Forward Physics at ATLAS

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Outline

1) Forward detectors at ATLAS
2) Early measurements with 2009/2010 data:
   - Hard and soft diffraction
   - Exclusive production
   - Forward Jets
3) Prospects for 2011 onwards

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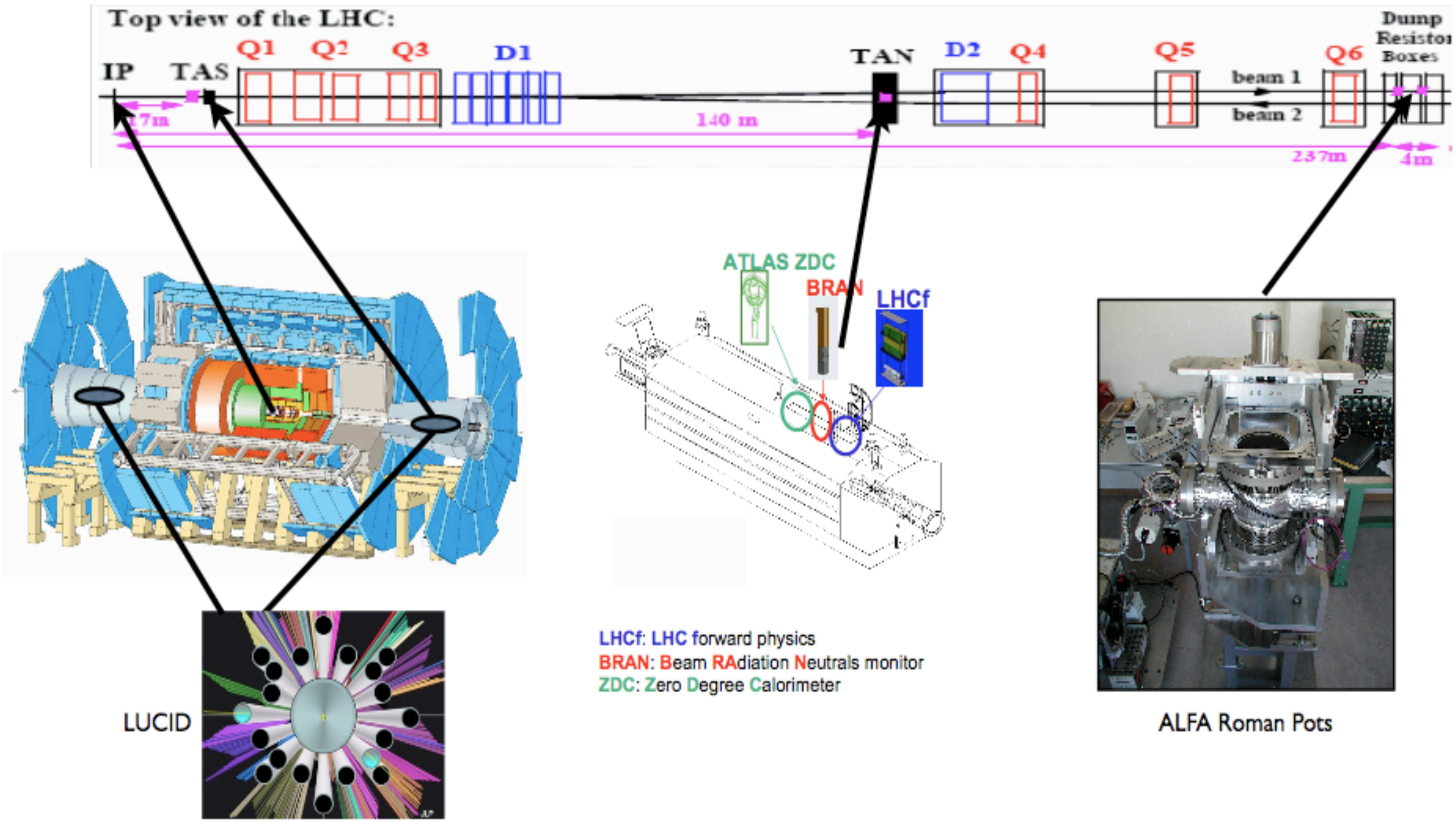
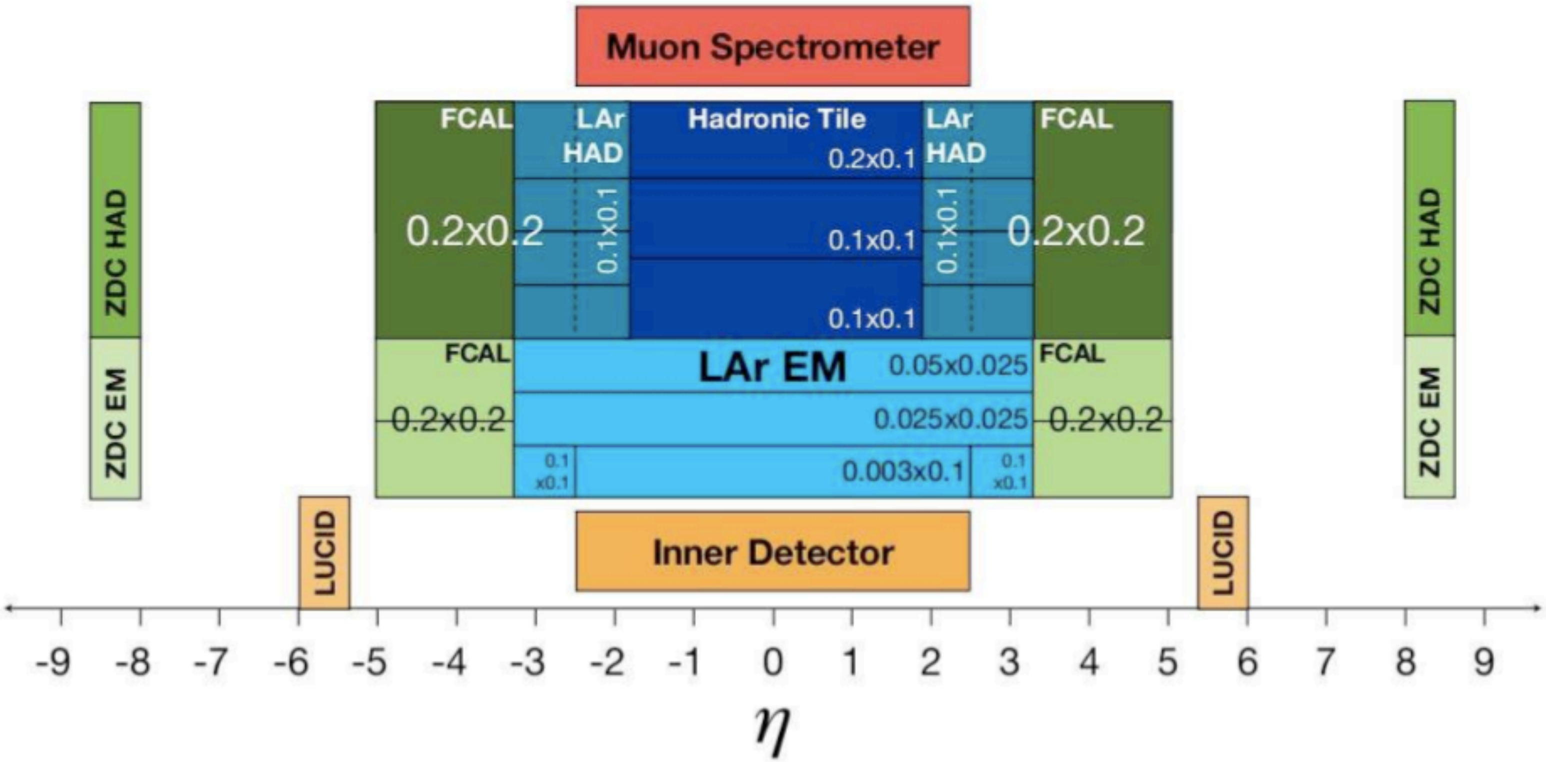
The ATLAS forward detector system



The ATLAS detector – η coverage



- Central detector consists of:
  - Inner tracking detector covering |η|<2.5.
  - Electromagnetic calorimeters covering |η|<3.2.
  - Hadronic calorimeters covering |η|<4.9.
  - Muon spectrometer covering |η|<2.7.

Possible LHC running scenario* (2009/2010)

- After commissioning at injection energy, collisions will take place at 3.5TeV per beam.
  - Current plan* is to take around $60pb^{-1}$ of data in this initial stage.
  - In the region of 40% of this data will be taken with approximately 0.8 interactions per bunch crossing.
  - In the region of 60% with an average of 1.6 interactions per bunch crossing.
  - Pile-up removal will be important for empty ‘rapidity gap’ definitions.

- Energy can then be increased to between 4-5 TeV per beam*. Discussion ongoing as to whether this will take place sooner or later.
  - Number of interactions kept to around 2 per bunch crossing -> pile-up removal techniques as above.
  - Luminosity reaches around $2\times10^{32}cm^{-2}s^{-1}$.
  - Approximately $250pb^{-1}$ of data.

This is just the ‘current’ running scenario. The situation could (i.e. is likely to) be different in some way

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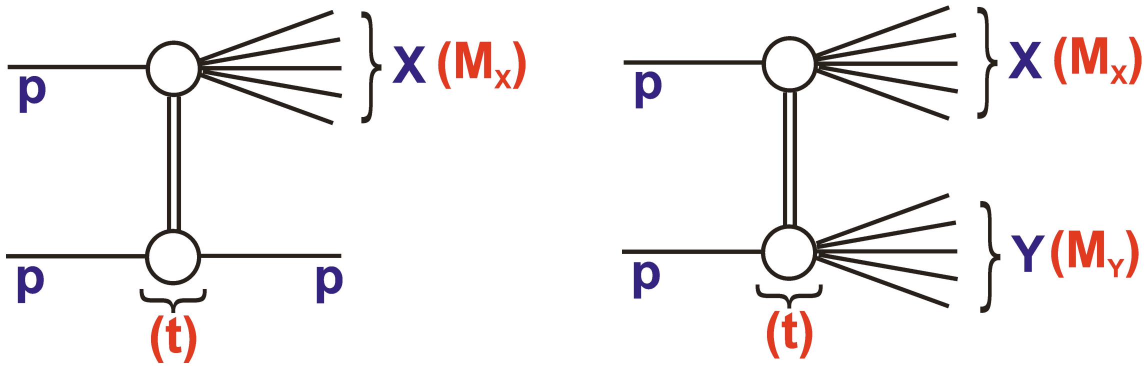
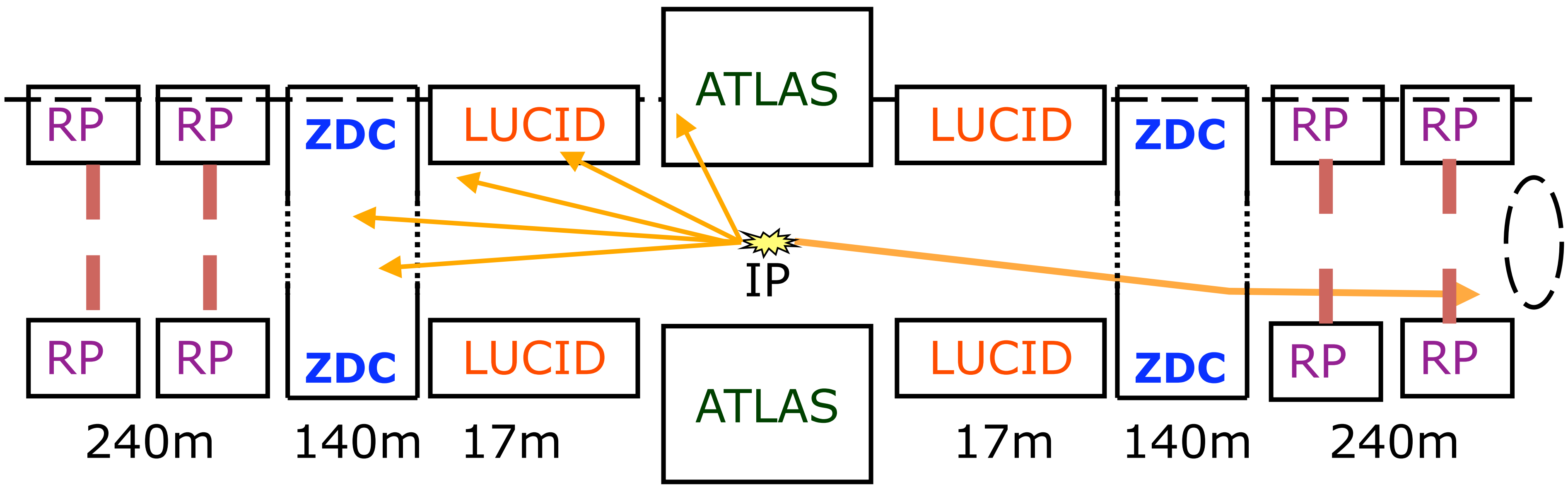
Soft diffraction



- 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 our understanding pile-up at high luminosity.



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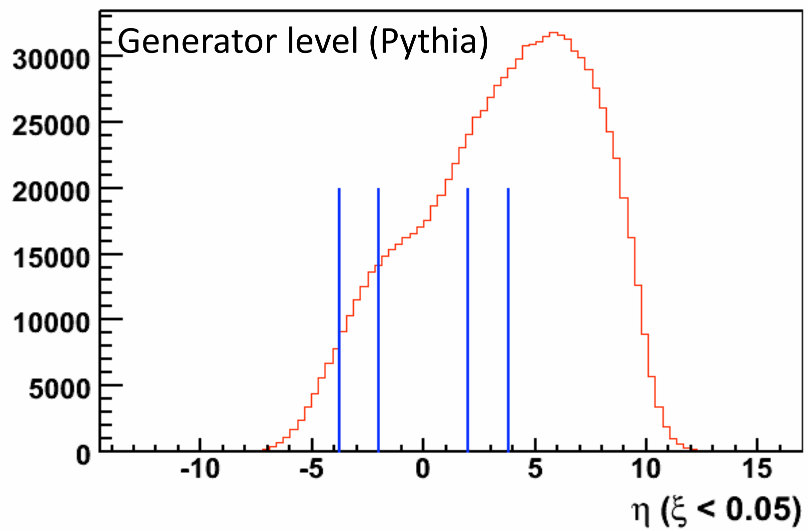
Soft diffraction (II)

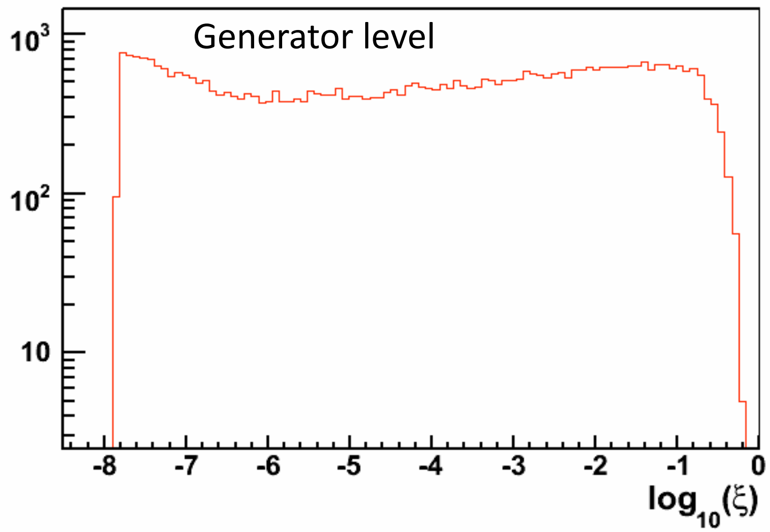
- Rapidity gaps in the calorimeters, LUCID and ZDC used to infer an outgoing proton.
  - Diffractive mass, M_X, of the dissociative system measured and the fractional momentum loss of the (intact) proton defined:

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

  - M_X measured using calorimeter clusters and tracking information.

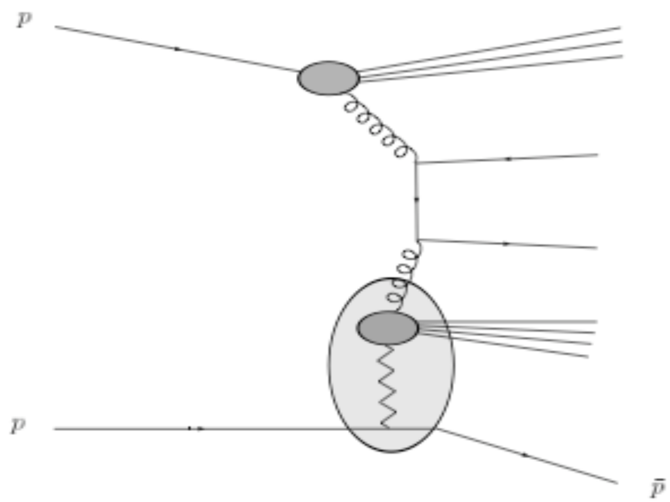
- Events retained using the Minimum Bias Trigger Scintillators (MBTS).
  - The MBTS are rings of trigger scintillators covering 2.09<|η|<3.84.
  - Expect millions of events for analysis.



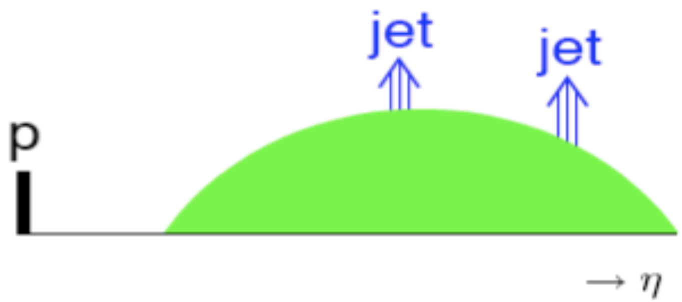


Diffractive di-jet production

- Aim to measure:
  - Ratio of single diffractive (SD) di-jets to non-diffractive (ND) di-jets.
  - Ratio of double pomeron (DPE) to single diffractive di-jets; infer soft-survival effects.
  - Diffractive structure functions.



- Trigger using single jet triggers.
  - Examining use of LUCID, ZDC, MBTS for gap requirement.
- Expect a few thousand SD di-jet events in $100pb^{-1}$ with E_T>20GeV (after trigger pre-scale and gap requirement).
- Expect approximately 10 DPE events in same kinematic region.



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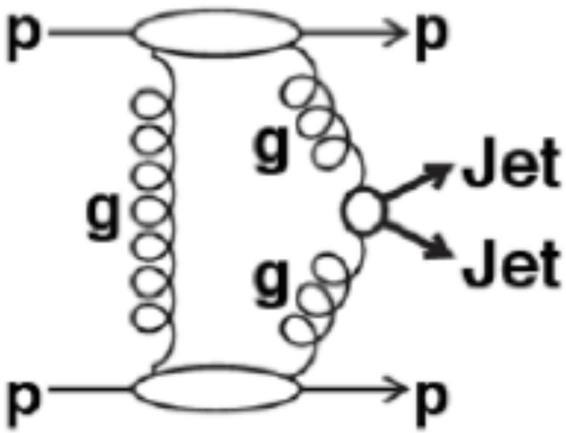
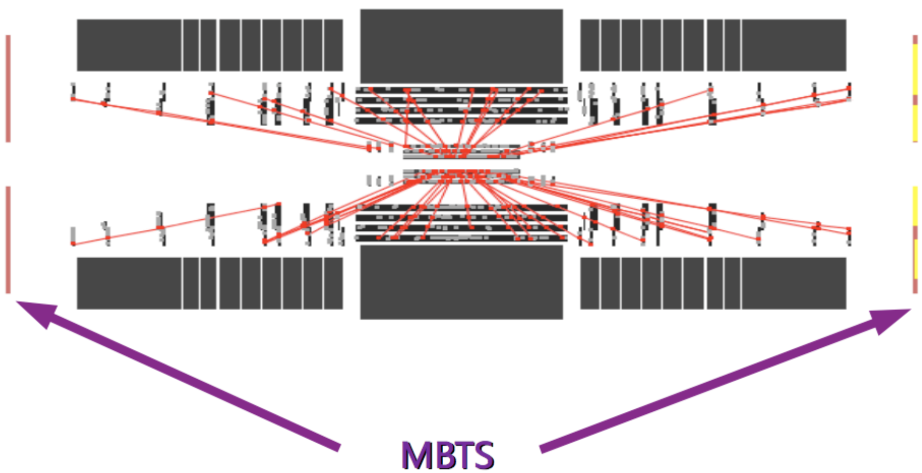
Central exclusive di-jet production



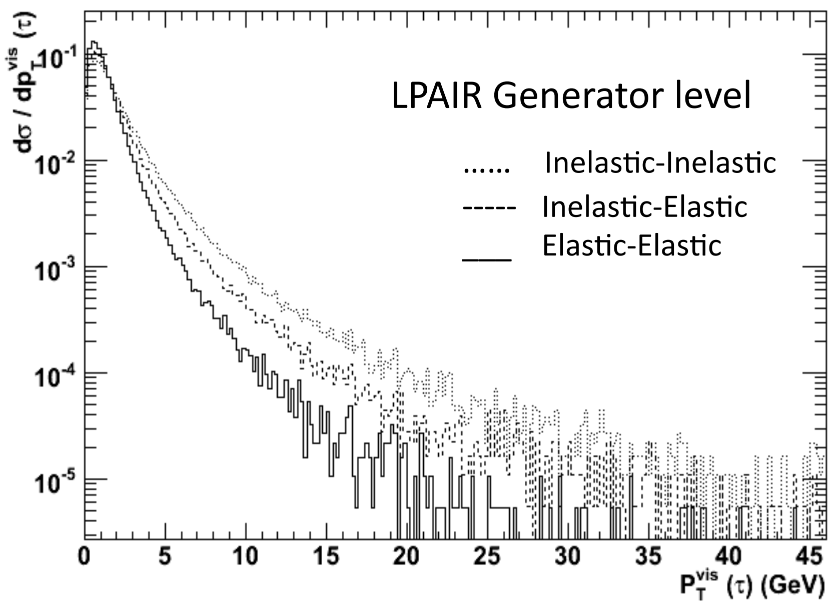
- Protons remain intact during interaction.
- Observable: Two jets and little extra hadronic activity.
- Allows study of theoretical framework, such as Sudakov effects and unintegrated PDFs.
- Constrain theoretical uncertainty (factor of 2-3).

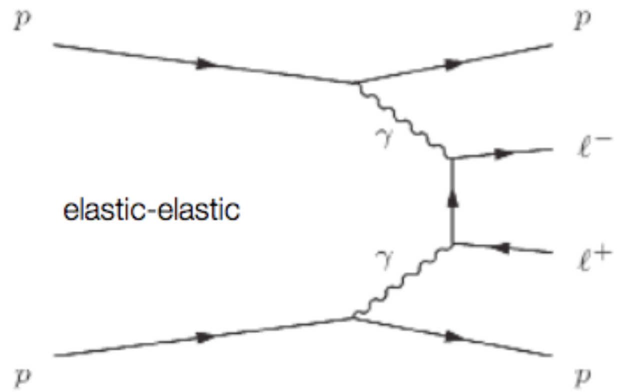
- New Level 1 trigger strategy developed for analysis using jet plus gap; gap defined by empty MBTS on one side of ATLAS.
  - Un-prescaled at $L=10^{31}cm^{-2}\ s^{-1}$.
  - Expect a few hundred CEP events after trigger and analysis cuts with E_T>20GeV in $20pb^{-1}$ of data.
- Trigger can also be used to retain a large statistics sample of low-ξ single diffractive di-jet events.

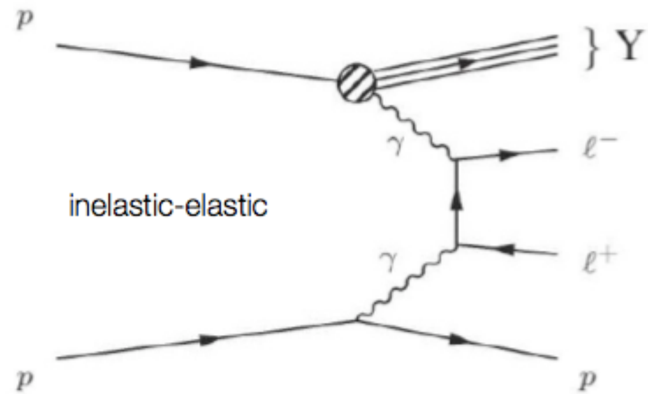


Exclusive ττ production

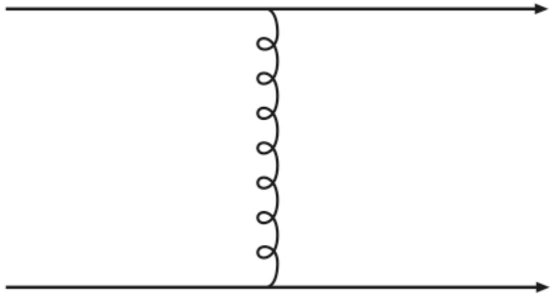
- Exclusive ττ production has a small theoretical uncertainty (<1%).
  - Cross section prediction (LPAIR) is 3pb (elastic + inelastic) for p_T(tau) > 10GeV.
  - From offline selection, expect around 100 events in $100pb^{-1}$
  - Events triggered using
    - (a) single lepton trigger and
    - (b) (b) jet + gap trigger used in exclusive di-jet study.

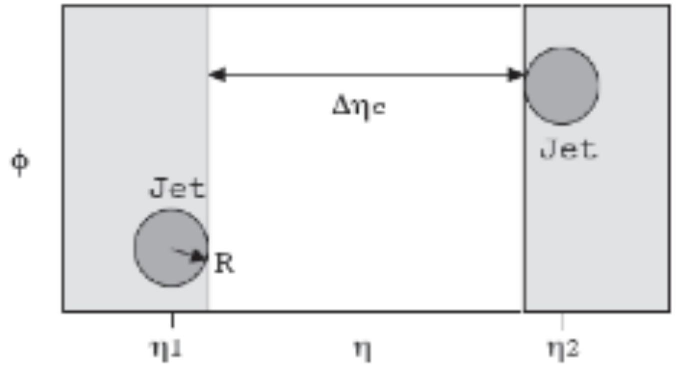


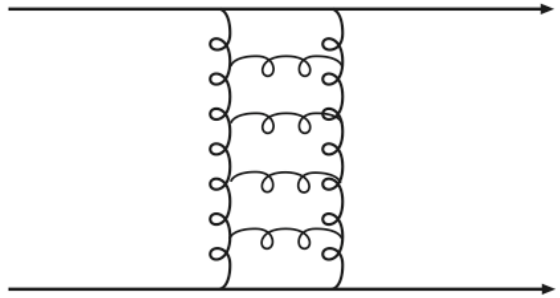




Forward jet studies (I)







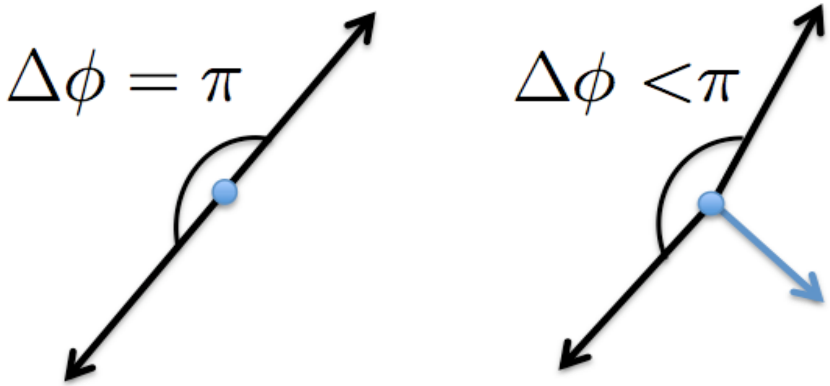
- Di-jet systems in which the jets are separated by at least 3 units of pseudo-rapidity.
- Two processes contribute:
  - Gluon (or quark) exchange between partonic 2->2 scatters (dominant).
  - Hard colour singlet (BFKL gluon ladder) exchange. Up to 10% of di-jet cross section.

- ATLAS measurements will focus on both inclusive measurements and those in which radiation between the jets is limited.
- Calorimeters give a lever arm of up to 9 units in jet-rapidity separation, when using jets with radius parameter set to 0.4.

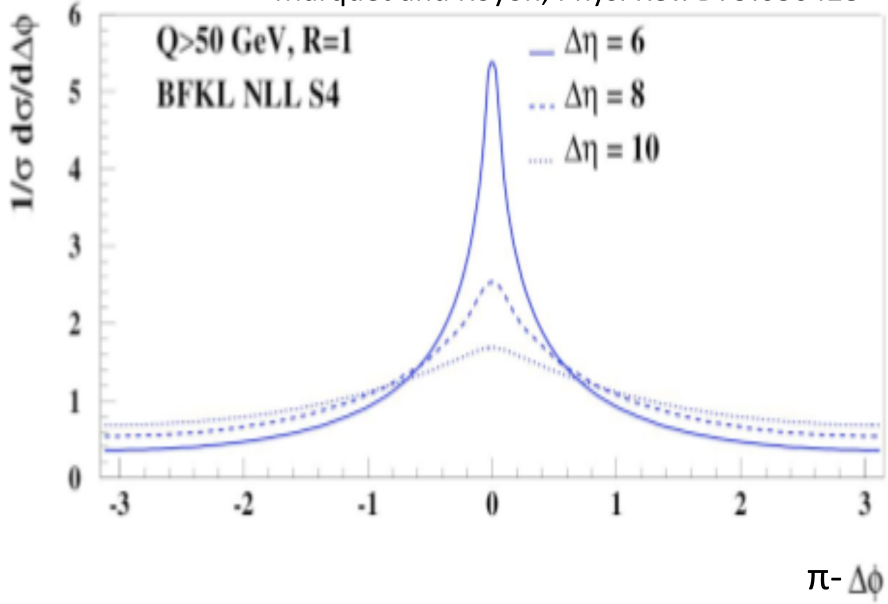
Forward Jets (II) – Azimuthal de-correlation

- Di-jets are back-to-back in azimuth, $\Delta\phi=\pi$, for leading order 2->2 scattering.
- Additional radiation means that $\Delta\phi<\pi$
- De-correlation depends on E_T of the additional radiation.
- Theoretical predictions can be made for this de-correlation using fixed order (NLO), parton shower and BFKL.

- For 1-5pb^{-1}, expect very early measurement for $|\eta|<2.5$.
- Observation of any BFKL effects at large $\Delta\eta$ will probably require more than 100pb^{-1} of data.

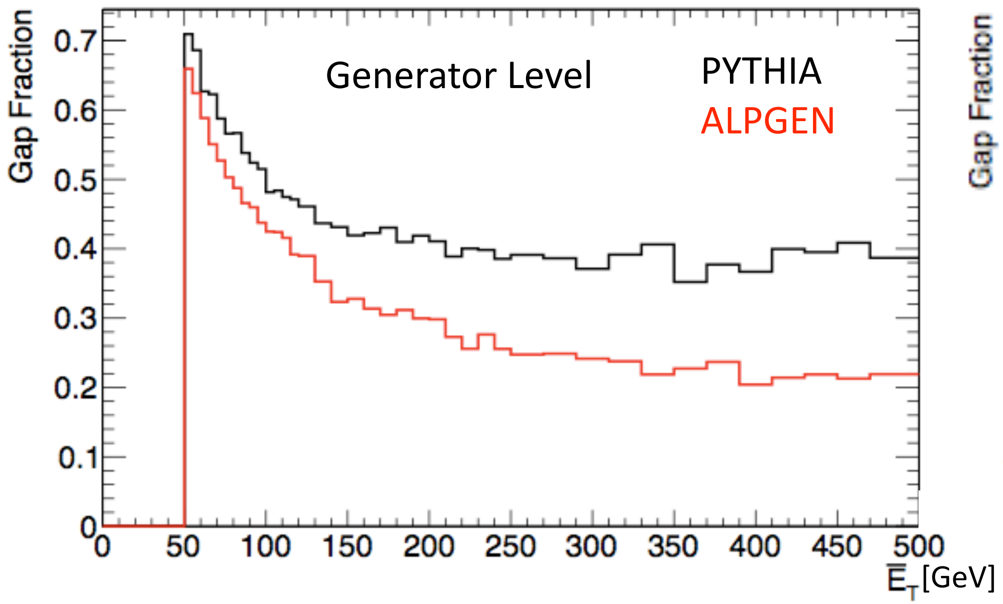


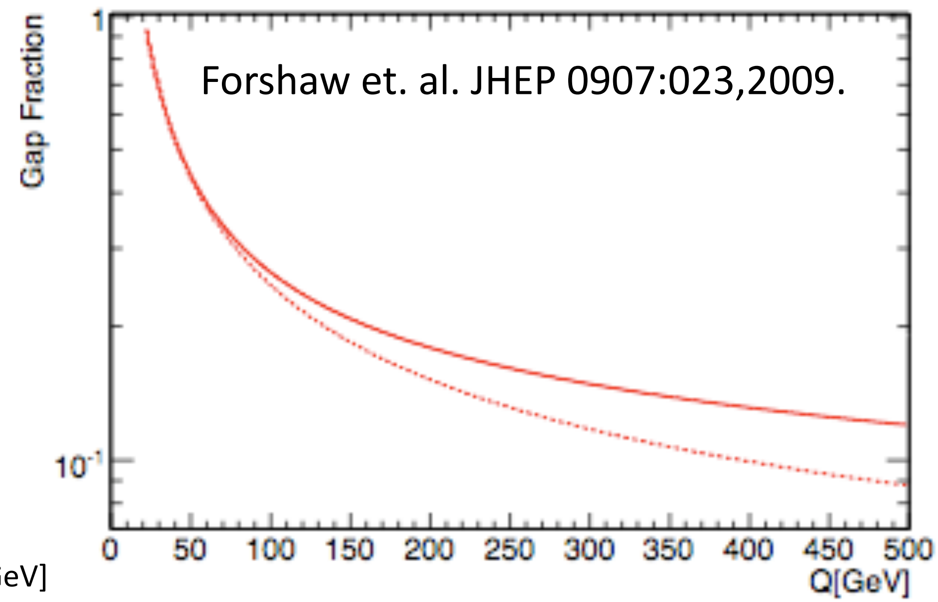
Marquet and Royon, Phys. Rev. D79:030428



Gaps-between-jets (I) – wide angle gluon radiation

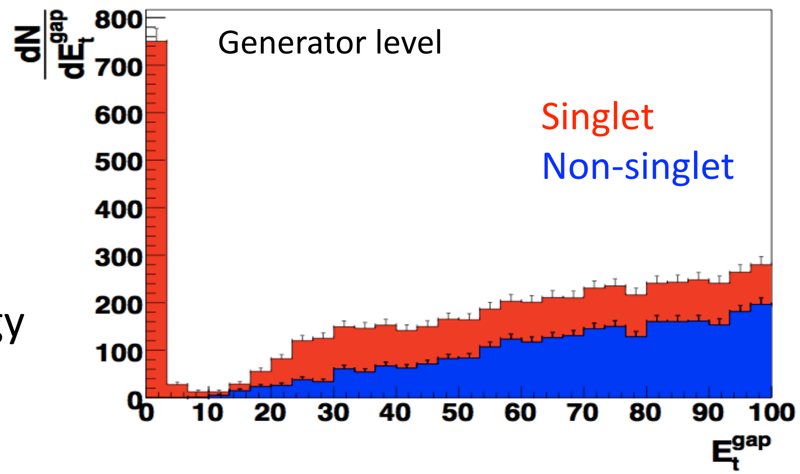
- Gaps-between-jets events identified by vetoing on additional radiation between the two leading jets.
- Infrared safe veto definition needed, such as E_T of veto-jet or ΣE_T in calorimeter.
- Observable of interest is the gap-fraction, i.e. the ratio of gap-events to inclusive di-jet events as a function of leading jet E_T and separation of jets.
- Moderately separated jets sensitive to higher order QCD effects, such as differences between parton shower and matrix element generators (left), Glauber-Coulomb gluons (right) etc.



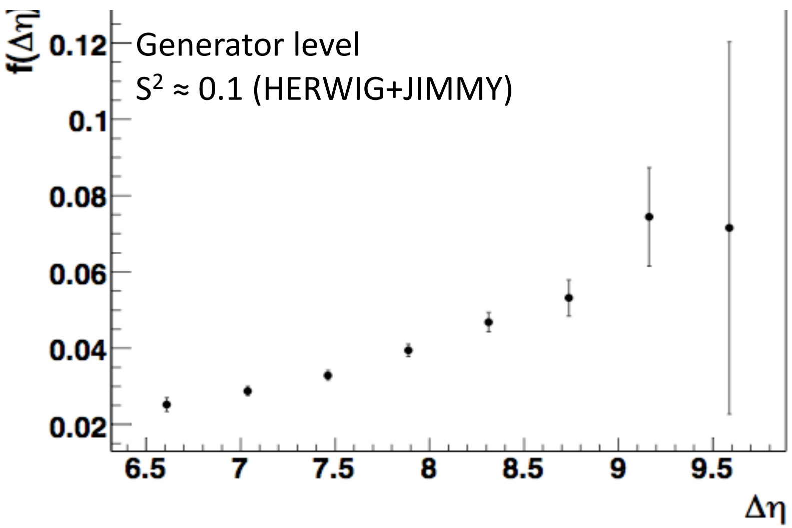


Gaps-between-jets (II) – hard colour singlet exchange

- For large jet pseudo-rapidity separation, colour singlet exchange starts to become increasingly important:
  - Two leading jets identified (E_T>30GeV).
  - Gap events defined (in this case) using the H1 methodology, by summing the transverse energy between leading jets, i.e E_T^{gap} < 10GeV .



- Expect CSE events to have $E_t^{gap} \approx 0$.
  - But get many events with higher values due to multiple parton-parton interactions.
  - Measurement should be possible with around $10pb^{-1}$ of data.
  - BFKL predicts a rise in the gap fraction due to hard colour singlet exchange.



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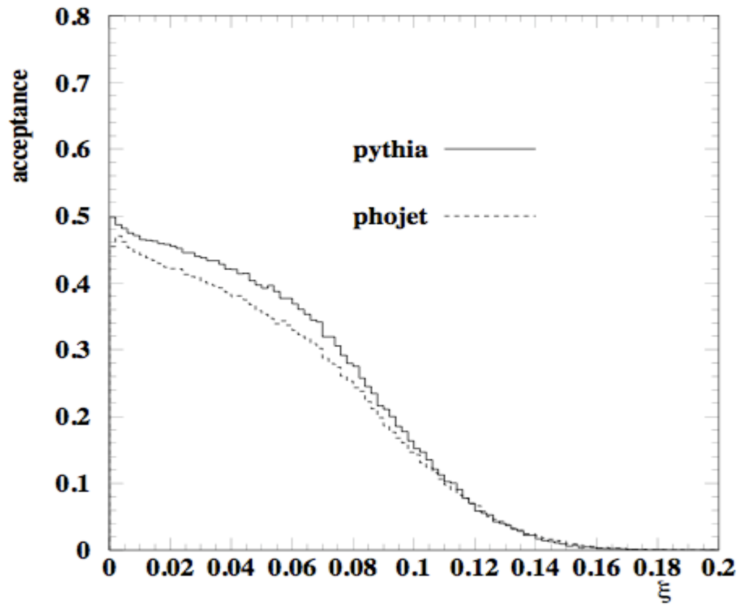
Beyond 2010 – ALFA based SD measurements

- ALFA can be used during special 'luminosity' runs to measure soft-SD proton spectrum.
- Hits in LUCID and energy in ZDC are used 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



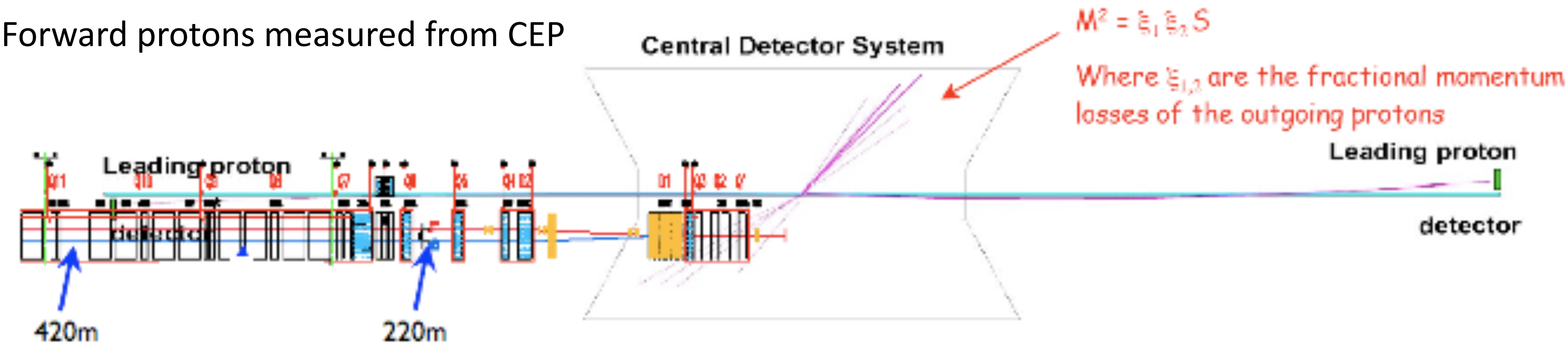
- Want to measure the diffractive ξ distribution:

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

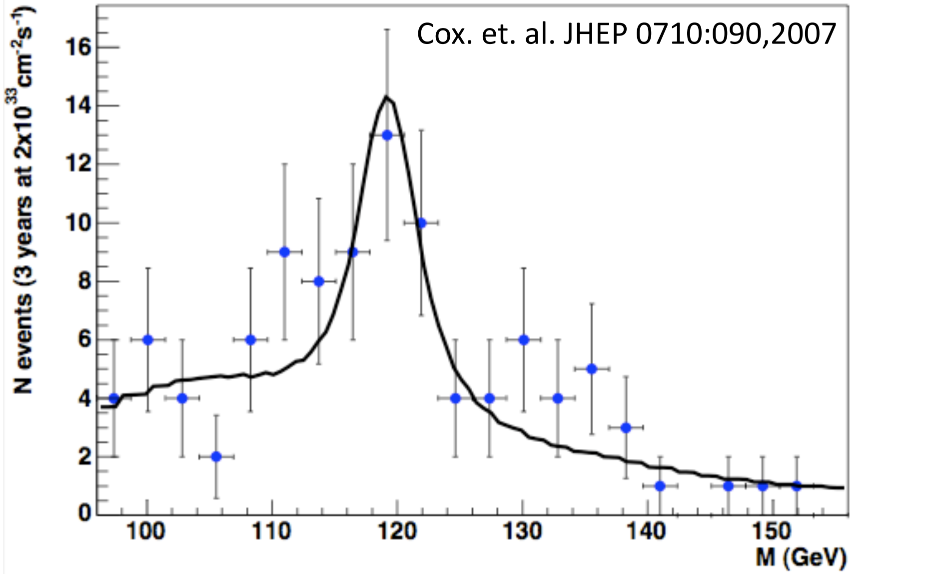
- p_z= beam momentum
- p_z'= outgoing proton momentum

The ATLAS Forward Proton project

Forward protons measured from CEP



- AFP project proposes to install new detectors at 220m and 420 either side of IP.
- Main aim: To detect both protons from exclusive interactions up to $L=10^{34}cm^{-2}\ s^{-1}$.
- SUSY, Higgs, BSM physics, plus wide range of QED and QCD possible
- Resonance mass measured regardless of decay channel.
- See detailed talk by M. Tasevsky.



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Summary

2009/2010 measurements with up to 10pb^{-1}:

1) Soft single and double diffraction.
2) Forward jet azimuthal de-correlations up to moderate $\Delta\eta$.
3) Gaps-between-jets.

2009/2010 measurements with up to 200pb^{-1}:

1) Exclusive di-jet and di-tau production.
2) Single diffractive di-jet production.
3) Extended phase space for forward jet studies.

Prospects after 2010:

1) Single diffraction (and elastic scattering) with ALFA.
2) New physics studies if AFP is installed.