Simulations for HL-LHC configuration

Kyriacos Skoufaris, Stephane Fartoukh, Nikos Karastathis,
Yannis Papaphilippou, Axel Poyet, Adriana Rossi and Guido Sterbini

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Outline

I. Introduction
- Quantification of the problem
- Proposed solution

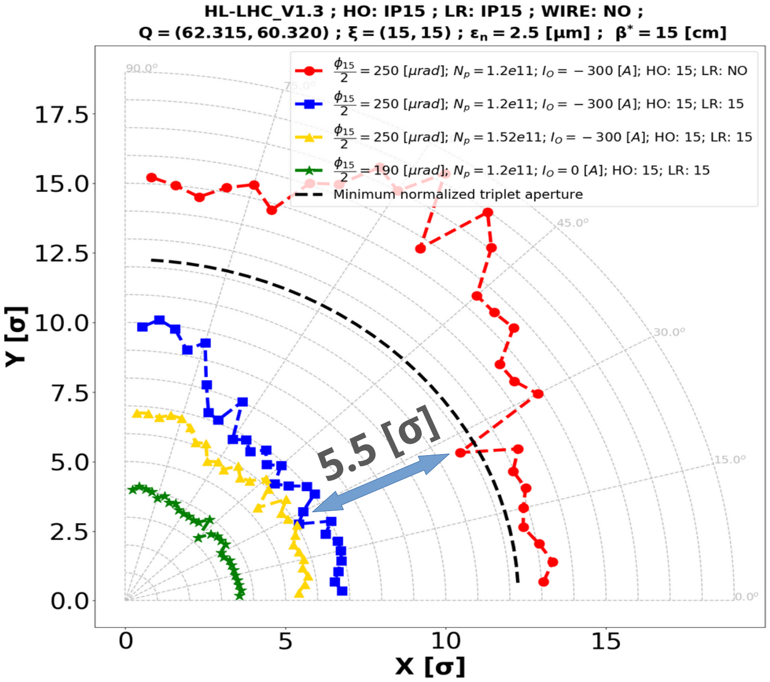
II. Numerical simulations
- Nominal scenario
- Ultimate scenario
- Pushed scenarios

III. Conclusions

Introduction - Problem quantification

The impact of the BBLR interactions on particle motion is stronger at the end of luminosity levelling (where β * is minimum) than at the start of collisions (for a constant X-ing angle).

For the nominal scenario of the HL-LHC (1.2E11 at the end of levelling with β* of 15 [cm]) **the minimum DA is reduced by 5.5 [σ] in the presence of the BBLR interactions.**

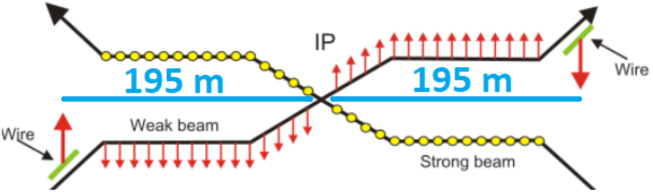


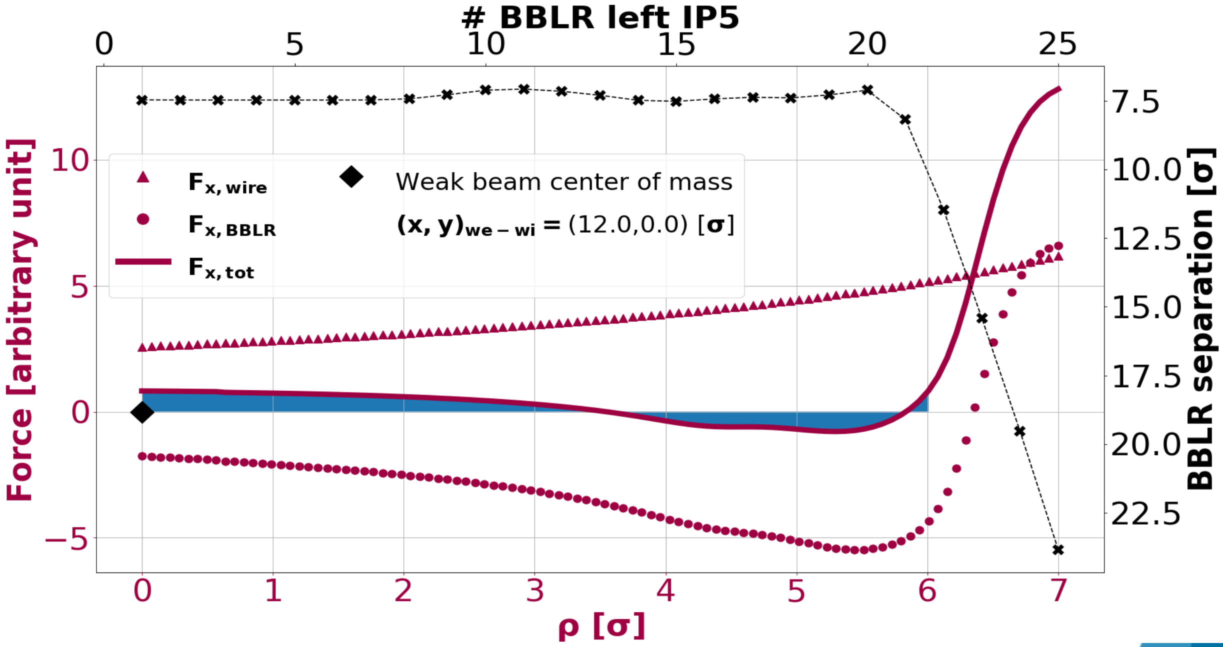
- For the **nominal scenario** (end of leveling) the **DA_{min} = 6.17 [σ]** after optimization (no IP2&8)
- **No margin for any unexpected detrimental effect on lifetime** (like e-cloud ; significantly present at the last run of the LHC)
- **Not enough margin for X-ing angle reduction or bunch intensity increment** (triplet protection from irradiation, crab cavities operation at lower voltage, extend the luminosity leveling)

Introduction – Proposed solution

The use of DC wires is an effective and simple solution for the BBLR compensation.

- 4 wires (1 per IP per site) are used
- longitudinal position ±195 [m] from IP1&5 (beta ratio 0.5 or 2 [a])
- transverse position D_w>10.4 [σ] (behind tertiaries)

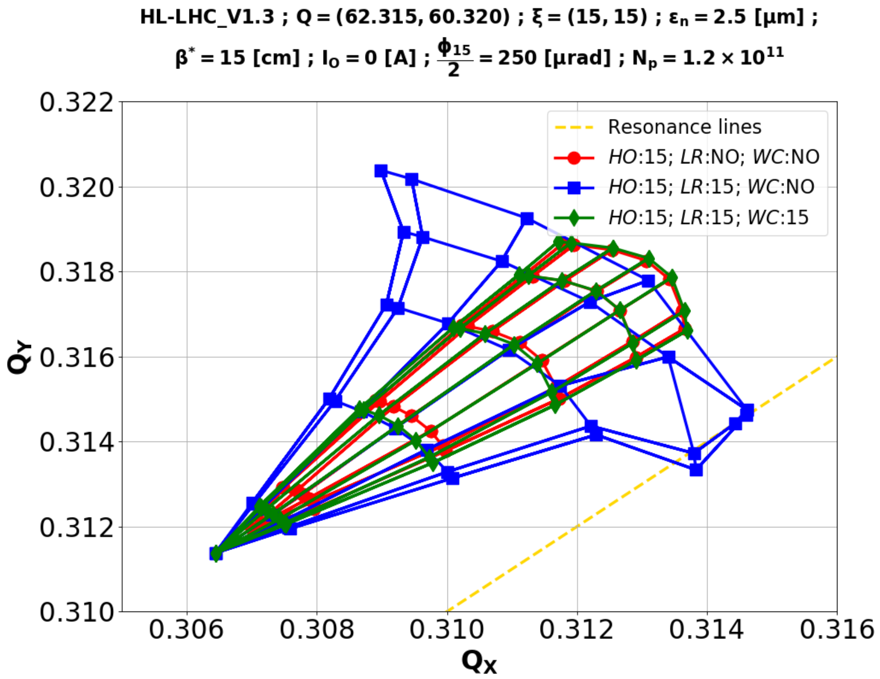




[a] DOI:10.1103/PhysRevSTAB.18.121001

Numerical simulations - Nominal scenario

The free parameters of the 4 wires are the transverse distance from the weak beam (D_w) and the current (I_w).

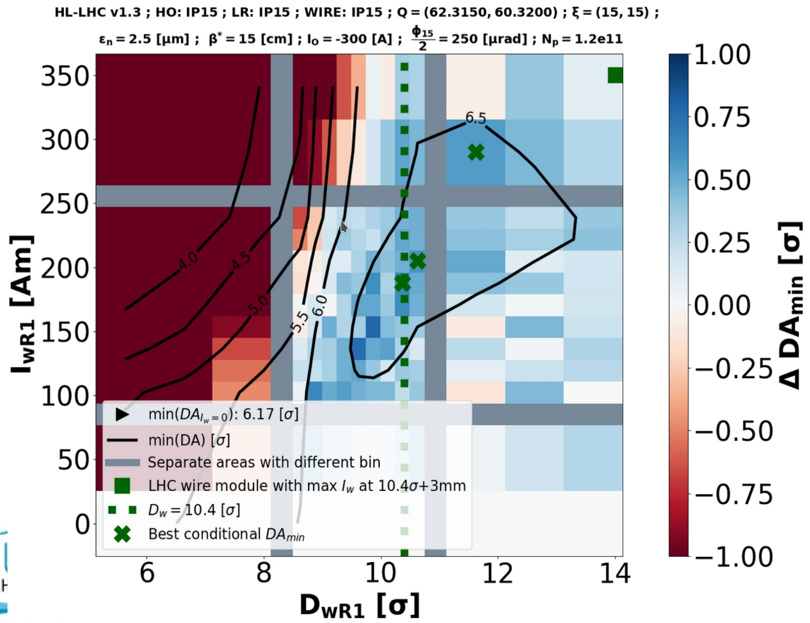


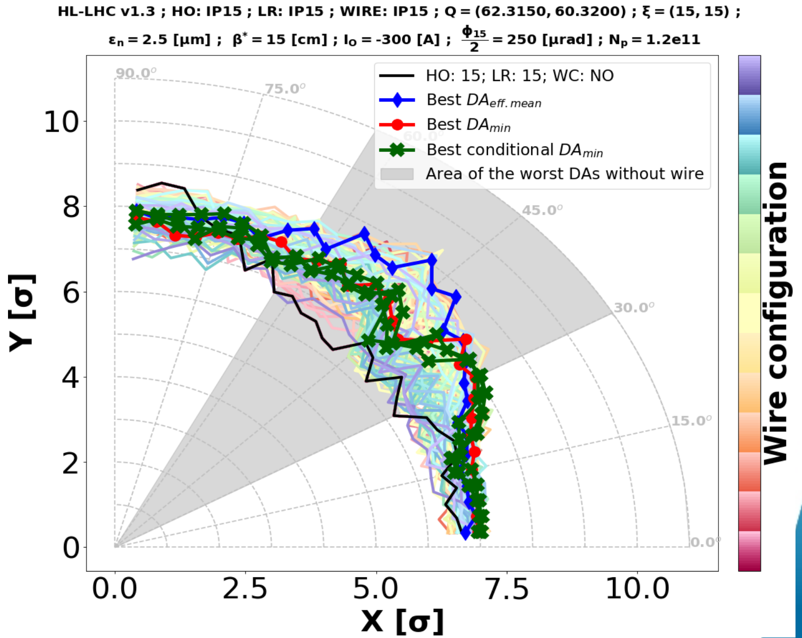
With appropriate choice of the D_w and I_w **the DC wires can perfectly compensate the octupolar tune spread with amplitude** (non-compensated by alternating crossing between IPs) generated by the BBLR interactions.

The most important observables that reflect the particle dynamics are the DA – beam lifetime.

Numerical simulations - Nominal scenario

- Different **wire configurations with D_w>10.4 [σ] improve the DA_{min} up to 0.7 [σ]** on top of the well optimized nominal scenario (DA_{min} = 6.17 [σ]) - Best conditional DA_{min}.
- The **existing LHC wire (green square) is not ideal** for the HL-LHC nominal scenario.
- The average DA gain along the different angles is even more significant.

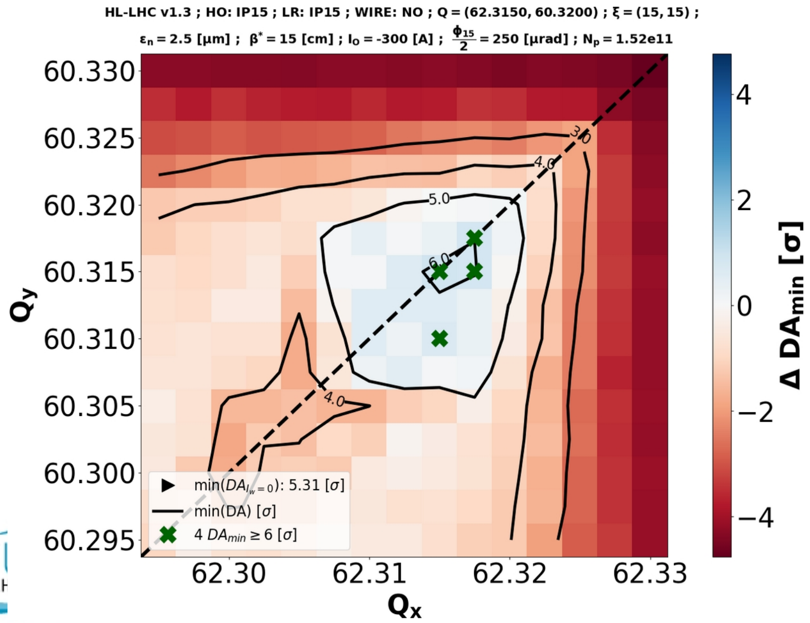


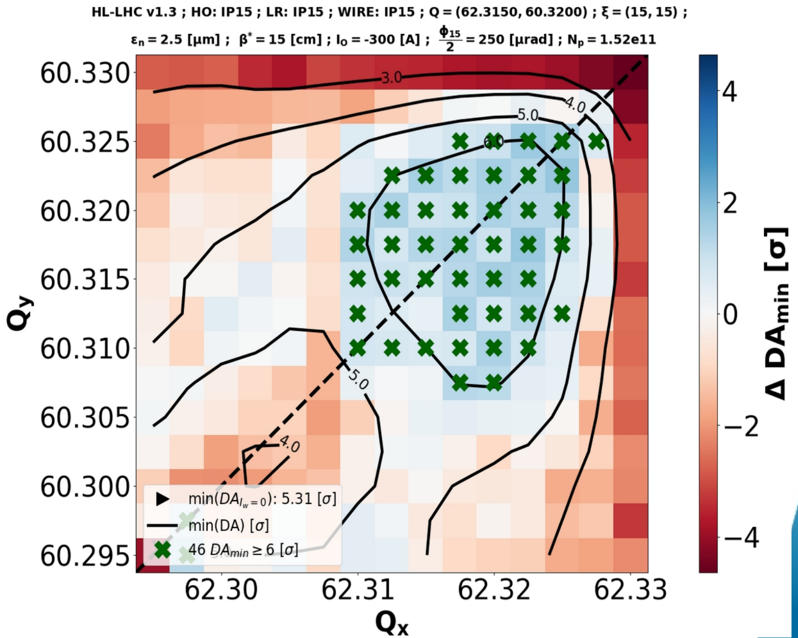


Numerical simulations - Ultimate scenario

Even with assisting octupole current (negative polarity for partial BBLR compensation) **there is not any tune configuration above the diagonal with DA_{min} ≥6 [σ]**.

Using the wire compensators (with one of the best DA configuration) **a large set of good WPs (DA_{min} ≥6 [σ]) can be used**.

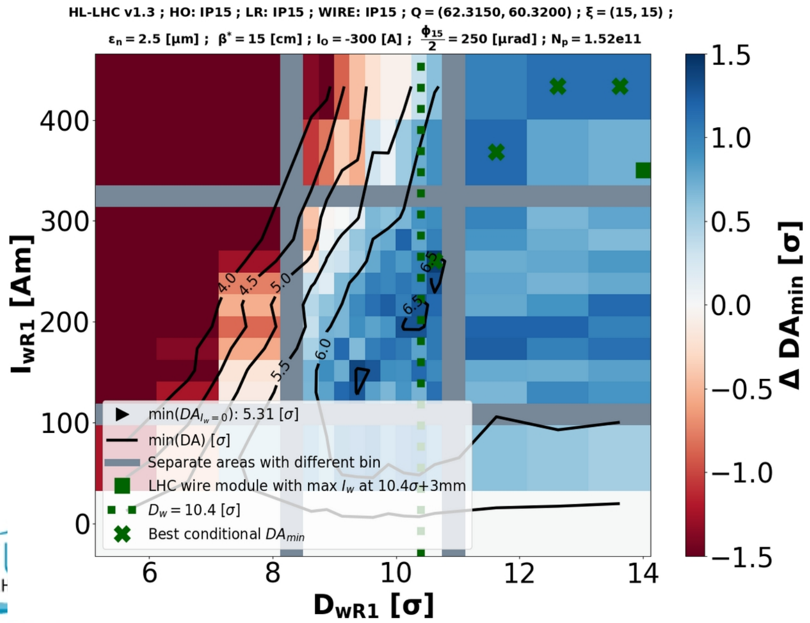


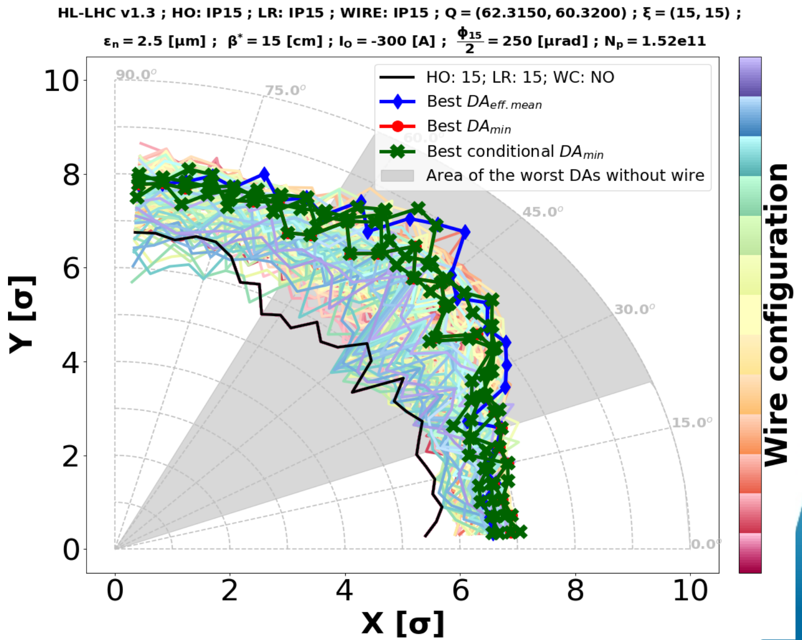


Numerical simulations - Ultimate scenario

The **wire compensators guarantee best conditional DA$_{min}$ up to 6.7 [σ]** (1.5 [σ] improvement).

- The DA gain along the different angles is even more significant.

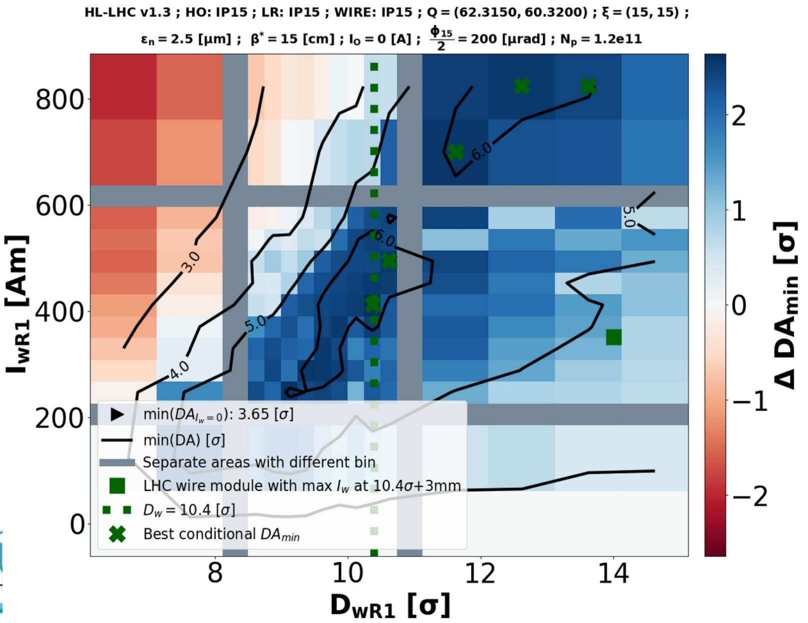


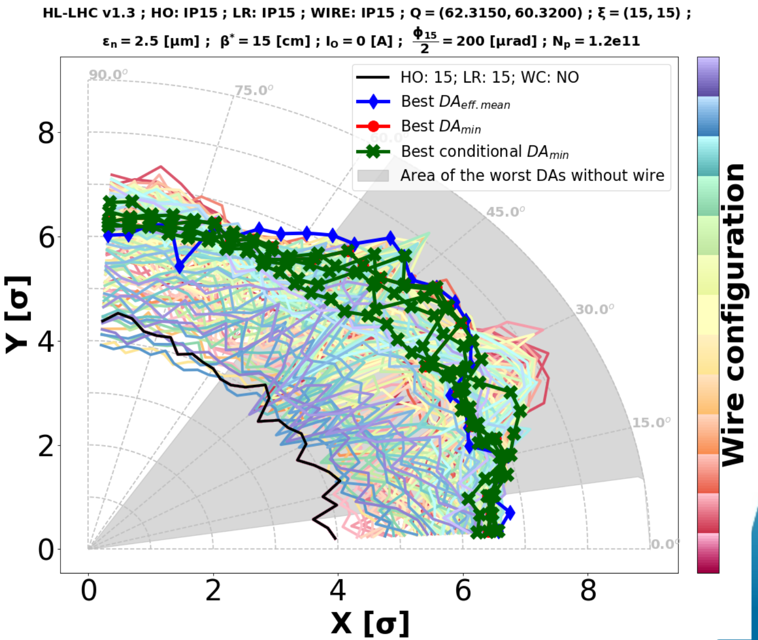


Numerical simulations - Pushed X-ing angle scenario 1

- Different wire configurations guaranty $DA_{min} \geq 6$ [σ].
- Many of them are with $D_w \geq 10.4$ [σ]. **The best of them (best conditional ones) can improve the DA_{min} up to 6.3 [σ].**

Pushed X-ing angle scenario 1	
Half crossing angle	200 [μrad]
Bunch intensity	1.2×10^{11}



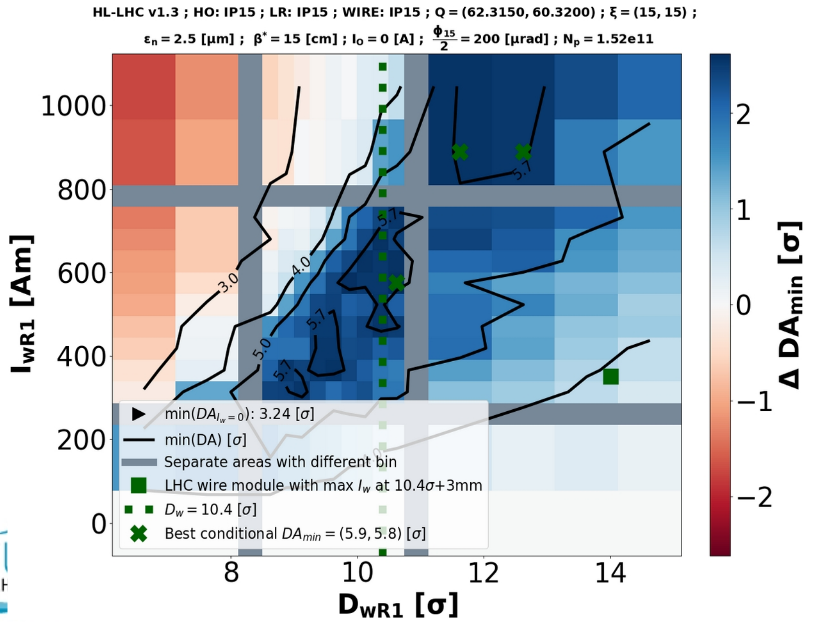


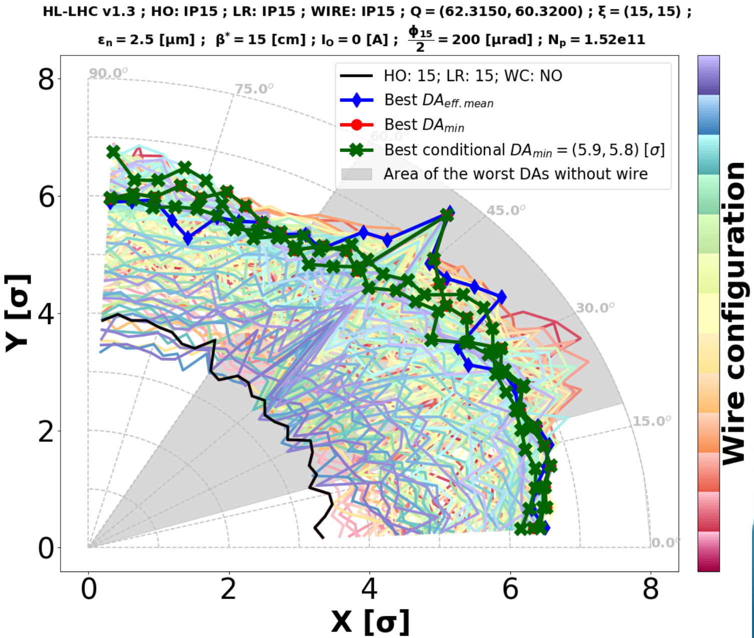
Numerical simulations - Pushed x-ing angle and Np scenario

- Even at this extreme (in Xing and bunch density) scenario **the DC wire can improve the DA_{min} up to 5.9 [σ] and with D_w≥10.4 [σ].**

- For all the best conditional (wire) configurations **the DA for the different angles is very close or above 6 [σ].**

Pushed X-ing angle and Np scenario	
Half crossing angle	200 [μrad]
Bunch intensity	1.52×10^{11}

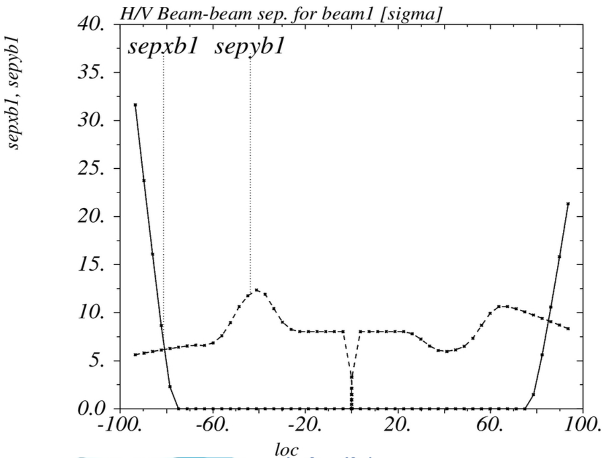


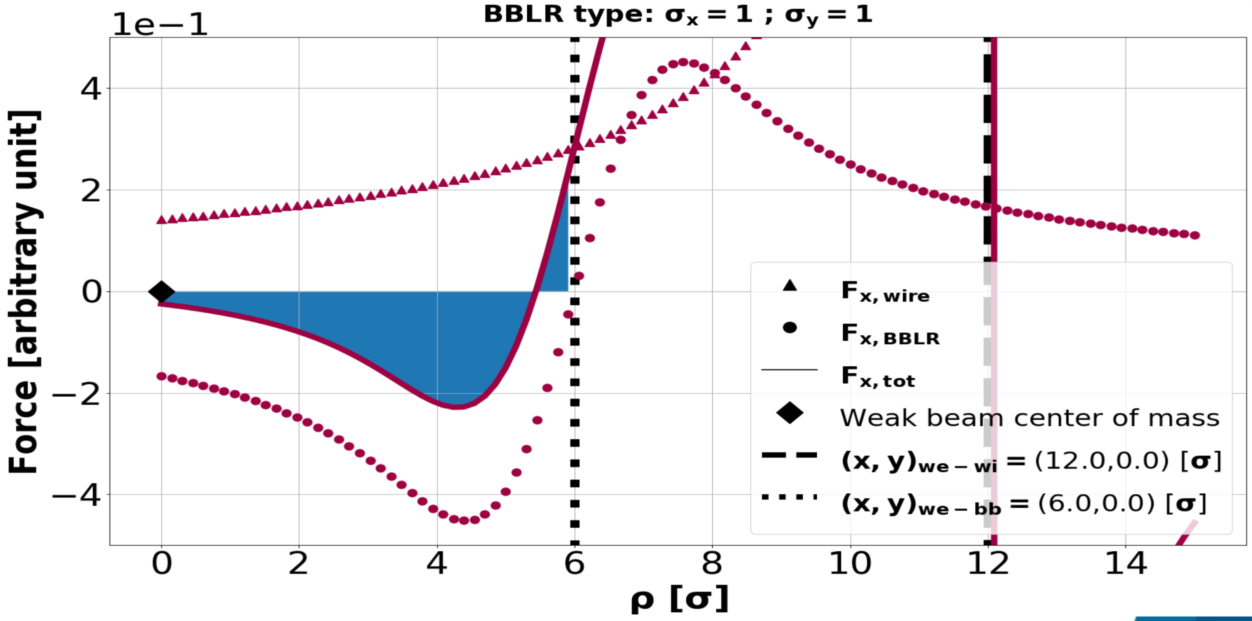


Numerical simulations - Pushed X-ing angle scenario 2

- At hXing = 190 [μrad] and β^* = 15 [cm] some BBLR are around 6 [σ] away from the strong beam.
- Although the 1/r field attenuation of these BBLRs stop at 3.5 [σ], the wire compensators placed far from the weak beam (D_w> 6 + 2.5 [σ]) performs extremely well.

Pushed X-ing angle scenario 2	
Half crossing angle	190 [μrad]
Bunch intensity	1.2×10^{11}

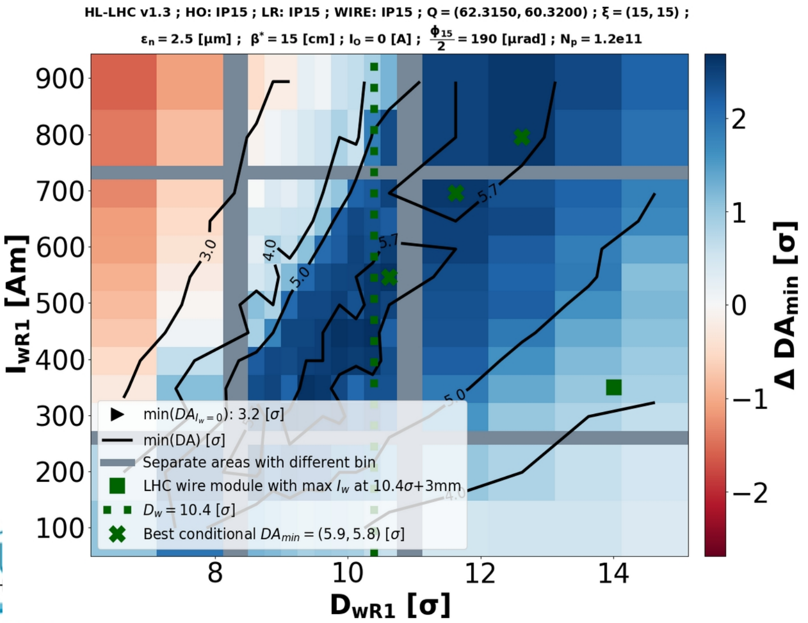


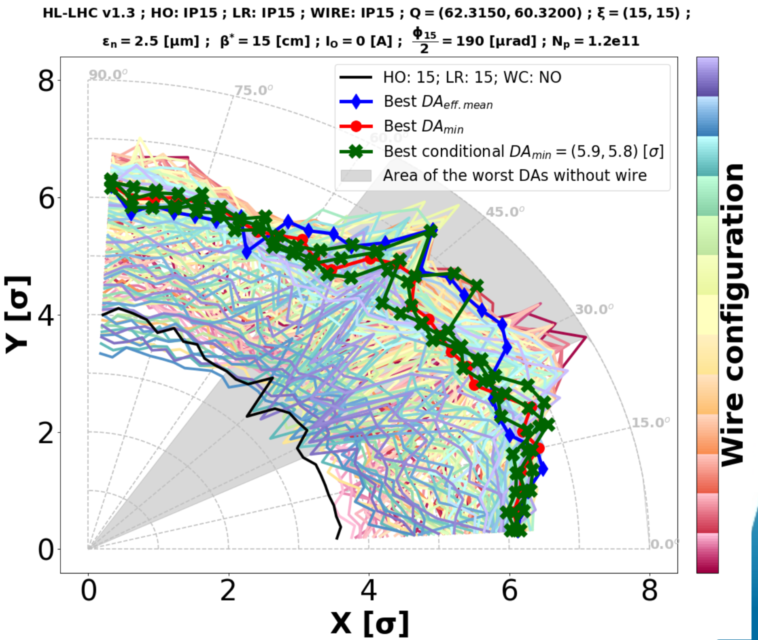


Numerical simulations - Pushed X-ing angle scenario 2

- **The DC wire can improve the DA_{min} up to 5.9 [σ] (2.7 [σ] gain) even with D_w≥10.4 [σ].**

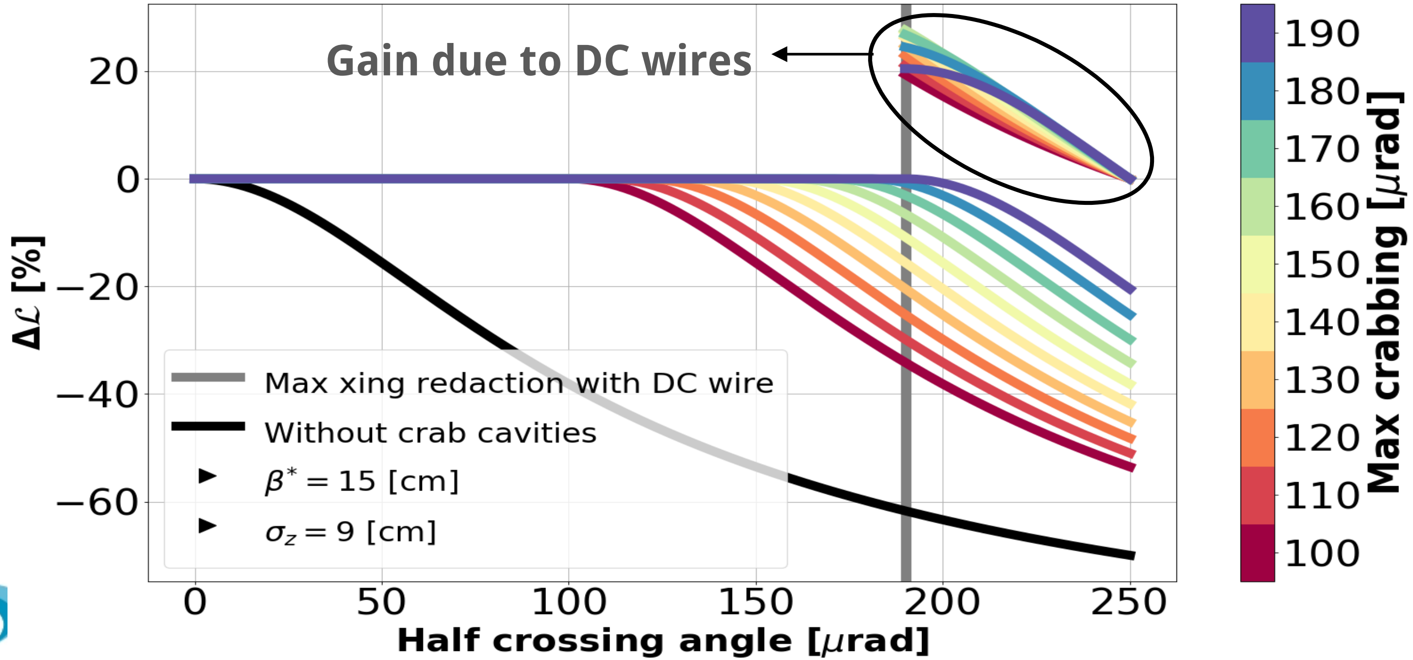
- For all the best conditional (wire) configurations **the DA for the different angles is very close or above 6 [σ].**





Numerical simulations - Pushed X-ing angle scenarios

- Reducing the X-ing angle with the help of the DC wires **the crab cavity voltage can be reduced without sacrificing the luminosity**.



Conclusions

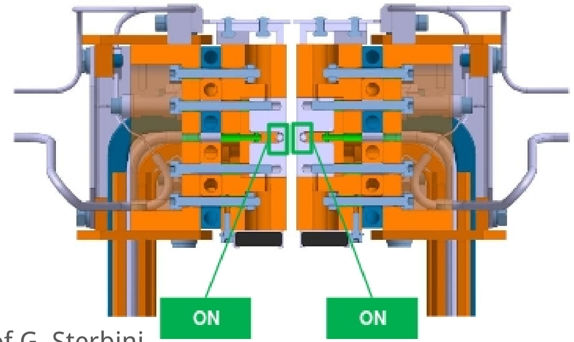
The **wire compensator guarantee DA_{min}≈≥ 6 [σ] for all the studied scenarios** without violating the machine protection restrictions.

- The lifetime gained makes the **machine more tolerant (flexible)** at any unexpected destructive effect.
- With all the good wire configurations the **area of the good working points (WPs) is enlarged**
  - WP can be kept constant during leveling
- With the reduction of the crossing angle and/or increase of the bunch population without sacrificing the lifetime (min DA>6σ):
  - the **crab cavities** can be operated at **lower voltage**
  - the **irradiation** of the triplets can be **reduced**
  - the **integrated luminosity** can be **increased**

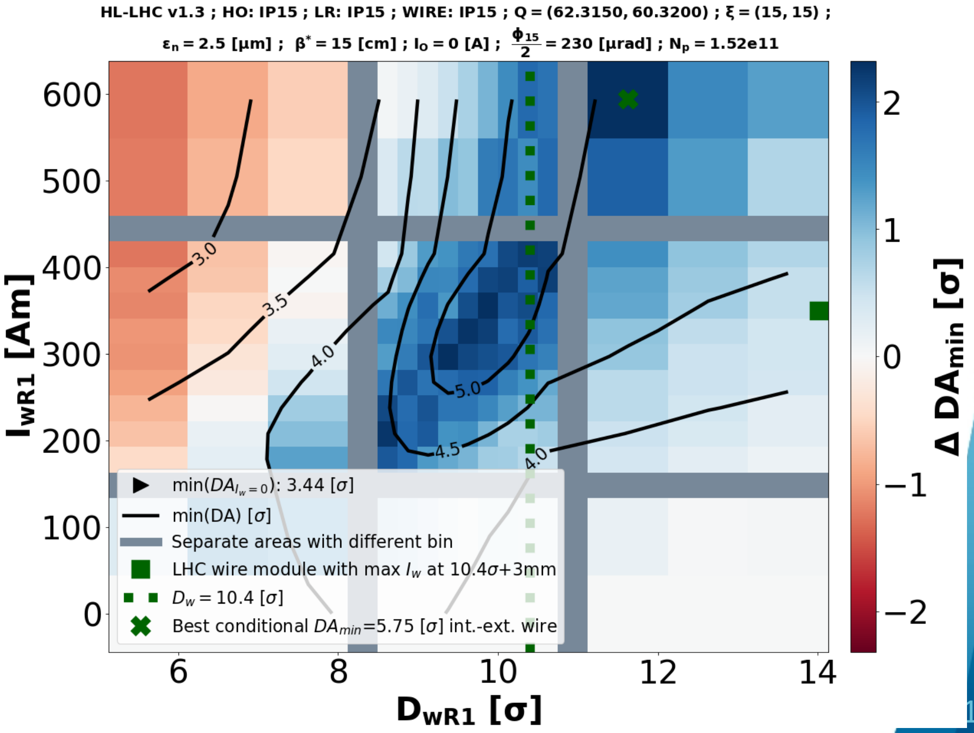
Thank you !

Backup

The wires of both jaws are powered



Courtesy of G. Sterbini



Backup

PACMAN+wire