Leveling Options and Strategy

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BE-OP-LHC

Inputs from:
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Outline

- Why to level?
  - Free parameters
- How to level?
- When and where to level?
  - 2015?
  - 2016?
- What is the overall cost and gain?
  - Implementation examples: IP1/5 & IP8
  - Commissioning time
- Closer look on details

Free parameters

$$\mathcal{L} = \frac{n_1 n_2 N f \gamma}{4\pi\varepsilon_N \beta^*} \times R(\beta^*, d, \phi, \sigma_z)$$

- Beam size
  - ***Emittance (ε_N)***
  - β* (**0.4m** and **0.6(5)m**)
  - **Bunch length (σ_z)**
    - **7.5cm**
- ***Bunch intensity (n) / number of bunches (N)***
- **Crossing angle (ϕ)**
  - **155µrad** (0.4m) and **170µrad** (0.65m)
- **Separation (d)**

When and where to level?

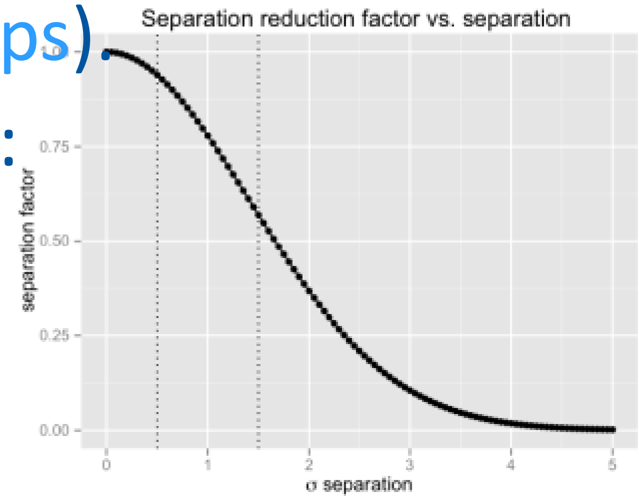
IP1/5 <μ> = 45
IP8 <μ> = 1.6

2015	2016+
β* 0.6m/3m	**β* 0.4m/3m**
25ns (1.2e11/ 2.6μm) 25ns BCMS (1.3e11/ 1.9μm)	25ns BCMS (1.3e11/ 1.9μm)
IP1/5 L_P/L_L is **100%** NO LEVELING NEEDED	IP1/5 L_P/L_L **is up to 180%** Leveling for max **2.5h** **(from β*= 0.7m)**
IP8 L_P/L_L **is up to 600%,** leveling throughout the fill (mixed method)	IP8 L_P/L_L **is up to 600%,** leveling throughout the fill (mixed method)

With 50ns/8b+4e LEVELING IS MANDATORY, IP1/5 up to 4h

Luminosity levelling by offset

- Successfully operated in LHCb during run1.
- Easy to operate (local orbit bumps).
- Possible full range of reductions:
  - **1σ = 76% ,**
  - **1.5σ = 55%,**
  - **2σ = 38% …**
- min. of stability is for **1.5σ– 2σ**
  - Limited range & (potentially) unstable above 2sigma if no other source of stabilization provided (HO in other IR’s)



X.Buffat, ICFA13

Luminosity levelling by β^*

- HO collisions as from the start of the process
  - Maximum beam-beam tune shift
  - Best source of Landau damping
    - Octupoles at 4TeV were at 500A!
- One β^* step produces max 5% of L excursion
  - Scope of the method only limited by available matched points
- For smaller values ensures larger Dynamic Aperture
- Requires orbit control at the level of 0.5σ (typically 10–50μm)
- Not regular so far - **Experience needed!**

Offset levelling for 2015

- ALICE will remain with offset levelling (~6σ).
- Remaining with LHCb offset leveling is possible.
  - Possible limitation on private bunches.
- Levelling all IRs with offsets bears the risk of instabilities.
  - Not more than ~1σ in IR1/5 → 25%. Ok for 'light' leveling?

Strategy for β* leveling for 2015

PROPOSAL

1. **Implementation in LHCb**
   a) Starting from 10m
   b) Starting from ~8m
2. Implementation as a **collide&squeeze in ATLAS/CMS**
   a) LHCb leveled by offset
   b) LHCb leveled like in strategy 1
   c) ATLAS/CMS with β* leveling
3. **MD's** in one of the IP's
4. **Implementation in ALICE**

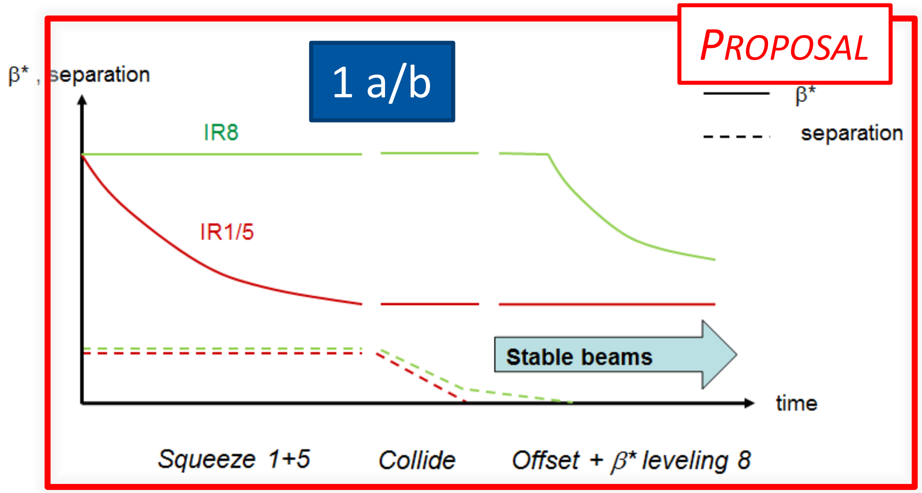
1
- ✓ Test bed!
- ✓ Mixture with offset leveling!
- ○ May cause global β* excursions leading to $L_{ATLAS}/L_{CMS} \neq$ const.
- ✓ Commissioning time ~4 shifts.

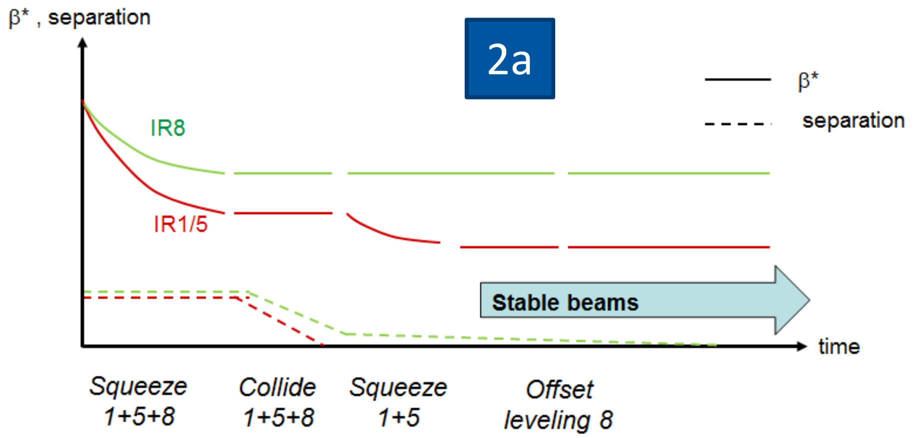
2
- ○ Do we need it as from the beginning?
- ○ Can we know we don't need it once it's implemented?
- ○ (a bit) longer commissioning time(β*)
- ✓ Ready for 50ns/8b+4e fall back
- ✓ Good for 2016+ ultimate performance

3
- ○ Not a regular experience!
- ○ Handling squeeze process (set up overhead)

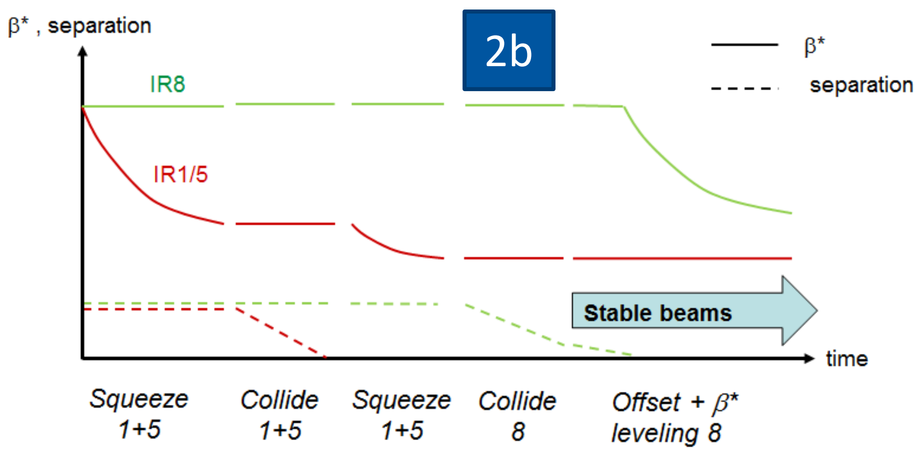
4
- ✓ local and independent implementation
- ○ Limited by β* range (1km)

Beam process point of view





- Split of the existing squeeze is essential!
  - Complexity of the split depends on scenario
- Need a tool to un-do the split



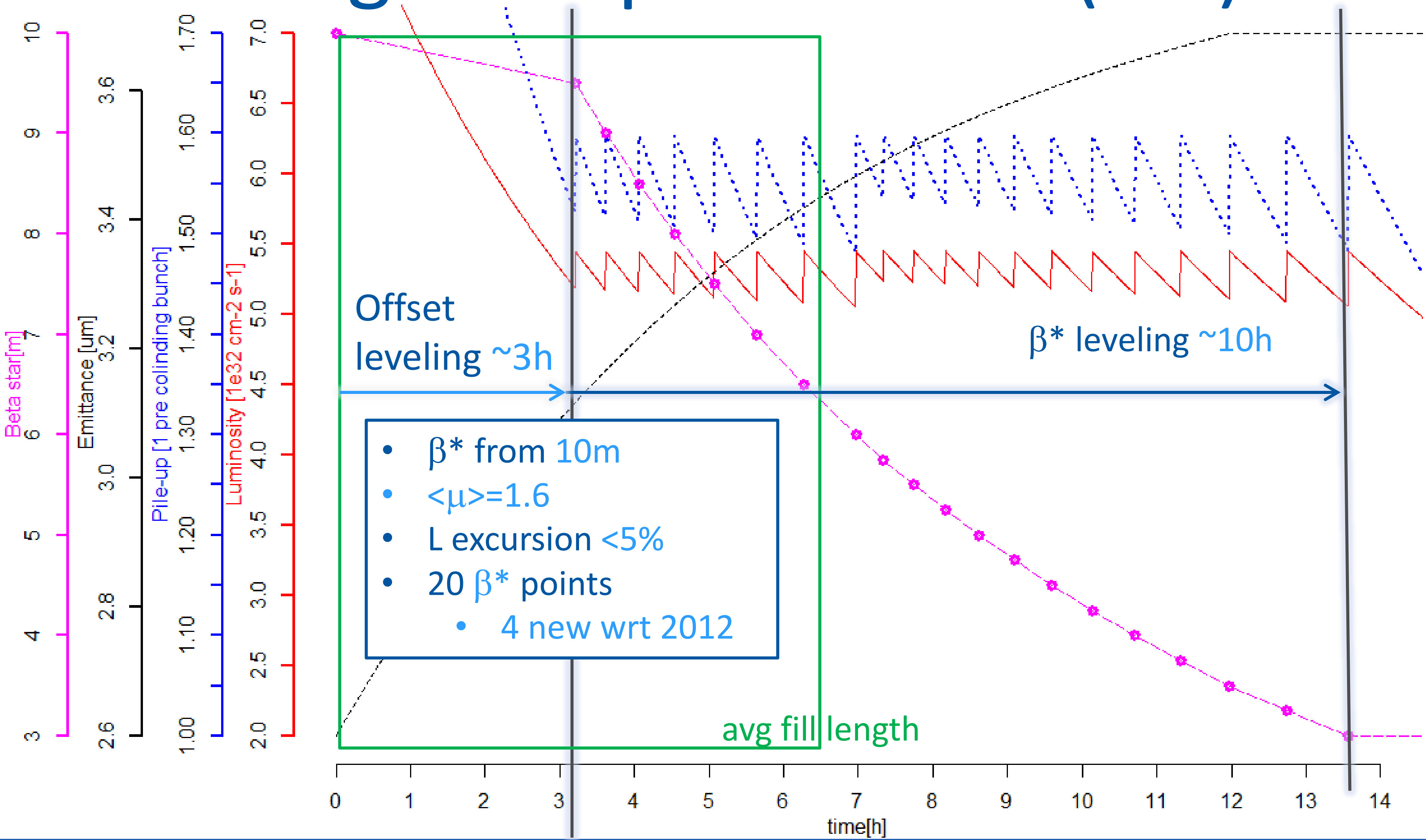
Leveling in details

Offset leveling
β* leveling

	25ns 1.15e11/ 3.75μm		25ns 1.2e11/ 2.6μm		25ns BCMS 1.3e11/ 1.9μm		8b+4e 1.6e11/ 2.6μm	
Final β* IP1/5	0.6m	0.4m	0.6m	0.4m	0.6m	0.4m	0.6m	0.4m
Total leveling time	0h	0h	0h	0h	0.25h	2.5h	1.5h	4h
Total number of steps needed	0	0	0	0	3	6	5	10
Initial/final β* IP 8	10m/3m	8m/3m	10m/3m	8m/3m	10m/3m	8m/3m	10m/3m	8m/3m
Total leveling time (offset leveling time)	All fill (0h)	All fill (2h)	All fill (3h)	All fill (5h)	All fill (6h)	All fill (8h)	All fill (8h)	All fill (10h)
Number of steps needed / initial separation	16 **0σ**	14 **0.8σ**	7 **1.3σ**	3 **1.6σ**	0[1] **1.9σ**	0[1] **2.1σ**	0[1] **2σ**	0[1] **2.2σ**

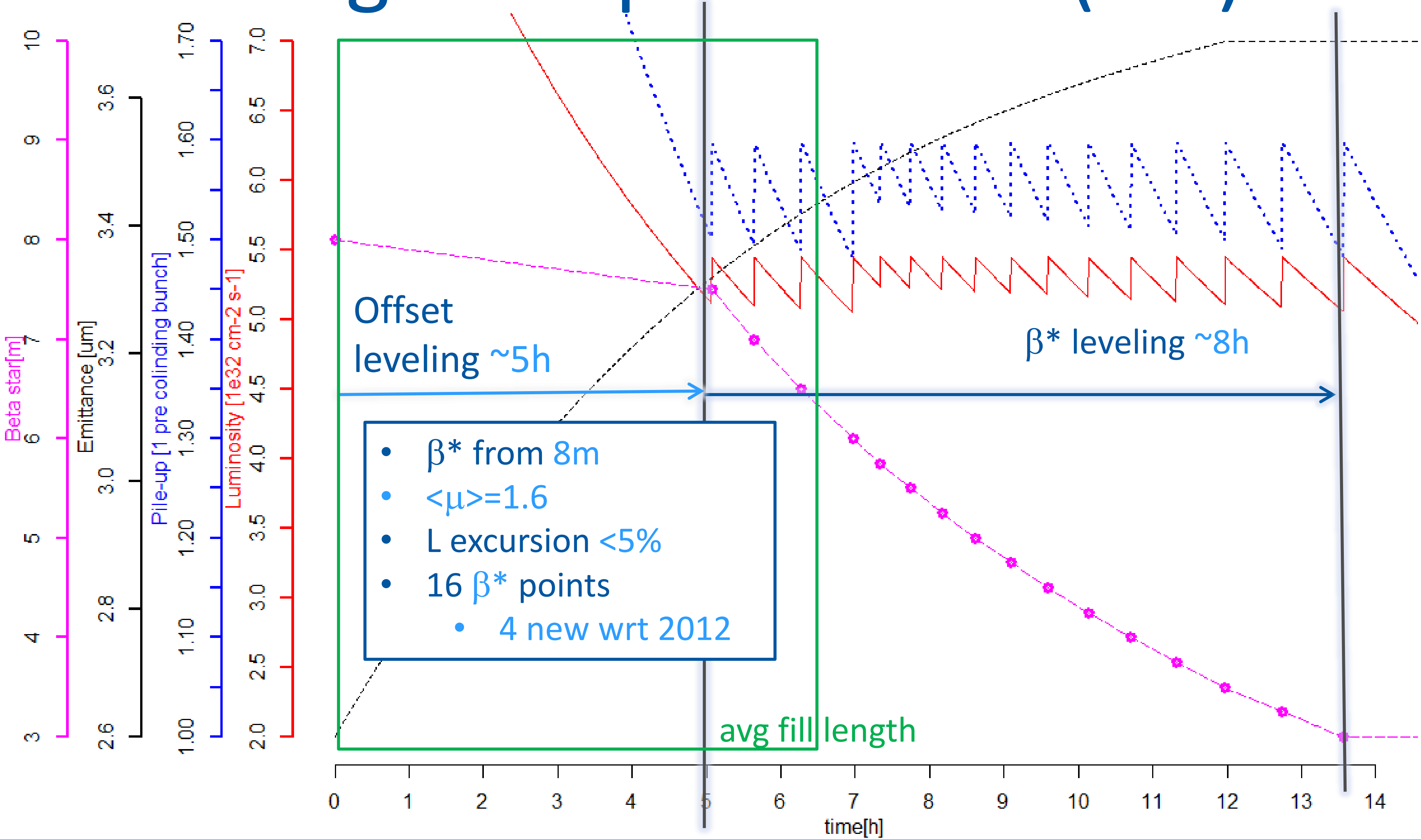
[1] 0 steps with current beta points and during avg length fill.

Leveling example at LHCb (1.a)

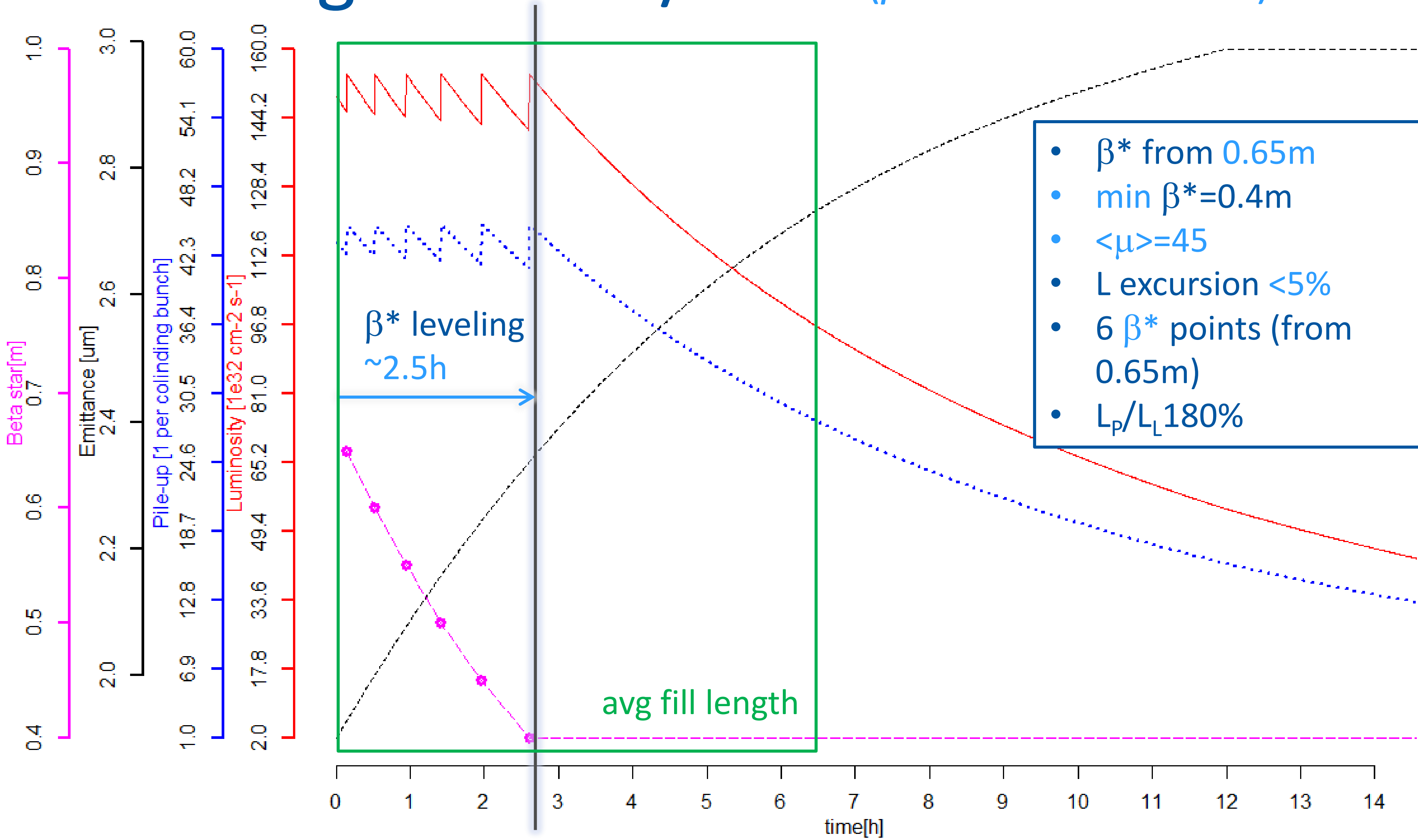


- β* from 10m
- <μ>=1.6
- L excursion <5%
- 20 β* points
  - 4 new wrt 2012

Leveling example at LHCb (1.b)



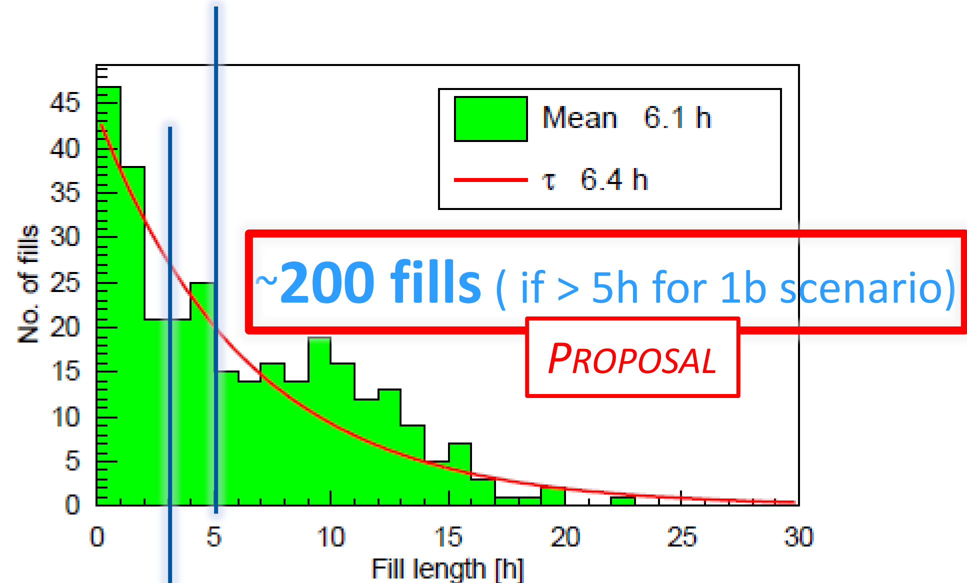
Leveling in ATLAS/CMS *(pushed 25ns BCMS)*



- β* from 0.65m
- min β*=0.4m
- <μ>=45
- L excursion <5%
- 6 β* points (from 0.65m)
- L_P/L_L180%

Net experience time (only LHCb)

- By MD's:
  - 4/year, 2/MD -> **8**
    - More realistic -> **3**
- By fill to fill experience:
  - 350fills/year
- For 2015 scaling factor needed!



~240 fills (if > 3h for 1a scenario)

Commissioning the process

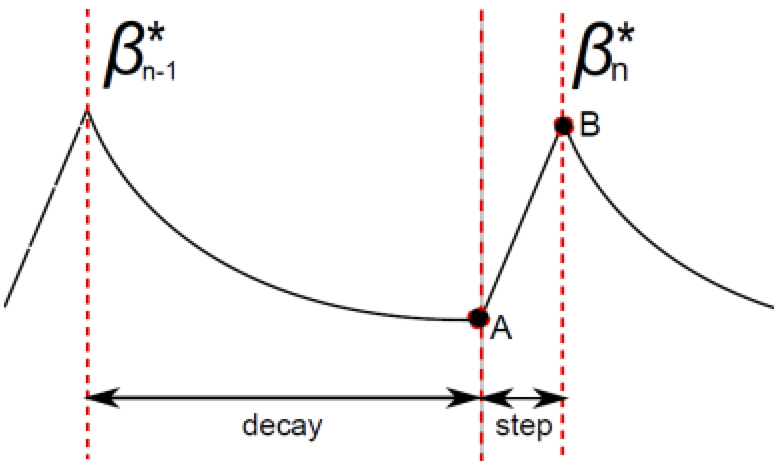
- While most of the LHC beam commissioning activities require more than **100 shifts**[1] following times are needed to prepare machine for β* leveling (or collide and squeeze):
  - Scenario 1 -> **4 shifts**
    - Measure & correct optics in detail along IR8 squeeze (leakage to IR1 and IR5),
    - Setup collisions, train once[2].
  - Scenario 2 -> **2 shifts**
    - Setup collisions for colliding part of squeeze, train once[2].

[1] Private estimation by J.Wenninger

[2] May need to train more than once

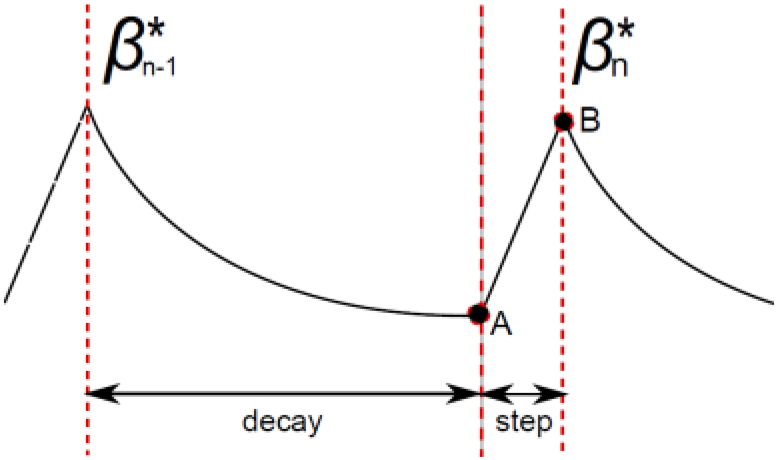
One step in β* leveling sequence

- A luminosity *decay phase* due to the intensity decrease and emittance blow up.
- *before the step* (**A**) starts, all the current functions are loaded into the power converter controllers as well as the collimator position functions.



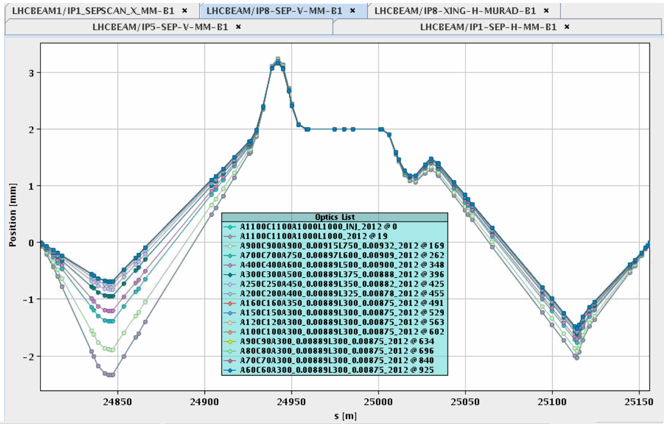
One step in β* leveling sequence

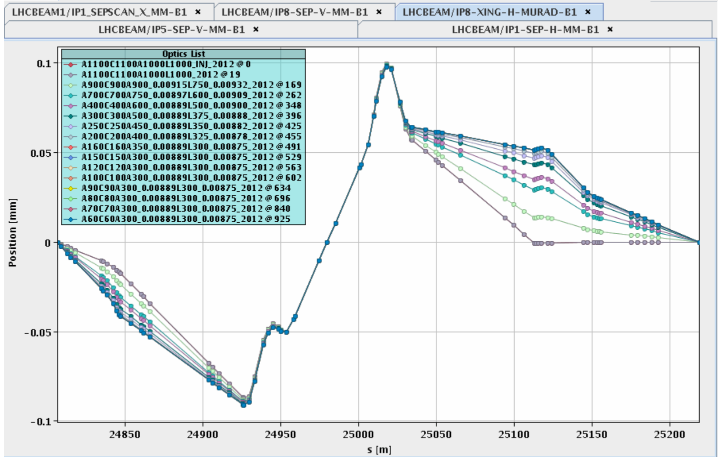
- step execution is done
- (**A -> B**). When power converters and collimator execute their function
- *when the step is done* (at **B**) collimators position thresholds have to be reloaded. At this moment all luminosity optimization can be done.



Orbit control during the process

- When leveling (doing the step **A -> B**) OFB must ensure that beams remain in collision!
  - Crossing angle bumps changes during process!
  - Reference orbit must be dynamically adapted
  - Tracebility of the changes is crucial!
  - New DOROS at the IP's will be an asset!





Additional software for β^* leveling

- Existing JAVA application
  - Possible concurrency problems
  - Difficult to extend
- A dedicated server that will consist of two modules:
  - Offset leveling / optimization module
  - β^* module

Pro-contra

Scenario	Pro	Con
Leveling IR8	1. Gain experience with limited complexity. 2. Short steps in β* - simpler for the start. 3. Late(r) in the fill – quieter.	1. In stable beams, must be ~ transparent for IR1/5. 2. Careful optics correction required (leakage to IR1/5). 3. New setup required to switch to β* leveling in IR1/5.
Colliding squeeze	1. Not in stable beams 2. Optics correction for β* uncritical (IR1/5). 3. Can be trivially transformed into β* leveling in IR1/5.	1. Long steps, more complex. 2. May require lengthy re-setup (collisions) if it goes wrong. 3. Beam may become unstable if beams move out of collisions.

For both scenarios the performance of the DOROS BPMs at the Q1 could have a decisive impact: need a RELATIVE stability of ~5 μm over 30 minutes.

Conclusions

- Leveling **will be** a part of the cycle
  - once we use bright beams!
- Experience (for β*) is crucial in this case
  - And will be need at the day we start level everywhere!
  - Or we need to run with collide&squeeze.
- LHCb is willing to be test bed for β* leveling
  - *Shouldn't we profit from it* ?

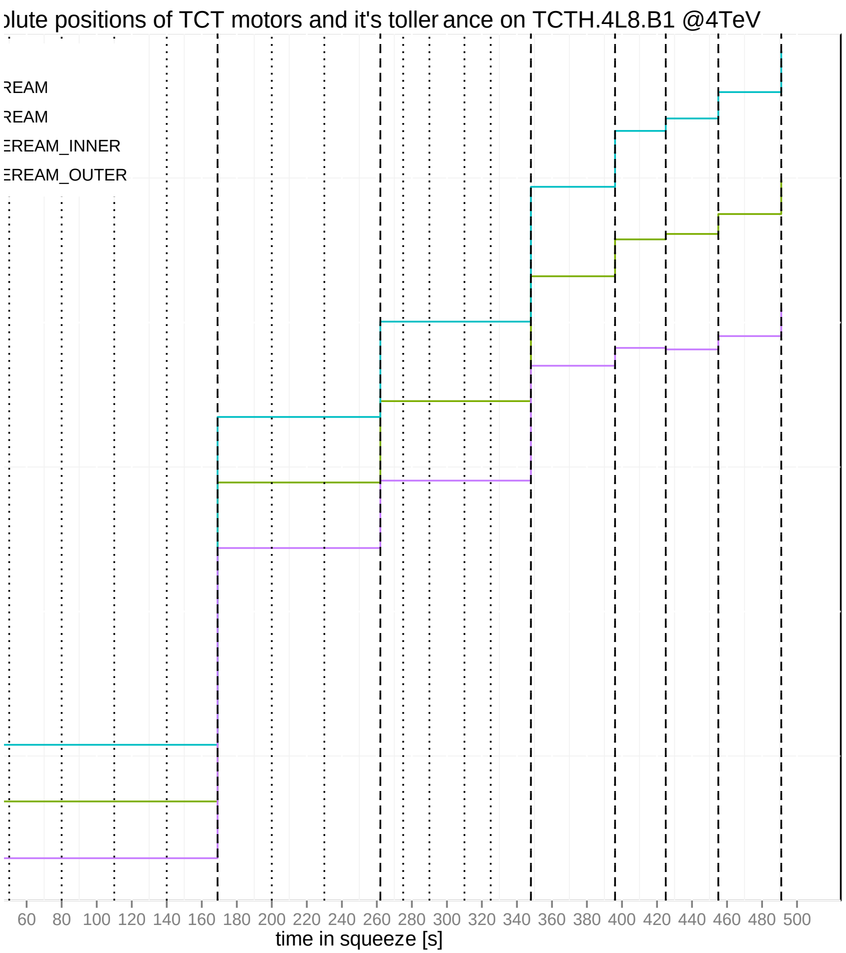
The end

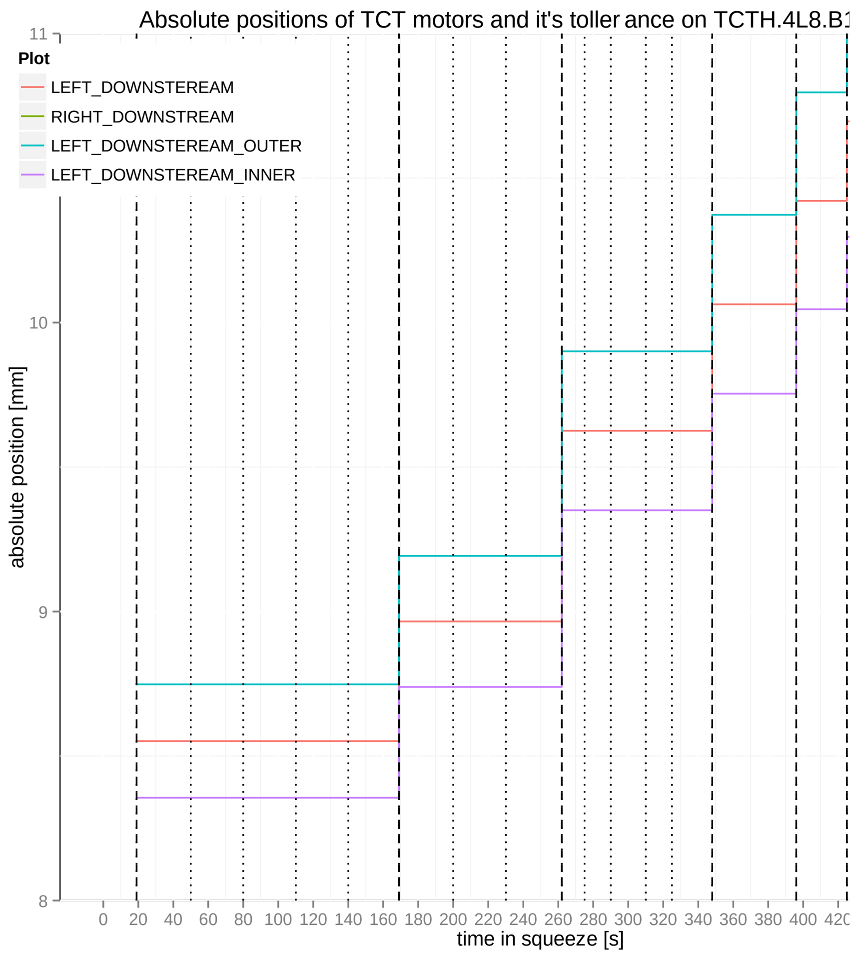
SPARE

Quick reminder on run1 parameters…

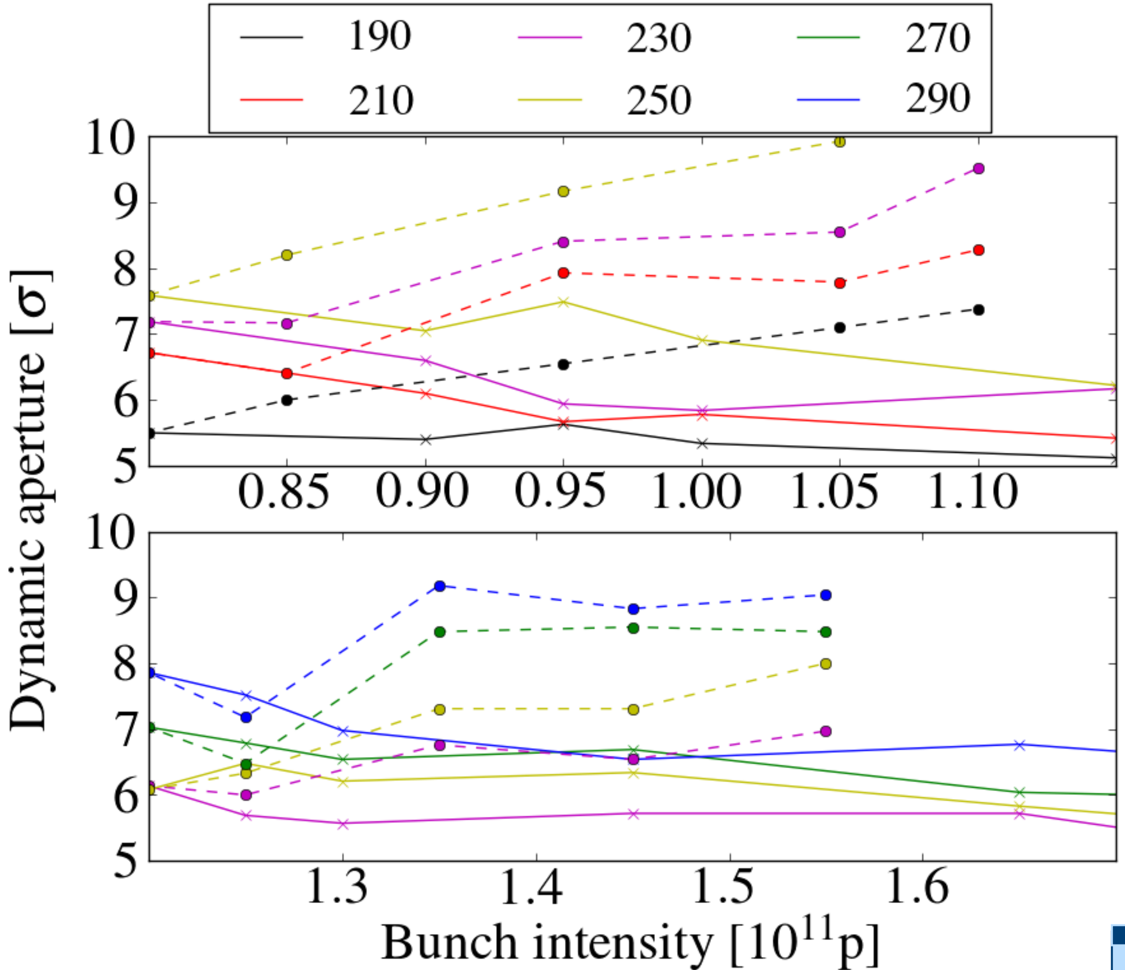
- Crossing angle IP1/5 = 145urad
- 4TeV, 50ns, n=1.6e11 and ε_n = 2.6μm, N=1370,
  - $\beta^*_{IP1/5}$ = 0.6m
  - β^*_{IP8} = 3m

Collimators: position thresholds





DA recent studies



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Collide and squeeze L_{peak} loss

BCMS_25ns[1.9E-6/1.3E11/2500.0]
NO Collide and squeeze L_peak[1e32] = 151.472
After C&S (3m->0.6/ 10steps/ total ~500s) L = 148.593
%1.901

BCMS_50ns[1.1E-6/1.7E11/1372.0]
NO Collide and squeeze L_peak[1e32] = 210.819
After C&S (3m->0.6/ 10steps/ total ~500s) L = 206.434
%2.08

RUN1_50ns[2.4E-6/1.6E11/1372.0]
NO Collide and squeeze L_peak[1e32] = 105.204
After C&S (3m->0.6/ 10steps/ total ~500s) L = 104.082
%1.067

STANDARD_25s_FAT[2.6E-6/1.2E11/2760.0]
NO Collide and squeeze L_peak[1e32] = 111.761
After C&S (3m->0.6/ 10steps/ total ~500s) L = 110.084
%1.501

STANDARD_25s_DESIGN[3.75E-6/1.15E11/2808.0]
NO Collide and squeeze L_peak[1e32] = 77.47
After C&S (3m->0.6/ 10steps/ total ~500s) L = 76.64
%1.072

BCMS_8b_4e[1.4E-6/1.8E11/1800.0]
NO Collide and squeeze L_peak[1e32] = 261.769
After C&S (3m->0.6/ 10steps/ total ~500s) L = 255.482
%2.402

STANDARD_8b_4e[2.6E-6/1.6E11/1800.0]
NO Collide and squeeze L_peak[1e32] = 129.578
After C&S (3m->0.6/ 10steps/ total ~500s) L = 127.885
%1.307