



# Luminosity Measurement with the CMS Experiment



Joscha Knolle  
on behalf of the CMS collaboration

## Luminosity

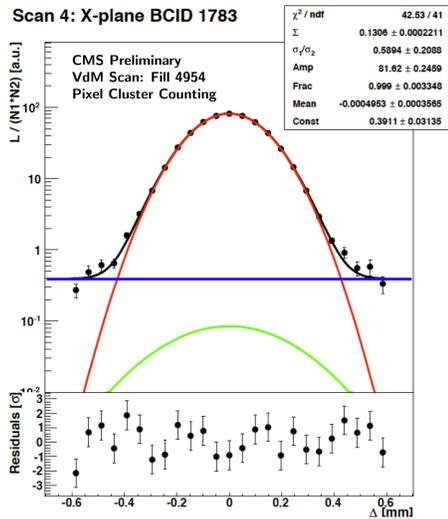
$$\frac{dN}{dt} = \mathcal{L} \cdot \sigma$$

event rate      cross section

- measure for collision rate
- important input to cross section measurements
- calibrated with Van der Meer method

## Van der Meer Method

- Van der Meer scan:** beams moved in steps across each other
- fit to event rate versus beam separation
- transverse width  $\Sigma$  of beam overlap from fit
- calibration constant  $\sigma_{vis}$  from two transverse  $\Sigma$  measurements and beam currents

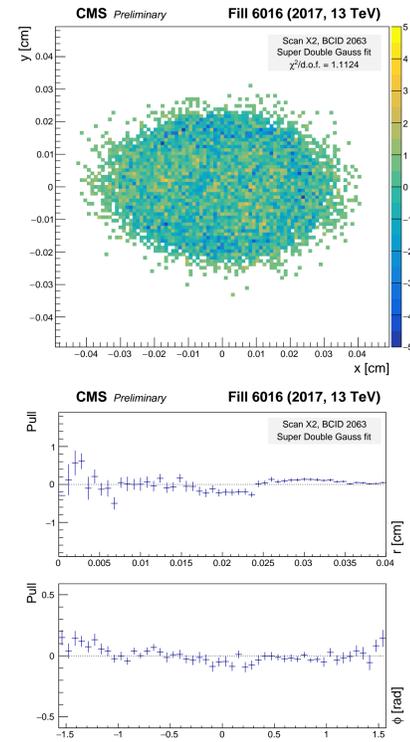


$$\sigma_{vis} = \frac{2\pi \Sigma_x \Sigma_y R_0}{N_1 N_2 f_{LHC}}$$

beam overlap size      peak rate  
visible cross section      number of protons      revolution frequency

## XY Correlations

- Van der Meer method assumes factorizable beam shapes
- Beam imaging scan:** one beam fixed, other beam moved across
- probe of scanned component of resting beam's proton density
- 2D proton density reconstructed from simultaneous fit
- modeled with 2D Gaussian distributions with correlation terms
- best fit: Super Double Gaussian (SupDG)
- use fit result to compute correction on  $\sigma_{vis}$

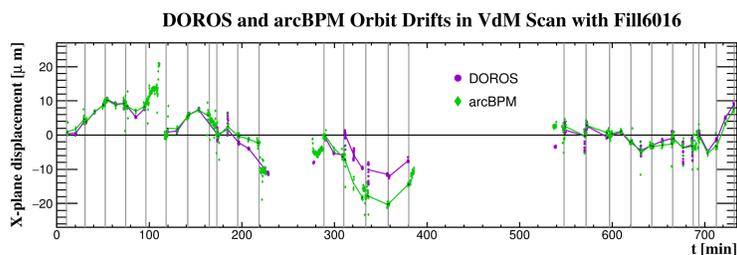


$$\text{SupDG}(x, y) = -w_N g_N(x, y) + w_M g_M(x, y) + w_W g_W(x, y)$$

negative narrow Gaussian, flattens central part      main Gaussian with largest weight      wide Gaussian, enlargens tails

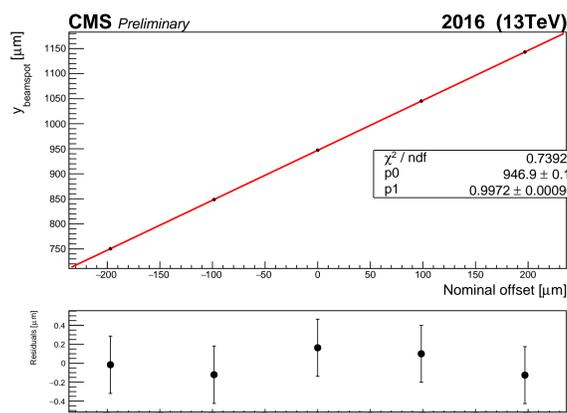
## Orbit Drift

- beams can drift off their nominal positions
- beam separation varies over duration of scan step
- use LHC beam position monitoring systems
- interpolate between head-on positions



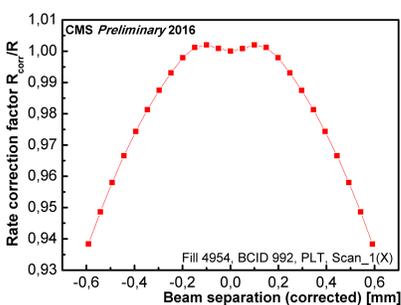
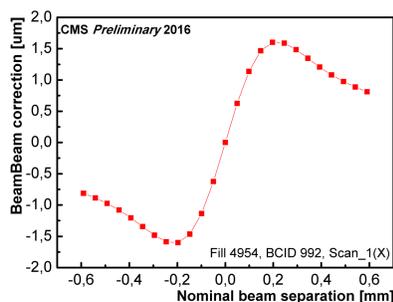
## Length Scale Calibration

- limited accuracy of nominal beam positions from LHC magnet currents
- use sub-micron accuracy of beamspot reconstruction with CMS tracker
- Length scale scan:** beams moved back and forth at constant separation
- linear fit to measured beamspot versus nominal offset
- slope  $\neq 1$  used as correction



## Beam-Beam Effects

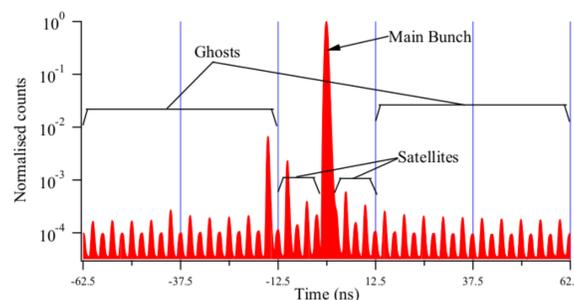
- Beam-beam deflection:** each beam deflected by other beam's electrical field
- actual beam separation larger than expected from nominal positions



- Dynamic  $\beta^*$ :** each beam defocused by other beam's quadrupole field
- collision rate decreased by up to 10%

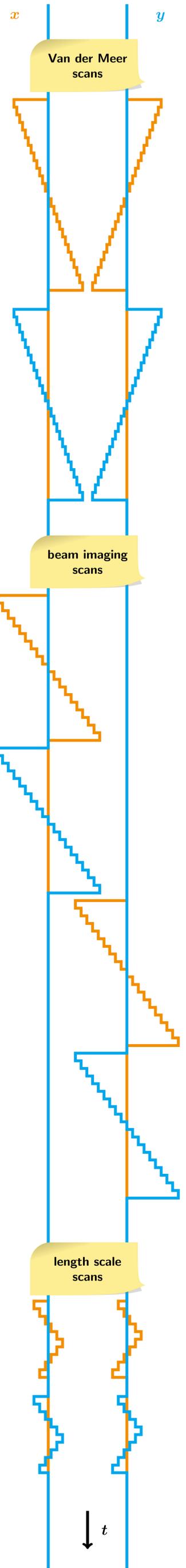
## Bunch Current Measurement

- proton numbers from bunch current measurements with LHC systems
- measurement affected by "ghosts & satellites", i.e. spurious charges not contributing to collisions (in run 2: small effect)



## Scan program

Beam 1      Beam 2



CMS-PAS-LUM-17-001

CMS-PAS-LUM-15-001

