Forward Physics and Low-x at the LHC

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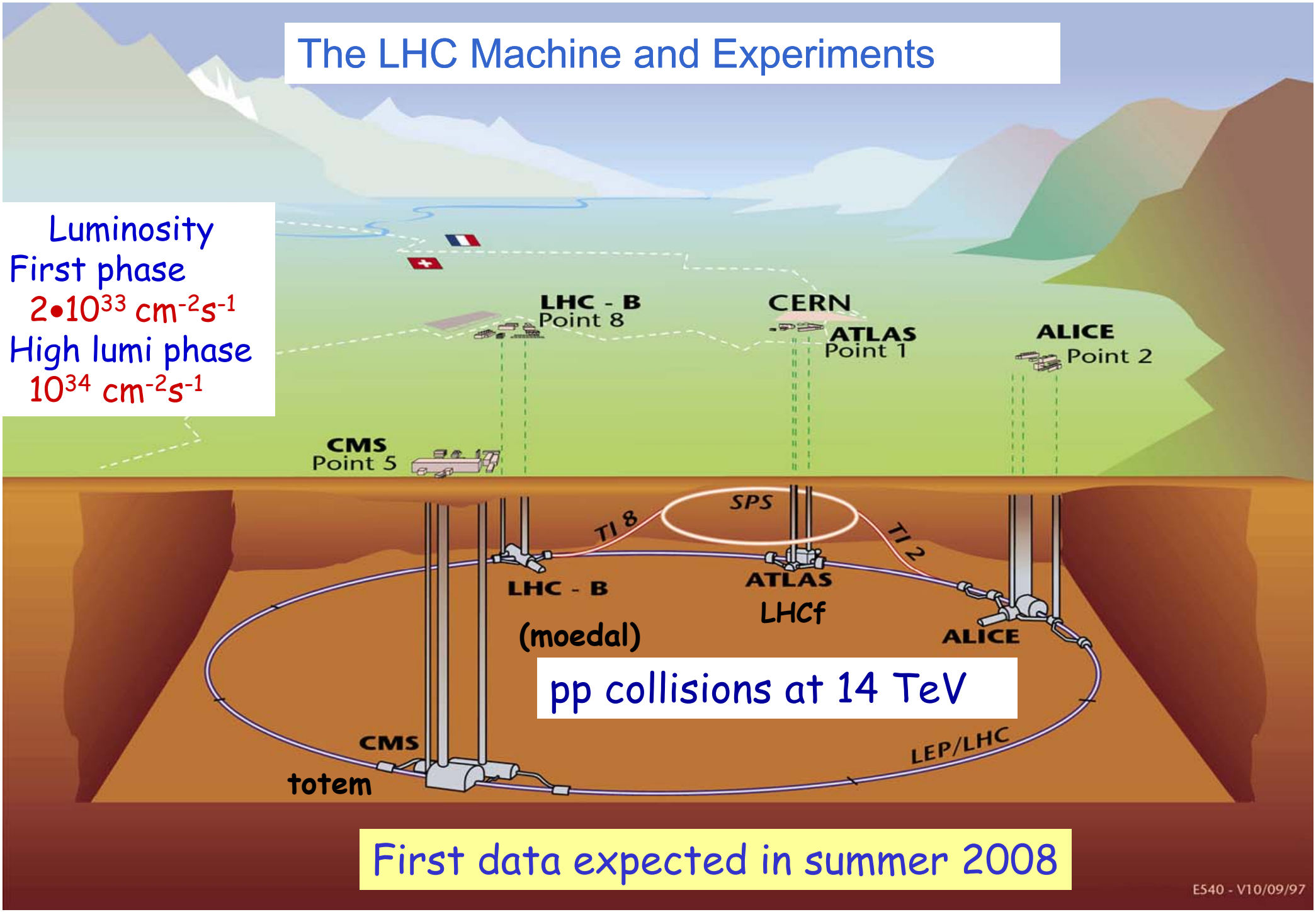
CERN

Low-x Meeting
Helsinki Finland 29 August – September 1 2007

The LHC Machine and Experiments

Luminosity
First phase
$2 \bullet 10^{33}\ cm^{-2}s^{-1}$
High lumi phase
$10^{34}\ cm^{-2}s^{-1}$



pp collisions at 14 TeV

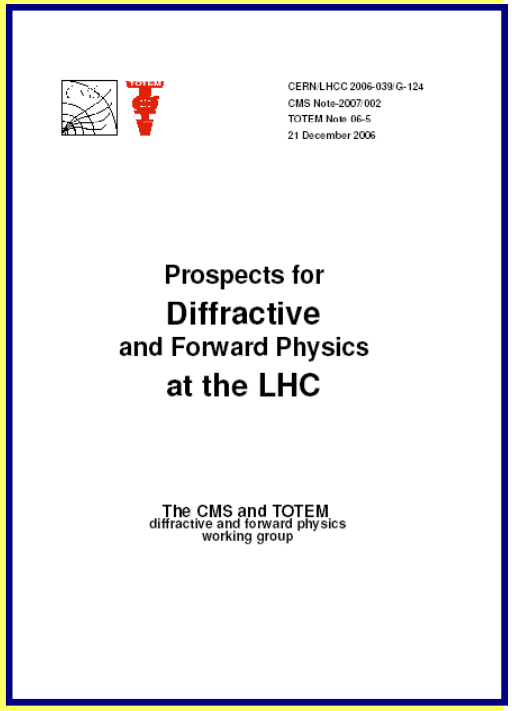
First data expected in summer 2008

History

- First discussion at the low-x meetings: Oxford (2000)
  "Low-x physics at the LHC" (ADR)

- At the time
  - No forward detectors at CMS/ATLAS (acceptance $|\eta|<5$)
  - No diffractive/low-x program
  - No connection between TOTEM & CMS

- Since then a lot has happened
  - Forward detectors proposed and several being built
  - Physics program elaborated as part of the CMS/ATLAS (ALICE/LHCB) program
  - CMS/TOTEM common physics study & data taking possibility
  - New experiment LHCf…



Forward Detectors at the LHC

1. **CMS** (fwd. EOI submitted Jan.'04, CMS+TOTEM LOI LHCC-2006-039):
   - → CASTOR, ZDCs, TAS (under consideration) + TOTEM
   - • Soft&hard diffraction (w/ TOTEM or rapgaps), low-x QCD, cosmic-rays, γ–p, γ–A, γ–γ

2. **ATLAS** (fwd. LOI submitted Mar.'04):
   - → ALPHA RPs (LOI R&D), LUCID, ZDC (approved 2007), TAS (under consideration)
   - • Total p-p cross-section, photo-production (UPC Pb-Pb)
   - • RP220: detectors for diffraction at 220 m

3. **ALICE**:
   - → ZDCs, fwd. muon spectrometer
   - • Diffraction, low-x QCD

4. **LHCb**:
   - → Forward muon spectrometer
   - • Low-x PDFs

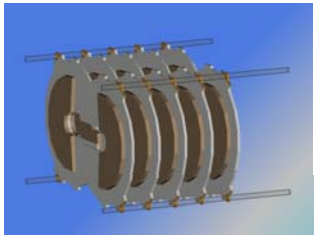
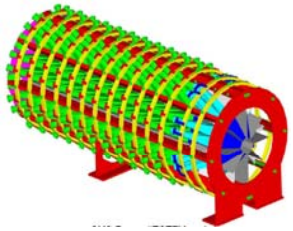
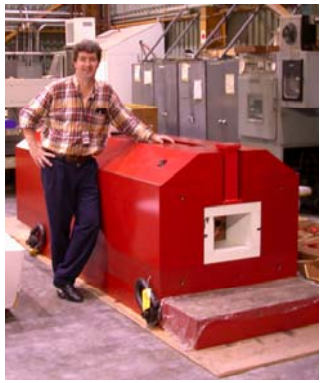
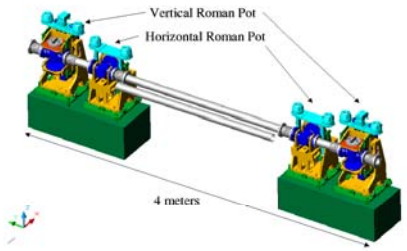
5. **TOTEM** (approved LHCC July'04):
   - → Roman pots (220 m), trackers (T1, T2)
   - • Elastic scattering, total p-p cross section, soft diffraction

6. **LHCf** (approved LHCC 2006):
   - → EM Calo (ATLAS-TAN, 140 m)
   - • Cosmic-rays (forward γ,π^0)

7. **FP420** (R&D collab. LHCC-2005-025):
   - → Feasibility studies for near-beam dets. at 420m
   - • QCD, exclusive Higgs, new physics

Forward Detectors at LHC

TOTEM -T2 CASTOR ZDC/FwdCal TOTEM-RP FP420

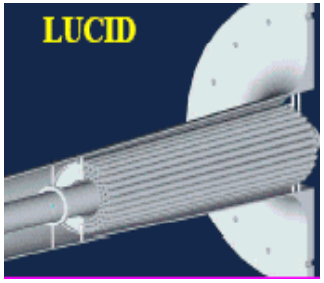





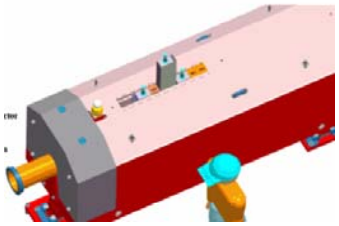
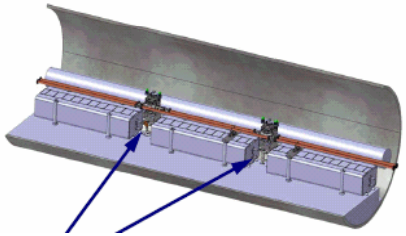
IP5

14 m 16 m 140 m 147m - 220 m

420 m

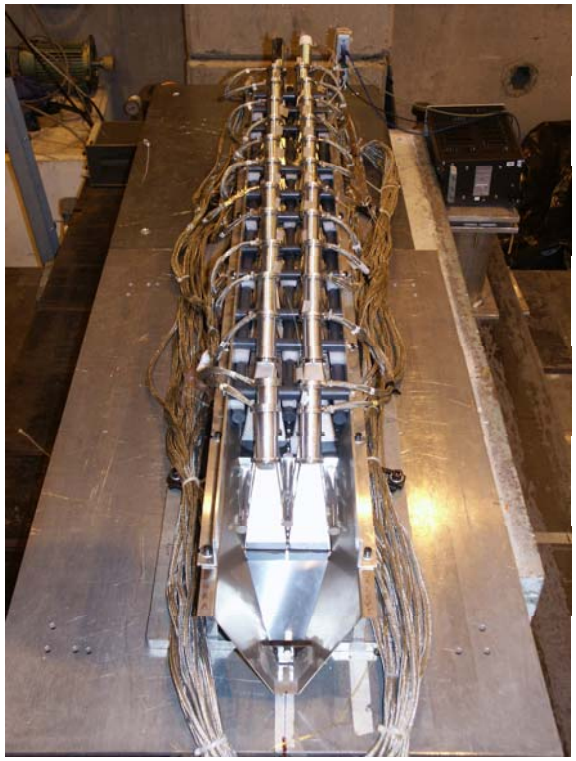
IP1

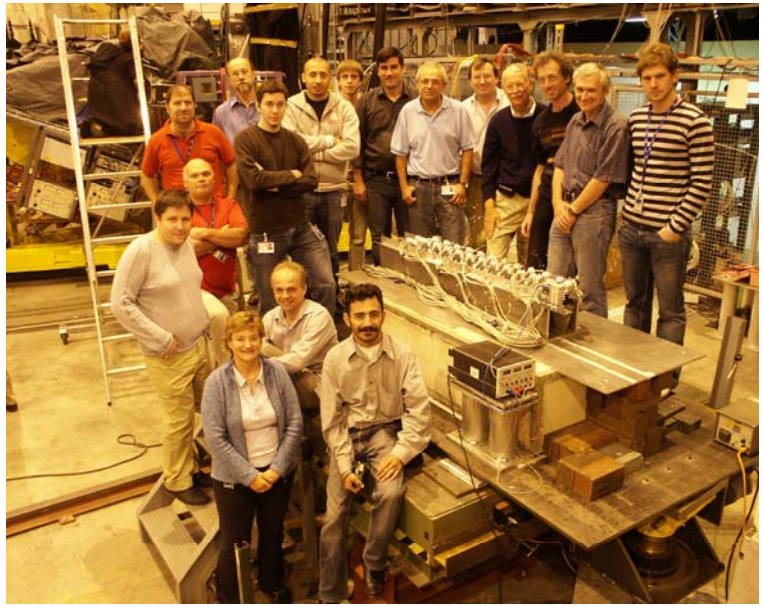



LUCID ZDC ALFA/RP220 FP420

Castor 2007 Testbeam (August 07)

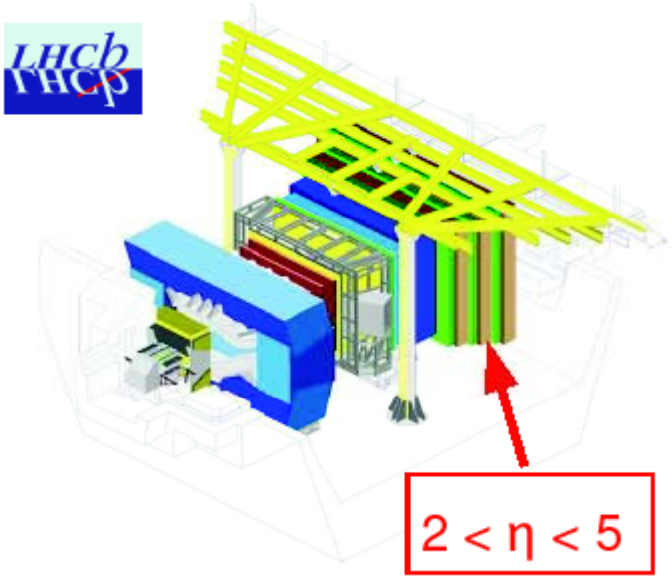


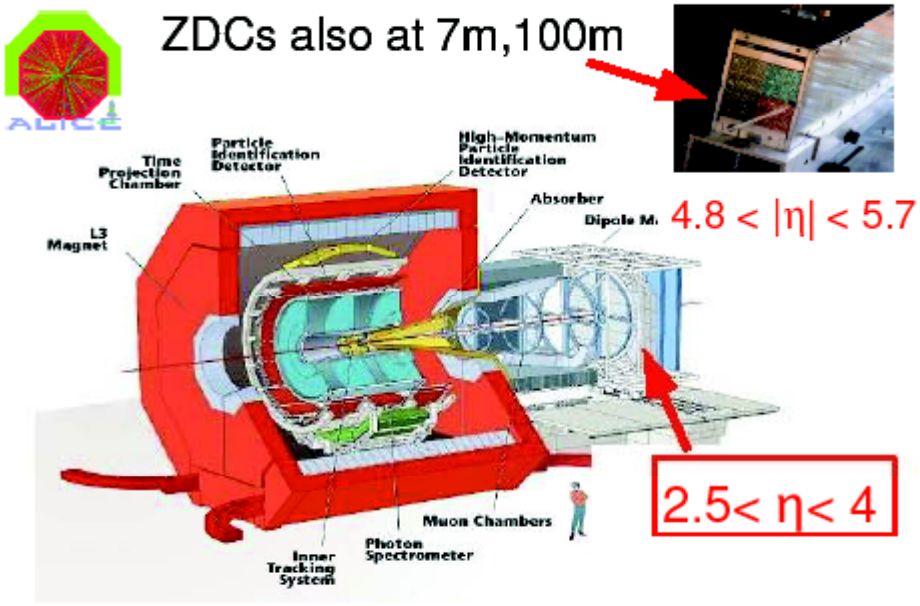


More from Pierre Van Mechelen on Saturday

But also ALICE and LHCb…

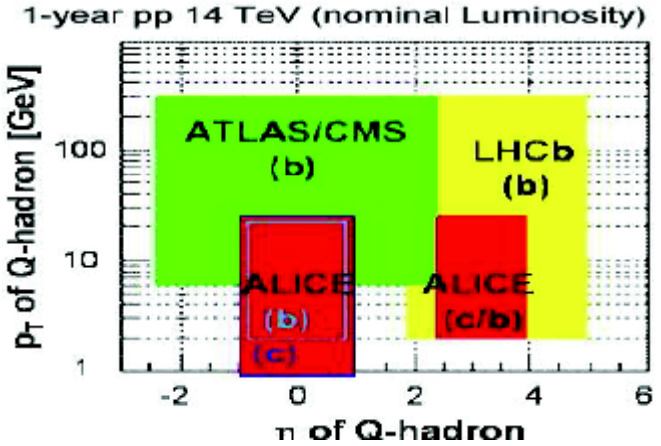
- Forward muon spectrometers:





- Good capabilities for fwd. heavy-Q, $Q\bar{Q}$, gauge bosons measurements:

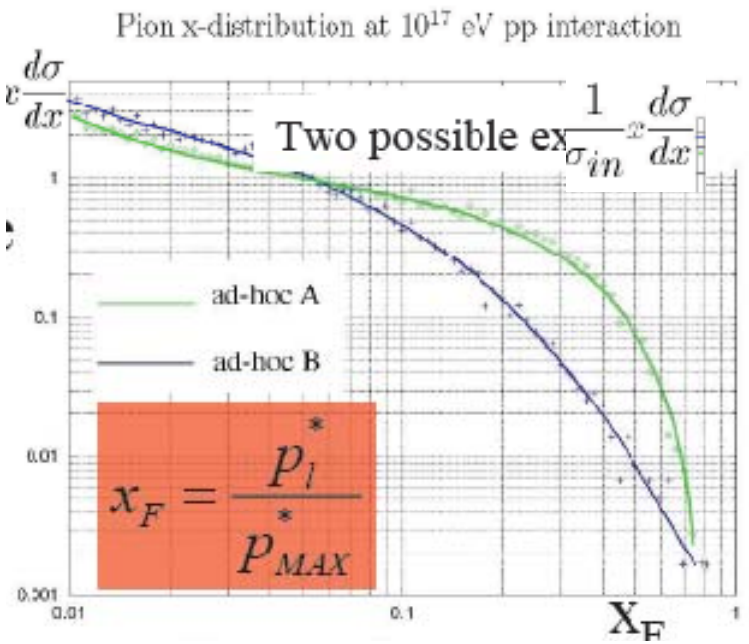
(low-x PDFs)

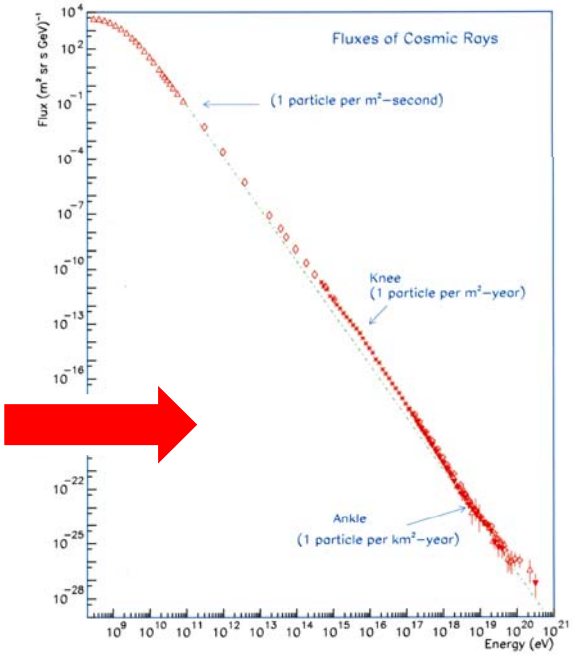


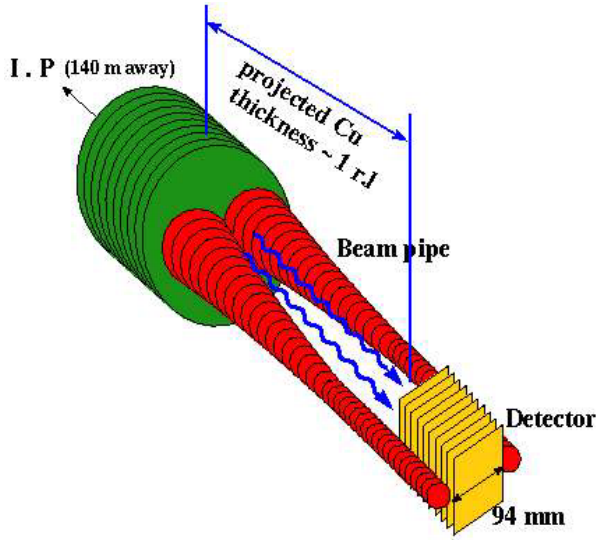
LHCf: an LHC Experiment for Astroparticle Physics

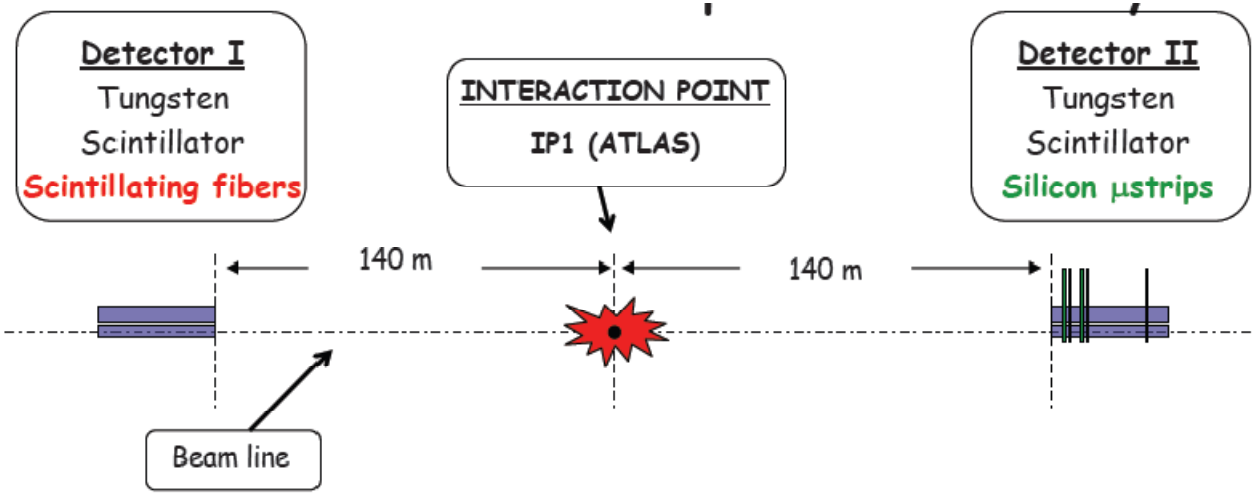
LHCf: measurement of photons and neutral Pions and neutrons in the very forward region of LHC

140 m from IP1 (ATLAS)

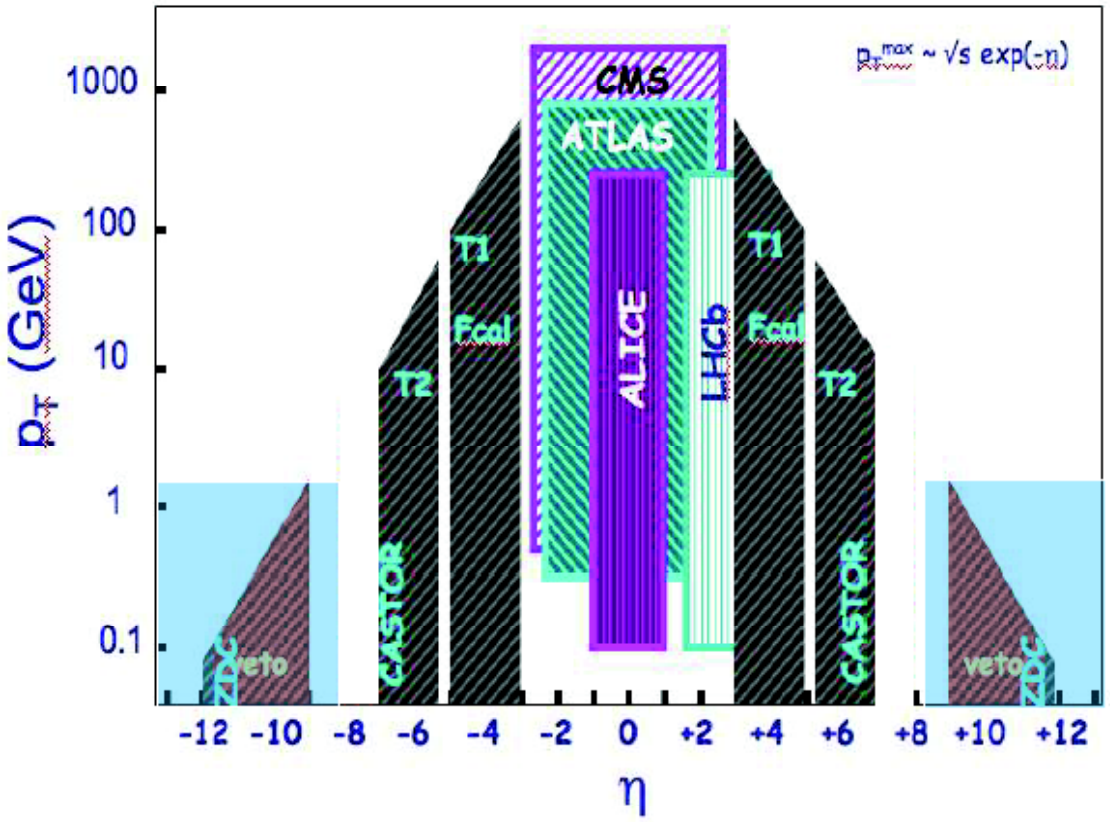


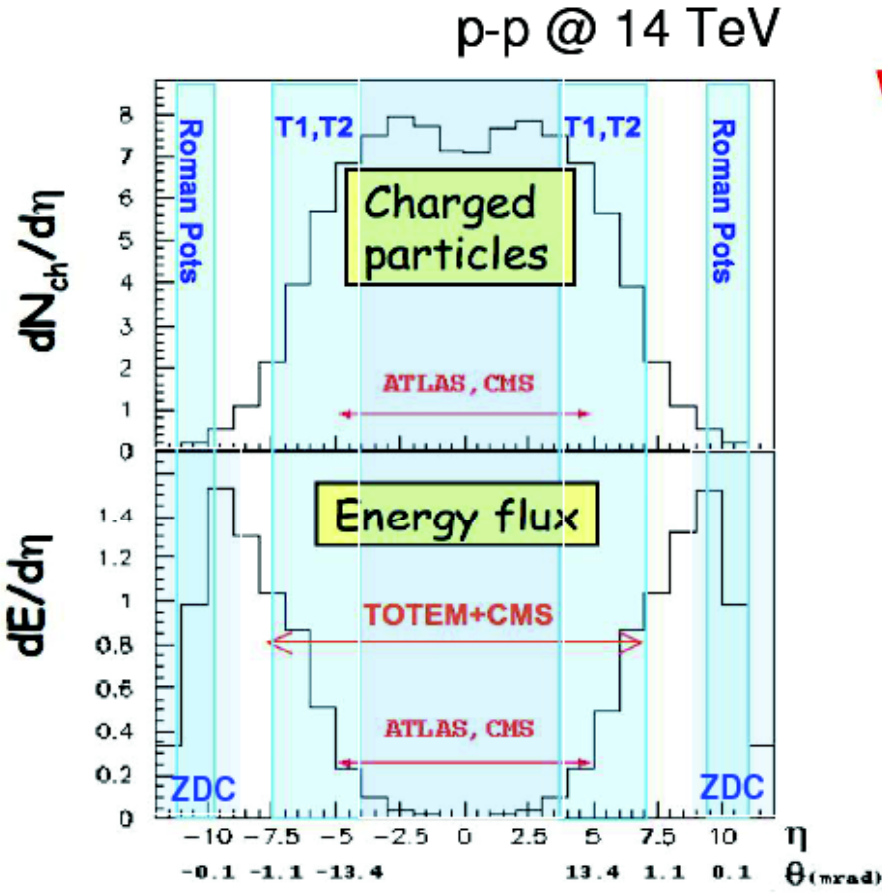






Acceptance of the LHC Detectors

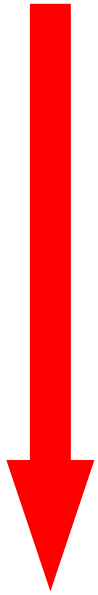




- All phase space virtually covered at the LHC
  — for the first time at a collider—
- Ongoing CMS/ATLAS studies to cover the 'remaining hole'

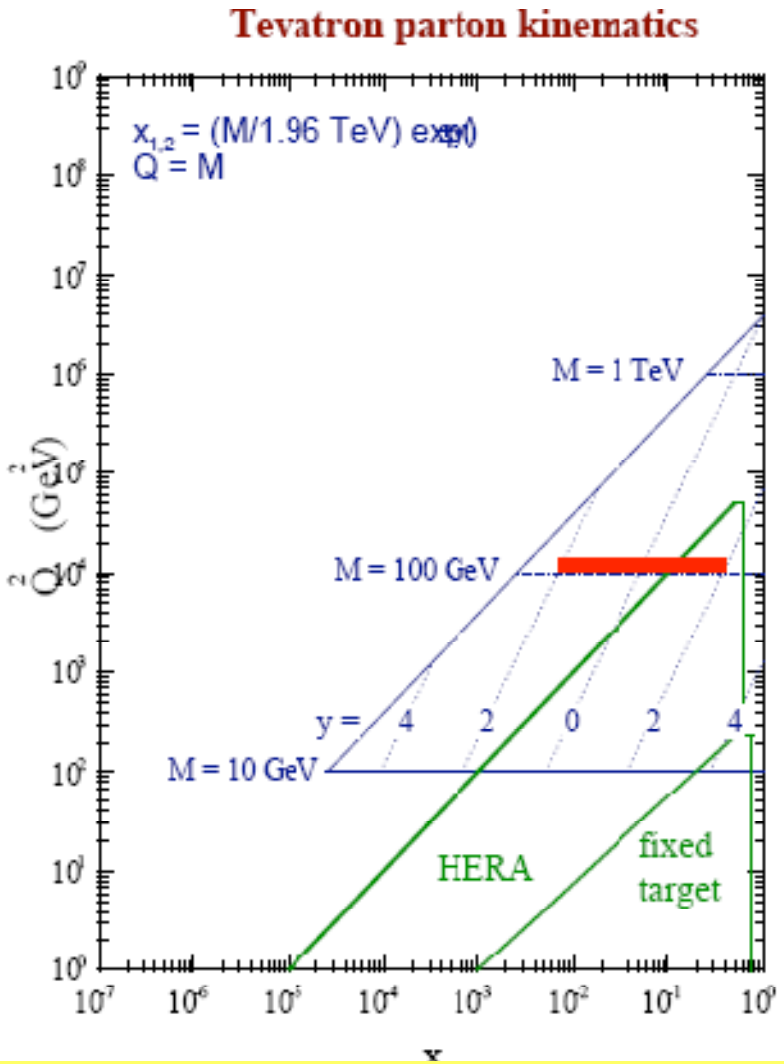
Forward Physics Program

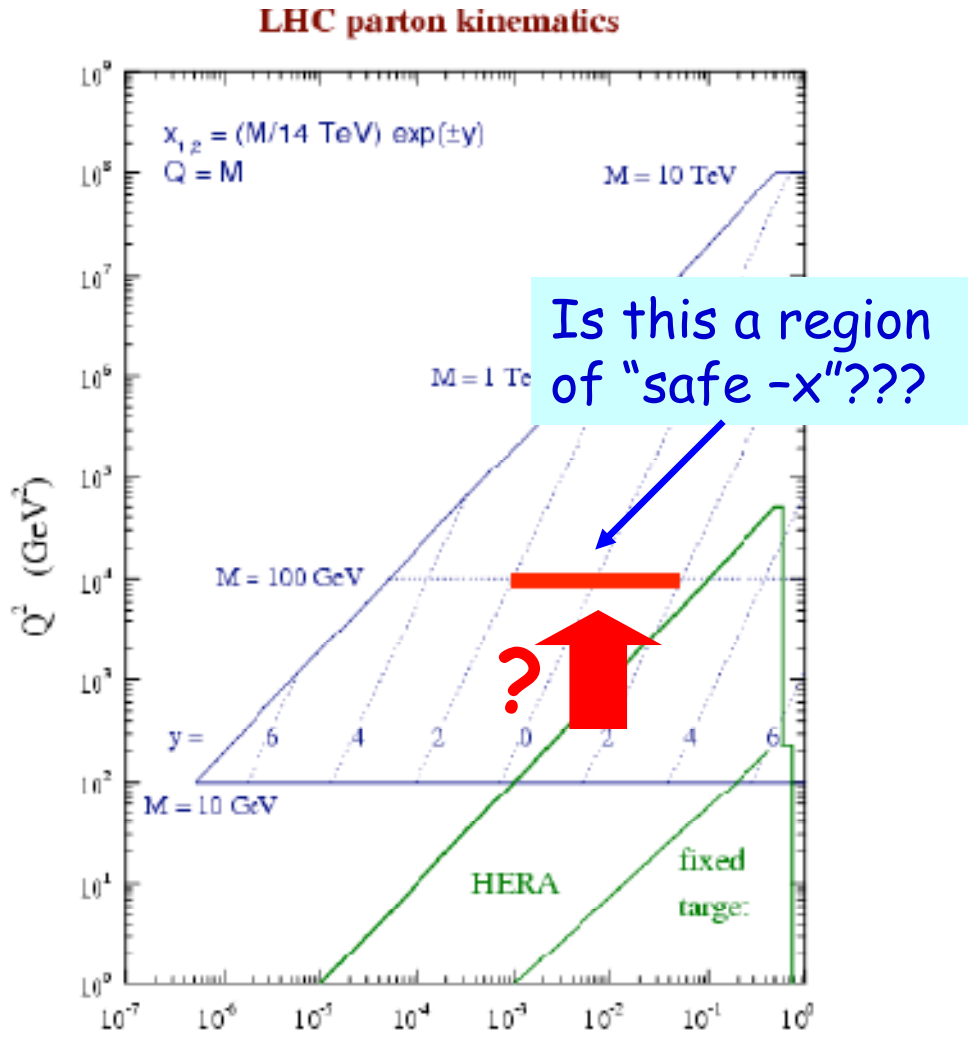
- Soft & Hard diffraction
  - Total cross section and elastic scattering (TOTEM (ATLAS), precision of O(1)%)
  - Gap survival dynamics, multi-gap events, proton light cone ($pp \rightarrow 3jets+p$), odderon
  - Diffractive structure: Production of jets, W, J/ψ, b, t, hard photons; GPDs
  - Double Pomeron exchange events as a gluon factory (anomalous W,Z production?)
- Exclusive production of new mass states
  - Exclusive Higgs production, (Exclusive Radion production?), exclusive SPE??
  - SUSY & other (low mass) exotics & exclusive processes
- Low-x Dynamics
  - Parton saturation, BFKL/CCFM dynamics, proton structure, MPI scattering…
- New Forward Physics phenomena
  - New phenomena such as DCCs, incoherent pion emission, Centauro's
- Strong interest from cosmic rays community
  - Forward energy and particle flows/minimum bias event structure
- Two-photon interactions and peripheral collisions
- Forward physics in pA and AA collisions
- Use QED processes to determine the luminosity to O(1%) ($pp \rightarrow ppee$, $pp \rightarrow pp\mu\mu$)



Many of these topics can be studied best at startup luminosities

LHC Kinematics/QCD evolution





Is this a region of "safe -x"???

Evolution of PDFs to high Q2 & low x important at the LHC
Precision? Level of approximation? CCFM/BFKL?, non-linear effects?

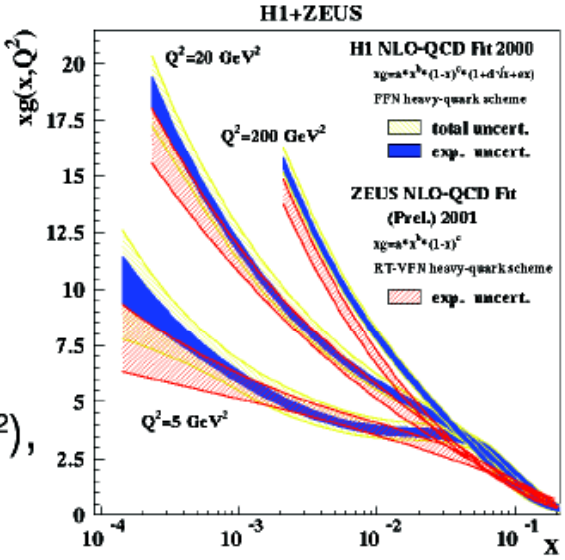
Parton Saturation and evolution at low-x

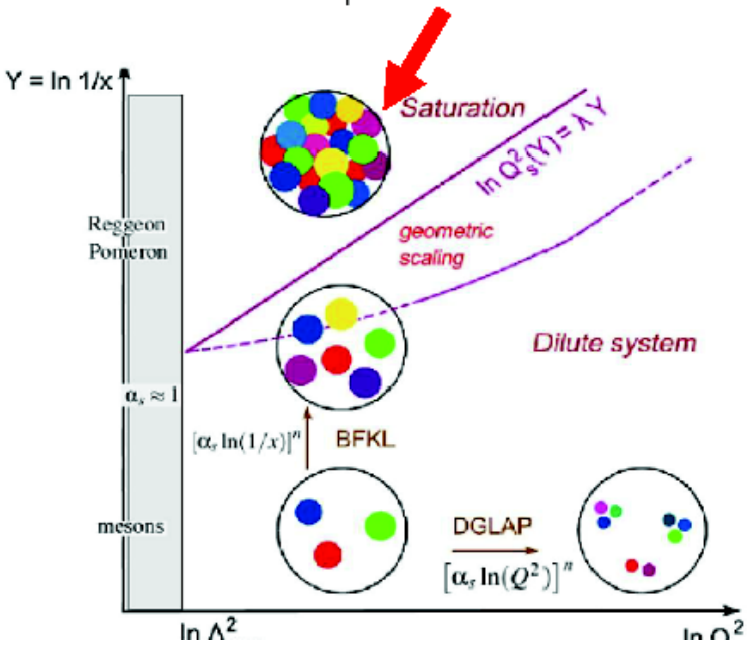
- Strong rise at low-x of gluons (HERA):
- Radiation controlled by QCD evolution eqs.:

  Q^2 - DGLAP: $F_2(Q^2) \sim \alpha_s \ln(Q^2/Q_0^2)^n$, $Q_0^2 \sim 1$ GeV^2

  x - BFKL: $F_2(x) \sim \alpha_s \ln(1/x)^n$

  Linear equations (single parton radiation/splitting) cannot work at low-x: Unitarity violated (even for $Q^2 >> \Lambda^2$), collinear & k_T factorization invalid





- Gluon-gluon fusion balances parton branchings below "saturation scale":
- Enhanced in nuclei ($A^{1/3} \sim 6$) :
- CGC = effective-field theory describes hadrons as classical fields below Q_s
- Non-linear JIMWLK/BK evolution eqs.

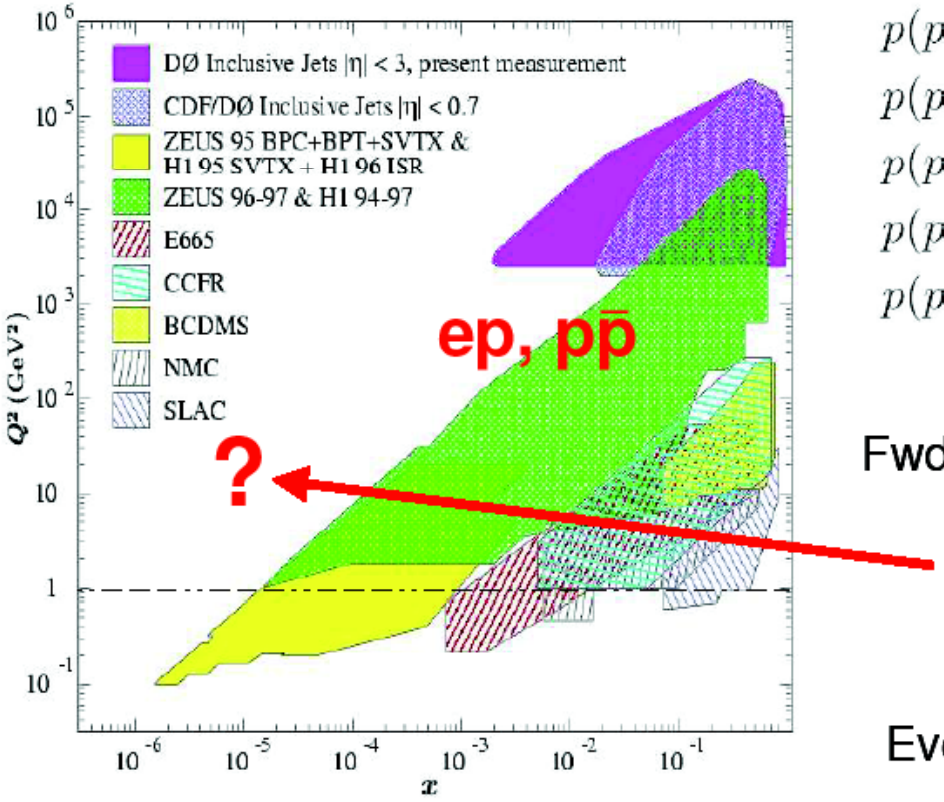
Low-x PDF studies

- pp @ 14 TeV : D. d'Enterria

(i) At y=0, $x=2p_T/\sqrt{s}\sim10^{-3}$ (domain probed at HERA,Tevatron). Go fwd. for $x<10^{-4}$

(ii) Saturation momentum: $Q_s^2 \sim$ 1 GeV^2 (y=0), 3 GeV^2 (y=5)

(iii) Very large perturbative cross-sections:



$p(p_1) + p(p_2) \rightarrow \text{jet} + \gamma + \text{X}$ Prompt γ

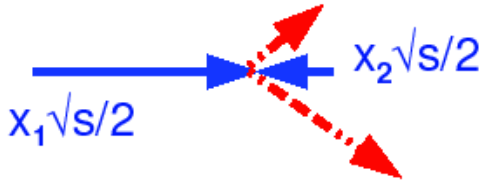
$p(p_1) + p(p_2) \rightarrow l\bar{l} + \text{X}$ Drell-Yan

$p(p_1) + p(p_2) \rightarrow \text{jet}_1 + \text{jet}_2 + \text{X}$ Jets

$p(p_1) + p(p_2) \rightarrow \text{Q} + \bar{\text{Q}} + \text{X}$ Heavy flavour

$p(p_1) + p(p_2) \rightarrow W/Z + \text{X}$ W,Z production

Fwd. production:



$x_2^{min} \sim p_T/\sqrt{s} \cdot e^{-y} = x_T \cdot e^{-y}$

Every 2-units of y, x^{min} decreases by ~10

Low-x nuclear PDF studies

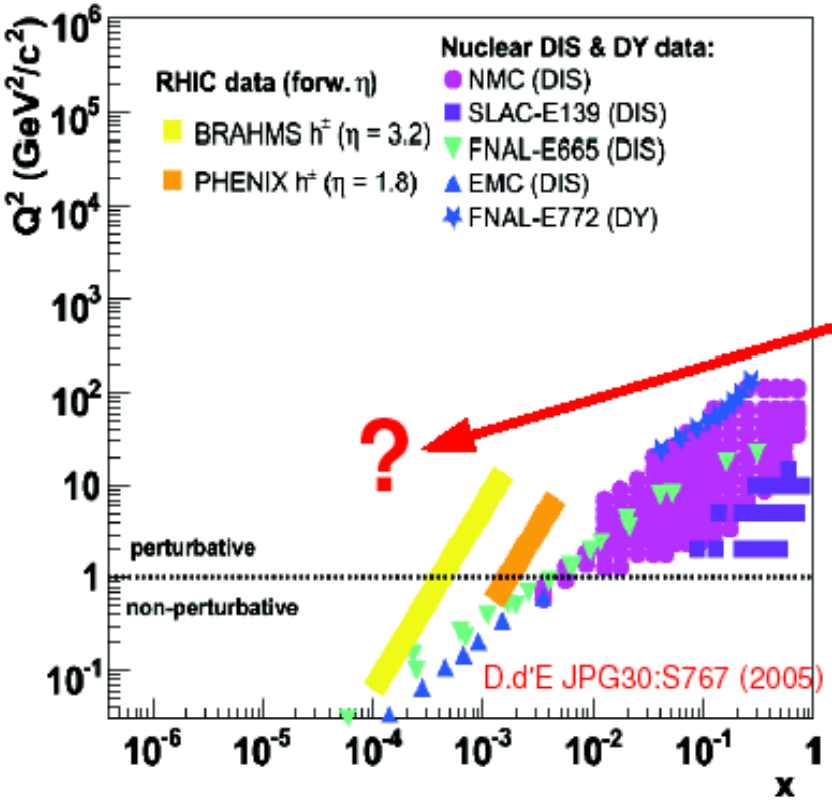
D. d'Enterria

- PbPb @ 5.5 TeV, pPb @ 8.8 TeV:

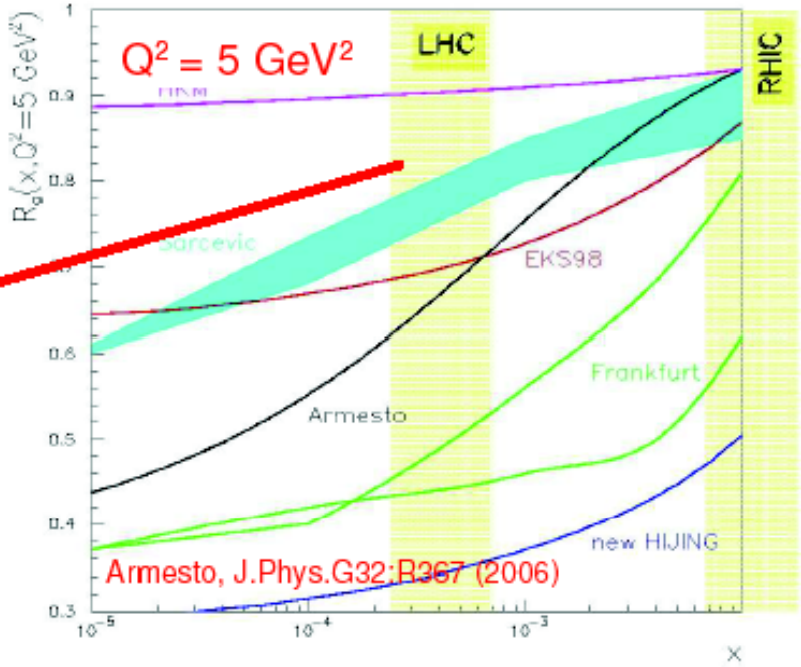
(i) Very high $\sqrt{s}$ $\Rightarrow$ Bjorken $x=2p_T/\sqrt{s}$~30-45 times lower than AuAu,dAu @ RHIC !

(ii) Saturation momentum ($A^{1/3}$~6) : $Q_s^2 \sim [5\ \mathrm{GeV}^2]e^{(0.3y)}$

(iii) Very large perturbative cross-sections.



Ratio of Pb/p gluon densities:



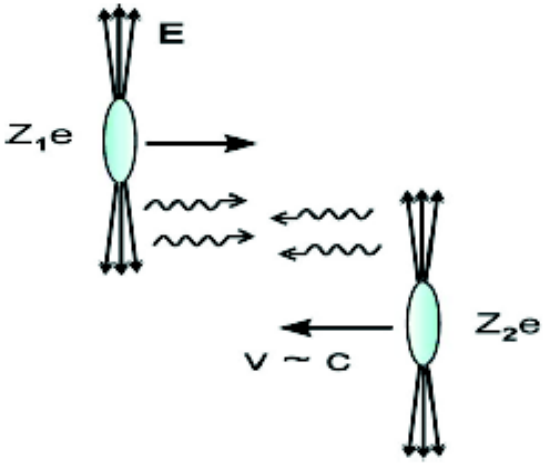
Nuclear $xG(x,Q^2)$ basically unknown for $x<10^{-3}$!

Example: Υ production

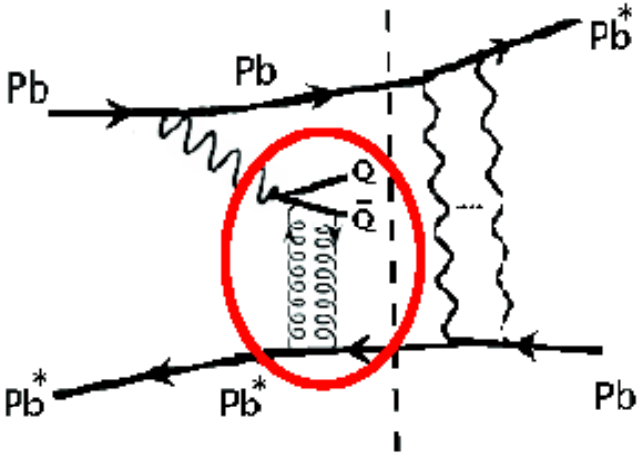
- High energy heavy-ions produce strong electromagnetic fields due to the coherent action of $Z_{Pb} = 82$ protons:
- Equivalent flux of photons in EM (aka. Ultra-Peripheral, $b_{min} \sim 2R_A \sim 20$ fm) AA colls.:

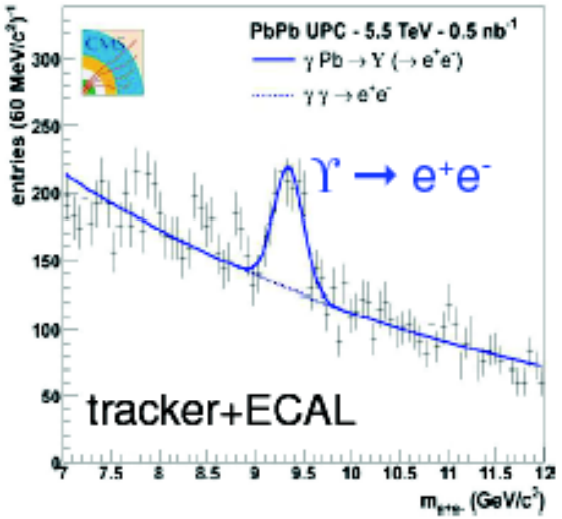
  Max. γ energy: $E_{\gamma max} \sim 80$ GeV (PbPb-LHC)

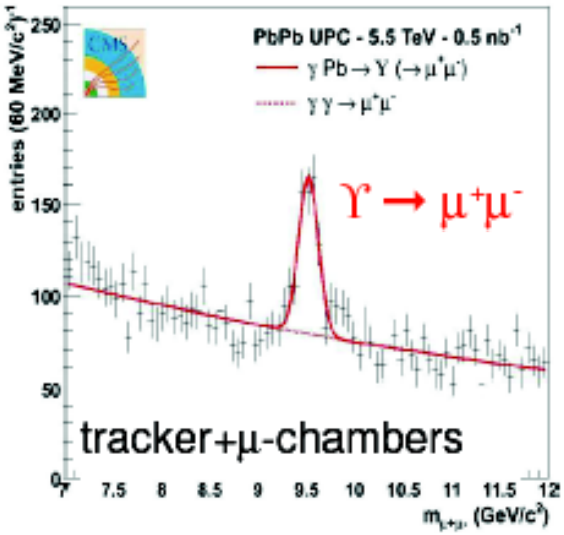
  γ Pb: max. $\sqrt{s}_{\gamma Pb} \approx 1.$ TeV $\approx$ 3. - 4. $\times \sqrt{s}_{\gamma p}$(HERA)



- $Q\bar{Q}$ diffractive photoprod. (ZDC n-tagging) sensitive to $|xG|^2$

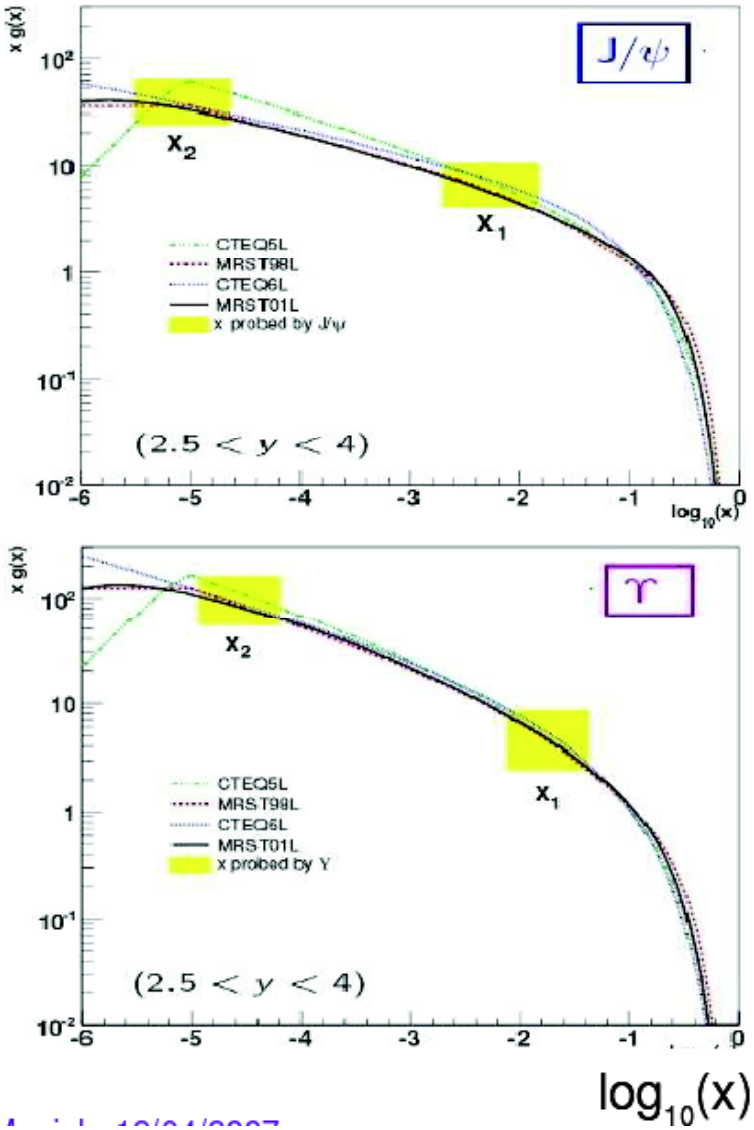




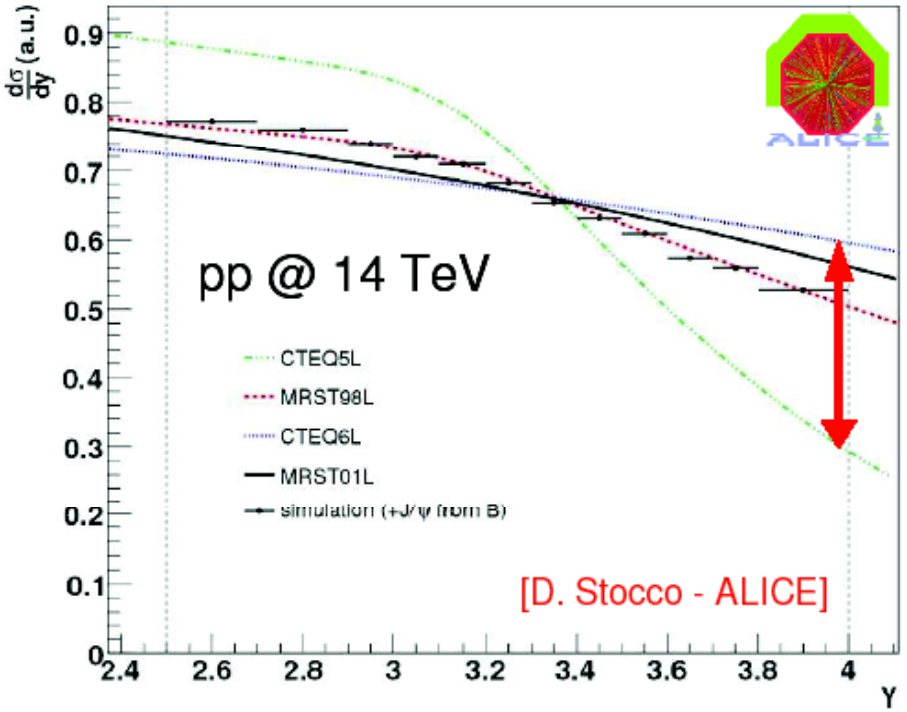


Forward QQ production in ALICE

- J/ψ measurement in μ-spectrometer (2.5 <|η|< 4): xg(x) at $x_2 \sim 10^{-5}$



dσ/dy J/ψ: NLO CEM w/ varying PDFs



QQbar: Sensitive to diff. PDFs

and DGLAP vs non-linear evolutions

Forward physics studies in ALICE

Diffractive J/ψ production in pp collisions

- First estimates by Schäfer, Mankiewicz, Nachtmann 1991
- pQCD estimate by Bzdak, Motyka, Szymanowski, Cudell
  - Photon: t-integrated $\left.\frac{d\sigma}{dy}\right|_{y=0}$ ~ 15 nb (2.4 - 27 nb)
  - Odderon: t-integrated $\left.\frac{d\sigma}{dy}\right|_{y=0}$ ~ 0.9 nb (0.3 - 4 nb)

Schicker EDS07

At L = 5×10^{30} $cm^{-2}s^{-1}$:

→ *0.15 J/Ψ in ALICE central barrel in 1 s, 150k in 10^6 s*

→ *9000 in e^+e^- channel in 10^6 s*

→ identify Photon and Odderon contribution by analysing p_T distribution (Odderon harder p_T spectrum)

Forward dijets in pp

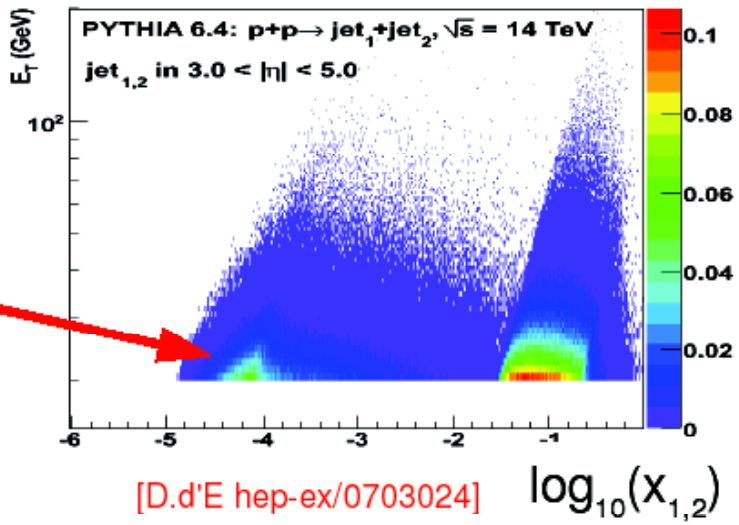
- Forward "soft" jets (E_T ~20-100 GeV):

  $p + p \rightarrow jet1 + jet2 + X$ (VBF-Higgs trigger)

  Jets in HFs sensitive to : $x_2 \sim 10^{-4}$

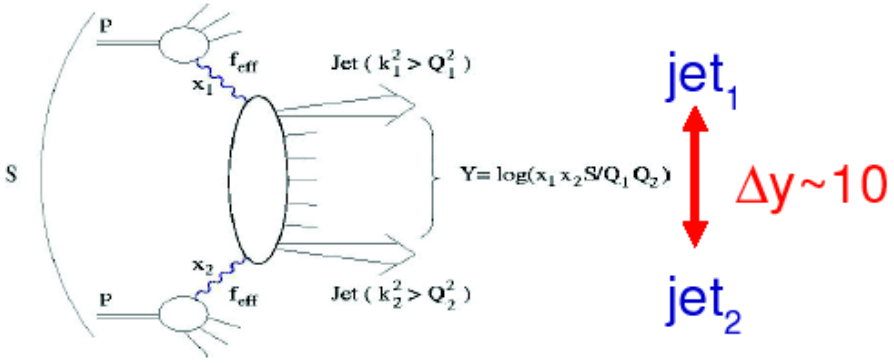
  Jets in CASTOR (5.3 <|η|< 6.6): $x_2 \sim 10^{-6}$!

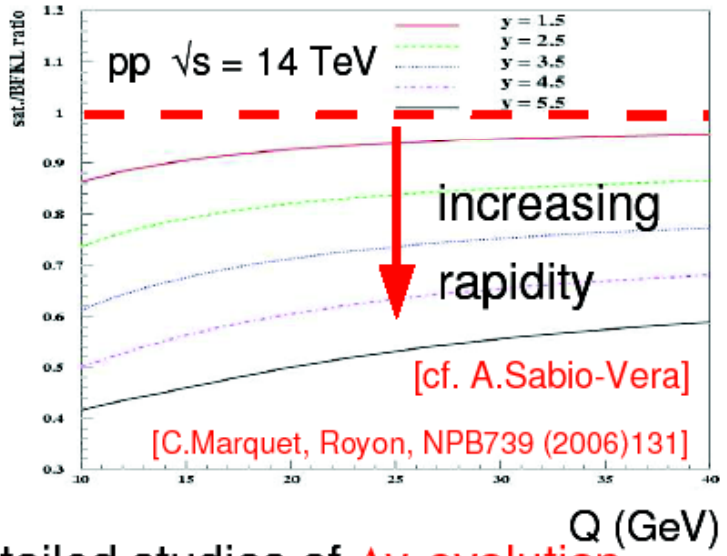
  Stats. ~10^7/1 pb^{-1}, large? jet reco systematics



[D.d'E hep-ex/0703024]

- Mueller-Navelet dijets separated by large Δy: very sensitive to non-DGLAP evolution



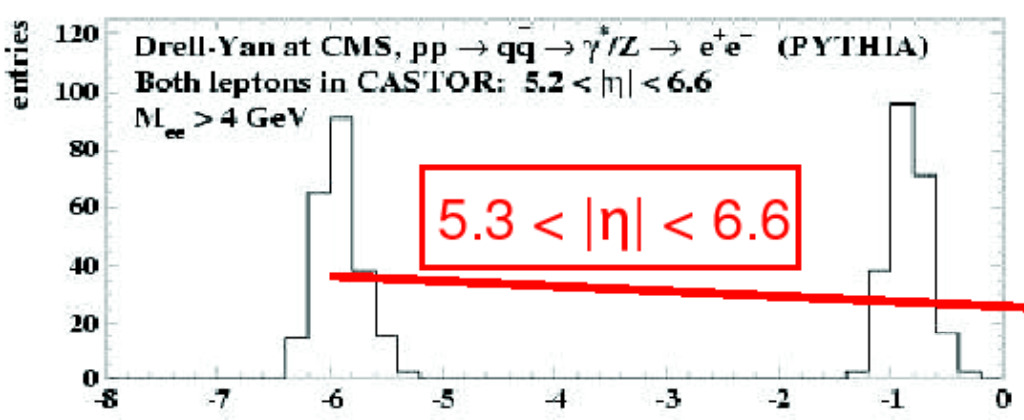


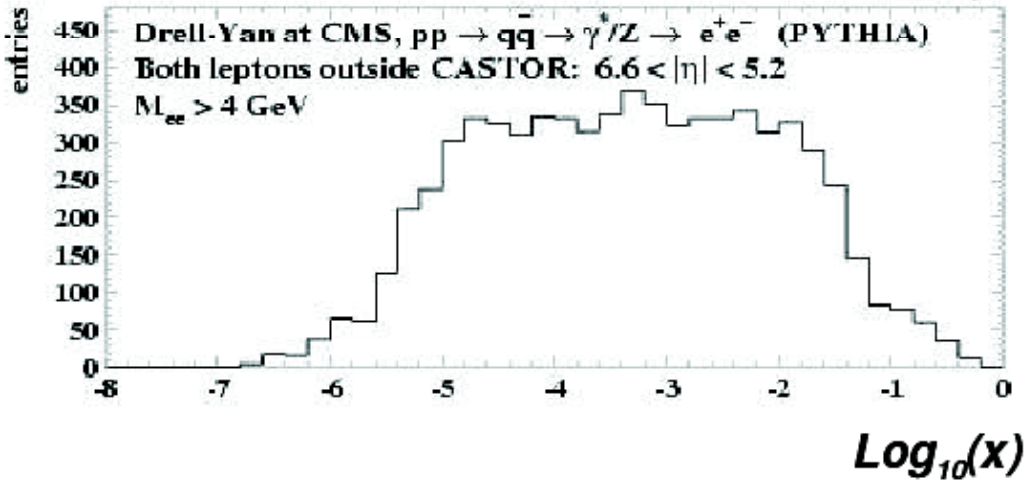
~10^4 dijets (HF$^{\pm}$,E_T>30 GeV): enough stats. for detailed studies of Δy-evolution

Forward Drell-Yan in pp

See P. Van Mechelen

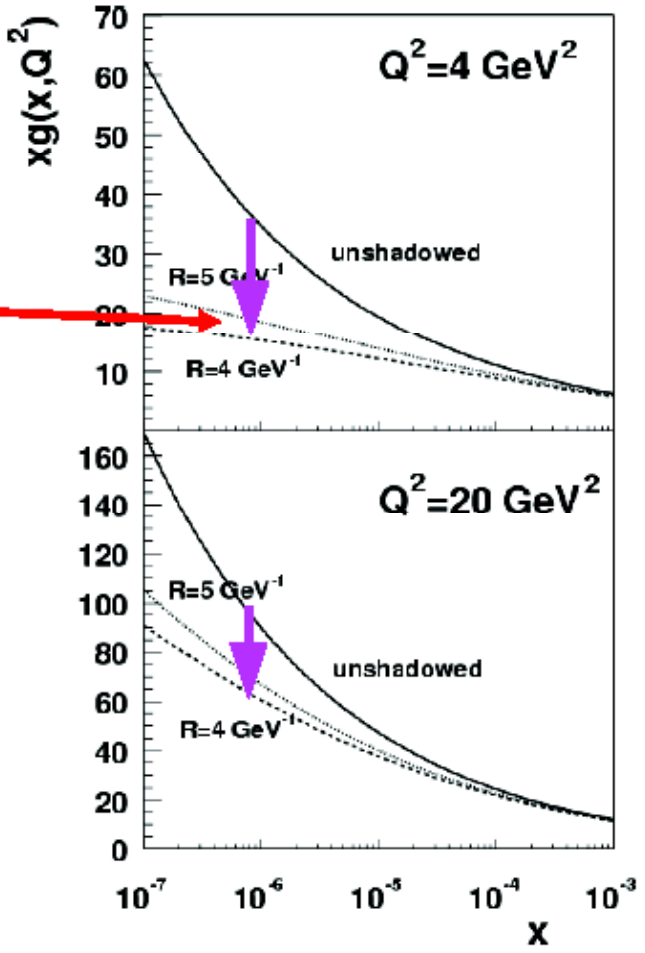
- Drell-Yan feasibility studies with CMS (CASTOR) + TOTEM (T2):
- Sensitive to low-x





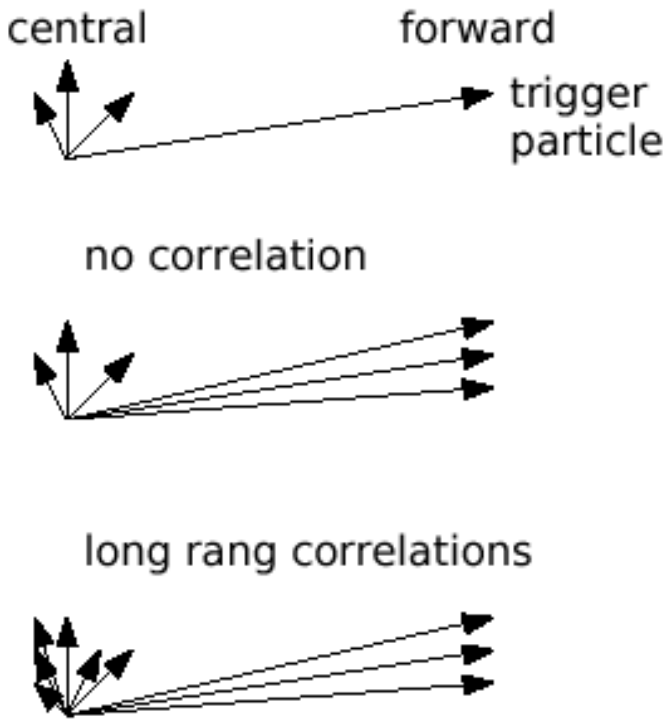
5.3 < |η| < 6.6

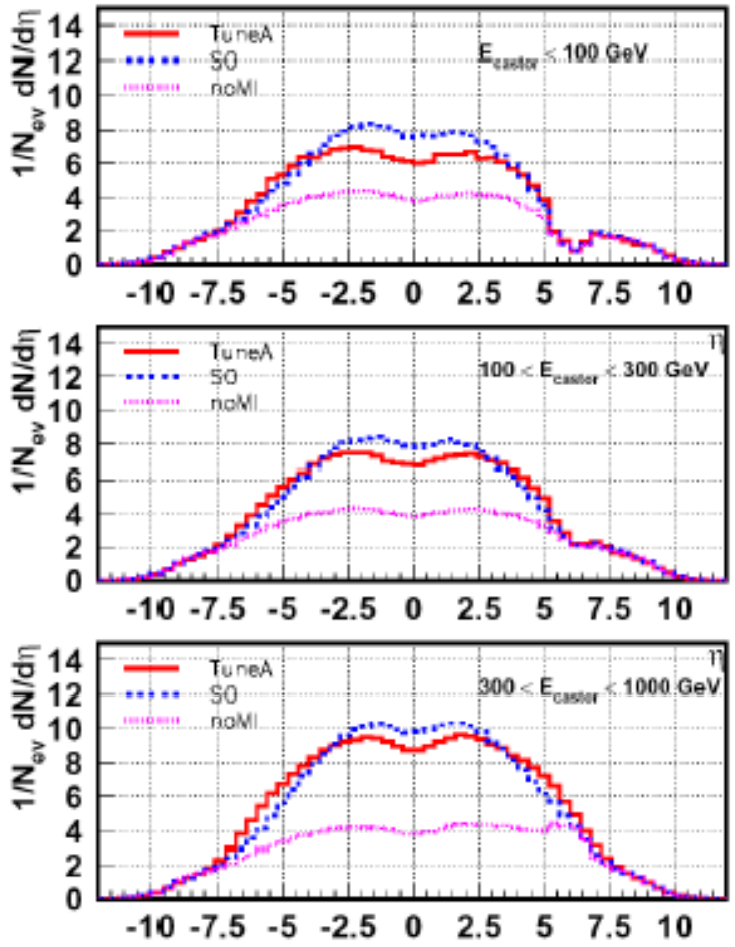
PDF parametrizations



TOTEM T2 tracker+ CASTOR needed to deal w/ large QCD (& QED) bckgd

Central/forward particle correlations





→ forward condition uncovers long range correlations

→ discriminative power for different M.I. tunes

[H. Jung]

Double Parton interactions

- Higgs: $p + p \to W + H + X$
  with $W \to l\nu, \quad H \to b\bar{b}$

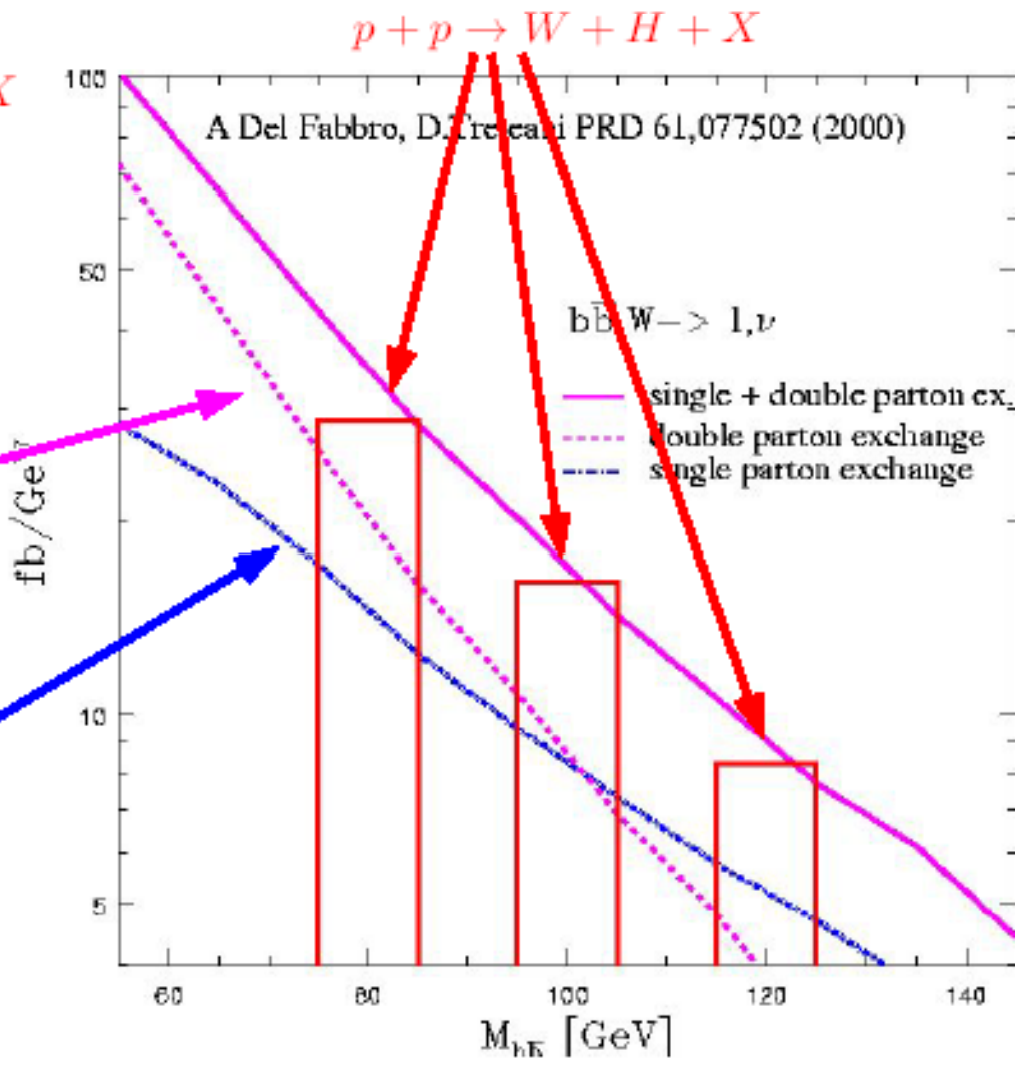
- Double parton scattering:

➔ $p + p \to W + X$

$p + p \to b\bar{b}X$

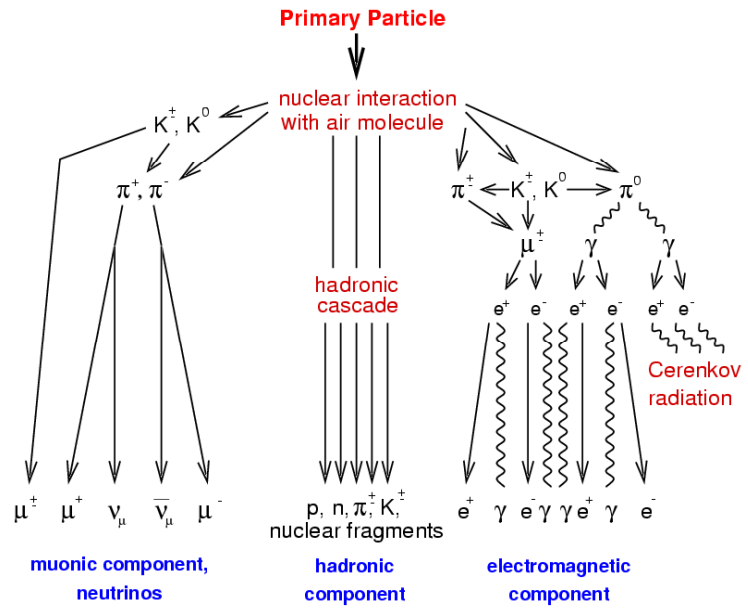
- compared to single parton scattering

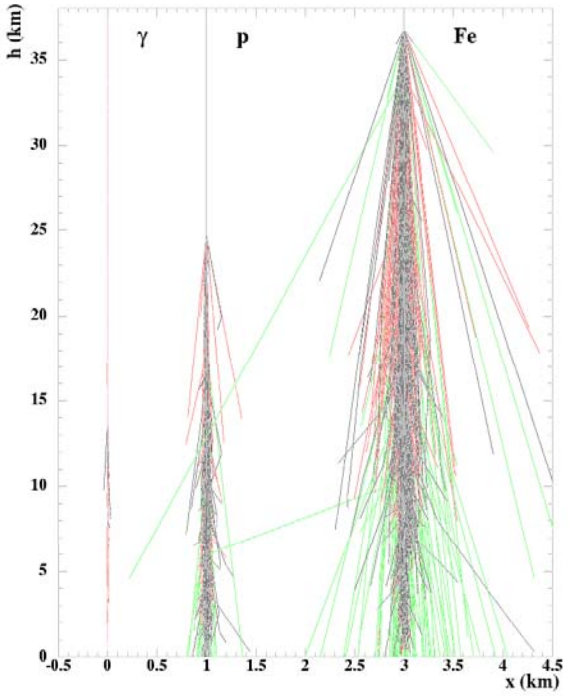
$p + p \to W + b\bar{b} + X$



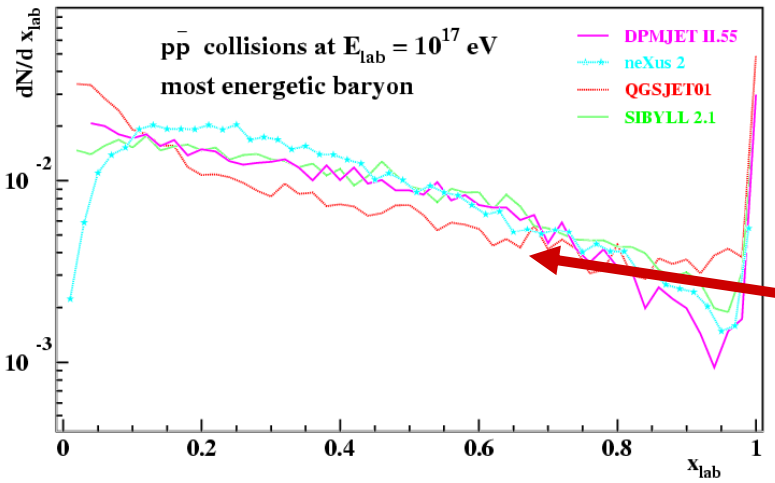
Not well know what to expect…

High Energy Cosmic Rays





Cosmic ray showers: Dynamics of the high energy particle spectrum is crucial

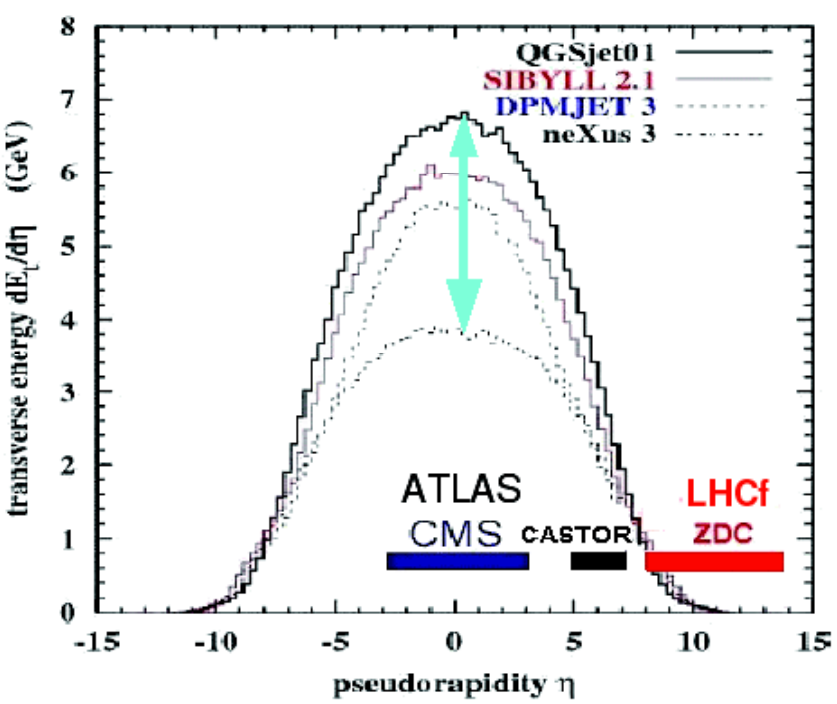


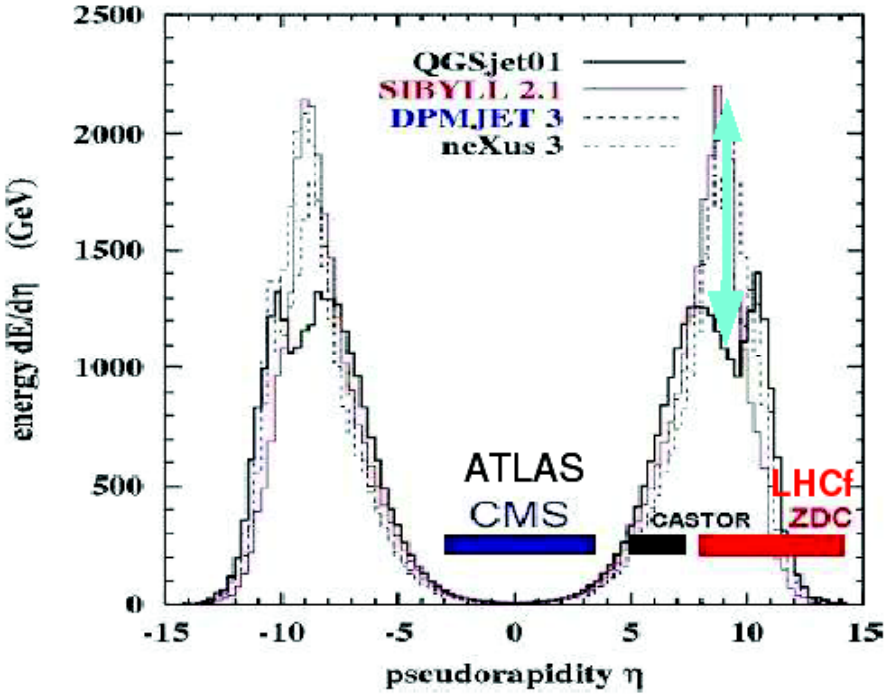
Interpreting cosmic ray data depends on hadronic simulation programs
Forward region poorly know/constrained
Models differ by factor 2 or more
Need forward particle/energy measurements
e.g. dE/dη…

CR: Calibration and tuning of hadronic models

- Model predictions of particle multiplicity & energy flow at LHC differ by up to a factor ~2:

[R.Engel]





- ZDCs,LHCf: Measurement of fwd dN/dη,dE/dη leading baryon (n), neutral meson (π^0,K^0_s) in pp, pA, AA at E_{lab}~100 PeV: Strong EAS model constraint

[CRs collisions: p-Air, α-Air, Fe-Air]

Cosmic Exotica

- E~10^{15}-10^{17} eV cosmic-rays ("Centauro") events observed:
  - (i) anomalous number of (N~0) electromagnetic secondaries } "strangelets"?
  - (ii) forward "long-flying" (i.e. non-interacting) component } "DCCs"?

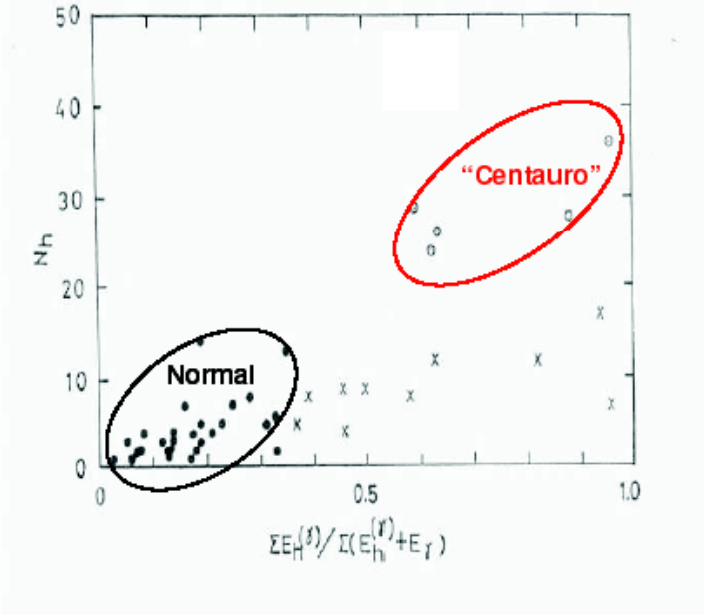
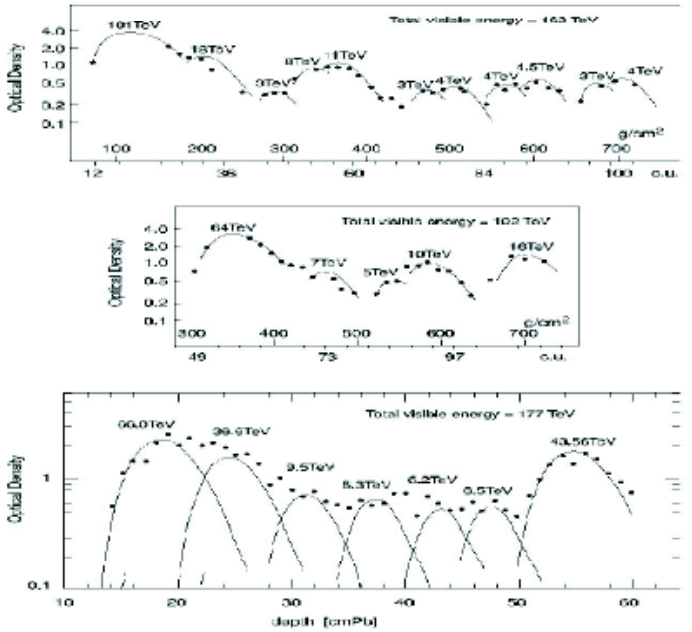


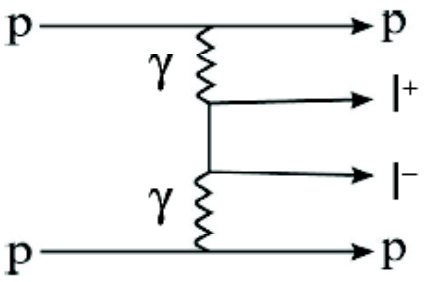
Figure 2.5: Diagram of the number of hadrons and hadronic energy fraction: Chacaltaya events with the total visible energy greater than 100 TeV [38]: (○) Centauro, (×) Mini-Centauro, (•) others; (⋆) C-K [36].



CMS-CASTOR (longitud. segmentation) can access this research programme.

Two photon and γW interactions

- Exclusive l^+l^- (e^+e^-,$\mu^+\mu^-$) production



(e^+e^- in T2/CASTOR)

($\mu^+\mu^-$ in muon-chambers)

(fwd. proton in RPs)

QED process: σ known precisely (LPAIR)

Signature: back-to-back leptons

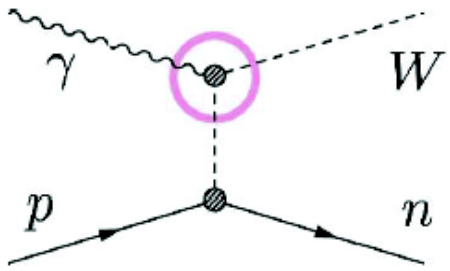
RPs: reco of proton ξ w/ resol. of 10^{-4}

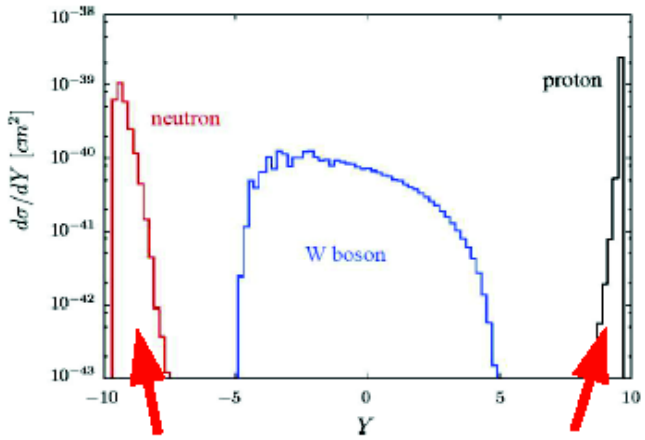
~300 evts./100 pb^{-1} after CMS μ trigger

- Absolute p-p luminosity within ~3% (theo)
- Cross-calibration of near-beam dets.

- W-photoproduction:

Triple (anomalous?) gauge couplings





n,p tagging in ZDC/RPs

~50 evts./100 pb^{-1} in p-p 14 TeV

[Also quartic couplings via γγ→WW,ZZ]

HERA and the LHC

Workshop and forum on the implication of HERA for LHC physics

- Low-x
- PDFs
- Diffraction…

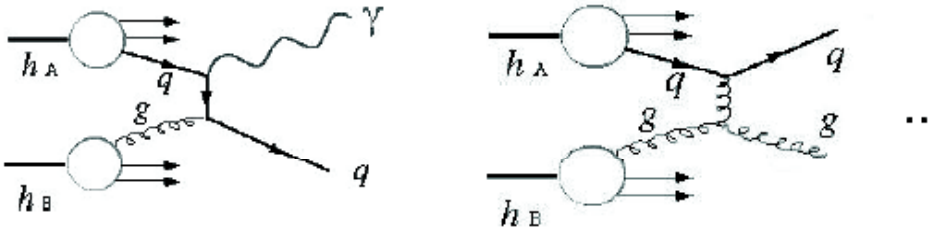
Next meeting 29 Oct-2 Nov @ DESY

⇒Working group meetings

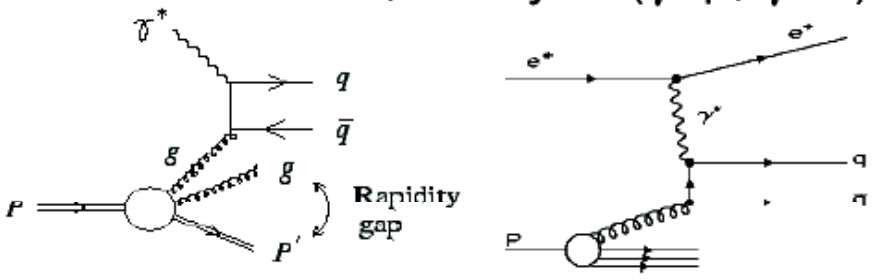
Eg. Experimental Probes of the Gluon

D. d'Enterria

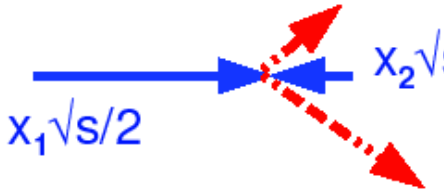
- Perturbative processes:
  - Prompt γ, (di)jets ($\gamma^{(*)}$p, pp, AA):



  - Diffractive $Q\bar{Q}$, heavy-Q ($\gamma^{(*)}$p, $\gamma^{(*)}$A):

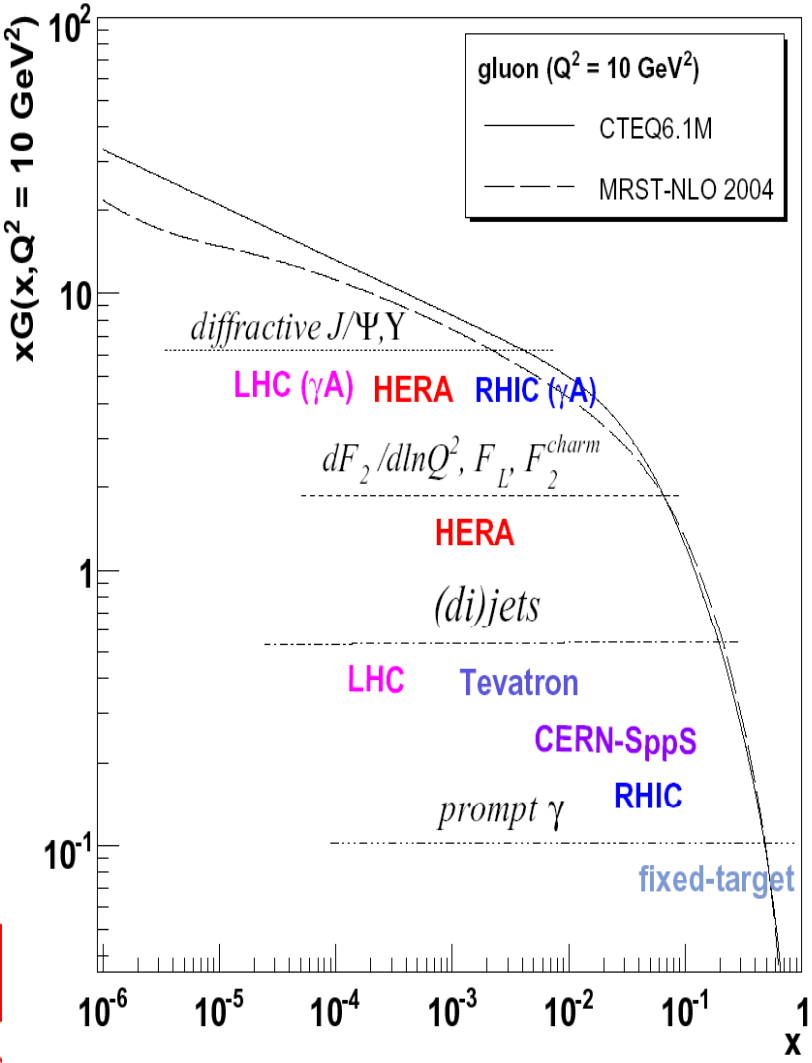


- Forward production:



$$x_2^{min} \sim p_T/\sqrt{s} \cdot e^{-y} = x_T \cdot e^{-y}$$

Every 2-units of y, x^{min} decreases by ~10



Finally:

Call for a working group/task force/LHC-study group …

FITPDF?

⇒The PDF + uncertainties

NEED A JOINT EFFORT OF THEORISTS AND LHC EXPERIMENTALISTS:

- WHICH PRECISION MEASUREMENTS ARE LIMITED BY PDFS?
- WHEN DOES LACK OF PDF KNOWLEDGE HIDE/SIMULATE NEW PHYSICS?
- HOW CAN LHC MEASUREMENTS IMPROVE PDF DETERMINATION?

Interest from theorists/fitters/HERA/ LHC/…?

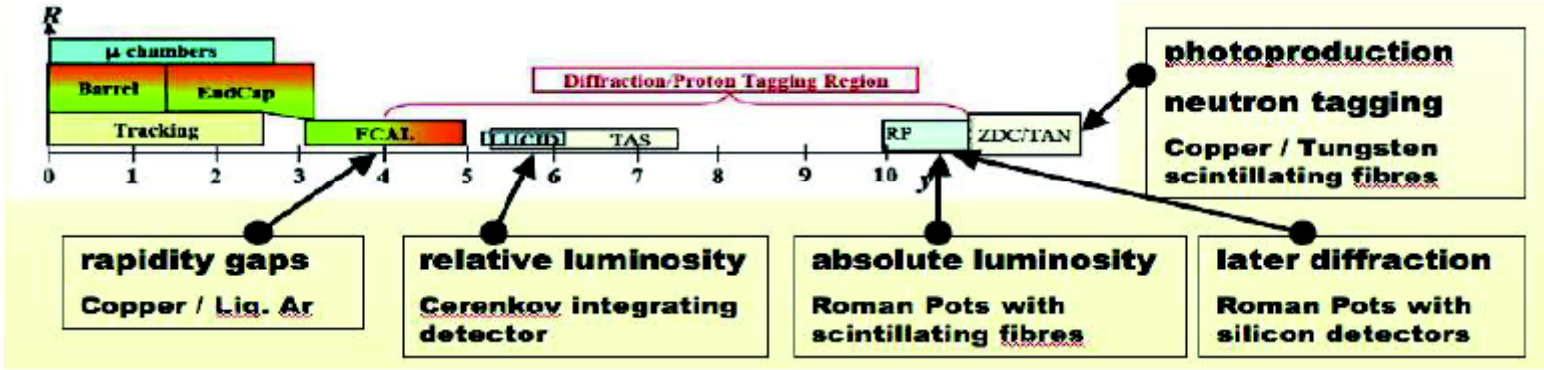
…Need to call for a meeting

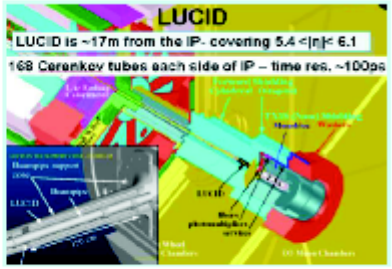
Conclusion

- LHC is coming on-line: expect the first 14 TeV collisions by summer 2008
- Forward physics @ LHC came a long way during the last years!! We saw
  - 2 experiments approved for forward physics (TOTEM, LHCf)
  - ATLAS and CMS planning to extend the detector coverage in the forward direction
  - CASTOR forward calorimeter in CMS (LUCID in ATLAS)
  - ZDCs in ATLAS and CMS
  - Roman Pots in ATLAS at 220 and 240 m (but not for start-up)
  - Common physics program/data taking for CMS and TOTEM
  - FP420 coming along…
- Diverse program for low-x physics (and diffraction) has been developed
  - Part of the "base-line" physics opportunities of the LHC
  - New ideas for measurements are still highly welcome to keep momentum
- Forward physics and diffraction now "in the blood" of the experiments.

Let's capture that opportunity!!

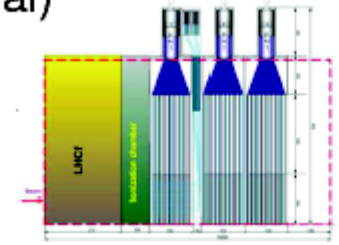
Backup



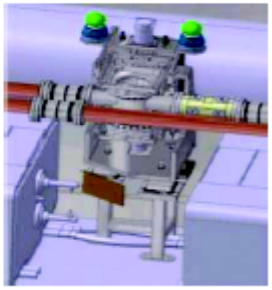


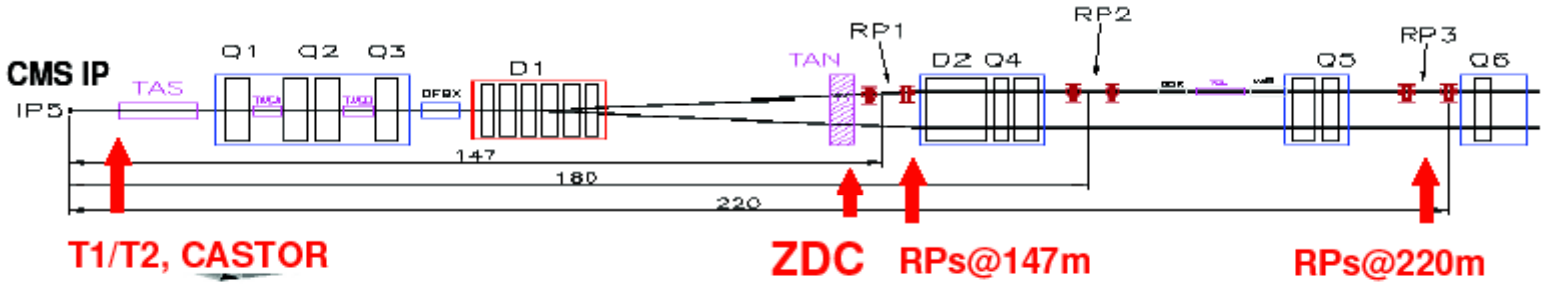
- LUCID (Cerenkov Tubes): 17 m, 5.4 < |η| < 6.1
  Relative luminosity

- ZDC (W/Q-fiber calo): 140m, |η| > 8.3 (neutral)
  n,γ detection: relative lumi, CRs, heavy-ions
  (L1 trigger, centrality, photoprod, ...)



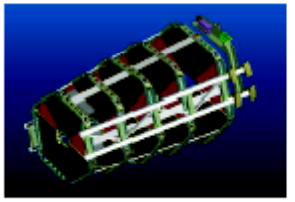
- ALPHA (Sci-Fi in RPs): 240 m.
  Abs. lumi (elastic scatt. in Coulomb interf. region)

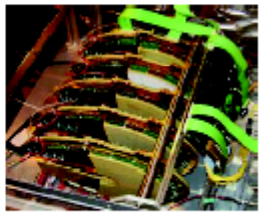




- TOTEM-T1 (CSC telescope): $3.1 < |\eta| < 4.7$
- TOTEM-T2 (GEM telescope): $5.3 < |\eta| < 6.7$

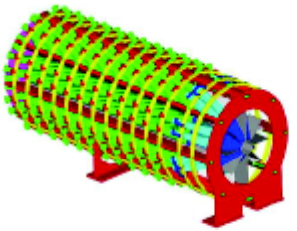
  Soft diffraction (SD,DPE), MB/UE/MPI

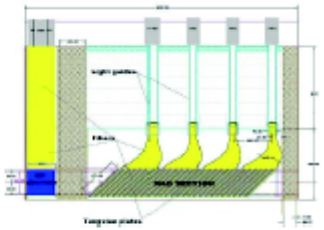




- CASTOR (W/-Q-fiber calo): $5.3 < |\eta| < 6.5$

  Miss.-E_T, diffract., low-x QCD, MB/UE/MPI, heavy-ions (L1 trigger, centrality, ...), CRs



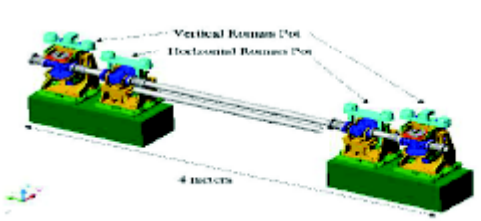


- ZDC (W/Q-fiber calo): $|\eta| > 8.3$ (neutral)

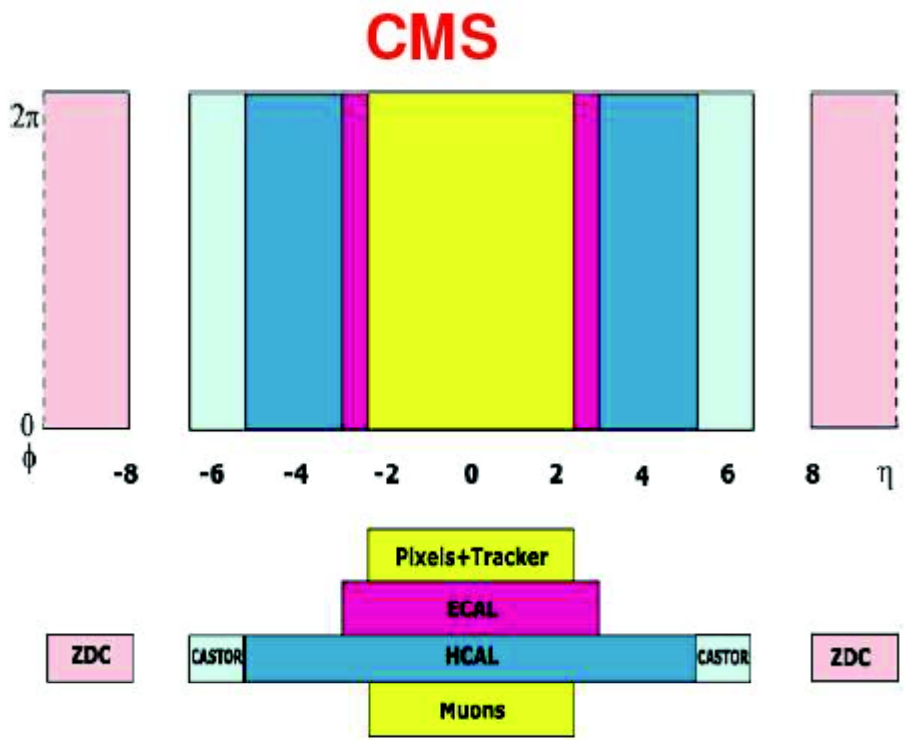
  CRs, heavy-ions (L1 trigger, centrality, γ-A, ..

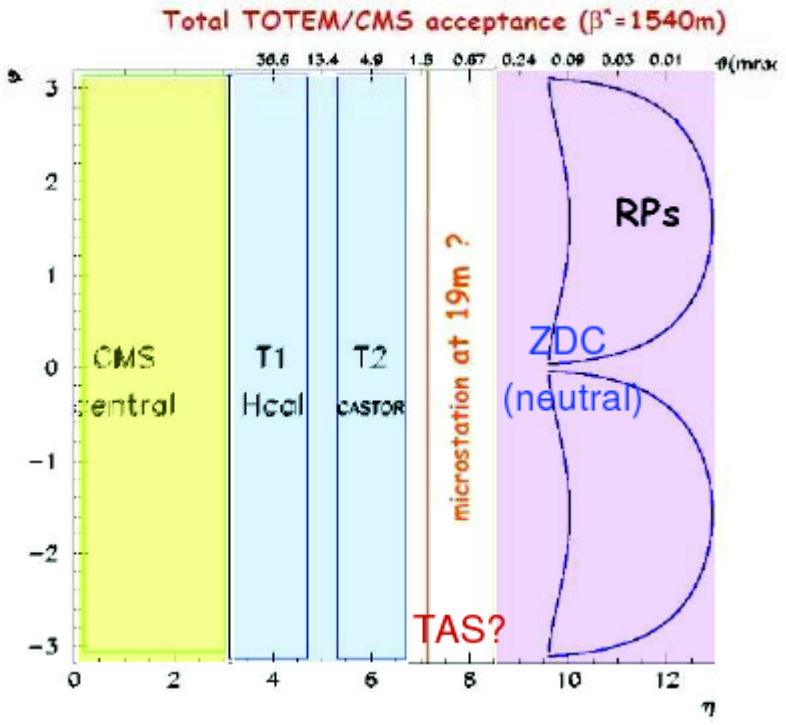
- TOTEM Roman pots: 147, 220 m

  Leading p: σ_{tot}, elastic scatt., diffraction



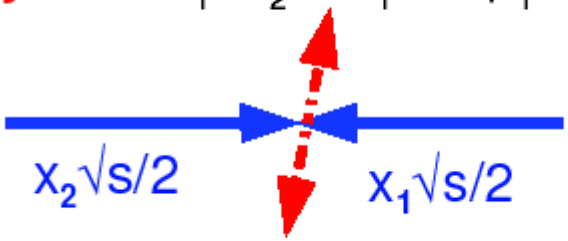
- CMS (central,CASTOR,ZDC)+TOTEM: largest acceptance ever at a collider



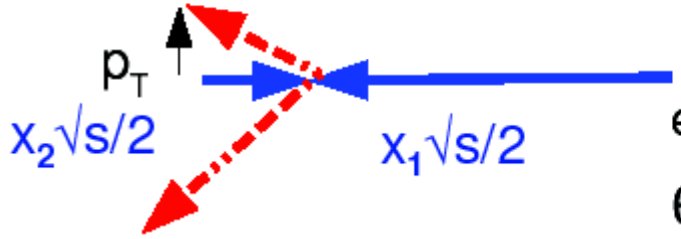


- 2 → 2 parton kinematics:

y = 0: $x_1 \sim x_2 \sim x_T = 2p_T/\sqrt{s}$



$$x_{1,2}^{2\to 2} = \frac{p_T}{\sqrt{s}}\left(e^{\pm y} + e^{\pm y'}\right) \Rightarrow x_2^{min} = \frac{x_T\, e^{-\eta}}{2 - x_T\, e^{\eta}}$$



e.g. LHC, p_T = 10 GeV/c

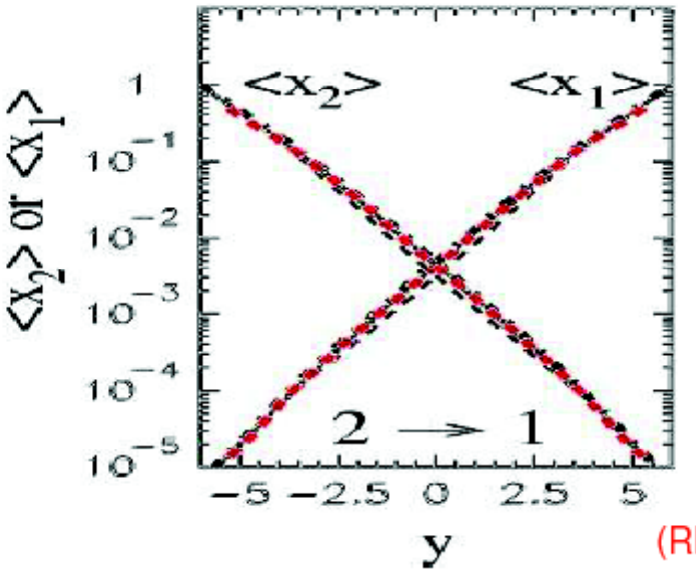
$\theta \sim 10^{-3}$ ($\eta \sim 7$): $x_{min} \sim 10^{-6}$

- 2 → 1 (gluon fusion) CGC kinematics: much lower *x* allowed ($x_2 \sim x_2^{min}$)

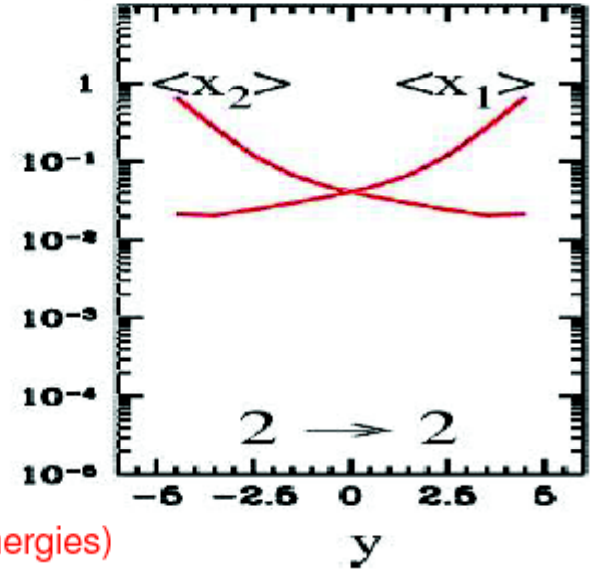
$$x_{1,2}^{2\to 1} = \frac{p_T}{\sqrt{s}}\left(e^{\pm y}\right)$$

Every 2-units of y,
x_2 decreases by ~10

CGC: x(y=4) ~ 10^{-4}



pQCD: x(y=4) ~ 10^{-2}



(RHIC energies)

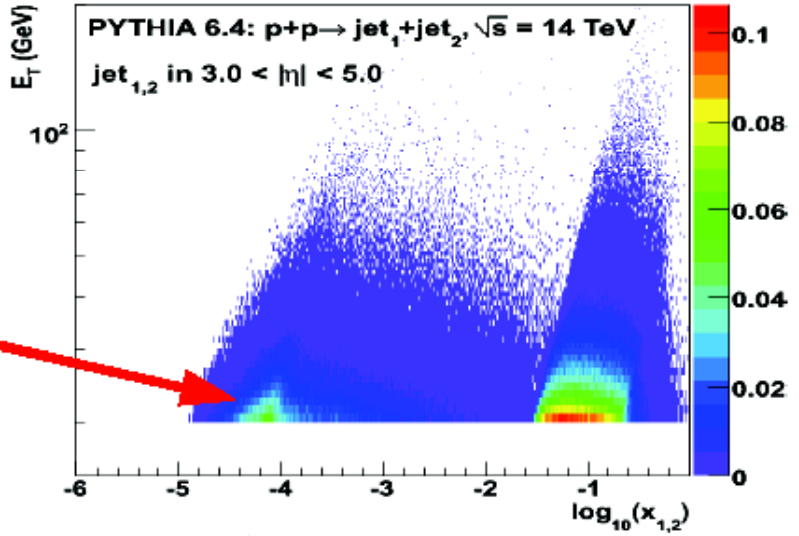
Forward Jets

- Forward "soft" jets (E_T ~20-100 GeV):

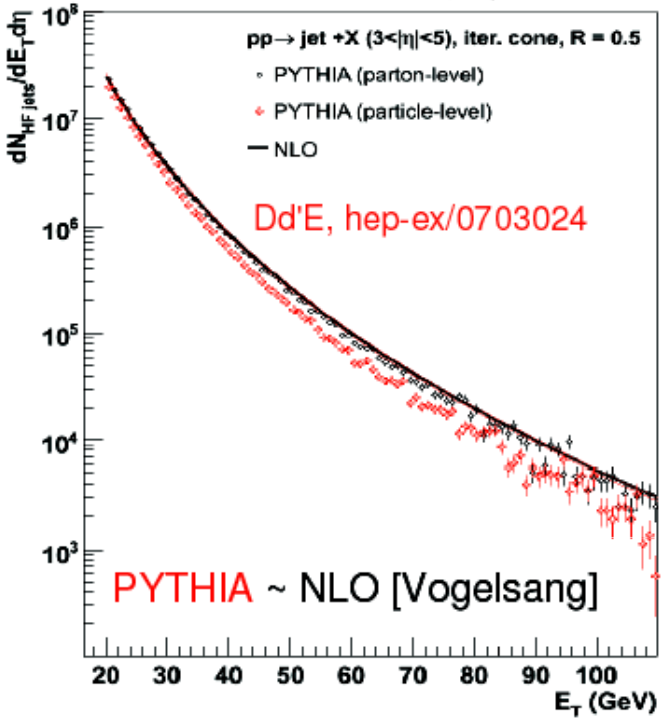
  $p + p \rightarrow jet1 + jet2 + X$ (VBF-Higgs trigger)

  Sensitive to partons with: $x_2 \sim 10^{-4}$

  Jets in CASTOR (5.3 <|η|< 6.6): $x_2 \sim 10^{-6}$



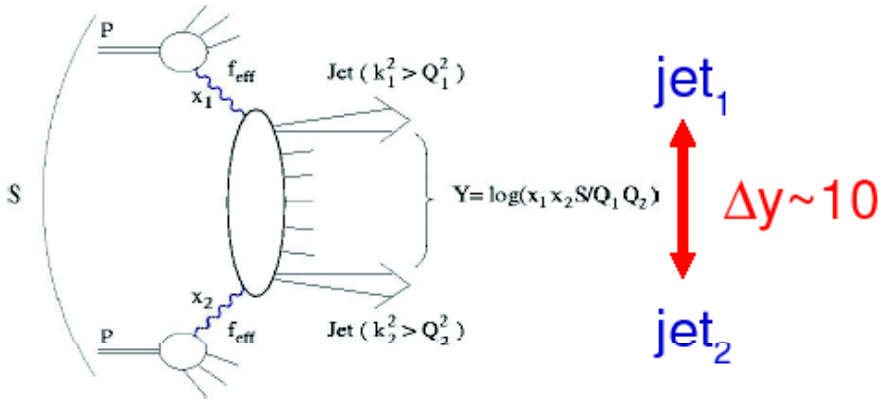
- Inclusive fwd. jet reconstruction (HF):
  - PYTHIA 6.4. min-bias (hard&soft QCD)
  - MC-level proof-of-principle only
  - HF grid: $\Delta\eta \times \Delta\phi = 0.175 \times 0.175$
  - Iterative cone, R=0.5, E_{thresh}=10 GeV, E_{seed}=3 GeV
  - Missing important corrections: underlying-evt. (PYTHIA CMS-Tune), hadronization (cluster vs. Lund)
  - Large yields. Low-E_T uncertainties to be determined.



Mueller Navelet Dijets

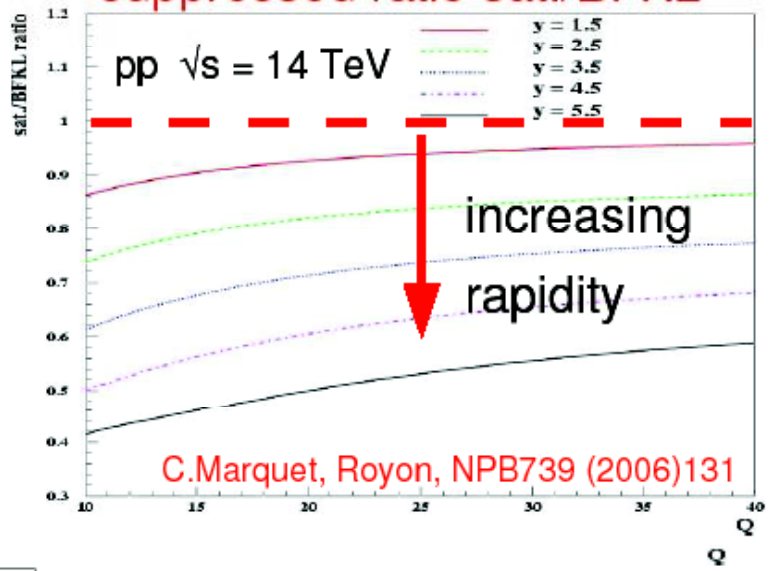
- Mueller-Navelet dijets separated by large Δy:

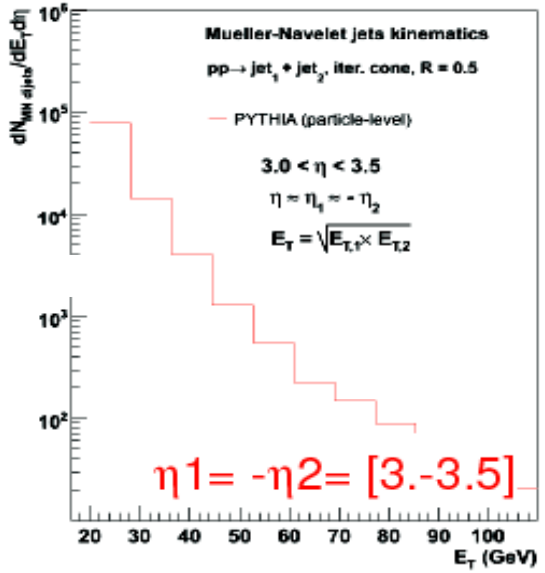
very sensitive to non-DGLAP evolution

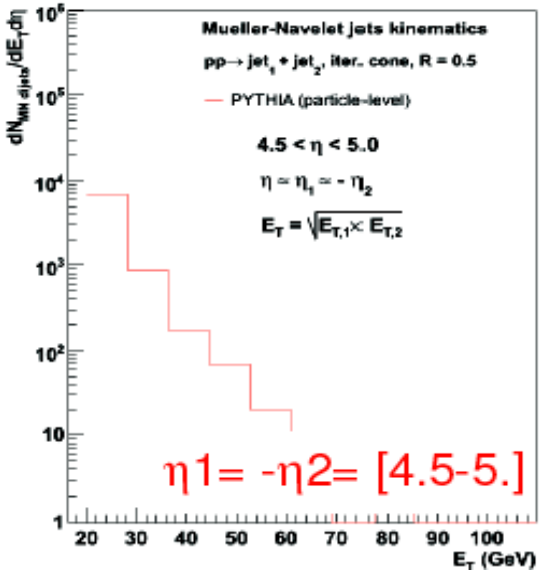


A.H.Mueller, H.Navelet, NPB282 (1987)727

suppressed ratio sat./BFKL





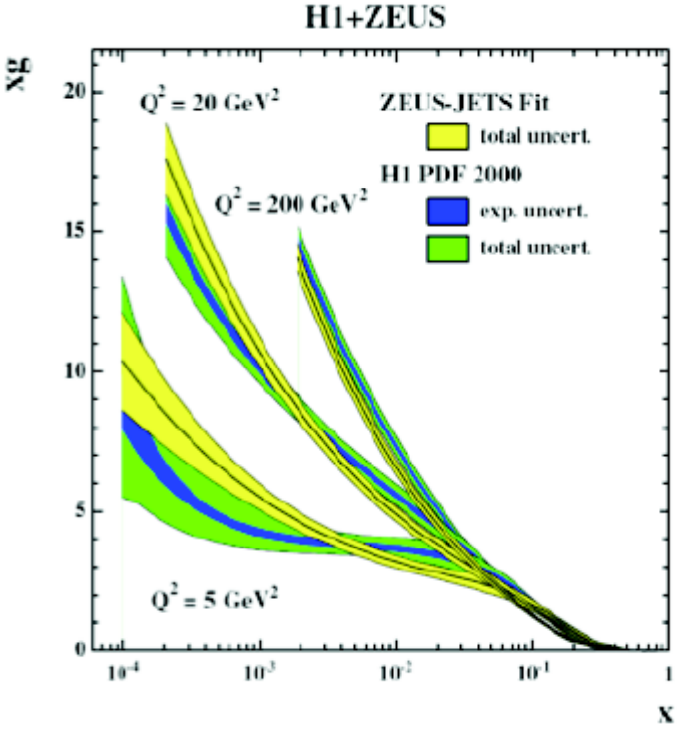


PYTHIA rates with M-N kin. cuts: ~10^4 dijets [E_T~30 GeV] in $\mathcal{L}$ ~ 1 pb^{-1} (low luminosity run): enough stats. for detailed studies of Δy-evolution.

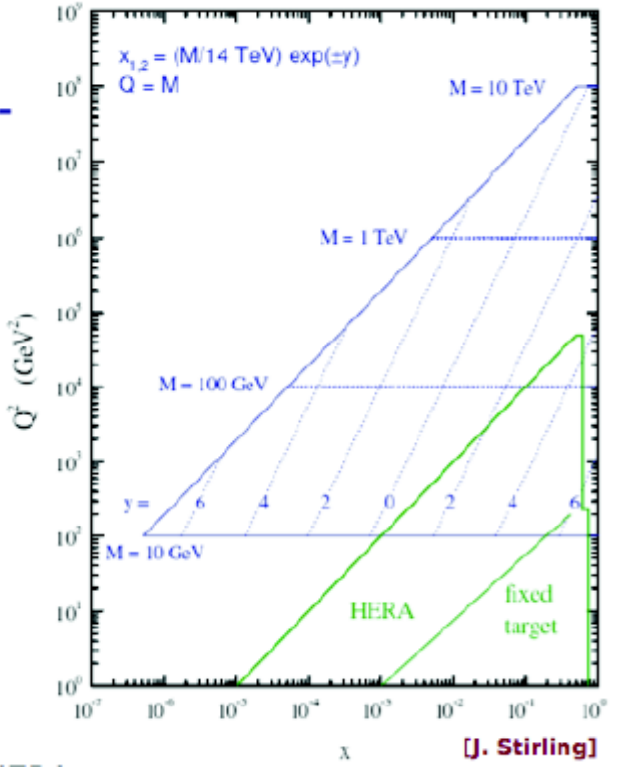
Dd'E, hep-ex/0703024

Forward Physics & Low-x

- M goes forward if $x_1 << x_2$
- M can be jets, DY, prompt-γ, b/c jets



- The strong rise of gluons at low-x → "*saturation*"
- How does this extrapolate to the LHC?
- Can the LHC see saturation effects?



ATLAS Forward Detectors

LUCID

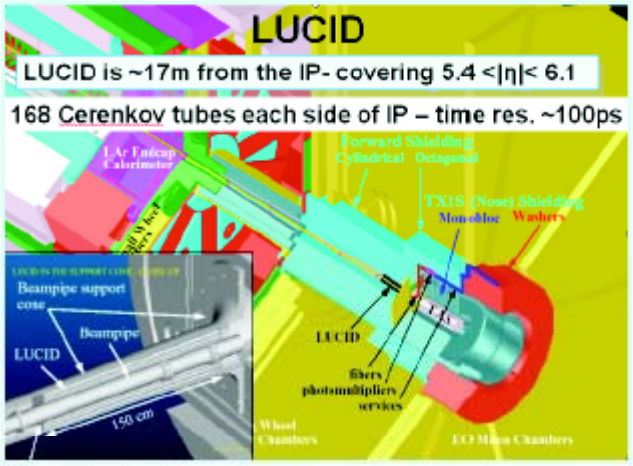
- C4F10 filled aluminized carbon tubes
- measures Cerenkov radiation of charged particles from interaction point
- $5.4 < |\eta| < 6.1$
- installation 2007

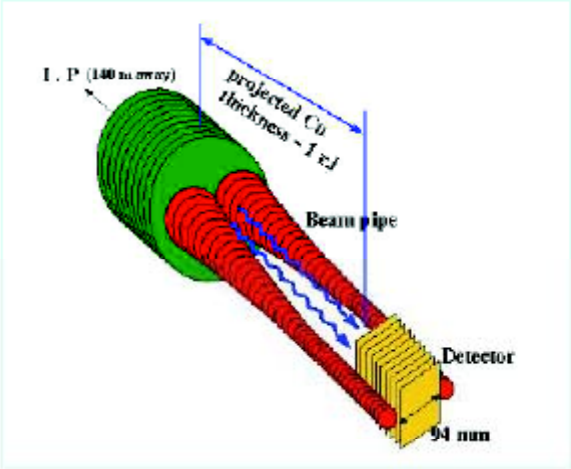
ATLAS-ZDC

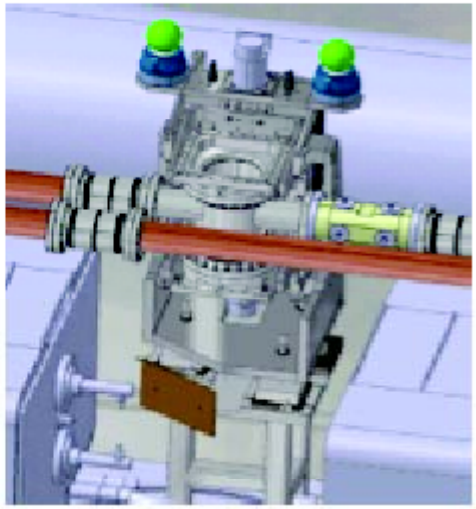
- Tungsten/quartz Cerenkov calorimeter
- in TAN shielding
- EM ($29X_0$) and HAD (4.6λ) sections
- $|\eta| > 8$ neutrals
- installation 2007/8

ALFA

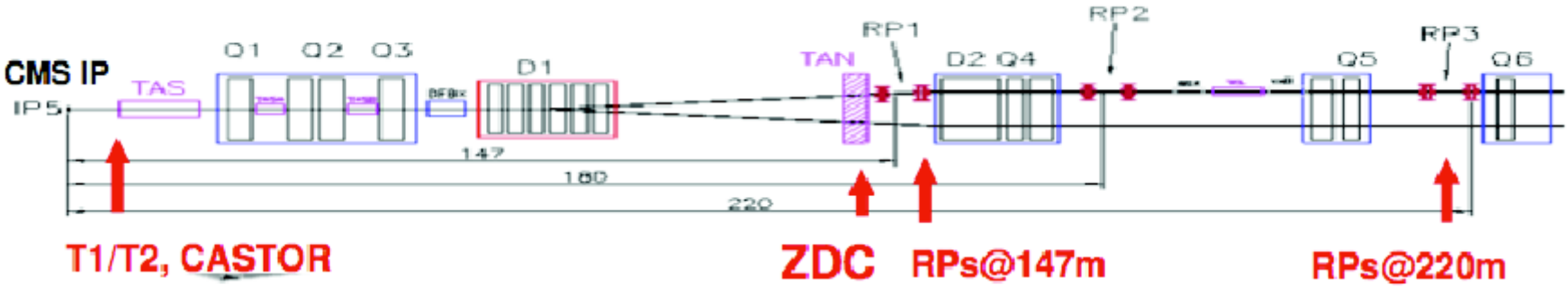
- 2 Roman Pot stations at ±240m from IP1
- 10+10 planes of scintillating fibre 1.5mm from beamline
- installation 2008/9

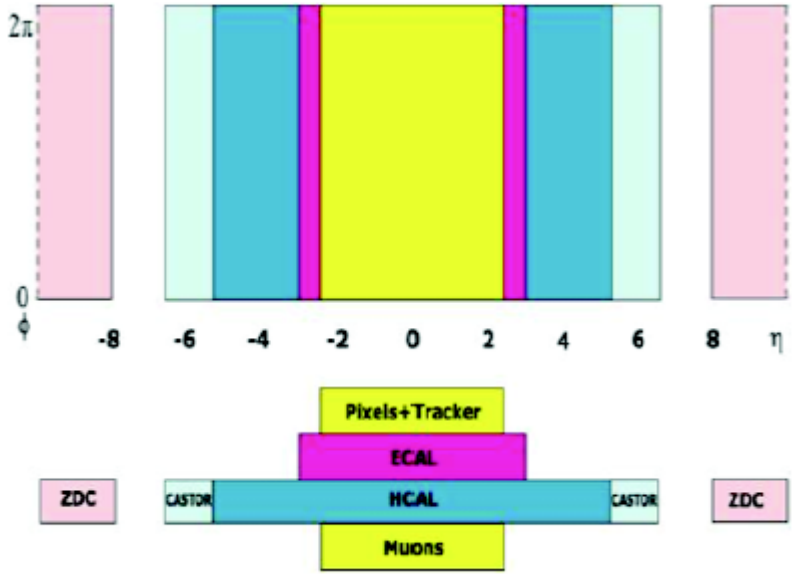






Forward Detectors at CMS IP :: Overview





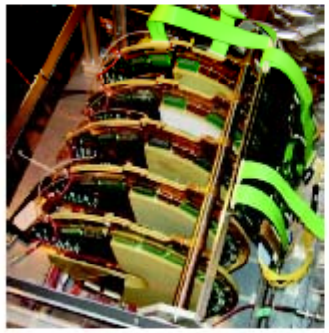
- CMS Central
- TOTEM-T2
- CMS-CASTOR
- ZDC
- TOTEM-RP

CMS+TOTEM have the largest acceptance ever at a hadron collider

Forward Detectors at CMS IP :: Detail

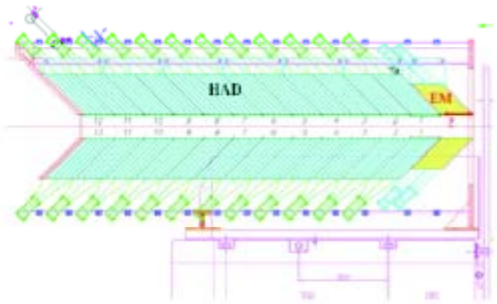
TOTEM-T2

- GEM tracking (Ar/CO_2)
- 10 half-planes of 512 strips
- $\Delta\eta \times \Delta\phi = 0.06 \times 0.05$
- $5.2 < |\eta| < 6.5$
- installation 2007



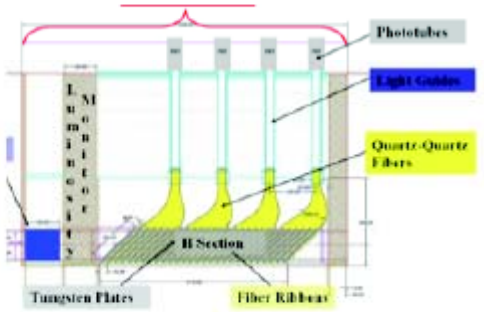
CASTOR

- Tungsten/quartz calorimeter
- EM ($20X_0$) and HAD (9.5λ) sections
- $5.2 < |\eta| < 6.6$
- installation 2008/9



CMS-ZDC

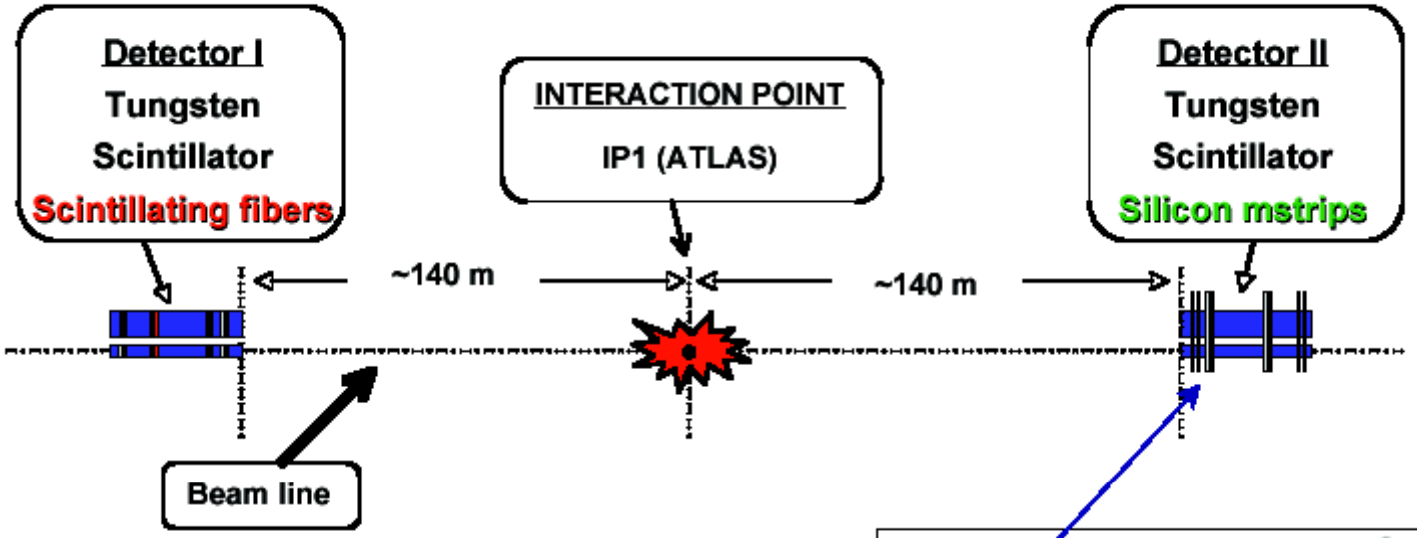
- Tungsten/quartz Cerenkov calorimeter
- EM ($19X_0$) and HAD (5.6λ) sections
- $|\eta| > 8$ neutrals
- installation 2007



TOTEM-RP

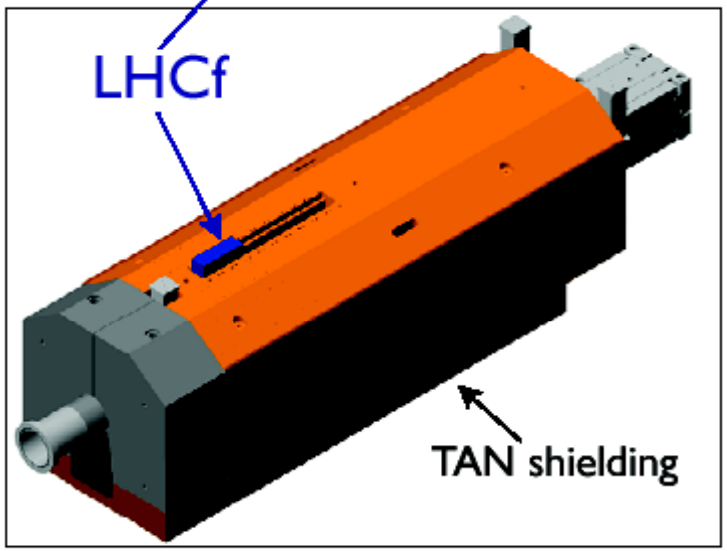
- 2 Roman Pot stations at ±220m from IP5
- installation 2008/9
- 5+5 planes of 'edgeless' silicon, 1.5mm from beamline
- special beam optics required for some studies

LHCf



- installed in TAN shielding
- silicon + scintillating fiber tracking with ~200μm resolution
- tungsten/scintillator energy measurement with resolution ~5%
- installation 2007 (first phase complete)

see A. Tricomi's talk

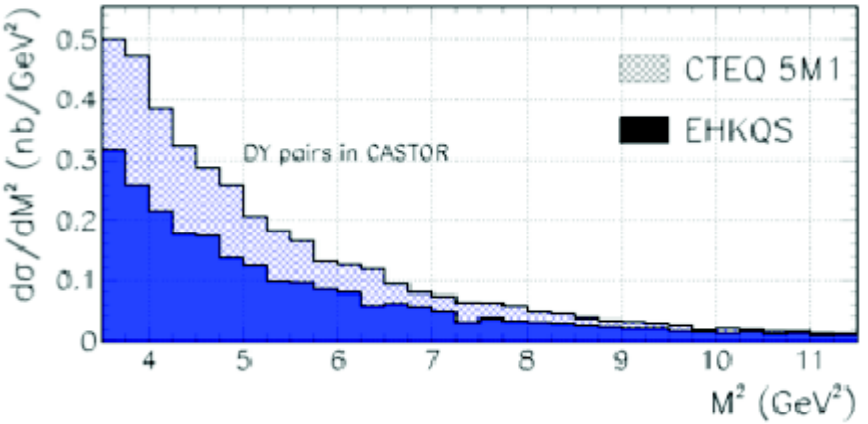


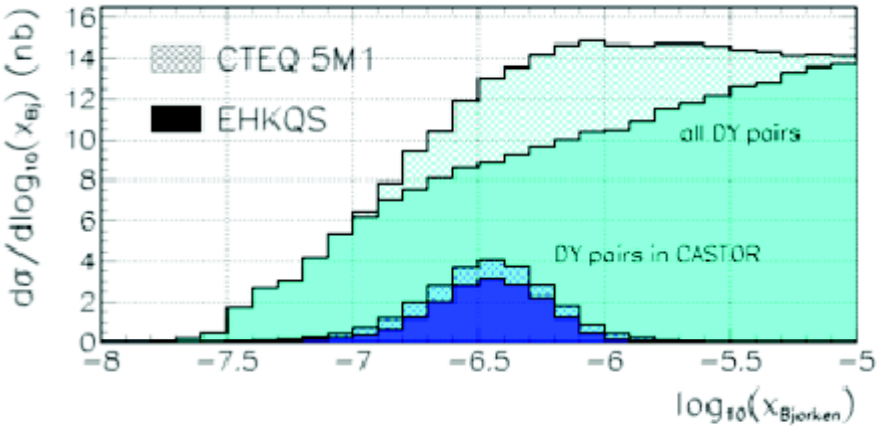
Forward Drell-Yan Pairs & Saturation

Rise of F_2 tamed by saturation?

- CTEQ 5M1: standard, "non-saturated" pdf
- EHKQS: "saturated" pdf with nonlinear terms in gluon evolution
  [A. Dainese et al., HERA-LHC Workshop proc.]

→ Saturation effects cause a 30% decrease in the DY cross section!





[CERN-LHCC 2006-039/G-124]

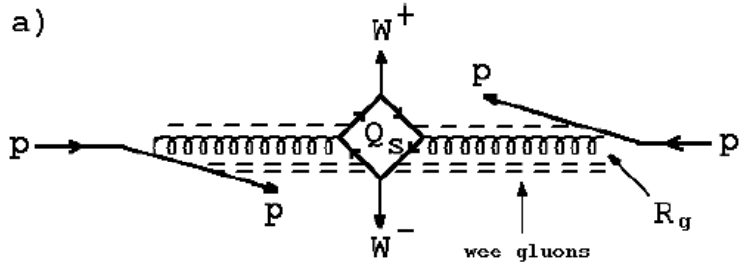
Event yield: ~2 million events/fb^{-1} in CASTOR

Anomalous WW Production?

Alan White: theory of supercritical pomeron→ reggeized gluon+many (infinite) wee gluons

- color sextet quarks required by asymptotic freedom, have strong colour charge, (at least) few 100 GeV constituent mass
- Sextet mesons → EWSB
- UDD neutron dark matter candidate
- Explain high energy cosmic rays, Knee?
- Color sextet quarks couple strongly to W and Z and to the pomeron
- Phenomenology: Anomalous production of WW when above threshold ie. At the LHC (with possibly some onset already detectable at the Tevatron

color triplets	color sextets
u c t	U
d s b	D



⇒Measure exclusive WW,ZZ cross sections in DPE at the LHC
Expected cross section to be orders of magnitude larger than in SM