Analysis of the May 2010 van der Meer scan in ALICE

K. Oyama* for the ALICE Collaboration
University of Heidelberg, Philosophenweg 12, 69120 Heidelberg, Germany

Abstract

A reference trigger cross section has been measured by the ALICE experiment in p+p collisions at $\sqrt{s} = 7$ TeV at the LHC, using the van der Meer scan method to evaluate the convolution of the beam profiles. The description of the measurements and analysis is presented in this document.

INTRODUCTION

The measurement of the absolute value of the cross-section σ_{trig} of a reference trigger process allows the determination of an absolute scale normalization for other cross-section measurements in the experiment and enables the on-line calculation of the luminosity based on the measurement of the trigger process' rate R_{trig}, via the relation $R_{trig}(t) = L(t) \cdot \sigma_{trig}$.

In the ALICE experiment[1], such a reference cross-section has been measured using the van der Meer (vdM) scan method [2]. In this method, the rate of the reference process is measured as function of the beams separation, providing information on the spatial convolution of the two colliding beams. This information, combined with the knowledge of the beam intensities, allows to determine the absolute luminosity, and hence to obtain a measurement of the absolute value of the cross-section of the reference process.

Target Precision

In ultra-relativistic heavy-ion collision experiments particle production in nucleus-nucleus collisions is often compared with the extrapolation from elementary pp collisions via binary scaling. The nuclear modification factor $R_{AA}^{(X)}$ for a given process X is defined as the ratio between the process yield in AA collisions $N_{AA}^{(X)}/N_{evt}$ and the yield expected by scaling the pp cross-section $\sigma_{pp}^{(X)}$ by the average nuclear overlap function $\langle T_{AA}\rangle$, that quantifies the average nucleon-nucleon "luminosity" per nucleus-nucleus collision for the sample under consideration:

$$R_{AA}^{(X)} = \frac{N_{AA}^{(X)}/N_{evt}}{\langle T_{AA}\rangle \cdot \sigma_{pp}^{(X)}} \quad (1)$$

For processes expected to scale like the number of binary nucleon-nucleon collisions (such as hard processes), deviation from unity in the nuclear modification factor allows to quantify the importance of nuclear effects such as parton energy loss in the medium formed in heavy ion collisions.

* oyama@physi.uni-heidelberg.de

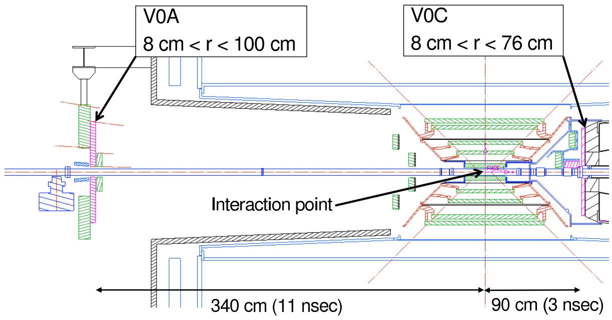

Figure 1: Locations of V0 detectors, V0-A and V0-C.

The desired precision for $R_{AA}^{(X)}$ studies is typically 10% or better. In order for the uncertainty on $\sigma_{pp}^{(X)}$ not to be dominant in the overall uncertainty, a precision of the order of 5% on absolute cross-sections in pp collisions, and hence on the vdM scan reference trigger process, is desired.

V0 TRIGGER SETUP

For the present study, the coincidence between the trigger signals from the two V0 scintillator arrays [1] has been chosen as the reference trigger process. The V0 layout is shown in Fig. 1. The detector consists of two arrays of scintillators placed at z =340 cm and 90 cm respectively for the A-side (V0-A, covering $2.8 < \eta < 5.1$) and C-side (V0-C, covering $-1.7 > \eta > -3.7$), with the scintillator tiles arranged in 2 (radial) $\times$ 16 (azimuthal) segments with individual photomultiplier-tube readout.

The V0 front-end electronics measures the pulse height and arrival time of the signals, with 32 channels of readout electronics each for the V0-A and V0-C arrays.

For each of the two arrays, pulse height thresholds are applied and discriminator outputs are fed into trigger logic circuits that combine the 32 channels into a logical OR. The individual thresholds are well separated from both the pedestal and the minimum ionization peak.

The two resulting trigger signals from V0-A and V0-C can then be combined in two ways: with an "OR" logic (VBOR) and with an "AND" logic (VBAND). To reduce the sensitivity to beam-gas and other machine-backgrounds, the VBAND logic was chosen for the present study. The VBAND logic requires at least one charged particle to be detected both on V0-A and V0-C. During the vdM scan the noise level of the VBAND trigger was negligibly small (below 0.1 Hz).

The photomultiplier tubes of the V0 detector are affected by after-pulsing: secondary pulses may follow the primary one up to 1 μs later. The effect of after-pulses is also suppressed to a negligible level using the VBAND coincidence.

VAN DER MEER SCAN

During the scan, the luminosity is varied by changing the distance between the two beams in the horizontal (x) and vertical (y) directions ($x - y$ being the plane transverse to the beam axis). The trigger rate follows the luminosity, and the dependence on the beam displacement in $x - y$ reflects the shape of the convolution of the two beams, as discussed below.

Principle of Cross Section Determination

In this analysis, the trigger cross section (σ_{V0}) of VBAND is measured. The luminosity depends on the transverse profiles ρ_1 and ρ_2 of the two colliding beams Beam-1 and Beam-2, and on the transverse displacement of the two beams (D_x, D_y):

$$L(D_x, D_y) = k_b f \iint \rho_1(x - D_x, y - Dy)\rho_2(x, y)dxdy \tag{2}$$

where k_b is the number of colliding bunches in the orbit, and f is the orbital frequency. The beam profiles are often approximated by gaussian shapes with standard deviations σ_{1x} and σ_{1y} for Beam-1 and σ_{2x} and σ_{2y} for Beam-2. With the above notation one obtains:

$$L(0,0) = \frac{k_b f N_1 N_2}{2\pi\sqrt{(\sigma_{1x}^2 + \sigma_{2x}^2)(\sigma_{1y}^2 + \sigma_{2y}^2)}} \tag{3}$$

where N_1 and N_2 are the average bunch intensities of the two colliding two beams.

During the vdM scan, one of either D_x or D_y was scanned, while beams were kept colliding head-on (zero separation) in the other direction, and the trigger rate

$$R_{\text{V0}} = \sigma_{\text{V0}} L \tag{4}$$

was recorded. Taking, for instance, the case of the horizontal scan (x-scan), in the gaussian approximation, the VBAND trigger rate will be reduced from the top luminosity value $R_{\text{V0}}(0, 0)$ to

$$R_{\text{V0}}(D_x, 0) = R_{\text{V0}}(0,0) \cdot \exp\left(-\frac{D_x^2}{2\sigma_{scan-x}^2}\right) \tag{5}$$

with the "scan standard deviation" defined as:

$$\sigma_{scan-x,y} = \sqrt{\sigma_{1x,y}^2 + \sigma_{2x,y}^2} = \sqrt{2}\sigma_{x,y}. \tag{6}$$

The width of the shape obtained by the vdM scan corresponds to the quadratic sum of the widths of the two beams.

Non-Gaussian Beam Profile

The above considerations are extended here to a more general case of non-gaussian beam profile.

Assuming the two beams to have the same shape in the transverse direction, and assuming factorization of the shapes in x and y, the beam profile can be written as

$$\rho_{1,2}(x, y) = N_{1,2} p_x(x) p_y(y) \tag{7}$$

where $p_x(x)$ and $p_y(y)$ are the normalized density profiles of the beams in the x and y directions.

For convenience, we define the "*shape factors*" as:

$$\int p_x^2(x)dx = Q_x, \quad \text{and} \quad \int p_y^2(y)dy = Q_y. \tag{8}$$

Using the above assumptions and definitions, the trigger rate for the x-scan becomes:

$$R_{\text{V0}}(D_x, 0) = \sigma_{\text{V0}} k_b f N_1 N_2 Q_y \int p_x(x - D_x)p_x(x)dx. \tag{9}$$

The integral of the convolution of the beams in the x direction is:

$$S_x = \int R_{\text{V0}}(D_x, 0)dD_x, \tag{10}$$

and similarly for y. The two convolution integrals can then be expressed as:

$$S_x = \sigma_{V0} k_b f N_1 N_2 Q_y \quad \text{and} \quad S_y = \sigma_{V0} k_b f N_1 N_2 Q_x. \tag{11}$$

The maximum value of the rate, corresponding to zero displacement, can be written as:

$$R(0,0) = \frac{k_b f N_1 N_2 Q_x \cdot Q_y}{\sigma_{V0}}. \tag{12}$$

From (11) and (12):

$$\frac{R(0,0)}{S_x} = Q_x \quad \text{and} \quad \frac{R(0,0)}{S_y} = Q_y. \tag{13}$$

The vdM scan can therefore be used to extract the shape factors $Q_{x,y}$ and, knowing the bunch intensities $N_{1,2}$, to evaluate the luminosity and hence the cross-section for the reference process.

VDM DATA ACQUISITION

Table 1 shows the summary of the conditions for the vdM scan performed in May 2010, that shall be referred to in the following as Scan-I.

During the scan, the data was recorded in coordination between ALICE (via the Detector Control System, DCS) and the LHC. The LHC operator scanned the beam separation in ALICE, while ALICE monitored the trigger rate (R_{V0}) every 10 seconds, and recorded it on a dedicated data-base along with time stamps. In order to avoid measuring the rate while the beams are in movement, an "*acquisition flag*" (AF) is sent by the LHC. The AF can take on a value of 0 or 1, with 1 indicating that the flag is active and the data is valid.

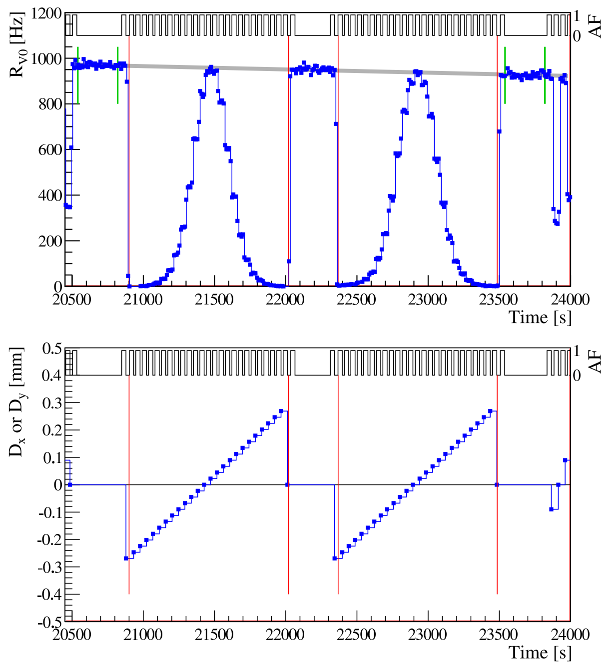

Figure 2: R_{V0} vs time (top) and separation value vs time (bottom) recorded in the ALICE DCS. For each plot, the status of the Acquisition Flag is shown on the upper part.

Fig. 2 shows the full view of the vdM scan period retrieved from the data-base before any correction is applied. The two peaks in the rate plot (top) correspond to the two scans. The scan was done first in the x direction, keeping the y position centered, and then in the y direction, keeping the position centered in x. Only data points recorded during the AF=1 periods are used in the analysis. An AF=1 period was declared at each separation step, for $\sim$ 30 seconds, allowing the recording of three R_{V0} data points with 10 seconds averaging time. In the present analysis, the data points belonging to the same separation value were combined and averaged.

BEAM INTENSITY

The absolute bunch intensities N_1 and N_2 are monitored by LHC beam instruments based on inductive current pickup devices. The corrections and calibrations of intensity data for the vdM scan fill were performed by the Beam Current Normalization Working Group (BCNWG), that provided intensity results together with systematic uncertainties[3]. According to the BCNWG result, the product of the two beam intensities ($N_1 \cdot N_2$) during the scan was 415.8×10^{18} with a systematic uncertainty of 4.4%.

The decrease of the bunch intensity during the scan time was as much as 0.25% and 0.06% for Beam-1 and Beam-2, respectively. This effect was corrected for in the analysis as part of the luminosity decay correction (see below).

Since the beam instrumentation used for the bunch intensity determination is not sensitive to the distribution of the charge within one LHC bunch (corresponding to 10 RF buckets), the effects of the decrease in the intensity of the main bucket due to debunching must be corrected for. The effect of such satellite bunches can be studied by reconstructing the interaction vertices from collisions displaced from the main luminous region. The intensity of satellite bunches and the ghost charge (charge distributed at longer distances over the orbit) were evaluated within the BCNWG. The collision rate involving satellite bunches is estimated to be less then 0.2% of the total rate. The amount of ghost charge in all slots is approximately (0.42±0.06)% and (0.41±0.06)% for Beam-1 and Beam-2, respectively. with an amount contained in slots near the colliding bunches of (0.24±0.05)% and (0.36±0.06)% for Beam-1 and Beam-2, respectively. The corrections based on these numbers (less than 1%) are already applied to the bunch intensity values provided by the BCNWG.

Table 1: Summary of the first ALICE vdM scan conditions

item	value, conditions
date	May 10, 2010
LHC fill number	1090
LHC fill scheme	Single_2b_1_1_1
intensity (Beam-1, Beam-2)	3.4×10^{10}, 3.8×10^{10}
nominal bunch size	1.8×10^{10}
β^*	2 m
nominal μ at head-on	0.09
crossing angle	internal only
beam spot size (σ_x, σ_y)	(44 μm, 47 μm)
ALICE run numbers	119156 (vdM)
	119159 (LSC)
scanned triggers	VBAND (DCS)
scan points	25 for each plane
scan step	22.42 μm
scan range	$\sim \pm 6\sigma$
scan points for LSC	3

DATA ANALYSIS

The vdM scan data were first corrected for pile-up and for the effect of the decrease in the luminosity during the fill due to emittance blow-up and bunch intensity decay. Then, the shape factors were calculated using different methods and compared. The separation values were checked using the results of the Length Scale Calibration (LSC) measurement. The individual analysis steps are described in the following subsections.

Pile-up Corrections

During Scan-I the trigger rate reached a maximum of about 1 kHz, with only one bunch crossing per orbit and an average number of collisions per bunch crossing (μ) of $\sim$0.1. Bunch crossings in which more than one interaction occurs are still counted as one interaction in the VBAND rate. This pile-up effect must therefore be corrected for.

Indicating with μ the average number of triggers per bunch crossing and using Poisson statistics, the probability of one ore more triggers in a bunch crossing is given by:

$$P_{\rm V0}(0;\mu) = 1 - e^{-\mu} \tag{14}$$

The value of μ can therefore be obtained from the raw trigger rate:

$$R^{raw}_{\rm V0} = k_b f (1 - e^{-\mu}), \tag{15}$$

and the corrected interaction rate can then be evaluated as:

$$R_{\rm V0} = k_b f \mu. \tag{16}$$

This correction has been applied to the V0 rates point by point. At about 1 kHz of interaction rate, the correction is as much as 5%.

Correction for the Luminosity Decay

As can be seen in Fig. 2, there is a systematic decrease of the top rate with time. This is dominated by the increase of the beam emittance. The bold gray line in the Fig. 2 is the result of a straight line fit using data points recorded outside of the scanning time. The fitting region is indicated by thin green vertical lines. The individual data points were then normalized so that the head-on luminosity corresponds to the value measured at an arbitrarily chosen neutral point at 22160 s in the plot. The maximal correction factors are -1.7% at the beginning of the x-scan and $+2.0\%$ at the end of the y-scan.

Length Scale Calibration

The scan separation values D_x and D_y were provided by the LHC. The calibration of the length scale has been verified by analyzing the data taken during a dedicated ("Length Scale Calibration", LSC) run during which both beams were moved in the same direction in either x or y. The data were then analyzed offline by reconstructing the primary vertex positions in order to determine the transversal displacement of the luminous region.

Fig. 3 shows the LSC data, with straight line fits to the data points for the x and y scans. According to the result of the fits, the actual separation is ~1.3% and ~0.9% smaller than the recorded values of D_x and D_y, respectively. In addition, there is some deviation from linearity, especially in the y direction (~2 μm). These values have been used in the evaluation of the systematic uncertainty (see later).

Shape Analysis with the Fitting Method

The data, corrected for pile-up and luminosity decrease, were analyzed using various fitting methods. The first is based on the use of a simple gaussian distribution (3 free parameters):

$$R_{\rm V0}(D_{x,y}) = A_{x,y} \exp\left\{-\frac{(D_{x,y} - m_{x,y})^2}{2\sigma^2_{scan-x,y}}\right\}. \tag{17}$$

Table 2: Summary of fit results with calculated luminosity and $\sigma_{\rm V0}$.

parameters	**single gaussian**	**double gaussian**
A_x [Hz]	970.4±2.9	1000.1±3.5
m_x [μm]	8.8±0.1	8.8±0.1
α_x	-	0.463±0.046
σ_{scan-x} [μm]	62.0±0.1	50.0±1.2
σ_x [μm]	43.8	35.4
$\sigma_{scan-xb}$ [μm]	-	68.8±0.7
σ_{xb} [μm]	-	48.6
fit $\chi^2/n.d.f.$	406.0 / 22	72.2 / 20
A_y [Hz]	984.4±2.8	998.8±2.8
m_y [μm]	-1.6±0.2	-1.7±0.0
α_y	-	0.978±0.000
σ_{scan-y} [μm]	66.4±0.1	64.3±0.0
σ_y [μm]	47.0	45.5
$\sigma_{scan-yb}$ [μm]	-	123.8±1.3
σ_{yb} [μm]	-	87.5
fit $\chi^2/n.d.f.$	637.2 / 22	168.5 / 20
$L(0,0)$ $\left[10^{28}\frac{1}{\text{cm}^2\text{s}}\right]$	1.81±0.01	1.89±0.04
$\sigma_{\rm V0}$ [mb]	54.06±0.17	52.95±1.00
with centering corr.	54.34±0.18	53.23±1.01

The results are shown in Fig. 4 as bold gray curves. While the single gaussian fit is acceptable for the x-scan, non-gaussian – and possibly asymmetric – tails are observed for the y-scan.

To improve on this, fits based on a double gaussian distribution were also performed, using the functional form:

$$\begin{aligned} & R_{\rm V0}(D_{x,y}) && (18) \\ = \; & A_{x,y}\left[\alpha_{x,y} \exp\left\{-\frac{(D_{x,y} - m_{x,y})^2}{2\sigma^2_{scan-x,y}}\right\}\right. \\ + \; & \left.(1-\alpha_{x,y}) \exp\left\{-\frac{(D_{x,y} - m_{x,y})^2}{2\sigma^2_{scan-x,yb}}\right\}\right] && (19) \end{aligned}$$

where the two gaussians have a common center $m_{x,y}$, but different magnitudes and widths. The relative amplitudes of the primary and secondary gaussians are determined by $0 < \alpha_{x,y} < 1$.

The results of the double gaussian fits are shown in Fig. 4 as solid lines, while the dashed lines show the secondary gaussian part of the fit function.

Table 2 shows the values of the parameters extracted from the fits, together with the values of the luminosity and cross-section. The values for σ_x and σ_y, and σ_{xb} and σ_{yb} are simple estimates of the beam spot sizes obtained by dividing $\sigma_{scan-x,y,xb,yb}$ by $\sqrt{2}$. It should be noted that the two widths of the double gaussian fits are anti-correlated, resulting in an over-estimation of the fit uncertainty. In addition, the value of α in the double gaussian fit is not strongly constrained if the shape is close to gaussian. Since

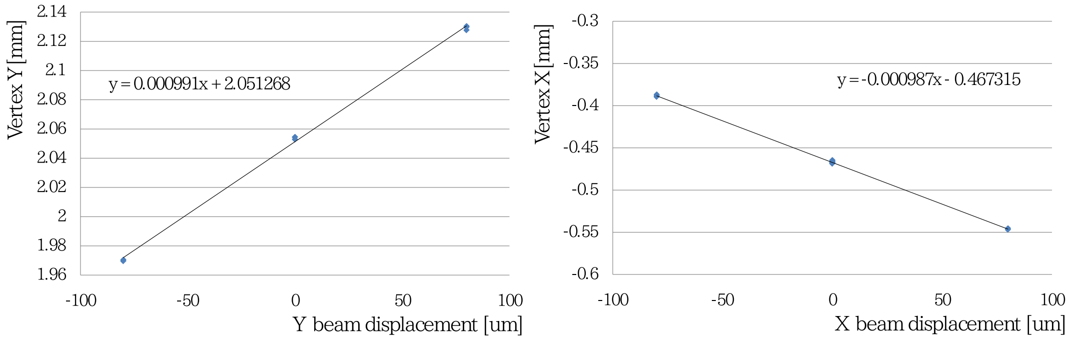

Figure 3: Results of straight line fits to the bump calibration data for the x-scan (left) and the y-scan (right).

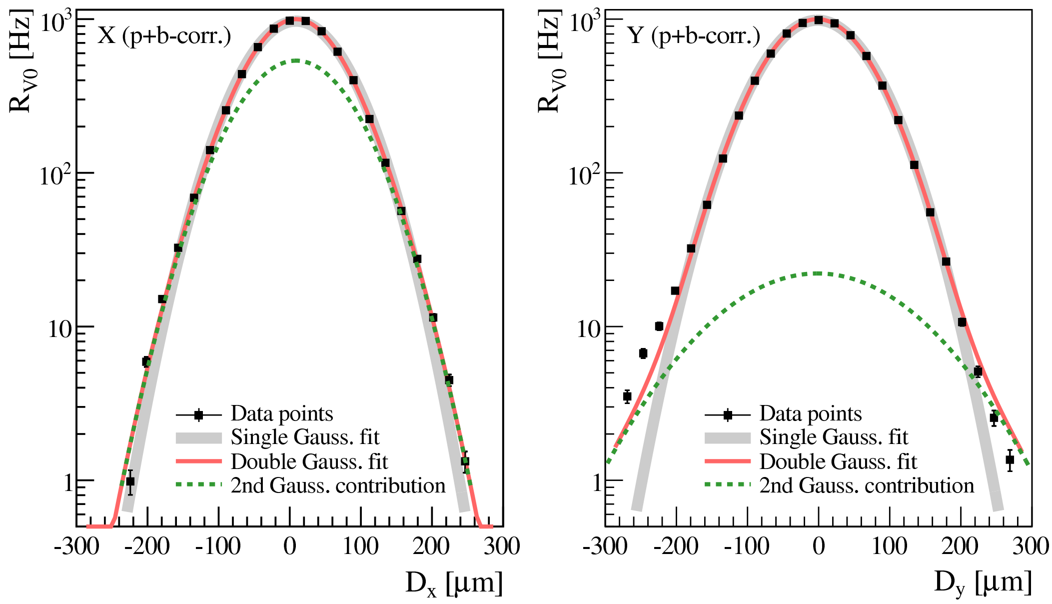

Figure 4: Data corrected for pile-up and luminosity decay, with fits by single gaussian (bold line) and double gaussian (solid line). The dashed lines show the secondary component of the double gaussian fit function.

the central value for the reference VBAND cross-section in this note will not be based on gaussian fits, but on numerical integration, the correlation of the fit errors is not discussed further here.

Beam Centering Correction

As can be seen from the fit results shown in Table 2, the values of D_x and D_y at which the luminosity is maximized are not exactly zero: $(m_x, m_y) = (8.8\ \mu\text{m}, -1.6\ \mu\text{m})$. During the scan, the separation $D_{x,y}$ for one direction is kept neutral (zero) while the beam is scanned in the other direction, which is therefore kept at the residual displacement determined by the values of (m_x, m_y).

The resulting luminosity decrease factors to be corrected for are estimated using (17). They are: 99.97% and 99.00% for the x- and y-scans, respectively.

The effect on the final value on cross section is +0.52%, taking into account the correlations among the parameters. In addition, conservatively, a 1% uncertainty is included in the final systematic error to account for possible residual centering effects.

Shape Analysis by Numerical Integration

The convolution integral can be calculated independently of the gaussian fits by numerical integration:

$$S_x = \sum_{i=1}^{n_x} R_{xi}\Delta_{xi} \quad \text{and} \quad S_y = \sum_{i=1}^{n_y} R_{yi}\Delta_{yi} \qquad (20)$$

where $n_{x,y}$ are the numbers of measured data points for each horizontal and vertical scan, R_{xi} and R_{yi} are the measured trigger rates, and Δ_{xi} and Δ_{yi} are the sizes of the bins. The results are shown in Table 3.

Table 3: Results of the numerical integration method for pile-up- and luminosity loss-corrected data together with intermediate results. σ_x and σ_y are the equivalent gaussian standard deviations corresponding to $S_{x,y}$.

parameters	**values**
$R(0,0)_x$ [Hz]	976.4±5.8
S_x [μm/s]	150696±339
Q_x [/cm]	64.79±0.41
σ_x [μm]	43.5
$R(0,0)_y$ [Hz]	986.4±5.9
S_y [μm/s]	164219±358
Q_y [/cm]	60.07±0.38
σ_y [μm]	47.0
$\langle R(0,0)\rangle$ [Hz]	981.4±4.1
with centering corr.	986.5±4.2
$L(0,0)$ $\left[10^{28}\frac{1}{\text{cm}^2\text{s}}\right]$	1.82±0.02
σ_{V0} [mb]	53.93±0.28
with centering corr.	54.21±0.28

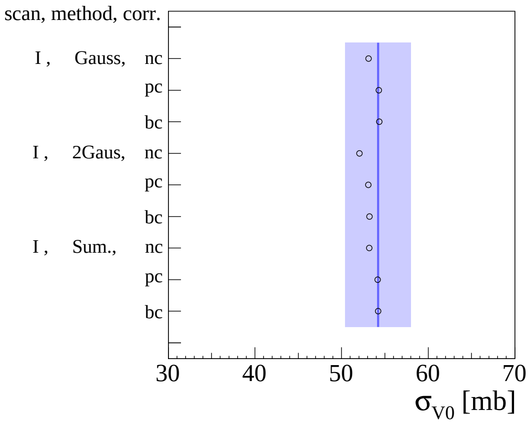

Figure 5: Comparison of the values obtained σ_{V0} for different methods and corrections (nc: no correction, pc: only pile-up correction, bc: full correction). The final value extracted from Scan-I and its systematic uncertainty are indicated by the vertical line and the gray band.

The numerical integration method does not rely on any assumption on the beam shape. In particular, the inclusion of any tails is straightforward. The result obtained based on numerical integration is used as final central value in the present note.

Fig. 5 summarizes how the cross section value varies according to the calculation methods and corrections. For the overall systematic uncertainty on the calculation of the convolution integral we have estimated a somewhat conservative value of 2%. The gray band in Fig. 5 indicates the range of the total systematic uncertainty.

Table 4: List of the systematic uncertainties on σ_{V0} taken into consideration.

item	**rel. uncertainty**
uncert. for $\delta(N_1 \cdot N_2)$	
bunch intensity	4.4%
uncert. for $\delta(S_x \cdot S_y)$	
length scale	2% $\oplus$ 2%
different methods	2%
rate determination	negligible
V0 time window	negligible
beam centering	1%
background and noise	negligible
pile-up	negligible
uncert. (additional)	
luminosity decrease	1%
scan-to-scan variation	2.5%
total $\delta\sigma_{\text{V0}}$	7%

SYSTEMATIC UNCERTAINTIES

Table 4 summarizes the systematic uncertainties associated with the σ_{V0} determination that have been taken into consideration in the present analysis:

Bunch intensity $\cdots$ for the uncertainty on the product of the bunch intensities $N_1 \cdot N_2$, the BCNWG estimate of 4.4% has been used.

Length scale $\cdots$ from the Length Scale Calibration described above, we estimate an uncertainty of 2% for each scan direction. No correlation between x and y is assumed, thus 2%$\oplus$2% is applied.

Integration methods $\cdots$ the variation of the results for the different shape analysis methods was of the order of 1%. Somewhat conservatively, we take a value of 2% for the product $S_x \cdot S_y$.

Rate determination $\cdots$ the rate is measured by the V0 electronics integrating the counts every 10 seconds. The timing is very well controlled, since the integration is performed on an FPGA driven by the 40 MHz LHC clock. We estimate the precision of the integration to be better than 1 ms / 10 s. The systematics associated to the rate measurement is therefore taken to be negligible.

V0 time window $\cdots$ the V0 coincidences are counted within a tunable time window, which was set to its maximum width during the vdM scan in order to avoid possible counting inefficiencies. The resulting systematics is considered to be negligible.

Beam centering $\cdots$ we estimate a residual systematics after the centering correction of the order of 1%.

Table 5: Summary of the Scan-II conditions.

item	value, conditions
date	Oct. 15, 2010 (vdM)
	Oct. 29 and 30, 2010 (LSC)
LHC fill number	1422 (vdM)
	1453 and 1455 (LSC)
LHC fill scheme	Single_16b_3_1_12_allVdmB
intensity in each Beam	1.2×10^{12}
nominal bunch size	7.5×10^{10}
β^*	3.5 m
μ at head-on	$\sim$0.75
crossing angle	internal + external
beam spot size (σ_x, σ_y)	(57 μm, 65 μm)
ALICE run numbers	134779 (candle run)
	134780 (vdM)
scan points in x and y	25 or 21
scan range	$\sim\pm6\sigma$
scan points for LSC	3 to 5

Background and noise $\cdots$ the total level of background is below 1 Hz, resulting in a negligibly small (<0.1%) effect on the luminosity calculation.

Pile-up $\cdots$ the residual systematics due to pile-up once the pile-up correction is applied is estimated to be negligible.

Luminosity decay $\cdots$ the rates have been corrected for the decrease of the luminosity during the fill due to emittance blow-up and intensity decay, as described above. A 1% discrepancy remains after the correction is applied. A 1% uncertainty has therefore been included in the systematics.

Scan-to-scan variation $\cdots$ a second scan was performed later during the year (Scan-II). The preliminary results (see below) give values of the VBAND cross-section up to 2.5% lower. This could be due to a systematics in the preliminary determination of the beam current, which would then in principle be included in the bunch intensity uncertainty. However, for safety, for the moment we include an additional systematic uncertainty of 2.5%.

Adding up quadratically the above uncertainties and rounding off, we obtain a total uncertainty on $\sigma_{\rm V0}$ of 7%. This estimate is somewhat conservative. We intend to review it once the results of the second scan will be final.

PRELIMINARY RESULTS OF THE SECOND VDM SCAN

The second vdM scan at 7 TeV (Scan-II) was performed in October 2010. In Scan-II, besides VBAND, other triggers were also measured. In the present document, we concentrate mainly on the results of the VBAND scan. Since the beam current analysis is still being finalized by the BCNWG at the time of writing this document, the results presented here are still preliminary. They are compared with those of Scan-I with the aim of obtaining an estimate of the possible systematics due to differences in the beam or instrumental conditions from scan to scan.

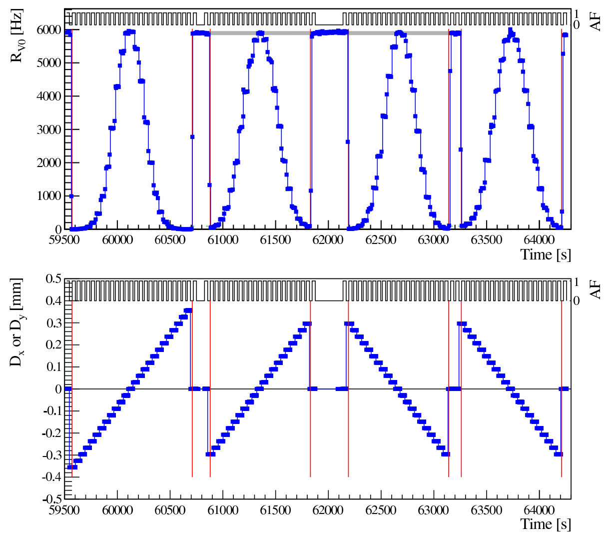

Figure 6: History of raw VBAND trigger rates (upper) and separation values (lower) during Scan-II.

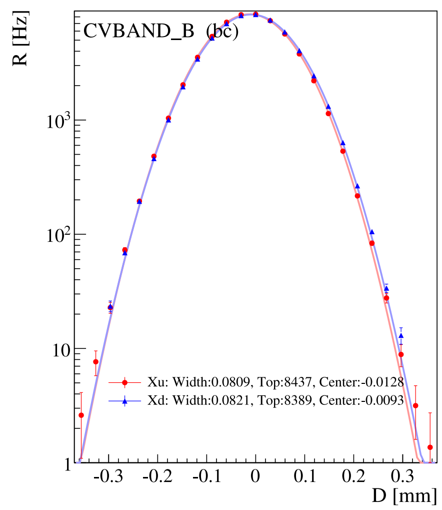

Figure 7: Comparison of scan shapes between u- and d-scans.

Table 5 summarizes the conditions for Scan-II. In addition to the vdM scan, two Length Scale Calibration scans were also performed.

The vdM scan scheme during Scan-II, was different from that of Scan-I. As can be seen from Fig. 6, four successive scans were performed. The first two are an x-scan and a y-scan for which D_x or D_y were increasing with time (u-

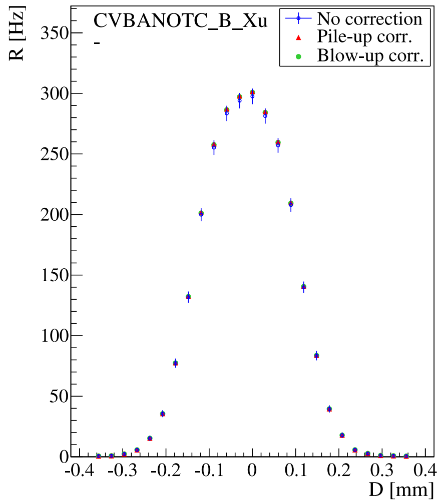

Figure 8: Obtained rate v.s. beam separation for VBA$\overline{\text{C}}$.

scan), the last two are again an x-scan and a y-scan, but this time D_x or D_y were decreasing with time (d-scan).

Scan-to-Scan Shape Stability

Fig. 7 shows the comparison between the data of the u-scan and d-scan in the x direction. The fits were performed using a gaussian function, on emittance-corrected data.

The shapes of the u-scan and of the d-scan deviate from one another for separations D$>$ 0.1 mm. While at D=0 the two scans agree within 0.15%, the discrepancy reaches 15% at high values of D. For the vertical scan, the differences are much smaller. The effect of these discrepancies on the fitted widths is about 1.5%, in x and 0.5% in y. The reason for these discrepancies is currently under investigation.

Beam Intensity

The beam intensity data are not yet fully corrected. The decrease of the bunch intensity during the vdM scan time is less than 0.13%, and can therefore be neglected. The preliminary values for the average intensities during the scan used here are: 83.6×10^{10} and 78.7×10^{10} for Beam-1 and Beam-2, respectively.

Pile-up of Excluded Events

In view of the high trigger rate values expected in Scan-II, two exclusive triggers were set up in order to estimate the effect on the VBAND rate of the pile-up of two events for which only V0-A had fired in one event and only V0-C in the other.

The two exclusive triggers are: VBA$\overline{\text{C}}$, firing when V0-A has fired but V0-C has not, and VB$\overline{\text{A}}$C , doing the opposite.

Fig. 8 shows the result of the scan of VBA$\overline{\text{C}}$. The top rate for VBA$\overline{\text{C}}$ and VB$\overline{\text{A}}$C are approximately 300 Hz and 250 Hz, to be compared with a top VBAND rate after pile-up correction of 8 kHz.

The scan shape for VBA$\overline{\text{C}}$ and VB$\overline{\text{A}}$C is close to gaussian, but slightly flattened at the top, precisely due to exclusive pile-up events of the type discussed above. With rates of the exclusive triggers of the order of 5% or less of the top interaction rate, the effect of exclusive pile-up on the top VBAND rate will be of the order of 0.3 %, and is neglected in the present analysis.

Table 6: Trigger cross sections measured in Scan-II.

trigger (scan dir.)	**cross sections [mb] Gauss fit**	**numerical sum**
VBAND (u-scan)	53.09 ± 0.20	52.90 ± 0.20
VBAND (d-scan)	53.93 ± 0.20	53.51 ± 0.20
MUS5 (u-scan)	0.77 ± 0.01	0.77 ± 0.03
MUS5 (d-scan)	0.76 ± 0.02	0.75 ± 0.03

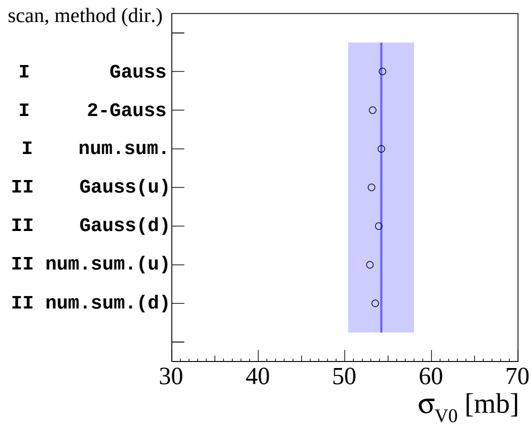

Figure 9: . Comparison between Scan-I and Scan-II results. Only pile-up and luminosity loss corrected data are compared. “(u)” and “(d)” indicate the scan direction. The final value extracted from Scan-I and its systematic uncertainty are indicated by the vertical line and the gray band.

Cross Sections and Comparison Between Fills

Table 6 shows the preliminary values of the cross section extracted from Scan-II data for VBAND and for one of the additional triggers scanned: MUS5 (single muon trigger at forward rapidity [1]). The values for the VBAND cross section vary from 52.9 to 53.9 mb depending on the integration method and on the scan direction. The variation between the u-scan and the d-scan is as much as 1.8%.

The scan-to-scan consistency is visualized in Fig. 9 for the VBAND trigger. The Scan-II values are somewhat lower than the Scan-I value of 54.2 mb which is indicated by the vertical bar, and within the systematic error of the Scan-1 measurement, indicated by the gray band.

The lowest value is the one obtained from numerical integration of the u-scan, which is 2.4% smaller than the Scan-I value. As discussed above, a 2.5% systematic uncertainty has been added in quadrature to the Scan-I results, to account for the possible systematics due to instrumental or beam-related effects.

As an additional consistency check, the ratio between the MUS5 and VBAND trigger cross-sections is compared to the ratio measured offline extracting the fraction of MUS5 events from the VBAND triggered sample recorded in low pile-up conditions. The two ratios agree to better than 1% accuracy, providing an important cross-check of the pile-up correction, which for Scan-II amounts to about 40% for VBAND, while it is negligible for MUS5.

CONCLUSION

Data from the May 2010 ALICE vdM scan (Scan-I) and, partially, from the October 2010 scan (Scan-II) have been analyzed.

The results obtained with different analysis methods (single gaussian fit, double gaussian fit and numerical integration) have been compared in order to estimate the systematics due to the uncertainty on the beam profile. The beam intensity calibration and the Length Scale Calibration for Scan-I are considered to be final.

The preliminary results of Scan-II have been compared to those of Scan-I in order to estimate the systematic uncertainty from scan-to-scan variations due to instrumental or beam effects.

The cross section for the process triggered by the ALICE V0 detector with the VBAND logic for 7 TeV p+p collision has been measured as:

$$\sigma_{\rm V0} = 54.2 \text{ mb} \pm 0.6\%\text{(stat.)} \pm 7.0\%\text{(syst.)}, \qquad (21)$$

and can now be used as a reference cross-section by the ALICE experiment.

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