First report to the LMC on Run III machine configurations (p-p runs)

S. Fartoukh and N. Karastathis on behalf of the LCR3 working group

https://indico.cern.ch/category/10387/

Acknowledgments: **all LCR3WG members + LPC**

- (Re-) Introduction to the LCR3 working group
- “Menu” from the injector & “natural” beam flavor for LHC
- Intensity limitations in the LHC
- Beam parameter targets for LHC-OP in Run III
- Other constraints & possible LHC cycle in Run III
- Performance estimate and triplet life time
- Next steps

Introduction: LCR3 working group & membership

- **Run III is a transition between LHC & HL-LHC** with key ingredients made available, gradually (LIU beam) or immediately (ATS optics), pending LS3 for the complete HL-LHC installation.

→Run III shall be exploited not only for performance but also as a full scale demonstrator of the HL-LHC in terms of beams, optics and beam manipulation (e.g. β^* levelling over a very large dynamic range).

- In this context, the LCR3 working group aims at **conceiving and proving the feasibility of the best possible machine configuration(s) for exploiting the LIU beam in Run III**, after identifying hard limits imposed by the LHC (intensity limitations from existing HW).

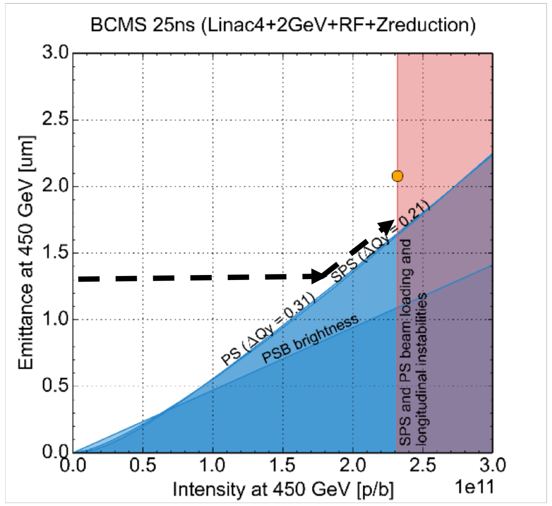
Activity	Participants
Coordination	S. Fartoukh, N. Karastathis
LIU beam	G. Rumolo, H. Bartosik
LHC Optics	S. Fartoukh, R. Tomas
LHC Collimation	A. Mereghetti
Alignment	D. Missiaen
LHC Injection and Beam Dump Systems (MKI, MKD, TCDQ, ..)	P[illegible]lard, M. Barnes
ANSYS and FLUKA simulations (TDE, TCDQ, Triplet,..)	[illegible]erutti, A. Lechner, [illegible]-X. Nuiry
Special **Beam manipulation**[illegible] general **Operation** aspe[illegible]	J. Wenninger, M. Solfaroli
Machine protection a[illegible]**locks**	J. Uythoven
RF	H. Timko
Beam-induced RF heating	B. Salvant
E-cloud and **heat-load** in LHC	G. Rumolo, G. Iadarola
LHC Impedance and **Landau damping**	X. Buffat, N. Mounet
Beam-beam effects and **Performance**	G. Sterbini, N. Karastathis
IT lumi life time vs. scenario	F. Cerutti

“Menu” from the injector and “natural” beam flavor for the LHC

LIU forecast at SPS extraction (G. Rumolo & H. Bartosik)

	2021	2022	2023	2024*)	Comments
Bunch charge [10^{11}]	**0 → 1.3-1.4**	**1.4 → 1.8**	**1.8 → 2.1**	**2.1 → 2.3**	**Max intensity reached at the end of each year**
Normalized emittance [μm] (i) *BCMS or 8b4e* (ii) *Standard 25 ns*	 1.30 1.65	 1.30 1.65	 1.30 → 1.55 1.65 → 1.90	 1.30 → 1.70 1.90 → 2.10	**Intensity ramp up at constant emittance in 2021/2022**

*) The LHC is shut down in 2024



LIU beam brightness curve reached end of 2022 (strategy agreed with LIU regardless of beam flavor)

BCMS beams are preferred, possibly mixed with **8b4e inserts**

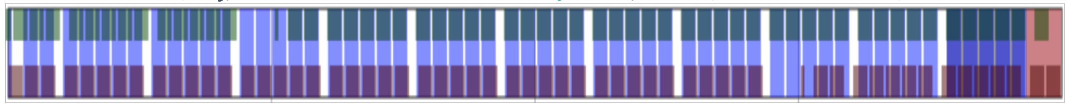
i. Smaller emittance at 450 GeV (less losses at injection and in the LHC ramp)

ii. Marginal impact on number of bunches w.r.t. a pure 25 ns filling scheme,

iii. ~10% less heat load from e-cloud w.r.t. 25 ns (see next slide)

Baseline: BCMS **(OKish @ 1.8e11 p/b for 195 W/cell in high load sectors)**

5x48 b/inj, **2736 collisions in ATLAS/CMS**, 2250/2376 in Alice/LHCb

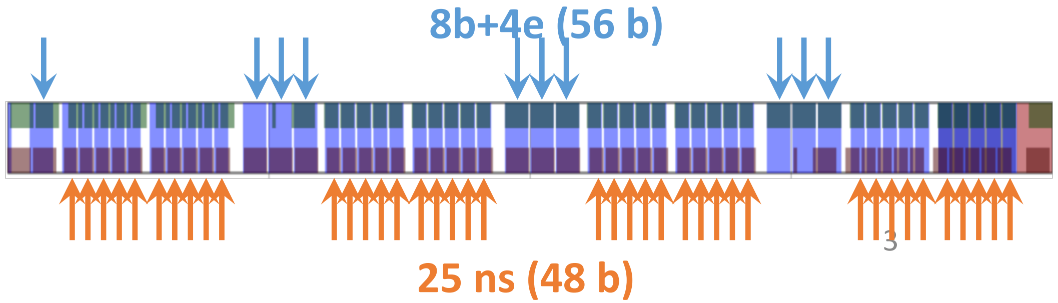


G. Iadarola

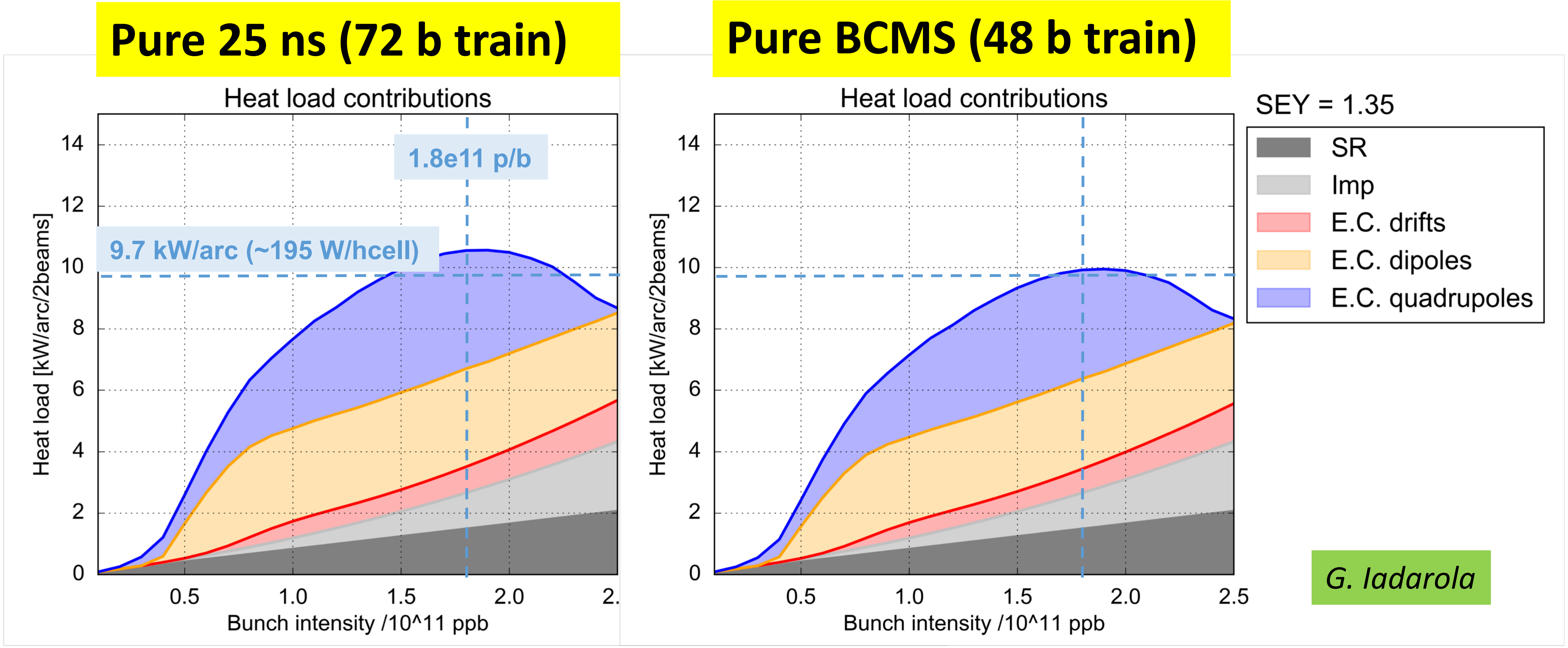
Back-up: MIXED scheme **(needed for 25% missing cryo-cooling capacity)**

25ns_2492b_2484_1949_2131_240bpi_13inj_800ns_bs200n_run3study

9.2% less collisions at IP1/5 compared to pure BCMS scheme



Pure 25 ns (72 b train) / Pure BCMS (48 b train)



- Almost there with the **worst case (1.8e11 ppb),** but within the error bars of the model (and pending LS2 possible surprises)

→ Therefore a few 8b4e (or 12e ..) inserts cannot yet be excluded at this stage.

- Operating so closed to this flat maximum, the strategy is clear
  - **Starting with BCMS in 2021** and testing the **mixed BCMS scheme in MD**,
  - **Decision in (mid of) 2022:** switch to the mixed scheme, or to the standard 25 ns beam (8% more collisions in LHCb).

Intensity limitations in the LHC *(other than heat load in the arcs and transverse impedance)*

→ Below a synthetic summary (a lot of on-going work, more details across the LCR3 meetings and dump review)

LHC sub-system	Limitation	Mitigation in mind for Run III	Intensity Limit [10^{11} p/b]
RF [H. Timko et al.]	Klystron power at injection. Controlled ε–blow-up in the ramp	**- Q20 in SPS** (nrj spread minimized). 6.4 MV in the LHC. **- ~ 1.2 ns (4 σ_z) targeted in the ramp**	**1.8** [RF power limitation in half-detuning beam-loading compensation scheme]
MKI [M. Barnes et al.]	Beam induced RF heating	**Longer bunches**, e.g. 1.3 ns corresponds to the MKI temperature limit at 1.8e11 ppb in permanent regime	**1.8** [for a couple of hours only for 1.2 ns bunch length, no restriction for 1.3 ns]
Cryo [K. Brodzinski et al.]	Triplet cooling capacity [non-conform bayonet]	**Level the lumi at 2.0e34 (53 PU for 2750 collisions)** with marginal impact (~2%) on the arc cryo-cooling capacity	**None in practice**
TCDQ [B. Goddard, F.X. Nuiry et al.]	Damage for erratic type II kicker firing. No dependency on beam sizes	**Limit the min. gap to 2.5 mm** (3.6 mm with OP margin), and adapt the IR6 optics accordingly (7.3 σ gap at 7 TeV)	**1.8** [pending complete material characterization]
TCDS [EN/STI]	Plastic deformation reached at 1.7e11 p/b from past simulation. No dependency on beam sizes	None (upgrade planned in LS3). **Simulation update on-going**	**1.7 - 1.8** [simulation update on-going]
TDE (body) [EN/STI]	Vibrations, displacement (inducing leaks), and possible damage (heating of the core from 1500° C for regular dumps at 1.8e11 p/b, up to 2400°C for worst case failure scenarios)	- New clamping mechanism or different seals in LS2, new gaskets, new collars . - **Better material characterization on-going**. Assess (accept?) risk of damage for worst case failure modes.	**1.8 (under discussion)** [TBC if OK for regular dump, risk of damage for worst case failures]
Downstream window [EN/STI]	Leaking in Run II. Not calibrated for high intensity beams. No dependency on beam sizes	- New windows, HiLumi compatible, will be installed in LS2	**> 2.3** [For the post-LS2 new window]
Upstream window [EN/STI]	High risk of damage for >1.3 e11 ppb: safety factor of 1.3 for worst case 6V2H MKB failure scenario, but beam brightness dependent	- **Minimize the risk in 2021 (<1.4 e11 ppb) to the level of Run II-OP with larger β's EoR at the TDE (TBC)** - **Change the window in the EYET 2021-2022**	**?? → Decision needed**
Collimation [LHC coll. Team]	Less than 8 HL-LHC bunches hitting the collimator in case of asynchronous dump.	- **Run II tight settings (TCDQ included), and careful MKD-TCDQ phase control** (impedance treated separately by ATS optics)	**> 1.8 (TBC)**

Beam parameters targets for LHC-OP in Run III

Betting on the decision of **replacing the upstream dump window** in the EYETS 2021-2022, **a maximum bunch population of 1.8E11 p/b** is the best we can reasonably expect and should be prepared for Run III.

	2021	2022	2023	(2024)	Comment
BEAM PARAMETERS @ Beginning of SB					
Beam energy [TeV]	7.0				**7 TeV under (re-)discussion for Run III [with marginal impact on the rest of the talk]**
Collisions at IP1/5 & IP2/IP8	2736/2736 & 2250/2376				**Possible heat-load limitation not included**
Bunch length (4 σ_z) [ns]	1.2	1.2	1.2	1.2	**1.0 ns after ~10 h of SB, then kept constant**
Normalized emittance [μm]	2.5 (1.8)	2.5 (1.8)	2.5 (1.8)	2.5 (1.8)	**50% (10%) emittance growth budget in the ramp + 30 % due to IBS on the injection plateau, vs. 1.3 μm injected**
Bunch charge [10^{11}]	0 → 1.3-1.4	1.4 → **1.8**	**1.8**	**1.8**	**Intensity ramp up within each year. Marginal losses (% level) assumed in the ramp**
Typical β^* [m] for a peak lumi of 2E34	**0.55 (0.80)**	**1.05 (1.50)**			**Estimated using the max intensity reach at the end of each year, for an emittance of $\gamma\varepsilon$=2.5 μm (1.8 μm)**

Other constraints & possible LHC cycle in Run III (1/3)

- **Baseline (.. priori) for lumi levelling & general considerations:**

  - **Collide and squeeze at the EoR with large enough β^* (the squeeze BP is skipped)**

  → the EoR β^* will be a priori increased in 2022 (IT quench limit)

  - **β^* levelling at IP1/5 with lumi limited to 2E34** with **parametric X-angle variation** (IT lifetime)

  → *Round optics in 2021* → **28/28 cm β^* reach @ 7TeV** (X-angle anti-levelling not included)

  → *Two possible variants for 2022/2023:* round optics vs. flat optics (50/15 cm β^* reach, X-bump rotation EoR, and optics flattening @ 50 cm)

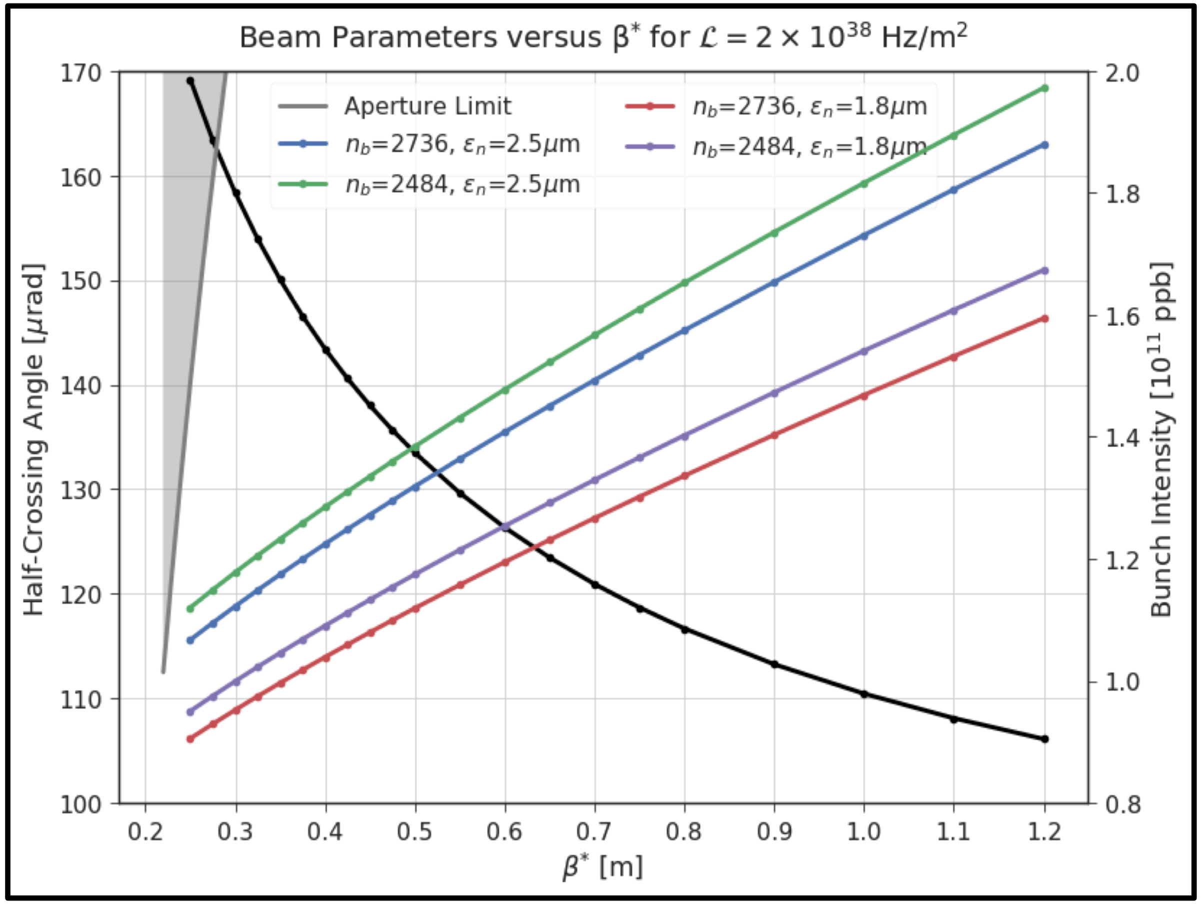
  → *Decision postponed for the EYETS-2021/2022* based on further MD in 2021 and IT lifetime considerations (refined performance forecast for Run III and/or update of the CERN master schedule).

  - **Offset levelling at LHCb with lumi limited to 2E33: β^* is reduced to 1.5 m** (vs. 3 m in Run II)

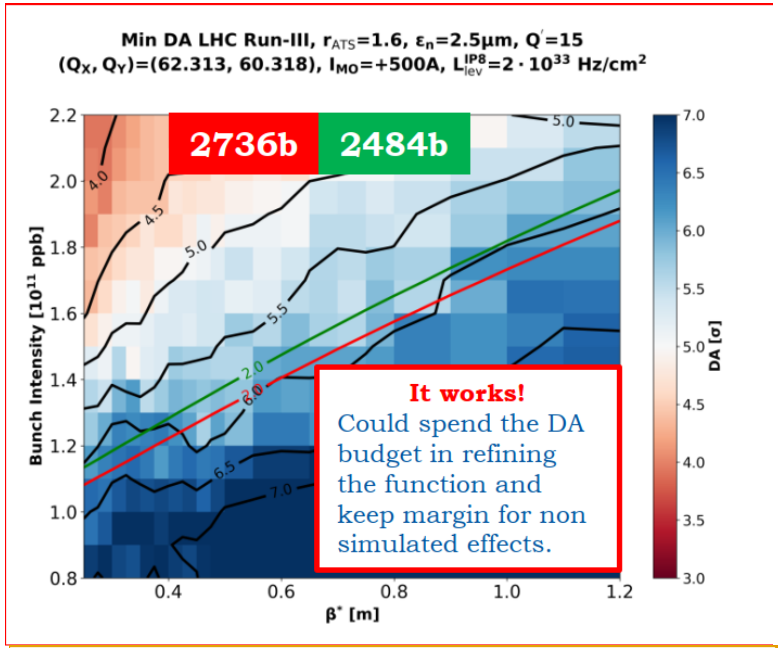
  → H external X-angle by default (250 μrad); V crossing angle gymnastic under discussion.

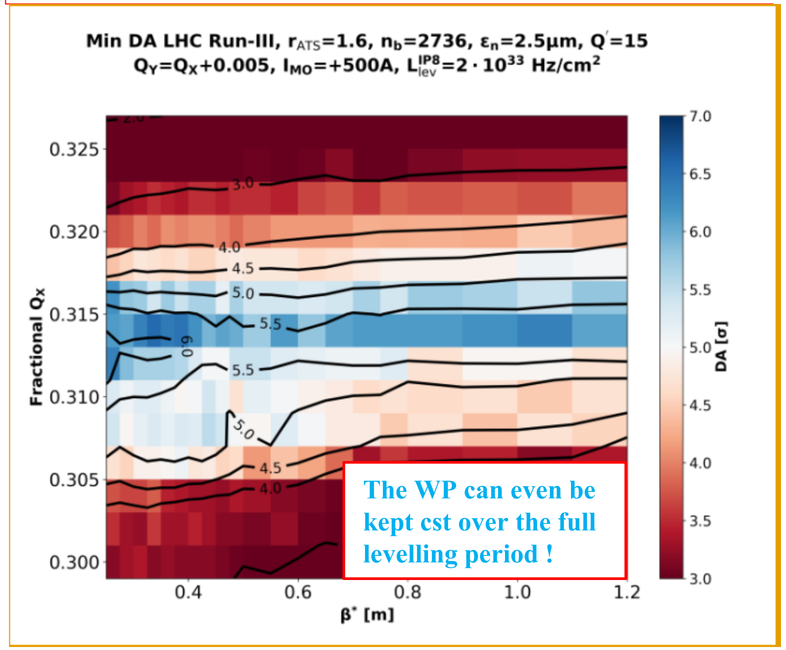
  - **Preparing Alice with lumi up to 1.3-1.4E31: β^* is kept to 10 m** (possible O-O and p-O Run in 2022 presently disconnected from the pp Run optimization)

Typical half-crossing parametric function vs β^* in IR1/5
(from ~100 µrad up to ~160 µrad)
and corresponding bunch charge evolution @ 2E34



First validation (using preliminary β^* levelling optics sequence)



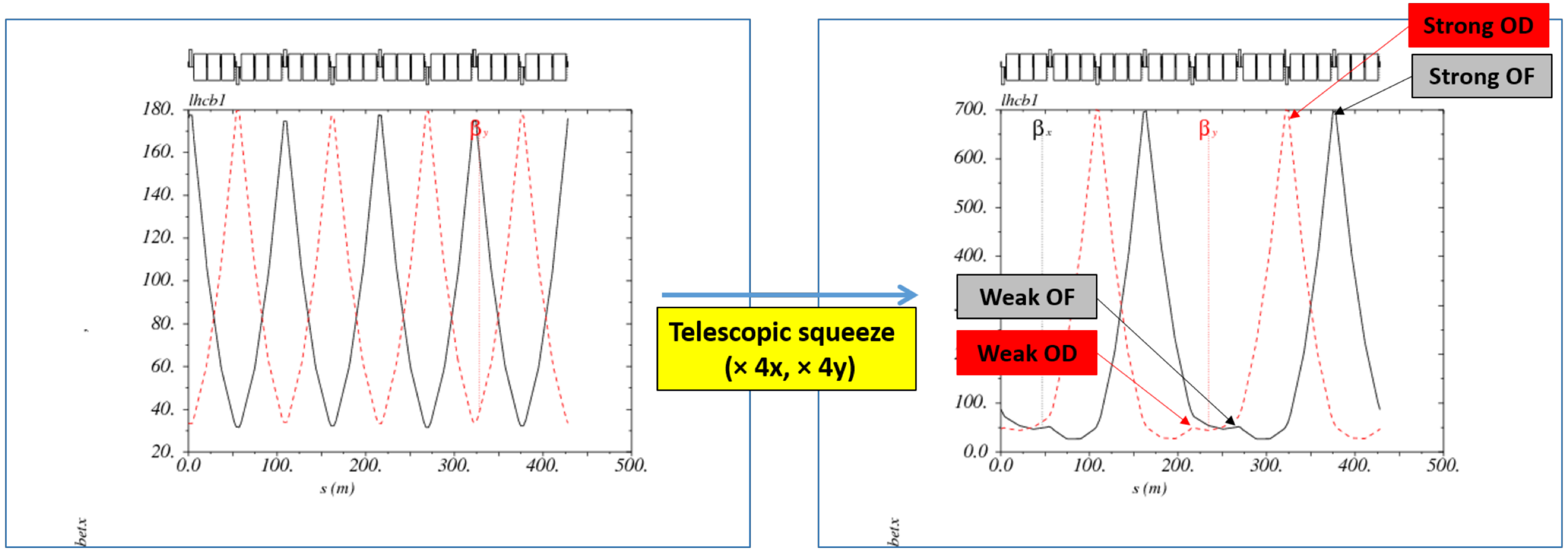


Keep in mind the very large β^* dynamic range in Run III of up to 400-500%, similar to HL-LHC, vs. 20% in 2018 !

Other constraints & possible LHC cycle in Run III (2/3)

- **Impedance**

→ **Telescopic optics** are needed to be deployed in the ramp for **Landau damping the brighter (and more rigid) Run III beam.**

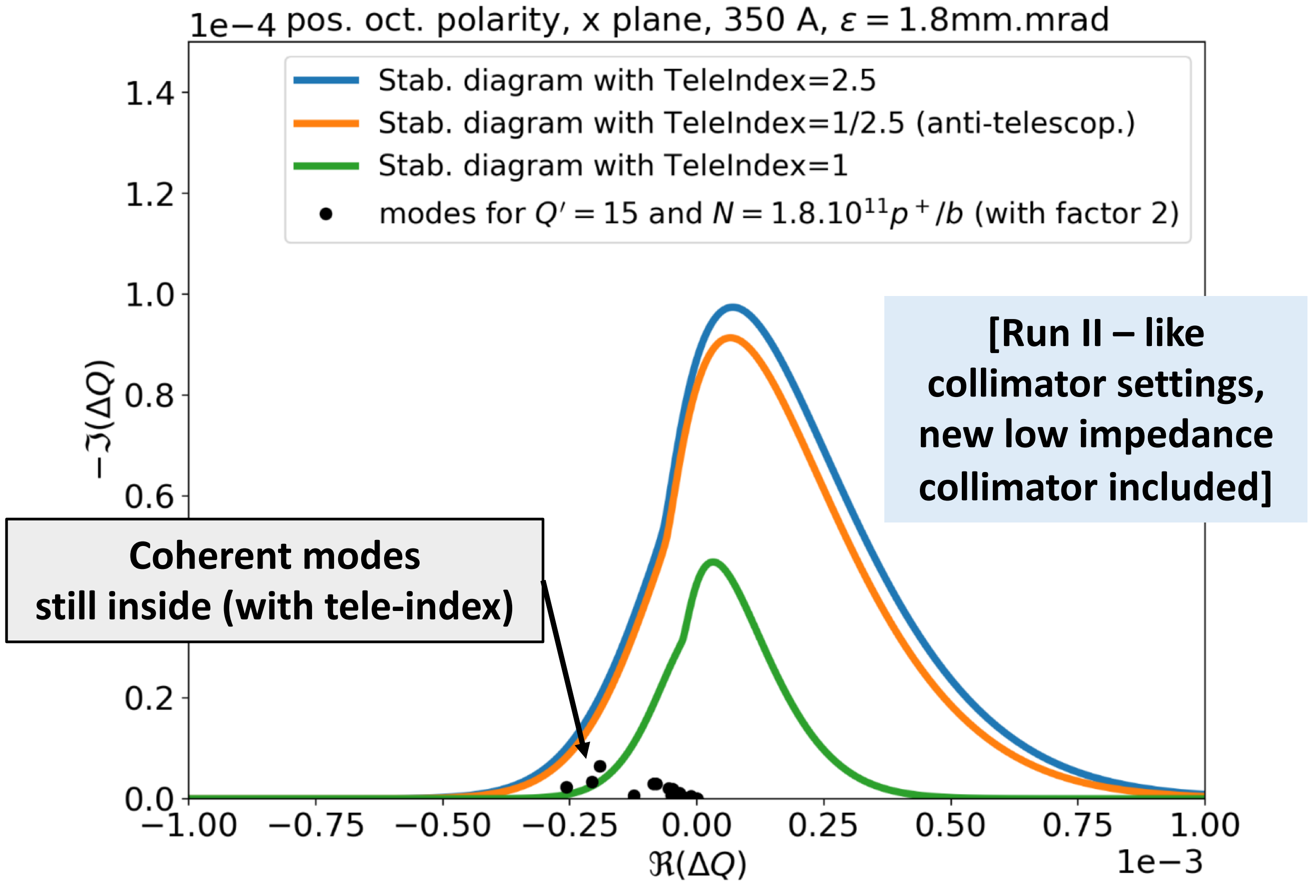


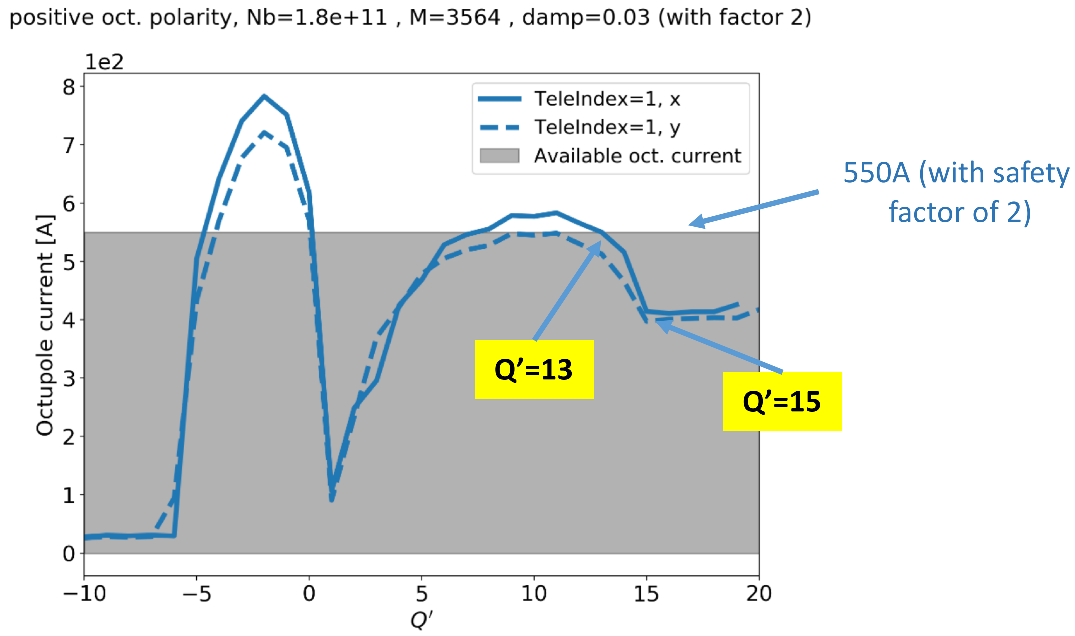
→ **Two categories of octupoles** in s81/12/45/56: the "optically strong" (with increased $\beta \propto r_{\text{tele}} \propto 1/\beta^*$) and the "optically weak" (with decreased $\beta \propto \beta^*$).

Beam 1/2	"Strong" OF.b1/OD.b2	Weak OF.b1/OD.b2	Strong OD.b1/OF.b2	Weak OD.b1/OF.b2
Sector 45 (81)	22.R4(8), 26.R4(8), 30.R4(8), 34.R4(8), 30.L5(1), 26.L5(1), 22.L5(1)	24.R4(8), 28.R4(8), 32.R4(8), 32.L5(1), 28.L5(1), 24.L5(1)	25.R4(8), 29.R4(8), 33.R4(8), 31.L5(1)	31.R4(8), 33.L5(1), 29.L5(1), 25.L5(1)
Sector 56 (12)	31.R5(1), 33.L6(2), 29.L6(2), 25.L6(2)	25.R5(1), 29.R5(1), 33.R5(1), 31.L6(2)	22.R5(1), 26.R5(1), 30.R5(1), 34.R5(1), 30.L6(2), 26.L6(2), 22.L6(2)	24.R5(1), **28.R5**(1), 32.R5(1), 32.L6(2), 28.L6(2), 24.L6(2)
Total	**7+4 = 11**	**6+4 =10**	**4+7 =11**	**4+6=10**

→ **Anti-telescopic optics** (*r* → *1/r*) also works, with the peak β-beating wave shifted by one FODO cell, i.e. the strong octupoles becoming weak, and vice et versa (strictly speaking the direct anharmonicity is reduced by 10%).

Comparison between telescopic and anti-telescopic optics in terms of stability diagram





W/o telescopic (or anti-telescopic) optics, **the MO threshold can be (at least) 550 A** in Run III (@ Q'=15+/-2, worst case) for a beam brightness of 1 (1.8e11 p/b within 1.8 μm)

N. Mounet

Other constraints & possible LHC cycle in Run III (3/3)

- **Forward physics experiment**

β^* levelling in telescopic mode is much preferred by the FP experiments (AFP & CT-PPS)

→ **Cst** R-matrix from the IP to the Roman Pot's (within the OMC knobs ..)

→ In telescopic squeezing mode: "tele-index range" = "β^* range"

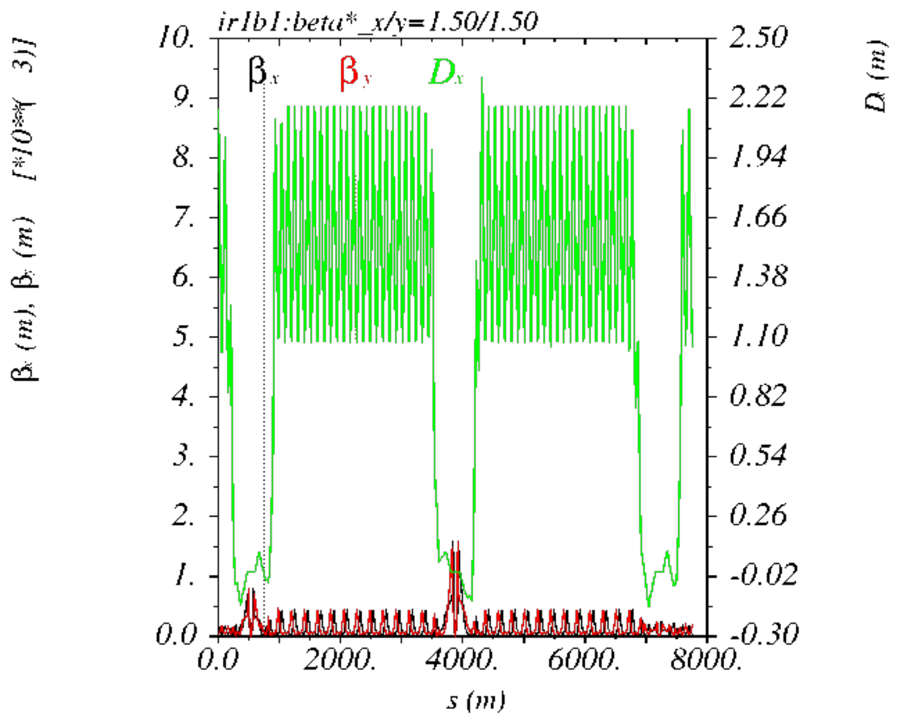
→ With **(i)** a tele-index of 2-2.5 recommended EoR (stability of non-colliding beams), **(ii)** a β^* dynamic range of up to 5 in SB (beams colliding), and **(iii)** a typical range of [1/3, 3-4] for the tele-index (optics flexibility/match-ability), the only possible approach is to start β^*-levelling from an **anti-telescopic optics**

- Even w/o constraint from impedance (no telescope in the ramp), a β^* levelling range of up to 5 in telescopic mode would require to start from an anti-telescopic optics at the EoR.
- Another possibility would be to bet on offset-levelling in Run III (with a much smaller β^*-levelling fraction in the end in tele-mode, as in 2018) …

.. Betting on the best (1.8e11 p/b within 1.8 μm) and investing for HL-LHC (β^*-levelling), this is how **the ramp** and the **β^*-levelling sequence** should look like in Run III

EoR = Beginning of SB parameters	2021	2022	2023
Max beam brightness [10^{11} /μm]	1.4/1.8	1.8/1.8=1	
β^* [m] at IP1 & IP5	1.1	1.5	
Max possible Lumi [10^{34}]@ beginning of SB	**1.55**	**1.98**	
EoR pre-squeezed β^* [m] (IPQ settings in IR1/5)	0.6		
EoR Tele-index (IPQ settings in IR8/2/4/6)	0.6/1.1 = **1/1.8**	0.6/1.5 = **1/2.5**	
Single-bunch MO threshold [A]	350	350	

Round: β^* levelling from 1.5 m down to 24 cm



.. This animation is still "fake" (with trombone matching matrix inserted in the layout ☹)
.. A lot of work is ahead to demonstrate the optics feasibility, which means **building the full optics transition** !

LHC cycle summary

1. Injection optics a priori unchanged w.r.t. 2017/2018 (see back-up slide)

2. Combined Ramp and Anti-Telescopic Squeeze (CRATS)

→ <u>2021:</u> β^*= 1.1/10/1.1/1.5 m @ IP1/2/5/8 with $\mathbf{r_{tele}=1/1.8}$ [pre-squeezed β^* of 60 cm @ IP1/5]

→ <u>2022/2023:</u> β^*= 1.5/10/1.5/1.5 m @ IP1/2/5/8 with $\mathbf{r_{tele}=1/2.5}$ [pre-squeezed β^* of 60 cm @ IP1/5]

→ <u>2022 optics tested/commissioned in 2021 (MD)</u>

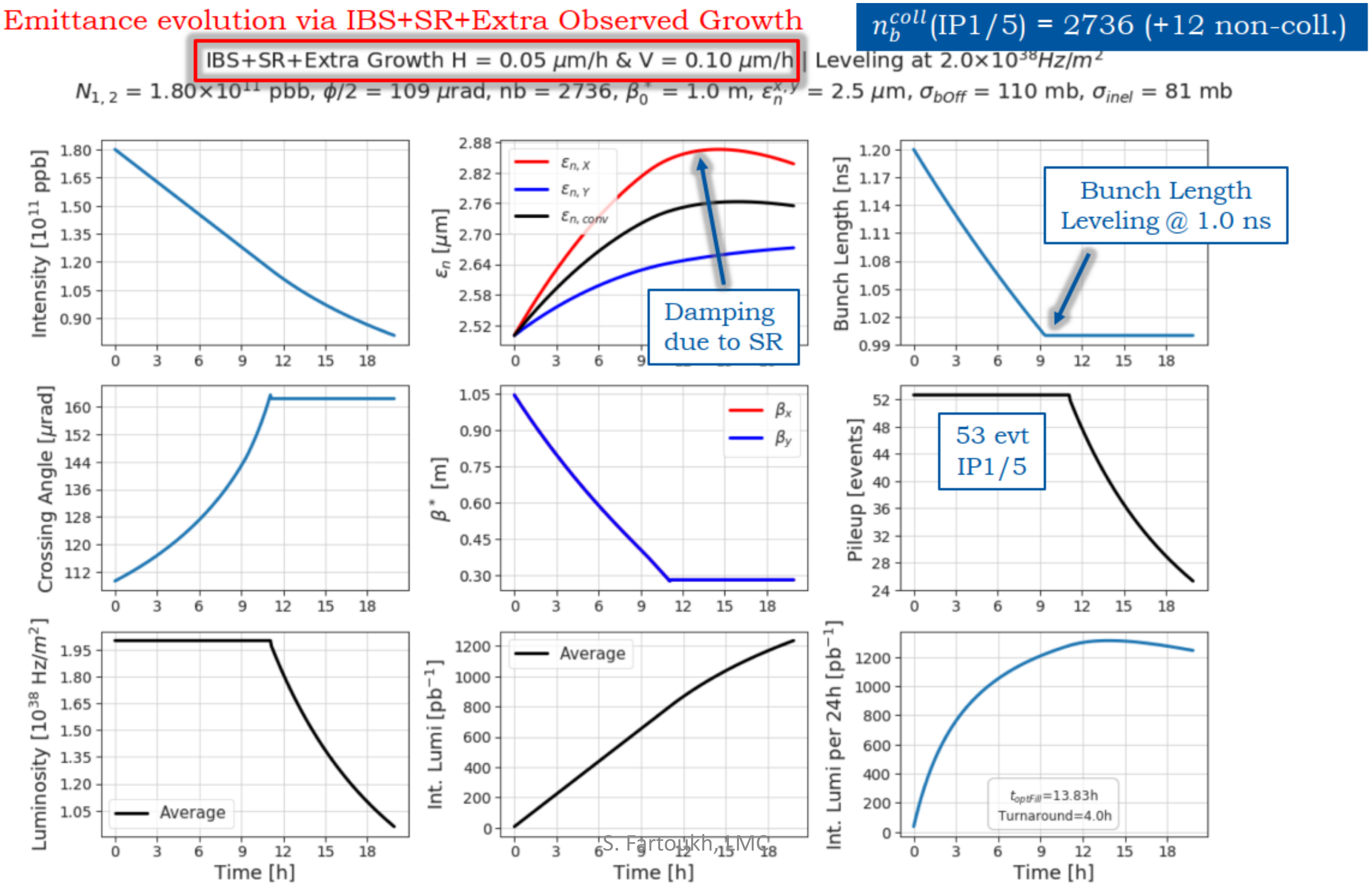
3. Collide & tele-squeeze [in SB ?] to reach prescribed lumi of 2E34 at IP1/5

4. β^* levelling at IP1/5 in **tele-mode** & **offset levelling** at IP2/8

[for flat optics, the optics flattening takes place when reaching β^*=50/50 cm]

Best possible performance reach and IT life time (1/4)

- Typical fill profile for **round optics** @ 1.8e11 p/b ($\gamma\varepsilon$=2.5 μm)

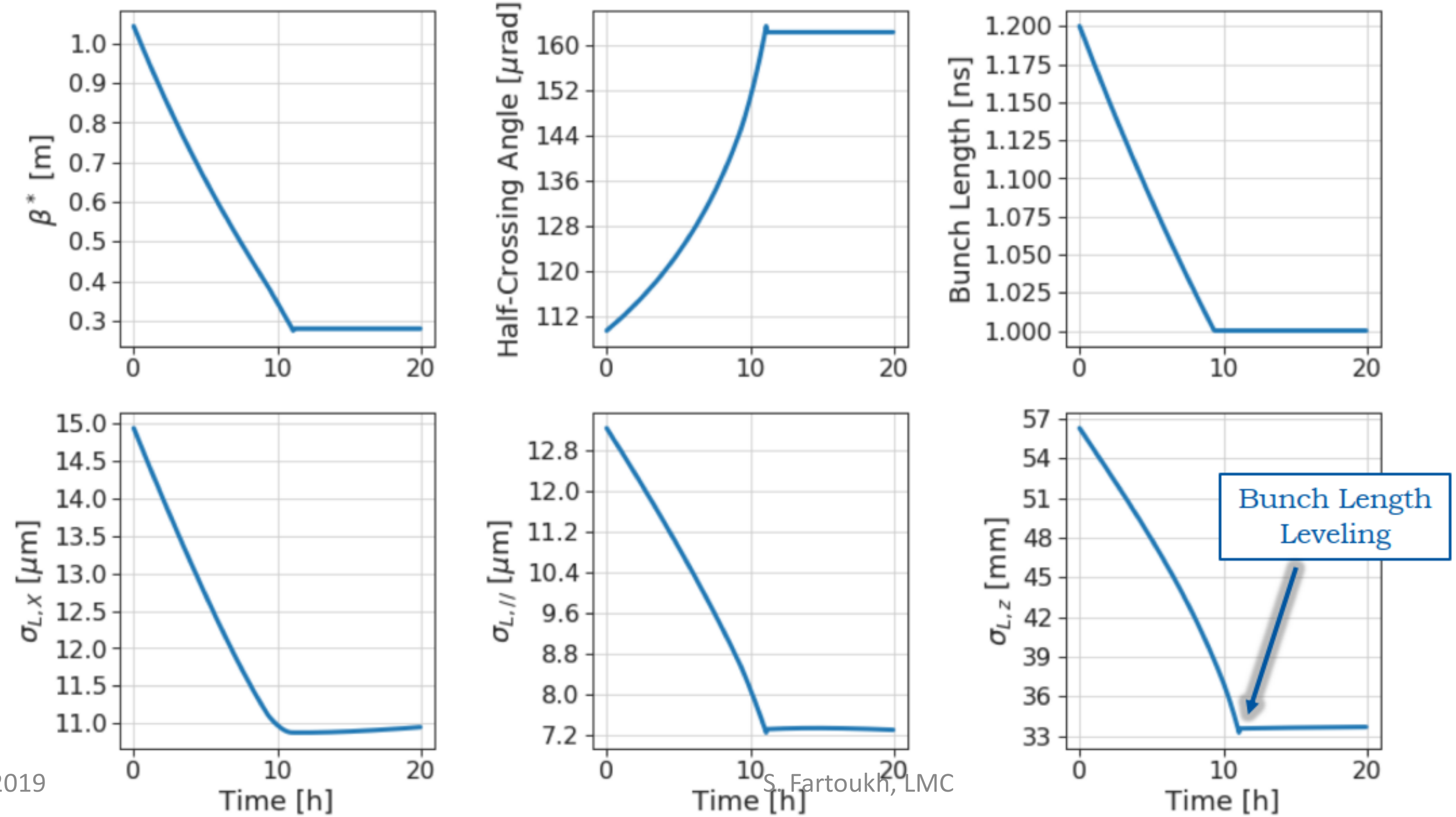


Best possible performance reach and IT life time (2/4)

- Luminous region evolution: example for ATLAS

Planes
X = y
// = x

n_b^{coll}**(IP1/5) = 2736**
$\beta^* \approx 1\,m$



Big variations driven by
- **β^* levelling**
- **X-angle variation**
- **Bunch length variation**

→ Is it OK ??

Best possible performance reach and IT life time (3/4)

Experiment	Target for Run III (LPC 14.01.2019)
ATLAS & CMS	**As much as possible** [see next slide for the triplet life time management]
Alice	**200 pb^{-1}**
LHCb	**> 15 fb^{-1}** (50 fb^{-1} by LS4)

(MAX) EXPECTATIONS WITH TYPICAL ASSUMPTIONS:

- **160 OP days (optimistic for 2021)**
- **Machine Efficiency: 20-30% (effective) in 2021, 50% later on**
- **Intensity ramp up: linear within a year**
- **Peak lumi: 2E34 at IP1/5, 1.3E31 at IP2, 2E33 at IP8**
- **Effective X-section: of 110 mb (vs. 105 mb to include LHCb)**

	2021	2022	2023
Intensity ramp up [10^{11} p/b]	0 → 1.4	1.4 → 1.8	1.8
Round optics (Flat optics variant for 2022/2023)			
Levelling time [h] @2E34 at IP1/5	-- → 4.1 (6.5)	4.1 (6.5) → 11.2 (13.2)	11.2 (13.2)
Optimal fill length [h]	-- → 9.6 (10.2)	9.6 (10.2) → 13.8 (15.3)	13.8 (15.3)
β^* [m] at IP1/5	**0.28 (0.50/0.15)**		
Integrated lumi in IR1/5 [fb^{-1}]	17-25	96 (101)	106 (108)
β^* [m] at IP2	**10.0**		
Integrated lumi in IR2 [pb^{-1}]	36-54	90	90
β^* [m] at IP8	**1.5**		
Integrated lumi in IR8 [fb^{-1}]	~ 3-4(1)	14	14

~ 220 (230) fb^{-1}
[~190 (210) for 1.4e11 p/b over the full Run III]

200 ++ pb^{-1}

~ 30 fb^{-1}

(1) **Lumi levelling at 2E33 in LHCb over the full fill length** is granted when the intensity ramp up reaches 1.4E11 p/b (resp. 1.15E11 p/b) with 2376 collisions/turn for negative (resp. positive) LHCb polarity. A performance reduction factor of 50% has been applied accordingly in 2021.

Best possible performance reach and IT life time (4/4)

F. Cerutti
10th LCR3 meeting

→ **Round optics in 2021** **(V/H crossing in IR1/5)** *with LHCf good X-angle polarity* in ATLAS

→ **Then 2 scenarios for 2022/2023**
- **Round (V/H crossing in IR1/5)**

X-angle polarity inversion in ATLAS from 2022 to 2023
- **Flat (H/V crossing in IR1/5)**

X-angle polarity inversion in CMS from 2022 to 2023

→ Finally **2 possible 2024 extensions**
- **Round optics**
- **Flat optics**

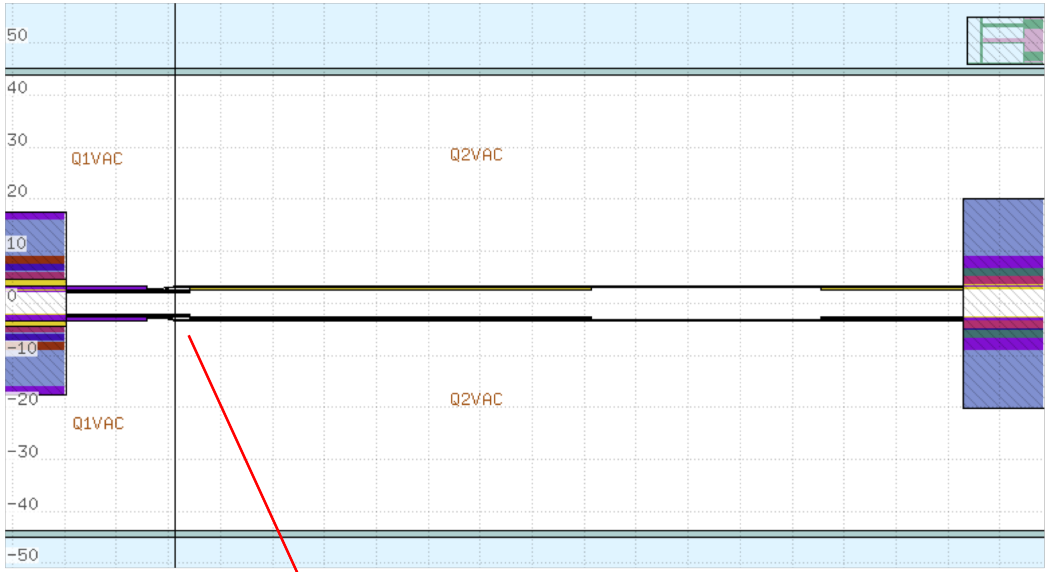
OPTICS	ROUND	FLAT*)	ROUND + 2024 FLAT*) (+2024 ROUND)	FLAT*) + 2024 FLAT*)
MAGNET	PEAK DOSE [MGy]			
Integrated lumi [inc. 190 fb^{-1} from Run I/II]	after 412 fb^{-1}	after 419 fb^{-1}	after 520 (518) fb^{-1}	after 527 fb^{-1}
Q1 IR1	21	20.5		
Q1 IR5	19	18		
Q2A IR1	**25.5**	**25**	**32 (32.5)**	**31.5**
Q2A IR5	19.5	17		
Q2B IR1	14	17.5		
Q2B IR5	**26.5**	21.5	**31 (34)**	26
Q3 IR1	12	14		
Q3 IR5	18.5	16.5		

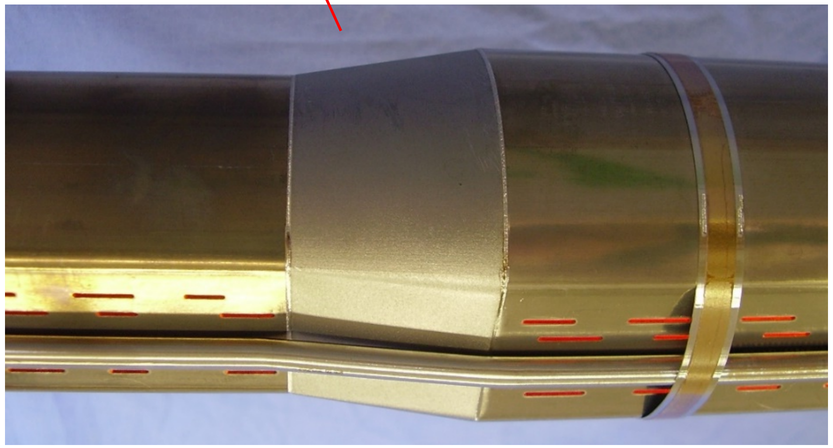
*) CMS IP shift assumed to be corrected for flat optics (i.e. machine perfectly realigned)

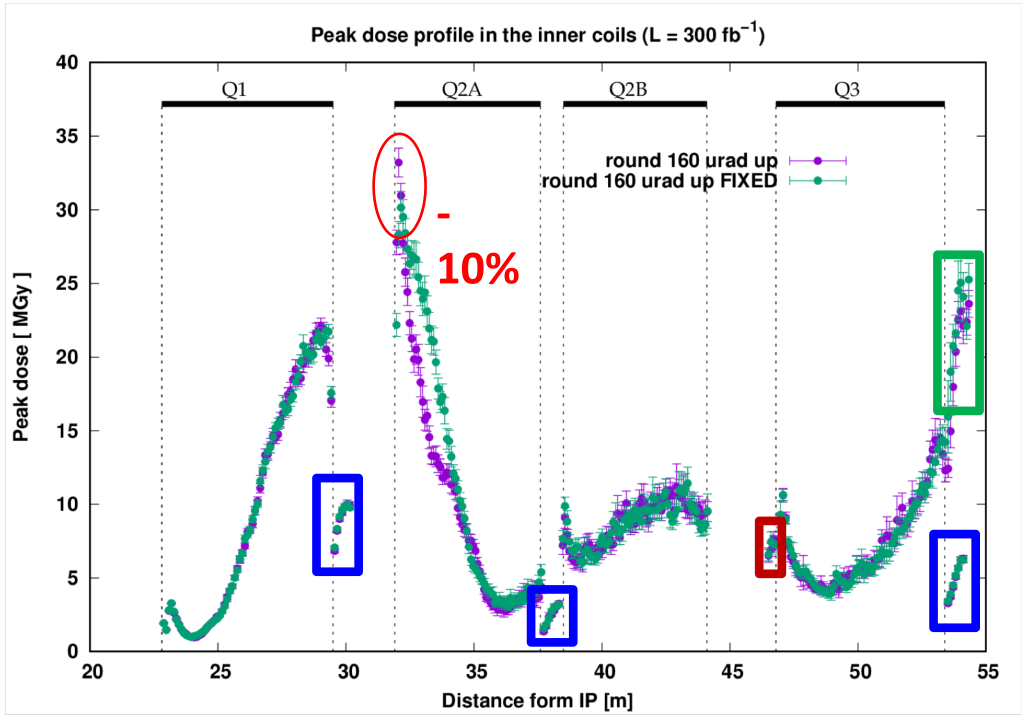
Possible running scenarios exist with 27 MGy with round optics (25 MGy with flat optics) after 420 fb^{-1}, offering a **possible extension for a 4th year, preferably with flat optics and 500 ++ fb^{-1}**

The **vertical X-angle polarity management** is **vital**, … but also a recent improvement of the model helped in the good direction for Q2A

F. Cerutti
10th LCR3 meeting







Concerning correctors … to be followed up:

- **MCBX**: larger aperture, lower dose, but less resistant (7 MGY dose limit)

→ Not mandatory for X-bumps (one surviving per IP side is OK in IR1/5) but vital to avoid very regular IT re-alignment.

- **MQSX**: coils off mid planes, lower dose, dose limits to be clarified

→ Big impact on performance unless “rolling back” the IT (see e.g. 2018 ion Run)

- **Non-linear (b3/b6 and a3/a4/a6) correctors**, are less a concern (maybe marginally impacting on the effective β^* reach: DA, linear optics vs. X-angle),

Summary and outlook

- Thanks to the active participation of many groups across the ATS sector, a clear possible direction has been established in order to extract the best of Run III.
- The present proposal still need however to be consolidated with in mind the following activities and timeline

1. Y2019 → Chamonix 2020:

- ✓ **Input (re-)confirmation** (LIU), and **consolidation** (intensity limitation, **TDE risk of damage, US windows** ..)
- ✓ **Proof a feasibility of the new Run III hypercycle: Run III optics V1**, can we built the corresponding ramp?..
- ✓ **Dedicated assessment of potential shortcomings** (e.g. non-nominal MKD-TCDQ phase advance for anti-telescopic optics at high β^*, not discussed)
- ✓ **Answer to general questions**, e.g. Commissioning time (including MP aspect) of a **β^* levelling range of up to 5** with minimal lumi unbalance requested between ATLAS and CMS (.. Idem for HL-LHC !!)
- ✓ **Feed-back from the experiments** and possible iteration (or drastic change) on the concept

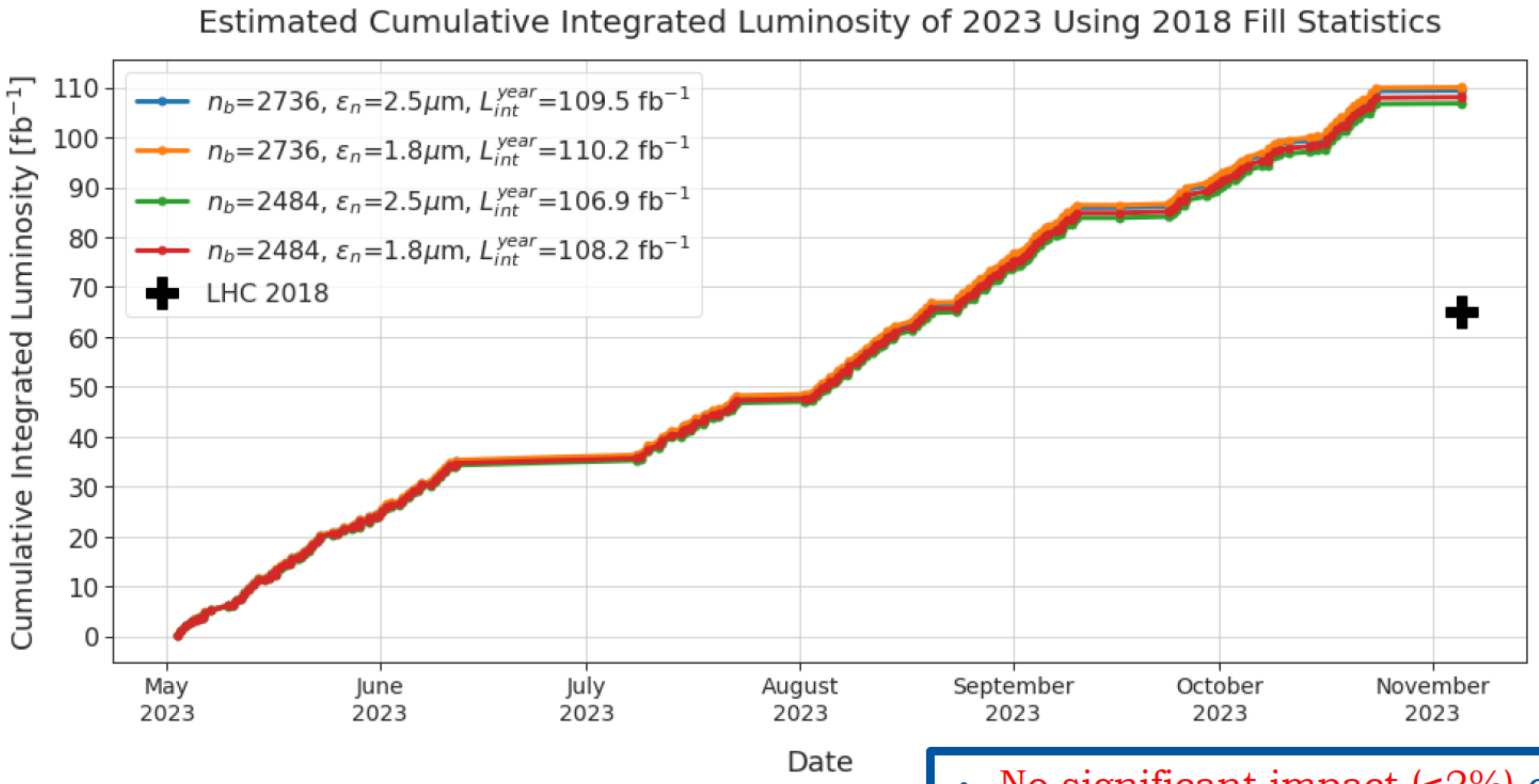
2. Y2020 → Spring 2021

- ✓ **Full validation on paper** (collimation, beam-beam, collective effects, machine protection, ..)
- ✓ Fine tuning and **optics delivery to OP** on time for the HW tests

Looking into our crystal ball

N. Karastathis @ Evian 2019

- Using the above (ideal) scenario and the 2018 fill statistics
- Possible impact of larger intensity and higher energy on the machine availability is not considered.

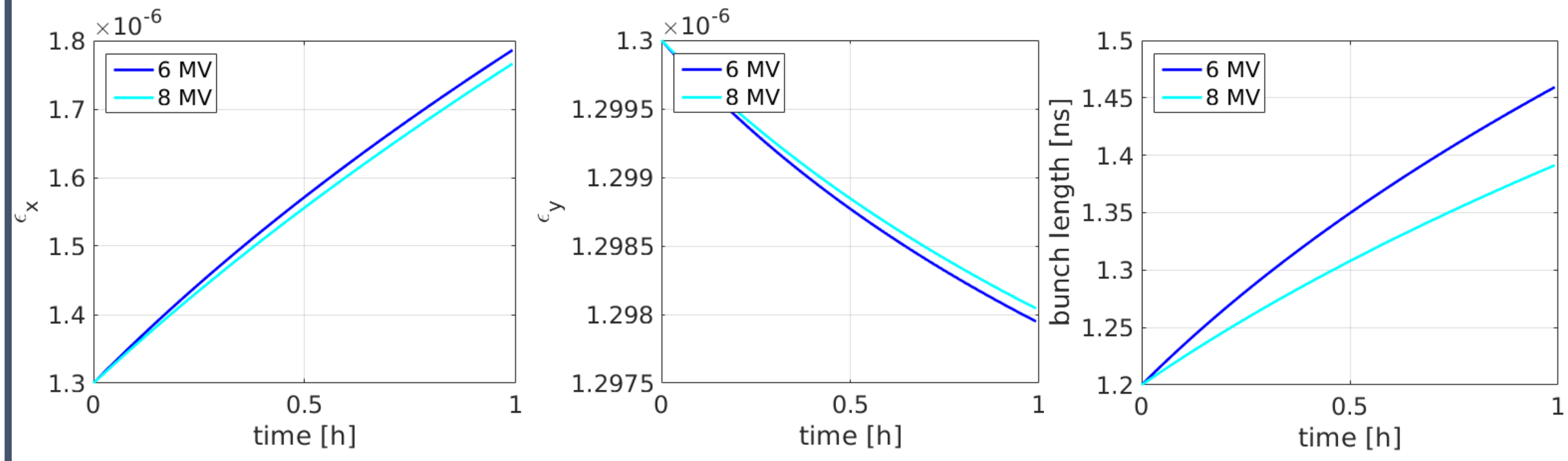


- Integrated performance of ≈ 108fb^{-1}
- Average (stat.) half-crossing angle 122.0 μrad
- Average value of β* at the time of dump 55 cm

- No significant impact (<2%) on the performance, from the number of bunches or emittance preservation due to leveling (assuming no other losses).

Back-up

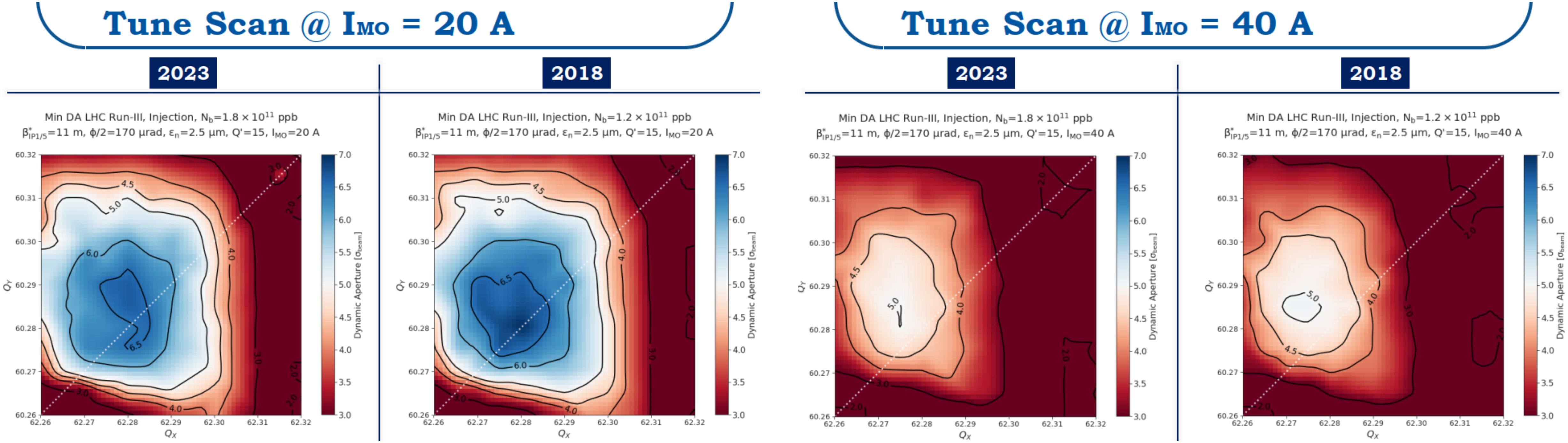
IBS Estimates on the injection plateau (typically 40 minutes)



- $N_b = 1.8\times10^{11}$ ppb, $\epsilon_n^{inj} = 1.3\ \mu m$ & $\sigma_L = 1.2$ ns
- Horizontal Emittance Growth @ FB: $\approx 0.5 \mu m/h$ (additional effects, e.g. e-cloud, not considered here)
- Two scenarios considered at Start SB: **1.8 μm** & **2.5 μm**

S. Papadopoulou, Y. Papaphilippou *et al.*

DA at injection for 1.8e11 p/b (keeping the 2017/2018 injection optics)



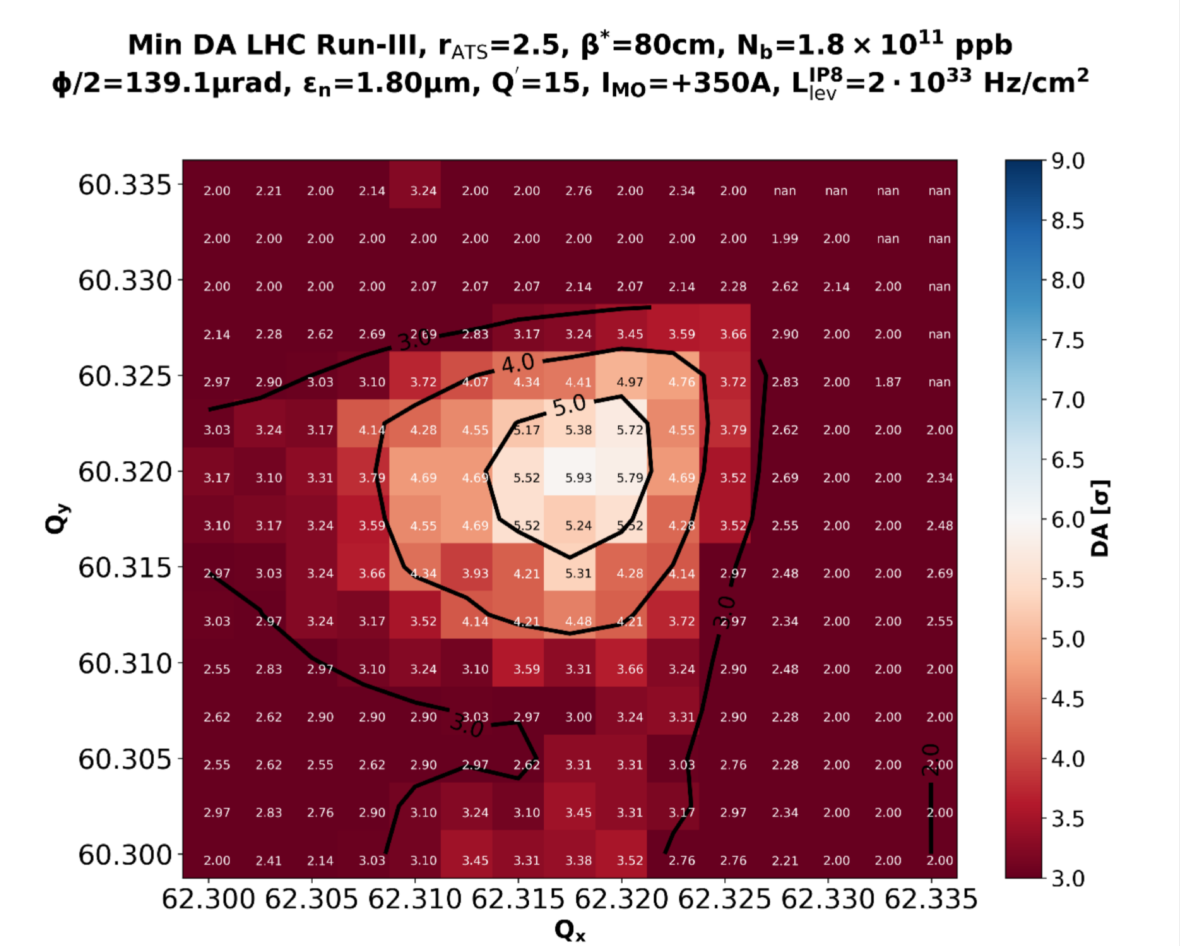
Even with huge margin taken in emittance ($\gamma\varepsilon$=2.5 μm)
the DA killer remains the octupole (at Q'=15), not the BBLR

[in terms of tune spread needed for Landau damping: 40 A @ $\gamma\varepsilon$=2.5 μm means 55 A @ $\gamma\varepsilon$=1.8 μm at ~cst DA in σ]

Some pre-checks before optics production (1/3)

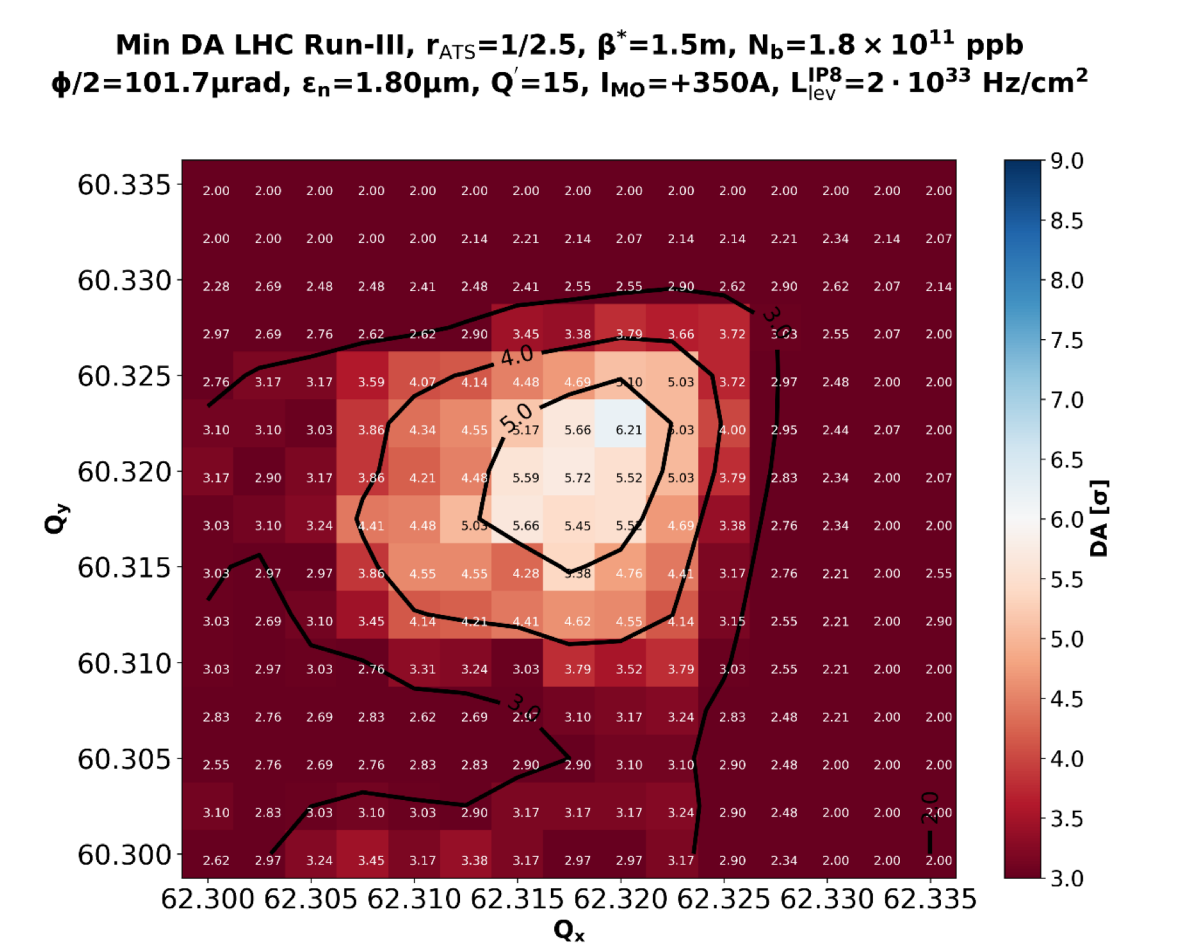
- **Tune scan comparison at "small" emittance (1.8 µm)** [different β^* but same norm. X-angle]

Telescopic EoR optics with r=2.5



/afs/cern.ch/eng/lhc/optics/runII/2018/RunIII_DEV/optics_EoR.madx

Anti-telescopic EoR optics with r=1/2.5

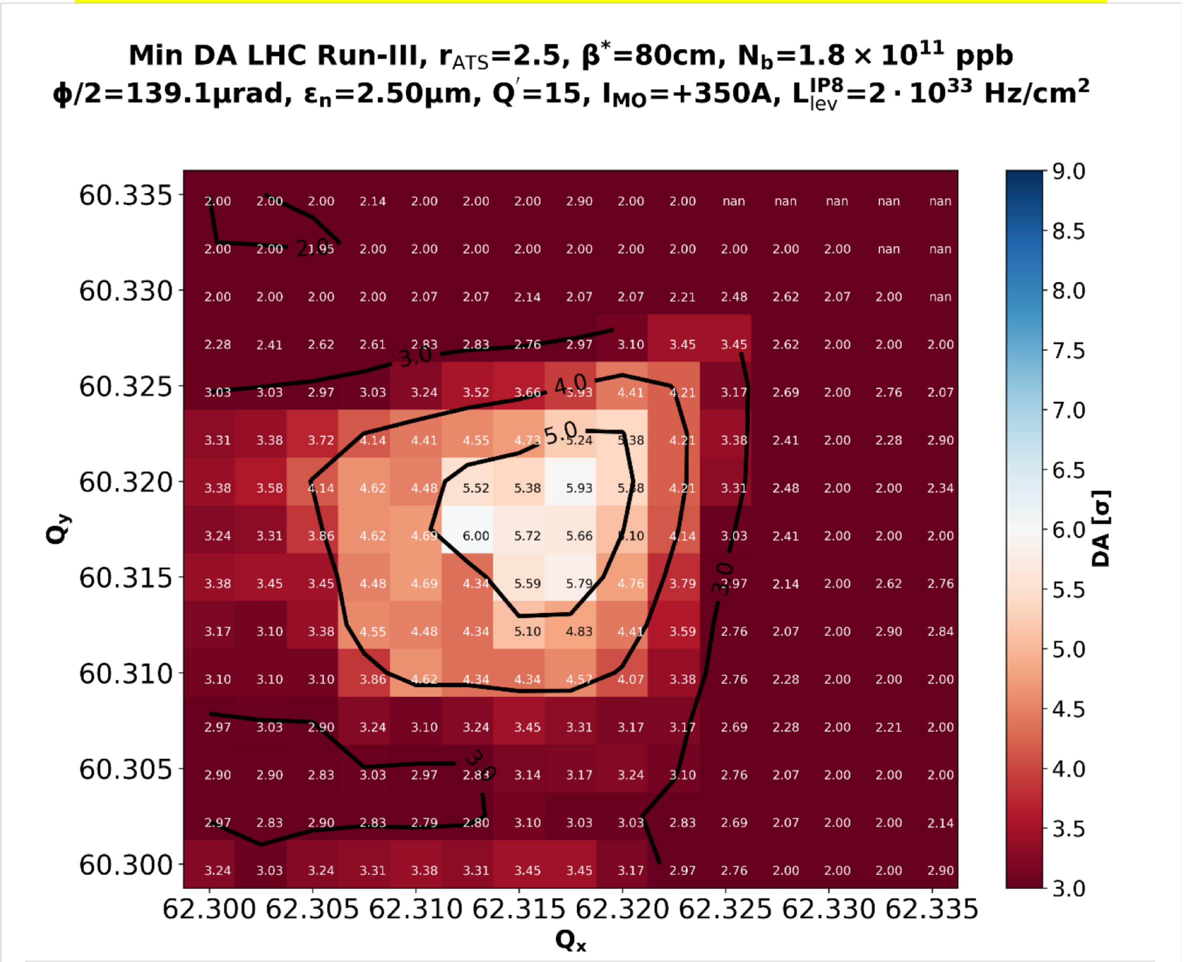


/afs/cern.ch/eng/lhc/optics/runII/2018/RunIII_DEV/optics_EoR_antitele.madx

Some pre-checks before optics production (2/3)

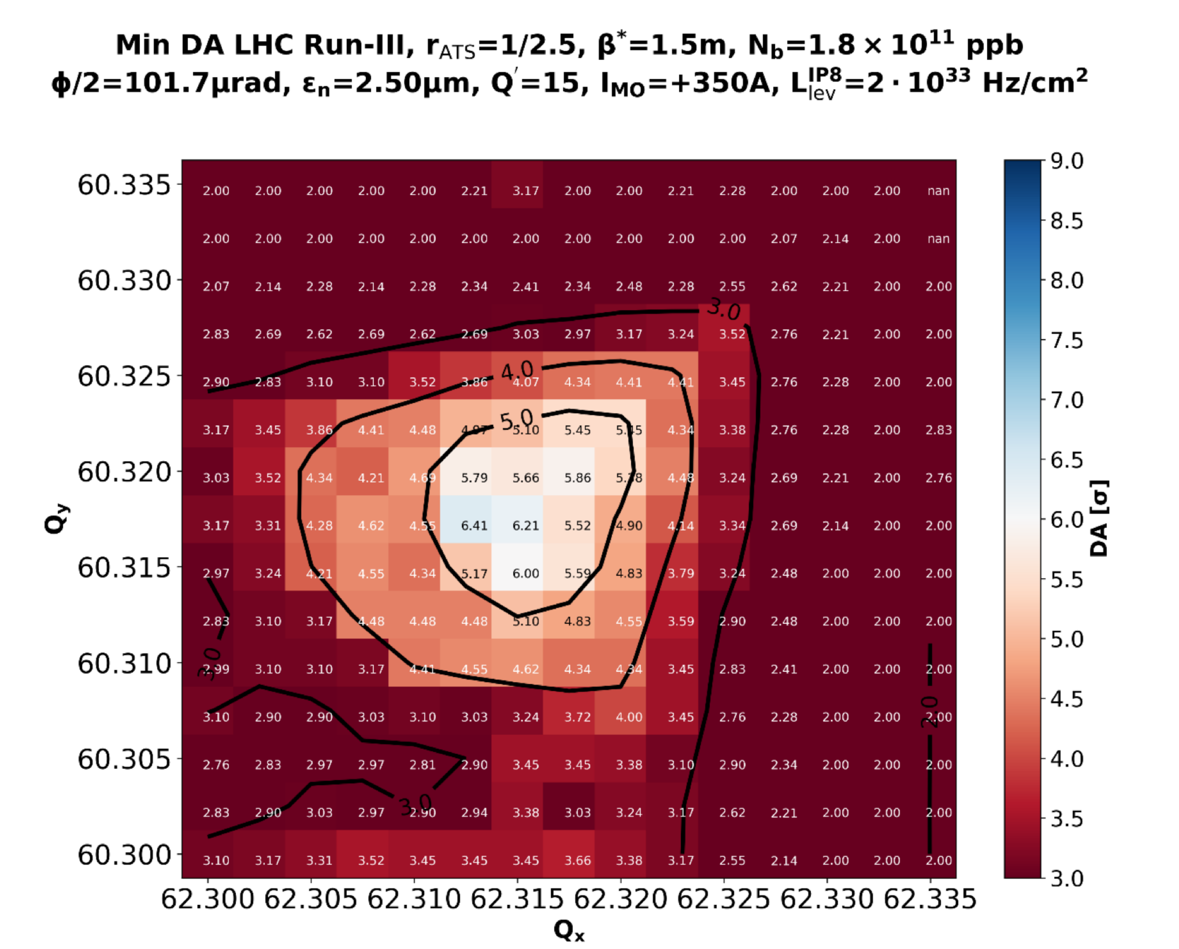
- **Tune scan comparison at "large" emittance (2.5 μm)** [different β^* but same norm. X-angle]

Telescopic EoR optics with r=2.5



/afs/cern.ch/eng/lhc/optics/runII/2018/RunIII_DEV/optics_EoR.madx

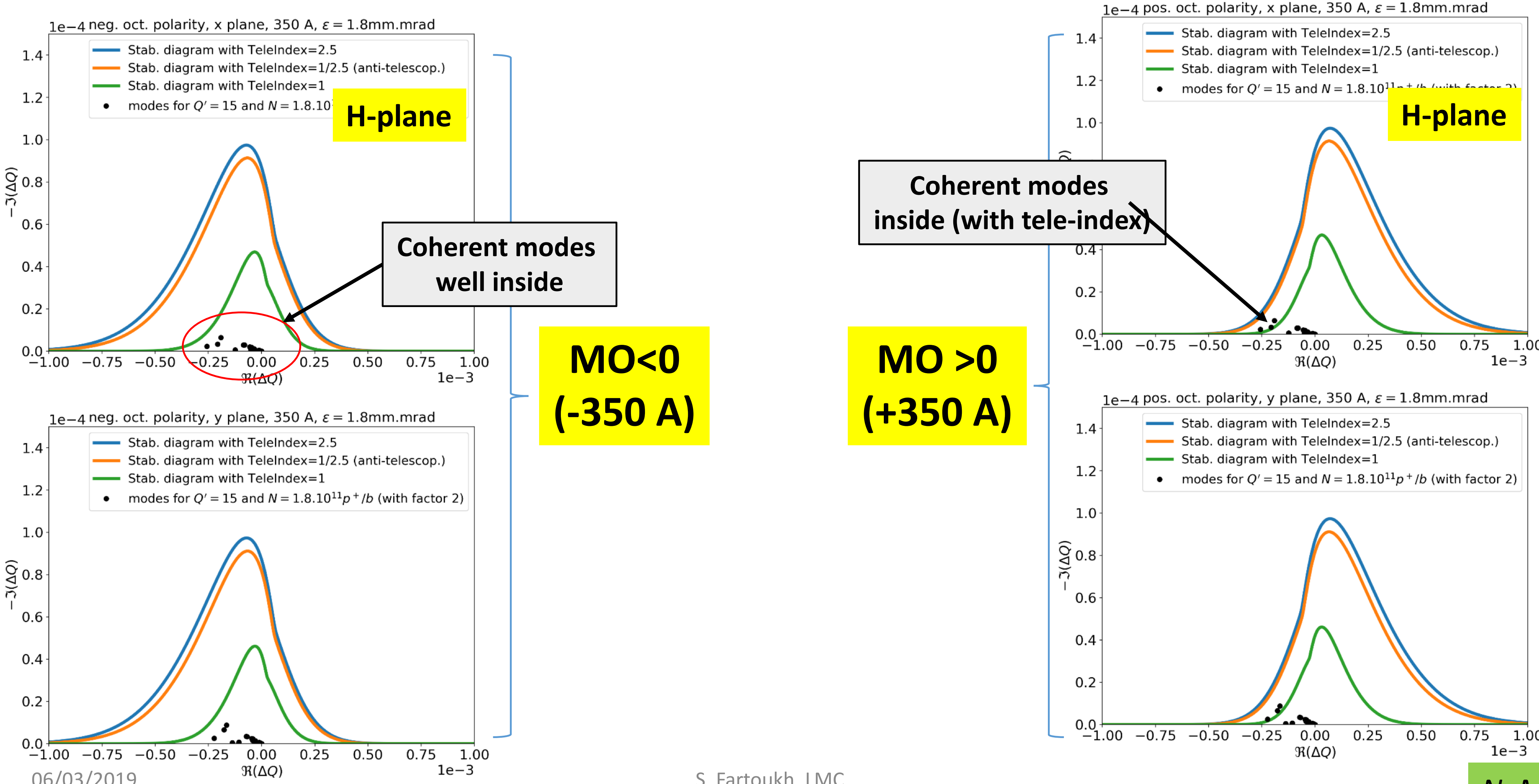
Anti-telescopic EoR optics with r=1/2.5



/afs/cern.ch/eng/lhc/optics/runII/2018/RunIII_DEV/optics_EoR_antitele.madx

Some pre-checks before optics production (3/3)

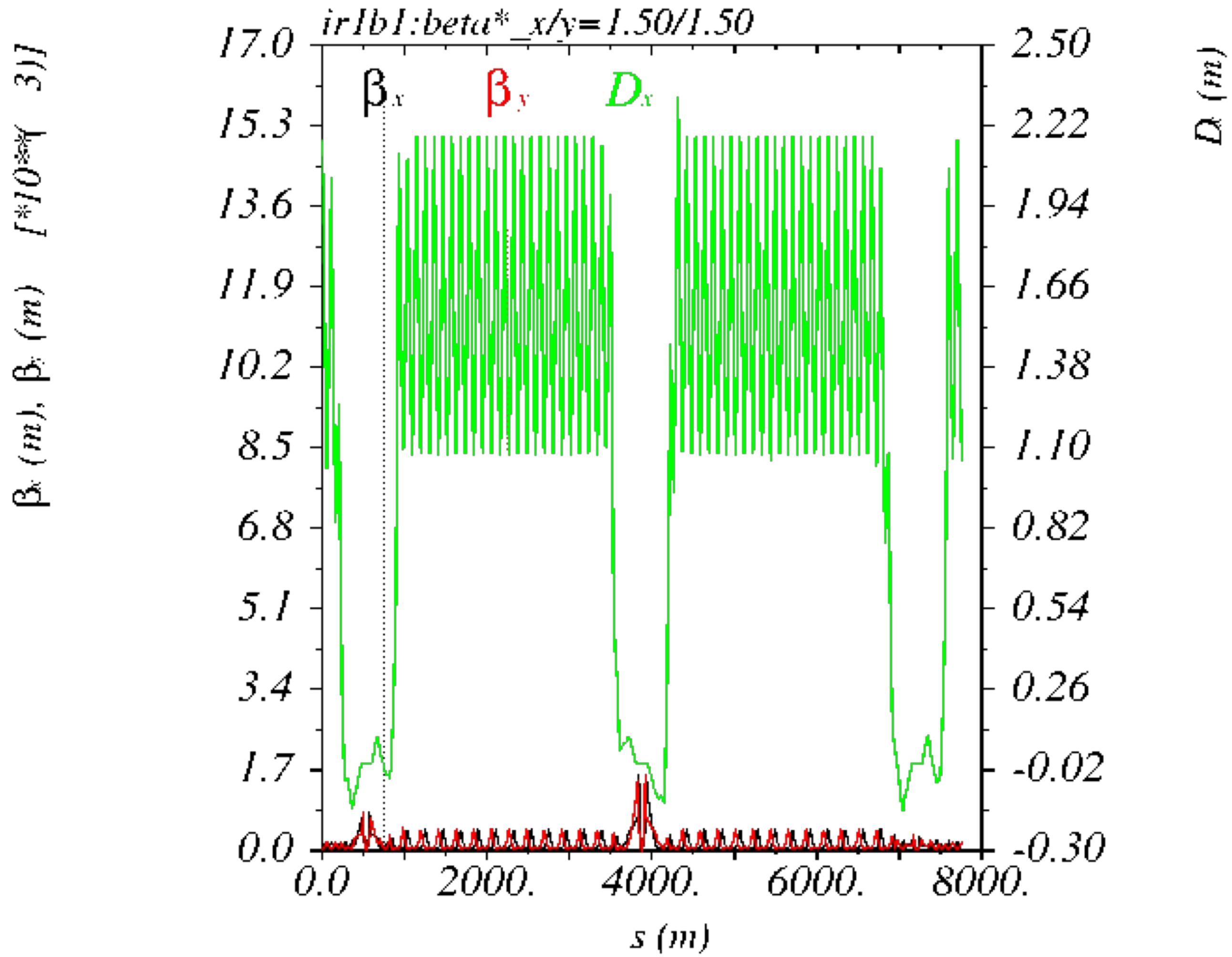
- **Stability diagram comparison (no BBLR), changing r_{tele} into $1/r_{tele}$**



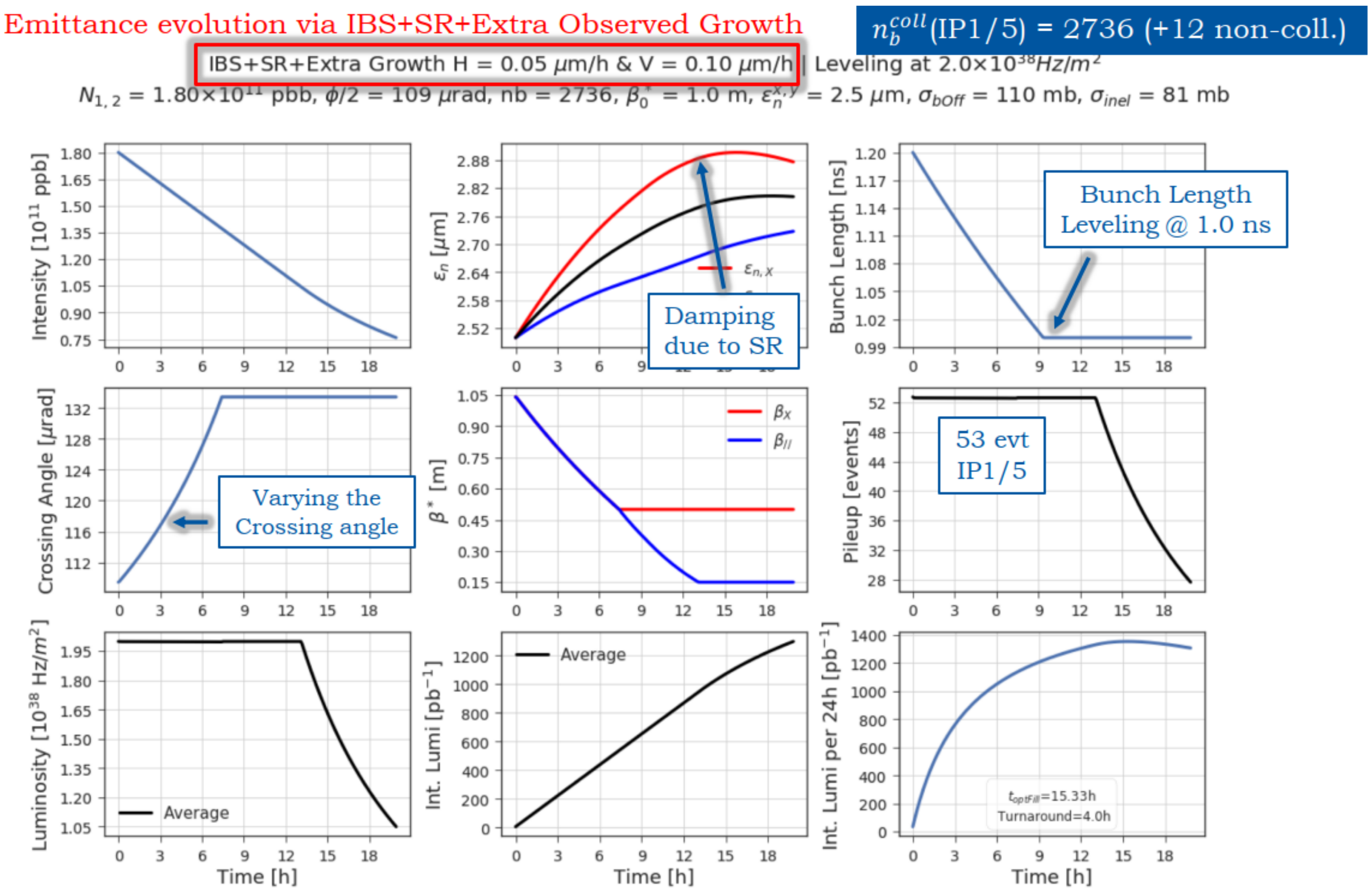
N. Mounet

Flat optics case:

β* levelling from 1.5 m down to 50/15 cm



- Typical fill profile [for flat optics](#) @ 1.8e11 p/b ($\gamma\varepsilon$=2.5 μm)

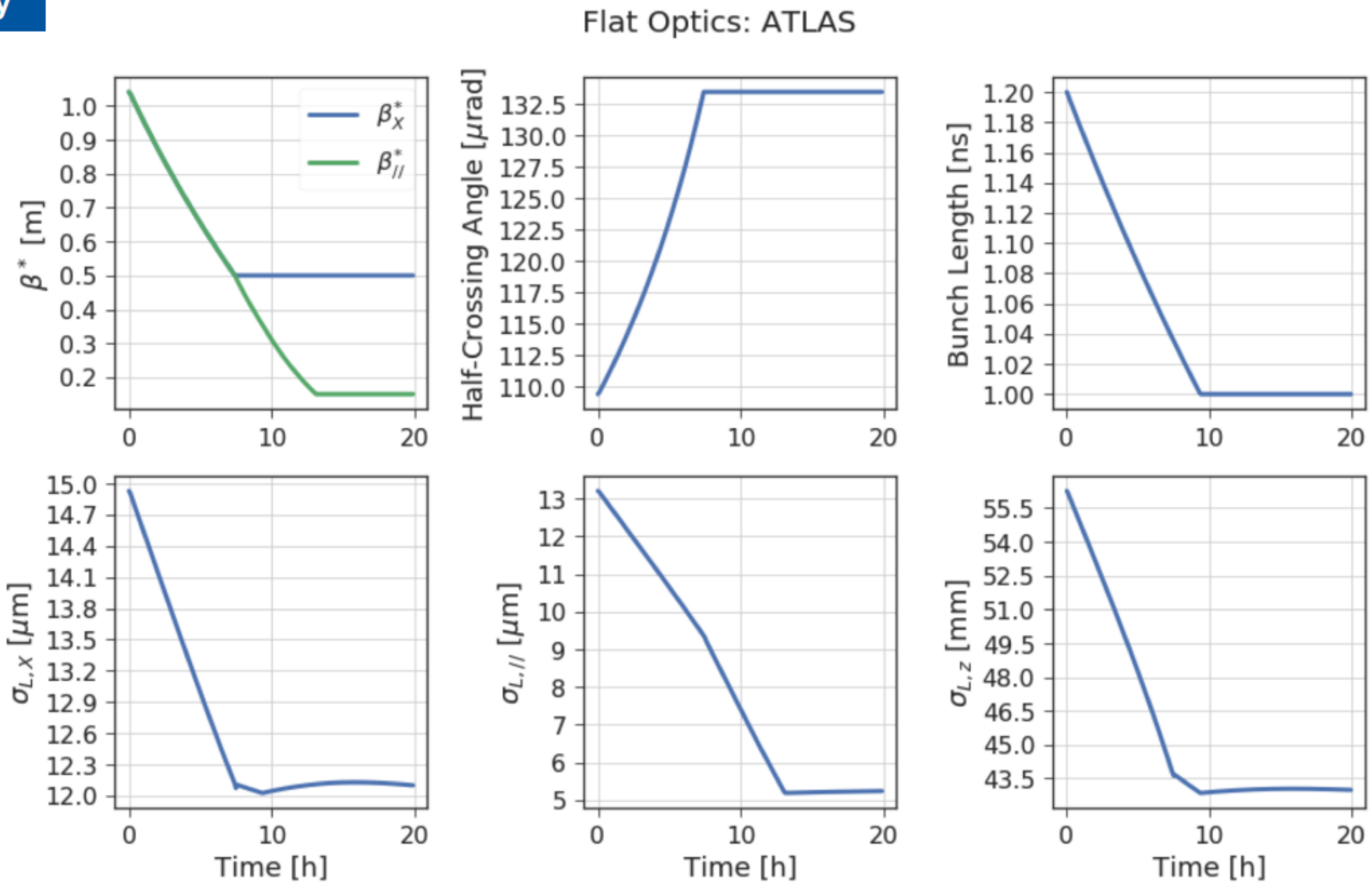


- Luminous region for **flat optics**: example for ATLAS

Planes
X = x
// = y

n_b^{coll}(IP1/5) = 2736
$\beta^* \approx 1\ m$

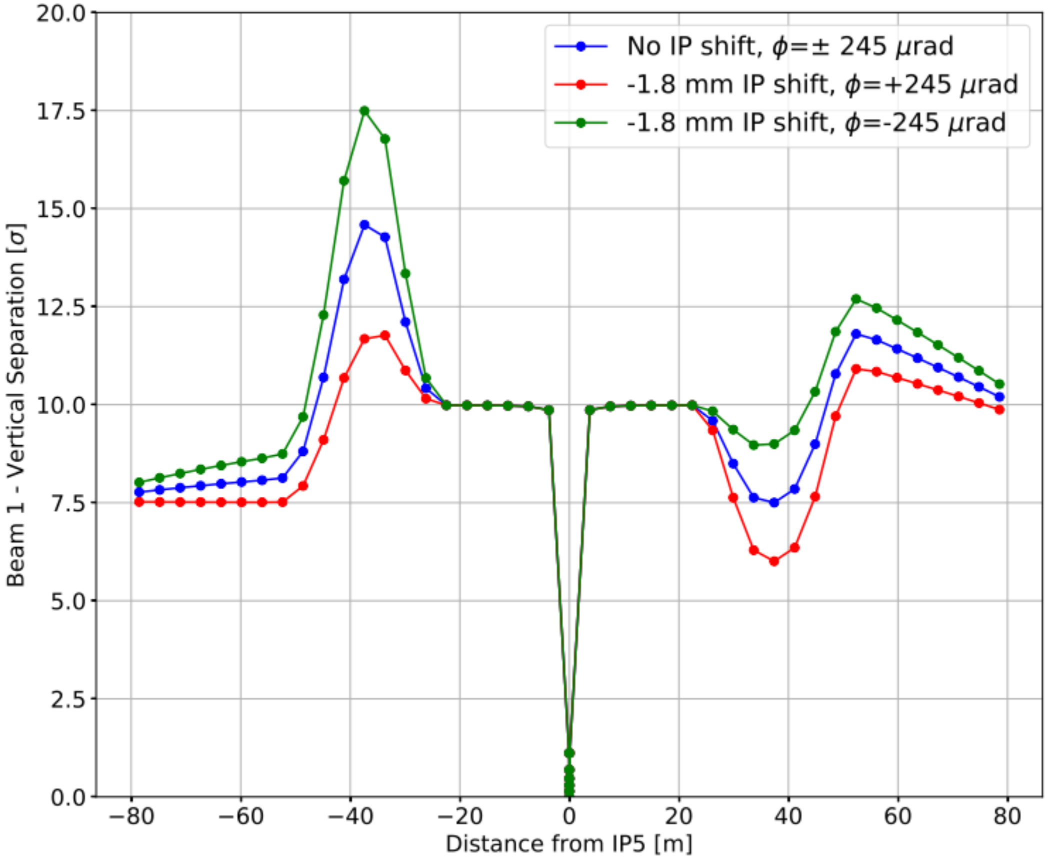
Variable Crossing Angle

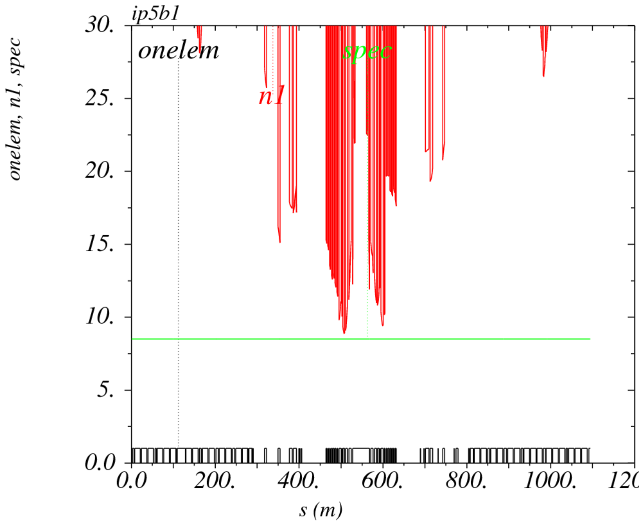


→ **Only 25 % variation** (mainly driven by the bunch length variations)
→ Marginally larger in average (5-10%) compared to round optics

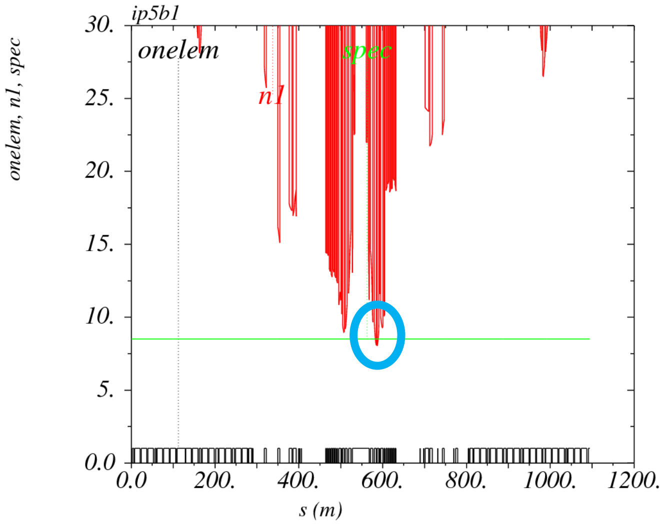
Realigning the machine around Pt5 in Run III is a pre-requisite for flat optics

CMS IP shift (-1.8 mm) .. Which is **in the X-plane** in the case of flat optics !





IT aperture in IR5
for positive X-angle
(6.5 TeV, 50/15 cm, 270 μrad)



IT aperture in IR5
for negative X-angle
(6.5 TeV, 50/15 cm, 270 μrad)

.. Assuming no machine re-alignment in LS2 (although approved at the LMC on October 3rd 2018)

- **One crossing polarity is “good” for BBLR and “bad” for aperture, and conversely for the other polarity → β* reach**
- **The beneficial impact of flat optics on the IT dose (essentially Q2B) can be strongly affected → 4th year option for Run III**

Run III optics readiness status (25/02/2019)

	Pres-squeeze	Anti-tele squeeze (round)	Tele-squeeze (round)
IR1/5	Not done[1)] (hard)	-	-
IR2	Done (from pp-2018)	Not done (hard)	Done[2)]
IR8	Done (from ion-2018)	Not done (hard)	Done[3)]
IR4	-	Not done (hard)	Done[4)]
IR6	-	Not done (very hard)	Done[5)]
IR1/5 crossing bumps	Not done (easy)	-	-
IR2/8 crossing bumps	Done (from 2018)	Not done (easy)	Not done (easy)
Sextupoles	Not done (easy)	Not done (easy)	Not done(easy)
Knobs (Q,Q',c, on_disp)	Not done (easy)	Not done (easy)	Not done (easy)
Optics master table assembly	Not done (easy)		
Matched point selection	Not done (time consuming but easy and pleasant !)		

[1)]: from 11 m down to 40 cm should be updated w.r.t. 2017/2018 to further minimize (at 60 cm) the normalized dispersion at the Roman Pots for AFP & CT-PPS

[2)]: up to a tele-index of 3 at β^*=10 m at IP2 , updated (smoother) w.r.t. to the Run II ATS optics and MDs

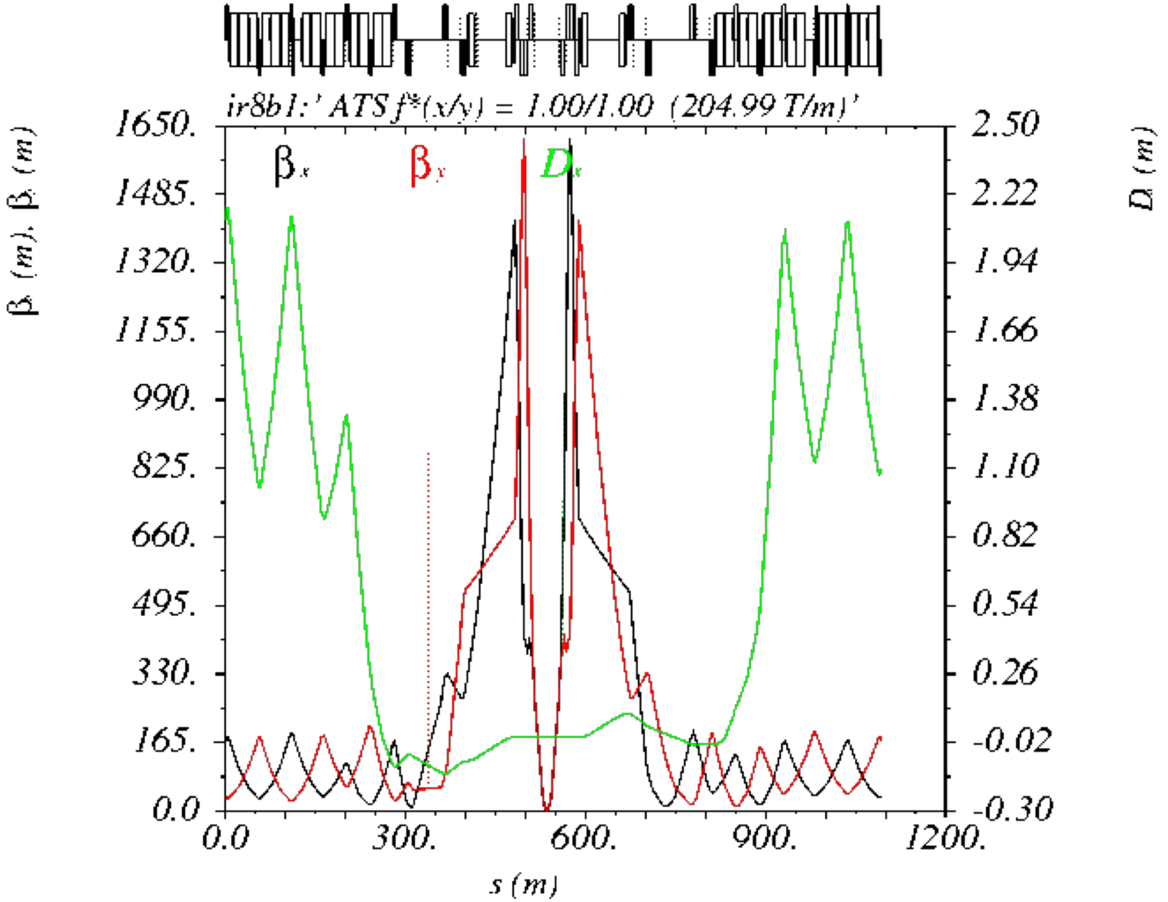
[3)]: up to a tele-index of 3 at β^*=1.5 m at IP8, vs. 3 m for the Run II ATS optics and MDs

[4)]: up to a tele-index of 3, new phases w.r.t. to the Run II optics and ATS MDs, now smoothly connected to the injection optics for beam1

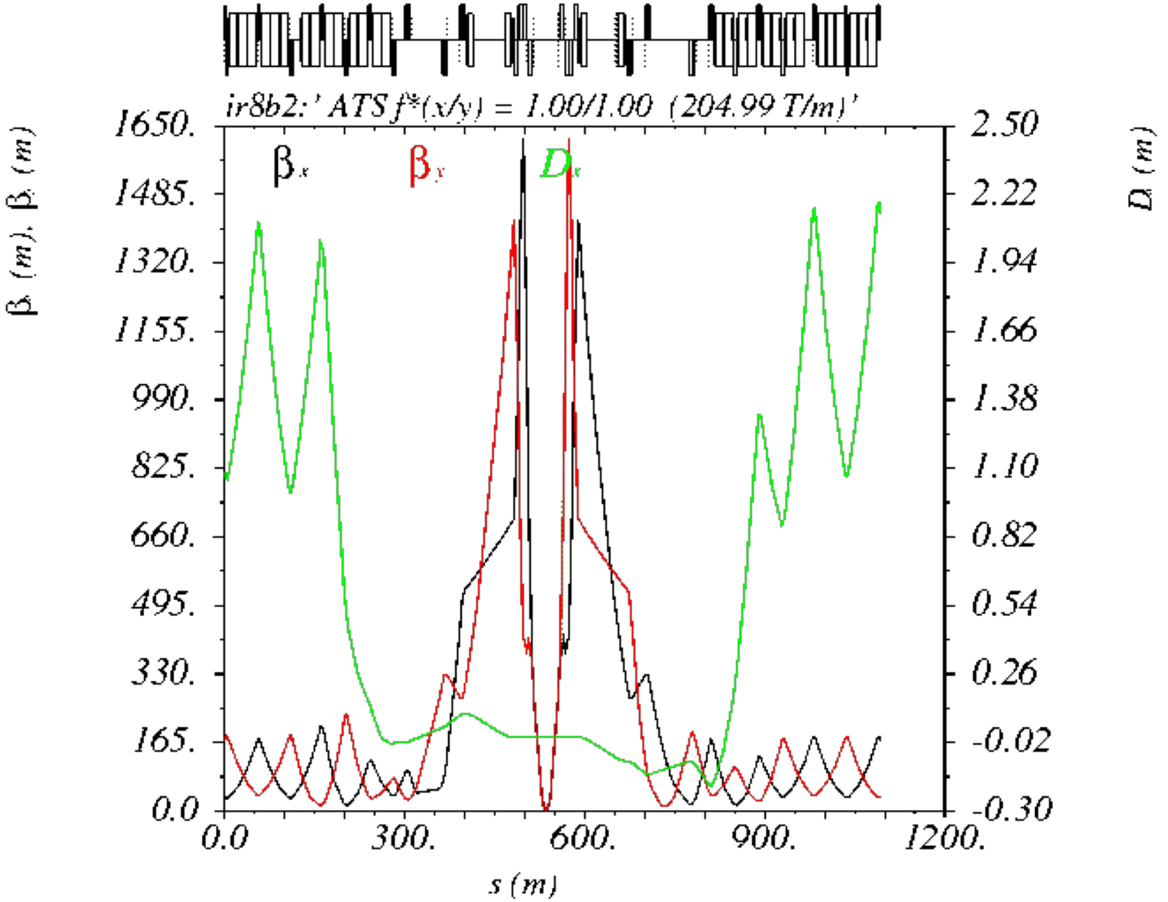
[5)]: up to a tele-index of 3, new phases w.r.t. to the Run II optics and ATS MDs, at constant βx at the TCDQ (and within tolerance for the MKD-TCDQ and MKD-TCT phases)

New IR8 telescopic squeeze at β^*=1.5 m @ IP8

Beam 1



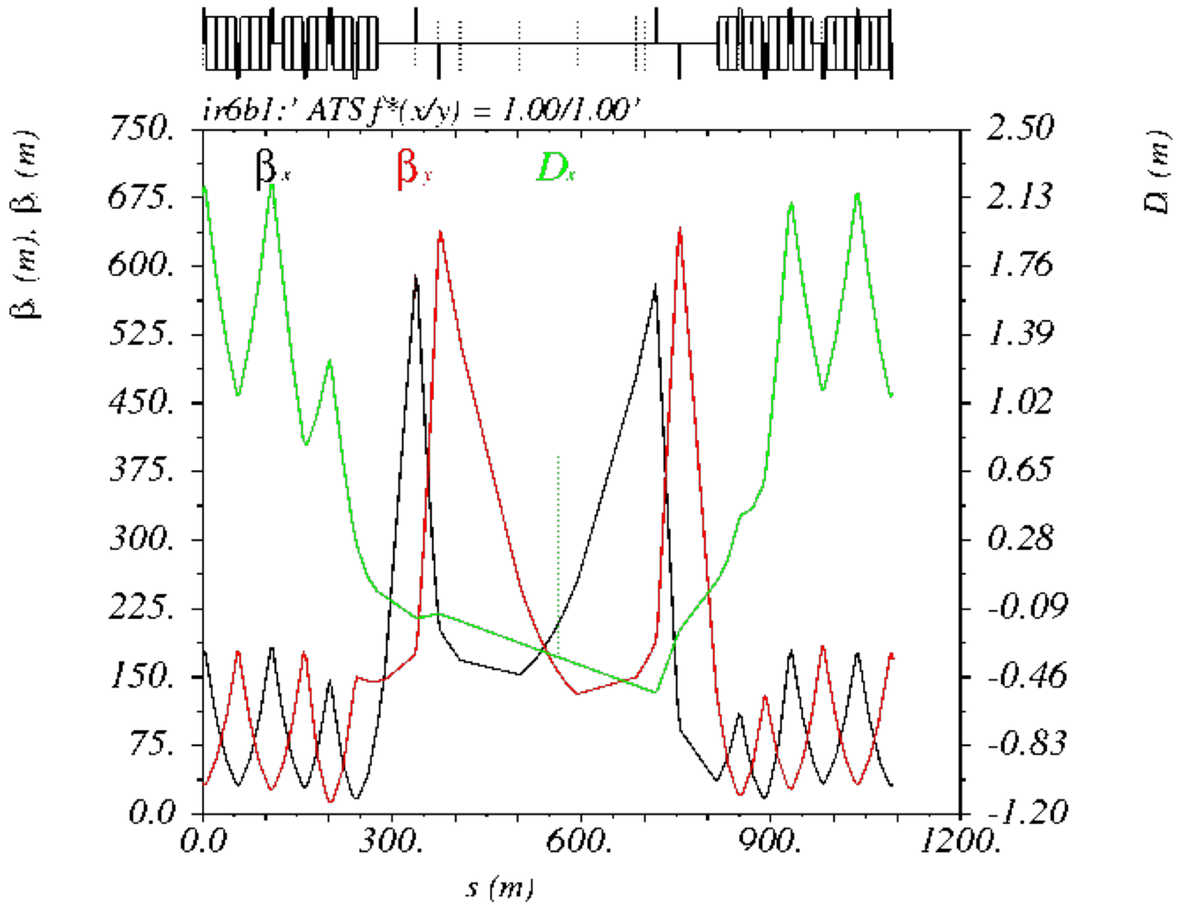
Beam 2



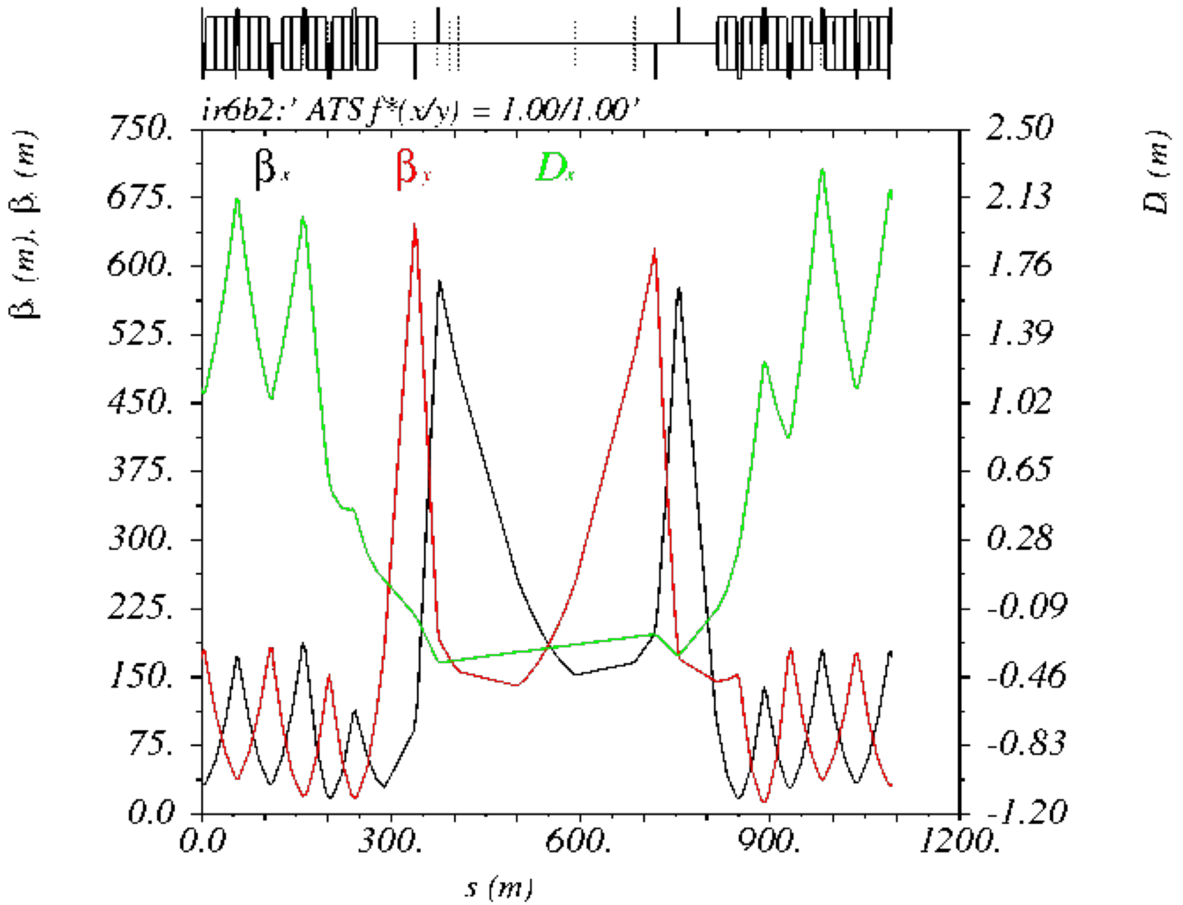
… The anti-telescopic squeeze needs to be proven

New IR6 telescopic squeeze at <u>cst β at the TCDQ</u> [MKD-TCT phase in tolerance]

Beam 1



Beam 2



An anti-telescopic squeeze with similar features needs to be proven: a gradual <u>degradation of the MKD-TCDQ phase advance</u> is anticipated (high β^*, but high intensity)