Prospects for Forward Energy Flow and Low-x Physics at LHC

Andrew Hamilton
Université de Genève
for the ATLAS, CMS, Totem, & LHCf Collaborations

Outline

Forward Physics Overview

LHC Forward Detectors

- ATLAS Forward Detectors
- CMS + TOTEM Forward Detectors
- FP420
- LHCf

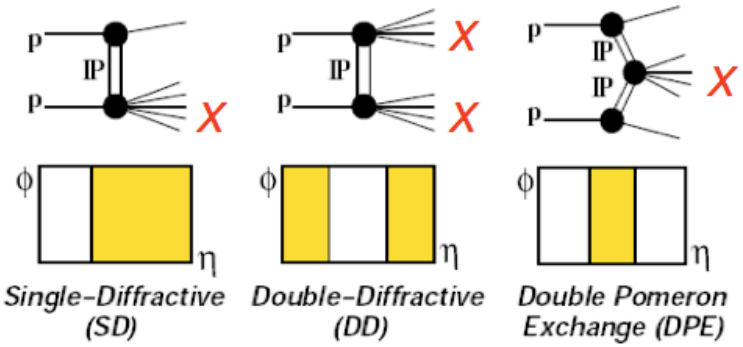
LHC Forward Physics Prospects

- Diffractive Physics
- New Physics
- Low-x QCD Physics
- Forward Energy Flow
- Elastic Scatter and Luminosity
- Photoproduction Physics

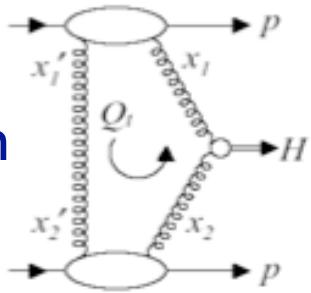
Forward Physics Overview

Forward Physics Overview

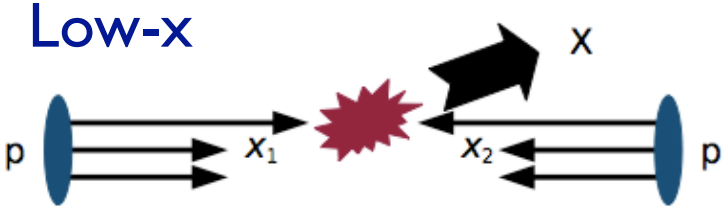
Inclusive Diffraction(soft and hard)



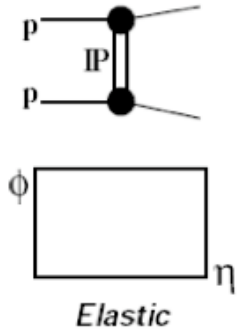
Exclusive Diffraction



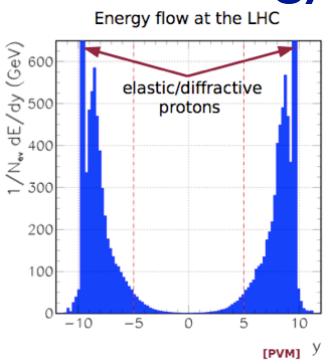
Low-x



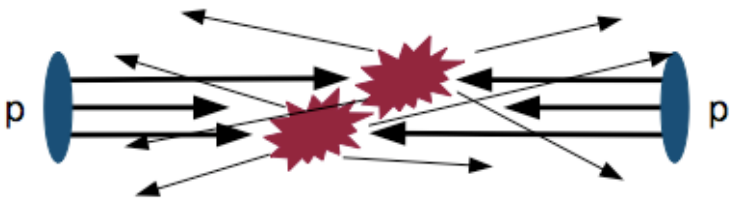
Elastic Scattering and Luminosity



Forward Energy Flow

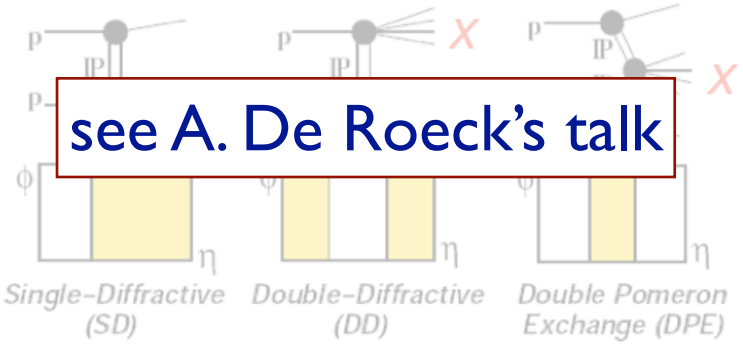


Multiple Interactions



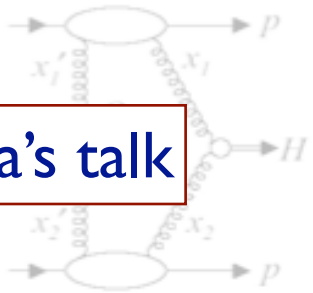
Forward Physics Overview

Inclusive Diffraction(soft and hard)



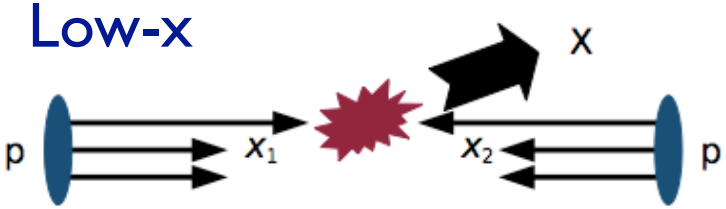
see A. De Roeck's talk

Exclusi



see O. Kepka's talk

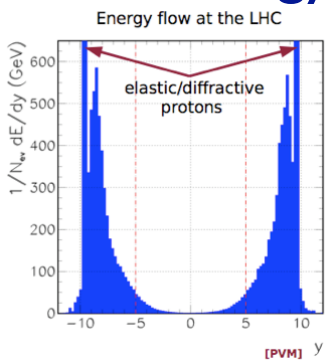
Low-x



Elastic Scattering

see C. Sbarra and M.Deile talks

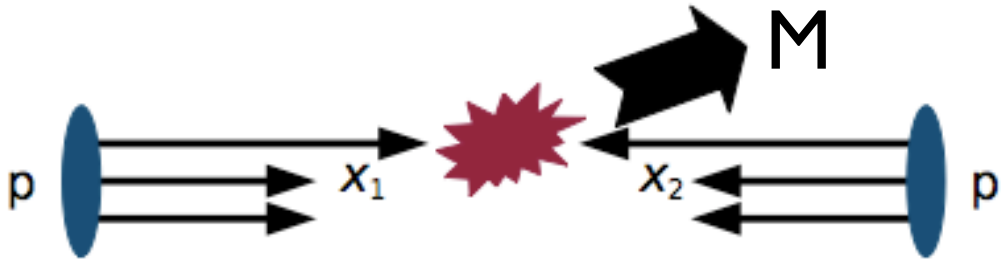
Forward Energy Flow



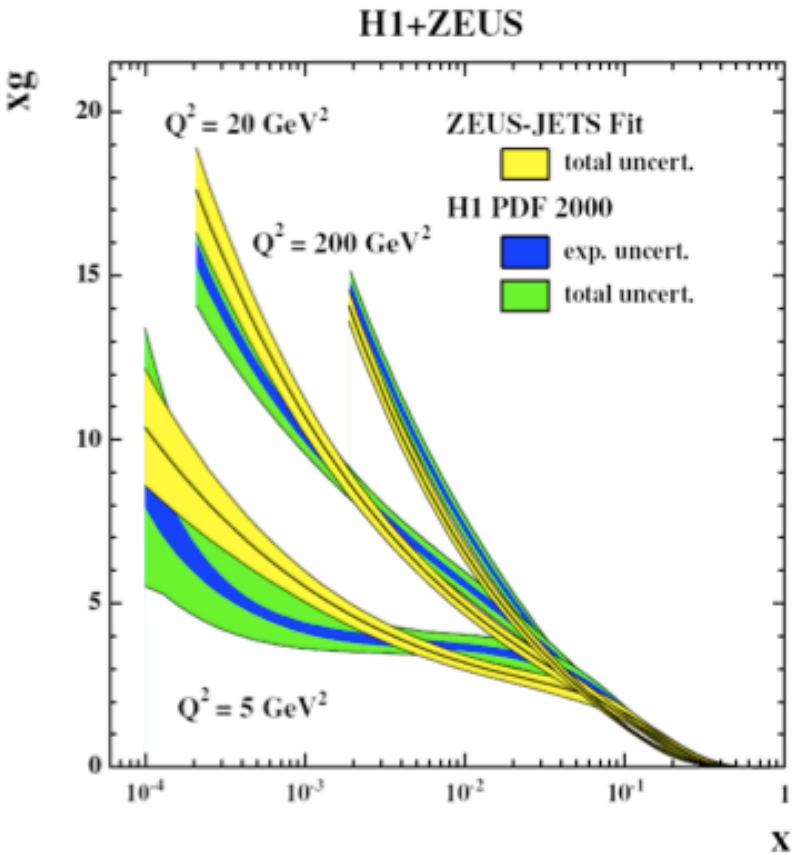
Multiple Interactions

see L. Fano talk

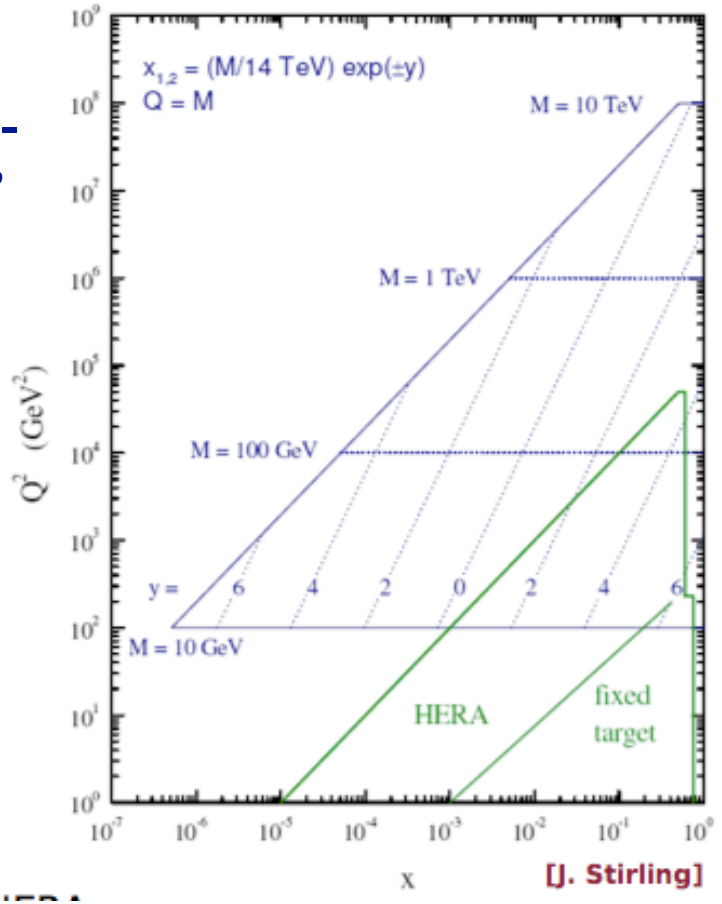
Forward Physics & Low-x



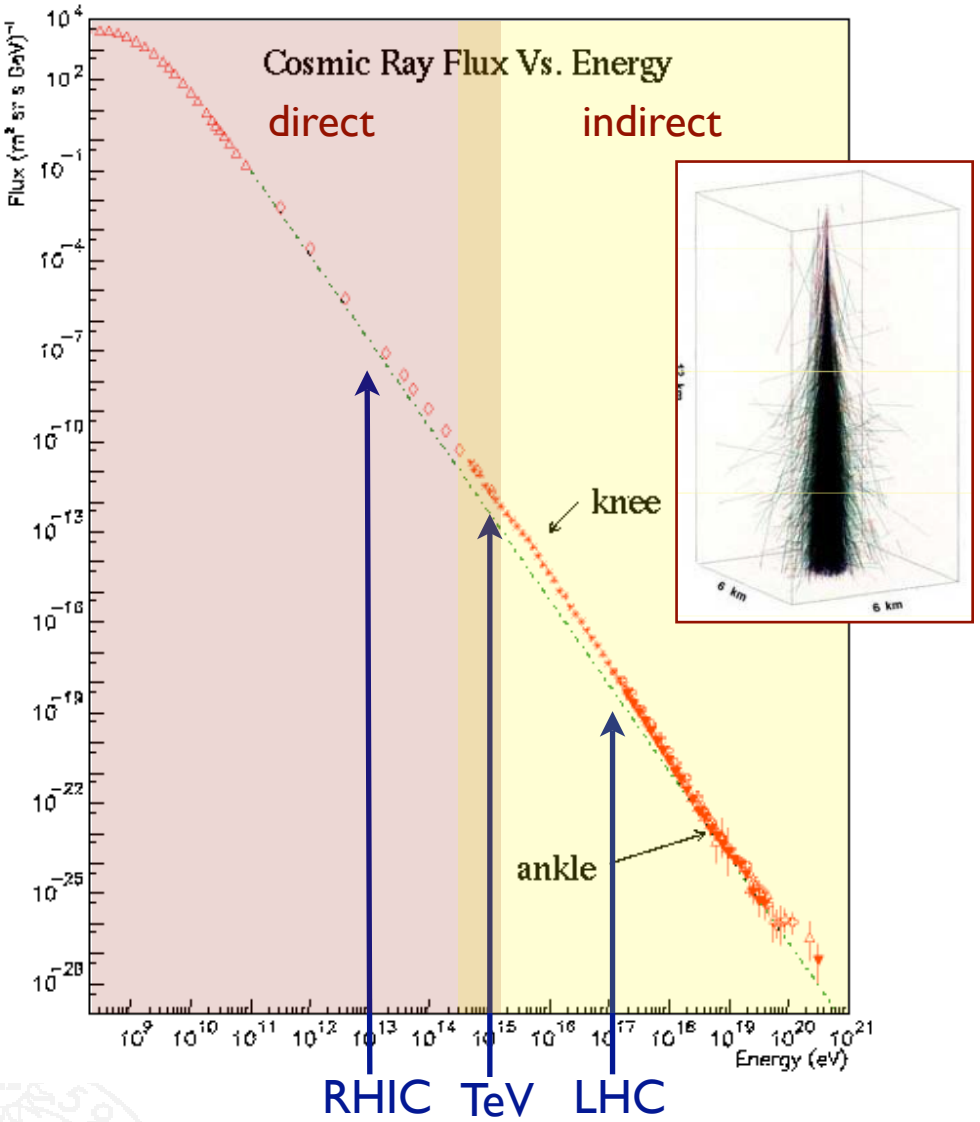
- M goes forward if $x_1 << x_2$
- M can be jets, DY, prompt-γ, b/c jets



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



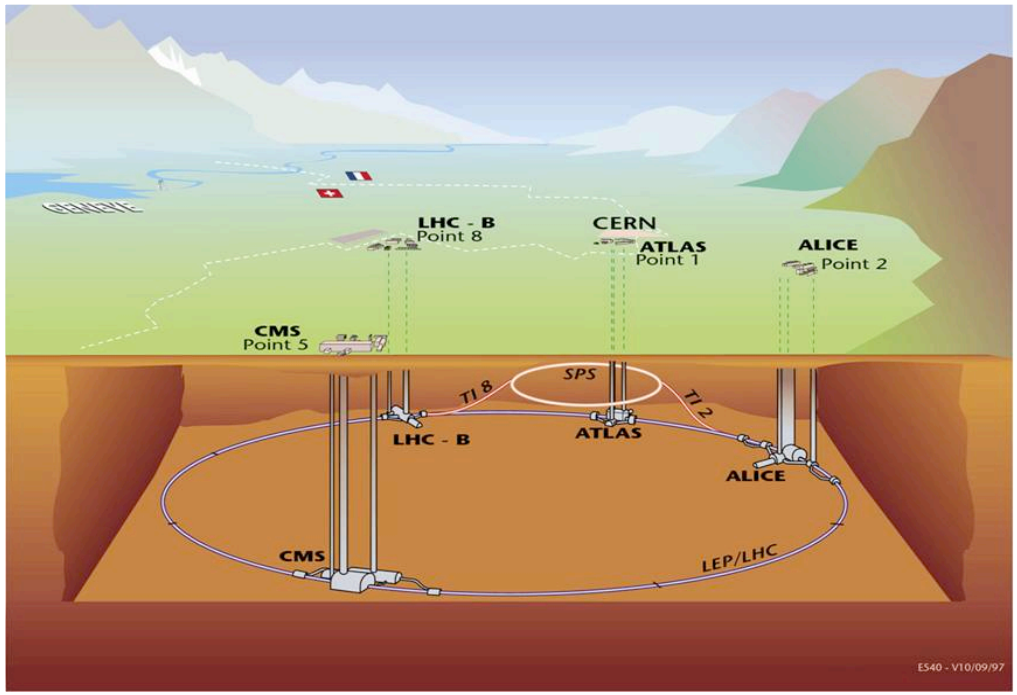
Forward Energy Flow & Cosmic Rays



- above E_{lab} ~10^{14} eV only indirect measurements are possible
- composition & energy of CR is determined from simulation
  - examples include: QGSJet, SIBYLL, DPMJET, and EPOS
- dominant contribution is soft QCD in forward energy flow
- LHC is the first chance to compare showering models at E_{lab} ~10^{17} eV
- need forward detectors to measure forward energy flow!

LHC Forward Detectors

LHC Quick Review

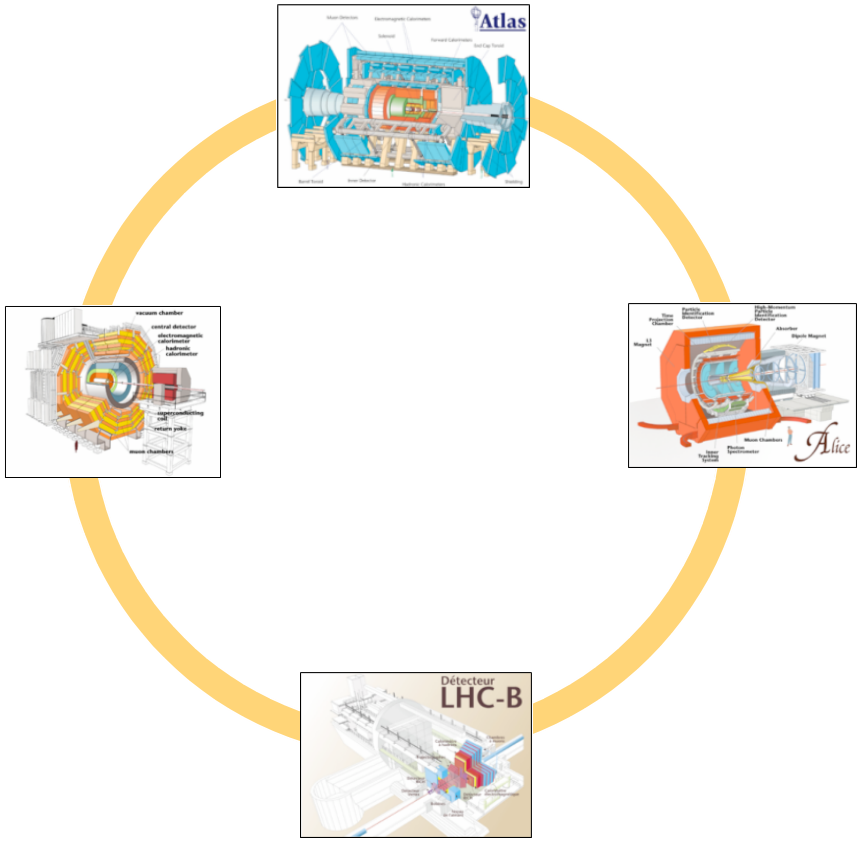


Large Hadron Collider:

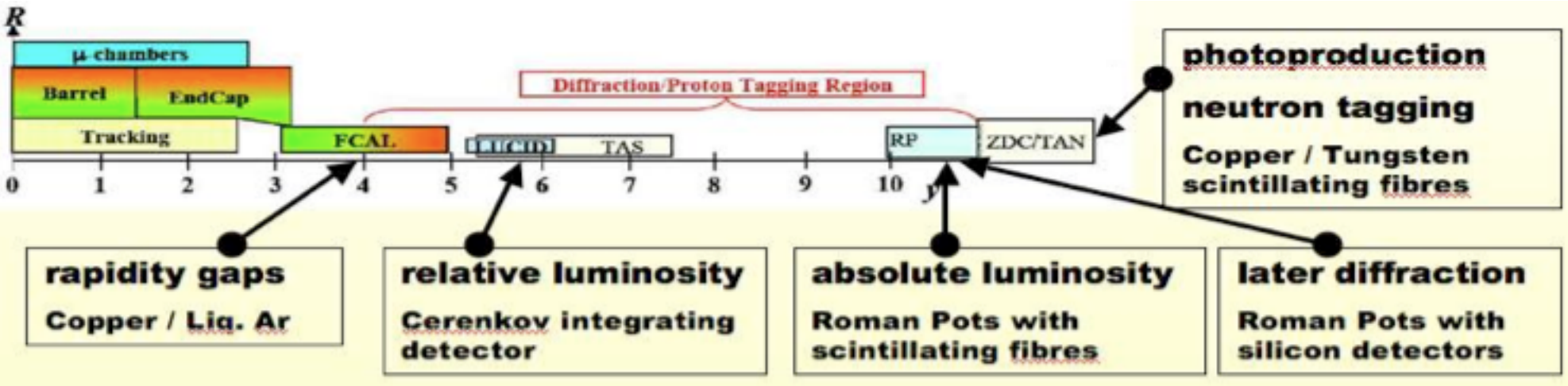
- 14 TeV pp collisions
- plus a Heavy Ion program

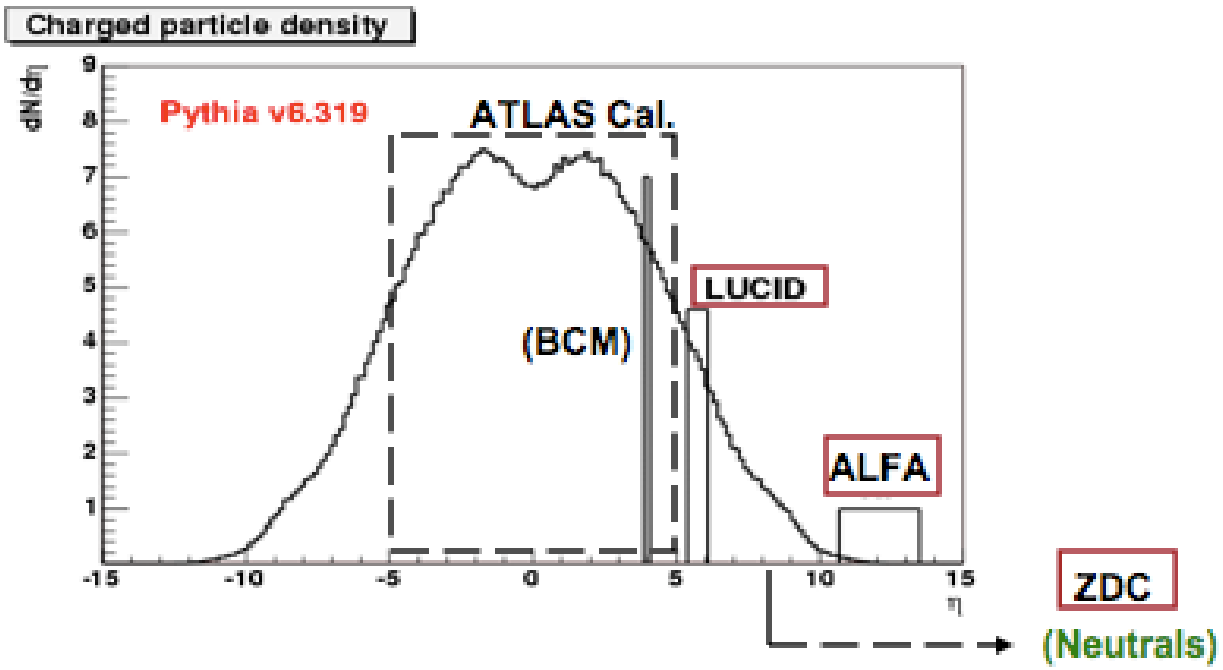
Experiments:

- 4 interaction points instrumented
- ATLAS & CMS: general purpose
- LHC-B: b-physics
- ALICE: heavy ions



ATLAS Forward Detectors



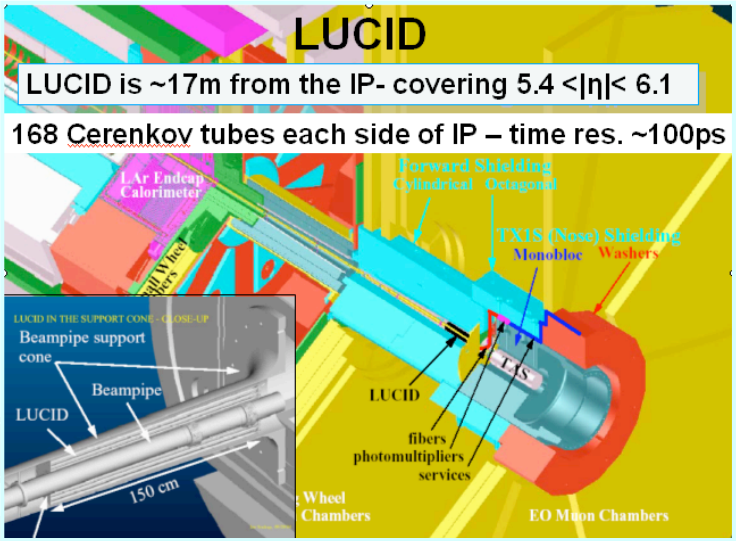


- LUCID
- ALFA RP
- ATLAS-ZDC

ATLAS Forward Detectors

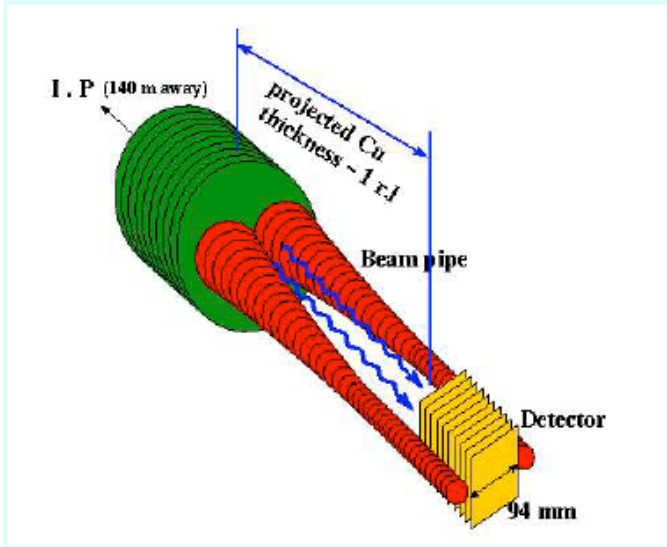
LUCID

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



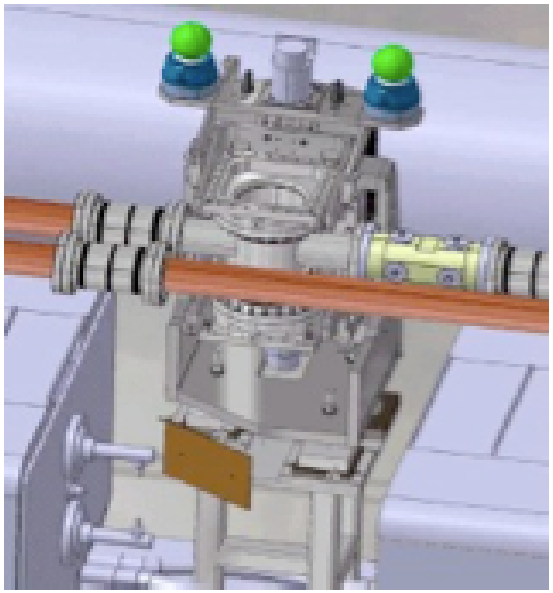
ATLAS-ZDC

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

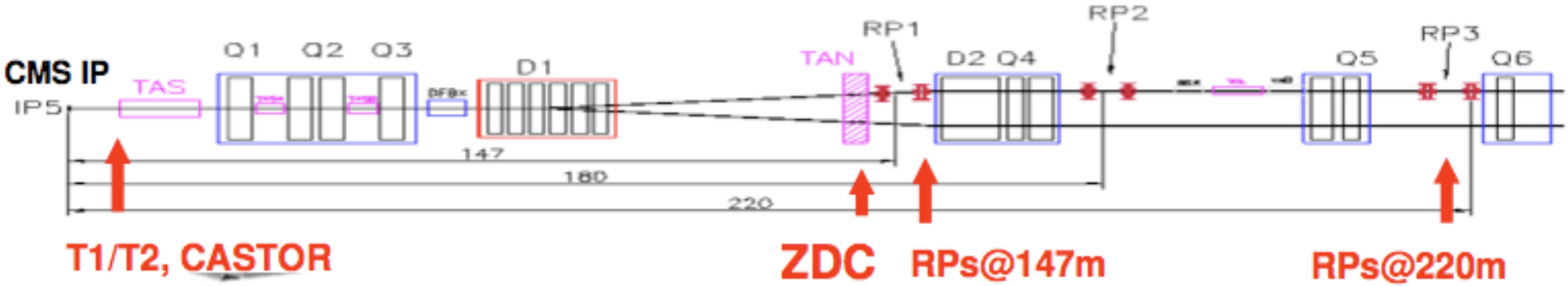


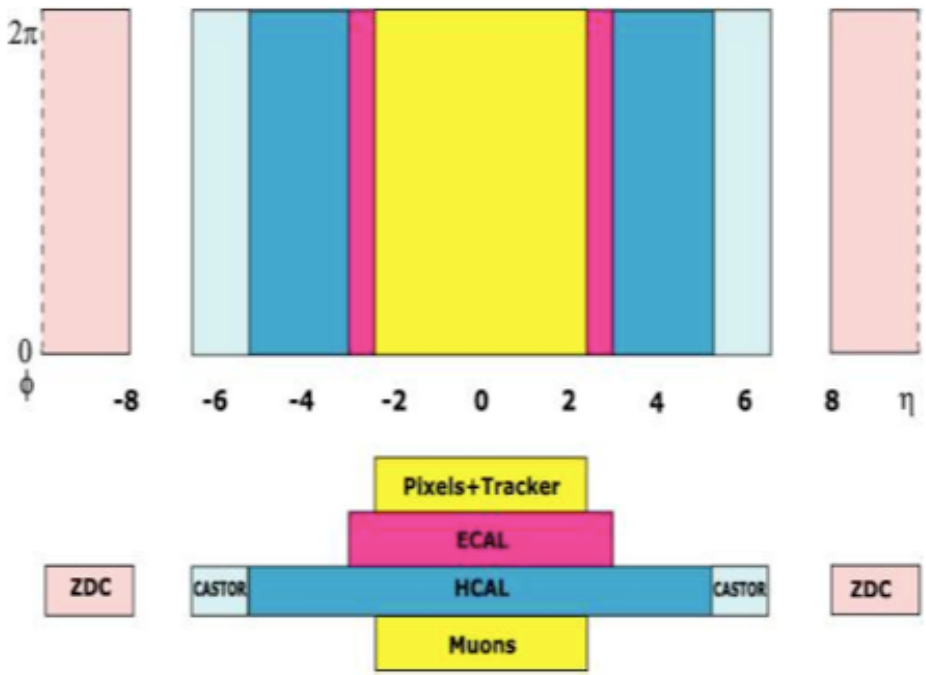
ALFA

- 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

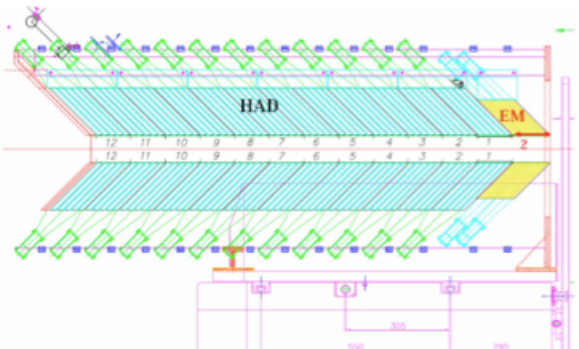
Forward Detectors at CMS IP :: Detail

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

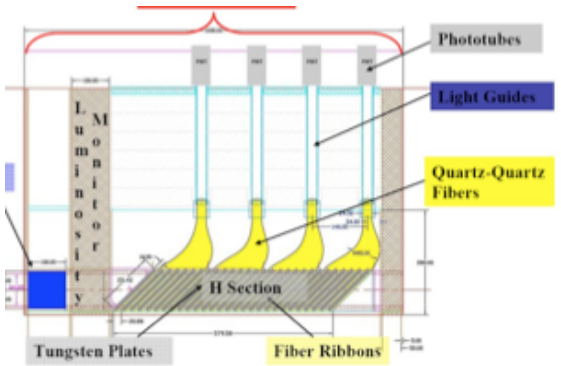
CASTOR

- 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



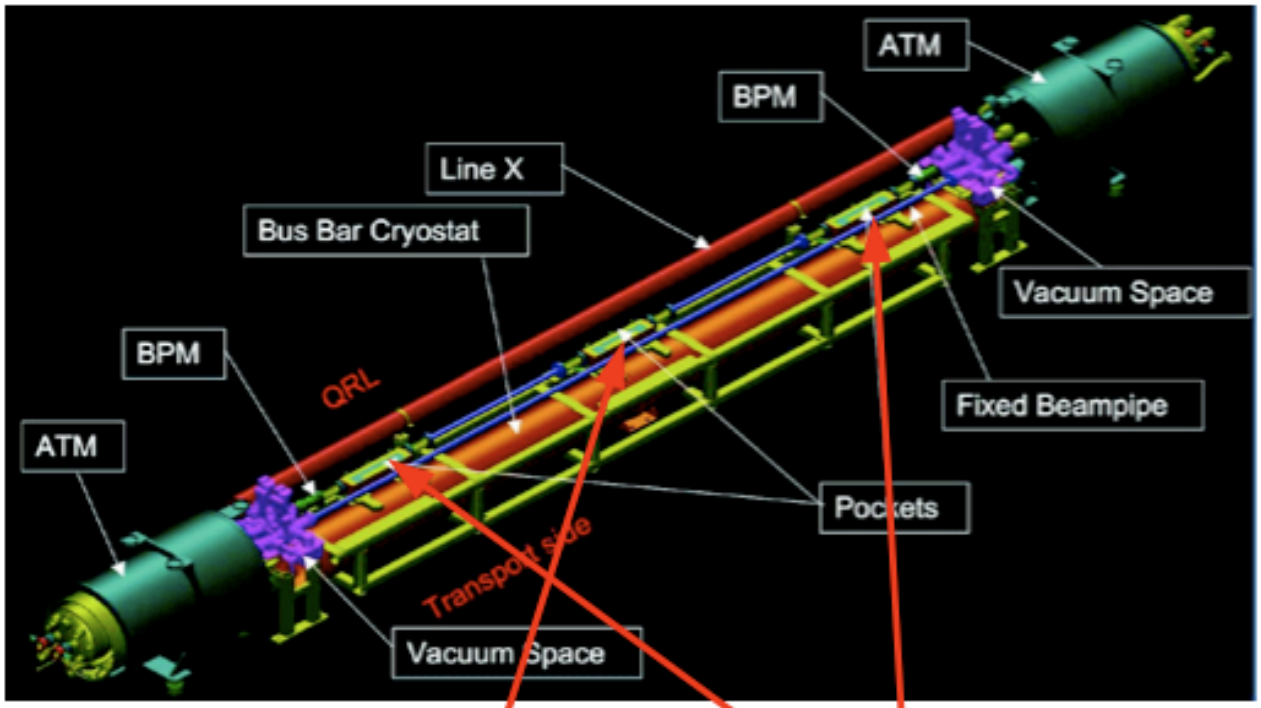
TOTEM-RP

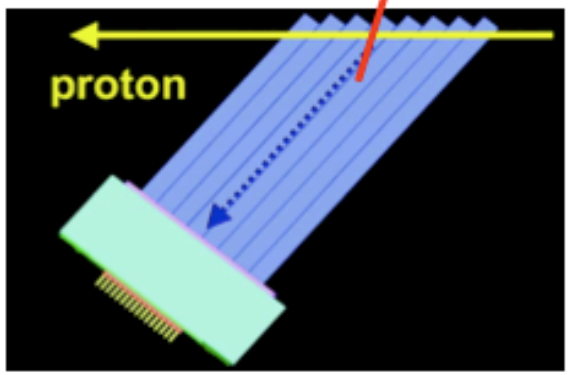
- 2 Roman Pot stations at ±220m from IP5
- installation 2008/9
- 5+5 planes of 'edgeless' silicon, 1.5mm from beamline
- special beam optics required for some studies

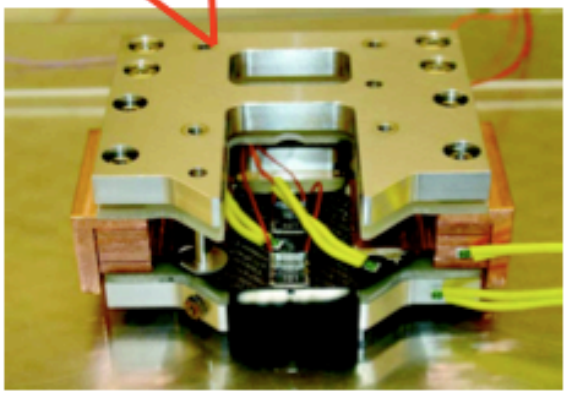
FP420

- Cryostat adaptation using moving beam pipe
- Will operate with standard high luminosity optics.
- Acceptance:
  $0.002 < \xi < 0.02$
  → exclusive central system in mass range
  $30 < M < 200$ GeV
- 3DSi detectors yielding
  $\Delta p/p \approx 10^{-4}$
  → $\delta M \approx 1$ GeV
- Čerenkov timing detector yielding 10 ps resolution
  → to sort out pile-up
- Installation (if approved) foreseen during 2008/2009 shutdown

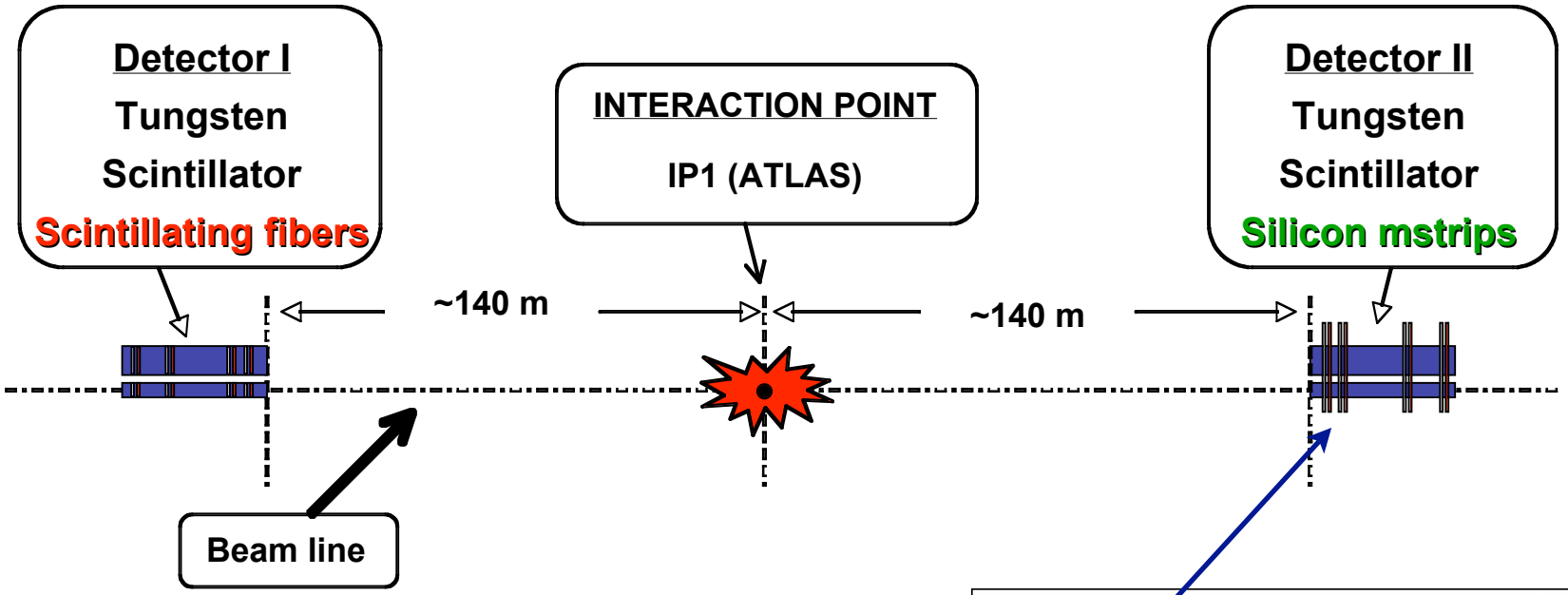
(for both ATLAS & CMS IPs)





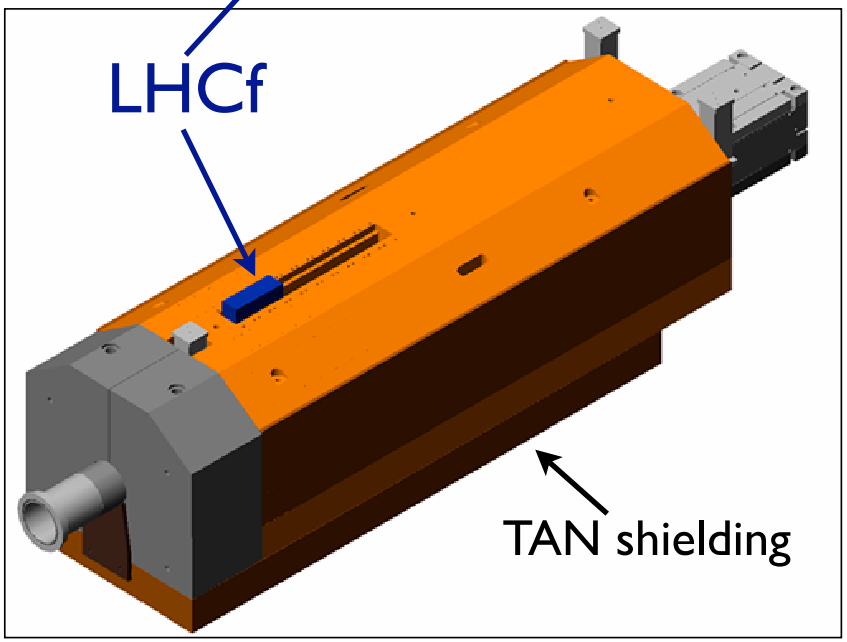


LHCf

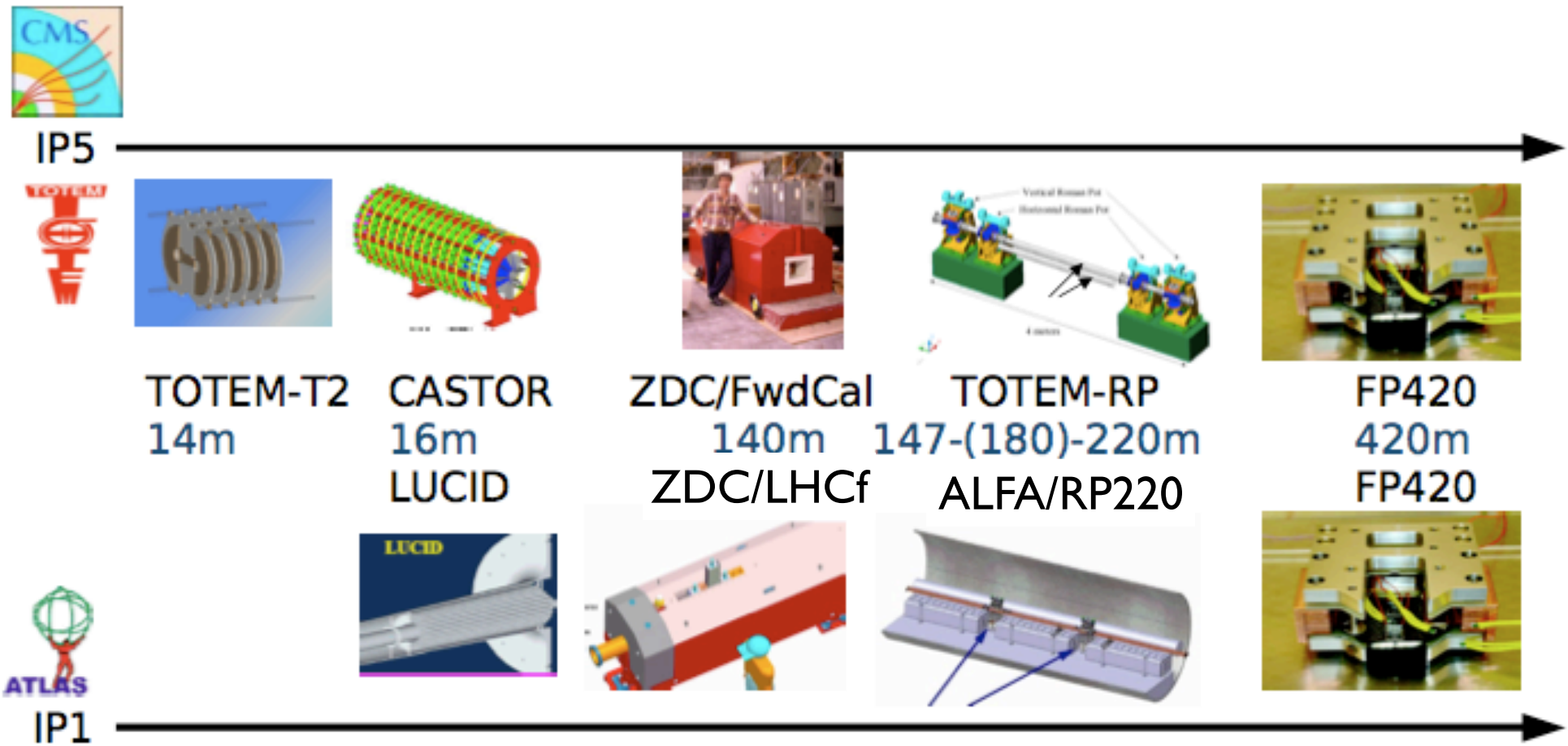


- installed in TAN shielding
- silicon + scintillating fiber tracking with ~200μm resolution
- tungsten/scintillator energy measurement with resolution ~5%
- installation 2007 (first phase complete)

see A. Tricomi's talk



Forward Detector Summary

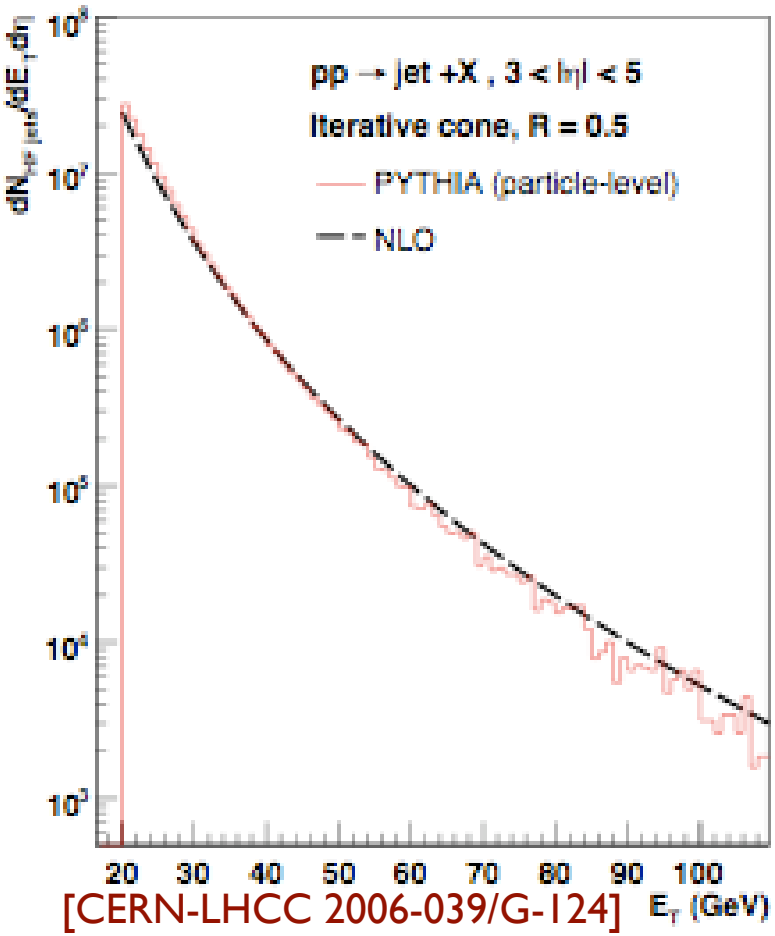


Forward Physics

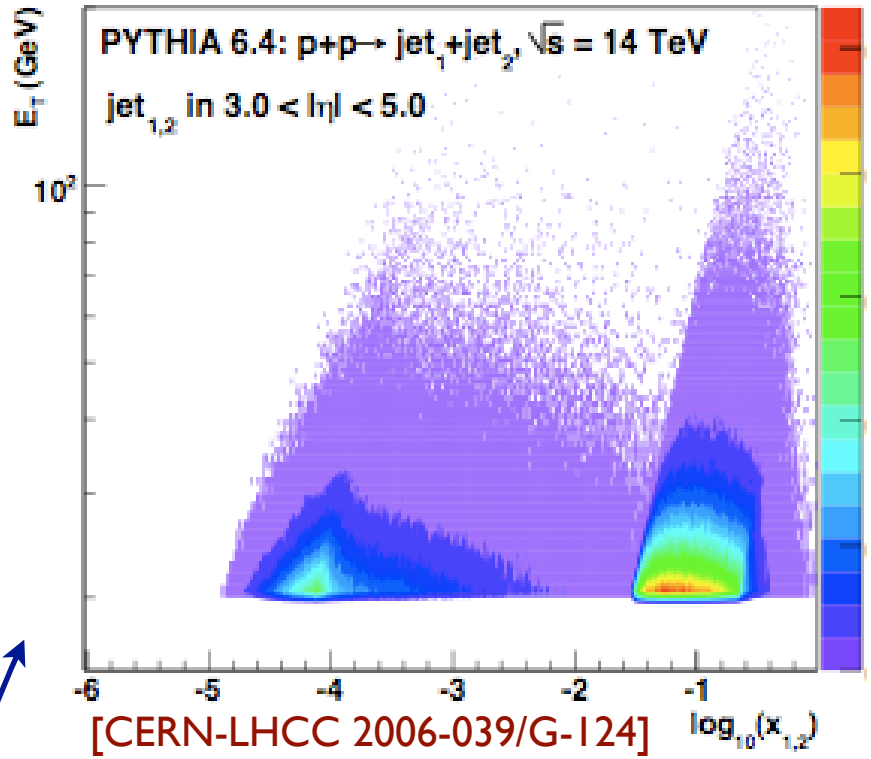
Forward Jets & Saturation

Forward jets could be sensitive to low-x saturation effects:

- saturation will reduce the single inclusive fwd jet cross section



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

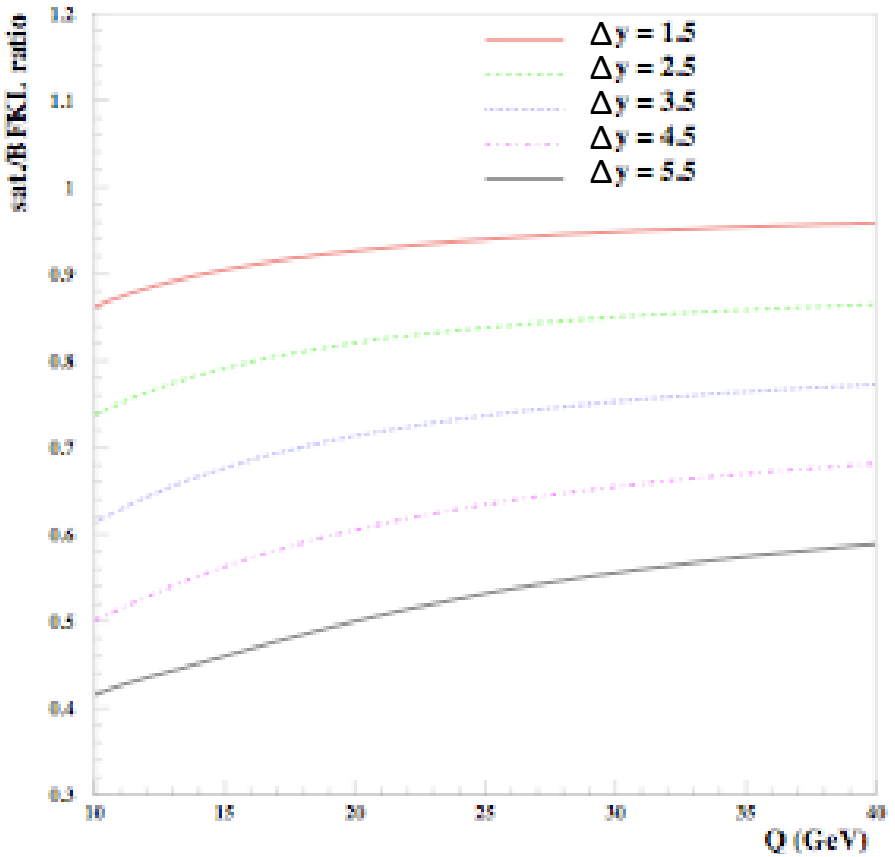


[CERN-LHCC 2006-039/G-124]

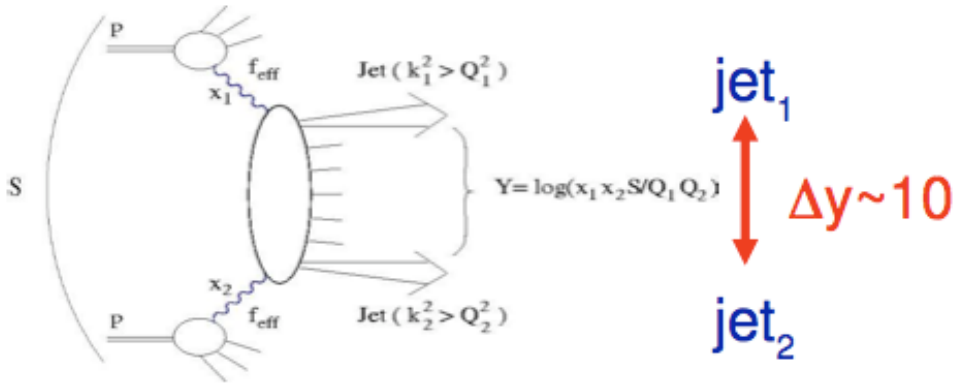
- require one forward jet in $3<|\eta|<5$ with $E_T>20$ GeV
- no detector effects applied yet
- $x_{1,2}$ distribution of the two partons
- measurement looks statistically feasible in $1 pb^{-1}$ of low luminosity (no pile-up) data

Muller-Navelet Dijets

- Muller-Navelet (MN) jets are described by a large rapidity separation between the two jets:



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



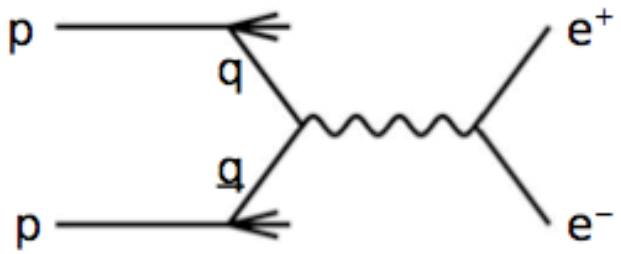
- in the presence of low-x saturation MN dijets are expected to be suppressed compared to BFKL predictions
- suppression increases with separation in rapidity
- larger rapidity separation means more sensitive to saturation effects

Forward Drell-Yan Pairs

- Kinematics of pp → e^+e^-X:

$$M^2 = sx^+x^- \qquad x^\pm = \frac{M}{\sqrt{s}}\exp^{\pm y}$$

$$x_F = \frac{p_z^+ + p_z^-}{\sqrt{s}/2} = x^+ - x^-$$



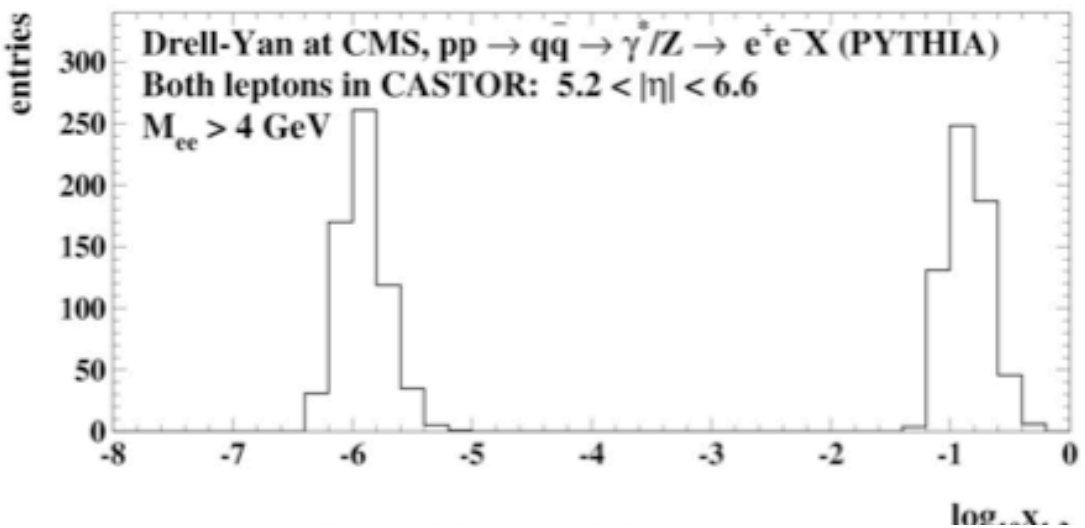
→ asymmetric x_{Bj} values ($x^- \ll x^+$) will boost the leptons to large rapidity

→ pdf known at high x^+ ⇒ extract pdf at low x^- (quark distributions)

- CASTOR acceptance:

→ low mass DY in CASTOR probes the proton down to $x_{Bj} = 10^{-6} - 10^{-7}$

→ constraint of global parton density fits!



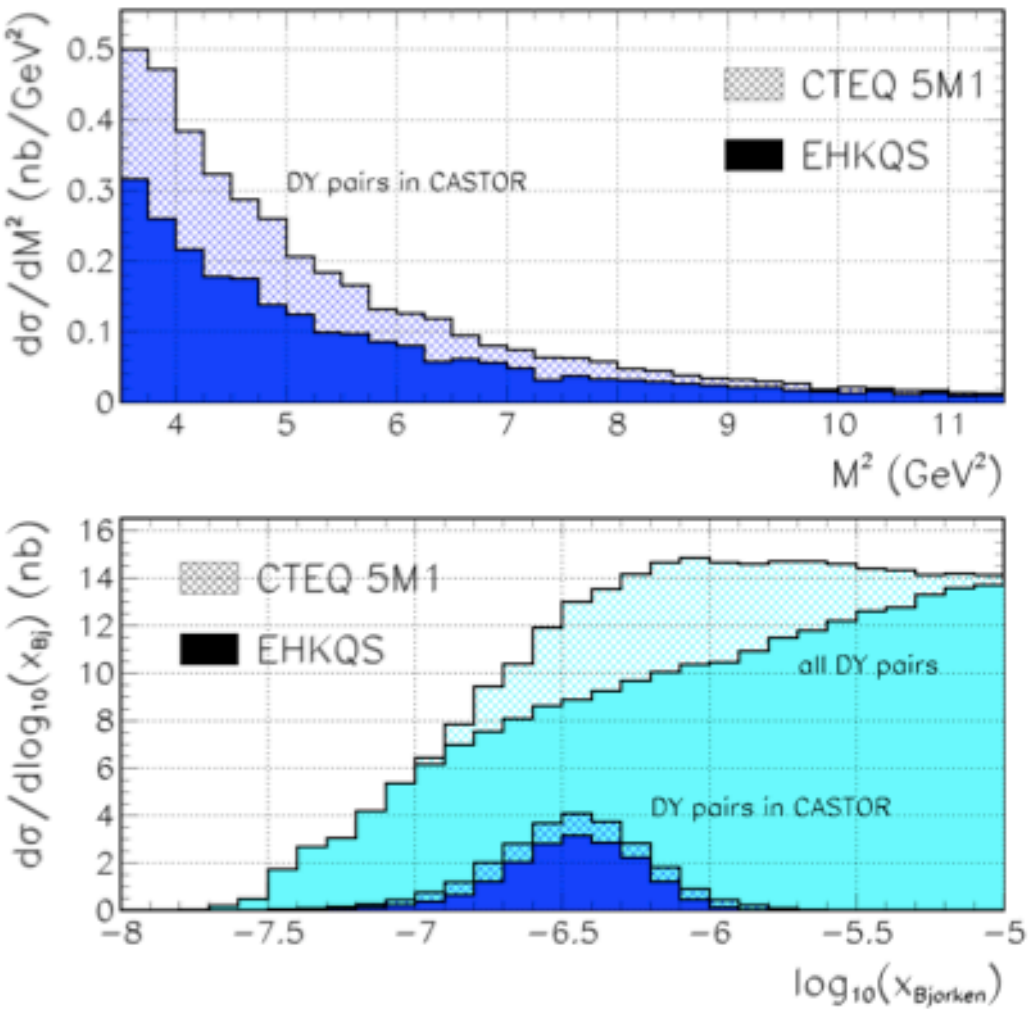
[CERN-LHCC 2006-039/G-124]

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!



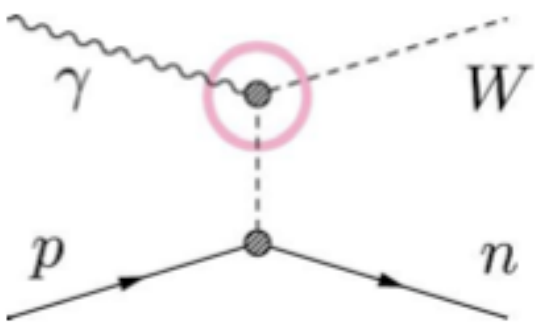
[CERN-LHCC 2006-039/G-124]

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

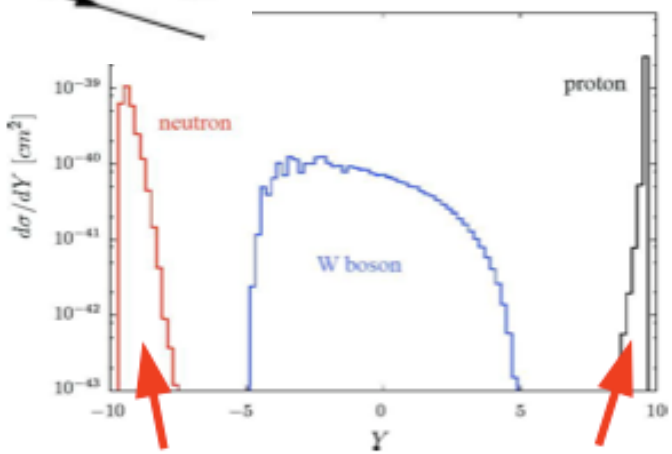
Forward Energy & Forward Particles

ATLAS-ZDC

- reconstruction of very forward neutral hadrons
- allows potential tagging of charge exchange events:

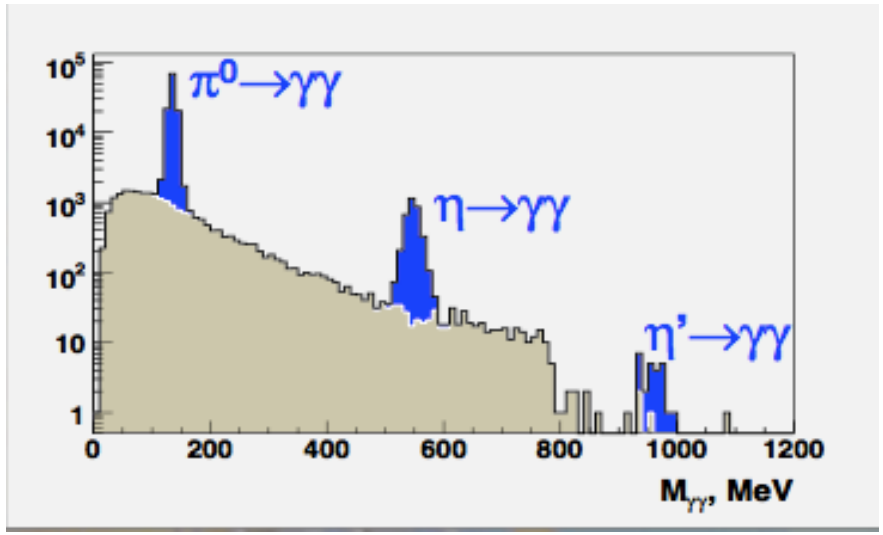


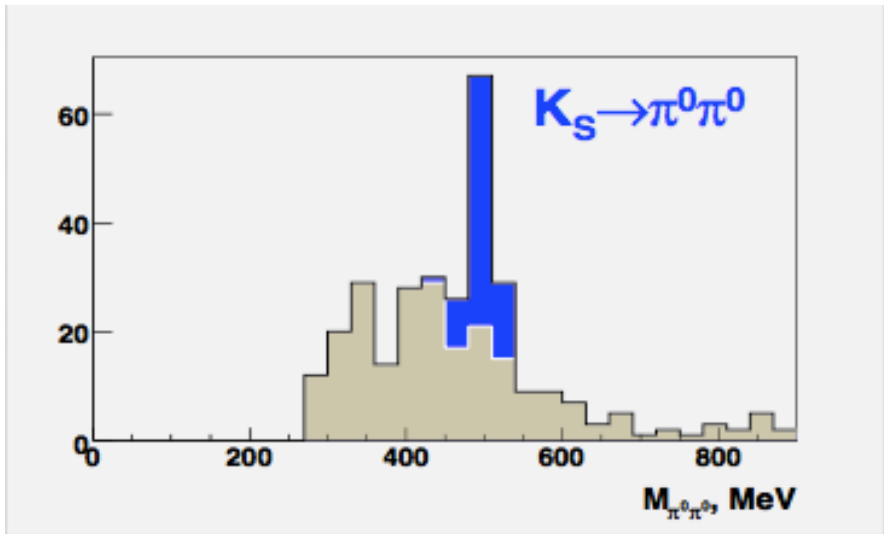
~50 events / 100pb^{-1}



n,p tagging in ZDC/RPs

[U.Dreyer, ECT-UPC-Workshop 2007]



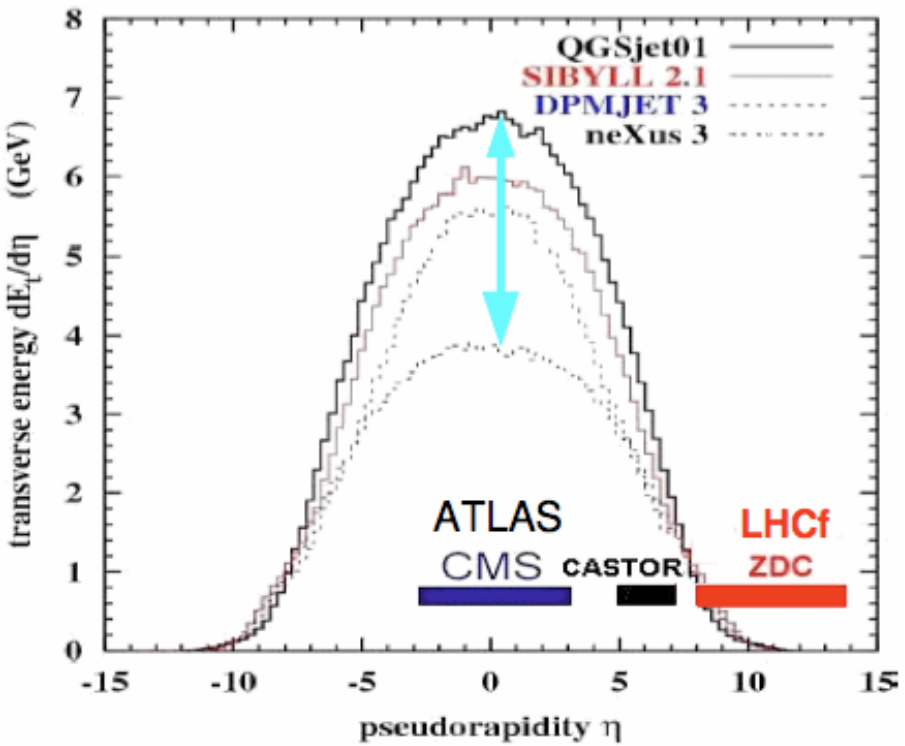


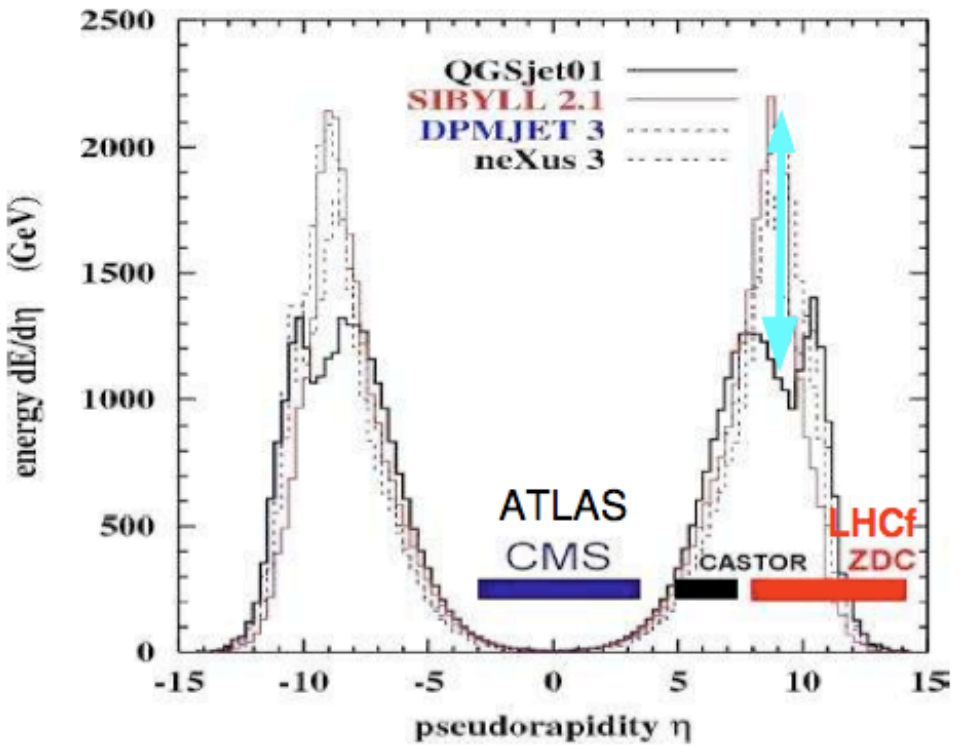
[S.White]

Forward Energy Flow & Cosmic Rays

- model predictions of particle multiplicity and energy flow differ by factor ~2

[R.Engel]





- ZDC's and LHCf will measure the energy flow of forward neutral hadrons
- operational in pp, pA, and AA collisions (note CRs are p-Air, α-Air, Fe-Air)
- direct measurements will put strong constraints air shower models

Conclusions

- Low-x physics at ATLAS & CMS will help us understand the structure of the proton
- Forward Energy Flow will help us understand multiple interactions and underlying event - essential for understanding new physics!
- Forward Energy Flow studies at ATLAS & CMS will improve modeling techniques for high energy cosmic ray air showers
- Many forward physics detector projects well under way at ATLAS & CMS

Thank-you very much to:
David d'Enterria, Pierre Van Mechelen, Oscar Adriani, James Pinfold, Stephan Ask