Machine Requirements from Muon WG

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NuFact05

Contents

- Muon beam requirements
- Machine reqirements
- J-PARC case
- FNAL case
- Summary

Muon Beam Requirements for Future Muon Program

Experiment	Charge	Intensity ($\mu/10^7$sec)	Pulse width (μs)	Pulse interval (μs)	Energy (MeV)	Mom. spread (%)	Polarization n/a	Note
$\mu \to e\gamma$	+	10^{15}	DC	≤ 1	1	≤ 10	Depol	e comtami. $\leq$ 10-2, beam size cm
$\mu N \to eN'$ (MECO type)	−	10^{21}	10-100	1-1000	<20	<10	n/a	
$\mu N \to eN'$ (PRISM type)	−	10^{20}	10-100	1-1000	≤ 20	3	n/a	π comtami. $\leq$ 10-15, beam size cm
g-2	±	10^{15}	≤ 15	≥ 1000	3100	10^{-2}	Pol	
edm	±	10^{18}	≤ 50	≥ 1000	200-400	10^{-3}	n/a	
μ lifetime	+	10^{14}	~100	30-100	4	1-10	π beam	
μ lifetime (π)	+	10^{14}	~100	30-100	4	1-10	100%	
Michel parmammeter	+	10^{16}	≤ 0.5	≥ 0.02	30-40	1-3	~100%	
Pol param.	+	10^{16}	≤ 0.5	≥ 0.02	30-40	1-3	Pol	
μ-atoms	−	10^{16}	≤ 100	100-1000	1-4	1-5	n/a	e comtami. $\leq$ 10-2, beam size cm
Life science	−	10^{15}	1	100-1000	1-4	1-5	n/a	beam size mm
μCF	−	10^{19}	1	≥ 1000	≥ 100			
μSR	±	10^9/s	DC	-	4	1-5	~100%	
μSR	±	$10^{10\text{-}20}$/s	0.001	100	4	1-5	~100%	

MEG@PSI

Muon Trio at NuFact

MLF@ J-PARC

New generation of Muon Trio

	current limit
$\mu N \rightarrow eN'$	BR(Ti)<10^{-13}
g-2	0.54 ppm
edm	10^{-19} e.cm

- Use the front end of NuFact
- Use a high intense proton driver and construct muon facility.

Machine Requirements

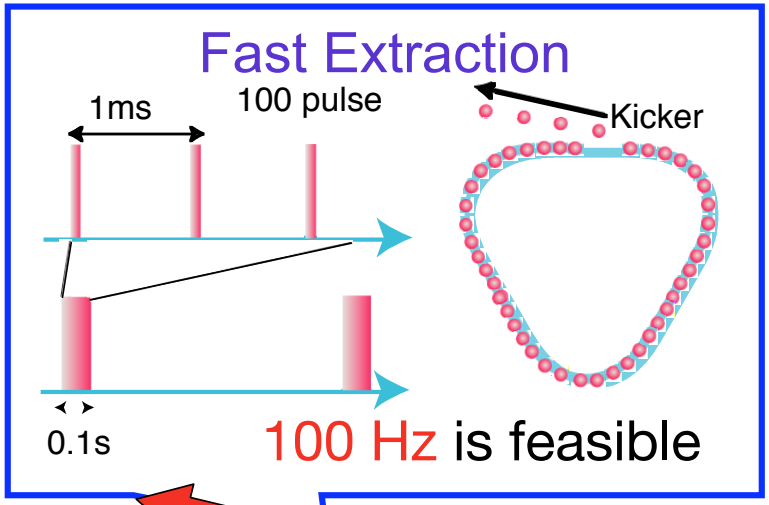
- To carry out these experiments, we need
  - high power proton beam ~1MW- a few MW
  - pulsed proton beam width ~10ns
  - single bunch fast extraction
- to change beam structure to muon experiment required one, accumulator ring would be necessary
  - ex. J-PARC : + 3GeV-RCS + 50GeV-MR
  - FNAL : 8GeV-Linac + recycler

Pulsed Proton Beam Facility at J-PARC

50GeV-PS at J-PARC

- High intensity 0.75 MW
  - 10^{14}proton/sec
  - Upgradable to 4×10^{14}proton/sec
- A narrow bunched :

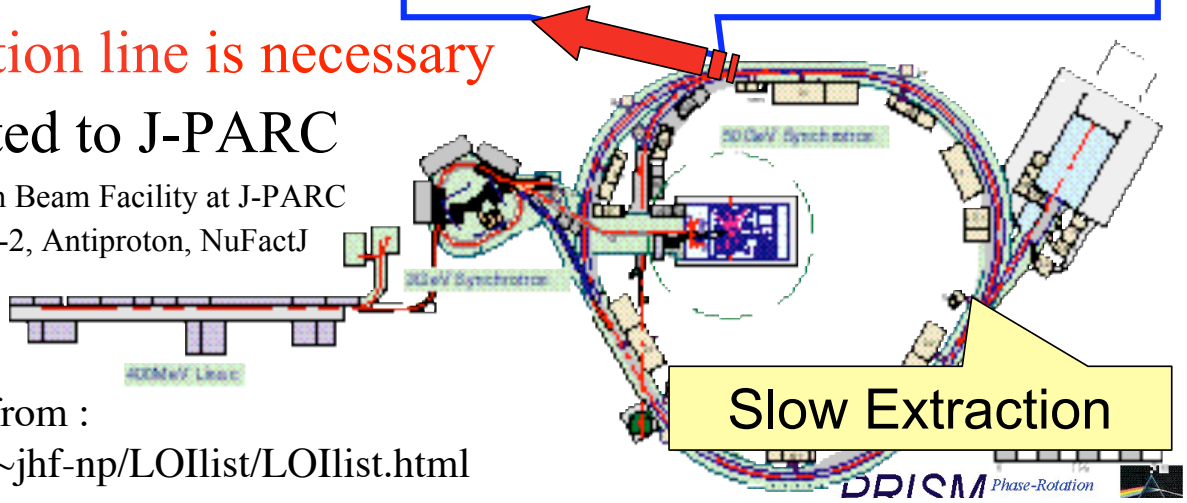
  for phase rotation



New Fast extraction line is necessary

LOI was submitted to J-PARC

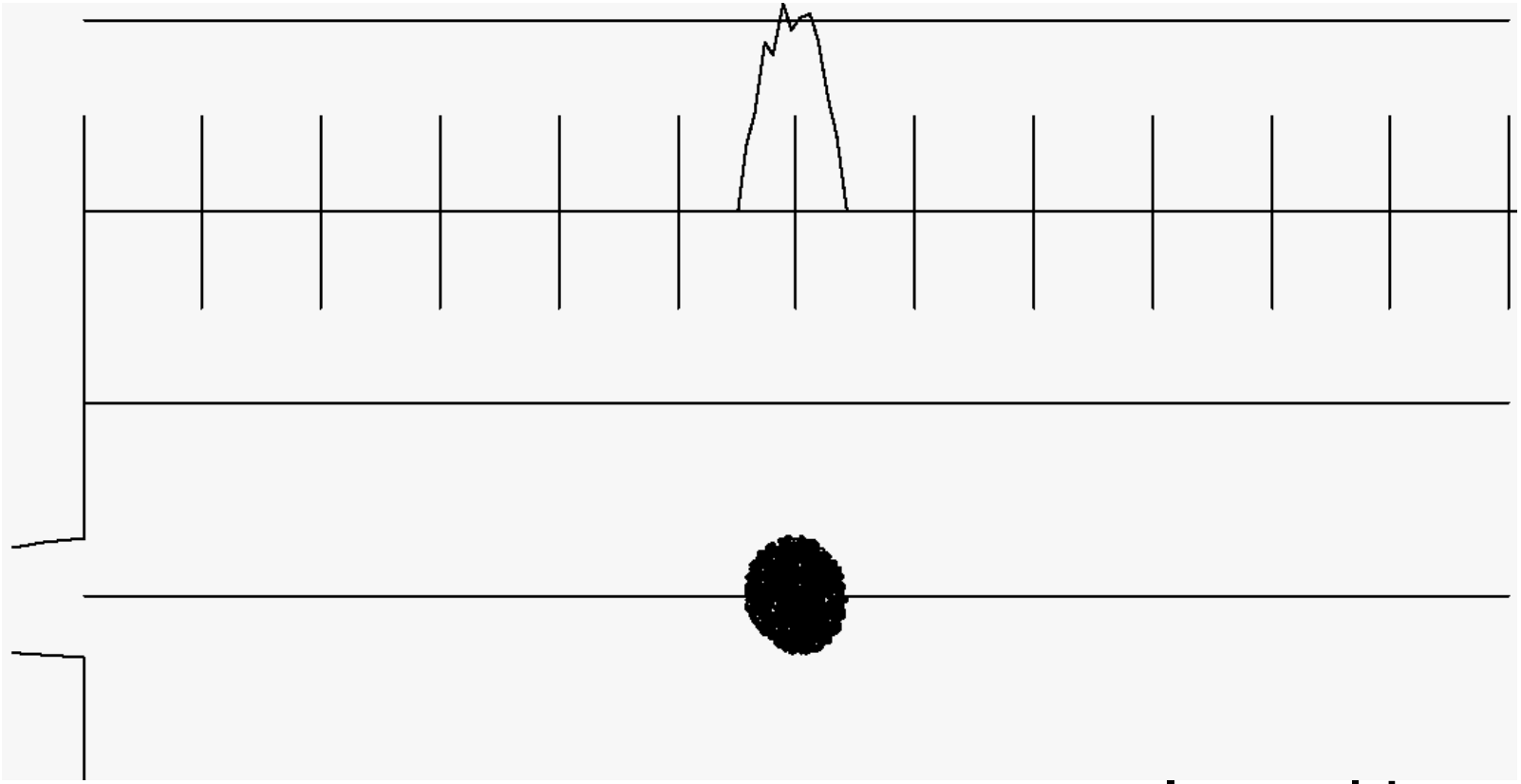
Request for A Pulsed Proton Beam Facility at J-PARC
PRISM/PRIME, EDM ,g-2, Antiproton, NuFactJ



LOIs are available from :
http://psux1.kek.jp/~jhf-np/LOIlist/LOIlist.html

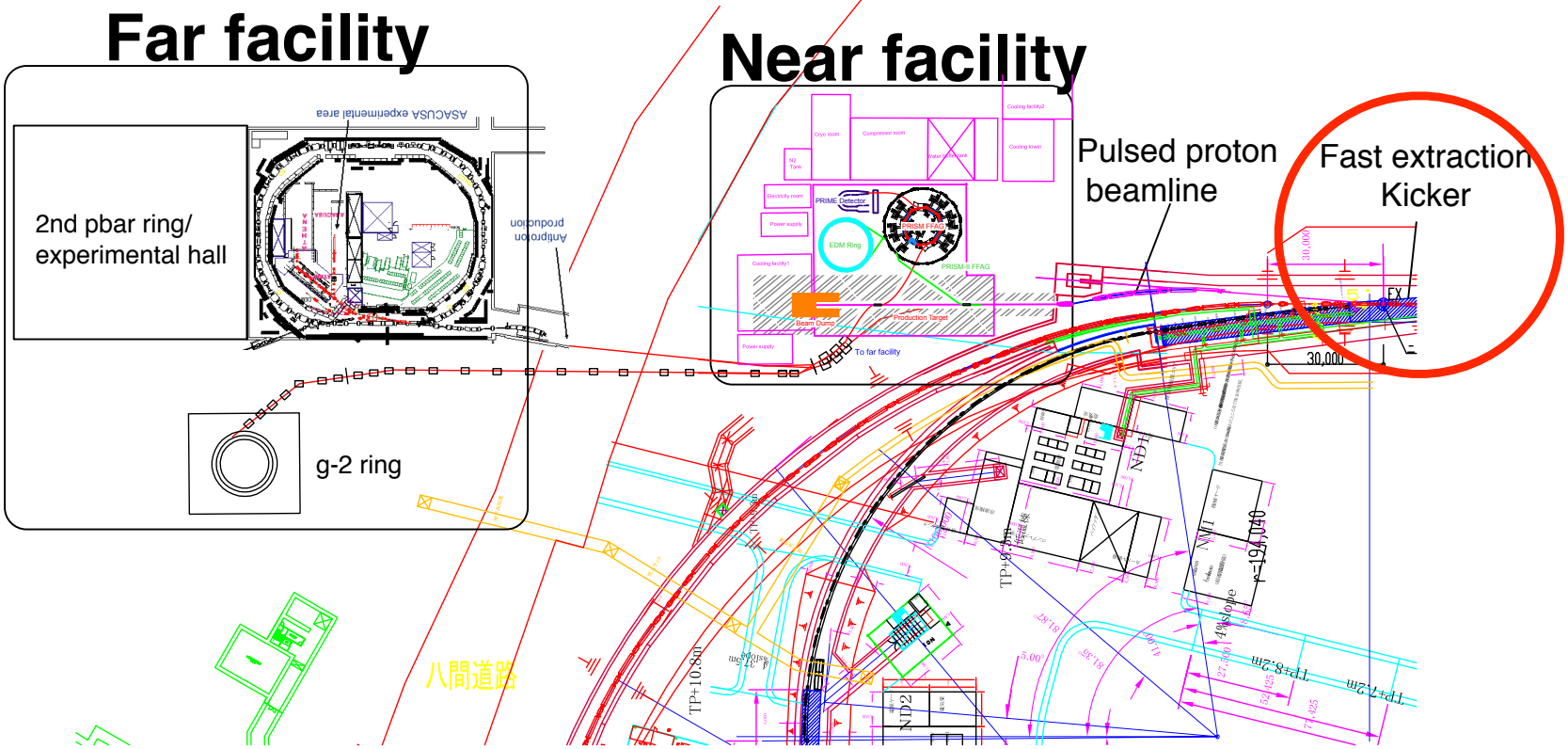
re-bunch in 50GeV-MR

C.Ohmori



It would work.
stability?

possible layout



design study of the fast extraction kicker

spec is almost same as the 50GeV-kicker, but ~10 times faster rise time is required. need idea and study.

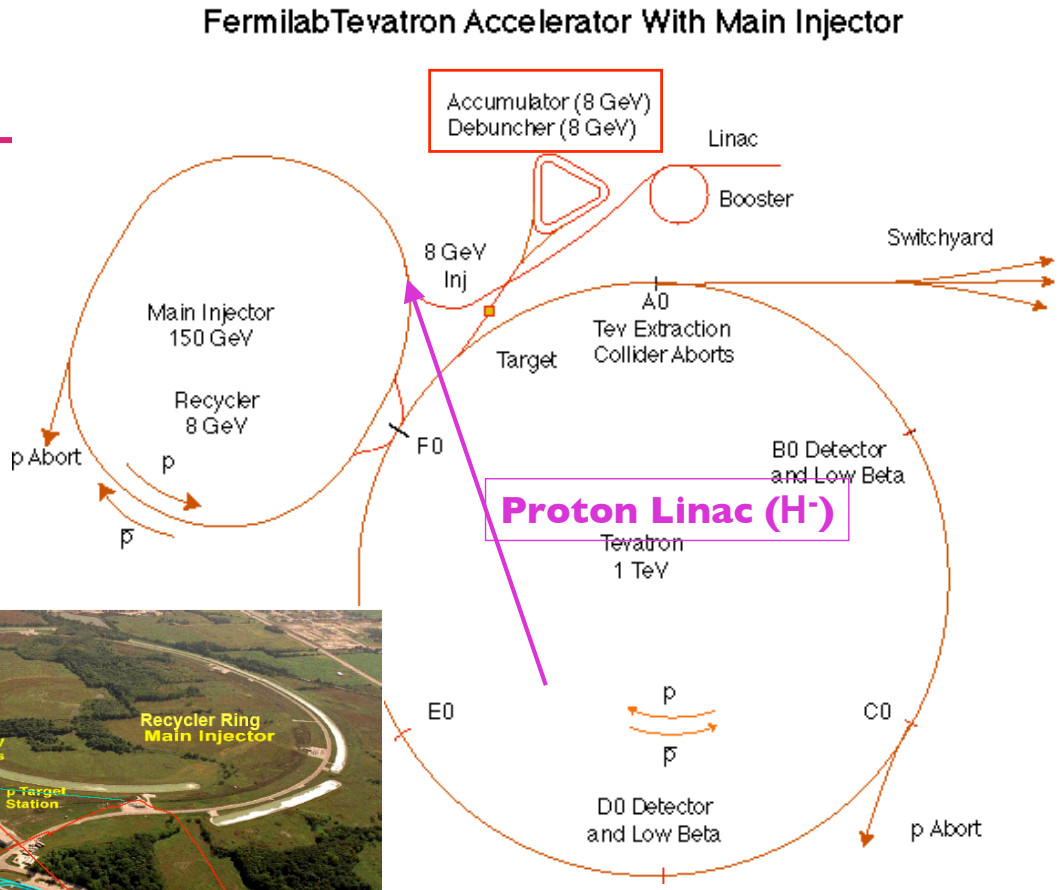
J-PARC50GeV引出キッカーパラメーター計算値

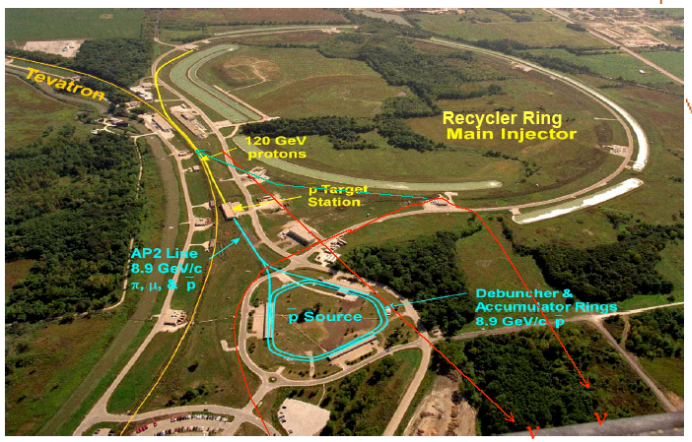
項目				導出式	J-PARC-50GeV引出		
場所	詳細項目	記号	単位		白壁案	川久保案031217	三菱電機作製
ｺｱ･ｷﾞｬｯﾌﾟ	ﾌｪﾗｲﾄ開口(ｷﾞｬｯﾌﾟ)部(高さ)	h	mm	入力	100.0	110.0	110.0
	ﾌｪﾗｲﾄ開口(ｷﾞｬｯﾌﾟ)部(幅)	w	mm	入力	100.0	100.0	100.0
	長さ	d	mm	$N_{sec}*d_{sec}$	2530.0	2525.0	2424.0
	内側ｺｲﾙ板厚み	d_{incoil}	mm	入力	15.0	15.0	15.0
	中央仕切板厚み	$d_{sepcoil}$	mm	入力	4.0	4.0	4.0
セクション	段数	N_{sec}		入力	110	101	101
	ﾌｪﾗｲﾄ厚み	d_{fer}	mm	入力	19.0	20.0	20.5
	高圧金属板厚み	d_{metal}	mm	入力	3.0	4.0	3.0
	溝の隙間（ガタ）	d_{room}	mm	入力	1.0	1.0	0.5
	アース板厚み	d_{ground}	mm	入力	7.0	12.0	12.0
	長さ	d_{sec}	m	$d_{fer}+d_{metal}+d_{room}$	23.0	25.0	24.0
	ﾌｪﾗｲﾄ充填率	α_{fer}	%	d_{fer}/d_{sec}	82.6	80.0	85.4
	インピーダンス	Z	Ω	入力	5.0	5.0	5.0
	ﾌｪﾗｲﾄ部ｲﾝﾀﾞｸﾀﾝｽ	L_{fer}	nH	$\mu_0*w*d_{fer}/(2h)$	11.93805	11.42397	11.70957
	ﾌｪﾗｲﾄ以外のｲﾝﾀﾞｸﾀﾝｽ	$L_{non\text{-}fer}$	nH	**脚注1**	0.90107	1.05334	0.73734
	合計ｲﾝﾀﾞｸﾀﾝｽ	L_{sec}	nH	$L_{fer}+L_{non\text{-}fer}$	12.83912	12.47732	12.44691
	キャパシタンス	C_{sec}	pF	L_{sec}/Z^2	513.5648	499.0927	497.8765
	時定数	τ_0	nsec	L_{sec}/Z	2.568	2.495	2.489
	立上り時間(1-99%)	$\tau_{1\text{-}99\%}$	nsec	$4.6*\tau_0$	11.812	11.479	11.451
	ｷｬﾊﾟｼﾀﾝｽ構成金属板面積	S_{sec}	mm^2	$((d_{fer}+d_{room}-d_{ground})/2)\cdot C_{sec}/(2\cdot\varepsilon_0)$	188508	126828	126519
	正方形金属板の場合の１辺	a_{sec}	mm	SQRT(S_{sec})	434.175	356.129	355.695
PFN	運転電圧	V_{PFN}	kV	入力	40.0	44.0	44.0
	最大ケーブル電圧	V_{max}	kV	入力	60.0	60.0	60.0
	インピーダンス	Z_{PFN}	Ω	入力	5.0	5.0	5.0
	使用ｹｰﾌﾞﾙｲﾝﾋﾟｰﾀﾞﾝｽ	$Z_{PFNcable}$	Ω	入力	20.0	20.0	20.0
	ｹｰﾌﾞﾙ並列本数	N_{cable}	本	$Z_{PFN}/Z_{PFNcable}$	4.0	4.0	4.0
伝送線	運転電圧	V_{tmc}	kV	$V_{PFN}/2$	20.0	22.0	22.0
	インピーダンス	Z_{tm}	Ω	入力	5.0	5.0	5.0
	使用ｹｰﾌﾞﾙｲﾝﾋﾟｰﾀﾞﾝｽ	$Z_{tmcable}$	Ω	入力	20.0	20.0	20.0
	ｹｰﾌﾞﾙ並列本数	N_{tm}	本	$Z_{tm}/Z_{tmcable}$	4.0	4.0	4.0
	(ｹｰﾌﾞﾙ1本当たり)運転電流	I_{tm}	kA	$V_{tmc}/Z_{tmcable}$	1.0	1.1	1.1
キッカー	通過電流	I_{kicker}	kA	$V_{tmc}/Z*2$	8.0	8.8	8.8
	ﾌｪﾗｲﾄ部でのｷﾞｬｯﾌﾟ内磁場	B_f	kG	$\mu_0\cdot I_{kicker}/h$	1.00531	1.00531	1.00531
	ﾌｪﾗｲﾄ以外でのｷﾞｬｯﾌﾟ内磁場	$B_{non\text{-}fer}$	kG	$B_f*L_{non\text{-}fer}/L_{fer}$	0.07588	0.09269	0.06330
	ｷﾞｬｯﾌﾟ内平均磁場	B_m	kG	$(B_f\cdot d_{fer}+B_{non\text{-}fer}\cdot(d_{metal}+d_{room}))/d_{sec}$	0.84367	0.82279	0.86793
	磁場充填率	α_B	%	B_m/B_f	83.9	81.8	86.3
	BL積（充填率考慮）	$(B*d)_{av}$	T･m	B_m*d	0.213448	0.207754	0.210387
	50GeV陽子蹴り角	$(\theta)_{50GeV}$	mr	$(B*d)_{av}/(B\rho)_{50GeV}$ $((Br)_{50GeV}=169.8829)$	1.256444	1.222922	1.238424
全体磁場	入力電流立上り時間	$\tau_{current}$	nsec	入力	400.000	400.000	400.000
	電流往復時間	τ_{round}	nsec	$2*N_{sec}*\tau_0$	564.921	504.084	502.855
	ｷﾞｬｯﾌﾟ内全体立上り時間	τ_{total}	nsec	$\tau_{current}+\tau_{1\text{-}99\%}+\tau_{round}$	976.733	915.563	914.306

FNAL case

- studied by David Neuffer, WG4 talk yesterday

- 8GeV Linac can produce streams of 1.5×10^{14} 8GeV protons at 10Hz
  - **$> 10^{22}$ protons/year**
- Only 1/15 of these needed for Main Injector
- Are there muon beam experiments that could use this intensity ??
- Tertiary muon beams:
  - $P + X \rightarrow \pi$
  - $\pi \rightarrow \mu + \nu$
- 10^{-2} $\mu/p \rightarrow$ **10^{20} μ/year or more**





Recycler as accumulator ring ?

- 8GeV Linac produces 1ms pulses at **10 Hz**
- H^- injection into Recycler
  - 1ms fills circumference
    - (100 turns)
- Bunch beam into pattern required for expt.
- Harmonic 10 buncher for MECO, slow extraction
- Harmonic 100 buncher for PRIME, single bunch extraction

Circumference	$C=2\pi R_{ave}$	3320m
Momentum	P	8.89 GeV/c
Rev. frequency, Period	f_0 T_0	89.8 kHz 11 μs
Slip factor	$\eta=1/\gamma^2-1/\gamma_t^2$	0.0085
Tunes	ν_x, ν_y	25.4,24.4

But:

Recycler circumference is large

100ms may be too short a time for bunching

Space Charge Difficulty

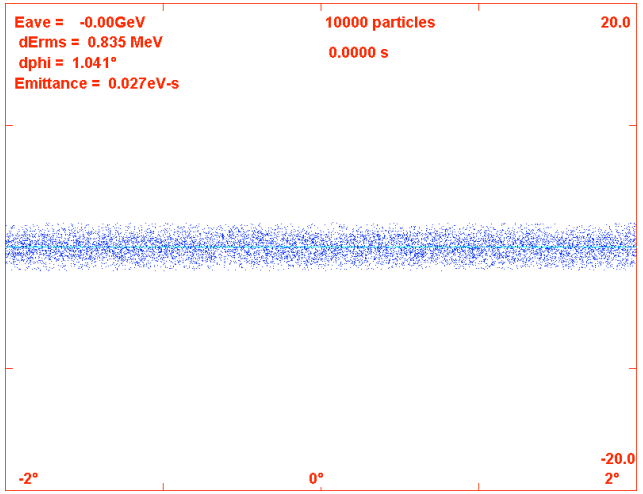
- Space Charge tune shift: $\delta\nu = \frac{3 r_p N_{tot}}{\beta\gamma^2 B_F \varepsilon_N}$
- Parameters: N_{tot}=1.5×10^{14},ϵ_N =20π mm-mrad $\quad \delta\nu = \frac{0.12}{B_F}$
- **MECO: 30ns/1μs** : B_F= 0.03 →δν = 4 : too large
  - Reduce N to 1.5×10^{13} →δν = 0.4
  - **Reduce N to 0.4×10^{13} →δν = 0.1**
- **PRISM/PRIME 10ns** bunches, 100/ring
  - B_F= 0.1 →δν =1.2: too large (but closer)
  - Larger ϵ_N, smaller N_{tot},
- Smaller circumference ring would be better

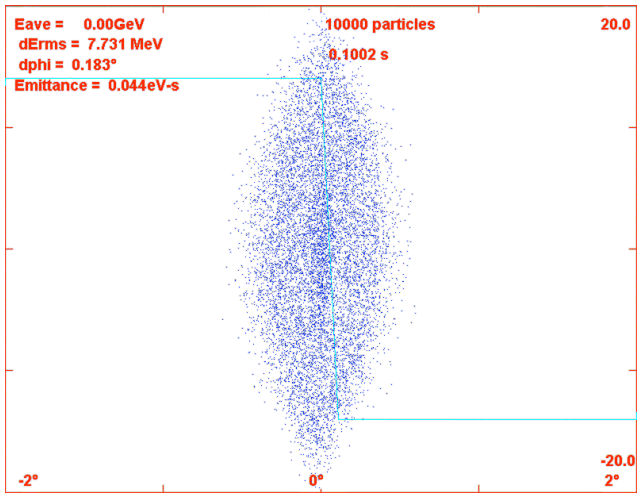
Recycler – Bunching (~for PRISM)

- Harmonic 100 buncher (9MHz)
- Bunch for 0.1s
  - (V_{rf} ramps to 140kV)
- Bunch lengths reduced to ~5ns rms

(Prism wants < 10ns full width.)

- Could then extract bunches one at a time over ~0.1s
- Uses 1/2 the possible linac pulses (500 bunches/s for PRISM) (100 at 5Hz)





Neuffer's Summary

- Muon Beams from the Proton Driver could be very useful
- Potential muon beam facilities could be developed:

- MECO, PRISM … could be hosted
- More Detailed design needed
  - Proton Collection
    - Recycler, Accumulator, Debuncher, …
    - New Stretcher/Buncher ring ??
  - Beam line(s)
  - Experimental area(s)

Summary

- high power proton beam ~1MW- a few MW
- pulsed proton beam width ~10ns
- single bunch fast extraction
- re-bunch in accumulator ring would be necessary
- kicker design
- These item should be studied for all candidates of NuFact's proton driver.