The 325 MHz Solution

David Neuffer
Fermilab

January 15, 2013

Outline

- **Front End for the IDS Neutrino Factory**
  - Basis for engineering/costs
    - Rf, requirements
    - Engineering required
  - Redesign for 325 MHz
    - ??

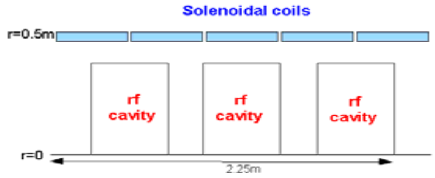
- **rf gradient/ B concerns**
  - Transit Time Factor
  - Pill-box radius

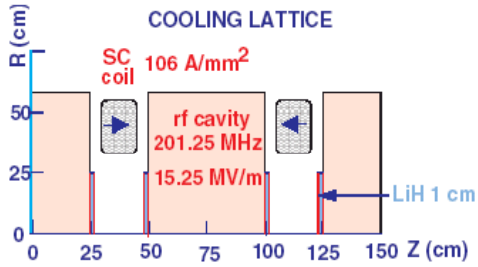
Front End rf

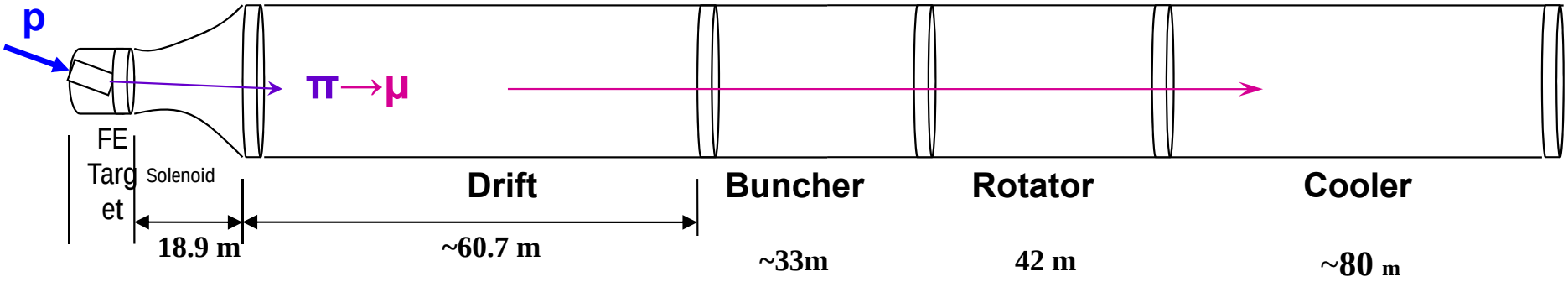
- **μCol-vFact Front End was matched to 201.25 MHz**
  - matched to Fermilab Linac
  - Cooling at **200,** 400, 600, **800** …MHz
- **Project X is matched to 1300 MHz (ILC)**
  - match to 650 /325/ 162.5…
    - 433, 216.67, …
  - match to 162.5 or 216.7 is similar to 201.25
- **Match to 325 MHz is not as straightforward**
  - requires ~500 → 325 MHz rf in Buncher /Rotator
  - apertures are more restricted

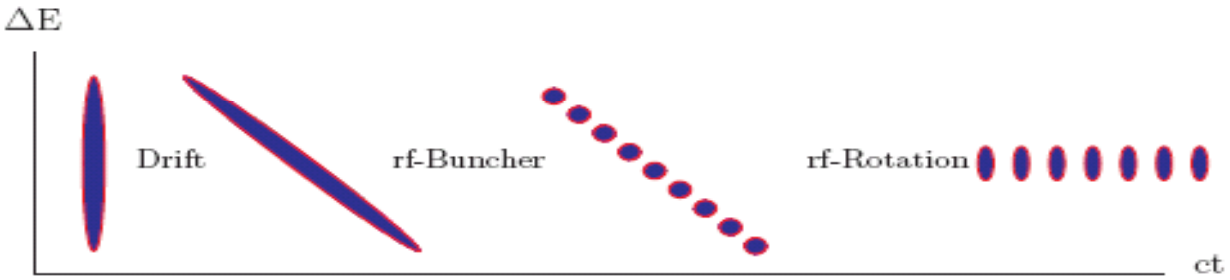
IDS Baseline Buncher and φ-E Rotator

- Drift (π→μ)
- "Adiabatically" bunch beam first (weak 320 to 232 MHz rf)
- Φ-E rotate bunches – align bunches to ~equal energies
  - 232 to 202 MHz, 12MV/m
- Cool beam 201.25MHz



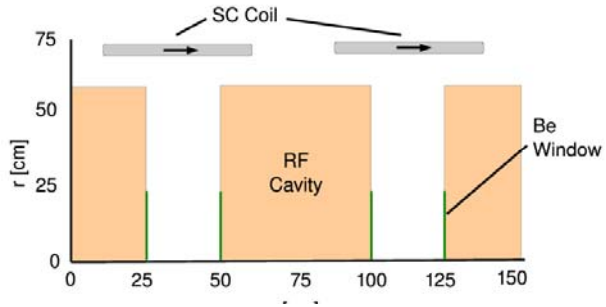


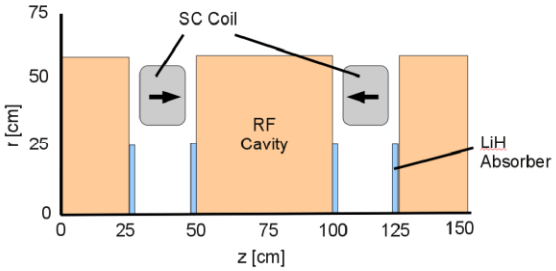




Rf Buncher/Rotator/Cooler requirements

- **Buncher**
  - **37** cavities (**13** frequencies)
  - **13** power supplies **(~1—3MW)**
- **RF Rotator**
  - **56** cavities (**15** frequencies)
  - 12 MV/m, 0.5m
  - **~2.5MW** (peak power) per cavity
- **Cooling System – 201.25 MHz**
  - 100 0.5m cavities (75m cooler), **15MV/m**
  - **~4MW** /cavity – most expensive item



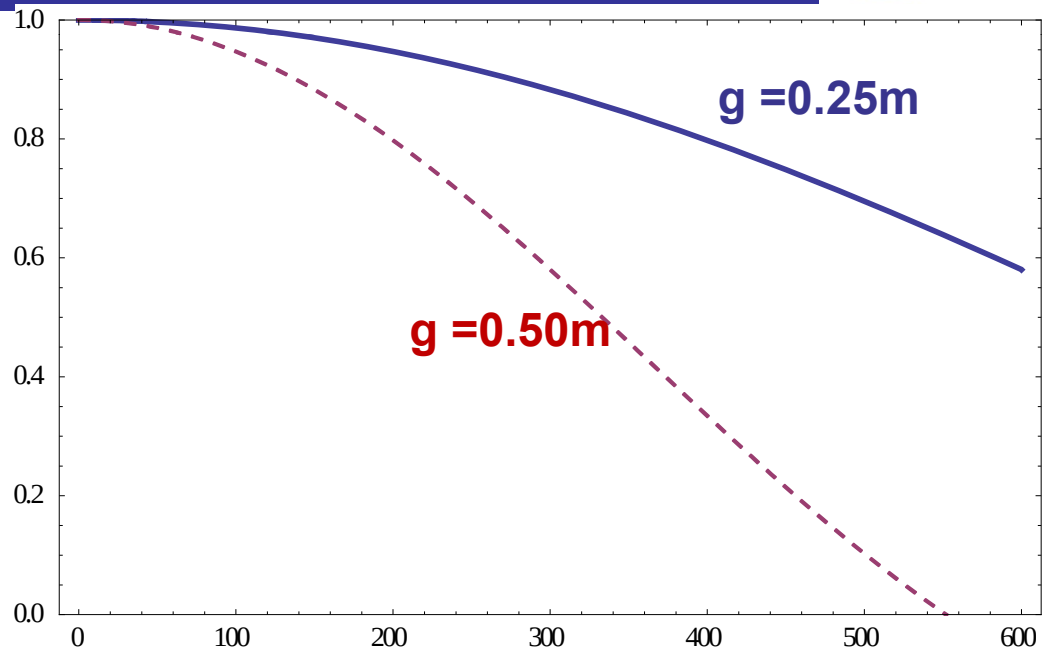


Front End section	Length	#rf cavities	frequencies	# of freq.	rf gradient	rf peak power requirements
Buncher	33m	37	319.6 to 233.6	13	4 to 8	~1 to 3.5 MW/freq.
Rotator	42m	56	230.2 to 202.3	15	12.5	~2.5MW/cavity
Cooler	75m	100	201.25MHz	1	16 MV/m	~4MW/cavity
Total	~240m	193		29	~1000MV	~550MW 400MW from cooling

rf constraints

- **Transit time factor**

$$T = \frac{Sin\left[\frac{\pi g}{\beta\lambda}\right]}{\frac{\pi g}{\beta\lambda}}$$

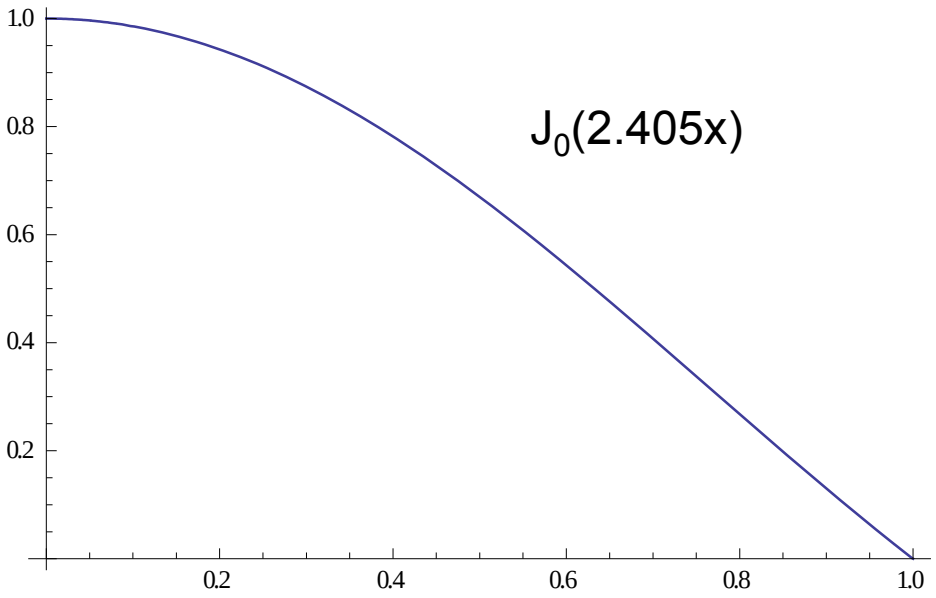


  - T = 0.8 (200MHz,0.5m)
  - → 0.52 (325MHz,0.5m)
  - → 0.21 (450 MHz,0.5m)
  - → 0.75(450 MHz,0.25m)
    - → must use shorter rf cavities

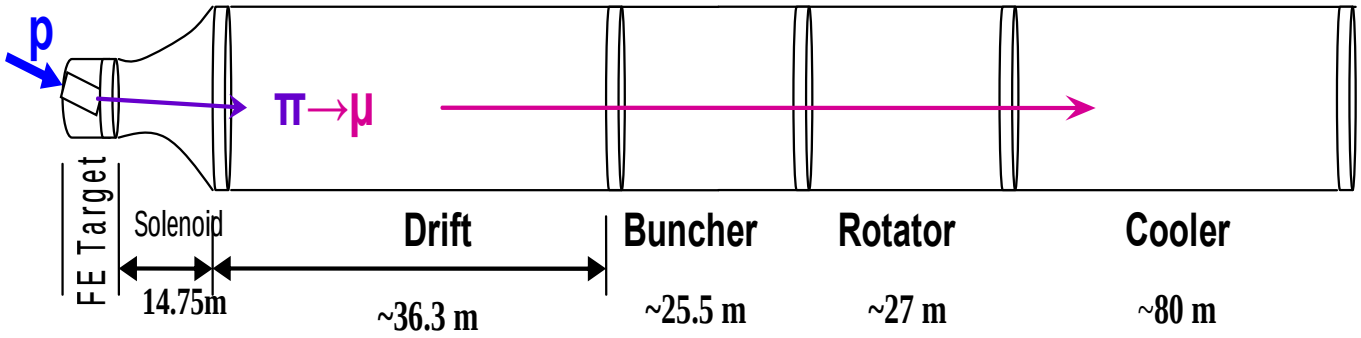
- **Pillbox radius:**

$$E = E_o J_o\left(2.405\frac{r}{r_0}\right) \qquad r_0 = \frac{2.405}{2\pi}\lambda_{RF}$$

  - r_0= 0.38 m at 300 MHz
  - r_0= 0.255 m at 450 MHz

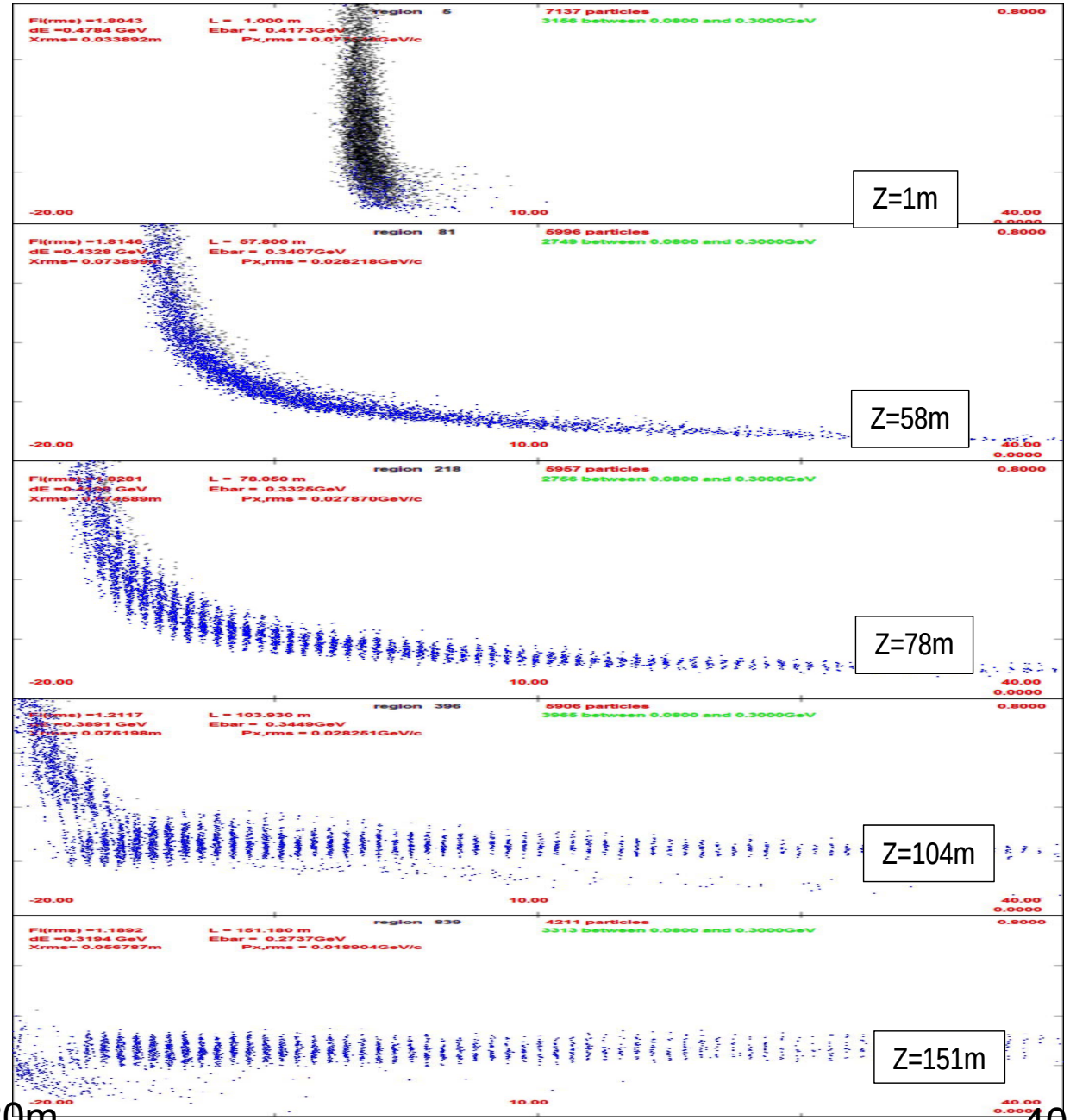


Components of 325MHz System



- **Drift**
  - 20T→ 2T
- **Buncher**
  - P_o=250MeV/c
  - P_N=154 MeV/c; N=12
  - V_{rf} : 0→ 15 MV/m
    - (2/3 occupied)
  - f_{RF} : 550→ 371MHz
- **Rotator**
  - V_{rf} : 20MV/m
    - (2/3 occupied)
  - f_{RF} : 370→ 326MHz
  - N=12.05
  - $P_{0,}$ P_N→245 MeV/c
- **Cooler**
  - 325 MHz
  - 25 MV/m
  - 2 1.5 cm LiH absorbers /0.75m

Propagation through the transport



0.8 GeV/c

0.0 GeV/c

0.8 GeV/c

0.0 GeV/c

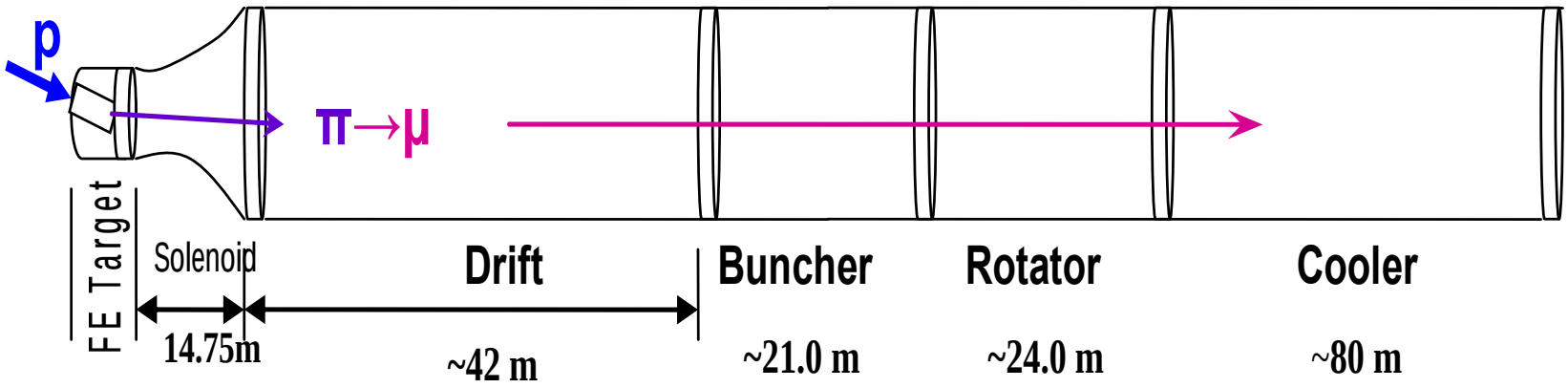
0.8 GeV/c

0.0 GeV/c

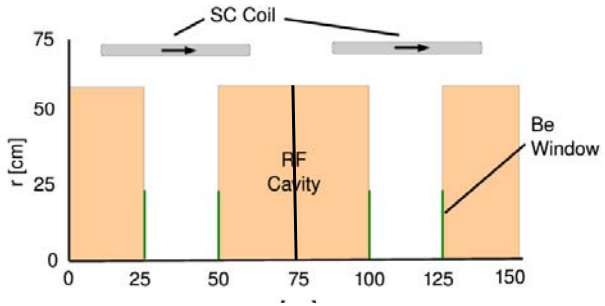
-20m

-40m

Variant 325MHz System



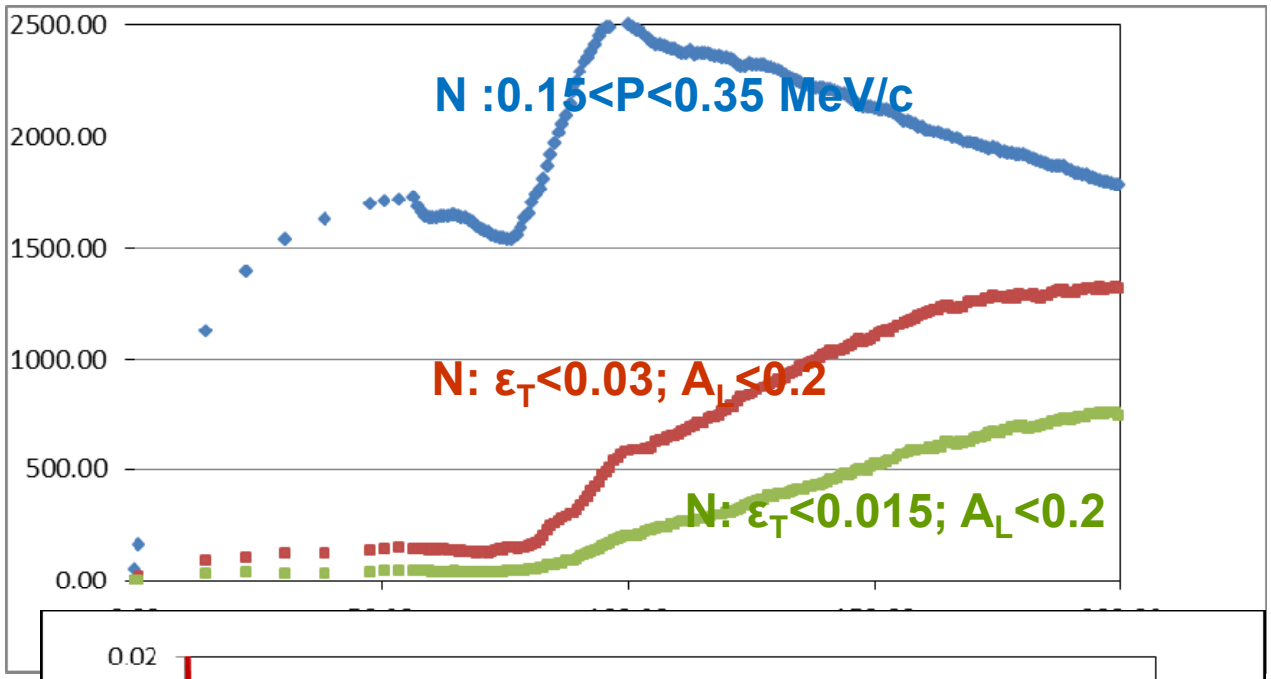
- **Drift**
  - 20T→ 2T
- **Buncher**
  - P_o=250MeV/c
  - P_N=154 MeV/c; N=12
  - V_{rf} : 0→ 15 MV/m
    - (2/3 occupied)
  - f_{RF} : 490→ 365MHz

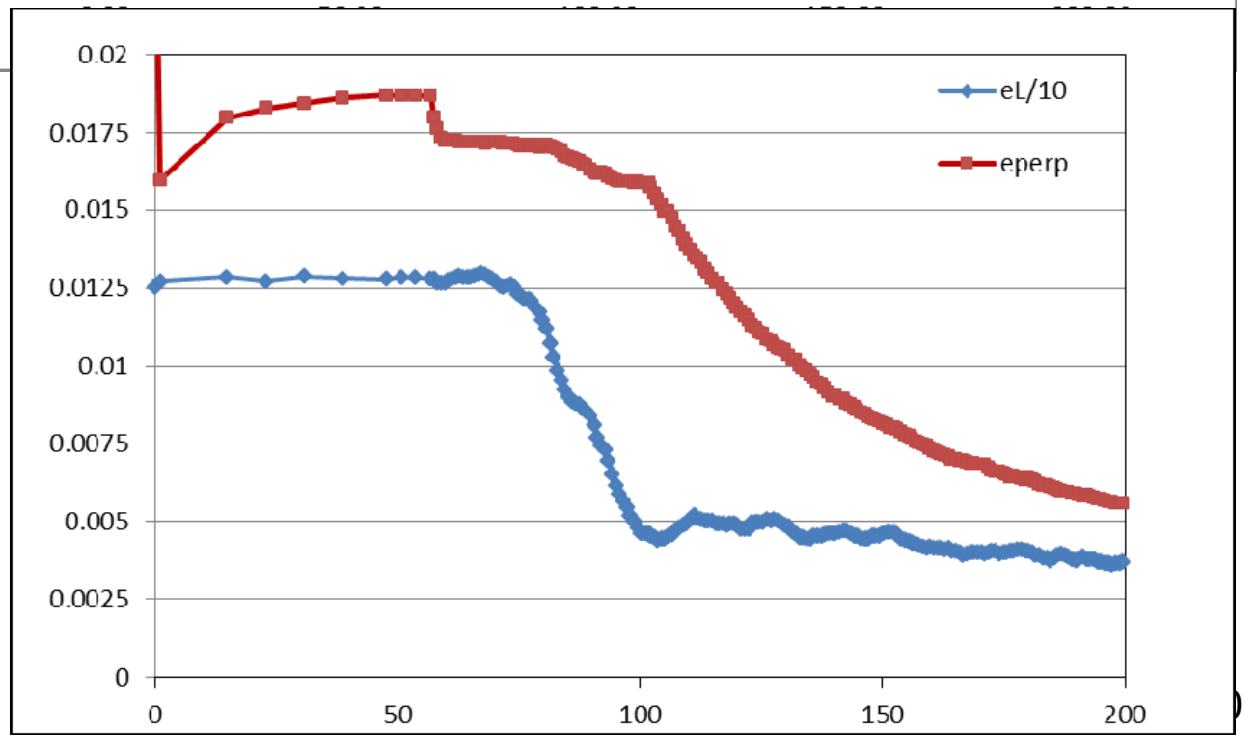


- **Rotator**
  - V_{rf} : 20MV/m
    - (2/3 occupied)
  - f_{RF} : 364→ 326MHz
  - N=12.045
  - $P_{0,}$ P_N→245 MeV/c
- **Cooler**
  - 325 MHz
  - 25 MV/m
  - 2 1.5 cm LiH absorbers /0.75m

Simulation Results

- **Simulation obtains**
  - ~0.125 μ/p within acceptances
  - with ~60m Cooler
  - shorter than baseline
- **But**
  - uses higher gradient
  - 325 MHz – less power





Variations

- **Gradient is a bit higher than IDS baseline or initial Muon Collider version**
  - 15/20/25 MV/m → 0.125 μ/p
  - 12.5/18/22.5 → 0.115
  - 12/16/20 MV/m → 0.102
  - 12/15/18 MV/m → 0.095

- **Apertures are smaller**
  - Use higher field transport to make beam smaller?
  - 2T → 3T ? (with stronger focusing making the beam smaller
    - first try had similar to baseline (not much better…)

Summary

- **325 Mhz Front End Possible**
  - similar capture to baseline
  - shorter system

- **Needs higher gradient rf and a bit stronger transverse focusing**

Answers to Questions