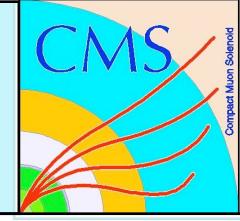




ETH Institute for
Particle Physics



Hadronic Event Shapes At CMS

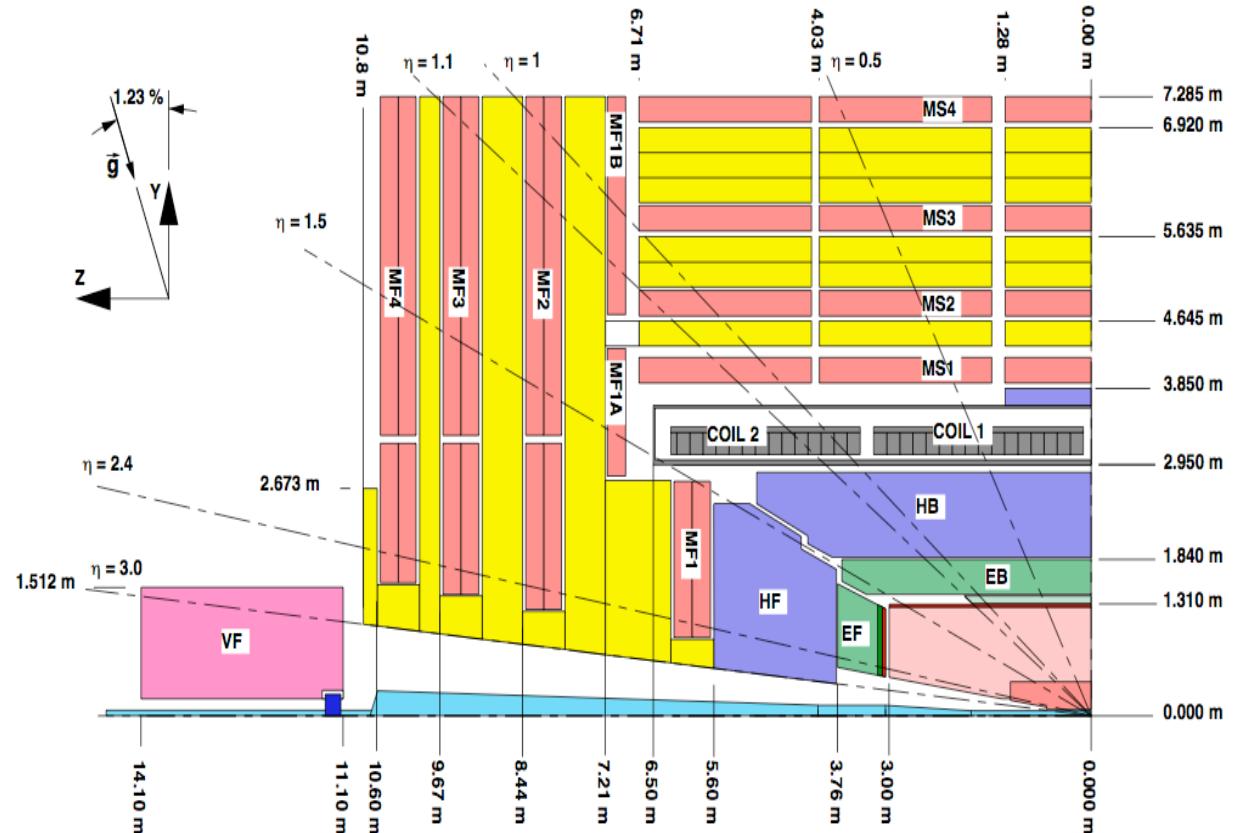
Matthias Weber
ETH Zurich

The Compact Muon Solenoid



The Compact Muon Solenoid (CMS) is a multi-purpose particle physics detector at the LHC:

- length: 21.6 m
- diameter: 14.6 m
- weight: 12500 tons
- magnetic field strength: 3.8 T
- Calorimeter coverage:
barrel region $|\eta| < 1.4$, endcap region: $1.4 < |\eta| < 3.0$



Motivation



- **Experimental:** Normalized event-shape distributions are expected to be robust against jet energy scale uncertainties and jet energy resolution effects
→ event shapes suitable for initial data analysis, here lies our main interest
- **Theoretical:** Event Shapes are collinear and infrared safe, which enables their computation in perturbative QCD
- Event Shapes can be used to **distinguish between different models** of QCD multi-jet production
→ this study intends to show this
- Possibility in the future: measurements of α_s

Definition of Event Shapes



- Variables defined in terms of four momenta in the transverse plane, in analogy to the e^+e^- case

Banfi, Salam, Zanderighi, JHEP **0408** (2004) 62

- Central transverse thrust:**



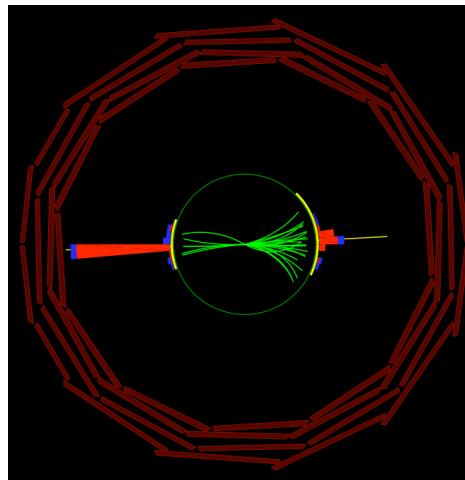
$$T_{\perp,C} \equiv \max_{\vec{n}_T} \frac{\sum_{i \in \mathcal{C}} |\vec{p}_{\perp,i} \cdot \vec{n}_T|}{\sum_{i \in \mathcal{C}} p_{\perp,i}}$$

- Calorimeter Jet momenta are used as **input** for the event shape calculation

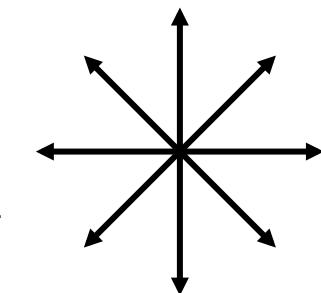
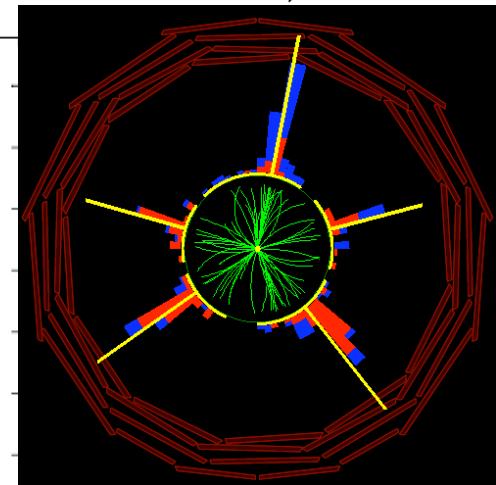
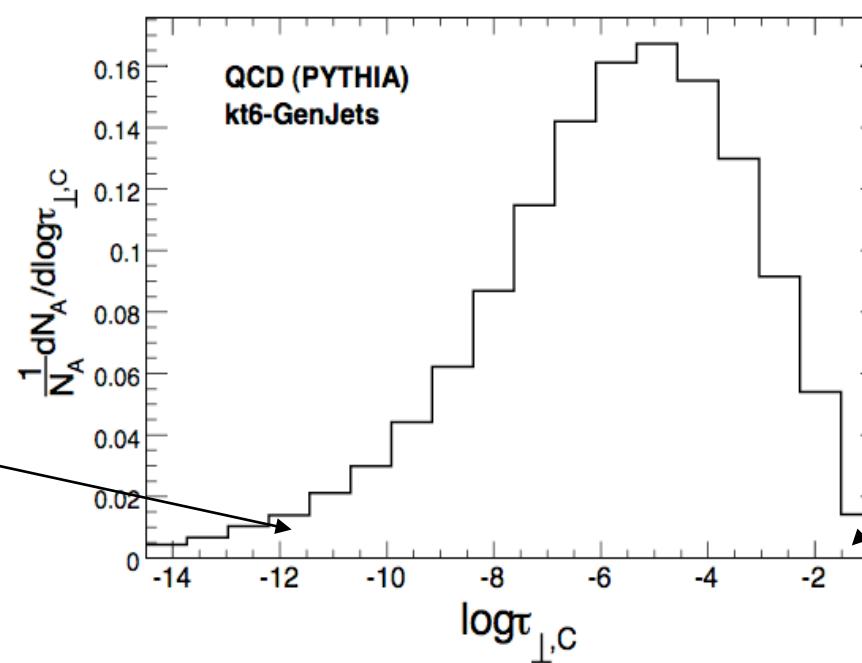
Illustration: central transverse thrust



- Normalized inclusive PYTHIA generator level distribution of the central transverse thrust:
plotted in a natural logarithm of $\log \tau_{\perp,C} = \log(1 - T_{\perp,C})$



$$\tau_{\perp,C} = 0$$



$$\tau_{\perp,C} = 1 - \frac{2}{\pi}$$

Preselection



- **Event Preselection:**
 - the two hardest jets are central $|\eta| < \eta_C = 1.3$
 - two or more jets with $p_T > 50 \text{ GeV}/c$ (corrected calorimeter, generator level)
 - use only central jets for the event-shape calculation
- **Samples used at $\sqrt{s} = 10 \text{ TeV}$:**
 - PYTHIA & HERWIG++ QCD samples:
 $2 \rightarrow 2$ processes involving gluons and light quarks, different Underlying Event & Hadronization Models
 - MADGRAPH QCD samples:
Matrix element calculation: 2 jets - 4 jets with $p_T^{\text{jets}} > 20 \text{ GeV}/c$
- The study is summarized in a CMS PAS QCD_08_003 for $\sqrt{s} = 14 \text{ TeV}$

Presentation of Results

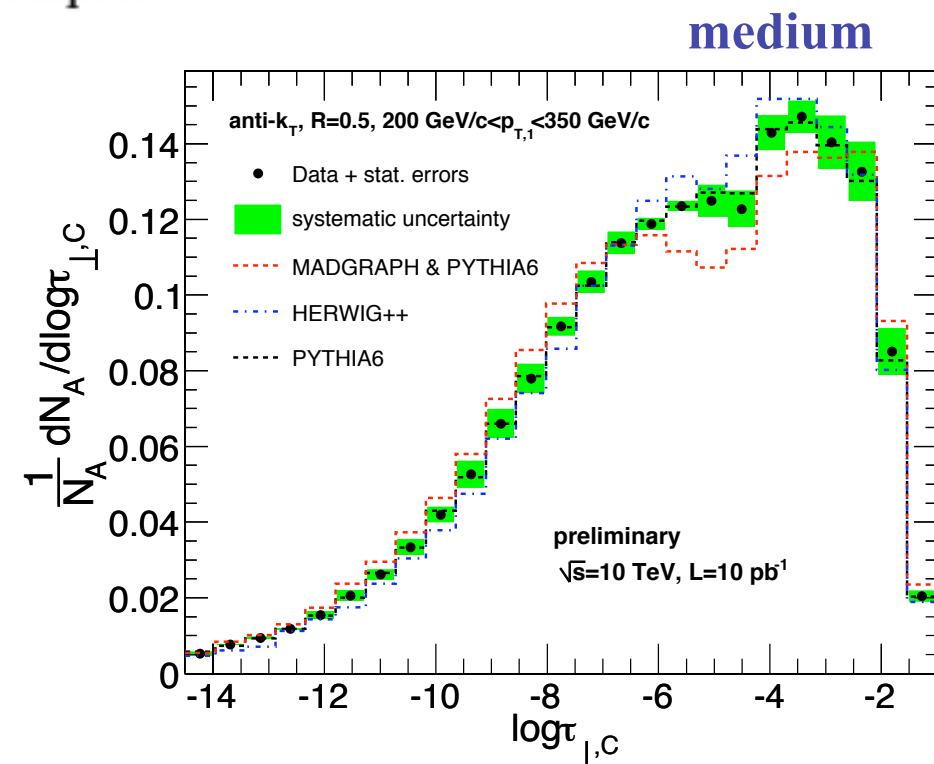
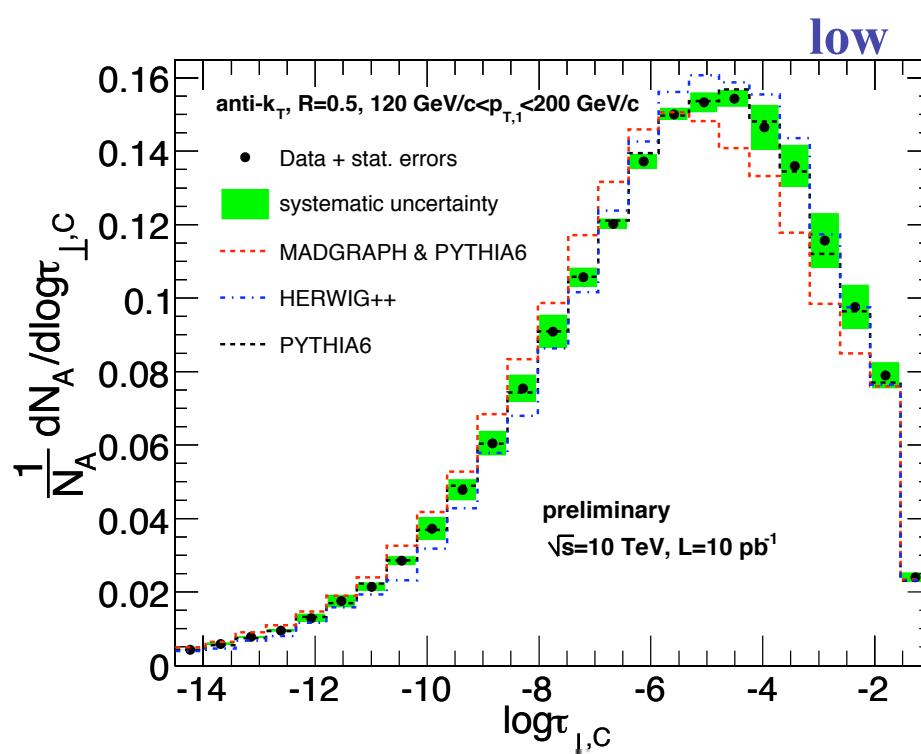


- The “**data points**” are evaluated from the PYTHIA sample using calorimeter jet momenta, corrected for their relative and absolute energy response
 - Jet algo : anti- k_T , $R=0.5$
- The **statistical uncertainty** corresponds to an integrated luminosity of 10 pb^{-1}
- The error bars of the data points include the **systematic errors** due to jet energy resolution, η and ϕ position resolution and the limited knowledge of the jet energy scale
- The **phase space is divided into two regions** according to the corrected transverse energy of the leading jet
 - low energy: $120 \text{ GeV}/c < p_{T,1} < 120 \text{ GeV}/c$
 - medium energy: $200 \text{ GeV}/c < p_{T,1} < 350 \text{ GeV}/c$
 - high energy: $p_{T,1} > 350 \text{ GeV}/c$

Results: central transverse thrust



- Compare the normalized event-shape distributions (calculated from corrected jet momenta) with the corresponding generator level predictions from PYTHIA, MADGRAPH and HERWIG++ QCD samples



- Already in early measurements differences between data and modelling of QCD-multijets in Monte Carlo generators can be studied.

Systematic Uncertainties

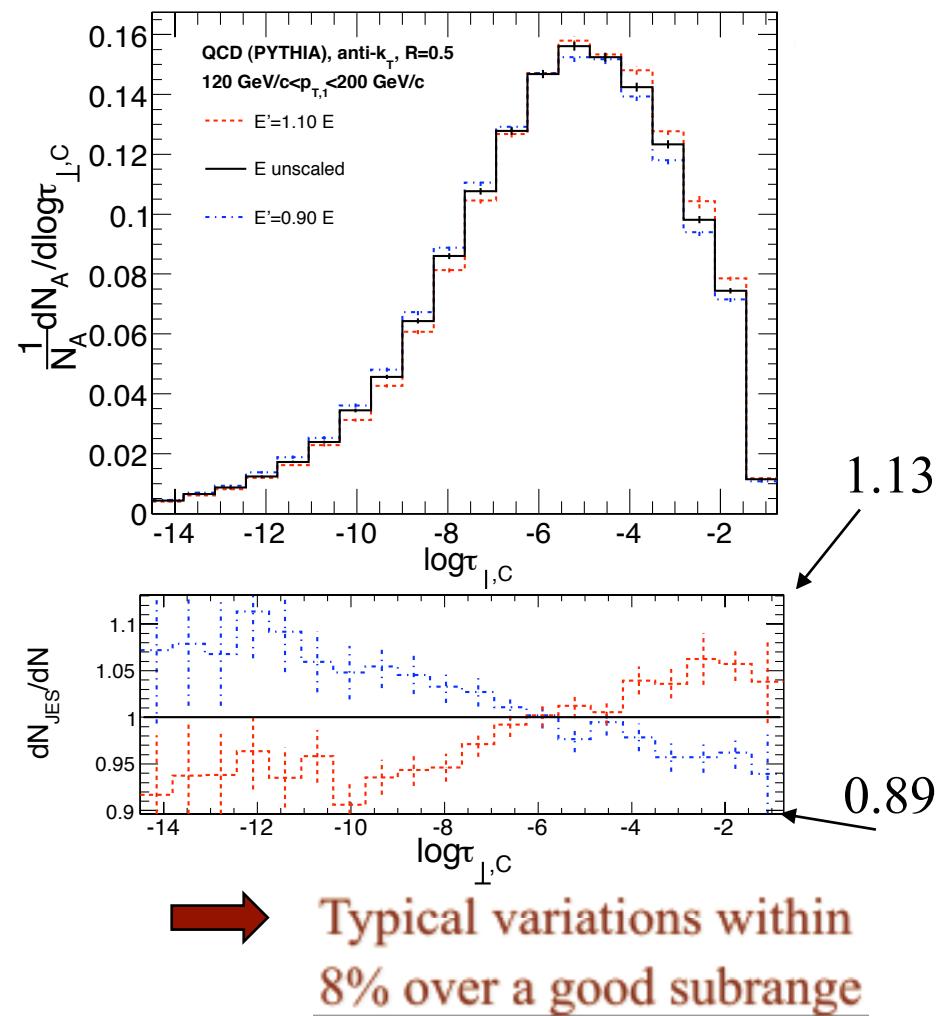
- Jet Energy Scale
- Jet Energy Resolution
- Jet Position Resolution

Systematic Uncertainty: Jet Energy Scale



- A global 10% uncertainty on the jet energy scale is assumed at startup (flat in pseudo-rapidity)
- Event-Shape variables are expected to be robust against jet energy scale variations, simply by their definition.
- Define observed differences as systematic uncertainties

- central transverse thrust:



Jet Energy and Position Resolution

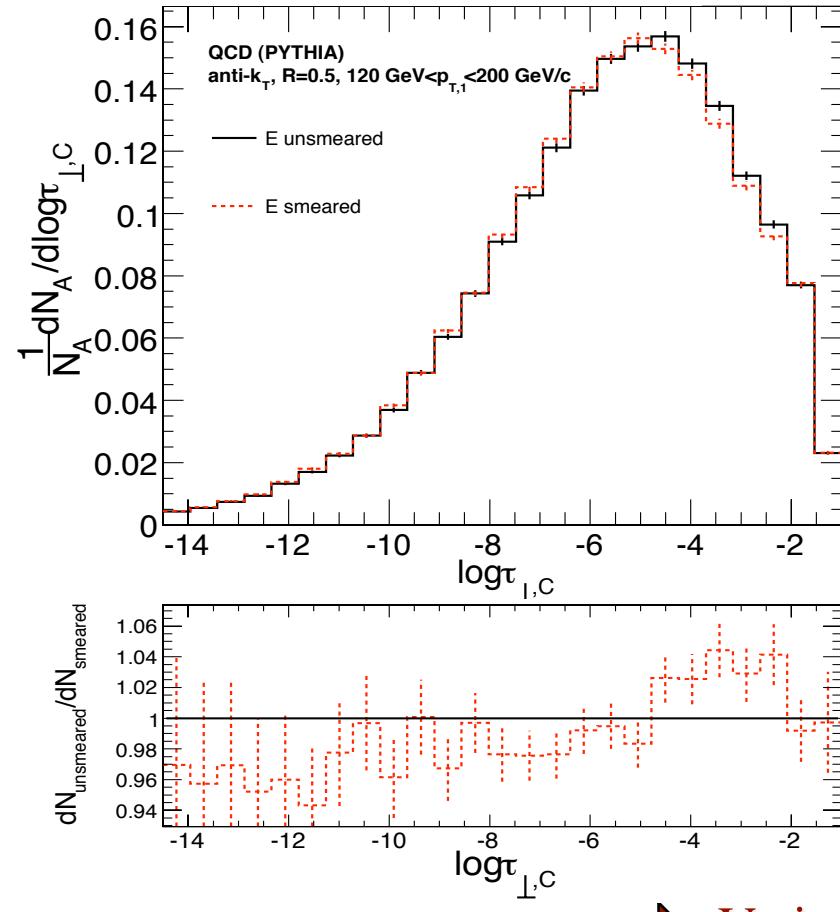


- A gaussian smearing is applied **on the generator level particle jet momenta** to evaluate the effect of the jet energy and jet position resolution:
 - The jets have been **reordered in p_T'** after applying the smearing, threshold $p_T' > 50 \text{ GeV}/c$
- The smearing functions were derived from Monte Carlo over PYTHIA6 QCD samples
- Define observed differences as systematic uncertainties

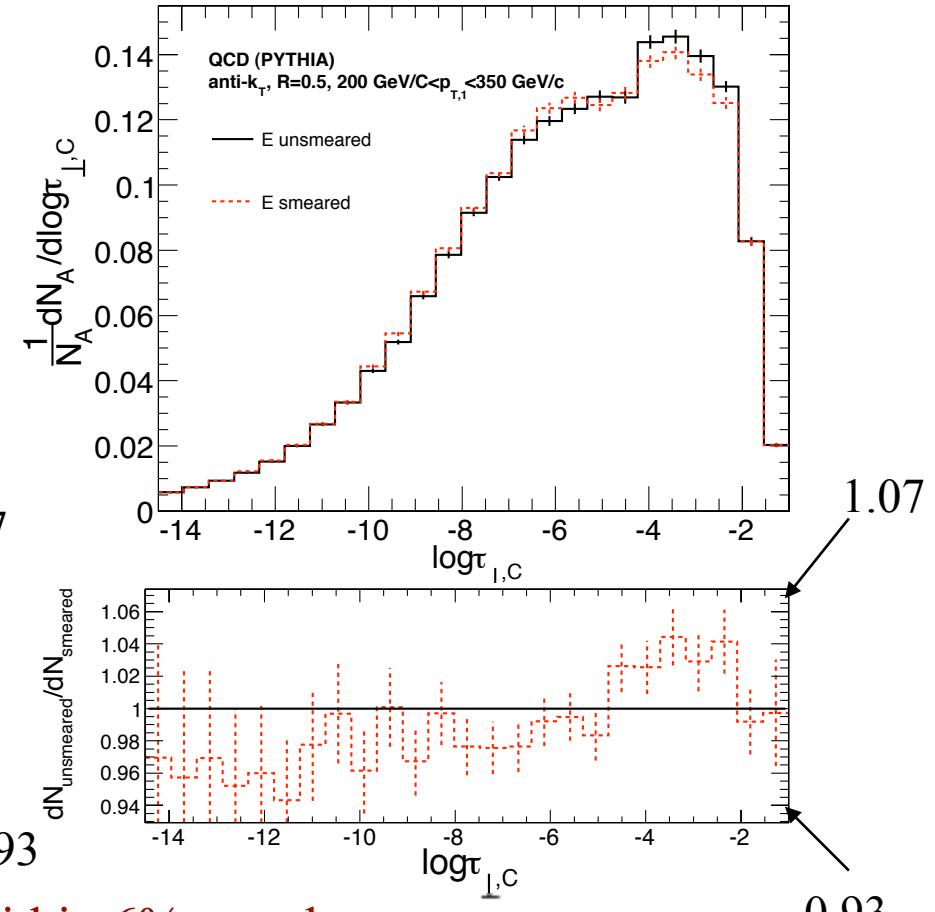
Systematics: Jet energy Resolution



central transverse thrust: low



central transverse thrust: medium

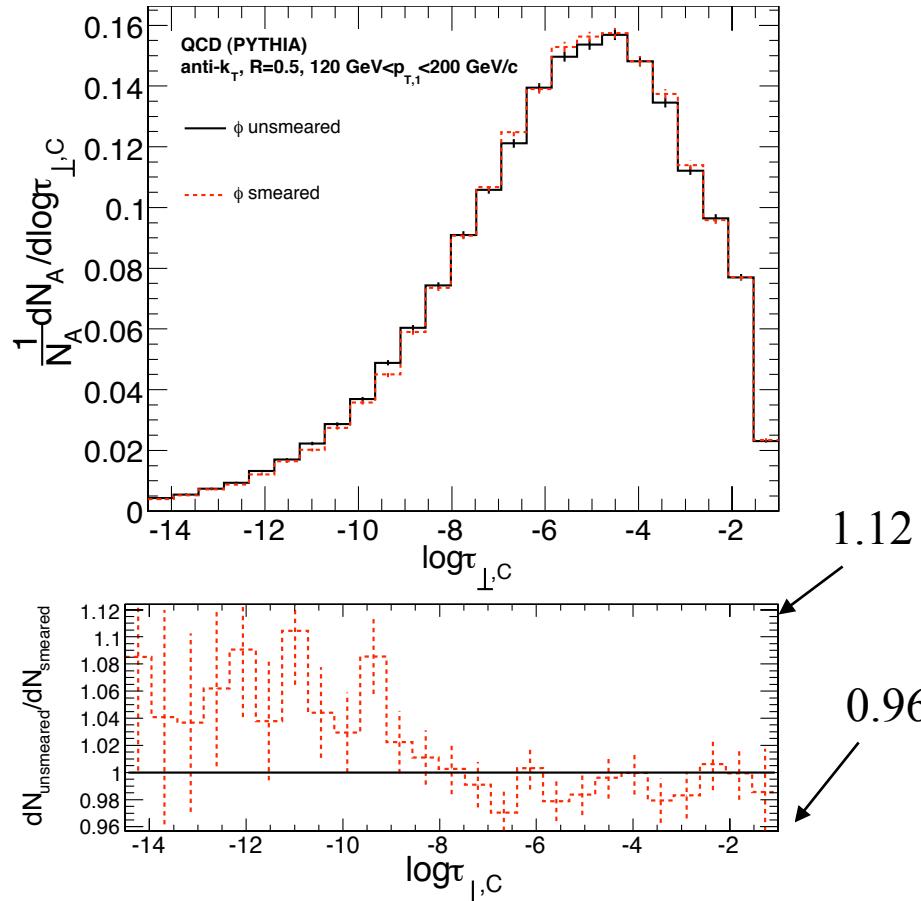


Variations within 6% over large range

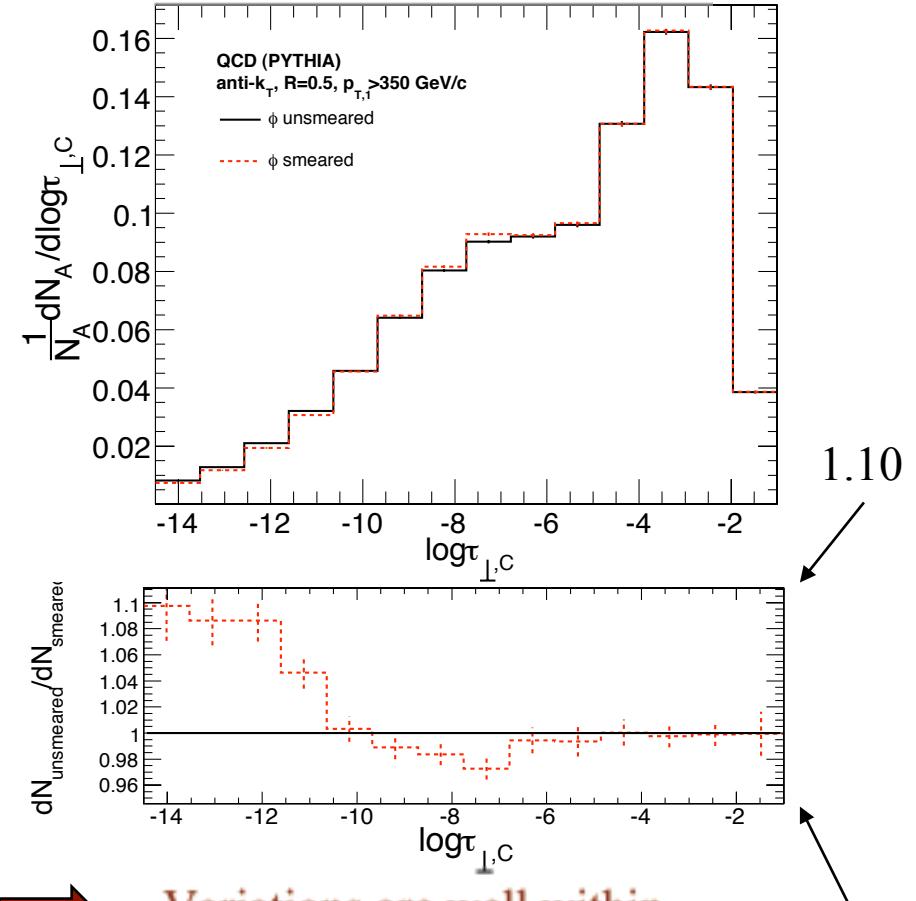
Systematics: Jet ϕ Resolution



central transverse thrust: **inclusive**



central transverse thrust: **high**



Variations are well within
4-10% over the large range

Summary and Outlook



- Systematic uncertainties expected at startup, from jet energy resolution effects and the limited knowledge of the jet energy scale, are small
 - within 8% for both effects
- Systematic uncertainties from the jet position resolutions in η and ϕ are small
 - within 1% respectively 4-10 % for both effects
- An early measurement of event-shape variables allows already to study differences in the modelling of multi-jet production
- Currently first studies of jets of CMS collision data
- Ready to compare predictions from various generators/tunes with larger statistics, as expected in 2010 run.

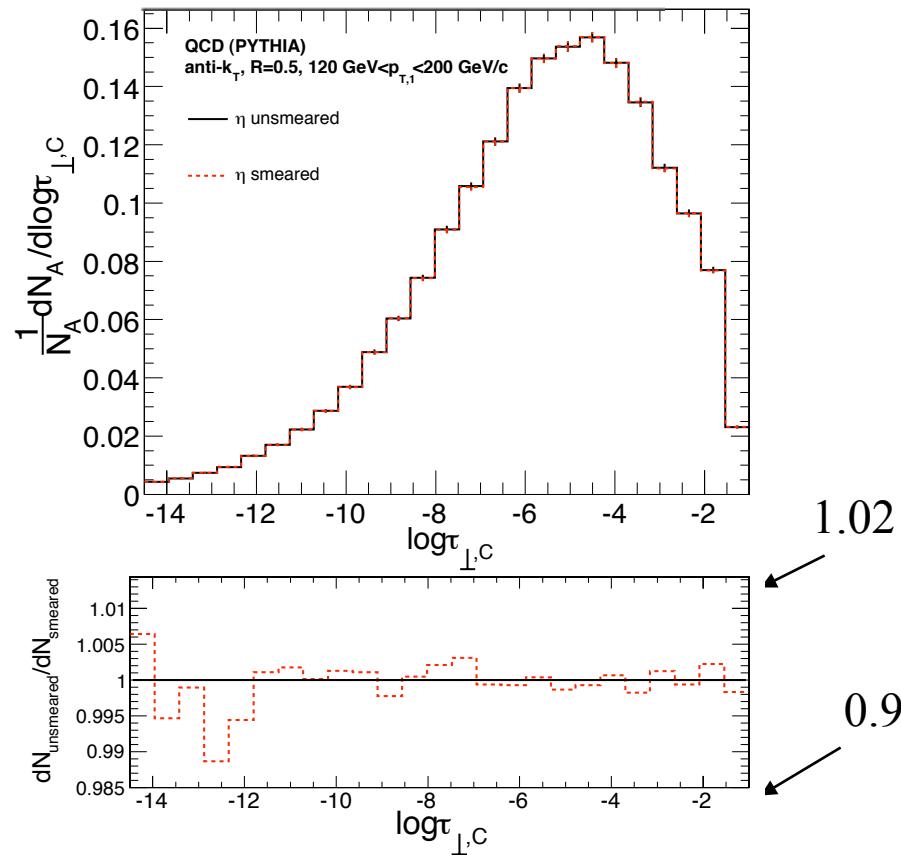


BACKUP

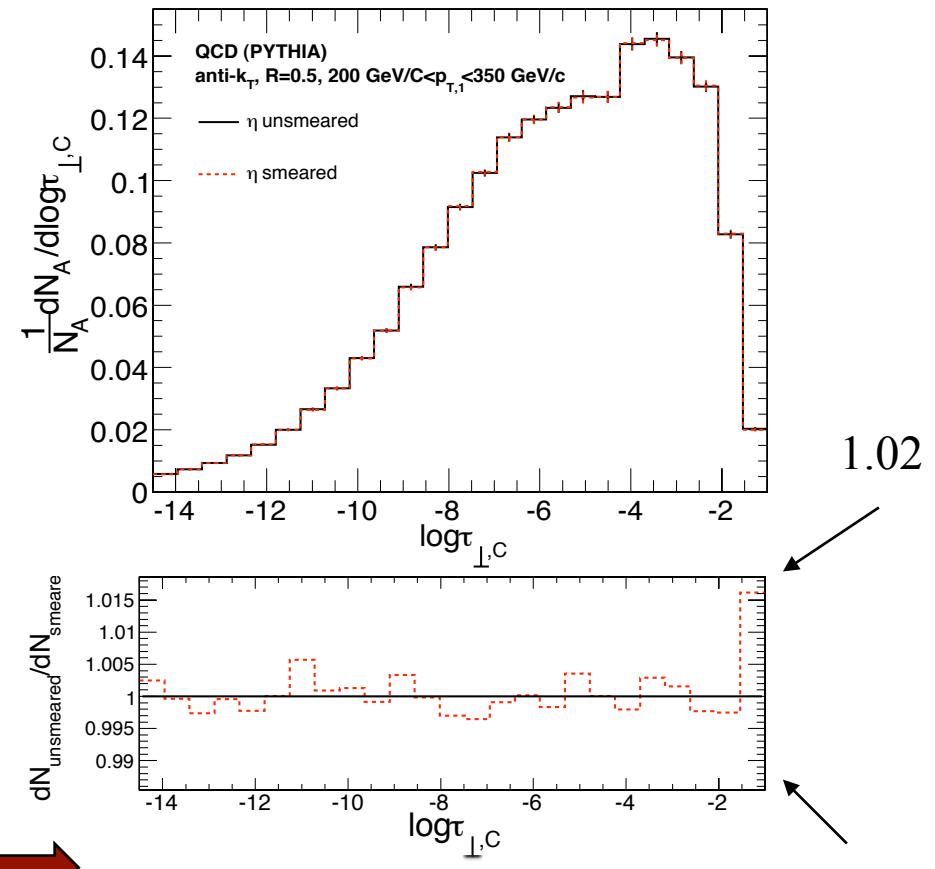
Systematics: Jet η Resolution



central transverse thrust: **low**



central transverse thrust: **high**



Variations are well within
1% over the whole range