CMS results on small-x QCD

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Epiphany Conference, 9th Jan. 2013

Outline

I am a PhD student from University of Warsaw, Faculty of Physics. I work in the CMS Warsaw Group. My PhD project deals with the small-x QCD physics.

Outline:

- Motivation for small-x QCD studies at CMS
- Apparatus
- Measurements (2010 data) and comparison to Monte Carlo:
    - Energy flow in the forward region
    - Forward and forward-central jets spectrum
    - Ratios of inclusive to exclusive cross-sections
- Summary and outlook

Small-x QCD (1)

- Term „small-x" corresponds to a small fraction of proton momentum carried by an interacting parton (gluon or quark).

- Why interactions between small-x objects are so interesting?

1. Commonly used Multi Parton Interaction (MPI) models have to be tuned to data. Parton densities become large at low-x ➔ increased probability for (MPI). We gain new region of phase space that can be used in tuning (Energy Flow measurement)

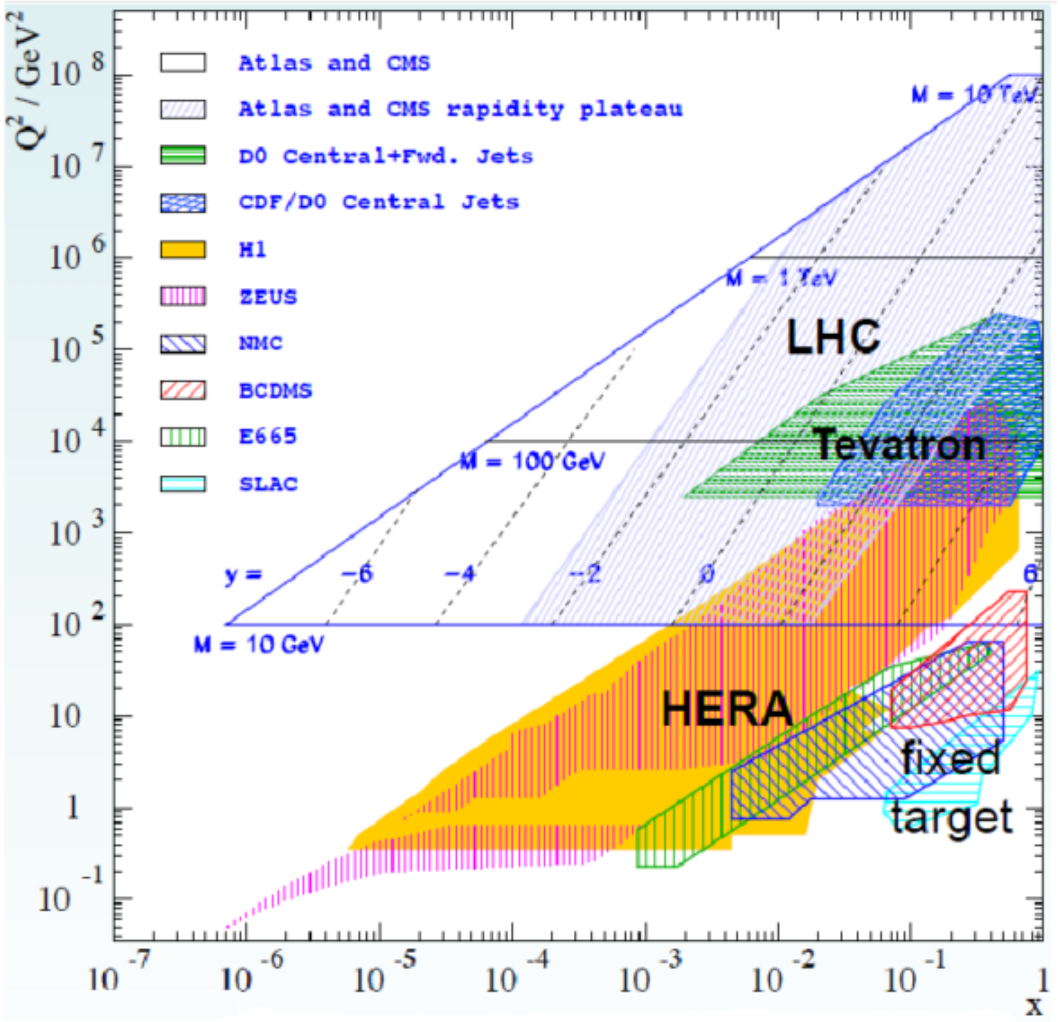
2. In small-x region standard approach to NLO QCD perturbative calculations (DGLAP, summation of log(Q^2) terms) is predicted to be not sufficient. An alternative is BFKL (summation of log(1/x) terms). This has not been checked experimentally (x-sections measurements)

Small-x QCD (2)

- A tool to study small-x QCD are forward jets – jets emitted at small angle with respect to the beam (large rapidity).

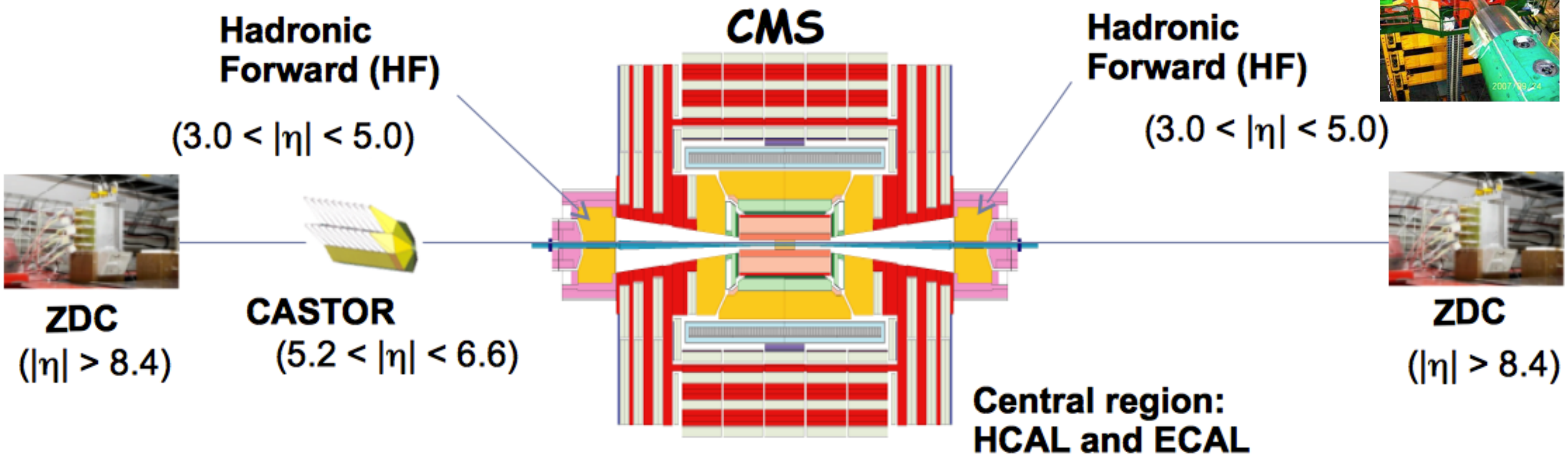
- Forward jets appear usually in asymmetric collisions $x_1 << x_2$.

- Forward jets with $p_T > 35$ GeV in forward calorimeter (HF) reach $x_1 \sim 10^{-4}$, $x_2 \sim 0.2$.



Apparatus

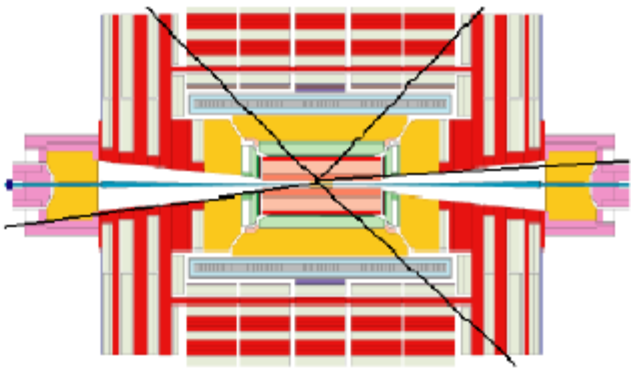
- CMS has calorimeter coverage up to |η|<5.0. Some detectors may extend measured η range up to 6.6 or even further.



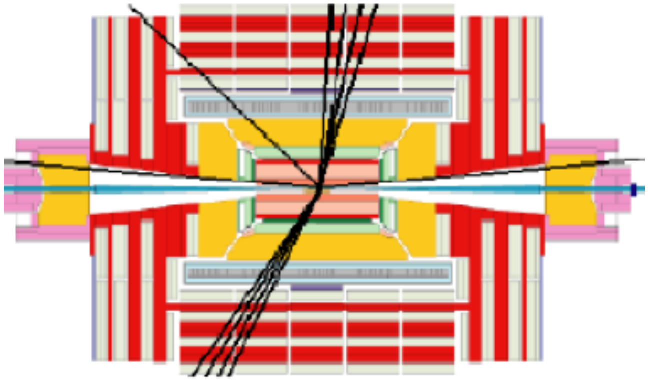
- For analyses presented here crucial are:
  - Brass/scintillator hadron calorimeter (HCAL) and crystal electromagnetic calorimeter (ECAL) for central rapidities.
  - Cherenkov-light Hadronic Forward(HF) calorimeter at 3<|η|<5 rapidity.

Forward energy flow (1)

- **Goal = measurements of MPI**
- Forward energy flow = average energy per event (energy flow) deposited in the forward region of detector (3.15<|η|<4.9).
- Measurement for two center-of-mass energies: 900 GeV and 7 TeV
- Two subsamples:



Minimum bias sample:
activity on both sides of IP,
vertex reconstructed.

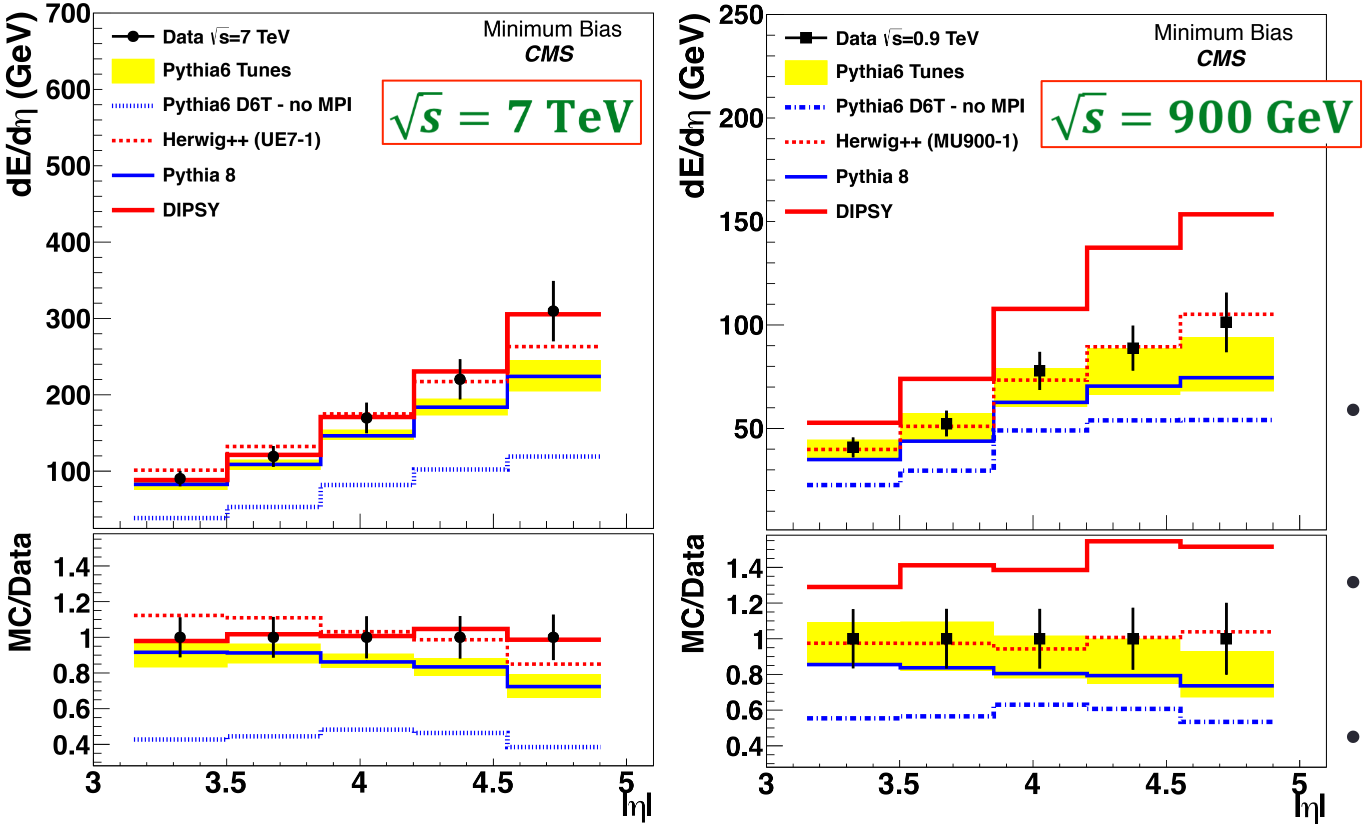


Hard scale sample:
two balanced back-to-back central jets (|η|<2.8) with $p_T > 8$ or 20 GeV
(for 900 GeV or 7 TeV)

**FWD-10-011,
JHEP 1111 (2011) 148**

Forward energy flow (2)

Minimum bias sample



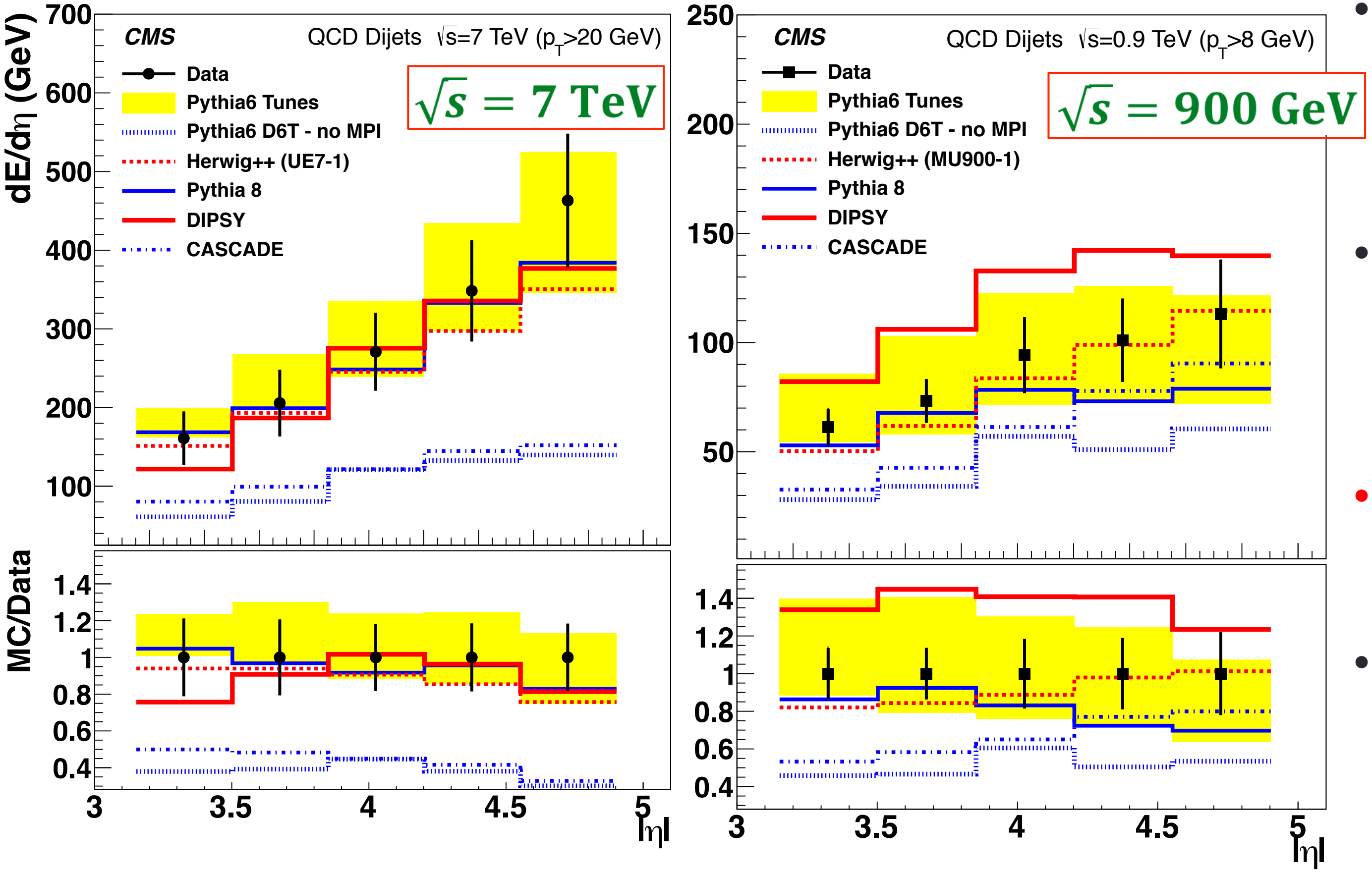
- Pythia 6 band (~20%) from differences between tunes. Inclusion of MPI necessary for description of data.
- Pythia 8 (no tuning) is flatter than data.
- DIPSY describes data for 7 TeV only.
- Herwig++ describes data well for both energies, except high rapidities.

MC generators – different physical models:

- Pythia, Herwig – general use MC models
- DIPSY – dipole picture of BFKL, no tuning

Forward energy flow (3)

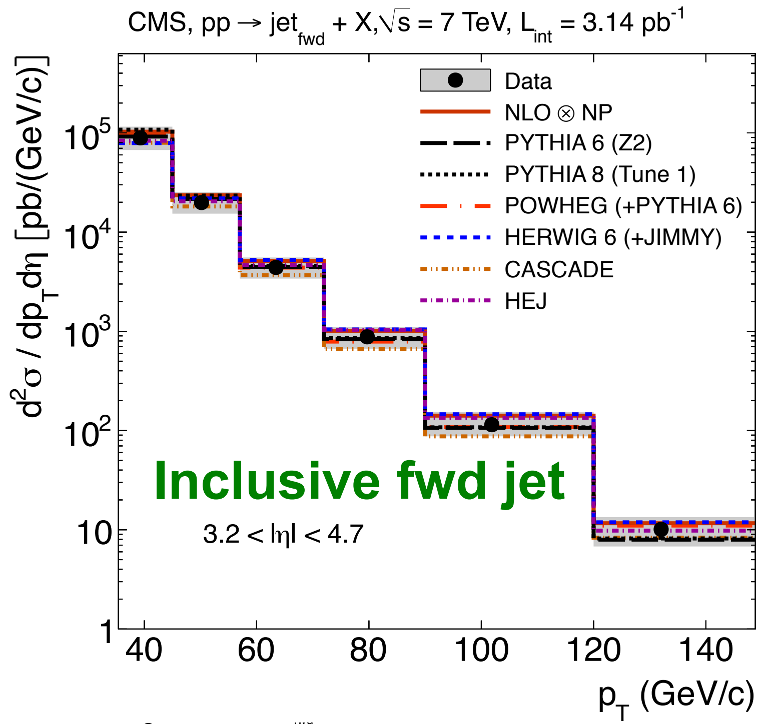
Hard scale sample

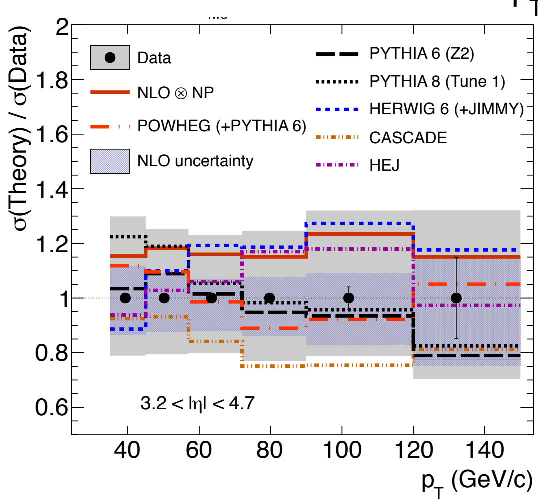


- Energy flow larger than in minimum bias sample.
- Pythia 6 band envelopes the data.
- Large contribution from MPI.
- Pythia 8 and Herwig++ describe data at 7 TeV.

Inclusive cross-sections (1)

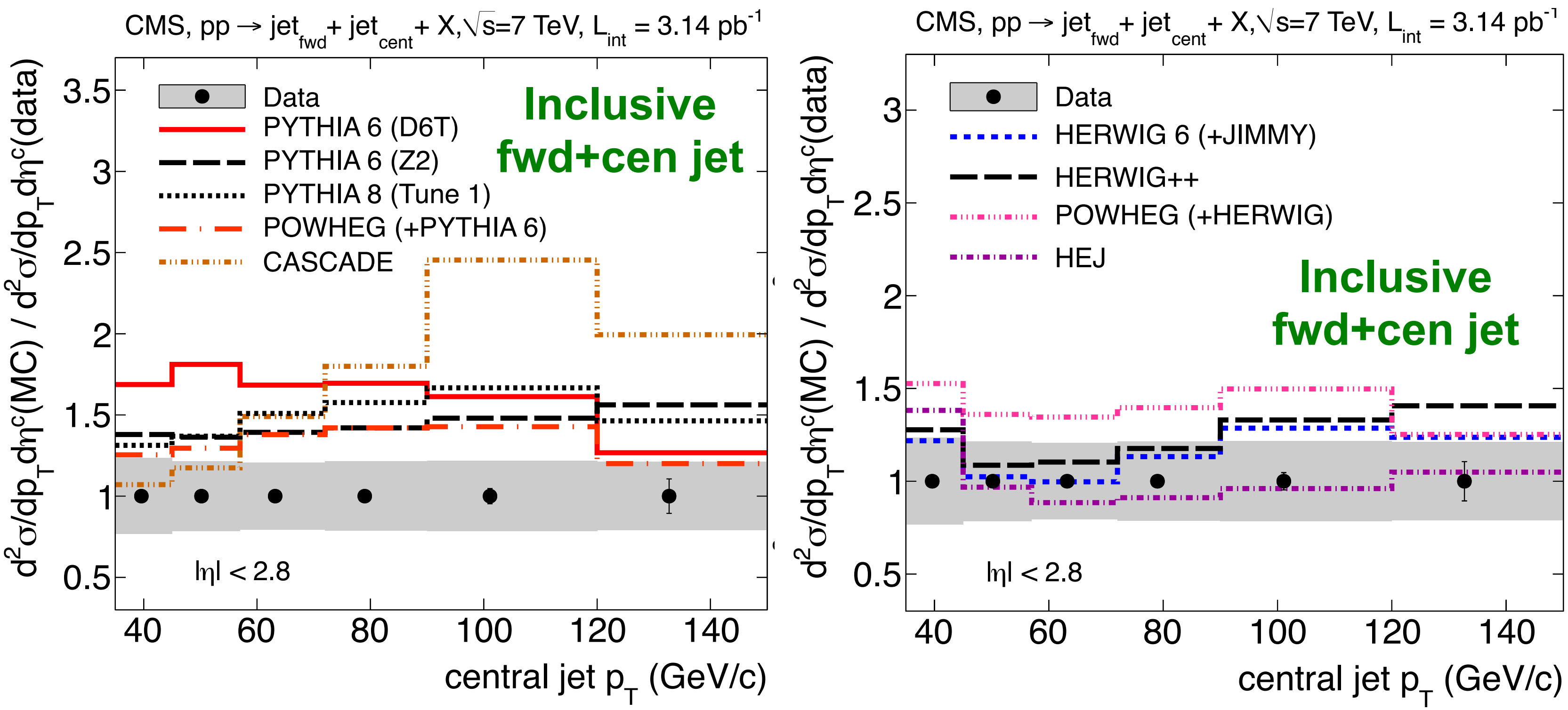
- BFKL searches.
- Inclusive measurement of two topologies:
  - Forward jet present (3.2<|η|<4.7).
  - Forward jet and central jet present.
- Measurement of differential cross-section $d\sigma/dp_T d\eta$ compared at stable-particle level to different MC models: Pythia (DGLAP), Herwig (DGLAP), Cascade & Hej (partially BFKL) and also NLO calculations.
- Single jet trigger used, pT in range 35-150 GeV.
- Inclusive forward jets described properly by different MC models (right).





FWD-11-002, JHEP 1206 (2012) 036

Inclusive cross-sections (2)



- Forward-central jets: similar selection as for forward jets, additionally requiring jet in the central region.
- Discrepancies for central jets, predicted values larger than observed.
- Herwig provides the best agreement.
- Cascade predicts different behavior than observed in data.

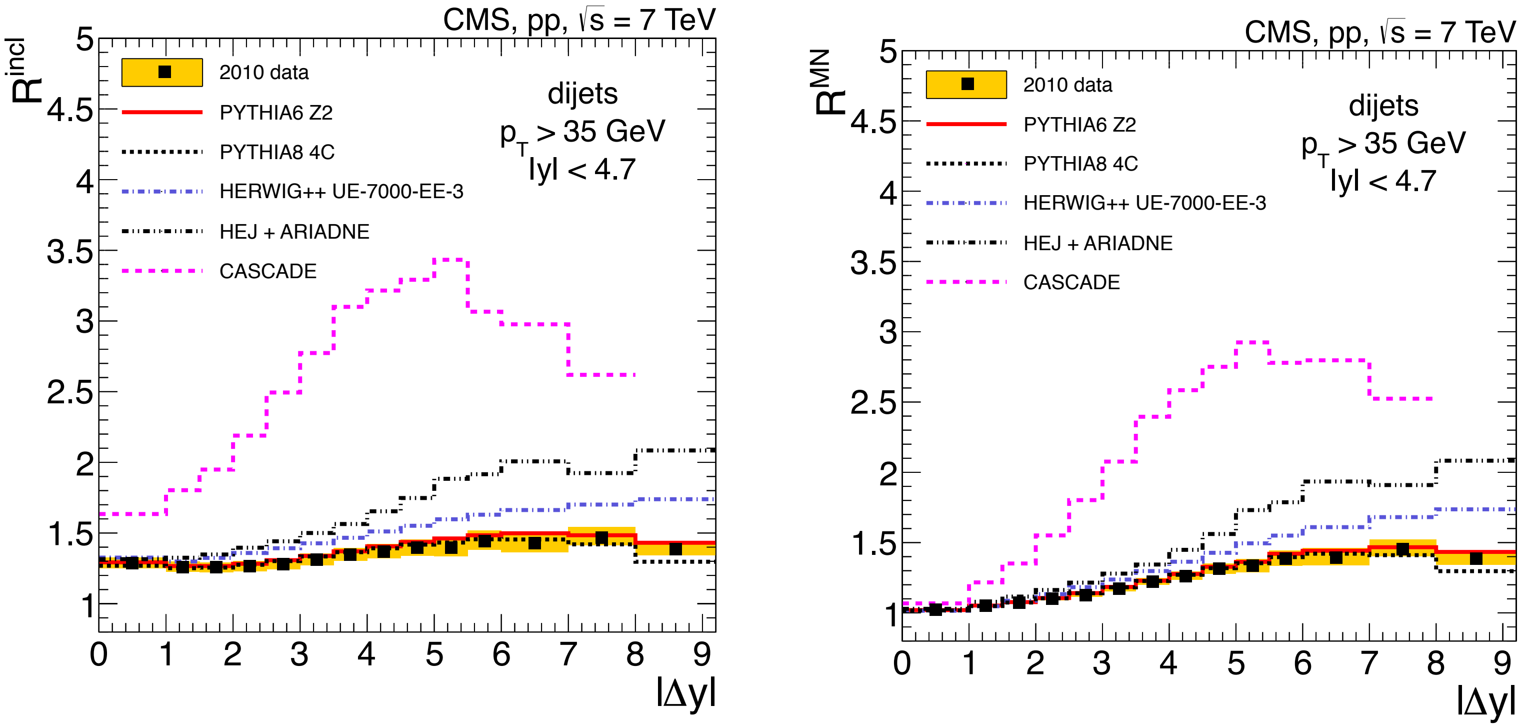
Cross-sections ratios (1)

- Published in Nov. 2012: Eur. Phys. J. C (2012) 72:2216.
- All events: two jets with pT>35 GeV in |η|<4.7 range.
- Three samples:
  - Inclusive (incl.) – all pairwise combinations of jets,
  - "Exclusive" (excl.) – only one pair of jets in each event,
  - Mueller-Navelet pair (MN) – from inclusive sample pair with the largest separation in η is selected.
- Observables we consider are ratios of inclusive/MN to exclusive cross-section:

$$R_{incl} = \frac{\sigma_{incl}(\text{dijet})}{\sigma_{excl}(\text{dijet})}, \quad R_{MN} = \frac{\sigma_{MN}(\text{dijet})}{\sigma_{excl}(\text{dijet})}$$

- Some systematical uncertainties cancel.
- Such observables should be sensitive to BFKL effects.

Cross-sections ratios (2)



- σ(inclusive) is of the order of (1.2-1.4)*σ(exclusive), ratios rise and for large |Δη| and then drop due to kinematic limits.
- Both Pythia MC describe data properly.
- Herwig++ predicts too large R at large and medium separations.
- BFKL basing MC generators, Hej and Cascade predict too large R.

Conclusions

- I have presented selected results for low-x QCD.
- Such kind of studies are important for understanding of QCD (tuning parameterization of models to data) and in searches for BFKL effects.
- MC generators predictions are less accurate at large rapidities. Proper Multi Parton Interaction simulation is vital. With estimated uncertainties we cannot conclude the BFKL effect presence in the data.
- Coming soon: Angular decorrelation of Mueller-Navelet jets. Stay tuned!

Thank you for your attention!