Summary of Mini-Workshop on Ring Magnets + Updates

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6/3/11

Mini Workshop at FNAL 5/19-20/11
Organizer: John Tompkins

- Cry efficiency
- Open mid-plane designs
- Tungsten liner option
- Conclusions

Cryogenic Efficiency

LBL-30824
SC-MAG-341

ESTIMATING THE COST OF SUPERCONDUCTING MAGNETS AND THE REFRIGERATORS NEEDED TO KEEP THEM COLD*

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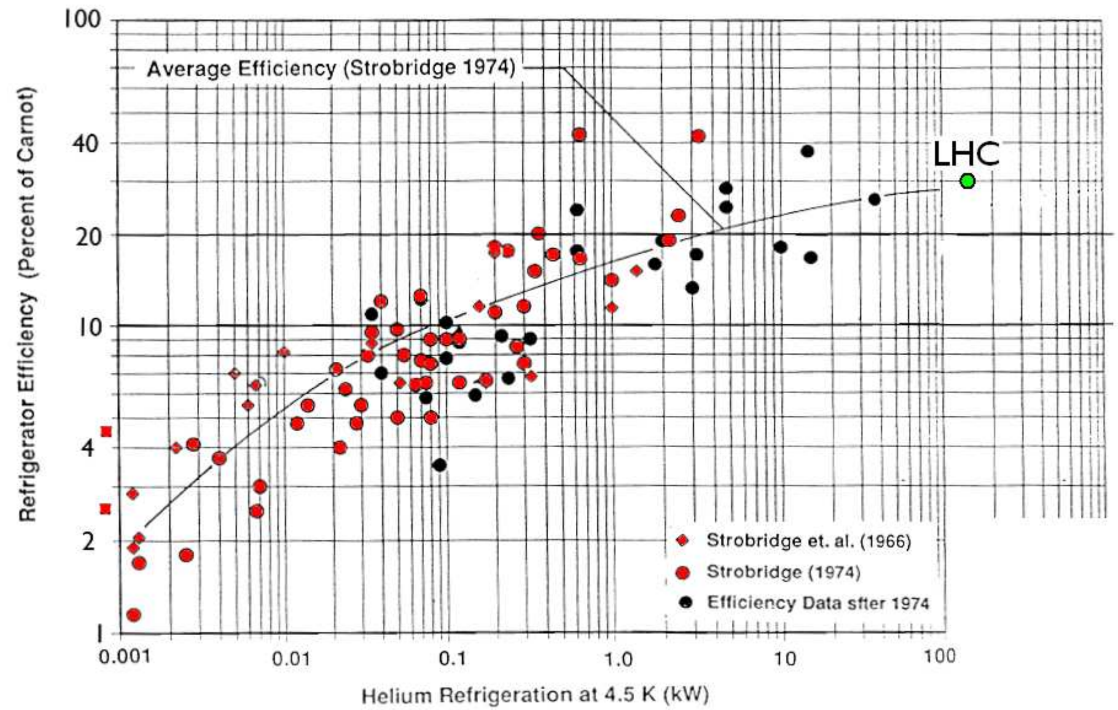


Figure 3. The Efficiency of Helium Refrigerators as a Function of 4.5 K Refrigeration

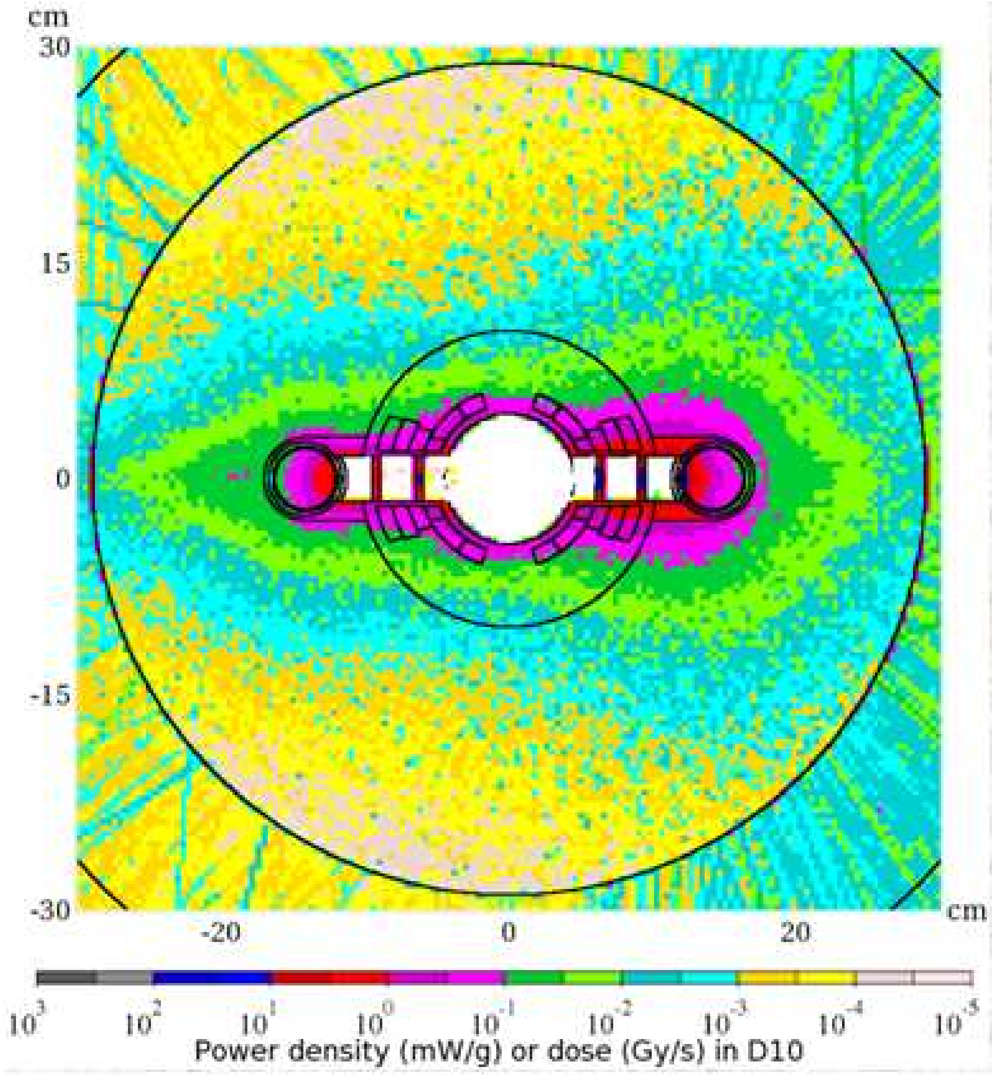
- LAC efficiency at 150 k at 4.5 beg =30% of Cannot (Shiltsev) is consistent
- LAC Distribution efficiency = 68% (Shiltsev)
- So assume efficiency 30 $\times$ 0.68 = 20 % of Cannot
- for 4 beg: $\boxed{\text{Efficiency} \approx 0.2 \times 4/300 \approx 1/375}$
- To keep Wall Power for 4 beg cryogenics below 10 MW: losses must be less than 10,000/375 = $\boxed{27\ \text{k}}$

Power to decay electrons and required attenuation

- Beam Power $= 2 N_\mu V e f \; = \; 4\ 10^{12} \times 750\ 10^{9} \times 1.6\ 10^{-19} \times 15 \; = \; 7.2$MW
- Beam power dissipated as electrons = 2.5 MW (as used by Mokhov)
- For loss at 4 degrees = 27 k
- Required shield attenuation = 27/2,500 = 0.0108 ≈ 1.0%
- Note that we are assuming the same attenuation for all regions despite the dipoles only representing only 67% of the ring

Option #1: Open Mid-Plane Dipole
Mokhov's Open Mid plane MARS15 simulation

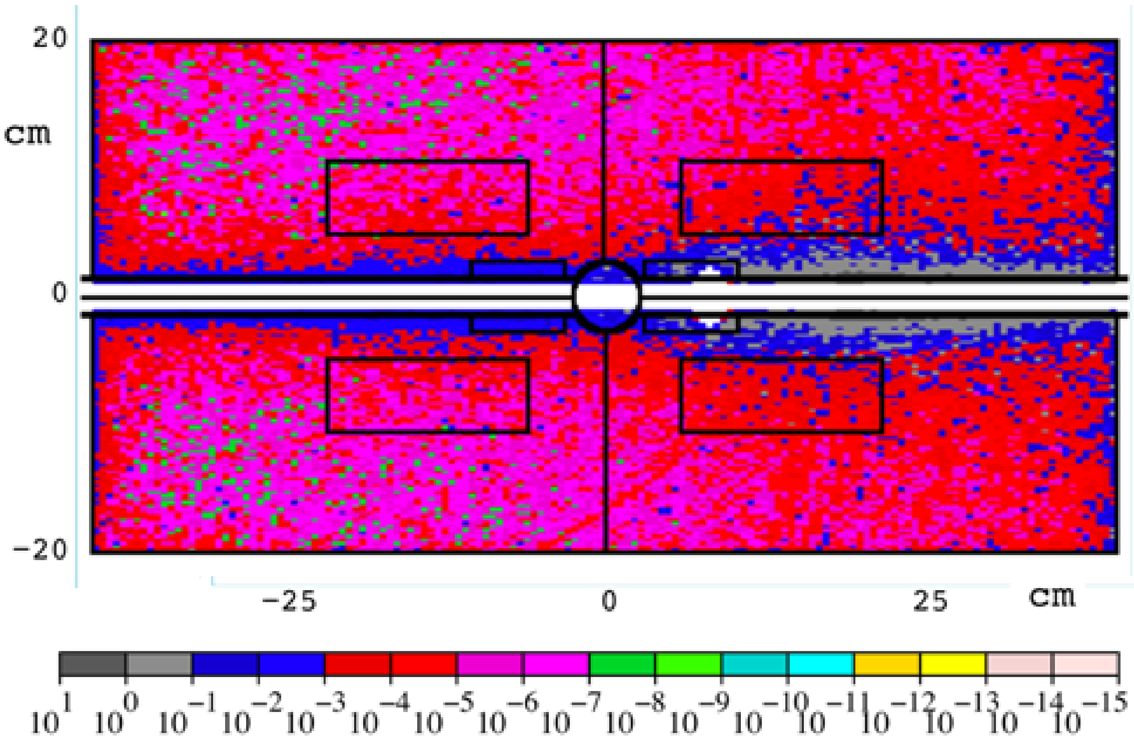
- Radiation on coils within quench limits
- Energy deposited in AlBe-Met bridge supports not apparently a problem
- But 45% of energy dumped in 4 degree coils and coil supports
- Distributions suggest upward and downward energy flows
- WHY ?



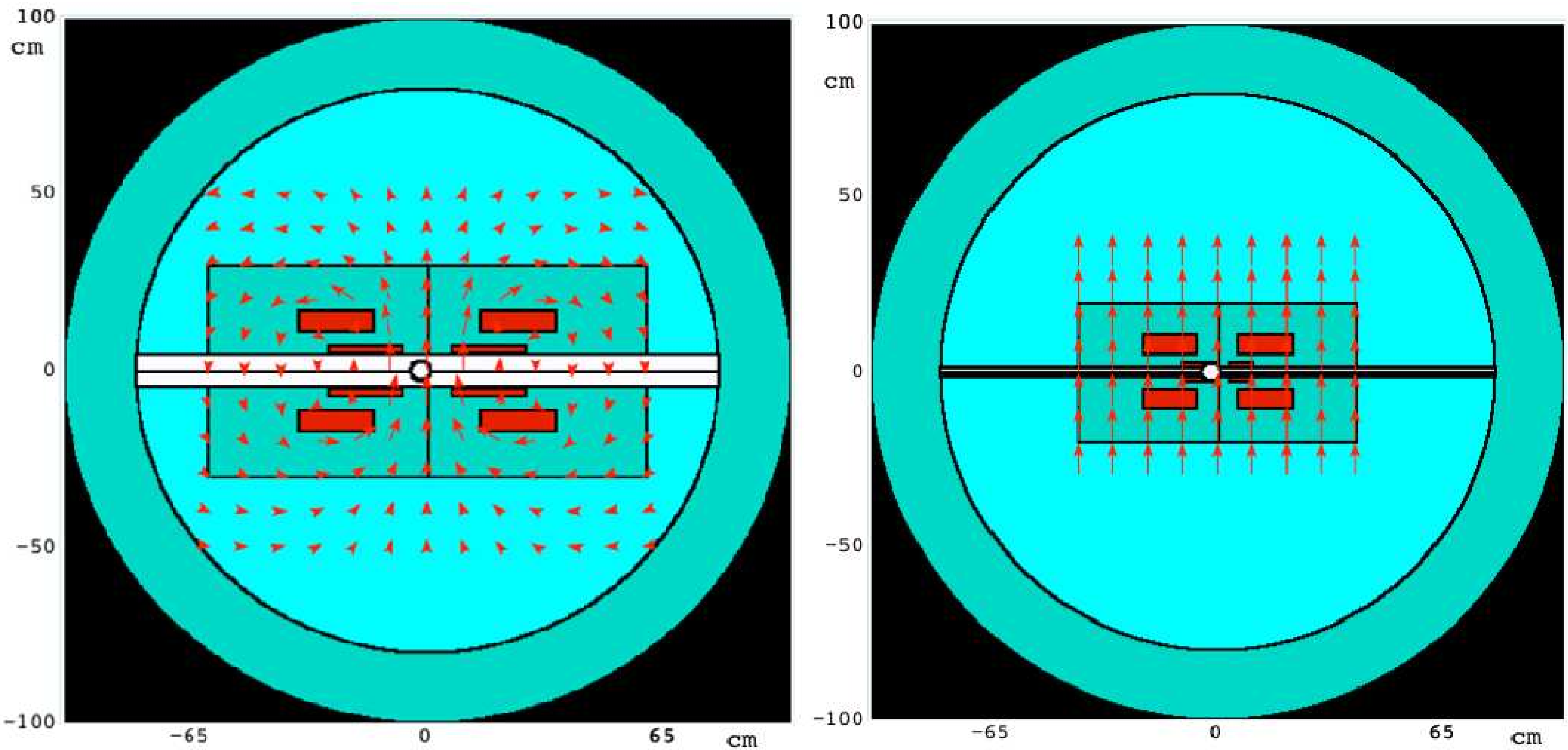
Is it backscatter from the Tungsten bars or scatter from AlBeMet ?

Ding

- Simulation of fully open mid-plane
- 3 cm full gap
- But with real fields from coils
- Circa 12.3 % of energy still dumped in coils
- So it is NOT backscatter from tungsten



New Ding studies



1. c.f. With real fields and full gap 3 cm: 12.3 % deposition in magnets
2. With real fields and full gap 10 cm: negligible deposition
3. With uniform field and full gap 3 cm: 0.48 % deposition

This demonstrates

- With sufficient gap deposition can be avoided
- Vertical defocusing by field reversal is significant

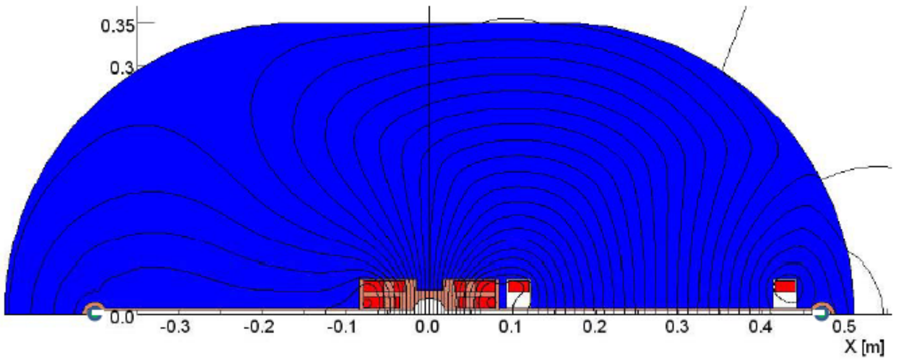
Variant without W bars

Transport tracks to absorbers at magnet ends

McIntyre

Open Midplane Active Return Dipole

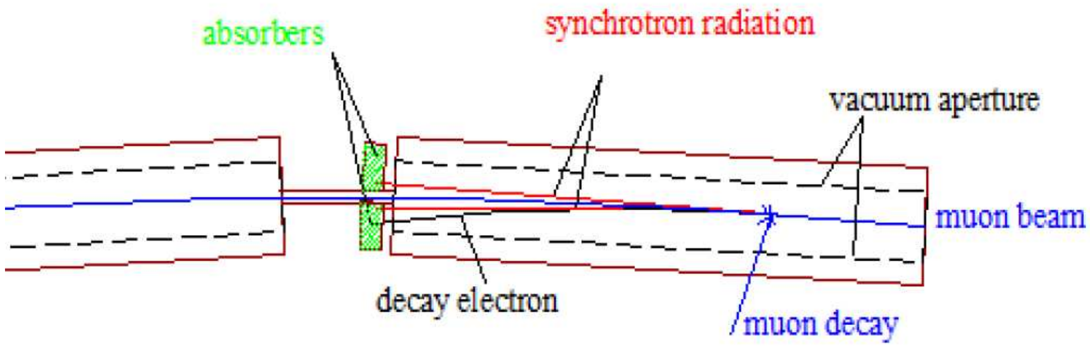
How to remove ***all*** decay electrons and synchrotron light from muon collider arc dipoles



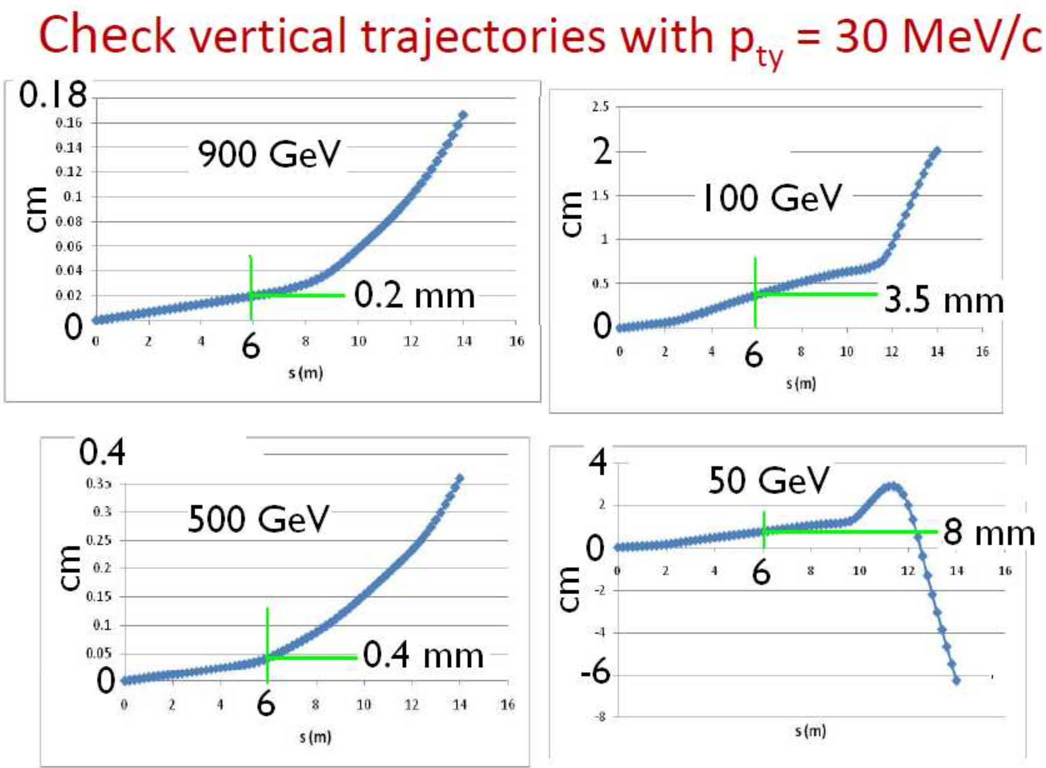
OMAR

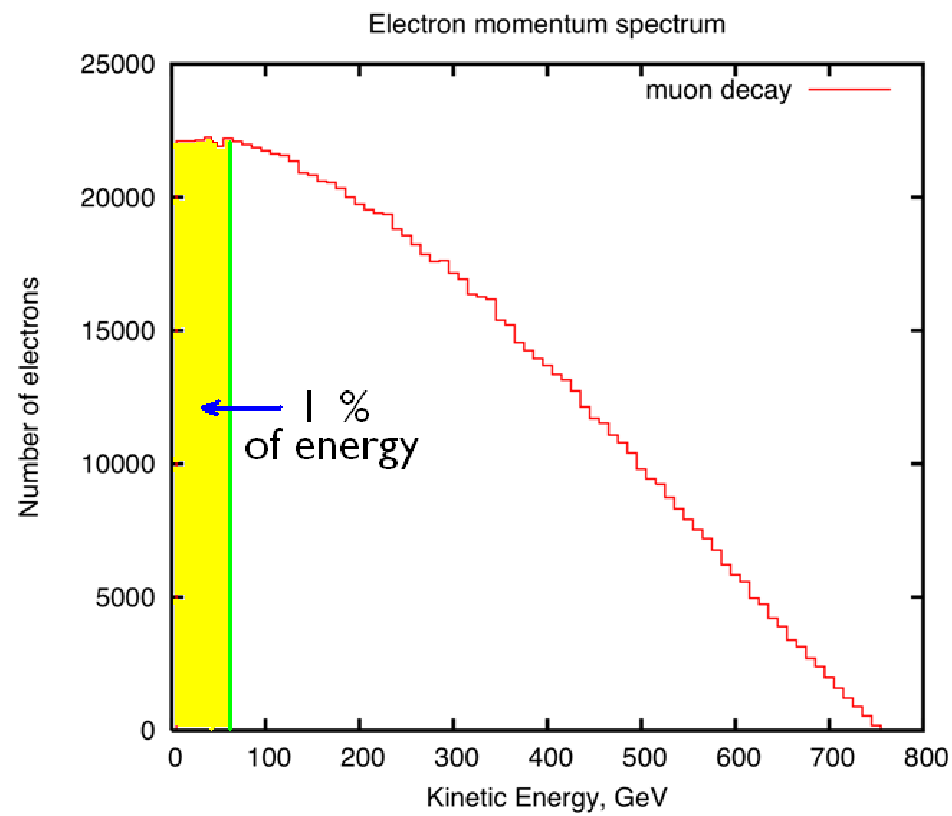
Peter McIntyre and Akhdiyor Sattarov
Texas A&M University

- Needed gap is ≈ 1 m wide
- Added coils needed to generate wide reverse field



Vertical trajectories   McIntyre

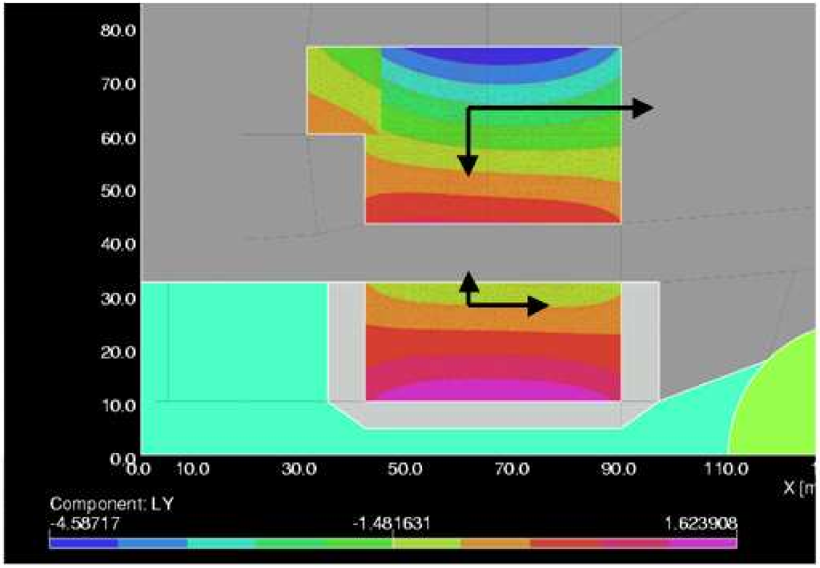




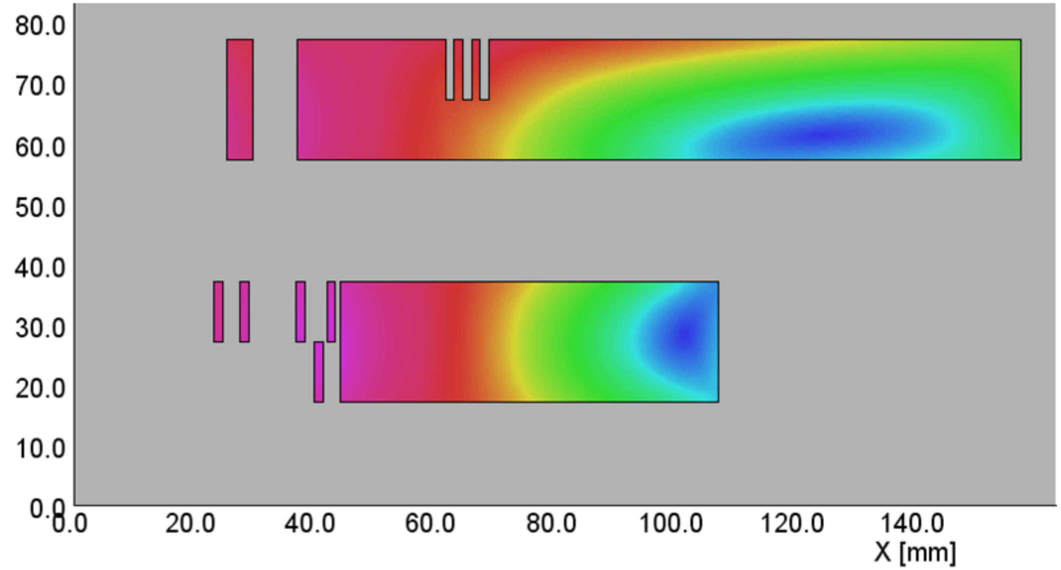
- To reduce heating below 1 % consider tracks down to 50 GeV
- for $p_\perp$=30 MeV/c vertical dip at 6 m = 8mm
- But maximum $p_\perp$ including emittance is 65 MeV/c so
- Max drift $\approx$ 17 mm
- So full gaps should be at least 4 cm

Engineering of open-mid-planes (BNL)

GU PTA



Principle of forces

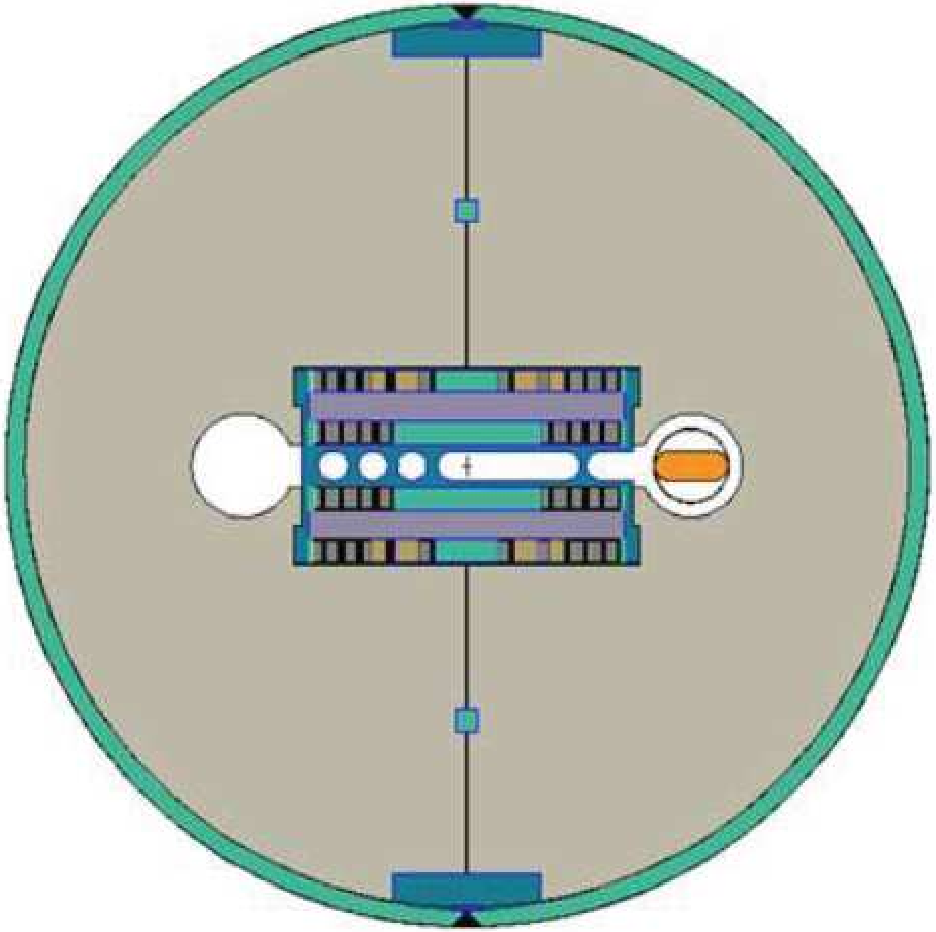


Design for Field Quality

- Designs for LAC Upgrade (CARP)
  - e.g. 13.6 T on axis 15 T on conductor deflections $< 150\ \mu$m b/B $< 3\ 10^{-5}$ to r=36 mm
- Design for SBIR POP
  - B(axis)=10 T T$<$ 400 Pa Deflections $< 90\ \mu$m

Engineering of open-mid-planes (FNAL)

Zlobin



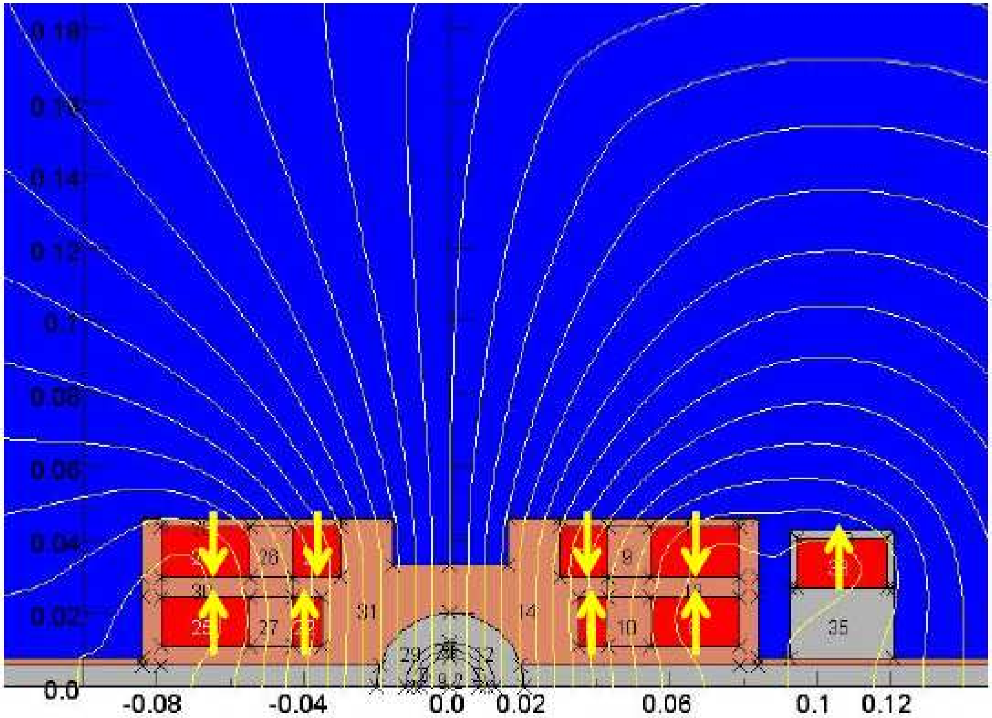
- Two double pancake block-type coils, wound around Ti poles with 22 mm thick interlayer stainless steel plates, are placed inside an Al cage.
- The cage provides the required vertical coil separation and contains holes for cooling pipes on one side and a slot for the beam pipe and an escape pass for the decay particles to the absorber placed in one of the two holes in the iron yoke.

- Forces between coils taken by AlBeMet   though fewer than shown here
- Mokhov shows that heat deposition in AlBeMet is negligible.
- But scattering may not be

Engineering of open-mid-planes (Texas)

McIntyre

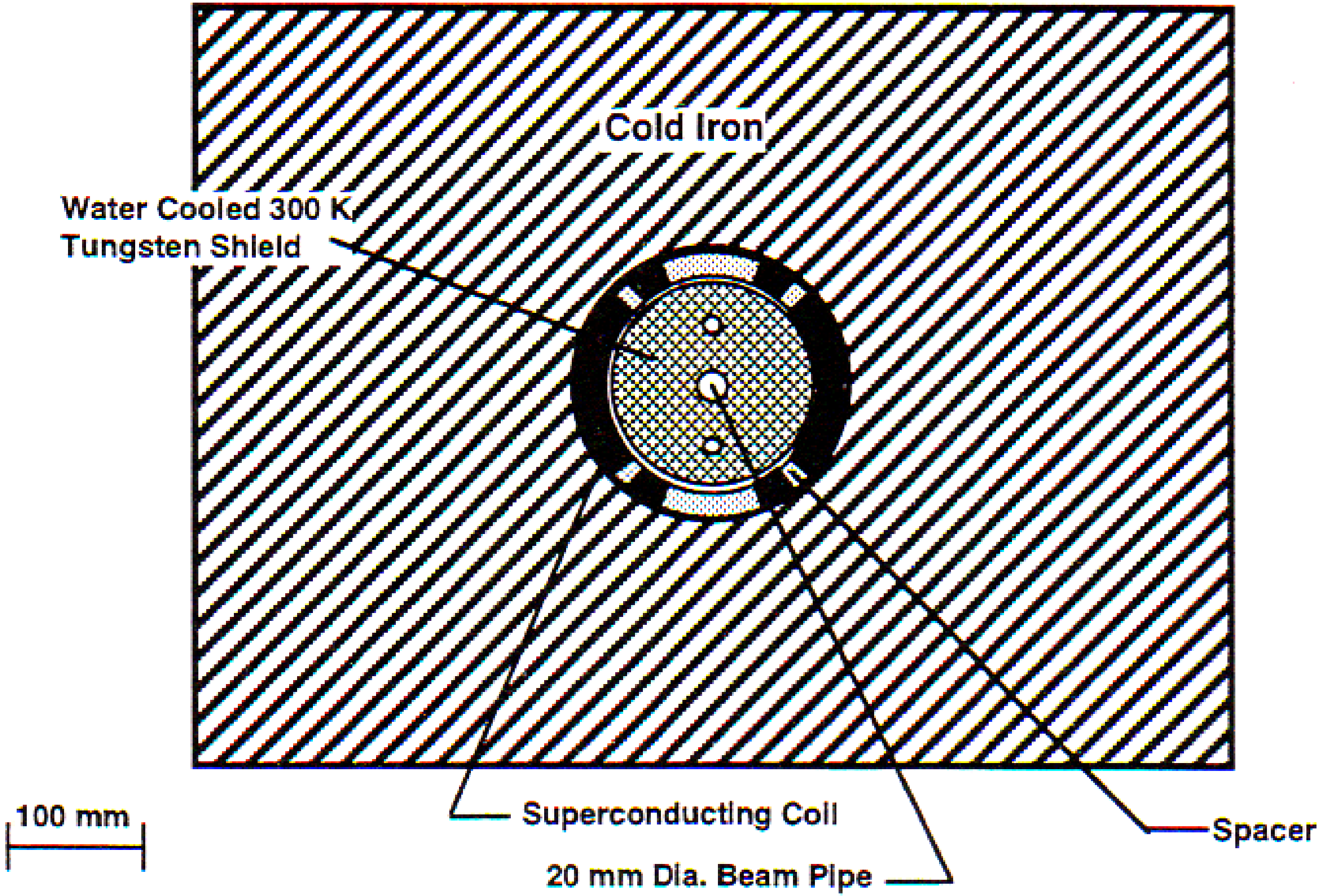
Inner set of windings are levitated, top/bottom windings supported by skyhook



- Geometry similar to GU PTA
- But uses "sky-hooks" to outer structure

Option # 2: Thick tungsten beam pipe

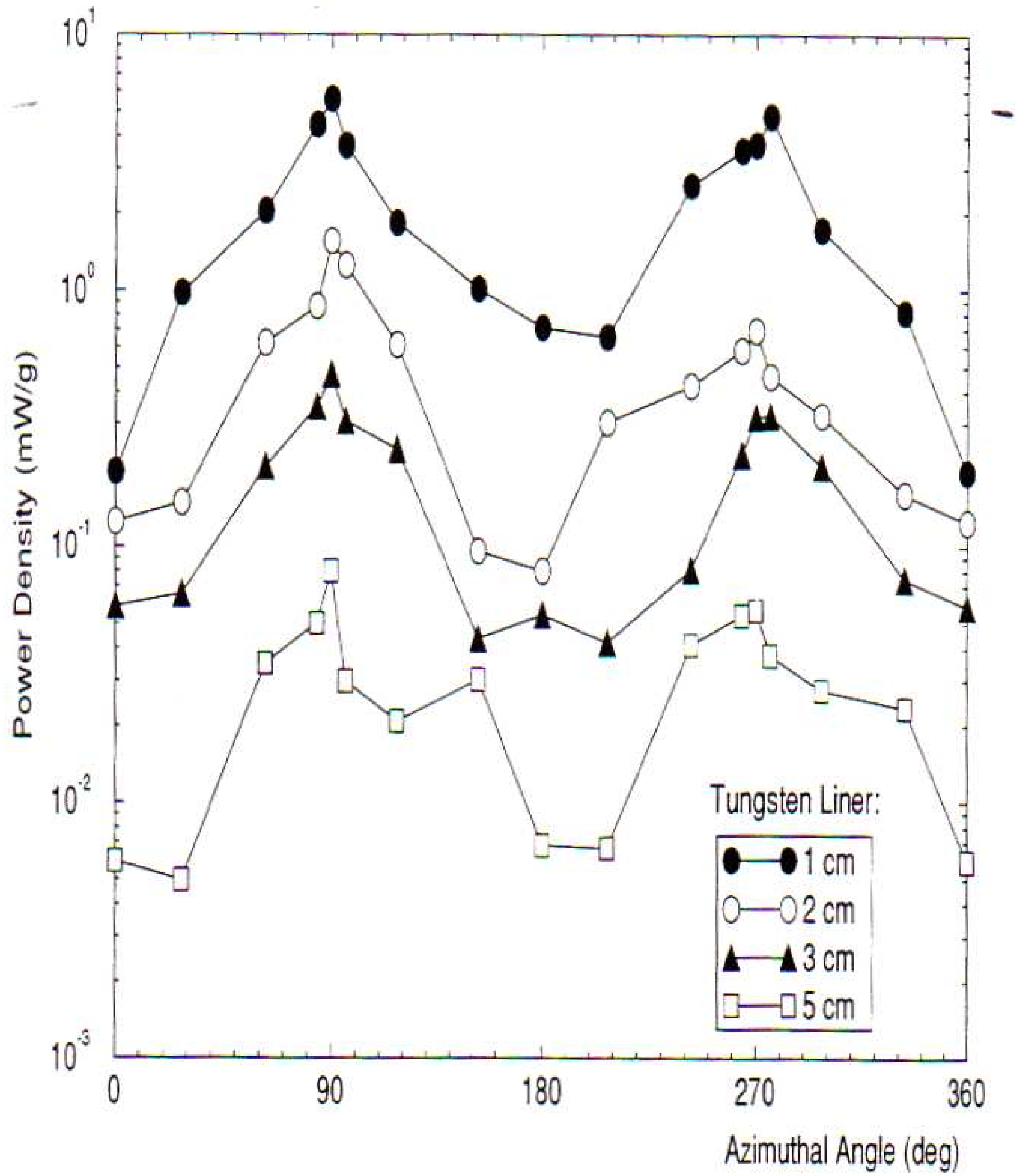
As discussed in 98 Feasibility Study



98 MARS for 4 TeV

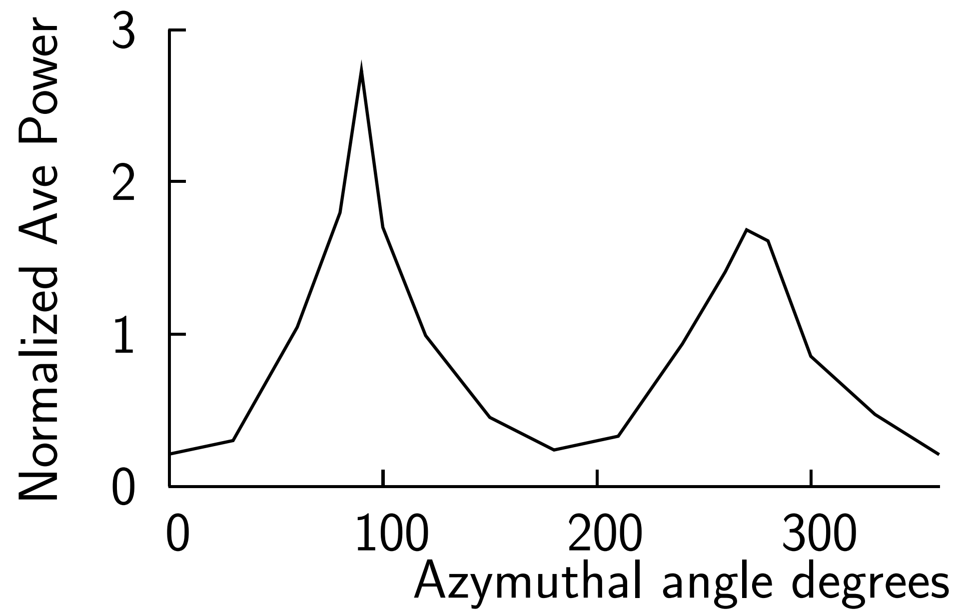
Mokhov 98 2+2 TeV distributions vs. angle for different thicknesses of tungsten shield

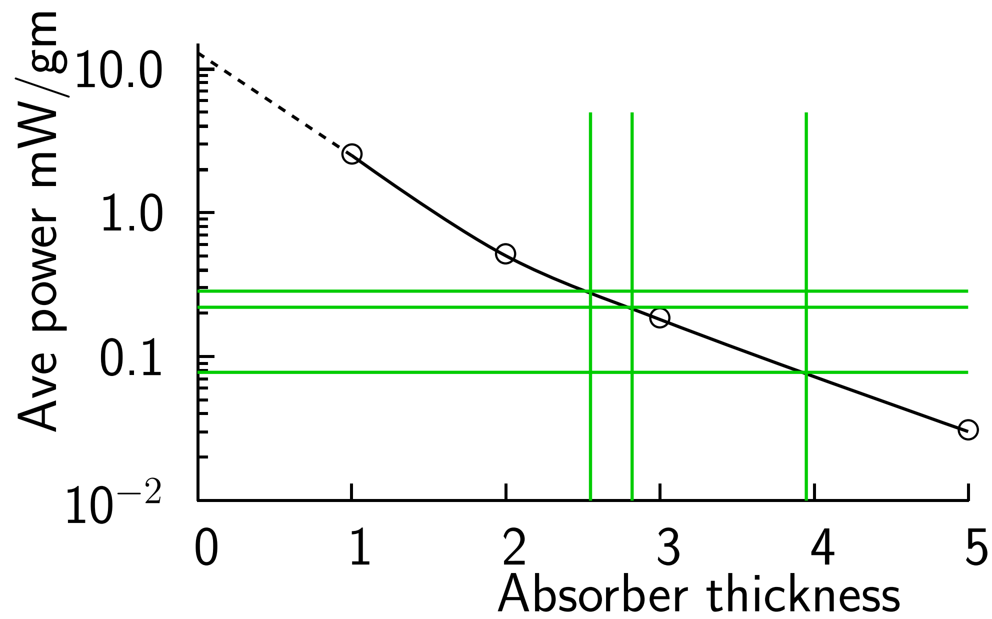
Shape of distributions approx independent of shield thickness



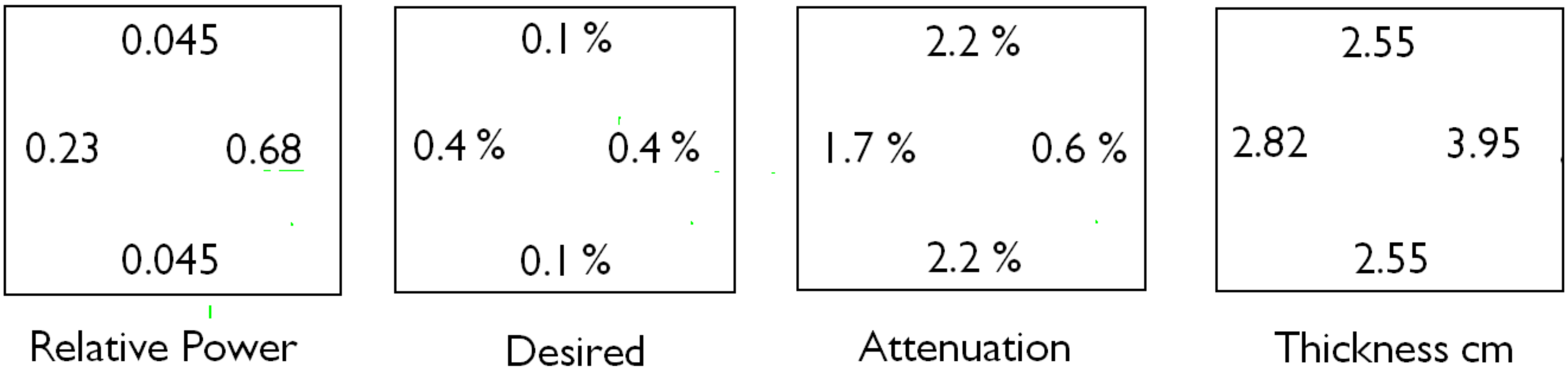
Attenuation and shape

- At 2+2 TeV
  - gamma radiation from higher E electrons (90 beg) is more than electron radiation ($\approx$ 4:3)
  - and more focused
  - up-down/side is $\approx 1/10$
- at 0.75+0.75 TeV
  - gamma ad. will be relatively much less (e.g. 1:3)
  - assume up-down/side still 1/10
- Attenuation length
  - extrapolate to zero
  - initial slope steeper from narrower showers?





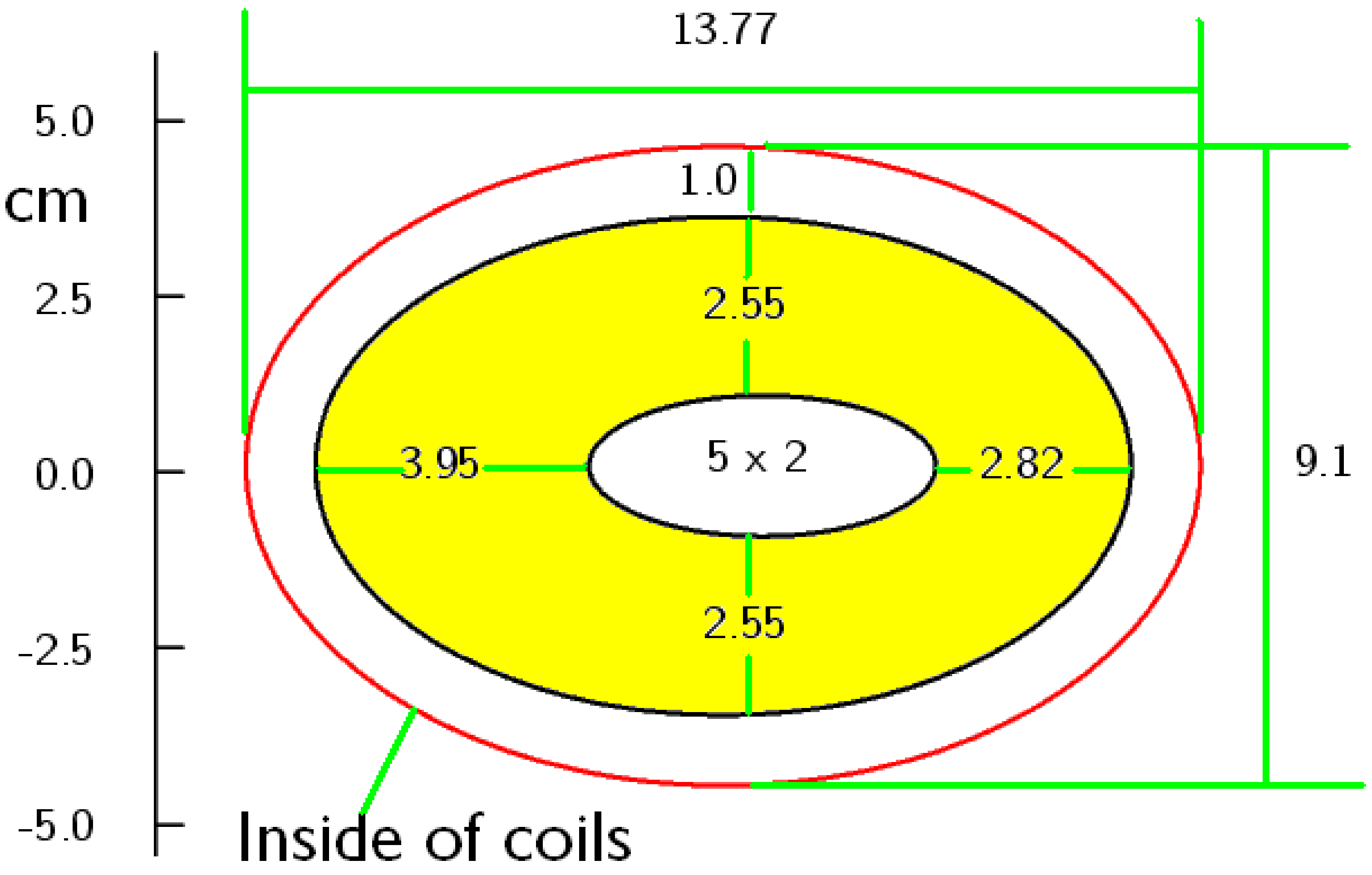
Required shield thicknesses



- Initial "Relative powers" (left, right, up, down) adding to 1.0
- "Desired" powers (left, right, up, down)) adding to 1 %
- Required "Attenuation"s = Desired/Initial
- Required shield "Thickness" as looked up from above plot
- This or like it would meet requirement

Section

- Inside pipe width = 5 cm
- Inside pipe height = 2 cm



Not quite as large as 98 study (14 x 14 cm) but large

Conclusion

- Cry efficiency from LAC, including distribution, = 20% x Cannot $\approx$ 0.3 %
- With 10 MW wall we can cool 27 k at 4 beg
- If 2.5 MW deposited from beam then shield attenuation $\leq$ 1%
- Open mid-plane options:
  - Open mid-plane designs with 3 cm gap deposit too much energy
  - This is NOT backscatter from absorber bars
  - Tracking suggests required full gap at least 4 cm
  - Too early to know if it will meet requirements
- Tungsten beam-pipe option
  - For beam pipe 5 x 2 cm and 1 cm gap, then:
  - Elliptical coil inside $\approx$ 13.8 x 9.1 cm
  - Can certainly meat shielding requirements, but requires large coils