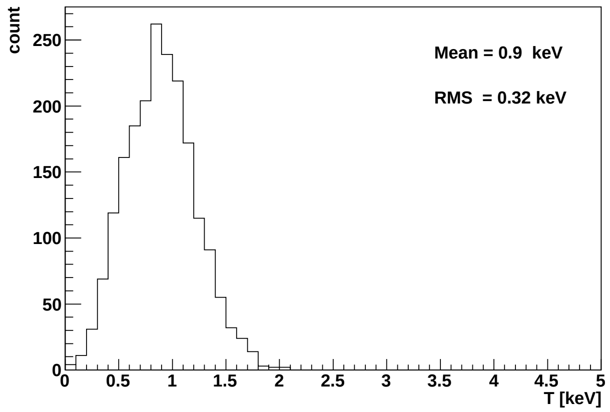


Figure 13: The energy distribution of the output $\mu^+$.

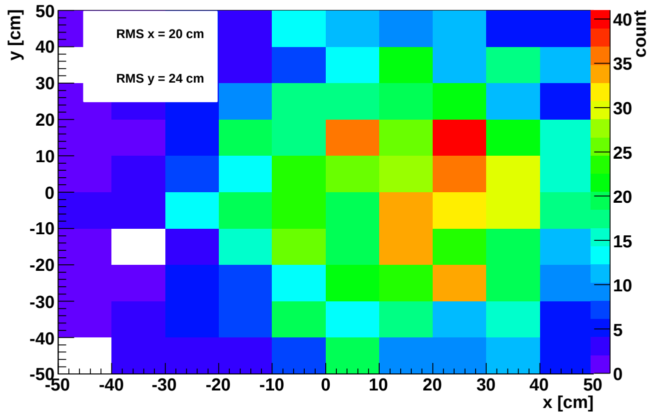


Figure 15: The transverse distribution of cooled muons exiting the dipole.

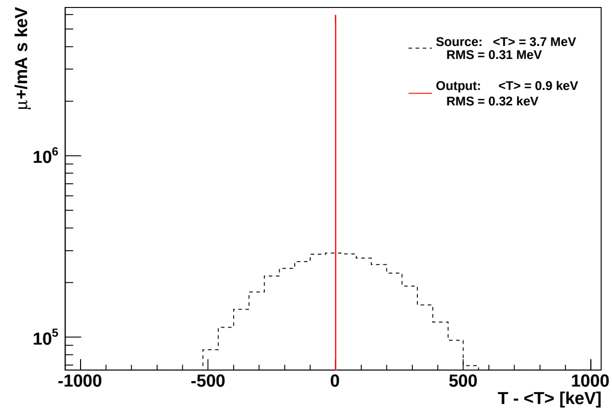


Figure 14: The energy distribution of the output beam compared to the input beam. The distributions are centered on their means.

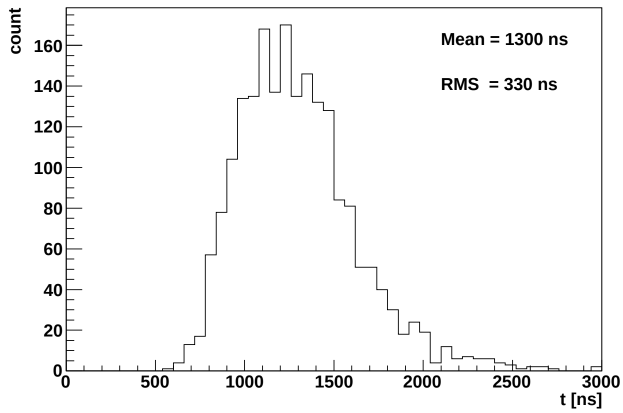


Figure 16: The distribution of time of flight of the cooled muons from source to the output.

muons' trajectories. Bucking coils could be used to reduce the fringe fields out of the cooling cell. The dipole can be put further away from the cooling cell to avoid the fringe field of the solenoid; or, the fringe field itself can replace the dipole and guide the cooled muons out. Realistic scenarios need to be simulated.

An additional radial electric field could focus the beam to the axis of the cell, where the radial component of the fringe magnetic field is much lower than at the edge of the solenoid. How to create such a field should be investigated.

### 5.2. *Electric fields in gas*

The frictional cooling scheme requires a strong electric field in gas. Frictional cooling experiments at the Max-Planck-Institute for Physics have used electric fields up to 500 kV/m over 10 cm in a gas cell filled with helium at pressures from $10^{-3}$ mbar to 1.25 bar without breakdown. Further investigations are needed to determine the feasibility of even higher fields in helium gas.

Muons lose a small fraction of their kinetic energy to ionization in the gas. We estimated an ionization rate of less than $10^{10}$ /s for a source flux of $4.2 \times 10^8$ /s. The removal or neutralization of the resultant charge in the cooling cell will have to be investigated.

### 5.3. *Window*

The window on the cooling cell must be thin and gas tight. 20 nm thin carbon films can be deposited on nickel grids with 55% open area [1]. These windows can hold high gas pressures over small areas. However, they cut the efficiency of the scheme in half. In our case, this would mean 1% overall efficiency. The feasibility of large-area thin gas-tight windows needs to be investigated. Focusing the beam in the cooling cell would be helpful by reducing the area required for the thin window. The material of the window should also be optimized to reduce beam neutralization. A layer of noble gas frozen onto the window can decrease neutralization of the cooled muons. Other technologies such as differential pumping systems could be considered to replace the window.

[1] Structure Probe Inc.: http://www.2spi.com