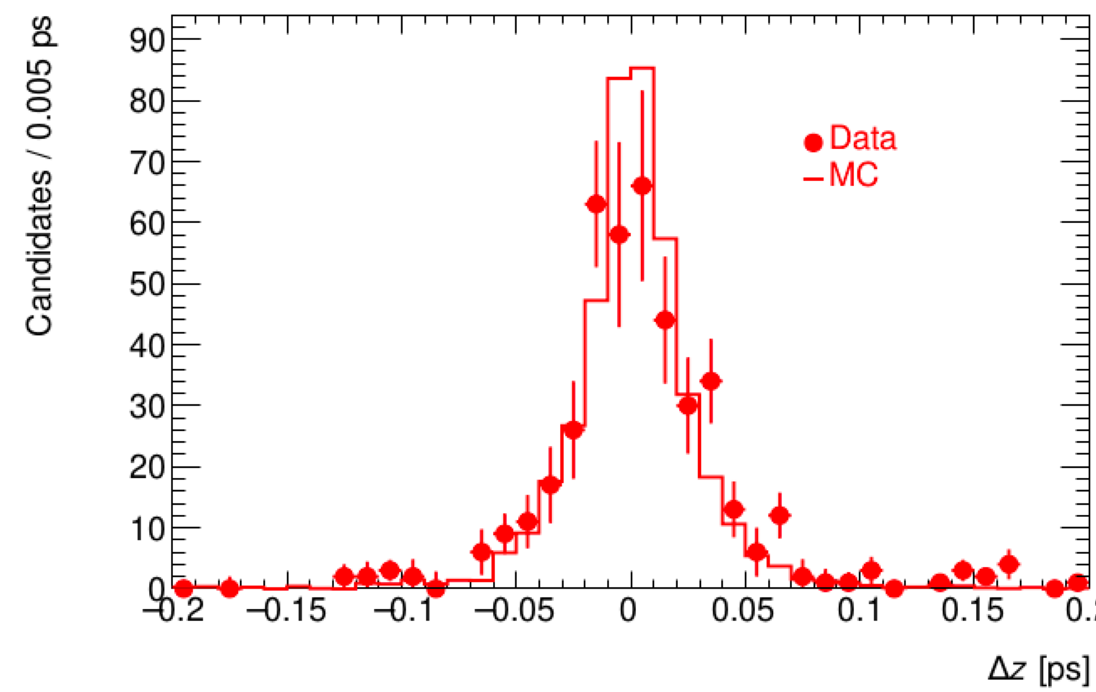
Validate **background** distributions: compare $B^0 \to \pi^0\pi^0$ sideband data and sideband MC15.

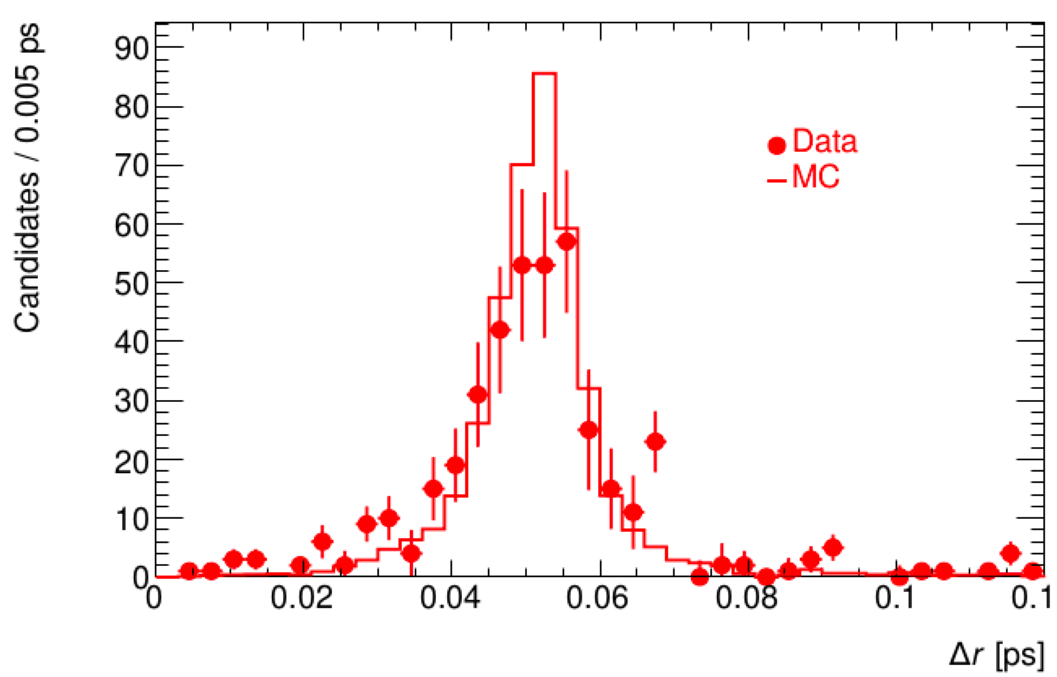


Inputs validation — Signal

Use $B \to D(K\pi\pi^0)\pi$ sideband-subtracted data and sideband-subtracted MC.







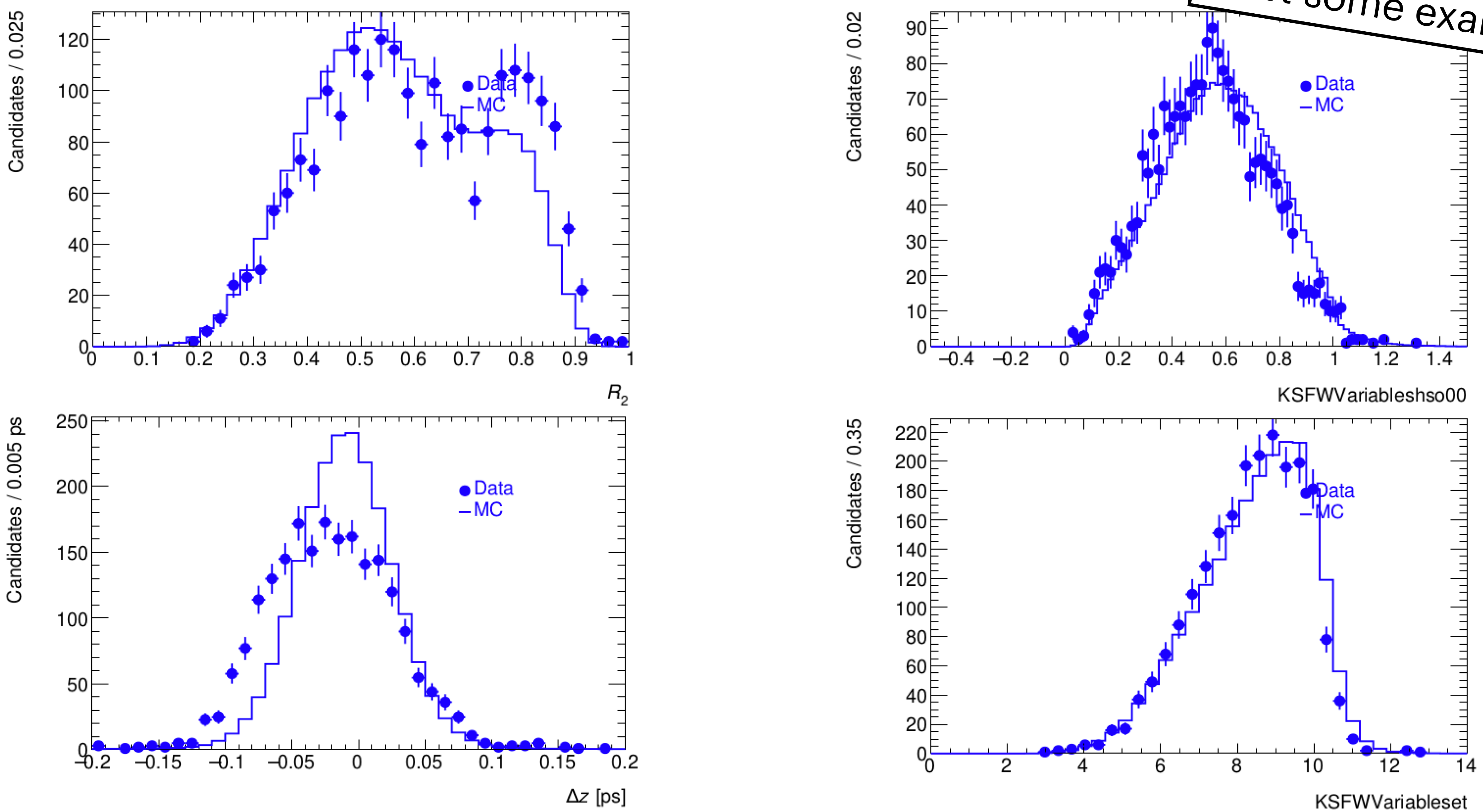
Just some examples, explored >30 different variables

Sample has low statistics.
No large discrepancies.

Inputs validation — Background

Use $B^0 \to \pi^0\pi^0$ sideband data and sideband MC.

Just some examples

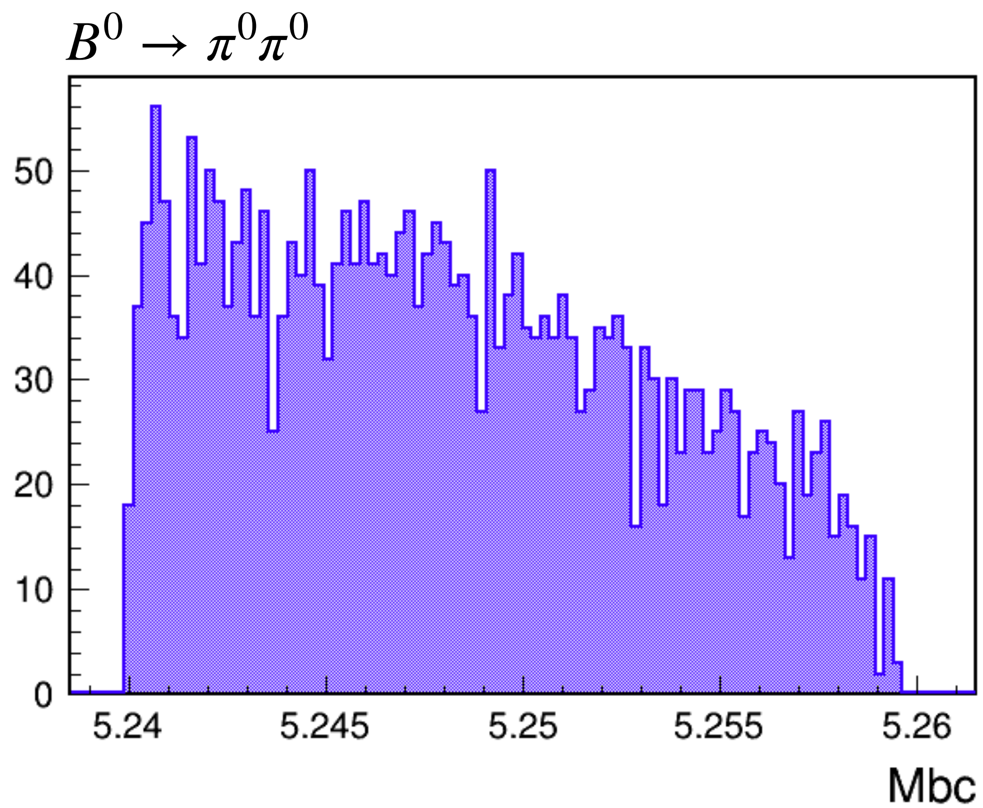


Observe large discrepancies.
Better training CSBDT using data only.

CSMVA using data to train bkg

Two options:

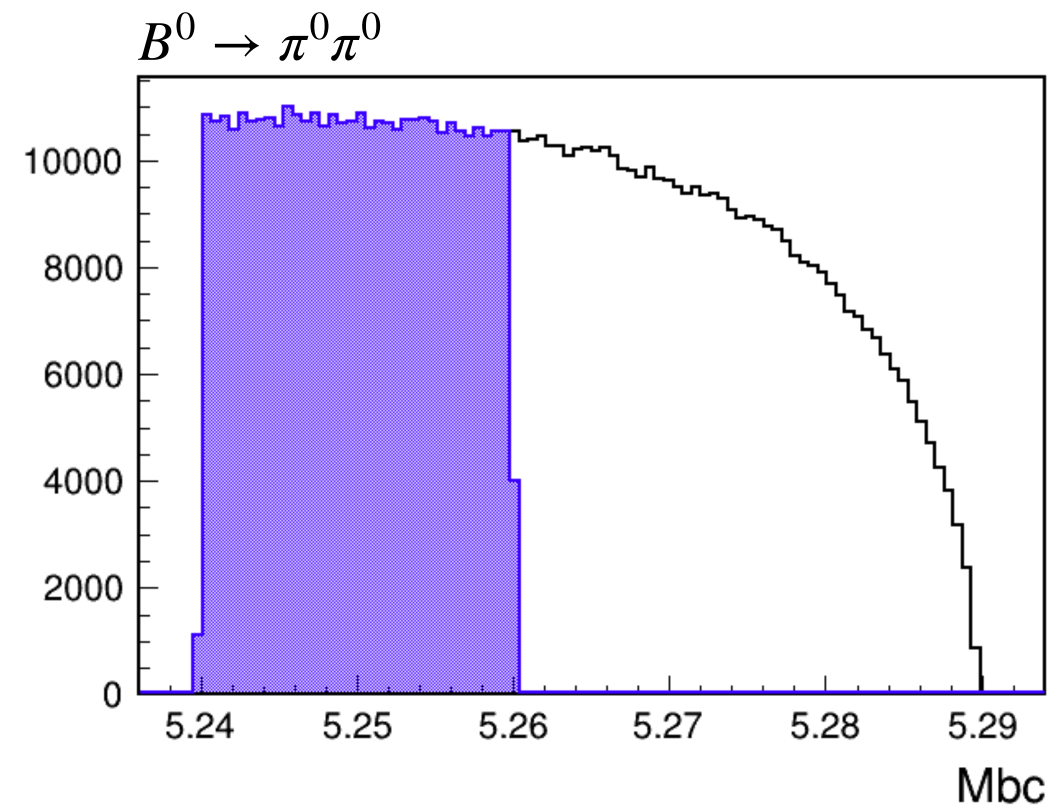
Off-resonance data



Pro: describes well the background in the signal-region in all the variables

Cons: very small amount of data

Sideband on-resonance data



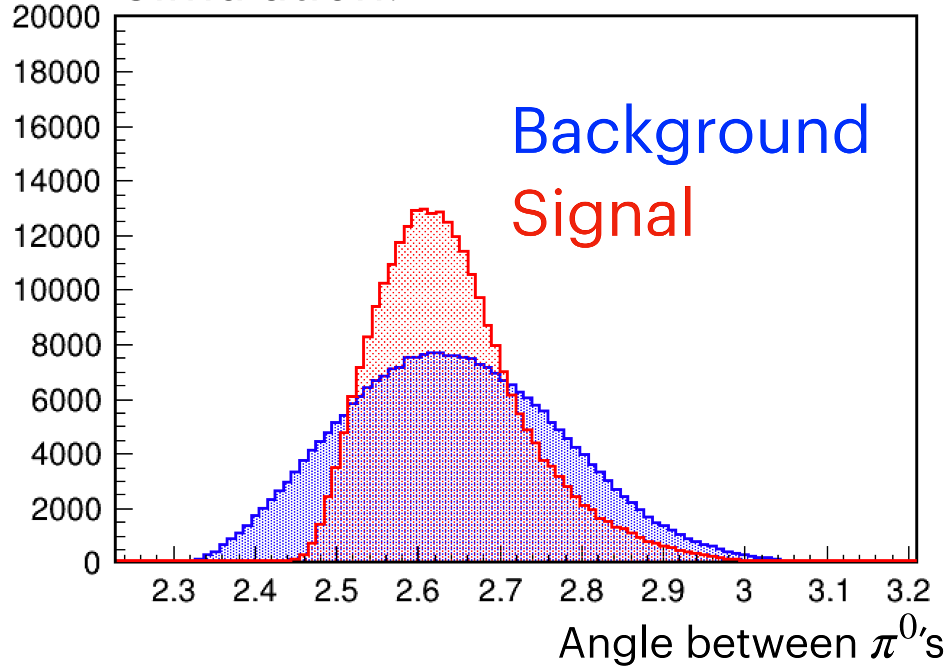
Pro: very large amount of data

Cons: doesn't describe well bkg in the signal region in two distributions (angles between pions)

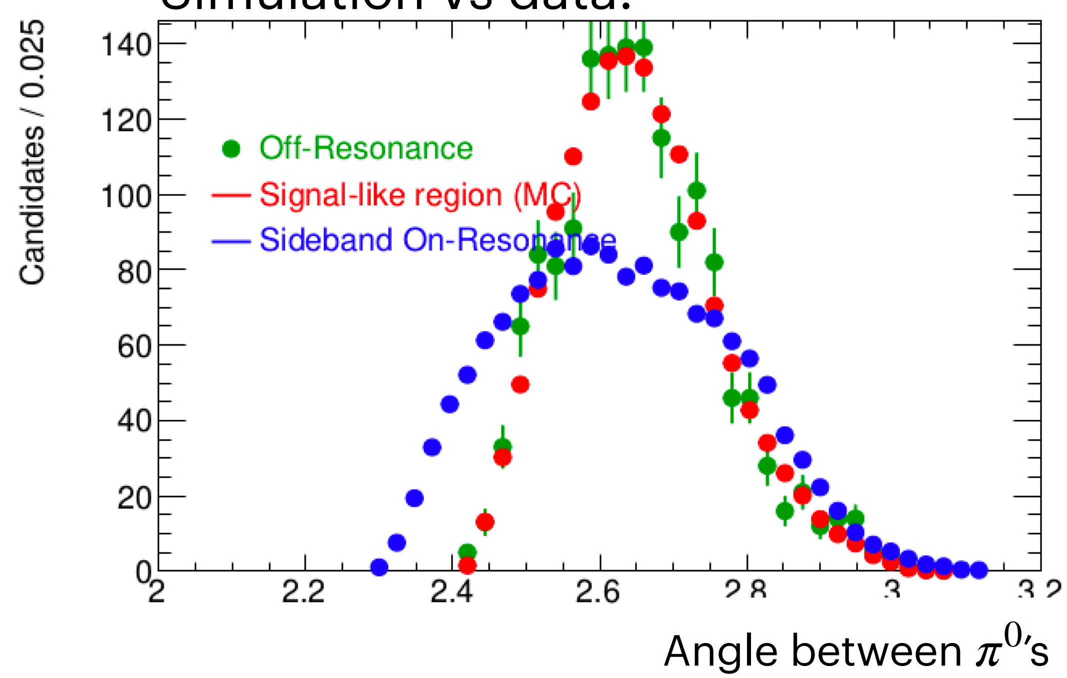
Poorly described variables in sideband data

Only two distributions not describing well bkg in signal region:

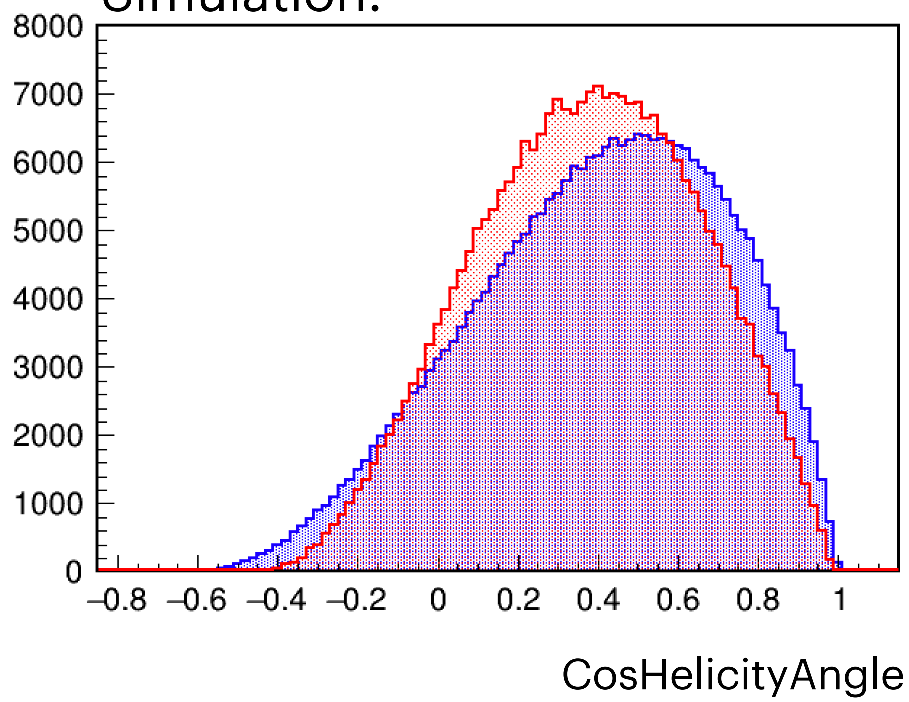
Simulation:



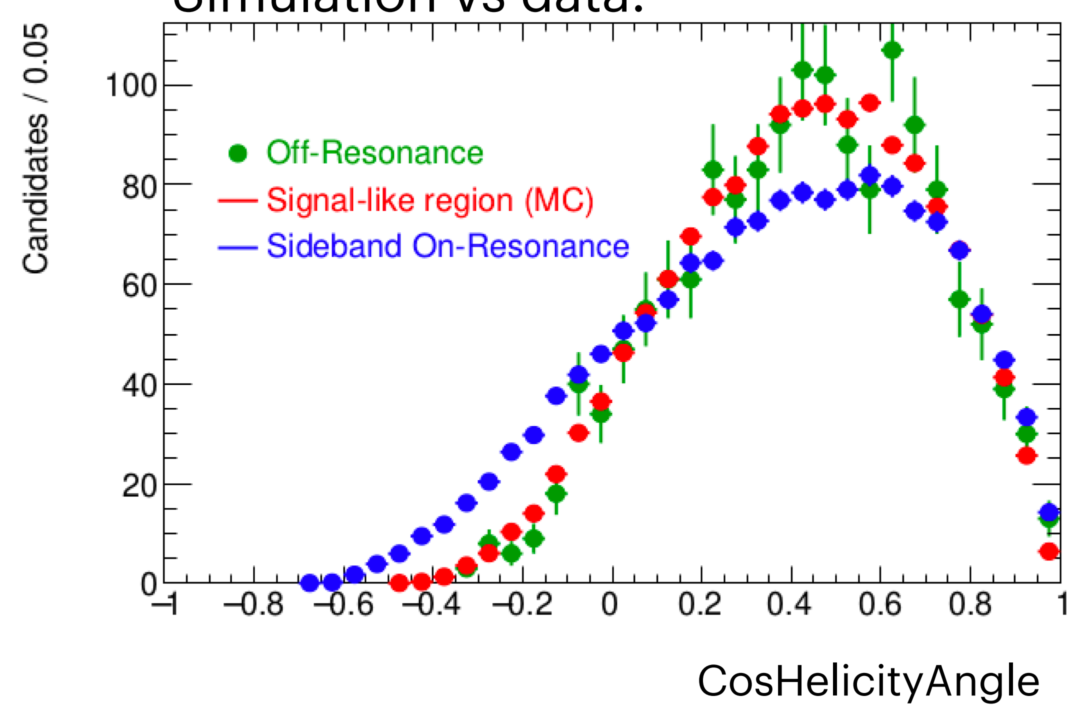
Simulation vs data:



Simulation:



Simulation vs data:

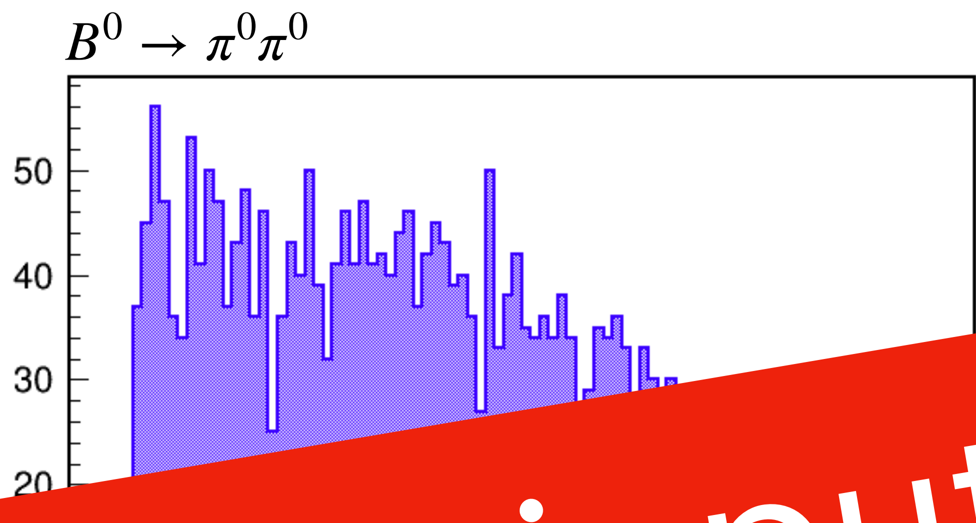


We're losing some good discriminating power.

CSMVA using data to train bkg

Two options:

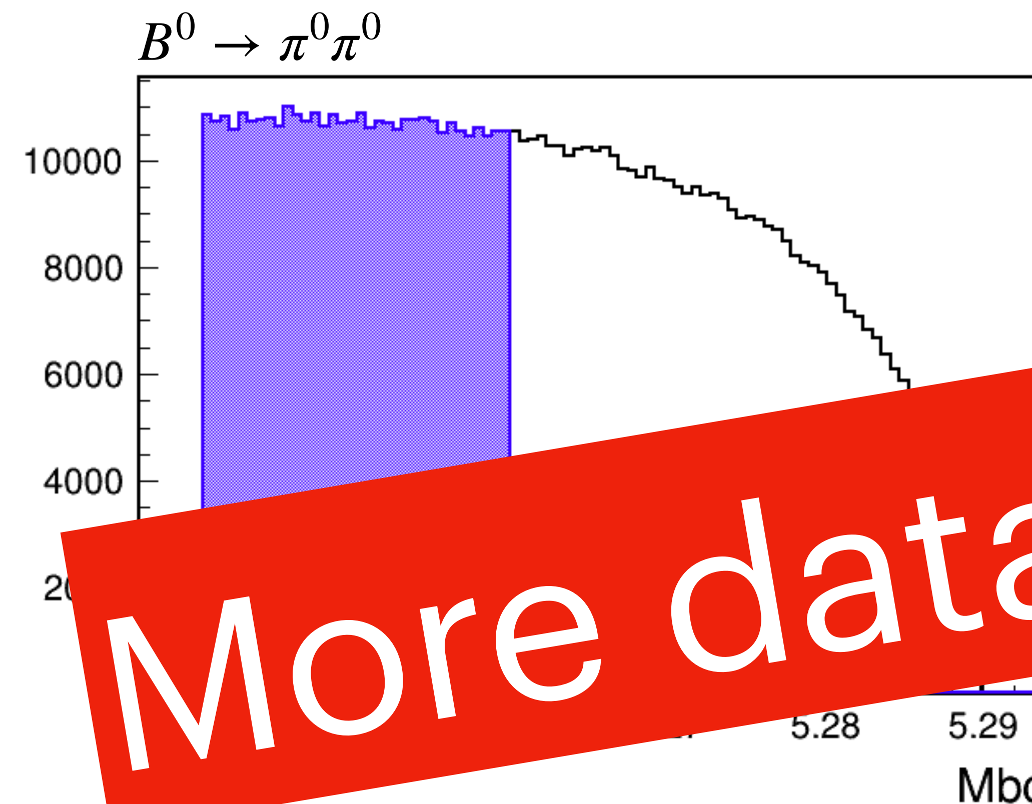
Off-resonance data



More input variables

Cons: very small amount of data

Sideband on-resonance data



More data

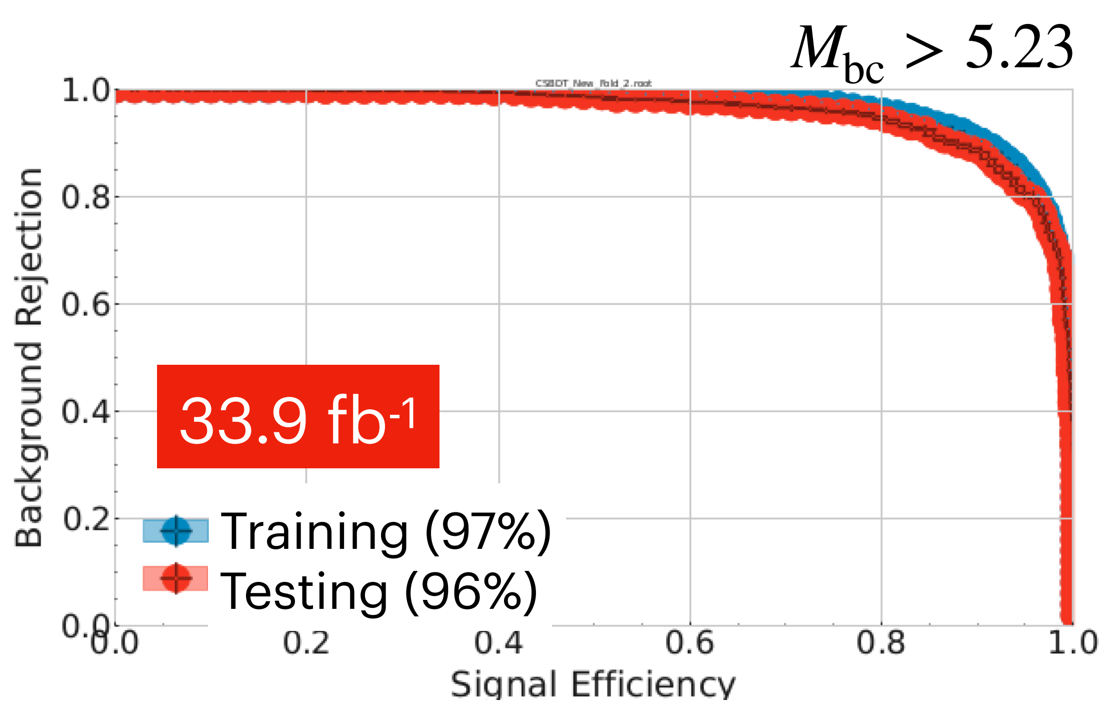
Pro: very large amount of data

Cons: doesn't describe well bkg in the signal region in two distributions (angles between pions)

CSMVA using data to train bkg

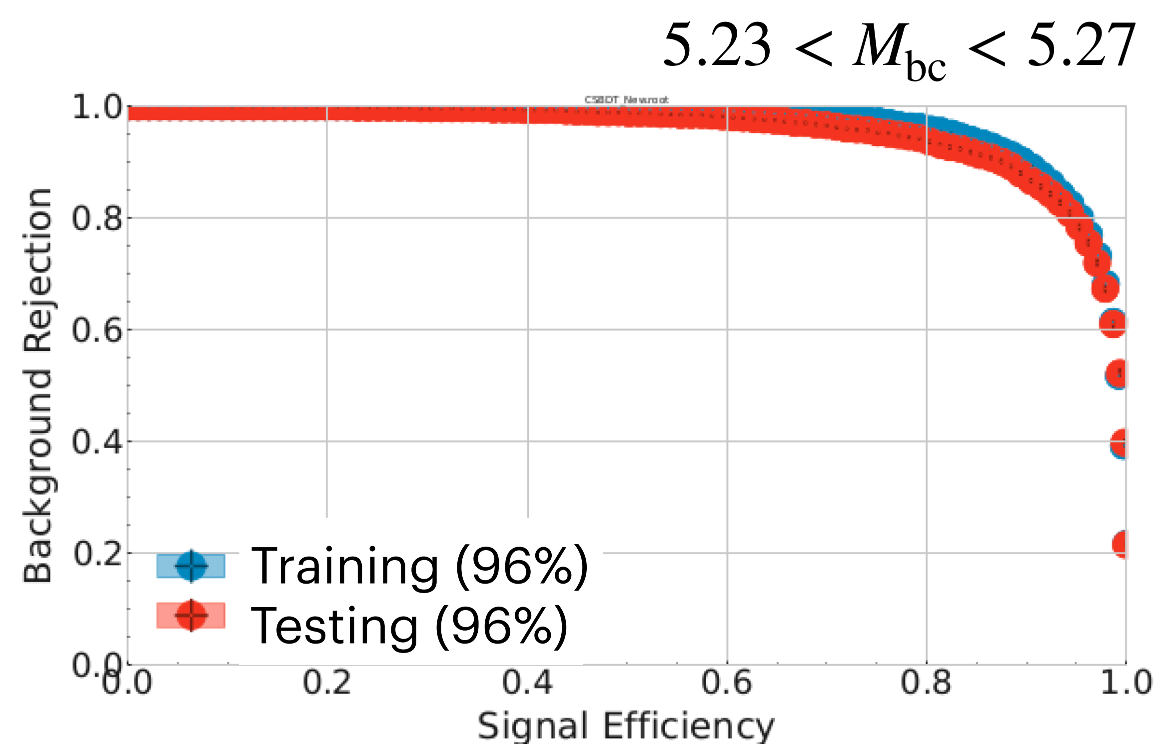
Off-resonance data

Do not exclude the 2 variables from the BDT (19 inputs).



Sideband on-resonance data

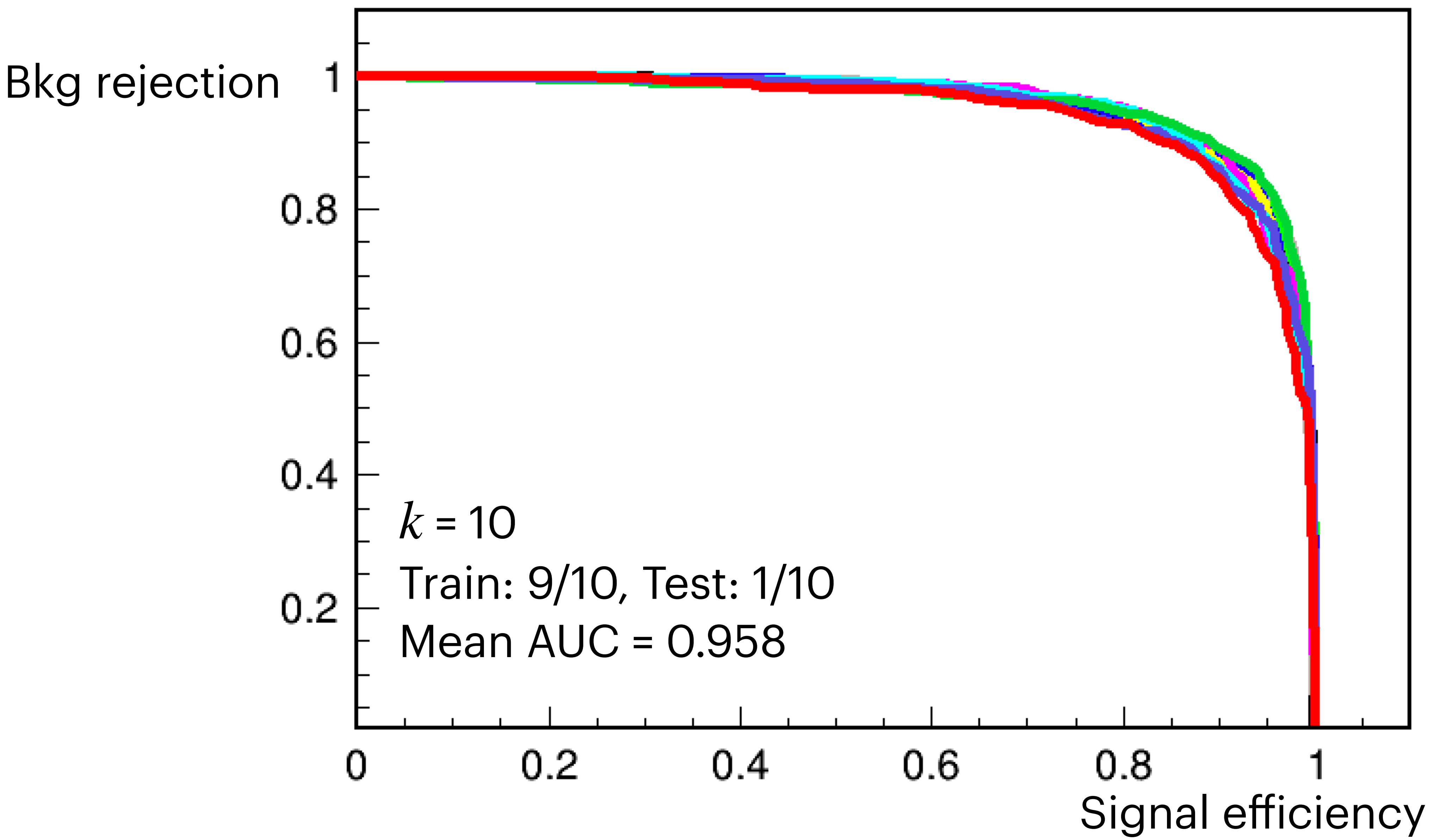
Exclude the 2 variables from the BDT (17 inputs).



AUC curves show same performance.

CSMVA using off-resonance data: k-fold cross validation

Split sample in $k = 10$ folds. Use each combination of 9 folds to train BDT and remaining fold to test it → obtain 10 ROC curves. Remove possible statistical effects.



CSBDT with off-res data is stable and reliable.

Performance is the same. Still deciding final choice.

Check on flavor tagger:
are Δr and ΔZ in CSBDT biasing the FT?

Flavor tagging check

All MC15

Compare flavour tagger parameters obtained in $B^0 \to \pi^0\pi^0$ after applying CSBDT selection and in control channel $B^0 \to D^-(K^+\pi^-\pi^-)\pi^+$ (largest BF btw those used by Sato-san in FT calibration).

$B^0 \to \pi^0\pi^0$

r- Interval	ε_i	$\Delta\varepsilon_i$	$w_i \pm \delta w_i$	$\Delta w_i \pm \delta\Delta w_i$	$\varepsilon_{eff,i} \pm \delta\varepsilon_{eff,i}$	$\Delta\varepsilon_{eff,i} \pm \delta\Delta\varepsilon_{eff,i}$
$0.000 - 0.100$	17.1	0.22	47.54 ± 0.26	2.60 ± 0.52	0.0414 ± 0.0087	-0.0866 ± 0.0212
$0.100 - 0.250$	16.6	0.06	40.97 ± 0.26	1.01 ± 0.52	0.5417 ± 0.0311	-0.1196 ± 0.0631
$0.250 - 0.500$	21.1	0.85	30.02 ± 0.21	0.34 ± 0.43	3.3760 ± 0.0737	0.0203 ± 0.1471
$0.500 - 0.625$	11.8	-0.38	20.87 ± 0.25	1.84 ± 0.51	3.9966 ± 0.0732	-0.6337 ± 0.1479
$0.625 - 0.750$	11.5	-0.07	15.08 ± 0.23	0.60 ± 0.45	5.5858 ± 0.0797	-0.2268 ± 0.1598
$0.750 - 0.875$	8.6	0.06	8.31 ± 0.20	0.56 ± 0.40	5.9602 ± 0.0712	-0.1181 ± 0.1425
$0.875 - 1.000$	13.4	-0.74	1.67 ± 0.07	0.24 ± 0.15	12.5174 ± 0.0785	-0.8171 ± 0.1573
Total			$\varepsilon_{eff} = \sum_i \varepsilon_i \cdot \langle 1-2w_i \rangle^2 = 32.02 \pm 0.17$			$\Delta\varepsilon_{eff} = -1.98 \pm 0.34$

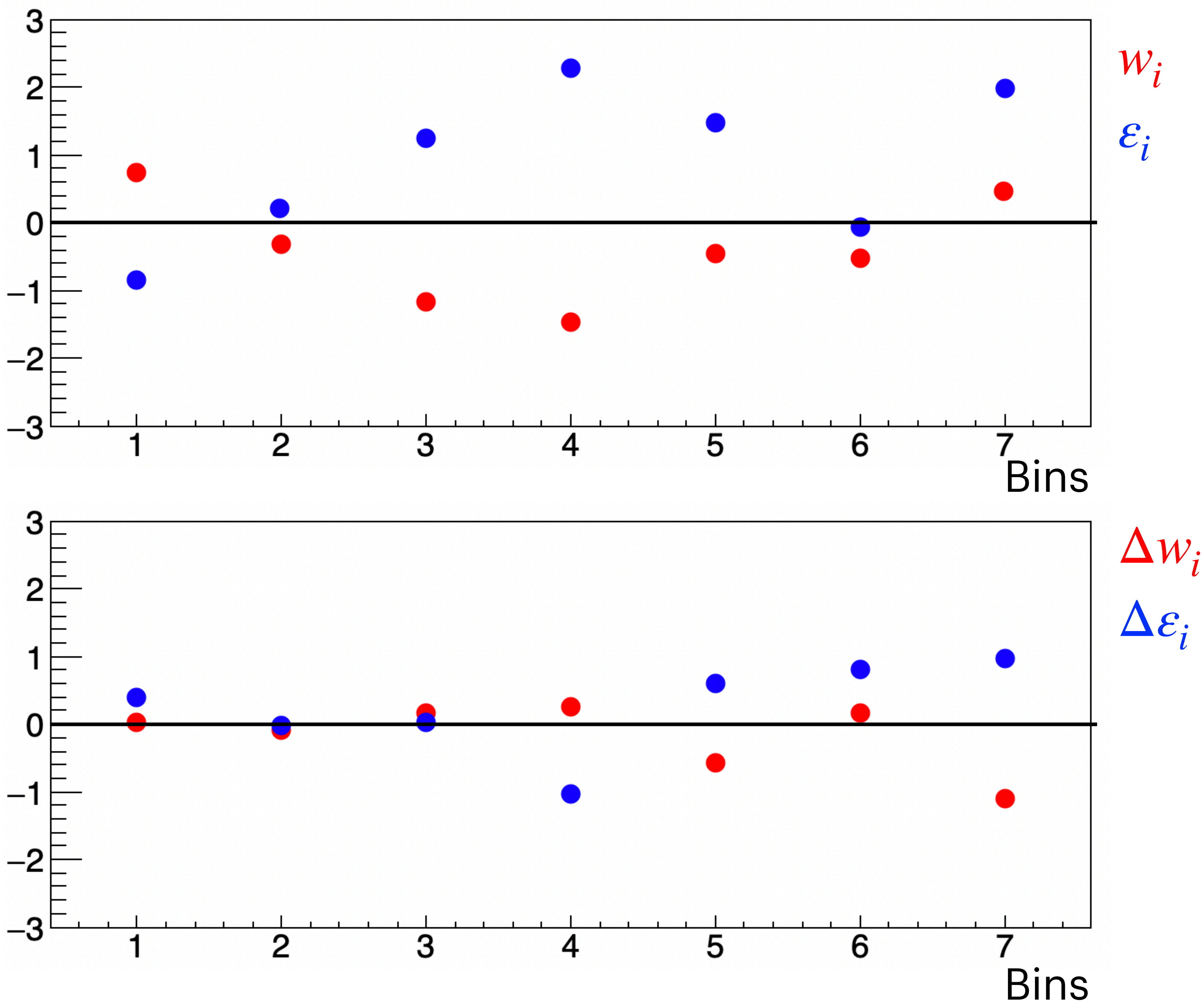
$B^0 \to D^-(K^+\pi^-\pi^-)\pi^+$

r- Interval	ε_i	$\Delta\varepsilon_i$	$w_i \pm \delta w_i$	$\Delta w_i \pm \delta\Delta w_i$	$\varepsilon_{eff,i} \pm \delta\varepsilon_{eff,i}$	$\Delta\varepsilon_{eff,i} \pm \delta\Delta\varepsilon_{eff,i}$
$0.000 - 0.100$	17.7	0.27	47.27 ± 0.26	2.58 ± 0.51	0.0526 ± 0.0099	-0.0986 ± 0.0217
$0.100 - 0.250$	16.8	0.26	41.09 ± 0.26	1.07 ± 0.52	0.5322 ± 0.0311	-0.1189 ± 0.0623
$0.250 - 0.500$	21.1	0.60	30.37 ± 0.22	0.24 ± 0.43	3.2461 ± 0.0728	0.0138 ± 0.1457
$0.500 - 0.625$	11.5	0.06	21.40 ± 0.26	1.66 ± 0.52	3.7607 ± 0.0723	-0.4175 ± 0.1445
$0.625 - 0.750$	11.2	-0.13	15.23 ± 0.23	0.97 ± 0.46	5.4192 ± 0.0794	-0.3649 ± 0.1588
$0.750 - 0.875$	8.6	-0.22	8.46 ± 0.20	0.46 ± 0.41	5.9675 ± 0.0721	-0.2828 ± 0.1442
$0.875 - 1.000$	13.1	-0.85	1.62 ± 0.08	0.47 ± 0.15	12.2983 ± 0.0783	-1.0309 ± 0.1565
Total			$\varepsilon_{eff} = \sum_i \varepsilon_i \cdot \langle 1-2w_i \rangle^2 = 31.28 \pm 0.17$			$\Delta\varepsilon_{eff} = -2.30 \pm 0.34$

Results are compatible. Waiting for the official numbers from Sato-san (end of month).

Flavor tagging check

Compare parameters using pulls.



Good results except for some points.

NEW SINCE LAST TIME

Add PID info

All MC15

Compare flavour tagger parameters obtained in $B^0 \to \pi^0\pi^0$ after applying CSBDT selection and in control channel $B^0 \to D^-(K^+\pi^-\pi^-)\pi^+$ (largest BF btw those used by Sato-san in FT calibration).

No PID

r- Interval	ε_i	$\Delta\varepsilon_i$	$w_i \pm \delta w_i$	$\Delta w_i \pm \delta\Delta w_i$	$\varepsilon_{eff,i} \pm \delta\varepsilon_{eff,i}$	$\Delta\varepsilon_{eff,i} \pm \delta\Delta\varepsilon_{eff,i}$
$0.000 - 0.100$	17.1	0.22	47.54 ± 0.26	2.60 ± 0.52	0.0414 ± 0.0087	-0.0866 ± 0.0212
$0.100 - 0.250$	16.6	0.06	40.97 ± 0.26	1.01 ± 0.52	0.5417 ± 0.0311	-0.1196 ± 0.0631
$0.250 - 0.500$	21.1	0.85	30.02 ± 0.21	0.34 ± 0.43	3.3760 ± 0.0737	0.0203 ± 0.1471
$0.500 - 0.625$	11.8	-0.38	20.87 ± 0.25	1.84 ± 0.51	3.9966 ± 0.0732	-0.6337 ± 0.1479
$0.625 - 0.750$	11.5	-0.07	15.08 ± 0.23	0.60 ± 0.45	5.5858 ± 0.0797	-0.2268 ± 0.1598
$0.750 - 0.875$	8.6	0.06	8.31 ± 0.20	0.56 ± 0.40	5.9602 ± 0.0712	-0.1181 ± 0.1425
$0.875 - 1.000$	13.4	-0.74	1.67 ± 0.07	0.24 ± 0.15	12.5174 ± 0.0785	-0.8171 ± 0.1573
Total			$\varepsilon_{eff} = \sum_i \varepsilon_i \cdot \langle 1 - 2w_i \rangle^2 = 32.02 \pm 0.17$		$\Delta\varepsilon_{eff} = -1.98 \pm 0.34$	

PID

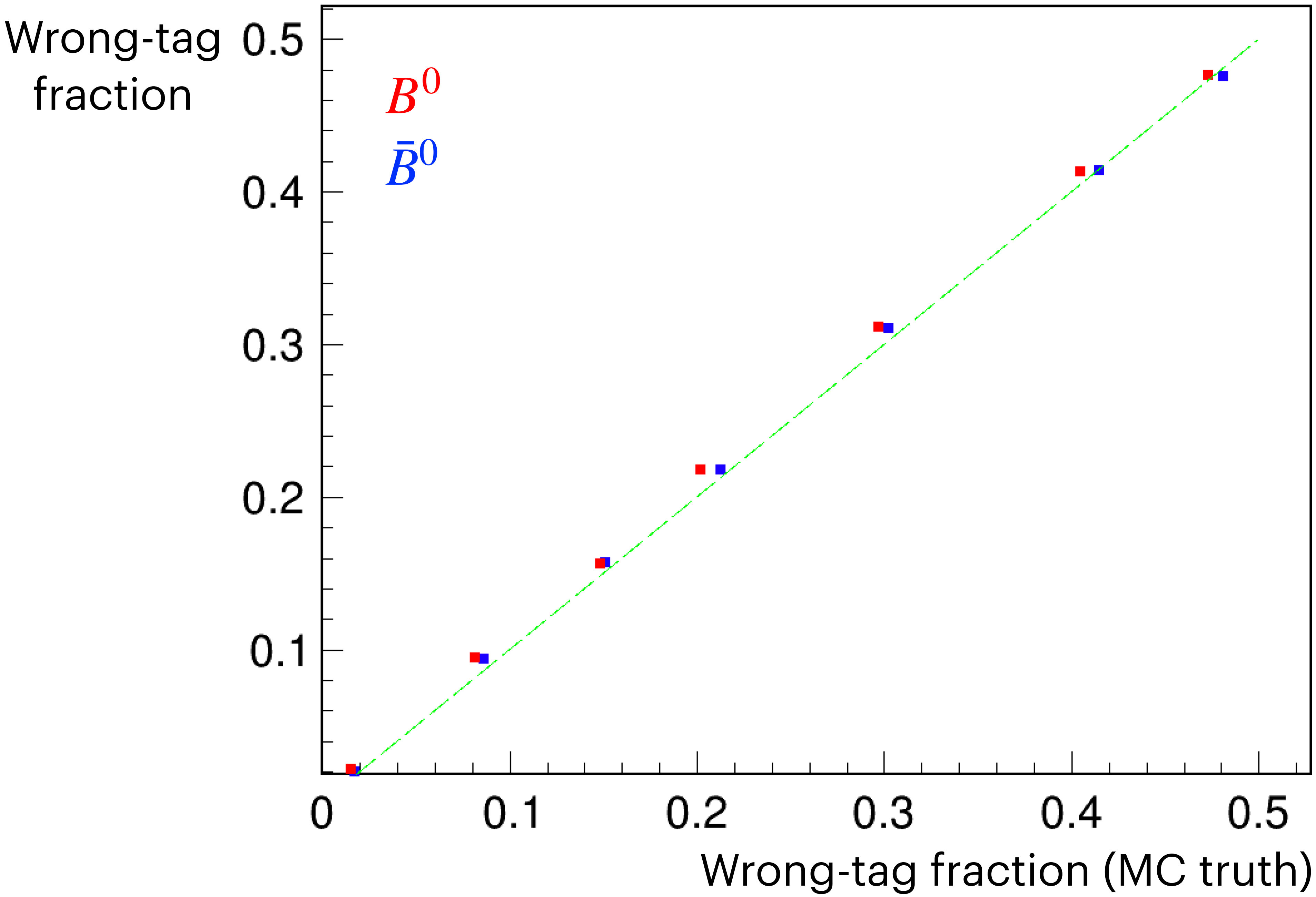
r- Interval	ε_i	$\Delta\varepsilon_i$	$w_i \pm \delta w_i$	$\Delta w_i \pm \delta\Delta w_i$	$\varepsilon_{eff,i} \pm \delta\varepsilon_{eff,i}$	$\Delta\varepsilon_{eff,i} \pm \delta\Delta\varepsilon_{eff,i}$
$0.000 - 0.100$	16.5	0.22	47.63 ± 0.26	2.52 ± 0.53	0.0373 ± 0.0083	-0.0787 ± 0.0202
$0.100 - 0.250$	16.2	0.06	40.99 ± 0.26	0.90 ± 0.52	0.5265 ± 0.0307	-0.1038 ± 0.0620
$0.250 - 0.500$	20.9	0.80	30.03 ± 0.22	0.30 ± 0.43	3.3337 ± 0.0731	0.0288 ± 0.1459
$0.500 - 0.625$	11.7	-0.31	20.91 ± 0.25	1.59 ± 0.51	3.9692 ± 0.0729	-0.5378 ± 0.1471
$0.625 - 0.750$	11.6	-0.07	15.07 ± 0.22	0.63 ± 0.45	5.6428 ± 0.0800	-0.2368 ± 0.1603
$0.750 - 0.875$	8.8	0.03	8.31 ± 0.20	0.50 ± 0.40	6.1016 ± 0.0719	-0.1233 ± 0.1439
$0.875 - 1.000$	14.3	-0.74	1.67 ± 0.07	0.20 ± 0.14	13.3349 ± 0.0806	-0.8013 ± 0.1615
Total			$\varepsilon_{eff} = \sum_i \varepsilon_i \cdot \langle 1 - 2w_i \rangle^2 = 32.95 \pm 0.17$		$\Delta\varepsilon_{eff} = -1.85 \pm 0.35$	

NEW SINCE LAST TIME

Add PID info

All MC15

Compare flavour tagger parameters obtained in $B^0 \to \pi^0\pi^0$ after applying CSBDT selection and in control channel $B^0 \to D^-(K^+\pi^-\pi^-)\pi^+$ (largest BF btw those used by Sato-san in FT calibration).



NEW SINCE LAST TIME

CS validation

Validate CS on control channel $B^- \to D^0(K^+\pi^-\pi^0)\pi^-$. Obtain binomial efficiency of CS selection using Francis CS and mine.

Tried using $B^0 \to D^0(K^+\pi^-\pi^0)\pi^0$ but small BF.

Still some problems in the fit.

At the current precision, using Δr and ΔZ as inputs does not bias the result after CS selection.

Need to check this again when official numbers will be available.

CSBDT comparison

190 fb^{-1} analysis

- 24 variables.
- Training using sideband data.
- Validate only CSBDT output in data and MC.
- AUC = 0.948.

This analysis

- 19 variables including Δr and ΔZ: no bias on flavour tagger.
- Validation of input variables.
- Include variables with larger correlation with fit variables (but no sculpting).
- Training using sideband data or off-resonance data.
- AUC = 0.96

1% improvement in AUC.

Next step: compare performance in data using control channel.

ρ MVA

ρ MVA

Beyond the CS: identify the principal bkg offenders.

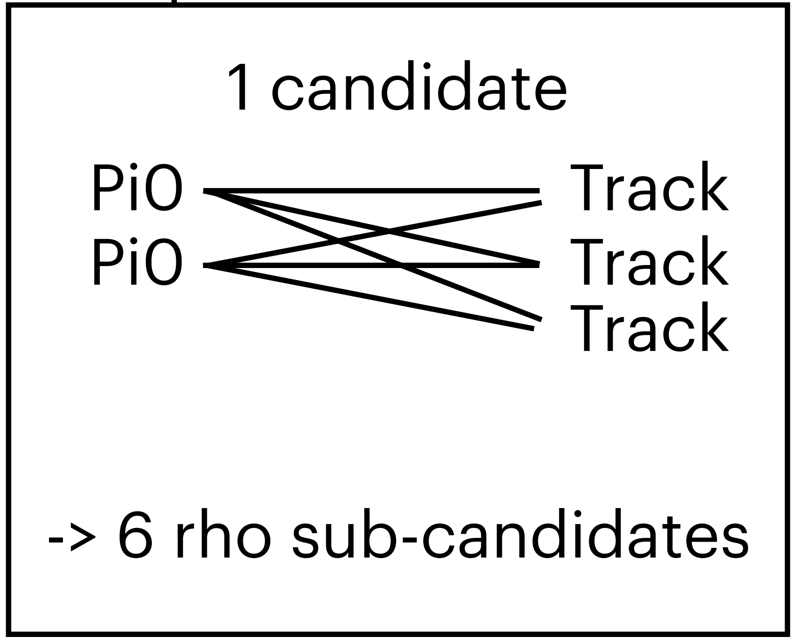
	Events that have at least a π^0 from ...
$\rho(770)^+$	47.1%
Z^0 (direct from e+e-)	75.0%

Large number of continuum π^0's come from a ρ.
Develop a specific BDT to identify them
(in addition to the default CSBDT).

Combine each track in the event with each π^0.

Use kinematic and angular variables to distinguish between ρ's and other particles.

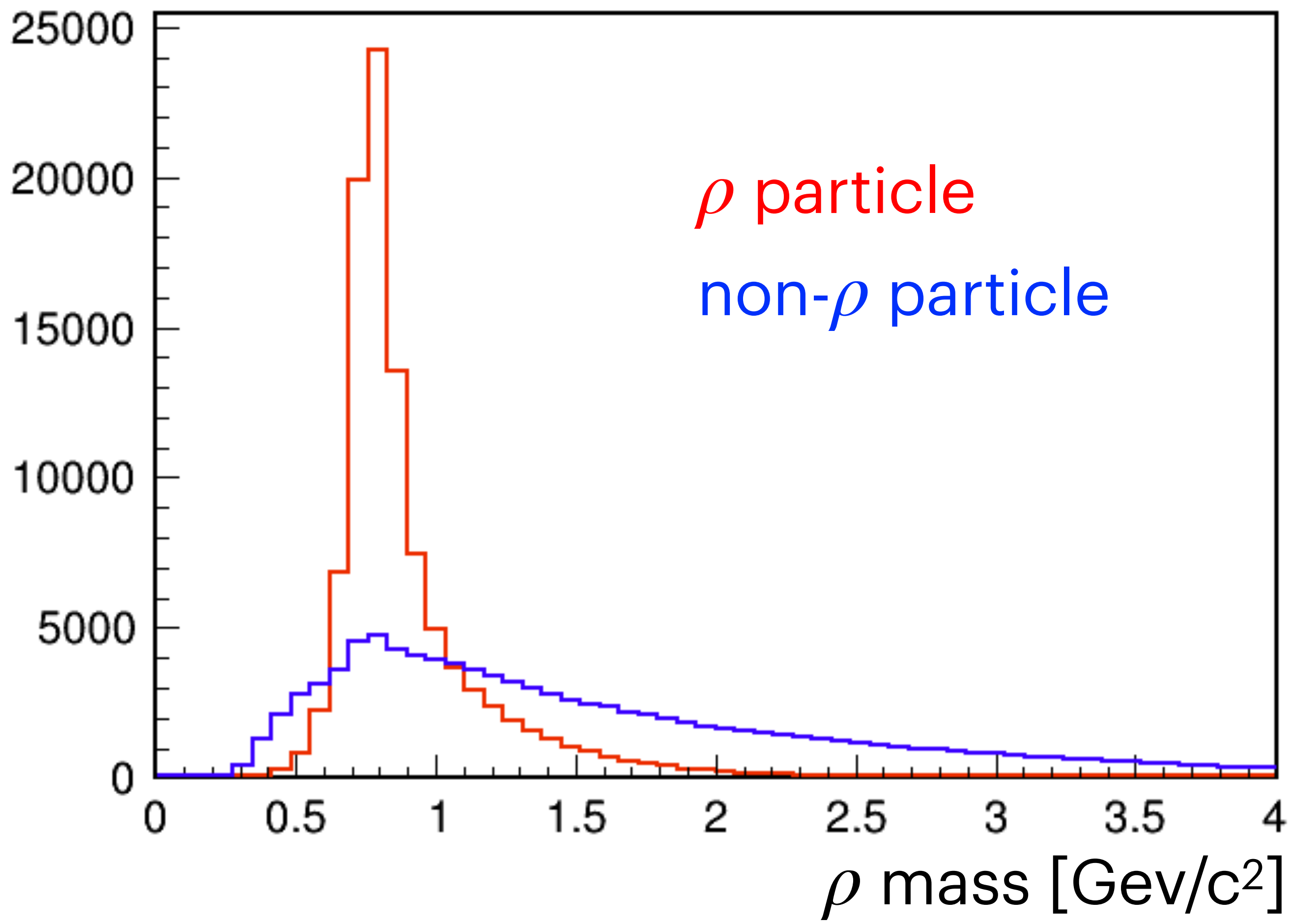
Example:

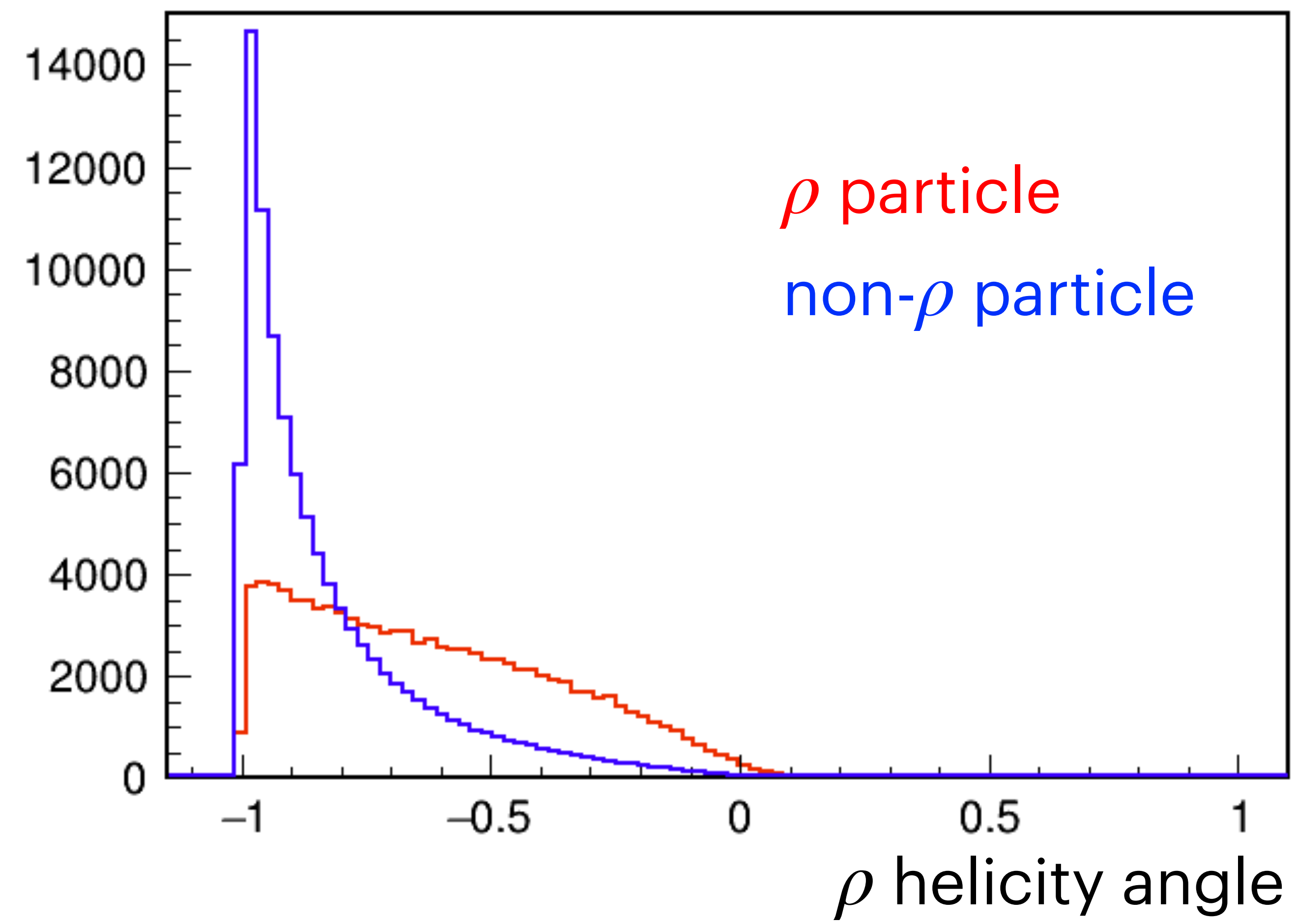


Challenge: the number of combinations (ρ^+ candidates) is large.
Not obvious how to exploit it efficiently in bkg rejection strategy.

ρ variables

Use kinematic and angular variables to distinguish between ρ's and other particles.



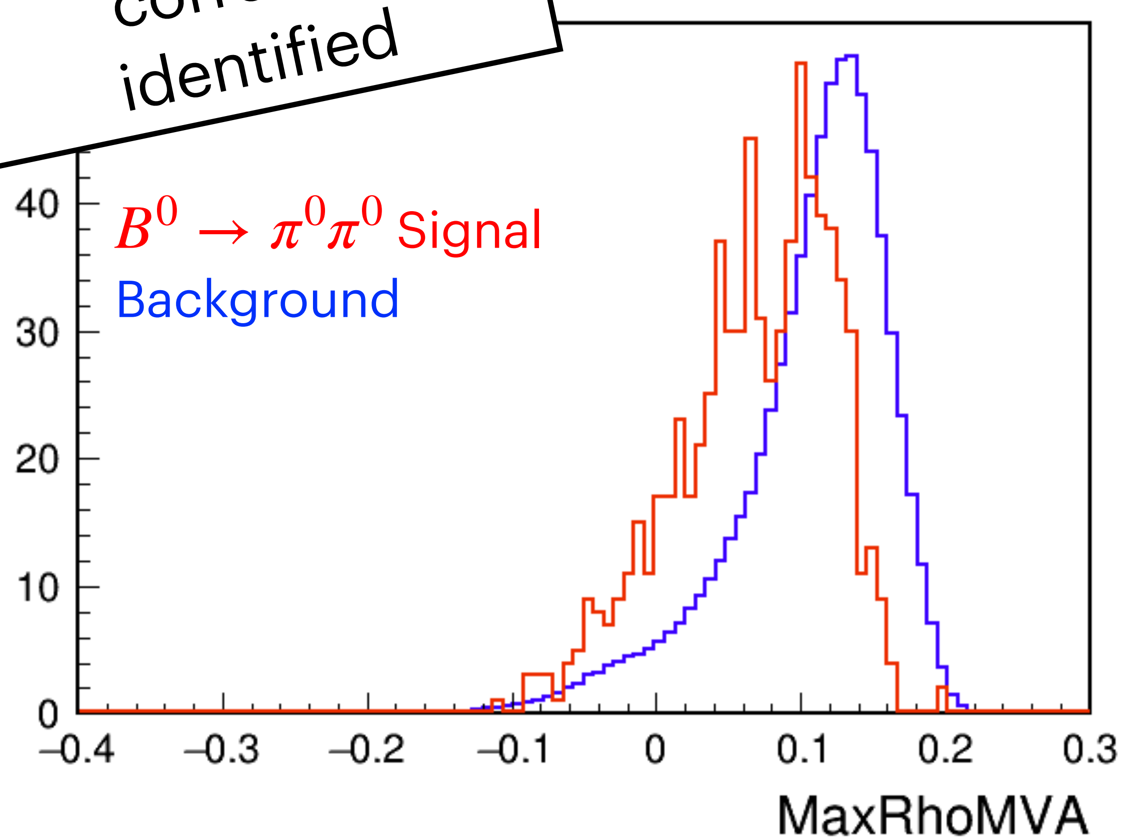


ρ mass and helicity angle have large discriminating power.

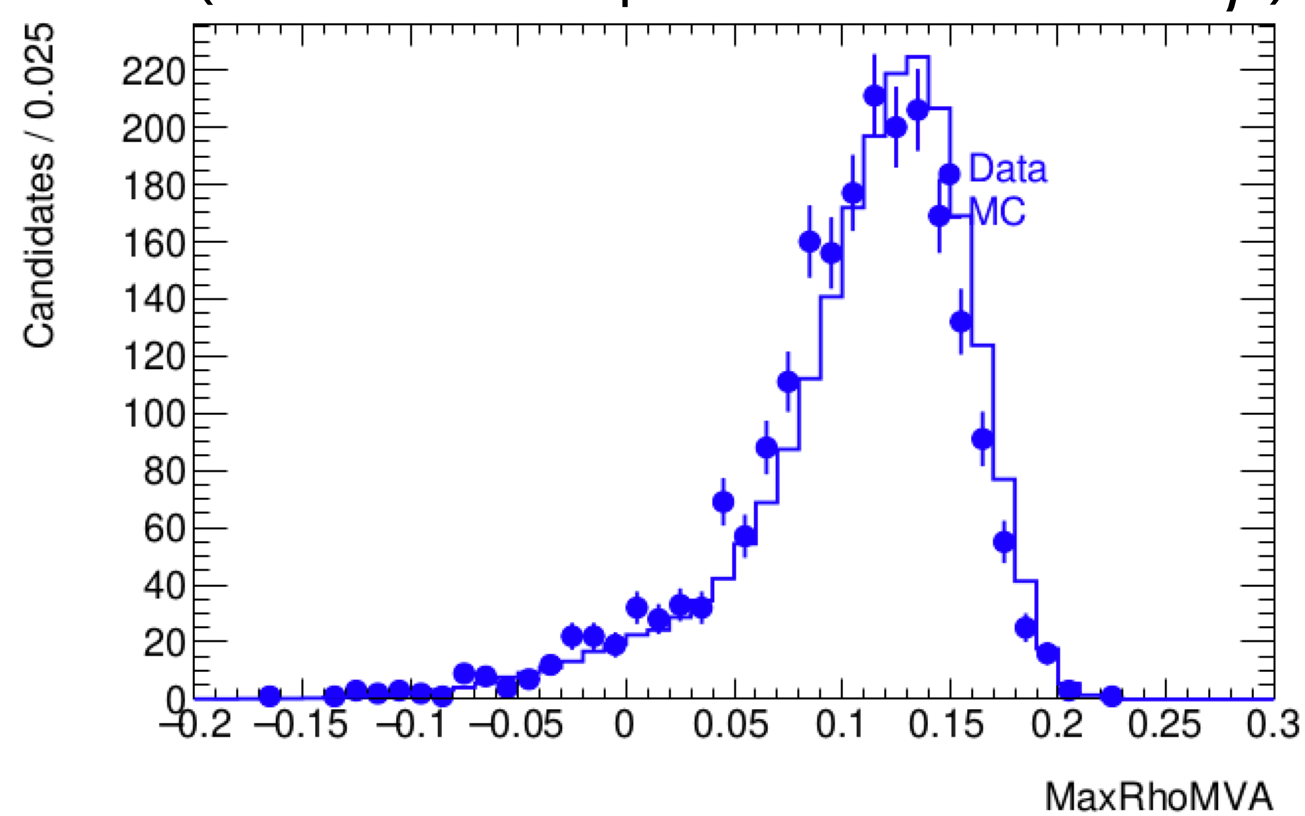
Max ρMVA distribution

Each candidate has for example 20 ρ sub-candidates. Take the one with largest rhoMVA (the one more similar to a ρ).

55% of ρ mesons correctly identified



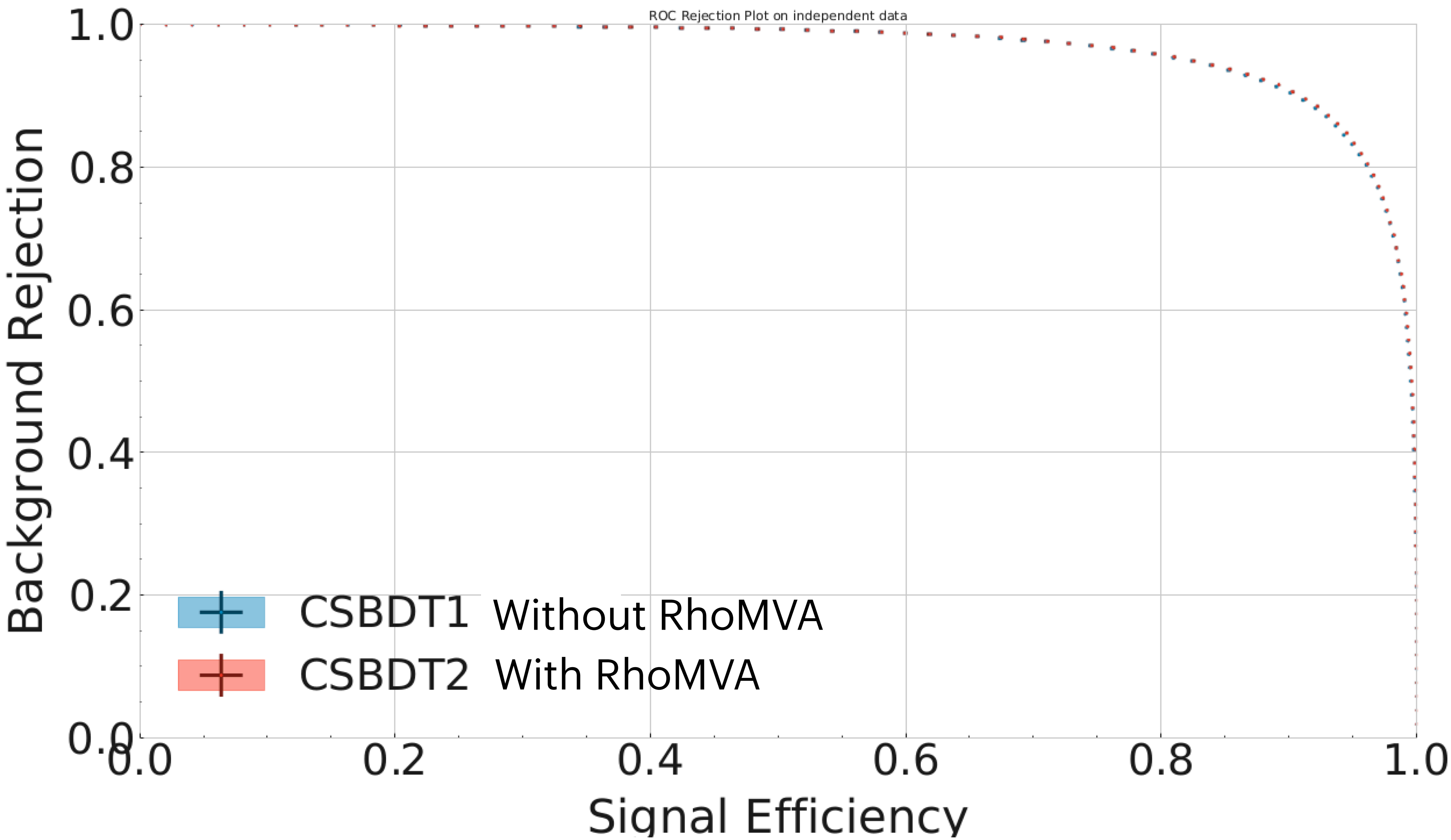
Validation: use $B^0 \to \pi^0\pi^0$ sideband (inclusive sample of true and false ρ).



Variable shows separation, modelling discrepancy is acceptable.

Additional discriminating power may be available from using multiple ρ^+ candidates.

Use ρMVA as input of the CSBDT



Inclusion of ρMVA gives no improvement

Summary

First steps towards LS1 update of $B^0 \to \pi^0\pi^0$ analysis.
Use Francis result as reference.

Today focus on selection:

- revisited photonMVA (use new variables with good data/MC agreement) $\to$ 3% improvement. At given $\varepsilon_{\mathrm{sig}}$, always better bkg rejection.

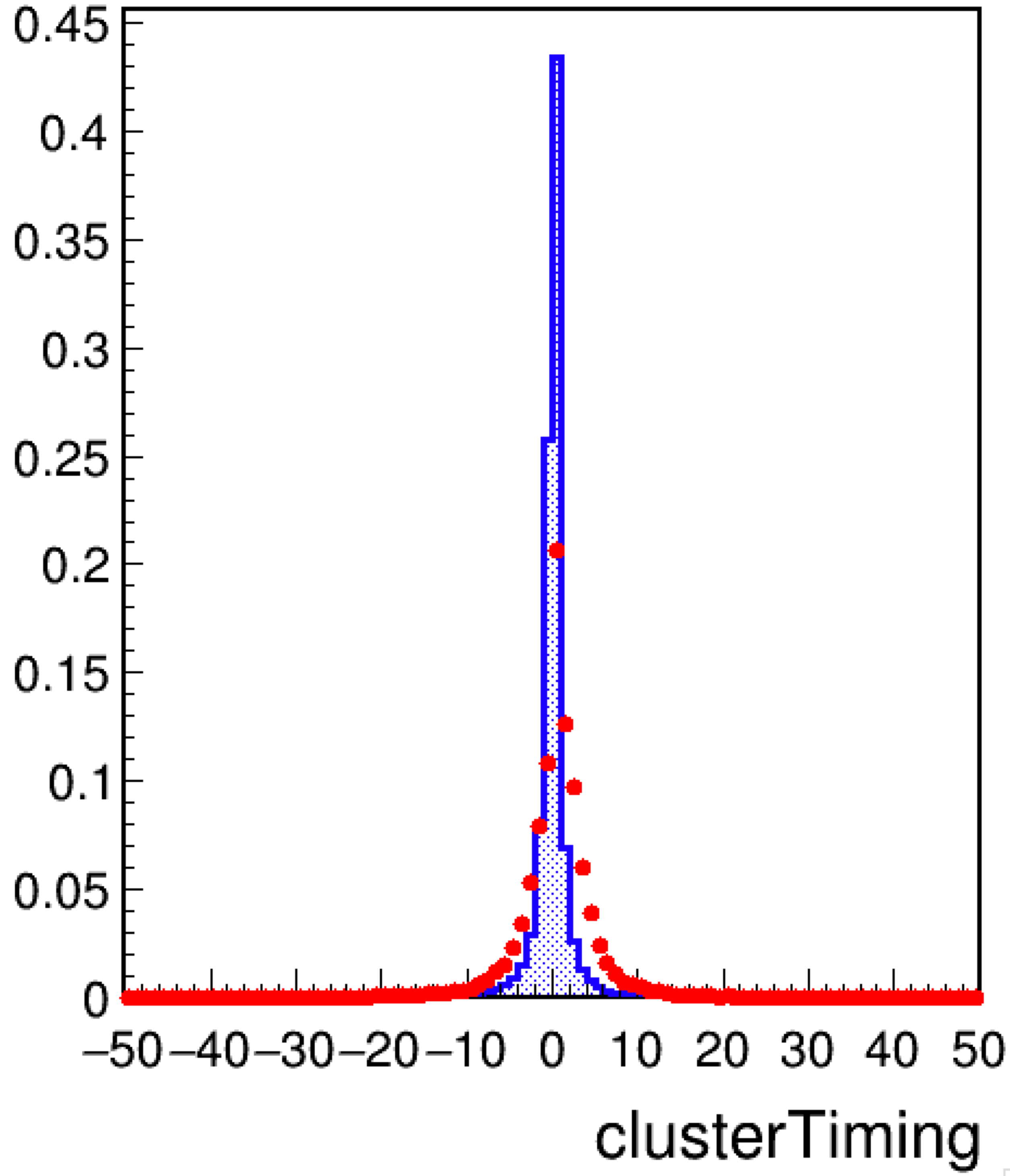
- revisited CSBDT: add B_{Tag} variables (no bias on FT). Use data to train BDT, validate inputs $\to$ 1% improvement.

- introduced ρBDT: improvement is negligible, do not add it in analysis $\to$ no improvement.

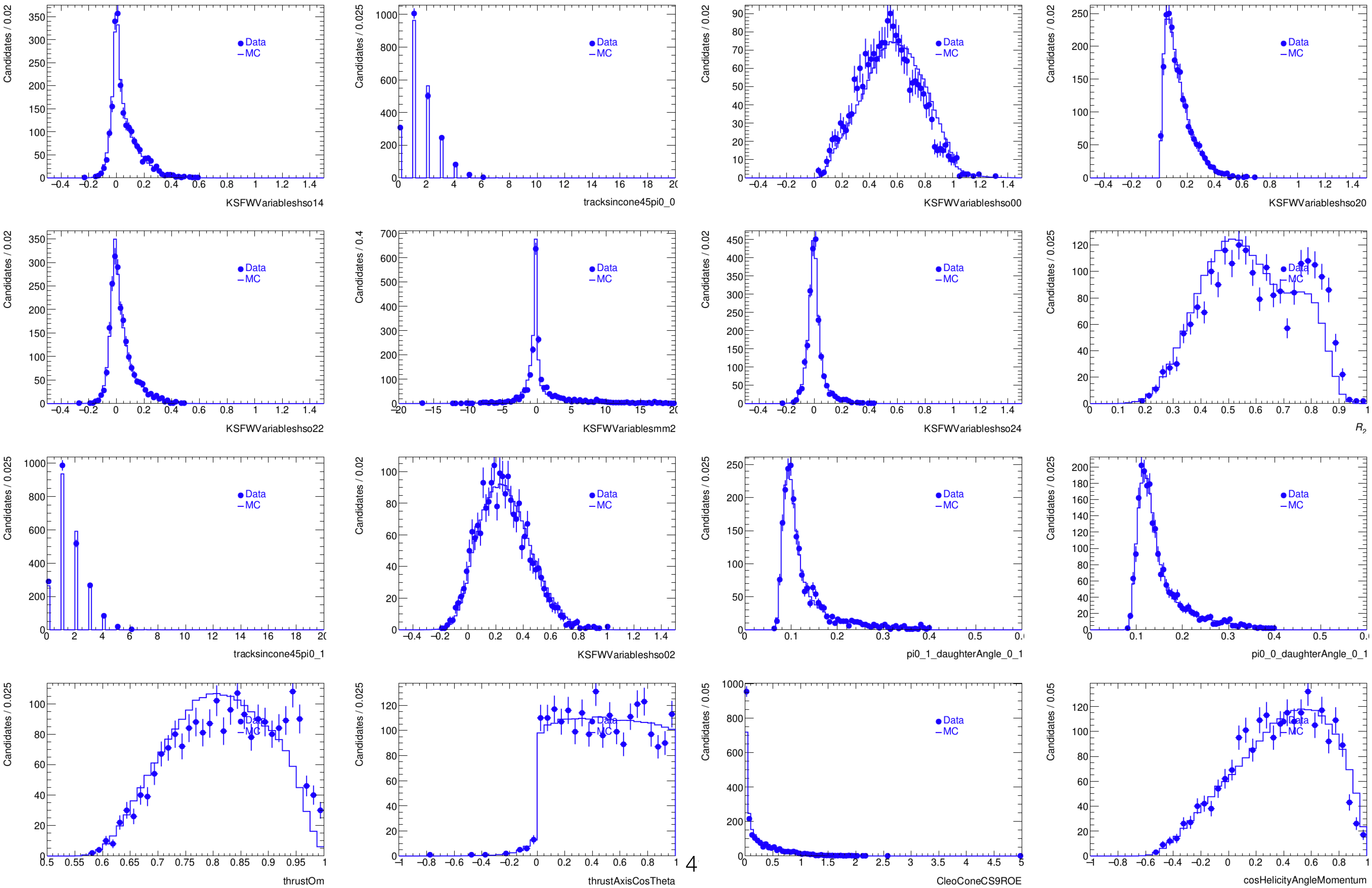
Don't expect major breakthrough wrt 190fb^{-1} analysis, but obtained various small improvements and refinements.

Backup

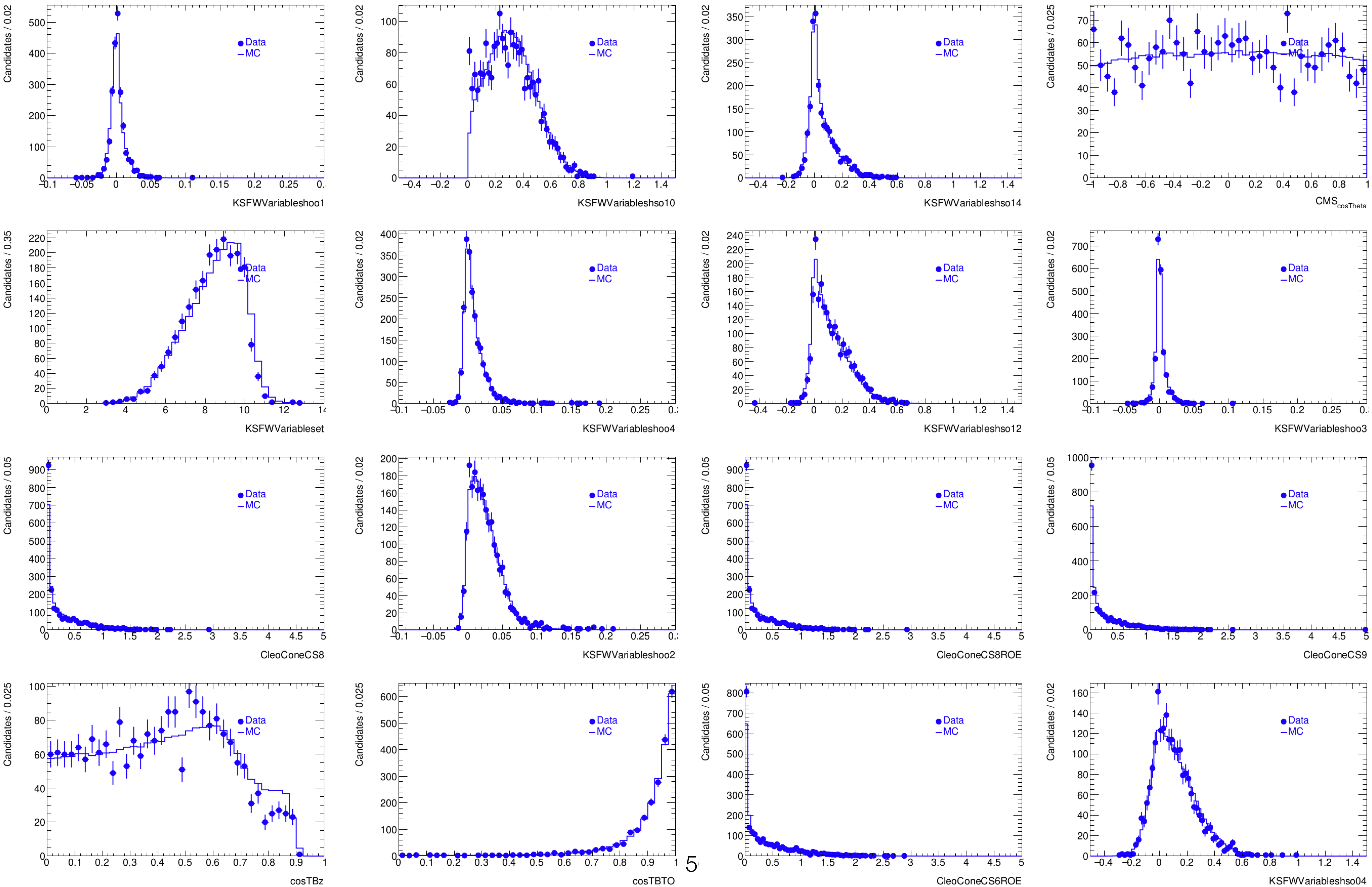
ClusterTiming (rel-06)



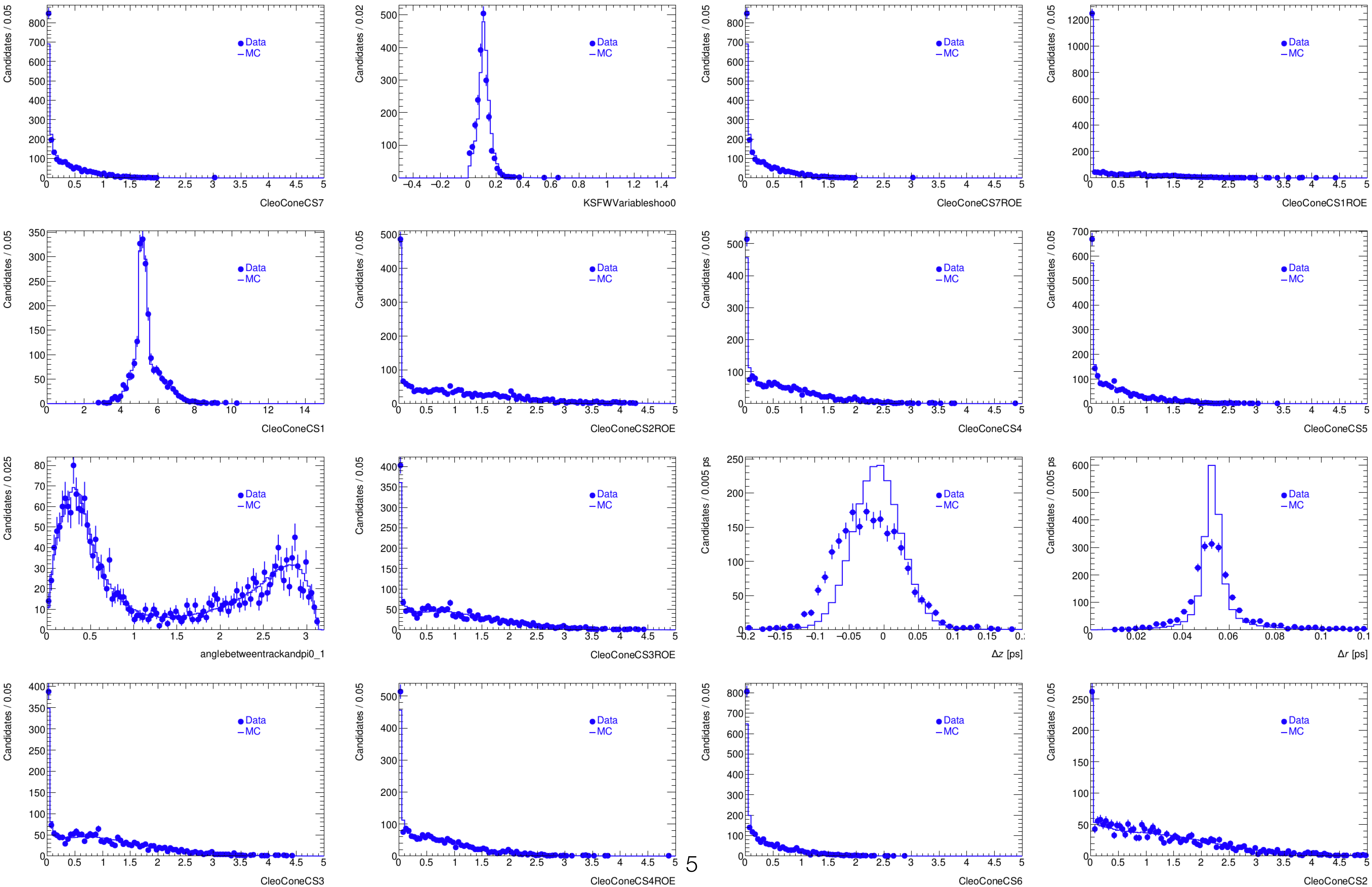
Inputs validation — Background only



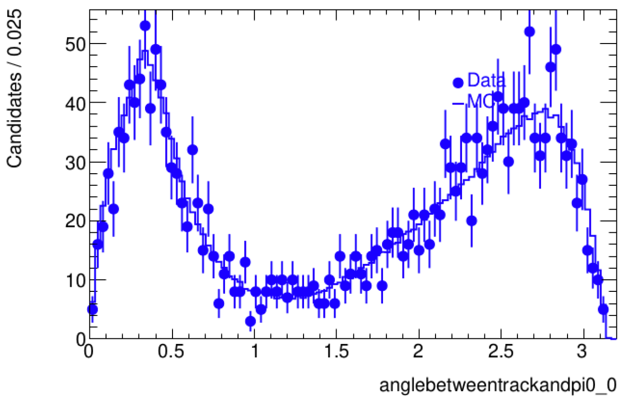
Inputs validation — Background only



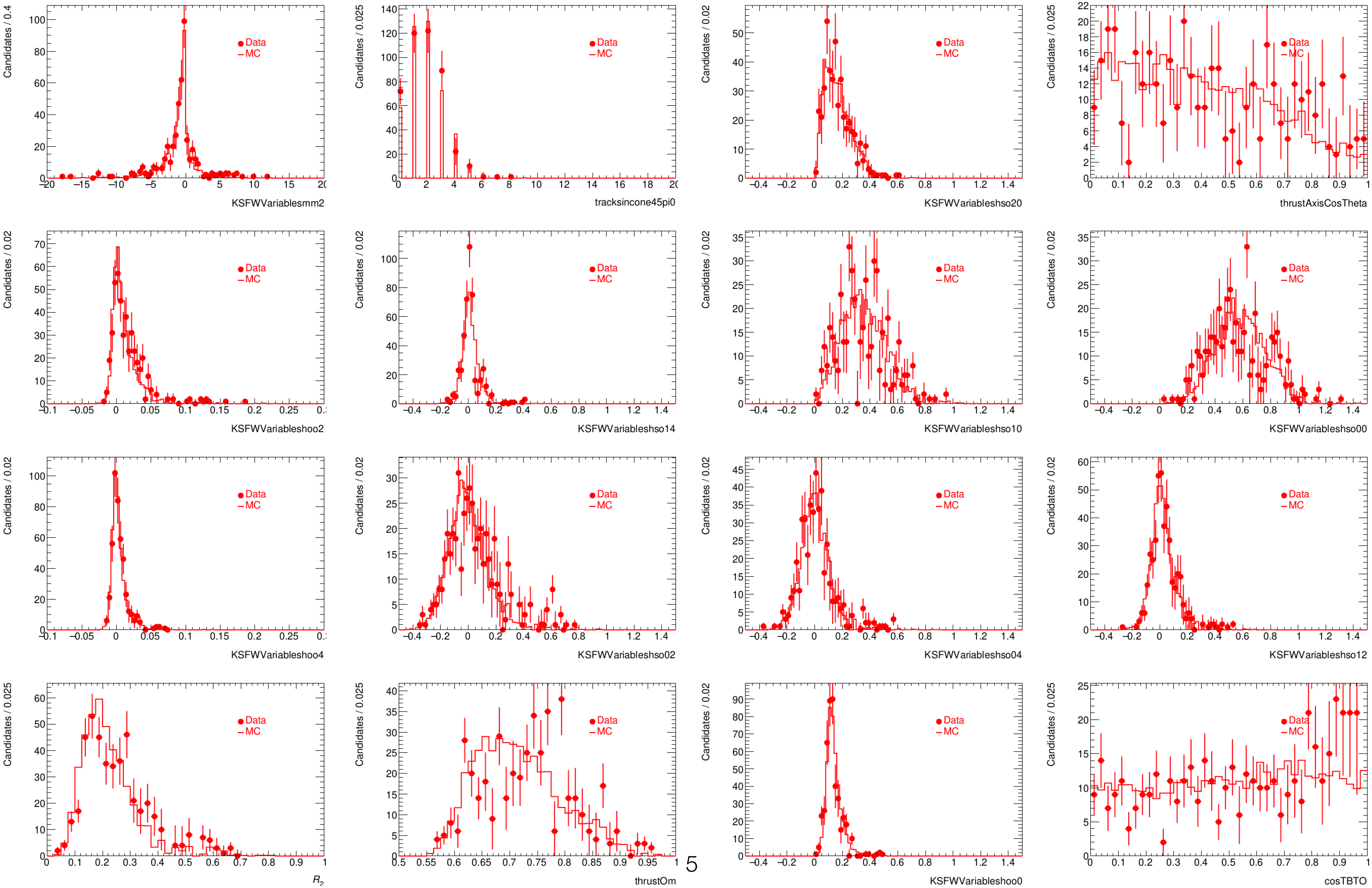
Inputs validation — Background only



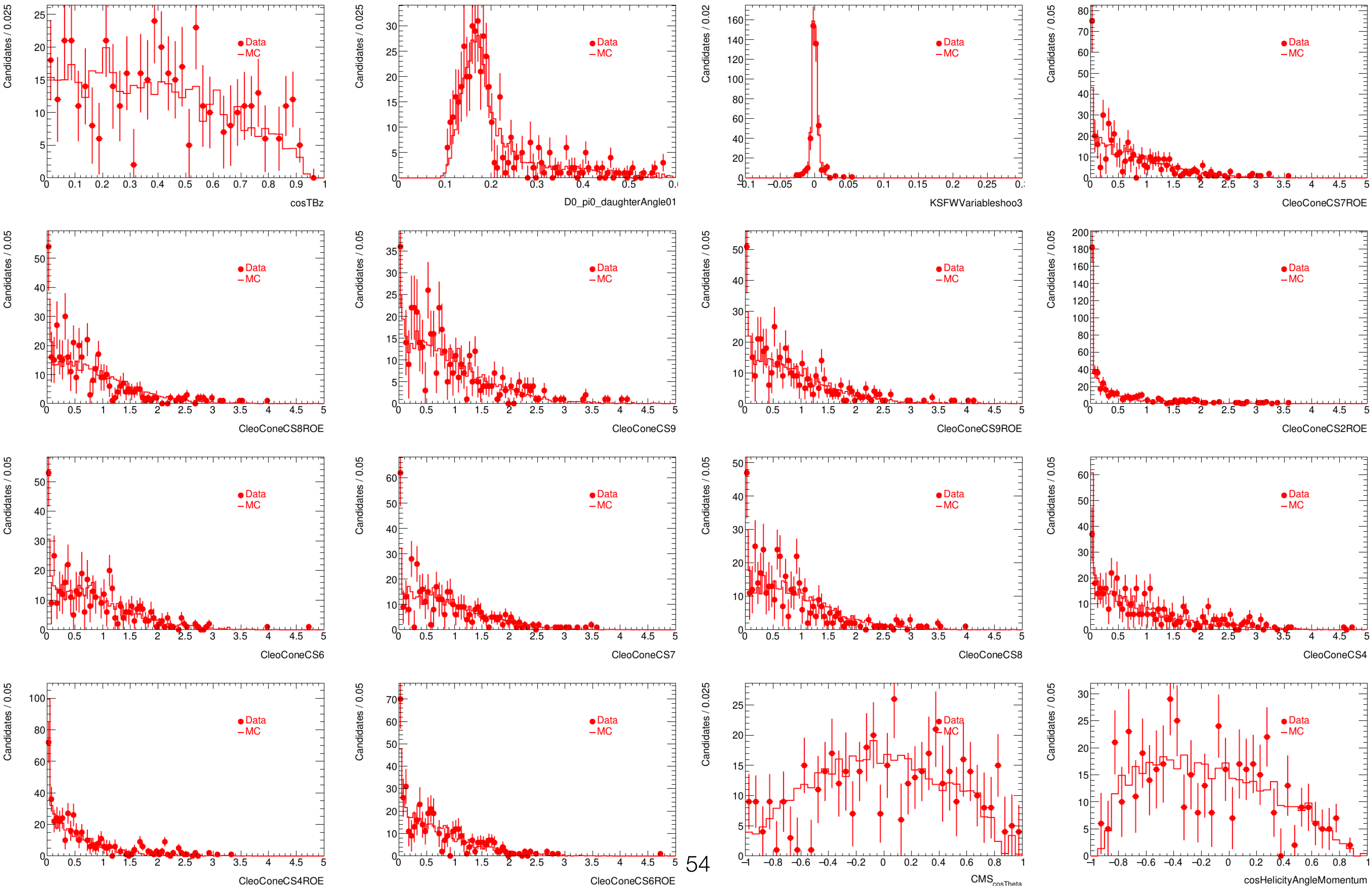
Inputs validation — Background only



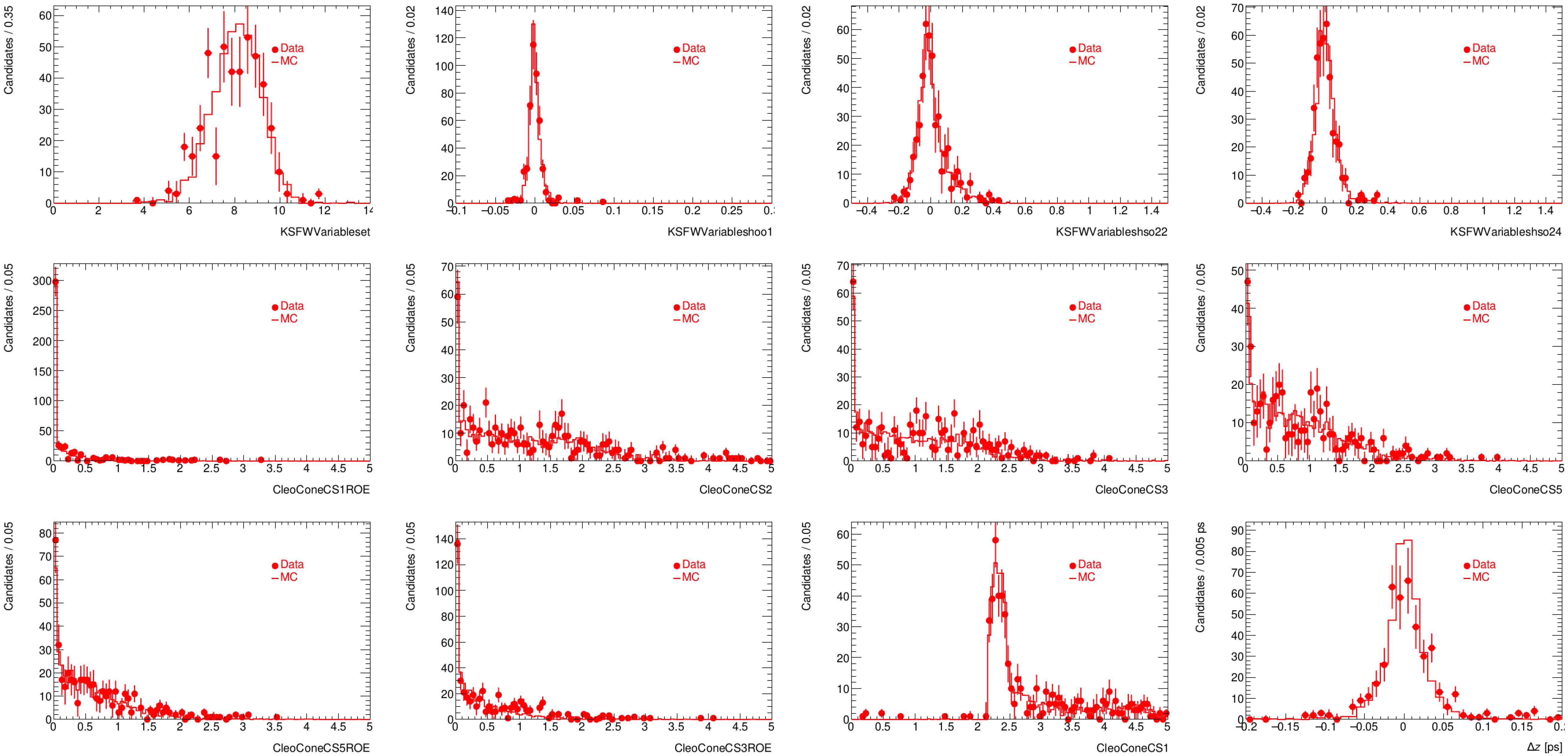
Inputs validation — Signal only

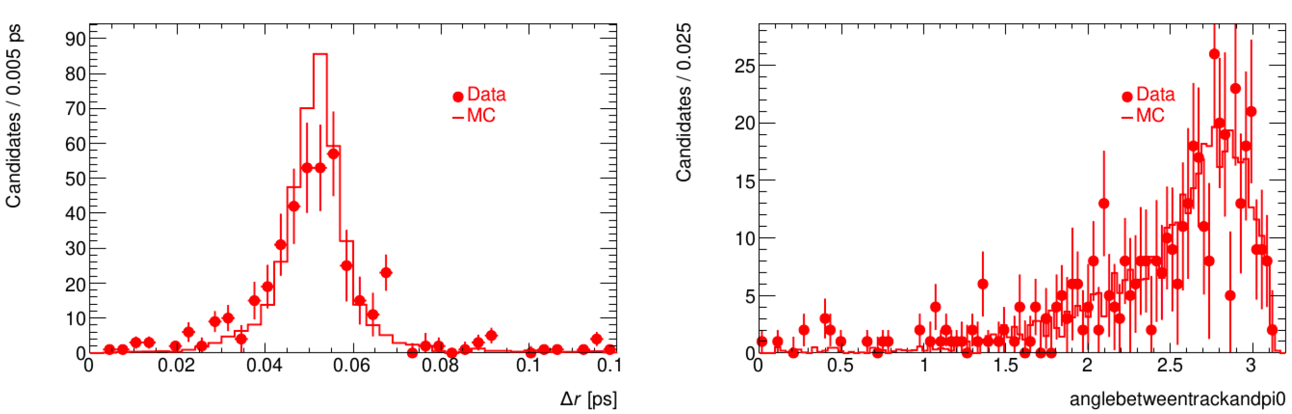


Inputs validation — Signal only



Inputs validation — Signal only





Need more statistics, but no large discrepancy observed

CSMVA inputs

Inputs (after pruning)
7 Kakuno-Super-Fox-Wolfram moments
cosTBTO
1 CleoCone
cosTheta*
R2
thrustOm
ΔZ (BTag)
Δr (BTag)
thrustAxisCosTheta
angle between π^0's
cosHelicityAngle
KSFWVariableset
KSFWVariablesmm2

Flavor tagging check: no ΔZ, no Δr

Compare flavour tagger parameters obtained in $B^0 \to \pi^0\pi^0$ after applying CSBDT selection and in control channel $B^0 \to D^-(K^+\pi^-\pi^-)\pi^+$ (largest BF btw those used by Sato-san in FT calibration). Use MC15.

$B^0 \to \pi^0\pi^0$

r- Interval	ε_i	$\Delta\varepsilon_i$	$w_i \pm \delta w_i$	$\Delta w_i \pm \delta\Delta w_i$	$\varepsilon_{eff,i} \pm \delta\varepsilon_{eff,i}$	$\Delta\varepsilon_{eff,i} \pm \delta\Delta\varepsilon_{eff,i}$
0.000 – 0.100	17.1	0.23	47.64 ± 0.26	2.35 ± 0.53	0.0382 ± 0.0085	-0.0752 ± 0.0204
0.100 – 0.250	16.6	0.09	41.07 ± 0.26	1.13 ± 0.53	0.5287 ± 0.0313	-0.1304 ± 0.0634
0.250 – 0.500	21.2	0.81	30.04 ± 0.22	0.36 ± 0.43	3.3799 ± 0.0749	0.0071 ± 0.1495
0.500 – 0.625	11.8	−0.36	20.94 ± 0.26	1.95 ± 0.51	3.9692 ± 0.0742	-0.6524 ± 0.1499
0.625 – 0.750	11.4	−0.08	15.17 ± 0.23	0.72 ± 0.46	5.5267 ± 0.0806	-0.2681 ± 0.1618
0.750 – 0.875	8.5	0.07	8.27 ± 0.20	0.44 ± 0.41	5.9513 ± 0.0722	-0.0788 ± 0.1445
0.875 – 1.000	13.4	−0.76	1.68 ± 0.08	0.19 ± 0.15	12.5437 ± 0.0799	-0.8107 ± 0.1601
Total			$\varepsilon_{eff} = \sum_i \varepsilon_i \cdot \langle 1-2w_i \rangle^2 = 31.94 \pm 0.17$		$\Delta\varepsilon_{eff} = -2.01 \pm 0.35$	

$B^0 \to D^-(K^+\pi^-\pi^-)\pi^+$

r- Interval	ε_i	$\Delta\varepsilon_i$	$w_i \pm \delta w_i$	$\Delta w_i \pm \delta\Delta w_i$	$\varepsilon_{eff,i} \pm \delta\varepsilon_{eff,i}$	$\Delta\varepsilon_{eff,i} \pm \delta\Delta\varepsilon_{eff,i}$
0.000 – 0.100	17.7	0.27	47.27 ± 0.26	2.58 ± 0.51	0.0526 ± 0.0099	-0.0986 ± 0.0217
0.100 – 0.250	16.8	0.26	41.09 ± 0.26	1.07 ± 0.52	0.5322 ± 0.0311	-0.1189 ± 0.0623
0.250 – 0.500	21.1	0.60	30.37 ± 0.22	0.24 ± 0.43	3.2461 ± 0.0728	0.0138 ± 0.1457
0.500 – 0.625	11.5	0.06	21.40 ± 0.26	1.66 ± 0.52	3.7607 ± 0.0723	-0.4175 ± 0.1445
0.625 – 0.750	11.2	−0.13	15.23 ± 0.23	0.97 ± 0.46	5.4192 ± 0.0794	-0.3649 ± 0.1588
0.750 – 0.875	8.6	−0.22	8.46 ± 0.20	0.46 ± 0.41	5.9675 ± 0.0721	-0.2828 ± 0.1442
0.875 – 1.000	13.1	−0.85	1.62 ± 0.08	0.47 ± 0.15	12.2983 ± 0.0783	-1.0309 ± 0.1565
Total			$\varepsilon_{eff} = \sum_i \varepsilon_i \cdot \langle 1-2w_i \rangle^2 = 31.28 \pm 0.17$		$\Delta\varepsilon_{eff} = -2.30 \pm 0.34$	

Results are compatible. Waiting for the official numbers from Sato-san (end of month).

Flavor tagging check: no ΔZ, no Δr

Compare flavour tagger parameters obtained in $B^0 \to \pi^0\pi^0$ after applying CSBDT selection including and excluding ΔZ and Δr.

r- Interval	ε_i	$\Delta\varepsilon_i$	$w_i \pm \delta w_i$	$\Delta w_i \pm \delta\Delta w_i$	$\varepsilon_{eff,i} \pm \delta\varepsilon_{eff,i}$	$\Delta\varepsilon_{eff,i} \pm \delta\Delta\varepsilon_{eff,i}$
$0.000 - 0.100$	17.1	0.23	47.64 ± 0.26	2.35 ± 0.53	0.0382 ± 0.0085	-0.0752 ± 0.0204
$0.100 - 0.250$	16.6	0.09	41.07 ± 0.26	1.13 ± 0.53	0.5287 ± 0.0313	-0.1304 ± 0.0634
$0.250 - 0.500$	21.2	0.81	30.04 ± 0.22	0.36 ± 0.43	3.3799 ± 0.0749	0.0071 ± 0.1495
$0.500 - 0.625$	11.8	-0.36	20.94 ± 0.26	1.95 ± 0.51	3.9692 ± 0.0742	-0.6524 ± 0.1499
$0.625 - 0.750$	11.4	-0.08	15.17 ± 0.23	0.72 ± 0.46	5.5267 ± 0.0806	-0.2681 ± 0.1618
$0.750 - 0.875$	8.5	0.07	8.27 ± 0.20	0.44 ± 0.41	5.9513 ± 0.0722	-0.0788 ± 0.1445
$0.875 - 1.000$	13.4	-0.76	1.68 ± 0.08	0.19 ± 0.15	12.5437 ± 0.0799	-0.8107 ± 0.1601
Total			$\varepsilon_{eff} = \sum_i \varepsilon_i \cdot \langle 1 - 2w_i \rangle^2 = 31.94 \pm 0.17$		$\Delta\varepsilon_{eff} = -2.01 \pm 0.35$	

$B^0 \to \pi^0\pi^0$

r- Interval	ε_i	$\Delta\varepsilon_i$	$w_i \pm \delta w_i$	$\Delta w_i \pm \delta\Delta w_i$	$\varepsilon_{eff,i} \pm \delta\varepsilon_{eff,i}$	$\Delta\varepsilon_{eff,i} \pm \delta\Delta\varepsilon_{eff,i}$
$0.000 - 0.100$	17.1	0.22	47.54 ± 0.26	2.60 ± 0.52	0.0414 ± 0.0087	-0.0866 ± 0.0212
$0.100 - 0.250$	16.6	0.06	40.97 ± 0.26	1.01 ± 0.52	0.5417 ± 0.0311	-0.1196 ± 0.0631
$0.250 - 0.500$	21.1	0.85	30.02 ± 0.21	0.34 ± 0.43	3.3760 ± 0.0737	0.0203 ± 0.1471
$0.500 - 0.625$	11.8	-0.38	20.87 ± 0.25	1.84 ± 0.51	3.9966 ± 0.0732	-0.6337 ± 0.1479
$0.625 - 0.750$	11.5	-0.07	15.08 ± 0.23	0.60 ± 0.45	5.5858 ± 0.0797	-0.2268 ± 0.1598
$0.750 - 0.875$	8.6	0.06	8.31 ± 0.20	0.56 ± 0.40	5.9602 ± 0.0712	-0.1181 ± 0.1425
$0.875 - 1.000$	13.4	-0.74	1.67 ± 0.07	0.24 ± 0.15	12.5174 ± 0.0785	-0.8171 ± 0.1573
Total			$\varepsilon_{eff} = \sum_i \varepsilon_i \cdot \langle 1 - 2w_i \rangle^2 = 32.02 \pm 0.17$		$\Delta\varepsilon_{eff} = -1.98 \pm 0.34$	

$B^0 \to \pi^0\pi^0$
with Δr and ΔZ

Results are compatible. Inclusion of ΔZ and Δr doesn't bias FT.

Photon MVA validation

Apply photonMVA to $D^* \to D^0(K\pi\pi^0)\pi$ data after applying signal π^0 selections and reweighting candidates based on signal $p(\pi^0)$.

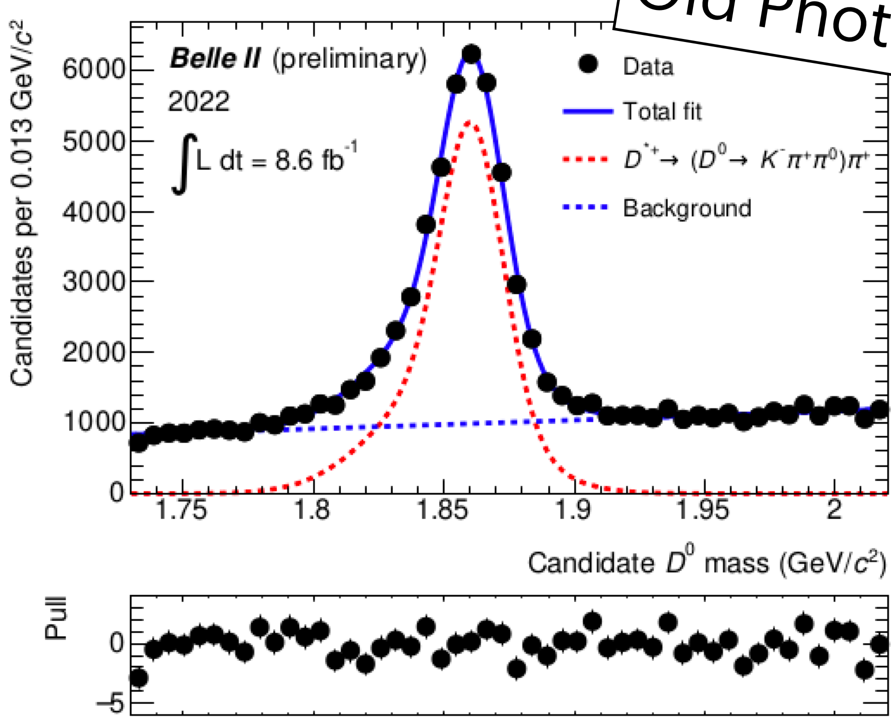
Compare background rejection at given signal efficiency.

Obtain signal efficiency as

$$\varepsilon_{\mathrm{sig}} = \frac{N_{\mathrm{pass}}}{N_{\mathrm{pass}} + N_{\mathrm{Not\ pass}}}$$

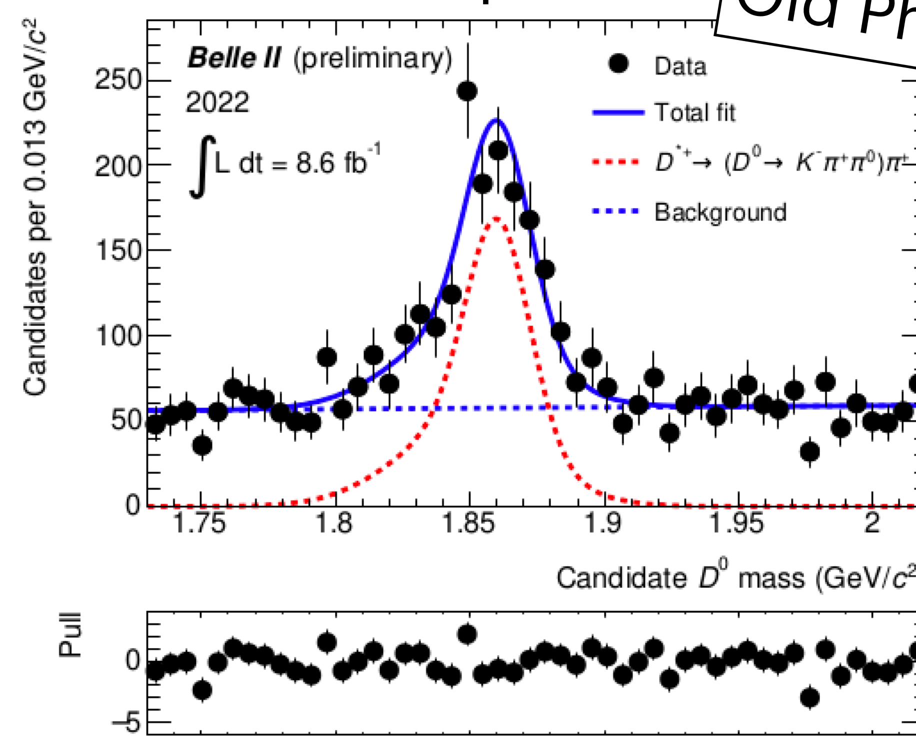
Passed

Old PhotonMVA



Not passed

Old PhotonMVA



$\varepsilon_{\mathrm{sig}}$: 96.6±0.1%

Bkg rejection: 5.1±0.1% $\longrightarrow$ My new bkg rejection: 9.4±0.1%