Review of the e-cloud estimates in the HL-LHC triplets/D1

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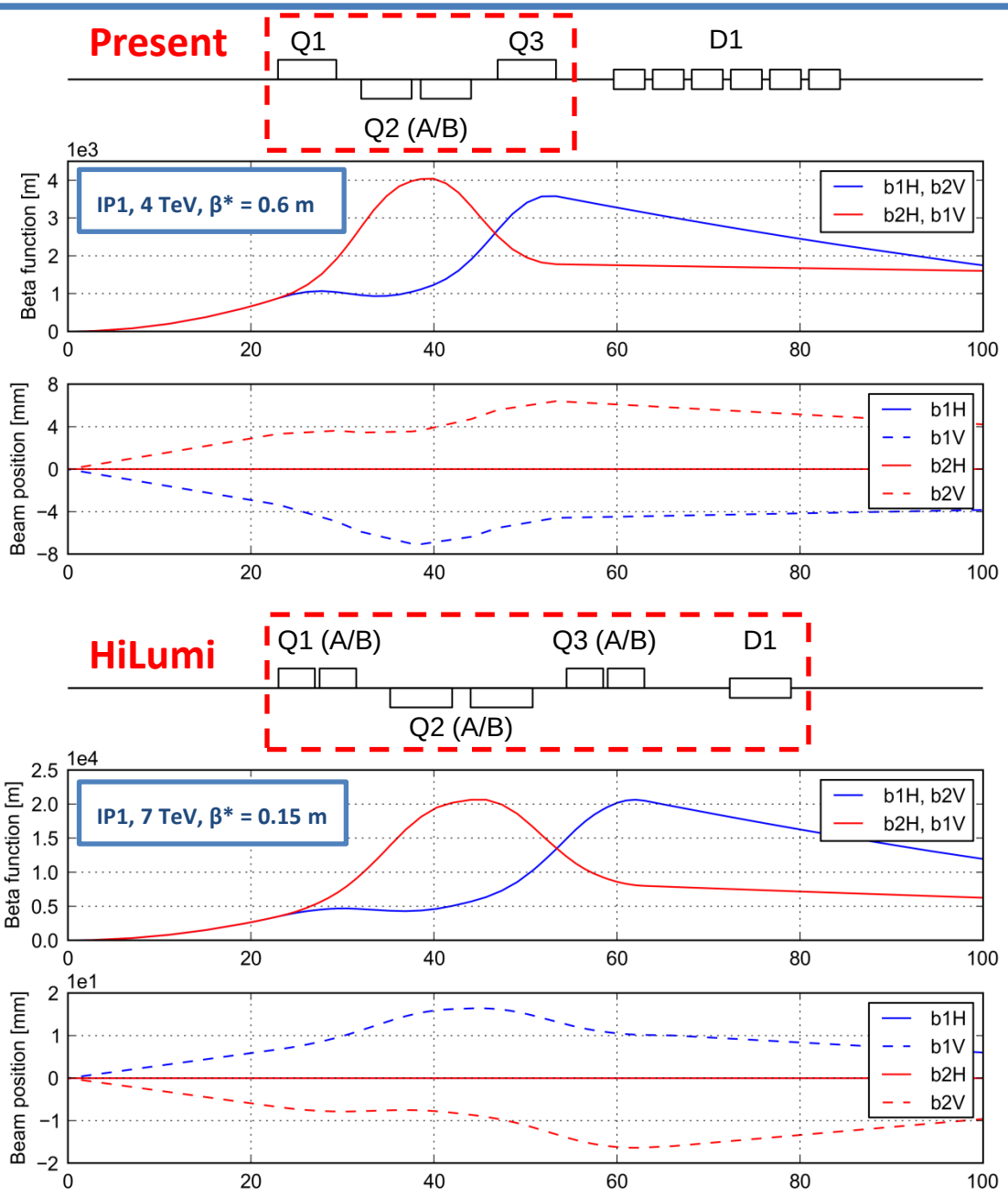
in 7th HiLumi WP2 Task 2.4 meeting

26/02/2014

Outline

- **Introduction: the HL-LHC triplets/D1 in IP1 (IP5)**
- **Electron cloud effects in the HL-LHC inner triplets**
  - Simulation results
  - Comparison with present triplets and mitigation
- **Observations for IP2 and IP8 triplets: open questions and extrapolation to HL-LHC operation**
- **Conclusions**

Inner triplets for HL-LHC upgrade



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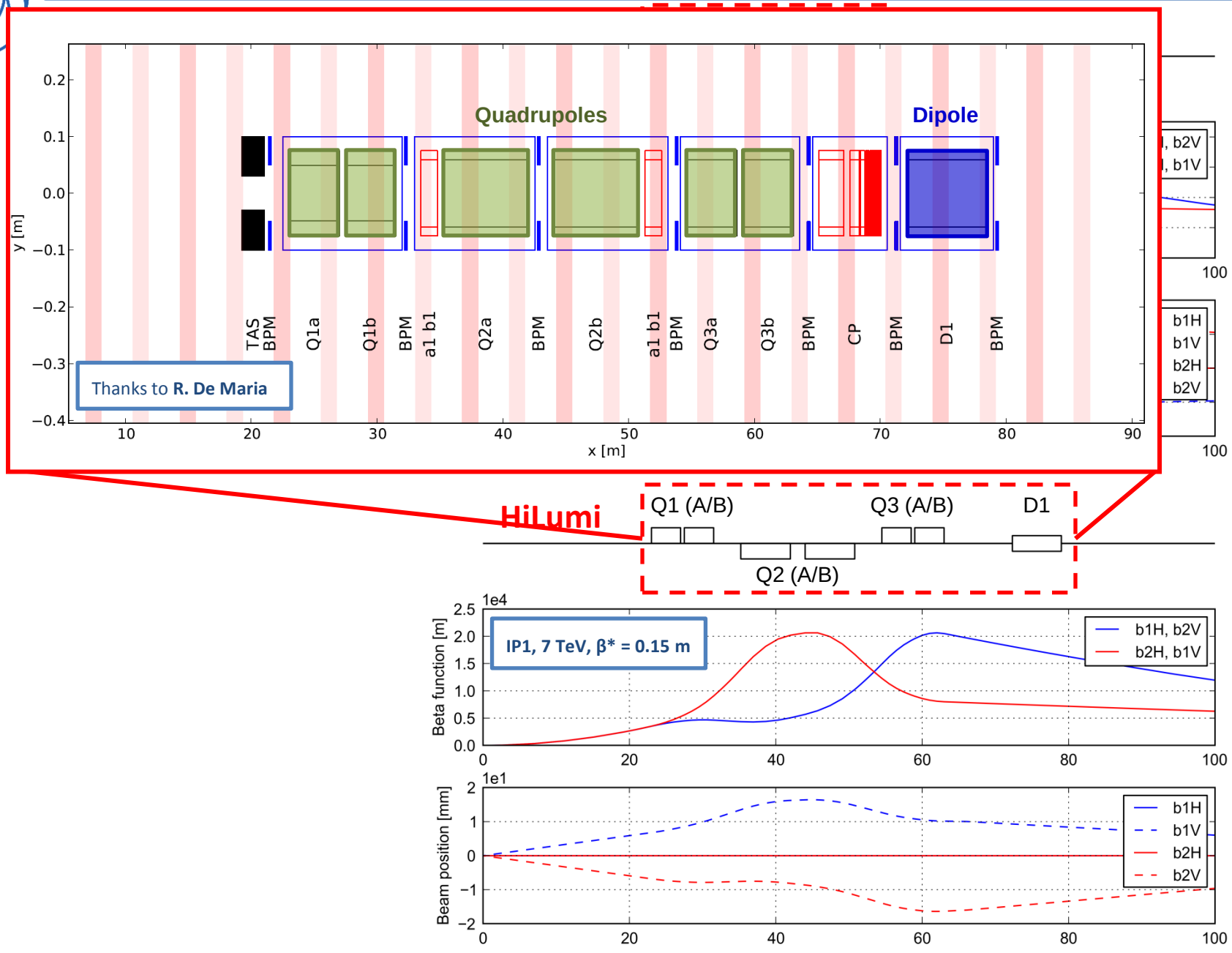

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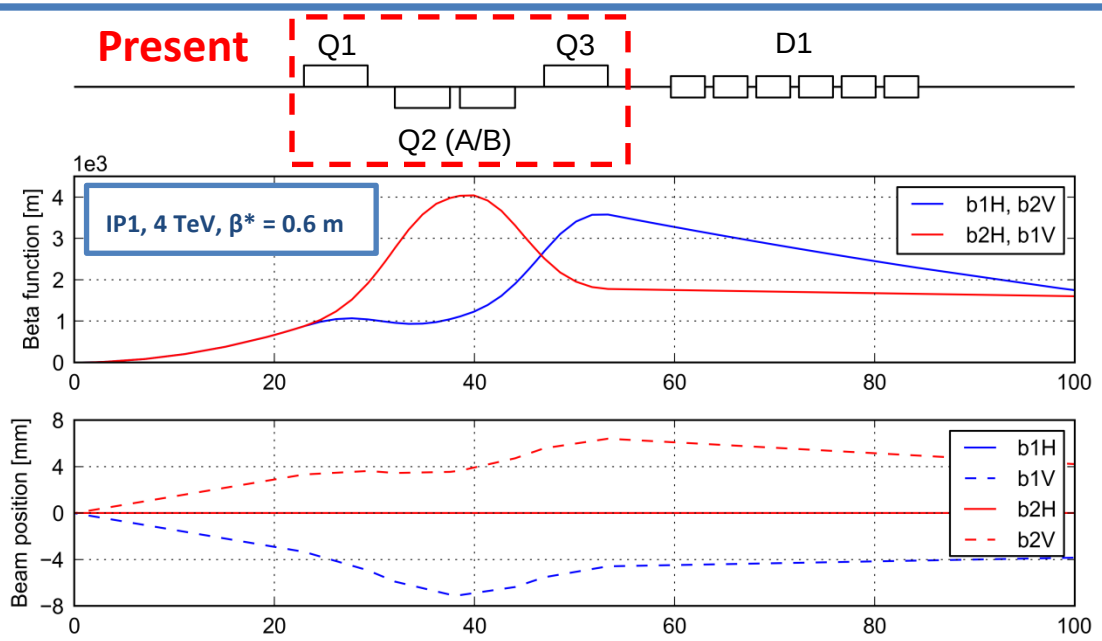
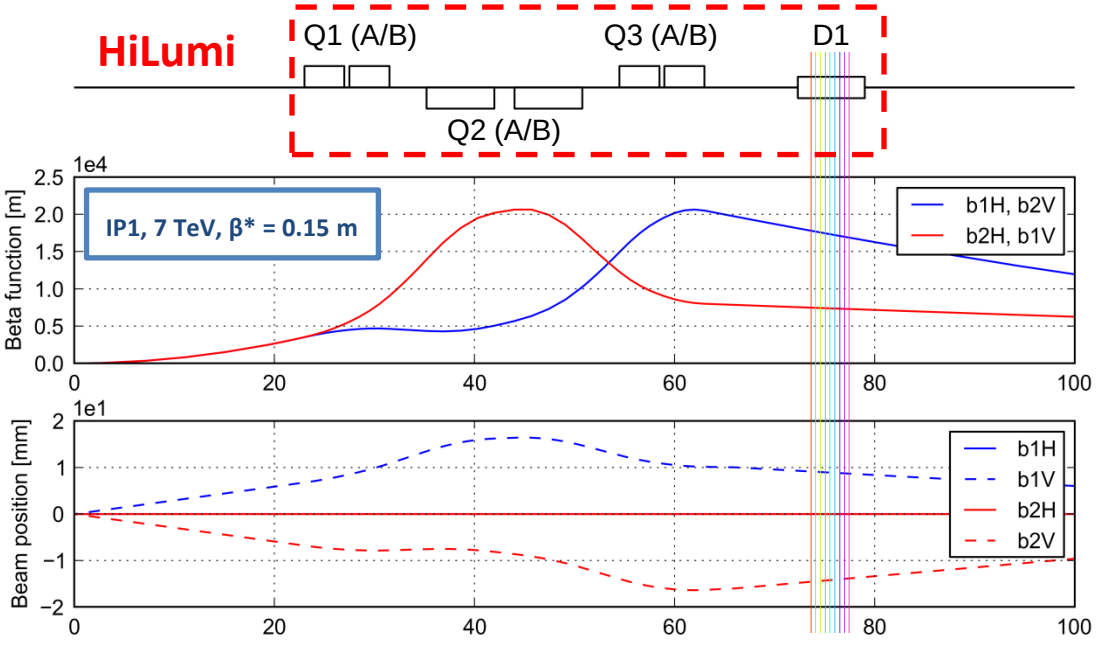
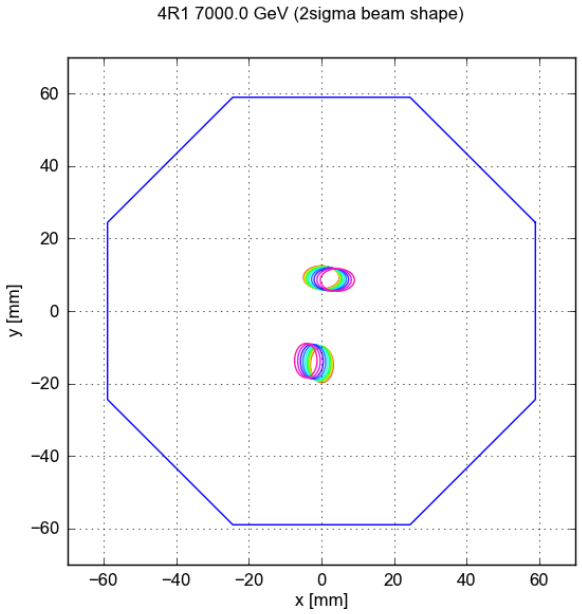




IP1



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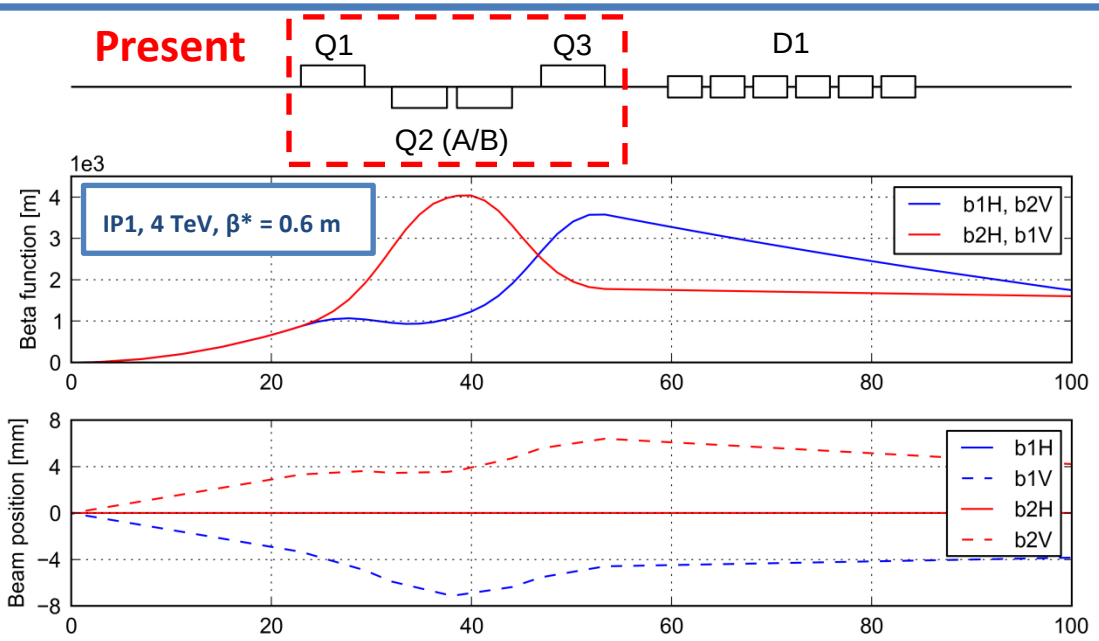

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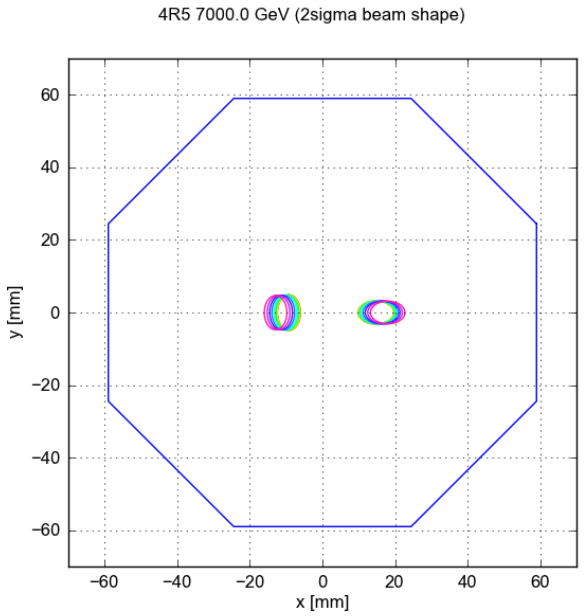

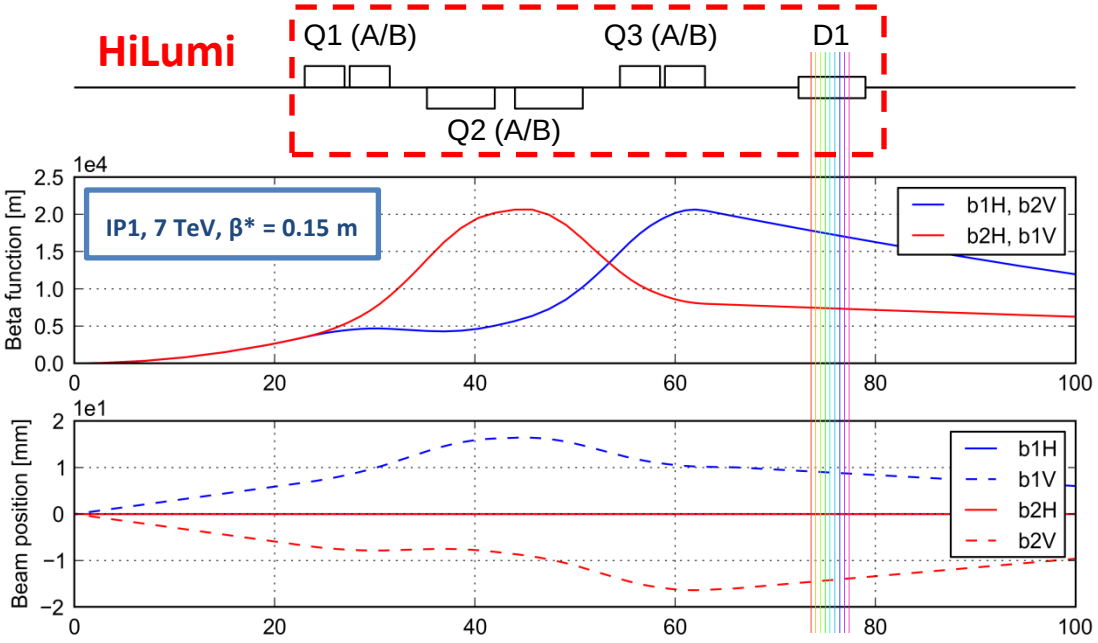

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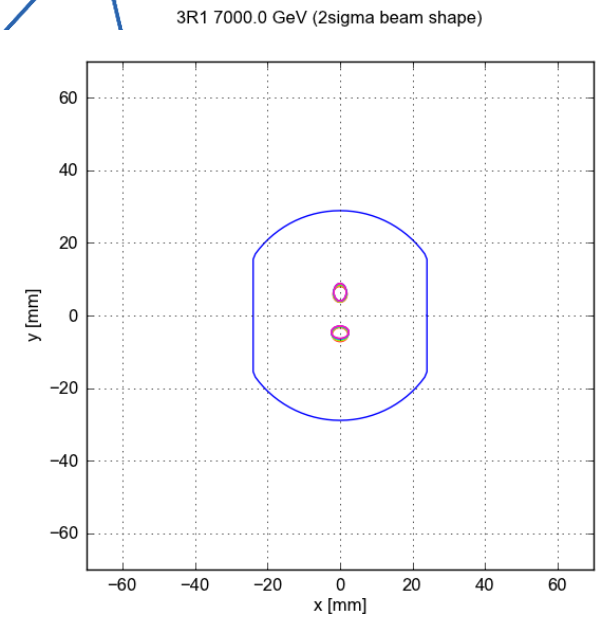

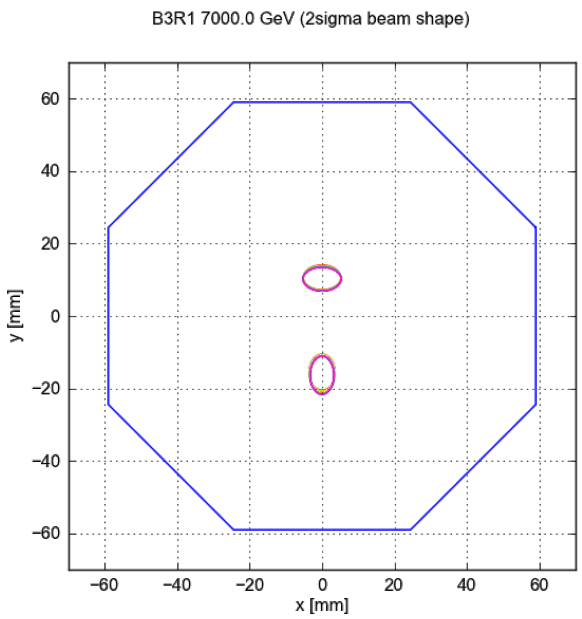

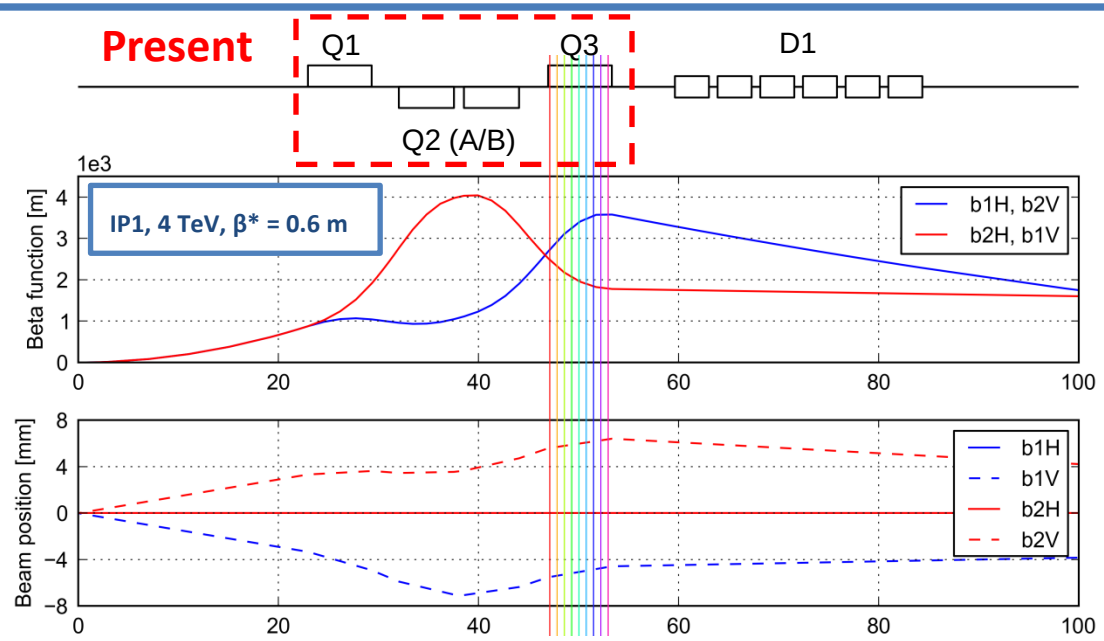

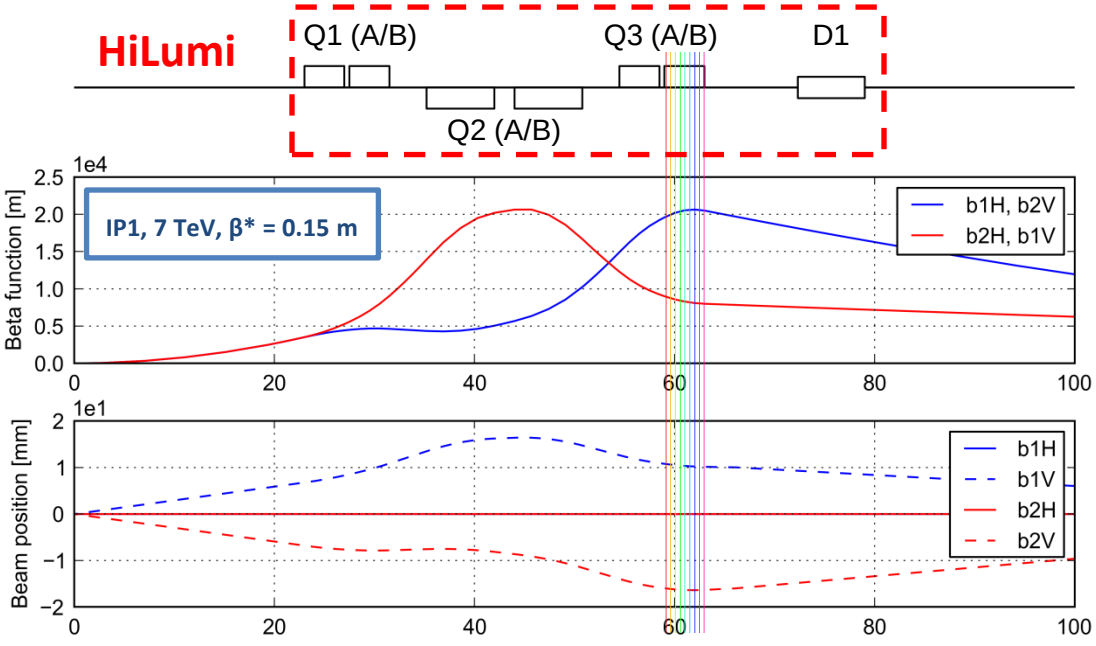

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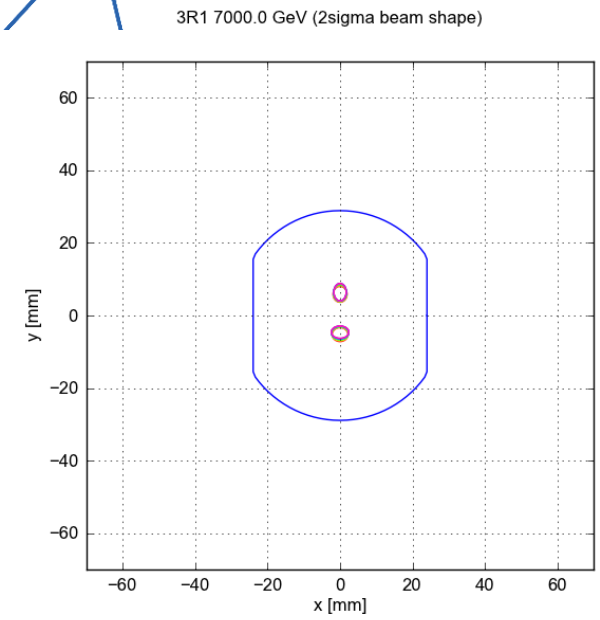

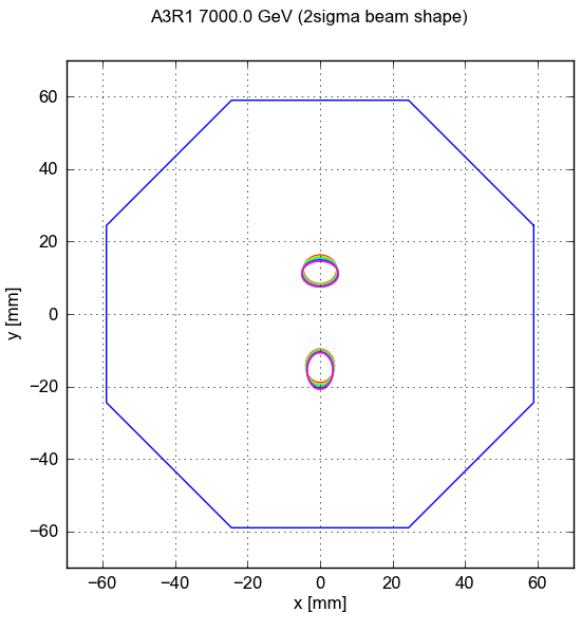

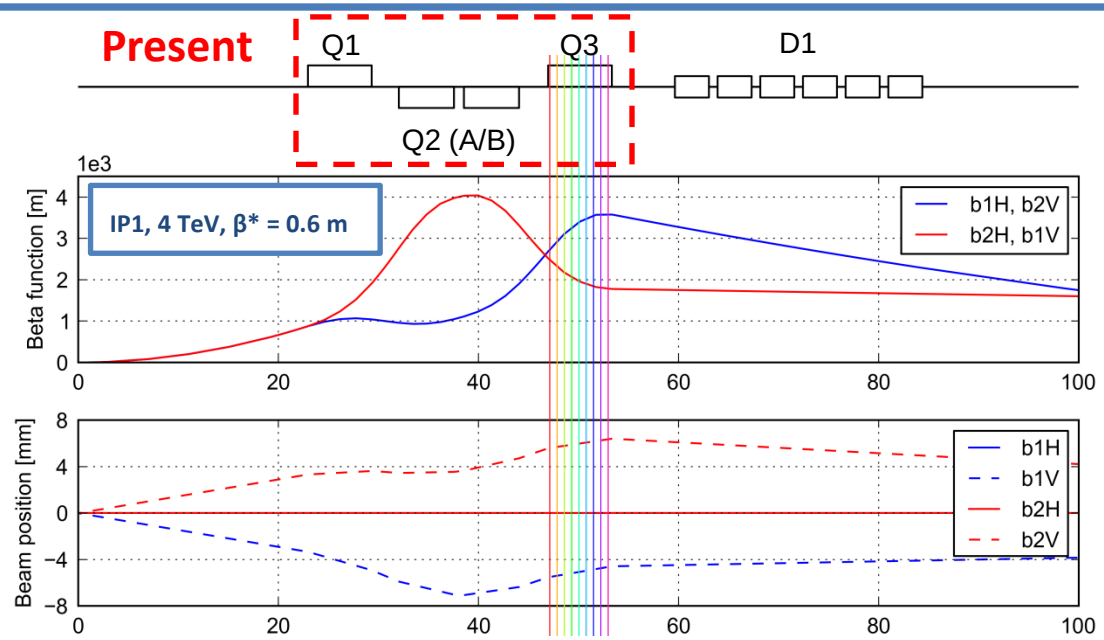

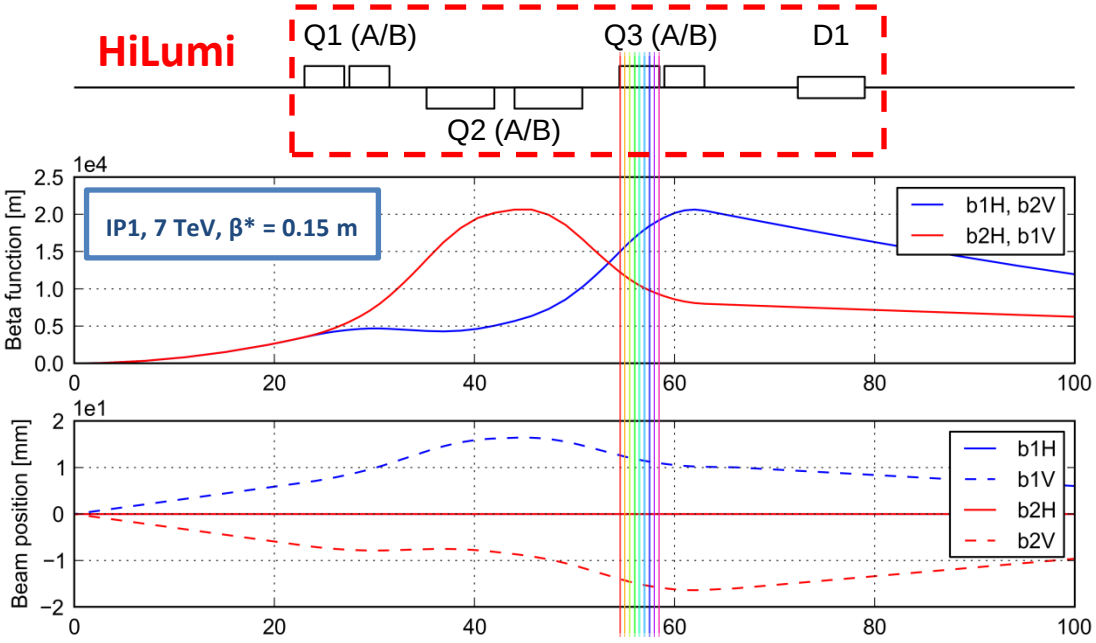

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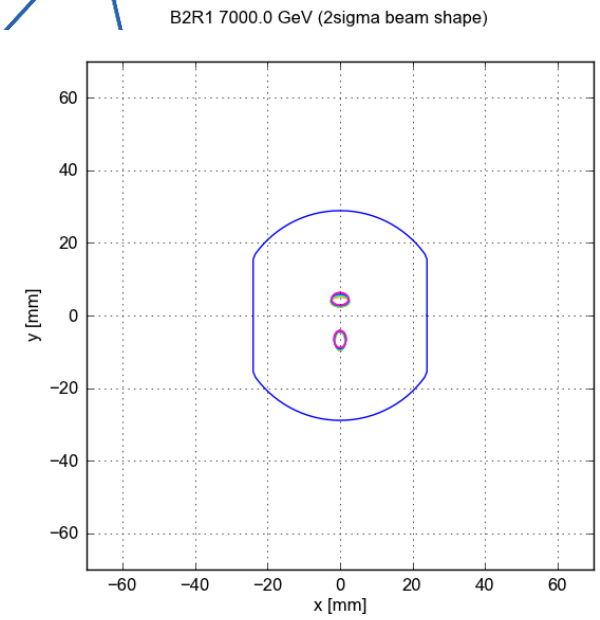

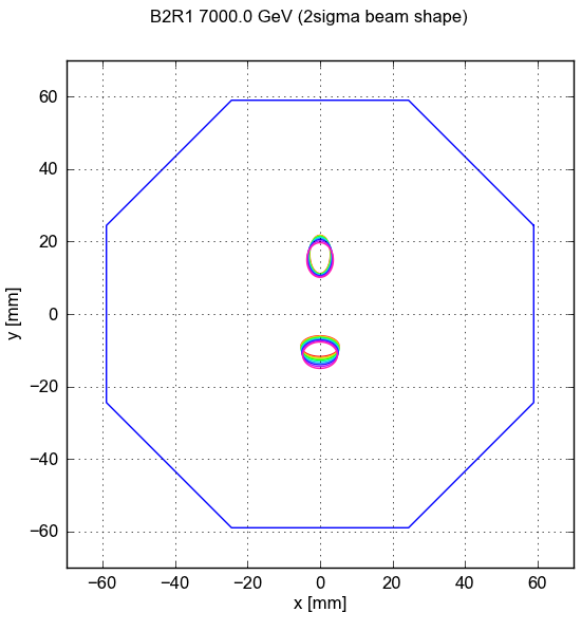

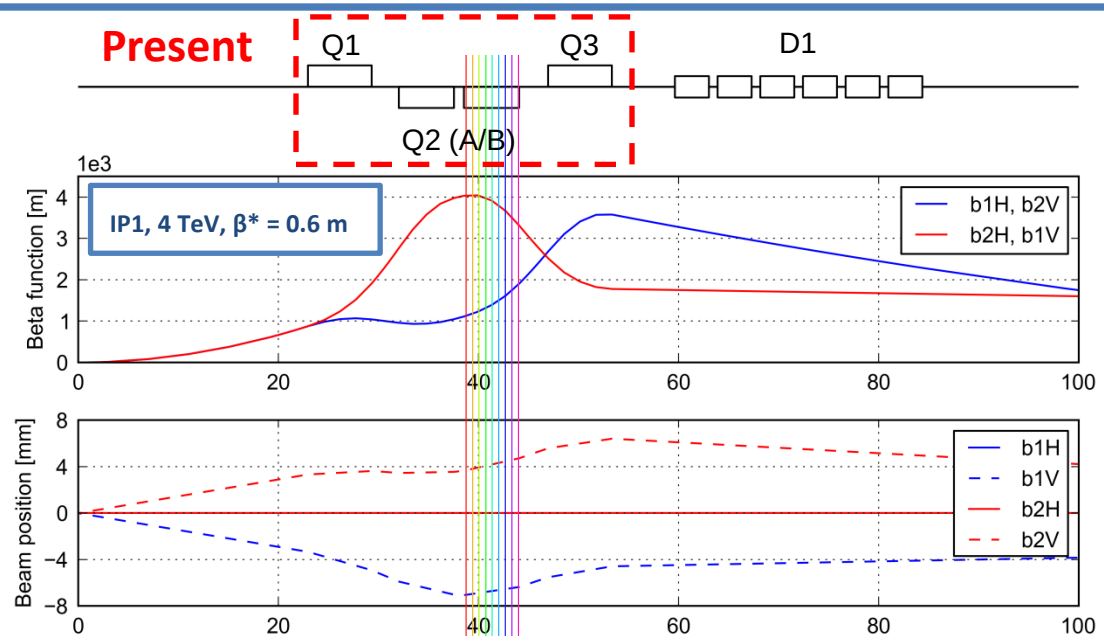

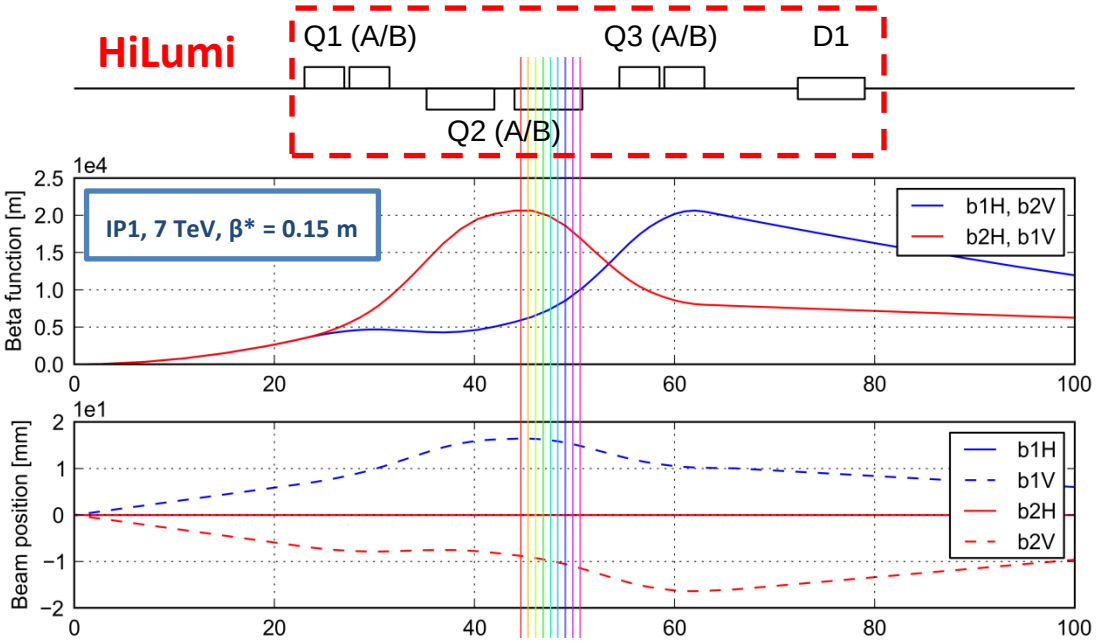

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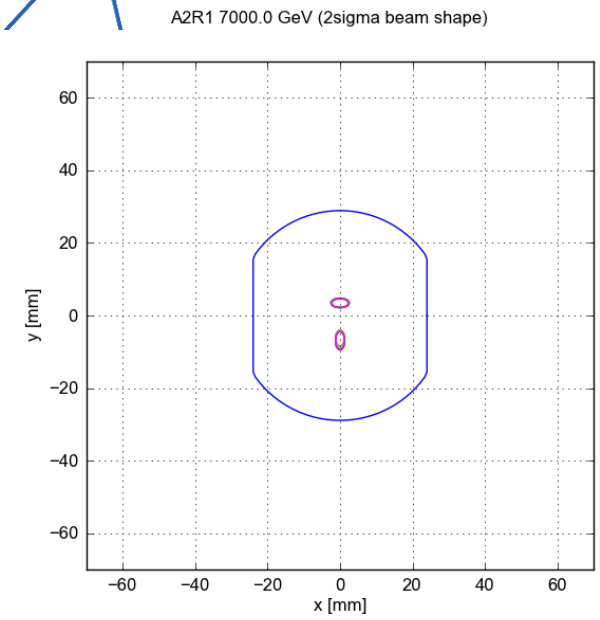

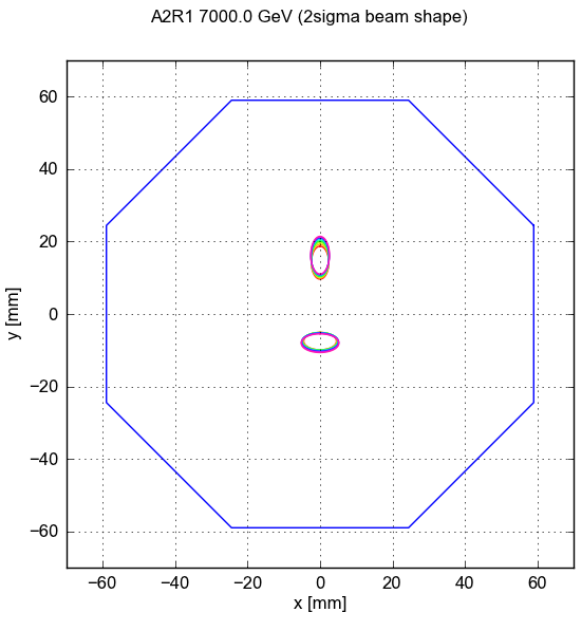

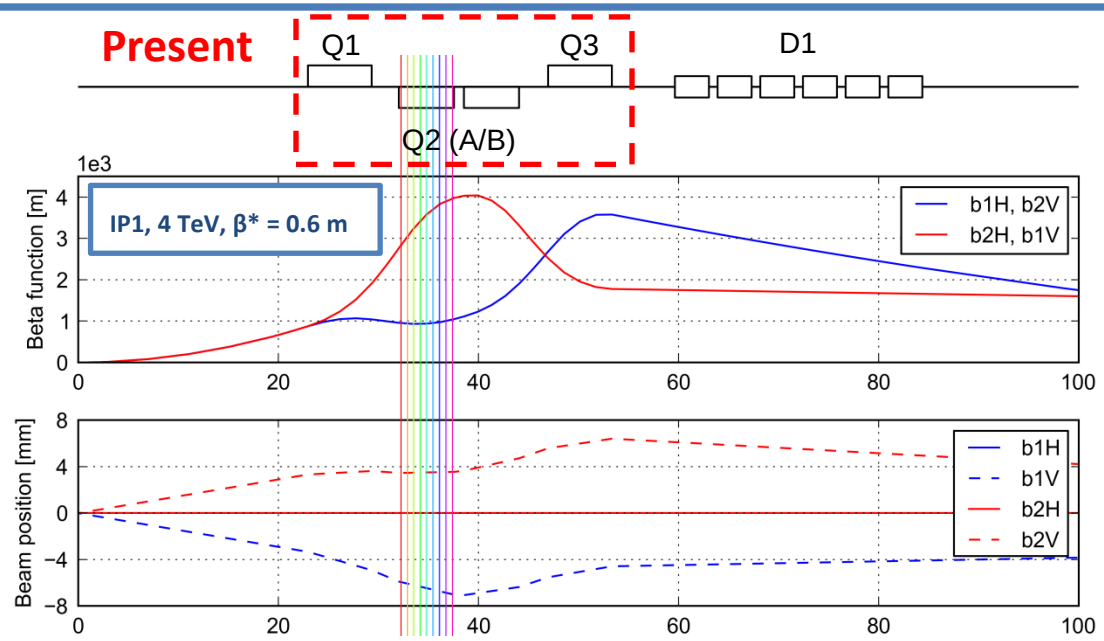

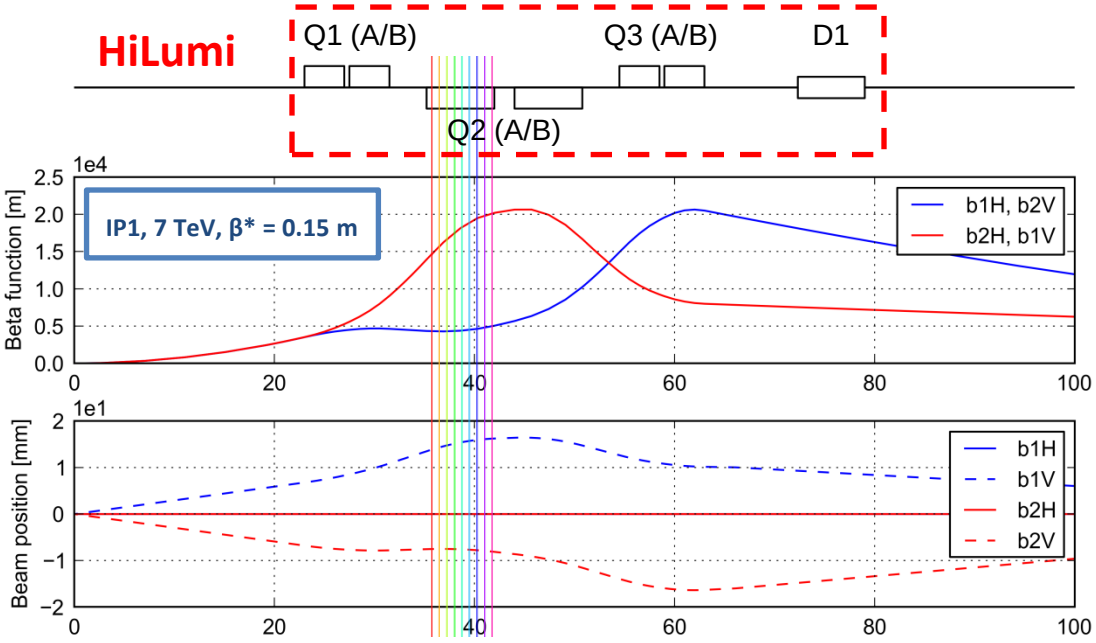

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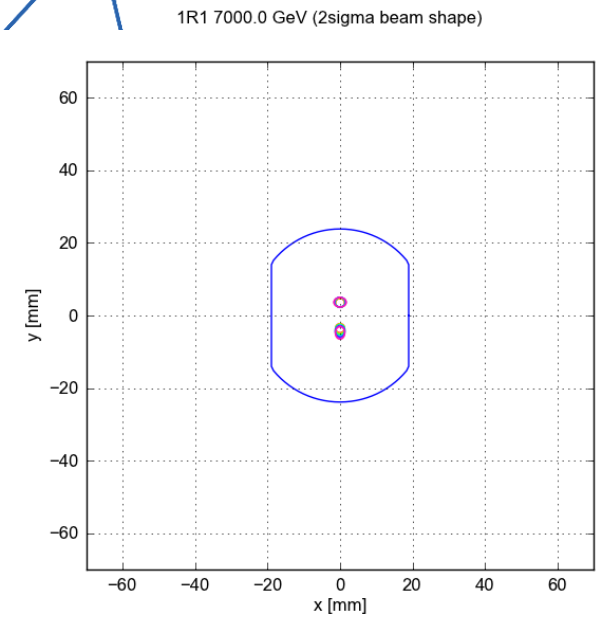

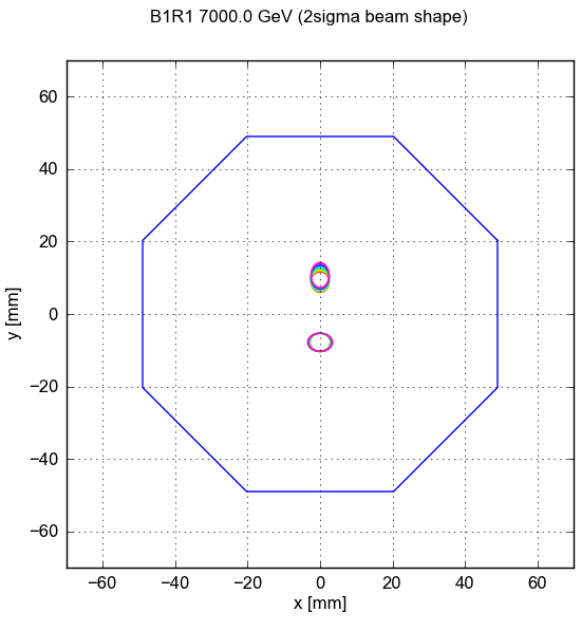

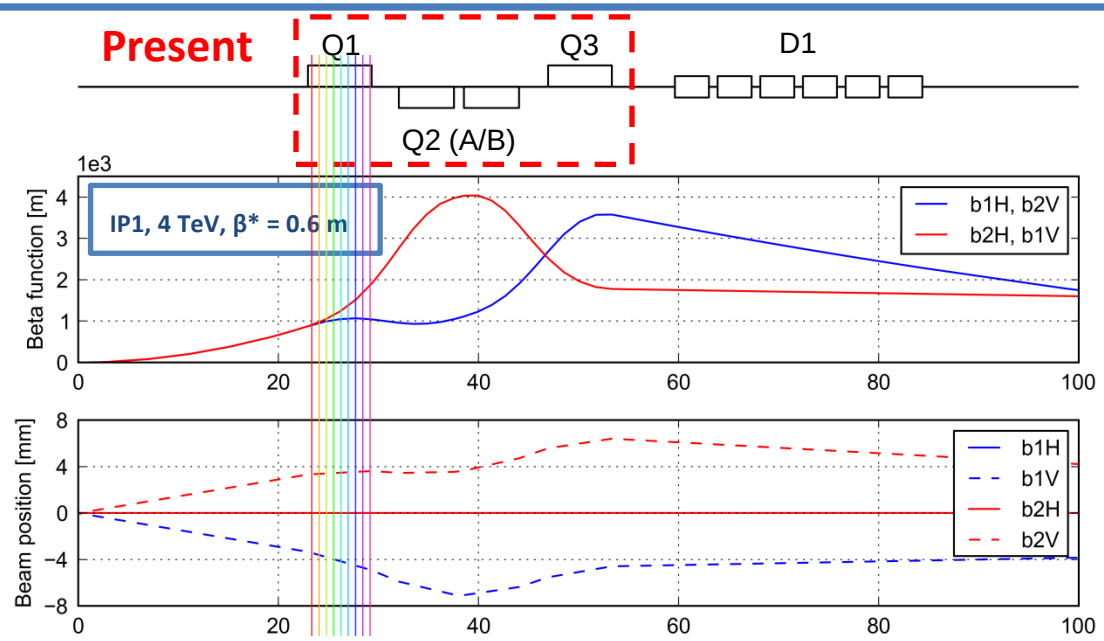

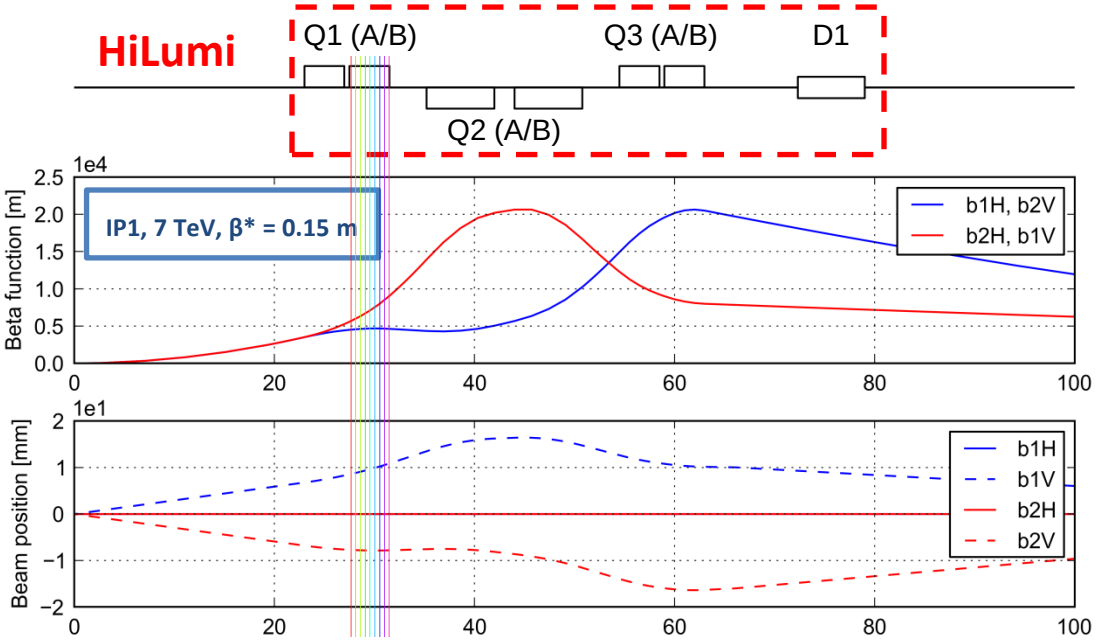

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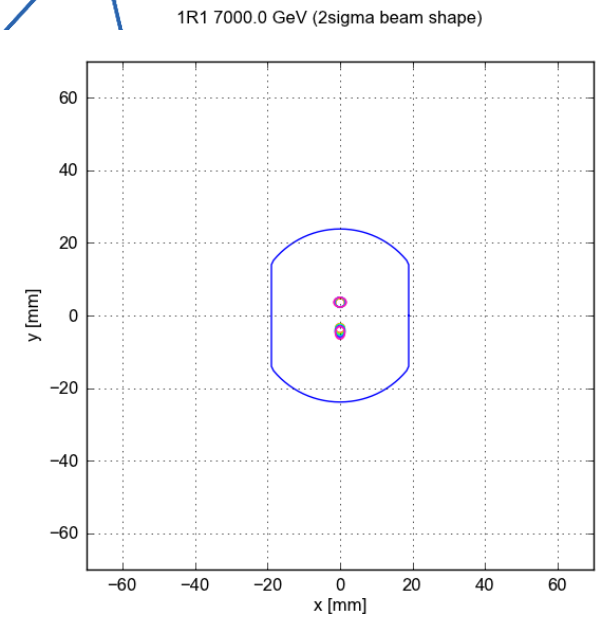
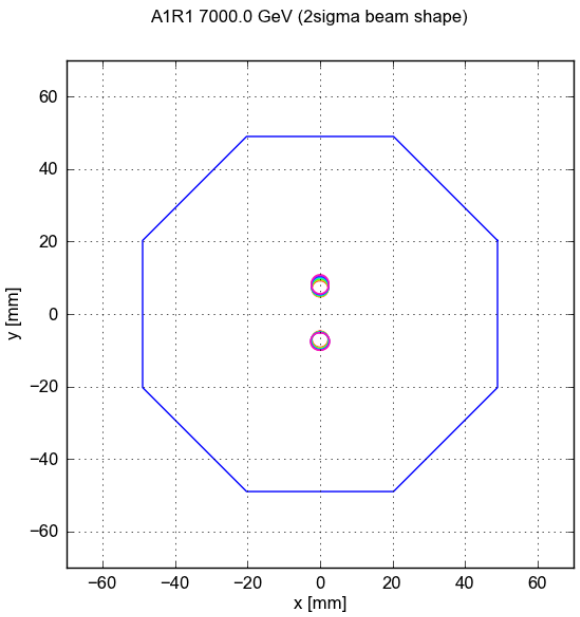
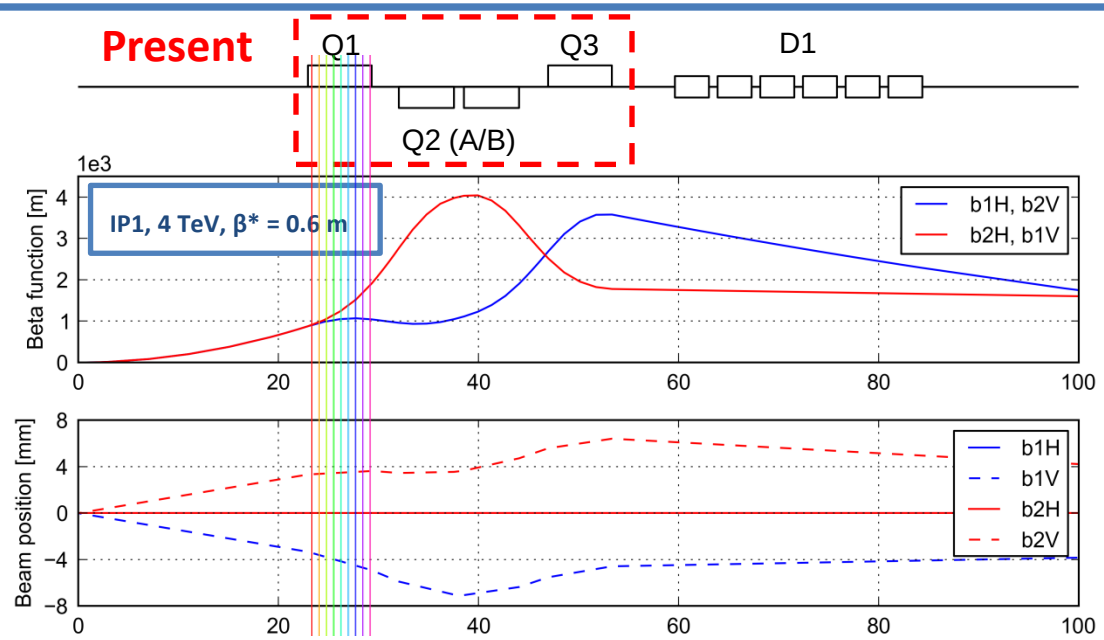
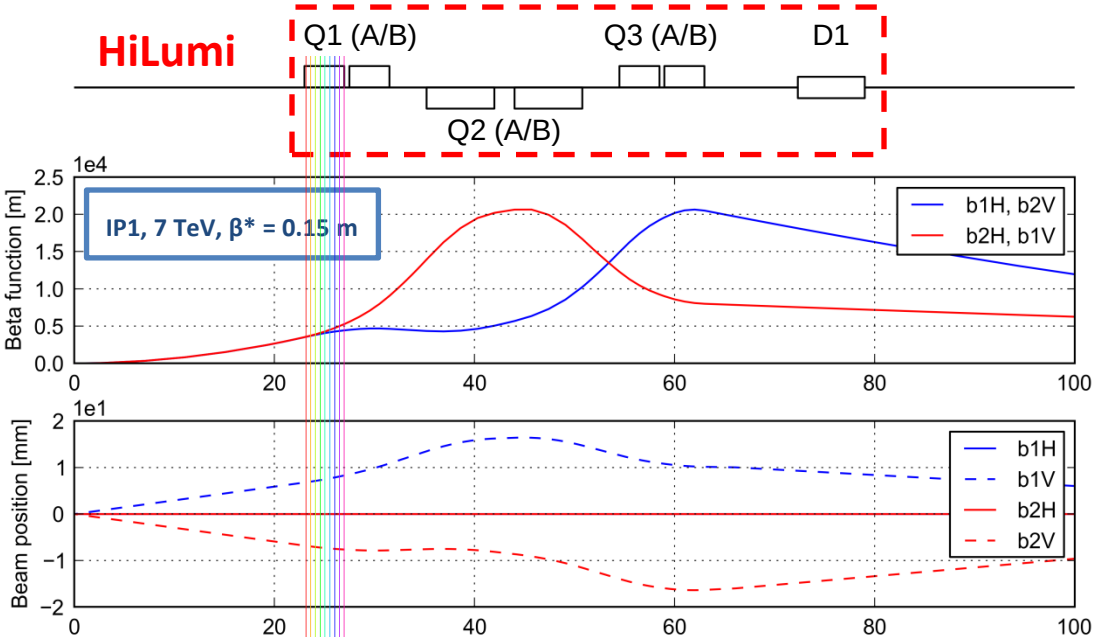




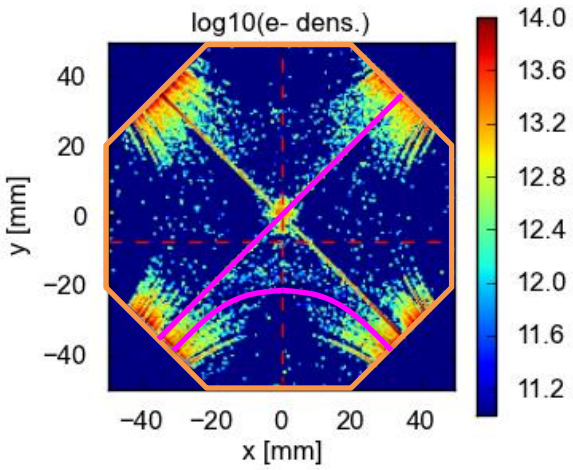


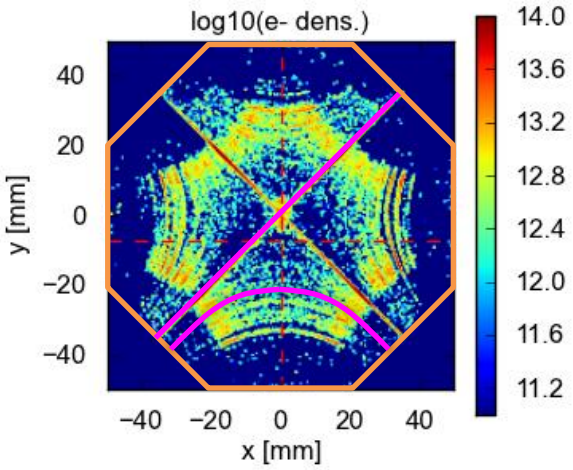


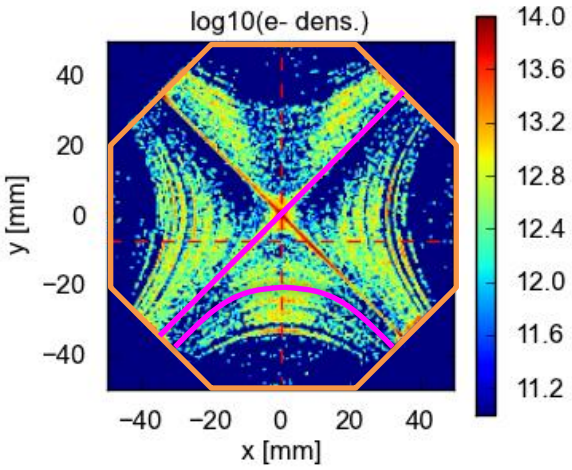
A look to the EC buildup – HL-LHC triplets

Few snapshots of the **electron distribution** → HL-LHC triplets develop thicker stripes along field lines farther from the center of the chamber

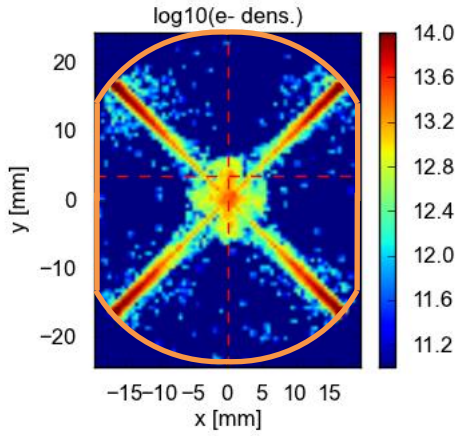
HL-LHC (2.20 x 10^{11} ppb)

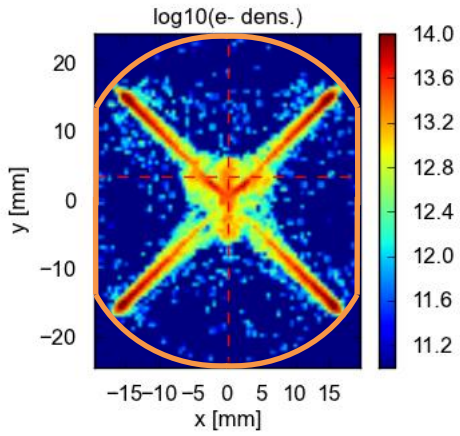


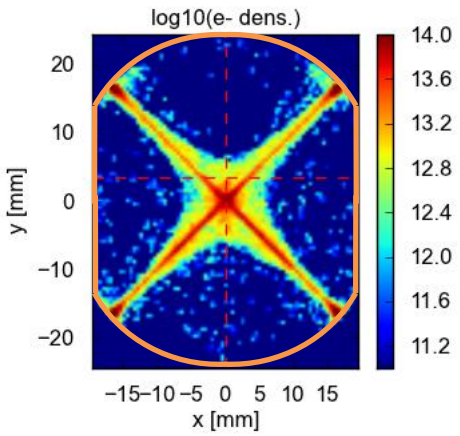




Present (1.15 x 10^{11} ppb)







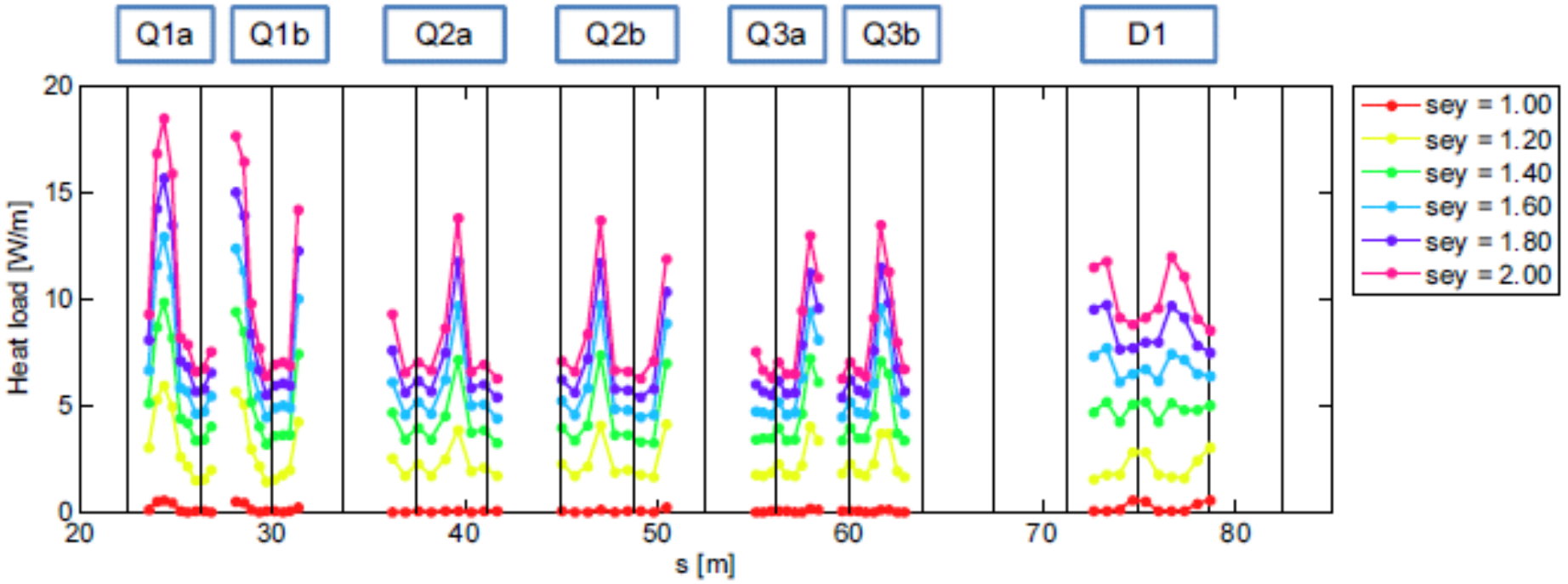
Distribution of heat load – HL-LHC triplets

Heat load distribution along HL-LHC triplets + D1

→ Build up more or less efficient at different locations mainly due to the different hybrid bunch spacings

→ The least efficient build up, i.e. lower heat load, at the locations of the long-range encounters (vertical dashed lines)

→ Values in D1 are comparable or higher than values in the quads

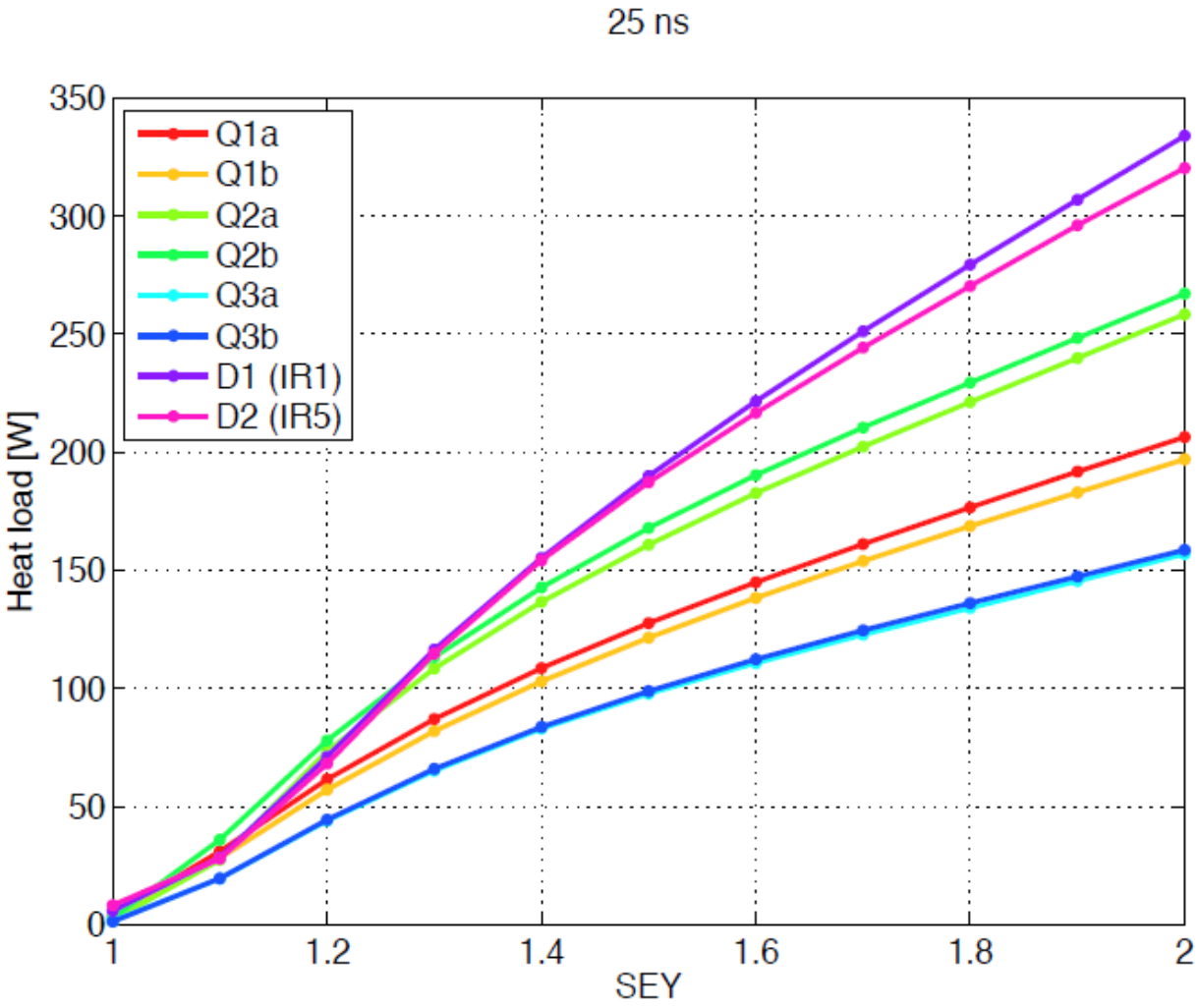


Total heat load per element – HL-LHC triplets

Total heat load per element in HL-LHC triplets + D1

→ Similar thresholds for quads and D1

→ Values in D1 higher than values in the quads for high SEY values



Total heat load on the triplet beam screen

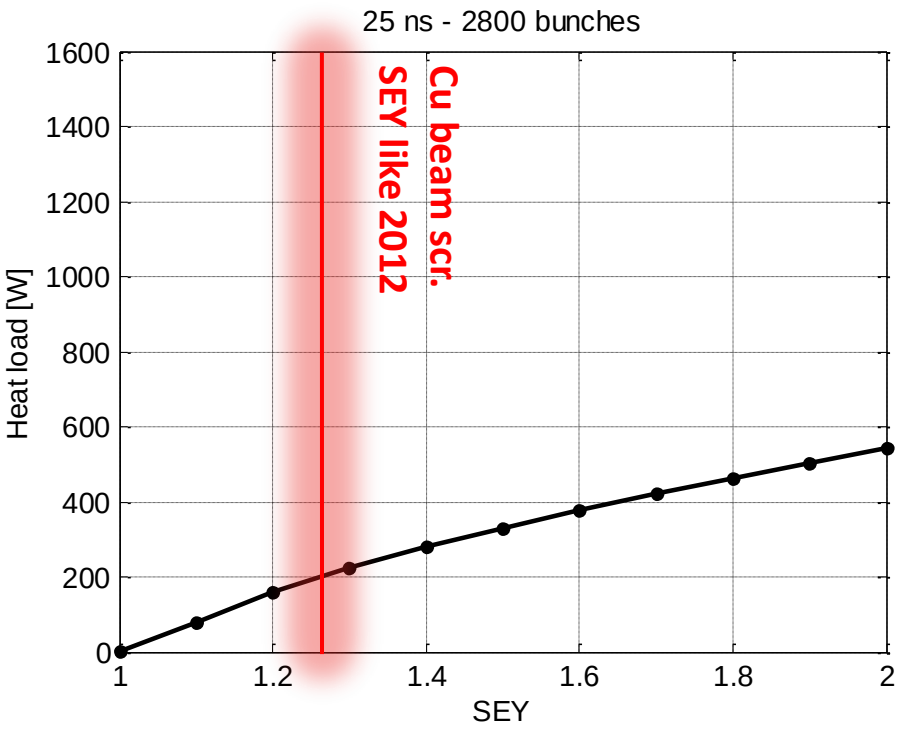
Effect of larger bunch population and chamber size. For the **same SEY**:

- Similar energy of multipacting electrons
- Larger number of impacting electrons

⇒ Total **heat load about x3 larger**

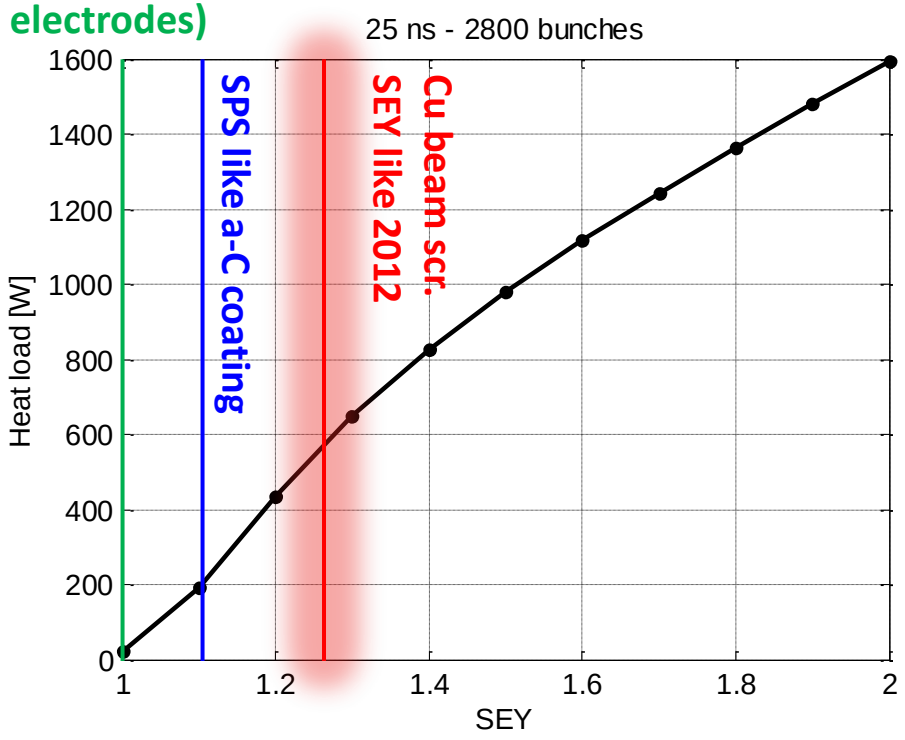
e-cloud suppression can be obtained using **low SEY coatings** and/or **clearing electrodes**

Present triplets
(1.15 x 10^{11} ppb)

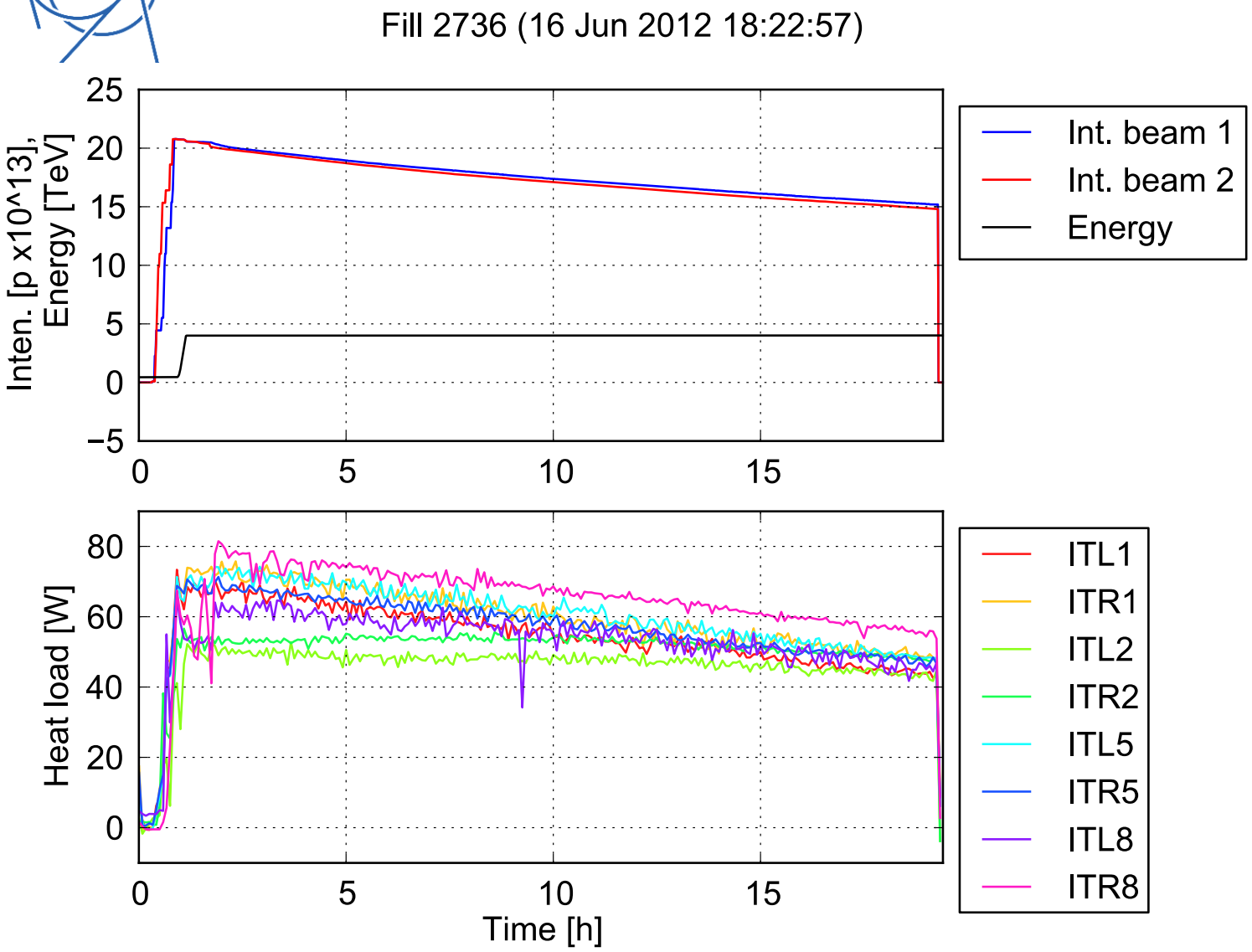


Full suppression (SEY≈1 or clearing electrodes)

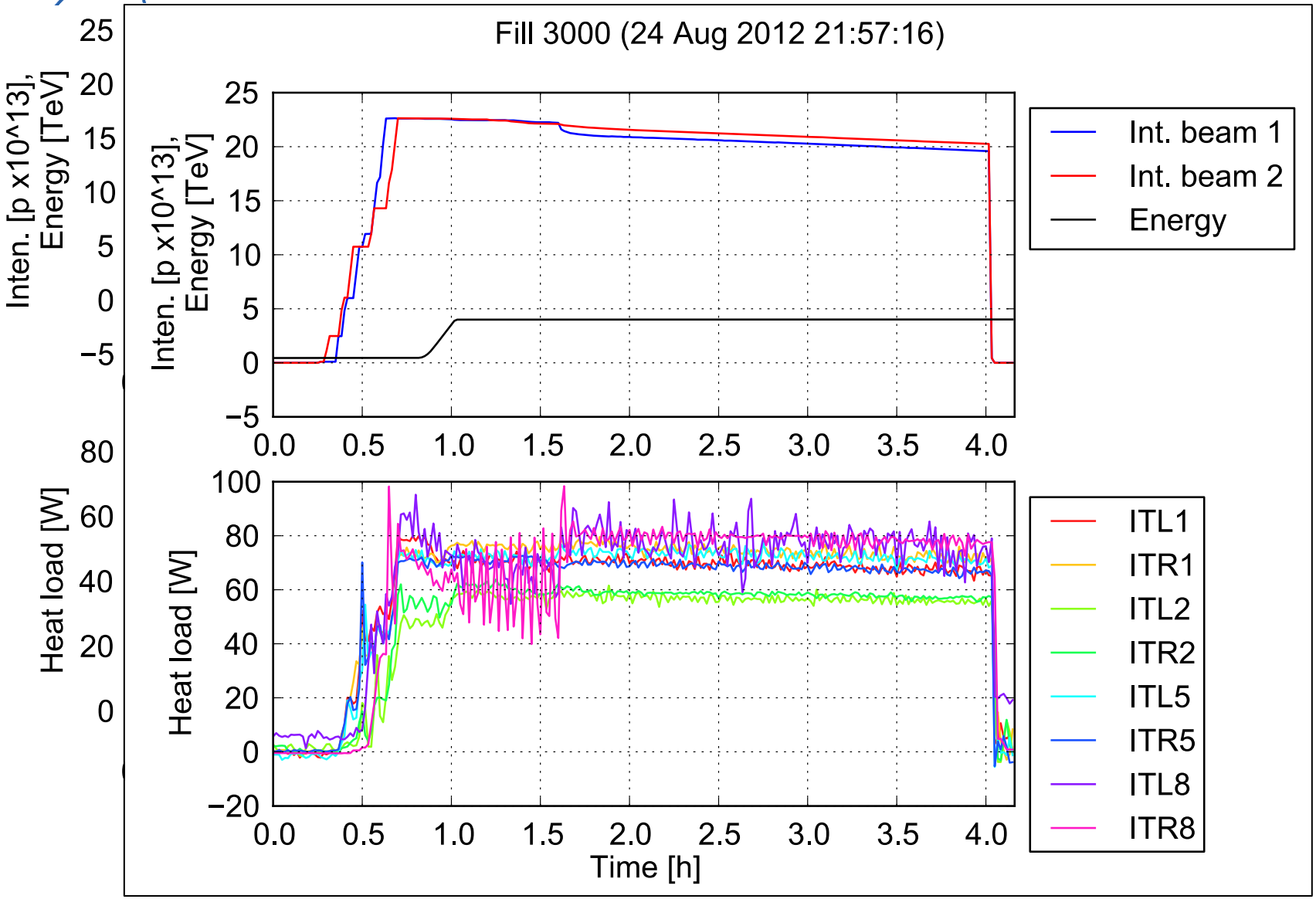
HiLumi triplets
(2.20 x 10^{11} ppb)



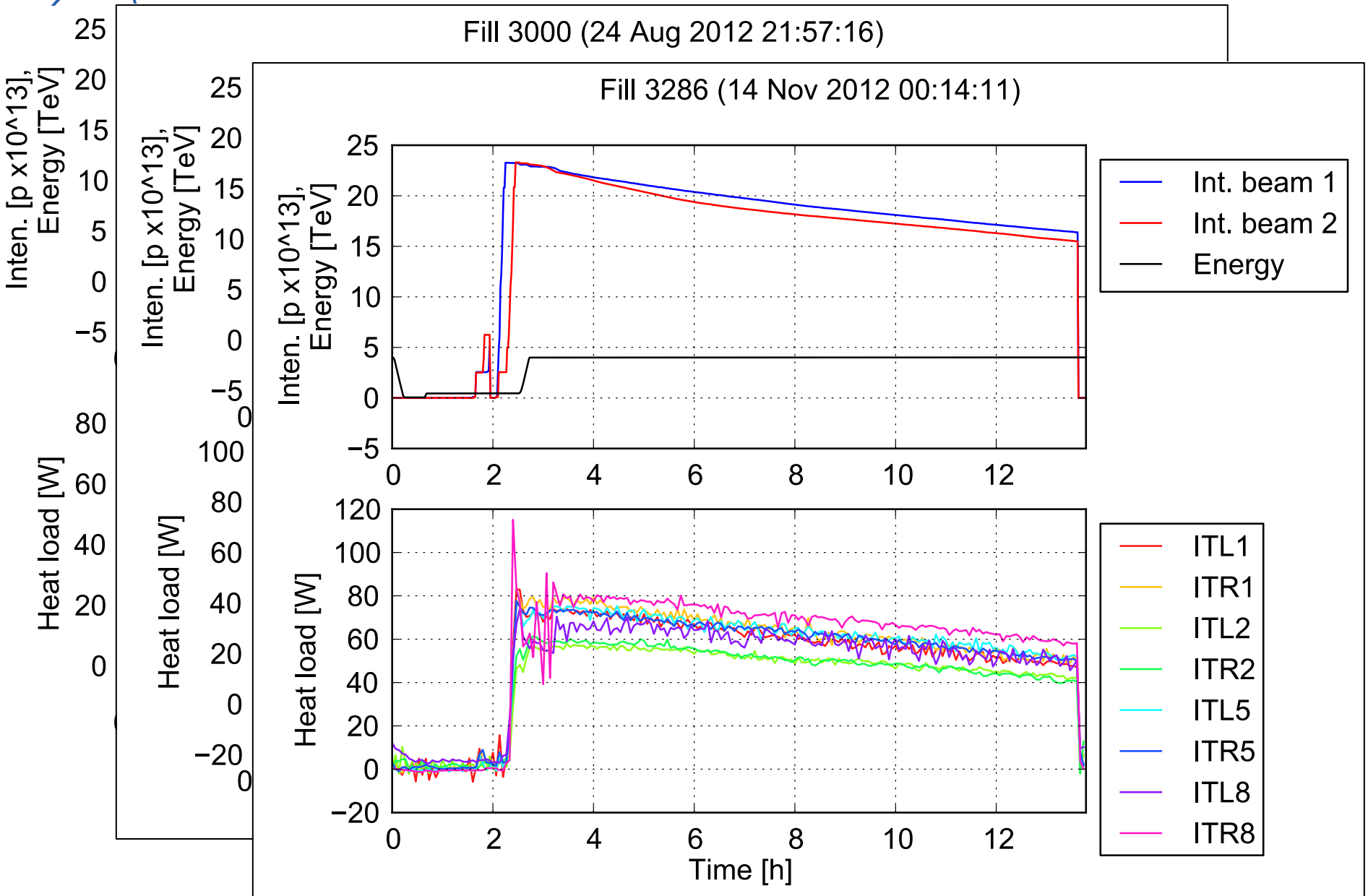
Measured heat load (50ns) – IP2 and IP8



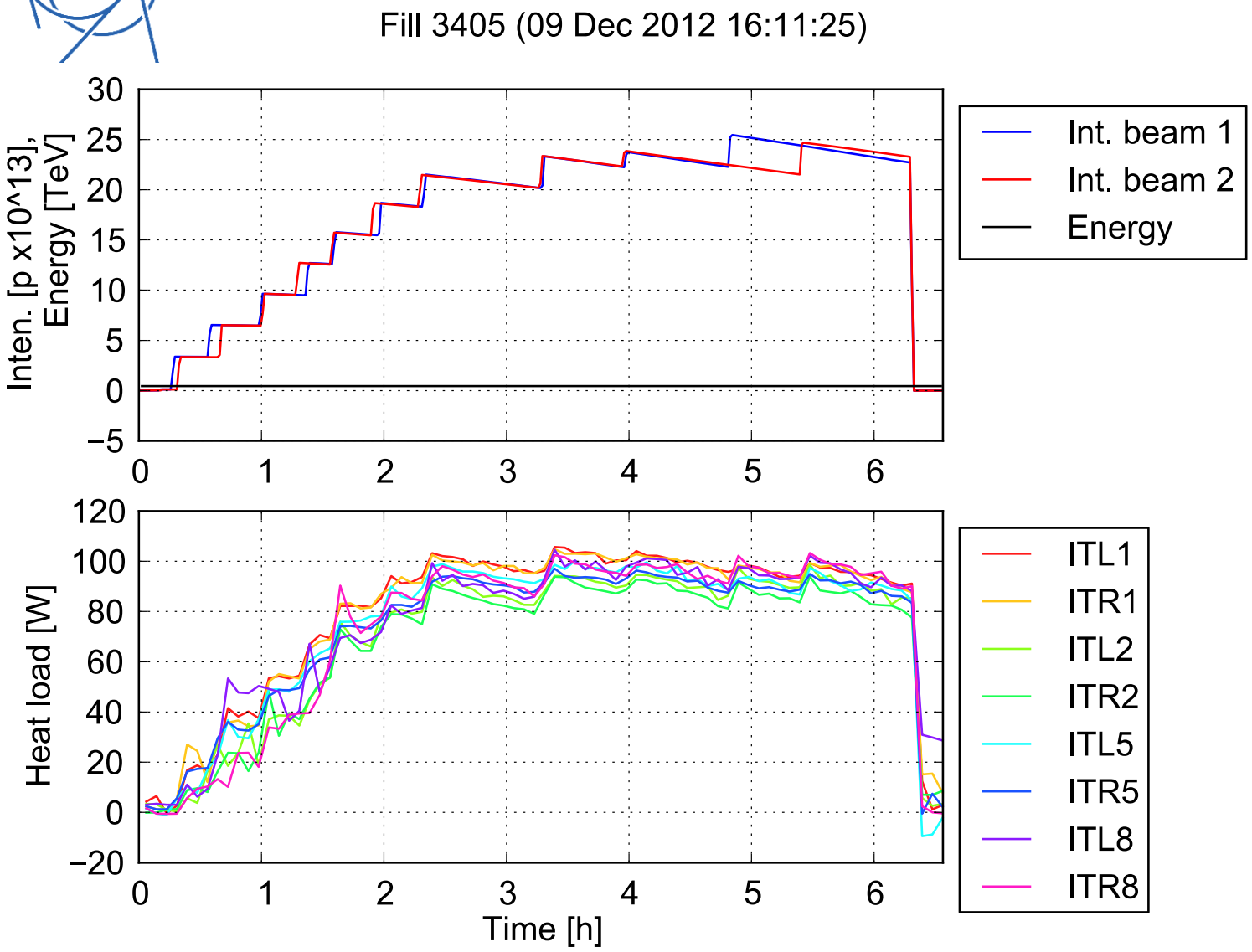
Measured heat load (50ns) – IP2 and IP8



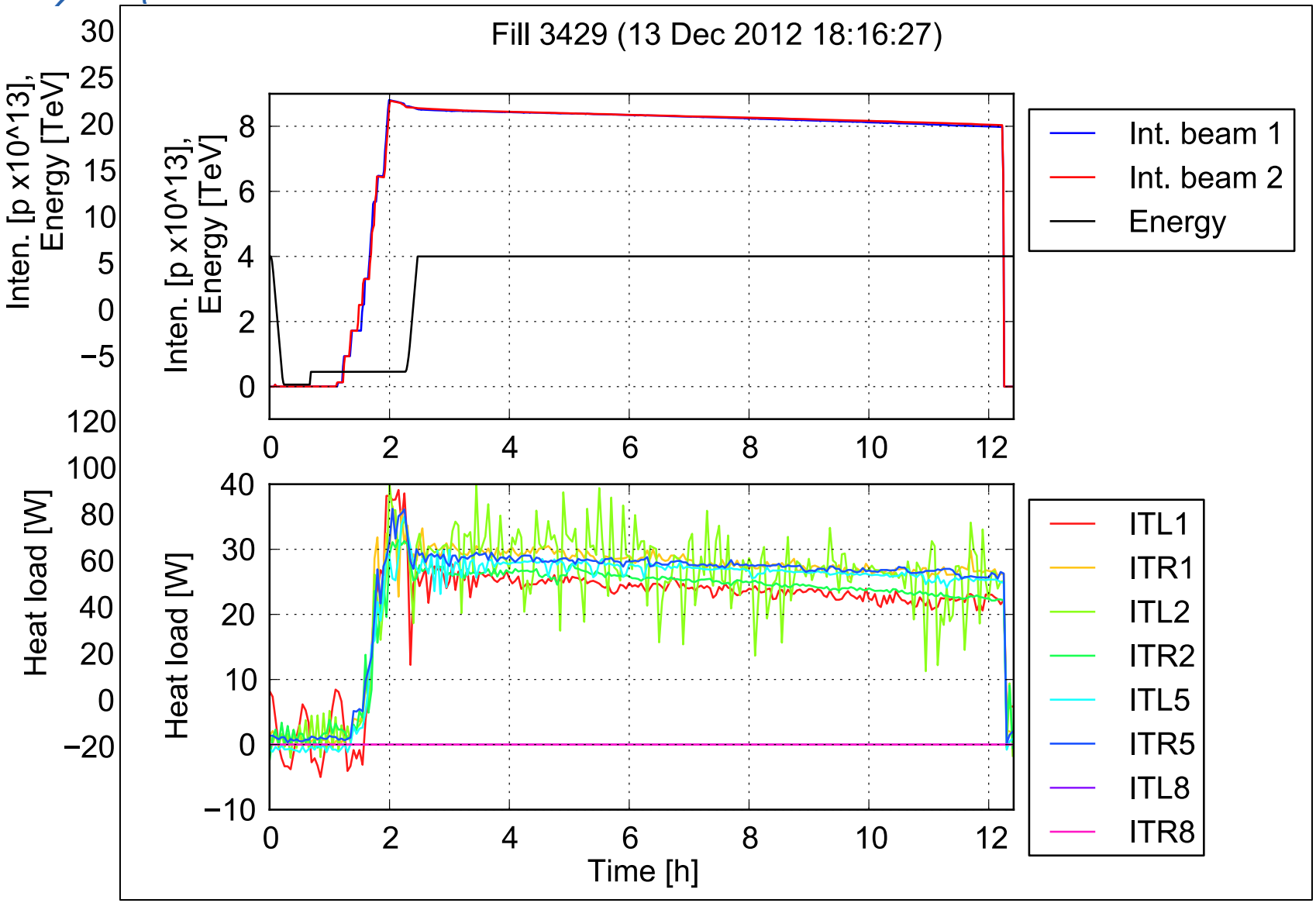
Measured heat load (50ns) – IP2 and IP8



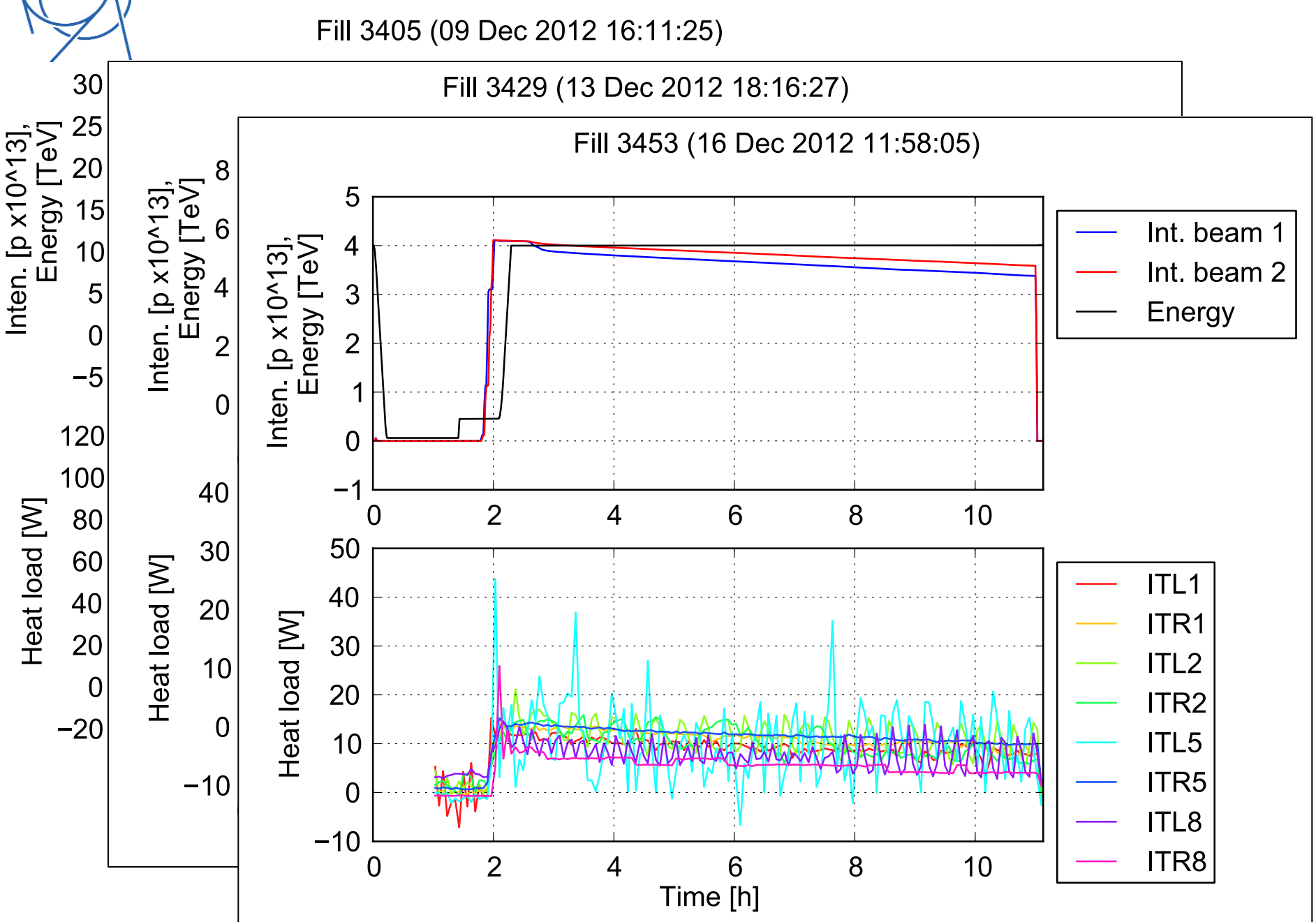
Measured heat load (25ns) – IP2 and IP8



Measured heat load (25ns) – IP2 and IP8



Measured heat load (25ns) – IP2 and IP8



Facts and observations – IP2 and IP8

→ Unlike IP1 and IP5, the cryostats in IP2 and IP8 already include D1 (about 10m long)

→ IP1 and IP5 exhibit similar behaviors for all our sample fills

→ The heat load on the beam screen of the IP8 triplets

- has a funny behavior between end of injection and beginning of stable beams (especially during squeeze and adjust)
- is similar to IP1 and IP5 in stable beams
- is similar to IP1 and IP5 for the 25ns cases

→ The heat load on the beam screen of the IP2 triplets remains systematically ~20% lower than all the other IPs throughout the 50ns fills

→ In the 25ns run, there is no important difference between the heat load for the IP2 triplets and the others

Facts and observations – IP2 and IP8

Some tentative explanations of all these observations

→ Optics gymnastics around IP8 during squeeze and adjust ?

→ In 50ns fills, IP8 has about 120 collisions less than IP1 and IP5, which should yield 5-10% less heat load. Perhaps this is compensated by extra heat load from D1 ?

→ Beams not colliding in IP2 with 50ns: this changes all the pattern of the LR encounters in the triplets and they become shifted into the quadrupoles ➔ estimated reduction by ~20% of the heat load, as measured, but then we do not see D1 ?

→ D1 does not contribute significantly to the global heat load of the triplets (as suggested by the 25ns fills) ?

- ❑ But simulations show similar thresholds, so no reason why it should be better scrubbed than the quadrupoles (unlike dipoles and quadrupoles in the arcs)
- ❑ But also in 25ns fills different numbers of collisions in IP2 and IP8 wrt IP1 and IP5, although enhancement due to two beams is less pronounced with 25 ns

Facts and observations – IP2 and IP8

Some tentative explanations of all these observations

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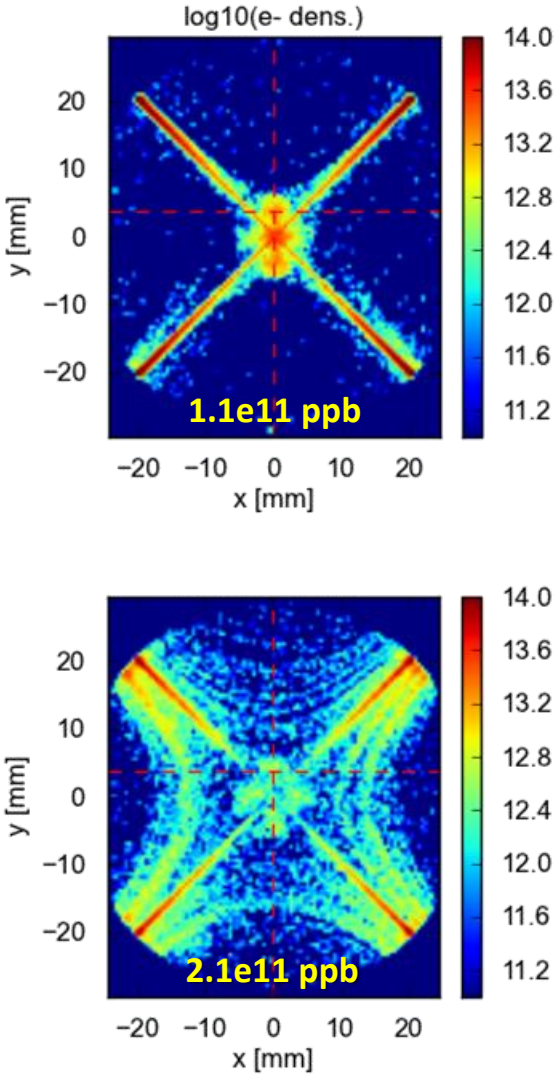
Simple scalings not easily applicable:

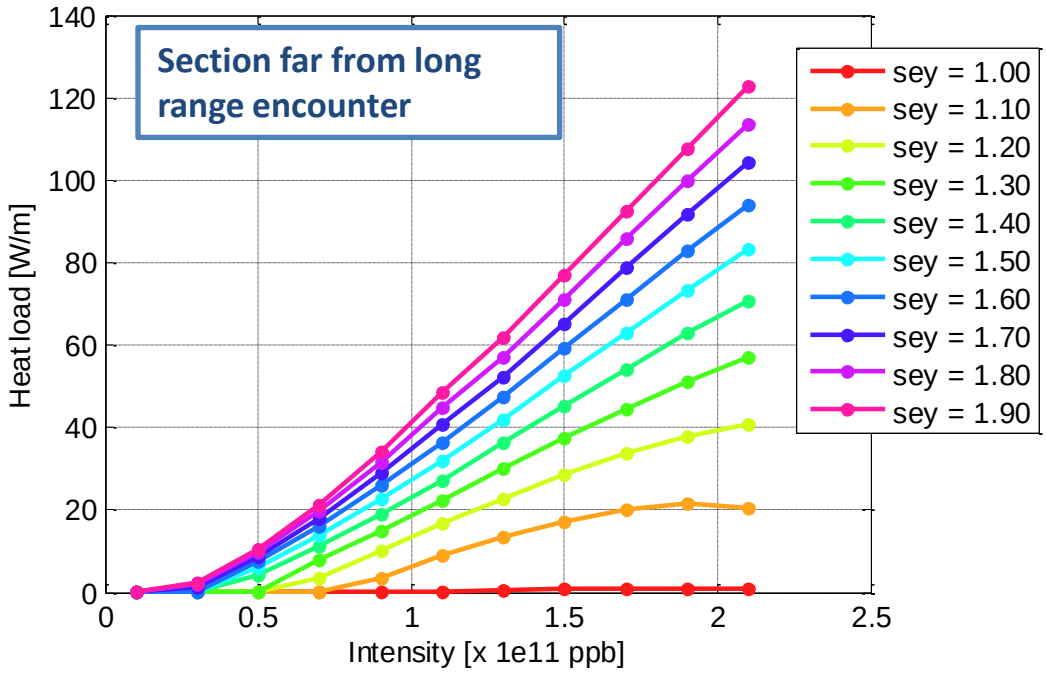
- Need to simulate in detail with real beam distribution from FastBCT some of the examined cases
- However
  - ❑ Huge storage space requirements to collect the results to analyse (more than 1 TB to process one single point for the four IRs)
  - ❑ Possible complications if rise and decay of electron cloud are not well modeled, as this may wrongly bias the results

Scaling with bunch population - IP2 and IP8



Electron cloud in present inner triplets, scaling with bunch population for one cut:

- Doubling bunch population leads to about **x3 larger heat load**
- e-cloud **suppression strategies needed** also for these magnets



Summary

- **HL-LHC Inner triplets IP1 and IP5 + D1**:
  - The presence **of two counter-rotating beams** enhances the electron cloud and makes the detailed calculation of the heat load complicated
  - Values of heat load on the beam screens about a factor 3 larger than with present triplets
  - **Suppression measures** (like low SEY coating or clearing electrodes) necessary to keep **heat loads within cooling capacity**
- **Inner triplets IP2 and IP8 + D1**
  - Data from 2012 do not clearly show the contribution of D1
  - More simulations needed, but time and storage space consuming and potentially depending on seeds/SEY modeling
  - Pure scaling with bunch population indicates that HL-LHC beams will lead to threefold heat load in the beam screen of IP2 and IP8 triplets