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Gas Filled Study 2A Cooling Section

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Abstract

In *Study 2A* the cooling cell is significantly simpler with an almost constant beta function; this suggests that the LiH absorbers at the windows may be replaced by an uniformly distributed high pressure hydrogen gas (GH). We present results of simulations carried out using ICOOL.

I. INTRODUCTION

In the present U.S. Neutrino Factory design [1], the so-called *Study 2A*, we have relaxed the requirements on the cooling channel by doubling the assumed acceptance of the acceleration section, i.e.,

$$\begin{aligned} A_T &= 30\,\pi mm - rad \\ A_L &= 150\,mm \end{aligned} \tag{1}$$

The cooling cell is significantly simpler and therefore, less expensive, as compared with the one discussed in *Study 2* [3], [2]. In particular, the beta function is almost constant, about $\approx 80\,cm$ all along the cooling channel. Figure 1 shows an schematic of a cooling cell. This

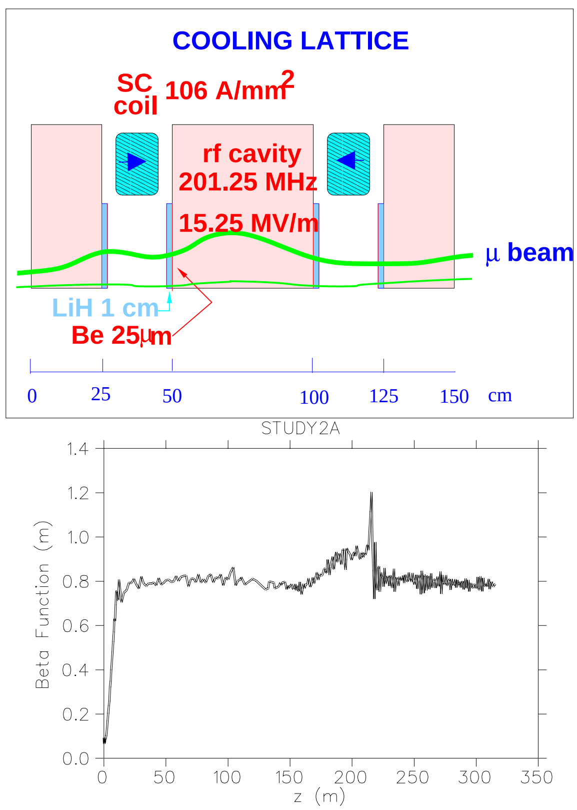

FIG. 1: (color) Top: Schematic of one cell of the cooling section. Bottom: Beta function along the front-end.

suggests that the LiH absorbers at the windows may be replaced by an uniformly distributed high pressure hydrogen gas (GH) [4]. We have performed ICOOL simulations to ascertain the performance of such a channel

II. CALCULATIONS

The cooling channel consists of 66 cells with 4 LiH windows of $1\,cm$ thickness each. The minimum of the energy loss for both GH and LiH are:

$$\begin{aligned} \frac{dE}{dx}|_{GH} &= 4.103\,\frac{MeV}{g}cm^2 \\ \frac{dE}{dx}|_{LiH} &= 2.038\,\frac{MeV}{g}cm^2 \end{aligned} \tag{2}$$

The total energy lost of the muon beam in the LiH window is

$$\Delta E|_{LiH} = 2.038 \times \rho_{LiH} \times 66 \times 4 \approx 420\,MeV \tag{3}$$

At 25°C and 1 atm, GH gives

$$\Delta E|_{GH} = 4.103 \times \rho_{GH} \times 66 \times 150 \approx 3.4\,MeV \tag{4}$$

where $\rho_{LiH} = 0.78\,\frac{g}{cm^3}$ and $\rho_{GH} = 8.38 \times 10^{-5}\,\frac{g}{cm^3}$. This implies we have to increase the density (pressure) of the GH by a factor of 124.

We have substituted the absorber LiH by GH and filled all the cooling section with GH, but we have not included GH containment windows at the beginning nor at the end of it. We have kept the Be window at each rf cavity. The results are shown in Figs. 2. Notice that we obtain the Study2A performance at a pressure of 175 atms, somewhat higher than the naive energy loss calculation (124 atms). The top graph indicates that a pressure of 200 atms is enough to have a better performance.

We assume that the reasonable pressure for the HG is about 200 atms at T=300 K; this pressures requires an upstream SS hemispherical window of radius $R = 25$ cm and thickness $h = 2.2$ cm and half the radius and thickness in the downstream one. The performance is shown in Figs. 3.

A lower temperature of the GH will clearly reduce the pressure and consequently the thickness of the containment windows; results are shown in Figs. 4

III. CONCLUSIONS

These preliminary simulations seems to indicate that we do achieve the performance required in Study2A, i.e., No.μs/p= 0.176. with a high pressure, $\approx$ 50 atms at T=77 K,

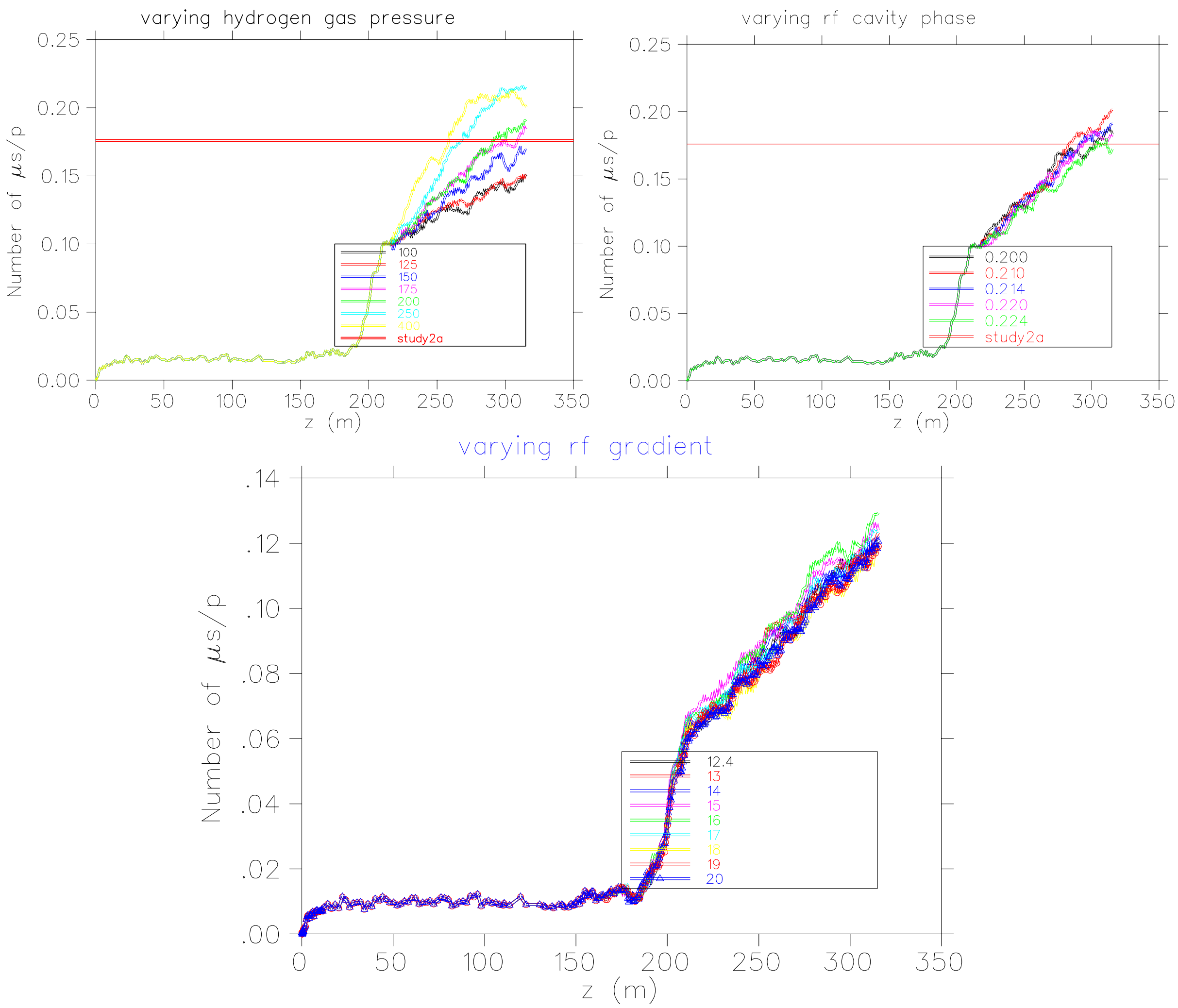

FIG. 2: Number of μs per proton on target into the accelerator transverse normalized acceptance $A_T = 30\,\mathrm{mm}$ rad and normalized longitudinal acceptance of $A_L = 150\,\mathrm{mm}$ for a momentum cut $0.1 \leq p \leq 0.3$ MeV/c along the front end. The horizontal red line represents the final performance achieved in Study2a.

Hydrogen gas filled cooling channel; the upstream containment window, assumed to be SS with a thickness of 0.55 cm, is the cause of the lesser performance. At pressures above 250 atms (at T=300 K) we begin to observe saturation in the performance.

It will also be interesting to explore other window materials, Be, Ti, etc.

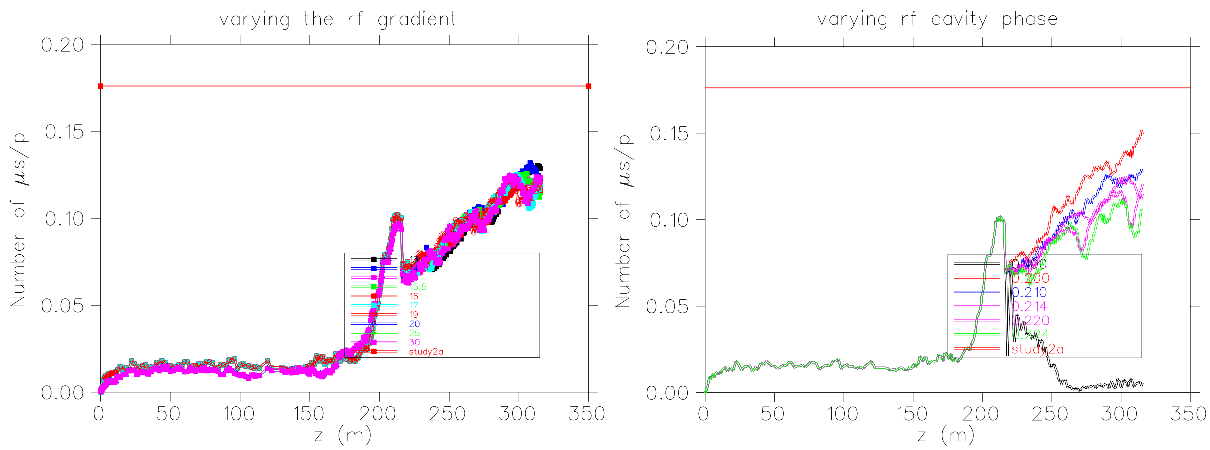

FIG. 3: Number of μs per proton on target into the accelerator transverse normalized acceptance $A_T = 30\,\text{mm}$ rad and normalized longitudinal acceptance of $A_L = 150\,\text{mm}$ for a momentum cut $0.1 \leq p \leq 0.3$ MeV/c along the front end. The horizontal red line represents the final performance achieved in Study2a.

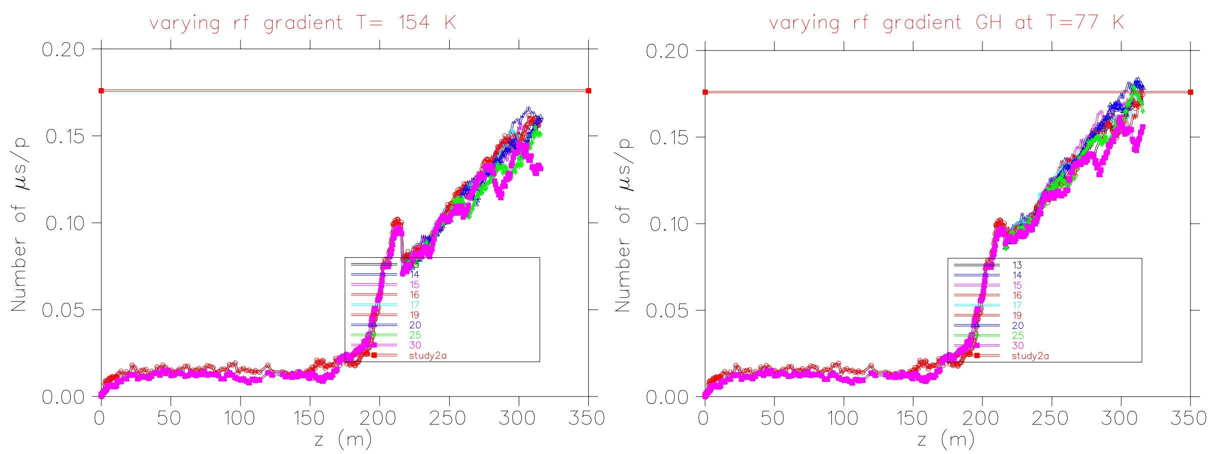

FIG. 4: The same as in Fig. 3 with GH at (left) T=150 K and (right) T=77 K

Acknowledgments

We wish to thanks R. Johnson for suggesting to investigate the performance for GH at lower temperatures.

[1] The Neutrino Factory and Muon Collider Collaboration, et al., *Neutrino Factory and Beta Beam Experiments and Development*, BNL-72369-2004, FNAL-TM-2259, LBNL-55478, see also, http://www.aps.org/neutrino/.

[2] S. Ozaki, R. Palmer, M. Zisman, J. Gallardo, Editors, *Feasibility Study II of a Muon Based Neutrino Source*, BNL-52623, June, 2001.

[3] The MC Collaboration, *Recent Progress in Neutrino Factory and Muon Collider Research within the Muon Collaboration*, to be published. (http://www.cap.bnl.gov/mumu/pubs/prstab-030422/prstab.pdf)

[4] R. Johnson *et al.* in *Proceedings of Particle Accelerator Conference* (2003), p. 1792; Muon Inc., MUC-NOTE-247; R. Johnson *et al.*, AIP Conf. Proc. **671**, 328 (2003).