High-Intensity Muon Sources

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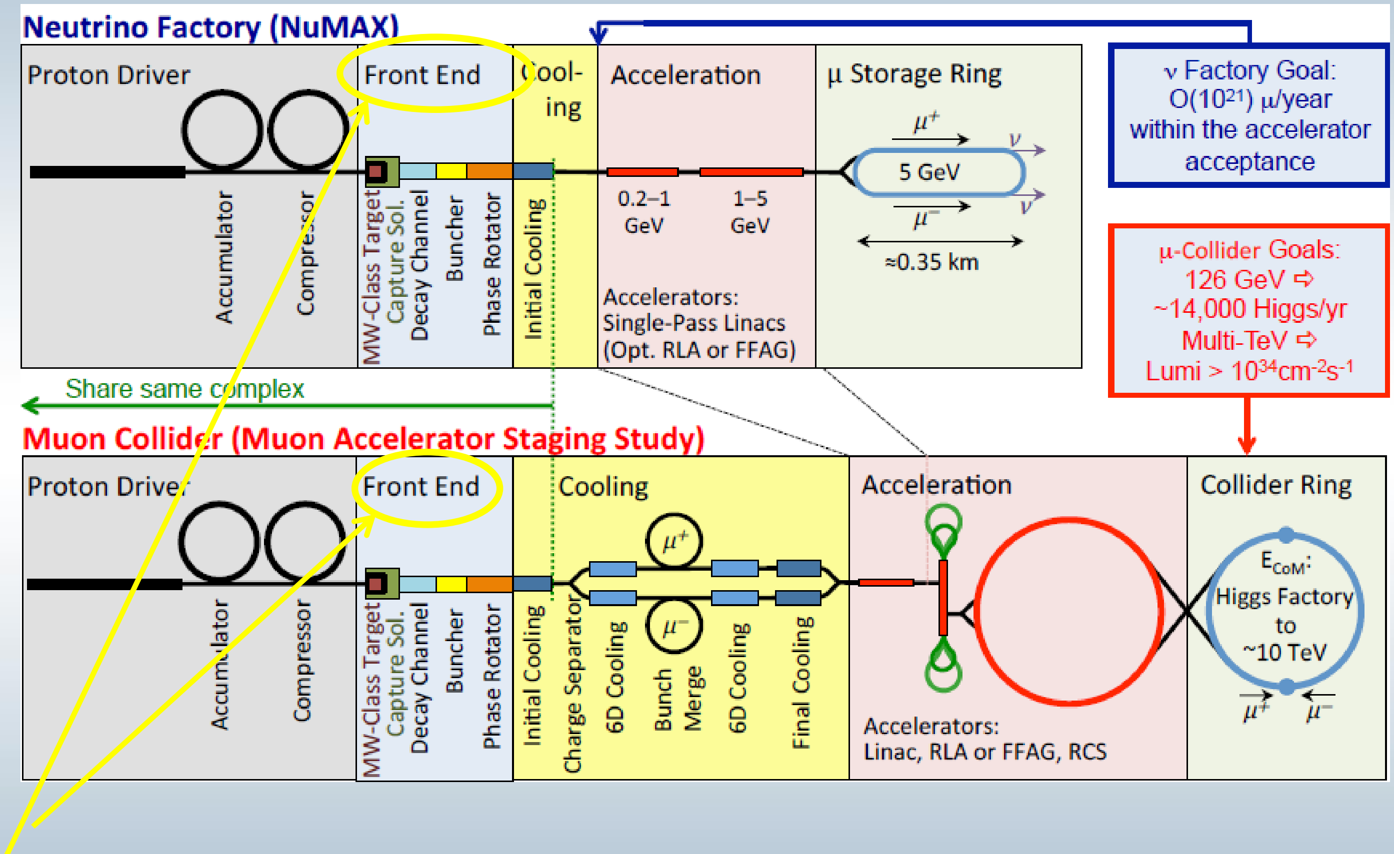
High-Intensity muon sources



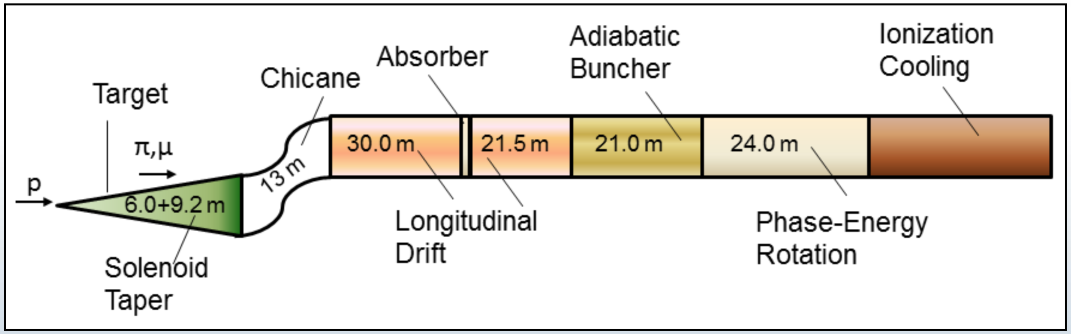
Neutrino Factory

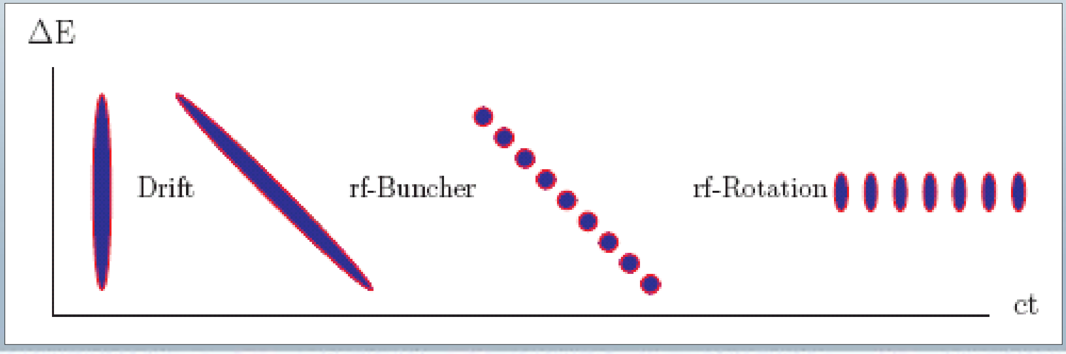
Muon Collider

- Is a core building block of a Neutrino Factory and a Muon Collider

Goals of a muon source

- Goals of a high-intensity muon source
  - Capture muons that result from the decay of pions that are produced by a high intensity proton beam impacting a target
  - Perform initial phase space manipulation of these muons to make them well-suited to subsequent accelerator systems and/or experiments
- Major components
  - Target & solenoid
  - Decay channel
  - Chicane
  - Buncher
  - Phase-Rotator





Outline

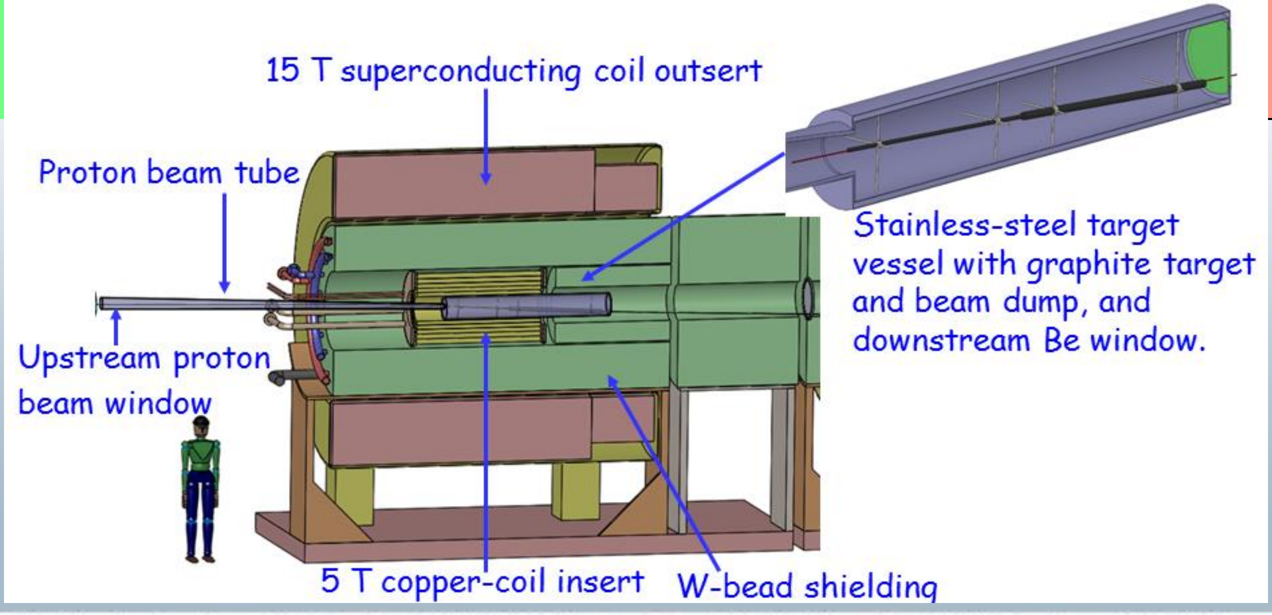
- Describe the major sub-systems of our muon source
  - Target & Capture Solenoid
  - Chicane
  - Drift Channel
  - Buncher
  - Phase-Rotator
- Future work & challenges
- Summary

Target & capture system

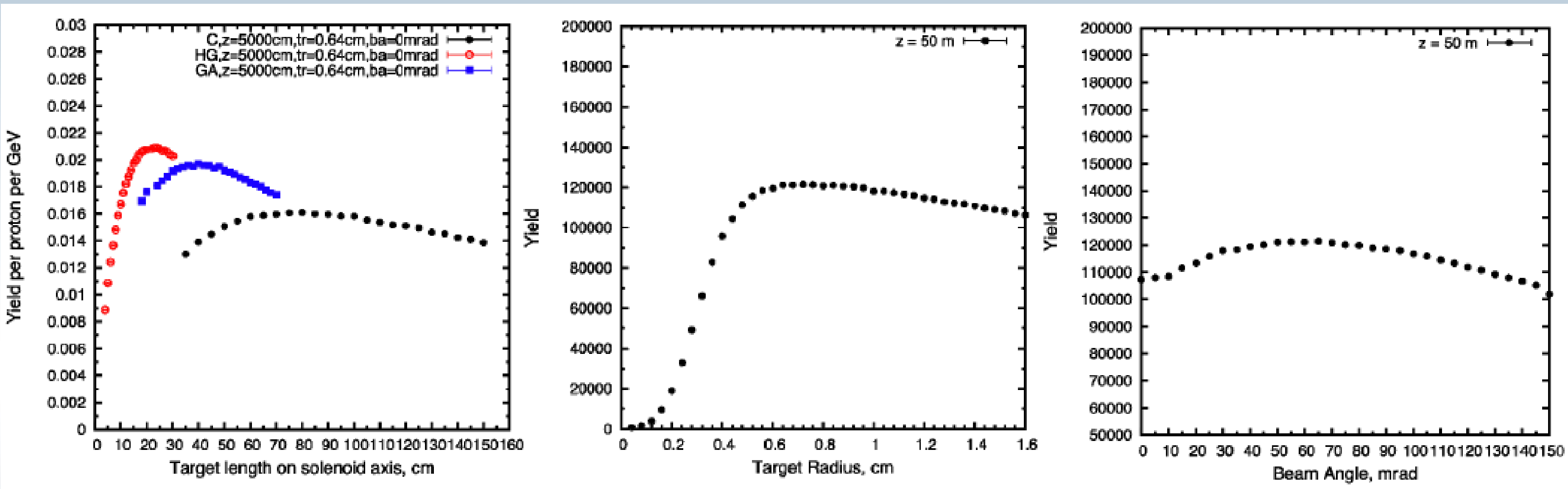
- Proton Driver:
  - 6.75 GeV (kinetic energy) proton with 3 ns pulse
  - 1 MW initial beam power
  - NF: 50 Hz rep rate, MC: 15 Hz rep rate

Target Concept:

- Graphite target
- Inside 20 T magnet
- Tilted in magnetic axis
- Proton beam dump via graphite rod downstream of the target

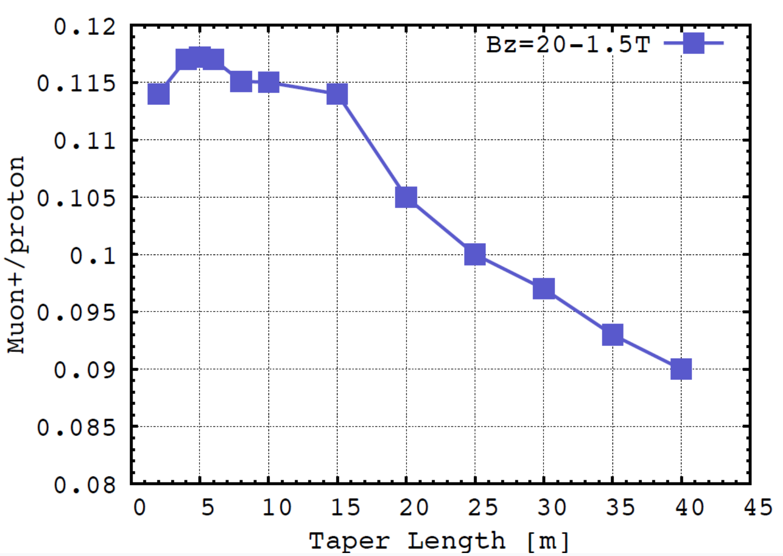


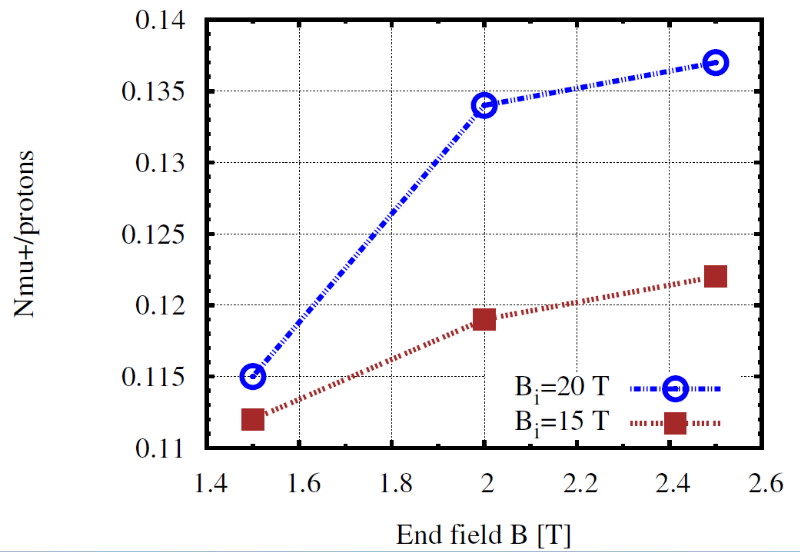
Target system optimizations



- Optimum C target: len.=80 cm, rad=8 mm, tilt = 65 mrad
- Optimum Graphite beam dump: len.=120 cm, rad=24 cm to intercept most of the proton beam

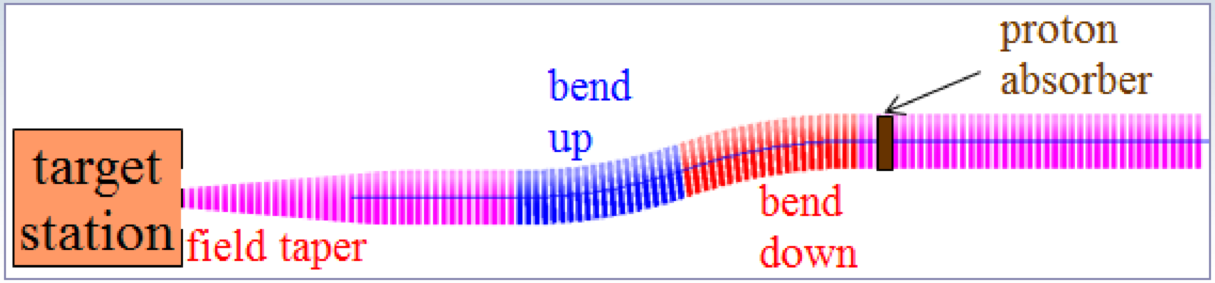
Optimizations of muon capture

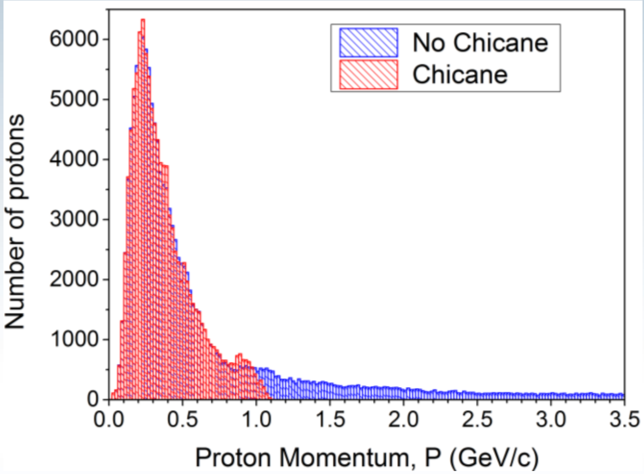




- Optimized for:
  - Peak target field, end field, length of field taper
- Results showed:
  - Shorter taper leads to higher muon yield (~5-6 m)
  - Favorable to increase the baseline end field (2.0 T)
  - Higher target peak field improves performance (20 T)

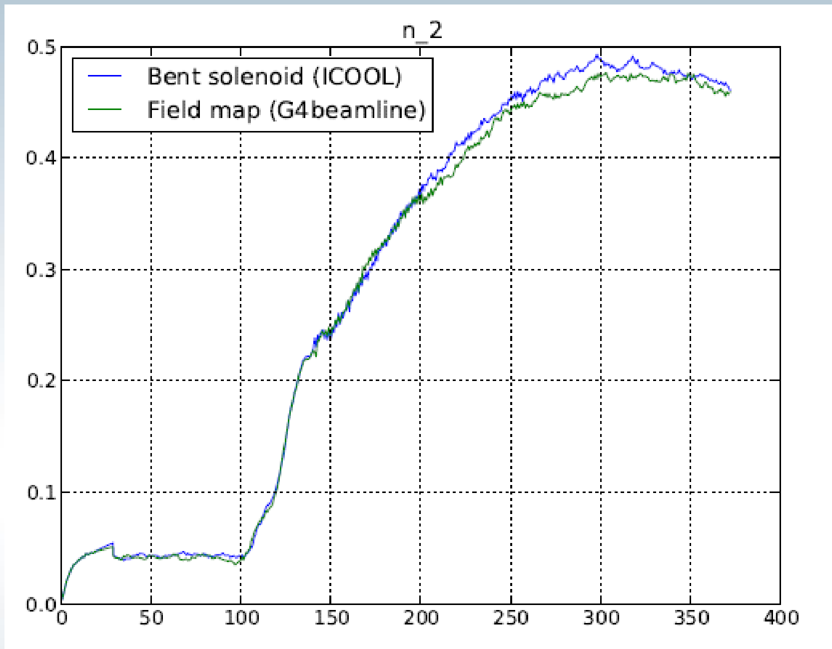
Chicane & absorber

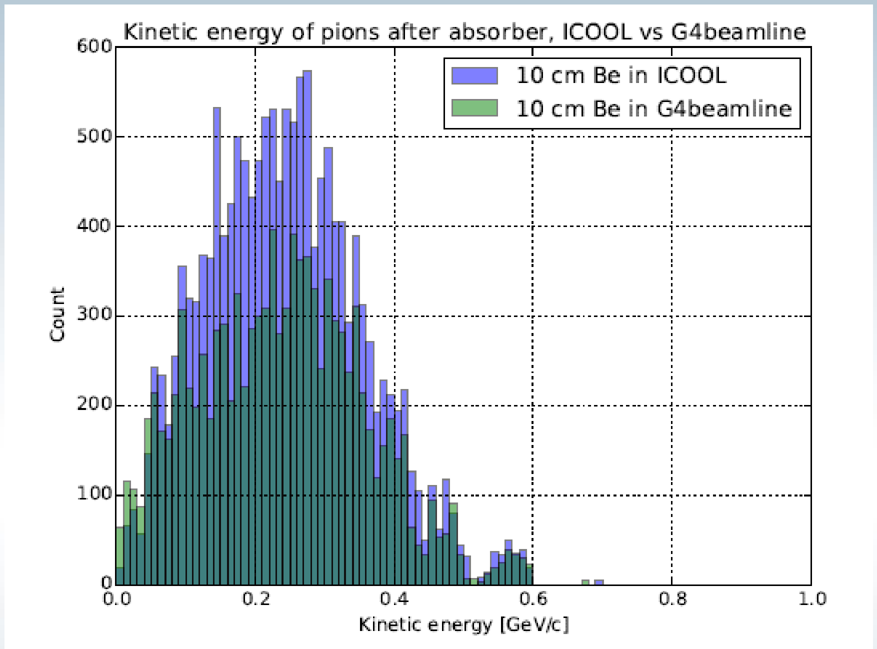




- High energy particles could activate the entire FE channel
- Bent solenoid chicane induces vertical dispersion in beam
  - High-Momentum particles scrape
  - Single chicane for both muon signs
- Proton absorber to remove low momentum protons

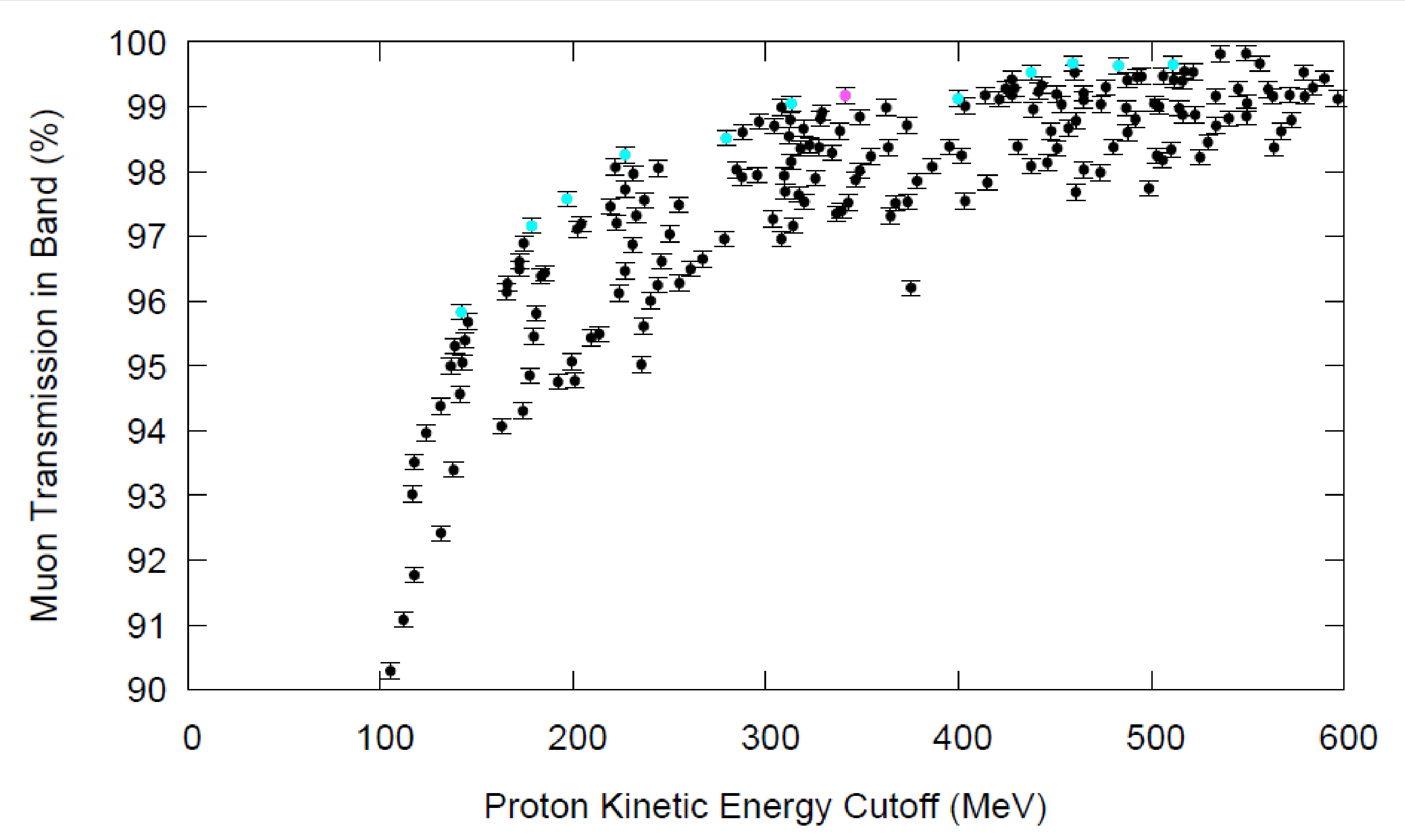
Chicane modeling



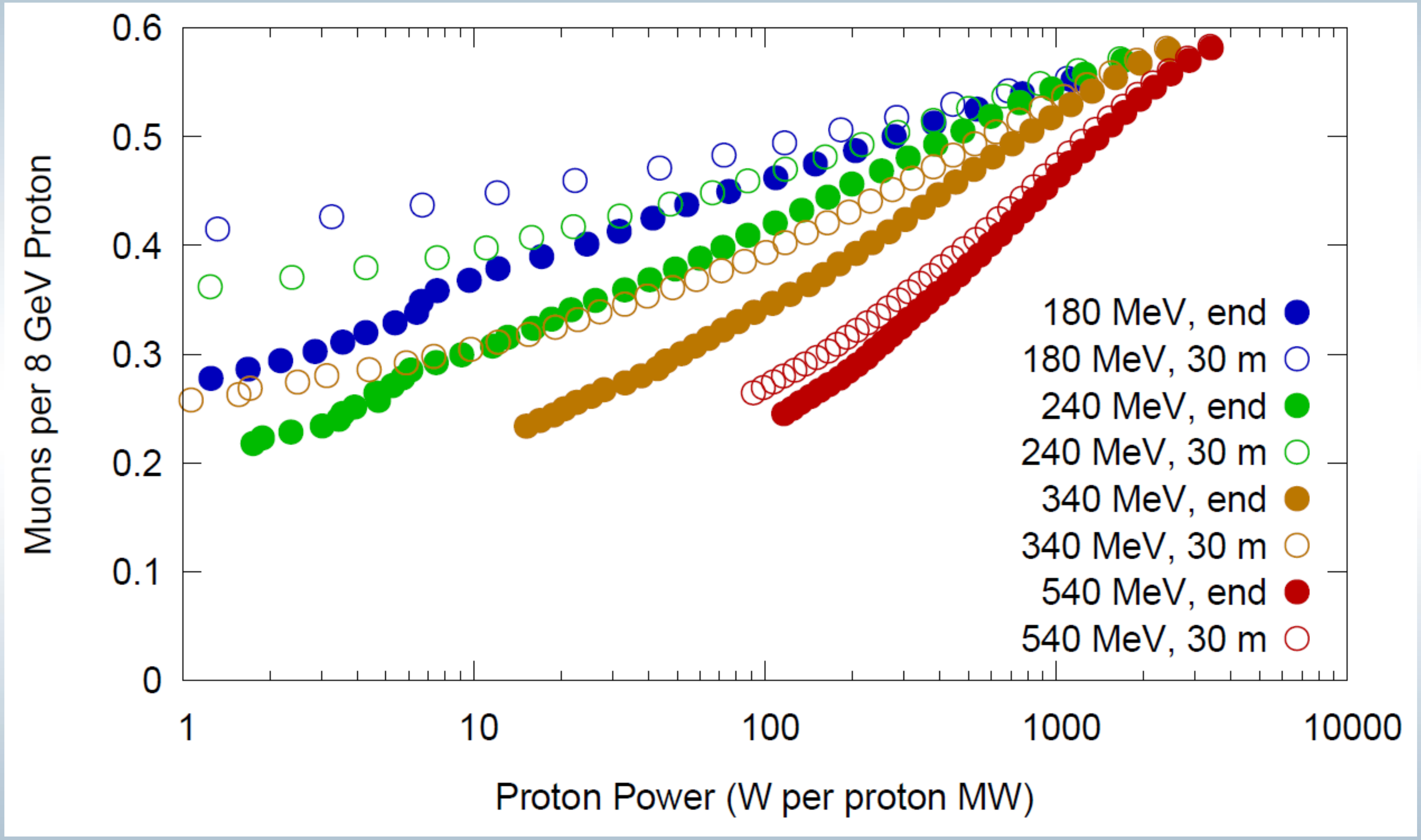


- Earlier simulations showed 15% discrepancy between ICOOL & G4BL
  - It was thought that this was due the different field model
  - Later studies showed that this was due the Be model in ICOOL
- For this reason Be absorber is pushed 30 m after chicane

Chicane optimization (1)



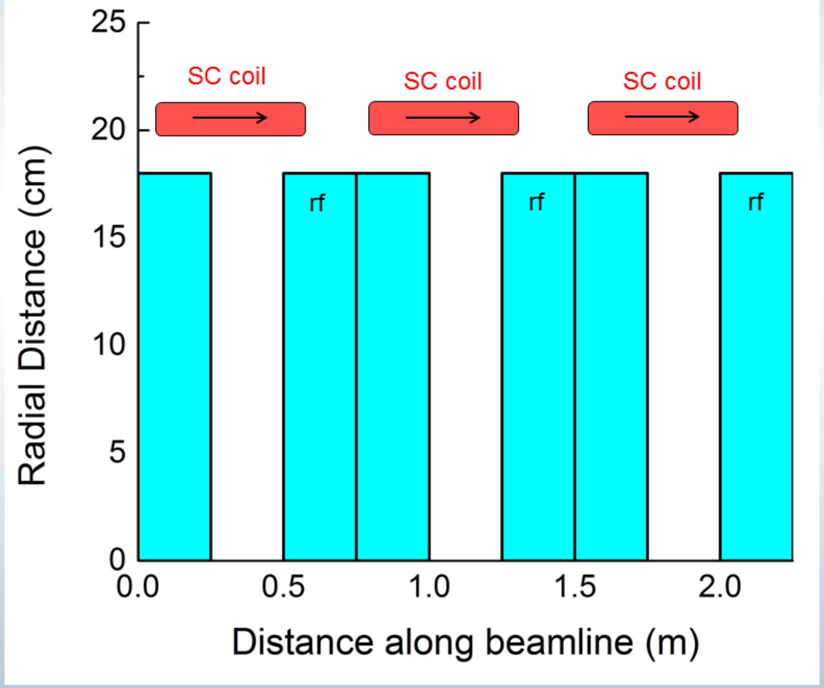
Chicane optimization (2)



- Significant tradeoff between muon transmission and downstream proton power

Buncher & Rotator parameters

- Re-designed to match to a 325 MHz cooler
- Buncher (21 m long)
  - 490 to 365.0 MHz (56 freq.)
  - RF voltage: 0.3 to 15.0 MV/m
  - 2.0 T magnetic field
- Rotator (24 m long)
  - 364.0 to 326.0 MV/m (64 freq.)
  - RF voltage: 20 MV/m
  - 2.0 T magnetic field
- Baseline has 120 different rf frequencies



Discretization of rf frequencies

- Our goal is to reduce the number of frequencies.
- Going from 120 to 30 frequencies -> 8-9% loss

Buncher rf parameters

Frequency (MHz)	Gradient (MV/m)
493.71	0.30
482.21	1.24
470.27	1.95
458.40	3.38
448.07	4.45
437.73	5.52
427.86	6.60
418.43	7.67
409.41	8.74
400.76	9.81
392.48	10.88
384.53	11.95
376.89	13.02
369.55	14.30

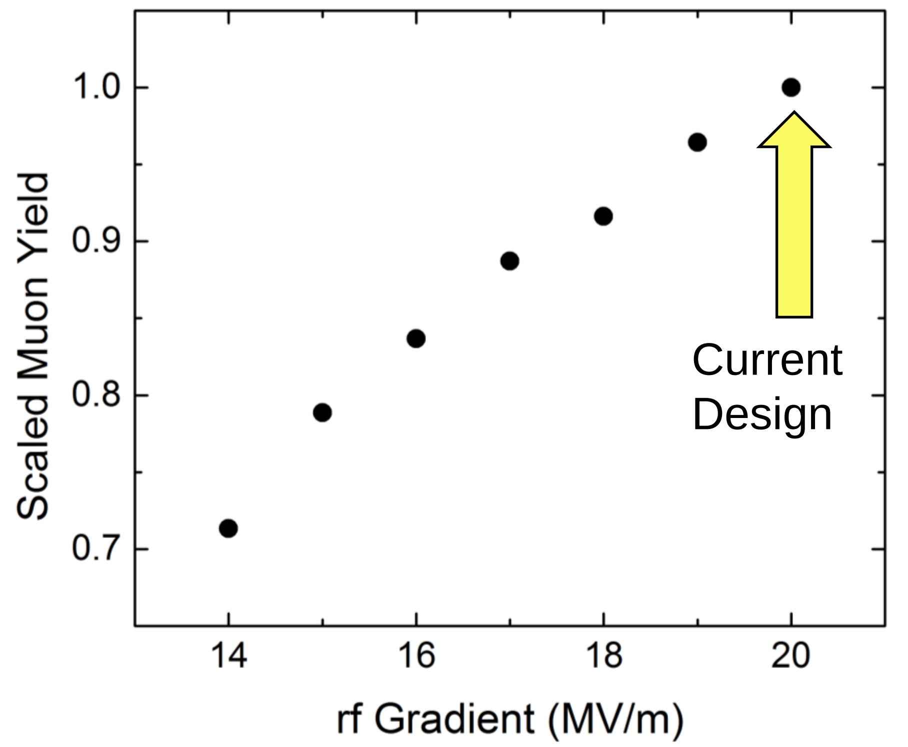
Rotator rf parameters

Frequency (MHz)	Gradient (MV/m)
363.86	20.0
357.57	20.0
352.20	20.0
347.59	20.0
343.65	20.0
340.27	20.0
337.39	20.0
334.95	20.0
332.88	20.0
331.16	20.0
329.75	20.0
328.62	20.0
327.73	20.0
327.08	20.0
326.65	20.0
326.41	20.0

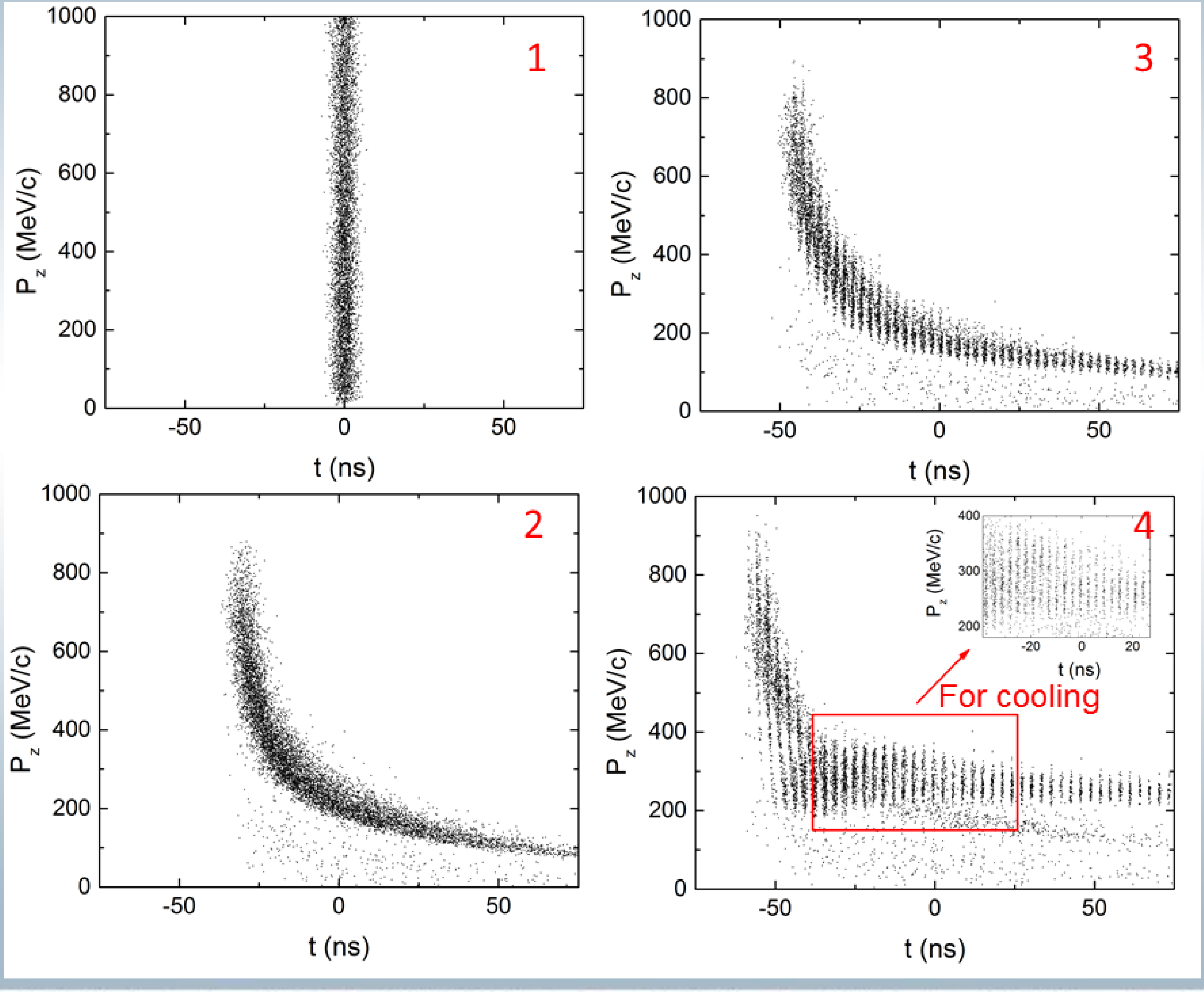
Lattice	No. of Buncher frequencies	No. of Rotator frequencies	Total No.	Relative Muon yield
1-rf pair	56	64	120	1
4-rf pair	14	16	30	0.91
8-rf pair	7	8	15	0.76

RF gradient sensitivity

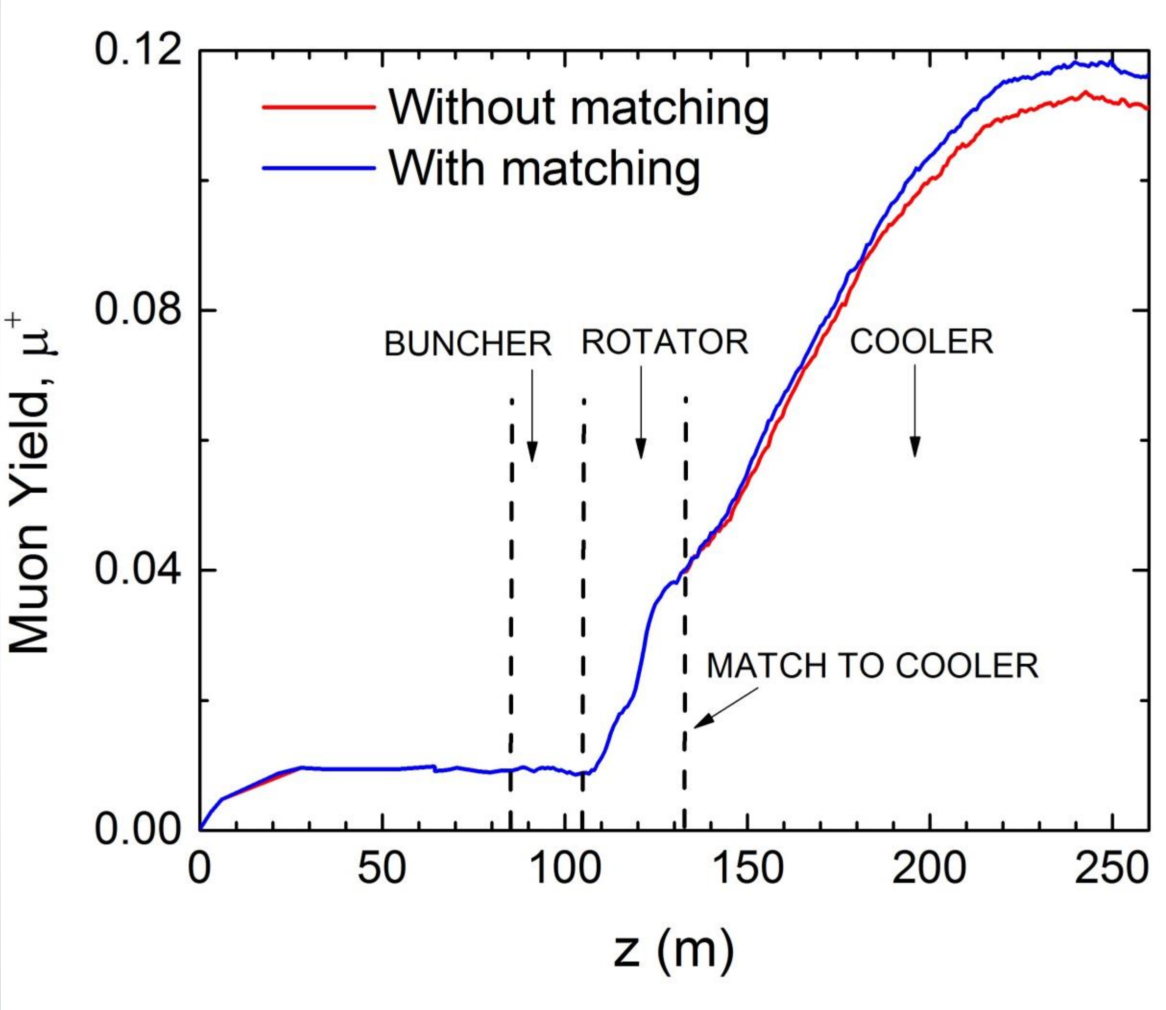
- Phase-Rotator baseline requirement
  - 20 MV/m rf gradient
  - 2 T magnetic field
- Results are sensitive to the rf gradient
  - Fixed rotator length
- Recent experiments showed that a 805 MHz can sustain 20 MV/m at 5 T which is encouraging!



Overall performance



Muon yield



- Muon yield is ~ 0.12 muons per 8 Gev proton

Future steps

- One challenge of a muon source is energy deposition from unwanted particles in the accelerator components which can exceed by 2-3 orders of magnitude its normal limit
  - Effectiveness of the chicane needs to be examined
- Rematch front-end for the new carbon target
  - Parametric studies of the muon per proton
- Find the maximum polarization we can achieve by changing parameters of our current design
- Potential applications of the muon source
  - Applications besides neutrino factories and muon colliders

Summary

- Significant progress in developing advanced concepts for the capture and transport of a muon beam produced by the interaction of a intense proton beam with a target
- Initial design of all FE subsystems (325 MHz) delivered
  - includes chicane/absorber to remove unwanted particles
- Significant progress on the target design
  - Moved to an initial design based on carbon that is suitable for Neutrino Factory applications
- Parametric studies of the front end, demonstrating improved performance with
  - Shorter field-taper at the target (~5 m)
  - higher capture solenoid, higher downstream fields (~20 T peak)