Hybrid Methods for Simulation of Muon Ionization Cooling Channels

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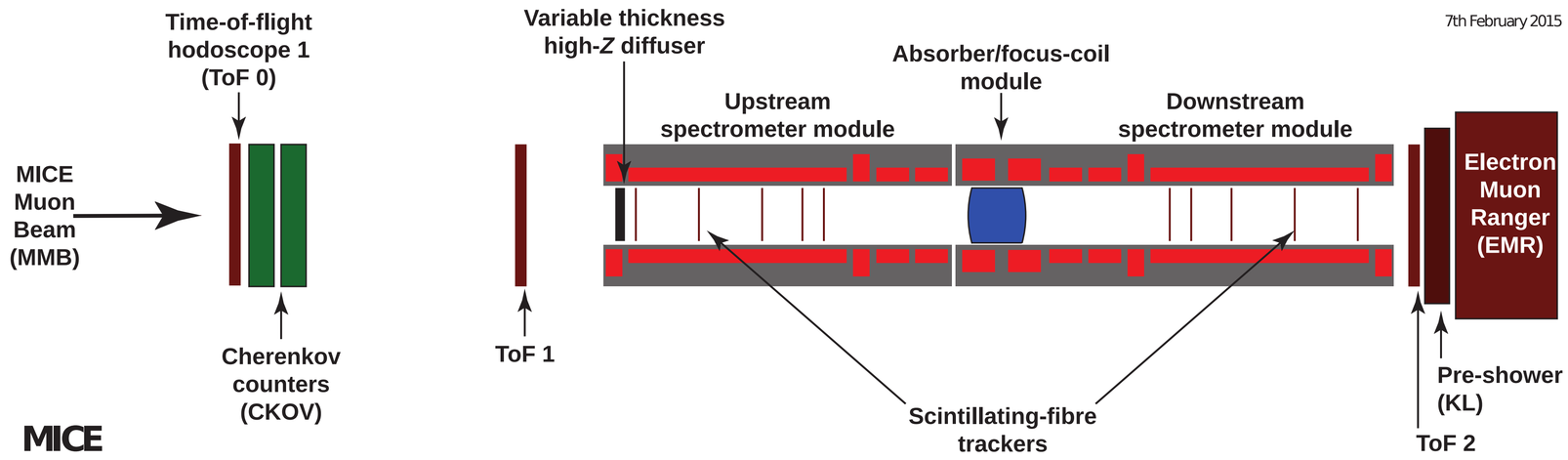
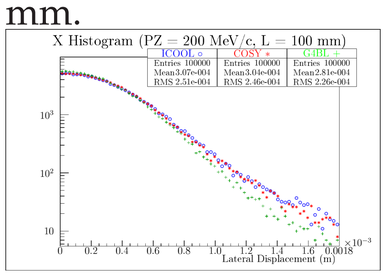
Muon Ionization Cooling Experiment (MICE) Layout

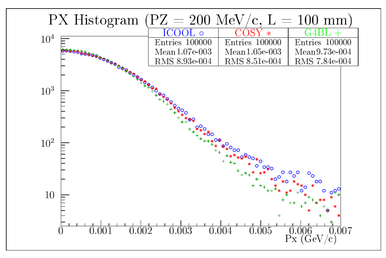


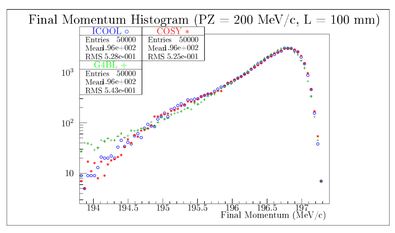
Absorbers

Recently [1], COSY Infinity [2] has been outfitted with new simulations tools for matter-dominated lattices, with the application of cooling absorbers as the motivation. Some of these results are reproduced here.

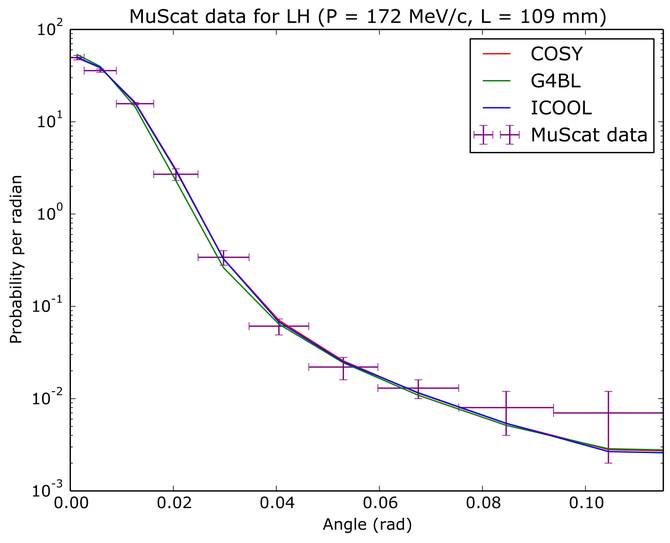
Excellent agreement has been achieved between COSY, G4Beamline [3], and ICOOL [4] for pencil beams of p = (100, 200, 300, 400) MeV/c through liquid hydrogen absorbers of lengths L = (1, 10, 100) mm. Shown below is an example of this agreement at typical cooling cell parameters: p = 200 MeV/c, L = 100 mm.





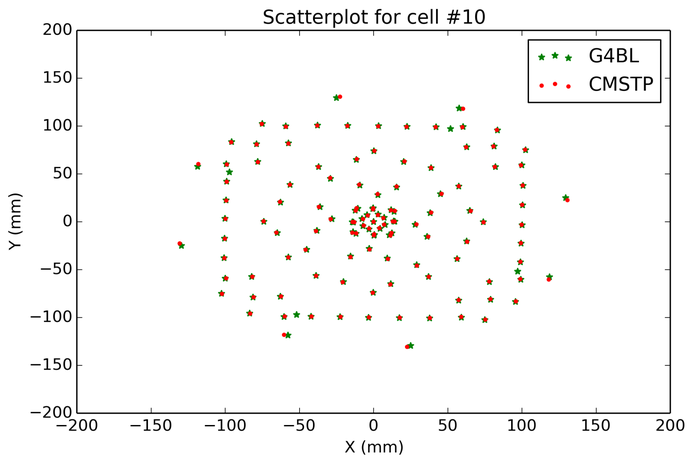


Moreover, COSY has been compared to the experimental results of the Muon Scattering Experiment [5]. Agreement has been shown for Be @ 3.73 mm, LH @ 159 mm, and LH @ 109 mm, with the last result reproduced below.



Magnetic coils

For compact magnetic solenoids, COSY uses the procedure `CMSTP` (Compact Magnetic Solenoid Thick Piece). Twelve "test coils" (see table of coil parameters) were benchmarked against G4Beamline's `coil` and `solenoid` combination routines. A single cell consisted of two postive current coils at z = 175, 325 mm and two negative current coils at z = 675, 825 mm. The initial distribution was a grid of muons with transverse ranges x = (-100, 100) mm, y = (-100, 100) mm. The result can be seen below.



Coil Parameters

Coil Name	z (mm)	Length (mm)	Inner R (mm)	Outer R (mm)	Current (A/mm^2)
Test	–	110	270	380	±165
End2	∓3200	111	258	326	±126
Center	∓3250	1314	258	280	±148
End1	∓1700	111	258	319	±133
Match2	∓1300	199	258	289	±132
Match1	∓861	201	258	304	±133

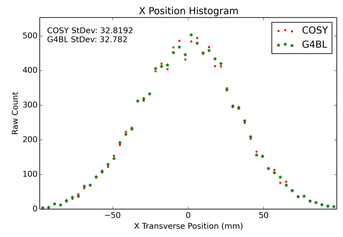
The MICE cell

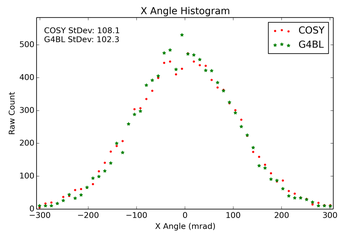
MICE was simulated in-parts by COSY and G4Beamline. The initial distribution can be seen in the table below, along with the results of these separate simualtions.

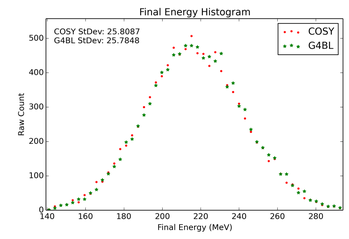
Initial Beam Parameters

Parameter	Value
Style	Gaussian on-axis
Total count	10^4
σ_x, σ_y	32 mm
$\sigma_{P_x}, \sigma_{P_y}$	19 MeV/c
σ_{P_z}	29 MeV/c
P_z	200 MeV/c

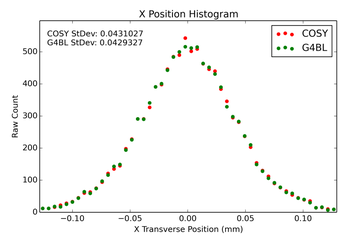
The absorber was a cylindrical lithium hydride block of 65 mm.

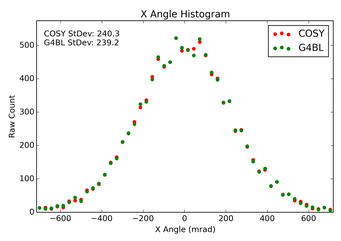


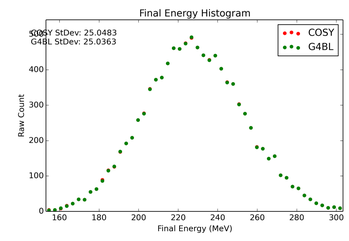




The coils (as seen in the MICE layout figure) were simulated to and from the scintillating-fibre trackers.







Current challenges

The details of how to superimpose the absorber and magnetic coils into COSY is still under consideration. Furthermore, a study of tilted coils is desired. In this study, a single cell would consist of four coils tilted about the transverse axis, a wedge absorber, and a radiofrequency cavity. However, a tilted coil routine does not exist in COSY, and so one is desired. Moreover, the differences in the COSY RF kick versus the G4Beamline pillbox model would be explored.

References

[1] J. Kunz *et al.* The advancement of cooling absorbers in cosy infinity. In *Proceedings of the* 6^{th} *International Particle Accelerator Conference*, 2015.

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[3] Tom Roberts. G4beamline. `http://www.muonsinternal.com/muons3/G4beamline`, 2014. Version 2.15w.

[4] R.C. Fernow *et. al.* Icool. `http://www.cap.bnl.gov/ICOOL/fernow/readme.html`, 2012. Version 3.30.

[5] D. Attwood *et al.* The scattering of muons in low z materials. *NIM*, 251, 2006.