Luminosity determination in ALICE

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Luminosity

- $\sigma = N/L_{int}$

  σ: cross-section, N: yield, $L_{int} = \int L\,(t)\,dt$: integrated luminosity

- $L = R_{vis}/\sigma_{vis} = f_{rev}N_1N_2/h_xh_y$ (* assume factorization stands)

  R_{vis}: visible rate, σ_{vis}: visible cross-section, f_{rev}: accelerator revolution frequency,

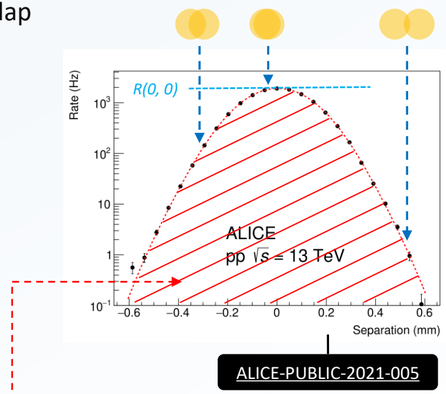
  N_1N_2: beam intensities of colliding bunches, h_xh_y: effective beam overlap width

van der Meer scan in ALICE

- vdM scan: estimate visible rate vs. beam overlap
- Goal: determine visible cross-section (σ_{vis})
- Compute σ_{vis} for each bunch crossing:

$$\sigma_{vis} = R(0,0)/L = R(0,0)h_xh_y/N_1N_2$$

1. N_1N_2: beam intensities of colliding bunches
   (* measured by using LHC instrumentation)
2. Beam separation info from LHC
3. R: visible rate measured in ALICE
   3-a. $R(0,0)$: head-on (highest) rate $\subset R$
   3-b. Relevant detectors: V0, T0, and ZDC_neutron
4. h_xh_y: area under the R vs. beam separation, normalized by $R(0,0)$



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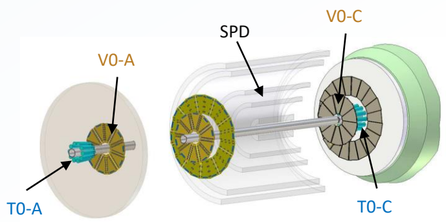

Major corrections and σ_{vis} estimation

1. N_1N_2 (beam intensity): ghost/satellite bunches removal
2. Beam separation: Length-scale calibration, Orbit drift, and Beam-Beam deflection
3. R (visible rate): BG (R_{BB}), pile-up (R_{PU}, in pp), and intensity decay (R_{DC})
4. h_xh_y: non-factorization

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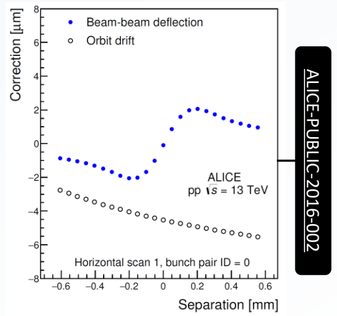

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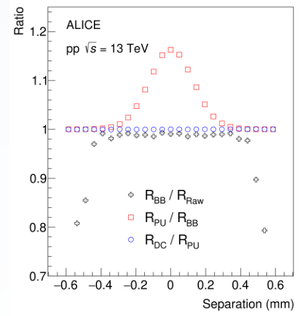

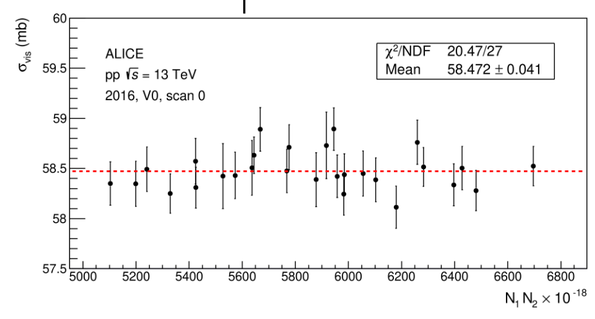

Recent results of pp 13 TeV and Pb-Pb 5.02 TeV

pp $\sqrt{s}$ = 13 TeV (2016, 2017, and 2018)

Uncertainty	2016 T0 | V0	2017 T0 | V0	2018 T0 | V0	Correlated?
Statistical	0.05% | 0.05%	0.07% | 0.07%	0.05% | 0.05%	No
Bunch intensity				
Beam current normalisation	0.5%	0.5%	0.4%	Yes
Relative bunch populations	0.1%	0.3%	0.1%	No
Ghost and satellite charge	< 0.1%	< 0.1%	< 0.1%	No
Non-factorisation	0.5%	0.2%	0.4%	Yes
Length-scale calibration	0.2%	0.3%	0.3%	No
Beam-beam effects	0.3%	0.3%	0.3%	Yes
Orbit drift	0.1%	0.1%	0.2%	No
Magnetic non-linearities	0.1%	0.2%	0.2%	Yes
Beam centring	< 0.1%	< 0.1%	0.1%	No
Luminosity decay	0.5%	0.5%	0.3%	No
Background subtraction	0.1% | 0.6%	0.1% | 0.8%	0.1% | 0.7%	Yes
Pile-up	0.1% | < 0.1%	0.5%	0.2% | < 0.1%	Yes
Fit model	0.2%	0.6%	0.4%	Yes
h_xh_y consistency (T0 vs V0)	0.1%	0.4%	0.4%	No
Bunch-by-bunch consistency	< 0.1% | < 0.1%	0.1% | 0.1%	0.1% | 0.1%	No
Scan-to-scan consistency	0.2% | 0.1%	0.1% | 0.1%	0.5% | 0.5%	No
Stability and consistency	1.5%	2.3%	1.6%	No
Total correlated	0.8% | 1.0%	1.0% | 1.2%	0.8% | 1.0%	Yes
Total uncorrelated	1.6% | 1.6%	2.4% | 2.4%	1.8% | 1.8%	No
Total	1.8% | 1.9%	2.6% | 2.7%	1.9% | 2.1%	Partially

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Major Uncertainty source

ALICE-PUBLIC-2021-001

Pb-Pb $\sqrt{s_{NN}}$ = 5.02 TeV (2015 + 2018)

Source	Uncertainty (%) V0M | ZED
Statistical	0.09 | 0.04
Bunch intensity	0.8
h_xh_y consistency (V0M vs ZED)	0.13
Length-scale calibration	1
Non-factorisation	1.1
Bunch-to-bunch consistency	0.1 | 0.4
Scan-to-scan consistency	1
Background subtraction	0.5 | 0.8
Magnetic non-linearities	0.2
Orbit drift	0.15
Beam–beam deflection and distortion	0.1
Fitting scheme	0.4
Total on visible cross section	2.1 | 2.2
Stability and consistency	0.7
Total on luminosity	2.2 | 2.3

Combined uncertainty: ~1.6% (~2.2%) for pp (Pb-Pb)