Demonstrator for Cooling Design Considerations

Science & Technology Facilities Council
ISIS Neutron and Muon Source

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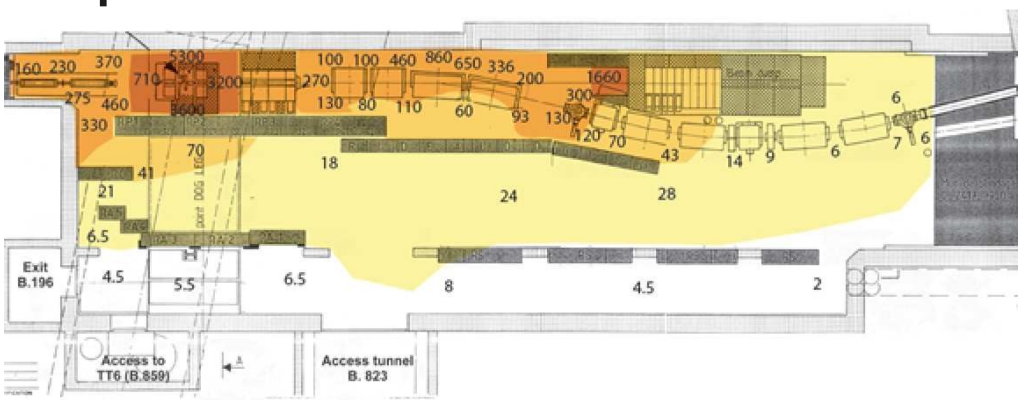
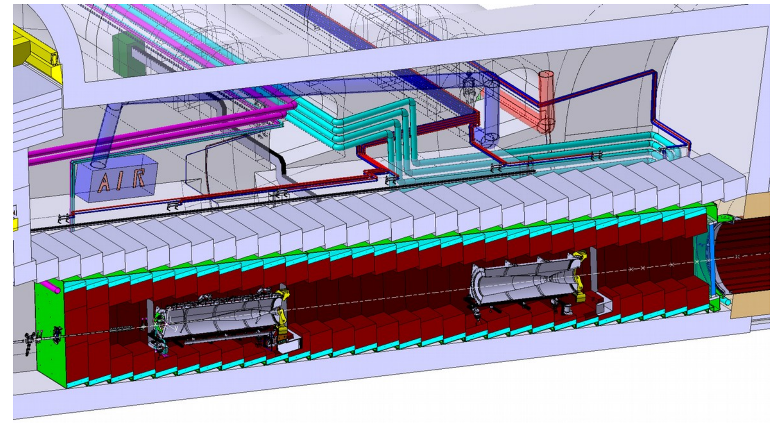
Rutherford Appleton Laboratory

νSTORM

International
MUON Collider
Collaboration

NuSTORM Accelerator Challenges





- Capture of high current pion beam
  - Normal conducting transport line near target
- Containment of muon beam
  - Large momentum spread and transverse size
  - FODO-based storage ring or FFA combined function storage ring

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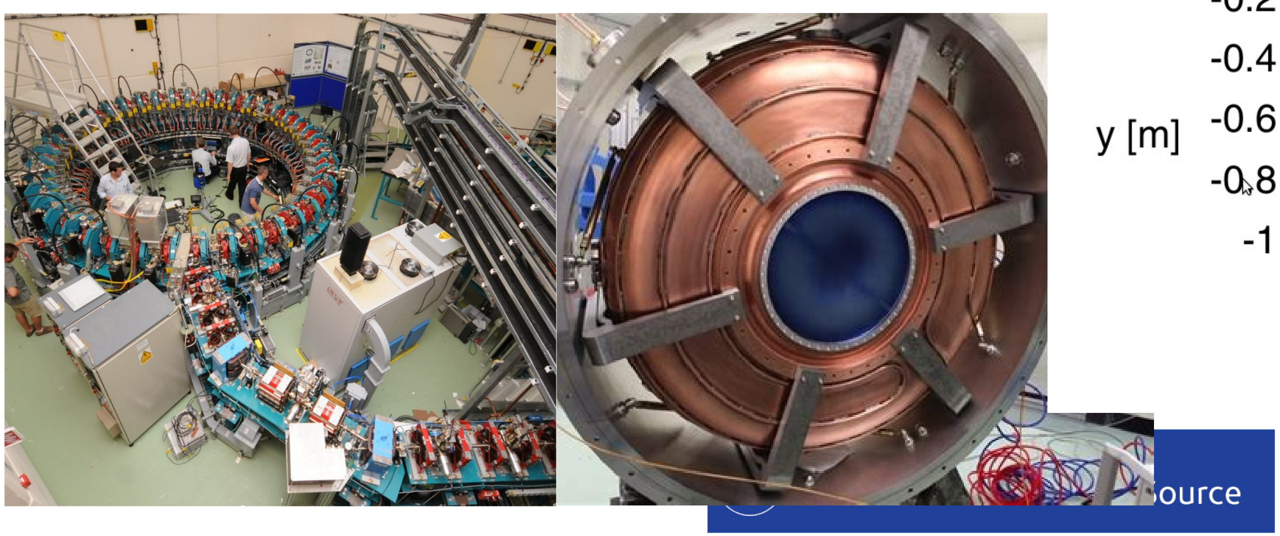
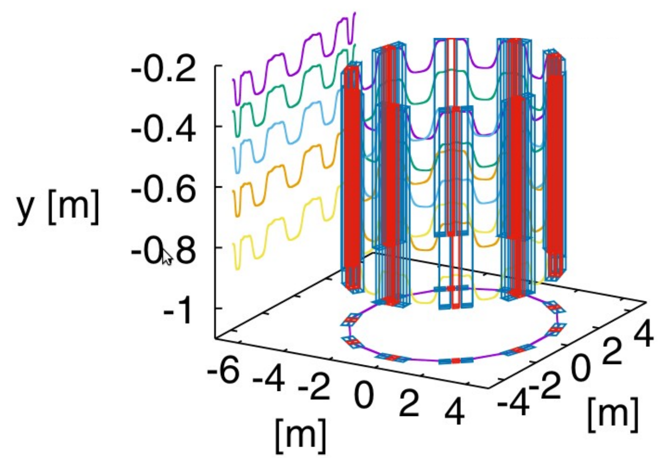
Muon Collider Challenges

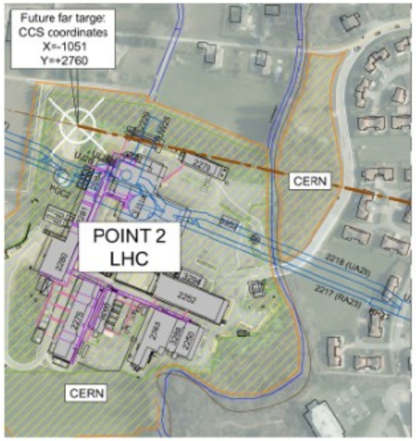
- Capture of high current pion beam
  - Superconducting transport line near target
- Muon Cooling
- Rapid acceleration and storage
  - FODO-based RCS or FFA combined function acceleration ring

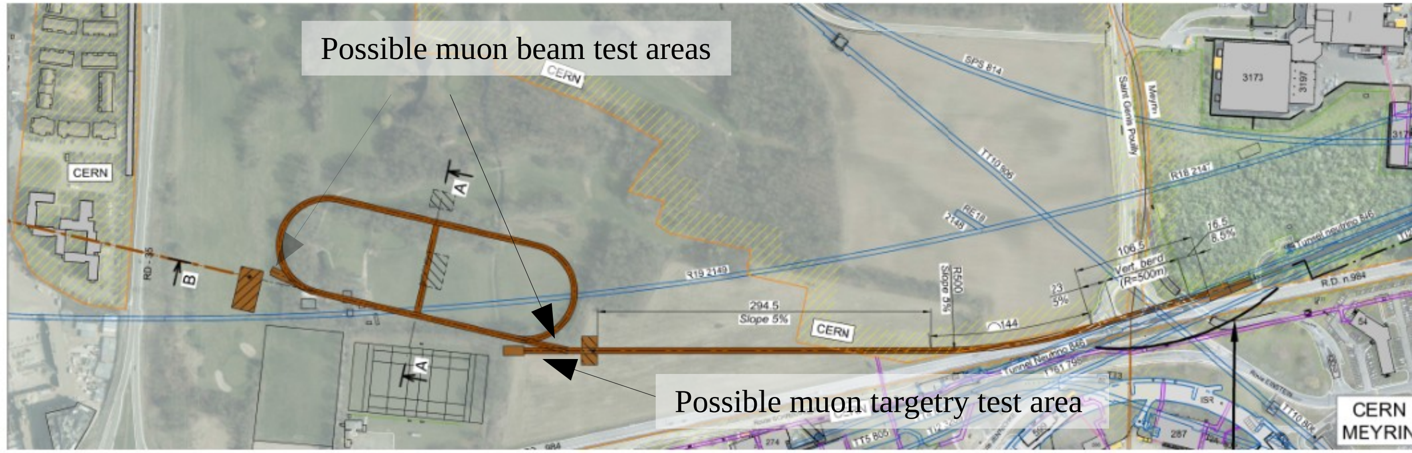


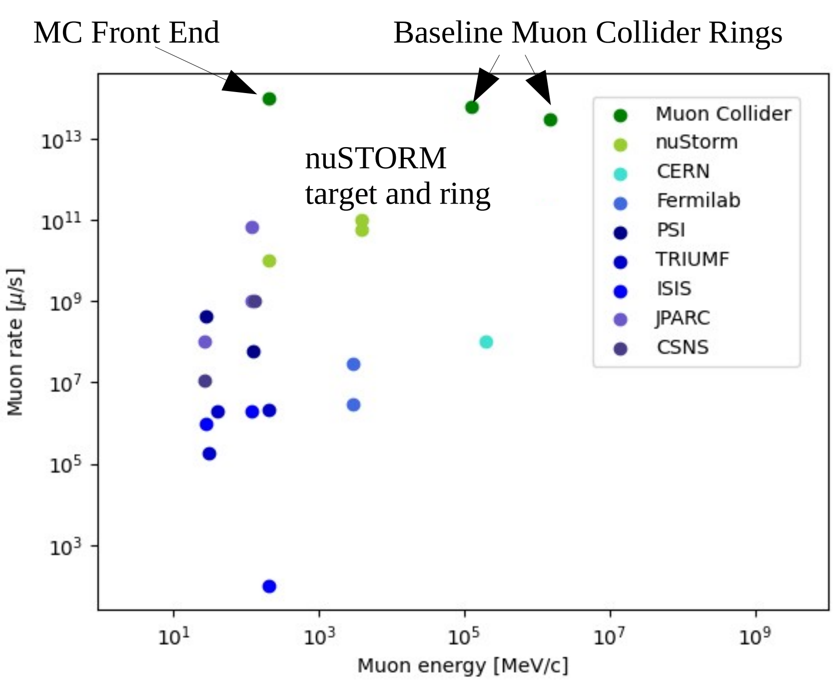
Low energy vFFA PoP
Arxiv 2011.10783 (accepted in PRAB)



Survey of Muon Beamlines

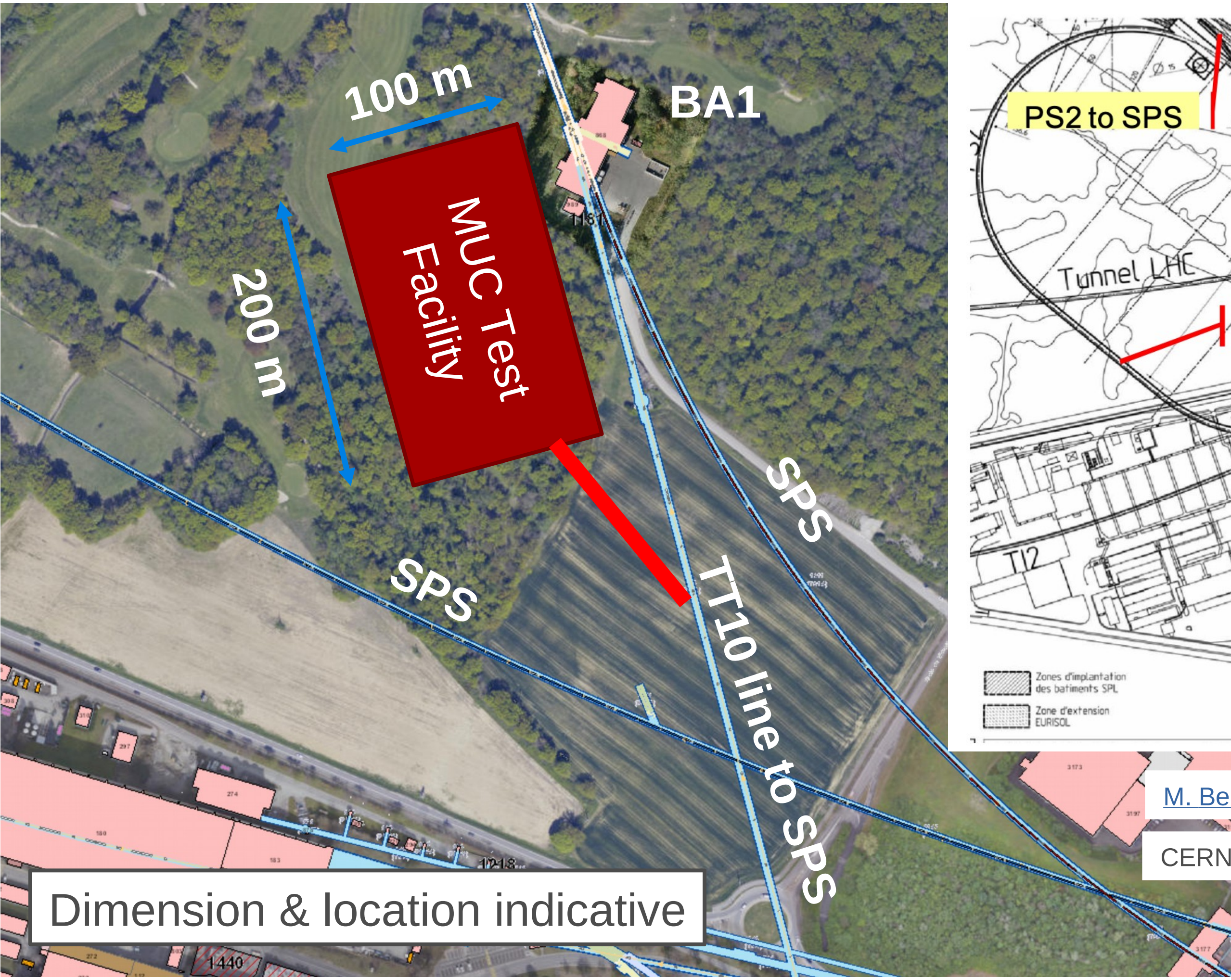


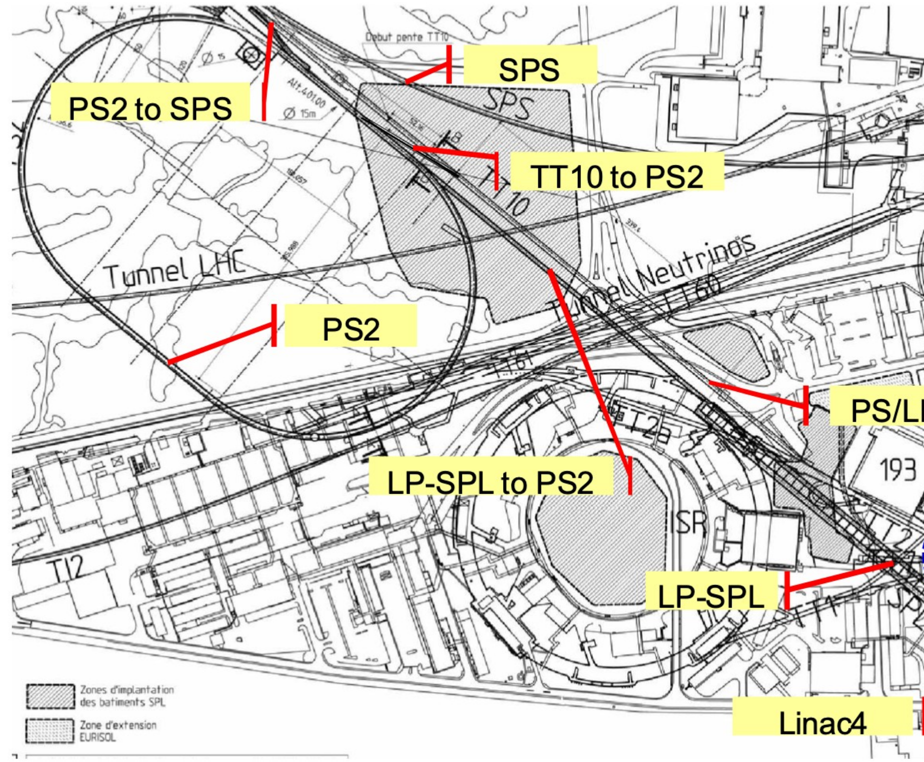




- NuSTORM would make an excellent facility
  - One of the highest current high energy muon beams
- Target/irradiation test area
- Muon beam physics tests
  - Especially **Muon Cooling**

PS-based option (M. Calviani)





M. Benedikt, LHC Performance Workshop, Chamonix 2010

CERN-AB-2007-061

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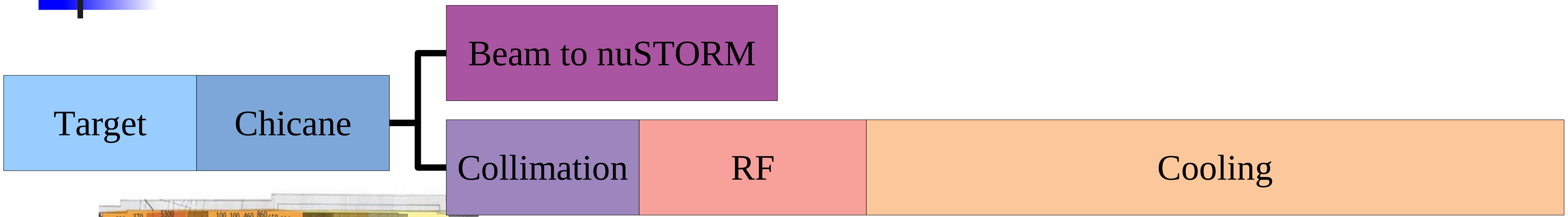
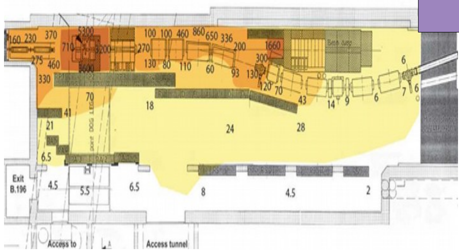
Beam test aims

- Headlines
  - 6D cooling
  - Reacceleration
  - Cooling at low emittance (longitudinal and transverse)
- More details
  - Engineering integration
  - High-gradient RF cavity in magnetic field
  - Fancy optics
  - High field magnets
  - Absorber infrastructure
  - Matching between different cooling cells
  - Energy straggling
  - Intensity effects
  - Diagnostics
  - Alignment and correction
  - Commissioning
  - Day-to-day operation and maintenance

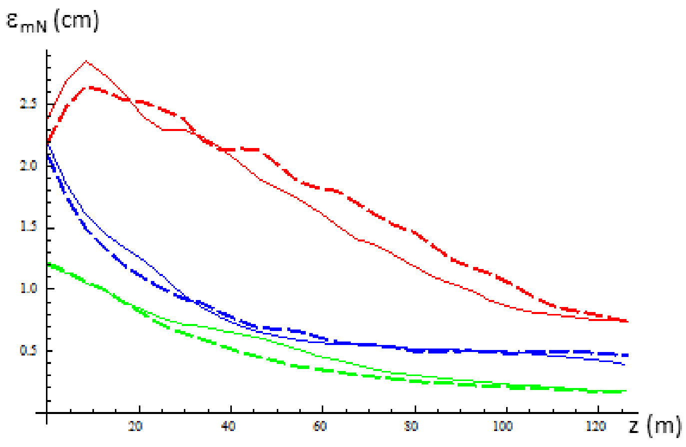
Muon beam test area layout

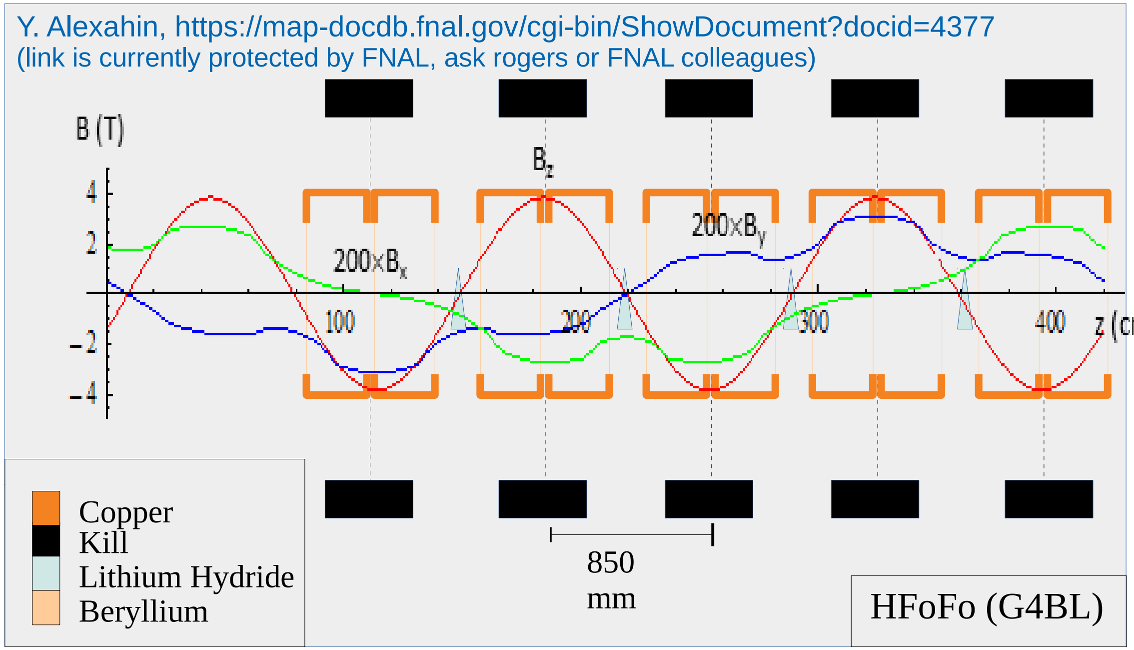




- Basic layout foreseen
  - Target
  - Chicane – first momentum selection (~200 MeV/c muons)
  - Transverse collimation
  - RF to set up the bucket
  - Maybe another short chicane
  - Cooling
- Various cooling channel options under study
  - Balance cost vs performance
  - Would like a clear signal of cooling using more-or-less conventional diagnostics → significant cooling factor

HFoFo Lattice





- HFoFo cooling channel
  - LiH wedges foreseen, but could be adapted to lH2
  - On the easier end of considered lattices
    - More like “MICE but with 6D cooling”
  - Reasonably good dynamic range in emittance

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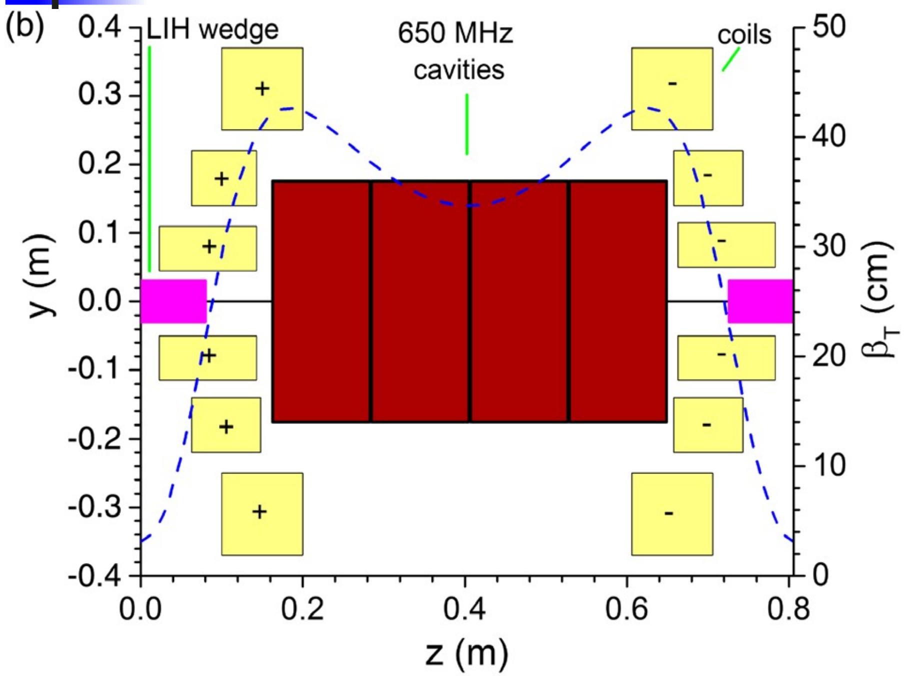
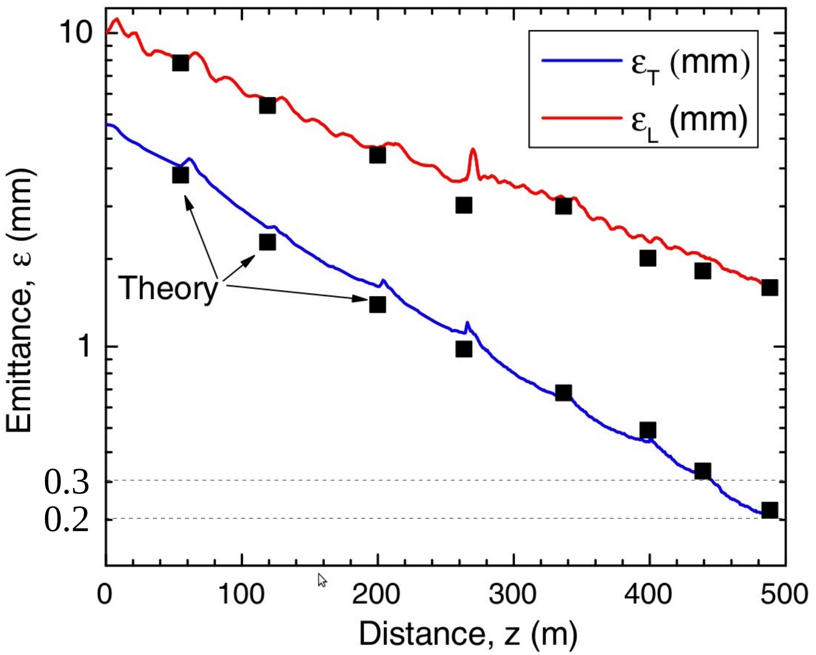
Rectilinear B8 Lattice



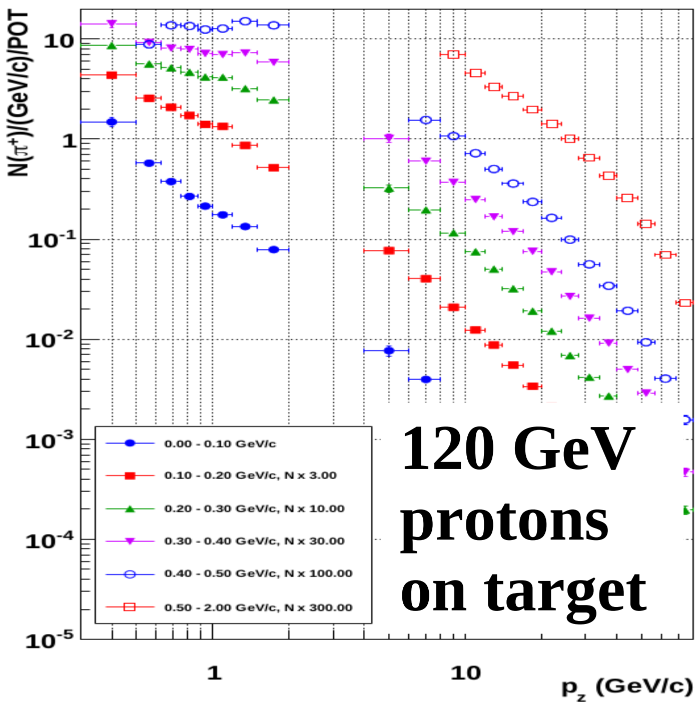


- Rectilinear B8 lattice
  - LiH wedges foreseen; not easily adapted to lH2 due to large opening angle
  - At the harder end of considered lattices
    - Concern about magnet engineering
  - Less dynamic range

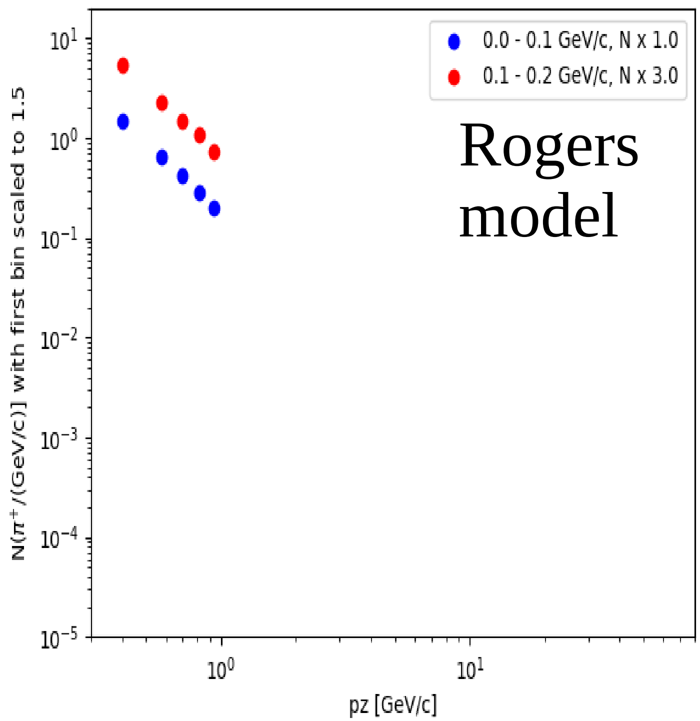
D. Stratakis et al, Rectilinear Six-Dimensional Ionization Cooling Channel for a Muon Collider: A theoretical and numerical study, PR ST AB 18 (2015)

Expected muon rate

Paley et al, Measurement of charged pion production yields off the NuMI target, PRD vol 90, 2014



(a)π^+ yields.



- Can guess at expected muon rate
  - Based on nuMI
  - Use sum of weighted Gaussian, tuned by eye

Expected muon rate

- Based on PS:
  - Shortest PS bunch is ~6 ns RMS (~20 ns total)
  - 7 10^{12} protons per bunch
  - Momentum selection → 6e-2 muons per proton
  - Time selection → 3e-3 muons per proton per cooling RF bucket
  - Transverse selection → 1e-6 muons per proton per RF bucket
  - Assume pion yield ~ beam energy → 20/120 [GeV] → 2e-7 muons per proton per RF bucket
  - Assume transport efficiency ~ 50 % → 1e-7 muons per proton per RF bucket
- Conclusion: 1e5 to 1e6 muons per RF bucket
  - Challenging for conventional diagnostics
- What is the bunch length for SPS?

Calviani et al, CERN n_TOF Facility: Performance Report,n _TOF-PUB-2010-001

Conclusions

- Cooling Demonstrator layout and initial calculations is proceeding
- Settling on options for cooling lattice parameters
- Starting to work up transport line model