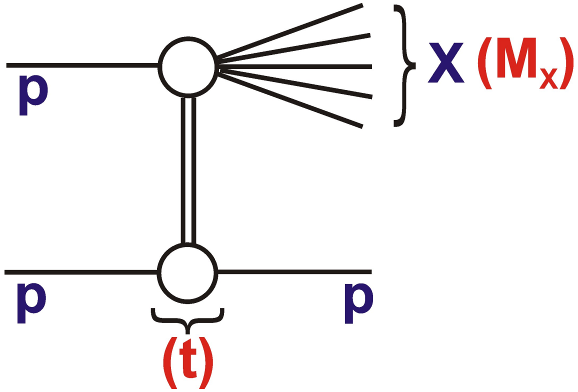
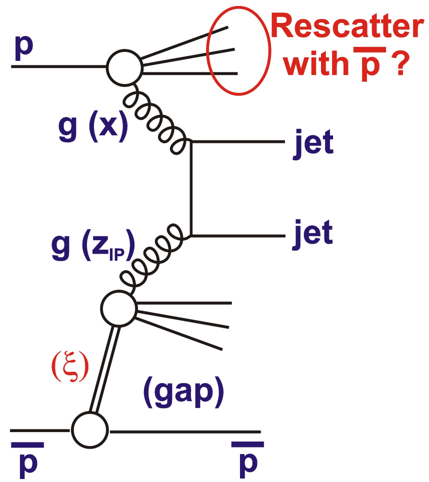
Diffractive, [Elastic and Total] Cross Sections from early LHC Data

Paul Newman (University of Birmingham, ATLAS Collaboration)



Durham Seminar
3 May 2012

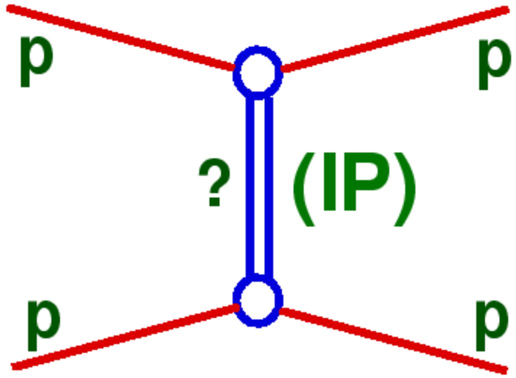


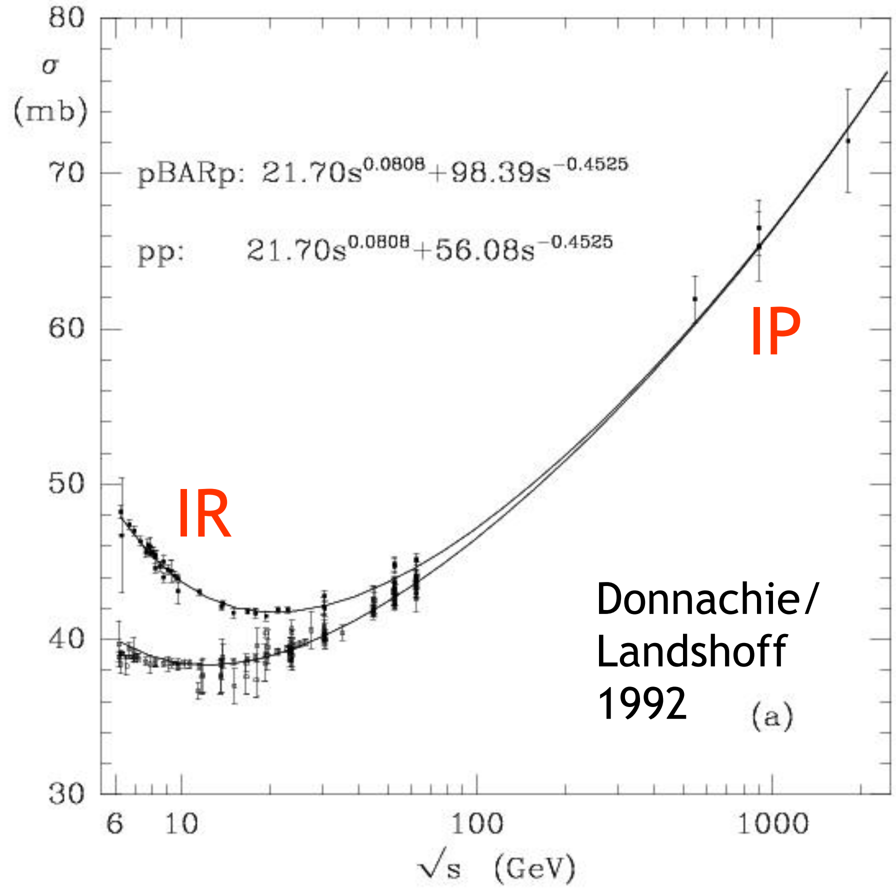
→ Brief Introduction to Diffraction
→ Soft diffractive cross sections at the LHC
→ Relation to the total and total inelastic cross section
→ First results on hard diffraction

Thanks to many colleagues who worked on these data, especially to Tim Martin

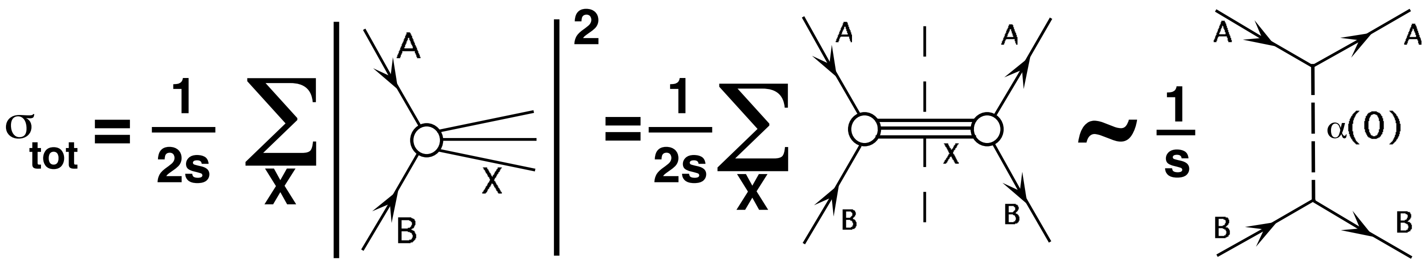
Diffraction, Vacuum Exchange and the Pomeron

What governs elastic scattering at high energies?



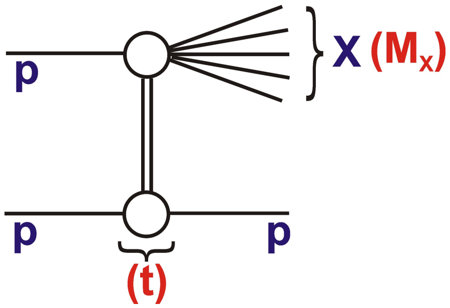


Closely related to the total cross section via the optical theorem

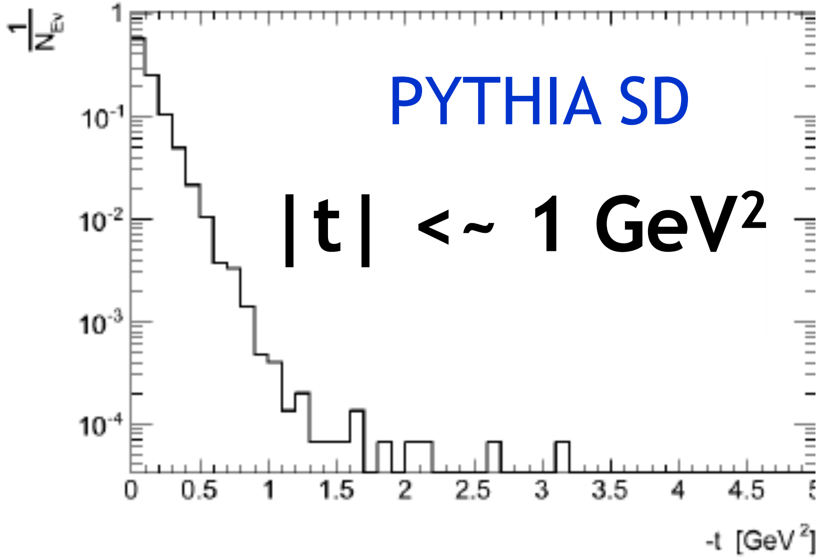


Inelastic Diffraction and Kinematics

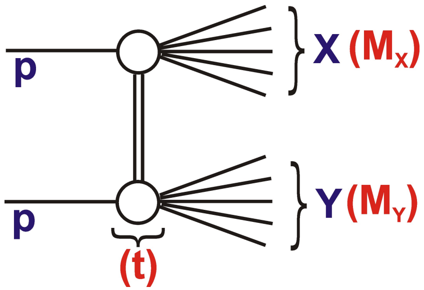
Single dissociation (SD), pp → Xp



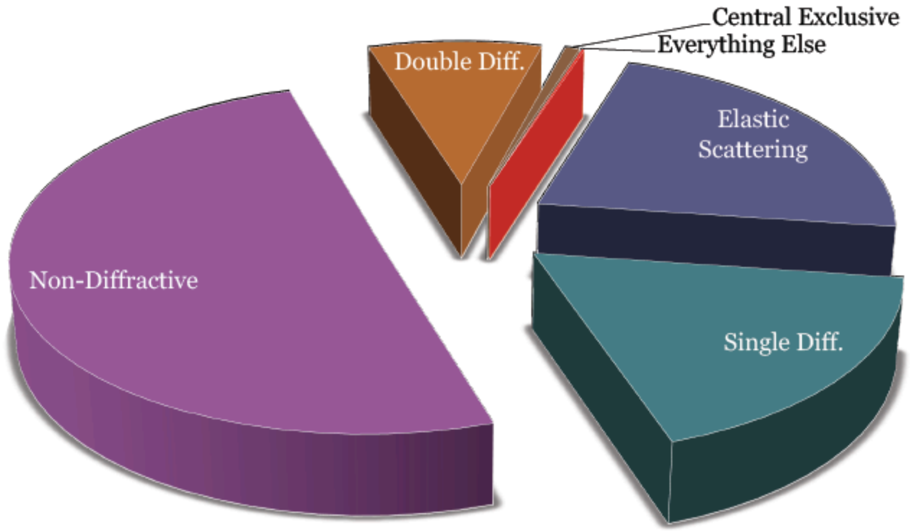
$$\xi = M_X^2/s$$



Double dissociation (DD), pp → XY



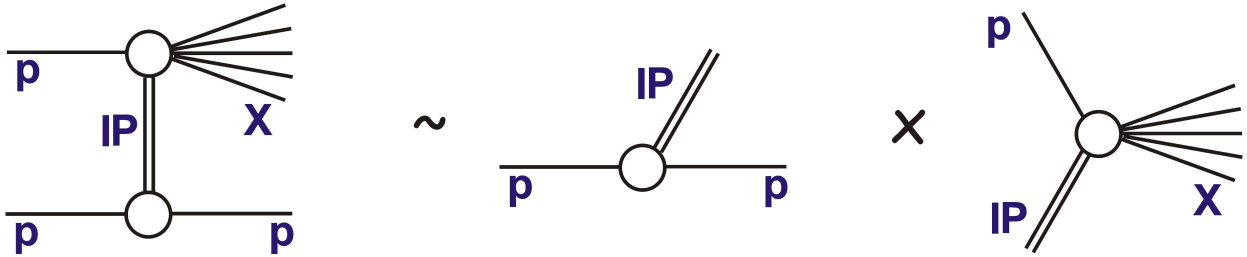
$$\xi_Y = M_Y^2/s$$



-At LHC energies, M_X, M_Y can range from m_p+m_π → ~1 TeV
- Diffractive channels together account for ~ half of total LHC cross section

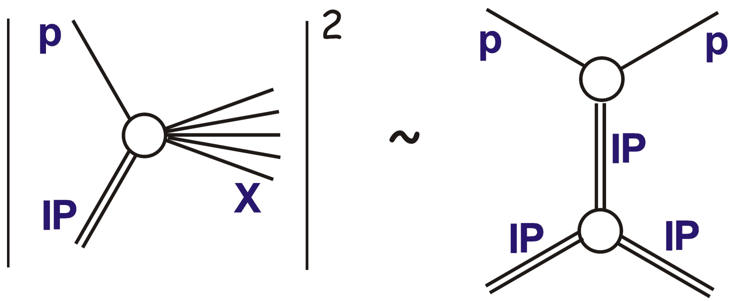
Generalised Optical Theorem

1) Factorise SD into a pomeron (IP) flux and a total p+IP cross section

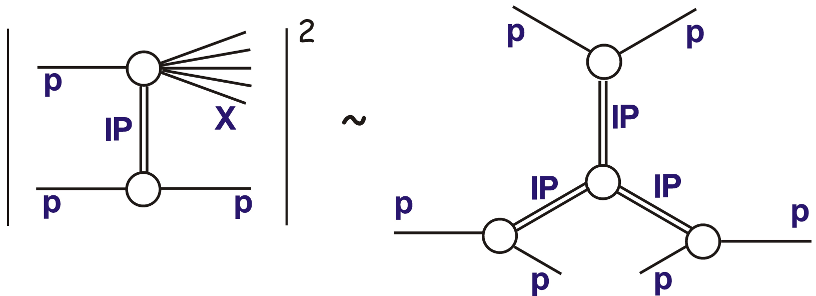


$f_{IP/p}(\xi,t)$ $\sigma_{tot}(IP+p\rightarrow X)$

2) Similarly to total pp cross section, relate total p+IP cross section to forward elastic amplitude via optical theorem

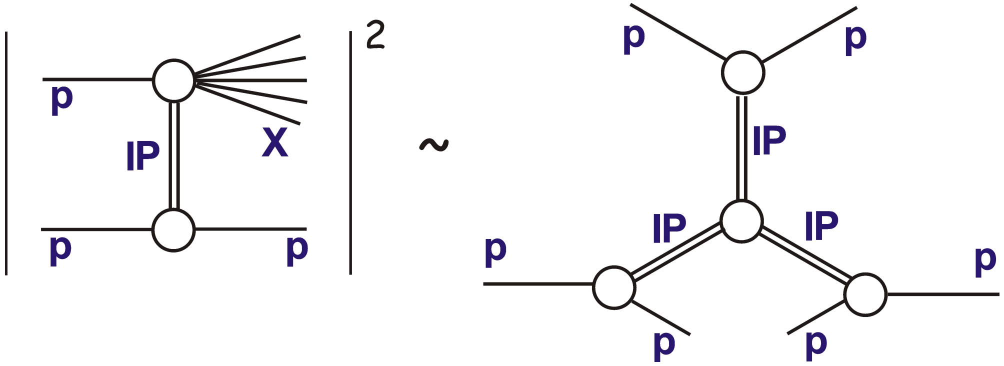


3) Calculate SD cross sections from triple pomeron amplitudes



[similar treatment for DD]

"Standard Model" of Soft Diffraction

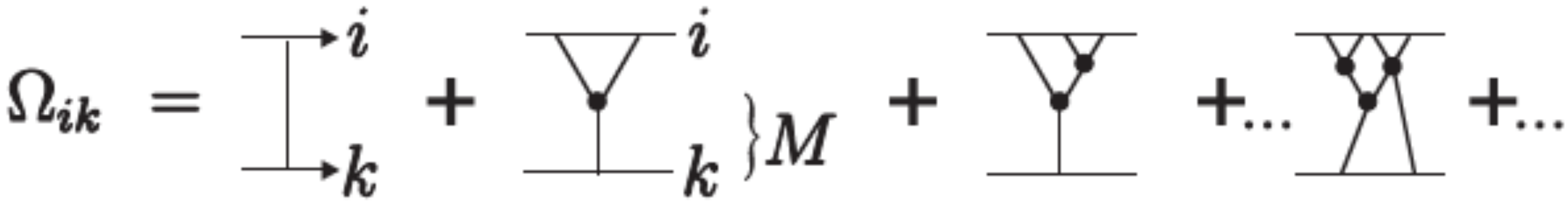


$$\frac{d\sigma}{d\xi\, dt} \propto \left(\frac{1}{\xi}\right)^{2\alpha(t)-\alpha(0)} e^{bt}$$

(fixed s) $\quad [\alpha(t) = \alpha(0) + \alpha' t]$

i.e $\quad \frac{d\sigma}{d\xi} \propto \frac{1}{\xi}$ to first approximation

Deviations from this behaviour sensitive to $\alpha_{IP}(t)$



... also sensitive to absorptive corrections (multiple soft exchanges in different configurations) e.g. Durham 3 channel eikonal analysis ...

Uncertainties in LHC Predictions

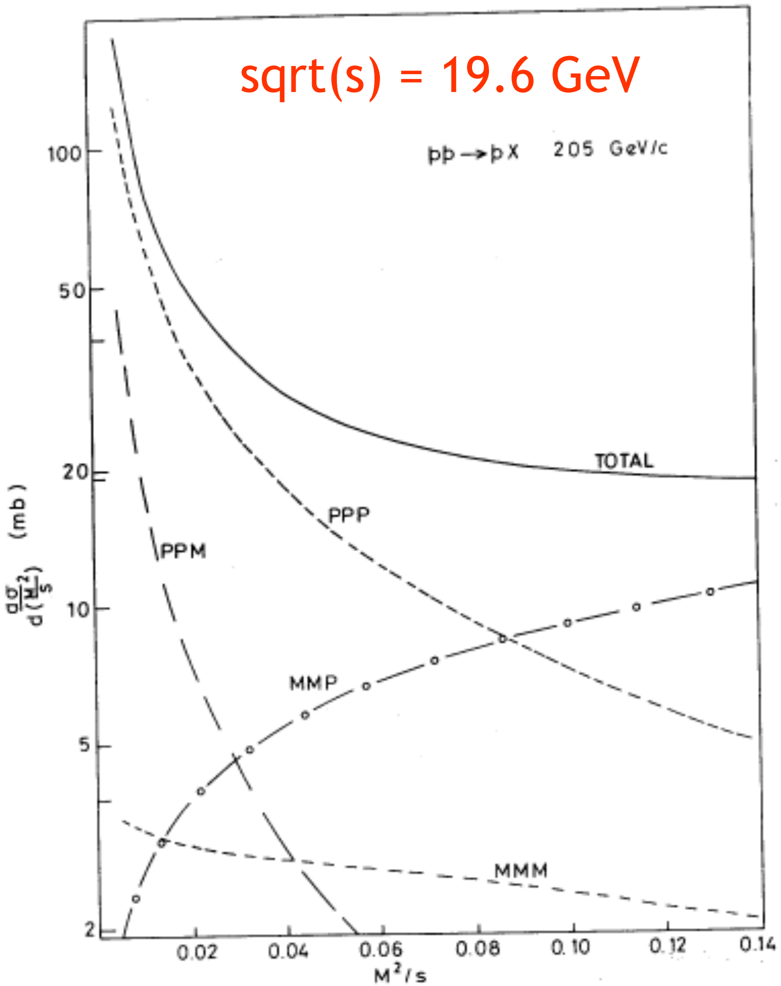
Single dissociation

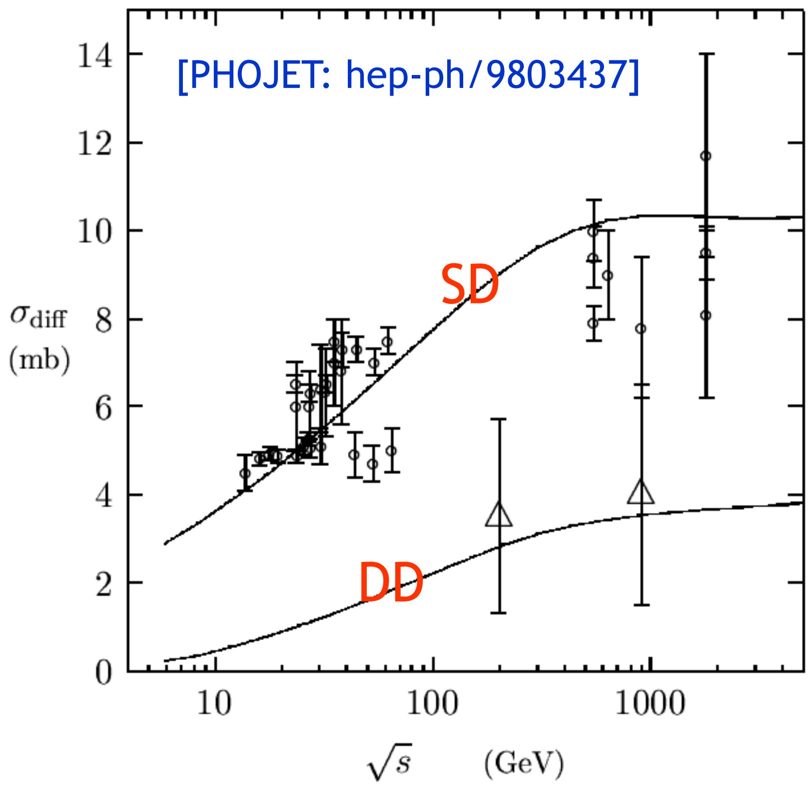
σ = 14mb (PYTHIA8)
σ = 10mb (PHOJET)

Double dissociation

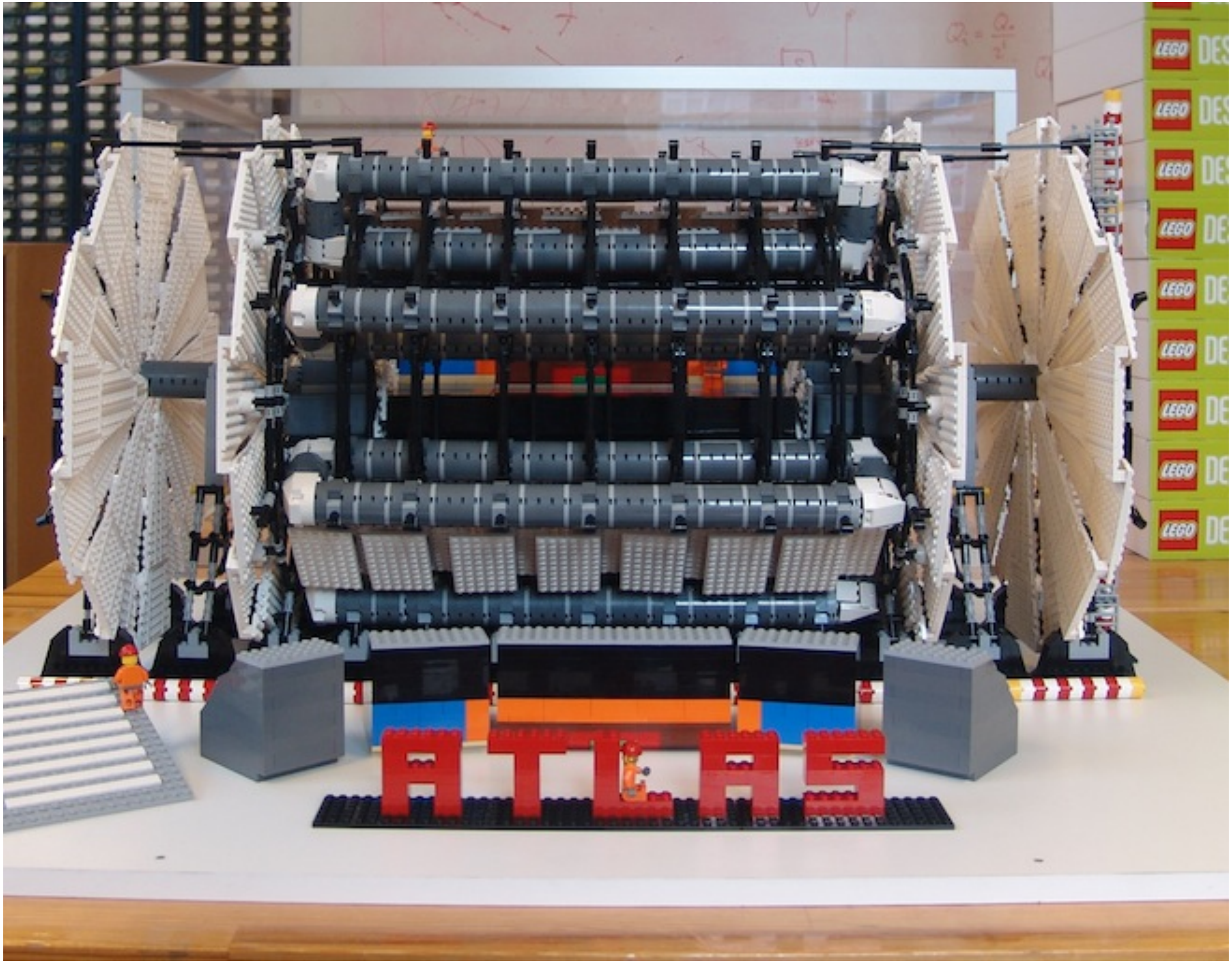
σ = 9mb (PYTHIA8)
σ = 4mb (PHOJET)

Parameterisations based on old low energy data, particularly poor for DD



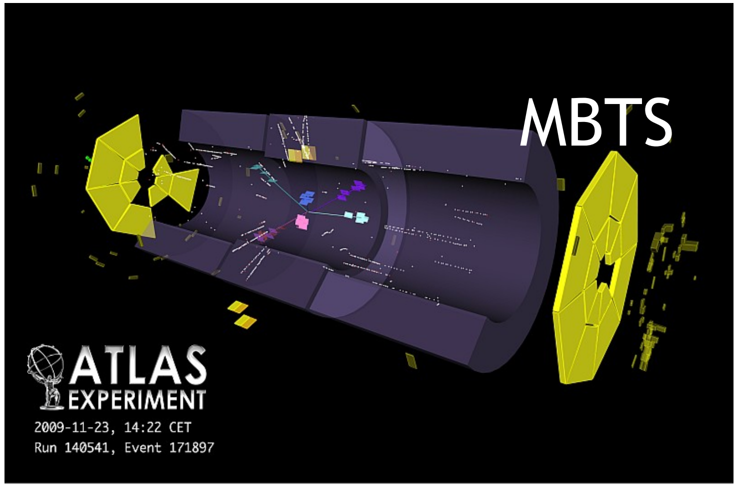


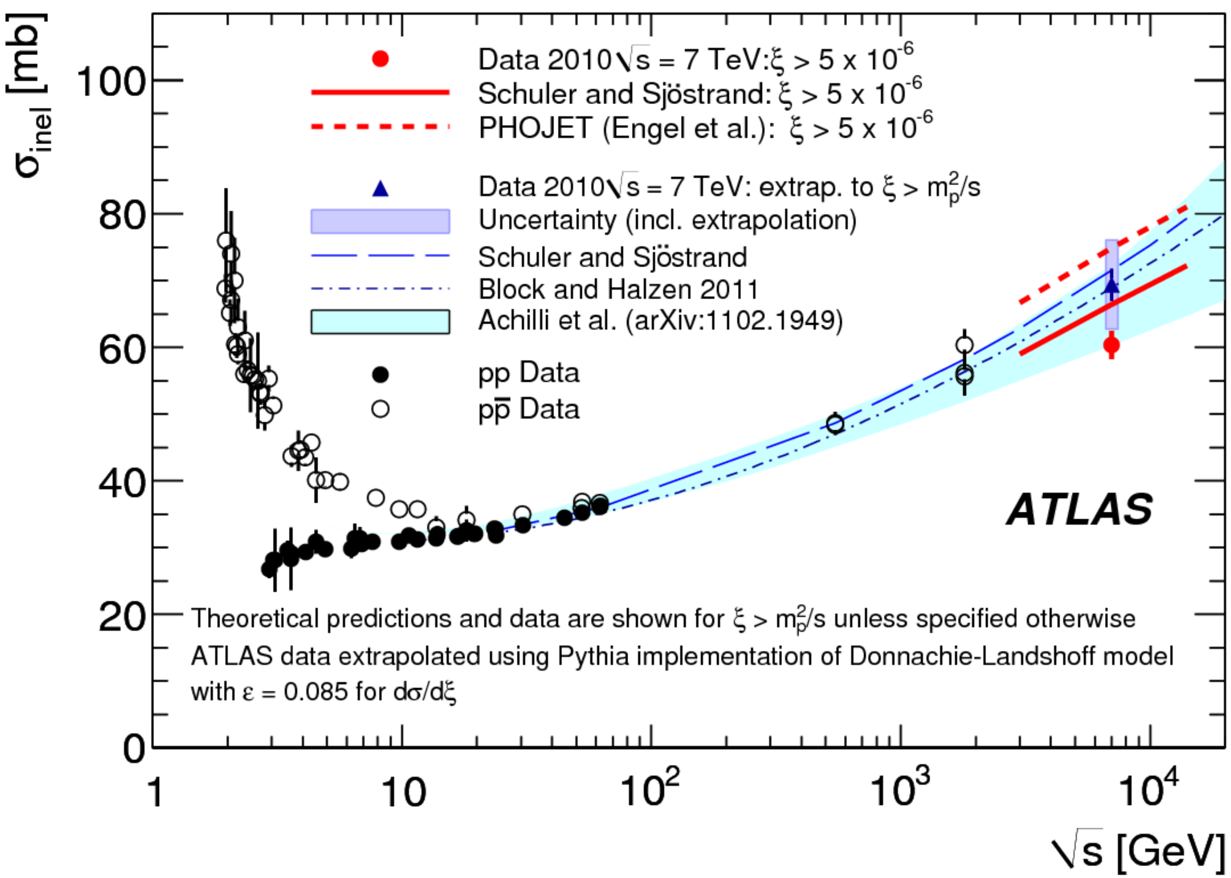
ATLAS Detector



Total Inelastic pp Cross Section

- Using MBTS trigger (2.1 < |η| < 3.8), miss only elastic (pp → pp) and low mass diffraction (pp → pX etc)





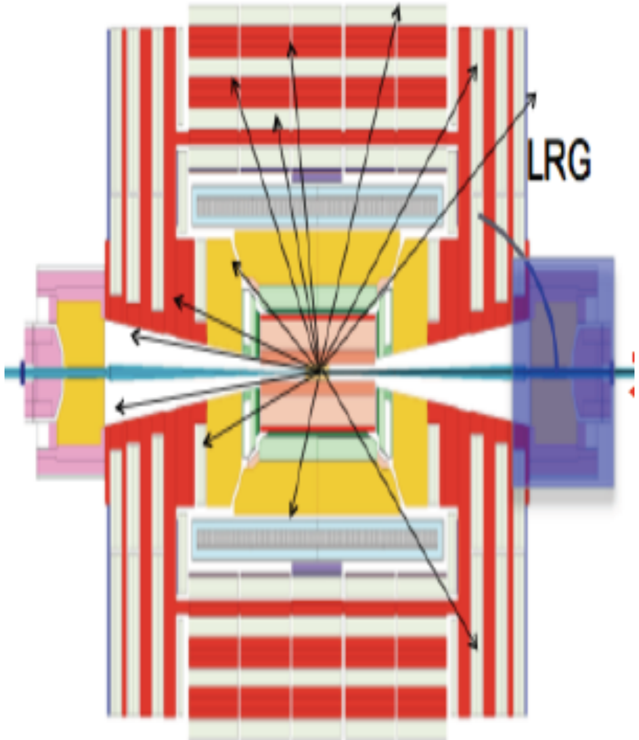
- Unextrapolated Result below PYTHIA and PHOJET

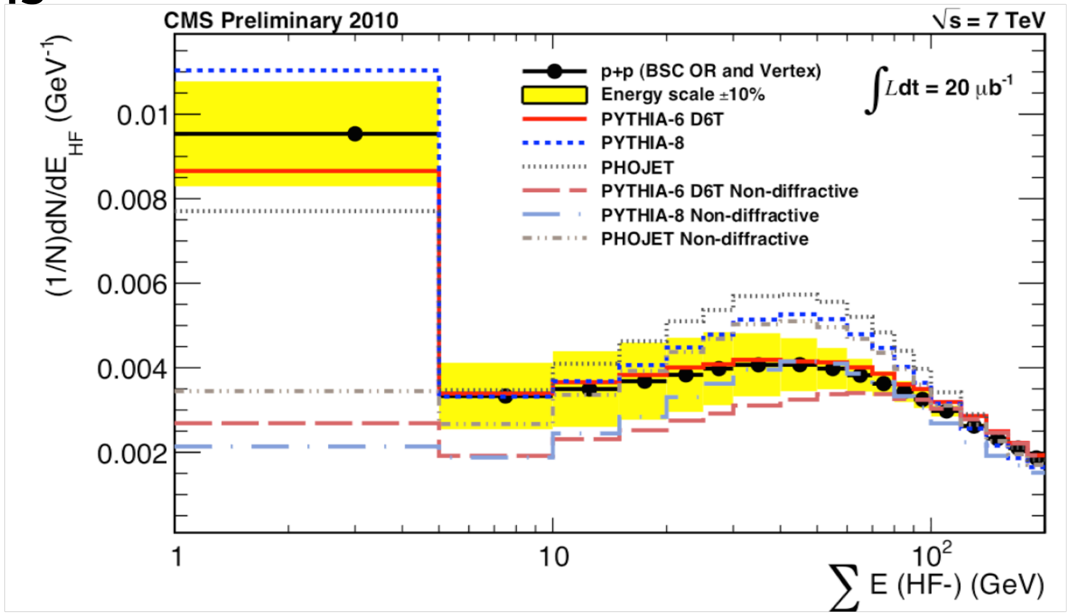
- 5-15% extrapolation yields total inelastic cross section

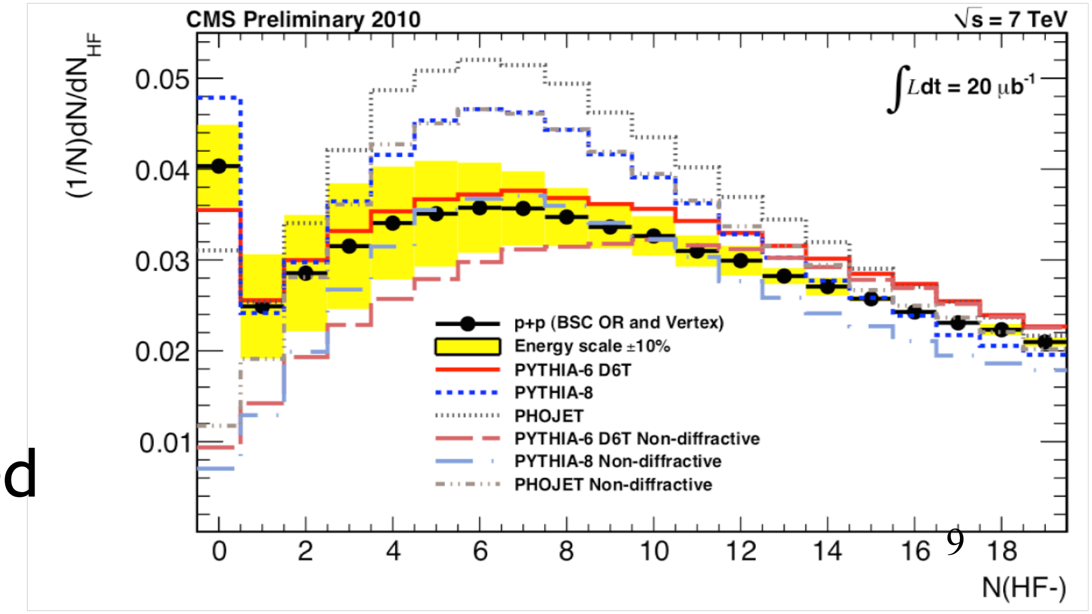
- Extrapolation includes large uncertainty on low ξ dissociation

CMS: First Direct LHC Dissoc^n Observation

Inclusive min-bias distributions of forward HCAL activity (2.9 < |η| < 5.2)

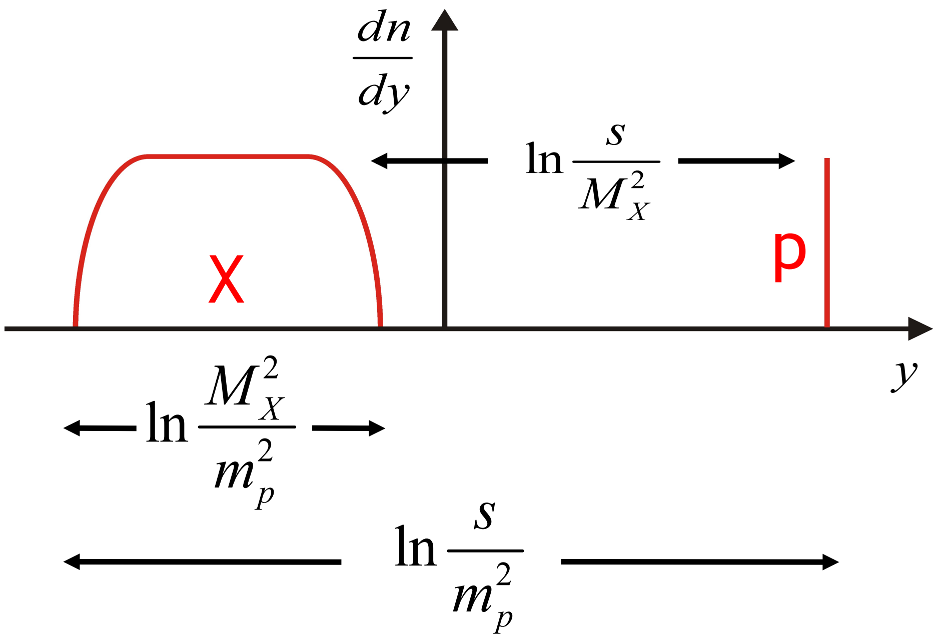






Excess of events with diffractive topology observed at all 3 LHC beam energies

Alternative Approach: Rapidity Gaps



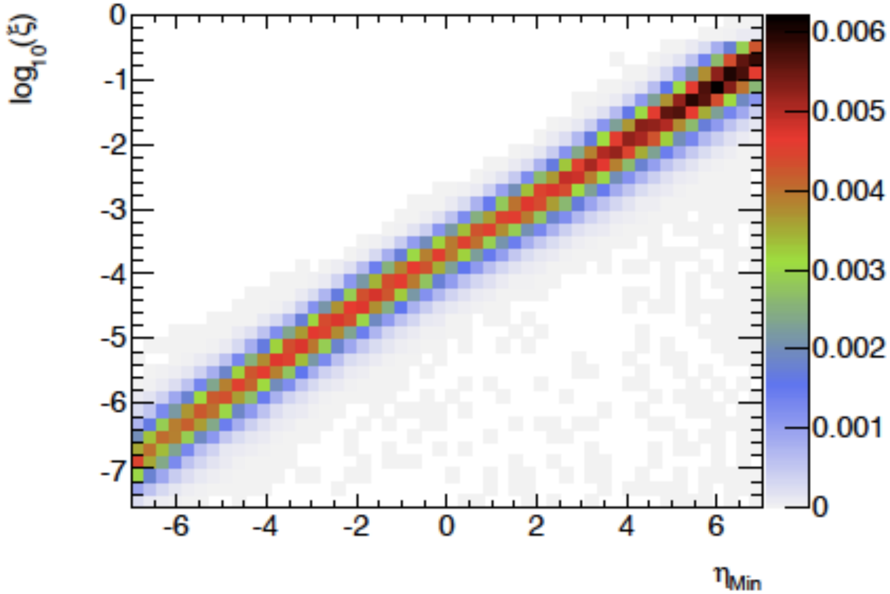
Up to event-by-event hadronisation fluctuations, ξ variables are predictable from empty rapidity regions

→Large rapidity gaps

$$\Delta\eta \approx -\ln\xi$$

and ~ flat gap distributions

$$\frac{d\sigma}{d\Delta\eta} \approx \text{const.}$$

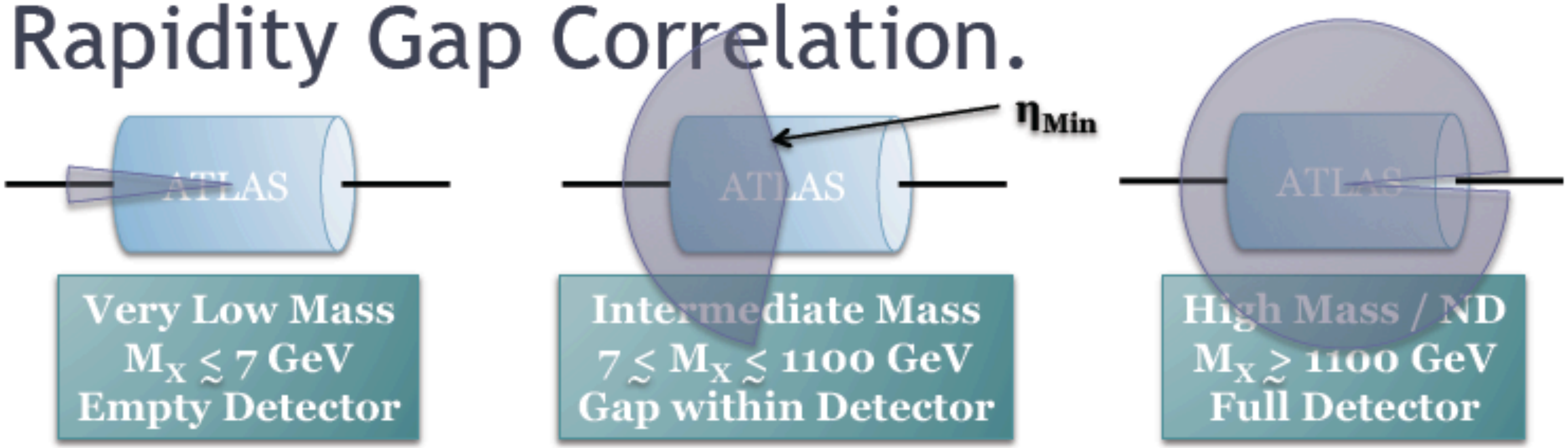


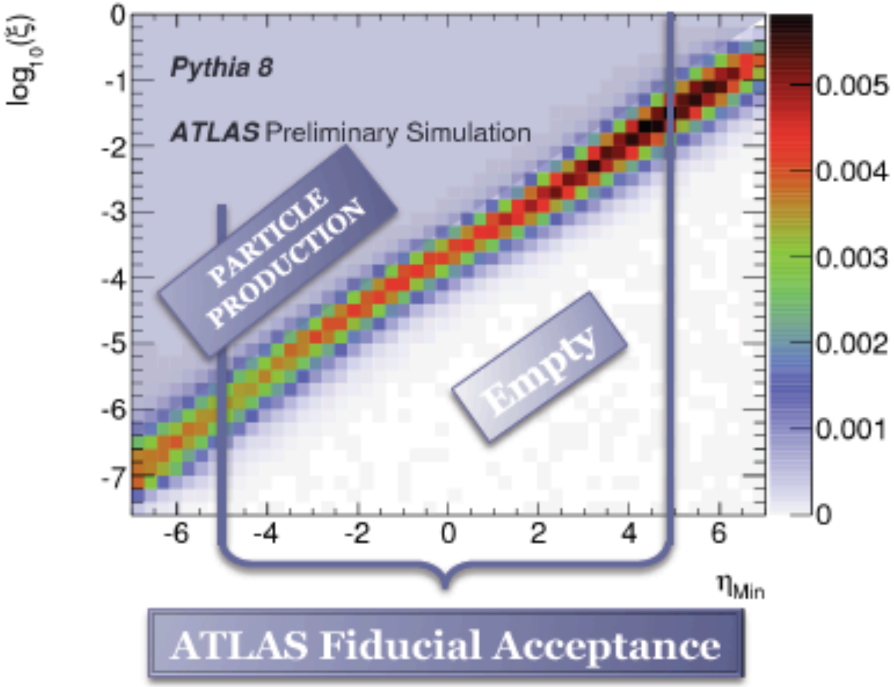
LHC coverage (|η| < 4.9) gives sensitivity with large gap to:

10^{-6} <~ ξ <~ 10^{-2}

(equivalently 7 <~ M_X <~ 700 GeV)

Rapidity Gap Correlation.

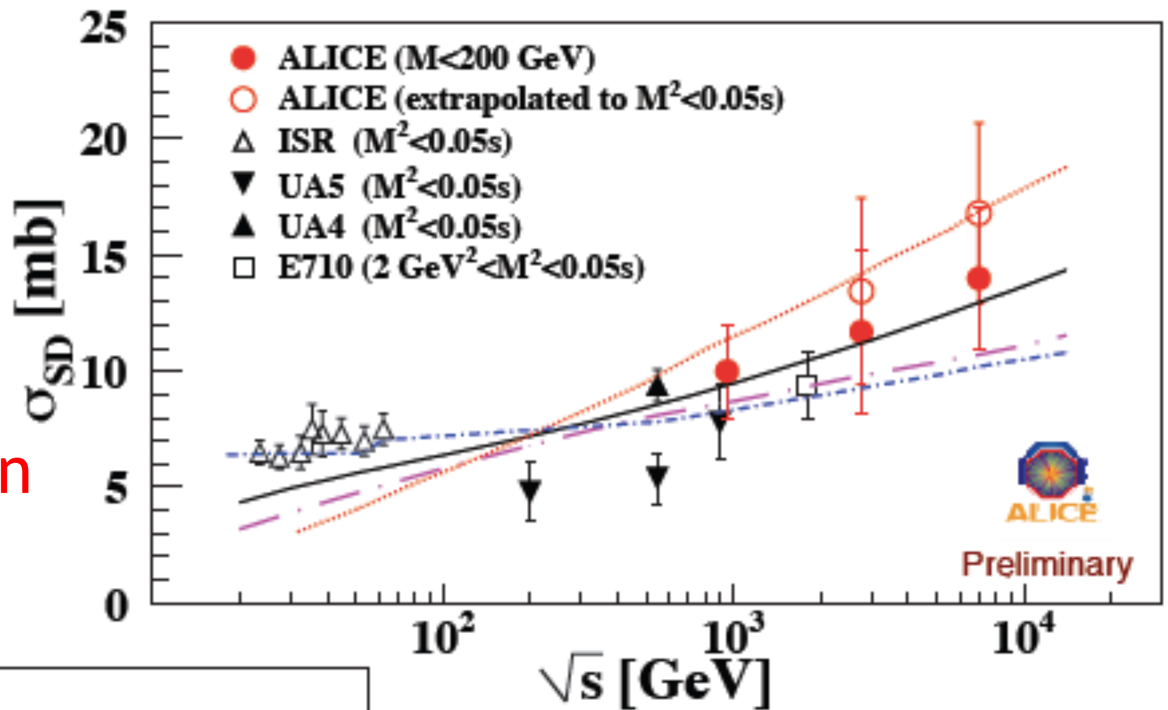


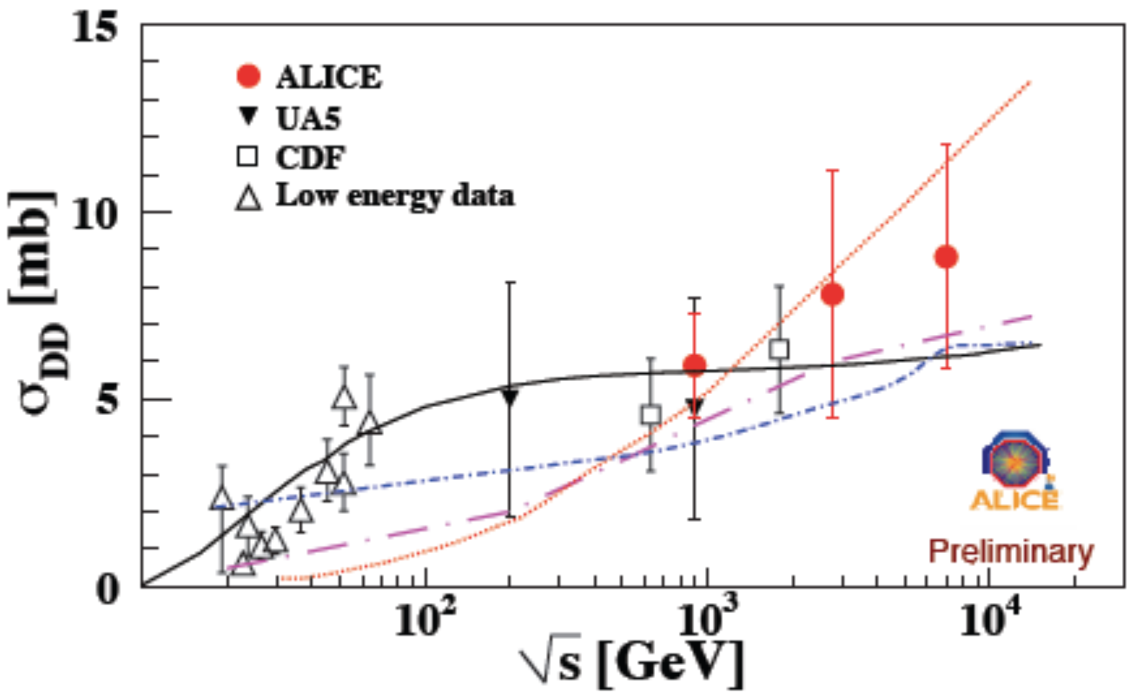


- Rapidity interval of final state kinematically linked to size of diffractive mass.
- Linear relation between η of edge of diffractive system and $\ln(M_X)$, smeared out slightly by hadronisation effects.

ALICE: Total SD and DD Cross Sections

ALICE: Unfold integrated SD and DD cross sections at all three CMS energies based on gap rates and topologies.
[implies some extrapolation Into lowest ξ regions]



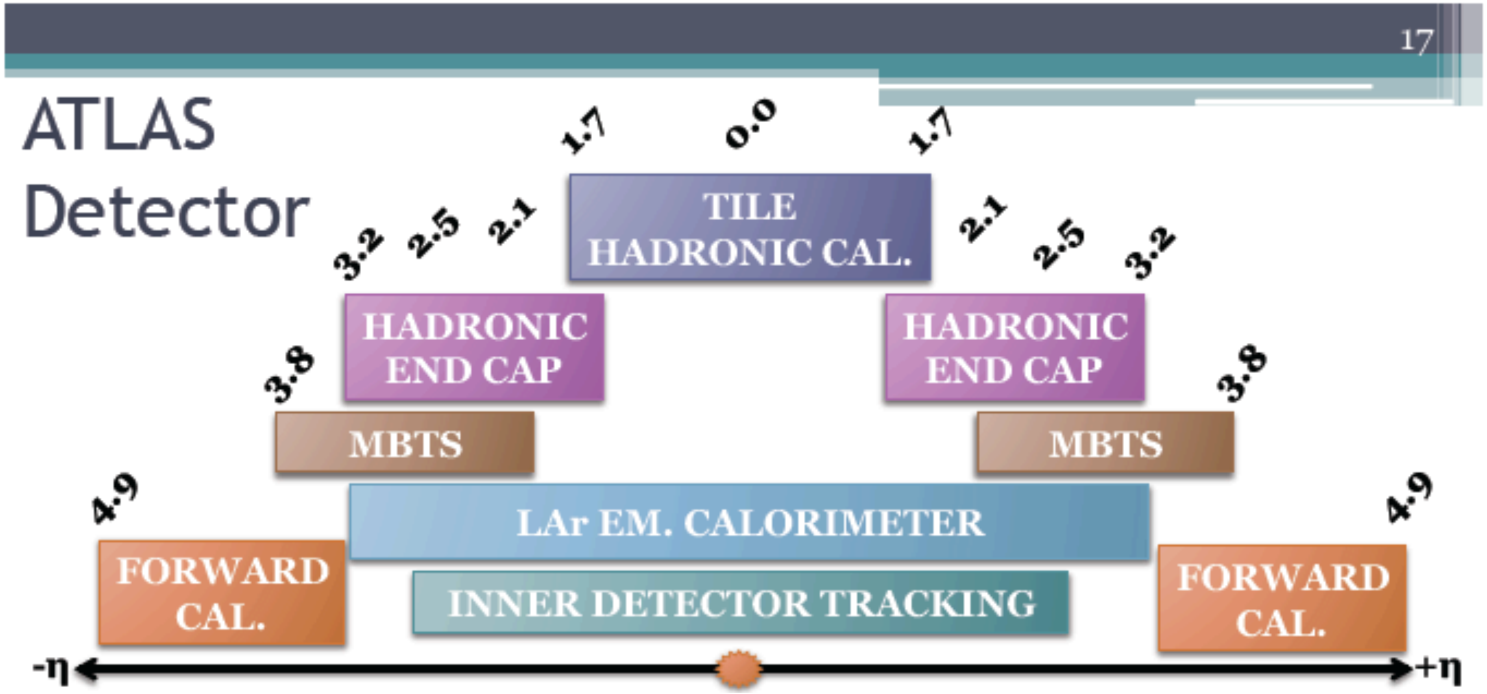


σ(SD) with ξ < 0.05

σ(DD) with gap Δη > 3

Good agreement with SPS data and wide range of model predictions

ATLAS Acceptance



Rapidity gaps identified using full range of calorimetry ($|\eta| < 4.9$) and inner tracking detector ($|\eta| < 2.5$)

Detector is sensitive to particle production with $p_T > 200$ MeV … Measurements defined by this requirement

Higher p_T cuts also applied to investigate dependence

ATLAS Measurement

Uses only the first ever physics run at $\sqrt{s} = 7$ TeV.

30th March 2010, from 13.24 to 16.38

7 minutes shorter than `Lord of the Rings: Return of the King'

Pile-up occurs in less than 1 event in 1000

Integrated luminosity of 7.1 μb^{-1}

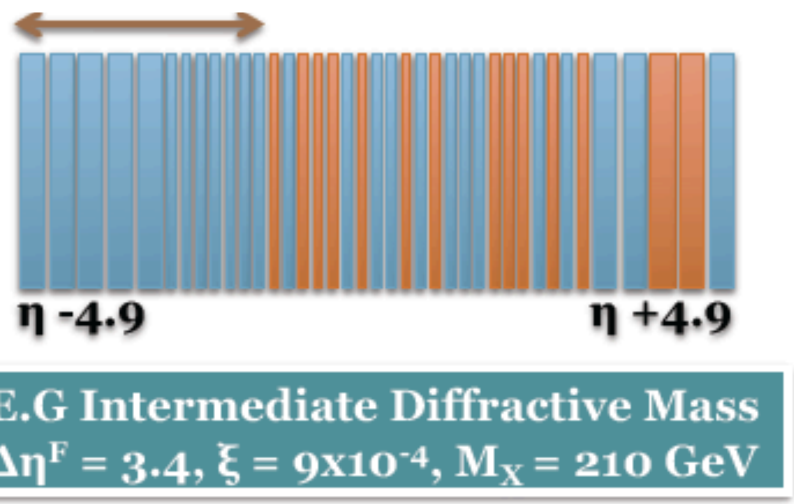
Peak instantaneous luminosity of 1.1 x 10^{27} cm^{-2} s^{-1} ☺

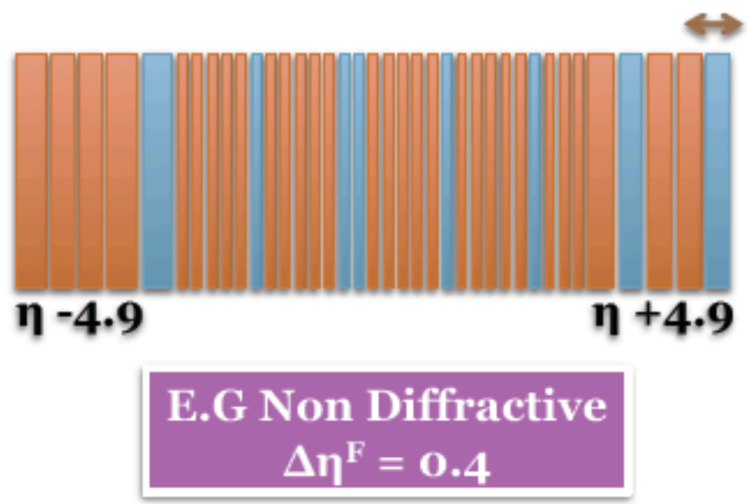
Gap Finding Algorithm / Observable

Divide detector into rings of width usually $\Delta\eta$ = 0.2

Decide whether there are particles with pT above threshold (usually 200 MeV) in each ring

Define $\Delta\eta^F$ = larger continuous run of empty rings extending to limit of acceptance in forward or backward direction





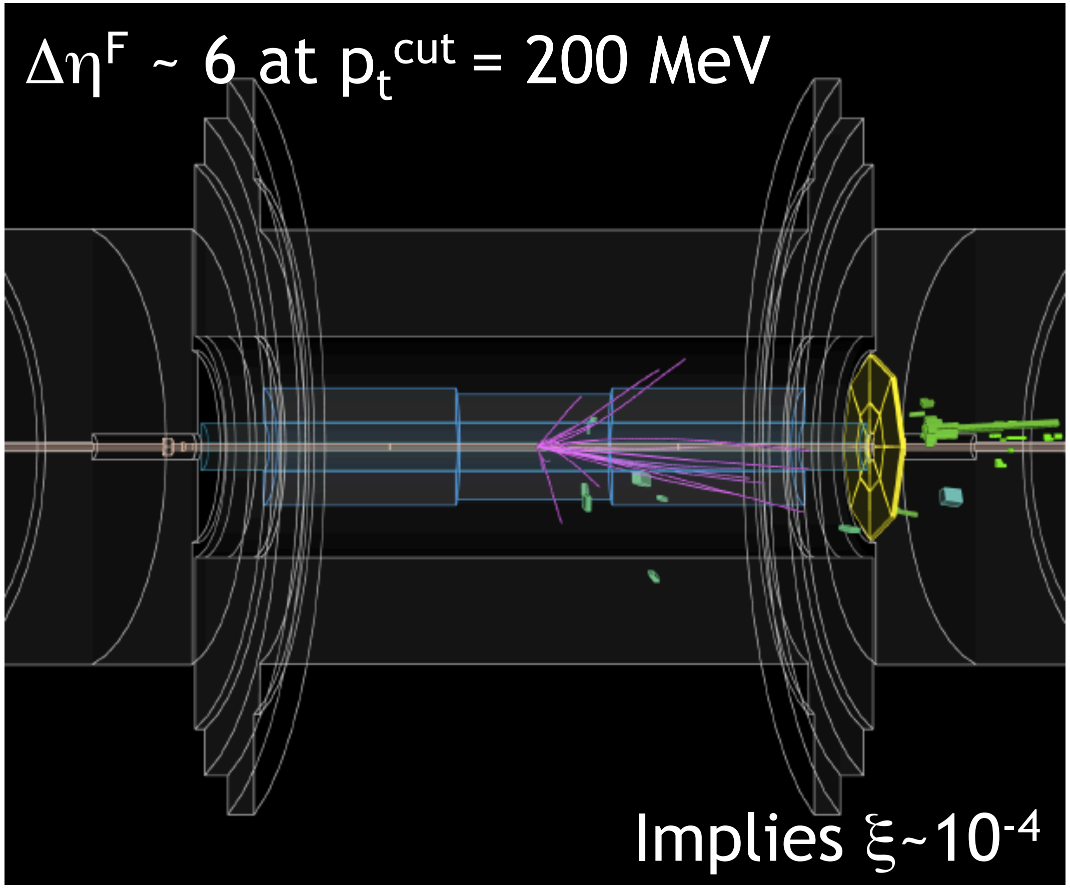
ATLAS: Differential gap cross-sections

- Cross sections measured from first $\sqrt{s}$ = 7 TeV LHC run
- Differential in rapidity gap size $\Delta\eta^F$
- $\Delta\eta^F$ extends from $\eta = \pm 4.9$ to first particle with $p_t > p_t^{cut}$

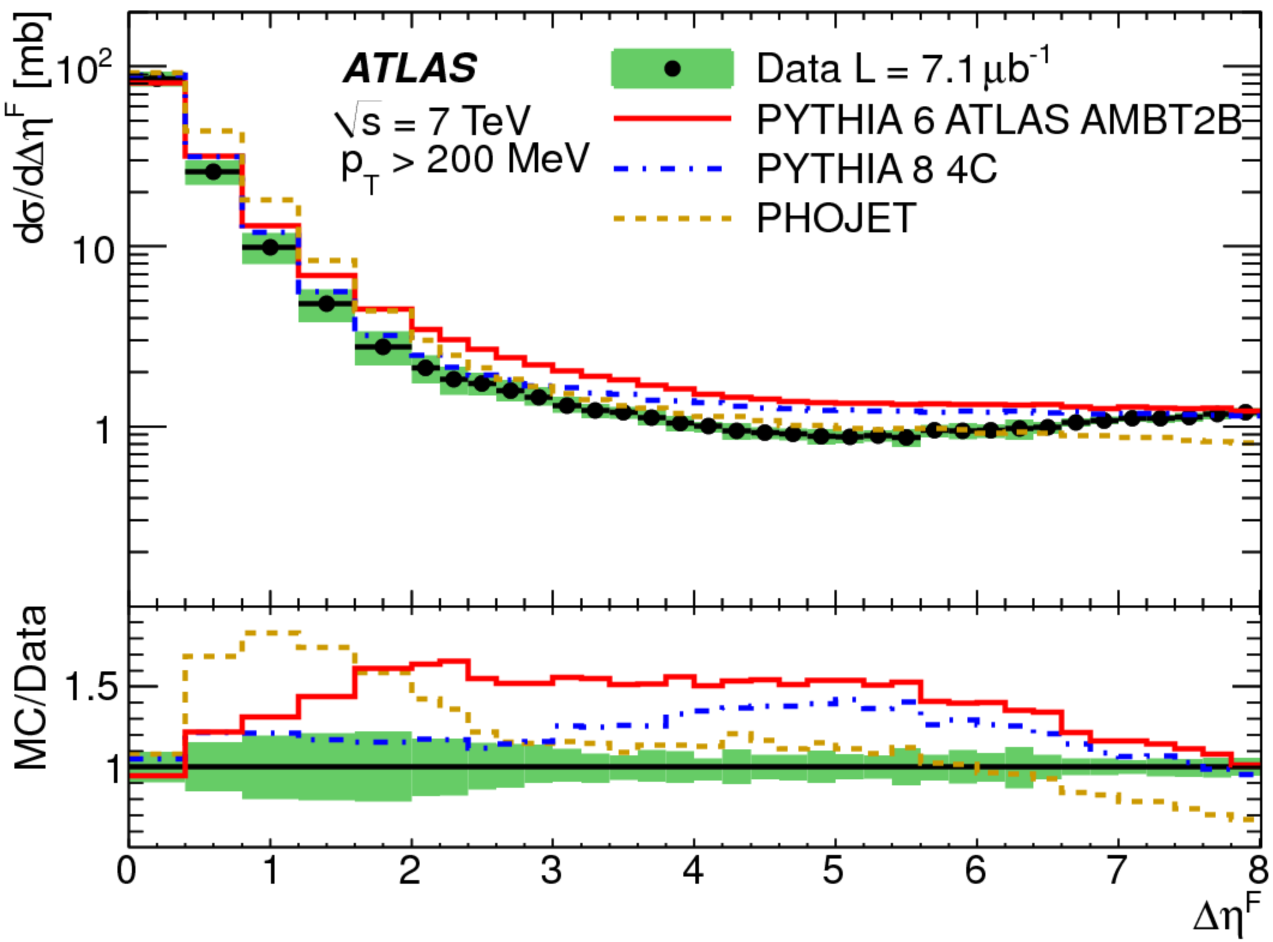
$200\ \text{MeV} < p_t^{cut} < 800\ \text{MeV}$

$0 < \Delta\eta^F < 8$

Corrected for experimental effects to level of stable hadrons



ATLAS Differential Gap Cross Section



- Precision between ~8% (large gaps) and ~20% ($\Delta\eta^F$ ~ 1.5)
- Small gaps sensitive to hadronisation fluctuations / MPI
- Large gaps measure x-sec for SD [+ DD with M_Y <~ 7 GeV]

Small Gaps & Hadronisation Fluctuations

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THE EUROPEAN PHYSICAL JOURNAL C

Regular Article - Theoretical Physics

Diffraction and correlations at the LHC: definitions and observables

V.A. Khoze[1,a], F. Krauss[1], A.D. Martin[1], M.G. Ryskin[1,2], K.C. Zapp[1,b]
[1]Institute for Particle Physics Phenomenology, University of Durham, Durham, DH1 3LE, UK
[2]Petersburg Nuclear Physics Institute, Gatchina, St. Petersburg 188300, Russia

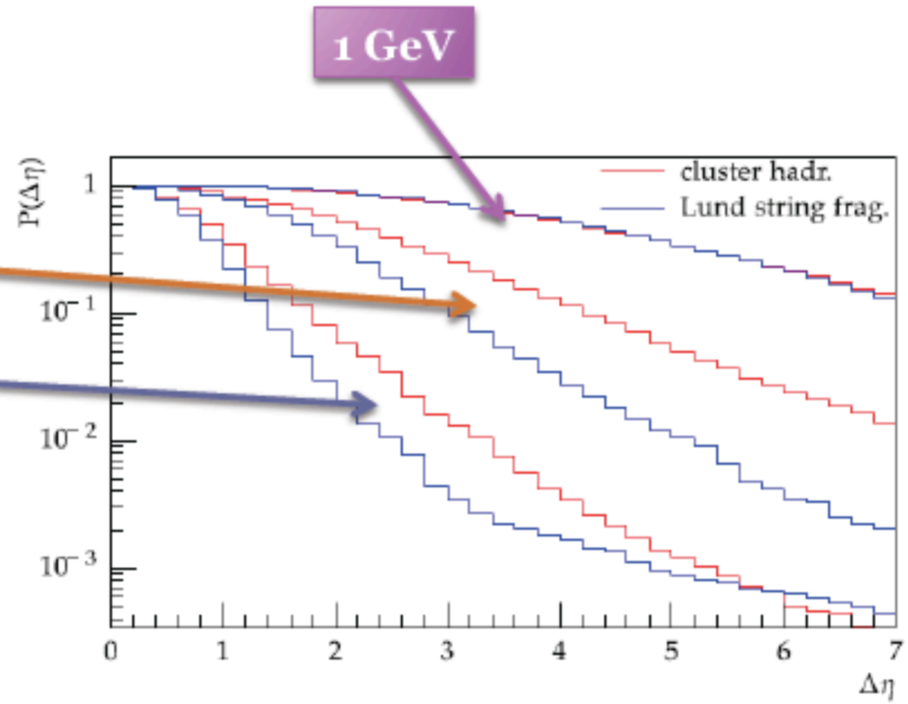
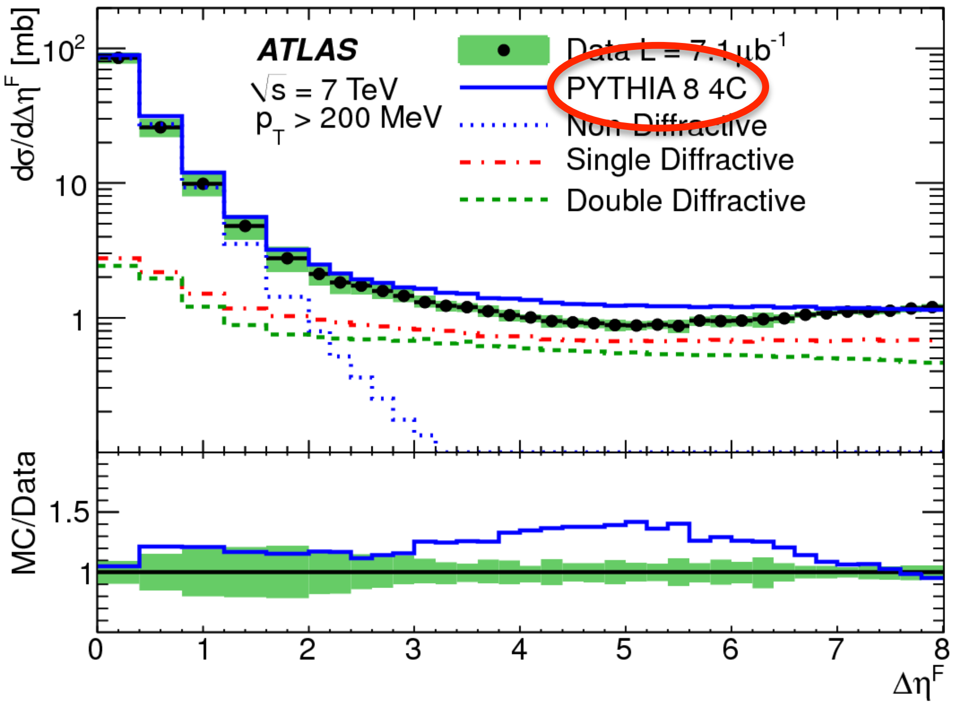


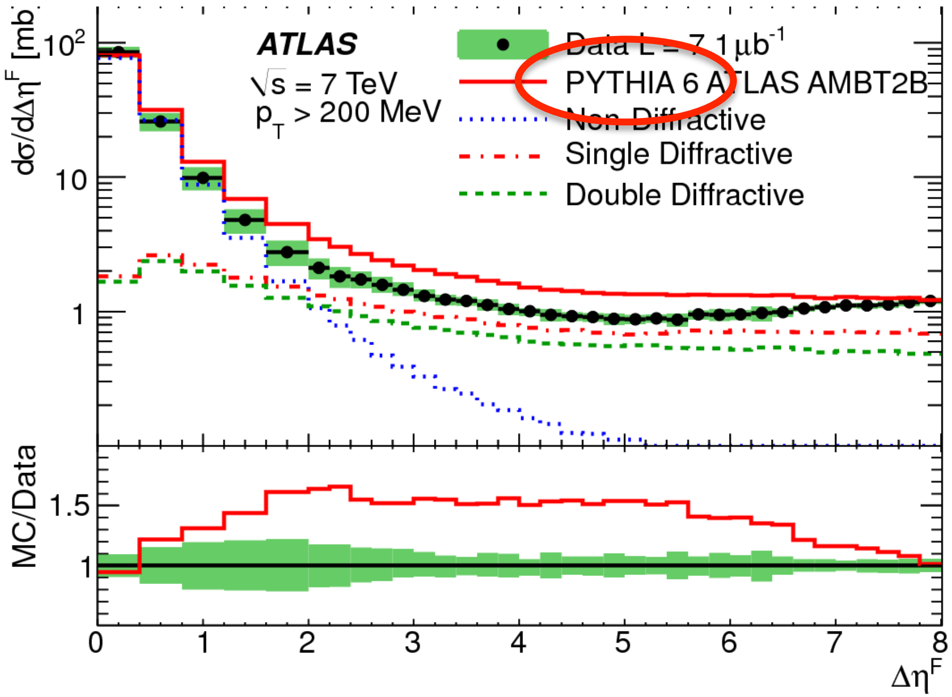
Fig. 4 Probability for finding a rapidity gap (definition 'all') larger than $\Delta\eta$ in an inclusive QCD event for different threshold $p_\perp$. From top to bottom the thresholds are $p_{\perp,\text{cut}} = 1.0, 0.5, 0.1$ GeV. Note that the lines for cluster and string hadronisation lie on top of each other for $p_{\perp,\text{cut}} = 1.0$ GeV. No trigger condition was required, $\sqrt{s} = 7$ TeV

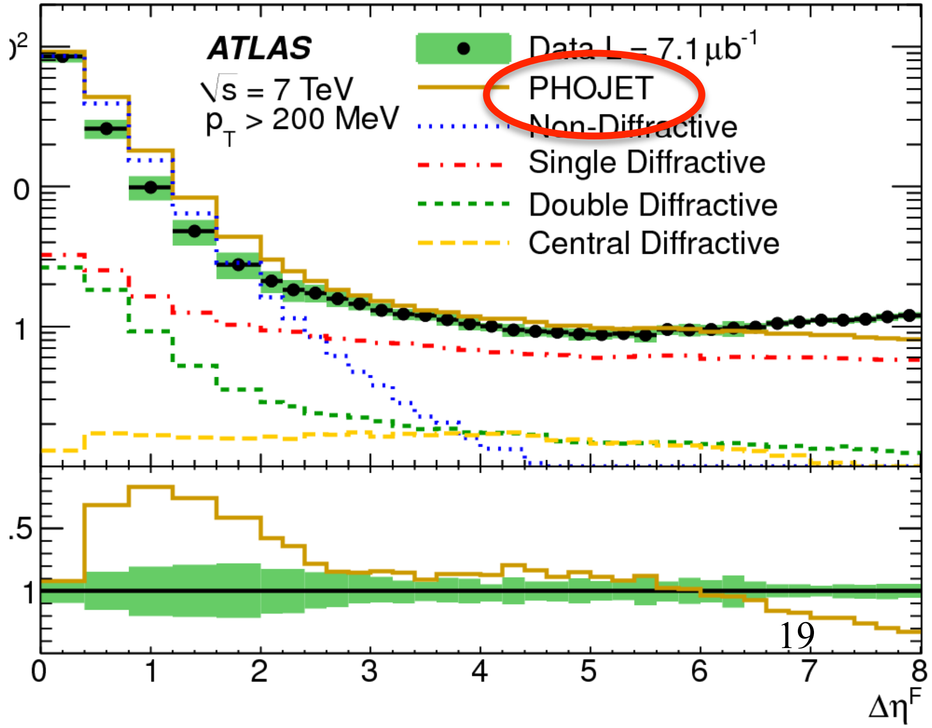
Very large uncertainties in probability for hadronisation fluctuations in non-diffractive events to produce large gaps

Small Gaps and Hadronisation

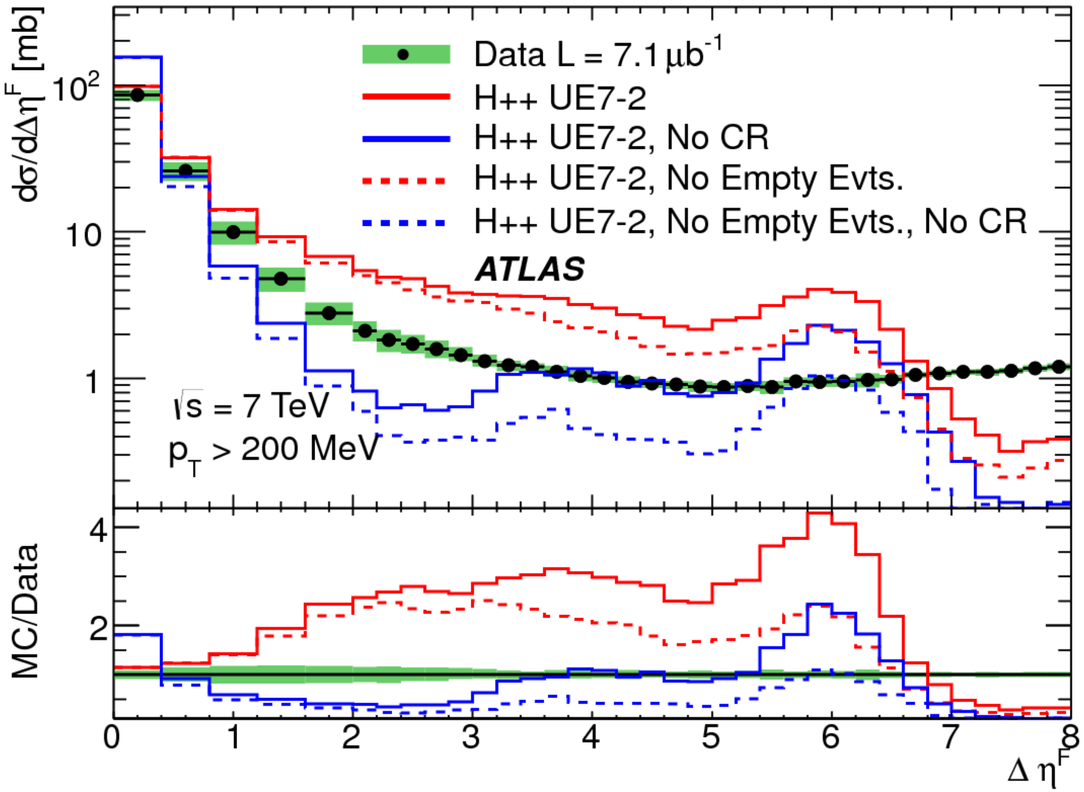


- Big variation between MCs in small non-zero gap production via ND → fluctuations / UE
- PYTHIA8 best at small gaps
- PHOJET > 50% high at $\Delta\eta^F \sim 1.5$





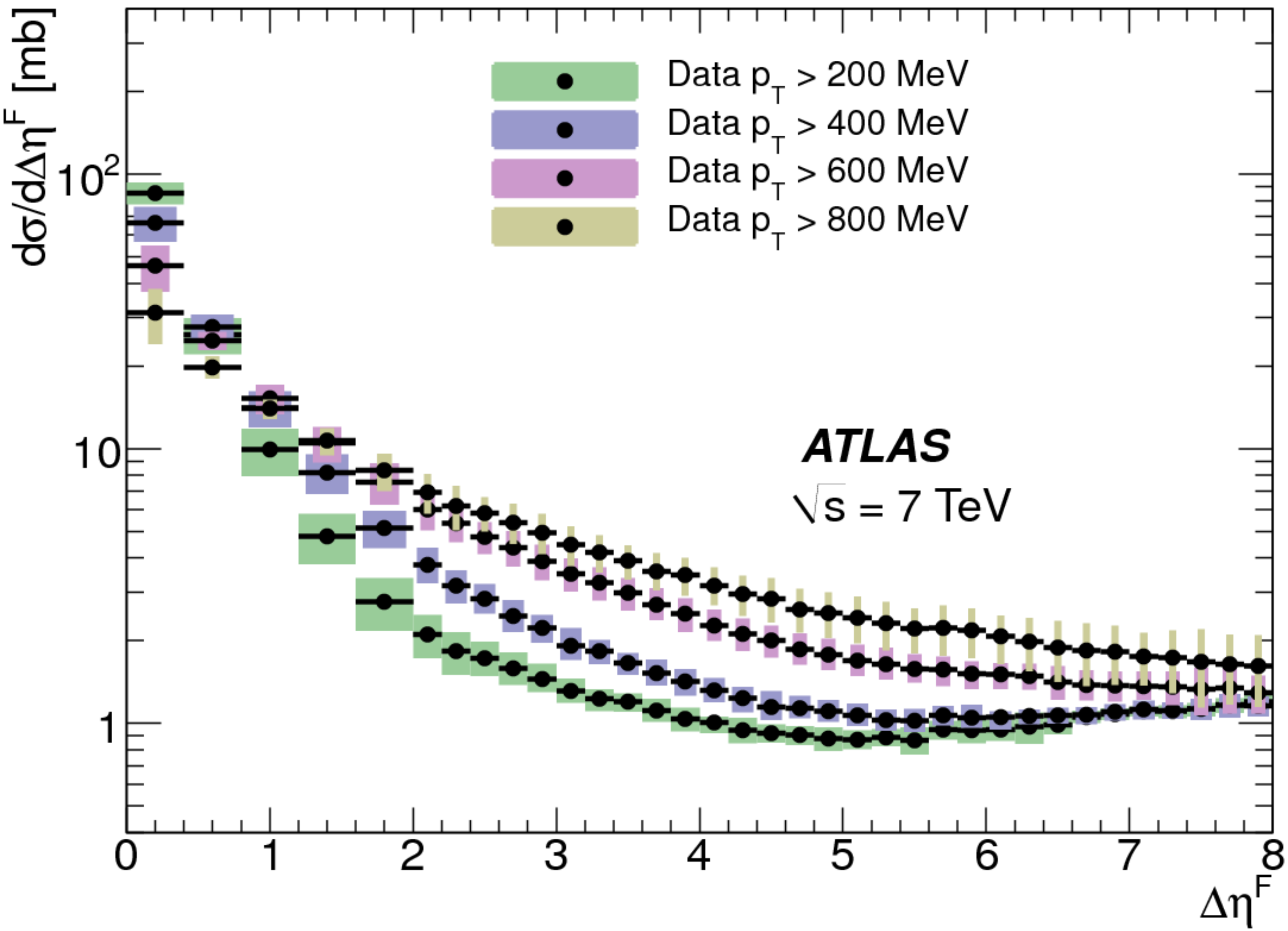
Cluster Fragmentation: HERWIG++



- HERWIG++ with underlying event tune UE7-2 contains no explicit model of diffraction, but produces large gaps at higher than measured rate and a "bump" near $\Delta\eta^F = 6$

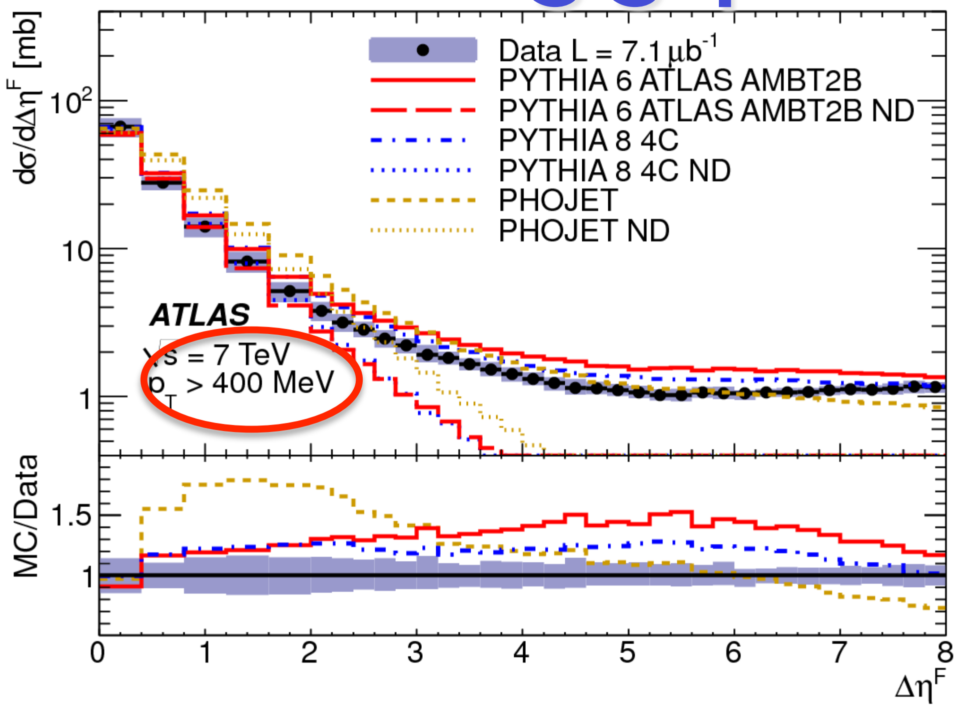
- Effect not killed by removing colour reconnection or events with zero soft or semi-hard scatters in eikonal model

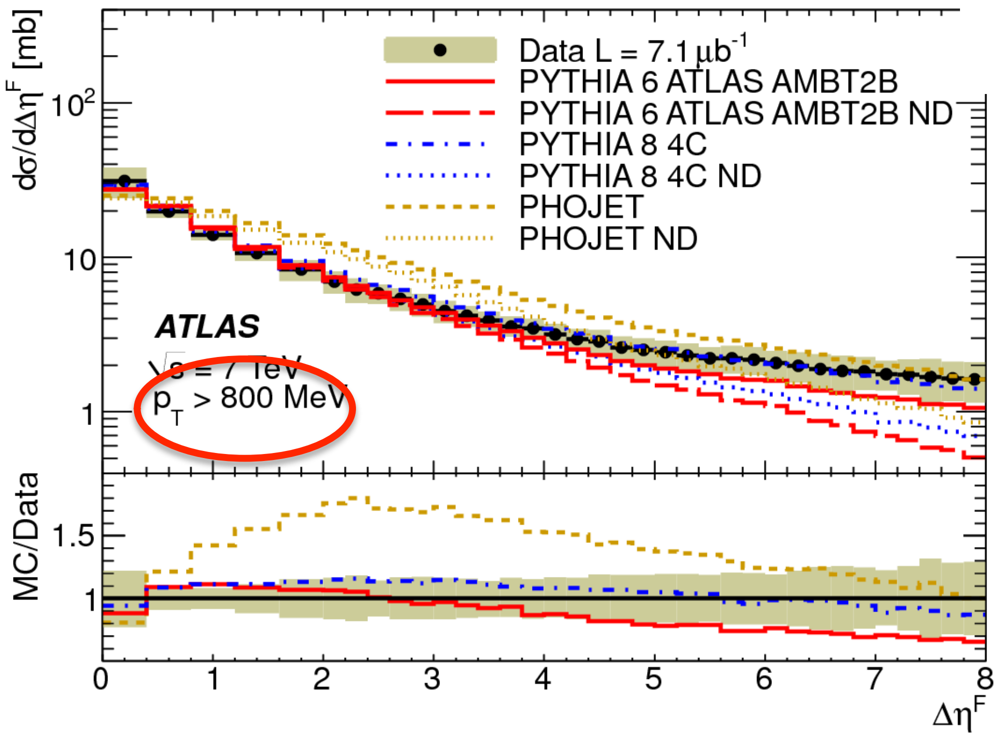
Increasing the pt cut defining gaps



Increasing the pt cut defining gaps

As p_t^{cut} increases, data shift to larger $\Delta\eta^F$ in a manner sensitive to hadronisation fluctuations and underlying event





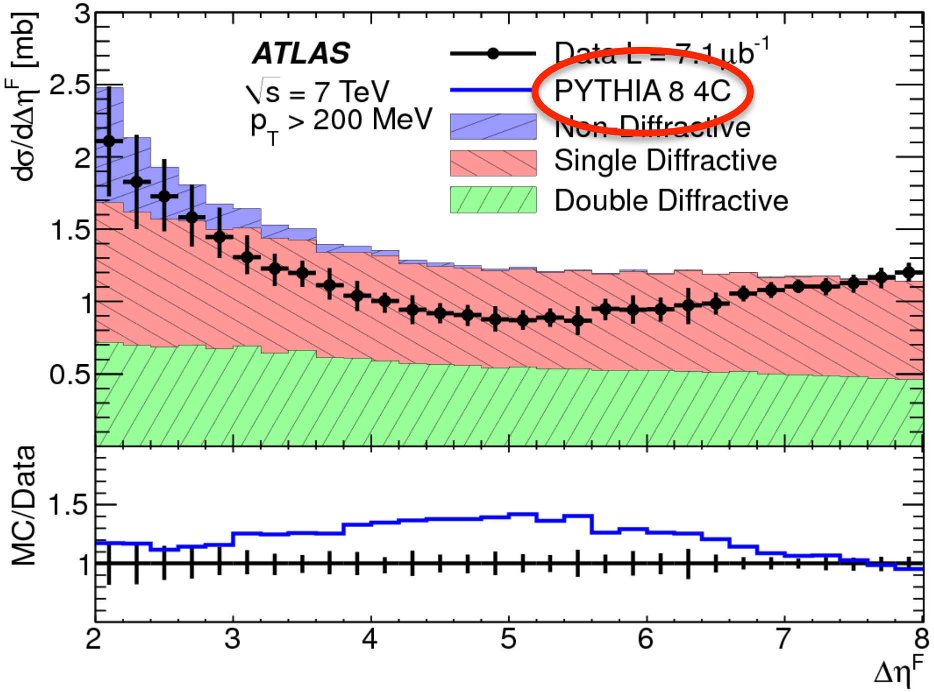
- Switching to p_t^{cut} = 400 MeV doesn't change qualitative picture

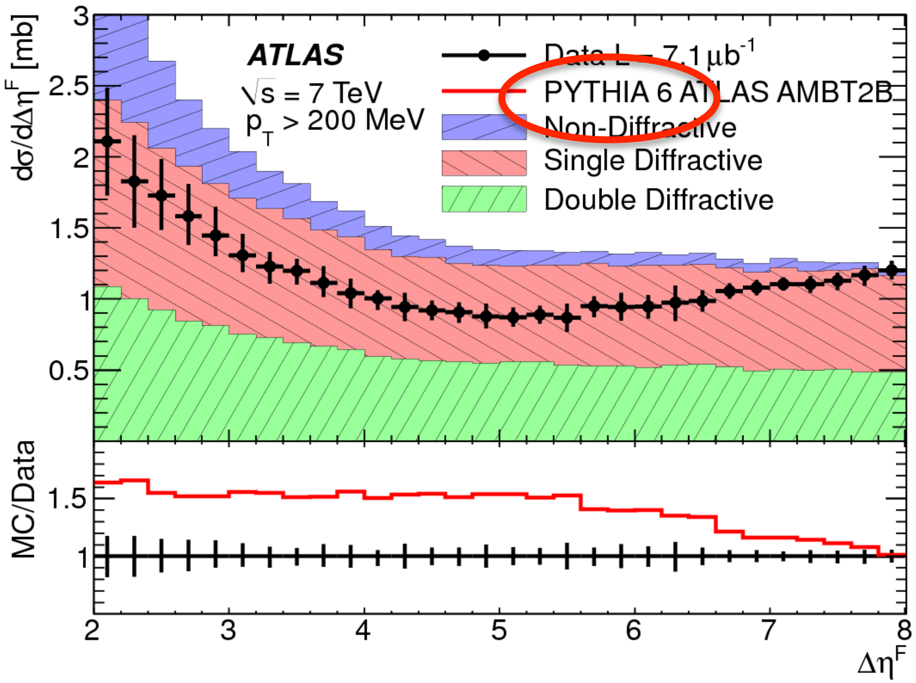
- Diffractive / non-diffractive processes barely distinguished at p_t^{cut} = 800 MeV

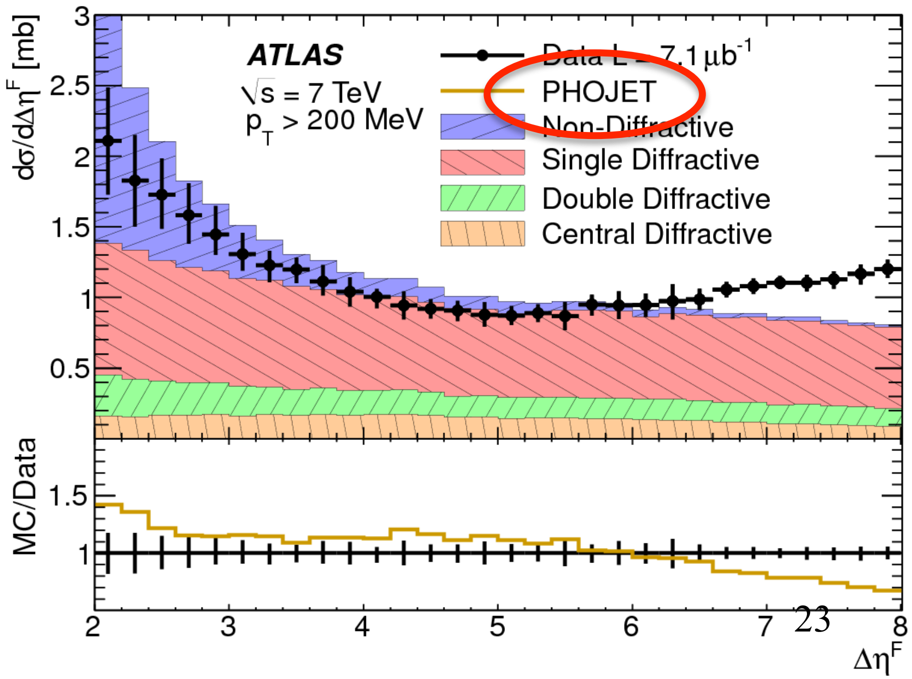
Large Gaps and Diffractive Dynamics

-Diffractive plateau with ~ 1 mb per unit of gap size for $\Delta\eta^F > 3$ broadly described by models

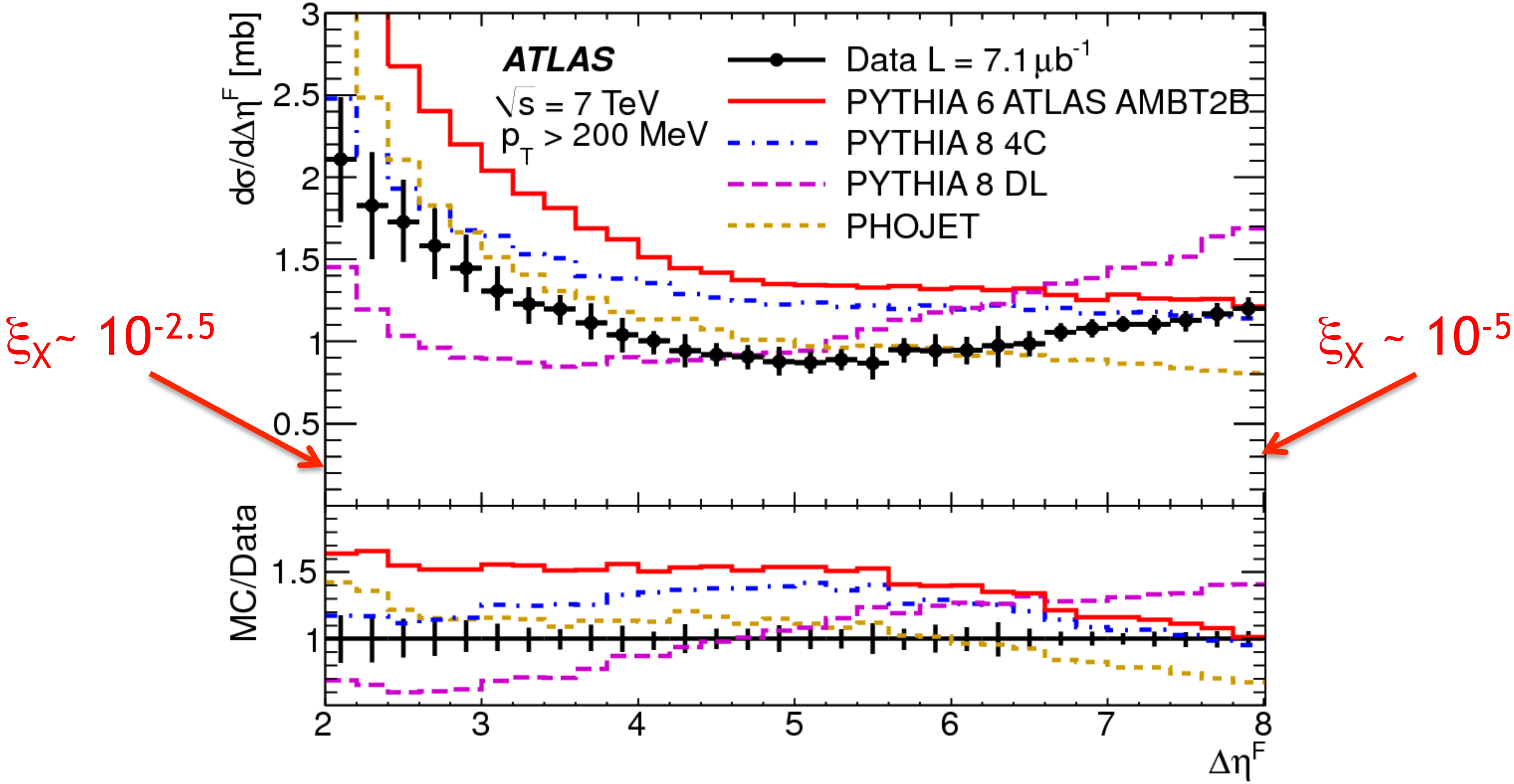
- PYTHIA high (DD much larger than in PHOJET)
- PHOJET low at high $\Delta\eta^F$







Large Gaps and Diffractive Dynamics



Default PHOJET and PYTHIA models have $\alpha_{IP}(0) = 1$

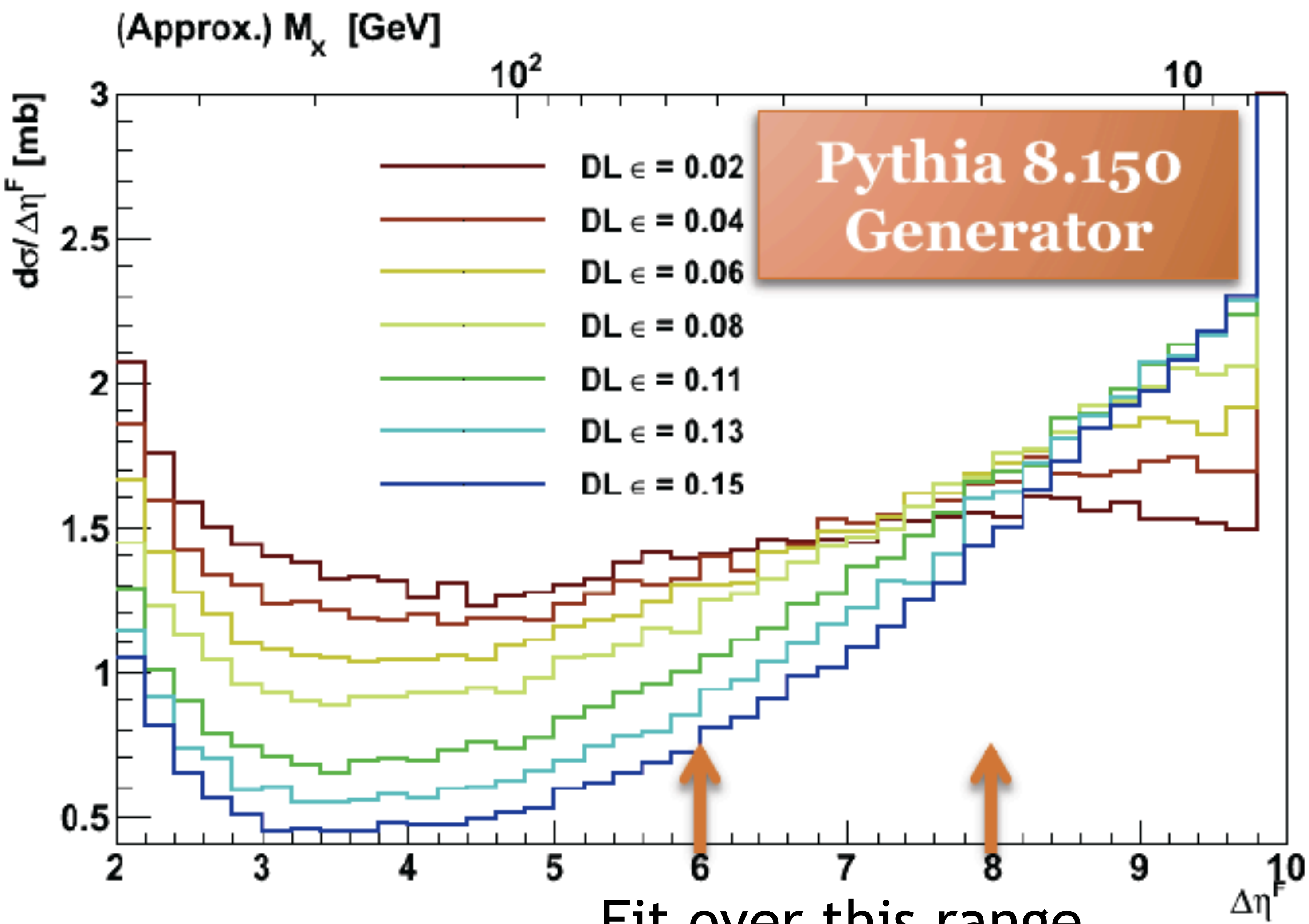
Donnachie-Landshoff flux has $\alpha_{IP}(0) = 1.085$

Data exhibit slope in between these models at large $\Delta\eta^F_{24}$

[No absorptive corrections in either case]

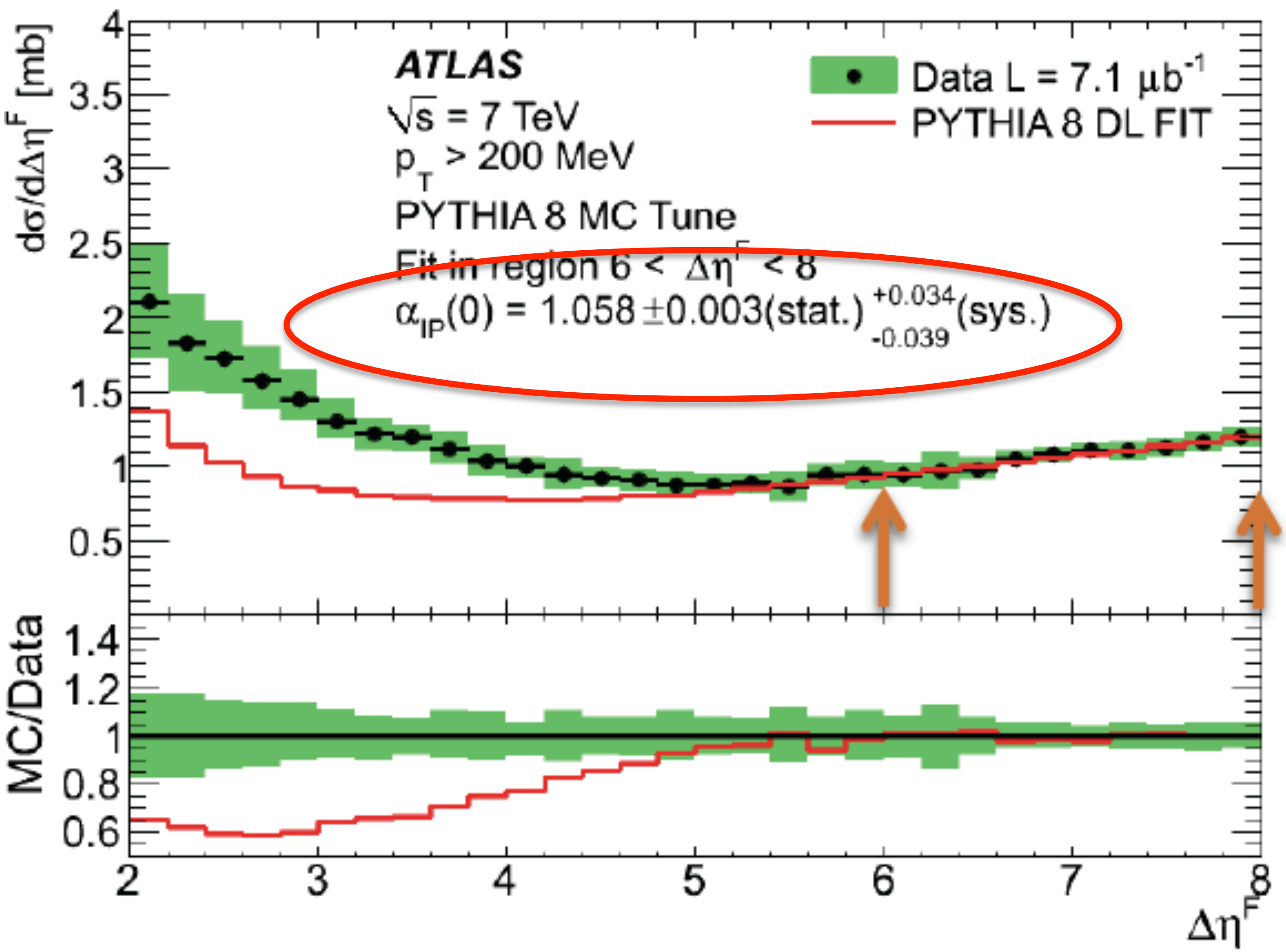
Sensitivity to Pomeron Intercept

Extract $\alpha_{IP}(0) = 1 + \varepsilon$ by optimising description by PYTHIA8 as ε varies in a region where ND contributions are negligible



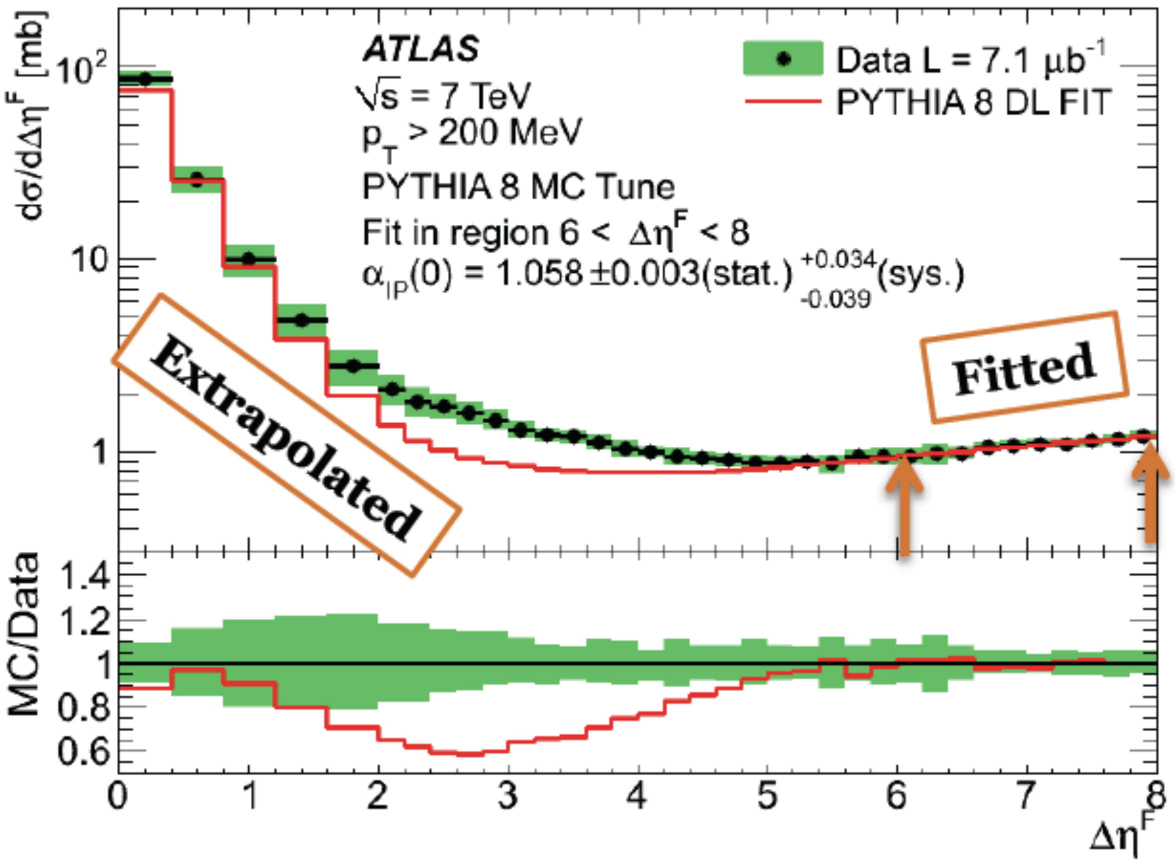
Fit over this range

Pomeron Intercept in Simple Pole Model



Uncertainty heavily dominated (factor 10) by model dependence of hadronisation in correcting to truth level

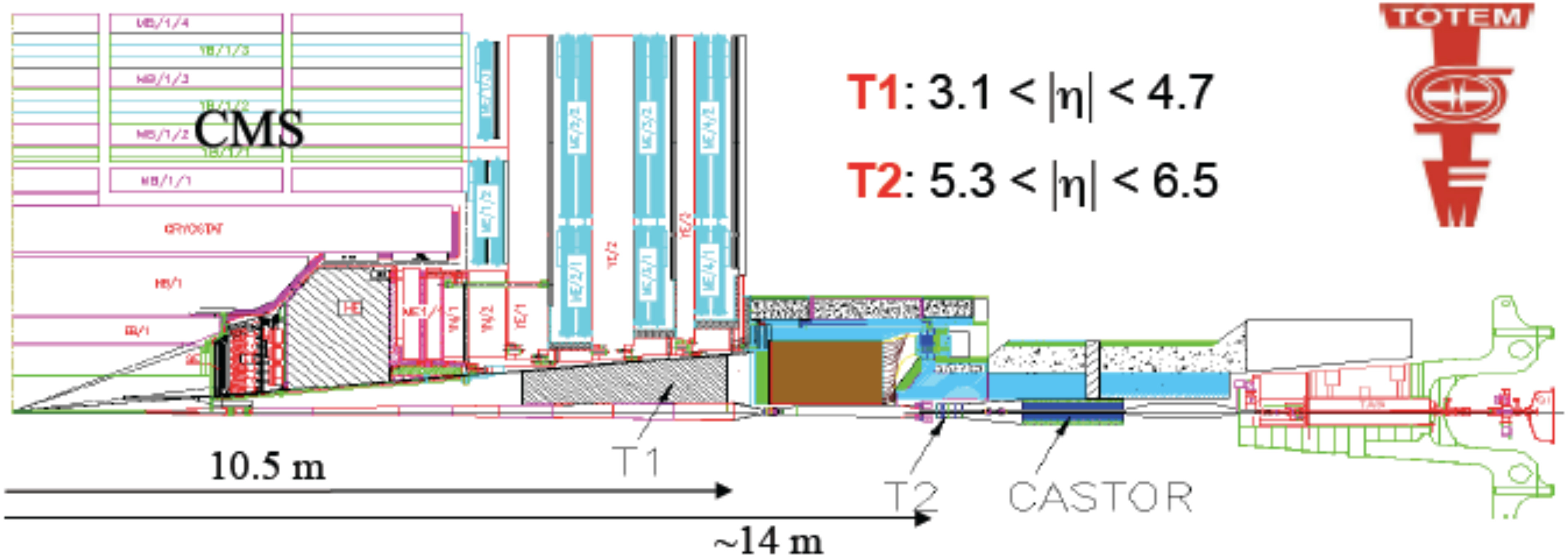
An attempt to tune PYTHIA8



Input to tuning is just $\alpha_{IP}(0)$ from fit and overall fraction of diffractive events (crudely) extracted in inelastic cross section paper.

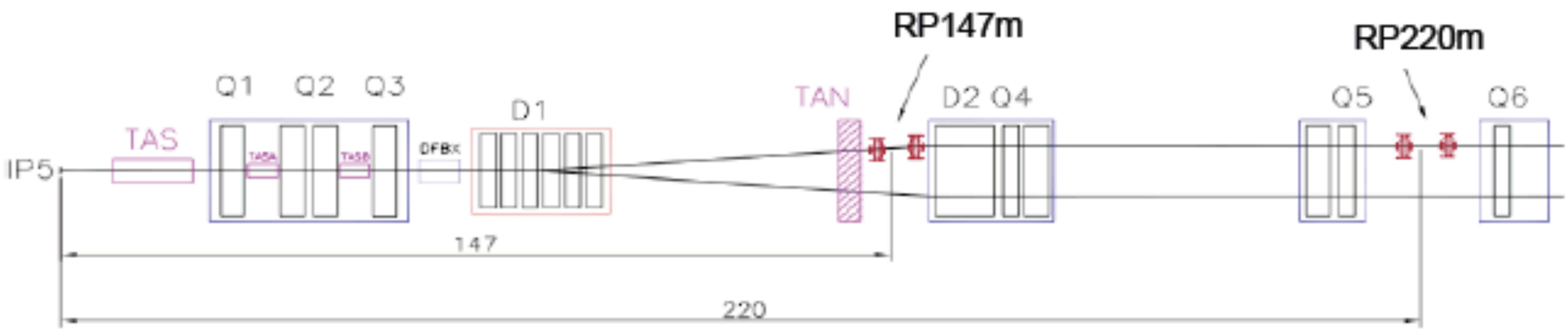
→ describes small gaps well, but not transition between non-diffractive and diffractive regions

A detour: TOTEM and the Elastic Cross Section



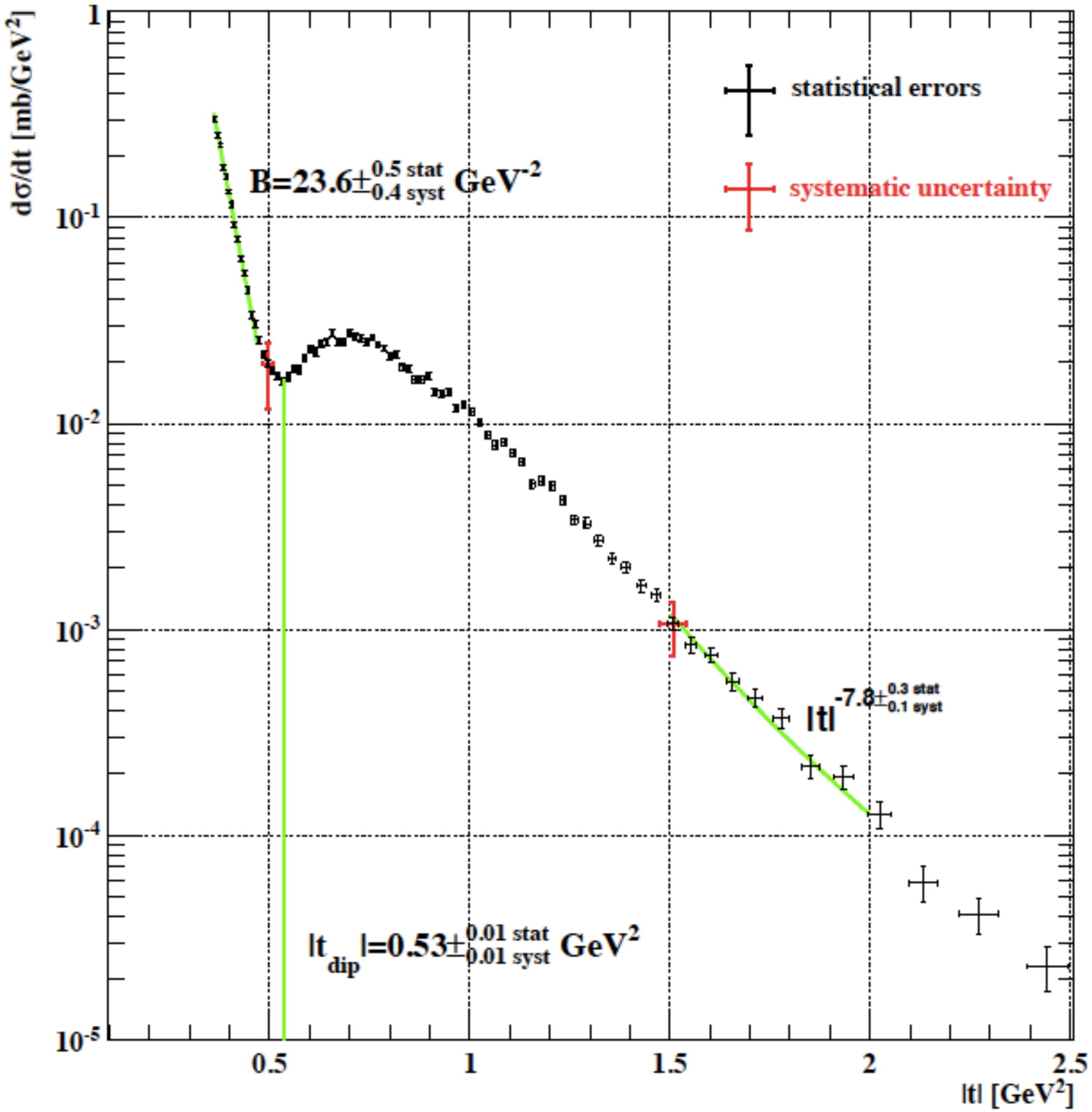
T1: $3.1 < |\eta| < 4.7$

T2: $5.3 < |\eta| < 6.5$



- The most hermetic detector ever?
- Elastic scattering measurement using Roman pots at 220m

Elastic Cross Section from TOTEM

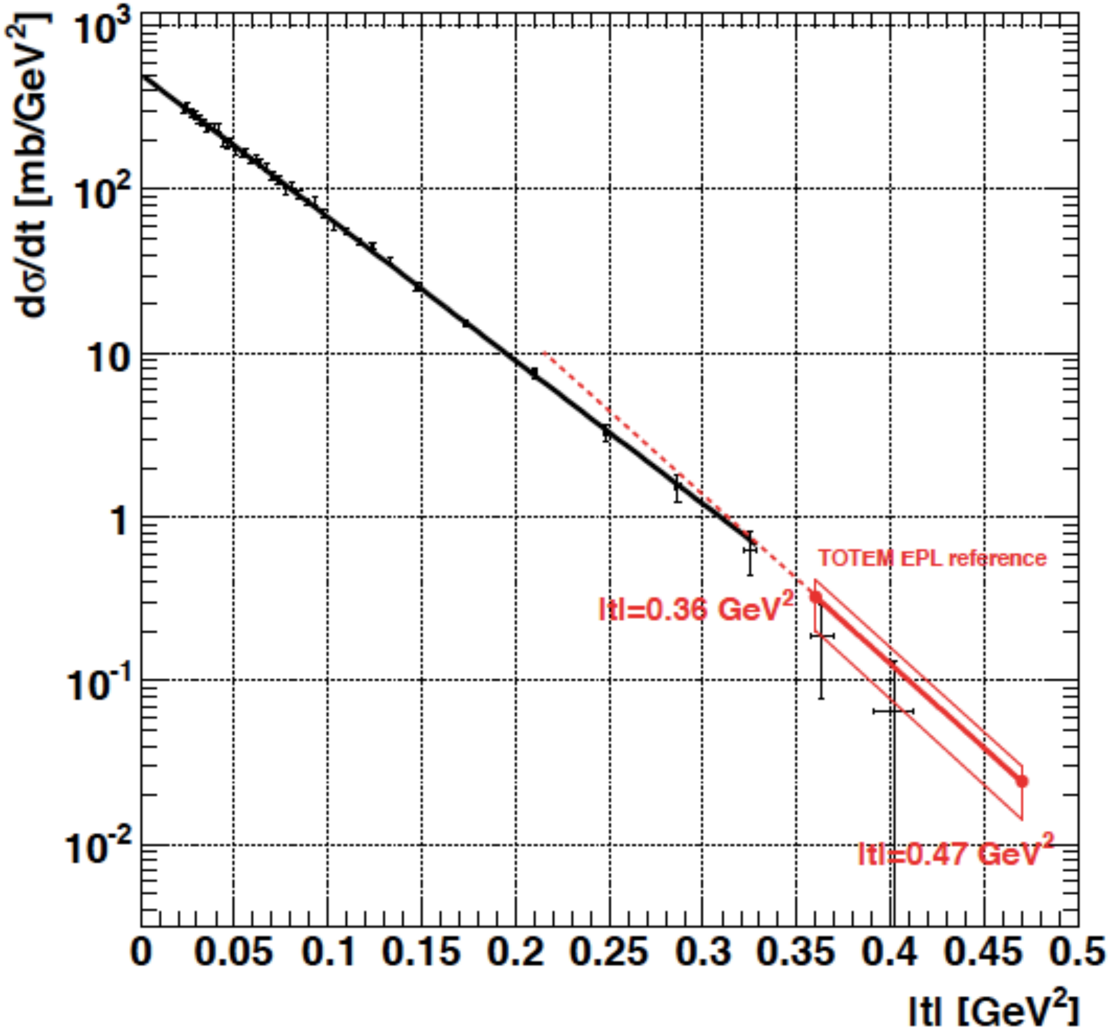


Precise t dependence of elastic (pp → pp) cross section for $|t| > 0.36$ GeV^2

$$\frac{d\sigma}{dt} \propto e^{bt}$$ at small |t|

Position of dip characteristic of transverse size of proton (moves to smaller |t| as s Increases)

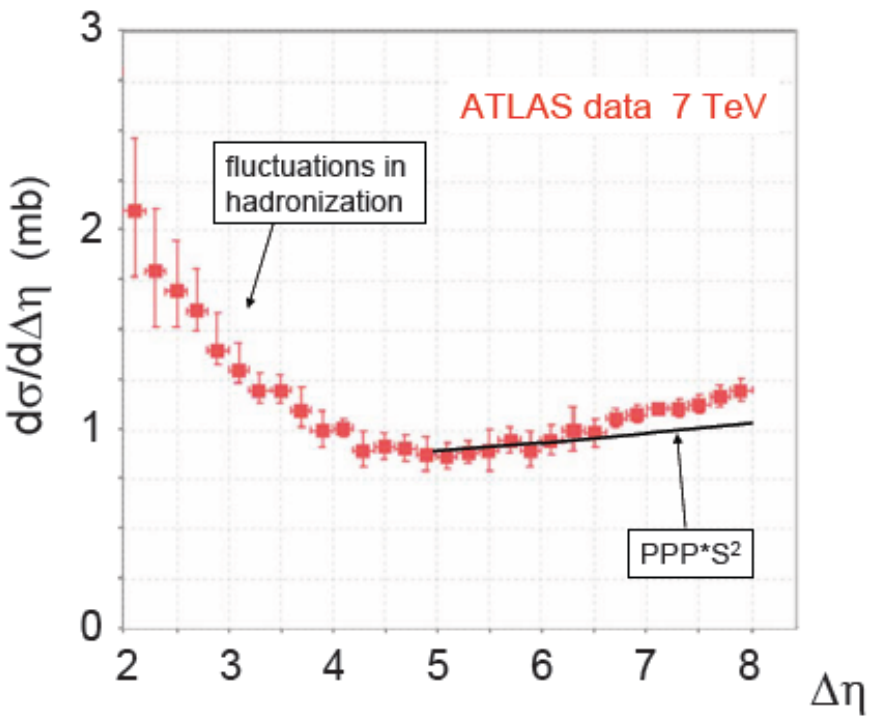
Low |t| Elastic Cross Section from TOTEM

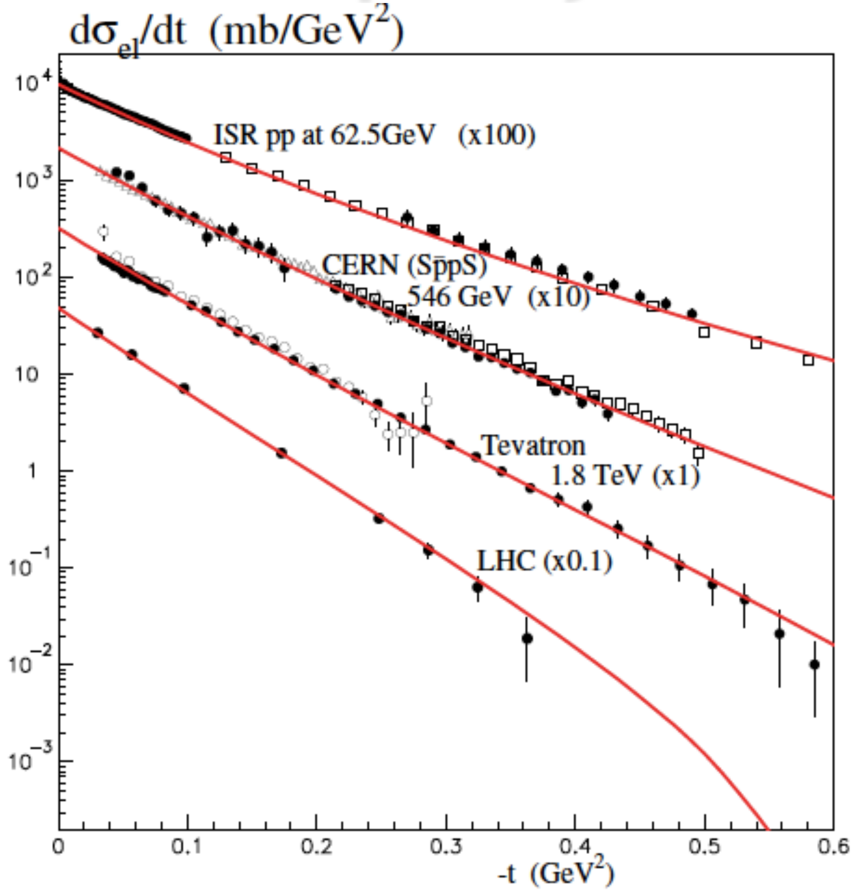


Dedicated run with special optics allows measurement down to $|t| = 0.02$ GeV^2

KMR Model with Proton Opacity

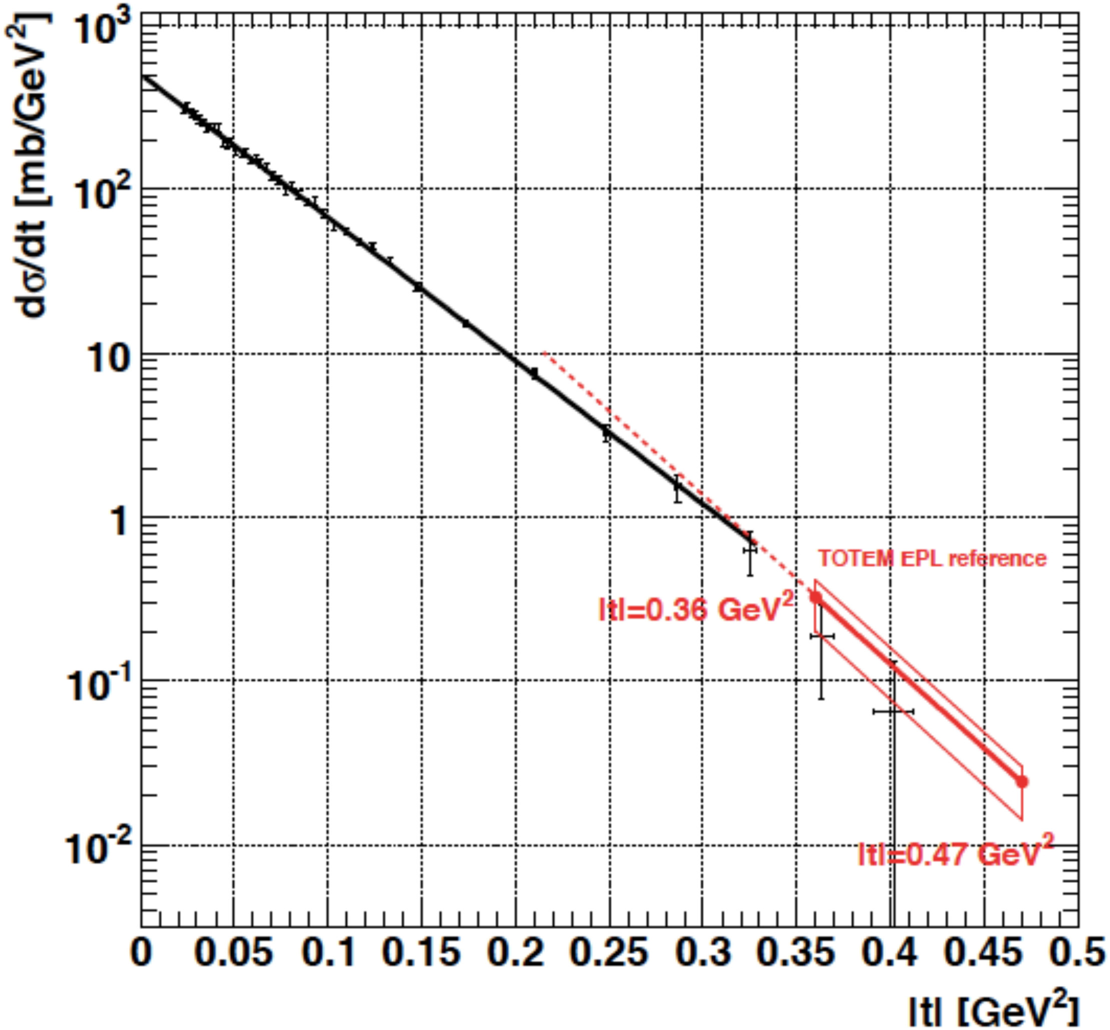
arXiv:1201.6298





... simultaneous description of ATLAS gaps data and elastic cross section data from ISR to Totem based on a single pomeron in a 3-channel eikonal model, with significant absorptive corrections in gaps / dissociation case

Low |t| Elastic Cross Section from TOTEM



Dedicated run with special optics allows measurement down to $|t| = 0.02$ GeV^2

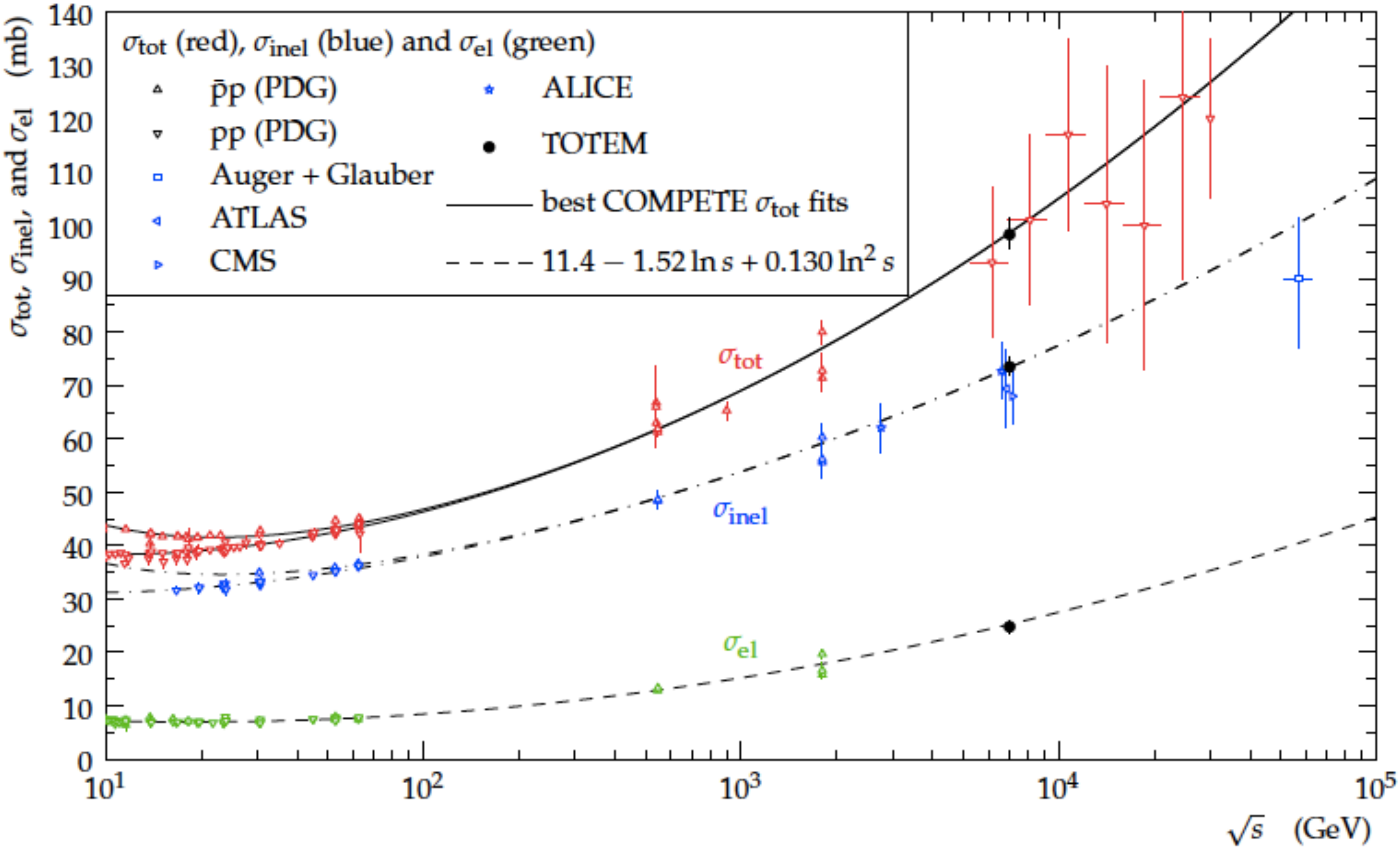
Small extrapolation to t=0 yields total cross section via optical theorem

$$\sigma_{TOT}^2 = \frac{16\pi(\hbar c)^2}{1+\rho^2} \cdot \left.\frac{d\sigma_{EL}}{dt}\right|_{t=0}$$

- Luminosity measurement from CMS
- ρ = ratio of real to imaginary parts of forward elastic amplitude from fits to previous data.

Totem Total (and Elastic) Cross Section

$$\sigma_{el} = \left(24.8 \pm 0.2^{(stat)} \pm 1.2^{(syst)}\right)\text{mb} \qquad \sigma_T = \left(98.3 \pm 0.2^{(stat)} \pm 2.7^{(syst)} \left[{}^{+0.8}_{-0.2}\right]^{(syst\ from\ \rho)}\right)\text{mb}$$

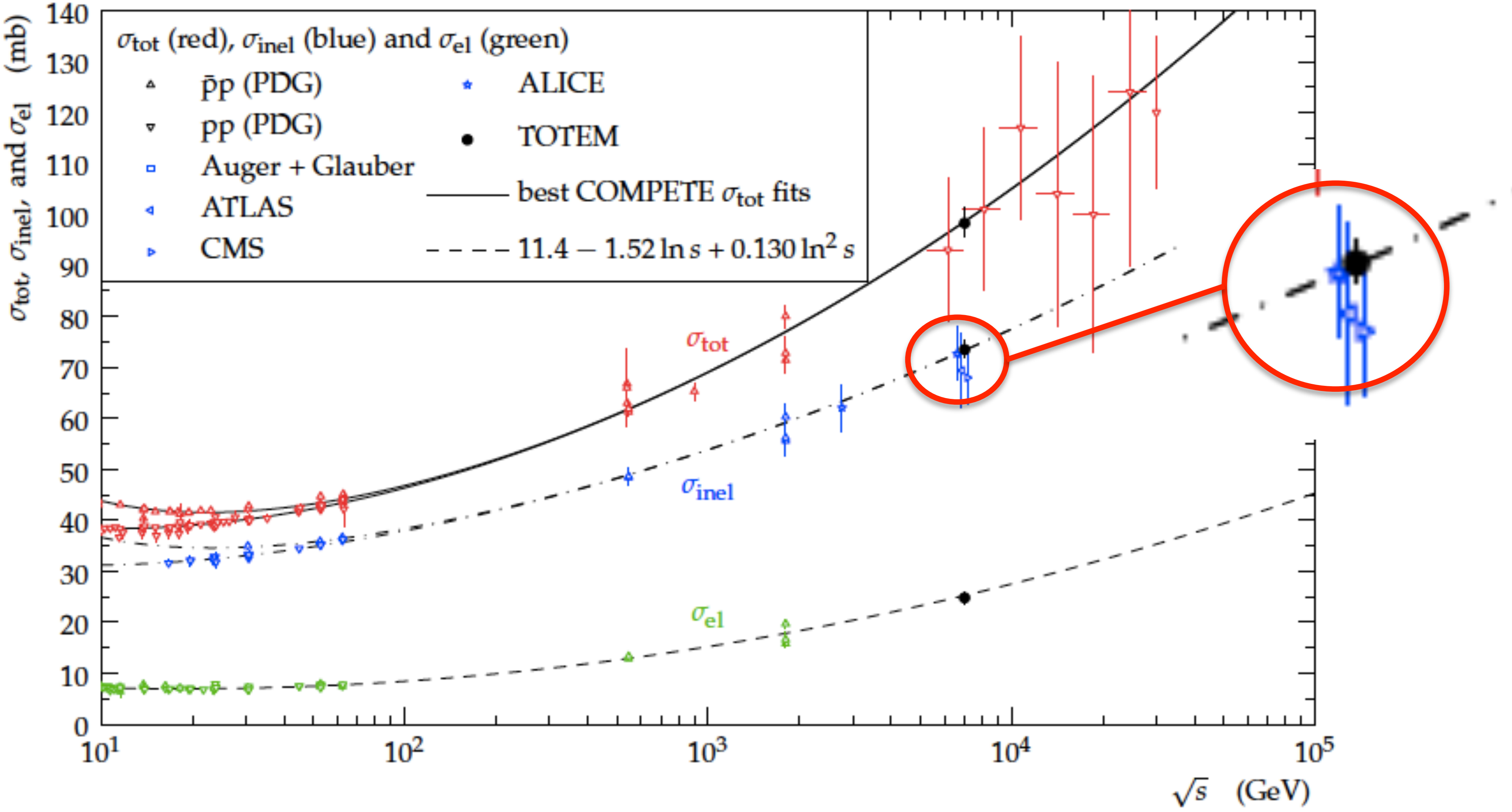


Totem **Inelastic Cross-Section**

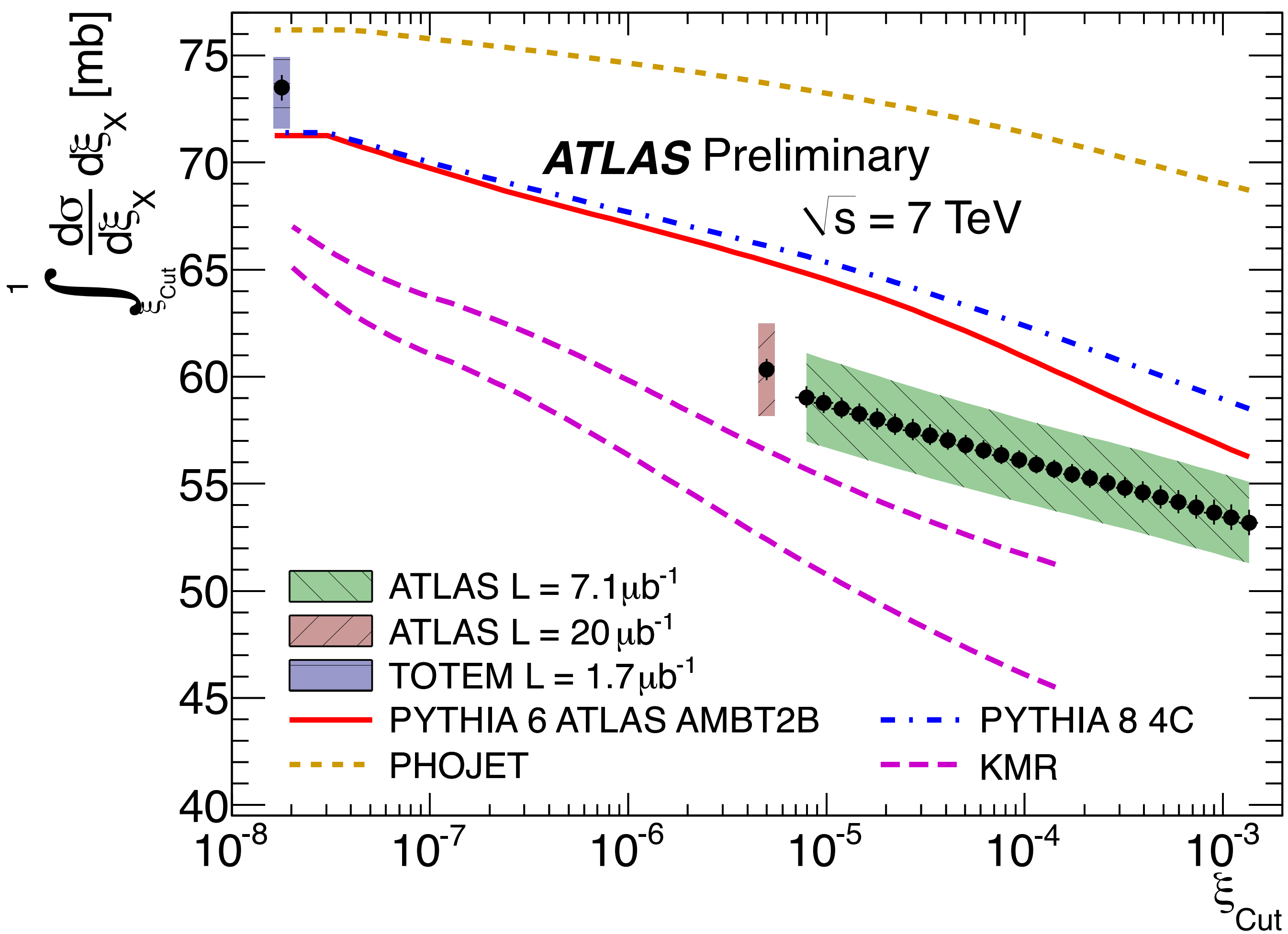
$$\sigma_{inel} = \sigma_{tot} - \sigma_{el} = \left(73.5 \pm 0.6^{(stat)} \begin{bmatrix} +1.8 \\ -1.3 \end{bmatrix}^{(syst)}\right) \text{ mb}$$

σ_{inel} (CMS) = $(68.0 \pm 2.0^{(syst)} \pm 2.4^{(lumi)} \pm 4.0^{(extrap)})$ mb
σ_{inel} (ATLAS) = $(69.4 \pm 2.4^{(exp)} \pm 6.9^{(extrap)})$ mb
σ_{inel} (ALICE) = $(72.7 \pm 1.1^{(mod)} \pm 5.1^{(lumi)})$ mb

ATLAS, CMS extrapolations to low ξ yield lower σ(inel) than Totem?



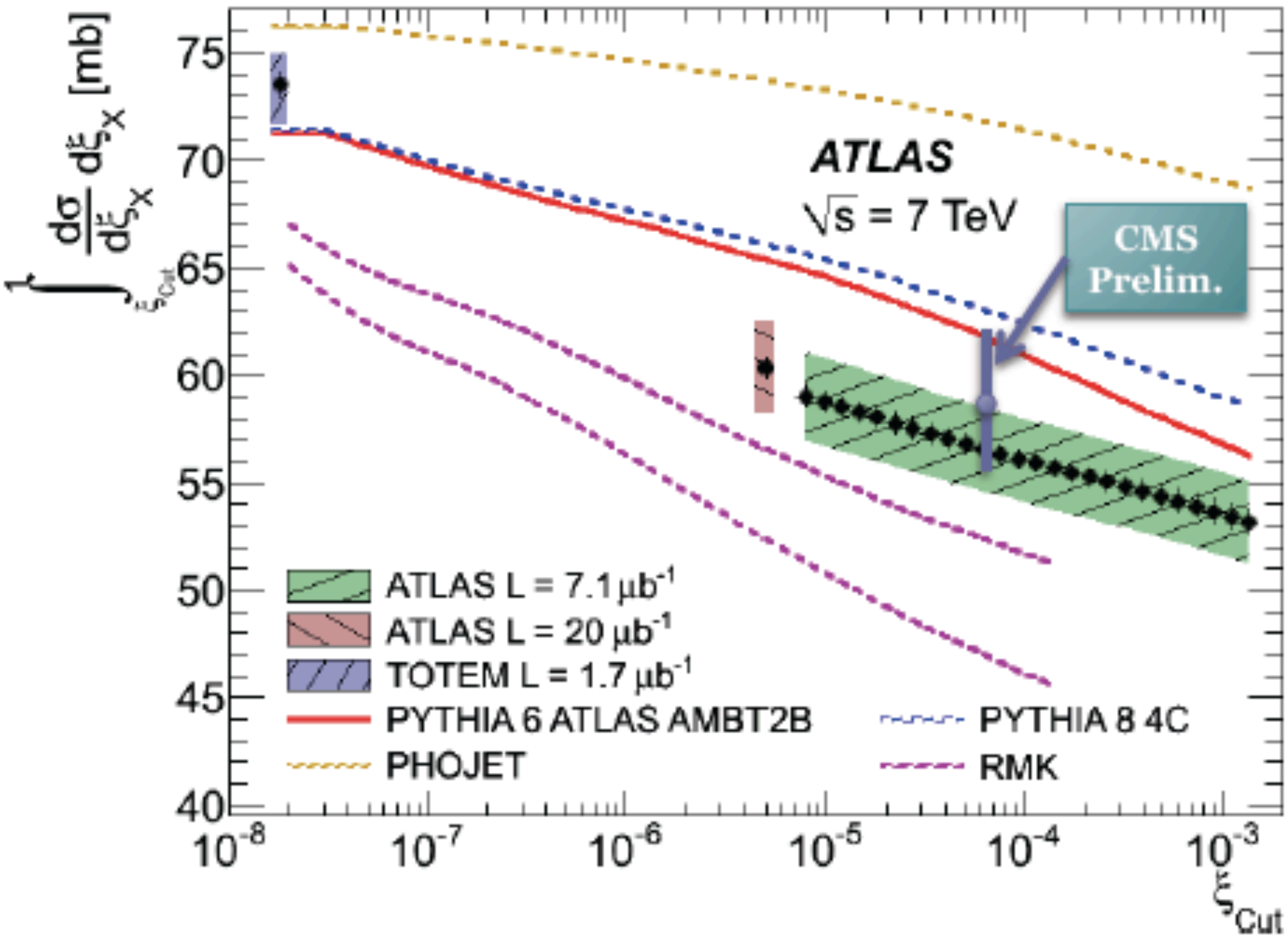
Investigating the Low ξ Extrapolations



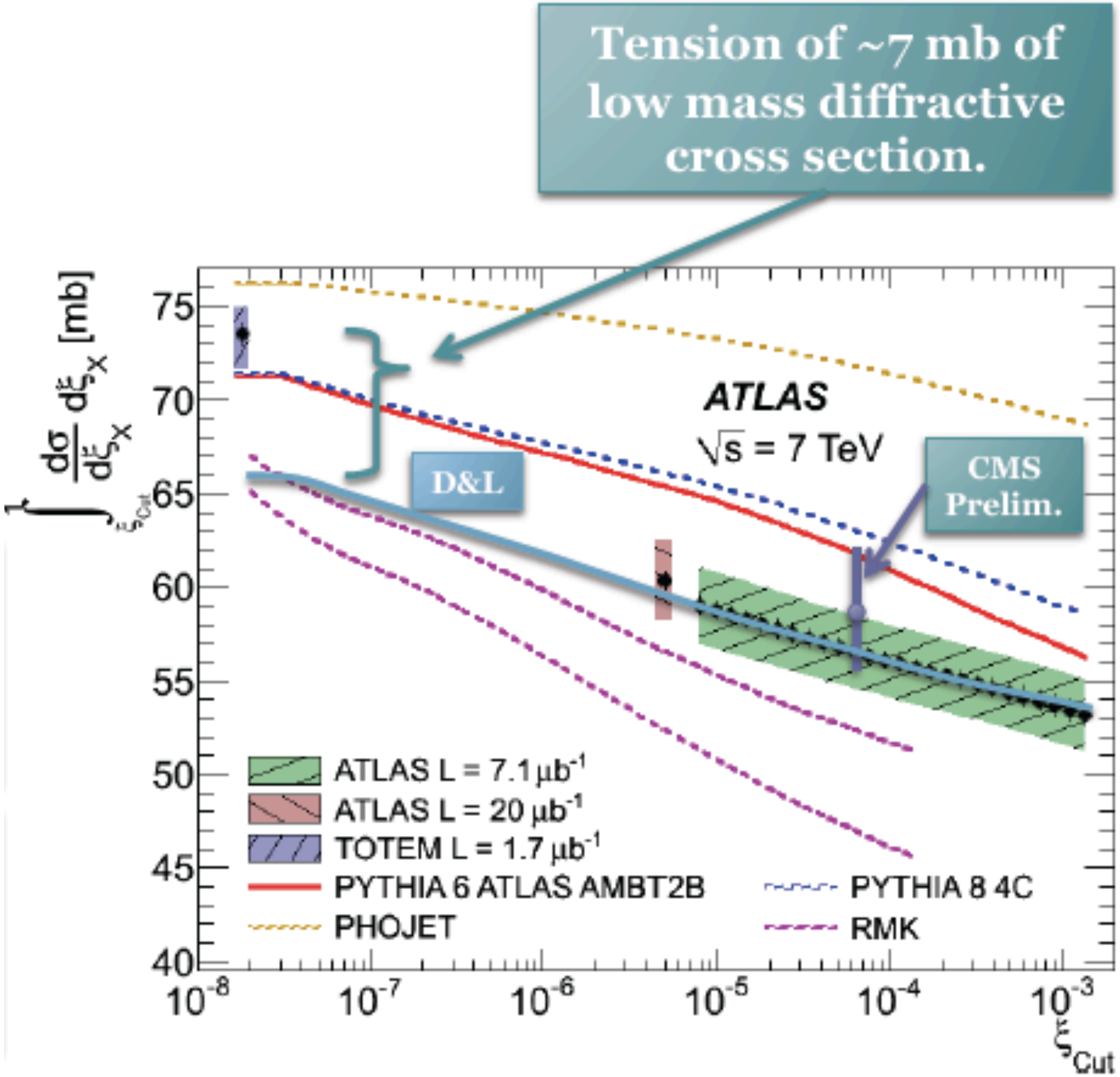
[Inelastic cross section excluding diffractive channels with $\xi < \xi_{cut}$]

- Integrating ATLAS gap cross section up to some max $\Delta\eta^F$ (equivalently min ξ_X) and comparing with TOTEM indicates that small ξ_X region underestimated in PHOJET and PYTHIA:
- 14 mb with $\xi < 10^{-5}$, compared to 6 (3) mb in PYTHIA (PHOJET)

Investigating the Low ξ Extrapolations



Investigating the Low ξ Extrapolations



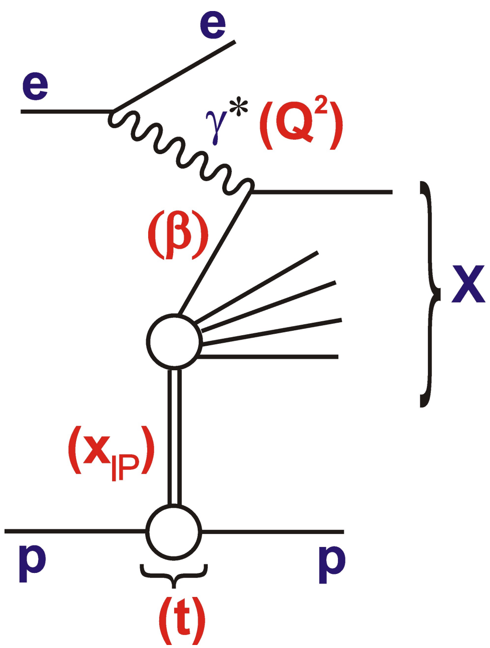
Not solved by increasing aIP(0) to Donnachie-Landshoff

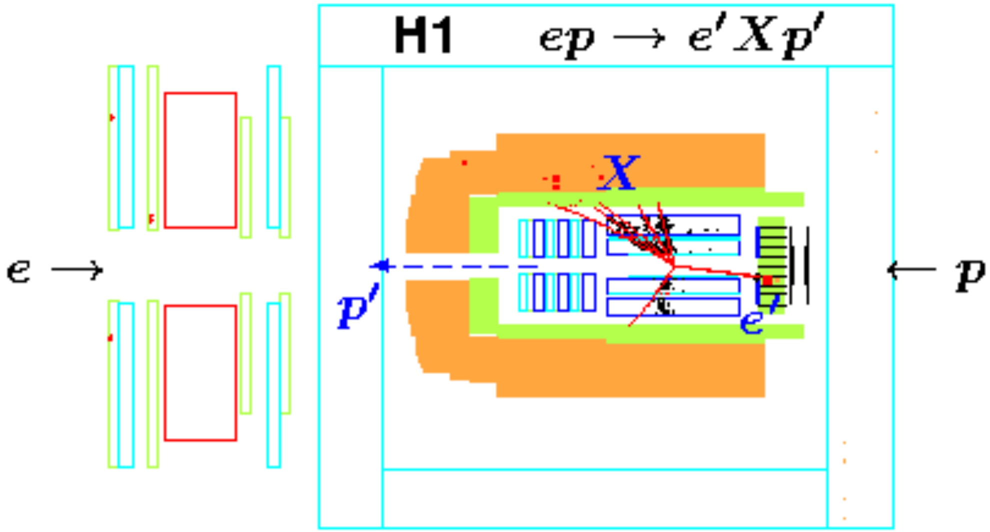
… required dependence more like $1/\xi^3$ than $1/\xi^2$ [PPR triple Regge term]

Success for Durham model (RMK) with enhanced low mass diffraction (~ Good & Walker - elastic scattering of excited proton eigenstates)

ATLAS (ALFA) result eagerly awaited to confirm TOTEM

HERA & Hard Diffraction

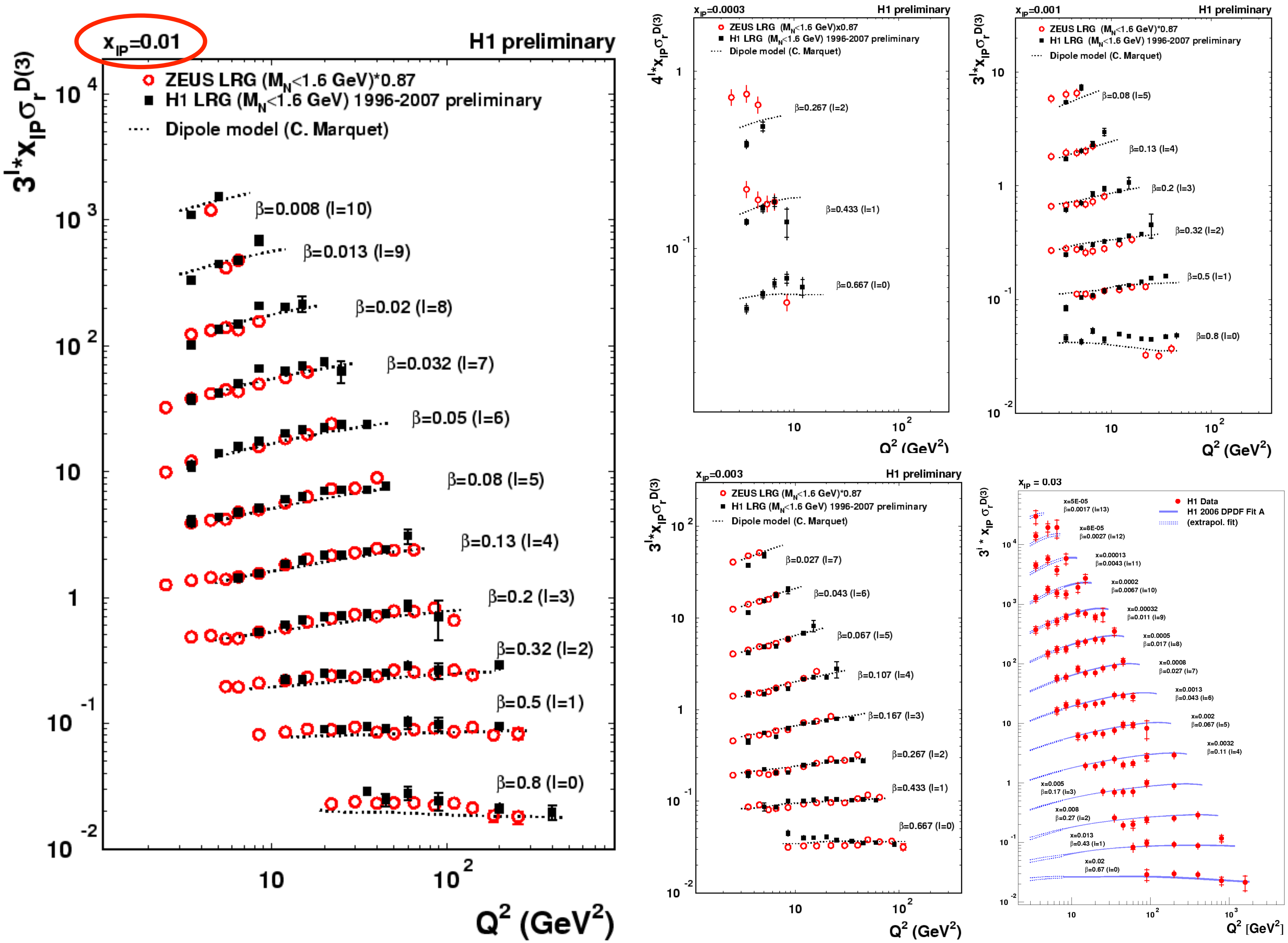


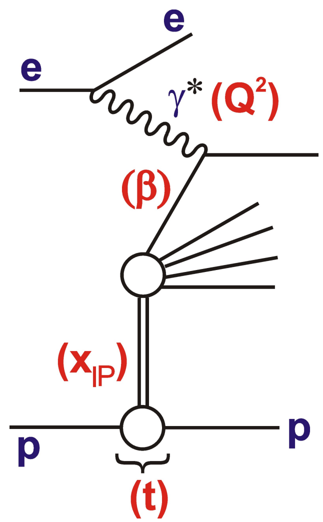


Virtual photon probes pomeron partonic structure rather like inclusive DIS …

>100 papers later …

ZEUS v H1 Diffractive DIS Data

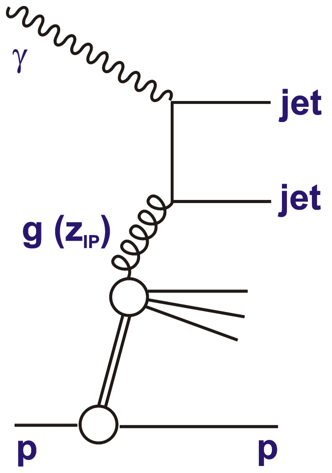


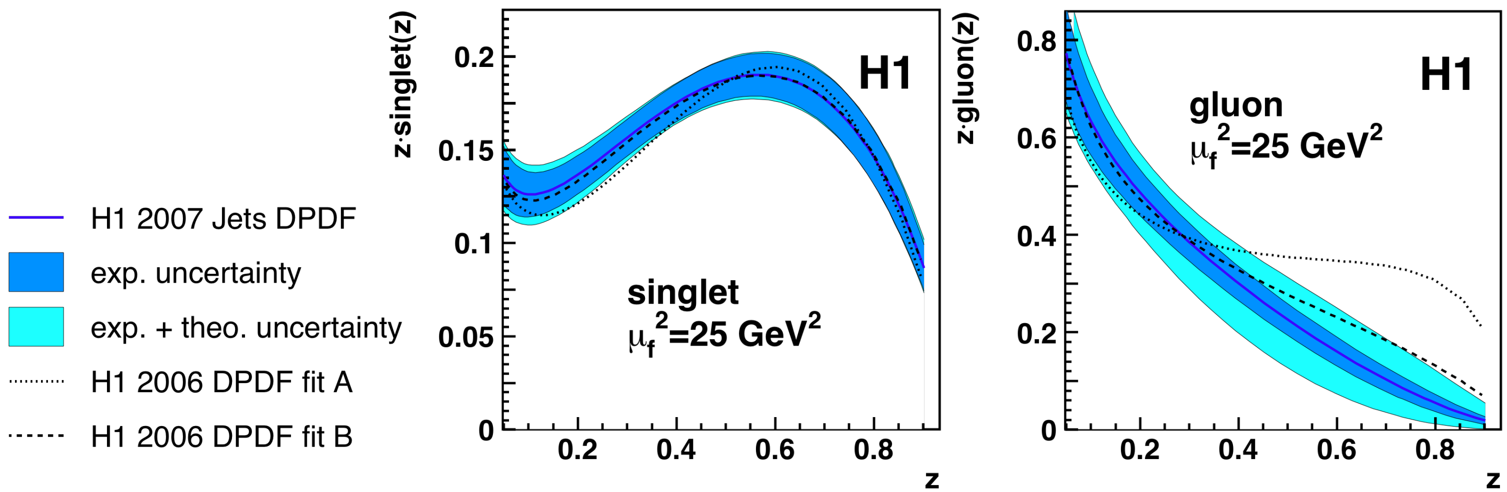


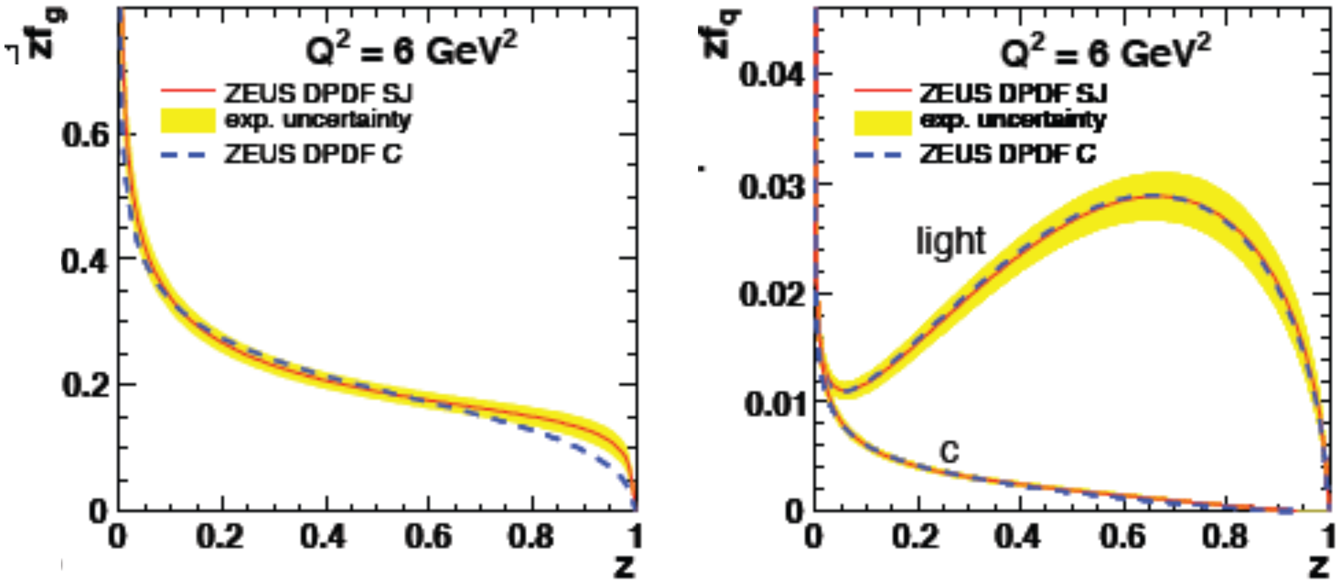
Few % precision over wide kinematic range

Reasonable agreement between H1 and ZEUS

Diffractive Parton Densities (DPDFs)



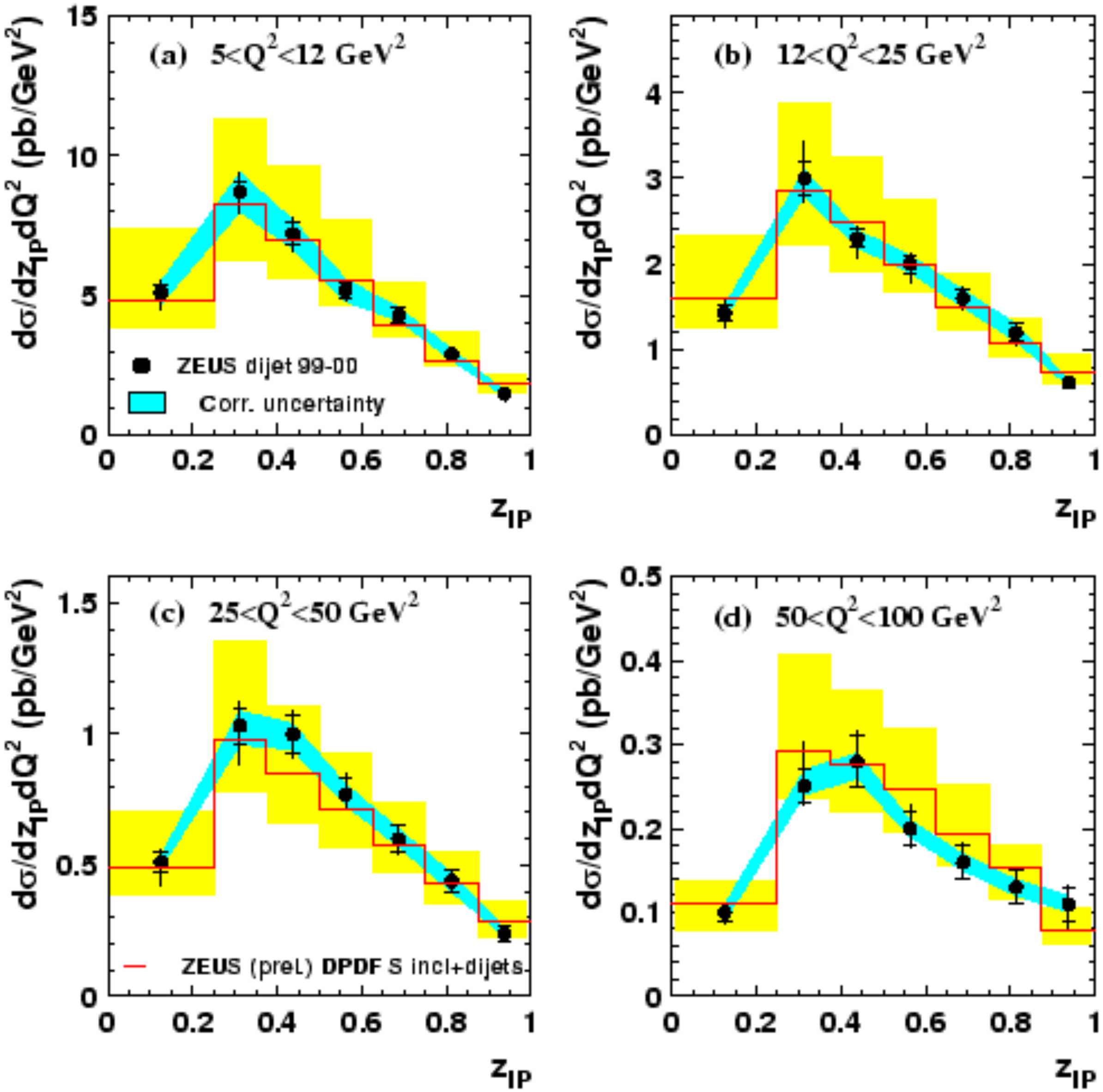


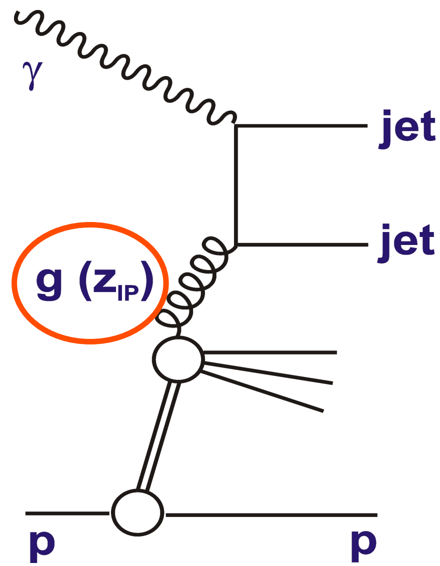


NLO DPDFs lead to impressive descriptions of all hard diffractive DIS data

DPDFs dominated by a gluon density which extends to large z

Example of DPDFs Predicting Diffractive DIS

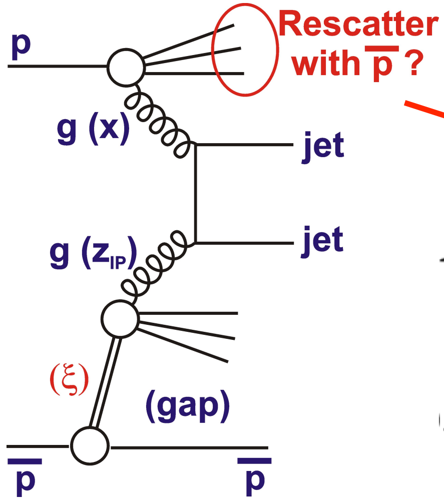


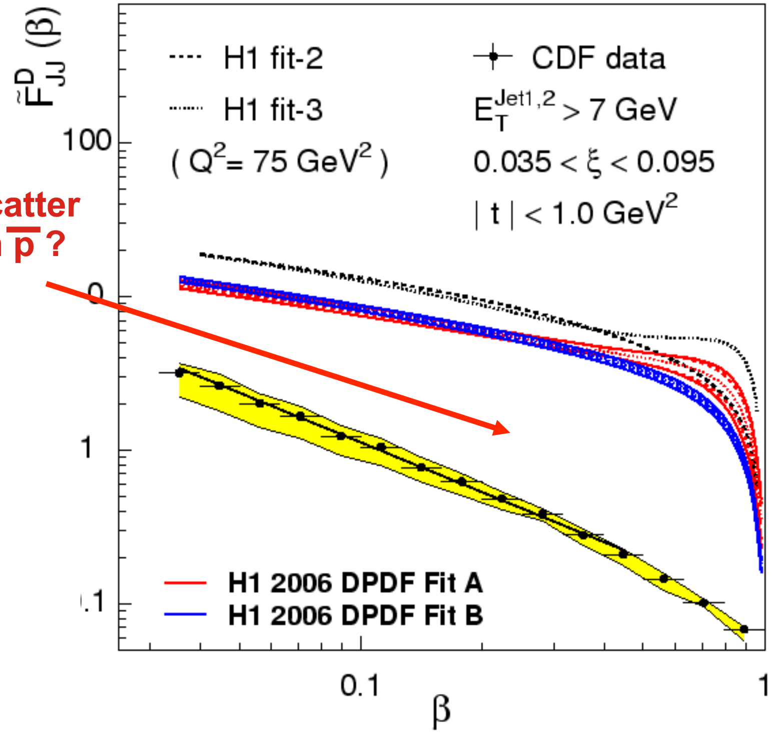


[Precision of tests limited by theory scale Uncertainties]

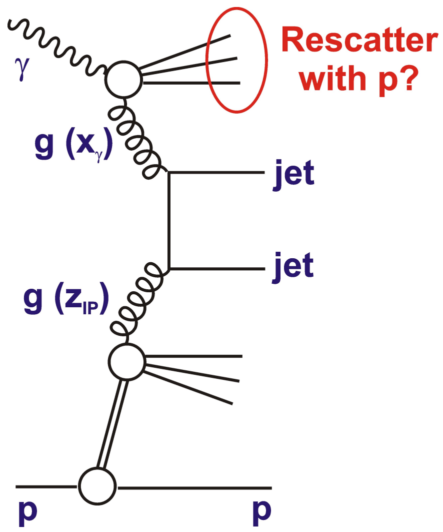
.. meanwhile in pp(bar) …

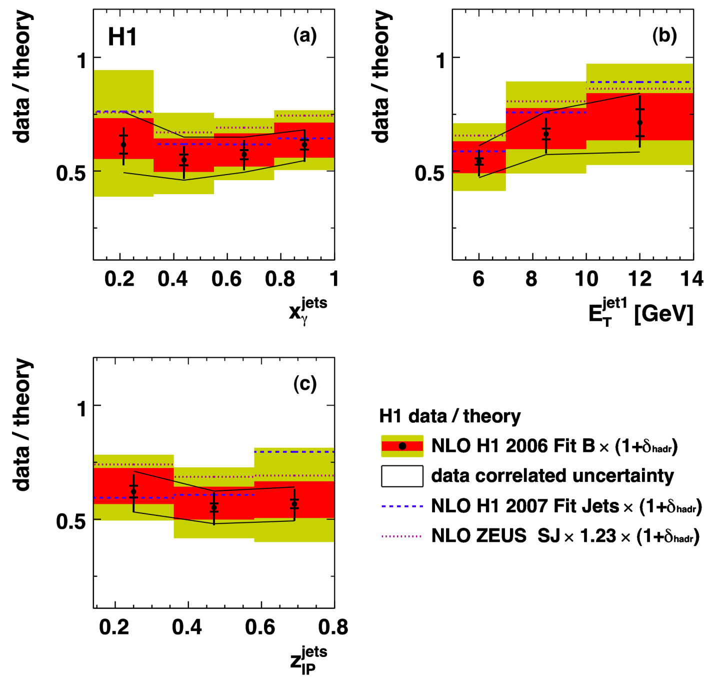
Strong evidence for absorptive effects in comparing Tevatron diffractive dijets with HERA DPDFs … `rapidity gap survival probability' $S^2 \sim 0.1$





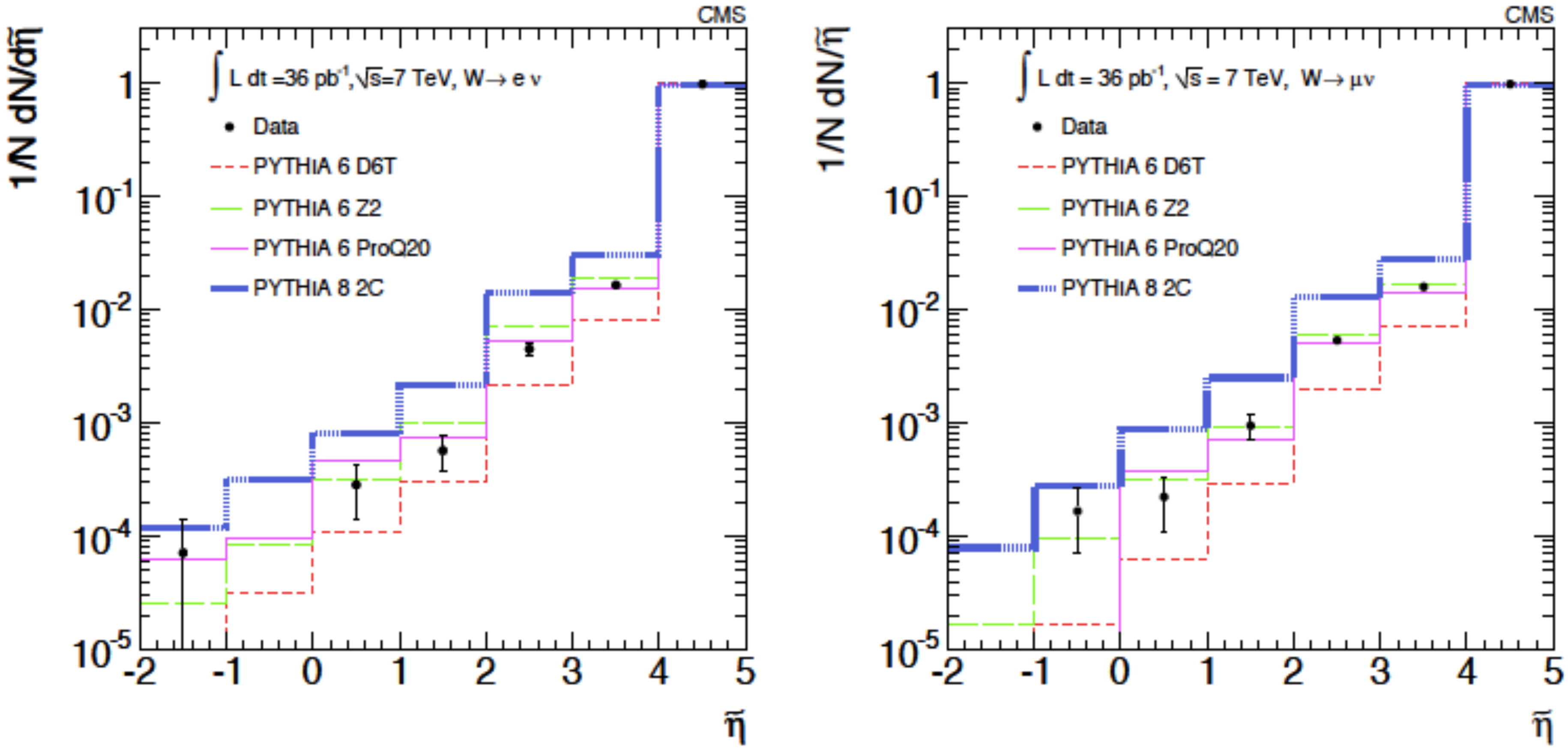
… photoproduction jets suggestive of similar effects at level of A factor of 2 [Hard to describe theoretically]





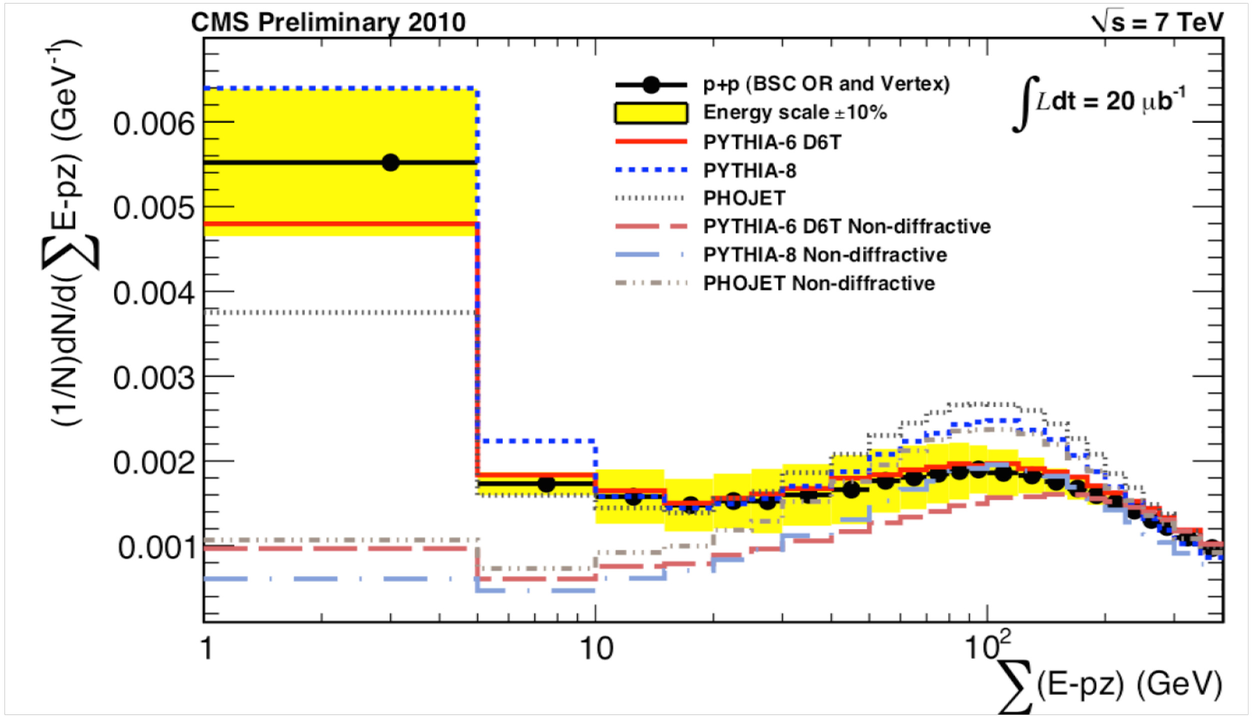
W and Z events with gaps at CMS

After pile-up corrections, ~1% of W and Z events exhibit no activity above noise thresholds over range 3 < ±η < 4.9 … interpretation complicated by non-diffractive hadronisation fluctuations …



$\tilde{\eta}$ (= 4.9 – Δη) end-point of gap - starting at acceptance limit

A Promising Variable to Reconstruct ξ_X in Hard Diffractive Processes



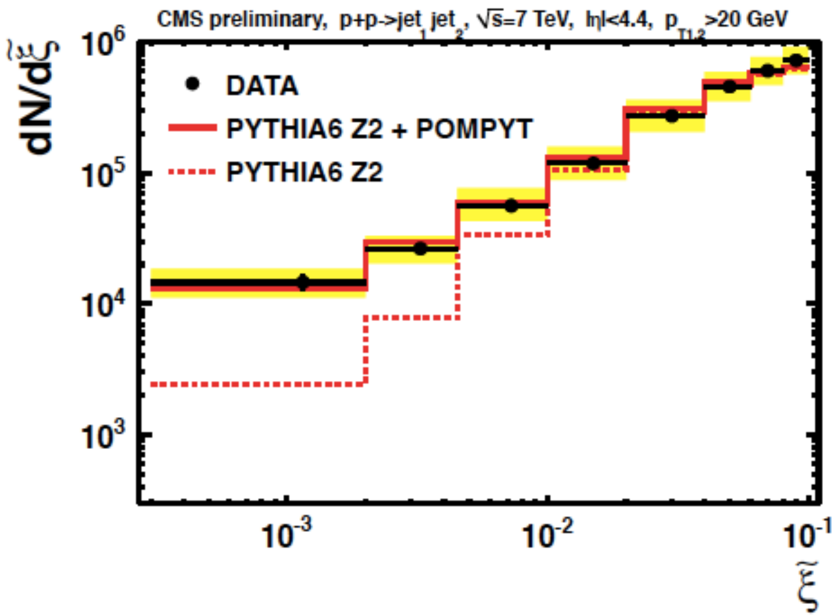
$$\sum_X E - p_z \approx 2E_p \cdot \xi_X$$

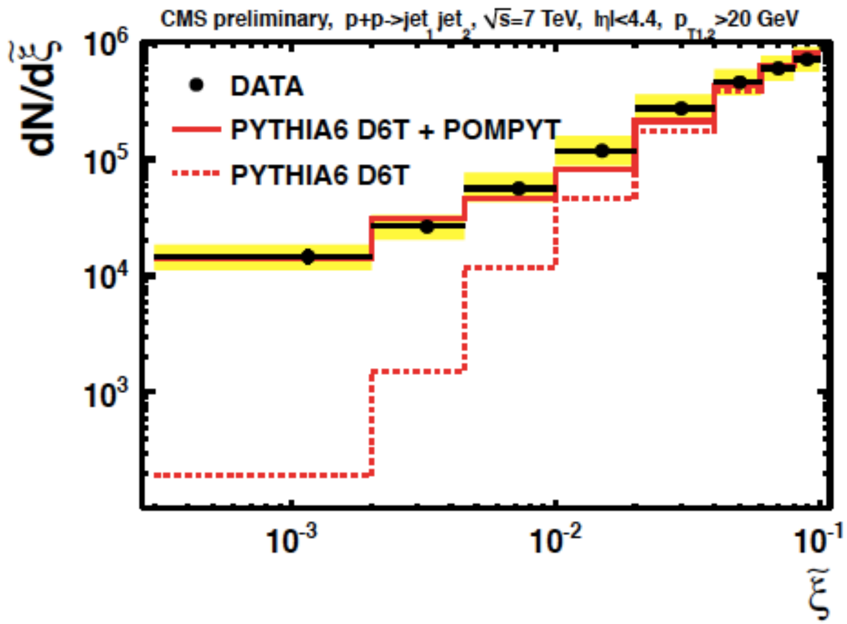
for dissociation system in +z direction
… and lost particles have E-p_z ~ 0

$$\tilde{\xi}^+ = C\frac{\sum(E^i + p_z^i)}{\sqrt{s}}$$

Define for dissociation system in the -z direction (and E+pz for +z dissociation).
… well correlated with ξ at low ξ

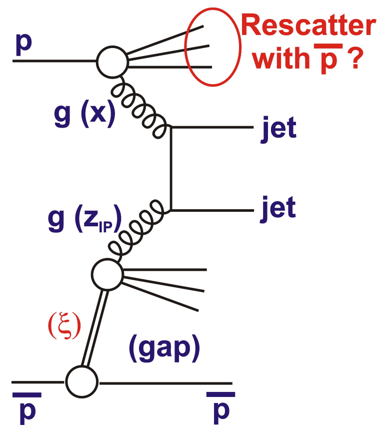
CMS Dijets with Low $E \pm p_z$





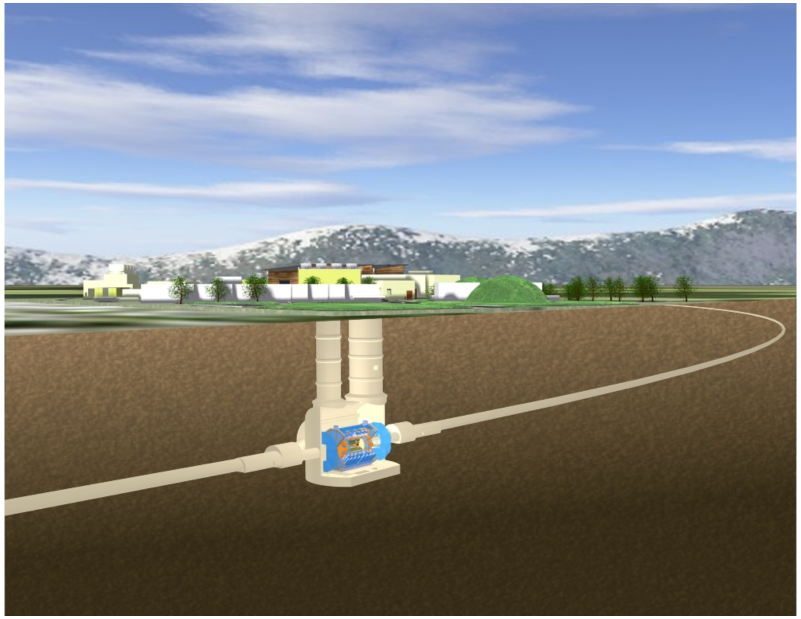
Fit linear combination of PYTHIA (ND) and POMPYT (DPDF-based diffraction)

Depending on ND model, gap survival probability ~ 0.17 – 0.23 (larger than Tevatron, and compared with predictions ~0.03!)



Non-diffractive gap fluctuations? Need proton-tagged data?

Summary



Precise LHC soft diffractive, elastic, total cross section data

- Broadly described by single pomeron with intercept larger than unity: $\alpha_{IP}(0) \sim 1.06$
- Possible to simulataneously describe ATLAS diffractive dissociation and TOTEM elastic scattering if absorptive corrections included.
- Low mass diffractive dissociation is large!

First data on diffractive hard scattering

- Suggestion of surprisingly large gap survival probability
- Need improved understanding of hadronisation fluctuations leading to large gaps in non-diff data
- Proton tagging can by-pass this issue

Hard Diffraction: Tevatron

Most recent paper from CDF: Phys Rev D82 (2010) 112004:
Using Roman pot proton taggers …
Diffraction with $0.03 < \xi < 0.1$, $|t| < 1$ GeV^2 accounts for

- 1.00 ± 0.05 (stat.) ± 0.10 (syst.) % of W production
- 0.88 ± 0.21 (stat.) ± 0.08 (syst.) % of Z production

at the Tevatron (suggests small gap survival probability)

Comparable with lots of other diffractive processes measured using large rapidity gap approach …

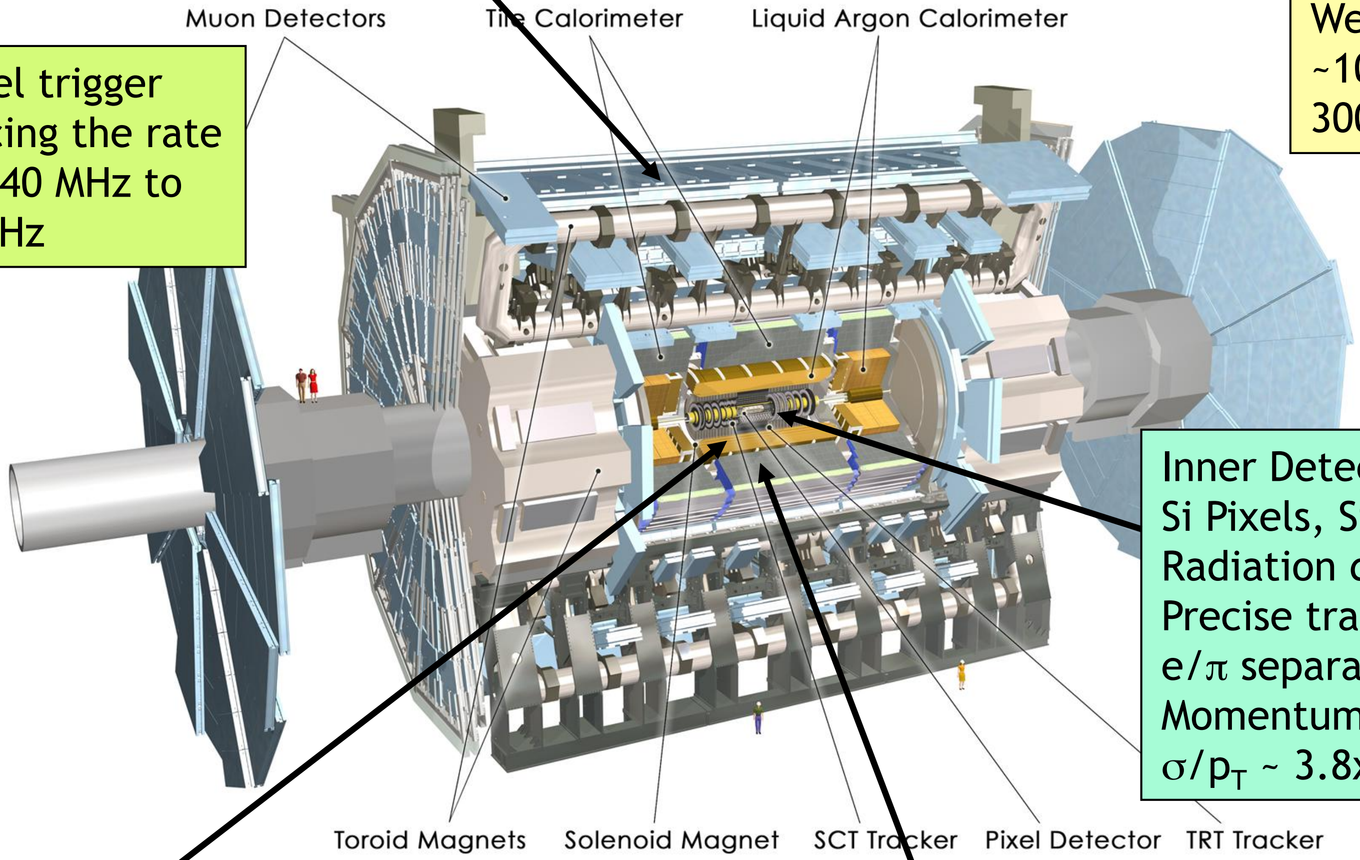
Hard component	Fraction (R) %
Dijet	0.75 ± 0.10
W	1.15 ± 0.55
b	0.62 ± 0.25
J/ψ	1.45 V 0.25

Universal suppression relative to factorised predictions?

Muon Spectrometer ($|\eta|<2.7$) : air-core toroids with gas-based muon chambers
Muon trigger and measurement with momentum resolution < 10% up to E_μ ~ 1 TeV

Length : ~ 46 m
Radius : ~ 12 m
Weight : ~ 7000 tons
~10^8 electronic channels
3000 km of cables

3-level trigger reducing the rate from 40 MHz to ~200 Hz



Inner Detector ($|\eta|<2.5$, B=2T):
Si Pixels, Si strips, Transition Radiation detector (straws)
Precise tracking and vertexing,
e/π separation
Momentum resolution:
$\sigma/p_T \sim 3.8\times10^{-4}\, p_T\,(\text{GeV}) \oplus 0.015$

EM calorimeter: Pb-LAr Accordion
e/γ trigger, identification and measurement
E-resolution: $\sigma/E \sim 10\%/\sqrt{E}$

HAD calorimetry ($|\eta|<5$): segmentation, hermeticity
Fe/scintillator Tiles (central), Cu/W-LAr (fwd)
Trigger and measurement of jets and missing E_T
E-resolution: $\sigma/E \sim 50\%/\sqrt{E} \oplus 0.03$

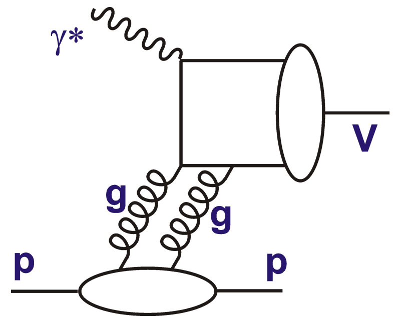
Diffraction & Multi-Parton Interactions

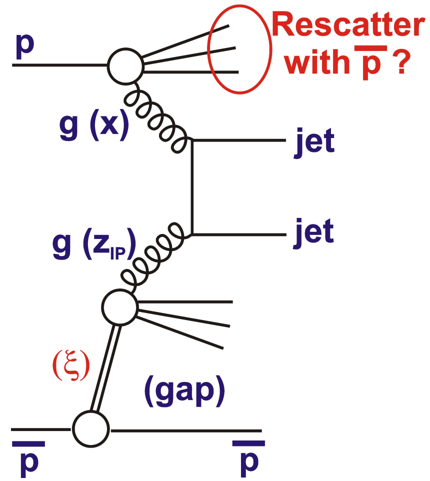
- Trivially, more than 1 parton in t channel

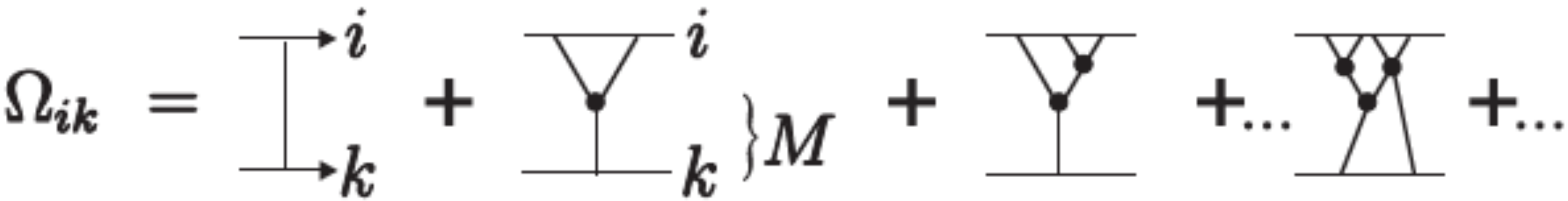
- Gap survival probabilities / absorption:
… multiple interactions with large impact parameters

- Absorptive effects due to multiple soft exchanges in minimum bias models

- Less obviously, small rapidity gaps as sensitive probe of hadronisation fluctuations and underlying event







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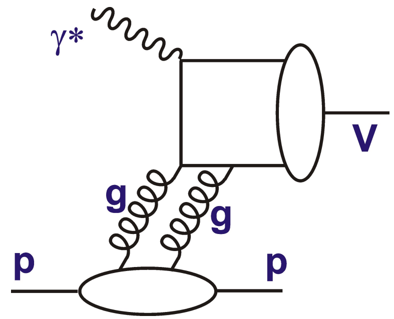
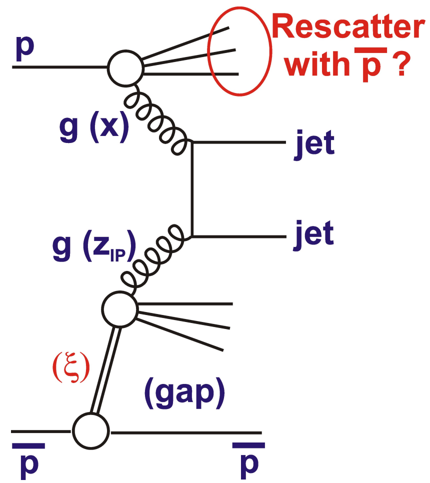


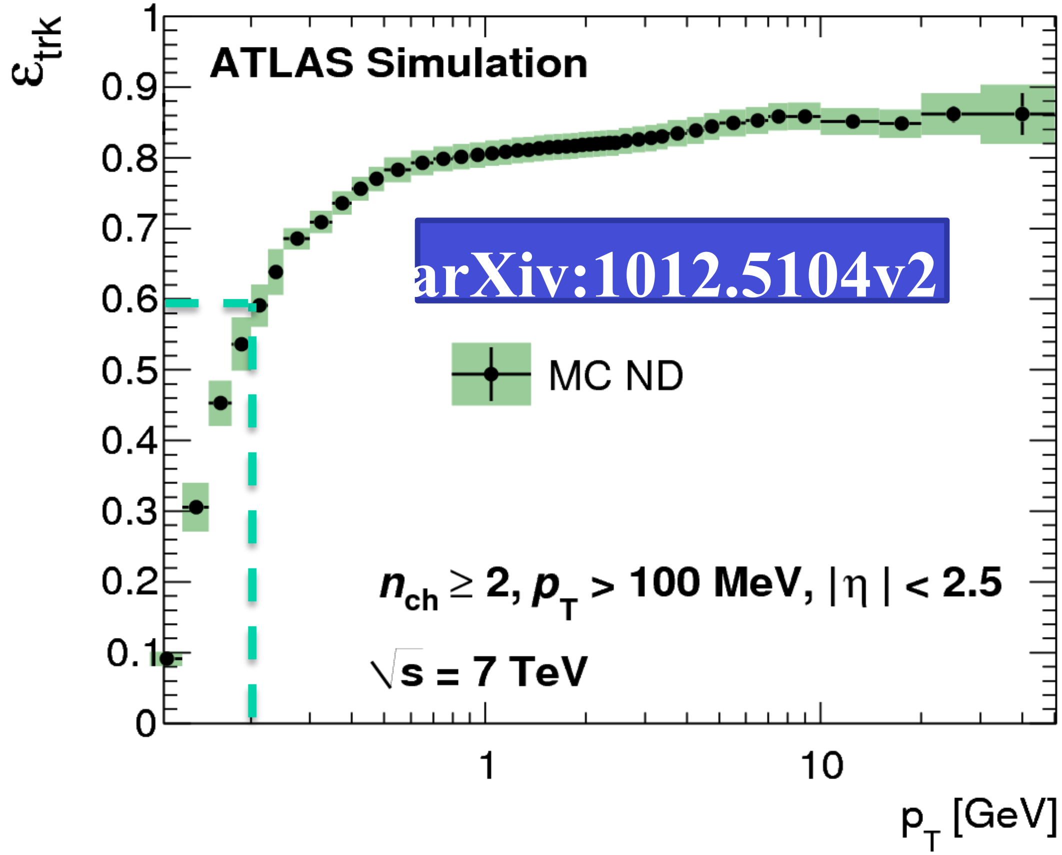


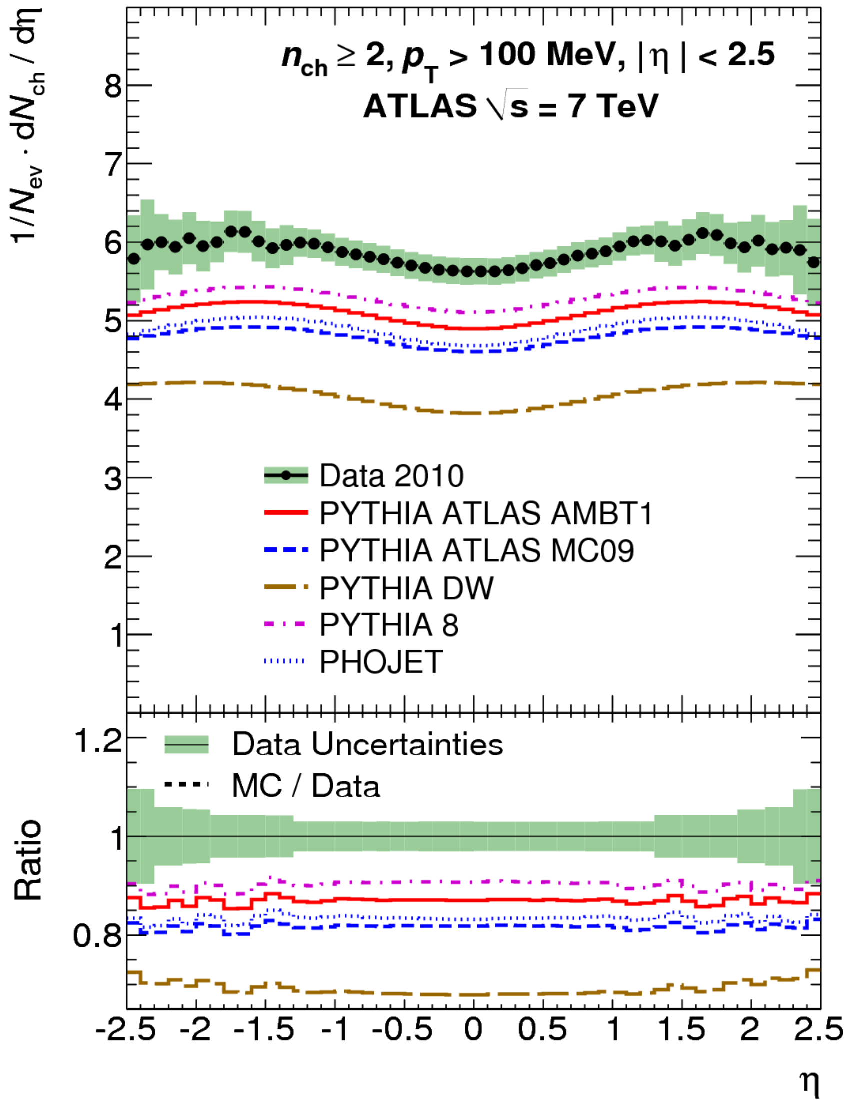
Not covered here

- Elastic scattering in pp / ppbar (see Ken Osterberg)
- Exclusive vector mesons in ep and pp (see Marcella Capua)

Inner Detector

We have plenty of experience with low-p_T, minimum bias tracking in ATLAS





Calorimeters

In the calorimeters **electronic noise is the primary concern**.

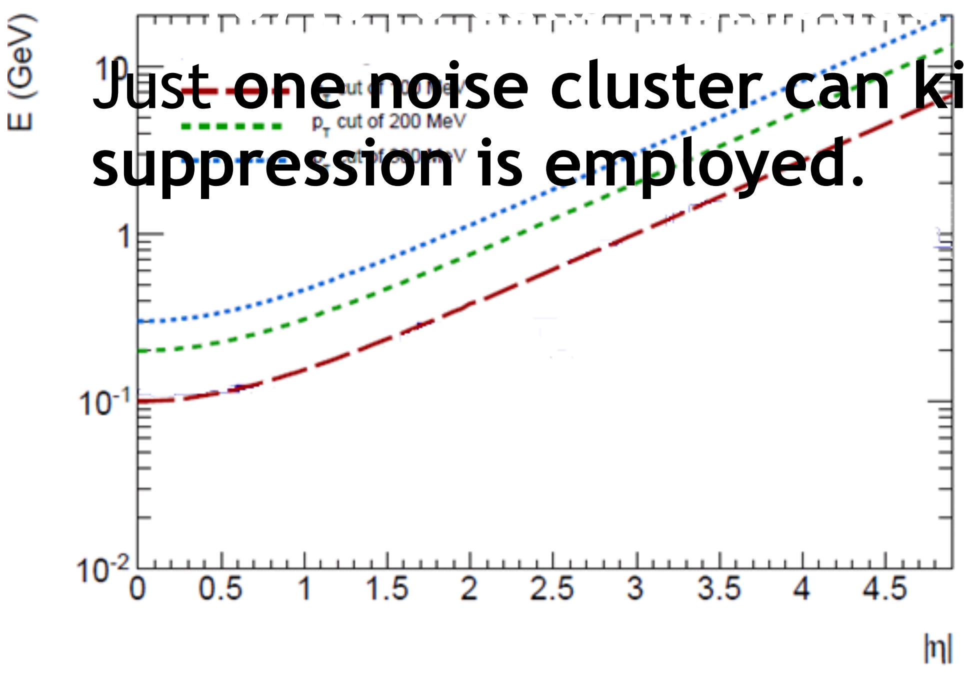
We use the **standard ATLAS Topological clustering of cells**.

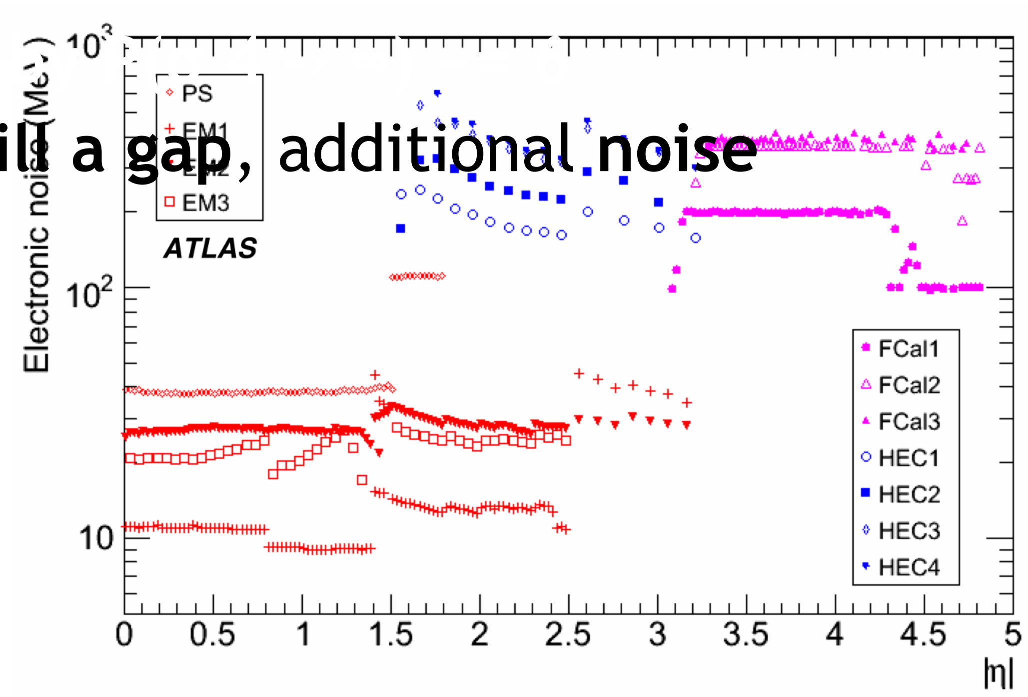
The seed cell is required to have an **energy significance $\sigma = E/\sigma_{Noise} > 4$**.

Statistically, we

.

Just one noise cluster can kill a gap, additional noise suppression is employed.





Total Inelastic pp Cross Section

Optical Theorem: $$\sigma_{TOT}^2 = \frac{16\pi(\hbar c)^2}{1+\rho^2} \cdot \left.\frac{d\sigma_{EL}}{dt}\right|_{t=0}$$

Using luminosity from CMS: $$\frac{d\sigma_{EL}}{dt} = \frac{1}{L} \cdot \frac{dN_{EL}}{dt}$$

ρ from COMPETE fit: $$\rho = 0.14^{+0.01}_{-0.08}$$

$$\sigma_{TOT} = \sqrt{19.20\,\text{mb GeV}^2 \cdot \left.\frac{d\sigma_{EL}}{dt}\right|_{t=0}}$$

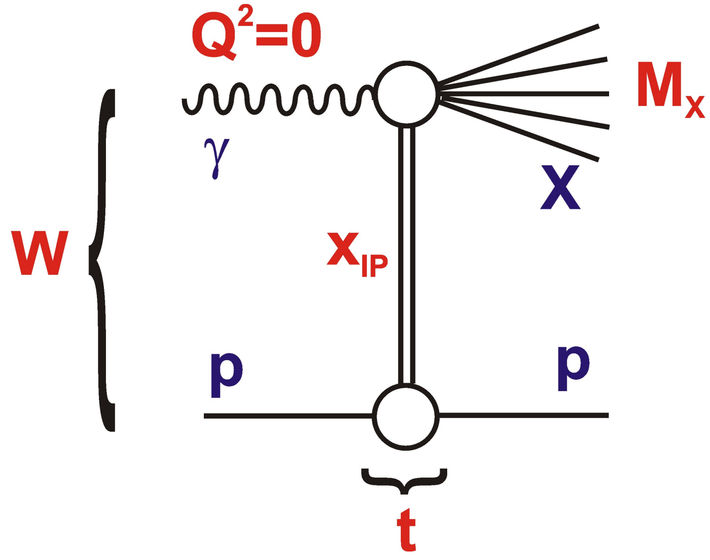
Single Diffractive Kinematics

For photon virtuality $Q^2 \rightarrow 0$:

W = γp centre of mass energy

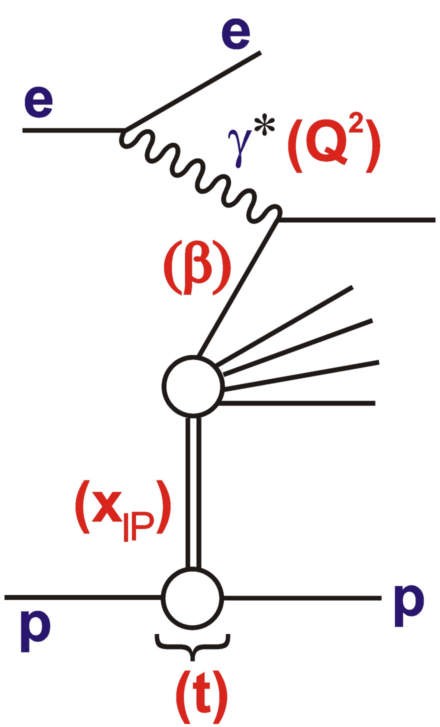
t = squared 4-momentum transfer at proton vertex

$x_{IP} = \xi = M_X{}^2/W^2$
= fractional momentum loss of proton (momentum fraction IP/p)

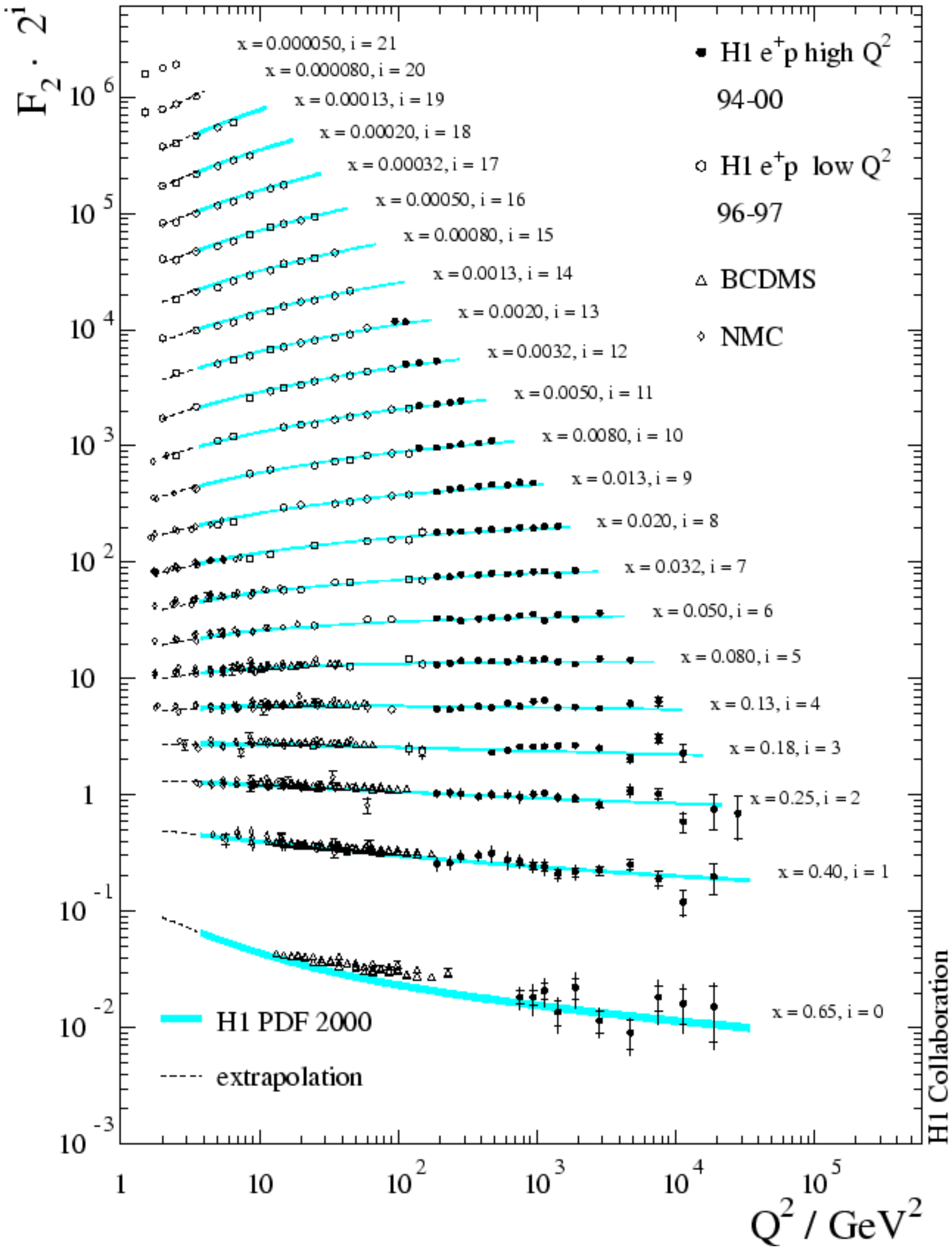


For large Q^2 (partonic structure resolved)

$\beta = x\ /\ x_{IP}$
(momentum fraction, struck q / IP)



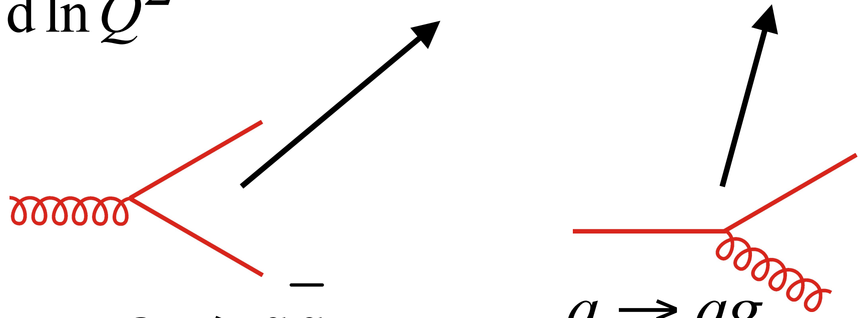
NOT NEEDED???????



The Gluon Density!

Q^2 evolution of F_2 is used to extract gluon density, assuming DGLAP evolution.

$$\frac{dF_2}{d\ln Q^2} \sim \alpha_s \left(P_{qg} \otimes g + P_{qq} \otimes q\right)$$

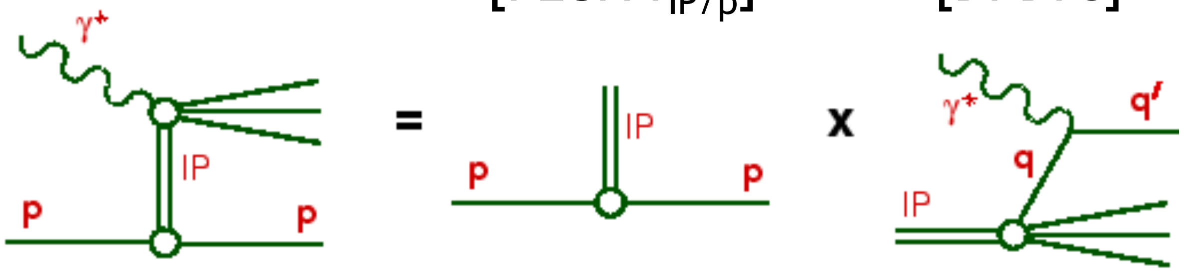


$g \to q\bar{q}$ $\qquad$ $q \to qg$

Internally self-consistent, but (unlike quark density extractions), this is model (DGLAP) dependent!

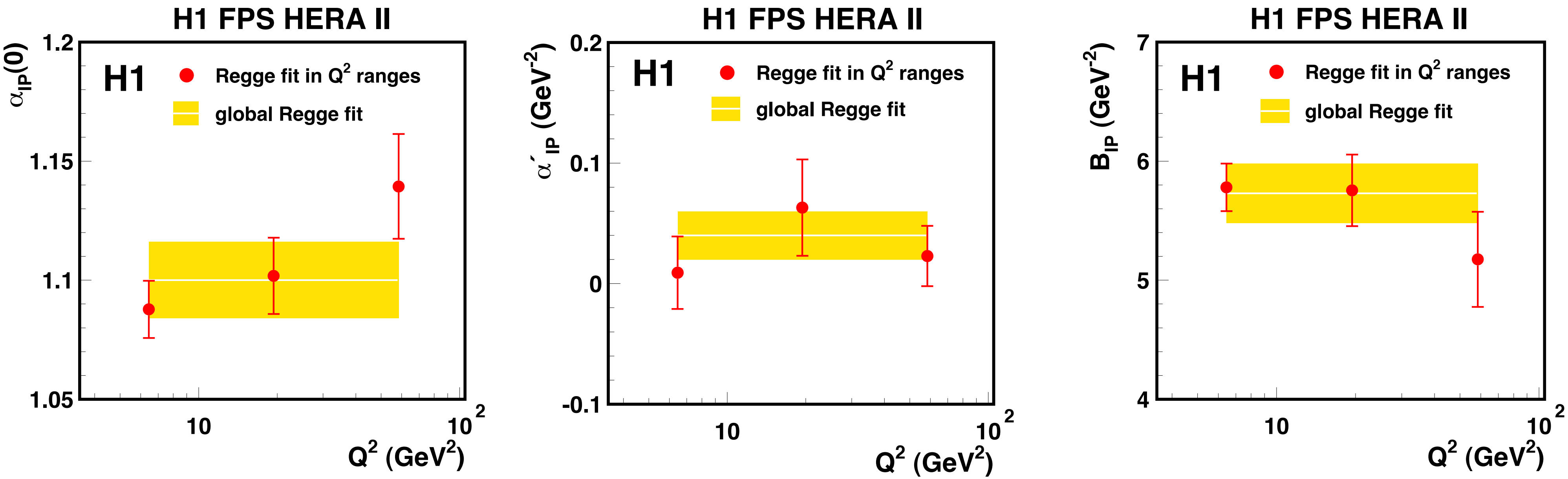
Factorisation and Pomeron Trajectory

[FLUX $f_{IP/p}$] [DPDFs]



$$f_{IP/p}(x_{IP}, t) = \frac{e^{B_{IP} t}}{x_{IP}^{2\alpha_{IP}(t)-1}}$$

$$\alpha_{IP}(t) = \alpha_{IP}(0) + \alpha'_{IP} t$$



No evidence for Q^2 or β dependence of $\alpha_{IP}(t)$ or t slope

$\alpha_{IP}(0)$ consistent with soft IP → Dominantly soft exchange

α_{IP}' smaller than soft IP → Absorptive effects?...

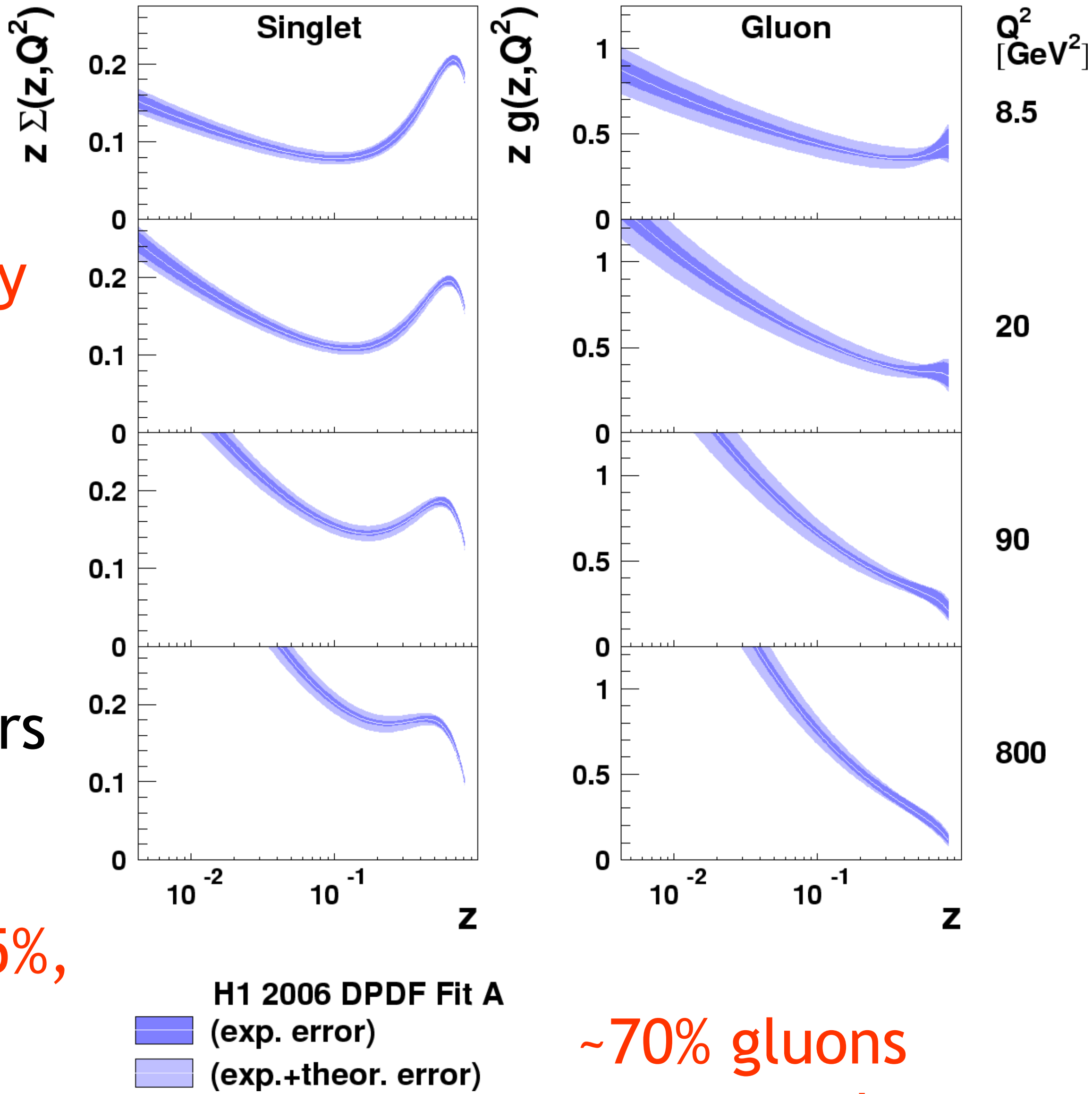
'H1 2006 DPDF Fit A' (log z scale)

χ^2 ~158 / 183 d.o.f.

- Experimental uncertainty obtained by propagating errors on data through χ^2 minimisation procedure

- Theoretical uncertainty by varying fixed parameters of fit and Q^2_0 (s.t. $\Delta\chi^2 = 1$)

- Singlet constrained to ~5%, gluon to ~15% at low z, growing a lot at high z



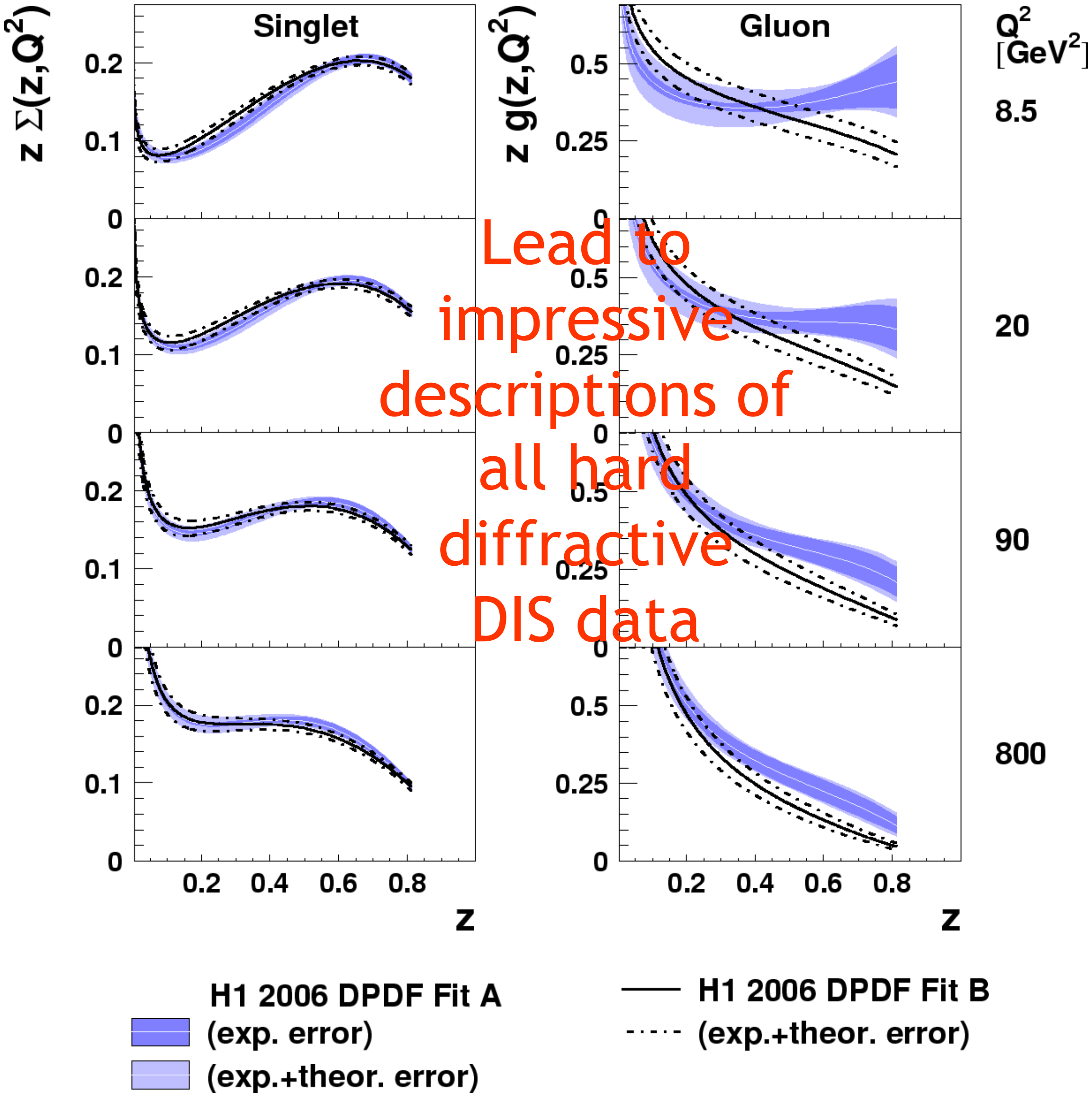
~70% gluons integrated over z

`Fit A' and `Fit B' DPDFs (linear z scale)

- Lack of sensitivity to high z gluon confirmed by dropping (high z) C_g parameter, so gluon is a constant at starting scale!

- **Fit B**
  χ^2 ~164 / 184 d.o.f.

- Quarks very stable
- Gluon similar at low z
- Substantial change to gluon at high z



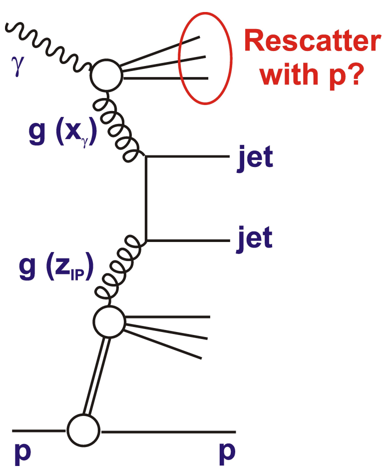
Lead to impressive descriptions of all hard diffractive DIS data

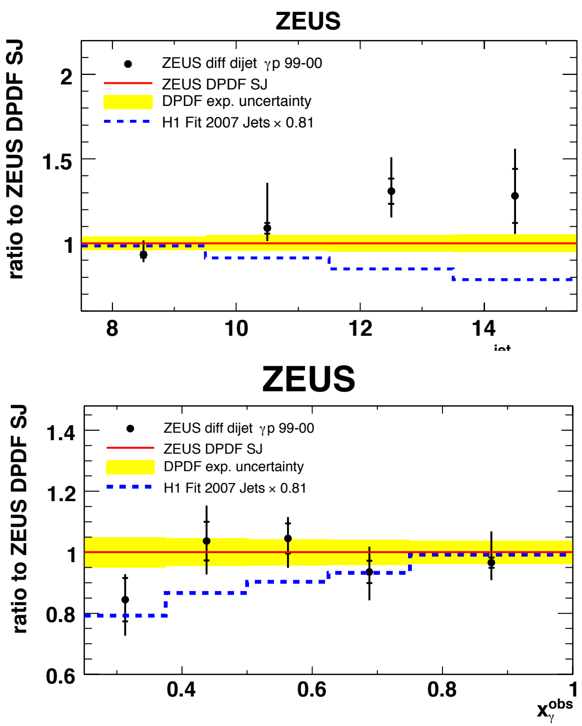
Rapidity Gap Survival Probability in Diffractive Dijet Photoproduction

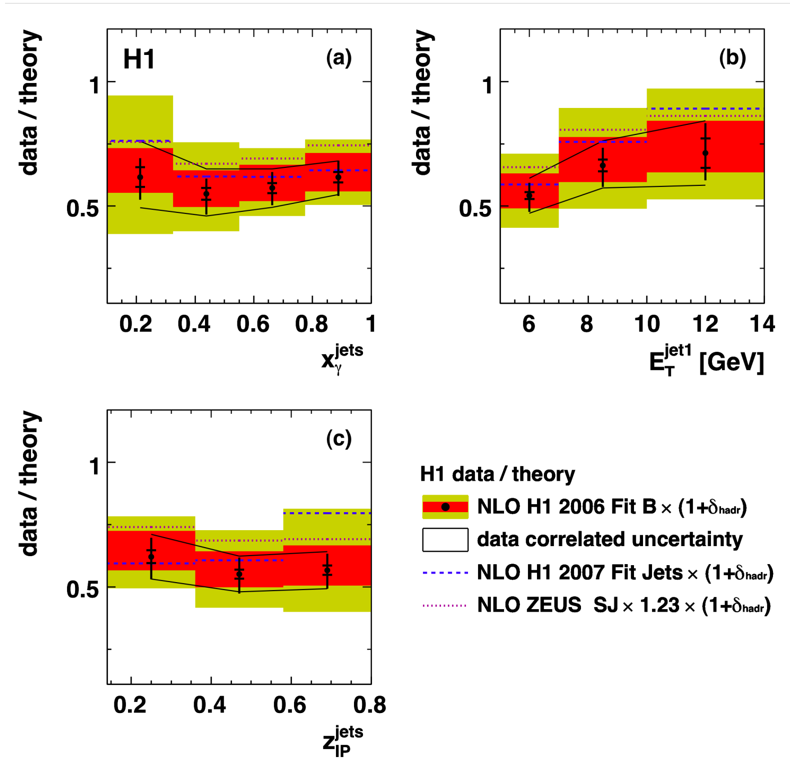
ZEUS [$E_T^1 > 7.5$ GeV]… No evidence for any gap destruction

H1 [$E_T^1 > 5$ GeV]… Survival probability < 1 at 2σ significance

$$\sigma(\text{H1 data}) / \sigma(\text{NLO}) = 0.58 \pm 0.12\ (\text{exp.}) \pm 0.14\ (\text{scale}) \pm 0.09\ (\text{DPDF})$$







- Gap survival unexpectedly has little dependence on x_γ
- Hint of a dependence on jet E_T?

Refined gap Survival Model (KKMR)

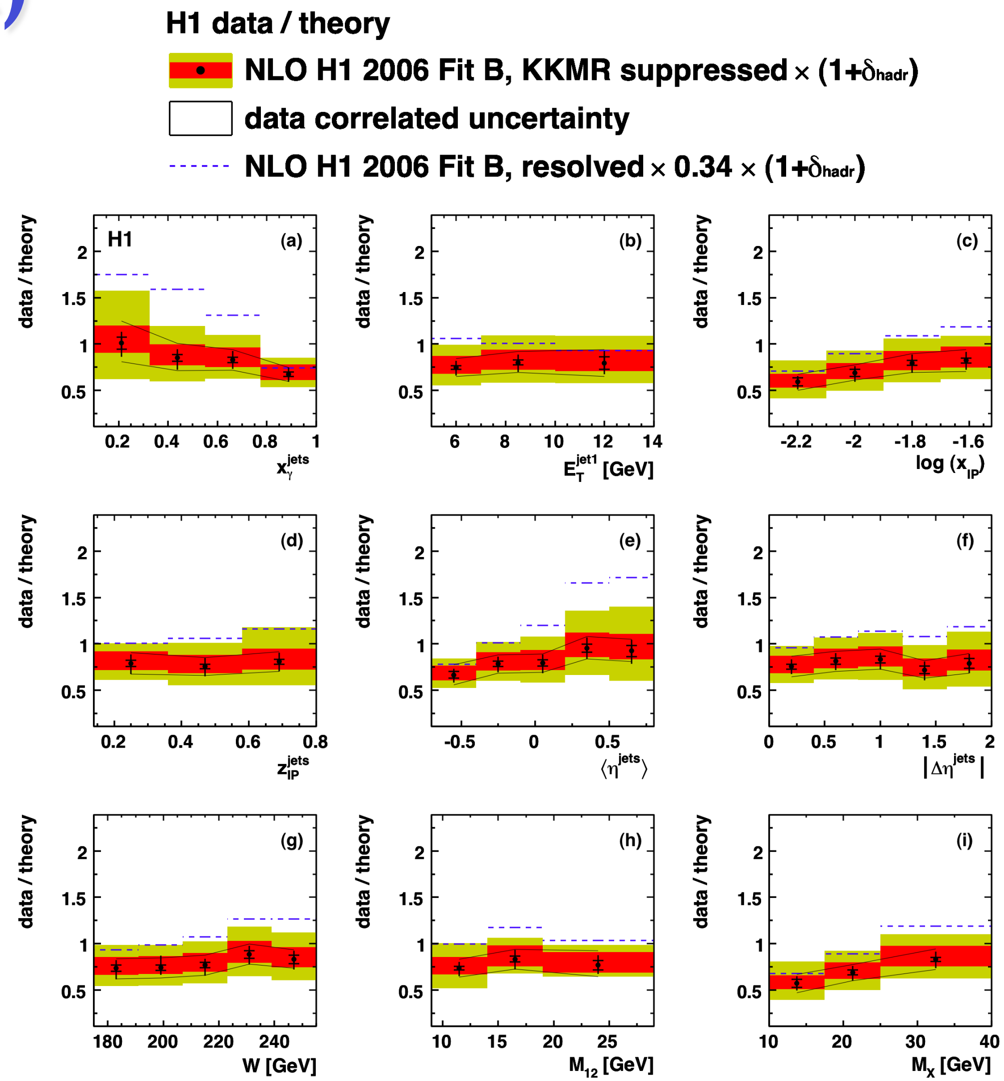
[hep-ph/0911.3716]

Direct contribution remains unsuppressed

Suppression factor 0.34 applies to Hadron-like (VMD) part of photon structure only (low $x_\gamma < 0.1$)

Point-like (anomalous) part of photon structure has less suppression (~0.7-0.8)

Smaller gap destruction effects with some E_T dependence



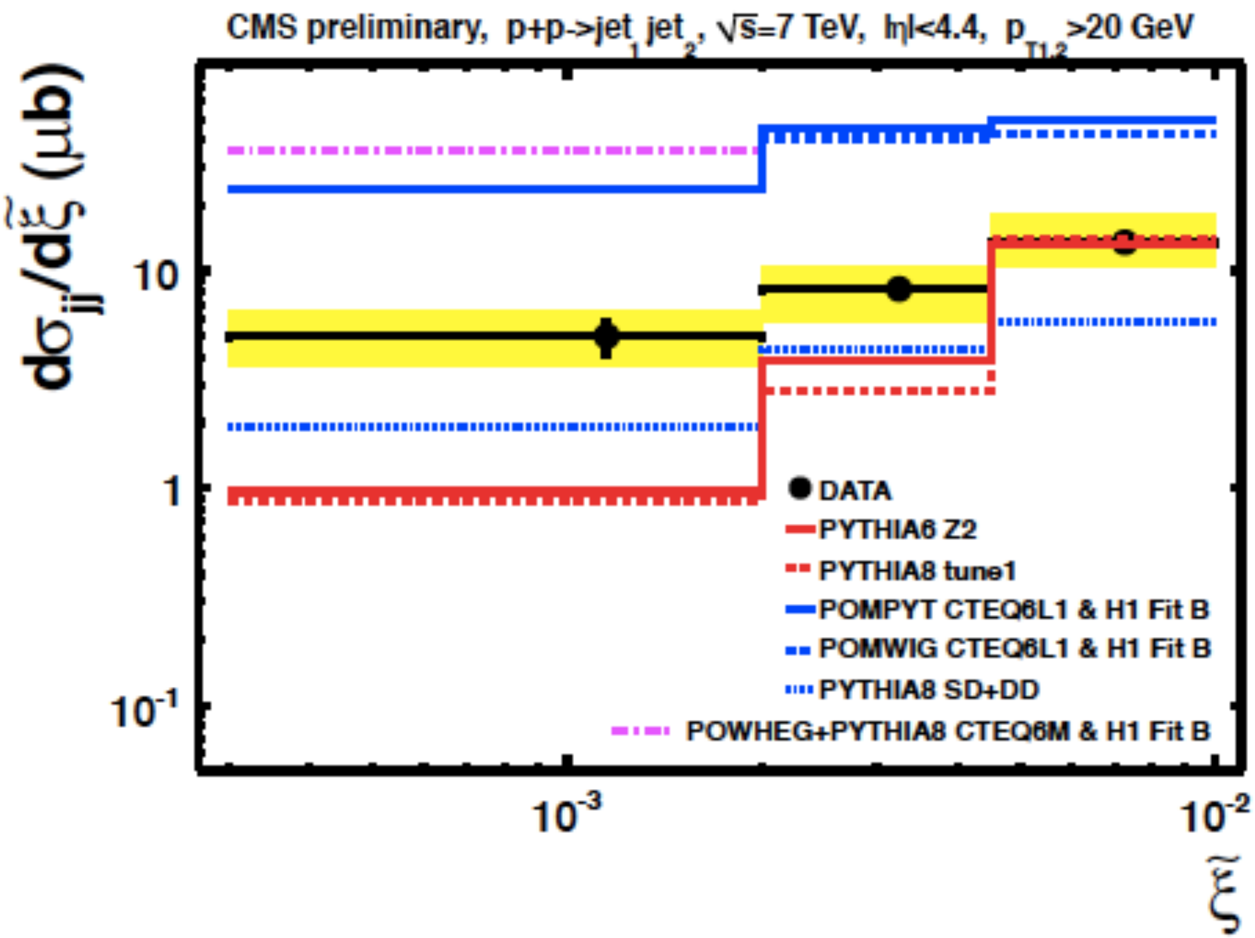
Fair agreement with both H1 and ZEUS data …

Now CMS Jets

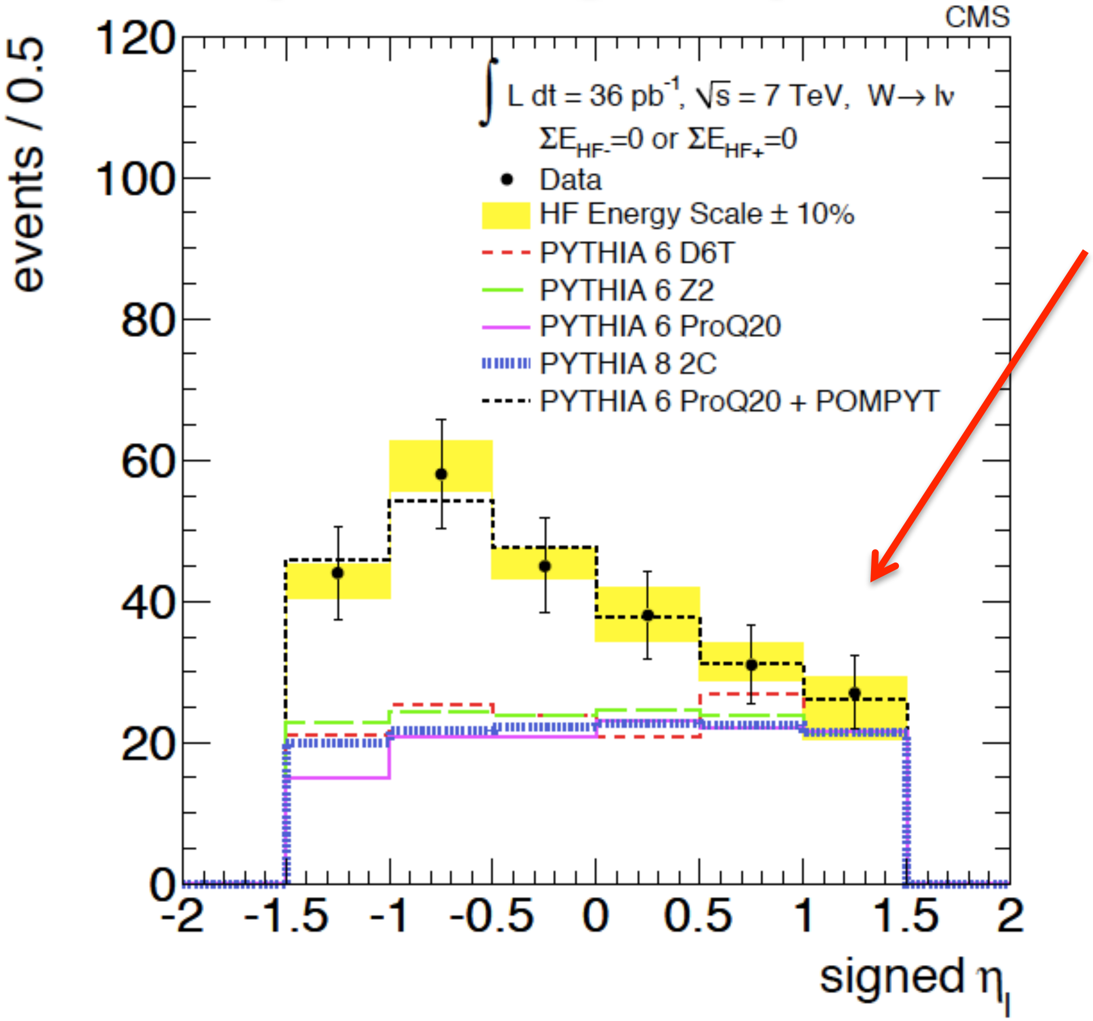
… after gap cut and correction to cross section level …

It's a mystery!

Only proton-tagged
Data can resolve
Really complicated
Issue of tails of
ND distribution to
Large gaps



Exploiting Gap-Lepton η Correlation



Lepton pseudorapidity with + sign if lepton in same hemisphere as gap, else – sign.

Fit to combination of PYTHIA and POMPYT hard diffraction model suggests significant (~50%) diffractive contribution

Extraction of (limits on?) gap survival probabilities at the LHC from diffractive W/Z and jet production eagerly awaited … survival may be small (~3% according to phenomenology)