

# $B \rightarrow \tau\nu$ Branching Ratio with Hadronic FEI

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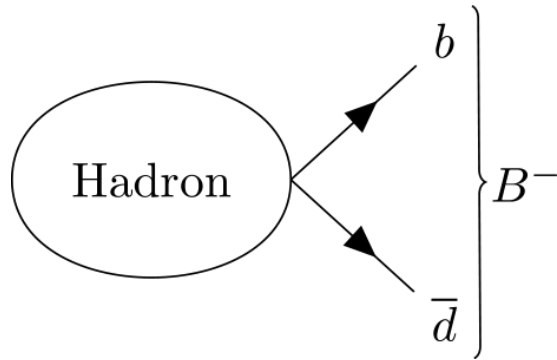
Physics Week in Valencia – Nov 29<sup>th</sup> 2022



# $B \rightarrow \tau \nu$ decay with Hadronic FEI

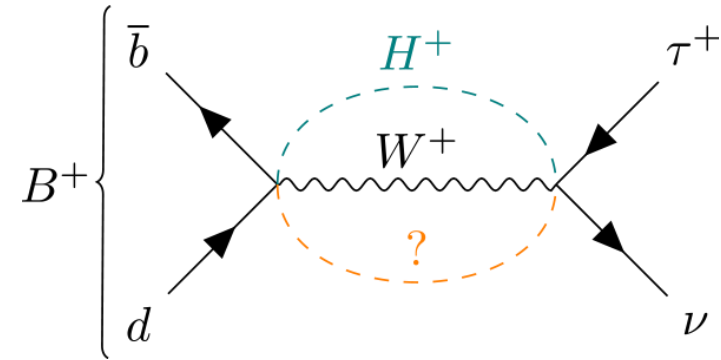
Hadronic FEI Skim

- TagProb > 0.001
- $|\Delta E| < 0.2 \text{ GeV}$
- $M_{bc} > 5.24 \text{ GeV}$



Rest of Event

- 0 Extra Tracks (from IP)
- Extra Energy in ECL must be 0 in signal events and larger in background.



$$\mathcal{BR}(B \rightarrow \ell \nu) = \frac{G_F^2 m_B m_\ell^2}{8\pi} \left[ 1 - \frac{m_\ell^2}{m_B^2} \right] f_B^2 |V_{ub}|^2 \tau_B \alpha \beta$$

Very clean theoretically, hard experimentally  
Standard Model is helicity suppressed

- 1 track with PID request ( $e, \mu$  or  $\pi$ ) with  $p > 0.4 \text{ GeV}$
- $\pi^0$  for  $\tau \rightarrow \rho \nu \rightarrow \pi \pi^0 \nu$  decay

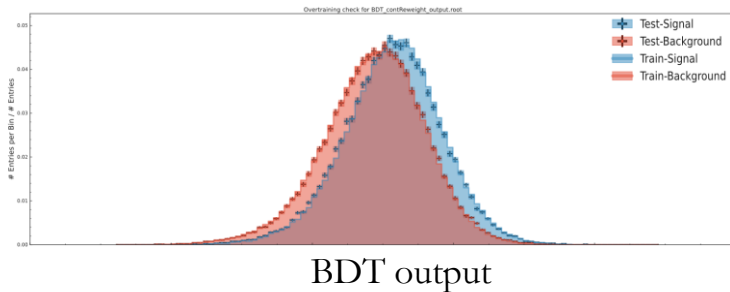
Dataset: 189/fb on res – 14/fb off res – 1000/fb MC14ri

# Analysis workflow

We choose the best candidate with respect to the tag probability and divide the sample in 4 channels (one for each  $\tau$  decay);

The  $q\bar{q}$  MC background is

1. Reweighted with a BDT-weight
2. Normalized to off peak yield

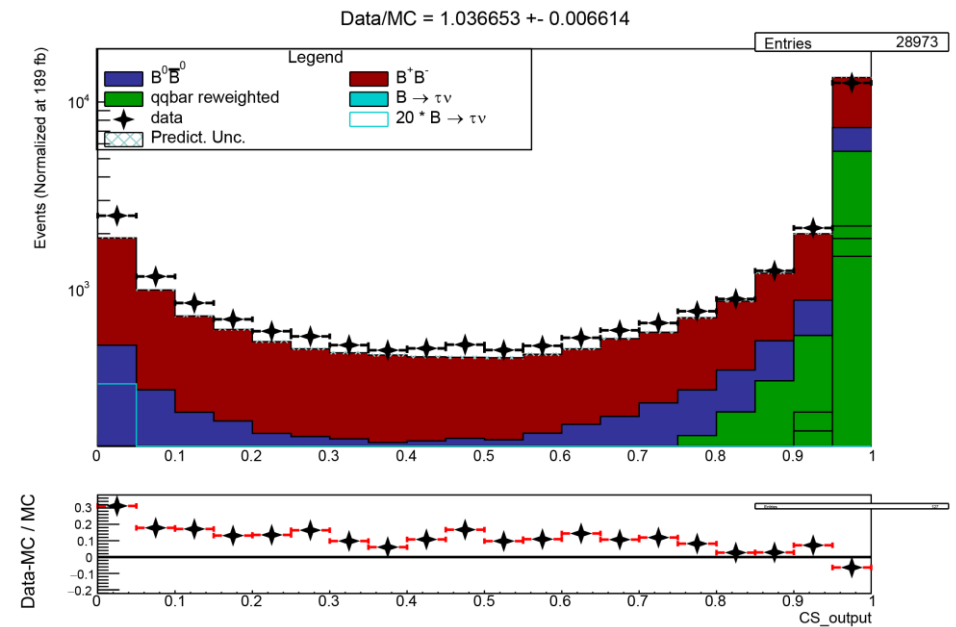


The  $B\bar{B}$  background is normalized with the FEI Calibration factors.

[Taken from here](#)

In order to reject the  $q\bar{q}$  background, a BDT-qq has been trained and the following cuts have been applied:

- $M_{bc} > 5.27$  GeV
- $R2 < 0.4$

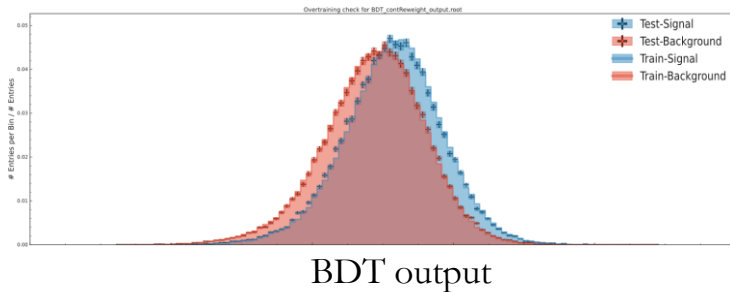


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- BDT output  $< 0.5$

We performed a fit to data in  $\Delta E$  distribution to normalize the  $B\bar{B}$  component in the  $E_{ECL}$  sideband (more in next slides).

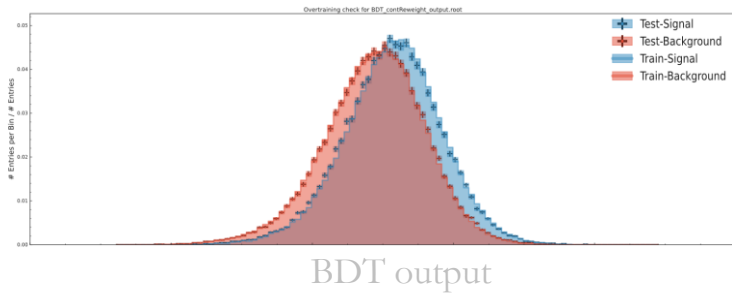
Finally, the cuts have been optimized for the best relative uncertainty in a 4 channel simultaneous fit to  $E_{ECL}$ .

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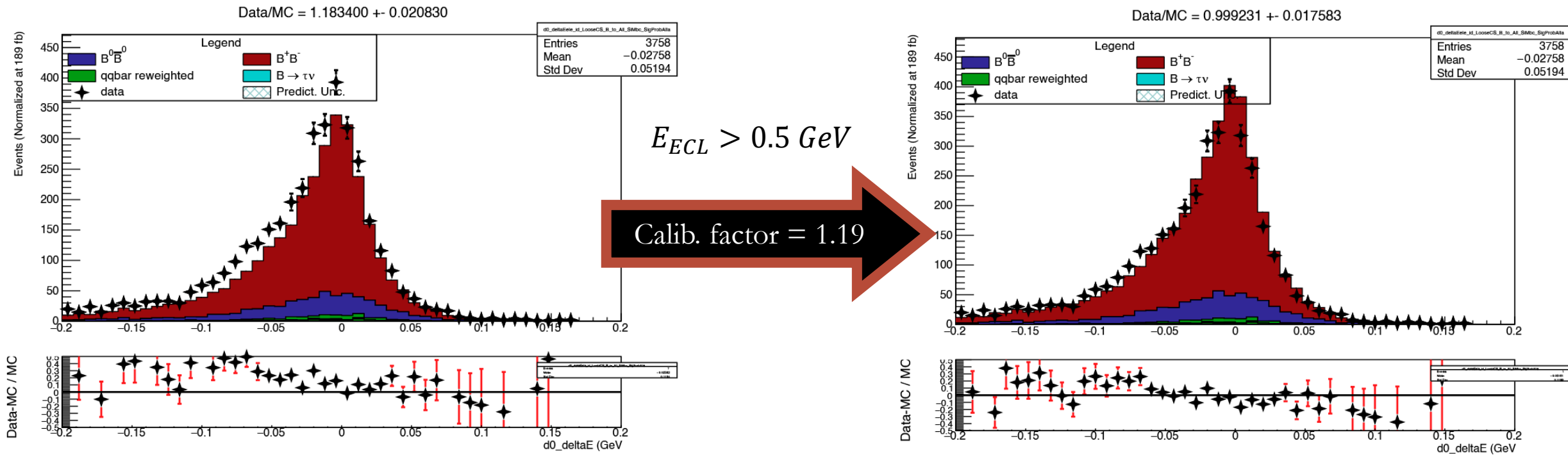
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# The $\Delta E$ distribution

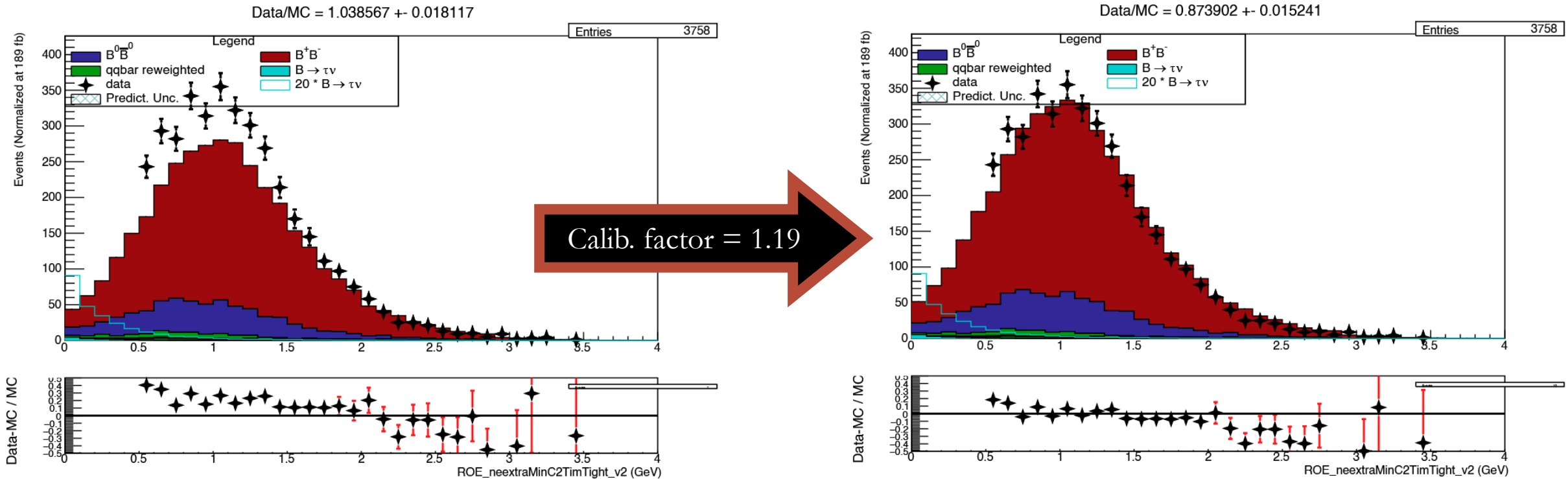
The  $\Delta E$  distribution, after a cut at 0.5 on the Continuum Suppression BDT output, looks like this and we tried to fit the MC on data to find a personal calibration value.



Electron channel

# The $\Delta E$ distribution

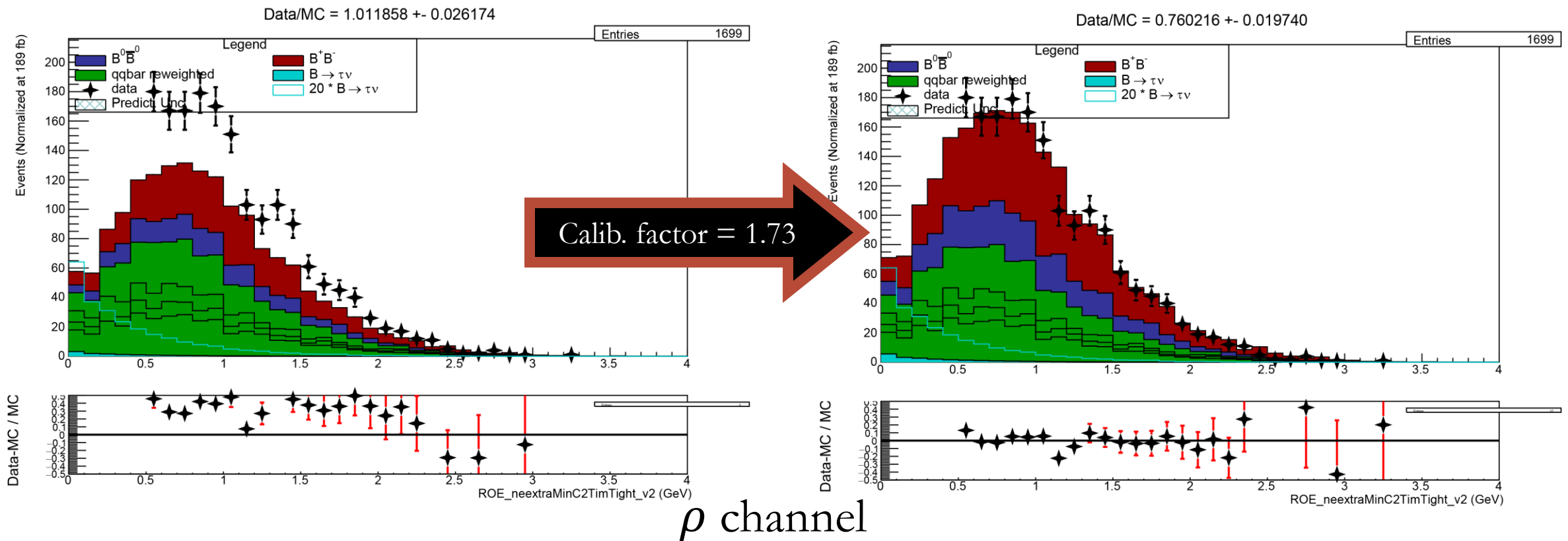
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# Results and conclusions

We obtained these values:

$\tau \rightarrow$	Tag Prob >	
	$10^{-3}$	$10^{-2}$
$e\nu\nu$	$1.15 \pm 0.02$	$1.19 \pm 0.02$
$\mu\nu\nu$	$1.16 \pm 0.02$	$1.17 \pm 0.02$
$\pi\nu$	$1.35 \pm 0.04$	$1.42 \pm 0.07$
$\rho\nu$	$1.39 \pm 0.04$	$1.73 \pm 0.06$

Checks and questions

1. Should we also apply the scaling factor to signal MC?
2. The scaling factor changes in the different channels and in the different Tag Probability cuts: has this behaviour a physical explanation?

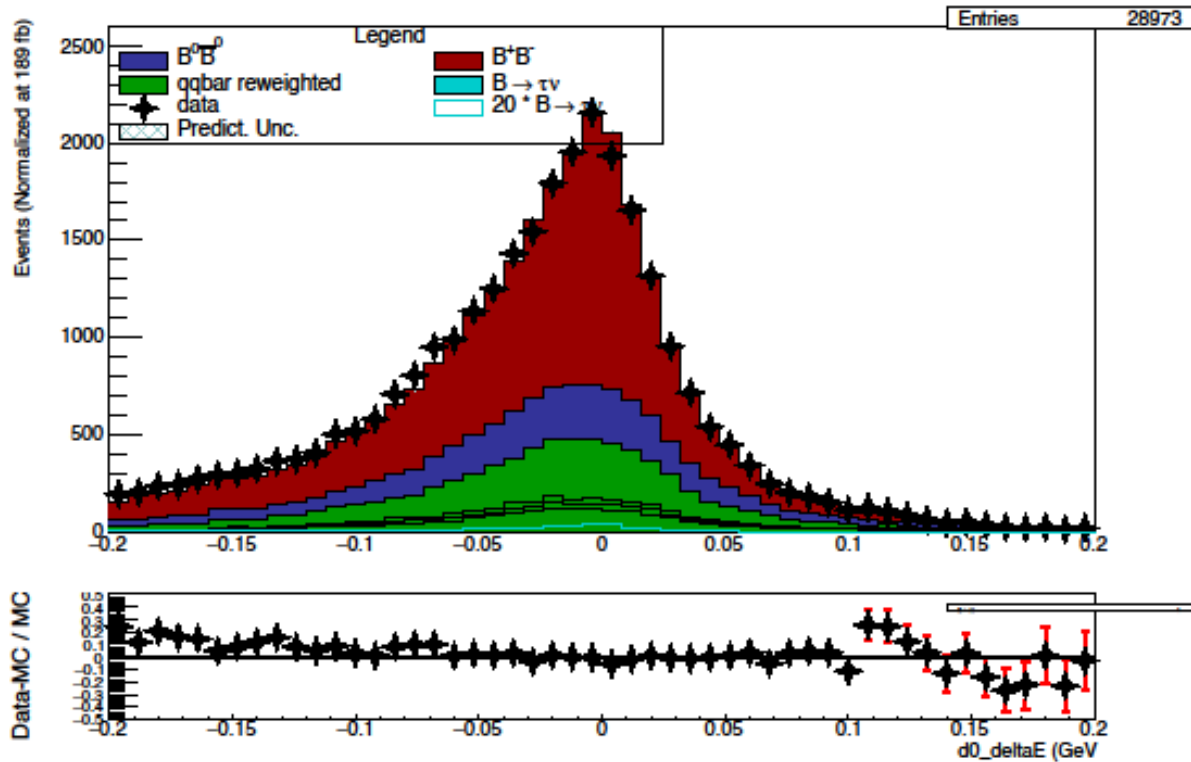
3 days after:

1. We applied the calibration factors  $B_{tag}$  mode dependent, provided by William (in the electron and muon channel);
2. We computed a scaling factor for the  $B\bar{B}$  and redesigned the distributions;
3. We also found the factors in different bins of  $B_{tag}$  mode decay
4. We found a possible Control Sample: Hadronic FEI and a «wrong» charged track in the signal side;
5. We will train the Continuum Suppression BDT and the Continuum Reweighting BDT without the cut on R2 and adding the cut on  $\cos \vartheta_{TBO} < 0,9$ .

# New Calibration Factors Tag Mode dependent

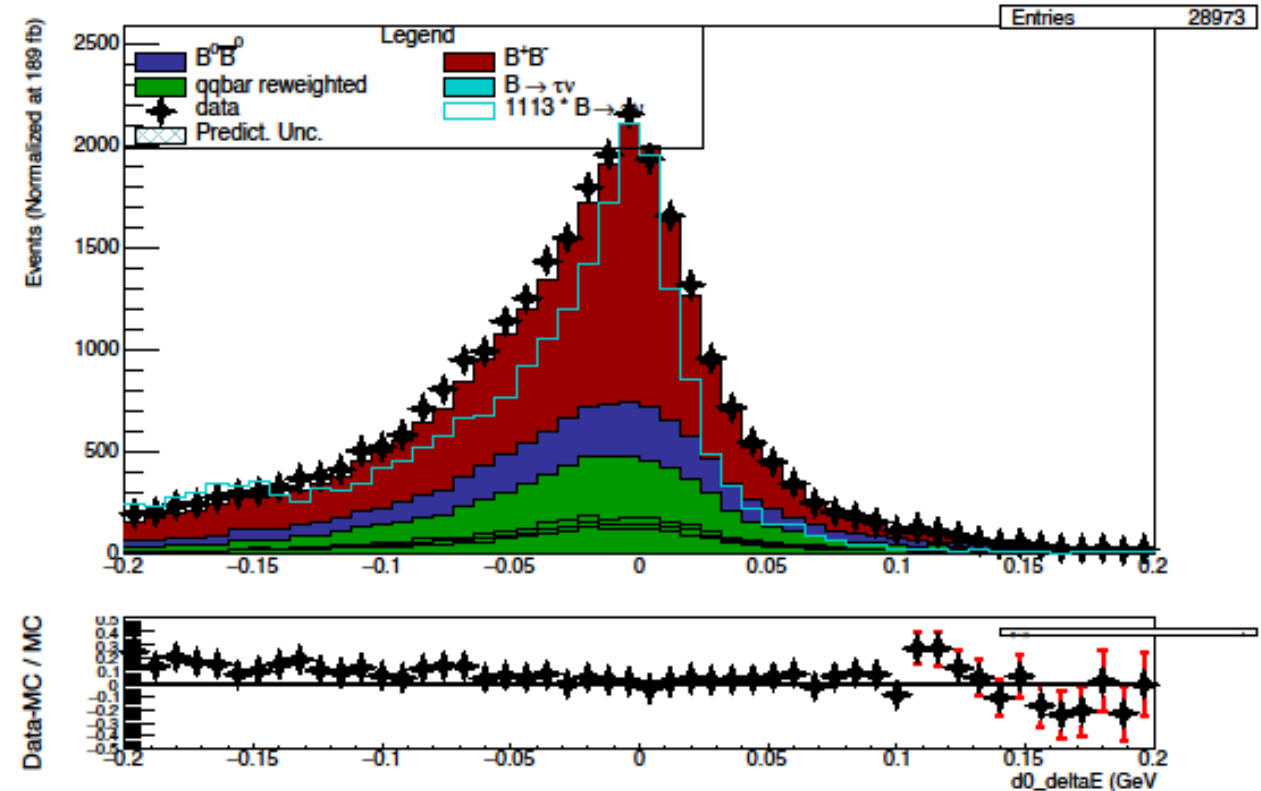
with global correction

Data/MC = 1.017969 ± 0.006444



with TagMode correction

Data/MC = 1.048806 ± 0.006669

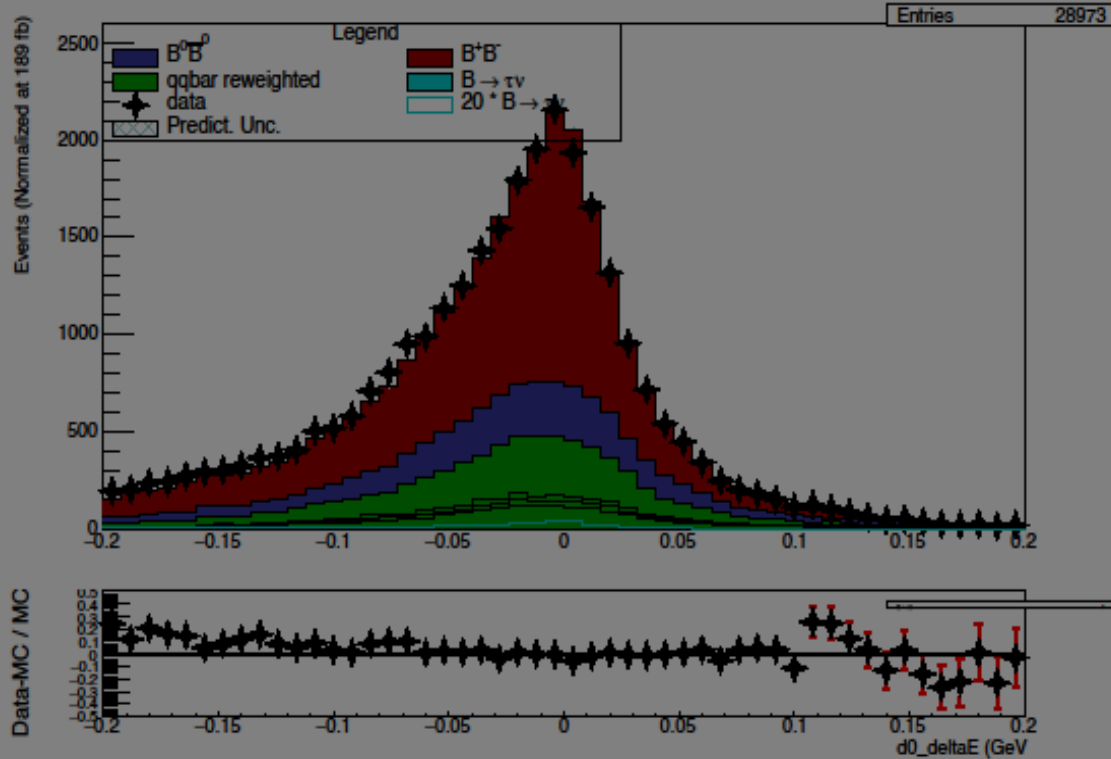


$\tau \rightarrow e \nu \nu$

# New Calibration Factors Tag Mode dependent

w/ global correction

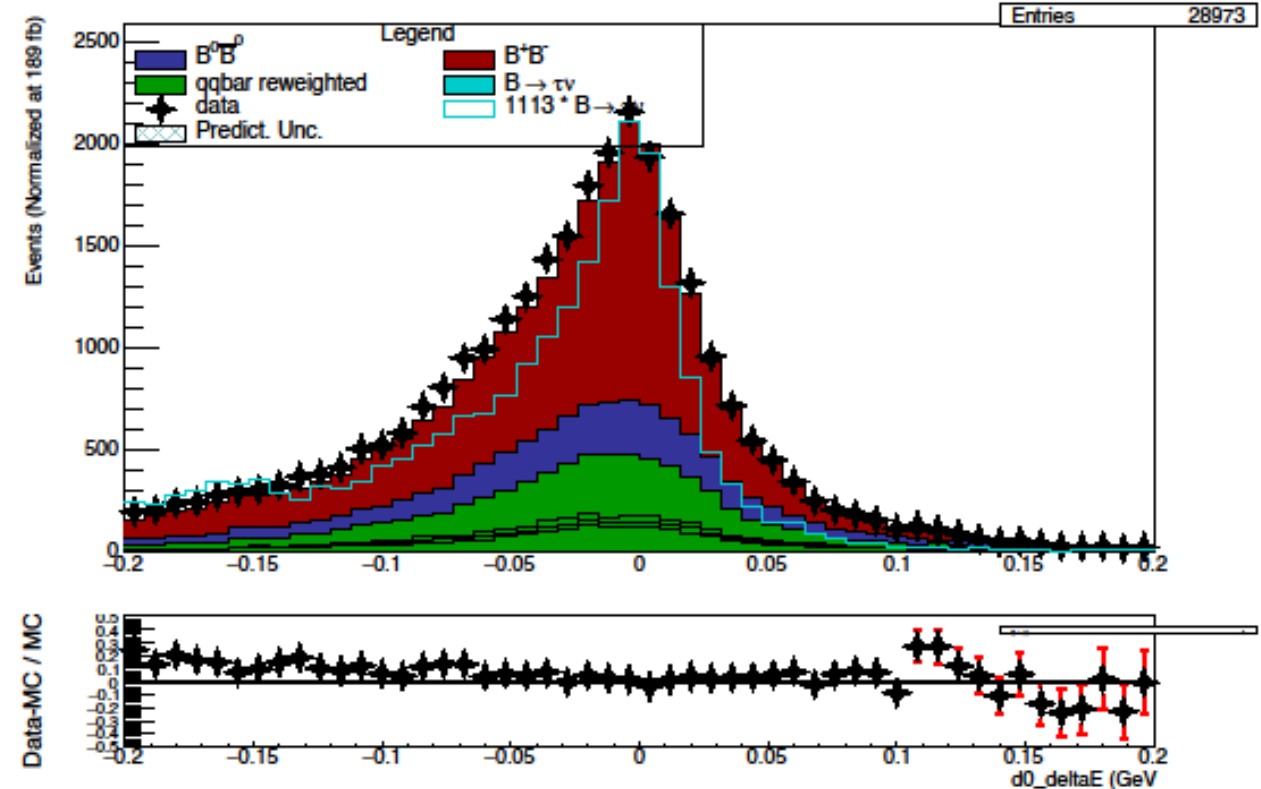
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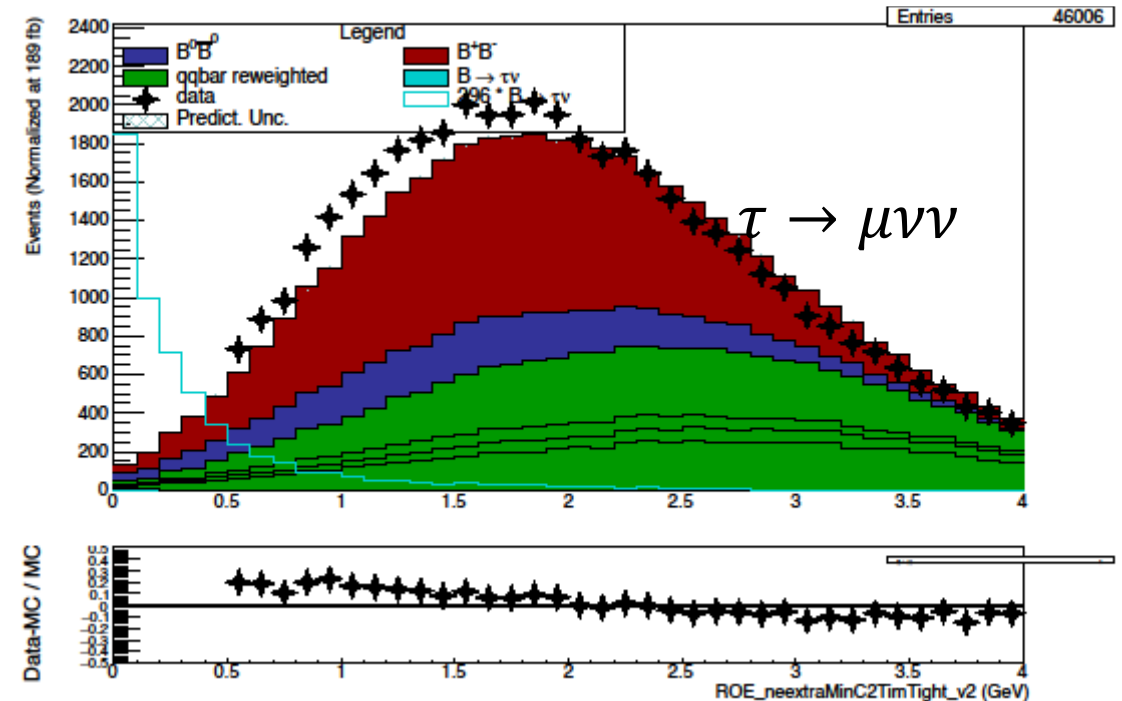
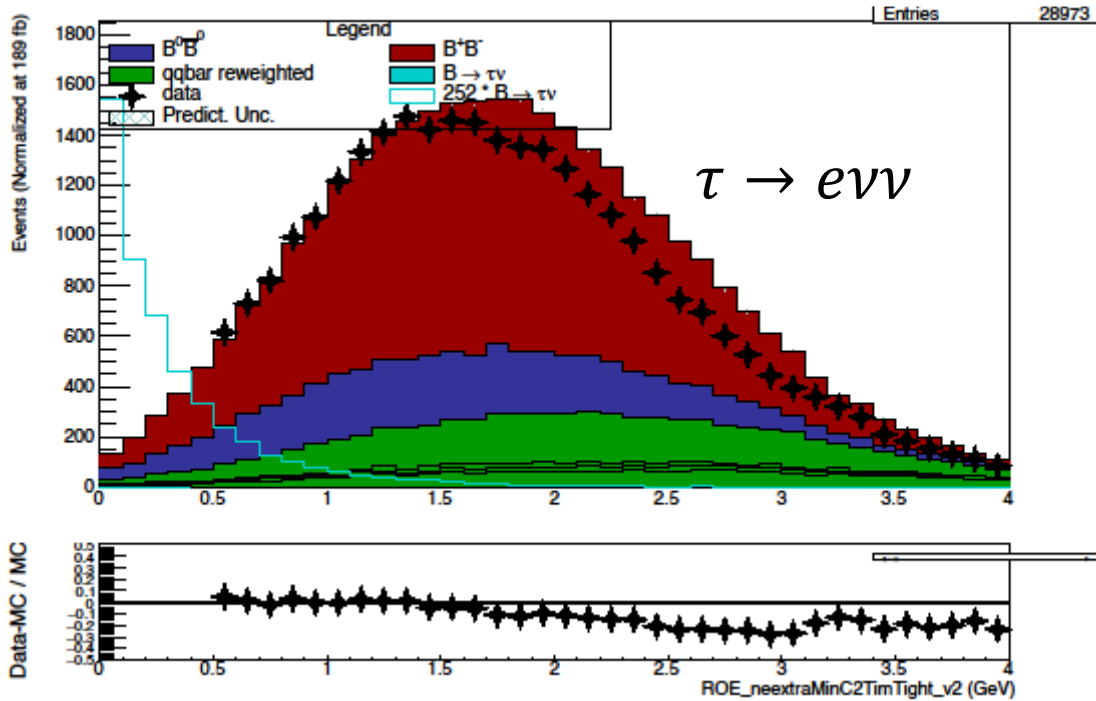
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Let's use this

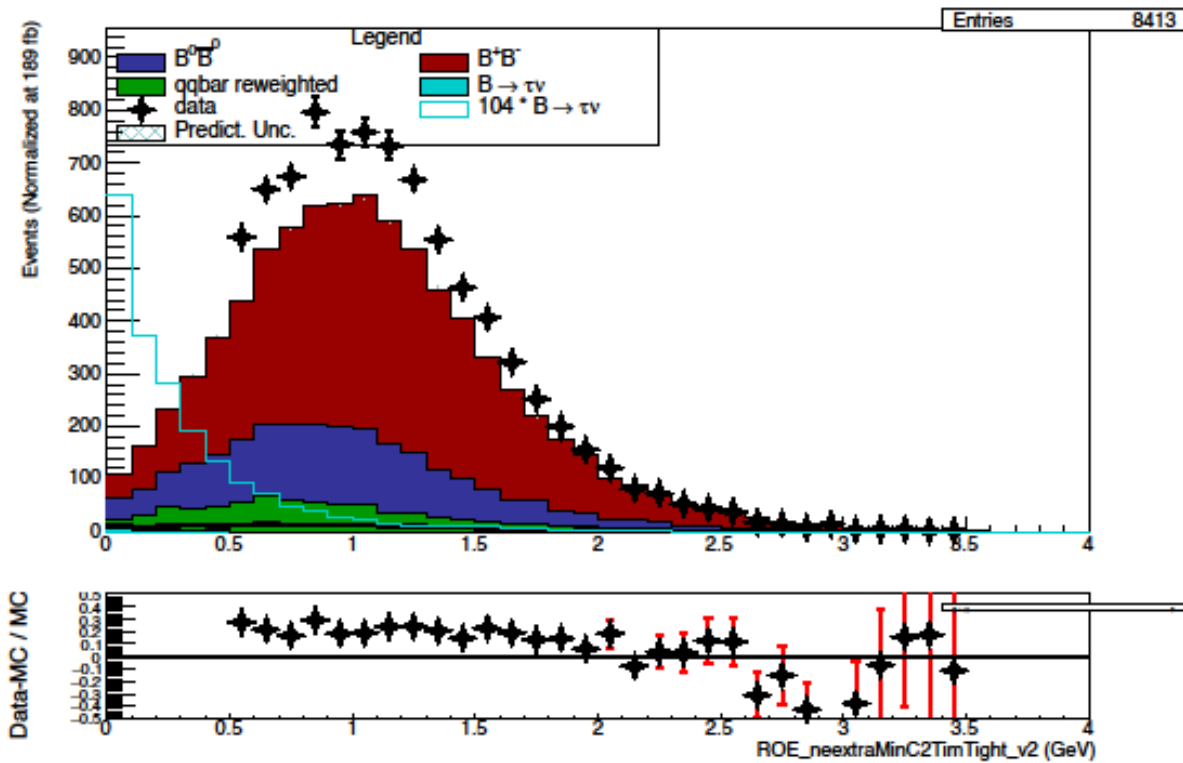
# $E_{ECL}$ distributions

There is a Data/MC shift on  $E_{ECL}$ . There are evidences from other analysis ( $K\nu\nu$  and  $K^*\tau\tau$ ) that the source could be the definition of  $E_{ECL}$ .

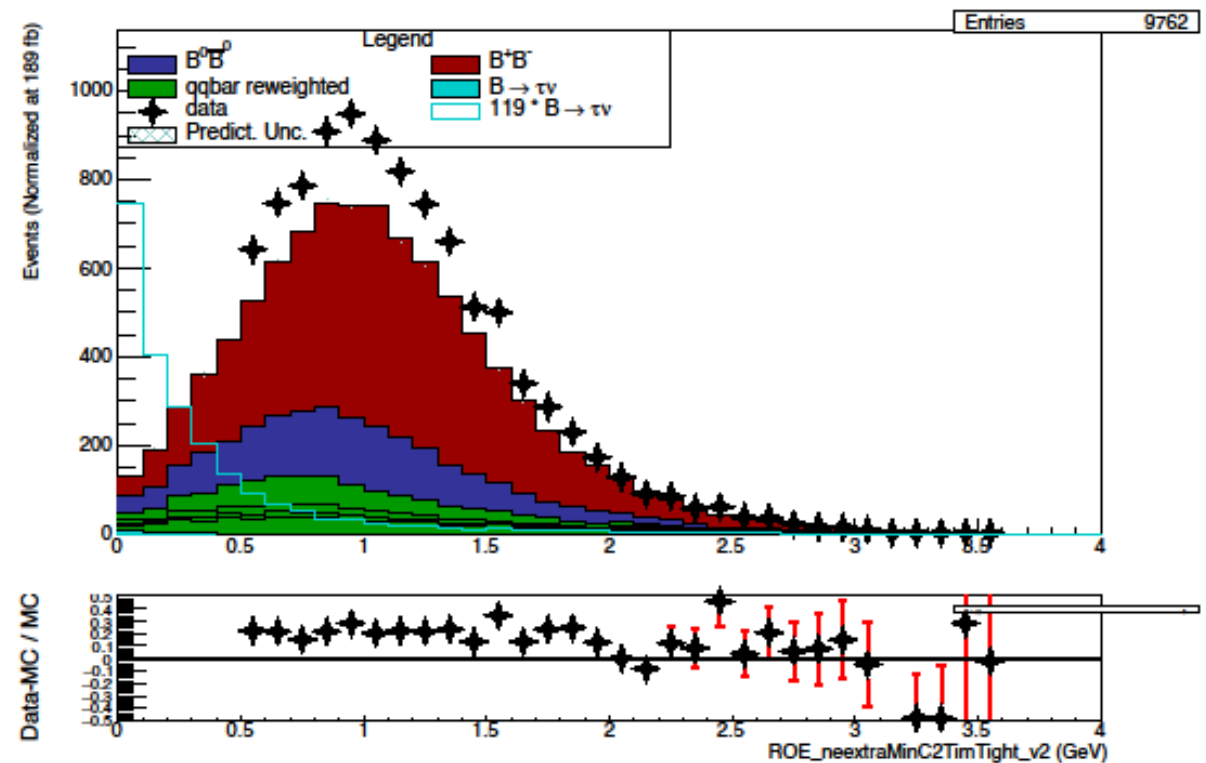


Our definition: `'E > 0.5 and minC2TDist>25 and abs(clusterTiming) < 200 and abs(clusterTiming/clusterErrorTiming) < 2.0'`  
 Their "best definition": `'[[clusterReg==1 and E>0.080] or [clusterReg==2 and E>0.030] or [clusterReg==3 and E>0.060]] and hadronicSplitOffSuppression>0.3 and beamBackgroundSuppression>0.5'`

# $E_{ECL}$ distributions after the CS

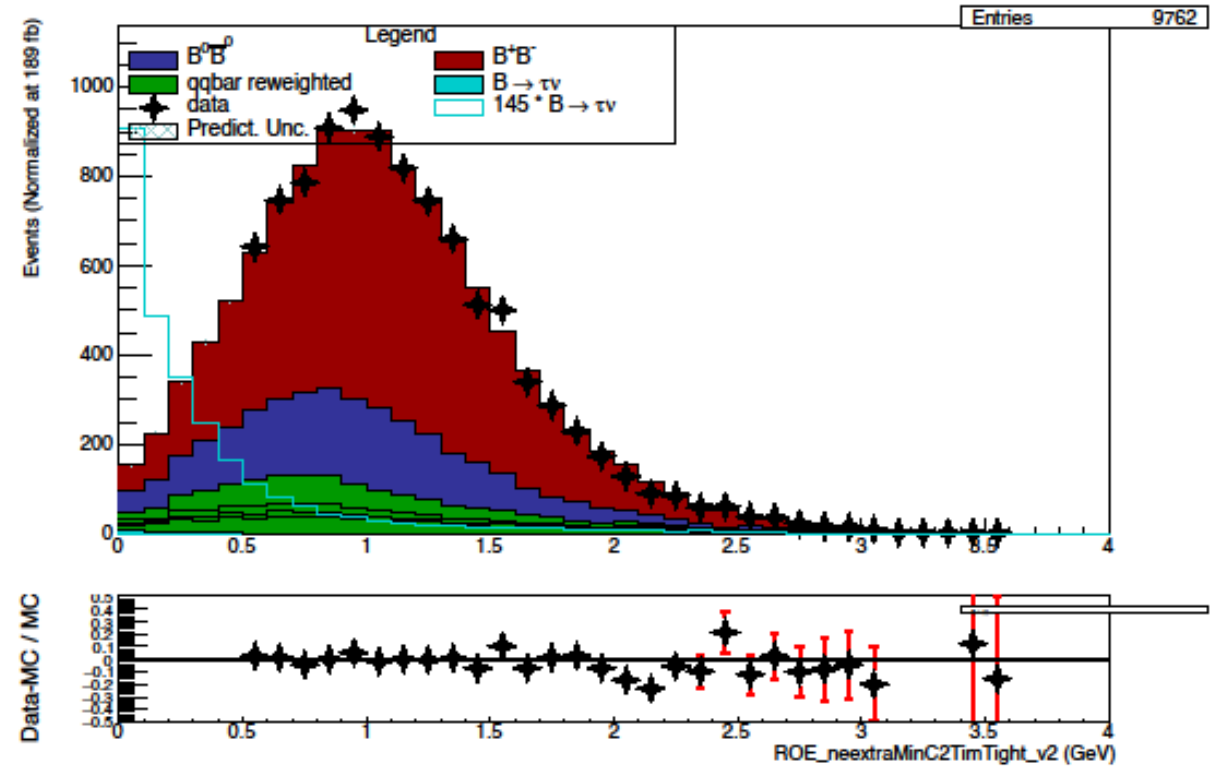
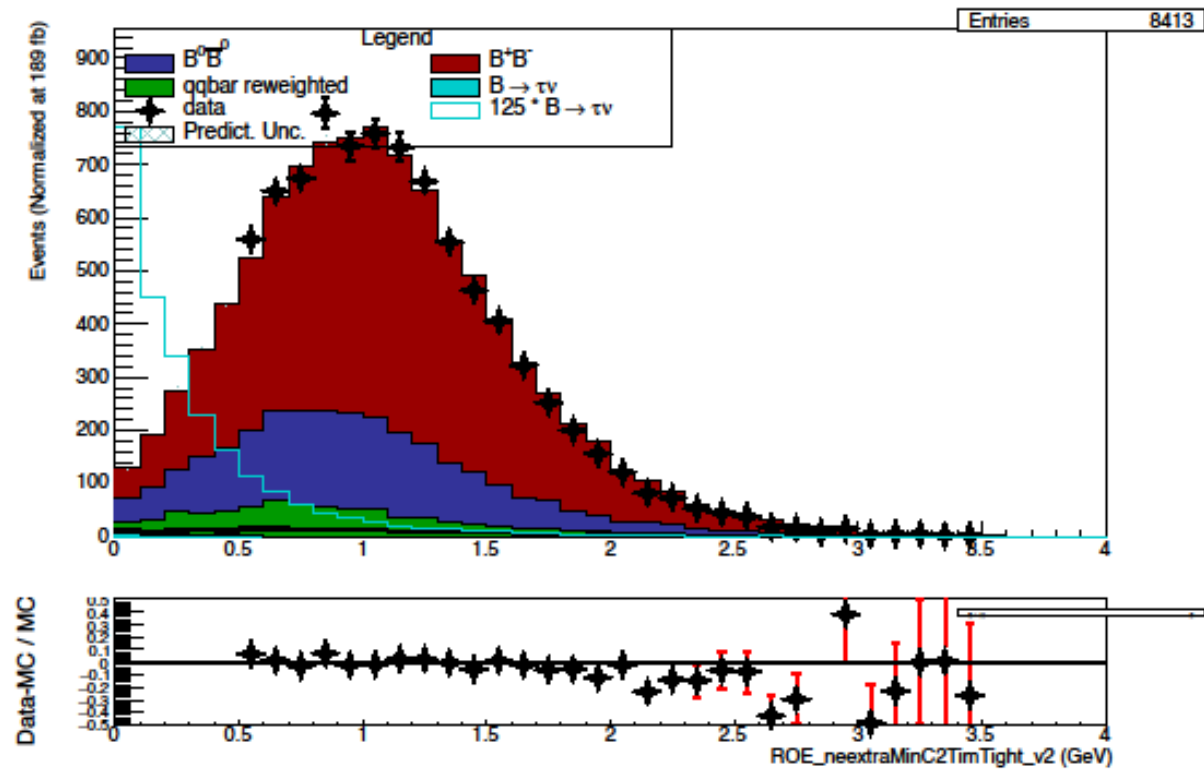


$\tau \rightarrow e \nu \nu$

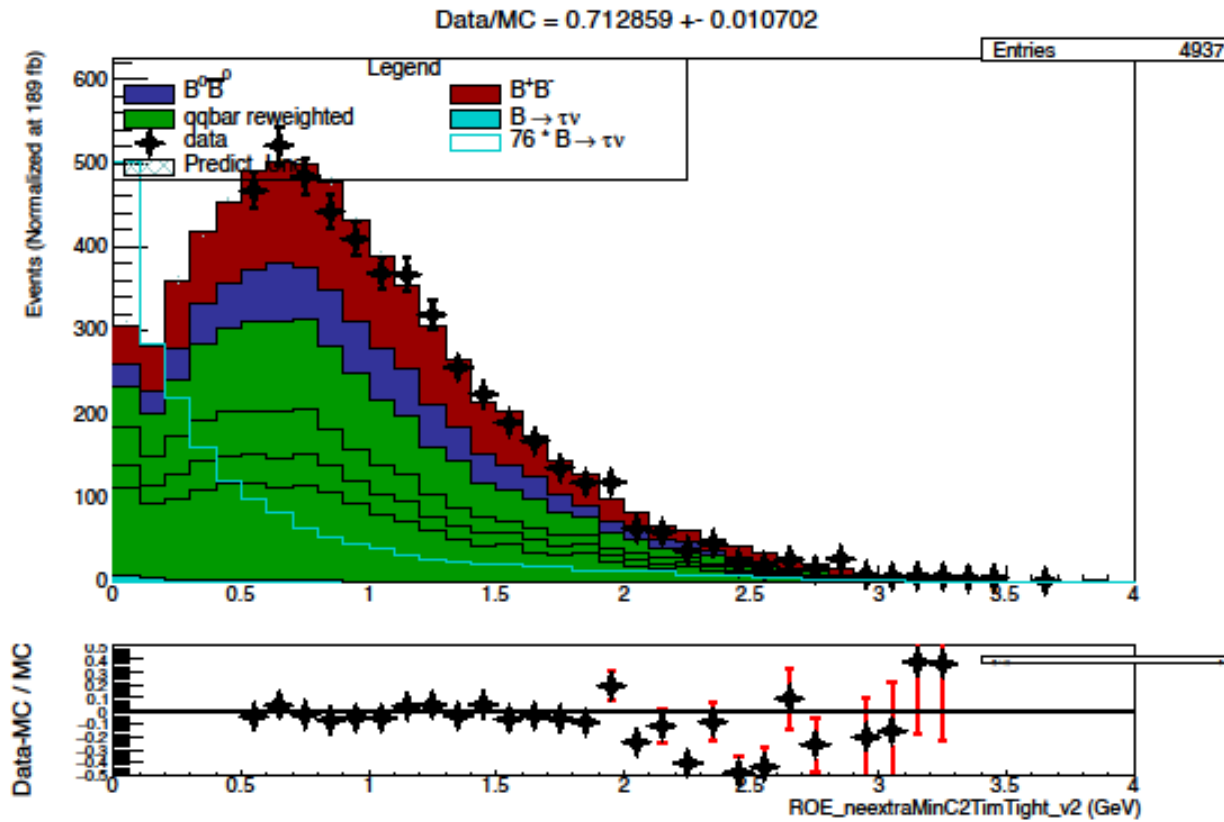


$\tau \rightarrow \mu \nu \nu$

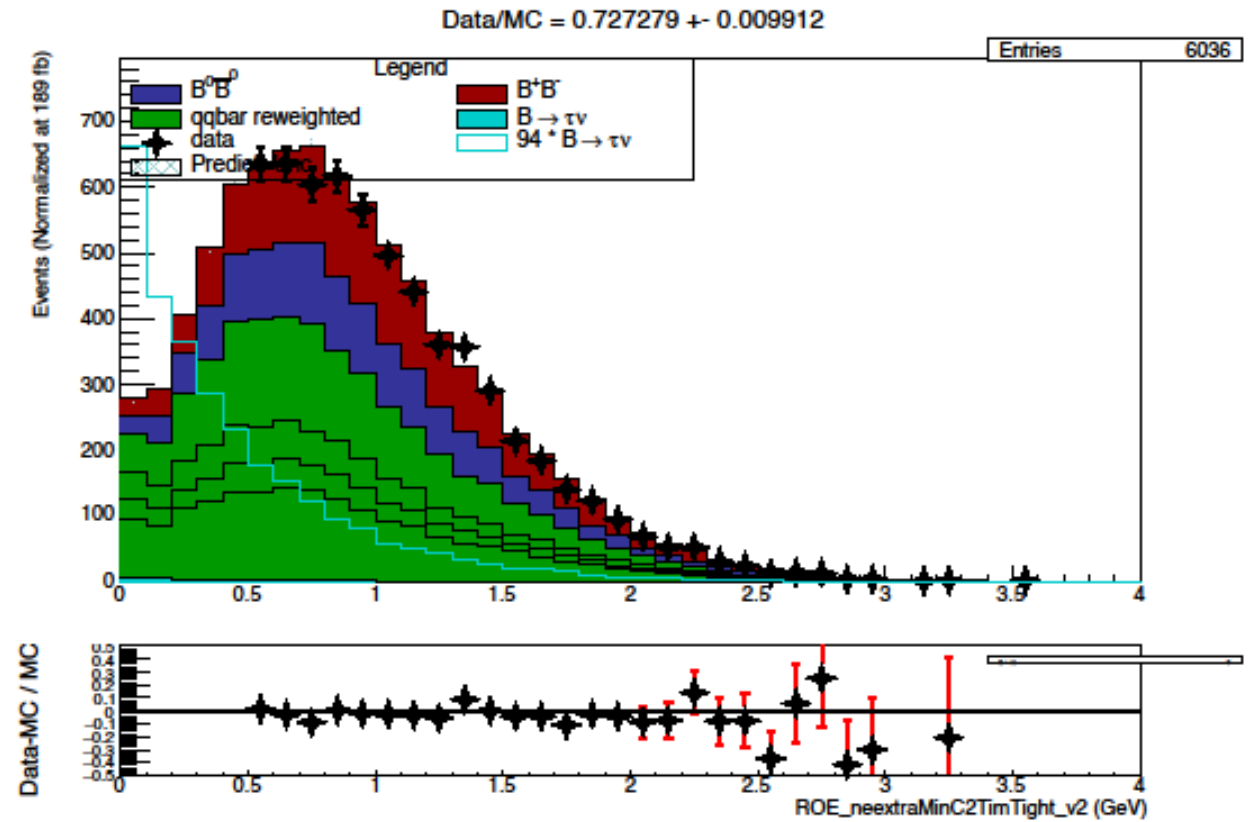
# $E_{ECL}$ distributions after the CS and the rescaling



# $E_{ECL}$ distributions after the CS

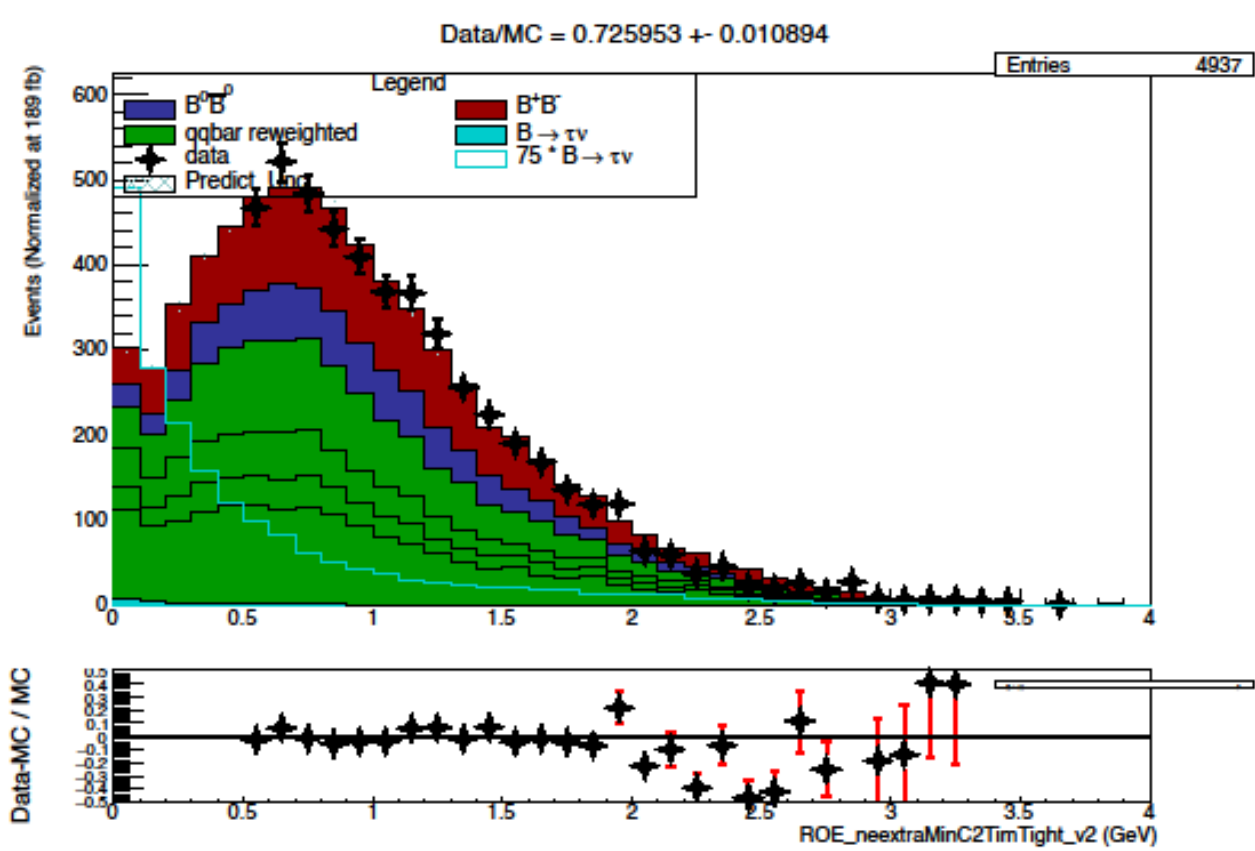


$\tau \rightarrow \pi \nu$

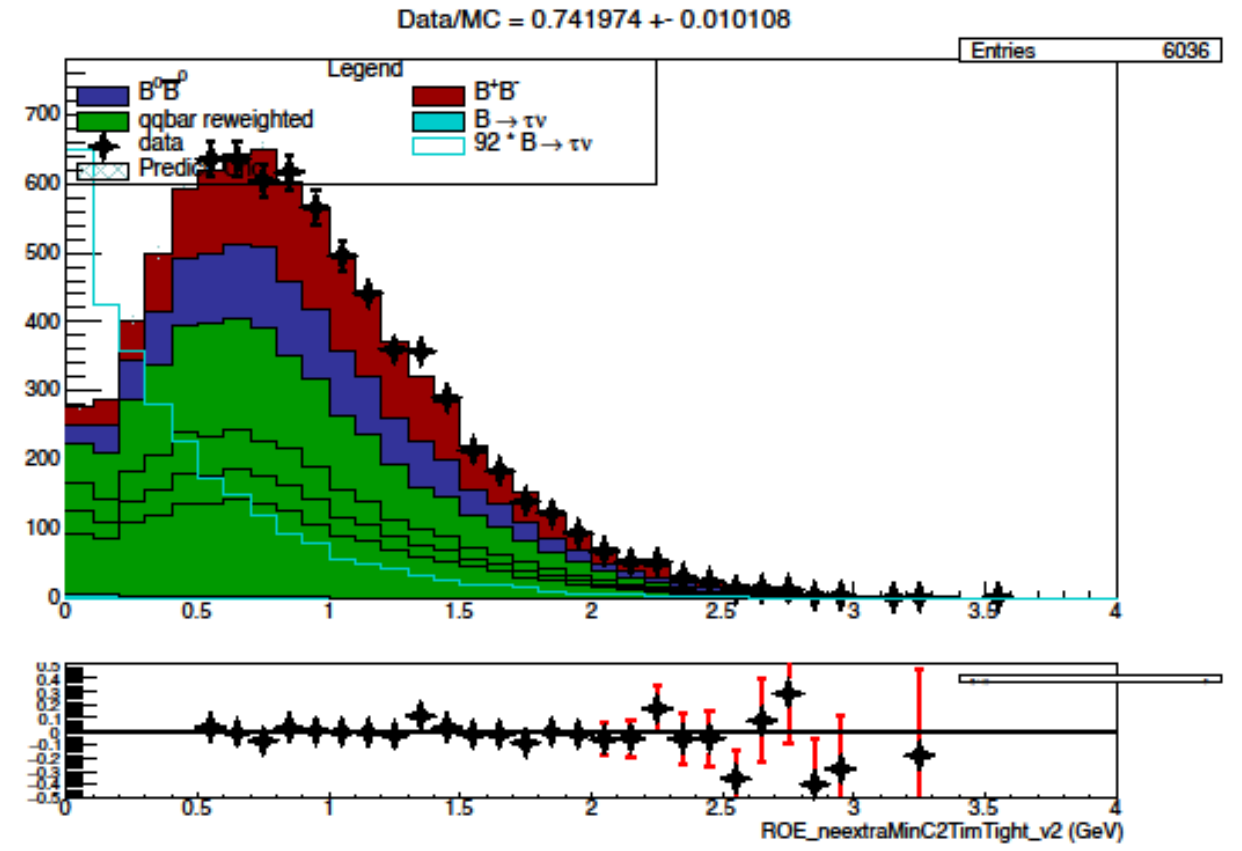


$\tau \rightarrow \rho \nu$

# $E_{ECL}$ distributions after the CS and the rescaling



$\tau \rightarrow \pi\nu$

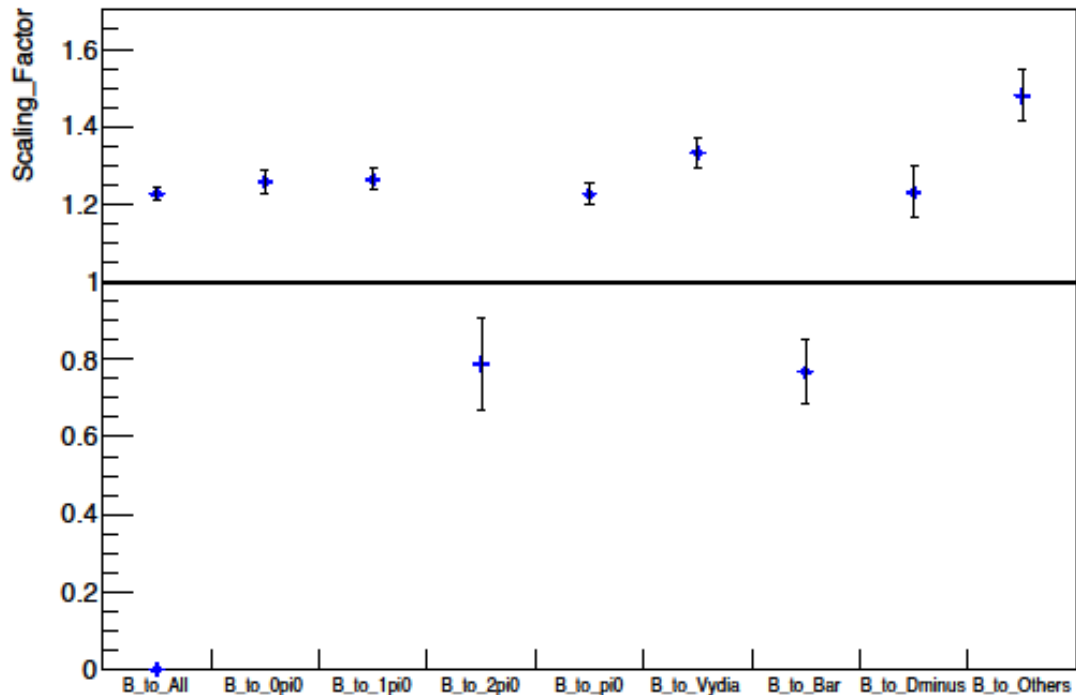


$\tau \rightarrow \rho\nu$

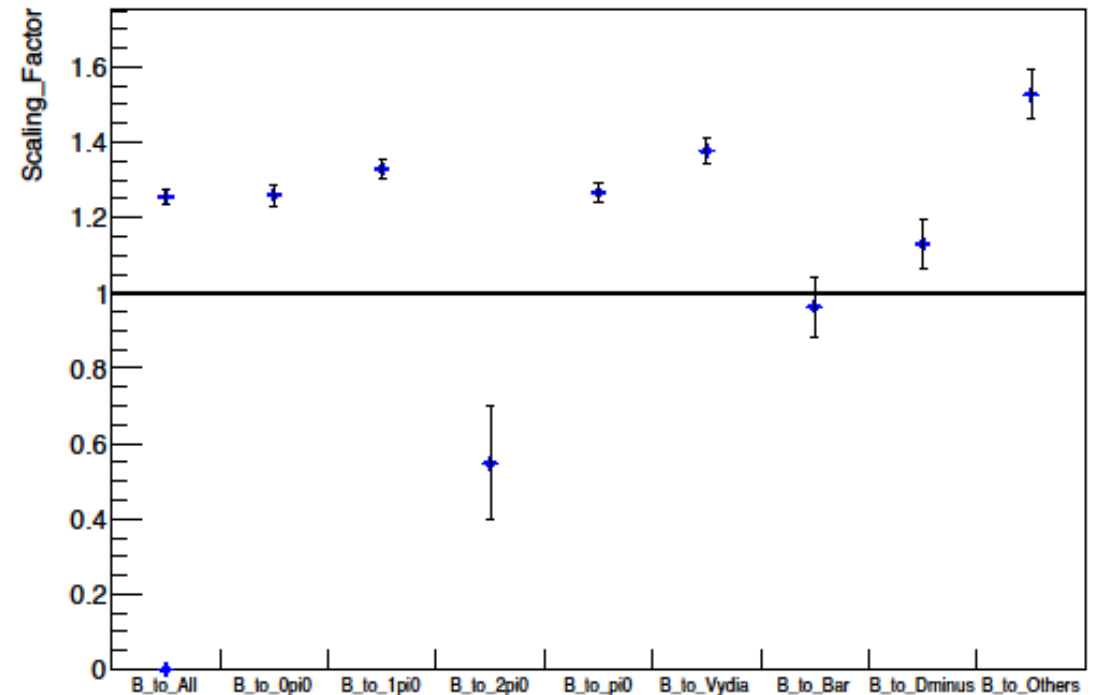


# Scaling factor with the $\Delta E$ fit in the different TagModes

I divided the sample in different groups with respect to the TagModes and we are checking which groups are the most efficient to us. The next step is to check the distribution with these new scaling factors.



$\tau \rightarrow e\nu\nu$

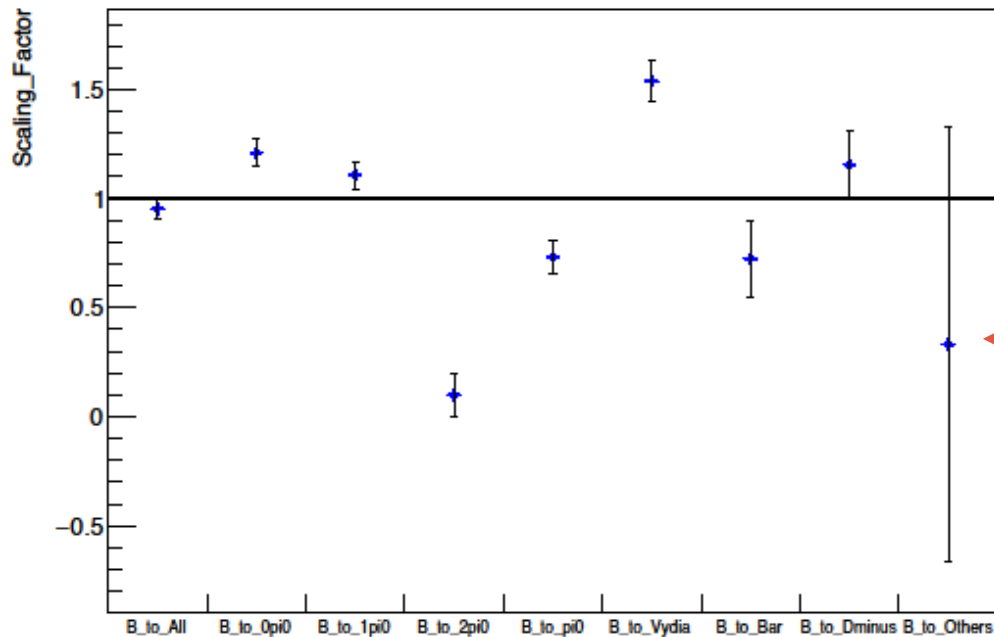


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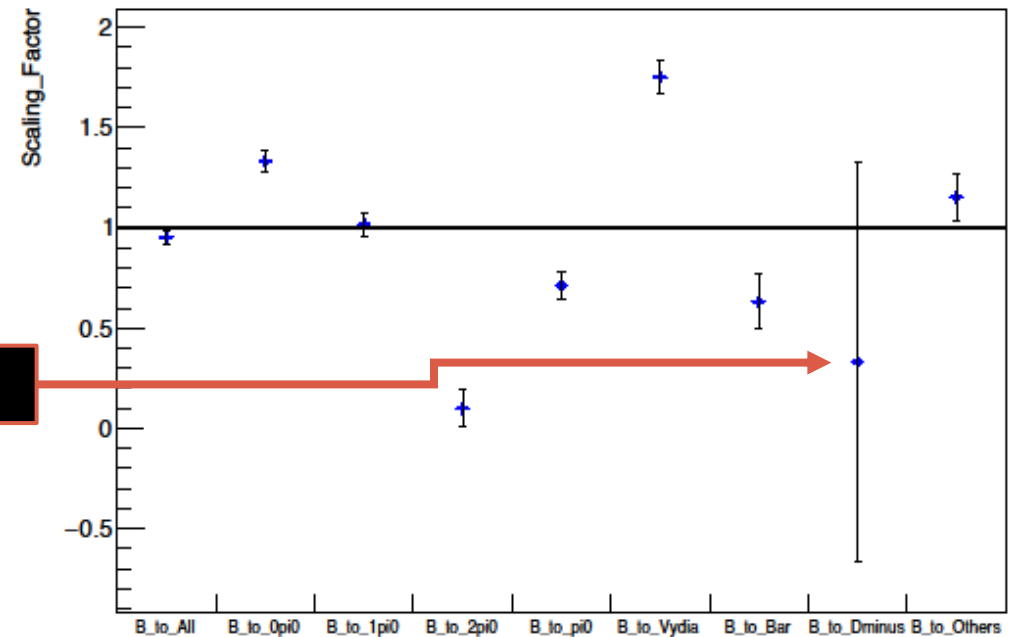
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pi\_idSigProbTot\_Scaling\_Factor



$\tau \rightarrow \pi \nu$

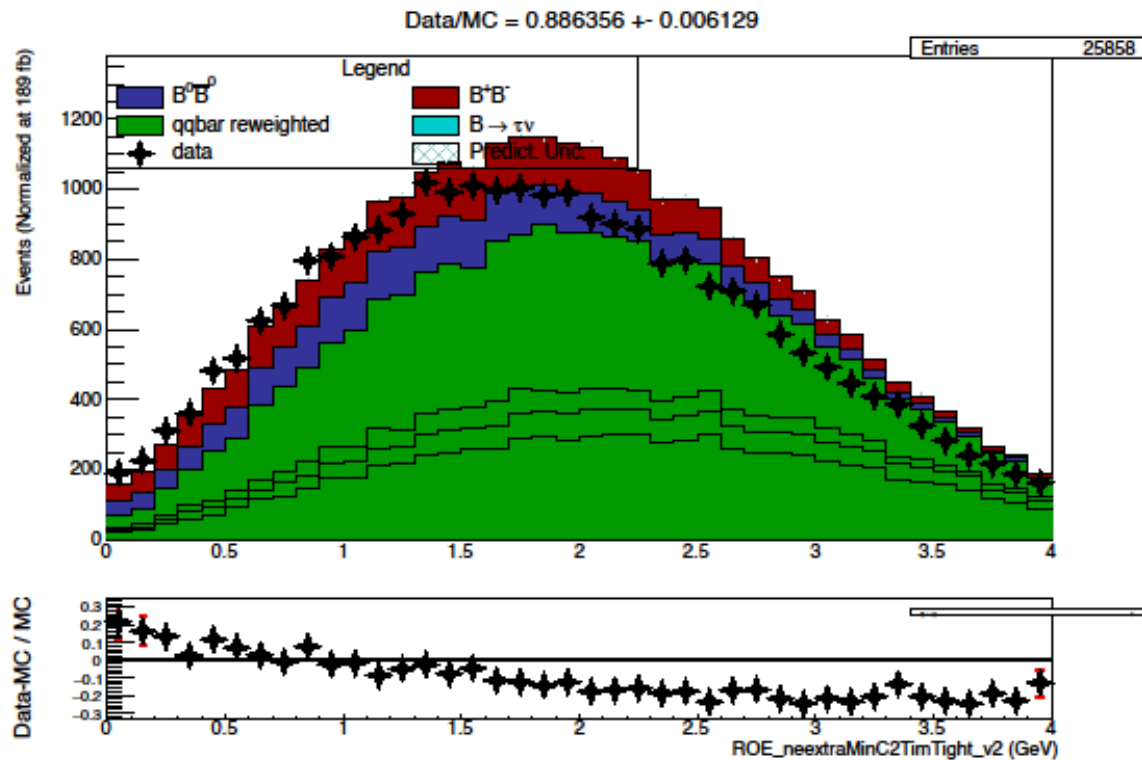
rho\_idSigProbTot\_Scaling\_Factor



$\tau \rightarrow \rho \nu$

The fit failed

# Control Sample $B^+(Had) + e^+$ : preliminary plot



$\tau \rightarrow e \nu \nu$

The  $E_{ECL}$  behaviour seems similar but we still have to do these corrections:

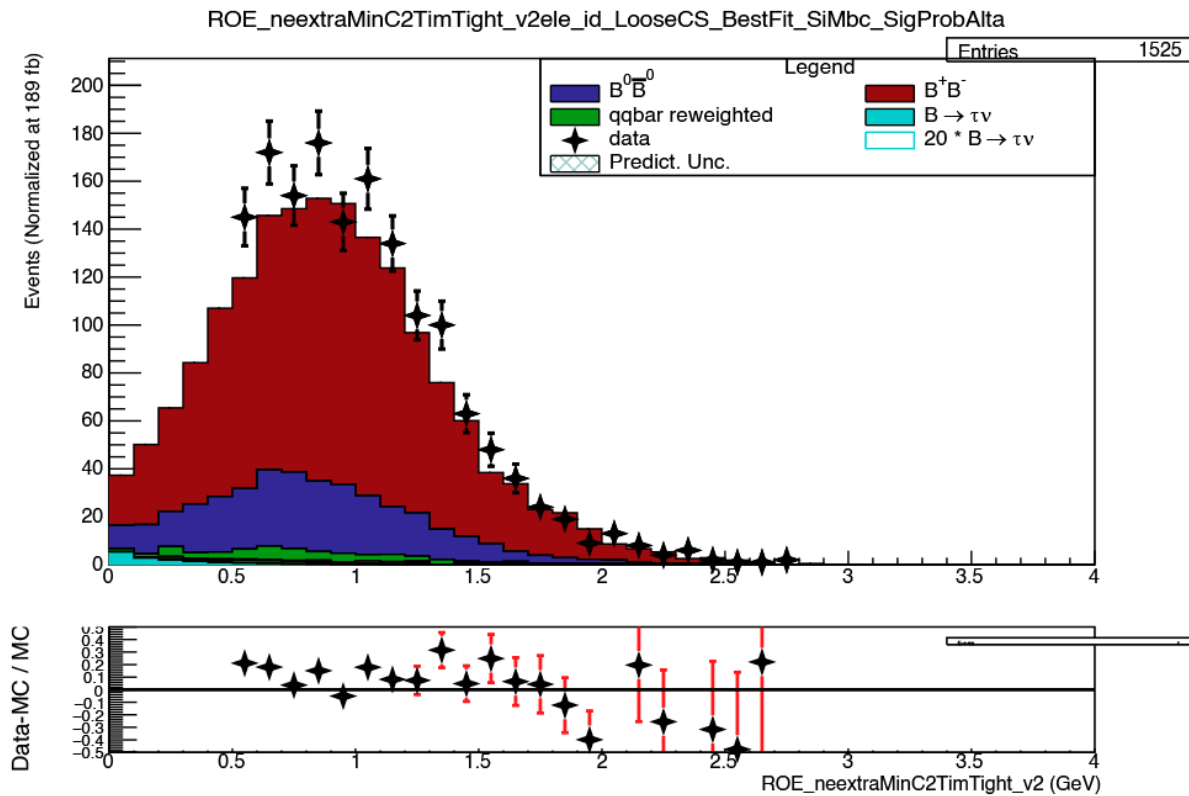
- The continuum must be reweighted and rescaled;
- The FEI Calibration factors must be applied;
- The Personal scaling factors must be found and applied;

**Thanks for the attention!**

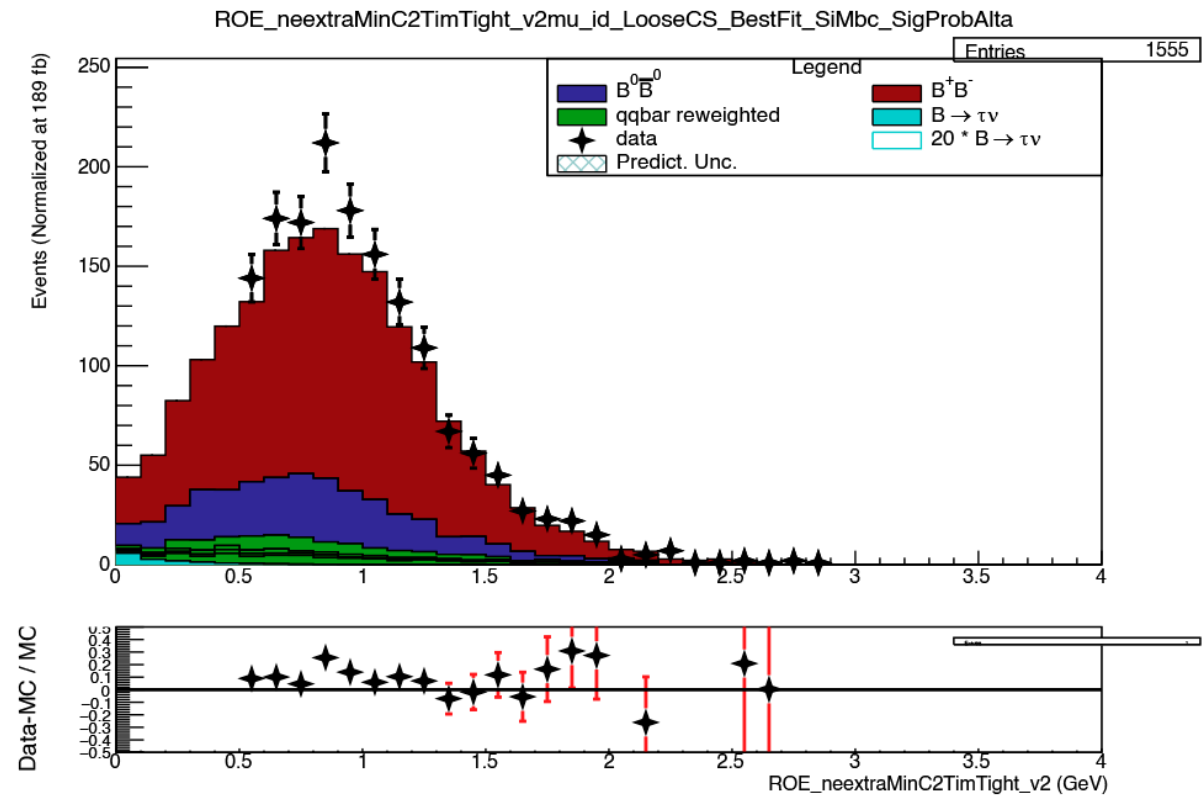
**Backup Slides**

# Best $E_{ECL}$ distributions: leptons

$\tau \rightarrow e\nu\nu$



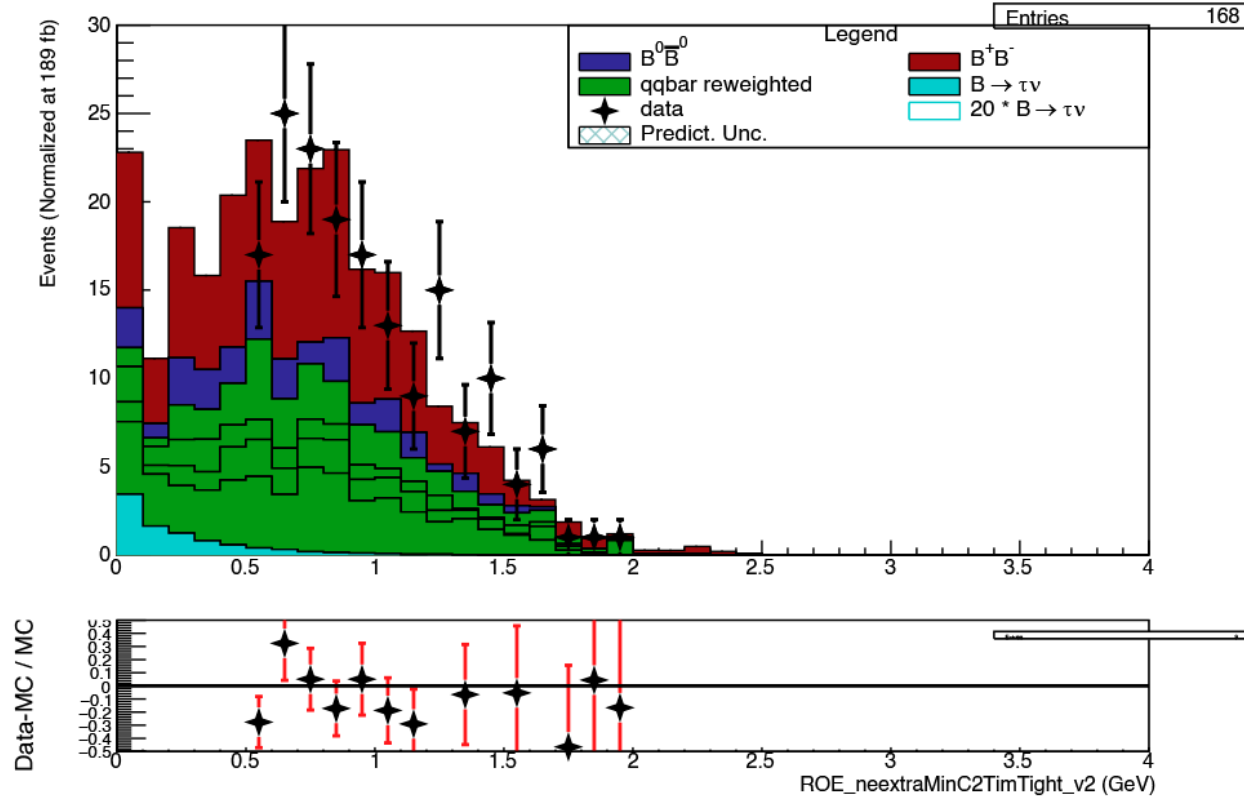
$\tau \rightarrow \mu\nu\nu$



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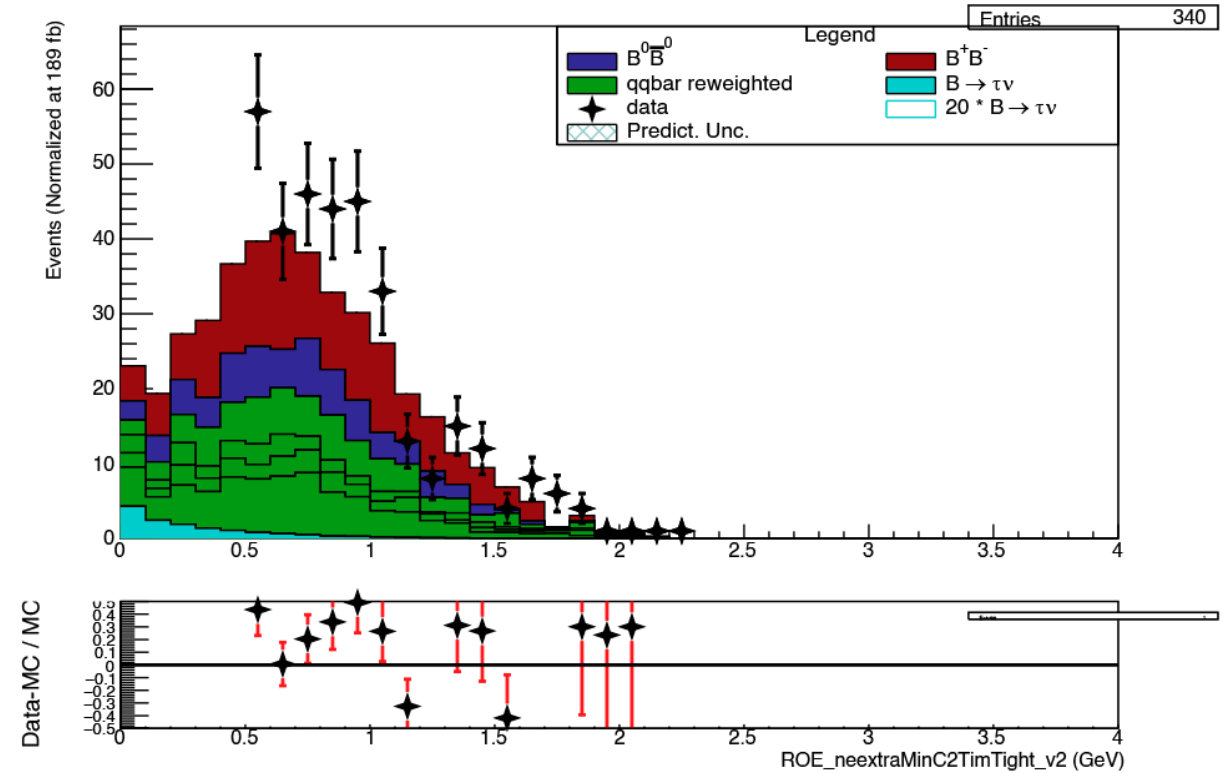
$\tau \rightarrow \pi\nu$

ROE\_neextraMinC2TimTight\_v2pi\_id\_LooseCS\_BestFit\_SiMbc\_SigProbAlta



$\tau \rightarrow \rho\nu$

ROE\_neextraMinC2TimTight\_v2rho\_id\_LooseCS\_BestFit\_SiMbc\_SigProbAlta



# Sensitivity study on Branching Ratio measurement

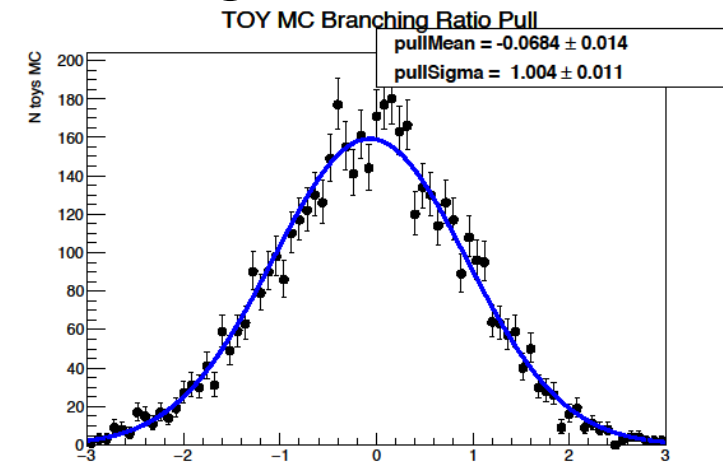
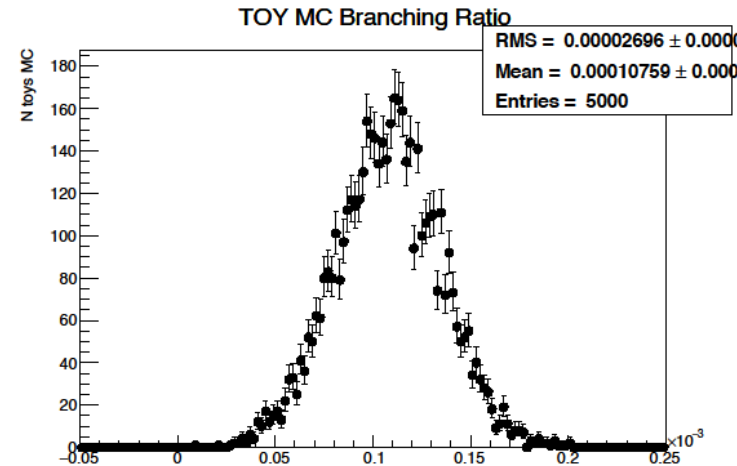
$$\mathcal{L}_k = \frac{e^{-(n_{s,k}+n_{b,k})}}{N_k!} \prod_{i=1}^{N_k} \left\{ n_{s,k} \mathcal{P}_k^s(E_{i,k}) + n_{b,k} \mathcal{P}_k^b(E_{i,k}) \right\}$$

$$n_{s,k} = 2L_{\text{int}} \sigma_{B^+B^-} \varepsilon_k \mathcal{BR}(B \rightarrow \tau \nu) = 2L_{\text{int}} \sigma_{B^+B^-} \frac{N^{\text{reco}}(\tau \rightarrow k)}{N^{\text{gen}}(B \rightarrow \tau \nu)} \mathcal{BR}(B \rightarrow \tau \nu)$$

$\tau \rightarrow$	$P_{\text{min}}(\text{GeV})$	TagProb	$E_{\text{miss}}(\text{GeV})$	BDT
$e\nu\nu$	0.4	0.01	2.5	0.5
$\mu\nu$	0.4	0.01	2.5	0.5
$\pi\nu$	1.2	0.01	2	0.5
$\rho\nu$	1.3	0.01	2	0.5

Optimal cut configuration by minimizing relative uncertainty on the Branching Ratio with TOY MC  
 The fit will be performed on «the best»  $E_{ECL}$  distribution: that is the one that gives the best relative error

Branching Ratio prediction in a simultaneous fit @ 364 /fb  
 $BR = 1.08 \pm 0.29$   
 Relative Error = 0.2677





# Reconstruction and preselection

- FEI Hadronic for  $B_{tag}$  with TagProb > 0.001
- $B_{sig} \rightarrow \tau \nu \rightarrow$ 
  1.  $\tau \rightarrow e$  (Track criteria + PID > 0.9)
  2.  $\tau \rightarrow \mu$  (Track criteria + PID > 0.9)
  3.  $\tau \rightarrow \pi$  (Track criteria + PID > 0.6 + !e + ! $\mu$ )
  4.  $\tau \rightarrow \pi\pi^0$  (same as  $\pi$  and  $\gamma$  for  $\pi^0$  criteria) (best  $\rho$  mass)
- We choose the candidate with the Best Tag Probability after the signal reconstruction
- Rest of Event requirements
  1. 0 Extra Tracks
  2. Extra neutral clusters with photon criteria

## Track criteria:

1.  $dr < 0.5$  cm
2.  $|dz| < 2$  cm
3.  $\vartheta$  in CDC Acceptance
4.  $p_{CMS} > 0.1$  GeV
5.  $nCDC\ Hits > 20$

## Photon criteria:

1.  $E > 50$  MeV
2.  $\vartheta$  in ECL Acceptance
3.  $minC2Tdist > 20$  cm
4.  $|t| < 200$  ns
5.  $|t|/\sigma_t < 2$

$\gamma$  for  $\pi^0$  criteria:  $\pi^0 eff40$  list