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CMS

18-02-2010

TOP PAG meeting

tW differential cross section analysis (TOP-19-003) approval

*Sergio Sánchez Cruz, **Víctor Rodríguez Bouza**, Enrique Palencia Cortezón*

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Documentation

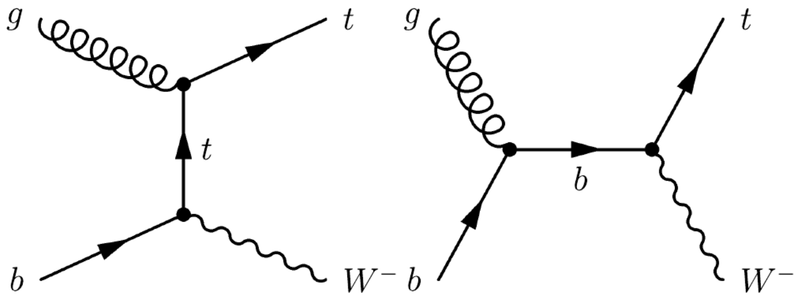
- **CADI line: TOP-19-003**.
  - Analysis note: AN-2018/173 (last version: v12).
  - **PAS** draft (last version: v8).
  - Internal twiki page .

- **Contact** person: Sergio Sánchez Cruz.
- **ARC:**
  - Andreas Bernhard Meyer (DESY, ARC Chair).
  - Seyed Mohsen Etesami (IPM).
  - Jacob Thomas Linacre (RAL), after Kate Mackay (Brunel) left.
  - Lutz Werner Feld (Aachen).
- **CCLE:** Enrique Palencia Cortezón.

- Status of comments to analysis and documentation: all answers detailed in internal twiki.
- List of requirements for preapproval and approval in the TOP PAG twiki fulfilled.
- All POG questionnaires filled.
  - Greenlight from Muon, EGM, JME and BTV POGs and from the Stat. Comm..

State of the art

- **Aim**: measurement of tW differential cross-section.



- Main challenge: background dominates signal, being the largest $t\bar{t}$.
- Already published by ATLAS
  - [10.1007/JHEP01(2018)063, arXiv:1612:07231]
- ATLAS approach: define a signal–enriched region by selecting events with high BDT discriminant:
  - Cannot unfold variables directly related to it.

*** [10.1007/JHEP10(2018)117 , arXiv:1805.07399 [hep-ex]]**

- Our approach:
  - Cut & count analysis: we control exactly our fiducial region definition.
  - Signal extraction performed by subtracting background, estimated through MC simulations.
  - Same structure, trigger paths, and object ID as in **tW inclusive cross section measurement analysis (TOP-17-018*)** and *almost* the same event selection.

Changes since preapproval

- Binning improved for the six chosen distributions.
  - Also small changed on binning to prevent lack of statistics in some (~5) bins of some uncertainty variations.
- Absolute results (in supplementary material) are expressed normalised to bin width.
- Uncertainties are taken as the average of the up and down variations. One-sided uncertainties are symmetrised.
- To tackle top p_T mismodeling, the reweighting is applied now not only to consider it as an uncertainty, but also as a nominal weight.

Data samples and trigger

- The analysis is performed over the complete 2016 dataset (35.9 fb^{-1}).
  - SingleElec, SingleMuon and MuonEG datasets.
  - Run2016B-Run2016H (03Feb2017 ReReco).
  - JSON: `Cert_271036-284044_13TeV_23Sep2016ReReco_Collisions16_JSON.txt`

- The **trigger** strategy (same as in TOP-17-018) follows the recommendations by the TOP trigger twiki (trigger SF obtained from TOP-17-001, thanks to Till *et al.*, AN-2016/025), using an **OR** of single and double triggers.

Run B-G and MC	Run H
HLT_Mu23_TrkIsoVVL_Ele12_CaloIdL_TrackIdL_IsoVL_v* HLT_Mu8_TrkIsoVVL_Ele23_CaloIdL_TrackIdL_IsoVL_v*	HLT_Mu23_TrkIsoVVL_Ele12_CaloIdL_TrackIdL_IsoVL_DZ_v* HLT_Mu8_TrkIsoVVL_Ele23_CaloIdL_TrackIdL_IsoVL_DZ_v*
HLT_Ele27_WPTight_Gsf v* HLT_IsoTkMu24_v* HLT_IsoMu24 v*	HLT_Ele27_WPTight_Gsf_v* HLT_IsoTkMu24_v* HLT_IsoMu24_v*

Simulation samples

- MC samples used in the analysis for tW and ttbar:
  - Most of them are used to estimate various systematic uncertainties.

- To get particle level information, the RIVET pseudoparticle producer is used as recommended by *“Object definitions for top quark analyses at the particle level”* (CMS-NOTE-2017-007) .

- Other samples used:
  - DY: M50 & M10to50 `amcatnloFXFX-pythia8`
  - VV+jets: `madgraphMLM`.
  - ttV: `amcatnloFXFX-pythia8`

Sample	σ [pb]	Events
/TT_TuneCUETP8M2T4_13TeV-powheg-pythia8	831.8	77,229,341
/TT_TuneCUETP8M2T4_13TeV-powheg-pythia8 (_backup)	831.8	78,006,311
/TTTo2L2Nu_TuneCUETP8M2_ttHtranche3_13TeV-powheg-pythia8	831.8	79,092,400
/ST_tW_top_5f_inclusiveDecays_13TeV-powheg-pythia8_TuneCUETP8M1 (_ext1-v1)	35.85	6,952,830
/ST_tW_antitop_5f_inclusiveDecays_13TeV-powheg-pythia8_TuneCUETP8M1 (_ext1-v1)	35.85	6,933,094
/ST_tW_top_5f_NoFullyHadronicDecays_13TeV-powheg_TuneCUETP8M1	19.467	5,372,991
/ST_tW_top_5f_NoFullyHadronicDecays_13TeV-powheg_TuneCUETP8M1 (_ext1-v1)	19.467	3,256,650
/ST_tW_top_5f_NoFullyHadronicDecays_13TeV-powheg_TuneCUETP8M1 (_ext2-v2)	19.467	2,715,978
/ST_tW_antitop_5f_NoFullyHadronicDecays_13TeV-powheg_TuneCUETP8M1	19.467	5,425,134
/ST_tW_antitop_5f_NoFullyHadronicDecays_13TeV-powheg_TuneCUETP8M1 (_ext1-v1)	19.467	3,256,407
/ST_tW_antitop_5f_NoFullyHadronicDecays_13TeV-powheg_TuneCUETP8M1 (_ext2-v1)	19.467	2,726,603

Sample	Events
/TT_TuneCUETP8M2T4_13TeV-powheg-isrdown-pythia8	29,084,029
/TT_TuneCUETP8M2T4_13TeV-powheg-isrdown-pythia8 (_ext1-v1)	29,915,551
/TT_TuneCUETP8M2T4_13TeV-powheg-isrdown-pythia8 (_ext1-v2)	90,763,410
/TT_TuneCUETP8M2T4_13TeV-powheg-isrup-pythia8 (_ext1-v1)	59,033,604
/TT_TuneCUETP8M2T4_13TeV-powheg-isrup-pythia8 (_ext2-v1)	97,436,211
/TT_TuneCUETP8M2T4_13TeV-powheg-fsrdown-pythia8	29,716,580
/TT_TuneCUETP8M2T4_13TeV-powheg-fsrdown-pythia8 (_ext1-v1)	29,590,326
/TT_TuneCUETP8M2T4_13TeV-powheg-fsrup-pythia8	29,777,488
/TT_TuneCUETP8M2T4_13TeV-powheg-fsrup-pythia8 (_ext1-v1)	29,453,411
/TT_TuneCUETP8M2T4_13TeV-powheg-fsrup-pythia8 (_ext1-v2)	93,386,680
/TT_hdampDOWN_TuneCUETP8M2T4_13TeV-powheg-pythia8	29,117,820
/TT_hdampDOWN_TuneCUETP8M2T4_13TeV-powheg-pythia8 (_ext1-v1)	29,046,156
/TTTo2L2Nu_hdampUP_TuneCUETP8M2T4_13TeV-powheg-pythia8/	9,693,881
/TT_hdampUP_TuneCUETP8M2T4_13TeV-powheg-pythia8	29,689,380
/TT_hdampUP_TuneCUETP8M2T4_13TeV-powheg-pythia8 (_ext1-v1)	29,169,226
/TTTo2L2Nu_hdampDOWN_TuneCUETP8M2T4_13TeV-powheg-pythia8	9,649,574
/TT_TuneCUETP8M2T4up_13TeV-powheg-pythia8	29,310,620
/TT_TuneCUETP8M2T4down_13TeV-powheg-pythia8	28,354,188
/TT_TuneCUETP8M2T4_mtop1665_13TeV-powheg-pythia8	19,380,254
/TT_TuneCUETP8M2T4_mtop1695_13TeV-powheg-pythia8 (_backup)	29,173,030
/TT_TuneCUETP8M2T4_mtop1695_13TeV-powheg-pythia8 (_ext1-v1)	9,954,200
/TT_TuneCUETP8M2T4_mtop1695_13TeV-powheg-pythia8 (_ext2-v1)	19,415,360
/TT_TuneCUETP8M2T4_mtop1715_13TeV-powheg-pythia8	19,578,812
/TT_TuneCUETP8M2T4_mtop1735_13TeV-powheg-pythia8	19,419,050
/TT_TuneCUETP8M2T4_mtop1755_13TeV-powheg-pythia8	29,459,232
/TT_TuneCUETP8M2T4_mtop1755_13TeV-powheg-pythia8 (_ext1-v1)	9,930,052
/TT_TuneCUETP8M2T4_mtop1755_13TeV-powheg-pythia8 (_ext2-v1)	19,995,376
/TT_TuneCUETP8M2T4_mtop1785_13TeV-powheg-pythia8	16,377,176
/TT_TuneCUETP8M2T4_erdON_13TeV-powheg-pythia8	29,943,330
/TT_TuneCUETP8M2T4_erdON_13TeV-powheg-pythia8 (_ext1-v1)	29,938,880
/TTTo2L2Nu_TuneCUETP8M2T4_erdON_13TeV-powheg-pythia8	9,537,400
/TT_TuneCUETP8M2T4_QCDbasedCRTune_erdON_13TeV-powheg-pythia8	29,983,790
/TT_TuneCUETP8M2T4_QCDbasedCRTune_erdON_13TeV-powheg-pythia8 (_ext1-v1)	29,636,416
TTTo2L2Nu_TuneCUETP8M2T4_QCDbasedCRTune_erdON_13TeV-powheg-pythia8	9,816,448
/TT_TuneCUETP8M2T4_GluonMoveCRTune_13TeV-powheg-pythia8	59,037,234
/TTTo2L2Nu_TuneCUETP8M2T4_GluonMoveCRTune_13TeV-powheg-pythia8	9,862,990
/TT_TuneCUETP8M2T4_GluonMoveCRTune_erdON_13TeV-powheg-pythia8	56,168,970
/TTJets_TuneCUETP8M2T4_13TeV-amcatnloFXFX-pythia8	43,561,608
/TT_TuneEE5C_13TeV-powheg-herwigpp	29,412,687
/TT_TuneEE5C_13TeV-powheg-herwigpp (_ext2-v1)	19,762,915

Object identification and SF

- Object ID (same as in TOP-17-018) follows recommendations from each object's POG.
- PU scale factors derived following recommendations.

- **Electrons**
  - Cut-based tight ID (POG).
  - Veto of transition region (1.4442 < |η| <1.5660).
  - p_T > 20 GeV, |η| < 2.4.
  - I_{rel} < 0.06 (exact values depend on η).
  - Using official electron scale factors.

- **Muons**
  - Tight ID (POG).
  - p_T > 20 GeV, |η| < 2.4.
  - I_{rel} < 0.15.
  - Using official muon scale factors.

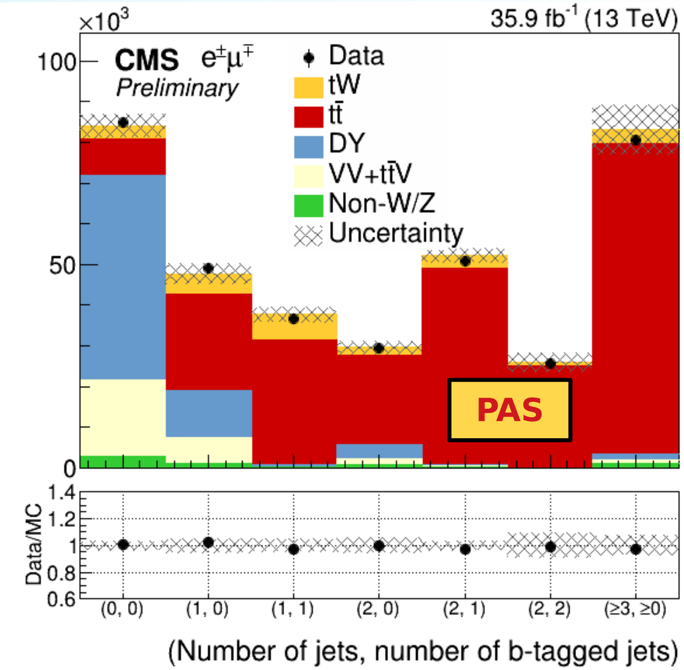
- **Jets**
  - PF jets with p_T > 30 GeV, |η| < 2.4, ΔR > 0.4 (for cleaning as well as cone size).
  - B-tagging:
    - CSVv2.
    - Medium working point (CSV > 0.8484).
    - Official recommended b-tagging SF used: CSVv2_Moriond17_B_H.csv
  - Loose jets are defined as those that fulfil p_T > 20 GeV and the other previous requirements.

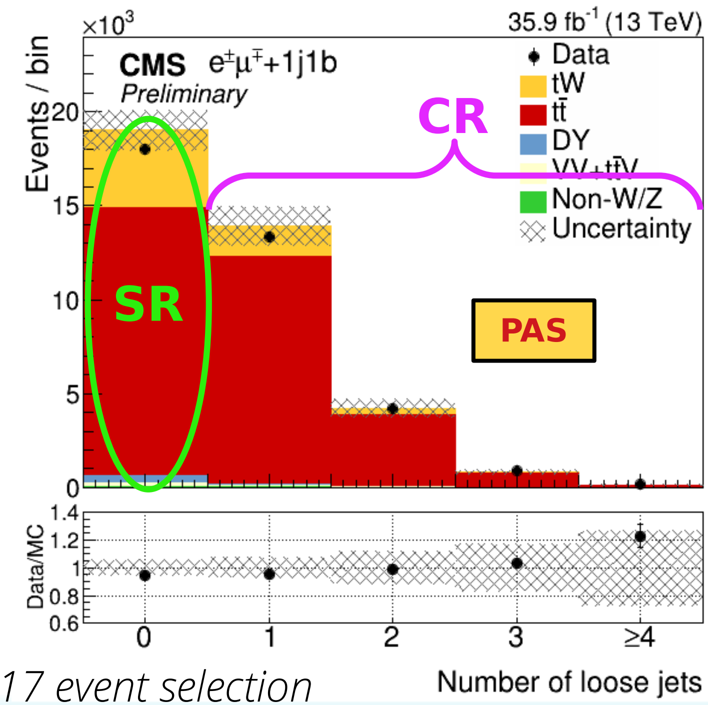
- **MET**
  - Type-I corrected MET (JET smeared).

- **Additional check**: as requested by the list of tasks to be done before preapproval, the effect of the prefiring issue of 2016 data has been checked.
  - Data – MC plots obtained with the corresponding weights show almost no difference.
  - Unfolded results idem.

Event selection

- At least two identified leptons.
- One of them must fulfil $p_T > 25$ GeV.
- The two first (in terms of p_T) must have opposite charge…
- … and be an electron and a muon (eμ channel)…
- …whose invariant mass satisfy m(e, μ) > 20 GeV.
- Exactly 1 jet that must be b-tagged.
- **Exactly zero loose jets**.
- **Top p_T reweighting** applied



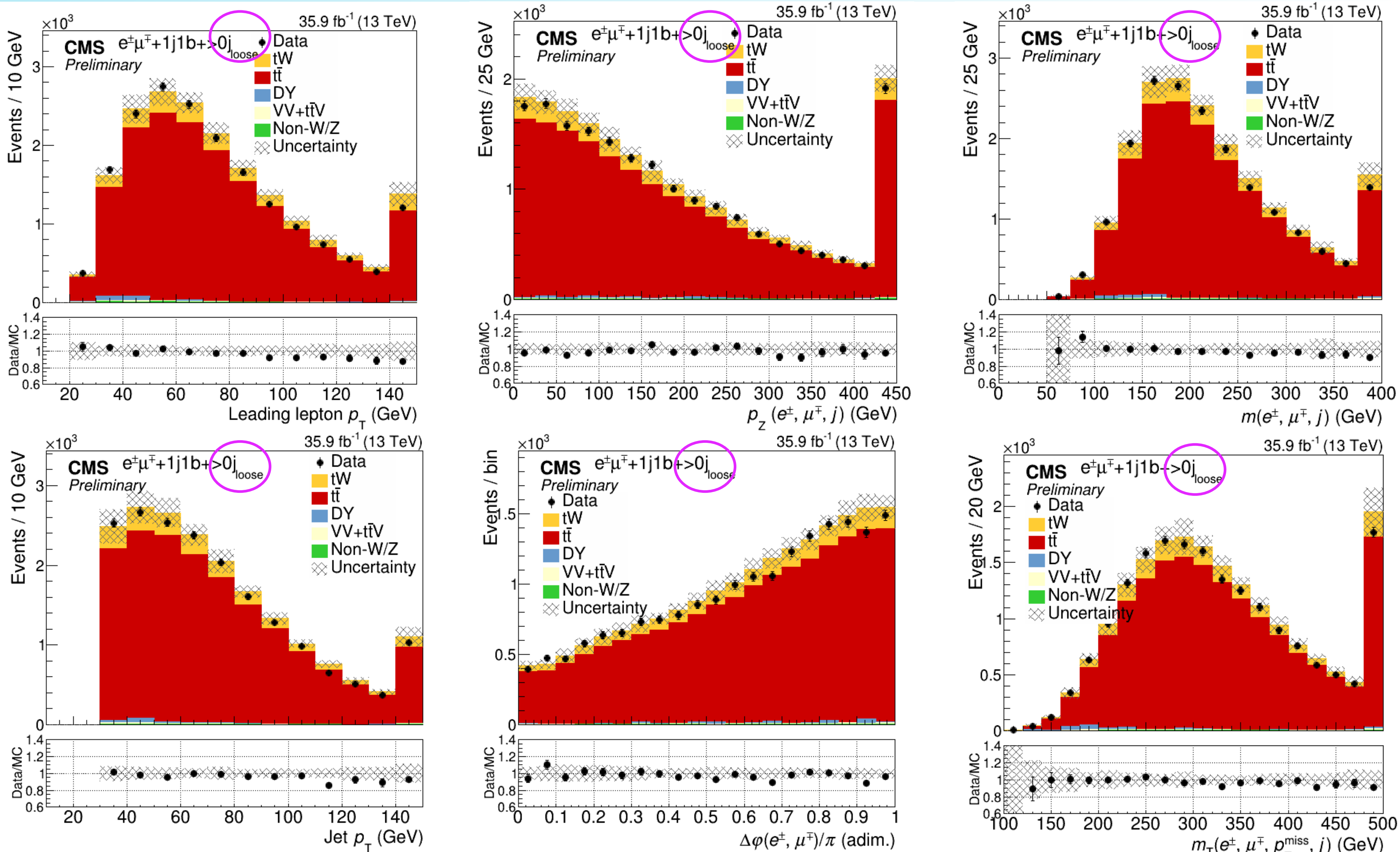


Differences w.r.t. TOP-17-018/10.1007/JHEP10(2018)117 event selection

Selected distributions

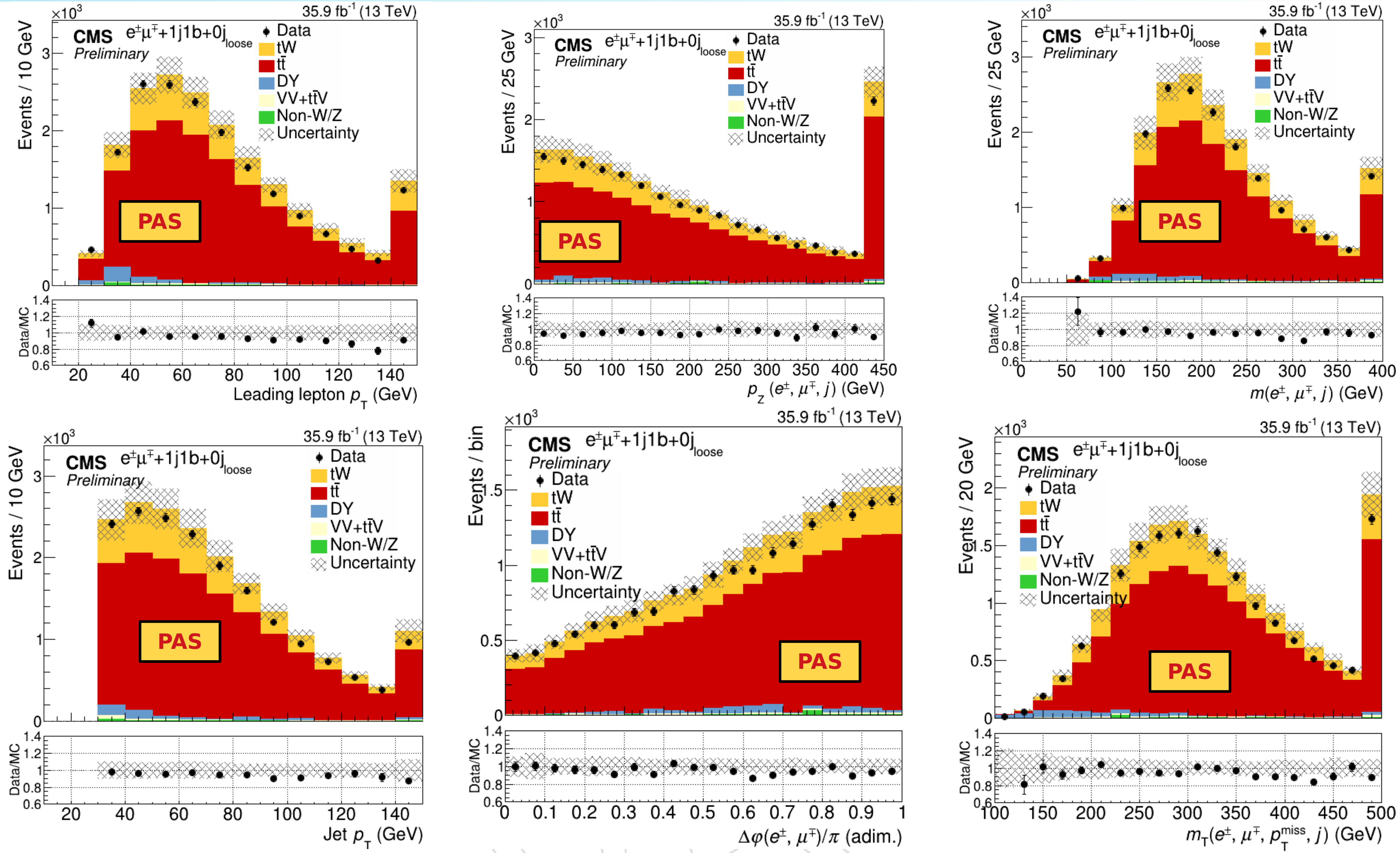
- $p_T(\ell_1)$: provides kinematic information of the process.
- $p_T(j)$: provides kinematic information of the process.
- $\Delta\varphi(\ell_1, \ell_2)$: sensible to spin features and correlations of both leptons.
- $m(\ell_1, \ell_2, j)$: explore correlations between objects.
- $m_T(\ell_1, \ell_2, j, \not{E}_T)$: explore correlations between objects (in the transversal plane).
- $p_Z(\ell_1, \ell_2, j)$: probe for the boost of the system.

Control region MC–data plots



Source	Non-W/Z	VV and $t\bar{t}$ V	Drell-Yan	$t\bar{t}$	Total background	tW (signal)	Total	Data
Amount	74	86	125	16875	17160	1989	19149	18581

Signal region MC–data plots



Source	$t\bar{t}$	Non W/Z	VV and $t\bar{t}$ V	Drell-Yan	Total background	tW (signal)	Total	Data
Amount	14215	79	157	363	14814	4160	18974	18025

Unfolding method

- Unfolding is implemented using `TUnfold`, allowing us to do the "jump" from detector to particle level.

- **Methodology:** (for each variable)

1) The response matrix is calculated using MC samples. Any binning used must fulfil a relation of 2 (reco.) : 1 (gen.).
2) Stabilities and purities are calculated for each bin in detector and particle level.
3) Bin width is optimised (using simulations) so that:
   - All bins of the distributions at detector level have enough signal events (≈>50-100).
   - Purities and stabilities are roughly uniform (what indirectly makes the response matrices diagonal).
4) The need for regularisation is checked with the chosen binning consulting the condition number of each matrix.
   - In case that it is needed, its intensity will be determined by the L-curve method.
5) The need for adding an area constraint term is checked by (using simulations) its effect with the chosen binning.

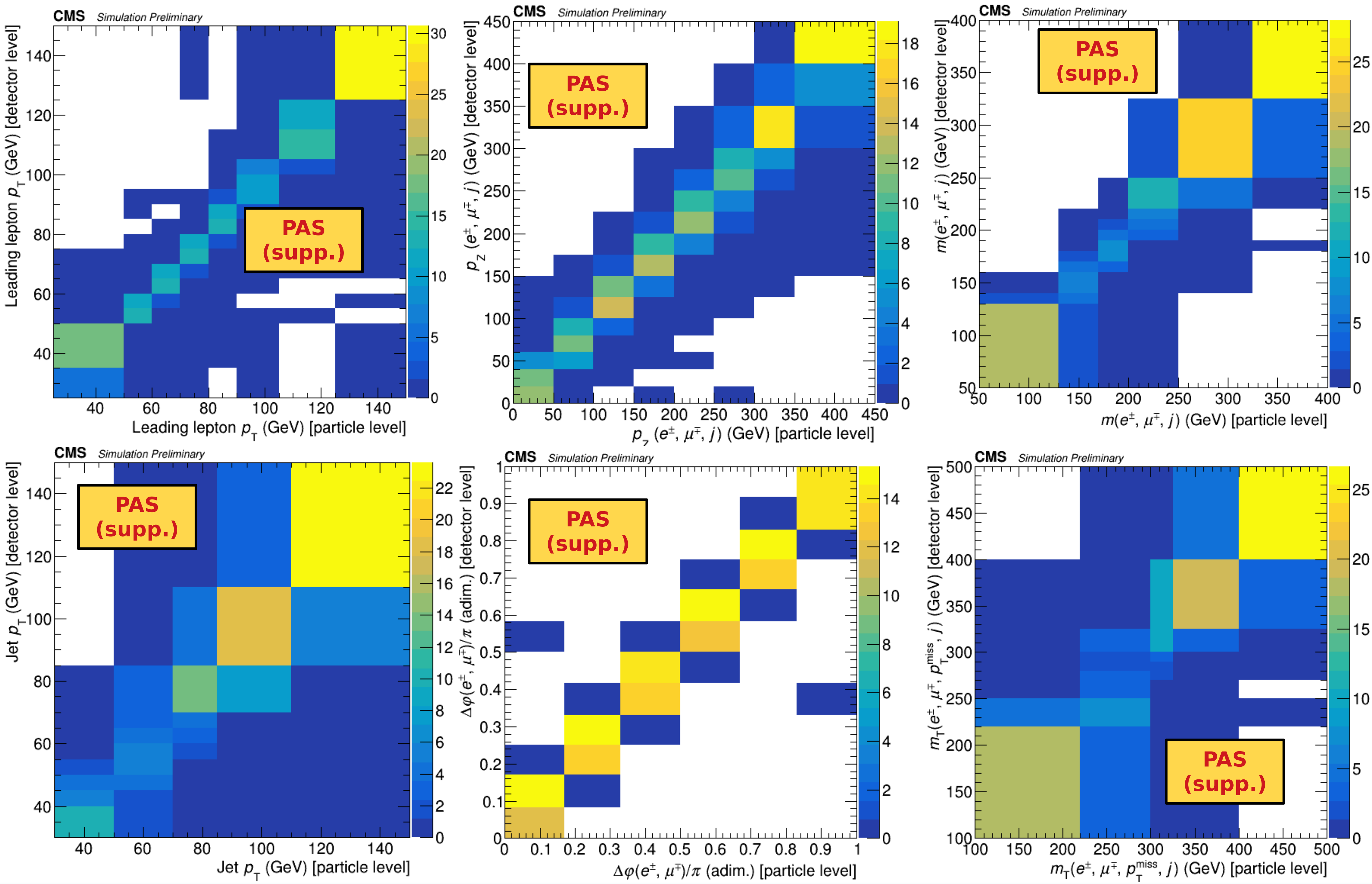
- **Tests and checks:**

- Closure tests (with Asimov dataset).

Fiducial region definition

- Events are required to have:
  - At least two leptons with p_T> 20 GeV and...
    - ...|η|< 2.4 (muons).
    - ...|η|< 1.4442 or |η|> 1.566 (electrons).
  - One of them, with at least p_T>25 GeV.
  - The two leptons with largest p_T must be an electron and a muon...
  - ...with opposite charge.
  - In addition, their invariant mass must be over 20 GeV.
  - There must be only one jet (with p_T > 30 GeV and separated with a cone of at least ΔR > 0.4 of any of the selected leptons with the previous properties (p_T > 20 GeV and the η requirements)...
  - ...and it must come from a b quark.
  - No other jet with p_T > 20 GeV is allowed to be present in the event.

Response matrices



Uncertainties

- All systematic uncertainties are **propagated** through unfolding by performing separated unfolding for each variation and afterwards taking the difference with respect to the nominal values.
  - Special attention is payed to correlations and correct derivations when obtaining the fiducial results.
  - Uncertainties can affect the background, but also the response matrix: in those cases, a varied response matrix is calculated for considering them.

Experimental

- **JES/JER**: smearing of the p_T of the jets w.r.t. their scale/resolution.
- **B–tagging** and **mistagging**: varying the SF by their uncertainties.
- **Pile–up**: varying ±4.6%
- **Lepton ID** and **trigger**: varying the SF by their uncertainties. σ_{in}
- **Luminosity**: 2.5% flat.

Background normalisation of MC samples

- ttbar: 4% (thanks to TOP-17-001).
- DY: 50% (from TOP-17-018).
- Non-W/Z: 50% (from TOP-17-018).
- VV+ttbarV: 50% (from TOP-17-018).

Statistical

- Size of data samples.
- Size of simulation samples.
- Size of the simulation samples used for obtaining the response matrices.

Uncertainties

<u>**Modelling-related**</u>

- **UE** (ttbar): using dedicated samples that vary the Pythia parameters that tune the measurements to the UE.
- **h_{damp}** (ME/PS matching; ttbar): using dedicated samples that vary the Pythia h_{damp} parameter by its own uncertainty.
- **ISR/FSR** (tW and ttbar): using dedicated samples that vary the PS scale by a factor of two and taking the variation over $\sqrt{2}$. The energy correction factors depending on the jet p_T have been implemented.
- Comparison with the **DS** schema (tW): using dedicated samples and the difference w.r.t. nominal values.
- **Colour reconnection** (ttbar): using dedicated samples and taking the envelope of their variations for various models.
- **Factorisation/renormalisation scales** (tW and ttbar): using weights that come from scaling μ_F and μ_R by 2 and 0.5.
- **PDF** (ttbar): using weights obtained according with the 100 NNPDF3.0 replicas.
- **m_{top}** (tW and ttbar): using varied samples with up and down values of m_{top}.
- **Top p_T reweighting** (ttbar): as it is applied to the nominal background estimation of the ttbar background, it is considered by taking the difference with the values w/o applying it.

Normalised values – Previous considerations

- The results are **normalised to** the **fiducial cross section** and the **bin width.**
  - Measurement of the fiducial cross section: $\sigma_{fid.} = 0.28^{+0.15}_{-0.14}\,\mathrm{pb}$(dominated by JES, ttbar norm. and ME/PS matching).
  - Apart from the normalised values, the absolute ones are present in the supplementary material of the PAS.
- For all variables, **no regularisation nor area constraint was needed**: direct response matrix (R) inversion is done, after signal is extracted by subtracting the background:

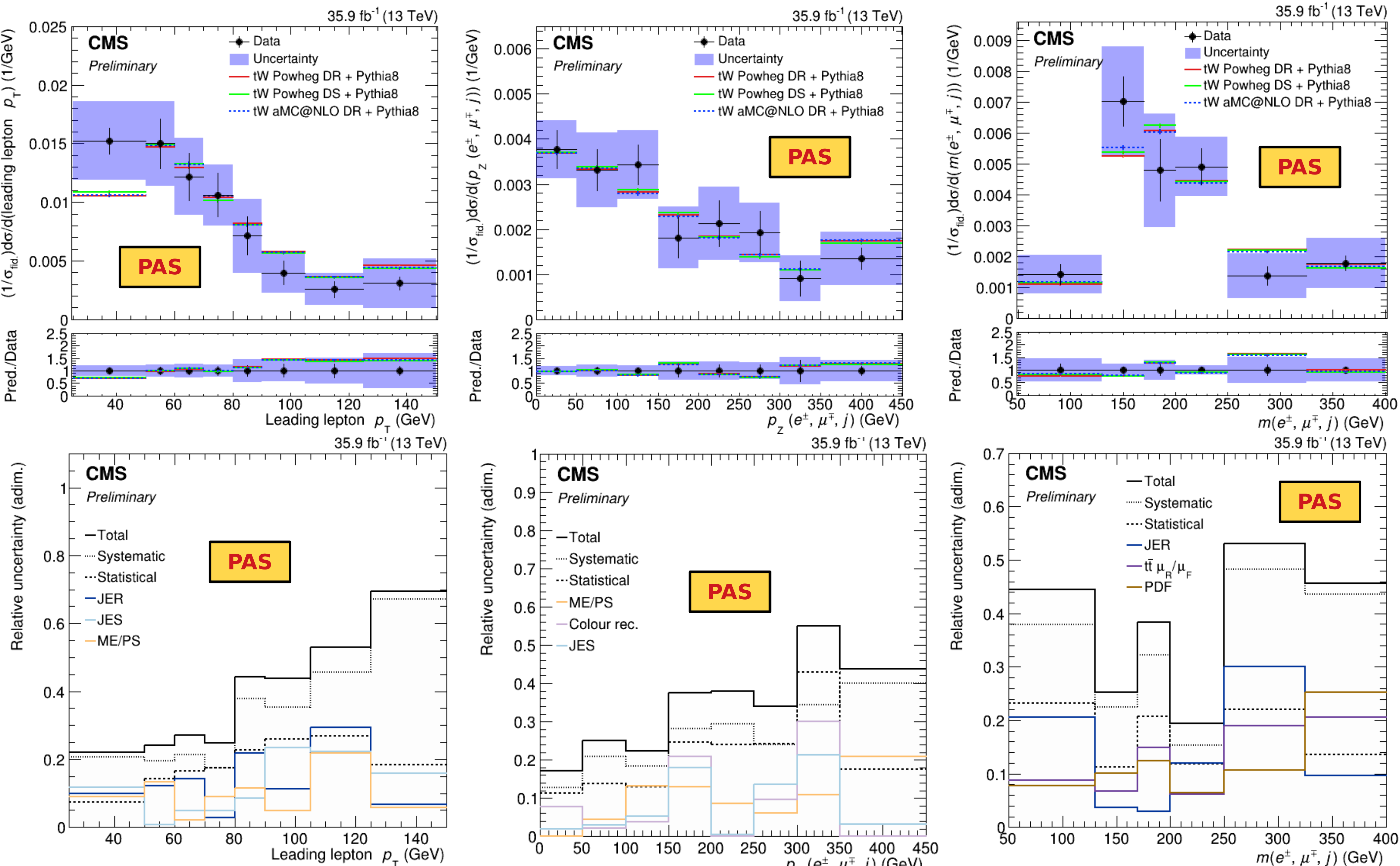
$$N_{\mathrm{i}}^{\mathrm{sig}} = N_{\mathrm{i}} - N_{\mathrm{i}}^{\mathrm{bkg}} = \sum_{\mathrm{j}=1} R_{\mathrm{ij}} N_{\mathrm{j}}^{\mathrm{sig,\,unf}}.$$

- Now follows the normalised results, calculated first as absolute values,

$$\left(\frac{\mathrm{d}\sigma}{\mathrm{d}X}\right)_{\mathrm{j}} = \frac{1}{\mathcal{L}} \frac{N_{\mathrm{j}}^{\mathrm{sig,\,unf}}}{\Delta_{\mathrm{j}}}$$ (for each particle level bin **j**)

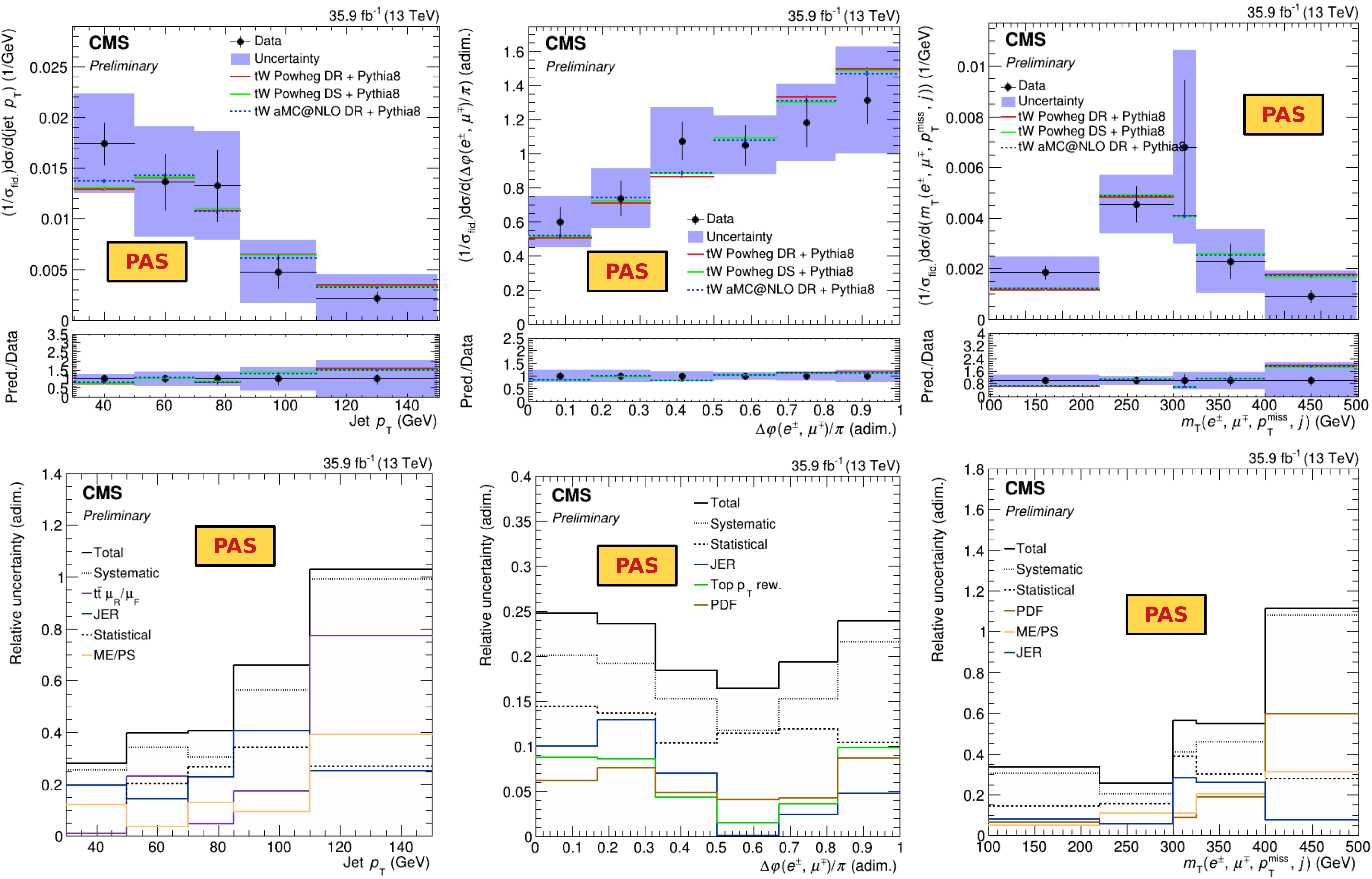
  and then divided by the fiducial cross section.
- The propagation of statistical uncertainties takes into account the correlations when normalising the absolute values. They are shown symmetrically, by taking the average of the two variations.
- A comparison with various generators is presented:
  - tW Powheg DR + Pythia8.
  - tW Powheg DS + Pythia8.
  - tW aMC@NLO DR + Pythia8.

Normalised values - I



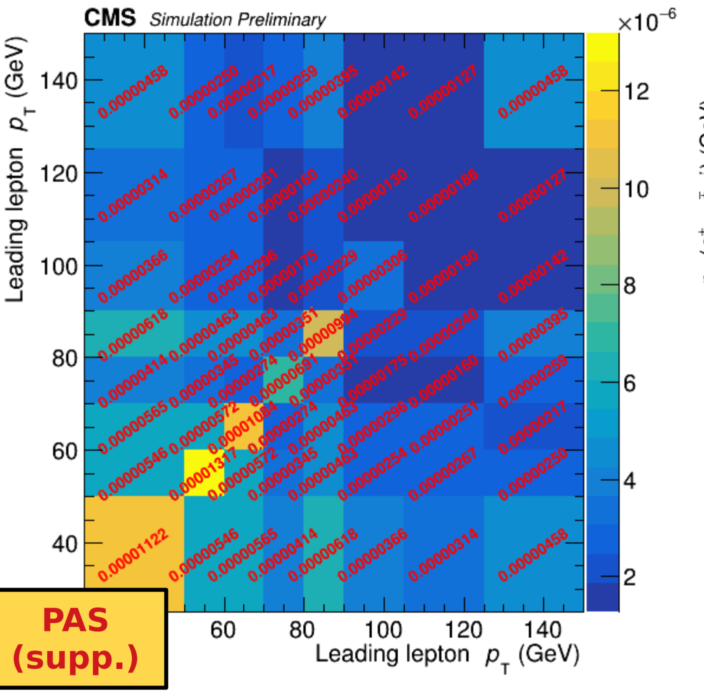
Main backgrounds: jet–related (JEC, JER) and modeling (e.g. ME/PS matching).

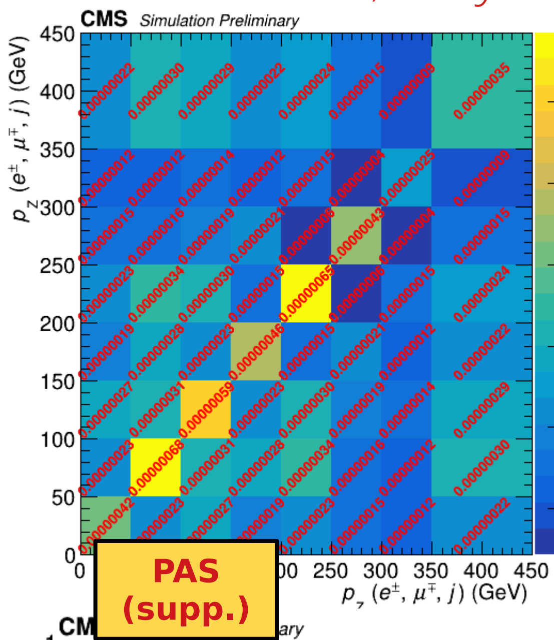
Normalised values - II

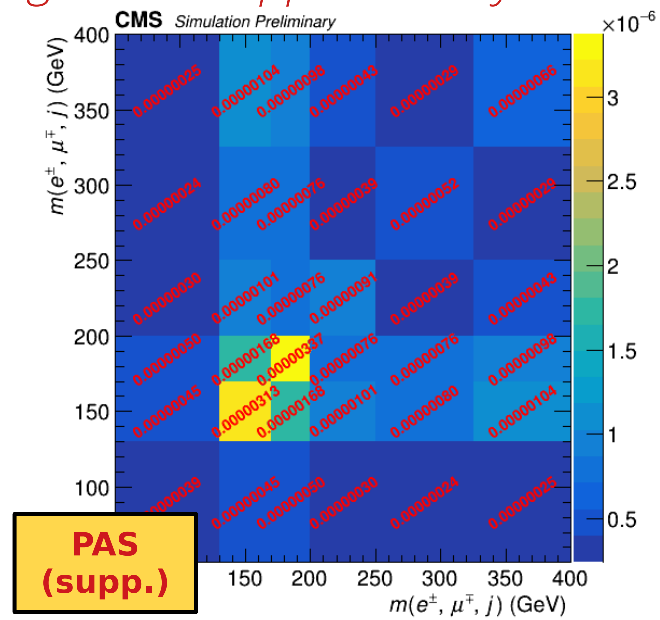


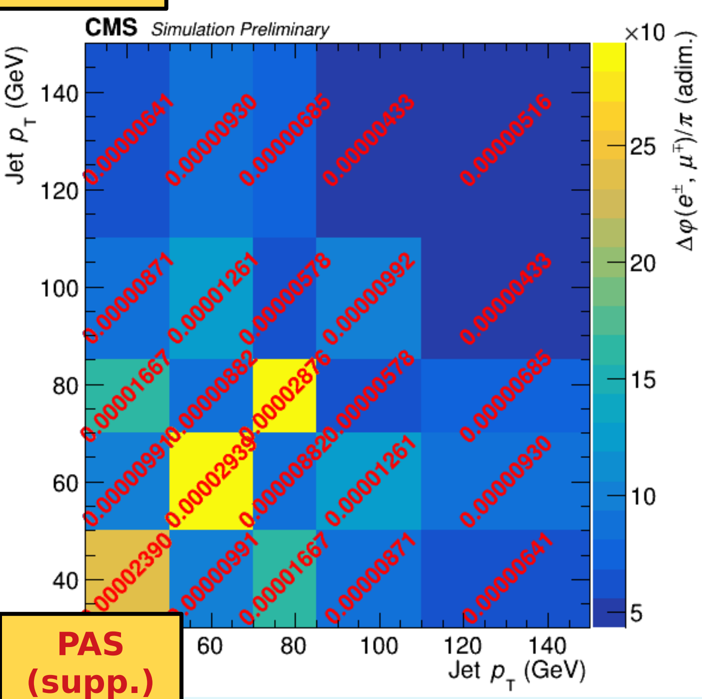
Normalised values – Covariance matrices

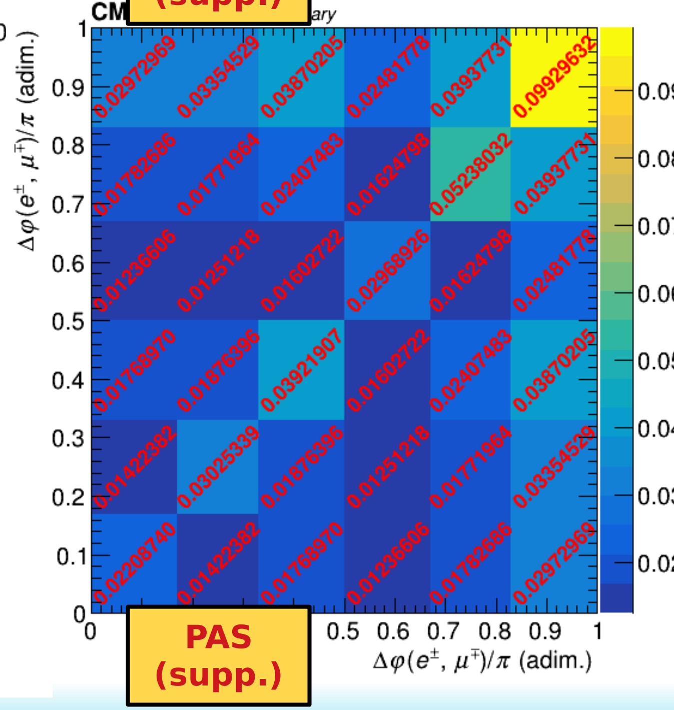
From this slide on, everything belongs to the supplementary material

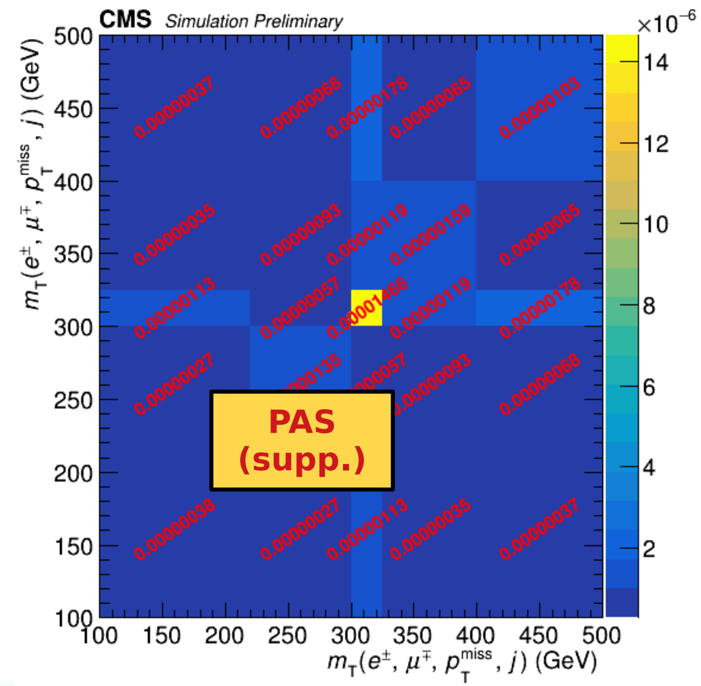












Normalised values – Numerical values

Leading lepton p_T (GeV)	[25, 50)	[50, 60)	[60, 70)	[70, 80)	[80, 90)	[90, 105)	[105, 125)	[125, ∞)
$(1/\sigma_{fid})d\sigma/d$ (Leading lepton p_T) (1/ GeV)	0.015	0.015	0.012	0.011	0.007	0.0040	0.0026	0.003
Uncertainty (1/ GeV)	0.003	0.004	0.003	0.003	0.003	0.0018	0.0014	0.002

Jet p_T (GeV)	[30, 50)	[50, 70)	[70, 85)	[85, 110)	[110, ∞)
$(1/\sigma_{fid})d\sigma/d$ (Jet p_T) (1/ GeV)	0.017	0.014	0.013	0.005	0.002
Uncertainty (1/ GeV)	0.005	0.005	0.005	0.003	0.002

PAS (supp.)

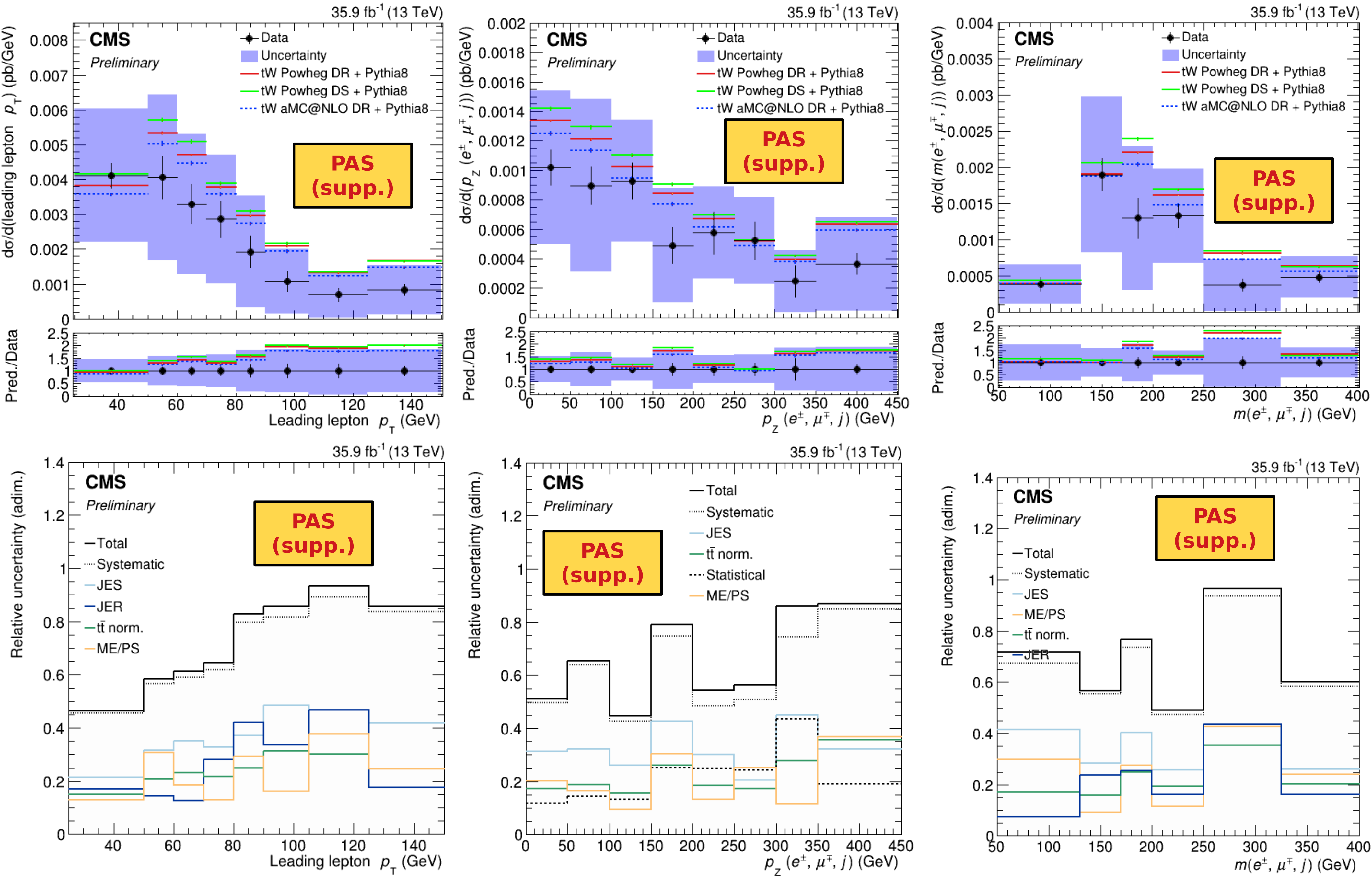
$\Delta\varphi(e^{\pm}, \mu^{\mp})/\pi$	[0.0, 0.17)	[0.17, 0.33)	[0.33, 0.5)	[0.5, 0.67)	[0.67, 0.83)	[0.83, 1]
$(1/\sigma_{fid})d\sigma/d\left(\Delta\varphi(e^{\pm}, \mu^{\mp})/\pi\right)$ (1/ GeV)	0.60	0.74	1.07	1.05	1.2	1.3
Uncertainty (1/ GeV)	0.15	0.17	0.20	0.17	0.2	0.3

$p_Z(e^{\pm}, \mu^{\mp}, j)$ (GeV)	[0, 50)	[50, 100)	[100, 150)	[150, 200)	[200, 250)	[250, 300)	[300, 350)	[350, ∞)
$(1/\sigma_{fid})d\sigma/d\left(p_Z(e^{\pm}, \mu^{\mp}, j)\right)$ (1/ GeV)	0.0038	0.0033	0.0034	0.0018	0.0021	0.0019	0.0009	0.0014
Uncertainty (1/ GeV)	0.0006	0.0008	0.0008	0.0007	0.0008	0.0007	0.0005	0.0006

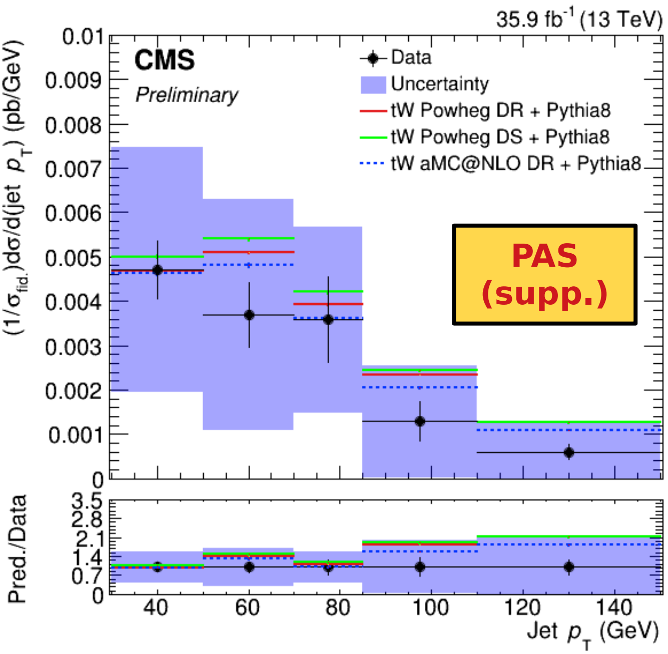
$m(e^{\pm}, \mu^{\mp}, j)$ (GeV)	[50, 130)	[130, 170)	[170, 200)	[200, 250)	[250, 325)	[325, ∞)
$(1/\sigma_{fid})d\sigma/d\left(m(e^{\pm}, \mu^{\mp}, j)\right)$ (1/ GeV)	0.0014	0.0070	0.0048	0.0049	0.0014	0.0018
Uncertainty (1/ GeV)	0.0006	0.0018	0.0018	0.0010	0.0007	0.0008

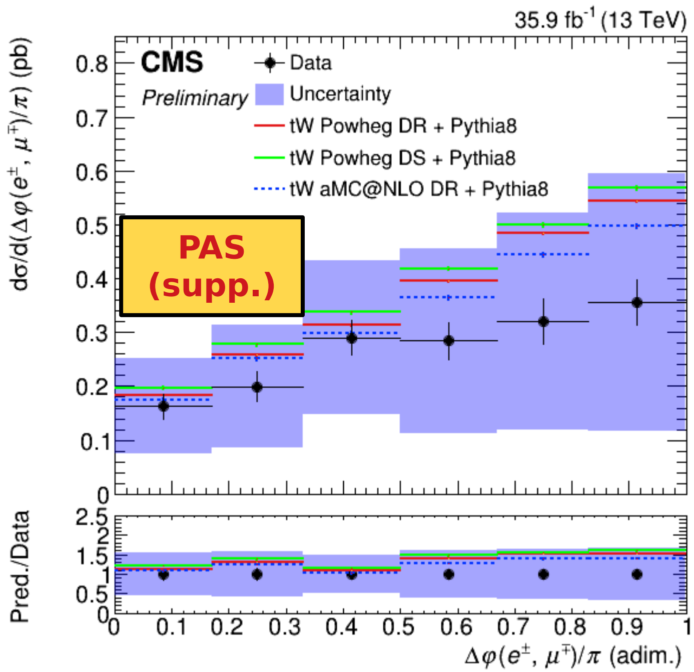
$m_T(e^{\pm}, \mu^{\mp}, j, p_T^{miss})$ (GeV)	[100, 220)	[220, 300)	[300, 325)	[325, 400)	[400, ∞)
$(1/\sigma_{fid})d\sigma/d\left(m_T(e^{\pm}, \mu^{\mp}, j, p_T^{miss})\right)$ (1/ GeV)	0.0018	0.0045	0.007	0.0023	0.0009
Uncertainty (1/ GeV)	0.0006	0.0012	0.004	0.0013	0.0010

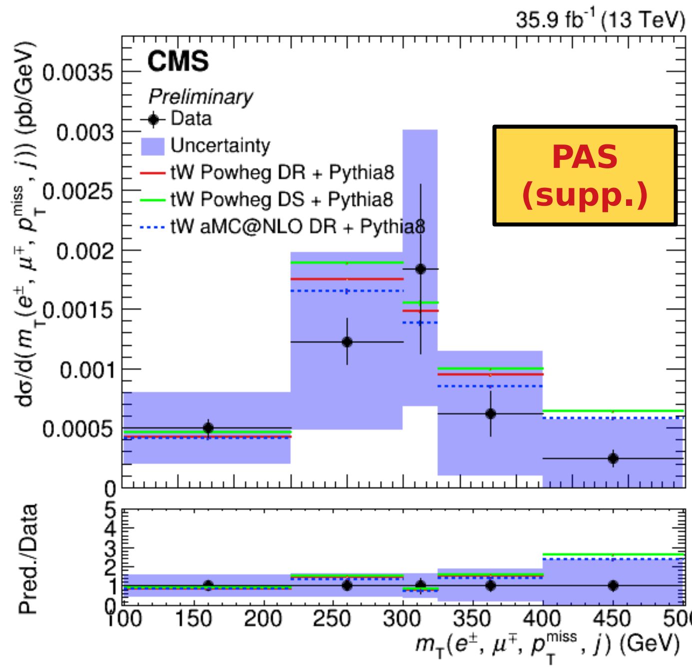
Absolute results - I

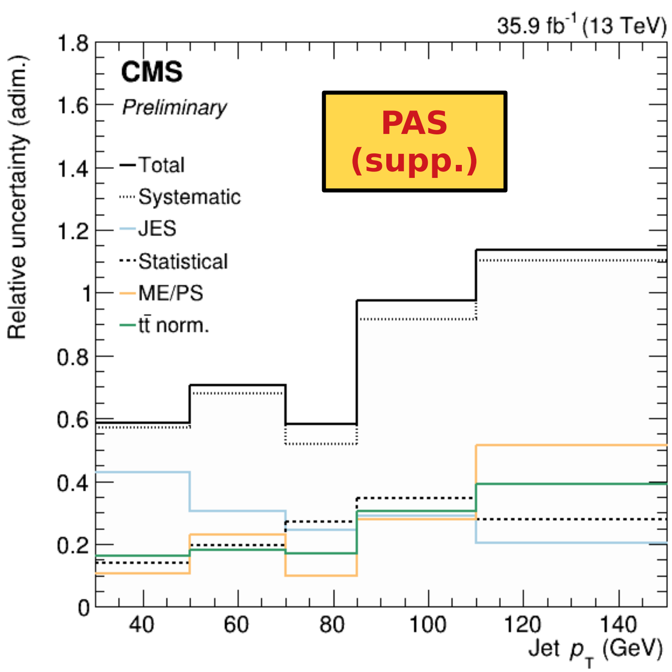


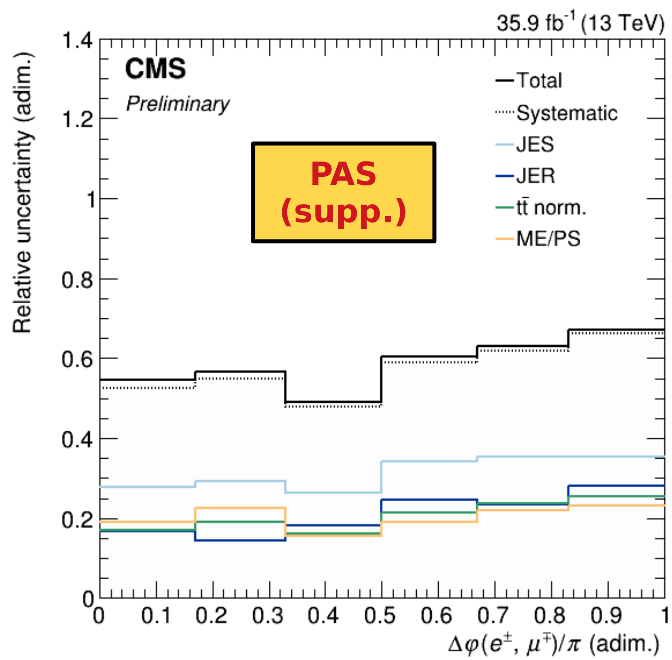
Absolute results - II

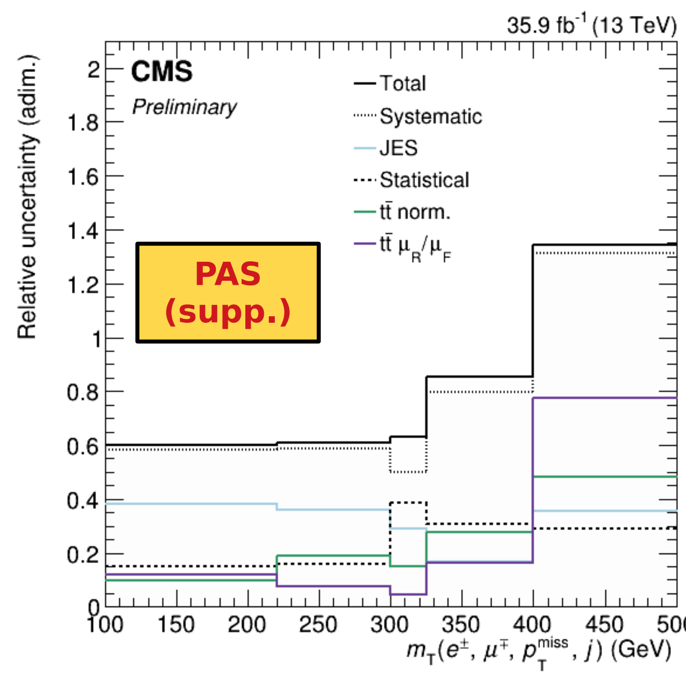




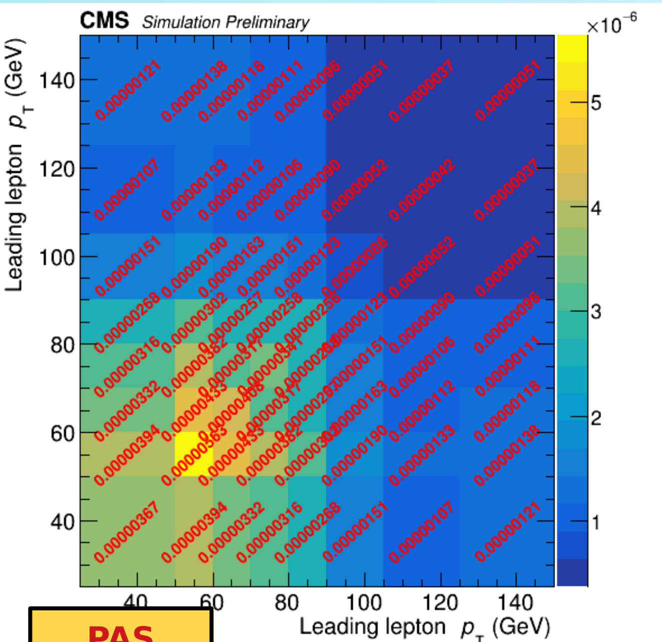


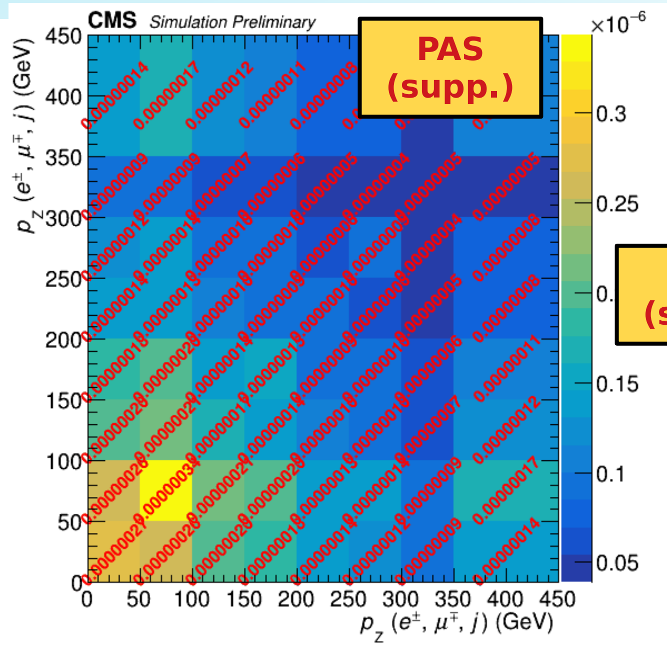


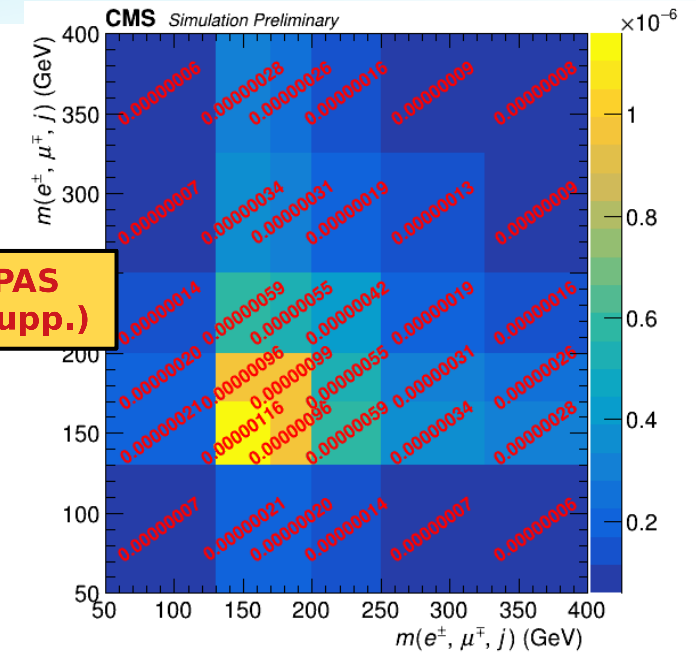




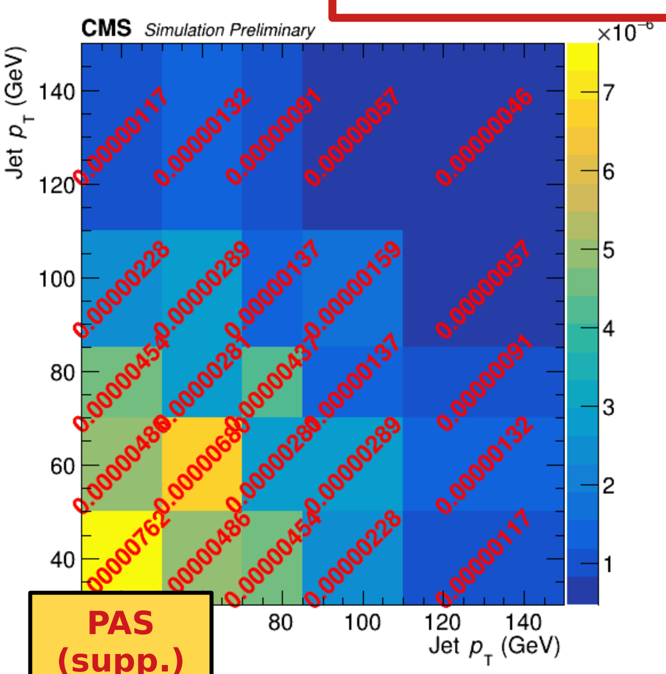
Absolute results – Covariance matrices

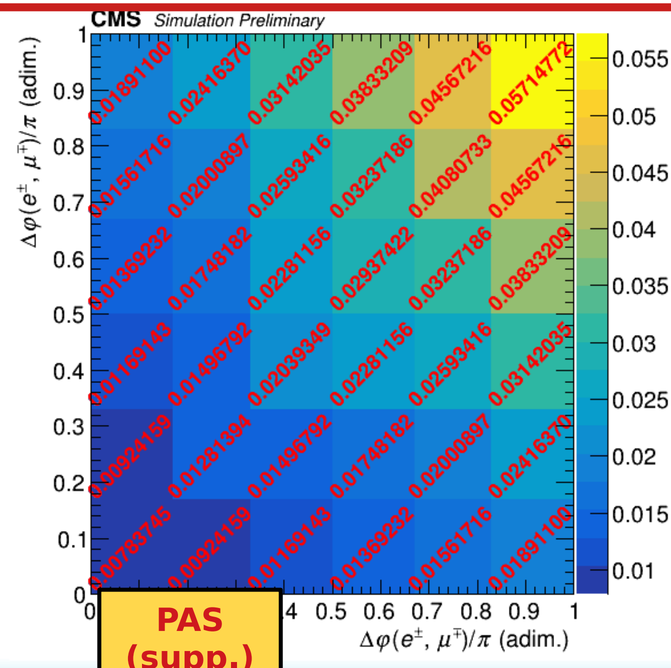


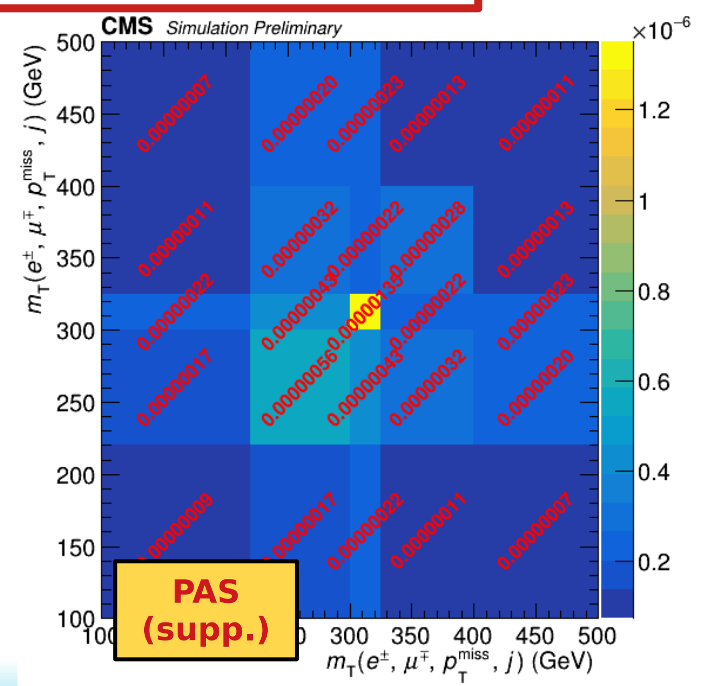




Due to a mistake, the figures shown in the current PAS & AN versions are not correct: these are the rightful ones.







Absolute results – Numerical values

Leading lepton p_T (GeV)	[25, 50)	[50, 60)	[60, 70)	[70, 80)	[80, 90)	[90, 105)	[105, 125)	[125, ∞)
$d\sigma/d$ (Leading lepton p_T) (pb/ GeV)	0.0041	0.004	0.003	0.0029	0.0019	0.0011	0.0007	0.0008
Uncertainty (pb/ GeV)	0.0019	0.002	0.002	0.0018	0.0016	0.0009	0.0006	0.0007

Jet p_T (GeV)	[30, 50)	[50, 70)	[70, 85)	[85, 110)	[110, ∞)
$d\sigma/d$ (Jet p_T) (pb/ GeV)	0.005	0.004	0.004	0.0013	0.0006
Uncertainty (pb/ GeV)	0.003	0.003	0.002	0.0013	0.0007

PAS (supp.)

$\Delta\varphi(e^\pm, \mu^\mp)/\pi$	[0.0, 0.17)	[0.17, 0.33)	[0.33, 0.5)	[0.5, 0.67)	[0.67, 0.83)	[0.83, 1]
$d\sigma/d\left(\Delta\varphi(e^\pm, \mu^\mp)/\pi\right)$ (pb/ GeV)	0.16	0.20	0.29	0.28	0.3	0.4
Uncertainty (pb/ GeV)	0.09	0.11	0.14	0.17	0.2	0.2

$p_Z(e^\pm, \mu^\mp, j)$ (GeV)	[0, 50)	[50, 100)	[100, 150)	[150, 200)	[200, 250)	[250, 300)	[300, 350)	[350, ∞)
$d\sigma/d\left(p_Z(e^\pm, \mu^\mp, j)\right)$ (pb/ GeV)	0.0010	0.0009	0.0009	0.0005	0.0006	0.0005	0.0002	0.0004
Uncertainty (pb/ GeV)	0.0005	0.0006	0.0004	0.0004	0.0003	0.0003	0.0002	0.0003

$m(e^\pm, \mu^\mp, j)$ (GeV)	[50, 130)	[130, 170)	[170, 200)	[200, 250)	[250, 325)	[325, ∞)
$d\sigma/d\left(m(e^\pm, \mu^\mp, j)\right)$ (pb/ GeV)	0.0004	0.0019	0.0013	0.0013	0.0004	0.0005
Uncertainty (pb/ GeV)	0.0003	0.0011	0.0010	0.0006	0.0004	0.0003

$m_T(e^\pm, \mu^\mp, j, p_T^{miss})$ (GeV)	[100, 220)	[220, 300)	[300, 325)	[325, 400)	[400, ∞)
$d\sigma/d\left(m_T(e^\pm, \mu^\mp, j, p_T^{miss})\right)$ (pb/ GeV)	0.0005	0.0012	0.0018	0.0006	0.0002
Uncertainty (pb/ GeV)	0.0003	0.0007	0.0012	0.0005	0.0003

Conclusions and perspectives

- A measurement of the differential cross section in the tW process using CMS 2016 data has been made depending on six observables of the events.
  - Absolute results and also normalised results to the fiducial cross section have been obtained.

- Comparable uncertainties to ATLAS' results, although with a different approach that allows the unfolding of any kind of observables.
  - Main sources: jet–related uncs. (e.g. JES, JER) and modeling (e.g. ME/PS matching).
  - Analysis largely dominated by systematic sources of uncertainties, whose main origin is the overwhelming ttbar background.
  - Depending on the bin and distribution, varying from ~15-40% (bulk of distributions) up to ~25-100% in the tails.

- We would like to kindly ask for the approval of this PAS.
  - The analysis is expected to be shown in tomorrow's LHCC poster session.

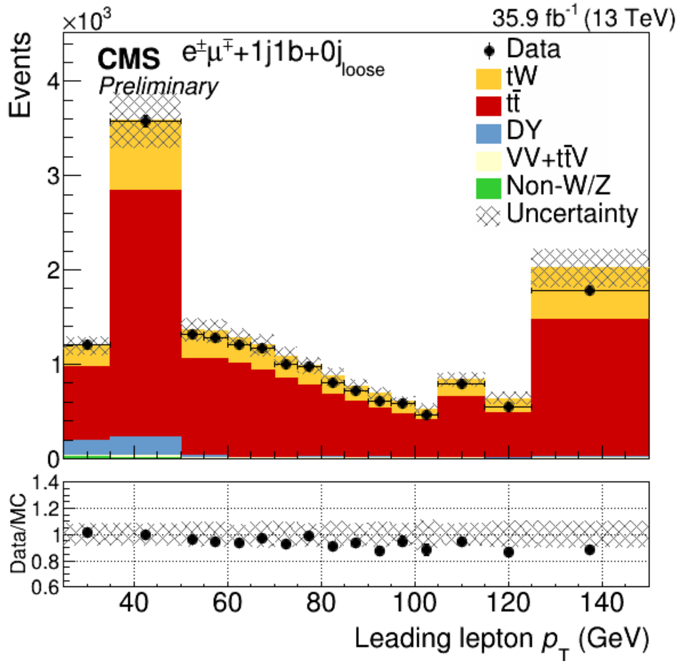
- Once we release this PAS we will focus on the inclusive and differential analysis with the full Run 2 dataset, to publish it.
  - Expectation: summer 2020.

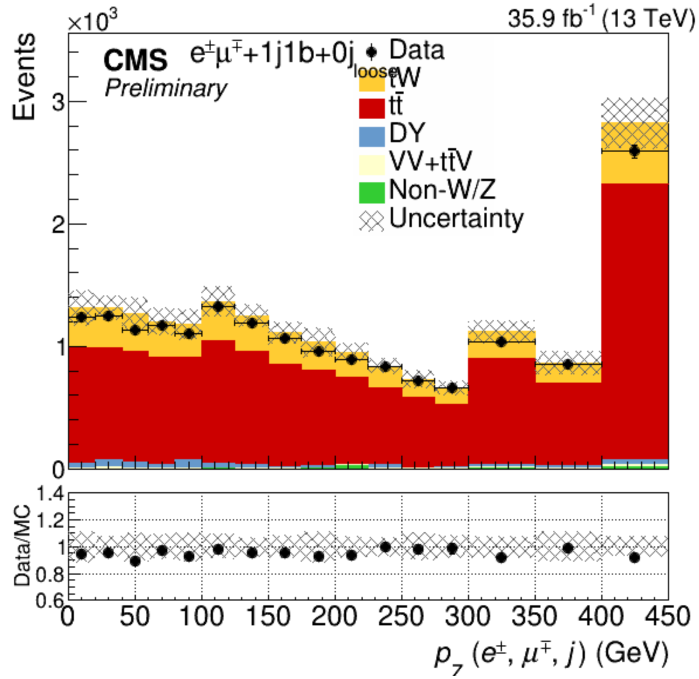
Thanks for your attention

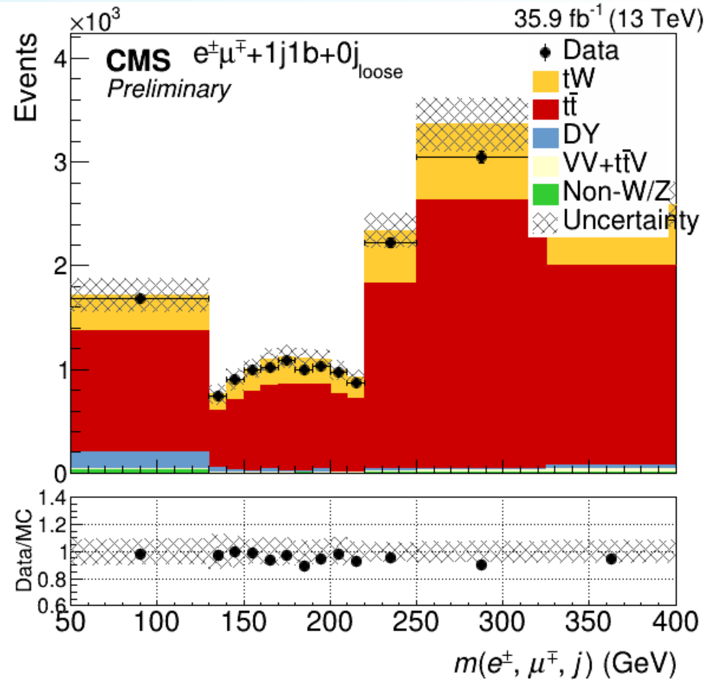
TOP PAG meeting

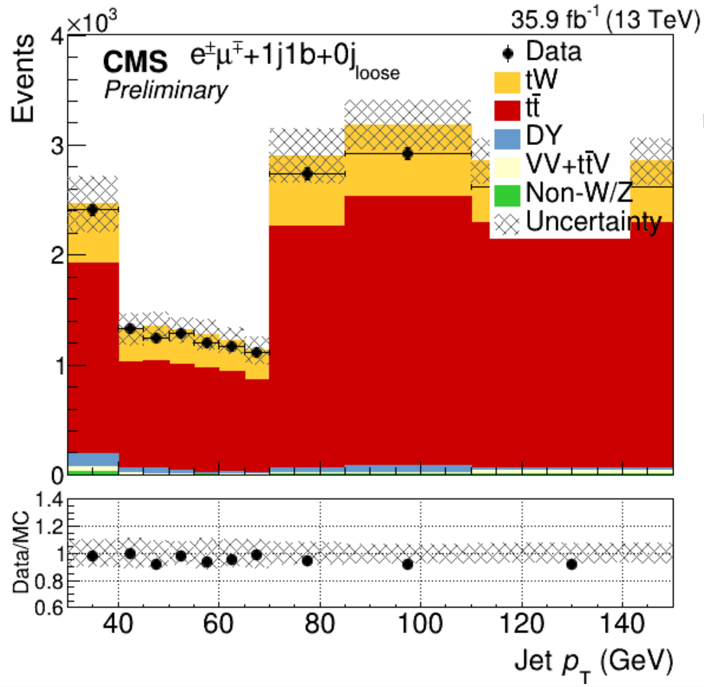
Extra slides

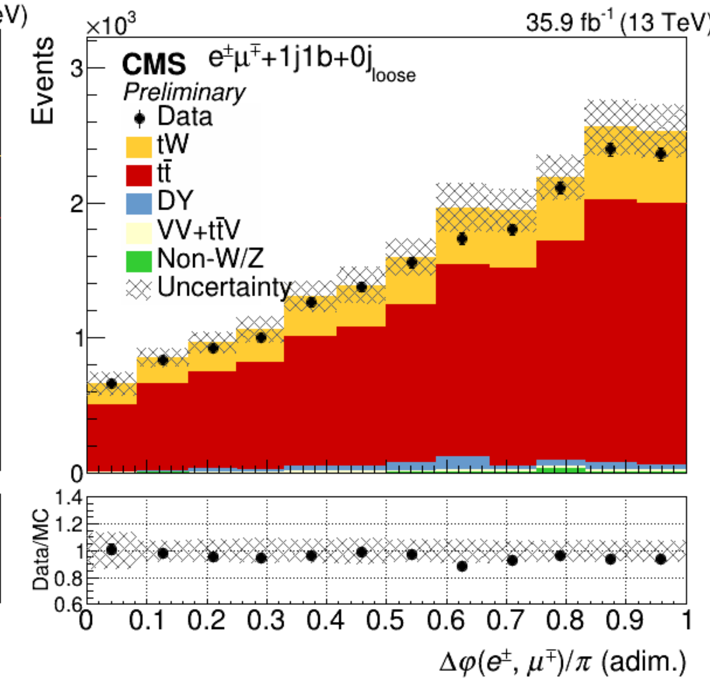
Signal region MC–data plots with detector level binning

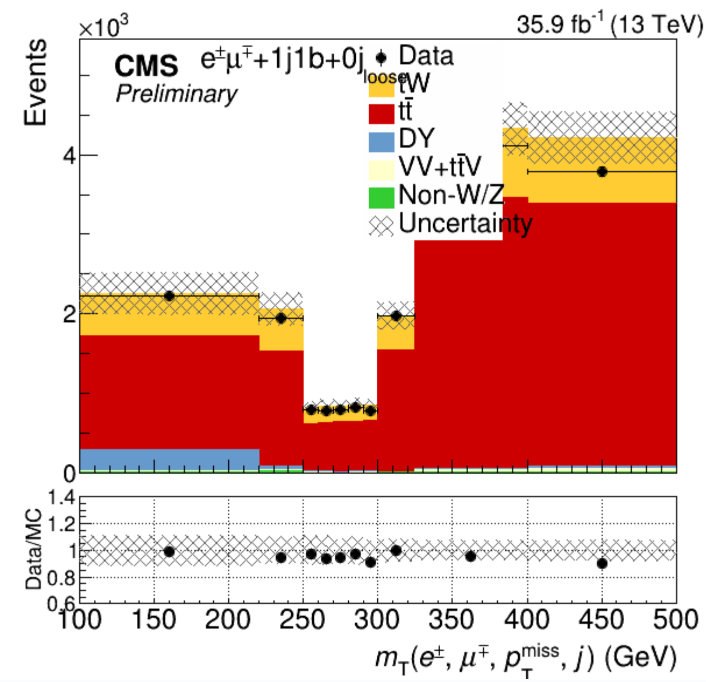




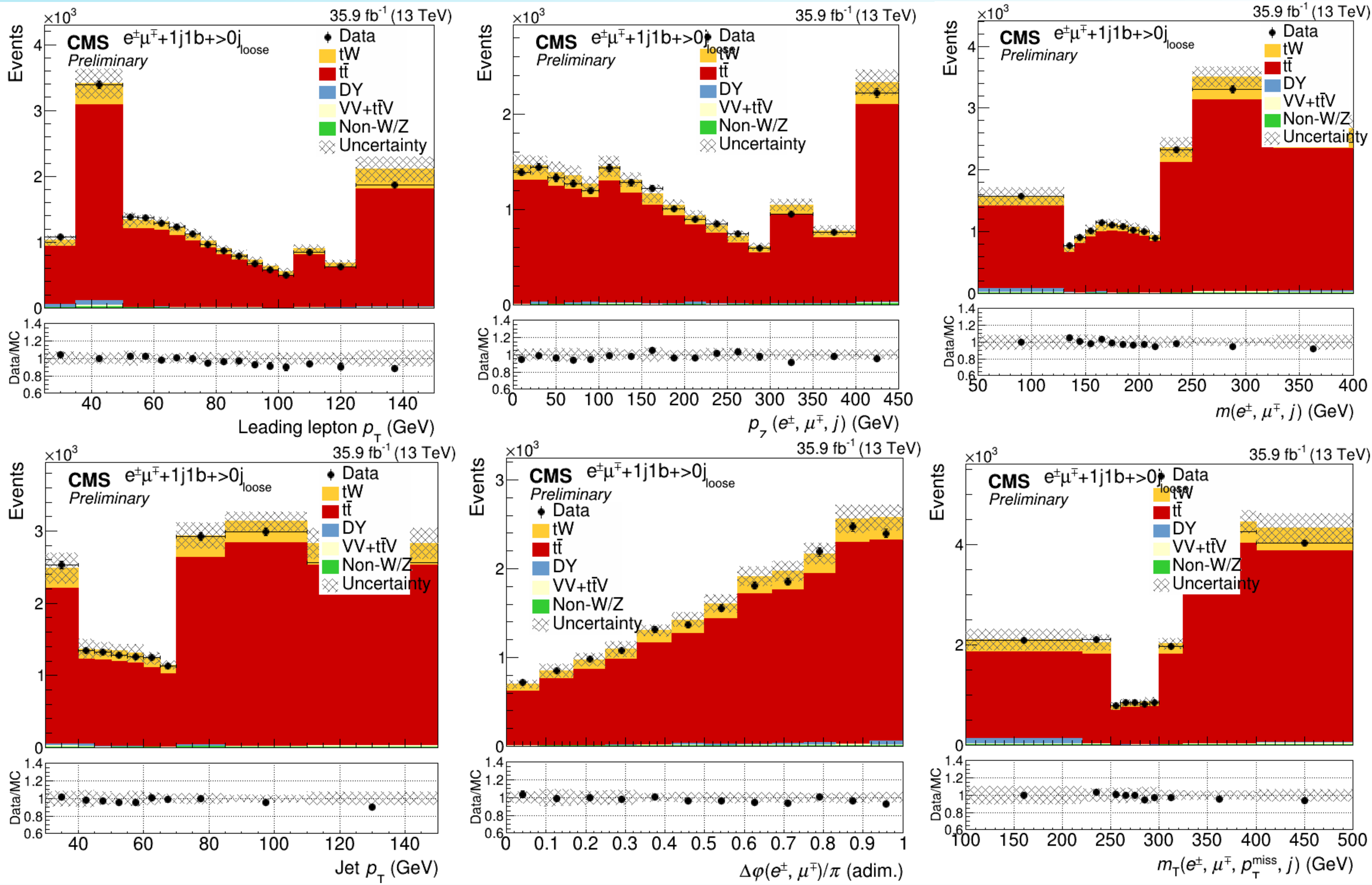




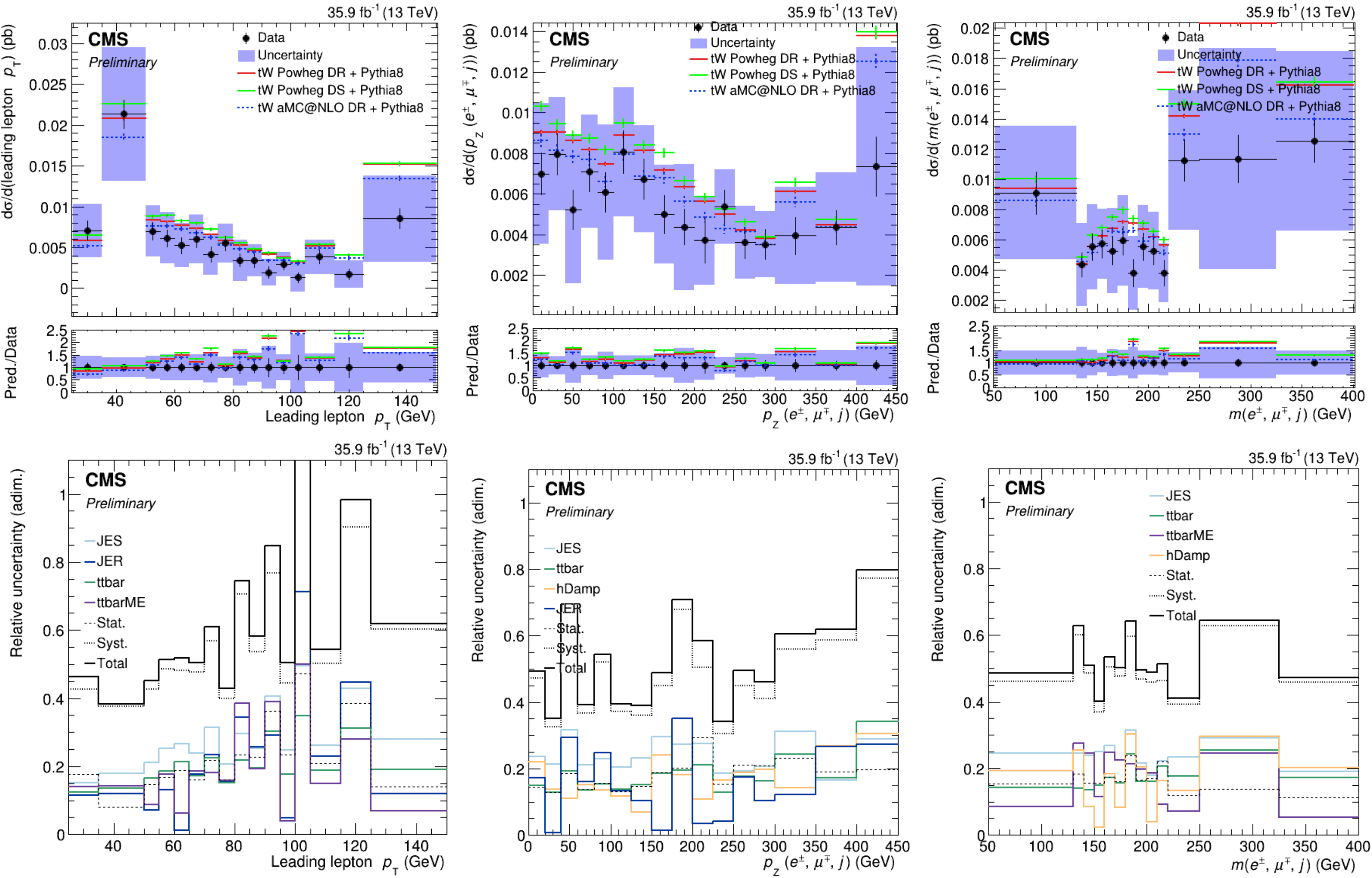




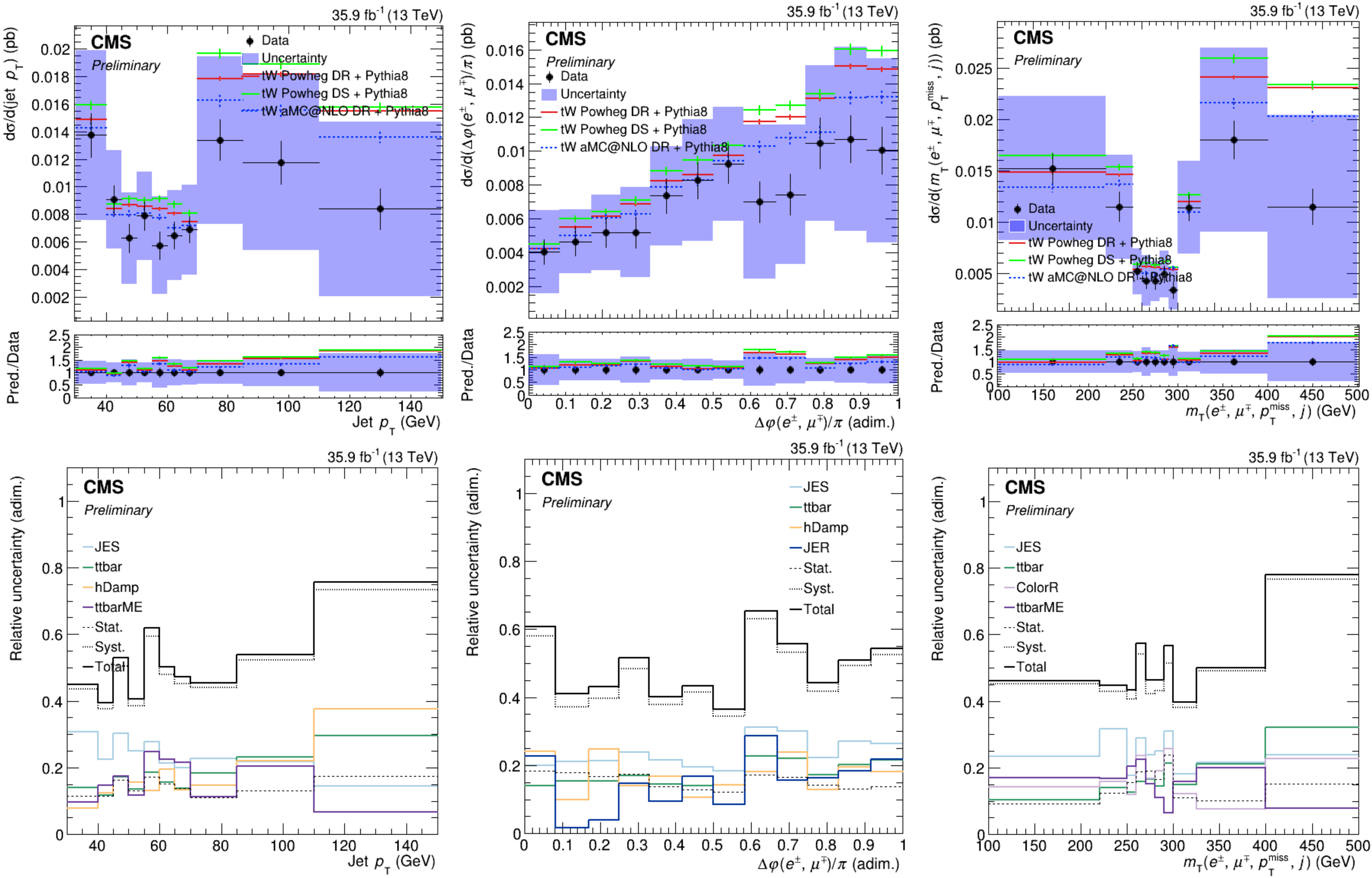
Control region MC–data plots with detector level binning



Results in detector (folded) space – I



Results in detector (folded) space – II



Response matrices' condition numbers

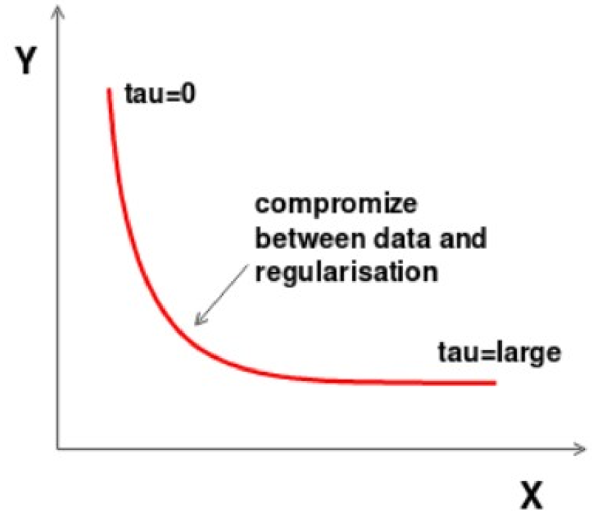
Syst./Variable	Leading lepton p_T (GeV)	Jet p_T (GeV)	$\Delta\varphi(e^{\pm},\mu^{\mp})/\pi$	$p_Z(e^{\pm},\mu^{\mp},j)$ (GeV)	$m_T(e^{\pm},\mu^{\mp},j,p_T^{miss})$ (GeV)	$m(e^{\pm},\mu^{\mp},j)$ (GeV)
JES up	2.05	4.59	1.04	2.05	6.05	3.33
JES down	2.07	4.27	1.03	2.02	5.31	3.35
JER	2.06	5.08	1.03	2.13	5.66	3.47
Electron eff. up	2.05	4.42	1.03	2.05	5.58	3.34
Electron eff. down	2.06	4.42	1.03	2.05	5.59	3.34
Muon eff. up	2.05	4.42	1.03	2.05	5.58	3.34
Muon eff. down	2.06	4.42	1.03	2.05	5.59	3.34
Trigger eff. up	2.05	4.42	1.03	2.05	5.59	3.34
Trigger eff. down	2.06	4.42	1.03	2.05	5.58	3.34
PU up	2.06	4.45	1.04	2.05	5.74	3.36
PU down	2.05	4.39	1.03	2.05	5.44	3.32
B-tagging up	2.05	4.42	1.03	2.05	5.58	3.34
B-tagging down	2.06	4.43	1.03	2.05	5.59	3.34
Mistagging up	2.05	4.42	1.03	2.05	5.58	3.34
Mistagging down	2.05	4.42	1.03	2.05	5.58	3.34
Top p_T rew. up	2.05	4.42	1.03	2.05	5.58	3.34
Top p_T rew. down	2.05	4.42	1.03	2.05	5.58	3.34
tW DS-DR	2.14	4.32	1.06	1.98	5.59	3.42
FSR up	2.06	4.41	1.05	1.97	5.35	3.34
FSR down	2.09	4.56	1.05	2.07	5.65	3.38
ISR up	2.07	4.16	1.04	1.99	5.56	3.27
ISR down	2.07	4.47	1.02	2.05	5.80	3.34
tW μ_R/μ_F up	2.06	4.54	1.09	1.95	5.52	3.23
tW μ_R/μ_F down	2.21	4.32	1.05	2.08	5.41	3.46
m_{top} unc. up	2.07	4.39	1.04	2.00	5.48	3.30
m_{top} unc. down	2.08	4.44	1.07	2.00	5.49	3.33
Nominal	2.05	4.42	1.03	2.05	5.58	3.34

Unfolding methodology definitions

$$\chi^2_{\text{unf.}}(\vec{\mu},\lambda) = \chi^2_R(\vec{\mu}) + \tau \cdot \chi^2_{\text{reg.}}(\vec{\mu}) + \lambda \sum_i (R\vec{\mu} - \vec{\nu})_i$$

$$R_{ij} = \frac{n_{ij}}{n_i} \qquad s_i := \frac{\sum_{j=1}^{N^{\text{fol.}}_{\text{bins}}} n_{ij}}{n_i} \qquad p_j := \frac{\sum_{i=1}^{N^{\text{unf.}}_{\text{bins}}} n_{ij}}{n_j^R}$$

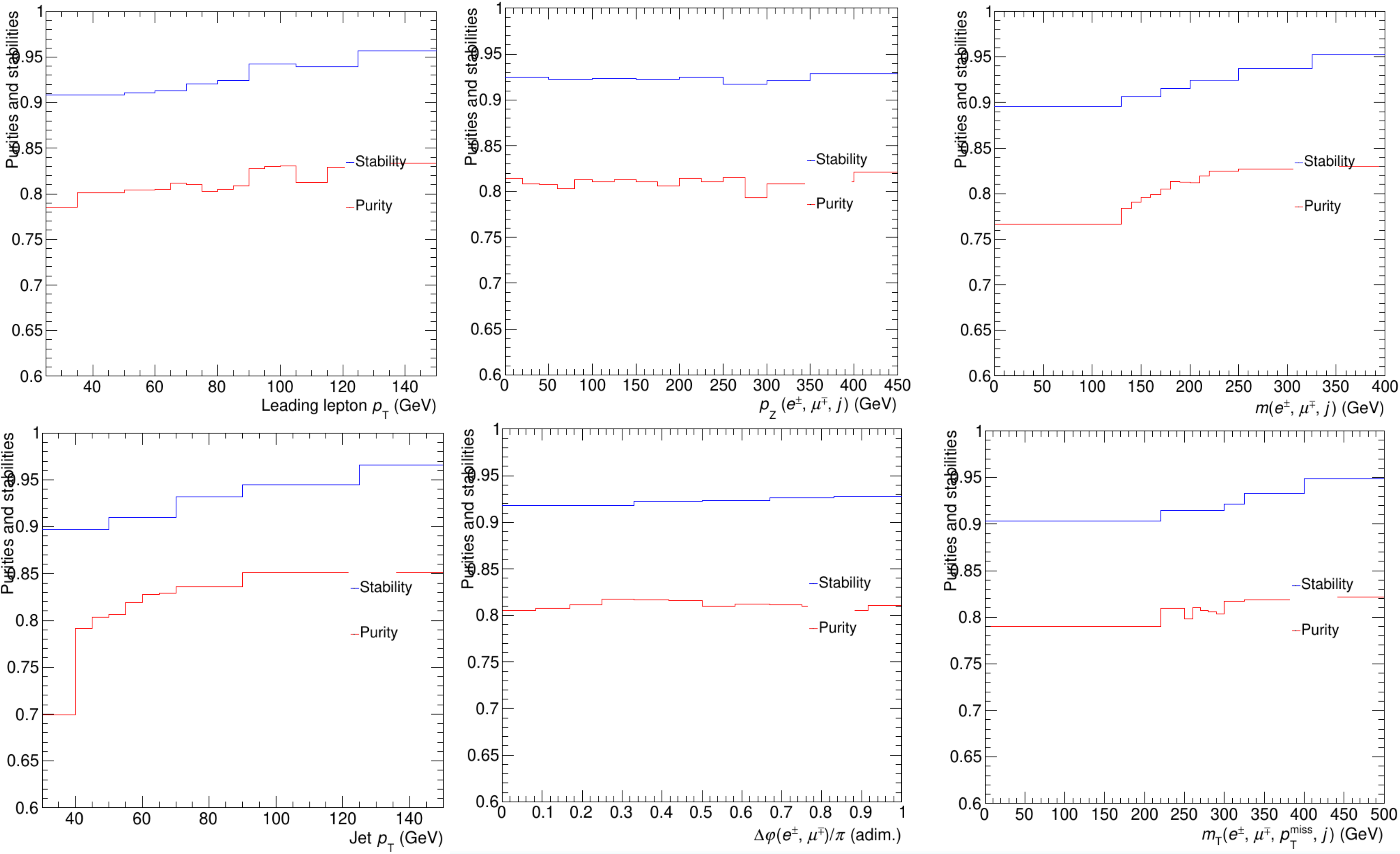
- **n_{ij}:=** # events with reconstructed value in bin **j** and generated value in bin **i**.
- **n_i:=** # generated events with their generated value in bin **i**.
- **n_j^R:=** # reconstructed events with their reconstructed value in bin **j**.



L-curve method

Purities and stabilities of the response matrices

Note: the effect of reconstruction has been disentangled.



GOF tests (p-value – test statistic)

- Absolute values:

Variable/MC sample	POWHEG DR	POWHEG DS	MG5_aMC@NLO
Leading lepton p_T	0.11 — 11.728	0.224 — 9.425	0.161 — 10.512
Jet p_T	0.732 — 2.022	0.797 — 1.667	0.863 — 1.292
$\Delta\varphi(e^\pm, \mu^\mp)/\pi$	0.719 — 2.877	0.77 — 2.543	0.782 — 2.461
$p_Z(e^\pm, \mu^\mp, j)$	0.69 — 4.755	0.699 — 4.679	0.675 — 4.876
$m_T(e^\pm, \mu^\mp, j, p_T^{miss})$	0.383 — 4.17	0.476 — 3.512	0.441 — 3.749
$m(e^\pm, \mu^\mp, j)$	0.26 — 6.503	0.29 — 6.166	0.396 — 5.169

- Normalised values:

Variable/MC sample	POWHEG DR	POWHEG DS	MG5_aMC@NLO
Leading lepton p_T	0.017 — 17.096	0.046 — 14.276	0.025 — 16.054
Jet p_T	0.297 — 4.903	0.392 — 4.106	0.587 — 2.828
$\Delta\varphi(e^\pm, \mu^\mp)/\pi$	0.345 — 5.618	0.469 — 4.578	0.513 — 4.259
$p_Z(e^\pm, \mu^\mp, j)$	0.653 — 5.054	0.67 — 4.916	0.635 — 5.202
$m_T(e^\pm, \mu^\mp, j, p_T^{miss})$	0.278 — 5.095	0.361 — 4.348	0.357 — 4.38
$m(e^\pm, \mu^\mp, j)$	0.103 — 9.165	0.168 — 7.786	0.238 — 6.768