ATLAS Forward Physics Program

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Workshop Low x
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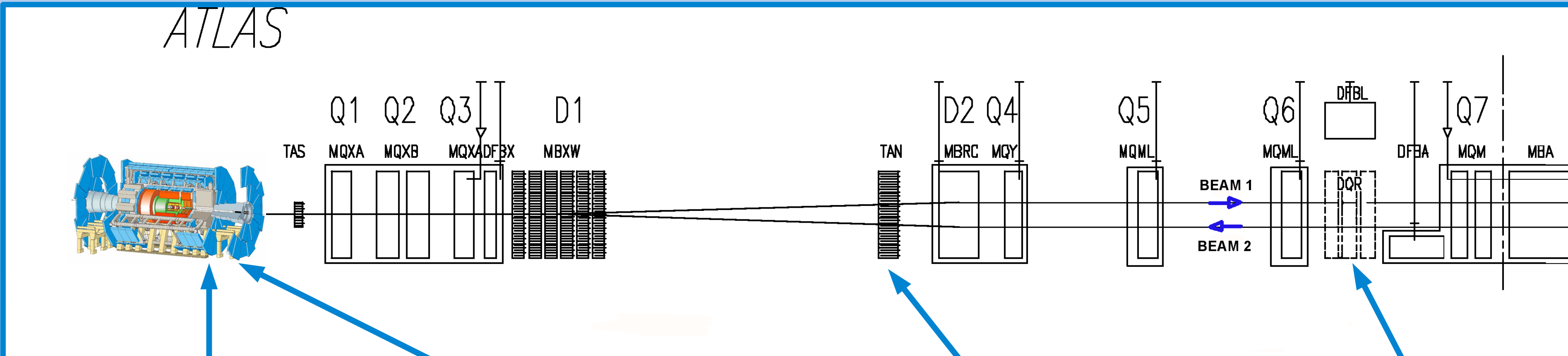
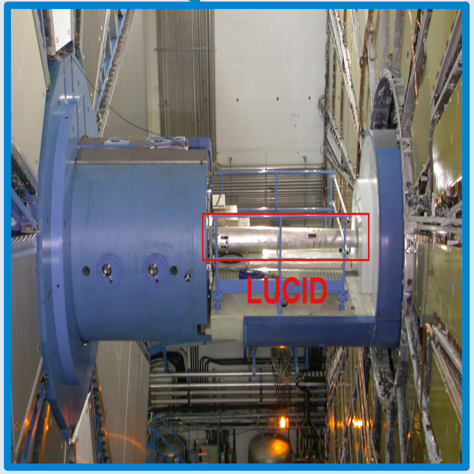
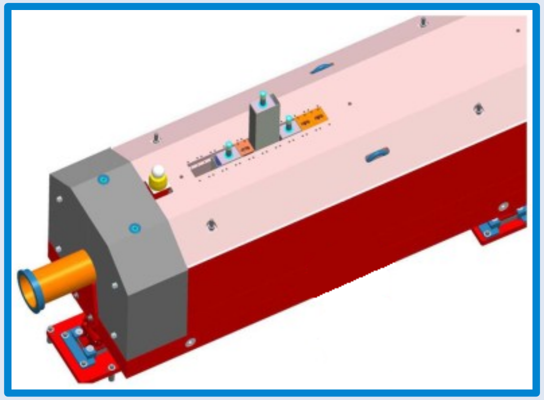
Outline

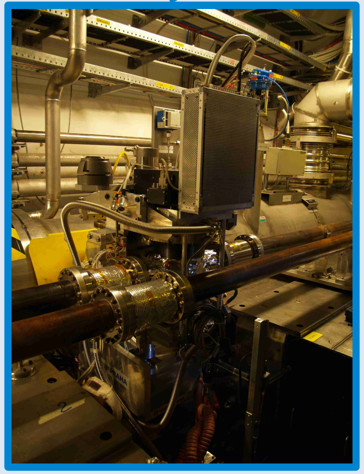
- *ATLAS forward detectors*
- *Forward physics and strategy in ATLAS*
- *Future plans: AFP*
- *First results on luminosity measurements*

ATLAS forward detectors









MBTS
at 3.6 m

LUCID
at 17 m

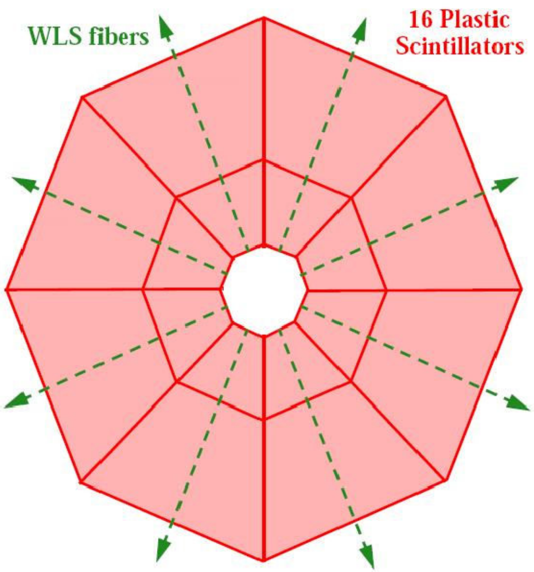
ZDC
at 140 m

ALFA
at 240 m

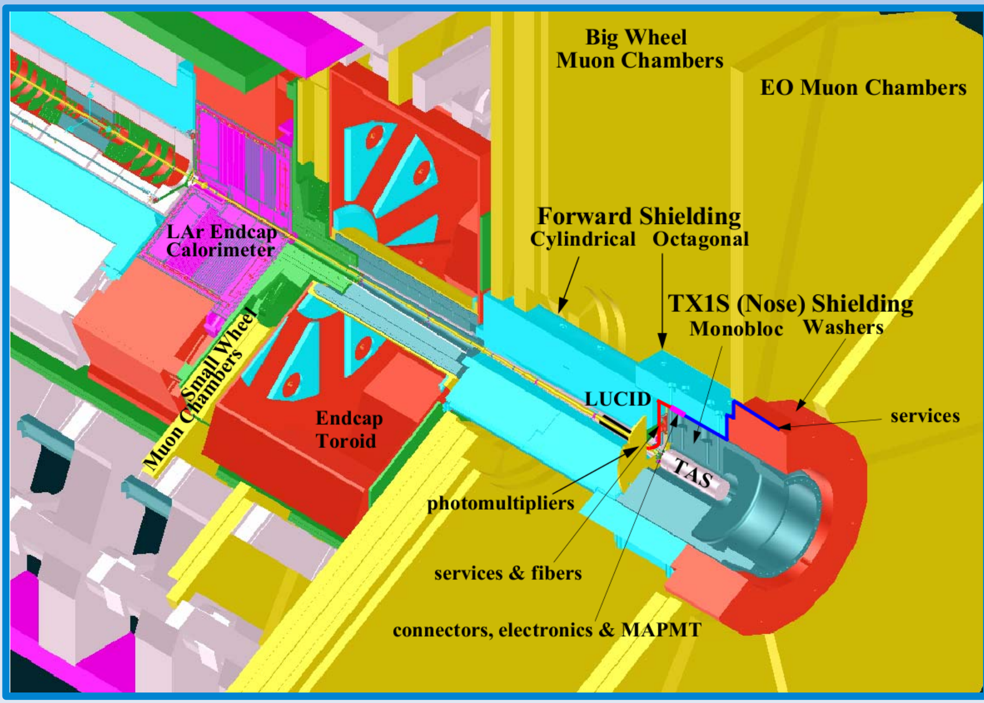
Minimum Bias Trigger Scintillator (MBTS)

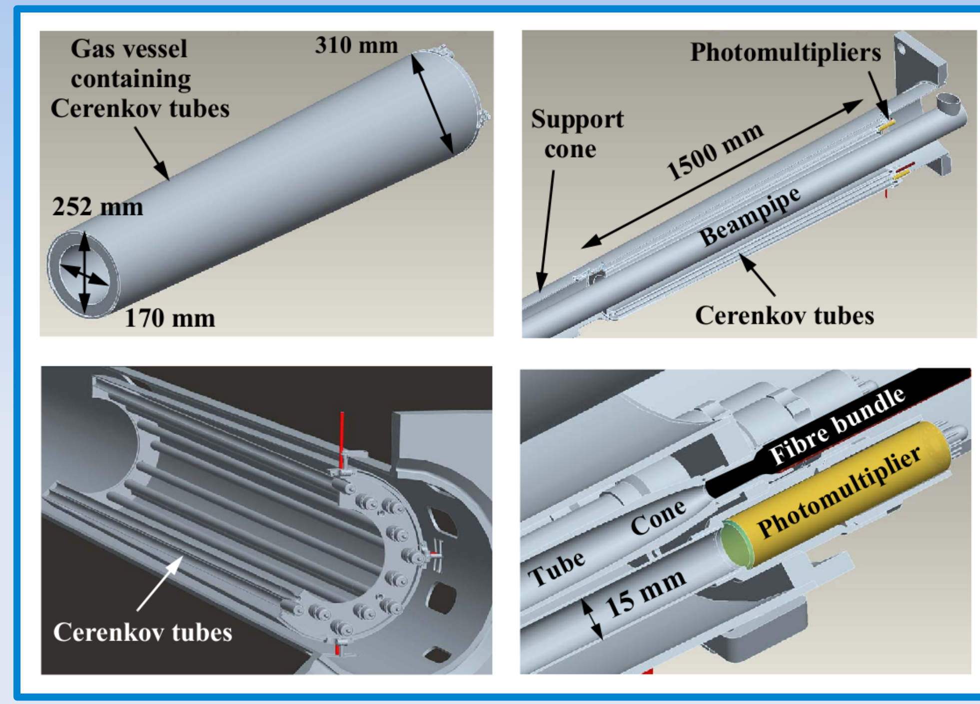
- 32 (16+16) wedge shaped plastic scintillators connected to PMTs
- Two segments in η
- $\Delta\Phi = \pi/4$, $2.1 < |\eta| < 3.8$

- Trigger on Minimum Bias events
- Vetos halo and beam gas events
- Provide LVL1 trigger information



LUminosity measurement using Cherenkov Integrating Detector (LUCID)





- Online Luminosity Monitor, Interaction trigger (low luminosity)
- Array of gaseous Cherenkov detectors
- Sensitive to charged particles pointing to the primary pp collisions

$$R_{pp} = \mu_{LUCID} \cdot f_{BX} = \sigma_{pp} \cdot \varepsilon_{LUCID} \cdot L$$

Instantaneous Luminosity

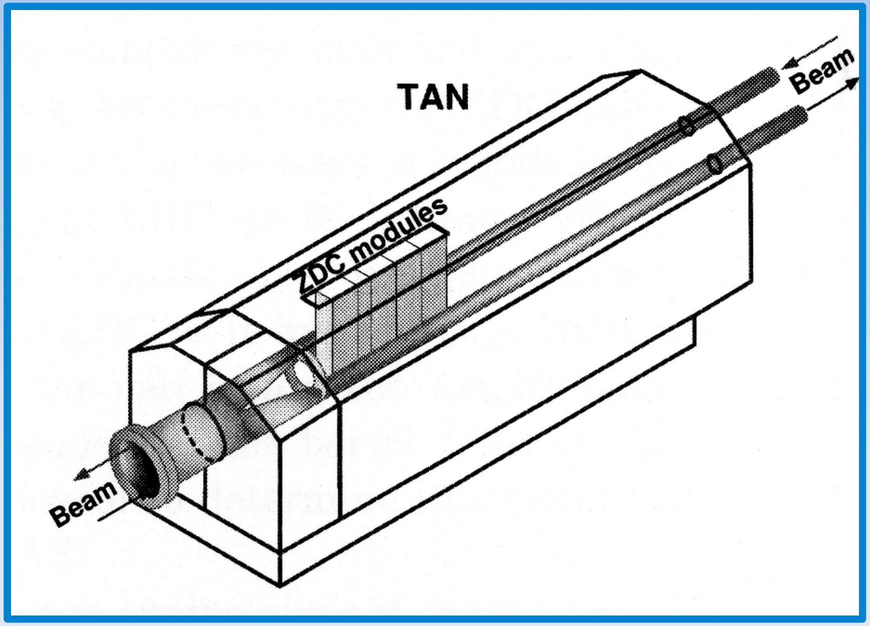
Rate of p-p interactions seen by LUCID

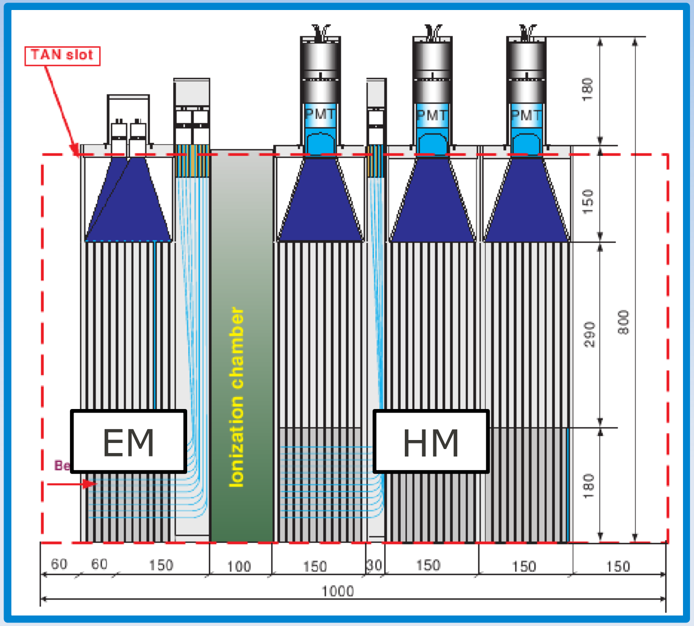
Number of p-p interactions/BC as measured by LUCID

Interaction rate

Efficiency and acceptance to detect p-p interactions

Zero Degree Calorimeter (ZDC)

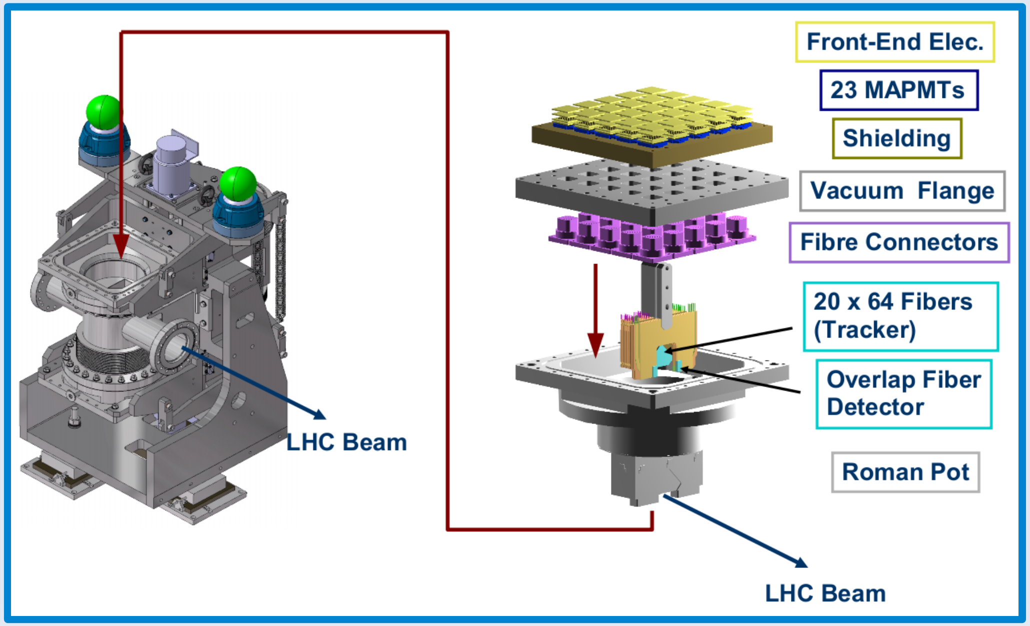


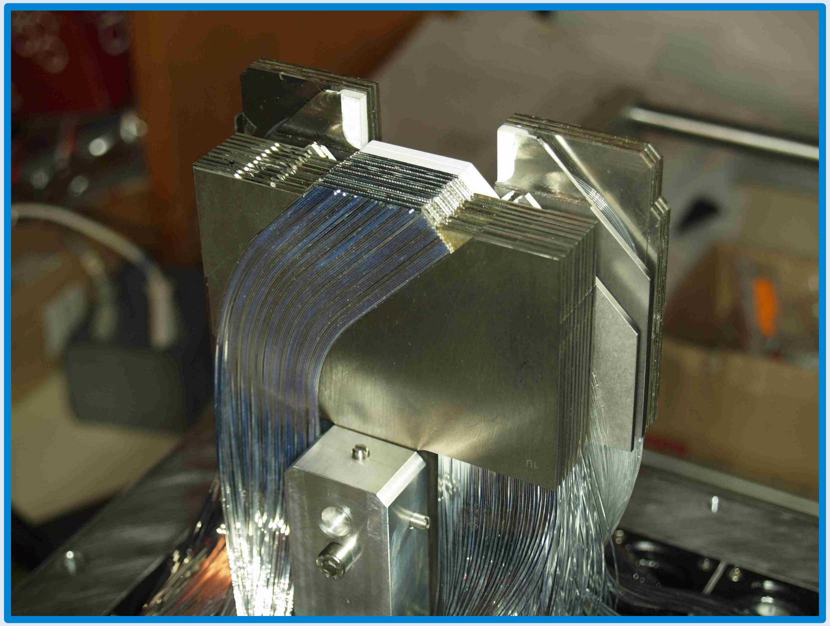


- The ZDC will measure production of neutral particles in the forward direction in heavy ions and p-p collisions
- 1 electromagnetic calorimeter (not yet installed) and 3 hadronic calorimeter modules
- Tungsten/Quartz calorimeter covering $|\eta| > 8.3$ for neutrals
  - Quartz strips for energy measurements
  - Horizontal rods for coordinate measurements

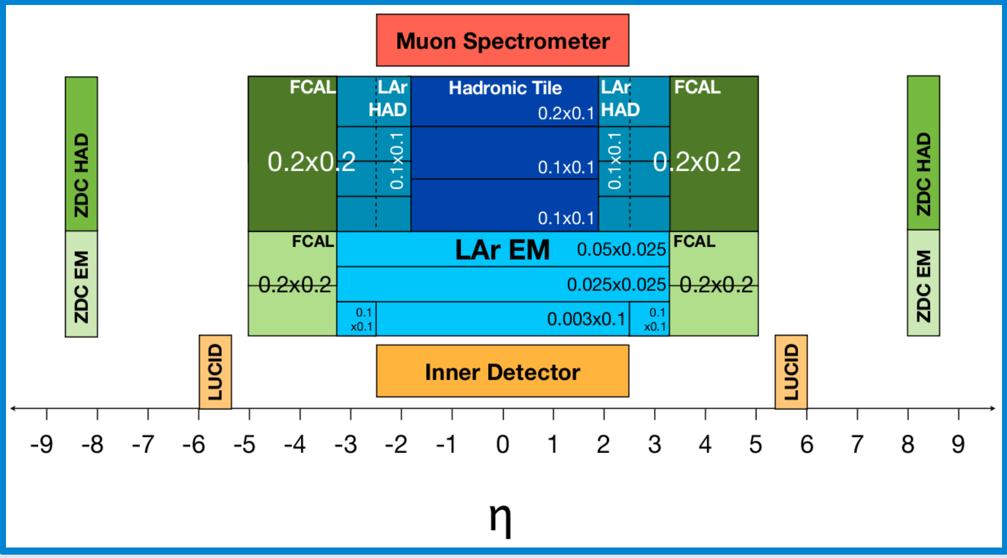
Absolute Luminosity For ATLAS (ALFA)

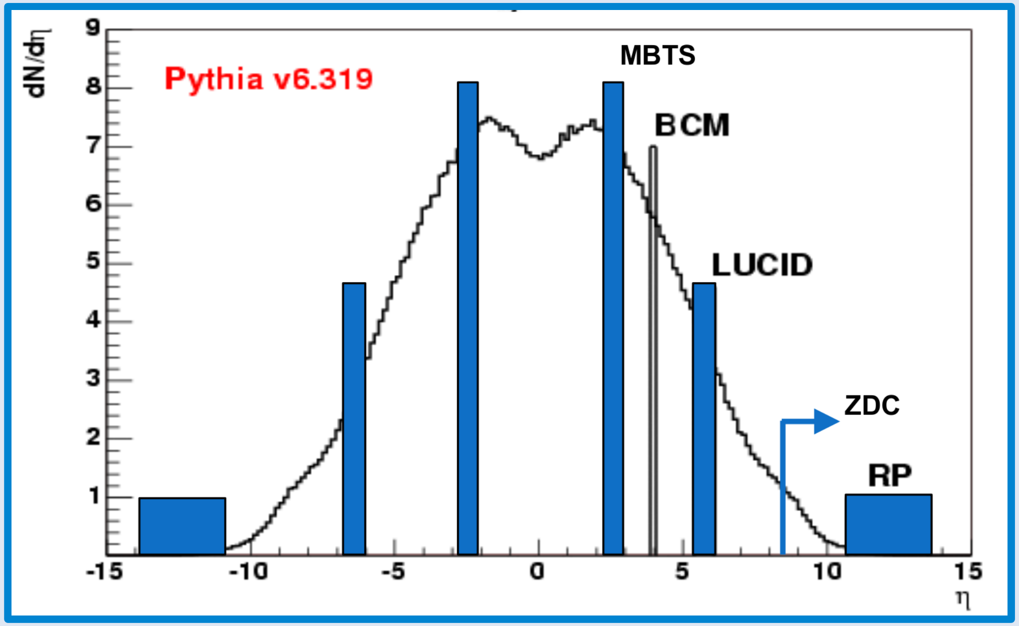
- Measure σ_{tot} and absolute luminosity with a precision of 2-3%
- Two roman pot stations on each side of the ATLAS IP. Each station is made of an upper and a lower detector
- The detectors are scintillating fiber trackers
- Need high-β* optics and low luminosity runs (10^{27} cm^{-2} s^{-1})
- One station installed, 3 others will be by Xmas 2010





ATLAS pseudo-rapidity coverage





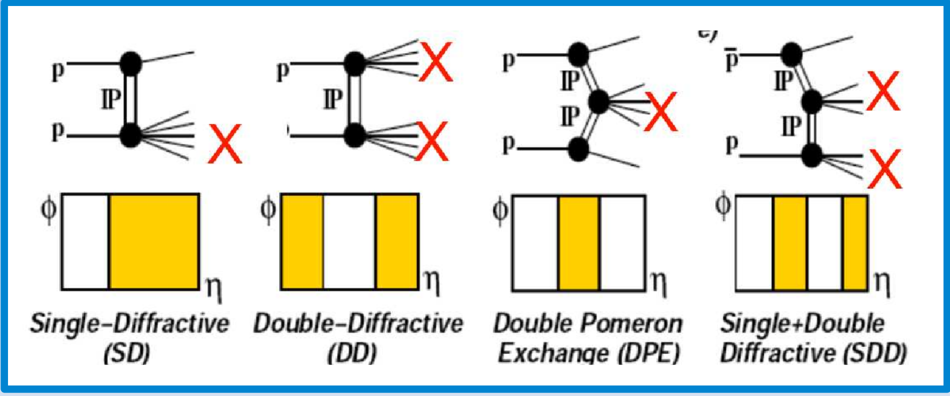
Main detector

- Inner detector $|\eta| < 2.5$
- EM calorimeters $|\eta| < 3.2$
- Hadronic calorimeters $|\eta| < 4.9$
- Muon spectromater $|\eta| < 2.7$

Forward detectors

- MBTS $2.1 < |\eta| < 3.8$
- LUCID $5.6 < |\eta| < 5.9$
- ZDC $|\eta| > 8.3$
- ALFA $10.6 < |\eta| < 13.5$

Forward physics to be studied



TOPICS

- **Soft diffraction**
- **Hard Diffraction**
- **Central Exclusive Production (CEP)**
- **Gaps between jets**
- **Elastic scattering**

STRATEGIES

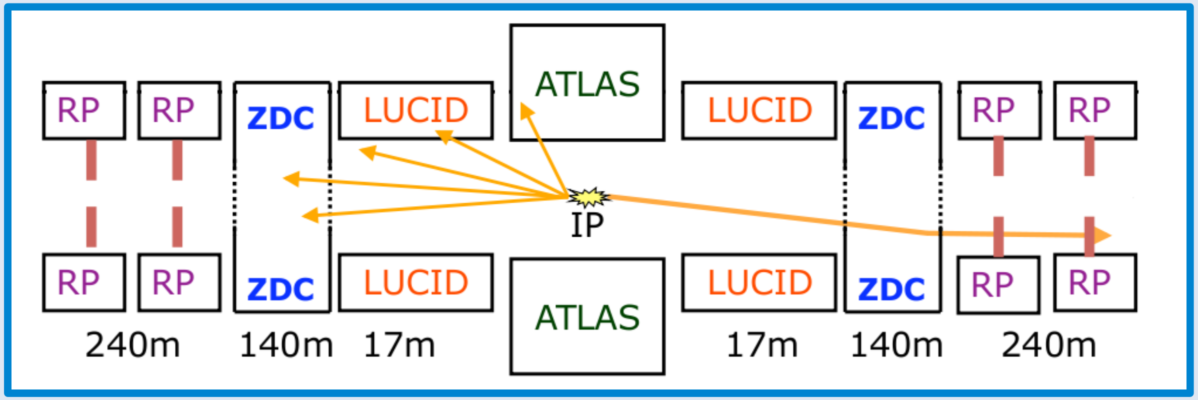
- Rapidity Gaps in different η regions and with different configurations and/or measurement of forward protons :
  - Forward regions for Single Diffractive (SD), double diffractive and Central Exclusive Production (CEP)
  - Central calorimeter (jet-jet, DPE)
- Requirements :
  - Dedicated detectors
  - Low noise in detectors
  - No pile-up

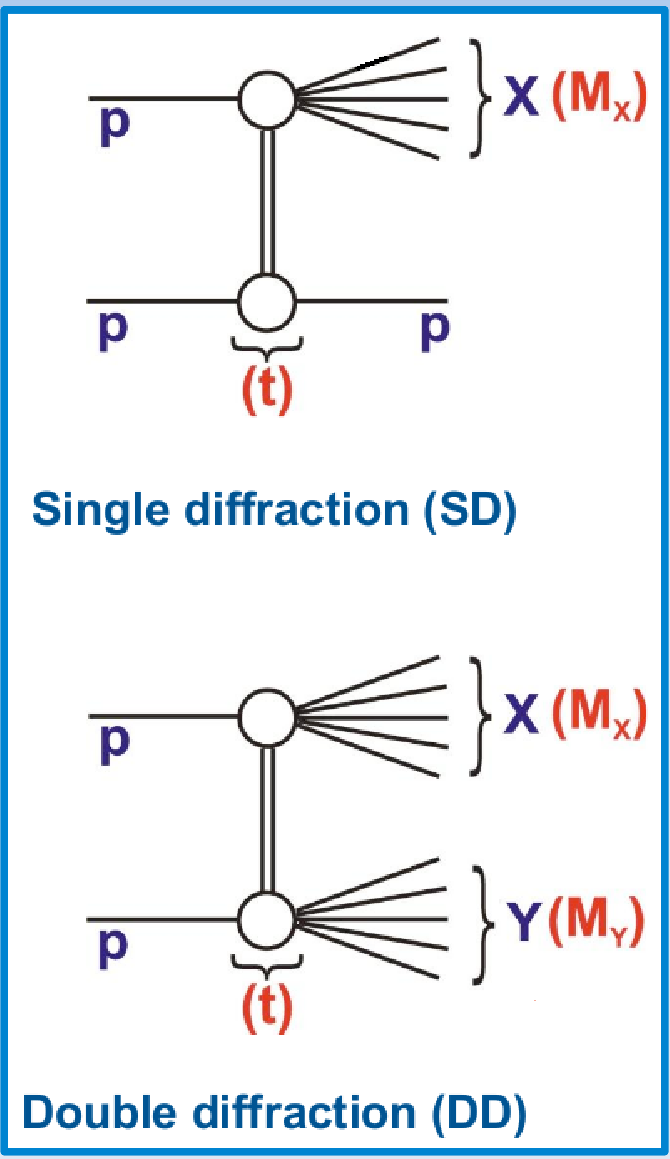
Soft single/double diffraction

- Low *t*-process where color singlet is exchanged between the two protons, and one or the two protons break up into a dissociative system

- Large cross sections at LHC :
  - σ_{SD} ~ 12mb
  - σ_{DD} ~ 7 mb

- Diffractive events can be tagged by identifying a rapidity gap between :
  - outgoing proton and dissociative system in SD
  - the two dissociative systems in DD





Soft single/double diffraction

Using central detector, FCAL, LUCID and the ZDC

- Rapidity gap in the central detector, 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:

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

- M_X measured using calorimeter clusters and tracking information
- The aim is to reconstruct ξ on an event-by-event basis
- Expect to collect ~ 1M events in two weeks at $L = 10^{31}\ cm^{-2}\ s^{-1}$

Using the ALFA detector

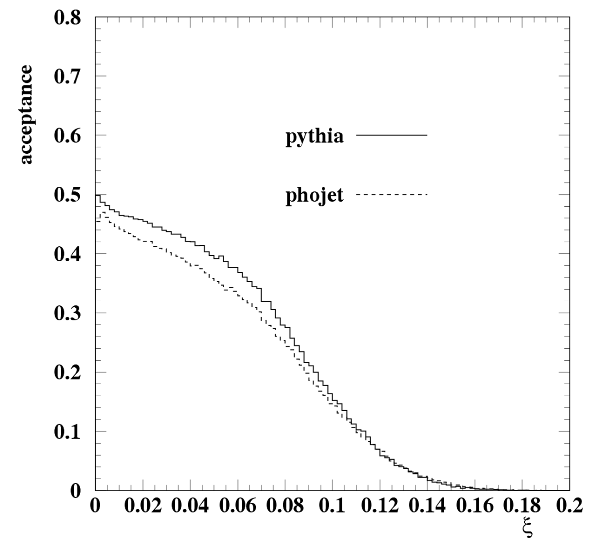
- ALFA as a good acceptance for SD events in dedicated runs :
  - 50% acceptance for ξ ~ 0.01
  - 10% acceptance for ξ ~ 0.1

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

- Accuracy on fractional momentum loss:

  ~ 8% for ξ ~ 0.01
  ~ 2% for ξ ~ 0.1

- Expect 1.2-1.8M events in 100 hrs at $L = 10^{27}\ cm^{-2}\ s^{-1}$

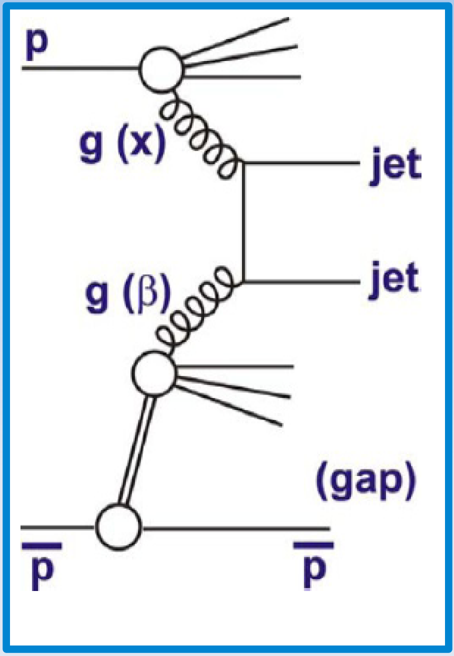


Diffractive dijets production

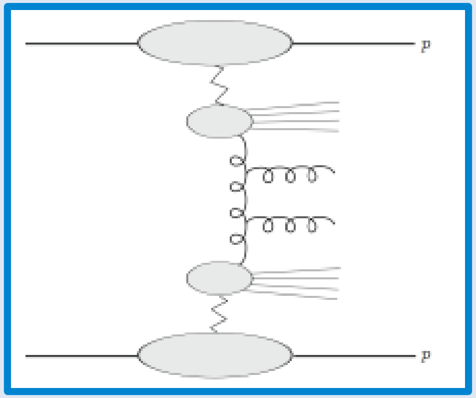
Experimental signal : Hard scattering events (Jets, W,...) with gap on one side of the detector

- Goal of the measurement :
  - Diffractive structure functions (dPDFs)
  - Factorization breaking :
    - R(SD/ND)
    - R(DPE/SD)
- Trigger using single jet triggers
  - Looking into LUCID, ZDC and MBTS for gap requirement

- Expect a few thousand SD di-jet events in 100 pb^{-1} with E_T>20 GeV (after trigger prescale and gap requirement)
- Expect approximatively 10 DPE events in the same kinematic region



Single diffractive dijet production



DPE

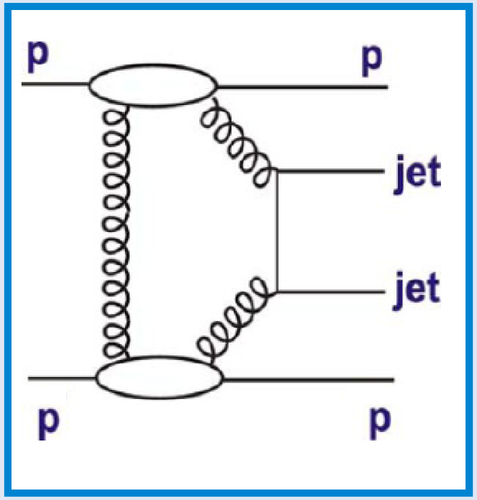
Central Exclusive dijet Production

Experimental signal : Two high p_T jets and no extra hadronic activity.
Gaps between the jets and protons

- Rapidity gaps between central dijet system ($|\eta| < 2.5$) and outgoing protons
  - No hadronic activity must be seen in FCAL, LUCID and ZDC
- Protons are scattered through very small angles, not detected by ATLAS.
- Expect CEP rate to be much larger than DPE with such criteria
- Measurement of DPE/CEP di-jet production at 14 TeV :
  - To constrain the theoretical model by comparing with CDF measurements
  - To understand the structure of diffractive exchange by comparision with prediction from electron-proton data

Expect a few hundred CEP events after trigger and analysis cuts with E_T>20 GeV in 20 pb^{-1} of data

See
Paolo Francavilla's talk for
jet studies



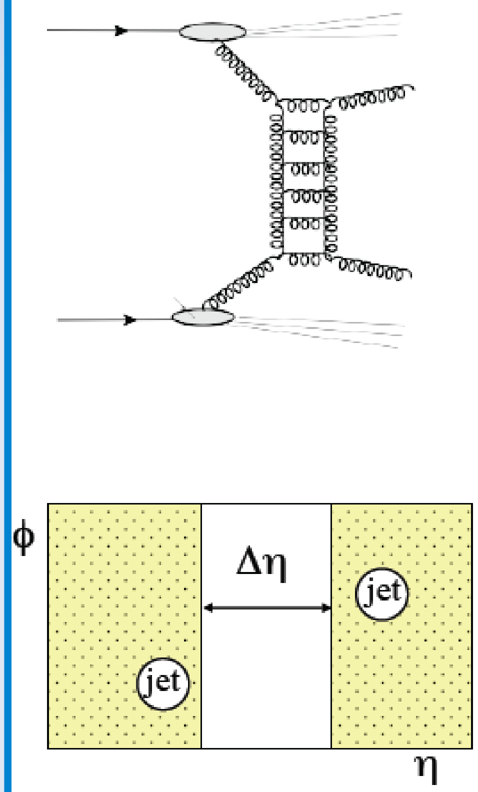
CEP

Gaps between jets

Experimental signal : Two high p_T jets separated in the detector by a large pseudo-rapidity gap ($\Delta\eta > 3$)

- Di-jet production via colour singlet exchange
- Observable of interest is the gap-fraction, i.e. the fraction of events with little activity between the jets
- ATLAS can make an improved measurement with increased E_{CM} and available phase space
- Measurement up to gap-fraction $\Delta\eta \sim 9, 9.5$

Measurements should be possible with 10 pb^{-1} of data



Jets separated by Δη

Elastic scattering (ALFA)

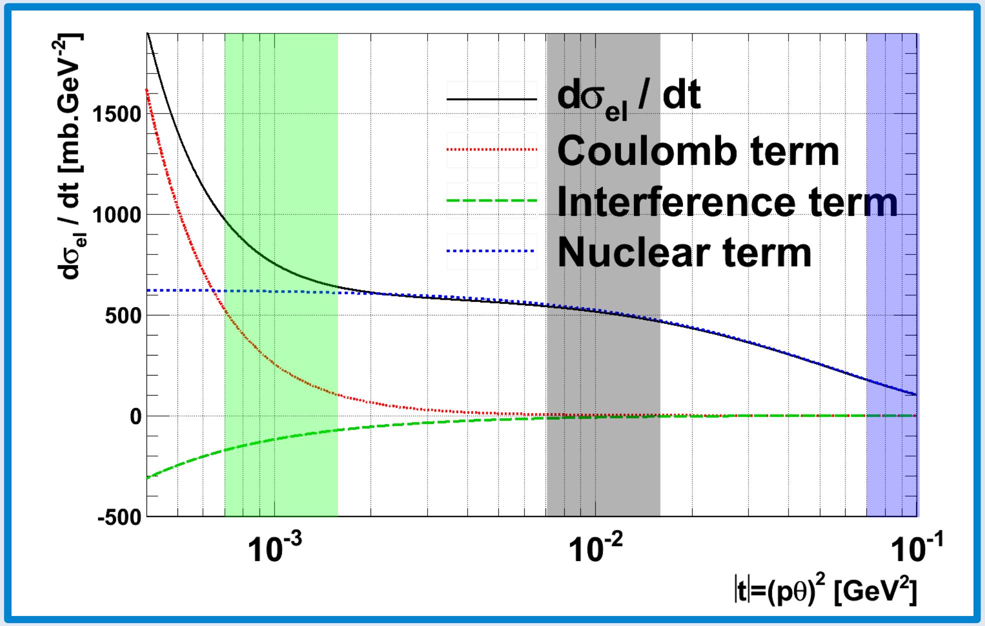
Measurement of the differential elastic cross section at very low *t* to be sensitive to the Coulomb and the interference region provides very good precision on absolute luminosity and total cross section measurements

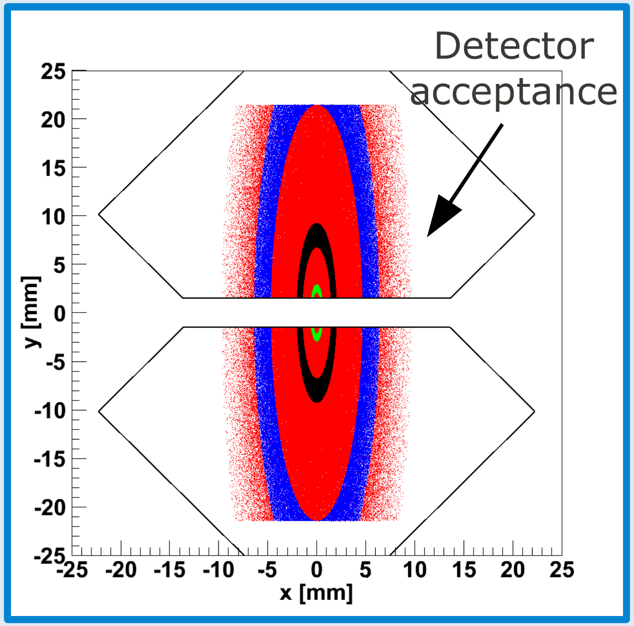
$$\frac{d\sigma_{el}}{dt}(t) = \frac{4\pi\alpha^2 G^4(t)}{|t|^2} - \frac{\sigma_{tot}\,\alpha\,(\rho - \alpha\phi)\,G^2(t)\,\exp(-b|t|/2)}{|t|} + \frac{(1+\rho^2)\,\sigma_{tot}^2\,\exp(-b|t|)}{16\pi}$$

$$\Rightarrow \quad \frac{dN_{el}}{dt} = \mathcal{L}\frac{d\sigma_{el}}{dt} = \mathcal{F}(\mathcal{L}, \sigma_{tot}, b, \rho)$$

$$-t_{inter} \approx \frac{8\pi(\hbar c)^2\alpha}{\sigma_{tot}} \approx 6.5\ 10^{-4}\ \mathrm{GeV}^2 \Leftrightarrow 3.5\ \mu\mathrm{rad}$$

At 7 TeV for σ_{tot}=100 mb





Sketched *t*-ranges

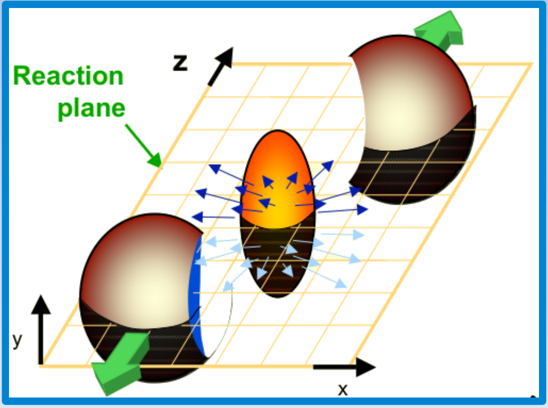
t ϵ [0.0007;0.0013]

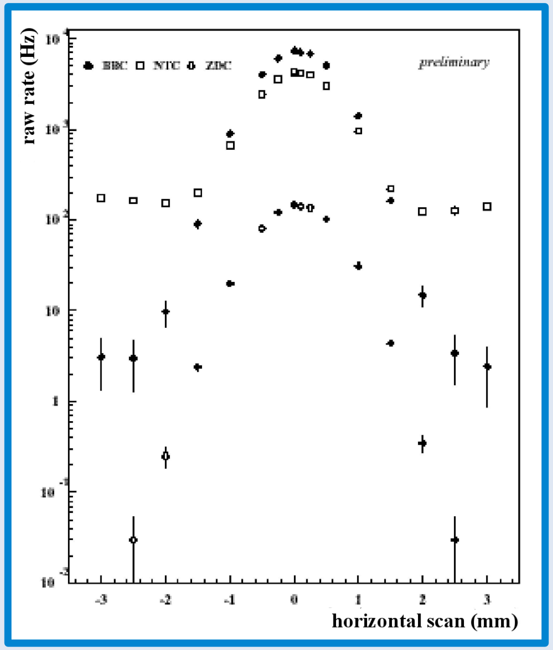
t ϵ [0.007;0.013]

t ϵ [0.07;0.13]

Zero Degree Calorimeter (ZDC)

- Will perform studies in both heavy ions and pp runs by measuring the production of neutral particles at 0° (n, γ, π)
- Direction and amplitude of the impact parameter
- Measures centrality
- Minimum Bias trigger
- Rapidity gap trigger veto
- Luminosity measurements :
    - during heavy ions runs with a precision better than 5 %
    - during p-p runs, the ZDC coincidence is a background free luminosity monitor

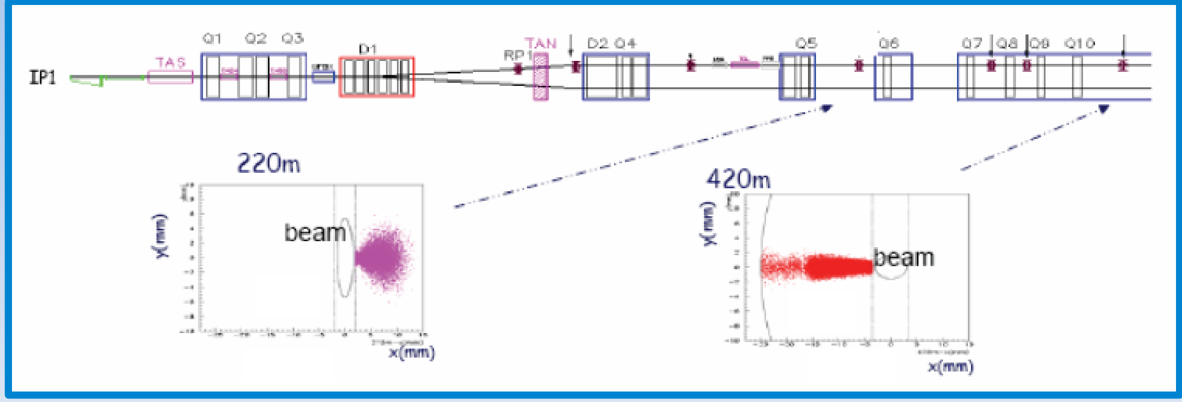




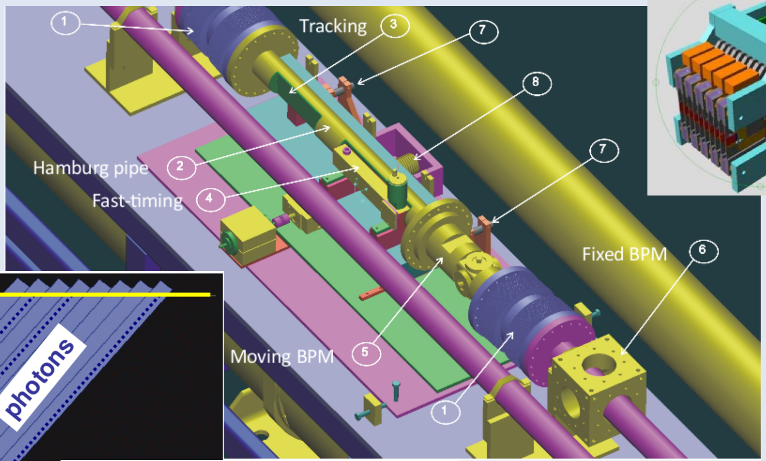
Vernier scan for PHENIX at RHIC

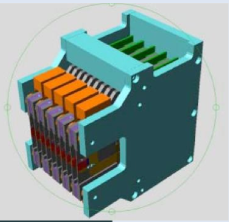
Future : ATLAS Forward Physics program (AFP)

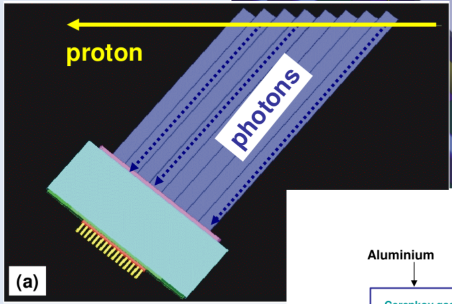
- At high luminosity, pile-up events will fill in the gaps, need to tag the very forward protons
- New detectors at ±220m and ±420m
- Use fast timing to reduce the background
- Good acceptance and mass resolution

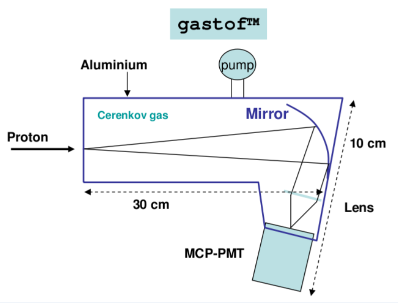


- Tracking system to detect and reconstruct the 2 leading protons (1 μrad angular resolution) → 3D Si detector
- Timing system (10-20 ps resolution) to identify the primary vertex → Cerenkov photon detectors
- Beam proximity → Radiation hardness









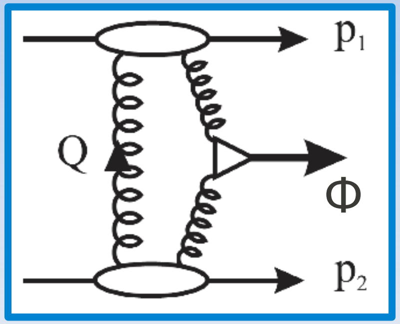
Future : ATLAS Forward Physics program (AFP)

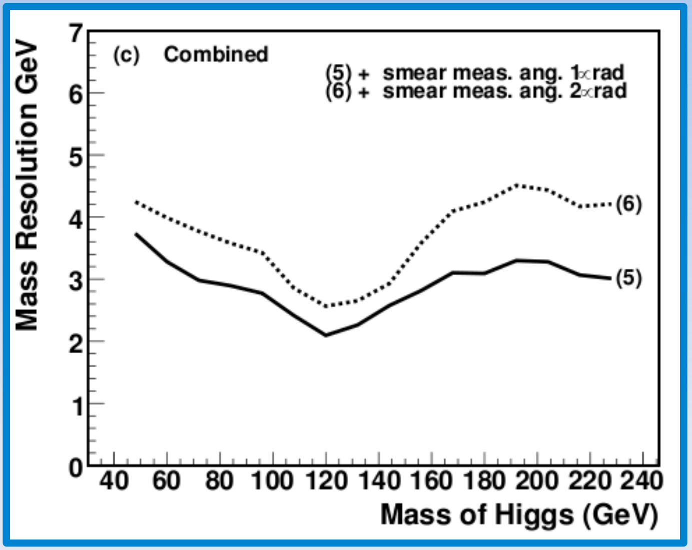
<u>Processes pp → p+Φ+p</u>

- Protons remain intact, scattered with very small angles
- All the momentum lost by the protons goes to the production of the central system Φ

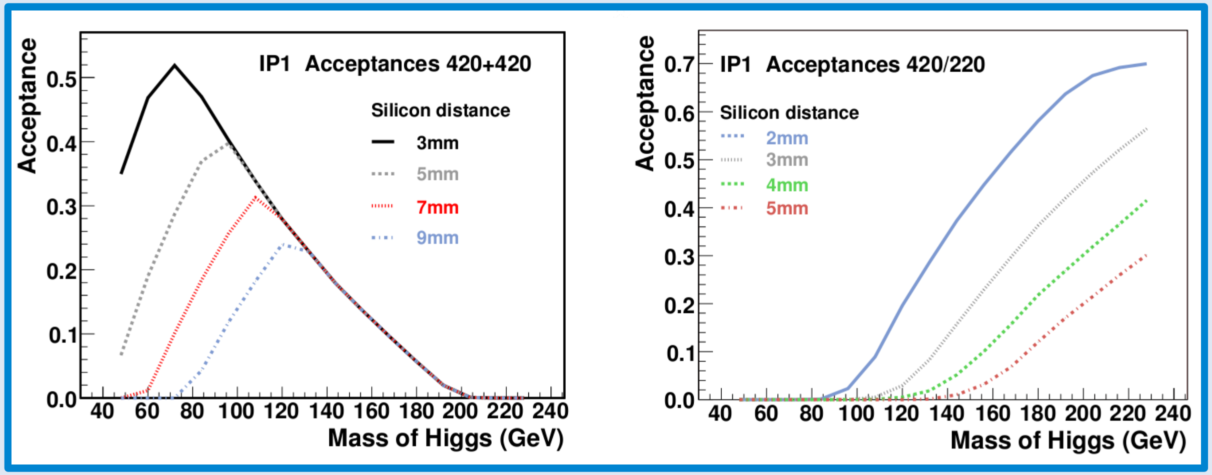
<u>Goal:</u> Measure the longitudinal momentum of the outgoing protons

- CEP Higgs Boson Studies (See Marek Tasevski and Rafal Staszewski)
  - Higgs mass, quantum numbers, discovery in certain regions of MSSM/NMSSM
- Slepton pair production
- Gluino pair production for split-SUSY models





Higgs mass resolution for 420+420 and 420+220



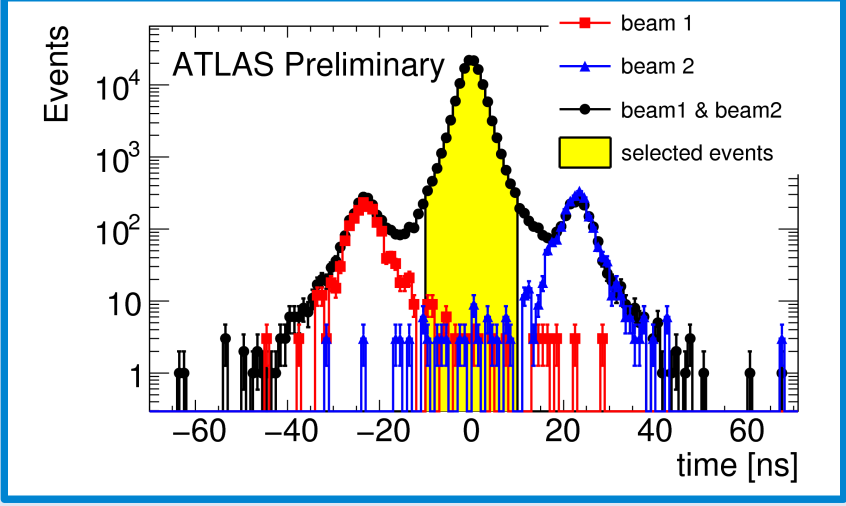
More details in : 2009 JINST 4 T10001

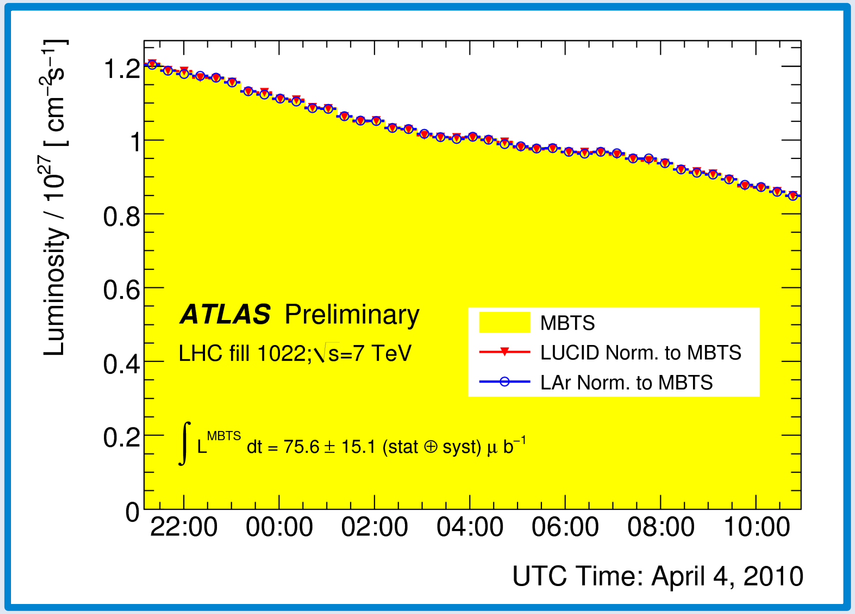
Instantaneaous luminosity measurement in ATLAS

- Based on instantaneous relative luminosity measurements normalized using calibration constants (MC or beam parameters)
- Overall method:

$$\int \mathscr{L}\, dt = \frac{\mu f}{\sigma_{vis}}$$

- Method applied with MBTS, LUCID and LAr EndCap, chargeg particle event counting
- Cross section used to normalize the measurements is 71.5 mb (ND, SD, DD from Pythia)
- Systematic uncertainties (~20%) are dominated by differences observed between PYTHIA and PHOJET prediction
- Systematics will be reduced with VdM scan calibration (~5-10 %)





More details in : ATL-COM-LUM-2010-002

First luminosity measurement with LUCID

Luminosity determination per bunch crossing with LUCID

HIT COUNTING

$$\mu_{HIT-OR} = \frac{N^{hits-or}}{N^{orbits}} \frac{1}{<N^{hits-or}>_{pp}}$$

$$\mu_{HIT-AND} = \frac{N^{hits-and}}{N^{orbits}} \frac{1}{<N^{hits-and}>_{pp}}$$

ZERO COUNTING

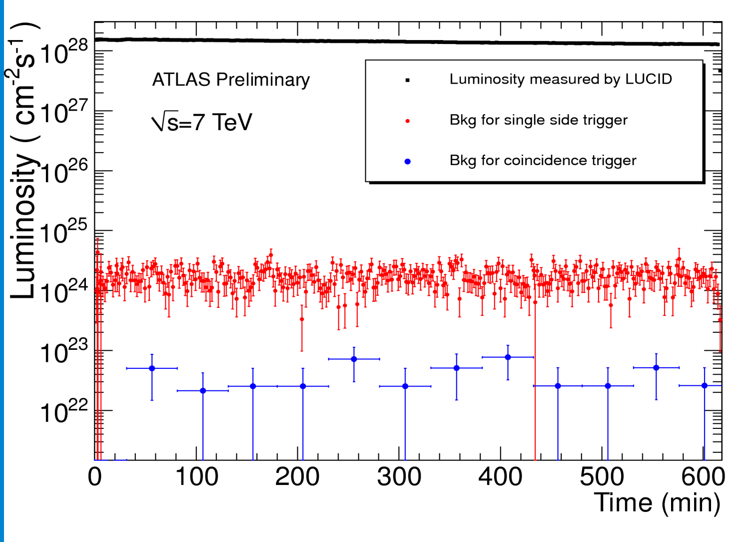
$$\mu_{ZERO-OR} = \frac{1}{\epsilon_{sing}} \ln\left(1 - \frac{N^{zero-or}}{N^{orbits}}\right)$$

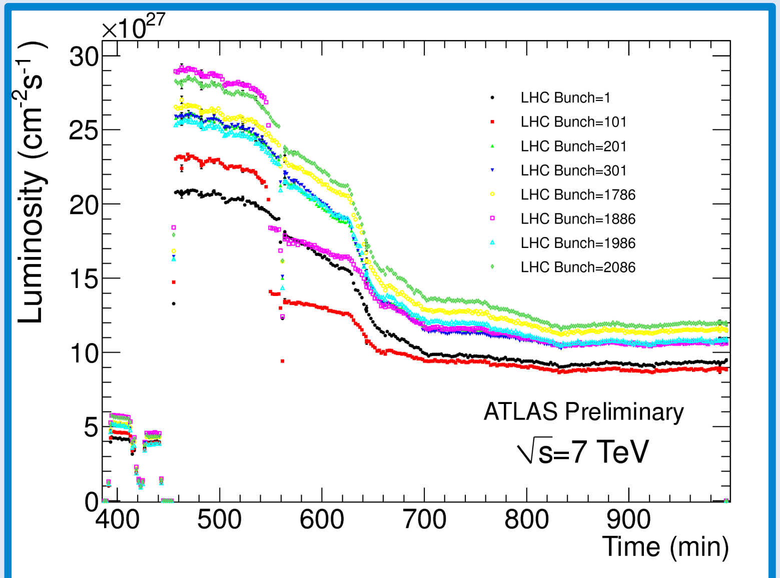
$$\mu_{ZERO-AND} = \frac{-1}{\epsilon_{coinc}} \ln\left(\frac{N^{zero-and}}{N^{orbits}}\right)$$

$$\mathscr{L} = \sum_{i \in BCID} \mu_i \frac{f}{\sigma_{inel}}$$

- Luminosity determination per bunch crossing
- Systematic uncertainty ~20%

More details in : ATL-COM-LUM-2010-020



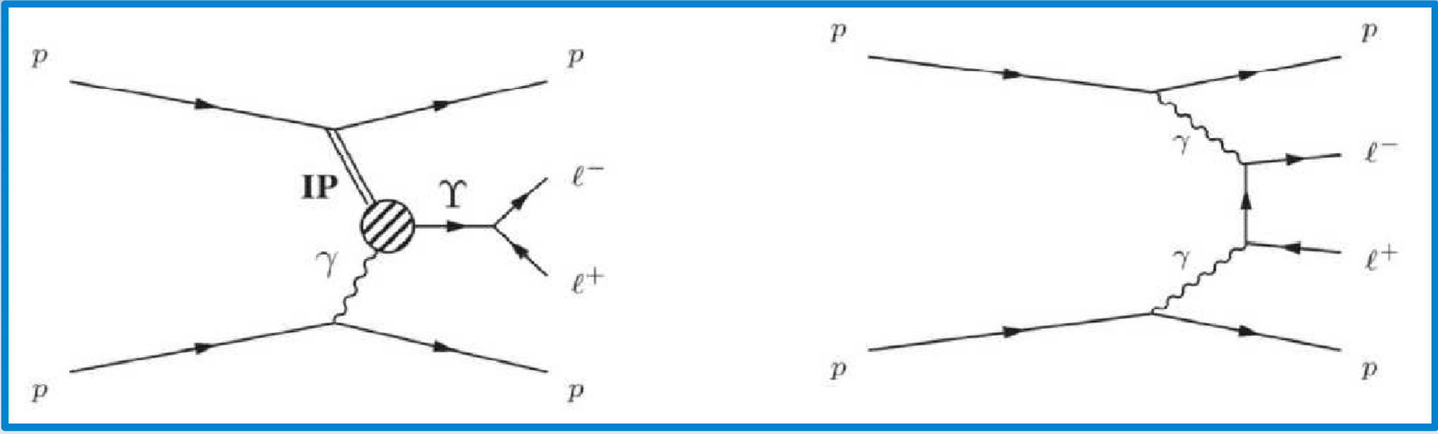


Conclusion

- ATLAS has variety of forward detectors: MBTS, LUCID, ZDC, ALFA
- At low luminosity several diffractive topics can be studied
- Handshake with machine for luminosity optimisation and measurement
- **Measurements with up to 10 pb^{-1} :**
  - Soft single and double diffraction
  - Gaps between jets
- **Measurements with up to 200 pb^{-1} :**
  - Exclusive di-jet production
  - Single diffractive di-jet production
- **Prospects after 2010 :**
  - Single diffraction and elastic scattering with ALFA
  - New physics studies if AFP is installed

BACKUP

Photon induced lepton pair production

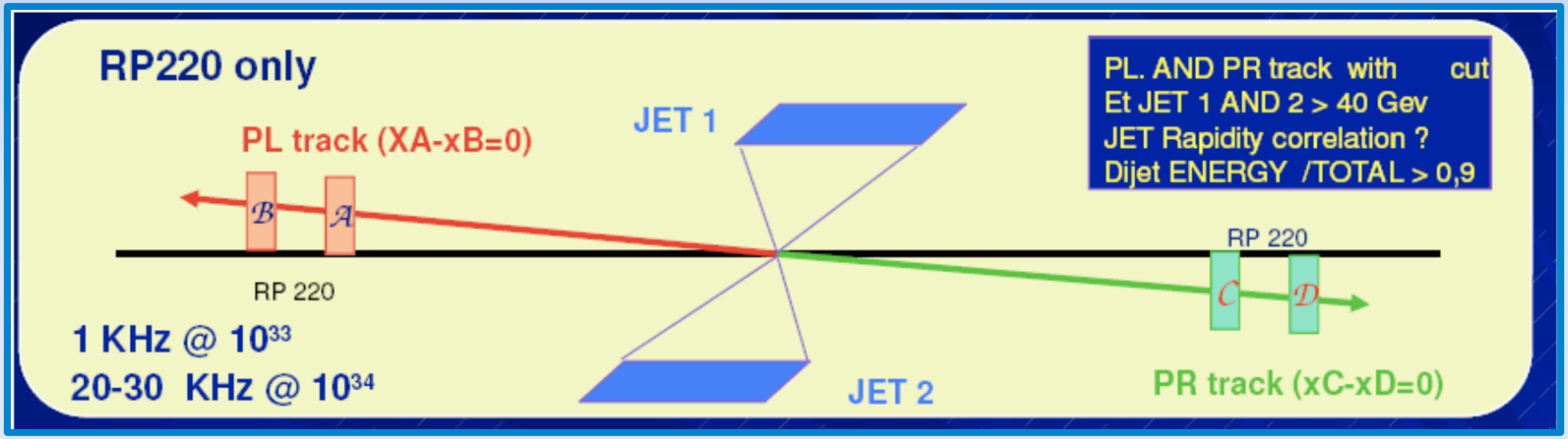


- Exclusive dilepton production :
  - two isolated leptons back-to-back
  - gaps in forward region
  - exclusive vertex (no other tracks than from leptons)
- Processes :
  - Photoproduction-lepton pairs through J/ψ and Υ resonnances
  - Two photon production → non-resonant lepton pairs from $\gamma\gamma \rightarrow l^+l^-$

Simulation predict several hundreds two-photon and Upsilon events in the di-muon channel selection for 100 pb^{-1}

AFP trigger

- Trigger scheme (LVL1 + HLT) :
  - LVL1 : high p_t in the central region + signal at both 220 m stations



- Quoted latency for LVL1 trigger : 1921 ns (with some uncertainties)
- Large LVL1 bandwidth (~30%) @ 10^{34} $cm^{-2}s^{-1}$