Front End: End-to-End Design Overview

Diktys Stratakis

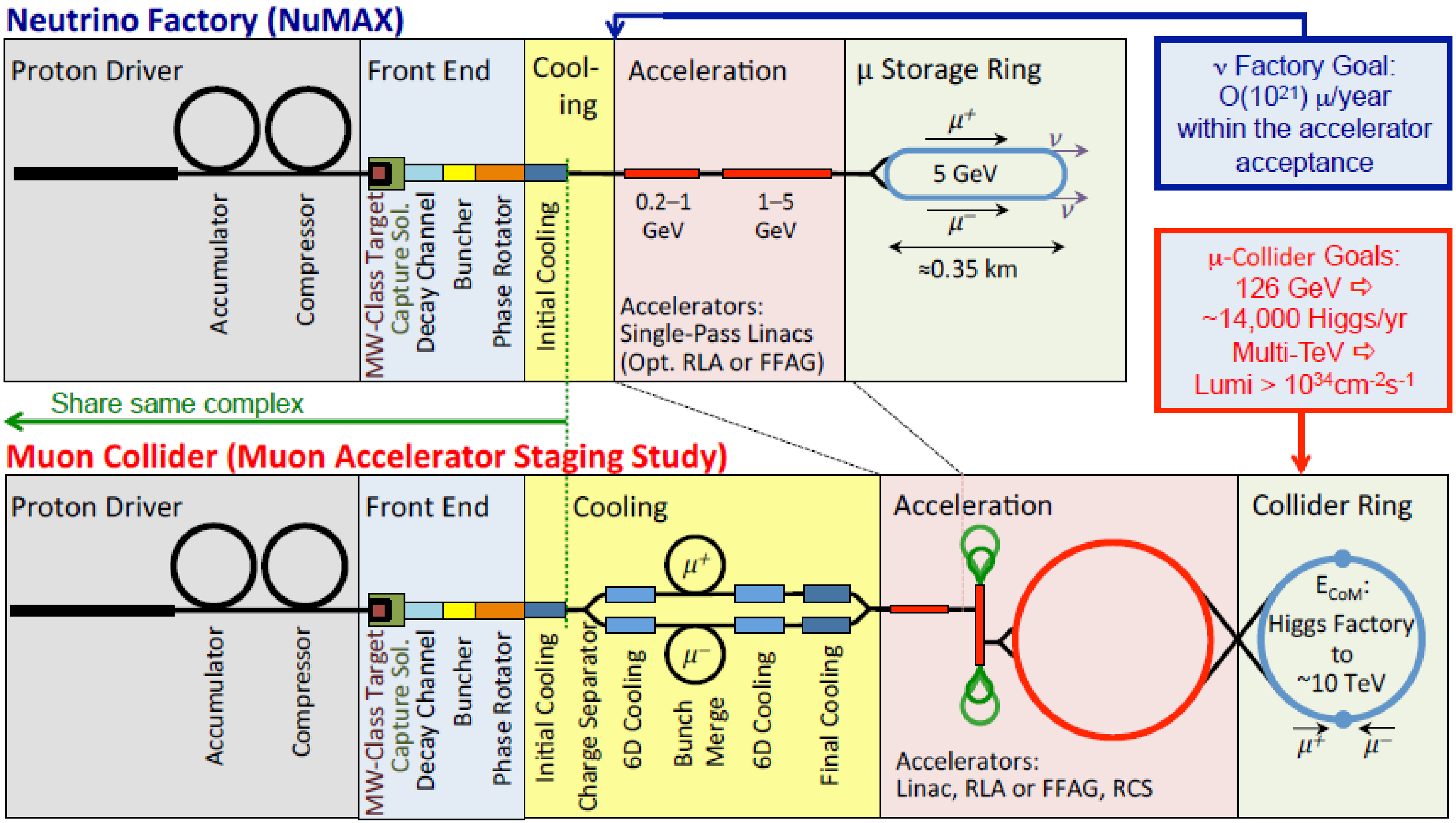
Brookhaven National Laboratory

January 7, 2013

Outline

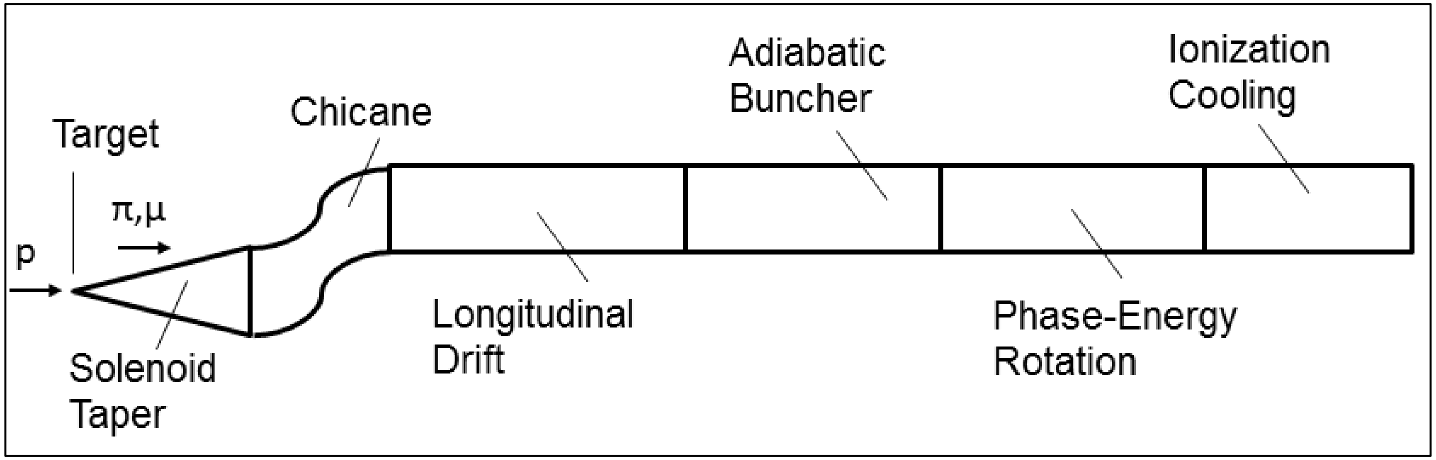
- Introduction
- Front-End major sub-systems
  - Target
  - Decay channel
  - Chicane
  - Buncher & phase-rotator
  - 4D Cooler
- Design challenges
- Initial Baseline selection schedule & personnel
- Summary

Muon Accelerator Front-End (FE)

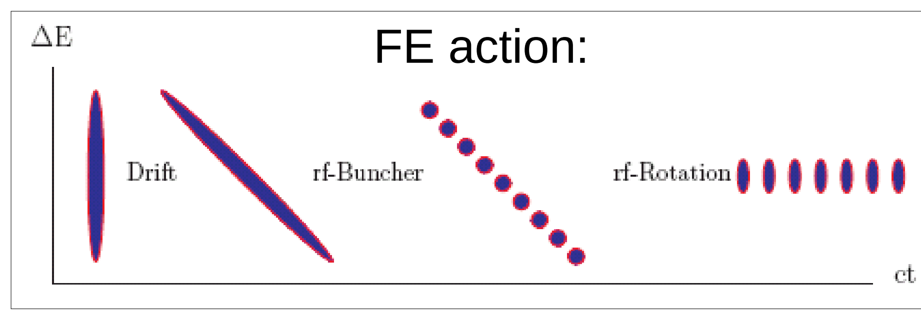


- Front-End (FE) is a core building block of a Neutrino Factory and a Muon Collider

Major Front-End sub-systems

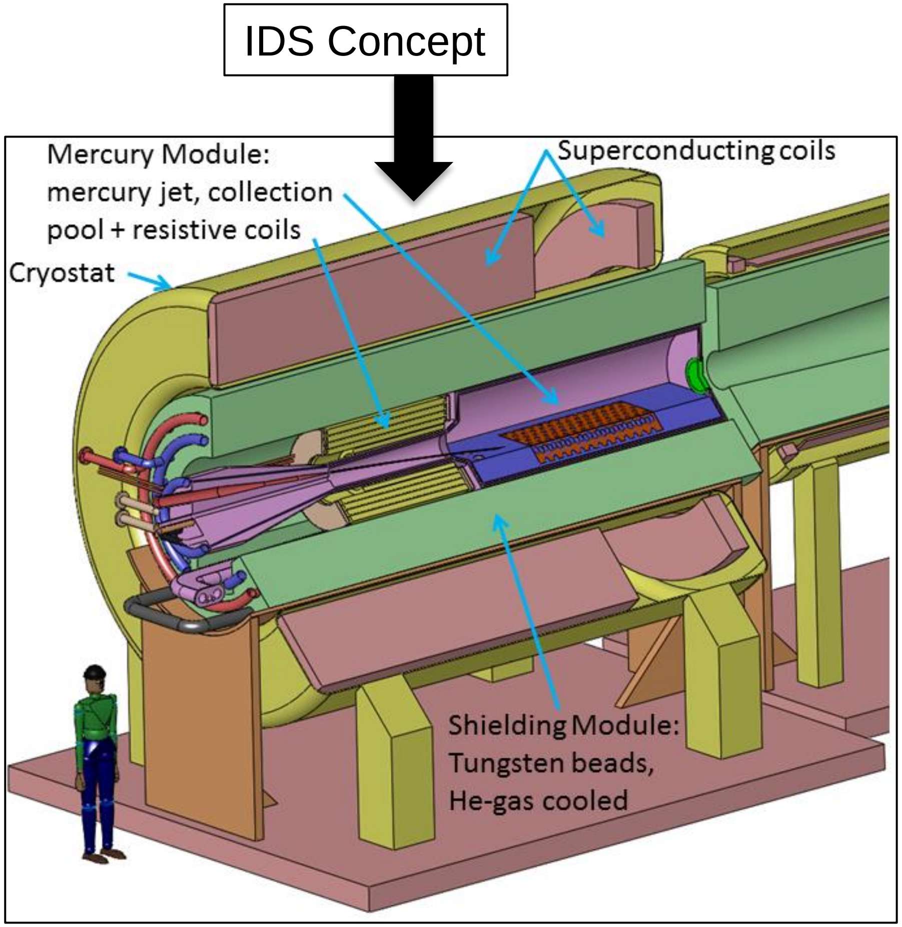


- Major FE components are:
  - Target
  - Pion Decay & drift
  - Buncher & Phase rotator
  - Chicane
  - 4D Cooler

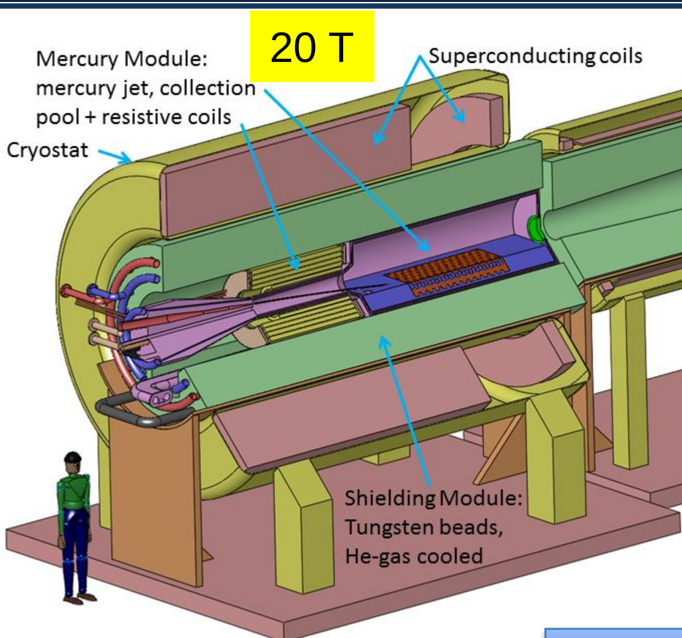


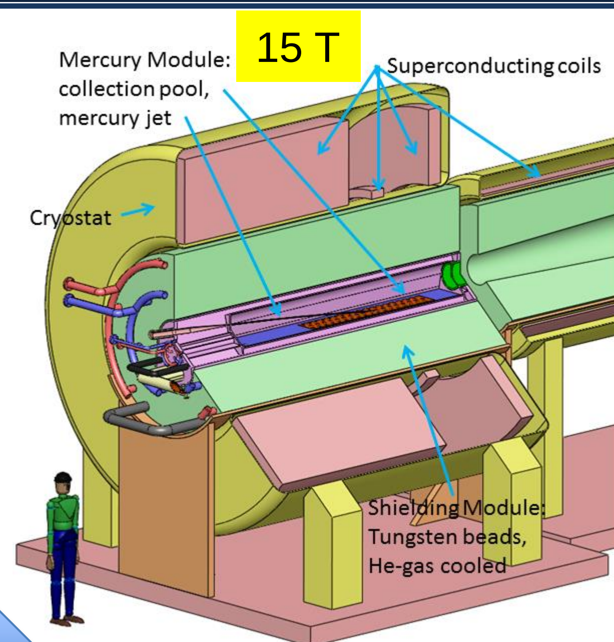
Target – IDS concept

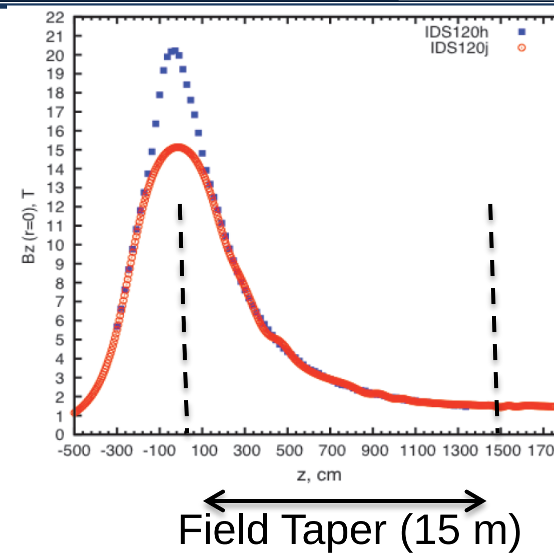
- Parameters optimized & documented for the IDS
- Proton Driver:
  - 4 MW Power
  - Max production for 8 GeV)
  - NF: 50 Hz/ MC: 15 HZ
  - NF: 3 bunch structure / MC: 1 bunch
- Target System:
  - Capture at 20 T
  - Liquid metal jet
  - Hg favored
  - 15 m taper



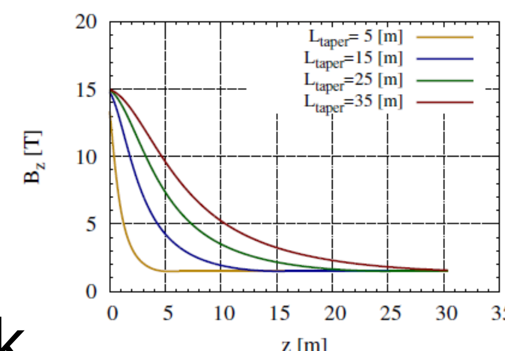
Target - Moving forward from the IDS



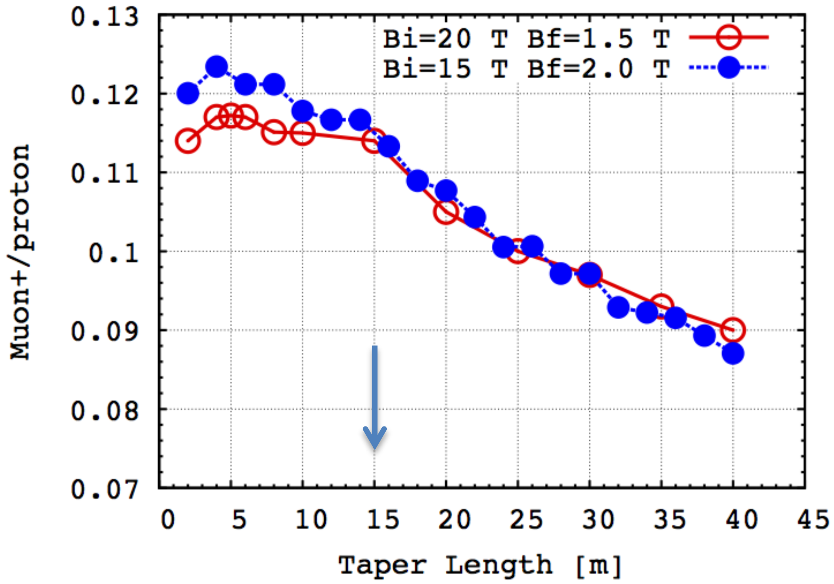


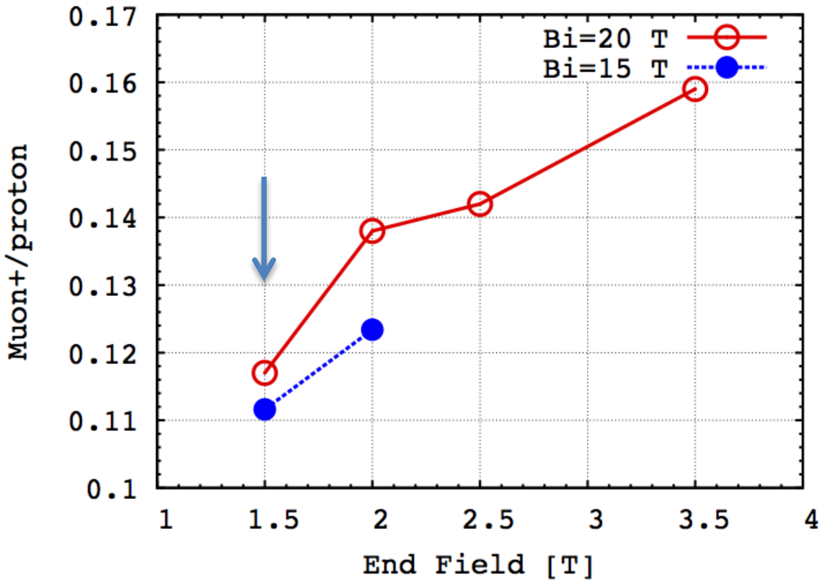


- Peak field from 20 T to 15 T → No need of 5 T resistive coil → simplifies configuration
- Reduce length of the 15 m field taper
- More Target details: See KT McDonald Talk



Pion decay channel optimization



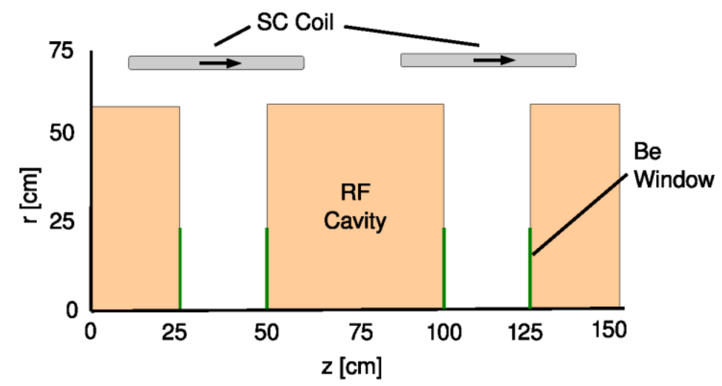


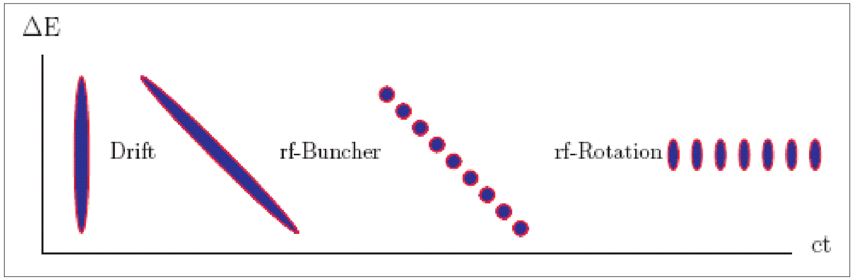
- Longitudinal acceptance improves when the field taper becomes shorter → Higher muon yield
- Favorable to increase field at FE above the baseline 1.5 T

H. Sayed *et al*, Proc. IPAC 2013, xxxx

Buncher & Phase Rotator

- IDS scheme (match to 201 MHz)
  - Cooling at 201, 402, 603, 805 MHz
  - High cost
- New scheme (match to 325 MHz)
  - Hopefully, cheaper
- But match to 325 MHz is challenging
  - Requires 500 to 325 MHz rf in buncher and phase rotator
  - Apertures are more restricted
  - Requires higher focusing fields





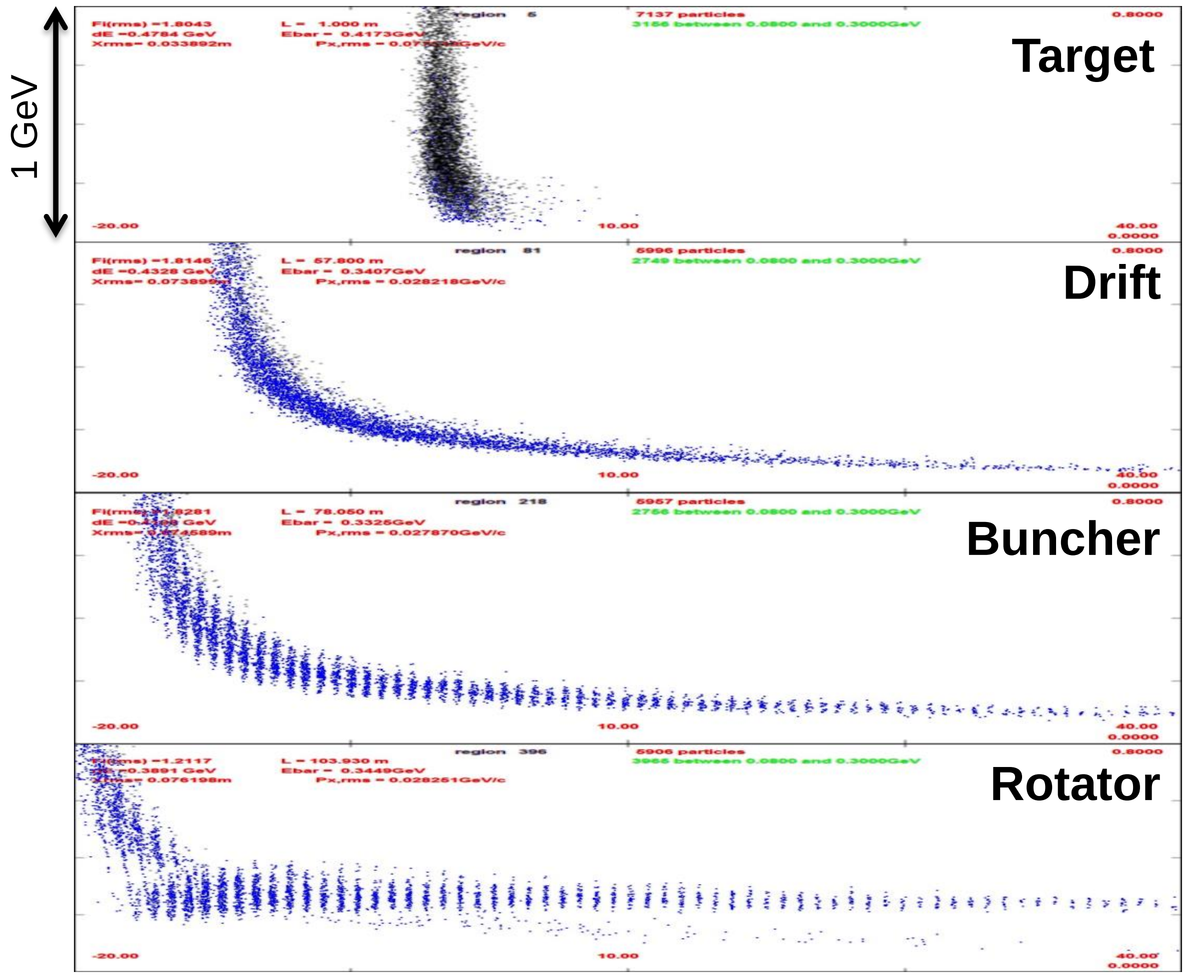
Buncher & rotator parameters

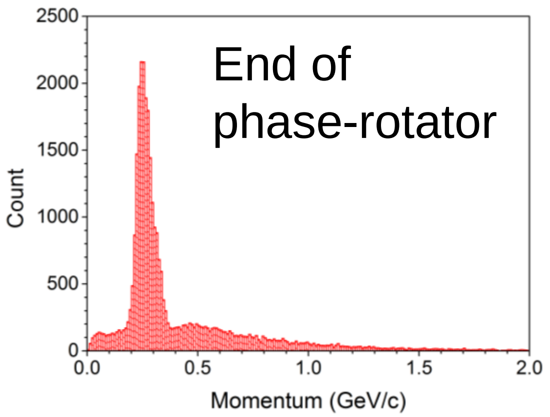
Match to 201 MHz	Len. (m)	No. of RF	f (MHz)	RF grad. (MV/m)	No. of f	B axis (T)
Buncher	33	37	319.6 to 233.6	3.4 to 9.0	13	1.5
Rotator	42	56	230.2 to 202.3	13.0	15	1.5
Total	75	93			28	

Match to 325 MHz*	Len. (m)	No. of RF	f (MHz)	RF grad. (MV/m)	No. of f	B axis (T)
Buncher	21	28	490.0 to 365.0	0.0 to 15.0	10	2.0
Rotator	24	32	364.0 to 326.0	20.0	11	2.0
Total	45	60			21	

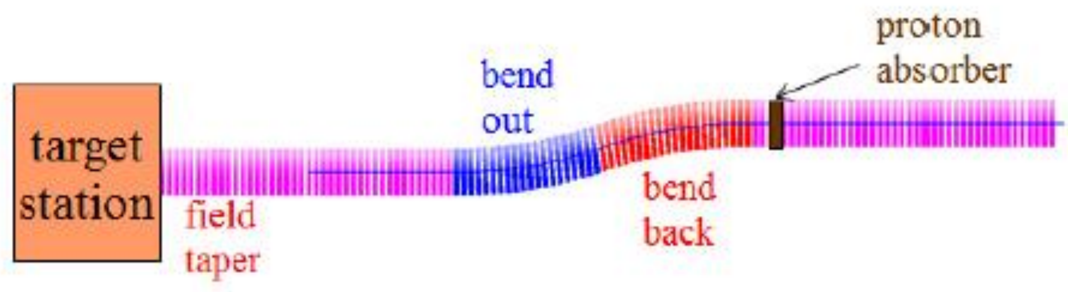
*Currently under study

Lattice performance



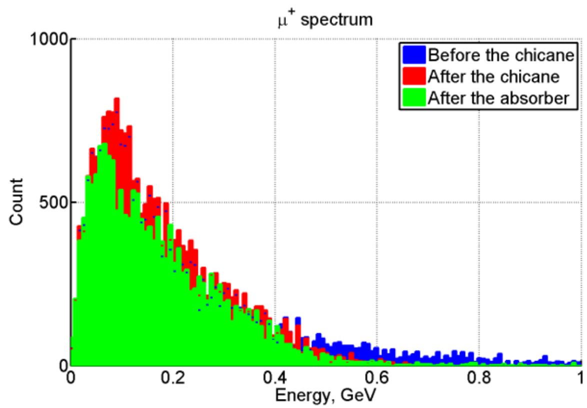


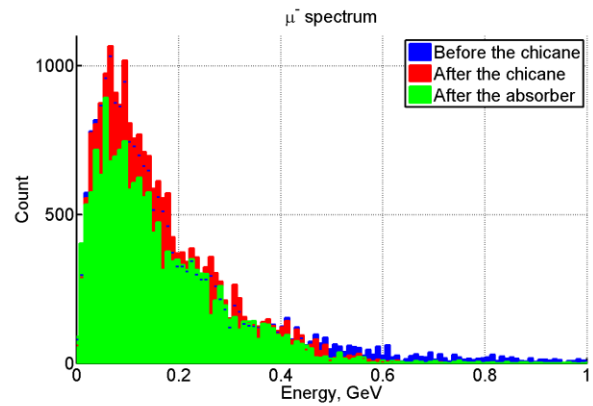
Front-End chicane



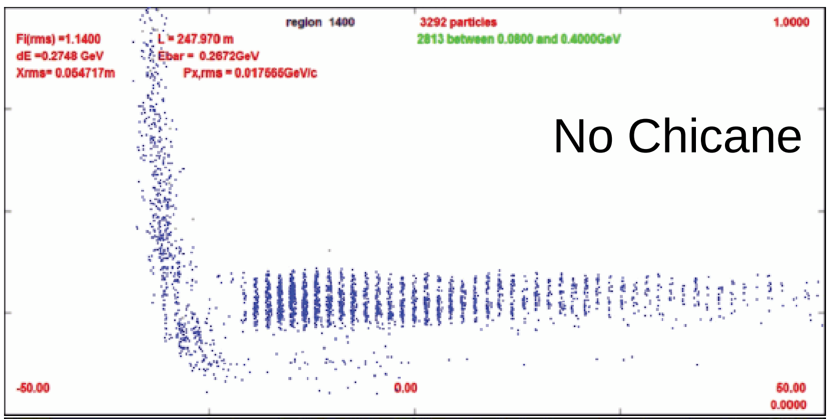
- High energy particles in the FE could activate the entire channel.
- Bent solenoid chicane induces vertical dispersion in beam
  - Bend out 5 m, 12.5 deg.
  - Single chicane will contain both signs
  - High momentum particles scrape
- Subsequent proton absorber to remove low momentum protons

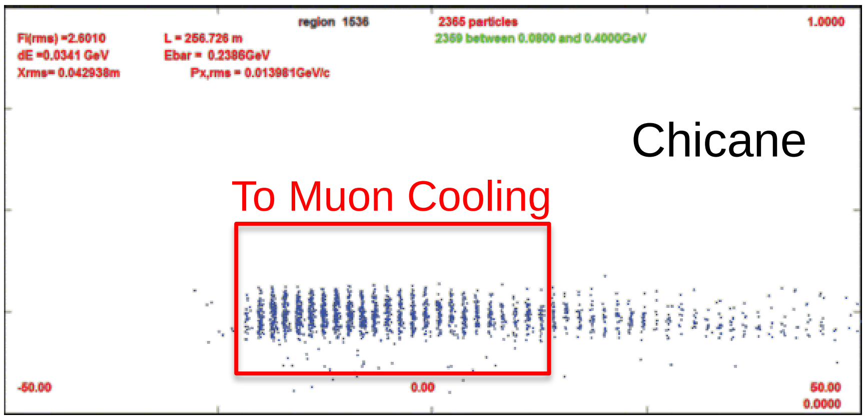
Chicane performance





- Beam distributions at the end of the FE channel:

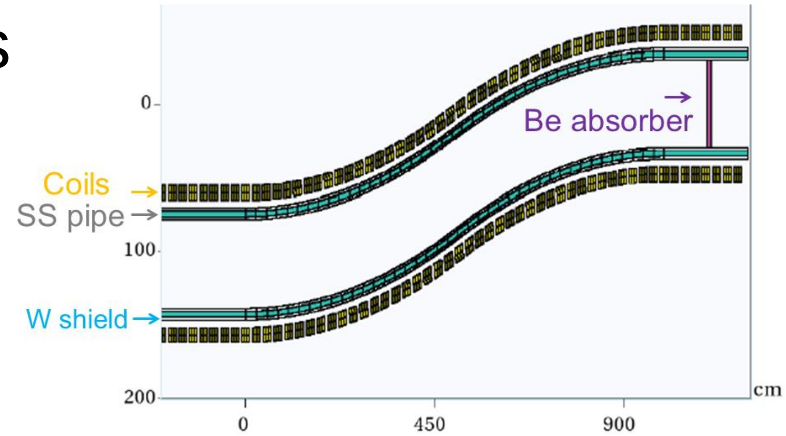


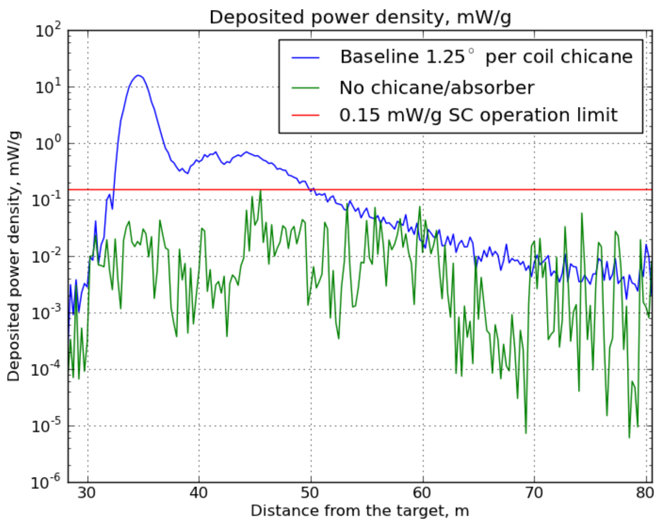


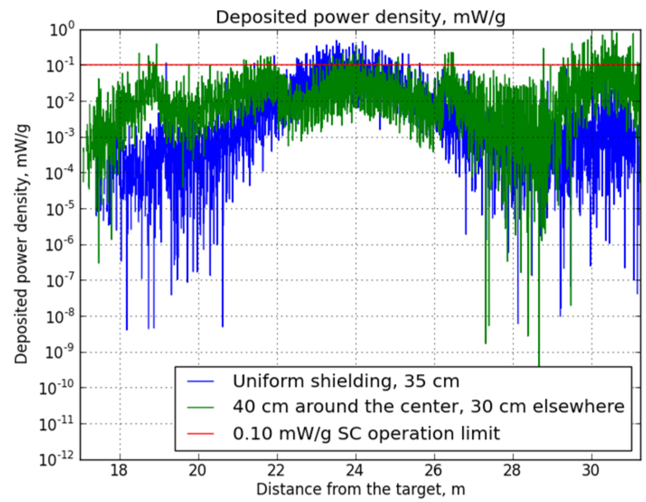
- Challenge: Muon yield is reduced by 10-15% and optimizations are underway to improve performance.

Energy deposition

- MARS 15 shows that a 40 cm thick sleeve of W beads is roughly the amount of shielding required for use with superconducting coils

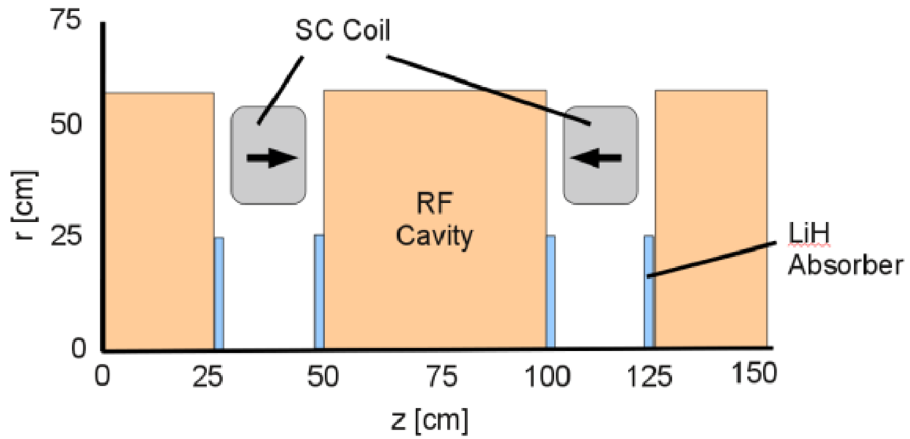


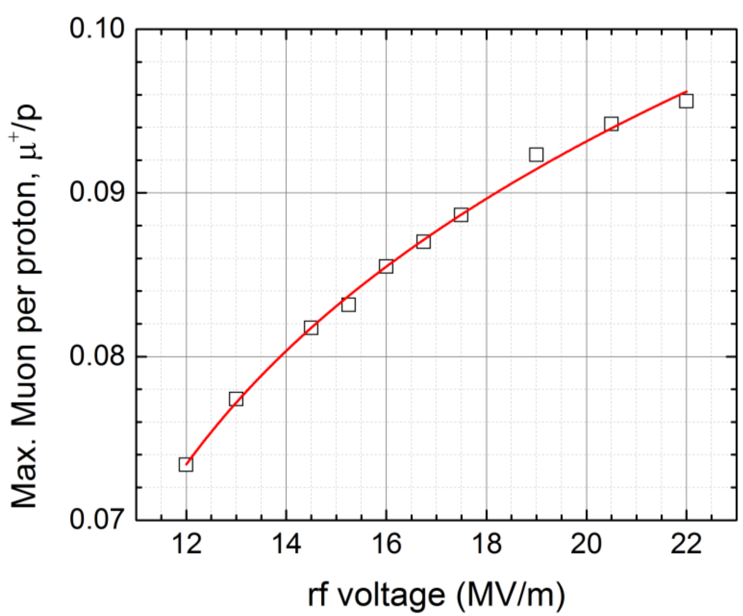




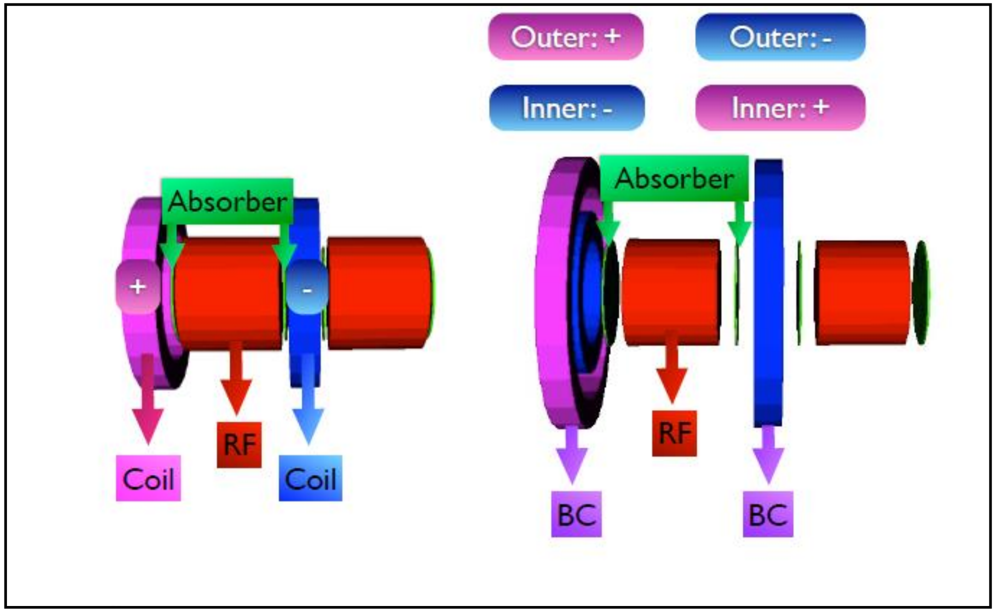
4D cooler

- 4D cooler required for a Neutrino Factory:
  - 60 m in length
  - 325 MHZ cavities, 0.25 m
  - No. of cavities is 120
  - 25 MV/m peak gradient
  - 2.8 T peak field
- Results sensitive to rf voltage
- 3 T field on cavity wall

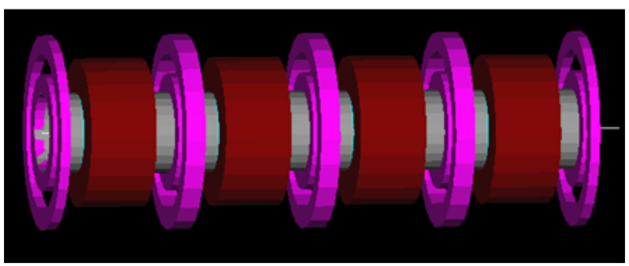


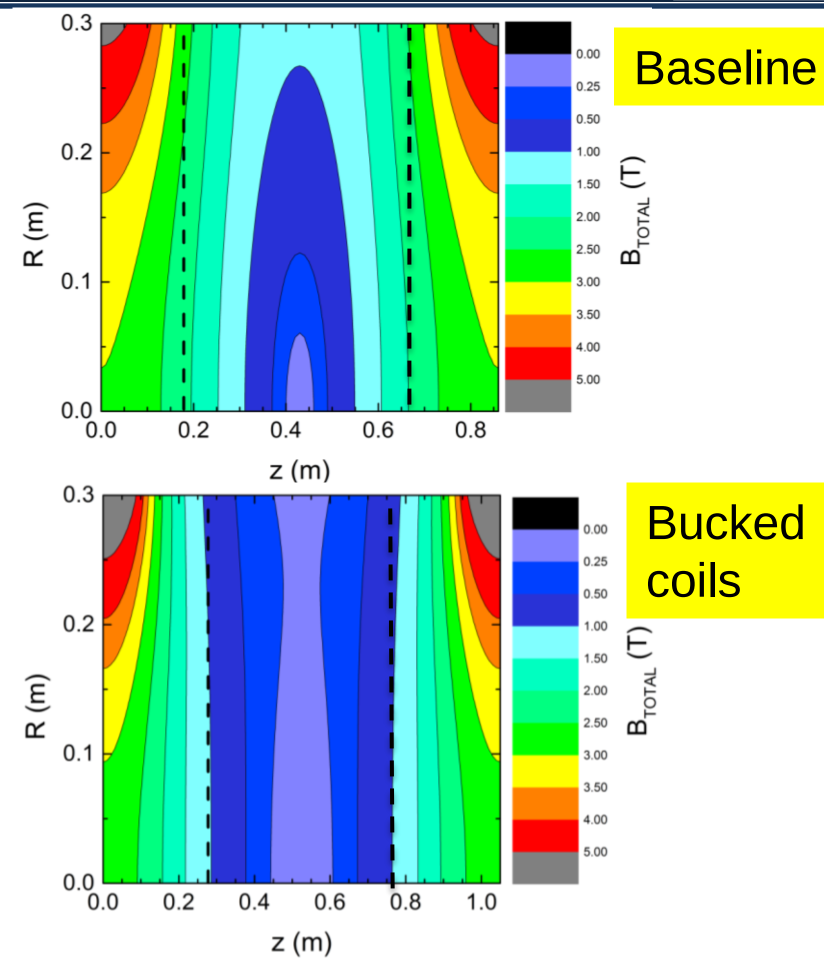


Cooling with bucked coils



4 lattice cells with bucked coils

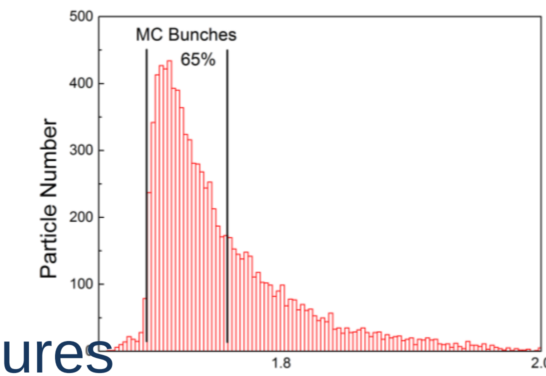




- Field on the cavity is reduced by at least a factor of 3 while the performance is reduced by 5% only.

Challenges & future work

- Target (June 2014)
  – Evaluate new target parameters (KT McDonald talk)
- Decay & drift channel (Oct. 2014)
  – Optimize taper length and field strength for new 325 MHz FE
- Chicane (Oct. 2014)
  – Design & simulation of a chicane for the 325 MHz FE
- Buncher & Phase Rotator (Oct. 2014)
  – Discretize rf cavities (reduce frequencies)
  – Simulate realistic solenoid coils
  – Design & simulation of cavity windows/ apertures
  – Maximize the number of particles in 21 bunches for a MC



Baseline schedule

- Provided by Mark

Key personnel FY 14

Investigators	Institution	Task	FTE	
KT McDonald	Princeton	Management 3.04	0.25	
Kolonko, Souchlas	PBL	Energy deposition studies	0.75	
Kolonko, Weggel	PBL	Magnet design	0.55	
X. Ding	UCLA	Beam/ Target optimization	0.50	
V. Graves	ORNL	Target handling system	0.25	
R. Samulyak	SUNY	Beam-jet simulations	1	
F.Ladeinde, Y. Zhan	SUNY	Nozzle-jet simulations	1	
D. Stratakis	BNL	Management of 2.02	0.25	
J. Berg	BNL	Beryllium windows & ICOOL maint.	0.20	
D. Neuffer	FNAL	Chicane integration & Discretization	0.30	
H. Kirk, H. Sayed	BNL	Taper & Global optimization	1.5	
P. Snopok	IIT/ FNAL	Energy deposition/ G4BL FE sim.	0.15	
		Chicane Magnet Design & Engin.	0.50	

Summary

- A new mercury target with a lower capture field (20 T to 15 T) has been designed.
- The muon yield is increased by shortening the field taper (15 m to ~ 5 m)
- Performance is also enhanced by raising the buncher & rotator field above the baseline 1.5 T
- A chicane/ absorber system to remove unwanted particles from the FE has been simulated.
- For the new 325 MHz FE:
  - Optimize taper length and constant B-field on decay channel/ Buncher/Phase-Rotator
  - Simulation of apertures & rf windows
  - Optimize chicane performance