Hybrid Methods for Simulation of Muon Ionization Cooling Channels

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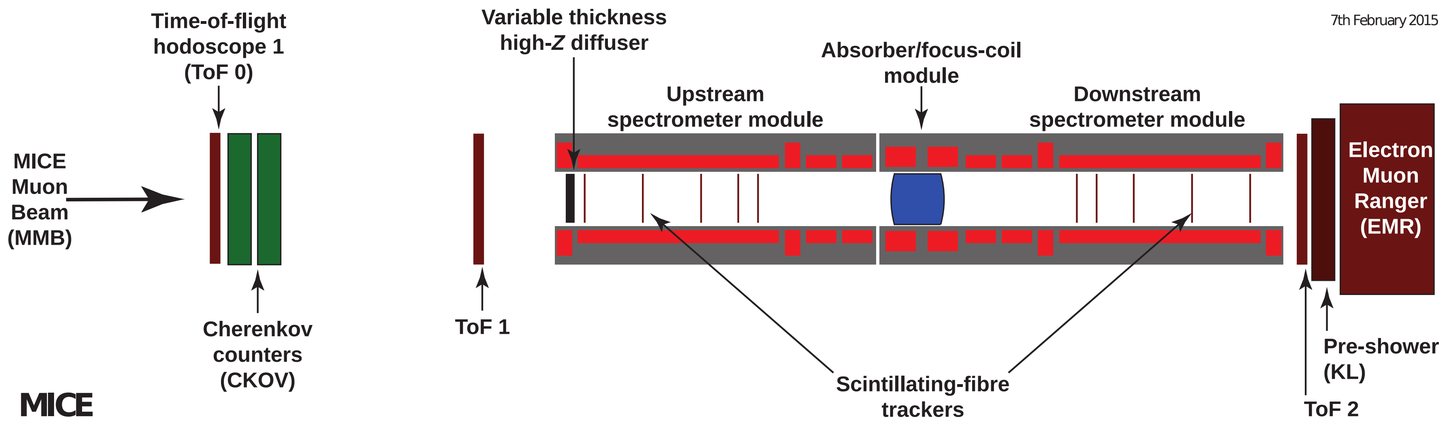
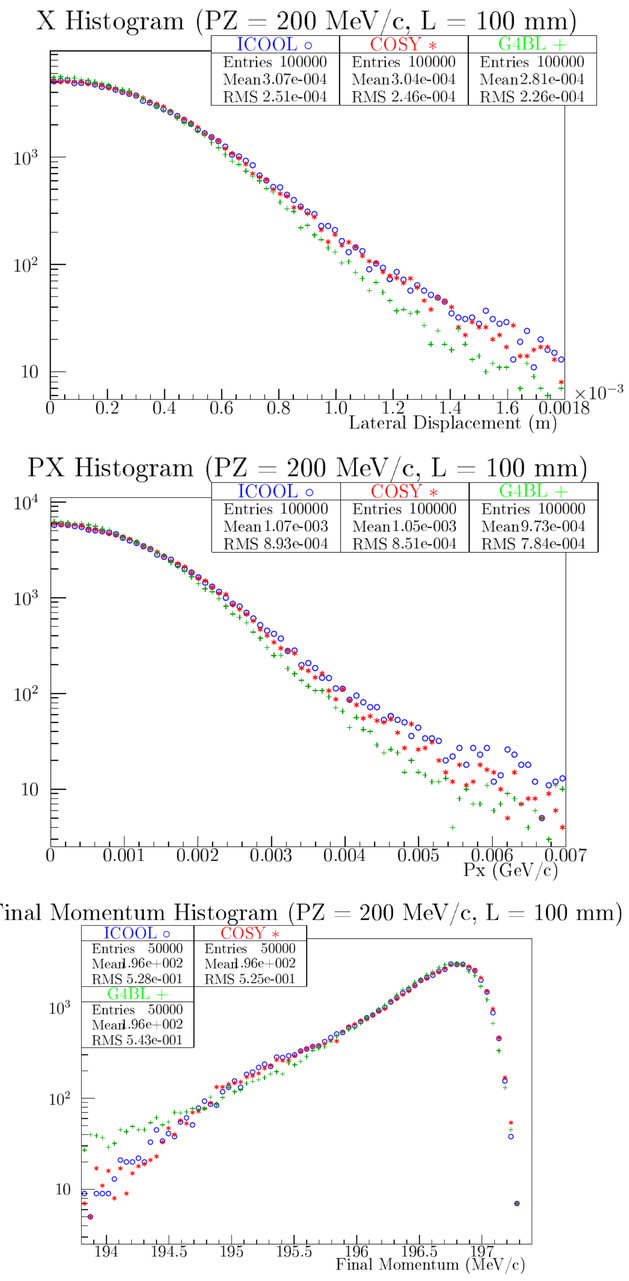
Muon Ionization Cooling Experiment (MICE) Layout



Absorbers

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

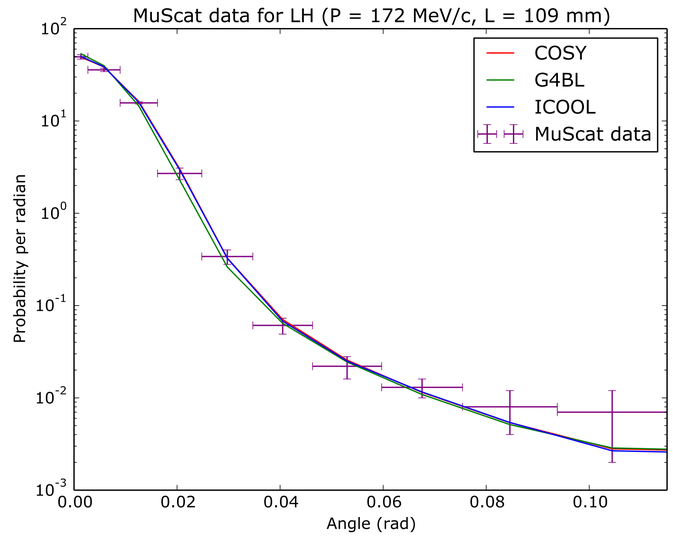
Excellent agreement has been achieved between COSY, G4Beamline [3], and ICOOL [4] for pencil beams of $p = (100, 200, 300, 400)$ MeV/c through liquid hydrogen absorbers of lengths $L = (1, 10, 100)$ mm. Shown below is an example of this agreement at typical cooling cell parameters: $p = 200$ MeV/c, $L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



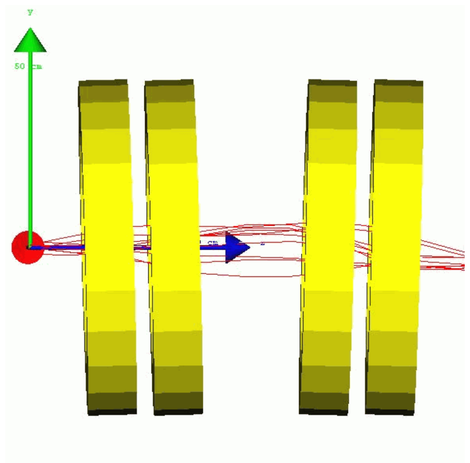
More comparisons using Gaussian beams are shown in the right column.

MuScat Simulation

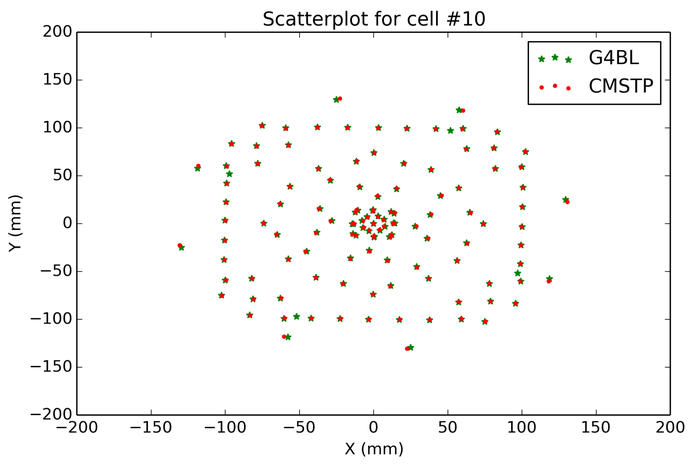
Moreover, COSY has been compared to the experimental results of the Muon Scattering Experiment [5]. Agreement has been shown for Be @ 3.73 mm, LH @ 159 mm, and LH @ 109 mm, with the last result reproduced below.



Magnetic coils



For compact magnetic solenoids, COSY uses the procedure `CMSTP` (Compact Magnetic Solenoid Thick Piece). Ten one-meter long rectilinear cooling channel cells consisting of two postive current coils at $z = 175, 325$ mm and two negative current coils at $z = 675, 825$ mm was benchmarked against G4Beamline's `coil/solenoid` combination routines. 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.

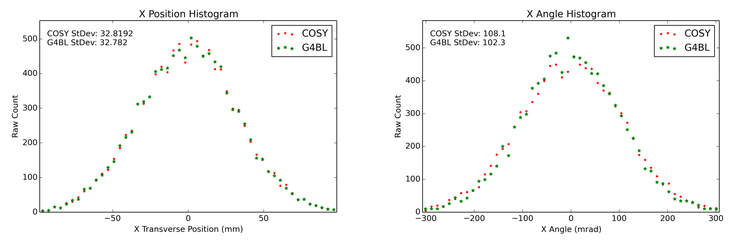


The MICE cell

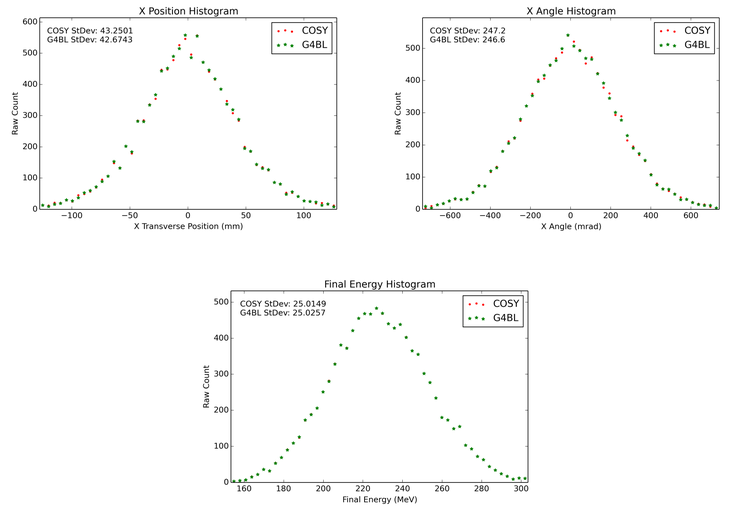
MICE was simulated in-parts by COSY and G4Beamline. The initial distribution can be seen in the table below, along with the results of these separate simualtions.

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.



Coil parameters are summarized in the table below.

Coil Parameters					
Coil Name	**z (mm)**	**Length (mm)**	**Inner R (mm)**	**Outer R (mm)**	**Current (A/mm^2)**
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
Focus	∓202	213	268	362	±104

Current challenges

- Superimposing the absorber and magnetic coils in COSY is underway.
- Some configurations use tilted coils for generating dispersion at the absorbers, those need to be implemented in COSY.
- Differences in the COSY RF kick versus the G4Beamline pillbox model need to be explored and addressed, potentially by implementing a new lattice element in COSY.

References

[1] M. Berz and K. Makino. *COSY Infinity Beam Physics Manual*, 2013. Version 9.1.

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

[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.