Frictional Cooling Studies

Studies at Columbia University/Nevis Labs
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Frictional Cooling

- Bring muons to a kinetic energy \(T\) range where \(dE/dx\) increases with \(T\)
- Constant E-field applied to muons resulting in equilibrium energy

![Graph showing stopping power vs. kinetic energy for helium](helium.png)
Problems/Comments:

- large dE/dx @ low kinetic energy → low average density
- Apply $\vec{E} \perp \vec{B}$ to get below the dE/dx peak
- $\mu^+$ has the problem of Muonium formation → $\sigma(M\mu)$ dominates over e-stripping $\sigma$ in all gases except He
- $\mu^-$ has the problem of Atomic capture → $\sigma$ calculated up to 80 eV not measured below $\sim$1KeV
- Cool $\mu$’s extracted from gas cell $T=1$ KeV so a scheme for reacceleration must be developed

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Basic Design

Proton Beam → Target

Drift Region → B → 30-50 m → Phase Rotation Region
(Induction Linac)

Cooling Channel

Solenoid → Solenoid → Solenoid
Cooling cell

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Muon Motion in Cooling Cell

- $B=5$ T, $E=5$ MV/m, $\rho_{He}=1 \times 10^{-4} \text{ g/cm}^3$

- $P_x=10 \text{ MeV/c}$, $P_y=0$, $P_z=10 \text{ MeV/c}$

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Target Optimization

- Want low energy muons hence need to optimize pion production accordingly for:
  - Proton Driver Energy
  - Target Material
  - Target Dimensions
  - Target Orientation
Magnet Capture

Peripheral

\[ p \rightarrow \pi^+, \mu^+, \pi^+, \mu^+, \pi^+, \mu^+, \pi^+, \mu^+, \pi^+, \mu^+ \]

\[ p \rightarrow \pi^-, \mu^-, \pi^-, \mu^-, \pi^-, \mu^-, \pi^-, \mu^-, \pi^-, \mu^- \]

- +ve & -ve in same channel

Central

- Separate charges at source

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Phase Rotation

- Apply simple E-field form:
- Optimize muon yield as a function of \( t_1, t_2 \) & Length of the phase rotation region
Length=2000cm, $t_1=175\text{ns}$, $t_2=375\text{ns}$

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--- before phase rotation
--- after phase rotation

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Multiple Scattering

• To date simulations only considered continuous \( \text{dE/dx} \)

• Technically difficult because of large angle scatters at low energies, and large cross sections. However, simulation almost ready.
Muon Capture Experiment

- Experiment at PSI studies Lamb Shift in Muonic Atoms – adopt general scheme.
- Muon Spectrum 10-40KeV
- 5T Magnet with D=20cm bore
Nevis Setup

SIDE VIEW:

-10 keV

alpha source ~5 MeV
Xray source ~2 keV

~9 cm

Plastic Rail

TOP VIEW:

alpha source ~5 MeV
Xray source ~2 keV

0 V

M.C.P
Hydrogen

density = 1.5e-6 g/cm³

E = 200 KV/m

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Goals of Experiment

• Measure X-ray released from capture in Gas Atom
• Check understanding of energy loss, multiple scattering
• Measure $\mu$- capture cross section at low energies in He & H2
Nevis lab:

- Multipurpose Vacuum Chamber
- Fast Logic Readout
- MCP Detector
- X-ray MWPC development underway
MWPC X-ray Detector

- 4 channel prototype
- Possible extension to tracker – track decay $e^-$ from captured $\mu^-$

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Summary

- Muon Colliders promise a bright future for HEP
  - Physics Factory, Higgs, ν’s, s-channel resonances
- Major hurdle is cooling but efforts are going forward with a plan to demonstrate emittance exchange
- Exciting alternative concept for muon cooling
  - Frictional Cooling
  - Possibility to cool both signs at once
  - Experiment to measure μ- capture cross section planned…..STAY TUNED

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