Front End for MAP Neutrino Factory/Collider rf considerations

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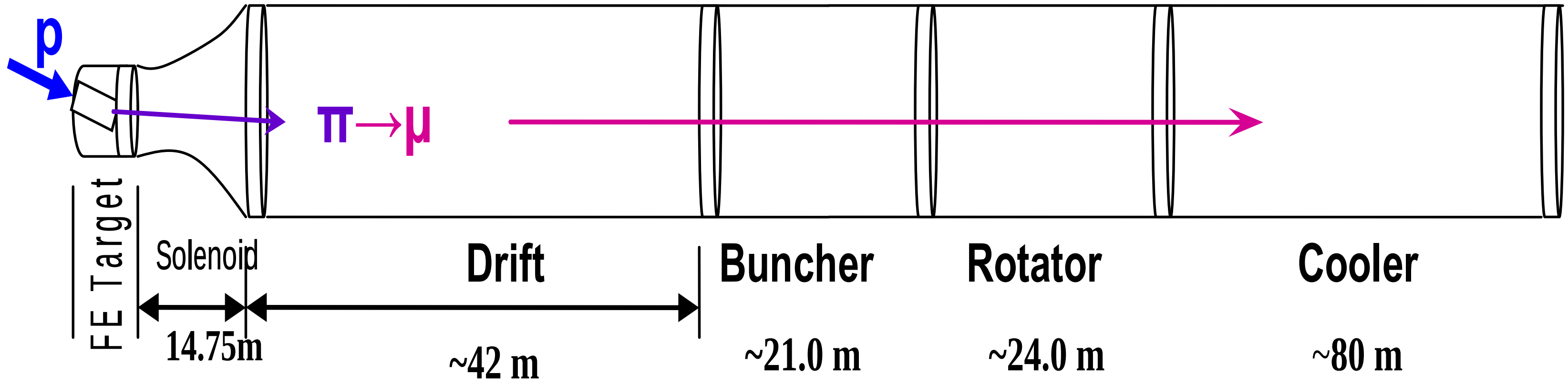
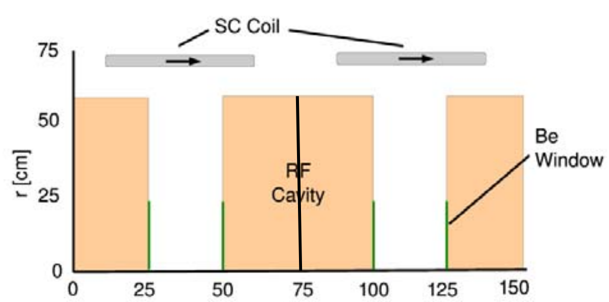
Outline

- Previous baseline was 200 MHz (IDS nu Factory)
  - Rf, power req.
- Front End for MAP NF/MC 325 MHz
  - Bunch train shorter than IDS …
  - With Chicane/Absorber
  - Current baseline
    - Use short taper
- Variations under study

325MHz System "Collider"

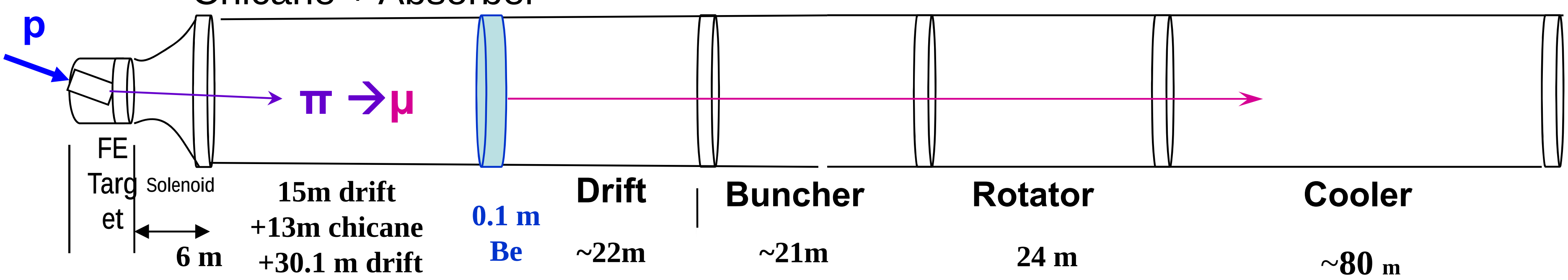


- **Drift**
  - 20T→ 2T
- **Buncher**
  - P_o=250MeV/c
  - P_N=154 MeV/c; N=10
  - V_{rf} : 0→ 15 MV/m
    - (2/3 occupied)
  - f_{RF} : 490→ 365MHz



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

325 Collider Update w/Chicane/Absorber



- **Add 30 m drift after chicane**
  - 6.5 m → +15°,-15°
- **Add chicane + absorber**
  - particle 1-283 MeV/c
  - particle 2-194 MeV/c
- absorber at 41m
  - 10 cm Be
  - particle 1-250 MeV/c
  - particle 2-154 MeV/c
- Bunch (N = 12) 0→15 MV/m: 496→ 365 MHz
- Rotate (N=12.045)- 20 MV/m: 365 → 326.5 MHz
- Cool -325 MHz -25 MV/m
  - P_{ref} = 245 MeV/c

```
SREGION        ! bentsol
6.5  1   1e-2
1  0.   1.0
BSOL
1 2.0 0.0 1 0.283 0.0  0.058181
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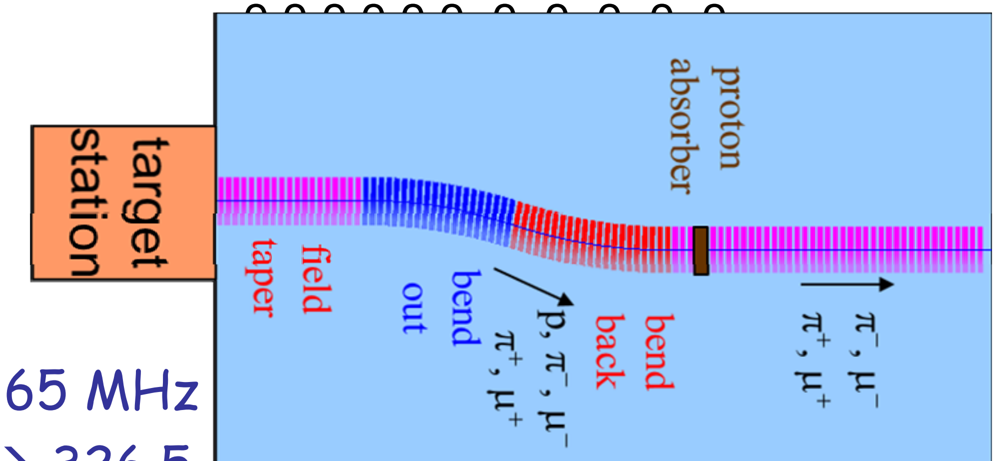


ICOOL results

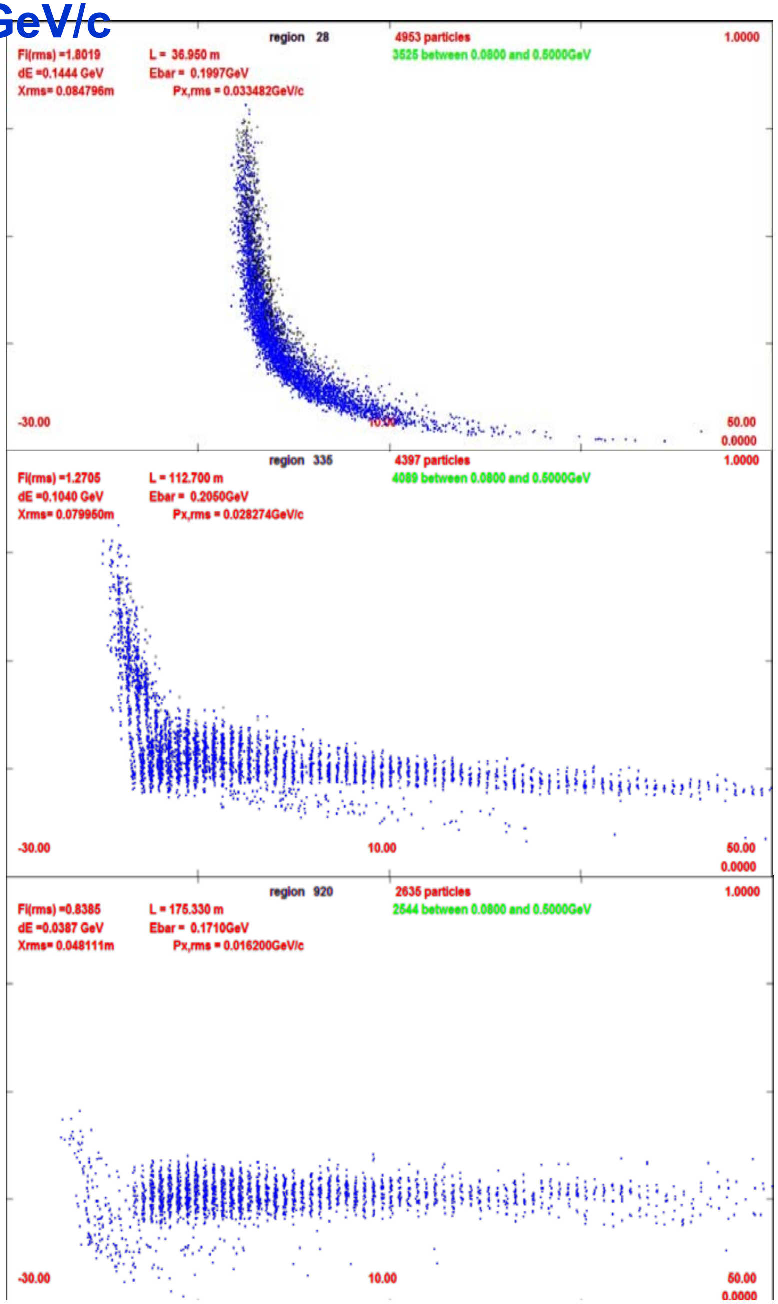
- 325 "muon collider" with chicane absorber
  - with added drifts between chicane and absorber
    - ~30 m
  - ~ 0.105 μ/p → but smaller emittance beams
    - scraped to better fit?
- Change to shorter taper
  - 15 m → 6 m
  - (Hisham) slight improvement in throughput (~ 5%)
  - We are using Hisham's more recent distributions
    - Gains ~ 5-10%
    - Total is now ~ 0.115 μ/p (in baseline ICOOL simulation units)
- Better Rotator/Cooler match (Diktys)
  - +5%
  - Cooler will be replaced by better 6-D cooler (Alexahin)

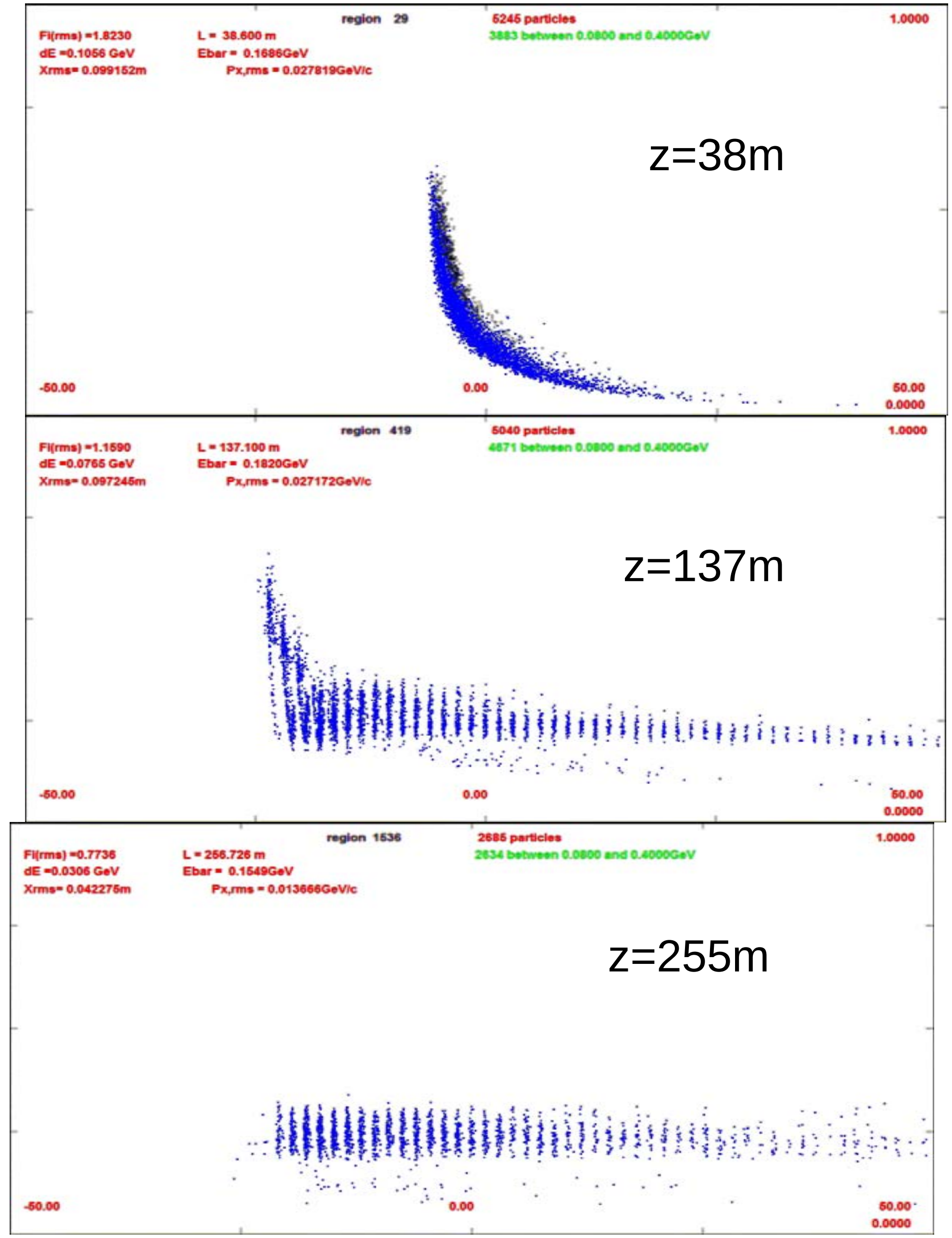
Compare 325 w chicane vs old 200

High P cutoff is ~700 MeV/c   (from ~500 MeV/c)

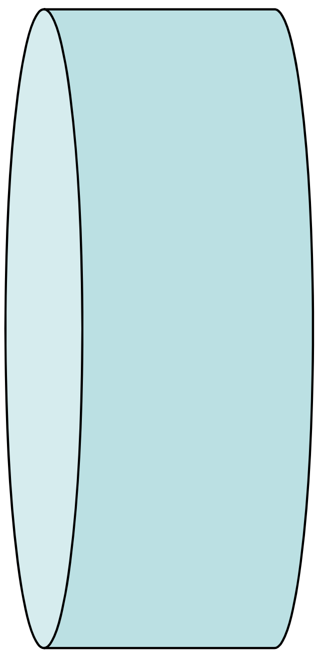
1.0 GeV/c

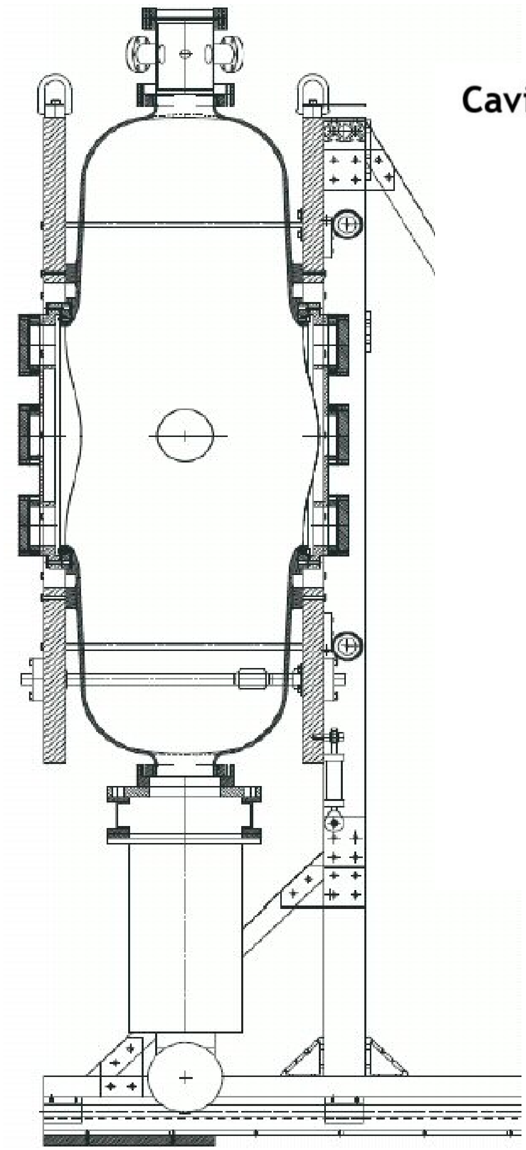
0

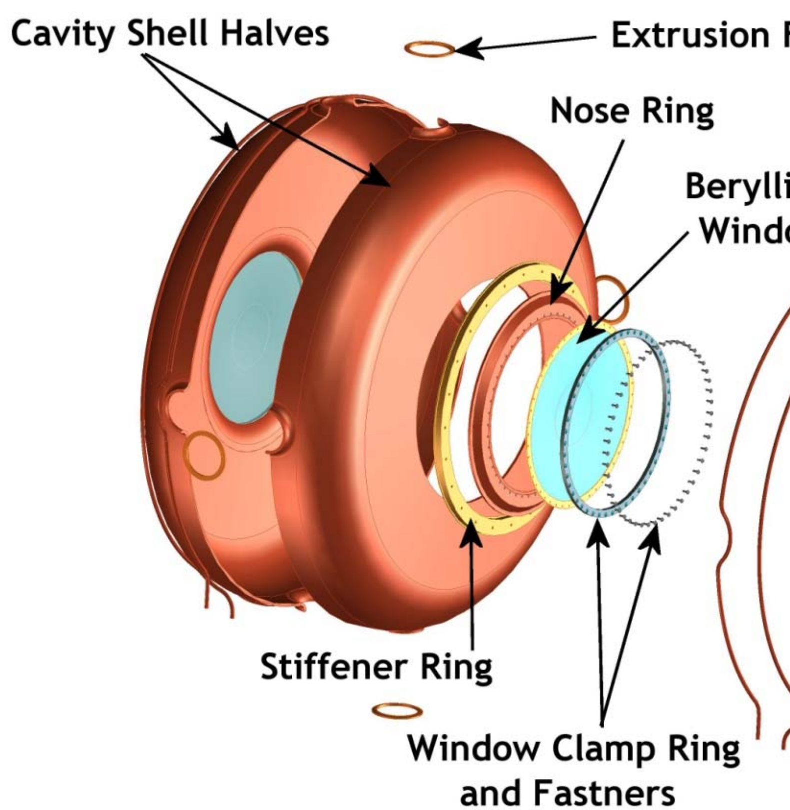




Rf cavity







Concept **design** **construction** **operation**

MAP rf properties (~ MICE rf)

- **Assume pillbox, Cu walls**
  - Compare with MICE rf
- **Q = ~58000**
  - a=0.574m, L=0.5, f=200MHz
  - T_t=0.83
- **P_0 = 1.35 MW at 10MV/m**
  - f=200MHz, L=0.5m, **E_0=10MV/m**
  - U_0 = 62J, **T_{fill} = 63.7μs**
  - P_0 = 3MW at 15MV/m

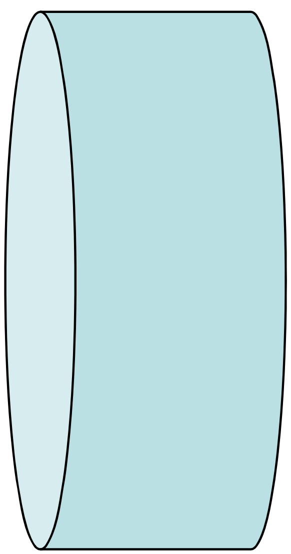
$$Q_0 = \frac{2.405\, Z_0}{2(\pi f_{rf}\, \rho \mu_0)^{\frac{1}{2}} (1+\frac{a}{L})}$$

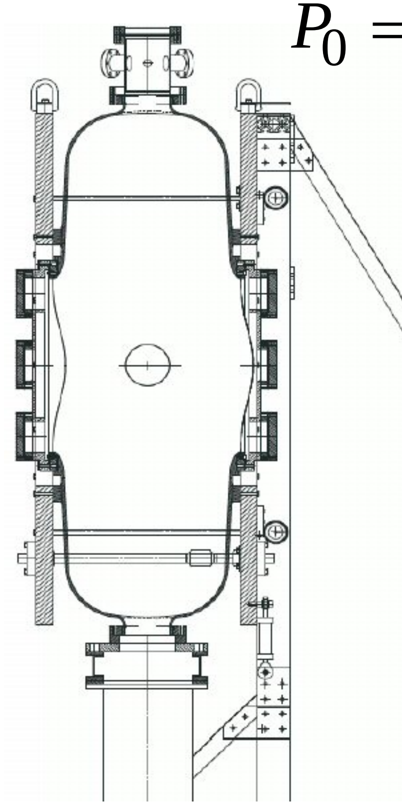
$$R_s = \sqrt{\rho_{Cu} \pi \mu_0 f_0}$$

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

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

MICE rf parameters	Value
Radius (mm)	610
Length (mm)	430
RT^2 (MΩ/m)	22
Power needed (16MV/m)	4MW
Quality factor, Q_0	**54,000**



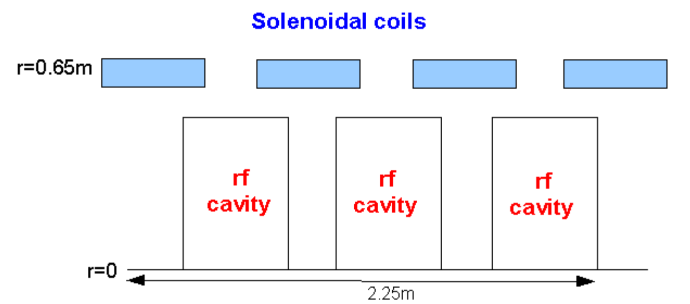


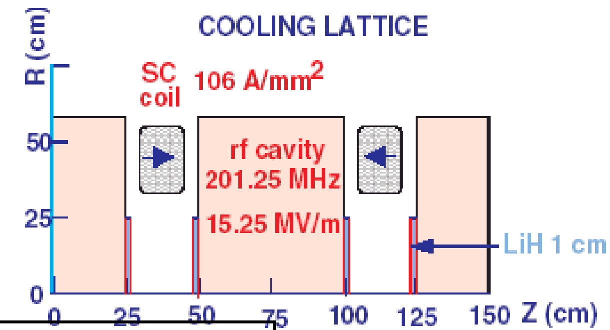
$$T_t = \frac{\sin\left(\frac{\pi f_{rf} L}{c}\right)}{\frac{\pi f_{rf} L}{c}}$$

$$T_{fill} = Q_0 \frac{\ln(2.0)}{\pi f_{rf}}$$
8

IDS RF 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





rf

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 7.5	~1 to 3.5 MW/freq.
Rotator	42m	56	230.2 to 202.3	15	12	~2.5MW/cavity
Cooler	75m	100	201.25MHz	1	15 MV/m	~4MW/cavity
Total drift)	~240m	193		29	~1000MV	~550MW

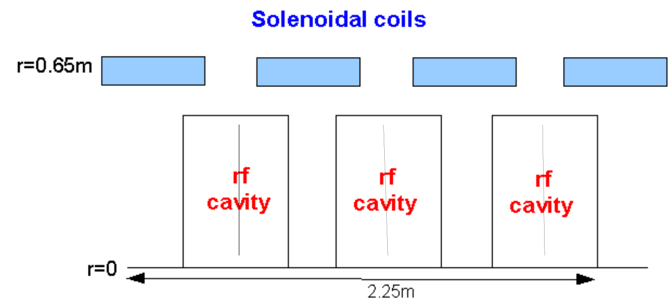
Magnet Requirements:

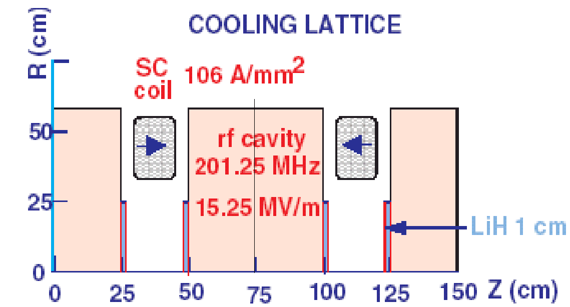
Table XIV. Summary of front-end magnet requirements.

	Length [m]	Inner radius [m]	Radial thickness [m]	Current density [A/mm^2]	Number
Initial transport	0.5	0.68	0.04	47.5	180
Cooling channel	0.15	0.35	0.15	±107	100

Rf Buncher/Rotator requirements

- **Buncher -21m**
  - 37 cavities (14 frequencies)
  - 13 power supplies **(~1—3MW)**
- **RF Rotator -24m**
  - 64 cavities (16 frequencies)
  - 20 MV/m, 0.25m
  - ~2 MW (peak power) per cavity
- **Cooling System – 201.25 MHz**
  - 200 0.25m cavities (75m cooler), **25MV/m**
  - **~4MW** /cavity





rf

Front End section	Length	#rf cavities	frequencies	# of freq.	rf gradient	rf peak power requirements
Buncher	21m	37	484 to 365	14	0 to 16	0—1.34 MW/cavity
Rotator	24m	56	364to 326	16	20	~2.4 MW/cavity
Cooler	75m	200	325	1	25 MV/m	~3.7MW/cavity
Total df+bxr+rttr	~134m	93		30	~500MV	140MW

First result on discretization

Discretization of rf frequencies

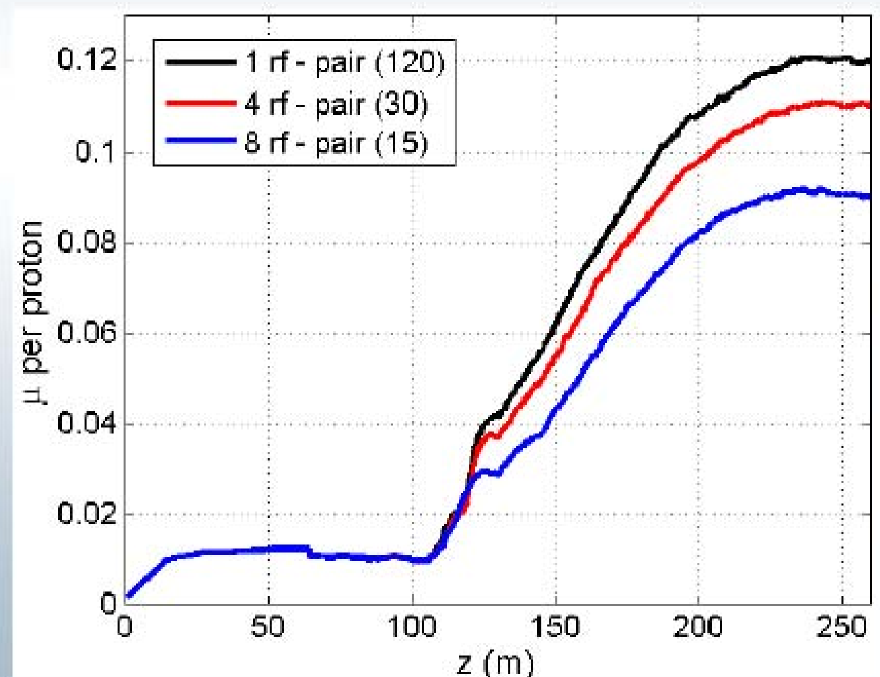
- Our goal is to reduce the number of frequencies.
- Going from 120 to 30 frequencies -> 8% loss

Buncher rf parameters

Frequency (MHz)	Gradient (MV/m)
493.71	0.30
482.21	1.24
470.27	1.95
458.40	3.38
448.07	4.45
437.73	5.52
427.86	6.60
418.43	7.67
409.41	8.74
400.76	9.81
392.48	10.88
384.53	11.95
376.89	13.02
369.55	14.30

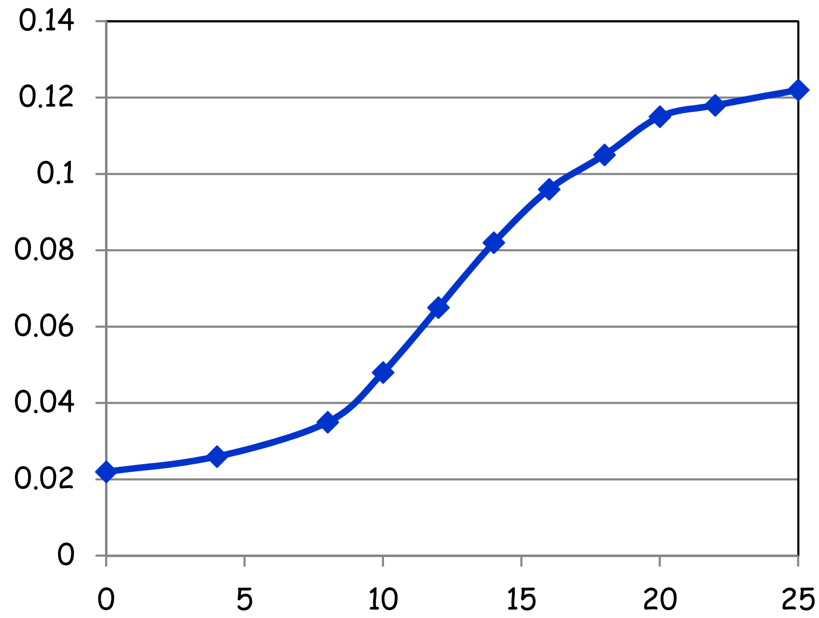
Rotator rf parameters

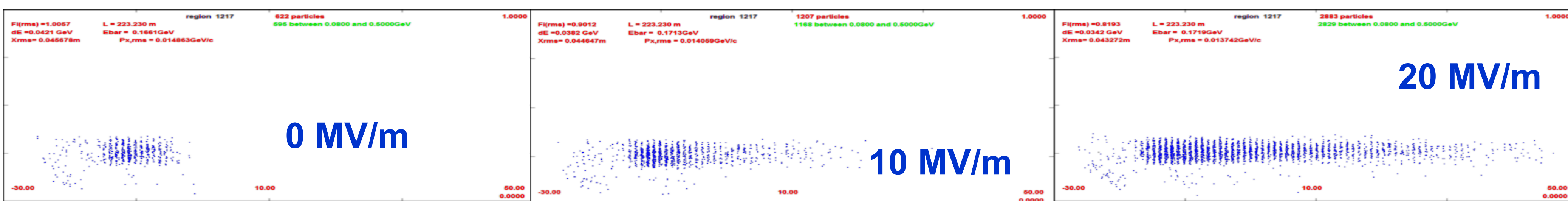
Frequency (MHz)	Gradient (MV/m)
363.86	20.0
357.57	20.0
352.20	20.0
347.59	20.0
343.65	20.0
340.27	20.0
337.39	20.0
334.95	20.0
332.88	20.0
331.16	20.0
329.75	20.0
328.62	20.0
327.73	20.0
327.08	20.0
326.65	20.0
326.41	20.0



Dependence on rf gradient

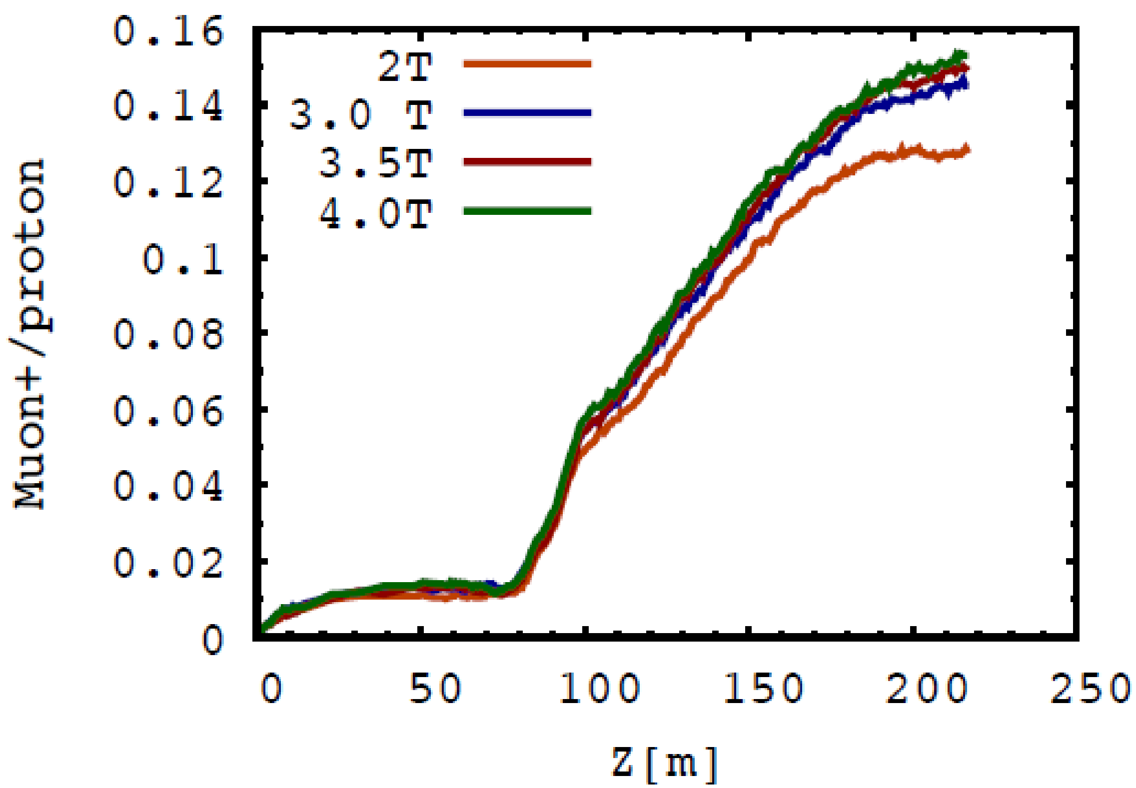
- With same cooling channel
  - 25MV/m IDS 4-D cooling
- Change Buncher/Rotator peak rf voltage
  - 0 -25 MV/m
- Longer bunch train captured with larger V'





Dependence on B_{final}

FRONT END PERFORMANCE AT DIFFERENT END FIELDS



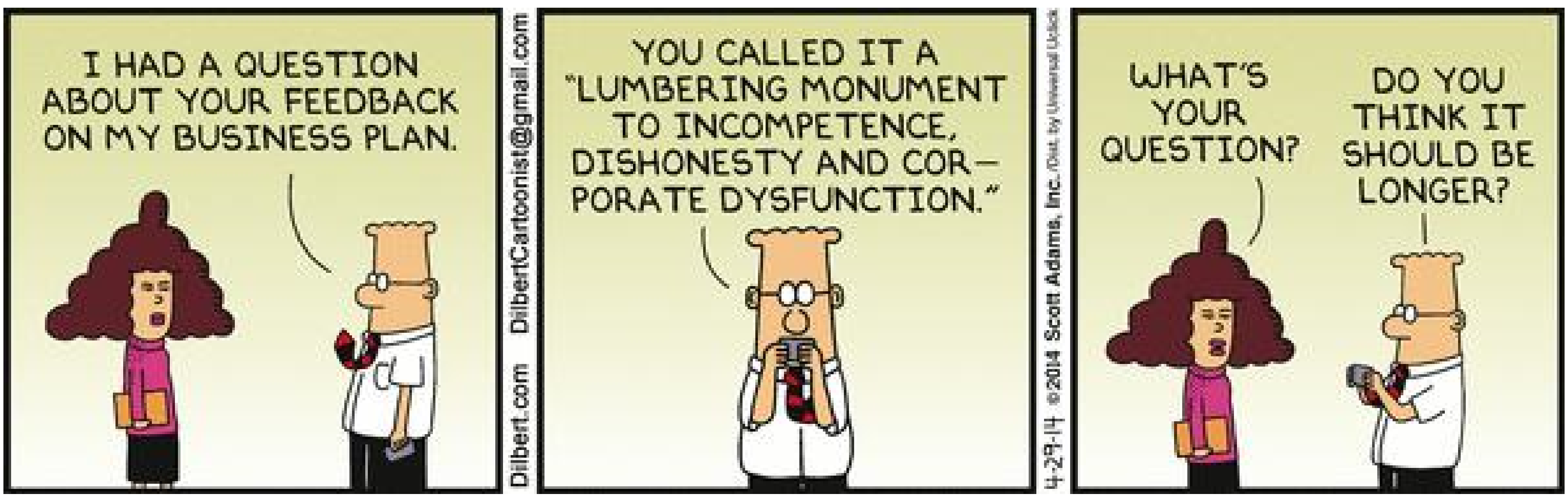
Summary

- **We are studying 325 MHz based front end**
  - produces more bunches in same length bunch train than 200 MHz
  - requires more bunches to be recombined ~12 → 21
    - more difficult … ?
    - HCC recombiner ?
  - Including chicane/absorber
    - Improved matching
  - Would like to fit more μ in fewer bunches

Current Status

P5 process:

P5 Result:

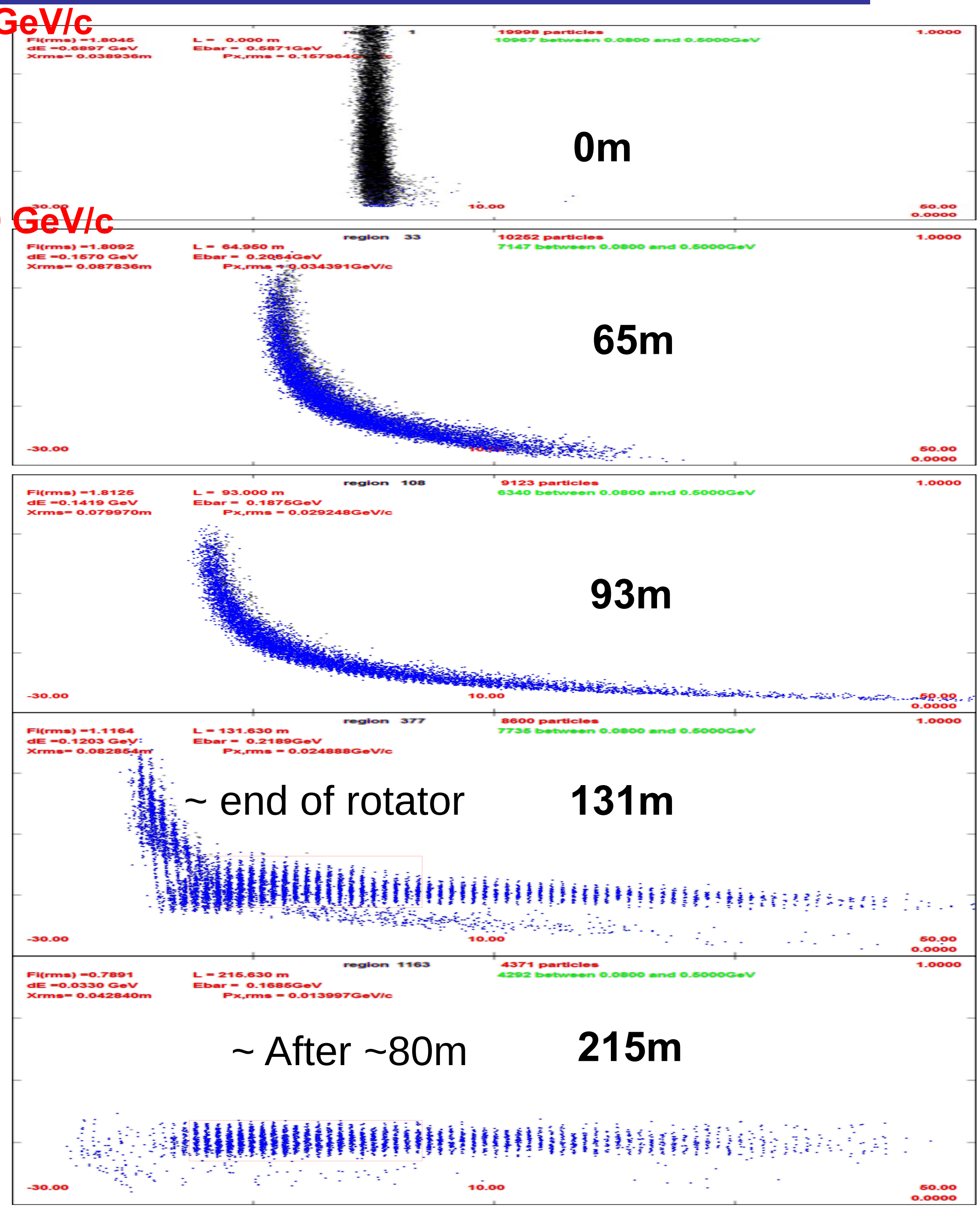


Supplemental slides

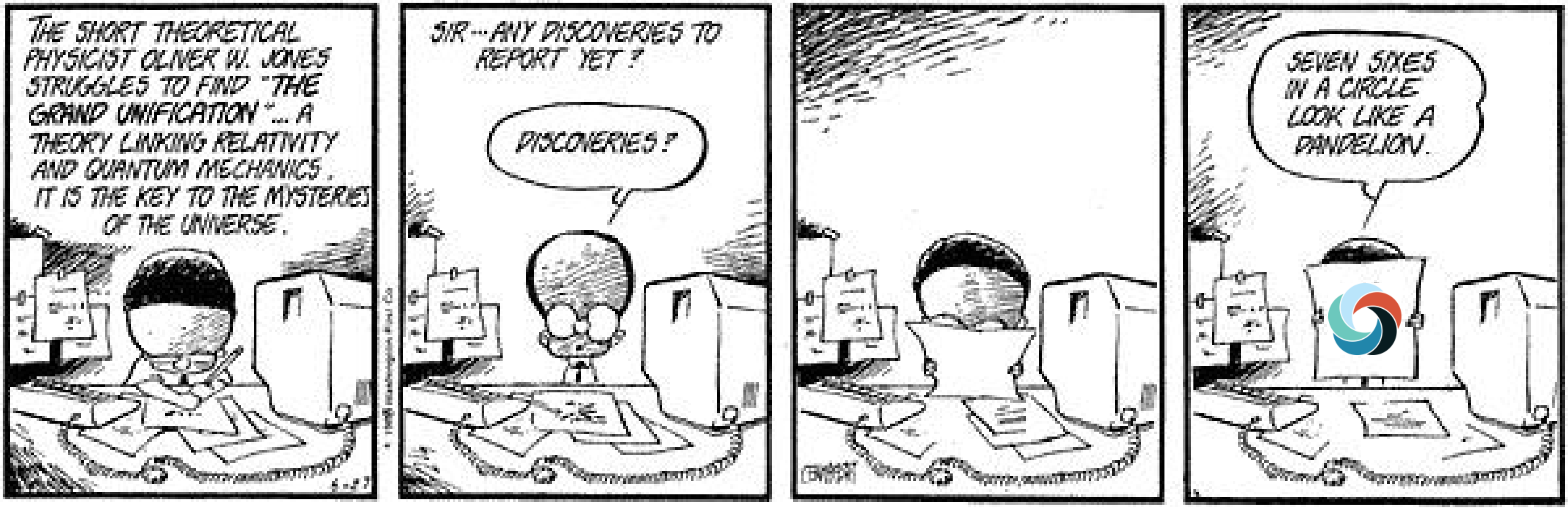
325 (w chicane/absorber)

- ~60 m long bunch train
  - ~60 325 MHz buckets
- For collider choose "best 21 bunches "
  - (~19m)
- Includes ~2/3 of captured μ's
  - many are lost
- 21bunches are recombined to 1 in collider scenario
  - It is more difficult to recombine 21 than 12

- Would like to extend acceptance or generate shorter train



P5 result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SIR -- ANY DISCOVERIES TO REPORT YET?
DISCOVERIES?
SEVEN SIXES IN A CIRCLE LOOK LIKE A DANDELION.