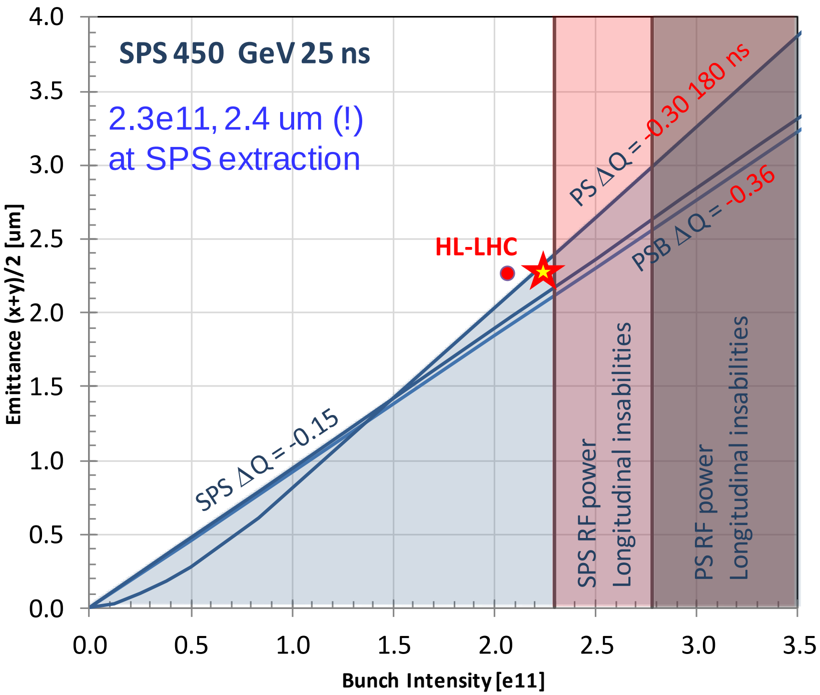
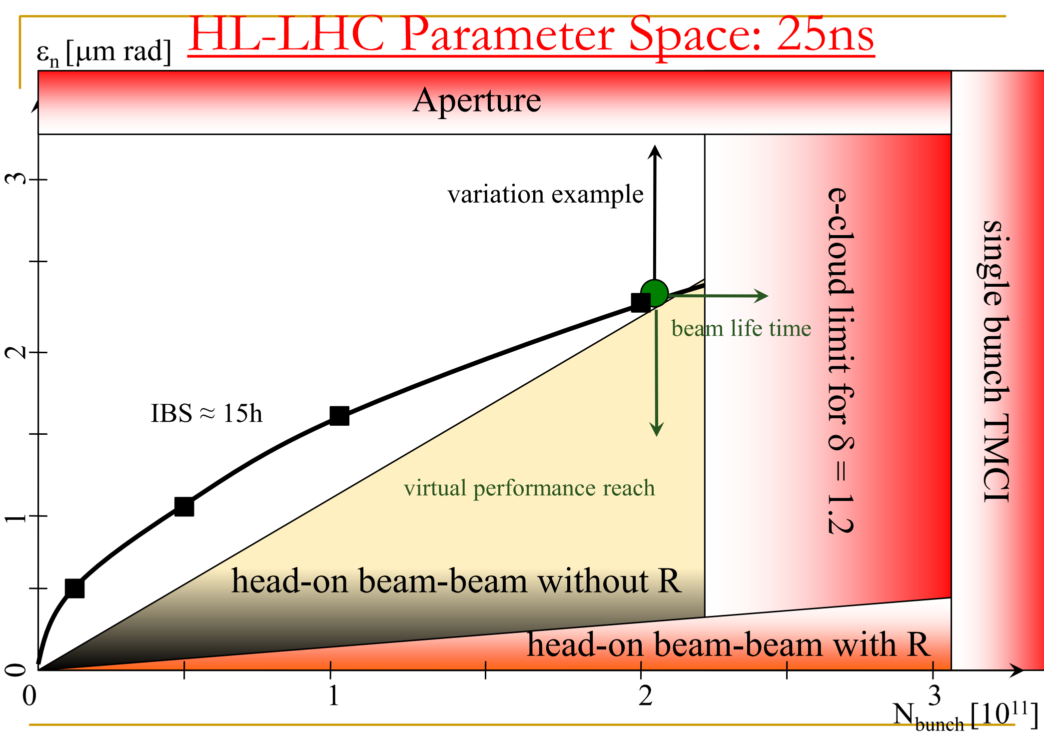
Overlapping LIU accessible beam parameters (areas) with LHC beam parameters regions (bands)

Including some optimism,
HL-LHC requirement “nearly” matched by LIU performances (with “Conceivable” improvements”)

	LHC requirements (injection)		SPS extraction (stretch)	
	N_b [10^{11}]	ε [μm]	N_b [10^{11}]	ε [μm]
25 ns	2.2	2.0	2.3	2.4
50 ns	3.5	2.5	3.4	2.6





Some observations

- Single bunch stability limits lifted in the SPS with low gamma transition optics. Next single bunch (TMCI) limit (~3.8×10^{11} p) compatible with LHC single bunch (TMCI) limit (~3.5×10^{11} p).

- Able to study and understand the space charge effects in all machines and evaluate possible cures

- IBS at LHC injection is one of the limitations of the beam brightness

Some observations

- If PU=100 is a strong limit and no strong limits for 25 ns
  - 25 ns operation would require efficiency for physics of ~40 %
  - 50 ns operation would require efficiency for physics of > 70% (this means a machine availability of >90 %)

- SEY of 1.3 seems to be within reach in the LHC with ~2 weeks of scrubbing time. Needs to be proven. Reproducibility after stops and venting needs to be proven.

- If e-cloud issues are not resolved in the injectors or LHC ➔ 50 ns might have to be reconsidered or alternative 25 ns schemes (μ batches)

Increase/maintain brightness

- Injectors:
  - Why the space charge “operational value” in the PSB is higher than in the PS and SPS? Is it because of the resonance compensation? Is it because of the lattice (C. Carli, M. Fitterer)? What is the time scale of the core blow-up?
  - Can we inject trains of 48 bunches in the SPS (LHC-Proj-Note 401) if space charge in PS an un-resolvable issue and if blow-up due to space charge is slow? Same with micro-batch scheme.
  - How can we fight longitudinal coupled bunch instabilities in PS and SPS? What is their origin?
  - Do we understand the measurements of the emittance? Why do we see a difference in emittance between 12 bunches and 72 bunches?

Increase/maintain brightness

- LHC:
  - Can we run with larger longitudinal emittance at injection:
    - Batch-by-batch longitudinal blow-up in the LHC. What prevent-us to go higher than 1 eV.s at injection taking into account that at 7 TeV we have 2.5 eV.s?
    - Can we extract >1 eV.s from SPS and install 200 MHz capture system in LHC?

Are assumption for losses correct?

- Depend on emittance blowup and beam loss. Assumptions made:
  - PSB inj-extr: 5% emittance blowup, 5% beamloss
  - PS inj-extr: 5% emittance blowup, 5% beamloss
  - SPS inj-extr: 10% emittance blowup, 10% beamloss (including scraping)
  - LHC inj-flat top: 10% emittance blowup, 10% beamloss

> 30% more required @ PSB injection

- Can we run with assumed losses? 10% in SPS and 10% in the LHC? At present we have higher transmission (>99%) in LHC
- Scraped beam (tails):
  - Does not count significantly for luminosity but counts for intensity/losses
  - Does it counts for evaluating intensity limits?
- Shall we scrape it in the PS/PSB? Are tail regenerated along the way? And why?

Room to improve integrated luminosity?

- Do we have a single number to qualify efficiency in leveling mode?

- How to increase efficiency for physics?
  - What are the main drivers of inefficiency?
  - How can we reduce injection time?
  - With more energy stored, will we get more beam dumps?

- How can we improve LHC reliability?

- Could one increase the LHC run from 150 to 160 days (with protons only)?
  - Reduce LHC-technical stop and optimize injectors technical stops?
  - Reduce the period of Intensity ramp-up?
  - Reduce the length of a scrubbing run? New and more effective schemes?
  - Can we afford an ion run? Or can we run for longer time?

“Exotic (?)” ideas

- Can we play with distributions both longitudinal and transverse to minimize space charge effects (and IBS?)

- Flat beams from optics (**or eventually from emittance**)?
  Will this bring to more integrated luminosity?

What the experiments can do for us?

- How hard is the PU limit at 100?
- How hard is the limit in bunch length? Does it help for the pile-up? Larger separation among vertices?

If bottleneck remains space-charge in PS …

Alternative scenarios to evaluate with usual triple-splitting

1) Double harmonics on injection flat-bottom h=7+h=14 coupled to either a single harmonics beam in the PSB or a double harmonics. **Aim**: longer bunches
2) Acceleration-deceleration scheme (during the 1.2 s inj. flat-bottom). **Aim**: larger energy on inj. flat bottom
3) Alternative optics on injection flat bottom. **Aim**: larger average beam size

Alternative scenarios with batch compression-merging

1) Tests 2012 for the batch-compression scheme. **Aim**: beam operational and deliverable to the SPS
2) Tests of the other schemes. **Aim:** start testing. The beam will not be sent to the SPS as the high-energy manipulations cannot be performed

Single batch beams with L4

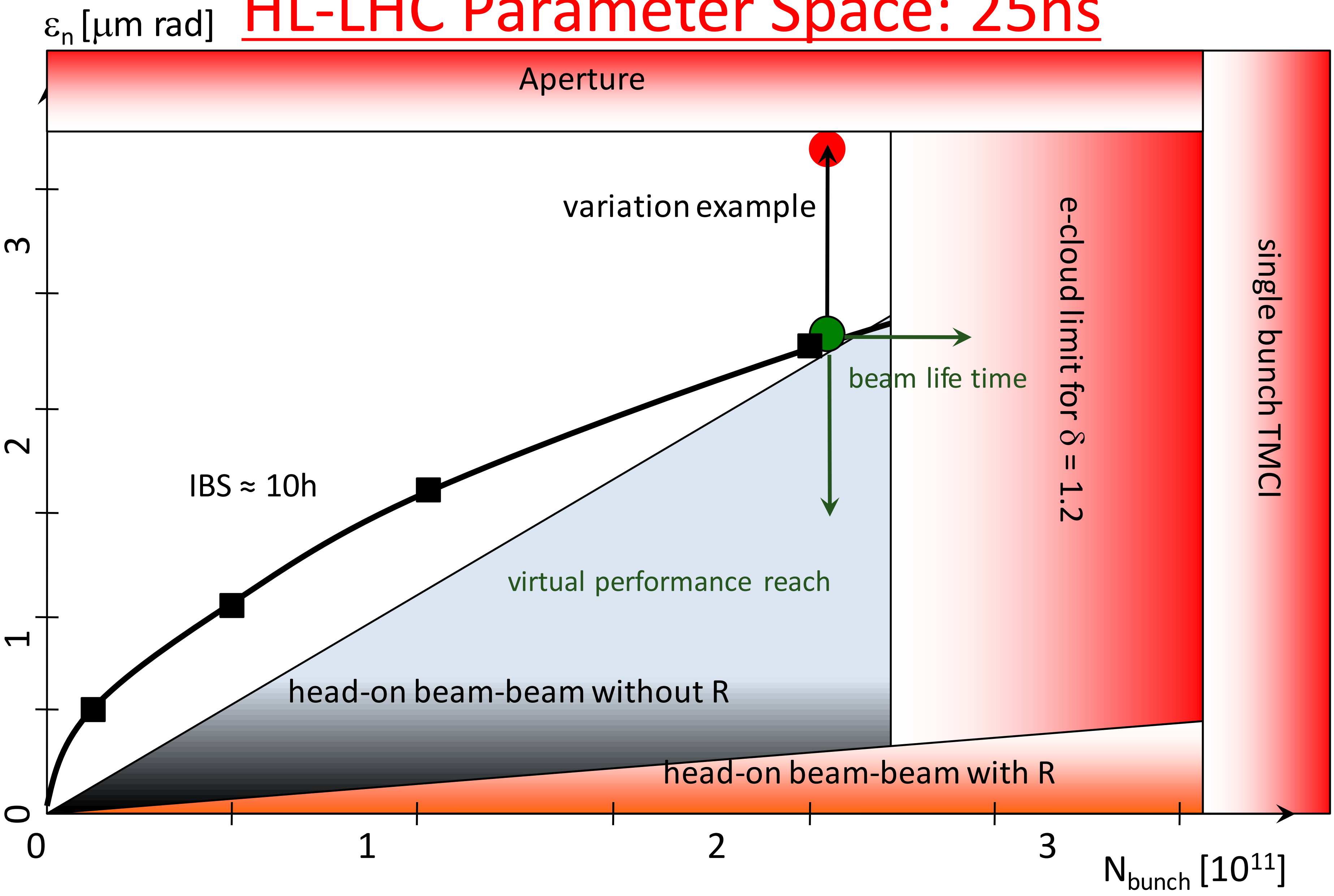
1) Define the max absolute Laslett to be compatible with a very short injection flat bottom (or eventually injection on a non-zero Bdot)

Tentative parameter lists

(from O. Bruning for the first 2 columns, with modifications for the X-angle, first estimate by Roland for the last column)

	25 ns	50 ns	Micro-batch (25 ns)	First LIU offer for micro-batch
# Bunches	2808	1404	1680	1680
p/bunch [10^{11}]	**2.0 (1.01 A)**	**3.3 (0.83 A)**	**2.8 (0.85 A)**	**2.0 (0.61 A)**
ε_L [eV.s]	2.5	2.5	2.5	2.5
σ_z [cm]	7.5	7.5	7.5	7.5
$\sigma_{\delta p/p}$ [10^{-3}]	0.1	0.1	0.1	0.1
$\gamma\varepsilon_{x,y}$ [μm]	**2.5**	**3.0**	**3.0**	**2.0**
β^* [cm]	15	15	15	15
X-angle [μrad]	590 (12.5 σ)	590 (11.4 σ)	590 (11.4 σ)	460 (10.9 σ)
Loss factor	0.30	0.33	0.33	0.34
Peak lumi [10^{34}]	6.0	7.4	6.4	5.1
Virtual lumi [10^{34}]	20.0	22.7	19.5	14.9
$T_{leveling}$ [h] @ 5E34	**7.8**	**6.8**	**6.5**	**3.9 !!!**
#Pile up @5E34	123	247	206	206

HL-LHC Parameter Space: 25ns



HL-LHC Parameter Space: 50ns

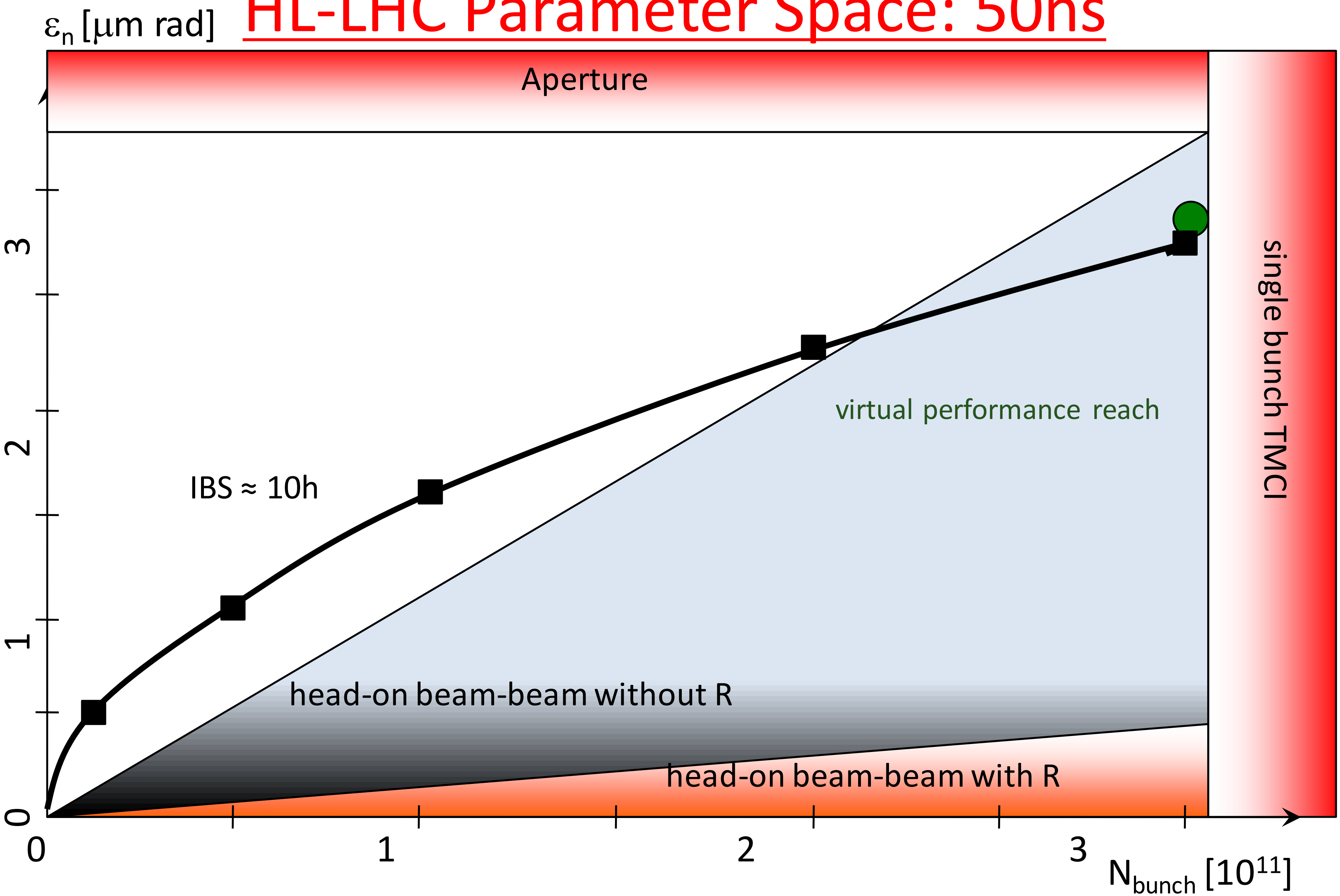


Table of dreams – updated (I)

25 ns	Ib [e11]	Exy [um]	scaled I_b^2/e_{xy}
HL-LHC target (LHC flat-top)	**2.0**	**2.5**	**1.00**
LIU scenario (SPS extraction)			
LIU baseline (>LS2)	2.3	3.6	0.68
+ PS ΔQ to -0.30, PSB DQ to -0.36 (>LS2)	2.2	2.5	0.89
+ "stretch" blowup/losses (>LS3)	2.3	2.4	1.18

50 ns	I [e11]	Exy [um]	scaled I_b^2/e_{xy}
HL-LHC target (LHC flat-top)	**3.3**	**3.0**	**1.00**
LIU scenario (SPS extraction)			
LIU baseline (>LS2)	2.7	2.7	0.55
+ PS longitudinal stability 3.7e11 (>LS3)	3.3	3.3	0.67
+ SPS ΔQ to -0.18 (>LS3)	3.3	2.8	0.79
+ "stretch" blowup/losses (>LS3)	3.4	2.6	1.05

Now including brightness dilution in LHC in final quality factor

Table of dreams – updated (II)

25 ns	Ib [e11]	Exy [um]	scaled I_b^2/e_{xy}
HL-LHC target (LHC flat-top)	**2.2**	**2.5**	**1.00**
LIU scenario (SPS extraction)			
LIU baseline (>LS2)	2.3	3.6	0.56
+ PS ΔQ to -0.30, PSB DQ to -0.36 (>LS3)	2.2	2.5	0.74
+ "stretch" blowup/losses (>LS3)	2.3	2.4	0.97

50 ns	I [e11]	Exy [um]	scaled I_b^2/e_{xy}
HL-LHC target (LHC flat-top)	**3.5**	**3.0**	**1.00**
LIU scenario (SPS extraction)			
LIU baseline (>LS2)	2.7	2.7	0.49
+ PS longitudinal stability 3.7e11 (>LS3)	3.3	3.3	0.60
+ SPS ΔQ to -0.18 (>LS3)	3.3	2.8	0.70
+ "stretch" blowup/losses (>LS3)	3.4	2.6	0.93

Now including brightness dilution in LHC in final quality factor

Alternative leveling mechanisms

- Dynamic β^* change
- Dynamic crossing angle change
- Dynamic separation