Front-End Design Overview

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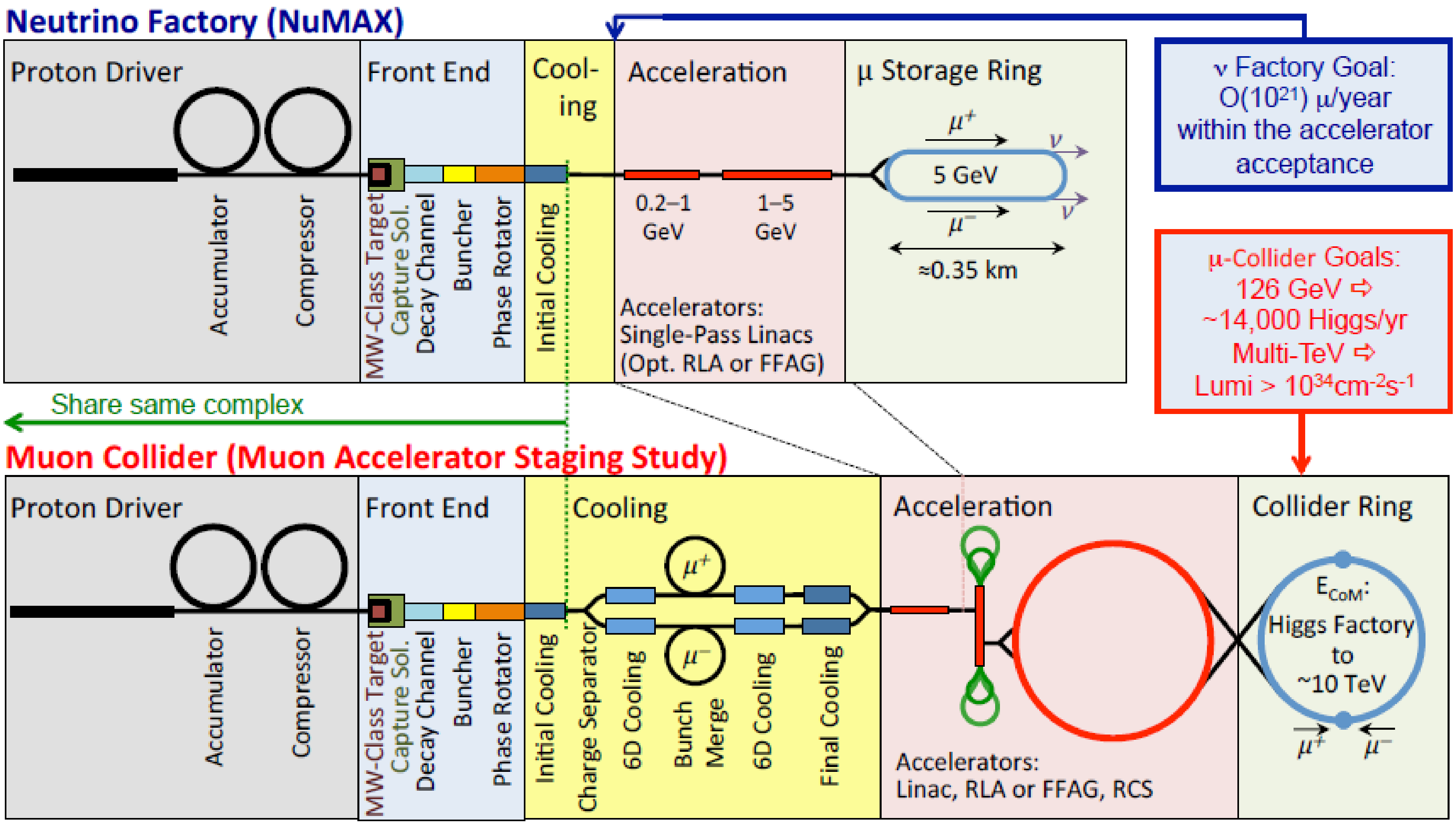
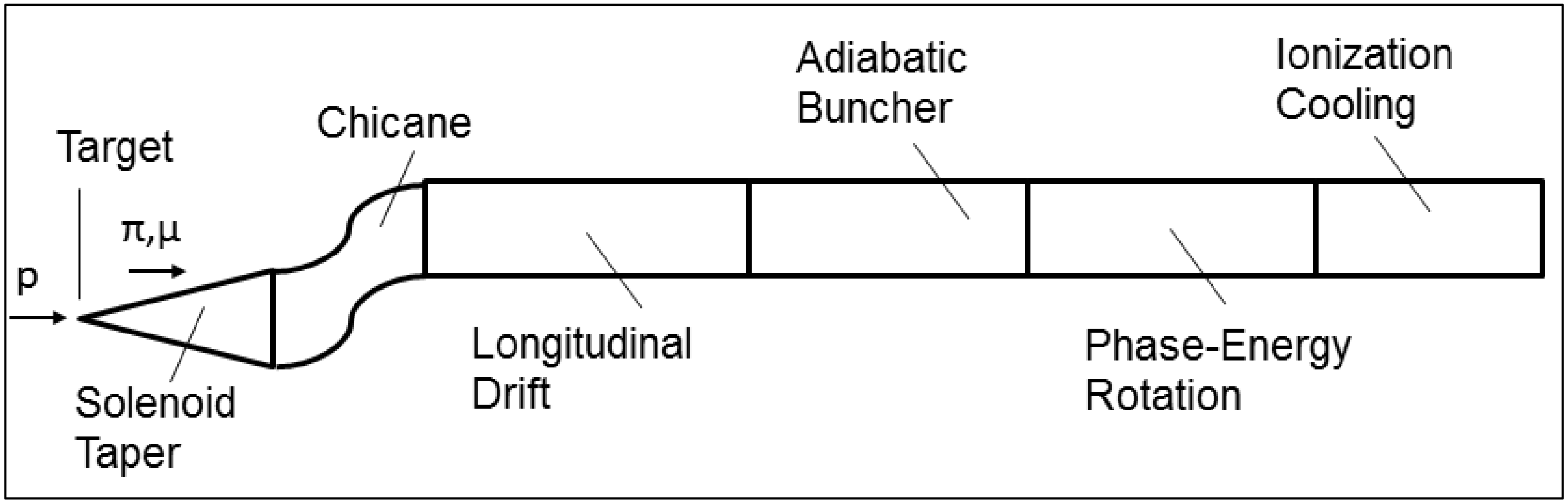
Muon Accelerator Front-End (FE)

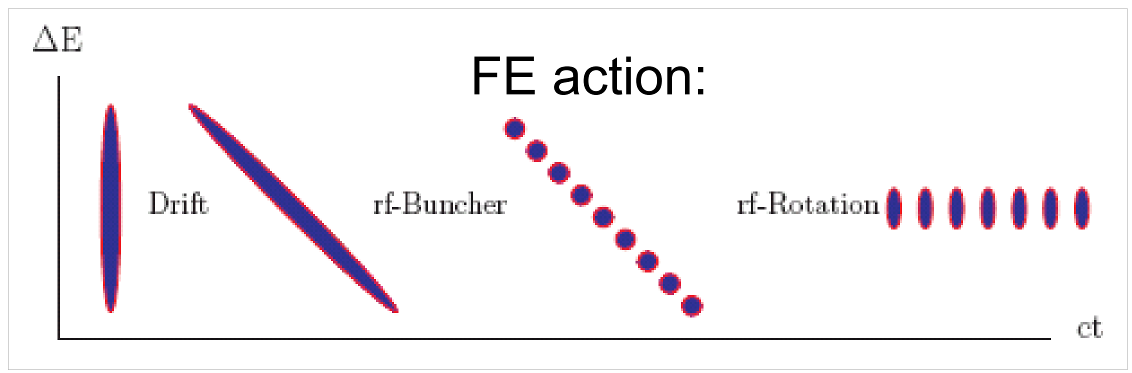


- Front-End (FE) is a core building block of a Neutrino Factory and a Muon Collider

Major Front-End sub-systems



- Major FE components are:
  - Target & Capture solenoid
  - Chicane
  - Drift channel
  - Buncher & Phase-rotator
  - 4D Cooler (IDS-NF)



Key FE Accomplishments Since the August 2012 MAP Review

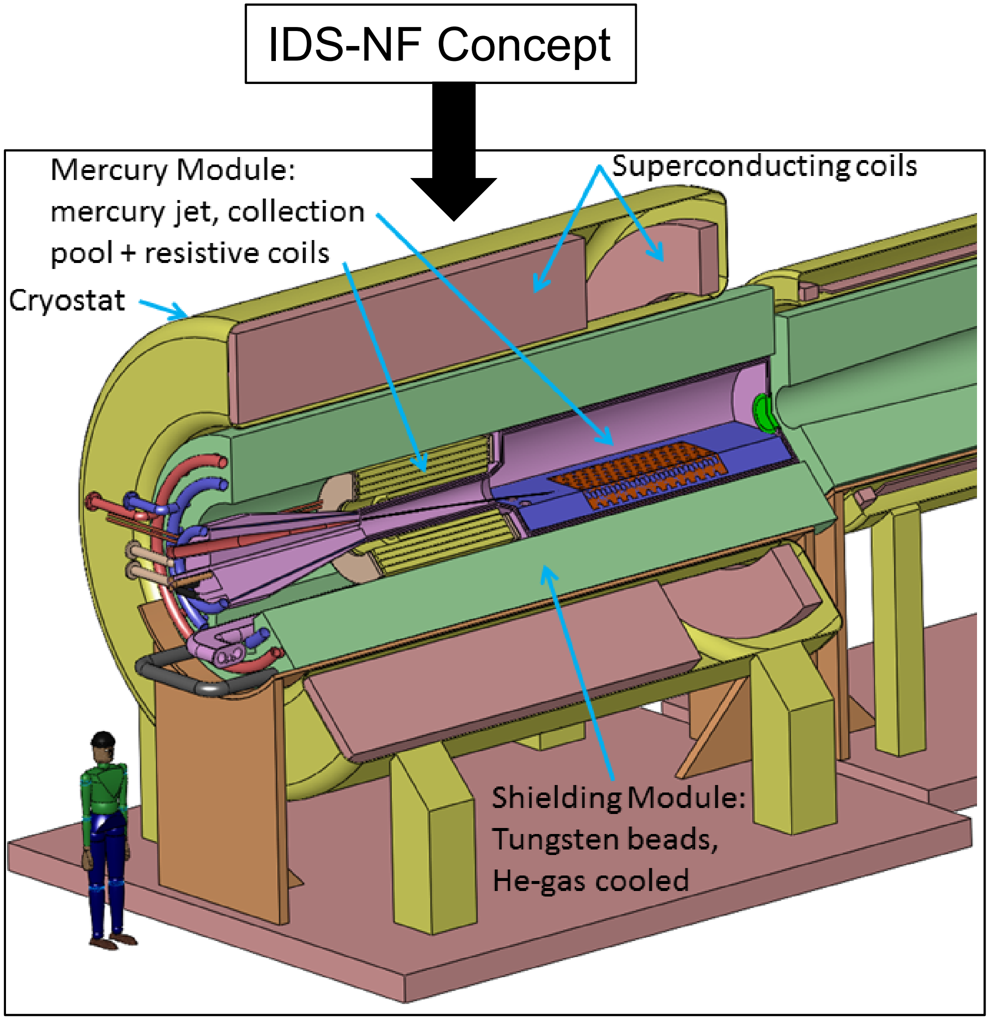
Date	Description
FY12 Q4	Design of a bucked coil system for reducing the field on Buncher & Phase-Rotator. Published at the Proc. of AAC 2012, p 855. Submitted also to PRST-AB.
FY13 Q1	MAP contribution to EUROnu Costing Report. Published at: http://euronu.org
FY13 Q1	Shielding solution for the chicane coils delivered. Published at the Proc. of IPAC 2013, p. 1505.
FY13 Q2	Detailed analysis of magnet misalignments for the Buncher & Phase-Rotator. Published at NA-PAC 2013, p. 1373.
FY13 Q2	FE performance evaluation for a 15 T Mercury Target. Published at Proc. Of IPAC 2013 p. 1520.
FY13 Q2	IDS-NF FE lattice completed and provided for the Reference Design Report (RDR). Results also published in Phys. Rev. ST 16, Accel. Beams 040104 (2013).
FY13 Q2	Development of global optimization algorithms for the FE. Published at NA-PAC 2013, p. 547.
FY13 Q3	Buncher & Phase-Rotator optimization for matching to a 325 MHz channel. MAP Doc 4355, 2013
FY13 Q3	FE performance evaluation for 3 GeV/ 1 MW proton driver. Published: Proc. NAPAC 2013, p. 1325
FY14 Q1	Preliminary design of a chicane for the new 325 MHz FE system

Outline

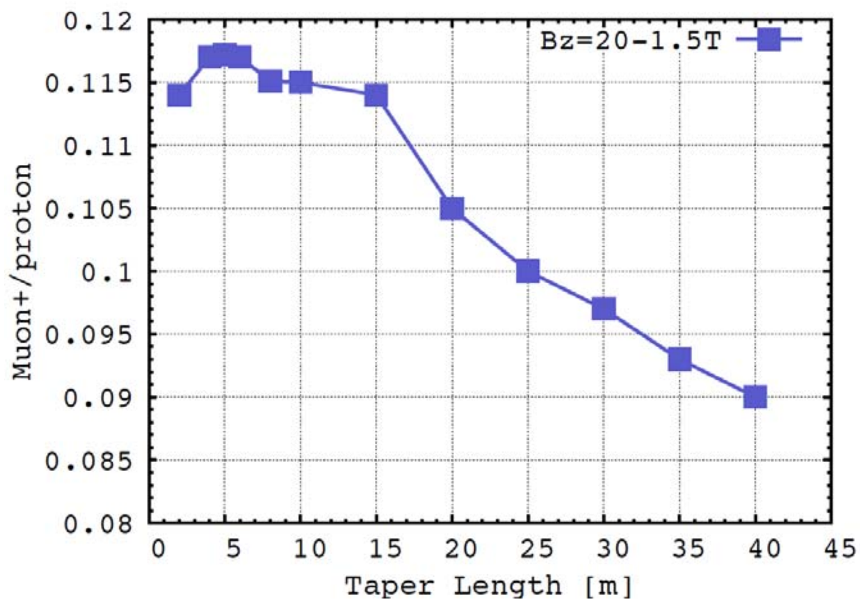
- Front-End major sub-systems
  - Target
  - Chicane
  - Drift channel
  - Buncher & phase-rotator
  - 4D Cooler (IDS-NF)
- Future work & challenges
  - Technology challenges will be discussed by H. Kirk (later talk)
- Initial Baseline Selection (IBS) schedule & personnel
- Summary

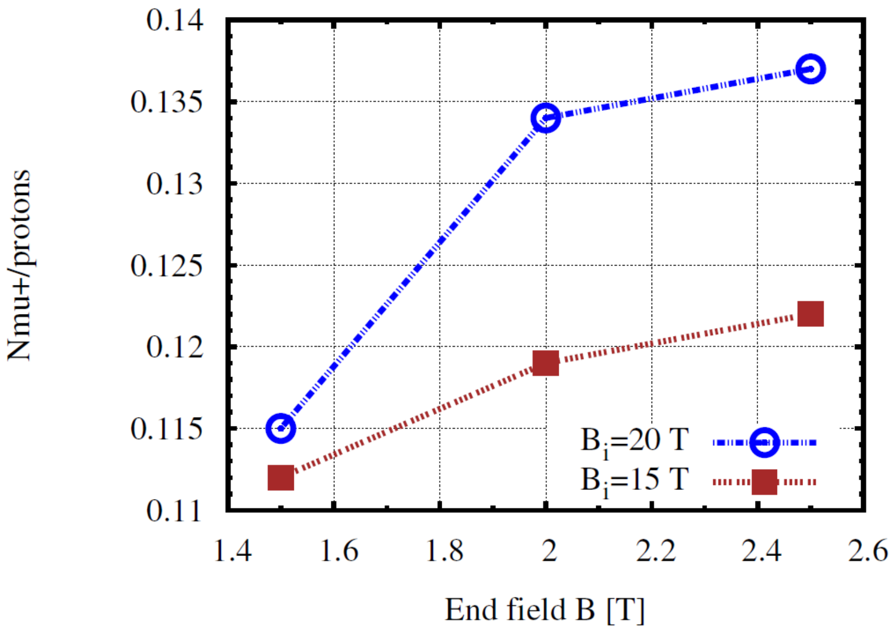
Target-Capture System: IDS-NF concept

- Parameters optimized & documented for the IDS-NF
- Proton Driver:
  - 4 MW Power
  - 8 GeV (for maximal π/μ production)
  - 50 Hz NF operation
  - 3 bunch structure for NF
  - [MC operation: 15 Hz, single bunch]
- Target-Capture System:
  - Liquid mercury jet
  - Capture at 20 T
  - End field at 1.5 T
  - Taper length is 15 m



Target-Capture global optimization

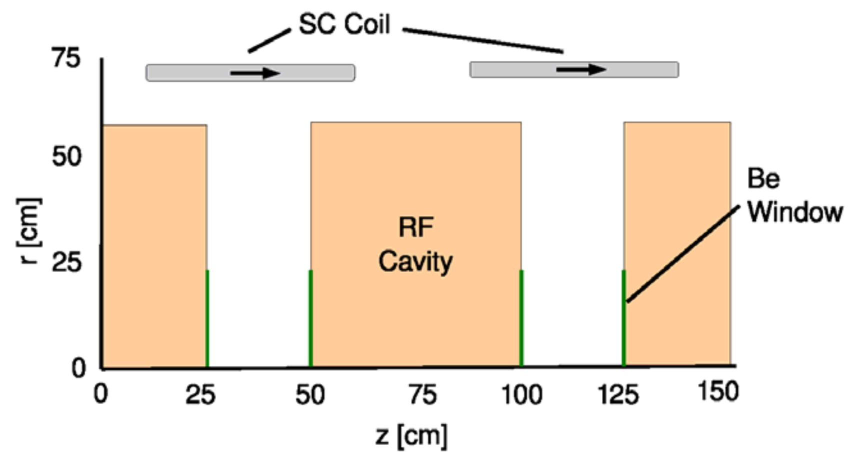




- Performed global optimization of the FE, by varying:
  - Peak target field
  - End field
  - Length of field taper
- Results demonstrated:
  - Shorter field taper length leads to a higher muon yield
  - Favorable to increase the end field above the baseline 1.5 T
  - A higher target peak field improves performance

Buncher & Phase-Rotator

- IDS-NF and early MAP scheme: Buncher & Phase-Rotator matched to 201 MHz
- New scheme: match to 325 MHz
  - Requires higher frequency cavities
    - → lower cost
  - Being pursued as the new baseline



- But matching to 325 MHz is challenging
  - Due to the higher frequencies, the apertures are more restricted

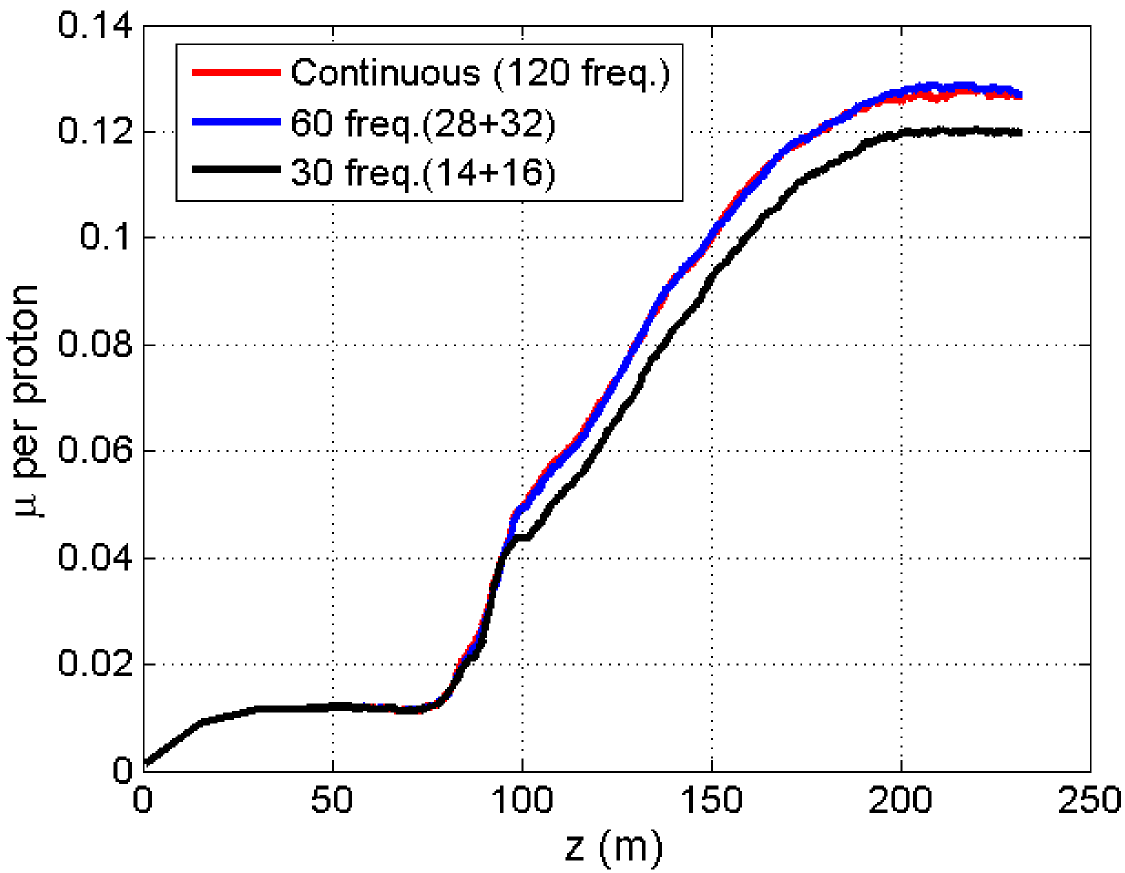
Buncher & rotator parameters

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

Match to 325 MHz	Len. (m)	No. of RF cavities	range of cavities (MHz)	No. of cavity frequencies	RF grad. (MV/m)	B axis (T)
Buncher	21	56	490.0 to 365.0	14	0.3 to 15.0	2.0
Rotator	24	64	364.0 to 326.0	16	20.0	2.0
Total	45	120		30		

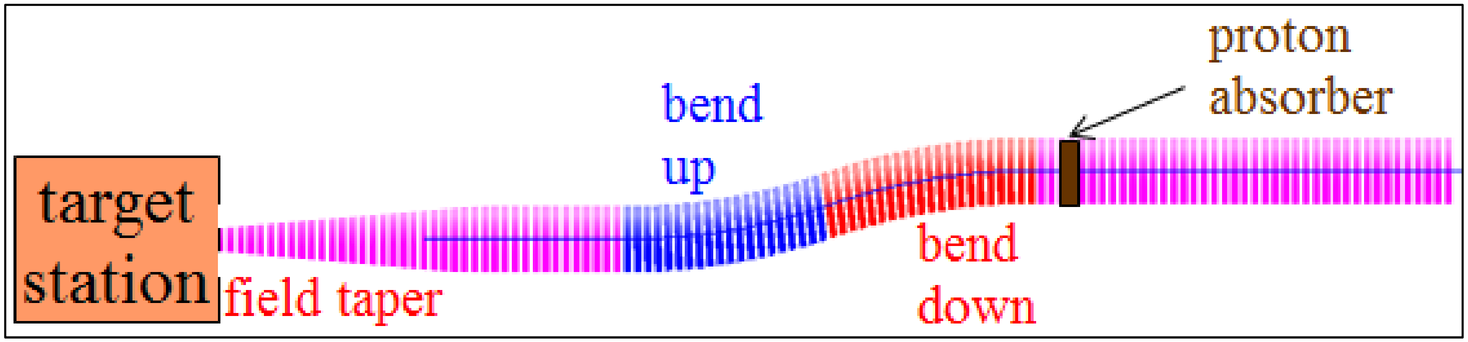
Currently being pursued for MAP IBS

Impact of rf frequency discretization



- First pass study towards a more realistic channel
  - Discretize rf cavity frequencies
- Our goal is to further reduce the No. of frequencies

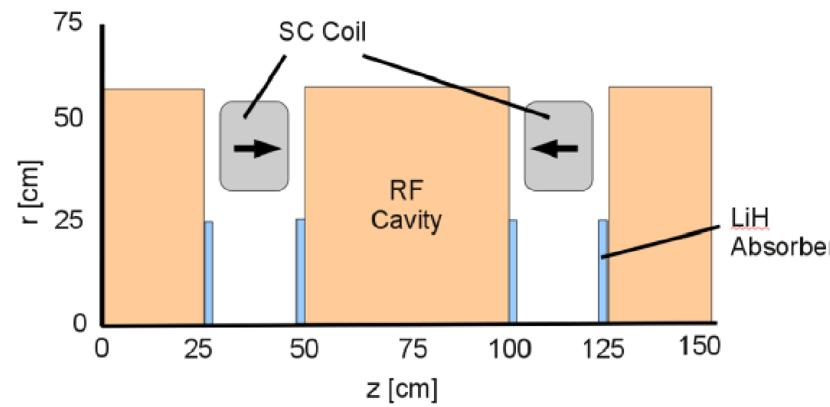
Front-End chicane

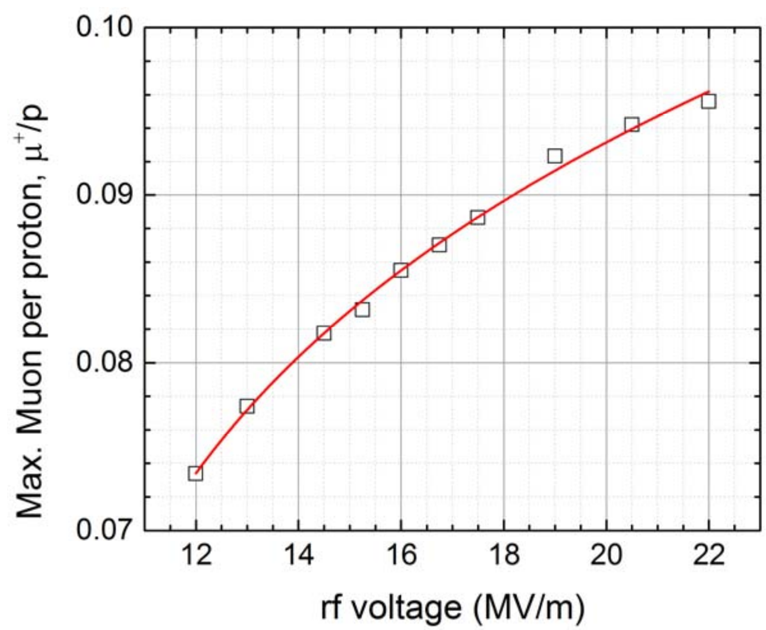


- High energy particles could activate the entire FE channel
- Bent-solenoid chicane induces vertical dispersion in beam
  - High-momentum particles scrape
  - Single chicane will contain both signs
- Proton absorber to remove low momentum protons
- With the chicane on, the muon yield is reduced by 10-15%

4D cooler

- 4D cooler completed and provided for the IDS-NF RDR
  - 100 m in length
  - 201 MHZ cavities, 0.50 m
  - No. of cavities is 100
  - 16 MV/m peak gradient
  - 2.8 T peak field
- Results sensitive to rf voltage
- MASS recommends that we consider 6D cooling for both signs simultaneously. In this scenario 4D cooler will not be part of MAP IBS





Future work towards the MAP IBS

- Target (Details by K.T. McDonald)
  - Optimize for 1 MW @ 6.75 GeV
  - Assume solid target initially
- Decay & drift channel
  - Optimize taper length and end field strength for new 325 MHz FE
- Chicane
  - Integrate chicane into the new 325 MHz FE
  - Include chicane into global optimization → Improve performance
- Buncher & Phase-Rotator
  - Discretization of cavities (reduce frequencies)
  - Simulation of realistic solenoid coils and inclusion of cavity windows

Detailed IBS Schedule

Front End (incl. Target)	Concept Specification	Lattice/Layout & Performace Eval	Lattice Sign-off	Global Optimization of Internal Systems	Interface Params	Technology Specification	Technology Sign-Off	IBS Review Ready Date	IBS Initial Review (where needed)	IBS Review	IB Specifications (Dependent on results from previous system)
Target Module	6/2/2014	9/2/2014	10/1/2014	6/23/2015	7/22/2015	3/2/2015	4/1/2015	7/22/2015		1/5/2016	2/3/2016
Capture Solenoid	6/2/2014	9/2/2014	10/1/2014		7/22/2015	3/2/2015	4/1/2015	7/22/2015			
Proton Dump	6/2/2014	9/2/2014	10/1/2014		7/22/2015	3/2/2015	4/1/2015	7/22/2015			
Chicane	10/1/2014	1/2/2015	2/2/2015		7/22/2015	7/1/2015	7/31/2015	11/2/2015			
Pion Decay Channel	10/1/2014	1/2/2015	2/2/2015		7/22/2015	7/1/2015	7/31/2015	11/2/2015			
Buncher/Phase Rotator	10/1/2014	1/2/2015	2/2/2015		7/22/2015	7/1/2015	7/31/2015	11/2/2015			
FE-Cool Interface Parameters	*10/1/2014*				*7/22/2015*						*2/3/2016*

Effort & Key personnel

	Investigators	Institution	Task	FTE-yrs (FY 14)
Target	KT McDonald	Princeton	Management 3.04	0.25
	Kolonko, Souchlas	PBL	Energy deposition studies	0.70
	Kolonko, Weggel	PBL	Magnet design	0.5
	X. Ding	UCLA	Beam/ Target optimization	0.5
	V. Graves	ORNL	Target handling system	0.25
Front-End	D. Stratakis	BNL	Management of 2.02 & rf Discretization	0.50
	J. S. Berg	BNL	ICOOL maintenance	0.33
	D. Neuffer	FNAL	Chicane integration & Discretization	0.60
	R. B. Palmer	BNL	Cavity windows	0.15
	H. Kirk, H. Sayed	BNL	Taper & Global optimization	0.75
	Snopok, Kanareykin	IIT/ FNAL	Energy deposition/ G4BL FE simulation	1.00
	Total			**5.53**

Summary

- Initial design of all FE subsystems (325 MHz) delivered
  - includes chicane/absorber to remove unwanted particles
- Performed global optimization
  - Varied the peak target field, end field and taper length
  - Muon yield improvement with shorter taper (15 m → 5 m)
- Next steps towards the MAP IBS schedule:
  - Deliver a complete set of initial lattice files by FY15 Q2
  - Work with Technology Development group to assure requirements can be met
- We are on track to complete FE IBS by FY16 Q2