Enlighten Me

Measuring Luminosity at CMS with the Pixel Luminosity Telescope

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BND SCHOOL 2024

B.O.B.B.E.R. COLLECTIVE

Who we are?

Bobber Collective:

Bnd

Outreaching

Beam

Beam

Experimental

Researchers

Our Mission: Luminosity

Theory

Lagrangian → Computation (Montecarlo) → σ_{proc}

Our Mission: Luminosity

Rates/
Number of
Events

More
Interactions
More Events

Smaller errors

Accese to rare
events

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Interactions rate depends on:

- N per beam
- Area of the beams
- Frequency

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

All In One Parameter

LUMINOSITY

Our Mission: Luminosity

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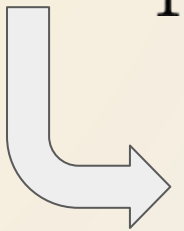
Our Mission: Luminosity

$$N_{\text{proc}} = \mathcal{L}\sigma_{\text{proc}}$$



Error in Luminosity → Error in Measurements

An accurate Luminosity measure is a NECESSITY

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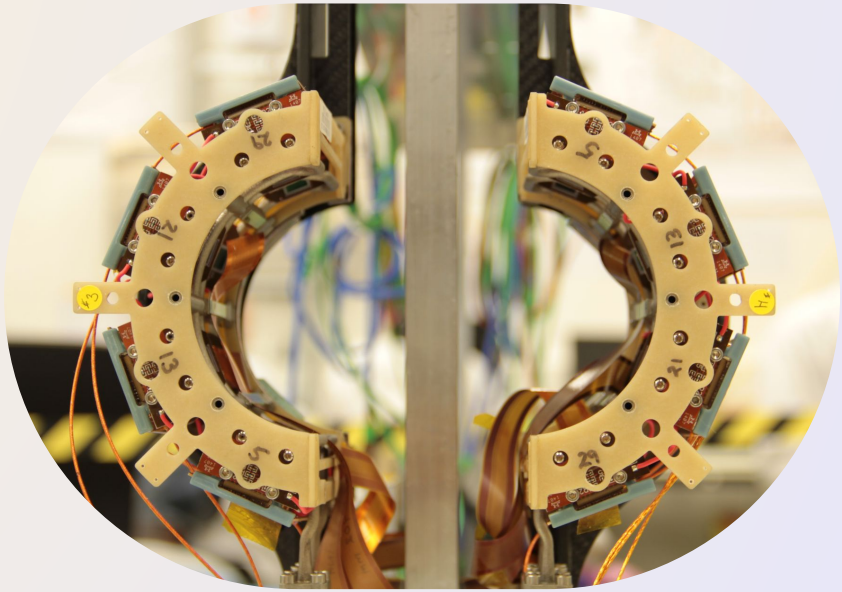
AN ACCURATE MEASURE OF A IS NECESSARY

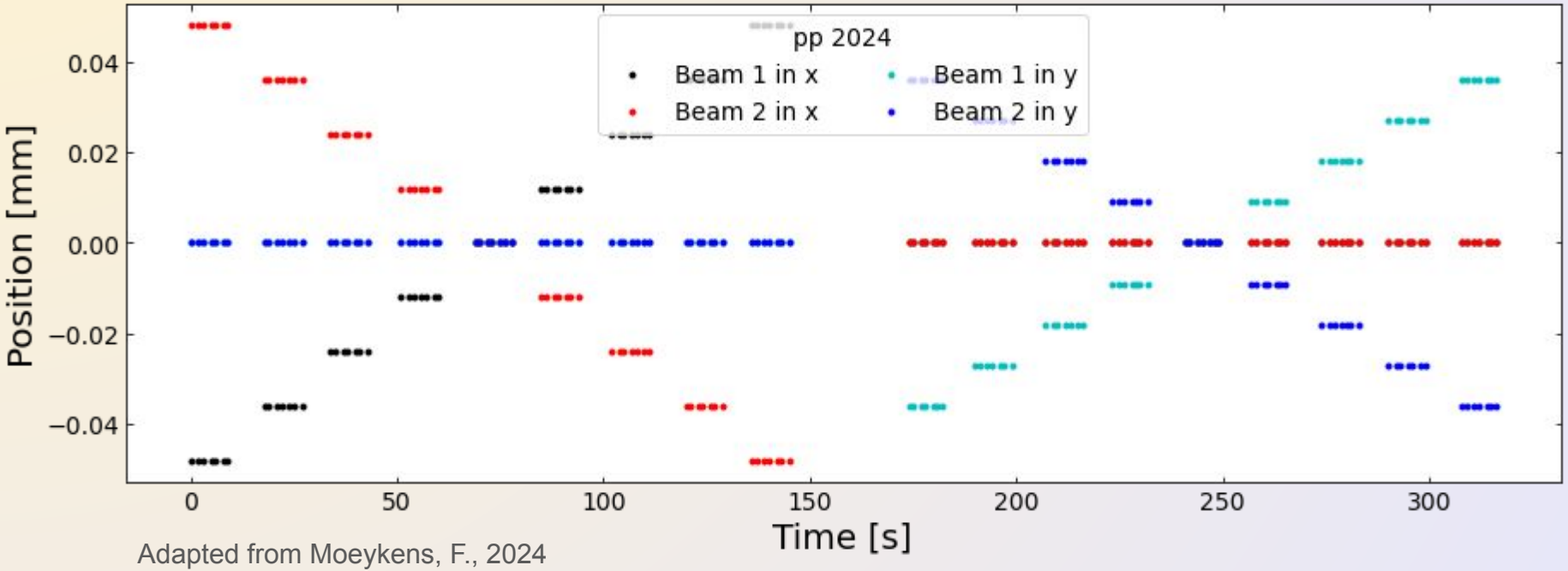
Our Values: Pixel Luminosity Telescope (PLT)

- Dedicated luminosity monitor
- 48 silicon pixel sensors
  - 16 telescopes each with 3 sensors
- single pulse produced if any pixel registers a hit above threshold during 25 ns
- events counted with 3-fold coincidence
  - reduce background from activated material



Measuring Luminosity with vdM scan

STEP 1: Change the separation of the beam in the x and in the y direction



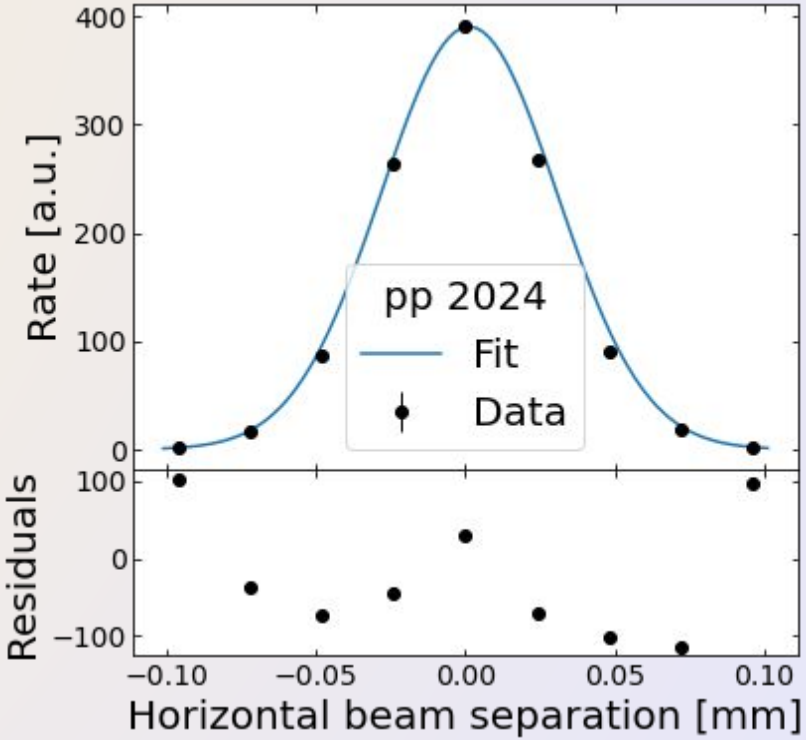
Adapted from Moeykens, F., 2024

Measuring Luminosity with vdM scan

STEP 2 : Fit rate as a function of horizontal and vertical separation.

STEP 3 : Use beam parameters and parameters of fit to get luminosity

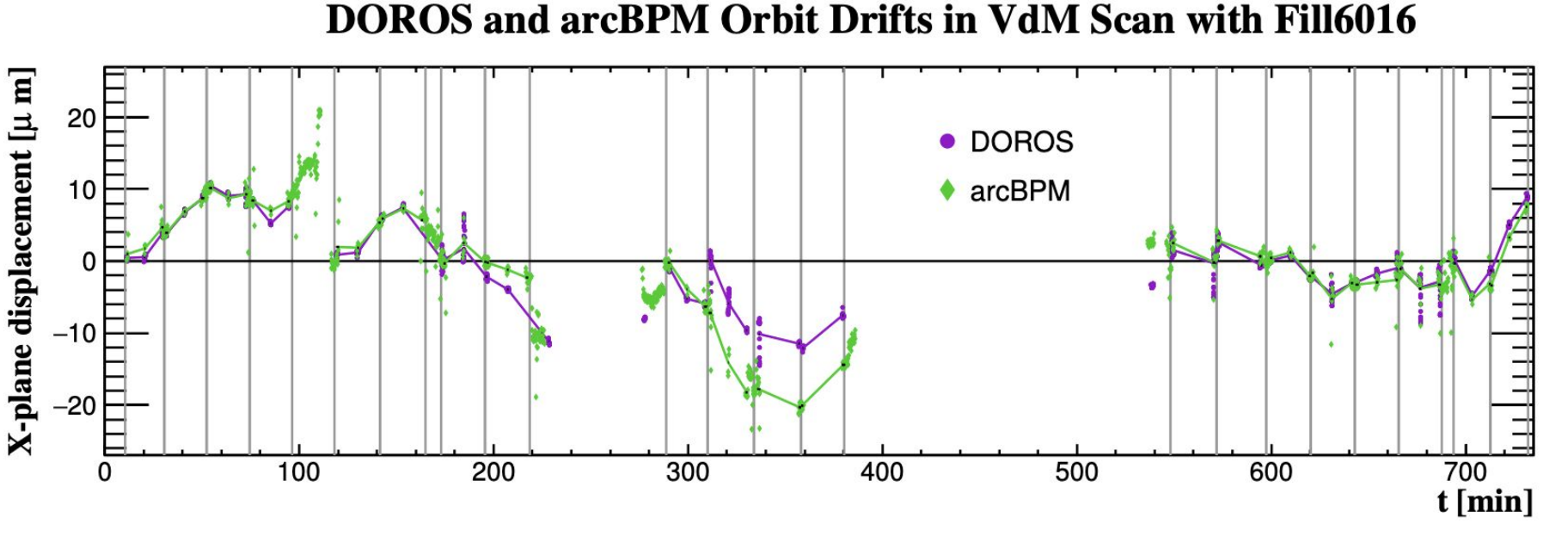
- LHC rev frequency
- number of bunch crossings
- number of particles per bunch in beams
- widths from fits



Moeykens, F., 2024

Beam effects

Orbit drift : Beams drift off their nominal positions

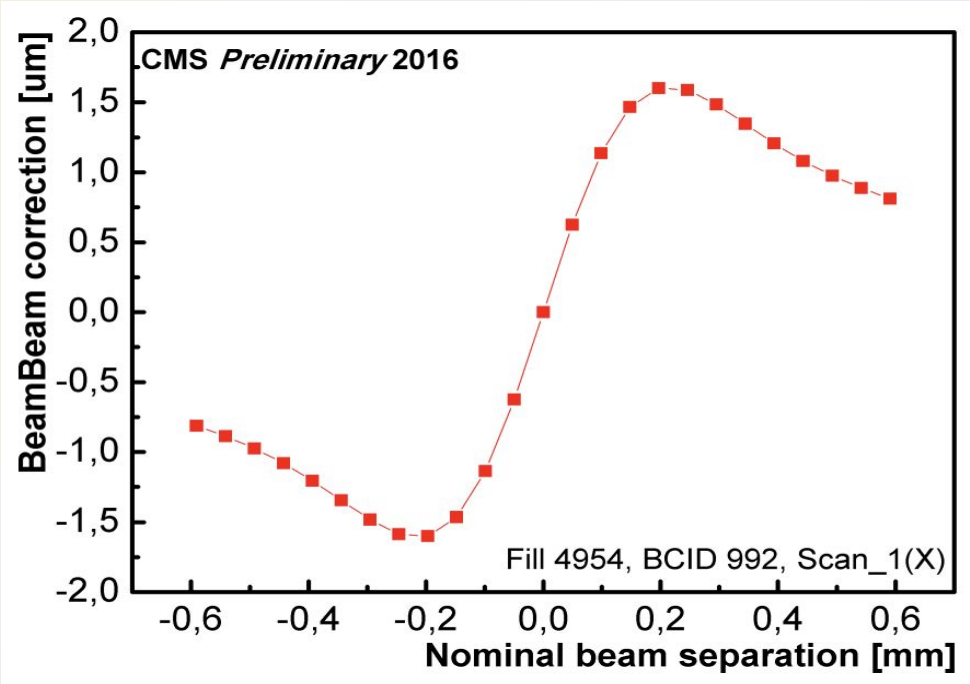


Knolle, J., 2016

Beam-beam effects

Beam-beam deflection

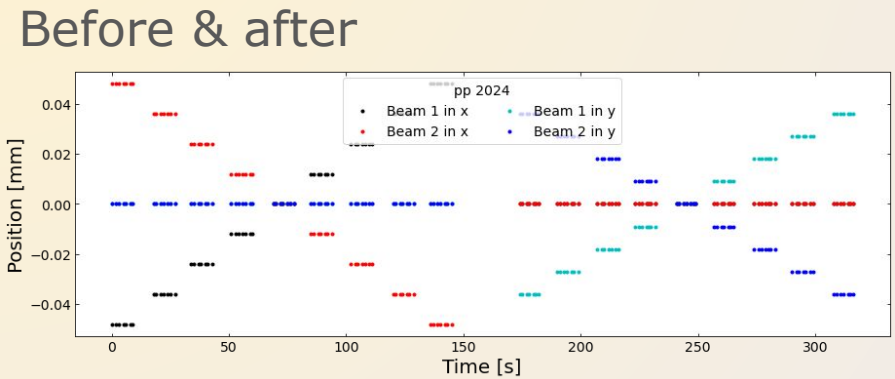
- By each other's electrical fields
- By each other's quadrupole fields

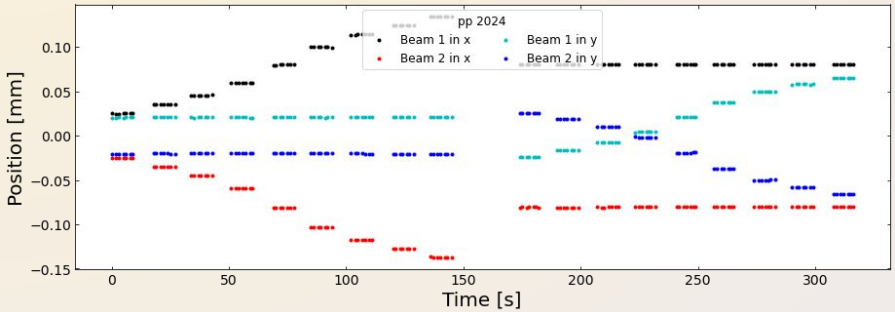


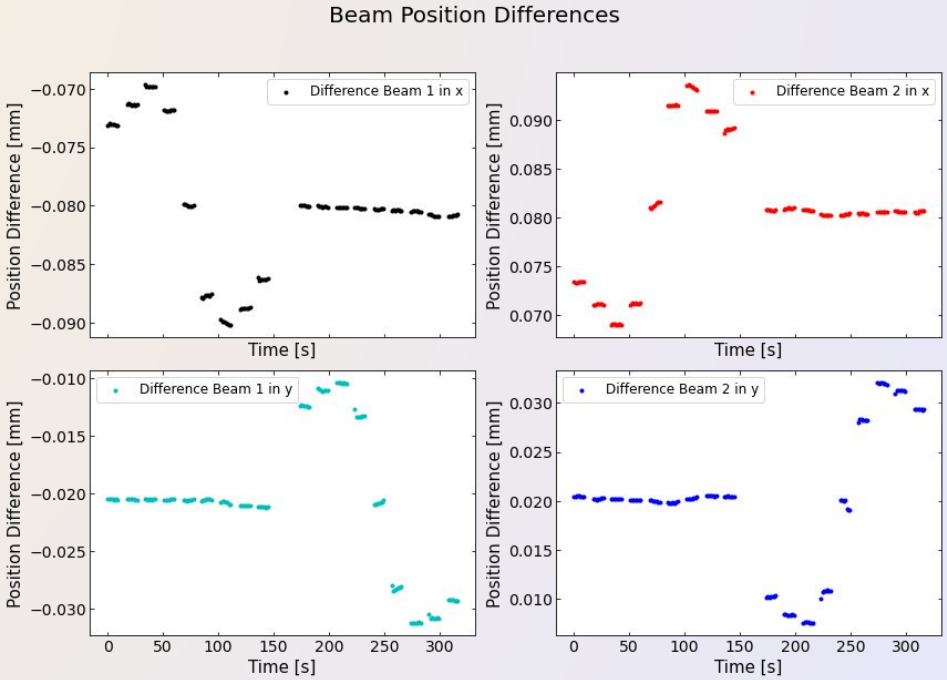
Knolle, J., 2016

Beam positions

Before & after







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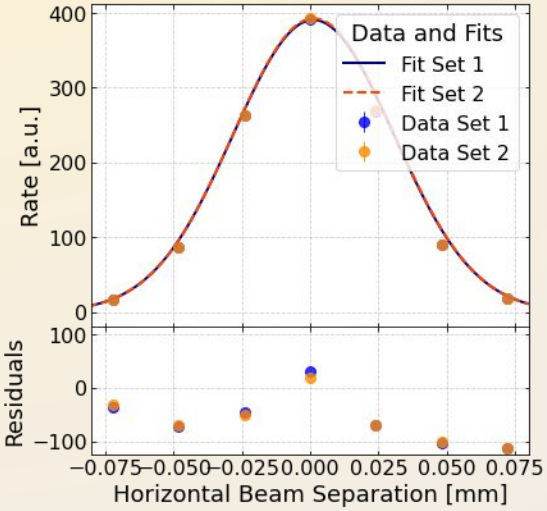
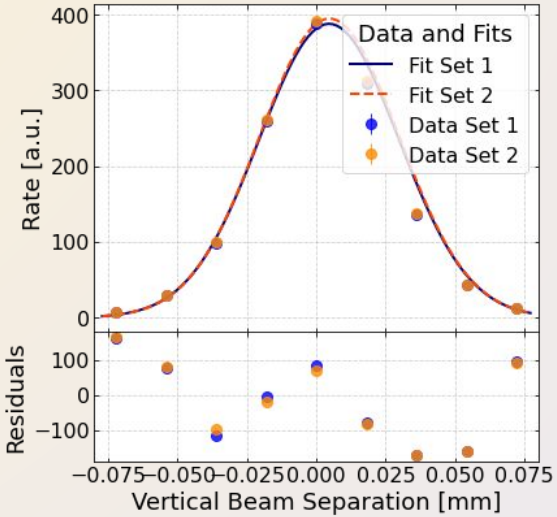
Normalise beam position

χ^2/d.o.f. in x: 57602 / 6 → 56189 / 6

χ^2/d.o.f. in y: 122561 / 6 → 118993 / 6





Bobber Collective, 2024

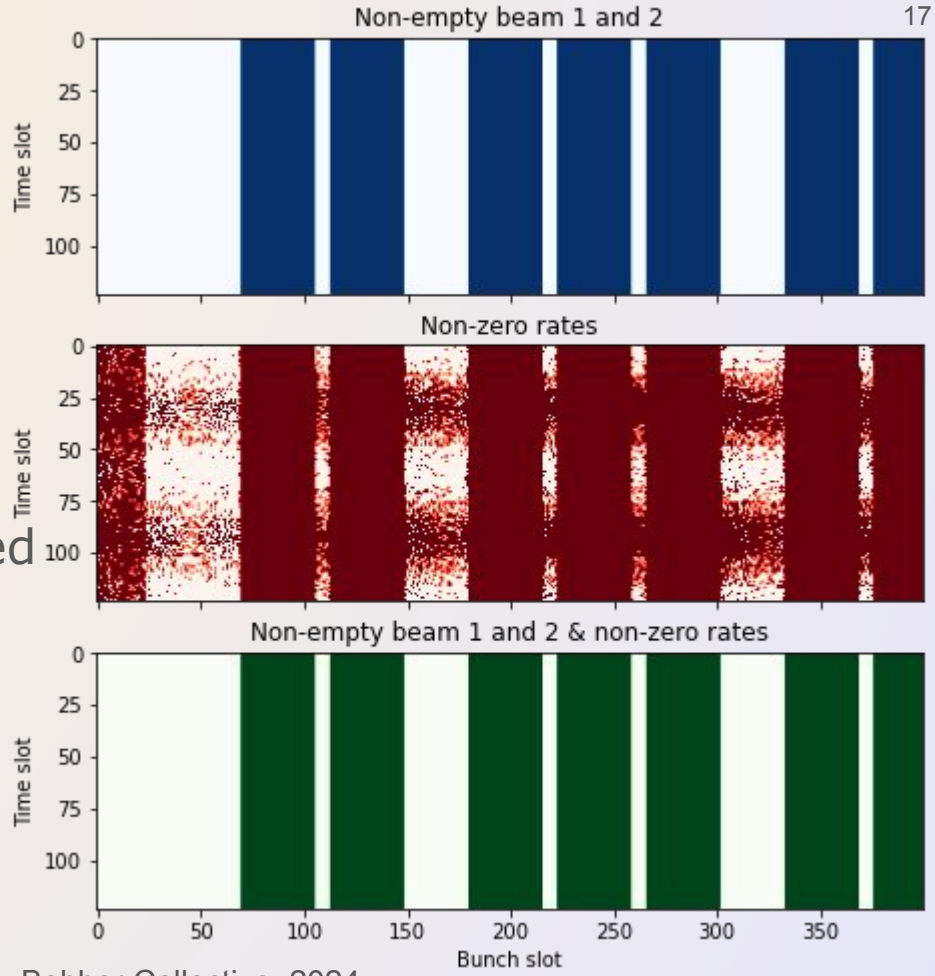
Beam & rates

Beams may be empty

Meanwhile a rate can be measured

Beams may not collide (n/a)

→ Only use when beam 1&2 are filled



Bobber Collective, 2024

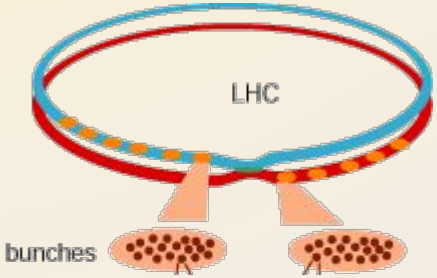
Beam shapes

Each bunch has a different shape, position, current & rate

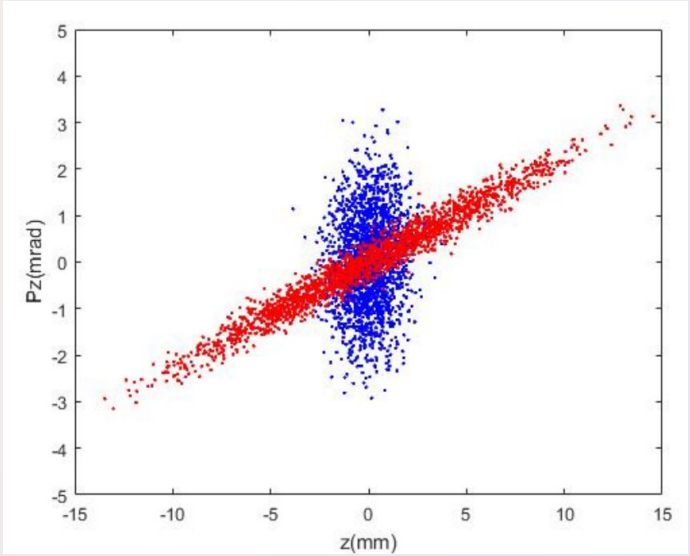
→ Average rate of all bunches has spread

→ Inaccurate beam shape fit

Solution: Fit each bunch separately.



Emre, S., 2021



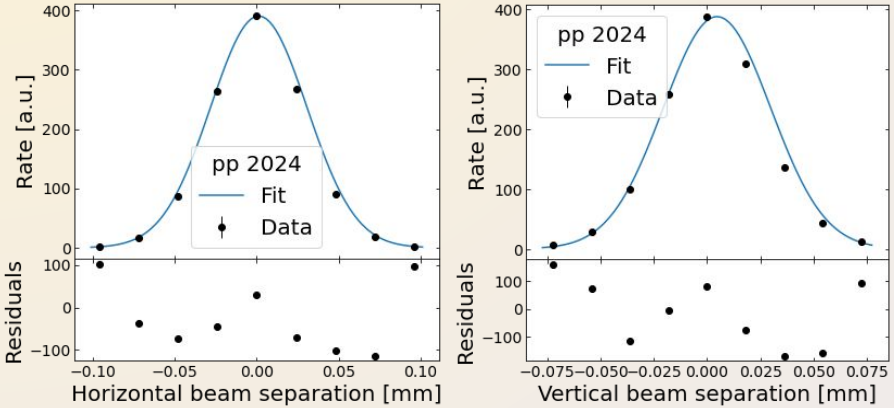
Choi, C. U. et al., 2016

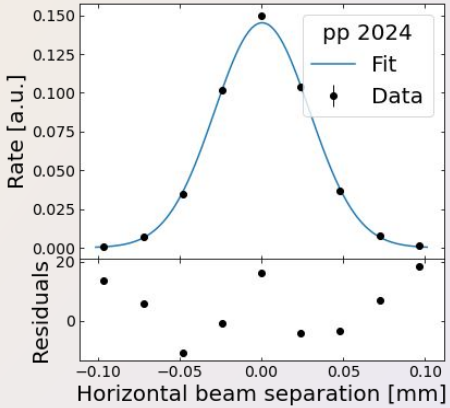
Beam fit

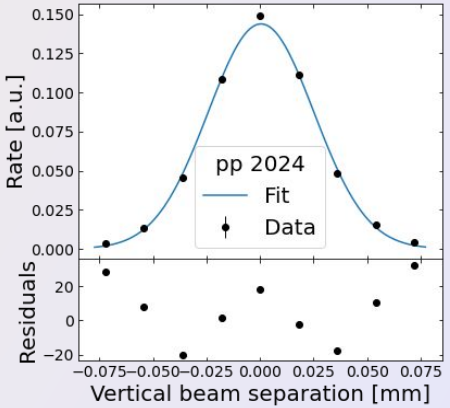
Averaged over al bunch slots → Per bunch slot (e.g. #71 below)

χ^2/d.o.f. in x: 57601 / 6 → 1013 / 6

χ^2/d.o.f. in y: 122561 / 6 → 3082 / 6







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Results & Conclusion

Fit beam & calculate cross section per bunch using normalised beam

Sum over all non-empty bunches

	Old	→ Normalized	→ Per bunch Normalization
L	= 14.83 ± 0.28 Hz/nb	→ 14.88 ± 0.27 Hz/nb	→ 15.46 ± 0.28 Hz/nb
L_{int}	= 247.8 ± 4.7 /pb	→ 245.7 ± 4.5 /pb	→ 267.7 ± 4.8 /pb
σ	= 18.01 ± 0.44 nb	→ 18.16 ± 0.42 nb	→ 16.67 ± 0.38 nb

Thank you for listening!

And for the gezellige week!

B.O.B.B.E.R. out

References

- Choi, C. U., Chung, M., UNIST, Shin, S., Lee, J., Lee, T.-Y., PAL, Hahn, G. R., & KIRAMS. (2016). SIMULATION CODE DEVELOPMENT FOR HIGH-POWER CYCLOTRON. In MOP09 Proceedings of Cyclotrons2016, Zurich, Switzerland. https://accelconf.web.cern.ch/cyclotrons2016/papers/mop09.pdf
- Emre, S. (2021, October 25). First 13 Tev proton-proton collisions at the Large Hadron Collider. Renaissance Universal. https://sureshemre.wordpress.com/2015/05/24/first-13-tev-proton-proton-collisions-at-the-large-hadron-collider/

Backup

Extra Results

Old		→ Per bunch Normalization With positions
L	= 14.83 ± 0.28 Hz/nb	→ 8.17 ± 0.28 Hz/nb
L_{int}	= 247.8 ± 4.7 /pb	→ 118.2 ± 2.2 /pb
σ	= 18.01 ± 0.44 nb	→ 37.77 ± 0.83 nb

Formulae

- Rate of any process,

$$R = L_{inst}\sigma_{vis}$$

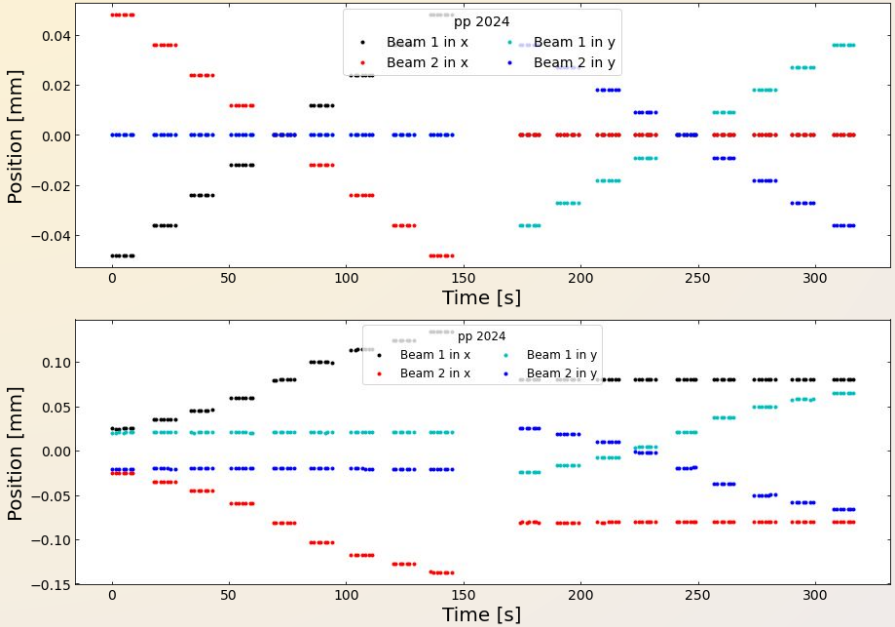
- Rate measured bunch by bunch,

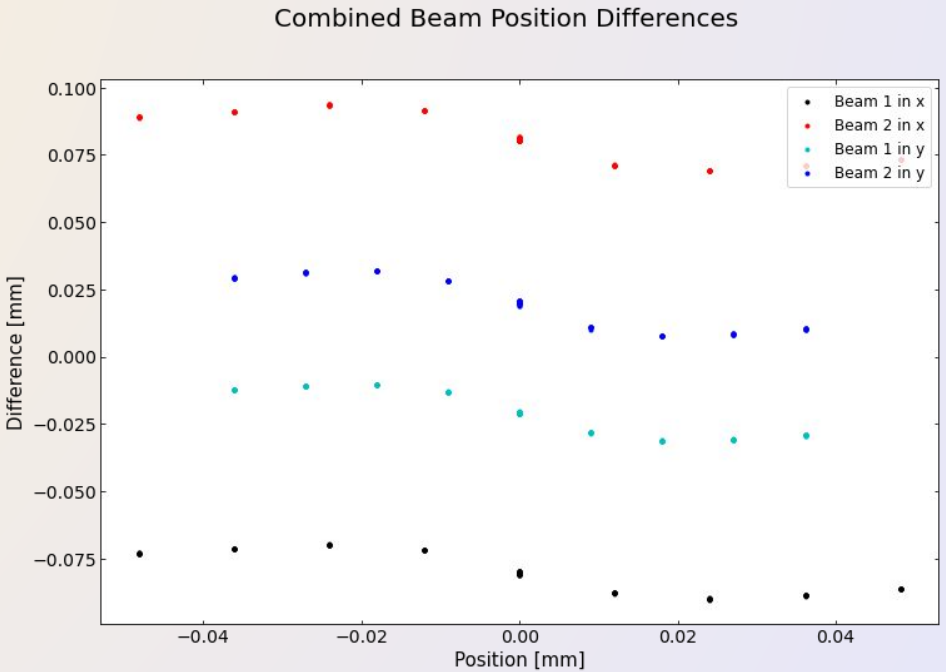
$$R_i = \mu_i f_{rev}$$

- Instantaneous

Beam positions

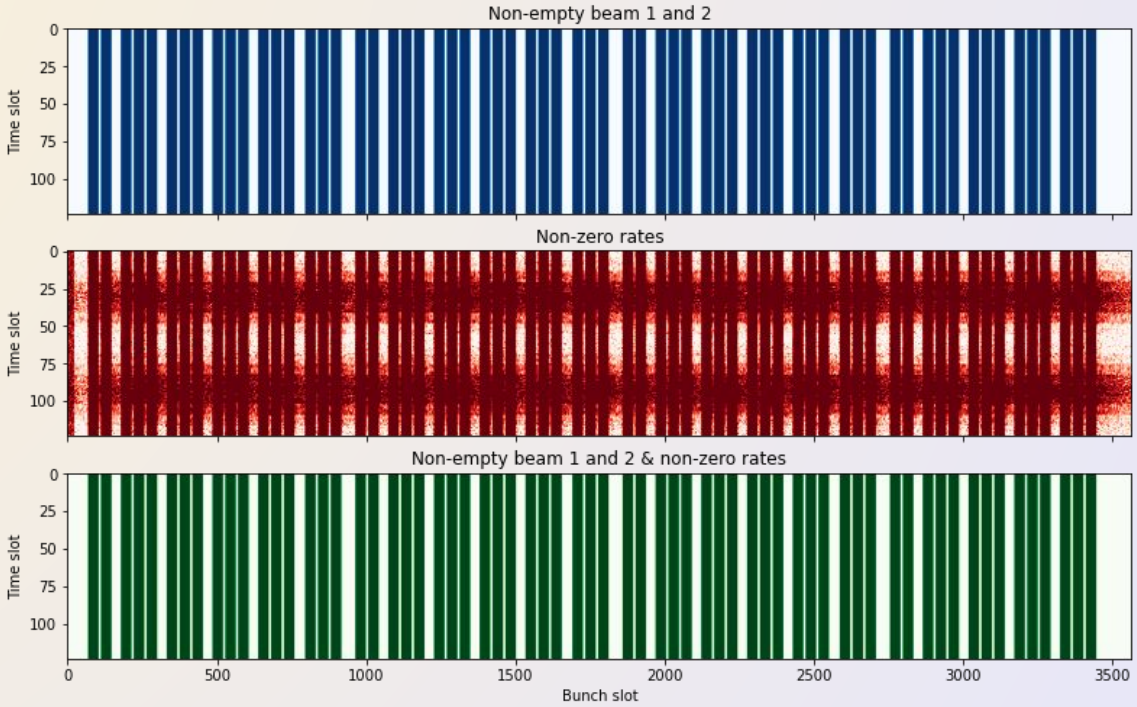
Before & after





Chiotopoulos, X., Kharbanda, P., Morren, W., Tentori, S., 2024

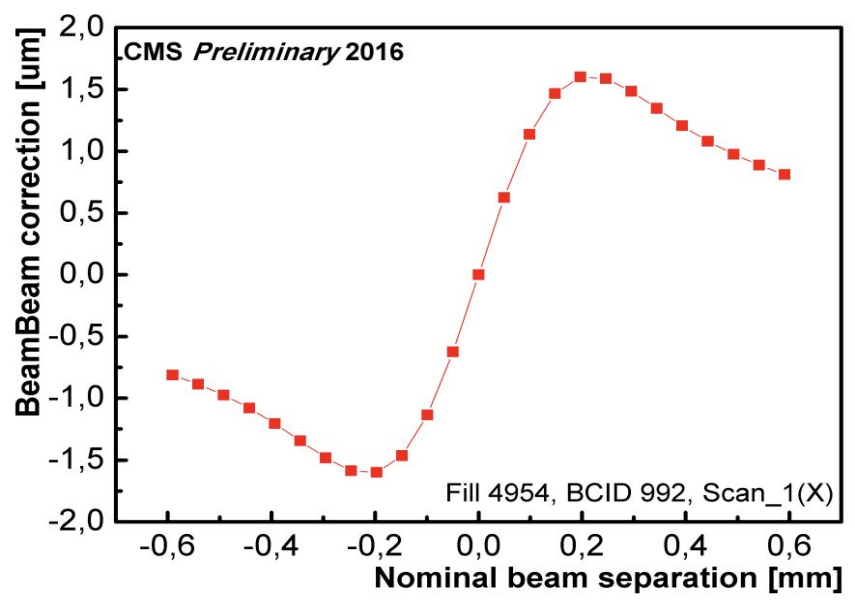
All bunches


Non-empty beam 1 and 2
Non-zero rates
Non-empty beam 1 and 2 & non-zero rates
Time slot
0
25
50
75
100
0
500
1000
1500
2000
2500
3000
3500
Bunch slot

Beam-beam effects

Beam-beam deflection

- By each other's electrical field



- By each other's quadrupole field