MICE Demonstration of Muon Ionization Cooling

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Introduction

- The international **Muon Ionization Cooling Experiment** (MICE) aims to demonstrate **sustainable ionization cooling**:

i. Muon beam is passed through absorbing material to reduce its occupied phase-space volume (emittance)

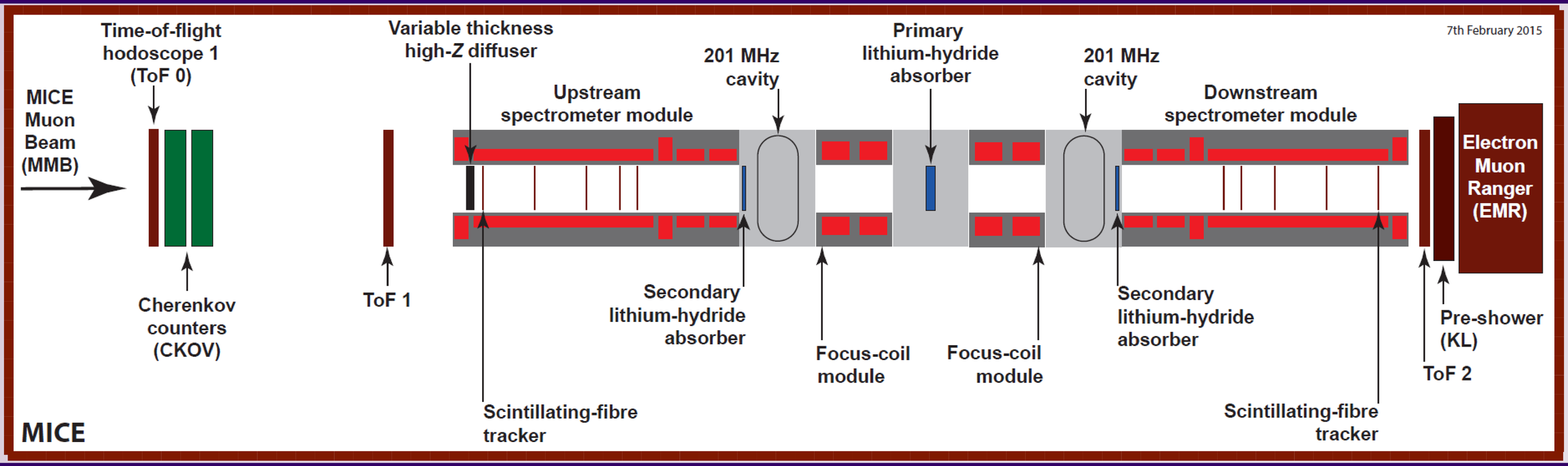
ii. Energy lost due to ionization in material is then replaced using radio frequency (RF) cavities

- **Rate of change of transverse emittance** in absorber [1, 2]:

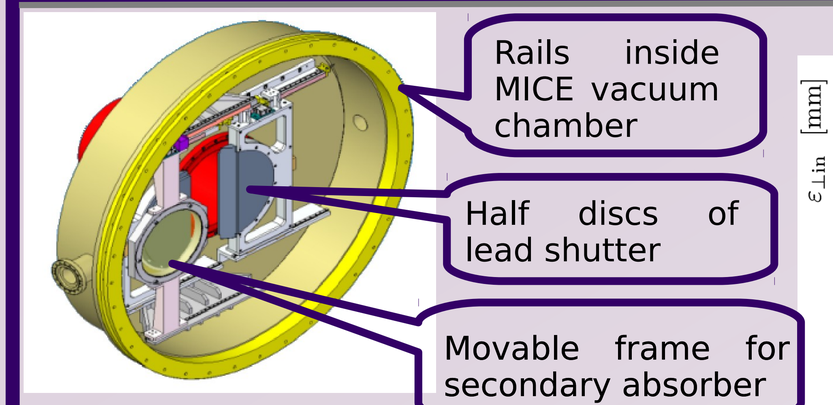
$$\frac{d\varepsilon_\perp}{ds} \simeq -\frac{\varepsilon_\perp}{\beta^2 E_\mu}\left\langle\frac{dE}{ds}\right\rangle + \frac{\beta_\perp (13.6\text{MeV})^2}{2\beta^3 E_\mu m_\mu X_0}$$

βc, E_μ, m_μ, dE/ds, X_0 and $\beta_\perp$= muon velocity, energy, mass, magnitude of energy loss rate through ionization, absorber radiation length, and transverse beta function at absorber.

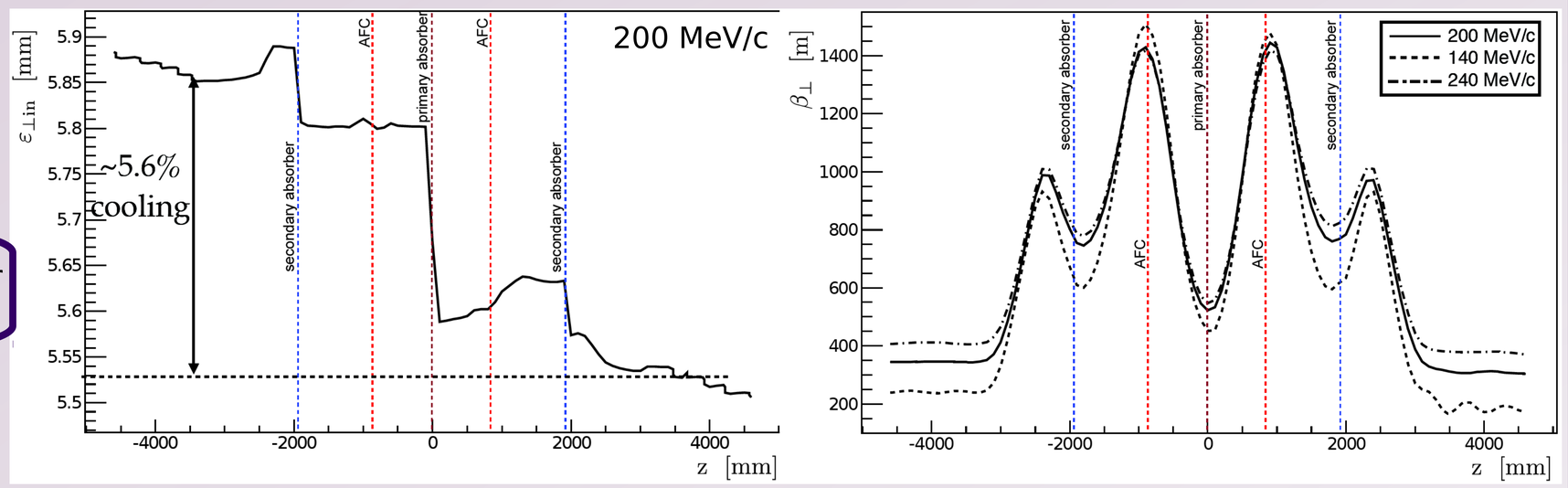
- Why muon beams of low emittance?
  - Neutrino Factory: for intense, well-characterised neutrino beams [3]
  - Lepton-antilepton Colliders: energy ≤ several TeV [3]
- Proposed configuration: lithium-hydride absorbers, superconducting focus coil modules, 201 MHz single-cavity modules [4], and spectrometer solenoids.



Cooling Demonstration Lattice

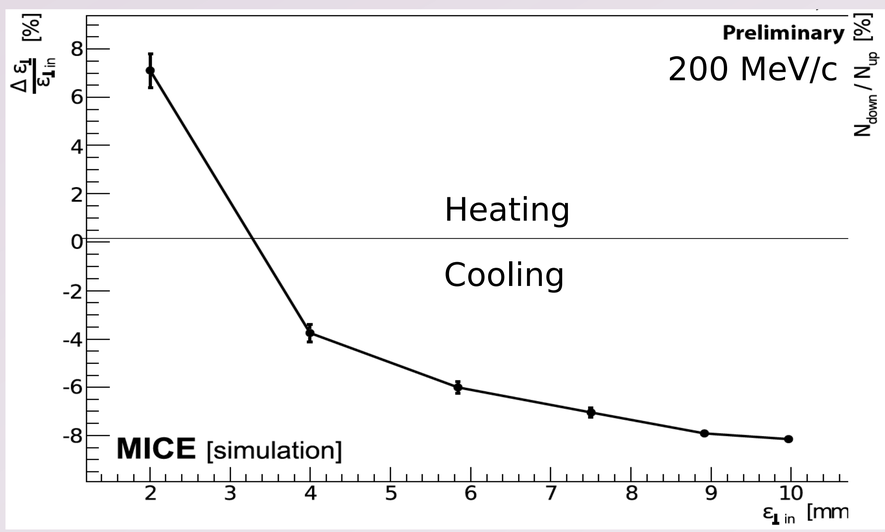


- Lattice Features:
  - Acceptable beam size at position of 201 MHz RF cavities
  - Small beta function at position of primary LiH absorber
  - Secondary LiH absorbers between cavities and trackers [5] to minimize exposure of trackers to dark-current electrons
- MICE Analysis User Software, MAUS [6] used for lattice Monte Carlo simulations → 5.6% transverse emittance reduction and 99% transmission for 6π mm input beam emittance

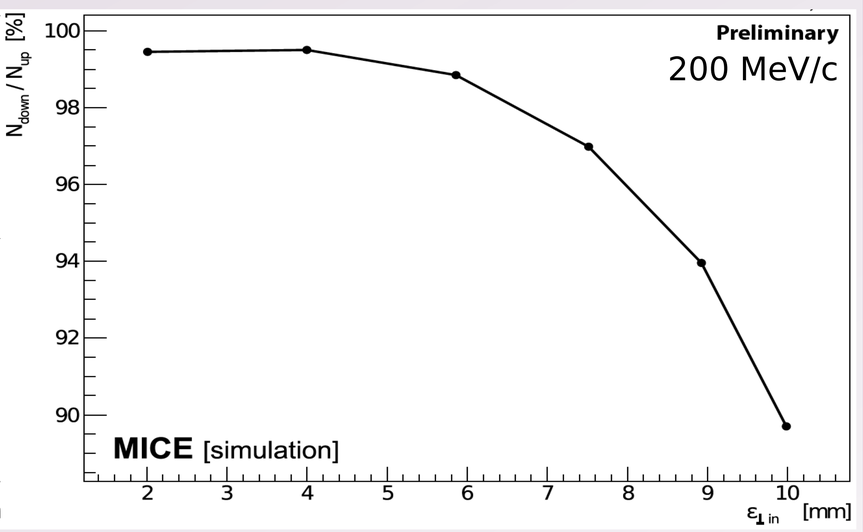


4D emittance Evolution

4D β function Profile



Change in normalised 4D emittance vs input emittance



Transmission vs input beam emittance

Conclusion

More economical cooling demonstration lattice using existing components: demonstrates performance required for detailed study of ionization cooling. A successful completion of MICE will herald **establishment of new technique for particle and accelerator physics**

Acknowledgements

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References

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