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Forward physics with early ATLAS data

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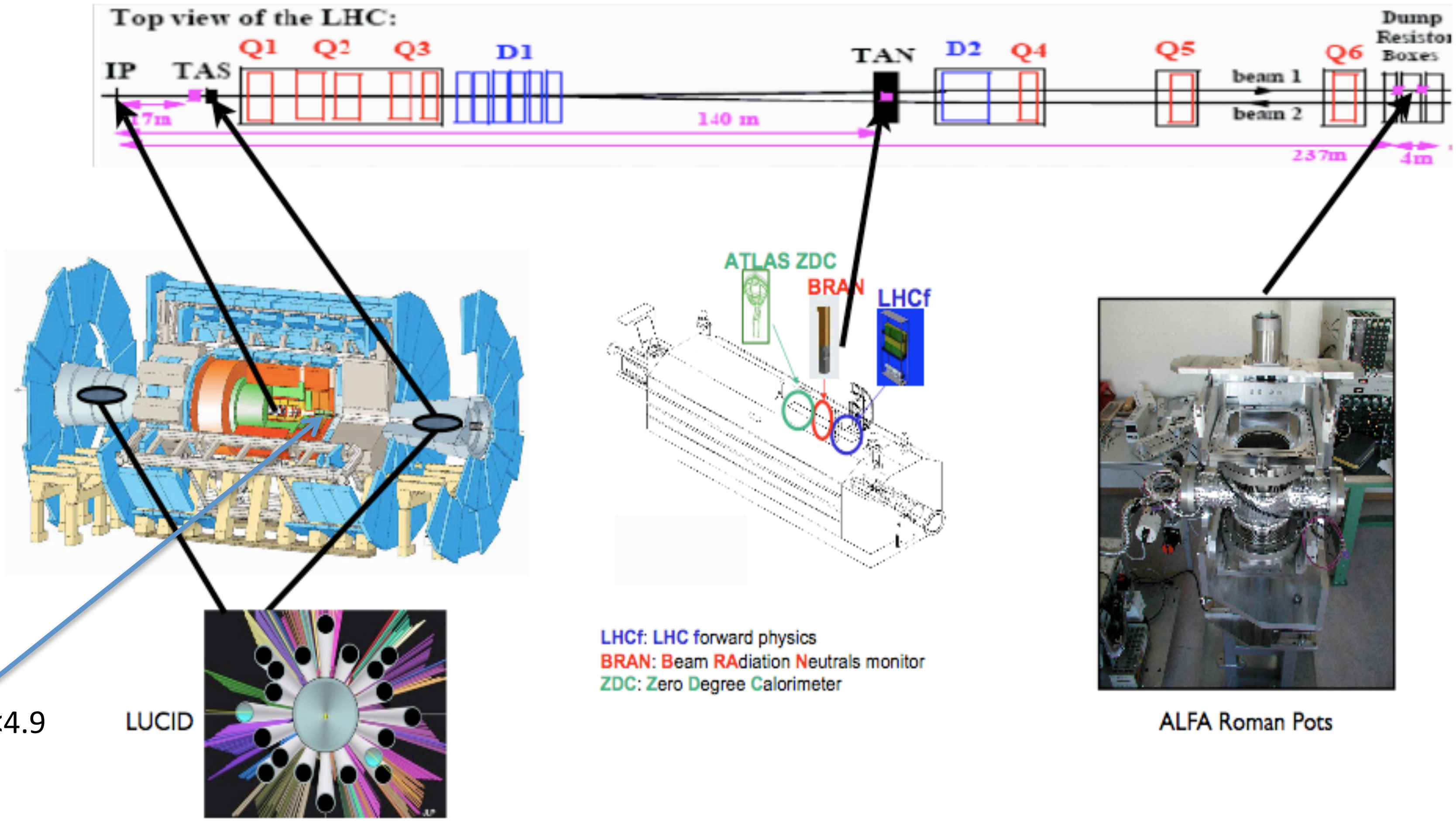
Talk given at the London Workshop on Early LHC SM Measurements,
UCL, London, 30th March 2009.

Overview

1) Forward physics using the ATLAS detector
2) Soft and hard diffraction
3) Central exclusive production
4) Gaps-between-jets

The ATLAS forward detector system



FCAL:
3.2<|η|<4.9

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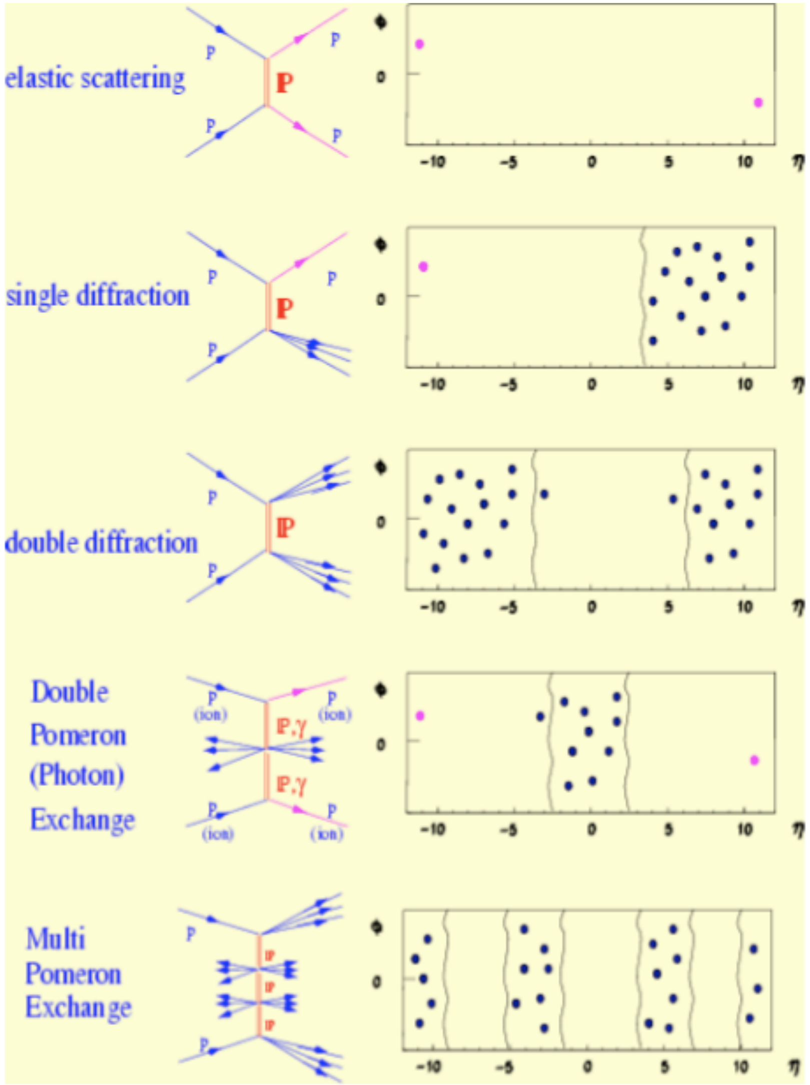
Forward physics processes at the LHC



- Forward physics processes are characterized by 'rapidity gaps' in the detector
  - Need to identify gaps using calorimeter and charged track information.
  - Have to measure before pile-up becomes a problem, or correct for pile-up.
  - Best time to do this physics is with early data. Expect approx 200pb^{-1} by end of 2010.

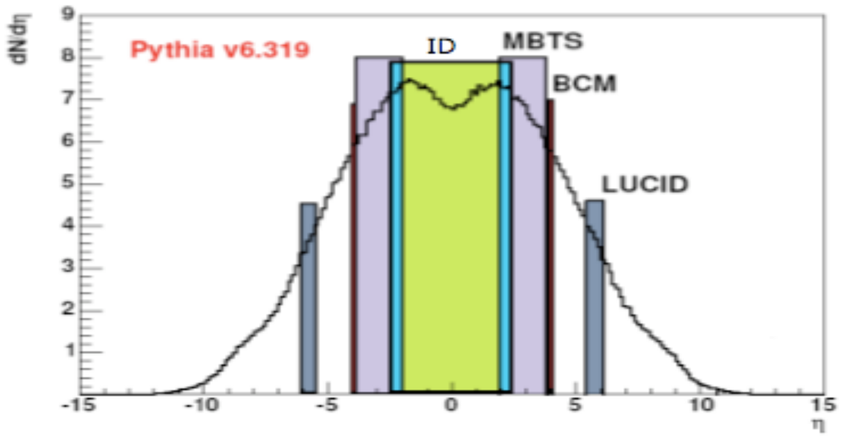
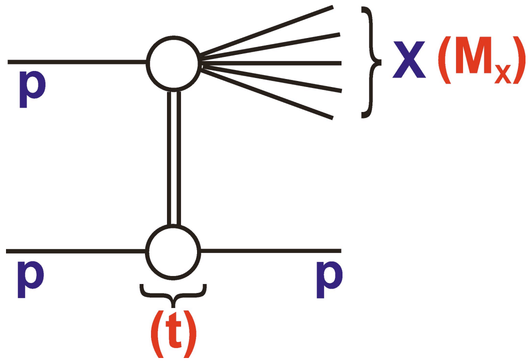
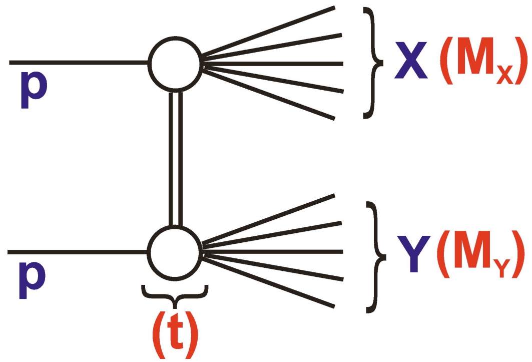


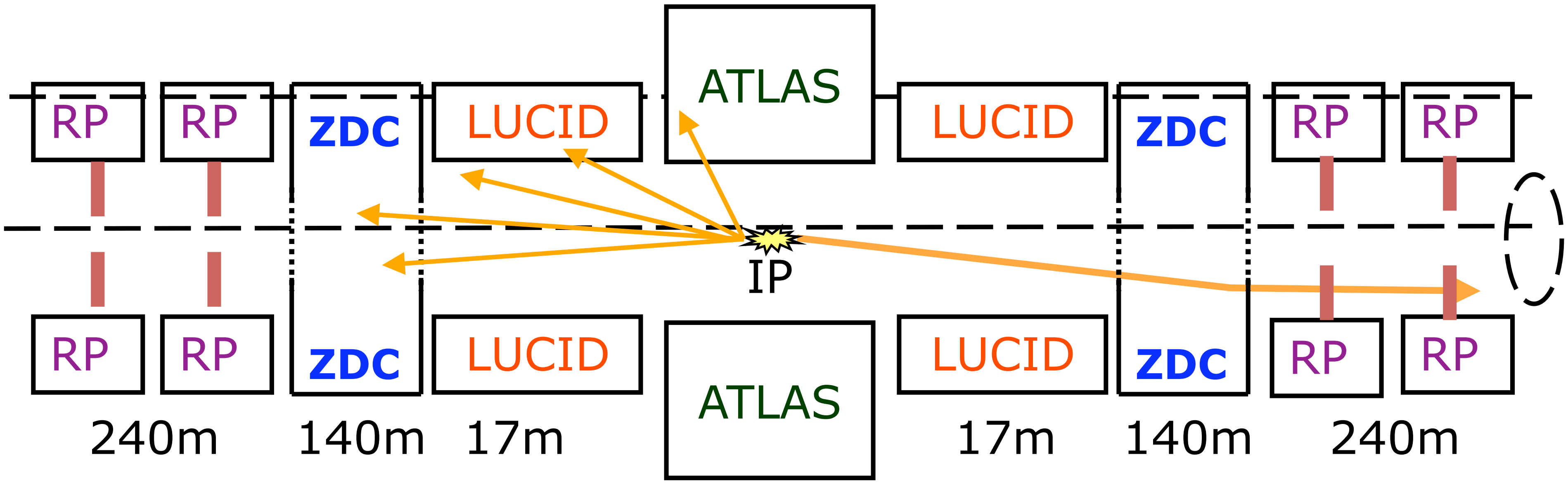
Fig.8: Detector acceptance of different sub-detectors for PYTHIA generated non-diffractive events

Soft diffraction





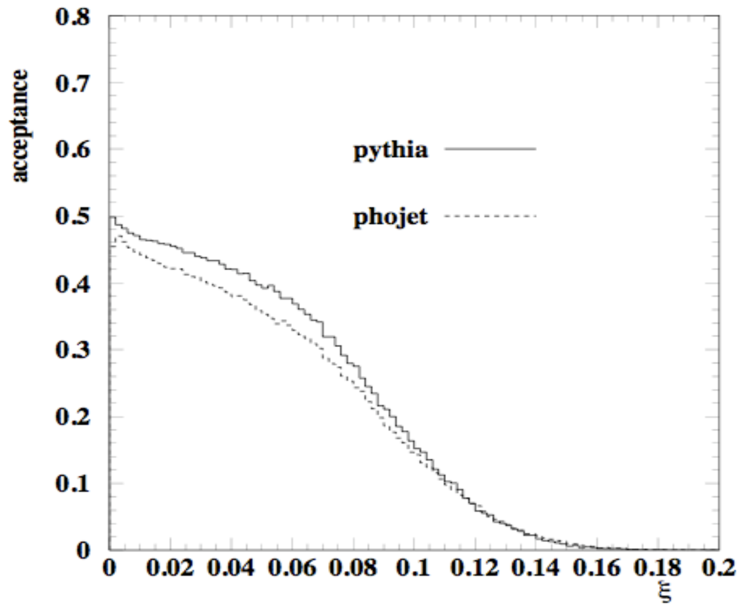
- Single and double diffractive dissociation have large cross section [O(mb)]
- First measurement of rapidity gap processes at LHC – study of underlying event/soft survival. Impacts on understanding pile-up at high luminosity.



Soft single diffraction (II)

- Most ATLAS studies have focused on using ALFA during special 'luminosity' runs to measure soft-SD proton spectrum.
- Require hits in LUCID and energy in ZDC to tag the diffractive dissociation.
- Proton tag in ALFA – measure proton ξ.
- 1.2-1.8 million events with 100hrs at $L=10^{27}cm^{-2}s^{-1}$.
- BUT, ALFA requires special running conditions

Efficiency [%]	Pythia	Phojet
Preselection		
ξ<0.2	97.1	94.8
ZDC [E>1 TeV]	53.9	38.7
LUCID [1 track]	45.2	57.3
Total preselection	75	74
RP selection		
ALFA (Relative to preselection)	60.1	54.2
Total acceptance	45.0	40.1



- Want to measure the diffractive ξ distribution:

$$\xi = 1 - \frac{|p'_z|}{|p_z|}$$

- p_z= beam momentum
- p_z'= outgoing proton momentum

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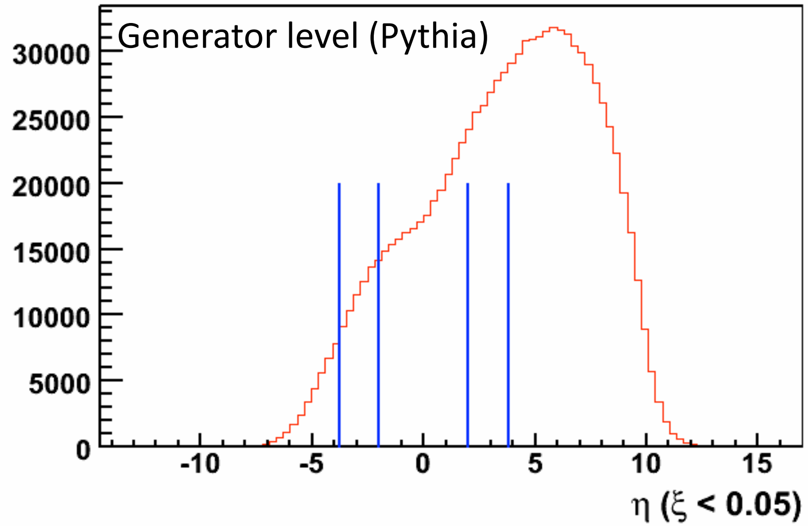
Soft diffraction (III)

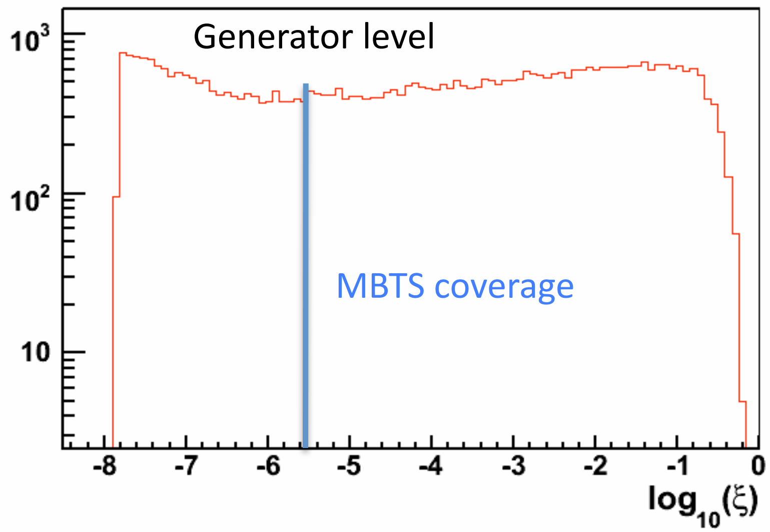
- Can measure SD without proton tag using same LUCID/ZDC requirements but using a rapidity gap to infer an outgoing proton.
  - Measure the diffractive mass, M_X, of the dissociative system rather than ξ:

$$\xi = \frac{\mathbf{M_X^2}}{\mathbf{s}}$$

  - M_X measured using calorimeter clusters and tracking information.

- Events retained using the Minimum Bias Trigger Scintillators (MBTS).
  - The MBTS are rings of trigger scintillators covering 2.09<|η|<3.84.
  - Particles from soft-SD events with ξ<0.05 can be found in both MBTS stations.





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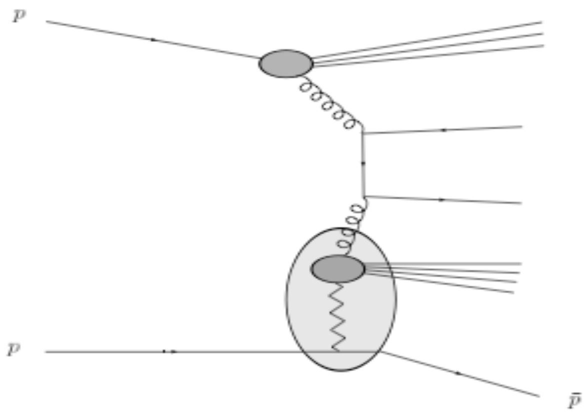
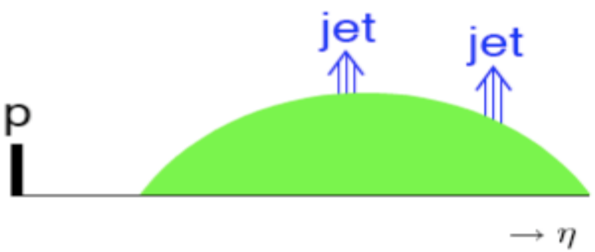
Diffractive di-jet production



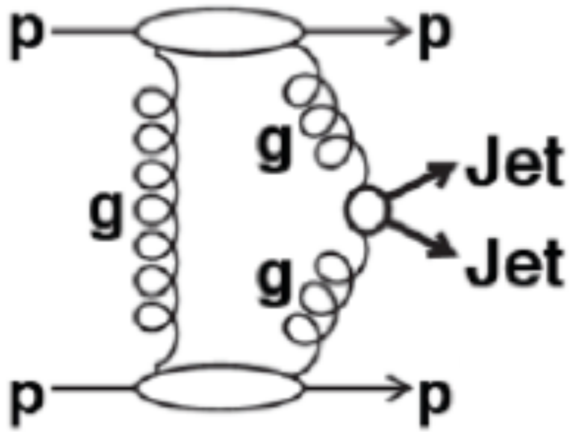


- Diffractive di-jet production:
  - Measure single diffractive to non-diffractive di-jet ratio, R(SD/ND).
  - Also look for double pomeron exchange (DPE) di-jet production, measure R(DPE/SD).
  - Allows study of soft-survival, diffractive PDFs.
- Impose one (or two) rapidity gaps in forward detectors to search for SD (DPE).
  - Expect a few thousand SD di-jet events in 100pb^{-1} with E_T>20GeV (after trigger pre-scale and gap requirement).
  - New trigger possibilities being examined to increase rate.

(No trigger prescale)

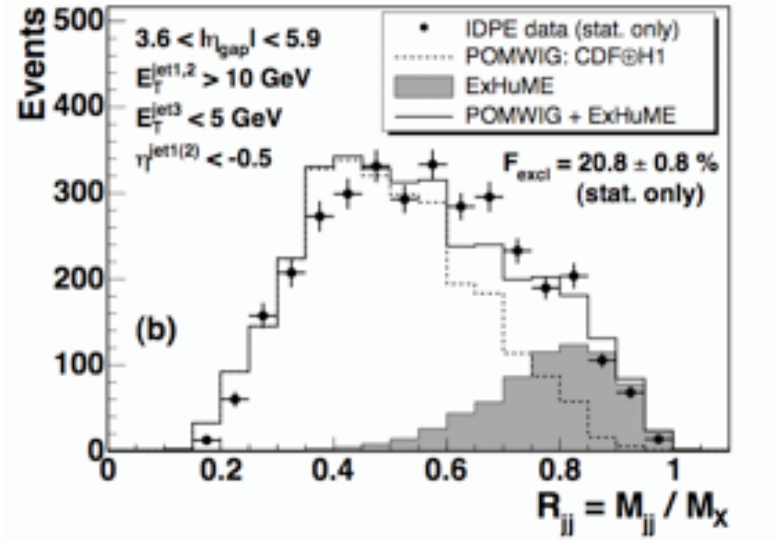
$p_T(GeV)$	x_{pom}	σ (pb)	gap type	efficiency	Events in 100 pb^{-1}
20	< 0.01	7.2×10^5	FCAL	0.4	2.9×10^7
20	< 0.1	3.6×10^6	FCAL	0.08	2.9×10^7
40	< 0.1	2.1×10^5	FCAL	0.05	1.0×10^6
40	< 0.1	2.1×10^5	LUCID,ZDC	0.44	9×10^6

Central exclusive di-jet production (I)



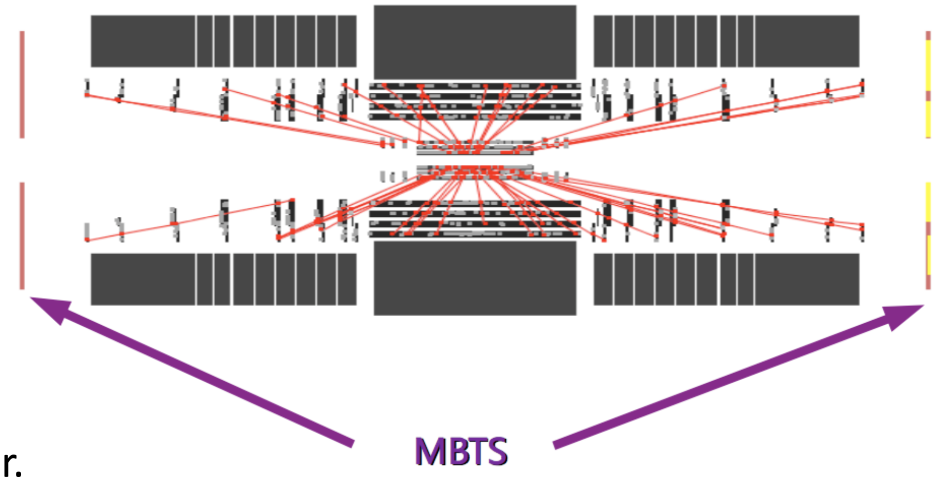
- Protons remain intact during interaction.
- Observable: Two jets and no other hadronic activity
- Allows study of theoretical framework, such as Sudakov effects and unintegrated PDFs.
- Early testing ground for exclusivity variables needed to observe exclusive Higgs production using new proposed forward proton detectors at ATLAS/CMS (arXiv: 08061097).

- CDF have observed a 6σ excess of events at Rjj≈1.
  - Rjj is an exclusivity variable that compares the invariant mass of the di-jets to the invariant mass of everything in the calorimeters.
  - Similar measurement possible at ATLAS.

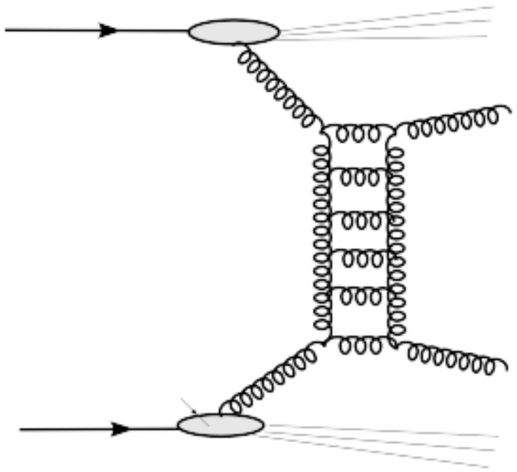


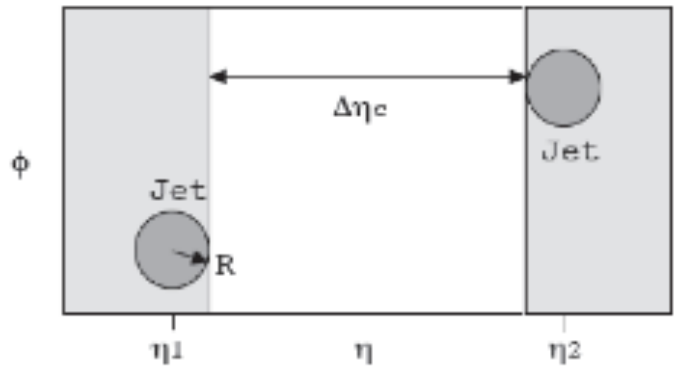
Central exclusive di-jet production (II)

- Standard jet triggers at ATLAS are heavily prescaled:
  - At L1, the L1_18 trigger (1 or more jets with E_T>18GeV) will have a prescale of 6000 at L=10^{31} cm^{-2} s^{-1} (70-100 pb^{-1} per year).
  - Less than 1 CEP di-jet event per 10pb^{-1} of data.
- New trigger developed: L1_J18_MV:
  - At least one jet with E_T>18GeV, plus an empty MBTS on one side of ATLAS
  - MBTS covers 2.09<|η|<3.84
- Expect that:
  - 65% of exclusive events retained by trigger with respect to the L1_J18 item.
  - Only 1 in 15000 inclusive events pass trigger.
  - Un-prescaled trigger rate of 0.5Hz at L=10^{31} cm^{-2} s^{-1}.
  - Approximately 400 CEP di-jet events per pb^{-1} of data.



Gaps-between-jets (I)

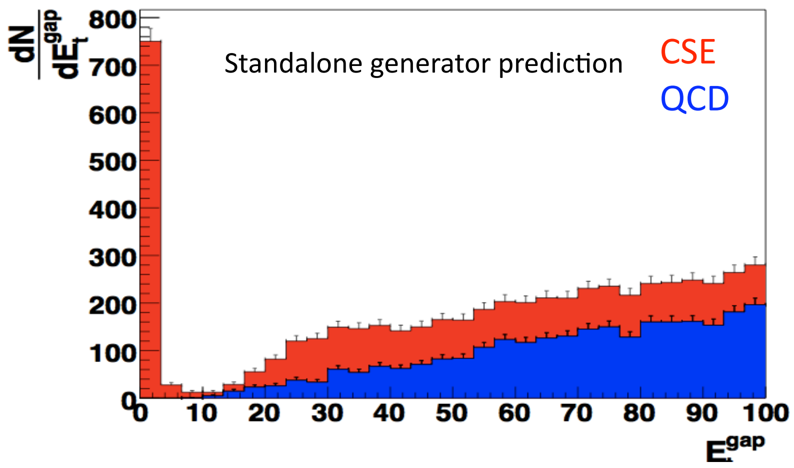




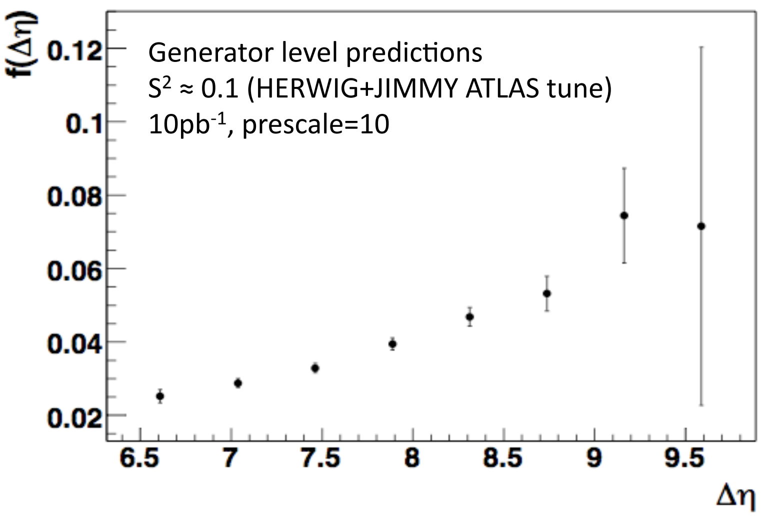
- Events containing two forward jets, separated by a large rapidity interval containing little hadronic activity.
  - Colour singlet exchange (CSE). No colour flow between jets
  - Observed by Tevatron and HERA, but exact nature of exchange not determined.
- Search through inclusive two-jet events for those that contain a rapidity gap (reduced activity) between the jets:
  - If CSE exchange is BFKL-like, then expect the fraction of events that contain a rapidity gap to increase with the separation of the jets.

Gaps-between-jets (II)

- H1 method used to identify events that have reduced activity between the jets:
  - K_T algorithm used to cluster calorimeter energy deposits into mini-jets.
  - Two leading jets identified (E_T>30GeV)
  - E_T of mini-jets between leading jets summed to give E_T^{gap}.

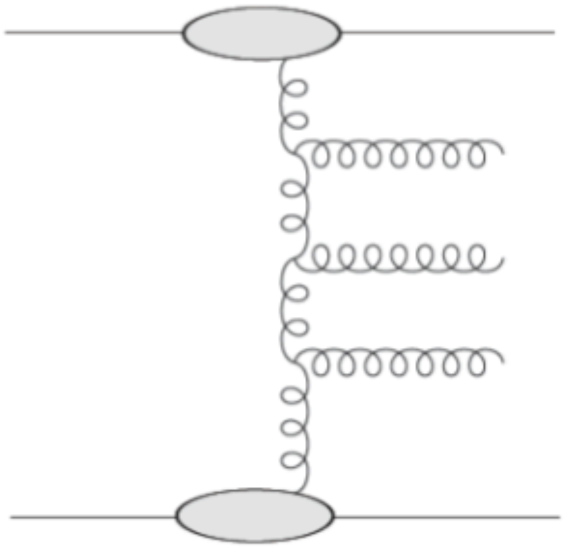


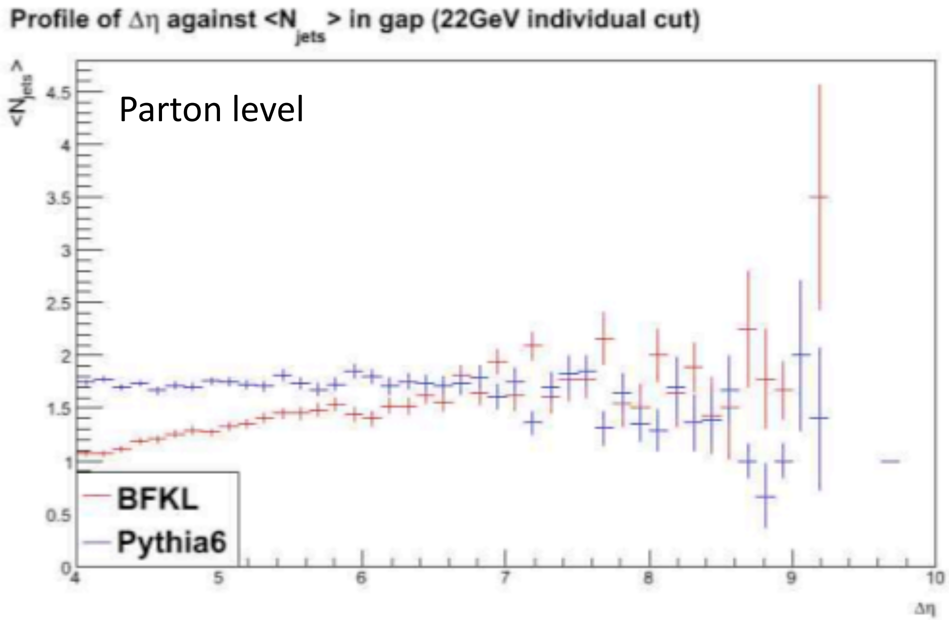
- Expect CSE events to have $E_t^{gap} \approx 0$.
  - But get many events with higher values due to multiple parton-parton interactions
  - Extract events with E_T^{gap} < 10GeV to obtain the gap fraction.
  - Measurement possible with around $10pb^{-1}$ of data.



Gaps-between-jets (III)

- Parallel inclusive forward jet studies pursued at ATLAS:
  - Mueller-Navelet jets and QCD evolution.
  - Radiation between jets – see also latest theory predictions by Simone Marzani.





Summary

Soft and hard diffraction

1) Soft single and double diffractive processes can be studied with very early data. Further studied with ALFA in special runs.
2) Single diffractive to non-diffractive di-jet ratio should be measured with $10\text{-}100pb^{-1}$

Central exclusive production

3) New jet-plus-gap trigger will yield a few thousand CEP events in $10pb^{-1}$ of data.

Gaps-between-jets

4) Nature of hard colour singlet exchange studied with around $10pb^{-1}$ of data.
5) Mueller-Navelet jets and QCD radiation between jets studied in parallel.