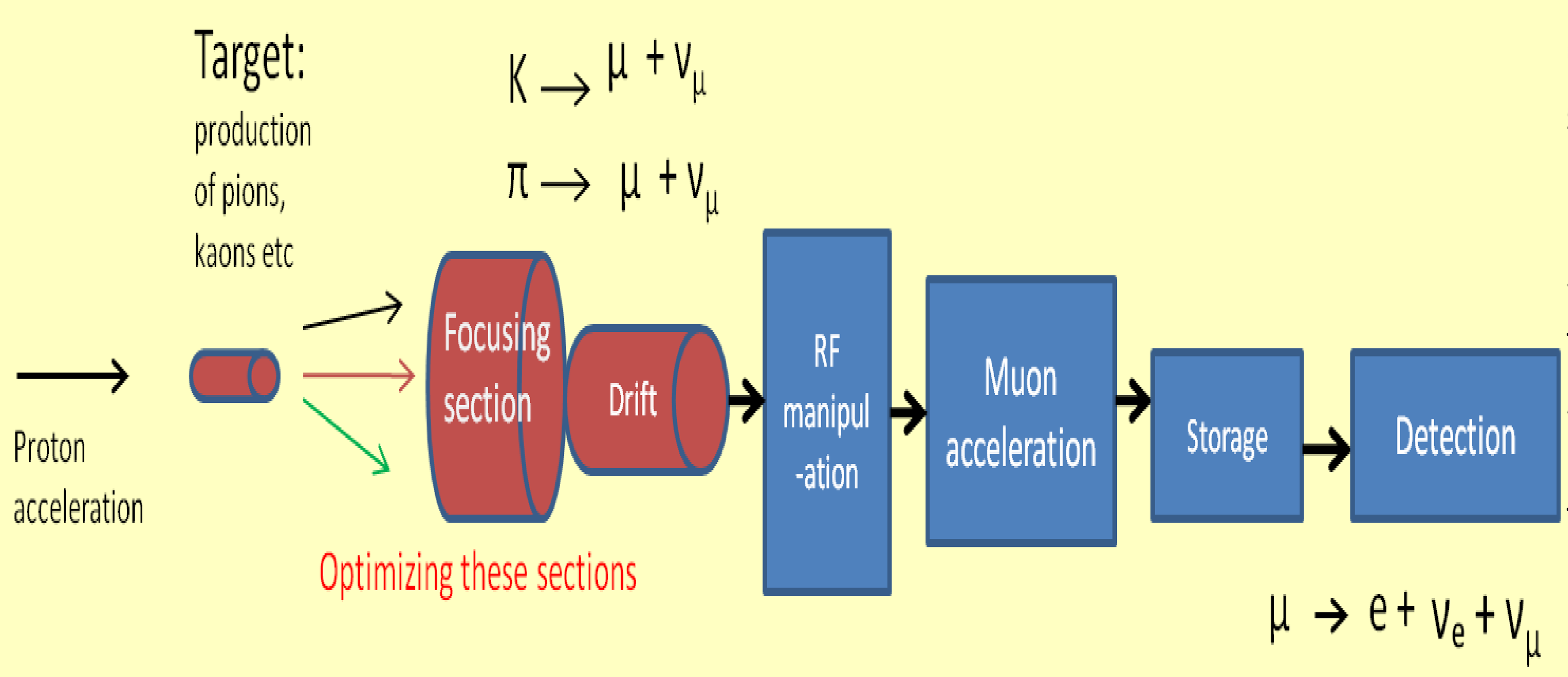
Optimization of the target and capture section of the Neutrino Factory

O.M. Hansen (CERN, UiO) and I. Eftymiopoulos (CERN)

The Neutrino Factory (ref: https://www.ids-nf.org/wiki/FrontPage/Documentation/IDR)

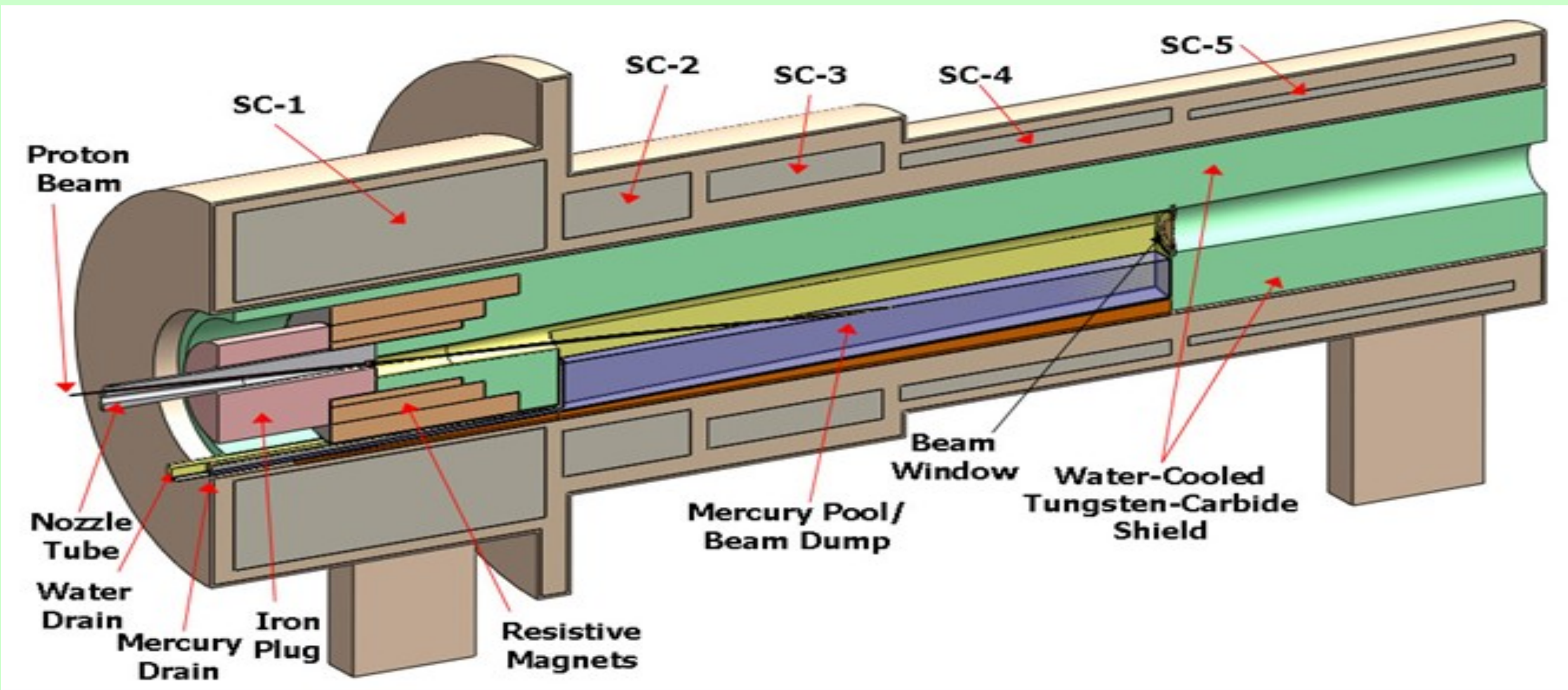
The Neutrino Factory uses a proton beam on a mercury target to produce particles, mainly pions and kaons, decaying into muons. These charged particles are focused in a magnetic field from the target and downstream. Manipulation of the phase-space is done in the RF-manipulation section to increase the number of particles accepted by the muon accelerator. Here they are accelerated up to 25GeV and enter into the storage ring before they decay into neutrinos. The neutrino factory investigates the neutrino mixing, where the neutrinos change flavor when traveling long distances, due to a mass difference between the neutrinos. The goal is to determine the mixing angle θ_{13}, CP invariance violation parameter δ_{CP}, and to determine the mass hierarchy by measuring Δm_{23}^2.

In the capture and focus section, solenoids are used to create a high magnetic field, starting with a 20 T field which is then tapered down to 1.75 T. The produced particles have a large energy spread and in the drift section the particles develop an energy-time correlation. Only particles within the correct momentum, time and position-intervals are *good* particles and acceptable for the muon accelerator. To maximize the number of good particles, the beam is bunched which makes it possible to manipulate the beam, accelerating particles lagging behind in time and decelerating particles arriving early in time. The RF-manipulation is useful only for the longitudinal manipulation of the phase space. But the transversal momentum also needs to be decreased. This process is called *ionization cooling*. In the ionization cooling section, the particles pass through a gas of hydrogen, reducing their total momentum and thus the transversal momentum. The longitudinal momentum can readily be restored with RF-manipulation. To get the best performance from the Neutrino Factory, optimization studies of the capture and target section are studied to give as many good particles as possible.



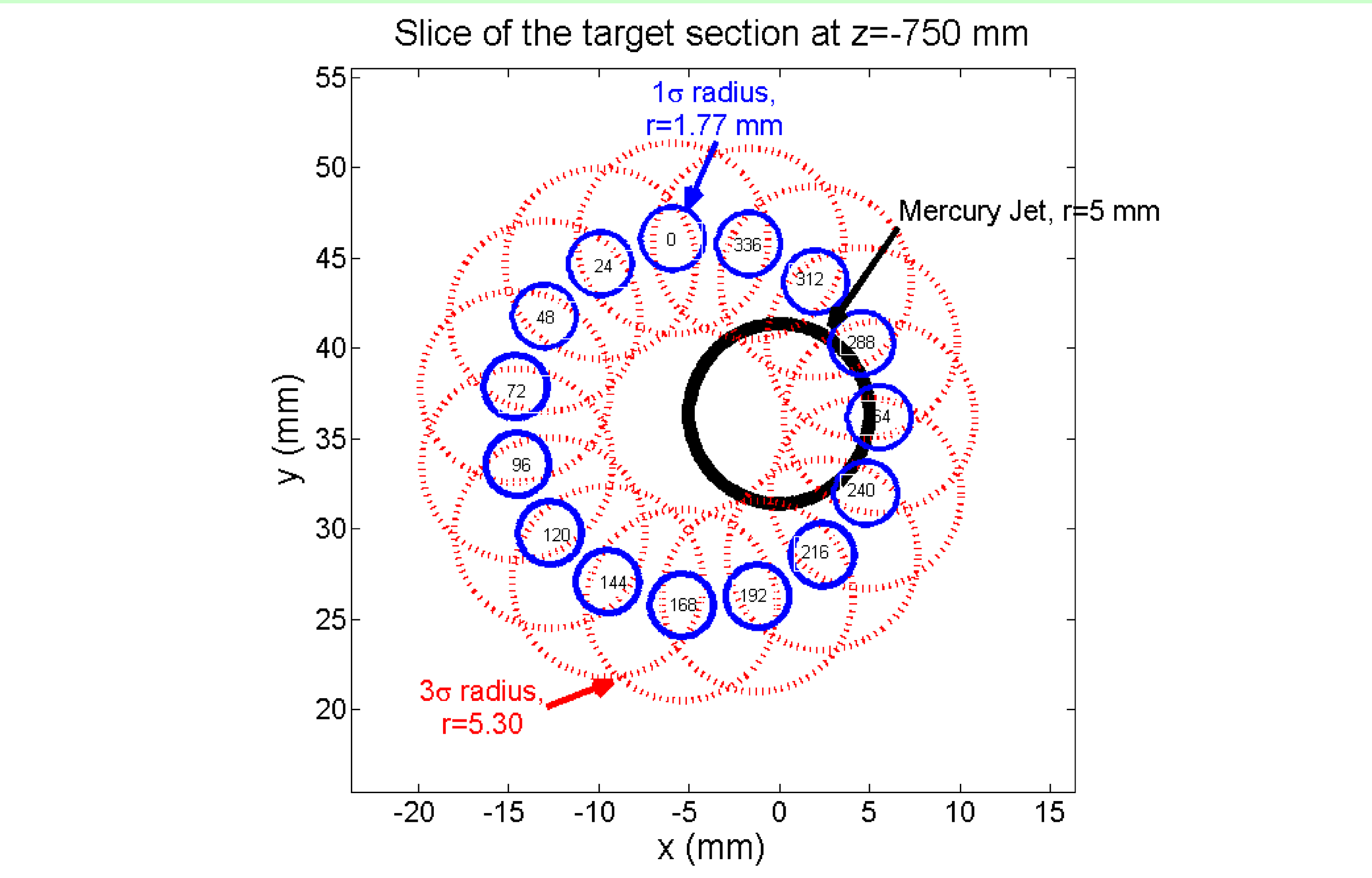
Current Baseline for the Focus & Drift Section, Is This the Optimal?

Superconducting (SC) solenoids makes the magnetic field. The field in the capture section is 20 T and gradually decreases to 1.75 T.

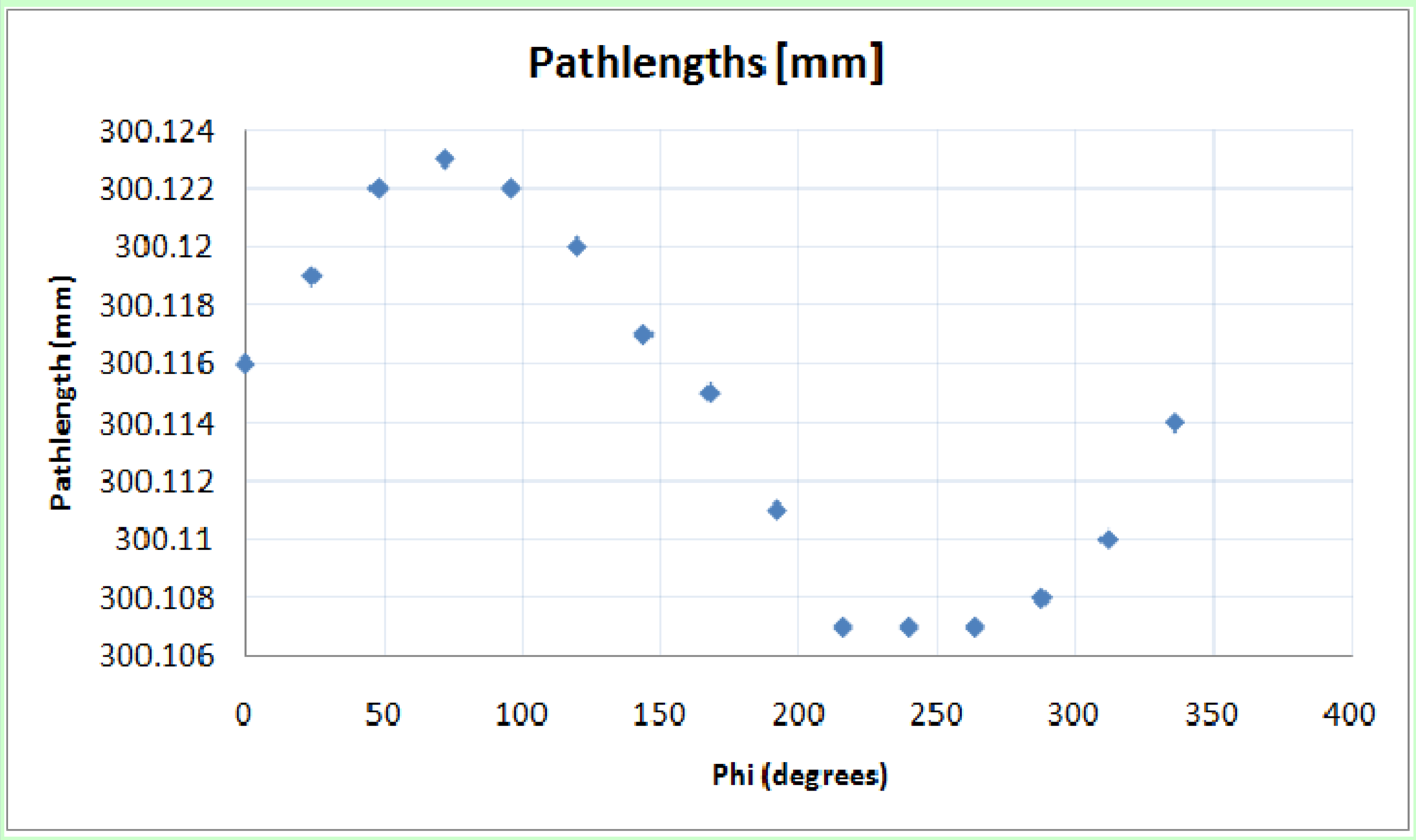


Beam-Target Angle

- How does the entry direction influence the pathlength?

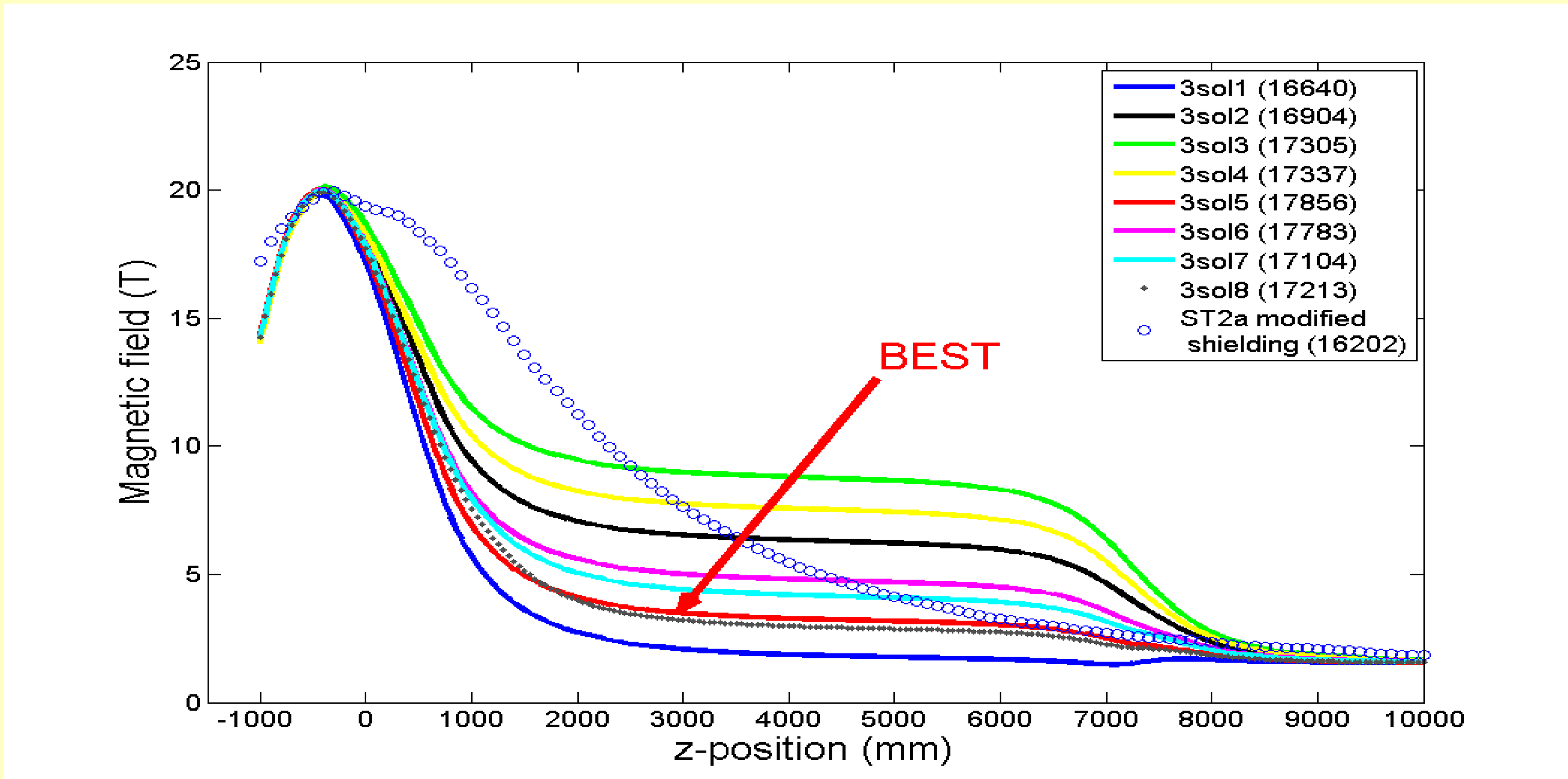


- The pathlength for the proton beam inside the target varies with the entry direction of the beam. Can this be used to find the optimal entry direction?



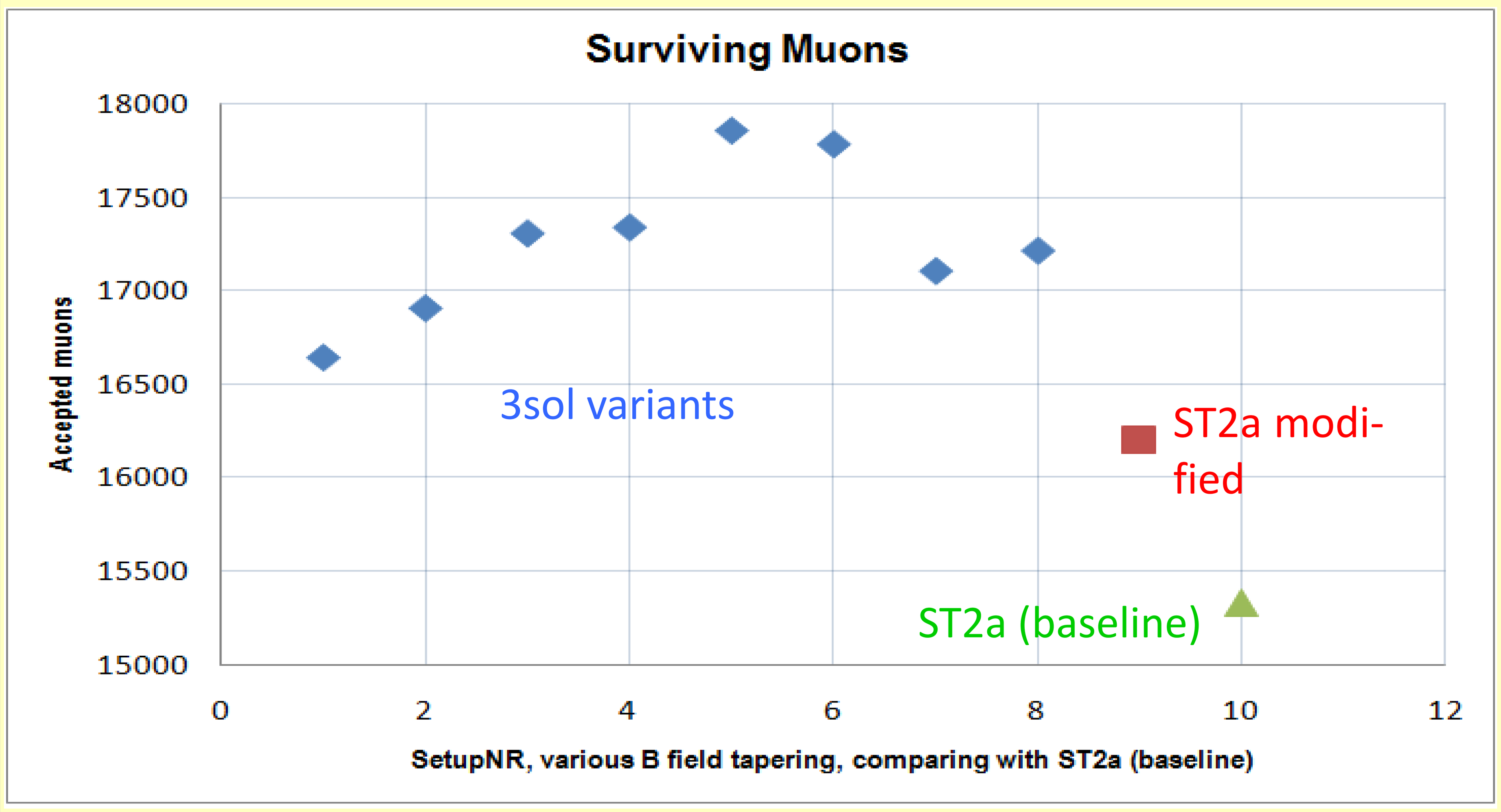
Magnetic Field Tapering

- Does the magnetic field influence the capture of particles?
- Does a slowly decreasing magnetic field increase the particle flux?
- Alternatively, can a rapidly decreasing magnetic field be equally good or better?



Preliminary Results with Various Magnetic Field Tapering

Results from simulations in G4beamline with different magnetic field tapering. Optimized by studying e.g. loss maps. Cuts have been applied in position, time and momentum to maximize the number of good particles. The simulations were run with 10^5 protons on target with the current baseline called the ST2a setup. 3sol is the setup used with various magnetic fields. The most promising result gives a 16% better performance than the current baseline.



Future Work

- Include the full geometry of mercury jet in the simulations to check difference in particle production, proton-target interaction length and beam-target angle dependencies.
- Study energy deposition in shielding, normal conducting solenoids and superconducting solenoids.
- Do full front-end simulations, including bunching, RF-rotation and ionization-cooling.