TOWARDS A GLOBAL OPTIMIZATION OF THE MUON ACCELERATOR FRONT END

H. K. Sayed,*[1] J.S. Berg,[1] H.G Kirk,[1] D. Stratakis,[1] K.T. McDonald,[2] D. Neuffer,[3] R. Ryne,[4] J. Qiang[4]

[1] *Brookhaven National Laboratory, Upton, NY*

[2] *Princeton University, Princeton, NJ*

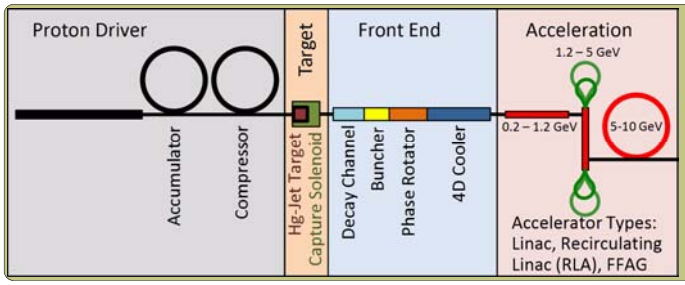
[3] *Fermilab, Batavia, IL*

[4] *LBNL, Berkeley, CA*

TUPBA11
NAPAC'13

CONCEPT

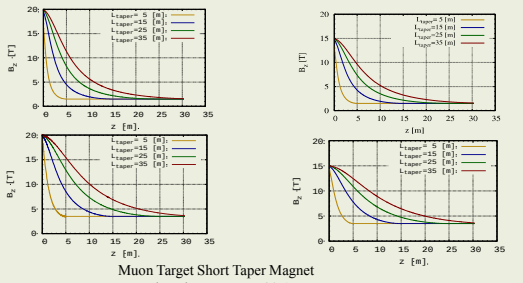
The baseline design for the Neutrino Factory/Muon Collider Front End consists of a five major components, namely the Target System, Decay Channel, Buncher, Phase Rotator, and the Ionization Cooling Channel. Although each of the mentioned systems has a complex design which is optimized for the best performance with its own set of local objectives, the integration of all of them into one system requires a global optimization to insure the effectiveness of the local objectives and overall performance. This global optimization represents a highly constrained multi-objective optimization problem. The figures of merit are the number of muons captured into a stable bunches and their transverse and longitudinal emittances. These objectives are constrained by the momentum and dynamic acceptance of the subsequent acceleration systems, in addition to the overall cost. A multi-objective global evolutionary algorithm is employed to address such a challenge. In this study a statement of optimization strategy is discussed along with preliminary results of the optimization.



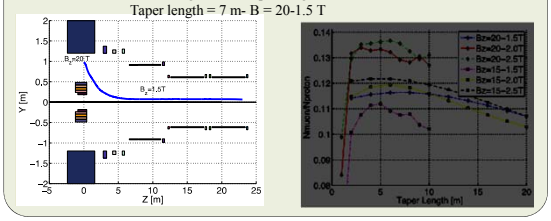
Parameters to be optimized:

- Target: capture solenoid field, and subsequent "taper"
- Decay Channel: length, constant solenoid field
- Buncher & Phase Rotator: RF phase, frequency, gradient
- Transverse match into Cooler
- Cooling Channel: RF phase, frequency, gradient, and solenoid focusing

TARGET TAPERED-SOLENOID PROFILE

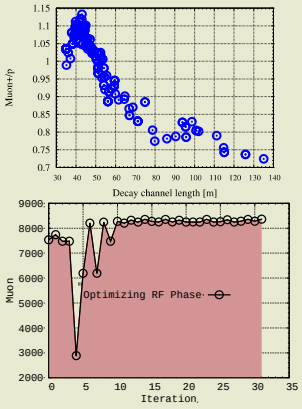


Muon Target Short Taper Magnet
Taper length = 7 m- B = 20-1.5 T

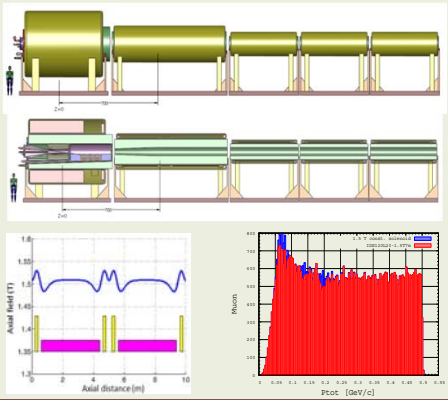


OPTIMIZING DECAY CHANNEL - BUNCHER – PHASE ROTATOR "DIFFERENTIAL EVOLUTION"

- Objective →N muons within accelerator acceptance cuts
- Decay Channel length
- Buncher , Rotator RF frequency & gradients
- Converged after 200 ICOOL calls (12 generations) .



Decay Solenoid Channel Optimization



- Optimize coil design (reduce losses due to momentum stop bands)
- Tracking Based Transmission:

Constant 1.5 Solenoid Field %67
IDS120L20to1.5T7m %66

Broadband Match to Ionization Cooling Channel

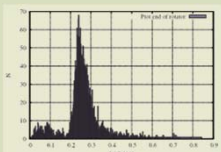
A set of 9 solenoid coils match the beam's phase space ellipse to fit within the acceptance of the Cooling Channel.
The objective of this optimization problem was constructed as a sum of the emittance magnification factor at various momenta weighted to the number of muons within the vicinity of a central momentum

$$EM=\frac{1}{2}[\frac{\beta_a}{\beta_s}+\frac{\beta_a}{\beta_s}+(\sqrt{\frac{\beta_a}{\beta_s}}\alpha_s-\sqrt{\frac{\beta_a}{\beta_s}}\alpha_a)^2]$$

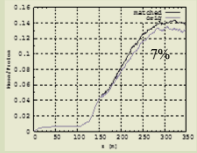
- Objective function $F=\chi_1$ EM1 + χ_2 EM2 + ….. + 1/Nmuon (end of cooling)

χ_1 → Number of particles with momentum Pz1
χ_2 → Number of particles with momentum Pz2

- Use optimizer to minimize the objective function "fit (match) the two ellipses"
- Multivariable problem:9 parameters for 9 Coils.



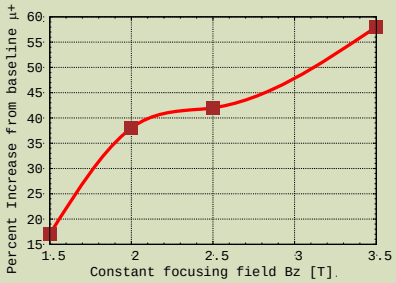
Muon beam momentum distribution at the end of the phase rotator.



Matching B = 2.5 T Front End to +/- 2.8 T baseline Cooler

Muons within Acceleration Acceptance Cuts at End of Transverse Cooling Channel

Optimized performance of the Front End versus the constant focusing field on the Decay Channel, Buncher, and Phase Rotator. The optimization included : target -olenoid taper length, Decay Channel length, phasing the Buncher and Rotator RF cavities, and the broadband match to the Ionization Cooling Channel.



SUMMARY AND FUTURE WORK

- Global optimization strategy for the muon Front End envisioned for Neutrino Factory (or Muon Collider)
- The first round of the multivariable optimization showed a significant improvement of the performance by
  - 15% - 60% from the current baseline.
- A future work may include the higher harmonic RF in the Buncher and Phase rotator, Ionization Cooling Channel parameters (focusing field, RF phase and RF gradient, absorber parameters).

*Email: hsayed@bnl.gov

Work supported in part by US DOE Contract No. DE-AC02-98CH10886.