EXPERIMENTAL SYSTEMATIC UNCERTAINTIES (AND OBJECT RECONSTRUCTION) ON TOP PHYSICS, THEIR CORRELATIONS, COMPARISON ATLAS VS CMS (VS TEVATRON) AND COMMON AGREEMENTS

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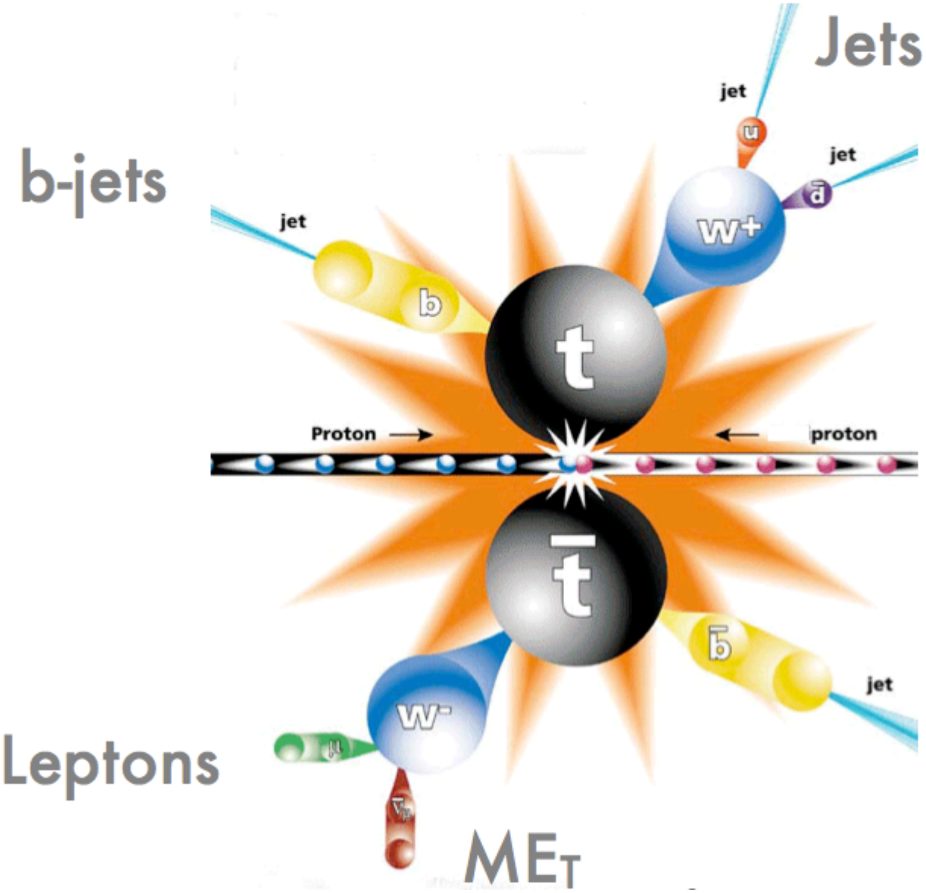
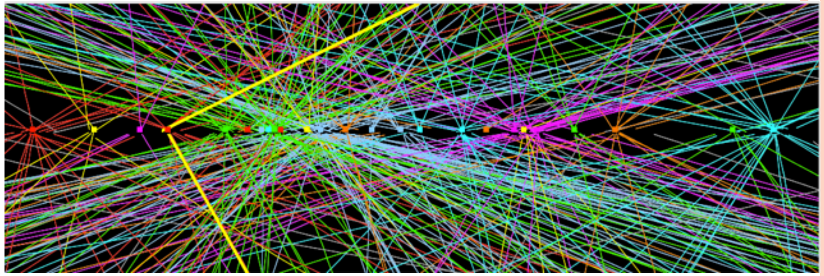
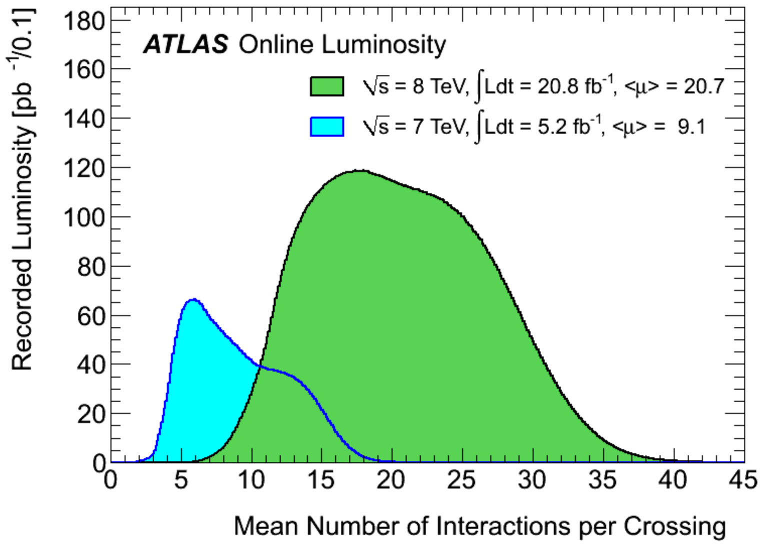
on behalf of CDF, D0, ATLAS and CMS Collaborations

INTRODUCTION







The experimental uncertainties associated to these objects within the LHC(Tevatron) conditions are propagated to all top physics analyses. How do we estimate them? What are the sources of the different components? What are their correlations across experiments?

INTRODUCTION

- Main experimental systematic uncertainties in most top analyses coming from Jets and b-tagging
- Detailed comparisons performed within the Tevatron (LHC) experiments in the context of Tevatron (LHC) combinations
  - Well established at Tevatron, work ongoing at LHC
  - Detailed ATLAS/CMS comparisons recently done for jets and b-tagging
- First across collider comparisons done in the context of the world top mass combination

	Input measurements and uncertainties in GeV										
	CDF				D0		ATLAS		CMS		
Uncertainty	l+jets	di-l	all jets	E_T^{miss}	l+jets	di-l	l+jets	di-l	l+jets	di-l	all jets
m_{top}	172.85	170.28	172.47	173.93	174.94	174.00	172.31	173.09	173.49	172.50	173.49
Stat	0.52	1.95	1.43	1.26	0.83	2.36	0.23	0.64	0.27	0.43	0.69
iJES	0.49	n.a.	0.95	1.05	0.47	0.55	0.72	n.a.	0.33	n.a.	n.a.
stdJES	0.53	2.99	0.45	0.44	0.63	0.56	0.70	0.89	0.24	0.78	0.78
flavourJES	0.09	0.14	0.03	0.10	0.26	0.40	0.36	0.02	0.11	0.58	0.58
bJES	0.16	0.33	0.15	0.17	0.07	0.20	0.08	0.71	0.61	0.76	0.49
MC	0.56	0.36	0.49	0.48	0.63	0.50	0.35	0.64	0.15	0.06	0.28
Rad	0.06	0.22	0.10	0.28	0.26	0.30	0.45	0.37	0.30	0.58	0.33
CR	0.21	0.51	0.32	0.28	0.28	0.55	0.32	0.29	0.54	0.13	0.15
PDF	0.08	0.31	0.19	0.16	0.21	0.30	0.17	0.12	0.07	0.09	0.06
DetMod	<0.01	<0.01	<0.01	<0.01	0.36	0.50	0.23	0.22	0.24	0.18	0.28
b-tag	0.03	n.e.	0.10	n.e.	0.10	<0.01	0.81	0.46	0.12	0.09	0.06
LepPt	0.03	0.27	n.a.	n.a.	0.18	0.35	0.04	0.12	0.02	0.14	n.a.
BGMC	0.12	0.24	n.a.	n.a.	0.18	n.a.	n.a.	0.14	0.13	0.05	n.a.
BGData	0.16	0.14	0.56	0.15	0.21	0.20	0.10	n.a.	n.a.	n.a.	0.13
Meth	0.05	0.12	0.38	0.21	0.16	0.51	0.13	0.07	0.06	0.40	0.13
MHI	0.07	0.23	0.08	0.18	0.05	<0.01	0.03	0.01	0.07	0.11	0.06
Total Syst	0.99	3.13	1.41	1.36	1.25	1.49	1.53	1.50	1.03	1.46	1.23
Total	1.12	3.69	2.01	1.85	1.50	2.79	1.55	1.63	1.06	1.52	1.41

INTRODUCTION

- Main experimental systematic uncertainties in most top analyses coming from Jets and b-tagging
- Detailed comparisons performed within the Tevatron and LHC experiments in the context combinations
  - Well established at Tevatron, work ongoing at LHC
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Main focus of this talk will therefore be:

- LHC (still continuously improving its understanding)
- Main systematics where in addition recent progress on ATLAS/CMS comparisons have been done in the context of the TOPLHCWG → jets and b-tagging
- Uncertainties that are common to most analyses (jets, b-tagging, electrons, muons, E_T^{miss}) → exclude taus and photons and boosted topologies (covered in E. Usai & J.Erdmann's talk)

Meth	0.05	0.12	0.38	0.21	0.16	0.51	0.13	0.07	0.06	0.40	0.13
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JET RECONSTRUCTION

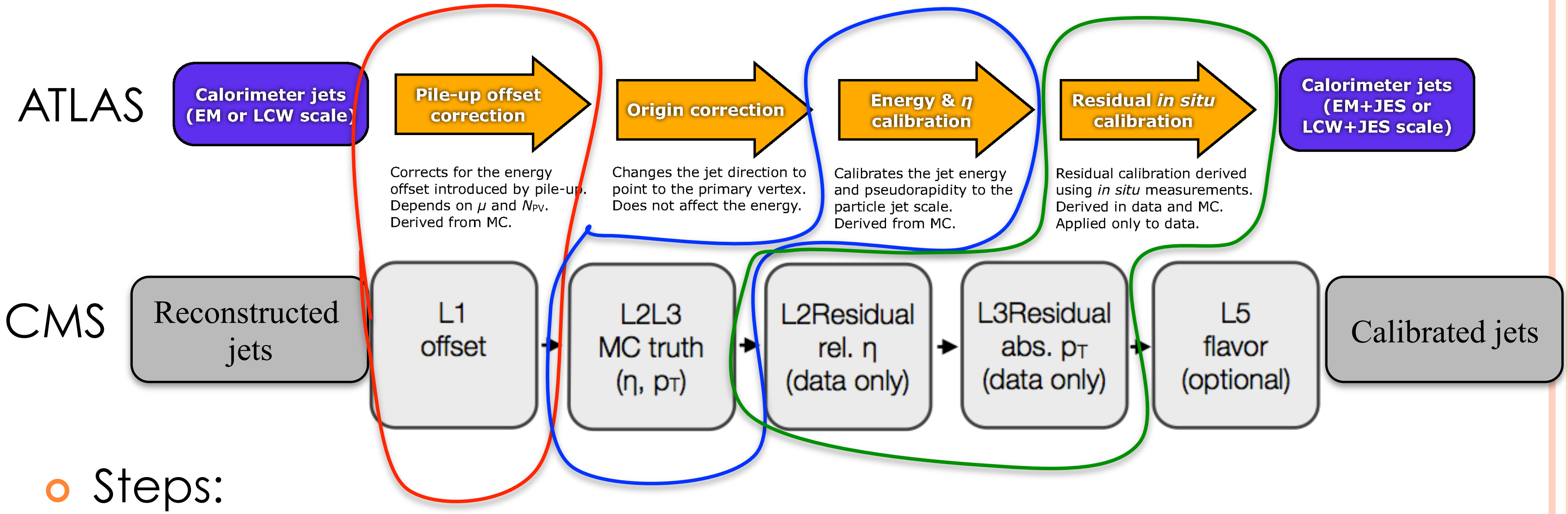
- CDF uses a cone algorithm with R = 0.4
- D0 uses a midpoint iterative cone algorithm with R = 0.5
- The anti-k_t algorithm with R=0.4 (0.5) is used for top physics at ATLAS (CMS) (several other R also used)
  - Produces cone-like jets that are infrared and colinear safe
- Various objects are used as input:
  - Calorimeter energy deposits:
    - ATLAS topo-clusters: EM scale (calibrated for EM shower deposits) or LCW scale (calibration corrects such that e/h =1)
    - CDF & D0: calorimeter towers
  - Particle flow candidates (CMS)
  - Simulated particles: stable particles except muons (in case of ATLAS) and neutrinos
- Jet quality criteria and pile-up rejection cuts are applied within analyses on the calibrated jets

Will **focus on the JES calibration** and uncertainties at the LHC, where a detailed ATLAS/CMS comparison has been done (see ATLAS-PHYS-PUB-2014-015 & CMS-PAS-JME-14-003 for details)

In addition, jet resolution and efficiency uncertainties also considered.

JET CALIBRATION @ LHC

- Restores the jet energy scale to that of jets from stable particles (truth particle level)



- Steps:

(1) Pile-up correction

(2) Origin correction (ATLAS, not needed for PF jets)

(3) MC based response correction

(4) Residual in-situ calibration

JET CALIBRATION @ TEVATRON

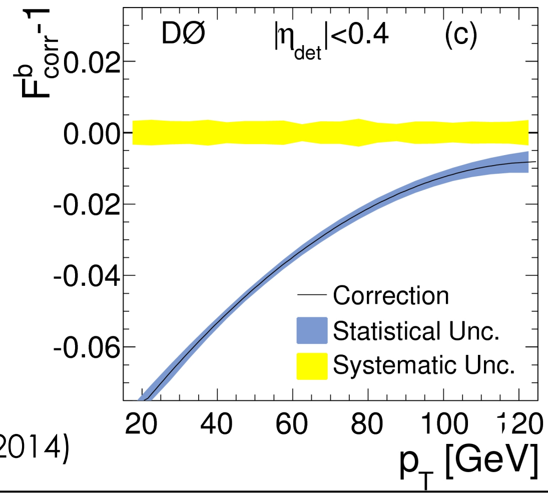
- Main differences with respect to LHC
  - CDF restores to the scale of partons
  - LHC experiments evaluate data/MC differences while D0 makes an absolute calibration
  - LHC experiments do not correct for the UE

CDF
$$p_T^{\text{parton}} = \frac{p_T^{\text{jet}} R_{\text{rel}} - C_{\text{MI}}}{R_{\text{abs}}} - C_{\text{UE}} + C_{\text{OC}},$$

D0
$$E^{\text{particle}} = \frac{E^{\text{jet}} - C_{\text{MI,UE}}}{R_{\text{abs}} R_{\text{rel}} F_{\text{OC}}}.$$

- R_{abs}: calorimeter response (MC based for CDF, from data for D0)
- R_{rel}: η uniformity
- CDF: C_{MI}: pile-up correction, C_{UE}: underlying event correction
- D0: $C_{MI,UE}$: for pile-up, underlying event, noise
- C_{OC}, F_{OC}: corrections for shower particles scattered in or out of the cone of radius R

D0 New calibration applies dedicated corrections for light, b and gluon jets (relevant for top mass latest result)



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LHC PILE-UP CORRECTION

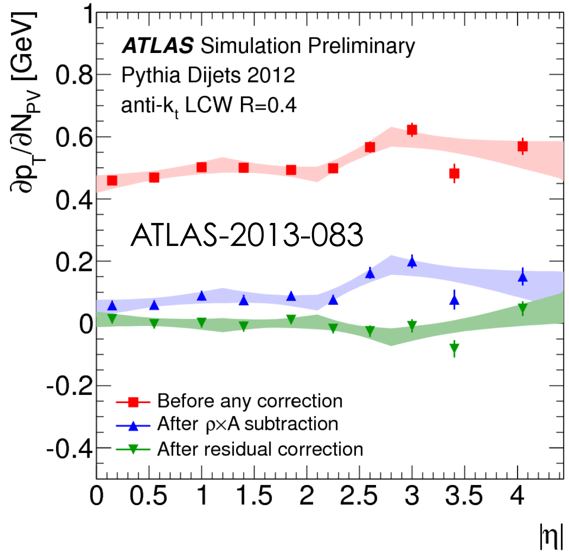
- Aim is to estimate and subtract the energy not associated with the hard scattering
  - Average offset (ATLAS for 2011 data)

$$p_T^{corr} = p_T - \alpha \cdot (N_{PV} - 1) - \beta \cdot \mu$$

μ= average # interactions/BC (related to out of time pile-up)

N_{PV} = #primary vertices (related to in-time pile-up)

α, β = parameters obtained from MC



  - Jet area and residual offset correction

(ATLAS for 2012 data)

$$p_T^{corr} = p_T - A \cdot \rho$$

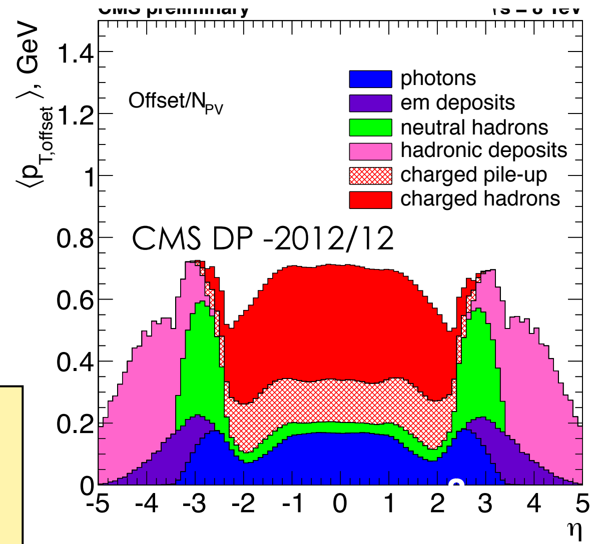
ρ= average E density

A = jet area

  - Hybrid jet area method (CMS)

$$C_{\text{hybrid}}(p_T^{\text{raw}}, \eta, A_j, \rho) = 1 - \frac{(\rho - \langle \rho_{\text{UE}} \rangle) \cdot \beta(\eta) \cdot A_j}{p_T^{\text{raw}}}.$$

ρ_{UE}= E density due to the UE and noise

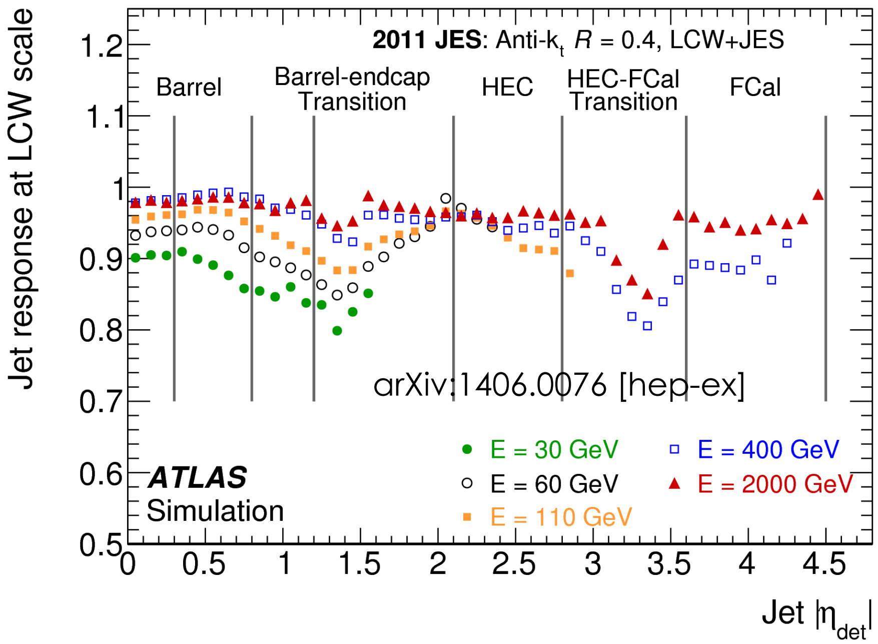


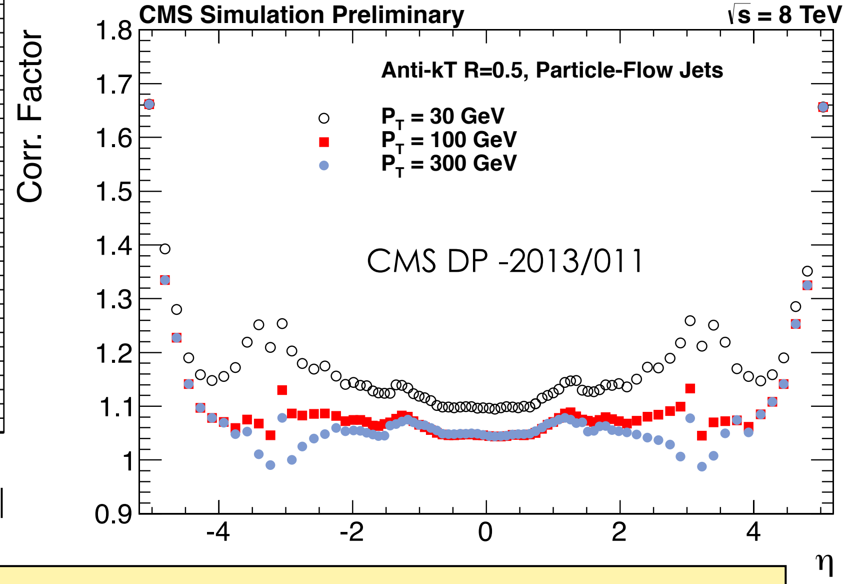
Different techniques used in ATLAS and CMS for 2011 data → Associated uncertainties treated as uncorrelated (detailed comparisons ongoing for 2012)

LHC RESPONSE CORRECTION (p_T, η)

- Calibrates the jet energy and pseudorapidity to the particle jet scale
- Derived from an inclusive jet MC sample (Pythia)
- The correction factor is defined as the inverse of the average response:

$R = \langle E_{jet}/E_{jet\text{-}truth} \rangle = 1/\text{Corr.Factor}$





Reference scale is the same in both experiments except for the fact that muons are included in CMS (and not in ATLAS) in the truth particle jets.

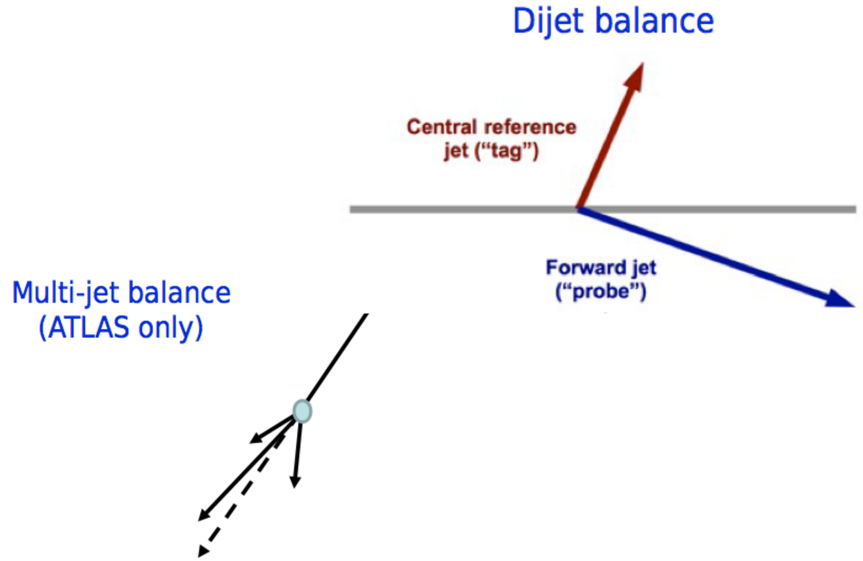
Percentage of muons is negligible in QCD inclusive jets → MC based calibrations still comparable

LHC RESIDUAL IN-SITU CALIBRATION

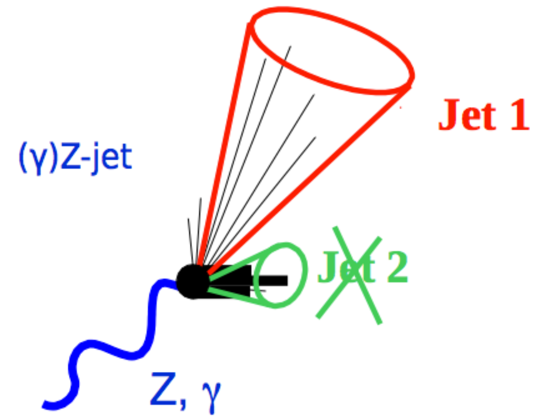
- The jet p_T in data is compared to that in MC simulation using in-situ techniques that exploit the p_T balance between the jet p_T and the p_T of a well measured reference object → residual JES correction factor:

$$\frac{\mathrm{Response}_{\mathrm{MC}}}{\mathrm{Response}_{\mathrm{Data}}} = \frac{\left\langle p_{\mathrm{T}}^{\mathrm{jet}} / p_{\mathrm{T}}^{\mathrm{ref}} \right\rangle_{\mathrm{MC}}}{\left\langle p_{\mathrm{T}}^{\mathrm{jet}} / p_{\mathrm{T}}^{\mathrm{ref}} \right\rangle_{\mathrm{Data}}}$$

Relative calibration
(η intercalibration)



Absolute calibration

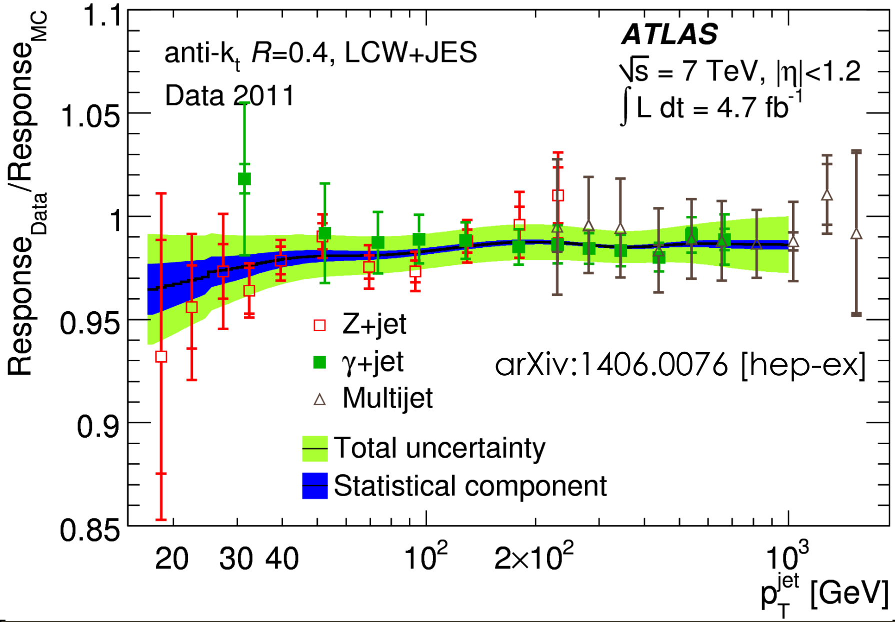


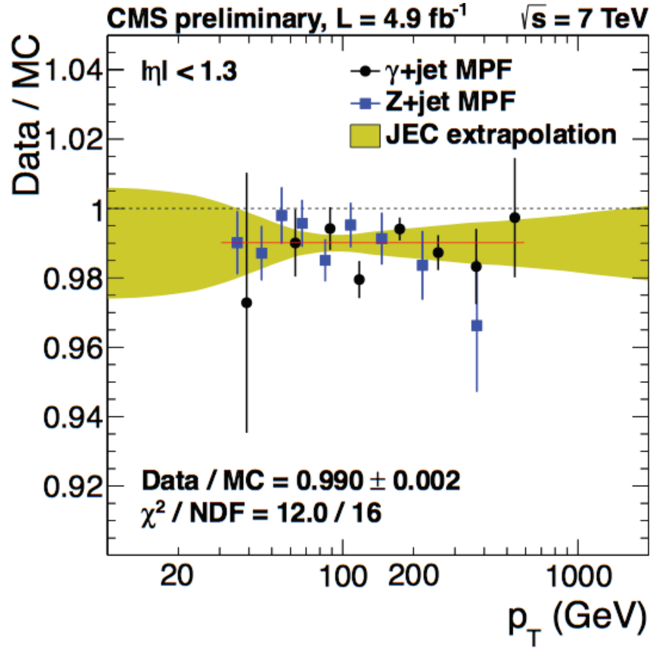
Several methods used to cover large kinematic phase space

In situ calibration assumes p_T balance, which can be modified by physics effects (e.g. additional radiation) (CMS extrapolates to no radiation, ATLAS uses differences after large variations of cuts changing additional radiation)

LHC RESIDUAL IN-SITU CALIBRATION

- A combination of the results obtained by the different techniques is performed:
  - ATLAS combines various in-situ methods for each p_T bin
  - CMS provides a p_T independent correction, accounting for the p_T dependence in the uncertainty. The procedure has now changed and it is already adapted in new measurements.



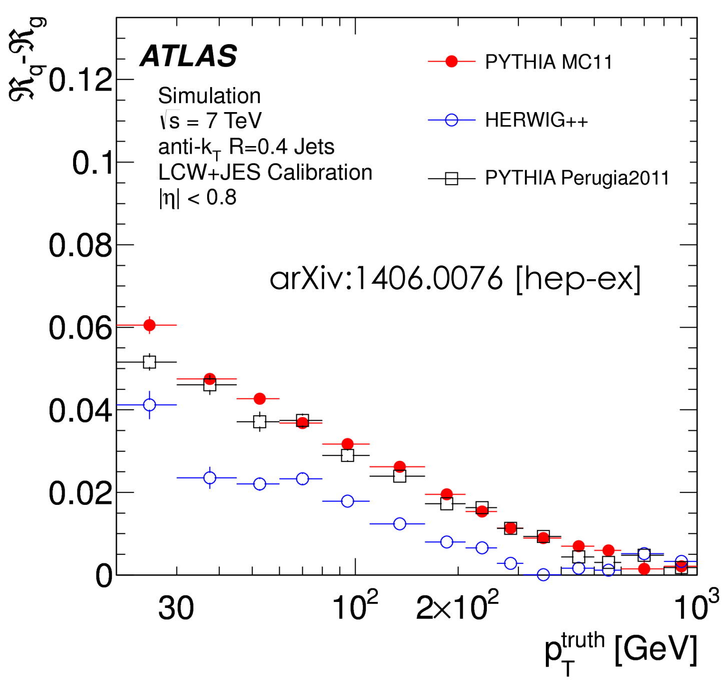


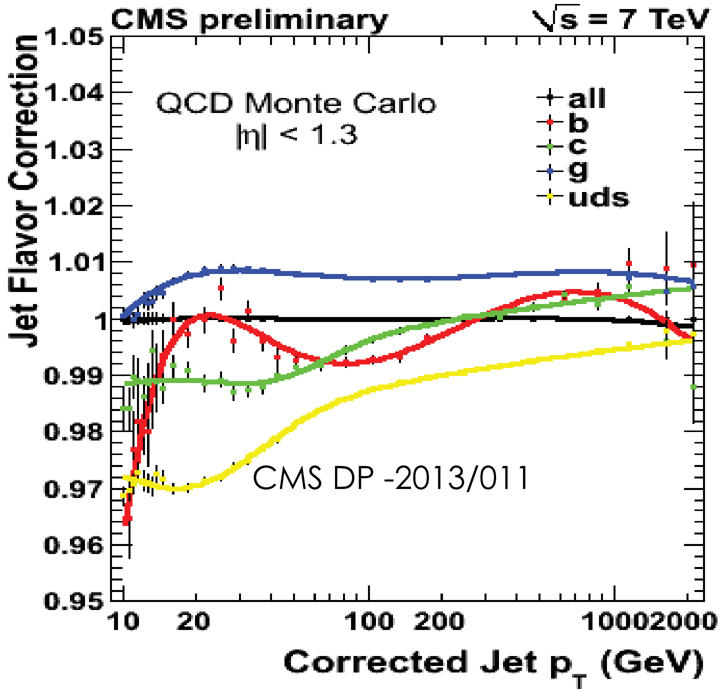
Individual source of uncertainty are studied in detail to understand ATLAS/ CMS correlations

- Calorimeter energy scale and statistical uncertainties: uncorrelated
- In-situ modeling uncertainties: ranging from 0 to 50%
- Relative calibration uncertainties: ranging from 50% to 100%

LHC FLAVOUR UNCERTAINTIES

- The jet calibration achieves an average response of the calorimeter to jets of ~1 for jets in the inclusive jet sample (dominated by gluon-induced jets)
- The detector response to jets exhibits variations depending on the flavour of the partons → An uncertainty that accounts for the sample dependence of the JES is evaluated by comparing Pythia/Herwig++

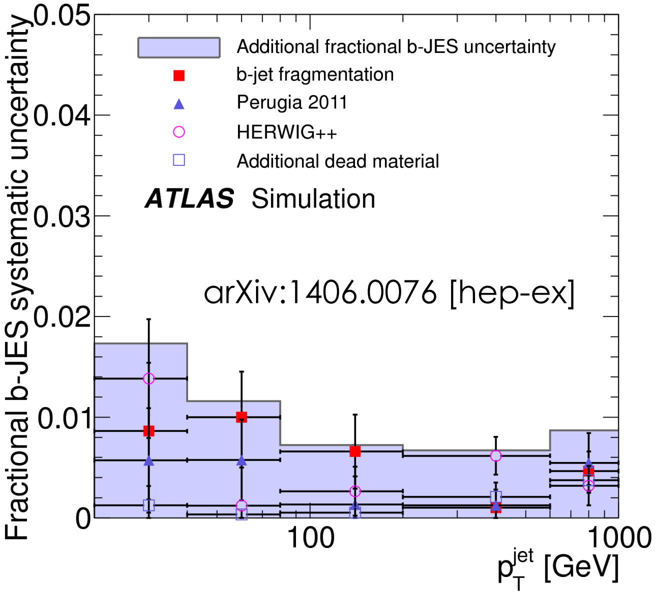


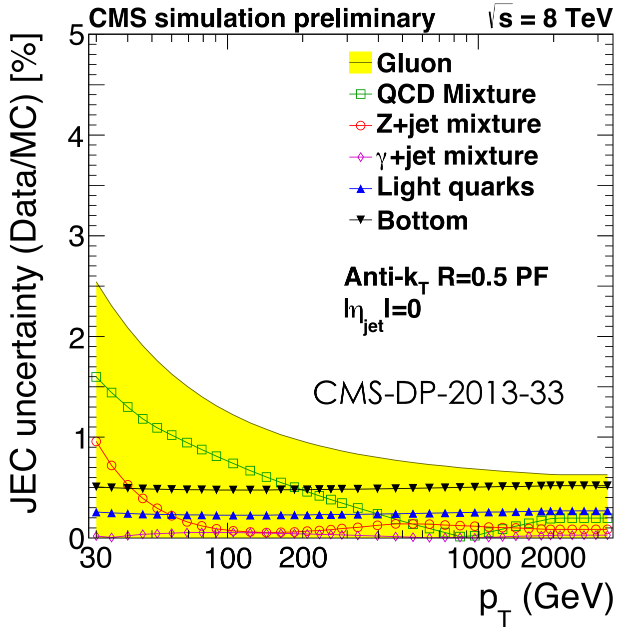


- Correlations between ATLAS and CMS range from 0% to 100%

LHC B-JES UNCERTAINTIES

- ATLAS: Specific b-JES uncertainty evaluated by comparing MC samples with different fragmentations and B-hadron decays, and cross checked using data.
- CMS: 2011 data: Full envelope of all possible jet flavours responses considered (b-jet response in between light quark and gluon responses)
  - 2012 data: Specific uncertainties for each flavour → b JES uncertainty reduced by a factor ~ 2.

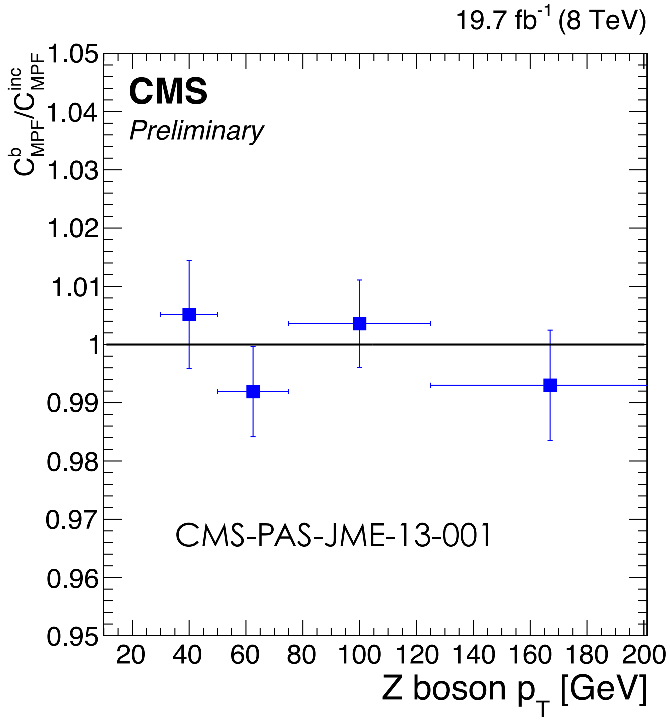




- Correlations between ATLAS and CMS range from 50% to 100%

LHC B-JES UNCERTAINTIES

- CMS has provided a NEW determination of b-jet energy corrections using Z+b events exploiting the p_T balance of the b-jet and Z-boson.
- The correction is the ratio of the energy correction for b-jets and the inclusive energy correction (both estimated as data/MC residual corrections)

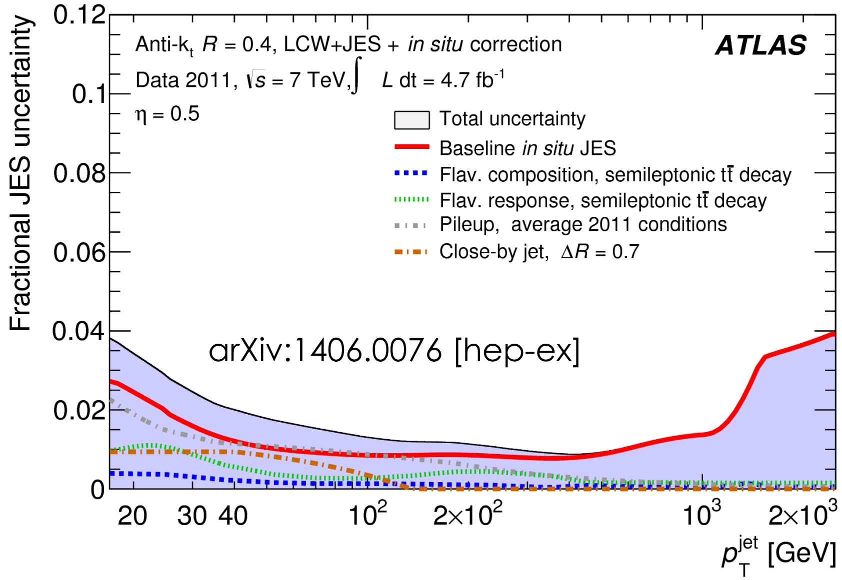


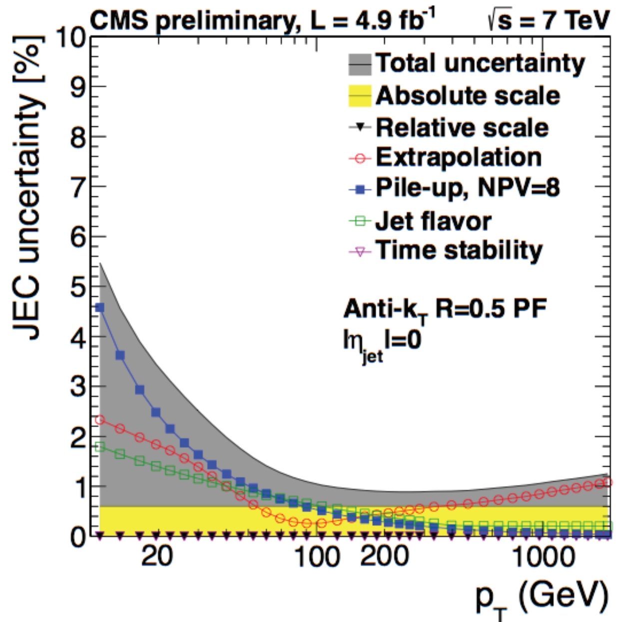
$$C_{corr} = 0.998 \pm 0.004(\text{stat}) \pm 0.004(\text{sys})$$

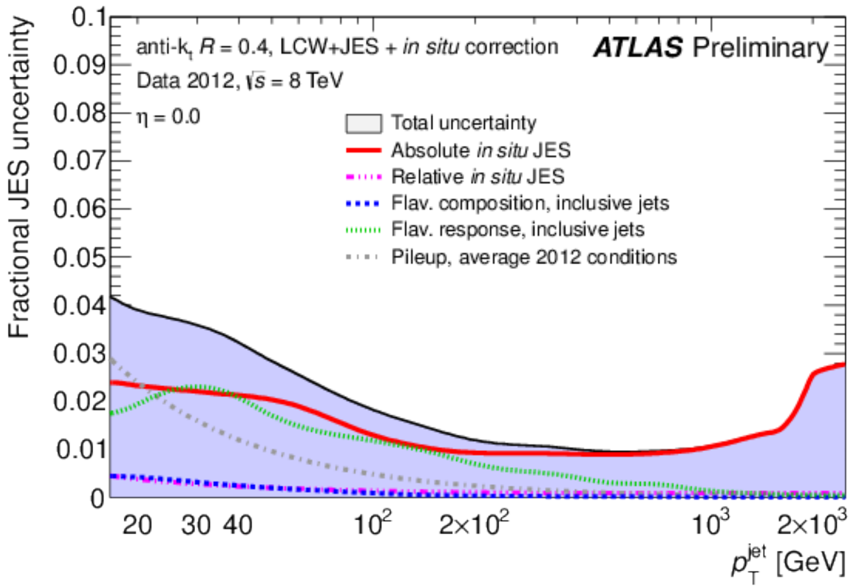
- The precision of this measurement (0.5%) is competitive with the estimates of the b-JES uncertainty based on Pythia vs Herwig++ differences (see previous slide).

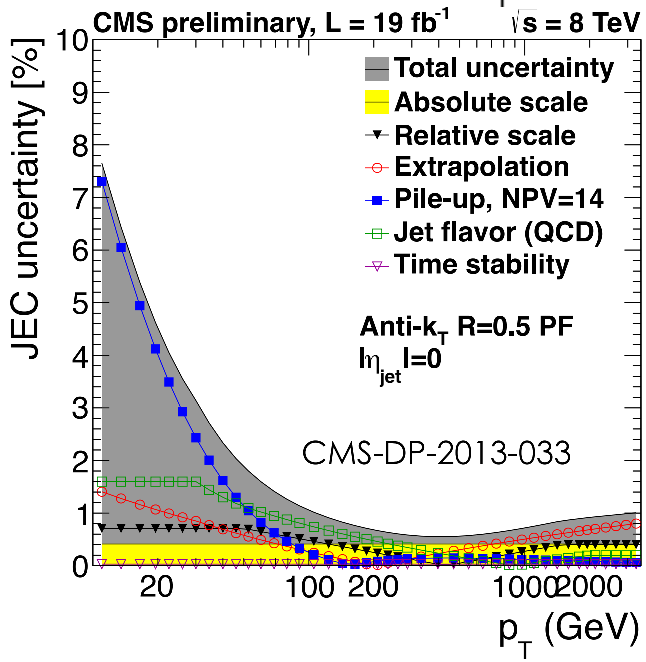
- The correction is found to be compatible with 1 → no additional correction needed for b-jets.

LHC JES UNCERTAINTIES

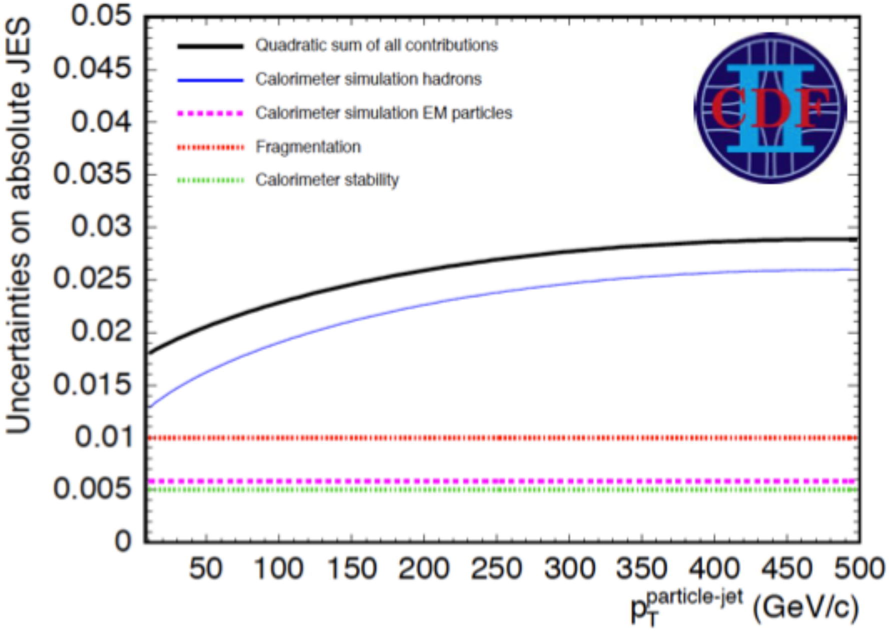


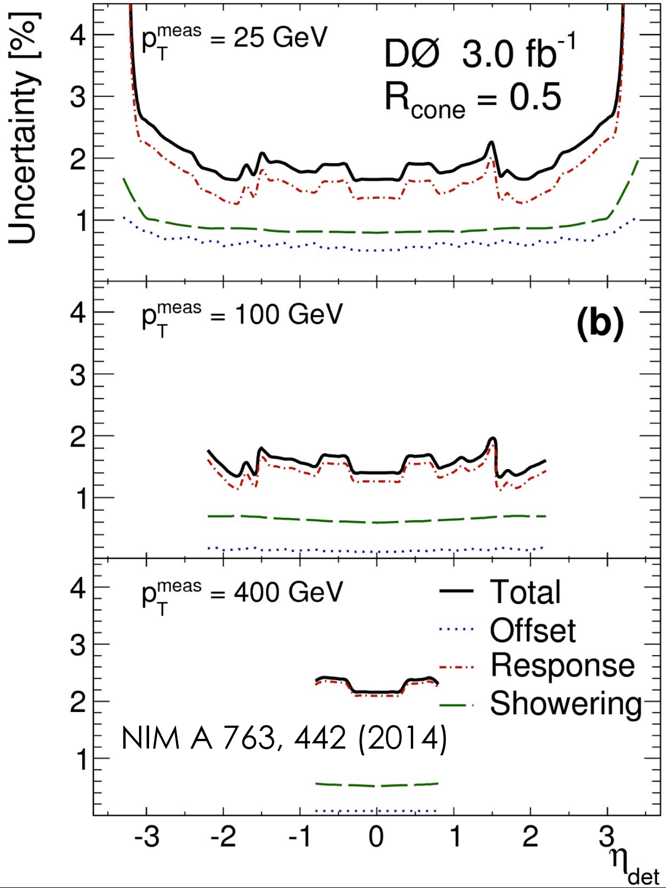






TEVATRON JES UNCERTAINTIES





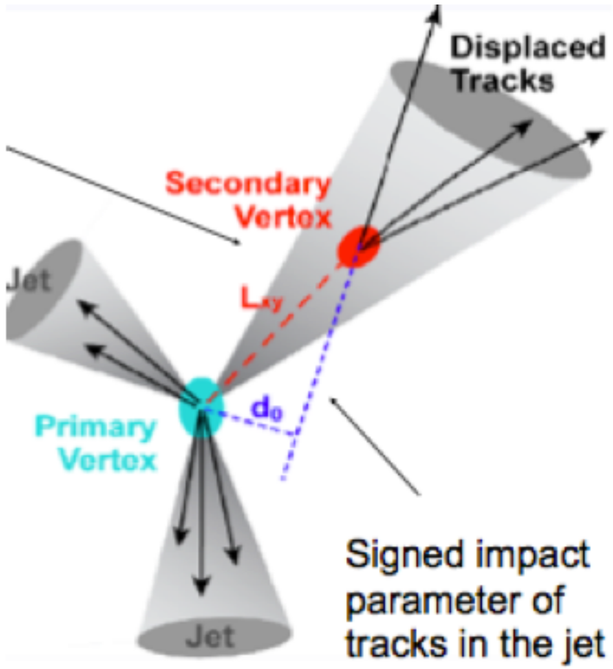
Summary of JES @ LHC and Tevatron experiments:

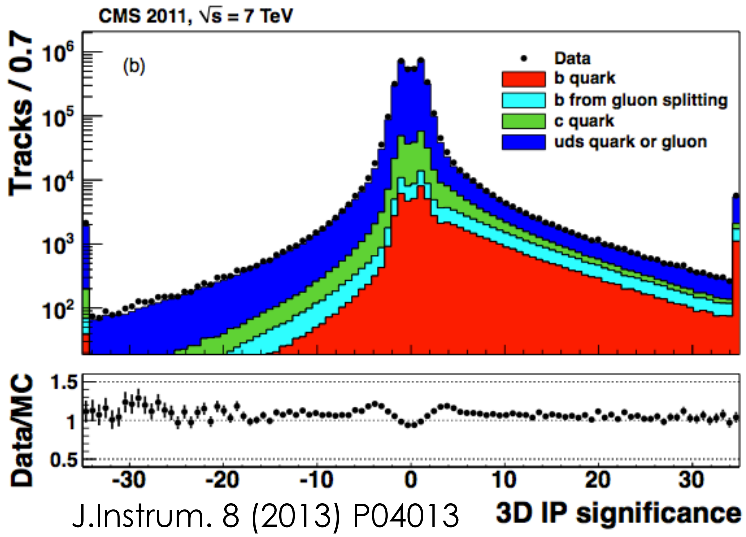
Jet energy calibrations exploiting the full dataset have lead to significant improvements on the JES uncertainties.

In addition, in some top analyses (top mass), in-situ calibration using W→jj decays are also important (e.g. to reduce the uncertainties coming from low p_T jets, which are larger at the LHC due to pileup)

B-TAGGING ALGORITHMS

- Various algorithms to identify jets from b quarks were developed exploiting two basic characteristics of B hadron decays:
  - Large lifetime (~1.5 ps) →
    - Tracks with large impact parameters (IP) wrt interaction primary vertex
    - Displaced secondary vertices
  - High semi-leptonic decay branching ratio (BR e, μ ~40%)→ Presence of low momentum leptons inside the jet





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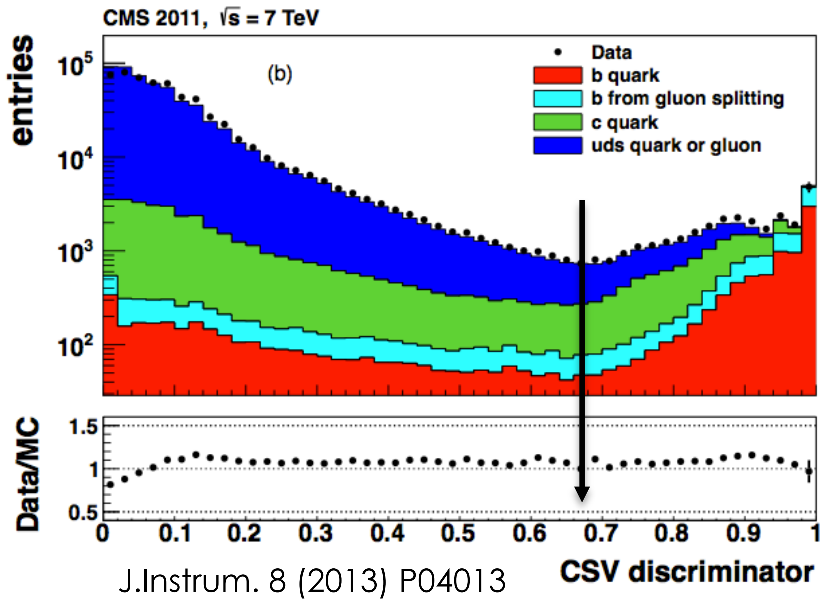
B-TAGGING ALGORITHMS

- The better performing algorithms use combinations of several variables to provide a b-jet discriminator. Mostly used in top analyses:
  - CMS: Combined Secondary Vertex (CSV) algorithm uses secondary vertices and track-based lifetime information to build a likelihood-based discriminator
  - ATLAS: MV1 algorithm combines the output of vertex based and IP based algorithms through a multivariate approach (neural network)
  - CDF: uses the significance of the displacement of the secondary vertex in the transverse plane (SecVtx), or an IP based algorithm (Jet Probability).
  - D0: combines nine track and secondary vertex related variables using a neural network (D0-NN), recent measurements use an improved MVA technique including an order of magnitude more variables (MVA)

- b-jets are identified by a selection in the b-tag discriminator in most analyses
  - Example: CSV > 0.679 mostly used in CMS analyses (mis-tag rate 1%)



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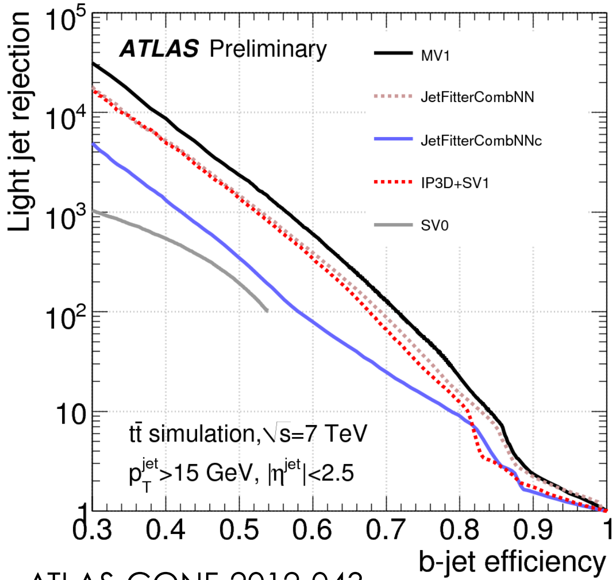
B-TAGGING ALGORITHMS

- Performance estimated from simulation (QCD multijets, ttbar events)



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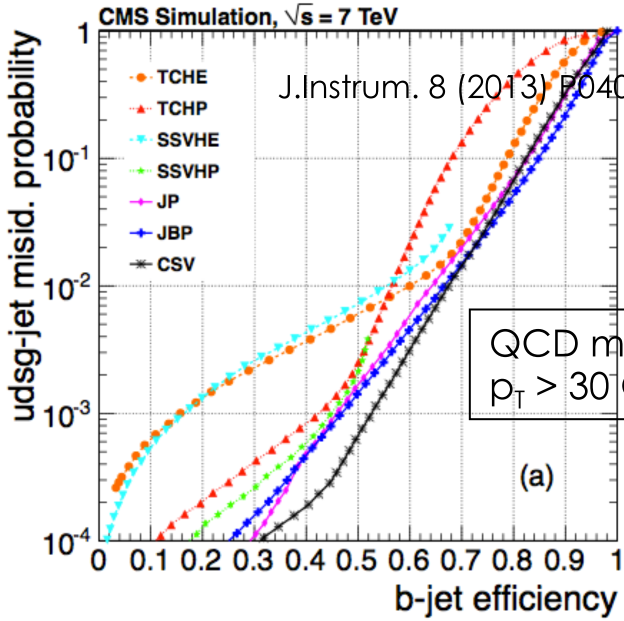

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QCD multijet, p_T > 30 GeV

Typical working points used @ LHC (8 TeV) and Tevatron in top pair events:

- ATLAS : ε_b = 70%, ε_{light} = 0.7 % (p_T^{jet} > 25 GeV, $|\eta|$<2.5)
- CMS: ε_b = 70%, ε_{light} ~1.5% (p_T^{jet} > 30 GeV, $|\eta|$<2.4)
- CDF: ε_b = 50%, ε_{light} ~1.%
- D0: ε_b = 60%, ε_{light} =1.2% (p_T^{jet} > 20 GeV, $|\eta|$<2.5)

Similar performance found in ATLAS and CMS for similar algorithms.

Default algorithms in ATLAS (MV1) performs better than the default CMS one (CSV) because based on MVA techniques

B-TAGGING CALIBRATIONS

- Need to check at which level the simulation predicts the discriminator shapes → Need to measure b/c-jet tagging efficiencies and light jet mis-tag rates, and compared them to the simulation prediction.
- Various techniques have been used at both Tevatron and LHC experiments to perform these measurements
- Calibrations expressed as data/MC scale factors for b-jet tagging efficiencies and for light jet mis-identification rates (ATLAS also has a c-jet calibration based on D*, CMS uses the b-jets calibration with larger uncertainties)

Will focus on b-tag efficiency calibration at LHC since a detailed comparison of the calibration methods and uncertainties has recently been done by experts

B-JET TAGGING EFFICIENCY MEASUREMENTS

- General idea is to measure the b-jet content of a b-enriched jet sample before and after the b-tagging requirement
- Standard techniques using jets with a soft muon exploited:
  - p_T^{rel}: Template fit of the muon p_T wrt the jet axis
  - System8: Define 3 independent selection criteria (p_T^{rel}, lifetime tag under study, opposite side jet tag), event counts
  - Extending p_T^{rel} method up to 800 GeV by looking at muon IP3D (CMS only)
  - Lifetime tagger method: template fit of a reference discriminator which is calibrated in data (CMS only)

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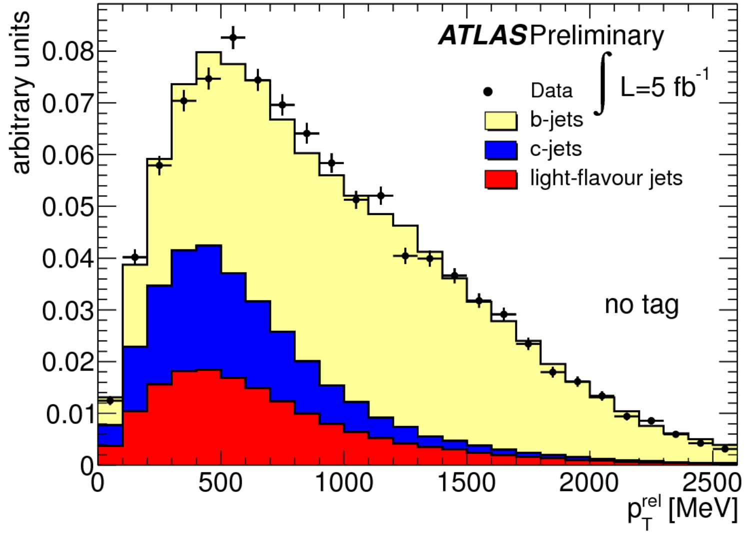


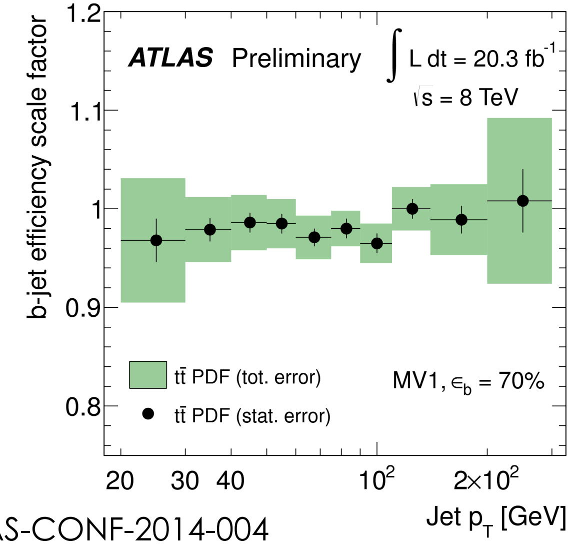
- These techniques allow selection of a sample of b-jets independent from top analyses, but the muon requirement can have a bias on IP based b-tagging algorithms → The extrapolation to inclusive b jets is the challenge!
- SFs obtained for jets with and without muons found to be compatible within uncertainties (ATLAS assigns a 4% uncertainty, CMS no additional uncertainty)

B-JET TAGGING EFFICIENCY MEASUREMENTS

- Calibration based on top quark pairs:
  - A pure sample of b-jets can be selected without b-tagging requirement
  - BR($t \rightarrow Wb$) ~100%
  - Isolated leptons from W decays to reduce background
  - Measurements made separately in dilepton and lepton+jets channel
  - Different techniques developed

- These techniques cover a larger range in p_T and have reached the best precision ~2% (for jet p_T ~100 GeV)
- However, attention should be paid when using them in top analyses (V_{tb} =1 assumption, statistical and systematic uncertainties correlations)

- NEW technique: PDF method in ATLAS (dilepton channel @ 8 TeV)
  - Exploits the event-by-event kinematic correlations between jets
  - Dominant uncertainties coming from ttbar modeling and JES

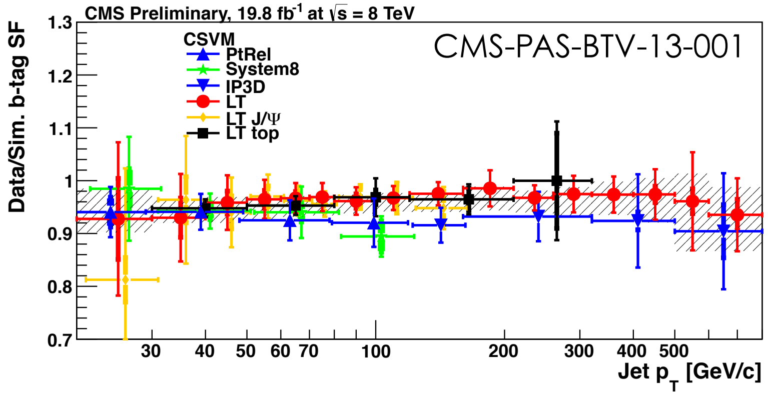


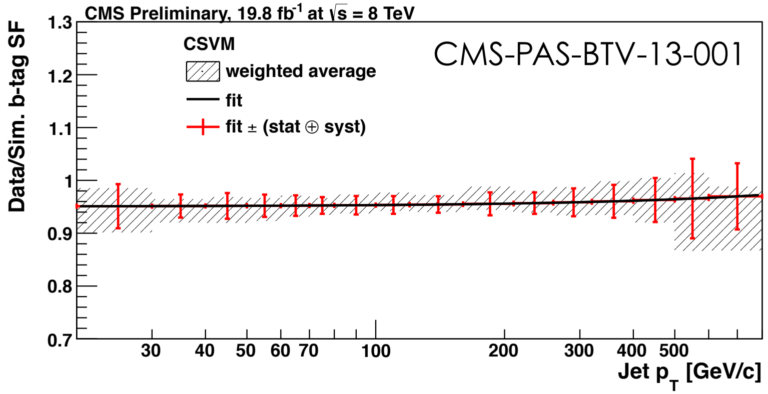
ATLAS-CONF-2014-004

B-JET TAGGING EFFICIENCY MEASUREMENTS

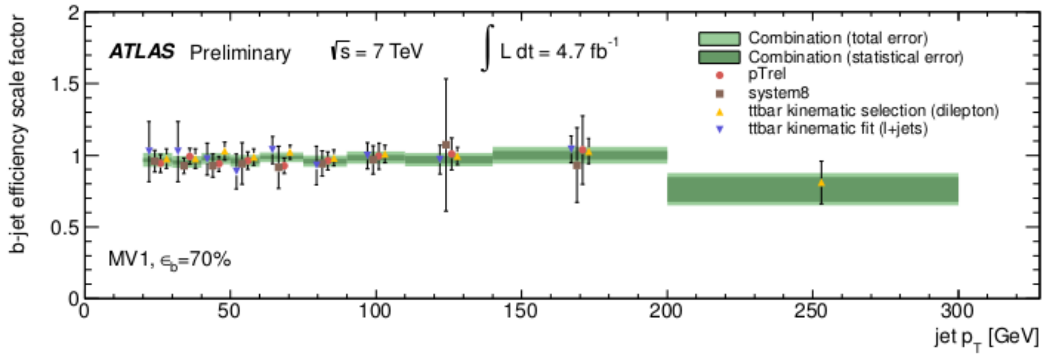
Combination of measurements:

- Both experiments provides several combinations of the results obtained with different techniques
- CMS: Using the least squared BLUE method taking sources of uncertainties common between methods correlated, in each pT bin. The SFs are then parametrised.





- ATLAS: Global fit with all systematic uncertainties as nuisance parameters in each (p_T, η) bin



- Good agreement between dijet muon based and ttbar based calibrations
- Different combination strategies are used in ATLAS and CMS, but the contribution from the individual components is provided by both.

SYSTEMATIC TREATMENT FOR LHC COMBINATIONS

- Each individual source of systematics has been compared (strategy, size) to come up with a recommended categorisation of systematics and correlations to be used when combining measurements at LHC

Recommendation: 6 components:

(1) Uncorrelated (stat, detector, method specific) ($\rho=0$)

(2) b/c production ($\rho=1$)

(3) Muon p_T spectrum ($\rho=1$)

(4) b fragmentation, c/l ratio ($\rho=1$)

(5) Top quark pair parton shower ($\rho=1$)

(6) Top quark pair ISR/FSR ($\rho=1$)

For more details, see: https://twiki.cern.ch/twiki/bin/view/LHCPhysics/BTaggingSystematics

source	size at ATLAS	size at CMS
b/c prod.	low pT: 0.1% - 0.2%, high pT for b-prod.: 1.2% - 2.0%	low pT: 0.1% - 0.3%, high pT: 0.5% - 1.3%
mu pT	first pT bin: 2.5%, 0.2% - 0.9% elsewhere	low pT: 0.1% - 1.1%, high pT: 0.1 - 0.9%
c/l ratio	<0.1% - 0.2%	<0.1% - 0.2%
b-frag	0.2% - 2.7%	0.2% - 0.8%
PS	0.1% - 1.5%	0.3% - 0.6%
IFSR	0.3% - 1.4%	0.3% - 0.6%

MET RECONSTRUCTION

- MET can indicate the presence of neutrinos or other new weakly interacting particles
- Defined based on the momentum conservation in the transverse plane
- CMS: calculates it from the Particle Flow candidates

with additional corrections

$$\vec{\not{E}}_{\mathrm{T}} = - \sum_{i}^{\text{PF objects}} \vec{p}_{\mathrm{T}i}$$

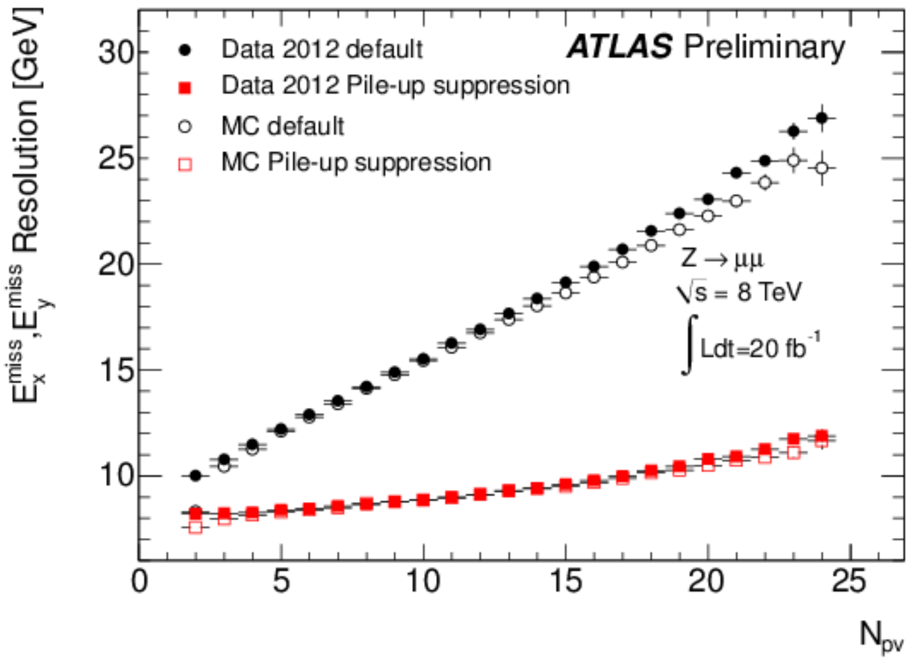
- ATLAS: calculates it from reconstructed and calibrated physics objects, and deposits not associated with such objects (Soft Term)

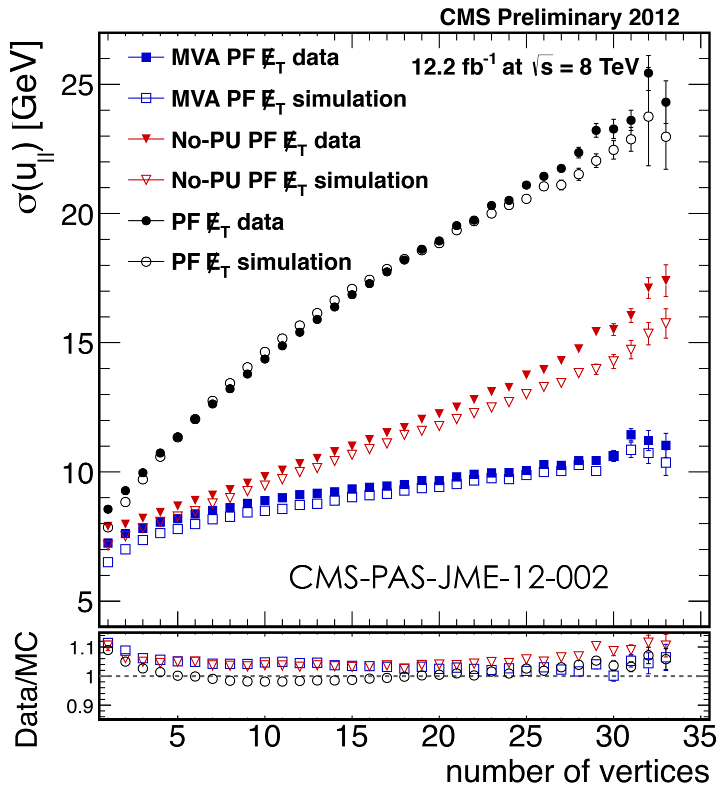
$$E_{x(y)}^{\text{miss}} = -\left(E_{x(y)}^{\text{jets}} + E_{x(y)}^{e} + E_{x(y)}^{\gamma} + E_{x(y)}^{\tau} + E_{x(y)}^{\mu} + E_{x(y)}^{\text{Soft Term}} \right)$$

- Several correction methods developed to correct for pile-up in ATLAS and CMS (ATLAS and CMS top analyses not yet using the most advanced techniques)
- Tevatron: vector sum of the transverse energies of all calorimeter cells, with additional corrections (energy scale corrections applied to reconstructed objects, muons)
- Uncertainties come from the scale and resolution uncertainties of the reconstructed objects (mainly jet in case of top events), as well as from the description of the additional soft term contribution (ATLAS) and unclustered energy (CMS).

MET PERFORMANCE

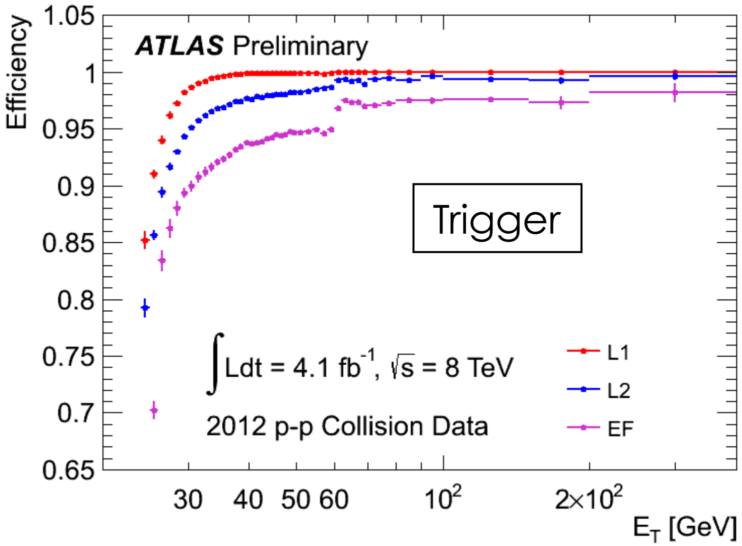
- MET resolution in Z → μμ events improved significantly with the pile-up correction (since it mainly addresses the soft terms)
- Effect much smaller in top events though

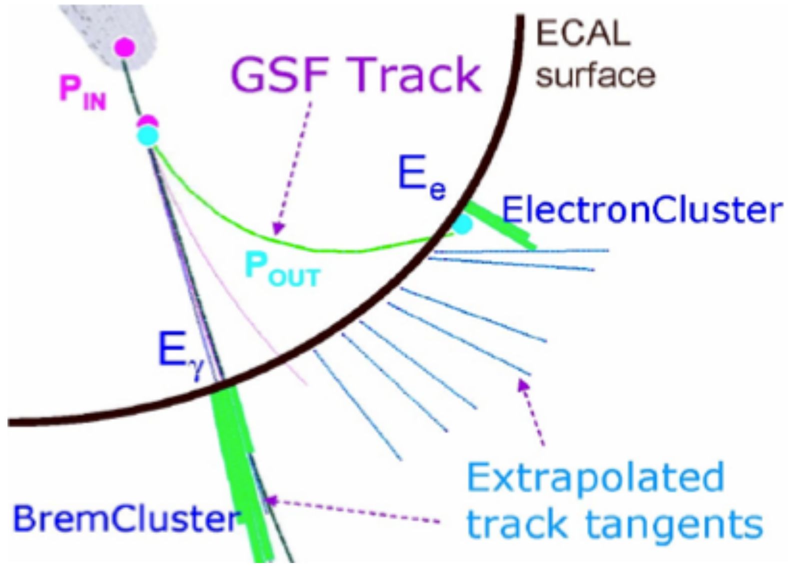


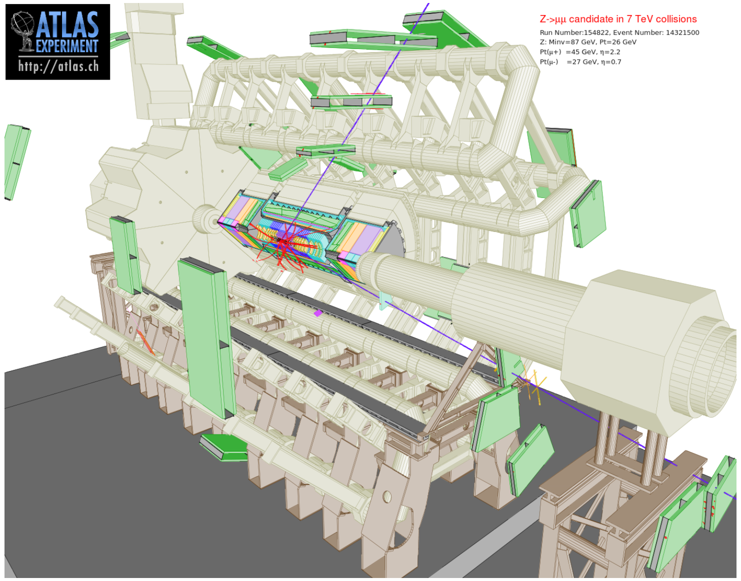


LEPTONS: MUONS AND ELECTRONS

- Measurements in leptonic channels use mostly unprescaled lepton triggers: Various setups, Threshold, isolation
  - Tevatron: 18 GeV (offline cuts 15-20 GeV)
  - LHC: 9-27 GeV (offline cuts 20-40 GeV)
- Reconstruction combining information from several sub-detectors and high ID capabilities by either making cuts or using MVA techniques
- Isolation requirements within the analyses

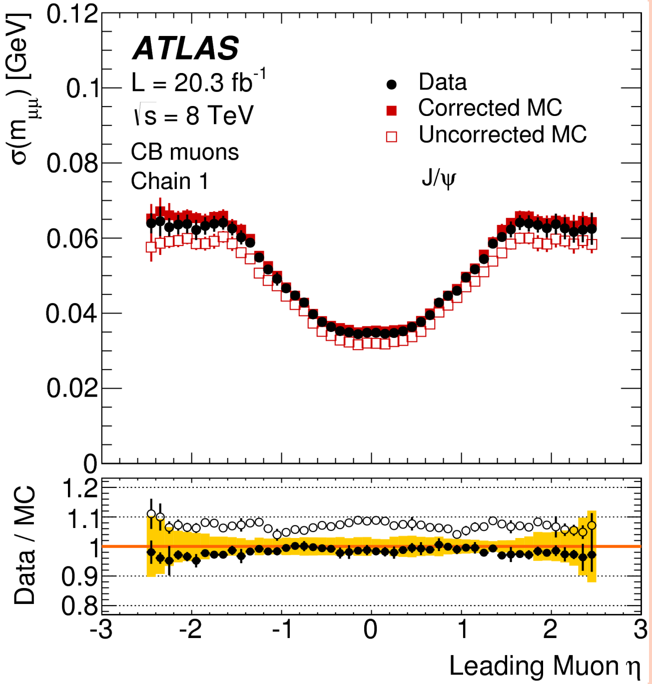




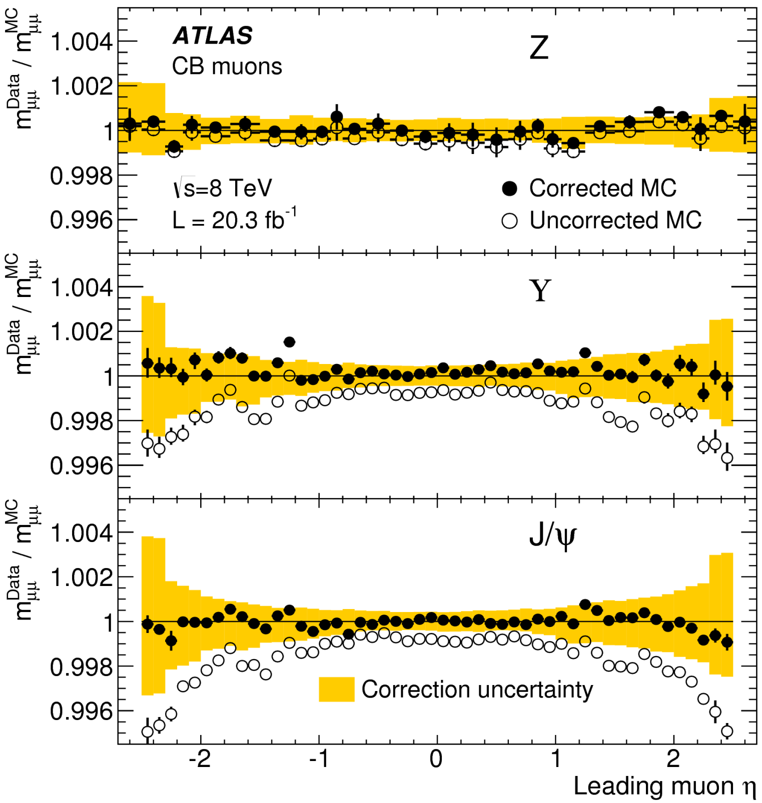


LEPTONS PERFORMANCE

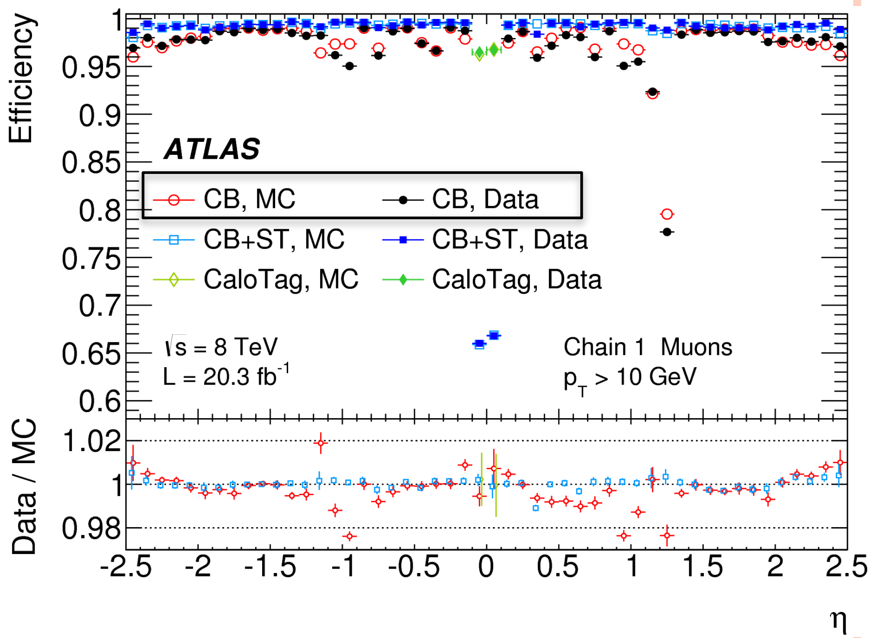
- Lepton efficiencies (trigger, reconstruction, ID, isolation), resolutions and scale measured in data using standard candles (e.g. Z, J/Psi, Upsilon decays), and compared to MC to provide data/MC SFs or smearing factors to be applied in analyses



Muon performance (e.g. ATLAS)



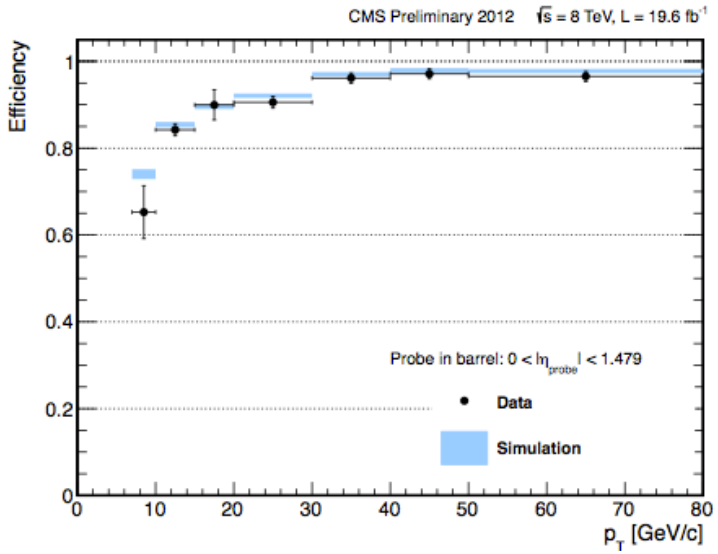
arXiv:1407.3935

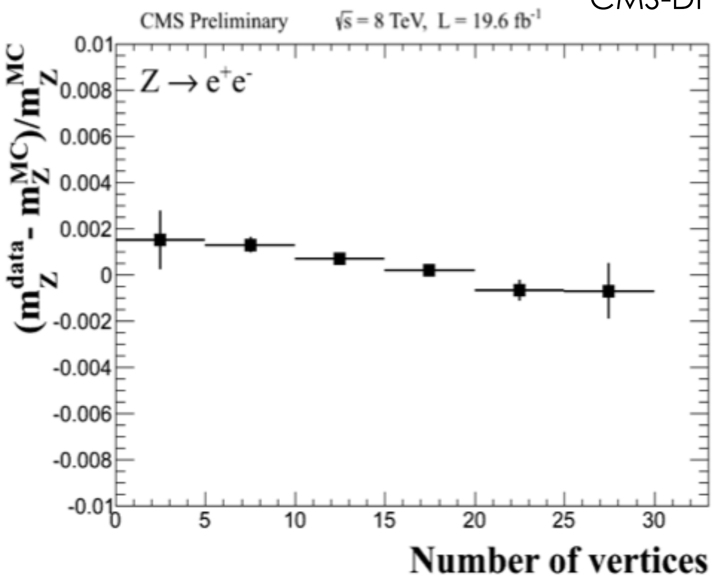


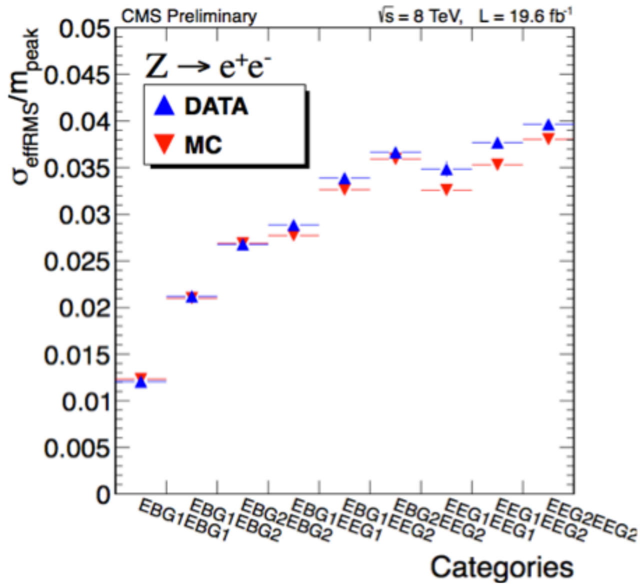
LEPTONS PERFORMANCE

Electron performance (e.g. CMS): Efficiency, scale and resolution

CMS-DP-2013-003



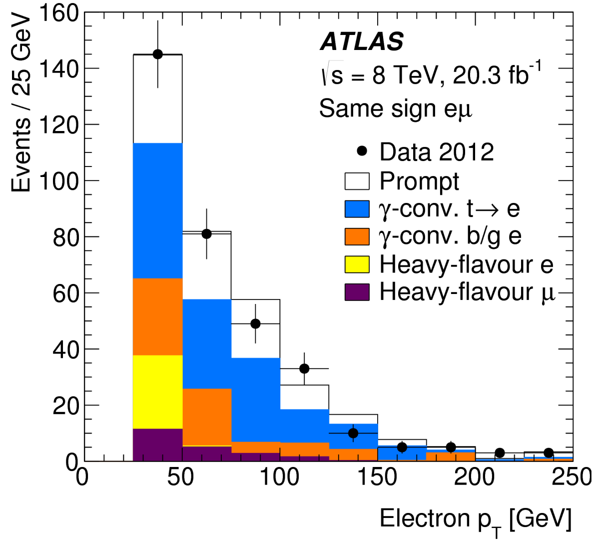




- The uncertainties on the lepton efficiency SFs, scale and resolution calibrations are propagated through the analyses.
- Recent significant improvements at LHC (mainly motivated by Higgs) on alignment, calibration and material description.

FAKE BACKGROUND

- Selection of top quark events often based on the identification of one or more charged isolated leptons (W→lν)
- Fake leptons (non-prompt leptons or non-leptonic particles as jets) can come from:



- Electrons: **photon conversions**, tracks overlapping with photons, jets, **semileptonic b/c quark decays**
- Muons: **b/c quark semileptonic decays**, punch-through hadrons, pion and kaon decays in flight

- Lepton isolation and kinematical cuts used to reduce this background

- Data driven methods developed to estimate this background (analysis dependent). Most common methods:
  - Matrix method
  - Fit methods (jet-lepton, anti-lepton)

ATLAS has just released a note (ATLAS-CONF-2014-058) providing detailed information about the methods commonly used and their applicability in top quark pair leptonic channels

FAKE BACKGROUND

Matrix method

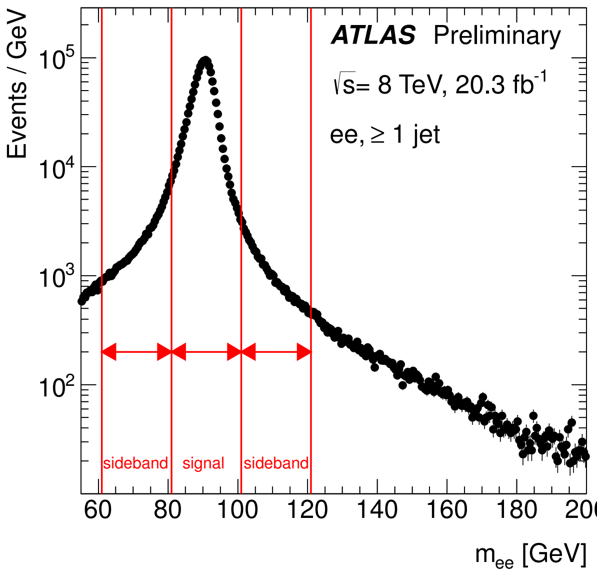
Basic form for lepton+jets (extension to 4x4 matrix in dilepton)

$$\begin{aligned} N^{loose} &= N^{loose}_{real} + N^{loose}_{fake} \\ N^{tight} &= \varepsilon_{real} \cdot N^{loose}_{real} + \varepsilon_{fake} \cdot N^{loose}_{fake} \end{aligned} \quad \Rightarrow \quad N^{tight}_{fake} = \frac{\varepsilon_{fake}}{\varepsilon_{real} - \varepsilon_{fake}} \cdot \left(\varepsilon_{real} \cdot N^{loose} - N^{tight}\right)$$

- Efficiencies measured from data:

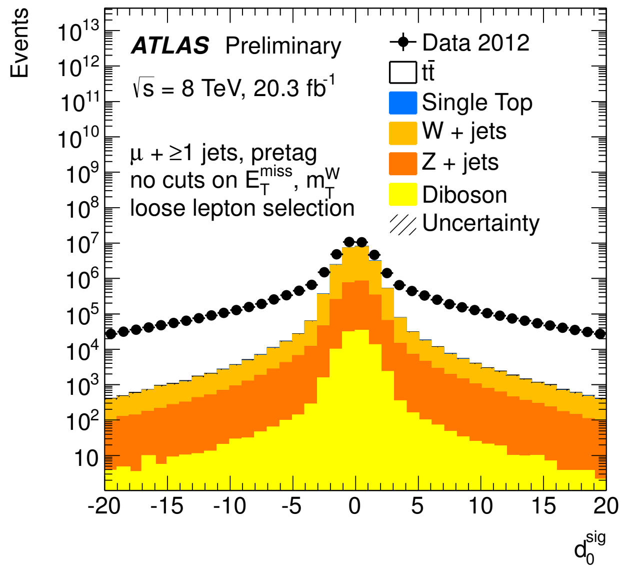
Real efficiency (ε_{real}):

- Tag & Probe using Z→ ll + top/Z MC corrections for electrons



Fake efficiency (ε_{fake}):

- From control regions dominated by fake leptons (low E_T^{miss}, low m_T^W, high d_0 significance)

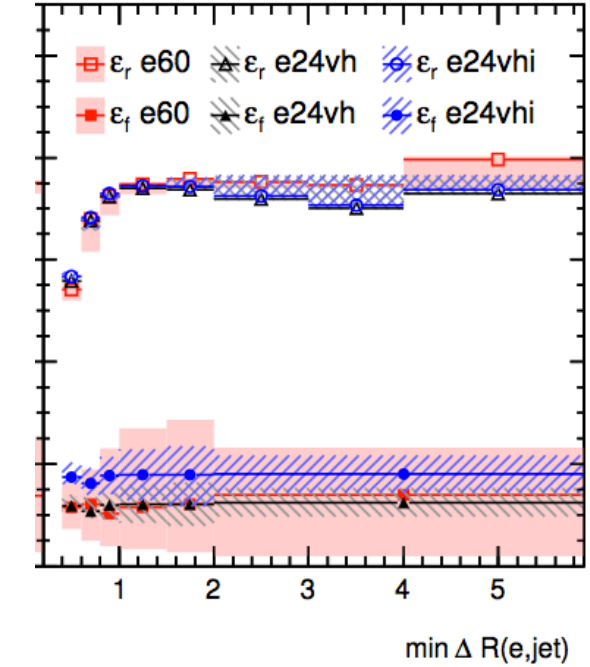


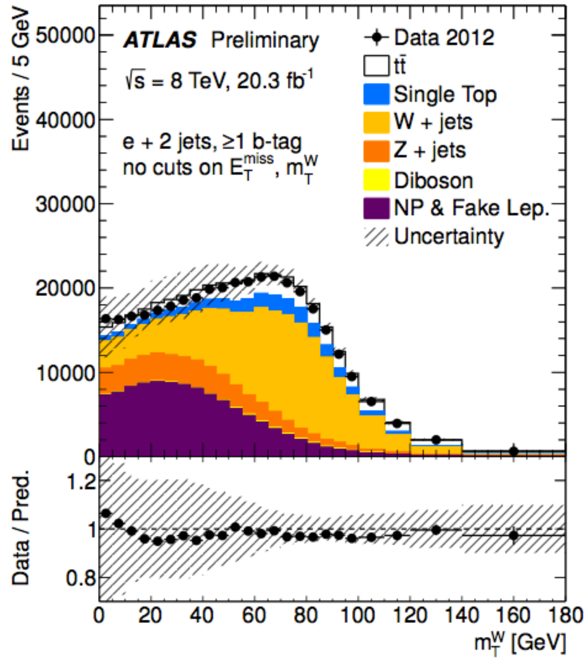
FAKE BACKGROUND

- Efficiencies are parametrised considering the observed dependencies, small correlations and agreement in CRs

	$\lvert\eta^{\ell}\rvert$	p_T^{ℓ}	$p_T^{\mathrm{lead.jet}}$	$\Delta R(\ell, \mathrm{jet})$	$\Delta\phi(\ell, \mathrm{E}_{\mathrm{T}}^{\mathrm{miss}})$	n_{jet}	$n_{b-\mathrm{jet}}$
$\varepsilon_{\mathrm{r}}(e)$	✓	✓		✓		✓	
$\varepsilon_{\mathrm{r}}(\mu)$	✓	✓		✓		✓	
$\varepsilon_{\mathrm{f}}(e)$	✓		✓		✓		✓
$\varepsilon_{\mathrm{f}}(\mu)$	✓	✓		✓			✓

- Systematic uncertainties (obtained from different CRs and parameterisations, varying amount of real leptons to subtract from the fake CR) are typically:
  - lepton+jets: 10-50% (depending on jet and tag multiplicity, larger for electrons, smaller for muons)
  - dileption eμ: 70-100% in signal region, 30-50% in the validation regions

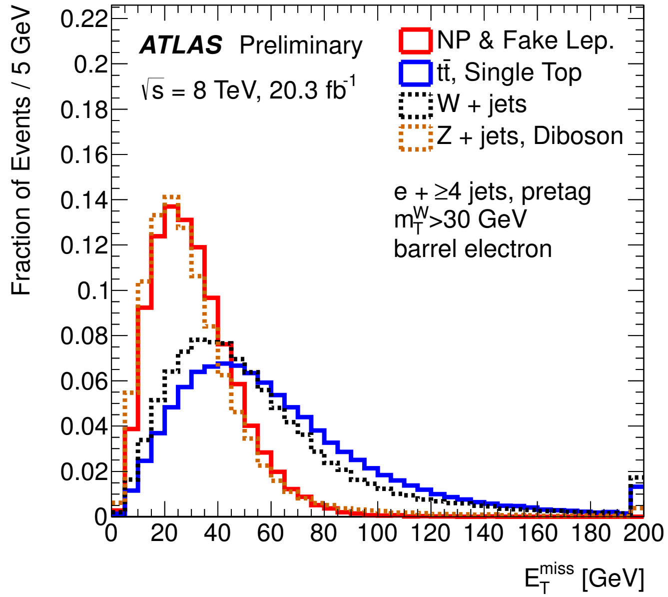


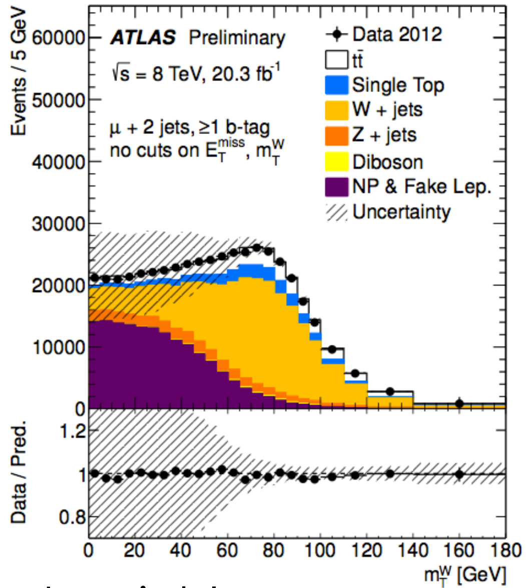


FAKE BACKGROUND

Fit method

- Define a fit model to predict the fake leptons background shape
  - Jet-electron: from a multijet MC sample asking one jet to be electron-like
  - Anti-muon: from data, selecting a sample enriched in non-prompt muons by inverting some of the muon identification cuts
- Choose a discriminating variable (E_T^{miss} for e+jets, m_T^W for μ+jets)
- Loosen/remove cuts on E_T^{miss} , m_T^W
- Perform maximum likelihood fit to predict its normalisation





- Systematic uncertainties (obtained from fitting different variables, variations on the fit constraints, W+jets and Z+jets modelling) lead to 50% uncertainty

CONCLUSIONS

- Object reconstruction and calibration techniques continuously evolving at the LHC to cope with the different LHC conditions and to address specific analysis needs.

- Recent progress also done in comparing strategies used in ATLAS and CMS for jet energy scale and b-tagging efficiency calibrations (dominant sources of uncertainties in most top analyses):

→ Recommendations on the proper categorisation of systematic components and ATLAS/CMS correlations to be used when doing LHC combinations provided:

JES: ATLAS-PHYS-PUB-2014-015/ CMS-PAS-JME-14-003

b-tagging:
https://twiki.cern.ch/twiki/bin/view/LHCPhysics/BTaggingSystematics

→ Some areas for future improvements in the experiments strategies also identified when going through this comparison

BACKUP

LEPTONS: MUONS AND ELECTRONS

- Isolation also required within the analysis:

  CMS: Cut on a relative isolation I_{rel} in a cone with ΔR = 0.3-0.4

  $I_{rel} = p_T$(charged Hadrons) $+p_T$ (Neutral Hadrons) $+p_T$ (photon)/p_T(lepton)

  ATLAS:

  - Electrons: Keep uniform isolation efficiency (e.g. @90%) across η and E_T:
    - EM Calorimeter Isolation ΔR = 0.2
    - Track isolation ΔR = 0.3
  - Muons: Use p_T dependent cone size relative isolation to improve the pile-up robustness and performance in boosted topologies @ 8 TeV