The Front End

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July 11, 2012

Outline

Define Front End

Major Sub-systems

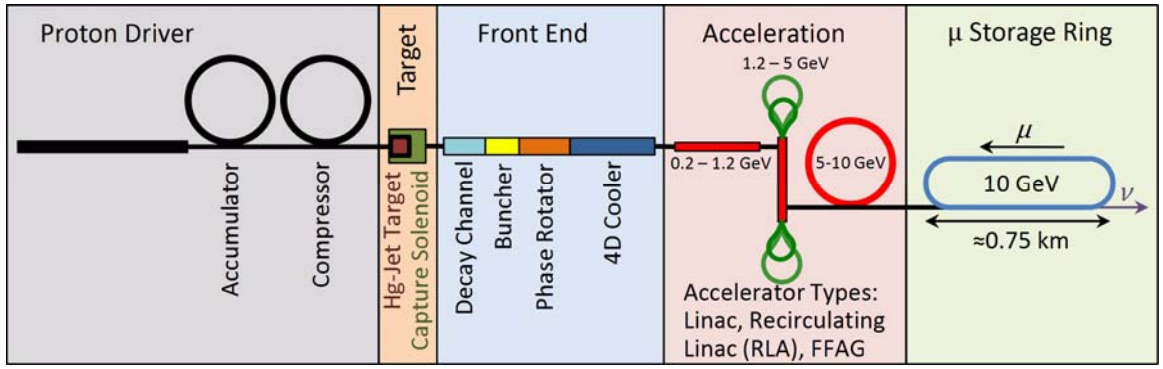
Key Challenges

Future R&D Activities

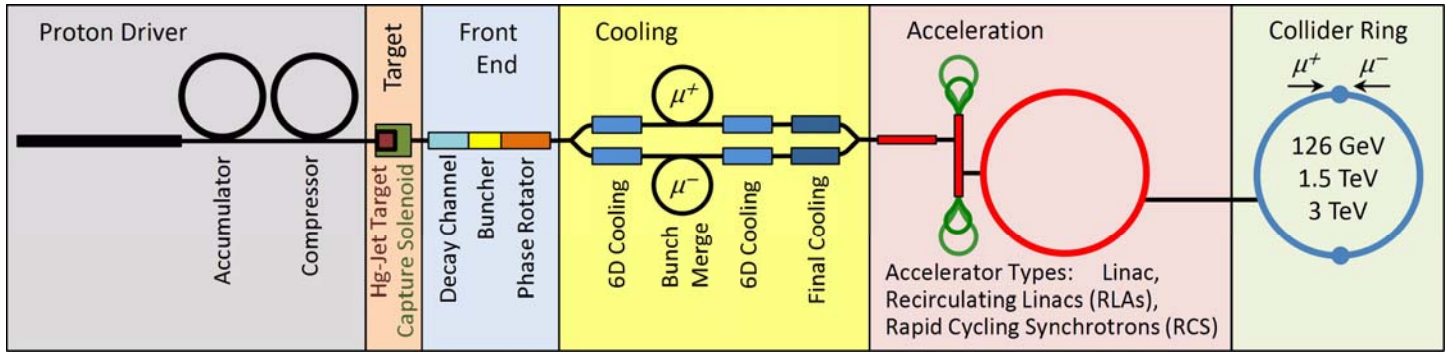
The Muon Collider/Neutrino Factory Front End

The Front End is that portion of the facility following the proton driver and target which delivers muons to the Muon Collider 6d cooling system or the Neutrino Factory acceleration system.

The proton source will have different bunch structures.



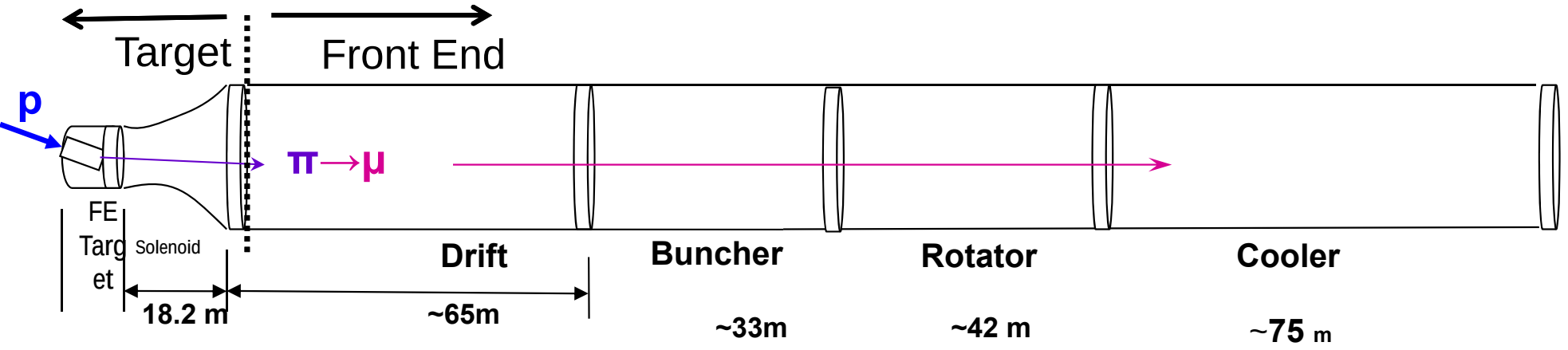
Neutrino Factory (with 4D cooler)



Muon Collider (no 4D Cooler)

The Major Front End Sub-Systems

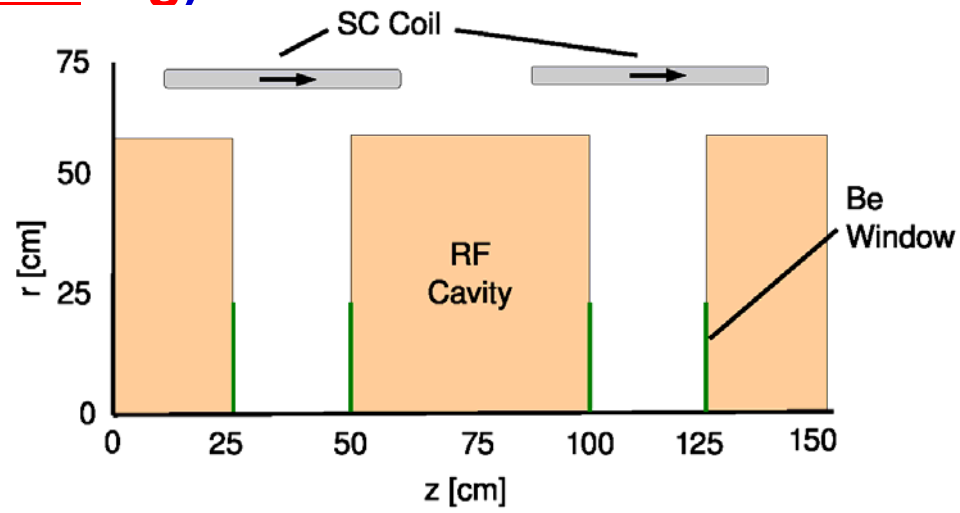
Drift/Decay Channel (π→μ)
Buncher
Rotator
4D Cooler



Key Buncher/Rotator Parameters

Buncher

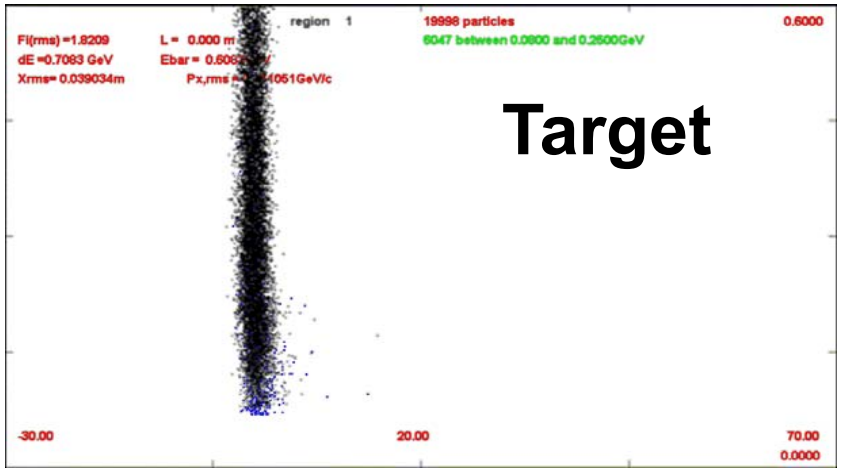
- 37 rf cavities
- 320 to 233.6 MHz (13 frequencies)
- 7.5 MV/m Peak rf gradient
- 24 MW Peak rf power (MC: 0.12 MW avg)
- 1.5T Peak magnetic field
- 33 m total length

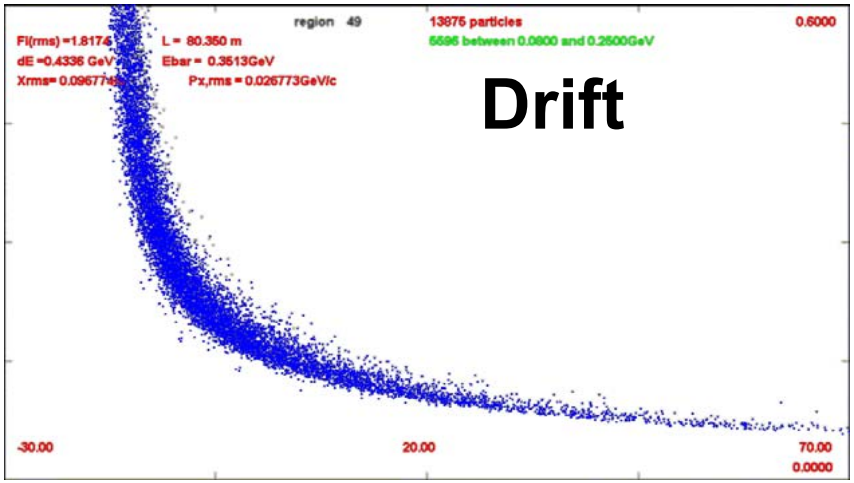


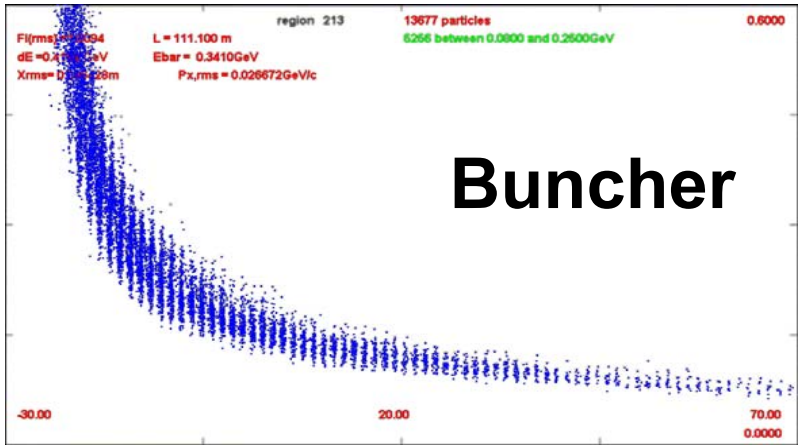
Rotator

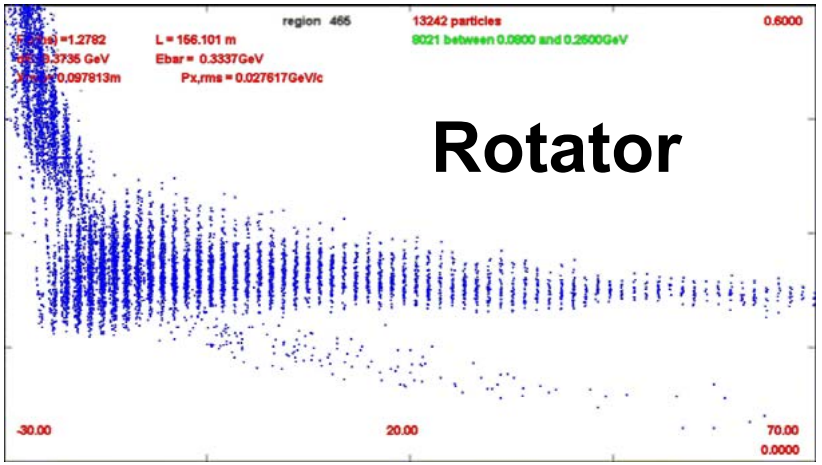
- 56 rf cavities
- 230 to 202.3 MHz (15 frequencies)
- 12 MV/m Peak rf gradient
- 140 MW Peak rf power (MC: 0.7 MW avg)
- 1.5 T Peak magnetic field
- 42 m total length

The Buncher/Rotator





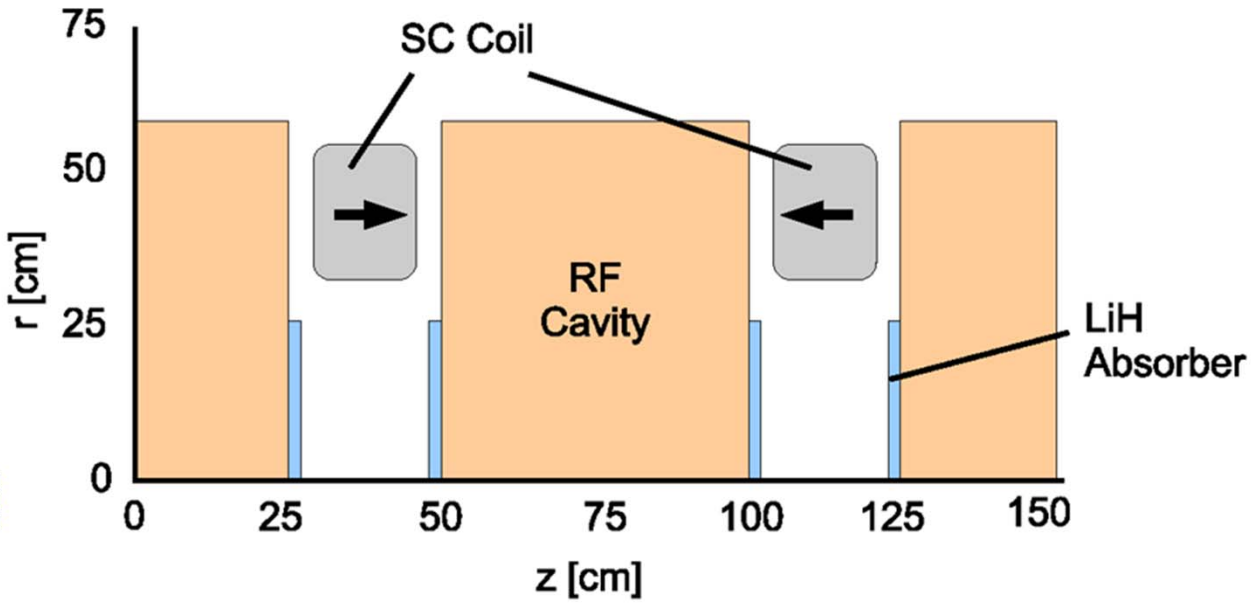




Pion/Muon Kinetic Energy

cτau

The Cooler



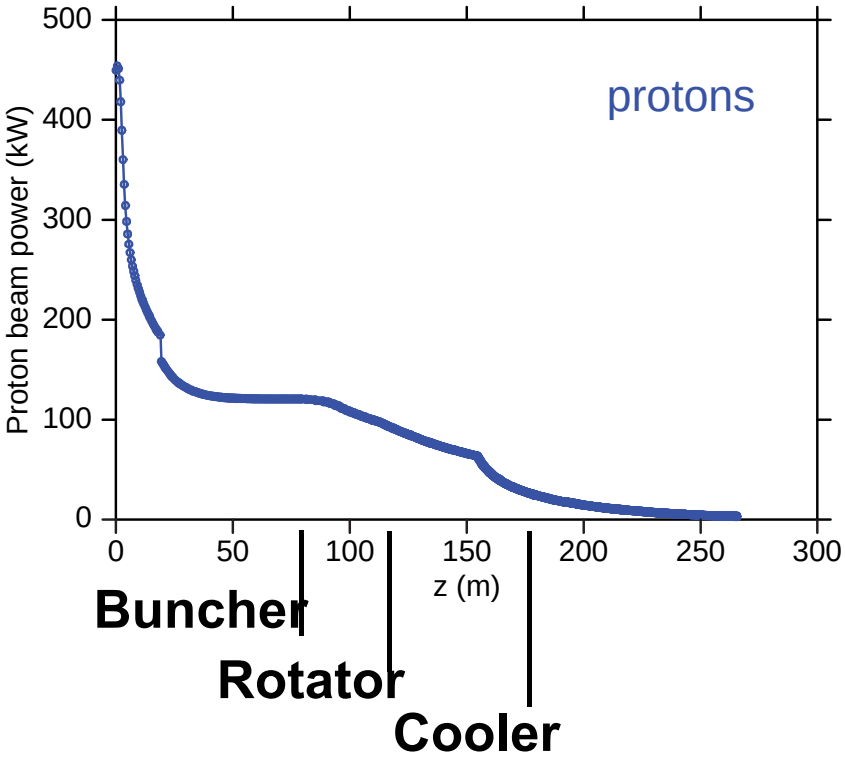
- 100 rf cavities
- 201.25 MHz
- 15 MV/m peak rf gradient
- 400 MW peak rf power (NF: 8 MW avg)
- 2.8T peak magnetic field

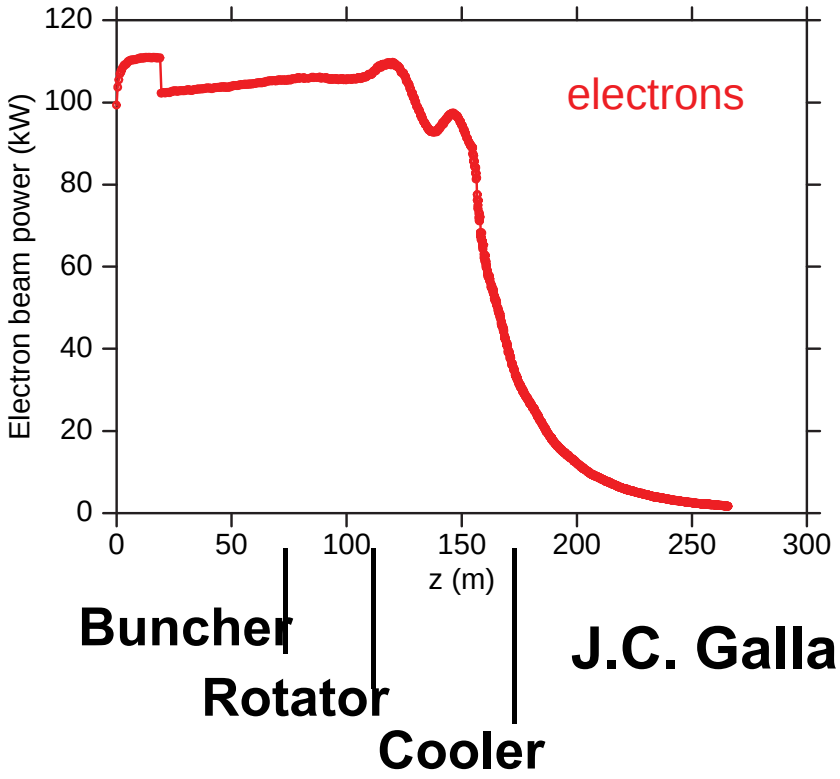
Front End Challenges

Buncher/Rotator/Cooler

- Shielding of beam line components
- Performance of rf cavities in magnetic field
- Engineering constraints

Front End Challenges- Beamline Shielding





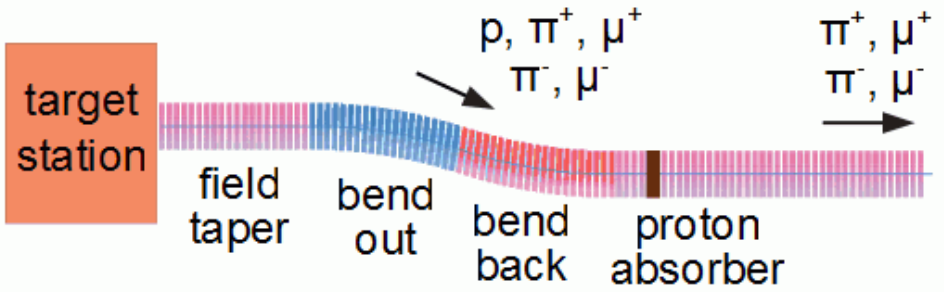
J.C. Gallardo

Mitigation Strategies

- Upstream bent solenoid
- Beryllium “beam stop” plugs

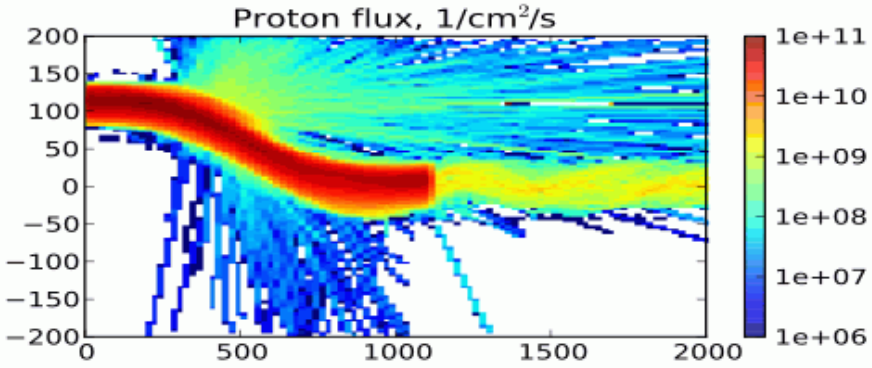
Bent Solenoid Chicane

P. Snopok

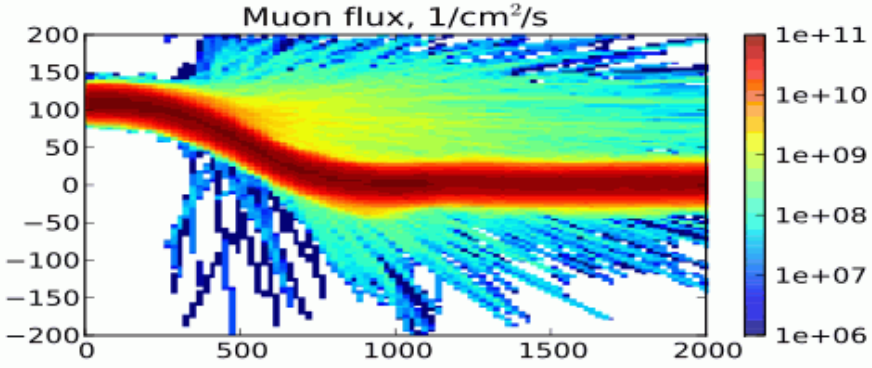


Chicane schematics

2 X 12.5°
L = 10m



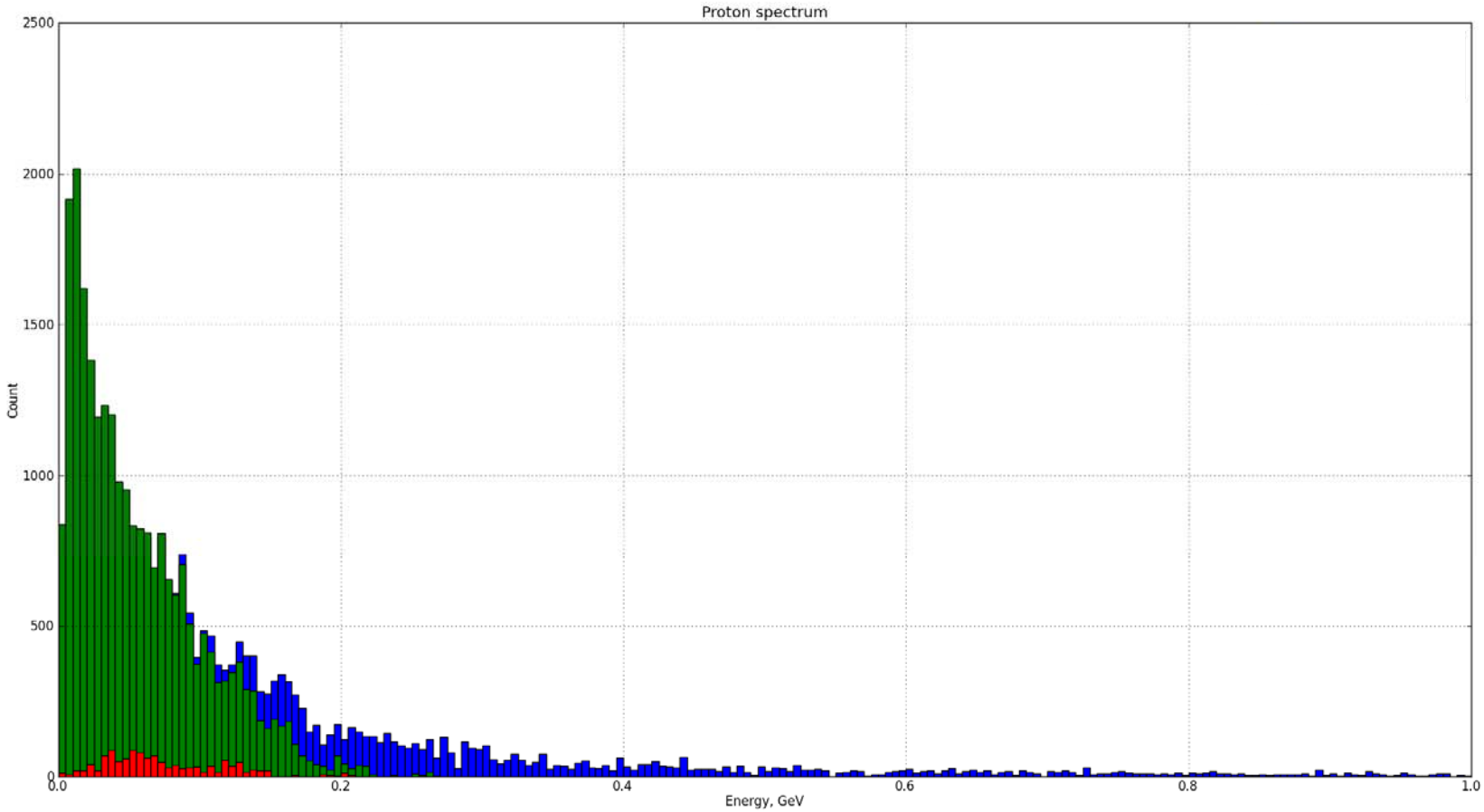
Proton flux, $1/cm^2/s$



Muon flux, $1/cm^2/s$

Proton Removal

Stacked plot of protons entering into the Chicane

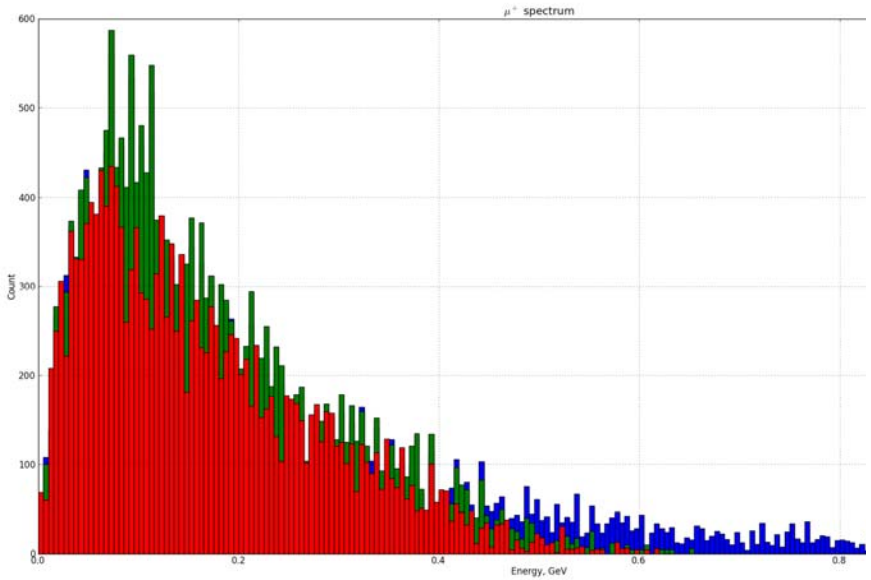


Blue: Removed by the chicane **Green: Removed by absorber** **Red: Survive**

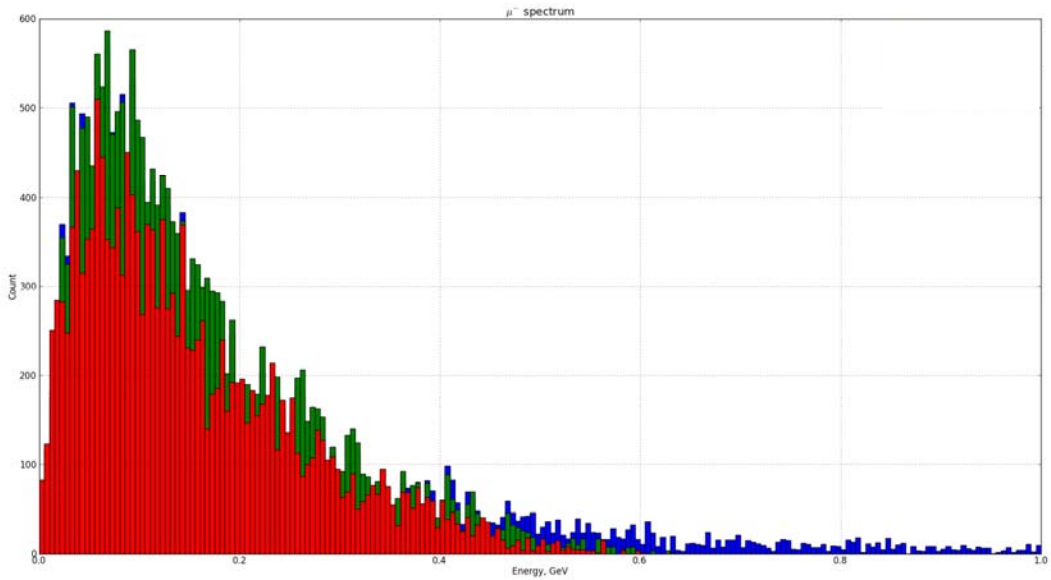
Proton beam power reduced by 99%

Muons through the Chicane

μ^+



μ^-

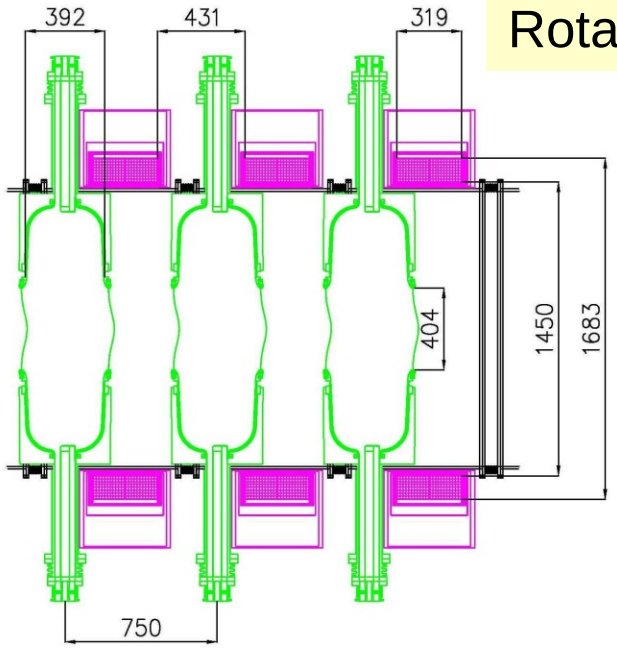


Blue: Removed by the chicane **Green: Removed by Absorber** **Red: Survive**

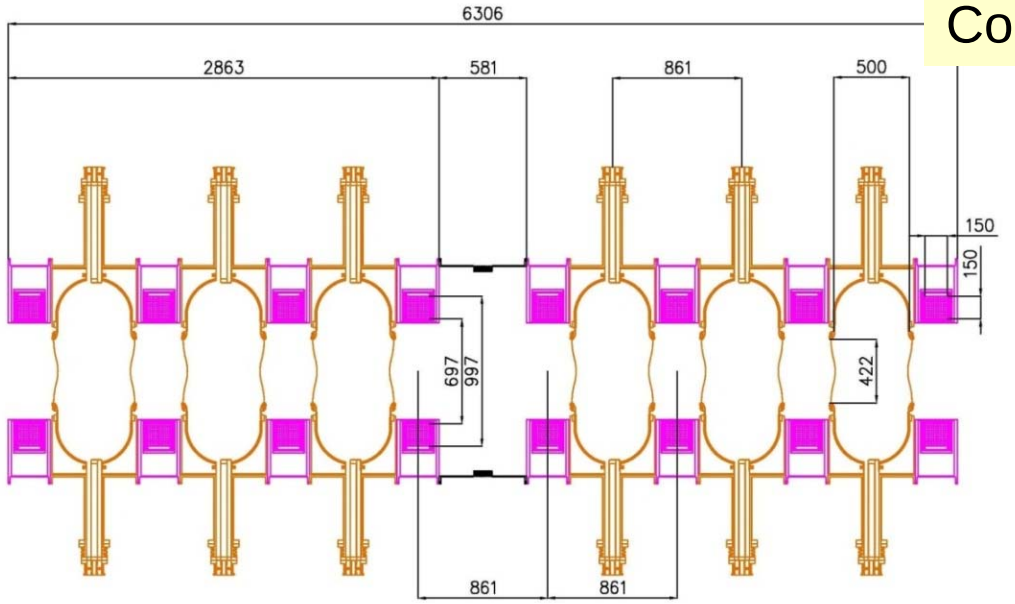
Muon Front End throughput reduced by 10-15%

Engineering challenges

Rotator



Cooler

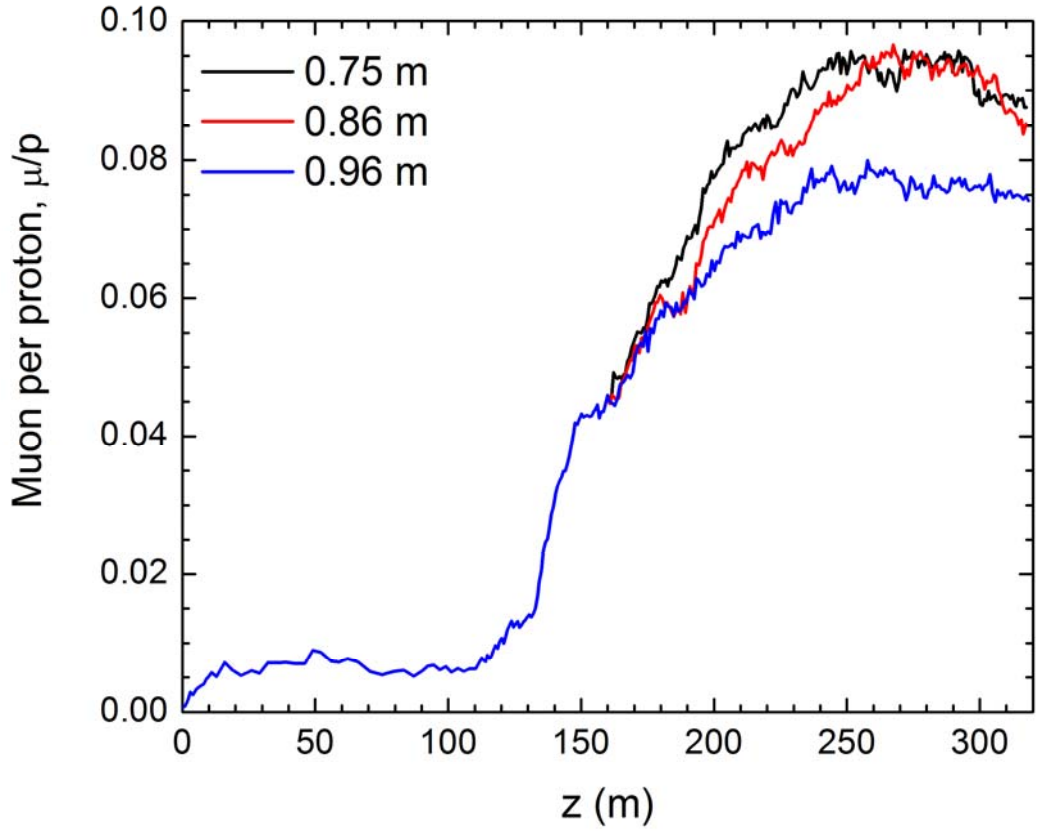


N. Bliss, IDS-NF Meeting (April, 2012)

- IFD-NF Engineering studies:
  - **Increase the gap between coils in buncher & rotator**
  - **Increase cooler cell length from 75 cm to 86 cm**
  - **Have one "empty" cell after a series of cavities**

Increasing the cell length

D. Stratakis

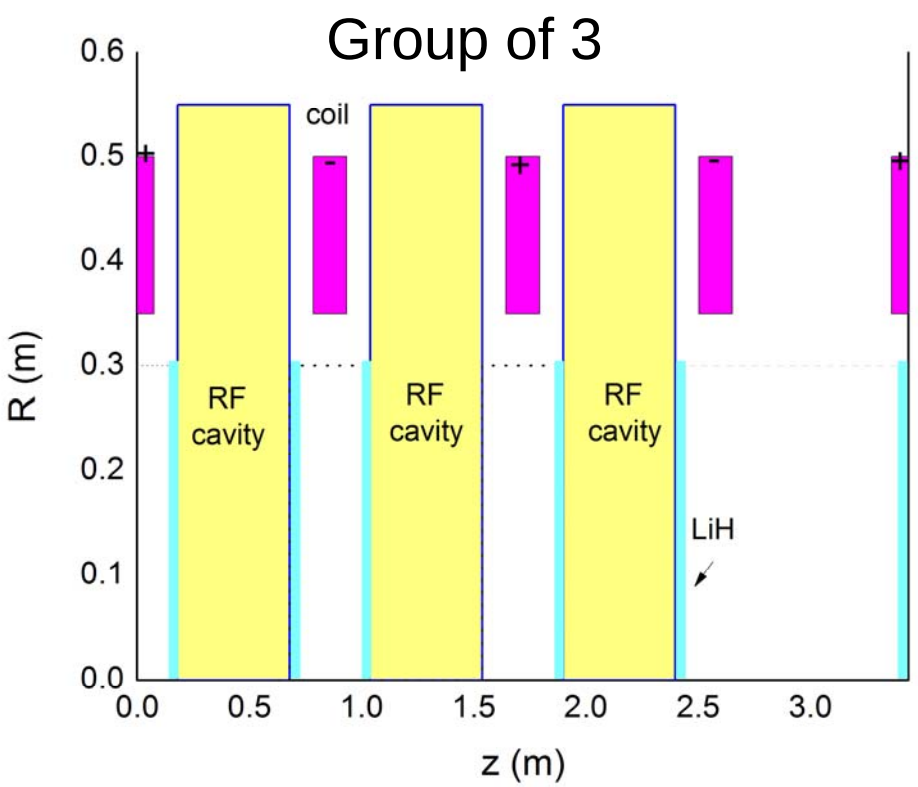


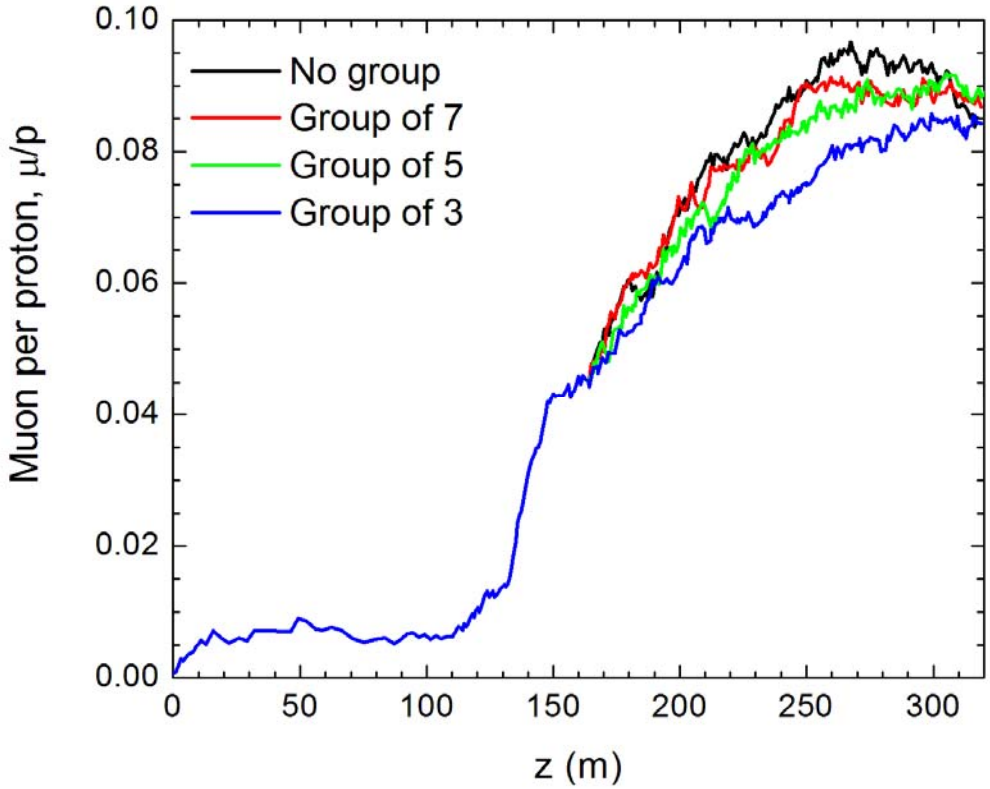
Acceptance plot
ε_T = 30mm
ε_L = 150mm

- **Simulations show that it is safe to increase the cooler cell to 86cm without loss of performance.**
- **Beyond that point, performance is reduced**

Adding a gap between cavities

D. Stratakis





There is a loss of ~5% if empty cell is after 5 or more cavities. Loss is ~12% for groups of 3

Front End Challenges- RF

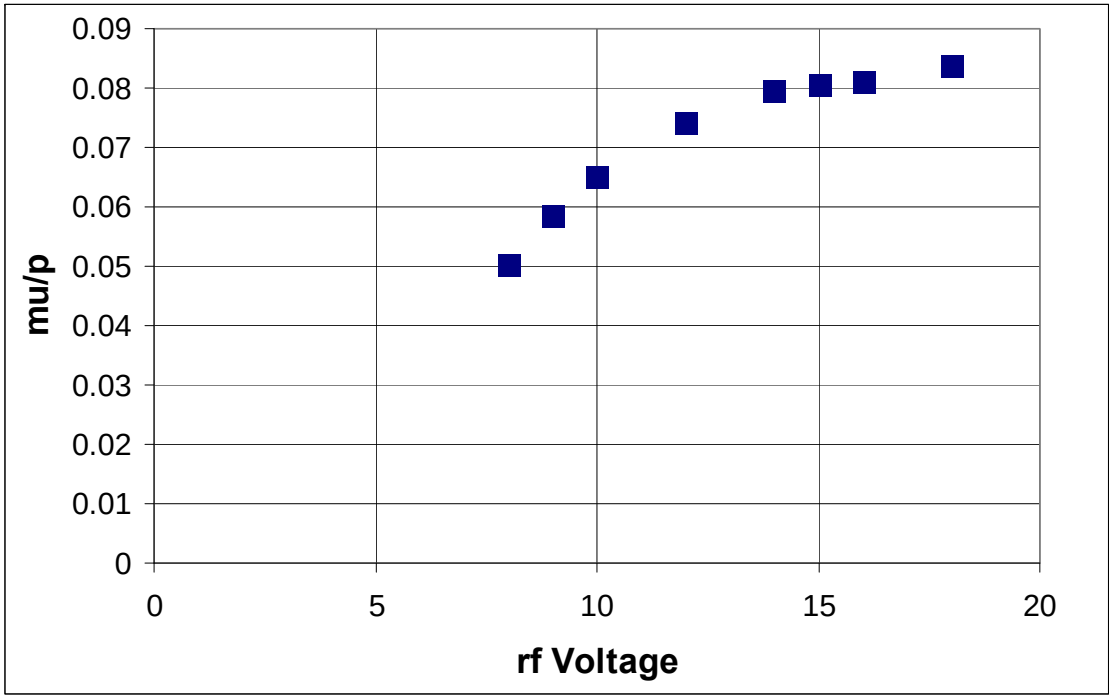
D. Neuffer

Machine performance reduced

- **μ/p ratio reduced with rf gradient limitations**

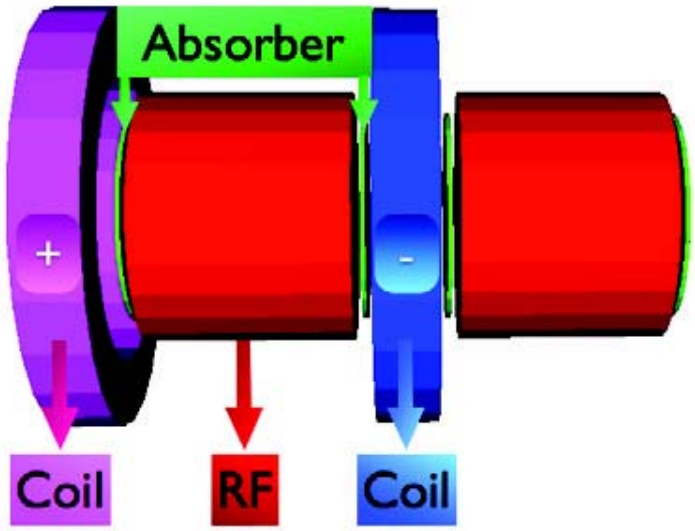
Mitigation Strategies:

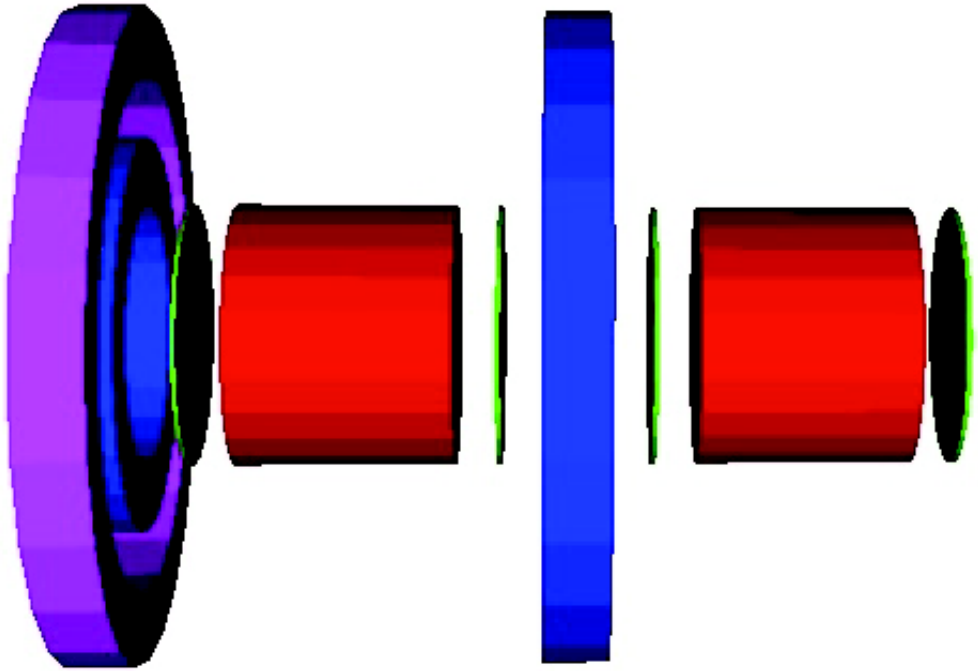
- **Beryllium walled cavities**
- **Bucked Coil Lattices**
- **High Pressure (GH_2 filled) rf cavities**

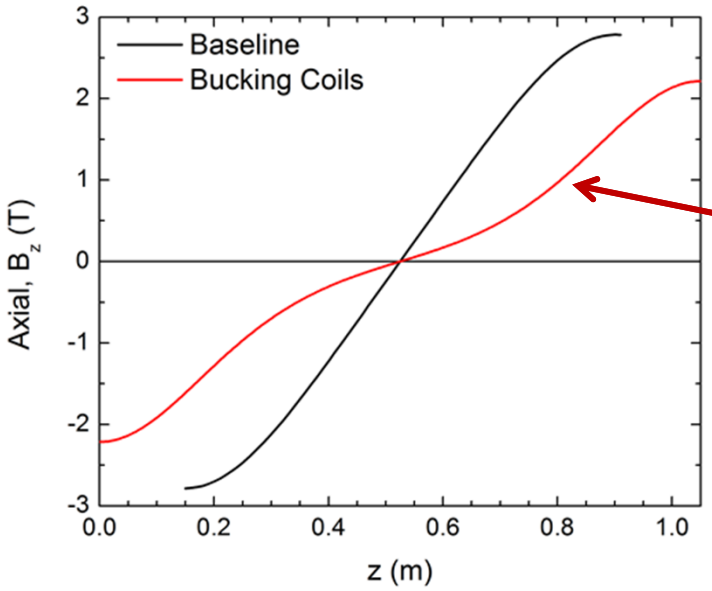


30% performance loss with factor 2 gradient reduction

Bucked Coils





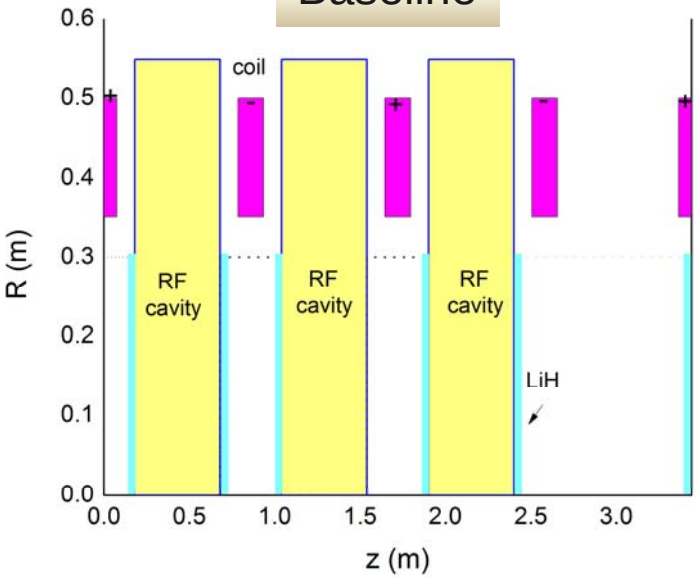


Axial field reduced at rf cavity walls

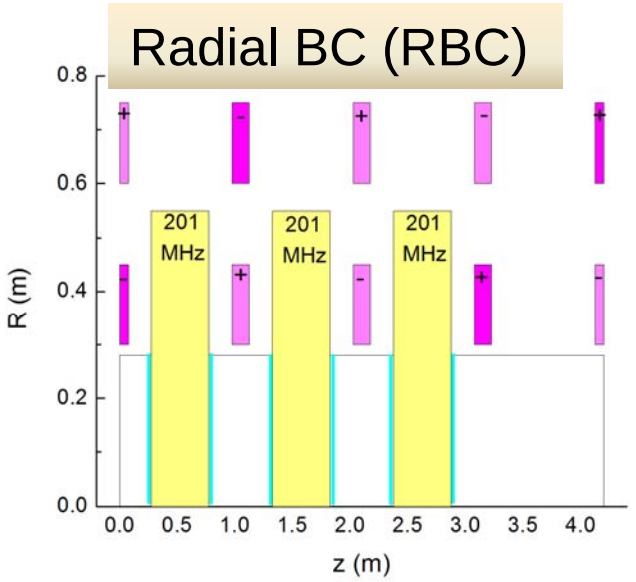
Bucked Coils for the Cooler

A. Alekou

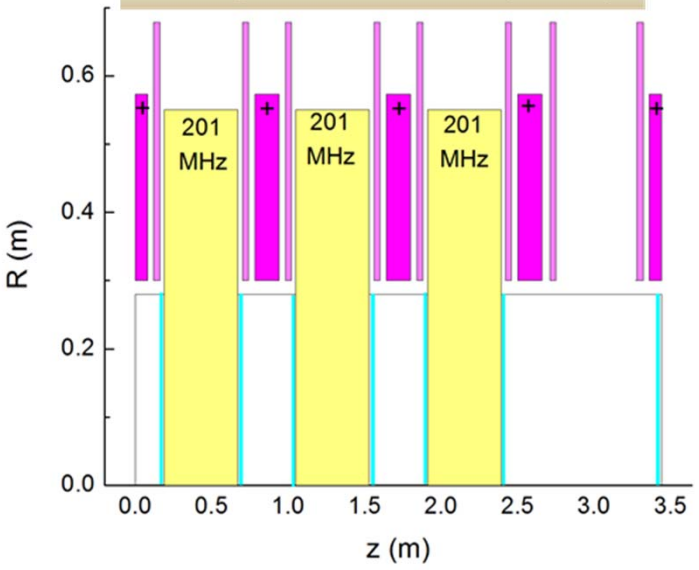
Baseline



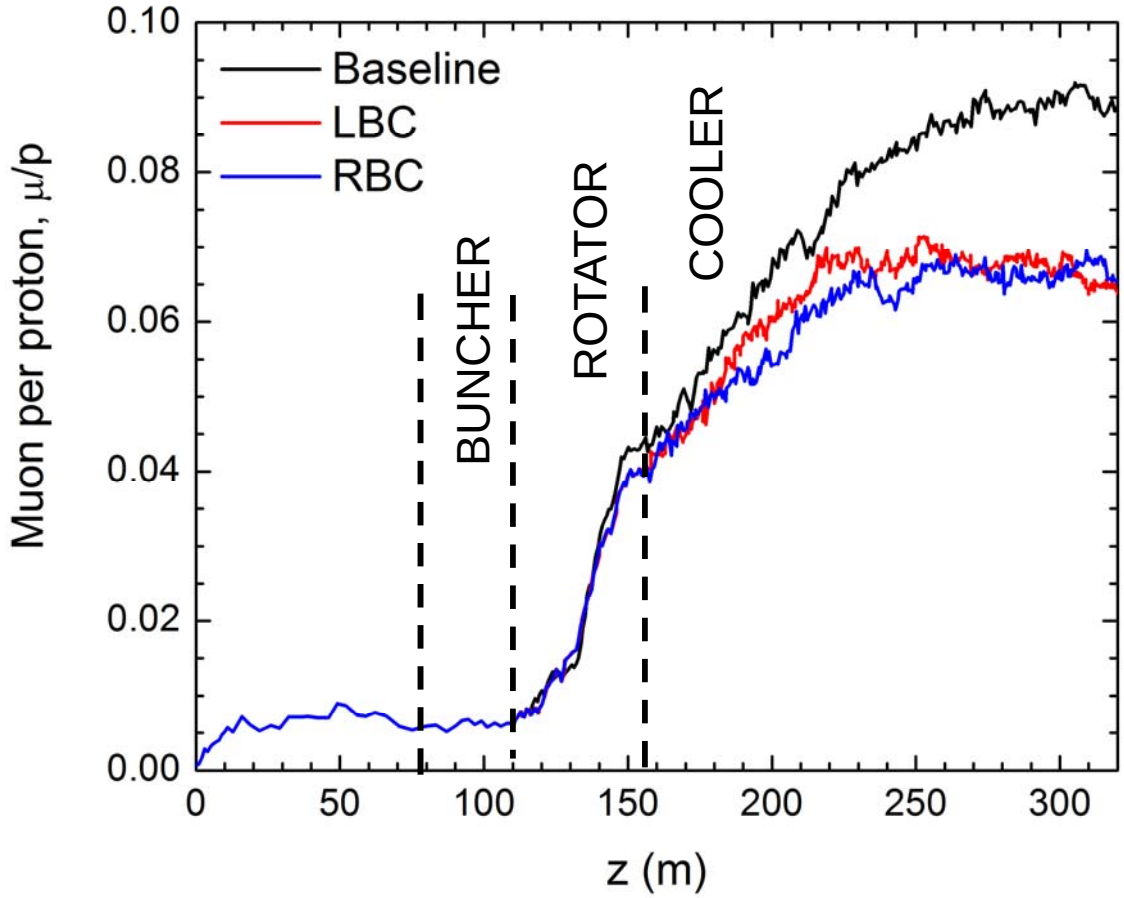
Radial BC (RBC)



Longitudinal BC (LBC)

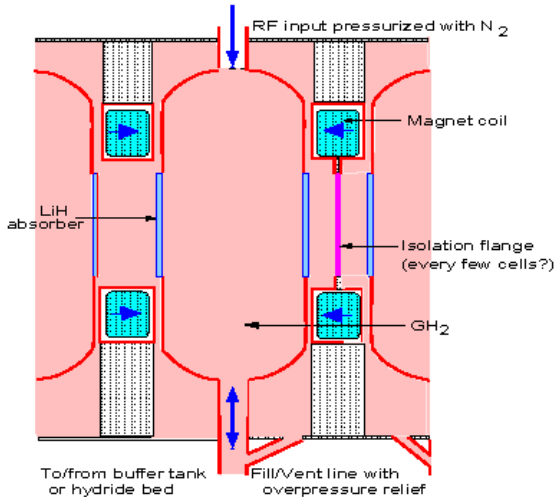


ICOOL Simulations



- **Similar results for both LBC and RBC schemes**
- **20% less muon per protons compared to baseline**

High Pressure Gas RF

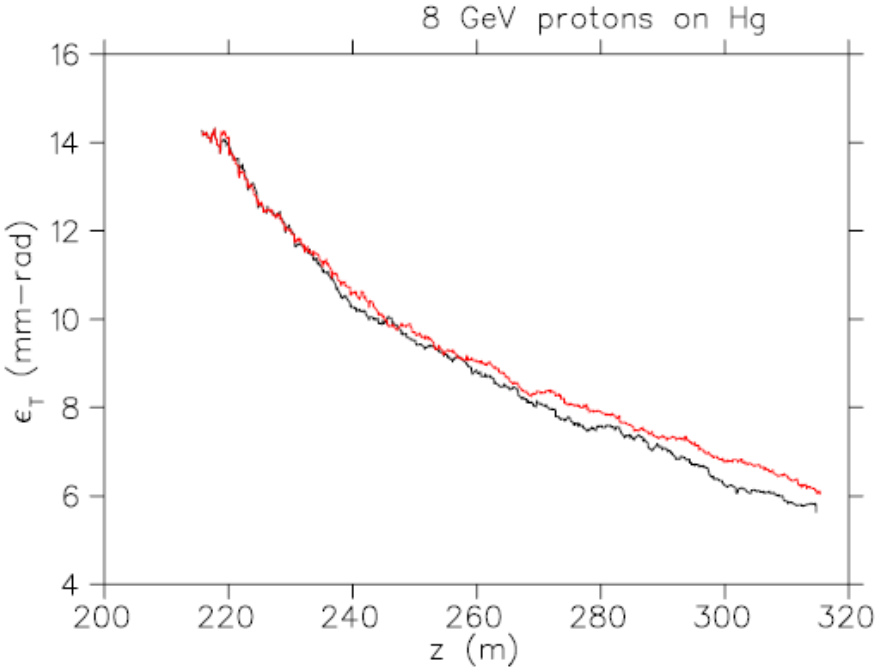


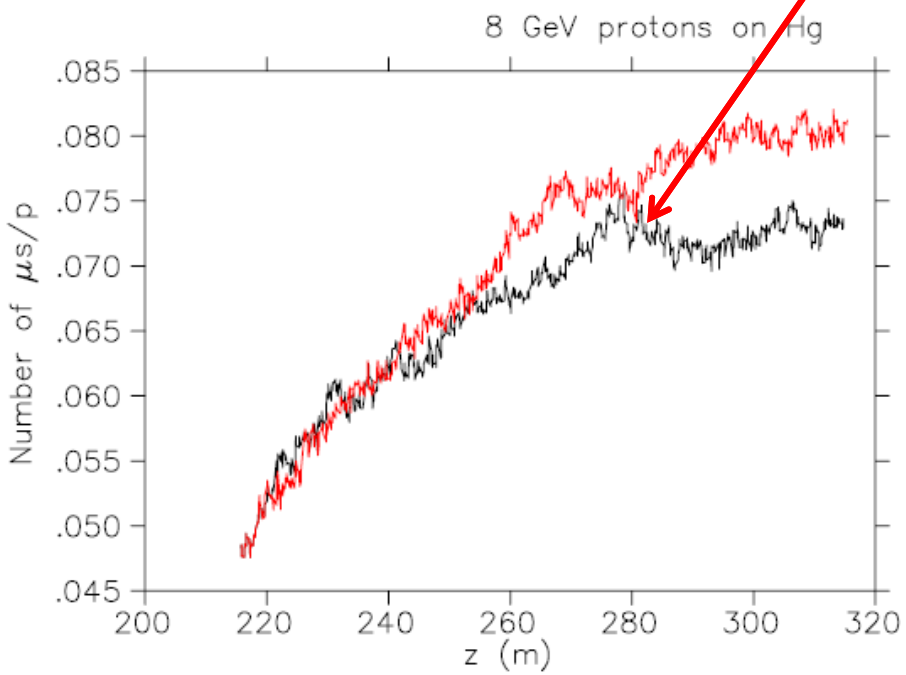
Simulation considers:

- **34 atms GH_2**
- **LiH absorbers**
- **Be Isolation windows**
- **15 MV/m rf gradients**

J.C. Gallardo
M. Zisman

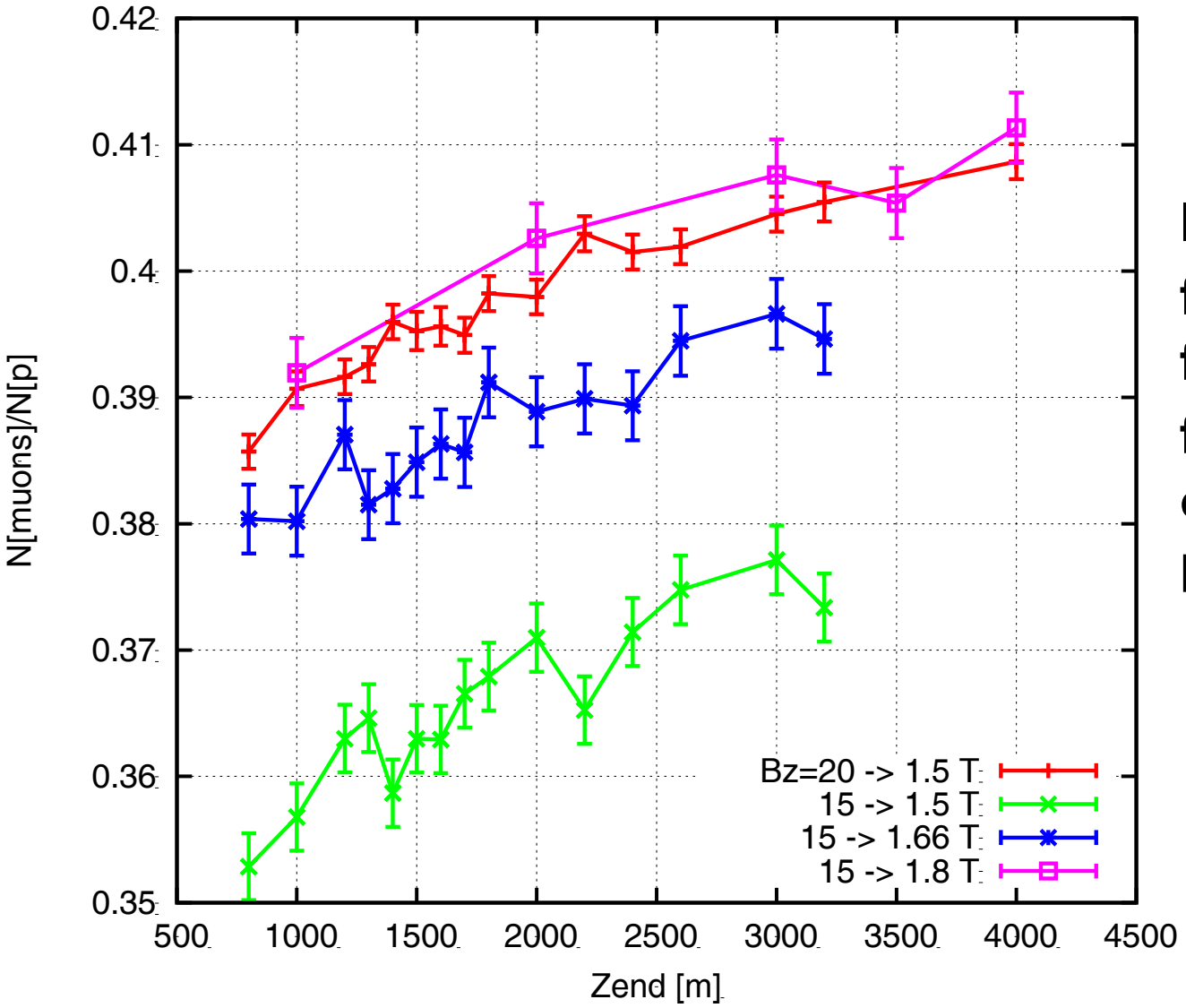
8% Reduction





ε_T **Red: Vacuum rf** **Black: HPRF** **Downstream Acceptance**

Target Taper



H. Sayed

If Target system goes from 20T to 15T peak field then end field goes from 1.5 T to 1.8T in order to maintain performance

FY 13 R&D Activities

- **Integrate Chicane into Decay region**
- **Respond to new Target taper 15T→1.8T**
  - **Set Decay channel, Buncher, Rotator to 1.8T**
  - **Establish new matching section into Cooler**
  - **Re-optimize Front End parameters**
  - **Evaluate Front End performance levels**
- **Support IDS-NF RDR activities**

FY 14 & 15 R&D Activities

- **Optimize Front End for Muon Collider**
- **Respond to rf cavity technology results**
- **Support MAPFP1 activities**

Summary

- **A Front End baseline has been established**
- **Optimization studies have resulted in a 0.08 μ/p throughput ratio for 8 GeV incoming protons**
- **Key Front End challenges**
  - **Performance of rf cavities in magnetic field**
  - **Energy deposition along Front End channel**
- **Mitigation strategies have been developed to address these challenges**