Initial beam

- Files from Harold Kirk, MARS15 simulation.
- Not the latest version, but fairly recent.
- $5 \times 10^4$ 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
Front end energy deposition (ICOOL + G4beamline)

Transverse emittance, muons, G4beamline and ICOOL

- G4beamline, $\mu^+$
- G4beamline, $\mu^-$
- ICOOL, $\mu^+$
- ICOOL, $\mu^-$
Longitudinal emittance, muons, G4beamline and ICOOL

- $G4_{\text{beamline}}, \mu^+$
- $G4_{\text{beamline}}, \mu^-$
- $ICOOL, \mu^+$
- $ICOOL, \mu^-$
Front end energy deposition (ICOOL + G4beamline)

6D emittance, muons, G4beamline and ICOOL

- G4beamline, $\mu^+$
- G4beamline, $\mu^-$
- ICOOL, $\mu^+$
- ICOOL, $\mu^-$
Particle yields
Front end energy deposition (ICOOL + G4beamline)
Front end energy deposition (ICOOL + G4beamline)

Muon yield per incident proton, G4beamline and ICOOL

All muons
Useful muons ($p \in [100, 300] \text{ MeV/c}$, trans. cut 0.03, long. cut 0.15)
Front end energy deposition (ICOOL + G4beamline)

Pion yield per incident proton, G4beamline and ICOOL

\[ \frac{\dot{\pi}}{\rho}, \frac{\dot{\pi}^+}{\rho}, \frac{\dot{\pi}^-}{\rho}, \frac{\dot{\pi}^+ + \dot{\pi}^-}{\rho} \]

- G4beamline, \( \pi^- \)
- G4beamline, \( \pi^+ \)
- G4beamline, \( \pi^+ \) and \( \pi^- \)
- ICOOL, \( \pi^- \)
- ICOOL, \( \pi^+ \)
- ICOOL, \( \pi^+ \) and \( \pi^- \)

\( z \) [m]
Proton yield per incident proton, G4beamline and ICOOL
Particle loss
Front end energy deposition (ICOOL + G4beamline)

Different approaches

G4beamline (aperture only)  G4beamline (all losses)
ICOOL vs G4beamline

Integrated losses per 8 GeV proton vs z [m]

- ICOOL: proton
- ICOOL: $\mu^+$ and $\mu^-$
- G4bl: proton
- G4bl: $\mu^+$ and $\mu^-$
- ICOOL: $\pi^+$ and $\pi^-$
- G4bl: $\pi^+$ and $\pi^-$
- ICOOL: $e^+$ and $e^-$
- G4bl: $e^+$ and $e^-$
Observations I – electrons

- **Particle loss**
  - Consistent

- **Particle yield**
Observations II – protons

Particle loss

- Consistent

Particle yield
Observations III – pions

Particle loss

- Consistent
Observations IV – muons

Particle loss

- Some inconsistency to address

Particle yield
Energy deposition
Energy deposition

Power deposited per unit length
(ICOOL)

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

Power deposited per unit length
(G4beamline)
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!