CERN PS MULTI TURN EXTRACTION

New MTE extraction scheme to mitigate irradiation of SMH16

S. Gilardoni, M. Giovannozzi

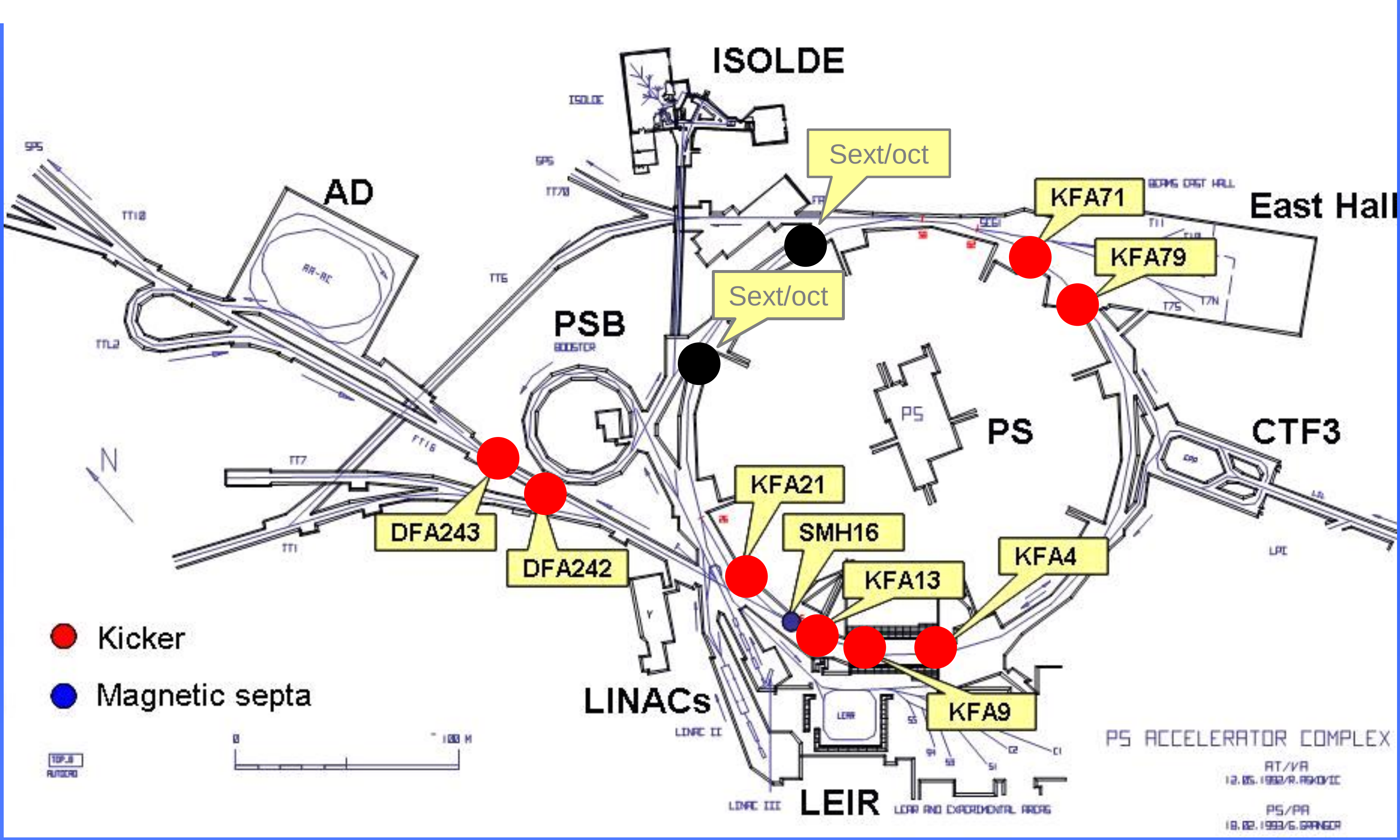
- Introduction
- Principle
- Required measurements

Acknowledgements: G. Arduini, B. Goddard, M. Newman, M. Widorski

Introduction - I

- The current extraction scheme: design choices
  - Minimise the hardware involved -> drop the electrostatic septum in SS31
  - Minimise the extension of the bumps (slow and fast)
- Result:
  - Slow bump around magnetic septum in SS16: improved with respect to the original version:
    - More magnets, individually controlled -> ensure closure and aperture
  - Fast bump
    - First four turns: KFA9, KFA13, KFA21
    - Fifth turn: as before with the addition of KFA71, KFA4

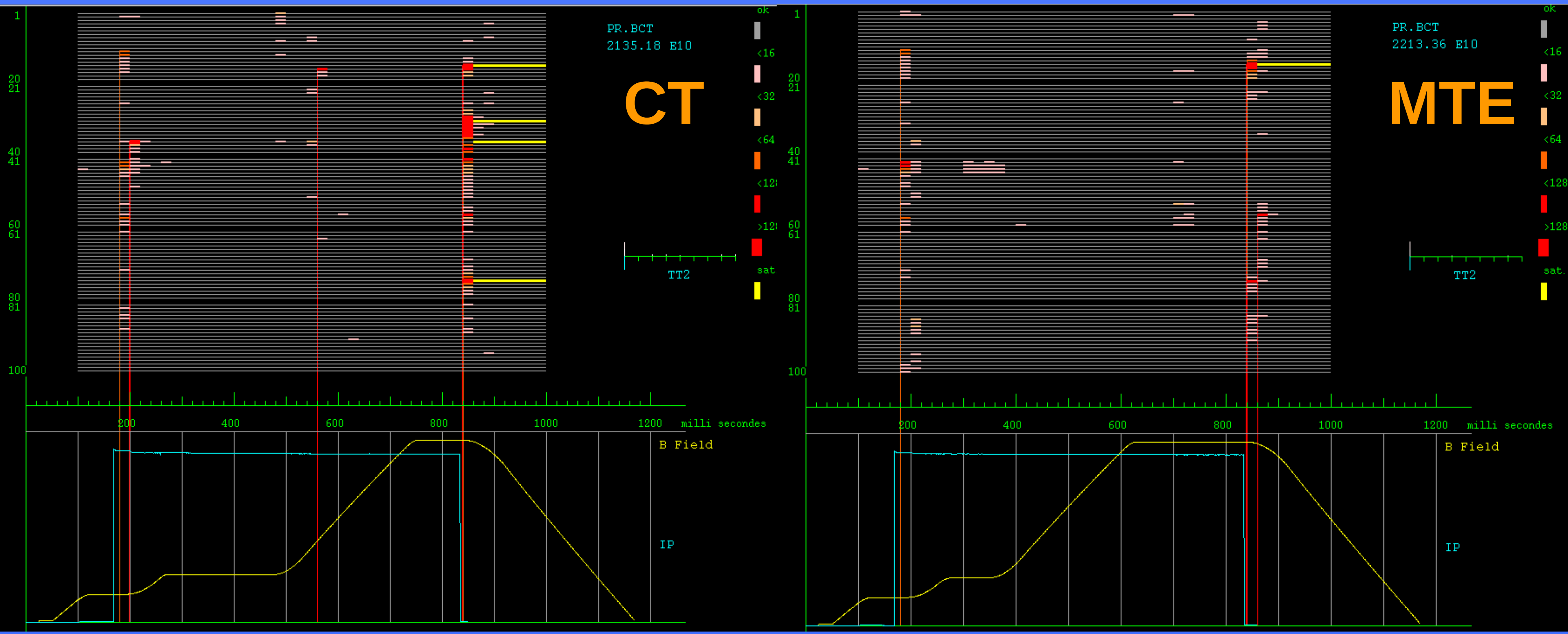
Introduction - II



Introduction - III

- Losses on septum 16
  - Due to longitudinal beam structure and kickers' rise time
  - Anticipated in the Design Report
  - At that time it was considered not possible to estimate the activation of the septum 16

CT vs. MTE: extraction beam losses

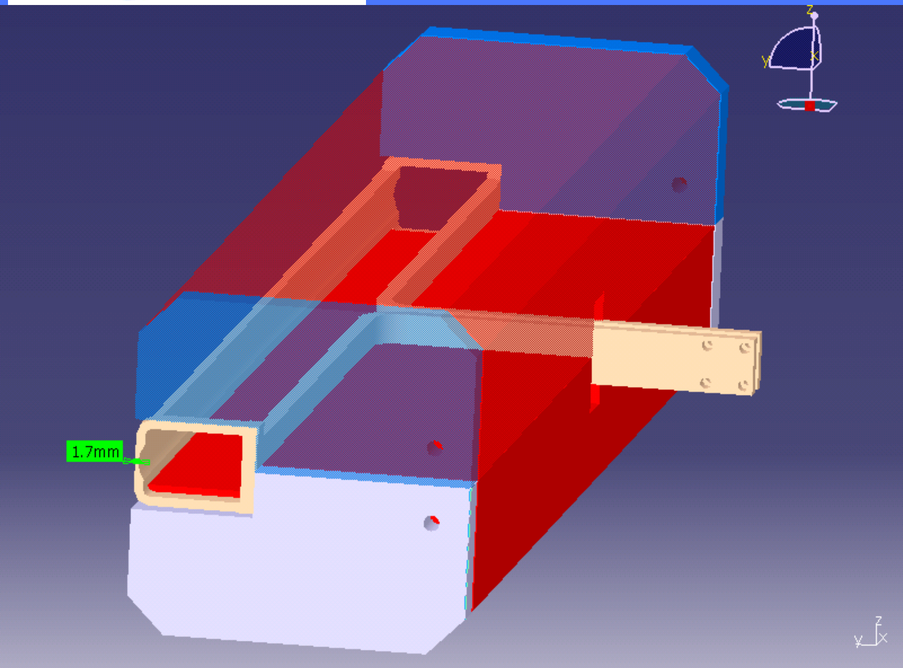


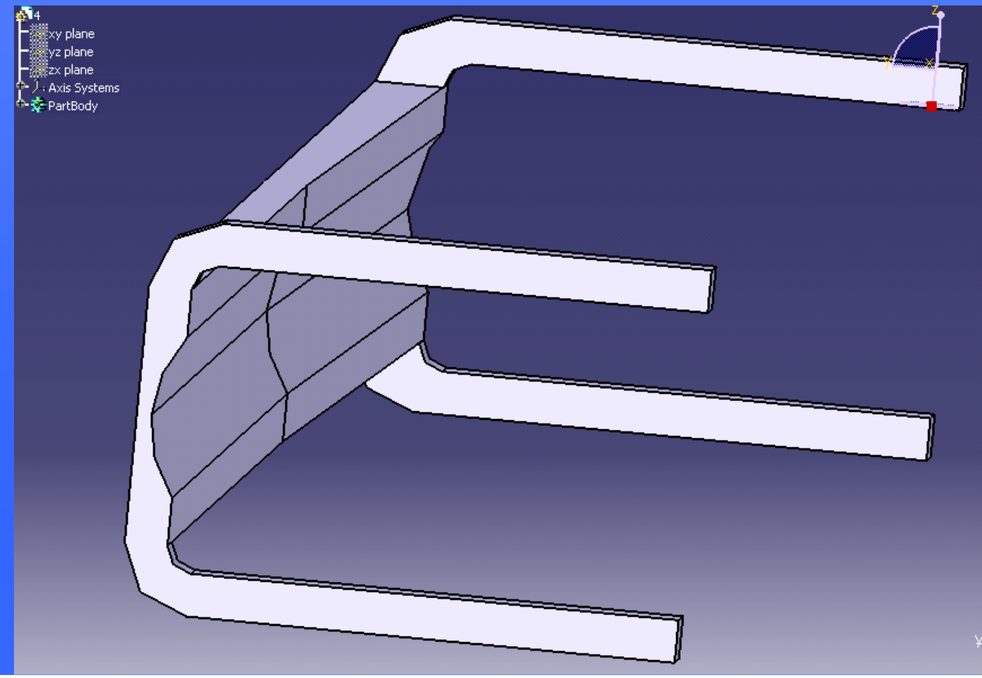
- Comment: BLM16 is saturated also for CT!
- An increased kick from SEH31 might be helpful…

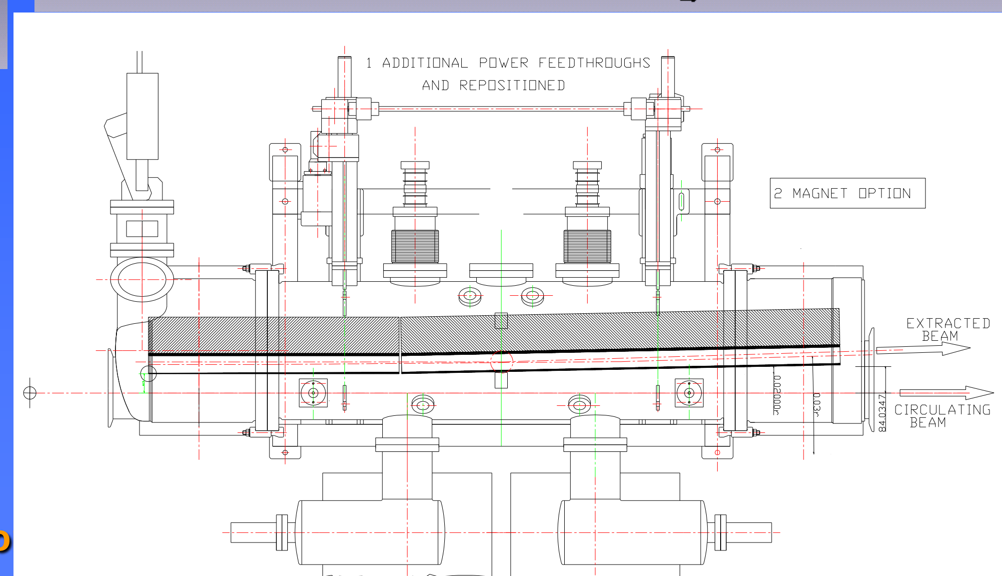
Possible mitigation measures - I

- **Faster kickers:**
  - Already considered at the design stage. Not feasible (within the tight boundary constrains – resources)
- **Thinner magnetic septum:**
  - Already proposed in the Design Report, but not retained as an option.
  - The maximum reduction in the septum thickness is a factor of 2 -> at most a factor of 2 in losses.
  - This does not solve the long-term issue of activation!
  - Other alternative: optimise the material (type and amount) to minimise the activation -> difficult and possibly not feasible.

Possible mitigation measures - II







Thinner magnetic septum

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Possible mitigation measures - III

- **Different longitudinal beam structure:**
  - **Use a bunched beam. Only h=8 would allow a sizeable reduction of losses.**
  - **This option would need synchronisation between PS and SPS.**
  - **Synchronisation requires time and voltage.**
  - **Tests performed in 2008 to study these points (reported by T. Bohl in RF Notes 2008-20, 21, 25):**
    - **Standard CT: two batches each of 1.2×10^{13}**

On h=16 "The comparison of the LARGER BCT datasets shows the inferior transmission of the beam in the 60 kV CT case. This corresponds to what had been observed in 2004 with a higher intensity beam.

Given the relatively low intensity of about $2\times1.3\times10^{13}$ the difference in total transmission between the 4 kV CT and the standard CT is marginal.

The peak line density increases by a factor of two for each step going from standard CT to 4 kV CT to 60 kV CT.

In the h = 8 CT case there are very high losses in the SPS, as expected from measurements in 2004."

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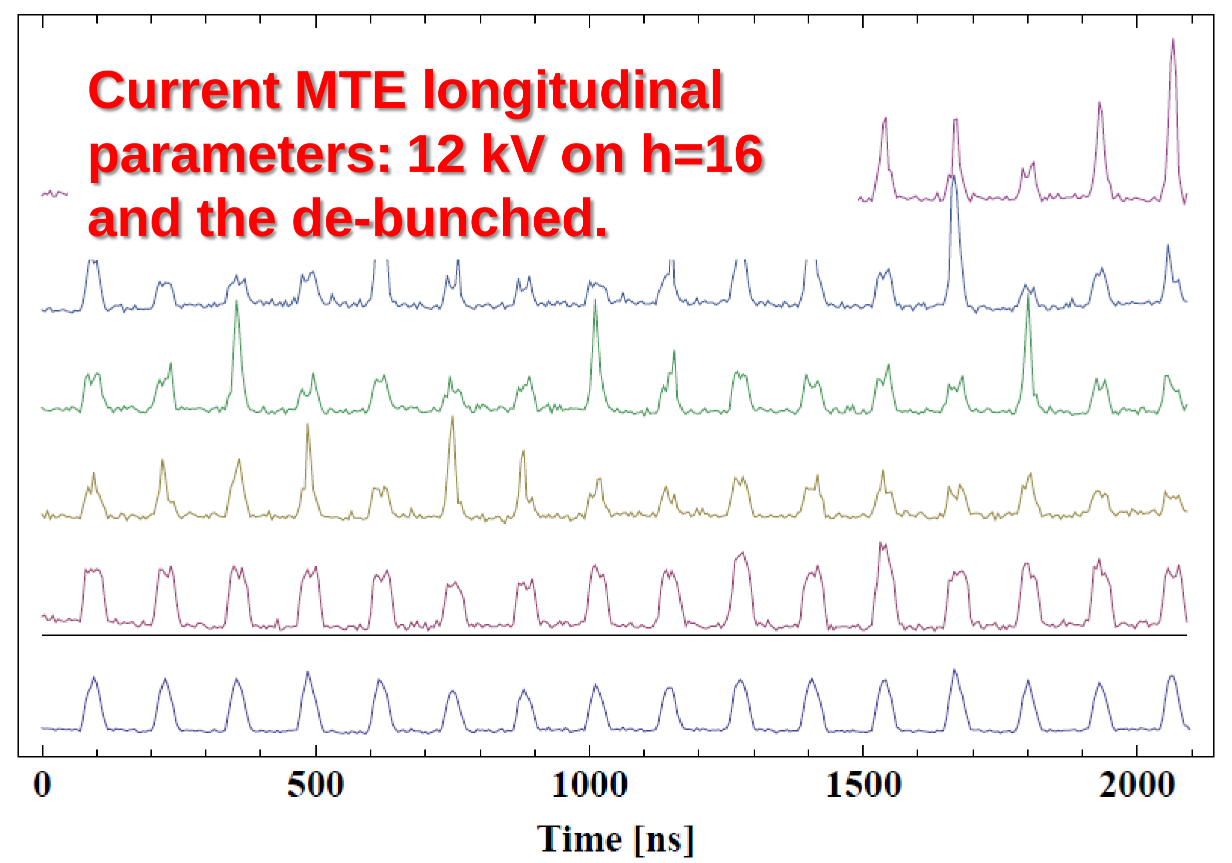
Possible mitigation measures - IV

- **Different longitudinal beam structure:**
  - MTE: two batches of 0.7×10^{13} on h=16 at 60 kV.
    - The situation was not optimal (transverse plane) and the conclusions were that bunching factor was 10 times more than CT.

Longitudinal profile of first five injected turns

Superposition of longitudinal profiles from the five turns



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Possible mitigation measures - V

- **Different longitudinal beam structure:**
  - Create a gap in the bunch structure at PS -> leave an empty bucket (e.g., 7 bunches injected from PSB on h=8 in PS)
    - Bunch intensity to be increased
    - Synchronisation between PS and SPS is needed
    - Synchronisation requires time and voltage
    - Gap will be filled (at least partially during de-bunching)
    - The gap will be repeated five times in the batch towards the SPS -> strong intensity modulation

It does not seem feasible/useful

Possible mitigation measures - VII

- Most promising alternatives found so far:
  - Install a dummy septum to shadow the blade of the magnetic septum 16 (discussed with Brennan – who launched the idea)
  - Use the electrostatic septum 31 (discussed with Gianluigi)
- Both should be studied to assess feasibility

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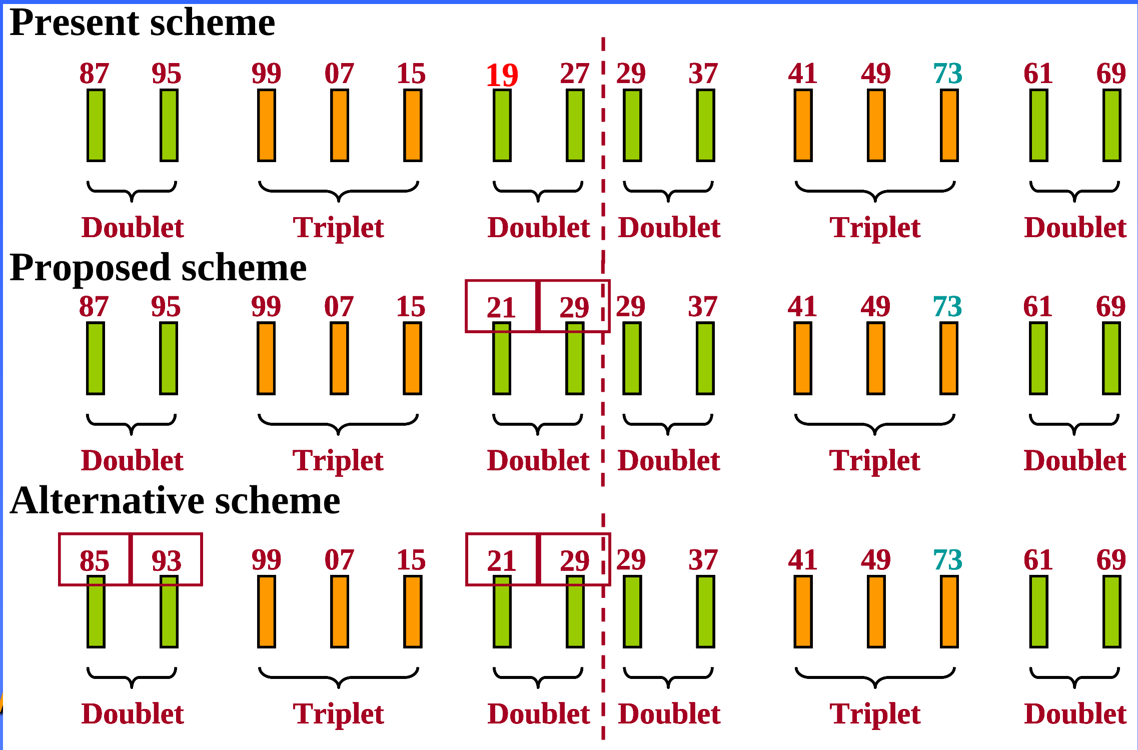
Dummy septum in PS - I

- It should be used to shadow the blade of the magnetic septum 16
- The extraction scheme would remain conceptually the same as the current one.
- Where to install such a device?
- SS15 is the only choice
- About 40 cm available
- DHZ15: dipole for closed orbit distortion correction and MTE slow bump (about 24 cm long)
- Triplet quadrupole for γ-jump (about 24 cm long)

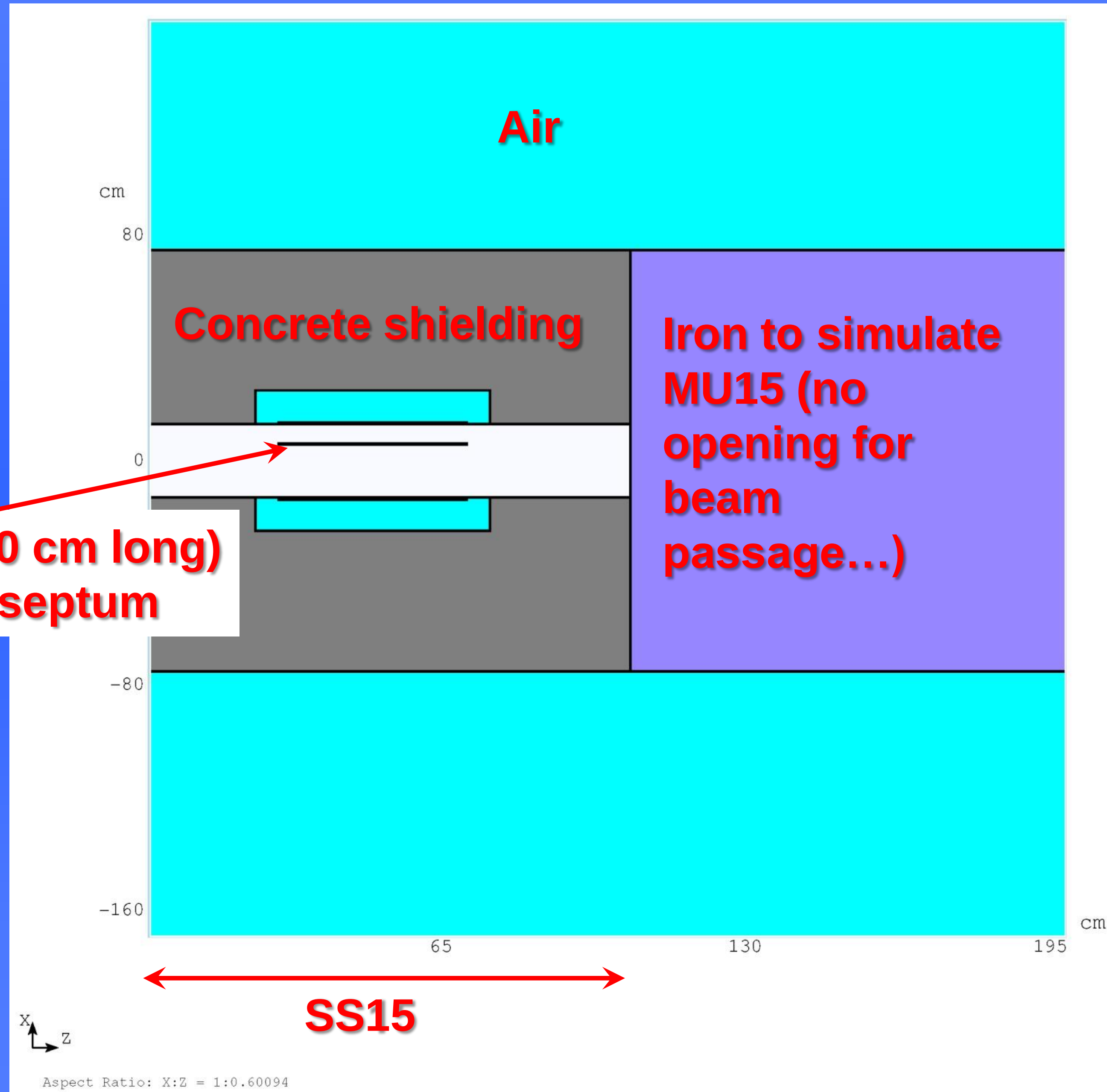
Dummy septum in PS - II

- **To make additional longitudinal space:**
  - **Remove DHZ15:**
    - implication for closed orbit deformation at high energy (probably a solution can be found)
    - Implication for slow bump for MTE: study required.
  - **Remove quadrupole:**
    - It could be moved in SS39 (the triplet in 41/49/73 is already split): impact on optics/dispersion during transition crossing to be studied. **XMT39 should be removed: to be studied**



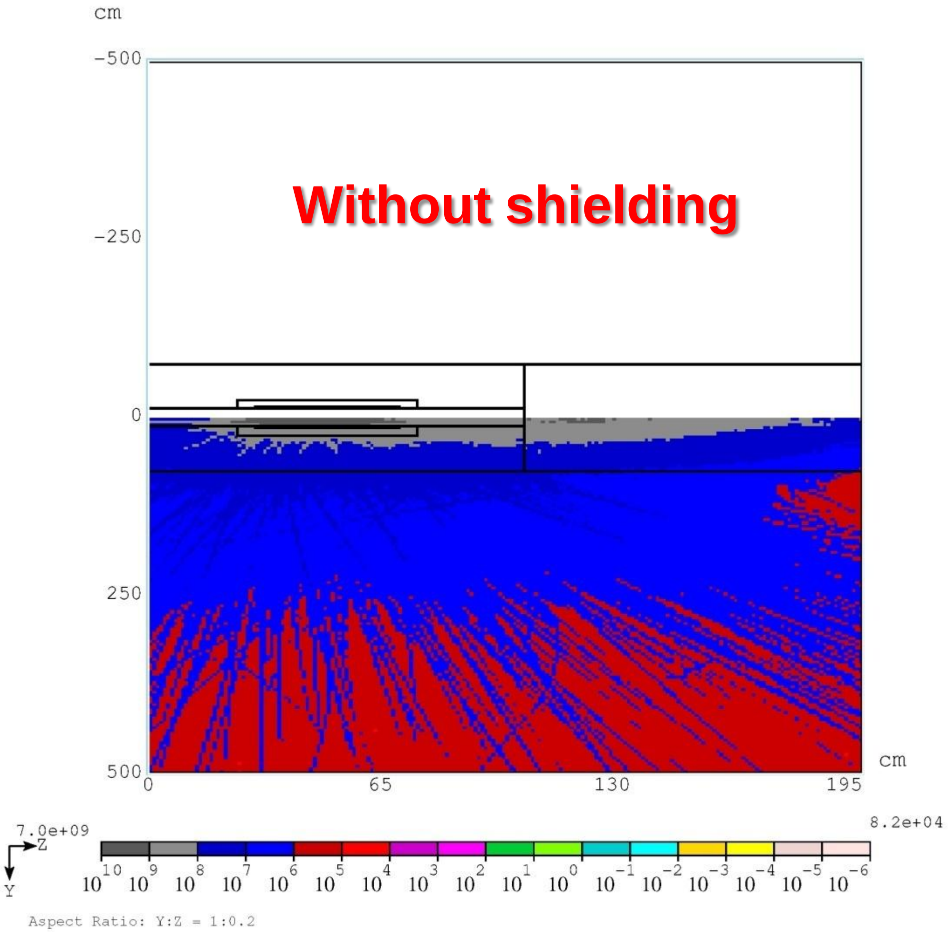
Dummy septum in PS - III

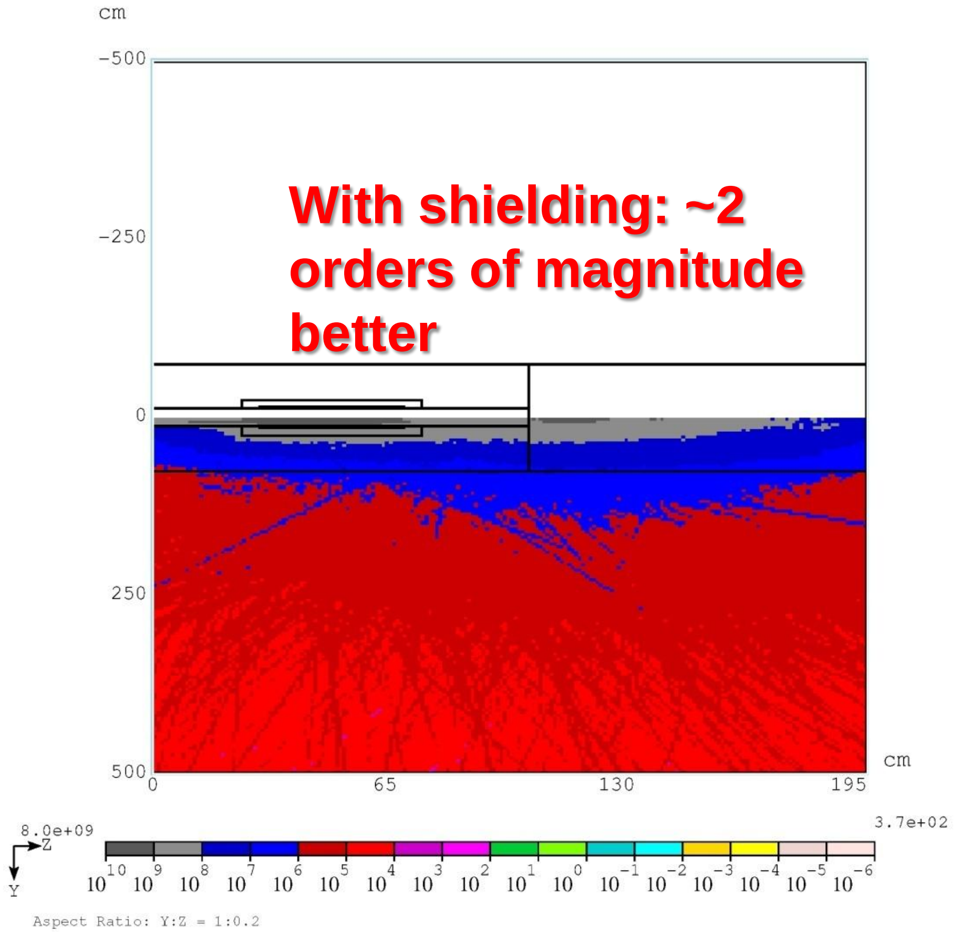
Simple model used from preliminary simulations (by Simone).



Dummy septum in PS - IV

Results normalised to 0.8×10^{13} p/s

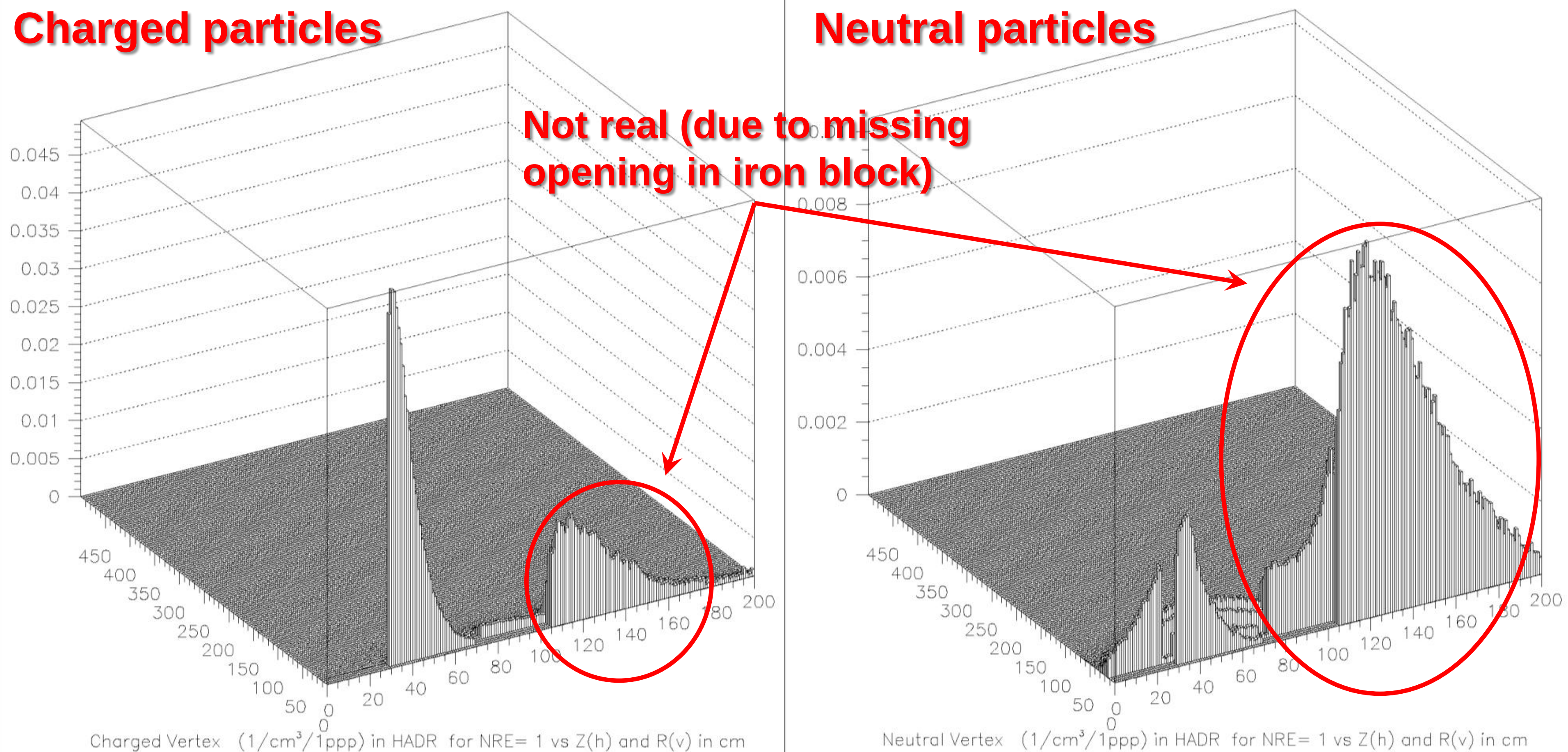




Dummy septum in PS - V

More realistic simulation should be done. Fluka model exists used to study the wall installation to protect the Linac3. To be organised with RP.

Results normalised to 0.8×10^{13} p/s



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Use SEH31 for MTE - I

- The standard MTE scheme is modified as follows:
  - Two slow bumps are used:
    - Around SEH31
    - Around SMH16
  - A single fast bump is generated around SEH31.
  - The split beam will cross the foil of the electrostatic septum (~0.2 mm against ~3 mm of SMH16) .
  - Beam losses will occur only during the rise of the kickers.
  - The SEH31 will kick the island beyond the SMH16.
- New fast bump generated by:
  - KFA21, BFA21, KFA9, KFA13

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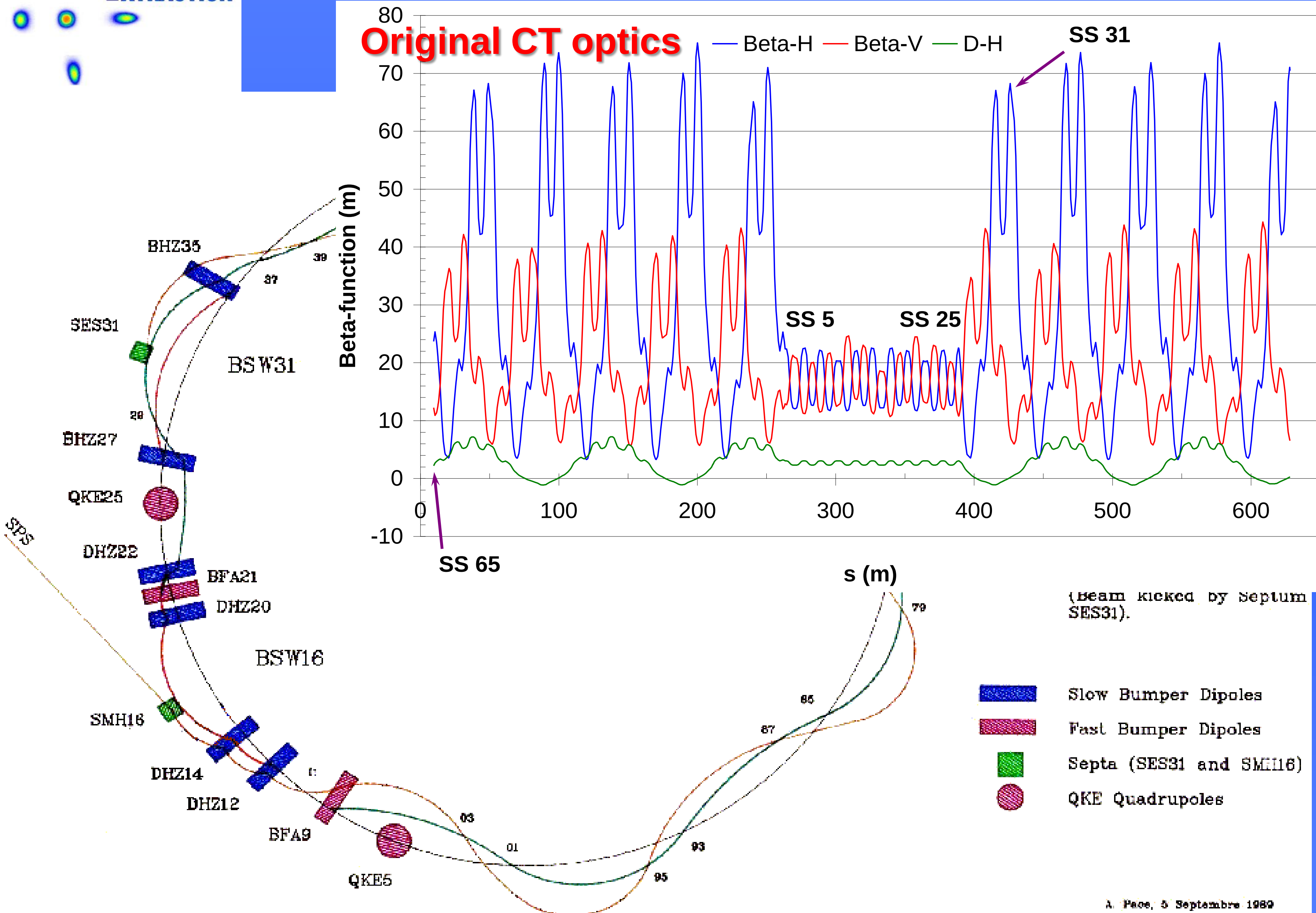
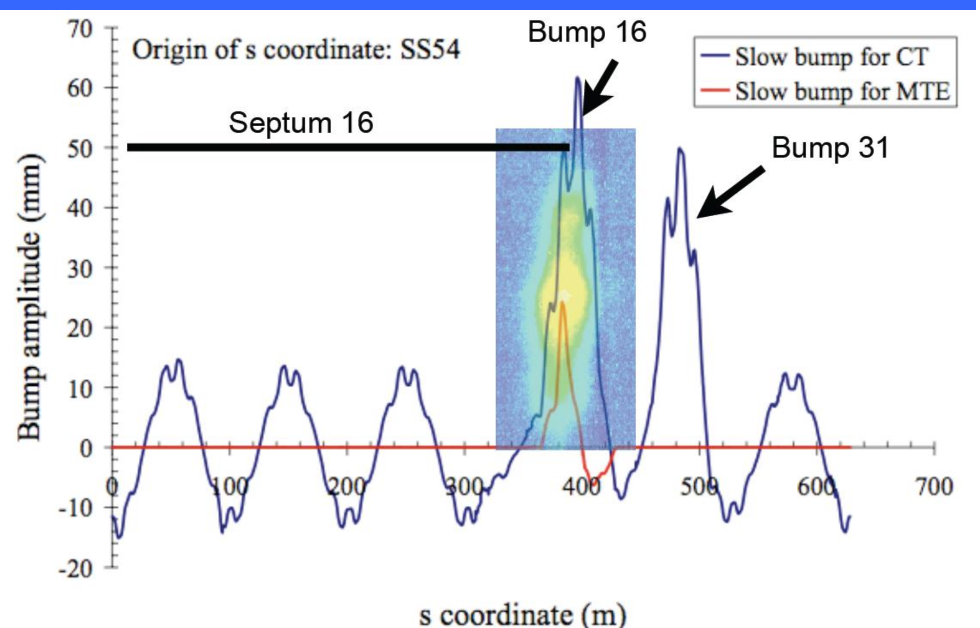
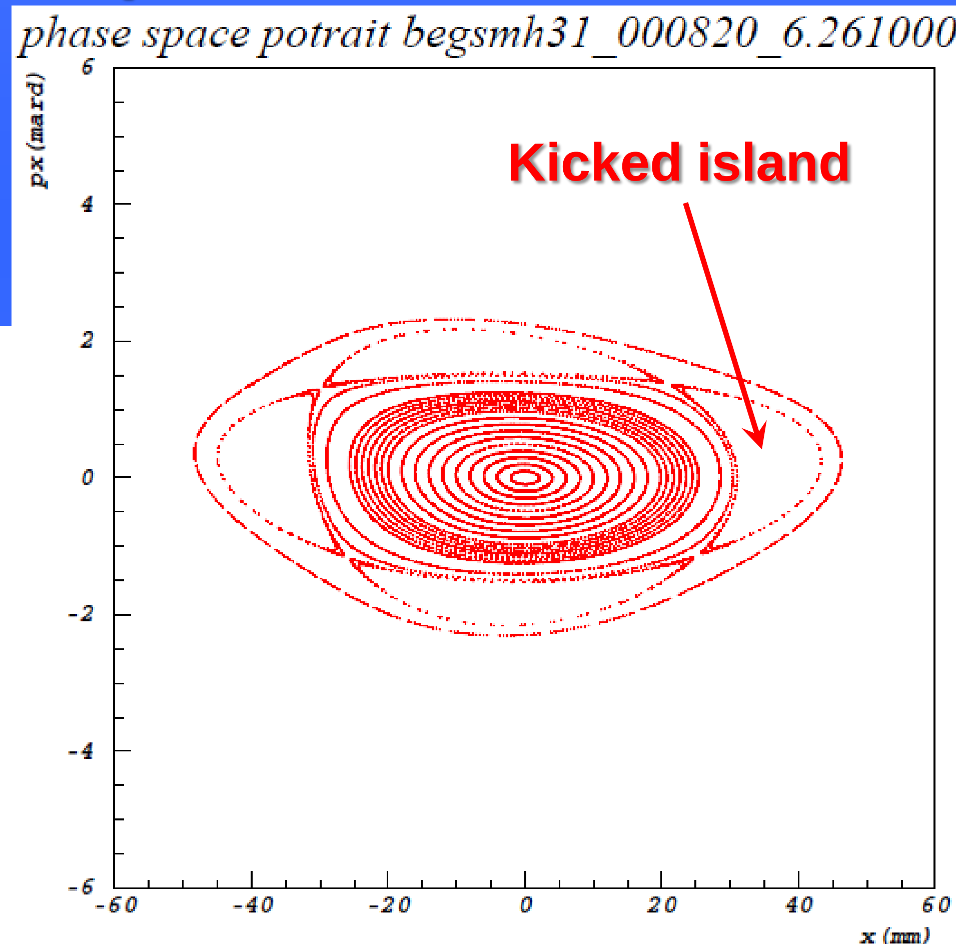
Recall of CT scheme



Use SEH31 for MTE - II

- First check: islands' phase at SEH31 -> OK
- **NB: the kicked beamlet will move as in a transfer line!!! The concept of stable island is lost!!!**





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Use SEH31 for MTE - III

- Observation: due to the presence of the islands, the slow bumps will have a lower amplitude than for the standard CT.
- Even if the extraction layout is very similar to the CT, the optics is not the same! The QKEs cannot be used as they induce a tune variation.
- Extraction of first four turns:
  - Long fast bump -> large trajectory excursions in large fraction of the machine. It might induce aperture problems.
  - Phase advance with nominal optics between SS21 and SS31 is not optimal. It might induce strength problems.
  - Strength of electrostatic septum might not be enough to jump beyond magnetic septum due lower slow bump.

Use SEH31 for MTE - IV

- **Extracted beamlets might experience aperture problems.**
- **Last turn:**
  - **Extraction via the electrostatic septum might not be possible due to lack of kicker strength (lower slow bump).**
  - **Alternatively, one could attempt a sort of fast extraction with the fast bump (KFA21, BFA21, KFA9, KFA13) and KFA71 and KFA4.**
  - **In this case, some beam losses due to the rise time of the KFA71, KFA4 should be expected.**
  - **However, rise time of KFA71, KFA4 is about 4 times faster than other MTE kickers -> losses should be proportionally reduced.**

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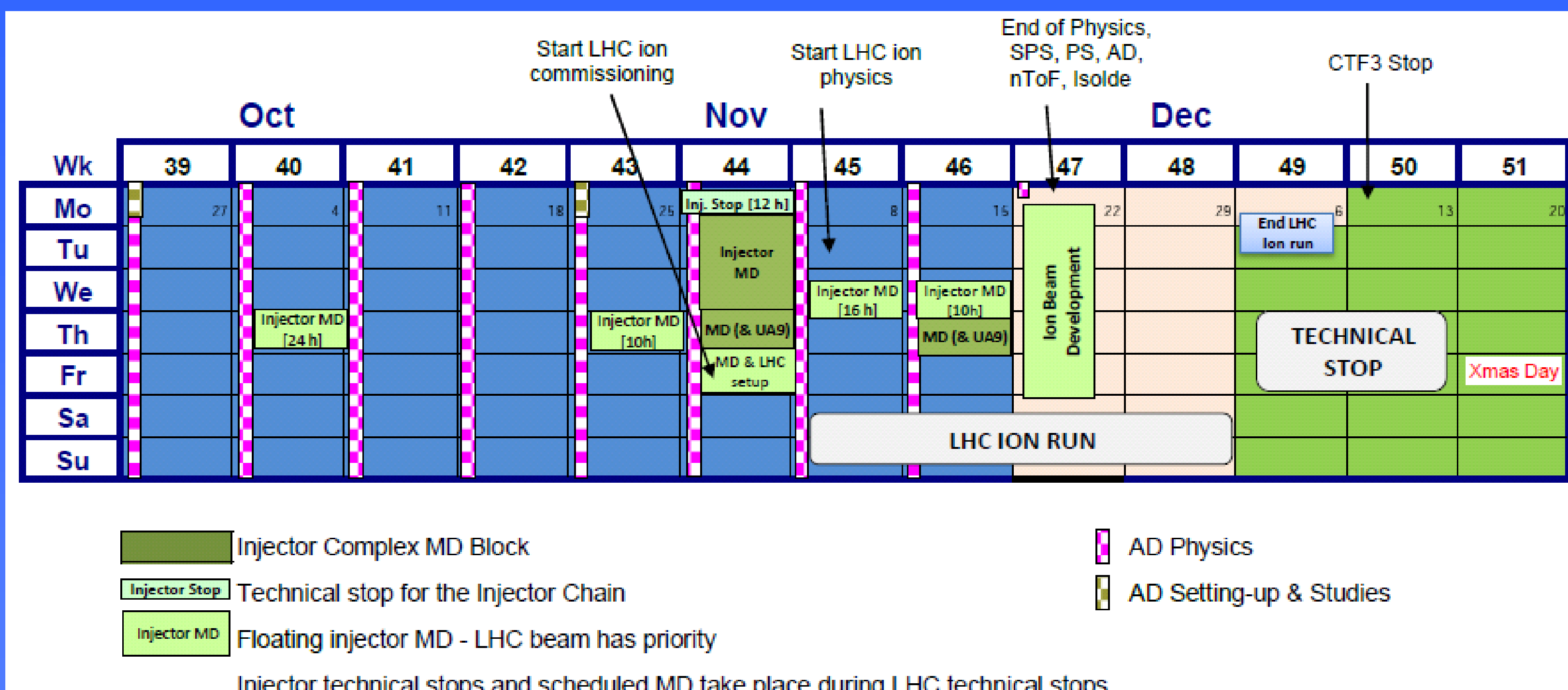
Experimental tests - I

- **Any experimental test of the use of SEH31 for MTE should be based on a more detailed analysis on paper.**
- **The polarity of the KFA21 should be changed!**
- **Target: injectors' stop on 1/11. This would give three more weeks of proton run.**



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Experimental tests - II

- Measurements:
  - Test to jump beyond SEH31 (pencil beam and split beam)
  - Test to extract the fifth turn
- Instrumentation:
  - BLMs should be fully operational, possibly also LHC-type (in SS16 and SS31)
  - Orbit system should be fully operational (trajectory measurements)
  - Pick-ups in TT2 would be extremely useful for measuring in detail extraction trajectories