

QCD with Forward Jets at the CMS experiment

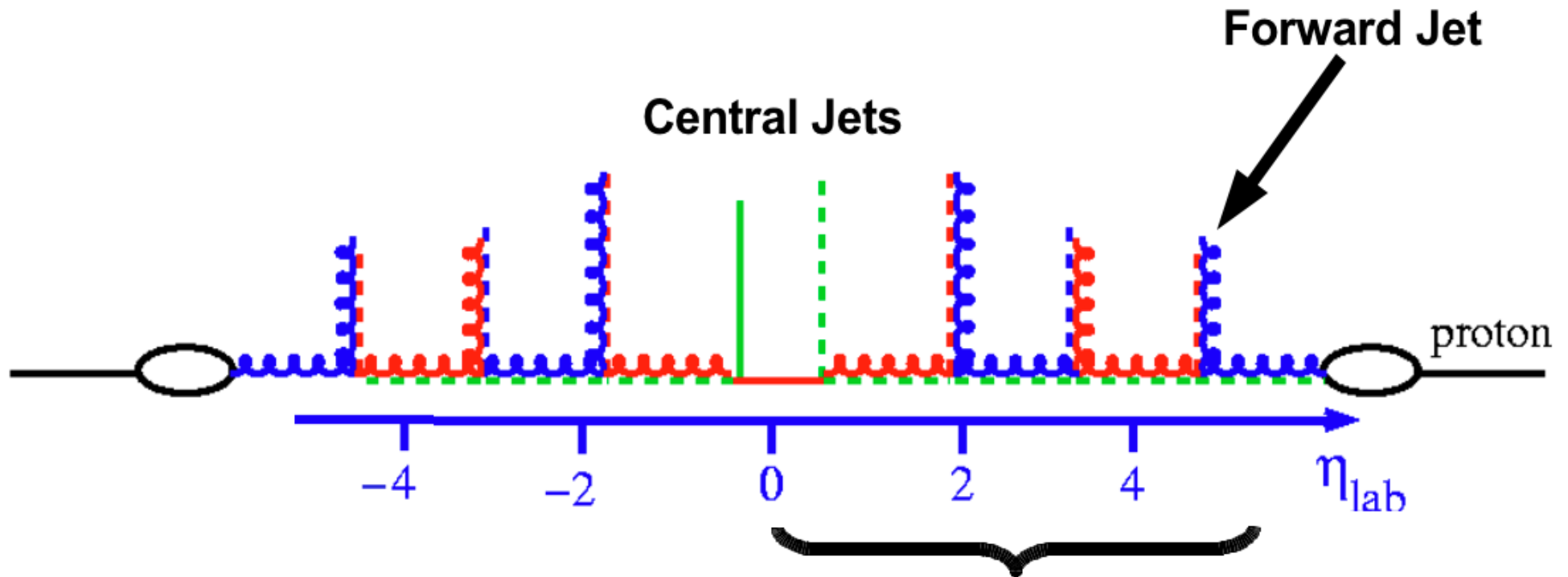
Niladri Sen, DESY

FSP CMS Annual Workshop '09

Outline

- **Physics Motivation**
- **Parton Dynamics Analysis**
- **Multiple Interactions**

Forward Physics at LHC



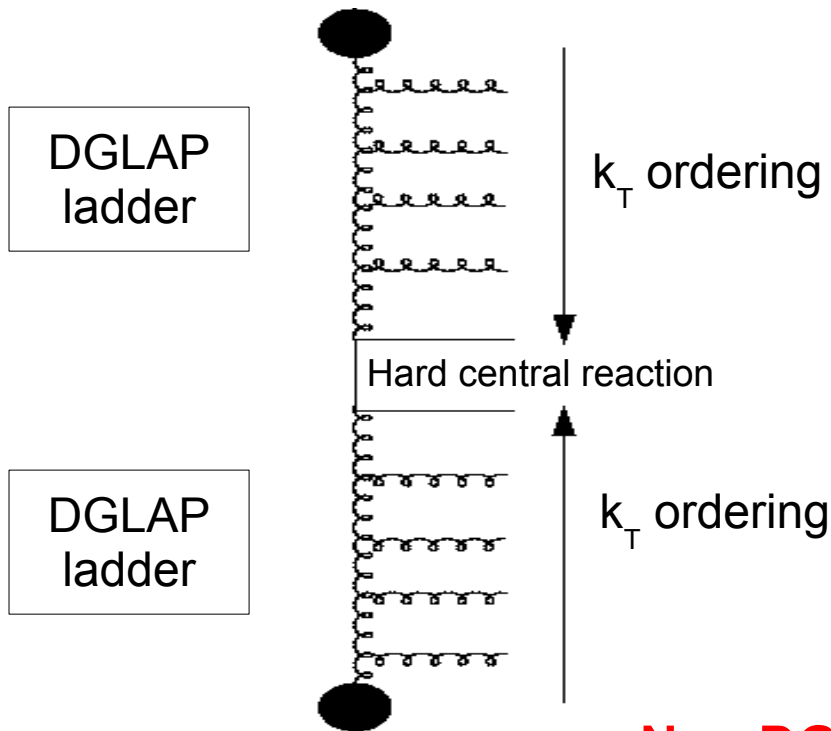
- Opens up phase space for emissions, higher order reactions
- Possible to apply constraints on parton ladder
- Gain information on the full parton evolution

→ Tool to study higher order QCD reactions

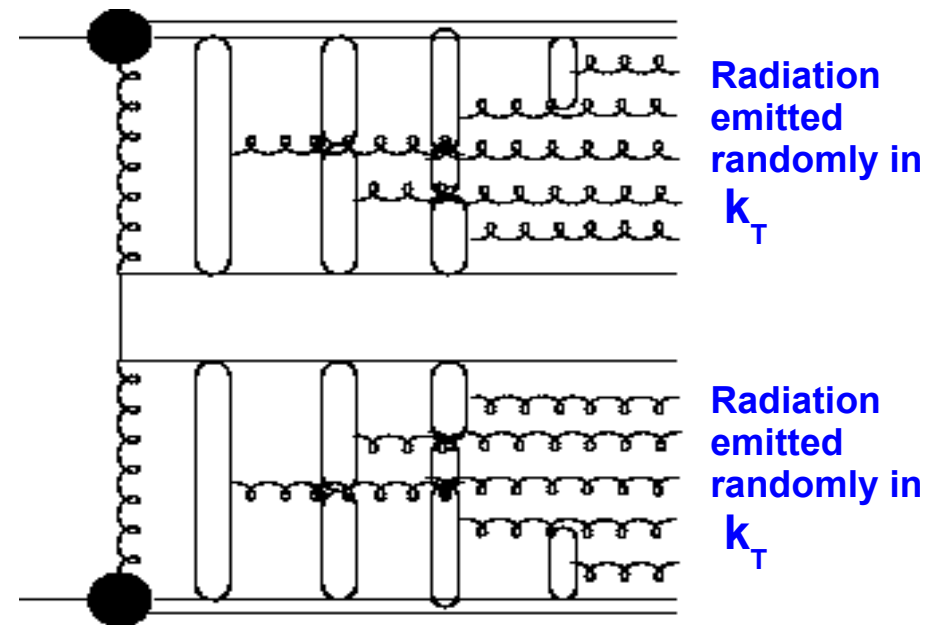
Parton Dynamics

DGLAP

(Dokshitzer-Gribov-Lipatov-Altarelli-Parisi)



Color Dipole Model (CDM)

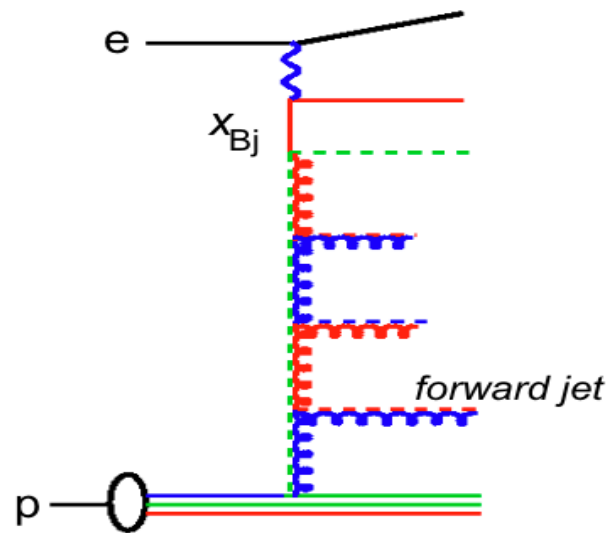


Non DGLAP calculations

- ➔ **No ordering in k_T of emitted partons**
- ➔ **Can expect more harder radiation close to proton remnant (the forward region)**

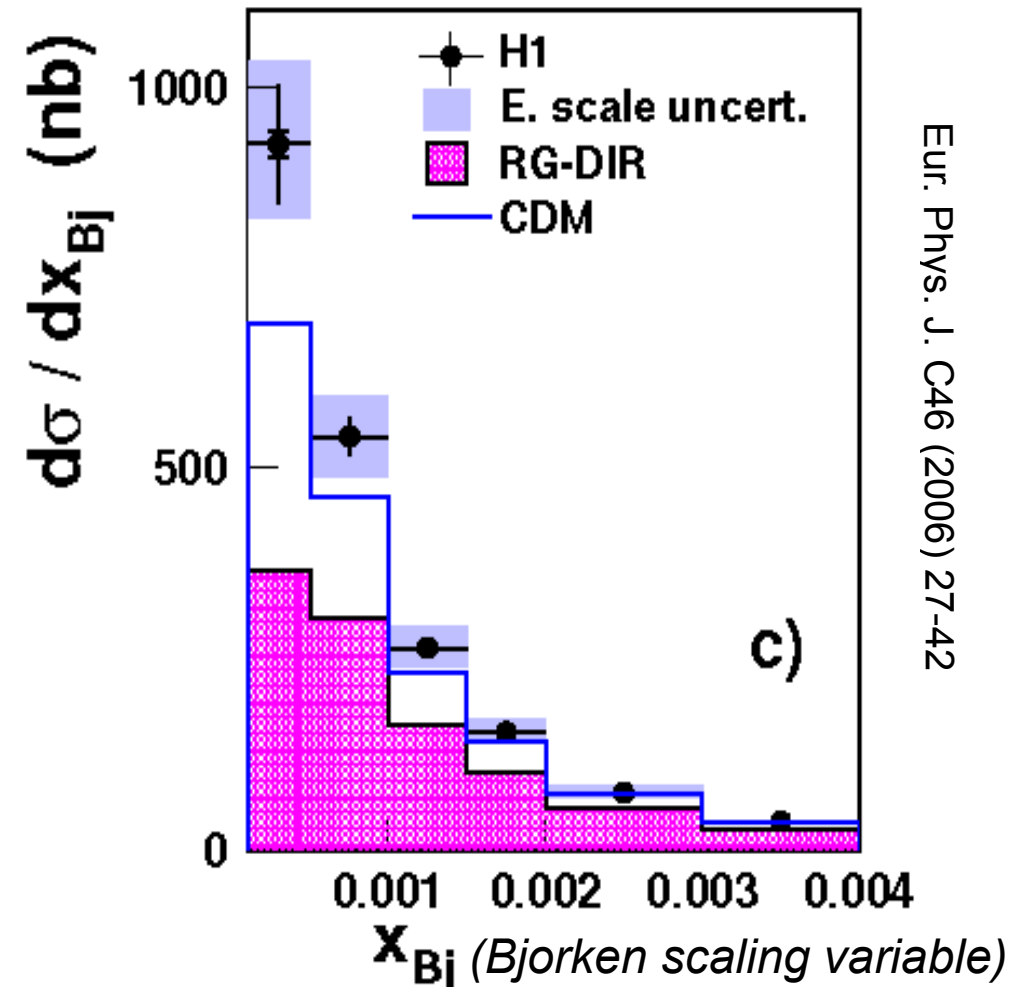
Parton Dynamics at H1

In **ep** physics at **H1**, **DGLAP** describes inclusive measurements (e.g. F_2) **successfully**, but **fails** for more **exclusive final states**, for example **forward jet production**:



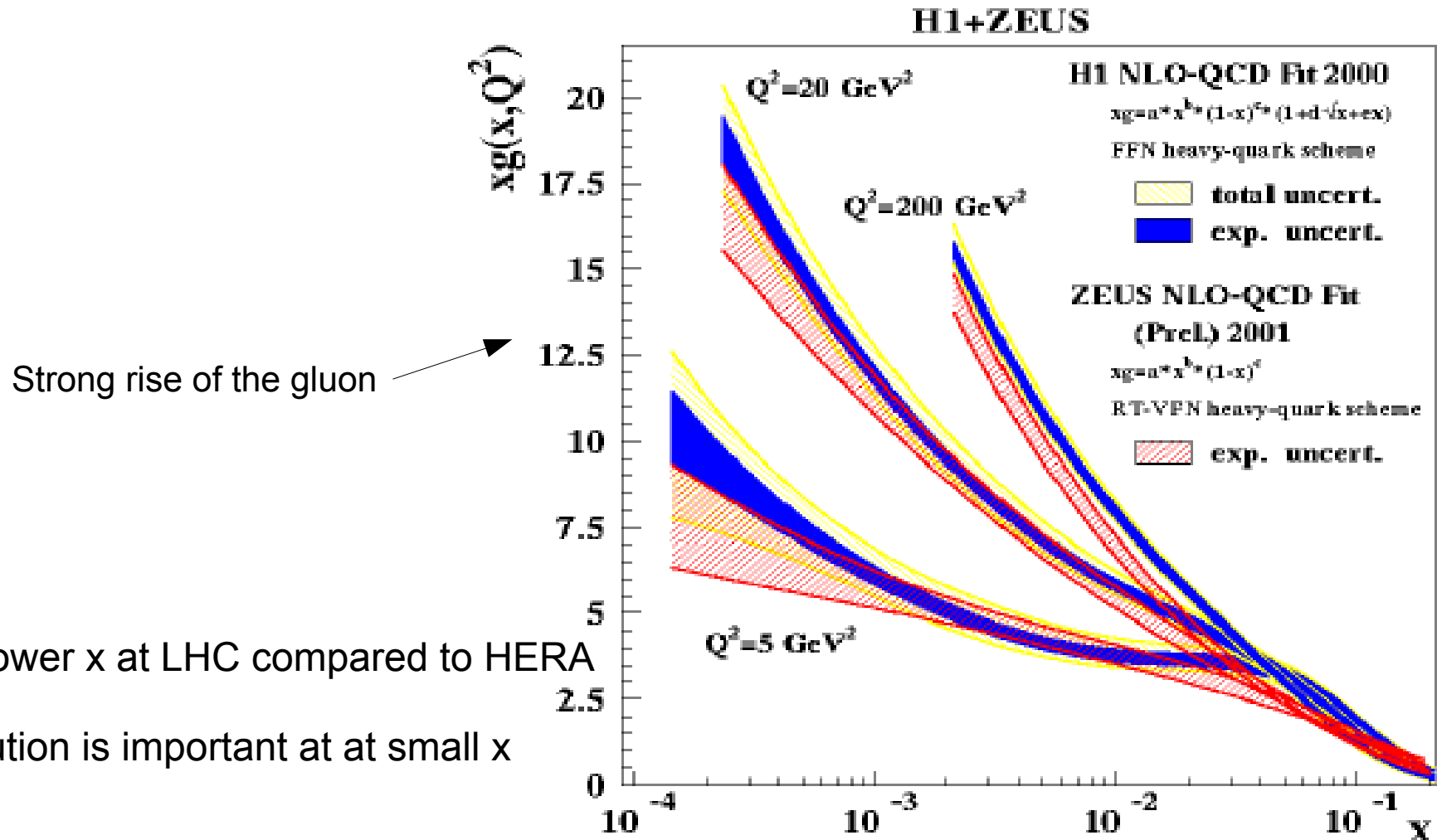
→ Kt-ordering of emissions (DGLAP) is not sufficient.

→ Need more hard emissions in forward region (e.g. CDM).

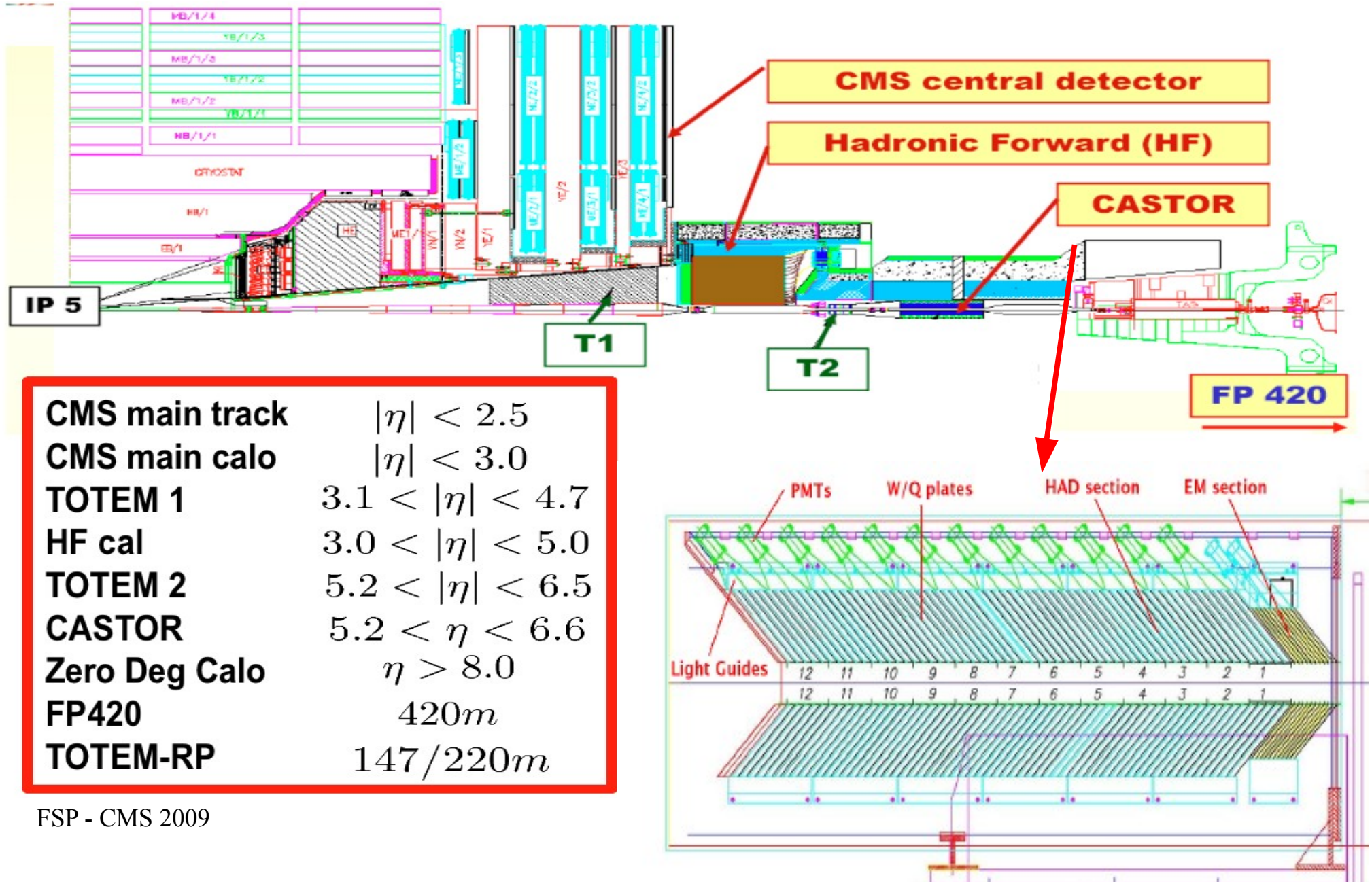


PDFs at Low x

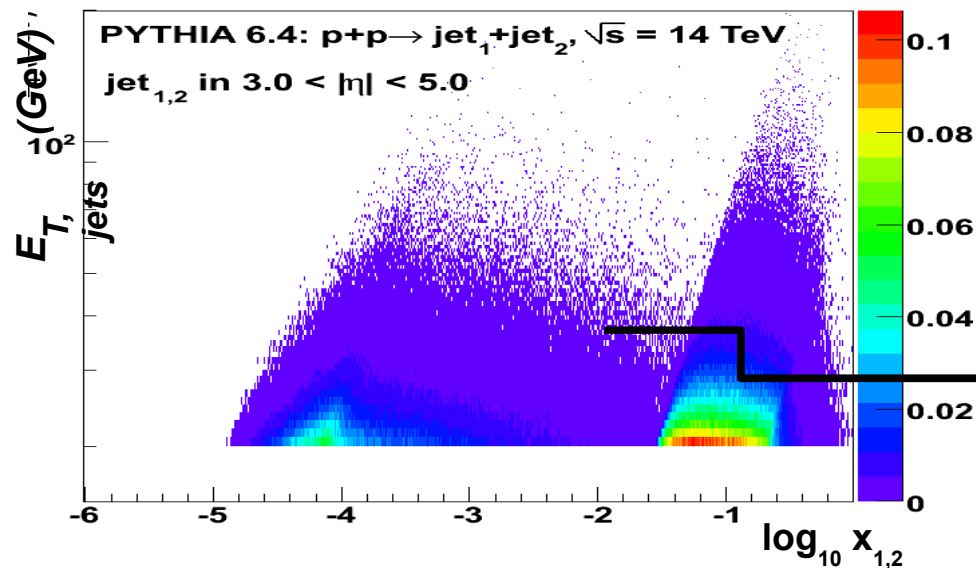
HERA experiments have determined PDFs down to $x \sim 10^{-4}$



Forward Detectors around IP5



Forward means Low x



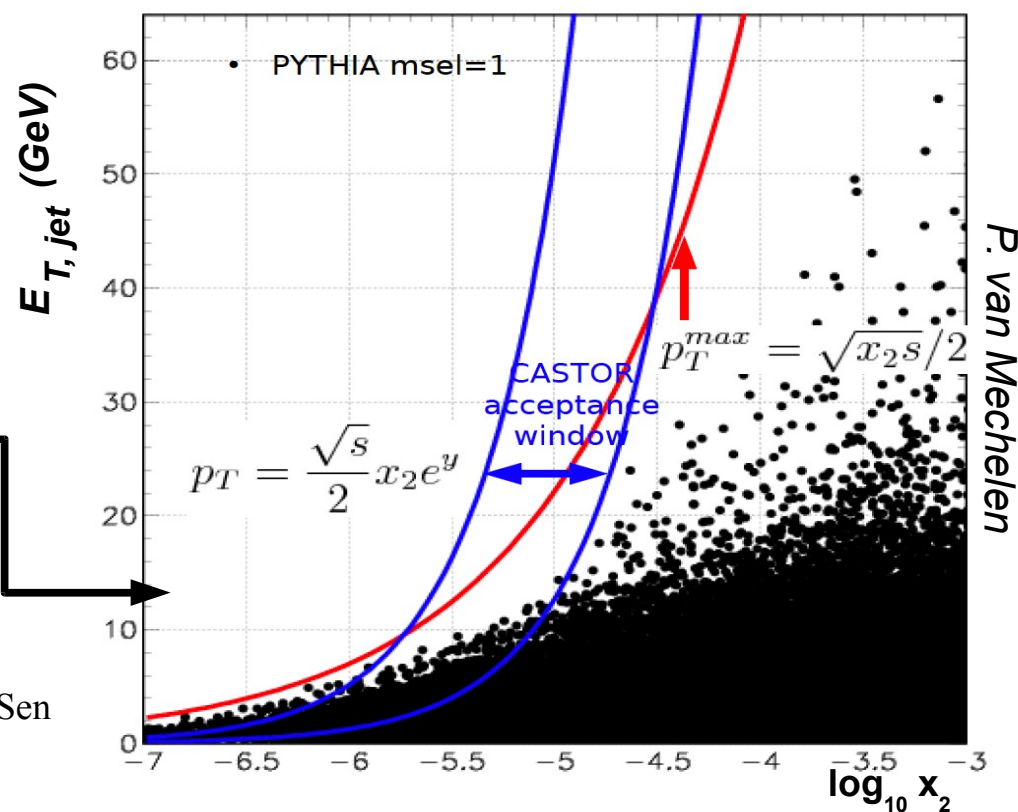
Jets in CMS Hadronic Forward Calorimeter
 $(3 < \eta < 5)$

$$x \sim 10^{-5}$$

Dijets, at least one jet in HF
 CMS note PAS-FWD-08-001

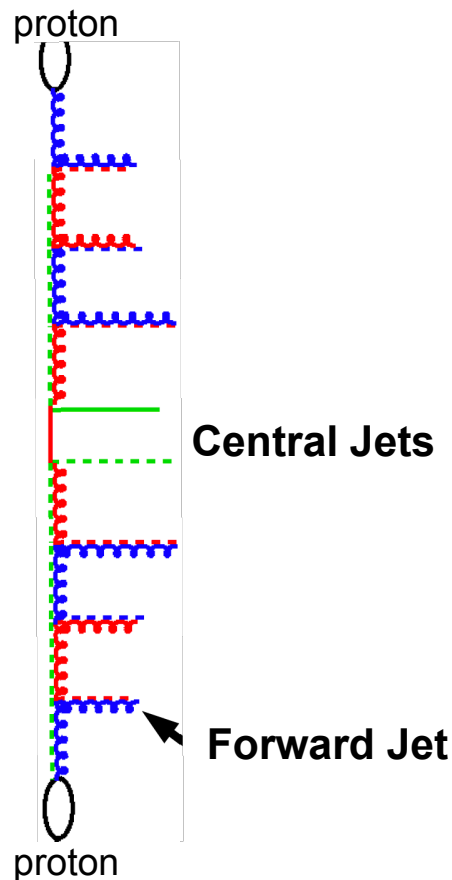
2 units in rapidity
 →
 Roughly 1 magnitude in x

Dijets with at least one jet in CASTOR
 $(5.2 < \eta < 6.6)$
 $x \sim 10^{-6}$

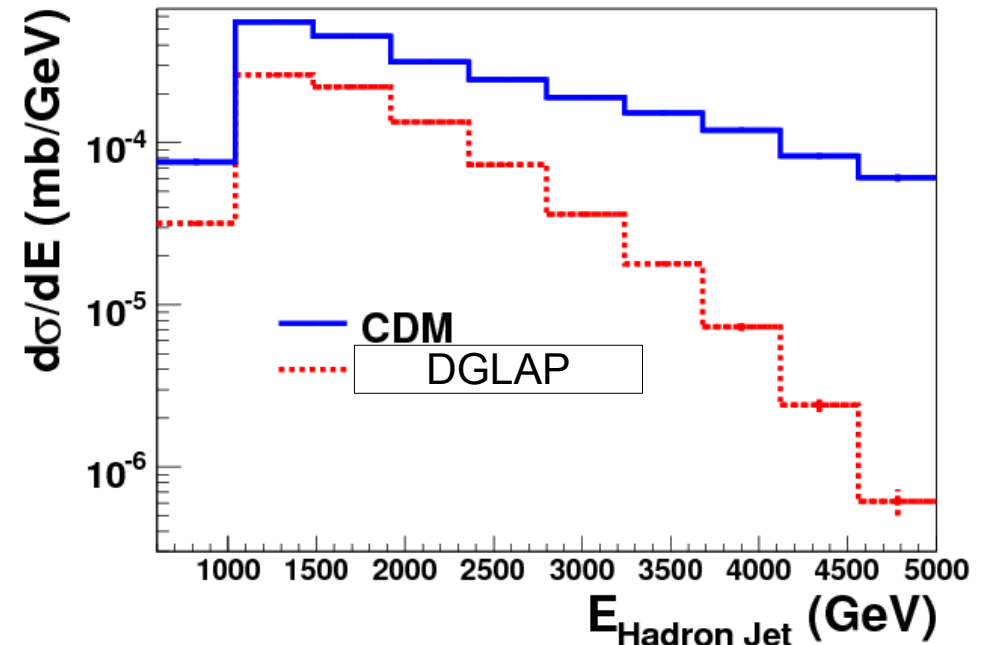


Forward Jets in CASTOR (with 7 TeV beams)

Selection: 2 central jets, 1 jet in CASTOR region ($5.2 < \eta < 6.6$) with $E_T > 10$ GeV



Hadron level – Generator studies



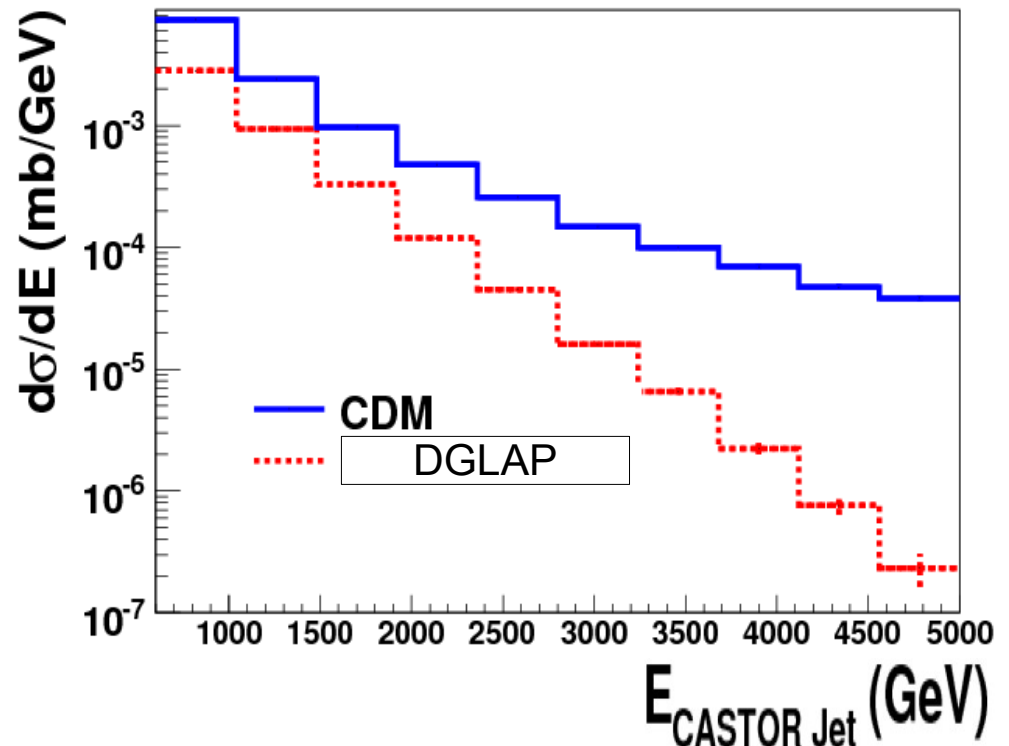
➡ CDM (BFKL like final state) predicts more hard jets in the CASTOR region

CASTOR Jets

- Selection: 2 central jets with $E_T > 10$ GeV , 1 jet in CASTOR region ($5.2 < \eta < 6.6$)
- Instead of conventional jet algorithm: **“CASTOR Jets”** (most active segment + neighbours)

Particle energy smeared according to test beam data

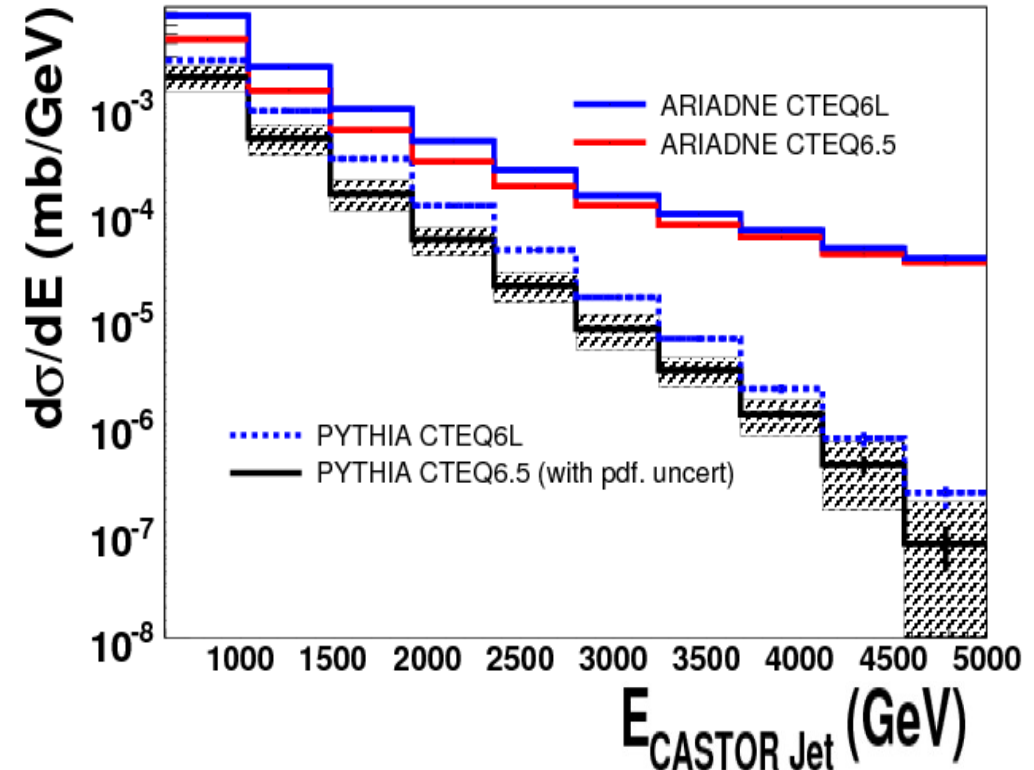
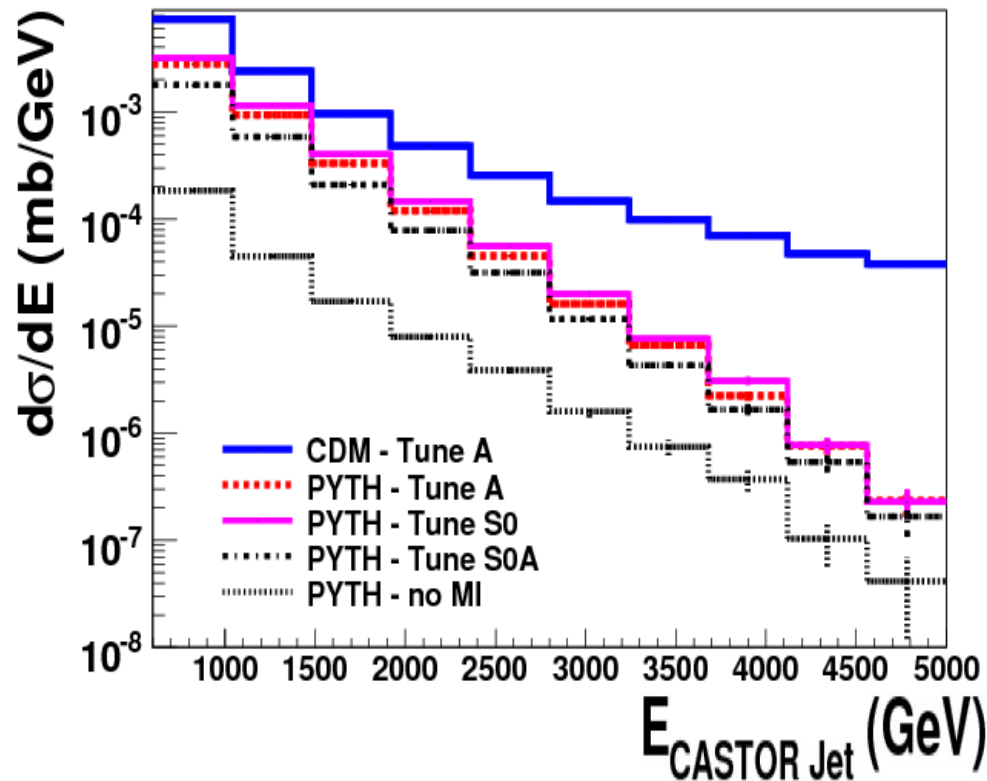
Noise cut of particles ($E_{\text{particles}} > 1$ GeV)



➔ **Measurements distinguish between different QCD models (DGLAP/non-DGLAP)**

Uncertainty from PDFs & MI

Selection: 2 central jets with $E_T > 10$ GeV, 1 jet in CASTOR region ($5.2 < \eta < 6.6$)

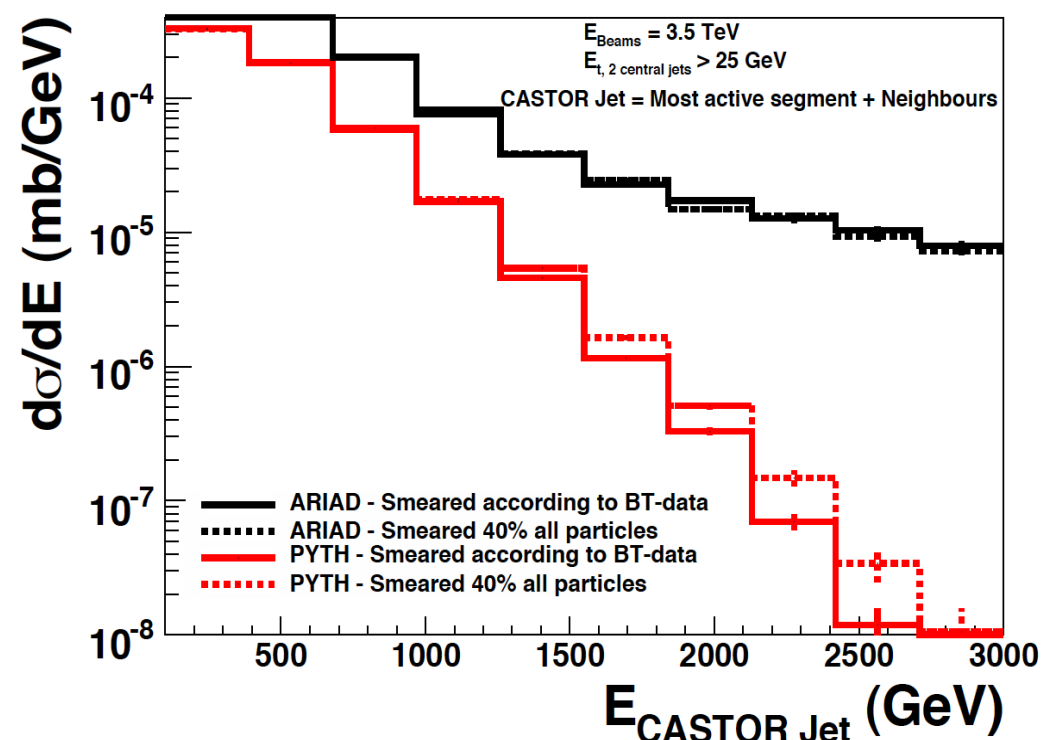
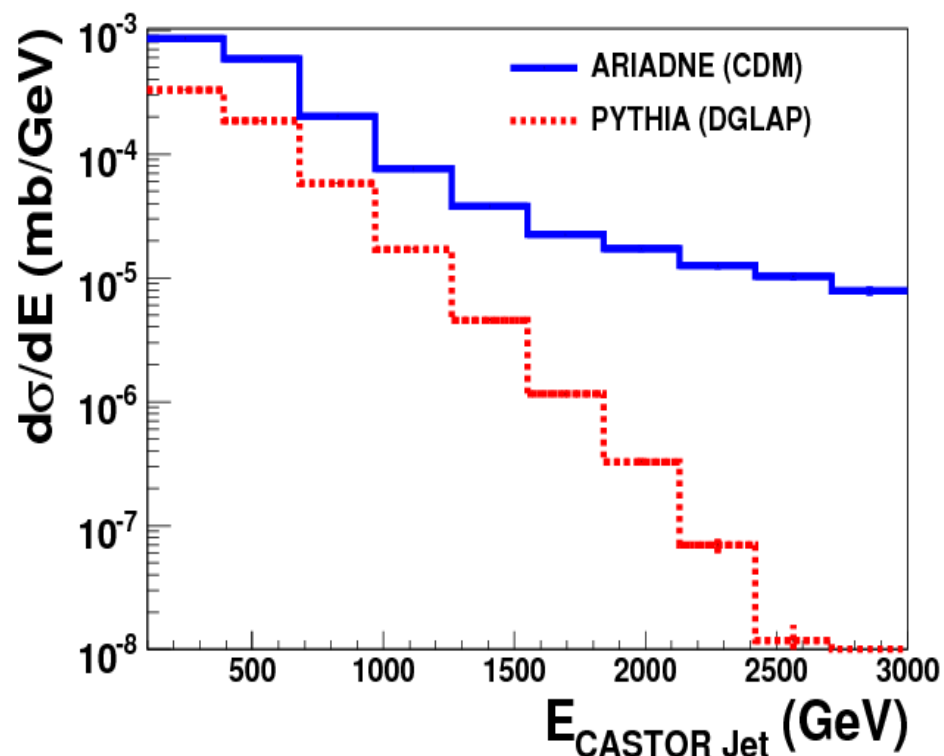


- Large effect from switching MI off in MC.
- Difference between CDM and PYTHIA still large at high energies
- DGLAP/non-DGLAP separation $\gg$ PDF uncertainty/sensitivity at high energies

Forward Jets in CASTOR (with 3.5 TeV beams)

Selection: 2 central jets with $E_T > 25 \text{ GeV}$, 1 jet in CASTOR region ($5.2 < \eta < 6.6$)

Study made for $< 1 \text{ pb}^{-1}$

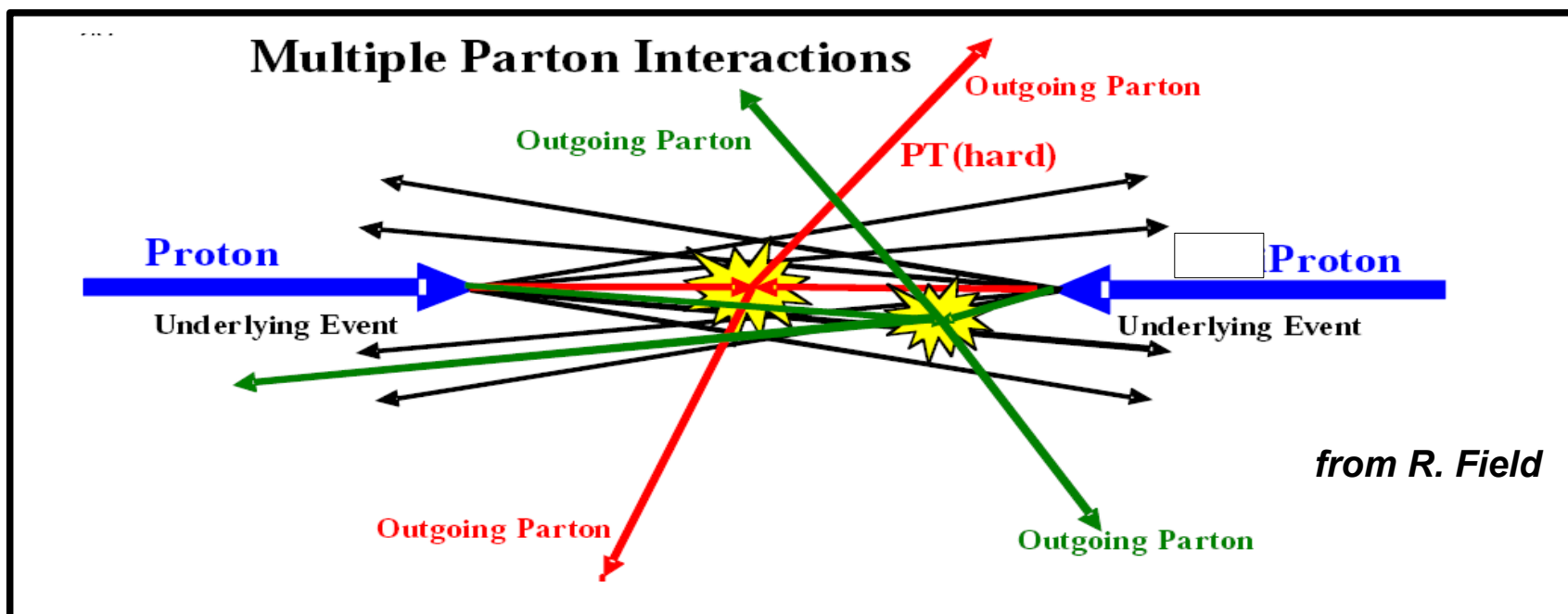


➔ One of the first topics to be analyzed using CASTOR

The Underlying Event

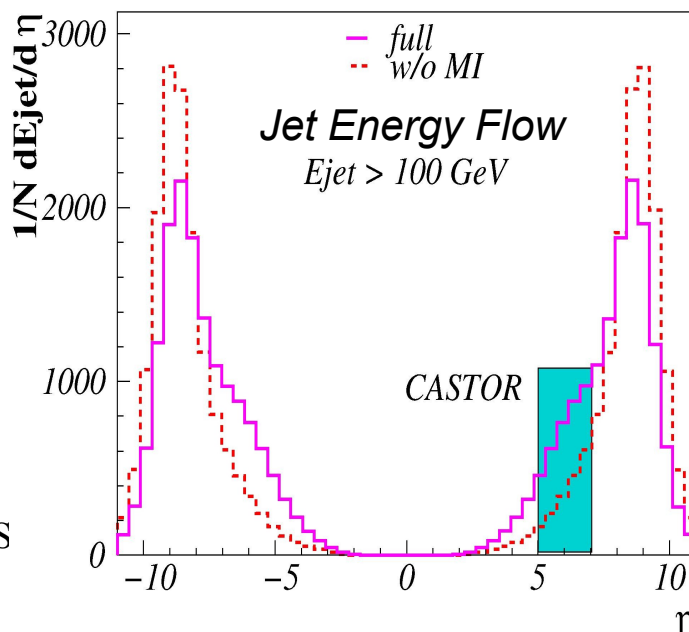
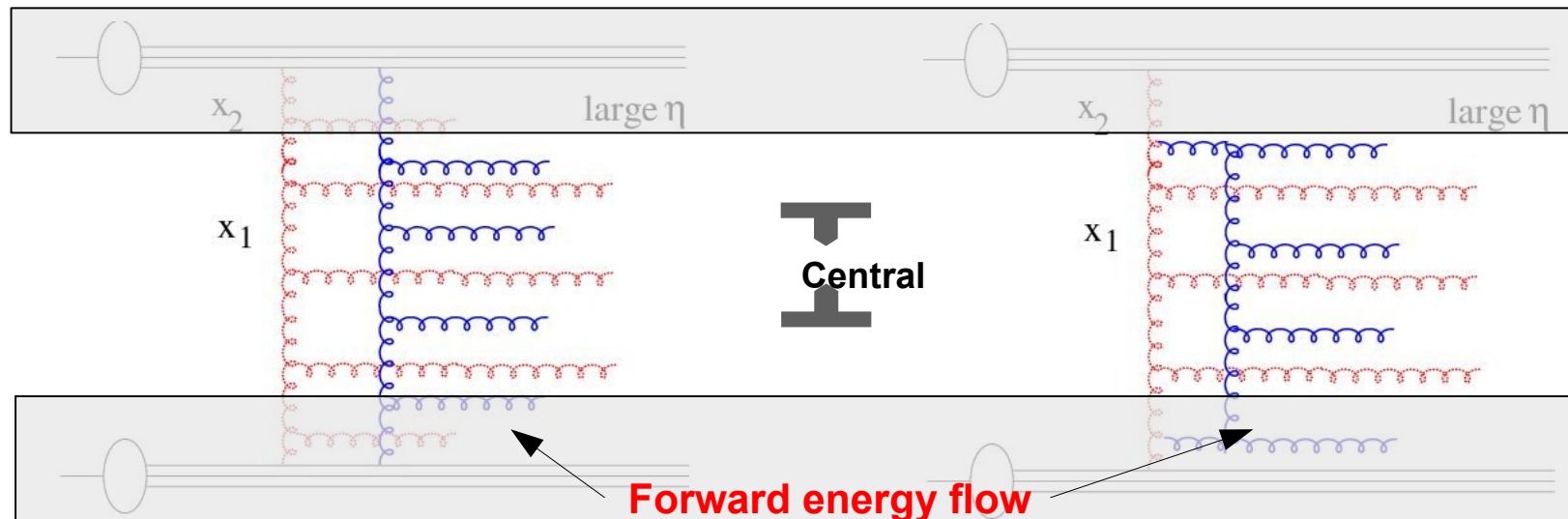
Everything except the studied LO process:

- Parton showers
- Multiple interactions:
 - Additional remnant-remnant, or parton-remnant, interactions (soft or hard)
- Not pile up



Multi-parton Interactions

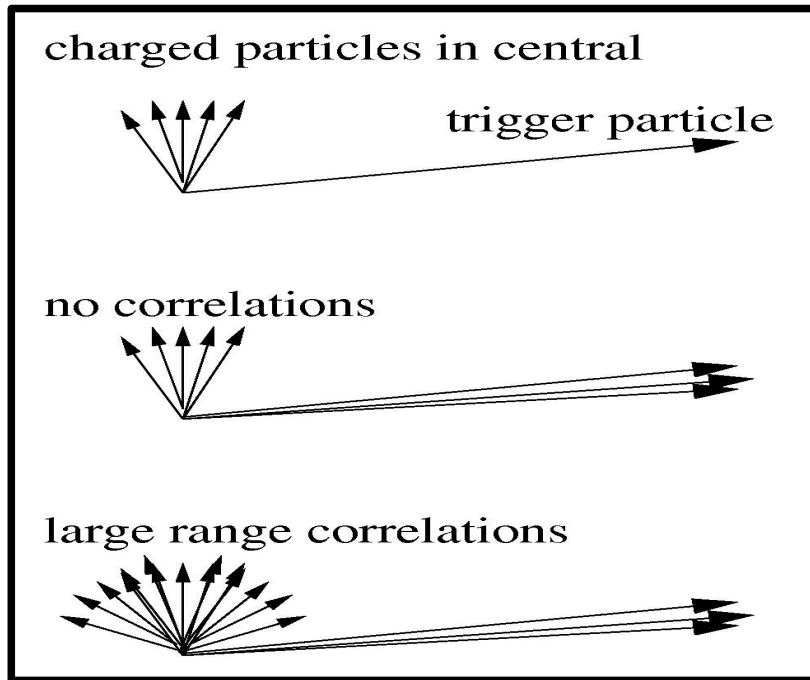
Can expect sensitivity to different MI scenarios close to the proton remnant (forward region).



MPIs affect the energy transferred from the beam remnant.

Sensitivity in the **CASTOR** region.

Long range correlations and MI

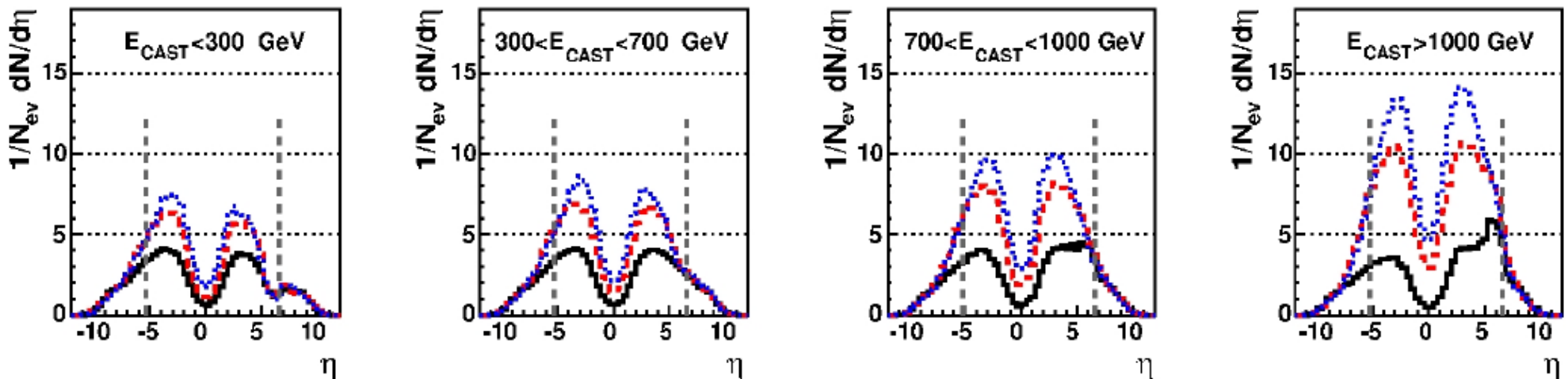


QCD events

- **With MPI:**
Large energy of trigger in CASTOR,
Higher particle multiplicity in central region
- **Without MPI:**
No, or very small, correlation

PYTHIA:

- Rick-Field's CDF tune A (tune A)
- Sandhoff-Skands tune 0 (tune S0)
- MI switched off



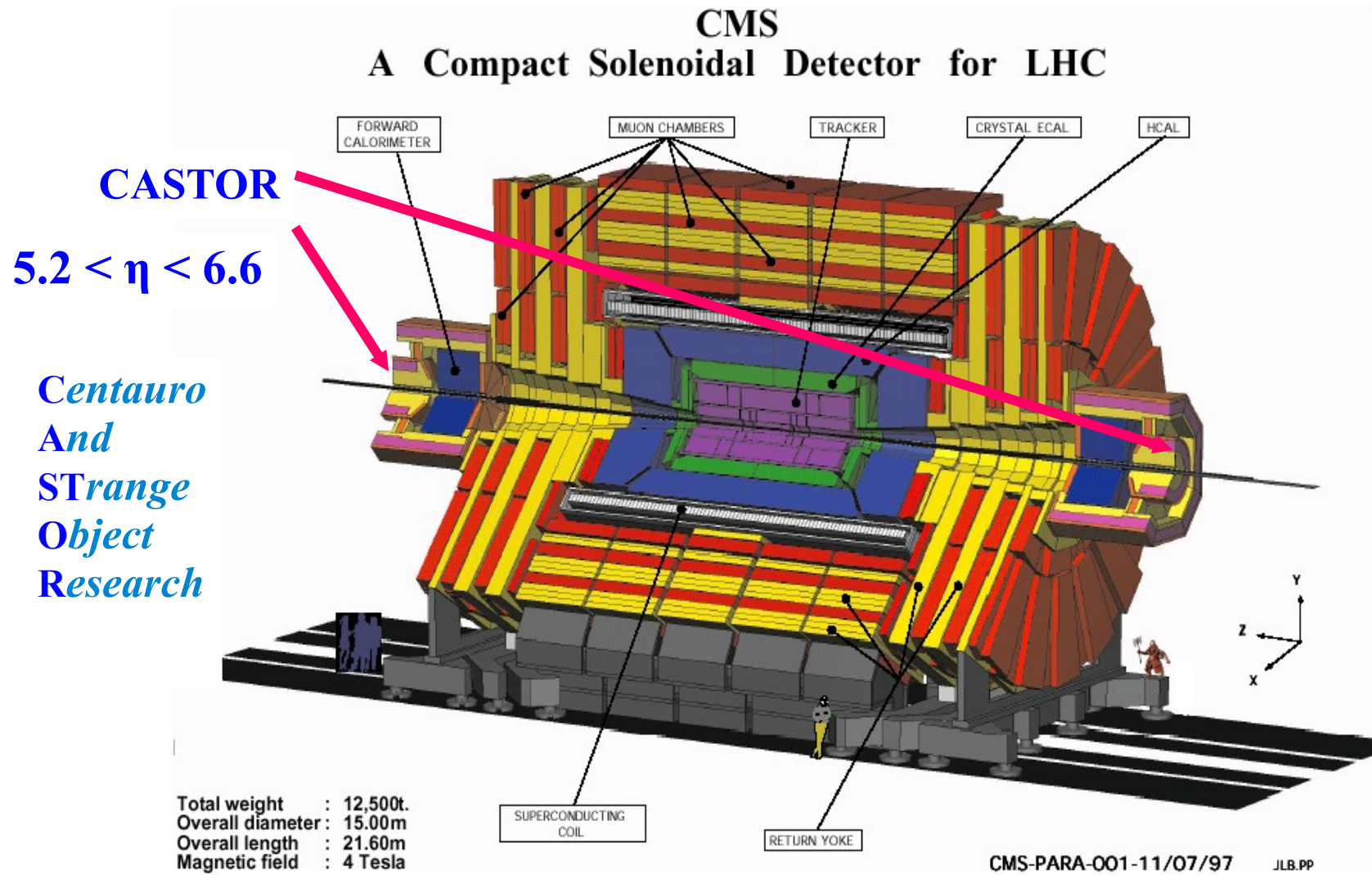
(CASTOR particles smeared according to beam test data + 1 GeV noise cut applied.)

Conclusions

- **QCD with forward jets will allow study of:**
 - **Low x physics: Parton dynamics beyond DGLAP**
 - **UE / Multiple interactions**
- **Previous experiments show the need more hard emissions in the forward region**
- **Measurements distinguish between different QCD models (DGLAP/non-DGLAP)**
- **Difference between models $\gg$ MI contributions & PDF uncertainties**
- **Triggering on forward jets can contribute to MI studies in the central region**
- **One of the first topics to be analyzed using CASTOR (study with 1 pb^{-1})**

Backup Slides

CASTOR in CMS



Technical Description

CASTOR – A Cherenkov radiation detector

Tungsten absorber plates

and

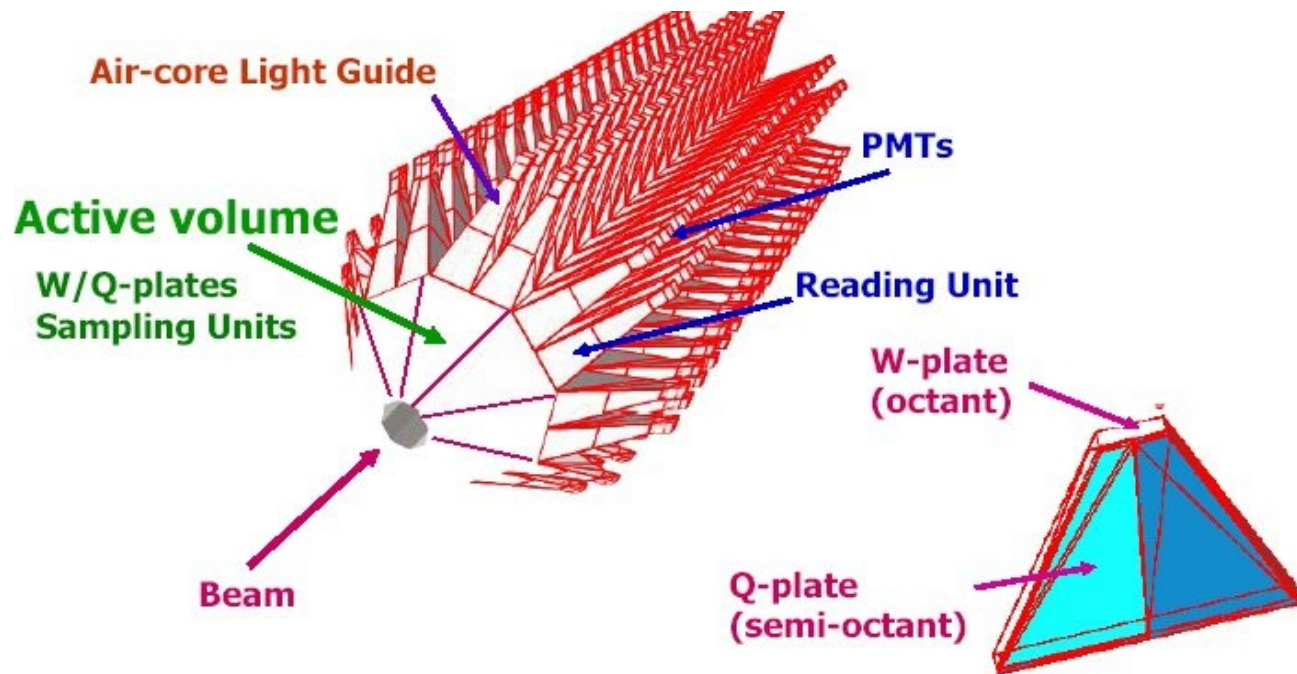
Quartz plates as active medium

sandwiched in

Octants with 2 columns of light guides and PMTs on top.

16 azimuthal * (2 EM + 12 HAD) longitudinal channels = 224 channels

Length: 1.6m, Diameter: 0.6m

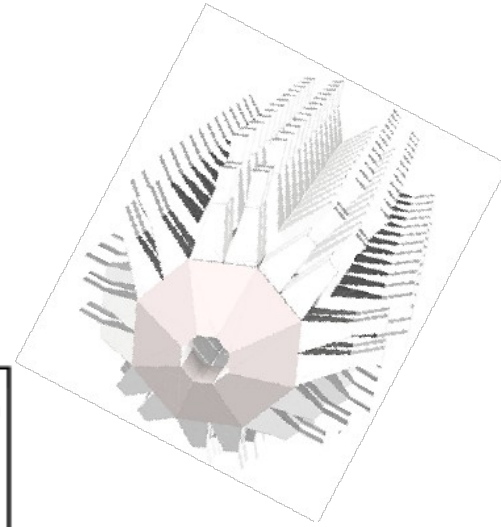
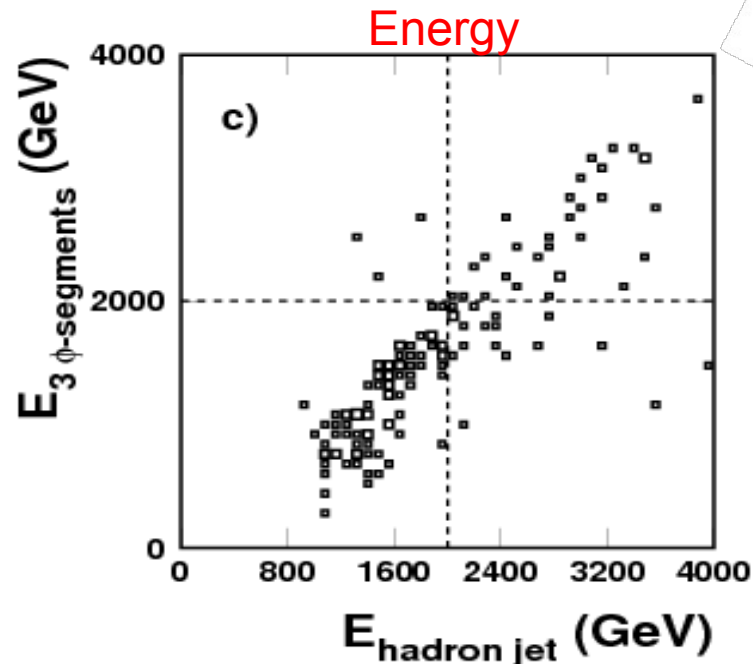
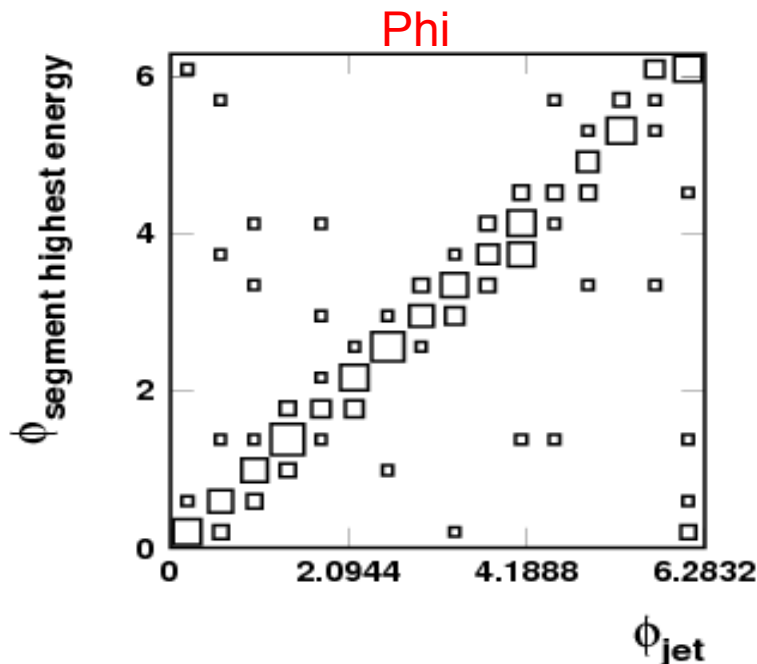


Jet Energy – CASTOR energy correlation

Measure deposit energy in CASTOR.

(MC studies – no detector simulation applied)

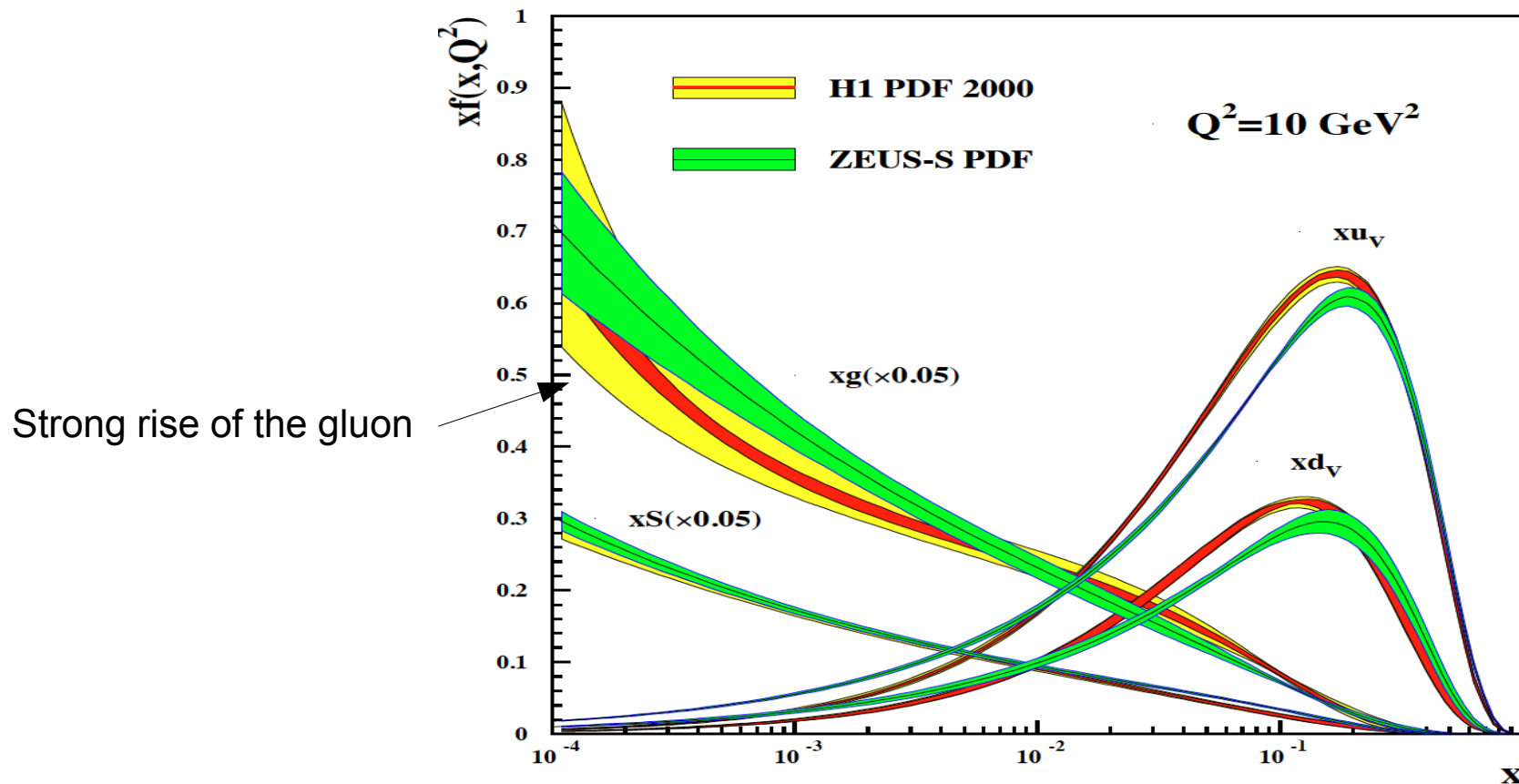
Reconstruct jet energy by summing energy in most active phi segment with neighboring segments.



- Good correlation in jet azimuthal angle and reasonable correlation in jet energy.
- Can be improved by more sophisticated algorithms

PDFs at Low x

HERA experiments have determined PDFs down to $x \sim 10^{-4}$



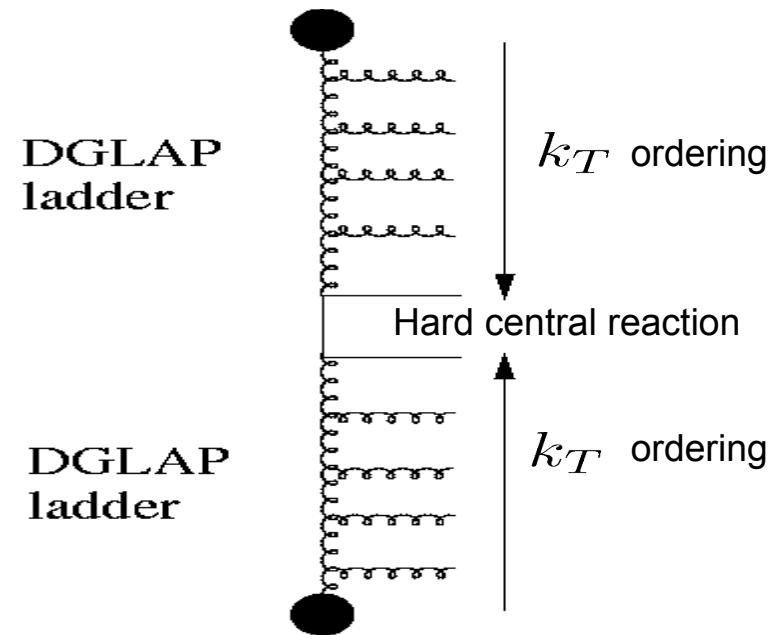
We will reach lower x at LHC compared to at HERA

Choice of evolution is important at small x

Parton Dynamics

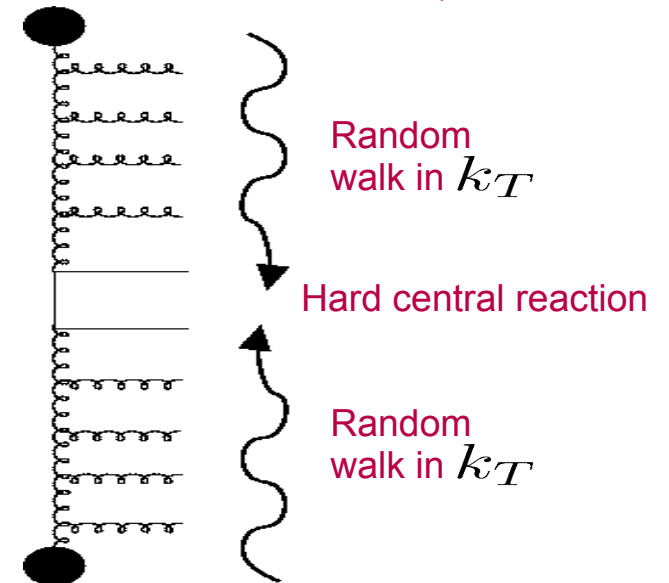
DGLAP

(Dokshitzer-Gribov-Lipatov-Altarelli-Parisi)

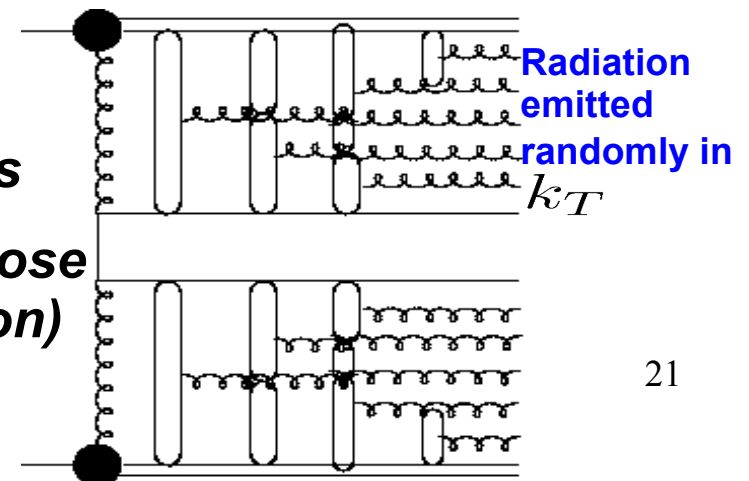


BFKL/CCFM

(Balitski-Fadin-Kripov-Lipatov)/
(Ciafaloni, Catani, Fiorani, Marchesini)



Color Dipole Model (CDM)



Non DGLAP calculations

- ➔ No ordering in k_t of emitted partons
- ➔ Can expect more harder radiation close to proton remnant (the forward region)