Superconducting Magnet Division

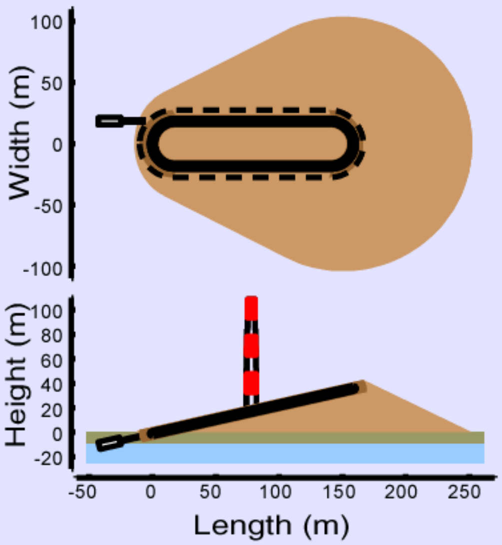
Muon Collaboration

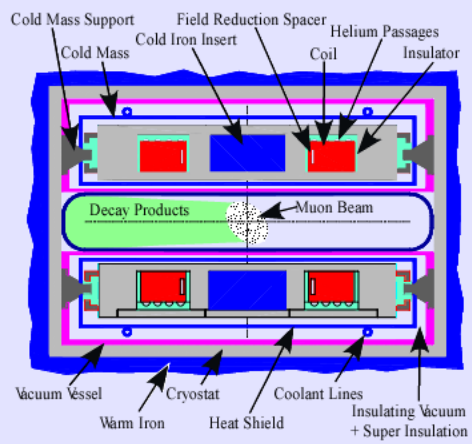
DOE Research and Development Review at BNL, 27–28 February 2002

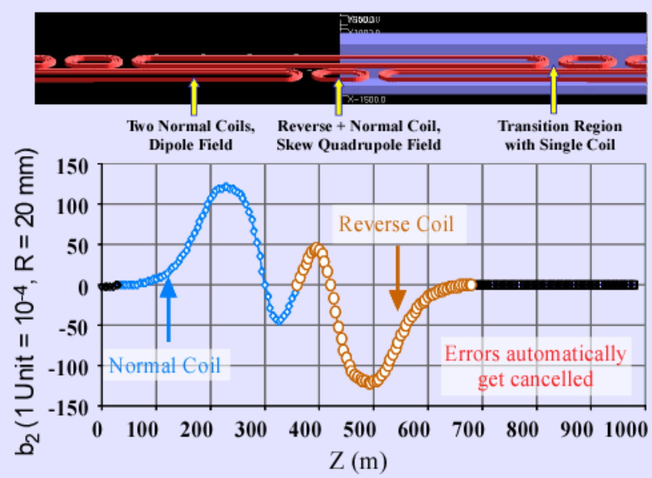
Neutrino Storage Ring Developments

presented by,

Brett Parker, BNL–SMD



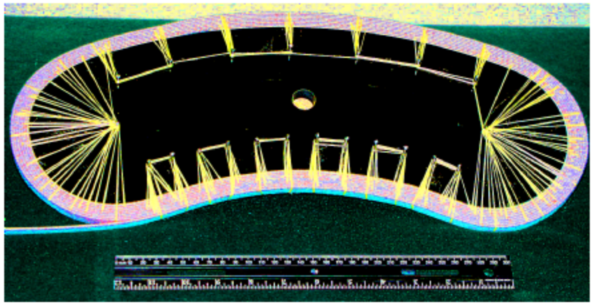




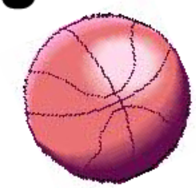
Some Muon Storage Ring Design Principles and Requirements.

Must keep the ring compact (*tilt* -> Δh).

- **For shortest arc use a large guide field.**
  - Go beyond NbTi, but then must work with brittle materials (Nb_3Sn or HTS).
  - The arc dipoles have significant sagitta.
  - Flat racetrack coils are conductor friendly.



- **"Minimize aperture" with short cell length.**
  - Poor muon ε means keeping β and dispersion low as possible.
  - But avoid wasting space with many dipole/quadrupole coil ends.



- **1/3 beam energy goes into decay electrons.**

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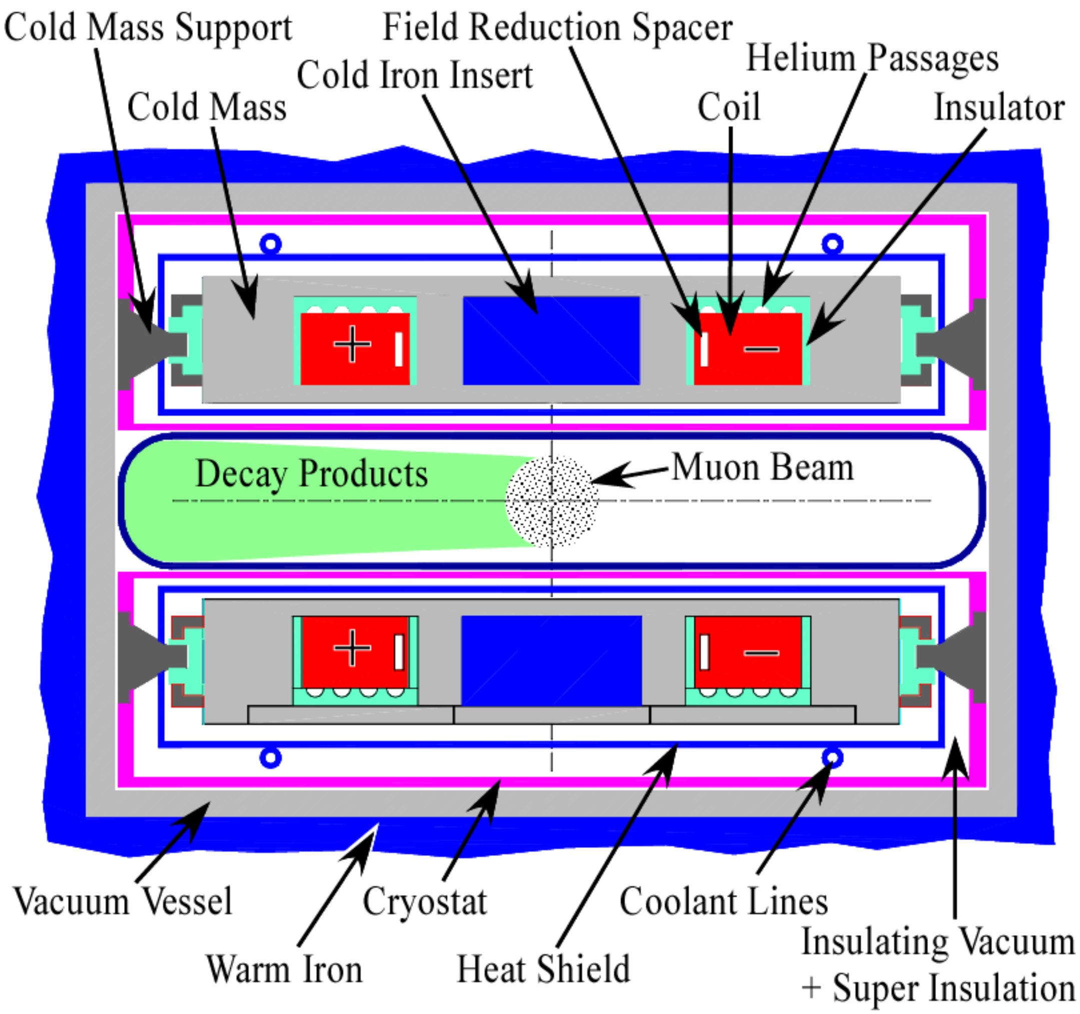
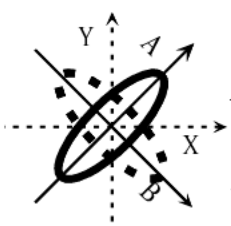
Muon Storage Ring Dipole Magnet Cross Section.

- Has simple racetrack coils and an open midplane.
- The large bend radius allows "react and wind."
- Warm iron yoke minimizes the cold mass.
- The decay products clear the superconducting coils.



Muon Storage Ring Quadrupole Magnet Cross Section (Skew).

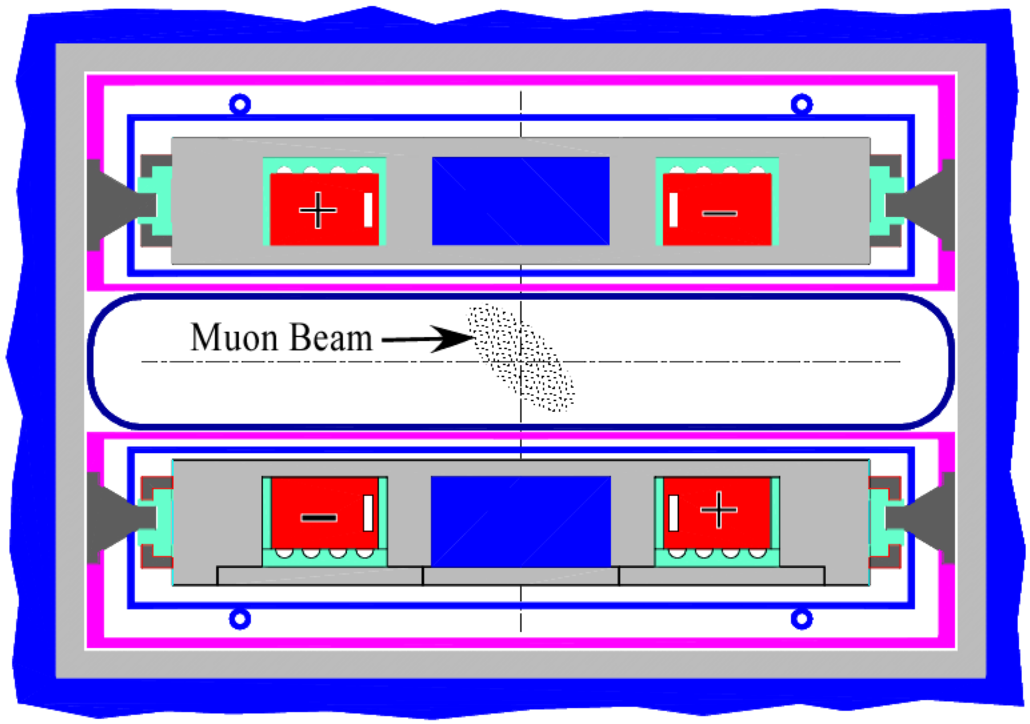
- The same construction as dipole.
- Do skew optics for decoupled motion in *A*–*B* eigenplanes.
- Follow standard prescription for dispersion matching and chromaticity correction.
- Can however get slightly more acceptance than from upright lattice, $\beta_{eff} = (\beta_A + \beta_B)/2$.



$$X = (A + B)/\sqrt{2} \qquad Y = (A - B)/\sqrt{2}$$

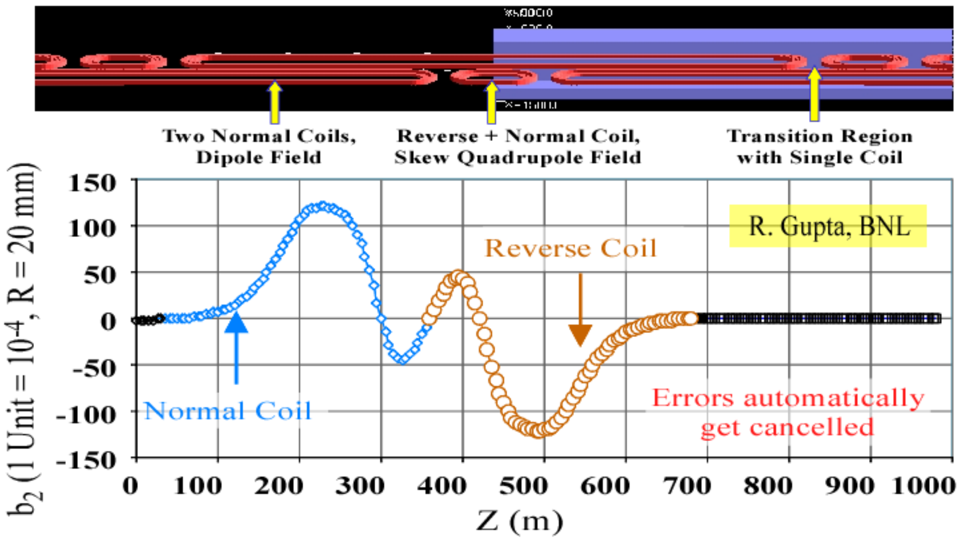
$$A = (X + Y)/\sqrt{2} \qquad B = (X - Y)/\sqrt{2}$$

Reverse polarity of one dipole coil to make a skew quadrupole.



Muon Storage Ring Magnet Coil Layout and Harmonic Cancelation.

- **Overlap coils for dipole or skew quad.**
- **No wasted space at coil ends (transition).**
- **Automatic cancelation of end harmonics.**



For estimated errors at right a 20 mm reference radius is used. $\langle b_n \rangle$ and $\langle a_n \rangle$ are the expected means to the normal and skew terms. $d(b_n)$ and $d(a_n)$ are systematic uncertainties arising from design and manufacturing errors, and $\sigma(b_n)$ and $\sigma(a_n)$ are the random uncertainties in those values. Note that n = 2 corresponds to a sextupole term.

Dipole Error Summary*

n	$\langle b_n \rangle$	$d(b_n)$	$\sigma(b_n)$	$\langle a_n \rangle$	$d(a_n)$	$\sigma(a_n)$
1	0	0.2	0.2	0	1	2
2	-1	1	2	0	0.1	0.5
3	0	0.1	0.1	0	0.3	1
4	-1	1	1	0	0.05	0.2
5	0	0.03	0.03	0	0.1	0.5
6	-0.3	0.2	0.1	0	0.03	0.1
7	0	0.03	0.01	0	0.03	0.1
8	-0.1	0.1	0.02	0	0.03	0.1
9	0	0.03	0.01	0	0.03	0.1
10	-0.03	0.02	0.02	0	0.03	0.1

Skew Quadrupole Error Summary*

n	$\langle b_n \rangle$	$d(b_n)$	$\sigma(b_n)$	$\langle a_n \rangle$	$d(a_n)$	$\sigma(a_n)$
1	0	0.2	0.2	0	1	2
2	-0.5	0.5	1	0	1	0.5
3	0	0.1	0.1	2	2	1
4	-0.5	0.5	0.5	0	0.05	0.2
5	0	0.03	0.03	1	1	2
6	0	0.2	0.1	0	0.03	0.1
7	0	0.03	0.01	0.5	0.5	0.3
8	0	0.1	0.05	0	0.03	0.1
9	0	0.03	0.01	0.1	0.03	0.1
10	0	0.02	0.01	0	0.03	0.1

*Errors given in units, 1 unit = 10^{-4} field deviation.

Muon Storage Ring Arc Optics and Magnet Design Parameters.

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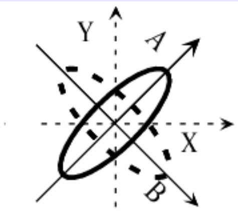
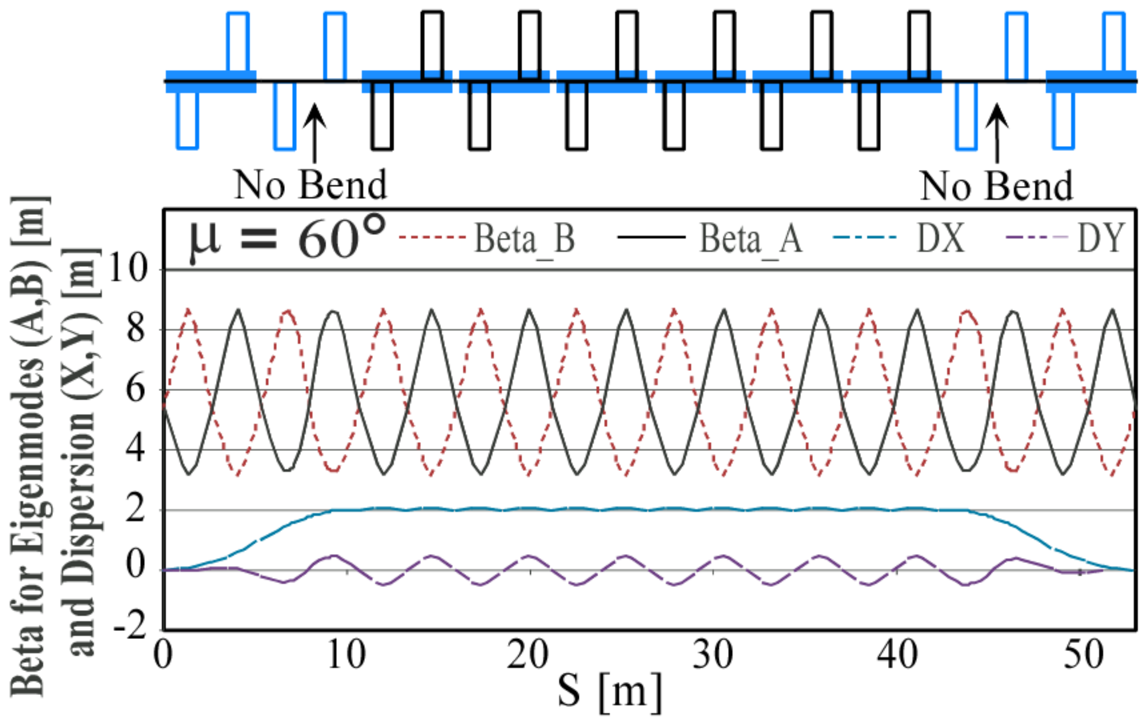
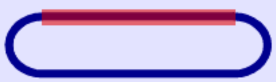
$B = 6.93$ T, $L_D = 1.89$ m
$G = 35$ T/m, $L_{SQ} = 0.76$ m
$L_{cell} = 5.3$ m
$L_{arc} = 10 \times L_{cell}$
$L_{straight} = 126$ m





$$\text{Decay Ratio} = \frac{126}{2(126+53)}$$



$= 35\%$

- The 163 m total length for ring is compatible with BNL site.
- Arcs are made up from three cryogenic sections (have conventional iron dominated quadrupoles elsewhere).
- Inject into up straight; ν down straight points at detector.
- There is no need for ultrahigh beam vacuum (insulating ok).

The Muon Storage Ring Model Magnet Test Program (LDRD).

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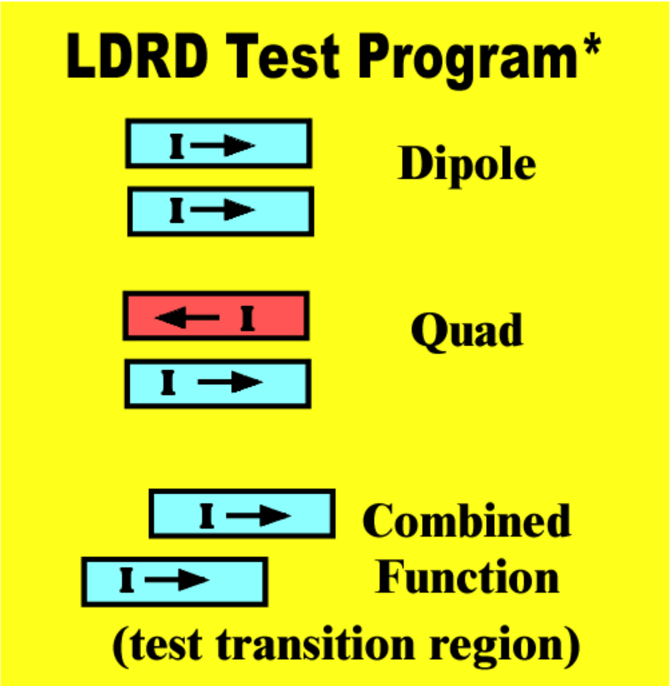
Want to test practical aspects for making a magnet:

- Make support structure to handle coil forces (heat leak).
- Work through coil winding, handling and the assembly into a coldmass.
- Test in many different configurations (dipole, skew quadrupole and skew combined function).
    - **Make Nb_3Sn coil of same size as the muon storage ring magnet small coil.**
    - **Design and construct cold mass side supports.**
    - **Estimate heat leak and verify coil performance in all configurations.**



*With two coil packs can change polarity and shift to test different magnet configurations.

Cut away view of storage ring arc lattice.