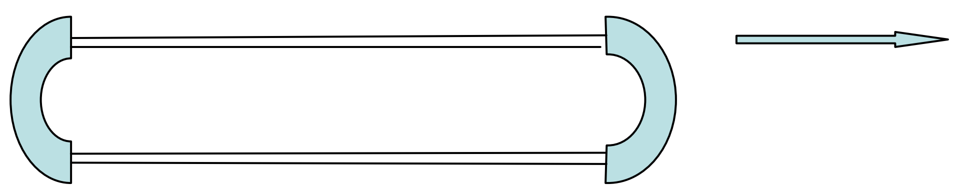
Storage Ring: Status, Issues and Plans

C Johnstone, FNAL and G H Rees, RAL

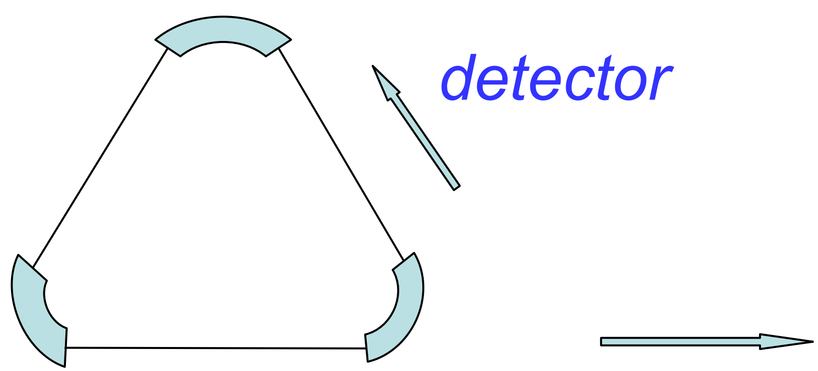
Current Storage Ring Designs

Ring(s)	T(GeV)	Beam	Detcs	P.dr(Hz,N,MW)	Circ(m)	Eff(%)
US2a(2)	20	μ^+, μ^-	1	3, 5, 1	358.2	35 (31)
J-Parc(1)	20	μ^+	1	0.66, 8, 4	820.0	35 (?)
Keil (1T)	50	μ^+	2	50, 140, 4	2074.8	2x28 (?)

Racetrack



Triangle



Features of Designs

1. *Tilting of the rings relative to the horizontal plane.*
2. *Very different proton drivers (24, 50 and 2.2 GeV).*
3. *Muon injection fillings in each storage cycle (n= 1).*
4. *Merging of the μ^+ and μ^- beams in one of designs.*
5. *Long straights reduced if weak dipoles are added.*
6. *RF systems needed to retain bunch structures.*
7. *High reactive beam loading of the RF cavities.*
8. *Muon beam powers large (≈ 0.25 and 1.25 MW).*

Muon Storage Ring Issues

1. Design for 20 or for 50 GeV rings, or for both?
2. Design Triangle & 2 detectors, or Racetrack &1?
3. Possibility of an Isosceles Triangle design?
4. Merging of μ^+ and μ^- beams in straights or not?
5. Cooling of warm bore of S/C magnets & straights.
6. S/C magnet shielding, and the effects of e^+ & e^-.
7. Protection from muon beam loss on the walls.
8. Influence of n and length of the muon bunch train.
9. Designs for lattice, RF, injection, diagnostics, etc.
10. Optimisation of the ring designs.

Beam Power Levels

Proton driver (50 Hz?):	4 MW	(with potential of 8 MW)
8-20 GeV Muon ring:	≈ 1 MW	(combined μ^+ and μ^-)
20 GeV Storage rings:	≈ 0.5 MW	(separate μ^+ and μ^-)
20-50 GeV Muon ring:	≈ 2.5 MW	(combined μ^+ and μ^-)
50 GeV Storage rings:	≈ 1.25 MW	(separate μ^+ and μ^-)

Peak beam loading at the fundamental ring RF frequency:
8-20 GeV,16-turn, ring: ≈ 50 MW (50 Hz, n = 5, C = 900 m)
(1 bunch train at a time) ≈ 1000 MW (25 Hz, n = 1, C = 450 m)

Storage rings: n (μ^+ or μ^-) bunch trains injected per cycle.
Reactive loading of cavities (402 MHz?) scales as 1/(2CF).

Effect of Length of Muon Bunch Train

CERN design: proton and muon bunch number = 140
length of muon bunch train ≈ 900 m
US bunch rotation scheme: muon bunch number = 90
length of n bunch trains ≈ n x 180 m
Here, n is the number of bunches in the proton driver;
length for five bunch trains ≈ 900 m

A 4 MW driver with 1 ns rms bunches needs n > ≈ 4
So, minimum length for muon storage rings ≈ 900 m
(short length of US2a is for a 20 GeV, 1 MW driver)

Storage Ring Filling

Repetition rate is that of the muon rings (50 Hz?)

The number of muon fillings per pulse = n (> 4?)

Interval between each of the "n" fillings ≈ 50 μs

(holding time in the proton driver (target shock) & acceleration time in 16 turn, 8-20 GeV, muon ring)

Injection of μ^+ and μ^- beams into separate rings (to prevent extension of the bunch train length)

Rise and fall time for injection kickers ≈ 150 ns

Multiple (x n) pulsing of kickers at ≈ 50 μs intervals

Lattice Design for the Arcs

Allow 0.4 m for the ends of the S/C magnet cryostats.
Allow 1.4 m (0.4+0.6+0.4 m) in between arc magnets.
Minimize arc length by using combined function units.
Adopt a FODO type for the lattice cell (BF O BD O).
Choose 6 T fields for the central orbits (≈ 5 to 7 T).

Circumference of 50 GeV rings of similar efficiencies:
Racetrack ≈ 0.9 km, Δ ≈ 1.5 km, Isosceles Δ ≈ 1 km.

cf 0.36/0.8 km (20GeV, 1MW), 2.1 km (50GeV, 4MW)

Lattice Design for the Straights

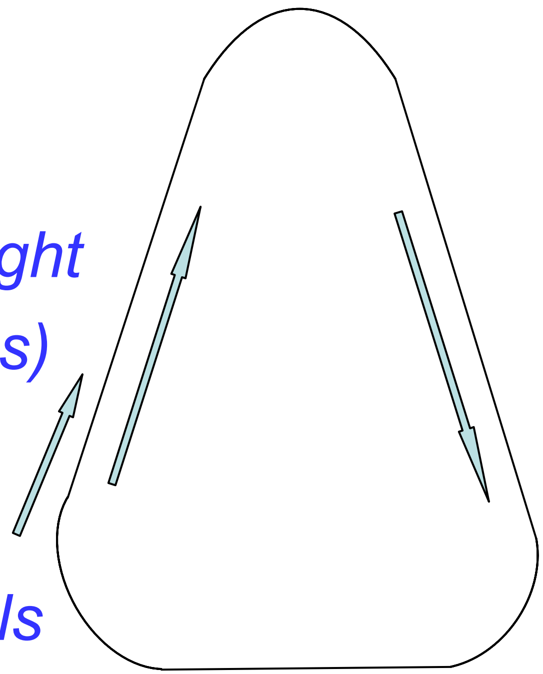
Use weak dipoles (1.8°) at ends of production region.
Match with the (1.8°) dipoles to have zero dispersion
and a reduced variation of β in the production region.
Length of the production region(s) is ≈ 230 to 360 m.

RF, loss protection & cooling easier if separate rings.
Best to inject the μ^+ and μ^- beams into separate rings.
Circumference larger & efficiency less if rings merge.
So, avoid merging the rings at the straight sections?

Possibility of Isosceles Triangle Design

(97 x 1.6)° arc of 16, μ =72° cells,
(ξ correction over groups of 5 cells)

Production straight
(1.8° end dipoles)



Production straight
(1.8° end dipoles)

Injection

97° arc of 10 cells

97° arc of 10 cells

Straight for loss protection, RF,
Q-control and 1.8° end dipoles

Beam Loss Protection

Losses are from $\mu^{\pm}$ decay, $\mu^{\pm}$ and $e^{\pm}$ interception and synchrotron radiation on outer wall of magnet bores. About ⅓ of the $\mu^{\pm}$ beam power appears in $e^{\pm}$ beams. Power loss in the arcs will be approximately uniform, but the density may be high in regions of the straights.

Effect of high energy $e^{\pm}$ at inner walls of the magnets? Loss protection proposed at downstream end of non-production straight to limit $\mu^{\pm}$ interceptions in the arcs. Primary and secondary collectors over three cells , to contain direct $\mu^{\pm}$ losses (up to approx ½ % level).

Cooling and Shielding

Cooling is needed for average power losses of:

≈ 420 kW per ring for the 50 GeV μ^+ & μ^- rings,

≈ 170 kW per ring for the 20 GeV μ^+ & μ^- rings.

Average loss in 0.9km racetrack: 467,189 W/m.

Design for 5 x these levels after weak dipoles.

Design for 2 kW/m for the beam loss collectors.

Shielding is needed for S/C magnets in the arcs

High density material, eg tungsten, is proposed.

Plans (prior to feedback from talk)

- *Liaise with proton driver & muon ring designs*
- *Liaise with detector group on ring orientations*
- *Design 20 and 20-50 GeV $\mu^{\pm}$ racetrack rings*
- *Design 20 and 20-50 GeV $\mu^{\pm}$ triangular rings*
- *Study possibility of an isosceles triangle ring*
- *Study $e^{\pm}$ effects, ring shielding and cooling*
- *Study injection, loss protection & tunnel safety*
- *Study chromaticity correction and RF issues*
- *Optimise and provide parameters for costing*