CERN

BBCW potentials for Run 4

P. Bélanger, A. Poyet, K. Skoufaris, G. Sterbini on behalf of BBCW team

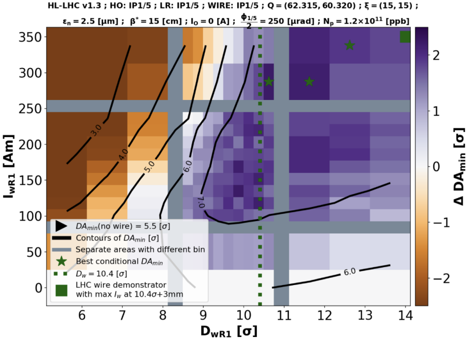
Our gratitude goes to **HL-LHC**, **CERN** *and* **TRIUMF** *management for the support,*
WP2/5/13 *for the inspiring discussions and encouragement,*
G. Iadarola *and* **S. Kostoglou** *for helping with the* **xsuite** *code* simulation framework.

Introduction

Assumption for the simulations

Results

HL-LHC configurations[1]

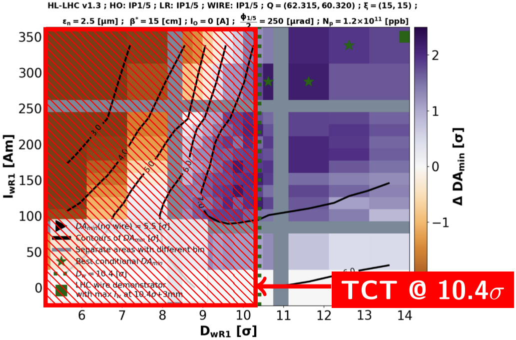


At the cost of $\int I_W dl$, the wire can be pushed away from the beam

$\rightarrow \int I_W dl =$ **450 Am.**

[1]From PRAB **24** 074001, 2021

HL-LHC configurations[1]



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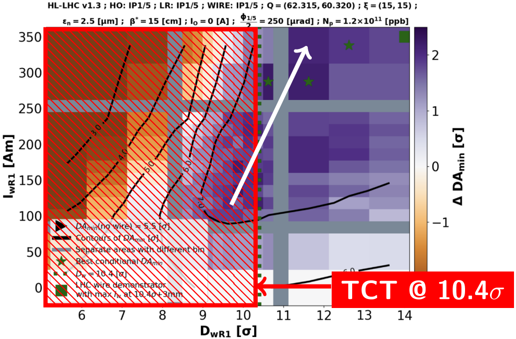

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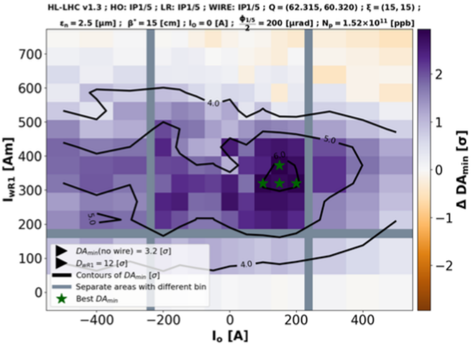
HL-LHC configurations[2]



Some synergies between the arc octupoles and the wires (at 12 σ).

[2]From PRAB **24** 074001, 2021

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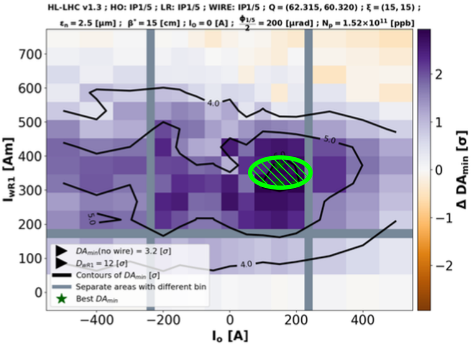

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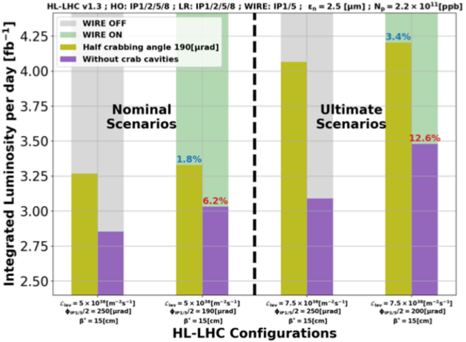

Performance gain by extending the levelling reach/time:

$\rightarrow$ w/ CC, BBCWs push $\int \mathcal{L} dt$ by 1.8-3.4%

$\rightarrow$ w/o CC, BBCWs push $\int \mathcal{L} dt$ by 6.2-12.6%

[3] From PRAB **24** 074001, 2021

EYETS scenario to fix intensity limitation (HEL, dilution kickers, RF?)

*under review

Year	ppb $[10^{11}]$	Virtual lumi. $[10^{34}\text{cm}^{-2}\text{s}^{-1}]$	Days in physics	θ [μrad]	β^*_{start} [cm]	β^*_{end} [cm]	CC	Max. PU
2029	1.8	4.4	90	380 *	70	30	exp	116
2030	1.8	9.0	120	500	100	20	on	132
			EYETS (≈5 months) HEL , dilution kickers?					
2031	2.2	13.5	90	500	100	20	on	132
2032	2.2	13.5	160	500	100	20	on	132
2033-34				Long shutdown 4				
2035	2.2	13.5	140	500	100	20	on	132
2036	2.2	16.9	170	500	100	15	on	132
2036	2.2	16.9	200	500	100	15	on	200

HEL cryo connections for efficient installation in EYETS (and avoiding sector warm-up) is extra scope.

R. Tomas in LHC performance workshop, January 2022 23

During the first years or Run 4, we expect a ramp-up of the HL-LHC performance (CC, β^*, . . .)

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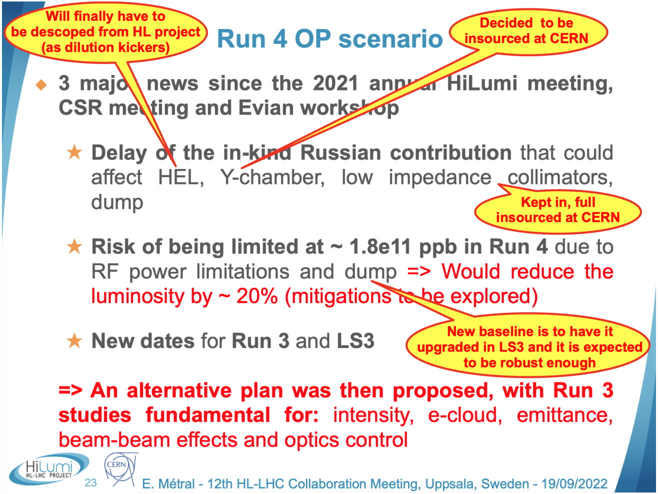

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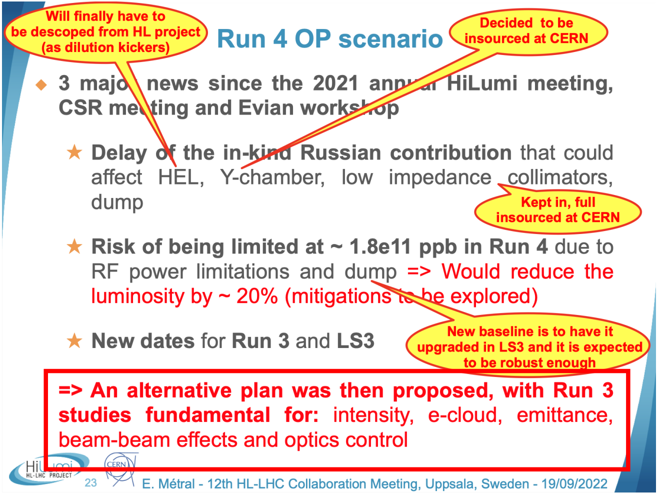

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BBCW potential for Run 4

- **Can we make use of the wire in an early stage of Run 4?**

BBCW potential for Run 4

- **Can we make use of the wire in an early stage of Run 4?**
- **What are the BBCW performance before reaching the β^*=15 cm?**
  $\rightarrow$ we will focus on β^*=30 cm and $N_b = 1.8\ 10^{11}$ ppb.

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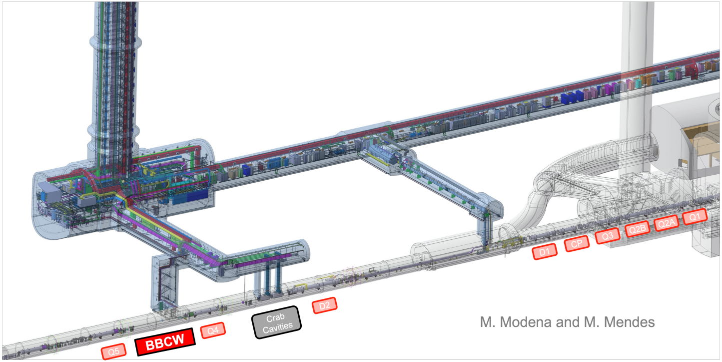
"Reserved" space for the wire [4]



[4] EDMS 2037987

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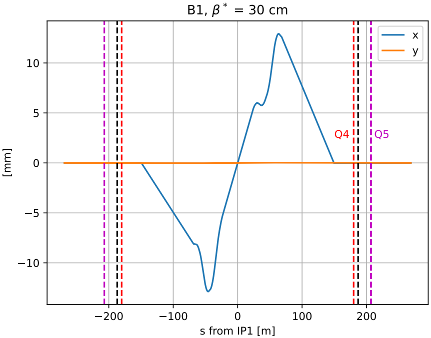
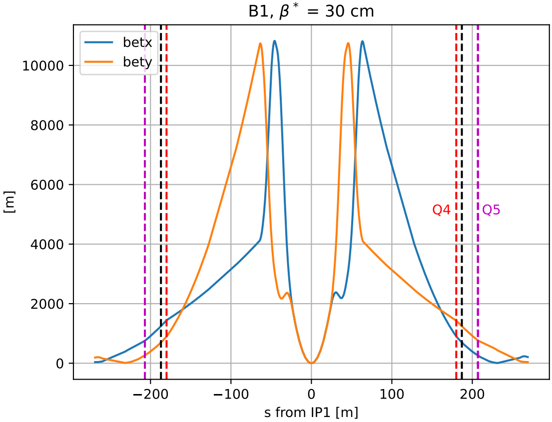


External to the crossing bump, close to the Q4.

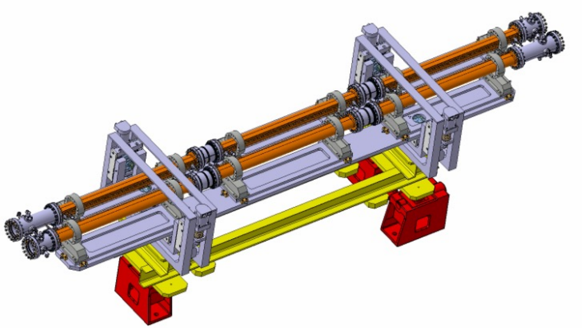
[4]EDMS 2037987

“Reserved” space



β_y/β_x close to the ones proposed of PRAB 18 121001, 2015.

Proposed wires' layout[5]



1 assembly/side/IP $\rightarrow$ 1 assembly $= 3 \times$ 1-m wire modules/beam

1 module can carry 150 A $\rightarrow$ 450 Am per beam/side/IP

[5] See Alessandro's presentation

Optics at $\beta^* = 30$ cm

	s from IP1 [m]	β_x [m]	β_y [m]	β_y/β_x
bbcw.i.3.**4l1**.b1	-189.50	1176.12	632.12	0.54
bbcw.i.2.**4l1**.b1	-188.25	1209.93	664.12	0.55
bbcw.i.1.**4l1**.b1	-187.00	1244.31	696.86	0.56
bbcw.i.1.**4r1**.b1	187.00	698.20	1243.97	1.78
bbcw.i.2.**4r1**.b1	188.25	664.72	1210.73	1.82
bbcw.i.3.**4r1**.b1	189.50	632.10	1177.87	1.86

In the simulations, we consider a 4.5 m assembly and 4$\times$3 wires per beams.

At $\beta^* = 30$ cm, 7 TeV, $\epsilon_n = 2.5\ \mu$m

	σ_x [mm]	σ_y [mm]
bbcw.i.3.**4l1**.b1:1	0.63	0.46
bbcw.i.2.**4l1**.b1:1	0.64	0.47
bbcw.i.1.**4l1**.b1:1	**0.65**	0.48
bbcw.i.1.**4r1**.b1:1	0.48	**0.65**
bbcw.i.2.**4r1**.b1:1	0.47	0.64
bbcw.i.3.**4r1**.b1:1	0.46	0.63

16 σ separation $\rightarrow$ $\approx$10 mm offset wrt the beam.

In the simulation, BBCWs are at the same **physical distance** from the beam. "BBCW at 16 σ" means that all BBCWs are at

$$16 \max_{BBWCs} \sigma. \tag{1}$$

DISCLAIMER: the present BBCW demonstrators are strongly coupled with the TCT settings. We assume the HL BBCW will be

- **NOT embedded in the TCTs**
- **STILL in the TCTs shadow** ($\rightarrow$ tight collimators setting are better for the BBCW, i.e. lower I_w).

Assuming the unfavourable collimators relaxed settings (TCT at 11.4 σ for $\beta^* = 0.15$ m), two scenarios envisaged:

- **Scenario A**: BBCW at $> 16.1\ \sigma$ at $\beta^* = 0.30$ m IF TCT position constant in mm
- **Scenario B**[6]: BBCW at $> 11.4\ \sigma$ at $\beta^* = 0.30$ m IF TCT position constant σ.

[6] specific MKD-TCT phase constraints are needed.

At $\beta^* = 6$ m, 0.45 TeV, $\epsilon_n = 2.5$ μm

	σ_x [mm]	σ_y [mm]
bbcw.i.3.**4l1**.b1:1	1.13	0.50
bbcw.i.2.**4l1**.b1:1	1.14	0.49
bbcw.i.1.**4l1**.b1:1	**1.16**	0.49
bbcw.i.1.**4r1**.b1:1	0.49	**1.17**
bbcw.i.2.**4r1**.b1:1	0.49	1.15
bbcw.i.3.**4r1**.b1:1	0.50	1.13

Garage position of the BBCW driven by the injection σ

Assuming 25 σ of garage position yields $\approx$30 mm offset wrt the beam $\rightarrow$ implication on the stroke of the BBCW movement.

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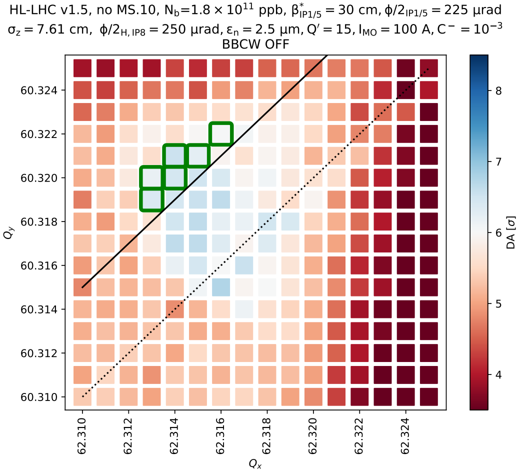
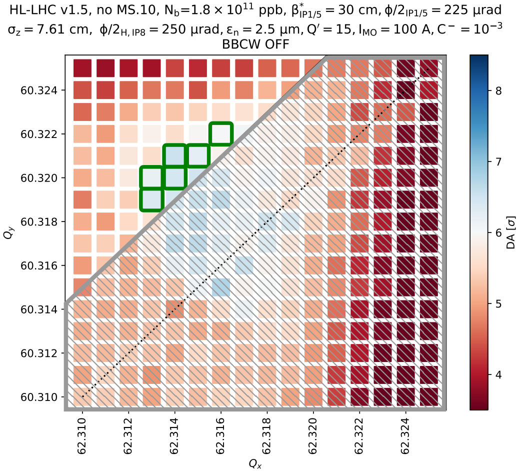


BBCW OFF with $\beta^* = 0.30$ m, $N_b = 1.8\ 10^{11}$ ppb, $\theta_c/2 = 225\ \mu$rad.



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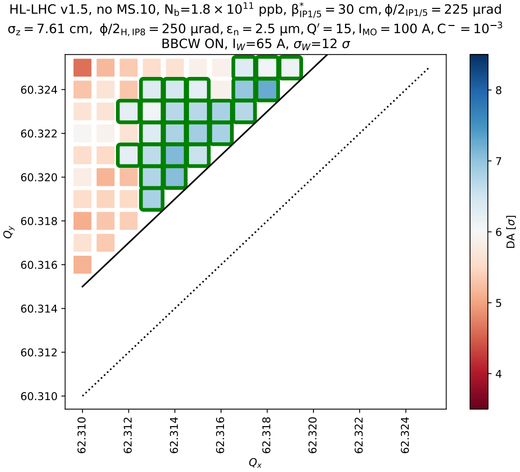
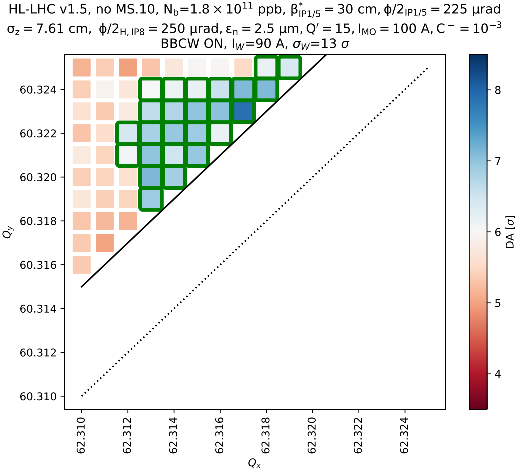
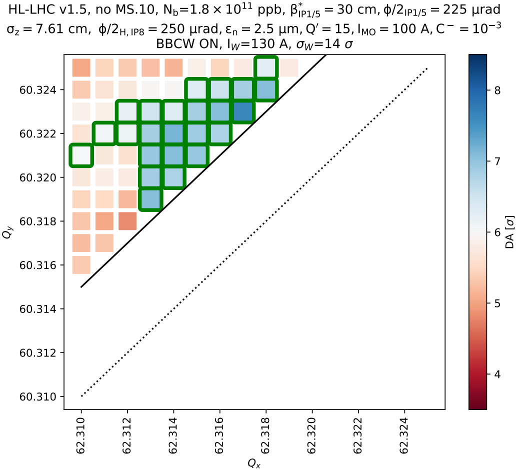


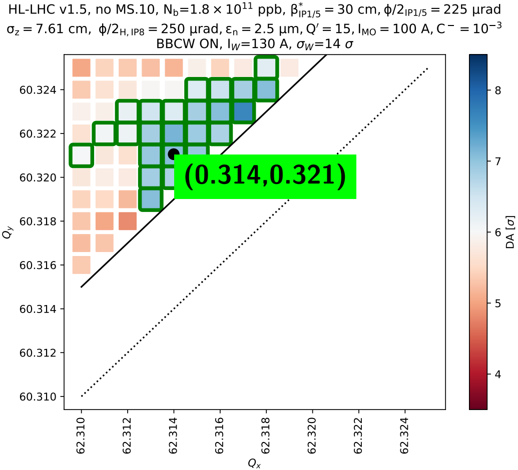
BBCW ON, I_w =65 A at 12 σ.



BBCW ON, I_w =90 A at 13 σ.



BBCW ON, I_w =130 A at 14 σ.



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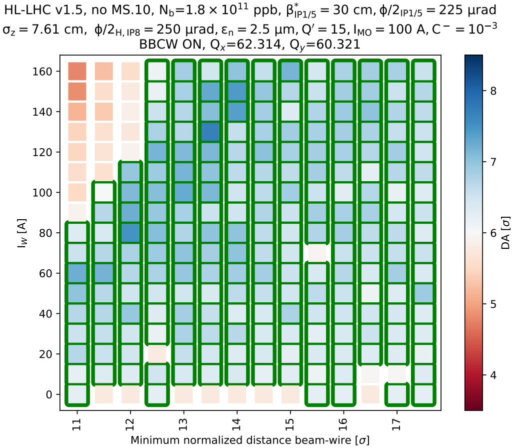
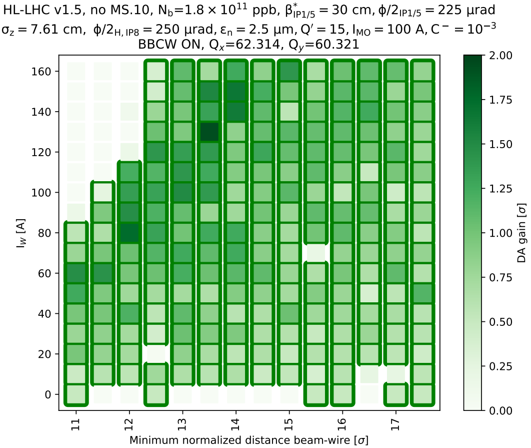


Distance vs I_w scan at Q=(0.314, 0.321): **up to 2 σ of DA gain**.



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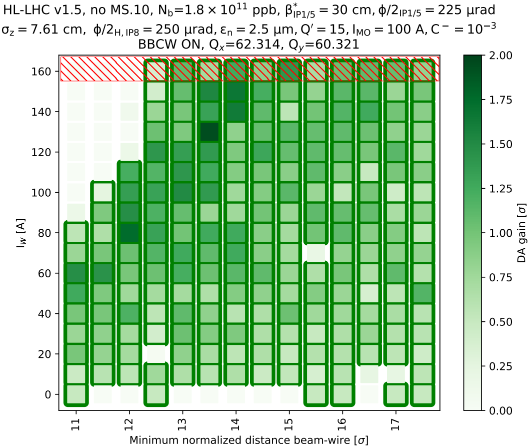

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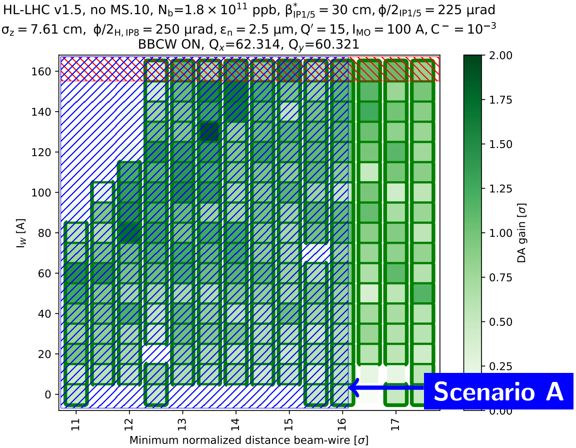

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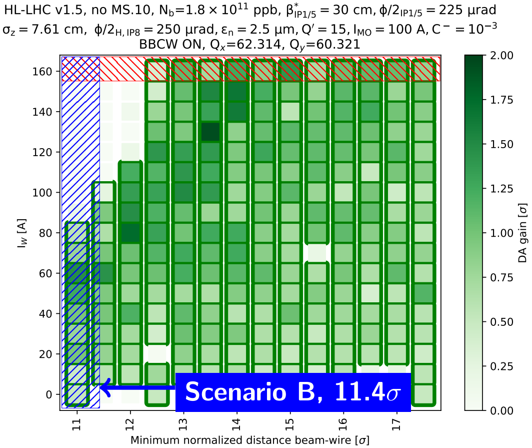

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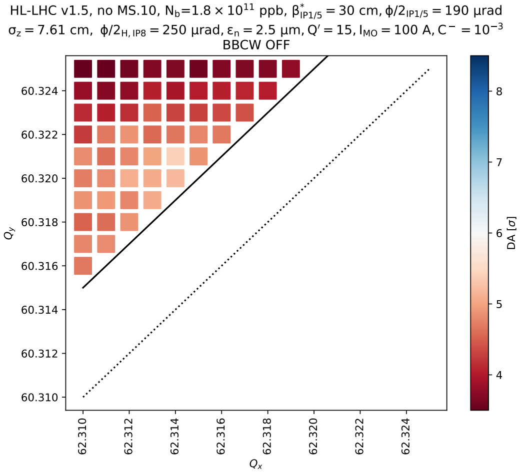
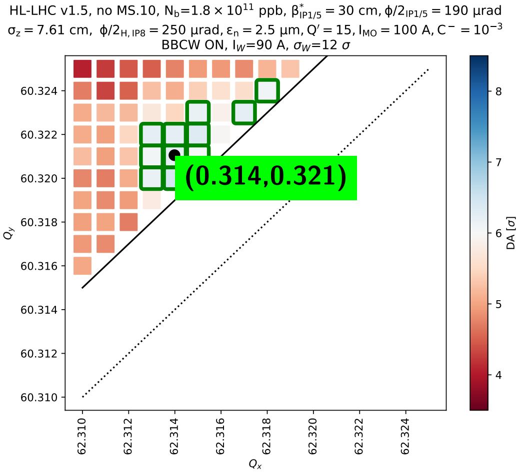
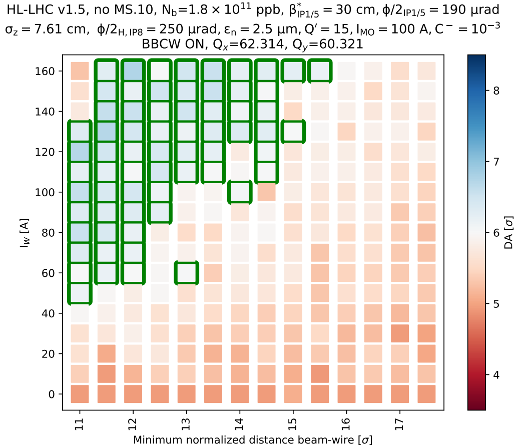


BBCW OFF with $\beta^* = 0.30$ m, $N_b = 1.8\ 10^{11}$ ppb, $\theta_c/2 = 190\ \mu$**rad**.



BBCW ON at 90 A and 12 σ.



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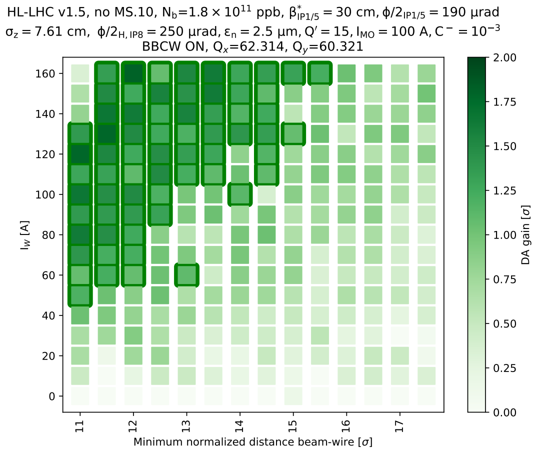

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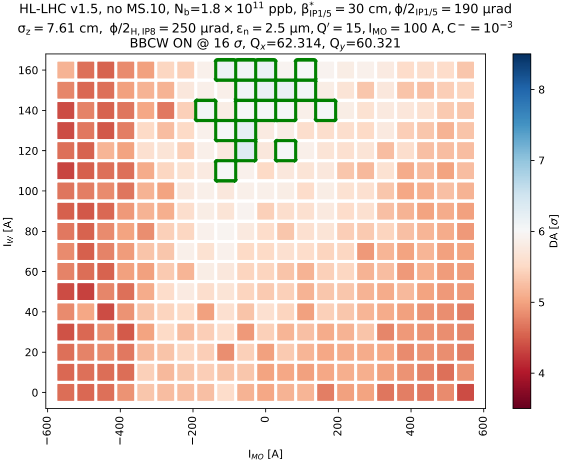
Interplay with arc octupoles



If BBCW too far (16 σ), can the arc octupole help? **Marginally**.

Special configurations

Special configurations

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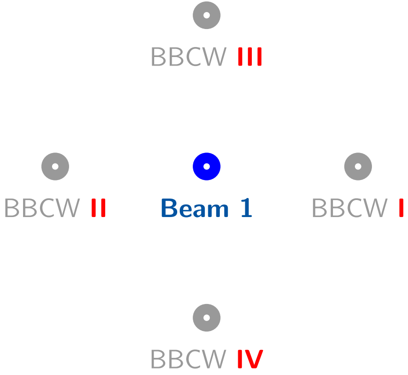
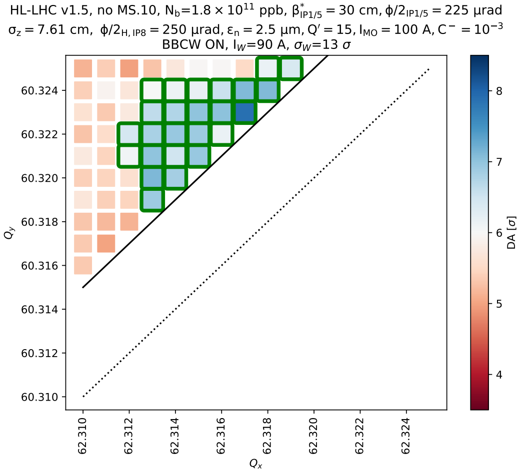
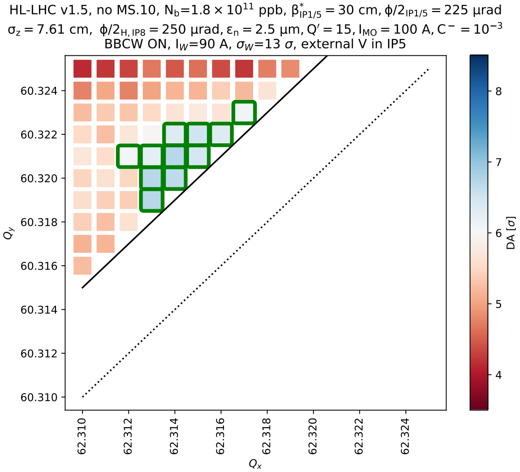
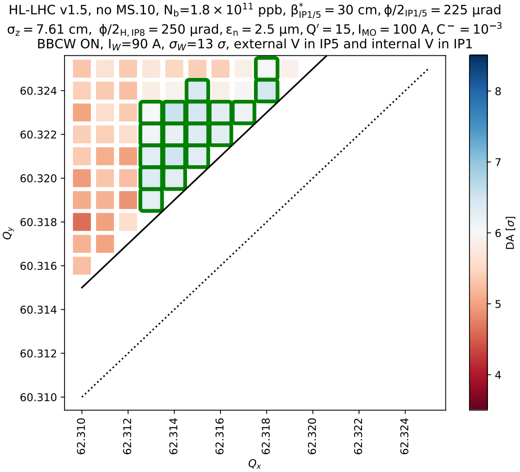




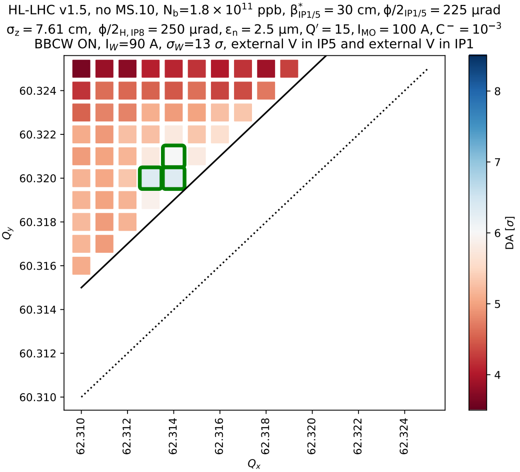
90 A @ 13σ, BBCW **|** in IP1, BBCW **|** in IP5



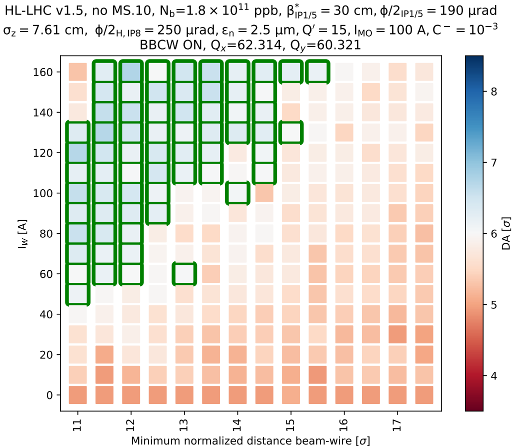
90 A @ 13σ, BBCW I in IP1, BBCW II in IP5



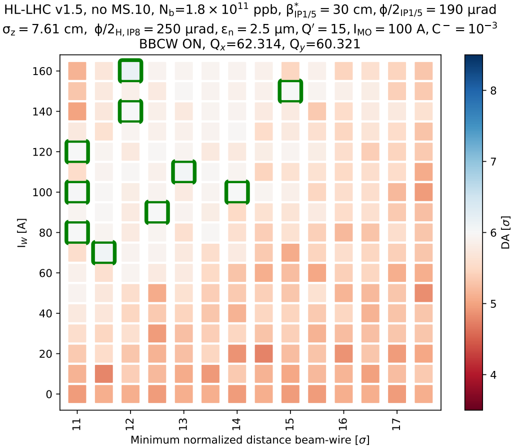
90 A @ 13σ, BBCW III in IP1, BBCW II in IP5



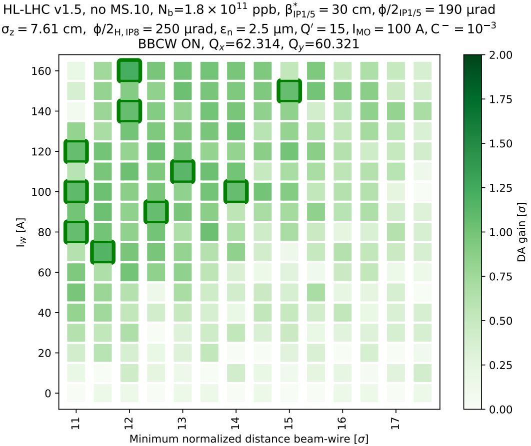
90 A @ 13σ, BBCW **IV** in IP1, BBCW **II** in IP5



BBCW ❙ in IP1, BBCW ❙ in IP5



BBCW **(I+II)/2** in IP1, BBCW **(I+II)/2** in IP5



BBCW **(I+II)/2** in IP1, BBCW **(I+II)/2** in IP5

Conclusions

- The BBCW can be used to improve the machine performance in a BB dominated regime: **its beneficial impact in an early stage of Run 3 was confirmed by the simulations**.
- **TCT settings** at 11.4 σ for $\beta^* = 30$ cm are crucial to relax the BBCW HW specifications.
- It could be used to prepare the high intensity beam at **190 μrad before the CC operational deployment**.
- The BBCW commissioning time and overall availability is expected not have a minimum impact to the overall time dedicated to the HL-LHC Physics Program.
- Preliminary results show that the "special configurations" are less effective than the nominal one.

Thank you for your attention.

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