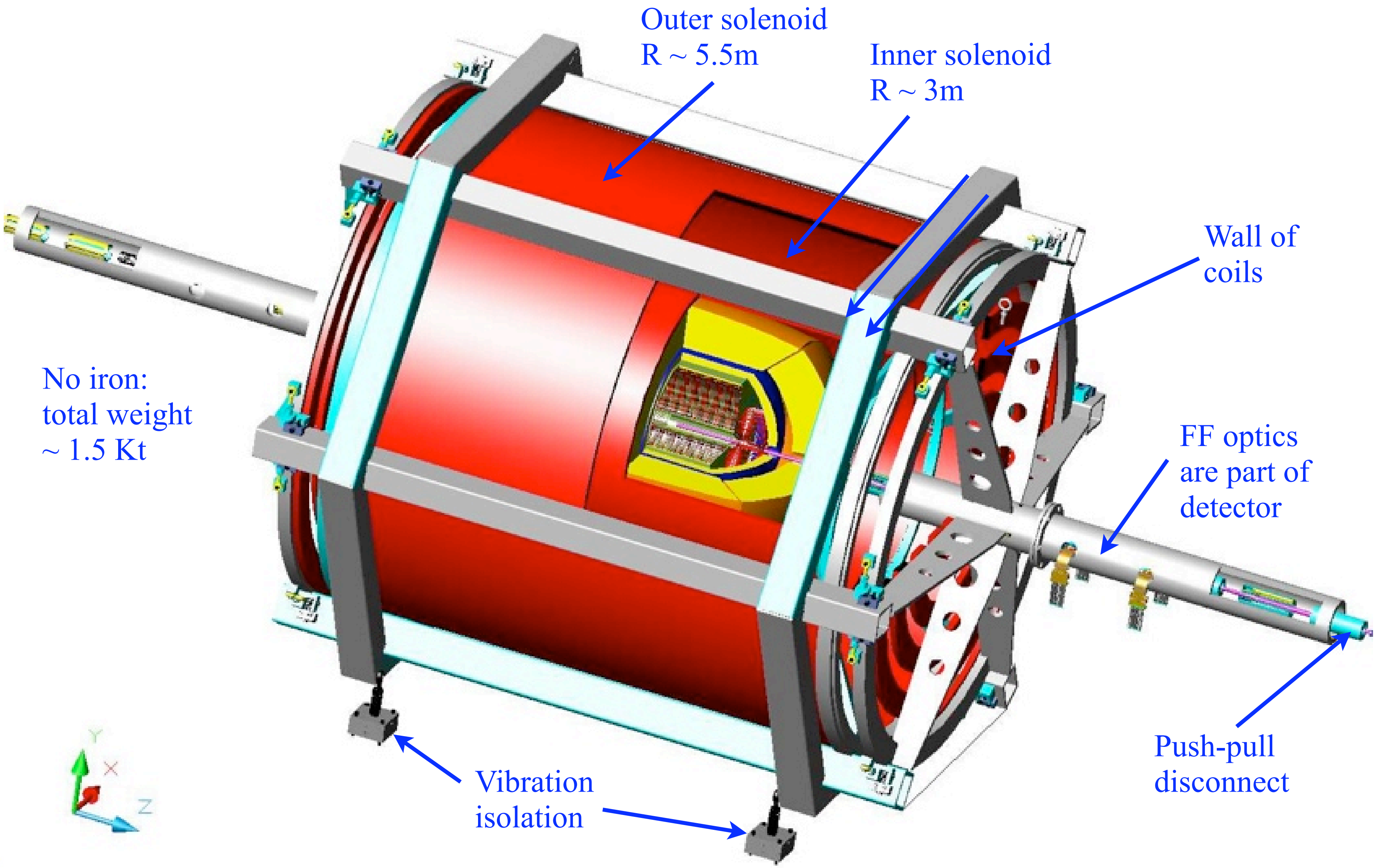
Iron vs. No-iron Muon Detection

ALCPG Fermilab 22-26 October 2007

John Hauptman
Alexander Mikhailichenko

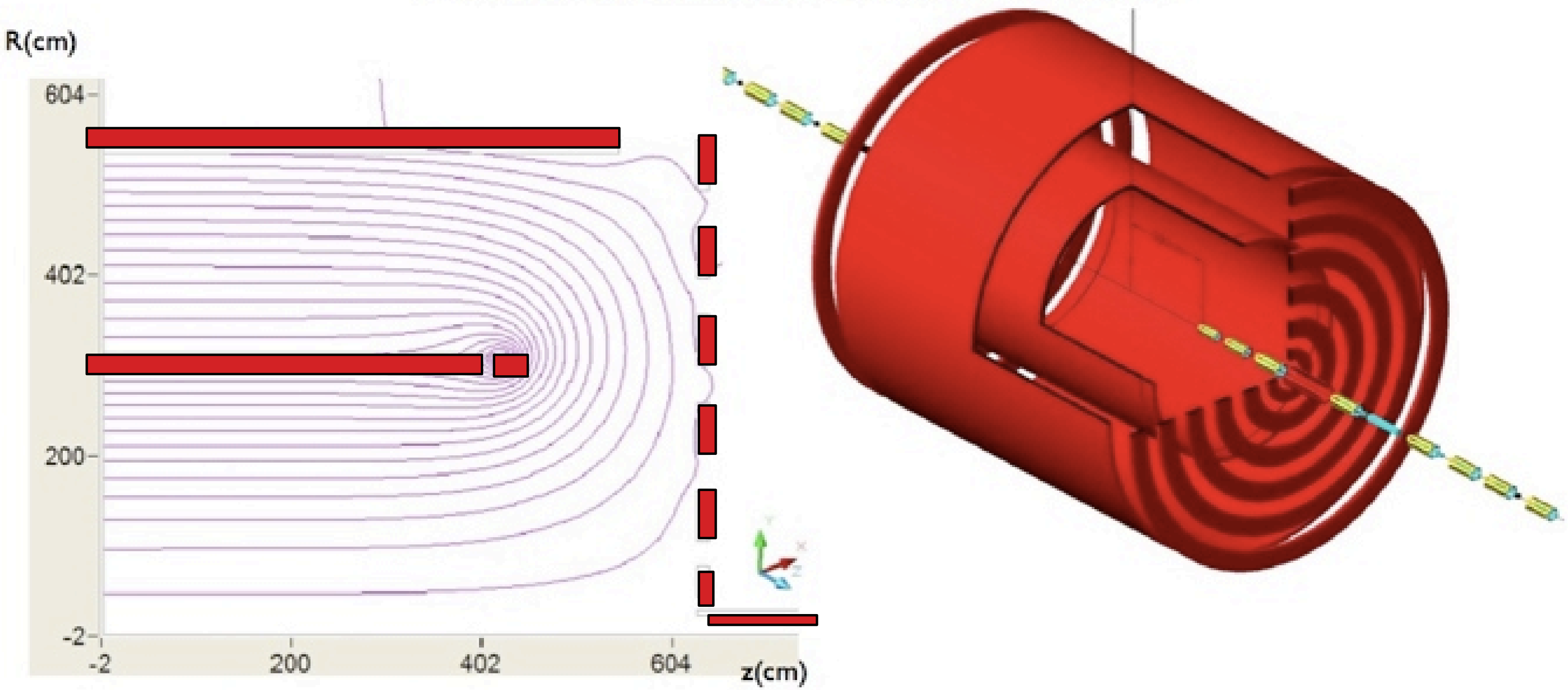
October 22, 2007

Quick overview of detector geometry



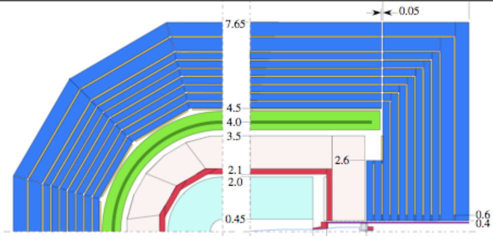
New magnetic field, new ``wall of coils”, iron-free:
many benefits to muon detection and MDI,
Alexander Mikhailichenko design

Magnetic field of dual solenoid and wall of coils



4th is "different" in almost every possible way (we are not trying to be different, or difficult)

- Flux return by a second solenoid (and therefore no iron mass) is a big deal.
  - 4th 1.5Kt
  - SiD 10 Kt
  - LDC 10 Kt
  - GLD 17 Kt
- As a consequence, almost every problem you can think of in the IR is easier; physics is better, too.
- "Self-shielding" solution (T. Sanami and A. Seryi) is discussed later.



"Iron Age" physics

- An iron yoke adds little to the magnetic environment, is not necessary for field uniformity, serves as only a crude pion filter, and ruins the momentum resolution on a muon.
- The iron may be good for hanging the calorimeter, but it also forecloses forever alterations, improvements and additions to the detector outside the calorimeter.
- Access and movement are more difficult, push-pull is more difficult, including supports and floor settling.
- It is not cheap: CMS iron is $35-75M.

Iron-free "basic principles"

Returning the flux with a second solenoid and the wall-of-coils

a) confines the field almost completely, no fringe field;

b) reduces detector-distorting forces associated with the field to almost zero;

c) allows a second muon momentum measurement and contributes to muon identification by energy matching;

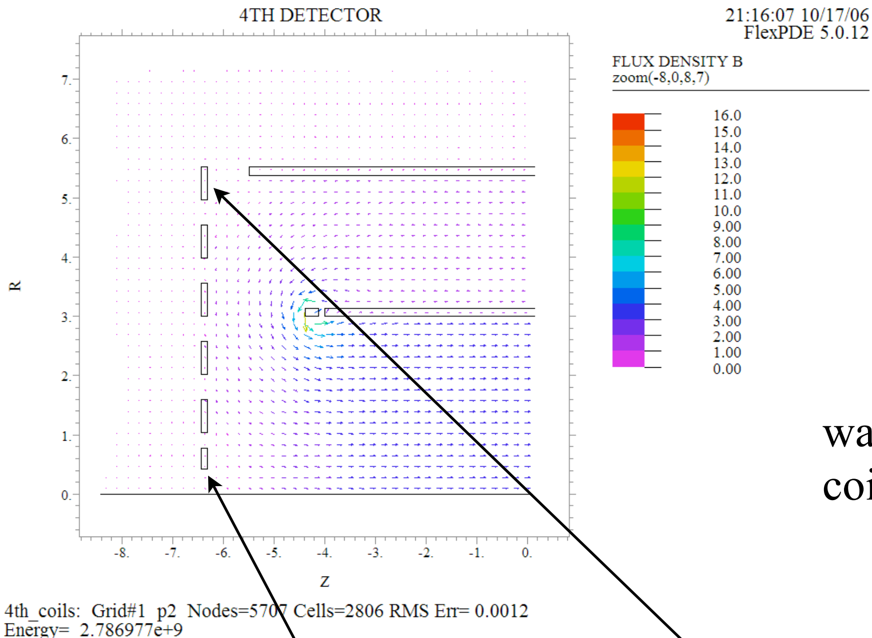
d) allows the cancellation of detector asymmetries in quark asymmetry measurements by B→ -B everywhere;

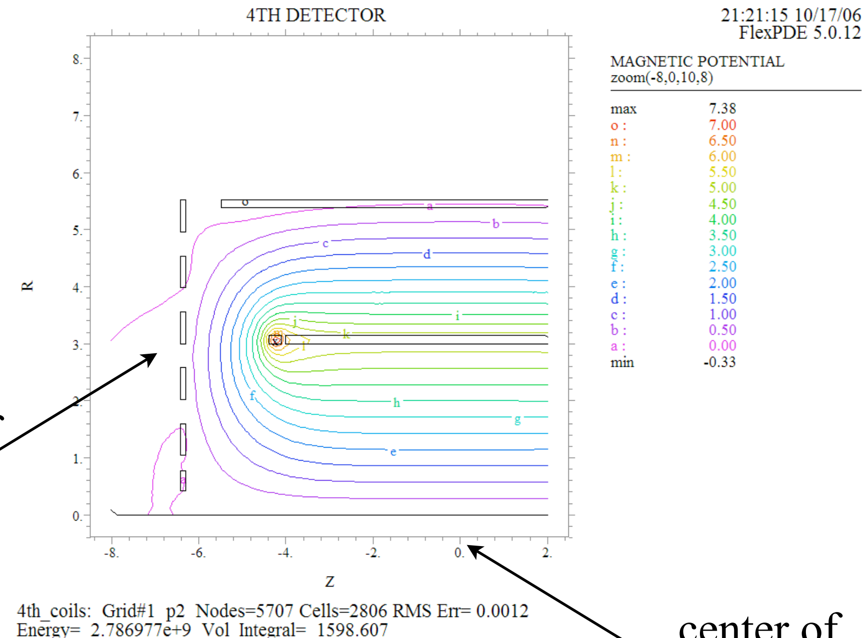
e) allows additions outside the calorimeter in future years (think Lead Glass Wall, or anti-neutron counters on the Magnetic Detector);

f) push-pull, repositioning, surveying are easier; and,

g) you have complete control of B on and near the beam.

Magnetic field configuration





wall of coils

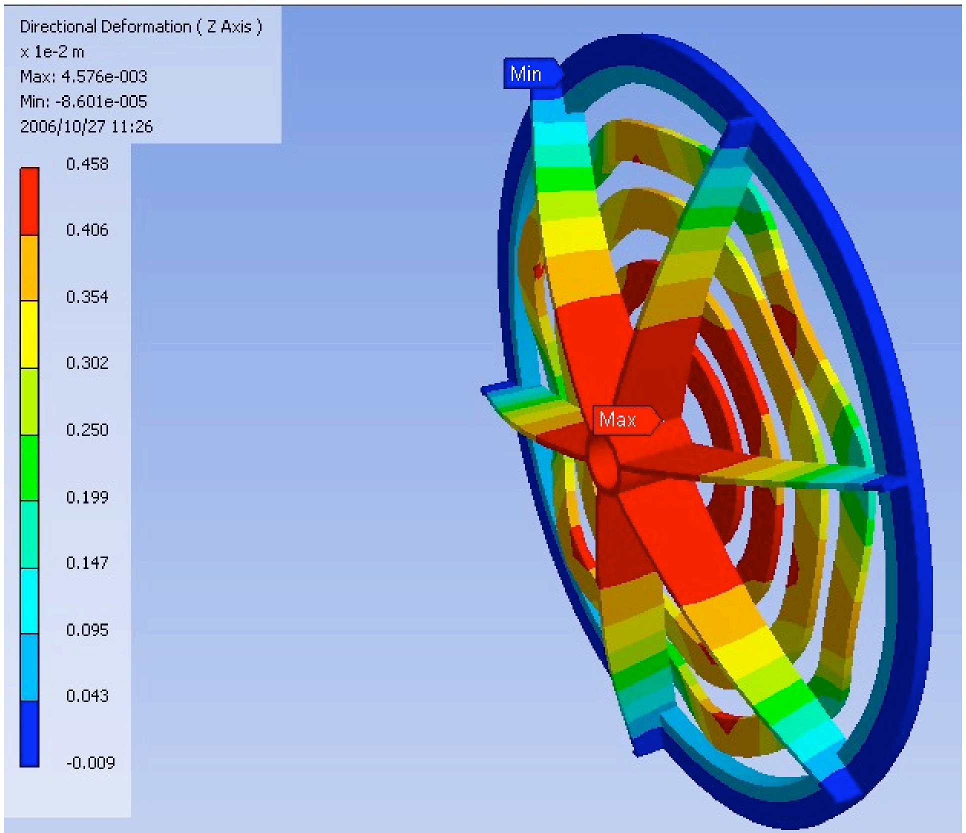
center of detector

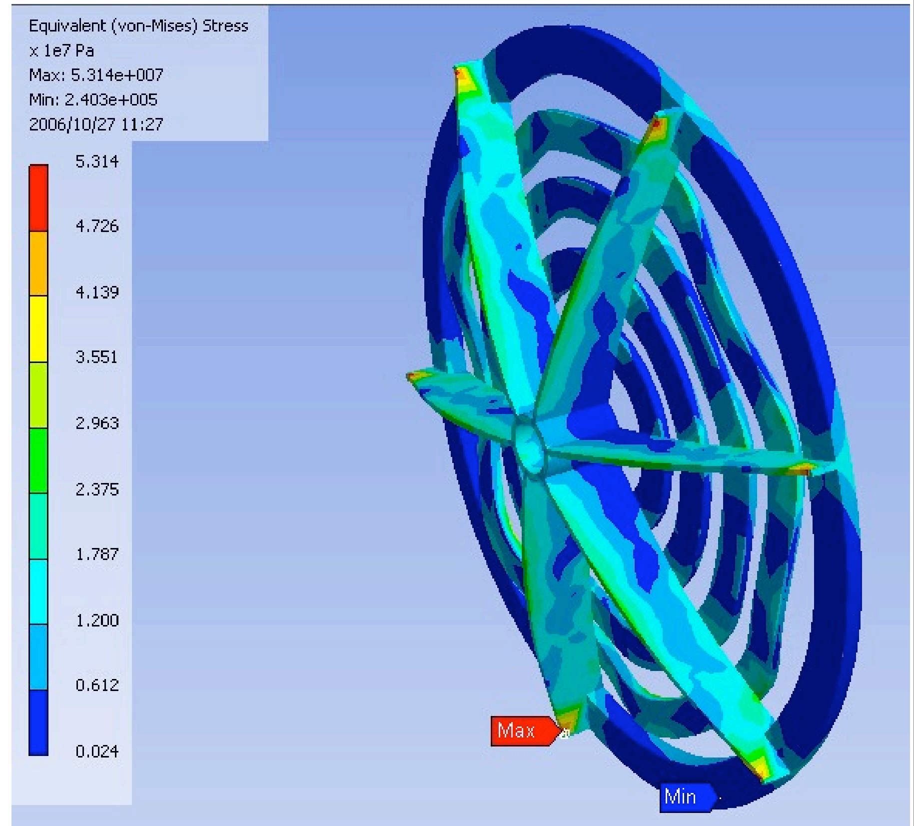
J(A/mm^2): 1; 8; 4.2; 3.3; 3.7; 1.7
Force(tons): 1.75; 102; 131; 135; 111; 10

- In a future optimization, all coils will have approximately the same current density
- Field outside the detector can be zeroed to any level required by a proper current distribution
- The coils can be fixed easily at the end plates

Deformations of end coils & support

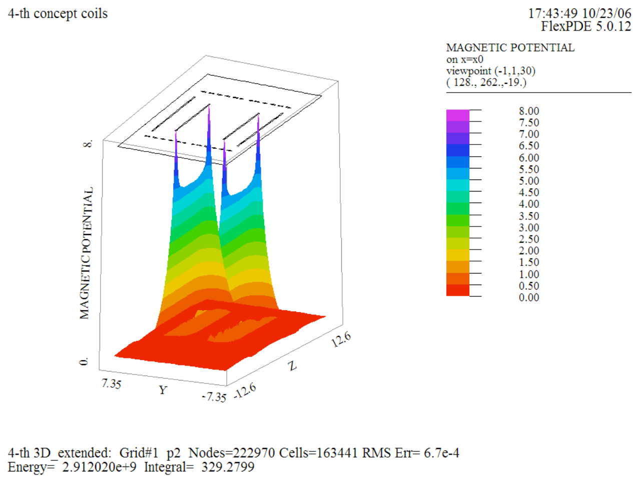
Maximum deformation is in z, it is less that 5mm, and in the middle of the holder. Active movers and reinforcements can compensate this.





Calculated by V. Medjidzade; calculations carried out by B. Wands, also.

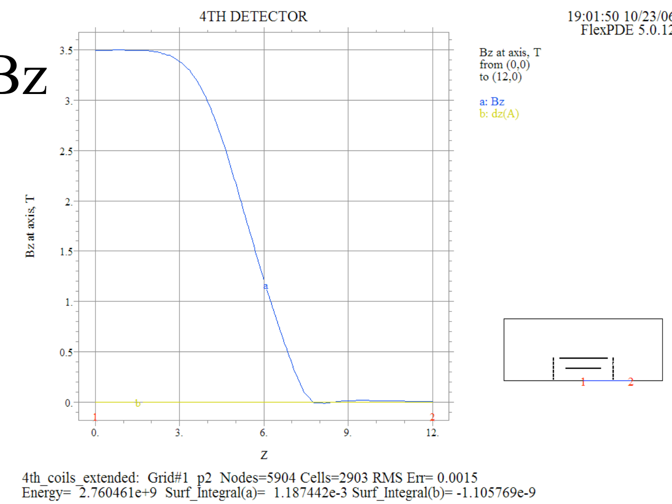
For tracking field homogeneity the current density in main coil has a quadratic longitudinal dependence. In a simple sense, it is a Helmholtz-type system with increased current at the ends.

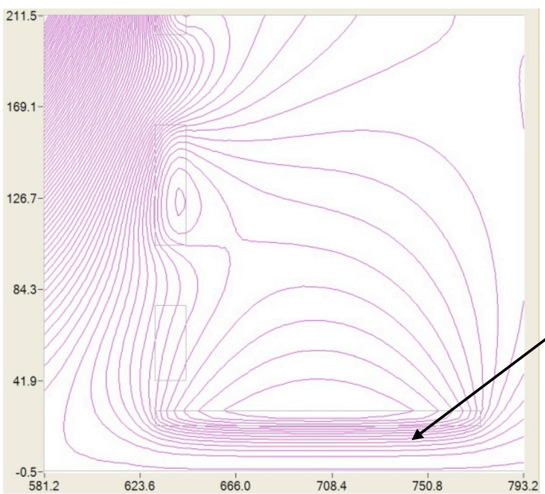


Magnetic potential

Stored energy is ~2.86 GJ for 3.5T axial field

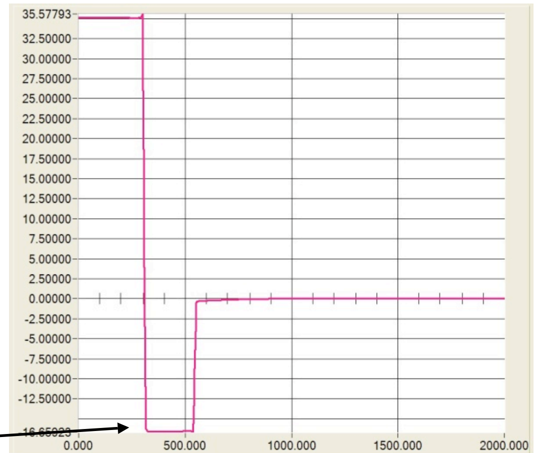
Bz



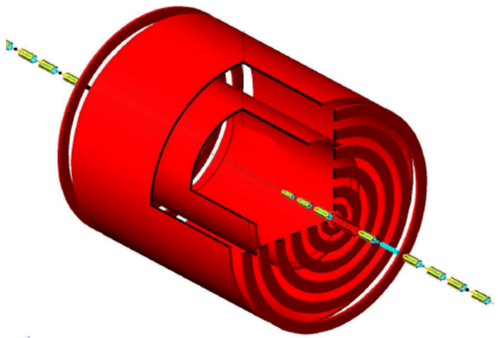


Compensational solenoid deals with residual part of transverse kick

Field for muon spectrometer



Field across detector



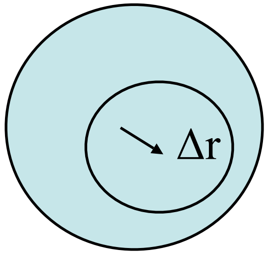
Fermilab
PPD/MD/Engineering Analysis Group

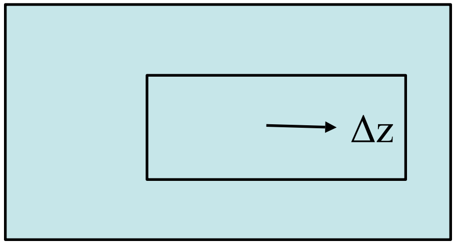
Magnets and Supports

Bob Wands October 20, 2006

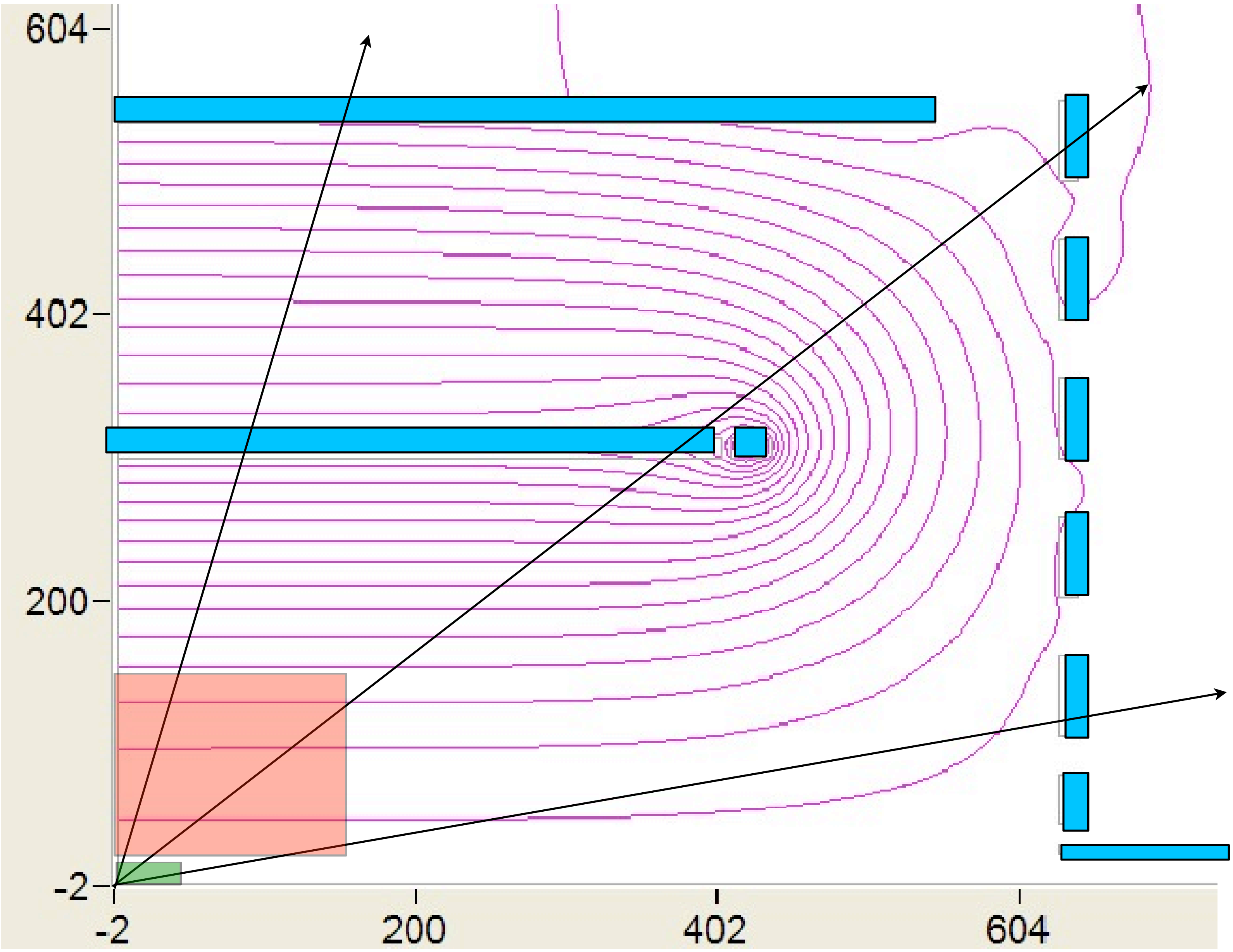
Magnetic field analysis; coil technologies; preliminary structural calculations; modal analysis

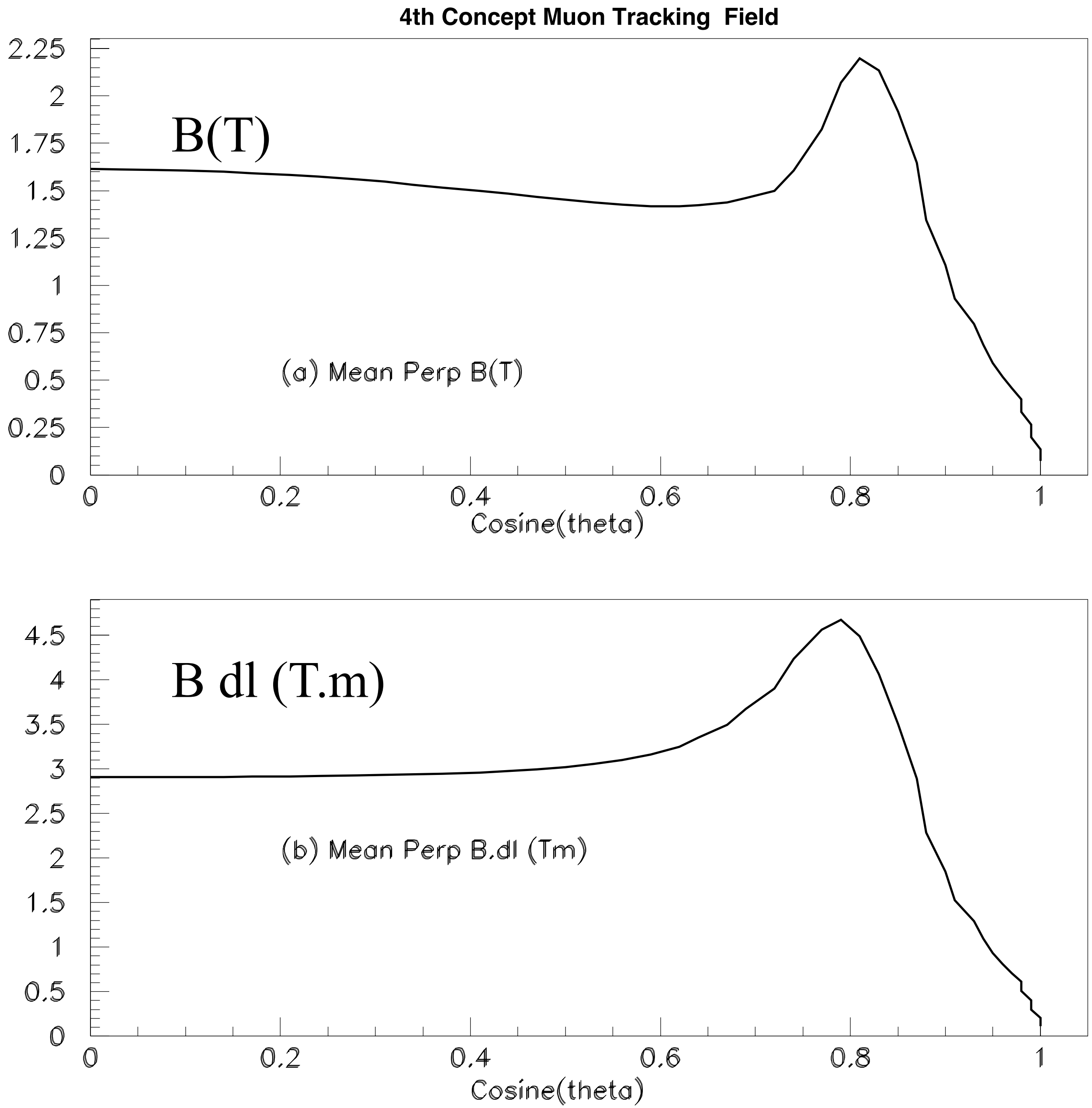
- Stored energy 2.86 GJ
- Radial force is decentering ~ 0.4 t/mm
- Axial force is centering ~ 0.8 t/mm
- We need to relieve forces on coil ends
- Optimize, but no show stoppers
- Excellent note on conductor options, mechanics, support, remedies, solutions





Muon measurements





Dual solenoid

tracking along muon trajectories in the annulus between solenoids.

Radiation shielding without iron

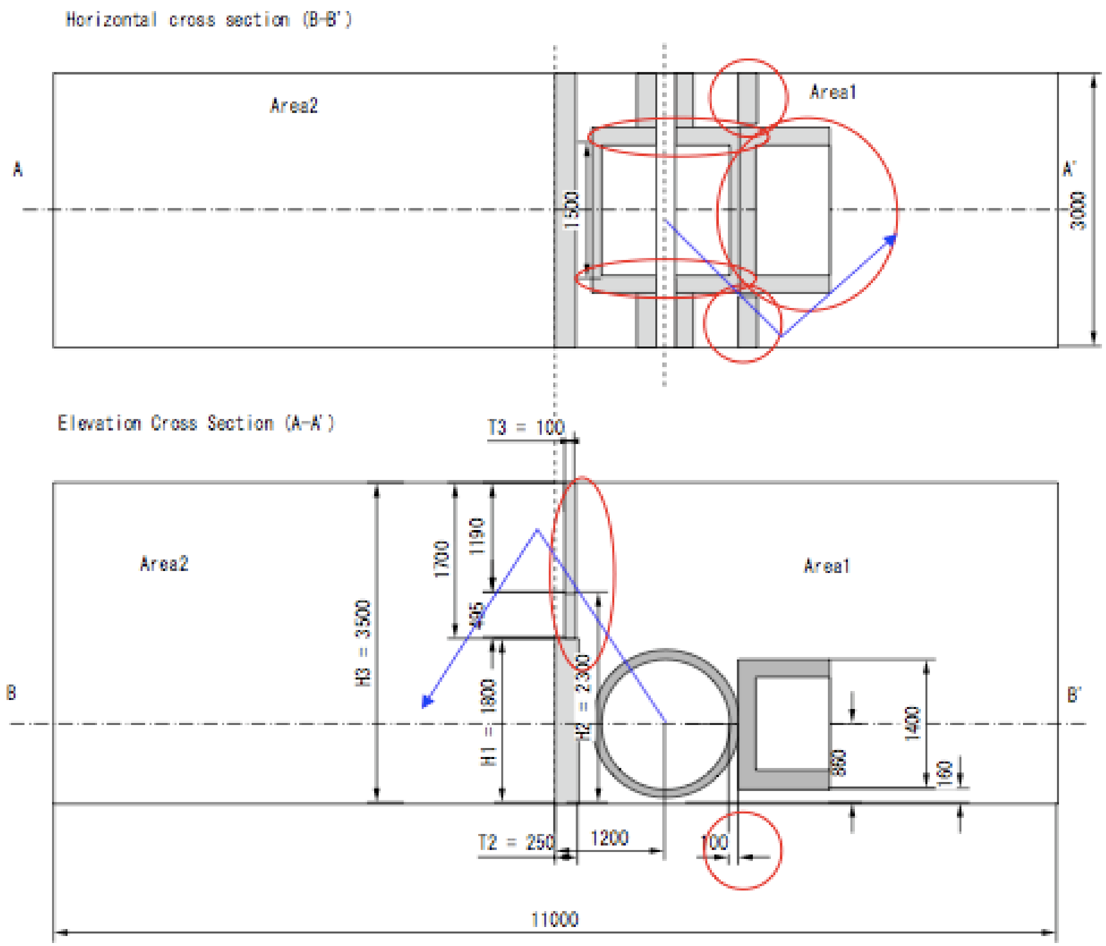
T. Sanami and A. Seryi have calculated the doses in the IR for an unshielded detector, e.g. 4th. This is excellent work that we could not have done ourselves:

"Detector without self-shielding in the IR hall", T. Sanami and A. Seryi, SLAC, *circa* July 2007.

The concrete shielding required would be instrumented with RPCs for timing, cosmic vetoing, time-of-flight for odd penetrating objects, tachyons, etc.

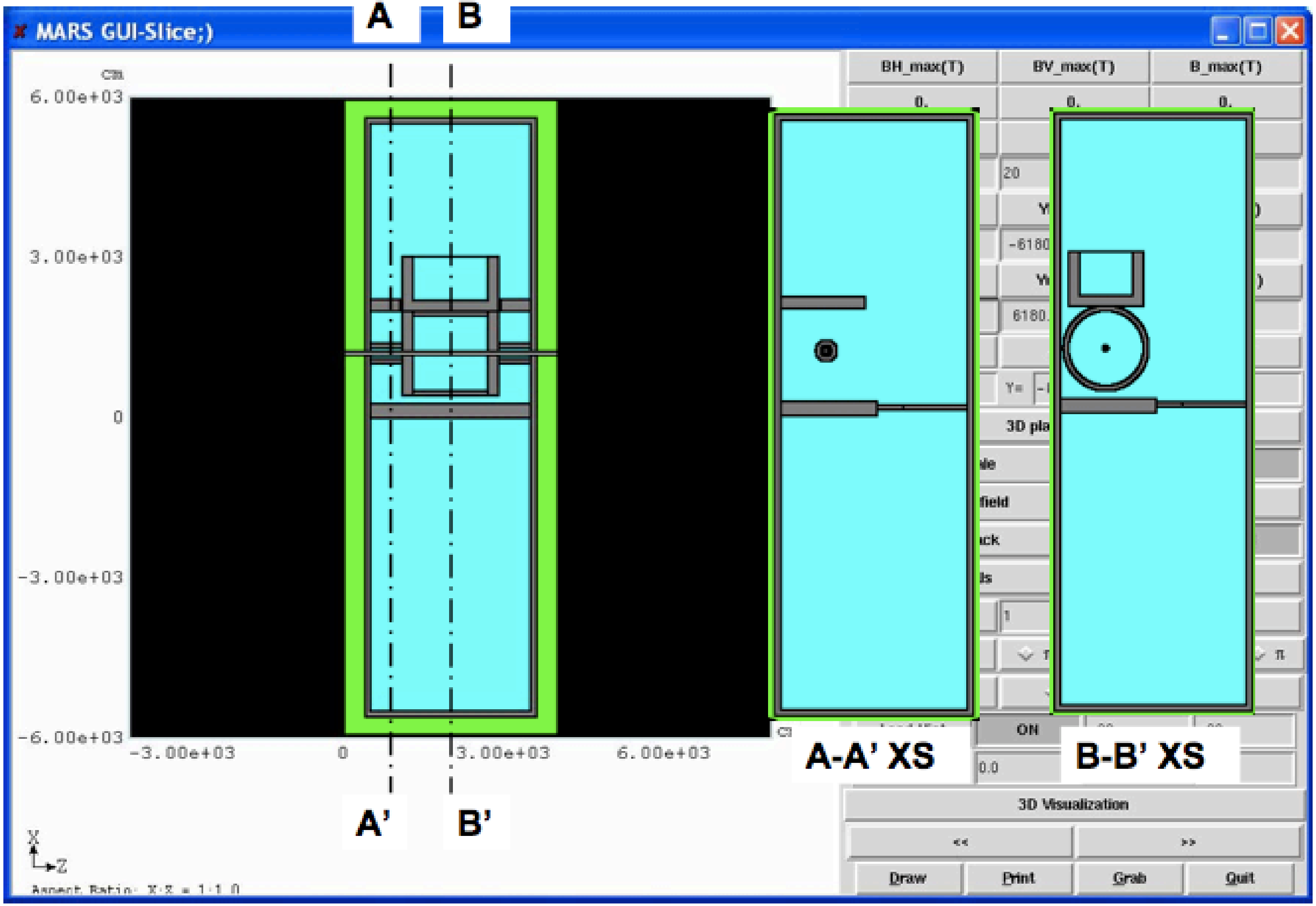
T. Sanami and A. Seryi

Case6, Higher curtain, local and supplemental shield

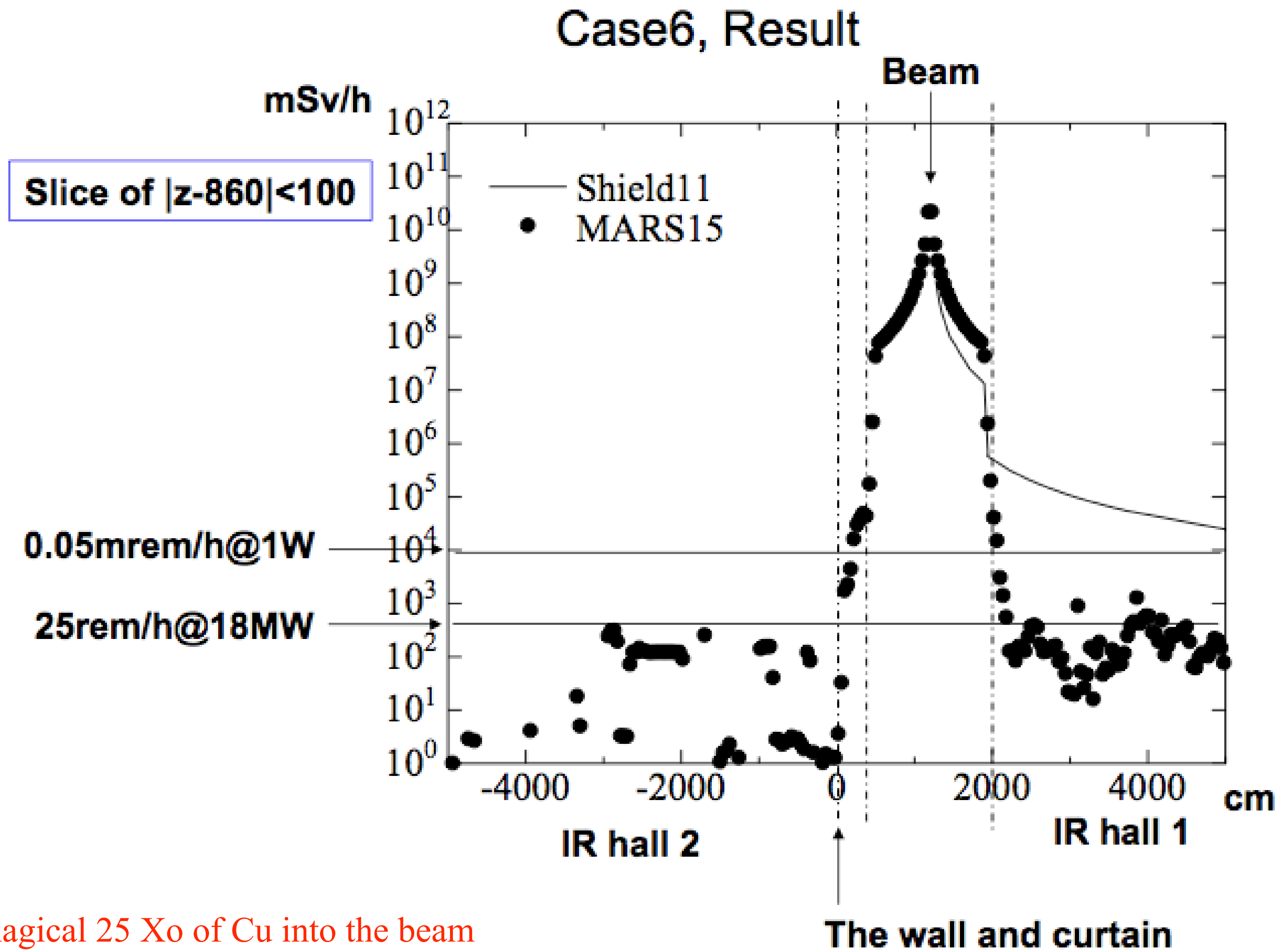


T. Sanami and A. Seryi

MARS15 geometry



T. Sanami and A. Seryi



Instantaneous, magical 25 Xo of Cu into the beam

Hermetic calorimeter as a shield

- The 4th dual-readout calorimeter is 10 λ_I and 100 X_o
- 2.5m of shielding concrete is 6 λ_I and 23 X_o
- 3m of Fe is 18 λ_I and 170 X_o

So, 4th+2.5m concrete ~ 3m Fe

We would want to "instrument" the shielding concrete with RPCs to serve as a cosmic veto, a time-of-flight counter for odd-objects (weak, neutral, slow SUSY), tachyons, or just as a time-history monitor of energetic activity in the IR.

Arguments and counter-arguments for iron vs. no-iron

Argument for no iron	Counter argument	Counter counter argument
Muon momentum is better measured in muon system	Doesn't matter; you can match to tracker momentum (AMiy)	Second measurement improves muon ID
Intra-detector distorting forces much reduced or non-existent	None ?	
Can reverse B and cancel detector asymmetries	Can achieve the same thing with Z--> mu mu events (JJar)	An independent check is essential and important
Allows additions and add-ons in later years	Unlikely to ever be done (JAle)	True; not many examples of this
Low mass: push-pull; (re-) positioning easier & cheaper	Not self-shielding	Can add concrete shielding walls; but it's not elegant
MDI advantages; complete control of B; no fringe field	Maybe not so (ASer)	To be discussed
Outer solenoid is easier than inner solenoid (~CMS)	Has to be built on-site due to size; expensive (P.Fabbricatore)	Both true; but maybe both can be ameliorated
Optical line-of-sight into detector: survey & alignment	Can align with Zs	... and lose luminosity; push-pull demands quick alignment