WG3 Summary

Proton Driver

Muon Acceleration

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Proton Drivers

3 WG talks + 1 Plenary talk

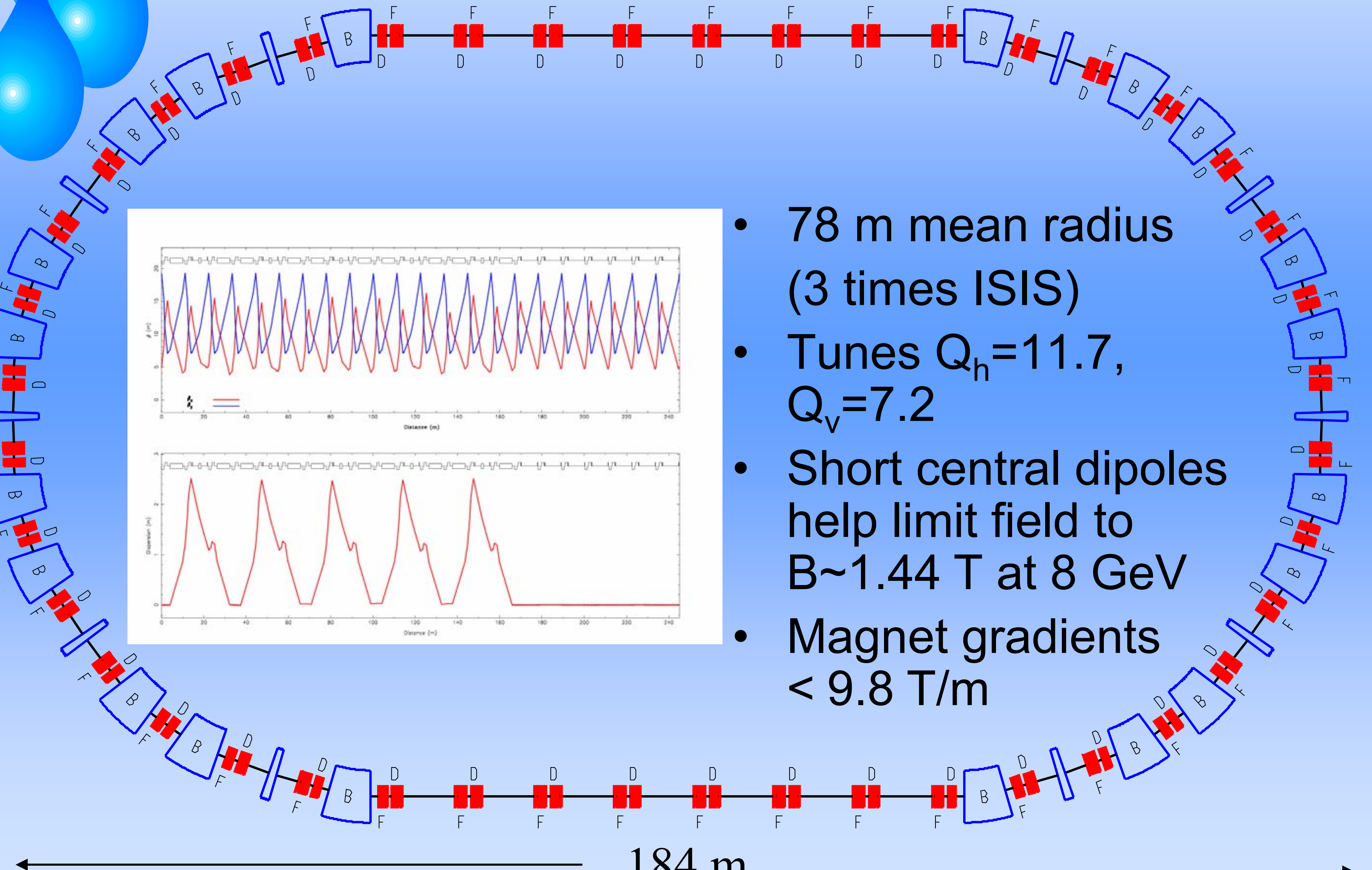
- on-going project
  - J-Parc (Mori)
- Hi intensity proton synchrotrons
  - AGS upgrade with 1.2 GeV SCL (Ruggiero)
  - ISIS upgrade with new synchrotrons (Prior)
- New scheme
  - FFAG (Nakano)

Proton Drivers - energy and power

	design goal	future upgrade
J-Parc	1MW (50GeV)	4MW (50GeV)
AGS upgrade		
with 1.2 GeV SCL	1MW (28GeV)	
ISIS upgrade		
with new synchrotrons	1MW (8GeV)	5MW (6GeV)
FFAG	?MW	

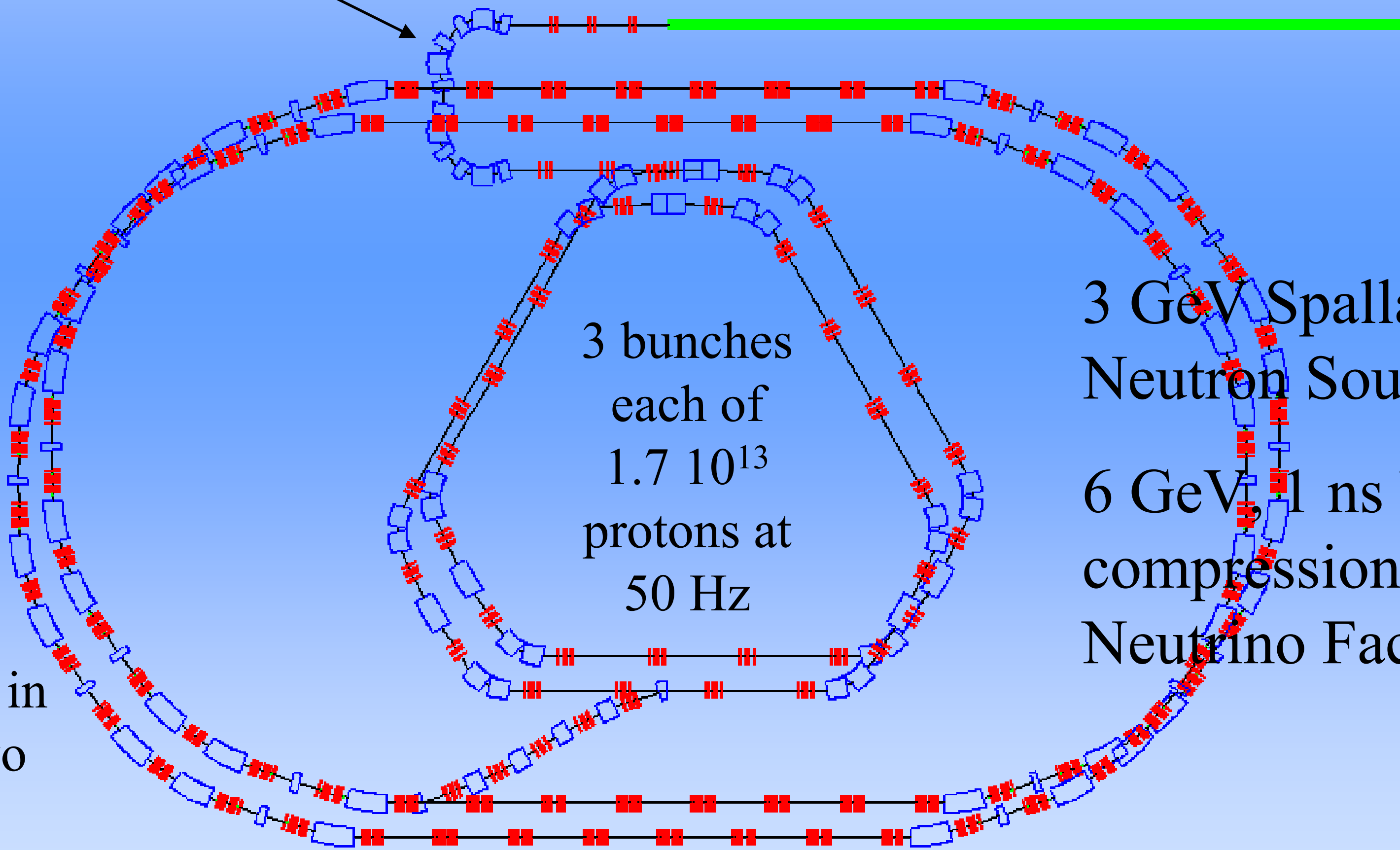
- We know the way to make 1MW facility although it is a big challenge.
- Future upgrade to a few MW is still a big jump.

Phase I: New Synchrotron



- 78 m mean radius (3 times ISIS)
- Tunes Q_h=11.7, Q_v=7.2
- Short central dipoles help limit field to B~1.44 T at 8 GeV
- Magnet gradients < 9.8 T/m

ISIS2 – a 5 MW Proton Driver



Proton Drivers - repetition rate

	design goal	future upgrade
J-Parc	1/3Hz (50GeV)	1Hz (50GeV)
AGS upgrade		
with 1.2 GeV SCL	2.5Hz (28GeV)	
ISIS upgrade		
with new synchrotrons	16.7Hz (8GeV)	25Hz (6GeV)
FFAG	1000Hz	

- Only way to increase average beam current is increasing repetition rate.
- In other words, number of particle per cycle is saturated.
- FFAG with 1000Hz repetition has potential compared with conventional synchrotrons.
  cf. VRCS (4600Hz) by Summers works only for very low duty.

Muon Acceleration (RLA)

3 WG talks

- 200MHz SC cavity development (Geng)
- Optics optimization (Bogacz)
- European scheme (Meot)

Initial beam emittance after cooling at 250 MeV/c

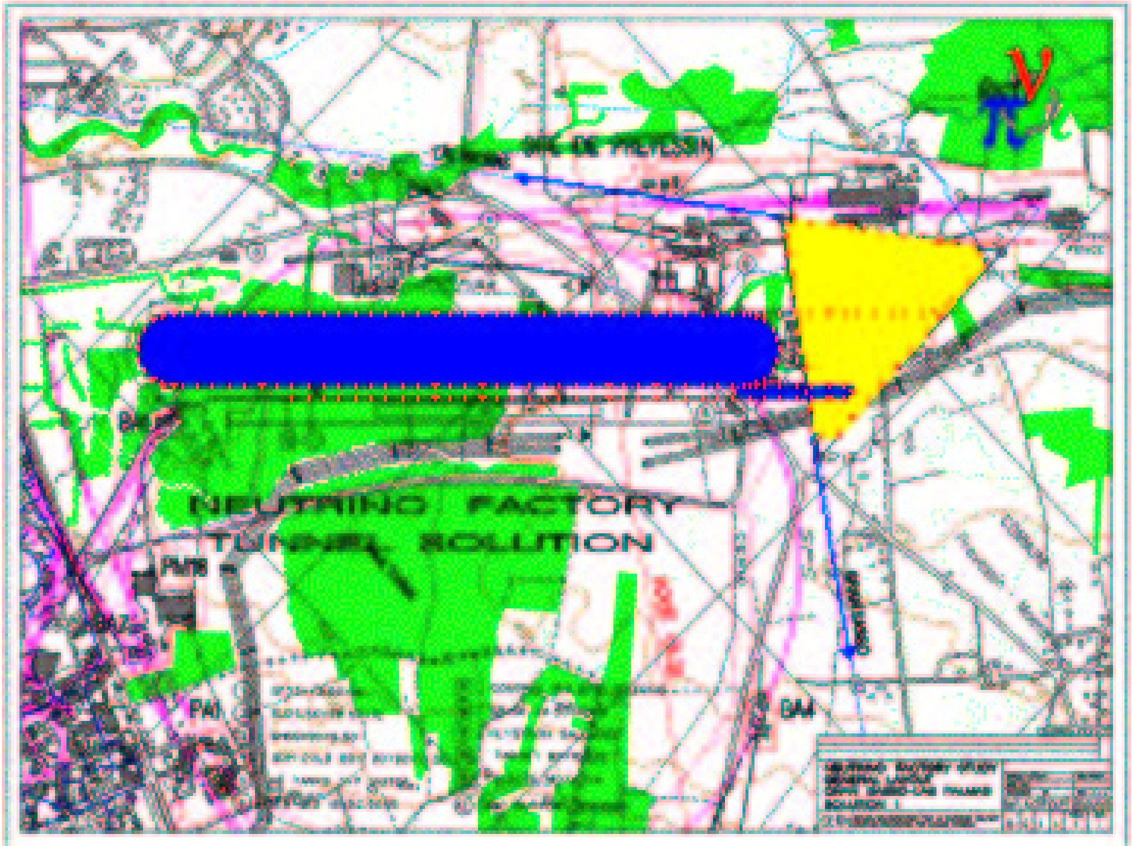
rms values		Cooling Channel*	Ring Cooler♣
normalized emittance: ε_x, ε_y	mm·rad	2.4	2.0
longitudinal emittance: ε_l ($\varepsilon_l = \sigma_{\Delta p}\, \sigma_z / m_\mu c$) momentum spread: $\sigma_{\Delta p/p}$ bunch length: σ_z	mm mm	27 0.08 163	3 0.025 50

*Study II

♣Palmer/Kirk/Balbekov

Present reference scheme in Europe : CERN design

- Pre-acceleration 0.3⟶ 3 GeV,
- followed by RLA1 that takes the beam from 3 to 11 GeV, drawn from US StudyI design,
- followed by RLA2 that takes the beam from 11 to 50 GeV ; assumes LEP cavity frequency, optics derived from former ELFE hadronic probe design,
- followed by 50 GeV triangle muSR.
- Transverse acceptance : 1.5 π cm
- CDR : CERN NuFact Note 122.



		Pre-acc.	**RLA1**	**RLA2**
kinetic energy	GeV	$0.3 \rightarrow 3$	$3 \rightarrow 11$	$11 \rightarrow 50$
number of pass		1	4	4
acceptance	πcm/πeV.s	3/0.1	1.5/0.1	1.5
linac length	m	450	2×350	2×1900
RF	MHz	88/220	220	352
	MV/m	4/10	4	4

Muon Acceleration (RLA) - summary

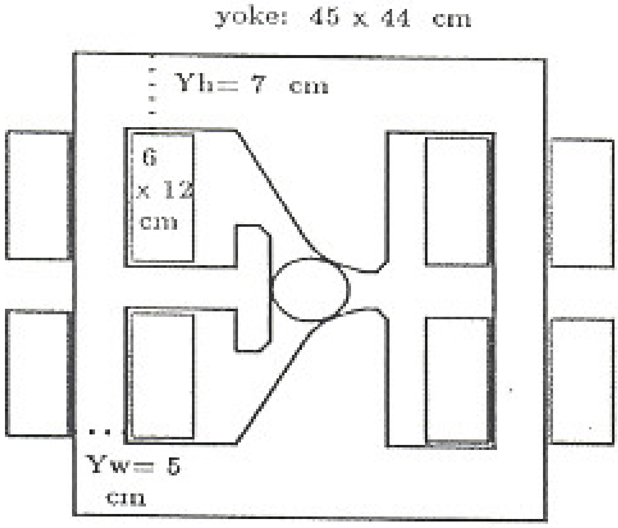
- SC cavity is ready (11MV/m is achieved.)
  - Some problems still remains such as Q-slope.
- Optimization can be done with ring cooler upstream.
  - Further optimization can be done.
    - Transverse as well as longitudinal acceptance.

Muon Acceleration (VRCS)

1 WG talks

VRCS (Summers)

COMBINED FUNCTION MAGNETS

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4    --> 20 GeV
19%  --> 95% B Field
11   --> 72 degrees
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61 degrees in 37 uSEC --> 4600 Hz

18 26.5 meter magnets
gradient changes inside the magnet
number of ends are minimized
100 kJoule stored in each

$$B = \frac{\mu_0 N I}{h} \to I = \frac{B h}{\mu_0 N} = 52\,\text{kA}; \qquad W = .5\, L\, I^2 \to L = 2W/I^2 = 80\,\mu\text{H}$$

$$f = \frac{1}{2\pi}\sqrt{\frac{1}{LC}} \to C = \frac{1}{L\,(2\pi f)^2} = 15\,\mu\text{F}; \; W = .5\, C\, V^2 \to V = \sqrt{2W/C} = 120\,\text{kV}$$

120 kV is big
center tap the SCR stacks --> +-60 kV

Bring coils out side slots;
leaving pole faces continuous

Muon Acceleration (VRCS) - summary

- Rapid cycling synchrotron is an option.
- Power consumption is low due to low duty factor.

- Effects of eddy current on a beam is an issue.

Muon Acceleration (FFAG)

5 WG talks

- non-scaling
  - longitudinal dynamics of non-scaling FFAG (Johnstone)
- scaling
  - lattice update and tracking (Machida and Yokoi)
  - super and normal conducting magnets (Yoshimoto and Ogitsu)
  - PRISM for phase rotator of muons (Sato)
- both
  - comparison and cost optimization (Palmer)

- FFAG has become an option since it was first proposed in 2000.

Muon Acceleration (FFAG) - scaling or nonscaling?

definition

scaling: Orbit, lattice functions scale with momentum.

Transverse tune is independent of momentum.

Lattice elements have nonlinearity.

cf. chromaticity correction sextupole in synchrotrons

nonscaling: Extreme of synchrotrons with small dispersion.

Transverse tune decreases with momentum.

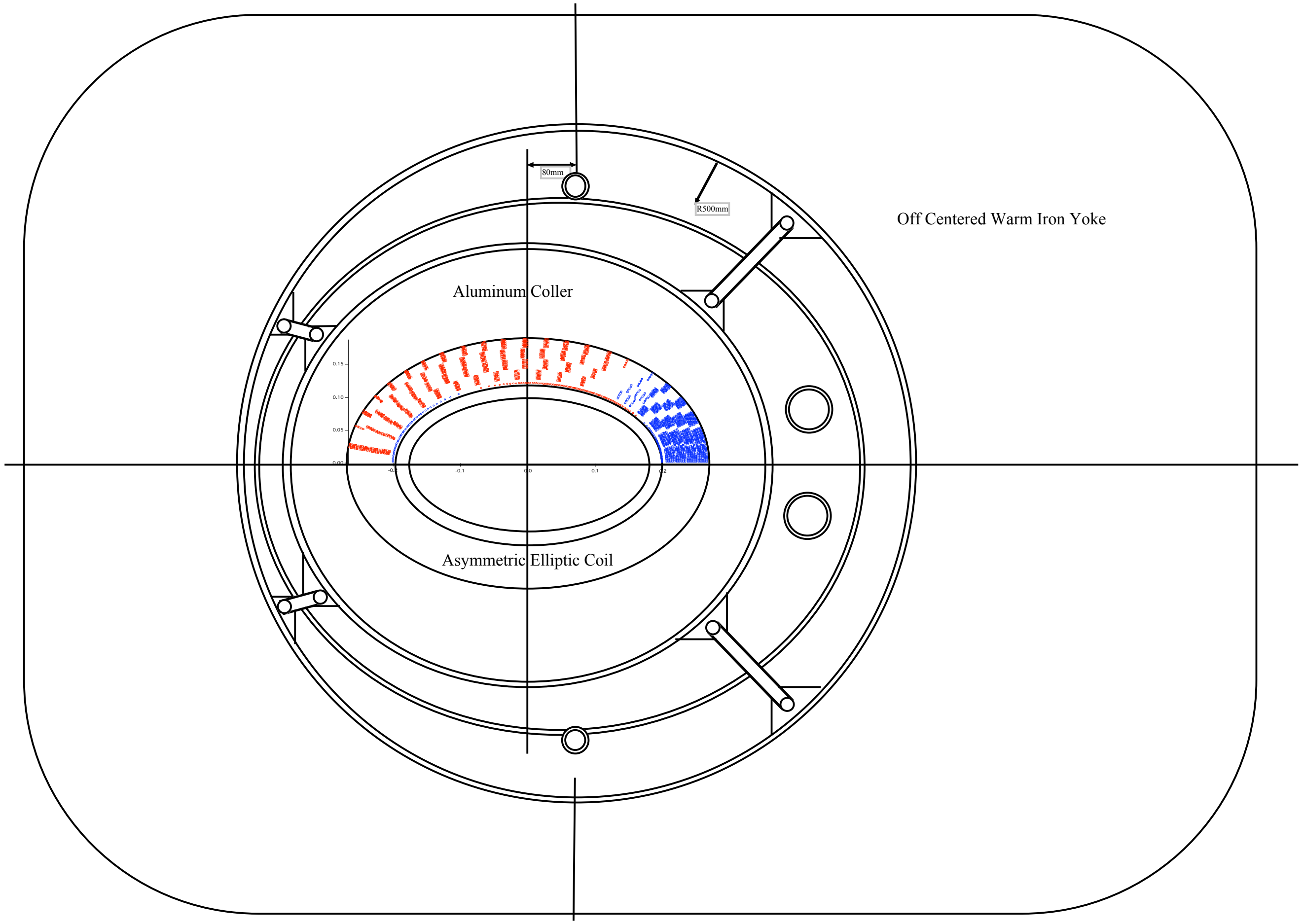
Lattice consists of linear elements (B and Q).

Muon Acceleration (FFAG) - scaling or nonscaling?

- SC magnet cost is cheaper in nonscaling (palmer).
  Need further study when more detailed design is made for both scaling and nonscaling.
- Technically, not much difference.
  Design study of scaling magnet is going on.

Reference Design 1a

- B_0=6.0T, r_0=120m, k=450, beam excursion 0.18m



1. Main Coil
   - Asymmetric & Elliptic
   - Rutherford Cable~ 2X15mm
   - Operation Current ~6.8kA
   - Stored Energy: ~1MJ/m
2. Corrector Coil
   - Wind & glue (BNL)
   - ~10A/delta-K
3. Collar
   - Pre-stress ~90MPa
   - Horizontal EMF ~ 3.9 MN
   - Aluminum collar to gain pre-stress during cool down
4. Iron Yoke
   - Off centered yoke for EMF balance
   - Warm Iron

Muon Acceleration (FFAG) - low or high frequency?

Low frequency: Moderate field gradient (1MV/m).
So far, it is for scaling.

High frequency: Higher gradient is preferable because of beam loading and cost.
So far, it is for nonscaling.

- Other combination (ex. high frequency with scaling) is possible.
- In cost wise, not much difference.

Muon Acceleration (FFAG) - with or without cooling?

Cost reduction due to smaller acceptance (15pi instead of 30pi) with cooling system.

vs.

Cost of the cooling system.

- Large acceptance magnet for non-cooled beams is cheaper (Palmer).
- Cooling system can be future option to obtain more muons.
- Choice of muon energy (0.2-0.3GeV/c is optimum?) without cooling muon yield, Neuffer's bunching scheme.

Muon Acceleration (FFAG) - kicker?

- Kicker for FFAG is easier than ring-cooler because of
  - help due to main lattice magnets
  - smaller aperture
  - larger circumference and longer rise time

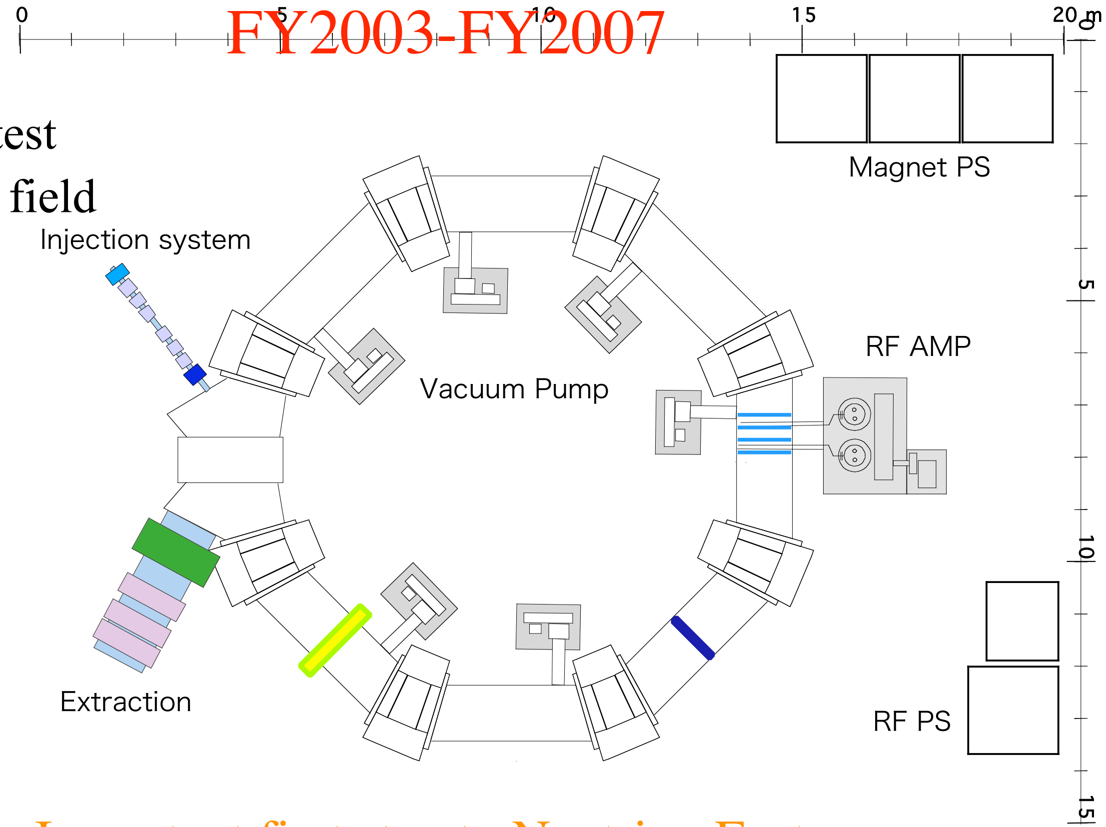
Muon Acceleration (FFAG) - staging?

- PRISM will be first muon accelerator.

Schedule of the PRISM-FFAG construction

- FY2003
  - Lattice design, Magnet design
  - RF R&D
- FY2004
  - RFx1gap construction & test
  - Magnetx1 construction & field meas.
- FY2005
  - RFx4gap tuning
  - Magnetx7 construction
  - FFAG-ring construction
- FY2006
  - Commissioning
  - Phase rotation
- FY2007
  - Muon acceleration
  - (Ionization cooling)

A budget for the PRISM-FFAG has been approved ! FY2003-FY2007



Important first step to Neutrino Factory

Summary

- MW proton driver will be ready.
  FFAG as a proton driver not only for muon acceleration.
- RLA becomes more realistic with ring-cooler.
  Hardware development supports the scheme.
- We should keep eyes on VRCS.
- More study will come on FFAG as a muon acceleration.