Top-quark charge asymmetry in $t\bar{t} + jets$ events

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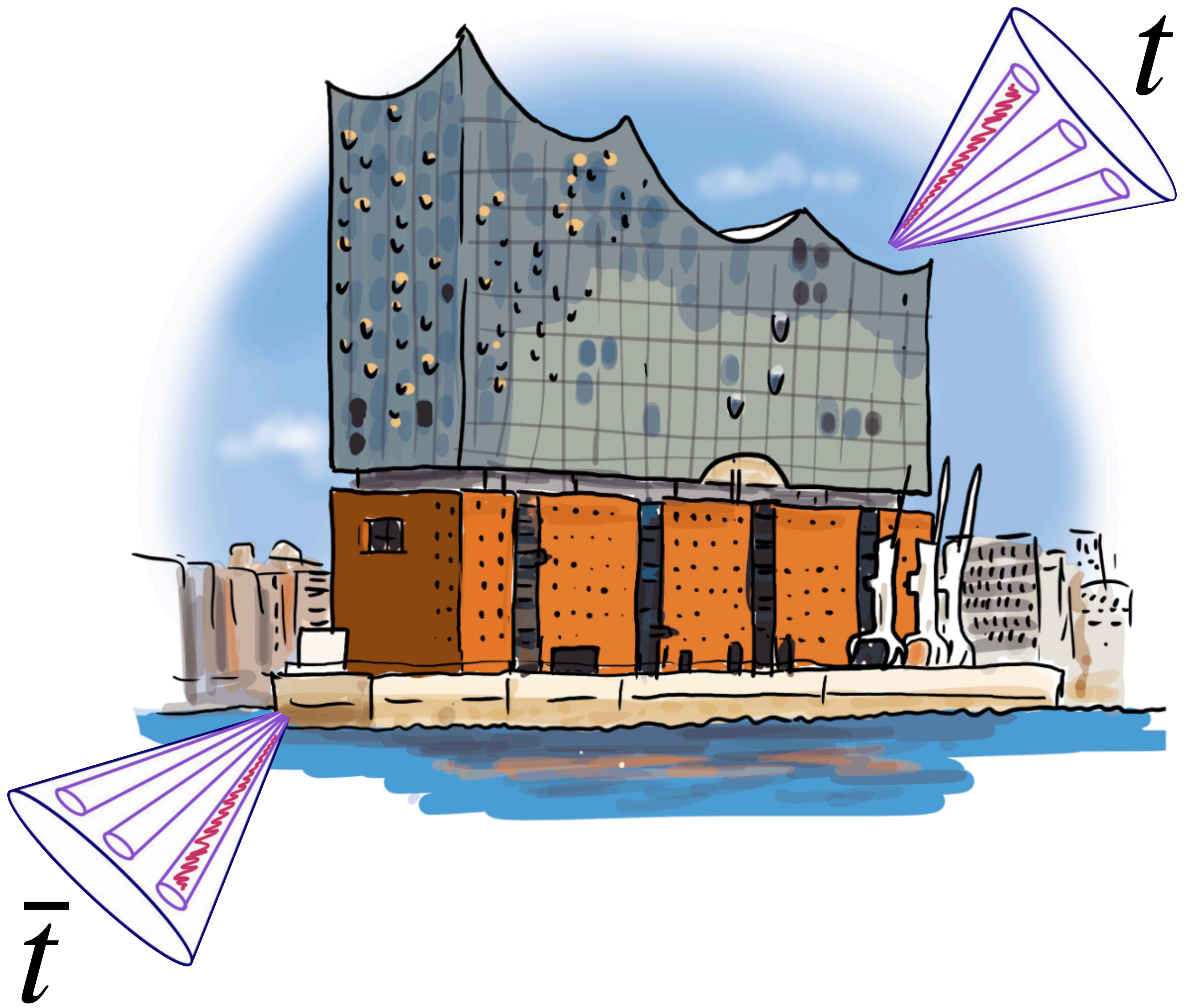

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New observables for the top charge asymmetry at the LHC

In contrast to AC in $t\bar{t}$ production, the asymmetry in $t\bar{t}$ + j final states has the advantage that it is non-vanishing at LO and NLO calculations are available

1. The incline asymmetry tests the charge asymmetry of the qq-channel with expected asymmetries of up to −4% (depending of the phase space definition)

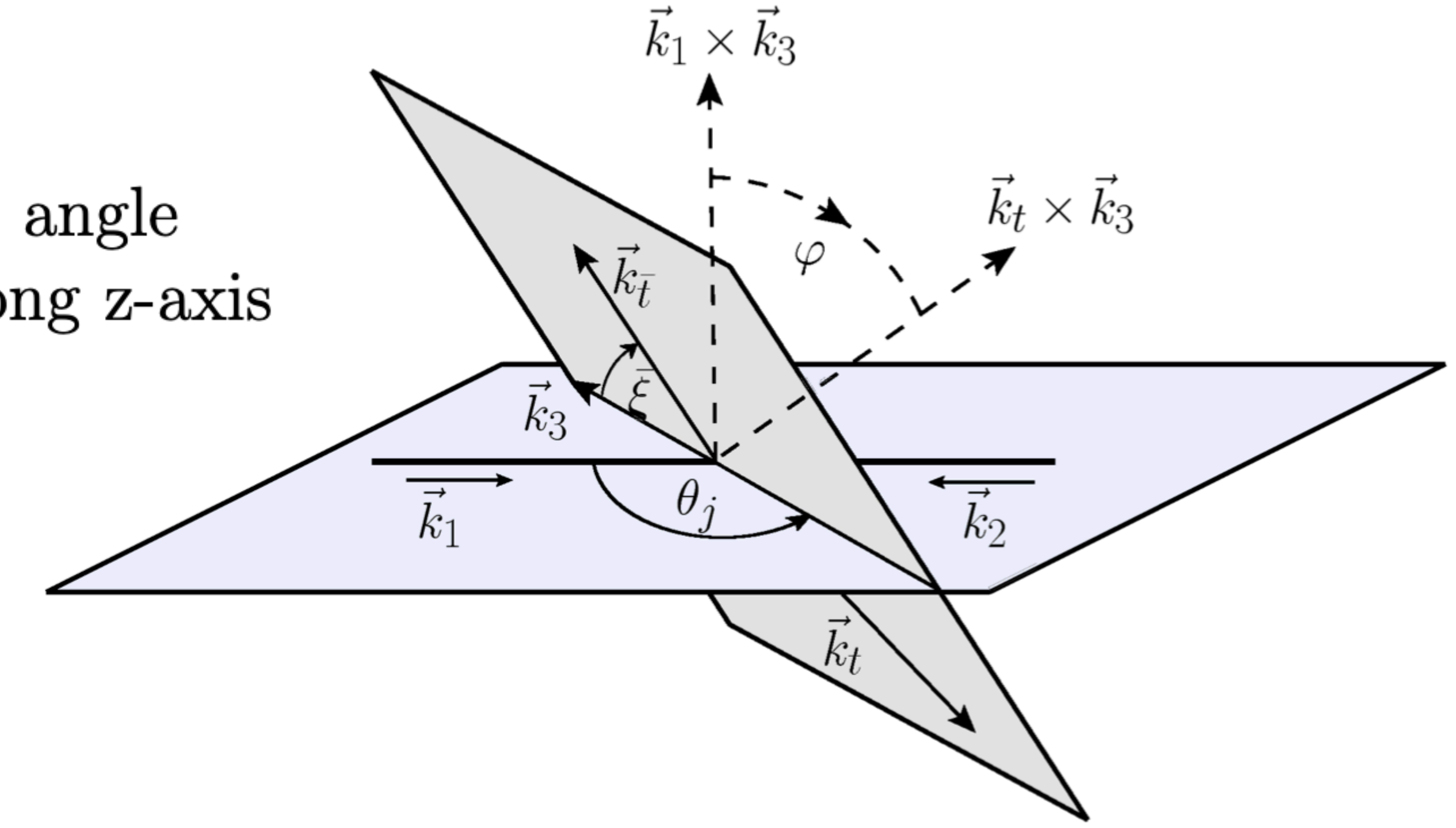
2. The energy asymmetry tests the charge asymmetry of the qg-channel with expected asymmetries of up to −11%

Incline Asymmetry at the LHC

Incline asymmetry $A^{\varphi,q}$ tests the charge asymmetry of the $q\bar{q}$-channel

$$A^{\varphi,q} \equiv \frac{\sigma_A^{\varphi}(y_{t\bar{t}j} > 0) - \sigma_A^{\varphi}(y_{t\bar{t}j} < 0)}{\sigma_S}$$

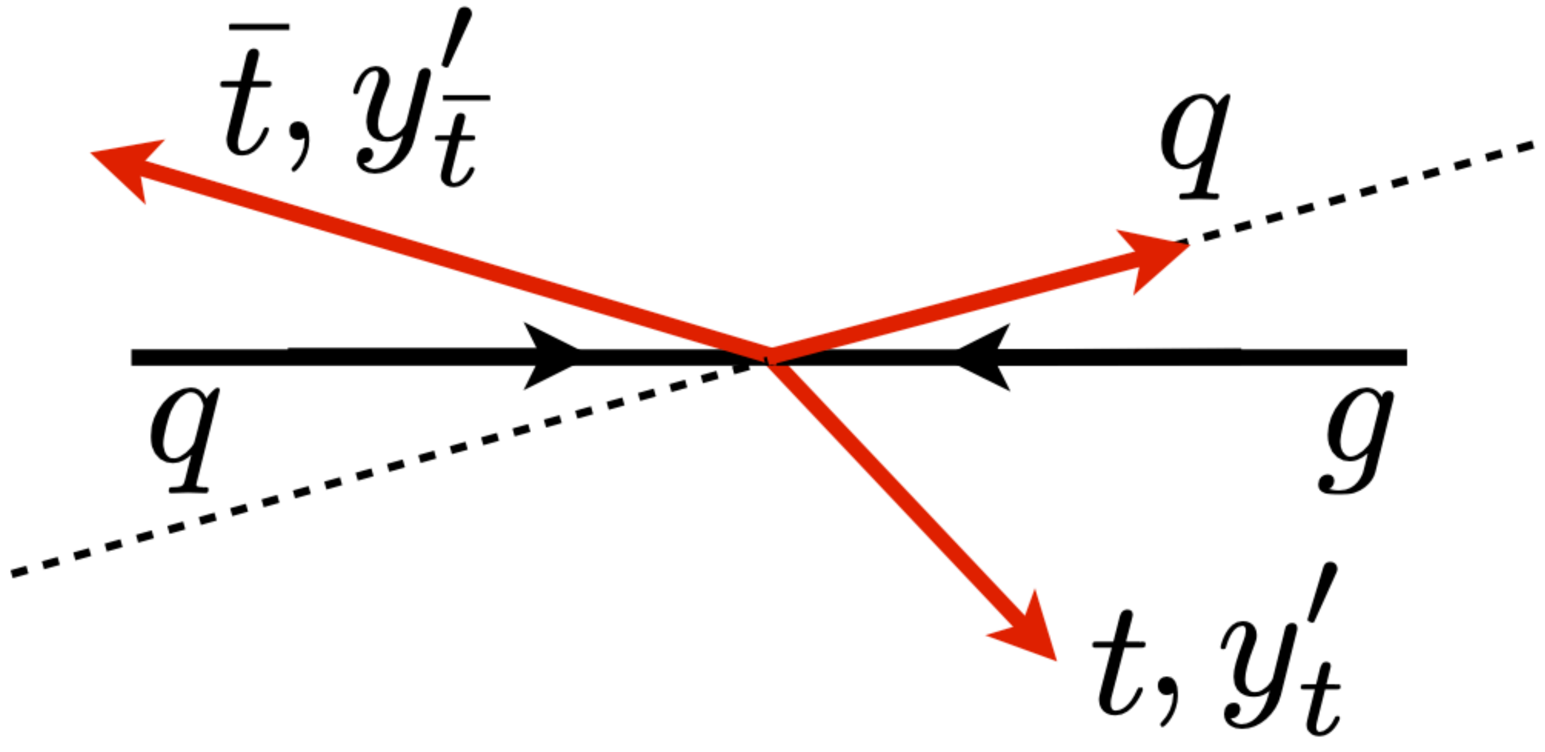
φ ... inclination angle
y_{ttj} ... boost along z-axis



Energy Asymmetry at the LHC

Energy asymmetry AE tests the charge asymmetry of the qg-channel $q\bar{q}$ contribution to A^E is exactly zero

$$A^E = \frac{\sigma_A(\Delta E \geq 0)}{\sigma_S} \qquad \Delta E = E_t - E_{\bar{t}}$$



$\Delta E, \varphi, y_{ttj}$ are all defined in the ttj CM rest frame

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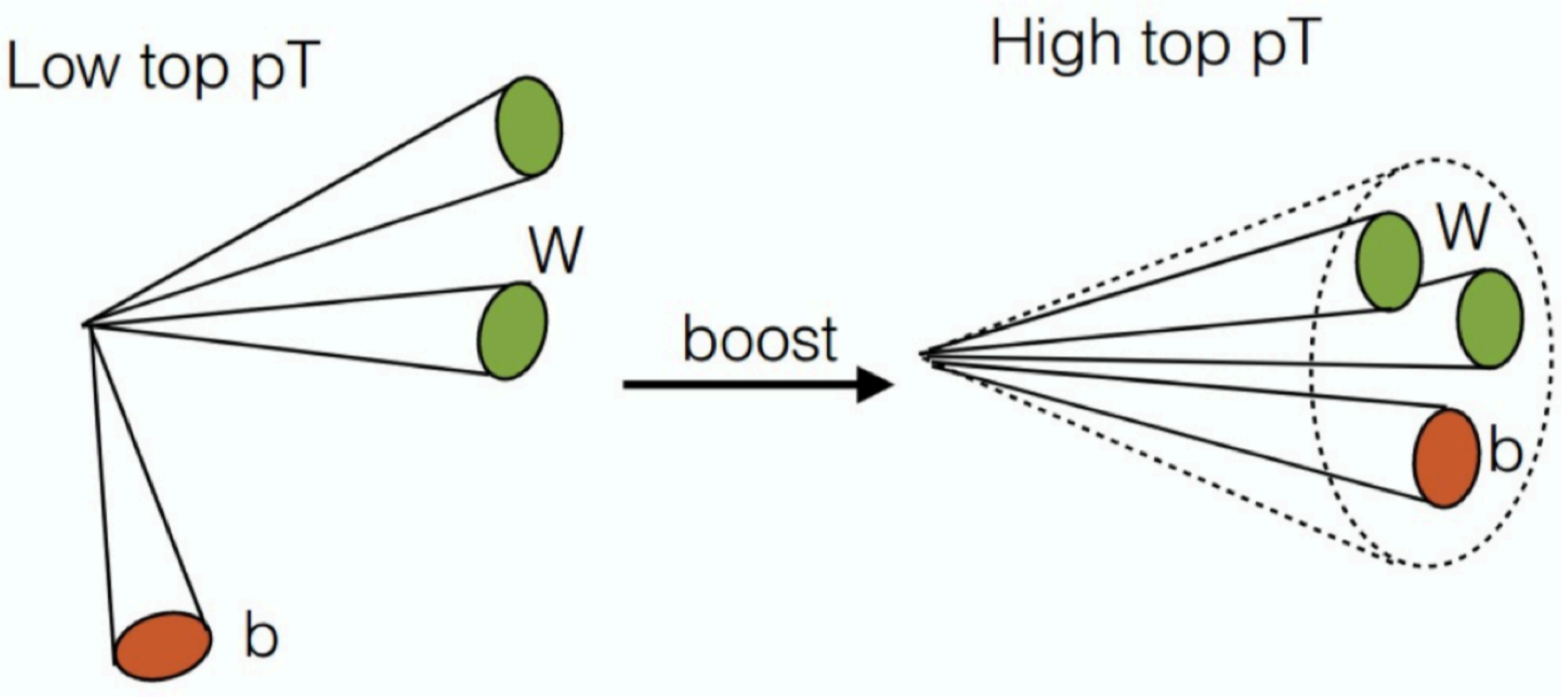
Baseline selection for semileptonic channel

- HLT_Mu50_v* / HLT_Ele50_WPTight_Gsf_v* or HLT_Ele115_CaloIdVT_GsfTrkIdT_v* (No isolation requirement!)
- 2D kinematic cut:
  - $\Delta R(l,j) > 0.4$ **OR**
  - $p_T^{rel}(l,j) > 25$ GeV
- Exactly one muon(electron)
  - Tight identification requirements for both e and μ channels
  - p_T^{lep} > 55(80) GeV and $|\eta|$ < 2.4
- MET > 50 GeV; H_T^{lep} > 150 GeV
- At least three high p_T AK4 jets with $|\eta|$ < 2.4
  - p_T(jet1) >150 GeV & p_T(jet2) > 50 GeV, p_T(add) > 100 GeV
- At least 1 b-jet identified with the medium criteria of the CMS DeepJet algorithm
- $M_{t\bar{t}}$ > 500 GeV, $\frac{1}{4}\pi < \theta_j^{opt} < \frac{3}{5}\pi,\ \chi^2 > 30$

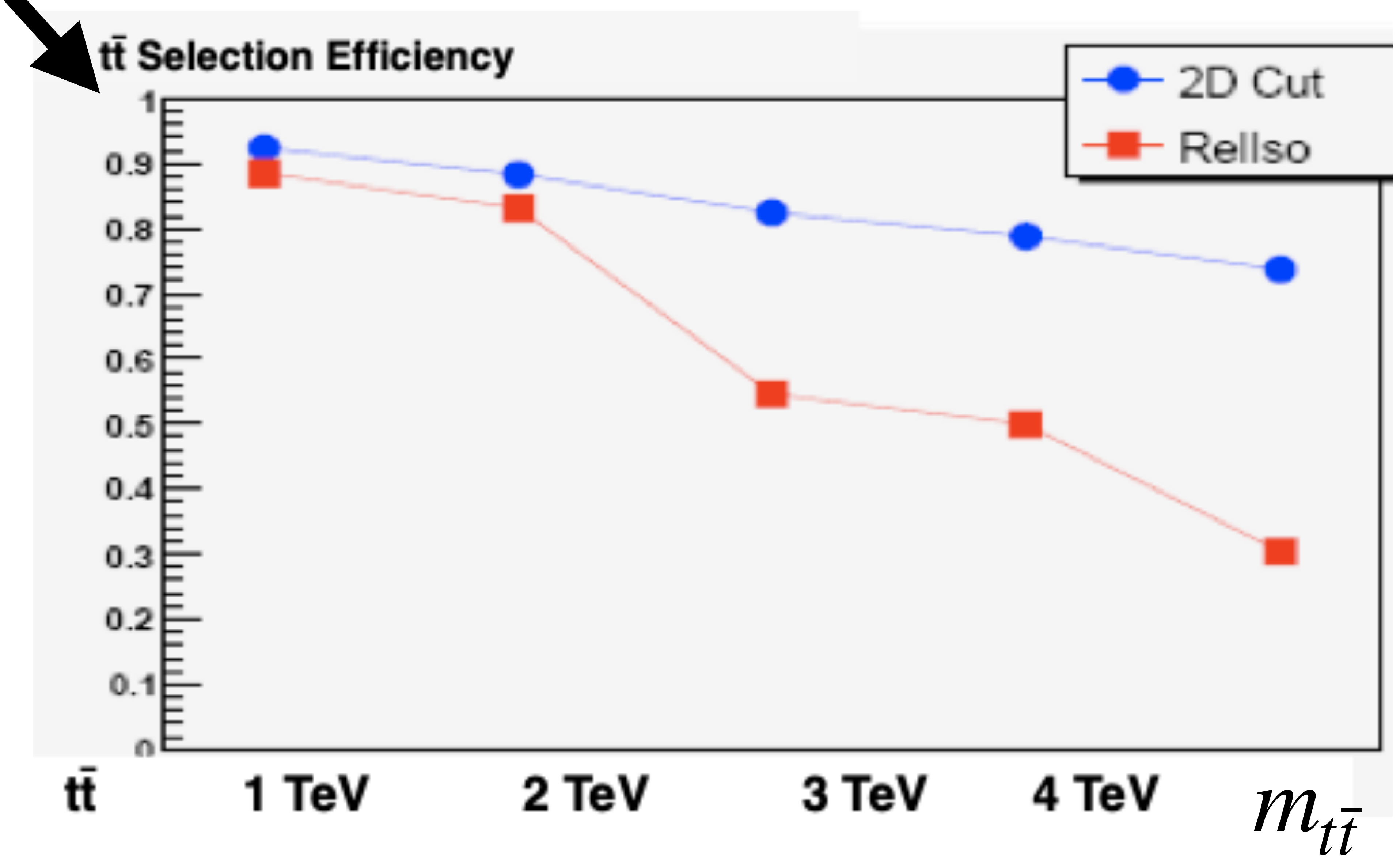
$$\theta_j^{opt} = \begin{cases} \theta_j & if\ \ y_{t\bar{t}j} > 0 \\ \pi - \theta_j & if\ \ y_{t\bar{t}j} < 0 \end{cases}$$

- AK8 PUPPI jets with p_T > 400 GeV and $|\eta|$ < 2.4 (in case of Boosted or Semi-Resolved reconstruction)



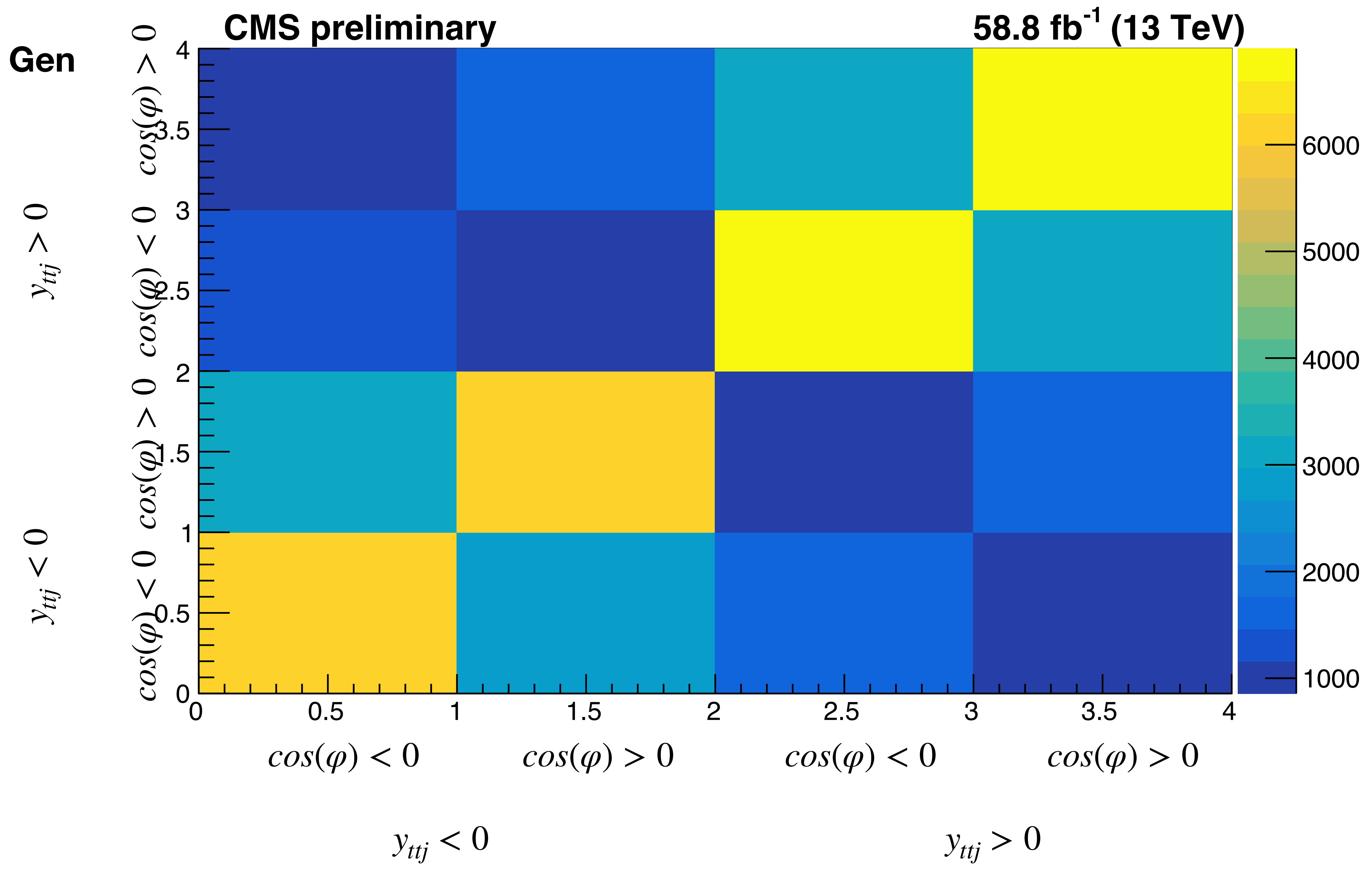
For boosted reconstruction:

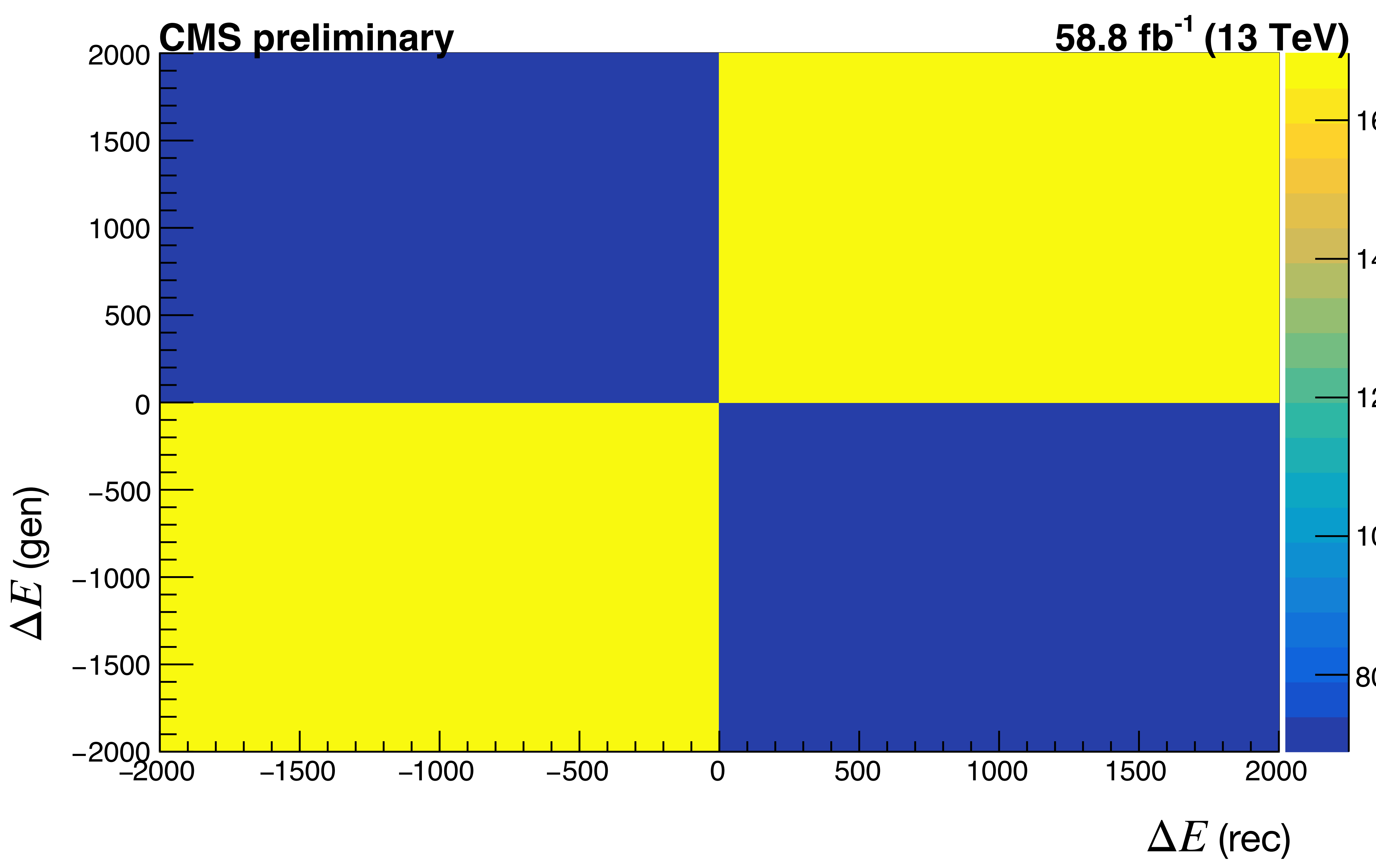
At least one top/W tagged jet (DeepAK8)



Control Plots

Binning scheme





JEC Uncertainty Correlation and Grouping for Run2

Uncertainty Source	JetMET grouping and correlation
	_year indicates a nuisance parameter uncorrelated across 3 years
Number of nuisances	4xAbsolute+4xBBEC1+4xEC2+4xHF+RelativeBal+3xRelativeSample+FlavorQCD = 21
AbsoluteMPFBias	Absolute
AbsoluteScale	Absolute
AbsoluteStat	Absolute_year
FlavorQCD	FlavorQCD
Fragmentation	Absolute
PileUpDataMC	Absolute
PileUpPtBB	BBEC1
PileUpPtEC1	BBEC1
PileUpPtEC2	EC2
PileUpPtHF	HF
PileUpPtRef	Absolute
RelativeFSR	Absolute
RelativeJEREC1	BBEC1_year
RelativeJEREC2	EC2_year
RelativeJERHF	HF
RelativePtBB	BBEC1
RelativePtEC1	BBEC1_year
RelativePtEC2	EC2_year
RelativePtHF	HF
RelativeBal	RelativeBal
RelativeSample	RelativeSample_year
RelativeStatEC	BBEC1_year
RelativeStatFSR	Absolute_year
RelativeStatHF	HF_year
SinglePionECAL	Absolute
SinglePionHCAL	Absolute
TimePtEta	Absolute_year

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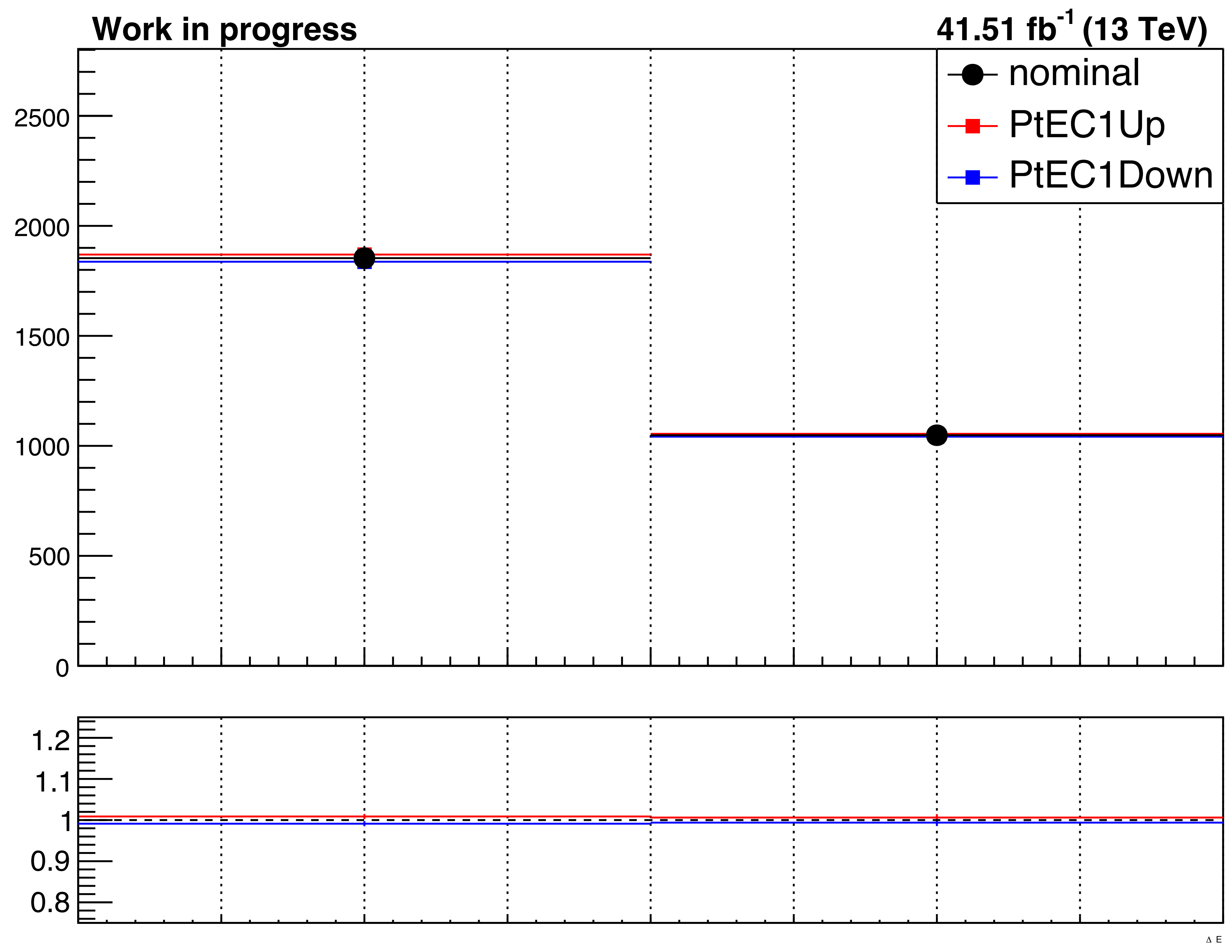
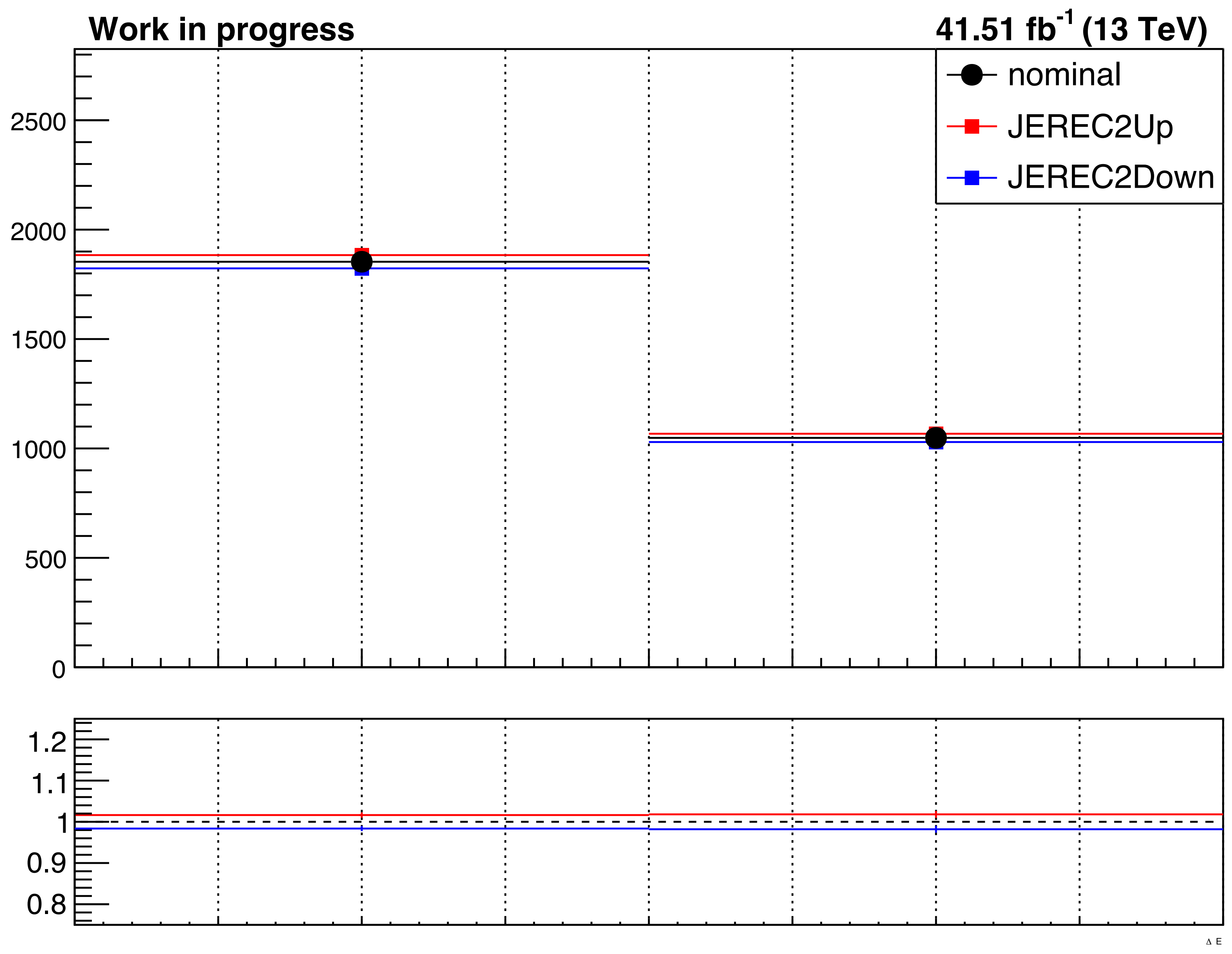
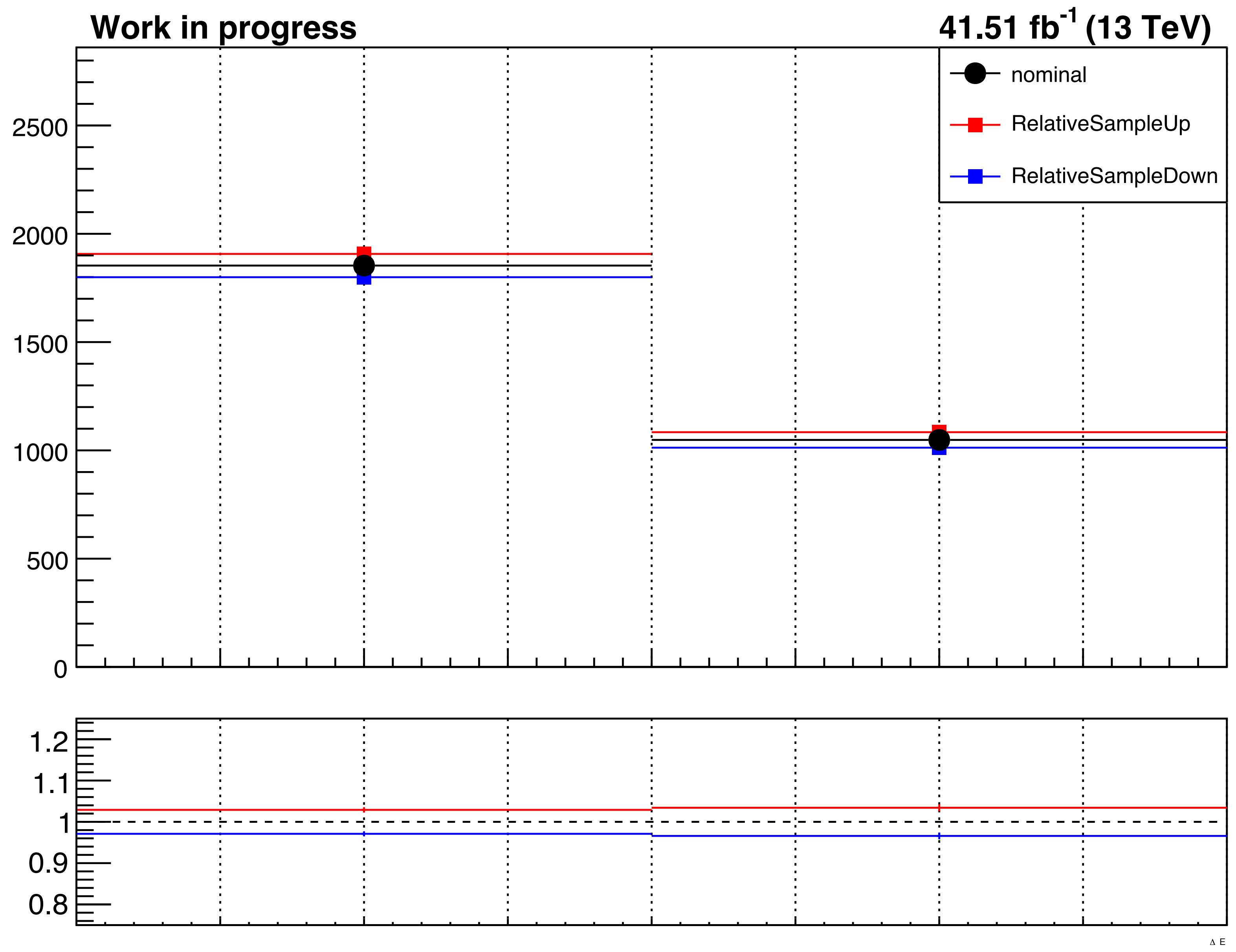

Work in progress
41.51 fb^{-1} (13 TeV)
nominal
PtEC1Up
PtEC1Down
0
500
1000
1500
2000
2500
0.8
0.9
1
1.1
1.2


Work in progress
41.51 fb^{-1} (13 TeV)
nominal
JEREC2Up
JEREC2Down
0
500
1000
1500
2000
2500
0.8
0.9
1
1.1
1.2


Work in progress
41.51 fb^{-1} (13 TeV)
nominal
RelativeSampleUp
RelativeSampleDown
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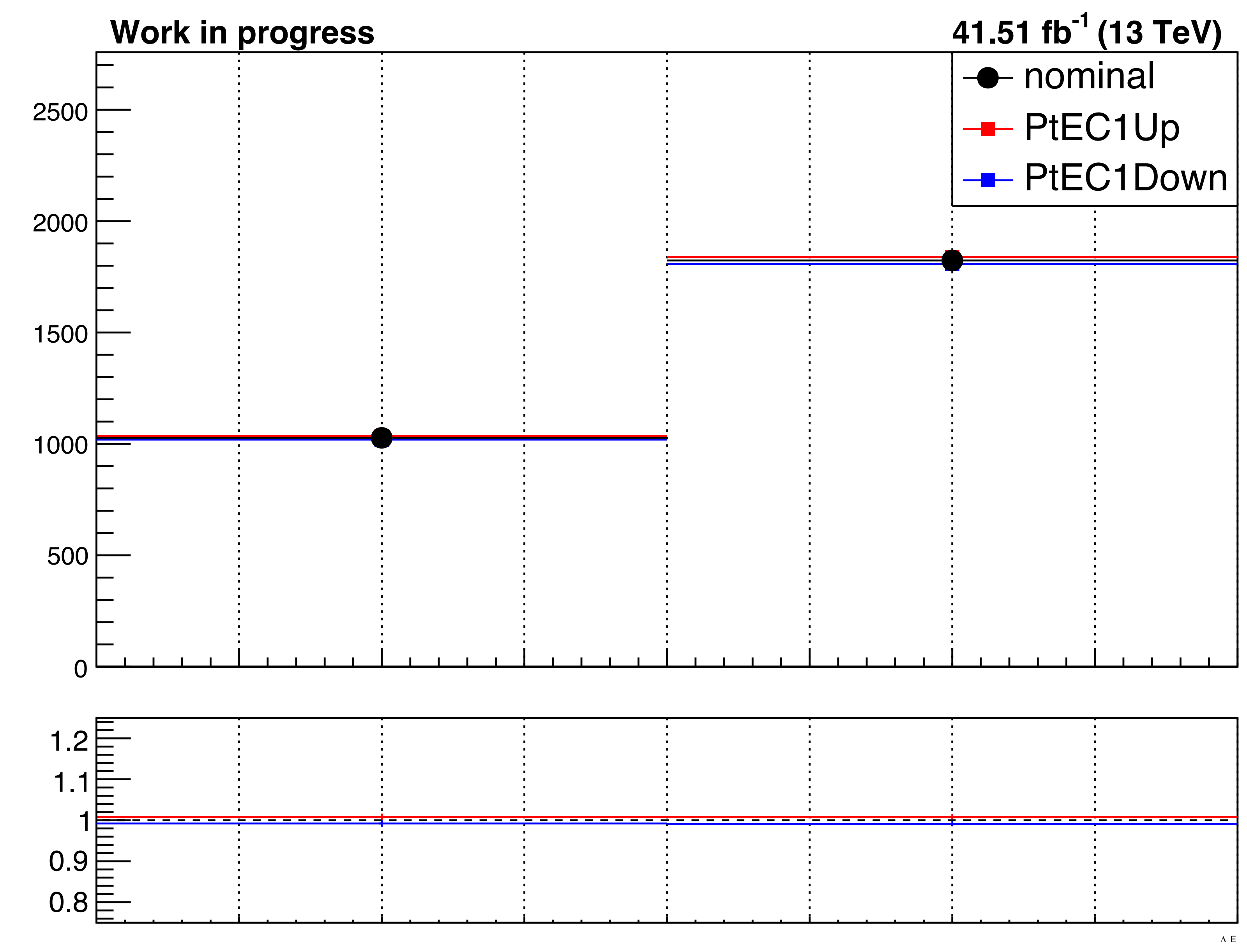
Work in progress
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nominal
PtEC1Up
PtEC1Down
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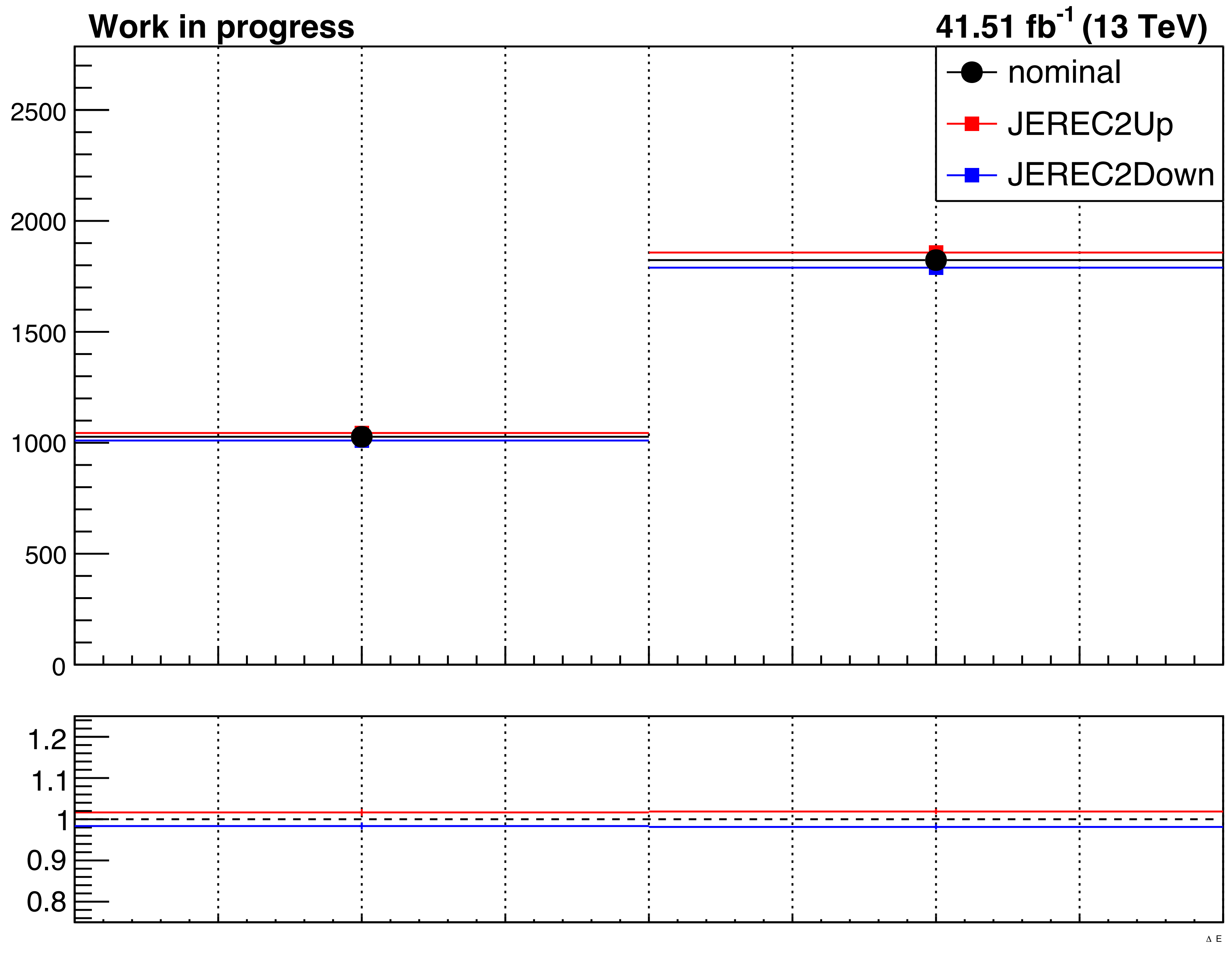
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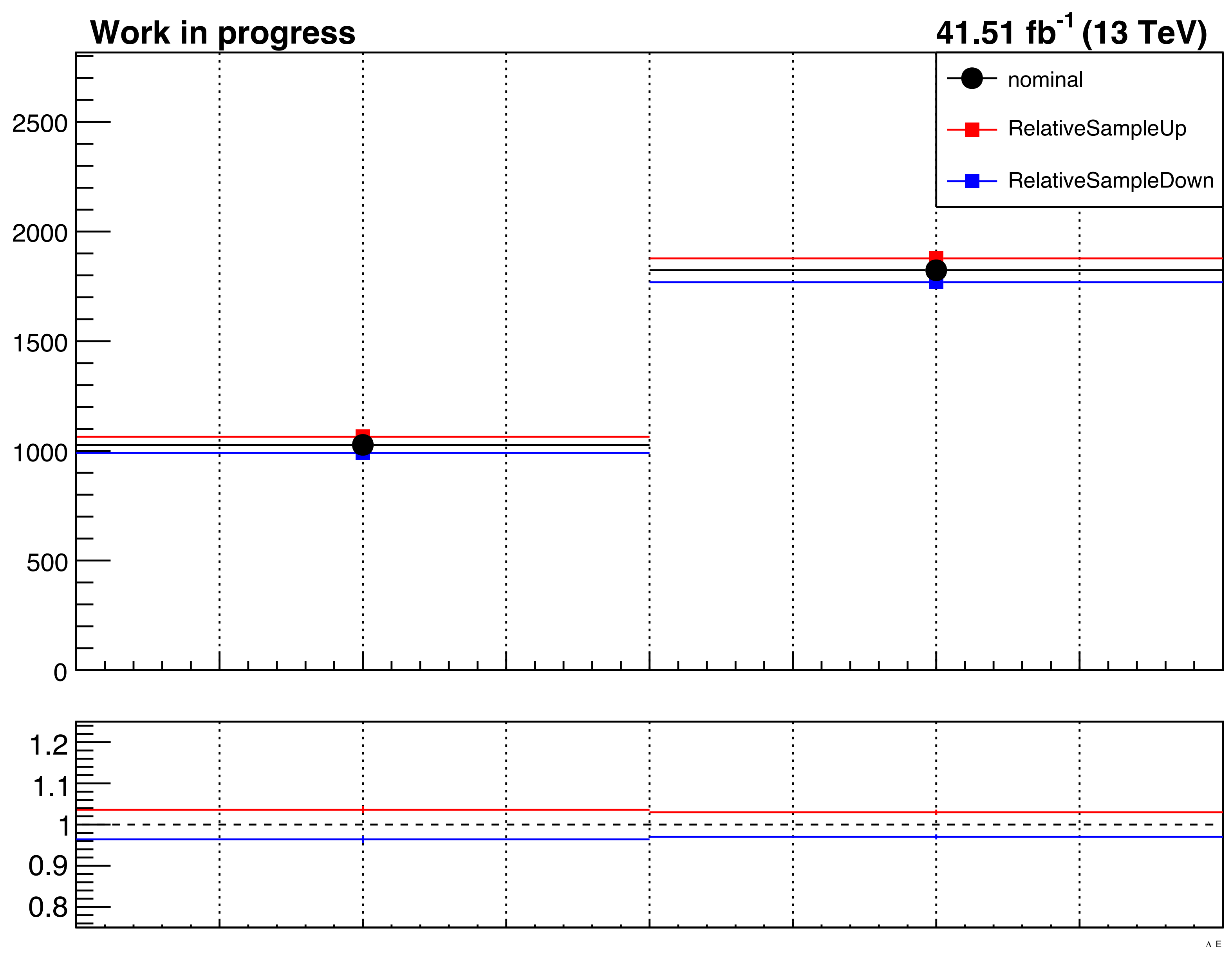

Work in progress
41.51 fb^{-1} (13 TeV)
nominal
RelativeSampleUp
RelativeSampleDown
0
500
1000
1500
2000
2500
0.8
0.9
1
1.1
1.2

Extracting the asymmetry directly from Combine

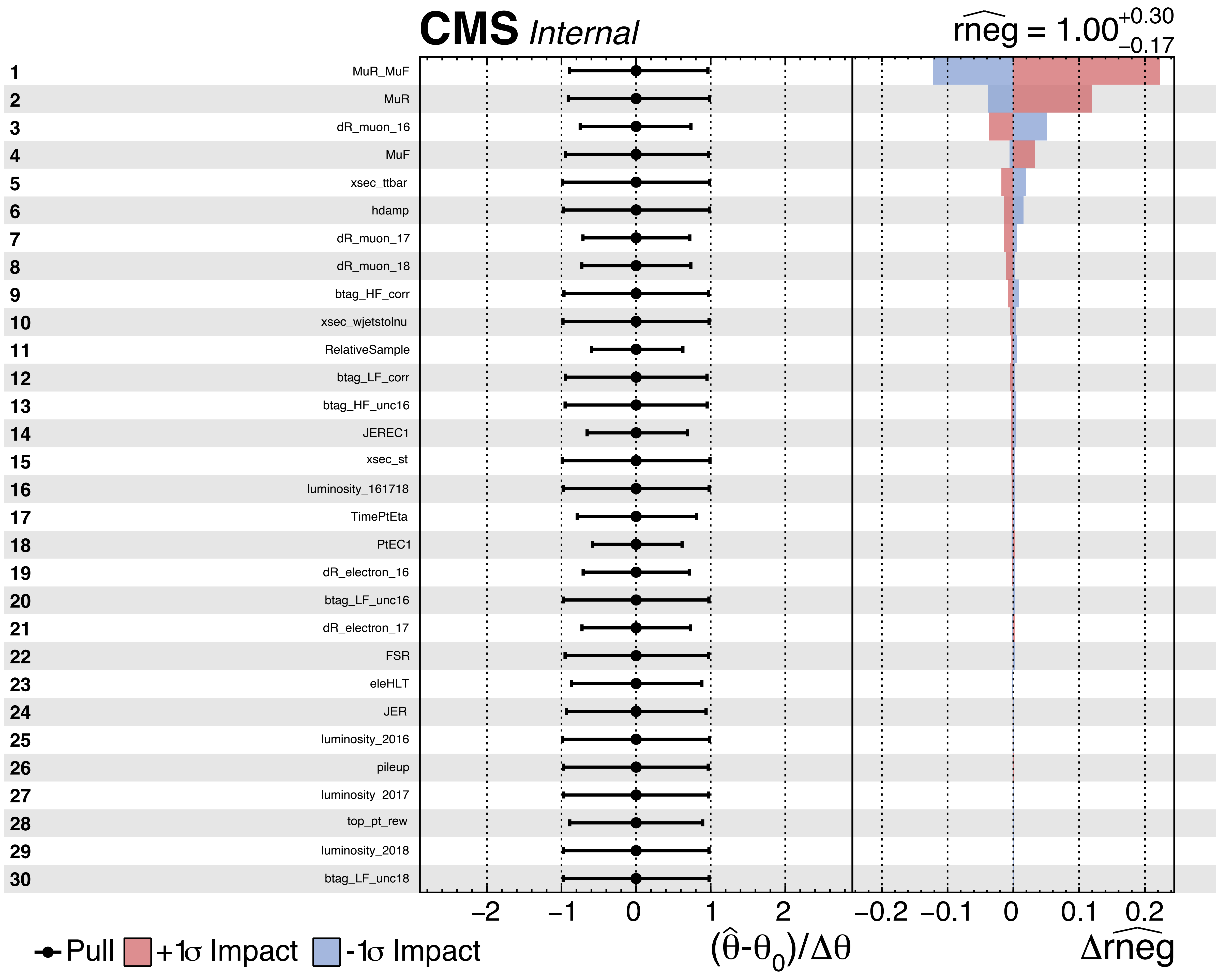
Unfolding with the Combine tool enables us to extract the asymmetries directly from the maximum likelihood fit that is performed, hence all error propagation is taken care of:

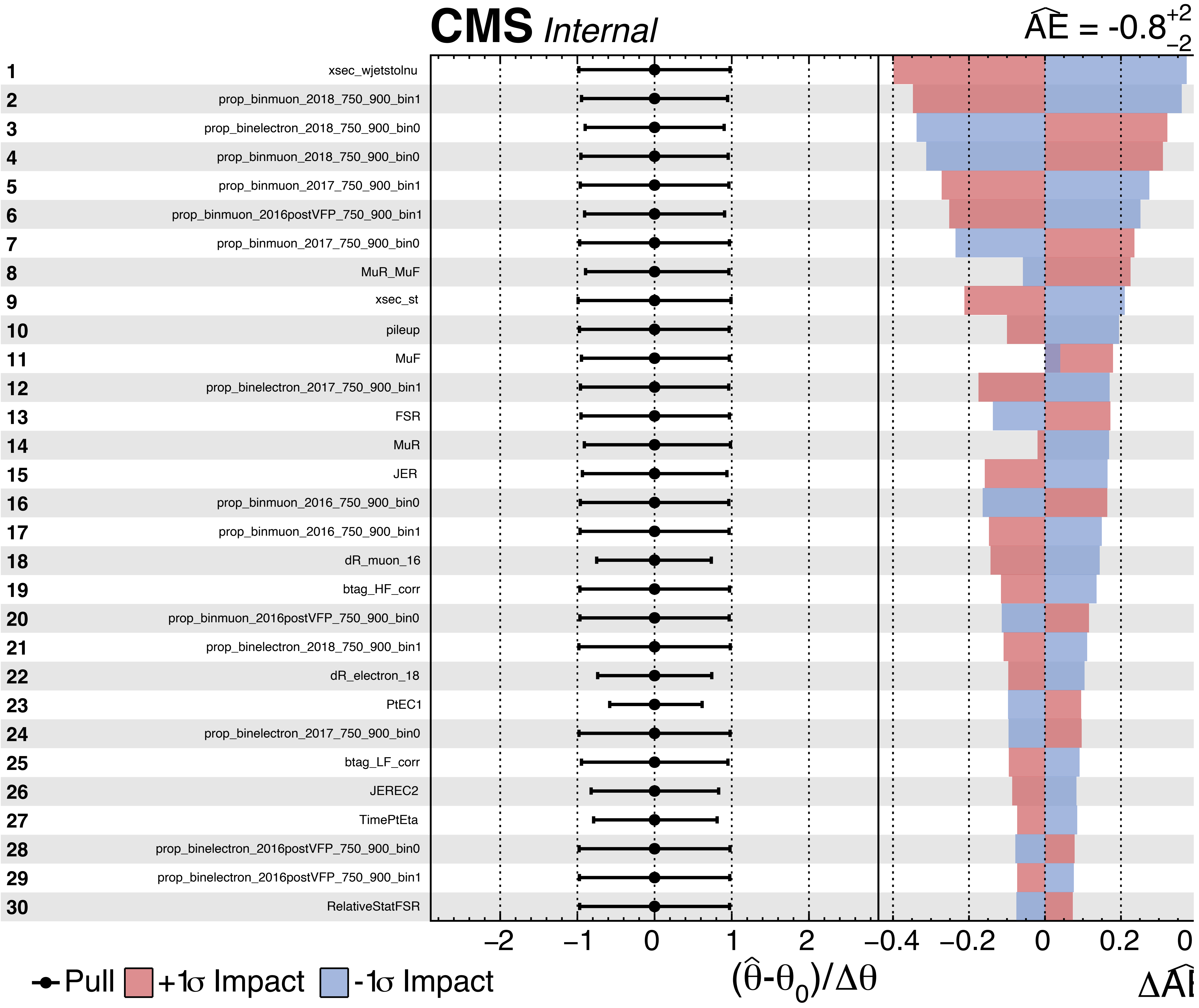
$$A_E = \frac{r_1 * N_{unf}(\Delta E > 0) - r_2 * N_{unf}(\Delta E < 0)}{r_1 * N_{unf}(\Delta E > 0) + r_2 * N_{unf}(\Delta E < 0)}$$

After few simple steps, we can introduce the asymmetry directly in the fit by using:

$$r_1 = \frac{N_{unf}(\Delta E < 0)}{N_{unf}(\Delta E > 0)} * r_2 * \frac{1 - A_E}{1 + A_E}$$

Blinded results (AE)





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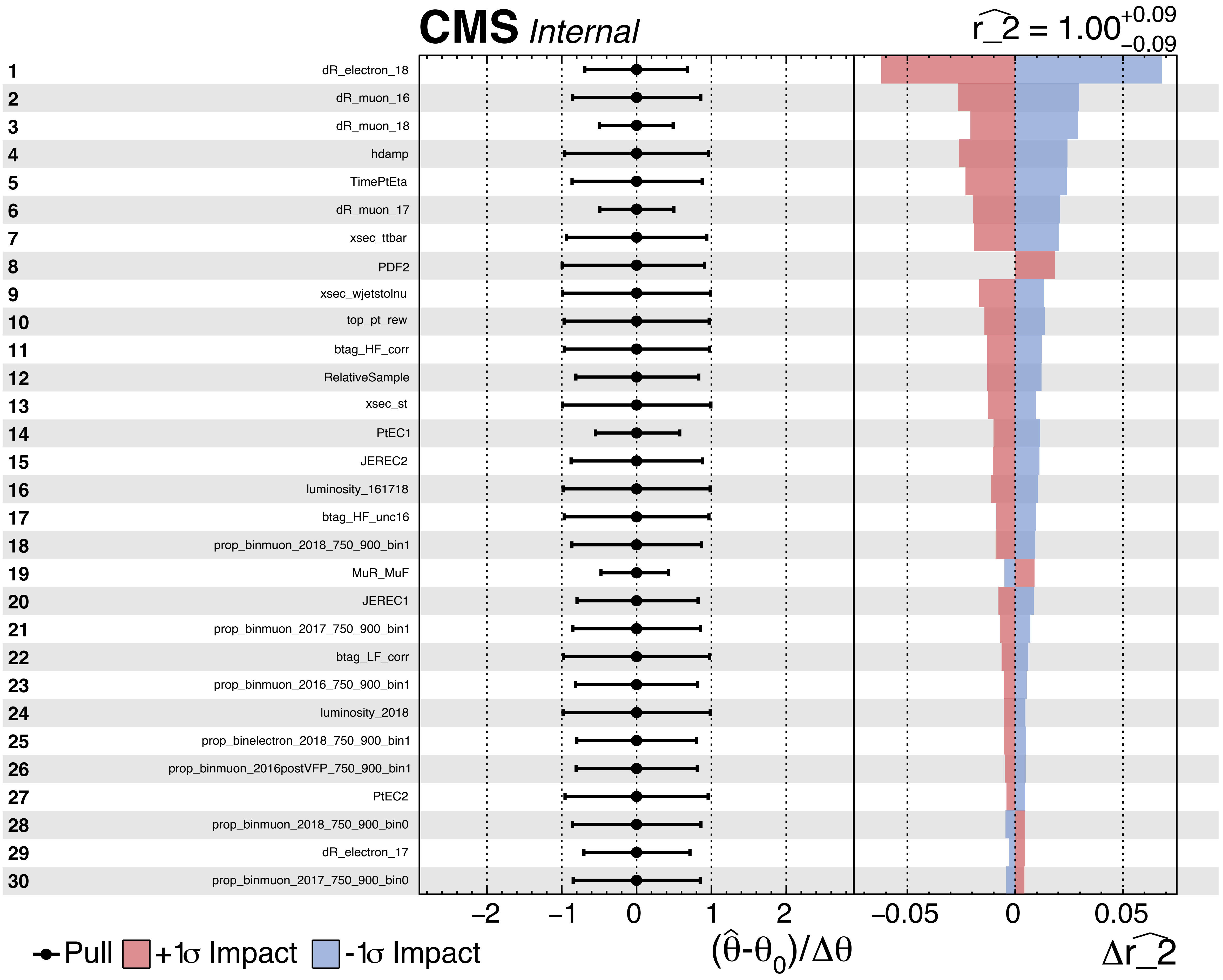
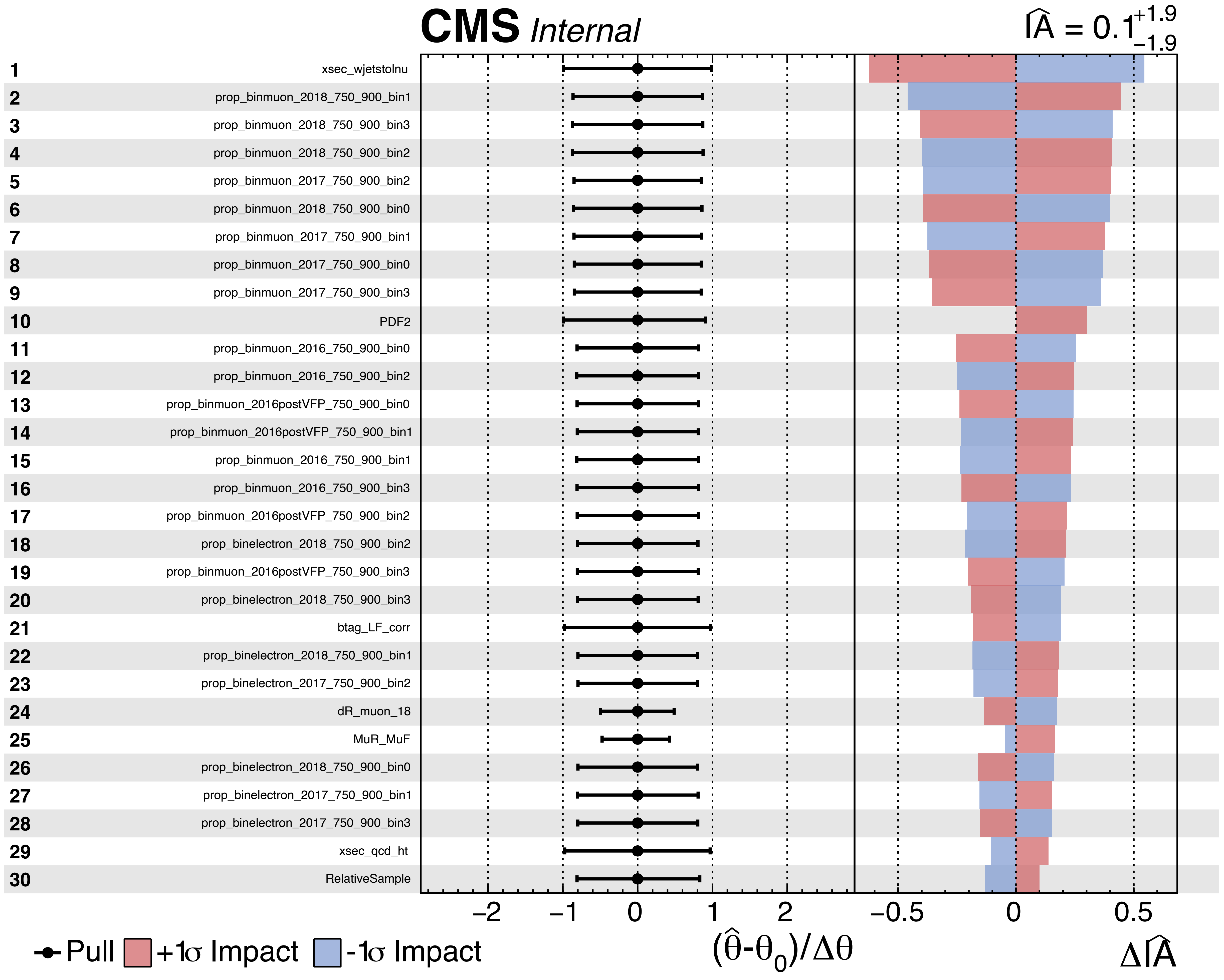
Blinded results (AI)

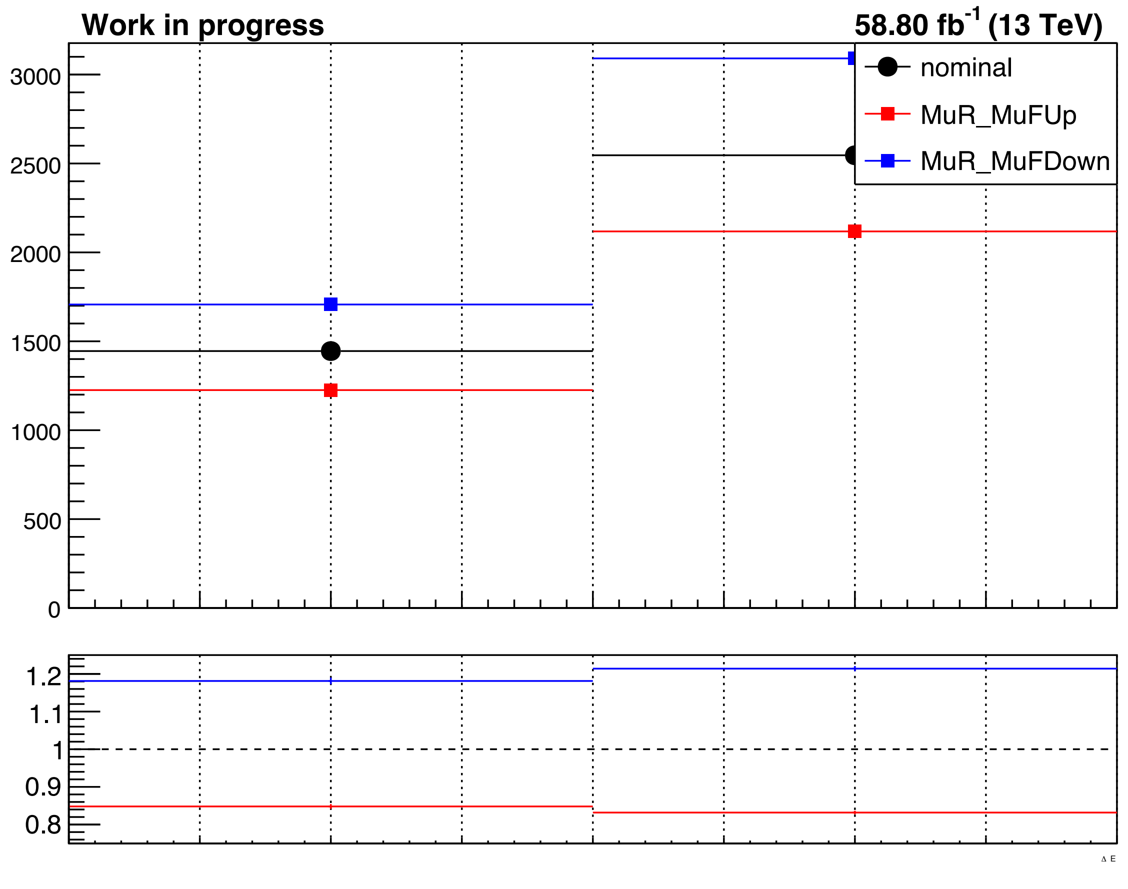


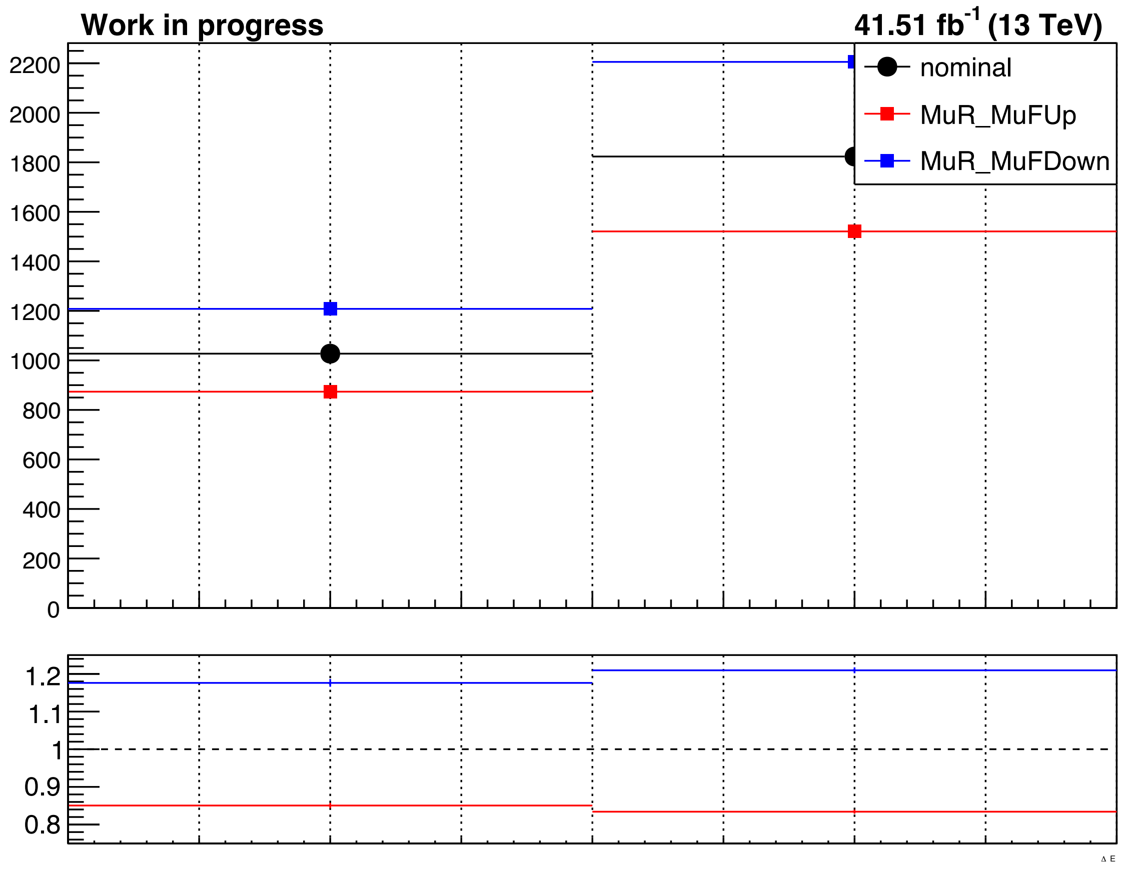


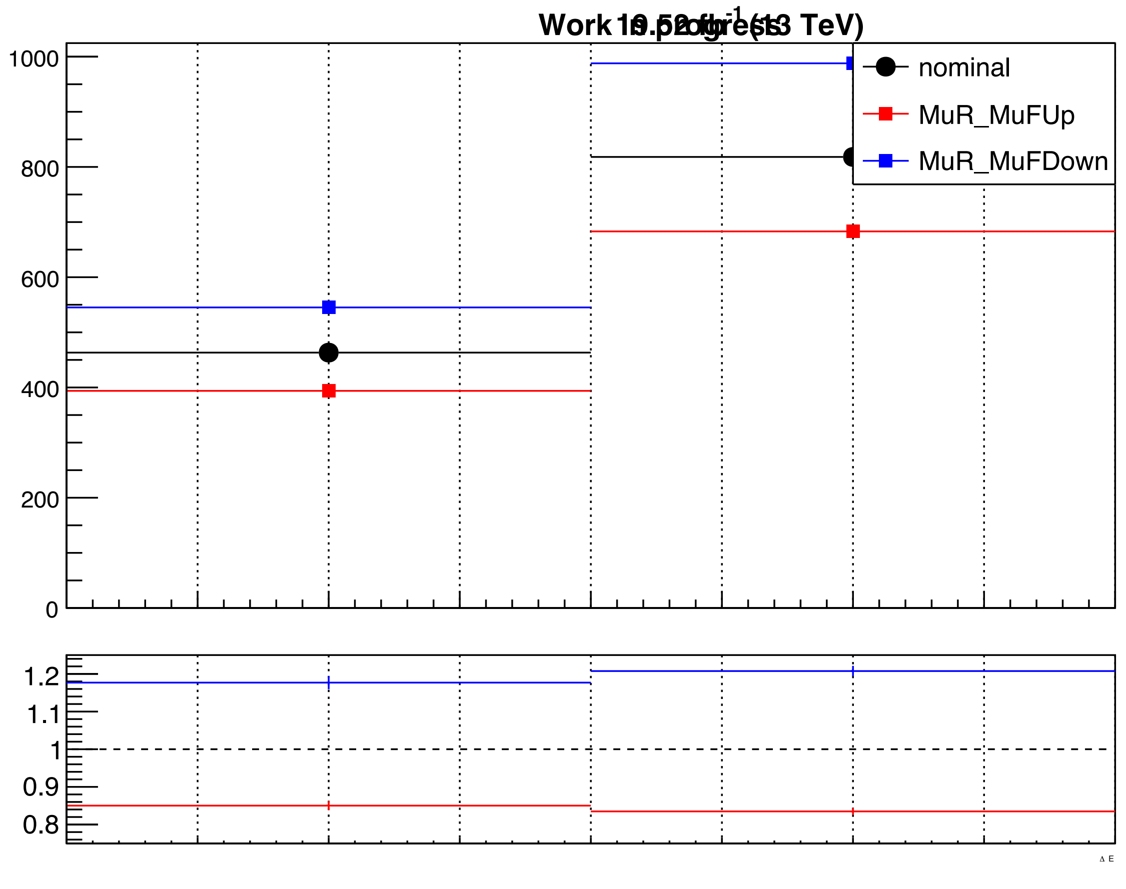
To do:

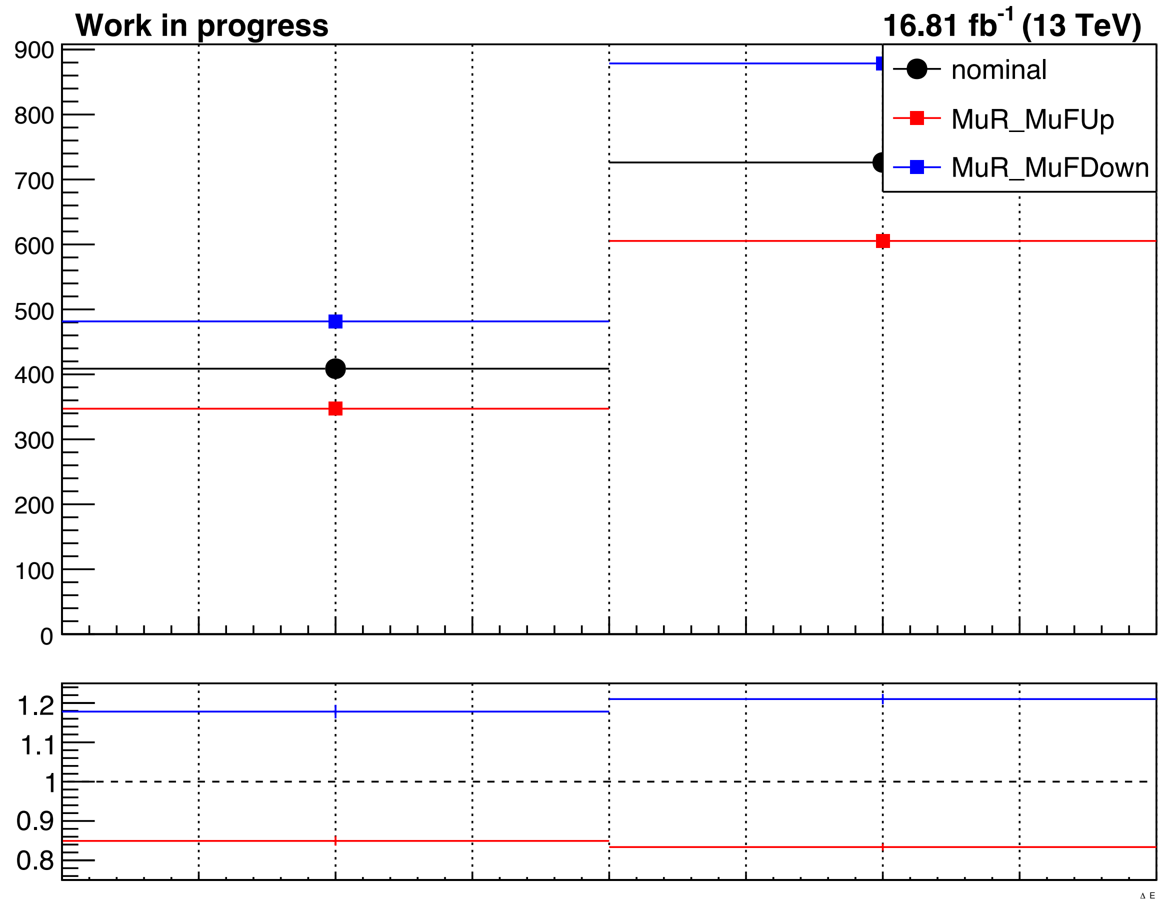
- The results section is not yet included in the analysis note
- Start the object review.
- Start looking into EFT interpretations

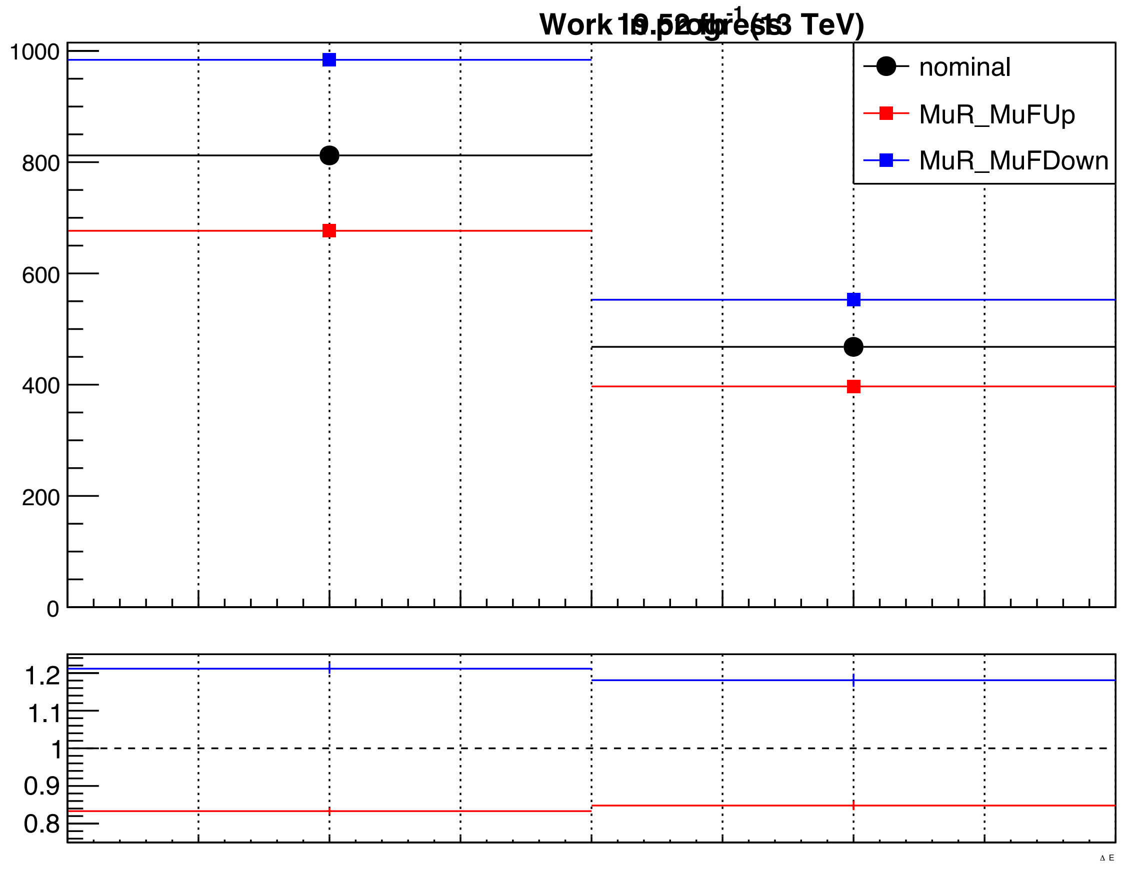
e + jets channel

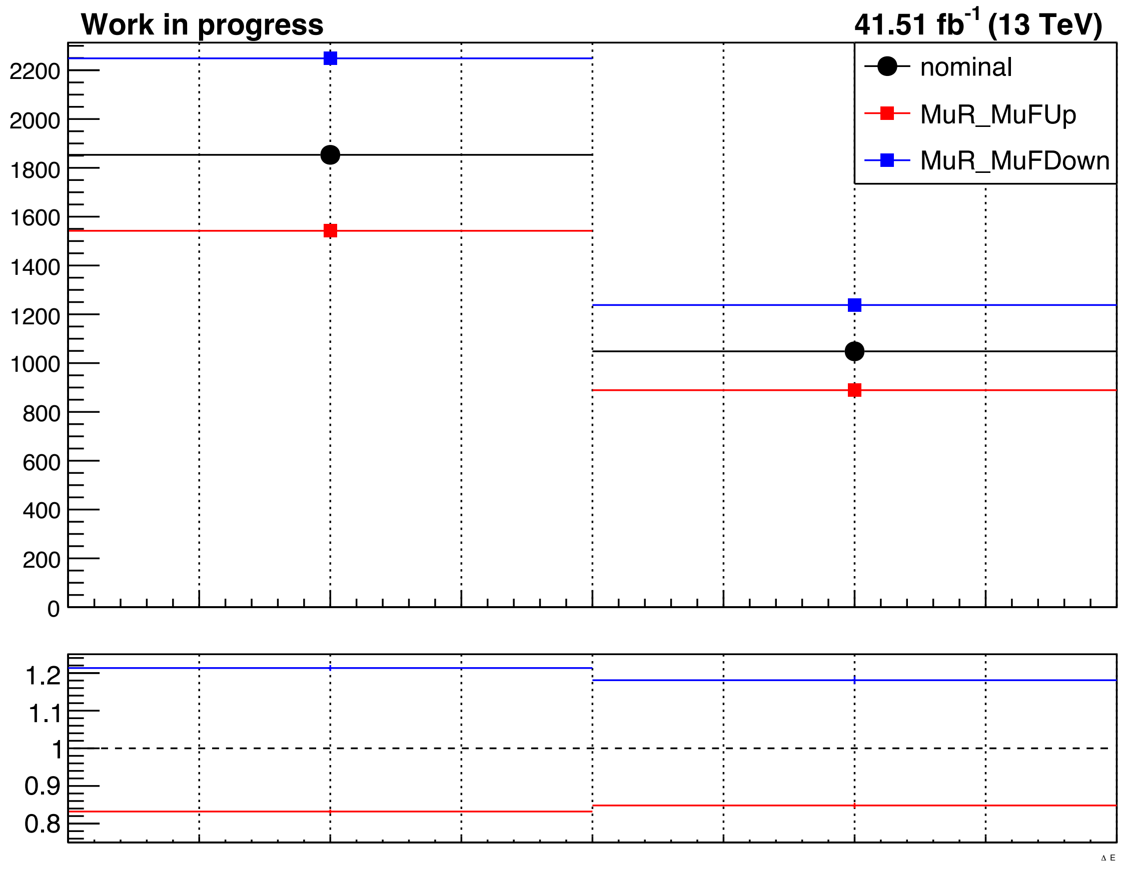


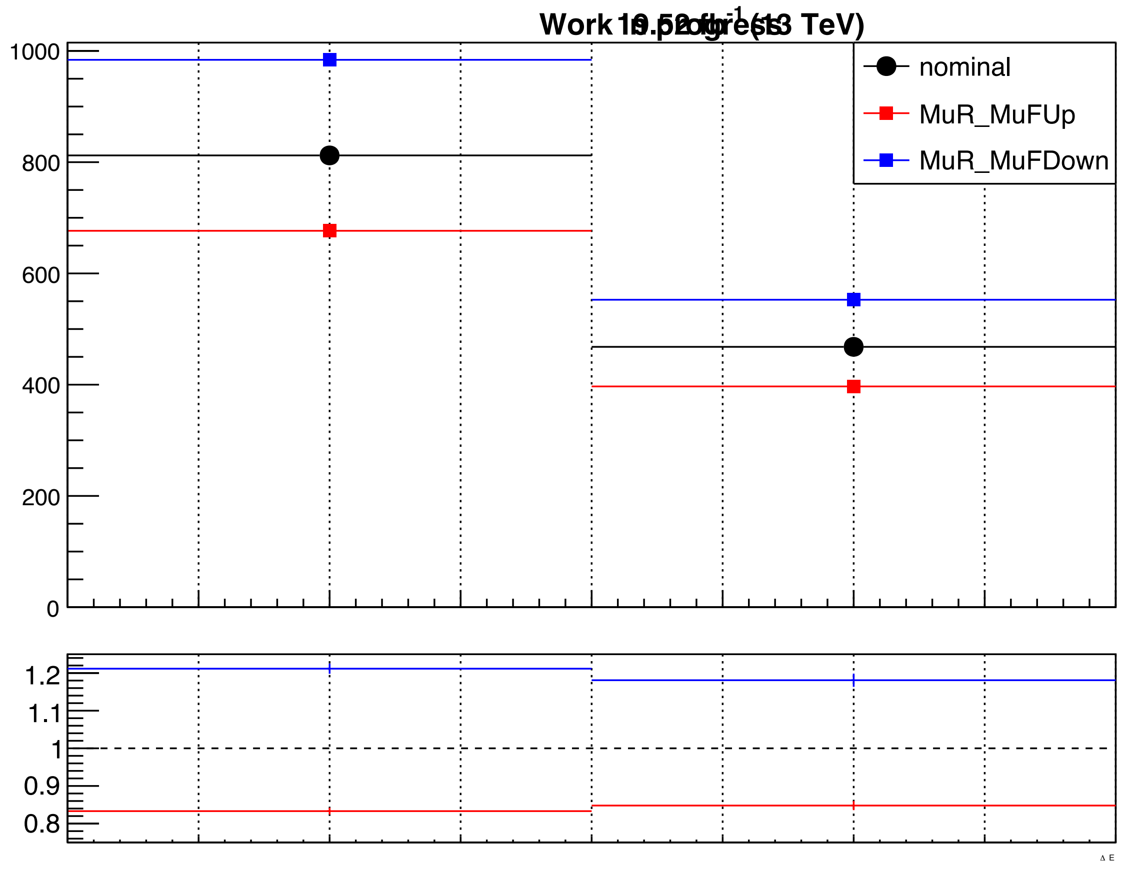


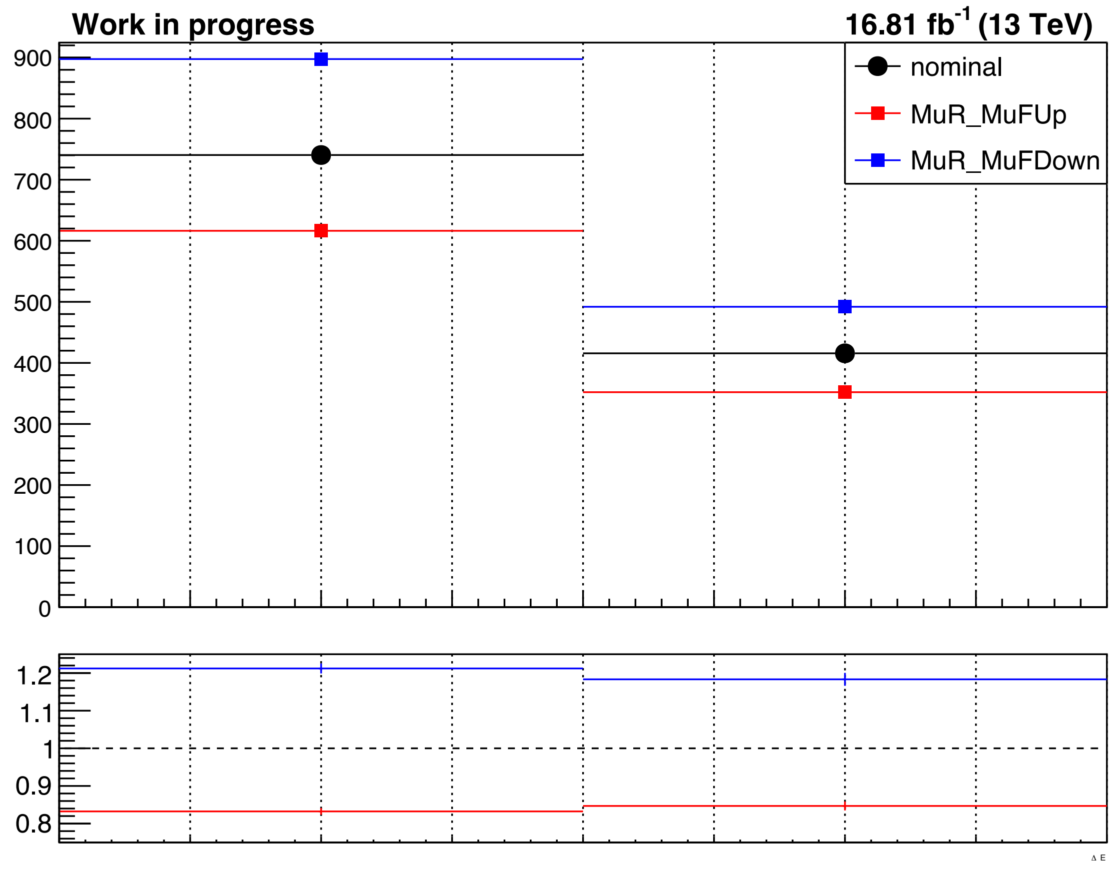




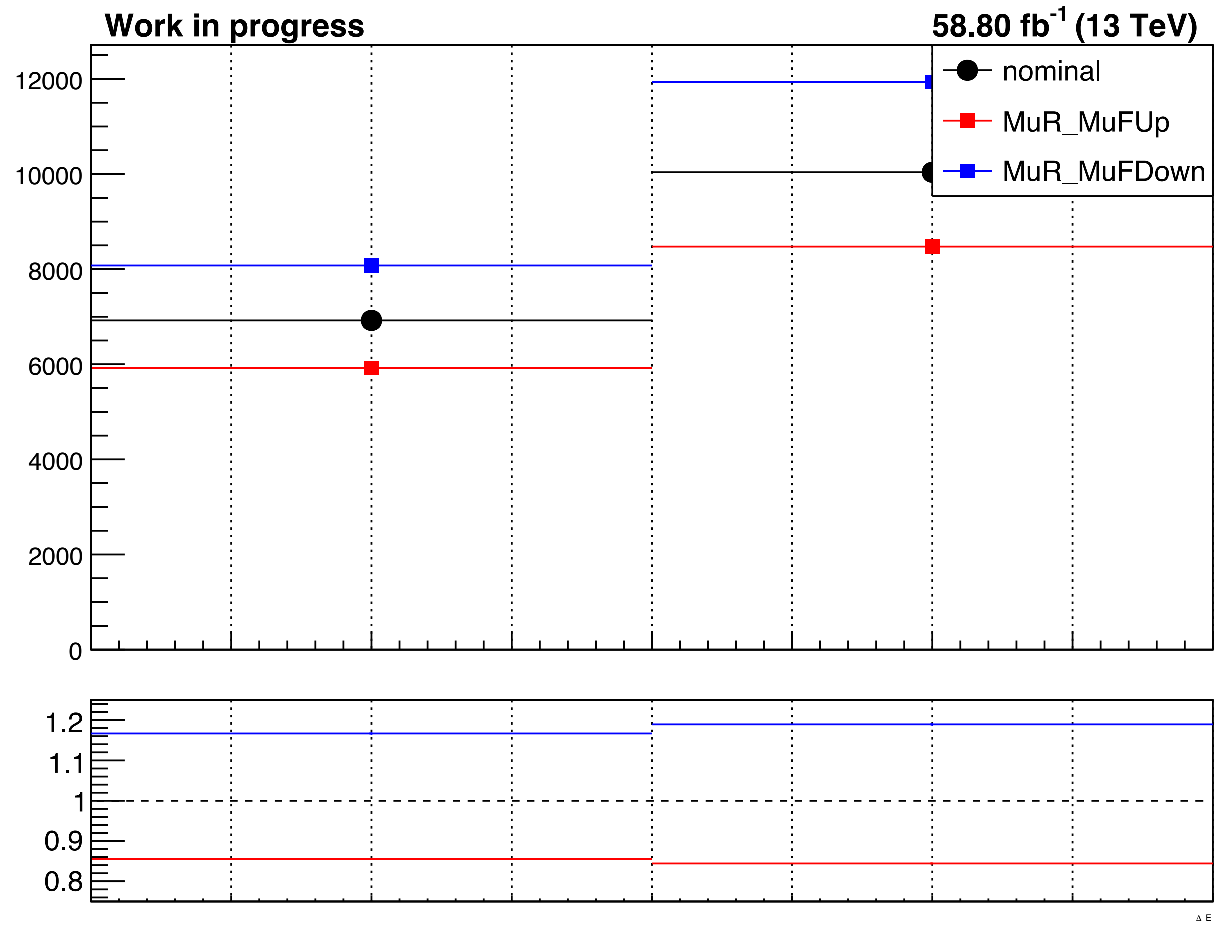


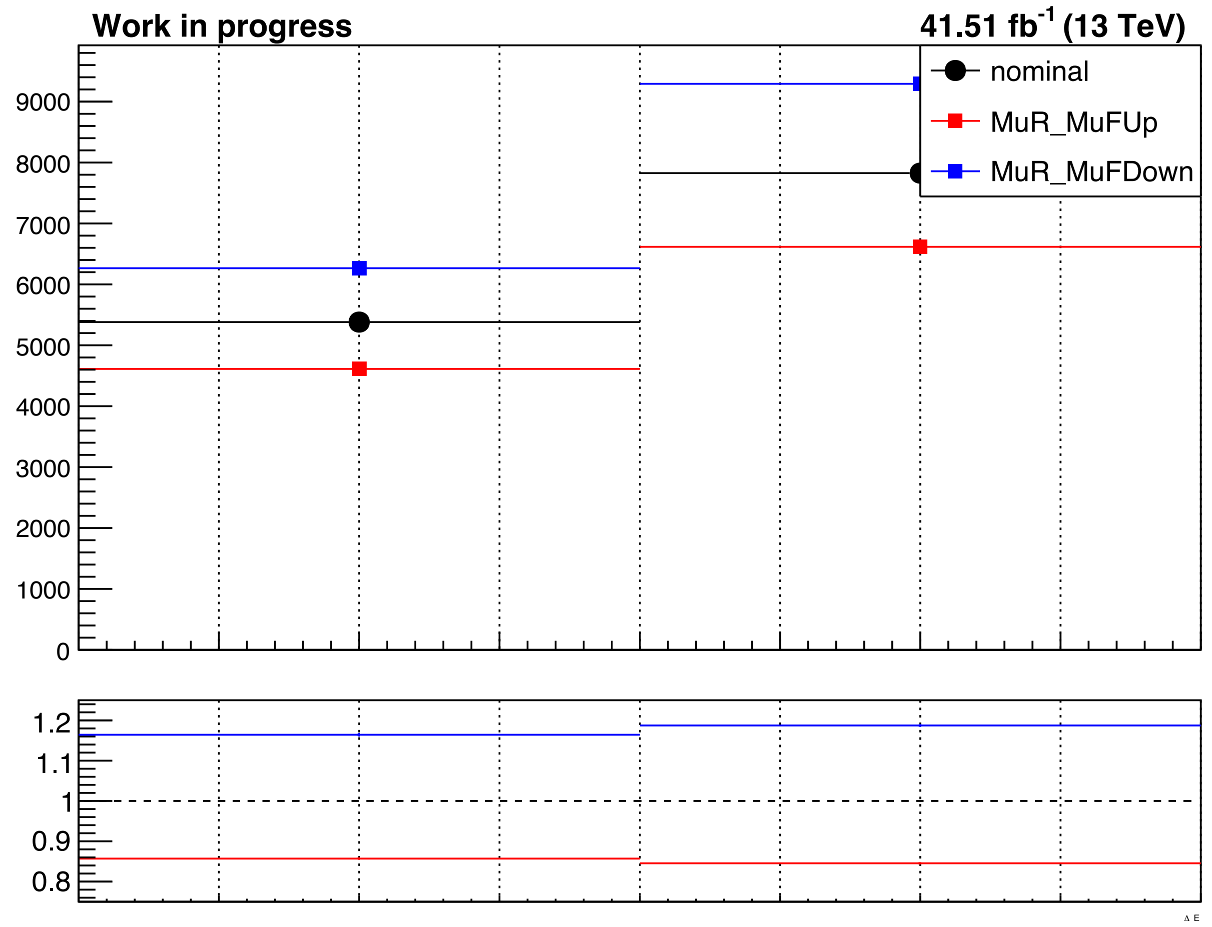


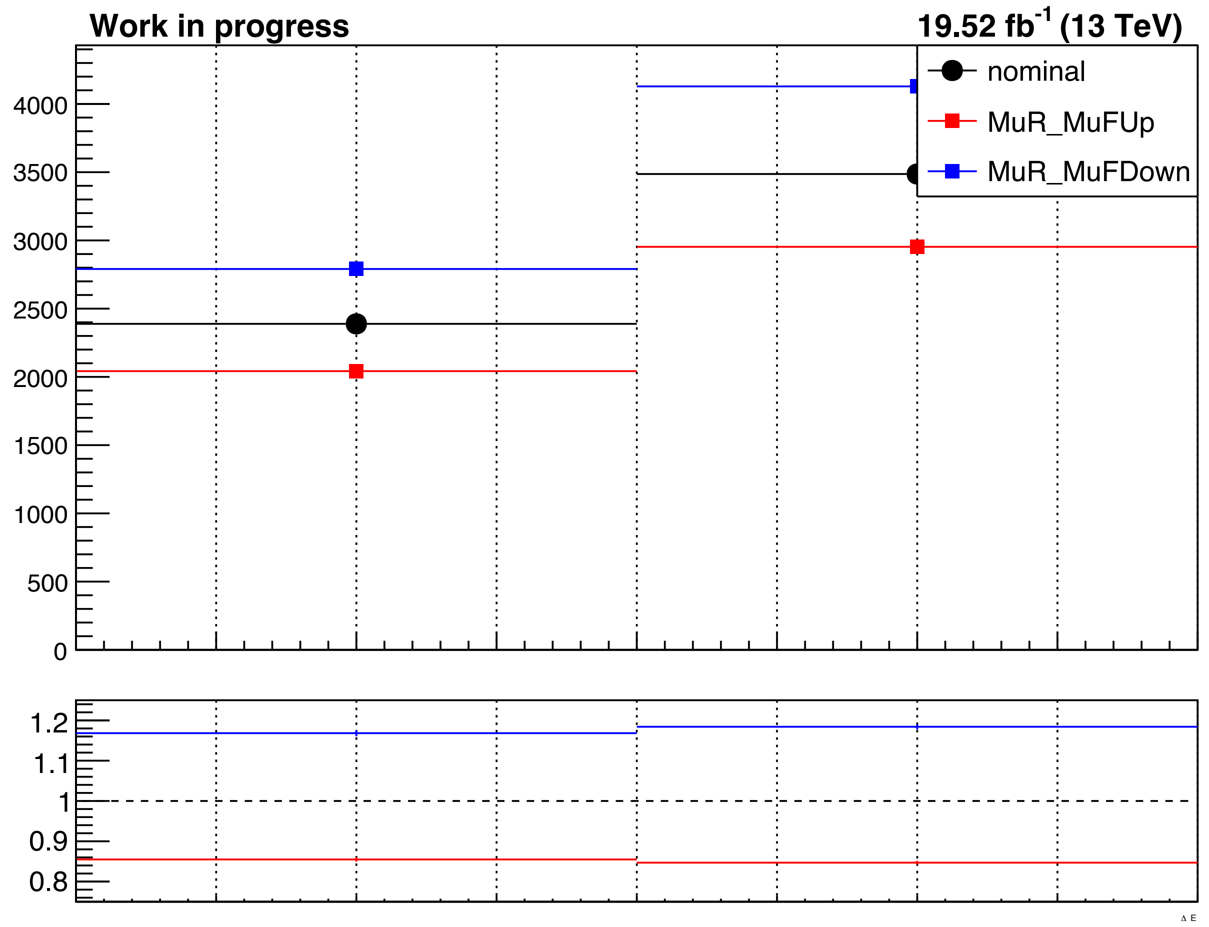


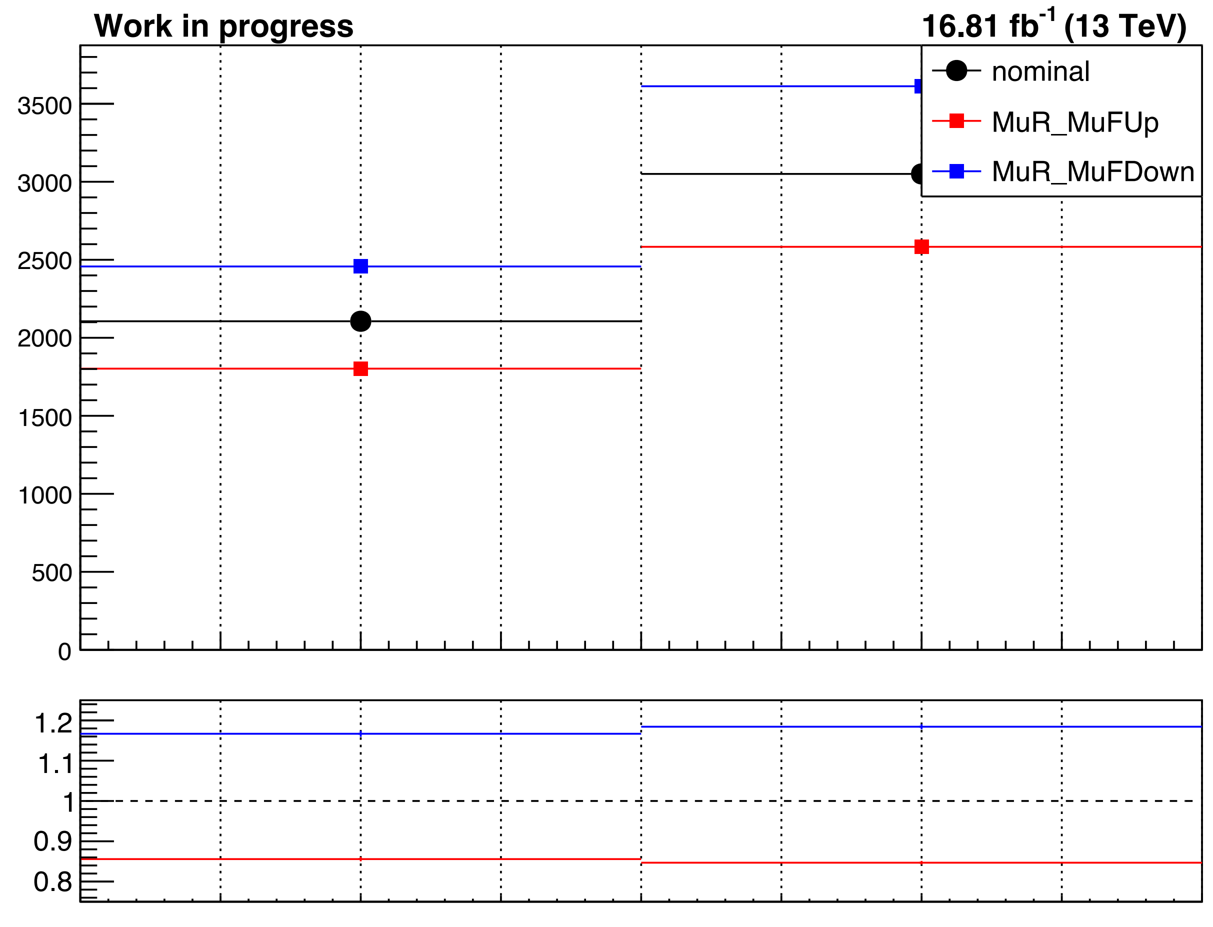


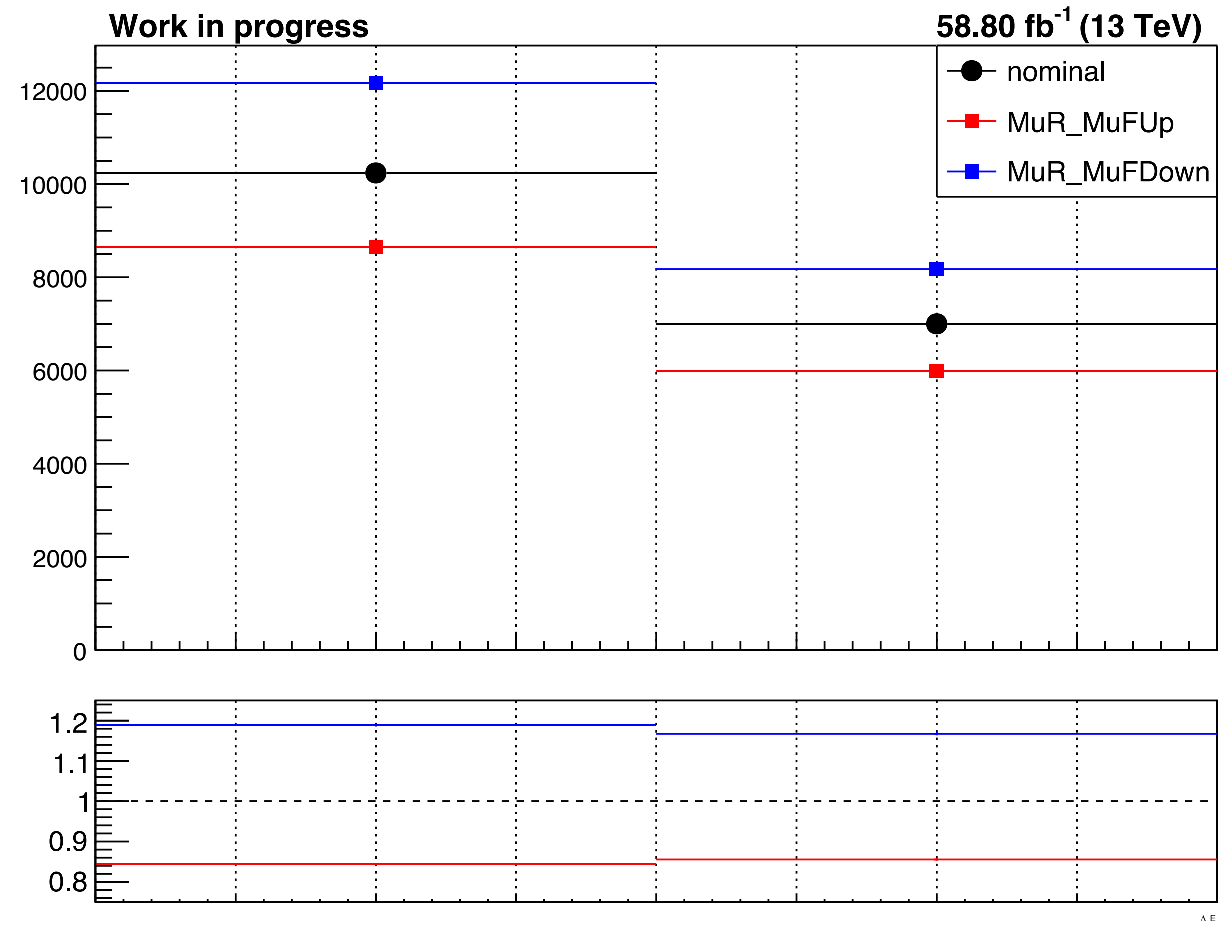
μ + jets channel

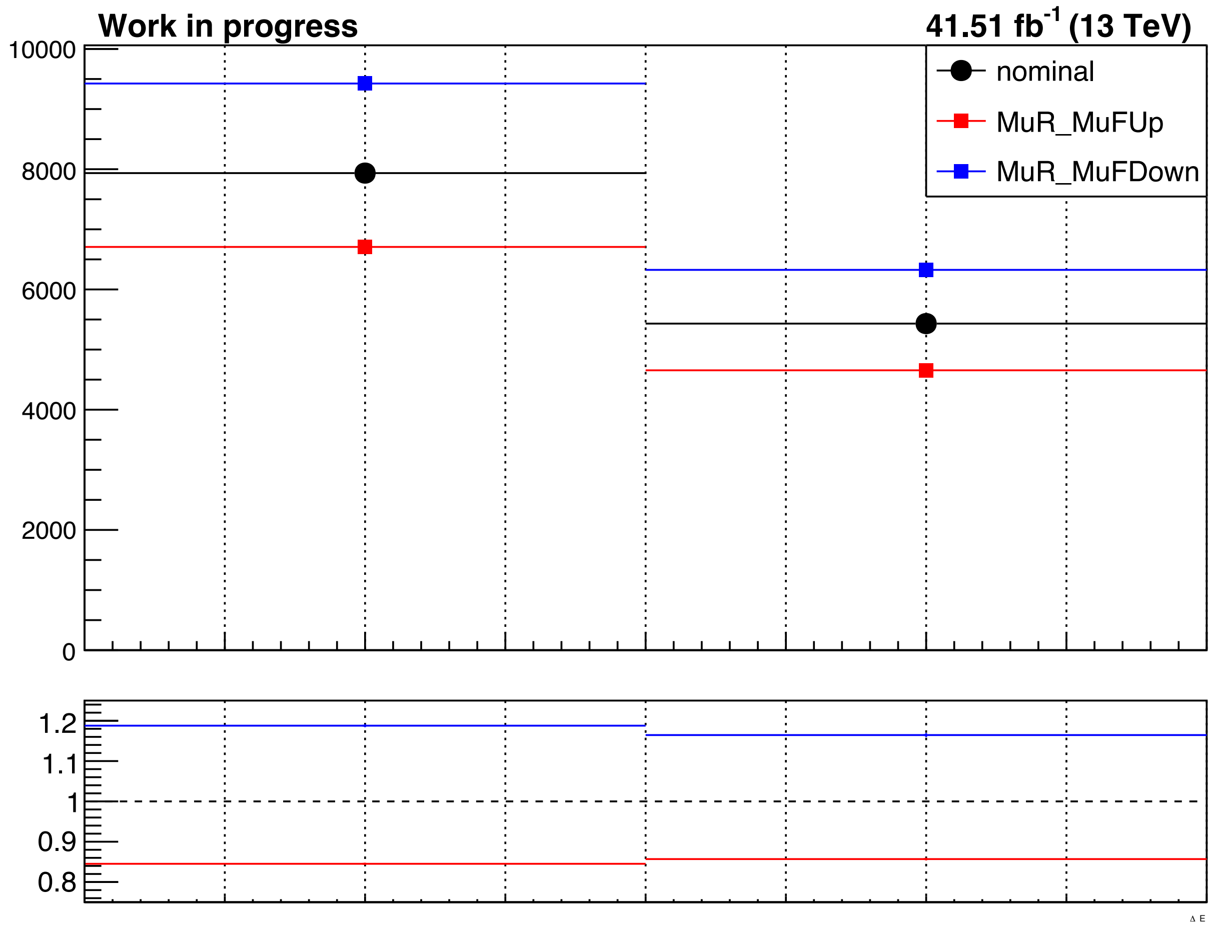


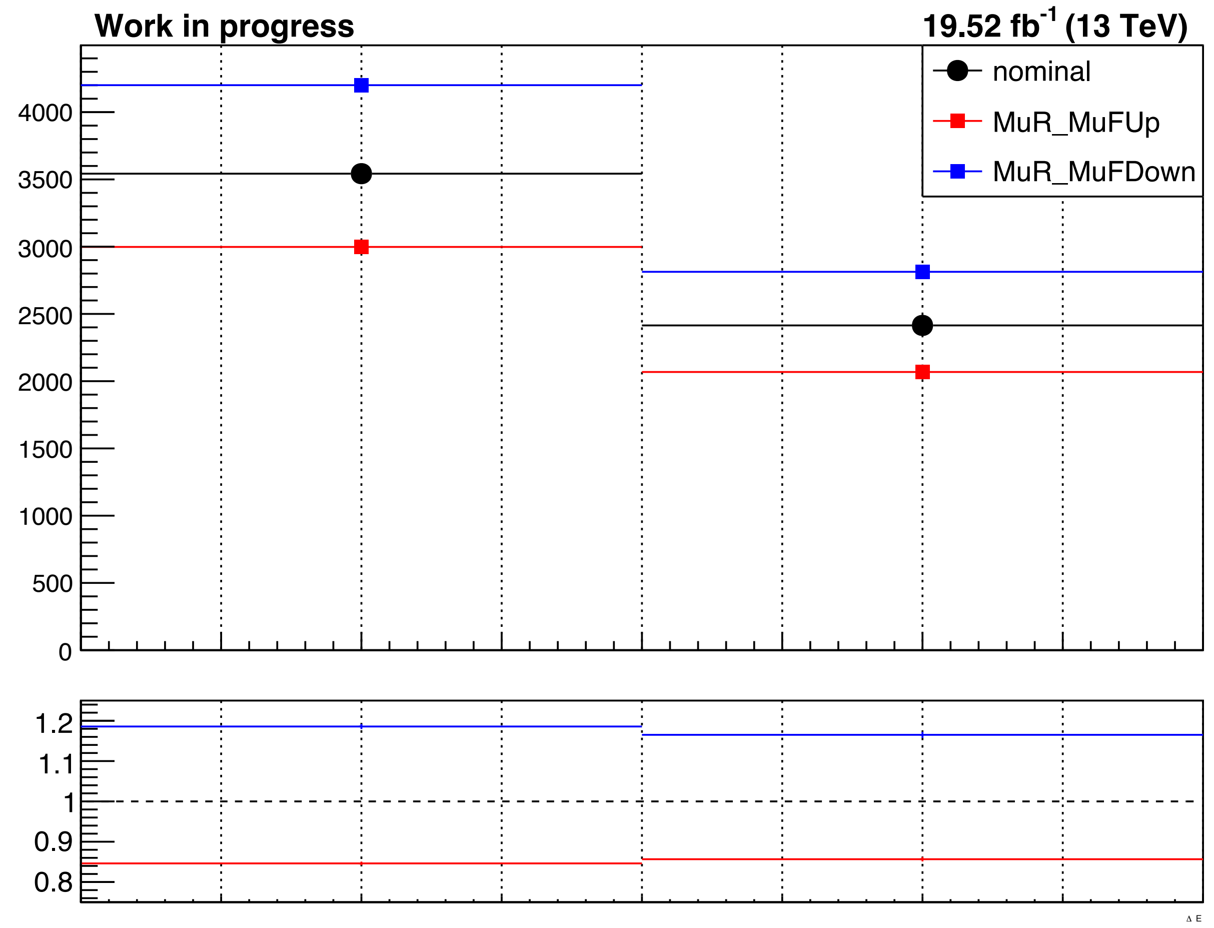


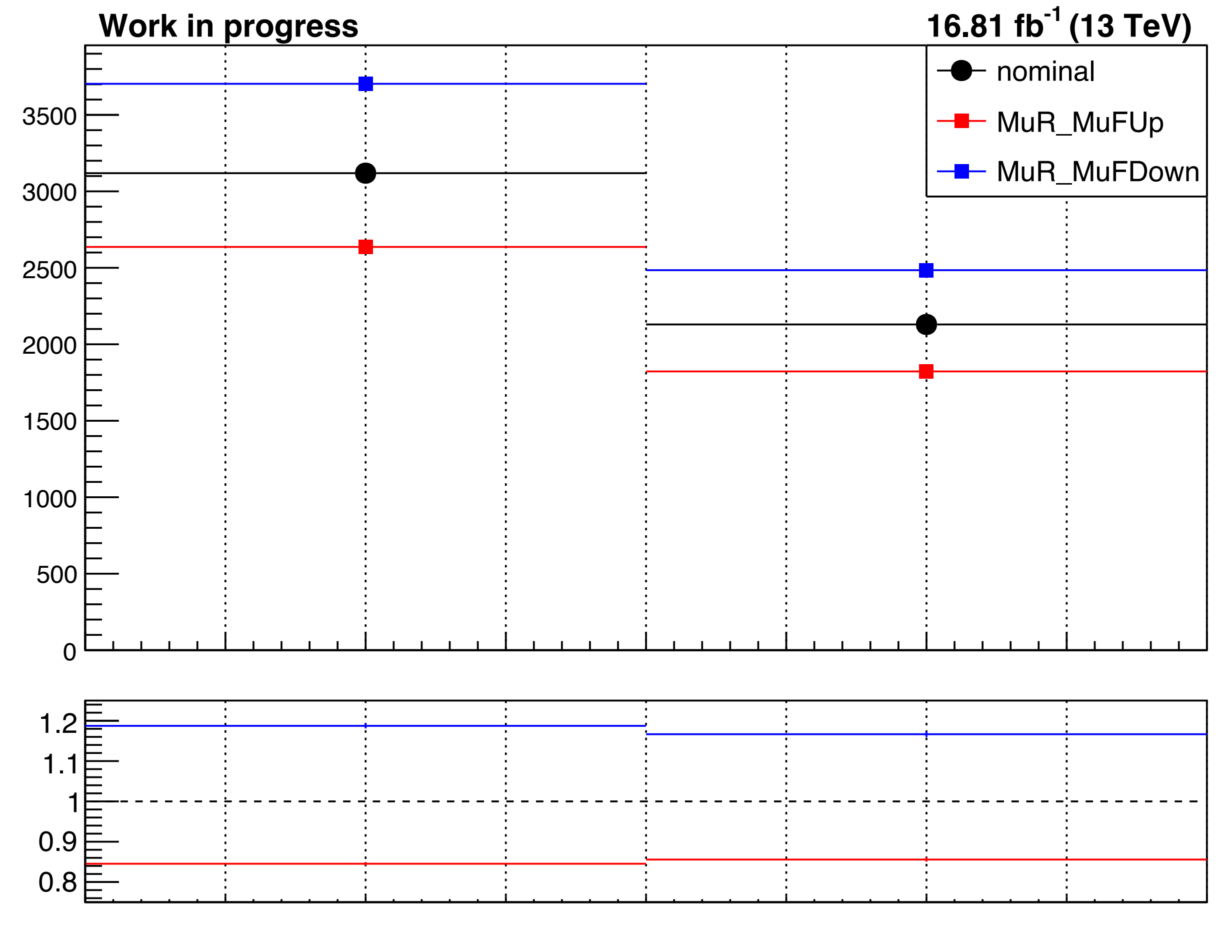




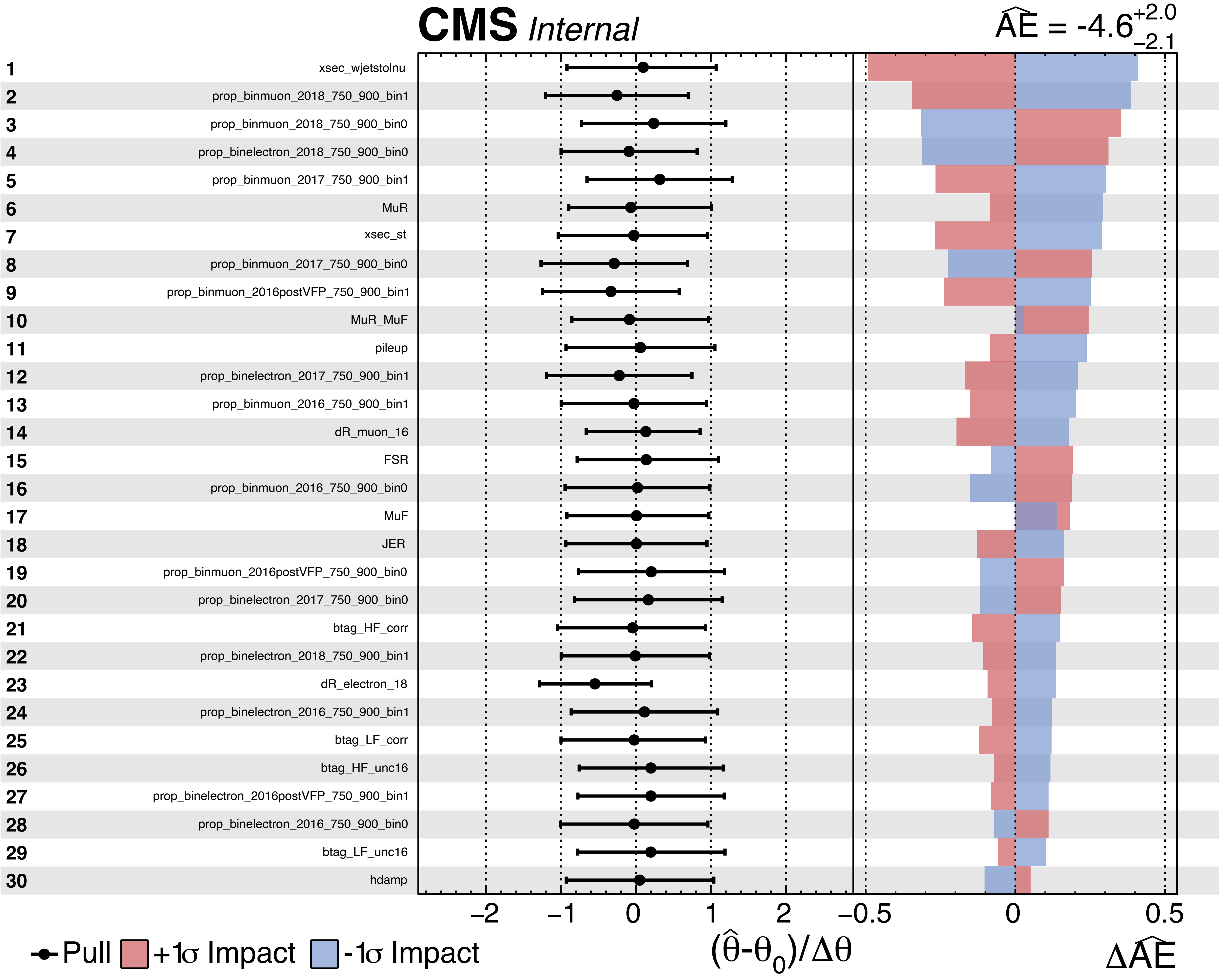


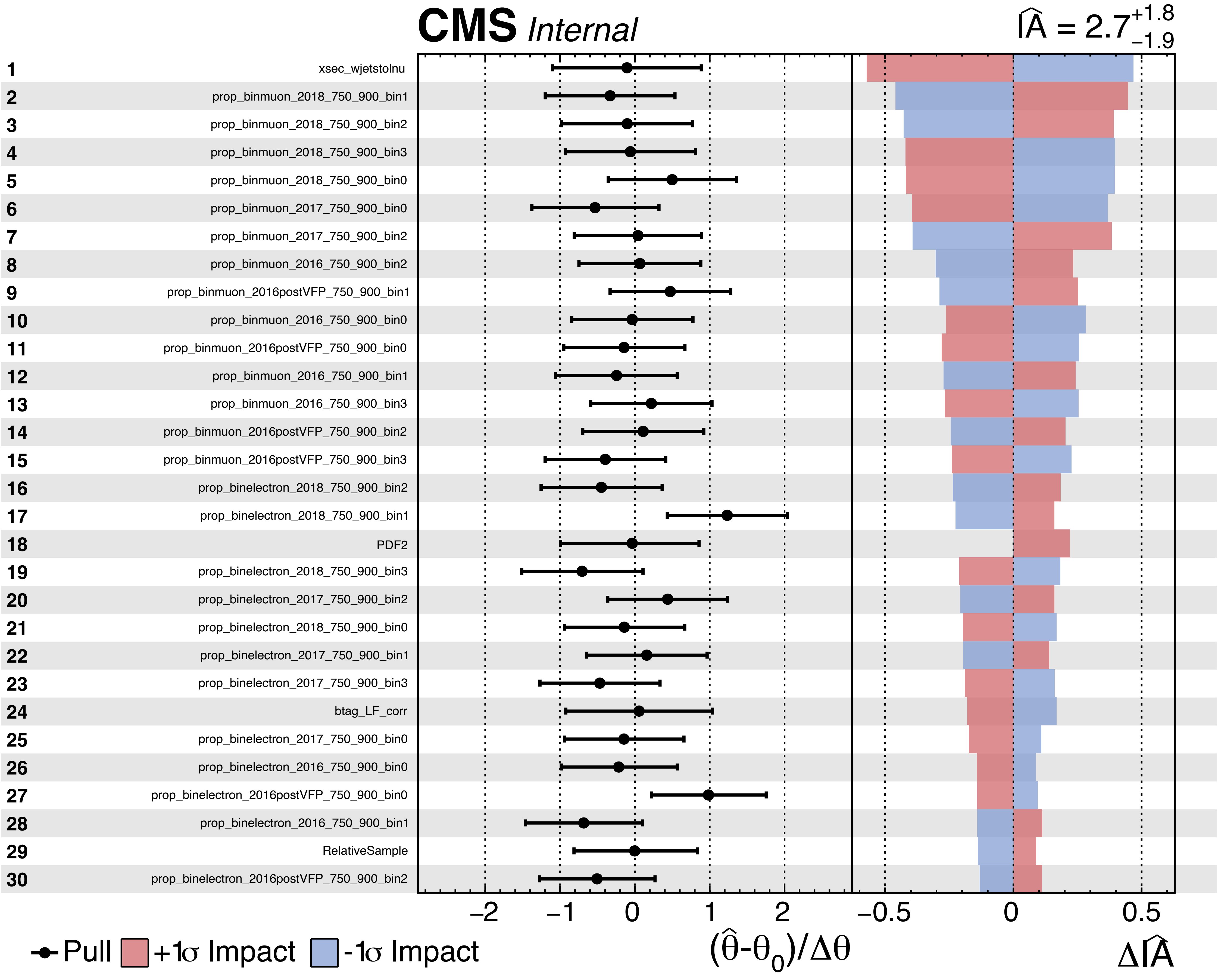






Unblinded results





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Control Region

Same selection as SR but:

- $\chi^2 > 30$
- $N_{jets} < 4$

CR region included on the fit ($M_{t\bar{t}}$) to try to constrain the W+jets normalization factor

Maybe train a BDT?