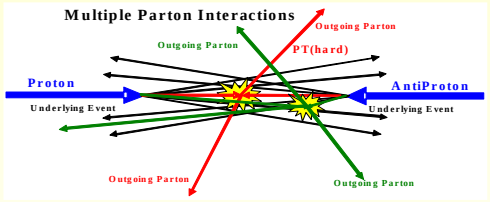
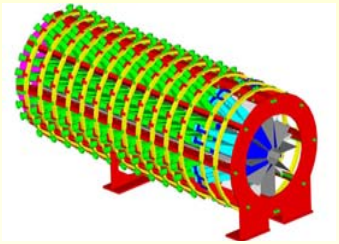
Multiple Interactions – Underlying Event
p p Physics with CASTOR





Kerstin Borras

on behalf of the

Small x and Multiple InteraXions Initiative

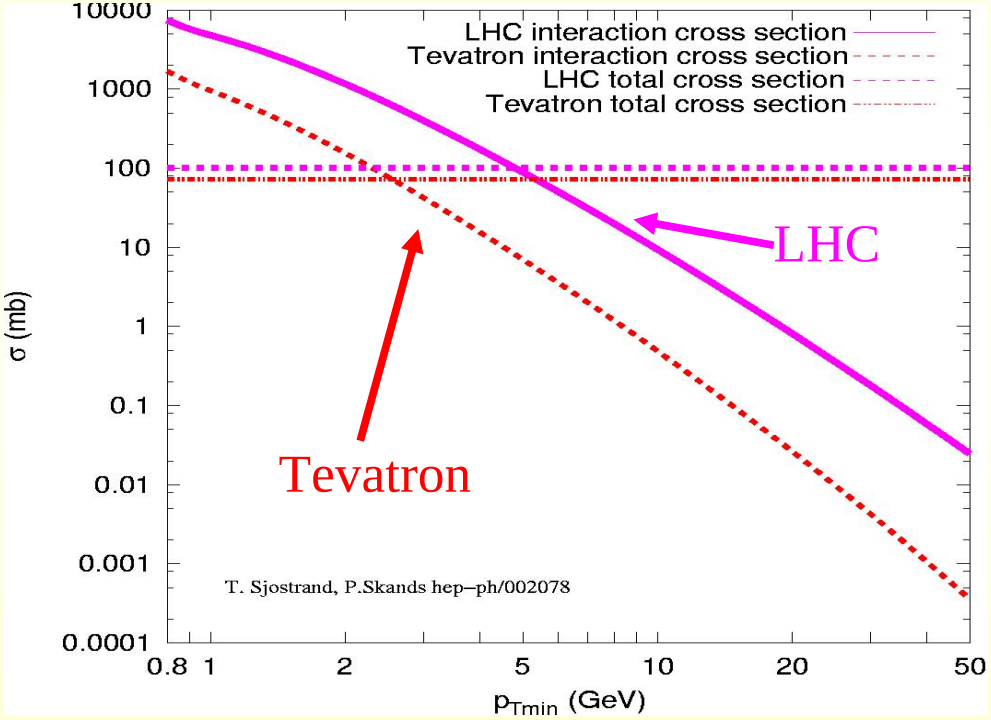
A. Campbell & H. Jung & K. Borras & M. Deak & Z. Staykova (DESY)
L.Lytkine & M. Kapichine (Dubna), V.F. Andreev (LPI), O. Lukina & L.Khein & I.Katkov (MSU), A. Buniatian (Yerevan)

- **Physics behind Multiple Interactions and Underlying Event**
- **Preliminary studies**
- **pp Physics with CASTOR**

The Physics of Multiple Interactions and Underlying Event

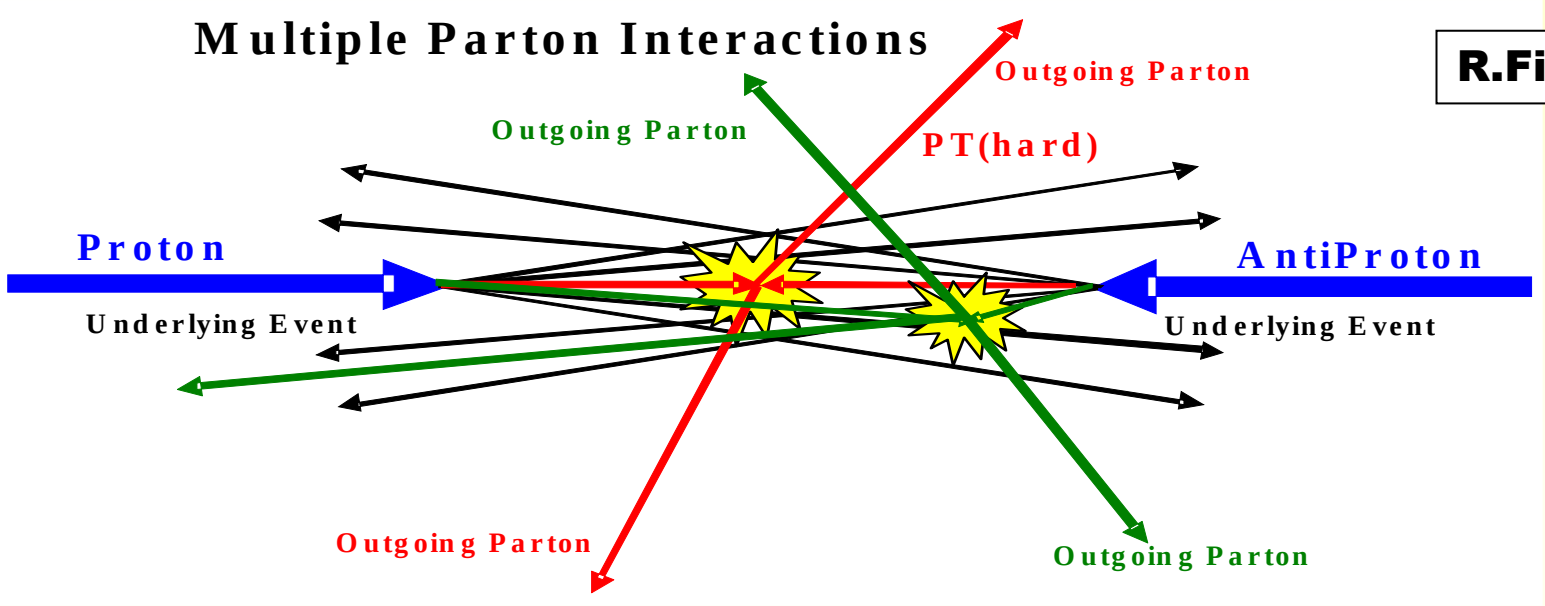
Basic partonic cross section

- **diverges faster than $(1/p_{Tmin})^4$ as $p_{Tmin} \rightarrow 0$**
- **exceeds total inelastic cross section**



➔ more than one interaction per pp collision
(note: no pile-up is meant !)

The Physics of Multiple Interactions and Underlying Event

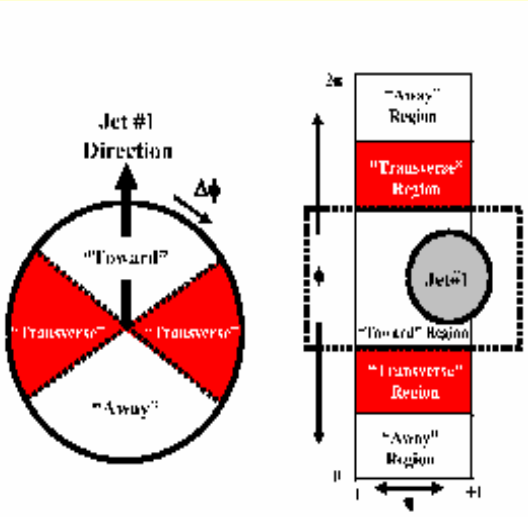


In addition to the single hard interaction with large p_T:

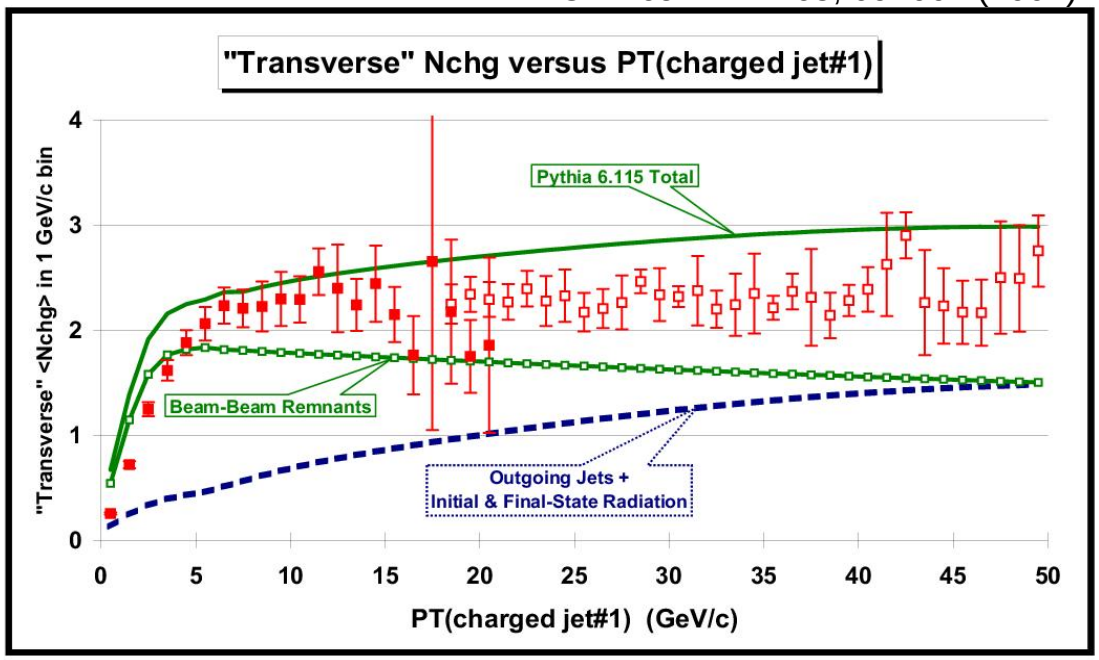
- **(soft) interactions with low p_T → Underlying Event**
  (remnant-remnant interactions and parton showers …
  → additional energy offset)
- **more hard interactions → Multi – Parton Interactions**
  (see evidence from CDF 1997: need > 50% double parton interaction for γ + 3 jet)

→ important for jet analyses (additional UE energy) or
$pp \to W+H+X$ with $W \to l+\nu$ and $H \to b\bar{b}$ (MI: $pp \to W+X_W + b\bar{b}+X_b$ without any Higgs!)

Studies from CDF



CDF coll. PRD 65, 092002 (2002)



➔ **need multiple interactions (remnant-remnant)**

Underlying event energy in di-jet events in non-diffraction (ND), single diffraction (SD) and Double Pomeron Exchange (DPE):

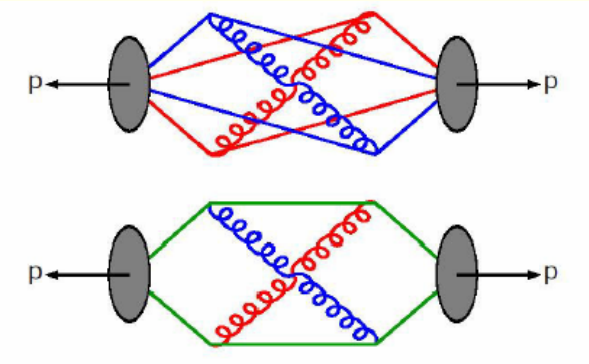
	ND (1800)	ND(630)	SD(1800)	SD(630)	DPE(1800)
eff. √s	1800	630	460	160	60
UE (R=0.7)	1.16	0.9	0.54	0.5	0.37

➔ **underlying event energy is PROCESS dependent !**

Tuning of Monte Carlo Generators

Agreement of data and MC depends strongly on how soft interactions are treated in the generator:

- **different models for UE & MI now available (color flow, string lengths …) :**



long strings (to remnants):

➔ large n_{ch} with low p_T in few interactions

short strings (more central):

➔ low n_{ch} with higher p_T in more interactions

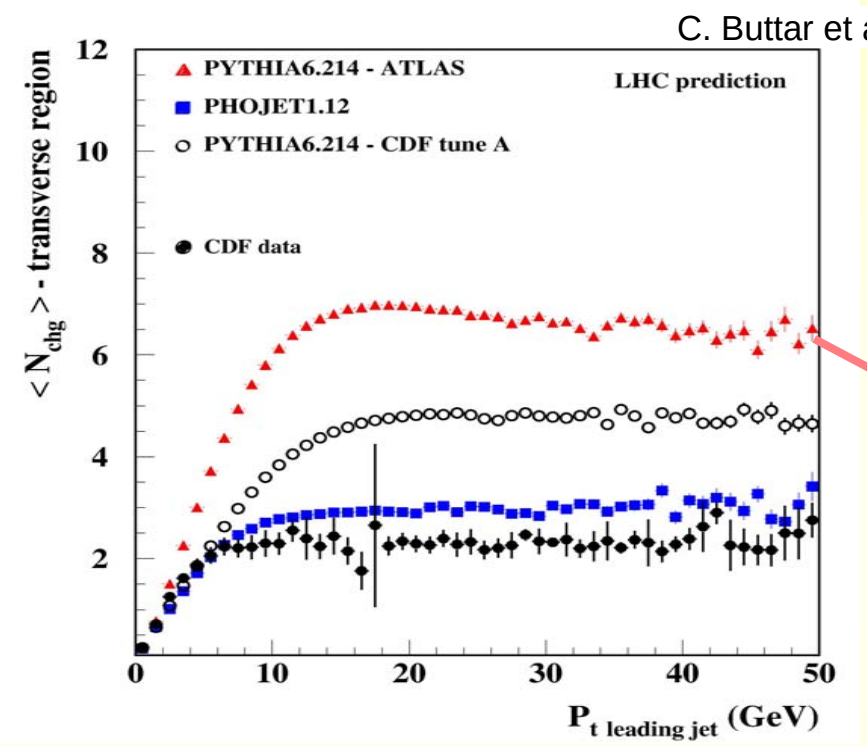
- **parameters in the generator versions can be tuned , but sometimes an approach cannot be tuned at all.**

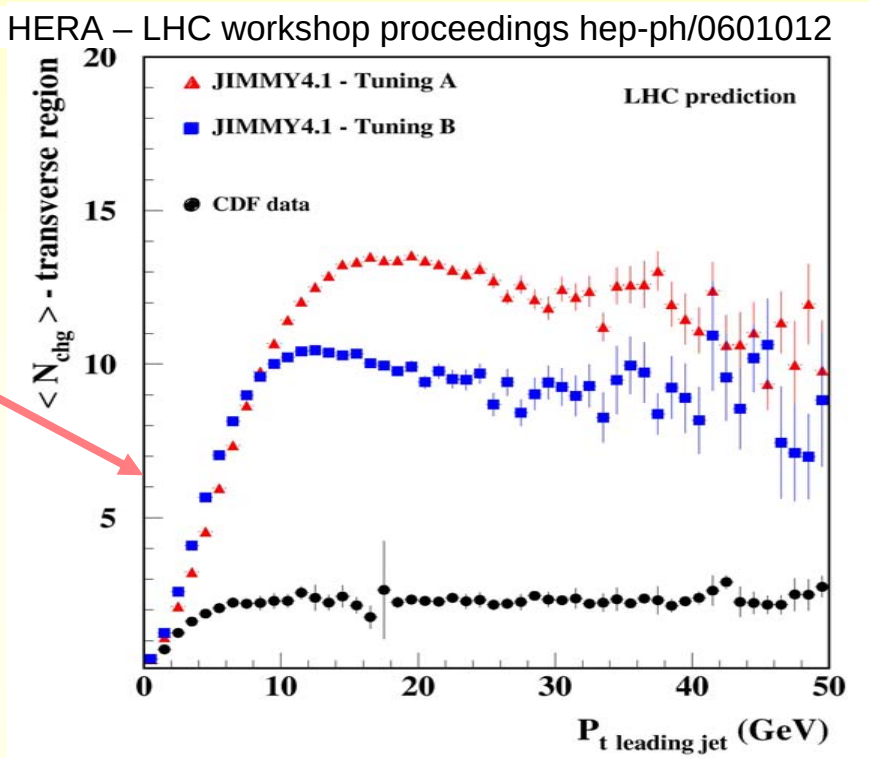
→ presently reasonable agreement achieved for TeVatron

→ what does it mean for LHC ?

Predictions for LHC

C. Buttar et al in HERA – LHC workshop proceedings hep-ph/0601012





➔ **huge differences for the different generators and tunes !**

➔ **better understand multiple interaction dependencies :**

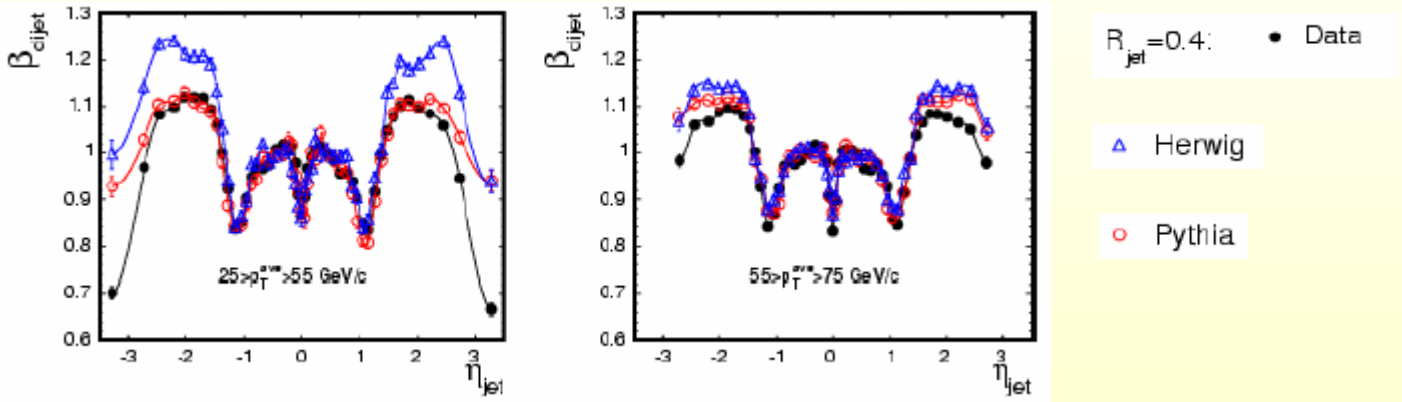
parton densities ← → factorization scheme
parton evolution (DGLAP/BFKL) / color correlations, …
→ speciality of HERA physics
(see also jet production in photo-production @ HERA)

Tuning of Monte Carlo Generators (cont.)

Limitations:

- **agreement @ TeVatron:**
  usually only good in one quantity, e.g. charged multiplicity or transverse energy flow → see the comment by Gosta Gustafson,
- **some tunes (TUNE A) are regarded as unrealistic by the authors, because they prefer unphysical color configurations**
- **tunes valid only in the central region**
  → what about the non-central regions ? → see talk by Stefan Mrenna)

pT(probe)/pT(trigger)



Tuned central region |η|<1 OK, but large deviations in non-central regions !

Tuning of Monte Carlo Generators (cont.)

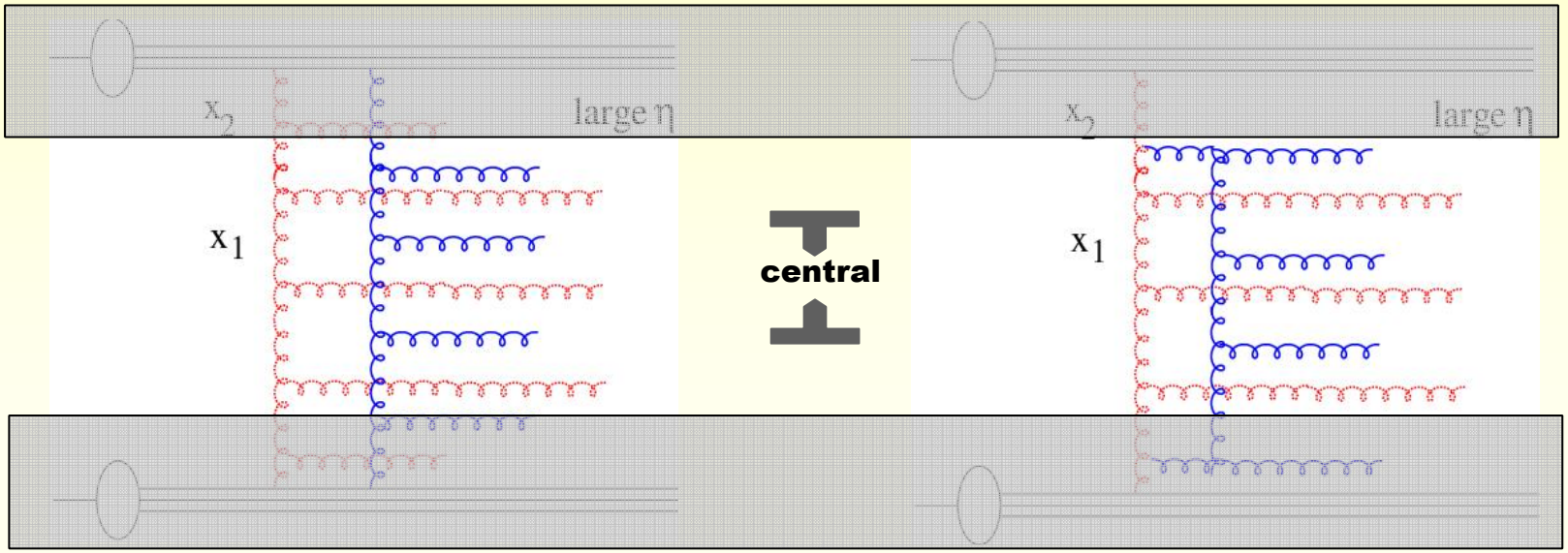
Limitations:

- **agreement @ TeVatron:**
  usually only good in one quantity, e.g. charged multiplicity or transverse energy flow → see the comment by Gosta Gustafson,
- **some tunes (TUNE A) are regarded as unrealistic by the authors, because they prefer unphysical color configurations**
- **tunes valid only in the central region**
  → what about the non-central regions ? → see talk by Stefan Mrenna)
  → what about the larger phase space @ LHC?
  → what about factorization (e.g. process dependence)?

Strategy for the first measurements:

- **pursue the same analysis strategy as @ CDF (tracking, central $|\eta| < 1$)**
  (→ Florian Bechtel (Uni HH) in the
  MB & UE study group (P. Bartalini, R. Field et al. → CMS Note 2006/067)
- **prepare for early measurements in forward direction**
  (calorimeter, CASTOR: $5.2<|\eta|<6.6$, or even further down: close to the ZDC)

Why into the forward region ?

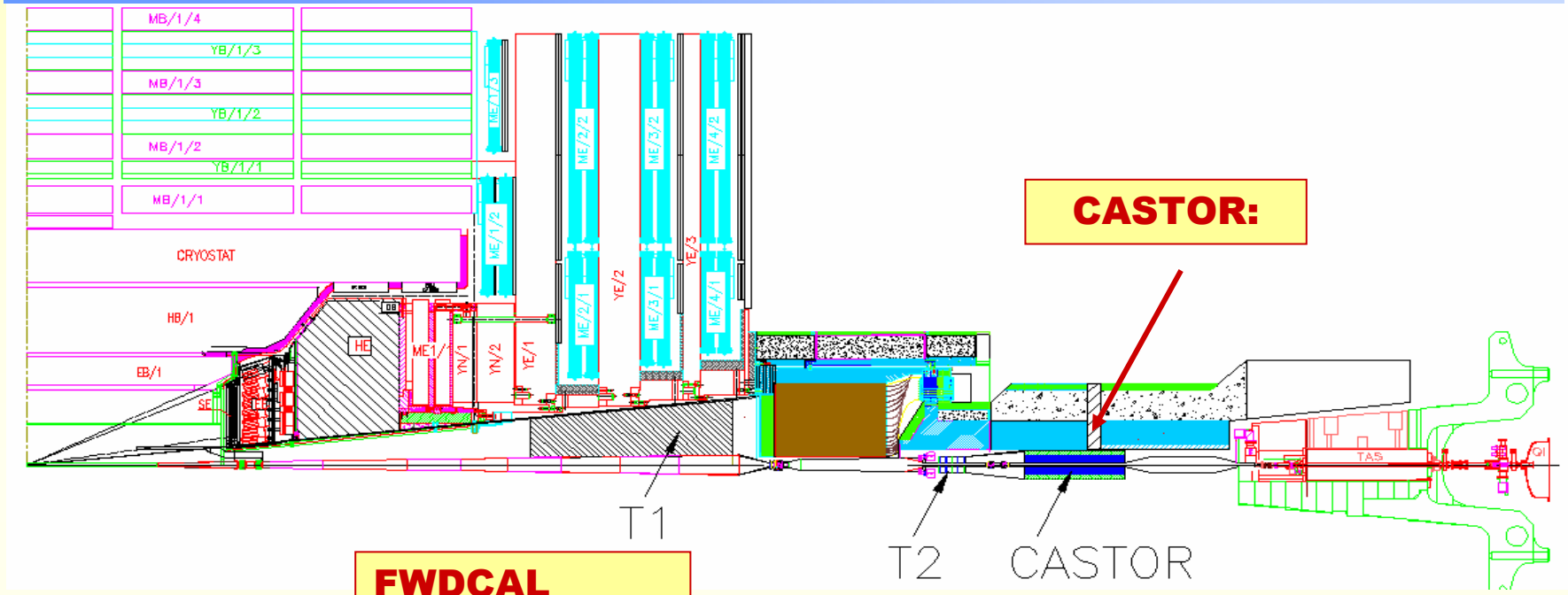


Central region does not distinguish between processes.

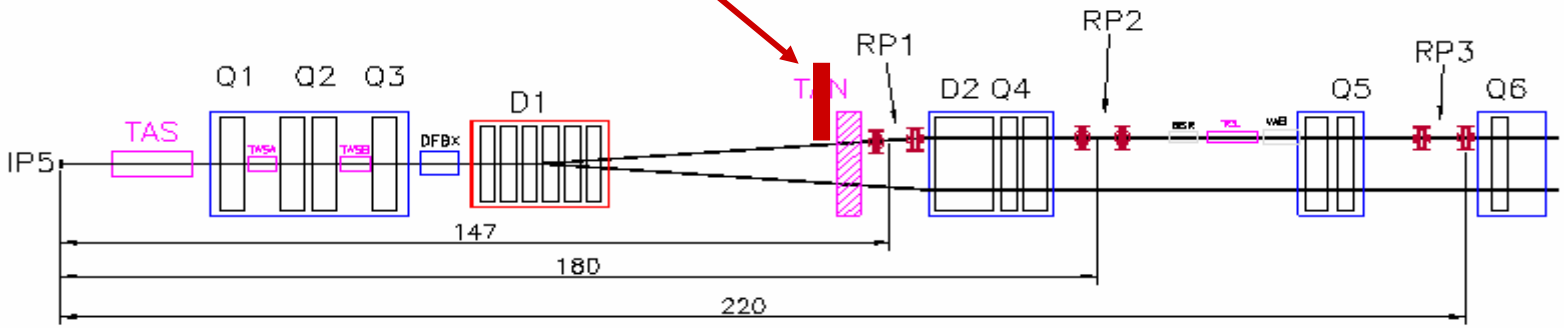
→ need to look forward :

- **jets in forward region 5 < |η| < 7 (CASTOR)**
- **correlations over large rapidity ranges (forward ←→ central)**
- **differences most clearly visible in the p-fragmentation region (energy taken differs)**
  → go to largest rapidities |η|~10 (→ more fwd detectors: FWDCAL near ZDC)

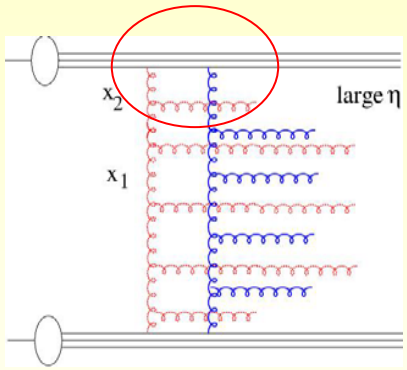
Detectors Studied

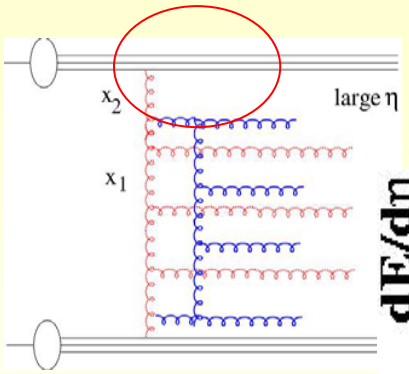


FWDCAL (near ZDC):



Energy Flow at Forward Rapidities





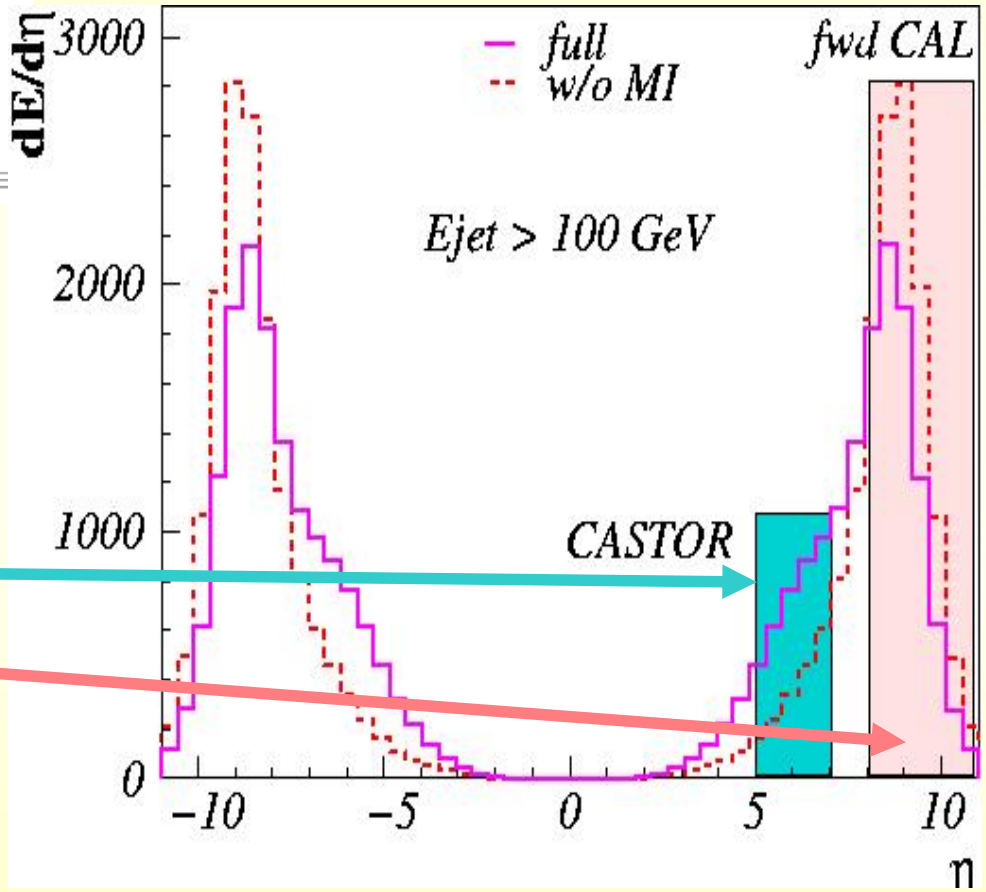
Depending on the ansatz for modelling MI more or less energy is taken from the beam remnant

→ differences in the energy flow in the forward region

|η| ~ 6

|η| ~ 9

M. Deak



Jet Cross Sections at Forward Rapidities

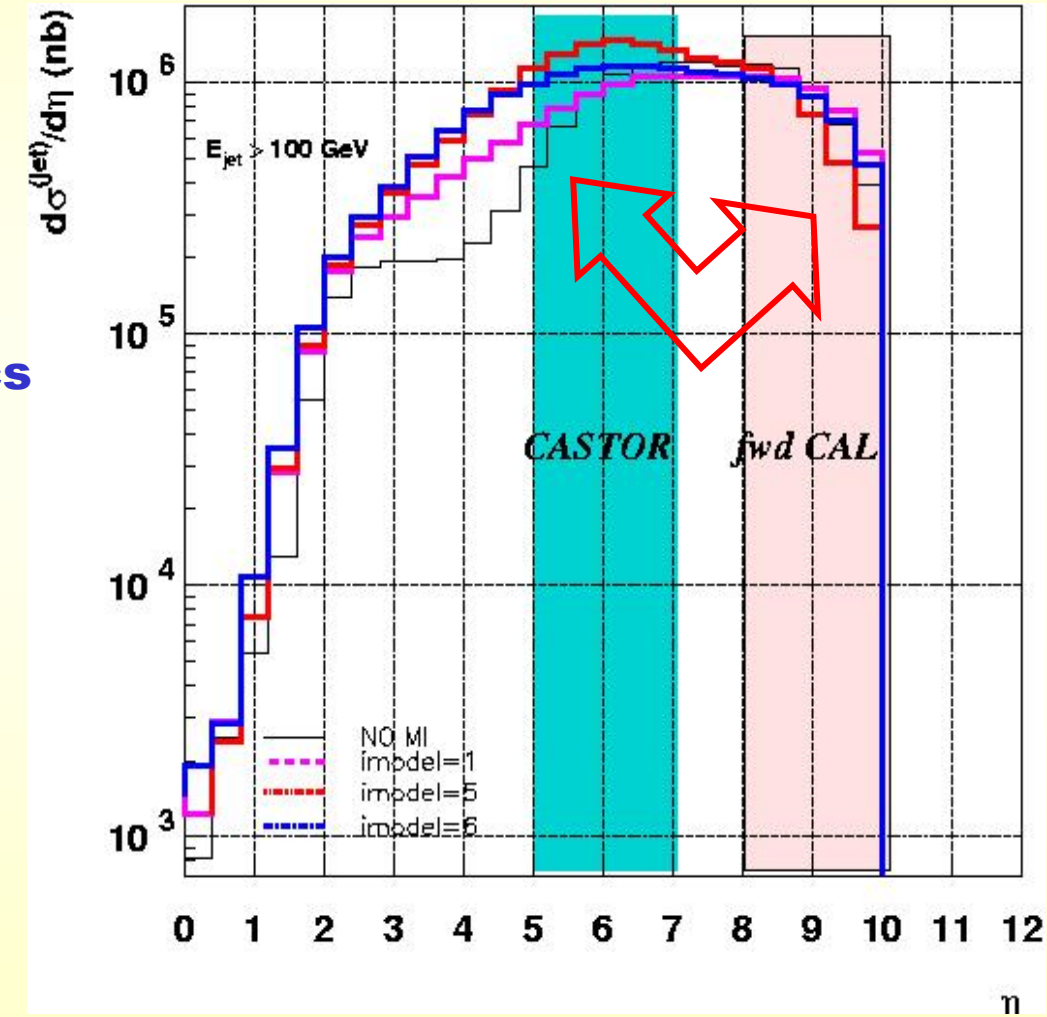
M. Deak

Different models for multiple interactions show large differences.

Understanding the dynamics

→ measure correlations between different rapidity ranges:

- **forward to very forward**
- **forward to central**

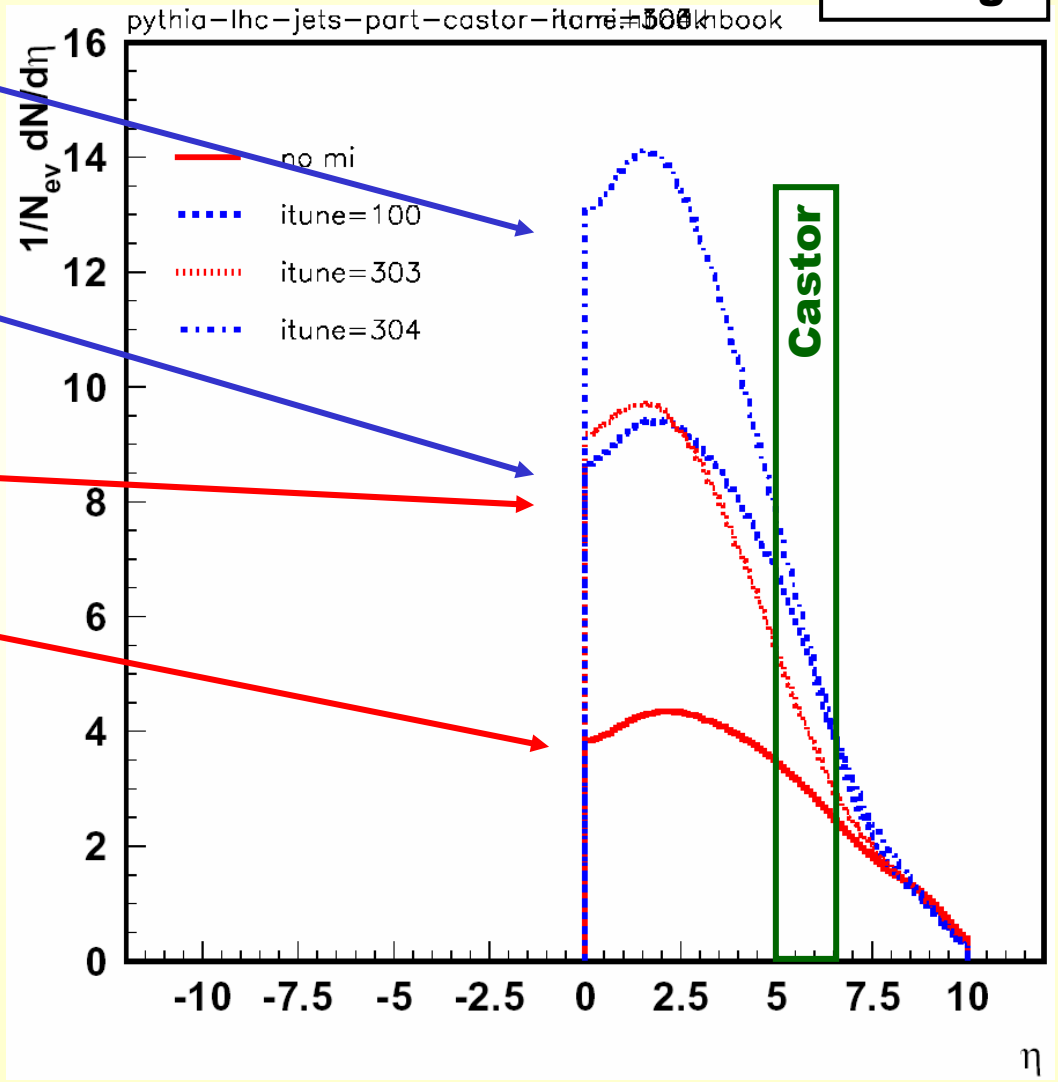


Particle Flow

H.Jung

Different models:

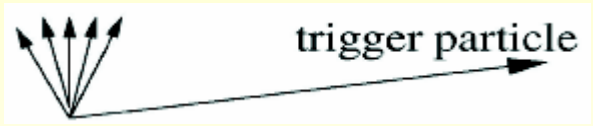
- **extreme model (energy dependence of p_T – cut)**
- **realistic models:**
  - **Pythia: Tune A (Rick Field)**
  - **new Pythia: ~Tune A (Sandhoff-Skands) new parton shower → new MI treatment**
- **no Multiple Interactions**
- **Multiplicities in CASTOR differ by a factor of 1.5 – 2**
- **Multiplicities in central region pretty similar → enhancement by triggering on CASTOR ?**



Long Range Correlations

H.Jung

central **forward**



no correlation

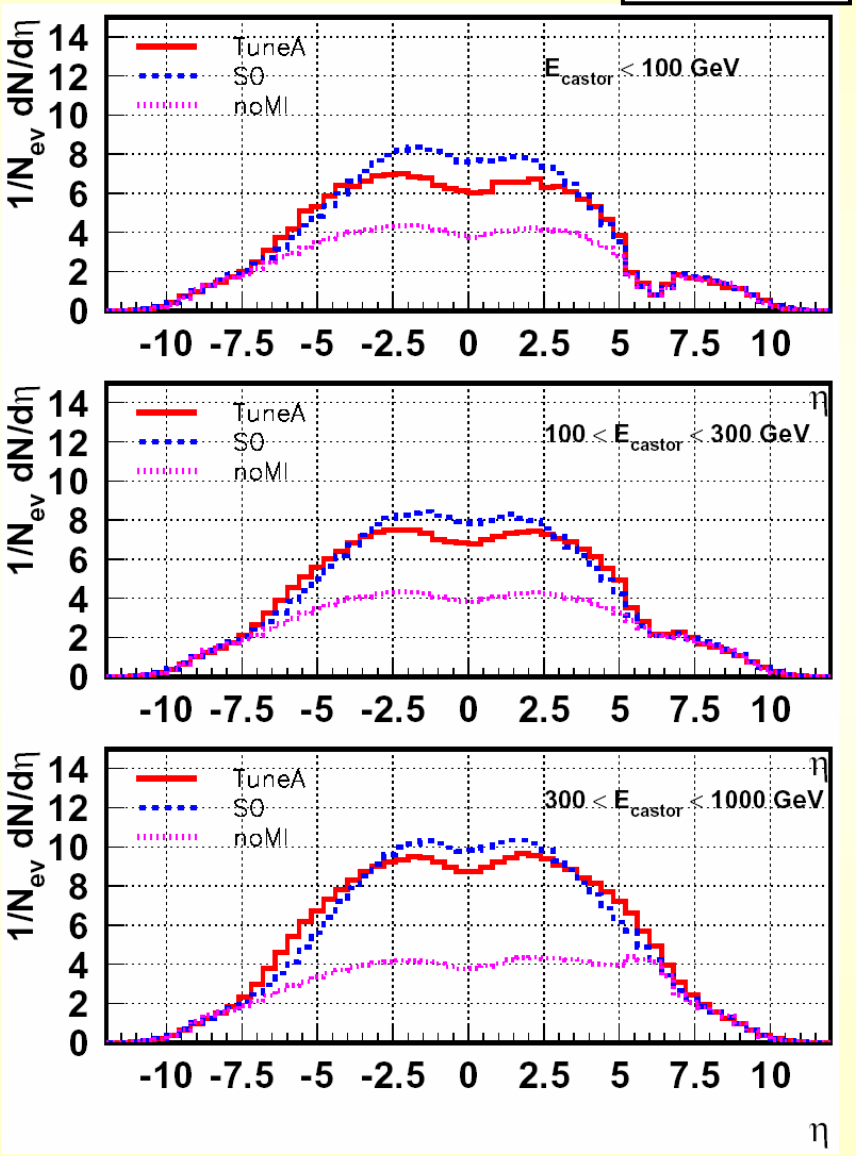
long range correlation

Pythia without MI → no correlation

Pythia with MI:

→ long range correlations, trigger enhancing differences in the central region

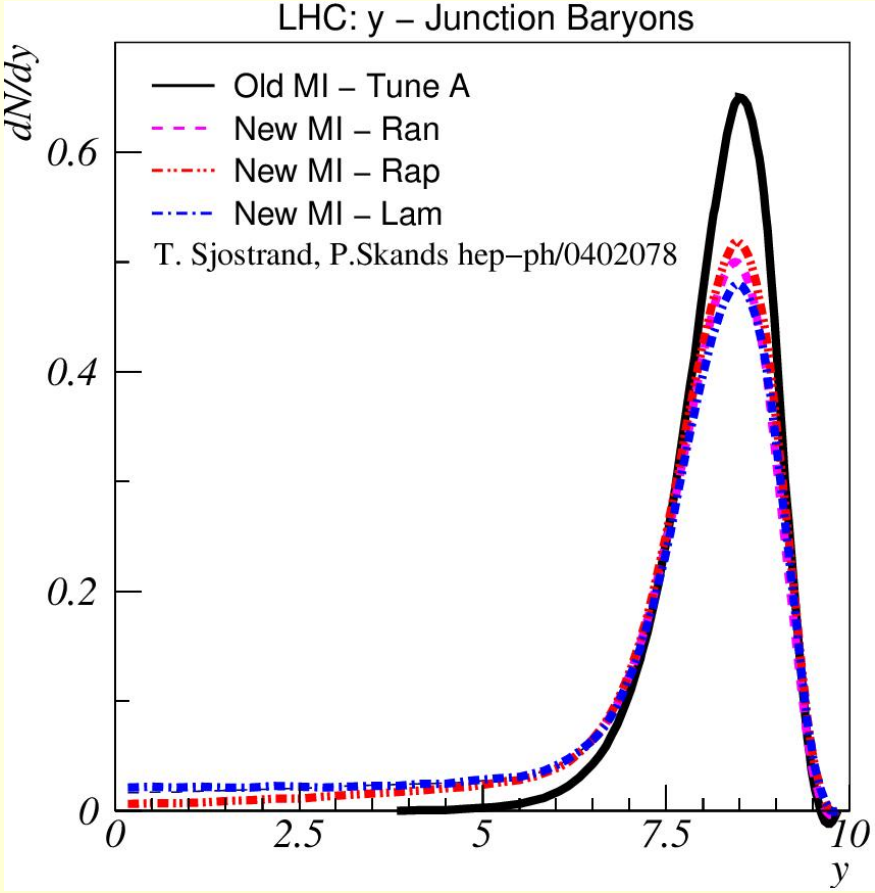
→ discriminative power



Flow of Leading Baryons

Baryon production at large rapidities depends also on multiple interactions !

→ see also talk by Bill Schmidke on results about leading neutron production @ HERA



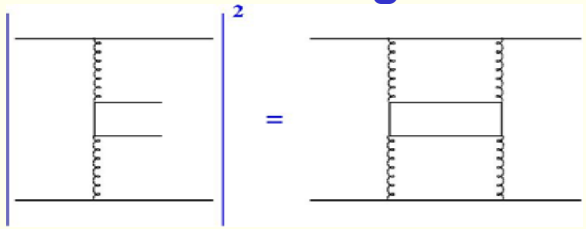
pp Physics with CASTOR

Multiple Interactions and Underlying Event structure are crucial for all precision measurements @ LHC

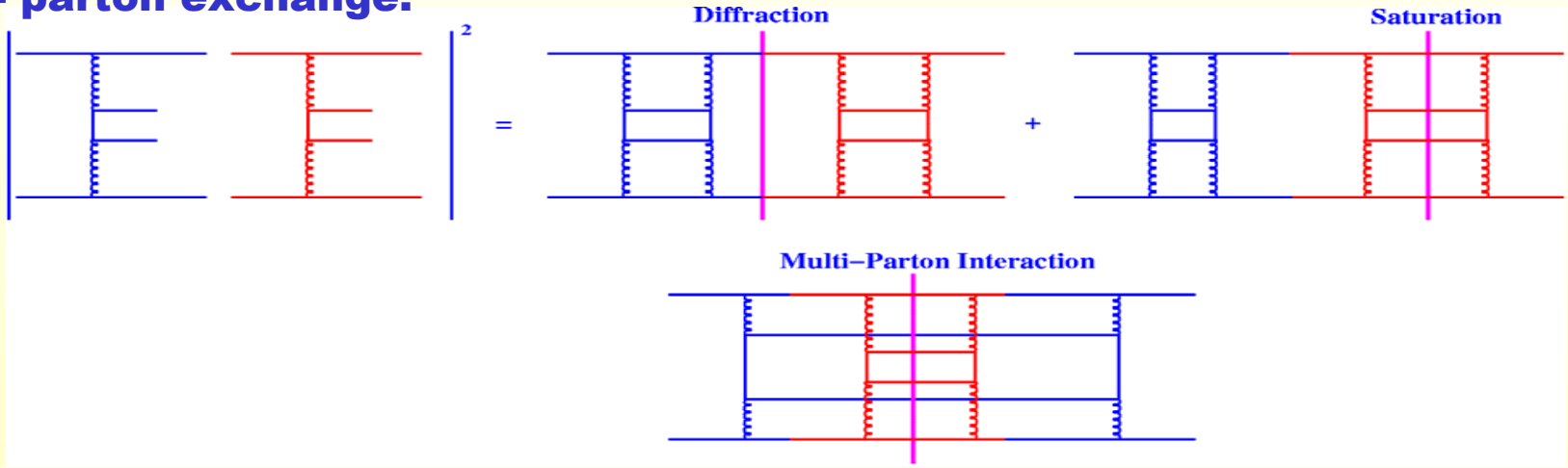
→ need to understand both: hard and soft multiple interactions

Multiple Interactions and Underlying Event are closely related to Diffraction and to Saturation: AGK cutting rules

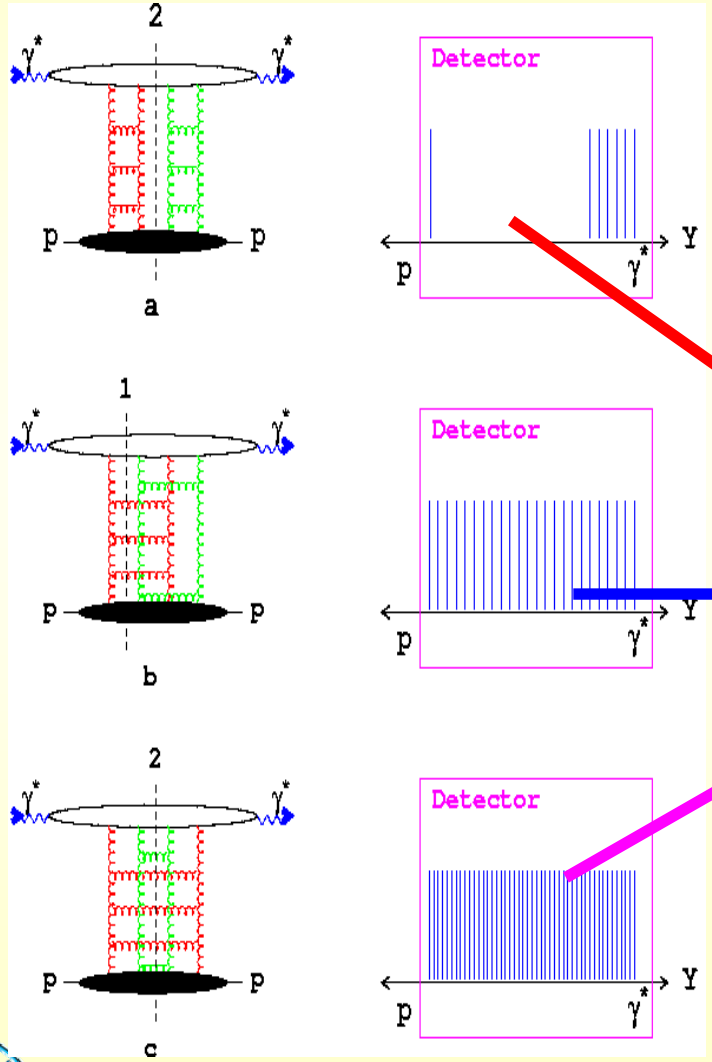
1 - parton exchange:



2 - parton exchange:



pp Physics with CASTOR (II)



Bartels, Kowalski, Sabio-Vera in HERA – LHC workshop proceedings
hep-ph/0601012/13

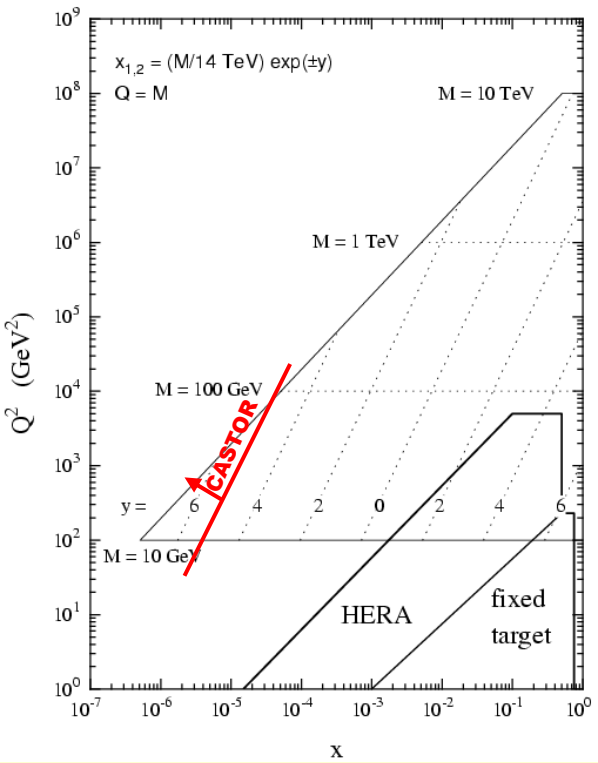
- **Cutting rules (AGK) extended to QCD**
- **Relate diffraction, saturation and multiple scatterings**
- **All from the same amplitude, but different factors:**
  - **+1 Diffraction**
  - **- 4 Saturation**
  - **+2 Multiple Interactions**
- **Extended now also to pp !!!!**
  - **BUT further work needed …**

➔ three main areas for pp physics with CASTOR:

MI & UE, small x, diffraction + …

pp Physics Menu

- **Multiple Interactions and Underlying Event**
  → crucial for precision
- **Saturation ➔ small – x physics**



- **Drell – Yan**
- **BFKL / CCFM phenomena, forward jets, gap between jets**

pp Physics Menu

- **Multiple Interactions and Underlying Event**
  → crucial for precision
- **Saturation → small – x physics**
  - **Drell – Yan**
  - **BFKL / CCFM phenomena, forward jets, gap between jets**
- **Diffraction:**
  - **full menu of hard & soft, single & double diffraction and DPE**
  - **rapidity gap and multi-gap dynamics (veto)**
  - **exclusive productions → gluon factory**
- **Minimum Bias trigger**
- **Cosmic ray physics: energy and particle flow**
- **Luminosity measurement**

(see talk by Monika)

Summary

- **Knowledge of Multiple Interactions and Underlying Event Structure is crucial for all searches and high p_T phenomena.**
- **Need to understand the dynamics of the underlying event, only tuning the parameters of a Monte Carlo generator might not be sufficient and includes large systematic uncertainties.**
- **Forward detectors deliver crucial inputs to mainstream physics and to heavy ion physics.**

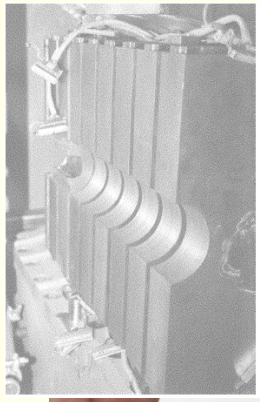
➔ **Need coverage at large η right in the beginning of LHC !**
➔ **People are working intensively to make it happen, still room for new contributions,**
➔ **new collaborators highly welcome ☺**

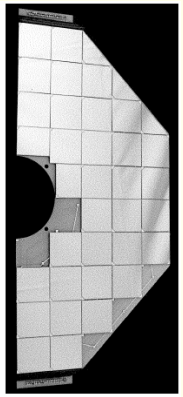
Backup Material

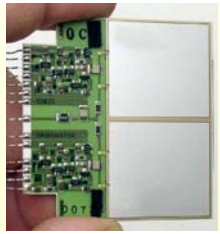
Fallback Calo-Candidates under study

in case the funding for the CASTOR calorimeters does not materialize: investigating if DESY calorimeters would be of help:

ZEUS-HES diodes with H1-Plug Cu-absorber:

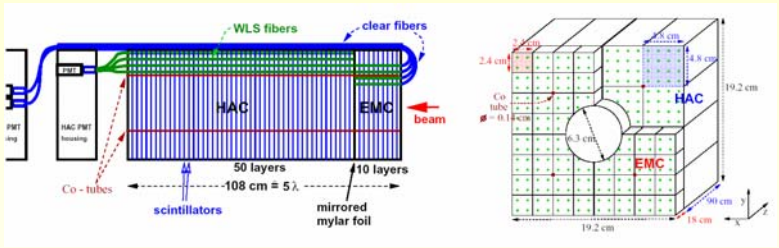






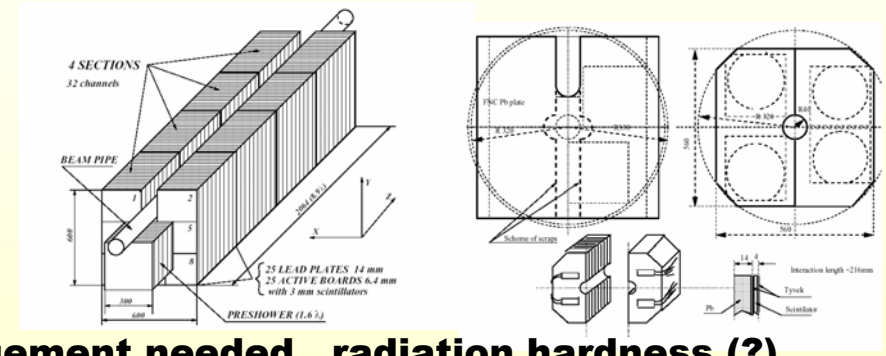
20.000 Si pad diodes
3.32×2.96 cm²
4 - 5 replacements possible.

ZEUS-FPC:



- **radiation hard for several 100 pb^{-1} (very conservative !)**
- **calorimeter itself already available right now**
- **but covers only ~ 1/4 of the space**

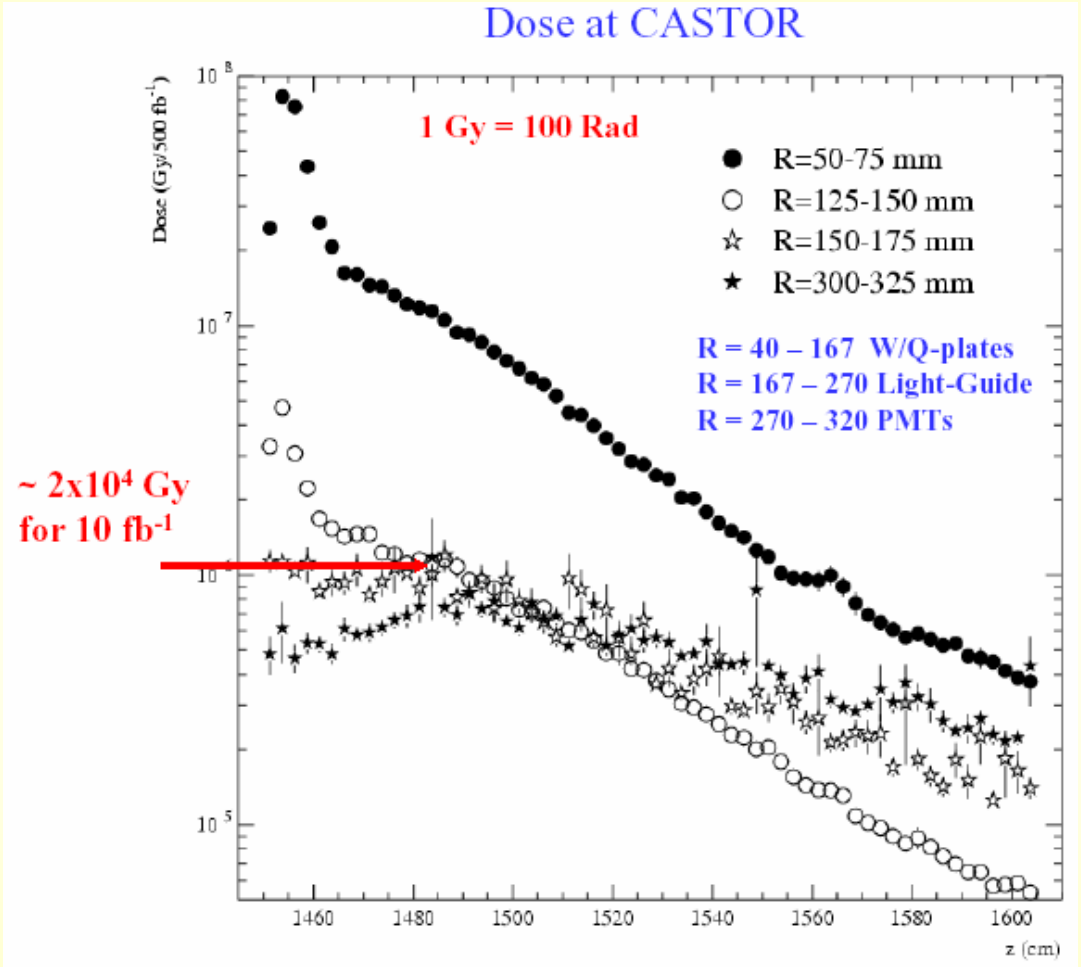
H1-FNC:



- **re-arrangement needed, radiation hardness (?)**

BUT also all these candidates do not come for free → still the readout is needed !

Radiation Level in CASTOR region



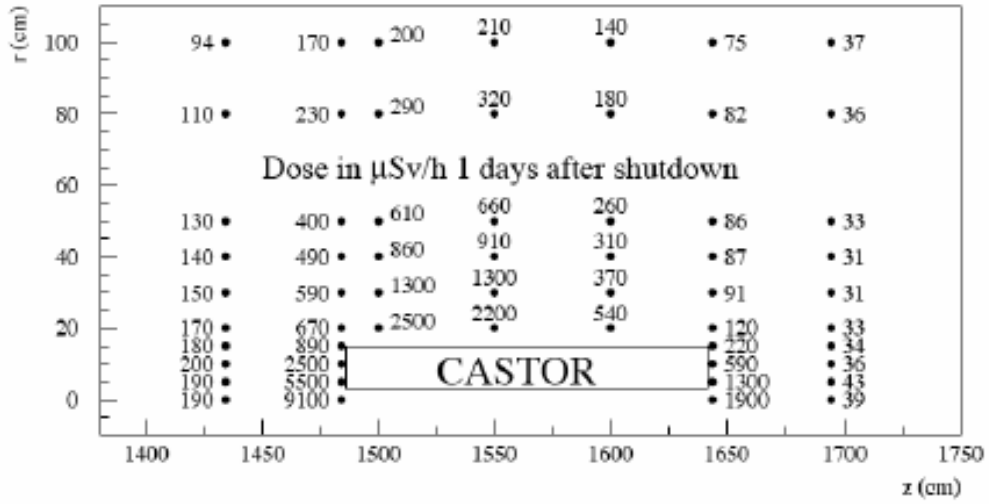
Rough estimate:

- **Si-diodes should be radiation hard up to 3 MRad (producer)**
- **2x104Gy = 20MRad for 10 fb-1**
  ➔ 2MRad / fb-1
  ➔ diodes will survive the first run, outer diodes even longer

Activation in CASTOR region

VERY ROUGH estimates for normal CMS scenario 10y LHC, 1d cooling

Activation of CASTOR ≈ 5 times lower than of TAS



(For short cooling) this scales with the last average luminosity, i.e <L>/5E33

(<L> averaged over O(cooling time)

4. May. 2006 Mika Huhtinen (CERN/PH-CMG) 12

Rough estimate:

- **10y LHC → 500 fb-1: 2500 – 10.000 μSv/h**
- **1 fb-1: 5 – 20 μSv/h , 2 fb-1: 10 – 40 μSv/h**

→ comparable with work at ZEUS Uranium calorimeter
lower lumi & longer cooling time decreases activation even further !