4th detector concept

IRENG07, SLAC, 17-21 Sept 2007

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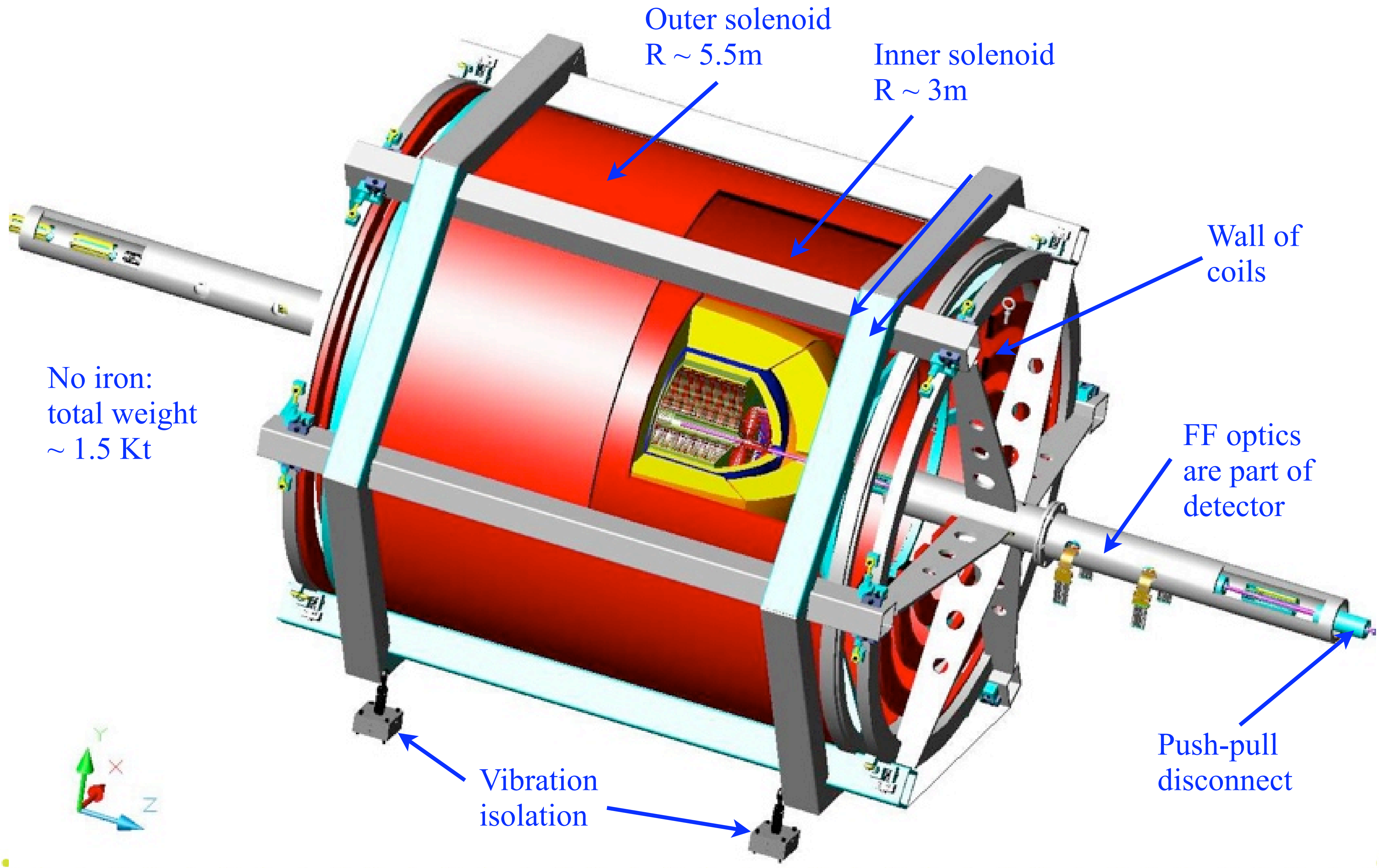
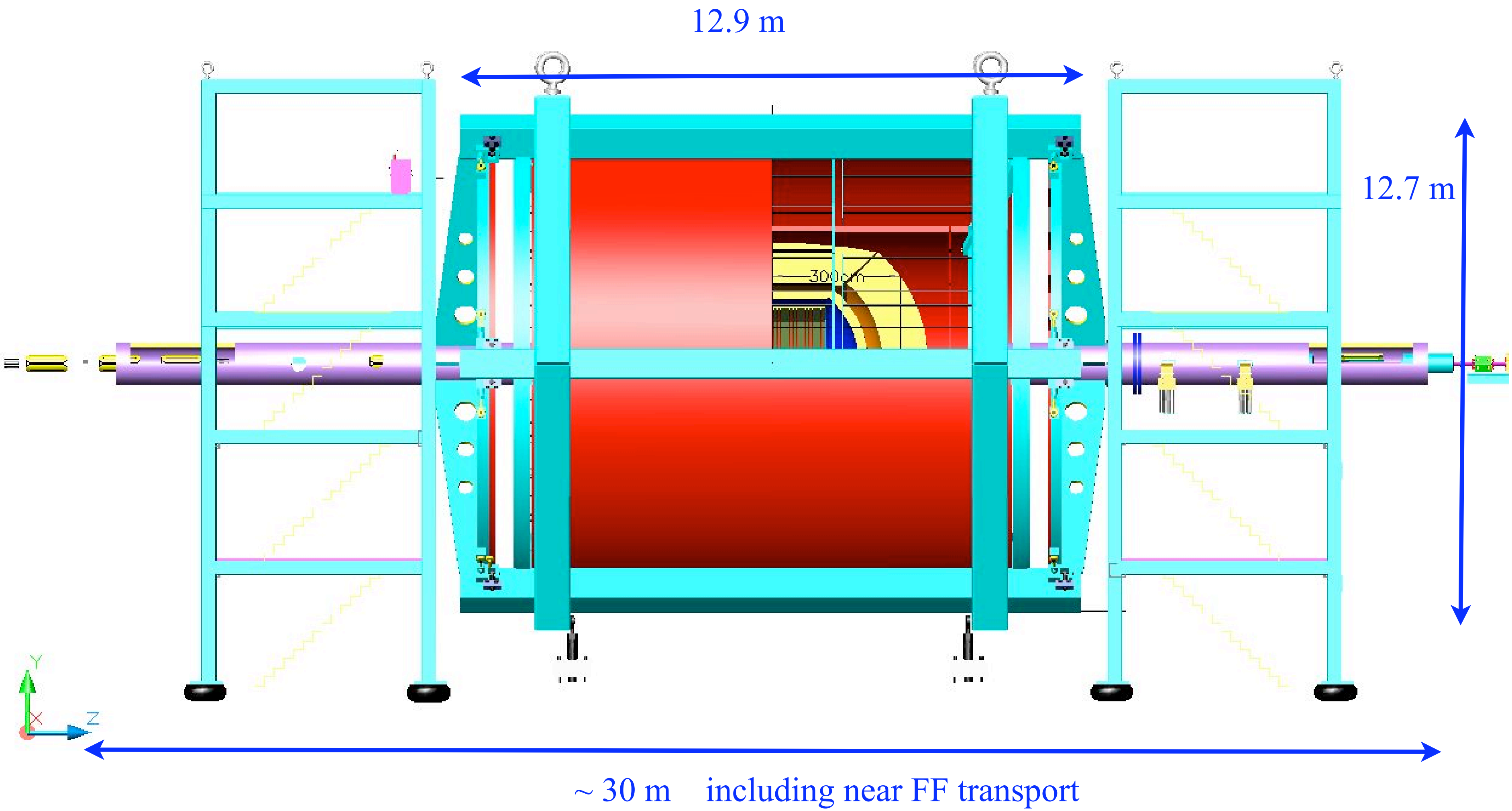
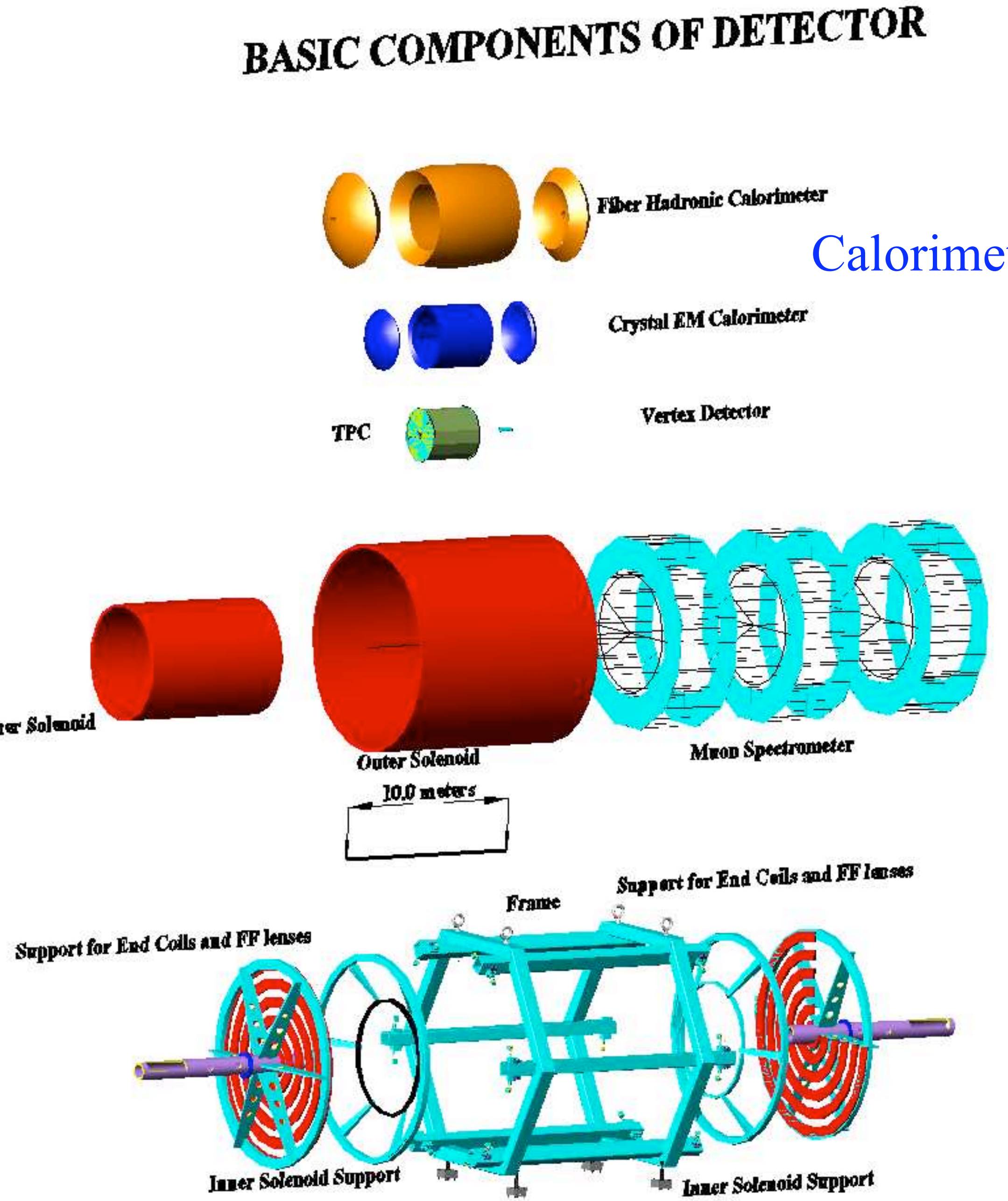
September 17, 2007

Quick overview of detector geometry



Gross dimensions, including FF optics transport tube and electronics platforms





Calorimeters ~ 1000 t

Solenoids ~
200 t each ?
Budker Inst?

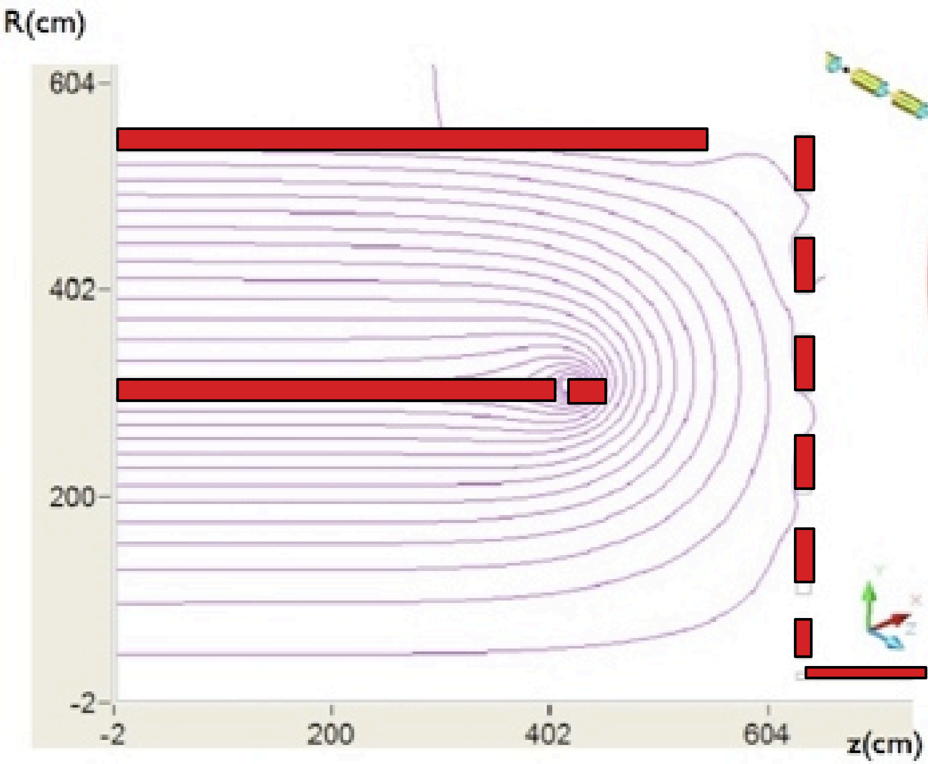
4th is "different" in almost every possible way (we are not trying to be different, or difficult)

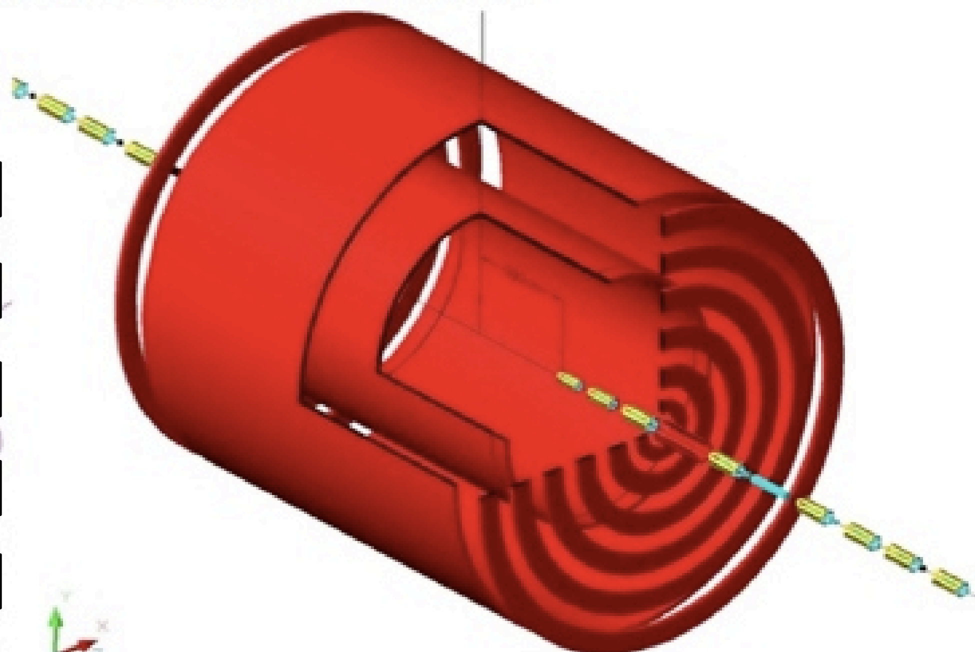
- Flux return by a second solenoid (and therefore no iron mass) is a big deal.
  - **4th 1.5 Kt**
  - **SiD 10 Kt**
  - **LDC 10 Kt**
  - **GLD 17 Kt**
- As a consequence, almost every problem you can think of in the IR is easier; physics is better, too.
- Self-shielding solution (T. Sanami and A. Seryi)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

General parameters

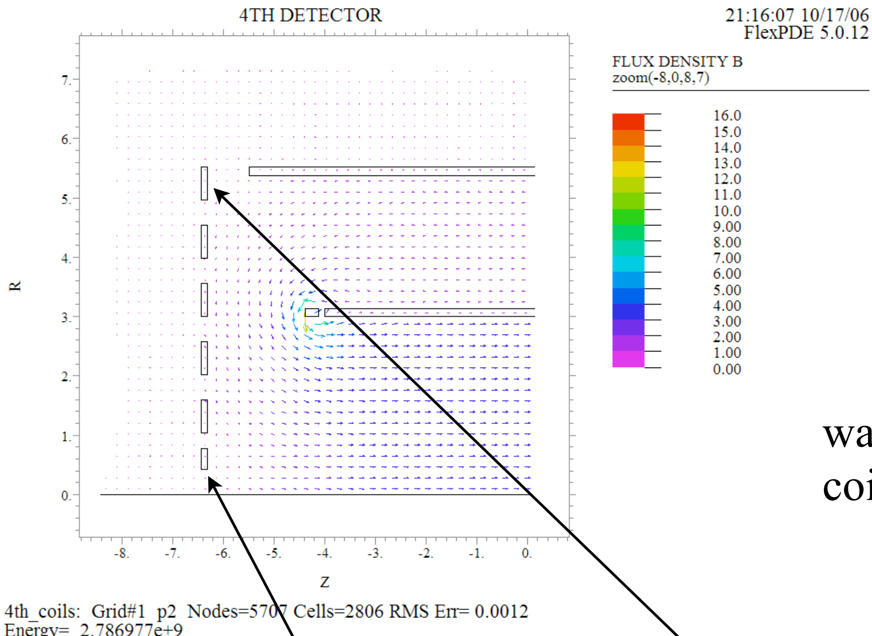
- **Gross dimensions**
  - 13m x 14m outside
  - Final Doublet attached to detector frame out to +/- 15m
- **Weight**
  - About 1.5 Kt ... mostly calorimeters and two solenoids
    - Calorimeters: 100 m^3 of brass ~ 900 Kt
    - Solenoids: ~ 2 x CMS ~ 2 x 200Kt ~ 400 Kt
- **B fields**
  - Tracking field: 3.5T
  - Muon tracking field in annulus between solenoids: -1.5T
  - Outside the outer solenoid: ~ 0
- **Range of acceptable L***
  - 2-4 m

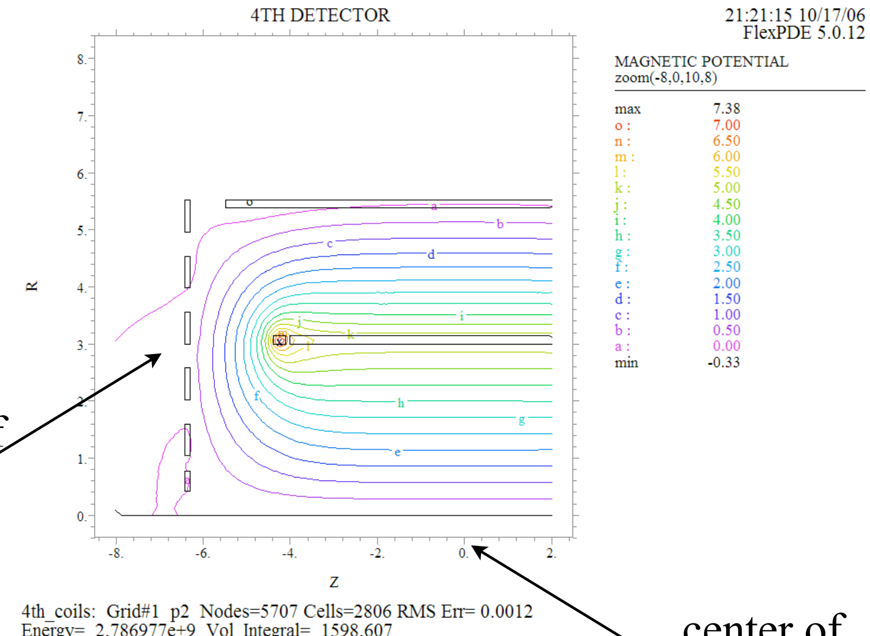
Magnetic field of dual solenoid and wall of coils





Magnetic field configuration





wall of coils

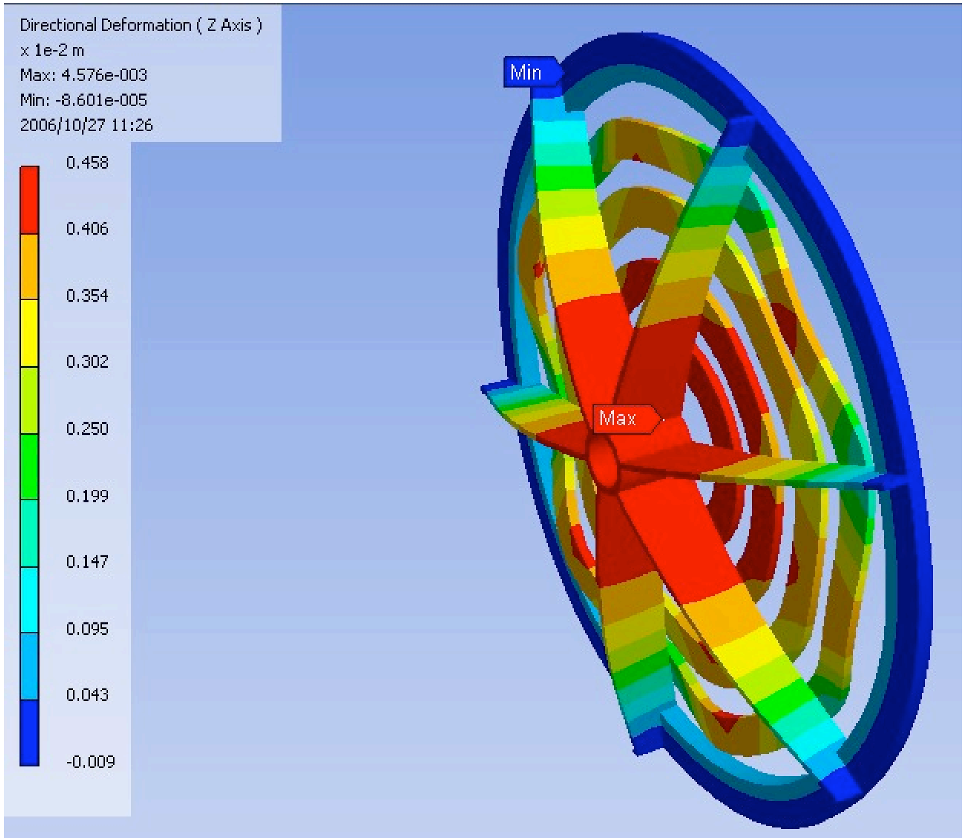
center of detector

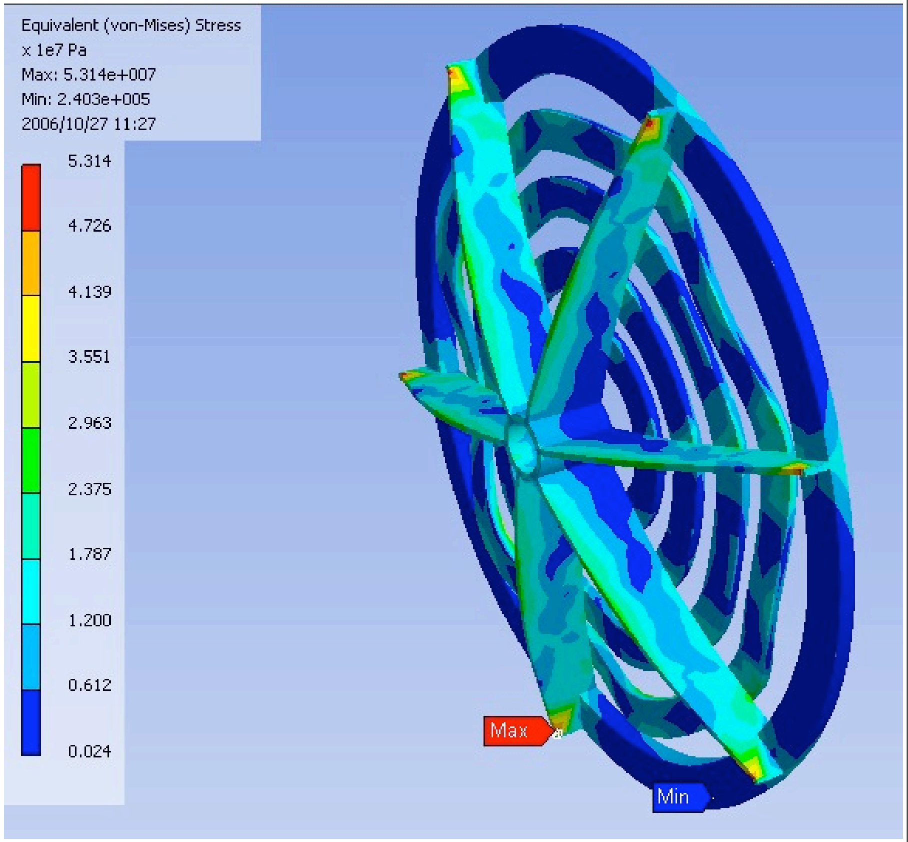
J(A/mm^2): 1; 8; 4.2; 3.3; 3.7; 1.7
Force(tons): 1.75; 102; 131; 135; 111; 10

- 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

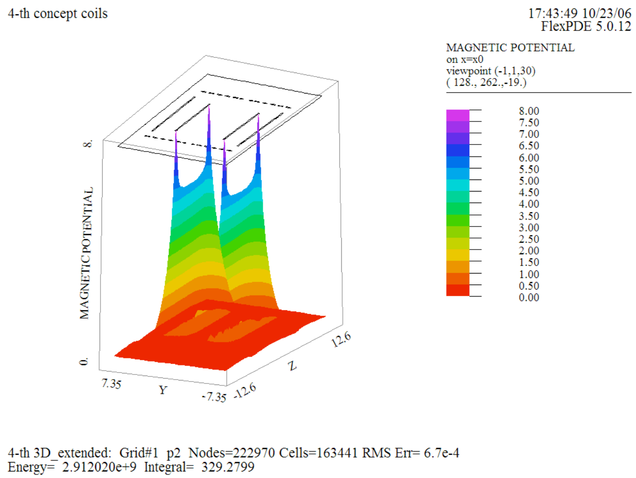
Maximum deformation is in z, it is less that 5mm, and in the middle of the holder. Active movers and reinforcements can compensate this.





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

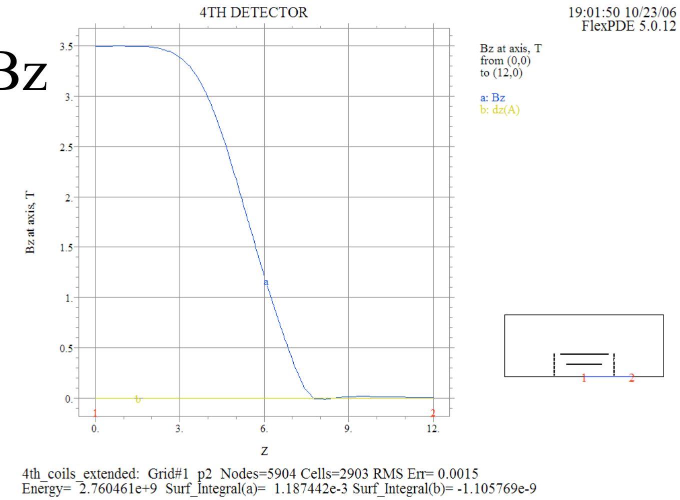
For tracking field homogeneity the current density in main coil has a quadratic longitudinal dependence. In a simple sense, it is a Helmholtz-type system with increased current at the ends.

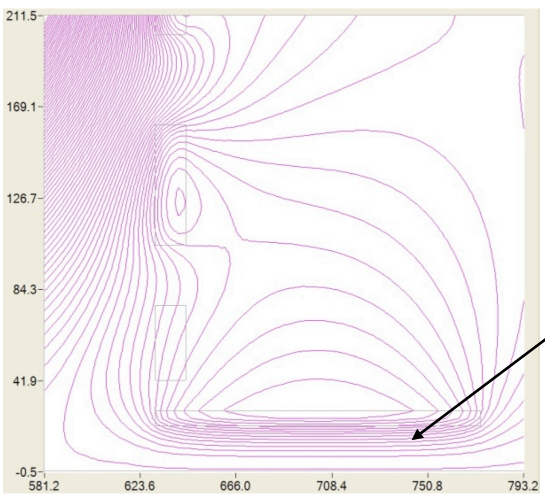


Magnetic potential

Stored energy is ~2.86 GJ for 3.5T axial field

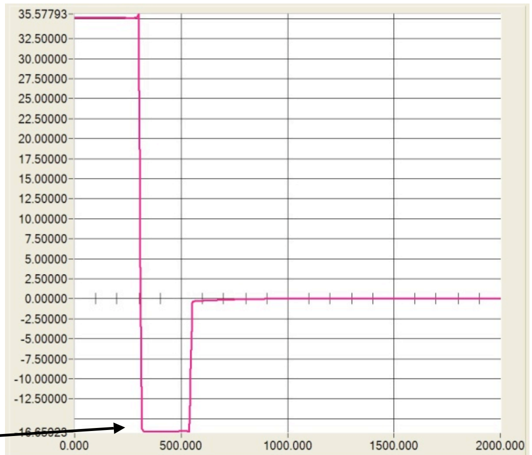
Bz





Compensational solenoid deals with residual part of transverse kick

Field for muon spectrometer



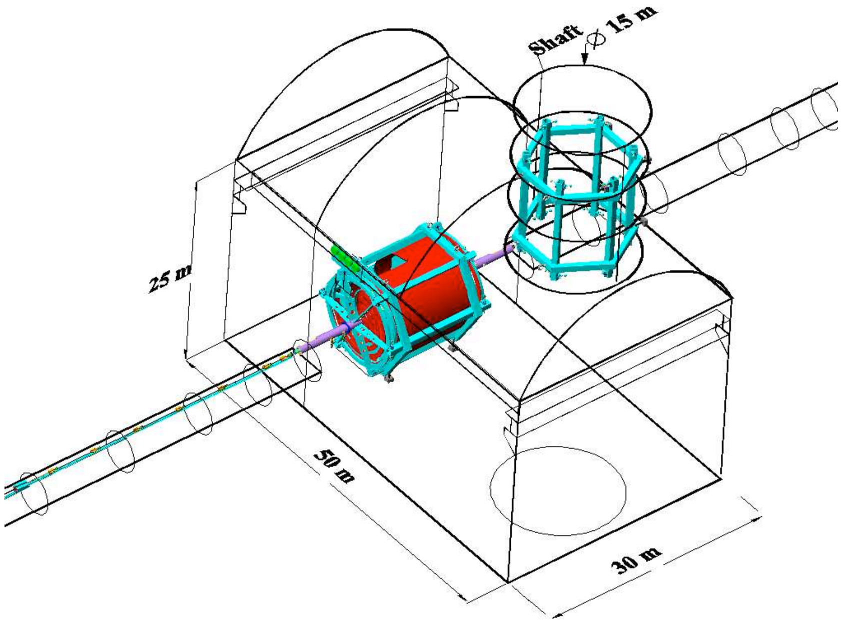
Field across detector

Surface (SX) assembly

- **surface space and volume**
  - 50m x 50m for assembly and storage
  - headroom of 30m
- **crane**
  - the largest and most massive single item is the outer solenoid; it will be assembled at the surface from five pieces, like the CMS solenoid, and inserted into its cryostat on the surface. We could use the full 50m x 50m with crane access.
- **calorimeter wedges**
  - the fiber dual-readout calorimeter consists of about 100 10t scalable modules in a truncated pyramid geometry. Assembly of arrays of calorimeter wedges can be done before lowering into the UX.

Underground (UX) assembly

– **Space and volume**
  - 30m x 50m x 25m is ample space
– **Crane**
  - 225 t (~ CMS coil cold mass) - this is maximum
  - Calorimeter in 10t wedges
– **shaft size**
  - 15 m diameter
– **disassembly and access**
  - Titanium frame;
  - wall of coils
  - muon chambers
  - calorimeter wedges



Repositioning accuracy & alignment

The absence of iron means that almost all points in the detector, even some interior points, can be viewed from an outside single point, or a few points. This opens up many possibilities for alignment, most naively, optical alignment to a wavelength with lasers.

- transverse and vertical position: ~ 1 micron
- along the beamline: ~10 microns
- rotational angles around three axes: ~1 micron over 5m
- intra-detector misalignments: optics by line-of-sight and, most importantly, the huge forces on an iron volume in a magnetic field are absent.
- probably limited by thermal expansions in different parts of the structure.

Opening procedures

- on beamline
  - move Lumi/Beam-Cals out
  - move wall-of-coils out 2m
  - lift muon spectrometer chambers out vertically
  - move calorimeter modules out axially

At this point, the interior and the tracker ends are accessible. The FF support has not been moved.

- the tracking chamber can be ‘push-pulled’ to the other end
- vertex chamber is moderately accessible in this position

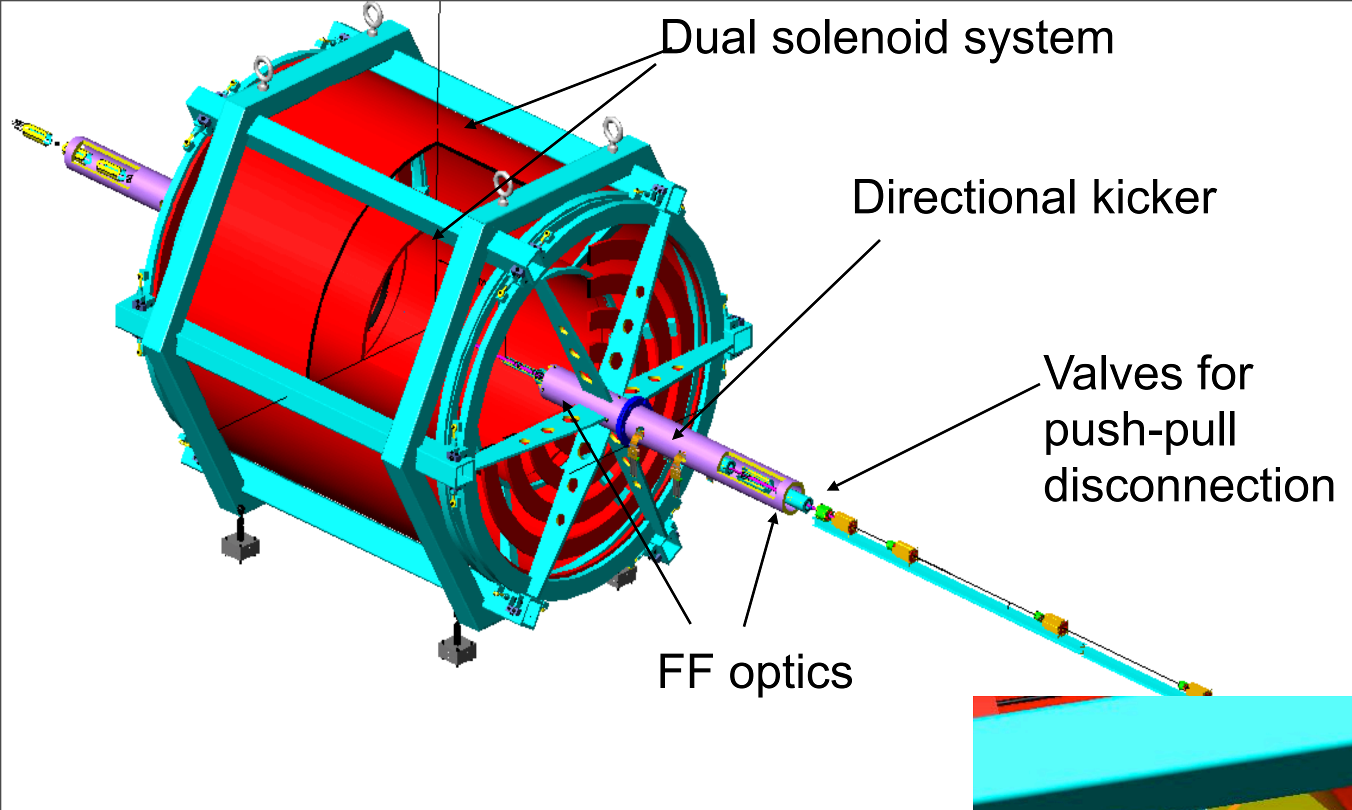
Opening procedures

- off beamline
  - move Lumi/Beam-Cals out
  - remove FF optics support tube, containing vertex chamber
  - move wall-of-coils out 2m
  - lift muon spectrometer chambers out vertically
  - move calorimeter modules out axially

Final Doublet support

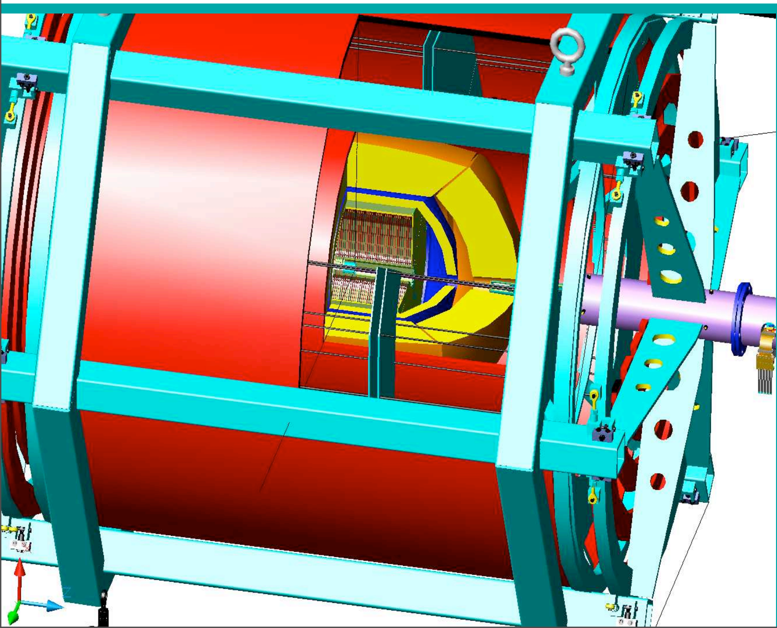
- The Final Doublet (FD) is attached to the detector as indicated in the figures on slides 2 and 3. Active corrections include slow mechanical and fast piezo-electric movers.

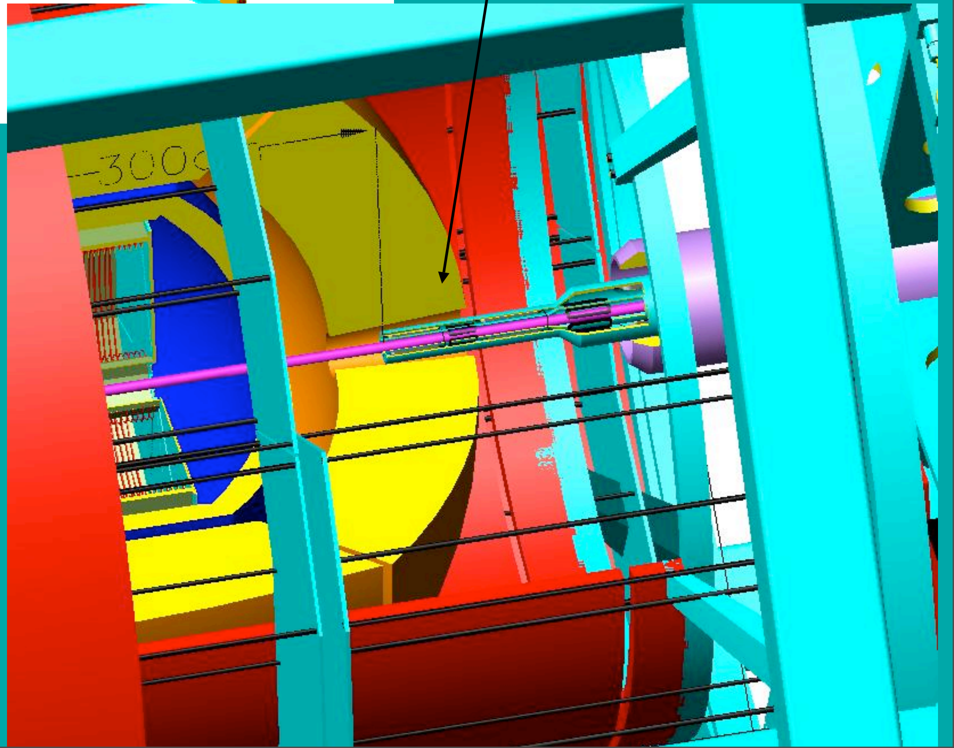
- The FF optics is integrated with the detector all the way to the vertex chamber, and all possibly cryogenic.



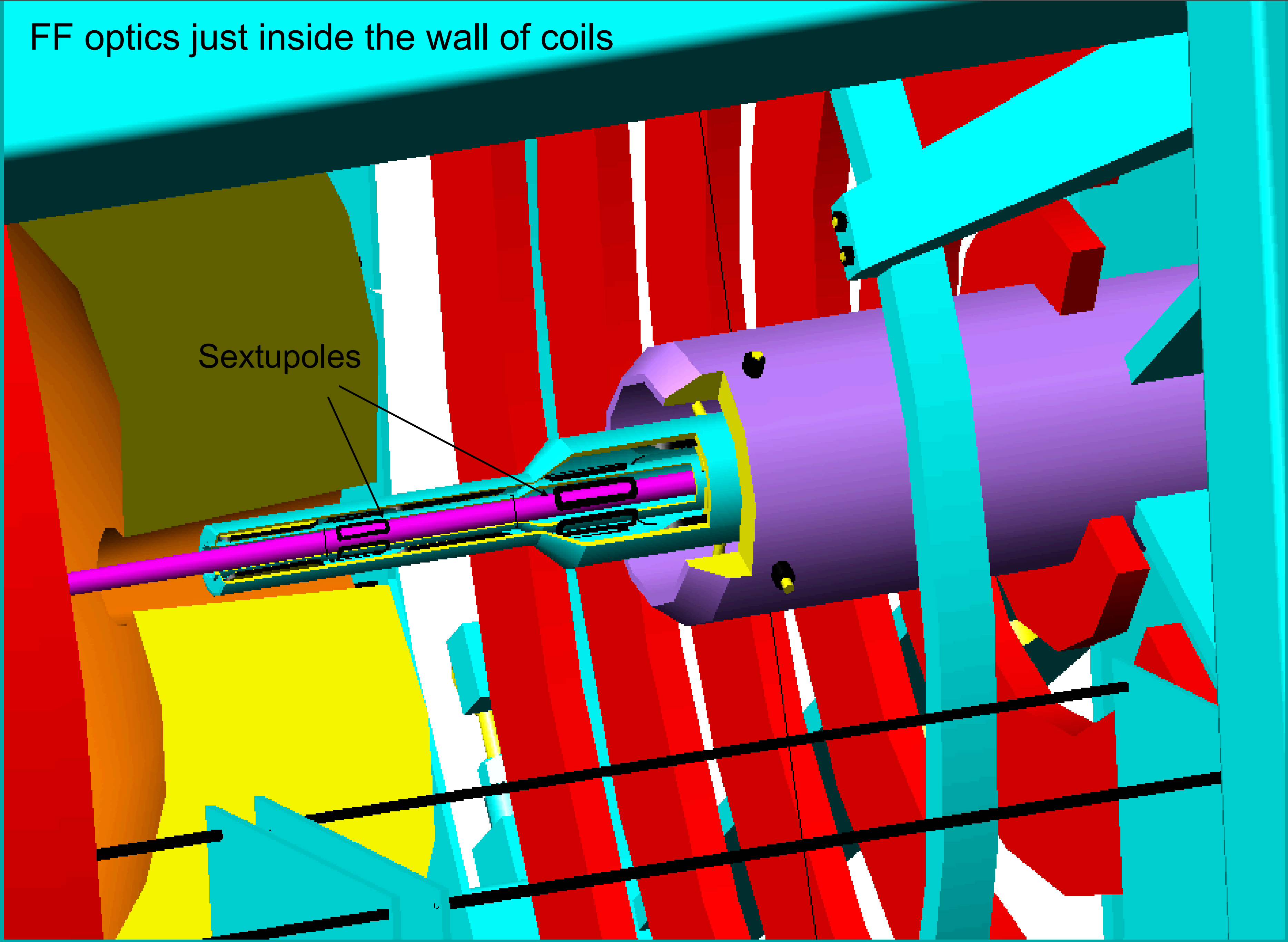
Final focus optics, mounted inside a cylinder attached to the detector by consoles.

This reduces influence of ground motion.

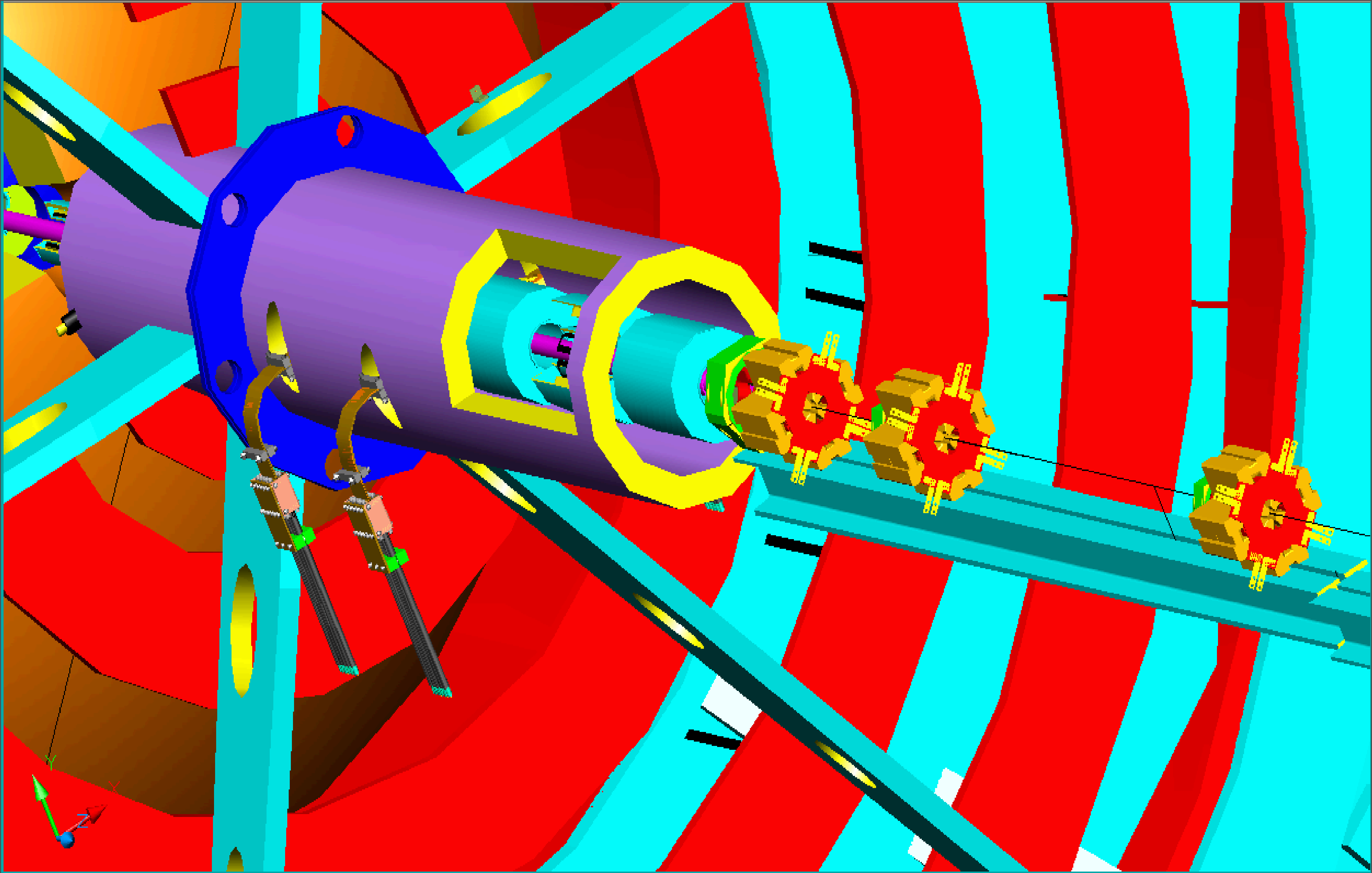




FF optics just inside the wall of coils

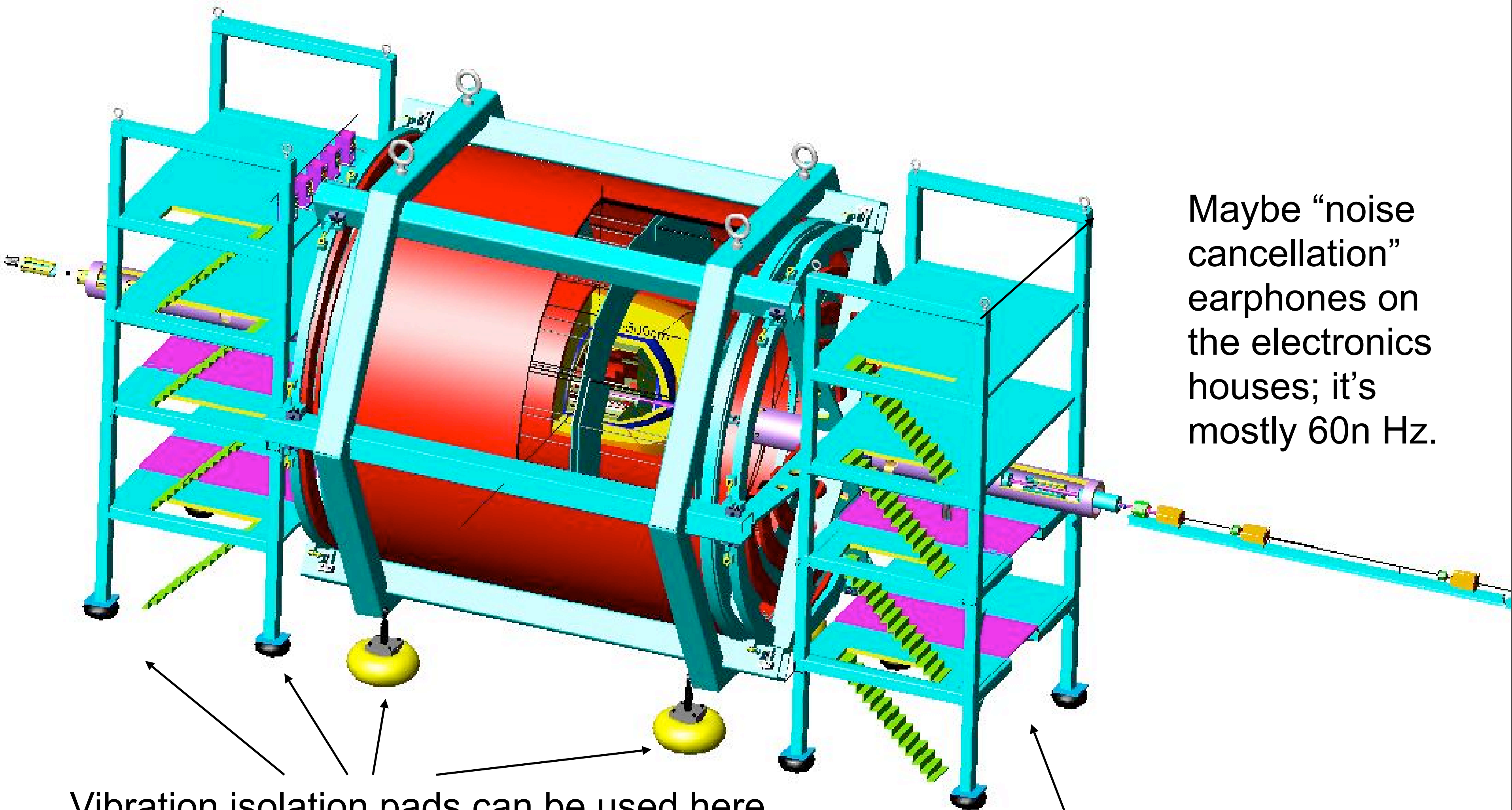


Cryostat with single bore quads and sextupoles



Detector FF optics from outside

It is not clear where to put the humming vibrating electronics houses (ends or sides), but like D0 they will move with the detector



Maybe "noise cancellation" earphones on the electronics houses; it's mostly 60n Hz.

Vibration isolation pads can be used here

During movement some restraints can be applied

Console (hut) has anti-vibration footers.

Forward Lumi/Beam-Cal supports

- The absence of Fe, and the Fe snout that captures the flux to be channeled around the detector, means that this region of the detector is wide open. There are muon chambers filling the volume out to the wall-of-coils at z=6.5m, a beam-twist compensation solenoid at small radius at z=7m, and open space after that.
- Therefore, the masks and calorimeters can be supported in a number of ways, either inside the 1.5m-deep fiber calorimeter or outside the calorimeter, and are easily moveable.

Inner detector beampipes

- What is geometry & sizes of inner beampipes, from IP to start of Final Doublet
- What is alignment accuracy needed for the internal beampipes and how it is achieved

This is not worked out; however, the entire FF optics and vertex chamber are inside one tube support through the detector, and with the open no-iron geometry we hope to align this tube after movement to some high precision.

Stability

- How is stability of FD supporting surface provided? (< 50nm rms/300 ns)
  - an active system can provide this stability
  - the FF beam delivery is isolated from the electronics racks and the IR hall, as well as can be done
- What rate of slow settlement (e.g. 100micron/ month) could be tolerated?
  - 10 mm/month correctable by mechanical and piezo-electric means is tolerable
- Temperature & humidity stability requirements, and acceptable gradients?
  - Active alignment and stabilization system takes care of these

Radiation shielding without iron

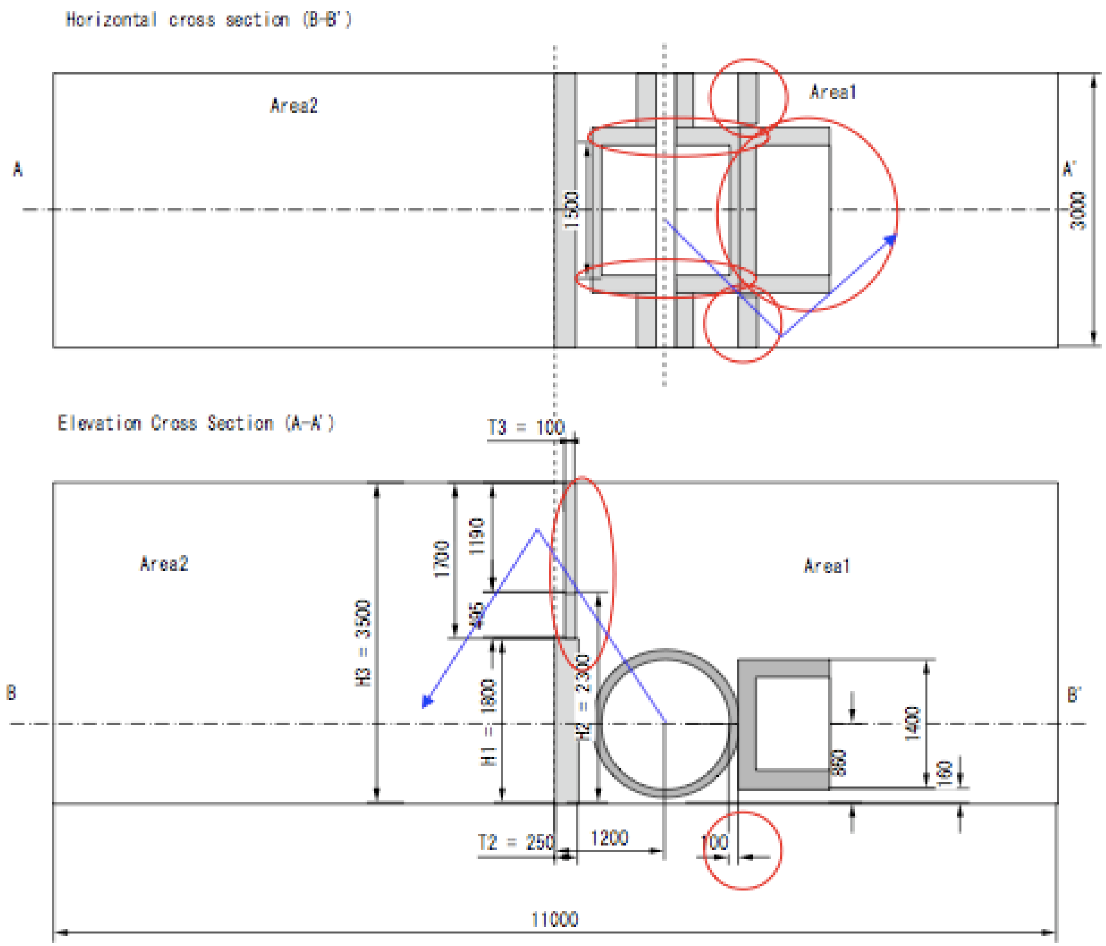
T. Sanami and A. Seryi have calculated the doses in the IR for an unshielded detector, e.g. 4th. This is excellent work that we could not have done ourselves:

"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.

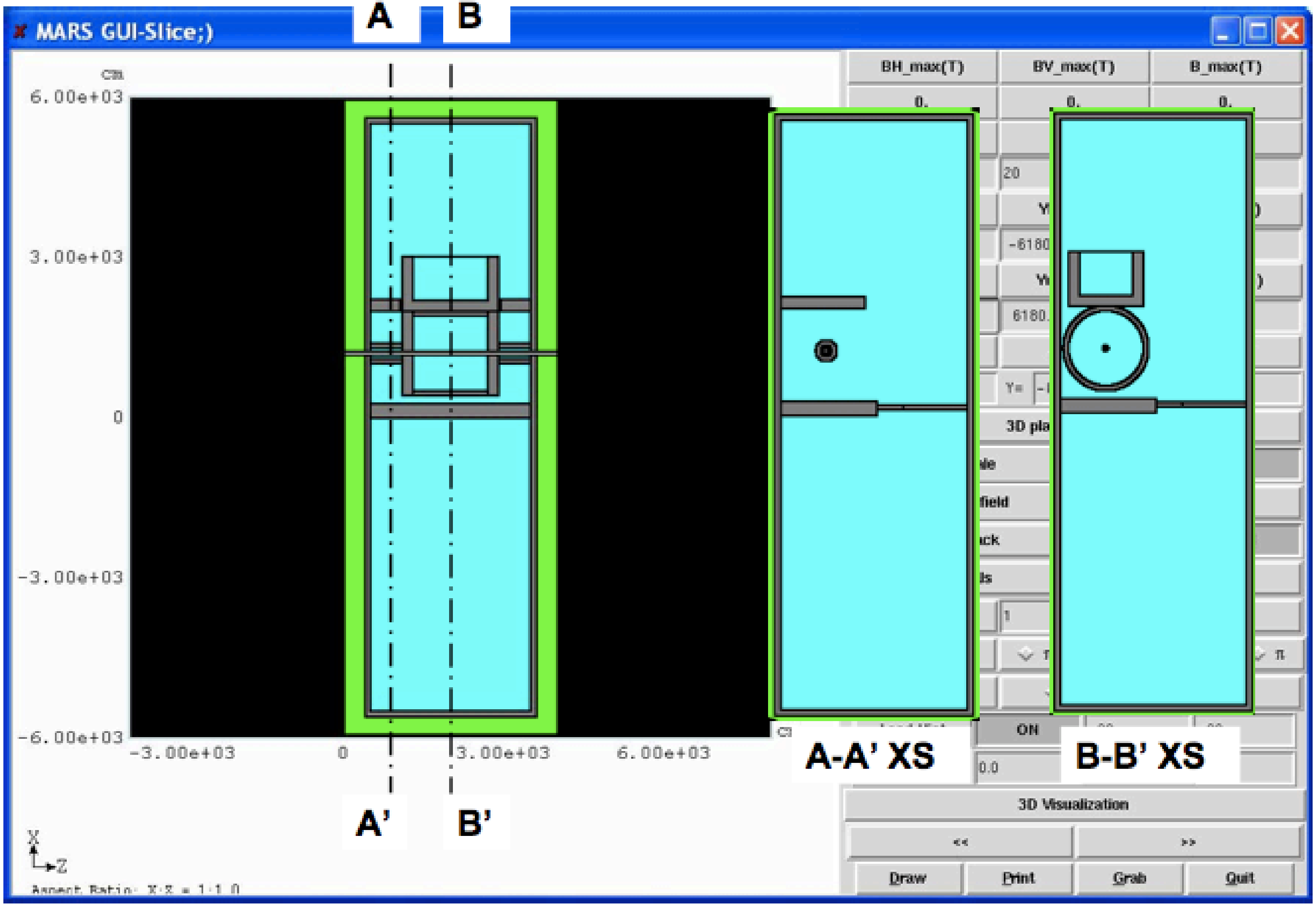
T. Sanami and A. Seryi

Case6, Higher curtain, local and supplemental shield

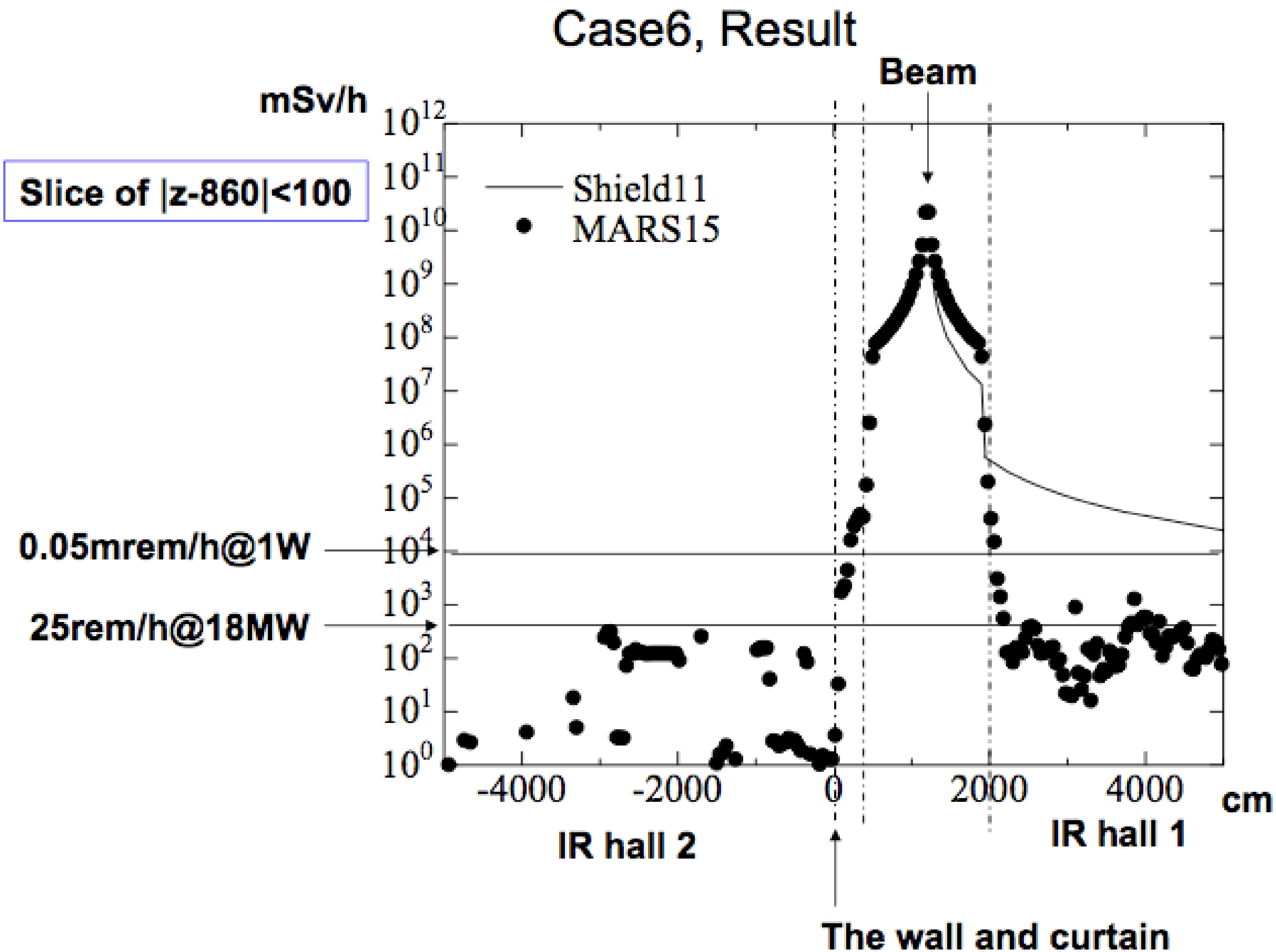


T. Sanami and A. Seryi

MARS15 geometry



T. Sanami and A. Seryi



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.

Services & connections

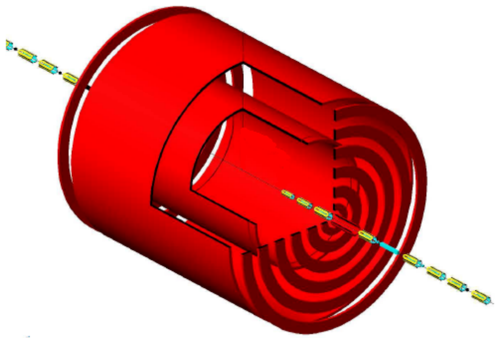
- What systems are connected to detector and travel with it and what are remote and fixed
  - The inner solenoid is essentially the CMS solenoid; the outer solenoid is easier. Not sure about remote/fixed.
  - electronic racks are proximate to detector, but vibration isolated.
- Parameters of these systems
  - Same as CMS for solenoids.
  - 4th has a modest number of channels, in particular the calorimeters have ~100K channels with on-board electronics

Fire safety

- **no flammable gas mixtures used underground**
  - OK
- **only the halogen-free cables can be used**
  - OK, CMS HF HV
- **smoke sensors with sufficient granularity installed inside the sub-detectors**
  - OK, detector is largely “open” to access almost everywhere

Mechanical structure

- Note by Bob Wands, 20 October 2006.
- The current first-cut design of the dual solenoids has a few problems, but no show-stoppers.
- The huge forces on Fe inside a B-field are absent.



4th Concept Detector at Fermilab
19-20 October, 2006

Fermilab

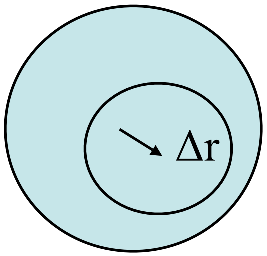
PPD/MD/Engineering Analysis Group

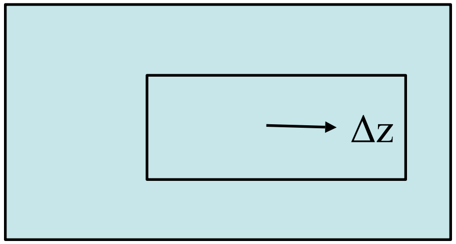
Magnets and Supports

Bob Wands October 20, 2006

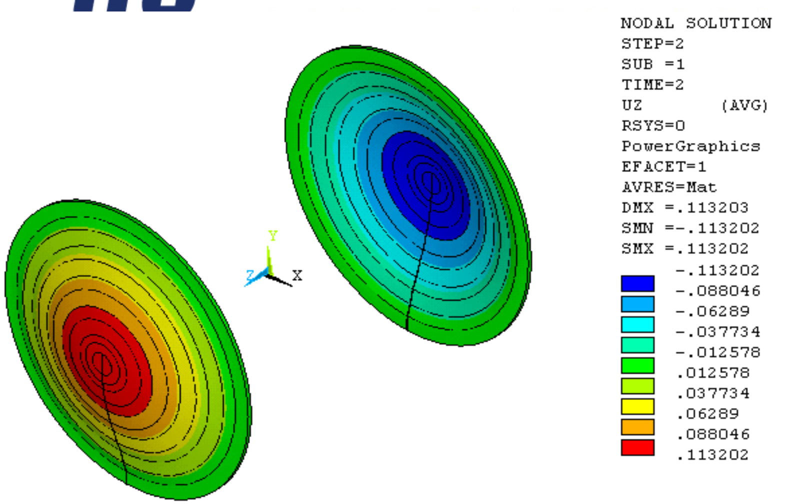
Magnetic field analysis; coil technologies; preliminary structural calculations; modal analysis

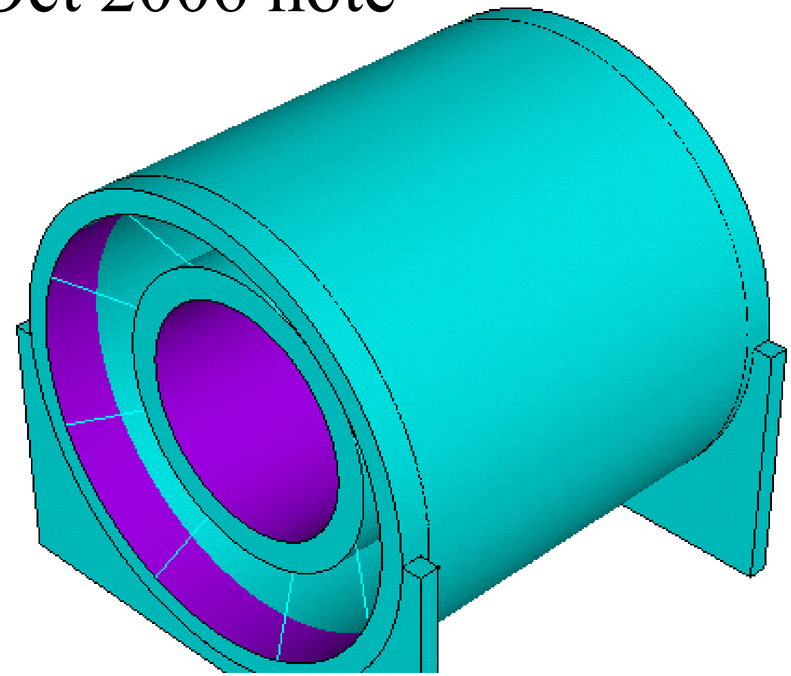
- Stored energy 2.86 GJ
- Radial force is decentering ~ 0.4 t/mm
- Axial force is centering ~ 0.8 t/mm
- We need to relieve forces on coil ends
- Optimize, but no show stoppers
- Excellent note on conductor options, mechanics, support, remedies, solutions

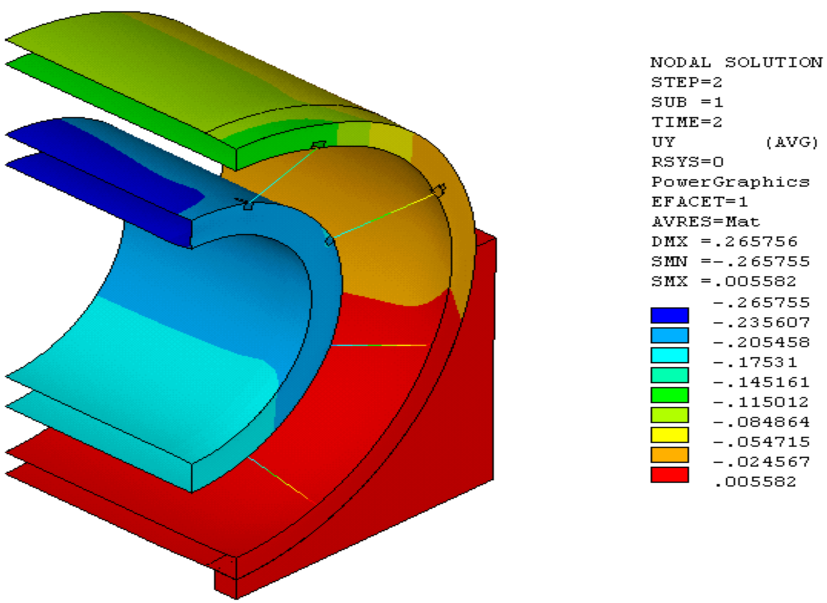


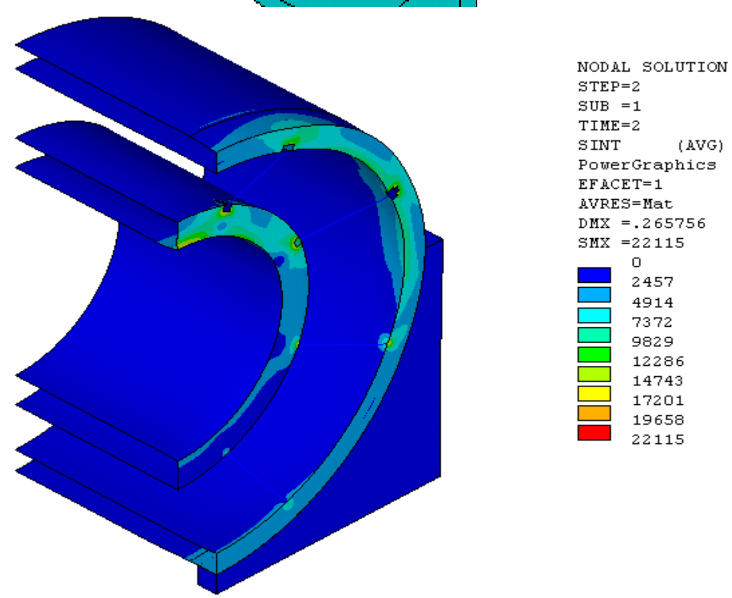


Bob Wands, 20 Oct 2006 note



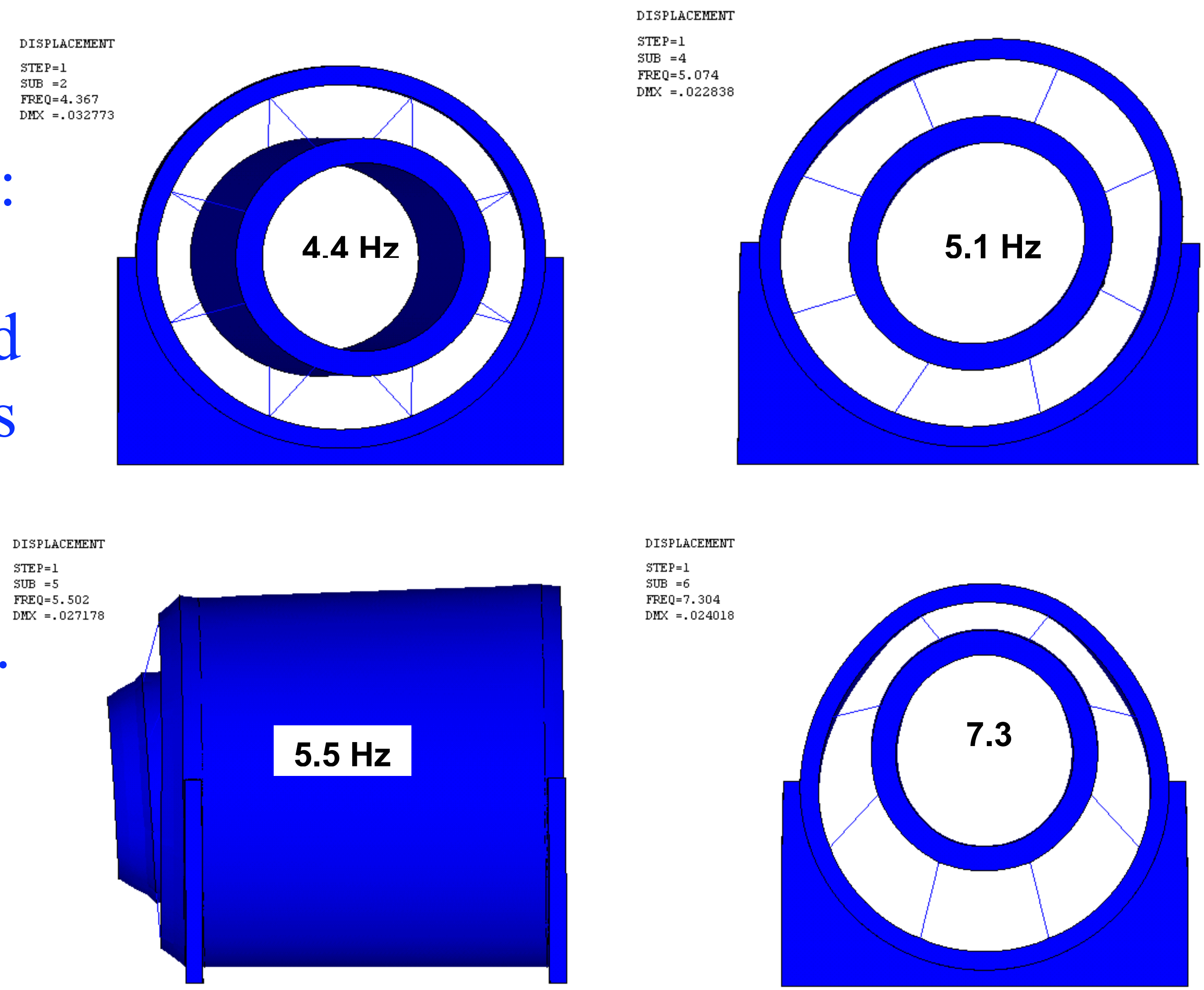






Seismic safety

Bob Wands modal analysis: these low frequencies and their harmonics will likely be a problem for ground motion.



Other issues: a neutron sink

- Problem: neutrons of a few MeV are liberated in the hadronic calorimeter at a rate of ~ 40 neutrons per GeV of hadronic showering energy. They proceed to fill the IR with a constant ambient level of thermal neutrons that can provide backgrounds in gaseous trackers and some electronics.
- Solution: line walls of the IR (or the detector) with a wax-Gd-wax-Gd-wax neutron sink.

Iron Age physics: why we don't like it

- 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 $75M.

Let me end with, rather than having begun with, some "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$\rightarrow$ -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 is easier; and,

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

backups

Other issues: a better solenoids

- the CMS is our standard, just like the SiD 5T.
- but, it is 20 years old. The world needs a better, cheaper solenoid.
- We should team with BINP physicists who built a couple of nice, but small, solenoids. Series

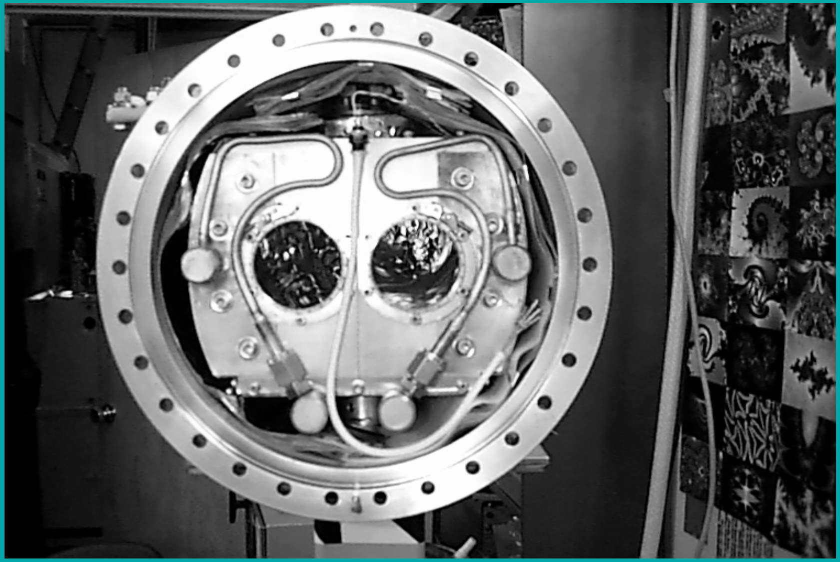
radius (m)	beam test purpose
0.3	vertex
1.0	tracker
3.0	tracker+calorimeter
5.0	experiment prototype

- at 2 x \$200M + push-pull costs, this is one BDS.

14 mrad crossing angle can be accommodated by 4th CD frame

Active system supposed to be in use for moving the lenses. It eliminates influence of asymmetric deformations induced by ponderomotive forces and ground motion

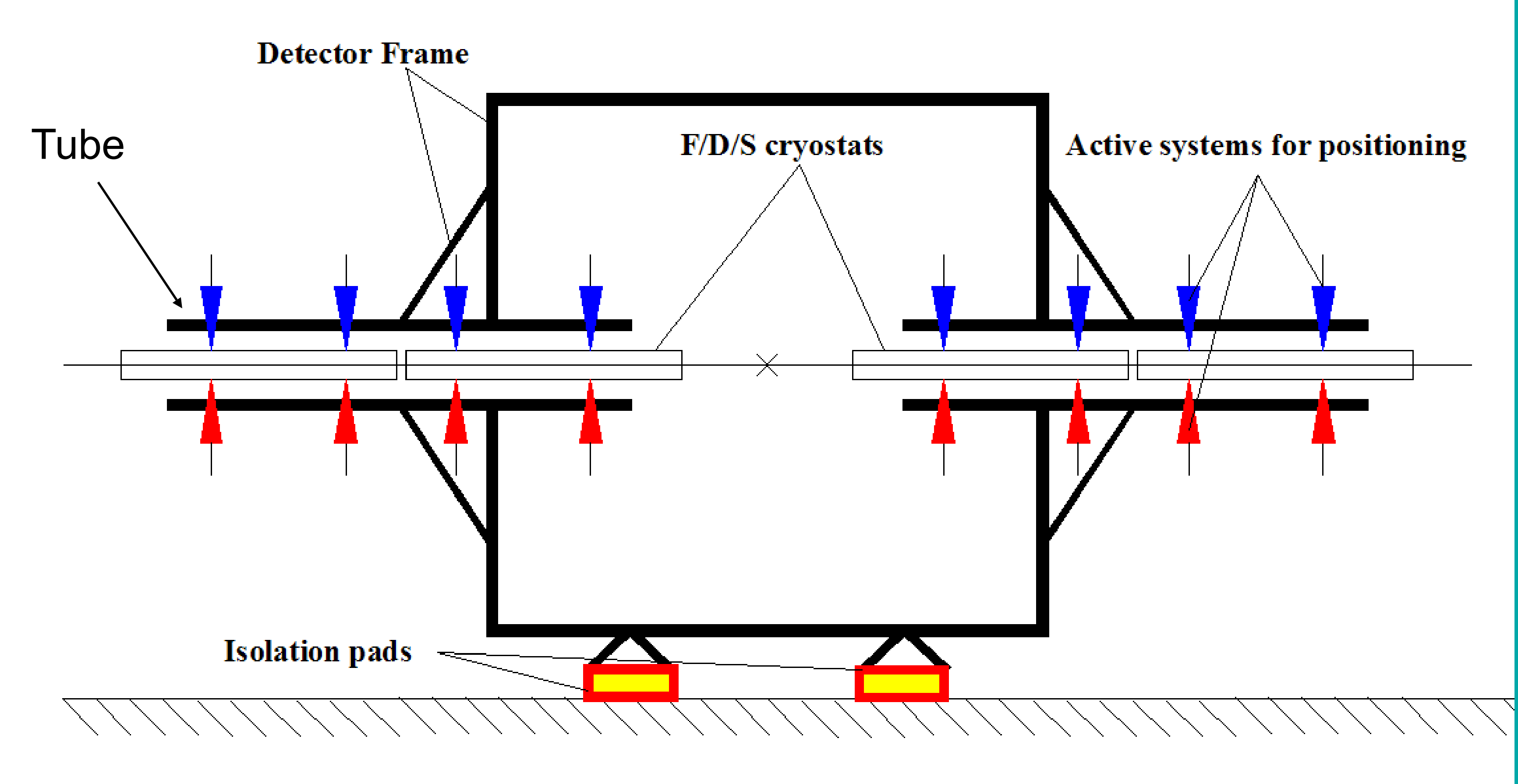
In addition to standard optics we are considering the adiabatic final focusing with local compensation of chromaticity and residual dispersion at IP



Dual bore SC quadrupole developed and tested at Cornell.
Distance between room temperature walls ~25mm
Septum between SC apertures~5 mm

Beam optics with crossing angle might look pretty similar.

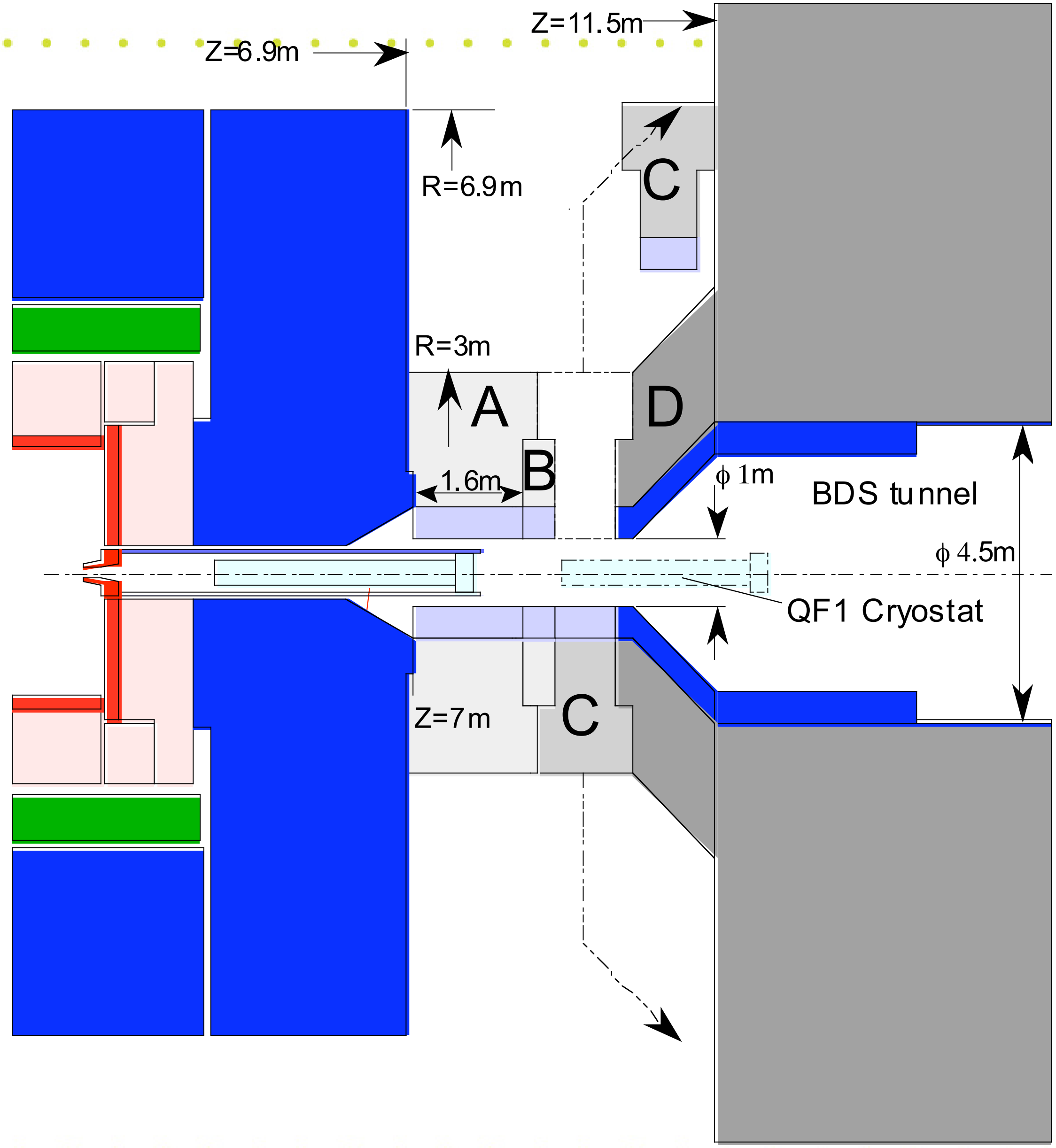
Concept of FF optics installation



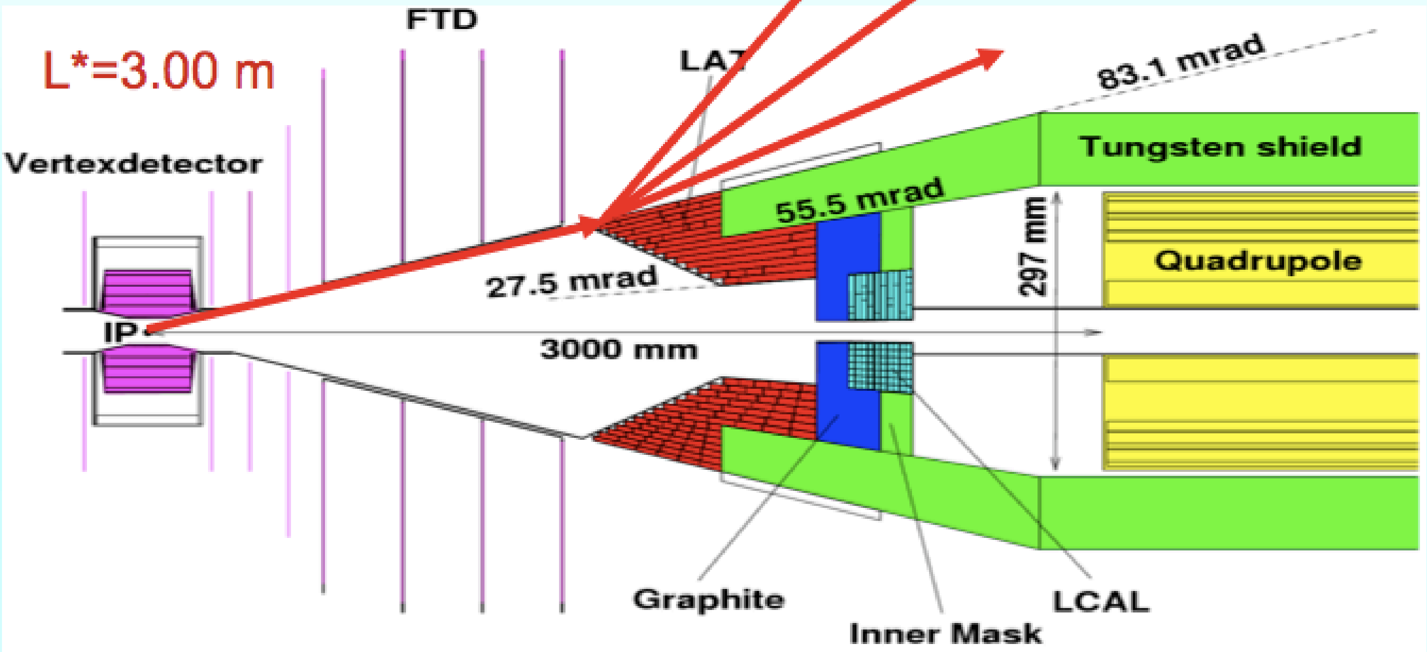
Active systems for positioning include stepping motor-driven micro-positioning movers plus piezoelectric fast movers with active loop feedback.

Thanks to the absence of iron all elements are visible from single point.

GLD


Z=11.5m
Z=6.9m
R=6.9m
C
R=3m
A
D
1.6m
B
ϕ 1m
BDS tunnel
ϕ 4.5m
QF1 Cryostat
Z=7m
C

IR Design L*=3m (TESLA)

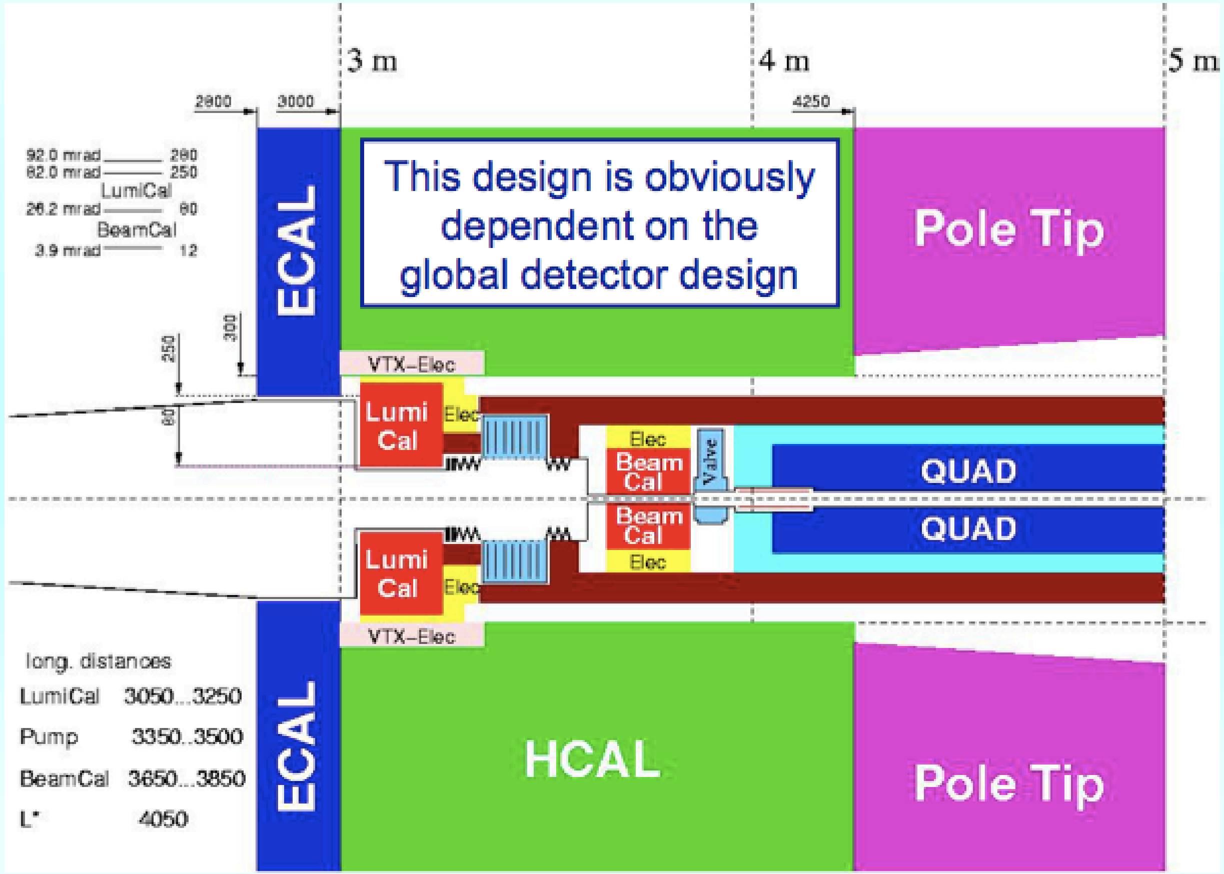


Problems:

- Precision Luminosity measurement with LAT is difficult
- Hermeticity gaps (LAT-ECAL)
- Fake photons

K. Büßer 1st ILC Workshop 14.11.2004

Proposed Design for L* ≥ 4.05 m



Design by Achim Stahl

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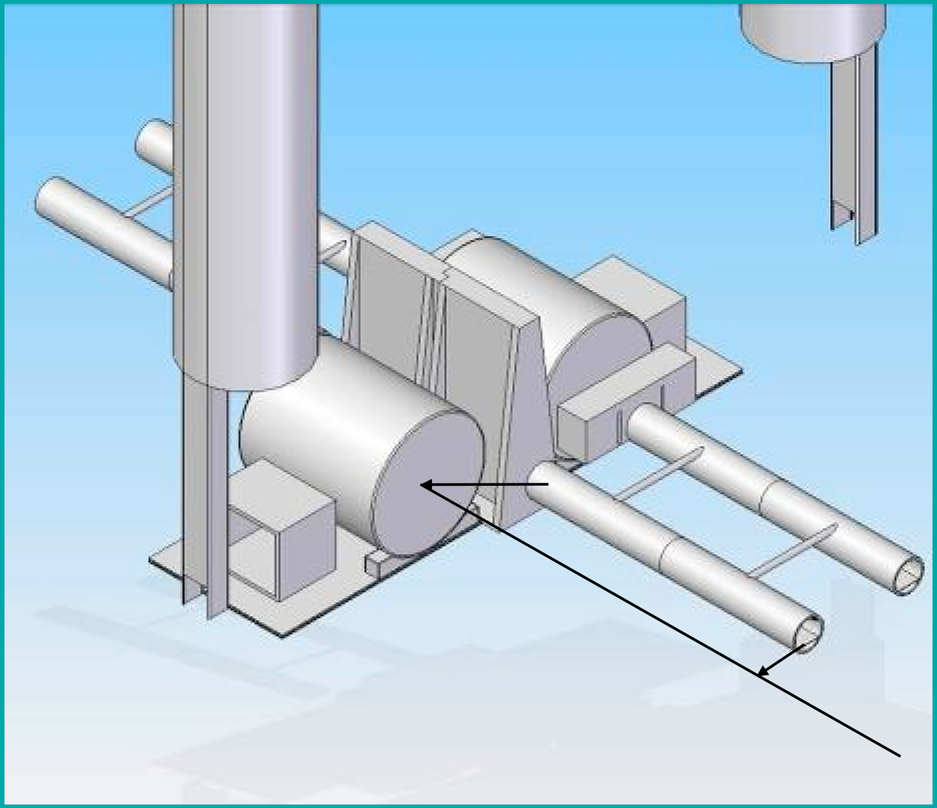
One recommendation…



The service tunnel must be shifted so its axis runs through the center of second detector even the only one detector will be in operation at the beginning.

This is in case …