BND school

BND school

what my mom thinks I do

BND school

what my mom thinks I do

what my colleagues think I do

BND school

what my mom thinks I do

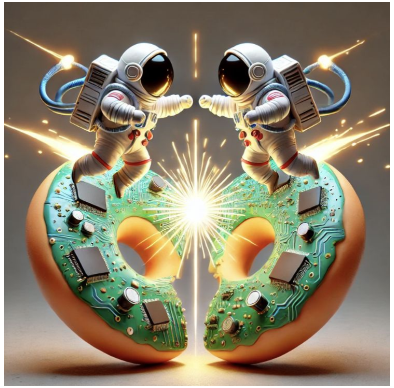
what my colleagues think I do

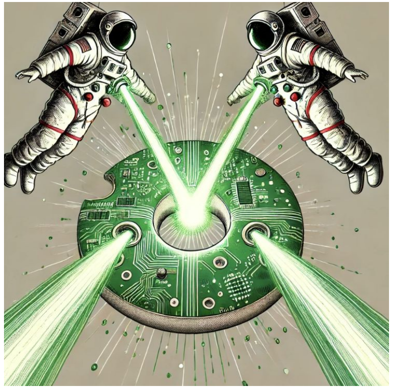
what my supervisor thinks I do

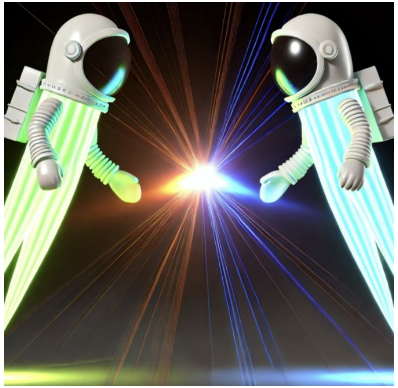
BND school

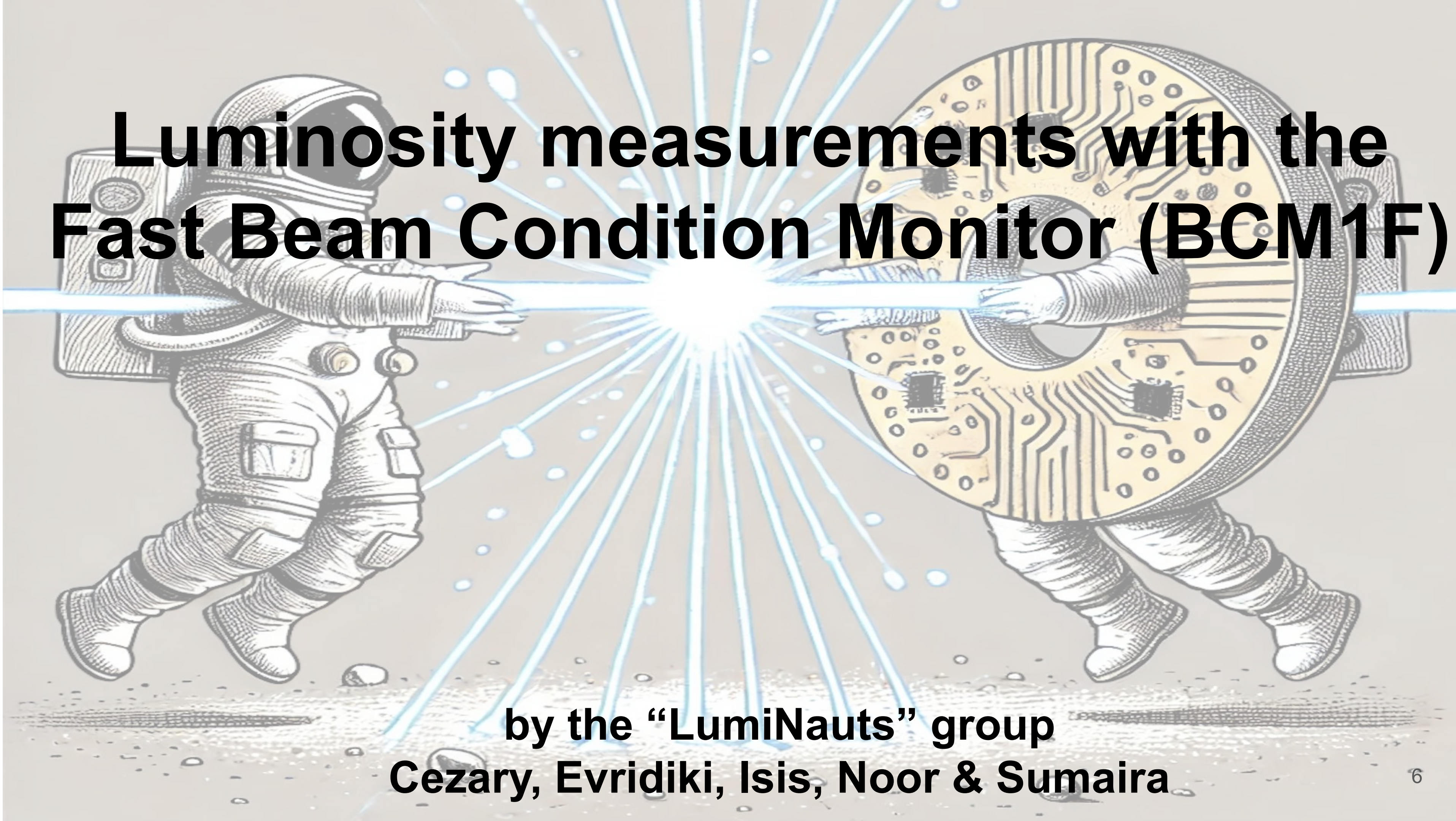
what I actually do

can you make a photo/ sketch for me of 2 beam munches dressed as astronauts colliding to each other (to use the name luminauts) ??









Luminosity measurements with the Fast Beam Condition Monitor (BCM1F)

by the “LumiNauts” group

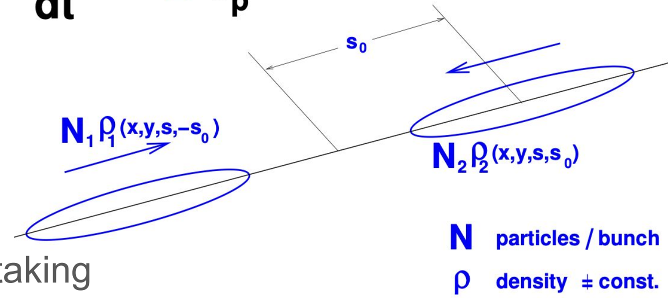
Cezary, Evridiki, Isis, Noor & Sumaira

Luminosity

Luminosity (L) is one of the most important parameters of an accelerator.

It´s a measurement of the **number of collisions** that can be produced in a detector **per cm2 and per second.** The bigger is the value of L, the bigger is the number of collisions. To calculate the number of collisions we need also to consider the cross section.

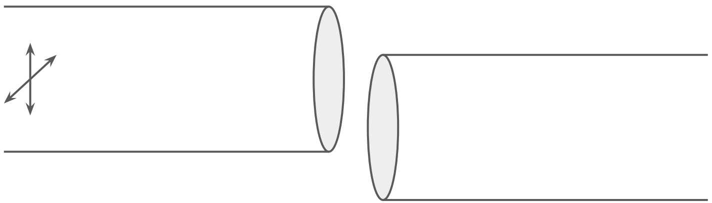
$$\frac{dR}{dt} = L \, \sigma_p$$

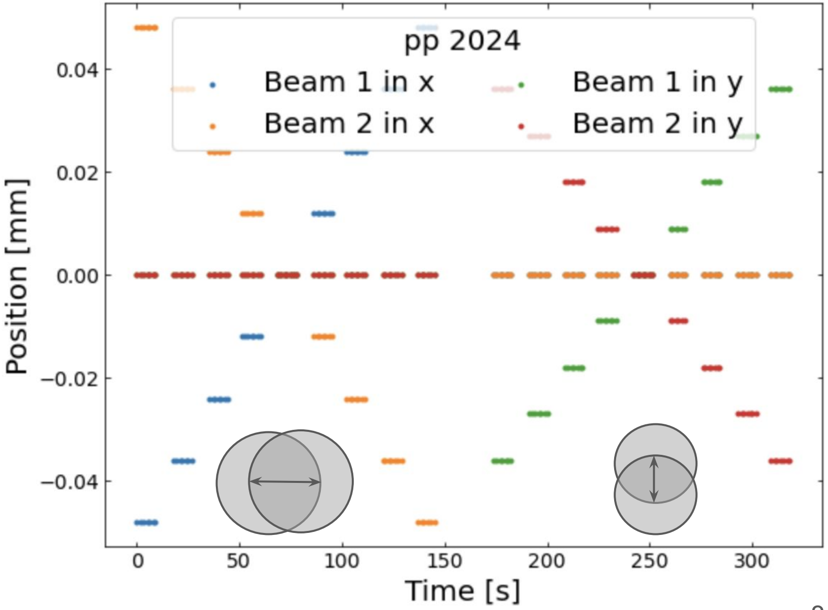


- Instantaneous Luminosity
  - measures how tightly particles are packed into a given space
- Integrated Luminosity
  - considers the total number of events during a period of data-taking

Van der Meer scan

- Beams moved horizontally and vertically relative to each other for scan over x and y
- Beam position determined by:
  - Estimate from LHC beam currents (nominal)
  - Direct measurement from RODOS detectors located at CMS (measured)
- Dedicated luminosity detector measures the rate at each step in time



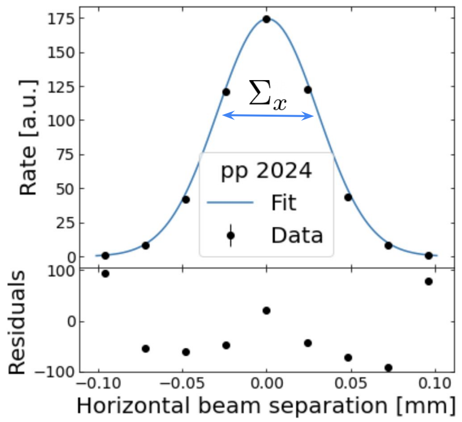


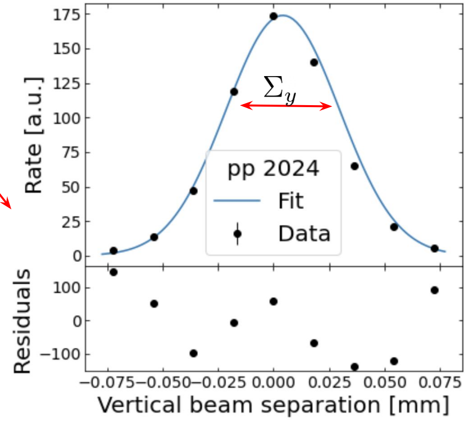
Parameters that affect luminosity

$$\mathcal{L} = \frac{\nu N_1 N_2}{A_{\text{luminous}}}$$

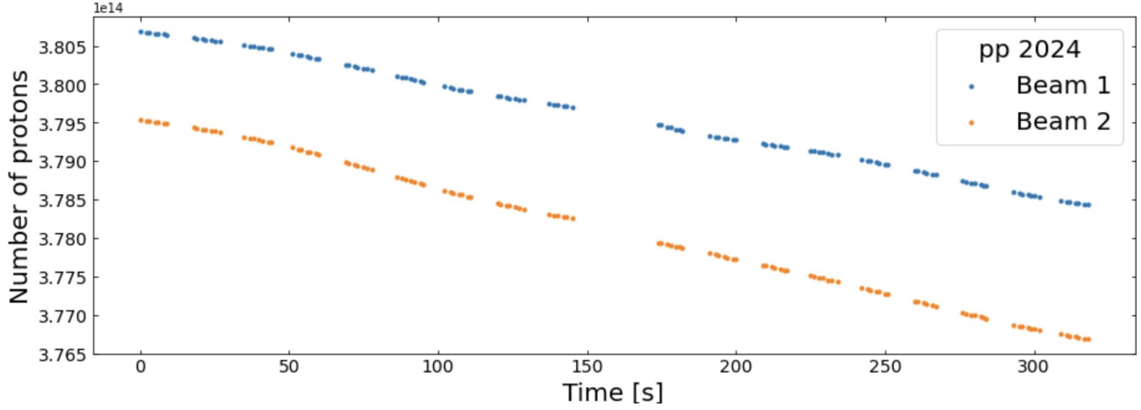
$$A_{\text{luminous}} = 2\pi \Sigma_x \Sigma_y$$

beam-overlap fit

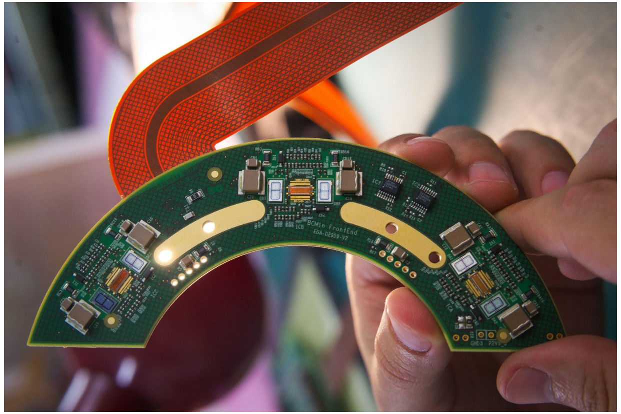




Beam currents

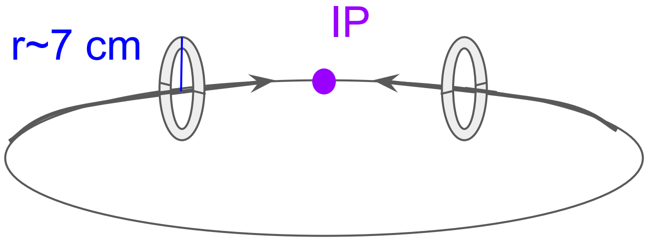


(2022, CMS)



The detector

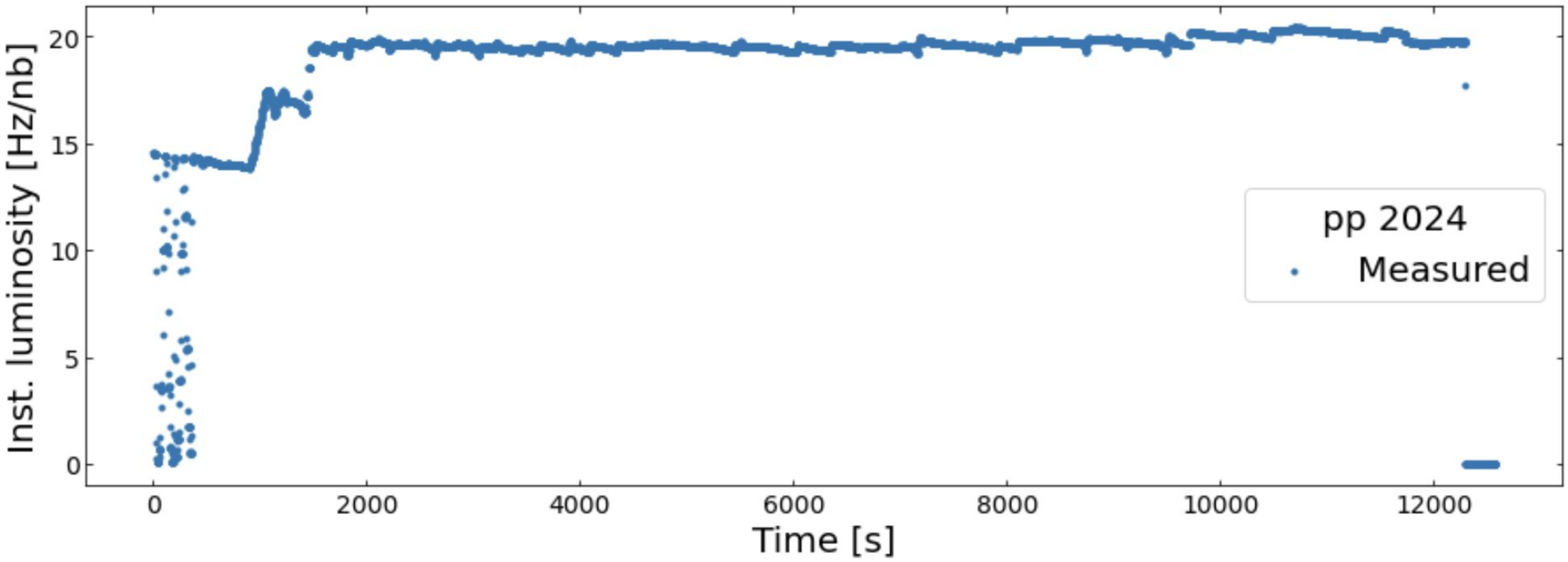
- Fast Beam Condition Monitor (BCM1F)
- Real-time luminosity measurements for CMS
- High timing resolution
  - sub-bunch crossing precision
  - Enables the measurement of beam induced backgrounds



- Info on
  - the LHC beams → intensity per beam per bunch slot (# protons)
  - properties related to the scan → beam positions
  - the BCM1F detector → measured rate

Luminosity measurement through the full fill

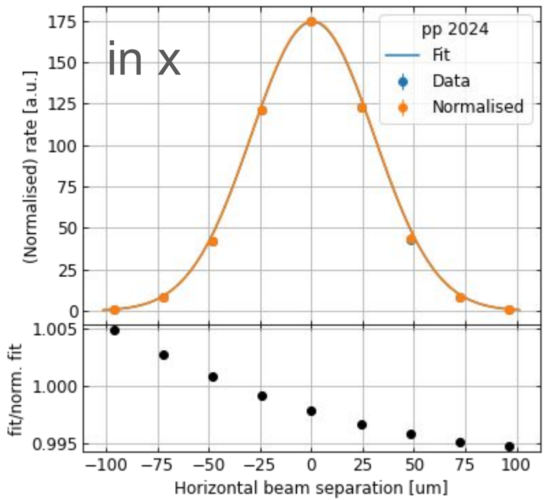
Integrating the measured instantaneous luminosity over time yields the integrated luminosity of the fill → 232.6/pb

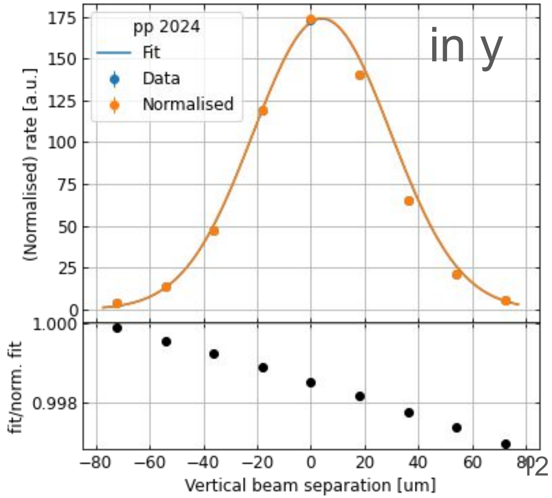


Normalisation of rate

- Scan is done using one fill
  - amount of protons decreases during the scan by 0.3-0.8%
- Correct for it by scaling the rate at each step

- Normalisation corrects for underestimation:
  - Head-on instantaneous luminosity by -0.02%
  - Visible cross section by -0.17%
- No improvement in χ^2:
  - in x: 39.7k → 40.6k
  - in y: 83.8k → 84.2k





Fitting with background constant

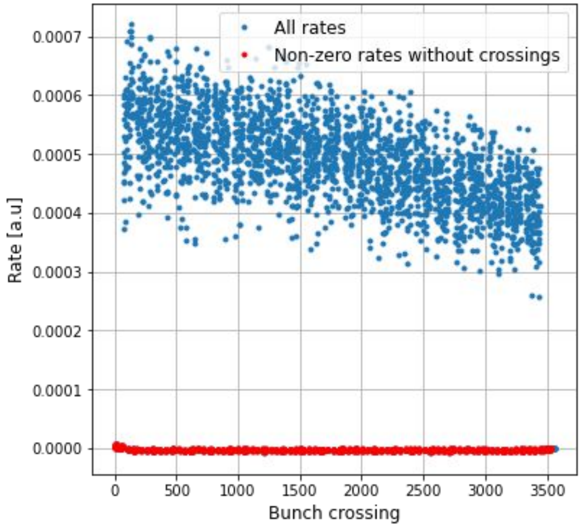
- A try to determine the beam induced background
- Include a constant *C* in the fit of the rate

$$\text{rate} = A \cdot \exp \frac{-(x - x_0)^2}{2 \cdot \Sigma^2} + C$$

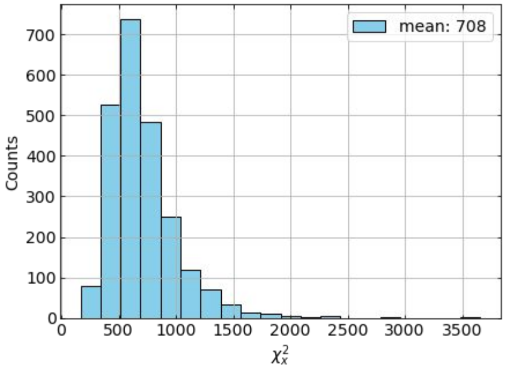
- Fitting the normalised rates:
  - in x: C~0.5 a.u (maximum rate of 174 a.u.)
  - in y: C~2.5 a.u (maximum rate of 172 a.u)
- Improvement of □^{2}
  - in x: 40.6k → 1.8k
  - in y: 84.2k → 7.7k

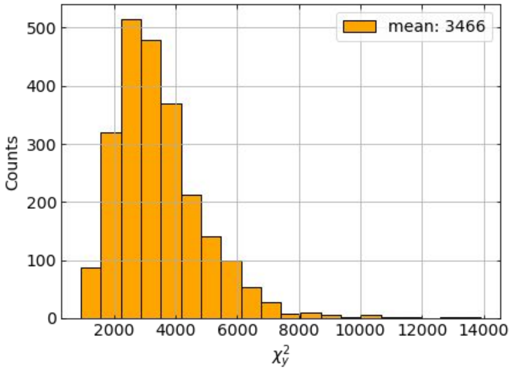
Bunch-by-bunch analysis

- Instead of using the average rate per beam position, analyse per bunch crossing



- Improvement in individual χ^2:
  - in x: 1.8k → 0.7k
  - in y: 7.7k → 3.5k
  - *C* = 0 !
- head-on luminosity:
  - 14.382 Hz/nb → 14.821 Hz/nb
- visible cross section:
  - 8.315 nb → 7.814 nb



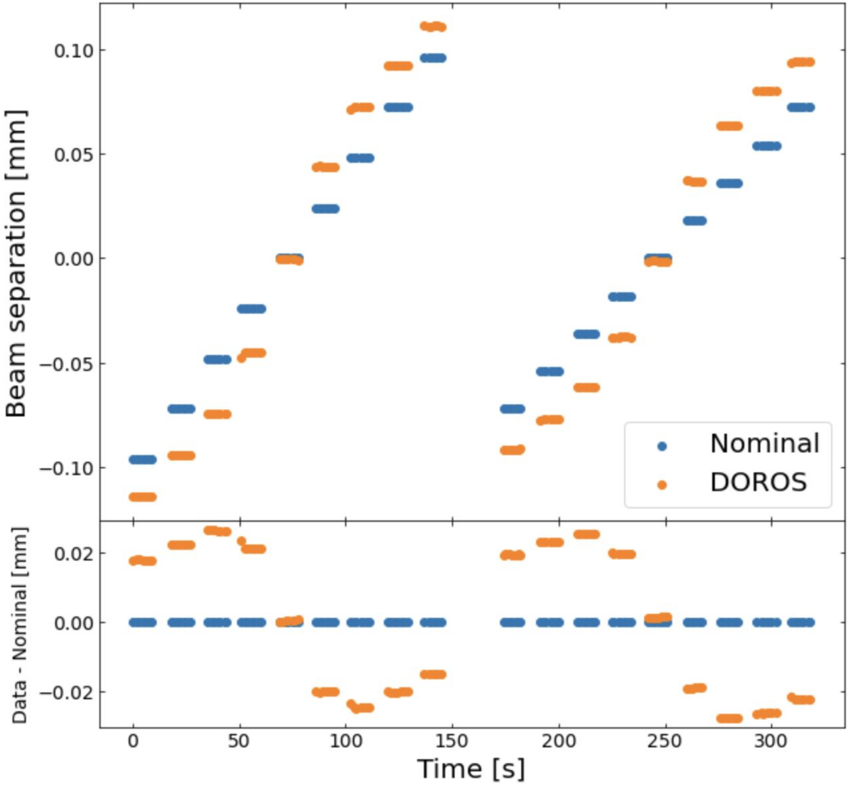


Beam-beam effects

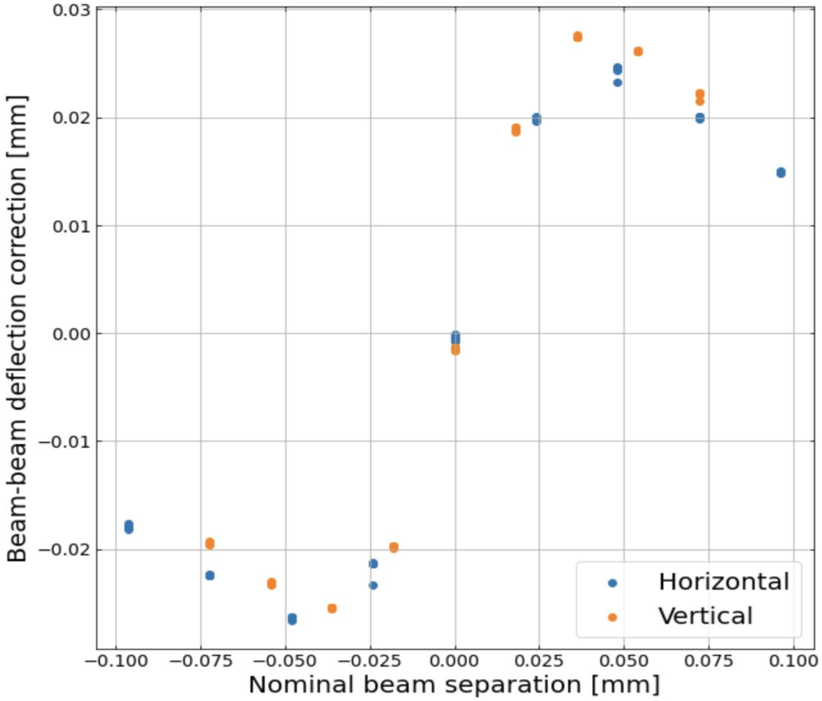
- The real time beam positions are measured by the DOROS beam position monitors @CMS

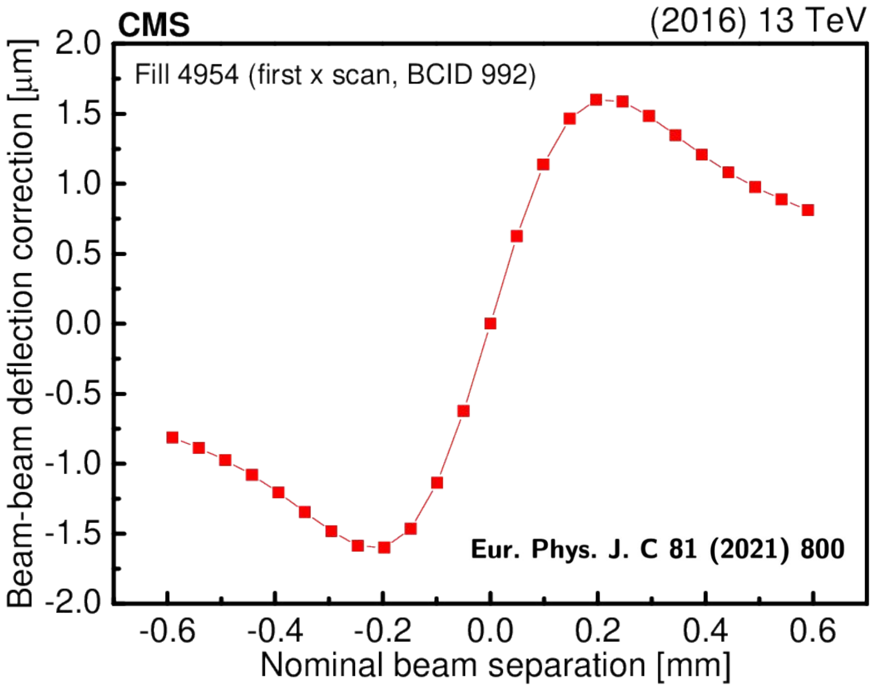
- Together with nominal position from LHC magnet currents we can study beam-beam deflection during scan

- Electric repulsion caused by positively charged beams



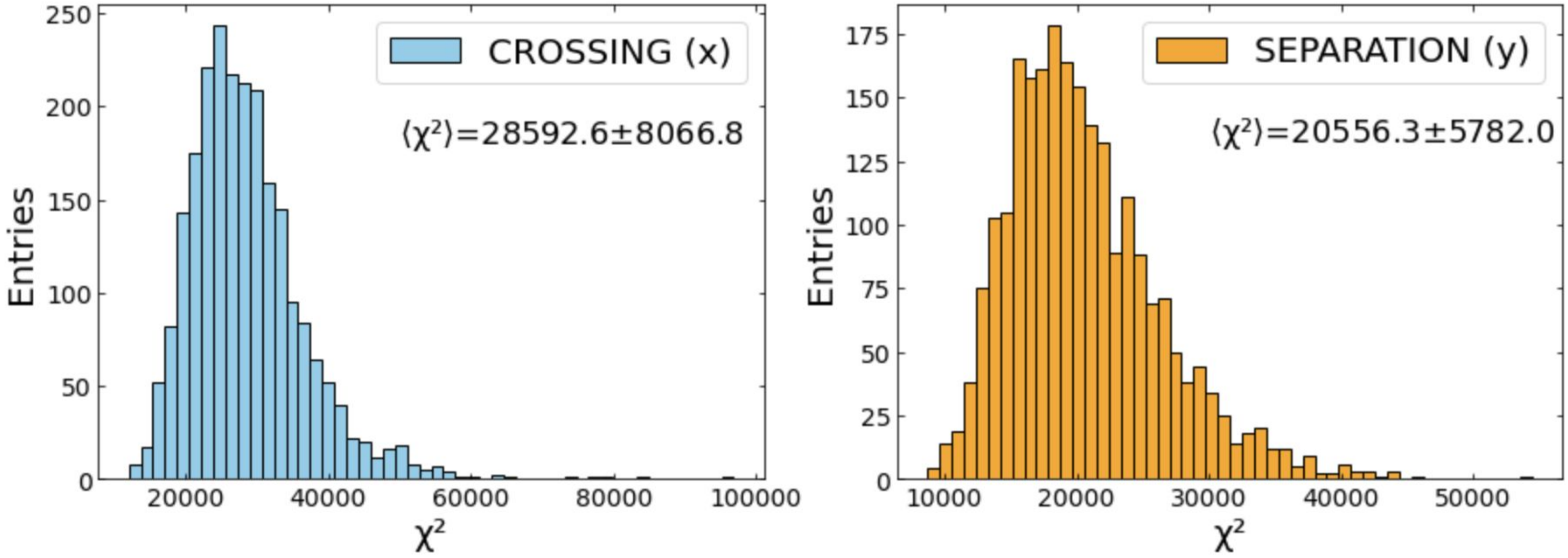
Beam-beam effects





- Data follows same trend as published CMS results

Fit results from RODOS' measured beam positions



- No improvement in fit results
  - in x: 40k → 0.7k → 29k (only normalisation → BbB crossing → RODOS beam positions)
  - in y: 84k → 3.5k → 21k
- Beam position deviations are among the largest sources of systematic uncertainty for the luminosity measurement

Conclusion

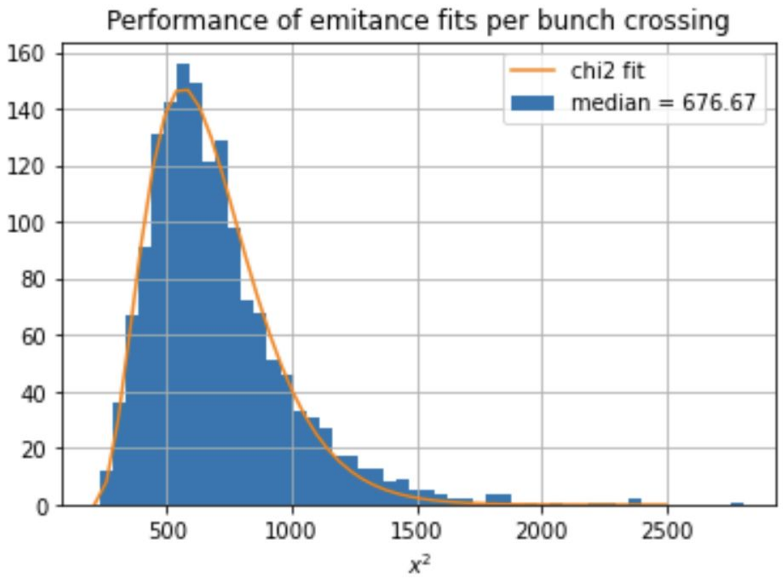
- An accurate luminosity measurement needs consideration of
  - a decrease of colliding protons over time
  - beam induced backgrounds
  - the properties of individual bunches
  - the influence of one beam on another
  - …..

Thank you!

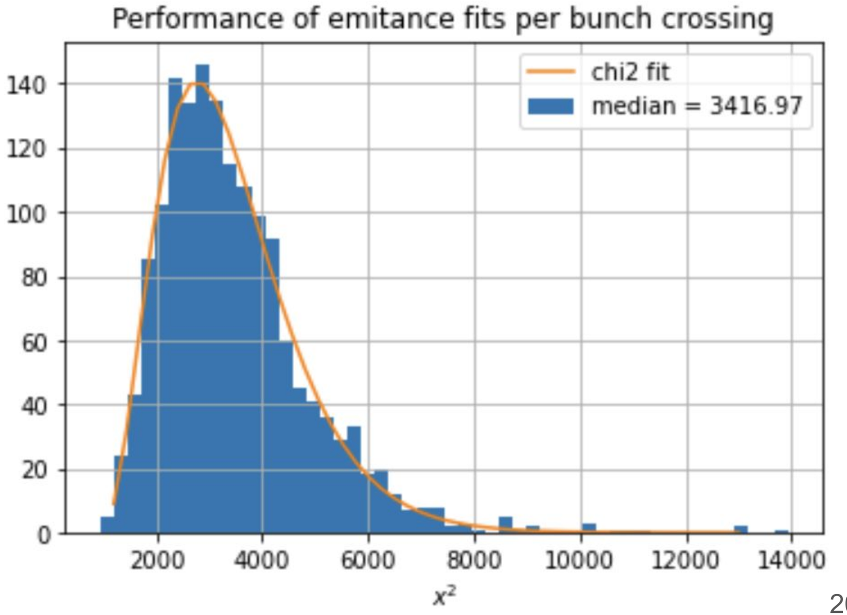
Backup

Performing χ^2 fit on per bunch-crossing analysis

x-axis
χ^2 ~677

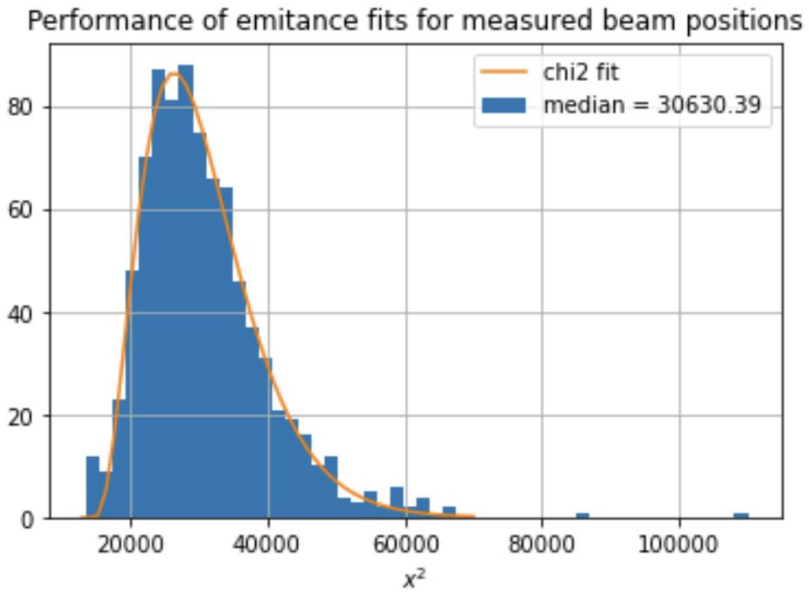


y-axis
χ^2 ~3.4k

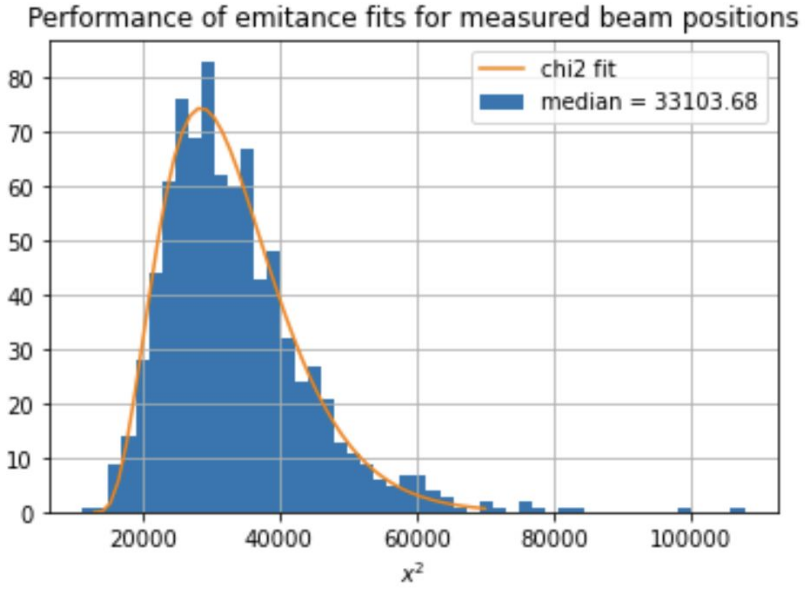


Performing χ^2 fit on measured positions analysis

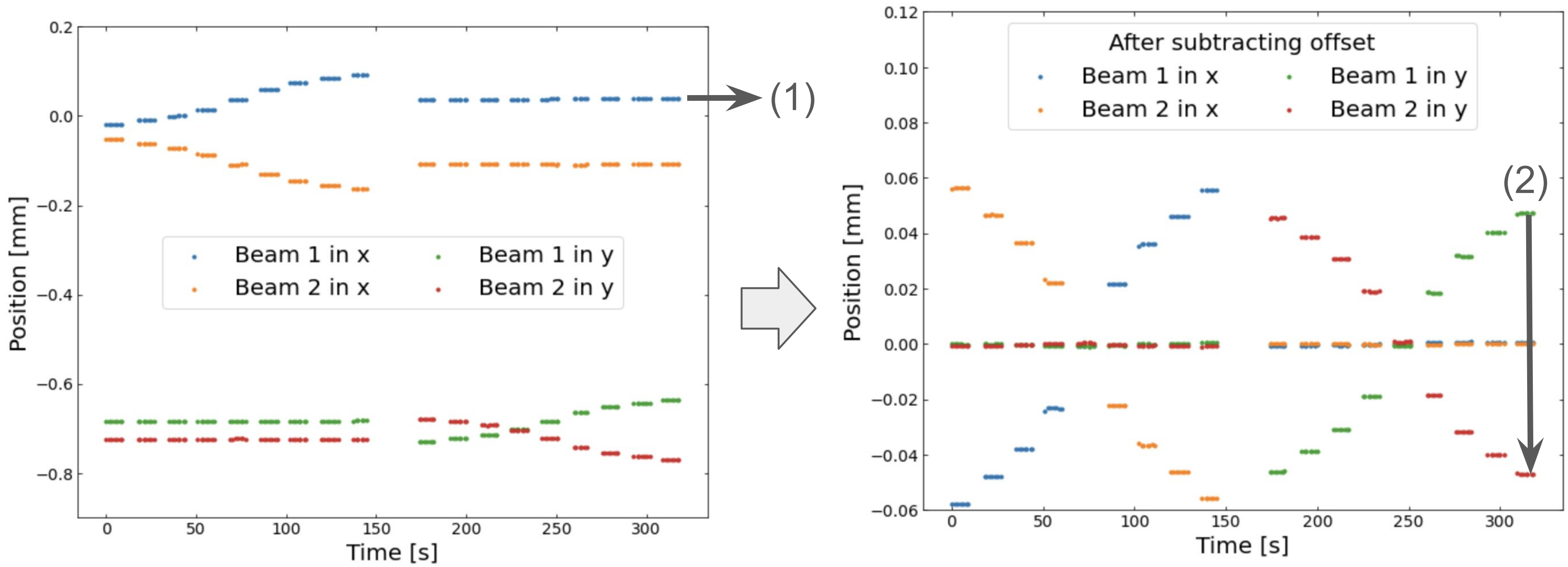
x-axis
χ^2 ~30k



y-axis
χ^2 ~33k



Beam Separation with DOROS



- The beam positions are measured by the DOROS beam position monitors.
- Located on either side of the CMS detector and measure the transverse position of beam 1 and beam 2 separately.
- Arbitrary offset (1) in both beams, subtract from positions during VDM scan to obtain the right beam separation at given time (2)

Beam Separation with DOROS vs. Nominal