Fermi National Accelerator Laboratory

**FERMILAB-FN-647**

# Deuterons or Tritons for Muon Collider Driver

A. Van Ginneken

*Fermi National Accelerator Laboratory*
*P.O. Box 500, Batavia, Illinois 60510*

August 1996

Operated by Universities Research Association Inc. under Contract No. DE-AC02-76CHO3000 with the United States Department of Energy

## Disclaimer

# Deuterons or Tritons for Muon Collider Driver

A. Van Ginneken
Fermi National Accelerator Laboratory*
P. O. Box 500, Batavia, IL 60510

July 1996

The present scenario [1] for the $\mu\mu$-Collider calls for protons to be accelerated in a 'driver' to somewhere in the 8–30 GeV range. Upon interaction in a target these protons produce—among other particles—pions and kaons which subsequently decay into the desired muons. This note briefly examines possible gains which may be realized by using either deuterons or tritons as projectiles in the driver. Particles with multiple charge are not considered here. Although they should not be summarily dismissed, at least two types of difficulties are exacerbated by higher $Z$ projectiles: space charge in the machine and energy deposited directly by the beam particles in the target ($dE/dx \propto Z^2$). The latter is often associated with the maximum energy deposition density in the target and thus critical when considering target integrity. It should be noted that tritium is not as readily available as either hydrogen or deuterium and is a low energy $\beta^-$ emitter ($E_{max}$=0.0187 MeV) with a 12.3 year half-life. But none of this appears to be a serious obstacle to its use in the driver.

To roughly quantify the benefits of the heavier projectiles their pion yields are calculated assuming that pion production—at constant momentum per nucleon—is proportional to nucleon number. This should really be modified to include effects such as stripping and shadowing as well as for differences in pion production between neutrons and protons. In a *thick target* these are likely to have only minor consequences and it is not clear *a priori* whether yields are positively or negatively affected by them. One plausible benefit: since protons tend to produce more $\pi^+$ than $\pi^-$, using deuterons and tritons may improve their balance. Kaons are ignored since they con-

*Work supported by the U.S. Department of Energy under contract No. DE-AC02-76CHO3000.

Table 1: Comparison of Pion Yields from Protons and Tritons

| | 0.05 −0.25 | 0.25 −0.75 | 0.75 −2.50 | Total pions |
|---|---|---|---|---|
| 10 GeV/c | 0.374 | 0.482 | 0.429 | 1.374 |
| 30 GeV/c | 0.591 | 0.770 | 1.018 | 3.064 |
| gain | 1.90 | 1.88 | 1.26 | 1.48 |

tribute at most a few percent of the muons eventually accepted [2, 3]. To compare protons with the heavier projectiles two MARS [4] files—available from earlier studies—are consulted: one for 8 GeV/c and one for 30 GeV/c protons on a 1.5 interaction length copper target. Pions recorded in these files are split into three contiguous groups: 0.05–0.25 GeV kinetic energy, 0.25–0.75 GeV, and 0.75–2.5 GeV. The first two cuts correspond roughly to energy ranges deemed suitable for RF rotation [5]. Combining all three cuts represents perhaps the most optimistic outlook on pion capture. To make a useful comparison of pion yields due to the various projectiles it is assumed that cost, cycle time, etc., of an accelerator scale with total momentum imparted to the particles. Thus if $p_0$ is the nominal proton momentum for the accelerator one compares its pion yield with that at $p_0/2$ per nucleon for deuterons or $p_0/3$ for tritons. Using the simple proportionality rule mentioned above this means comparing the pion yield for protons at $p_0$ with twice the yield for protons at $p_0/2$ or with three times that at $p_0/3$. Table 1 shows such a comparison between protons and tritons. Given the files at hand, $p_0$=30 GeV/c is suggested and the required 10 GeV/c yields are obtained by adjusting yields at 8 GeV/c uniformly upward by 10% [3]. The first row contains the cuts in pion kinetic energy in GeV. In the next two rows are the total number of pions per proton within each cut for 10 and 30 GeV/c protons, respectively. The last row represents the projected gain in pion yield from using 10 (GeV/c)/nucleon tritons *versus* 30 GeV/c protons, i.e., three times the second row divided by the third row in the simple model used here.

In the same spirit one could compare 15 (GeV/c)/nucleon deuterons with 30 GeV/c protons. Presumably gains will be somewhere between unity and those shown for tritons. More detailed optimizations, including variation of $p_0$, target material and dimensions, etc., would be desirable. Comparisons of energy deposition profiles with those for protons in both the target and its surroundings also would be useful. Since total energy incident on the target is about the same, large differences are not expected. The Fermi motion of the nucleons in a deuteron or triton may cause the phase space of the produced pions to be somewhat larger although some or all of this will be offset by the smaller average $p_T$ of pions produced at 10 *vs* 30 GeV/c. All of this best awaits simulation with a refined nuclear collision model. Such a model should include some detail about stripping, etc., formulated specifically for deuterons and tritons with their relatively loose nuclear binding. Experimental checks of key model ingredients and predictions should be performed. Because of the stripping—which leaves the 'spectator' nucleon(s) free to interact downstream—thick target experiments would provide the most convincing validation. For now the preliminary conclusion is that a gain of up to a factor of two in yield—four in luminosity—appears feasible with tritons. This makes further investigation worthwhile.

Thanks to C. Ankenbrandt, N. Mokhov, D. Neuffer and R. Noble for discussion. N. Mokhov also provided the MARS files.

## References

[1] R. Palmer et al., *Muon Collider Design*, BNL-62949 (1996).

[2] N. V. Mokhov, R. J. Noble, and A. Van Ginneken, *Target and Collection Optimization for Muon Colliders*, Proc. 9th Adv. ICFA Beam Dynamics Workshop, Ed. J. C. Gallardo, AIP Press, to be published.

[3] see Chapter 4 in *$\mu^+\mu^-$-Collider: A Feasibility Study*, Ed. J. C. Gallardo, Fermilab-Conf.-96/092 (1996).

[4] N. V. Mokhov, *The* MARS *Code System User's Guide, version 13 (95)*, FNAL-FN-628 (1995).

[5] see Chapter 5 of ref. [3].