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Introduction to Hadronic Final State Reconstruction in Collider Experiments (Part XIII)

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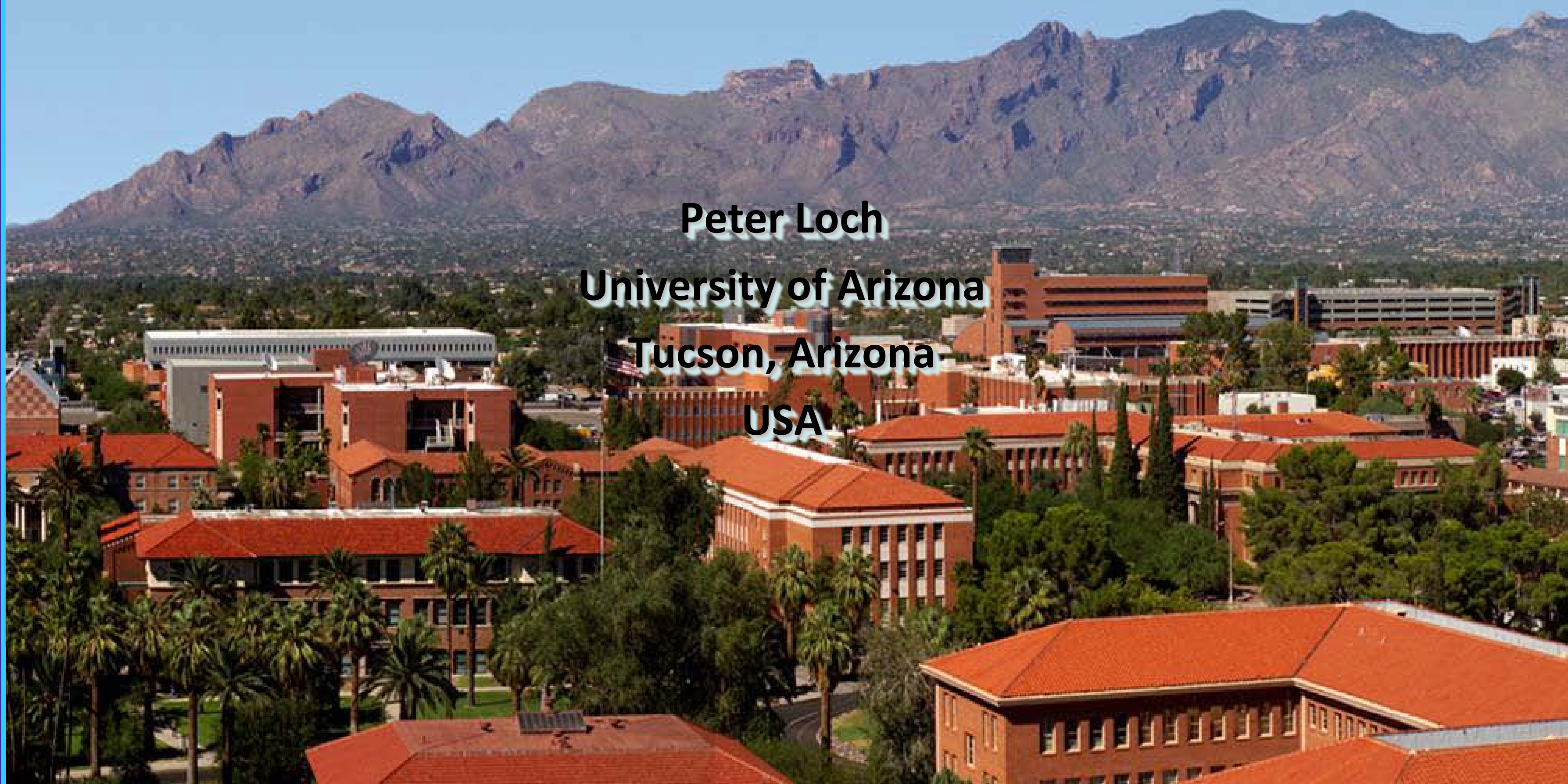

CMS Factorized Jet Calibration

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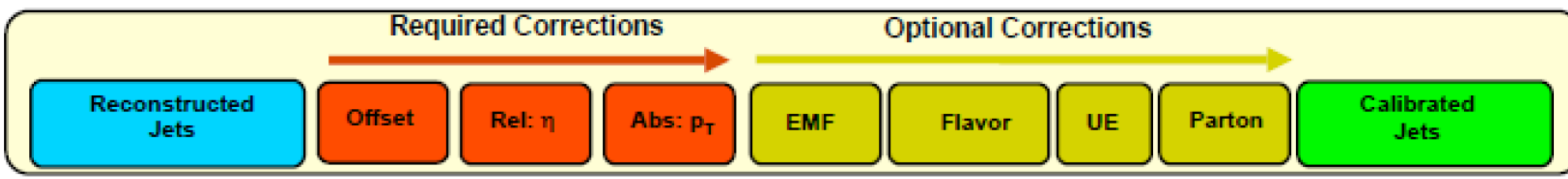
April 20, 2010

Factorized calibration allows use of collision data

- CMS sequence applies factorized scheme with required and optional corrections
- Required corrections can initially be extracted from collision data
  - Average signal offset from pile-up and UE can be extracted from minimum bias triggers
  - Relative direction dependence of response can be corrected from di-jet pT balance
  - The absolute pT scale correction can be derived from prompt photon production
- Optional corrections refine jet calibration
  - Use jet by jet calorimeter or track observables to reduce fluctuations
  - Includes energy fractions in EMC, track pT fractions, underlying event corrections using jet areas, flavor dependencies and others…
  - May need very good simulations!



Correct CaloJets to have same pT as GenJet on average

correcctions back to parton level quantities

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ATLAS JES Correction Model for First Data

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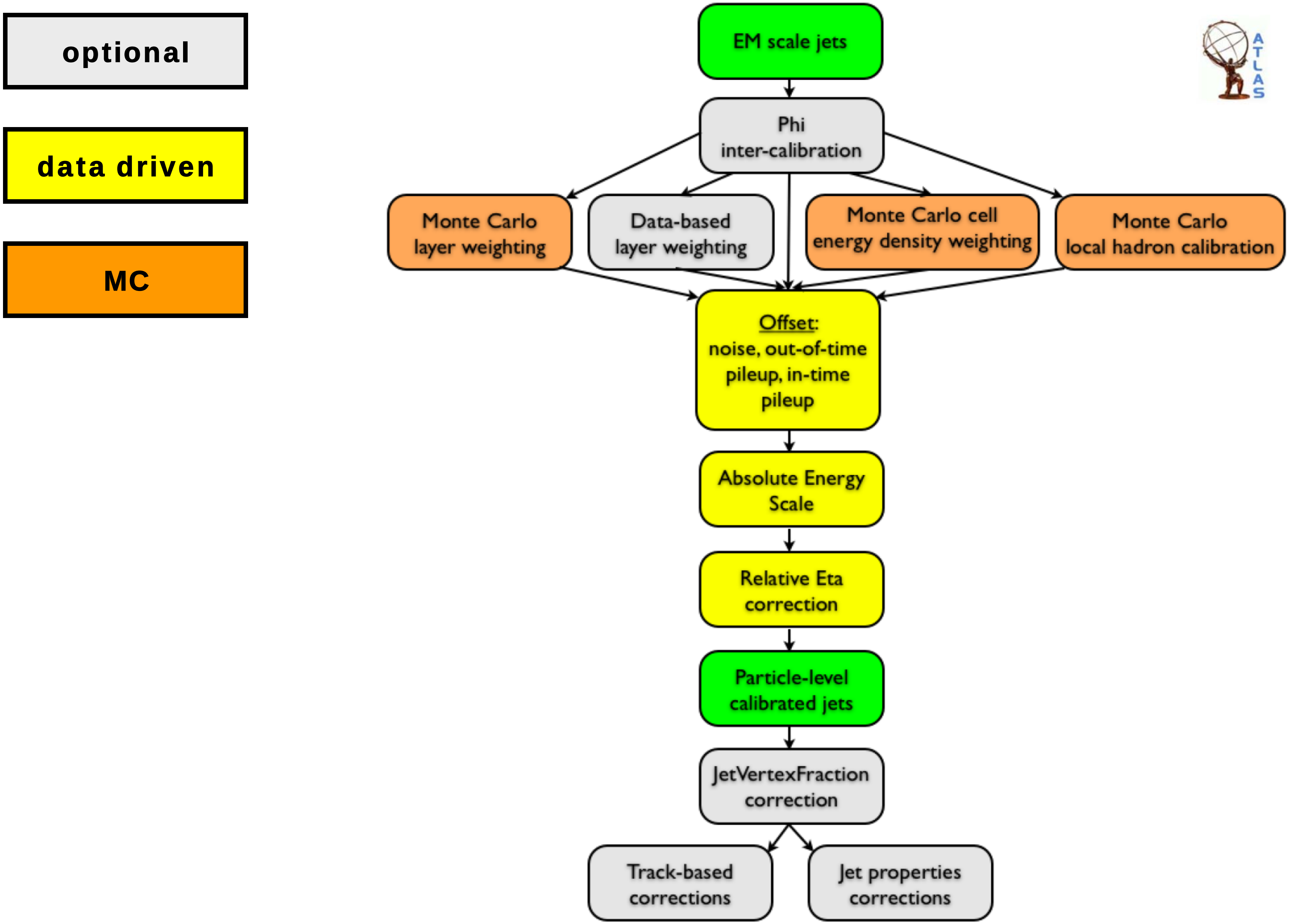

Data Driven JES Corrections: PileUp

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PileUp subtraction

Goal:

Correct in-time and residual out-of-time pile-up contribution to a jet on average

Tools:

Zero bias (random) events, minimum bias events

Measurement:

Et density in $\Delta\eta \times \Delta\varphi$ bins as function of

vertices

TopoCluster feature (size, average energy as function of depth) changes as function of # vertices

Remarks:

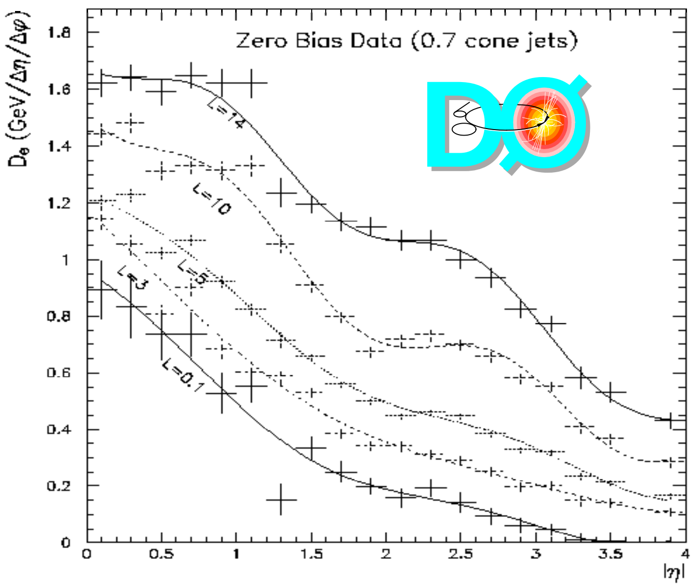
Uses expectations from the average Et flow for a given instantaneous luminosity

Instantaneous luminosity is measured by the # vertices in the event

Requires measure of jet size (AntiKt advantage)

Concerns:

Stable and safe determination of average



Determination of the Absolute Jet Energy Scale in the D0 Calorimeters. NIM A424, 352 (1999)

$$\rho_{PU}(\eta,\mathcal{L}) = \rho_{PU}(\eta,N_{vtx}) = \frac{\left\langle E_T^{PU}\right\rangle(\eta,N_{vtx})}{\Delta\eta\times\Delta\varphi}$$

$$E_{\text{offset,jet}}^{PU} = \underbrace{\rho_{PU}(\eta,N_{vtx})\cdot \overbrace{A_{\text{jet}}}^{\text{jet area}}}_{E_{T,\text{jet}}^{PU}}$$

Note that magnitude of correction depends on calorimeter signal processing & definition – application easier to see for tower based jets!

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In-Situ Calibration Validation

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Balancing jet pT with electromagnetic system

- Truth from collision
  - Based on idea that electromagnetic particles are well measured
  - Limits accuracy to precision of photon or electron signal reconstruction
- Provides interaction (parton) level reference
  - Note that simulation based approaches use particle level reference
- Can use direct photon production
  - Kinematic reach for jet pT ~200-400 GeV for 1% precision – depends on center of mass energy
  - Relatively large cross-section
  - Background from QCD di-jets – one jet fluctuates into π^0 faking photon
- Can also use *Z*+jet(s)
  - Cross-section suppressed, but less background – two electron final state cleaner
  - Can also use two muon final state

Note specific physics environment

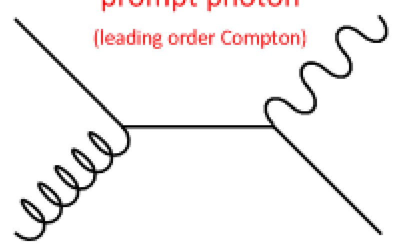
- Underlying event different from other final states
  - Less radiation in photon/*Z* hemisphere
- Often only good reference for quark jets
  - Narrow jets in lower radiation environment

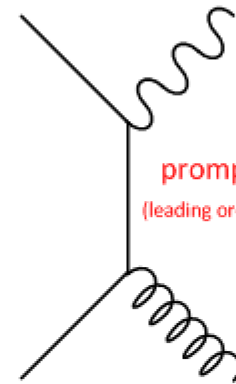
prompt (direct) photon production:

$gq \rightarrow \gamma q$ QCD Compton scattering

$(\sim 95\% \text{ of } \sigma_\gamma^{\text{tot}})$

$q\bar{q} \rightarrow \gamma g$ annihilation





balance photon with (mostly) quark jet pT to validate or constrain $p_{\text{T,reco,jet}}$

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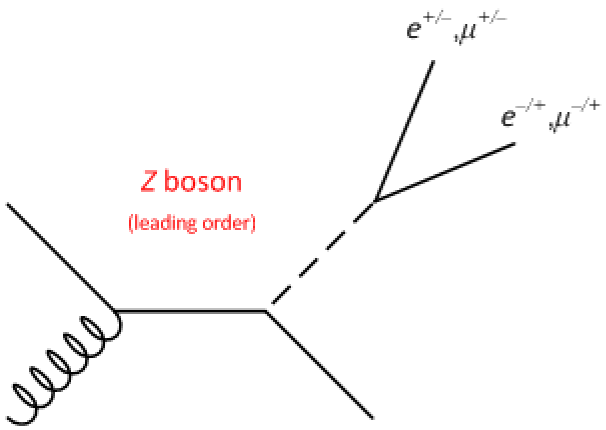
Z-boson + jet production:



balance Z pT reconstructed from decay leptons with quark jet pT to validate or constrain $p_{\mathrm{T,reco,jet}}$

Data Driven JES Corrections: Scale

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April 20, 2010

Absolute response

Goal:

Correct for energy (pT) dependent jet response

Tools:

Direct photons, *Z*+jet(s),…

Measurement:

pT balance of well calibrated system (photon, *Z*) against jet in central region

Remarks:

Usually uses central reference and central jets (region of flat reponse)

Concerns:

Limit in precision and estimates for systematics w/o well understood simulations not clear

Needs corrections to undo out-of-cone etc. to compare to particle level calibrations

ratio test variable ($\kappa = \gamma, Z$):

$$f_{\mathrm{absolute}}(\zeta_{\mathrm{probe}}) = \underbrace{\left[1 + \frac{p_{\mathrm{T,reco,jet}} - p_{\mathrm{T},\kappa}}{p_{\mathrm{T},\kappa}}\right]^{-1}}_{\text{variation of jet response with photon/}Z\ p_{\mathrm{T}}}$$

with

$$\zeta_{\mathrm{T,probe}} = \begin{cases} p_{\mathrm{T},\kappa} & \text{reference pT} \\ \dfrac{p_{\mathrm{T},\kappa} + p_{\mathrm{T,reco,jet}}}{2} & \text{average pT} \\ E' = p_{\mathrm{T},\kappa} \cosh \eta_{\mathrm{reco,jet}} & \text{expected jet energy} \end{cases}$$

(relate to reconstructed jet variables with numerical inversion)

relative projection along reference pT:

$$\frac{\mathcal{P}_{\parallel}}{p_{\mathrm{T},\kappa}} = \frac{p_{\mathrm{T,reco,jet}} \cos\sphericalangle(\vec{p}_{\mathrm{T,reco,jet}}, \vec{p}_{\mathrm{T},\kappa})}{p_{\mathrm{T},\kappa}} = \frac{\vec{p}_{\mathrm{T,reco,jet}} \cdot \vec{p}_{\mathrm{T},\kappa}}{p_{\mathrm{T},\kappa}^{2}}$$

correction from $\dfrac{\mathcal{P}_{\parallel}}{p_{\mathrm{T},\kappa}} + 1 \equiv 0$ for well calibrated jets:

$$f_{\mathrm{absolute}}(\zeta_{\mathrm{probe}}) = \left|\frac{p_{\mathrm{T},\kappa}}{\mathcal{P}_{\parallel}}\right|$$

ATLAS

Data Driven JES Evaluation

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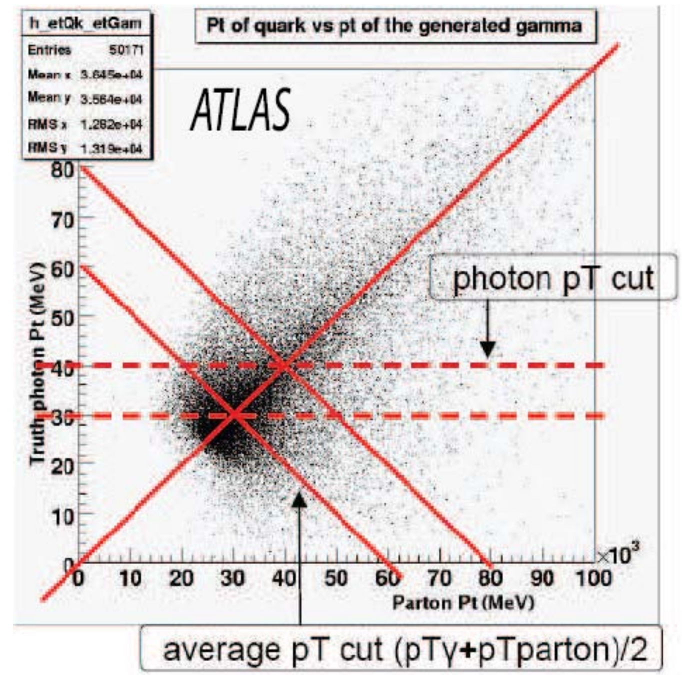
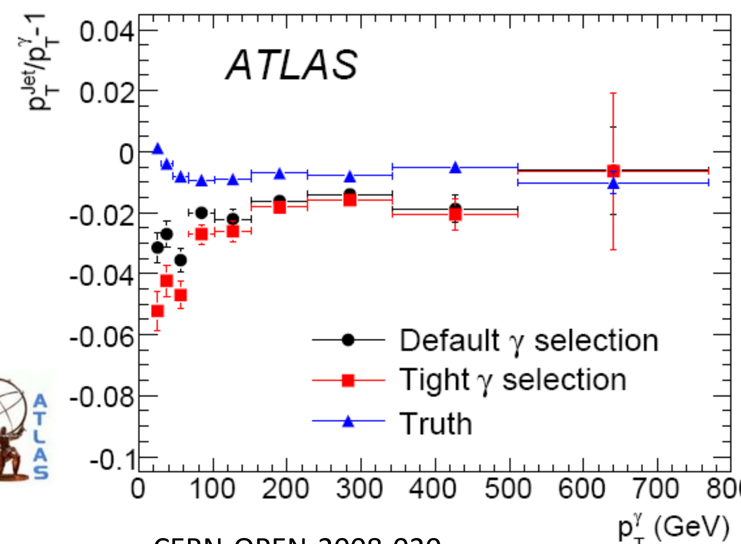
Photon+jet(s)

- Well measured electromagnetic system balances jet response
  - Central value theoretical uncertainty ~2% limits precision
    - Due to photon isolation requirements
  - But very good final state for evaluating calibrations
- Can test different correction levels in factorized calibrations
  - E.g., local hadronic calibration in ATLAS
- Limited pT reach for 1-2% precision
  - 25->300 GeV within 100 pb^{-1}

Z+jet(s)

- Similar idea, but less initial statistics
  - Smaller reach but less background





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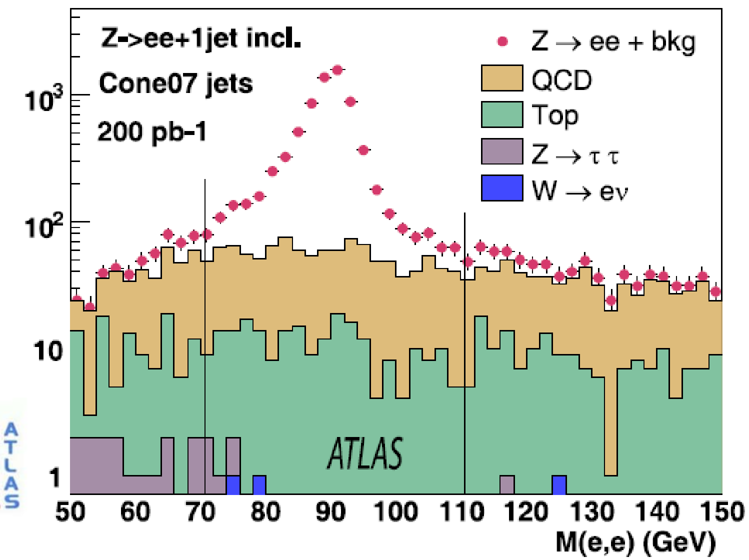

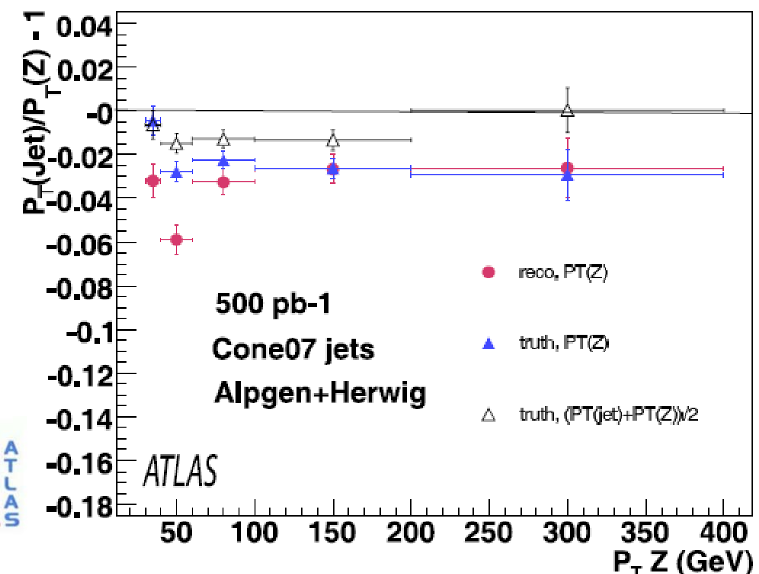

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W Mass Spectroscopy

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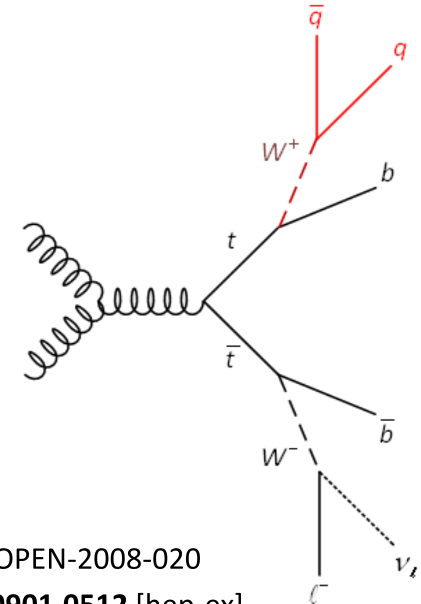
April 20, 2010

In-situ calibration validation handle

- Precise reference in ttbar events
  - Hadronically decaying W-bosons
- Jet calibrations should reproduce W-mass
  - Note color singlet source
  - No color connection to rest of collision – different underlying event as QCD
  - Also only light quark jet reference
- Expected to be sensitive to jet algorithms
  - Narrow jets perform better – as expected



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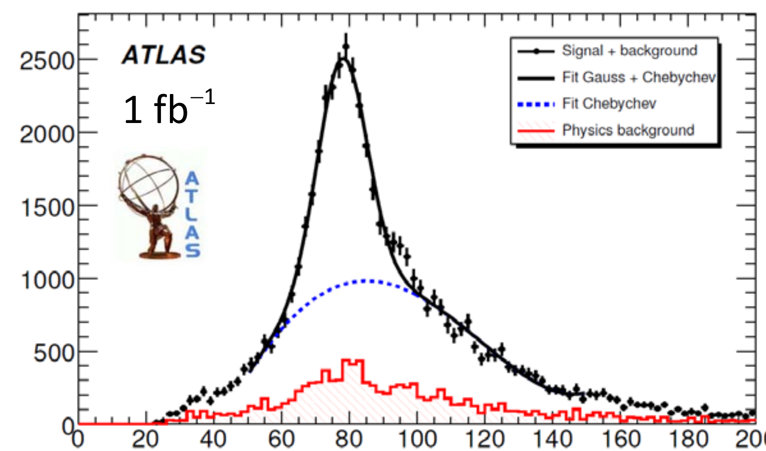
arXiv:0901.0512 [hep-ex]



Simulated di-jet invariant mass ($M_{W,\text{reco}}$) spectrum for kT jets with $R = 0.4$ (narrow jets) in $t\bar{t}$ final states at $\sqrt{s} = 14$ TeV

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JES From *W* Mass Reconstruction

W boson mass from two jets

- Clean event sample can be accumulated quickly
  - Original studies for center of mass energy of 14 TeV and luminosity of 10^{33} cm^{-2}s^{-1}
  - ~130 clean events/day in ttbar
- Angular and energy scale component in reconstruction
  - Energy scale dominant

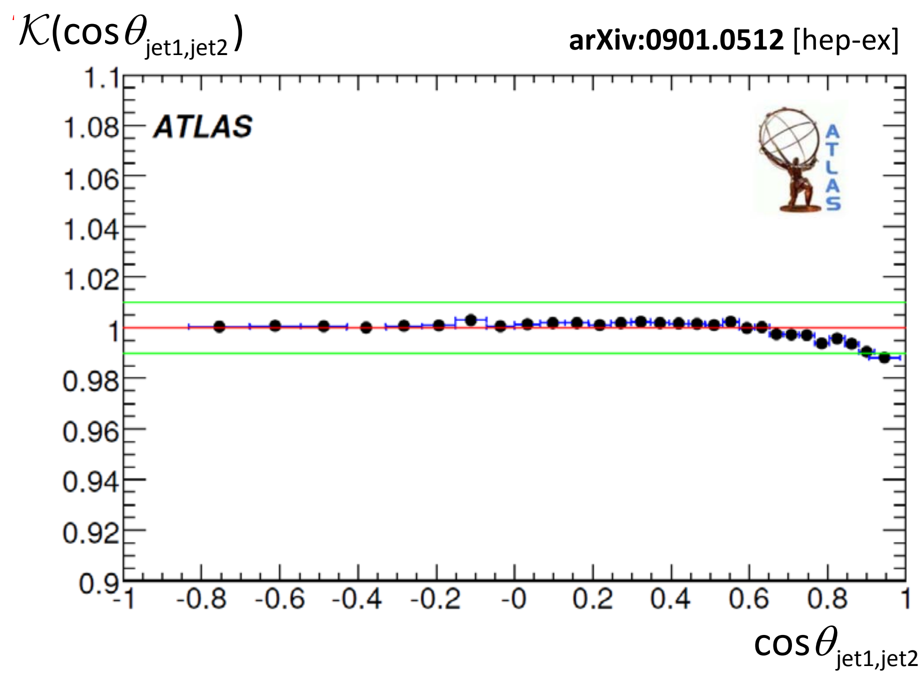
invariant mass from decay jets:

$$M_{W,\mathrm{reco}} = \sqrt{2E_{\mathrm{jet},1}E_{\mathrm{jet},2}\left(1-\cos\theta_{\mathrm{jet1,jet2}}\right)}$$

bias from angular mismeasurement:

$$\mathcal{K}(\cos\theta_{\mathrm{jet1,jet2}}) = \frac{1-\cos\theta_{\mathrm{parton1,parton2}}}{1-\cos\theta_{\mathrm{jet1,jet2}}} \approx 1$$

is small



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April 20, 2010

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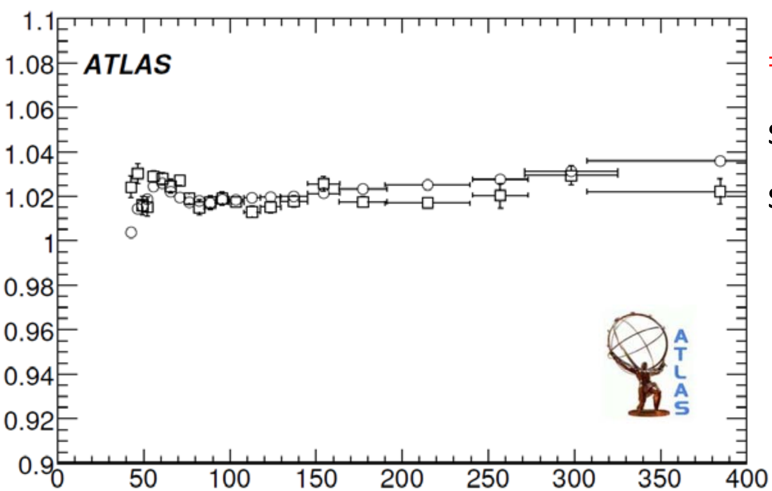
κ arXiv:0901.0512 [hep-ex]



E_{jet} (GeV)

invariant mass from decay jets:

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bias from angular mismeasurement:

$$\mathcal{K}(\cos\theta_{\text{jet1,jet2}}) = \frac{1-\cos\theta_{\text{parton1,parton2}}}{1-\cos\theta_{\text{jet1,jet2}}} \approx 1$$

is small $\rightarrow$ major contribution from energy scale:

$$M_{W,\text{PDG}}$$

$$= \sqrt{2\kappa(E_{\text{jet},1})E_{\text{jet},1}\kappa(E_{\text{jet},2})E_{\text{jet},2}\mathcal{K}(\cos\theta_{\text{jet1,jet2}})\left(1-\cos\theta_{\text{jet1,jet2}}\right)}$$

$$\approx \sqrt{2\kappa(E_{\text{jet},1})E_{\text{jet},1}\kappa(E_{\text{jet},2})E_{\text{jet},2}\left(1-\cos\theta_{\text{jet1,jet2}}\right)}$$

$$= \sqrt{\kappa(E_{\text{jet},1})\kappa(E_{\text{jet},2})}\cdot M_{W,\text{reco}}$$

simple rescaling method assuming energy independent scale shift $\rightarrow \kappa(E_{\text{jet},1}) = \kappa(E_{\text{jet},2}) = \kappa$ works reasonably well

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JES From *W* Mass Reconstruction

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W mass from templates

- Produce W mass distribution templates
  - Use parton or particle level simulations
  - Smear with JES and resolution variations
  - Store W mass distributions as function of smearing parameters
- Find response and resolution smearing parameters
  - Find best fit template

JES scale α relative to perfect jet response;

resolution parameter β relative to nominal jet energy resolution;

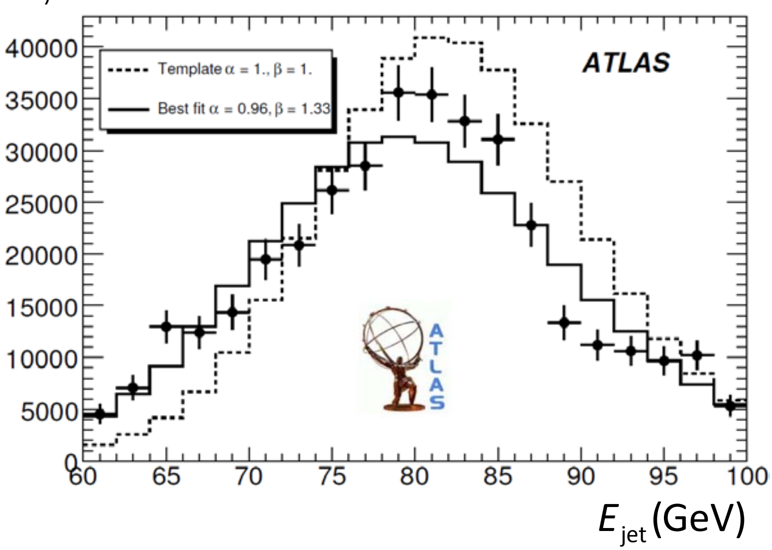
find best matching template distribution $\mathcal{T}_{\alpha\beta}(M_W)$

for reconstructed distribution $\mathcal{R}(M_W)$:

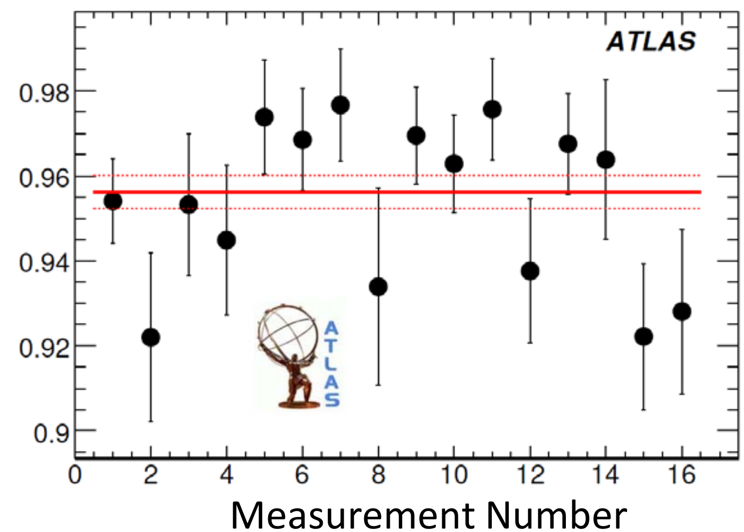
$$\chi^2 = \int \left(\mathcal{T}_{\alpha\beta}(M_W) - \mathcal{R}(M_W)\right)^2 \Big/ \left(\sigma^2_{\mathcal{T}_{\alpha\beta}(M_W)} + \sigma^2_{\mathcal{R}(M_W)}\right) dM_W = \min$$

stability of fit tested by subdividing total sample into 16 "measurements" (770 pb^{-1} $\rightarrow 16 \times 48$ pb^{-1}):

$\mathcal{T}_{\alpha\beta}(M_W), \mathcal{R}(M_W)$ **arXiv:0901.0512** [hep-ex]



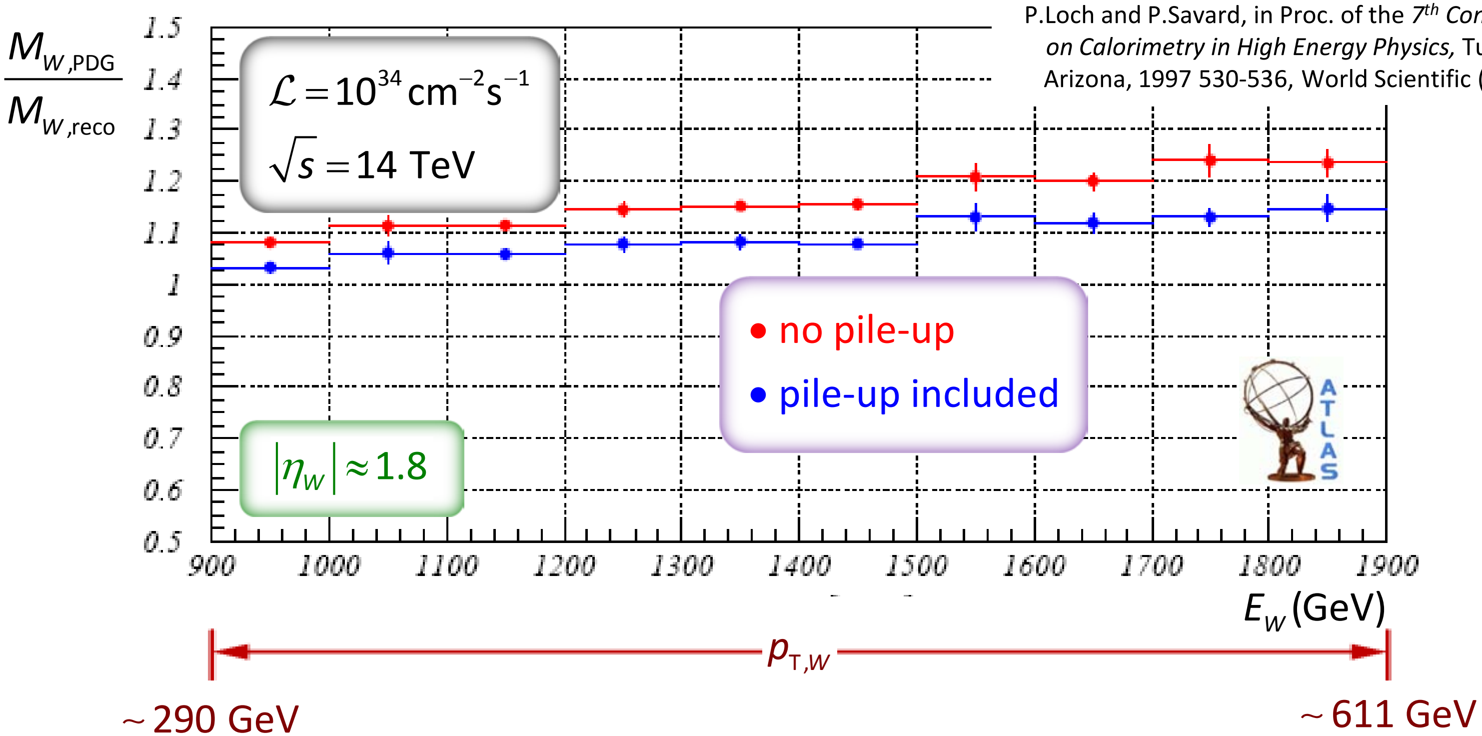
α **arXiv:0901.0512** [hep-ex]



Boosted *W*

- pT boost reduces angle between decay jets
  - Reconstructed mass underestimates true *W* mass
  - See example below for *W* boosted into the ATLAS end-cap calorimeter region
- Pile-up can add energy to the system
  - Not an improvement of the measurement – accidental and thus uncorrelated jet energy shifts lead to shift in reconstructed mass

P.Loch and P.Savard, in Proc. of the *7th Conference on Calorimetry in High Energy Physics,* Tucson, Arizona, 1997 530-536, World Scientific (1998)



Data Driven JES Corrections: Direction

Di-jet balance

- Calibrate jet in “golden” reference region
  - Use e.g. photon pT balance
  - Use this jet as “truth” reference
- Balance pT with jet in more complex calorimeter region
  - Note: relative energy resolution of reference jet can be worse than probe jet – more forward jet has more energy at same pT
  - Resolution bias needs to be controlled
- Apply corrections to all jets at given direction
  - Need to understand topology – additional soft jet contribution
- Can also be used to measure jet energy resolution
  - Need to consider phase space sharing with possible additional soft jets

Multi-jet balance

- Validation of very high pT jets
  - In-situ calibrations with photons etc. only reaches 200-300 GeV (pT)
  - But need to validate very high pT jet scale as well
- Bootstrap approach
  - Find multi-jet events with one hard jet in non-validated phase-space
  - Balance hard jet with several well calibrated lower pT jets (e.g., from photons)
  - Look for more harder jets and use scale corrections from lower pT jets (bootstrap corrections)
- Note that errors evolve from low to high pT
  - Hard to achieve O(1%) precision
  - Likely need simulation based approach

Di-jet balance

Correct direction-dependent jet response

- Establish absolute scale in “golden region” of the detector
  - Balancing pT of a central (lower energy) jet with a more forward (higher energy jet)
  - Avoid biases by compensating reference jet response first
- Determine direction dependent correction factors
  - Use pT asymmetry measure for back-to-back jet
  - Careful – resolution bias due to different jet energy ranges can still be present!

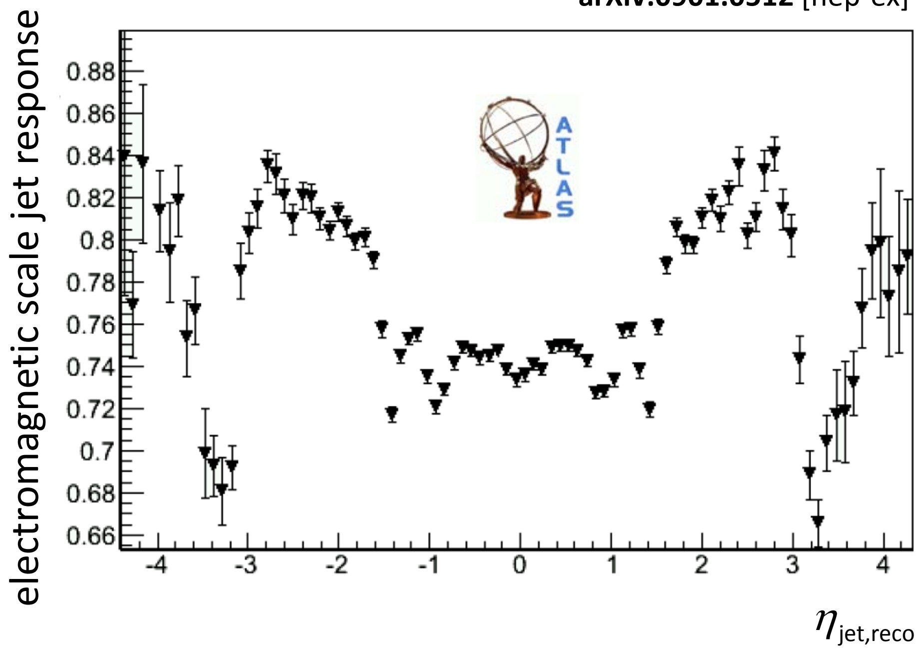
Jet energy resolution from di-jet pT balance

- Select event topology
  - Di-jets back-to-back in azimuth
  - Same rapidity region
  - Similar pT
- Use asymmetry measure to calculate jet energy resolution
  - Width of the distribution of *A*

Understand soft radiation contribution

- pT balance approach (DØ)
  - Use di-jet energy resolution dependence on third jet pT as scale to unfold radiation contribution
- kT balance approach (UA2, CDF)
  - Determination of radiation contribution using bisector decomposition

arXiv:0901.0512 [hep-ex]



asymmetry measure:

$$A = \frac{p_{\mathrm{T,reco}}^{\mathrm{probe}} - p_{\mathrm{T,reco}}^{\mathrm{reference}}}{\left(p_{\mathrm{T,reco}}^{\mathrm{probe}} + p_{\mathrm{T,reco}}^{\mathrm{reference}}\right)/2} = \frac{p_{\mathrm{T,reco}}^{\mathrm{probe}} - p_{\mathrm{T,reco}}^{\mathrm{reference}}}{p_{\mathrm{T,reco}}^{\mathrm{average}}}$$

correction factors (use numerical inversion):

$$c(p_{\mathrm{T,reco}}^{\mathrm{average}}, \eta_{\mathrm{probe}}) = \frac{2 - A(p_{\mathrm{T,reco}}^{\mathrm{average}}, \eta_{\mathrm{probe}})}{2 + A(p_{\mathrm{T,reco}}^{\mathrm{average}}, \eta_{\mathrm{probe}})} \mapsto c(p_{\mathrm{T,reco}}^{\mathrm{probe}}, \eta_{\mathrm{probe}})$$

Di-jet balance

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April 20, 2010

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asymmetry measure (slightly modified):

$$A = \frac{p_{\mathrm{T,reco}}^{\mathrm{jet1}} - p_{\mathrm{T,reco}}^{\mathrm{jet2}}}{p_{\mathrm{T,reco}}^{\mathrm{jet1}} + p_{\mathrm{T,reco}}^{\mathrm{jet2}}} = \frac{p_{\mathrm{T,reco}}^{\mathrm{jet1}} - p_{\mathrm{T,reco}}^{\mathrm{jet2}}}{2p_{\mathrm{T,reco}}^{\mathrm{average}}}$$

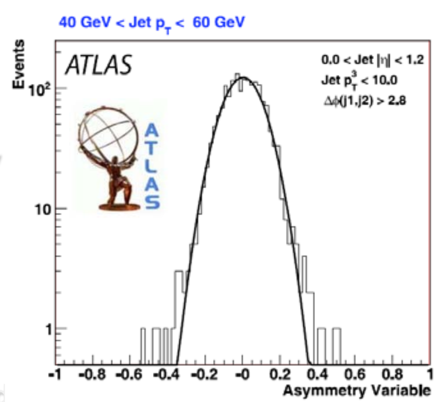
p_{T} resolution for jets in same η region with similar p_{T}:

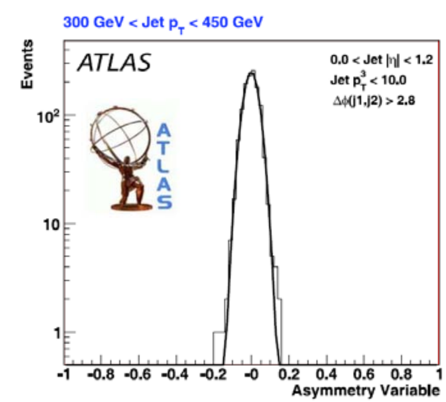
$$\frac{\sigma_{p_{\mathrm{T}}}}{p_{\mathrm{T,reco}}^{\mathrm{average}}} = \sqrt{2}\sigma_A \approx \frac{\sigma_E}{E}$$

resolution is symmetrized by randomly computing

$p_{\mathrm{T,reco}}^{\mathrm{jet1}} - p_{\mathrm{T,reco}}^{\mathrm{jet2}}$ or $p_{\mathrm{T,reco}}^{\mathrm{jet2}} - p_{\mathrm{T,reco}}^{\mathrm{jet1}}$

for each event





arXiv:0901.0512 [hep-ex]

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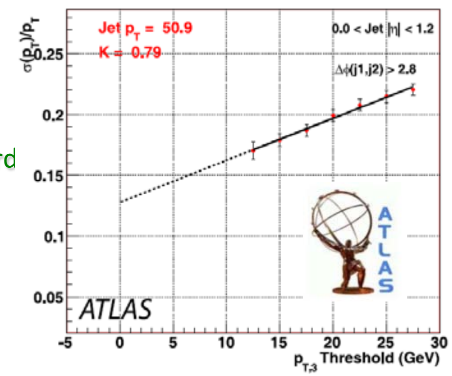
determine clean di-jet resolution by linear extrapolation of

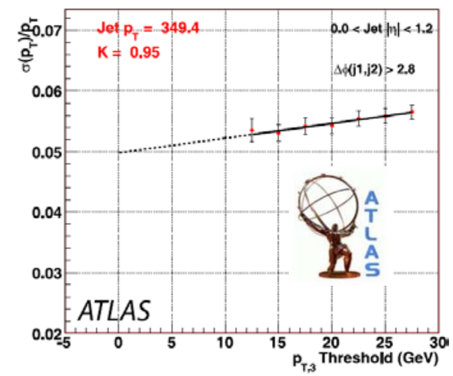
$$\frac{\sigma_{p_T}}{p_T}(p_{T,reco,jet3} < p_{T,threshold}, p_{T,reco}^{average}),$$

typically with $p_{T,theshold} \geq p_{T,min} = (7-10)\text{ GeV}$, implied by calorimeter jet reconstruction, to $p_{T,reco,jet3} = 0$:

$$\lim_{p_{T,reco,jet3} \to 0} \frac{\sigma_{p_T}}{p_T}(p_{T,reco}^{average})$$

fit has some bias problems due to phase space limitations at low $p_{T,reco}^{average}$ together in the presence of $p_{T,min}$





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resolution correction factor from

$$\mathcal{K}(p_{\mathrm{T,reco}}^{\mathrm{average}}) = \mathcal{K}(p_{\mathrm{T,reco}}) = \frac{\lim\limits_{p_{\mathrm{T,reco,jet3}}\to\infty}\left(\sigma_{p_{\mathrm{T}}}/p_{\mathrm{T,reco}}\right)(p_{\mathrm{T,reco}})}{\sigma_{p_{\mathrm{T}}}/p_{\mathrm{T,reco}}\,(p_{\mathrm{T,reco,jet3}} < 10\ \mathrm{GeV}, p_{\mathrm{T,reco}})}$$

such that

$$\left(\frac{\sigma_{p_{\mathrm{T}}}}{p_{\mathrm{T,reco}}}\right)_{\mathrm{corrected}} = \mathcal{K}(p_{\mathrm{T,reco}})\frac{\sigma_{p_{\mathrm{T}}}}{p_{\mathrm{T,reco}}}(p_{\mathrm{T,reco,jet3}} < 10\ \mathrm{GeV}, p_{\mathrm{T,reco}})$$

with a parameterization of the p_{T} dependence of the correction by

$$\mathcal{K}(p_{\mathrm{T,reco}}) = a + b\cdot\log p_{\mathrm{T,reco}}$$

The detailed documentation of this approach, including a full systematic evaluation and discussion of the low pT bias using ATLAS simulations, is available to ATLAS members only in:

E.Hughes, *D.Lopez*, *A.Schwartzman*,
ATL-COM-PHYS-2009-408 (2009)

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Di-jet balance

P. Loch
U of Arizona
April 20, 2010

Correct direction-dependent jet response

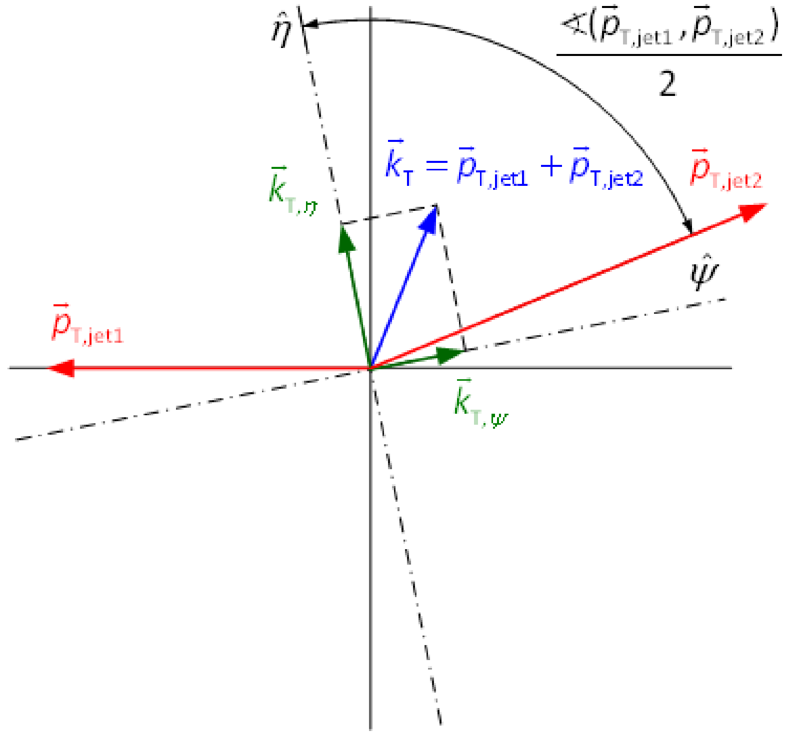
- Establish absolute scale in "golden region" of the detector
  - Balancing pT of a central (lower energy) jet with a more forward (higher energy jet)
  - Avoid biases by compensating reference jet response first
- Determine direction dependent correction factors
  - Use pT asymmetry measure for back-to-back jet
  - Careful – resolution bias due to different jet energy ranges can still be present!

Jet energy resolution from di-jet pT balance

- Select event topology
  - Di-jets back-to-back in azimuth
  - Same rapidity region
  - Similar pT
- Use asymmetry measure to calculate jet energy resolution
  - Width of the distribution of *A*

Understand soft radiation contribution

- pT balance approach (DØ)
  - Use di-jet energy resolution dependence on third jet pT as scale to unfold radiation contribution
- kT balance approach (UA2, CDF)
  - Determination of radiation contribution using bisector decomposition



$\vec{k}_{T,\psi}$ most sensitive to calorimeter resolution effects:

$$\sigma_\psi^2 = \sigma_{E,\mathrm{calo}}^2 + \sigma_{\mathrm{radiation},\parallel}^2, \text{ with } \sigma_{E,\mathrm{calo}} \gg \sigma_{\mathrm{radiation},\parallel}$$

$\vec{k}_{T,\eta}$ most sensitive to (gluon) radiation effects:

$$\sigma_\eta^2 = \sigma_{\mathrm{radiation},\perp}^2$$

(ignoring effects from angular resolution, underlying event, out of cone losses)

assume radiation is random wrt jet directions:

$$\sigma_{\mathrm{radiation},\perp}^2 = \sigma_{\mathrm{radiation},\parallel} \Rightarrow \sigma_{E,\mathrm{calo}}^2 = \sqrt{\sigma_\psi^2 - \sigma_\eta^2}$$

ATLAS

Di-jet balance

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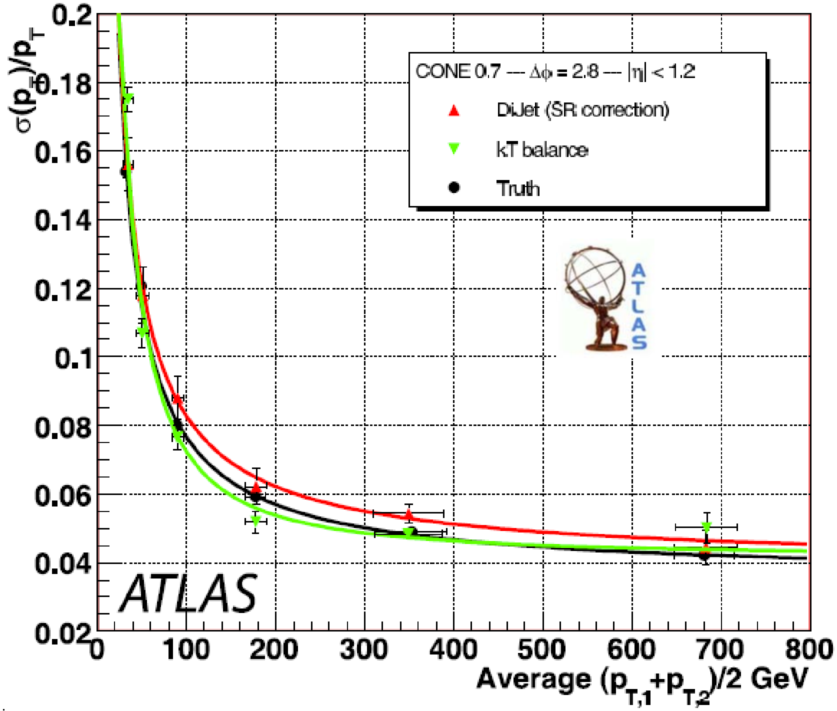
note $\sigma_{\psi}(p_{\mathrm{T,reco}}^{\mathrm{average}}) \propto \sqrt{p_{\mathrm{T,reco}}^{\mathrm{average}}}$, and

$\sigma_{\eta} \approx const < \sigma_{\psi}(p_{\mathrm{T,reco}}^{\mathrm{average}} > p_{\mathrm{T,min}})$

as expected!



arXiv:0901.0512 [hep-ex]

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Jets Not From Hard Scatter

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U of Arizona
April 20, 2010

Dangerous background for W+n jets cross-sections etc.

- Lowest pT jet of final state can be faked or misinterpreted as coming from underlying event or multiple interactions

Extra jets from UE are hard to handle

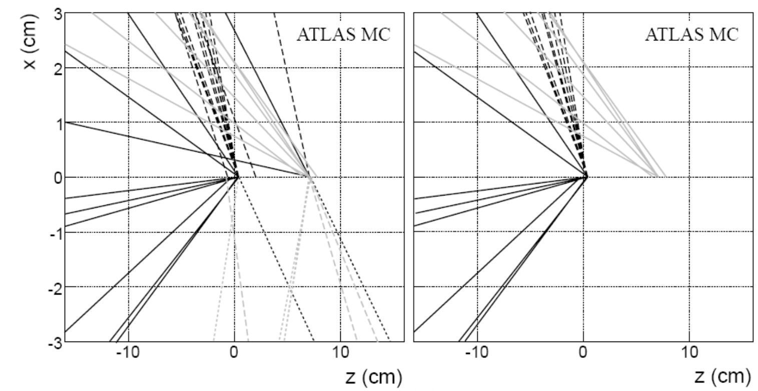
- No real experimental indication of jet source
- Some correlation with hard scattering?
- Jet area?
- No separate vertex

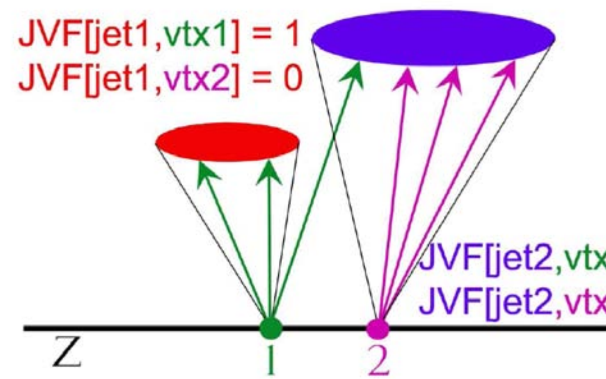
Jet-by-jet handle for multiple proton interactions

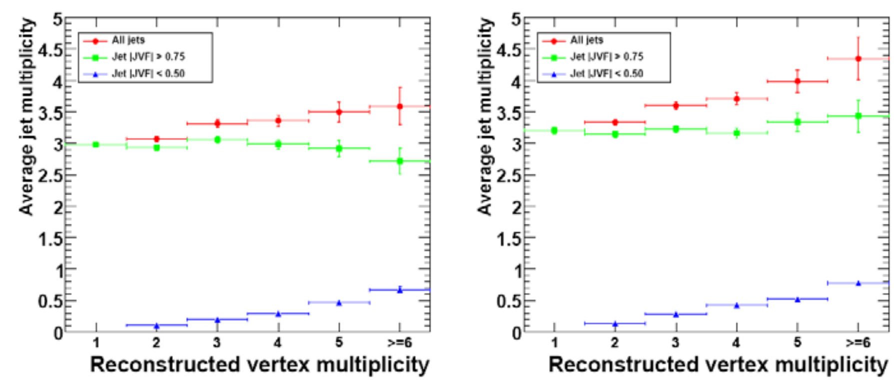
- Match tracks with vertices to calorimeter jet
  - Calculate track pT fraction from given vertex
- Classic indicator for multiple interactions is number of reconstructed vertices in event
  - Tevatron with RMS(z_vertex) ~ 30 cm
  - LHC RMS(z_vertex) ~ 8 cm
- If we can attach vertices to reconstructed jets, we can in principle identify jets not from hard scattering

Limited to pseudorapidities within 2.5!

CERN-OPEN-2008-020







(c) Di-jet (J6)

(d) $t\bar{t}$, $W \to$jets

Jets Not From Hard Scatter

Track jets

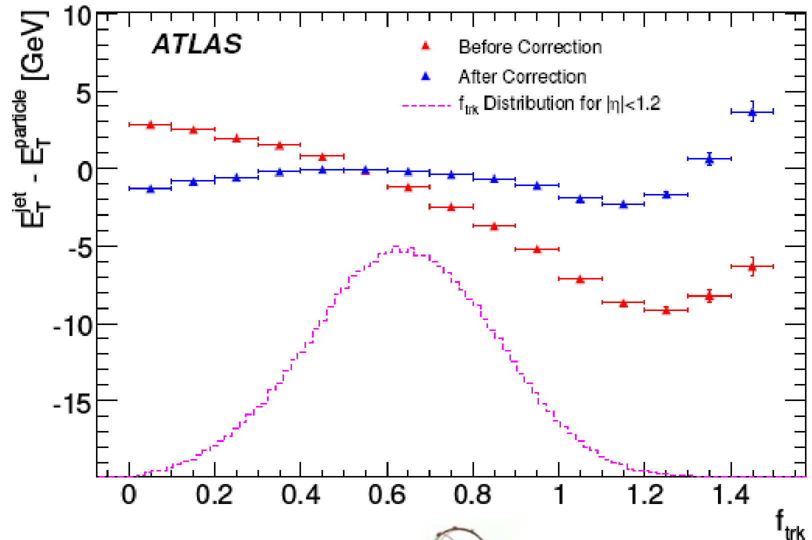
- Find jets in reconstructed tracks
- ~60% of jet pT, with RMS ~0.3 – not a good kinematic estimator

Dedicated 3-dim jet algorithm

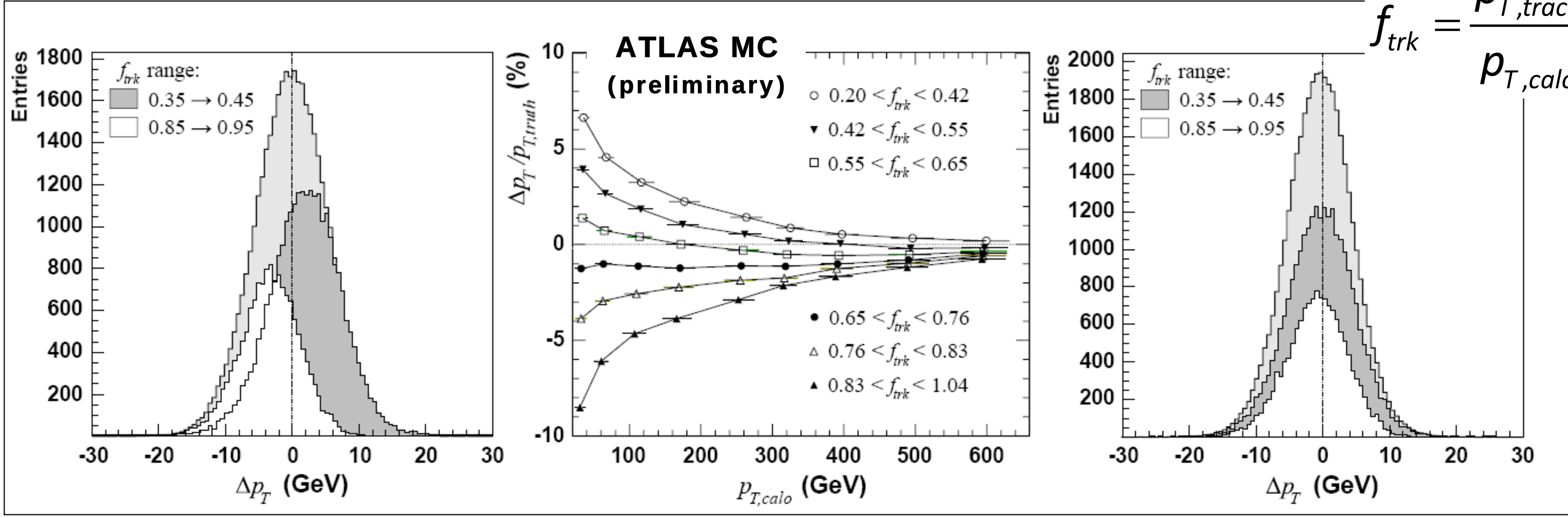
- Cluster track jets in pseudo-rapidity, azimuth, and delta(ZVertex)

Match track and calorimeter jet

- Helps response!



$$f_{trk} = \frac{p_{T,track}}{p_{T,calo}}$$



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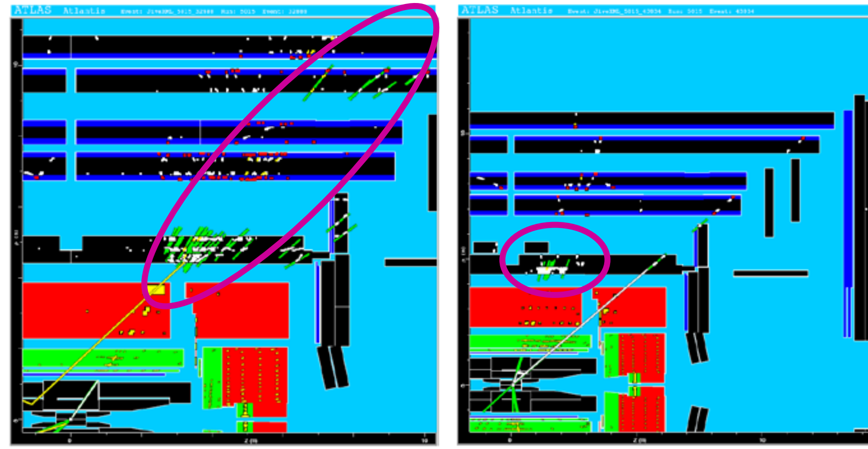
Other Sources Of JES Uncertainties



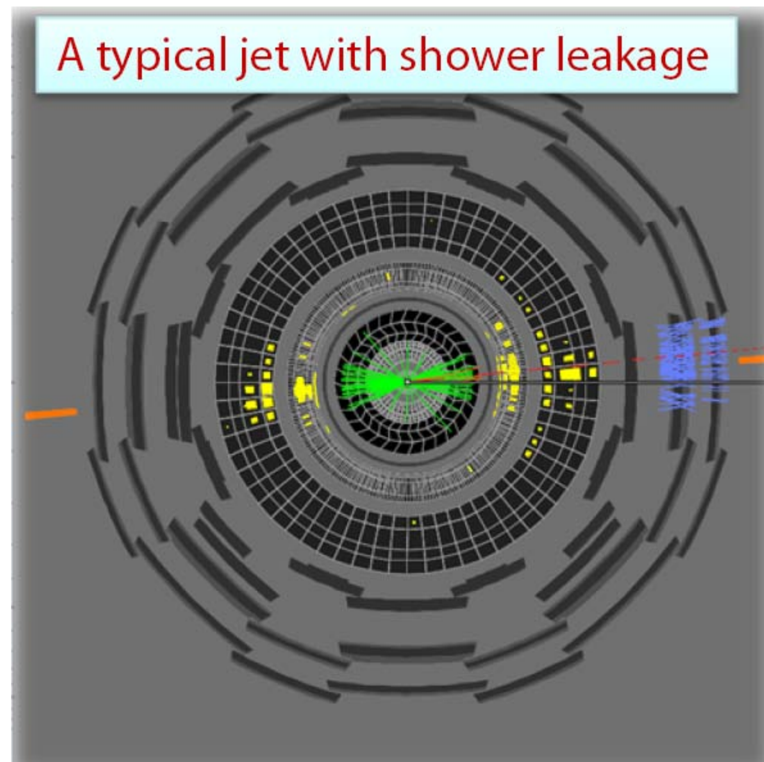
Longidtudinal jet energy leakage

- Dangerous – can changes jet pT cross-section shape at high pT
  - Fake compositeness signal

Correlated with muon spectrometer hits

- Not strong correlation expected
  - Insufficient for precise JES
  - Will likely not produce reconstructed tracks, only
- Helps to tag suspicious jets
  - Suppress suspicious events/jets
- Careful – real muon may be inside jet
  - b decay
  - Should produce track – cleaner signal inside jet

Also background for missing transverse energy!

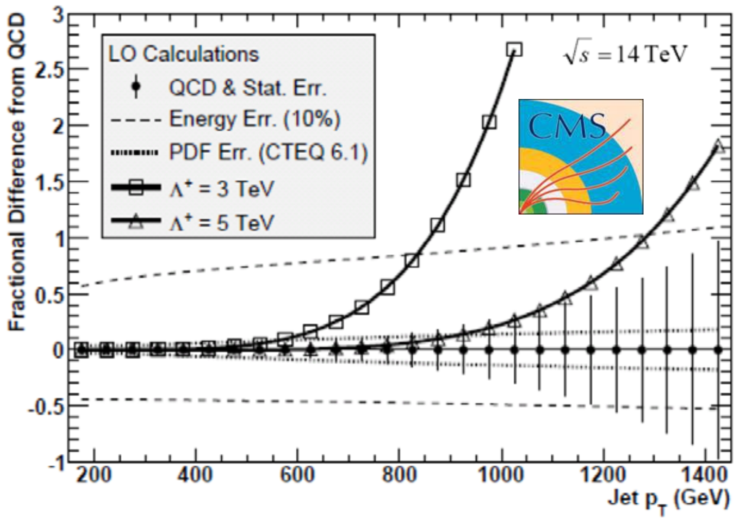


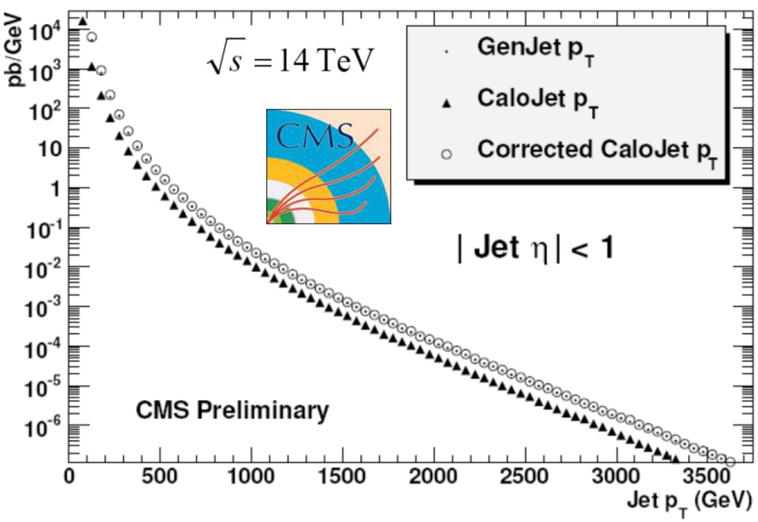
A typical jet with shower leakage

Jet Performance Evaluations (3)

Effect of calibration on inclusive jet cross-section

One the first physics results expected from ATLAS & CMS





CMS PAS SBM-07-001

Extras

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QCD Dominates Cross-sections

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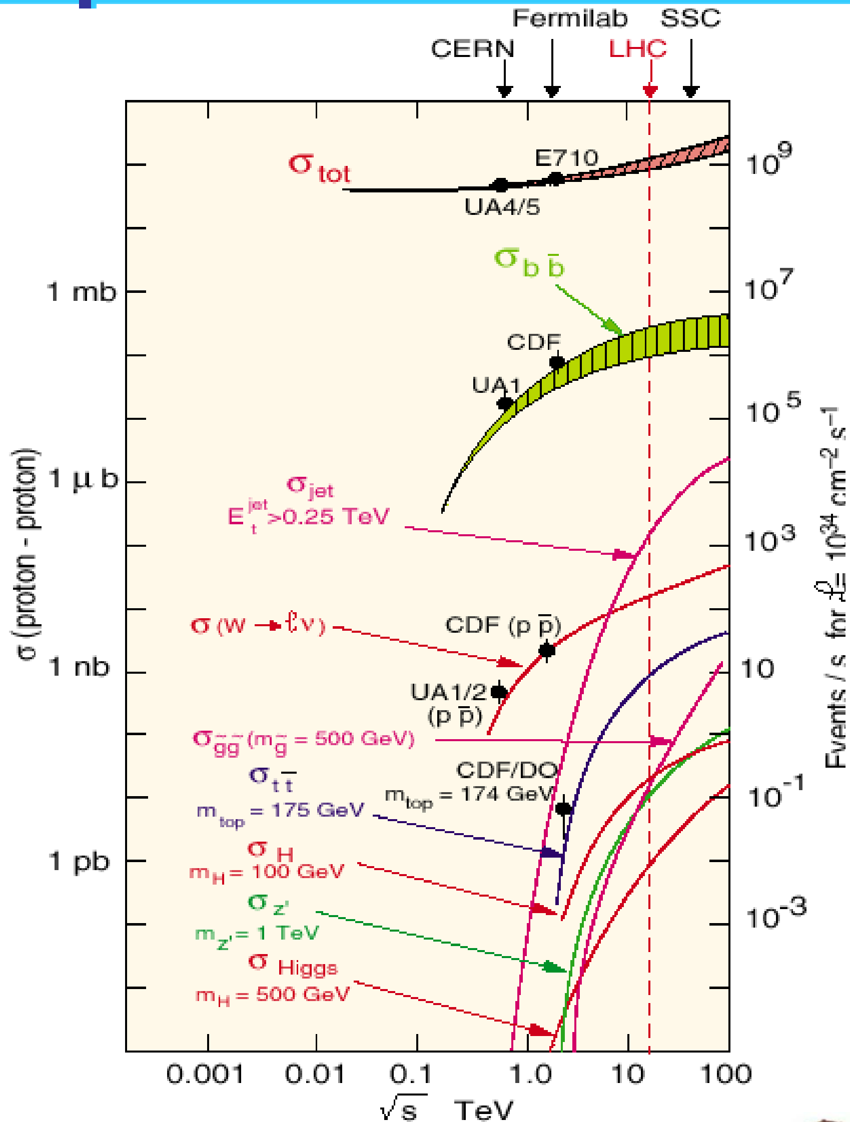
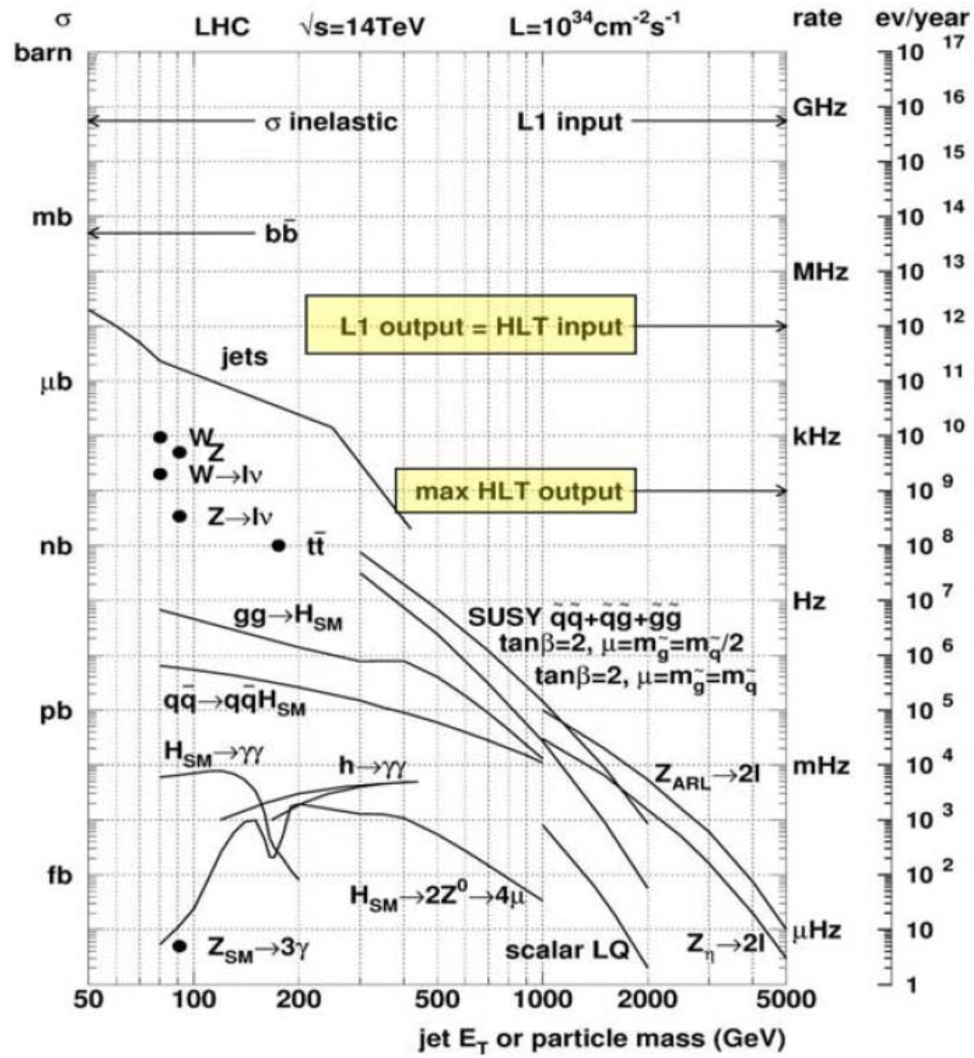
April 20, 2010





QCD Jet Production @ LHC

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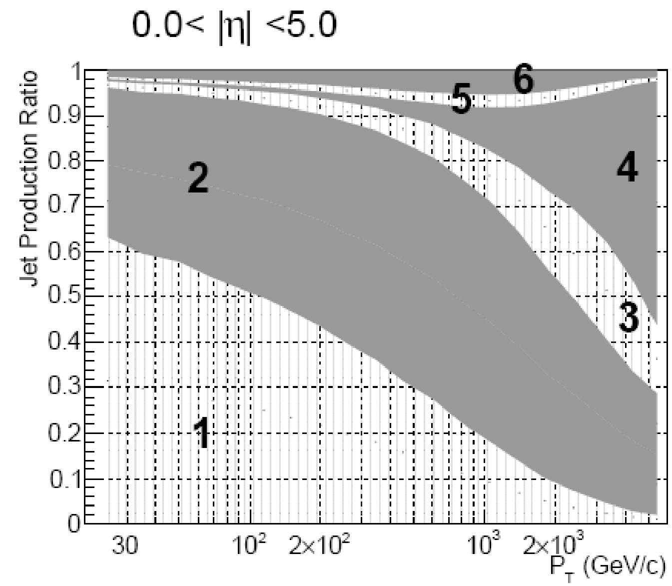
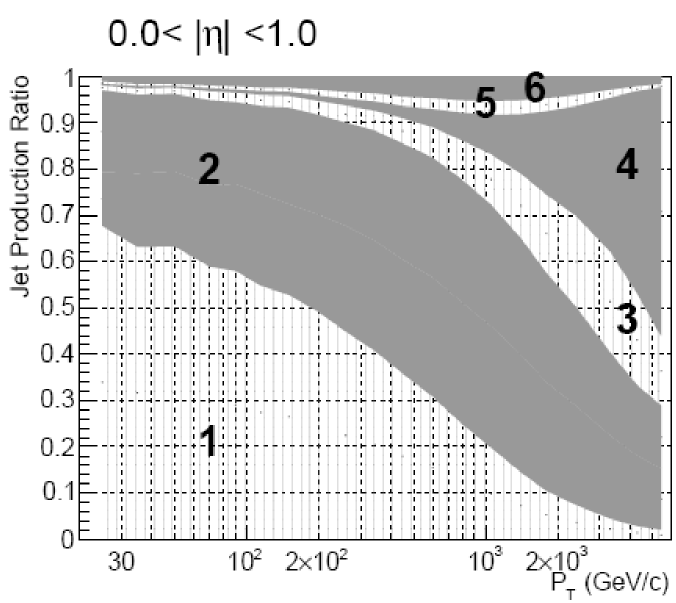
Jet physics

- High transverse momentum jets quickly accessible!
- 100,000 jets with pT > 1 TeV at 1 fb-1

Early attempt at inclusive cross-section

- Most likely jet origin changes with pT and direction





1 gg

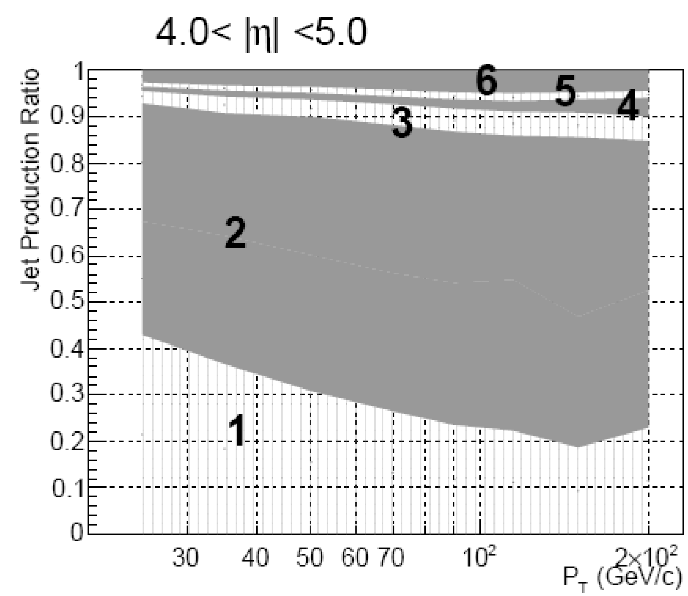
2 gq

3 qq

4 qq'

5 $q\bar{q}$

6 $q\bar{q}'$



Francavilla/Roda, ATL-PHYS-2008-062

Jet Cross-section Theoretical Uncertainties

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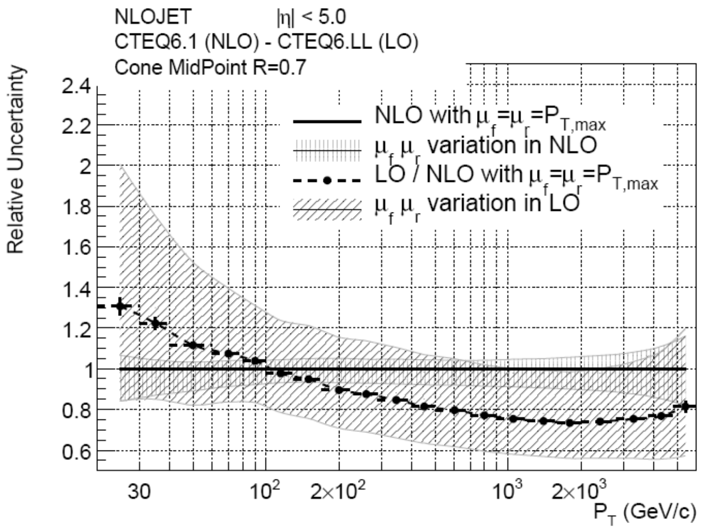
April 20, 2010

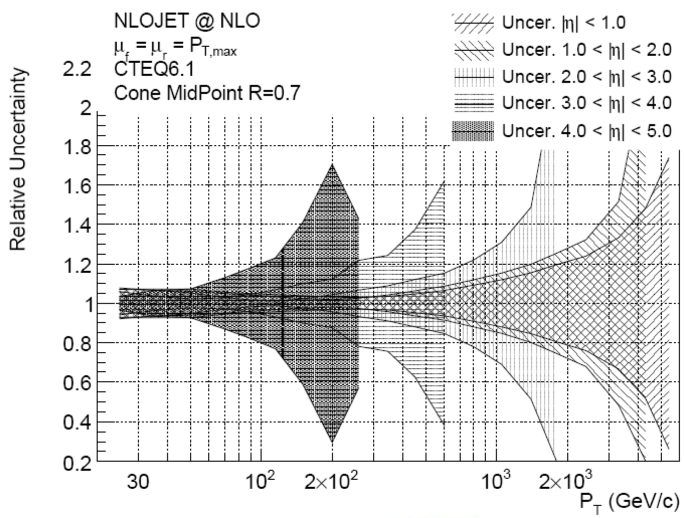
Neglecting orders in ME calculations

- K-factor NLO-LO can be significant
- Much smaller effect of scale variations in NLO

PDF uncertainties

- Diven by gluon structure function uncertainties
  - Especially at higher pT
- Plot shows error PDFs in various regions
  - CTEQ 6.1 family





Francavilla/Roda, ATL-PHYS-2008-062

Inclusive Jet Cross-section Measurement

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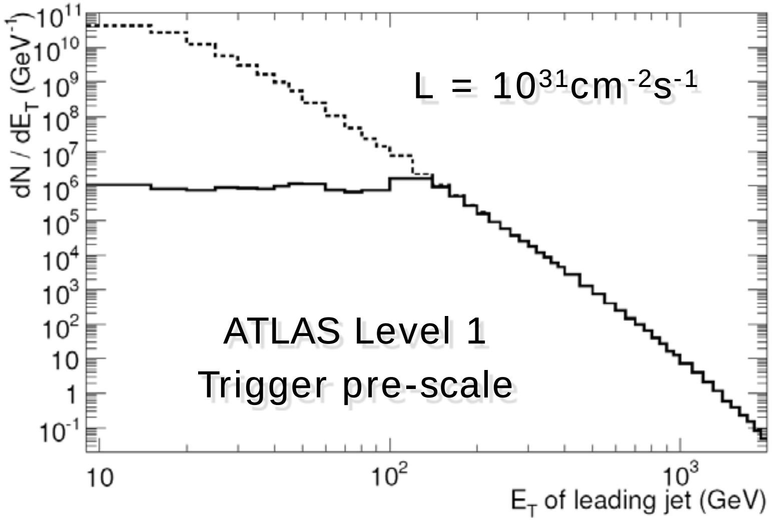
April 20, 2010

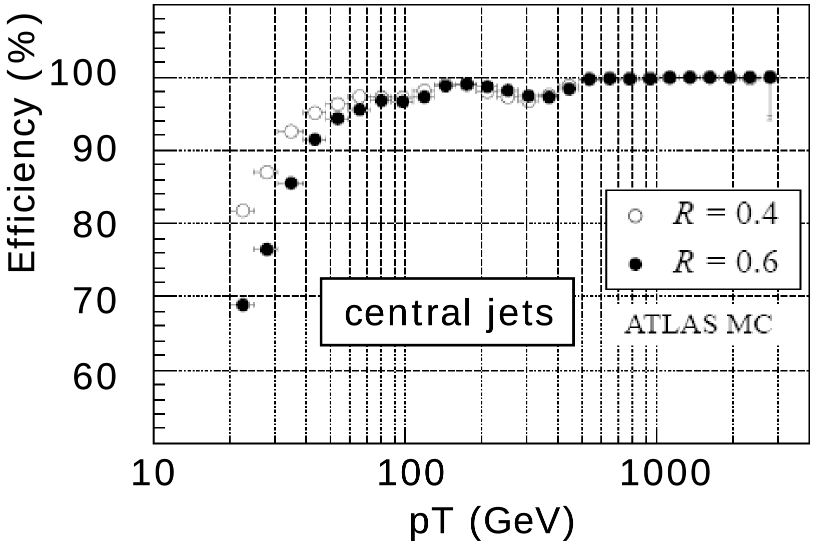
QCD swamps trigger and acquisition band width

- Highly prescaled low pT triggers
- Trigger rates follow cross-section for pT>~300 GeV
  - Depending on luminosity

Need to understand trigger bias effect on cross-section measurement

- Low pT problematic due to efficiency and purity issues anyway!
- Safe pT>~60-80 GeV





Fake Jets

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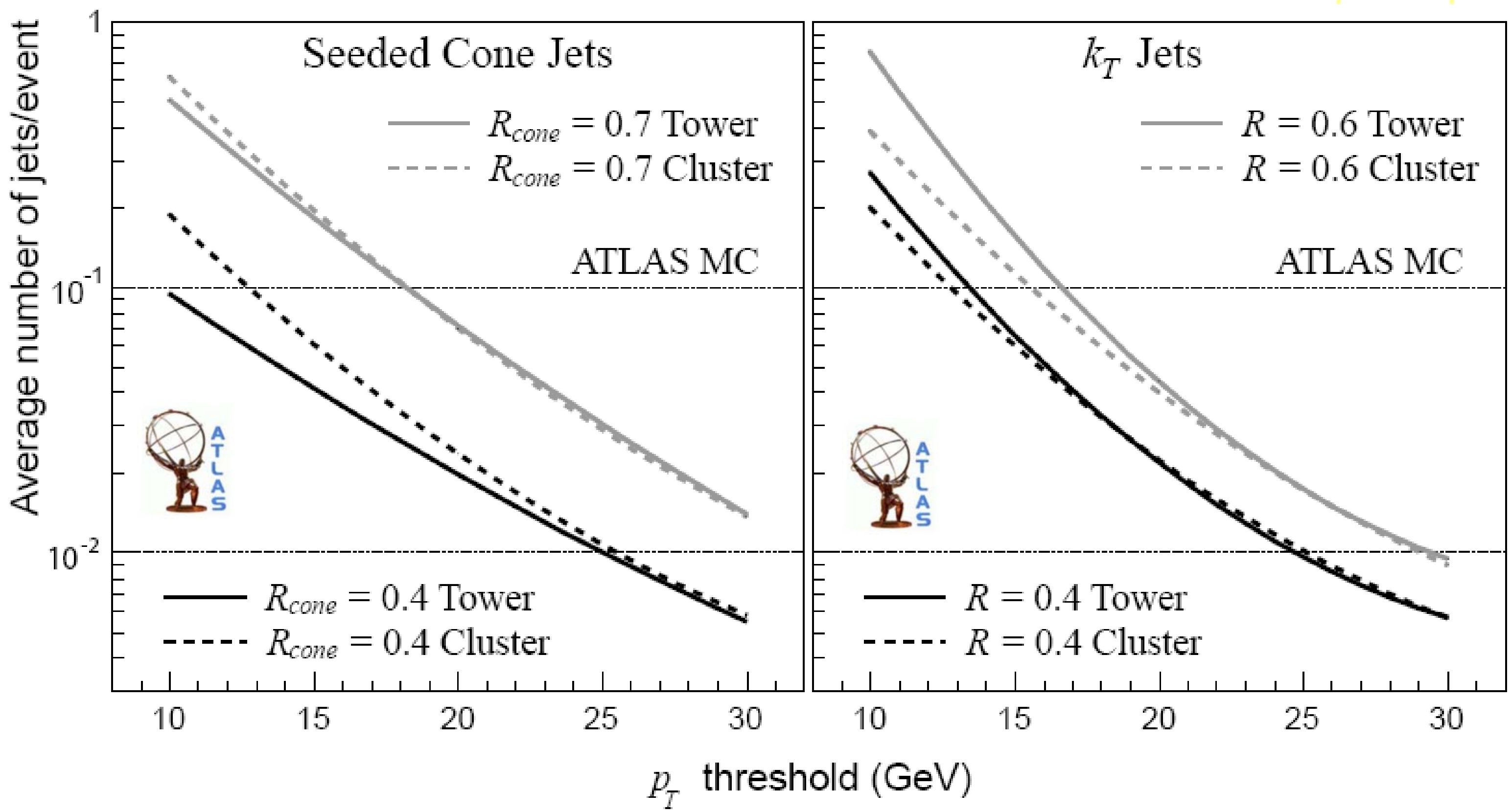
Average number of jets in minimum bias events estimates fake jet reconstruction rate as function of pT threshold

no pileup!



Extracting PDFs

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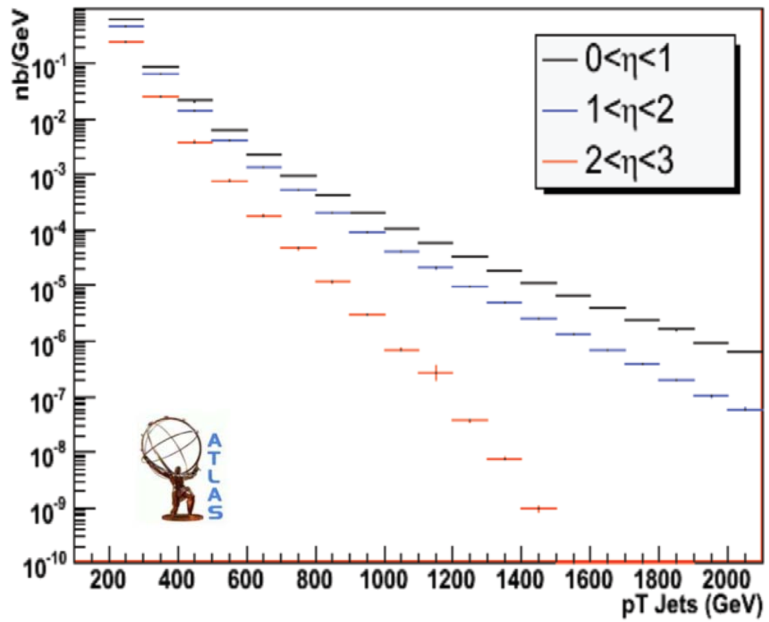
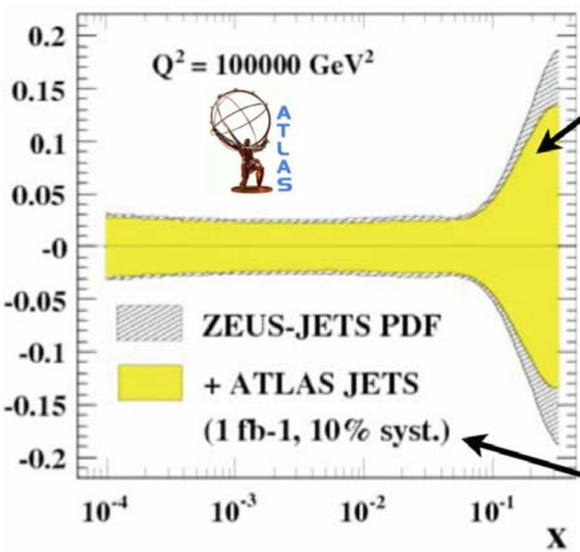
From inclusive jet cross-sections

- Measure cross-section in regions of pseudo-rapidity

Statistical error quickly reduced

- Trigger, JES more important





Preliminary indications suggest that ATLAS data can constrain the high x-gluon.

Systematic uncertainties are uncorrelated, $10fb^{-1}$=1 year of nominal data-taking