

beta* levelling in 2023

M. Hostettler, A. Calia, S. Fartoukh,
D. Jacquet, D. Mirarchi, J. Wenninger

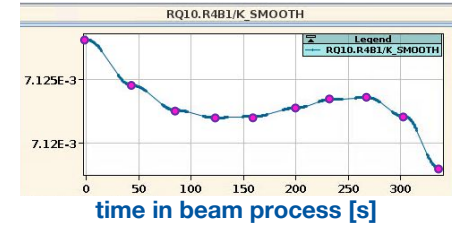
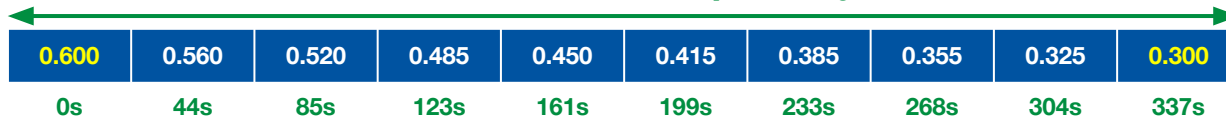
recap: beta* levelling settings management

- settings are stored in a "repository BP" that spans the full levelling range
 - e.g. 60cm → 30cm for 2022

- optics match points in BP = possible levelling targets

- identified by position (seconds) in the BP

2022: 60cm → 30cm repository BP



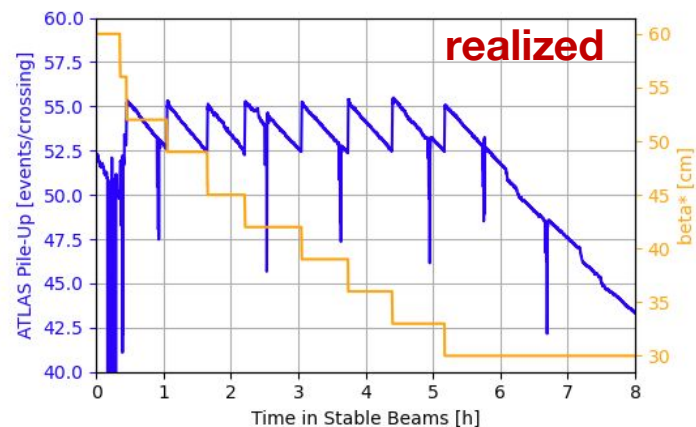
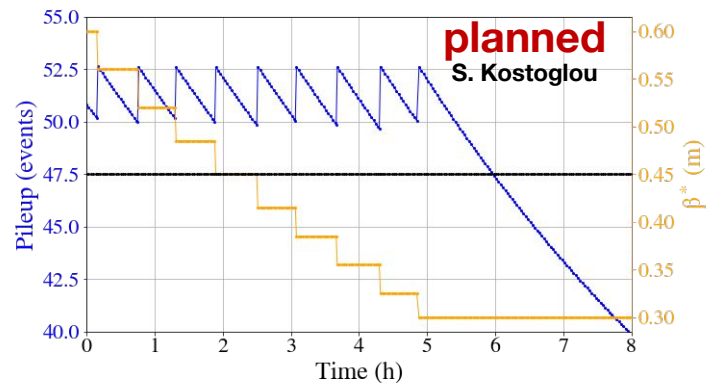
- high-level levelling logic (or OP) decides to execute a step
- lumi server identifies start and end point (seconds in BP)
- functions to play are sliced by lumi server
 - similar to the squeeze in steps
 - start point of the functions are required to match actual settings (except corrections)

recap: beta* levelling machine protection

- **beta* levelling is more dynamic than a "standard squeeze"**
 - the situation in SB is less static than the cycle before: knobs, corrections
 - tight requirements on orbit control in collisions: few μm @ IPs
 - OFB reference, collimator centres calculated from orbit response
 - magnet kick & PC current functions automatically "incorporated" for corrections
 - orbit, tune, chroma, coupling = relative corrections
 - in general, the "orchestration" steps are equivalent to the sequencer squeeze
- **principle: lumi server shall NOT become critical for machine protection**
 - safe envelope guarded by external systems:
 - collimators: pre-programmed limits checked by the PRS
 - magnets: PCInterlock (orbit, quads including optics)
 - within these safe envelopes, lumi server can calculate settings
 - ➔ **moving the limits during levelling needs to be carefully considered**

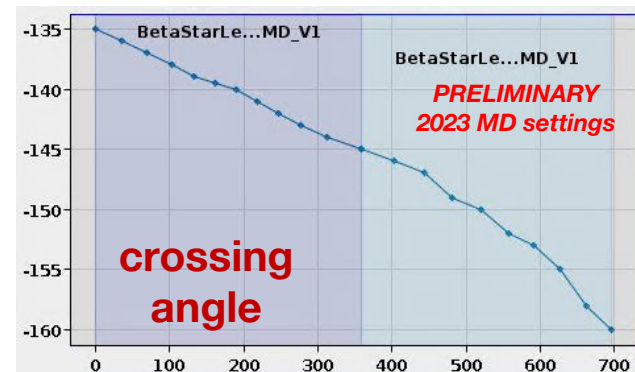
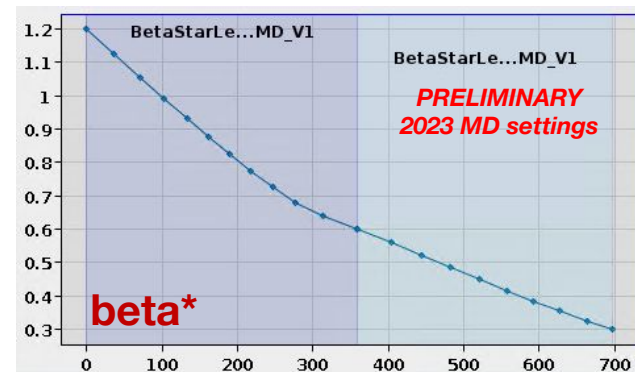
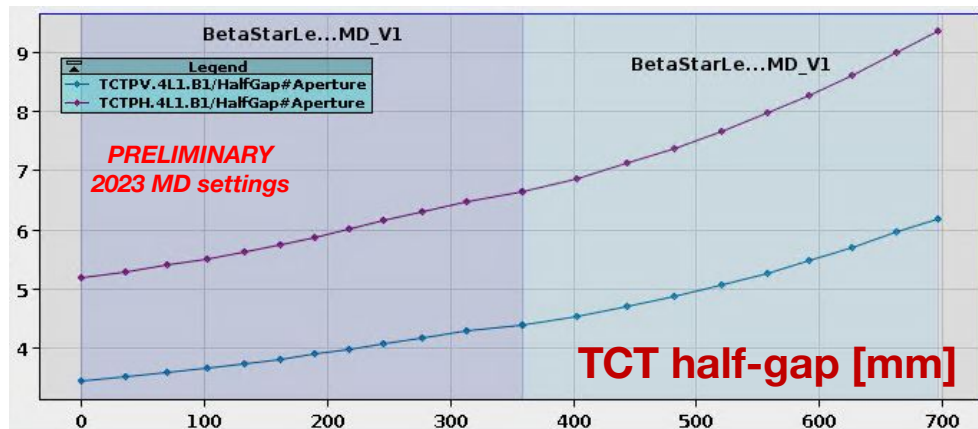
beta* levelling in 2022 operation

- **60cm → 30cm beta* / constant xing angle**
 - constant TCT/TCL gaps
 - negligible centre changes @ TCT/TCL
- **automated step-taking**
 - based on experiment pile-up
 - signal from either ATLAS or CMS - OP choice
- **orchestration logic commissioned**
 - PCs, feedbacks, collimators & PCInterlock
 - behaved as expected throughout the year
 - following MPP meeting #222 recommendation: "almost flat" collimator limits driven to validate the functionality



beta* levelling plans for 2023

- **120cm / 135 urad** → **30cm / 160 urad**
 - large beta* range: need to change TCT/TCL gaps
 - crossing angle change: follow with TCT/TCL centres→ need to follow with interlock limits
- **no change to the orchestration logic**
 - functionality ready & tested in 2023 configuration MD



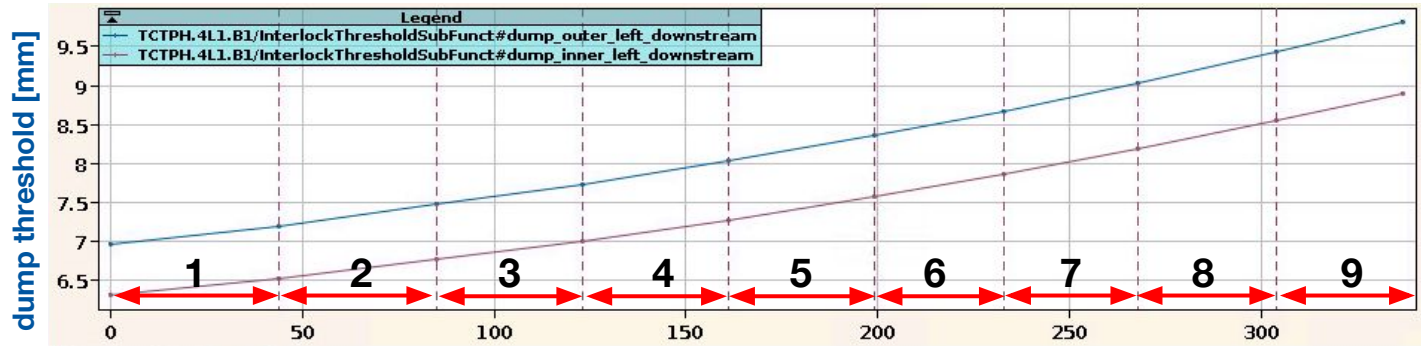
recap: moving TCT/TCL jaws

- **TCTs/TCLs moved during crossing angle levelling in run 2**
 - centres calculated from expected bump changes
- **beta* levelling reusing the same logic**
 - centres calculated from orbit changes
 - same approach (and largely the same code) now also used for TCT settings generation throughout the cycle
 - gaps from pre-programmed functions
- **"best effort" pre-flight check of interlock limits**
 - not 100% reliable due to LVDT offsets
 - not for protection - avoid dumps due to mistakes
- **tested in 2022 (flat) & 2023 MD (real)**

```
java.lang.IllegalArgumentException: The set value violates the limits on Collimator [element=TCL.5R5.B1, beam=BEAM1, plane=H]:
...
---- TIME PT1M1S ----
Motor [DOWNSTREAM, RIGHT]:
  InnerLimit = -6.3763
  OLD Position = -6.77
  NEW Position = -6.3556
  OuterLimit = -25.407
...
```

recap: moving TCT/TCL limits

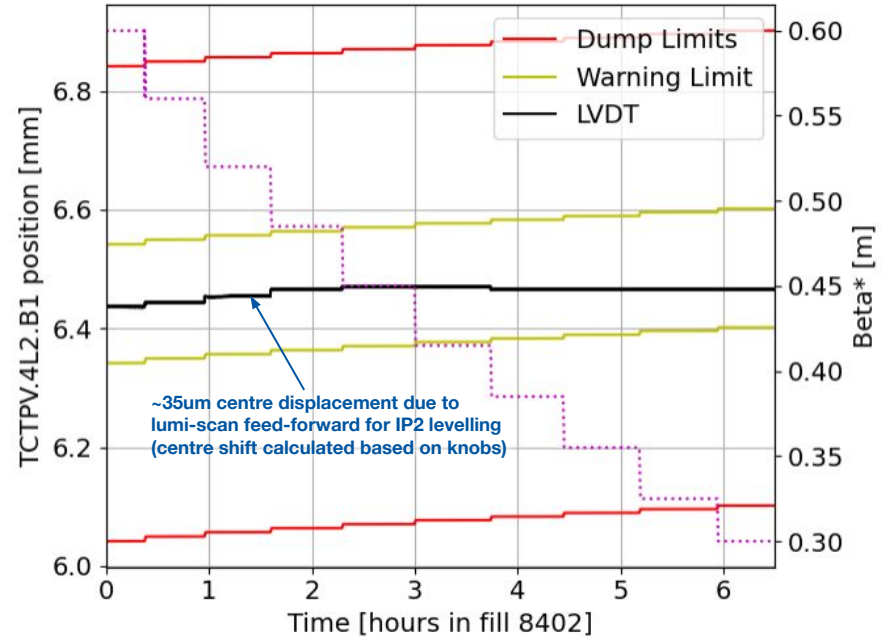
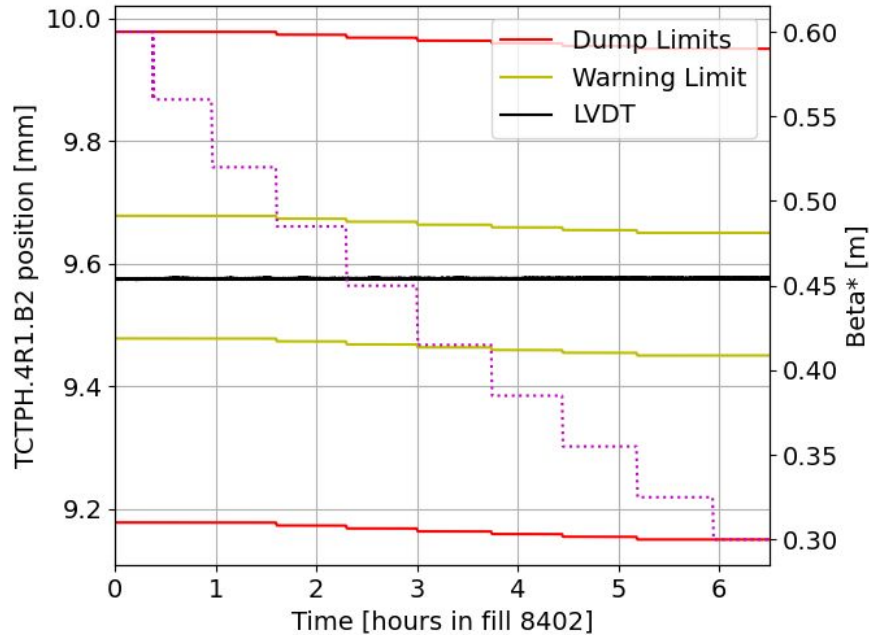
- **collimator limits are Machine Critical Settings (MCS)**
 - digitally signed on creation, can only be loaded & played as a whole
- **implemented solution for beta* levelling**
 - at generation time, split the TCT/TCL limit functions at optics match points
 - pre-generate MCS signature for every segment
 - lumi server looks up segment & the corresponding signature for a beta* levelling step



PARAMETER	#
TCTPH.4L1.B1/InterlockThresholdSubFunc#sub_signatures	1 1bfb078e4790391b448d16c70b5fefed47d7c7aeff37a7ee587e17eafeb288657dc3004baa85048d946cb683490f0ce4b72dbe7f296a48b8947e9ae1768acc6e
	2 8ae20eb075e7fd3656881987e44e1f3c302840da2830518b212267cea82944acf9dba0a14bc0cd9f5de02b19d3bce21910c0c70a980d661335e572723a2d36
	3 86277cf8eb0f35053f693ed1fd57be0397254c2963d21f4afd67e7f2c3a70ef52874be2e71c172acacdfb826b0fd7ccc0c82eb4ec0cf8e9f00e2b92ed220
	4 32da1c173506b7d763684bc947f8d23f8f40effd6bb5a5247c047547c1c390f77b6f5f624ebfc745845a433fedb0cee38f88208e0fc7b096fd5e06dd20cf12
	5 3754dd217752c2765231d86709a55ee7eb347a1fbc7395c8a532ba4fc7c521de8428e0b7e9cb7f79828ab9af1c5ab5b6e2a1e2881c407fe225e63c66offca5e
	6 5deabab2cbd1b726d13efebbd4a9276be63898de6d818443c45b8f662eb9aec7552c20d64b4310b8ae8586357558f534882a78a3cbfe268fcd6bc1b27099f00c

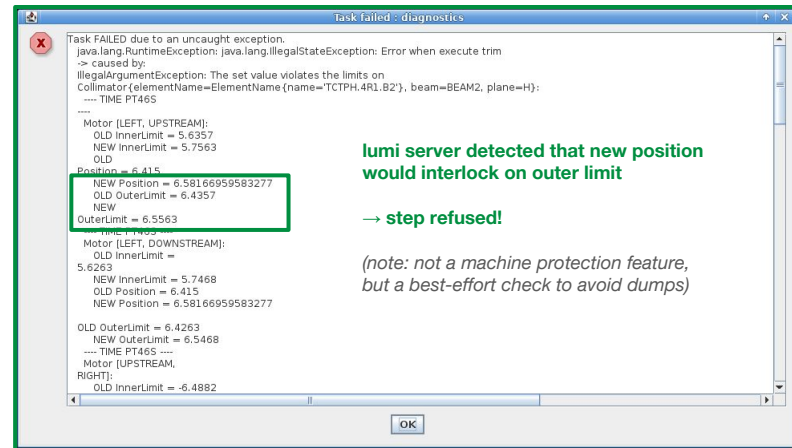
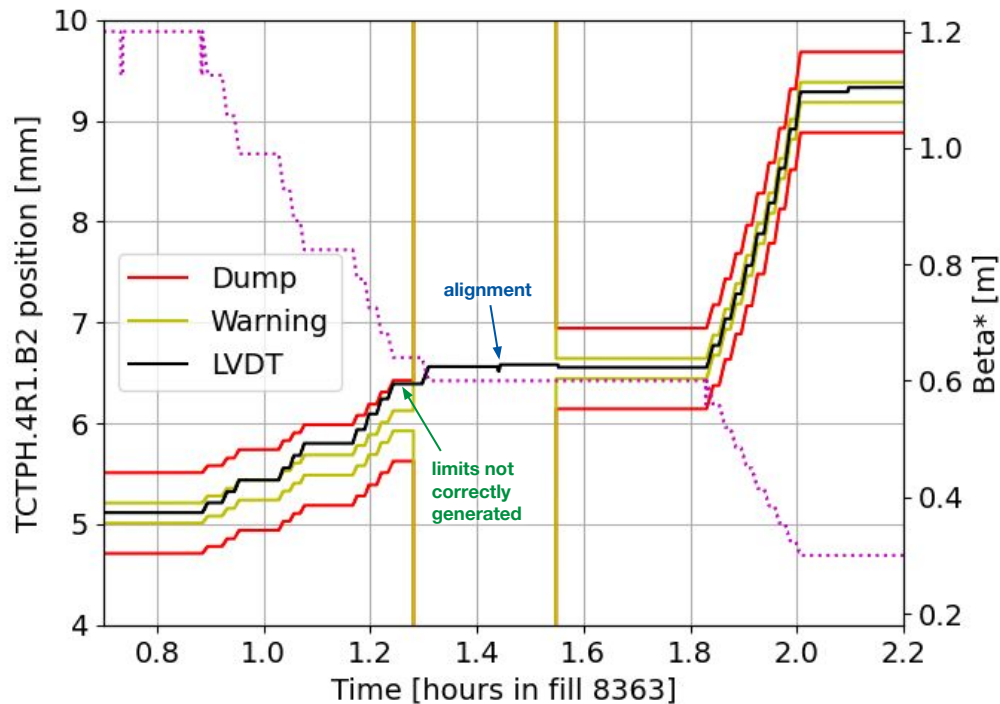
driving collimators & limits: 2022 fills

centre shift calculated from knobs - no gap changes - almost-flat limits (~50um changes)



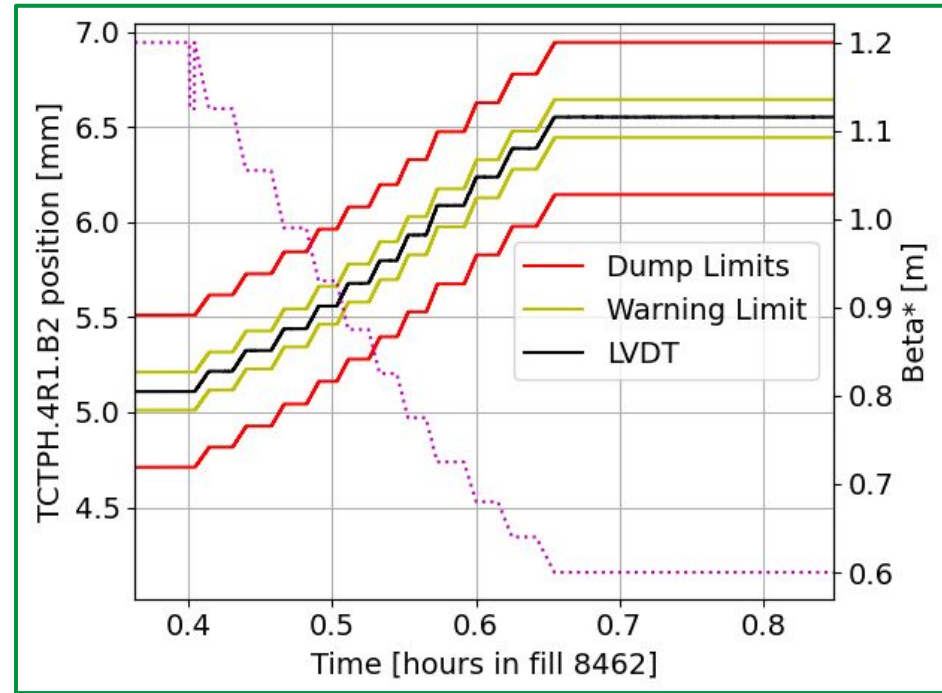
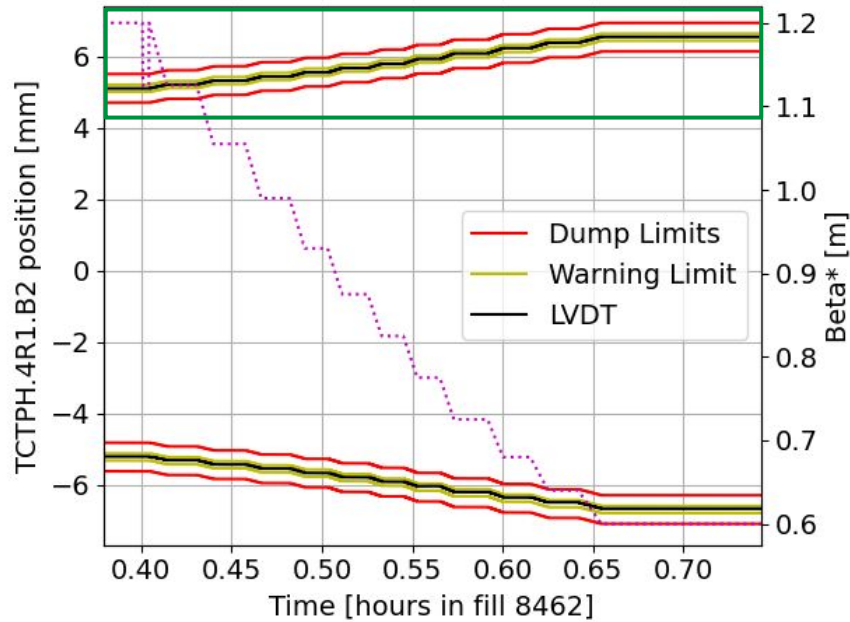
driving collimators & limits: 2023 MD

centre shift calculated from knobs - gap changes from settings - limits driven
first fill: aligning on-the-go, settings not final



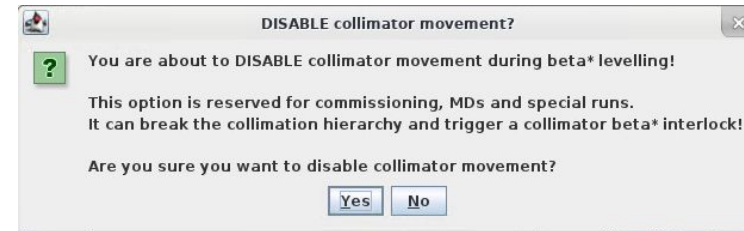
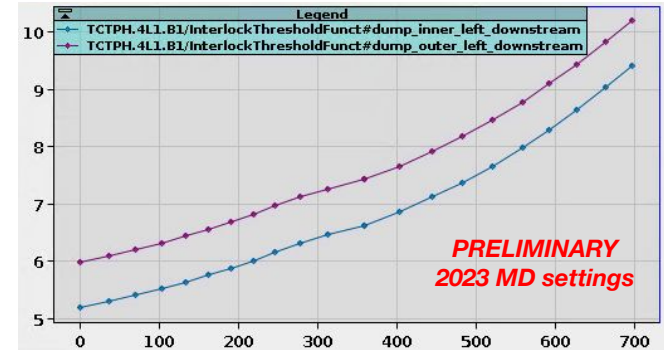
driving collimators & limits: 2023 MD

centre shift calculated from knobs - gap changes from settings - limits driven
last fill: all collimators aligned with final settings



update on discussed failure cases (MPP #222)

- **wrong limit function loaded by lumi server**
 - what if lumi server picks wrong limit segment?
 - collimator PRS checks continuity, start point mismatches actual limits → exception
 - **2023 settings: monotonous limits for beta* levelling**
 - strongly dominated by gap changes (~mm)
 - any wrong limit segment will always mismatch
- **collimators not driven at all**
 - driving collimators can be skipped by the EiC
 - not much different from sequencer
 - guarded by collimator beta* interlock
 - **GUI option guarded by a confirmation popup**
 - courtesy to avoid mis-clicks
 - further (soft) protection required?



conclusions

- **beta* levelling successfully used in 2022**
 - fully automatic step-taking (based on lumi/pile-up)
 - commissioned & tested full orchestration
 - including driving of TCTs/TCLs and limits
- **2023: larger beta* levelling range & crossing angle change**
 - need to drive TCT/TCL gaps, centres & limits with significant (~mm) changes
 - settings & logic tested in 2023 configuration MDs
 - all tests successful, including refused step when limits were wrong
- **failure cases discussed in MPP #222 addressed**
 - limits for 2023 are monotonic - no risk of playing wrong segment
 - option to disable collimator movements protected by confirmation
 - same "risk" exists in the sequencer - sequences can be skipped ad hoc
 - further protection necessary?

thanks for your attention!