CERN

LHC weak-strong beam-beam simulations and experiments

Beam-Beam Effects in circular colliders, 5-7 February 2018, LBNL

D. Pellegrini

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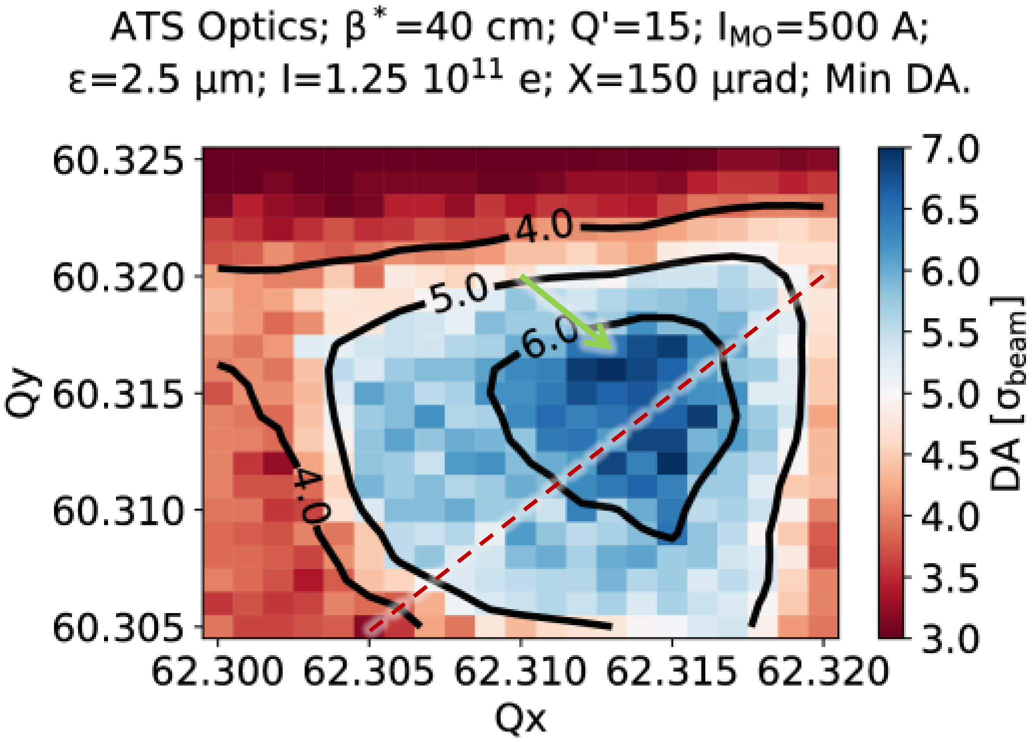
Outline

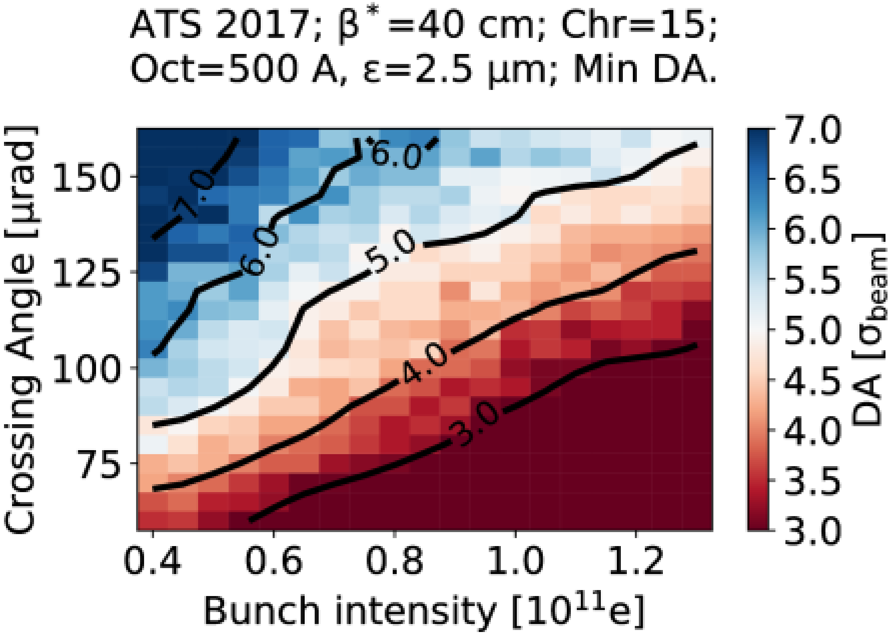
- Recap of **DA sensitivity** from weak-strong beam-beam simulations (tune, chromaticity, octupoles) with sixtrack.
- Predictions and effects on **DA during 2017**:
  - 30 cm beta*,
  - 8b4e filling scheme,
  - crossing angle anti-levelling.
- **Correlation** between DA and lifetime
- **Comments** on computing and instrumentations

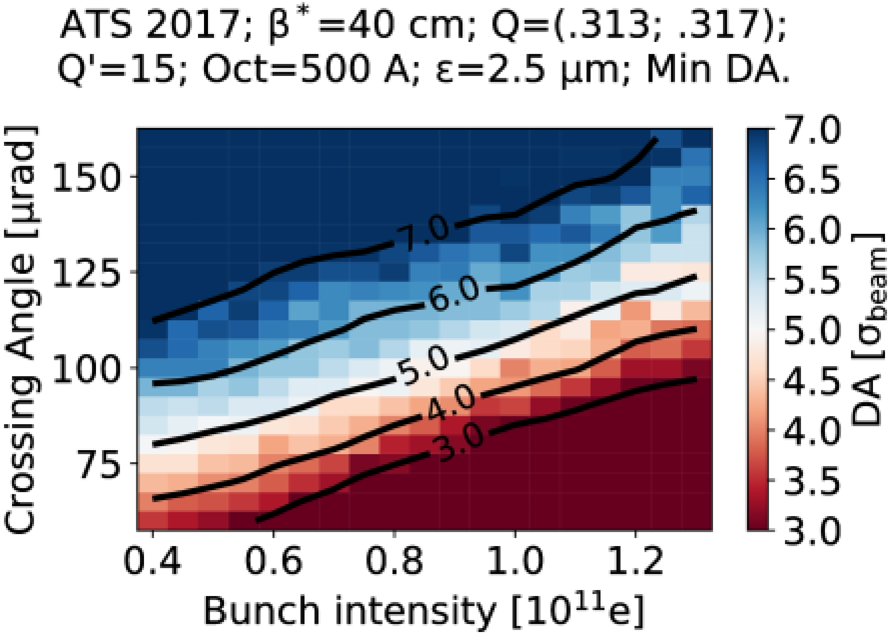
Impact of tunes



- High sensitivity to tune adjustments, **1-2 σ** DA lost within a few 1e-3 trims.
- First test performed at the end of 2016, immediate lifetime **improvement**.
- Tune optimisation **routinely** applied in 2017, e.g. after crossing angle steps.
- Care not to excessively approach the **diagonal** to avoid instabilities.
- Optimised tunes are now considered a **"must"** for lifetime and DA studies.

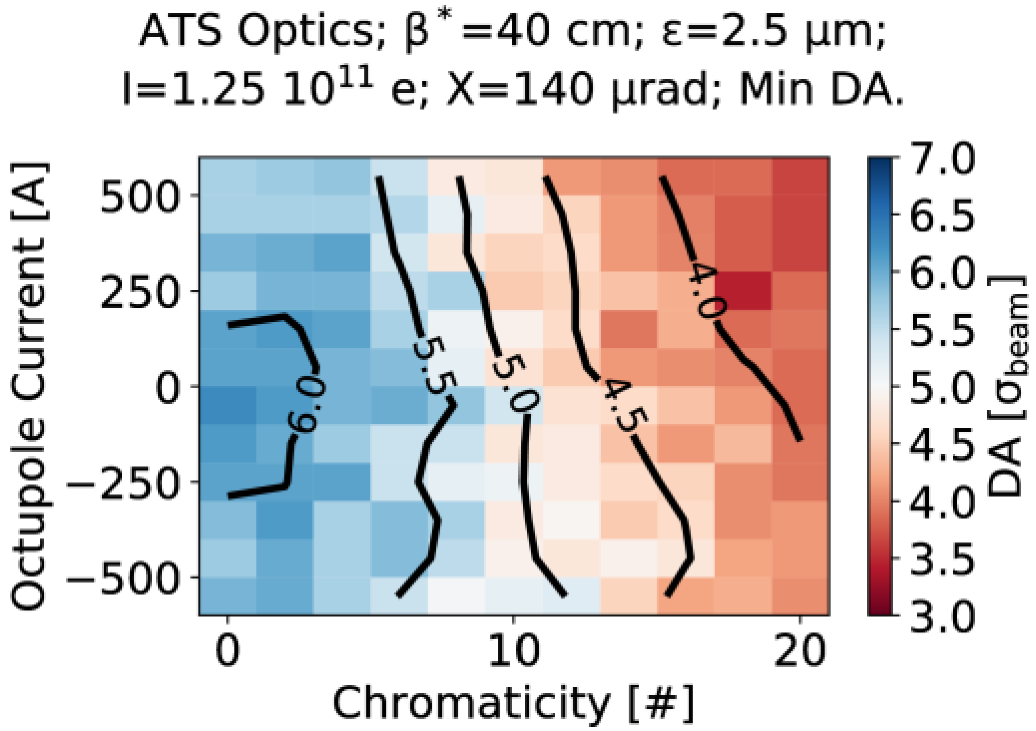
Impact of tunes (II)





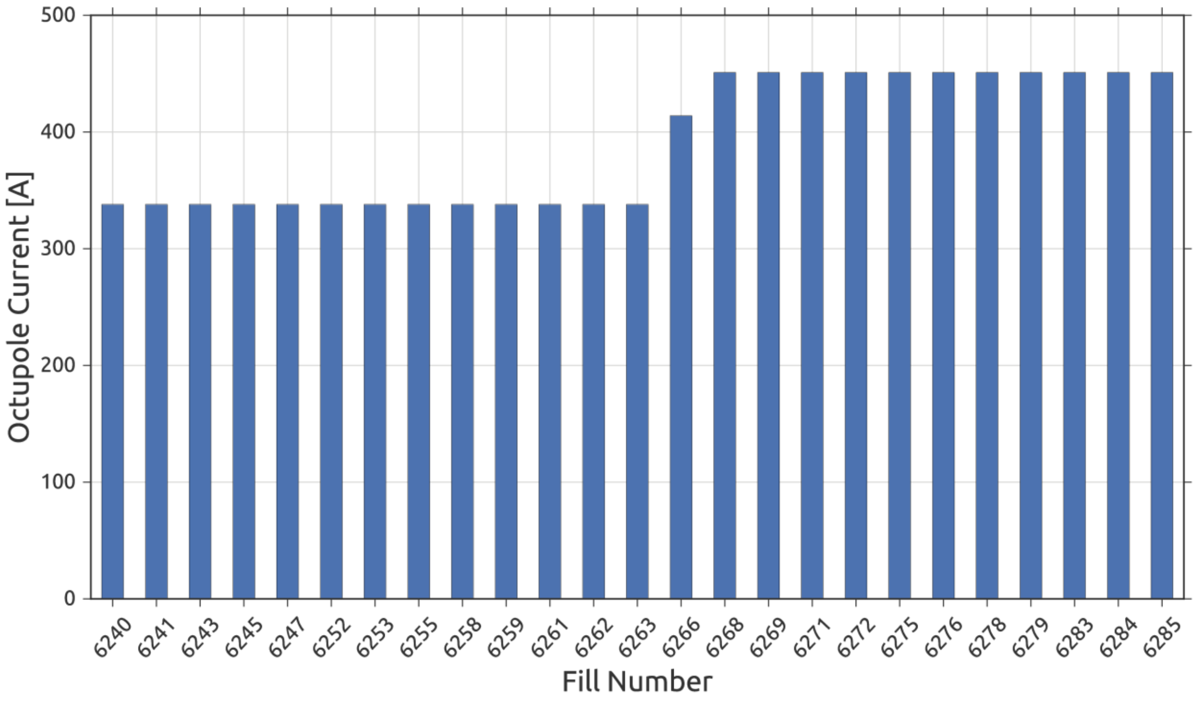
Optimised tunes can allow as much as **30 μrad** reduction of half crossing angle (2 σ BB separation @ 40cm) → **10%** increase in peak luminosity

Chromaticity and Octupoles



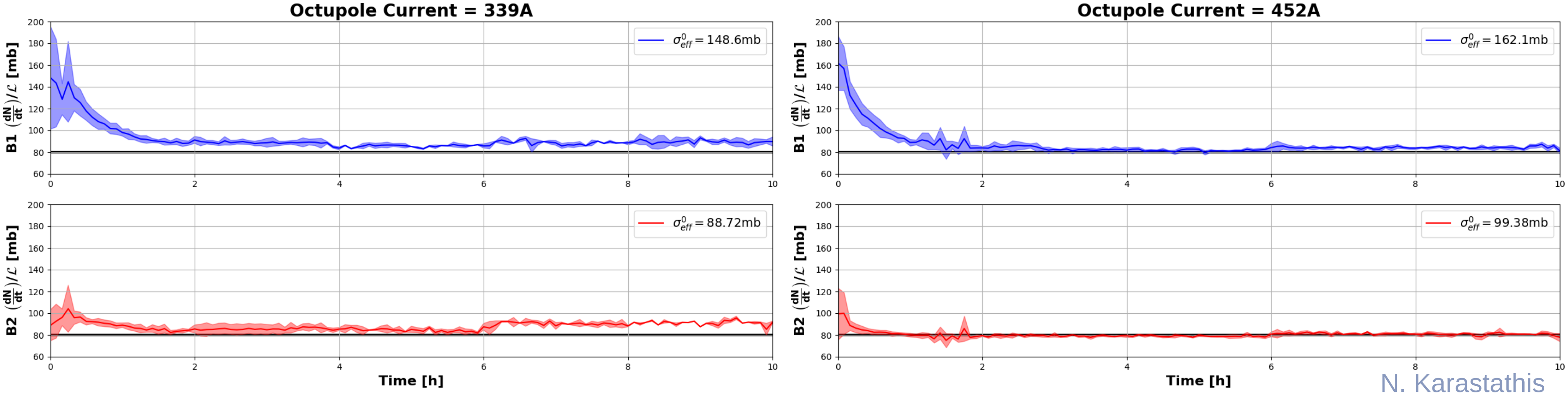
- 1 σ DA for ~10 units of **chromaticity**.
- Limited impact (< 0.5 σ) of **octupoles** in the range usually exploited: 300-500 A.
- Demonstrated lifetime improvement for telescope-enhanced **negative octupoles** (MD 2269, S. Fartoukh et al.)

Octupole raise during the run



- On Oct 2 octupoles where **raised** to improve beam stability.
- Check the effective **cross section** (losses normalised to luminosity) on few fills before and after.

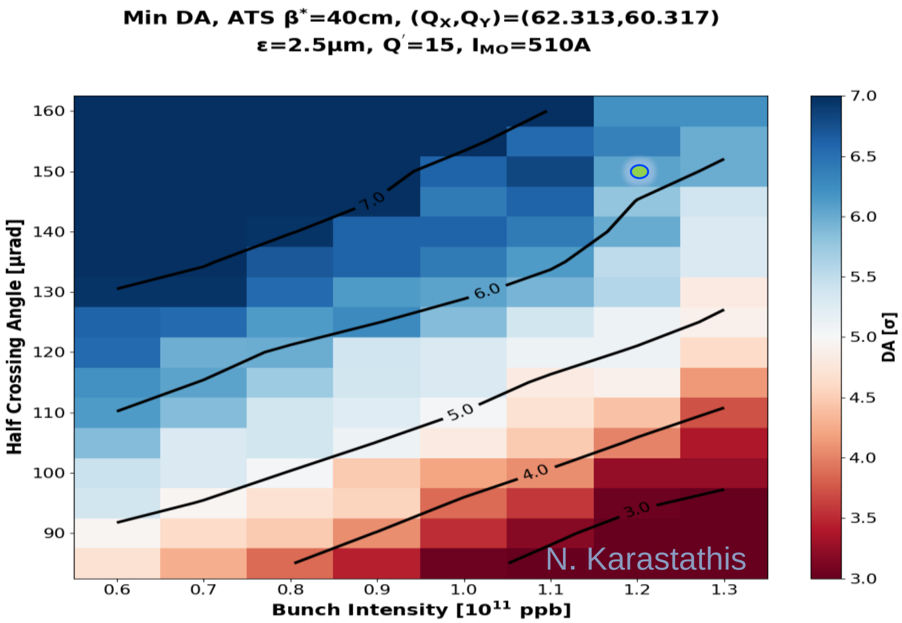
Octupole raise during the run

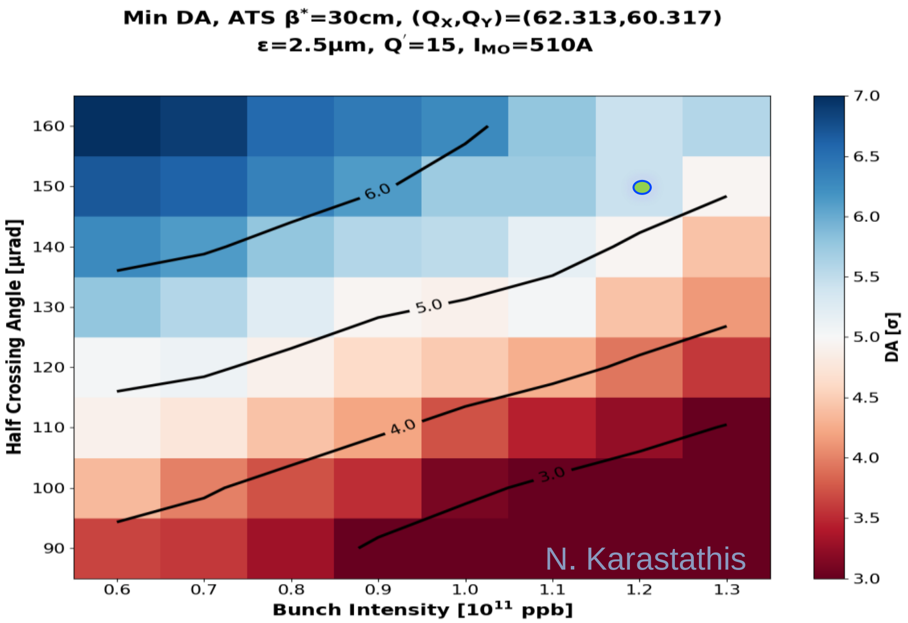


N. Karastathis

- Small increase of losses at the beginning of the fill (within the uncertainty), compatibly with simulations.
- No long term effect on losses.

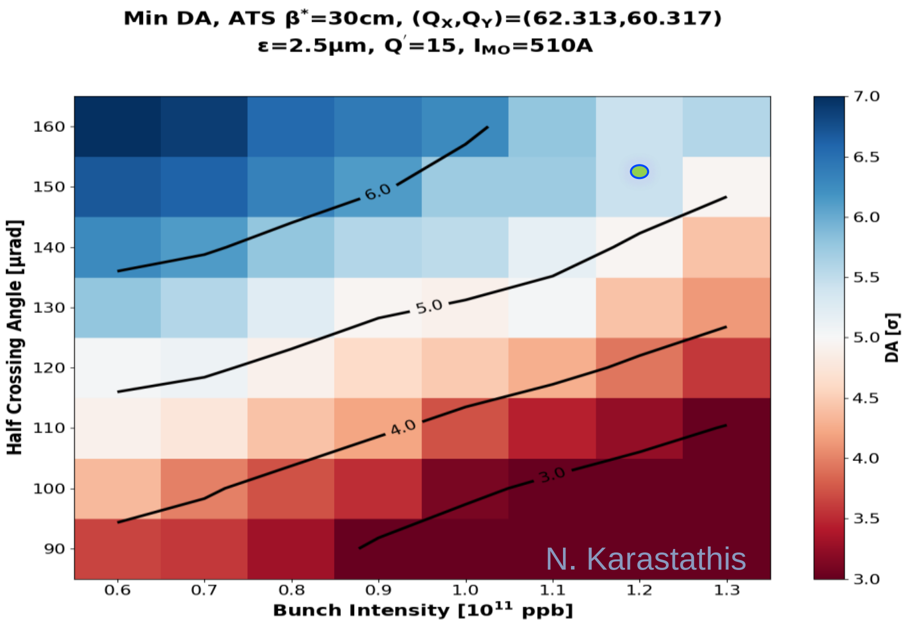
Reduction of β*

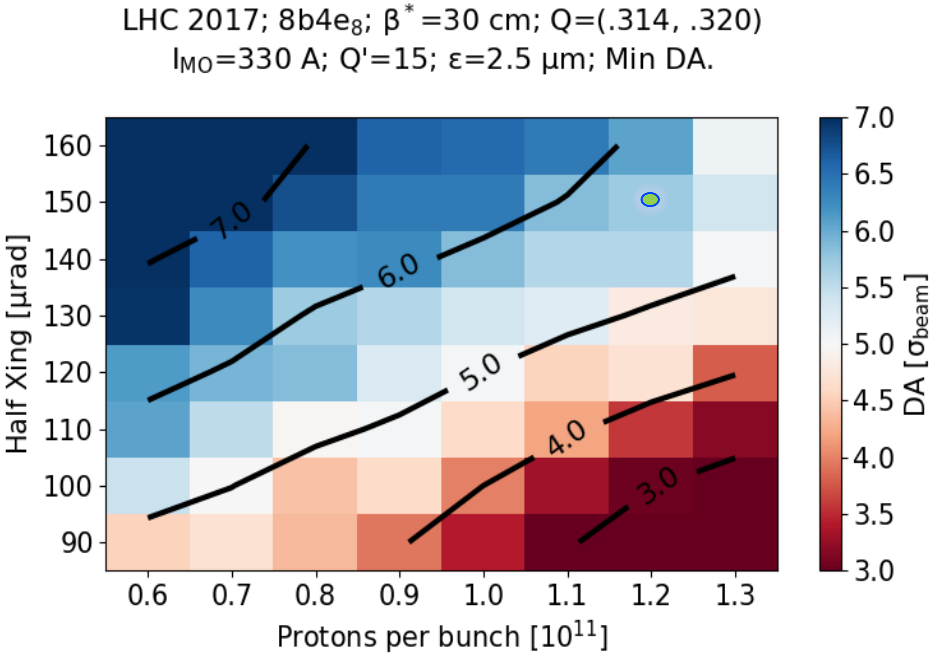




- Xing maintained at 150 μrad levering on tune optimisations.
- Beam-beam separation reduced from 10 to 8.5 σ.

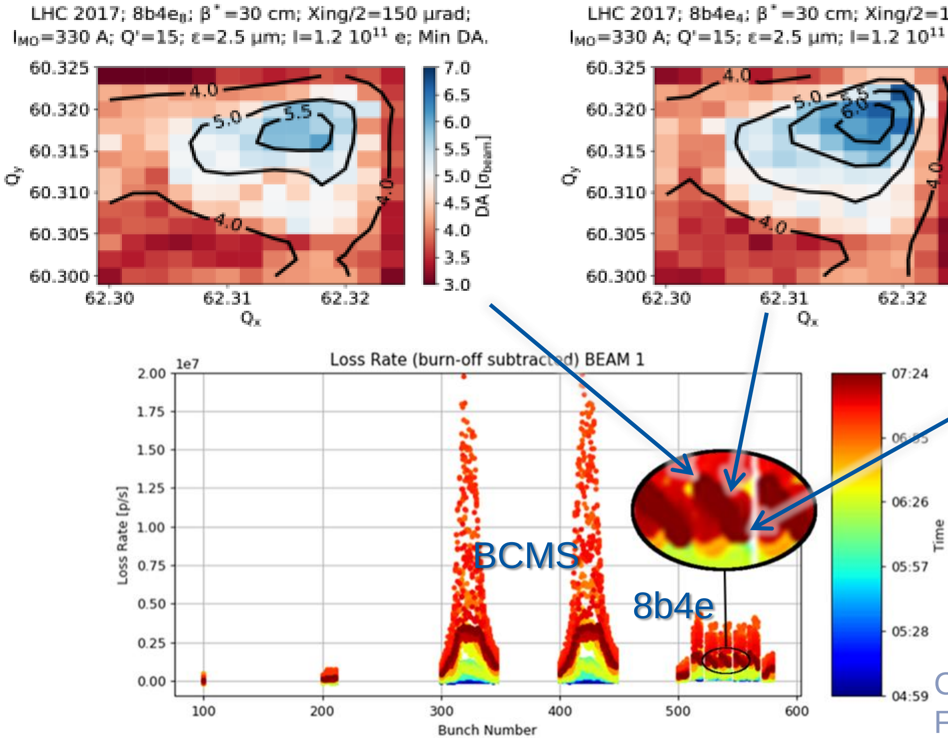
Beam-Beam with 8b4e





DA recovered also thanks to the 8b4e beam (worst case shown here), having less long range beam-beam encounters.

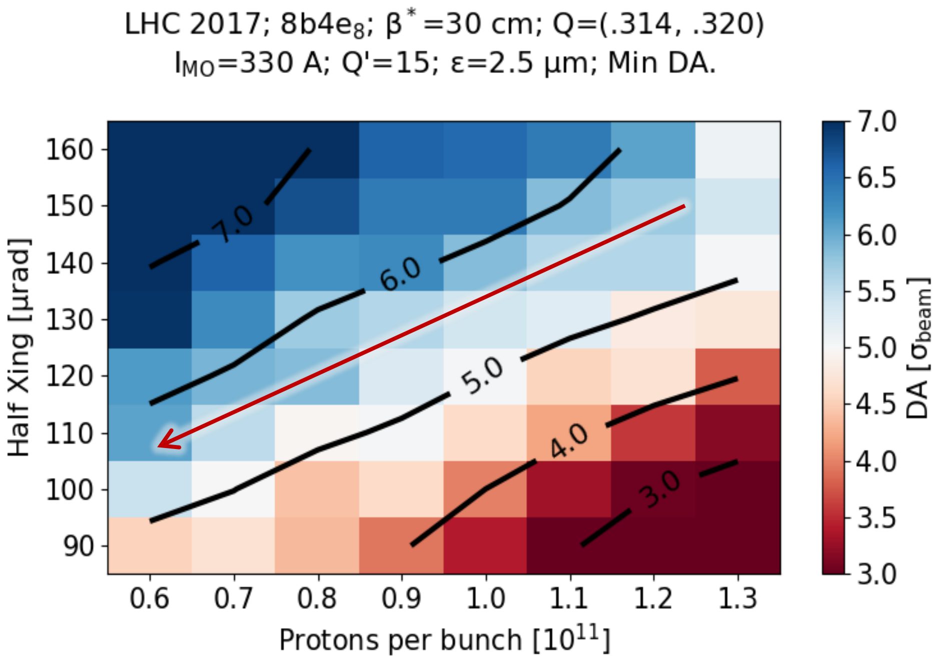
Different 8b4e classes



- Precise predictions also for 8b4e trains.
- The bunches in the front of the 8b mini-trains suffer more.
- Observed both in MDs and simulations.

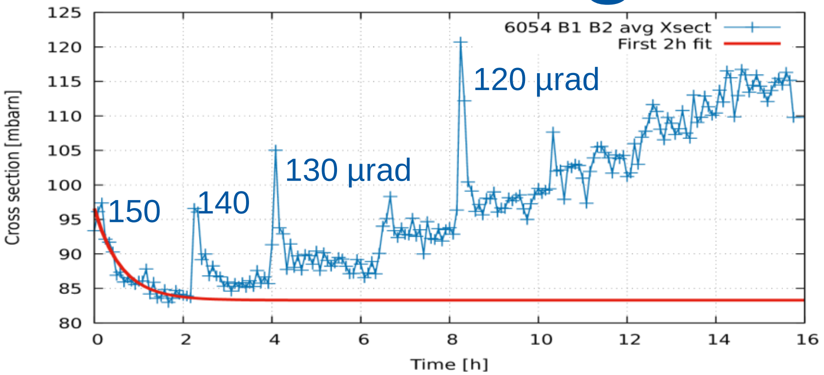
Courtesy M. Hostettler
From MD 2201 G. Sterbini et al.

Crossing angle anti-leveling

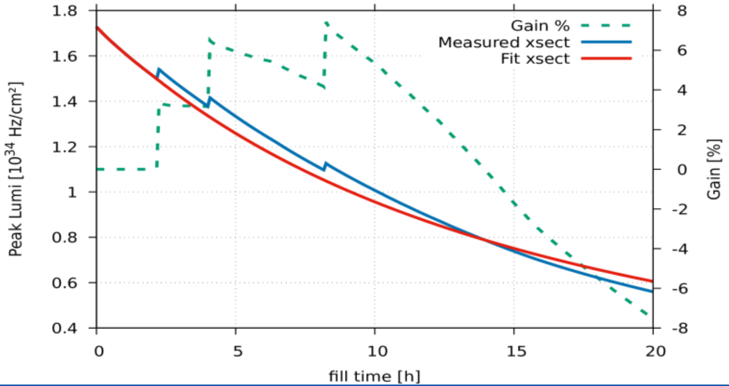


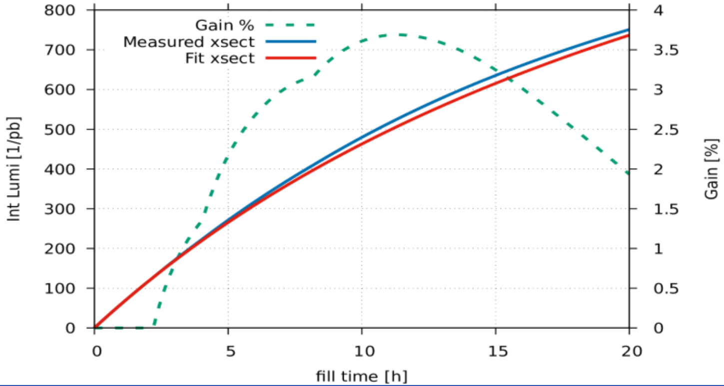
- Idea: follow the intensity decay with the crossing angle along the **iso-DA** curve.
- Act on the geometric reduction factor, for **more luminosity**.
- Agreed on 10 μrad **steps** performed at 2, 4, 8 h into the fill.
- Potential for introducing **extra losses** if not done properly (steps too aggressive or taken too early, unforeseen emittance blowup…)

Anti-leveling with extra losses

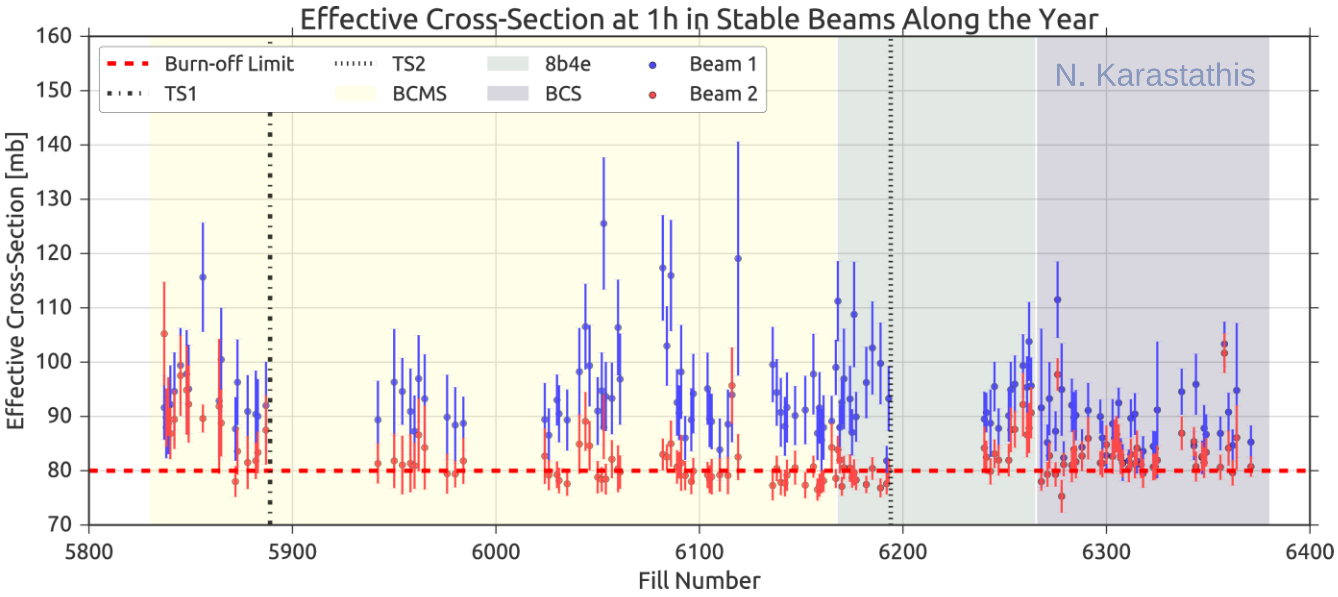


- Luminosity integrated with **measured** (fill 6054) or **fitted** cross section for intensity decay, with or without crossing angle steps.
- Slightly aggressive crossing steps
- **~3% gain** of integrated luminosity compared to ideal 5%.





Observed cross section along the year

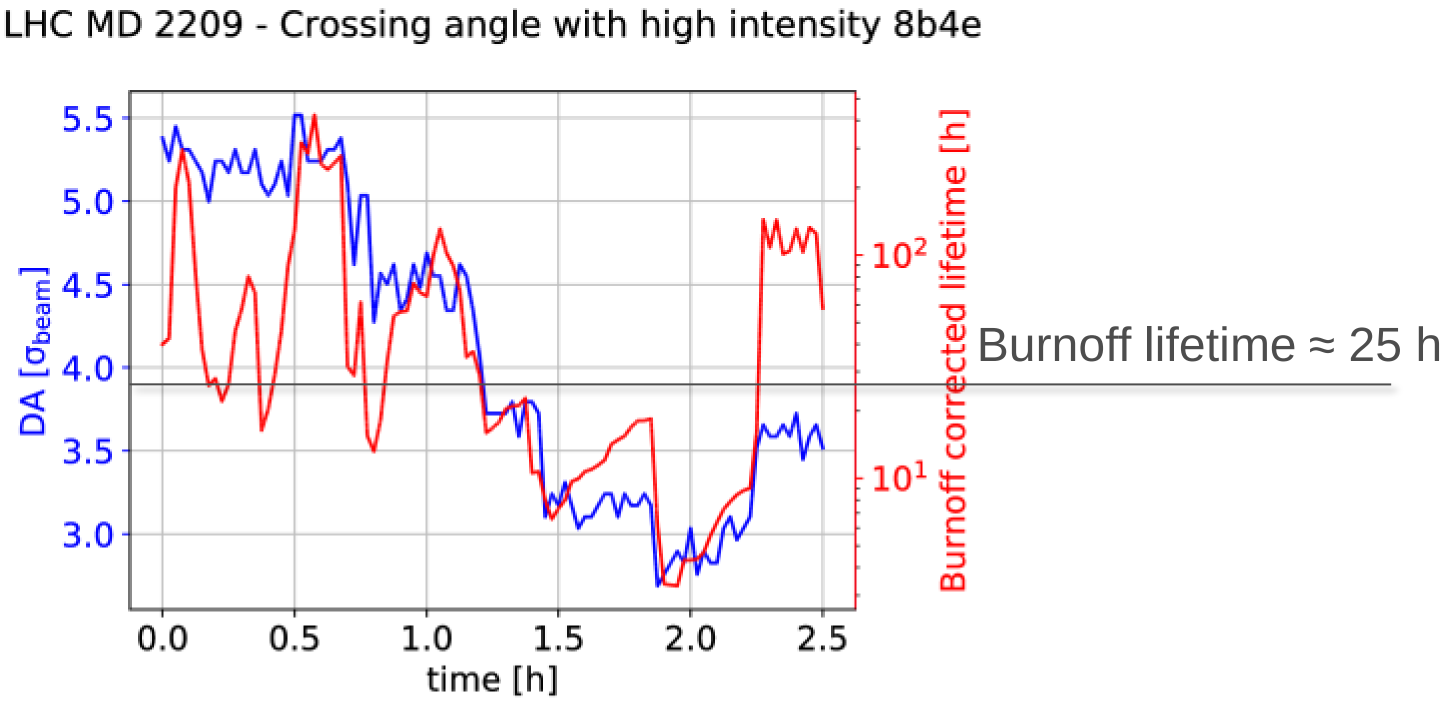


- The effective cross section (loss rate normalised with luminosity) is kept **constant** over the year across the various configurations.
- Difference between the two beams under investigation.
- More in S. Papadopoulou’s talk.

Lifetime vs DA with 8b4e

Idea: **feed** the machine settings and beam measurements along **MDs** with significant lifetime degradation to **DA simulations**.

Observe **correlations** between DA and lifetime.

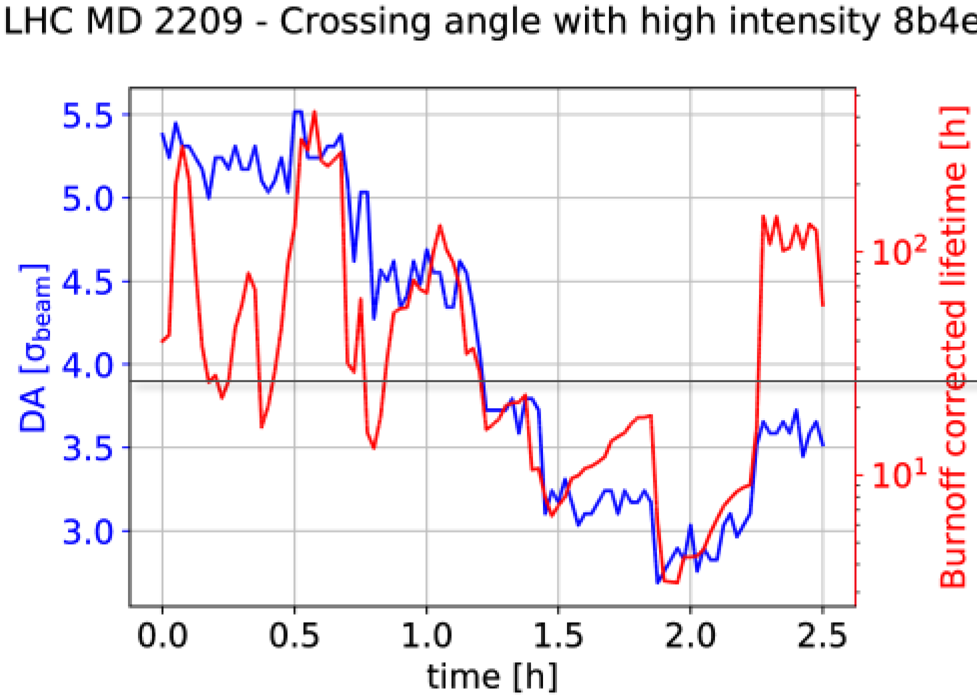


Lifetime vs DA with 8b4e

- Linear scale for DA, logarithmic for lifetime
- In agreement with:

$$\frac{I(t)}{I_0} = 1 - e^{-\mathrm{DA}^2(t)/2}$$

(M. Giovannozzi, PRST-AB, 2012)



Burnoff lifetime ≈ 25 h

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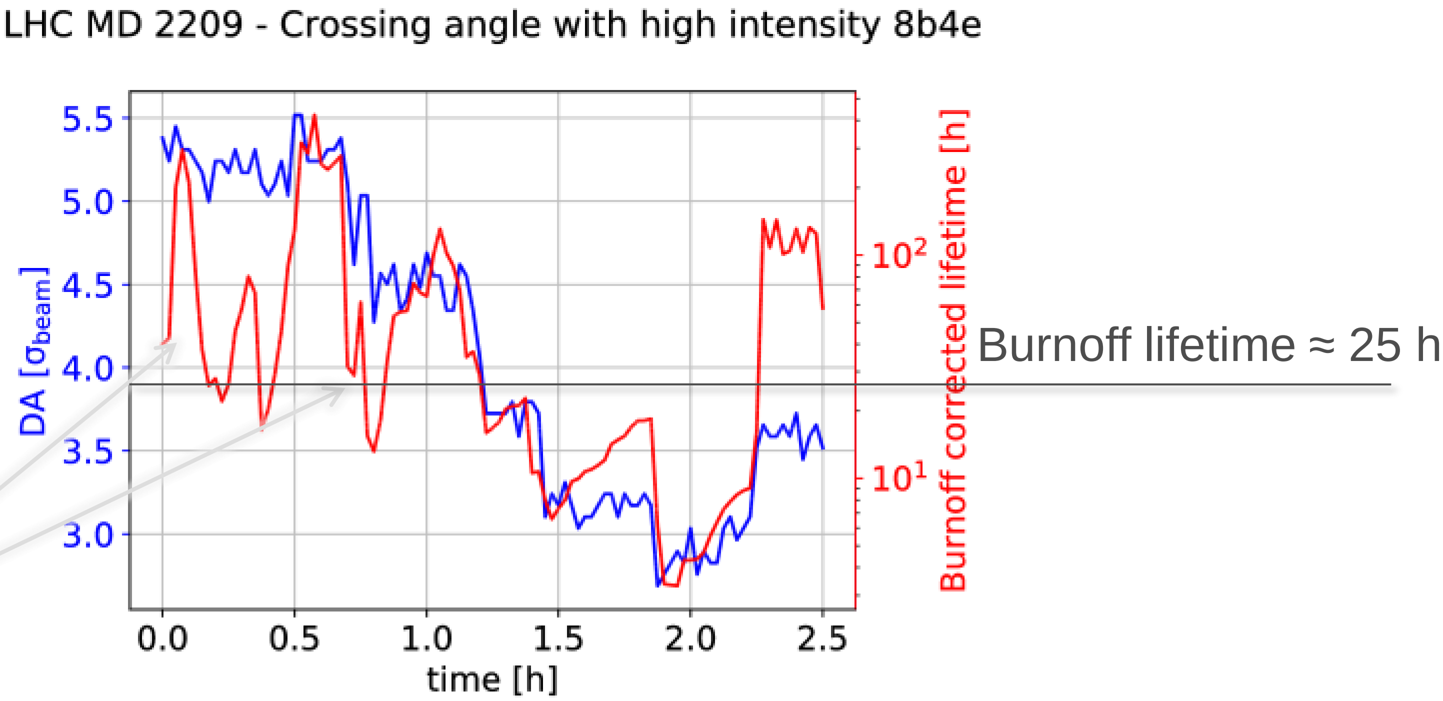

Tune and Luminosity optimisation

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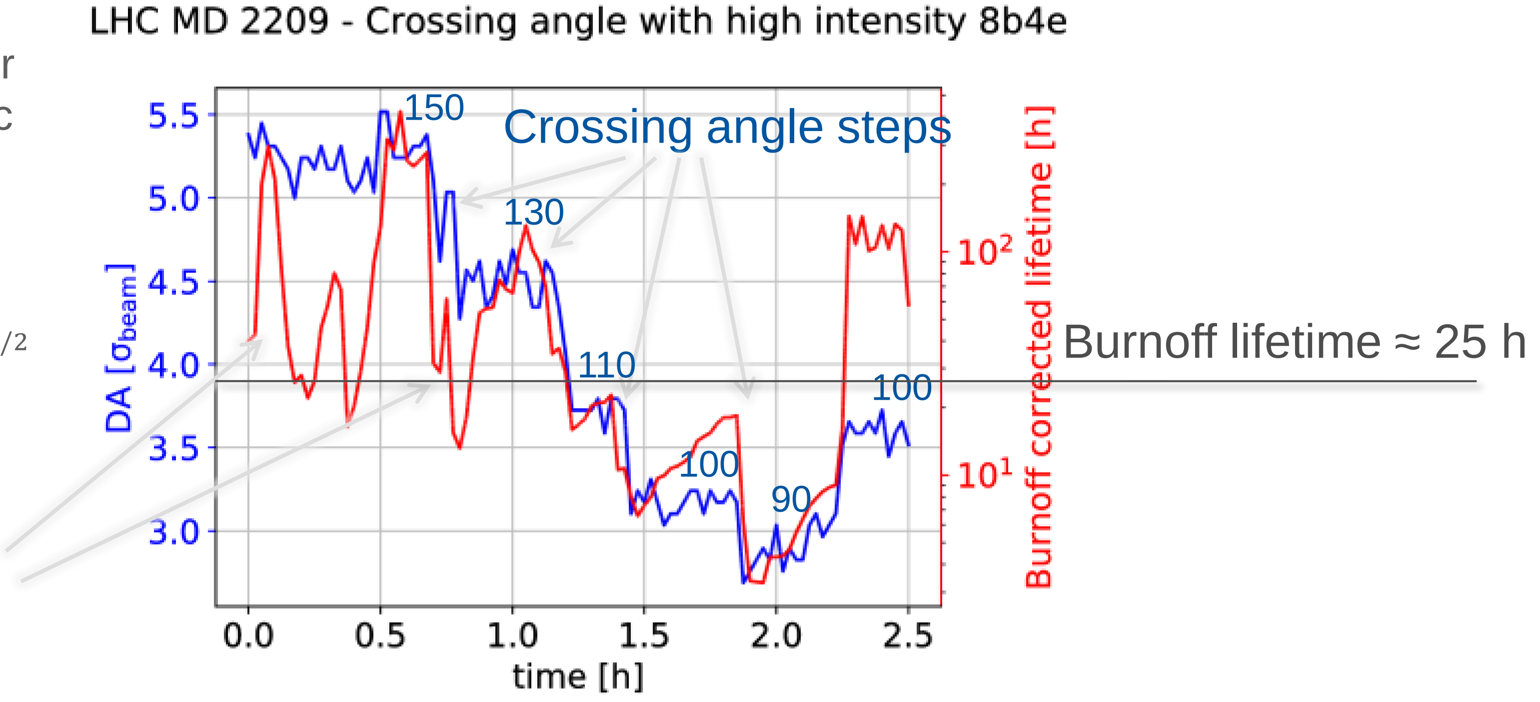

Lifetime vs DA with 8b4e

- Linear scale for DA, logarithmic for lifetime
- In agreement with:

$$-e^{-\mathrm{DA}^2(t)/2}\frac{I(t)}{I_0}=1$$

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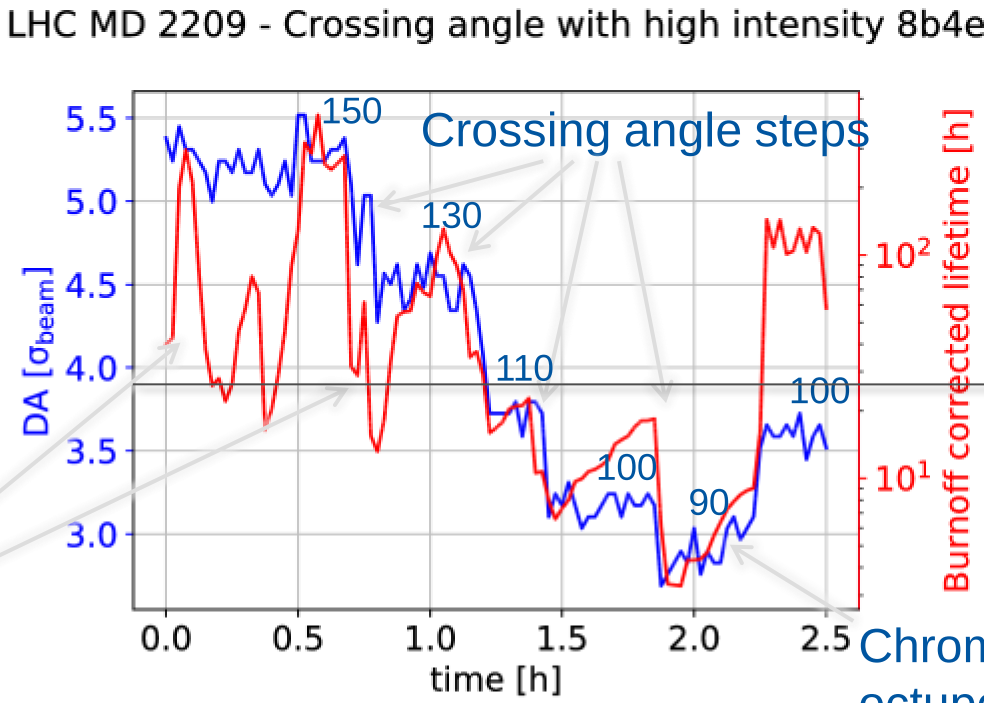

Crossing angle steps

Burnoff lifetime ≈ 25 h

Tune and Luminosity optimisation

Chromaticity and octupoles reduction

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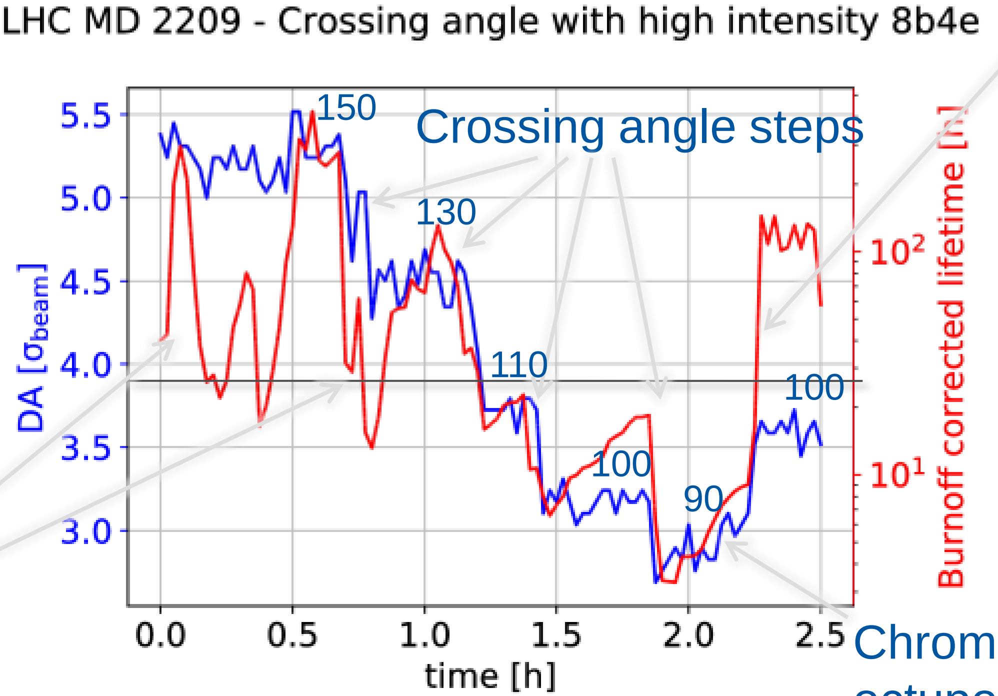


Tune and Luminosity optimisation

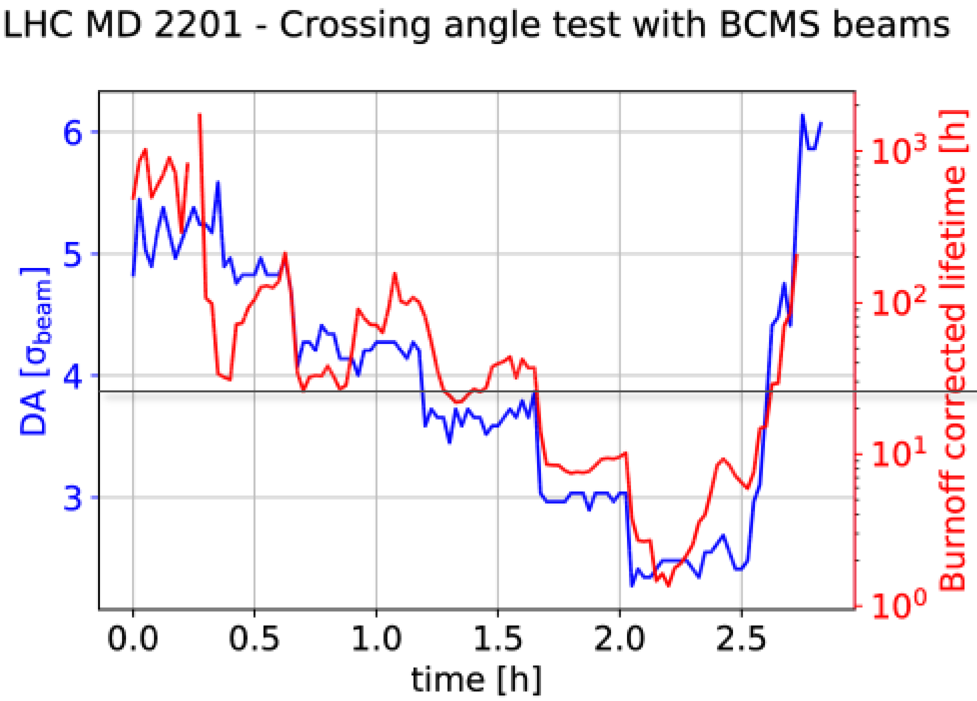
Chromaticity and octupoles reduction

Crossing angle relaxation

- Cannot well reproduce.
- Need lifetime simulations taking into account particles lost previously.
- Possible degradation of the core.

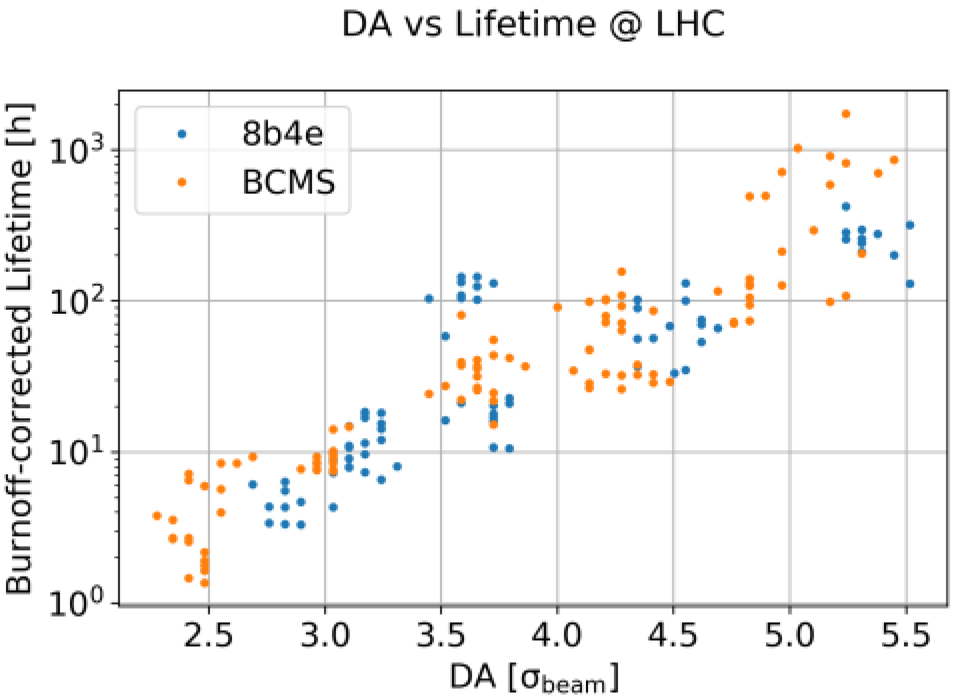
Lifetime vs DA with BCMS beams

Exercise repeated for MD 2201, observing BCMS beams.



Burnoff lifetime ≈ 25 h

DA vs Lifetime



Good agreement between 8b4e and BCMS (non-pacman):

- **4 σ:** give a lifetime equivalent to burnoff.
- **5 σ:** grants lifetimes of ~100 h. Minimum target for operation if well in control.
- **6 σ:** suitable for studies further in the future in presence of larger uncertainties.

Summary

- Assessed **sensitivity** to tunes, chromaticity and octupoles, with both operational experience and simulations.
- Spot-on **predictions** of the crossing angle requirements in various scenarios, including anti-levelling.
- Better understanding on DA and lifetime **correlations** and DA targets.

Comments on Computing

- DA plots massively relying on the CERN computing resources (~1 year CPU time/plot).
- Greatly suffered from the switch to **HTCondor**.
- Follow up by **ABP-CWG**, slow improvements along 2017.
- Ticket system not always effective, profited from having a **direct line** with IT specialists (thank you Ben Jones!).
- Still some issues from time to time (authentication, scheduler reachability) being reported, but definitely bearable.

Comments on Instrumentation

Outstanding performance of the instrumentation:

- Inputs from many instruments: fBCT, BSRT, Luminosity Monitor, BLM, BBQ, Schottky.
- Relatively easy access with pyTimber and pjLSA.

But few wishes:

- **Tune** determination in collision difficult, trims are often performed almost “blindly”.
- Transverse profile **tail** knowledge (up to ~6 σ) would be desirable for guiding lifetime simulations (coronagraph?).

Thank you!

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