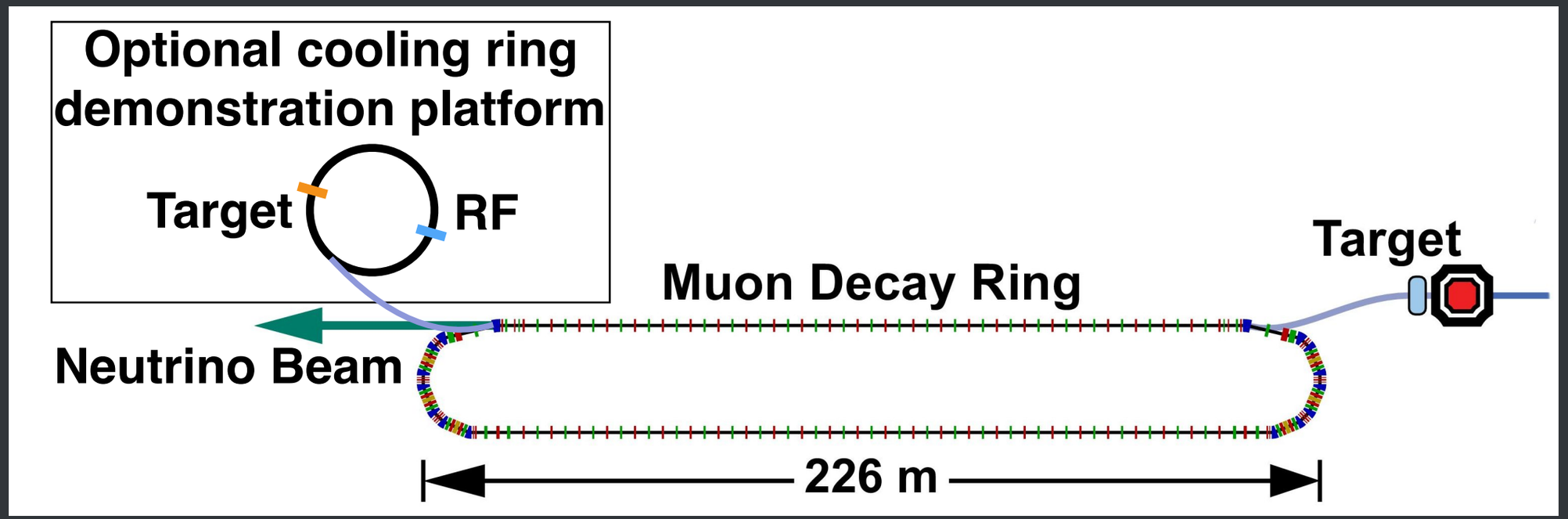
nuSTORM decay ring

JB. Lagrange, on behalf of nuSTORM study team

Outline

- Overview
- FODO solution
- FFA solution
- Hybrid solution

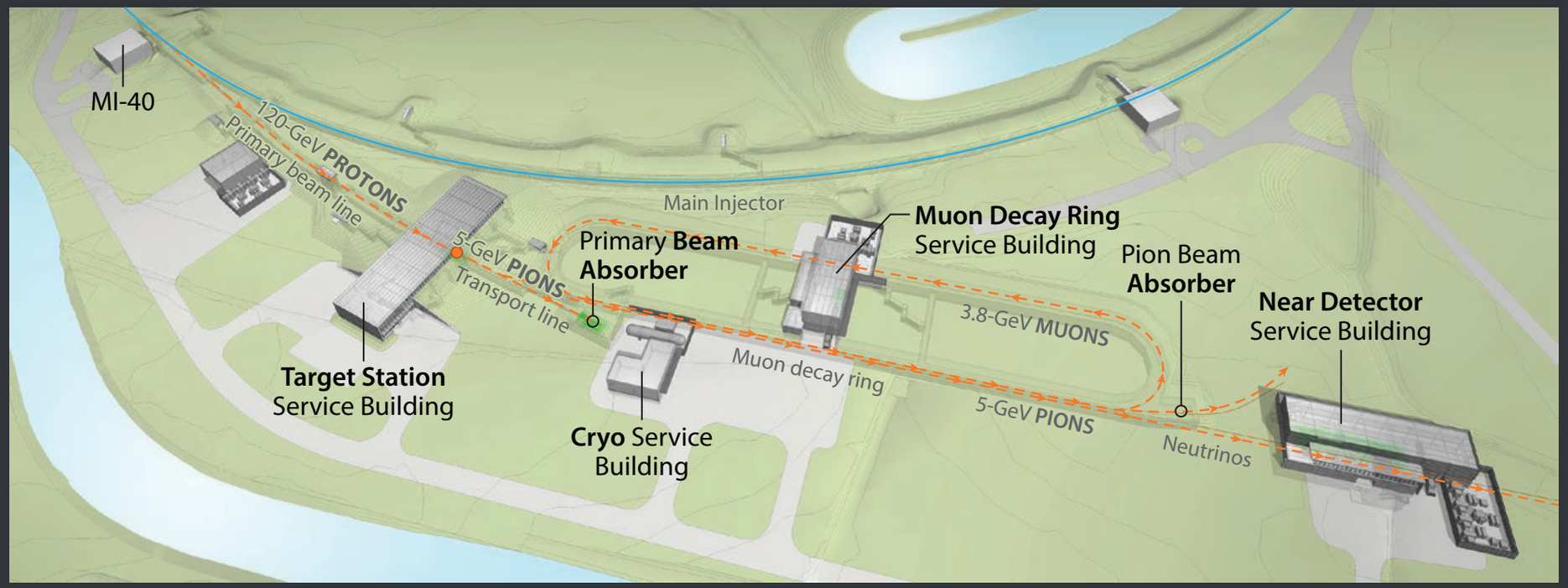
Overview

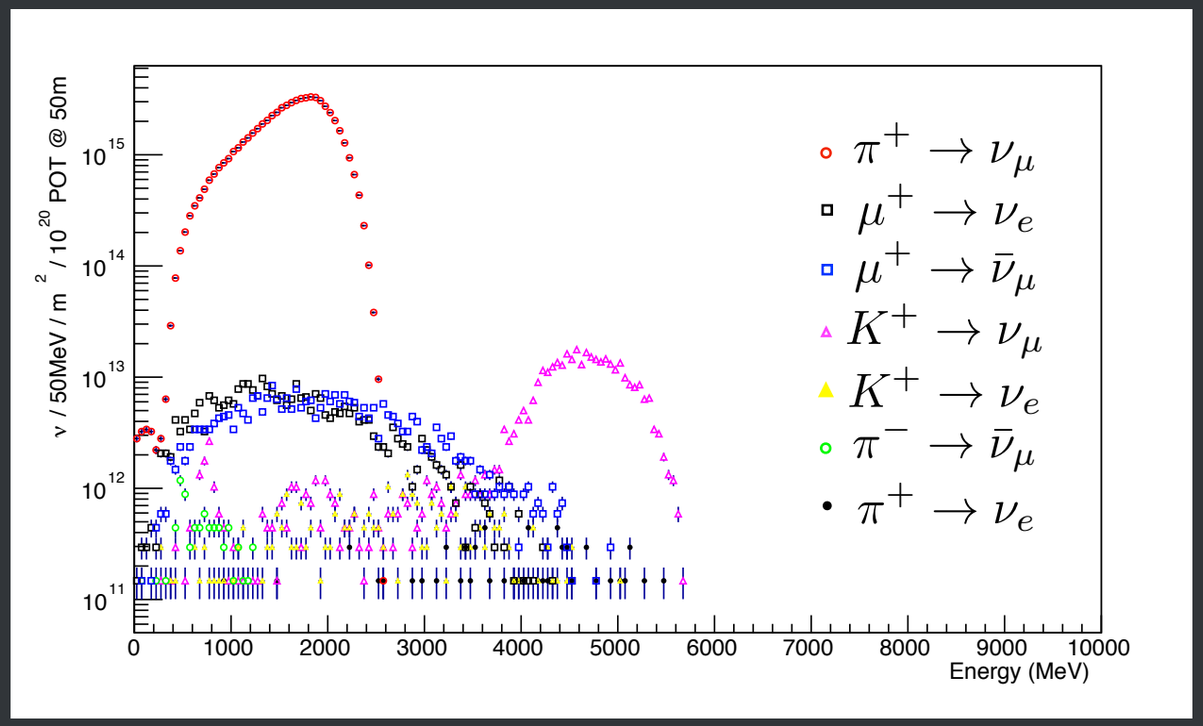


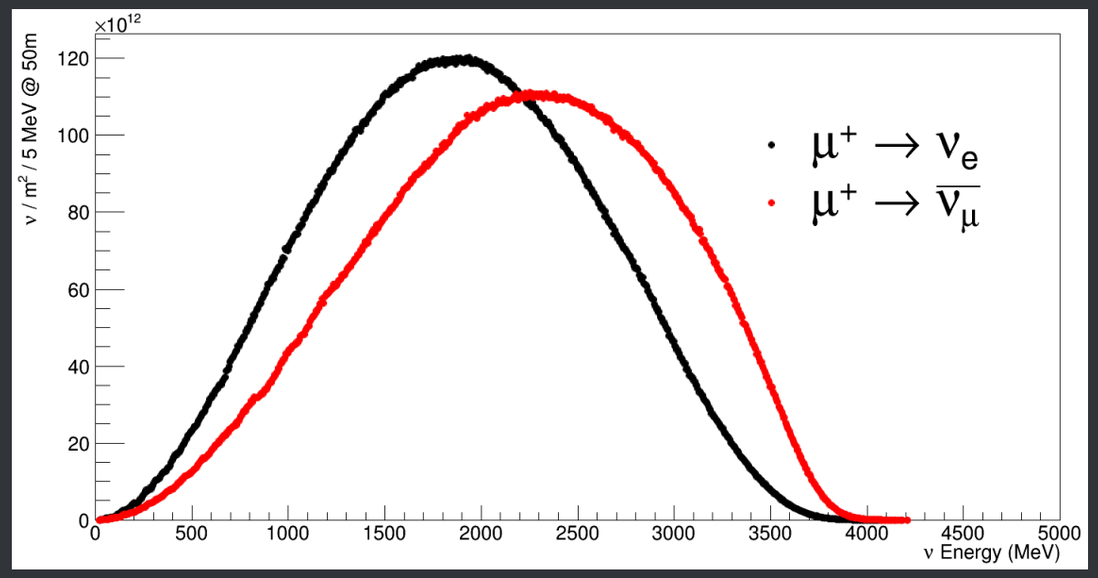
1. Facility to provide a muon beam for precision neutrino interaction physics
2. Study of sterile neutrinos
3. Accelerator & Detector technology test bed
   - Potential for intense low energy muon beam
   - Enables μ decay ring R&D (instrumentation) & technology demonstration platform
   - Provides a neutrino Detector Test Facility
   - Test bed for a new type of conventional neutrino beam

$$\mu^- \longrightarrow e^- + \bar{\nu}_e + \nu_\mu$$
$$\mu^+ \longrightarrow e^+ + \nu_e + \bar{\nu}_\mu$$
$$\pi^- \longrightarrow \mu^- + \bar{\nu}_\mu$$
$$\pi^+ \longrightarrow \mu^+ + \nu_\mu$$

Previous study: FNAL

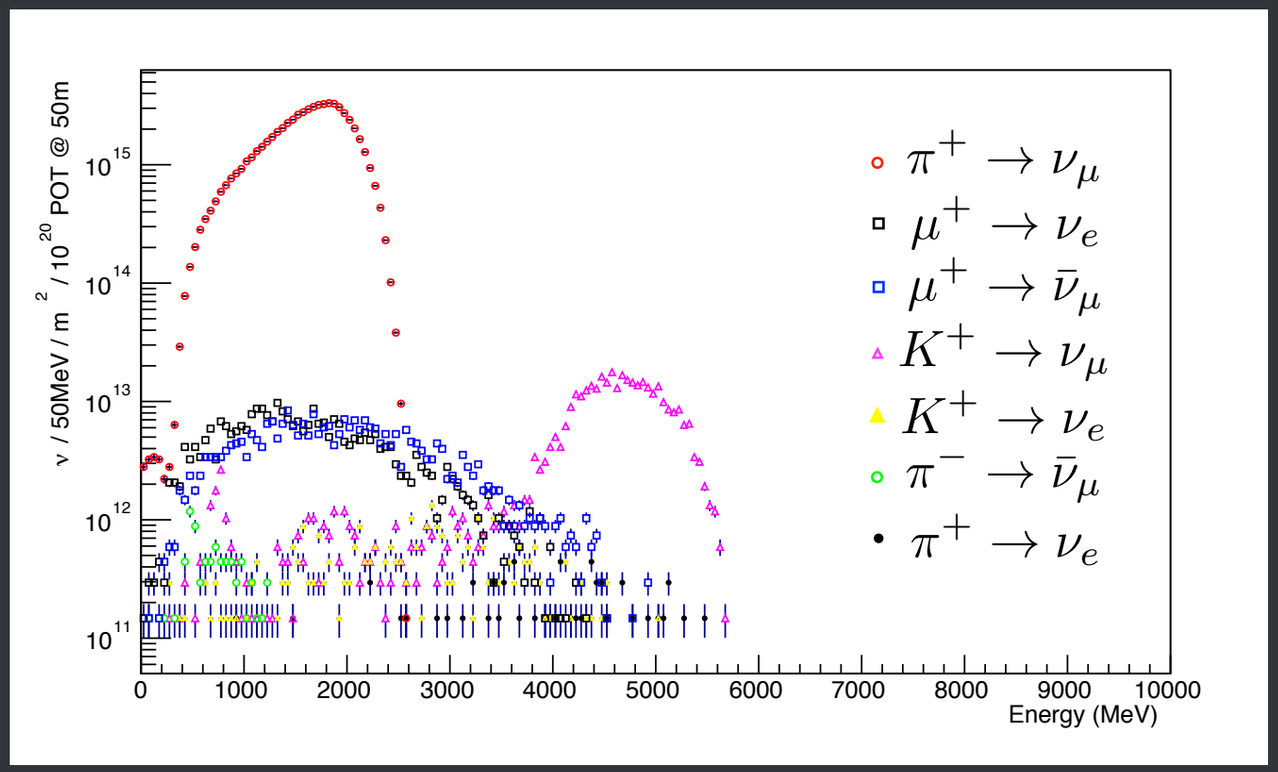


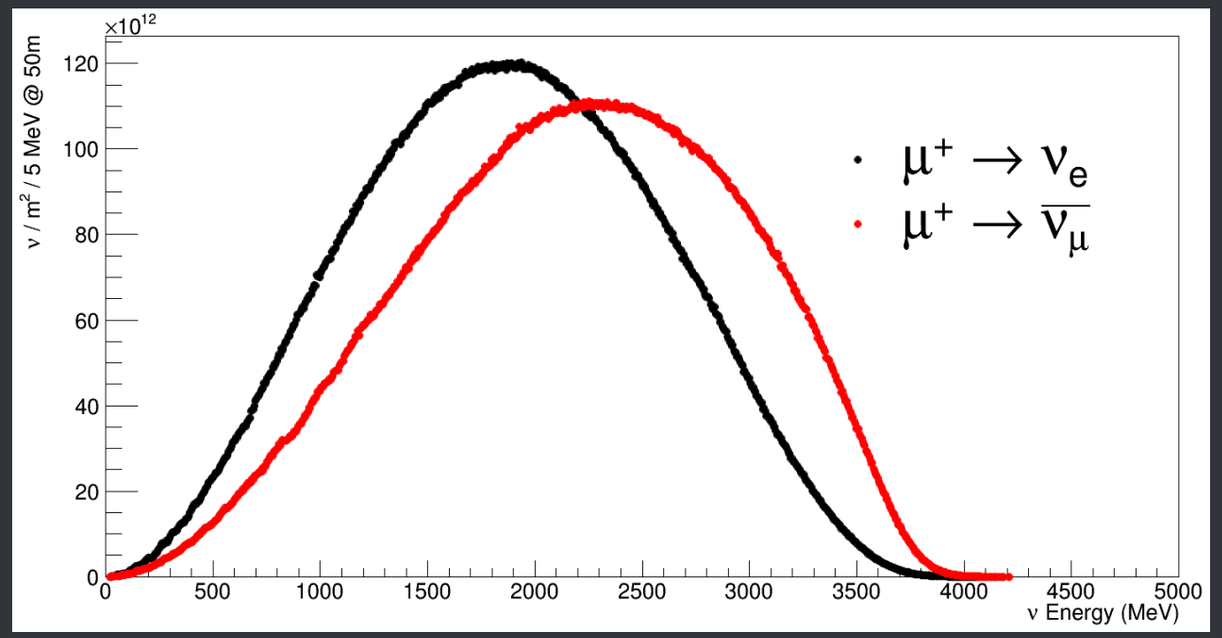


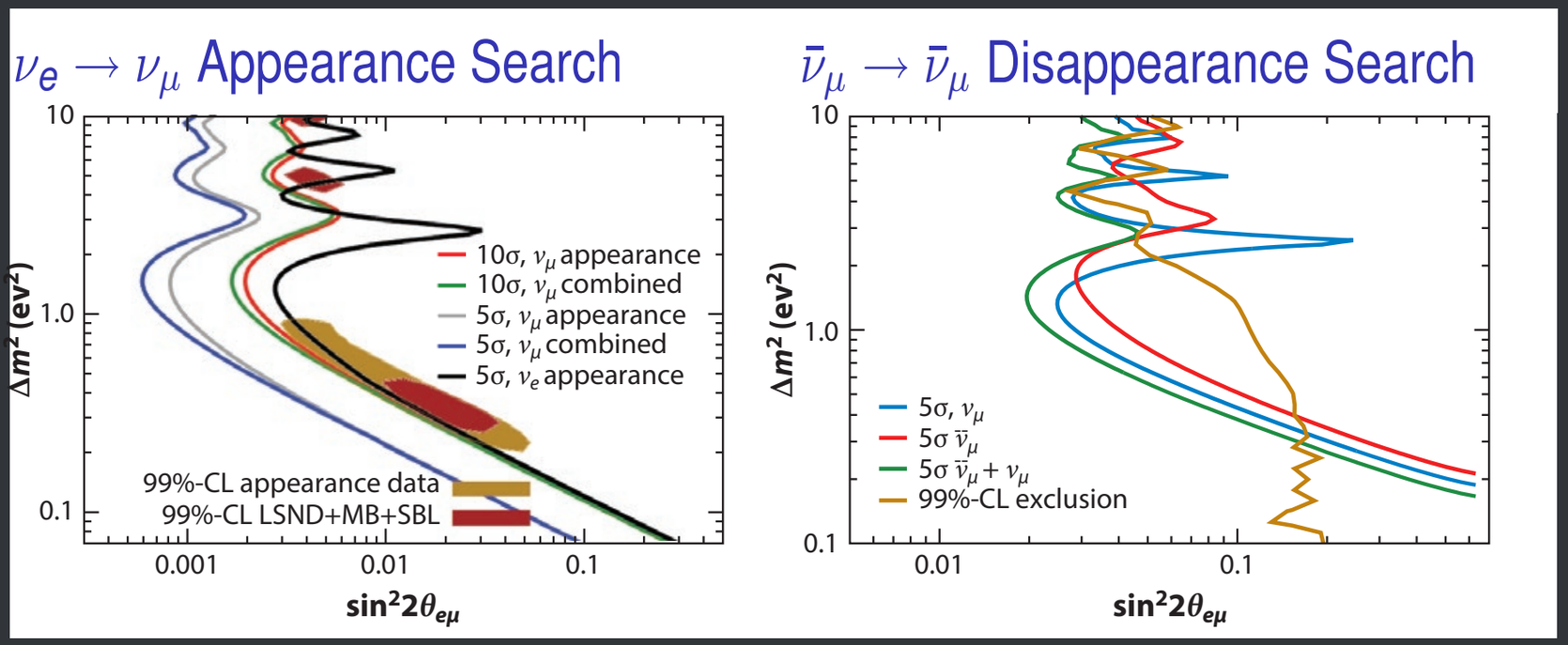


- Multiple channels,
- Good time separation,
- Source of electron neutrinos

Previous study: FNAL







- Multiple channels,
- Good time separation,
- Source of electron neutrinos,
- Sterile neutrino search.

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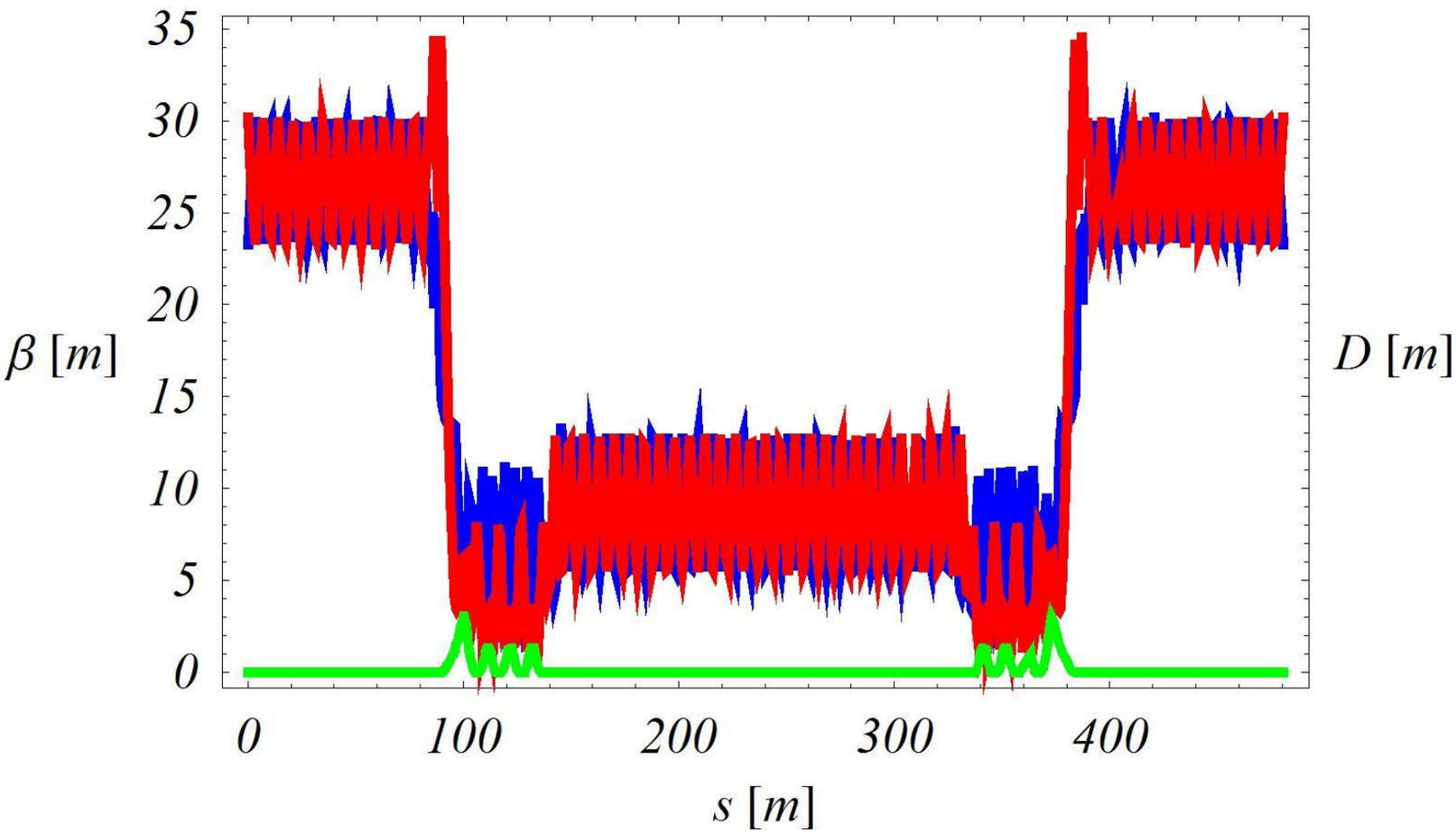
FoDo (FNAL)

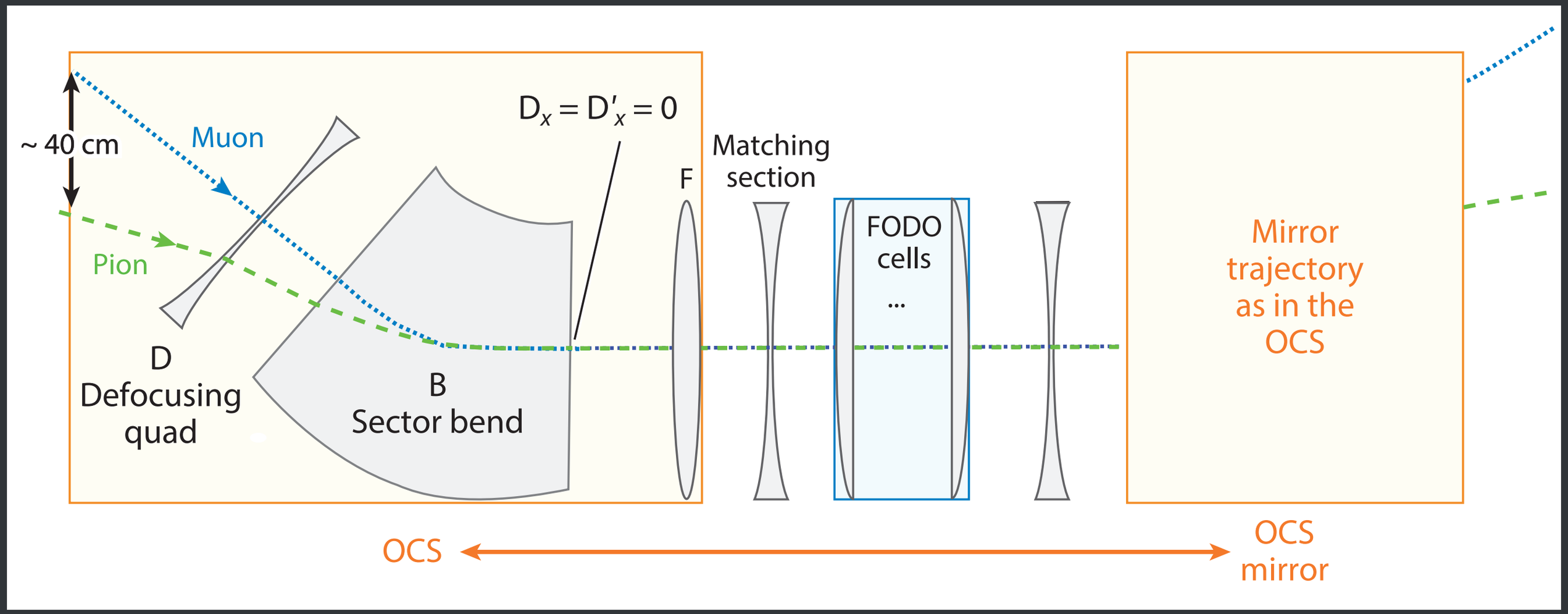
Ring Layout



- FODO ring design is based on SC separated function magnets in the arc
- Only quads are used in the straight sections
- Zero dispersion is kept in straight section.

(A. Liu)

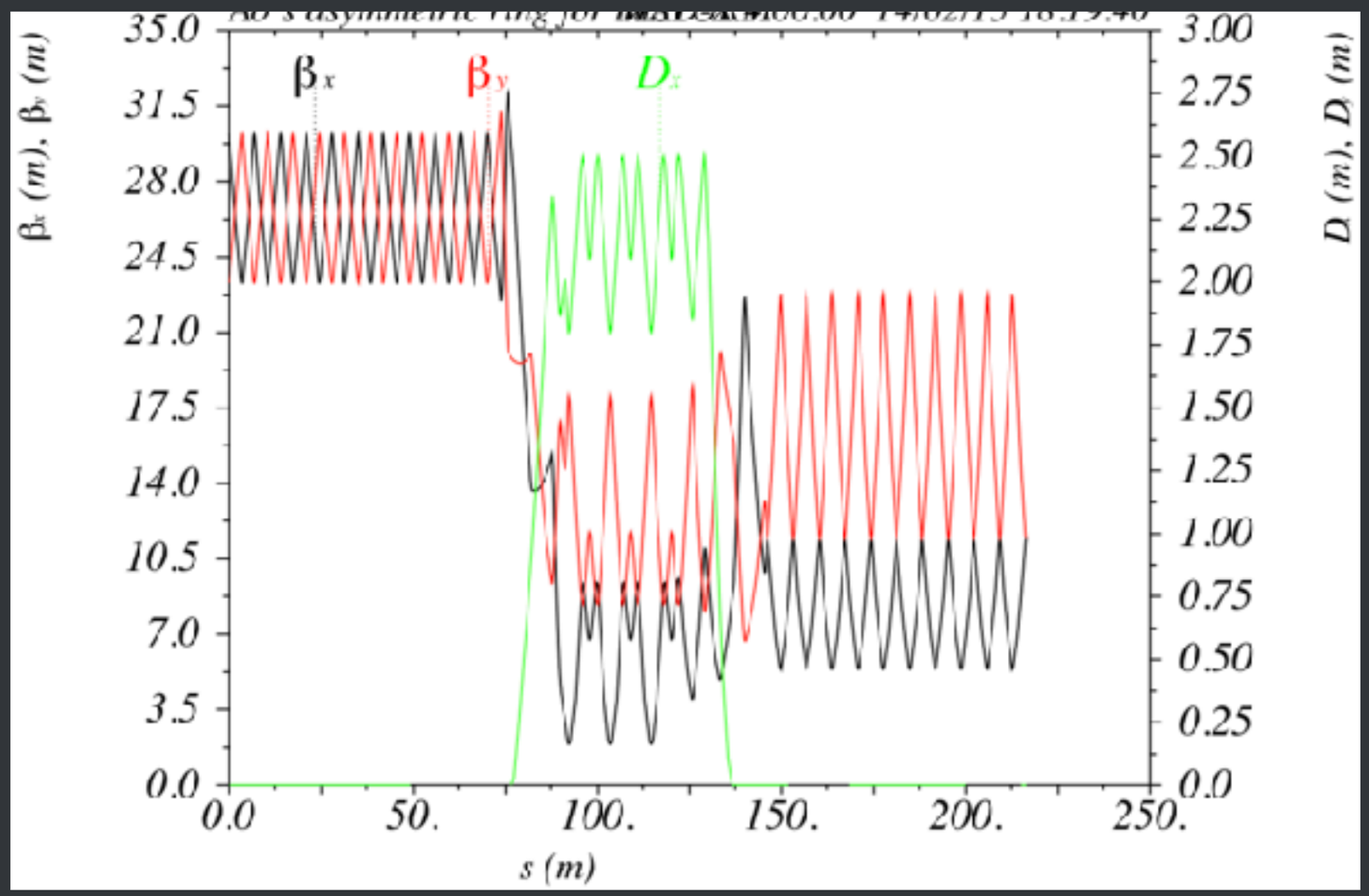
Stochastic injection



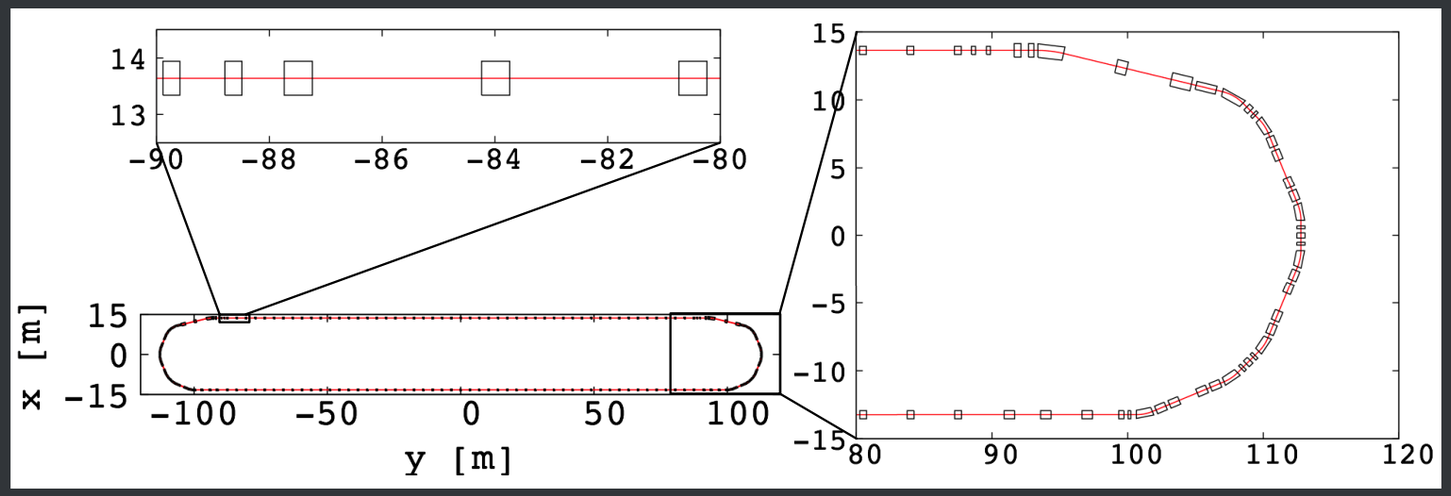
- D. Neuffer's concept (1980)
- Pion injection without kicker

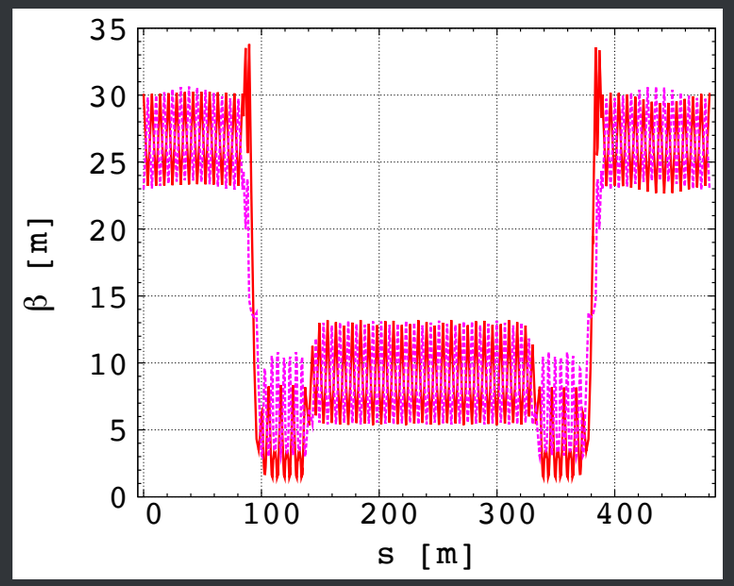
FODO parameters

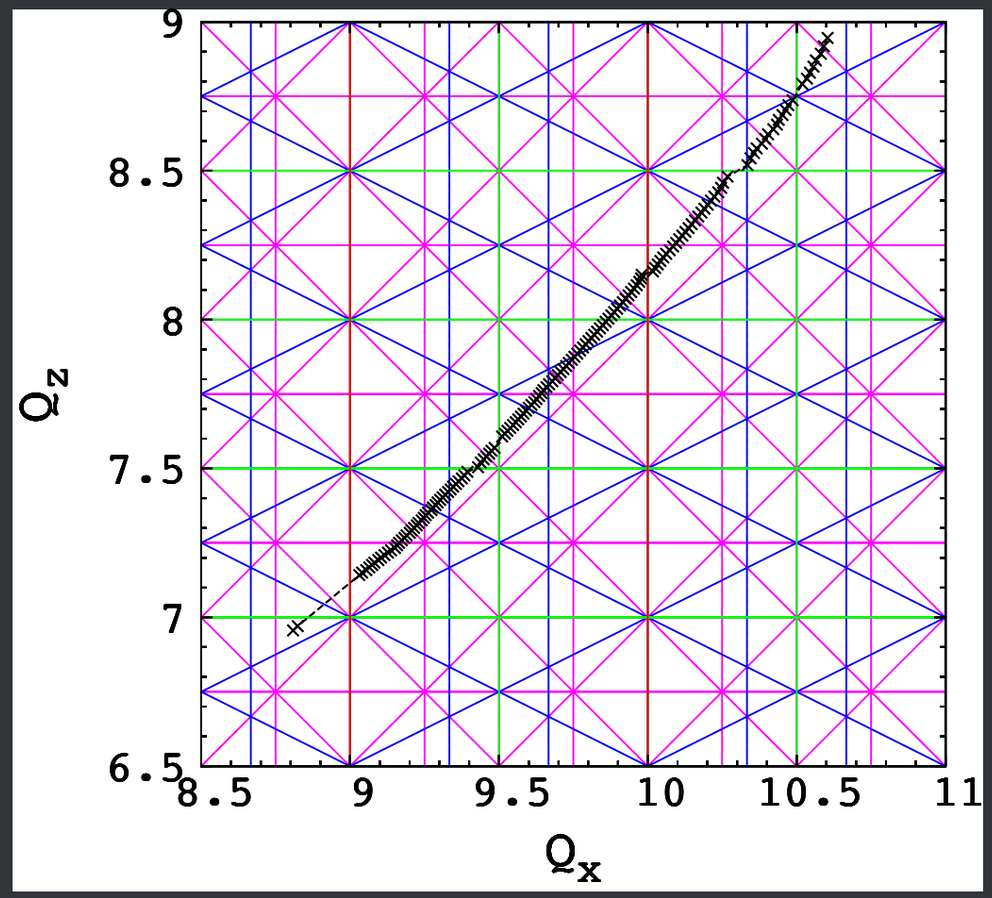
Ring type	F0D0
Circumference	535.9 m
Straight length	181.56 m
Particle	muon
Central momentum p_0	3.8 GeV/c
Ring tune point (H/V)	(6.23, 7.21)
Chromaticity (H/V)	(-3.21, -12.73)



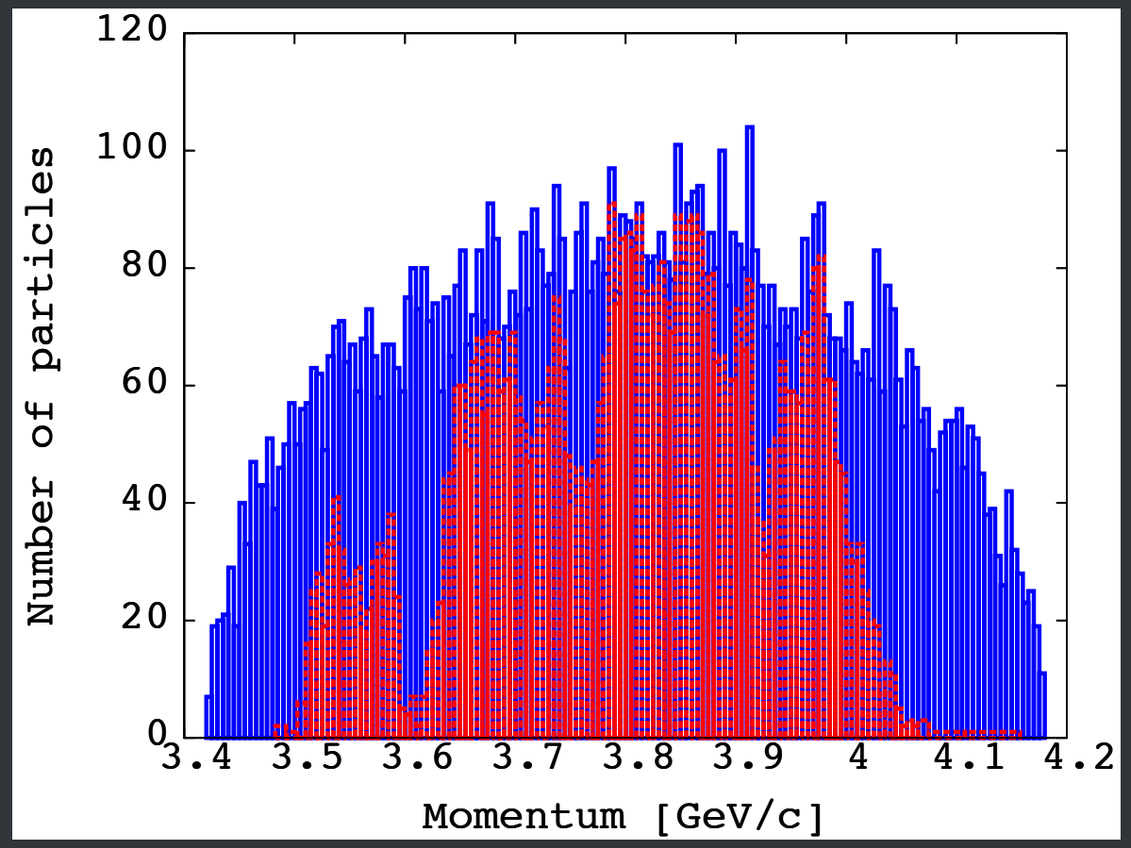
FODO losses





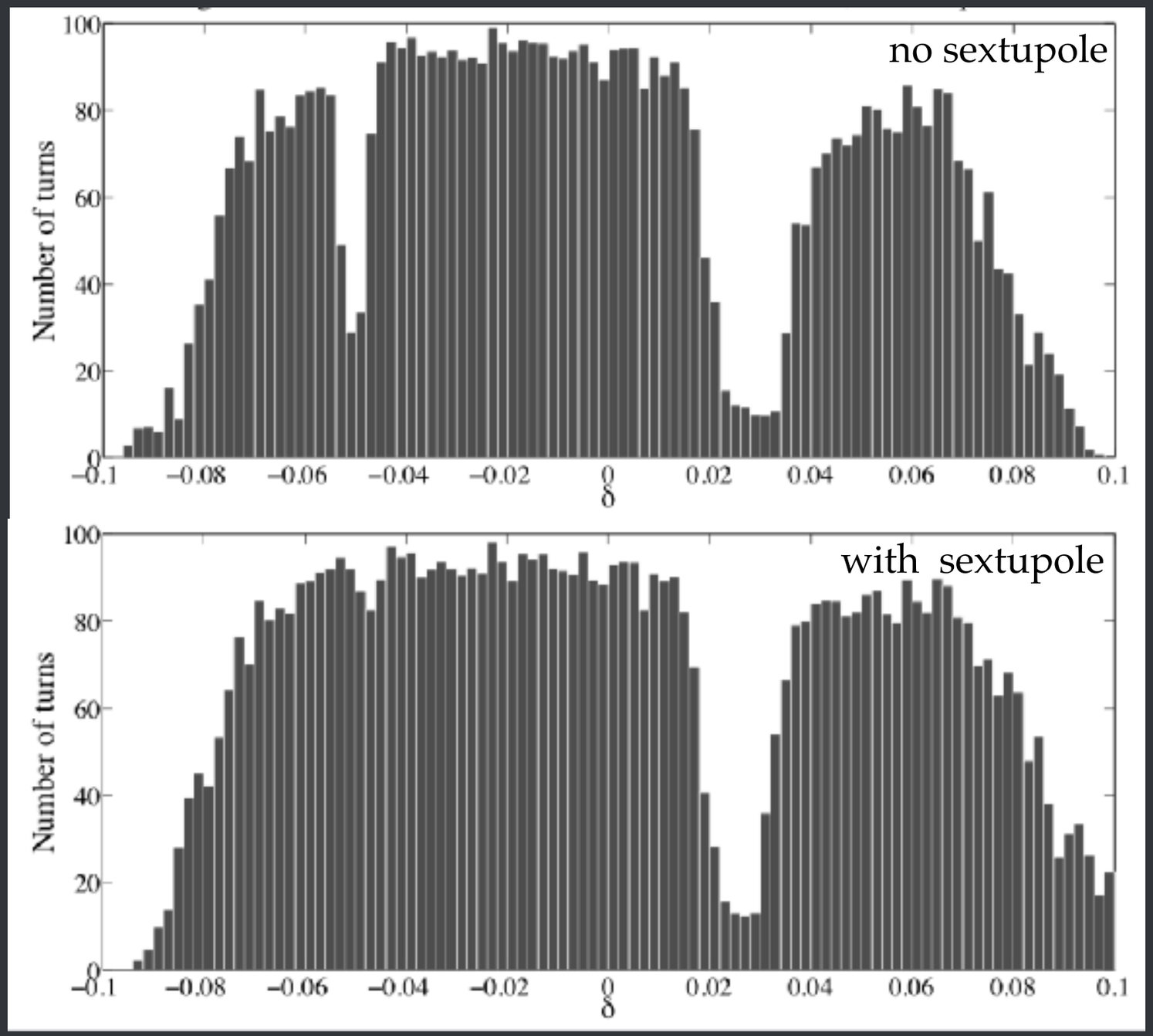


Tune spread for -8% and +9% momentum, p_0 (9.71, 7.83)



Losses from waterbag distribution (ε=2 mm)

FODO with sextupoles



~10% improvement

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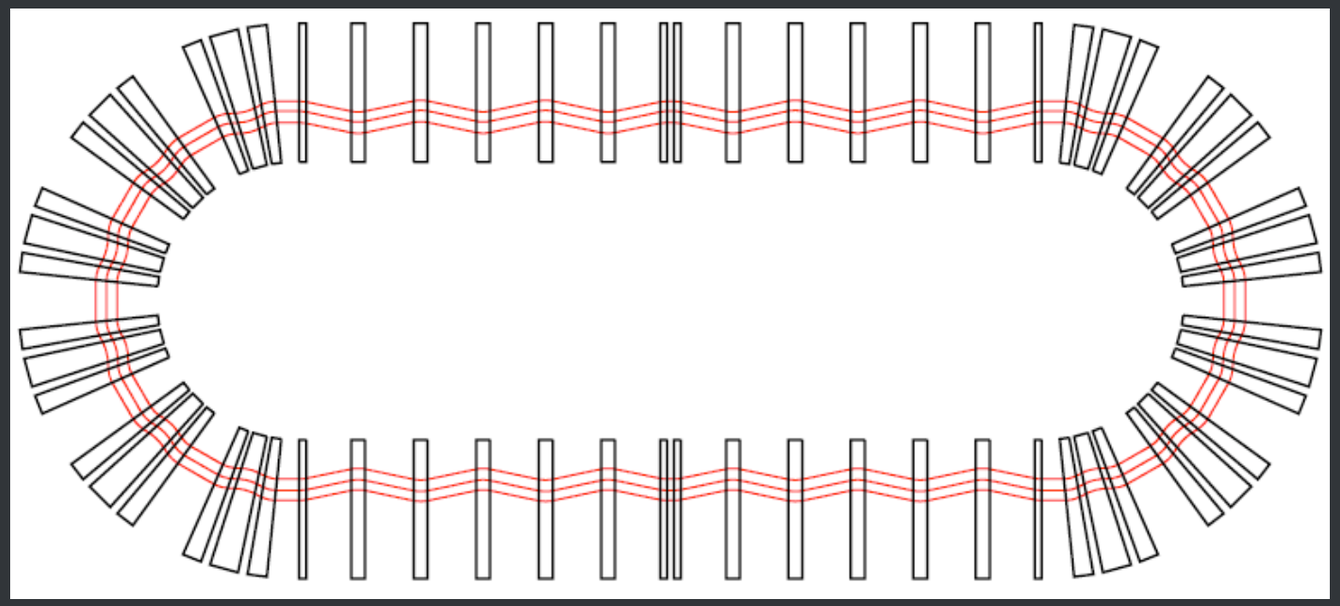
FFA solution



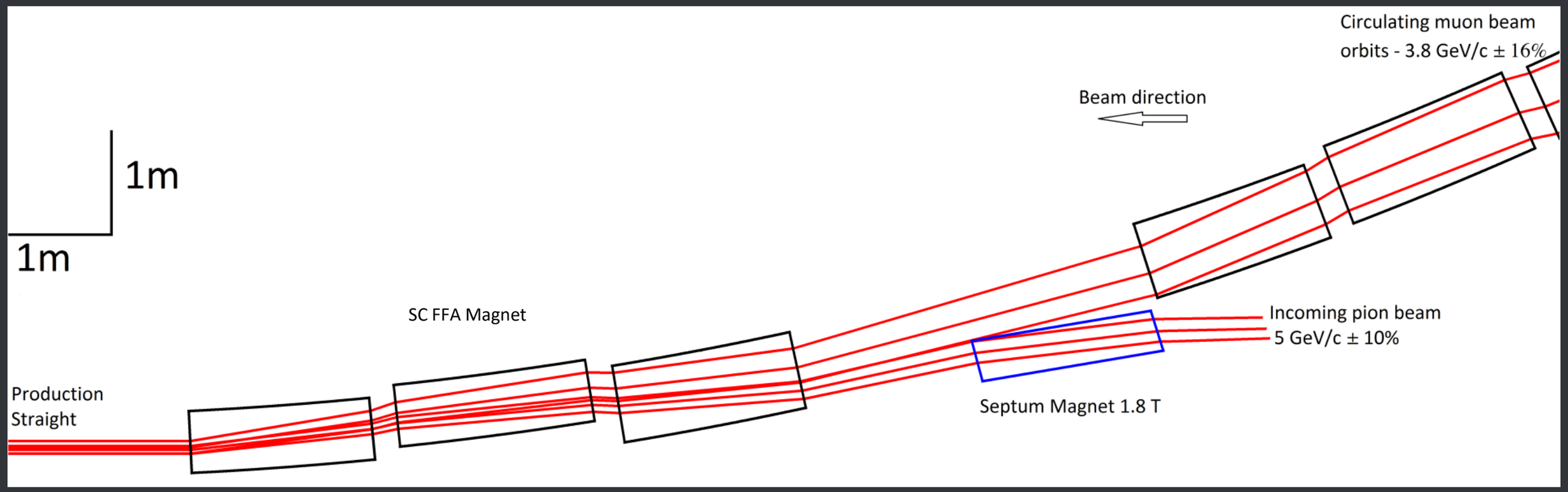
Designed with FixField.

- Pros:
  - Large momentum acceptance
  - Possible large transverse acceptance

→ Larger number of stored muons

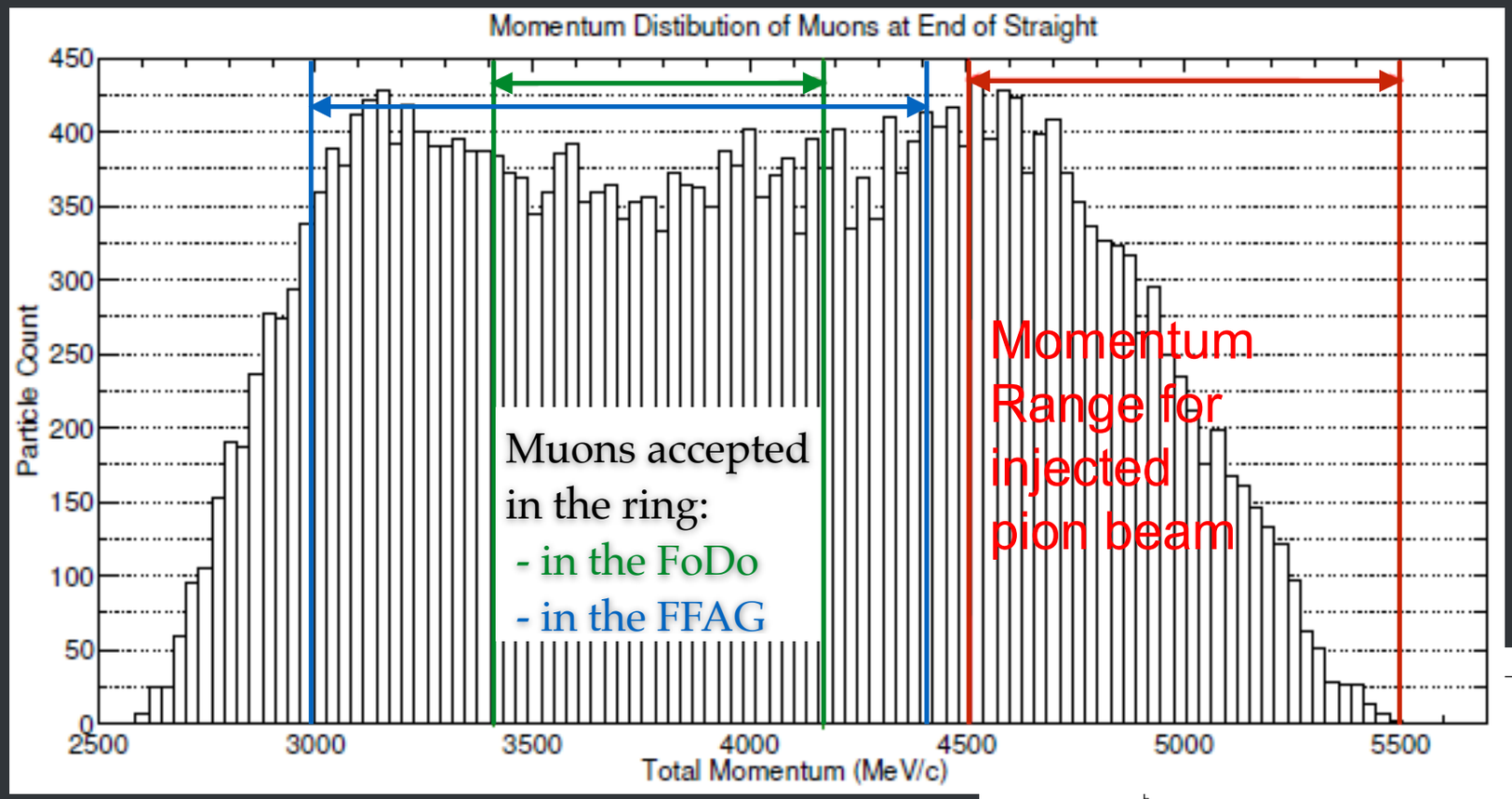
- Cons:
  - Scallop in the production spread
  - Reduced pion capture (dispersion in production straight)

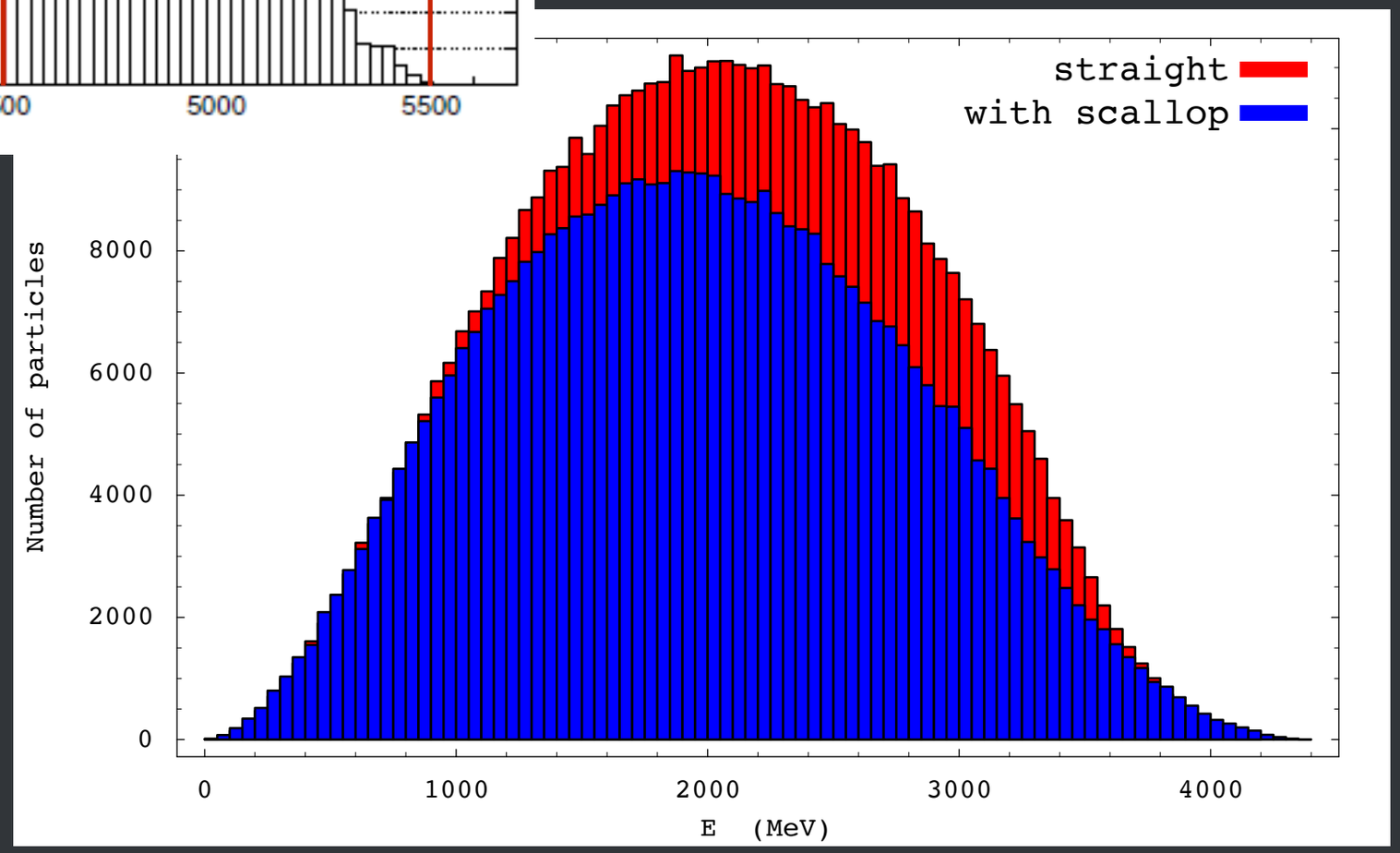
Stochastic injection



Stochastic injection also possible with septum magnet (no kicker)

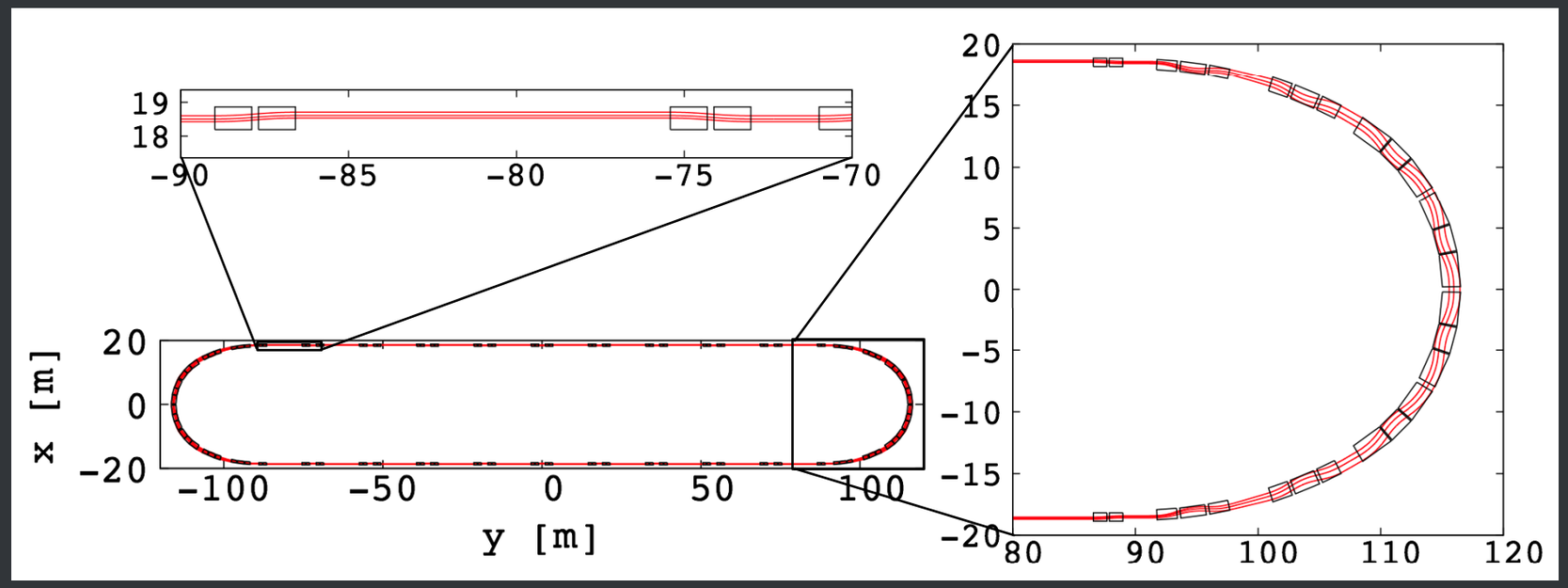
Momentum acceptance & Scallop effect



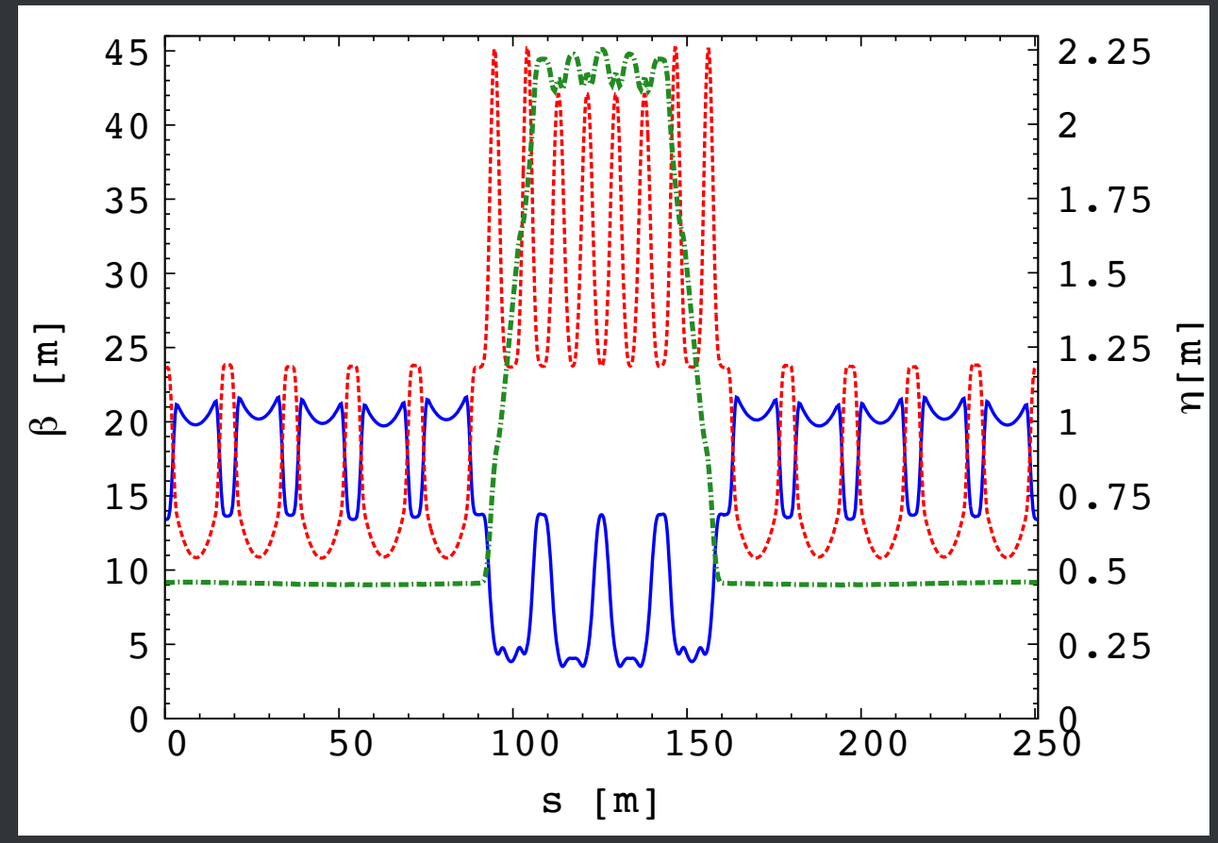


- Momentum acceptance: x2
- Scallop effect: ~20%

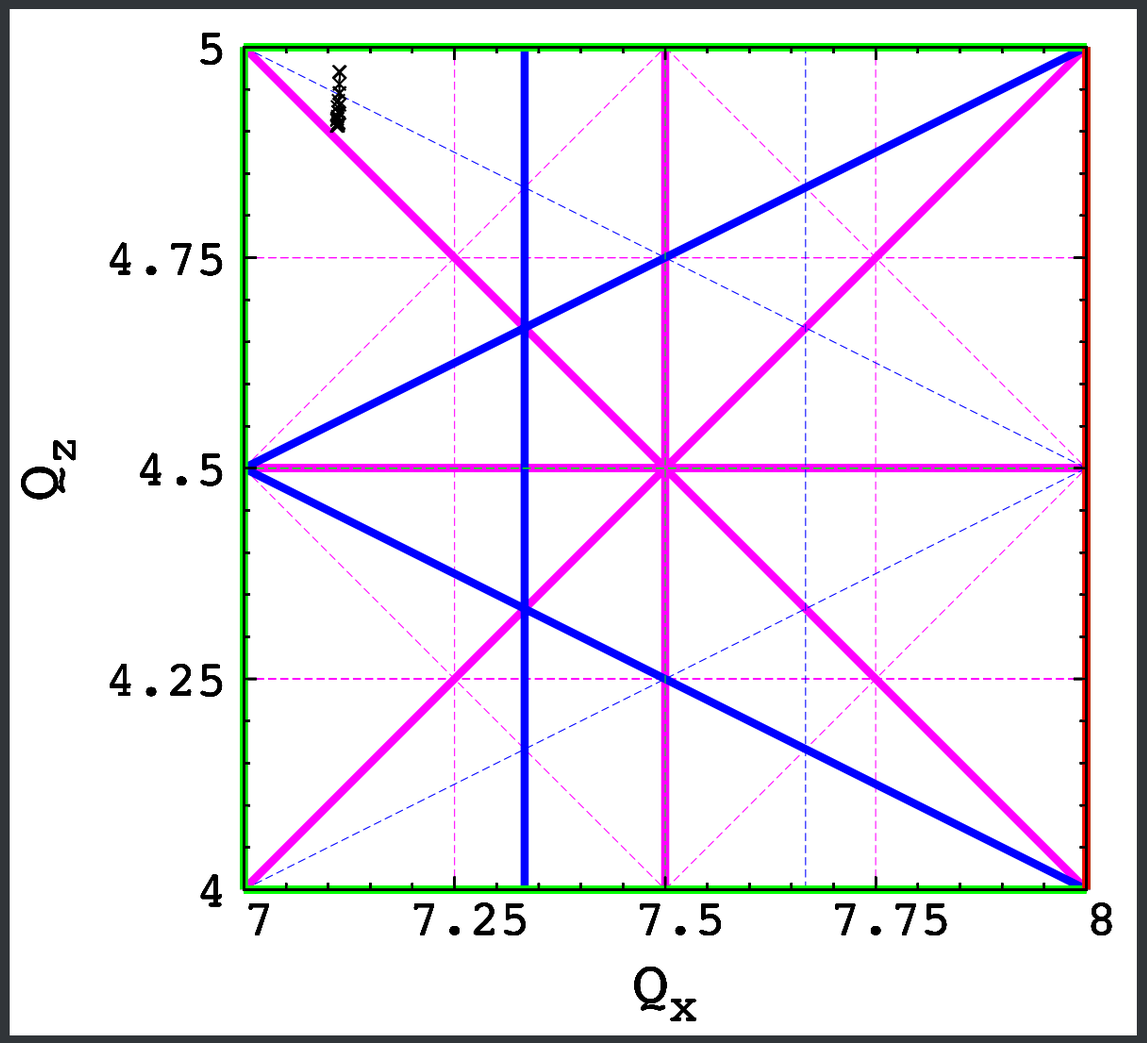
FFA quadruplet

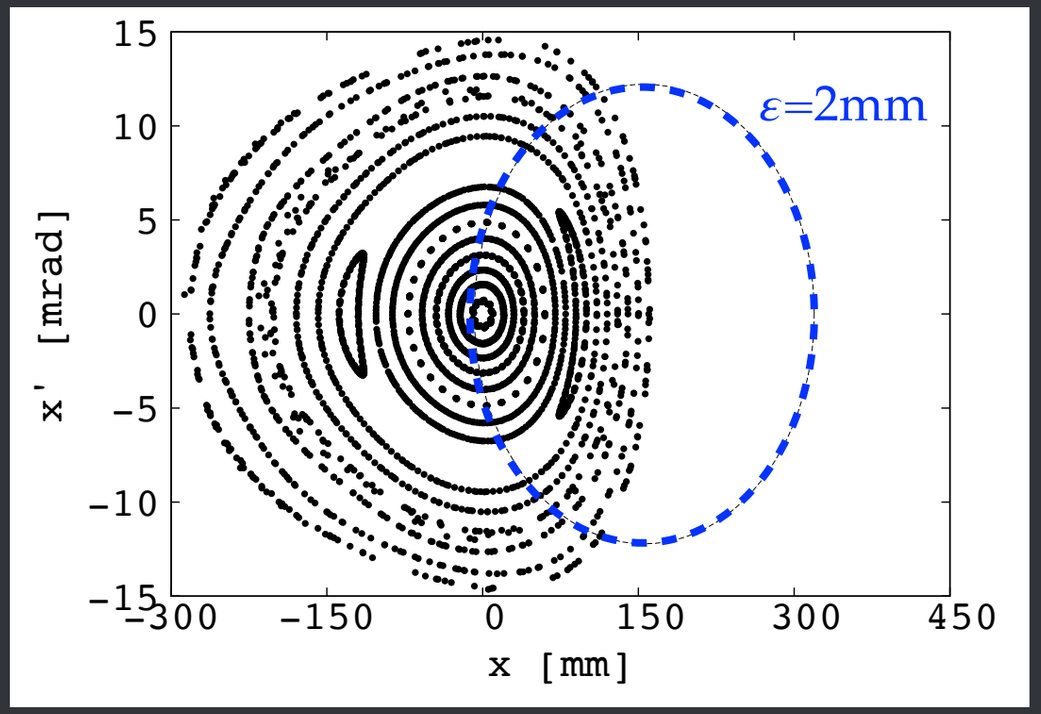


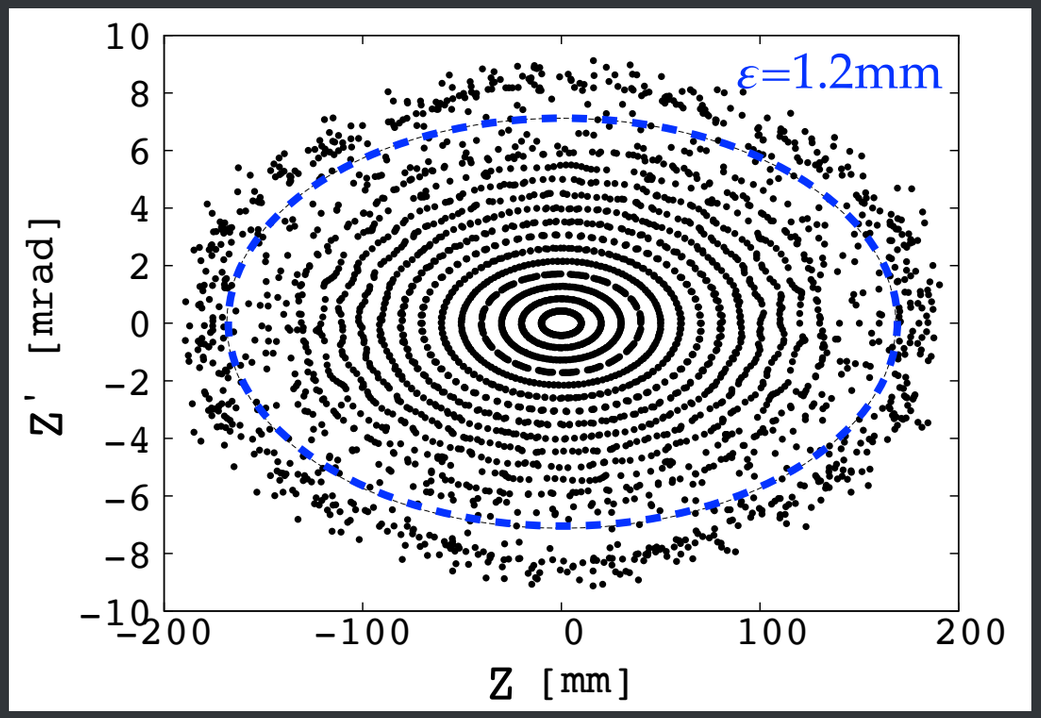
	Circular Section	Matching Section	Straight Section
Type	FDF	FDF	DFFD
Cell radius/length [m]	15.8	36.1	18
Opening angle [deg]	30	15	
k-value/m-value	6.056	26.027	2.2 m^{-1}
Packing factor	0.92	0.58	0.24
Maximum magnetic field [T]	2.9	3.3	1.7
horizontal excursion [m]	1.5	0.9/1.3	0.7
Full gap height [m]	0.5	0.5	0.3
Average dispersion /cell [m]	2.24	1.34	0.45
Number of cells /ring	4×2	4×2	10×2



FFA quadruplet







- Tune spread ±19%
- Single particle DA study
- Pion capture issue!

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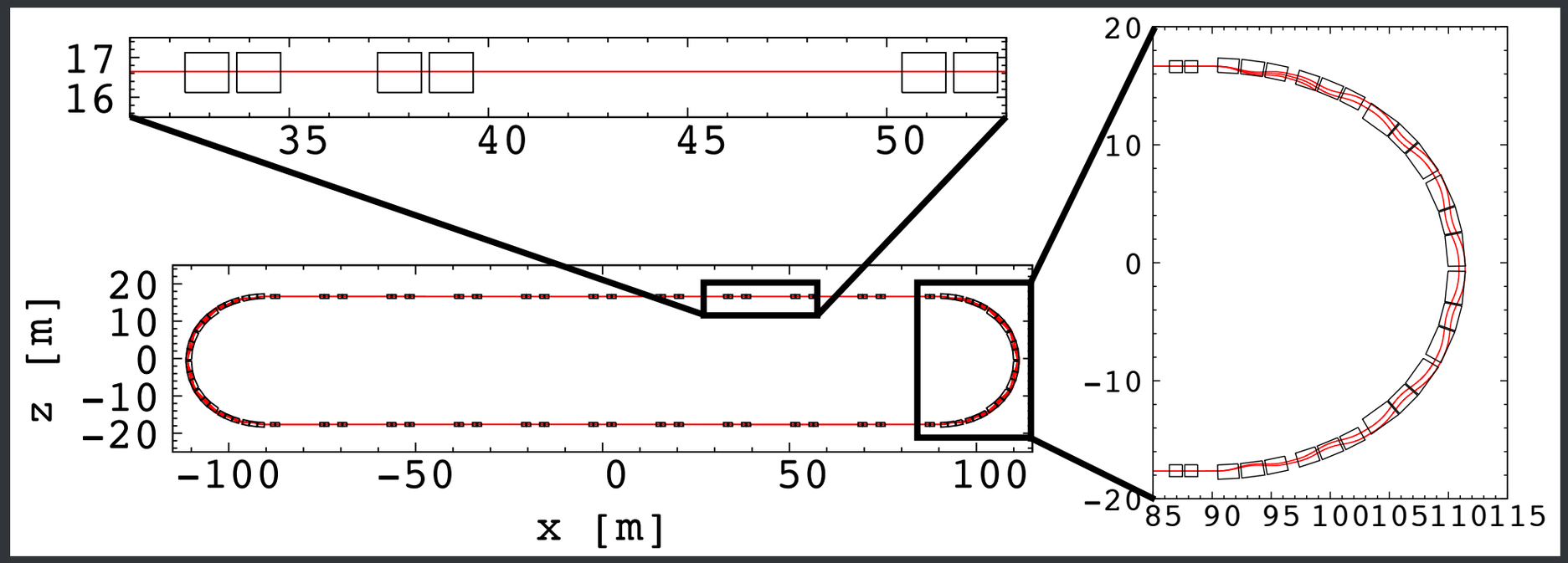
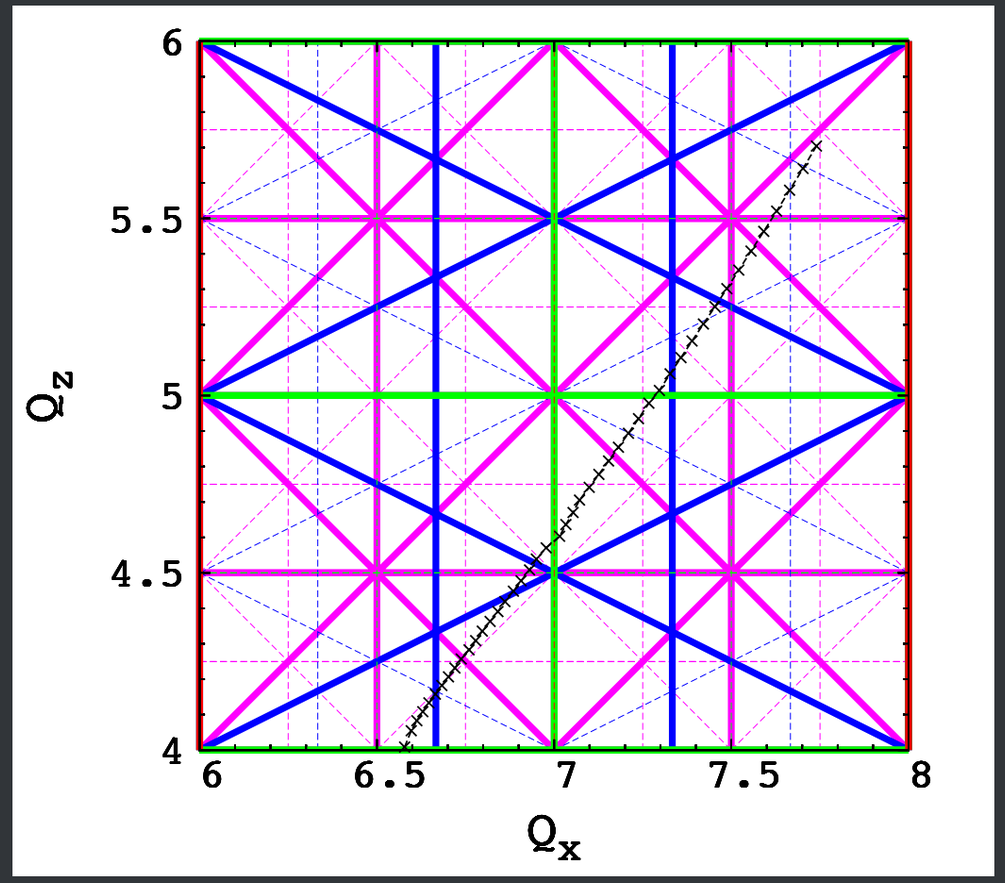
Hybrid solution

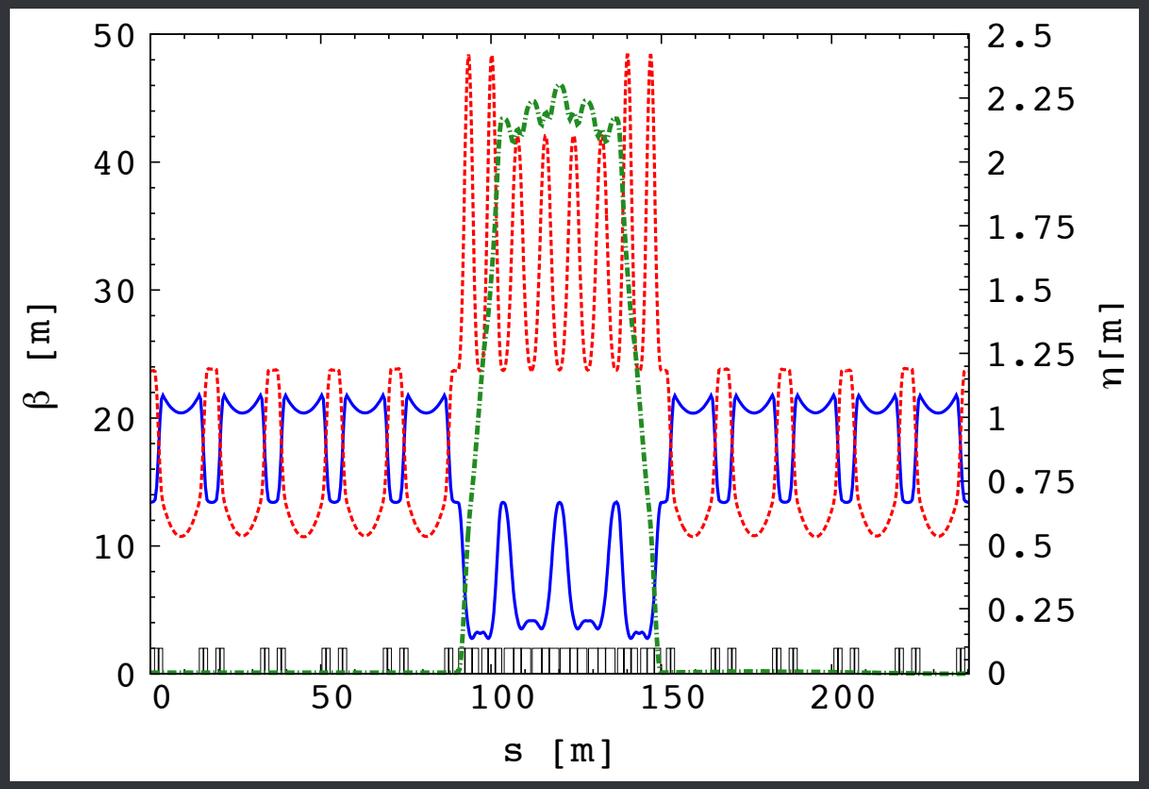
- Zero-dispersion straight section for injection/production
- FFA magnets in the arcs.

→ keep large transverse and longitudinal acceptance, with high capture efficiency.

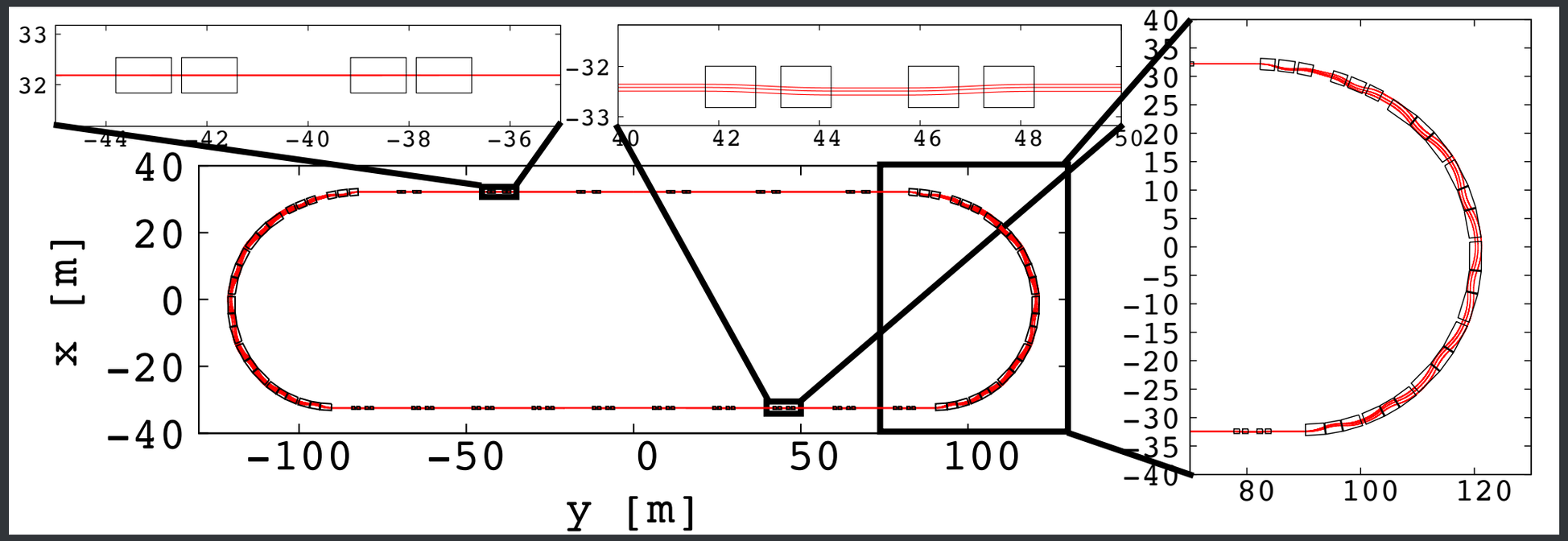
First attempt: 2-fold symmetry

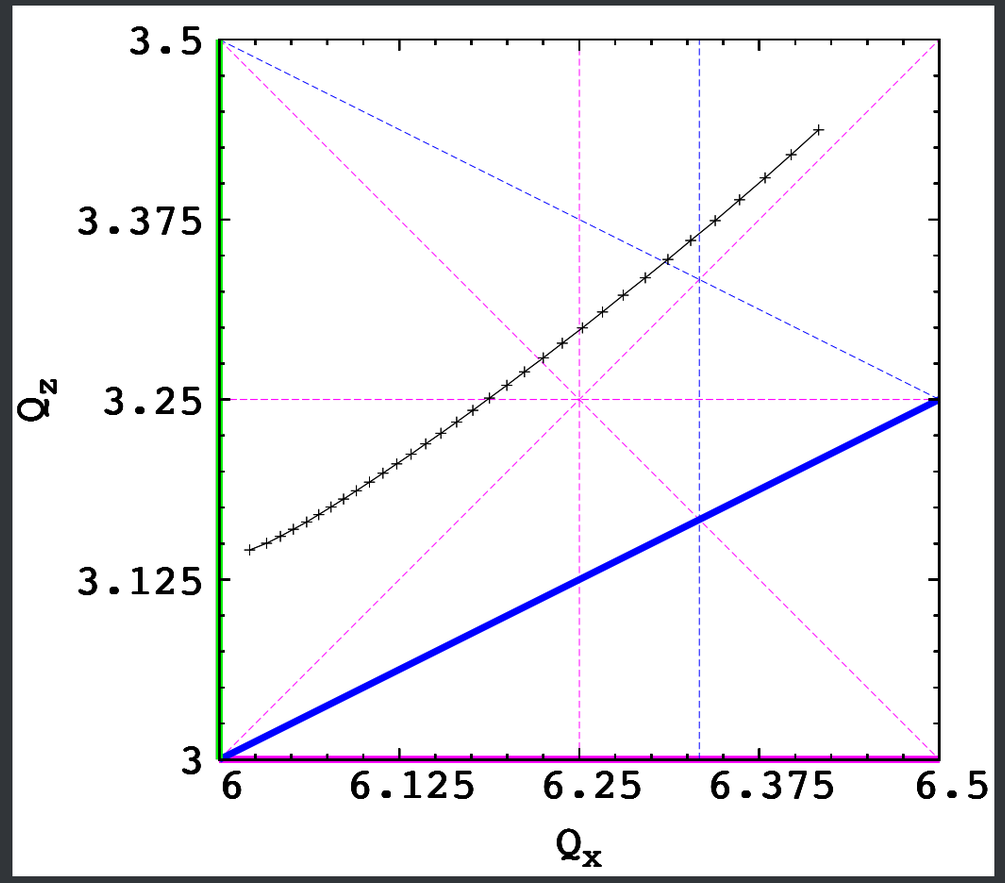


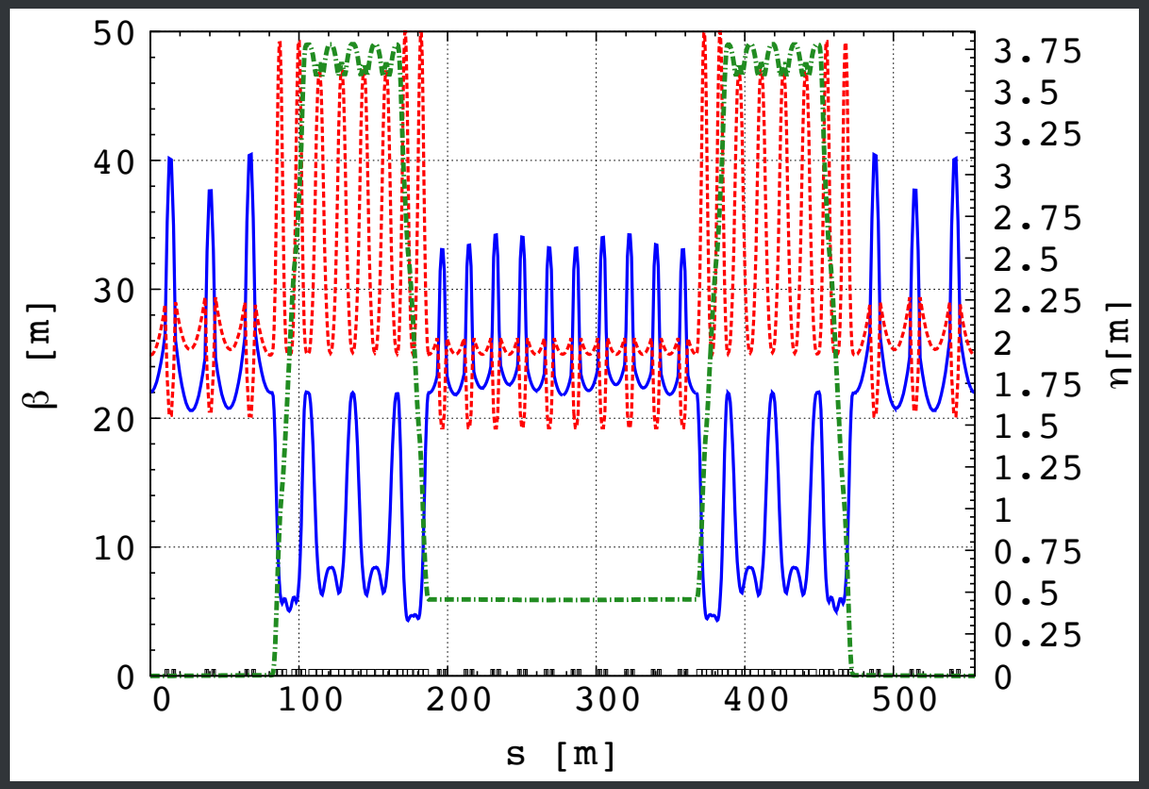




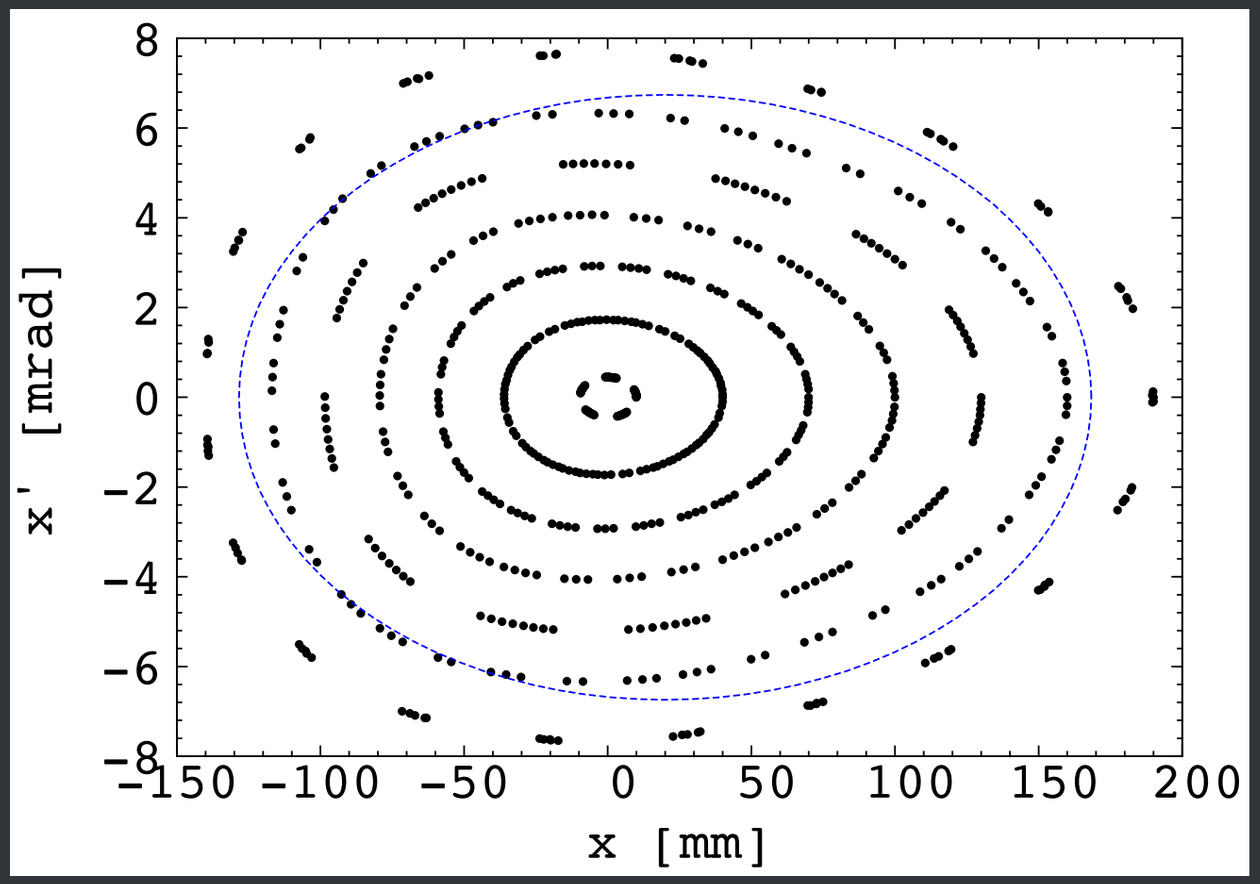
Second attempt:1-fold-symmetry



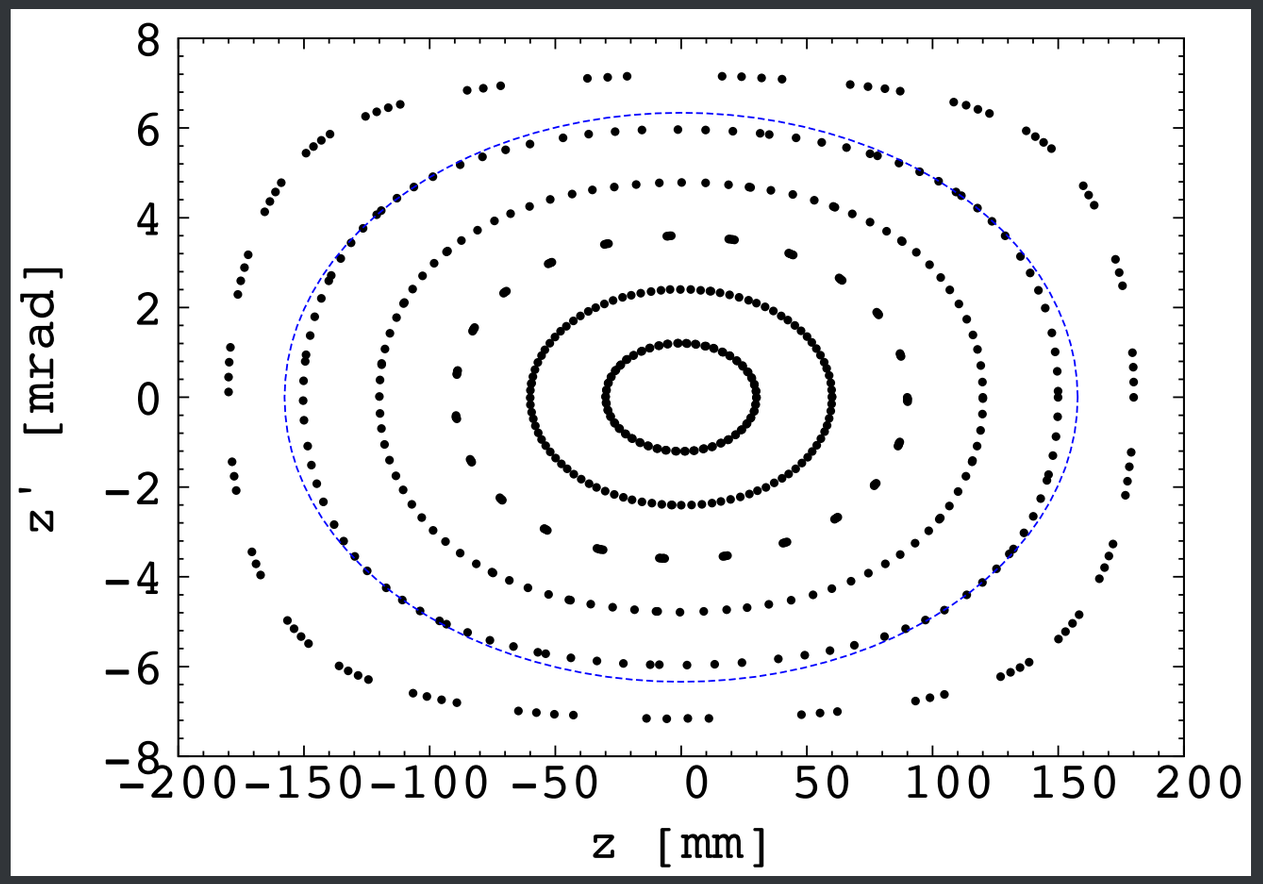




Single particle DA study

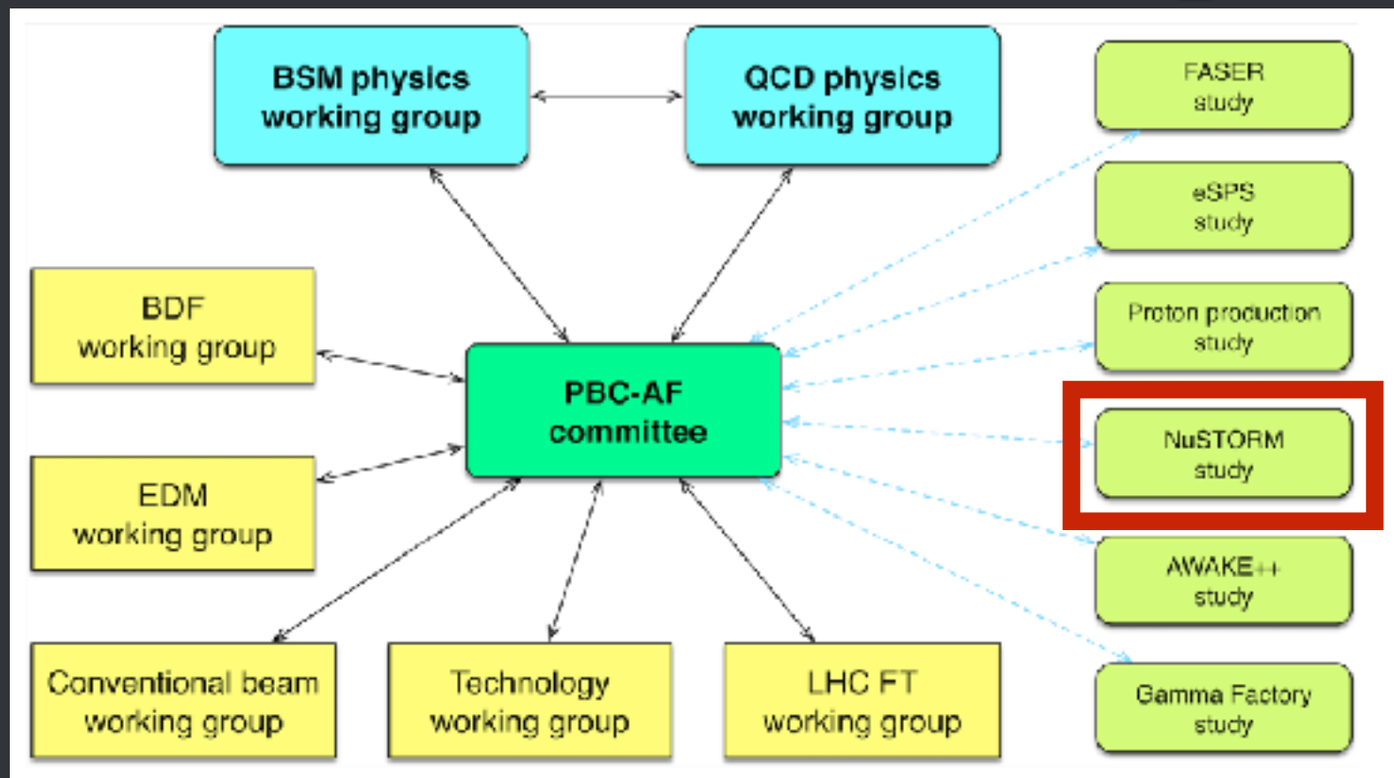


Maximum horizontal stable amplitude over 100 turns

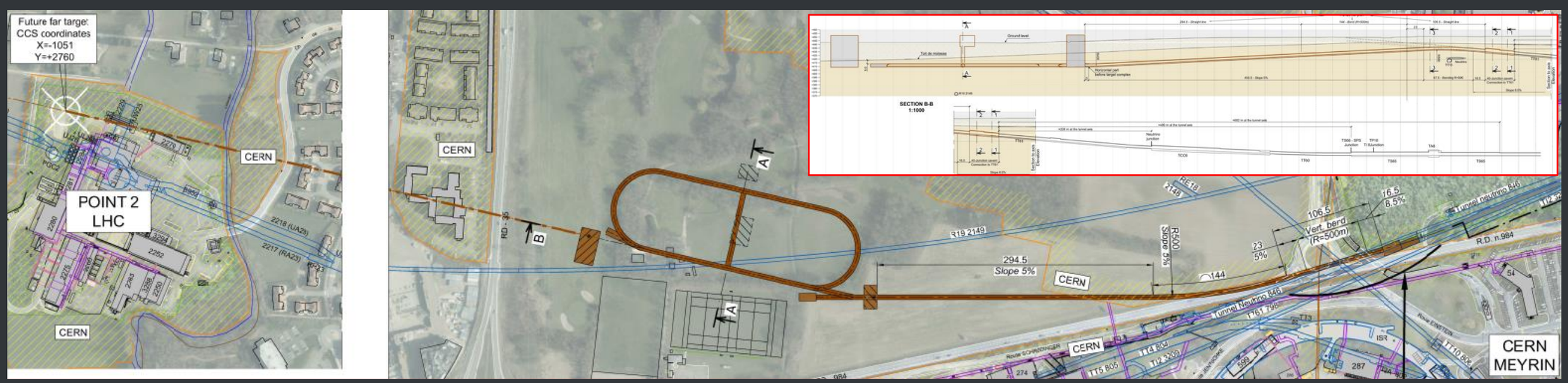


Maximum vertical stable amplitude over 100 turns

Studied implementation at CERN

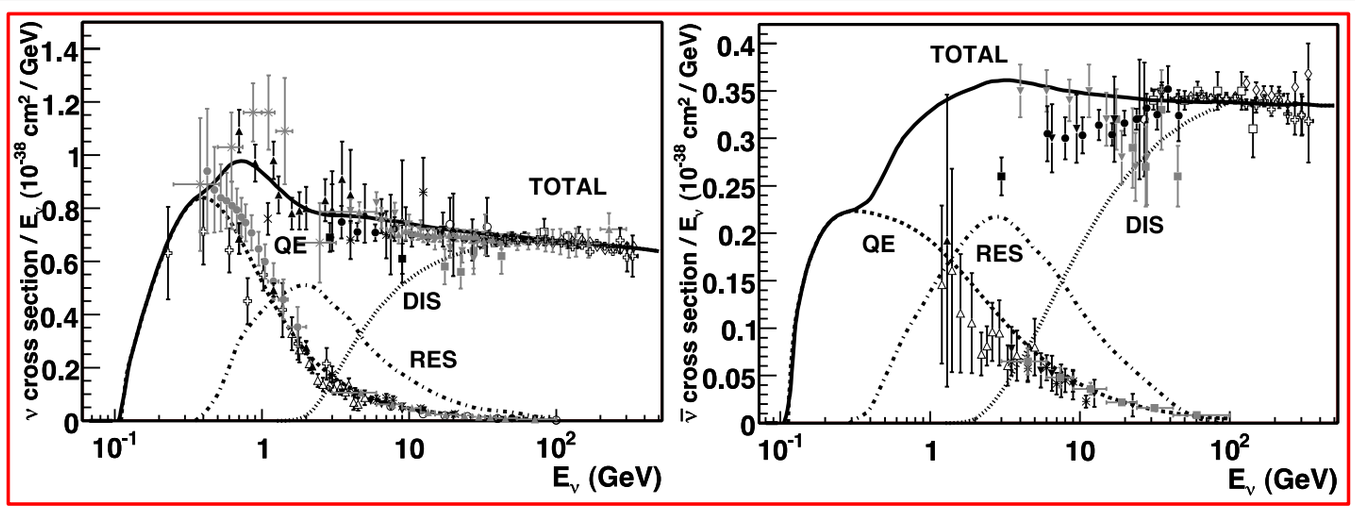


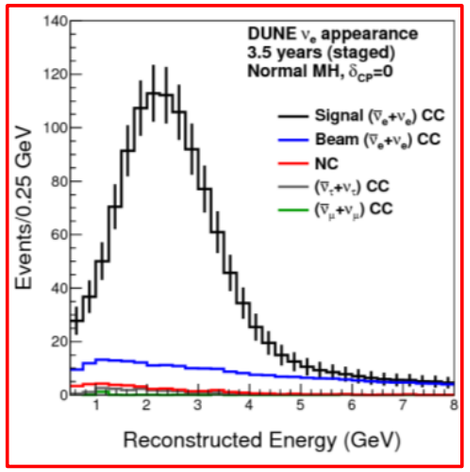
- Muon energy range
- SPS requirements
- Fast extraction, beam-line
- Siting
- Target and target complex
- Horn
- Civil engineering
- Radiation-protection implications

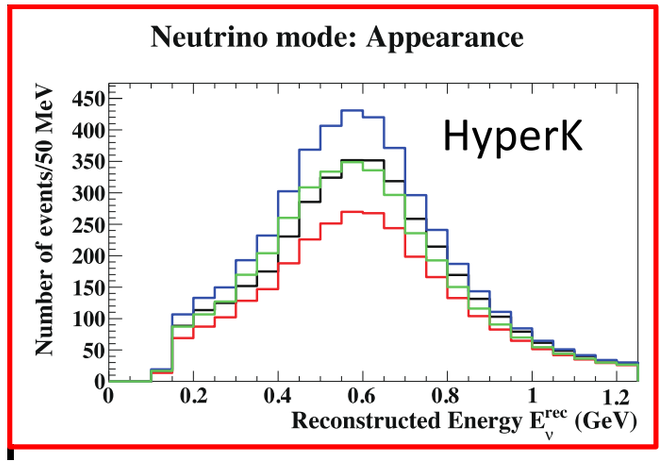


New energy range

- Guidance from
  - Models - region of overlap: 0.5 - 8 GeV
  - DUNE/Hyper-K far detector spectra: 0.3-6 GeV
- Cross sections depend on Q^2 and W (reconstructed by detector)

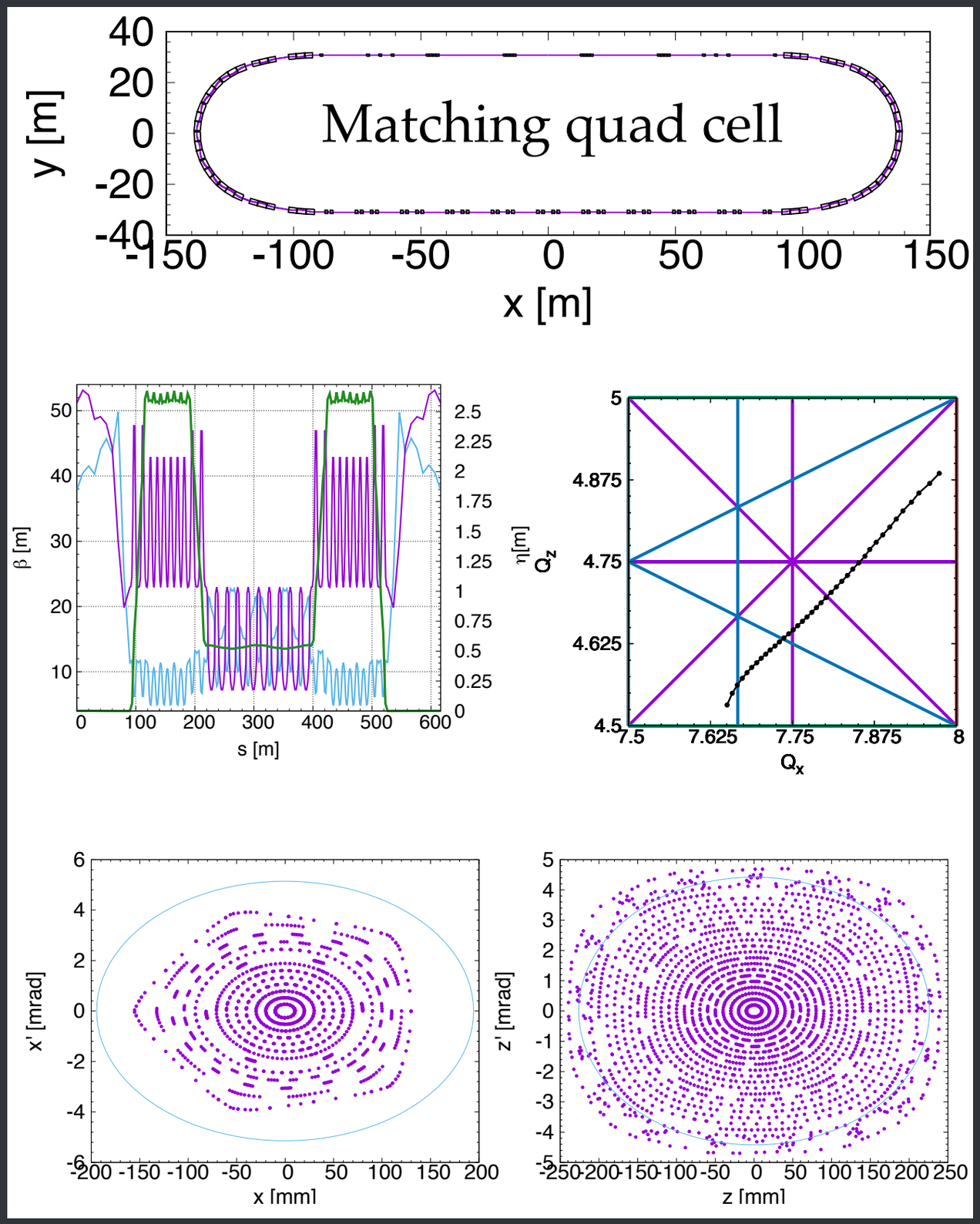


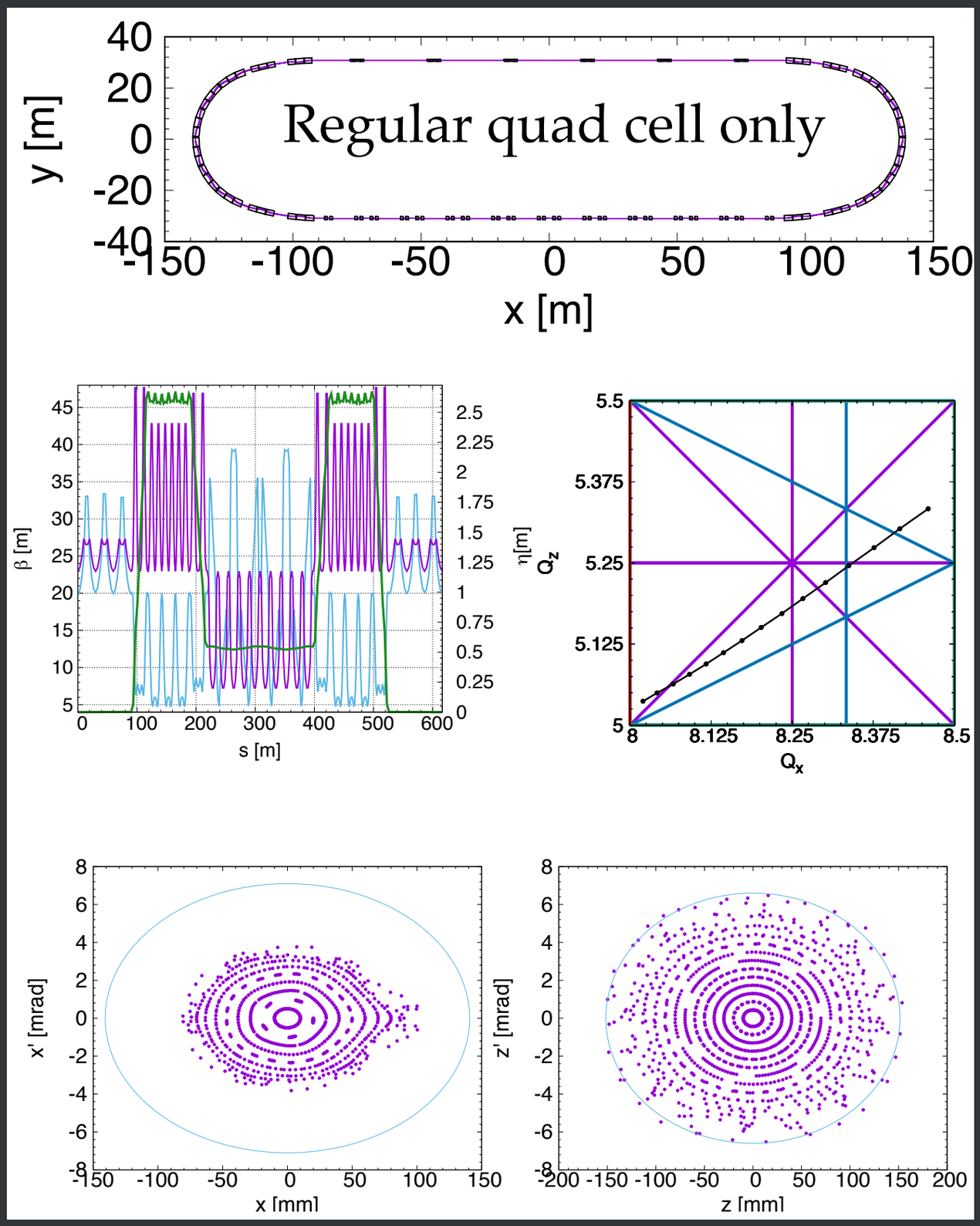




$$1\ \text{GeV} < E_\mu < 6\ \text{GeV}$$

Third attempts: reduced dispersion





Future plans & Summary

- nuSTORM can measure neutrino interaction precisely, which can reduce systematic errors of neutrino oscillation experiments seeking CP violation signal (Hyper-K, DUNE) and can contribute to the sterile neutrino search.
- Siting at CERN option was identified (within PBC) and civil engineering study is in the advanced stage.
- Promising results for hybrid solution, to be finalised (recover horizontal DA).
- Further design optimisation to continue within PBC and report will be submitted to the European Particle Physics Strategy Update.
- Computation and comparison of the neutrino flux to choose the preferred lattice.