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JECUncertaintySources

Jet energy scale uncertainty sources

This page provides a description on the use of jet energy scale uncertainty sources.

Description

The JEC uncertainty sources provide detailed information on JEC uncertainties for use in statistical data analysis. The sources are fully uncorrelated **between** themselves, but describe JEC variations that are fully correlated **within** a given source. For example, a given source may describe that JEC may vary by s_1(pT1, eta1) at one point, and by s_2(pT2, eta2) at another. Another source can describe different variations s_2(pT1, eta1) and s_2(pT2, eta1). In general, any allowed variation of JEC can be described by a linear combination s(pT, eta; alpha_i) = sum_i alpha_i s_i(pT, eta), where the a-priori expectation is that the multipliers alpha_i have a Gaussian distribution with mean 0 and width 1. Note that s_i are **signed**, and it is possible to have s_i(pT1, eta1)>0, s_i(pT2, eta2)<0.

The uncertainty sources effectively encode **uncertainty correlations**, but in a form that is more flexible than a traditional correlation matrix. They can be likened to the set of PDF eigenvectors provided by the CTEQ collaboration, and are used in a similar fashion. The uncertainty sources are related to the total uncertainty at any given point by a simple quadratic sum: total_uncertainty(pT,eta) = sum_i s_i(pT, eta)^2. The correlation matrix can be easily calculated from the information contained in uncertainty sources.

Main uncertainties (2012/53X)

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The JEC uncertainties are grouped together in a way that makes the correlations transparent. The **absolute scale** is a single fixed number, hence the absolute scale uncertainty is fully correlated across pT and eta. However, the MC prediction of the pT dependence may be off so extra uncertainties based on Pythia and Herwig differences as well as single particle response in ECAL and HCAL is assigned for high and low pT extrapolation. Similarly, the L2 **relative eta** correction and most of its uncertainties are parameterized only as function of eta, but extra uncertainty sources also cover for possible residual log-linear pT dependence relative to barrel. The various detector regions are generally strongly correlated within themselves, and thus the L2 sources are only provided for wide regions: barrel (letal<1.3), endcap within tracking (1.3<letal<2.5), endcap outside tracking (2.5-3.0), and HF (3.0-5.2). The L1 **pile-up** correction and most of its uncertainties are parameterized as a constant offset and thus fall as 1/pT for JEC, but extra jet pT dependence sources account for residual (MC truth) pT dependence relative to the pTgen=30-35 GeV reference bin. The additional **flavor** uncertainties cover for data/MC differences when applied to jet flavor mixtures other than the Z+jet/gamma+jet mixture (even when not explicitly applying L5).

The main differences compared to the earlier list of uncertainty sources are:

- L3 absolute scale pT dependence broken up by ECAL and HCAL for more detailed description
- L2 relative eta uncertainty excludes RelativeFSR source (negligible with improved MPF method) and adds residual pT dependence (of which there is some evidence in 2012, possibly due to HE/HF radiation damage)
- L1 pile-up uncertainty excludes small and obsolete out-of-time PileUpOOT (not an issue with 2 time-slice reco) and jet rate PileUpJetRate (was pile-up noise degrading JER, while JEC ok) uncertainties, and re-parameterizes pT dependence with a proper envelope relative to 30-35 GeV to reduce effective uncertainty, particularly near the typical jet threshold of pT>30 GeV used by many analyses

The full list of uncertainty sources currently accessible is listed below:

- **Absolute** : absolute scale uncertainty. Mainly uncertainty in combined photon (EM) and Z->mumu (tracking) reference scale and correction for FSR+ISR.
- **HighPtExtra** : high pT extrapolation. Based on Pythia6 Z2/Herwig++2.3 differences in fragmentation and underlying event (FullSim). **old and recycled**
- **SinglePion[ECAL][HCAL]** : high pT extrapolation. Based on propagation of +/-3% variation in single particle response (in ECAL/HCAL) to PF Jets (FastSim).
- **FlavorQCD** : jet flavor. Based on Pythia6 Z2/Herwig++2.3 differences in uds/c/b-quark and gluon responses. It describes the uncertainty when extrapolating from the flavor composition in gammea/Z+jet events that are used to measure the absolute scale in data to the QCD mixture. This flavor uncertainty is recommended for most analyses. There exist alternative flavor uncertainty sources for other flavor compositions: FlavorZJet (Z+jet events), FlavorPhotonJet (gamma+jet events), FlavorPureGluon (only gluons), FlavorPureQuark (only uds), FlavorPureCharm (only c) and FlavorPureBottom (only b).
- **Time** : JEC time dependence. Observed instability in the endcap region, presumed to be due to the HE/HF radiation damage, and possibly also due to ECAL transparency loss.
- **RelativeJER[EC1][EC2][HF]** : eta-dependence uncertainty from jet pT resolution (JER). The JER uncertainties are assumed fully correlated for endcap within tracking (EC1), endcap outside tracking (EC2) and hadronic forward (HF).
- **RelativePt[EC1][EC2][HF]**: residual pT dependence relative to the constant fit central value, parameterized as a log-linear fit. Possibly due to HE/HF radiation damage (high pT jets deposit more energy in HCAL than low pT jets). **new**
- **RelativeStat[EC2][HF]** : statistical uncertainty in determination of eta-dependence. Fixed uncertainty over wider detector regions. Only important in endcap outside tracking (EC2) and in HF.
- **RelativeSample**: currently set to 0. Would parameterize observed differences between dijet and Z/gamma+jet samples, but these seem to be within other systematics already, so avoid double-counting. **always 0**
- **PileUpDataMC**: taking 20% of data/MC difference observed in the data-based Random Cone method in Zero Bias data (RCZB) as uncertainty (not 100% because we provide separate corrections for data and MC).
- **PileUpPt[BB][EC][HF]**: pile-up offset dependence on jet pT relative to pTgen=30-35 GeV, as estimated on MC. Source not yet understood (could be zero suppression), but effect confirmed by two independent methods and samples. Parameterized as an envelope that covers variation in pT dependence vs number of vertices. Assumed to be the same dependence on data and MC, so **not included in MC total uncertainty**, which is meant for analyses based on data/MC ratio.
- **PileUpBias** : taking 100% of the data-based RCZB method bias in MC as uncertainty (not so well understood, but possibly linked to pT dependence). Only refers to the bias relative to the pTgen=30-35 GeV bin, because pT dependence is accounted for by extra sources above.

The following uncertainties are not sources, but quadratic sums of subsets of sources described above. Their main purpose is to facilitate the uncertainty studies and cross-check the totals.

- **SubTotalPileUp**: sum of pile-up uncertainties (PileUp[*])
- **SubTotalRelative**: eta-dependence uncertainties (Relative[*])
- **SubTotalPt**: high/low pT extrapolation (Absolute, HighPtExtra, SinglePion[*], Flavor)
- **SubTotalMC**: sum of all uncertainties in which Data to MC ratios are considered on the full 20/fb sample. This includes all uncertainty sources except **PileUpPt**.
- **TotalNoFlavor**: sum of all uncertainties excluding any flavor uncertainty added in quadrature
- **Total** : sum of all uncertainties in quadrature

Please look below on how to get the uncertainty sources files.

Main uncertainties (2011, 2012/52X)

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The JEC uncertainties are grouped together in a way that makes the correlations transparent. The absolute scale is a single fixed number, hence the absolute scale uncertainty is fully correlated across pT and eta. However, the MC prediction of the pT dependence may be off so extra uncertainties based on Pythia and Herwig differences as well as single particles response is assigned for high and low pT extrapolation. The L2 correction is only a function of eta, and hence fully correlated across pT. The various detector regions are generally strongly correlated within themselves, and thus the L2 sources are only provided for wide regions: barrel, endcap within tracking, endcap outside tracking, and HF. The L1 uncertainty and jet flavor uncertainties are only important at low pT, and the sources strive to cover the possible variations in shape vs pT and eta.

The full list of uncertainty sources currently accessible is listed below:

- **Absolute** : absolute scale uncertainty. Mainly uncertainty in combined photon (EM) and Z->mumu (tracking) reference scale and correction for FSR+ISR.
- **HighPtExtra** : high pT extrapolation. Based on Pythia6 Z2/Herwig++2.3 differences in fragmentation and underlying event (FullSim).
- **SinglePion** : high pT extrapolation. Based on propagation of +/-3% variation in single particle response to PF Jets (FastSim).
- **Flavor** : jet flavor (quark/gluon/charm/b-jet). Based on Pythia6 Z2/Herwig++2.3 differences in quark and gluon responses relative to QCD mixture (charm and b-jets are in betweed uds and g).
- **Time** : JEC time dependence. Observed instability in the endcap region, presumed to be due to the EM laser correction instability for prompt 42X data.
- **RelativeJER[EC1][EC2][HF]** : eta-dependence uncertainty from jet pT resolution (JER). The JER uncertainties are assumed fully correlated for endcap within tracking (EC1), endcap outside tracking (EC2) and hadronic forward (HF).
- **RelativeFSR** : eta-dependence uncertainty due to correction for final state radiation. Uncertainty increases toward HF, but is correlated from one region to the other.
- **RelativeStat[EC2][HF]** : statistical uncertainty in determination of eta-dependence. Averaged out over wider detector regions, and only important in endcap outside tracking (EC2) and in HF.
- **PileUp[DataMC][OOT][Pt][Bias][JetRate]** : uncertainties for pile-up corrections. The [DataMC] parameterizes data/MC differences vs eta in Zero Bias data. The OOT estimates residual out-of-time pile-up for prescaled triggers, if reweighing MC to unprescaled data. The [Pt] covers for the offset dependence on jet pT (due to e.g. zero suppression effects), when the correction is calibrated for jets in the pT=20-30 GeV range. The [Bias] covers for the differences in measured offset from Zero Bias (neutrino gun) MC and from MC truth in the QCD sample, which is not yet fully understood. The [JetRate] covers for observed jet rate variation versus <Nvtx> in 2011 single jet triggers, after applying L1 corrections.

The following uncertainties are not sources, but quadratic sums of subsets of sources described above. Their main purpose is to facilitate the uncertainty studies and cross-check the totals.

- **SubTotalPileUp**: sum of pile-up uncertainties (PileUp[*])
- **SubTotalRelative**: eta-dependence uncertainties (Relative[*])
- **SubTotalPt**: high/low pT extrapolation (Absolute, HighPtExtra, SinglePion, Flavor)
- **SubTotalDataMC**: sum of all uncertainties in which Data to MC ratios are considered on the full 4.7/fb sample. This includes all uncertainty sources except **PileUpPt**, **PileUpBias** and **Time**.
- **Total** : sum of all uncertainties in quadrature

2011 JEC uncertainty correlations

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In the framework of the TOPLHC working group, the correlation of JES uncertainties between ATLAS and CMS were discussed by representatives of both experiments. The discussion of the foreseen correlation groups for 2011 analyses is documented in the shared talk at the open TOPLHCWG-meeting 18/19 April 2013. This presentation also contains estimates of correlation coefficients for each correlation group. The mapping of these groups to CMS uncertainties was presented at the JetMET meeting 29 April 2013. In order to facilitate the treatment of JES correlations, the **Absolute** uncertainty source of CMS was split into four sub-components (MPFBias, FlavorMapping, Statistics, Scale) and corresponding correlation groups were added to the uncertainty sources framework.

In detail, the following changes were made:

- ~~**Absolute**~~: absolute scale uncertainty. Replaced by the following subcomponents **Absolute[Statistics][Scale][MPFBias][FlavorMapping]**:
  - **AbsoluteStatistical** -Z+jet/gamma+jet statistics - 0.22%
  - **AbsoluteScale** - Uncertainty from ECAL scale and scale of Z-boson - 0.3%
  - **AbsoluteMPFBias** - From extrapolation to zero additional event activity and remaining non-closure with pt-balance - 0.4%
  - **AbsoluteFlavorMapping** - Half of the nominal flavor uncertainty for mapping QCD mixture to Z+jet/gamma+jet mixture - 0.25%

In detail, the following additions were made:

- **CorrelationGroup**: uncertainties matching the common ATLAS/CMS correlation categories grouped together. **CorrelationGroup[InSitu][Flavor][Intercalibration][Uncorrelated]** add up to total uncertainty. **CorrelationGroupbJES** listed extra to account for treatment of b-jets specific to top mass analyses. Detailed listing:
  - **CorrelationGroupInSitu** At CMS: same as **AbsoluteMPFBias**. Groups partially correlated systematic uncertainties from Z+jet/gamma+jet absolute scale determination (e.g. radiation suppression and out-of-cone effects).
  - **CorrelationGroupFlavor** At CMS: contains **AbsoluteFlavorMapping** and **Flavor** uncertainty source. Partially correlated with corresponding ATLAS sources due to similar use of PYTHIA/Herwig++ for flavor uncertainty determination
  - **CorrelationGroupInterCalibration** At CMS: same as **RelativeFSR**. Partially correlated with ATLAS eta intercalibration modelling uncertainties (PYTHIA/Herwig++ non-closure)
  - **CorrelationGroupUncorrelated** Remaining sources which are estimated as being uncorrelated between ATLAS and CMS.
  - **CorrelationGroupbJES** At CMS specifically for top mass measurements: same as **Flavor** uncertainty. Used to model response differences between uds/b. Partially correlated to ATLAS bJES uncertainty.

The updated uncertainty sources files are attached to the Twiki-page: JEC11_V13_UncertaintySources_AK5PF.txt and JEC11_V13_UncertaintySources_AK7PF.txt.

The listed correlation groups should be evaluated individually to facilitate combinations of physics measurements taking into account the JES correlations.

Recommendation for analysis

The recommendation of the JEC group for the usage of uncertainties depending on the analysis is detailed at https://twiki.cern.ch/twiki/bin/view/CMS/JECDataMC

Example implementation

The uncertainty sources are provided as ASCII text files compatible with the JetCorrectorParameters and JetCorrectionUncertainty classes already used for uncertainties in CMSSW. The only difference is that a specific constructor for JetCorrectorParameters needs to be used to access the different sections of the text file. It is left up to the user to create separate instances of JetCorrectionUncertainty for any and each of the uncertainty sources. The ASCII text files and example source code are provided below.

2011 JEC

Uncertainty sources for final 2011 JEC (GT to be announced) with 4.7/fb of prompt 42X reco (V4, V6, 2011B V1) and May10+Aug05 re-reco:

- JEC11_V12_AK5PF_UncertaintySources.txt: Uncertainty sources for AK5PF
- JEC11_V12_AK7PF_UncertaintySources.txt: Uncertainty sources for AK7PF

Updates: added subset SubTotalDataMC for analyses using Data/MC ratios on the full 4.7/fb data set (e.g. type-I MET uncertainty). Fixed Flavor uncertainty that was zero for AK7PF in V10. Update (May 2013): For the implementation of correlation groups fit for combinations of measurements with other experiments refer to 2011 JEC uncertainty correlations.

2012 JEC

New uncertainty sources for 53X Summer13_V1 JEC (20/fb at 8 TeV in 2012, using full 2012 re-reco)

- Summer13_V4_Uncertainties.tgz: archive for new total uncertainties and uncertainty sources

NB: This new uncertainty files contains updates to the JetFlavor systematics. They contain a extra set of uncertainties which allow for a better flavor treatment that will reduce uncertainties for pure uds, b and c flavors as well as for the QCD and Z/gamma+jet mixtures. FlavorQCD is used for the flavor uncertainty in the total uncertainty and recommended for analysis that analyse final states with a gluon fraction equal or lower to the QCD jets.

Old uncertainty sources for 53X Fall12_V5 JEC (11/fb at 8 TeV in 2012, using 2012A+B re-reco, 2012C prompt reco):

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- FALL12_V7_Uncertainties.tgz: archive for new total uncertainties and uncertainty sources

We had identified a problem with PileUpBias source having a runaway behavior at low pT for the first set to uncertainty files. The archive file contains newer total uncertainties than in the current global tag. Please use these new uncertainty files consistently!:

NB: Don't let the V7 in the name bother you, this is internal numbering and refers to Fall12_V5. Note that the Fall12_V7_DATA_UncertaintySources_AK5PFchs.txt file is for small cone size with CHS, meant for most analyses, while Fall12_V7_DATA_UncertaintySources_AK7PF.txt is for large cone size without CHS, targeted for QCD. We have not produced all the other variants to avoid confusion; let us (hn-cms-jes) know if you have a valid user case and these can be added later.

Old uncertainty sources for the first 2012 JEC with 1.6/fb of 52X data at sqrt(s)=8 TeV:

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- Summer12_V2_DATA_AK5PF_UncertaintySources.txt: Uncertainty sources for 2012 52X data (AK5PF)
- Summer12_V2_DATA_AK7PF_UncertaintySources.txt: Uncertainty sources for 2012 52X data (AK7PF)

These files contain the Data/MC ratio uncertainty for the full 4.7/fb sample to be used e.g. with type-I MET uncertainty (SubTotalDataMC instead of Total):

- JEC11_V12_UncertaintyDataMC_AK5PF.txt: SubTotalDataMC for AK5PF as a single uncertainty file
- JEC11_V12_UncertaintyDataMC_AK7PF.txt: SubTotalDataMC for AK7PF as a single uncertainty file

Caveat: be extra careful, because the time dependence systematic is completely removed.

These files contain the Data/MC ratio uncertainty for the 1.6/fb sample in 52X:

- Summer12_V2_DATA_AK5PF_UncertaintyDataMC.txt: SubTotalDataMC for AK5PF as a single uncertainty file
- Summer12_V2_DATA_AK7PF_UncertaintyDataMC.txt: SubTotalDataMC for AK7PF as a single uncertainty file

Code example

In compiler mk_code.C (not needed for linking under CMSSW):

```
gROOT->ProcessLine(".L CondFormats/JetMETObjects/src/Utilities.cc+");
gROOT->ProcessLine(".L CondFormats/JetMETObjects/src/JetCorrectorParameters.cc+");
gROOT->ProcessLine(".L CondFormats/JetMETObjects/src/SimpleJetCorrectionUncertainty.cc+");
gROOT->ProcessLine(".L CondFormats/JetMETObjects/src/JetCorrectionUncertainty.cc+");
```

In header code.h:

```
#include "CondFormats/JetMETObjects/interface/JetCorrectorParameters.h"
#include "CondFormats/JetMETObjects/interface/JetCorrectionUncertainty.h"
#include <vector>
```

In source code code.C:

```
// Instantiate uncertainty sources
const int nsrc = 21;//19;
const char* srcnames[nsrc] =
  {"Absolute", "HighPtExtra", /*"SinglePion",*/ "SinglePionECAL", "SinglePionHCAL",
   "Flavor", "Time",
   "RelativeJEREC1", "RelativeJEREC2", "RelativeJERHF",
   "RelativePtBB"/*new*/,"RelativePtEC1", "RelativePtEC2", "RelativePtHF",
   "RelativeStatEC2", "RelativeStatHF", "RelativeFSR"/*renew*/, /*"RelativeSample",*/
   "PileUpDataMC", /*"PileUpOOT",*/ "PileUpBias", /*"PileUpJetRate"*/
   /*"PileUpPt",*/ "PileUpPtBB", "PileUpPtEC", "PileUpPtHF"};
std::vector<JetCorrectionUncertainty*> vsrc(nsrc);

for (int isrc = 0; isrc < nsrc; isrc++) {

   const char *name = srcnames[isrc];
   JetCorrectorParameters *p = new JetCorrectorParameters("Summer13_V1_DATA_UncertaintySources_AK
   JetCorrectionUncertainty *unc = new JetCorrectionUncertainty(*p);
   vsrc[isrc] = unc;
} // for isrc

// Total uncertainty for reference
```

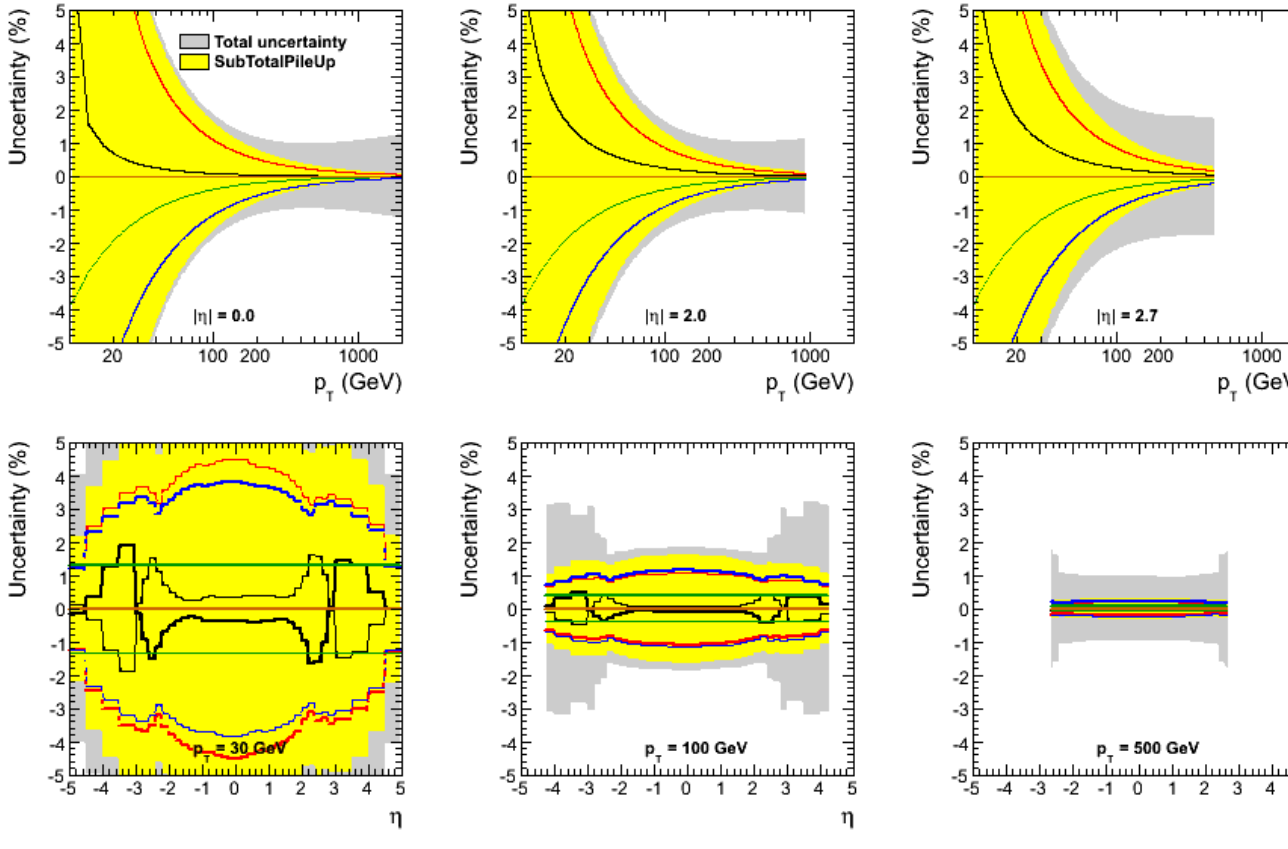
```
JetCorrectionUncertainty *total = new JetCorrectionUncertainty(*(new JetCorrectorParameters("Summ

// Calculate uncertainty per source and as a total
double jetpt(50.);
double jeteta(2.4);
double sum2_up(0), sum2_dw(0);

for (int isrc = 0; isrc < nsrc; isrc++) {

      JetCorrectionUncertainty *unc = vsrc[isrc];
      unc->setJetPt(jetpt);
      unc->setJetEta(jeteta);
      double sup = unc->getUncertainty(true); // up variation
      unc->setJetPt(jetpt);
      unc->setJetEta(jeteta);
      double sdw = unc->getUncertainty(false); // down variation

      sum2_up += pow(max(sup,sdw),2);
      sum2_dw += pow(min(sup,sdw),2);
} // for isrc

total->setJetPt(jetpt);
total->setJetEta(jeteta);
double uncert = total->getUncertainty(true);

// Check that quadratic sum of sources equals total uncertainty
assert(fabs(uncert - sqrt(sum2_up)) < 1e-3);
```

Plots of uncertainty sources:

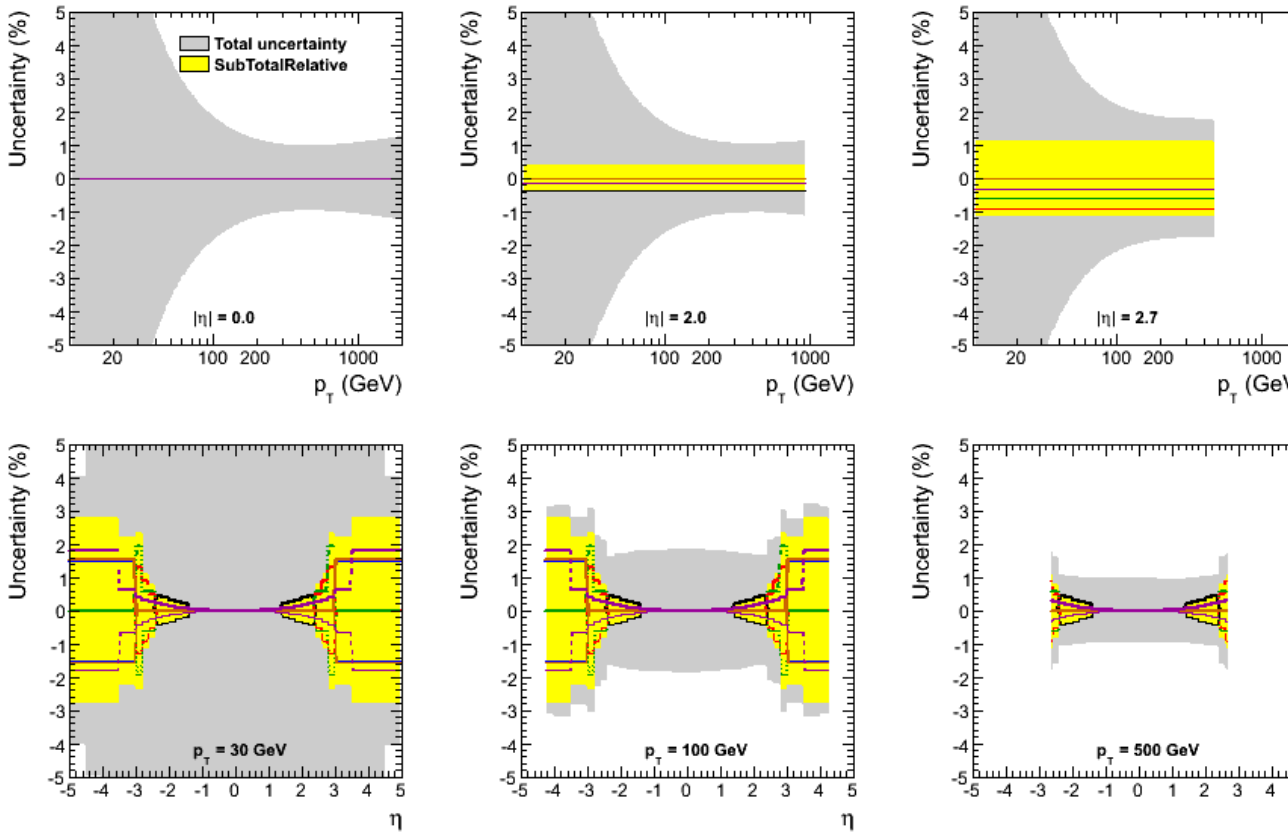
Sources for 2012 JEC:

Show Hide

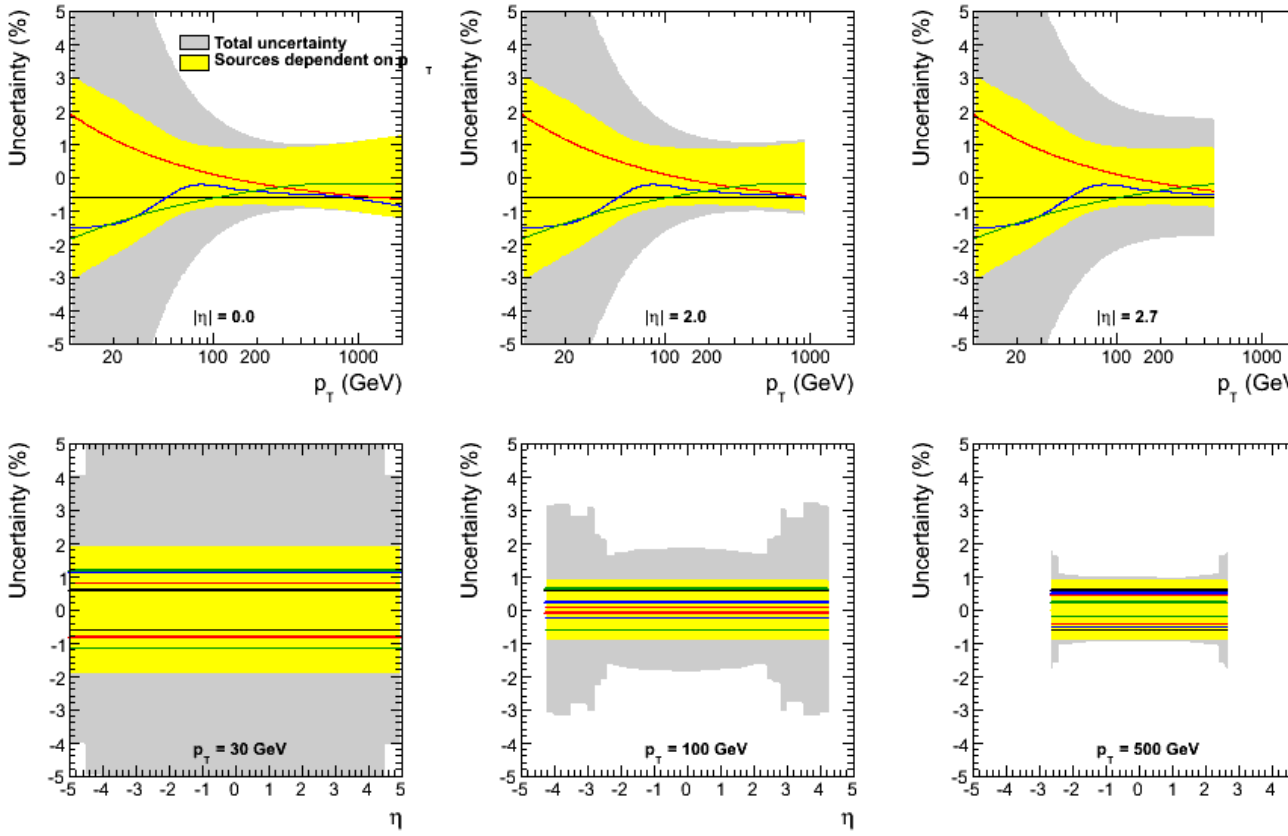
- sources_summer12v2_pfak7_0.pdf: Uncertainty sources for AK7PF (pile-up)



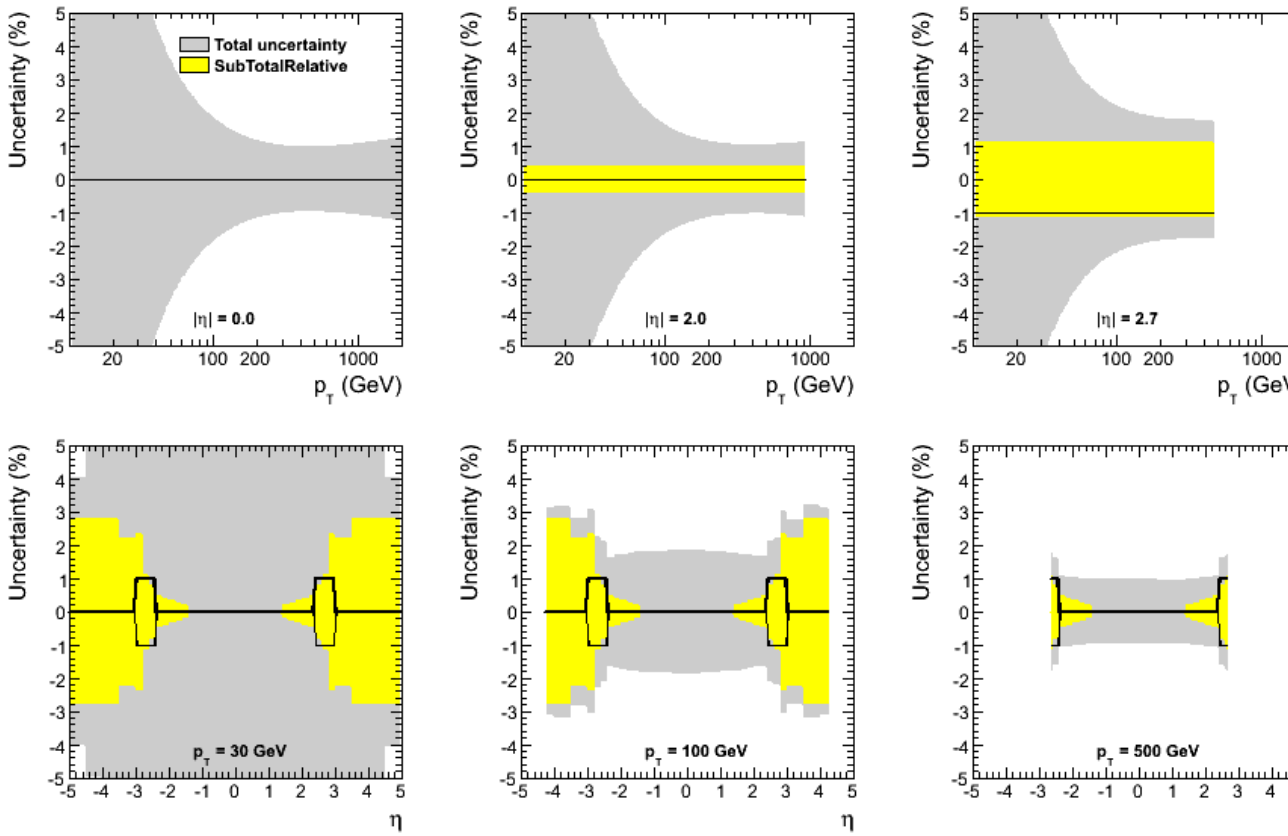
- sources_summer12v2_pfak7_1.pdf: Uncertainty sources for AK7PF (eta-dependence)



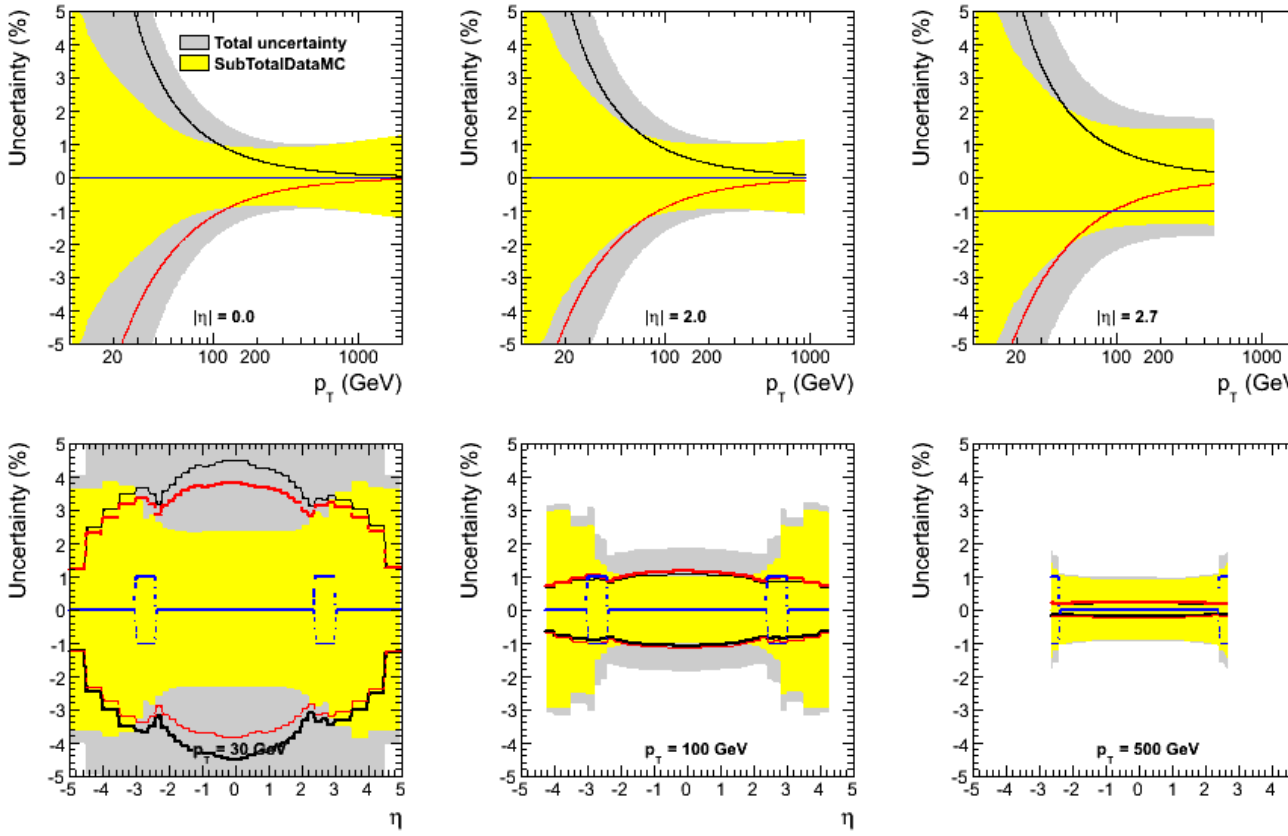
- sources_summer12v2_pfak7_2.pdf: Uncertainty sources for AK7PF (pT dependence)



- sources_summer12v2_pfak7_3.pdf: Uncertainty sources for AK7PF (time dependence)



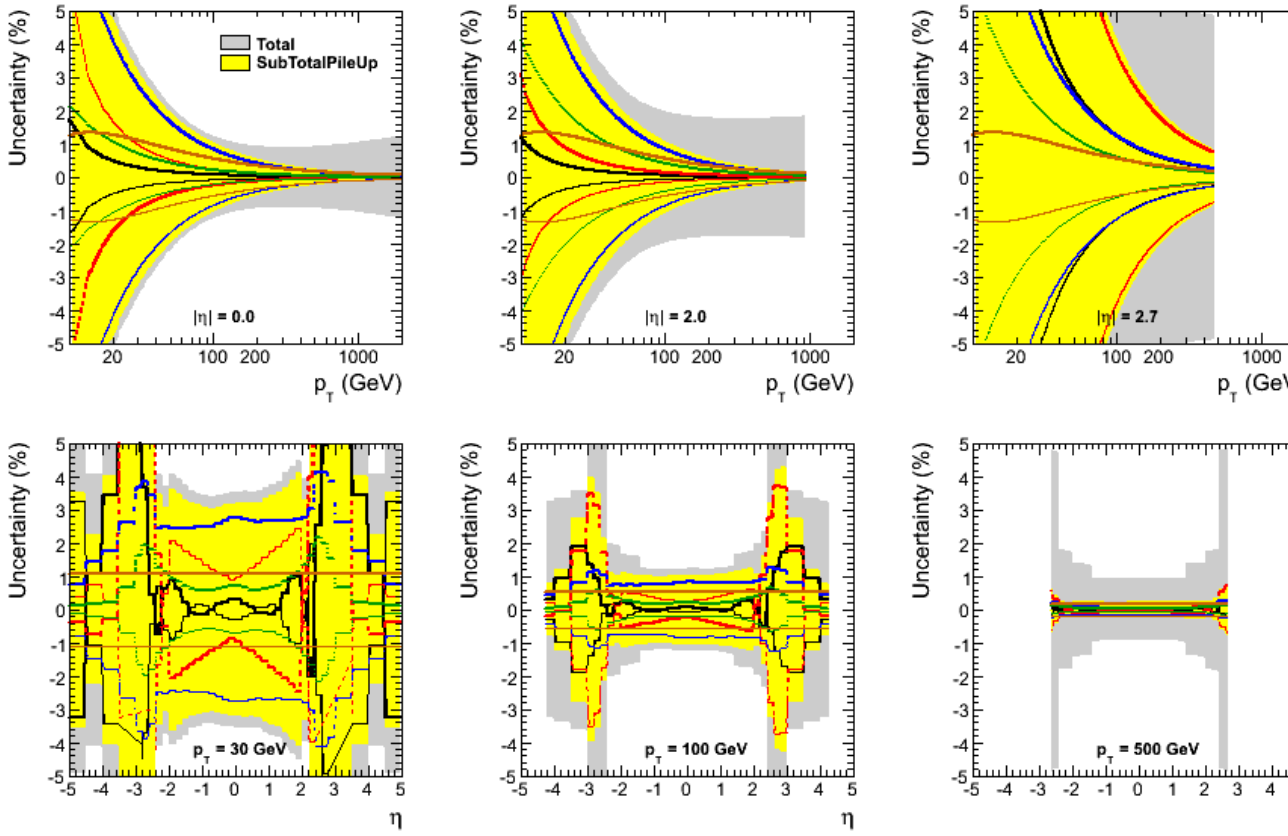
- sources_summer12v2_pfak7_4.pdf: SubTotalDataMC compared to Total and to excluded sources for AK7PF



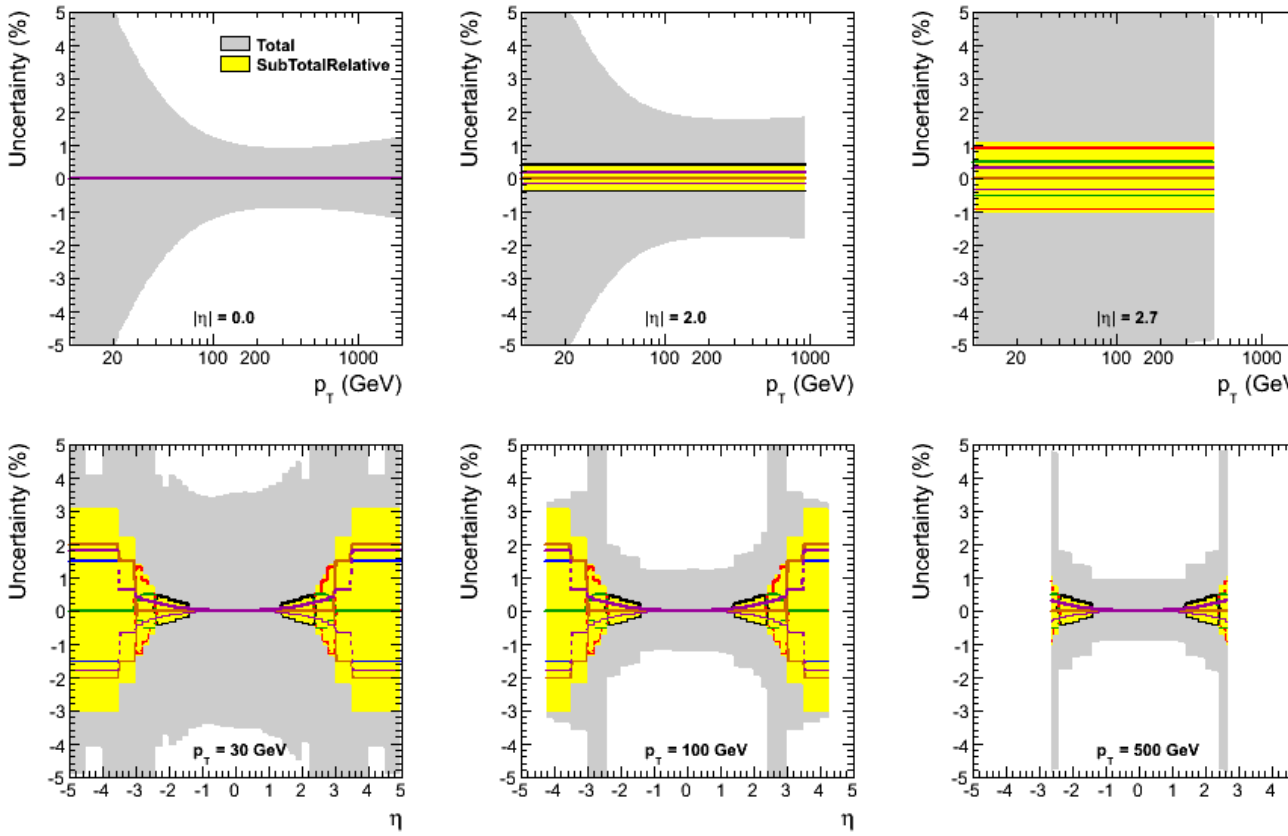
Sources for 2011 JEC:

Show Hide

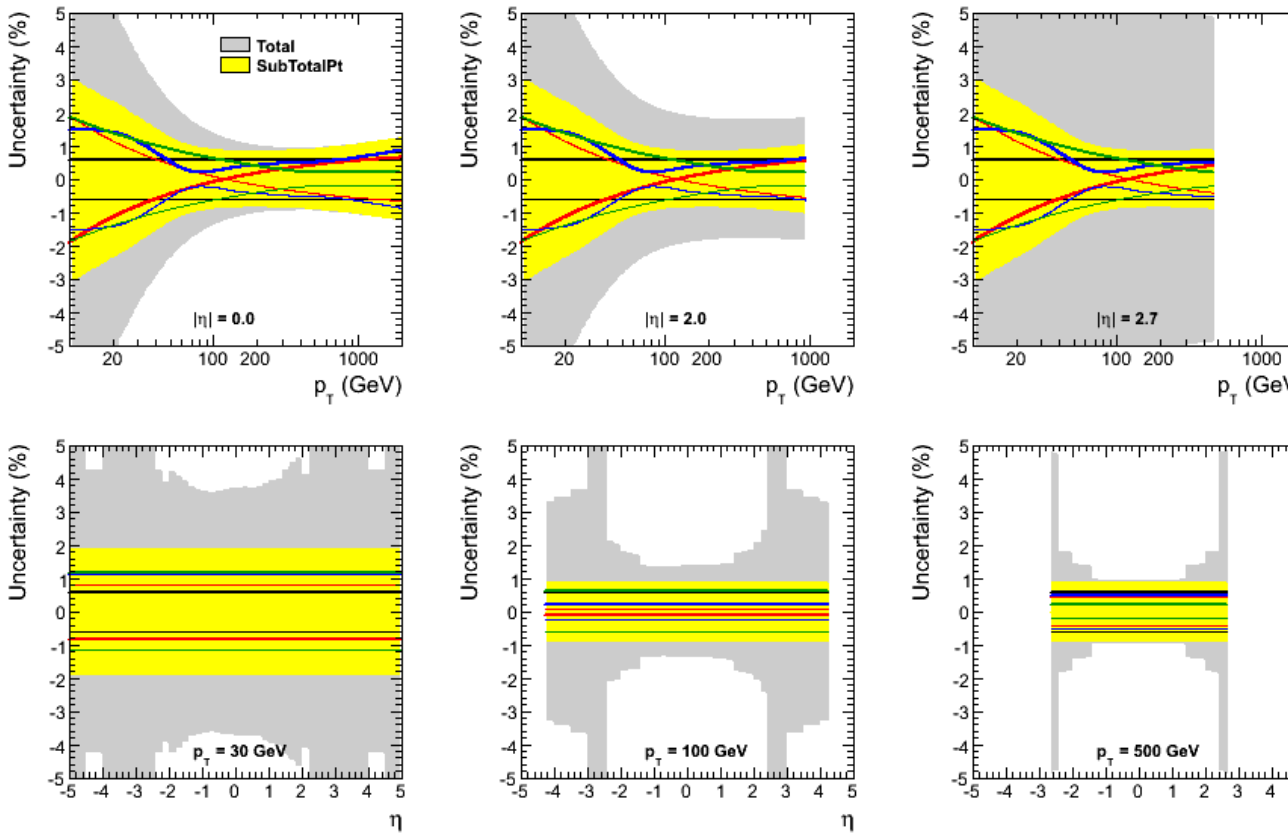
- sources_0.pdf: Uncertainty sources for AK7PF (pile-up)



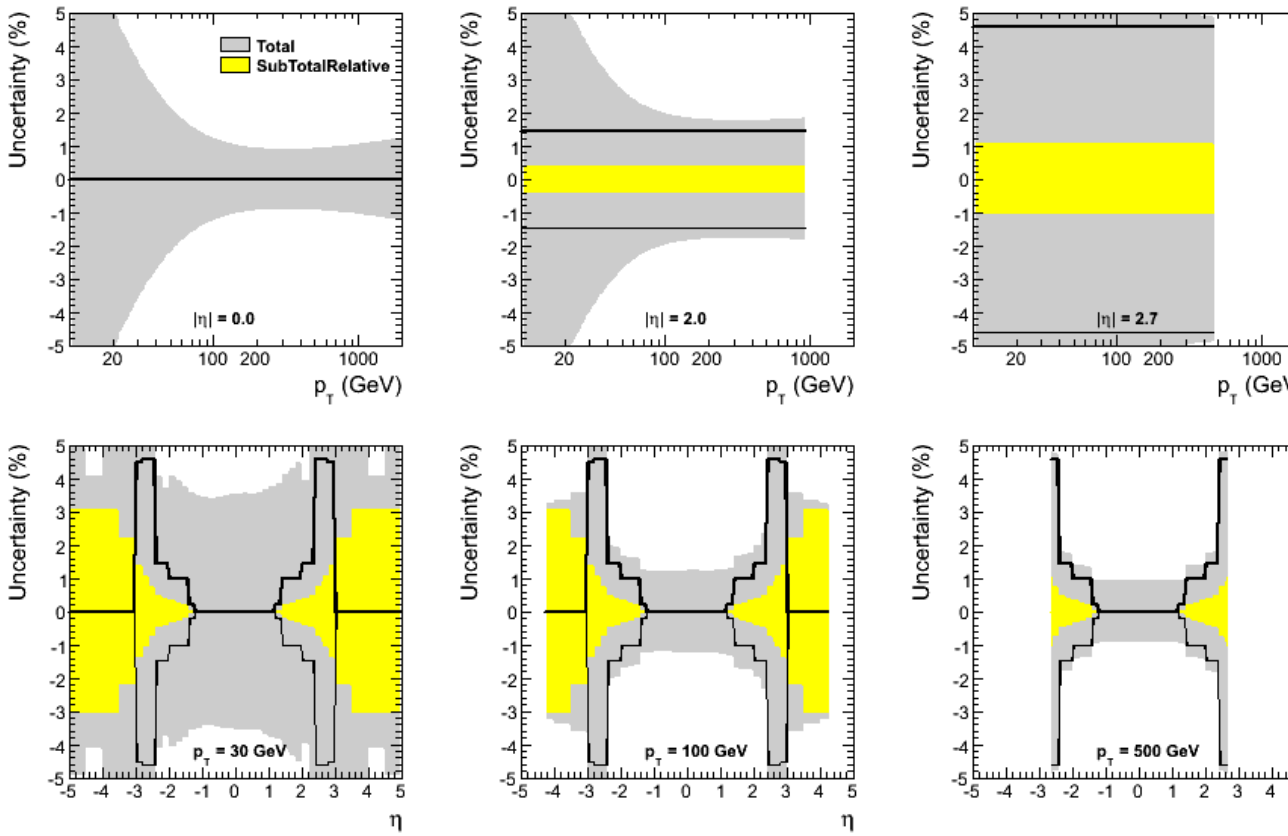
- sources_1.pdf: Uncertainty sources for AK7PF (eta-dependence)



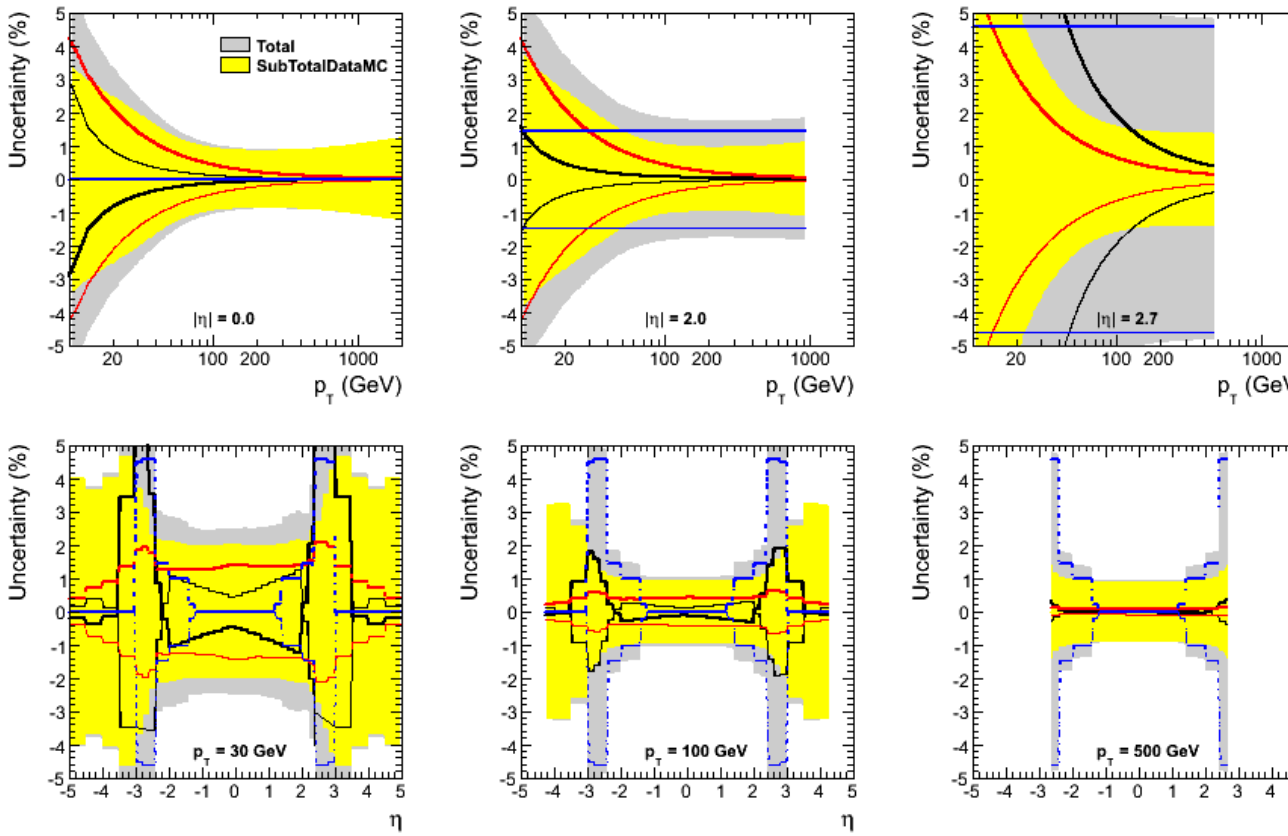
- sources_2.pdf: Uncertainty sources for AK7PF (pT dependence)



- sources_3.pdf: Uncertainty sources for AK7PF (time dependence)



- sources_4.pdf: SubTotalDataMC compared to Total and to excluded sources for **AK5PF** (others above AK7PF)



2011 JEC correlation discussions (TOPLHCWG):

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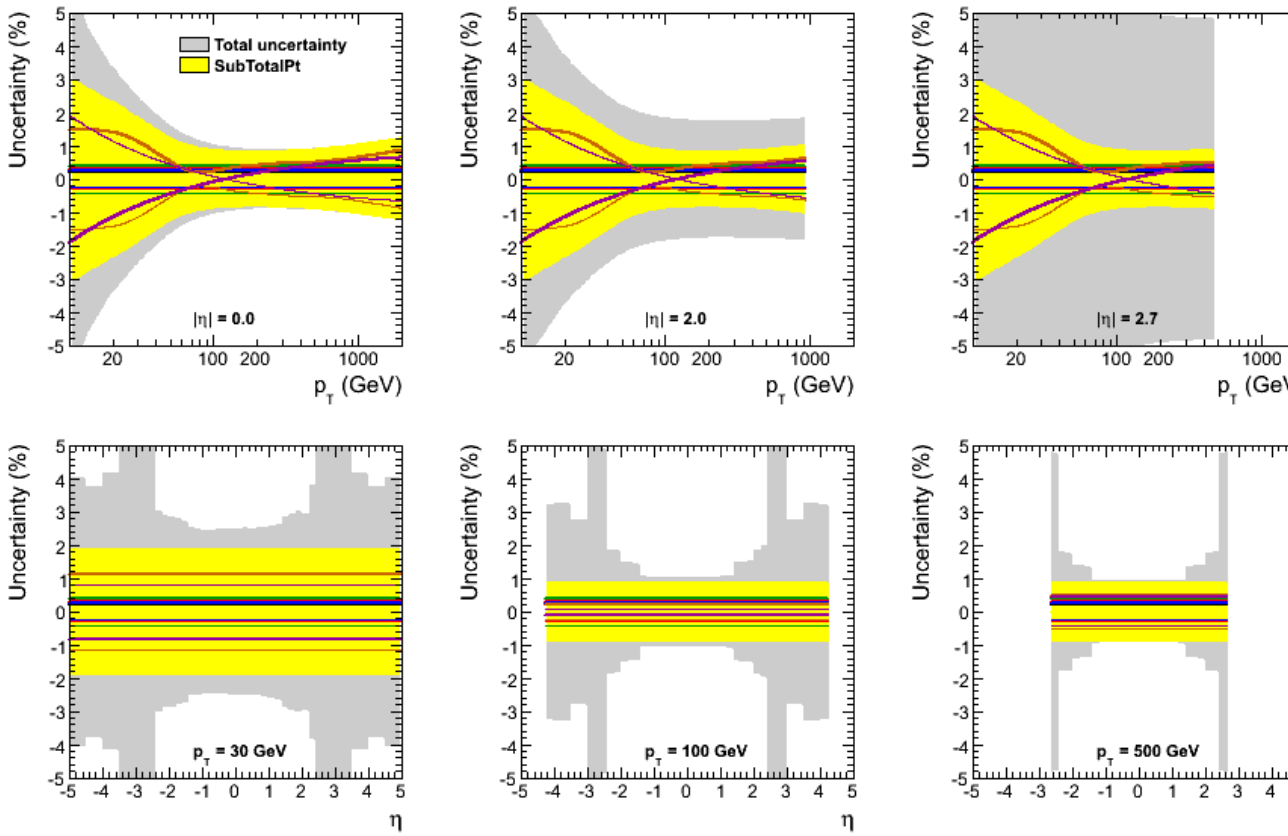
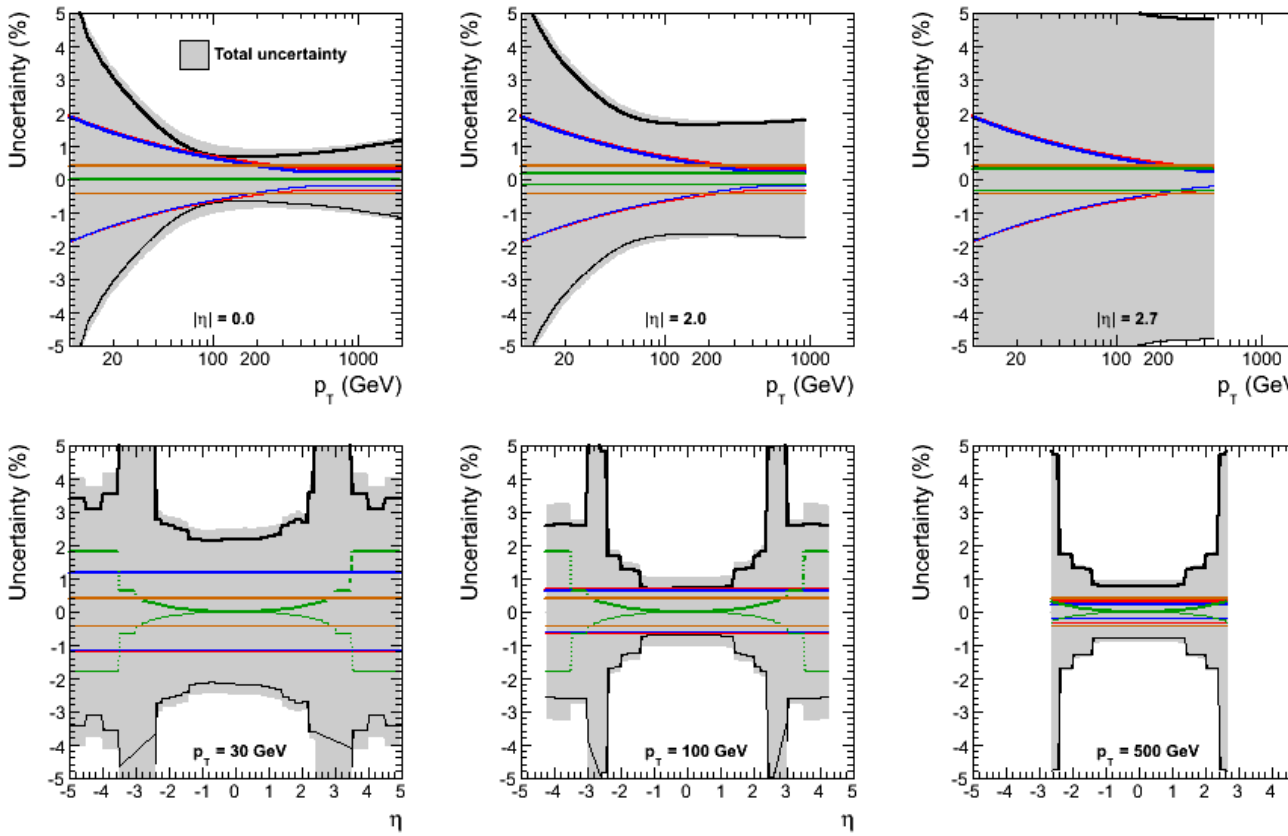
- sources_JEC11_V13_pfak7_0.pdf: Uncertainty sources for AK7PF (pT dependence (including absolute scale split-up))



- sources_JEC11_V13_pfak7_1.pdf: Uncertainty correlation groups for AK7PF



-- MikkoVoutilainen - 02-Jan-2012

- FALL12_V7_Uncertainties.tgz: archive for new total uncertainties and uncertainty sources for

This topic: CMS > JECUncertaintySources
Topic revision: r19 - 16-Jul-2013 - HartmutStadie