Magnet and Beam Commissioning at Step IV

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Outline

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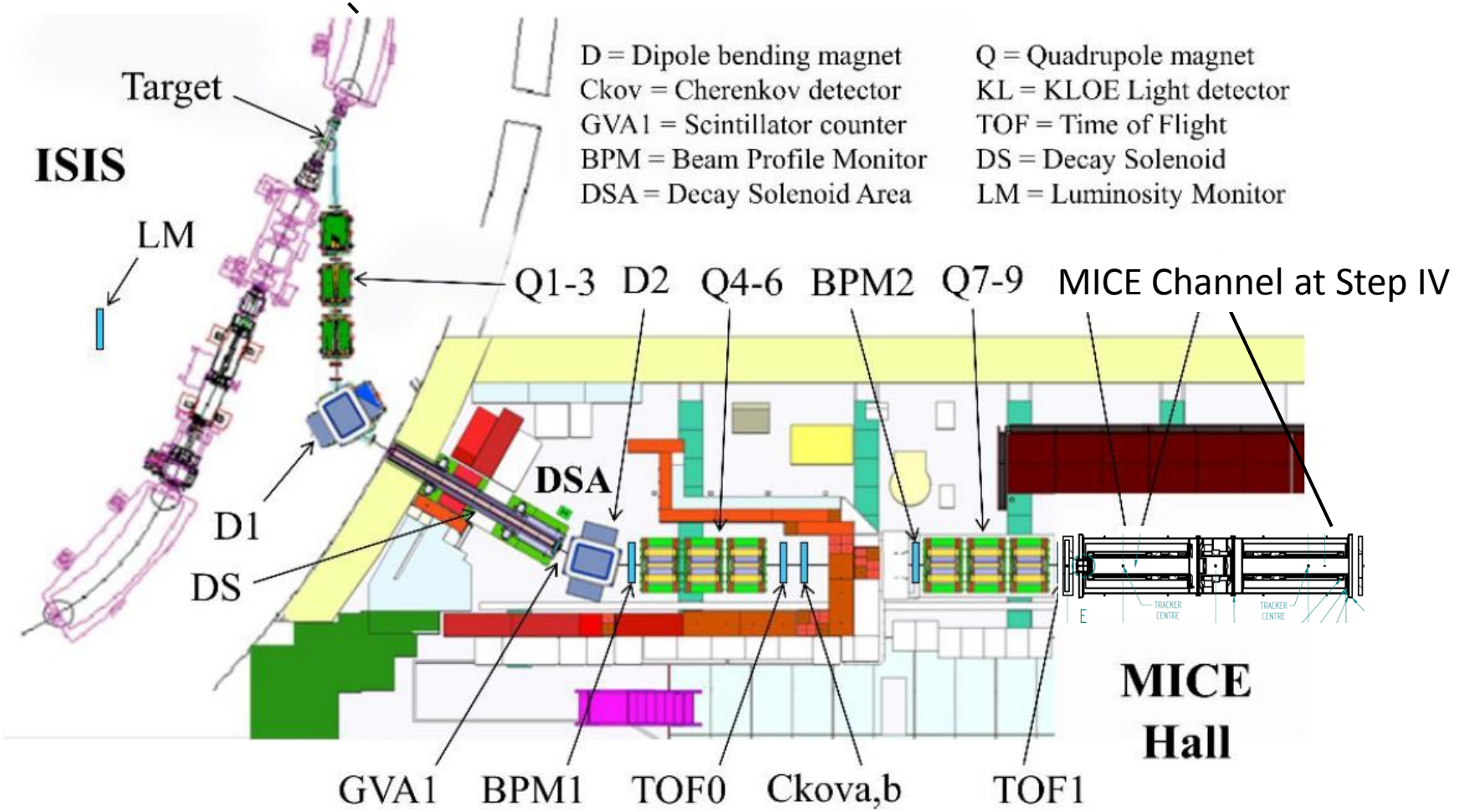
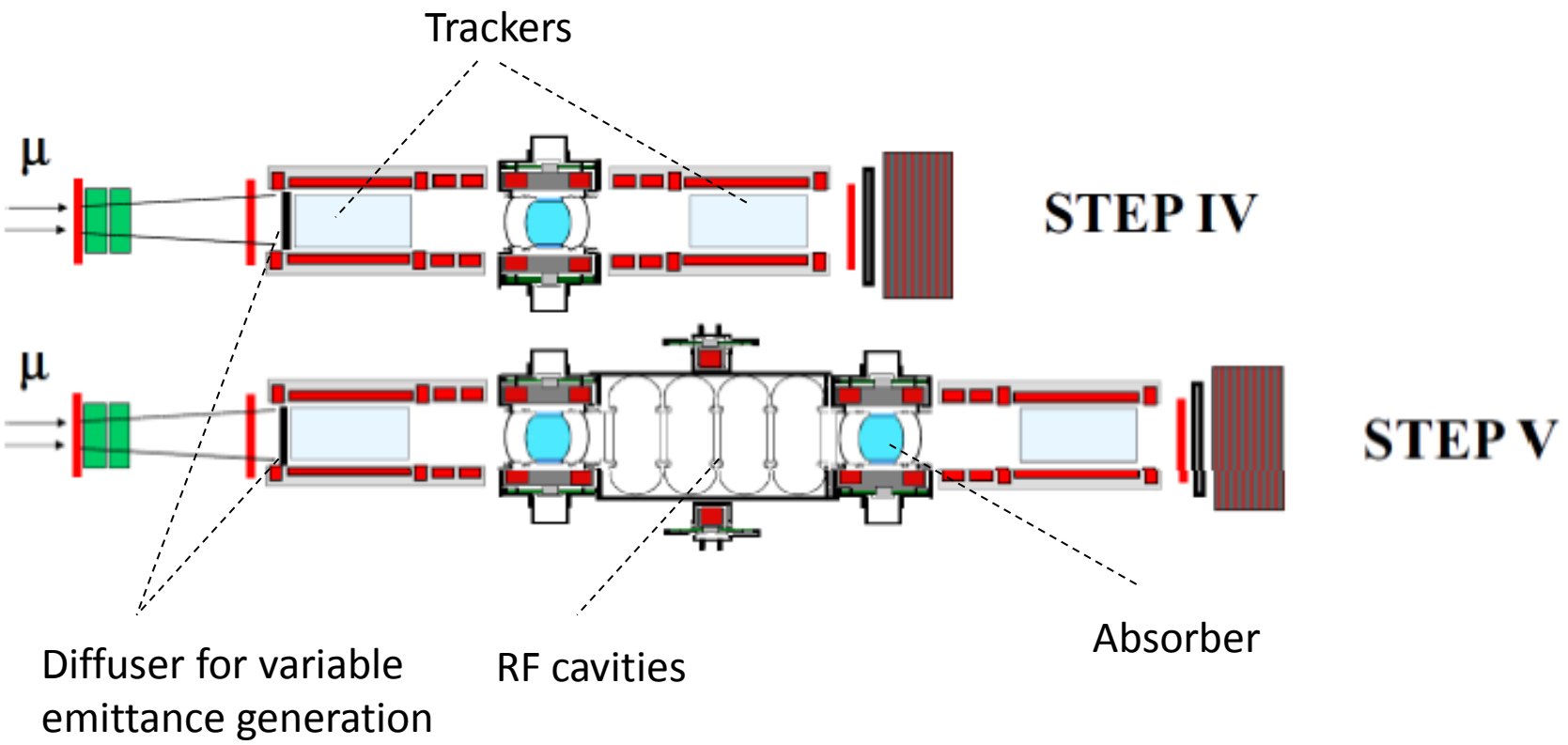
- Beam line Pre-Commissioning
- Beam line Commissioning
- Magnet Commissioning
- Beam Commissioning of MICE Channel
- Summary

Introduction



MICE Beam Line
Conceptual Layout

Introduction (2)



MICE Step IV and V conceptual layouts

Beam line Pre-Commissioning

- Required to test new beam settings for the operations and Tracker commissioning without B field
- Hardware needs to be re-tested
  - Nothing new beyond Step I operations, however hardware not used for many months
- Step I setting needs to be repeated (~10k useful triggers)
  - Again to test if nothing changed! It will also allow to cross-check with improved MC modelling
- Updated momentum settings need to be tested against matching at TOF0 with Step I tomography
  - Requires new settings to be developed and their MC performed (ASAP, latest CM40)
  - Requires DS, proton absorber, all beam line magnets, TOF0 and TOF1
- Large beta (beam size) setting for Tracker commissioning without magnetic field needs to be tested
- In summary: 10h of useful beam including tuning time and contingency -> 4 shifts (data taking is only a small fraction of the estimated time)
  - May need to be repeated ->8 shifts, the time may be shared with Trackers
  - Should be done before the Magnet Commissioning
  - First Spring ISIS Run (17.03-24.04) or the Magnet Commissioning during the Summer Run (2.06- 24.07).

Beam line Commissioning

- Necessary to test the muon beam matching to the MICE Channel
  - Requires DS, proton absorber, all beam line magnets, TOF0 and TOF1, the Diffuser and commissioned Upstream Tracker (requires B field in USS)
  - Requires beta, alpha and emittance reconstruction at all 5 Tracker planes to test the behaviour of the beam
  - 9 settings (beam matrix), each ~10k triggers, ~10h of useful beam
  - Most likely will need to be repeated – 15 shifts (including the contingency)
  - Needs to be done after Magnet Commissioning (at least USS)

Magnet Commissioning

Results of study performed by

MICE Magnet Integration Task Force (MMITF)

Requirements for the Magnet Commissioning

- The realistic goal is to achieve stable operation in solenoid mode first and in flip mode afterwards.
  In both modes with sufficient margins in M1 and M2 currents for tuning (below the quench limit)
  - ❑ This will provide us with sufficient flexibility for beam operation (data taking).
- Commissioning will also establish the necessary standards and knowledge required for operations
  - ❑ How to tune the channel
  - ❑ How to switch on/off
  - ❑ How to go from one setting to the other

Assumptions for the magnet commissioning

- A quench in any of the magnets will result in the full MICE channel quench event (please see additional slides)
- Quench may propagate between SSs even if FC is off.
- The 48h minimal time between quenches for the FC sets the recovery time for the MICE channel (SSs can quench 1,2 times per day).
  - May be we can take the beam in this period for beam line commissioning, if needed?
- This allows to estimate the time duration and LHe requirements for various scenarios.

Recommended Scenario for MICE magnets commissioning at STEP IV (1)

- Magnets will be installed, connected and a ramping test completed in advance.
- Sufficient supply of LHe needs to be secured
  - ❑ Discussions with BOC indicate Liquid Helium availability will not be an issue!
  - ❑ Each magnet will be equipped with its own dewar and the transmission line.
- It will be followed by individual magnet training
  - ❑ SS will be trained in parallel, but, only 1 magnet will be ramped at a time (1 quench per magnet per day and 2 quenches per day in 24/7 training operations).
  - ❑ We will start most likely in solenoid mode.
- Once all magnets reached their independent nominal settings, set nominal current in both SSs and start raising current in the FC.
  - ❑ Detecting which coil quenches first knowing the FC current will allow to assess how far we are from the nominal setting:
  - ❑ Depending on experimental findings the procedure may be followed by:
    - ❑ Training the FC with SS currents fixed at nominal (repeating the procedure).
    - ❑ Training the FC with SS currents fixed at derated value (to be defined).
    - ❑ Switching to combined training (Scenario 1 with ramping all magnets simultaneously at approximately 2.5 quench per week incl. 40% contingency)

Additional observations

- We will start in solenoid mode
  - MC studies (please see additional slides) show comparable cooling performance and the forces are relaxed in the solenoid mode (easier magnet commissioning)
- If magnets are commissioned quickly at the solenoid mode the commissioning of the flip mode will follow.
  - If not, the commissioning of the solenoid mode will be followed by physics run in this mode and the flip commissioning will be made afterwards.

Beam Commissioning of MICE Channel

- This is needed to assess the beam optics in Step IV Channel
  - Requires all beam line elements and magnets in the channel, TOF0, TOF1 and both Trackers, but no absorber.
- This will allow to asses the orbit
  - By checking if means of transverse position and divergence are sufficiently close to zero
- Optics can be assessed be checking the beta function at all 10 Tracker planes (in both Trackers).
- Transfer matrix through the channel can be measured and compared with simulations.
- The baseline setting with an intermediate emittance can be assessed (10k triggers,~ 1h), however we may already take 100k for precision (~3 shifts- including magnet tuning, beam line setting etc.).

Beam Commissioning of MICE Channel (2)

- We can choose one setting to make detailed study
  - Symmetric with an intermediate emittance, 200 MeV/c (baseline?)
- Before filling the absorber we may still want to assess off momentum behaviour of optics by performing measurements for two other momenta.
  - In principle 10k triggers would be sufficient, but again we may want to go for the precision (100k) for each -> 6 shifts in total.
- This will allow us to build knowledge and confidence before the start of the real physics with the absorber filled!

Summary for shift request for beam commissioning

- Beam line pre-commissioning with beam (does not require Tracker)– 8 shifts
- Beam line commissioning (requires Tracker - essential) – 15 shifts
- Beam Commissioning of MICE Channel - 21 shifts
  - At this stage we do not know, how much time is required for magnet tuning, so this is only a guess.

Summary

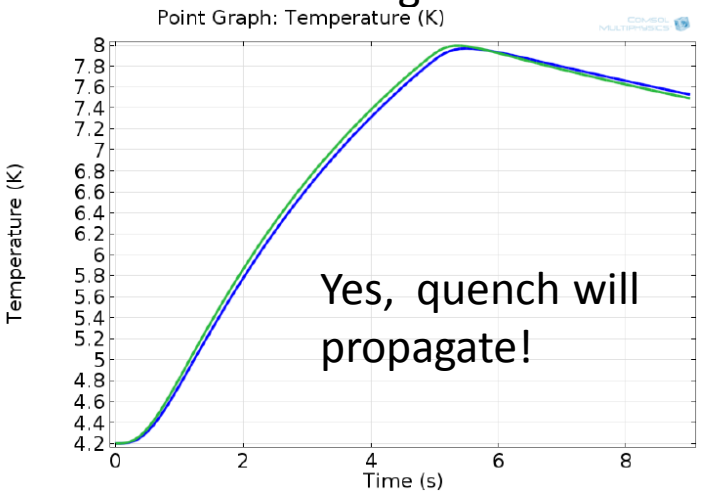
- Beam line pre-commissioning will allow to prepare the main commissioning. We aim to perform it still during the construction phase.
- We have the plan for magnet commissioning (thanks to the hard work done by MMITF). Although the combined operation of the MICE channel will be challenging, we are convinced it will be successful.
- The beam commissioning will allow to build knowledge and confidence before the start of the real physics with the absorber filled. We have the consistent plan of actions.

Acknowledgements

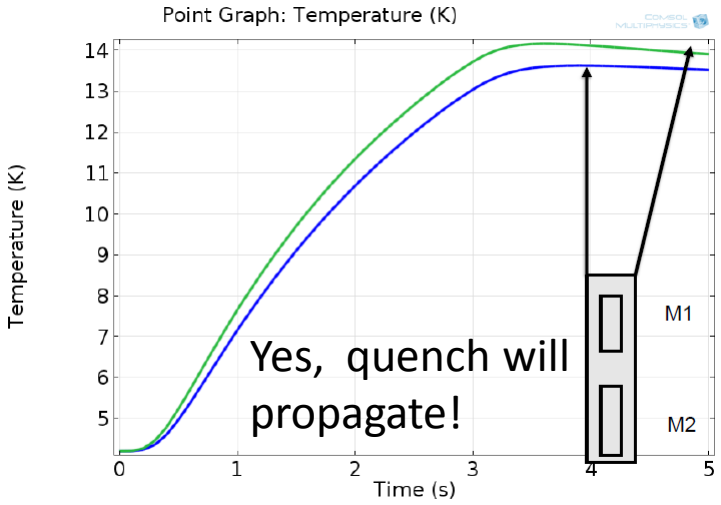
- I would like to thank members of the MICE Magnets Integration Task Force: V Bayliss, S Boyd , T Bradshaw, A D Bross, J Cobb, M Courthold, S Feher , S Griffiths , P Hanlet, T Harnett, K Long, D Orris, R Preece, S Prestemon, M Tucker, S Virostek , S Watson and H Witte for their essential input.
- Special thanks to V Blackmore, M Palmer and C Rogers for their input.

Quench back issues

Does quench of one module trigger quench of neighbour modules (via eddy currents heating in Aluminium mandrels)?



FC temperatures induced by SS quench

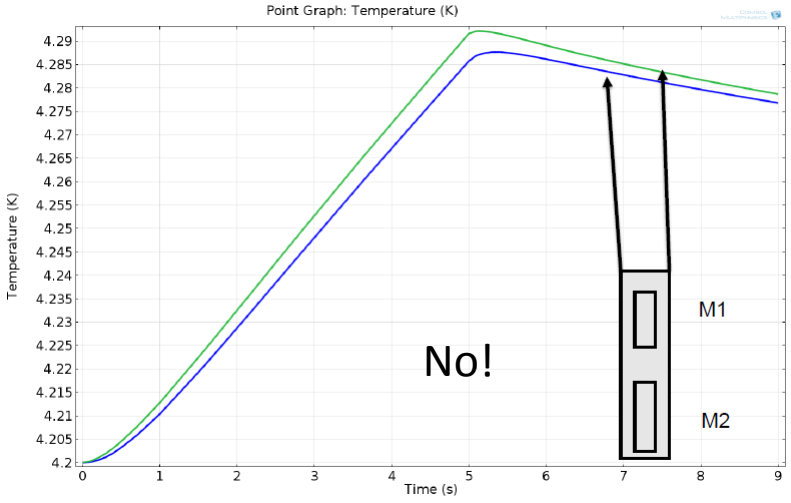


Yes

SS (M1,M2) temperatures induced by FC quench

- Coupled multiphysics analysis (E-M and thermal)
- Material properties taken into account
- Magnet switch-off times: FC 3s and SS 5s.
- Conclusion:

Quench induced via eddy currents heating will propagate through the MICE channel, if FC is switched on.



SS (M1,M2) temperatures induced by the second SS quench

Quench propagation issues

- Does quench of one SS trigger quench of second SS (via inducing a fake quench signal in the Quench Detection (QD) system triggering the quench event)?
- We need the inductance matrix at Step IV geometry:

	E2	SS	E1	M2	M1	FC	FC	M1	M2	E1	SS	E2
E2	12.241	3.690	0.053	0.022	0.019	0.025	0.017	0.004	0.002	0.002	0.004	0.001
SS	3.690	42.227	3.297	0.533	0.262	0.230	0.134	0.024	0.010	0.009	0.022	0.004
E1	0.053	3.297	10.001	0.934	0.285	0.167	0.084	0.013	0.005	0.004	0.009	0.002
M2	0.022	0.533	0.934	6.356	1.033	0.318	0.132	0.017	0.006	0.005	0.010	0.002
M1	0.019	0.262	0.285	1.033	14.326	1.825	0.541	0.051	0.017	0.013	0.024	0.004
FC	0.025	0.230	0.167	0.318	1.825	81.302	12.848	0.541	0.132	0.084	0.134	0.017
FC	0.017	0.134	0.084	0.132	0.541	12.848	81.302	1.825	0.318	0.167	0.230	0.025
M1	0.004	0.024	0.013	0.017	0.051	0.541	1.825	14.326	1.033	0.285	0.262	0.019
M2	0.002	0.010	0.005	0.006	0.017	0.132	0.318	1.033	6.356	0.934	0.533	0.022
E1	0.002	0.009	0.004	0.005	0.013	0.084	0.167	0.285	0.934	10.001	3.297	0.053
SS	0.004	0.022	0.009	0.010	0.024	0.134	0.230	0.262	0.533	3.297	42.227	3.690
E2	0.001	0.004	0.002	0.002	0.004	0.017	0.025	0.019	0.022	0.053	3.690	12.241

All values in H

(SS should be C here according to the notation used in this presentation)

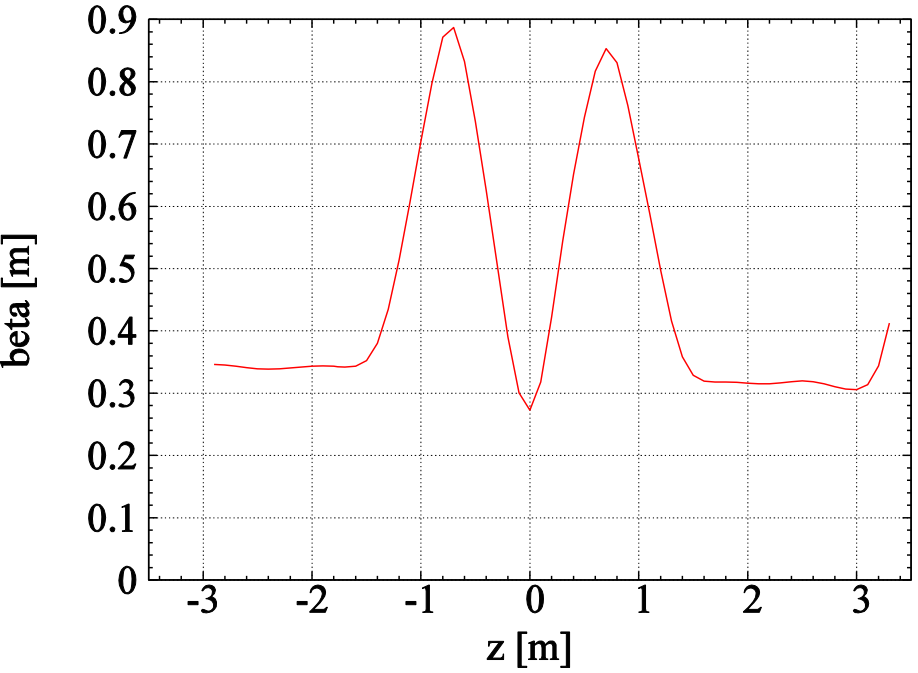
• Using the above inductance matrix, assuming SS at nominal currents and switch off time of 5s, the voltages induces in the second SS coils can be estimated (in linear approximation):

$(V_{E2}, V_C, V_{E2}, V_{M2}, V_{M1})=(0.6, 3.2, 1.5, 1.8, 4.9)$ [V]

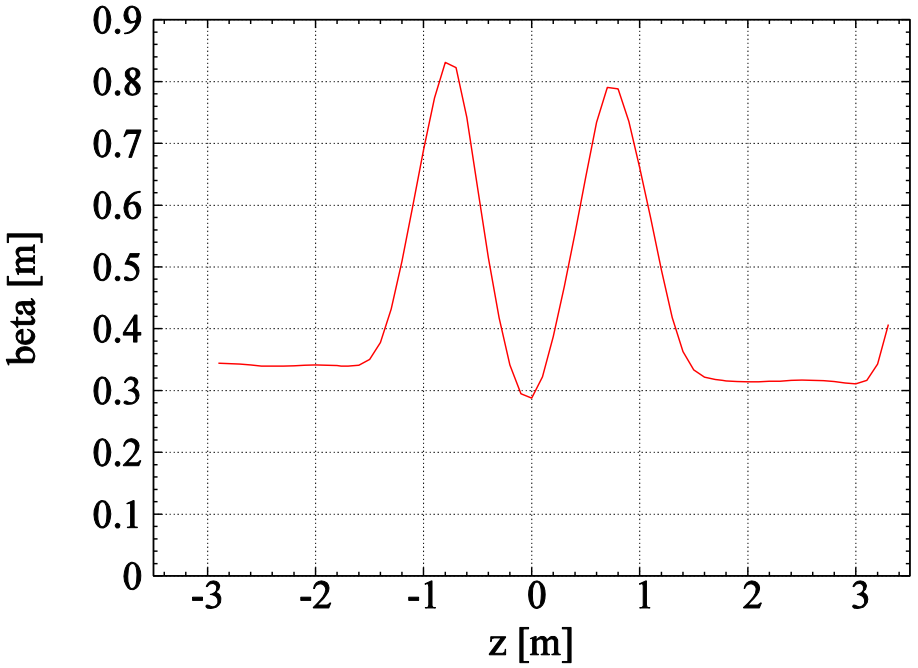
• As this values are similar to the thresholds set in QD system, quench of one SS may induce quench in the second SS via triggering its Quench Protection (QP) system.

Solenoid versus Flip modes MC studies (beta function)

Flip mode

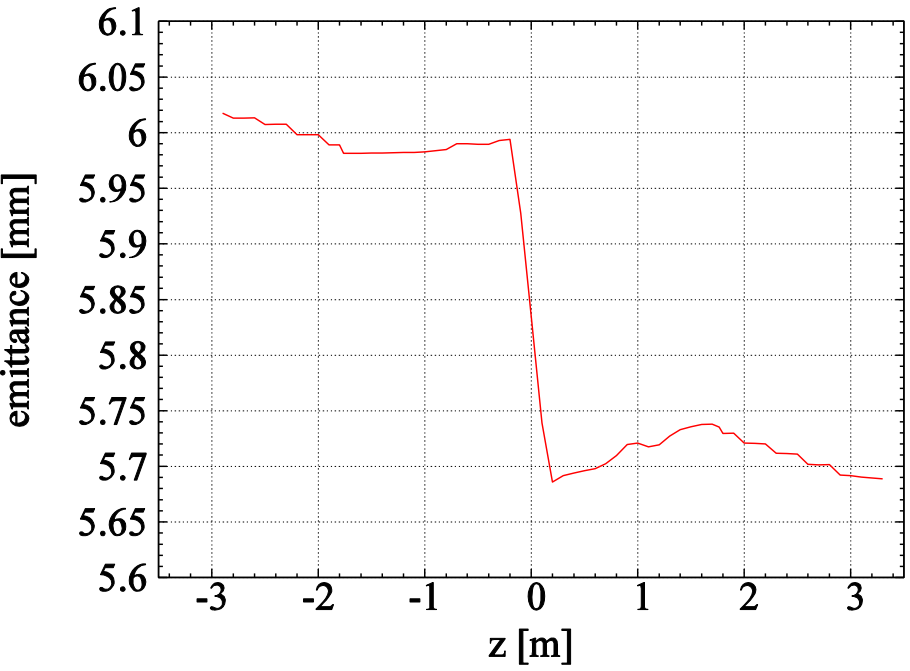


Solenoid mode

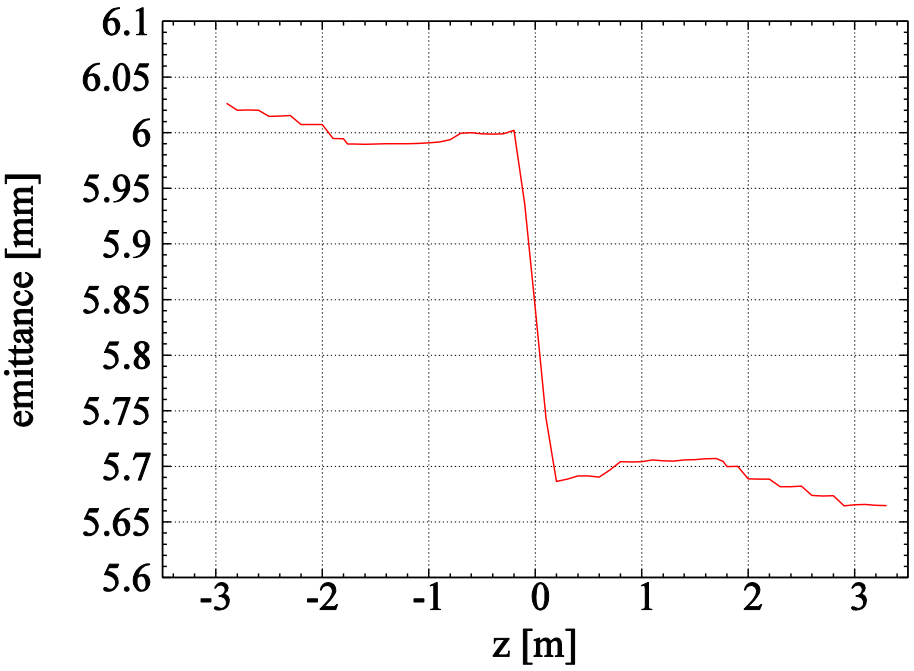


Solenoid versus Flip modes MC studies (emittance evolution)

Flip mode



Solenoid mode



Conclusion: Solenoid and Flip mode have comparable cooling performance with some indications of solenoid mode being better (higher acceptance and emittance reduction). Taking into account that the solenoid mode may be easier in commissioning due to the lower Current requirements in the FC, this study suggests to start MICE in the solenoid mode.