Alternative Cooling Lattices for a Neutrino Factory

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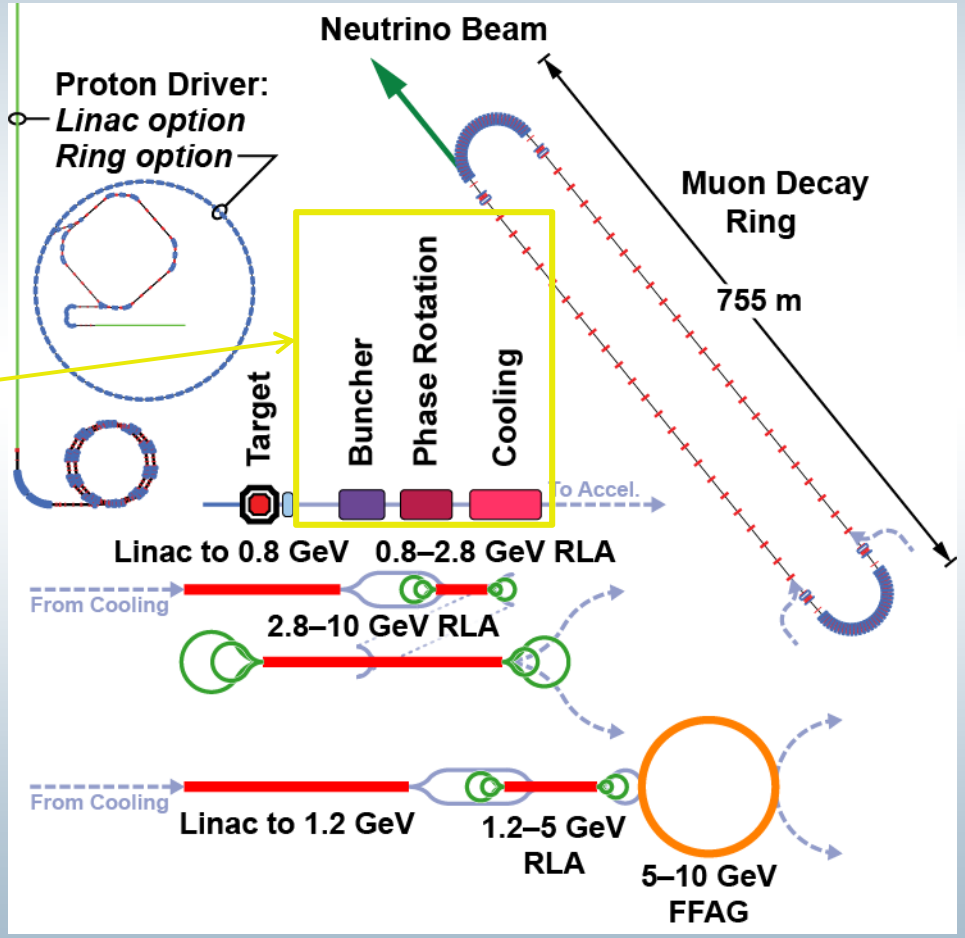
Ingredients of a Neutrino Factory

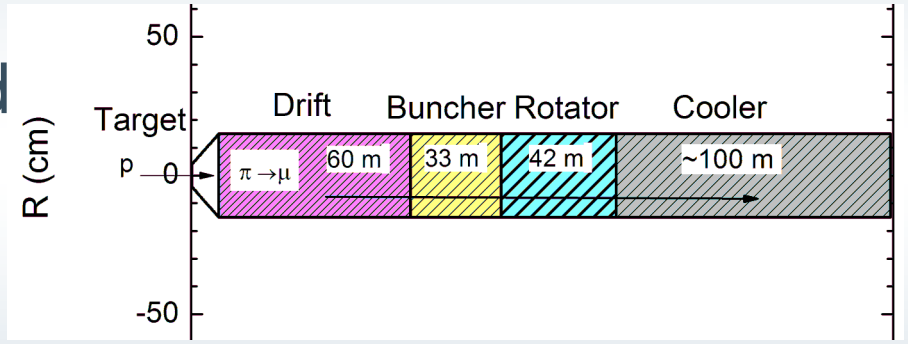
- Proton Driver
  - ~8 GeV protons
- Target, π Capture
  - π→μ
- **Front-End**
  - μ transport and cooling
- Acceleration
  - Linac, RLAs, FFAG
- Storage & decay ring
- Detectors

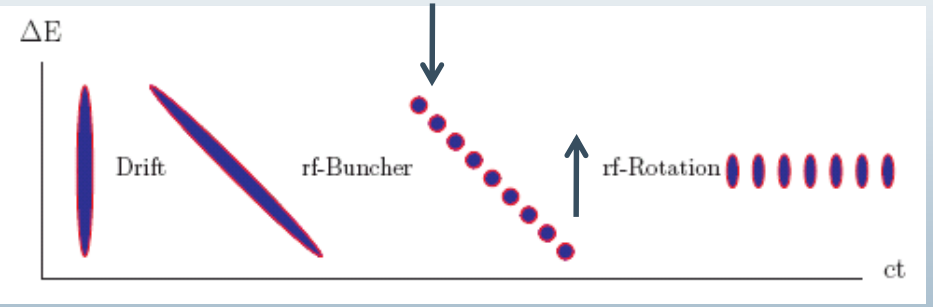


Front-End (FE) channel

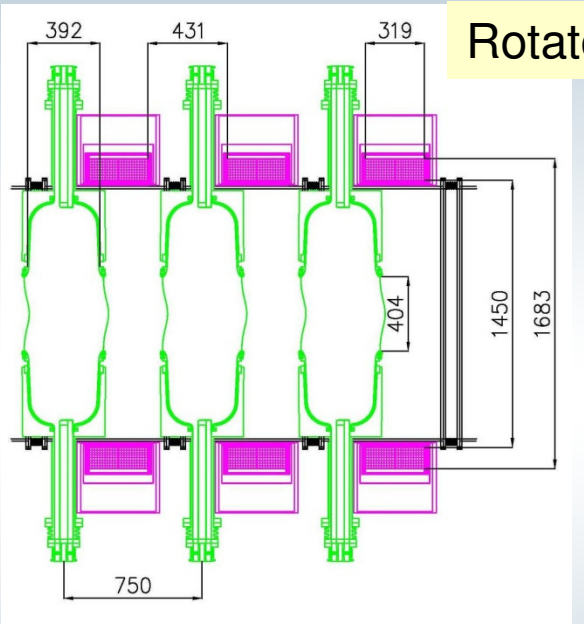
- Purpose of FE: Reduce beam phase-space volume to meet the acceptance criteria of downstream accelerators

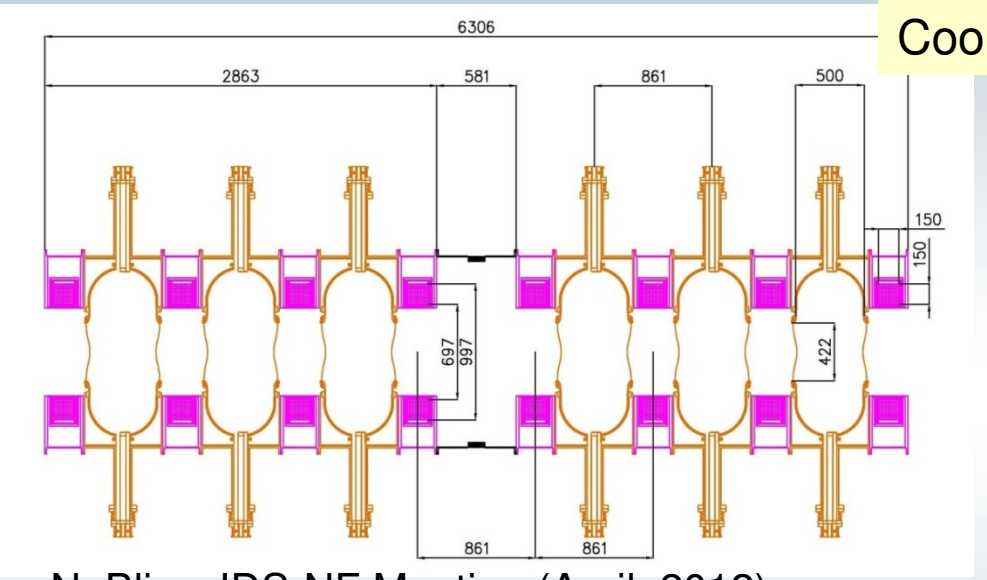
- π capture in a ~20T solenoid
- Drift and π→μ
- Progressively increase rf voltage to bunch beam
- Rotate bunches – align to equal energies
- Cool the beam





Engineering challenges for a Muon Accelerator

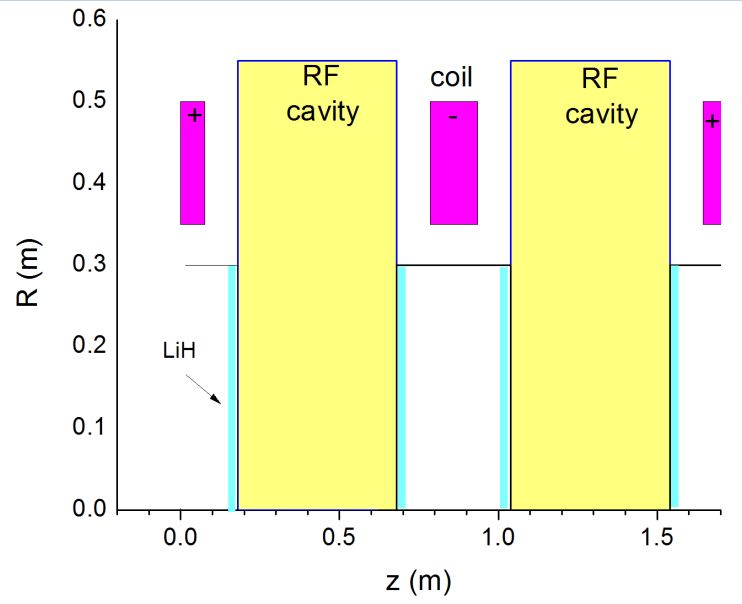


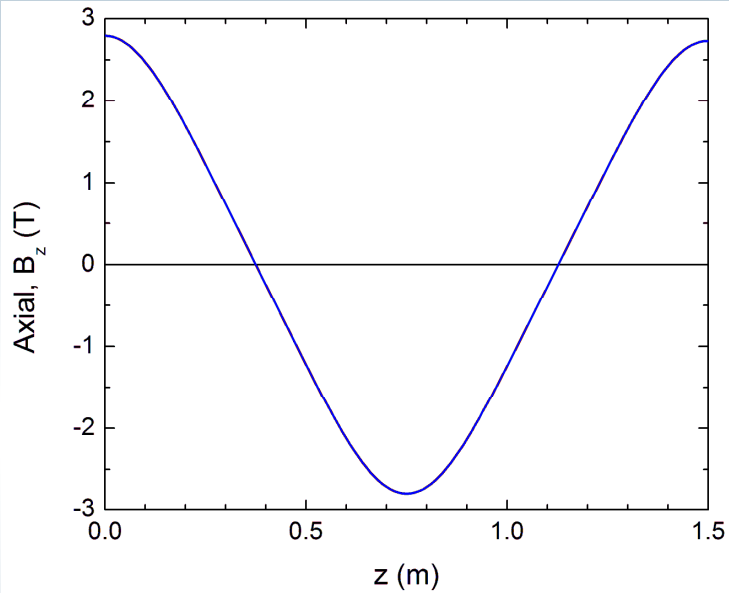


N. Bliss, IDS-NF Meeting (April, 2012)

- Recent engineering studies suggest to:
  - Increase the gap between coils in buncher & rotator
  - Increase cooler cell length from 0.75 m to 0.86 m
  - Have one “empty” cell after a series of cavities

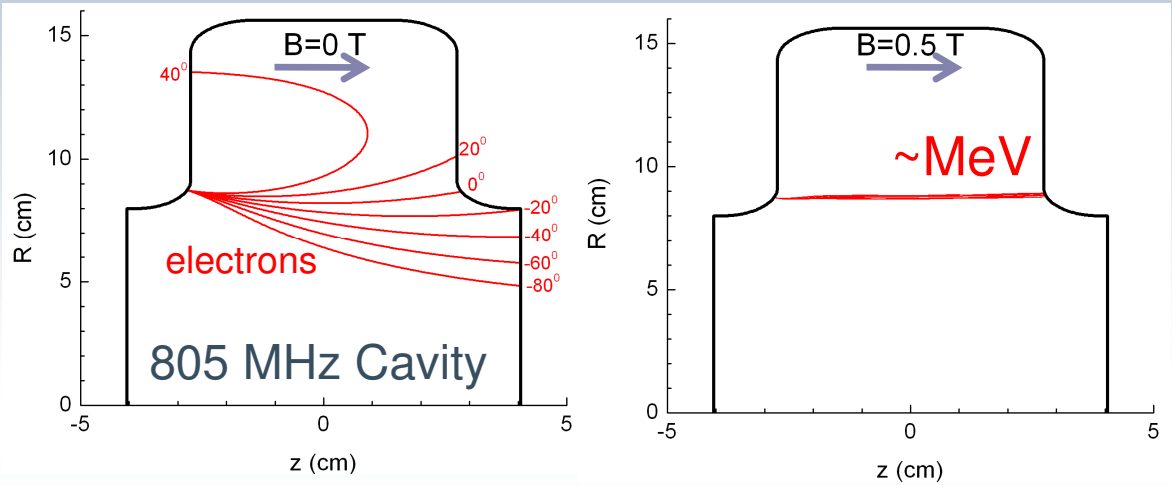
Cooling challenges for a Muon Accelerator





- Current FE designs require 201 MHz cavities to operate within 2 T external fields
- There is some experimental evidence that rf cavities may not operate well within magnetic fields
- Can we reduce the external B-field inside the cavity?

Possible rf problems in B-fields

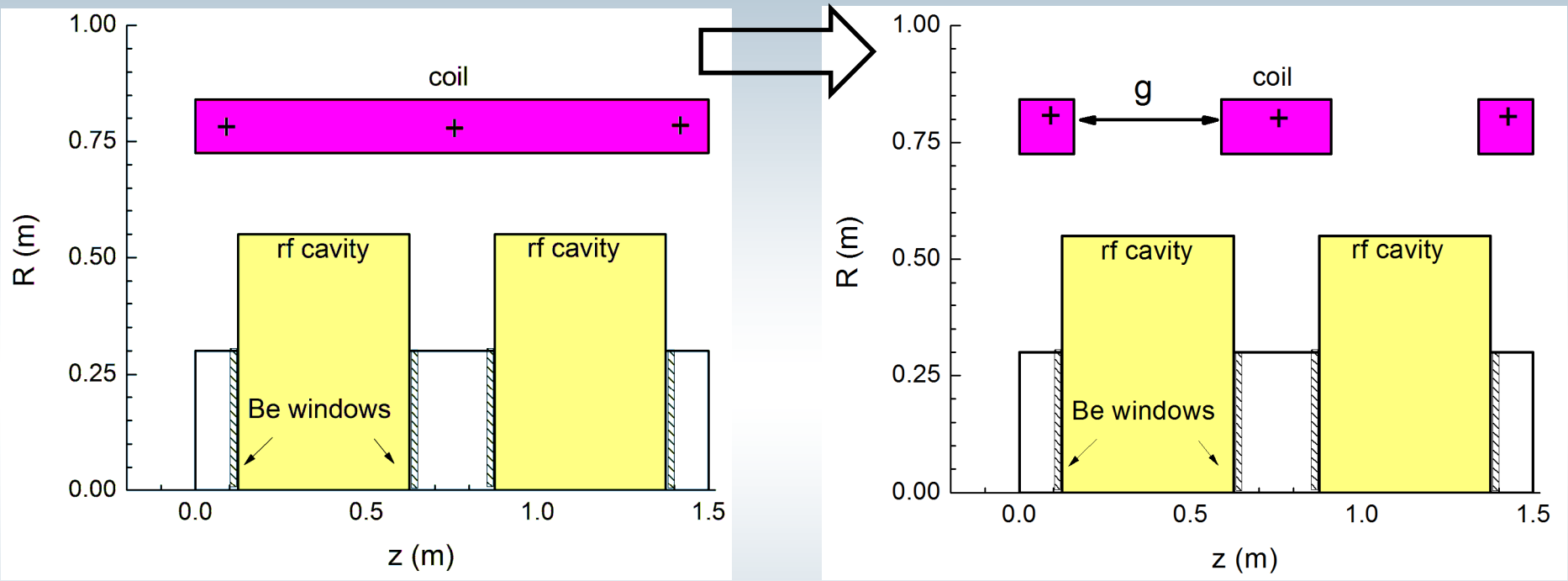


- With B-field dense electron beams strike the opposing wall of the cavity and may cause rf damage
- References:
  - Palmer et al. PRST-AB 12, 031002 (2009)
  - Stratakis et al. PRST-AB 14, 011001 (2011)

Scope of this work

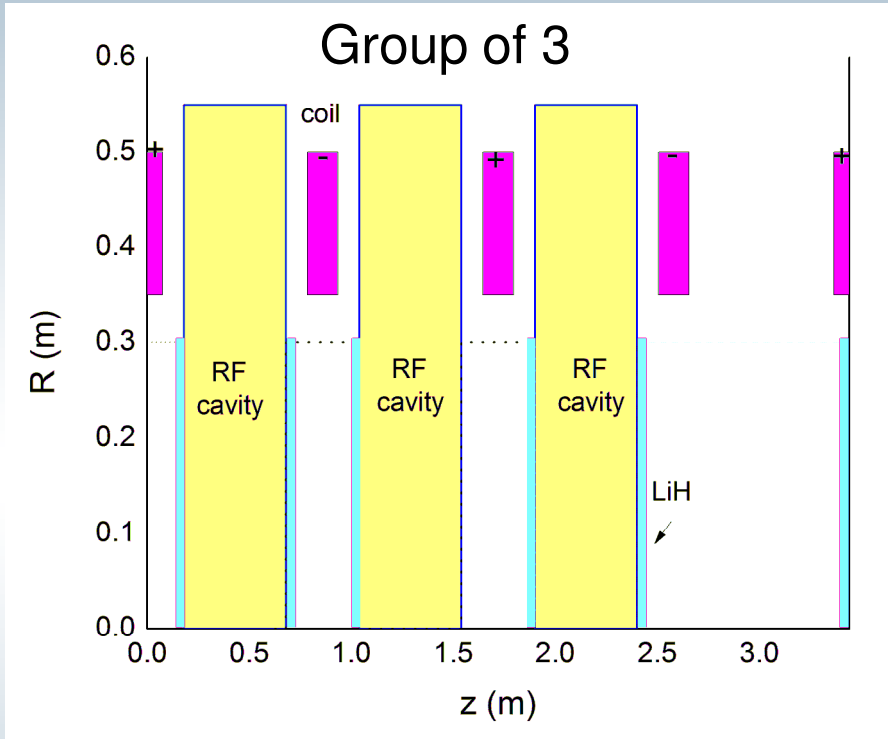
- Report a new front-end lattice that includes the engineering requirements
- Report an alternative front-end channel with bucked coils that reduces B-fields
- Simulate and compare above channels

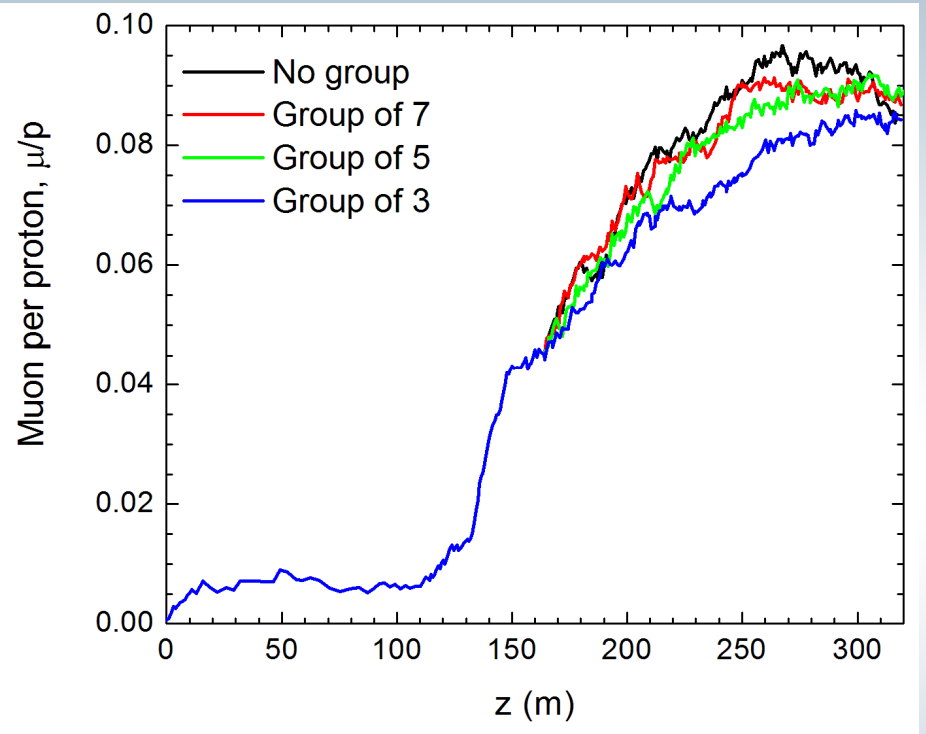
New Buncher/ Rotator for Baseline



- Engineering studies suggest g to be > 0.4 m
- Simulations suggest that it is safe to increase the gap up to g=0.5 m without loss of performance or presence of stop bands

New cooler for Baseline (empty cell)

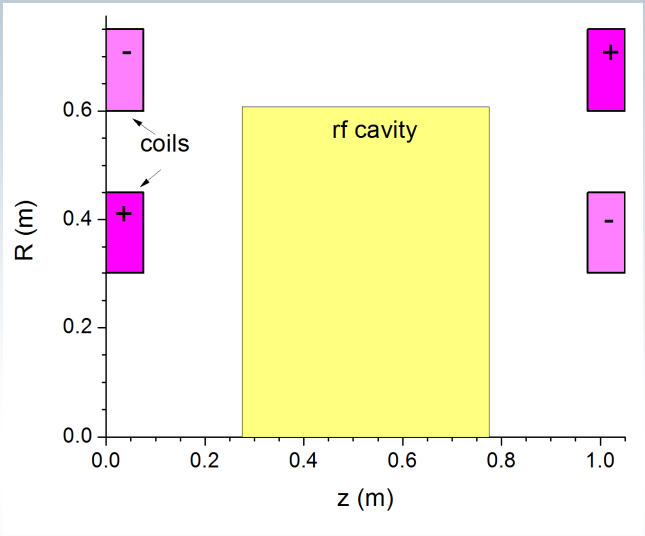


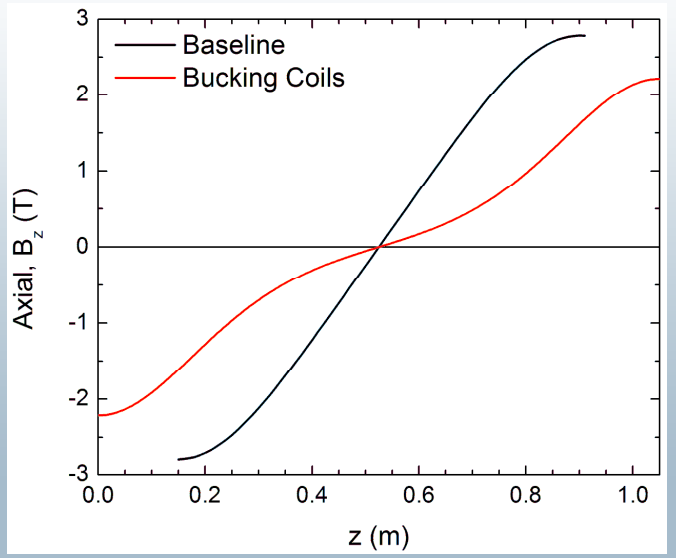


- Engineering studies suggest the addition of an “empty cell’
- There is a loss of ~5% if empty cell is after 5 cavities
- There is a loss of ~15% if empty cell is after 3 cavities

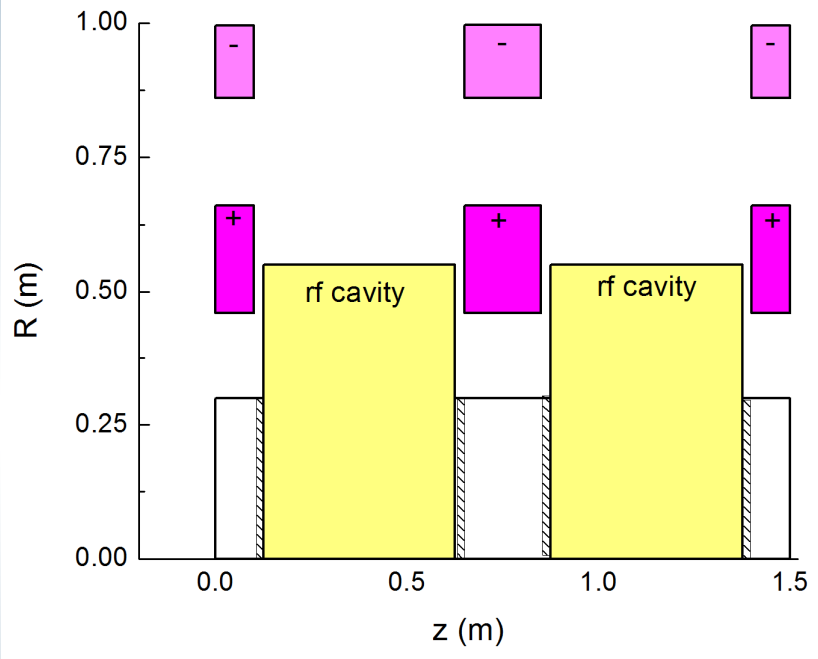
Bucked Coils (BC) scheme

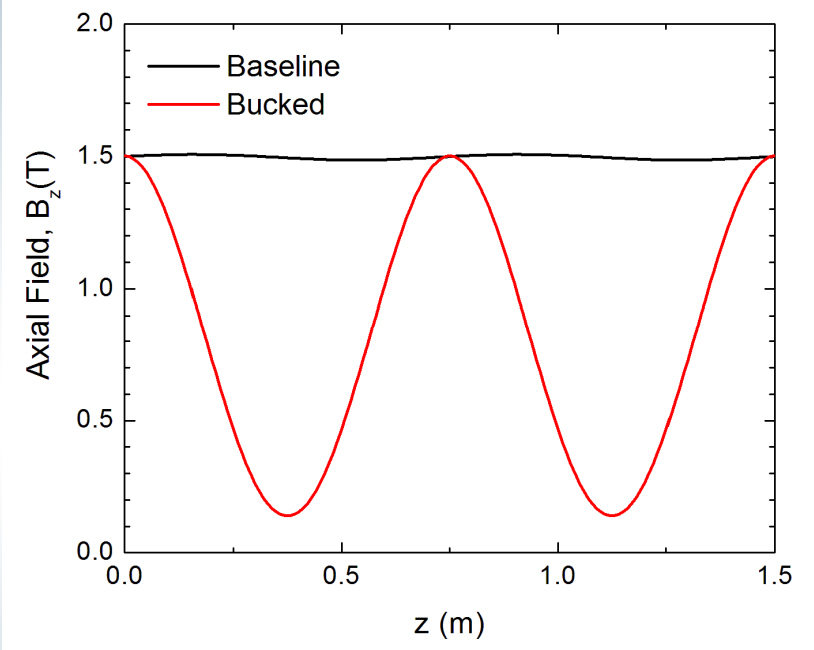
- Idea presented by R. Fernow in IDS-NF (2008) and A. Alekou at the IDS-NF (2010-2012)
- With bucked coils, the magnetic field drops within the cavity area.
- The concept shows promising cooling results (details later)





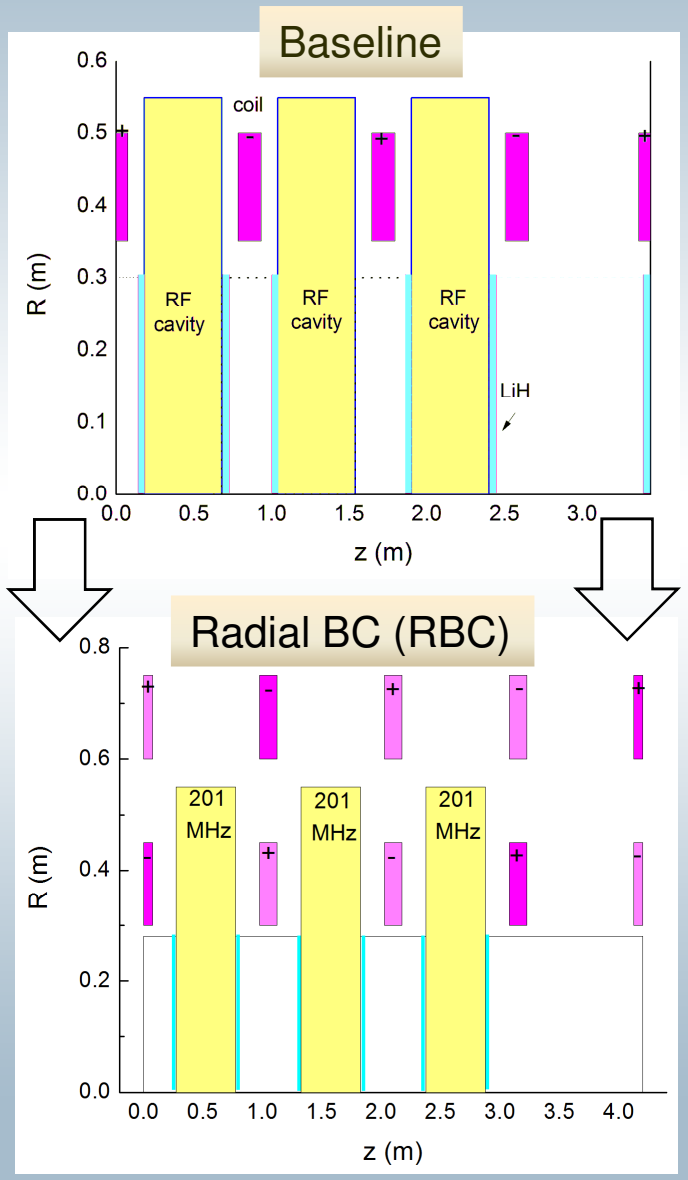
Bucked coils for Phase-Rotator

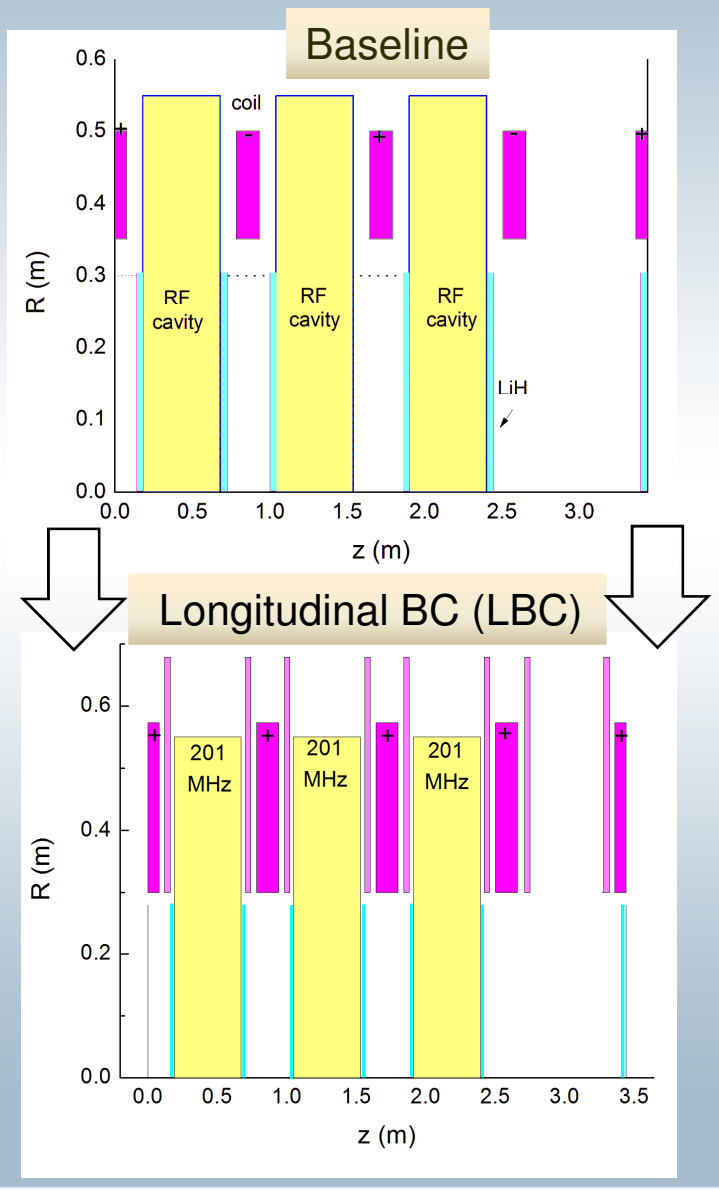




- There is a loss of ~3-5% when adding bucked coils on phase rotator.

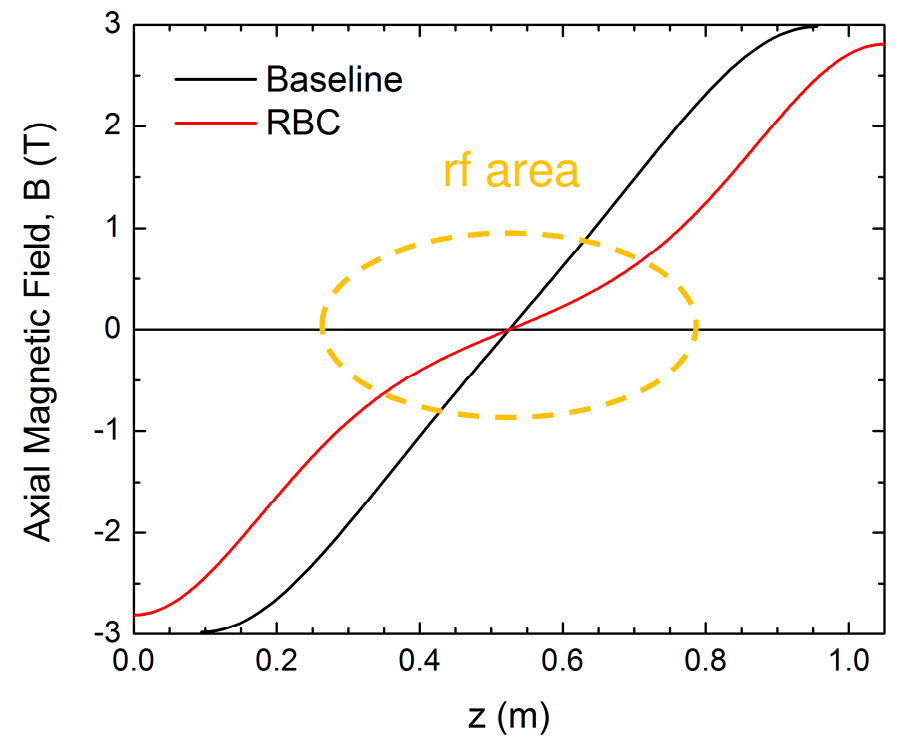
Bucked coils for Cooler: Two schemes



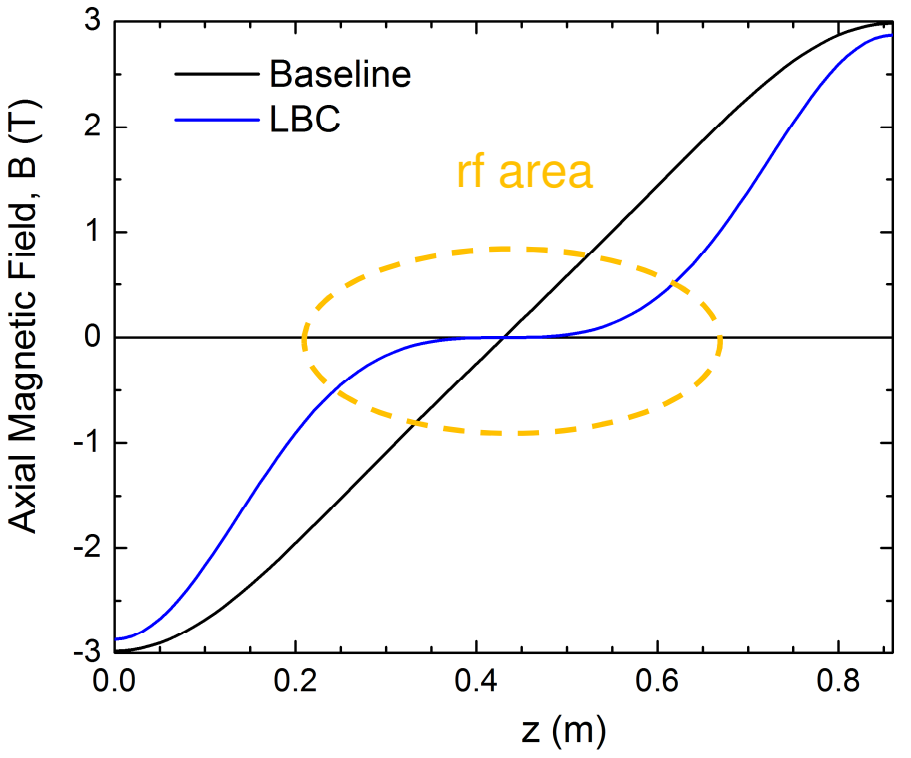


On-Axis B-Fields

- Radial BC

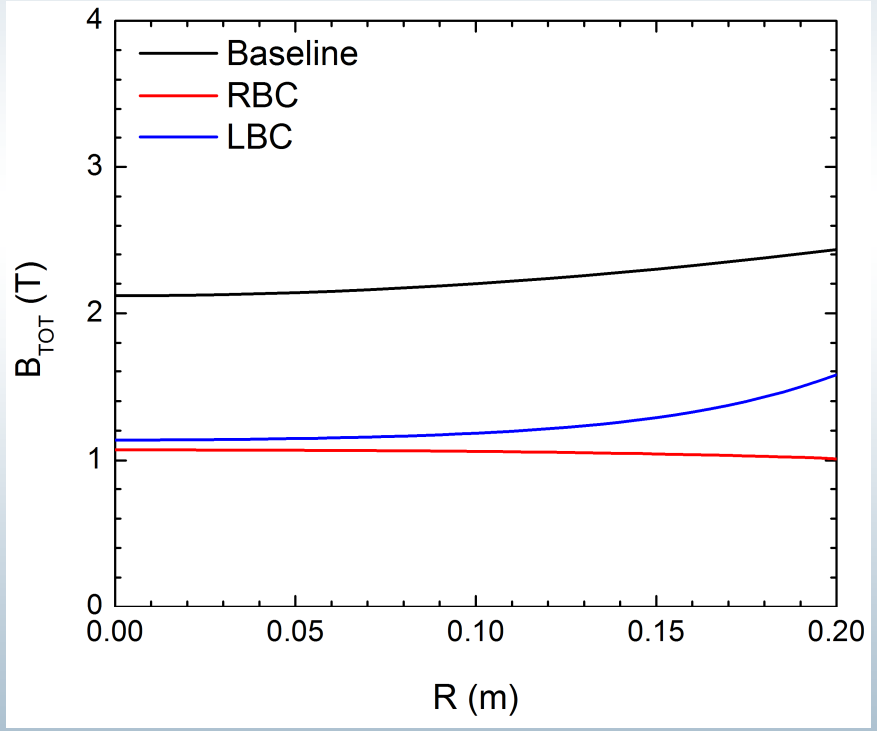


- Longitudinal BC

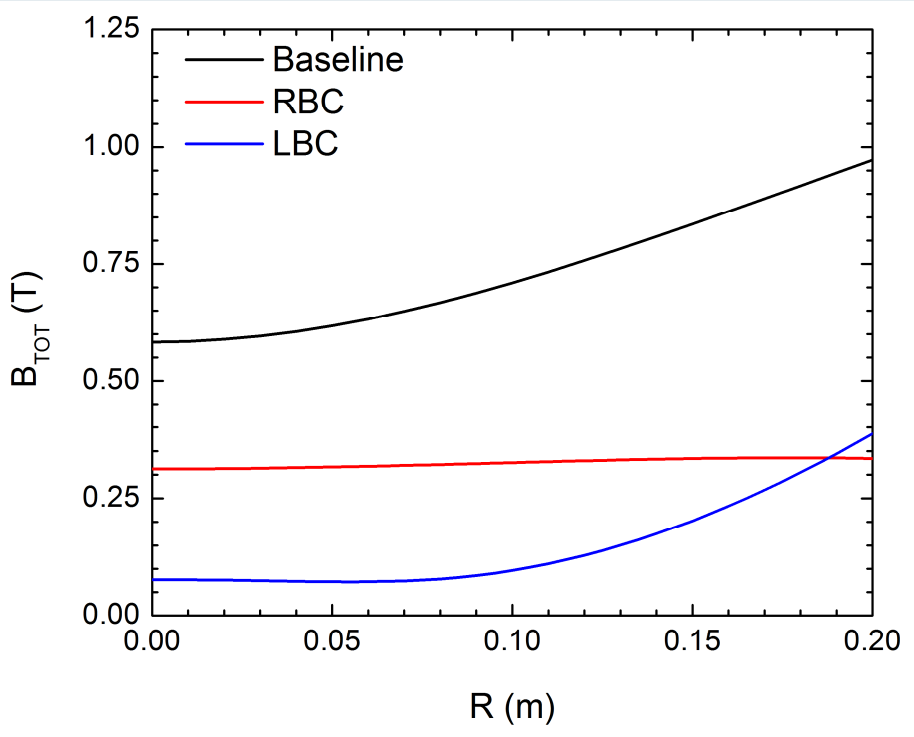


Off-axis B-Fields

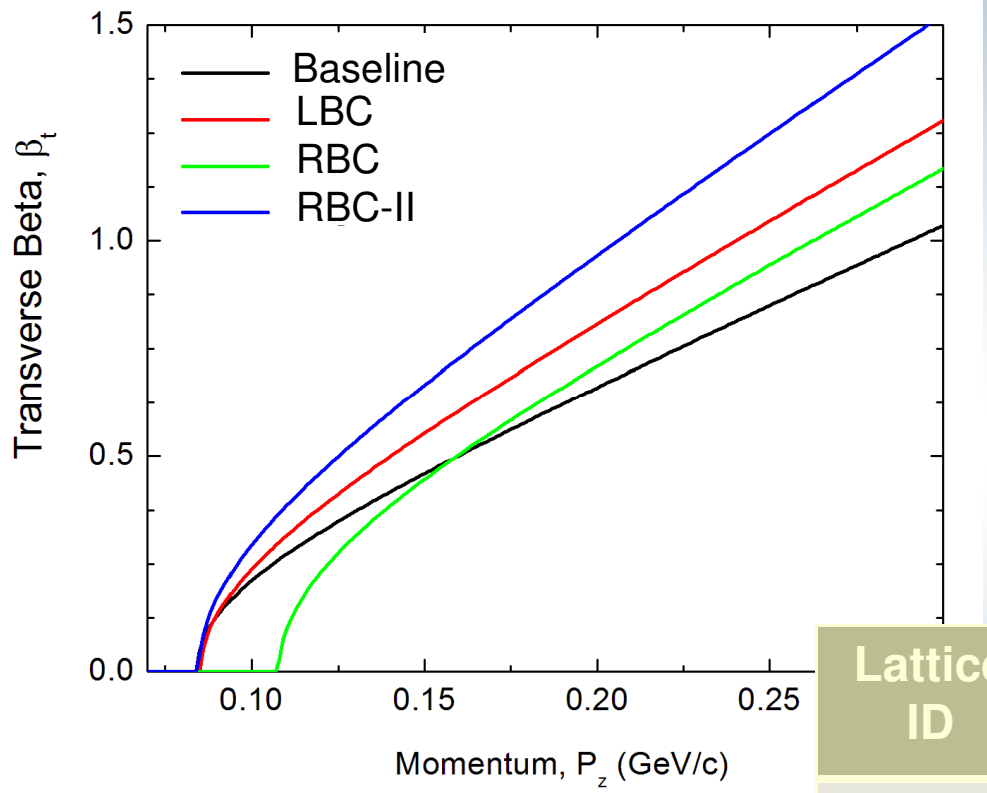
- End of rf (near rf iris)



- 10 cm from rf center



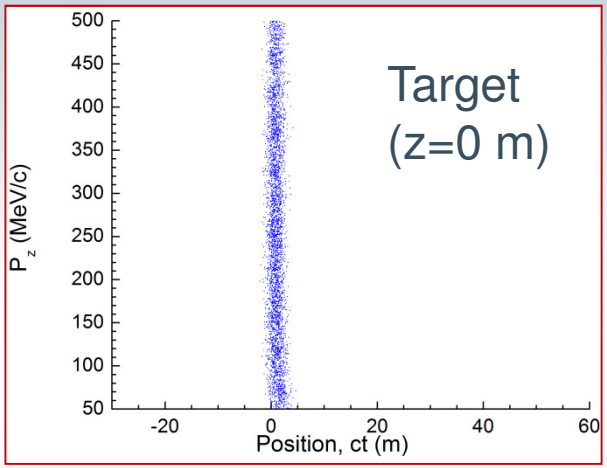
Lattice quality

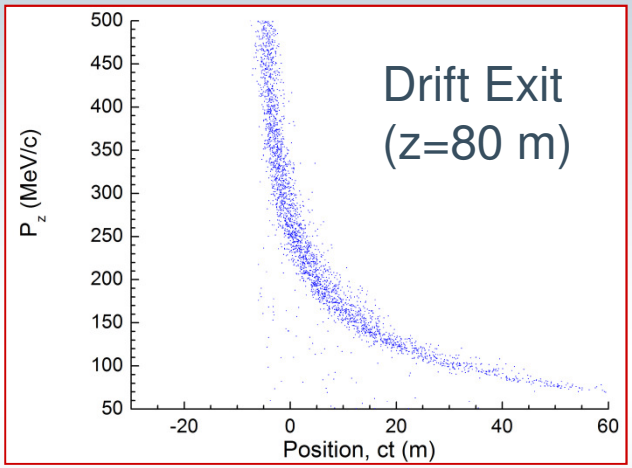


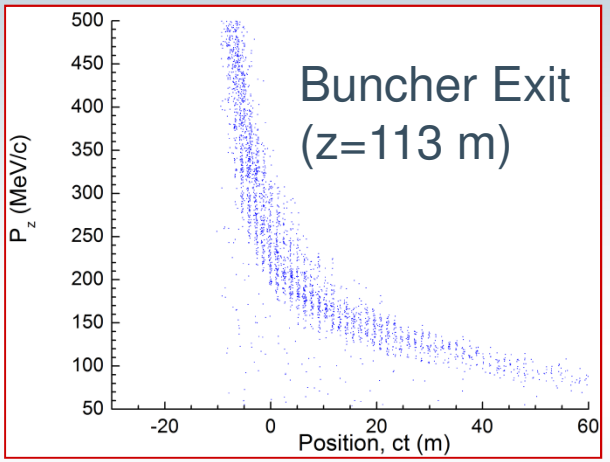
Lattice	β min (cm)	β max (cm)
Baseline	77.5	85.7
LBC	95.1	108.1
RBC	85.2	104.4

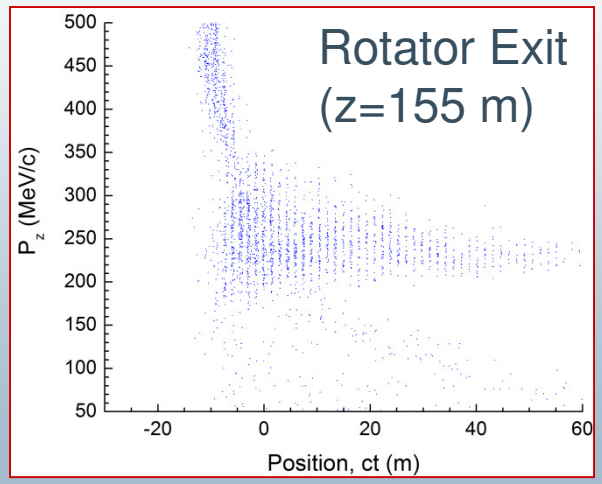
Lattice ID	Inner Coil (A/mm^2)	Outer Coil (A/mm^2)	Period (m)
Baseline	105.65		0.75
LBC	219.0	270.09	0.86
RBC	120.0	90.24	1.05

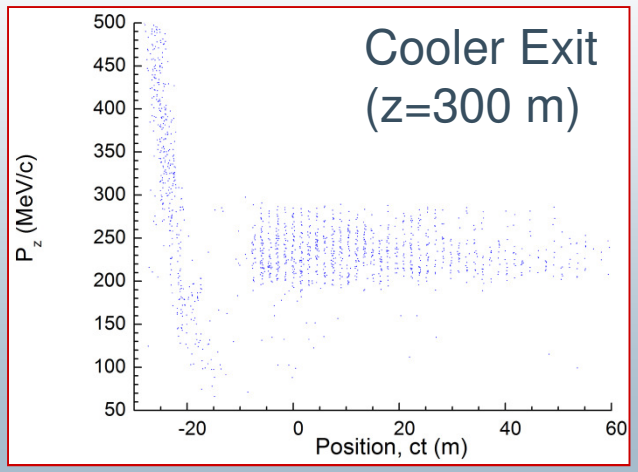
Muon evolution in a bucked-coil front-end channel (ICOOL)



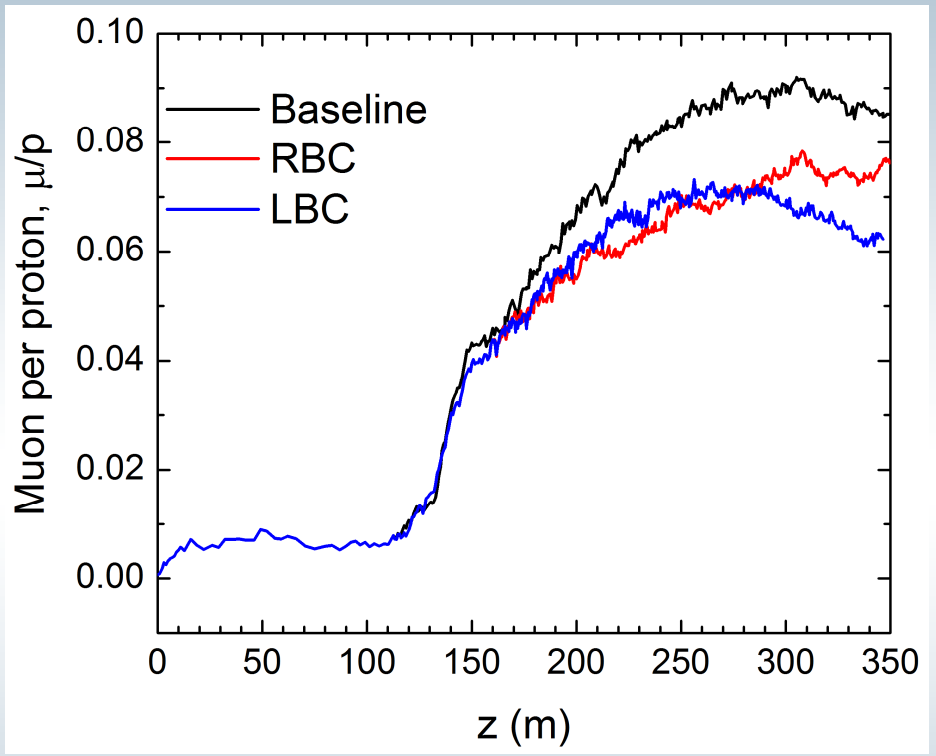






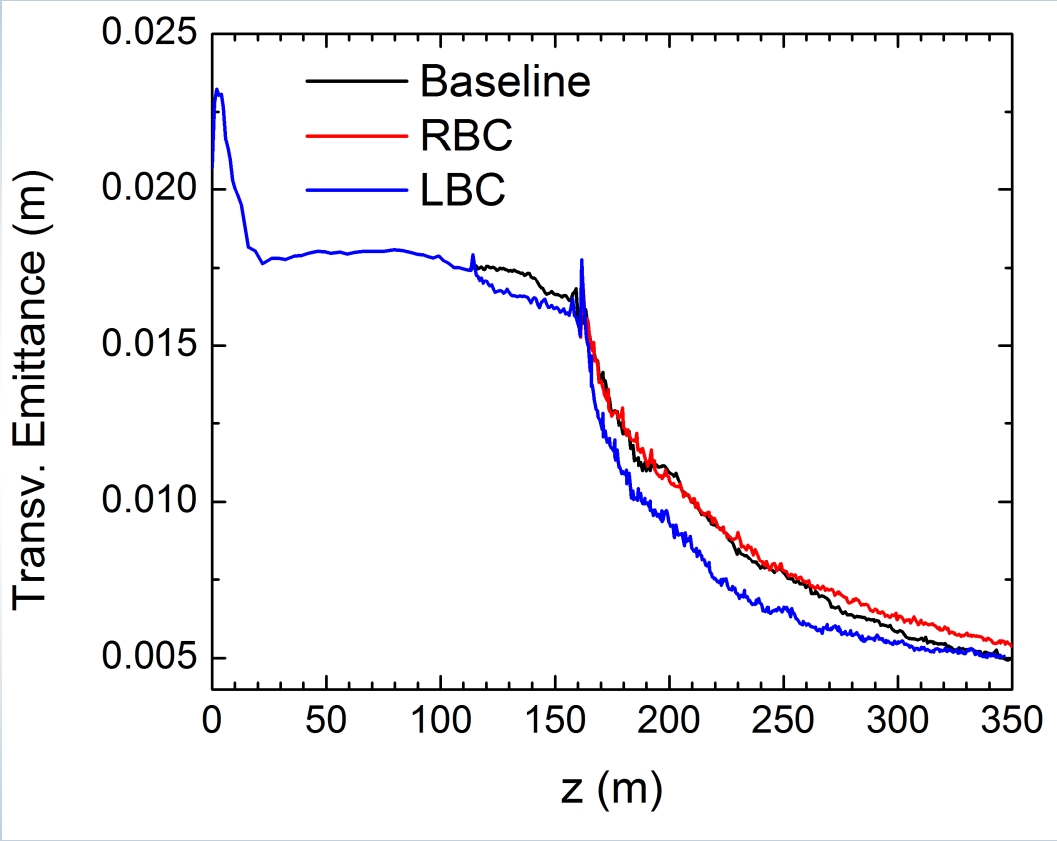


ICOOL simulation (1)



- The μ/p rate is within acceptance A_T < 30 mm, A_L< 150 mm and cut in momentum 100<Pz<300 MeV/c
- RBC performs better than LBC
- RBC gives 13% less muon per protons than baseline

ICOOL simulation (2)



- Cooling performance of BC schemes is comparable to baseline

Summary

- For the baseline:
  - It safe to increase the gap between the coils in the buncher & rotator as desired by the engineering studies. ‘Safe’ means same good cooling and a high muon/p rate.
  - It is also safe to increase the cooler cell length up to 0.86 m
  - It is better if the gap is placed every 5 or 7 cavities instead of 3
  - Performance goes down by 5-7%
- Bucked Coils (BC) were applied in both rotator and cooler.
- Two schemes tested on cooler, but RBC looks better so far
- With bucked coils and after optimization the losses are ~13%