6D Cooling with MICE

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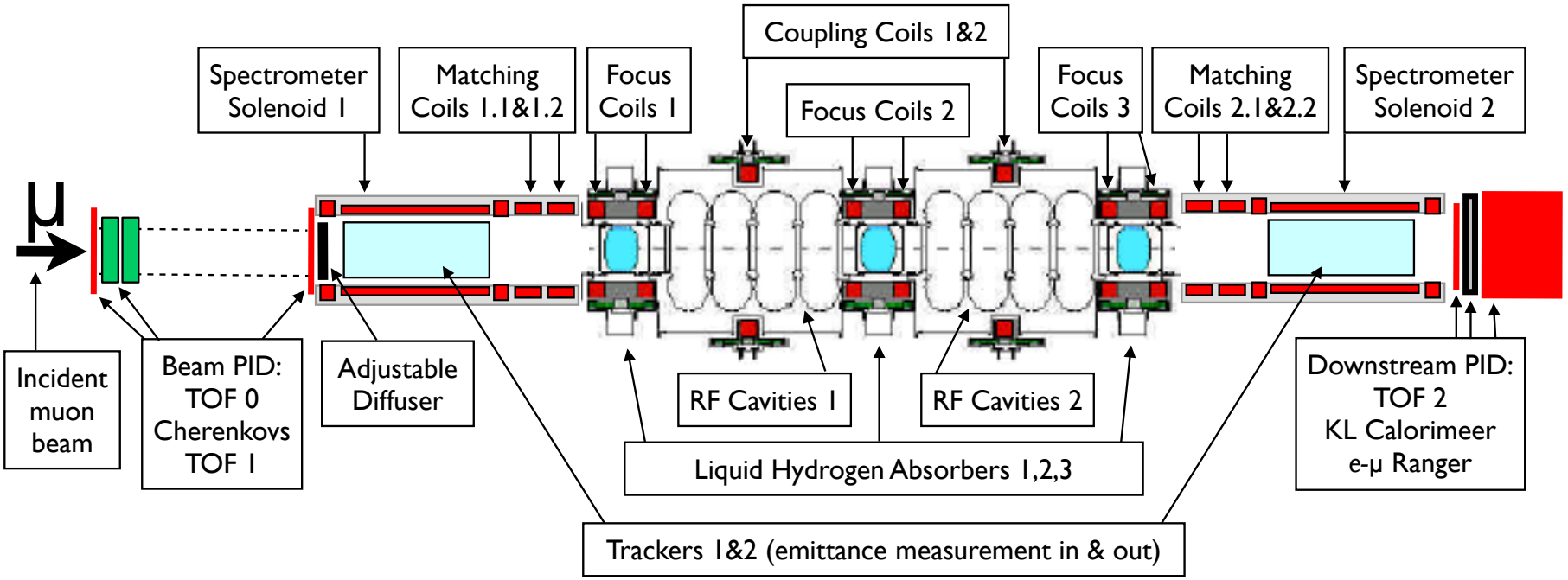
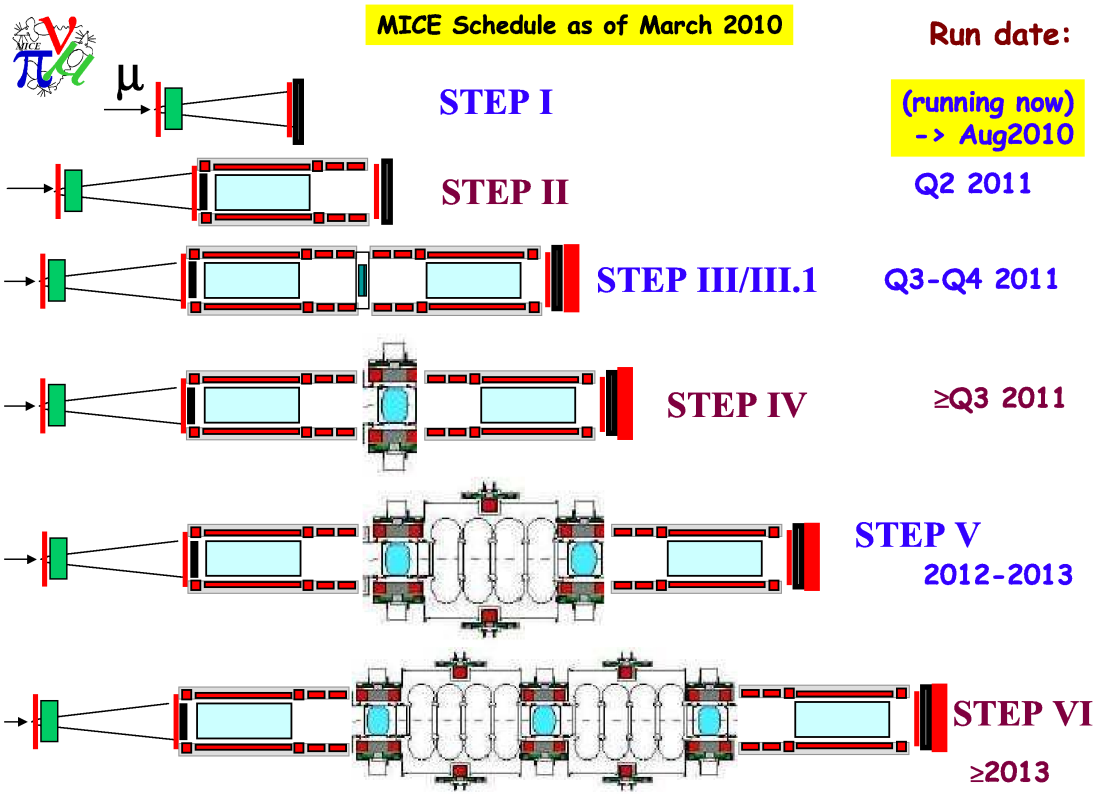
MICE Layout



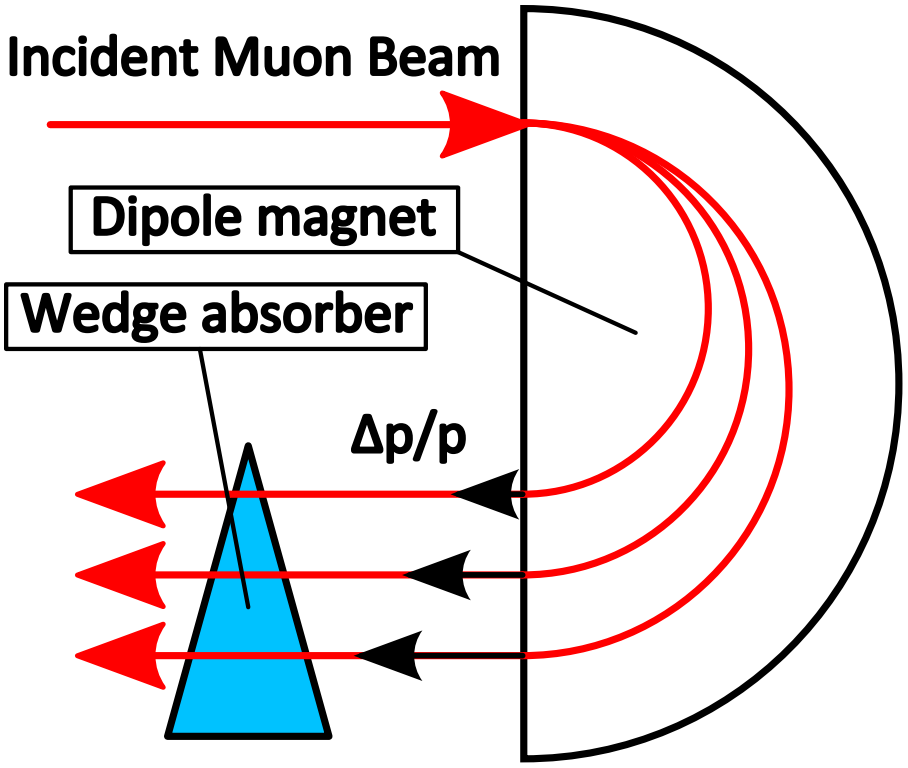
MICE layout scheme

MICE Step-Wise Implementation



MICE implementation schedule, we are interested in Step IV

Emittance Exchange



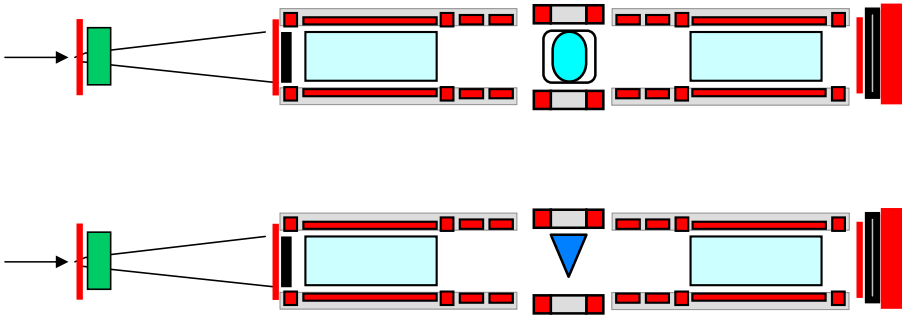
Based on the image by Muons, Inc.

- Introduce dispersion (in MICE: by careful beam selection).
- Let particles pass through a wedge absorber in such a way that particles with larger momentum lose more energy.
- Longitudinal emittance is reduced at the expense of deliberately increasing transverse emittance slightly (emittance exchange).

MICE Step IV with Wedge

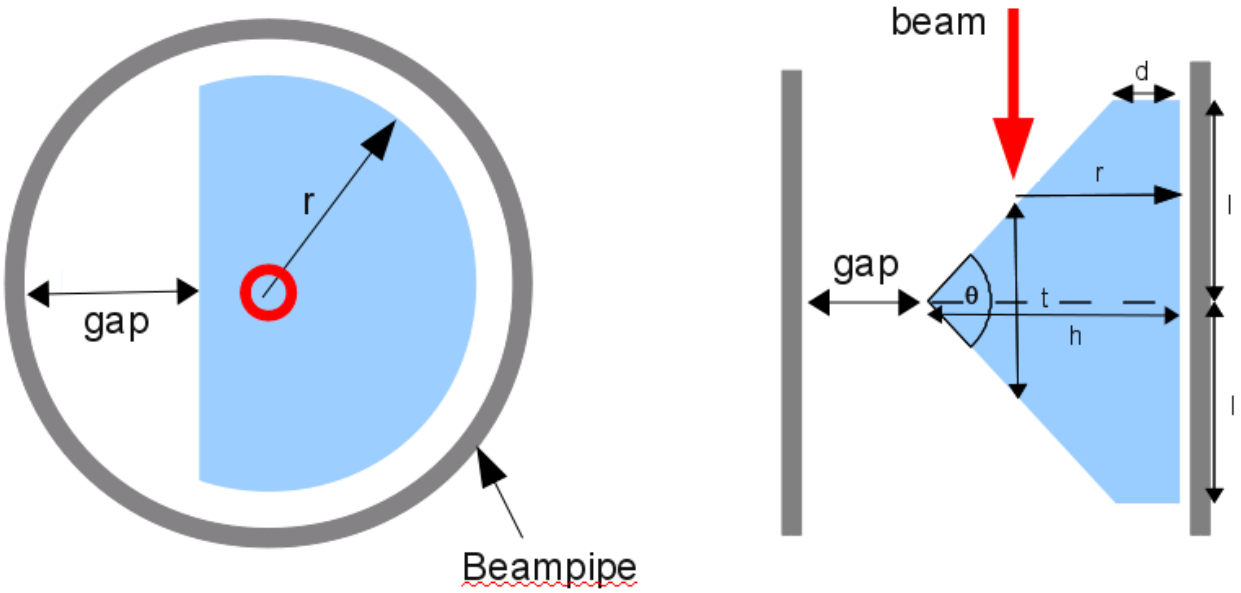
- Top: MICE Step IV with a liquid hydrogen absorber.

  MICE is a 4D cooling experiment: transverse emittance is reduced while longitudinal emittance stays the same or increases slightly due to stochastic processes in the energy loss.



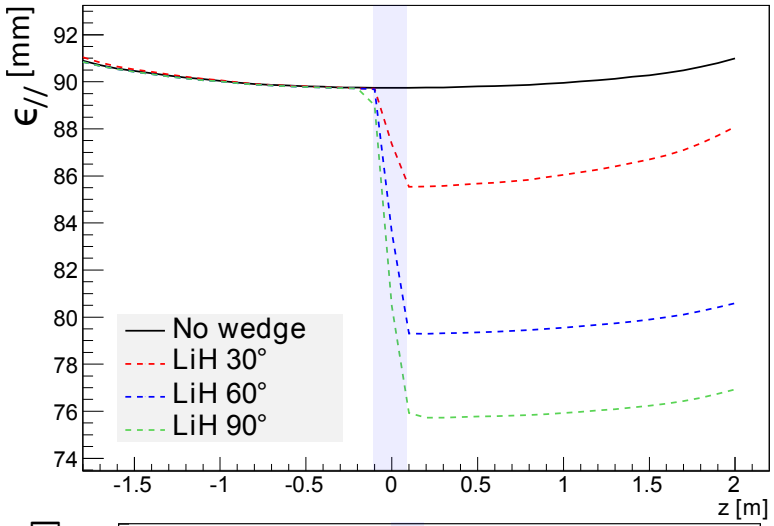
- Bottom: LH_2 absorber is replaced with a solid wedge absorber. This way emittance exchange can be observed if the beam is properly matched (dispersion is introduced).

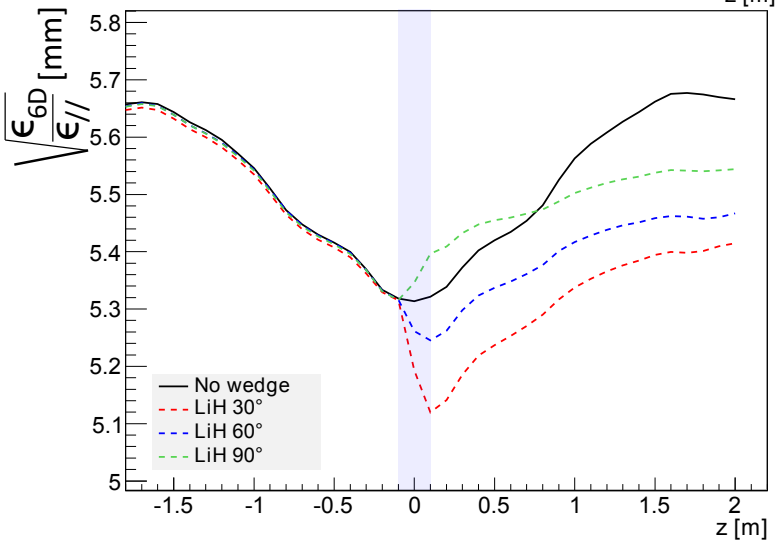
Wedge Schematic

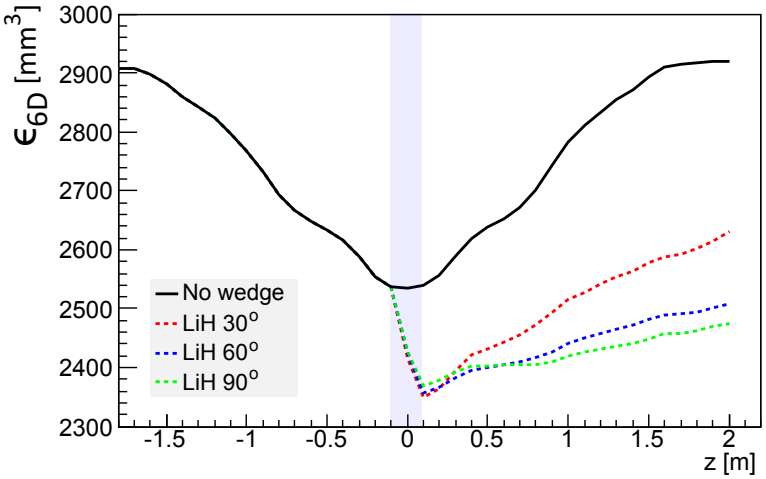


- Wedge absorber = cylinder intersected with a triangular prism.
- One of the typical sizes: opening angle = 90°, on-axis length = 75.4 mm (corresp. to 12 MeV energy loss at p=200 MeV/c), radius=225 mm, gap=187.3 mm.

Cooling Performance







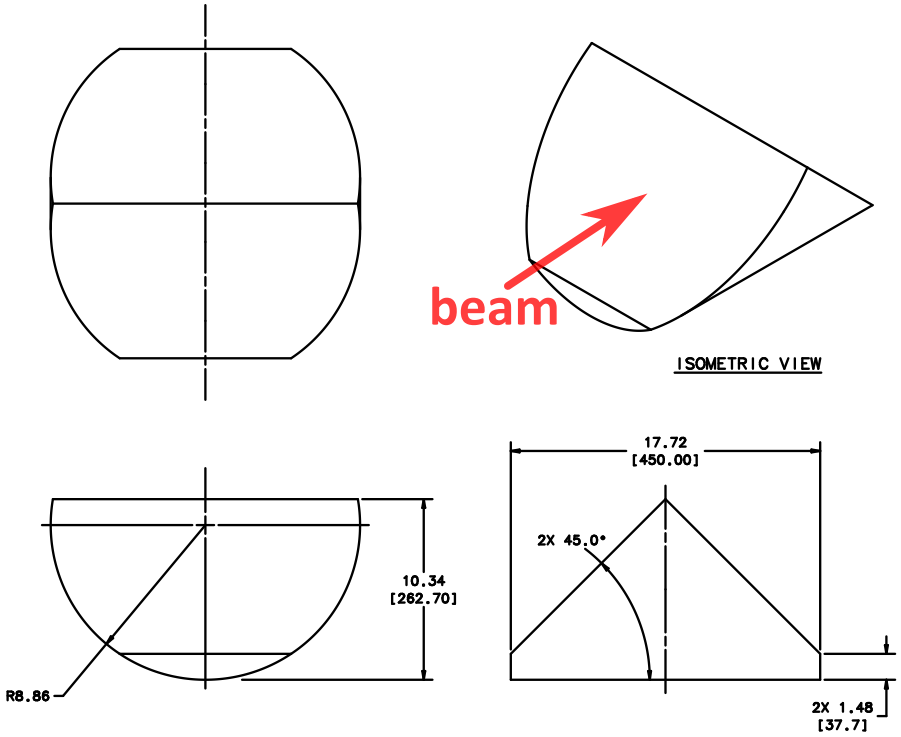
- Cooling effect observed for different angles (red – 30°, blue – 60°, green – 90°)

$$\varepsilon_{\parallel} = \frac{c}{m^3}\sqrt{\det(\mathbf{V}(\mathbf{ct},\mathbf{E}))},$$

$$\varepsilon_{6D} = \frac{c}{m}\sqrt{\det(\mathbf{V}(\mathbf{ct},\mathbf{E},\mathbf{x},\mathbf{p_x},\mathbf{y},\mathbf{p_y}))},$$

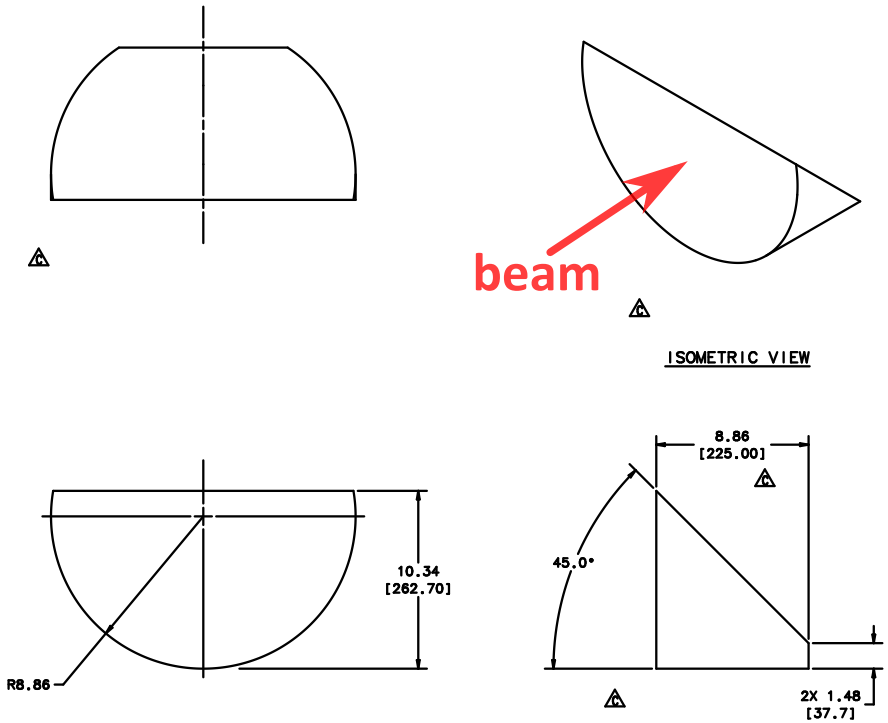
$\mathbf{V}$ – covar. matrix of the specified space.

Wedge Geometries



- Two wedge shapes were chosen to request a quote from Y12:
  - 90° LiH wedge: best longitudinal cooling / emittance exchange,
  - 30° LiH wedge: cools in both longitudinal and transverse directions, covers the whole aperture.

LiH Wedge as Ordered



- Good news: a 90° LiH wedge has been ordered (consisting of two parts for cost reduction).
- Beam behavior with a 45° half-wedge needs to be simulated.
- In addition to the LiH wedge it would be good to have a set (90°, 60°, and 30°) of plastic wedges to test properties of different materials (time permitting).

Summary

- Different wedge configurations were thoroughly studied and simulated using G4MICE and G4Beamline.
- 90° LiH wedge was ordered.
- Task: 45° half-wedge simulation.
- Task: wedge support design & engineering.
- Task: plastic wedge fabrication (alternate material studies).