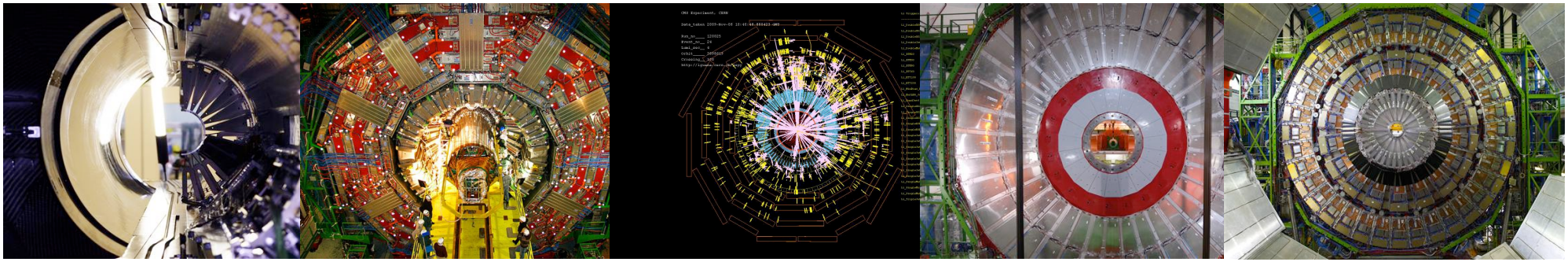
Jets and Multijets at Large Rapidities

with the CMS Experiment



Thomas Schörner-Sadenius

DESY

PHYSICS AT THE TERA SCALE Helmholtz Alliance

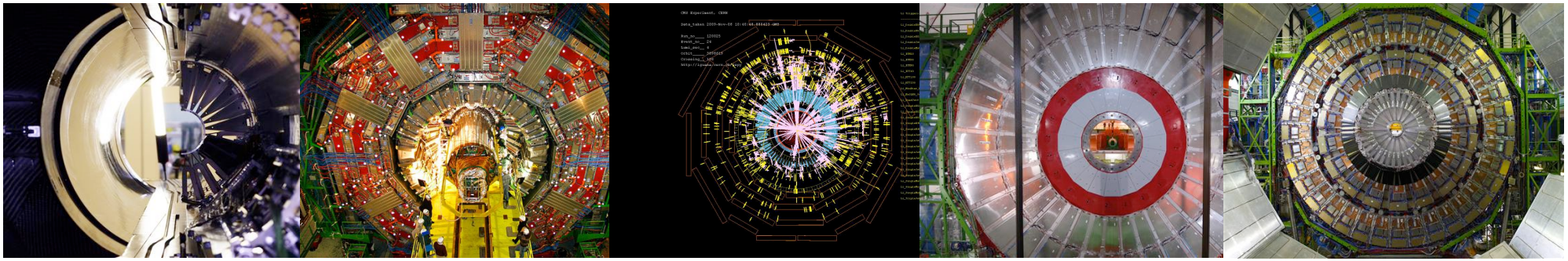
universitätbonn
Rheinische Friedrich-Wilhelms-Universität Bonn

DIS 2012
Bonn, 26-30 March 2012

Jets and Multijets at Large Rapidities

with the CMS Experiment

- CMS and jets
- The interest in large Δy
- Forward and forward +central jets
- Inclusive / exclusive dijets at large Δy



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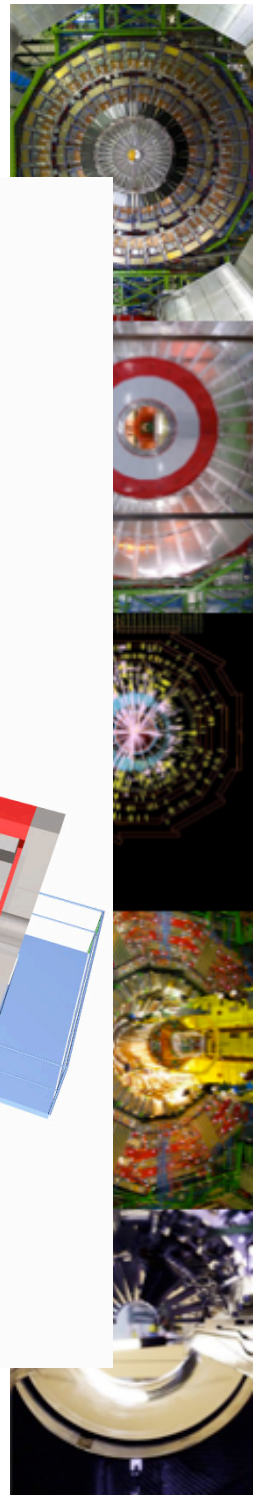
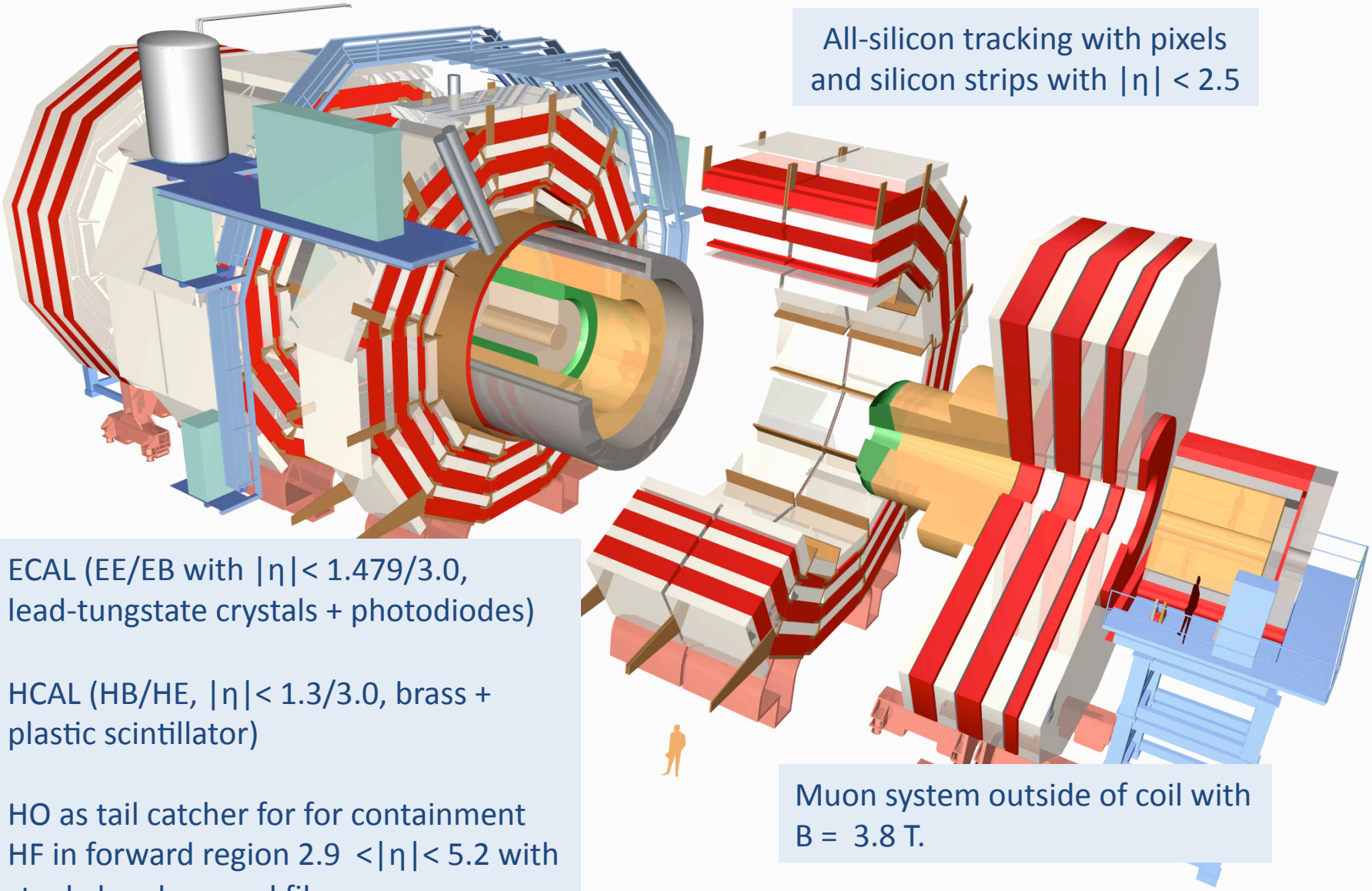
THE CMS EXPERIMENT





All-silicon tracking with pixels and silicon strips with $|\eta| < 2.5$

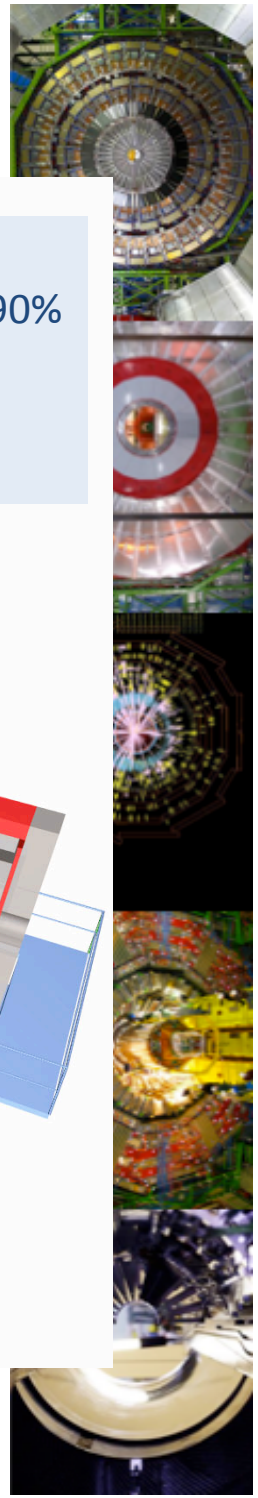
ECAL (EE/EB with $|\eta| < 1.479/3.0$, lead-tungstate crystals + photodiodes)

HCAL (HB/HE, $|\eta| < 1.3/3.0$, brass + plastic scintillator)

HO as tail catcher for for containment
HF in forward region $2.9 < |\eta| < 5.2$ with steel absorbers and fibers.

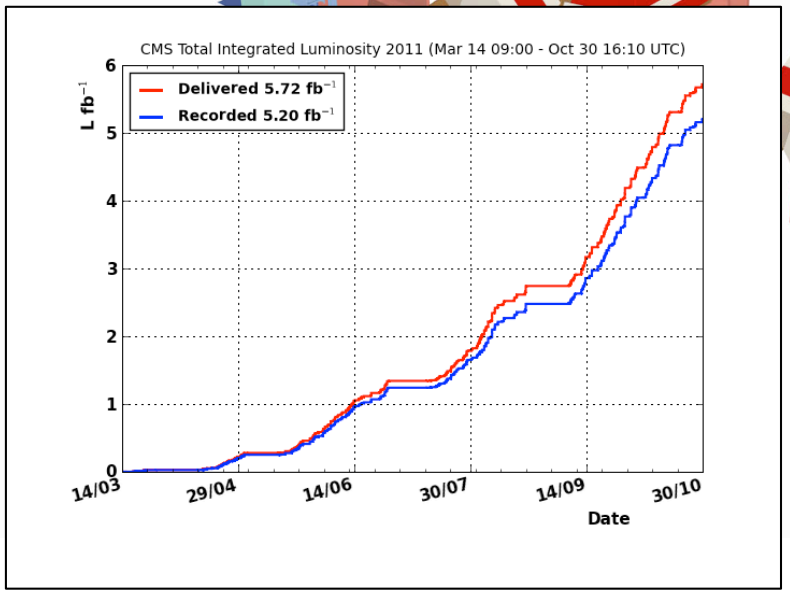
Muon system outside of coil with B = 3.8 T.

THE CMS EXPERIMENT



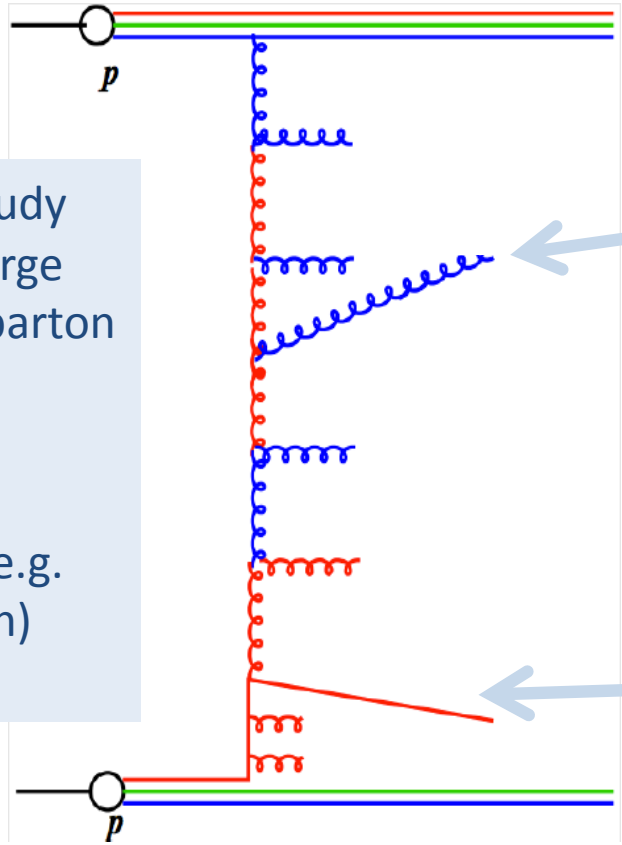
Total lumi so far: > 5 fb^{-1}
Data taking efficiency > 90%

Luminosities used here:
33nb^{-1} – 5 pb^{-1} (2010)



THE INTEREST IN FORWARD JETS

Small-x physics and parton dynamics

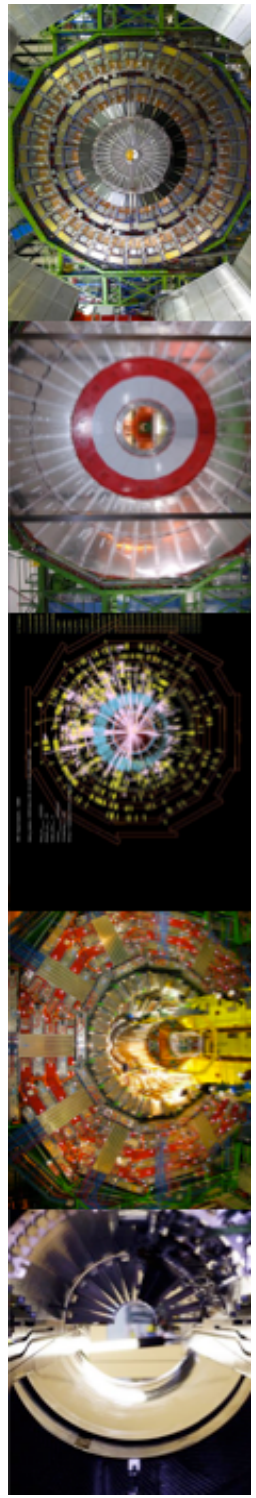


Forward jets to study
– physics of the large rapidity range (parton evolution).
– small-x physics
– PDFs at small x
– VBF processes (e.g. Higgs production)
– …

(Central) Jets as vital tool for QCD studies, but limited to central pseudo-rapidities (<2.5)
➔ medium/large and symmetric x values

LHC / CMS:
– Large CMS energy and
– large rapidity range (coverage to $\eta > 4.7$)
➔ forward jets

Questions to be answered:
– DGLAP versus BFKL versus CCFM versus gluon saturation versus … ?
– using correlations between central and forward jets
– more detailed final-state studies: non-global logs, super-leading logs …

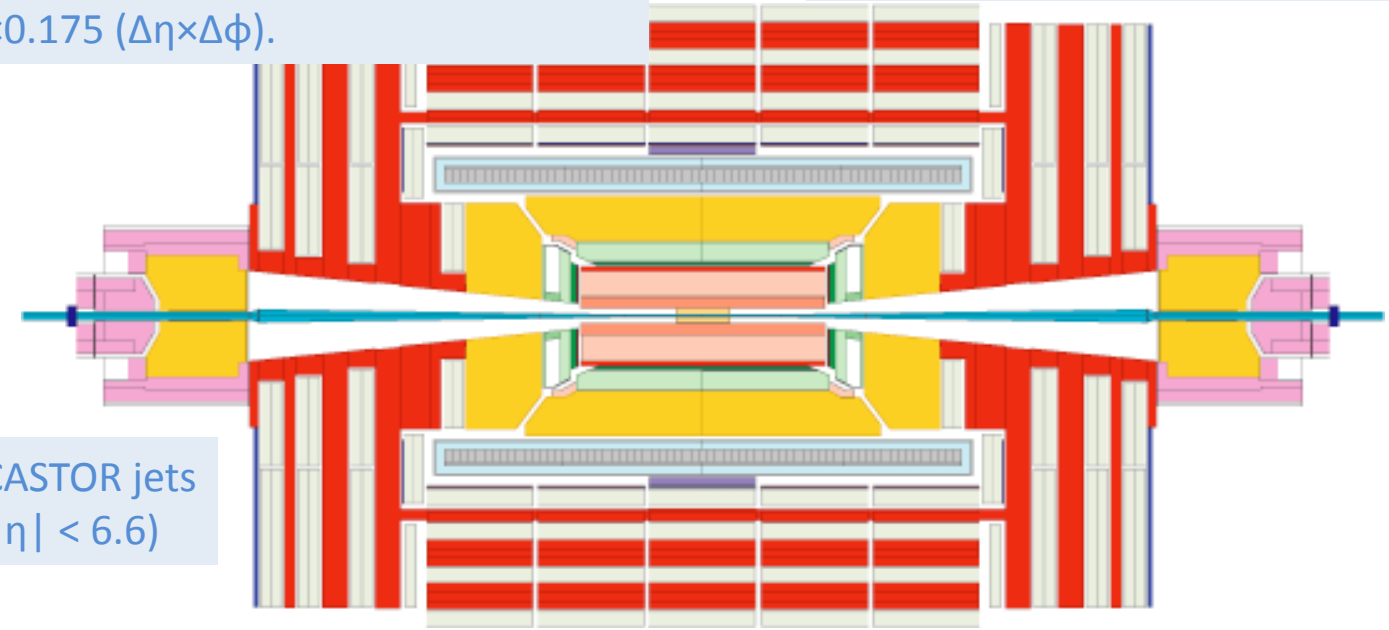


JETS IN CMS

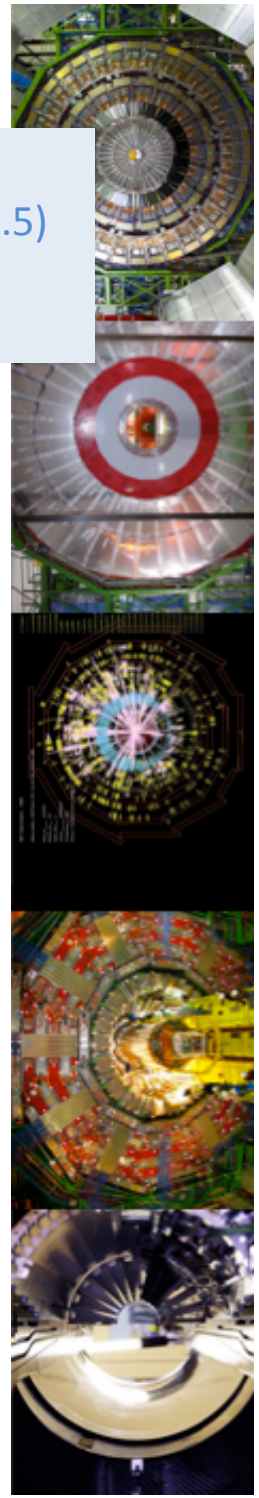
Detectors and Methods

Central jets within $|\eta| < 2.8$
(CAL/tracking coverage to η=3.0/2.5)
HCAL cells: 0.087×0.087 ($\Delta\eta \times \Delta\phi$)
ECAL: ~5×5 cells per HCAL cell

Forward jets with $3.2 < \eta < 4.7$ in Hadronic Forward (HF) calorimeter region ($2.9 < |\eta| < 5.2$, mostly 0.175×0.175 ($\Delta\eta \times \Delta\phi$).



Future: CASTOR jets
($5.2 < |\eta| < 6.6$)



– Calorimeter jets from energy deposits in ECAL, HCAL and HF
anti-k_T algorithm with R=0.5 and $p_T > 35$ GeV
– In CMS also track jets and particle-flow (PF) jets with improved resolution due to usage of tracker and calorimeters; PF not yet used in forward region.

FORWARD JETS AT 7 TeV

(CMS-PAS-FWD-11-002, arXiv:1202.0704)

Data and event selection:

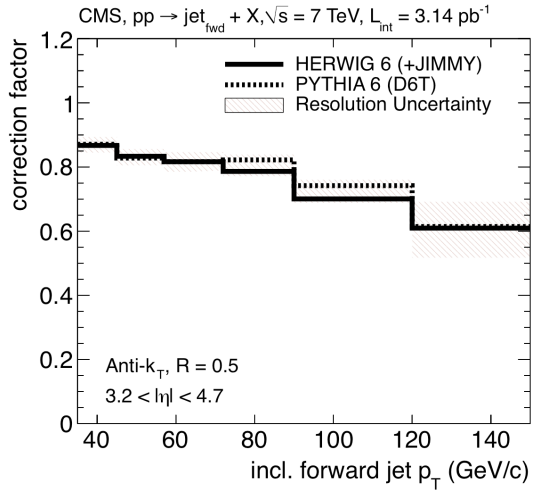
– 3.14 pb^{-1} from 2010 data taking at CMS energies of 7 TeV.

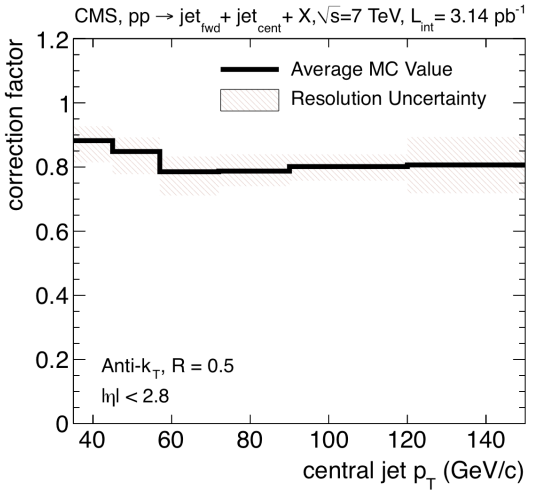
– inclusive forward jets: single-jet trigger with uncorrected p_T threshold of 15 GeV

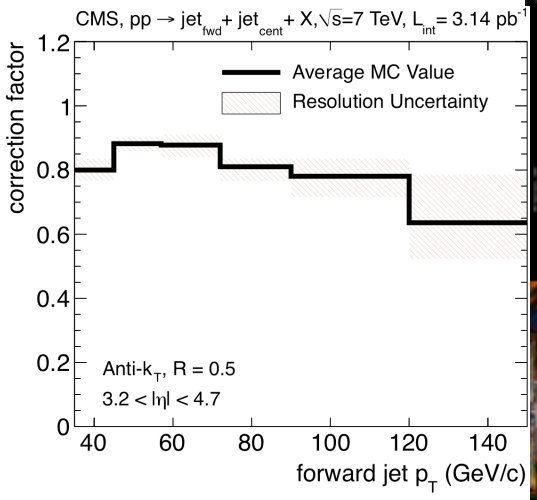
– forward + central jets (dijets): dijet trigger with threshold at 30 GeV.

➔ both triggers fully efficient over p_T = 35 GeV.

– Good vertex and other cleaning criteria.



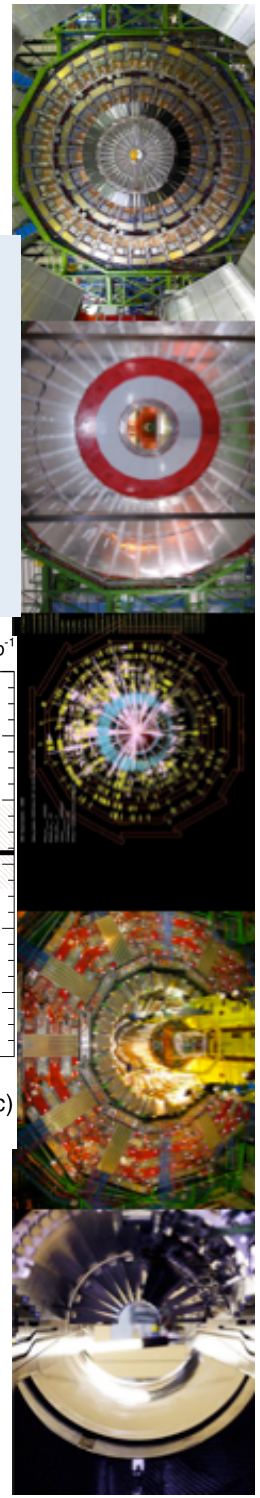




Data corrections:

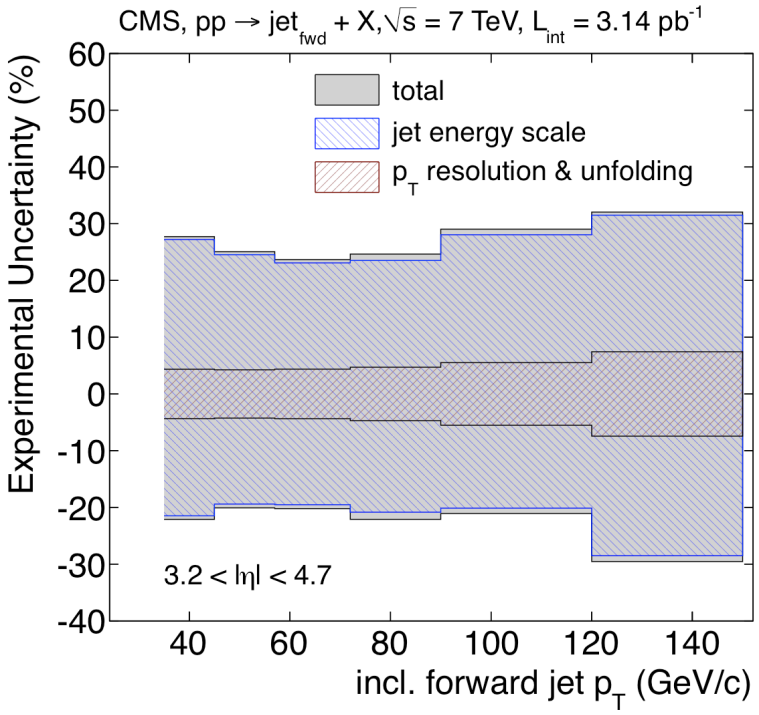
– p_T / η calibration dependence removed using dijet / photon+jet events (data)

– unsmearing correction for resolution effects (12% above p_T = 35 GeV):
bin-by-bin using MC and *ansatz* method with similar results.

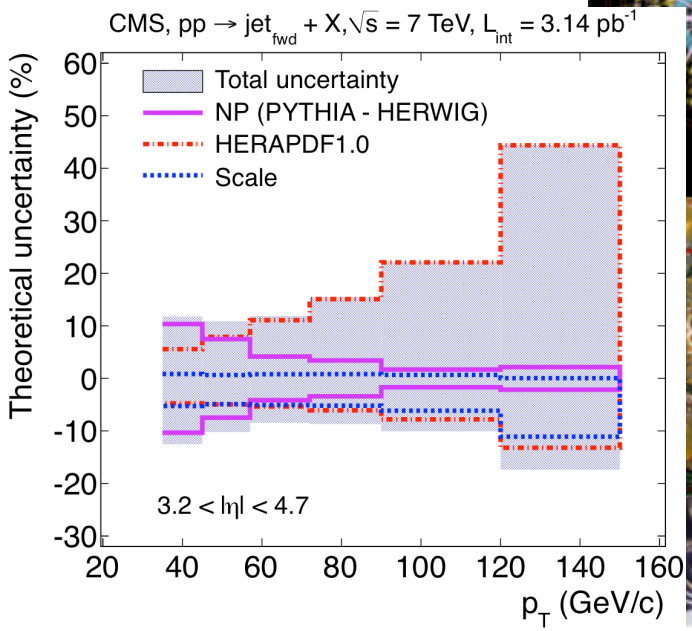


FORWARD JETS AT 7 TeV

Uncertainties



Experimental uncertainties:
- Statistical error small (1-10%).
- JES uncertainty 2.5-3.5 (6%) for central (fwd) jets
  → 20-30% effect on cross sections.
- Resolution + unfolding: 3-6% + 3% effect on cross sections (growing with p_T)
- 4% luminosity uncertainty.

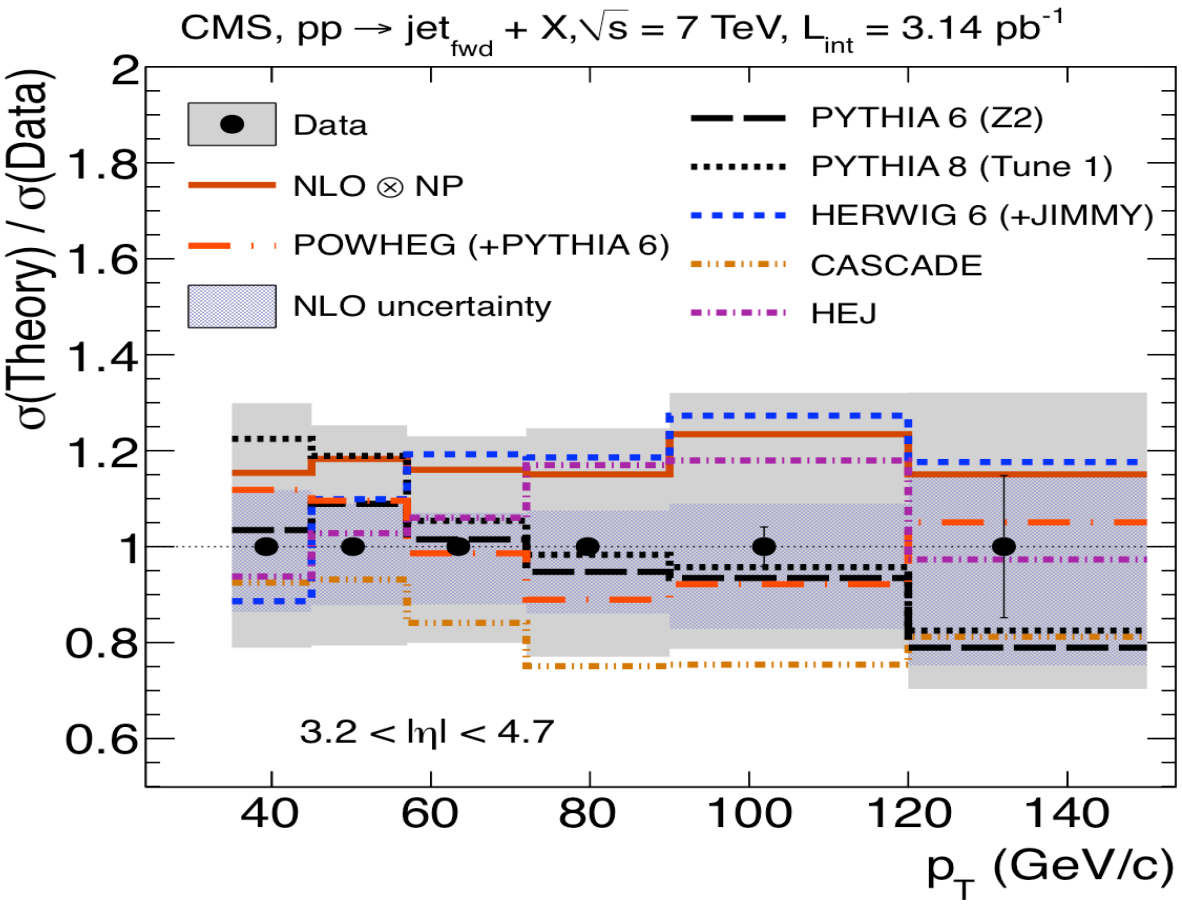


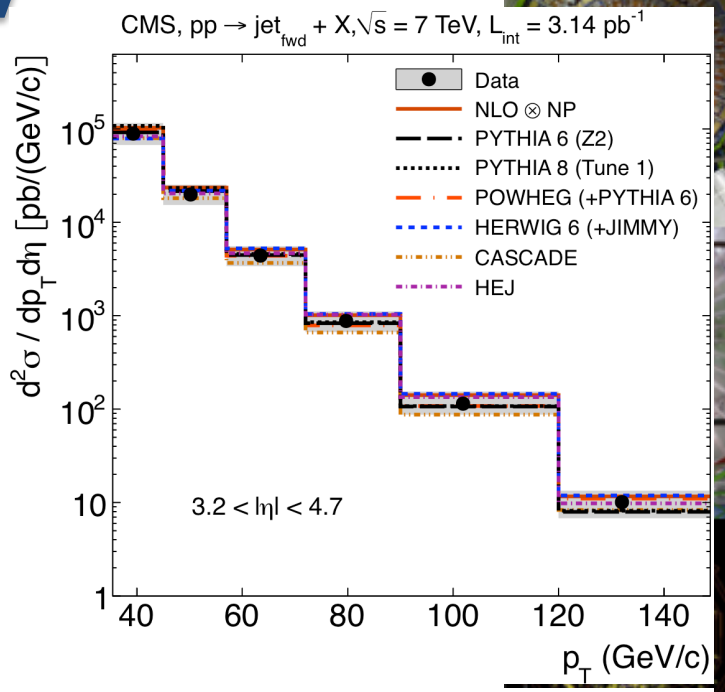
Theoretical uncertainties:
- low p_T: dominated by non-perturbative effects (model difference of hadronisation corrections): up to 10%
- high p_T: PDF uncertainty up to 40% (HERA-PDF)!
- Scale uncertainty between 5 and 10%.

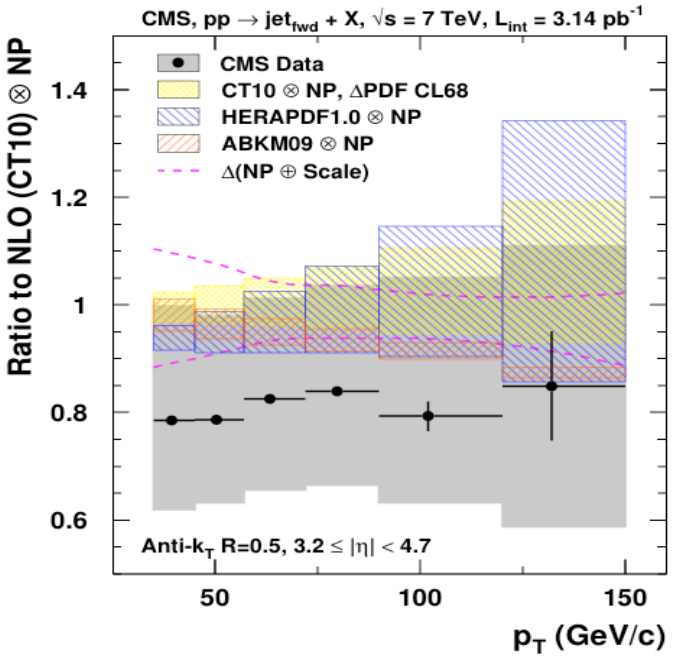
FORWARD JETS AT 7 TeV

Results, description by theory

– fixed-order QCD, NLO+PS models and DGLAP-based MC models describe the data within errors.
– Also CCFM model CASCADE and BFKL-type HEJ ok.
– NLO overshoots central data value by ~20%.

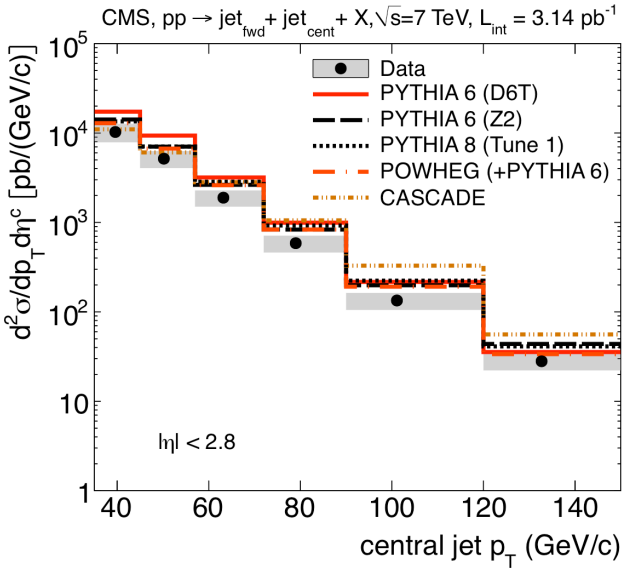


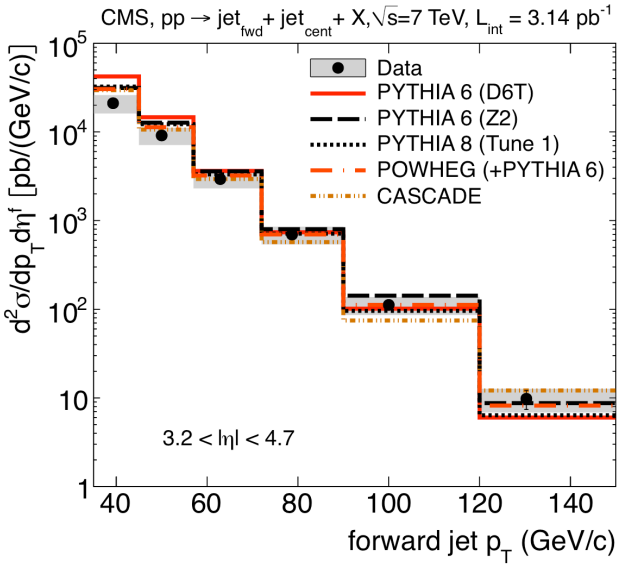


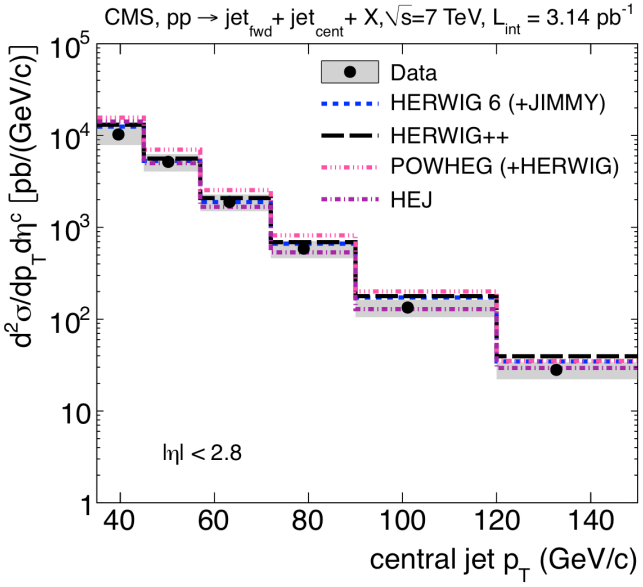


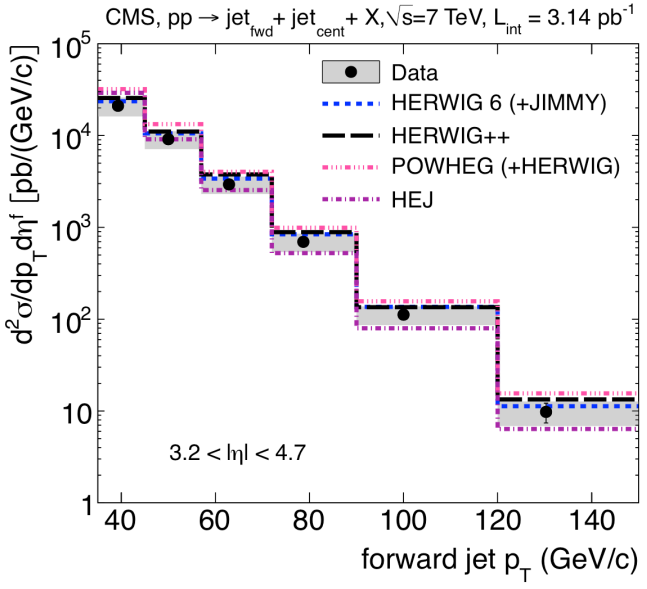
CENTRAL+FORWARD DIJETS

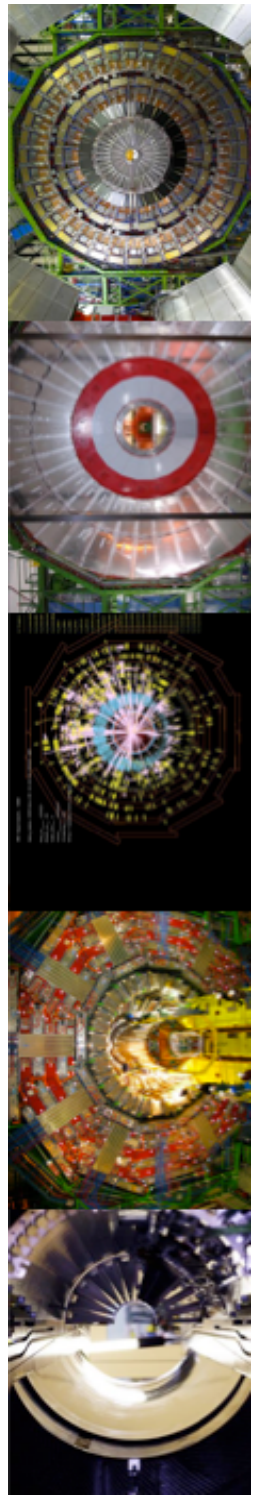
Results, description by theory





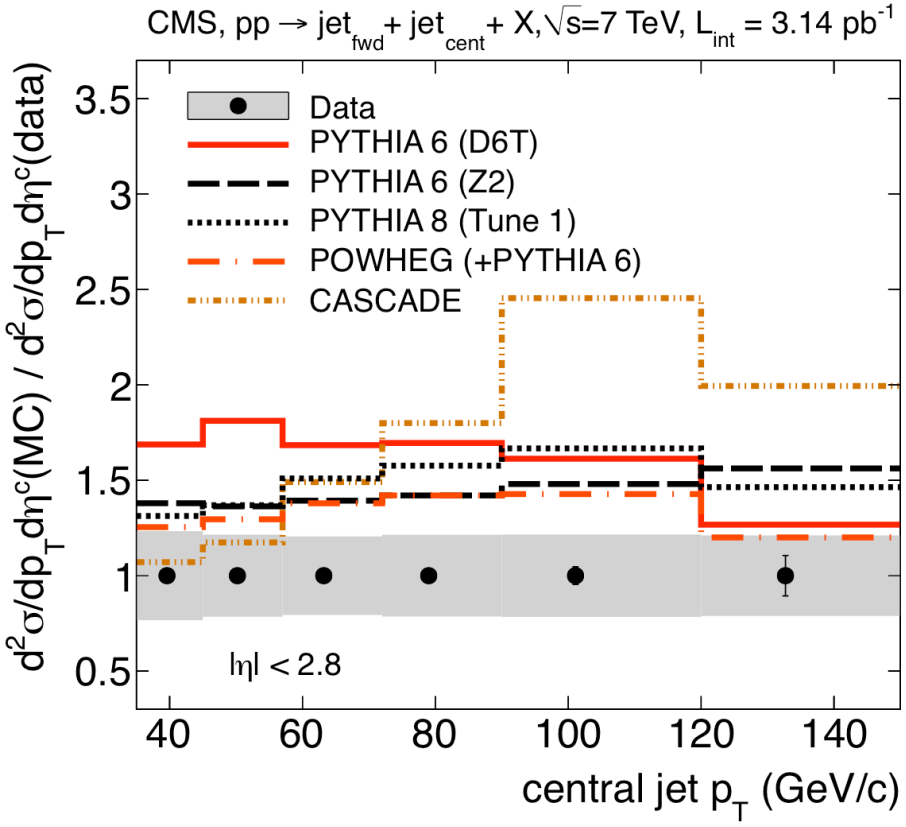


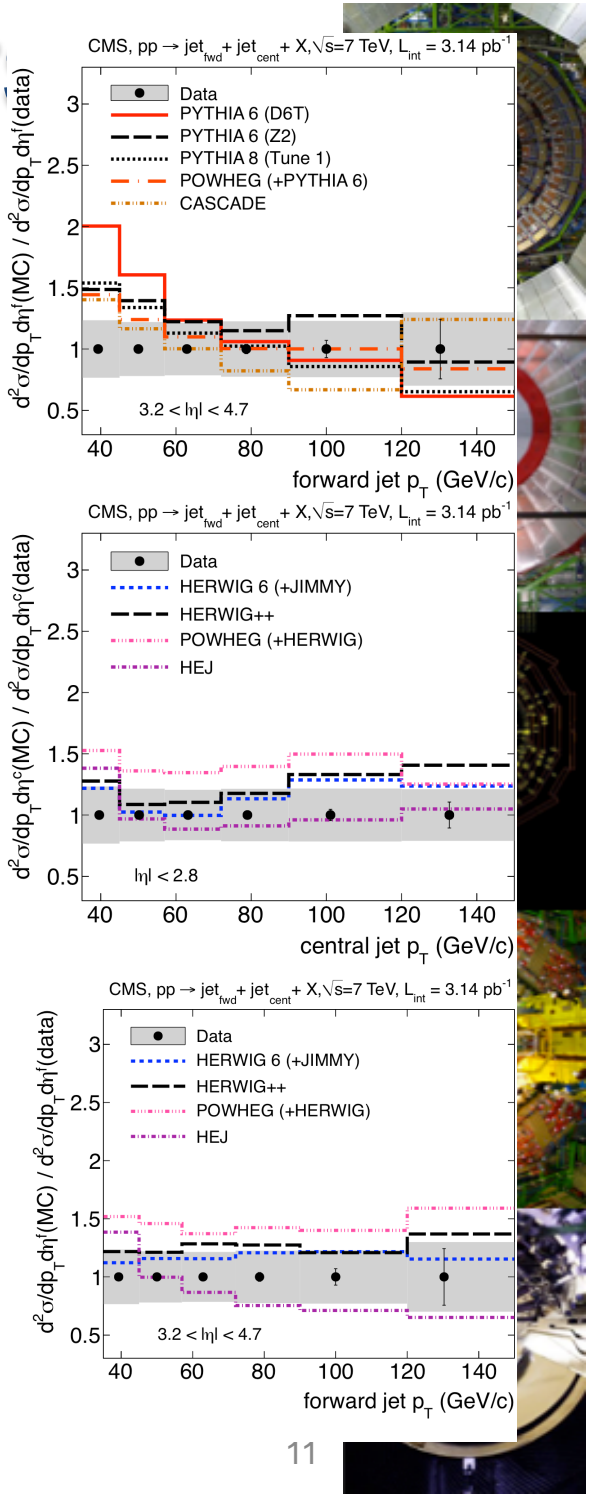




CENTRAL+FORWARD DIJET

Results, description by theory





– Most models tend to overshoot the data.
– HERWIG and HERWIG++ (with angular ordering) consistent with data.
– Other generators cannot describe the data over the full p_T range.
– CASCADE has different pT dependence at all – initial state shower?
– HEJ (parton level) describes data reasonably well.
– Larger discrepancies for central jets.

INCLUSIVE / EXCLUSIVE DIJETS

(CMS-PAS-FWD-10-014)

– Measurement of the ratios as function of separation $|\Delta y|$ for calorimeter jets with p_T>35 GeV and $|\eta|$<4.7

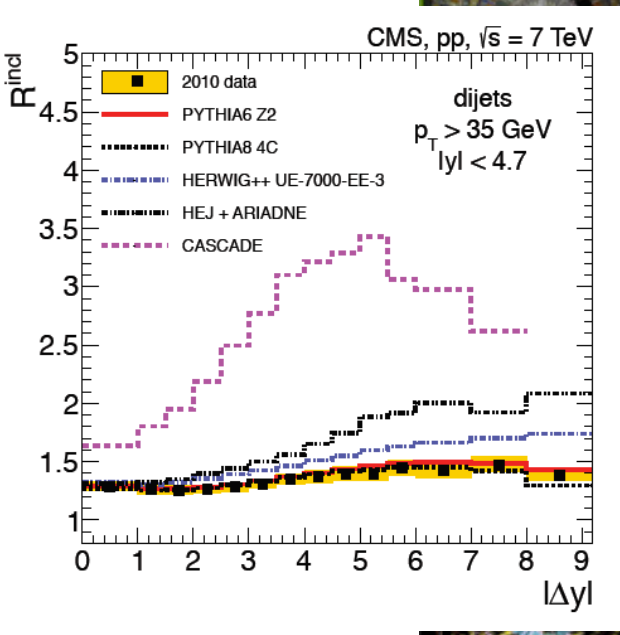
$$R = \frac{\sigma_{dijet}(\text{inclusive or MN})}{\sigma_{dijet}(\text{exclusive})}$$

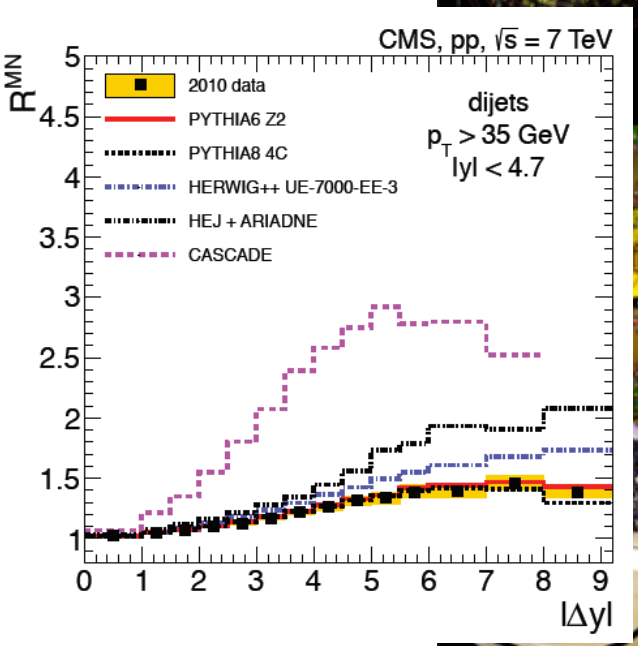
– exclusive: only two selected jets allowed per event.
– inclusive: each pair of selected jets considered
– Mueller-Navelet (MN): Subset of inclusive with most fwd and most bw jet

– Aim: Pin down effects beyond collinear factorisation, like BFKL evolution etc.

– Selection: single-jet trigger above 15 GeV for moderate Δη (33nb^{-1}) and dedicated fwd-bw jet-pair trigger for large Δη (5pb^{-1}).

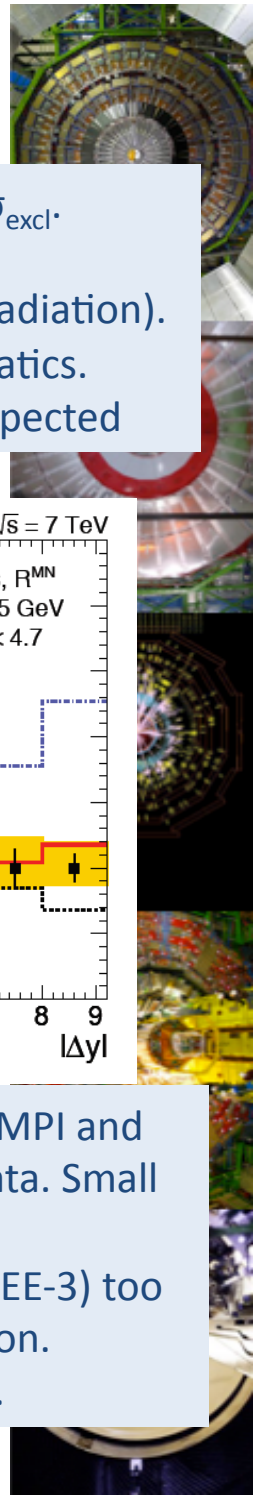
– Bin-by-bin correction for detector effects from HERWIG6+Jimmy and PYTHIA6 (Z2) (default PYTHIA, HERWIG for uncertainty).
– small corrections, but largest uncertainty of 1.3-8.0%.



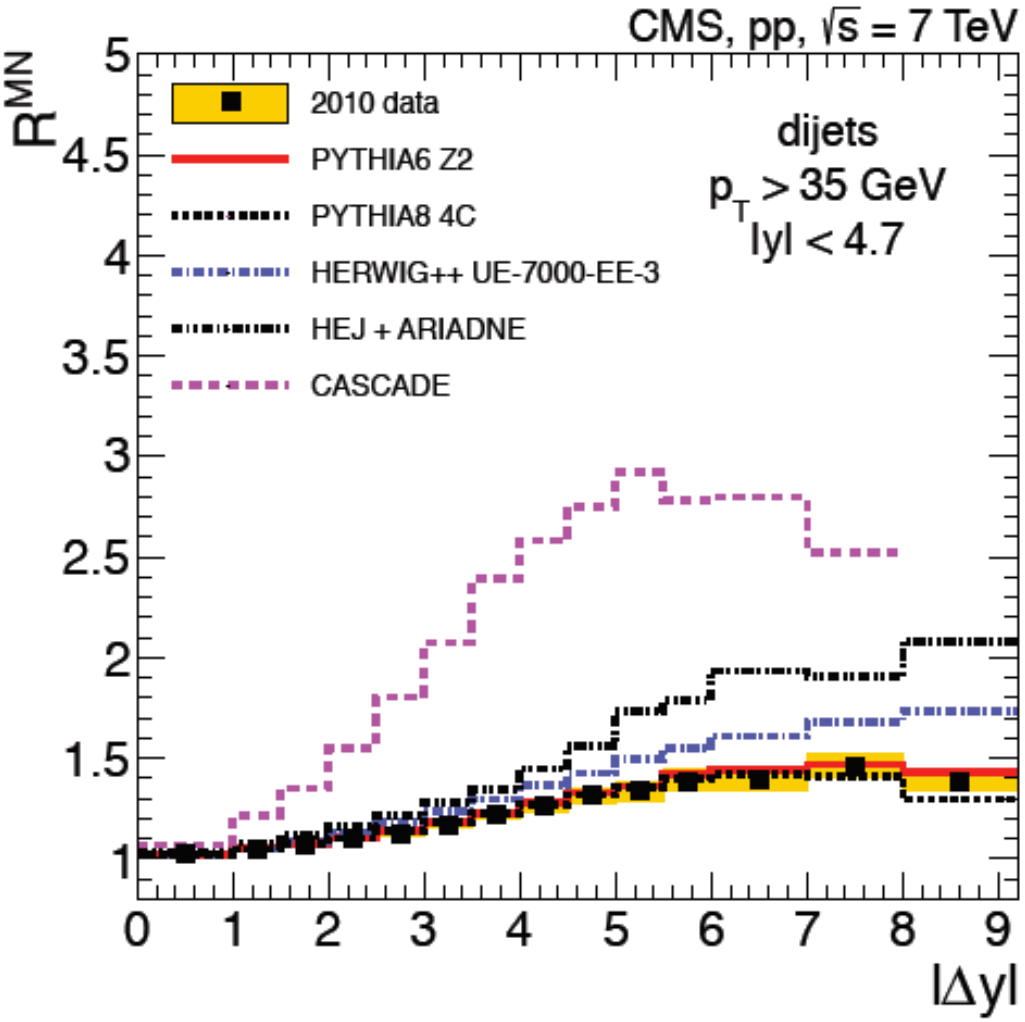


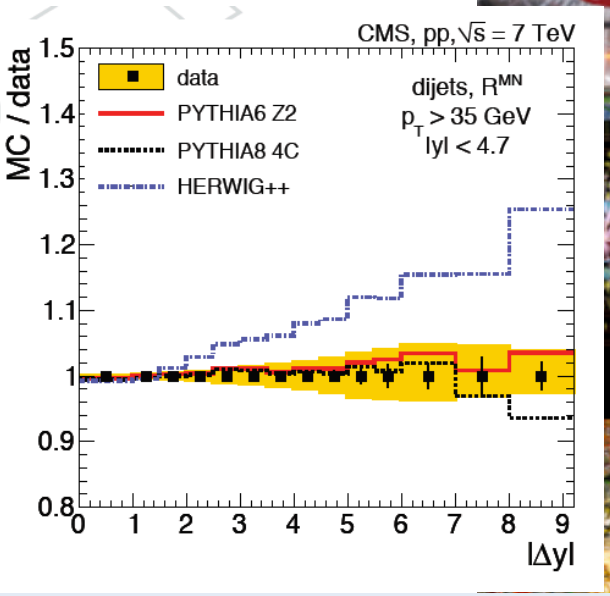
INCLUSIVE / EXCLUSIVE DIJETS

Result, description by MC



– σ_{incl} 1.0-1.4 times larger than σ_{excl}.
– Expected rise of R with Δy
(phase space for hard parton radiation).
– Decrease at highest Δy: kinematics.
– at largest |Δy| $R_{incl} \sim R_{MN}$ as expected





– PYTHIA6 (Z2) with and without MPI and PYTHIA8 (4C) agree well with data. Small MPI effect!
– HERWIG++ 2.51 (tune UE-7000-EE-3) too high at medium / large separation.
– CASCADE and HEJ+ARIADNE off.

SUMMARY

Conclusions and outlook

- Forward and small-x physics at the LHC is a fascinating and rich field – opportunity to tackle many non-understood issues!
  - Huge CMS rapidity coverage and very large LHC energy help!
  - Parton evolution? DGLAP vs. BFKL vs. CCFM etc.?

- Forward and forward+central (di)jet measurements as natural extrapolation of central jet measurements to smaller x values
  - Specific sensitivity to parton evolution schemes and low-x PDFs.
  - Data not perfectly described by any model; HERWIG and HEJ show best agreement with forward+central dijet events.

- Ratio of inclusive to exclusive dijet as function of rapidity separation:
  - Good description by PYTHIA6/8; HERWIG with difficulties
  - Small sensitivity to MPI simulation.

- Measurements can clearly further constrain models for multijet production over large rapidity range. More detailed studies to follow:
  - Correlations between forward and central jets
  - Studies of non-global effects and super-leading logs
  - ….