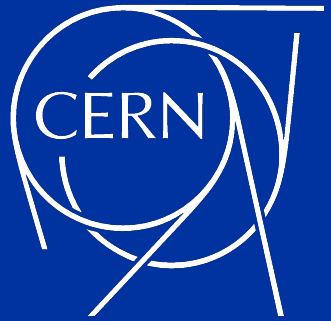

MD10483: Investigations of UFO release mechanisms using displaced bunches

Philipp Ziegler (philipp.ziegler@cern.ch)
MD participants: Anton Lechner, Bjorn Hans Filip Lindstrom, Cedric Hernalsteens, Christoph Wiesner, Daniel Valuch, Daniel Wollmann, Eva Calvo Giraldo, Manuel Gonzalez Berges, Michael Artur Hostettler, Xavier Buffat

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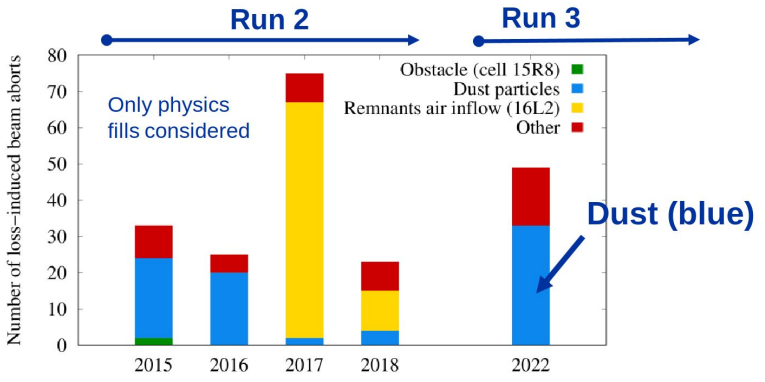
MD Motivation

- **UFOs** (Unidentified “Falling?” Objects) trigger many premature beam dumps at LHC and might impact operation of future high-energy colliders
- UFO-Dynamics well understood (Lindstrom et al. 2020)
- **But: Release Mechanism** is still unclear
- **Goal: Validate a method to reconstruct the UFO trajectory**
- **How: Perform wire scans with displaced bunches** and use **bbb-dBLM Signal** in IR7 for trajectory reconstruction
- **Displacement:**
  - Recurrent ADT Kick (Dipole Mode)
  - Reduced physics filling scheme with maximal Long-Range and Head-On Beam-Beam Effect that allows wire scans



A. Lechner et al. (2023)

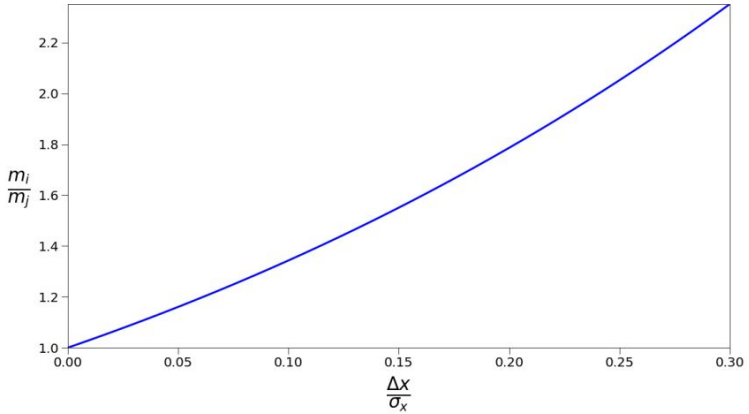


Figure 1: Ratio of normalised losses against bunch displacement, for a UFO at position $x_j = 3\sigma_x$

J. Sadler, 2023

MD Overview

	Injection Energy	Top Energy
Beam-Beam Effect	Part 1a (non-colliding): ● Beam 1: 135b vs Beam 2: 312b ● Comparable beam-beam effect as in physics operation (up to 0.3σ peak-to-peak orbit spread)	Part 2a (colliding): ● Beam 1: 10b vs Beam 2: 310b ● Collisions at β^*=30cm ● Comparable beam-beam effect as in physics operation (up to 0.5σ peak-to-peak orbit spread)
ADT recurrent Kick	Part 1b (non-colliding): ● 24 INDIVs in Beam 1 ● 16 of 24 INDIVs displaced with ADT ● Displacement of 0.26σ at BWS	Part 2b (Beam-Beam + ADT, colliding): ● Beam 1: 10b vs Beam 2: 310b ● Collisions at β^*=30cm ● ADT-Kick of 6 bunches that are not colliding in IP1/5 by <0.1σ

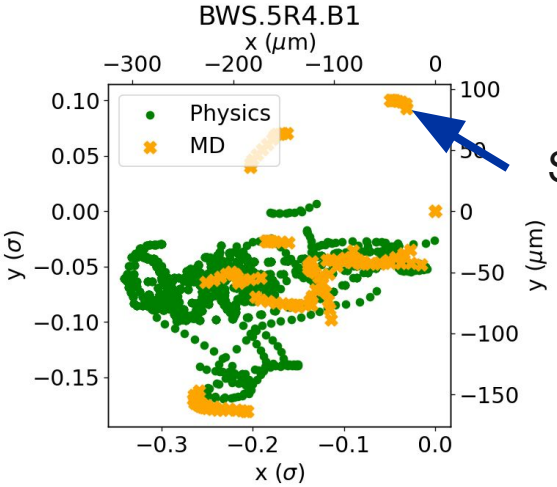
- Performing wire scans at each step of the MD
- Monitoring bbb-dBLM Losses and orbit data

Detailed procedure on ASM

MD Part 1a

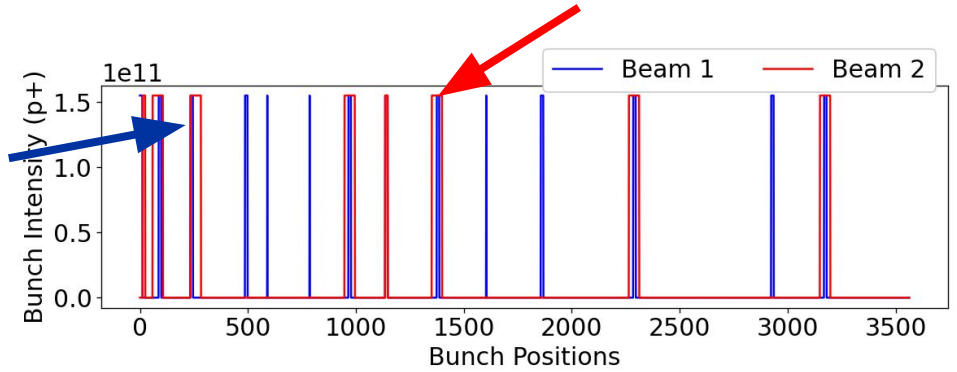
450 GeV,
Beam-Beam effect

- Bunch displacement by beam-beam effect: **135b in Beam 1** and **312b in Beam 2**
- Use reduced physics filling scheme* with single 12b and 1x48b trains and corresponding LR beam-beam effect
- Perform wire scans and dump



Single 12b train

Single 48b train



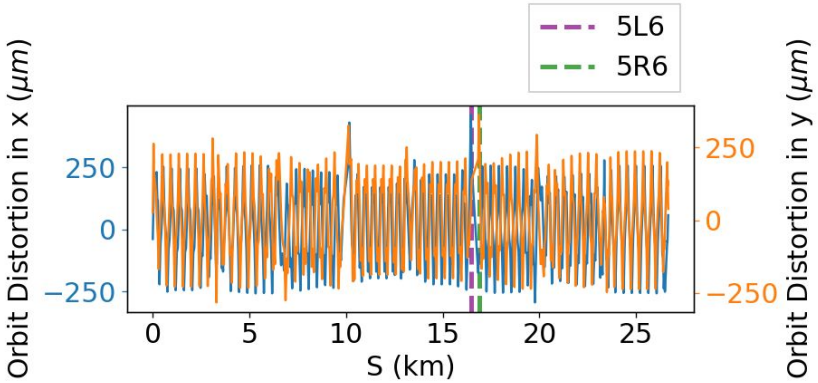
ε_x = 2.1e-6m, ε_y=1.9e-6m

*25ns_2352b_2340_2004_2133_108bpi_24inj

MD Part 1b

450 GeV,
recurrent ADT Excitation

- Kick at 7.5 kV correspond to **orbit change** of **~240 μm** or **~0.26σ** at the BWS
- Displace 16 INDIVs with recurrent kick from the ADT (±H and ±V)
  - Note: max. allowed number of bunches excited by the ADT is 480b (211th MPP)
- ADT will need to be switched to the expert mode (excitation limitations disabled)
- ADT excitation scheme prepared by expert. ADT kick will be ramped up adiabatically in 10 second up to max. value
  - Note: ADT damping kept on with nominal gain
- Perform wire scans and dump



Max. displacement is 461 μm in x (**5L6**) and 363 μm in y (**5R6**)

Beam size:

- (906, 1163) μm at BWS
- (816, 550) μm at TCP.D6

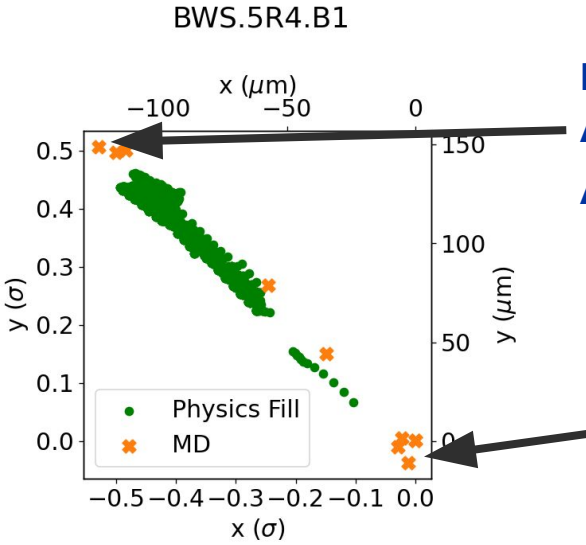
Phase Advances:

- ADT-BWS: 15.5° (x), 10.5° (y)
- BWS-TCP: 225.8° (x), 25.2° (y)

MD Part 2a

6.8 TeV,
Beam-Beam effect

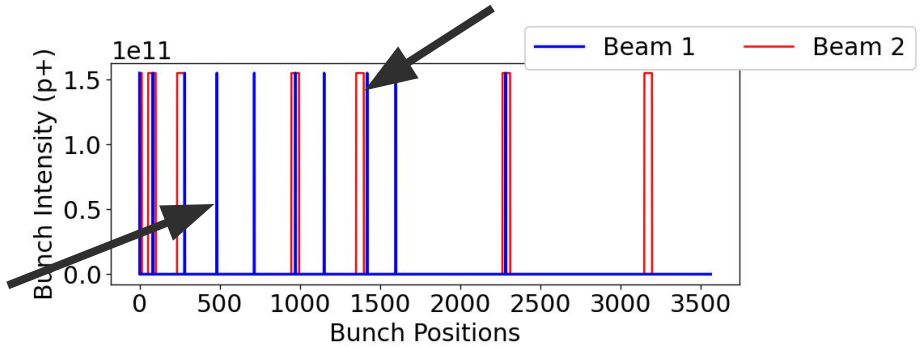
- Bunch-Displacement with weak-strong beams: **10b in Beam 1** and **300b in Beam 2**
- Reduction of physics filling scheme* to INDIVs and 12b or 1x48b trains result in LR and Head-On beam-beam effect
- **Comparable bbb orbit spread as to normal physics fill**



Maximum spread:
Δx=0.5σ,
Δy=0.5σ

INDIV

Single 48b train



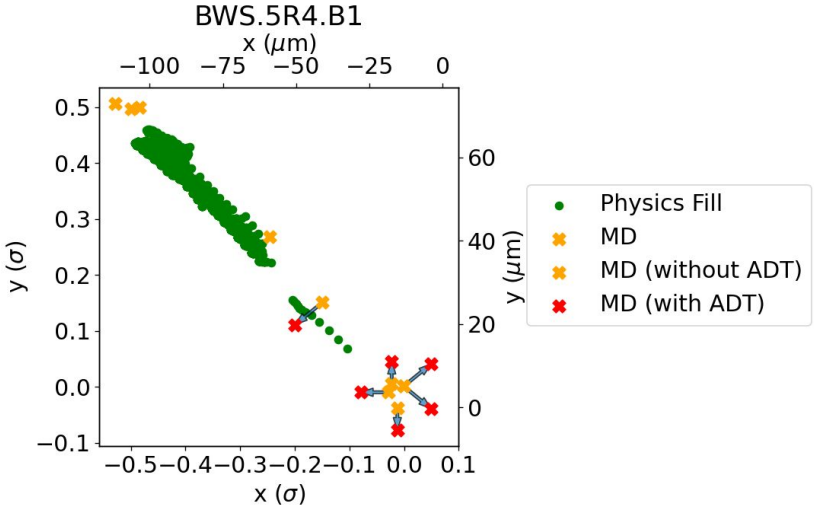
ε_x = 2.1e-6m, ε_y=1.9e-6m

*25ns_2352b_2340_2004_2133_108bpi_24inj

MD Part 2b

6.8 TeV,
Beam-Beam effect and
ADT Kick

- Additionally excite 6 bunches by ADT (marked in red and non colliding in IP1/5) to get better (off-diagonal) spread
- Kick at 7.5 kV correspond to orbit change of 15 μm or 0.06σ at the BWS
- Max. displacement is 42 μm in x and 37 μm in
- Perform wire scans and dump



Beam size:

- (233, 294) μm at BWS
- (211, 144) μm at TCP.D6

Phase Advances:

- ADT-BWS: 29.7° (x), 24.0° (y)
- BWS-TCP: 170.5° (x), 47.0° (y)

Summary: Machine-protection relevant aspects (1/2)

- No changes of optics, collimation settings, RF, interlocks
- Desired bunch intensity: 1.55e11 protons
- MD part 1: injection
  - Part 1a) Beam-Beam effect
    - Beam 1: **135b** (below wire scanner limit) and Beam 2: **312b**
    - **bbb orbit spread:** < **300 µm** at Wire Scanner
  - Part 1b) ADT
    - **Beam 1: 24b**
    - **bbb displacement:** < **250 µm** at Wire Scanner
- MD part 2: top energy
  - Beam 1: **10b** (below wire scanner limit) and Beam 2: **310b**
  - Part 2a) additional bbb orbit spread compared to standard physics fill (beam-beam): **< 22 µm** at Wire Scanner
  - Part 2b) additional bbb displacement (ADT): **< 15 µm** at Wire Scanner

Summary: Machine-protection relevant aspects (2/2)

- **ADT Changes:**
  - ADT excitation scheme prepared by expert
  - ADT will need to be switched to the expert mode (excitation limitations disabled)
  - Switch on ADT kick adiabatically in 10 second up to max. value
  - Note: ADT damper will be kept on with nominal gain
  - ADT expert will be present and a revert checklist will be followed
- Note: Luminosity needed for Part 2 (collisions)

Backup

MD Procedure

- **MD Part 1a) 450 GeV, <450b**
  - Inject Weak-Strong Beam 135b in Beam 1 and 312b in Beam 2
  - Filling Scheme consists of single injected INDIVs, 12b and 48b trains
  - Maximum spread of $\Delta x=0.26\sigma$ and $\Delta y=0.28\sigma$
  - Perform wire scans (B1, H/V)
  - Dump beams
- **MD Part 1b) 450 GeV, 24b**
  - Inject INDIVs with 2 μs spacing in beam 1
  - Displace 16 bunches trains with recurrent kick from the ADT (±H and ±V) (max. number of ADT excitations: https://indico.cern.ch/event/1058861/
  - Keep ADT damper on with nominal gain
  - Switch on ADT kick adiabatically in 10 second up to max. value
  - Excitation pattern prepared by ADT Expert (Daniel Valuch)
  - Perform wire scans (B1, H/V)
  - Maximal displacement: ± 0.25σ
  - Dump beams

MD Procedure

- **MD Part 2a) 6.8 TeV, 310b**
  - Inject Weak-Strong Beam 10b in Beam 1 and 300b in Beam 2 and ramp to 6.8 TeV
  - Filling Scheme consists of single injected INDIVs, 12b and 48b trains
  - Perform wire scans (B1, H/V)
  - Maximal displacement in x: 0.5σ and in y: 0.5σ
- **MD Part 2b) 6.8 TeV, 310b**
  - Displace 6 specified bunches (non-colliding in IP 1/5) with recurrent ADT Kick in x ±0.05 σ and in y ±0.04 σ
  - Perform wire scans (B1, H/V)
  - Dump beams
- **MD recovery**
  - Disable timing event for WS dBLM triggering for Beam 1 and Beam 2
  - Disable the bunch-by-bunch orbit acquisition
  - Disable the dBLM write to file option
  - Roll back dBLM autotrigger to nominal settings (trigger level, peaks above threshold) if modified
  - Roll back ADT settings

MD Planning

- **Requested time**: 8 hours
- **MD participants:** X. Buffat, E. Calvo Giraldo, M. Hostettler, M. Gonzalez Berges, C. Hernalsteens, A. Lechner, P. Belanger, B. Lindstrom, D. Valuch, C. Wiesner, D. Wollmann, P. Ziegler
- **Outlook: Depending on the outcome**
  - Define follow-up MD
  - Develop method that profits from the existing bunch-by-bunch orbit spread during physics fill
  - Prepare dedicated test with displaced bunches