Front end energy deposition (ICOOL + G4beamline)

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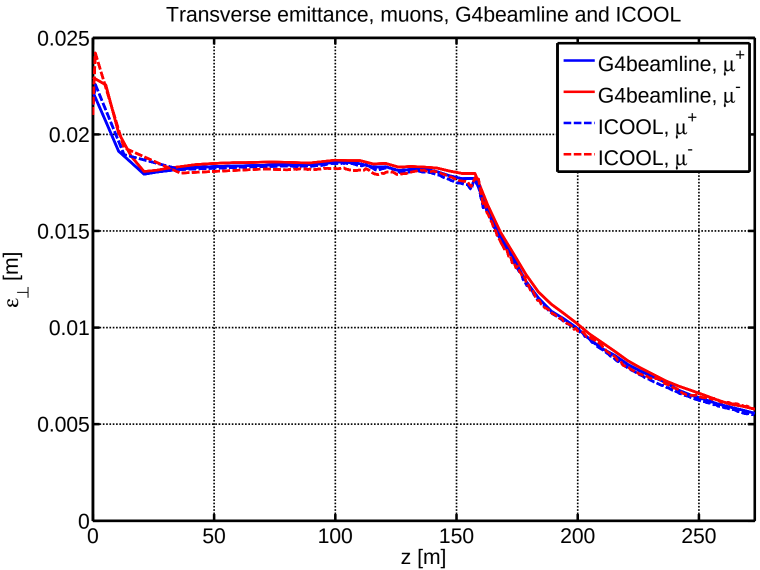
Initial beam

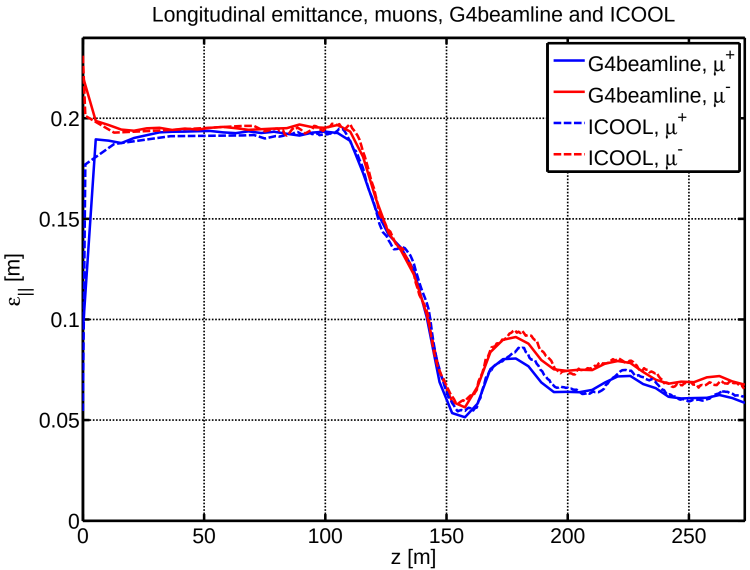
- Files from Harold Kirk, MARS15 simulation.
- Not the latest version, but fairly recent.
- 5e4 protons on target.
- A total of 354k positive particles (including protons), and 142k negative particles.

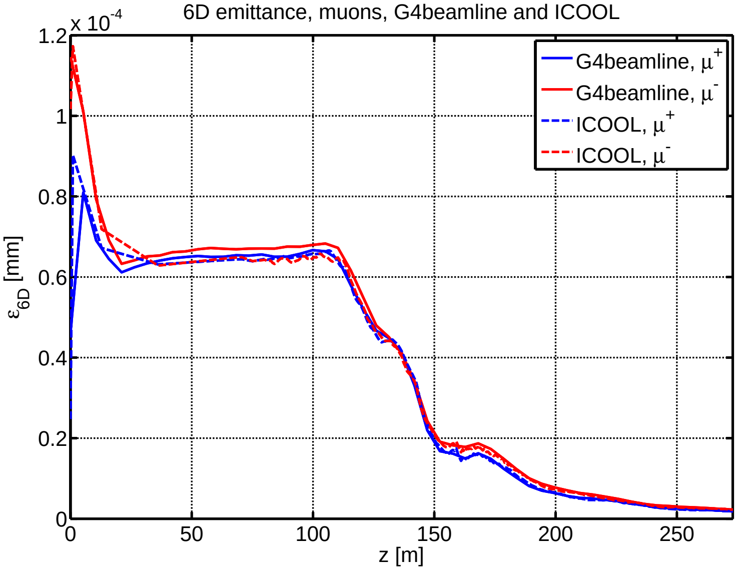
G4beamline lattice for the front end

- Derived from the baseline ICOOL lattice.
- RF timing partially derived from analytic expressions, partially tuned using the reference particle immune to E field and energy loss in material (only works in version 2.04+).
- Checked for consistency: magnetic field, geometry, emittances, particle yield, particle loss.
- Versions used for comparison: ICOOL 3.20 and G4beamline 2.06.

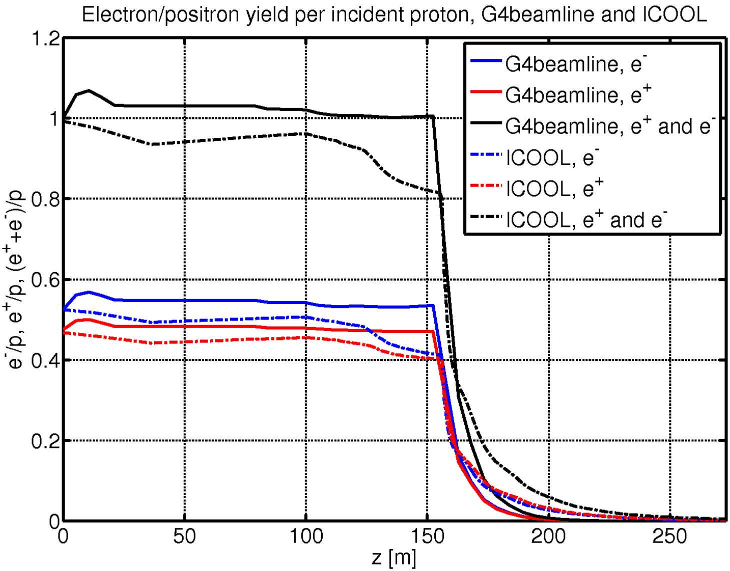
Emittances

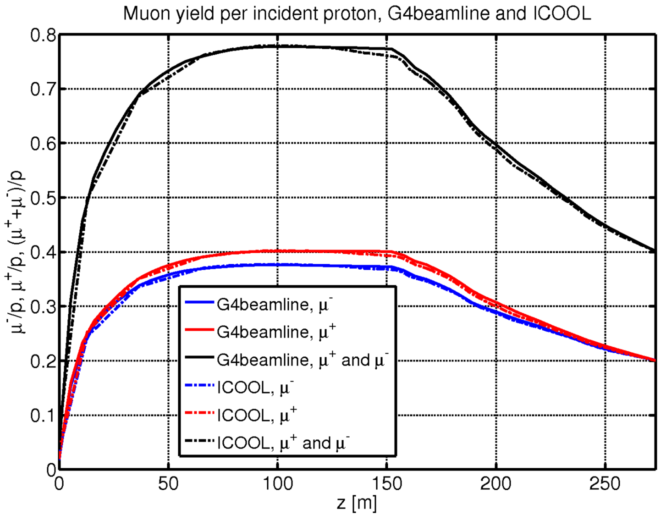

Transverse emittance, muons, G4beamline and ICOOL
G4beamline, μ+
G4beamline, μ-
ICOOL, μ+
ICOOL, μ-
0.025
0.02
0.015
0.01
0.005
0
ε⊥ [m]
0
50
100
150
200
250
z [m]


Longitudinal emittance, muons, G4beamline and ICOOL
G4beamline, μ+
G4beamline, μ-
ICOOL, μ+
ICOOL, μ-
ε|| [m]
z [m]
0
0.05
0.1
0.15
0.2
0
50
100
150
200
250

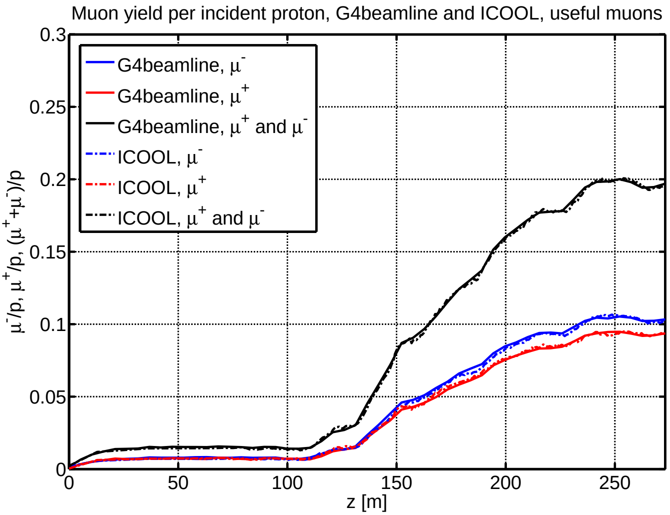

6D emittance, muons, G4beamline and ICOOL
x 10^-4
1.2
1
0.8
0.6
0.4
0.2
0
ε6D [mm]
0
50
100
150
200
250
z [m]
G4beamline, μ+
G4beamline, μ-
ICOOL, μ+
ICOOL, μ-

Particle yields

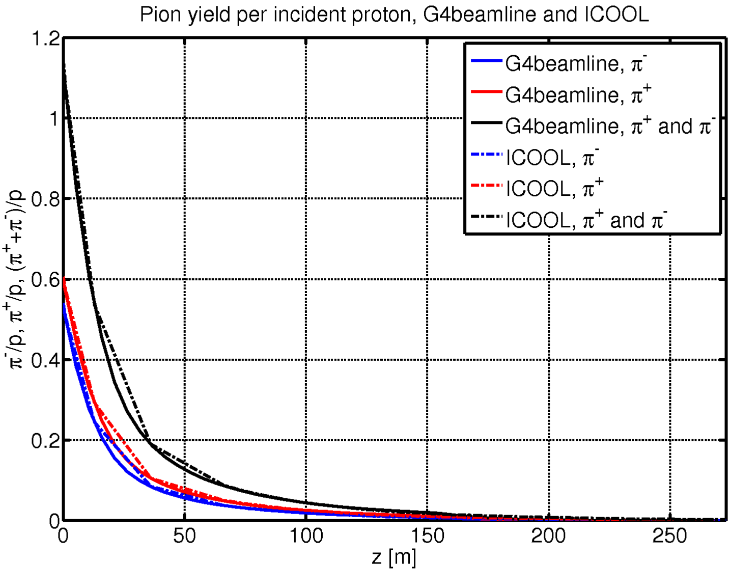

Electron/positron yield per incident proton, G4beamline and ICOOL
G4beamline, e-
G4beamline, e+
G4beamline, e+ and e-
ICOOL, e-
ICOOL, e+
ICOOL, e+ and e-
e-/p, e+/p, (e+ +e-)/p
z [m]
0
0.2
0.4
0.6
0.8
1
1.2
0
50
100
150
200
250


Muon yield per incident proton, G4beamline and ICOOL
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
50
100
150
200
250
z [m]
μ⁻/p, μ⁺/p, (μ⁺+μ⁻)/p
G4beamline, μ⁻
G4beamline, μ⁺
G4beamline, μ⁺ and μ⁻
ICOOL, μ⁻
ICOOL, μ⁺
ICOOL, μ⁺ and μ⁻

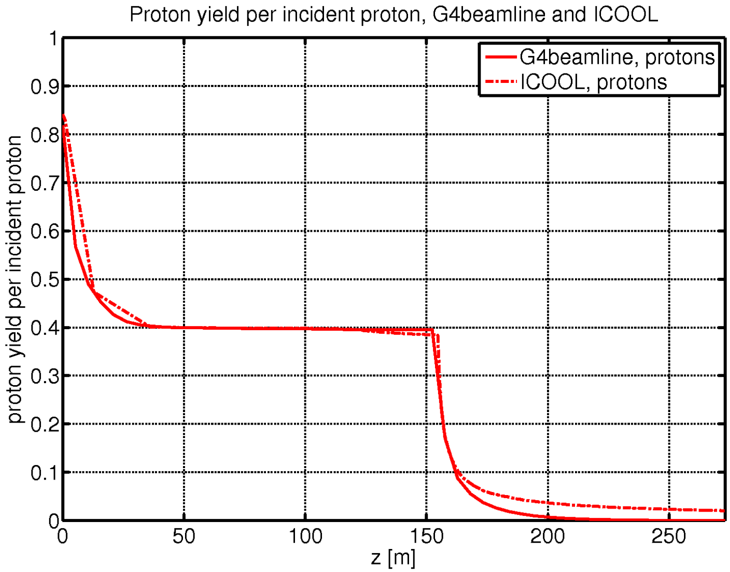
All muons



Useful muons ($p \in [100, 300]$ MeV/c, trans. cut 0.03, long. cut 0.15)

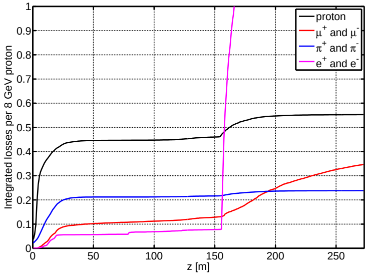


Pion yield per incident proton, G4beamline and ICOOL
G4beamline, π-
G4beamline, π+
G4beamline, π+ and π-
ICOOL, π-
ICOOL, π+
ICOOL, π+ and π-
π-/p, π+/p, (π+ +π-)/p
z [m]
0
0.2
0.4
0.6
0.8
1
1.2
0
50
100
150
200
250

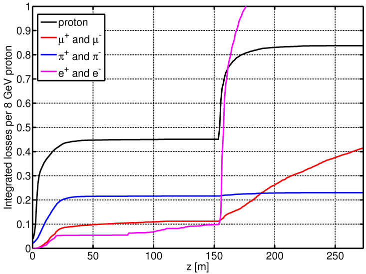

Proton yield per incident proton, G4beamline and ICOOL
G4beamline, protons
ICOOL, protons
proton yield per incident proton
z [m]
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
50
100
150
200
250

Particle loss

Different approaches

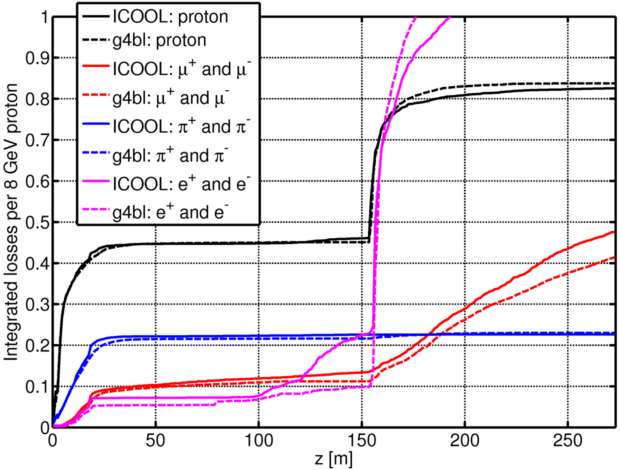


G4beamline (aperture only)

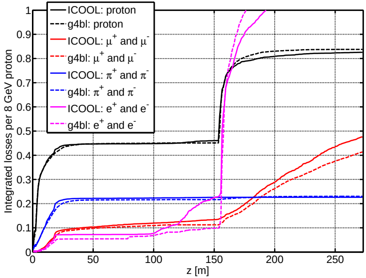


G4beamline (all losses)

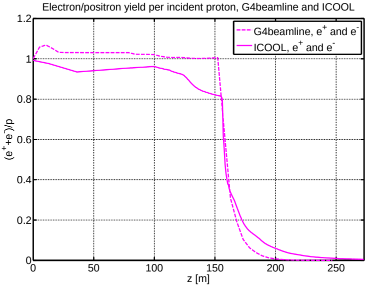
ICOOL vs G4beamline



Observations I – electrons



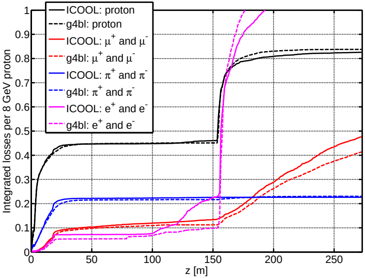
Particle loss



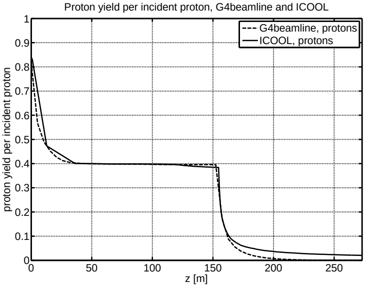
Particle yield

- Consistent

Observations II – protons



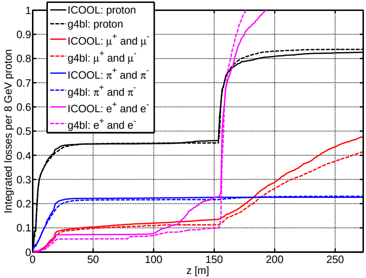
Particle loss



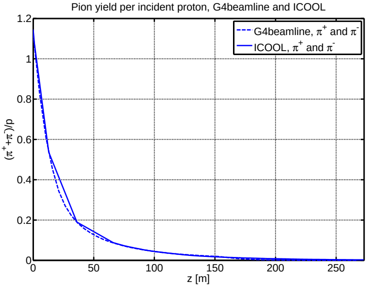
Particle yield

- Consistent

Observations III – pions



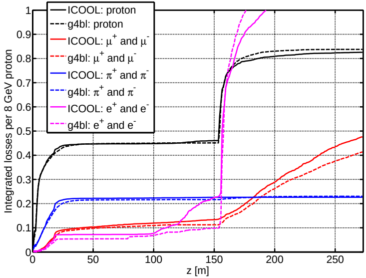
Particle loss



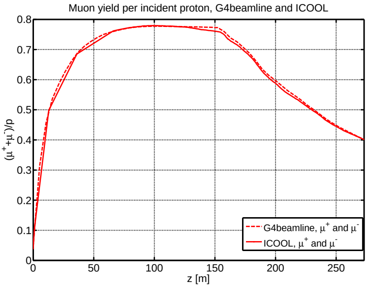
Particle yield

- Consistent

Observations IV – muons



Particle loss

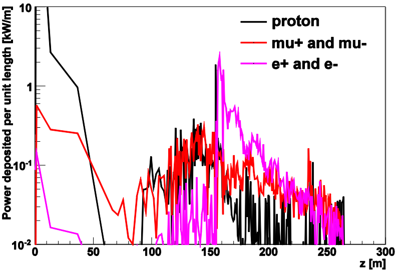


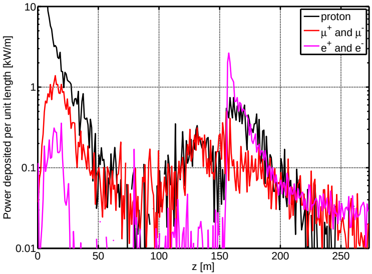
Particle yield

- Some inconsistency to address

Energy deposition

Energy deposition





Power deposited per unit length (ICOOL)

Power deposited per unit length (G4beamline)

- More than 1 kW/m in the capture region + the beginning of cooling.
- 1 W/m is the limit for manual handling, $\Rightarrow$ need a solution.

Mitigation strategies under study

- Low momentum protons may be removed using a proton absorber. This device takes advantage of the different stopping distance of protons and other particles in material. An initial study has demonstrated satisfactory performance for the removal of protons with momenta below 500 MeV/c.
- Particles with high momenta outside of the acceptance of the front end may be removed using a double chicane. Dispersion is induced in the beam by means of bending magnets and high momentum particles are passed onto a beam dump. A double chicane is used to bring the beam back onto the original trajectory, enabling a symmetric arrangement that captures muons of both signs.
- Particles with transverse amplitude outside of the acceptance of the front end may be removed using transverse collimators.

Actions

- Chris Rogers to design the chicane.
- Pavel Snopok to assume the chicane is 20 m long and removes high energy particles, and design a transverse collimation scheme for the rest of the drift.

Thank you!