6th Collimation Upgrade Specification Meeting
CERN, Geneva, Switzerland
April 20th, 2012

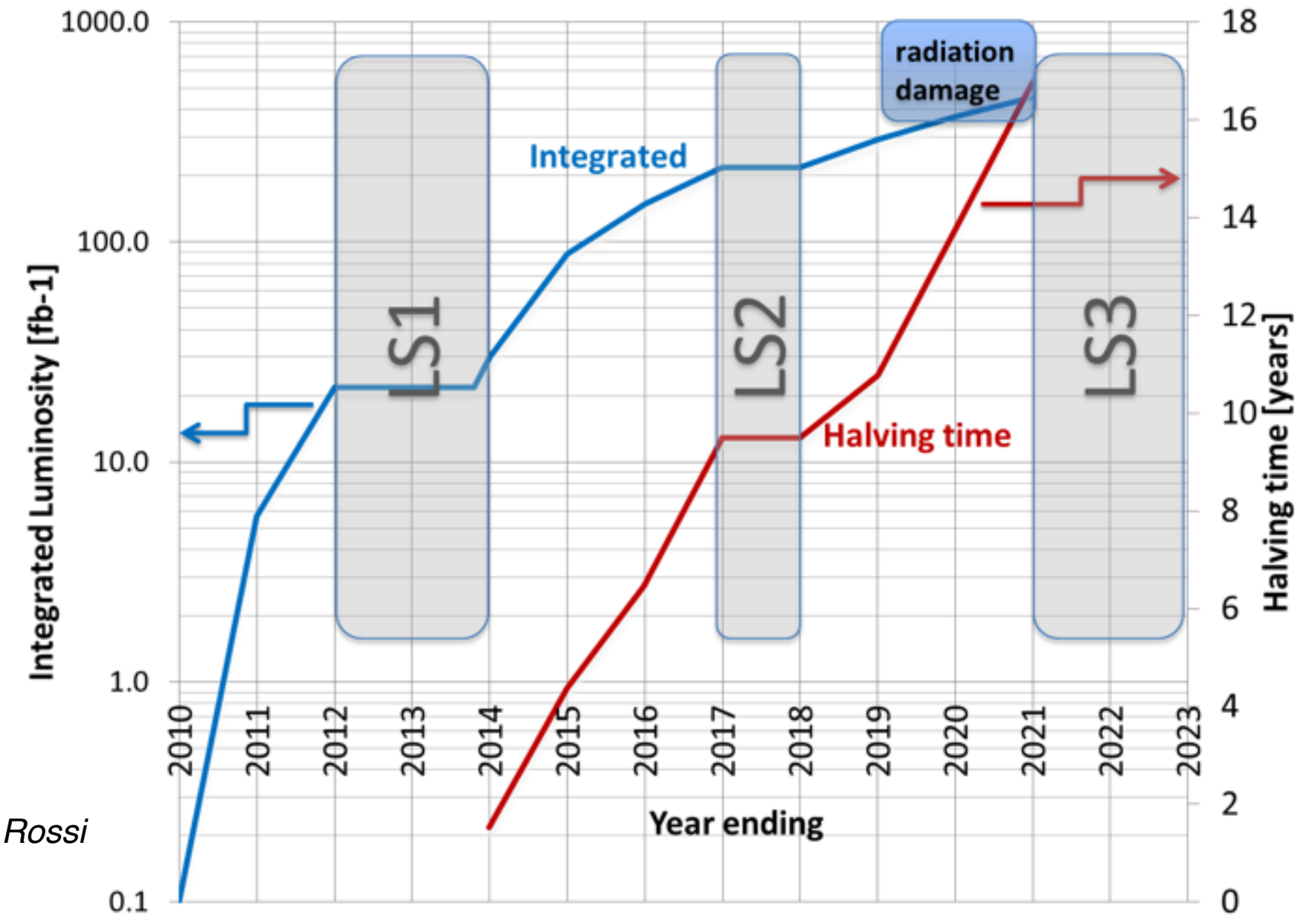
Collimator upgrade scenarios for impedance calculations

S. Redaelli and R. Bruce
based on previous studies by the collimation team

Outline

- ☑ Introduction
- ☑ Upgrade strategy
- ☑ Scenarios for settings
- ☑ Conclusions

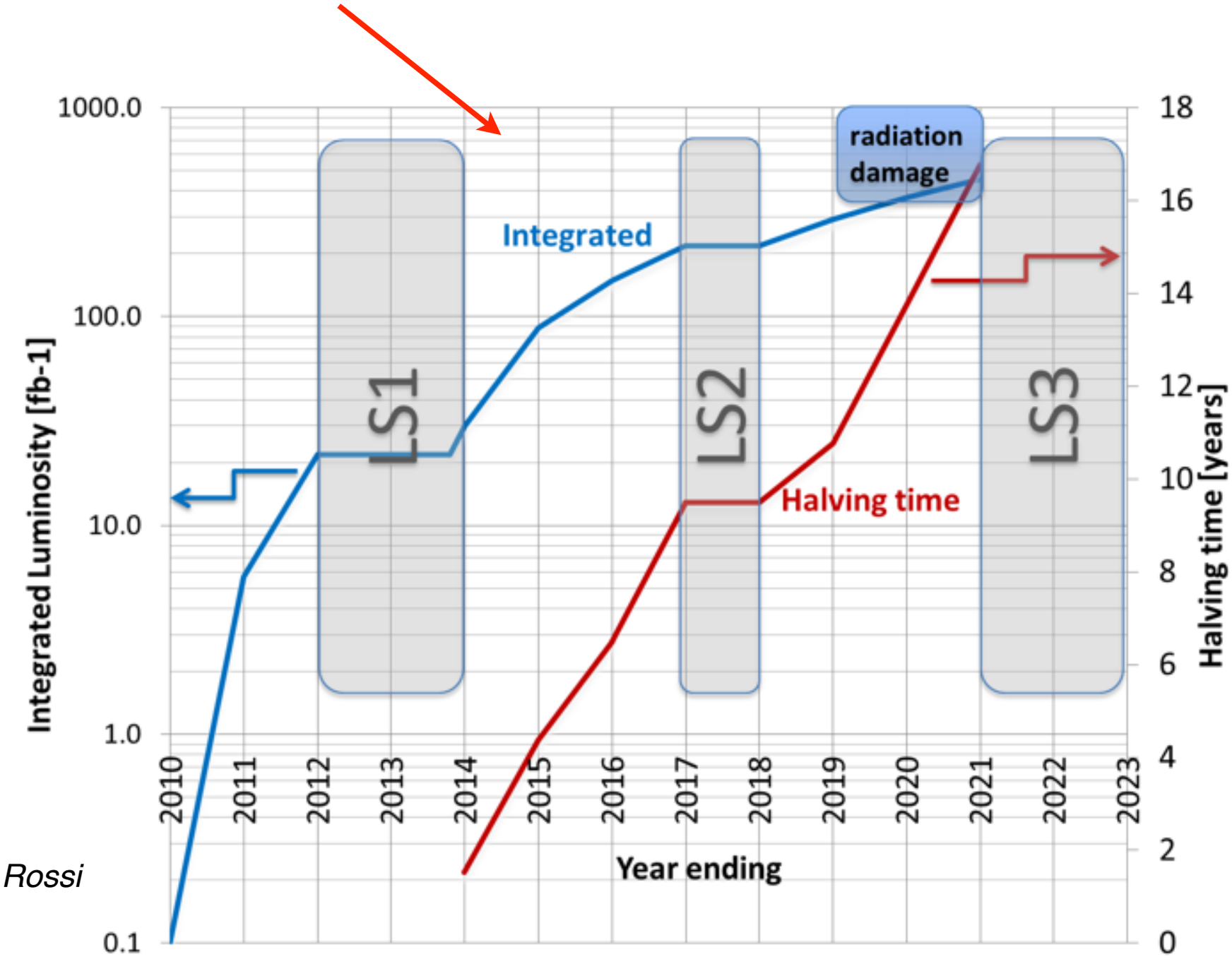
Present HL timeline



L. Rossi

Present HL timeline

~ Nominal energy and Luminosity



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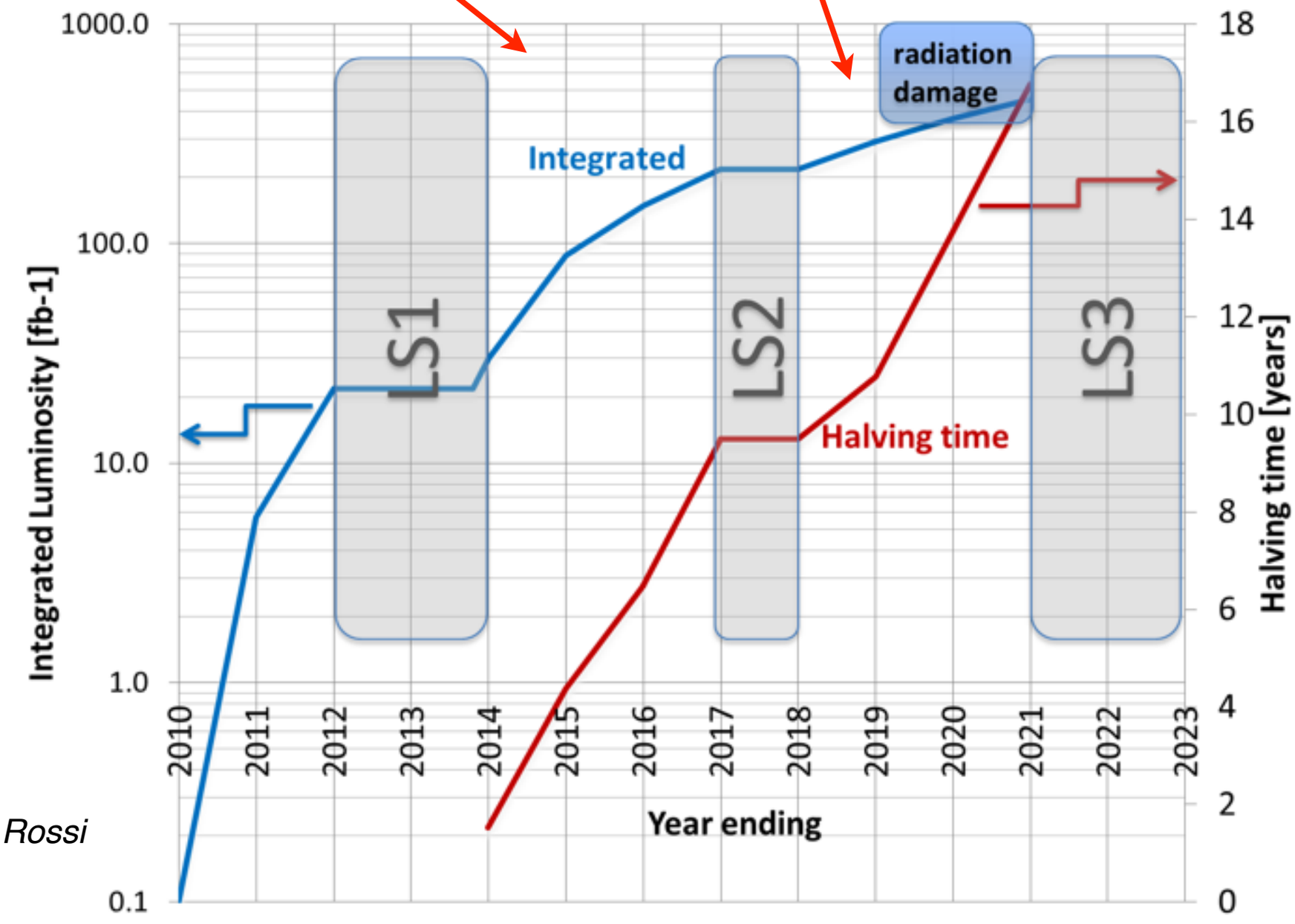
Double the LHC luminosity



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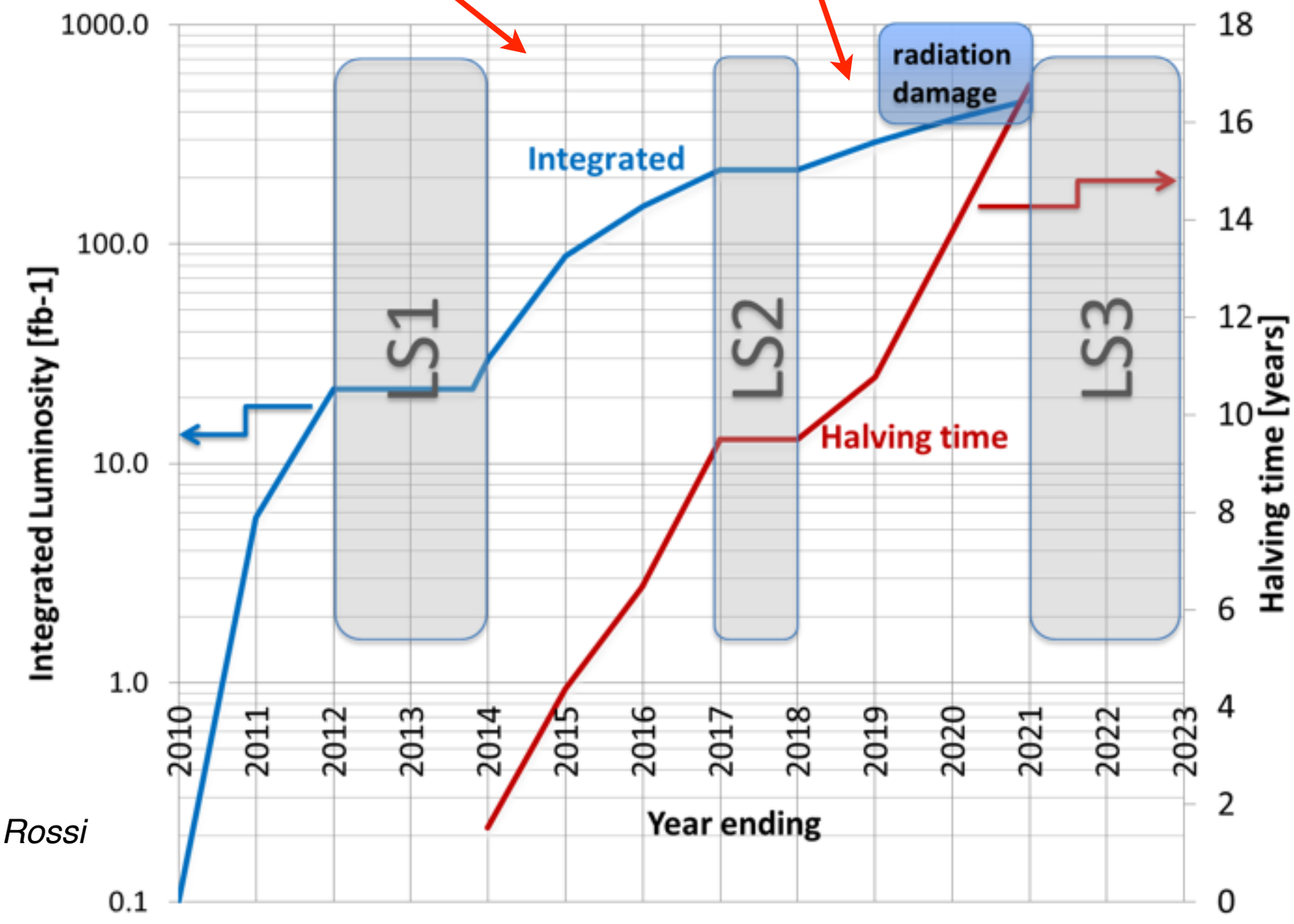
~ 3000 fb^{-1}!



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  - *Re-think IR1/5 collimation for new optics options/constraints*

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- ☑ New injection / dump collimation → *Injection&dump team*

Upgrade strategy (I)

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- **Shutdowns 2010-11 and 2011-12**
  - New IR2 layout for improved ALICE data taking
  - Software for faster and more robust collimator alignment
  - Improved protection strategy (β^* limits)
  - Improved controls HW: OP efficiency against downtimes from radiation

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- **LS1 (LHC energy to nominal)**
  - **BPM-integrated design** in experimental and dump regions (16 tertiary and 2 secondary) → **Faster** alignment in the IP's, **smaller β^***, improved **machine protection.**
  - New IP8 layout (to allow installation of TCTs with BPMs)
  - Considering **new passive absorbers in IP3** (longer lifetime of warm magnets)
  - Replacement of electronics components to improve redundancy
  - Update the **air duct** in the cleaning insertion

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- **LS2 (double LHC luminosity)**
  - Possible first upgrade of experimental regions: **DS collimators**
  - Additional collimators equipped with **BPMs** (faster alignment, better protection)
  - **Improved design** and **new materials** (less impedance, more robustness)
  - In particular, new robust TCTs for improved beta* reach
  - Investigate collimator HW **aging** / lifetime
  - Remote handling (partly)

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LS3 (Hi-Lumi LHC)

- Re-design of **collimator layout** in the experiments regions

  (DS collimators + additional local protection for ATS optics)
- Complete **DS collimation** in all the required IRs (also IR3/7 if needed)
- New collimator materials to **replace collimators** that have aged. BPM design.
- Fully remote handling in radiation environment
- New concepts for improved cleaning (crystal, hollow e-lens) - if needed

“Relaxed” and “tight” settings

$$\mathrm{NSIG}_{\mathrm{tight}}^{4\ \mathrm{TeV}} = \mathrm{NSIG}_{7\ \mathrm{TeV}} \times \sqrt{\frac{4\ \mathrm{TeV}}{7\ \mathrm{TeV}}}$$

	Relaxed 2011	Nominal	Tight at 4 TeV
TCP-IR7	5.7	6.0	4.5
TCSG-IR7	8.5	7.0	5.3
TCLA-IR7	17.7	10.0	7.6
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TCSG-IR6	9.3	7.5	5.7
TCDQ-IR6	10.6	8.0	6.0

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  - *Only TCP gaps are equivalent to the nominal 7 TeV settings in mm*

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- Estimates to be updated: target beta* and benefits of BPM design

2012 settings

Parameter	Unit	Plane	Type	Set 1	Set 2	Set 3	Set 4
				Injection	Top energy	Squeezed	Collision
Energy	[GeV]	n.a.	n.a.	450	4000	4000	4000
β^* in IR1/5	[m]	n.a.	n.a.	11.0	11.0	0.6	0.6
β^* in IR2	[m]	n.a.	n.a.	10.0	10.0	3.0	3.0
β^* in IR8	[m]	n.a.	n.a.	10.0	10.0	3.0	3.0
Crossing angle IR1/5	[μrad]	n.a.	n.a.	170	145	145	145
Crossing angle IR2	[μrad]	n.a.	n.a.	170	220 (H)	220 (H)	100 (V)
Crossing angle IR8	[μrad]	n.a.	n.a.	170	90	90	90
Beam separation	[mm]	n.a.	n.a.	2.0	0.65	0.65	0.0
Primary cut IR7	[σ]	H,V,S	TCP	5.7	4.3	4.3	4.3
Secondary cut IR7	[σ]	H,V,S	TCSG	6.7	6.3	6.3	6.3
Quartiary cut IR7	[σ]	H,V	TCLA	10.0	8.3	8.3	8.3
Primary cut IR3	[σ]	H	TCP	8.0	12.0	12.0	12.0
Secondary cut IR3	[σ]	H	TCSG	9.3	15.6	15.6	15.6
Quartiary cut IR3	[σ]	H,V	TCLA	10.0	17.6	17.6	17.6
Tertiary cut IR1/5	[σ]	H,V	TCT	13.0	26.0	9.0	9.0
Tertiary cut IR2/8	[σ]	H,V	TCT	13.0	26.0	12.0	12.0
Physics debris collimators	[σ]	H	TCL	out	out	out	10.0
Primary protection IR6	[σ]	H	TCSG	7.0	7.1	7.1	7.1
Secondary protection IR6	[σ]	H	TCDQ	8.0	7.6	7.6	7.6

4 sets of beam-based settings, smooth transition between different sets.

Each setting set must be validated by loss maps.

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Quartiary cut IR7	[σ]	H,V	TCLA	10.0	8.3	8.3	8.3
Primary cut IR3	[σ]	H	TCP	8.0	12.0	12.0	12.0
Secondary cut IR3	[σ]	H	TCSG	9.3	15.6	15.6	15.6
Quartiary cut IR3	[σ]	H,V	TCLA	10.0	17.6	17.6	17.6
Tertiary cut IR1/5	[σ]	H,V	TCT	13.0	26.0	9.0	9.0
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Primary cut IR3	[σ]	H	TCP	8.0	12.0	12.0	12.0
Secondary cut IR3	[σ]	H	TCSG	9.3	15.6	15.6	15.6
Quartiary cut IR3	[σ]	H,V	TCLA	10.0	17.6	17.6	17.6
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Secondary protection IR6	[σ]	H	TCDQ	8.0	7.6	7.6	7.6

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Reminder of present collimation

Table 1: List of movable LHC collimators.

Functional type	Name	Plane	Num.	Material
Primary IR3	TCP	H	2	CFC
Secondary IR3	TCSG	H	8	CFC
Absorbers IR3	TCLA	H,V	8	W
Primary IR7	TCP	H,V,S	6	CFC
Secondary IR7	TCSG	H,V,S	22	CFC
Absorbers IR7	TCLA	H,V	10	W
Tertiary IR1/2/5/8	TCT	H,V	16	W
Physics debris absor.	TCL	H	4	Cu
Dump protection	TCSG	H	2	CFC
	TCDQ	H	2	C
Inj. prot. (lines)	TCDI	H,V	13	CFC
Inj. prot. (ring)	TDI	V	2	C
	TCLI	V	4	CFC
	TCDD	V	1	CFC

Reminder: all settings will be given in units of the betatron beam size along the collimator axis:

$$\sigma_{\mathrm{coll}} = \sqrt{\beta_{\mathrm{coll}} \epsilon_{\mathrm{nom.}}}$$

$$\beta_{\mathrm{coll}} = \sqrt{\beta_x^2 \cos^2(\theta_{\mathrm{coll}}) + \beta_y^2 \sin^2(\theta_{\mathrm{coll}})}$$

Scenarios after LS1 at 6.5-7.0 TeV

Parameter	Unit	Plane	Type	Mat.	Case 1	Case 2
Primary cut IR7	[σ]	H,V,S	TCP	C	5.7	5.7
Secondary cut IR7	[σ]	H,V,S	TCSG	C	7.7	6.7
Quartiary cut IR7	[σ]	H,V	TCLA	W	9.7	9.0
Tertiary cut IR1/5	[σ]	H,V	TCT	W	10.4	9.5
Tertiary cut IR2/8	[σ]	H,V	TCT	W	12.0	12.0
Physics debris collimators	[σ]	H	TCL	Cu	12.0	12.0
Primary protection IR6	[σ]	H	TCSG	C	8.5	7.5
Secondary protection IR6	[σ]	H	TCDQ	C	9.0	8.0
Primary cut IR3	[σ]	H	TCP	C	12.0	12.0
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Quartiary cut IR3	[σ]	H,V	TCLA	W	17.6	17.6

- ☑ Case 1: essentially the same settings in mm than in 2012
  - *Based on R. Bruce's work presented at Evian2011*
  - *Case 1 is slightly tighter than 2012 settings: kept a 2 sigma retraction*

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Secondary cut IR3	[σ]	H	TCSG	C	15.6	15.6
Quartiary cut IR3	[σ]	H,V	TCLA	W	17.6	17.6

- ☑ Case 1: essentially the same settings in mm than in 2012
  - *Based on R. Bruce's work presented at Evian2011*
  - *Case 1 is slightly tighter than 2012 settings: kept a 2 sigma retraction*
- ☑ Case 2: we are confident that we can achieve nominal settings
  - *If achievable, updated beta* will be established!*

Scenarios after LS1 at 6.5-7.0 TeV

Parameter	Unit	Plane	Type	Mat.	Case 1	Case 2
Primary cut IR7	[σ]	H,V,S	TCP	C	5.7	5.7
Secondary cut IR7	[σ]	H,V,S	TCSG	C	7.7	6.7
Quartiary cut IR7	[σ]	H,V	TCLA	W	9.7	9.0
Tertiary cut IR1/5	[σ]	H,V	TCT	W	10.4	9.5
Tertiary cut IR2/8	[σ]	H,V	TCT	W	12.0	12.0
Physics debris collimators	[σ]	H	TCL	Cu	12.0	12.0
Primary protection IR6	[σ]	H	TCSG	C	8.5	7.5
Secondary protection IR6	[σ]	H	TCDQ	C	9.0	8.0
Primary cut IR3	[σ]	H	TCP	C	12.0	12.0
Secondary cut IR3	[σ]	H	TCSG	C	15.6	15.6
Quartiary cut IR3	[σ]	H,V	TCLA	W	17.6	17.6

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  - *Based on R. Bruce's work presented at Evian2011*
  - *Case 1 is slightly tighter than 2012 settings: kept a 2 sigma retraction*
- ☑ Case 2: we are confident that we can achieve nominal settings
  - *If achievable, updated beta* will be established!*
- ☑ Remark: BPM-design benefits not taken into account
  - *They will have an impact on the minimum TCT settings.*

Scenarios after LS2 at 6.5-7.0 TeV

Parameter	Unit	Plane	Type	Mat.	Case 1	Case 2
Primary cut IR7	[σ]	H,V,S	TCP	C	5.7	5.7
Secondary cut IR7	[σ]	H,V,S	TCSG	C	7.7	6.7
Secondary cut IR7	[σ]	H,V,S	TCSM	W	7.7	6.7
Quartiary cut IR7	[σ]	H,V	TCLA	W	9.7	9.0
Tertiary cut IR1/5	[σ]	H,V	TCT	W	10.4	9.5
Tertiary cut IR2/8	[σ]	H,V	TCT	W	12.0	12.0
Physics debris collimators	[σ]	H	TCL	Cu	12.0	12.0
Primary protection IR6	[σ]	H	TCSG	C	8.5	7.5
Secondary protection IR6	[σ]	H	TCDQ	C	9.0	8.0
Primary cut IR3	[σ]	H	TCP	C	12.0	12.0
Secondary cut IR3	[σ]	H	TCSG	C	15.6	15.6
Quartiary cut IR3	[σ]	H,V	TCLA	W	17.6	17.6
Local DS cleaning in IR1/5 or IR2	[σ]	H	TCLD	Cu/W	12.0	12.0

Scenarios after LS2 at 6.5-7.0 TeV

Parameter	Unit	Plane	Type	Mat.	Case 1	Case 2
Primary cut IR7	[σ]	H,V,S	TCP	C	5.7	5.7
Secondary cut IR7	[σ]	H,V,S	TCSG	C	7.7	6.7
Secondary cut IR7	[σ]	H,V,S	TCSM	W	7.7	6.7
Quartiary cut IR7	[σ]	H,V	TCLA	W	9.7	9.0
Tertiary cut IR1/5	[σ]	H,V	TCT	W	10.4	9.5
Tertiary cut IR2/8	[σ]	H,V	TCT	W	12.0	12.0
Physics debris collimators	[σ]	H	TCL	Cu	12.0	12.0
Primary protection IR6	[σ]	H	TCSG	C	8.5	7.5
Secondary protection IR6	[σ]	H	TCDQ	C	9.0	8.0
Primary cut IR3	[σ]	H	TCP	C	12.0	12.0
Secondary cut IR3	[σ]	H	TCSG	C	15.6	15.6
Quartiary cut IR3	[σ]	H,V	TCLA	W	17.6	17.6
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Quartiary cut IR3	[σ]	H,V	TCLA	W	17.6	17.6
Local DS cleaning in IR1/5 or IR2	[σ]	H	TCLD	Cu/W	12.0	12.0

- Two differences from previous cases:
  - *A. Possibility to have new metallic (low-impedance) TCSG's in IR7.*
  - *B. Possibility to equip some IRs with new DS collimators*

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Physics debris collimators	[σ]	H	TCL	Cu	12.0	12.0
Primary protection IR6	[σ]	H	TCSG	C	8.5	7.5
Secondary protection IR6	[σ]	H	TCDQ	C	9.0	8.0
Primary cut IR3	[σ]	H	TCP	C	12.0	12.0
Secondary cut IR3	[σ]	H	TCSG	C	15.6	15.6
Quartiary cut IR3	[σ]	H,V	TCLA	W	17.6	17.6
Local DS cleaning in IR1/5 or IR2	[σ]	H	TCLD	Cu/W	12.0	12.0

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- Additional BPM-design collimators in the cleaning insertions

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Parameter	Unit	Plane	Type	Mat.	Case 1	Case 2
Primary cut IR7	[σ]	H,V,S	TCP	C	5.7	5.7
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Quartiary cut IR7	[σ]	H,V	TCLA	W	9.7	9.0
Tertiary cut IR1/5	[σ]	H,V	TCT	W	10.4	9.5
Tertiary cut IR2/8	[σ]	H,V	TCT	W	12.0	12.0
Physics debris collimators	[σ]	H	TCL	Cu	12.0	12.0
Primary protection IR6	[σ]	H	TCSG	C	8.5	7.5
Secondary protection IR6	[σ]	H	TCDQ	C	9.0	8.0
Primary cut IR3	[σ]	H	TCP	C	12.0	12.0
Secondary cut IR3	[σ]	H	TCSG	C	15.6	15.6
Quartiary cut IR3	[σ]	H,V	TCLA	W	17.6	17.6
Local DS cleaning in IR1/5 or IR2	[σ]	H	TCLD	Cu/W	12.0	12.0

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  - *B. Possibility to equip some IRs with new DS collimators*
- Additional BPM-design collimators in the cleaning insertions
- Possible new design for robust TCTs in the pipeline
  - *- Not yet considered in this table*

Hi-Lumi scenarios

Parameter	Unit	Plane	Type	Mat.	Case 1	Case 2	Case 3	Case 4
Primary cut IR7	[σ]	H,V,S	TCP	C	5.7	5.7	5.7	–
Secondary cut IR7	[σ]	H,V,S	TCSG	C	7.7	6.7	6.7	–
Secondary cut IR7	[σ]	H,V,S	TCSM	W	7.7	6.7	6.7	–
Quartiary cut IR7	[σ]	H,V	TCLA	W	9.7	9.0	9.0	–
Tertiary cut IR1/5	[σ]	H,V	TCT	W	10.4	9.5	9.5	9.5
Tertiary cut IR2/8	[σ]	H,V	TCT	W	12.0	12.0	12.0	12.0
Physics debris collimators	[σ]	H	TCL	Cu	12.0	12.0	12.0	12.0
Primary protection IR6	[σ]	H	TCSG	C	8.5	7.5	7.5	7.5
Secondary protection IR6	[σ]	H	TCDQ	C	9.0	8.0	8.0	8.0
Primary cut IR3	[σ]	H	TCP	C	12.0	12.0	12.0	5.7
Secondary cut IR3	[σ]	H	TCSG	C	15.6	15.6	15.6	6.7
Secondary cut IR3	[σ]	H	TCSM	W	15.6	15.6	15.6	6.7
Quartiary cut IR3	[σ]	H,V	TCLA	W	17.6	17.6	17.6	7.7
Local DS cleaning in IR1/5	[σ]	H	TCLD	Cu/W	12.0	12.0	12.0	12.0
Local DS cleaning in IR2	[σ]	H	TCLD	Cu/W	12.0	12.0	12.0	12.0
Local DS cleaning in IR3	[σ]	H	TCLD	Cu/W	12.0	12.0	–	15.0
Local DS cleaning in IR7	[σ]	H	TCLD	Cu/W	12.0	12.0	15.0	–

Hi-Lumi scenarios

Parameter	Unit	Plane	Type	Mat.	Case 1	Case 2	Case 3	Case 4
Primary cut IR7	[σ]	H,V,S	TCP	C	5.7	5.7	5.7	–
Secondary cut IR7	[σ]	H,V,S	TCSG	C	7.7	6.7	6.7	–
Secondary cut IR7	[σ]	H,V,S	TCSM	W	7.7	6.7	6.7	–
Quartiary cut IR7	[σ]	H,V	TCLA	W	9.7	9.0	9.0	–
Tertiary cut IR1/5	[σ]	H,V	TCT	W	10.4	9.5	9.5	9.5
Tertiary cut IR2/8	[σ]	H,V	TCT	W	12.0	12.0	12.0	12.0
Physics debris collimators	[σ]	H	TCL	Cu	12.0	12.0	12.0	12.0
Primary protection IR6	[σ]	H	TCSG	C	8.5	7.5	7.5	7.5
Secondary protection IR6	[σ]	H	TCDQ	C	9.0	8.0	8.0	8.0
Primary cut IR3	[σ]	H	TCP	C	12.0	12.0	12.0	5.7
Secondary cut IR3	[σ]	H	TCSG	C	15.6	15.6	15.6	6.7
Secondary cut IR3	[σ]	H	TCSM	W	15.6	15.6	15.6	6.7
Quartiary cut IR3	[σ]	H,V	TCLA	W	17.6	17.6	17.6	7.7
Local DS cleaning in IR1/5	[σ]	H	TCLD	Cu/W	12.0	12.0	12.0	12.0
Local DS cleaning in IR2	[σ]	H	TCLD	Cu/W	12.0	12.0	12.0	12.0
Local DS cleaning in IR3	[σ]	H	TCLD	Cu/W	12.0	12.0	–	15.0
Local DS cleaning in IR7	[σ]	H	TCLD	Cu/W	12.0	12.0	15.0	–

- Four scenarios:

  Cases 1-2: Equivalent of previous scenarios, with possibly more metallic collimators in IR7 and DS collimators in IR1/2/5.

  Case 3: Additional DS collimators in IR7?

  Case 4: Combined momentum cleaning (possibly with metallic TCSGs)

Hi-Lumi scenarios

Parameter	Unit	Plane	Type	Mat.	Case 1	Case 2	Case 3	Case 4
Primary cut IR7	[σ]	H,V,S	TCP	C	5.7	5.7	5.7	–
Secondary cut IR7	[σ]	H,V,S	TCSG	C	7.7	6.7	6.7	–
Secondary cut IR7	[σ]	H,V,S	TCSM	W	7.7	6.7	6.7	–
Quartiary cut IR7	[σ]	H,V	TCLA	W	9.7	9.0	9.0	–
Tertiary cut IR1/5	[σ]	H,V	TCT	W	10.4	9.5	9.5	9.5
Tertiary cut IR2/8	[σ]	H,V	TCT	W	12.0	12.0	12.0	12.0
Physics debris collimators	[σ]	H	TCL	Cu	12.0	12.0	12.0	12.0
Primary protection IR6	[σ]	H	TCSG	C	8.5	7.5	7.5	7.5
Secondary protection IR6	[σ]	H	TCDQ	C	9.0	8.0	8.0	8.0
Primary cut IR3	[σ]	H	TCP	C	12.0	12.0	12.0	5.7
Secondary cut IR3	[σ]	H	TCSG	C	15.6	15.6	15.6	6.7
Secondary cut IR3	[σ]	H	TCSM	W	15.6	15.6	15.6	6.7
Quartiary cut IR3	[σ]	H,V	TCLA	W	17.6	17.6	17.6	7.7
Local DS cleaning in IR1/5	[σ]	H	TCLD	Cu/W	12.0	12.0	12.0	12.0
Local DS cleaning in IR2	[σ]	H	TCLD	Cu/W	12.0	12.0	12.0	12.0
Local DS cleaning in IR3	[σ]	H	TCLD	Cu/W	12.0	12.0	–	15.0
Local DS cleaning in IR7	[σ]	H	TCLD	Cu/W	12.0	12.0	15.0	–

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  Case 4: Combined momentum cleaning (possibly with metallic TCSGs)

- Complete re-design of the IRs in the pipeline, following ATS:

  - New TCT materials, protection of Q4-Q6 - too early for precise figures

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- Established a baseline for discussion
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- Still many uncertainties on the final layouts
  - *Do we really need local collimation in the DSs?*
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  - *How many IRs can we equip in LS2 and LS3?*
  - *Will we need to add metallic collimators in IR7?*
- Benefits from integrated BLM design is under evaluation (R. Bruce)
  - *What can we gain after LS1 with BPMs in IP6 and at the TCTs?*
  - *Possible actions for LS2: BPM-collimators for the TCSG-H in IP7*
  - *How many more collimators with BPMs could be added in LS2?*