Parton dynamics with the CASTOR calorimeter

CMS meeting. DESY 17/6-2009

Albert Knutsson

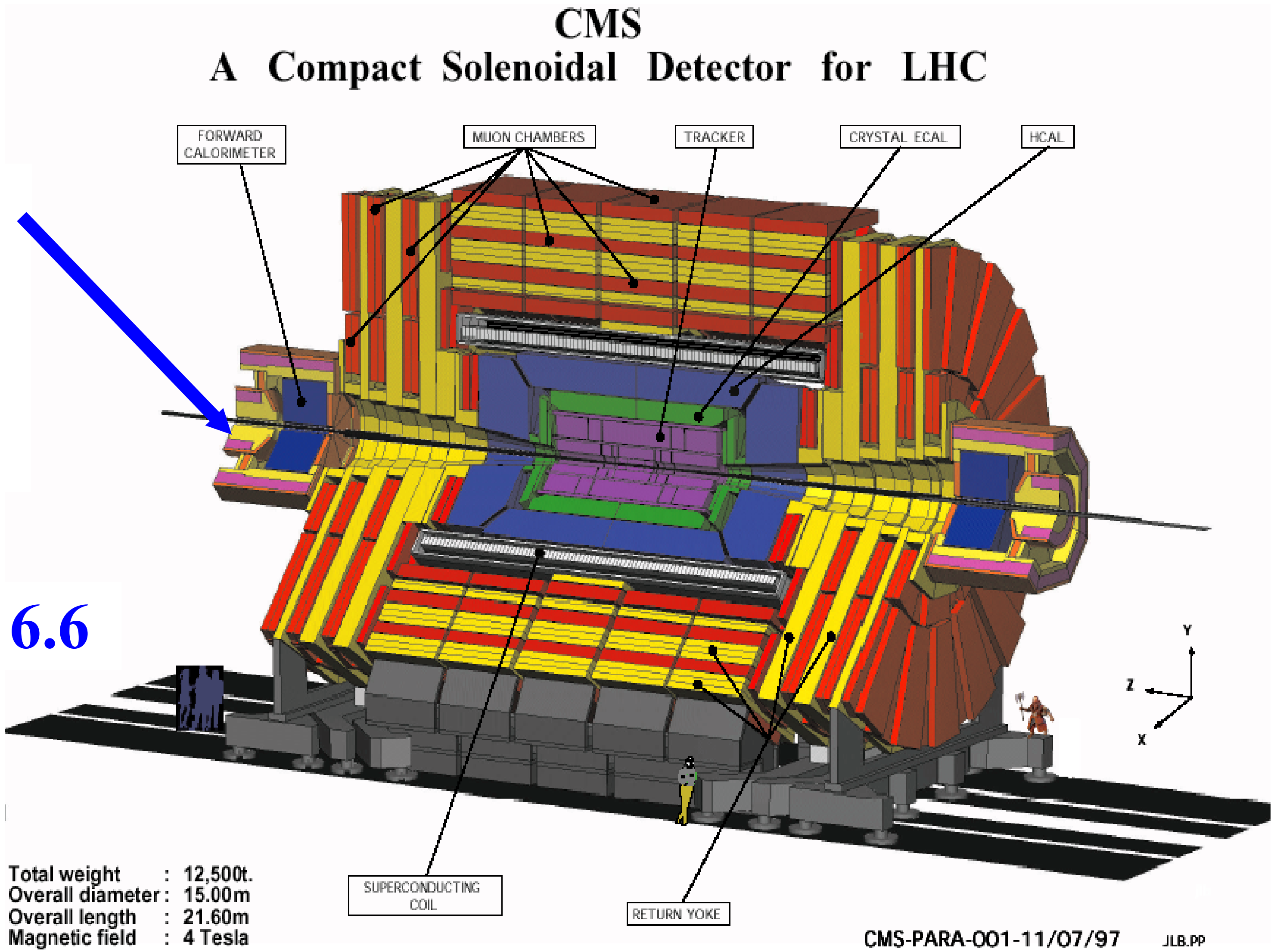
<u>Outline</u>

- **Introduction to CASTOR and parton dynamics**
- **2+Forward Jets and Mueller Navelet Jets**
- **Underlying event**
- **Summary**

The position of CASTOR

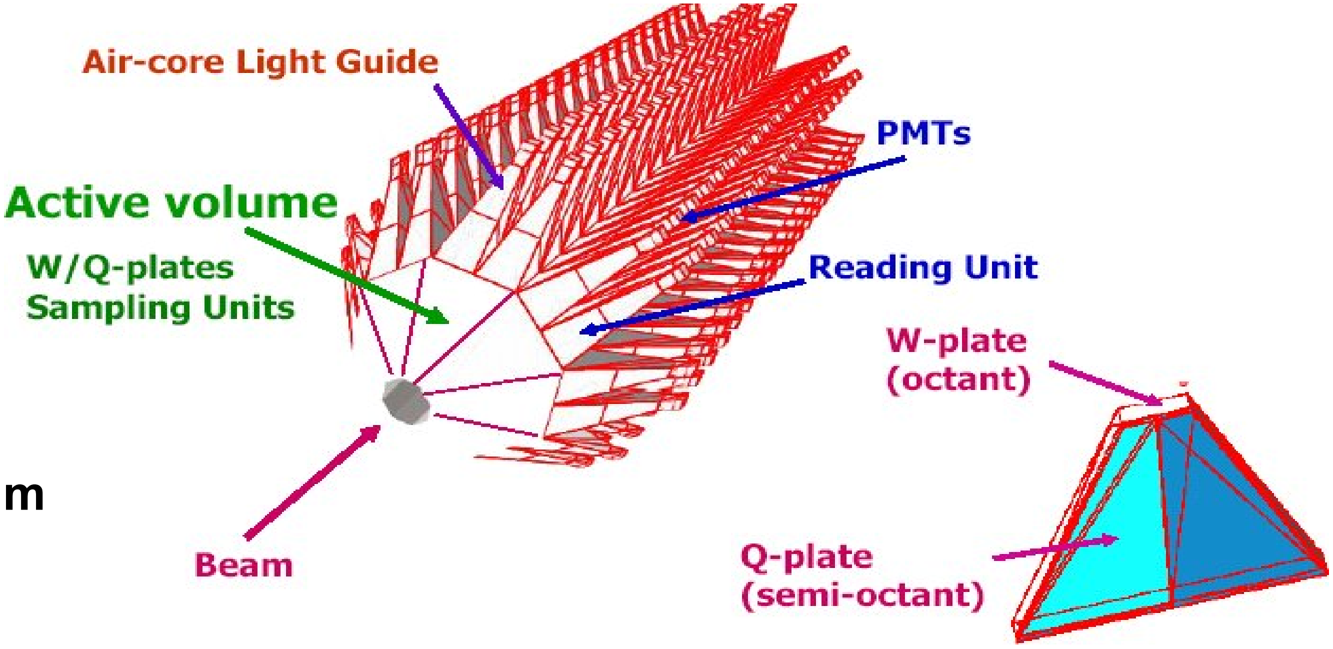
CASTOR
Centauro
And
STrange
Object
Research

$5.2 < \eta < 6.6$



Full CASTOR now assembling on CERN site.
Installation at IP5 next week!

CASTOR – A Cherenkov radiation detector



Tungsten absorber plates

and

Quartz plates as active medium

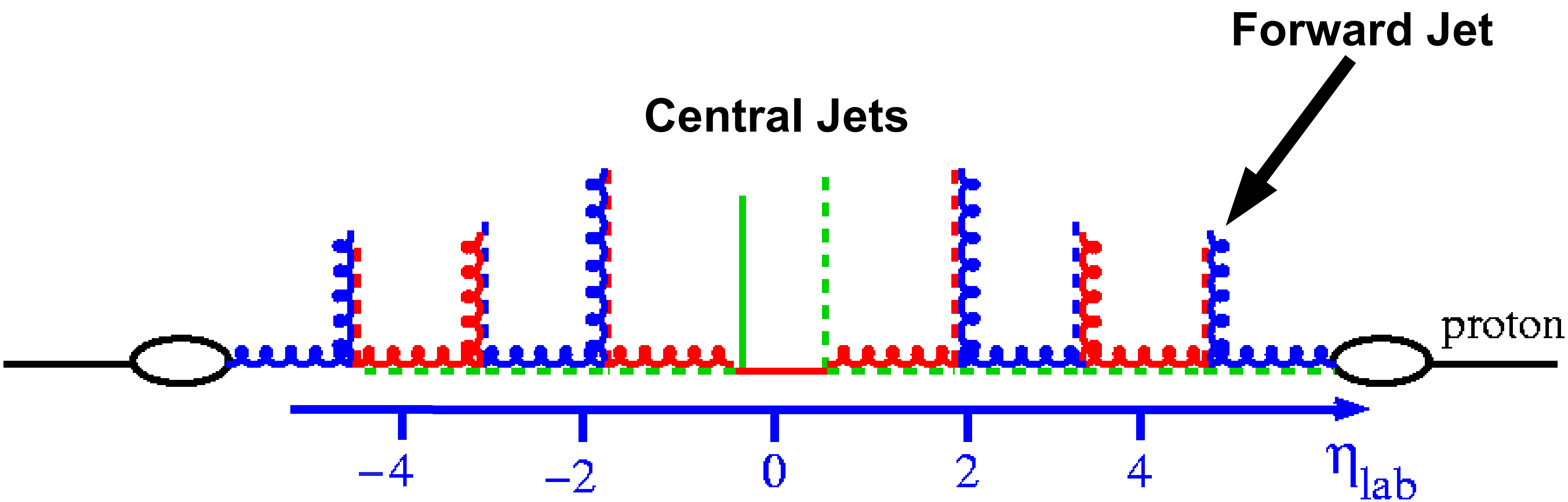
sandwiched in

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

16 azimuthal * (2 EM + 12 HAD) longitudinal channels.
Length: 1.6m, Diameter: 0.6m

Good segmentation in phi. No segmentation in rapidity.

Forward Physics - motivation



Hard jet or particle in forward region,
large rapidity range between central and and forward region

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

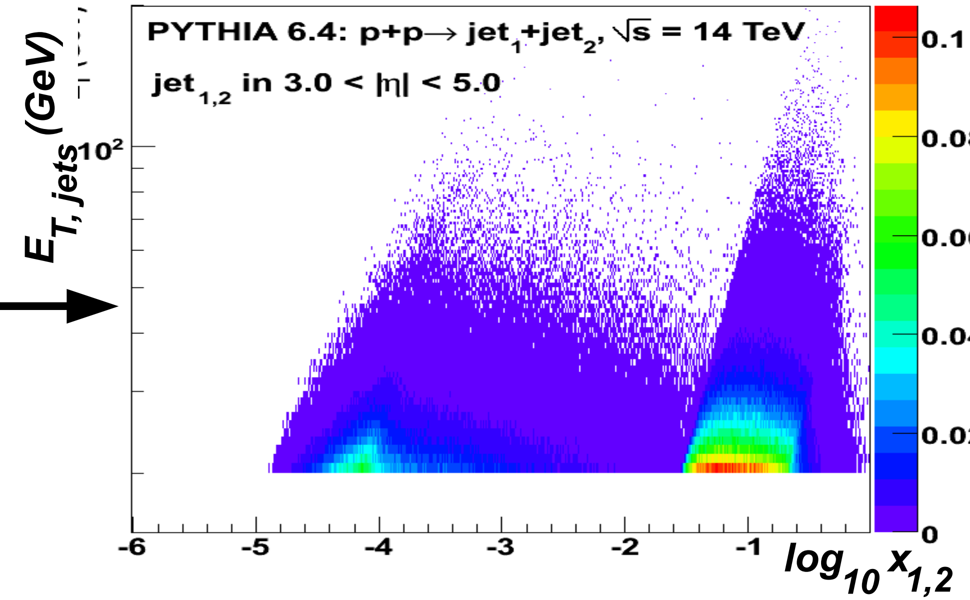
Tool to study higher order QCD reactions

Forward means Low x

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

$x \sim 10^{-5}$

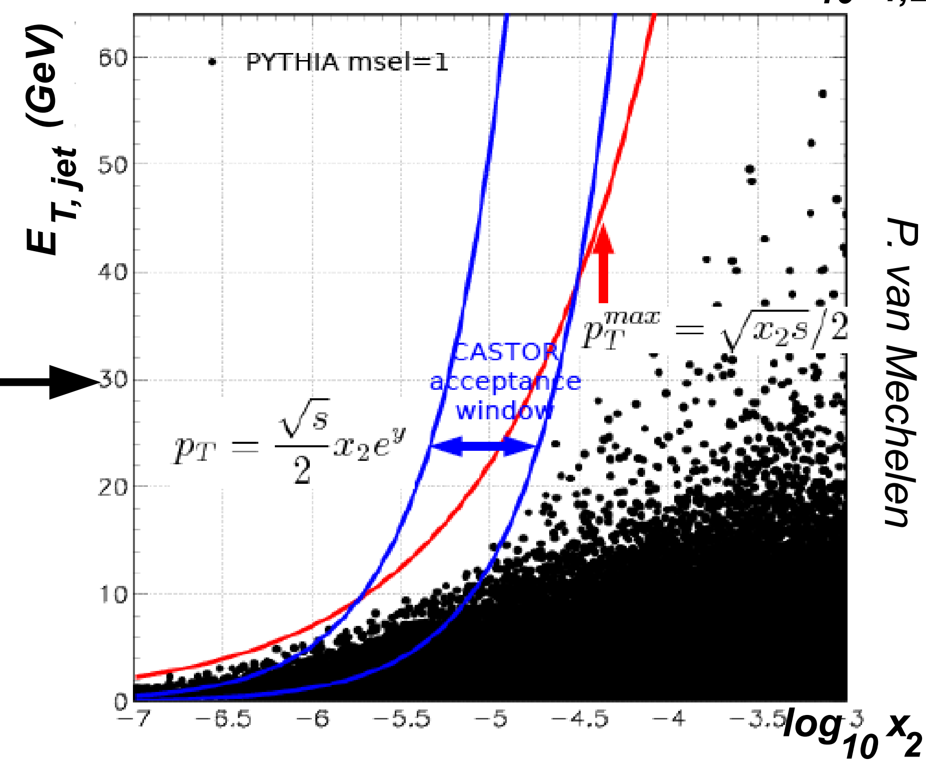
Dijets, at least one jet in HF
CMS note PAS-FWD-08-001



2 units in rapidity
→
Roughly 1 magnitude in *x*

Dijets with at least one jet in CASTOR
$(5.2 < \eta < 6.6)$

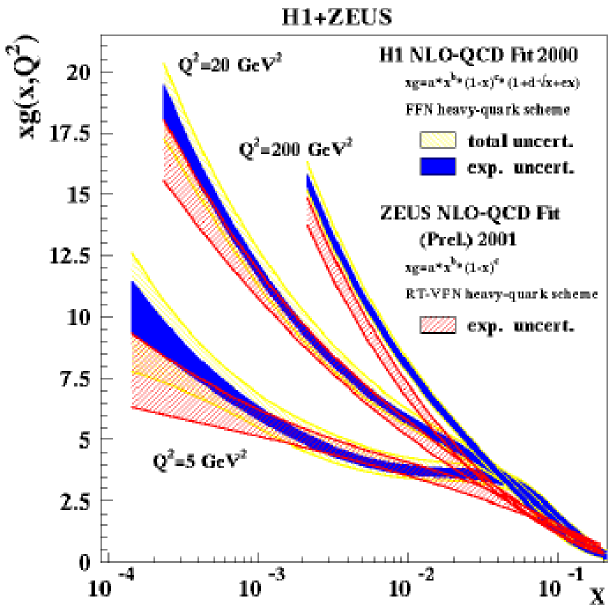
$x \sim 10^{-6}$



P. van Mechelen

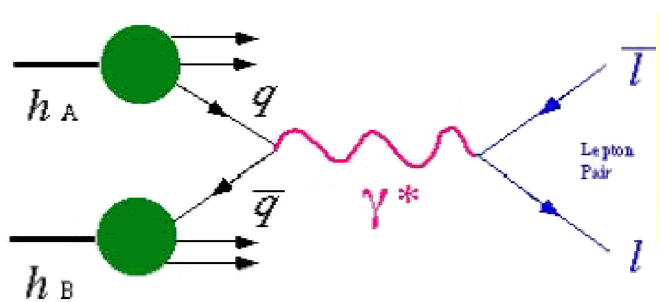
PDFs at Low x

-5

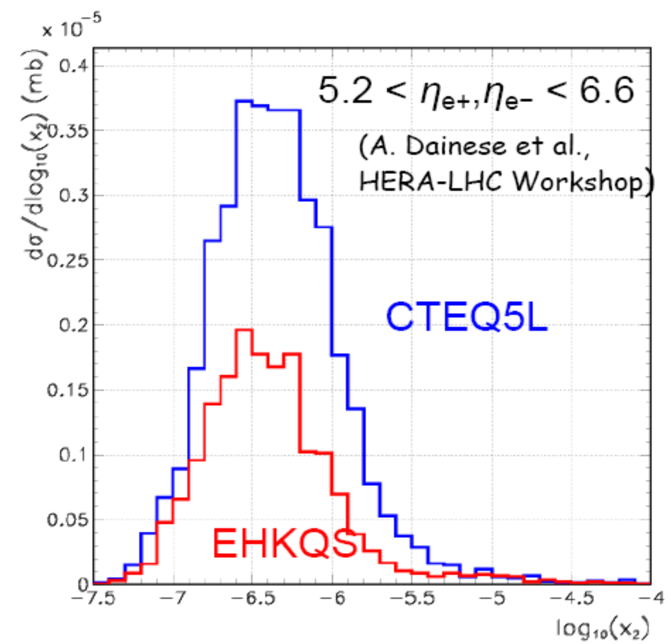


HERA experiments have measured PDFs down to x ~ 10^{-4}
Strong rise of the gluon

Measure Drell-Yang pairs in CASTOR



→ **Target low x (10^{-6}) region and possible sensitivity to saturation**



Saturated PDF suppress DY production by a factor of 2

Matrix element QCD calculations exist only for up to Next-to-Leading-Order O(α_s^3).

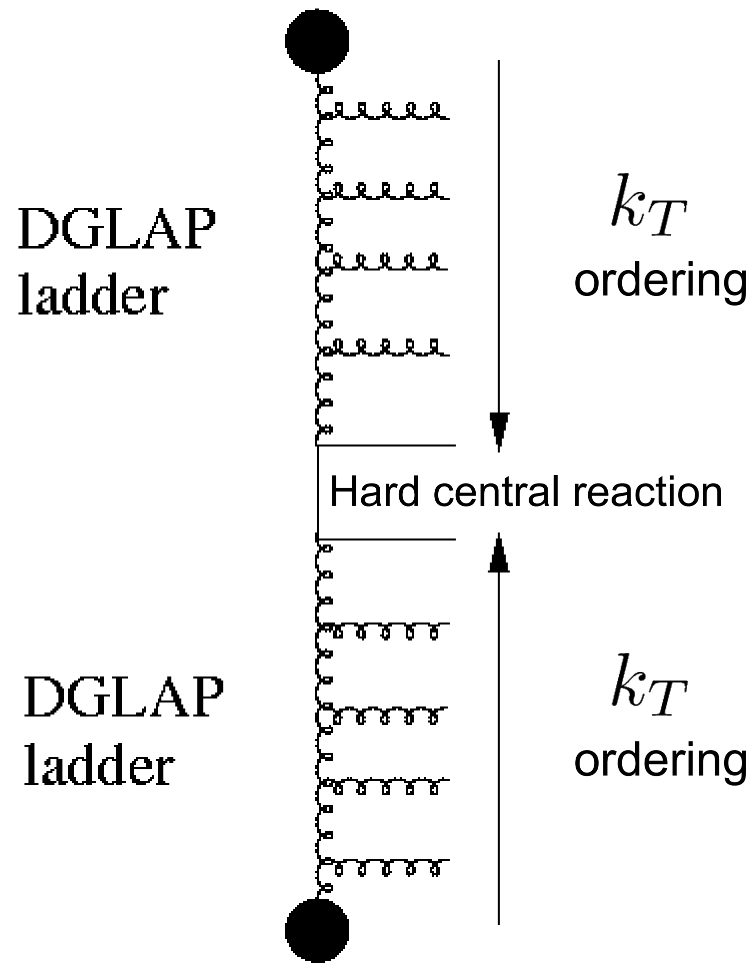
Higher order reactions estimated by using approximate calculations,
so called evolution equations.
Different evolution equations resum different terms in the pertubative expansion.

DGLAP

(*Dokshitzer-Gribov-Lipatov-Altarelli-Parisi*)

Resums terms depending on parton virtuality, resulting in ordering of virtuality of propagators ~ kt of emitted partons.

Implemented in e.g. the Monte Carlo generators **RAPGAP** **(ep)** and **PYTHIA** **(pp)**



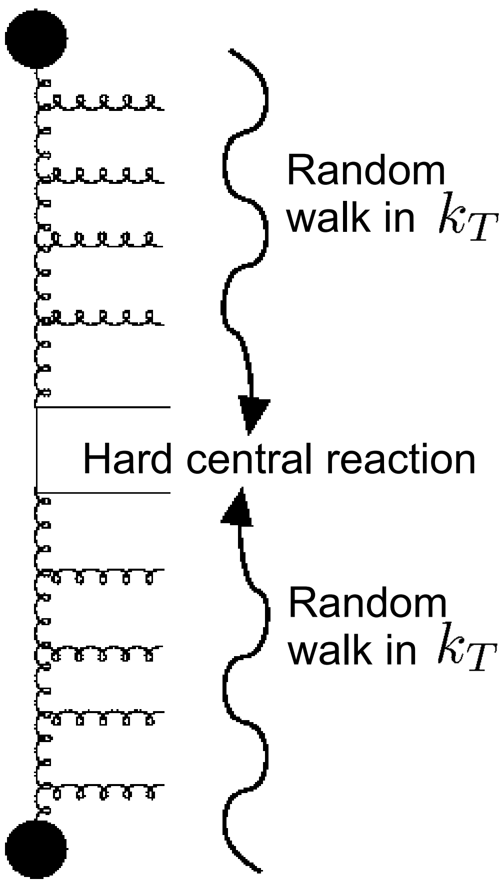
Parton Dynamics

Non DGLAP calculations

→ ***No ordering in k_t of emitted partons***

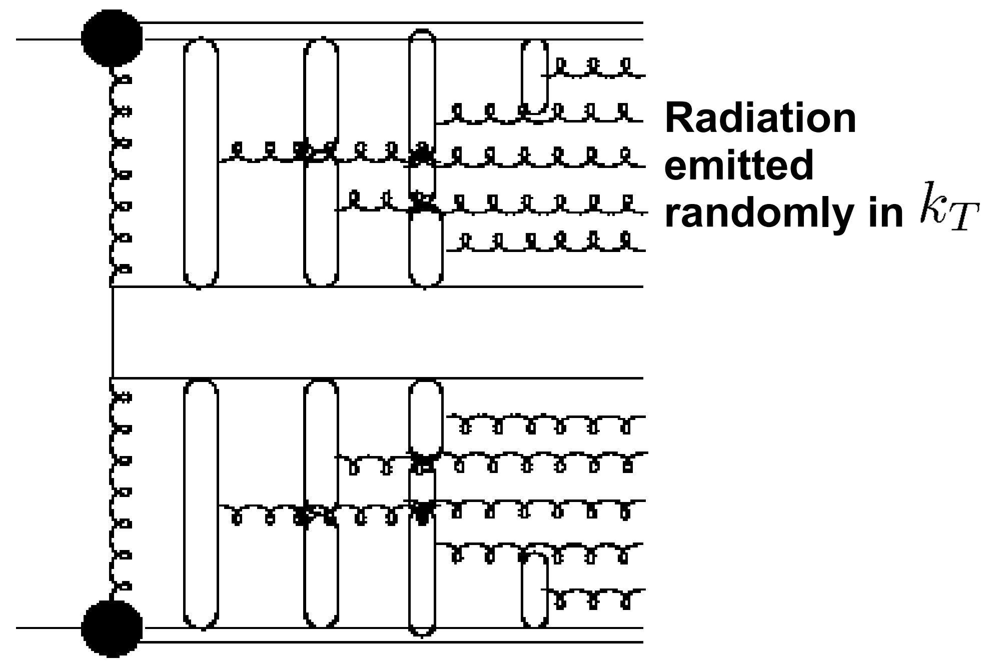
BFKL/CCFM

(Balitski,Fadin,Kuraev,Lipatov)/
(Ciafaloni,Catani,Fiorani,Marchesini)



Color Dipole Model (CDM)

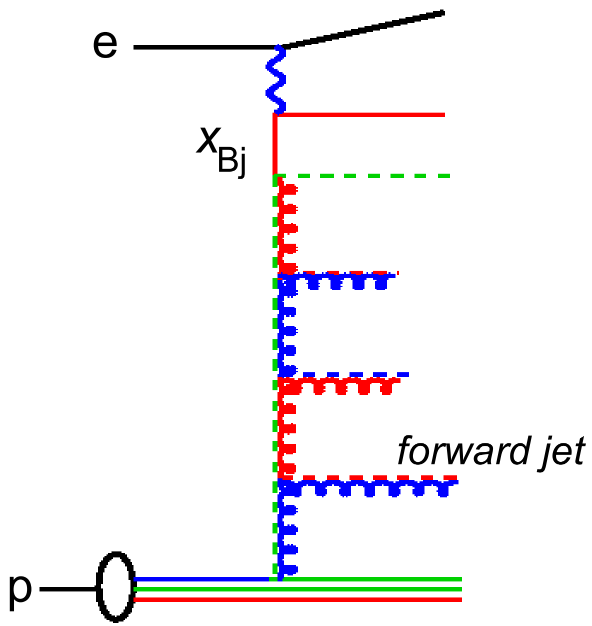
Colored objects span color dipoles in between.
Dipoles decays into gluons...
....which in turn spans new color dipoles, and so on...



No ordering in k_T: Can expect more harder radiation close to proton remnant (the forward region).

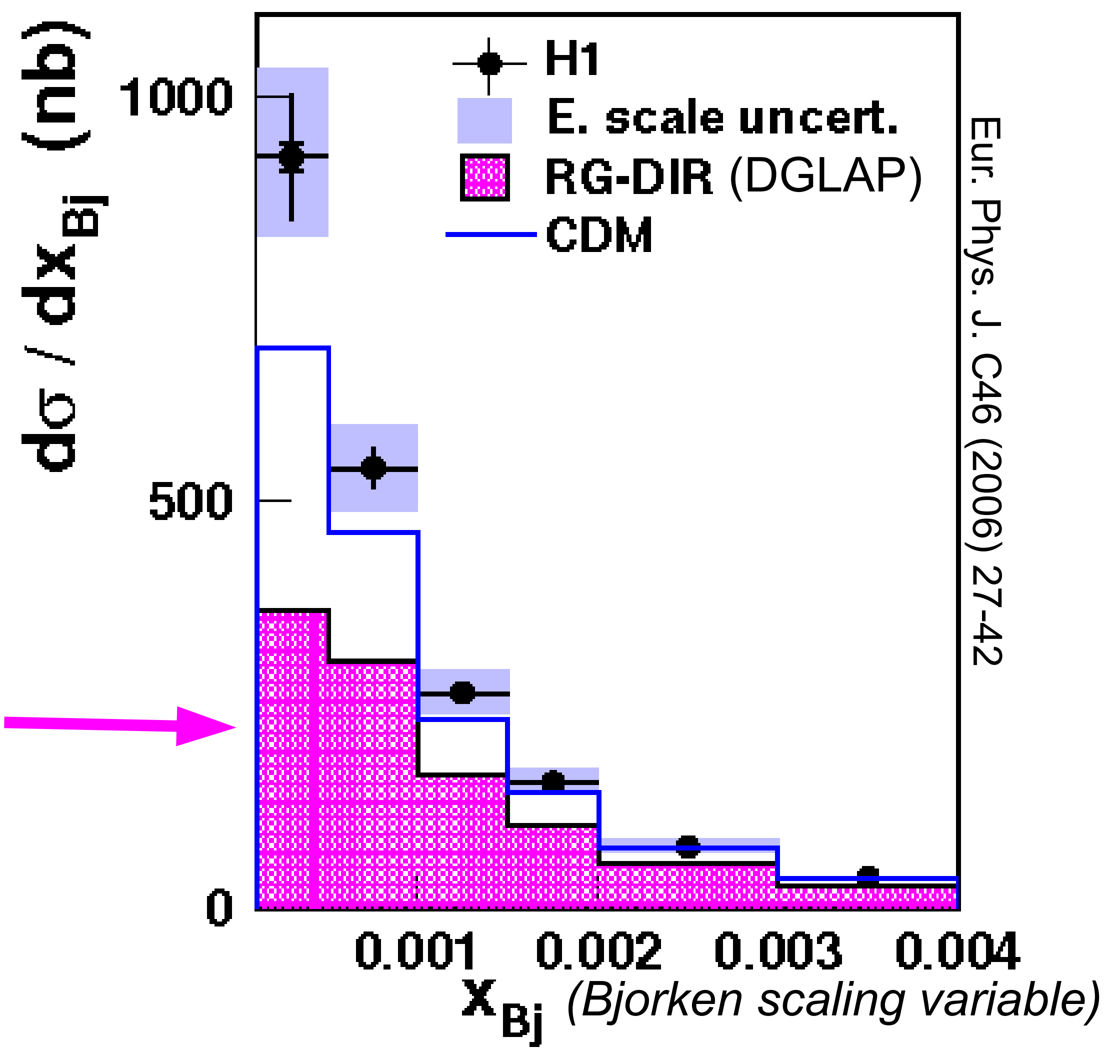
Parton Dynamics

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



Ordering of kt of emissions (DGLAP) are not sufficient.

Need more hard emissions in forward region.



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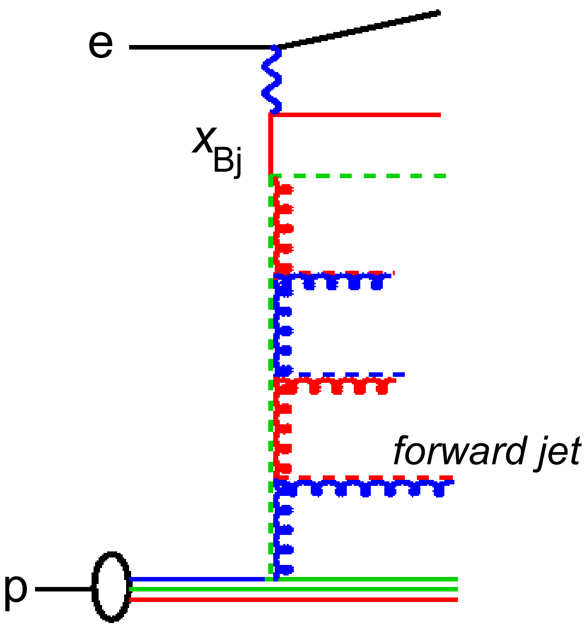
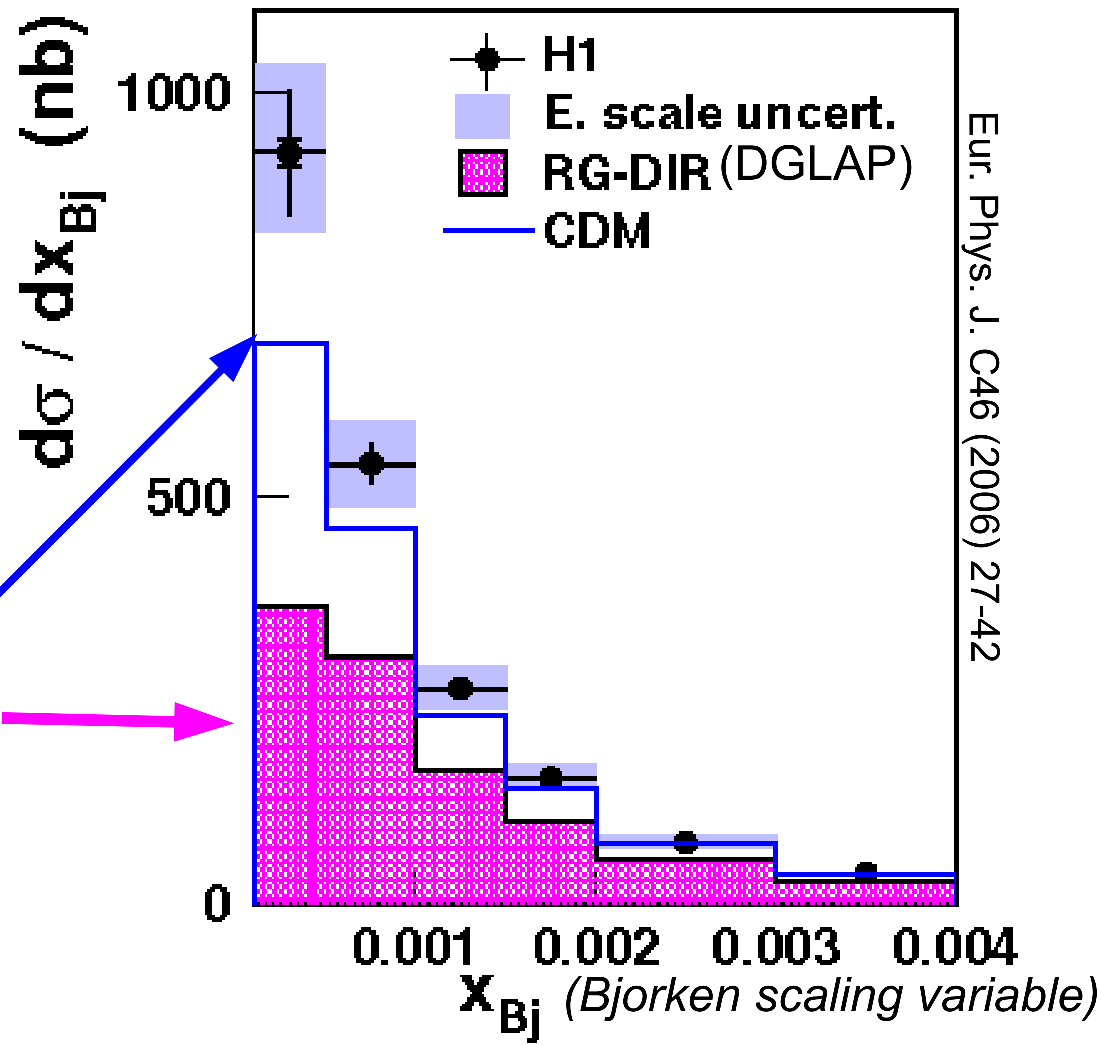




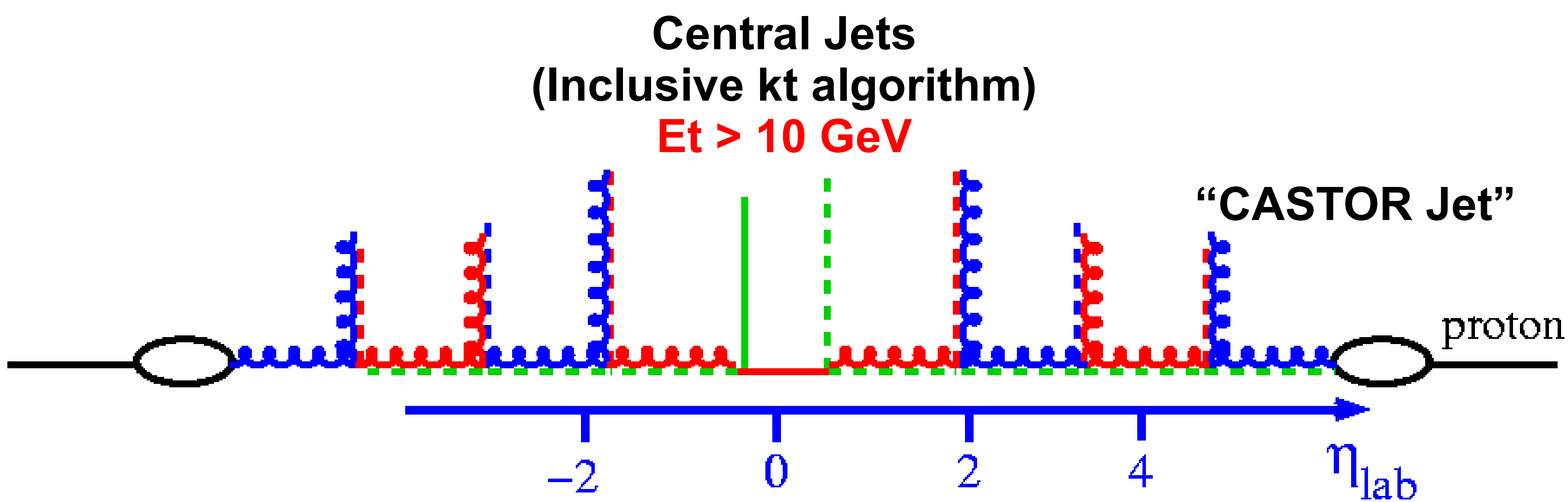
Ordering of kt of emissions (DGLAP) are not sufficient.

Need more hard emissions in forward region.

As for example in the Color Dipole Model (BFKL like scenario).

Event selection / Physics motivation

2 central jets + 1 CASTOR jet



Hard jet or particle in forward region,
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- **Opens up phase space for emissions, higher order reactions**
- **Small x physics**
- **Possible to apply constraints on parton ladder**
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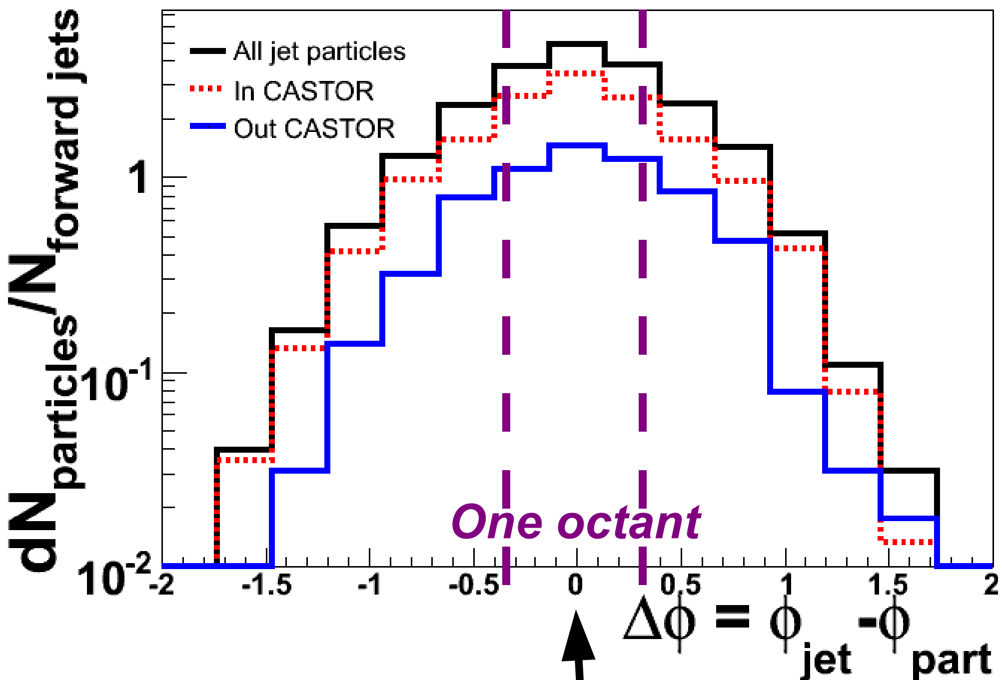
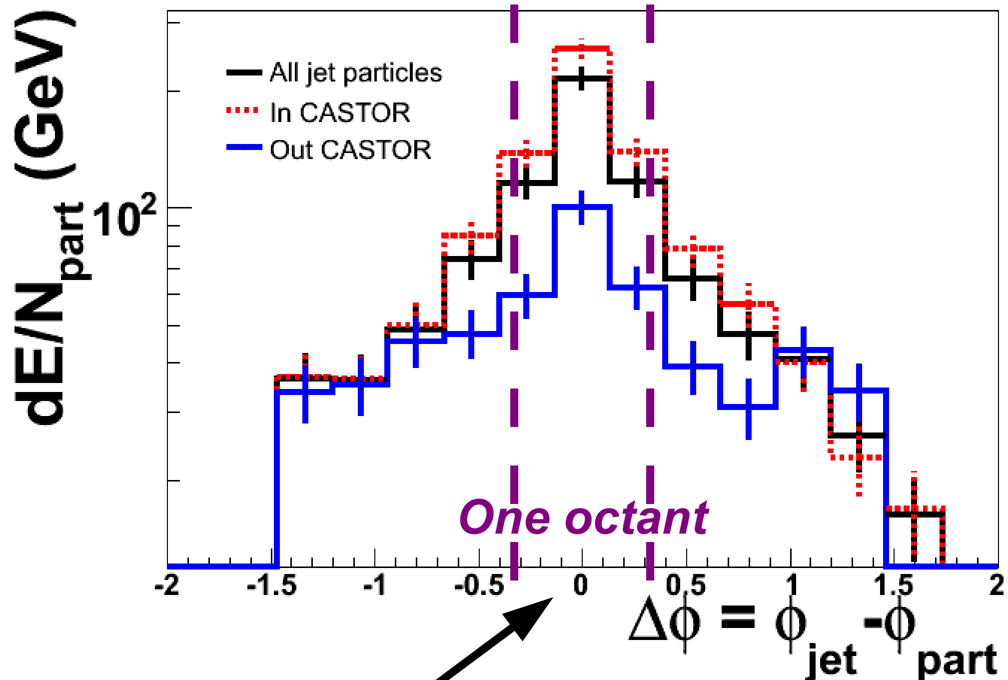
Tool to study higher order QCD reactions

Forward Jets in CASTOR

Forward jet events: How much **activity** can we expect in CASTOR?

"JET PROFILES"





- On event average ~ 10 particles/most active octant
- On average 100 GeV/particle in octant around jet axis

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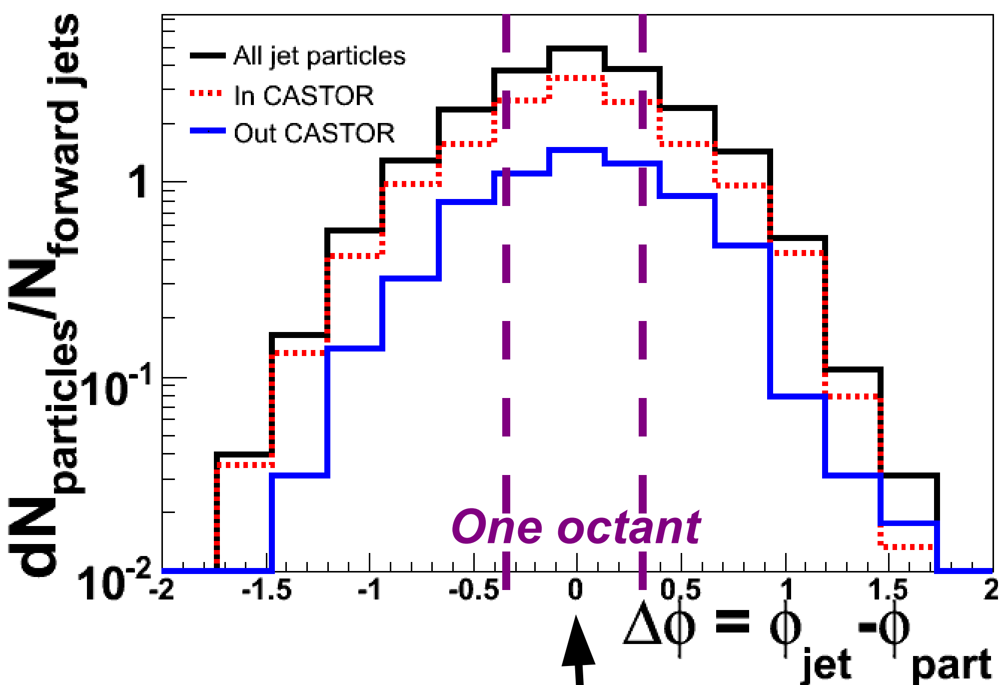

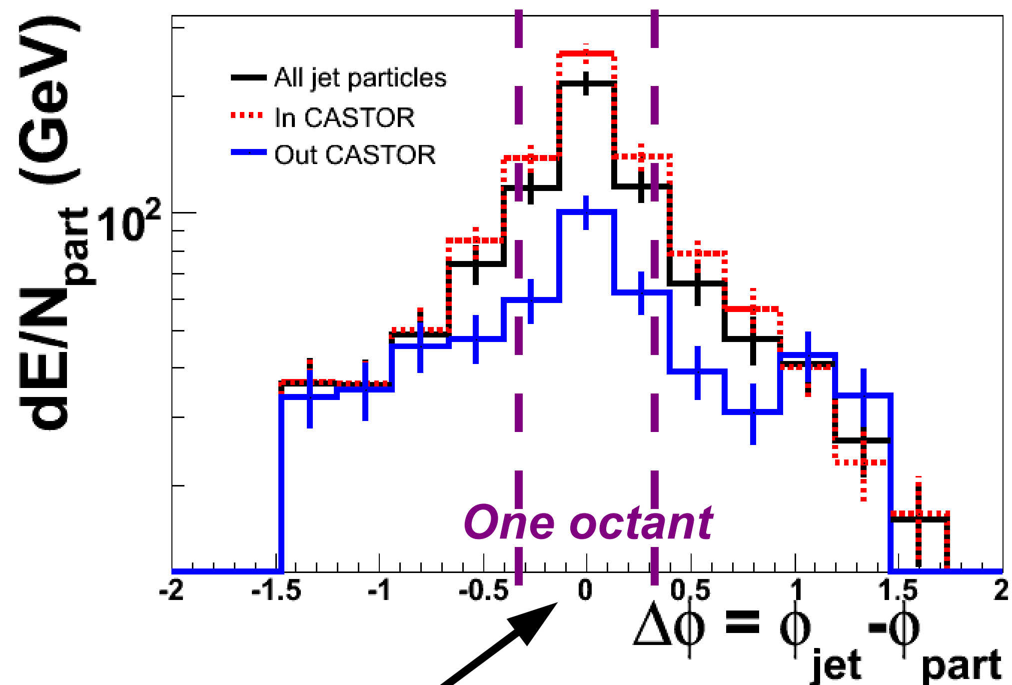

- On event average ~ 10 particles/most active octant
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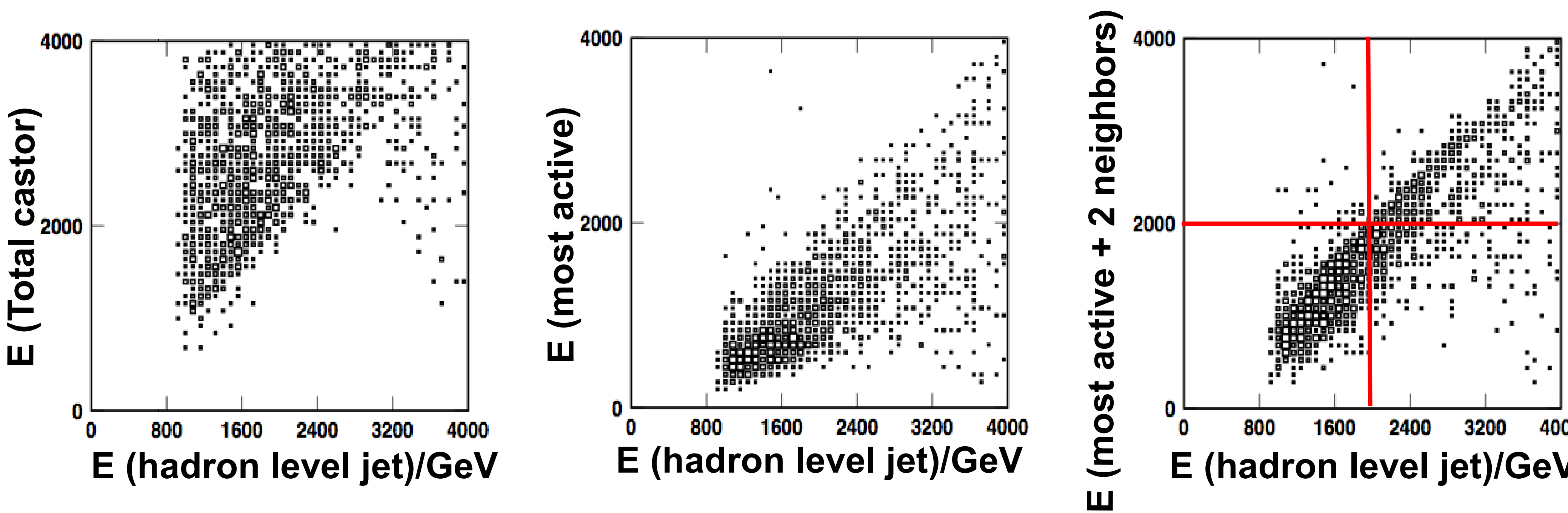
In addition *no rapidity segmentaion* in CASTOR.

Too much activity to separate particles and run a conventional jet algorithm

Jet Energy – CASTOR energy correlation

Measure deposit energy in CASTOR.

- **Total energy deposit in CASTOR**
- **Energy in most active Phi-segment**
- **Energy in most active Phi-segment + Energy in two neighbouring Phi-segments**

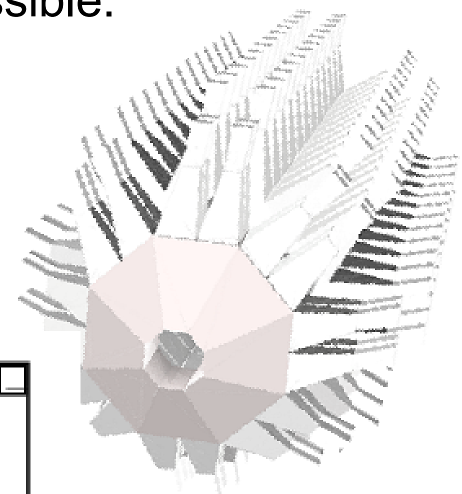


E (hadron level jet) > 10 GeV

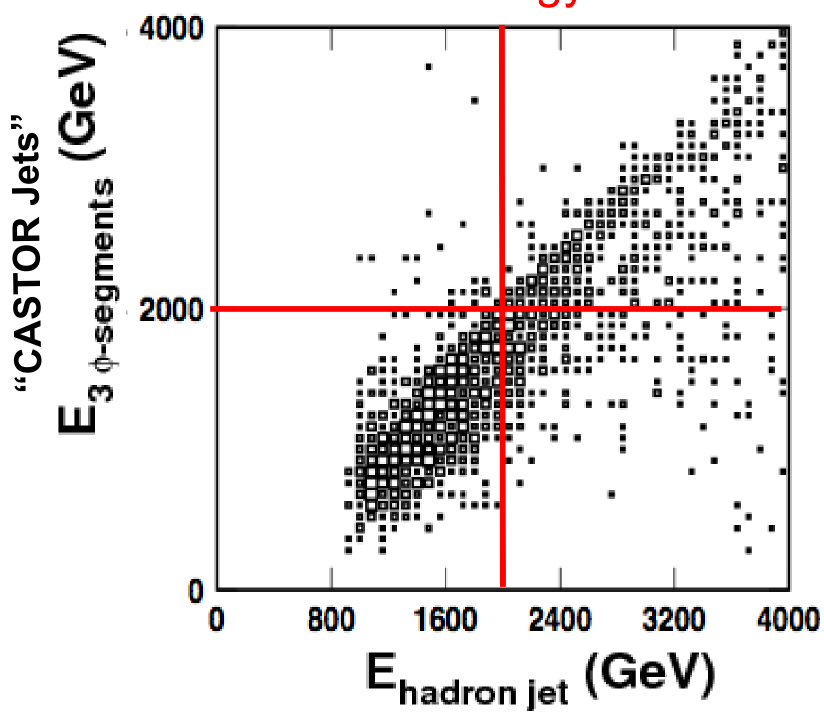
CASTOR Jet reconstruction

No eta segmentation in CASTOR. Conventional jet algorithm is not possible.

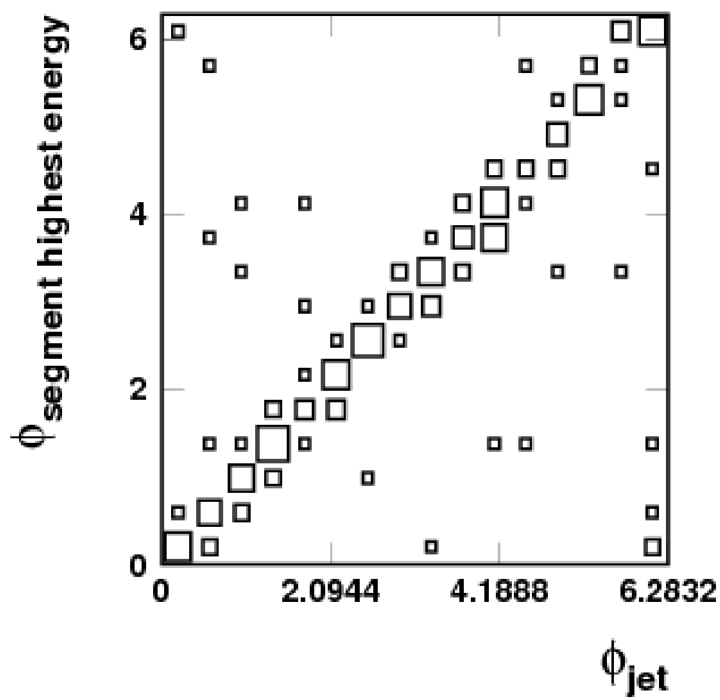
Reconstruct jets by summing energy in most active phi segment (= 2*pi/16) with neighboring segments = CASTOR Jet



Energy



Phi



In these slides: Everything is “CASTOR jets”, if not else stated.
A more sophisticated jet algorithm for CASTOR exist and is implemented in the CMSSW by the Antwerpen group.

CASTOR 2+Forward Jet Cross-section

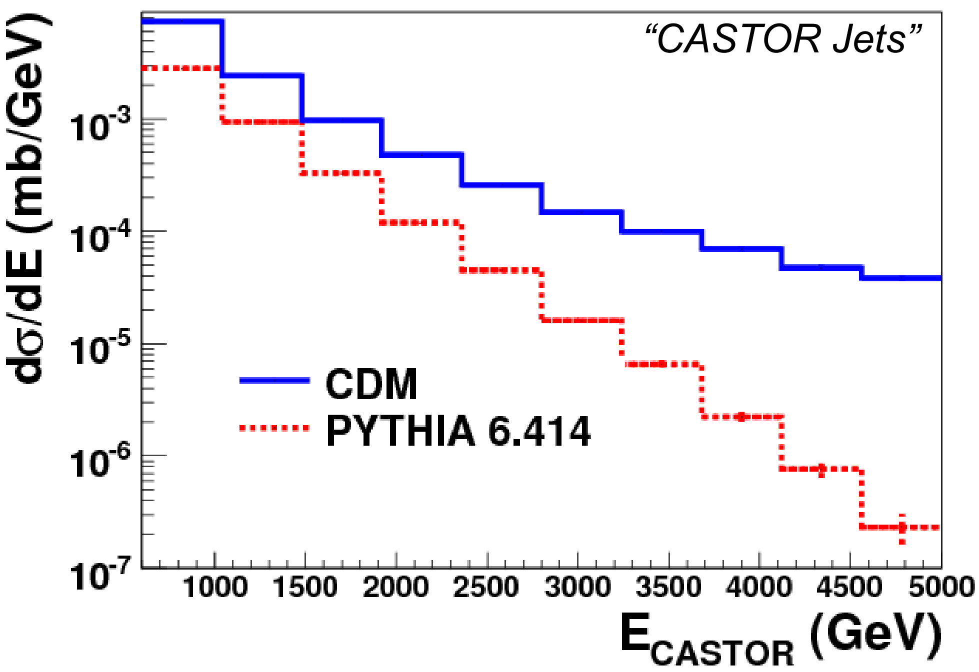
Multi-jet selection: at least **2 central jets** and **1 jet in CASTOR region** ($5.2 < \eta < 6.6$) with $E_t > 10\ \mathrm{GeV}$

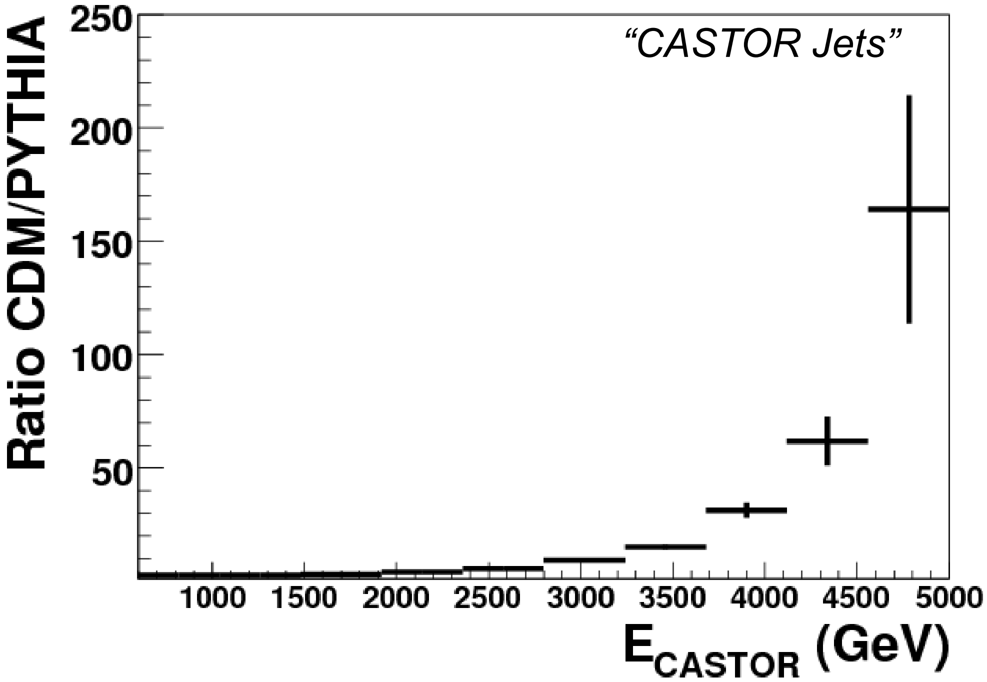
MC studies – No detector simulation. However:

-"CASTOR Jets": Jet reconstruction as described on last slide

-Particle energy smeared according to test beam data

-Noise cut of particles (E_particles > 1 GeV)





CDM – giving a more BFKL like final state – with partons unordered in kt (with respect to rapidity) – predicts more hard jets in CASTOR.

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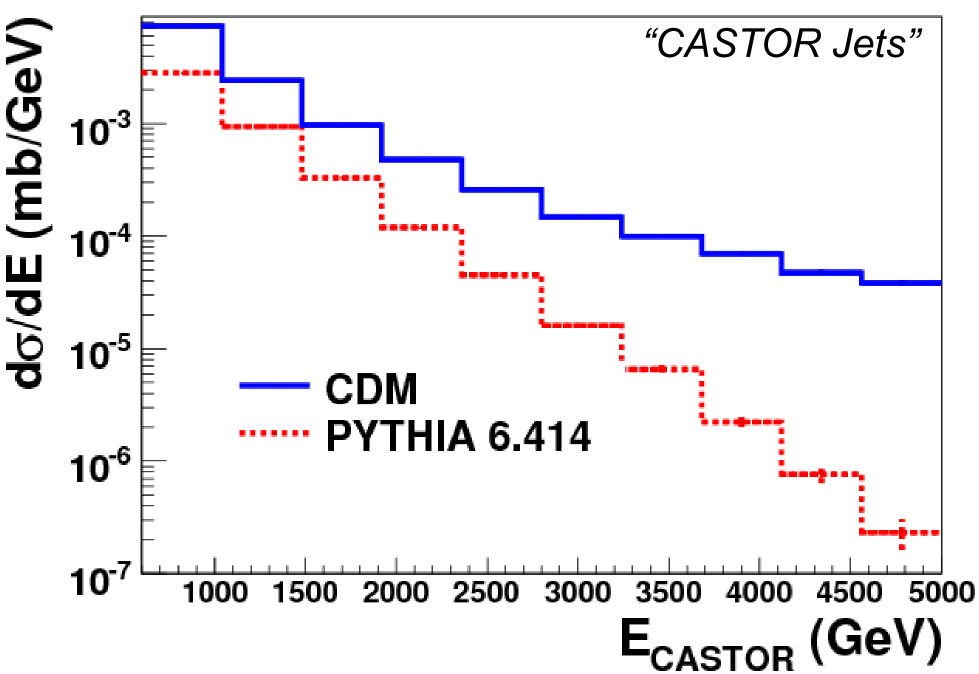
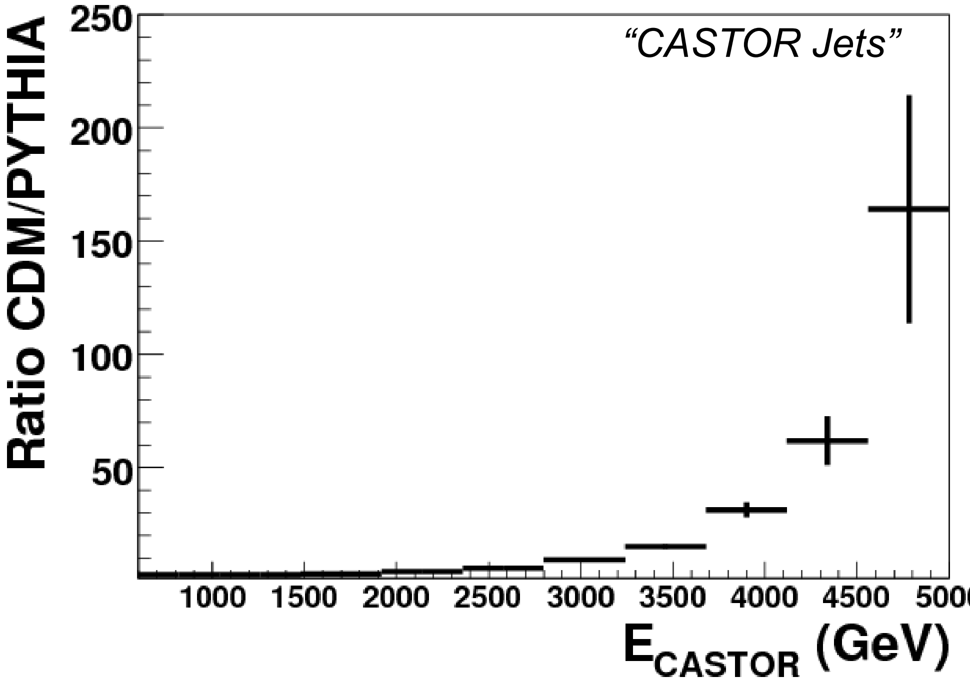


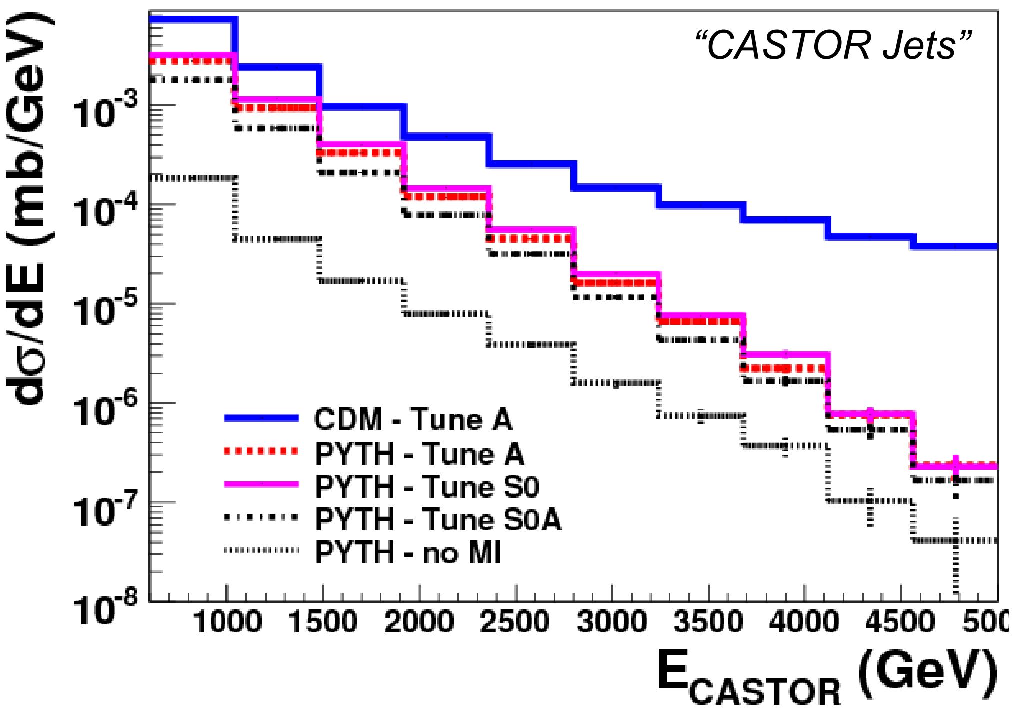


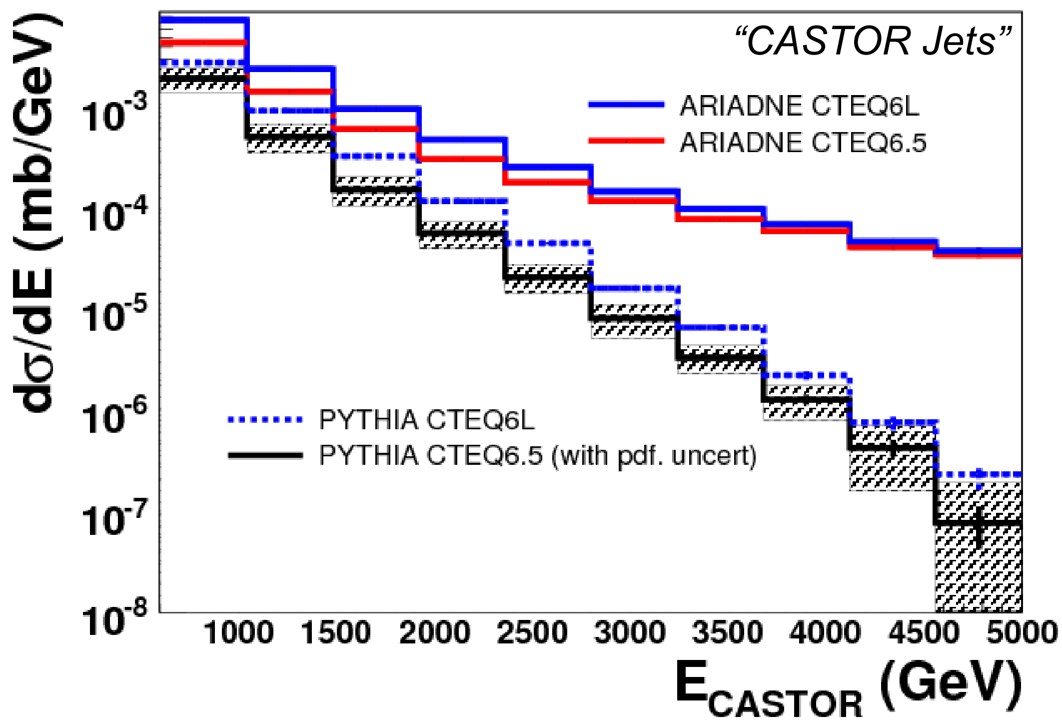
CDM – giving a more BFKL like final state – with partons unordered in kt (with respect to rapidity) – predicts more hard jets in CASTOR.

- **With "CASTOR Jets" we can make measurements that distinguish between the different QCD models (DGLAP/non-DGLAP).**
- **Study made at < 1pb^{-1}. One of the first topics to be analysis by using CASTOR**

MI and PDF uncertainty

Multi-jet selection: at least **2 central jets** and **1 jet in CASTOR region** ($5.2 < \eta < 6.6$) with $E_t > 10\ \mathrm{GeV}$





- **At high energy: DGLAP/non-DGLAP separation >> Difference between MI tunes**
- **At high energy: DGLAP/non-DGLAP separation >> PDF uncertainty/sensitivity**

Mueller-Navelet Jets

Study higher order QCD effects. Parton dynamics beyond DGLAP. BFKL effects.

CASTOR has good segmentation in Phi. Make use of it!

Azimuthal decorrelations for Mueller-Navelet jets

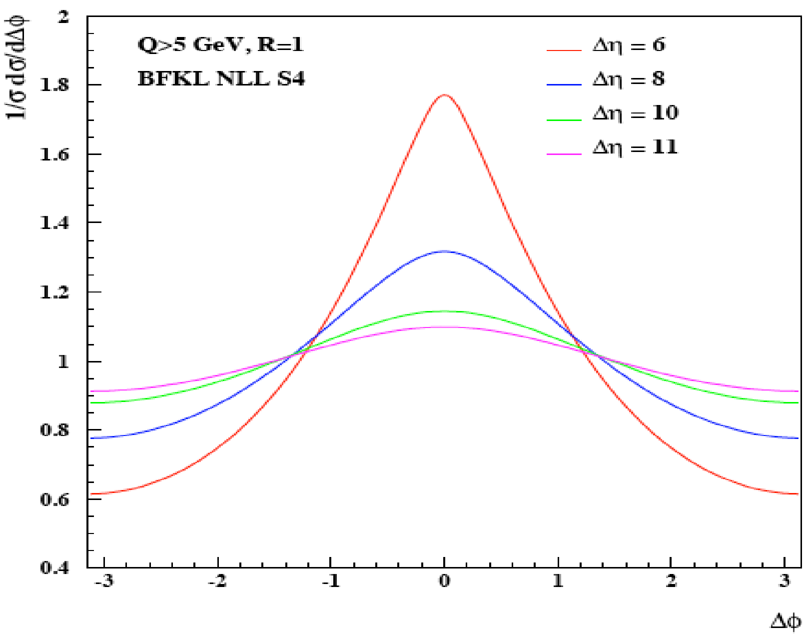
At LO: Delta Phi =180

Higher order reactions:
In **DGLAP** the momentum balance between the two jets is expected to be more **conserved**, while H.O **BFKL** emissions expects to give a **flatter** Delta Phi distribution.

Large rapidity range between jets to open up phase space for more emissions

Azimuthal decorrelation between Mueller-Navelet jets at TEVATRON energies as predicted by BFKL NLL (C. Royon - DIS2007 proceeding).

Larger eta separation - > Flatter distribution.



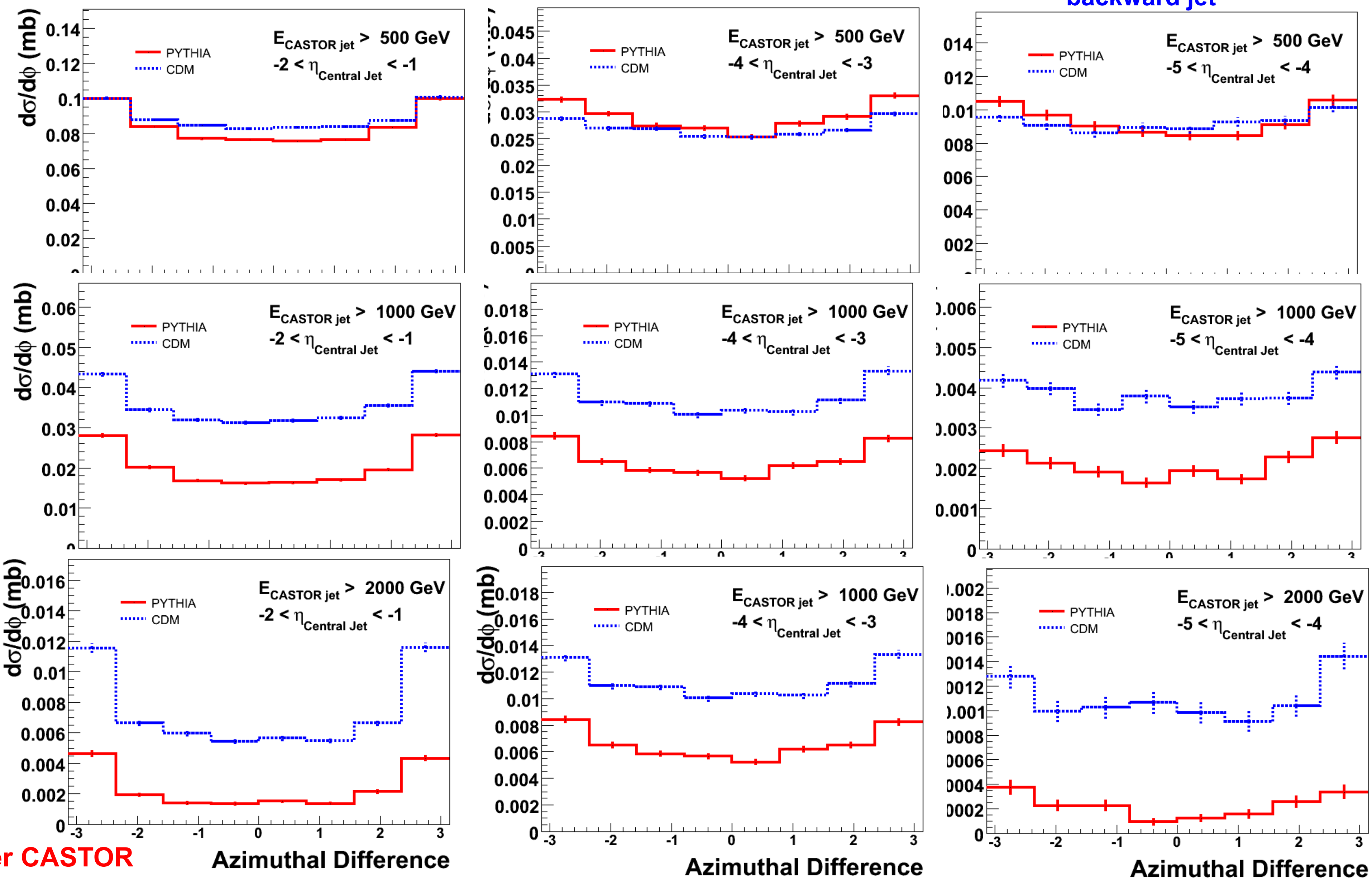
Additional effects from using unintegrated gluon densities.
Input k_t from gluon PDF > 0. => Delta Phi < 180 already at LO

Mueller-Navelet Jets

Selection: Central Jet with Et > 25 GeV + “CASTOR Jet”.
5.2 < Eta(CASTOR) < 6.4
(“CASTOR Jet” energy defined as most active azimuthal segment (2*pi/16) + Neighbours.)

Larger Rapidity Separation between “CASTOR jet” and backward jet

Mueller Navelet Jet Cross-section



Larger CASTOR jet energy

Mueller-Navelet Jets

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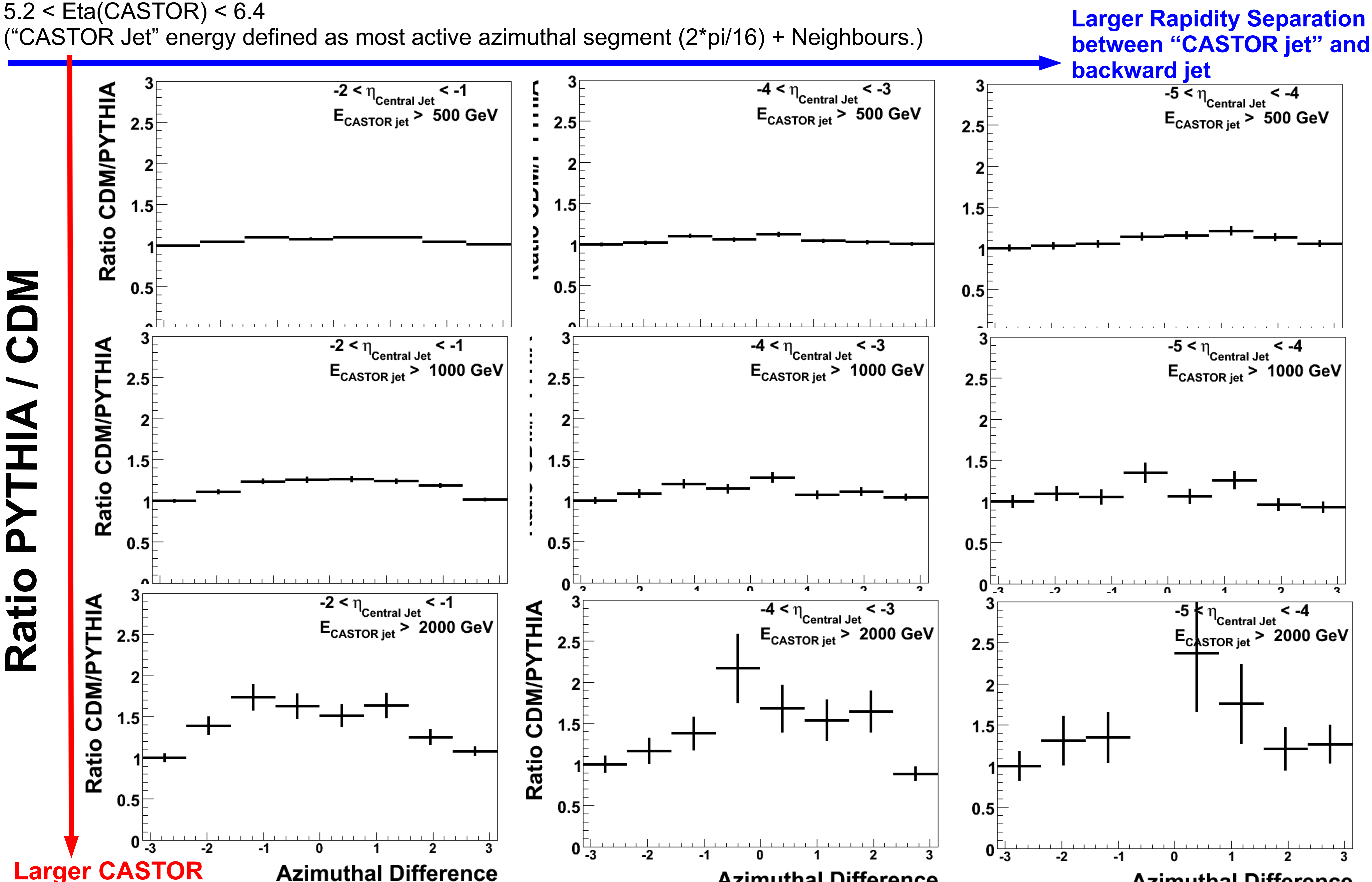
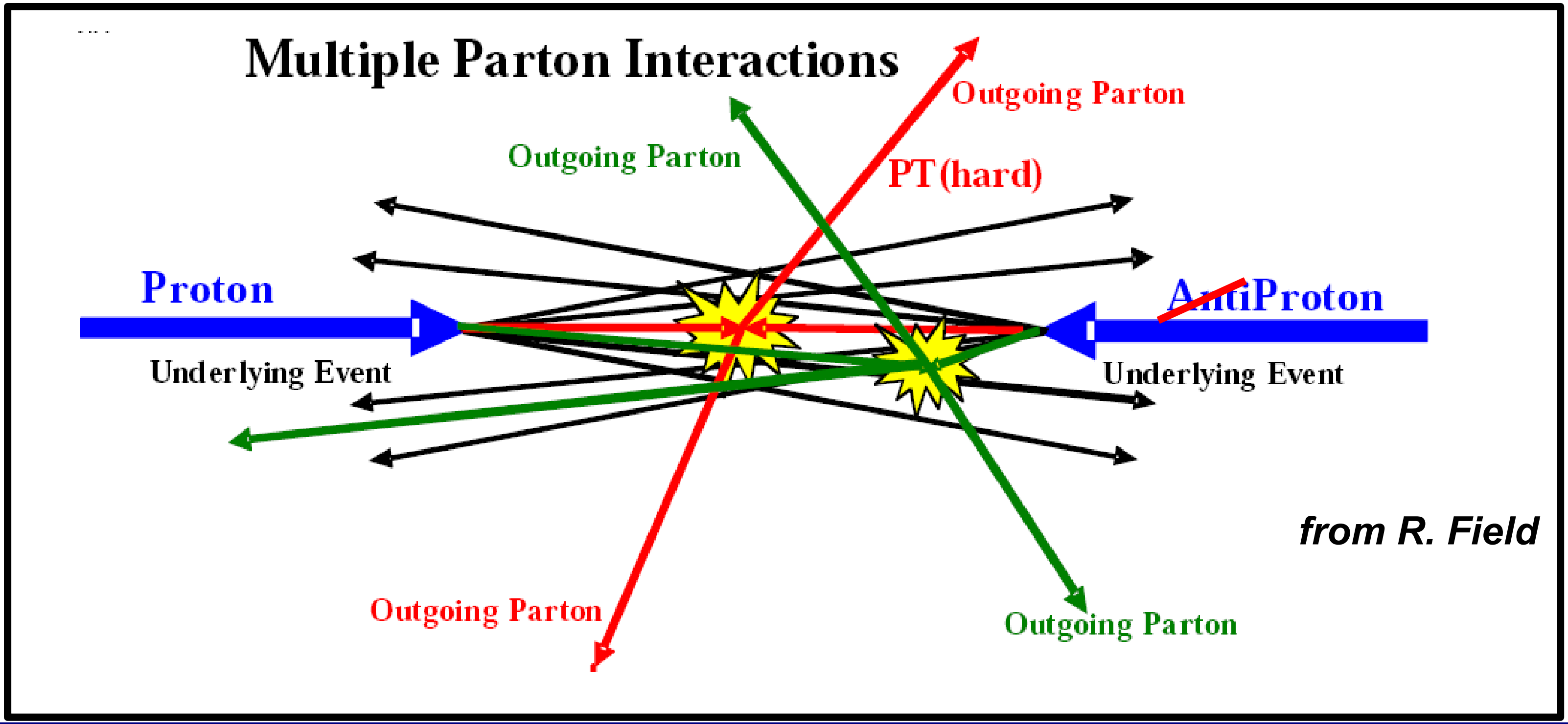


First bin in each histo normalized to 1.0

The Underlying Event

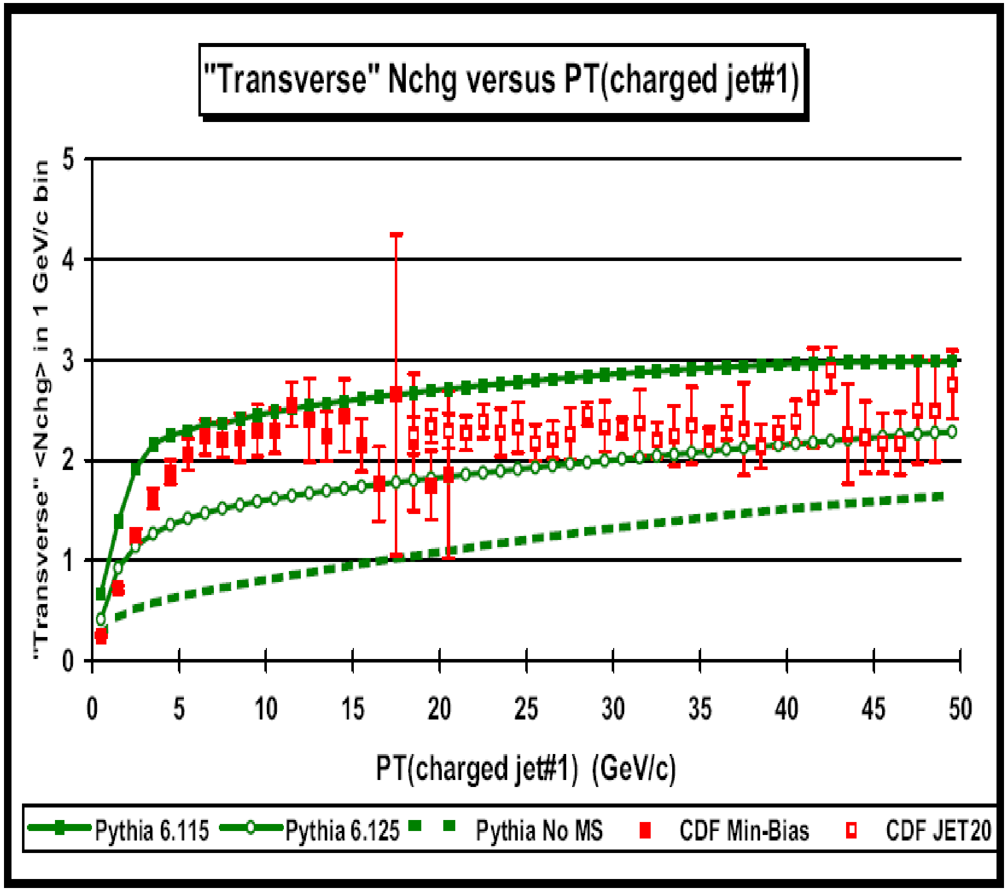
Everything except the studied LO process:

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



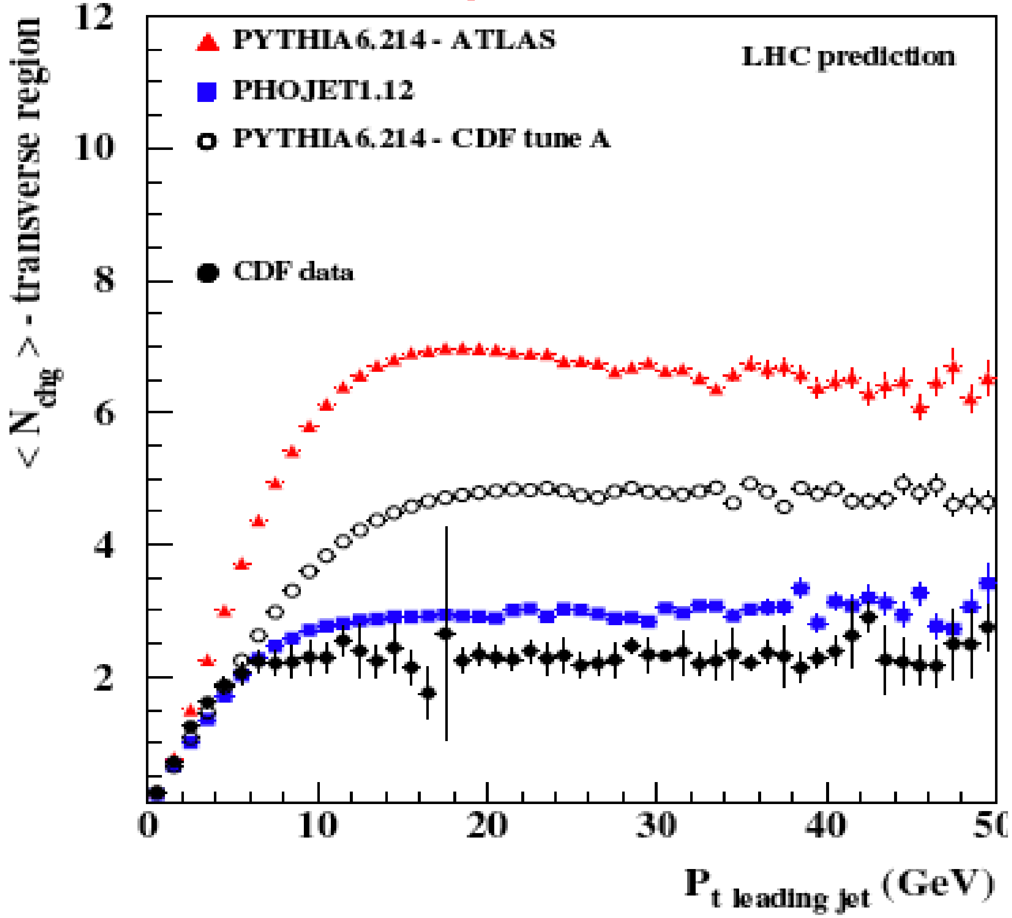
Multiparton Interactions (MI)

MI needed to describe TEVATRON data



FERMILAB-Pub-01/211-E CDF

Extrapolation to LHC

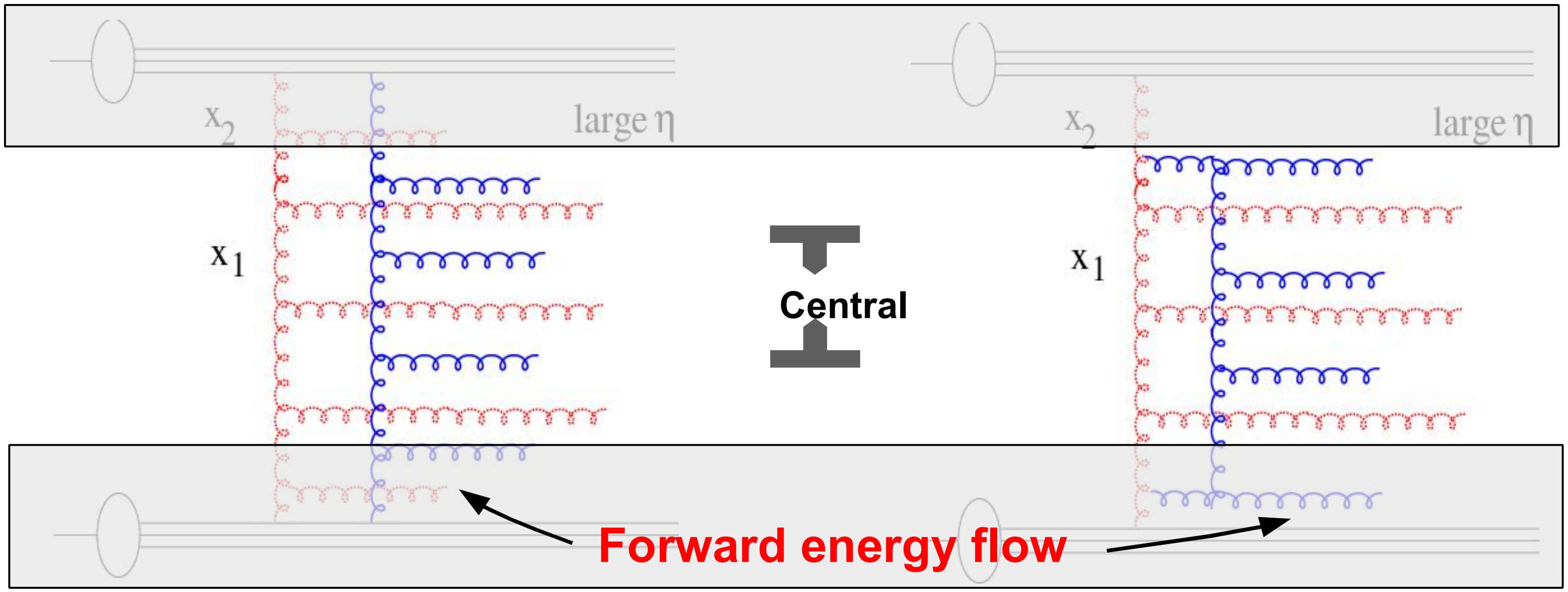


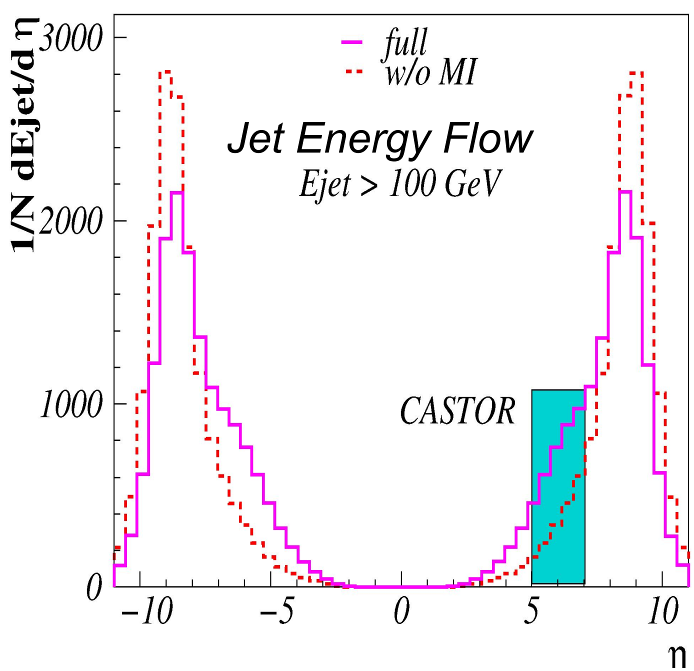
Buttar et al., HERA-LHC proceedings

- **MI models tuned to describe Tevatron data give large differences at LHC**
- **Need to tune MI models as soon as LHC data are available**

Multiparton Interactions

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

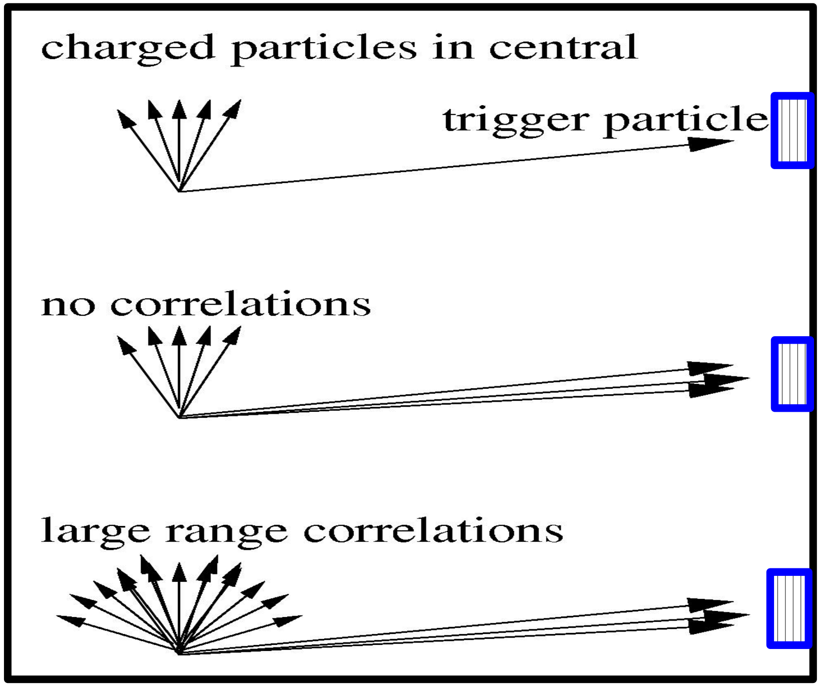




Multiple interactions effects the energy transferred from the beam remnant.

Sensitivity in the CASTOR region.

Long range correlations and MI

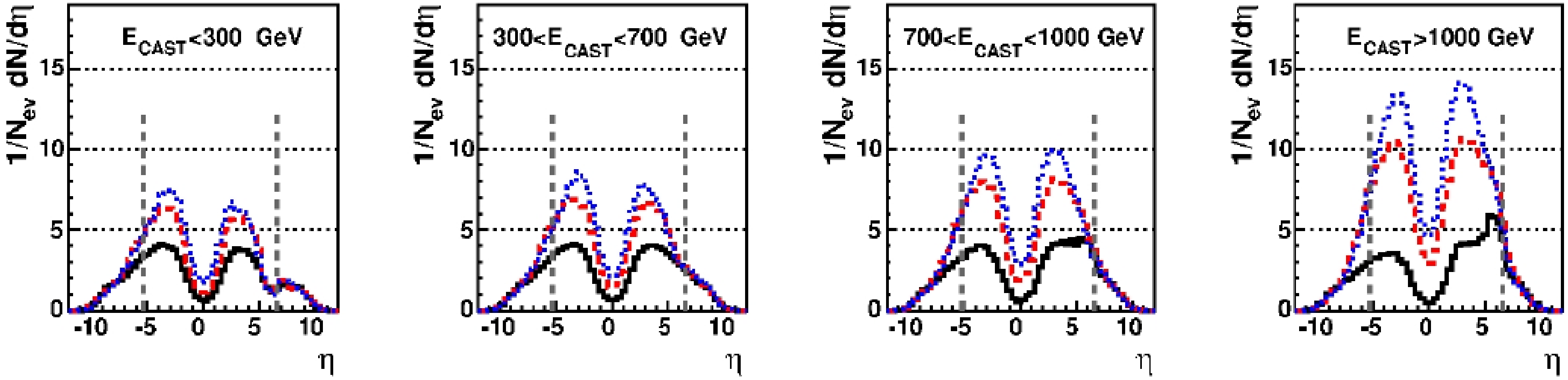


•**With MPI**:
Large energy of trigger in CASTOR,
→ Higher particle multiplicity in central region

•**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

QCD events



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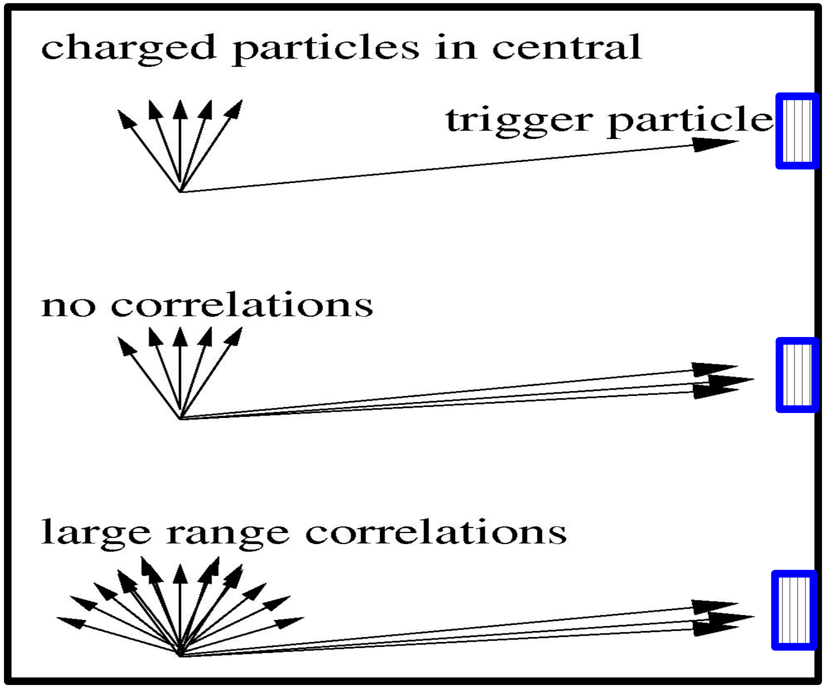

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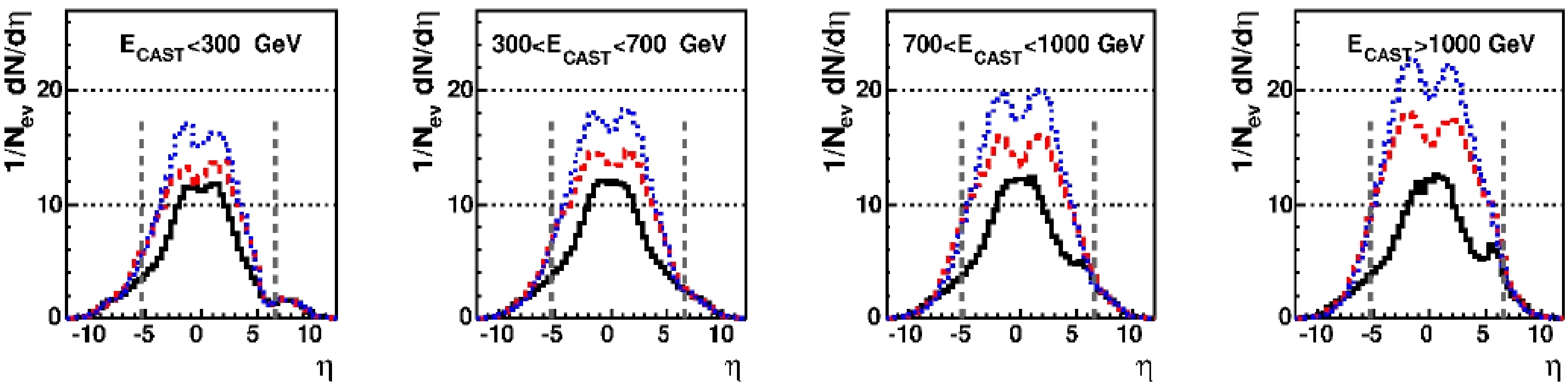
Top events



Top events much higher activity in the UE

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

Summary

- CASTOR is a calorimeter without segmentation in rapidity and the particle multiplicity within a detector segment can be high. Good correlation between energy deposit in CASTOR azimuthal segments and the jet energy. Possible way to reconstruct jet energies and azimuthal angle.

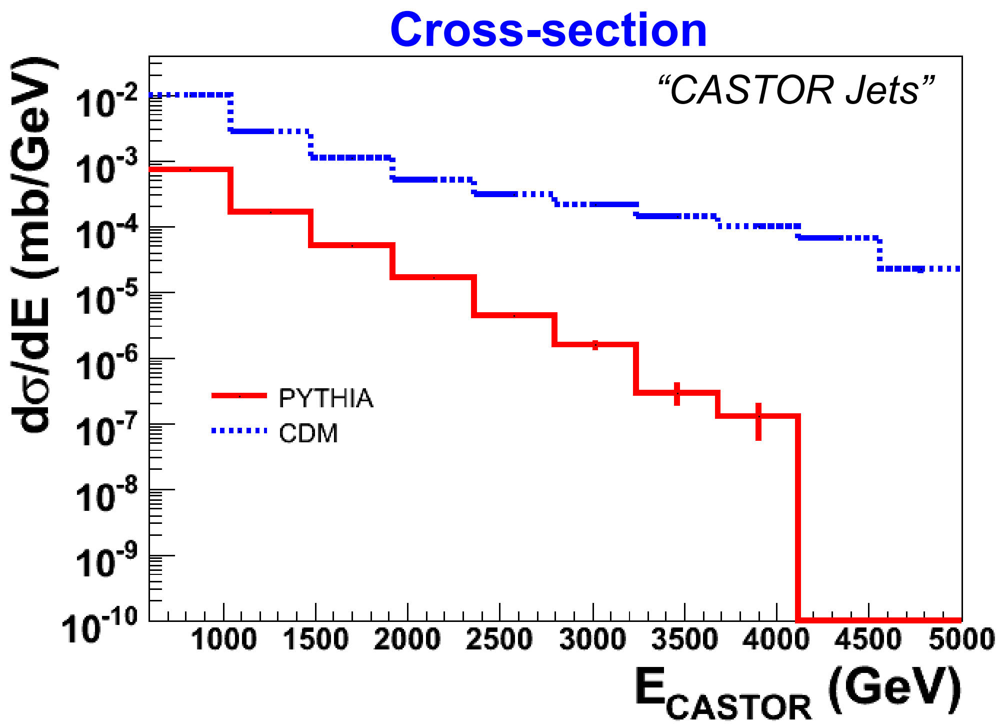
- 2+foward jet or Mueller-Navelet jet events with with one jet in CASTOR, gives sensitivity to parton dynamics beyond DGLAP.

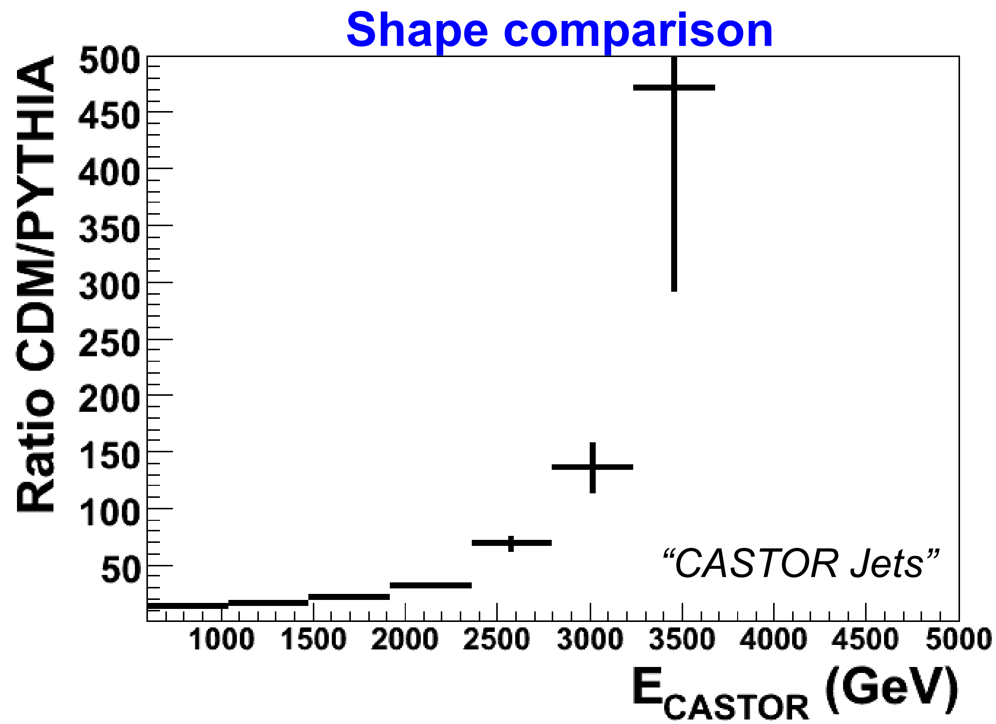
- Use CASTOR to measure long range correlations and the underlying event.

BACK UPS

5 TeV beams

Hadron level MC studies – (No detector simulation applied)



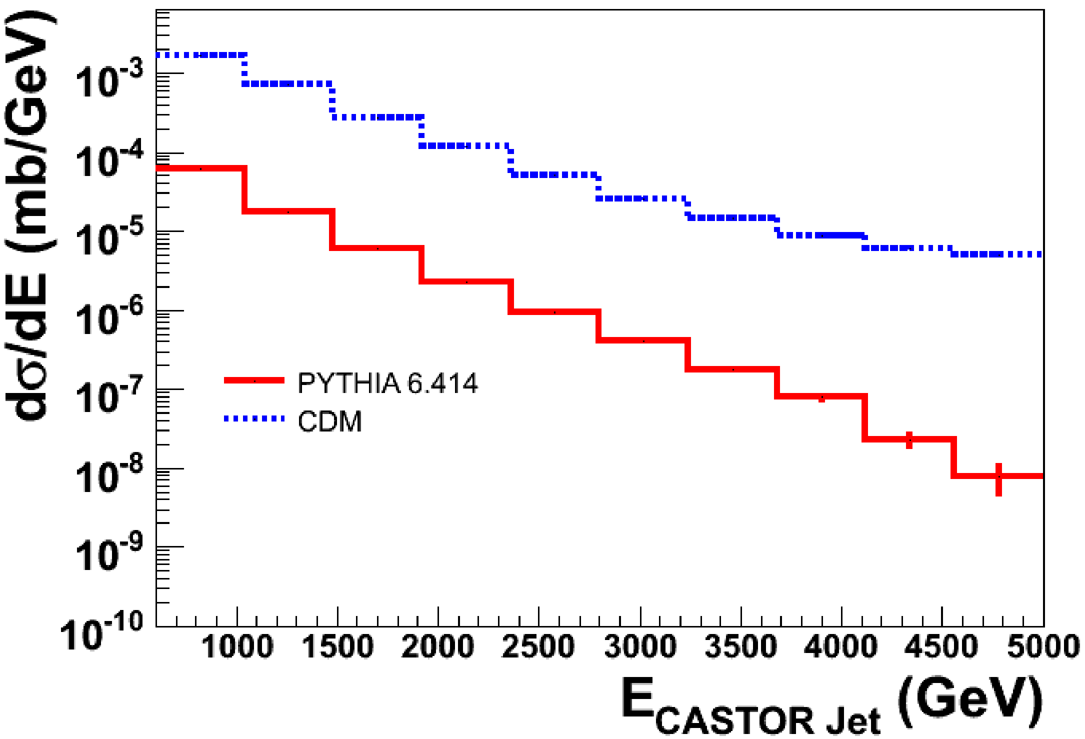


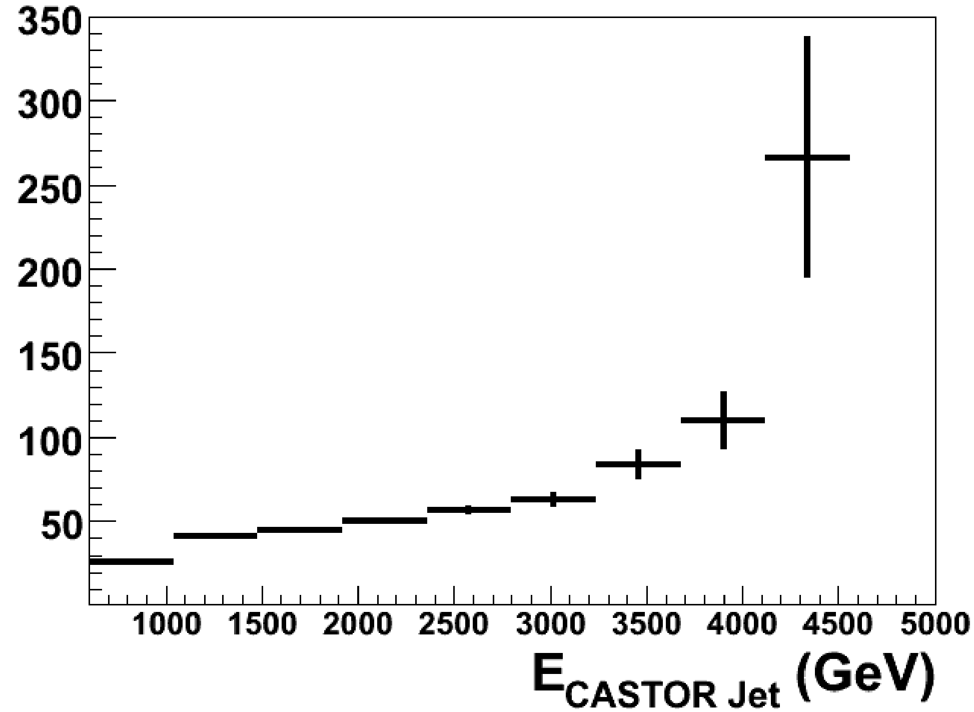
→ Ok! Can expect physics signal for 5 TeV beams

→ This study: 250000 events, sigma_tot=5mb => Lumi<<1 pb^-1

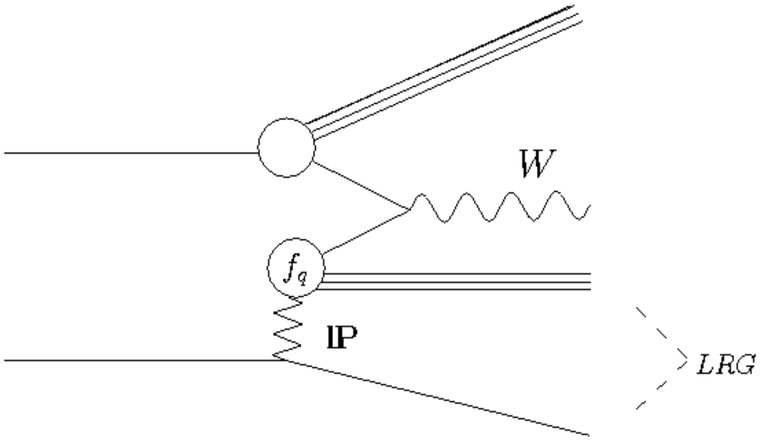
Harder central jets. P_t > 25 GeV

Pt (central jets) > 25 GeV



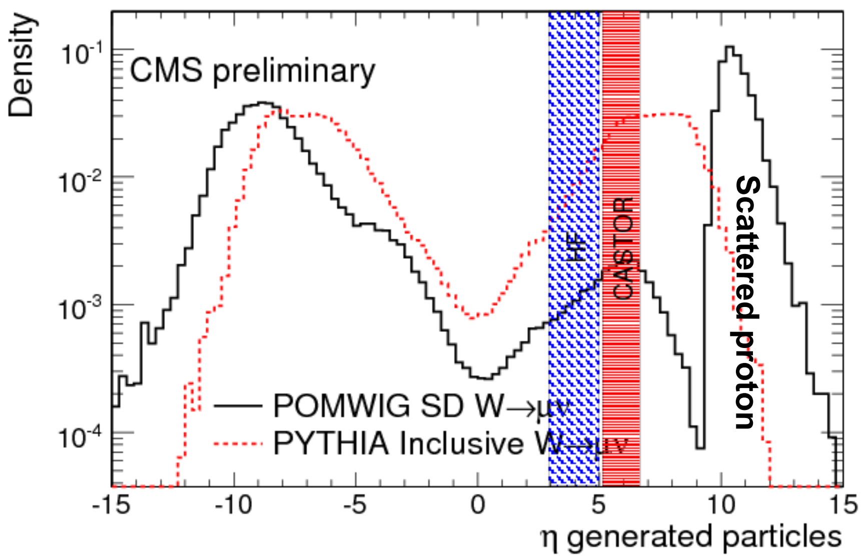


CASTOR as a veto detector



- Study on single diffractive production of W ***(CMS PAS DIF-07002)***
- Study on diffractive production of dijets ***(CMS PAS FWD-08-002)***

CASTOR ~ middle of rapidy gap:



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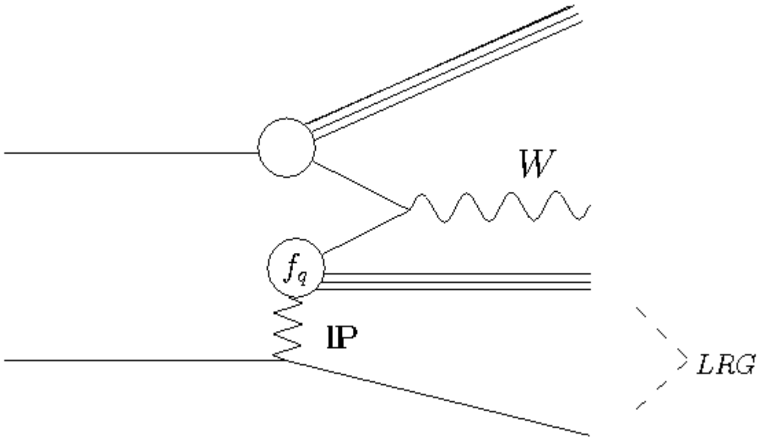

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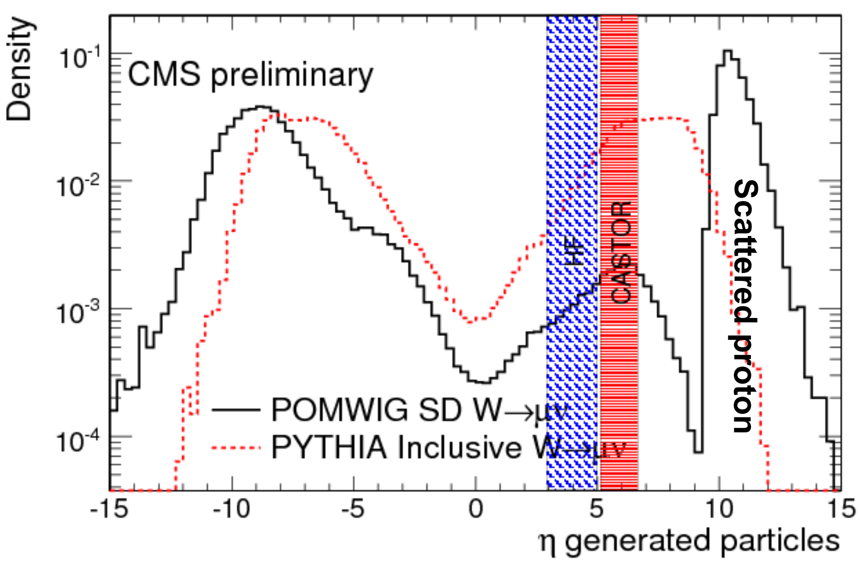
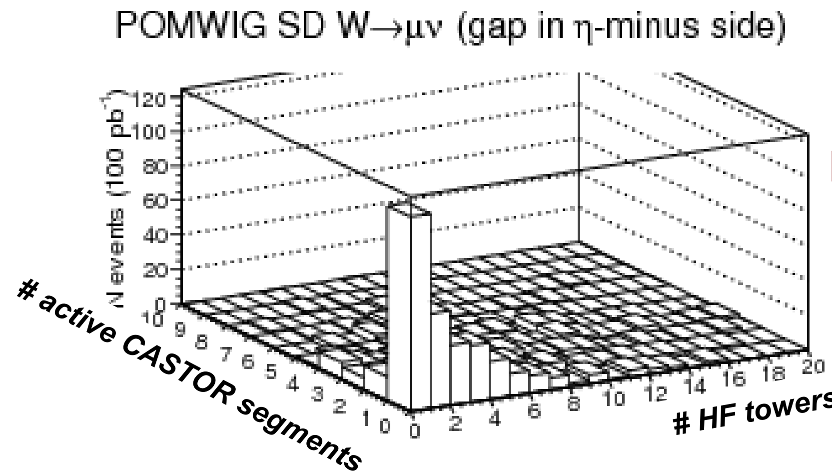
  (CMS PAS DIF-07002)
- Study on diffractive production of dijets
  (CMS PAS FWD-08-002)

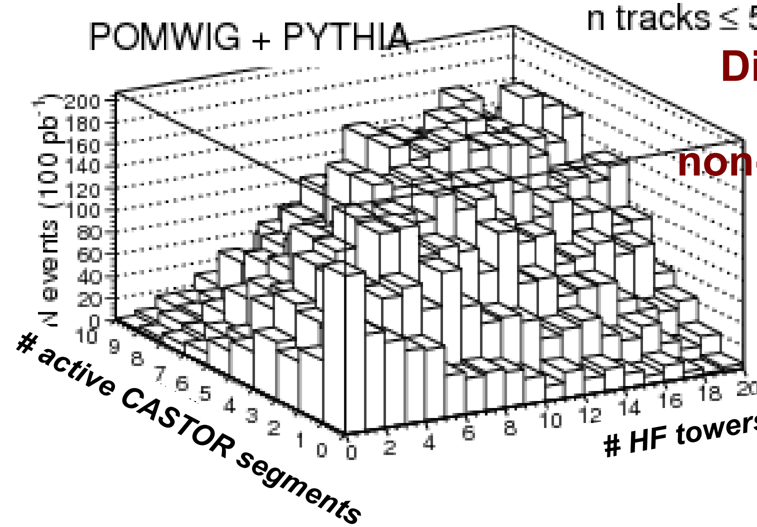
CASTOR ~ middle of rapidy gap:





Diffractive events

CMS preliminary



Diffractive + non-diffractive events

→ Improve diffractive selection by using/vetoing CASTOR