# Electron cloud studies for the HL-LHC: where do we stand and the next steps

G. Iadarola, G. Rumolo

**Many thanks to:**
H. Bartosik, R. De Maria, O. Dominguez, L. Mether, R. Tomas

11th HiLumi WP2 Task 2.4 meeting - April 30, 2014

# Outline

- **Studies for the arc main magnets**
  - Scaling with bunch intensity
  - 200 MHz option
  - 8b+4e scheme
  - “Doublet” scrubbing beam
- **Studies for the inner triplets**
  - New triplets in IP1/5
  - Present triplets in IP1/8
- **Studies for the matching sections – preliminary considerations**

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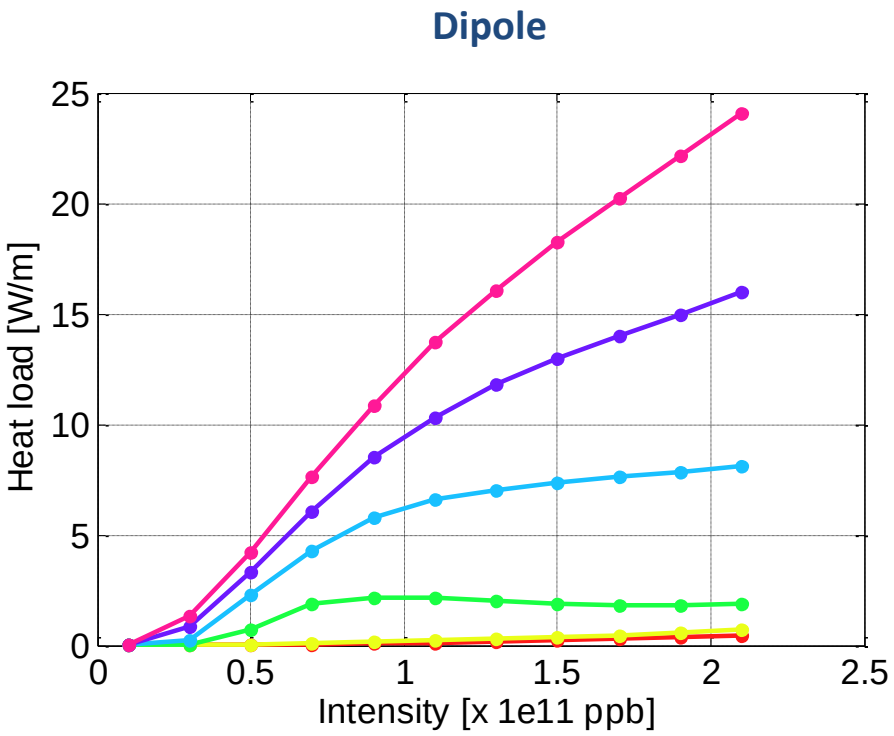
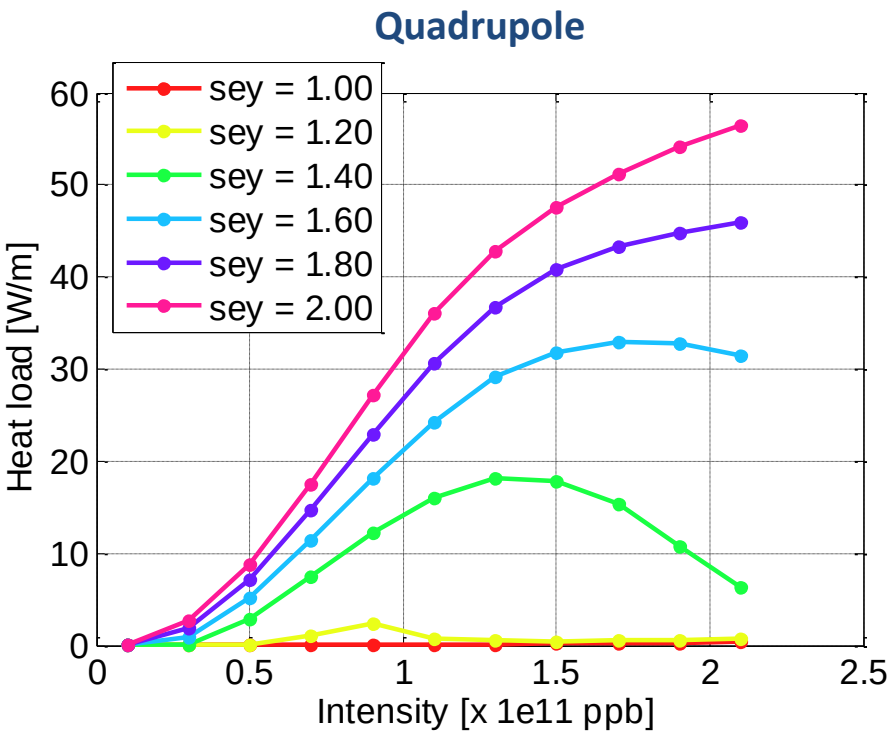
# Bunch intensity dependence for the arc main magnets

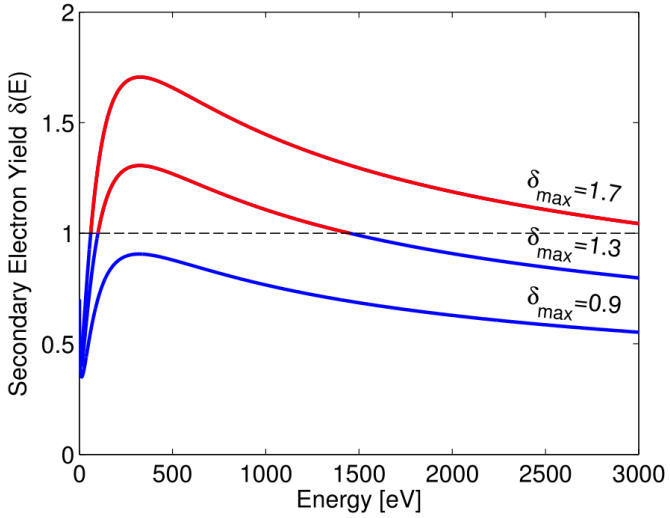


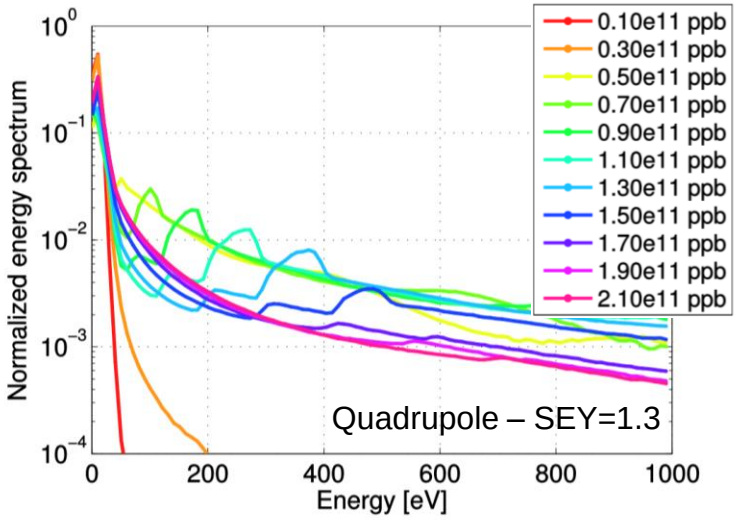
# Bunch intensity dependence for the arc main magnets

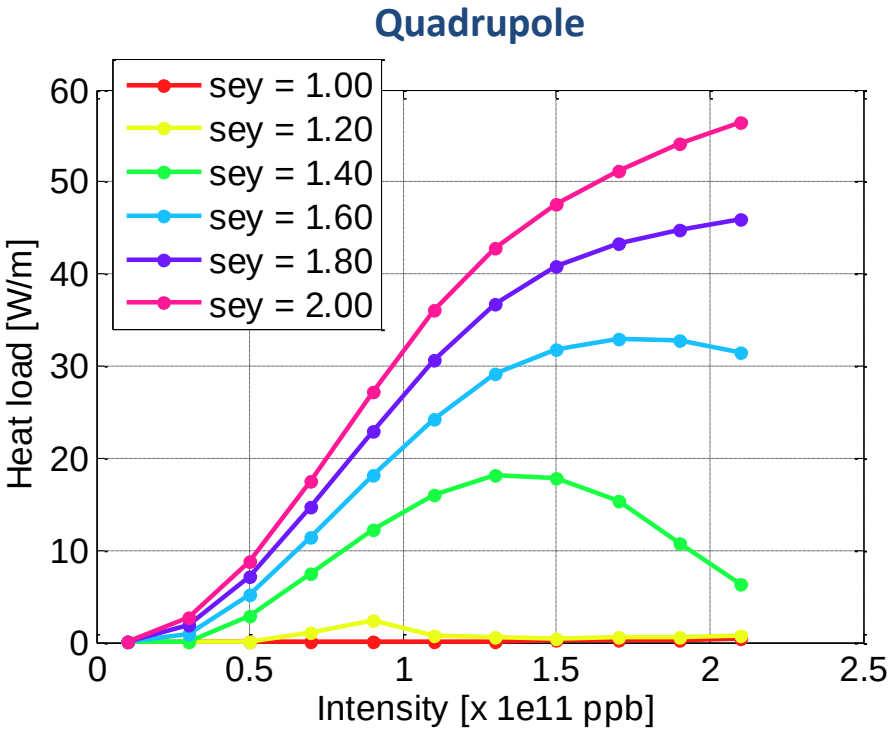
**Underlying mechanism:**

- When the SEY decreases the energy window for multipacting becomes narrower



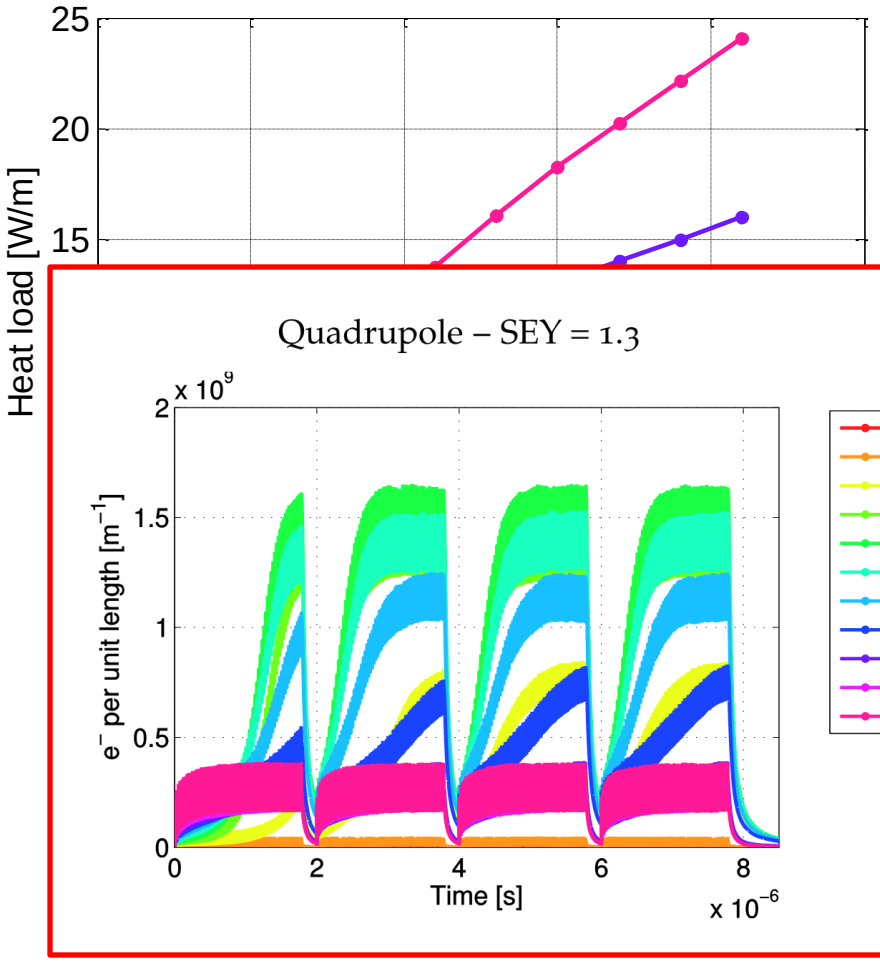

- For high bunch intensity the e- spectrum drifts to higher energies



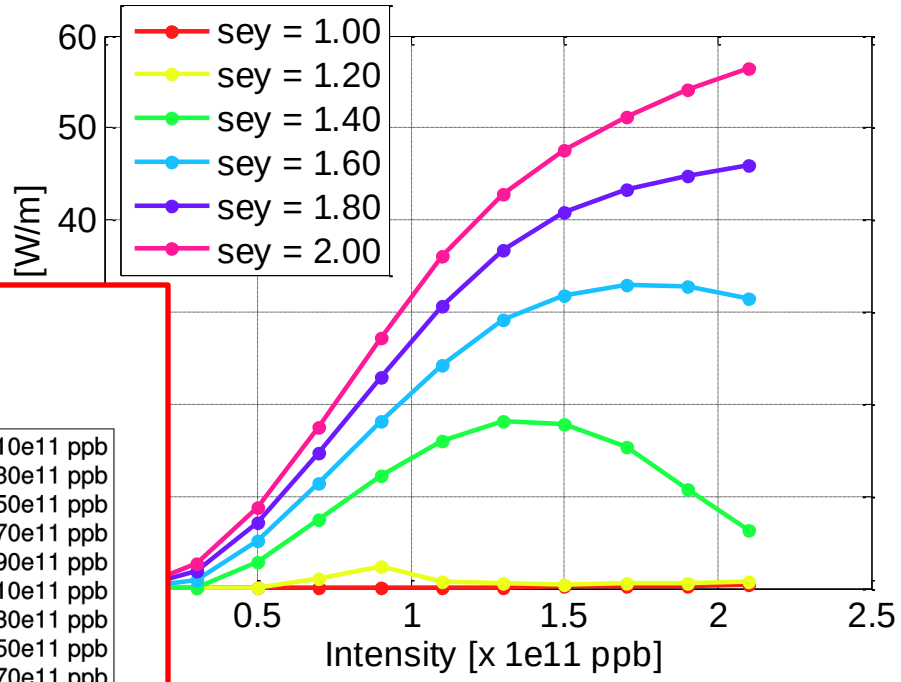



# Bunch intensity dependence for the arc main magnets

## Dipole

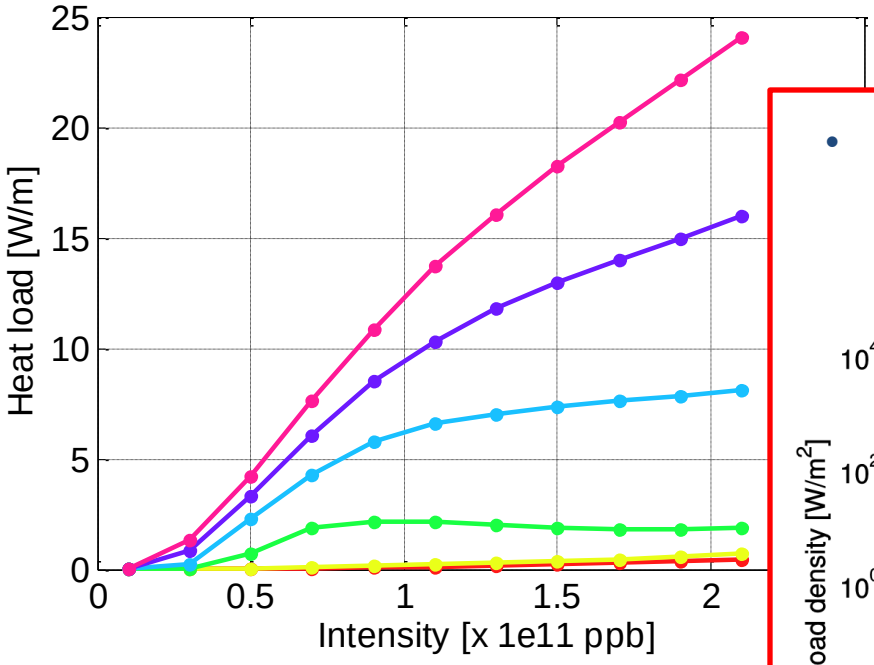



## Quadrupole

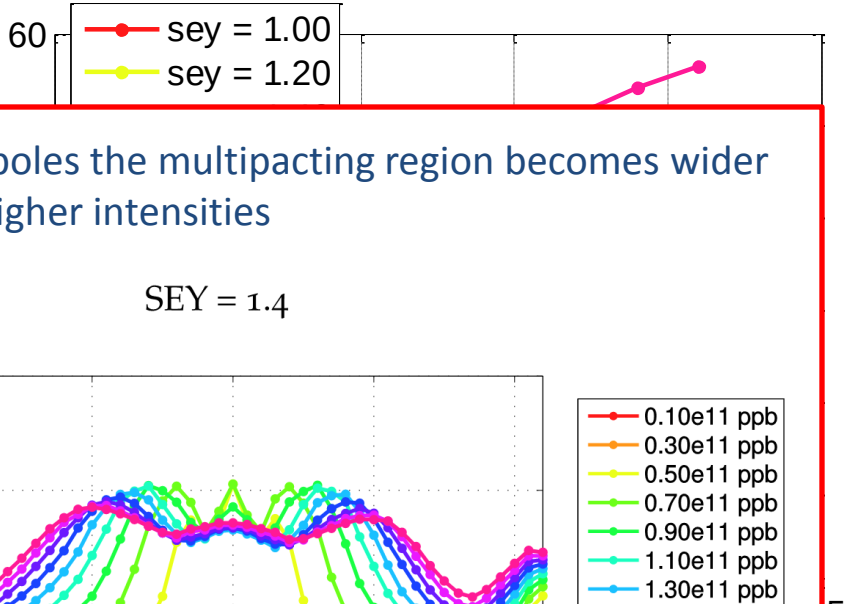


# Bunch intensity dependence for the arc main magnets

**Dipole**

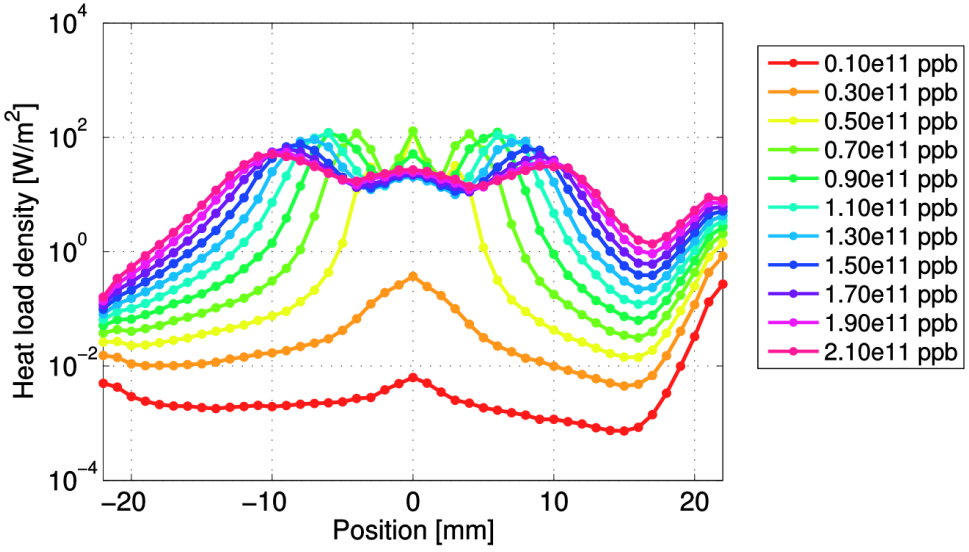



**Quadrupole**




- In dipoles the multipacting region becomes wider for higher intensities

SEY = 1.4



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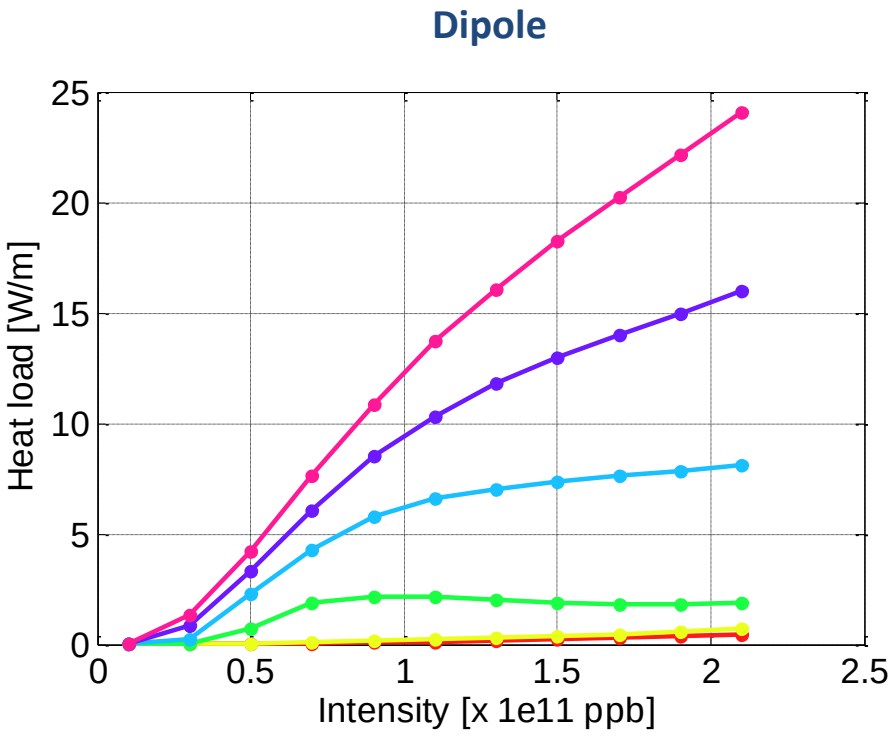
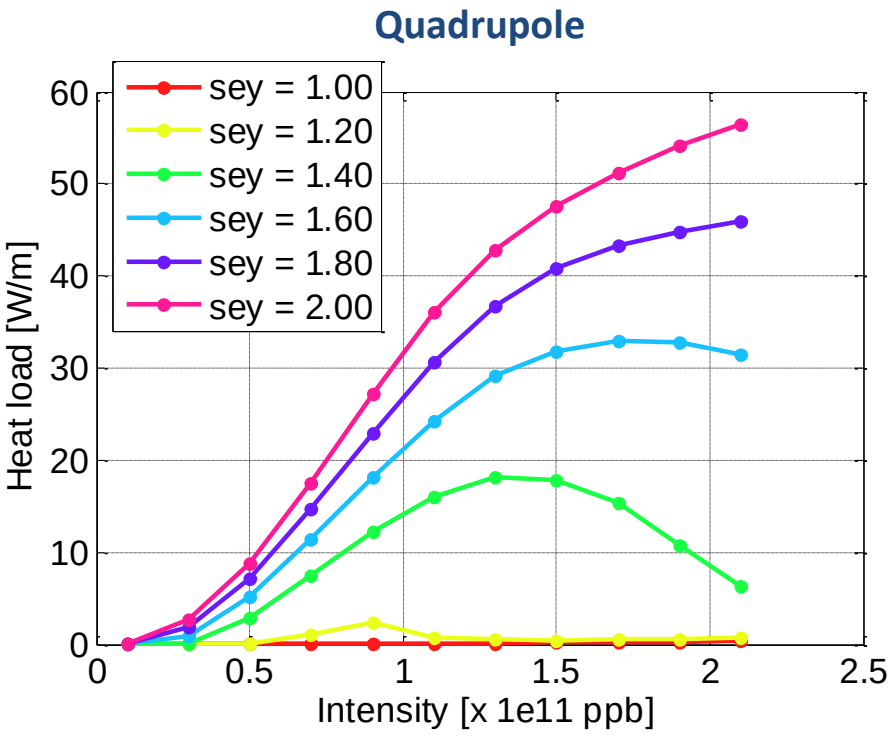
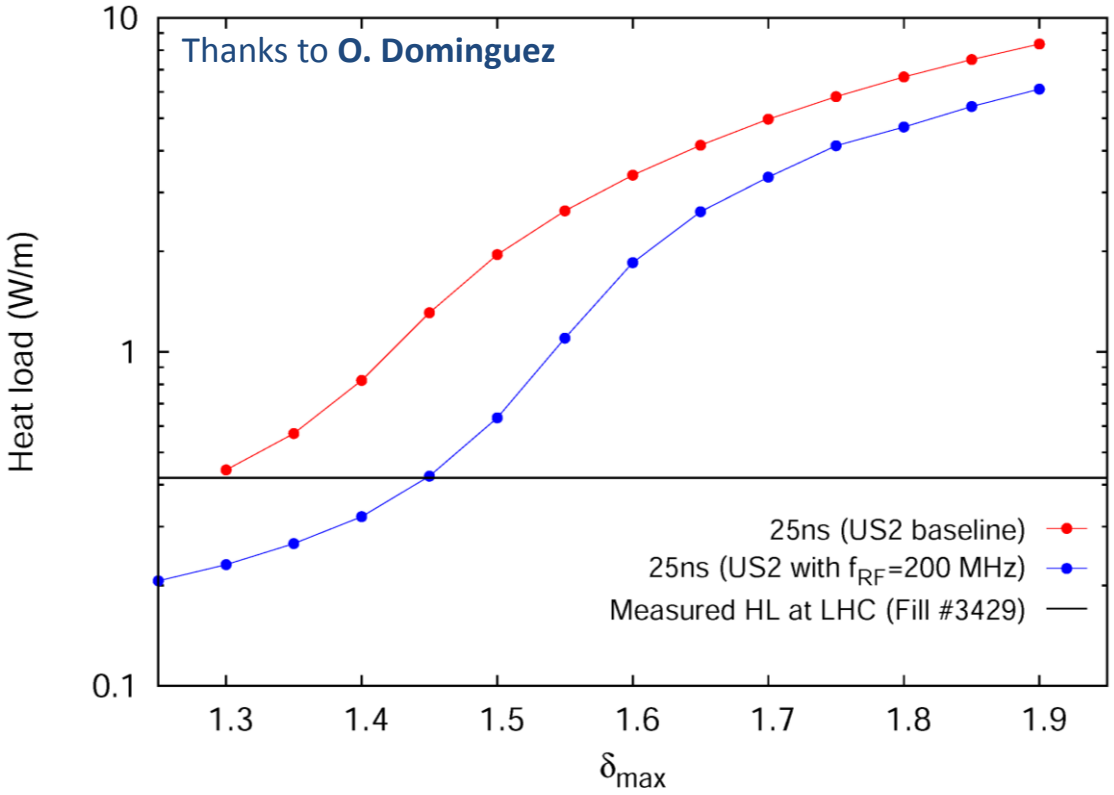


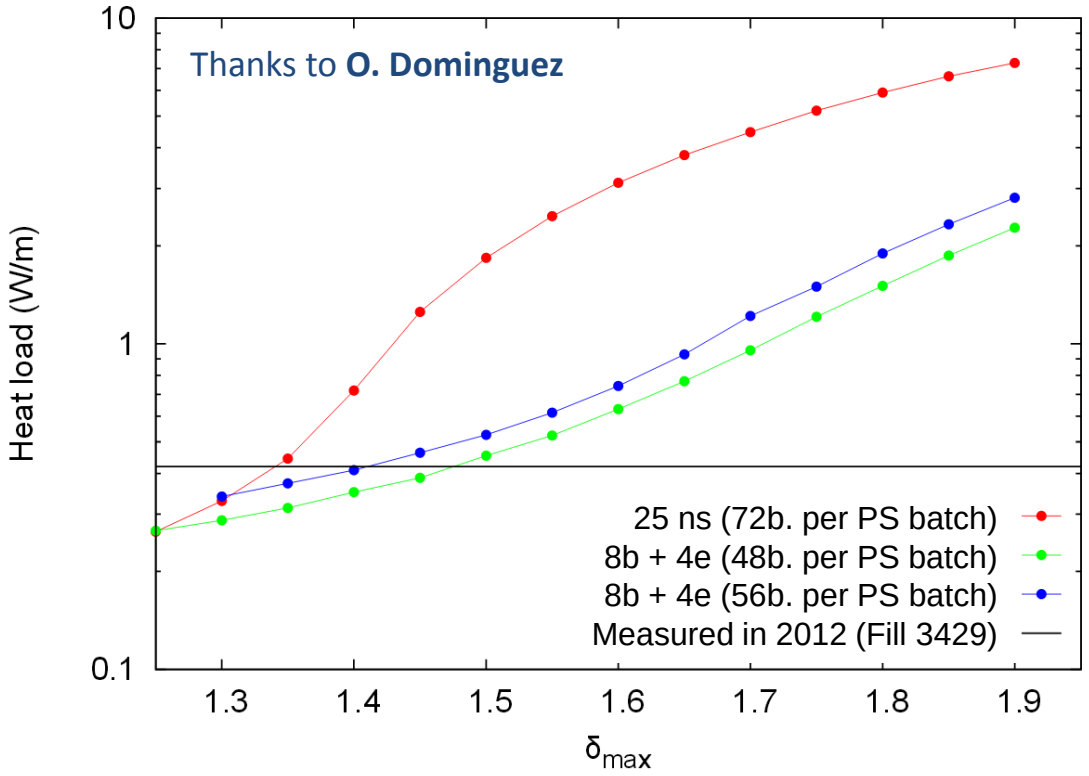

- Warning: dependencies rely on **assumptions on $E_{max}$ and uniform SEY** on the wall
- Provided that we manage to access a **low SEY regime,** increased **bunch intensity** should be **acceptable for heat load**, **effect on the beam still to be assessed**

# 200 MHz option: effect on e-cloud in the dipoles




- If option with **200 MHz main RF** is adopted, longer bunches will have a **positive impact also on electron cloud**
- Impact of bunch length on e-cloud to be studied experimentally in Run 2 (e.g. to mitigate degradation at low energy)

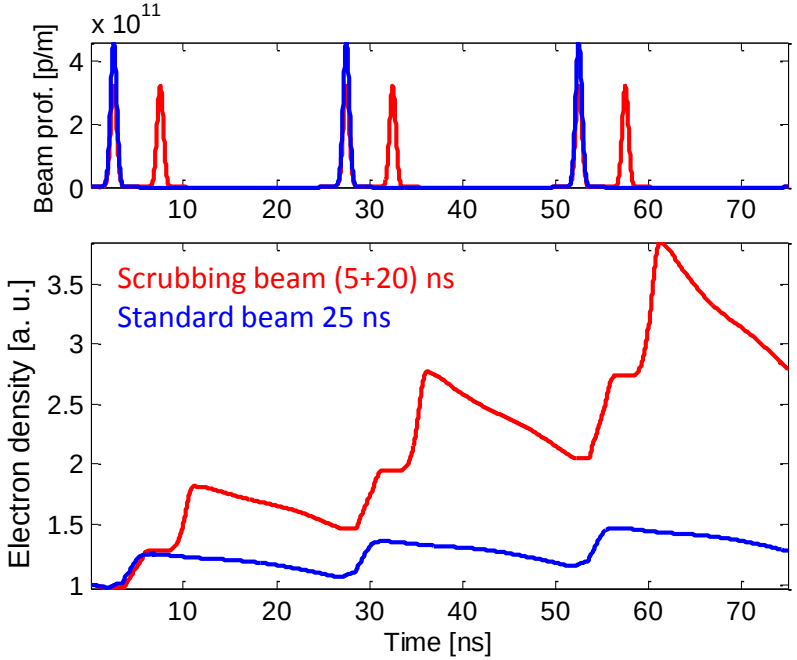
# 8b+4e fallback scenario

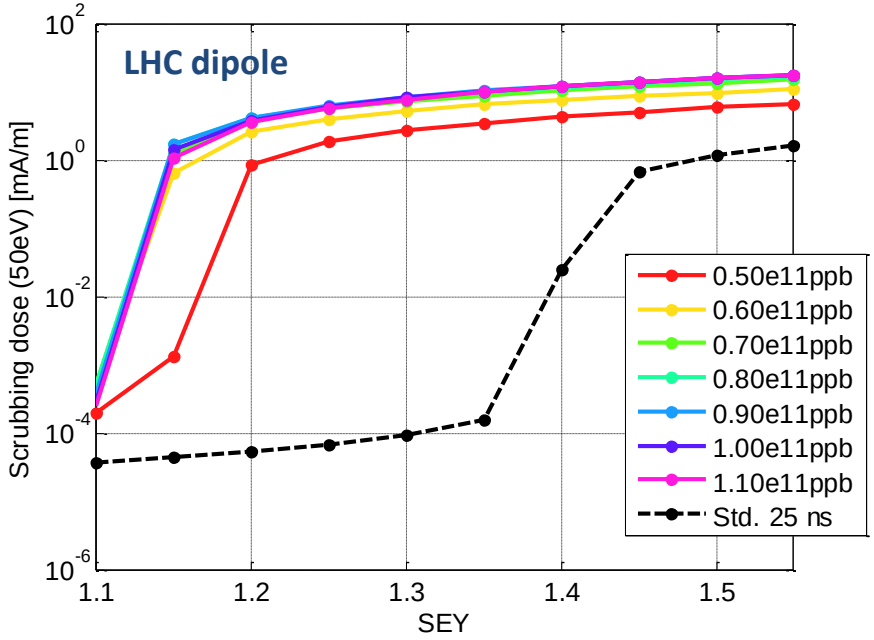



- Filling pattern with 25 ns spacing interleaving **batches of 8 bunches with gaps of 4 slots**, showed a significantly **increased multipacting threshold** compared the standard scheme
  - **backup scheme** in case safe operation with 25 ns beam is hampered by e-cloud (still 50% more bunches wrt 50 ns)
- The effectiveness of this scheme will have to be confirmed during Run 2

# “Doublet” scrubbing beam

- Operation with 25 ns will rely on SEY reduction by beam induced scrubbing
- To operate with 25 ns beams (~2800b.) it is **mandatory to achieve lower values in SEY compared to what was achieved in Run**
  - **Dedicated scrubbing beams** with **hybrid bunch spacing (5+20 ns)** are presently under study (e-cloud enhancement shown experimentally at SPS)
  - If possible to be used for scrubbing already during Run 2 (SPS and LHC)




**PyECLOUD** simulations

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  - New triplets in IP1/5
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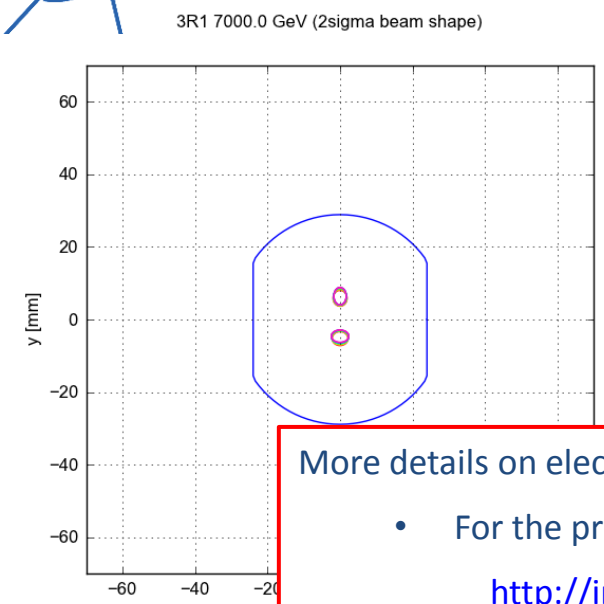
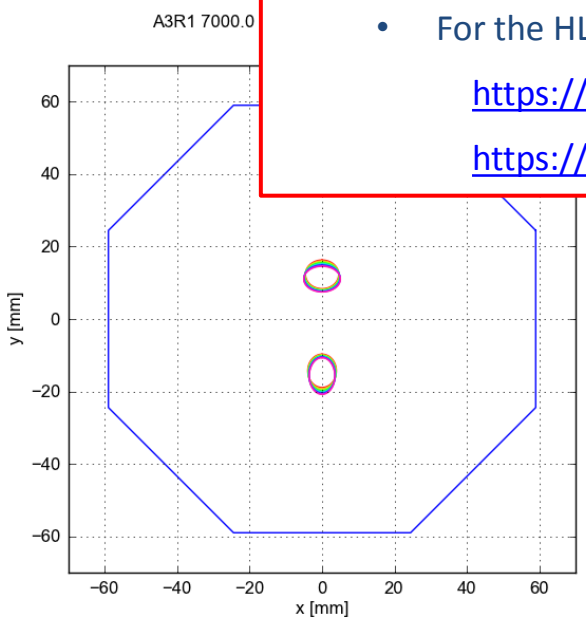
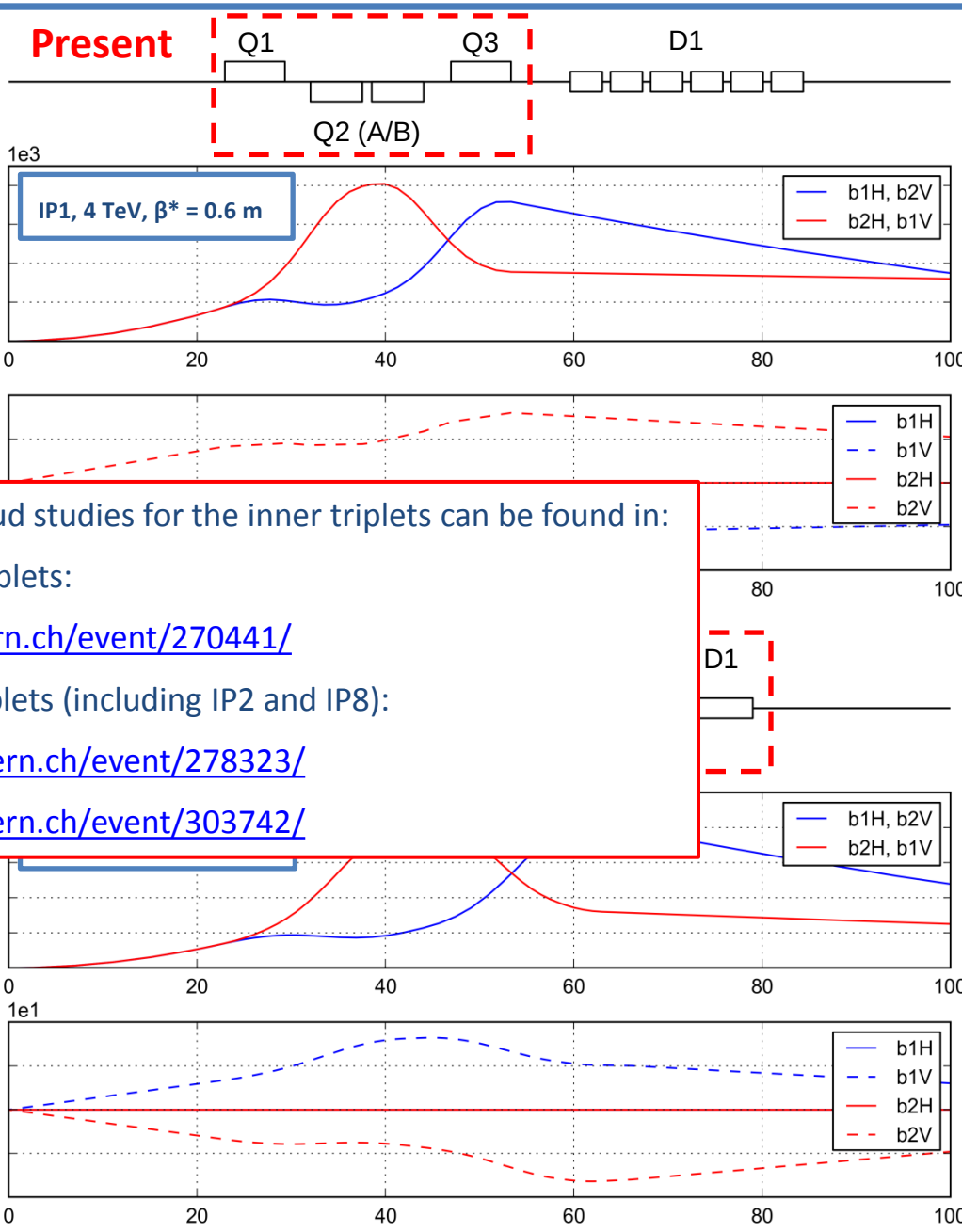
# Inner triplets for HL-LHC upgrade




More details on electron cloud studies for the inner triplets can be found in:

- For the present triplets:

  http://indico.cern.ch/event/270441/

- For the HL LHC triplets (including IP2 and IP8):

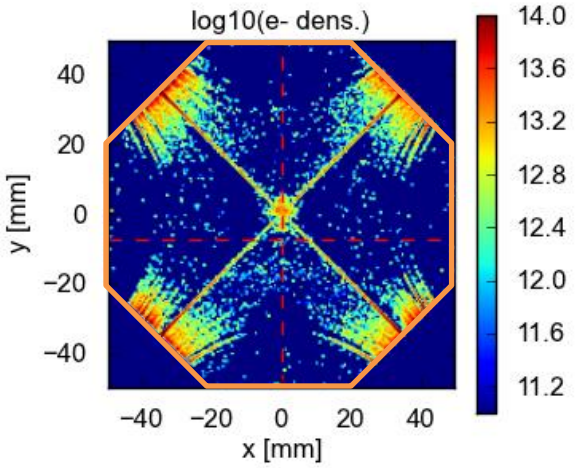
  https://indico.cern.ch/event/278323/

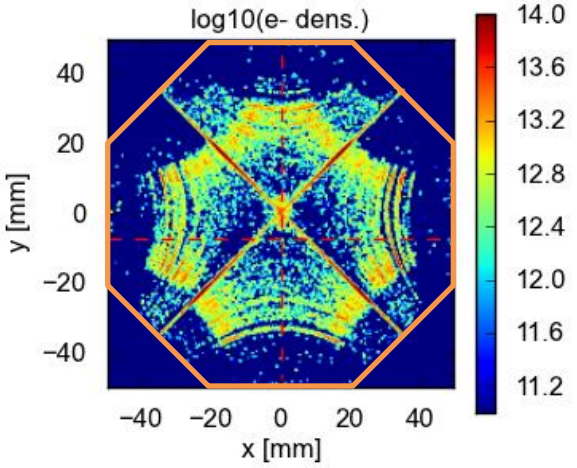
  https://indico.cern.ch/event/303742/

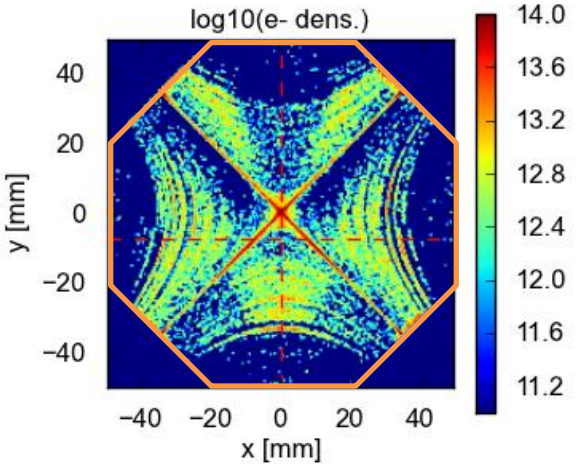
# A look to the EC buildup – HL-LHC triplets

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

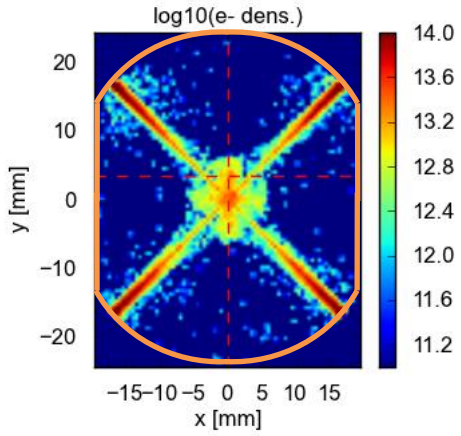
## **HL-LHC** (2.20 x $10^{11}$ ppb)

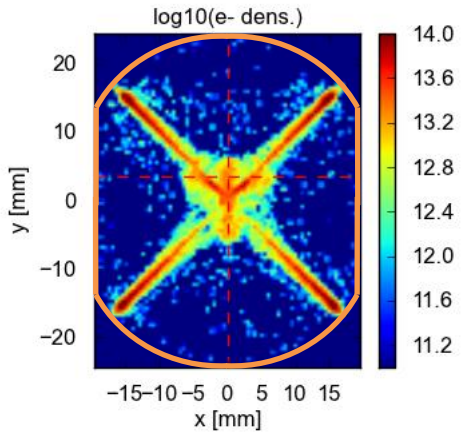


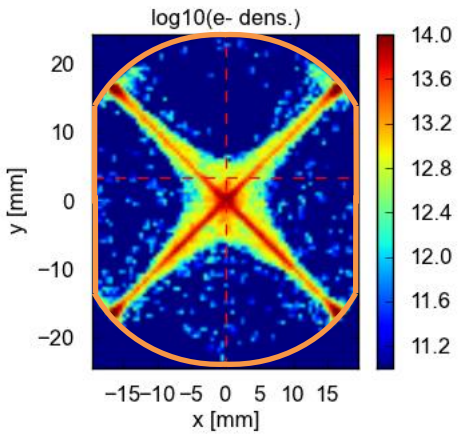




## **Present** (1.15 x $10^{11}$ ppb)



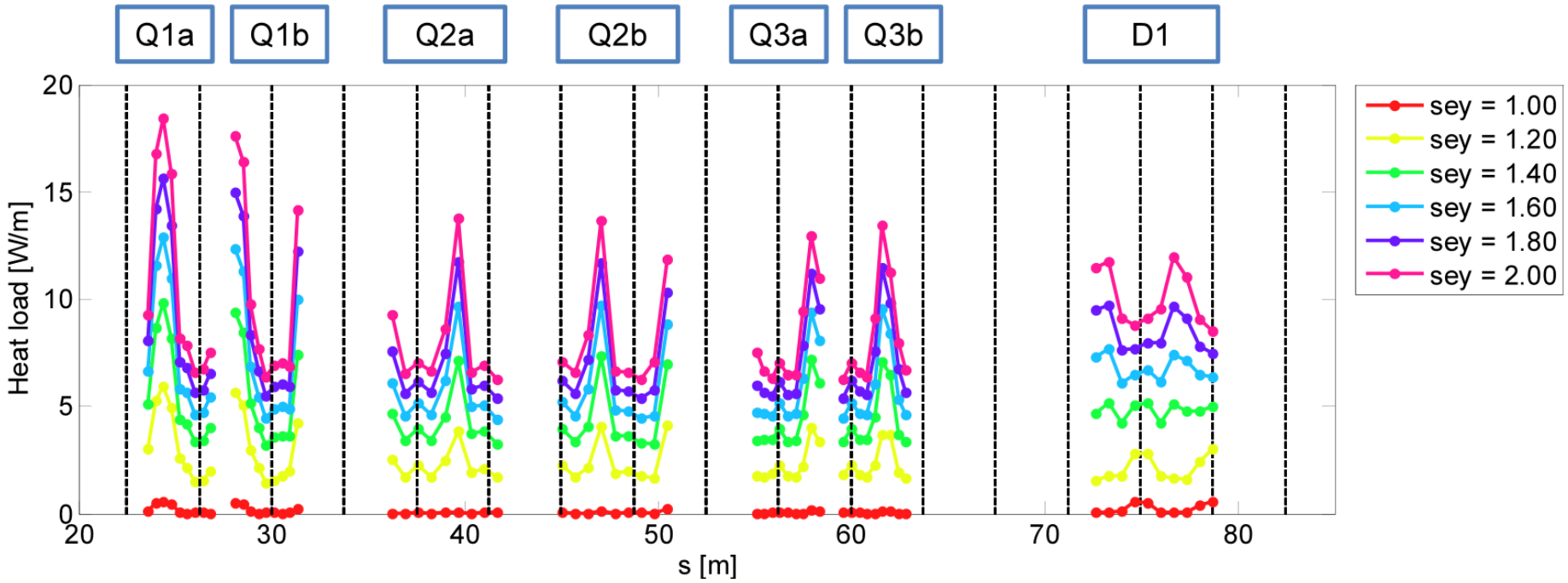



# Distribution of heat load – HL-LHC triplets

Heat load distribution along HL-LHC **triplets + D1**

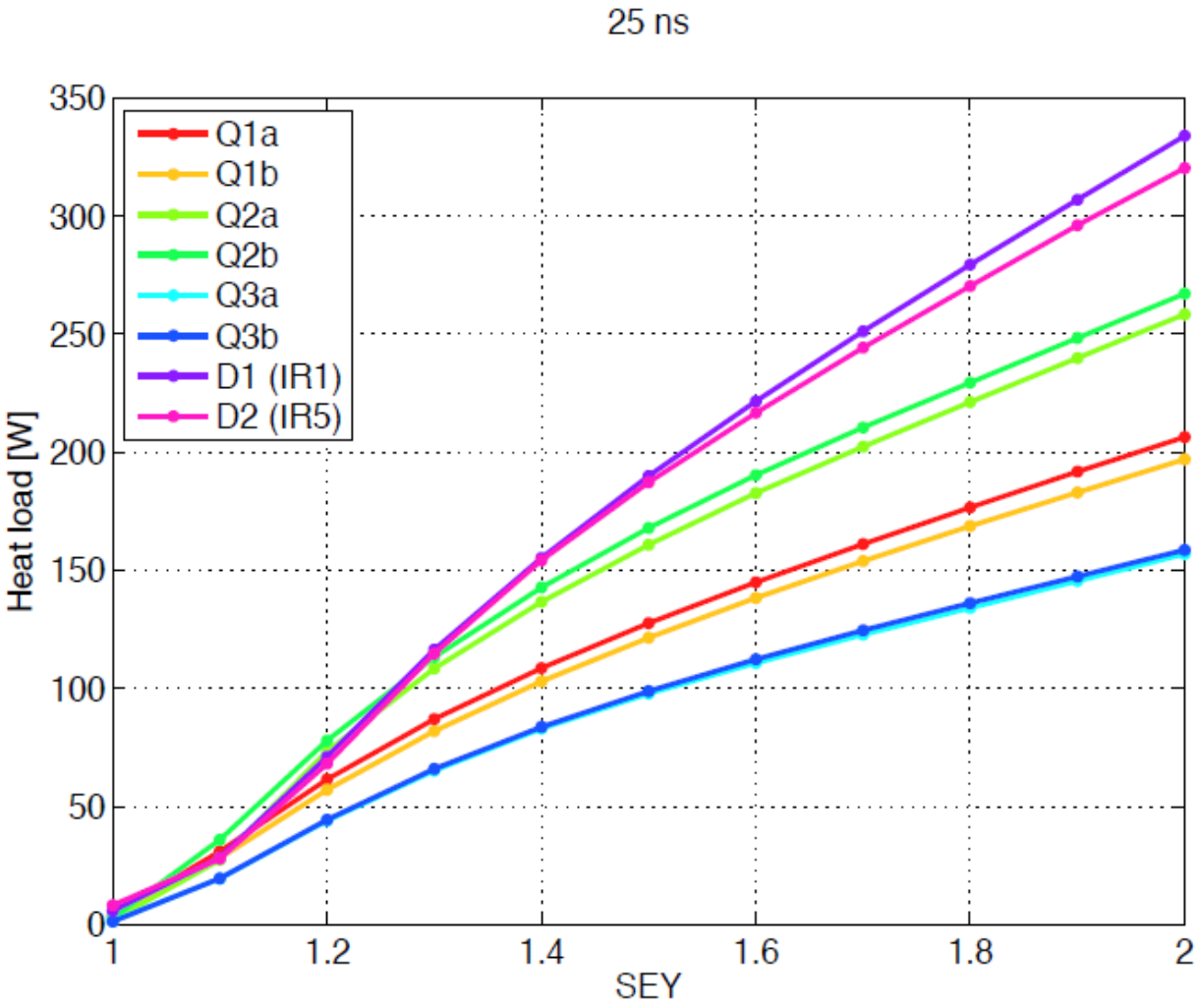
- **Build up more or less efficient at different locations** mainly due to the different hybrid bunch spacings
- The least efficient build up, i.e. lower heat load, at the locations of the **long-range encounters** (vertical dashed lines)
- Values in **D1 are comparable or higher than values in the quads**



# 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

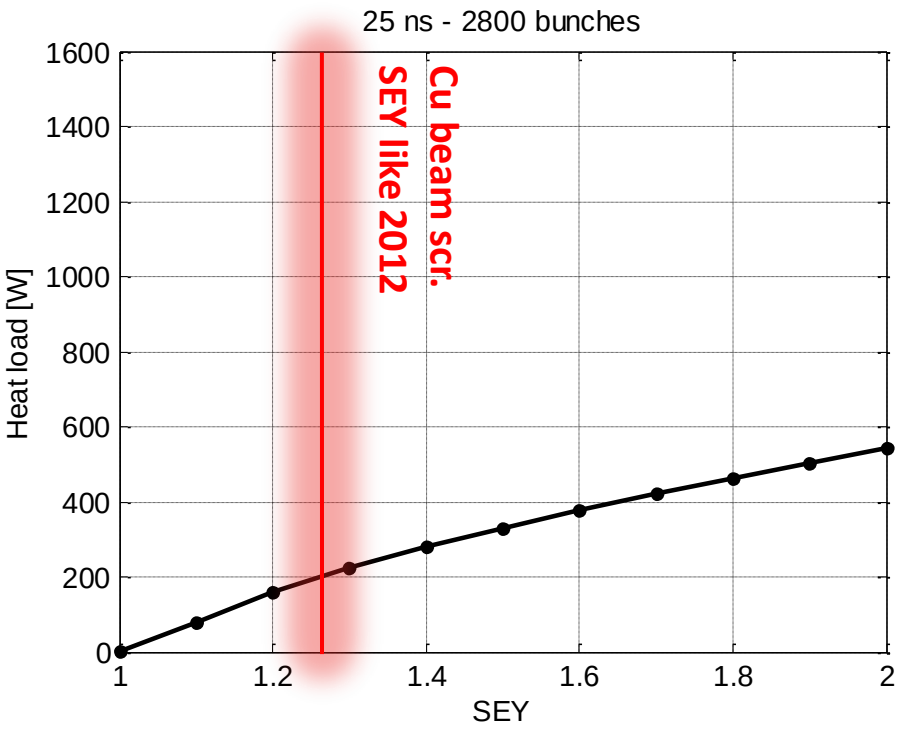
Effect of larger bunch population and chamber size. For the **same SEY**:

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

⇒ Total **heat load about x3 larger**

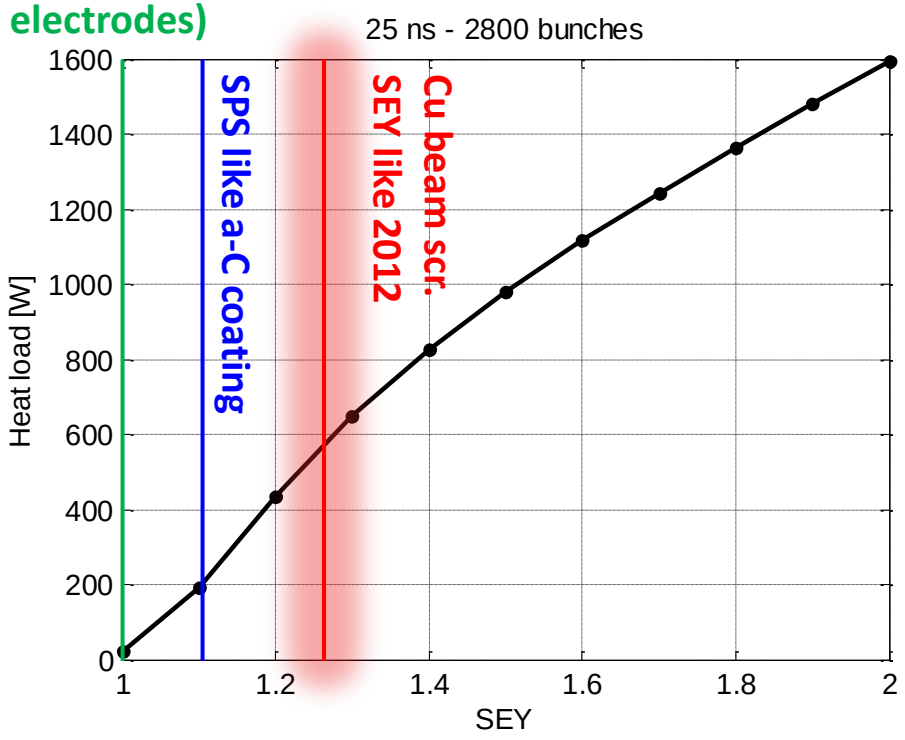
**e-cloud suppression** can be obtained using **low SEY coatings** and/or **clearing electrodes**

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




**Full suppression (SEY≈1 or clearing electrodes)**

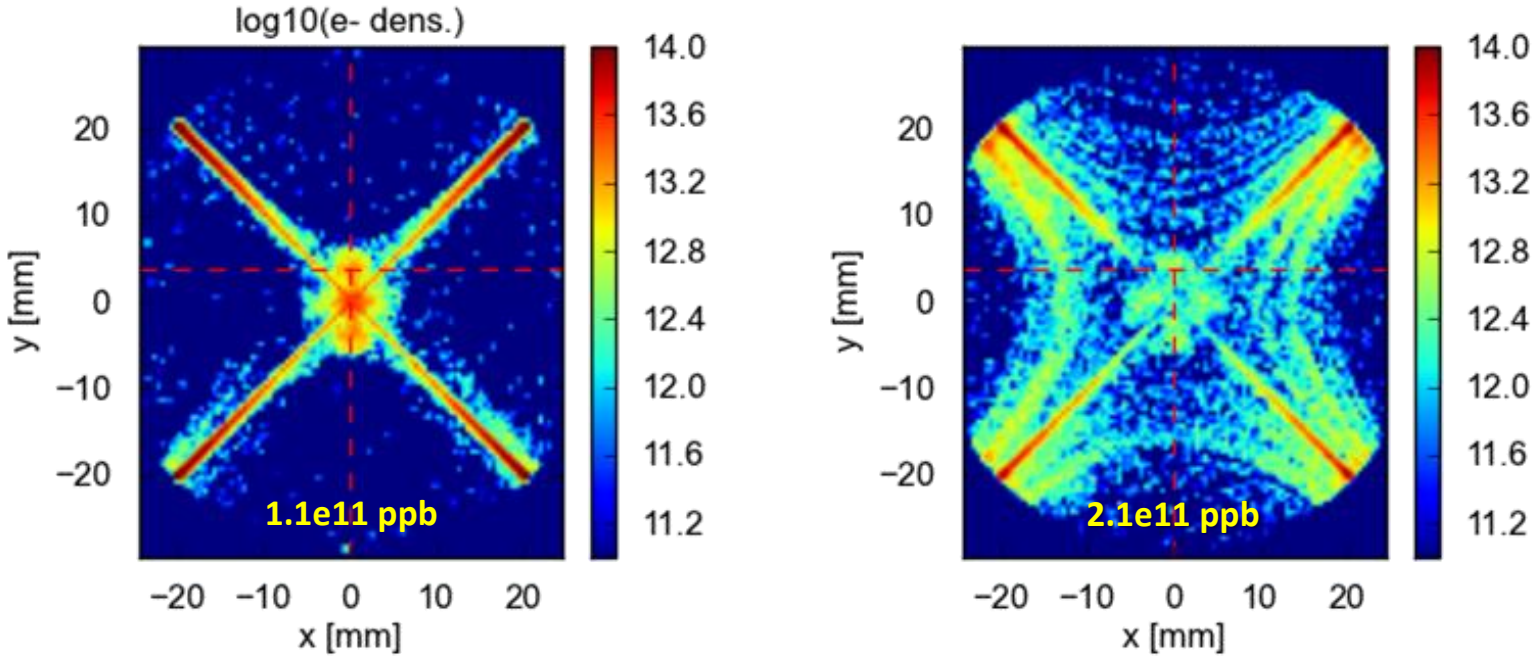
**HiLumi triplets**
(2.20 x $10^{11}$ ppb)



# Scaling with bunch population - IP2 and IP8

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

- **Wider multipacting region** for high bunch intensity

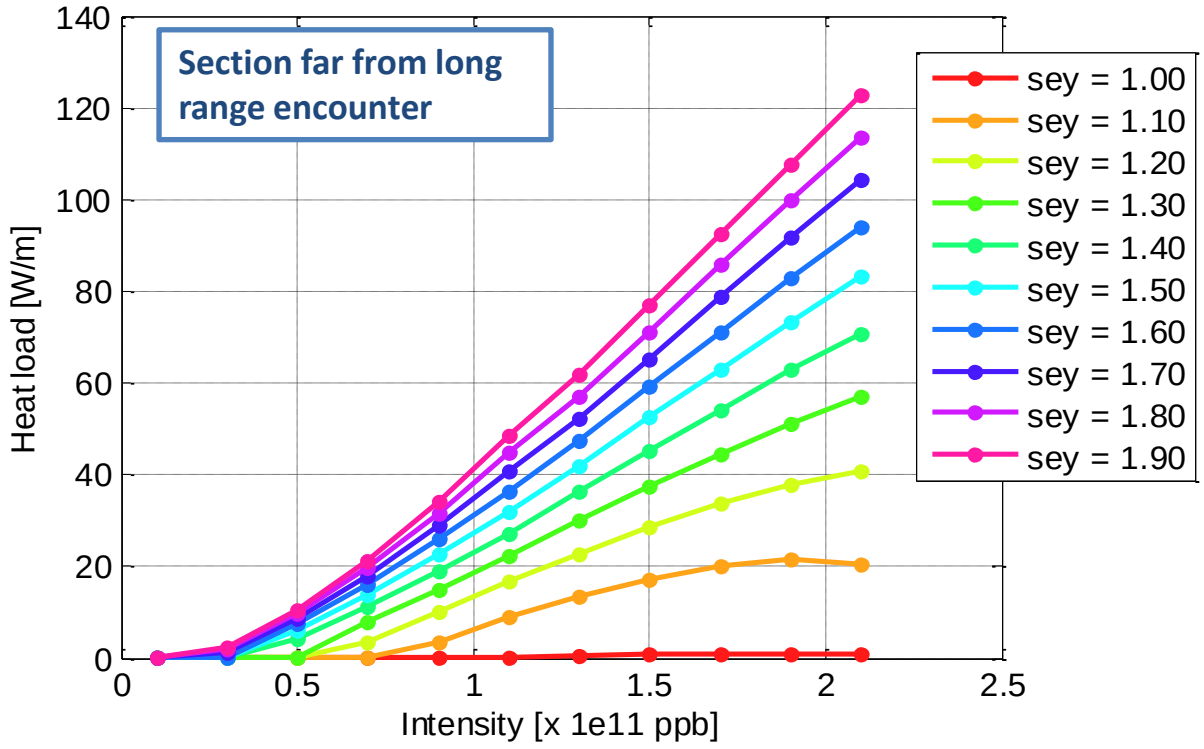


# Scaling with bunch population - IP2 and IP8

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

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

**Detailed study for precise heat load estimation** still needs to be performed



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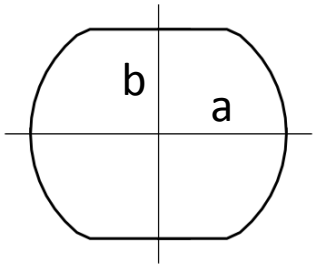
# Matching section IP5 - Present LHC



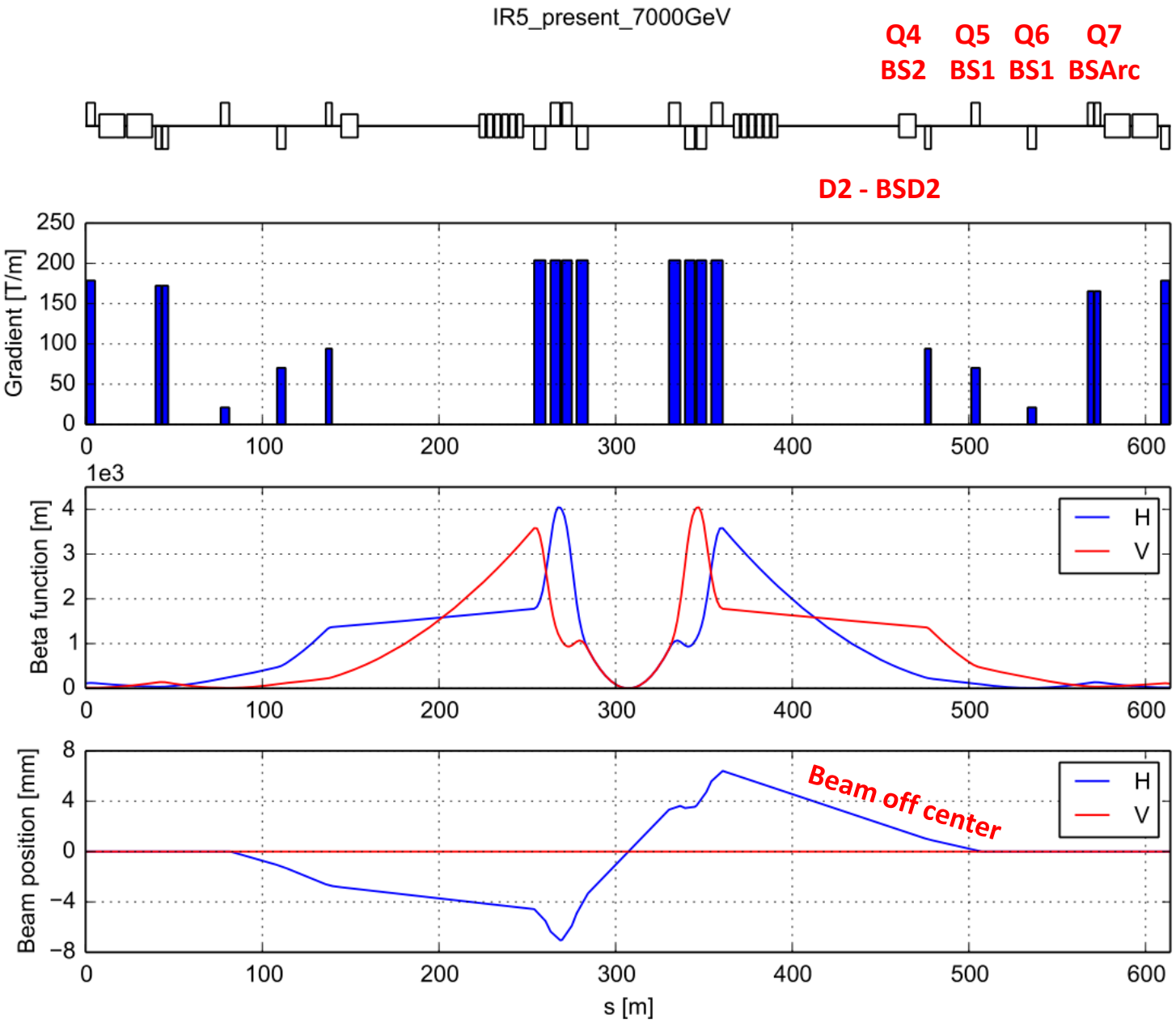

BSArc
a=22, b=17.15

BS1
a=22.5, b=17.6

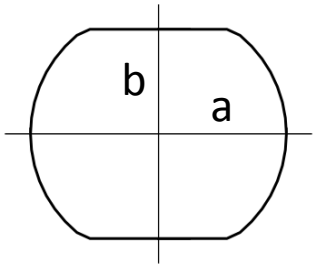
BS2
a=28.9, b=24

BSD2
a=31.3, b=26.4

Beam screens can be rotated



# Matching section IP5 – HL-LHC



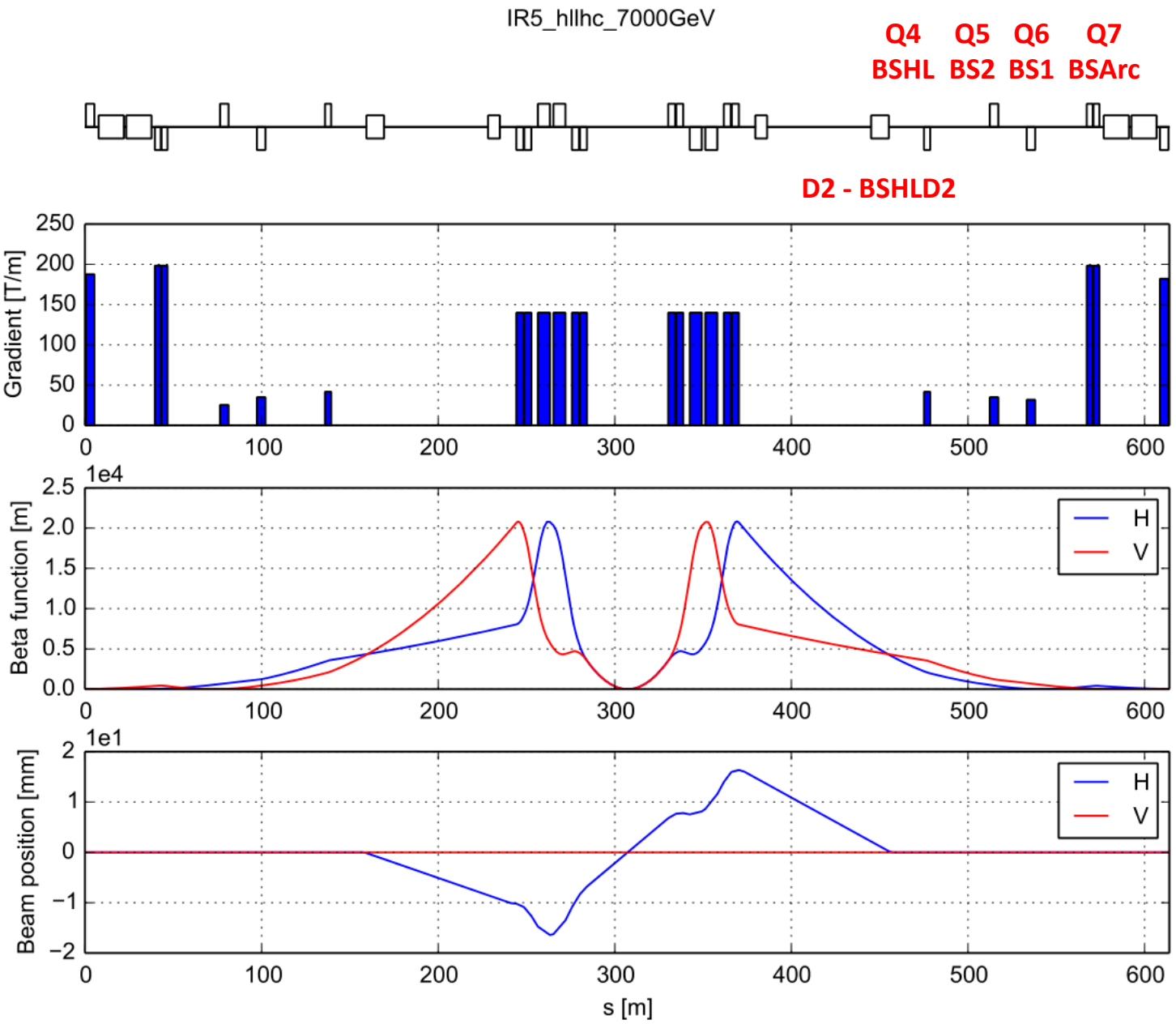

BSArc
a=22, b=17.15

BS1
a=22.5, b=17.6

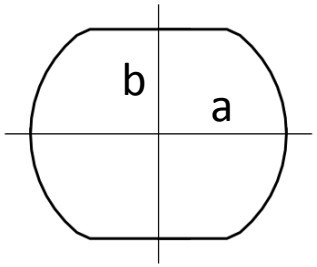
BS2
a=28.9, b=24

BSHL
a=37, b=32

BSHLD2
a=41, b=36



# Matching section IP2 – Present LHC

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Beam screens
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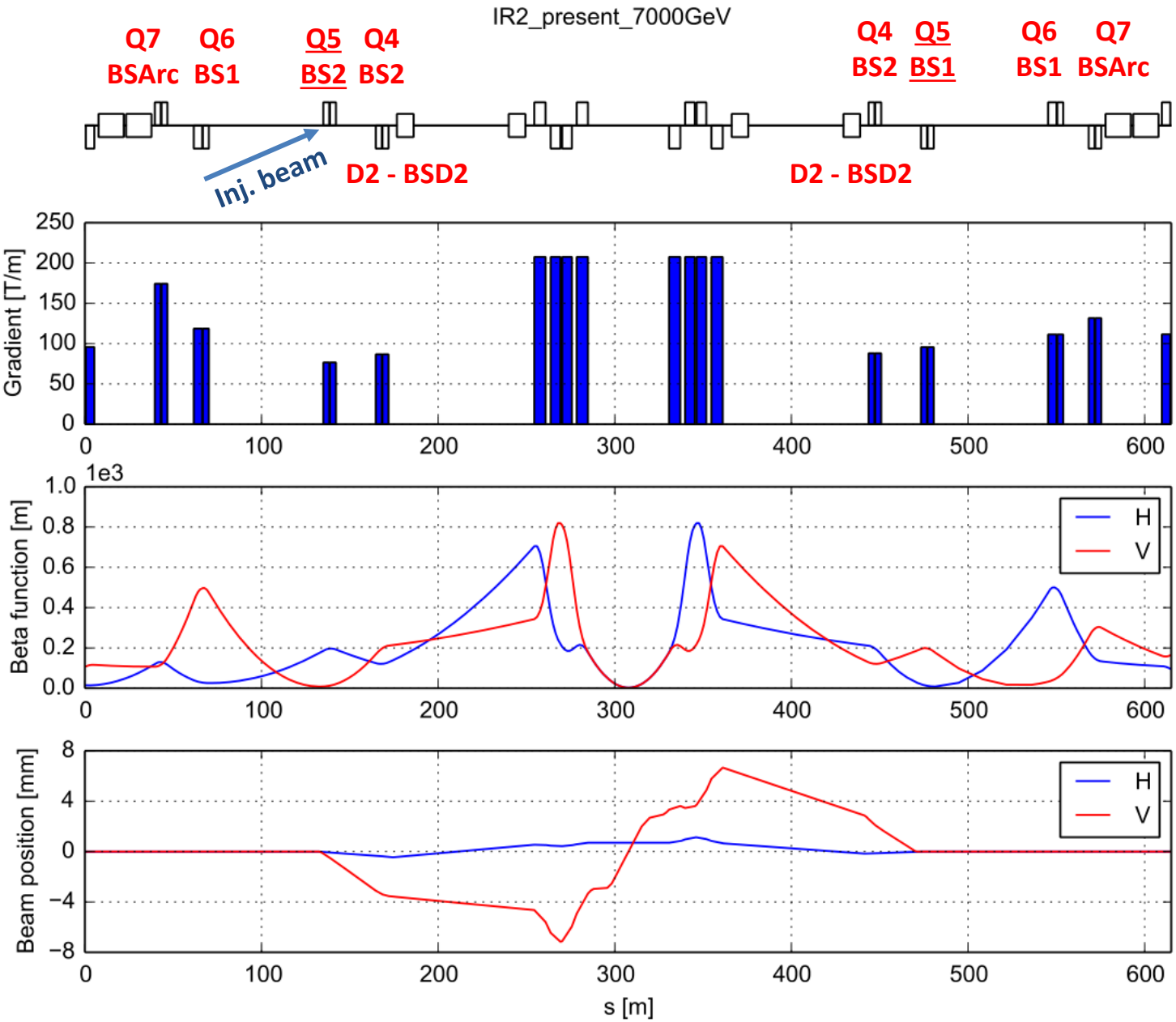
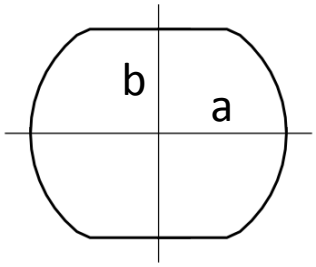


# Matching sections

In total **6 beam screen shapes** (all rect-ellipse):

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BS2
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BSHL
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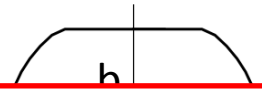
BSHLD2
a=41, b=36

**Many, many, many configurations** in terms of **B field/gradient**, **beam size** and **beam position** considering energy ramp, squeeze, separation, β*-leveling etc…

Need for parametric scans to asses which of these dependencies strongly impact the EC buildup

# Matching sections

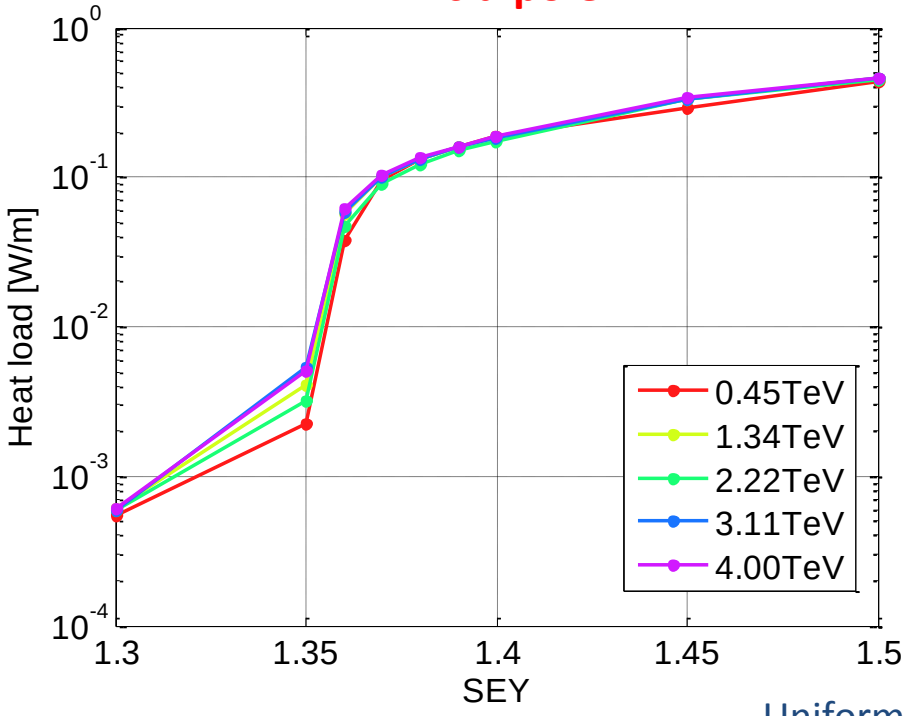
In total **6 beam screen shapes** (all rect-ellipse):



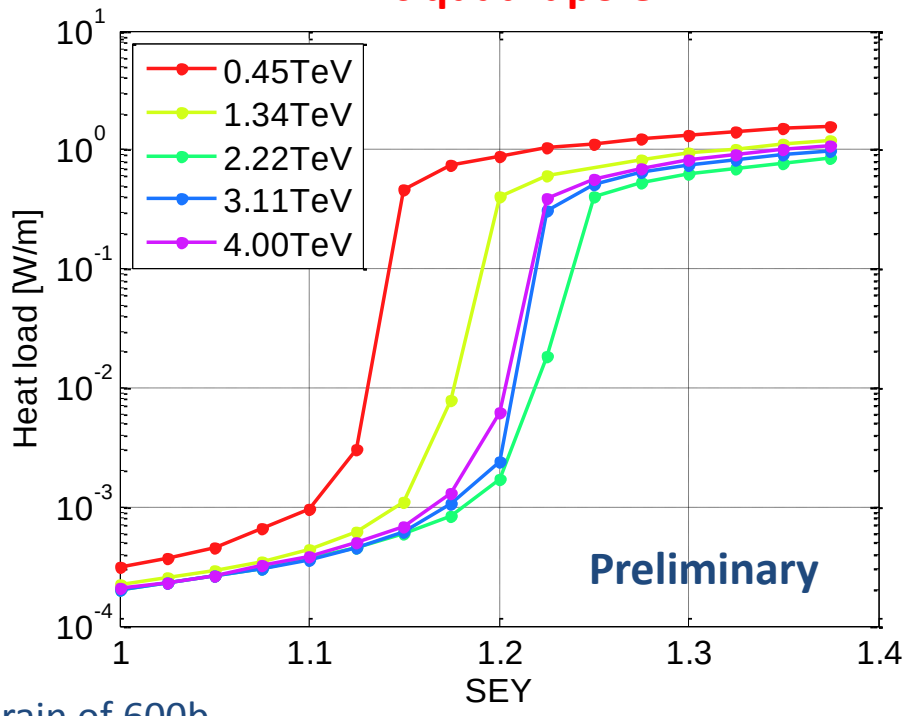

| BSArc | BS1 | BS2 | BSD2 |
|---|---|---|---|
| a=22, b=17.15 | a=22.5, b=17.6 | a=28.9, b=24 | a=31.3, b=26.4 |

Some preliminary indication: effect of **beam size and B field** variation during the energy ramp (nominal intensity)

**Arc dipole**




**Arc quadrupole**

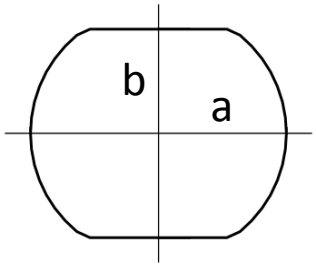



Uniform train of 600b.

Thanks to **L. Mether**

# Matching sections

In total **6 beam screen shapes** (all rect-ellipse):




| BSArc | BS1 | BS2 | BSD2 |
|---|---|---|---|
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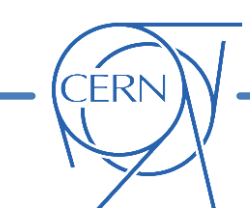
| BSHL | BSHLD2 |
|---|---|
| a=37, b=32 | a=41, b=36 |

**Many many many configurations** in terms of **B field/gradient**, **beam size** and **beam position** considering energy ramp, squeeze, separation, β*-leveling etc…

**Next steps:**

Effects of beam size
Effect of B gradient
} Arc quadrupole (practically also matching quad with BS1)

Effect of beam position — Q4 IP2 (where the effect is stronger)




# Thanks for your attention!