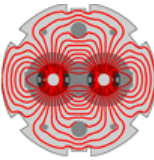
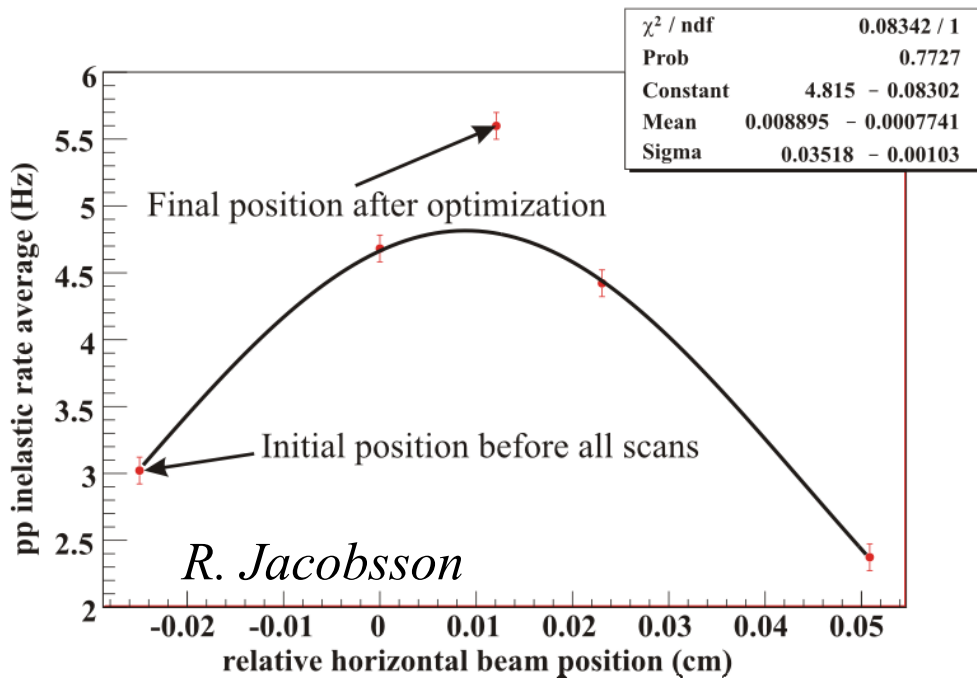


# Strategy for Luminosity Optimization

S. White

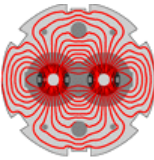


- **First experience with collisions at 450 GeV:**
  - ⇒ **Initial optimization with BPMs.**
  - ⇒ **“Manual” optimization. Low rates, very lengthy (~ 40 minutes/plane).**

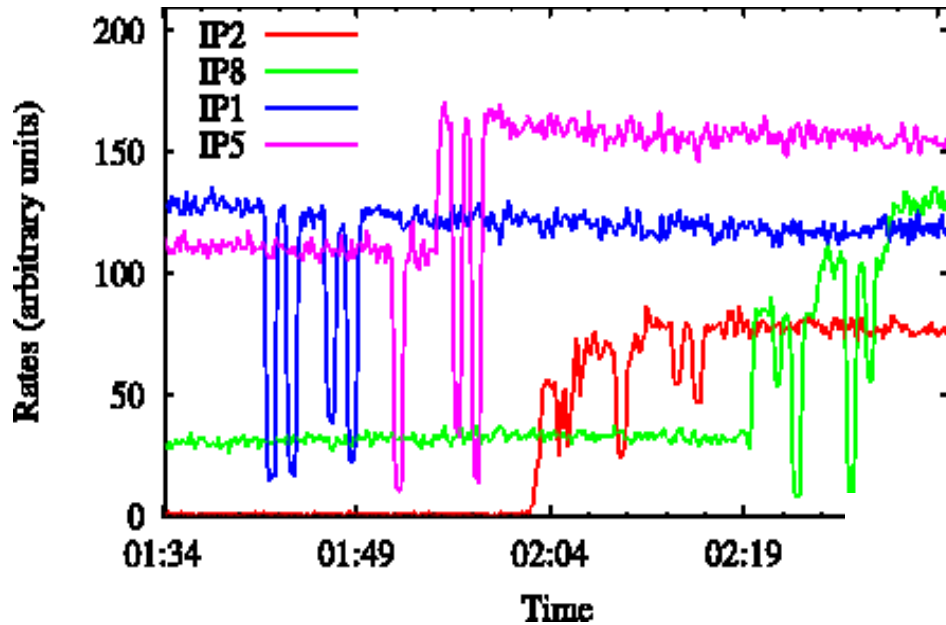


- **Example of LHCb:**
  - ⇒ **Only three points / plane**
  - ⇒ **Established communication protocol with experiments, test software and procedure.**

- **Conclusions from last year:**
  - ⇒ **Move on to an automated procedure and include in routine operation.**
  - ⇒ **Assess impact on machine protection.**



- Slowly moved on to a fully automated procedure:



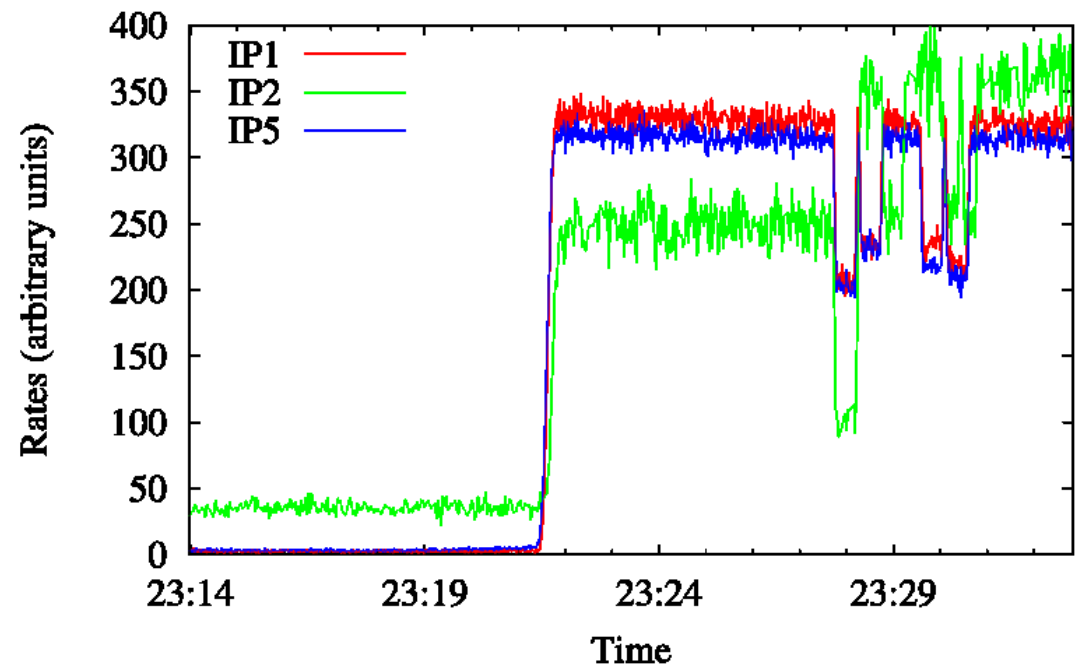
- November 2010:
  - ⇒ Ions physics fill.
  - ⇒ Optimization in parallel.
  - ⇒ Full procedure few minutes.
  - ⇒ Operational efficiency significantly improved.

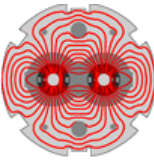
- April 2010:

⇒  $L \sim 5.0 \times 10^{27} \text{ cm}^{-2}\text{s}^{-1}$ .

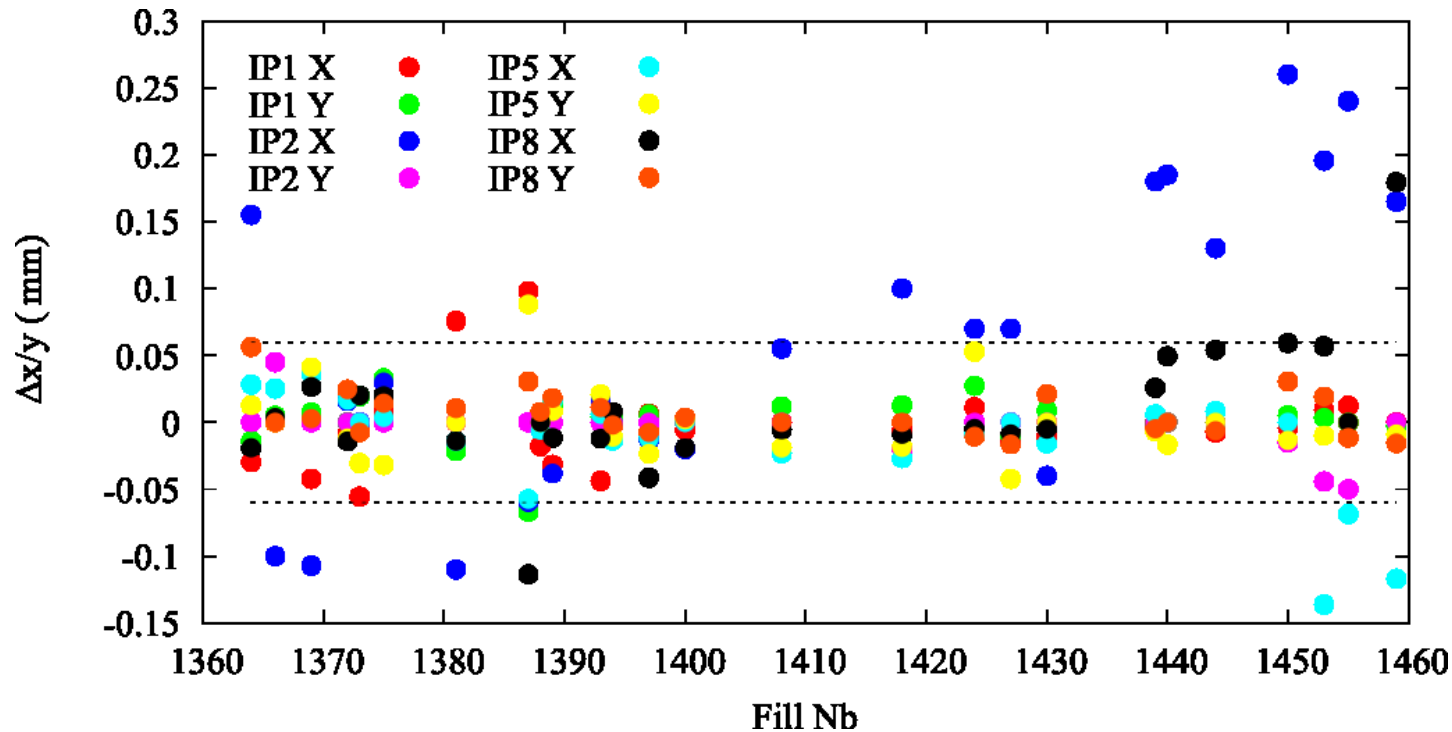
⇒ Automated scan operational.

⇒ Optimization in series, **full procedure ~ 45 minutes.**





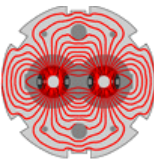
- Amplitude of the corrections (B1-B2) applied. Fills since 10A/s ramp:



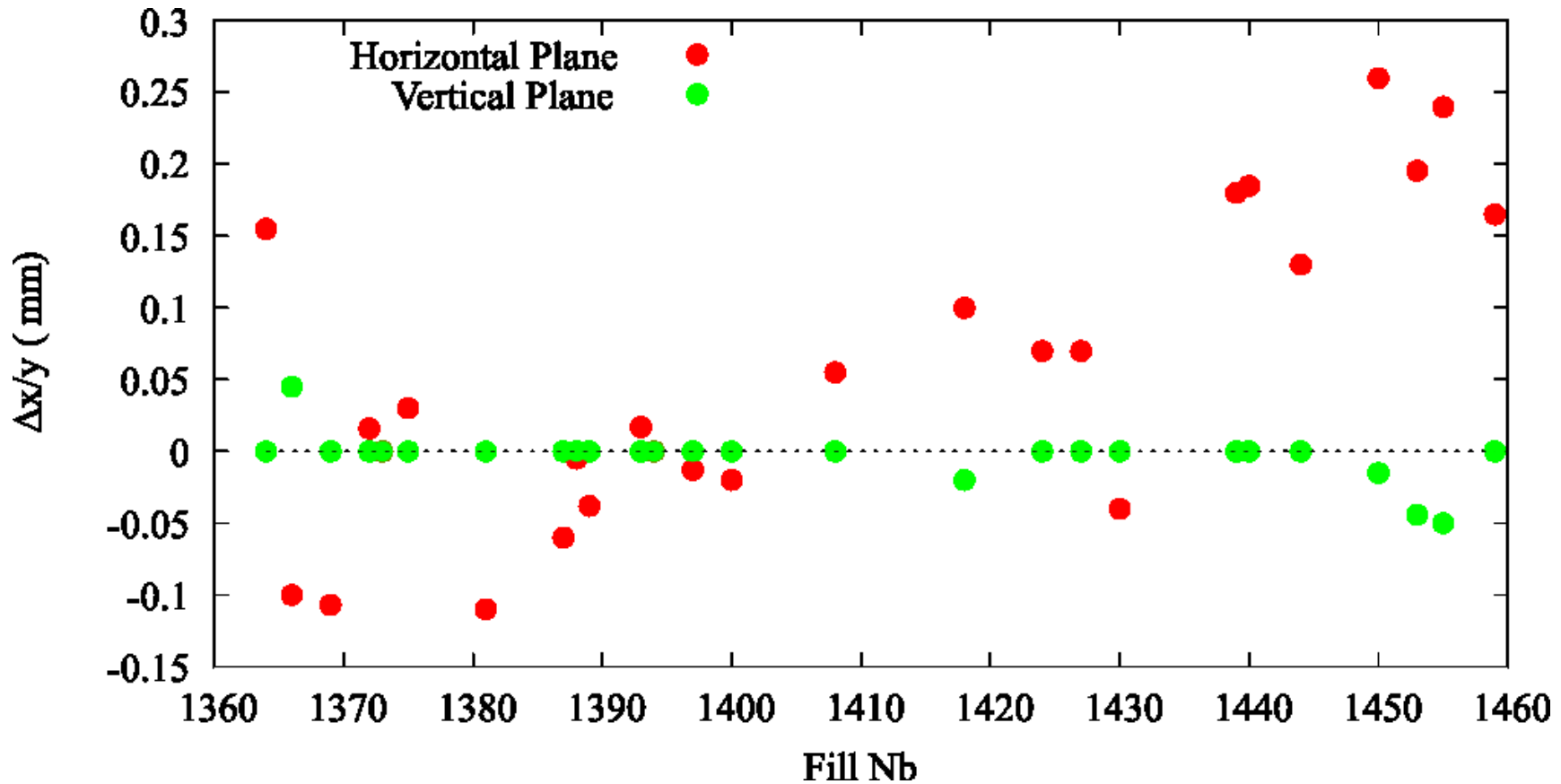
*Statistics over all fills excluding IP2:*

|                         |                   |
|-------------------------|-------------------|
| $\Delta x_{\text{rms}}$ | 41 $\mu\text{m}$  |
| $\Delta x_{\text{max}}$ | 180 $\mu\text{m}$ |
| $\Delta y_{\text{rms}}$ | 21 $\mu\text{m}$  |
| $\Delta y_{\text{max}}$ | 90 $\mu\text{m}$  |

- ⇒ **Fill-to-fill reproducibility: in general within +/- 60  $\mu\text{m}$ .** Sufficient to find collision point with actual beam parameters ( $\sigma \sim 60 \mu\text{m}$ ).
- ⇒ **Horizontal plane worse than vertical plane.**
- ⇒ **Nominal LHC:  $\sigma \sim 16 \mu\text{m}$ . Could become more difficult.**
- ⇒ **IP2: large differences due to offset collisions.**

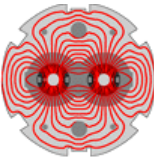


- **Amplitude of the corrections for IP2 ONLY:**



⇒ Separation applied in the horizontal plane.

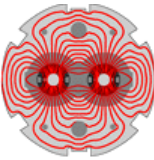
⇒ Vertical plane, most of the time no corrections. **Optimizing the vertical plane systematically would help control the orbit.**



- Optimization performed only at the beginning of fills. Few checks done at the end of fills:

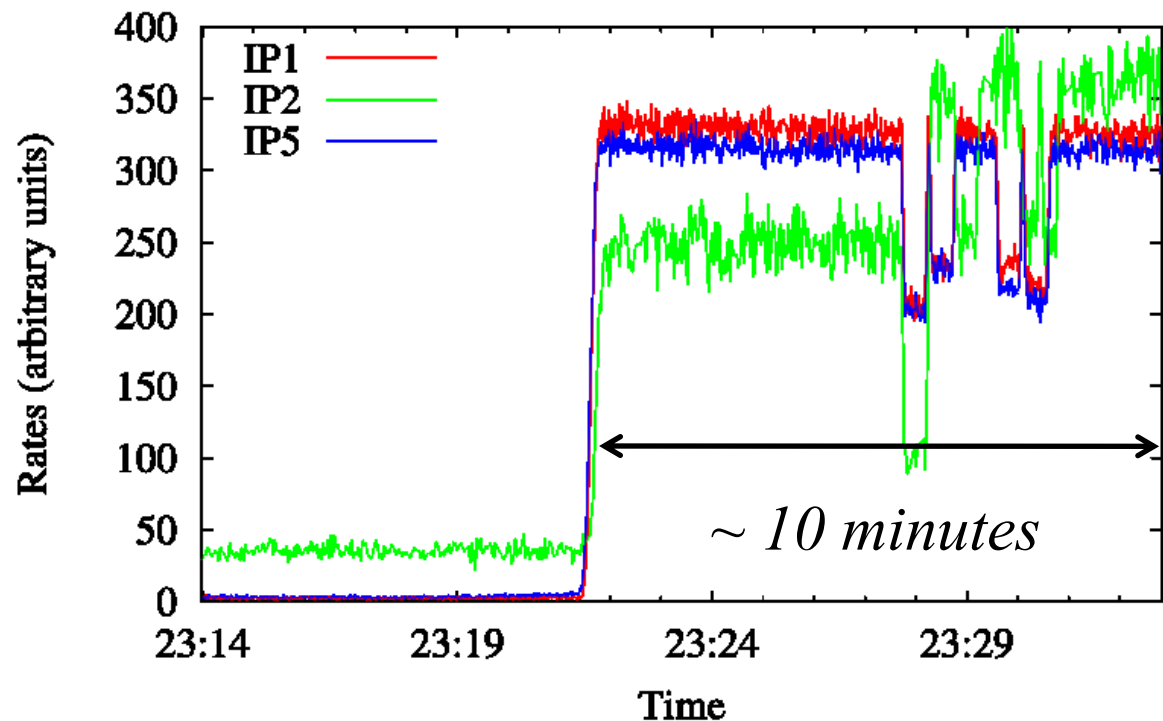
| Fill Nb. | IP1 X ( $\mu\text{m}$ ) | IP1 Y ( $\mu\text{m}$ ) | IP5 X ( $\mu\text{m}$ ) | IP5 Y ( $\mu\text{m}$ ) |
|----------|-------------------------|-------------------------|-------------------------|-------------------------|
| 1366     | 3                       | 3                       | 2                       | 10                      |
| 1372     | 1                       | -4                      | 7                       | -2                      |
| 1373     | 6                       | 16                      | -5                      | -3                      |
| 1393     | -5                      | -2                      | -2                      | -5                      |
| 1450     | -1                      | 4                       | -                       | -                       |

- ⇒ Done only for IP1 and IP5.
- ⇒ No significant orbit (separation) drift observed within a fill.
- ⇒ Corrections could have been applied in a few cases (gain few %).
- ⇒ Need more systematic checks: try mini-scans every hour to confirm (could be done during regular physics fill).

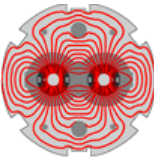


- **Beams are brought into collision with a ‘PHYSICS’ beam process:**
  - ⇒ Ramps down the injection separation bumps (all IPs).
  - ⇒ Loads the corrections from last fill.
  - ⇒ Optimization scans launched manually by the operator.
  - ⇒ **Now done in ‘ADJUST’, no physics data acquired.**

- **Latest fills:**
  - ⇒ Once all the bumps are loaded it takes ~10 minutes to go in **STABLE BEAM**.
  - ⇒ From logbook: orbit corrections + lumi-scans.



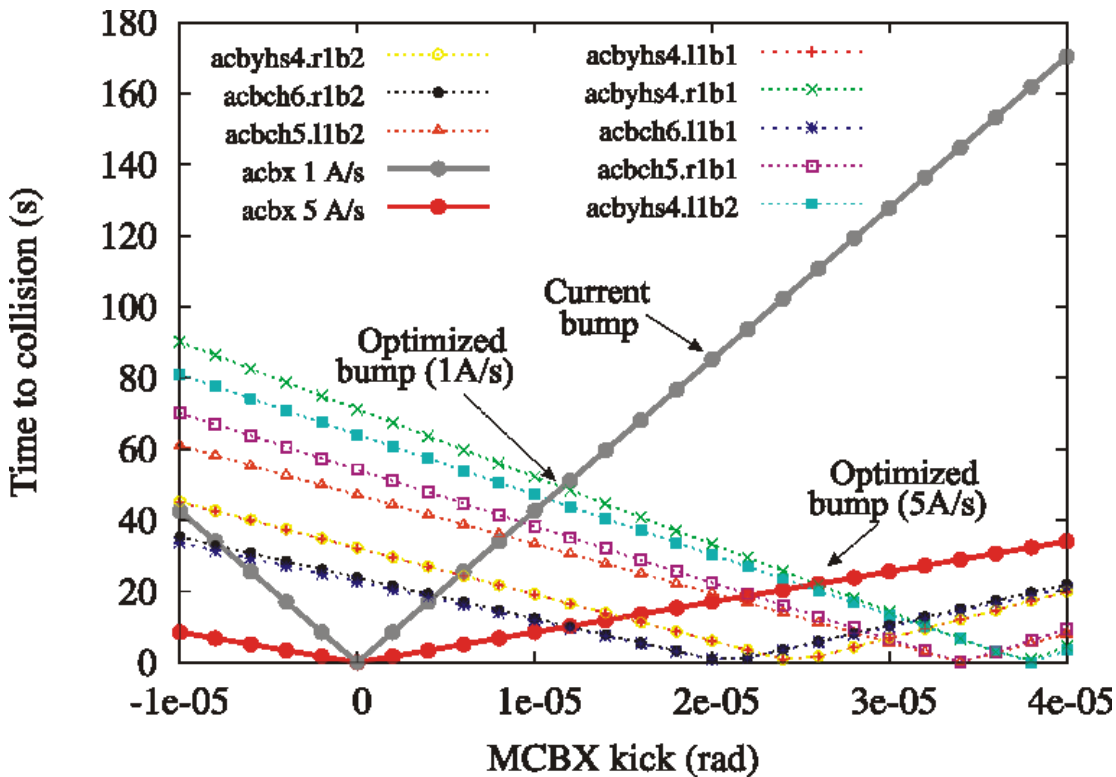
- ⇒ **How can we optimize further? Can't we declare STABLE BEAM earlier?**



- ‘PHYSICS’ beam process takes 108 seconds:
- ⇒ Procedure well optimized.
- ⇒ Duration scales with energy, constrained by slowest magnet.

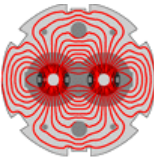
Duration can be further optimized with optics matching:

- ⇒ Example of IP1 (linear approximation). **Gain ~ 30 seconds.**
- ⇒ Limited by MCBX. Initial specifications 5 A/s. **Down to 20 seconds.**



- **Alternative solution:** split the strength between MCBXs, existing scheme for IR8 (E. Laface).
- Separation bumps are ramped down from 2mm. Could be reduced during other operation phases.



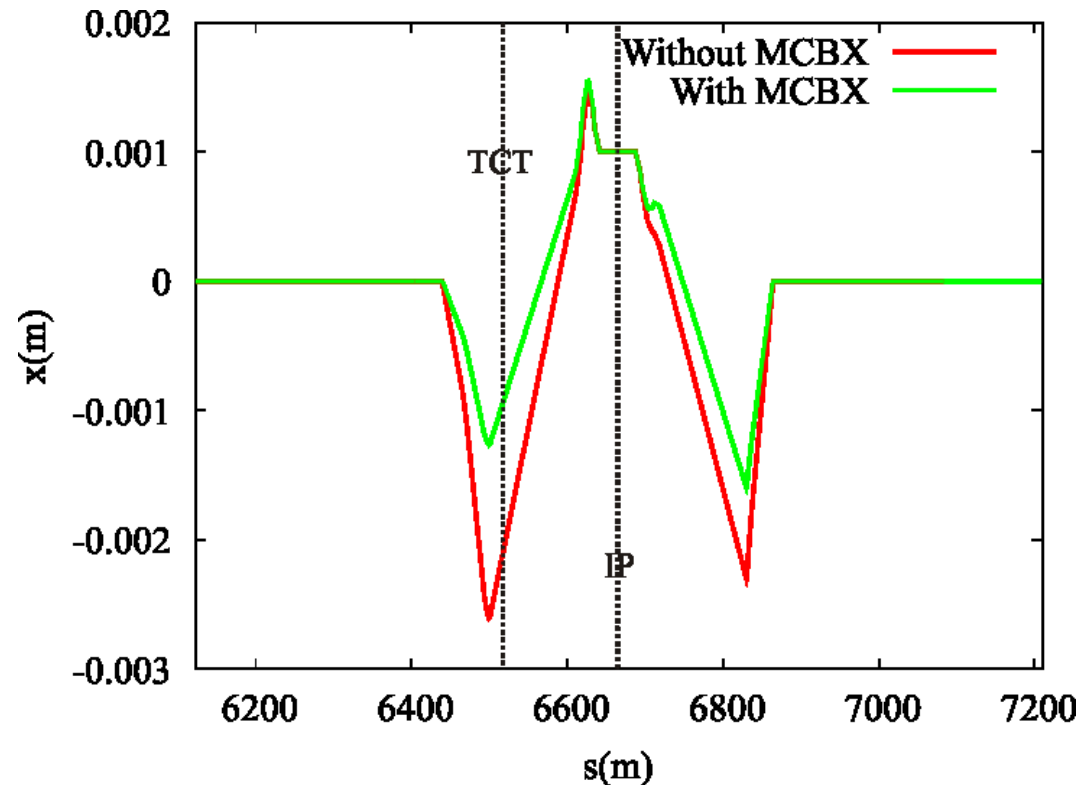


## Example of an IP bump with and without MCBX:

⇒ Creates a large offset in the TCT region.

⇒ MCBX magnets not used for luminosity optimization.

⇒ **Split the amplitude between beams.**



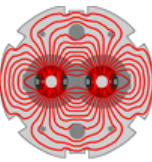
⇒ Changing the orbit at the TCT cannot be avoided.

⇒ Collimators settings based on reference orbit. **A large deviation from this reference can affect the hierarchy and the triplet protection.**

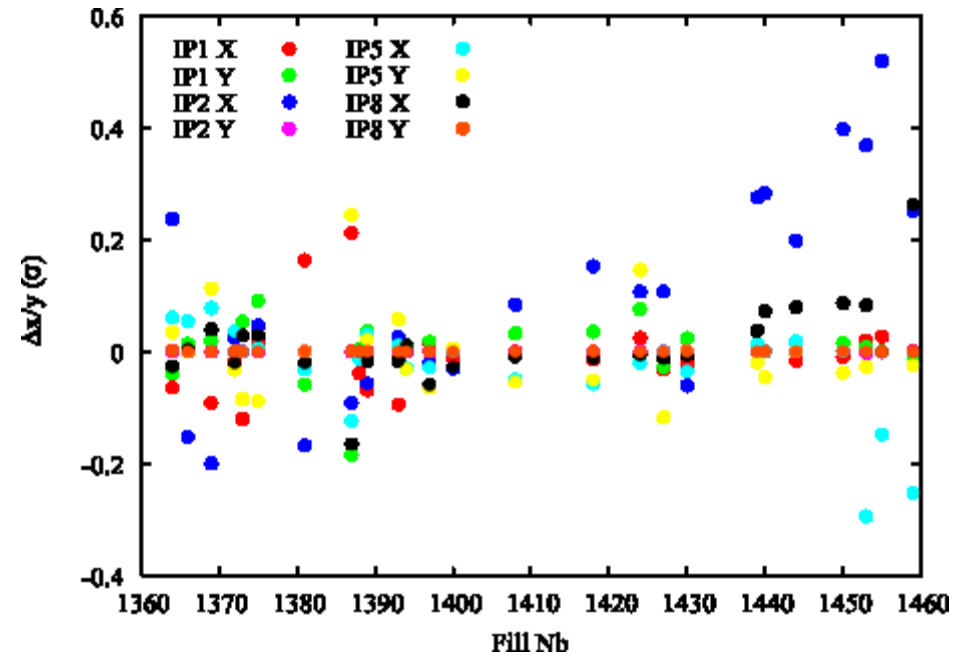
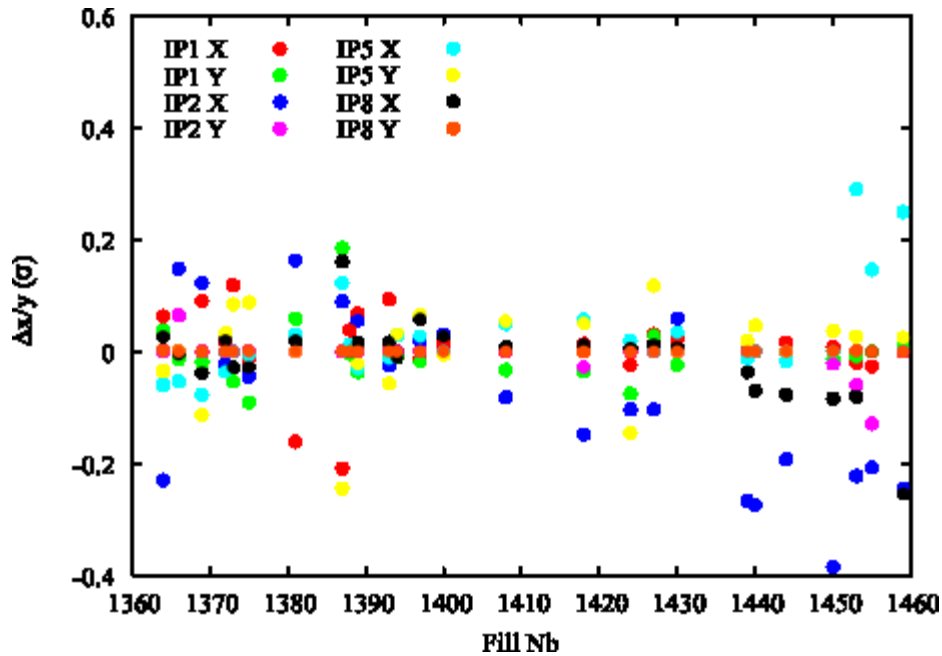
⇒ Define the available margins (see talk by R. Bruce).

⇒ Quantify what is needed for luminosity optimization.

⇒ **Set limits accordingly / find alternative solutions (move the TCTs?).**



- Displacements at the TCTs from the scans **ONLY**:



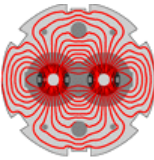
*Statistics over all fills  
excluding IP2 (beam 1):*

| $\Delta x_{\text{rms}}$ | $\Delta x_{\text{max}}$ | $\Delta y_{\text{rms}}$ | $\Delta y_{\text{max}}$ |
|-------------------------|-------------------------|-------------------------|-------------------------|
| 0.08 $\sigma$           | 0.29 $\sigma$           | 0.05 $\sigma$           | 0.24 $\sigma$           |

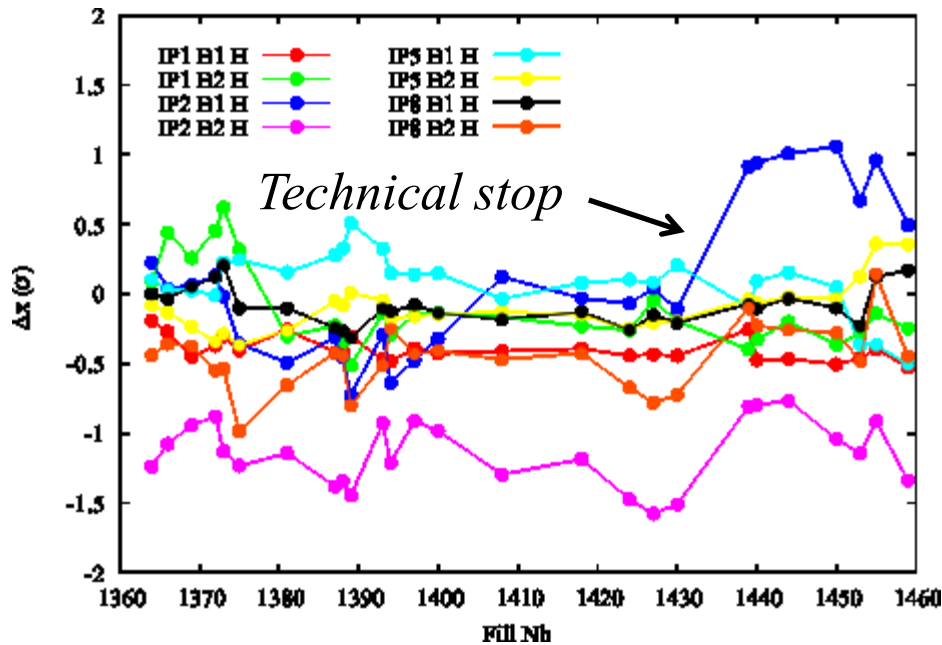
⇒ **In general, within +/- 0.2  $\sigma$ . Few cases above.**

⇒ **IP2: goes up to 0.5  $\sigma$  in the horizontal plane due to offset collisions.**

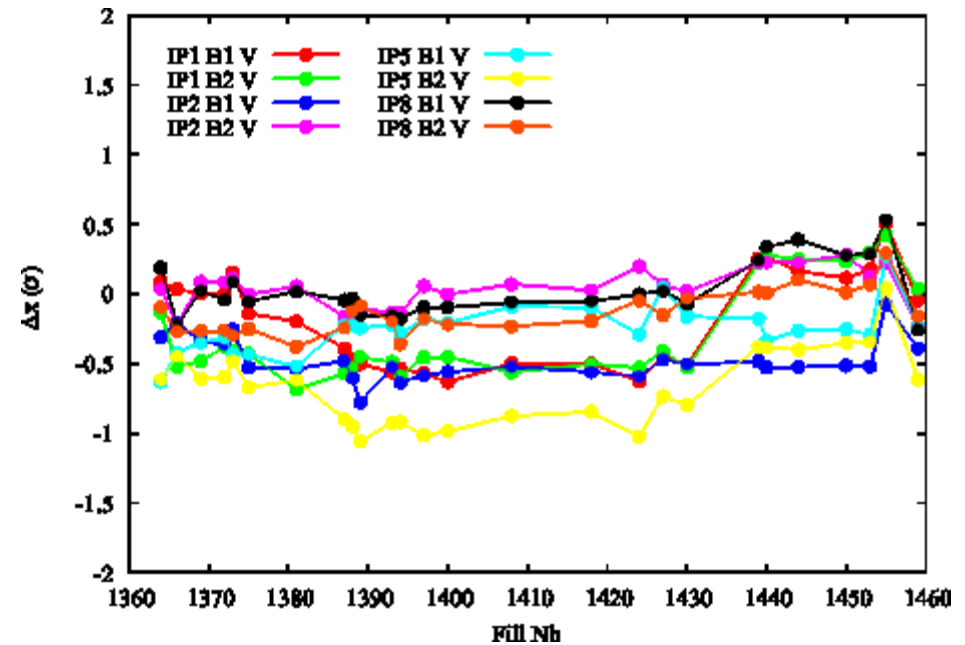
⇒ **3.5 m optics : well within margin in all cases (~ 2.5  $\sigma$ ).**



*Horizontal plane*



*Vertical plane*



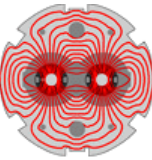
• **Difference with respect to the reference orbit at the TCTs in STABLE BEAM (includes scans + other sources):**

⇒ From the beginning several  $0.1 \sigma$  offset (reaches  $\sim 1.5 \sigma$  in IR2).

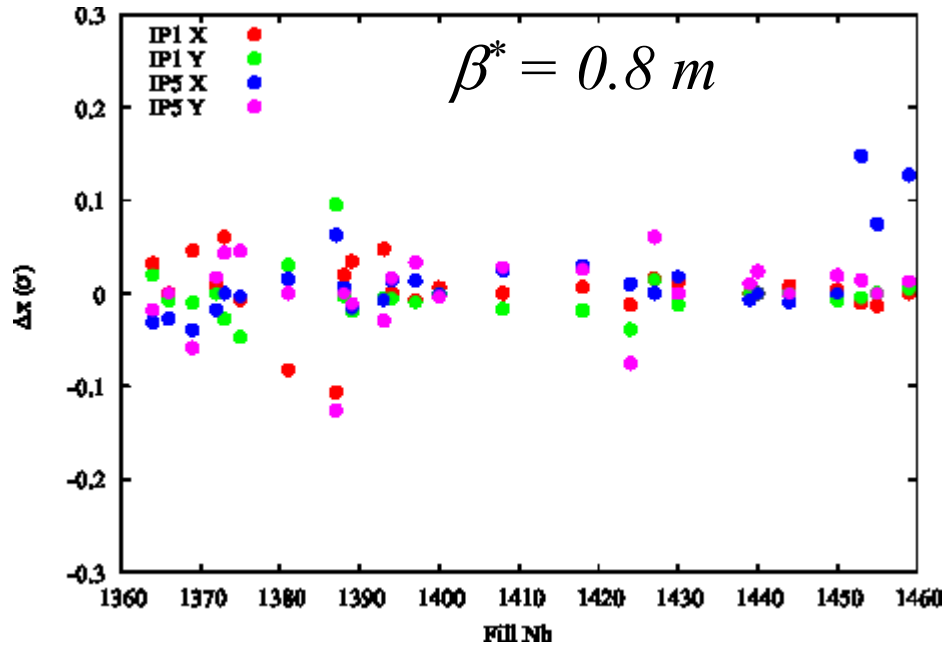
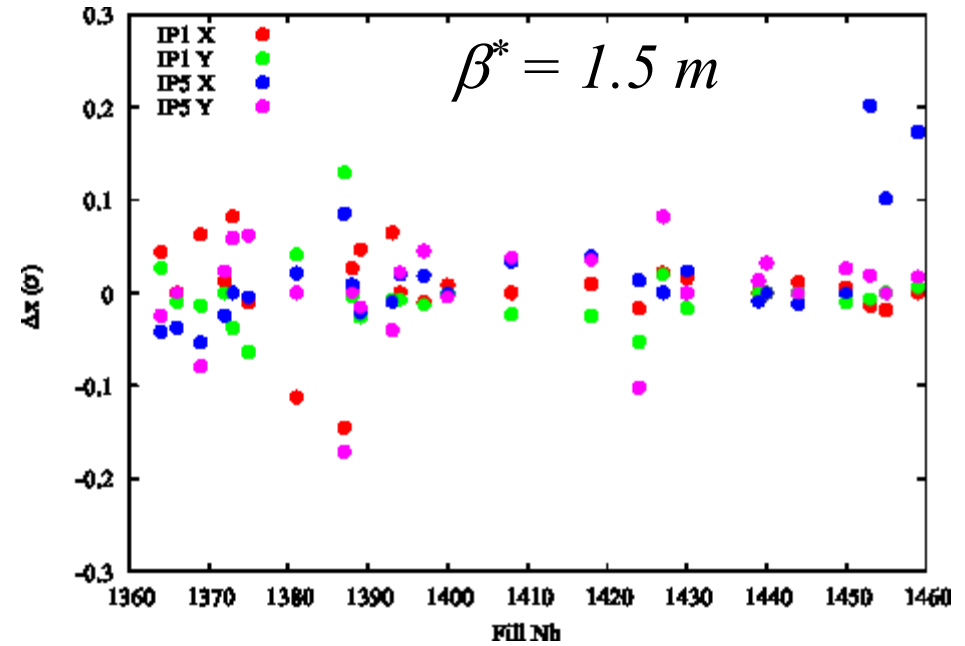
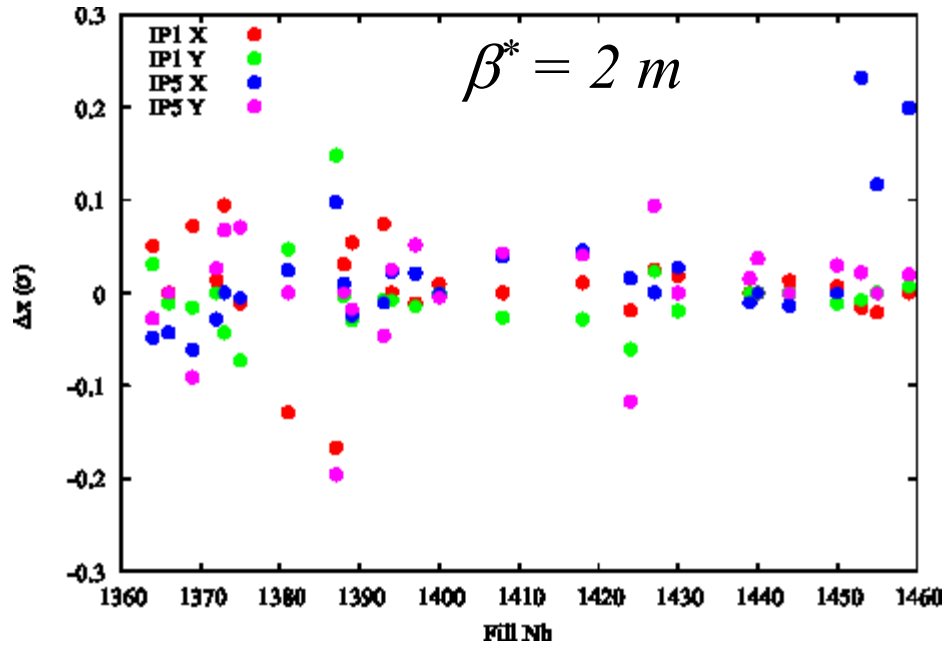
⇒ **No significant orbit drift observed.**

⇒ In some cases, fill-to-fill fluctuations  $\gg 0.2 \sigma$ . **Larger than what is expected from the scans.**

⇒ The horizontal plane is worse than the vertical plane: consistent with the scans observations.

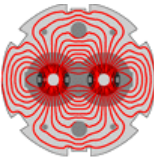


- Three scenarios considered for next year (see talk by R. Bruce):

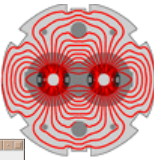


| $\beta^*$ (m) | Margin       | $\Delta x_{\text{max}}$ | $\Delta x_{\text{rms}}$ |
|---------------|--------------|-------------------------|-------------------------|
| 2.0           | 2.5 $\sigma$ | 0.23 $\sigma$           | 0.06 $\sigma$           |
| 1.5           | 1.5 $\sigma$ | 0.2 $\sigma$            | 0.05 $\sigma$           |
| 0.8           | 0.5 $\sigma$ | 0.15 $\sigma$           | 0.04 $\sigma$           |

**$\Rightarrow$  Contribution from the scans well within margin in all cases.**

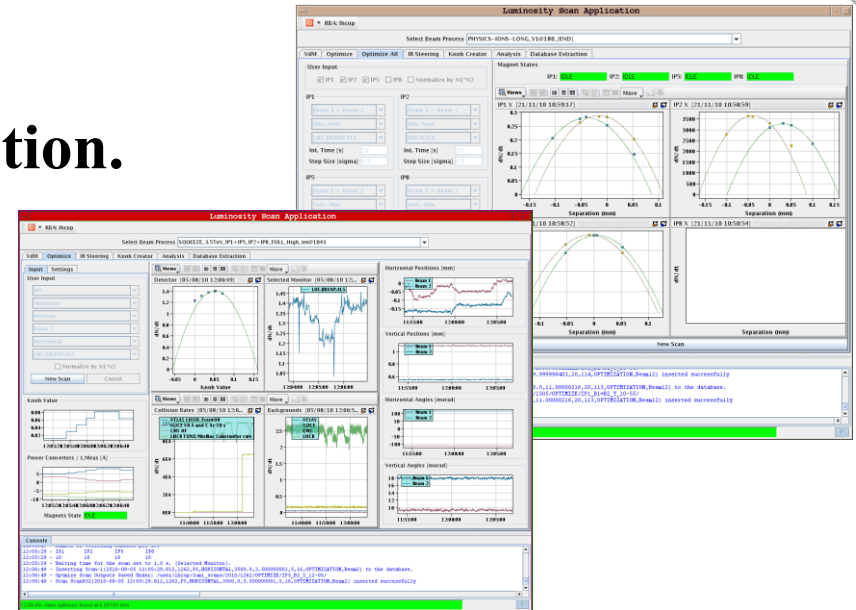


- Requested by the collimation team, several cases should be considered:
- **Luminosity optimization:**
  - ⇒ Done on a daily basis. Orbit variations at the TCT within tolerances.
  - ⇒ **Not necessary, would imply dynamic orbit reference.**
- **Luminosity calibration (to be discussed in more details at Chamonix):**
  - ⇒ Done over larger separation, few times a year.
  - ⇒ **Required for +/- 6  $\sigma$  scan range.**
- **Luminosity leveling (strategy to be defined). In case we use separation:**
  - ⇒ Experience from IP2 shows large fluctuations: **could become necessary (or use MCBXs?) in case of large dynamic range.**
  - ⇒ **Would give more flexibility in general for MDs and specific measurements.**



- **Operational functionalities:**

- ⇒ Automated single / parallel optimization.
- ⇒ Manual IR steering.
- ⇒ Automated calibration scans.
- ⇒ Online analysis.

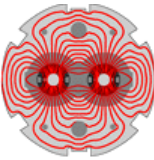


- **To be added:**

- ⇒ Moving the TCTs with the beam when necessary. **Implementation ready in LSA (P. Meira). Requires specific RBAC rights, difficult to test and develop. How do we use/operate them?**
- ⇒ Luminosity leveling: implement a set method? Same software? To be defined based on the outcome of Chamonix.

- **Maintenance and development:**

- ⇒ Daily maintenance and debugging should be handled by OP.
- ⇒ New developments and strategy to be discussed within LPC+LBS.



- **Reproducibility and stability:**

- ⇒ **Good fill-to-fill reproducibility: in general  $< \pm 60 \mu\text{m}$ . Could become more difficult with smaller beams.**

- ⇒ **No significant drifts during a fill observed (to confirmed).**

- ⇒ **The horizontal plane is worse than the vertical plane.**

- **Procedure to collide:**

- ⇒ **Declare STABLE BEAM as soon as possible.**

- ⇒ **Displacement at the TCT due to the scans well within tolerances.**

- ⇒ **Optimization can be done in STABLE BEAM.**

- **Software:**

- ⇒ **Main functionalities operational.**

- ⇒ **Move the TCTs with the beam: Required for calibration scans (luminosity leveling?). Strategy to be defined.**

- ⇒ **Luminosity leveling: requested by ALICE and LHCb. New tools required. Specifications, procedure and strategy to be defined.**