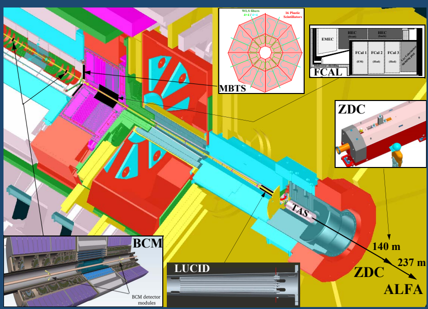
LHCC Poster Session - CERN, 23 March 2011

Measurement of the Luminosity by the ATLAS Experiment

Luminosity sub-detectors in ATLAS



Online and Offline:

- BCM (Beam Condition Monitor): $|\eta| \sim 4$
- MBTS (Minimum Bias Trigger): $2.09 < |\eta| < 3.84$
- FCAL (Forward CALorimeter): $3.2 < |\eta| < 4.9$
- LUCID (Cherenkov Detector): $5.6 < |\eta| < 6$
- ZDC (Zero Degree Calorimeter): $8.3 < |\eta|$

Offline:

- Primary vertex event counting
- Charged particle event counting

Different algorithms per sub-detector:
Each detector uses a different set of counting methods such as **Hit counting, Event counting or Particle counting**.
Measurements can be required to be:

- On just one detector side (**XOR** algorithms)
- On either detector side (**OR** algorithms)
- On both detector sides (**AND** algorithms)

Currently **16 different luminosity measurements** are constantly monitored and stored to the conditions database.

Luminosity Measurements in ATLAS

- The instantaneous luminosity of pp collisions can be calculated as:

$$L = \frac{R_{inel}}{\sigma_{inel}}$$

R_{inel}= Rate of pp interactions
σ_{inel}= Inelastic cross-section

- Anything that is sensitive to inelastic pp interactions can be used as a source for **relative** luminosity measurements. These must be calibrated by **absolute** measurements.

To control and understand the systematic uncertainties affecting the luminosity determination, the **ATLAS strategy** is to compare the measurements of **several luminosity detectors**, most of which use more than one counting technique.

$\mu_{vis} = \varepsilon\,\mu$ visible number of interactions per bunch crossing (measured quantity)

$$L = \frac{\mu \cdot n_b f_r}{\sigma_{inel}} = \frac{\boxed{\mu_{vis}} \cdot n_b f_r}{\boxed{\sigma_{vis}}}$$

μ = Number of interactions per bunch crossing
n_b = Number of bunch pairs colliding in ATLAS
f_r = LHC revolution frequency [11245.5 Hz]

$\sigma_{vis} = \varepsilon\,\sigma_{inel}$ visible cross-section, to be determined via calibration for each detector/algorithm

Absolute Calibration using van der Meer Scans

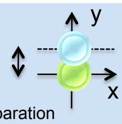
- Determination of the absolute luminosity via beam parameters

$$L = \frac{n_b f_r I_1 I_2}{2\pi \Sigma_X \Sigma_Y}$$

I_1, I_2 = Number of particles in beam 1,2
Σ_X, Σ_Y = Horizontal and vertical convolved beam sizes.

Procedure:

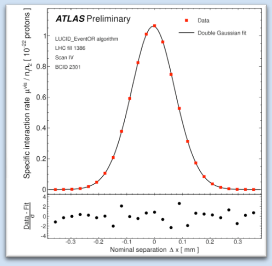
- Center beams at the IP *mini-scans*
- Scan one beam in x-plane by ±6σ (~25 steps)
- Re-center beams (if needed) and scan in y-plane
- Measure rate per sub-detector and algorithm vs. separation
- Fit the scan curves



$$\boxed{\sigma_{vis} = \mu_{vis}^{MAX}} \frac{2\pi \boxed{\Sigma_X \Sigma_Y}}{n_1 n_2}$$

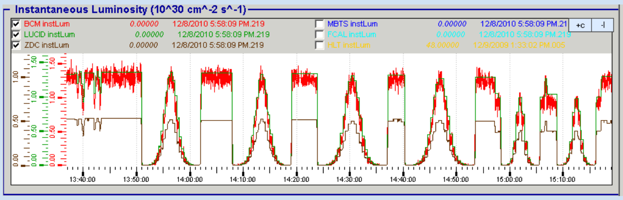
Dependent on algorithm

Independent of algorithm



Double Gaussian fit to Event OR counts from LUCID vs. horizontal separation.

Snapshot of the **online luminosity** reported by three different sub-detectors during the latest vdM scan.



Systematic Uncertainties

Scan Number	I	II–III	IV–V	
Fill Number	1059	1089	1386	
Bunch charge product	5.6%	4.4%	3.1%	Partially correlated
Beam centering	2%	2%	0.04%	Uncorrelated
Emittance growth and other non-reproducibility	3%	3%	0.5%	Uncorrelated
Beam-position jitter	–	–	0.3%	Uncorrelated
Length scale calibration	2%	2%	0.3%	Partially Correlated
Absolute ID length scale	0.3%	0.3%	0.3%	Correlated
Fit model	1%	1%	0.2%	Partially Correlated
Transverse correlations	3%	2%	0.9%	Partially Correlated
μ dependence	2%	2%	0.5%	Correlated
Total	7.8%	6.8%	3.4%	

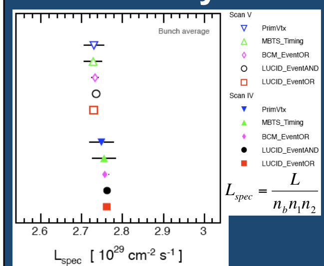
Relative systematic uncertainties on the determination of σ_{vis}

Big improvement on the total systematic error, mainly due to a dramatic drop in **bunch current** uncertainty.

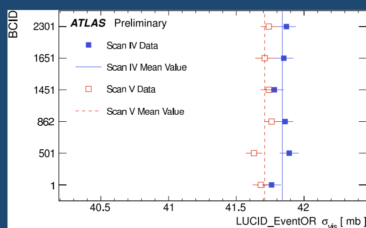
Luminosity measured to a precision of **3.4%**

…but a lot needs to be done to maintain this!

Consistency and results in Scans IV and V

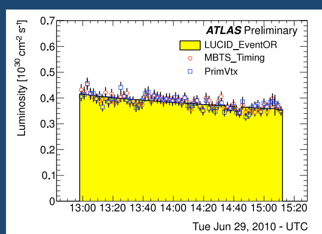


Bunch averaged specific luminosity at the peak.



Visible cross-section per Bunch Crossing. Small difference ~0.3% due to non reproducibility issues.

Comparison of luminosity measurements from different algorithms for LHC fill 1185.



Challenges for 2011

- Foreseen interactions per bunch crossing of **μ~10-13**, which results in larger **pile-up** and leads many algorithms towards **saturation**.
- **Stability of the calibrations** for the upcoming μ-range.
- Reduction of the bunch spacing to **~75ns**, challenge on the **performance** of the luminosity sub-detectors.

Details on the analysis to be found in:
[1] Luminosity Determination Using the ATLAS Detector, arXiv:1101.2185
[2] Updated Luminosity Determination using the ATLAS Detector, ATLAS-CONF-2011-011

Stefan Mättig, for the ATLAS Collaboration

ATLAS EXPERIMENT