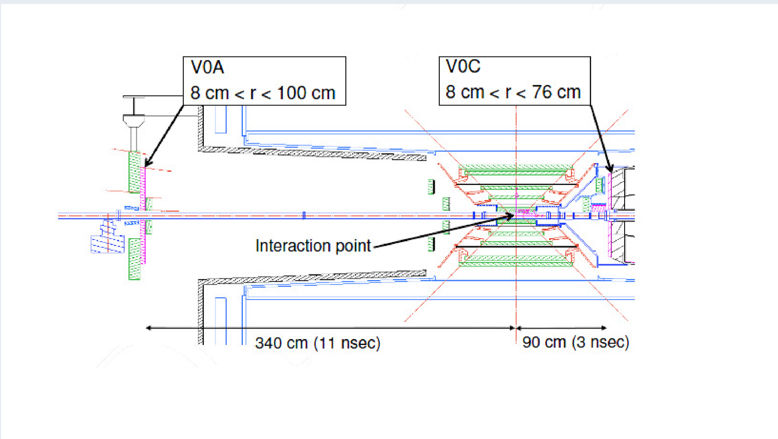
Reference cross section measurements in pp and Pb-Pb collisions at the LHC with the ALICE detector

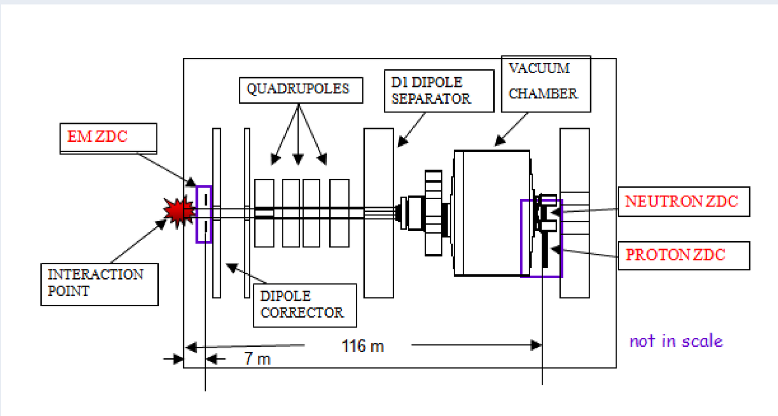
Emilia Leogrande[1], on behalf of the ALICE Collaboration
[1]Universiteit Utrecht
emilia.leogrande@cern.ch

Abstract

Luminosity is an essential ingredient for the measurement of the cross section of physical processes. Luminosity determination in ALICE at the LHC is based on the visible cross sections measured in dedicated calibration experiments (van der Meer scans). Results are presented for vdM scans in pp collisions at $\sqrt{s} = 2.76$ and 7 TeV, and in Pb-Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV, together with a description of the experimental apparatus and analysis technique.

Detector setup





VZERO detector

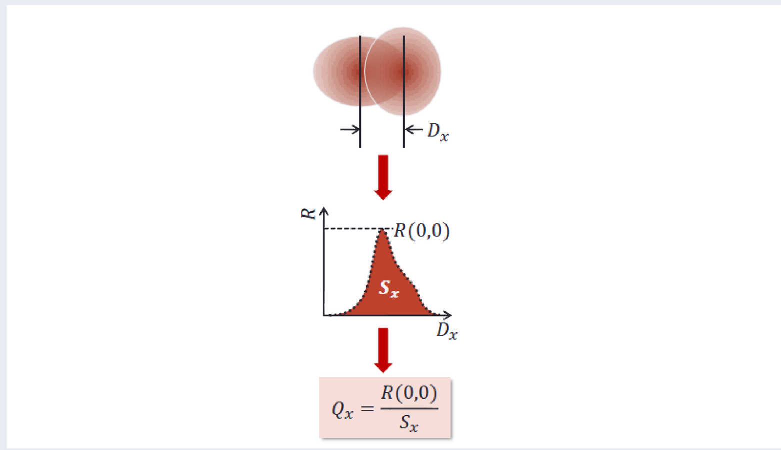
1. Two arrays of scintillators, asymmetrically placed on opposite sides of IP (VZEROA & VZEROC)
2. Main scanned triggers:
   (a) pp collisions: V0AND (simultaneous hits in VZEROA and VZEROC)
   (b) Pb-Pb collisions: V0LN (semi-central trigger, signal on both sides with amplitude threshold)

ZDC detector

3. Zero Degree neutron Calorimeters (ZDC), on opposite sides of IP (ZNA & ZNC)
4. Main scanned trigger:
   (a) Pb-Pb collisions: ZNor (a hit in ZNA or ZNC)

vdM scan technique

The method consists in measuring reference trigger rates while changing the transverse distance of colliding beams, in the x and y directions separately. The trigger rate follows the luminosity and the dependence of beam displacement reflects the shape of the beam.



Steps

- Measure the rate of the reference process as a function of beam displacement $R(x, y)$
- Compute the shape factor

$$Q = \frac{R(0,0)}{S} \quad (1)$$

where S is the scanned area (see fig.)

- Calculate luminosity:

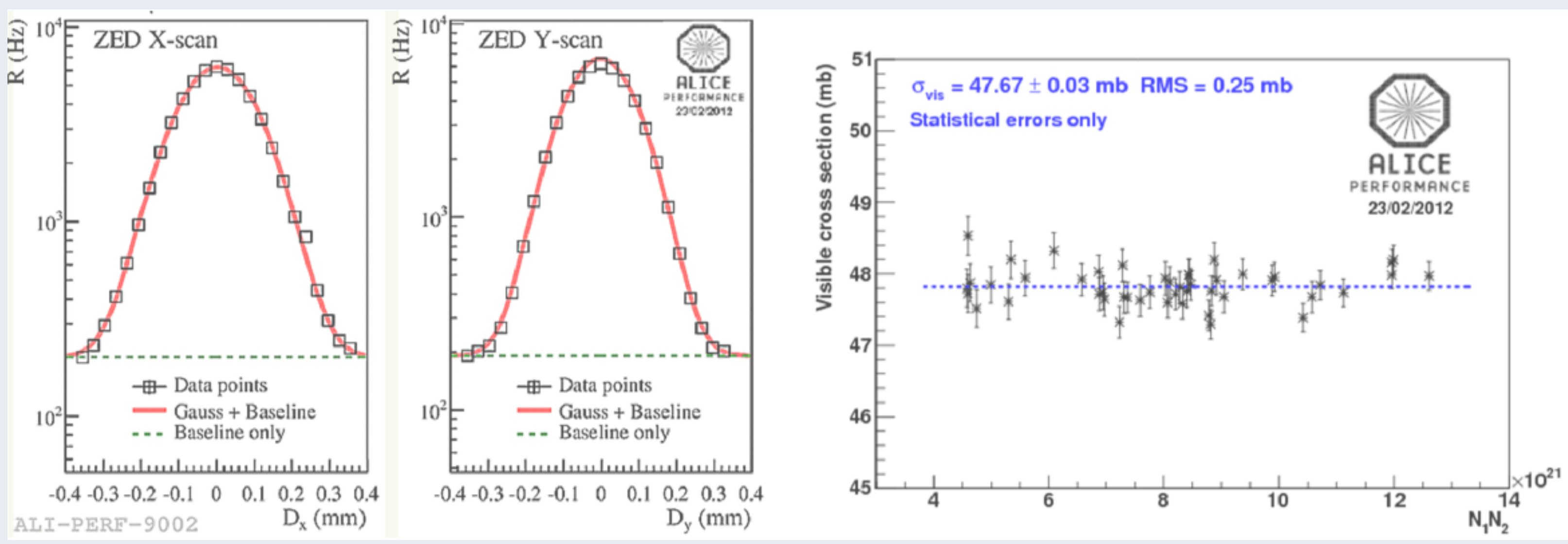
$$L = f_{rev} N_1 N_2 Q_x Q_y \quad (2)$$

- Obtain reference cross section

$$\sigma_{ref} = \frac{R(0,0)}{L} \quad (3)$$

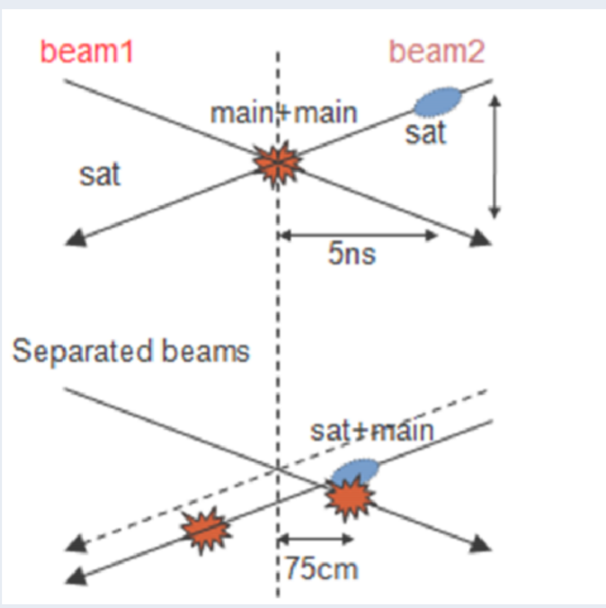
Data Analysis

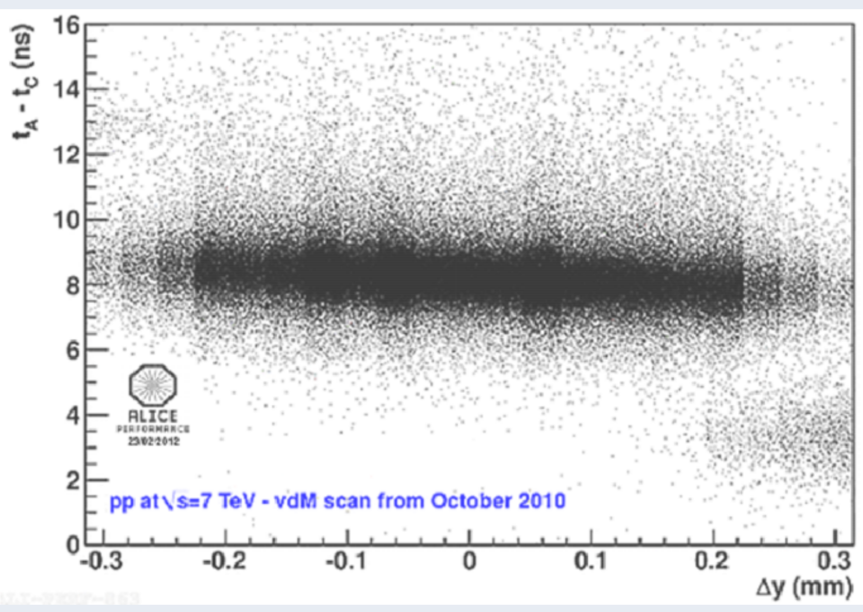
Trigger rates vs separation are recorded. In case of multiple colliding bunches, cross section is evaluated bunch-by-bunch.



Corrections are applied to the raw rates:

1) **Satellite and beam-gas collisions**
Charges trapped in non-nominal RF buckets lead to displaced collisions (enhanced by beam displacement). These cases are spotted and quantified via the signal arrival time difference between the A side and the C side; with the same method, beam-gas collisions can be identified and corrected for.



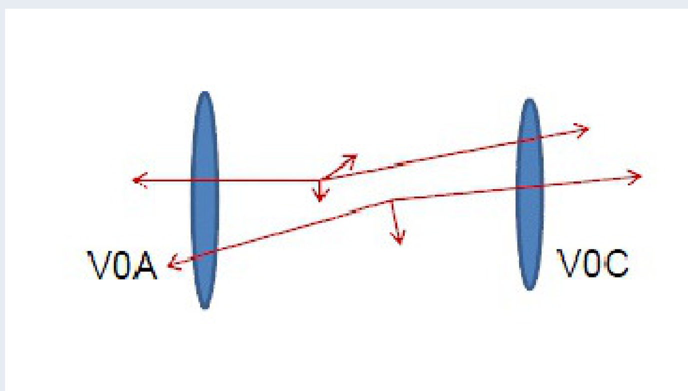


2) **Luminosity decay** Luminosity variation during the scan, due to beam intensity decay and emittance growth. The time-dependence of the top rate has been parametrized and fitted; correction is applied point by point via

$$R_{trigger\_corr}(t) = R_{trigger\_raw} \frac{R_{trig}(t_0)_{fit}}{R_{trig}(t)_{fit}} \quad (4)$$

3) **Pile-up correction**
Multiple V0AND events in the same bunch crossing are not distinguished by the trigger, so they should be treated statistically with a Poissonian distribution; correction is applied point by point via

$$R_{int} = f_{rev} \ln\left(\frac{f_{rev}}{f_{rev} - R_{trig}}\right) \quad (5)$$



4) **Length Scale Calibration (LSC)** Special run aiming at calibrating the nominal vs. the real beam separation by moving the beams in the same direction and measuring the primary vertex displacement with the Silicon Pixel Detector (SPD).

5) **Beam centering** Non-perfect overlap of the beams in one direction while the other is being scanned. The misalignment is known once the scan shapes have been measured.

vdM Cross Section Results

Results for the main scanned triggers are presented in the table below.

Scan	System	Colliding bunches	β^*	Cross section
May2010	pp @ $\sqrt{s} = 7$ TeV	1x1	2 m	$\sigma_{V0AND} = 54.2 \pm 2.9$ mb
Oct2010	pp @ $\sqrt{s} = 7$ TeV	1x1	3.5 m	$\sigma_{V0AND} = 54.3 \pm 1.9$ mb
Nov2010	Pb-Pb @ $\sqrt{s_{NN}} = 2.76$ TeV	114x114	3.5 m	$\sigma_{ZNor} = 371^{+24}_{-19}$ b
March2011	pp @ $\sqrt{s} = 2.76$ TeV	48x48	10 m	$\sigma_{V0AND} = 47.7 \pm 0.9$ mb
Dec2011	Pb-Pb @ $\sqrt{s_{NN}} = 2.76$ TeV	324x324	1 m	$\sigma_{V0LN} = 4.1^{+0.22}_{-0.13}$ b

The uncertainties are the combined statistical and systematic ones. The systematics uncertainties include the contributions from both the bunch intensity measurement (from LHC) and the ALICE vdM analysis. While the vdM uncertainties are dominant for pp collisions, the uncertainties in Pb-Pb are dominated by the measurement of non colliding ("ghost") charge in the LHC beams.

Conclusions

Reference cross sections for several trigger configurations have been measured by ALICE in vdM scans. These are used for luminosity normalisation in the measurement of physical cross sections. The uncertainties are on the order of $2-3\%$ for pp collisions and $5-7\%$ for Pb-Pb collisions.