Design of a common beam line for ENUBET/nuSTORM

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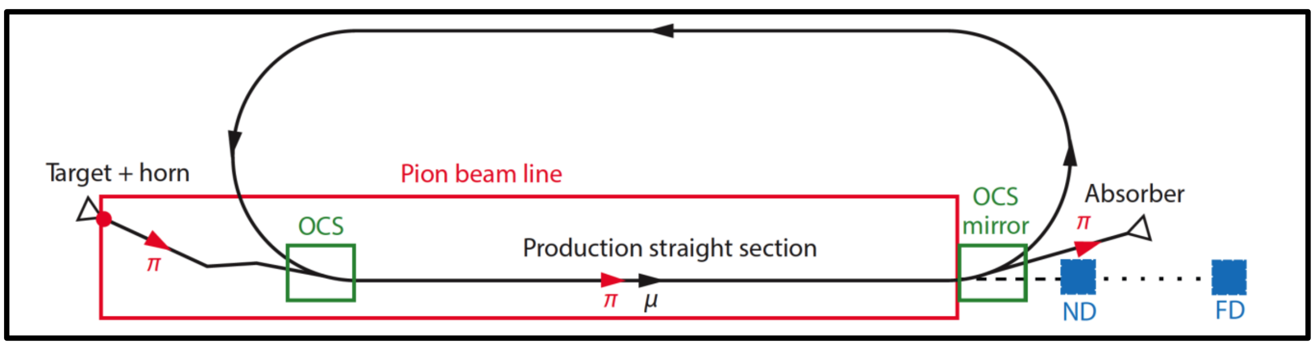
nuSTORM - Origin - Idea

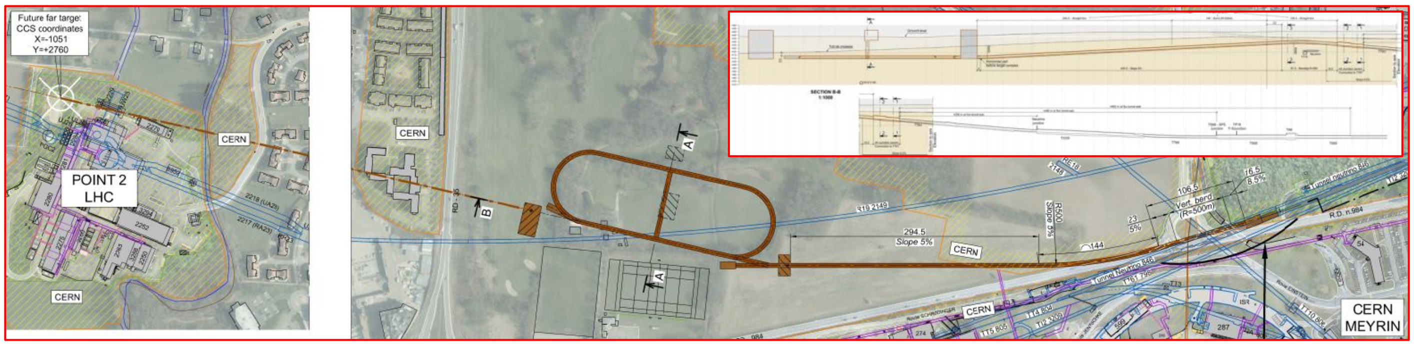
- nuSTORM (`NeUtrinos from STORed Muons') is a facility based on a low-energy muon decay ring.
- Can use existing proton driver (like SPS at CERN)
- Conventional pion production and capture (horn)
  - Quadrupole pion-transport channel to decay ring
  - Direct injection of pions into the decay ring to form circulating muon beam subsequently used as a source of neutrinos w/o a kicker



nuSTORM - Motivation

- Neutrino interaction physics – nuSTORM can measure neutrino cross sections precisely
  - Significantly reduce the main source of systematic errors for long base-line oscillation experiments
- Short baseline neutrino oscillation physics – search for sterile neutrinos
- Accelerator and Detector Technology Test Bed
  - Proof of principle for the Neutrino Factory concept
  - Muon Collider R&D platform

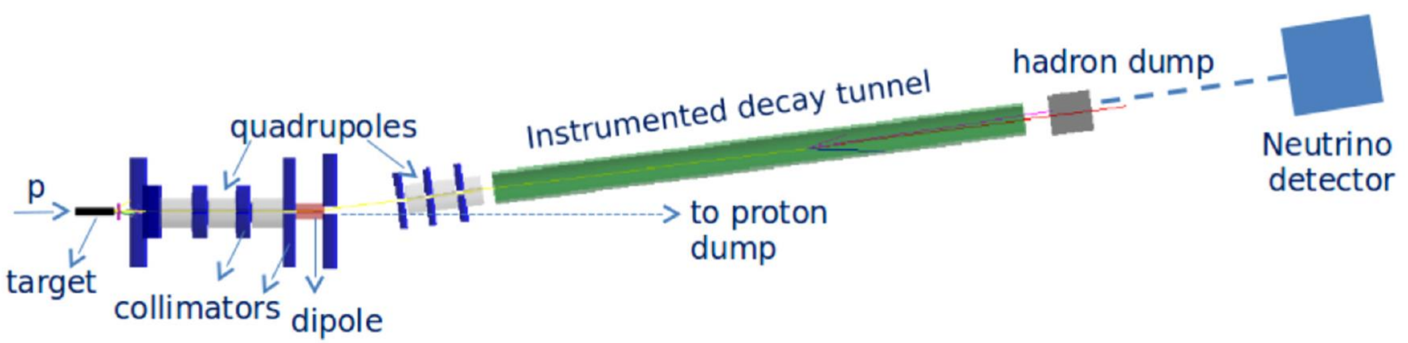
nuSTORM siting at CERN



- Extraction from SPS through existing tunnel
- Siting of storage ring:
  - Allows measurements to be made 'on or off axis'
  - Preserves sterile-neutrino search option

ENUBET

- ENUBET is a facility based on a narrow band beam to produce an intense source of electron neutrinos
- A key element of the project is the instrumentation of the decay tunnel to monitor large angle positrons produced together with neutrinos in the three body decays of kaons (Ke3) and to discriminate them from neutral and charged pions
- ENUBET can also contribute, together with nuSTORM, to a precise determination of the absolute neutrino cross section
- SPS beam can also be used for ENUBET



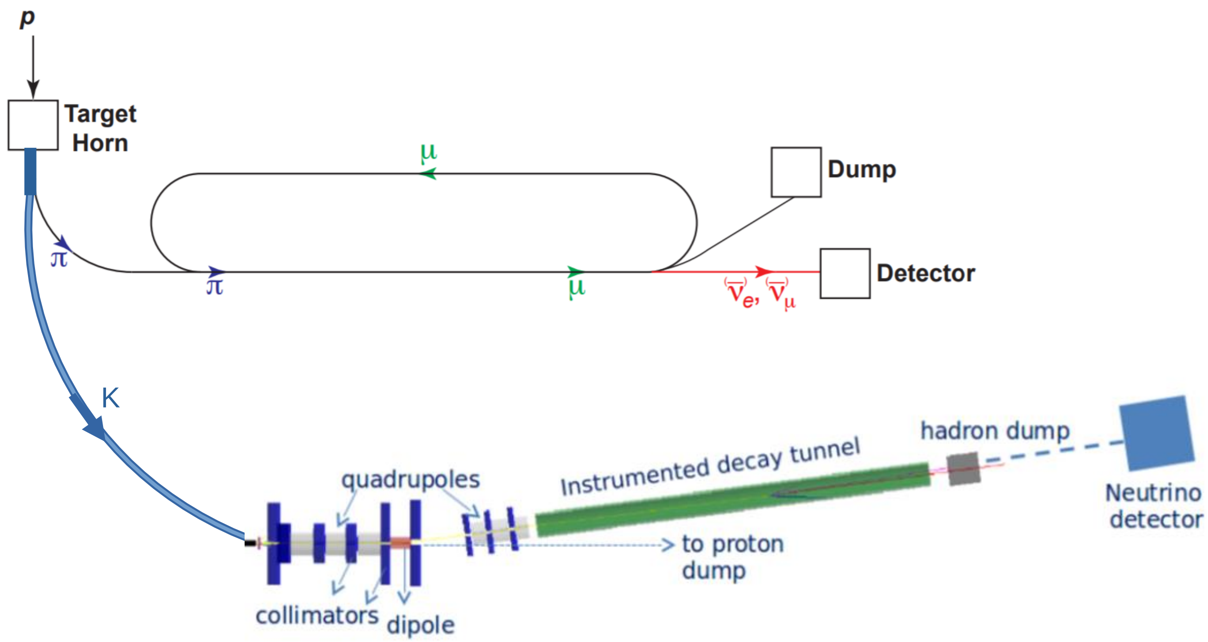
Motivation

+ The nuSTORM and ENUBET experiments are meant to exploit the SPS proton beam ~ 100GeV to produce beam of neutrino => enhance our understanding in neutrino physics.

➜ The transport line lattice could be constructed for parallel running of both nuSTORM and ENUBET.

➜ We want to optimize the number of pions and kaons that go through the transport line, with the suitable matching of optical functions at the end points

A novel pion transport line front-end



Conceptual layout that allows parallel running of both nuSTORM and ENUBET experiments

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Initial assumptions

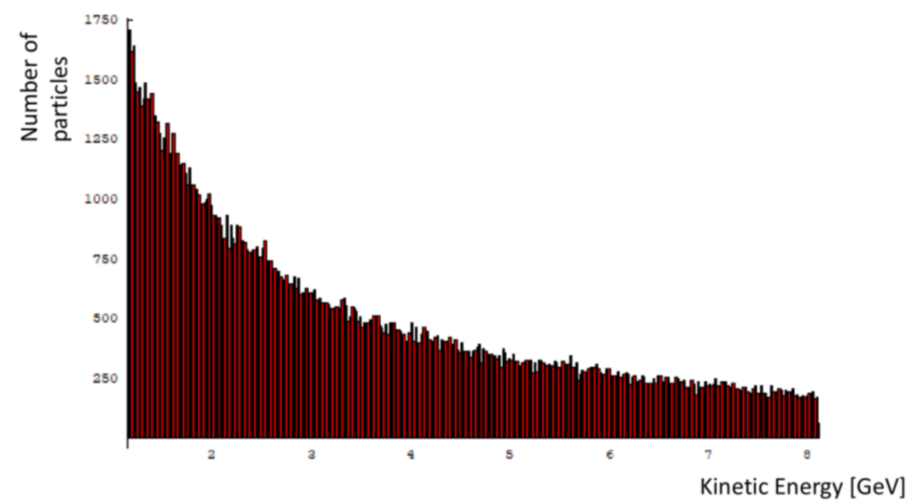
- SPS beam at 100 GeV will be sent to the target immersed in the horn
  - Solenoid capture was discarded due to a very high field requirements for multi-GeV/c particle focusing
    - This makes simple sign flipping impossible
- The higher momentum beam will be sent to ENUBET (~7.5 GeV/c) and lower momentum one (5 GeV/c) to nuSTORM (this is just an example for the start of the design work)
  - Both beams will have the same polarity
- In order to separate the two beams and send them to two experimental facilities, dispersion needs to be generated after the target
  - Preliminary estimate requires dispersion of 1.75m

- CERN summer student from Vietnam: Ho Quoc Trung performed the initial design and optimization

Target modelling in MARS code

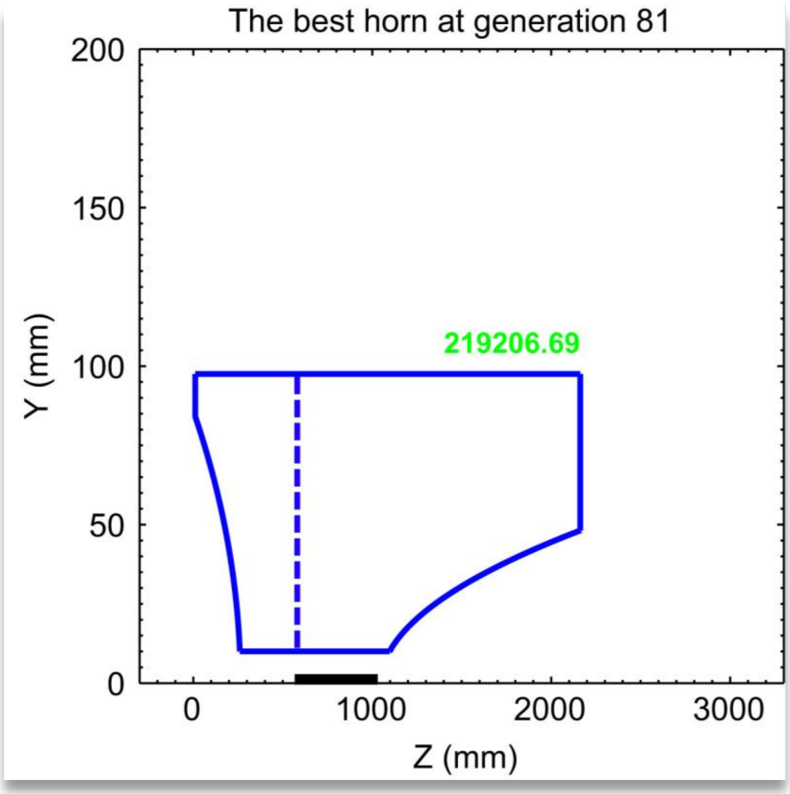
- Beam and target parameters used in MARS simulation (courtesy of S. Striganov):
  - Beam size: $\sigma_x = \sigma_y = 0.267$ cm
  - Proton beam energy: 100 GeV
  - Target material: inconel
  - Target size: radius=0.63cm, length=46cm

Pion spectrum from MARS simulation

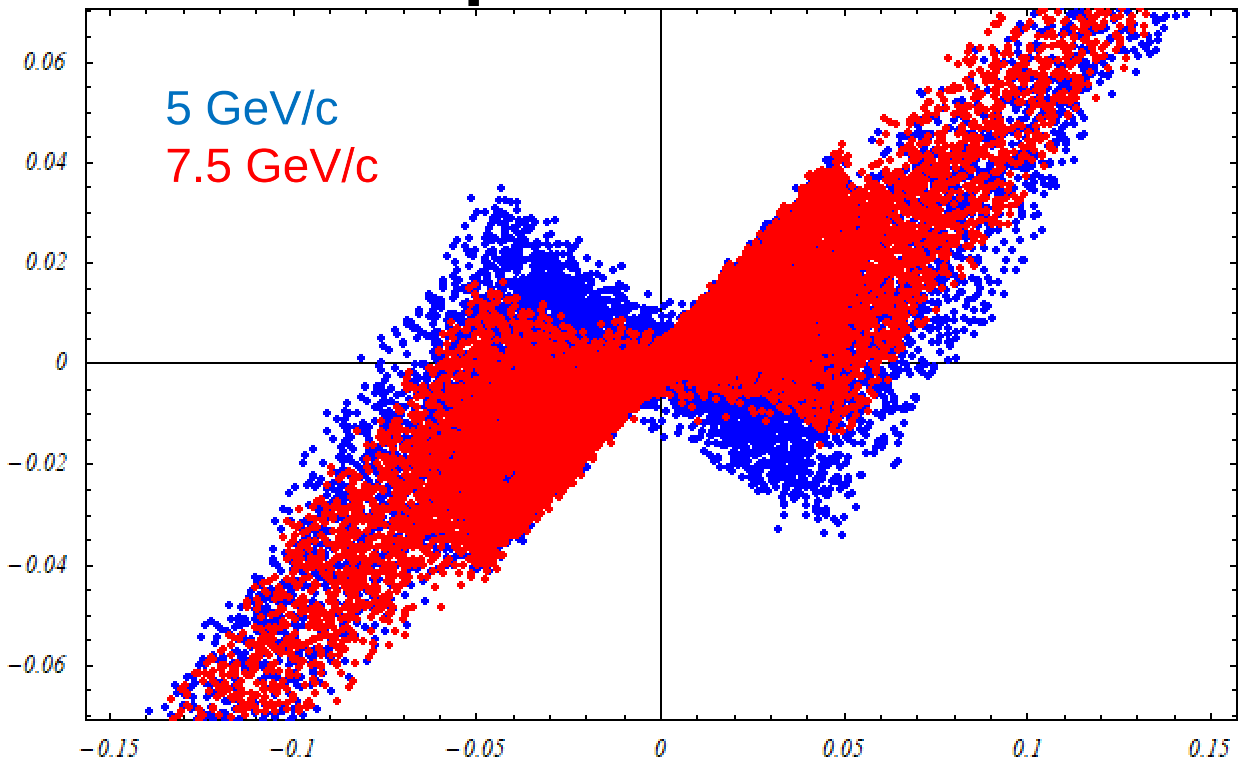


Horn modelling

- Fermilab design by A. Liu was used
- Only forward part was modelled
- Magnetic field was modelled, but scattering in the conductor still needs to be incorporated
- Current was scaled for different energies

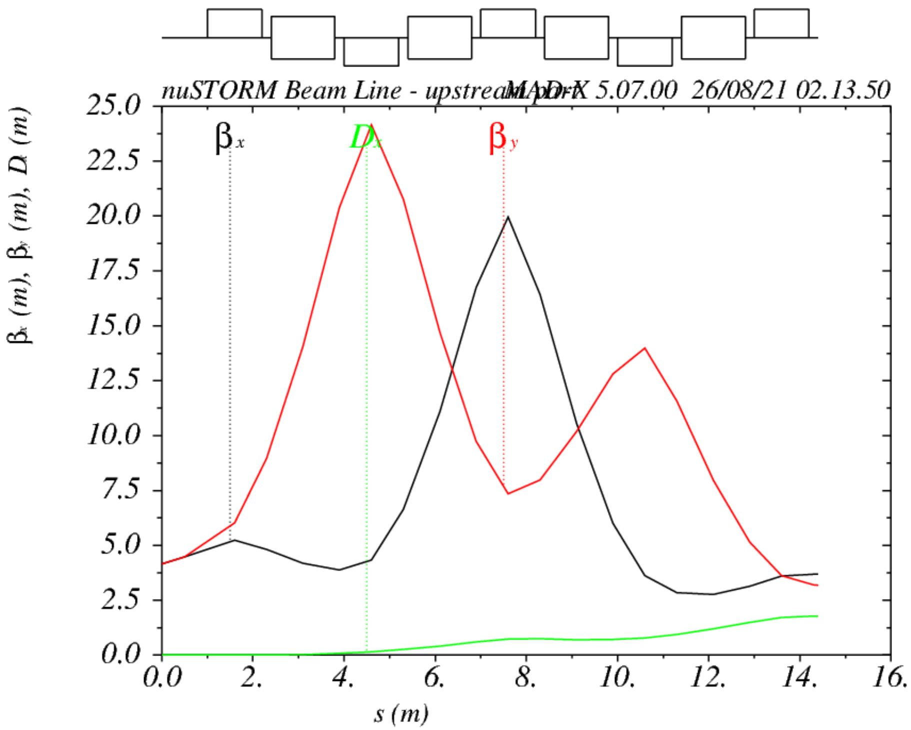


HORN output



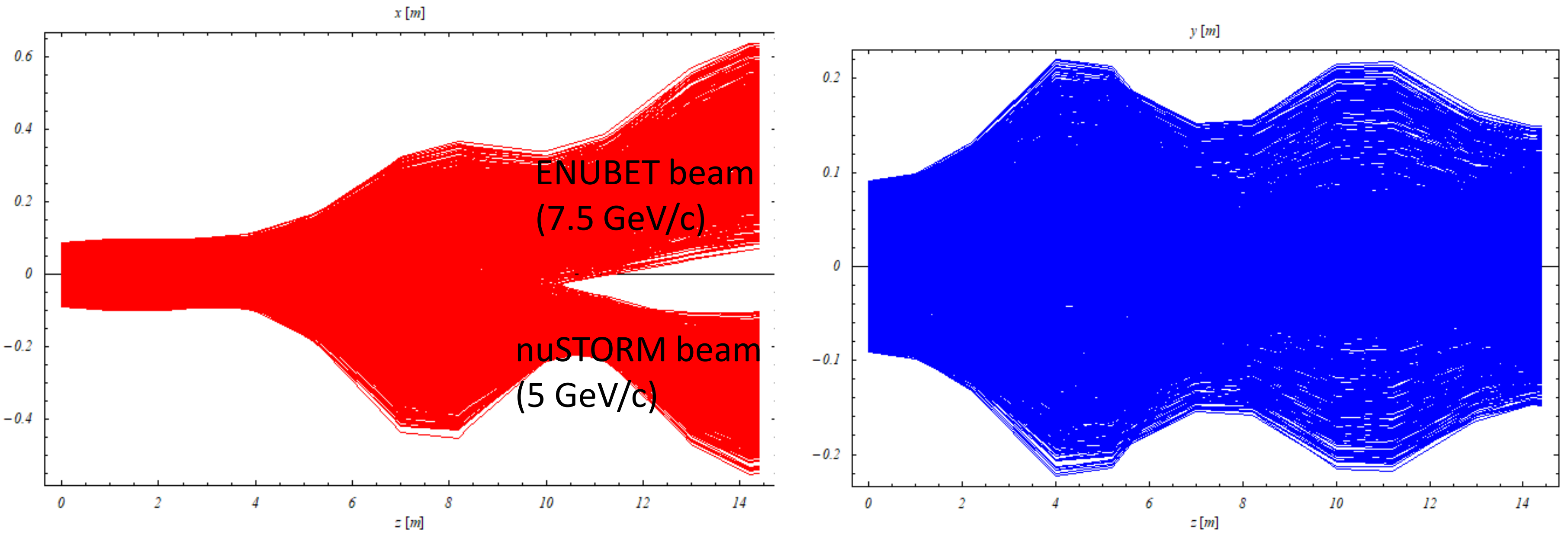
- Horn can simultaneously provide the beams for momenta of 5GeV/c and 7.5GeV/c
    - The same current is assumed
    - The optical conditions are not identical

Lattice for the common part



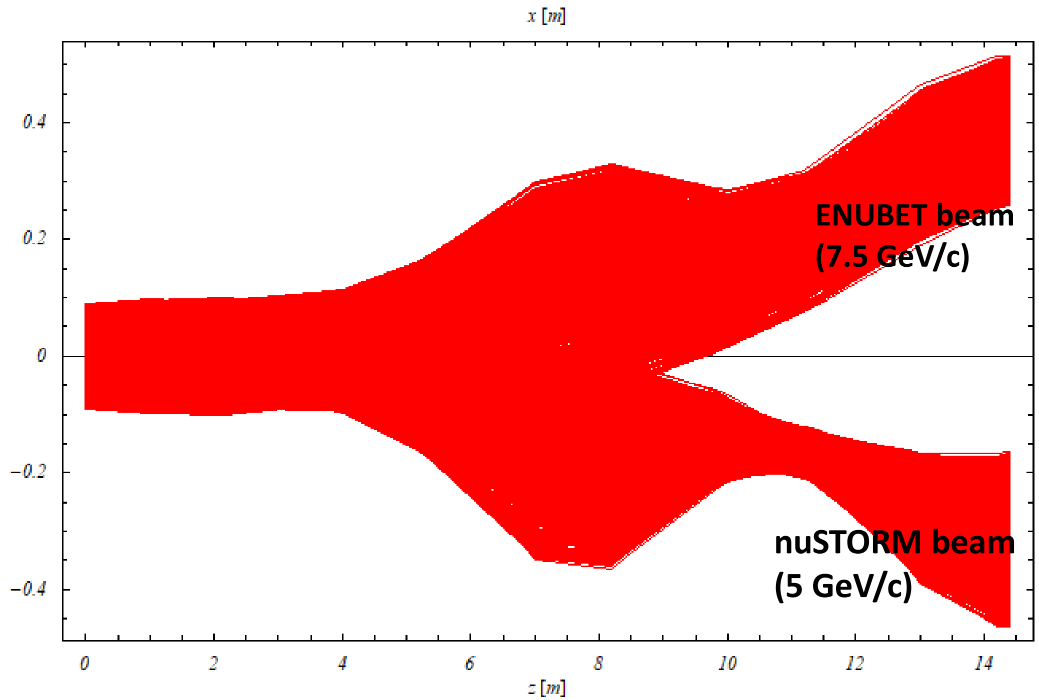
- Lattice uses separate function magnets (quads and dipoles) and aims at normal conducting design, however some of the quads may need to be SC
- Preliminary design performed by Ho Quoc Trung assumes the initial condition optimized for 5 GeV/c pions
- Lattice is designed around the mean momentum of the two modes 6.25 GeV/c

Tracking studies with large momentum spread



Tracking ~1000 particles along the common transport line with large momentum spread (10%). The initial alpha and beta are assumed to be the same. Good beam separation was achieved.

Tracking studies with small momentum spread



Tracking ~1000 particles along the common transport line with small momentum spread (1%). The chromatic effects are obvious for the two beams at the end of common transport line.

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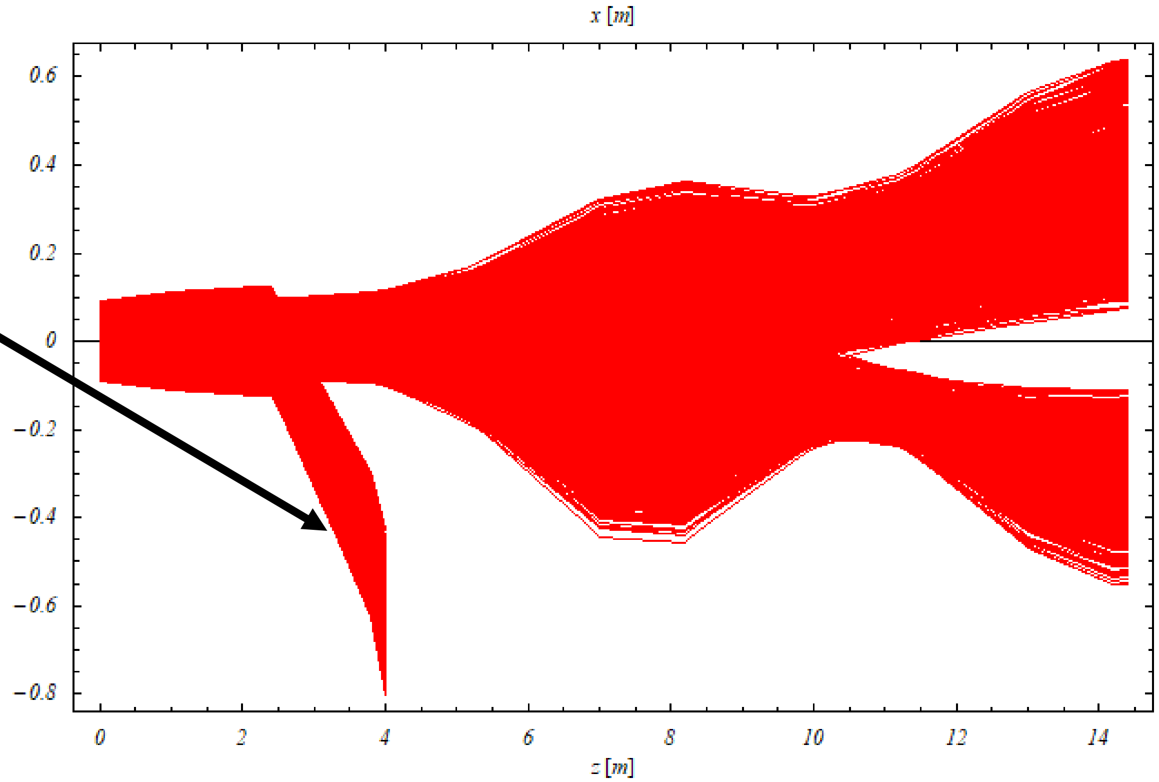
Beam for the muon cooling test facility

300 MeV/c beam for muon test facility:

- Horn and first quad tuned for 300 MeV/c and the first dipole reduced in field by a factor of 3 with respect to 6.25 GeV/c optics
- Seems to be able to clear the second quad
- Current design may not allow for running simultaneously the muon cooling facility and nuSTORM/ENUBET



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Summary

- The preliminary design of the first part of the common transport line for parallel running of ENUBET and nuSTORM was implement using a system with 5 quadrupoles and 4 bending dipoles that are placed alternatively to allow an effective generation of x-axis dispersion for separating the beams for two facilities
  - The current design requires quadrupole coefficients to be relatively large, and possibly requires to be operated with superconducting quadrupoles with the field at the poles as large as 3.5 T, subject of further optimization
  - We also started working on FFA-type lattice
  - No short stopper was found
- Further work will include the design and performance studies of downstream parts of the transport lines matched to ENUBET and nuSTORM experiments
  - Optimization of lengths and beam parameters
  - Investigation of flexibility for different operating modes