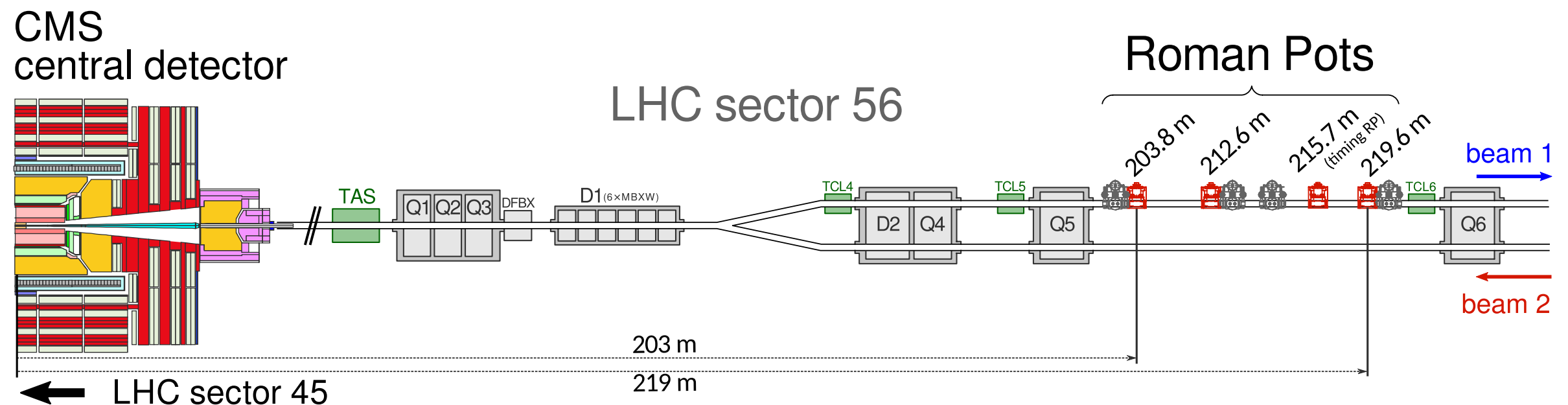# (Brief) notes on alignment with the PPS Roman Pots at the LHC

PPS (Precision Proton Spectrometer)

- Horizontal Roman Pots ~200-220m from LHC Point 5 (CMS)

  - Began as a joint project of CMS+TOTEM in 2016, CMS sub-detector since 2018

  - Designed to operate in standard LHC conditions, with low-beta* and very high luminosity/pileup

    - Recorded >100fb^{-1} for physics in LHC Run 2 (2016-2018)

- Two horizontal tracking RPs (3D pixels), with 1 horizontal timing RP (diamond) in between

- During special alignment runs, also make use of the vertical RPs (Si-strip detectors) of the TOTEM collaboration

(symmetric on other arm)

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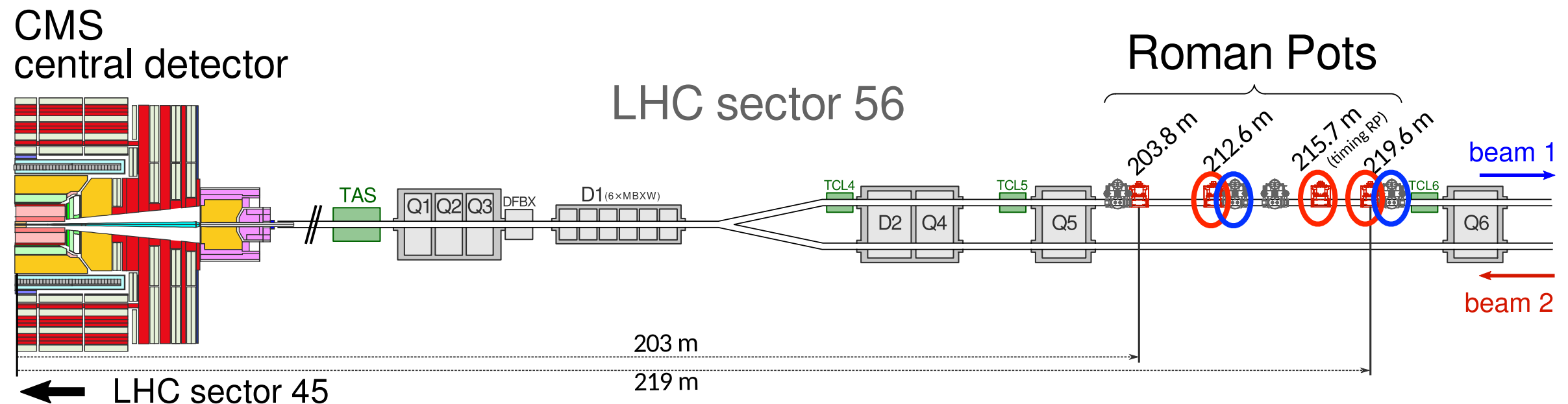
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Alignment fill

- **At least once/year, the LHC performs a dedicated Roman Pot alignment fill**

  - During the initial intensity ramp up, and after any major changes to the machine conditions or interventions on the Roman Pot detector packages

  - Maximum energy and nominal intensity, but only 1-2 colliding bunches

  - Both the PPS horizontal RPs, and the TOTEM vertical RPs (normally not used for standard high-intensity physics runs) are inserted
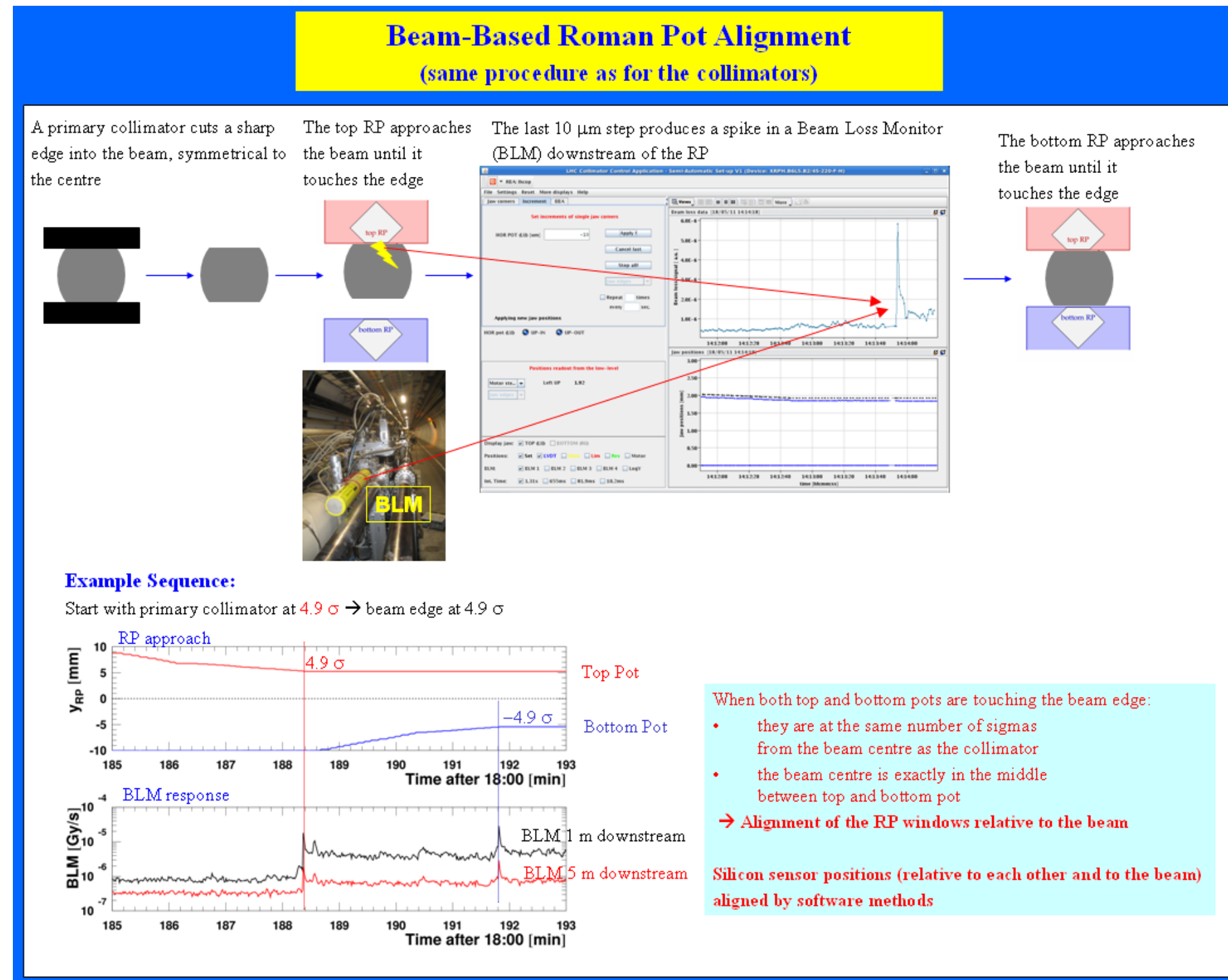
- This fill consists of 2 parts

  1. **Beam-based alignment**

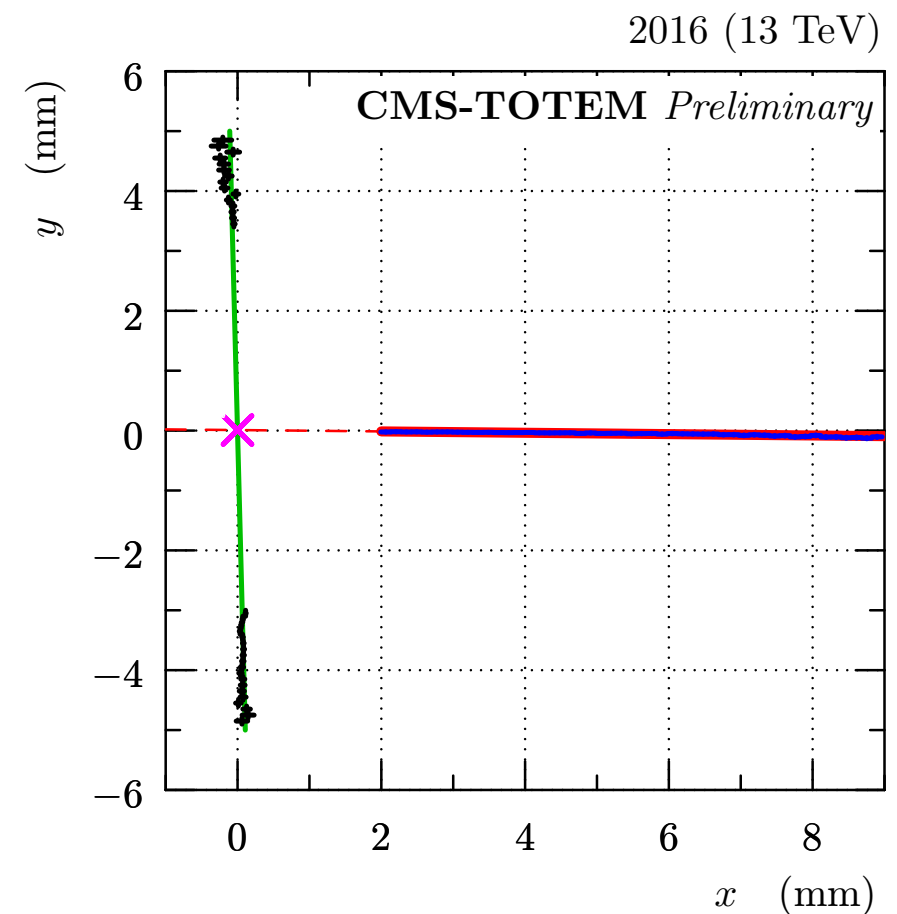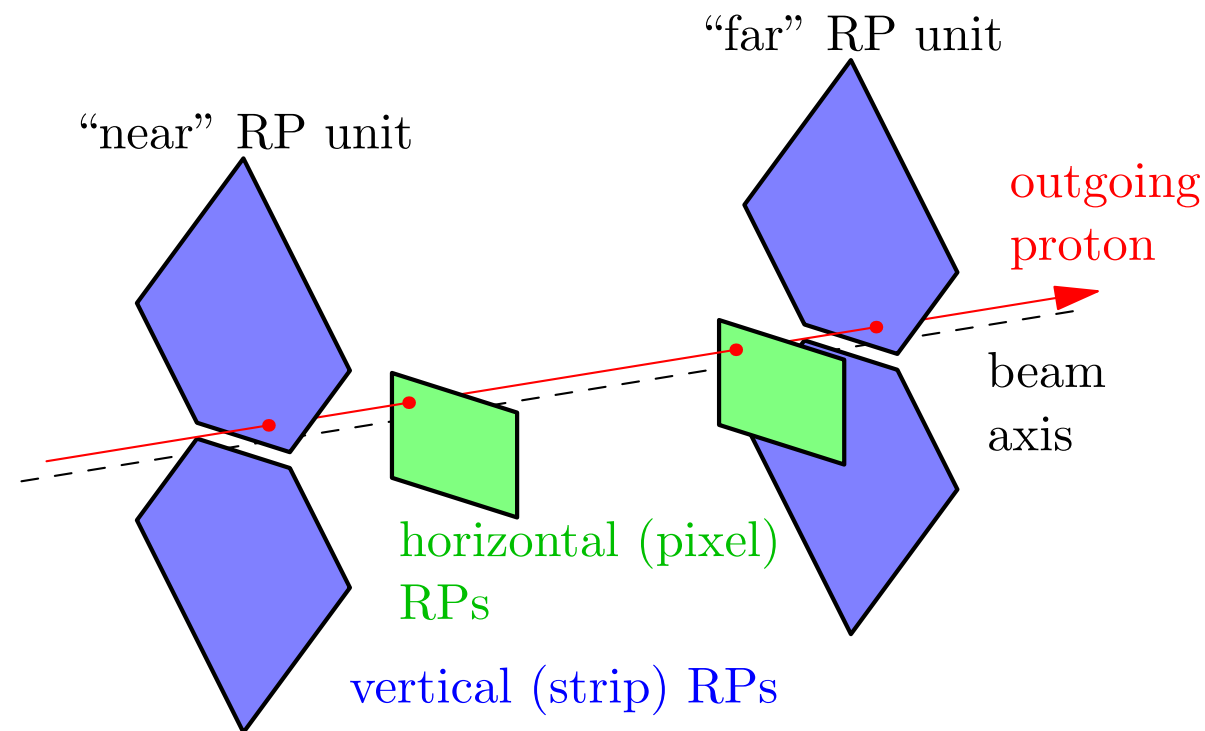 2. **Data-taking for physics alignment and optics matching**

1: Beam-based alignment

Procedure is illustrated for vertical RPs, similar for horizontal PPS RPs

Used to calculate physics position settings and limits, programmed for all subsequent insertions in high-lumi fills
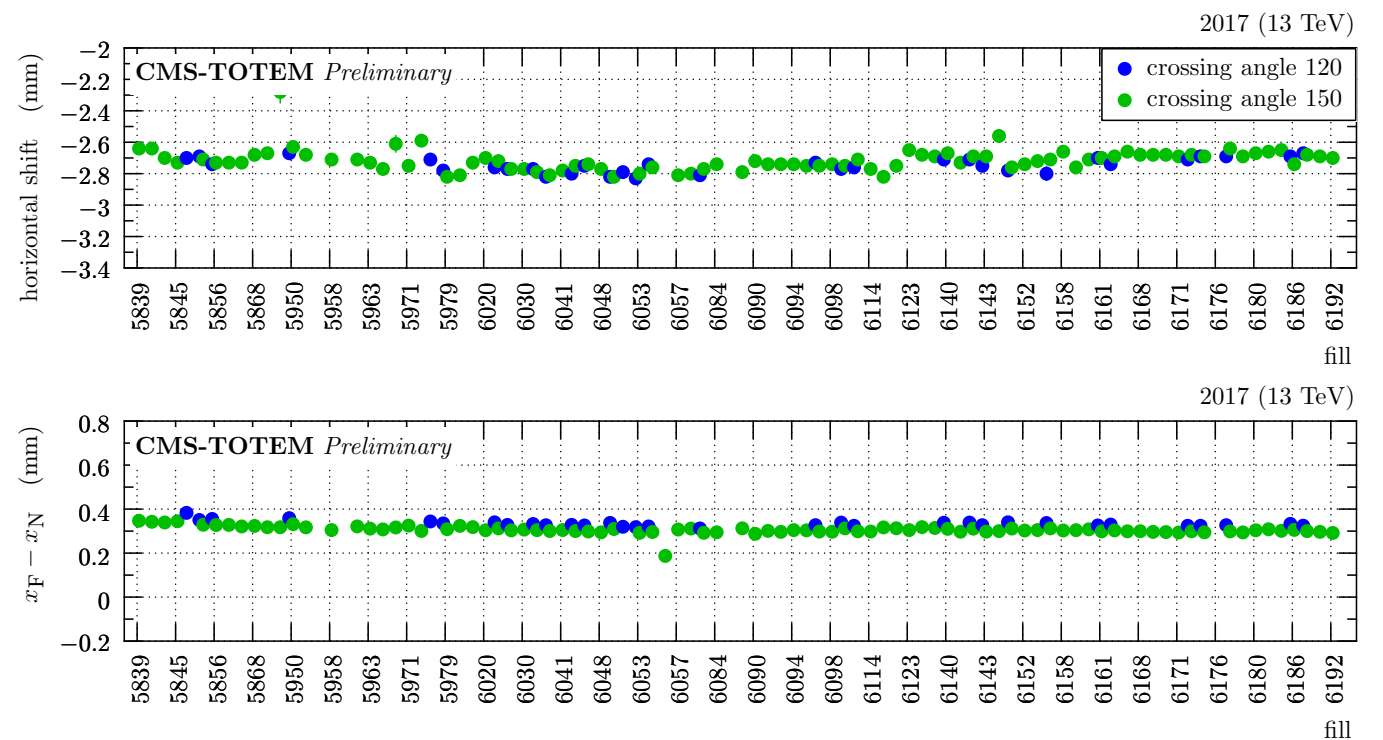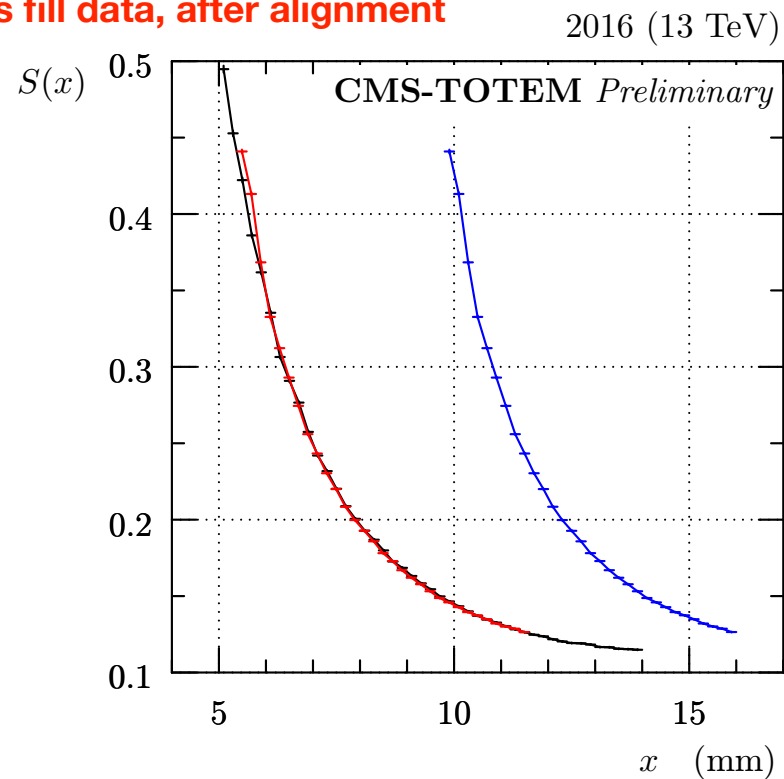
2a: Alignment for physics

- After the beam-based alignment, LHC continues the fill with all RPs inserted closer than normal

  - By exceptionally having the vertical RPs inserted, a sample of elastic scattering (pp->pp) is recorded to constrain horizontal position and possible x-y rotations

  - By having the RPs inserted close to the beam there is an overlap between the horizontal and vertical RPs, allowing relative alignment of RPs

- Data collected in this fill is also used to perform the optics matching, needed to reconstruct the proton ξ, t

2b: Alignment for physics

Alignment fill reference data
Physics fill data, uncorrected
Physics fill data, after alignment

- After the alignment fill, corrections are derived after every RP insertion+retraction throughout the year by matching track distributions to the alignment fill reference data (assuming the physics is always the same)

  - Provides fill-by-fill corrections for absolute and relative near-far alignments, that are used to reconstruct the physics data

References

- Beam-based alignment

  - IPAC2011 poster+proceedings (arXiv:1110.5808)

- Alignment and optics matching for physics

  - [Proton reconstruction with the CMS Precision Proton Spectrometer in Run 2](#) (CMS-PAS-PRO-21-001 ; TOTEM-NOTE-2022-001)

  - [LHC optics determination with proton tracks measured in the CT-PPS detectors in 2016, before TS2](#) (CERN-TOTEM-NOTE-2017-002)

  - [Alignment of CT-PPS detectors in 2016, before TS2](#) (CERN-TOTEM-NOTE-2017-001)