# The Front End

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**Brookhaven National Lab**
**August 30, 2012**

# Outline

**Define Front End**

**Major Sub-systems**

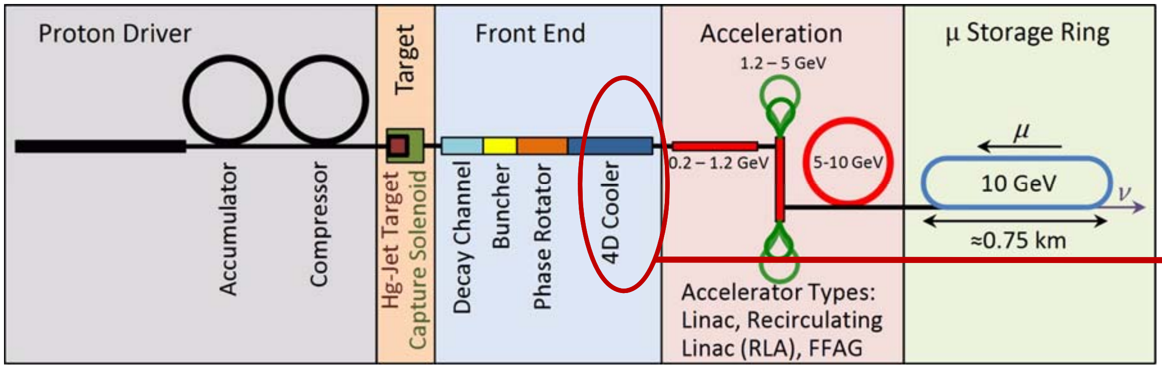
**Key Challenges**

**Future R&D Activities**

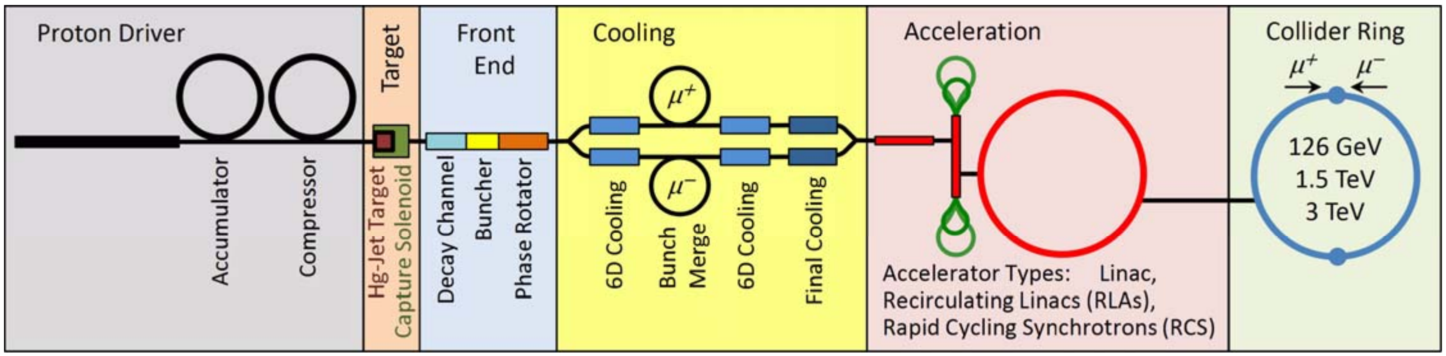
# The Muon Collider/Neutrino Factory Front End

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)

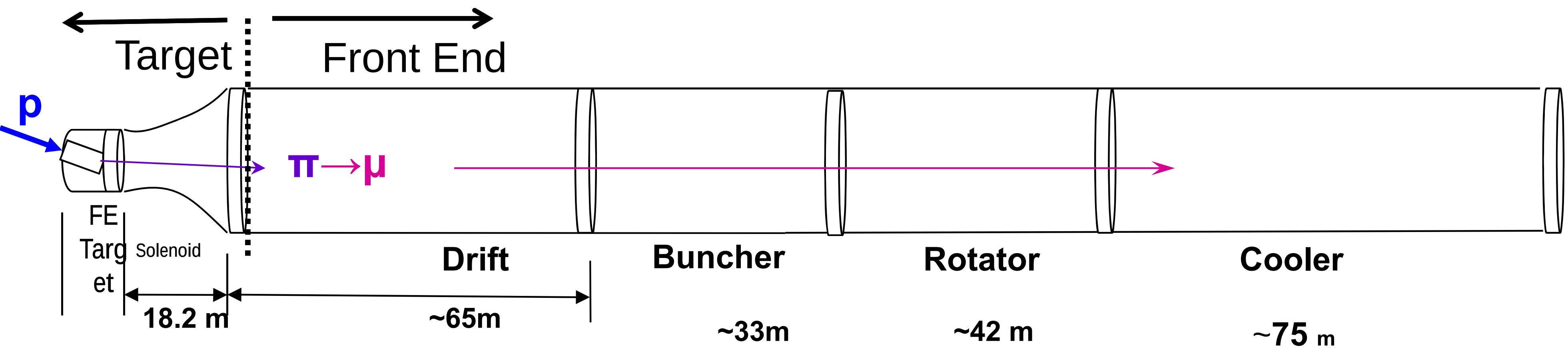



Muon Collider (no Front End 4D Cooler)

# The Major Front End Sub-Systems



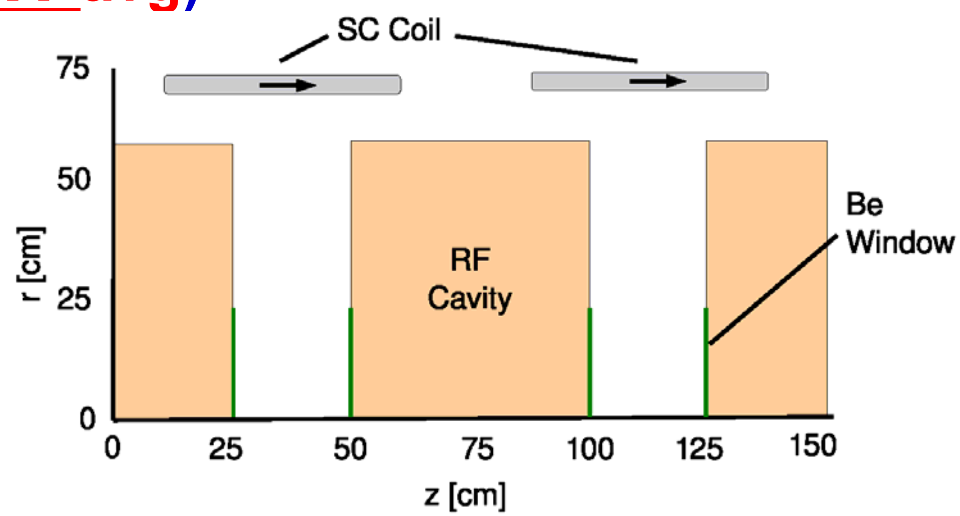
## Drift/Decay Channel ($\pi \rightarrow \mu$)
## Buncher
## Rotator
## 4D Cooler



# 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



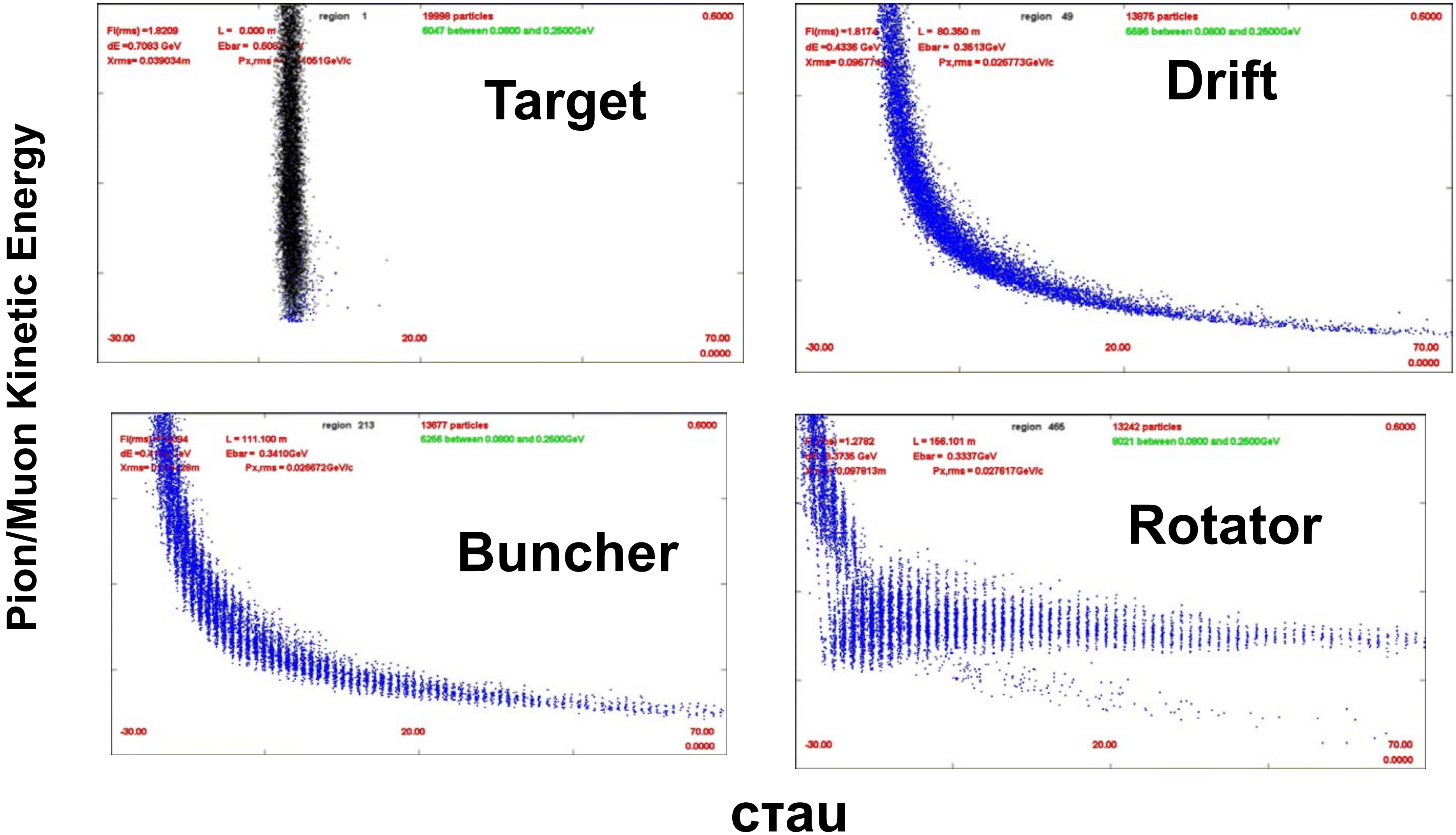

## Rotator

- 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

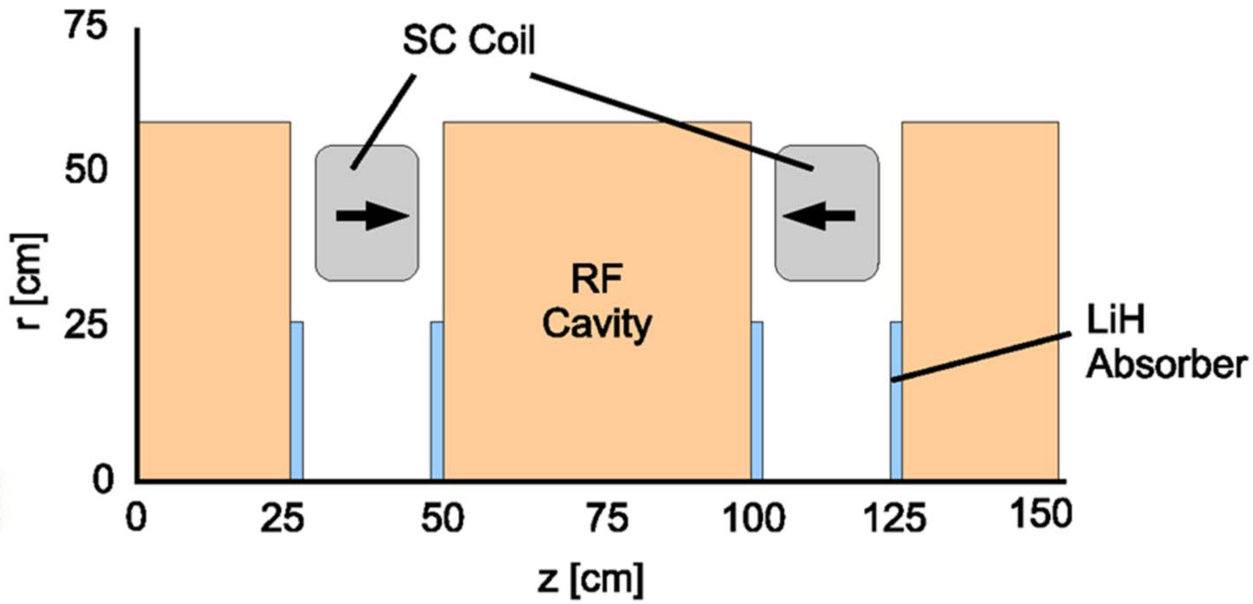
# The Buncher/Rotator



D. Neuffer



# The Cooler

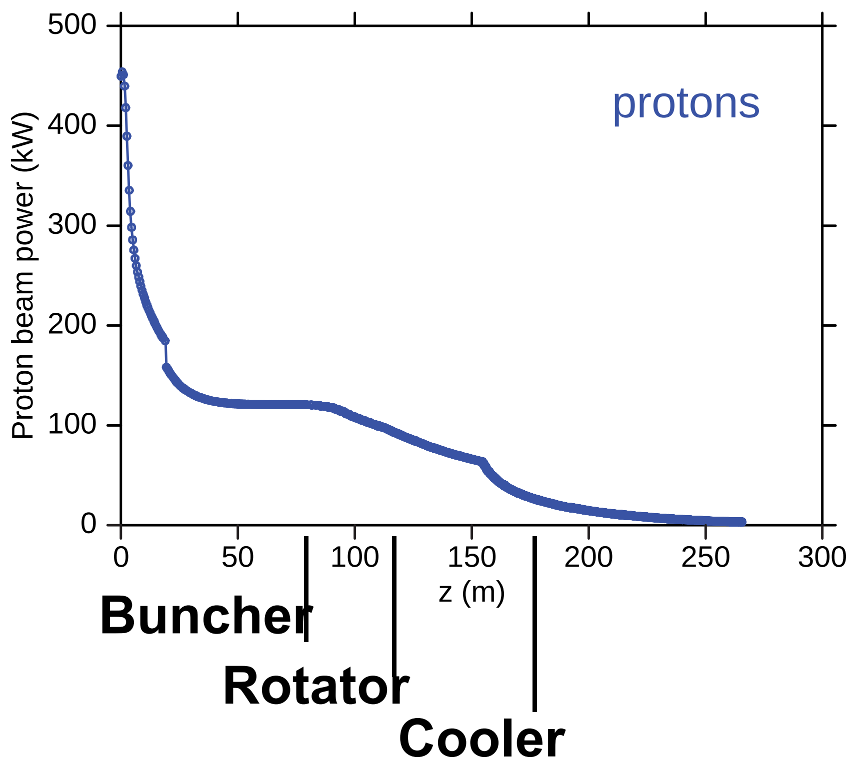


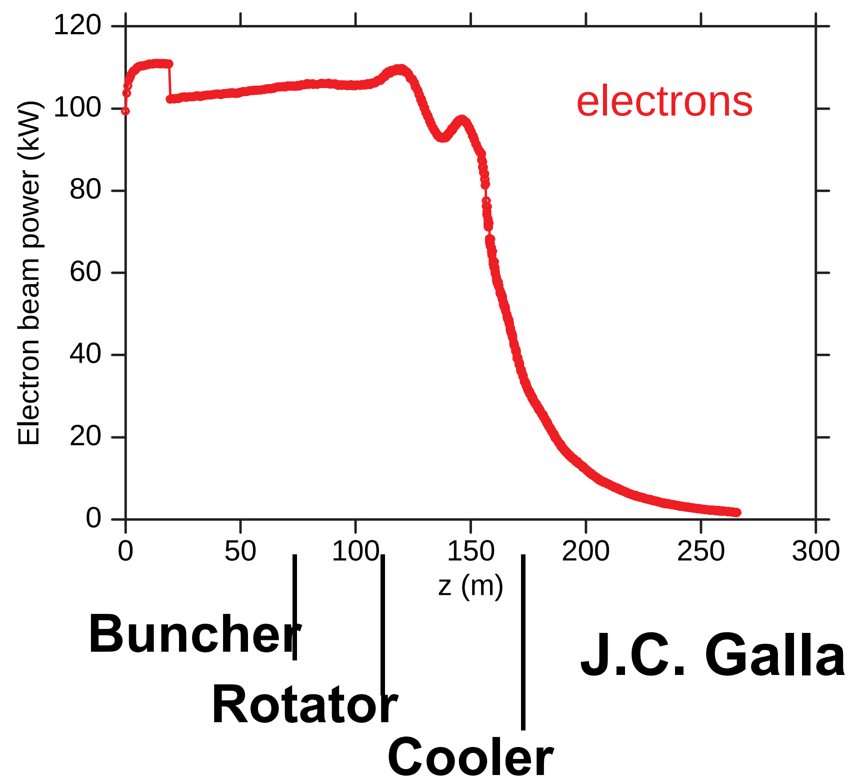

- **100 rf cavities**
- **201.25 MHz**
- **15 MV/m peak rf gradient**
- **400 MW peak rf power (NF: 8 MW avg)**
- **2.8T peak magnetic field**

# 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**

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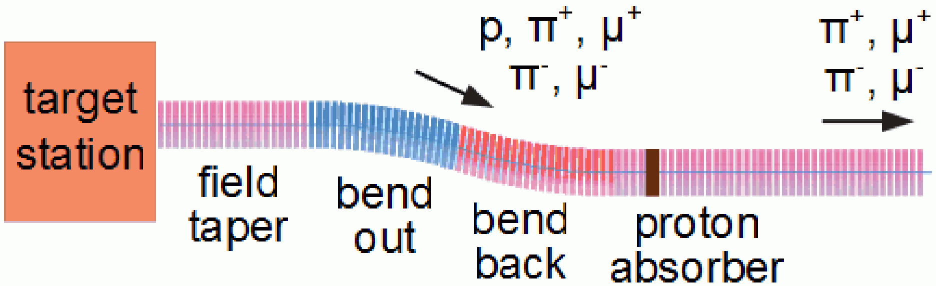
# Bent Solenoid Chicane

Muon Accelerator Program

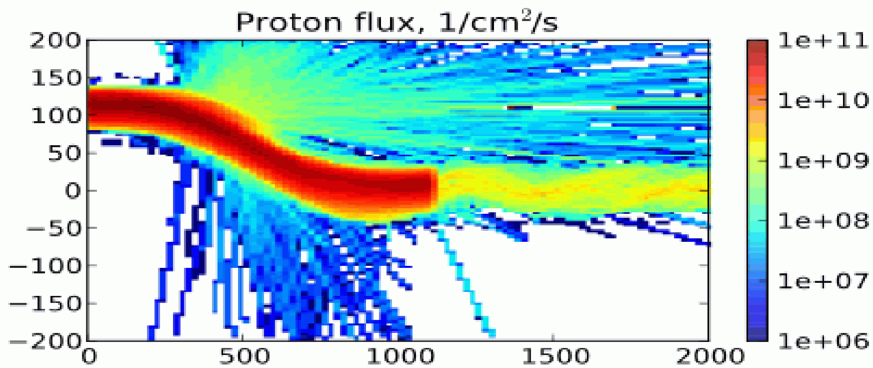
10m

C. Rogers, P. Snopok

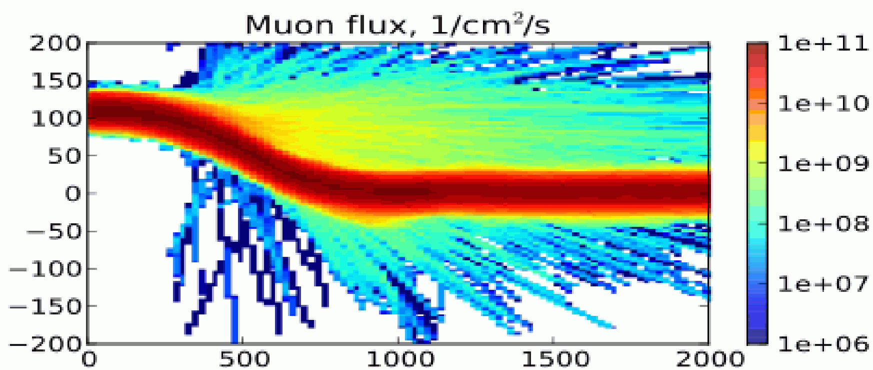



Chicane schematics

**2 X 12.5°**
**L = 10m**




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

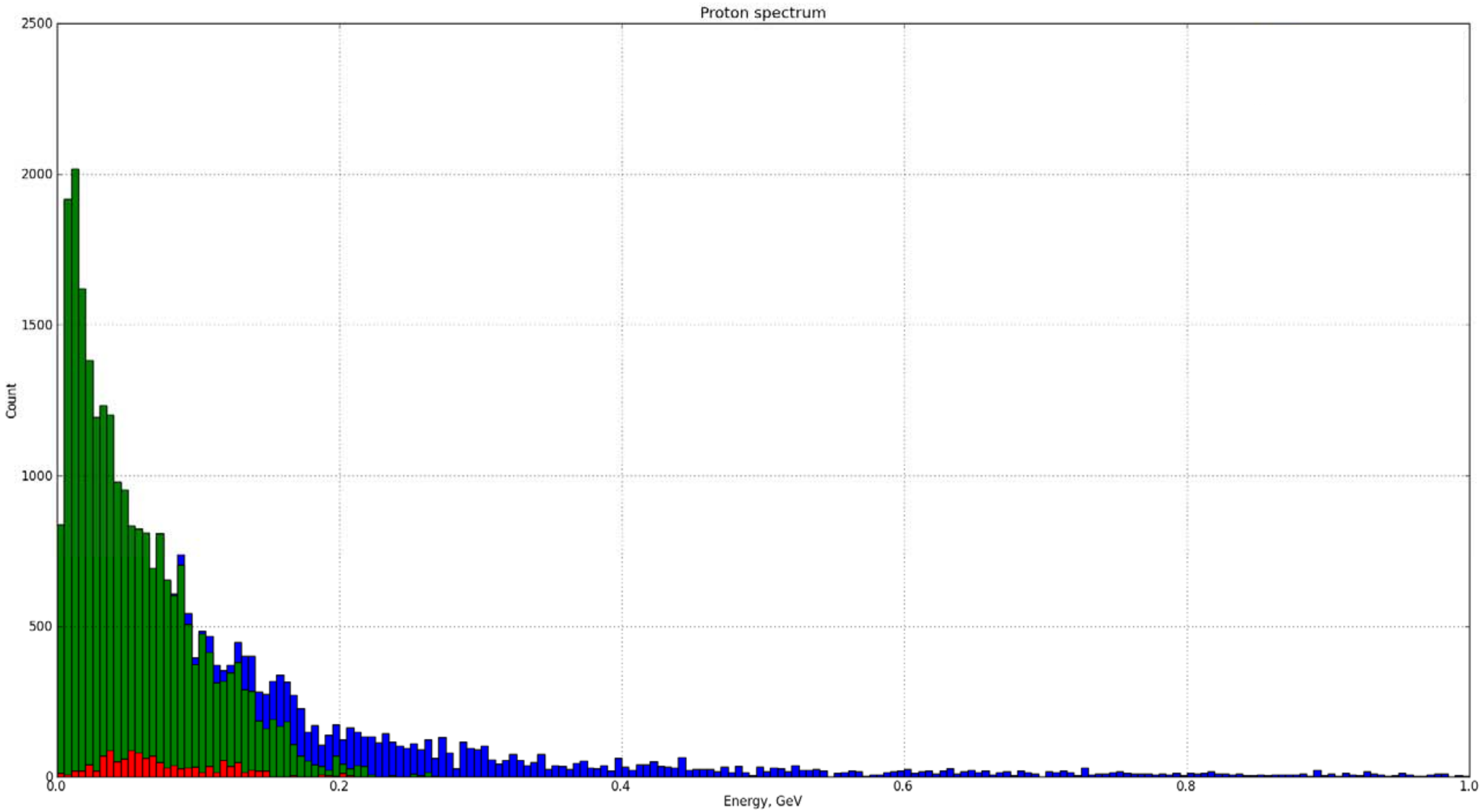



Muon flux, $1/cm^2/s$

# Proton Removal



**Stacked plot of protons entering into the Chicane**



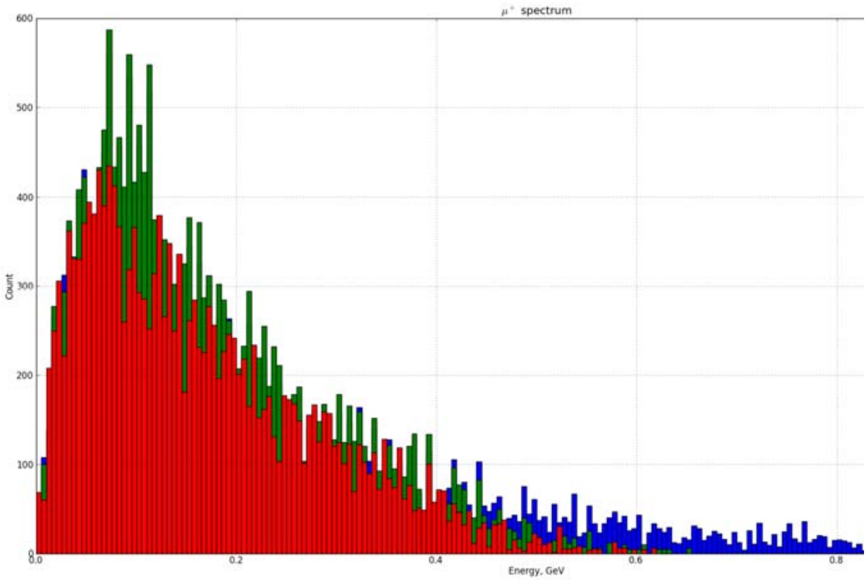

**Blue: Removed by the chicane** **Green: Removed by absorber** **Red: Survive**

## Proton beam power reduced by 99%

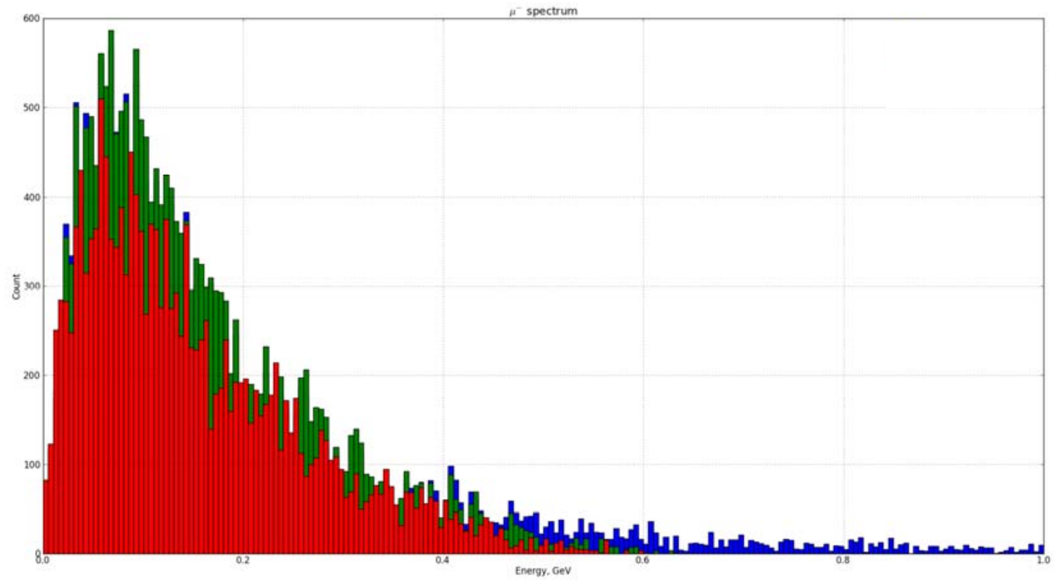
# Muons through the Chicane



**$\mu^+$**



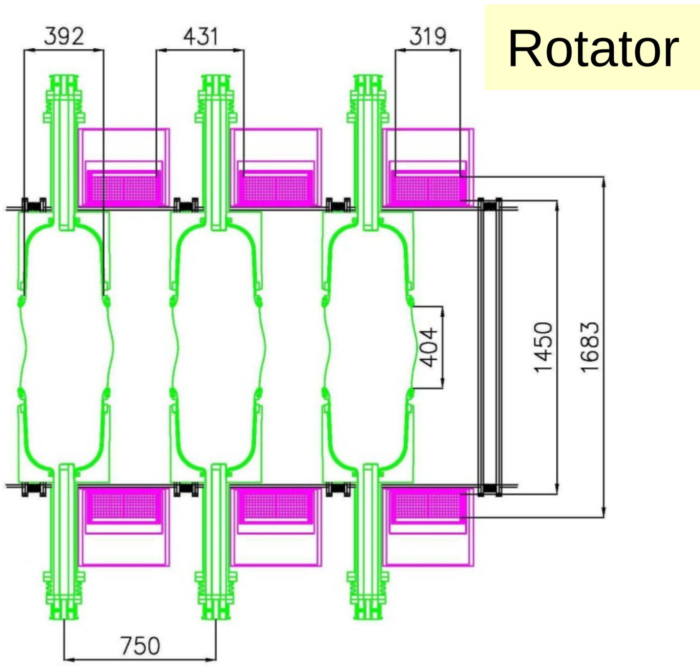

**$\mu^-$**

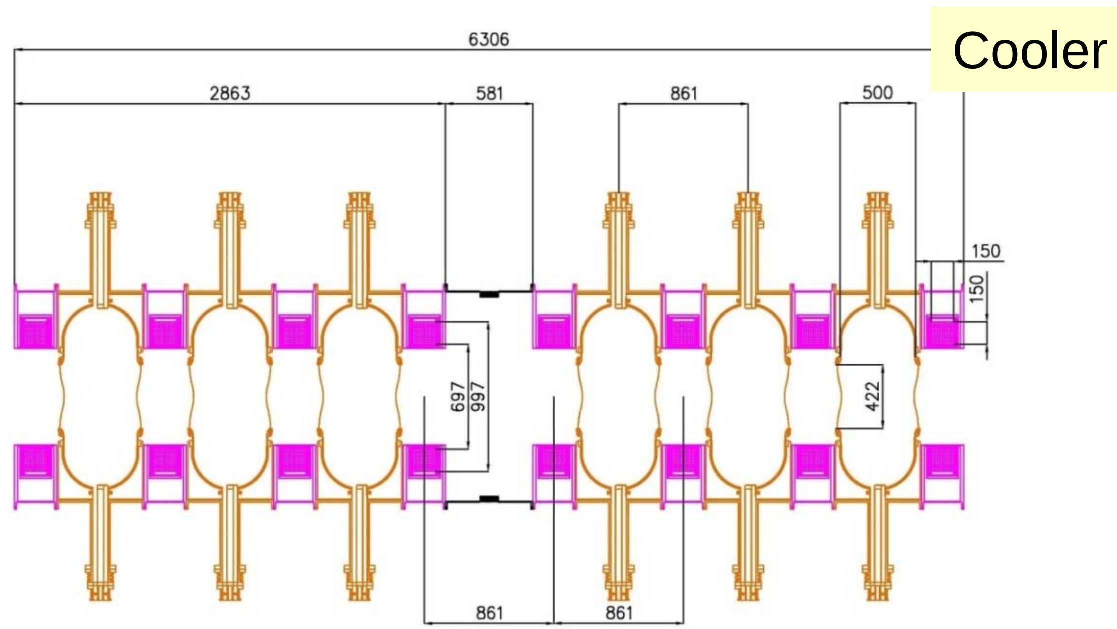



**Blue: Removed by the chicane** **Green: Removed by Absorber** **Red: Survive**

**Muon Front End throughput reduced by 10-15%**

# Engineering challenges



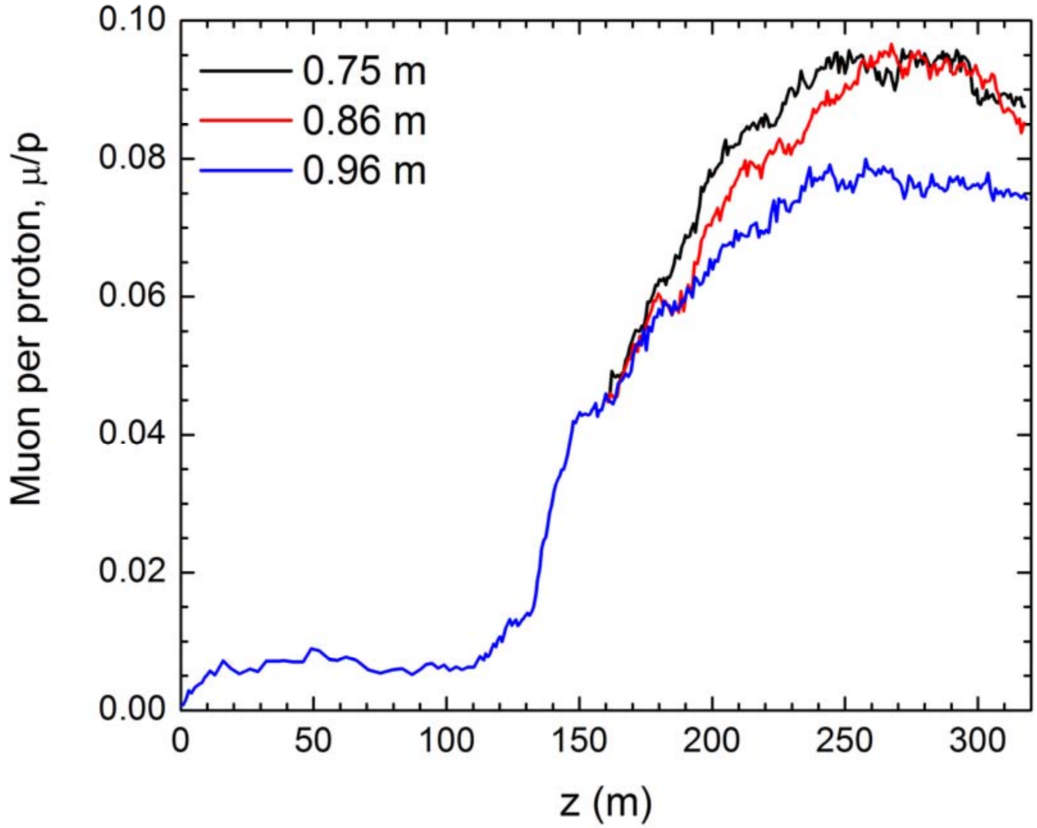




N. Bliss, IDS-NF Meeting (April, 2012)

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

# Increasing the cell length

D. Stratakis



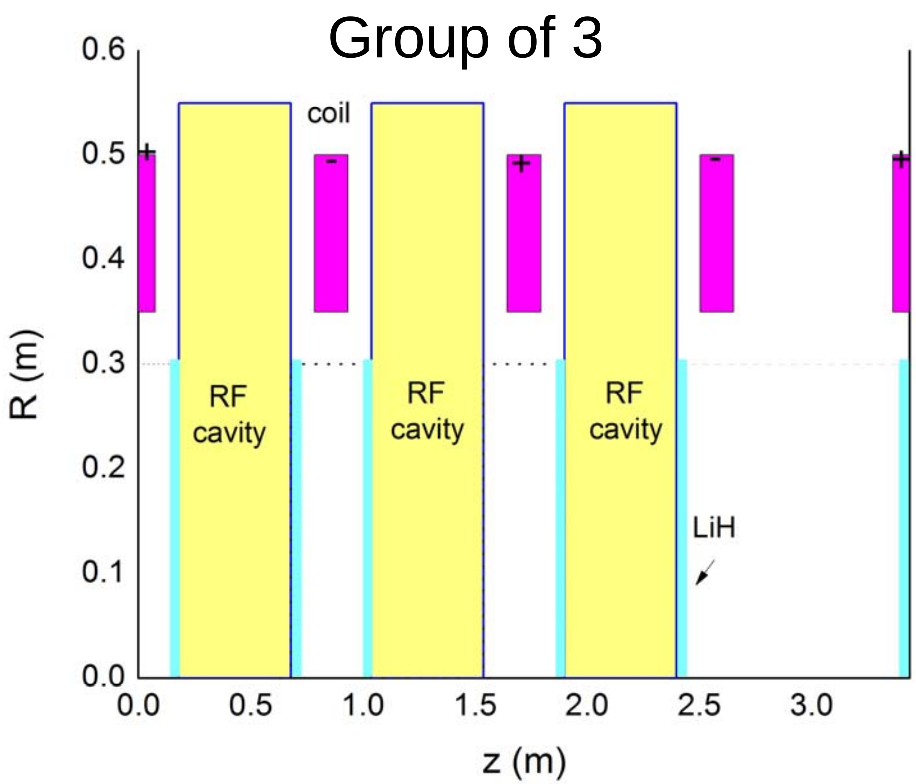

**Acceptance plot**
**$\varepsilon_T$ = 30mm**
**$\varepsilon_L$ = 150mm**

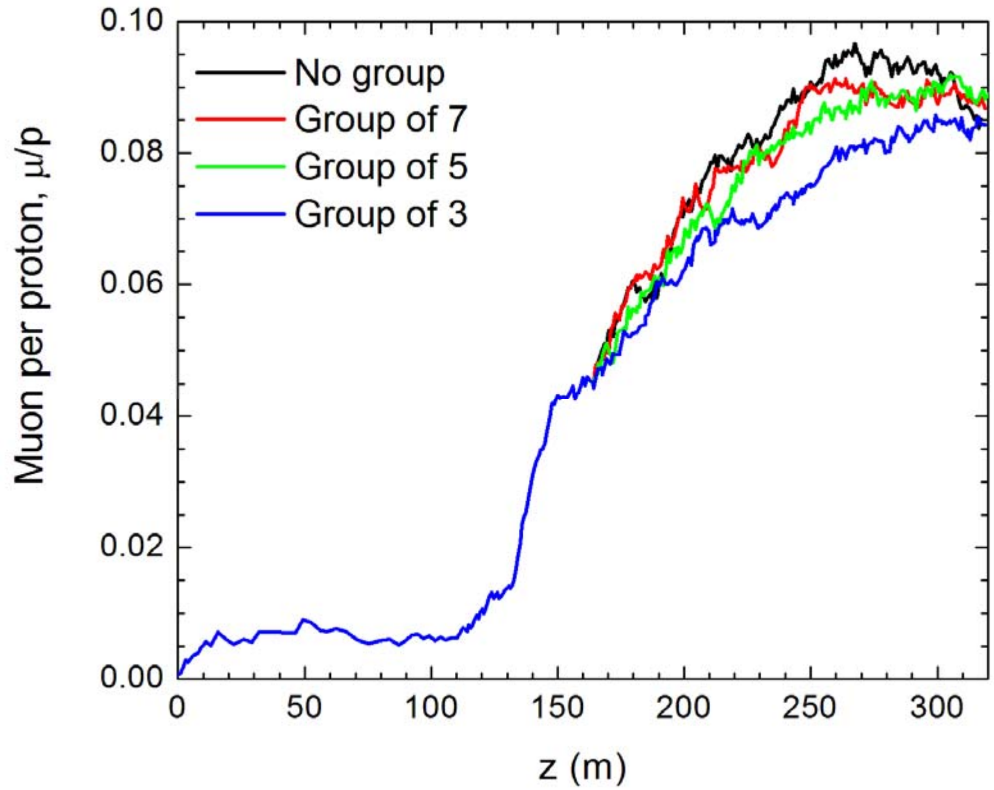
- **Simulations show that it is safe to increase the cooler cell to 86cm without loss of performance.**
- **Beyond that point, performance is reduced**

# 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

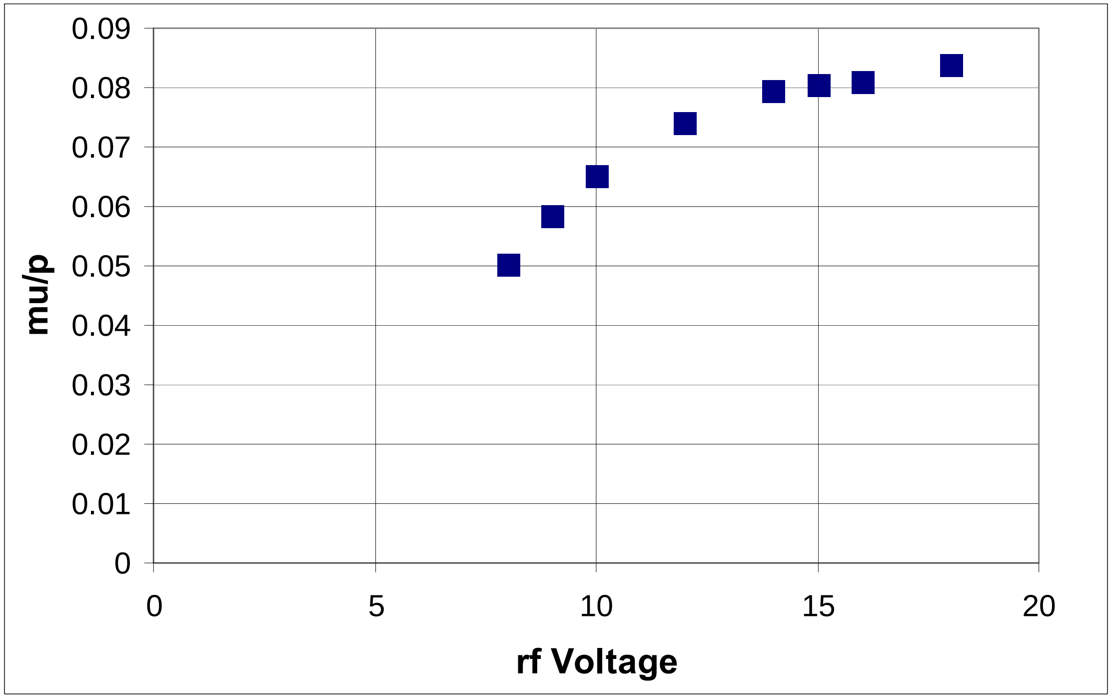
# Front End Challenges- RF



**D. Neuffer**

## Machine performance reduced

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



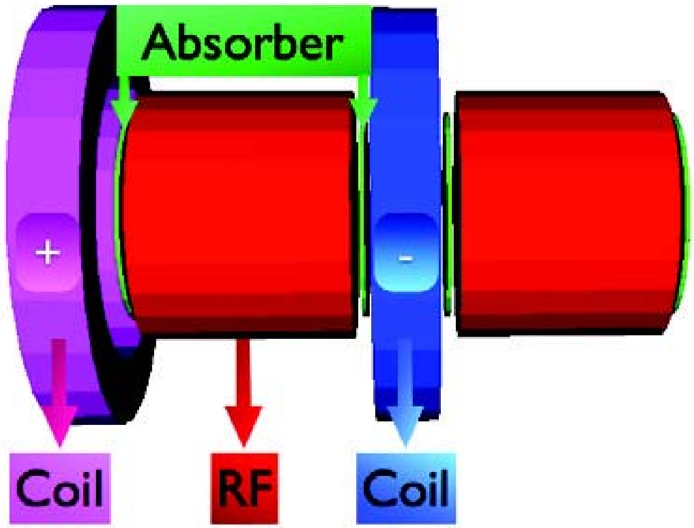

## Mitigation Strategies:

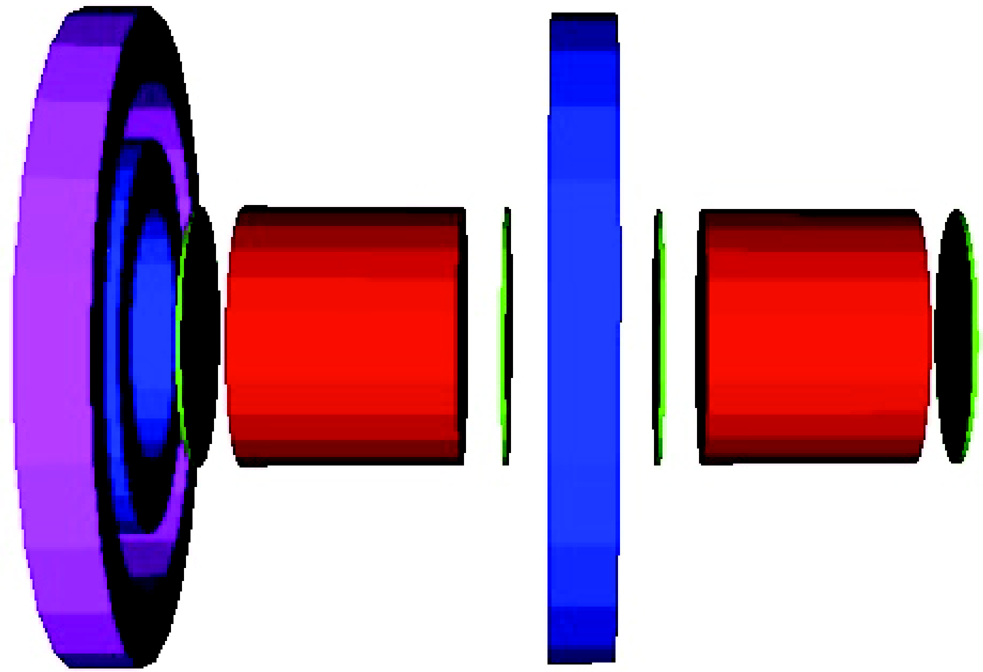
- **Beryllium walled cavities**
- **Bucked Coil Lattices**
- **High Pressure ($GH_2$ filled) rf cavities**

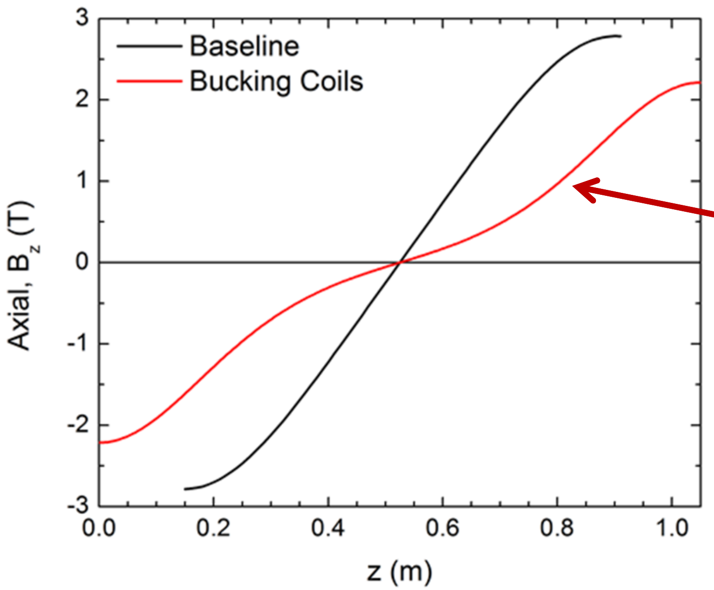
**30% performance loss with factor 2 gradient reduction**

# Bucked Coils





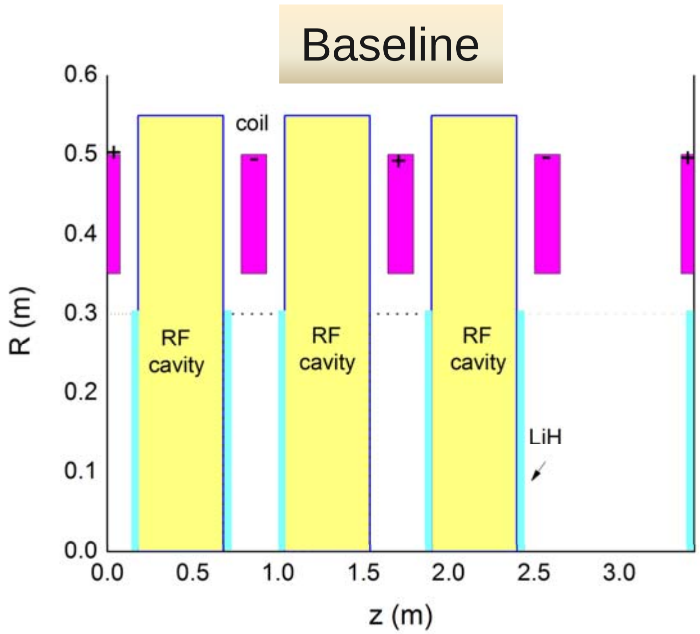


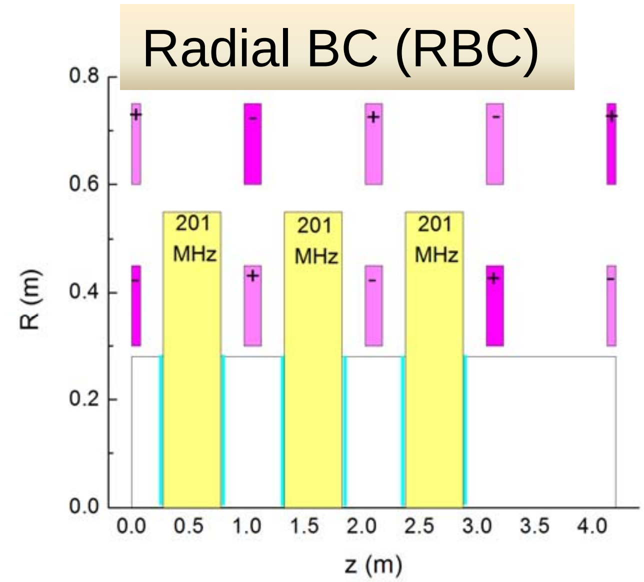

**Axial field reduced at rf cavity walls**

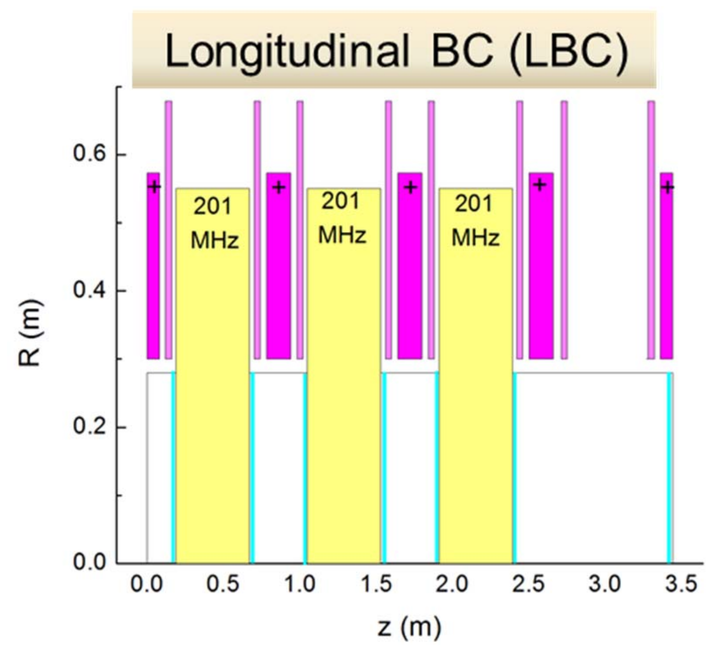
# Bucked Coils for the Cooler



## A. Alekou

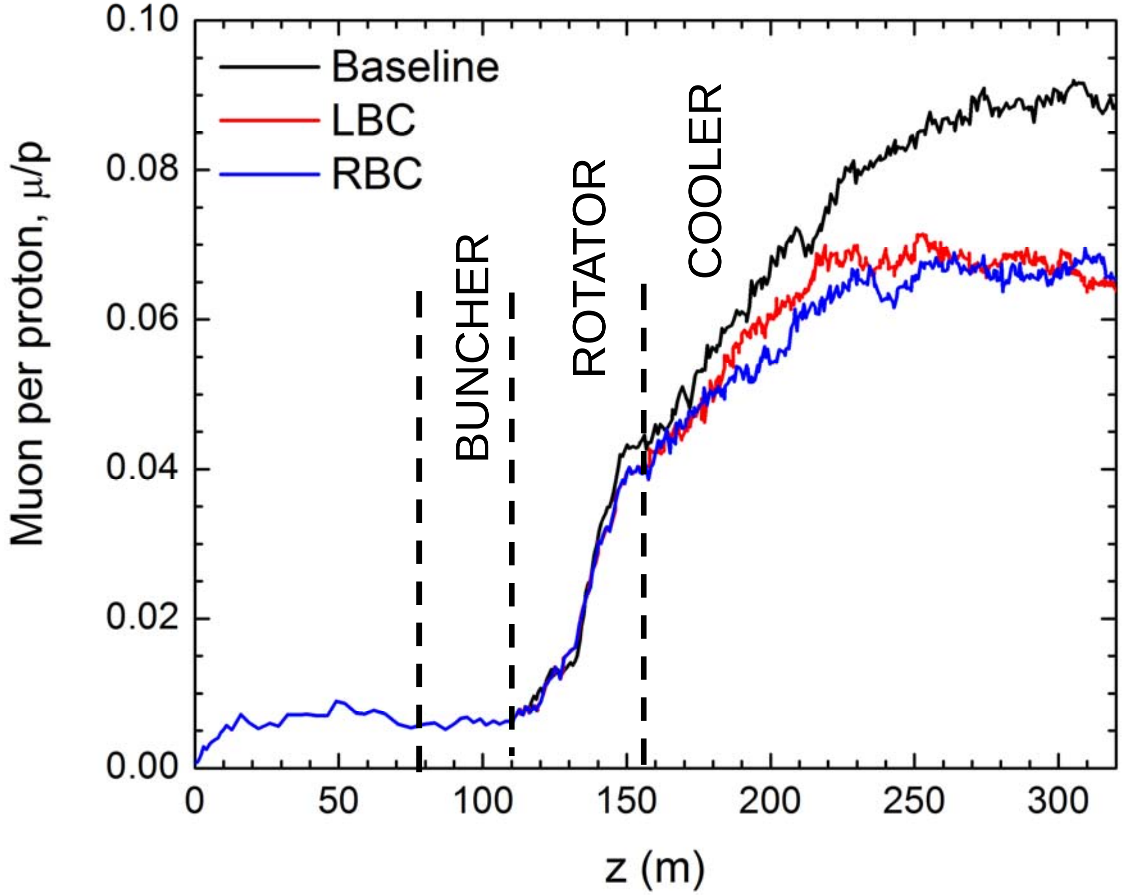


# ICOOL Simulations

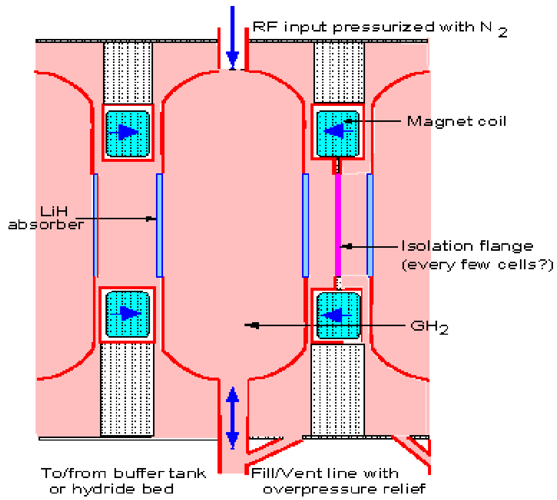





- **Similar results for both LBC and RBC schemes**
- **20% less muon per protons compared to baseline**

# High Pressure Gas RF

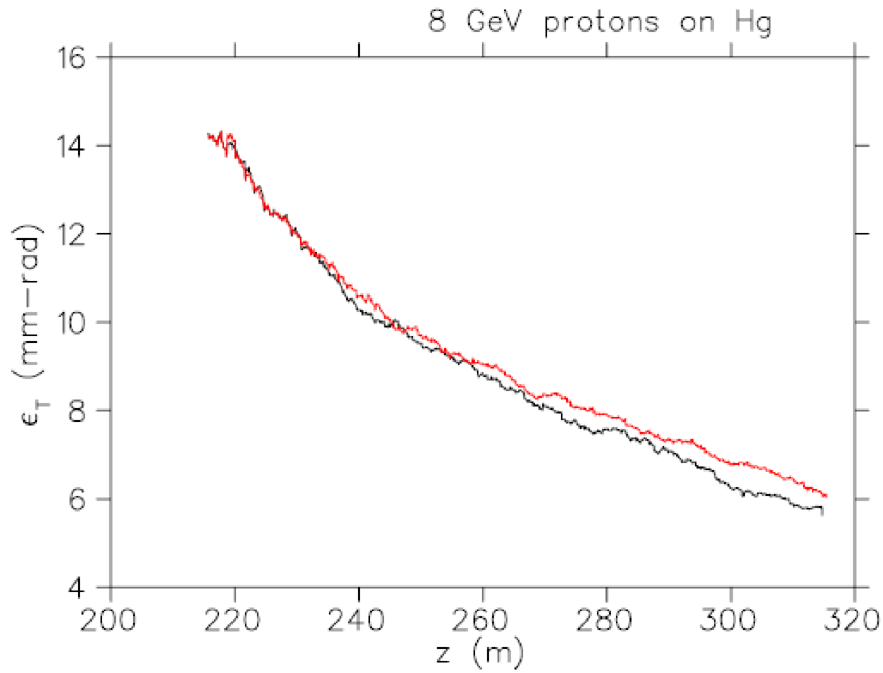


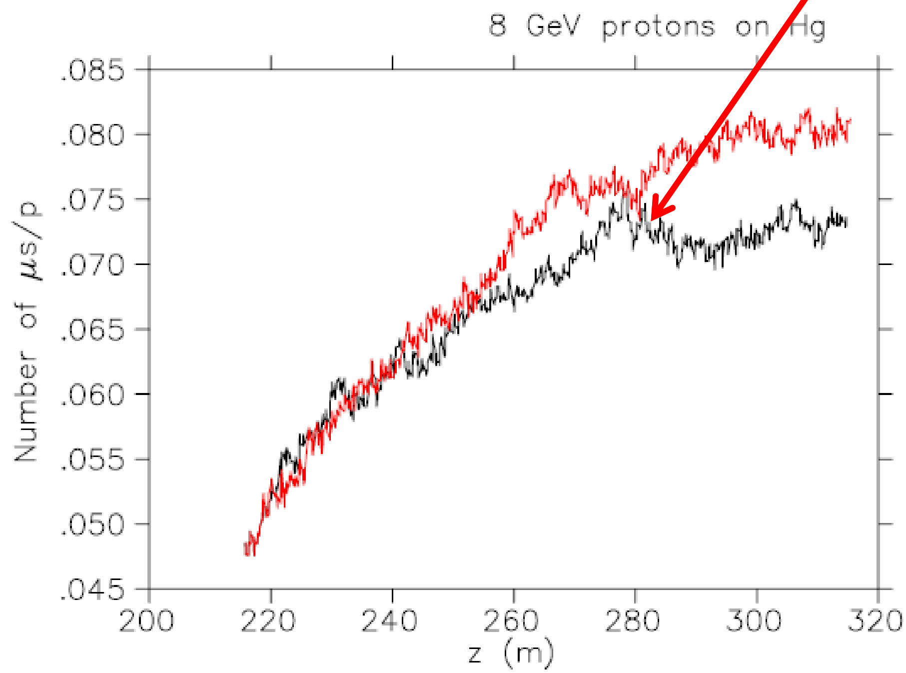



**Simulation considers:**
- **34 atms $GH_2$**
- **LiH absorbers**
- **Be Isolation windows**
- **15 MV/m rf gradients**

**J.C. Gallardo**
**M. Zisman**

**8% Reduction**

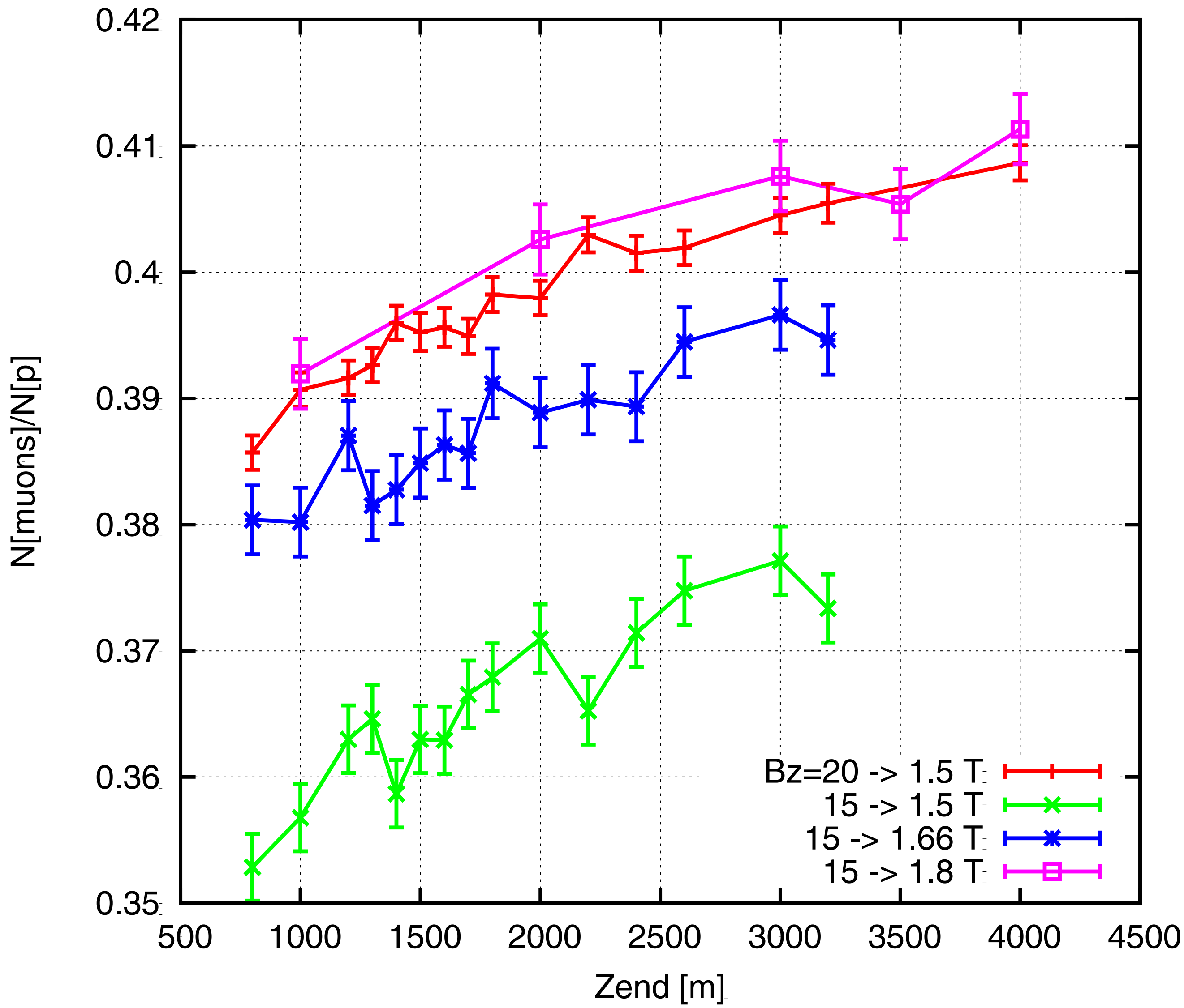



**$\varepsilon_T$**

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

# Target Taper




**H. Sayed**

**If target system goes from <u>20T to 15T</u> peak field then end field goes from <u>1.5 T to 1.8T</u> in order to maintain performance**

# FY 13 R&D Activities

- **Integrate Chicane into Decay region**
- **Respond to new target tapers (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**