$B \to \tau\nu$ Branching Ratio with Hadronic FEI

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SSM Scuola Superiore Meridionale

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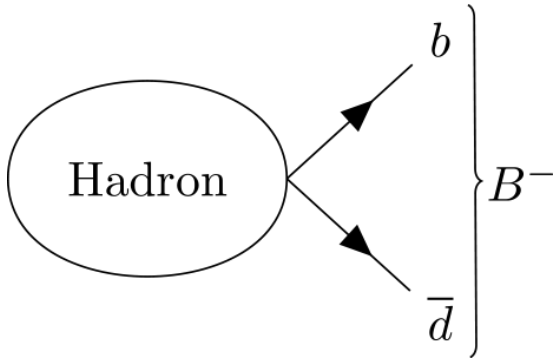
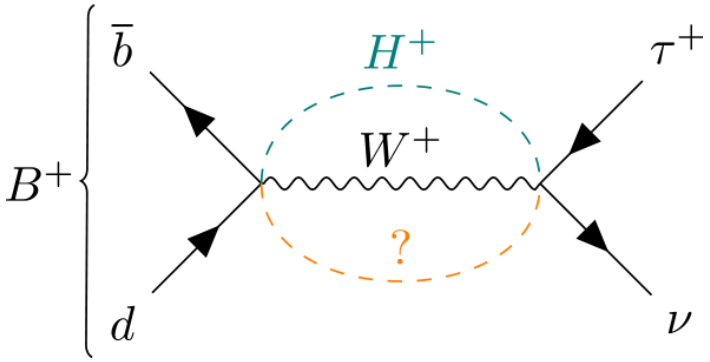
Belle II

$B \to \tau\nu$ decay with Hadronic FEI

Hadronic FEI Skim

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





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

Very clean theoretically, hard experimentally

Standard Model is helicity suppressed

- 1 track with PID request (e, μ or π) with $p > 0.4$ GeV
- π^0 for $\tau \to \rho\nu \to \pi\pi^0\nu$ decay

Rest of Event

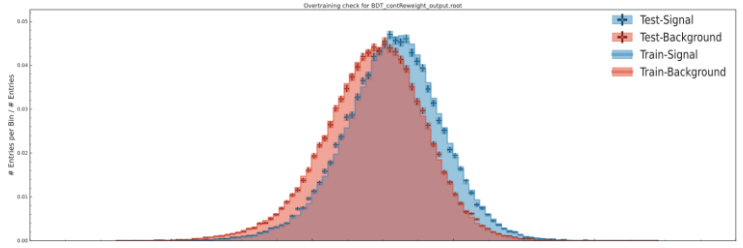
- 0 Extra Tracks (from IP)
- Extra Energy in ECL must be 0 in signal events and larger in background.

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 τ decay);

The $q\overline{q}$ MC background is
1. Reweighted with a BDT-weight
2. Normalized to off peak yield



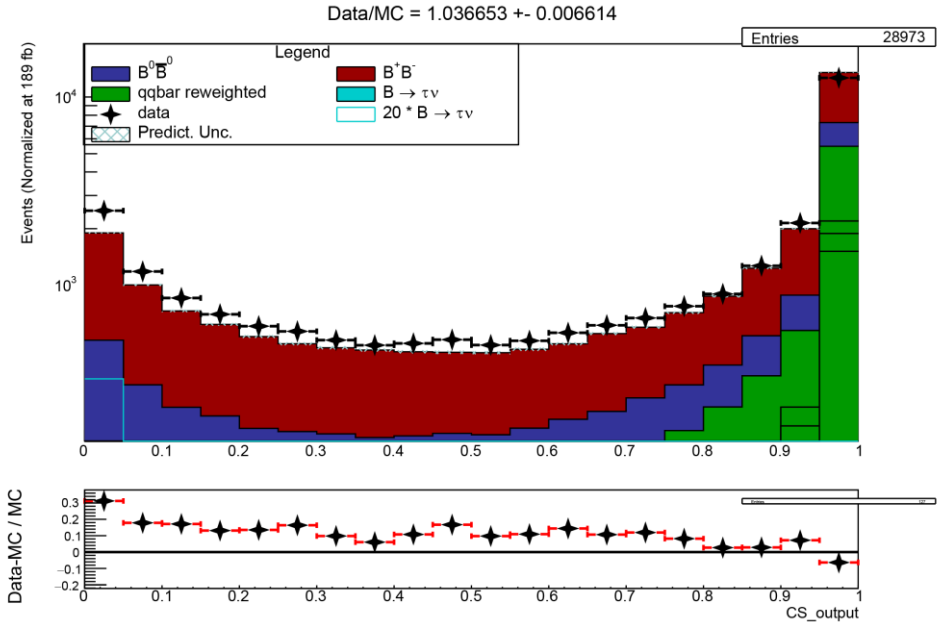
BDT output

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

Taken from here

In order to reject the $q\overline{q}$ 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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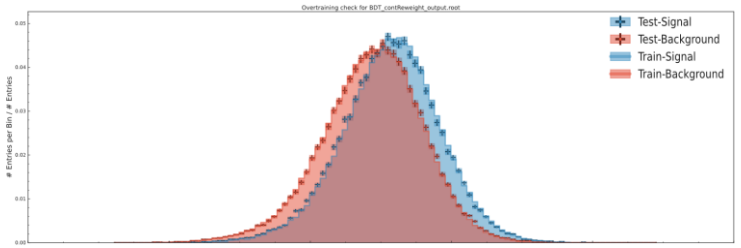

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We performed a fit to data in ΔE distribution to normalize the $B\overline{B}$ component in the E_{ECL} sideband (more in next slides).

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

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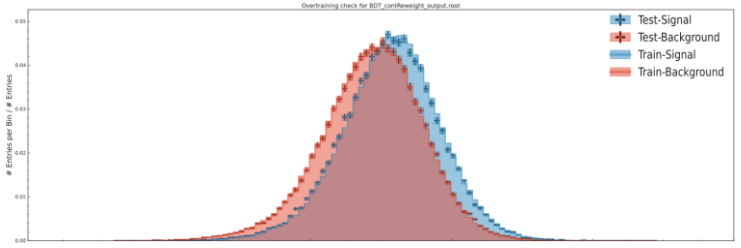

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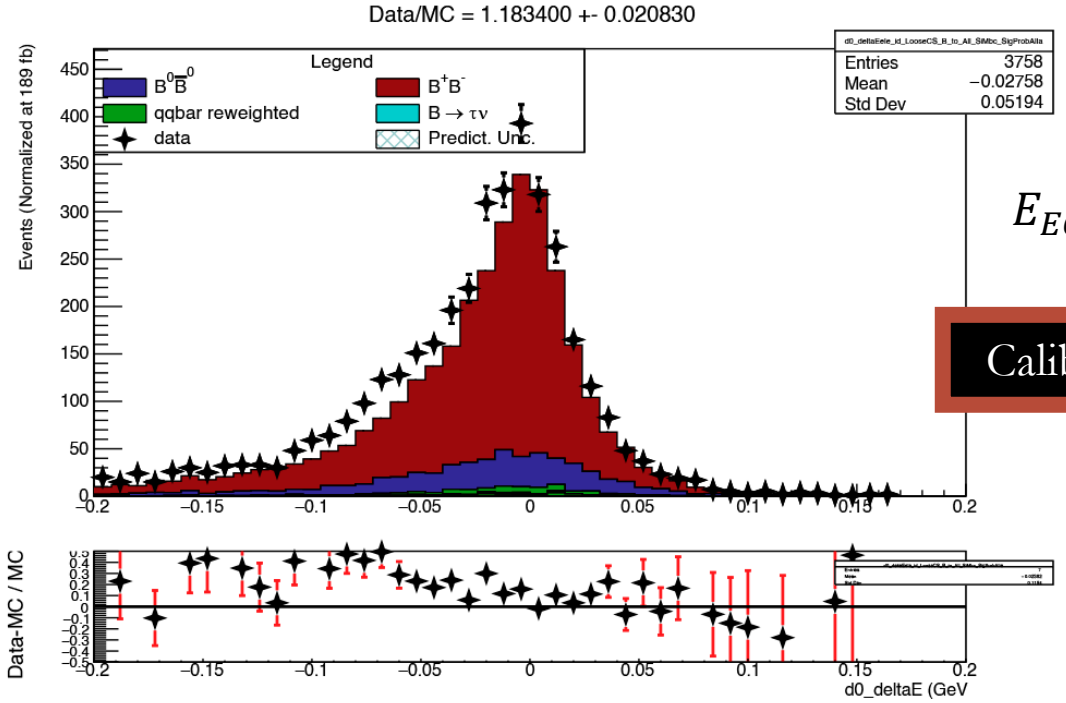
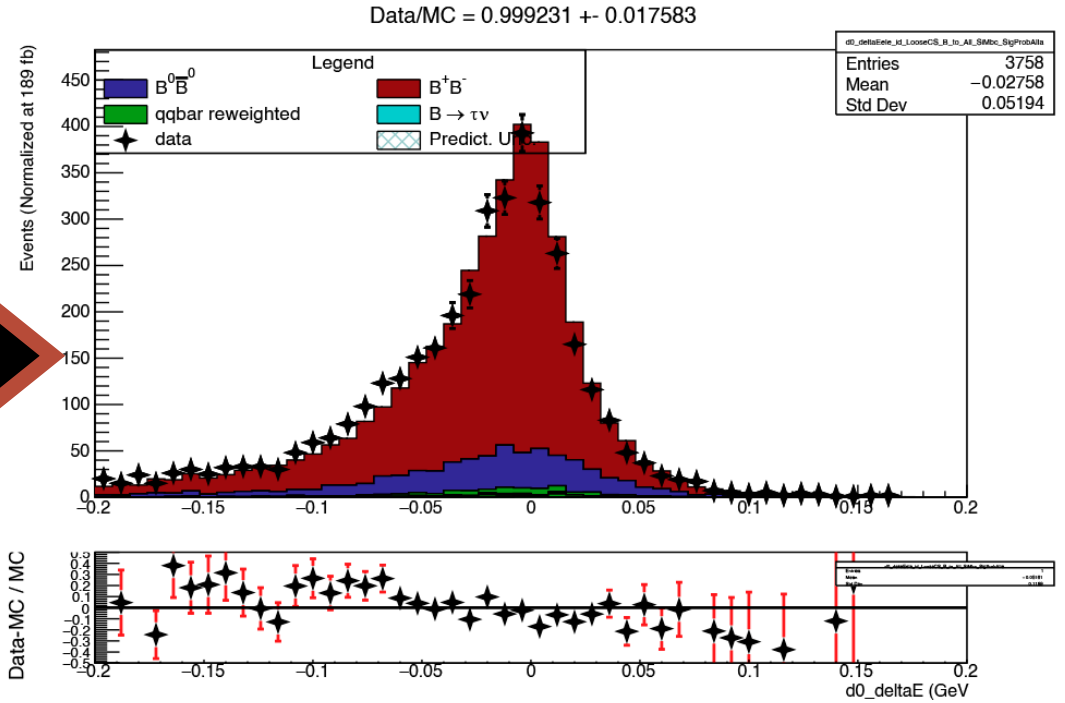
The ΔE distribution

The ΔE 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.



$E_{ECL} > 0.5\ GeV$

Calib. factor = 1.19



Electron channel

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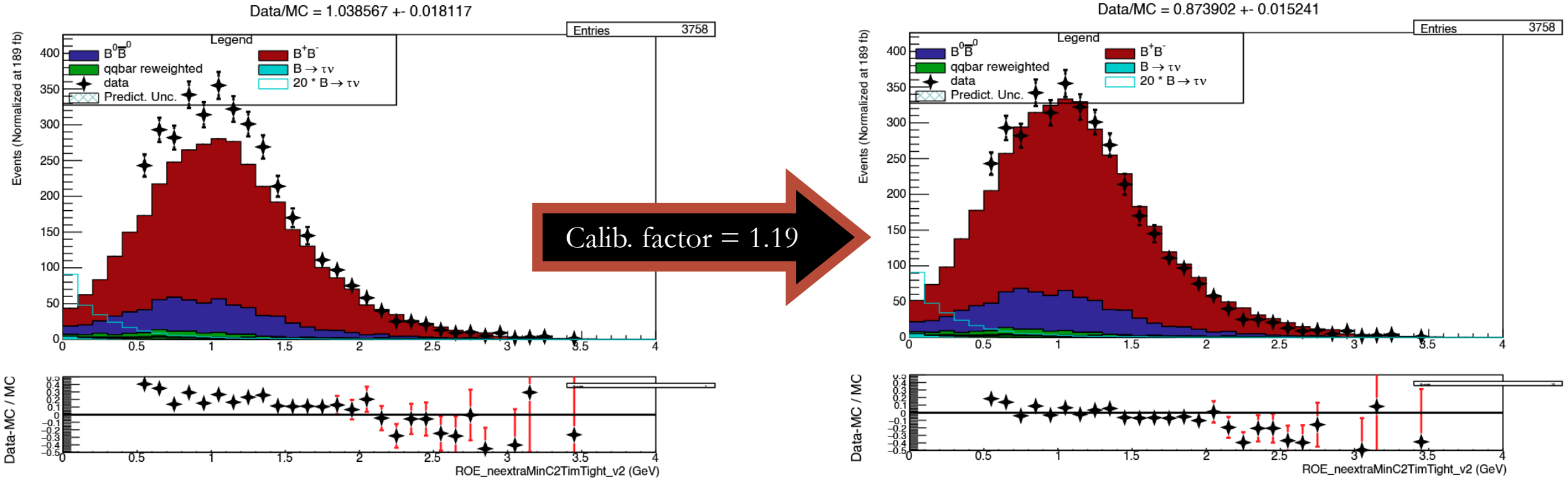

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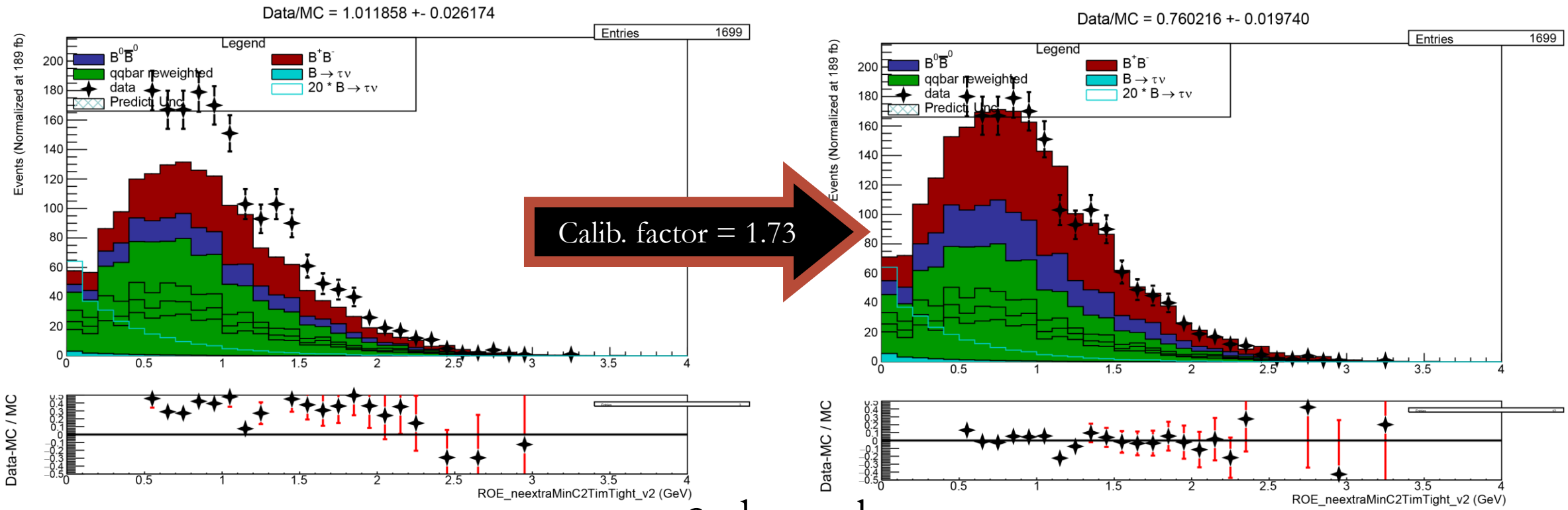


ρ channel

Results and conclusions

We obtained these values:

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

Checks and questions

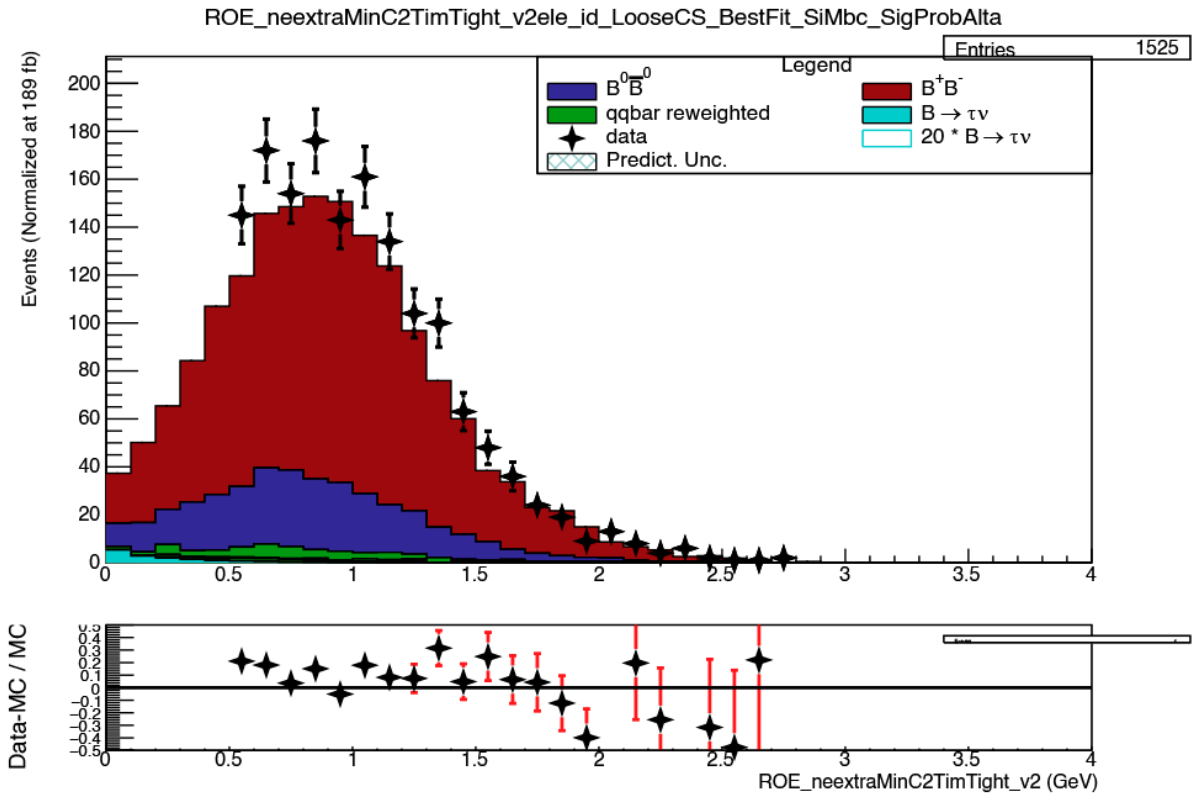
1. Should we also apply the scaling factor to signal MC?

2. The scaling factor changes in the different channels and in the different Tag Probability cuts: has this behaviour a physical explaination?

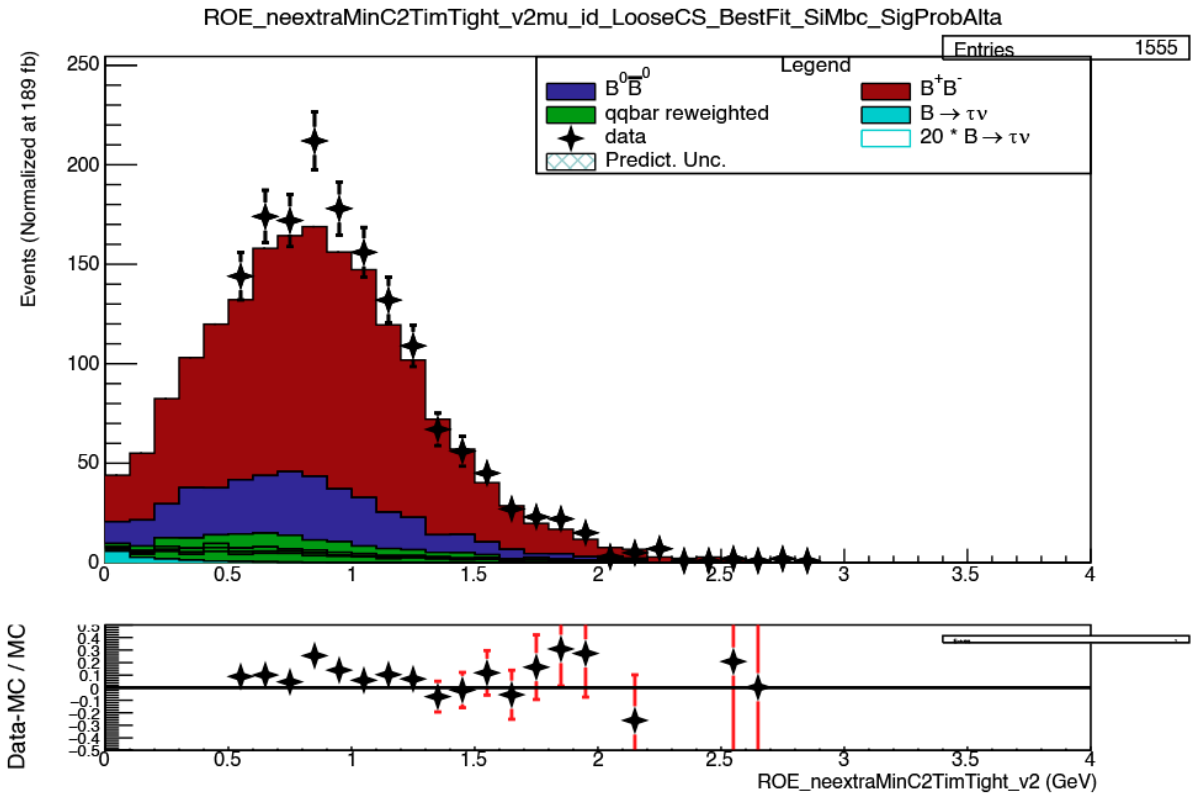
Backup slides

Best E_{ECL} distributions: leptons

$\tau \to e\nu\nu$

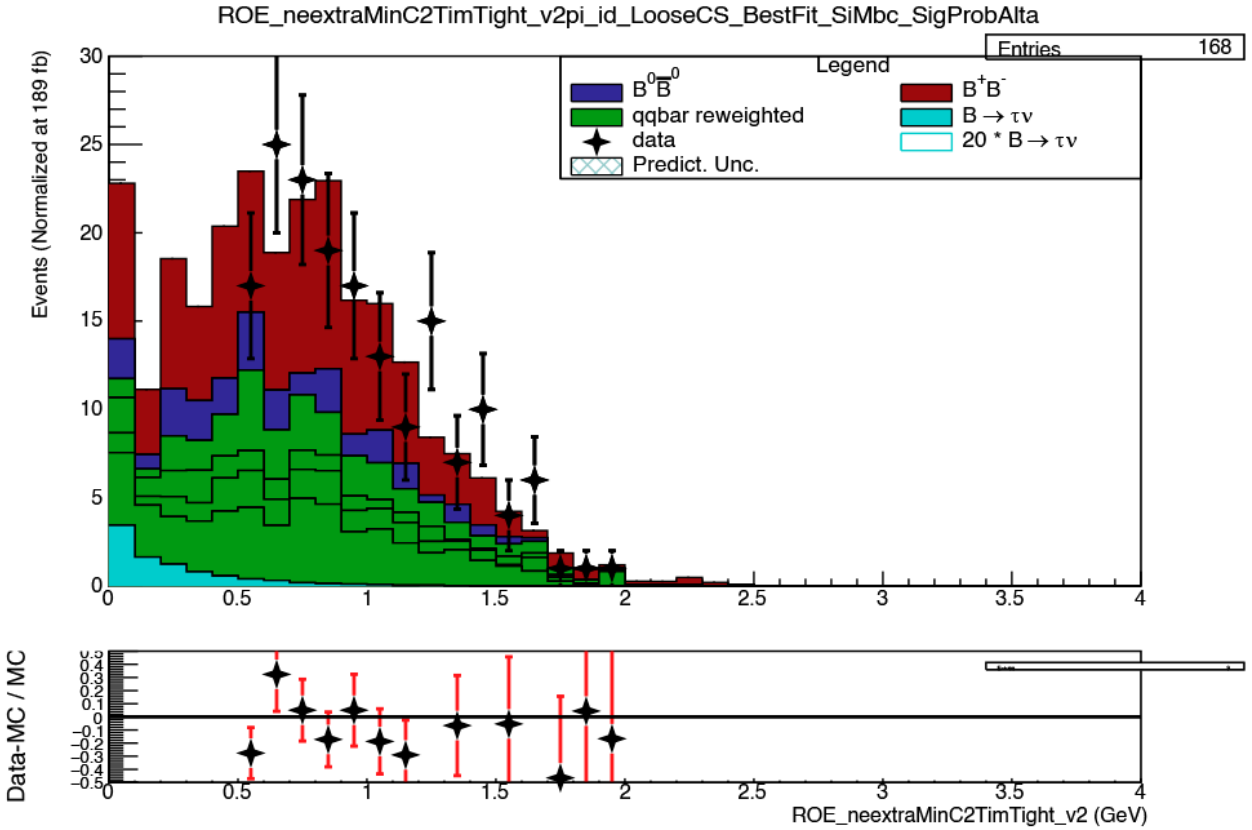


$\tau \to \mu\nu\nu$

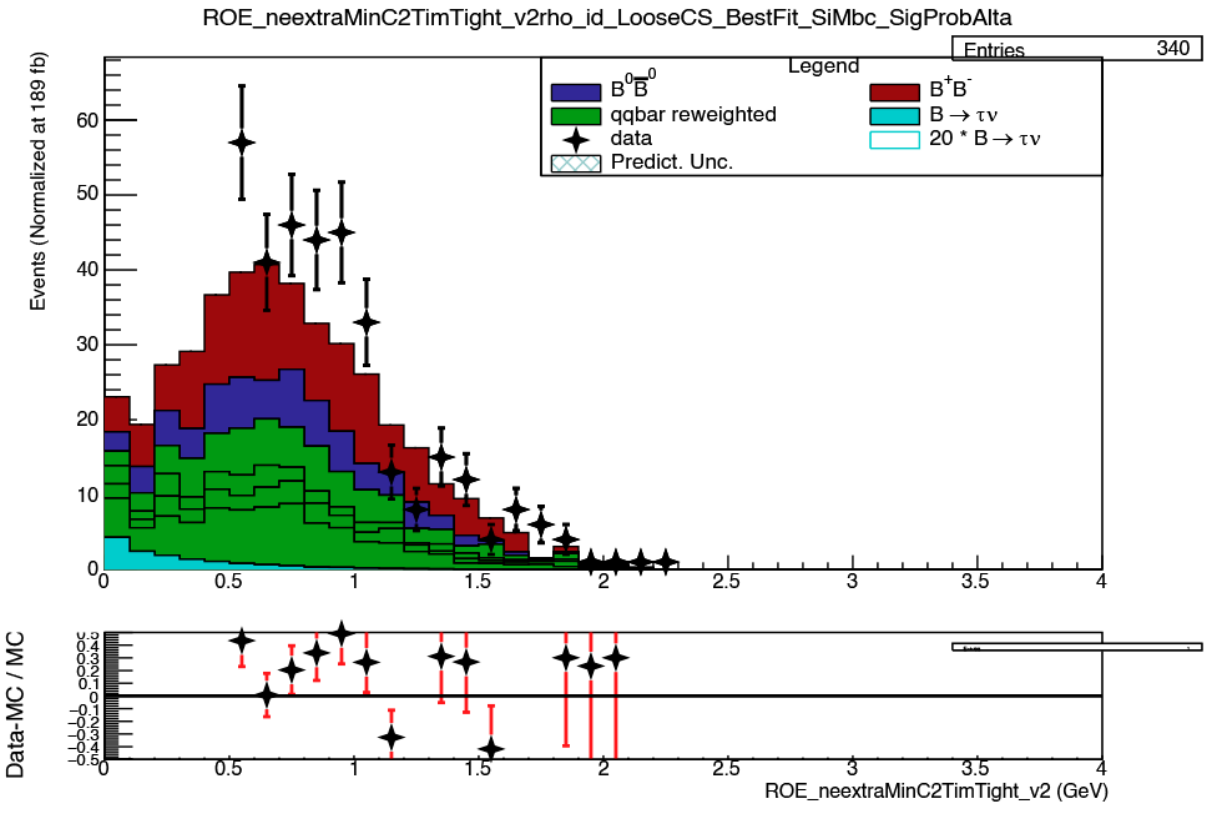


Best E_{ECL} distributions: leptons

$\tau \to \pi\nu$



$\tau \to \rho\nu$



Sensitivity study on Branching Ratio measurement

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

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

$\tau\to$	P_{min}(GeV)	TagProb	E_{miss}(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

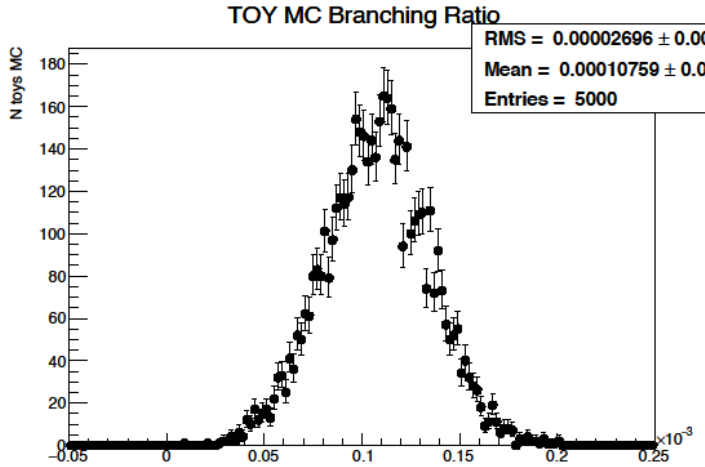
Optimal cut configuration by minimizing relative uncertanty on the Branching Ratio with TOY MC

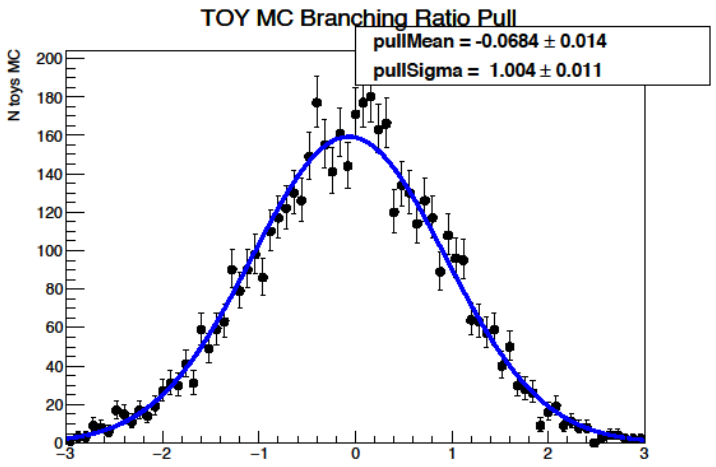
The fit will be performed on «the best» E_{ECL} distribution: that is the one that gives the best relative error

Branching Ratio prediction in a simultaneous fit @ 364 /fb

$BR = 1.08 \pm 0.29$

Relative Error = 0.2677





Reconstruction and preselections

- FEI Hadronic for B_{tag} with TagProb > 0.001

- $B_{sig} \to \tau\nu \to$
  1. $\tau \to e$ (Track criteria + PID > 0.9)
  2. $\tau \to \mu$ (Track criteria + PID > 0.9)
  3. $\tau \to \pi$ (Track criteria + PID > 0.6 + !e + ! μ)
  4. $\tau \to \pi\pi^0$ (same as π and γ for π^0 criteria) (best ρ 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. ϑ in CDC Acceptance
4. $p_{CMS} > 0.1$ GeV
5. $nCDC\ Hits > 20$

Photon criteria:

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

γ for π^0 criteria: $\pi^0 eff40$ list