Front End Studies- International Design Study Update

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Outline

- **Front End for the Neutrino Factory/MC**
  - Concepts developed during study 2A
- **Concern on V_{rf}' as function of B_{sol}**
- **Need baseline design for IDS**
  - need baseline for engineering study
    - ~lower fields; medium bunch length
- **Other variations**

Official IDS layout

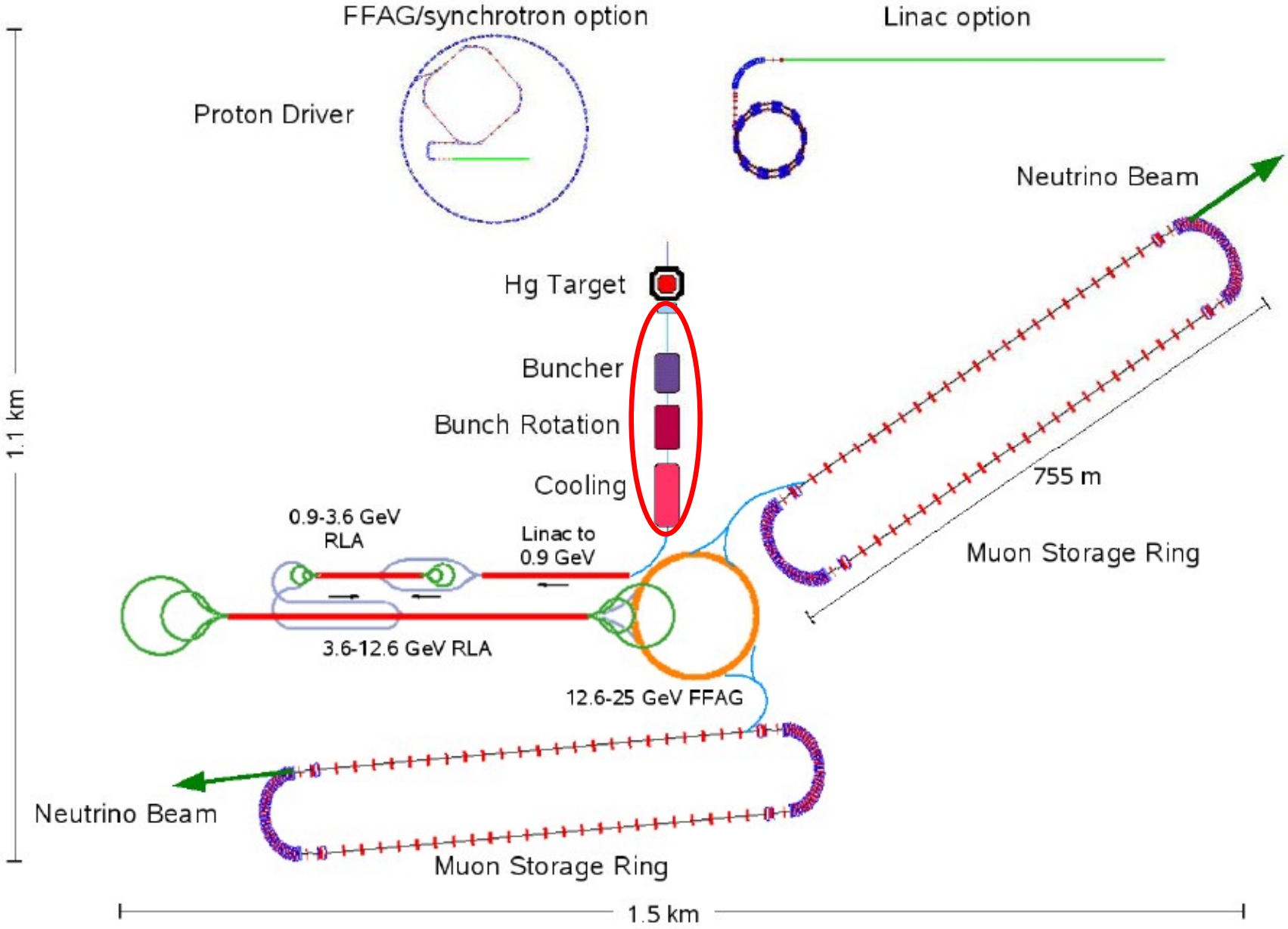
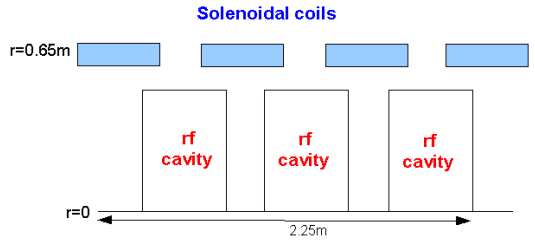
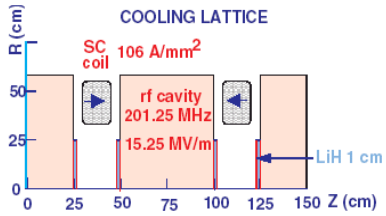


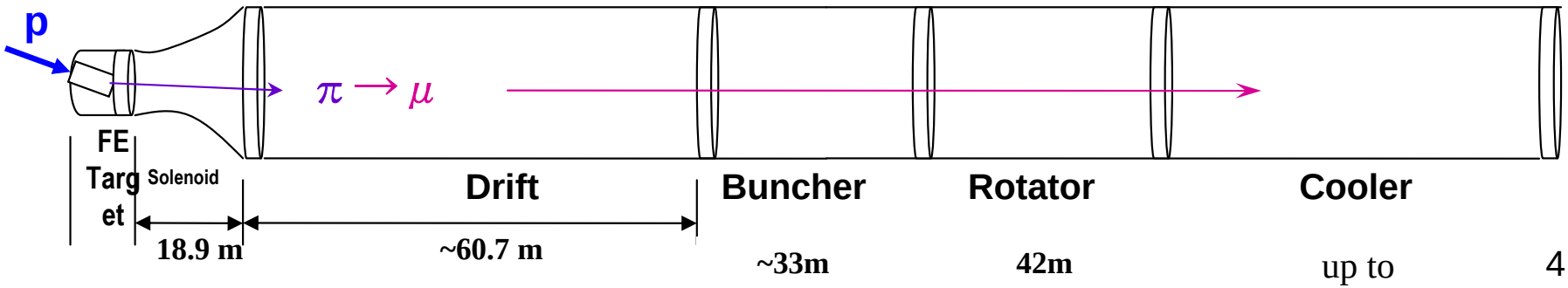
Figure 1: Schematic drawing of the ISS baseline for the Neutrino Factory accelerator complex. The various systems have been drawn to scale.

Front End ReOptimization

- **Change reference B-field to 1.5T**
  - constant B to end of rotator
- **changing to n_B ="12" example**
  - A bit longer than n_B = 10
  - optimize with lower fields
    - V'_{rf} < 12 MV/m
- **Will see if we can get "better" optimum**

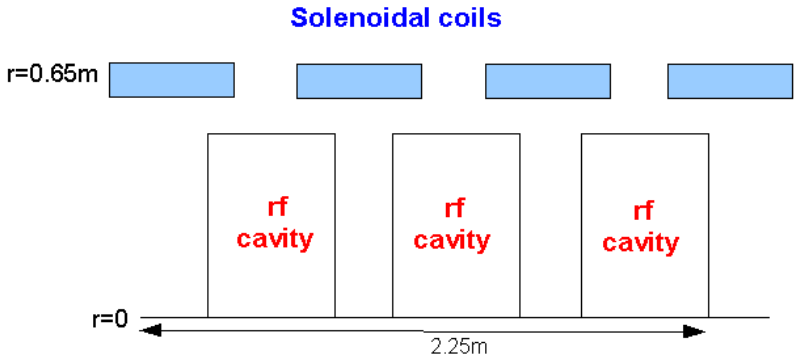


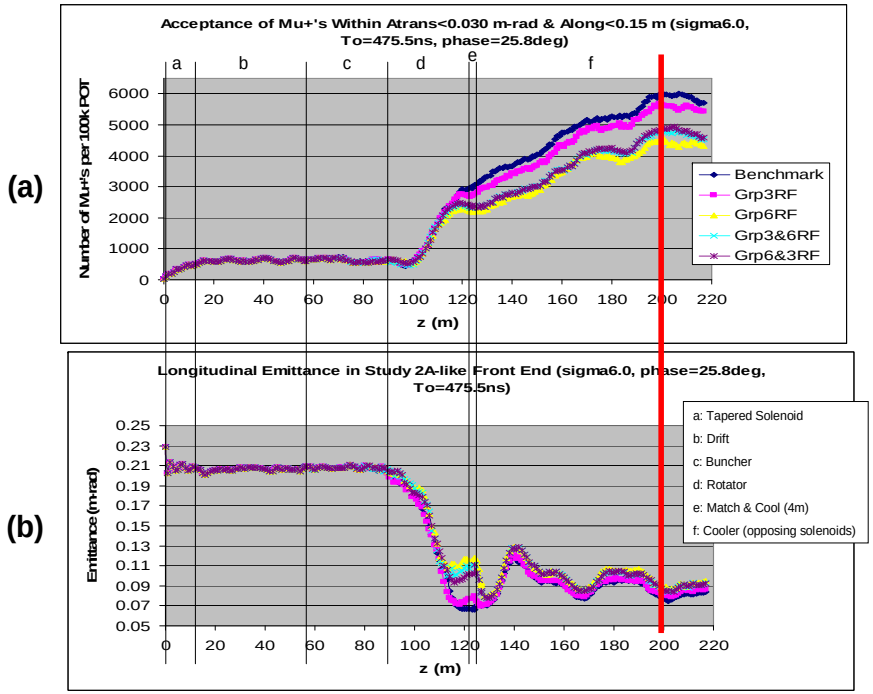




More realistic models

- For buncher & rotator replace B=1.5T with "realistic" solenoid coils
  - (B ~1.5T)
  - 0.5 m long, 0.25m spacing
  - ~OK for rf feed in between
- ICOOL simulation shows no change in performance
  - (<~1%)
- Next: rf
  - smaller number of rf frequencies
    - 14 ,B 16 R rf freq. OK
    - 7,8 20% less
  - Set rf power requirements





rf requirements

- **Buncher – 13 rf frequencies**
  - 319.63, 305.56, 293.93,285.46, 278.59, 272.05, 265.80, 259.83, 254.13, 248.67, 243.44, 238.42, 233.61 (13 f)
  - **~100MV total**
- **Rotator – 15 rf frequencies**
  - 230.19, 226.13, 222.59, 219.48, 216.76, 214.37,212.28, 210.46,208.64, 206.90, 205.49,204.25, 203.26, 202.63,202.33 (15 f)
  - **336MV** total, 56 rf cavities
- **Cooler**
  - **201.25**MHz –up to 75m ~750MV
    - ~15 MV/m, 100 rf cavities

rf properties

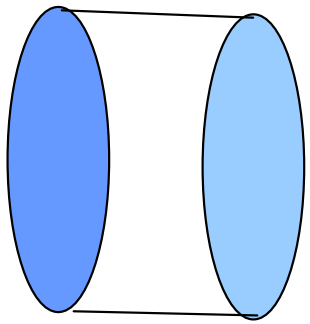
- **Assume pillbox, Cu walls**
- **Q = ~58000**
  - a=0.574m, L=0.5, f=200MHz
- **P_0 = 1.35 MW**
  - f=200MHz, L=0.5m, E_0=10MV/m
  - U_0 = 62J, T_{fill} = 63.7μs

$$Q_0 = \frac{2.405\, Z_0}{2(\pi f_{rf} \rho \mu_0)^{\frac{1}{2}}\left(1+\frac{a}{L}\right)}$$

$$U_0 = \pi \varepsilon_0 L\, a^2\, 0.52^2\, \frac{E_0^2}{2}$$

$$P_0 = \frac{\pi R_s\, 0.519^2\, E_0^2\, a(L+a)}{Z_0^2}$$

$$T_t = \frac{\sin\left(\frac{\pi f_{rf} L}{c}\right)}{\frac{\pi f_{rf} L}{c}}$$



$$T_{fill} = Q_0 \frac{\ln(2.0)}{\pi f_{rf}}$$

Buncher rf cavity requirements

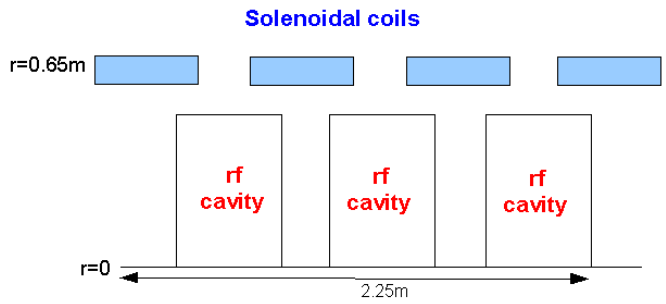
RF frequency	Total voltage	cavities	Gradient	Rf Power
319.63	1.368	1 (0.4m)	4 MV/m	0.2
305.56	3.915	2 (0.4m)	5MV/m	0.6
293.93	3.336	2 (0.4m)	4.25 MV/m	0.6
285.46	4.803	2 (0.45m)	5.5MV/m	1.0
278.59	5.724	2 (0.45m)	6.4 MV/m	1.25
272.05	6.664	3 (0.45m)	5MV/m	1.5
265.80	7.565	3 (0.45m)	5.7MV/m	1.5
259.83	8.484	3 (0.45m)	6.5MV/m	2
254.13	9.405	3 (0.45m)	7MV/m	2.25
248.67	10.326	4 (0.45m)	6MV/m	2.25
243.44	11.225	4(0.45m)	6.5MV/m	2.5
238.42	12.16	4 (0.45m)	7MV/m	3
233.61	13.11	4 (0.45m)	7.5MV/m	3.5
	98.085			MW

Rotator rf Components

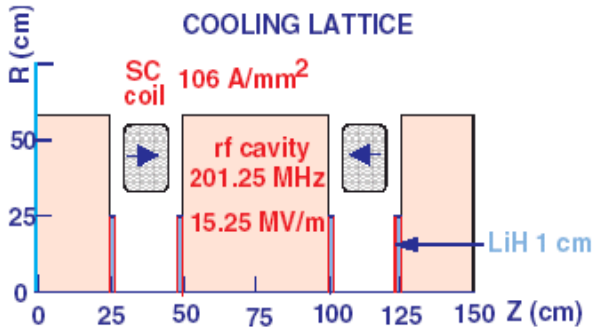
rf frequency	# of cav.	gradient	P_0/cavity	Peak power
230.19	3	12 MV/m	1.68 MW	2.25 MW
226.13	3		1.71	2.3
222.59	3		1.74	2.35
219.48	3		1.76	2.35
216.76	3		1.78	2.4
214.37	3		1.80	2.4
212.48	3		1.82	2.45
210.46	3		1.84	2.45
208.64	4		1.85	2.5
206.90	4		1.86	2.5
205.49	4		1.88	2.5
204.25	5		1.90	2.55
203.26	5		1.91	2.55
202.63	5		1.92	2.55
202.33	5		1.92	2.55

Rf Rotator/ Cooler requirements

- **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
  - **~5MW** /cavity

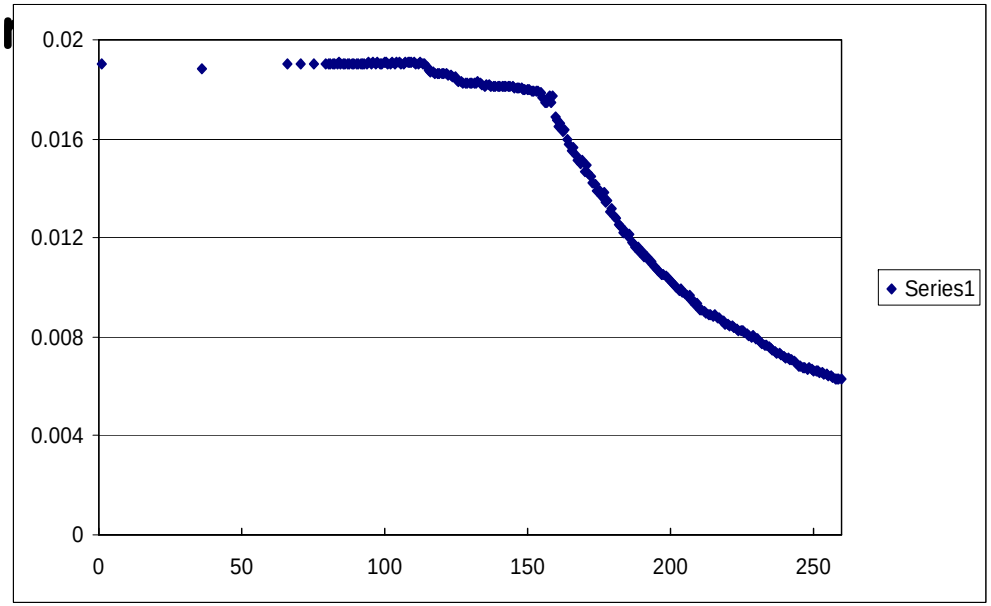


Add Windows effects

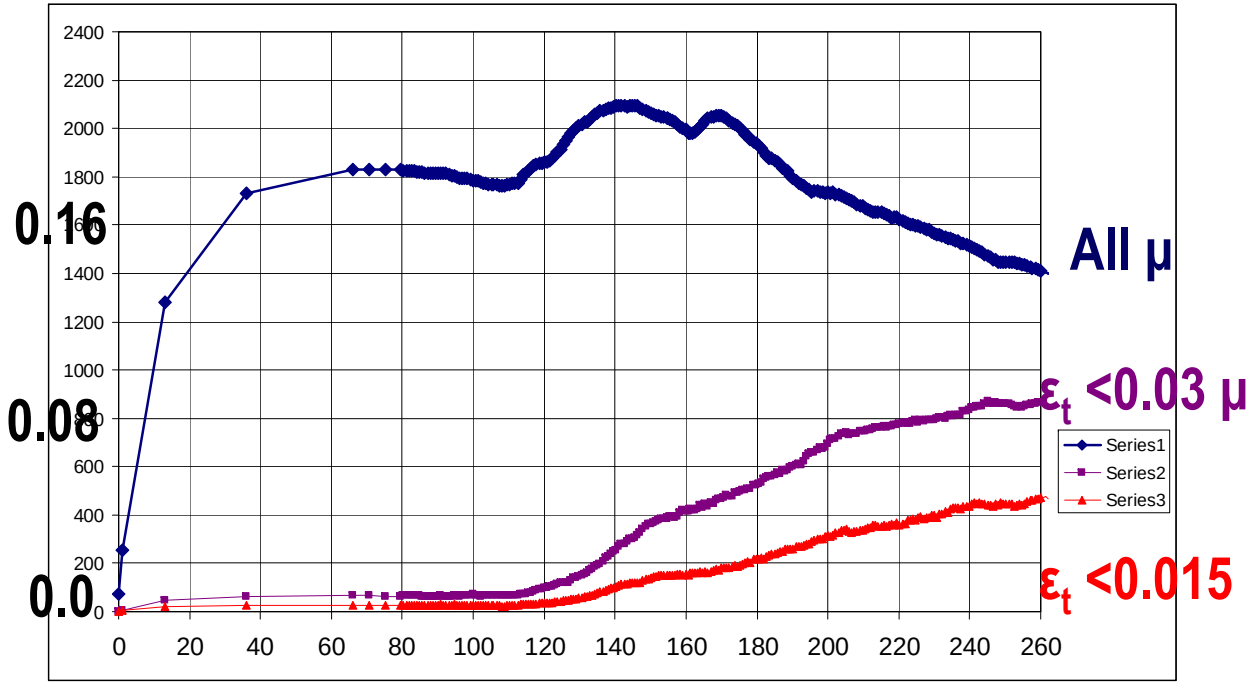
- **ISS had windows …**
  - 200μ Be – 7MV/m cavities
    - (0.12 MeV energy loss)
  - 395 μ Be – 10MV/m cavities
    - (0.24 MeV energy loss)
  - 750 μ Be – 12.5MV/m cavities (Rotator)
    - (0.45 MeV energy loss)
- **MICE rf cavities**
  - 380 μ Be window design
- **For IDS ??**
  - Use 200 μ Be for Buncher
  - Use 400 μ Be for Rotator
- **Could use Be-grid or "open-cell" ?**

Windows Effects

- **Added 0.4mm Be windows in Rotator**
  - ~0.24 MeV energy loss/ rf cavity
    - ~13.5MeV total
  - Similar to MICE windows



- **Very small change in "performance"**
  - μ/p reduced by 1—2%
  - μ/p ~0.085
  - Some cooling in rotator
    - ε_t .: 0.019 → 0.018

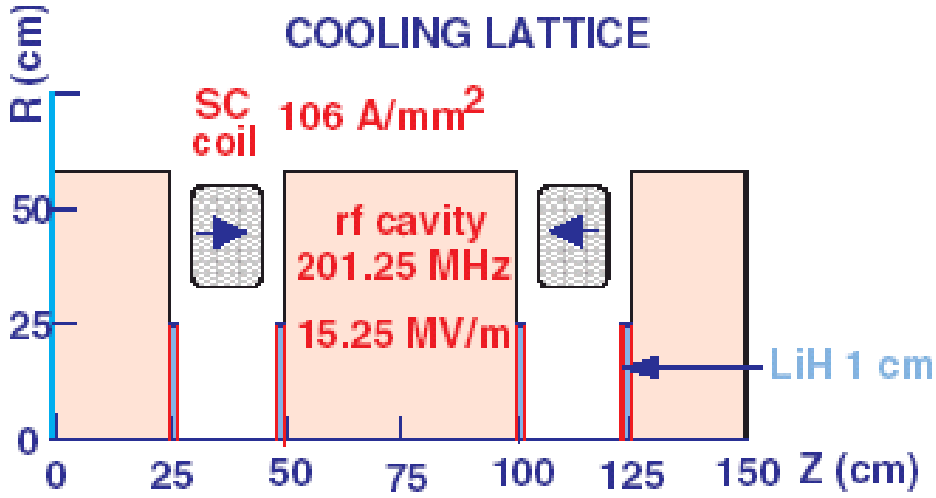


Effect of reduced # of freq in Rotator

- First try at reducing number of rf freq. in new RC
- Used rf frequency/cavities of the previous table
  - 400 μ windows in Rotator
- Rf phasing set by 233.5 MeV/c particle (?)
  - Less adapted to actual beam conditions
  - Somewhat shifted from previous optimization
- μ/p reduced from ~0.085 to ~0.081 at z =245m
  - ~5% worse ?

Variation: lower gradient cooling

- **Reduce cooling rf to 12 MV/m**
  - From 15 to 16 MV/m
- **Reduce cooling LiH from 1.1/1.15 cm to 0.8/0.85**
  - Keep same cooling lattice
- **Cooling/performance reduced**
  - μ/p at z=245m: 0.085→0.070
  - ε_t at z=245m: 0.071→0.0845
  - At equal cooling ~0.079→0.070
    - z=220 ~ z= 245m
    - 65m cooling;90m cooling



Plans etc.

- **Move toward "realistic" configuration**
  - add Buncher changes

- **Set up design for cost algorithm**
  - rf cavity design (pillbox, dielectric)
  - rf power requirements
  - Magnet design

- **Continuing front end IDS design study**
    - C. Rogers, G. Prior, D. Neuffer, C. Yoshikawa, K. Yonehara, Y. Alexahin, M. Popovic, Y. Torun, S. Berg, J. Gallardo, D. Stratakis …
  - ~Biweekly phone Conference
  - Cost meeting at CERN March
  - April at Fermilab (IDS meeting)
    - April 8-10 ??