# SoLID Magnet Update

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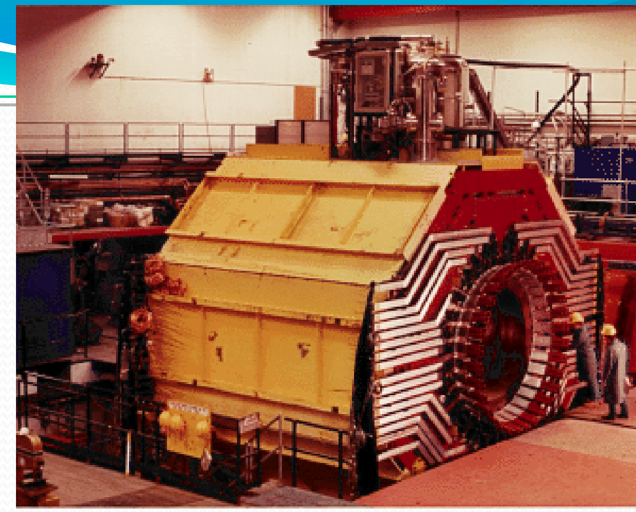
SoLID  Collboration Meeting

2013/03

# CLEO

- CLEO-II magnet was built in early 1980s by Oxford in England.
- Coil is divided into 3 sections, each section has two layers
- Coil total 1282 turns. Upstream: 166; Central: 309; Downstream: 166 turns per layer. The current density in the end sections is 4% higher than in the middle section.
- Max current is 3266A and average current density of 1.2MA/m, this reach 1.5T field



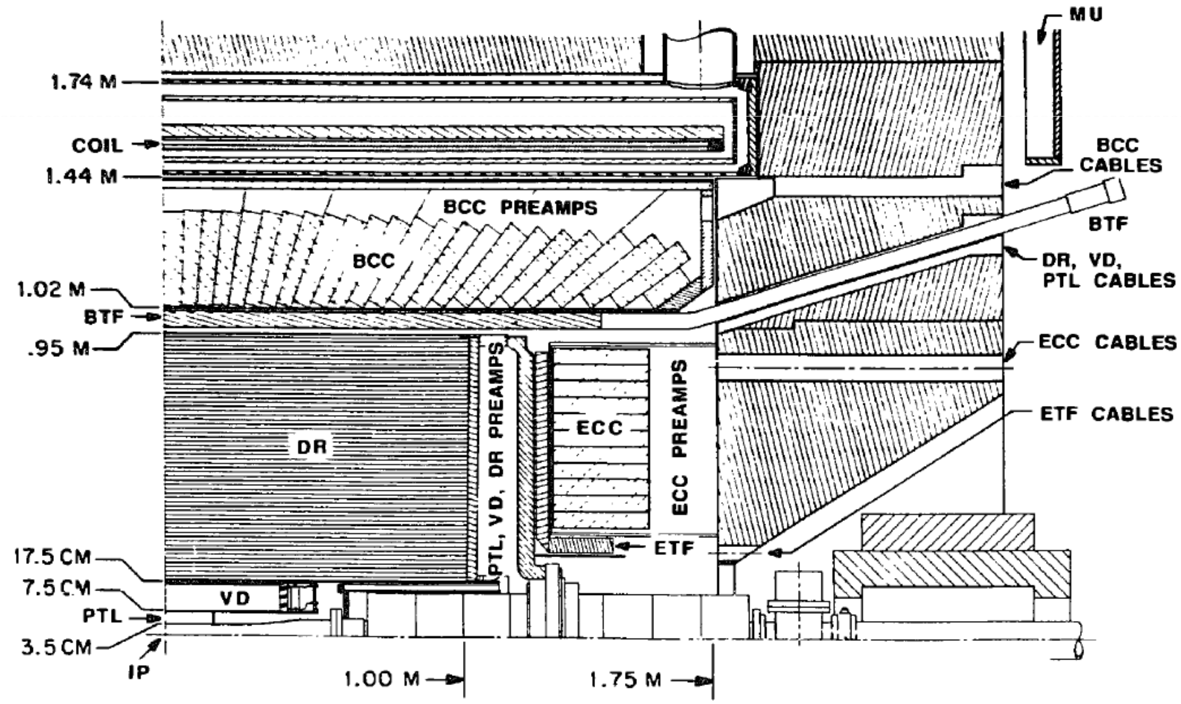
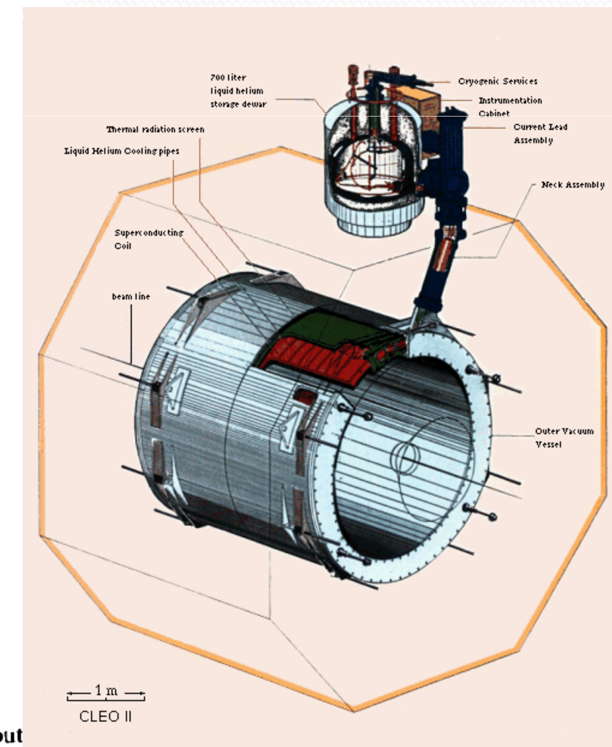
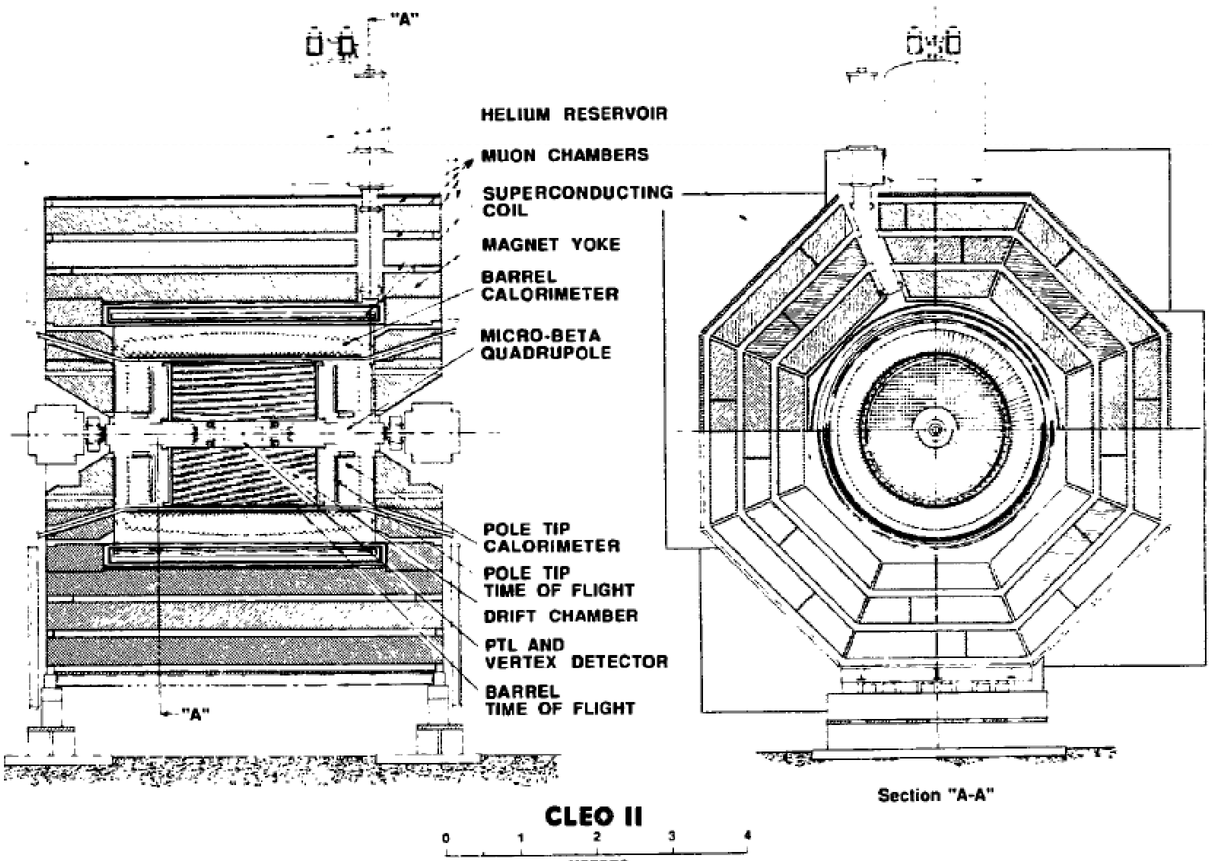


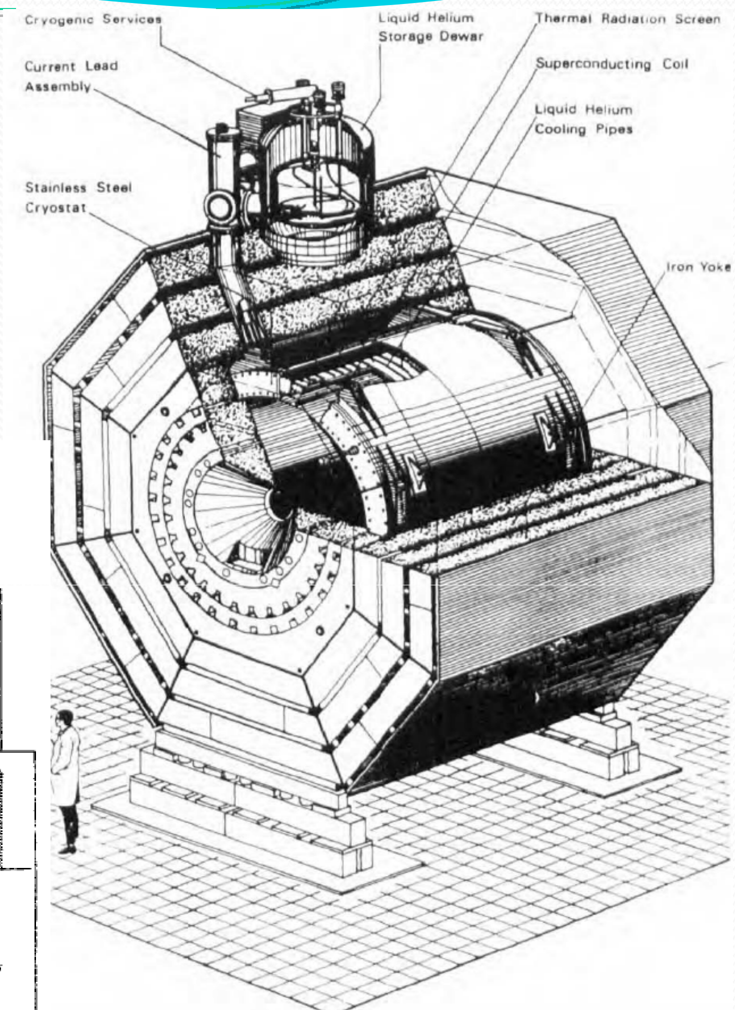

Fig. 2. Schematic Drawing of one quadrant of the CLEO II detector. The following acronyms are used – DR, VD, PTL: The out intermediate and inner drift chambers. TF, CC, MU: The time-of-flight counters, crystal calorimeter and muon identification system. P[illegible]



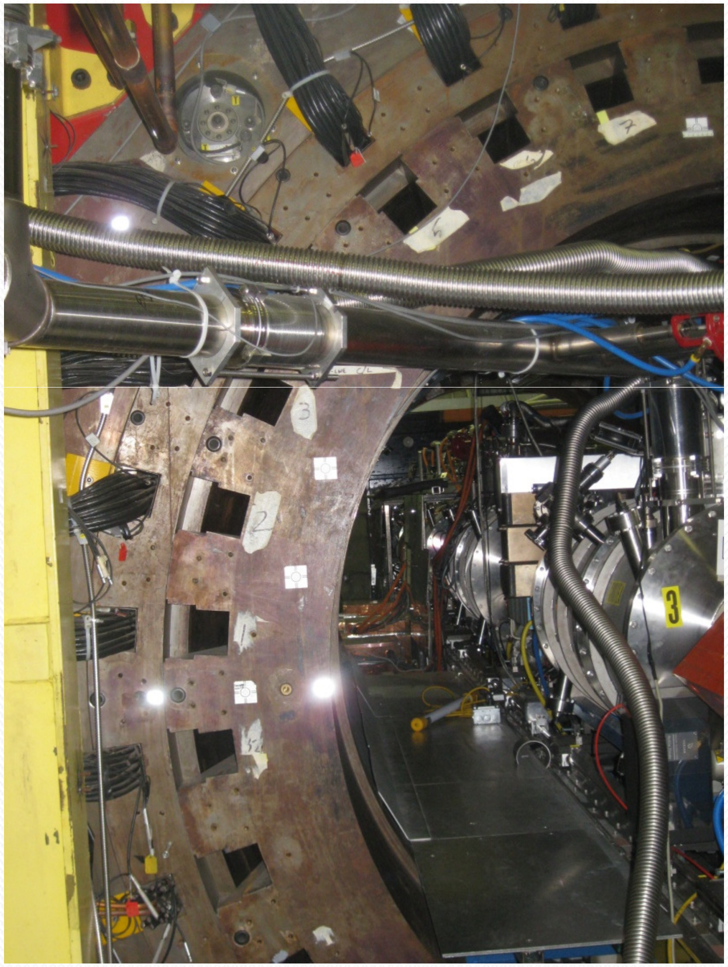
# CLEO

- Barrel flux return is provided by 3 layers of iron separated by spacers
- It's in octagon
- 2 collars supports barrel irons and holding 4 coil rods in horizontal direction.

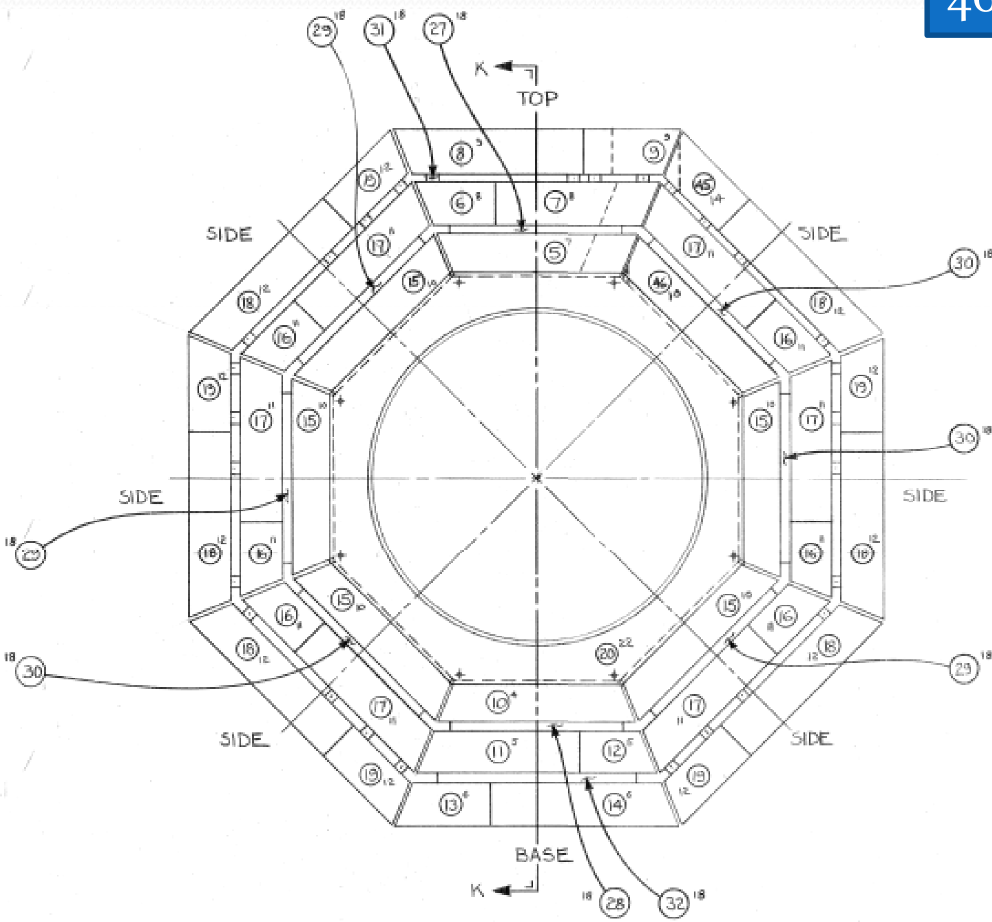


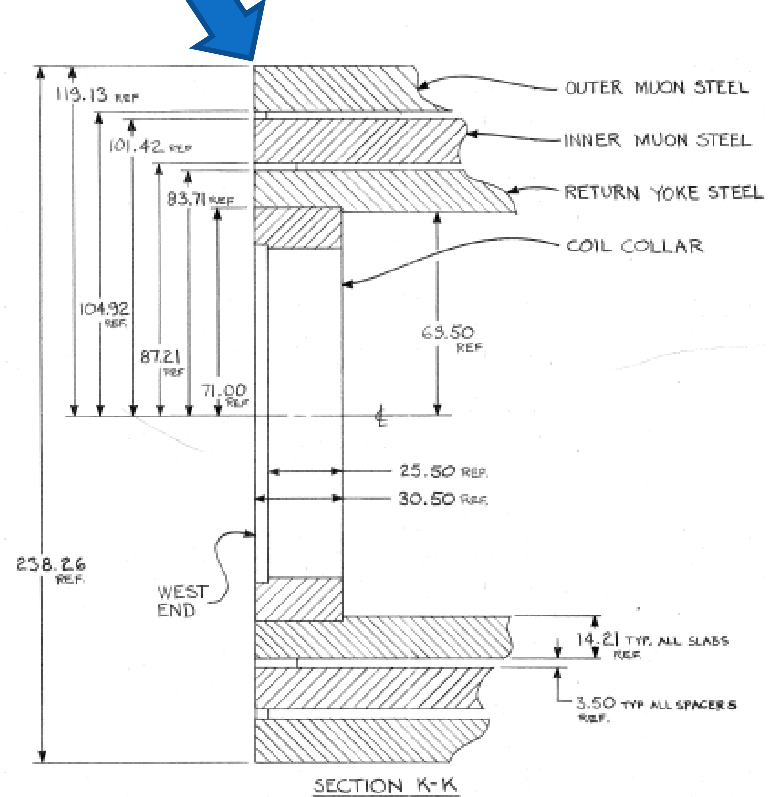



# Will Oren visited Cornell



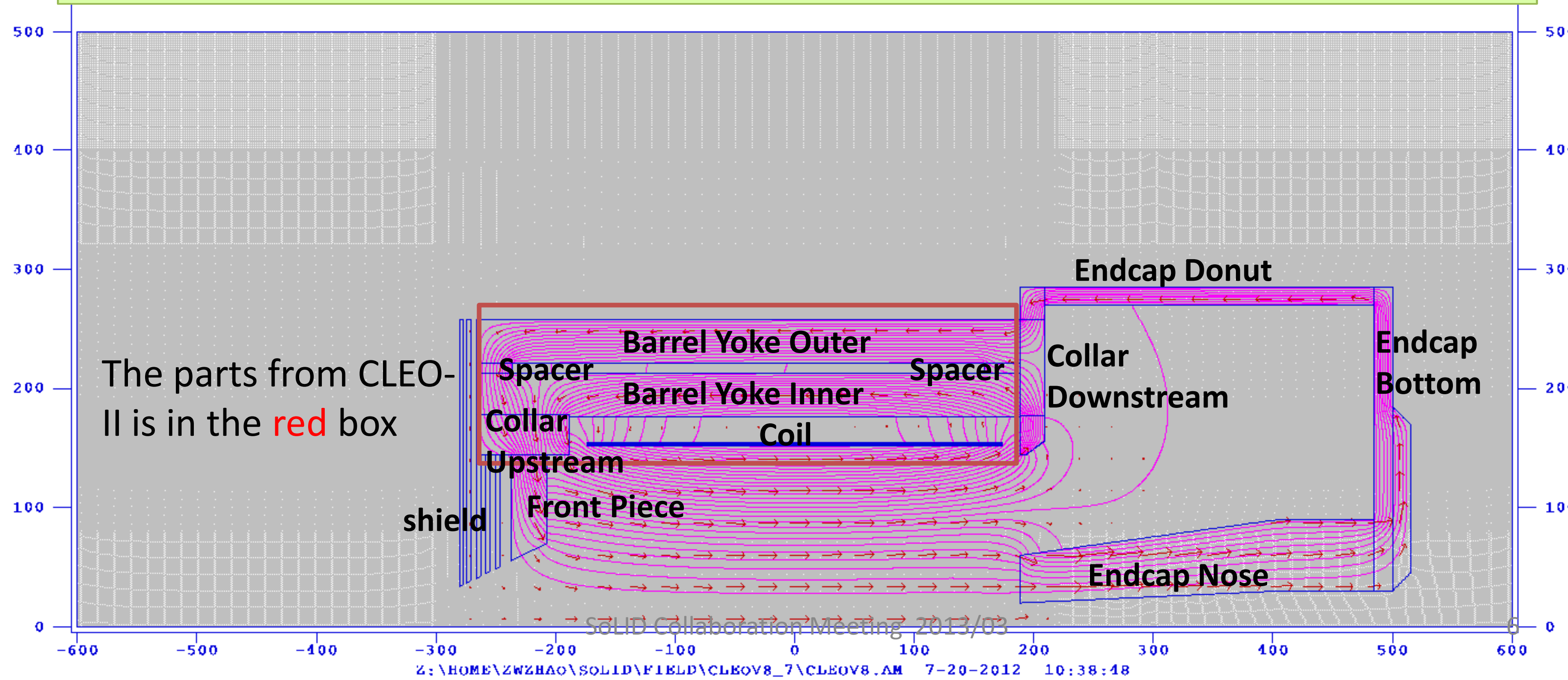
The outer layer 46cm thick



# From CLEO-II to SoLID (reused parts)

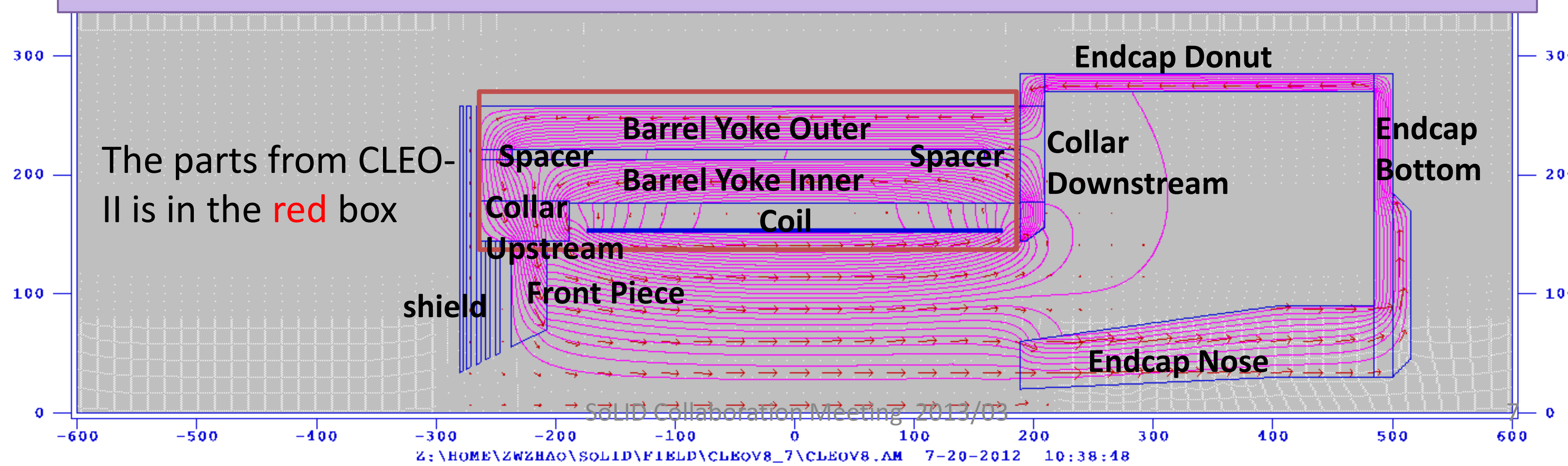
- Reuse coil and cryostat
- Take two layers of barrel yoke and spacer, keep the upstream ends unchanged, cut the downstream ends (75cm) to our need.
- Take the upstream collar unchanged, and cut the downstream collar or make a new one to satisfy the acceptance requirement.  Make sure the coil rods can still be supported by two collars under axial force
- All other parts of yokes are new.



# From CLEO-II to SoLID (new parts)

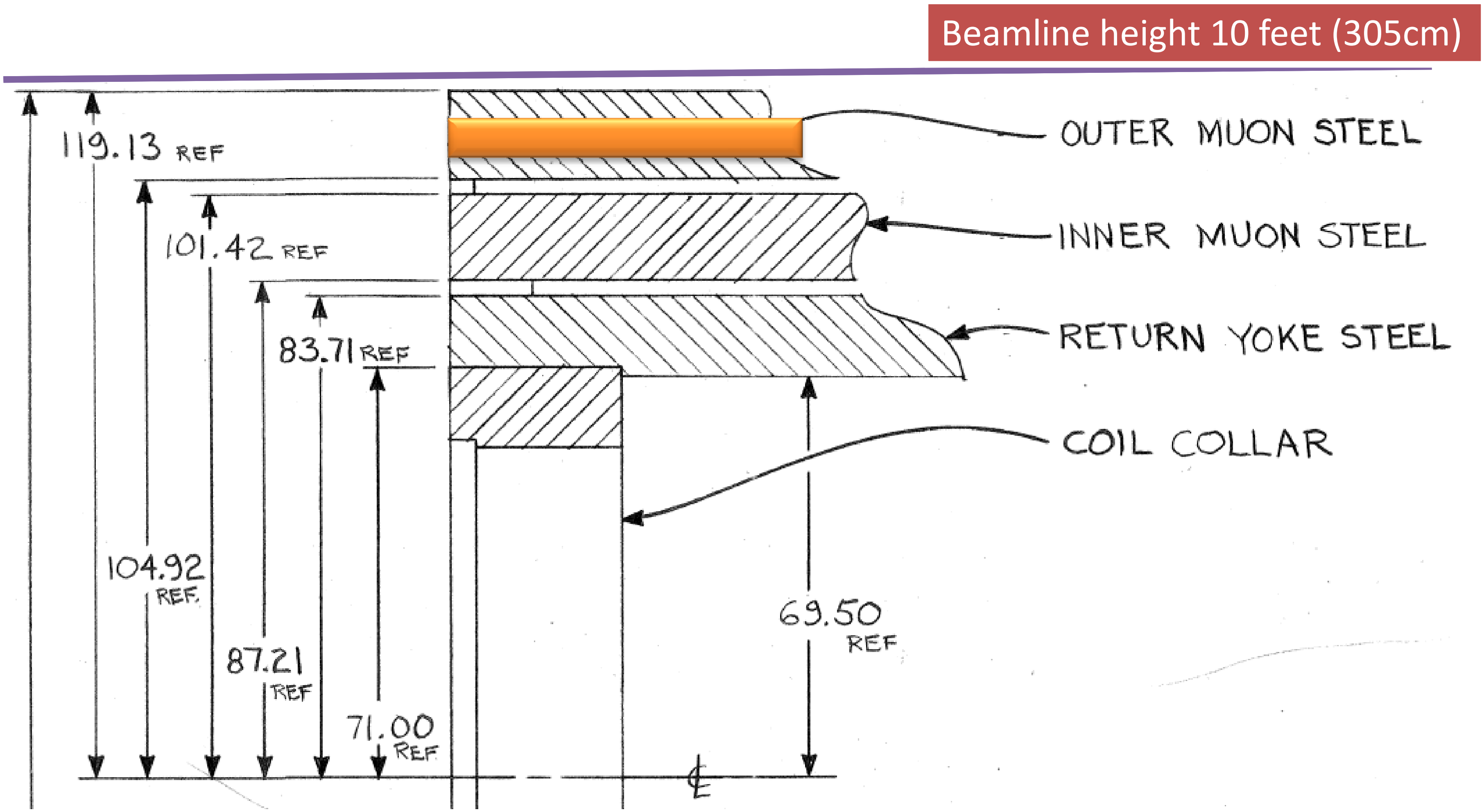
- All new parts need to be customized made.
- But it's unclear if they will be made of newly machined iron ($6/lb) or we can get some unused CLEO-II iron machined (cost?)
- We might try to use some "stock" parts to save machining cost.

- **Endcap donut: 15cm thick and has 15cm clearance to HallA floor (10 feet high)**
- Endcap bottom: two 15cm plates
- Endcap nose: flat at back to give clearance for SIDIS forward angle EC and has slope at front to give clearance for cherenkov.
- Collar downstream: 20cm thick and can be in one piece
- Front Piece: 30cm thick and can move along z to adjust force on coil
- shielding: a few 4cm thick plates with gaps in between.



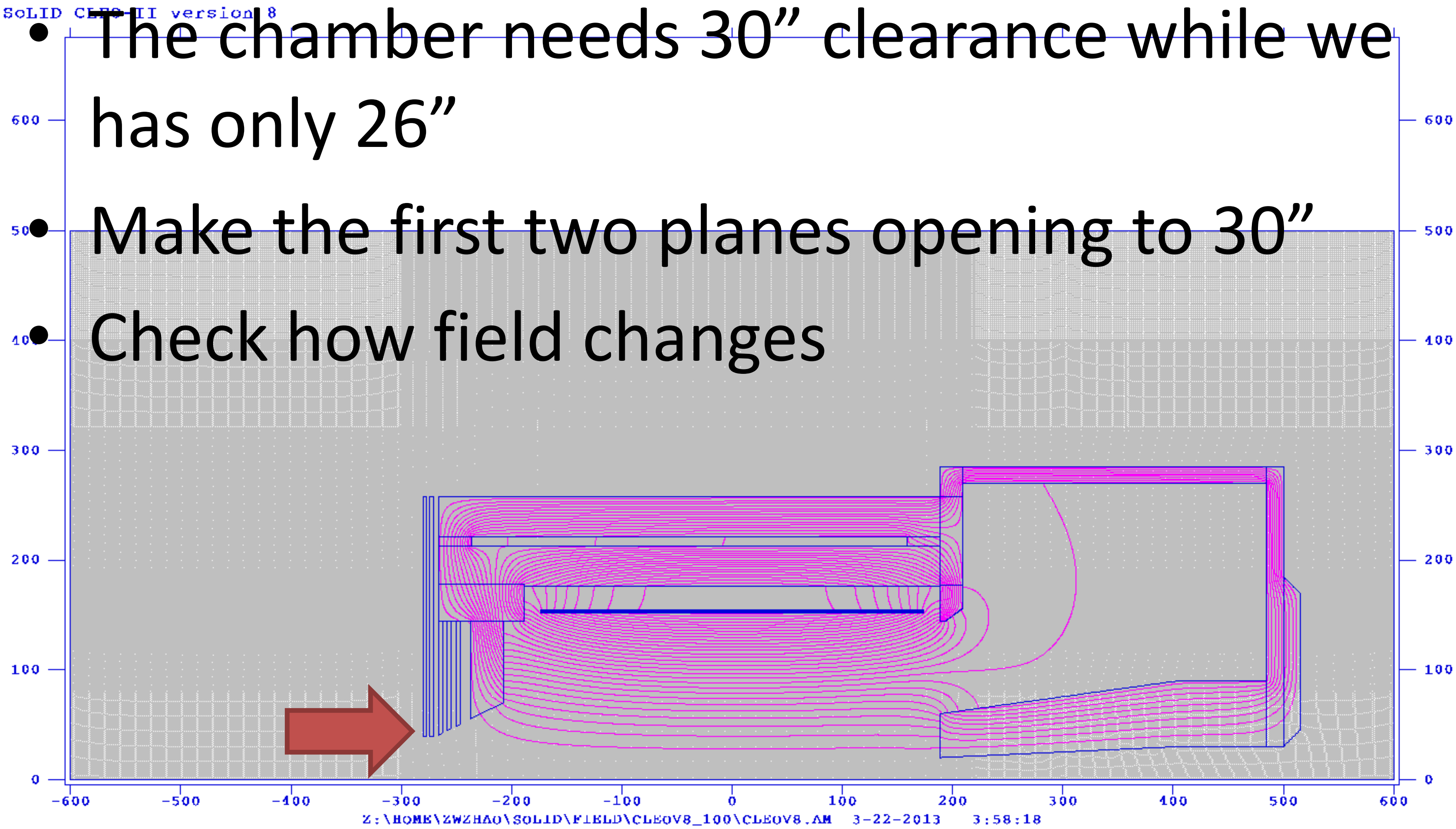

The parts from CLEO-II is in the red box

# Cut the donut (15cm thick, 276cm long) out of the outer layer (46cm thick, 533cm long)

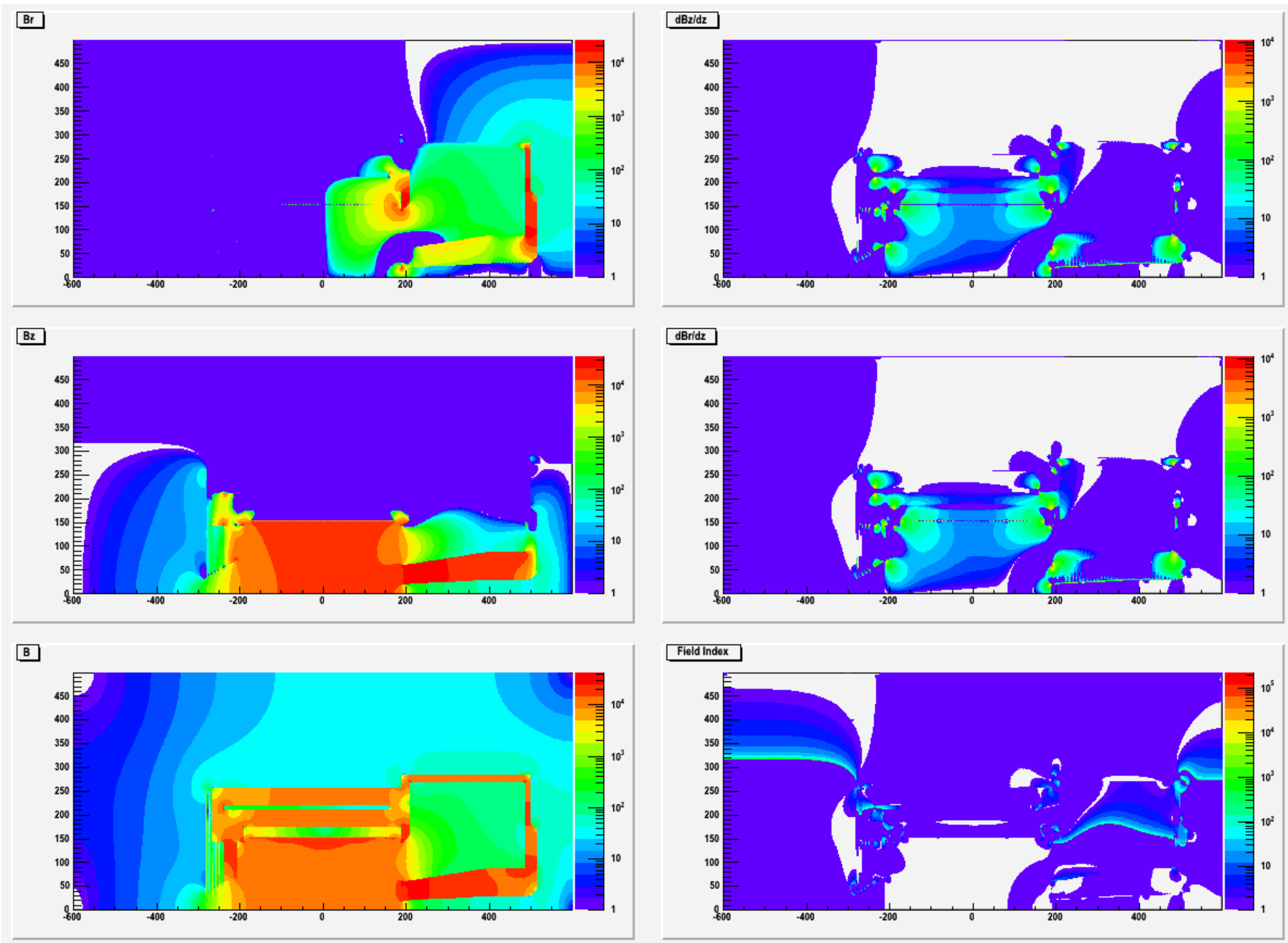


# PVDIS target requirement

- The chamber needs 30” clearance while we has only 26”
- Make the first two planes opening to 30”
- Check how field changes

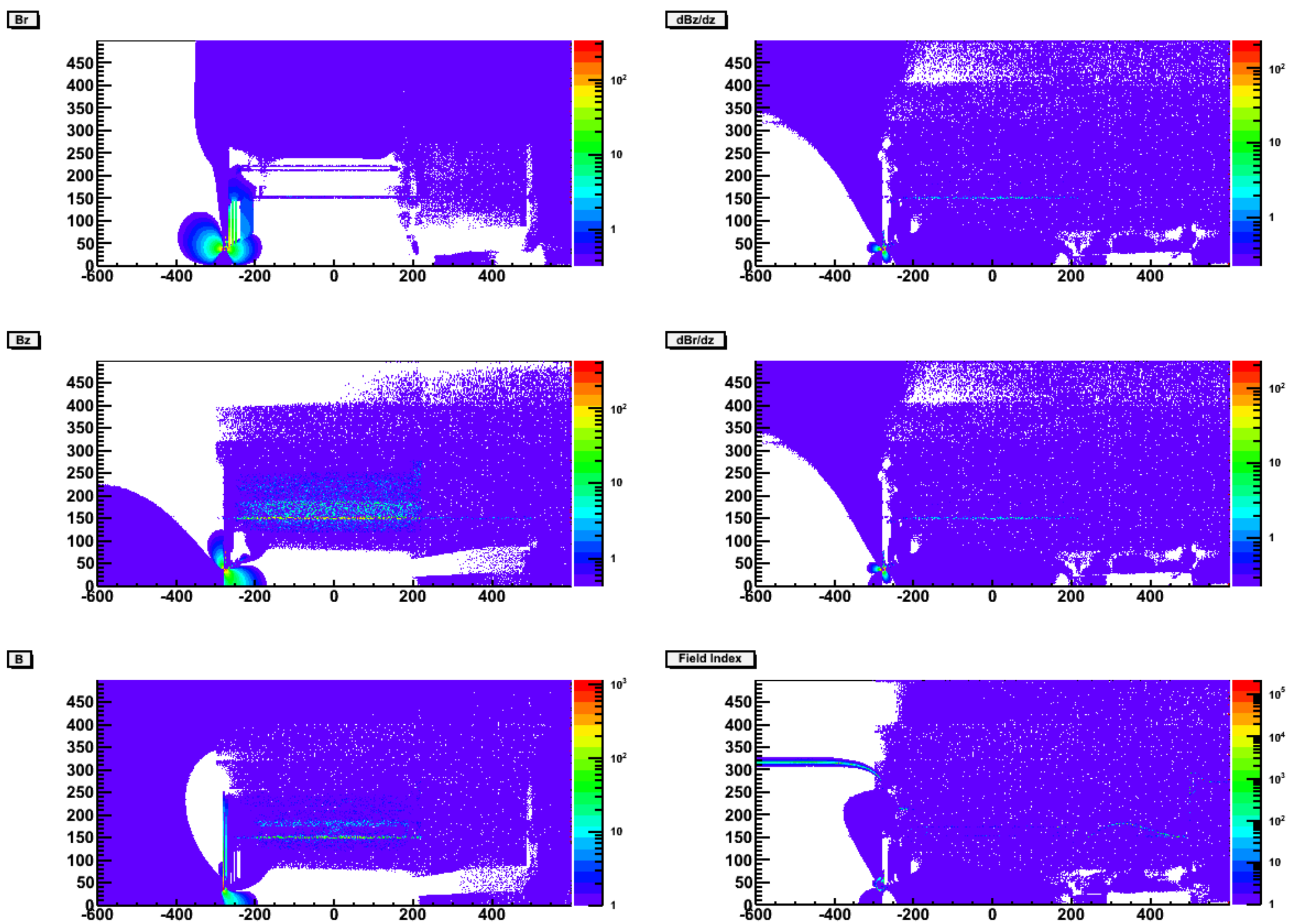


# Field



# Field Difference

- The field change is small within solenoid
- Need to study the fringe field at SIDIS target



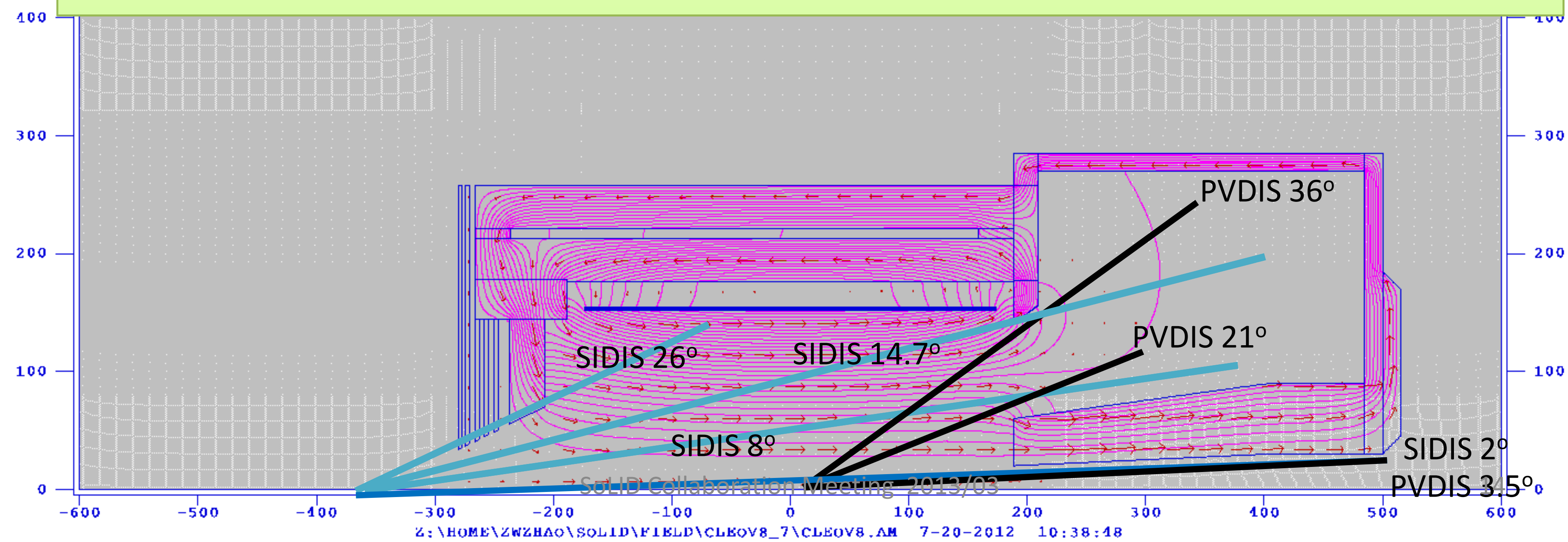
# Summary

- To use the extra iron or not is more or less a cost question.
- Fringe field can be tuned (correction coil alike), need more time.
- More advanced software like TOSCA to do further work
- More input from CLEO people will help fine tune things. We need to gather more info from them.
- Iteration with engineering.

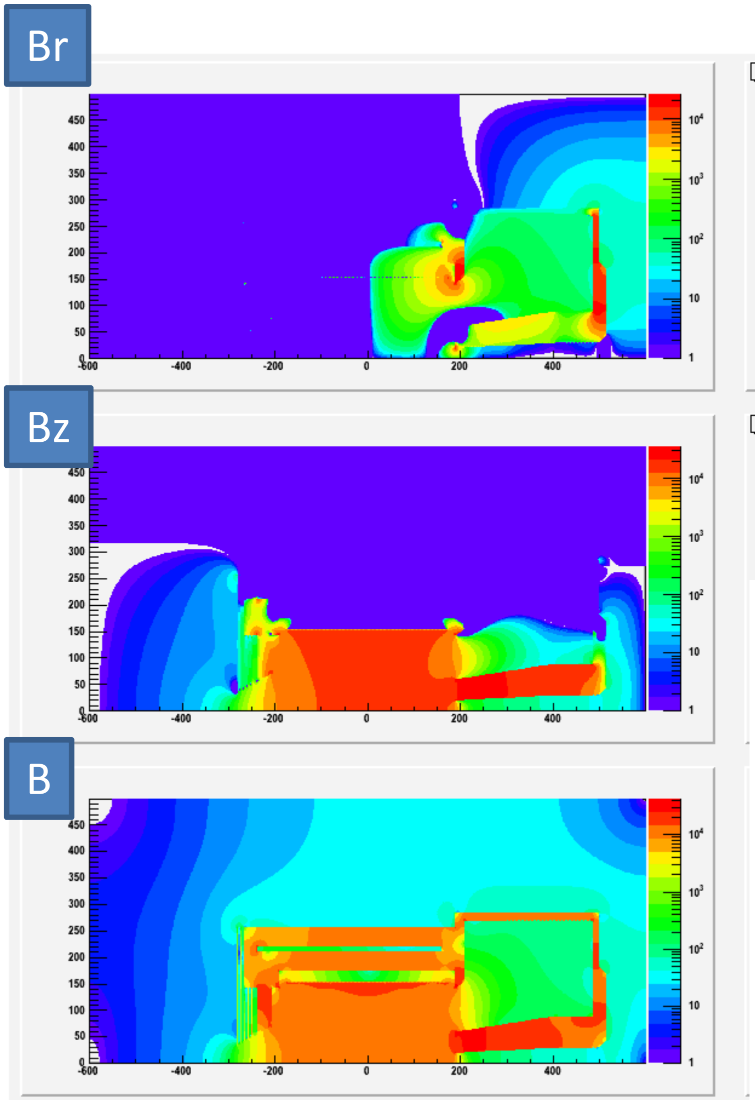
# backup

# SOLID CLEO Acceptance

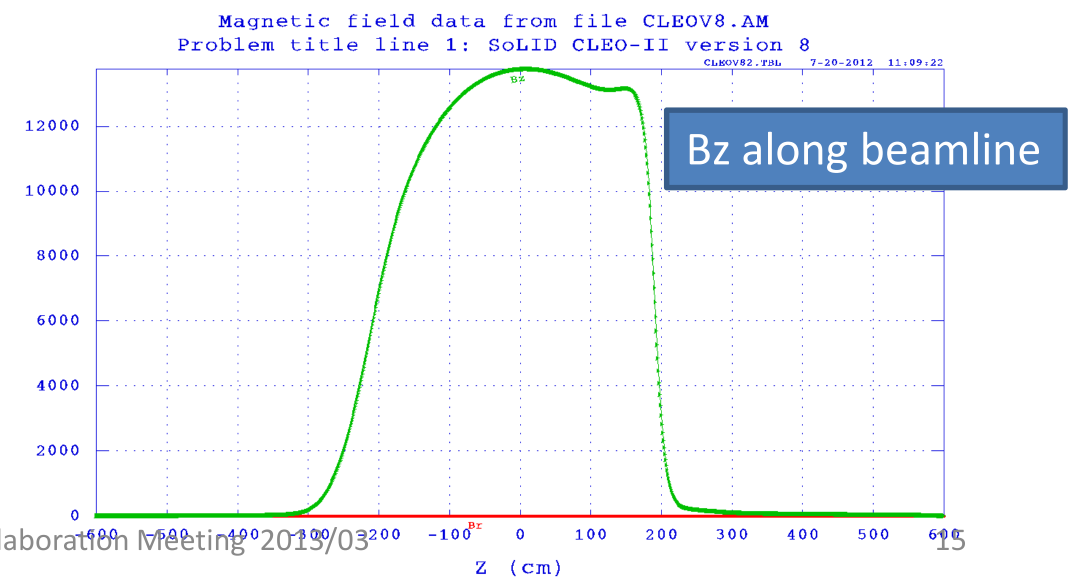
- PVDIS physics requires opening angle from 22 - 35°
  - target at z= 10cm
  - geometry openings is 21 - 36°
  - clearance to endcup nose at endcup entrance (z=189cm) is 12cm for 22° and 8cm for 21°
  - clearance to endcup donut at forwardangle EC back (z=370cm) is 10cm for 35° and 5cm for 35.5°
  - beamline opening angle at endcup bottom is 3.5°
- SIDIS physics requires opening angle from 8 - 24°, JPsi physics requires opening angle from 8 - 26°
  - target at z= -350cm
  - geometry openings is 7.5 – 26.3°
  - clearance to endcup nose at endcup entrance (z=189cm) is 15cm for 8°
  - clearance to endcup nose at forwardangle EC front (z=405cm) is 15cm for 8°
  - beamline opening angle at endcup bottom is 2°



# SoLID CLEO Field



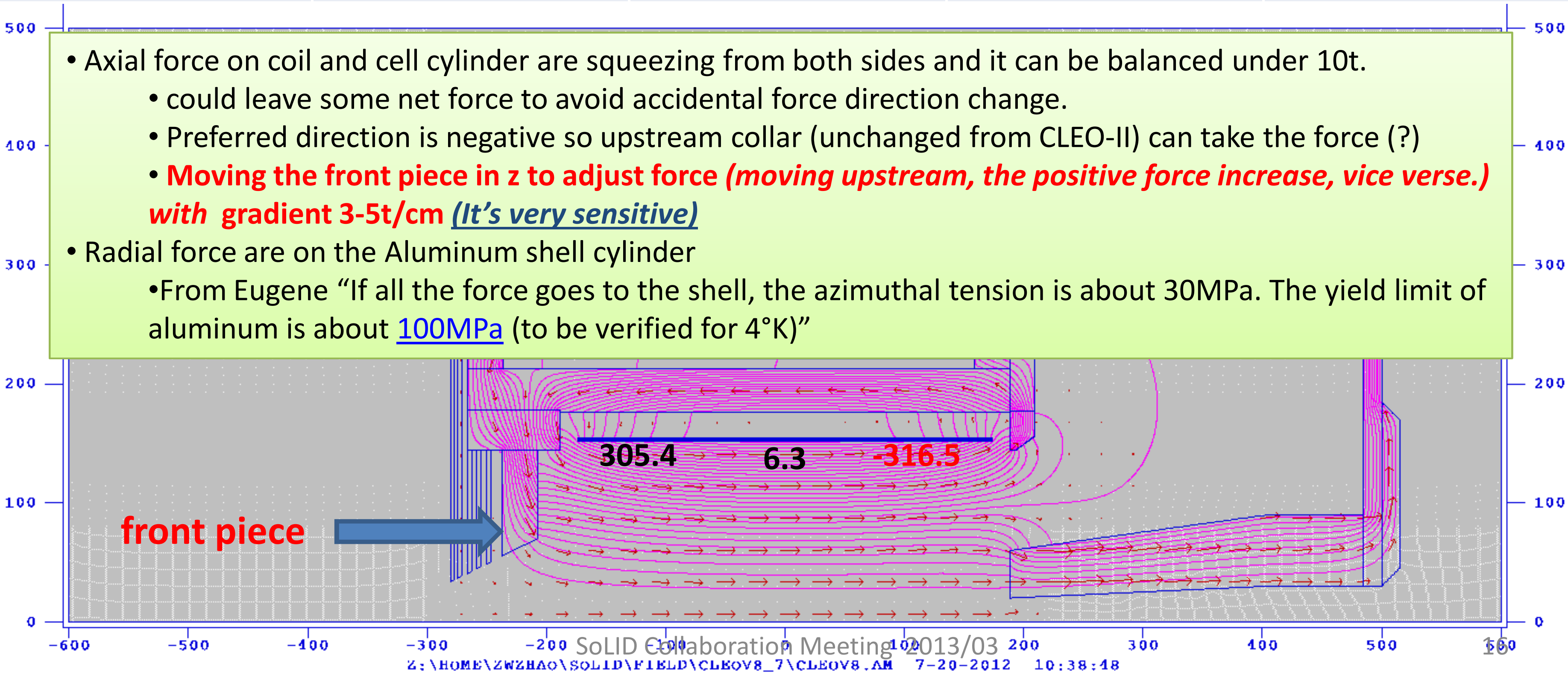

- CLEO-II can still reach 1.48T Bz
- SoLID CLEO only reaches 1.38T Bz, due to large opening and asymmetric yoke design. Unlikely CLEO-II can run higher current (?)
- The iron of the endcap nose could be saturated with >2T field.
- The radial field Br can reach a few 1000G where PVDIS GEM plane 1 and 2 are.
- The field drops to a few 100G in endcap. They are <200G where Cherenkov readout is.



# SoLID CLEO Force on coil

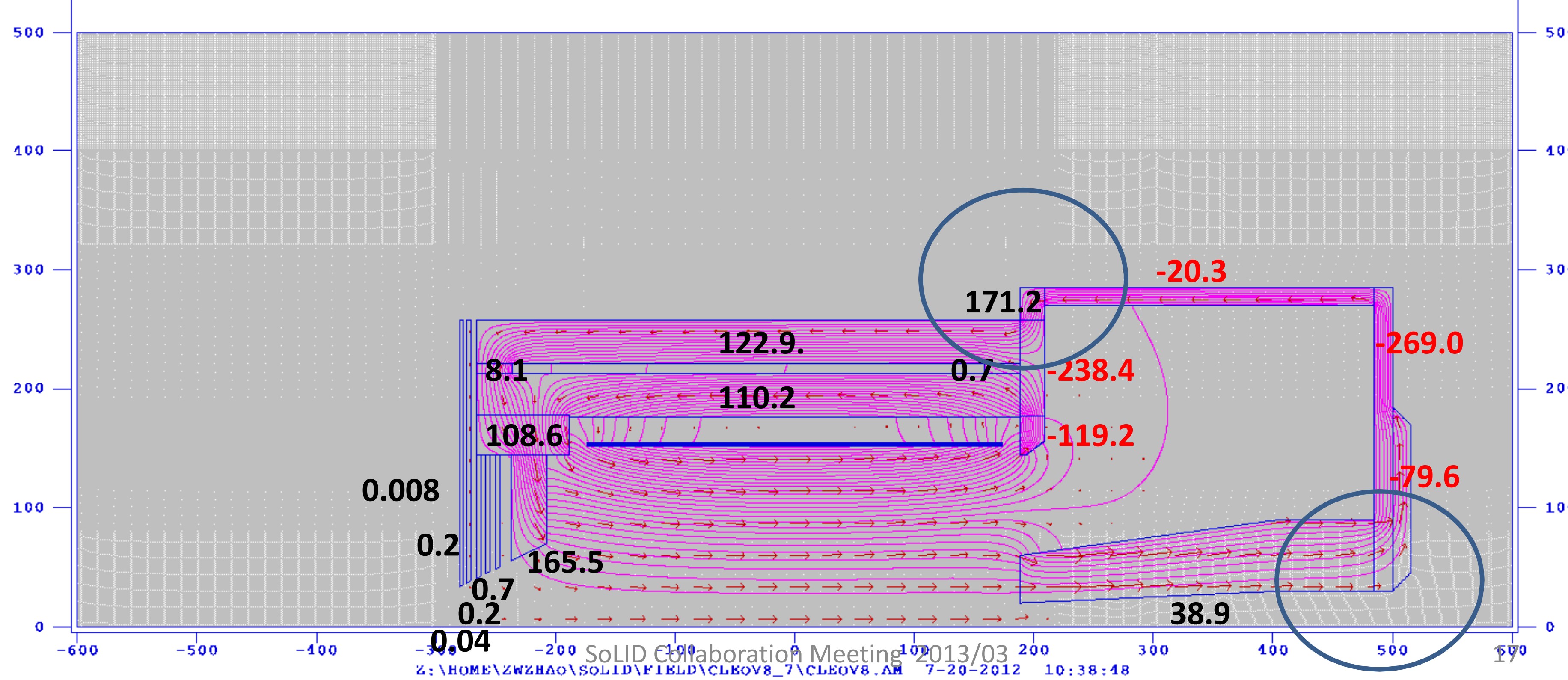
| *unit in t* | upstream | middle | downstream | total |
|---|---|---|---|---|
| inner 2piFz | 154.1 | 3.6 | -159.1 | -1.4 |
| outer 2piFz | 154.7 | 3.5 | -159.6 | -1.4 |
| Total 2piFz | 308.8 | 7.1 | -318.7 | -2.4 |
| inner Fr/radian | 87.9 | 170.2 | 87.2 | 345.3 |
| outer Fr/radian | 24.8 | 54.5 | 24.2 | 103.5 |
| Total Fr/radian | 112.7 | 224.7 | 111.4 | 448.8 |

- Axial force on coil and cell cylinder are squeezing from both sides and it can be balanced under 10t.
  - could leave some net force to avoid accidental force direction change.
  - Preferred direction is negative so upstream collar (unchanged from CLEO-II) can take the force (?)
  - **Moving the front piece in z to adjust force *(moving upstream, the positive force increase, vice verse.) with* gradient 3-5t/cm *(It's very sensitive)***
- Radial force are on the Aluminum shell cylinder
  - From Eugene "If all the force goes to the shell, the azimuthal tension is about 30MPa. The yield limit of aluminum is about 100MPa (to be verified for 4°K)"



# SoLID CLEO Force on yoke (axial force only)

- 2piFz (unit in t) represents the axial force integrated over the whole part in 2pi.
- positive direction in black, negative direction in Red
- The opposite force meets at two locations where the endcup connects.
- Some analysis of potential problems with the coil and yoke mechanical integrity should be done.
- no calculation of the radial force yet.

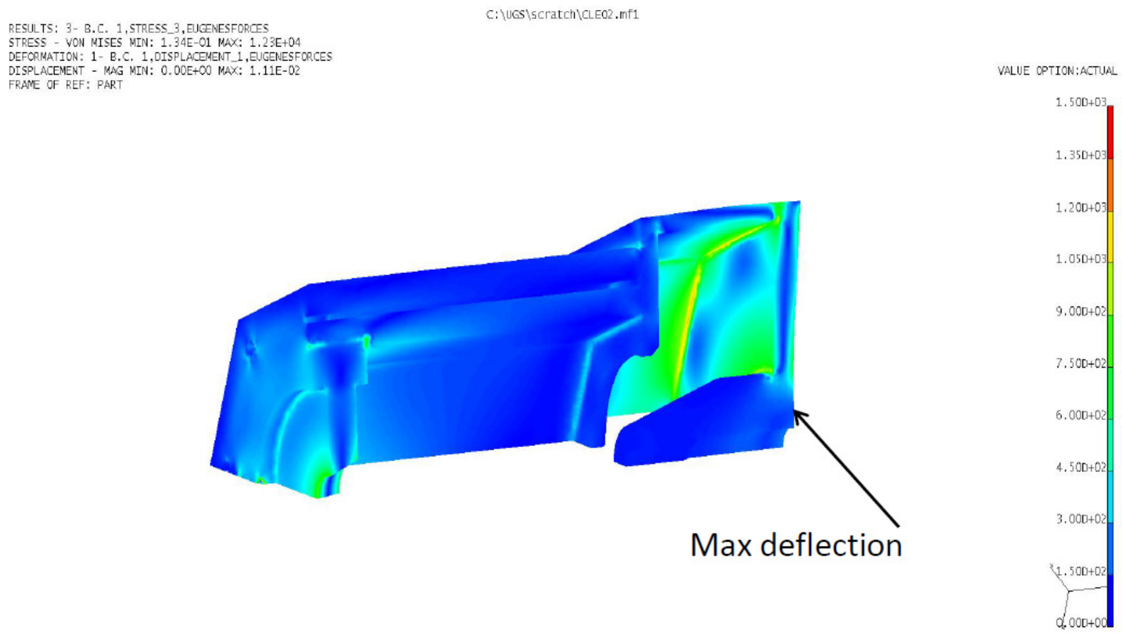


# SoLID CLEO: FEA study of axial force

- Static weight are ignored for now.

Maximum Von Mises stresses on the model

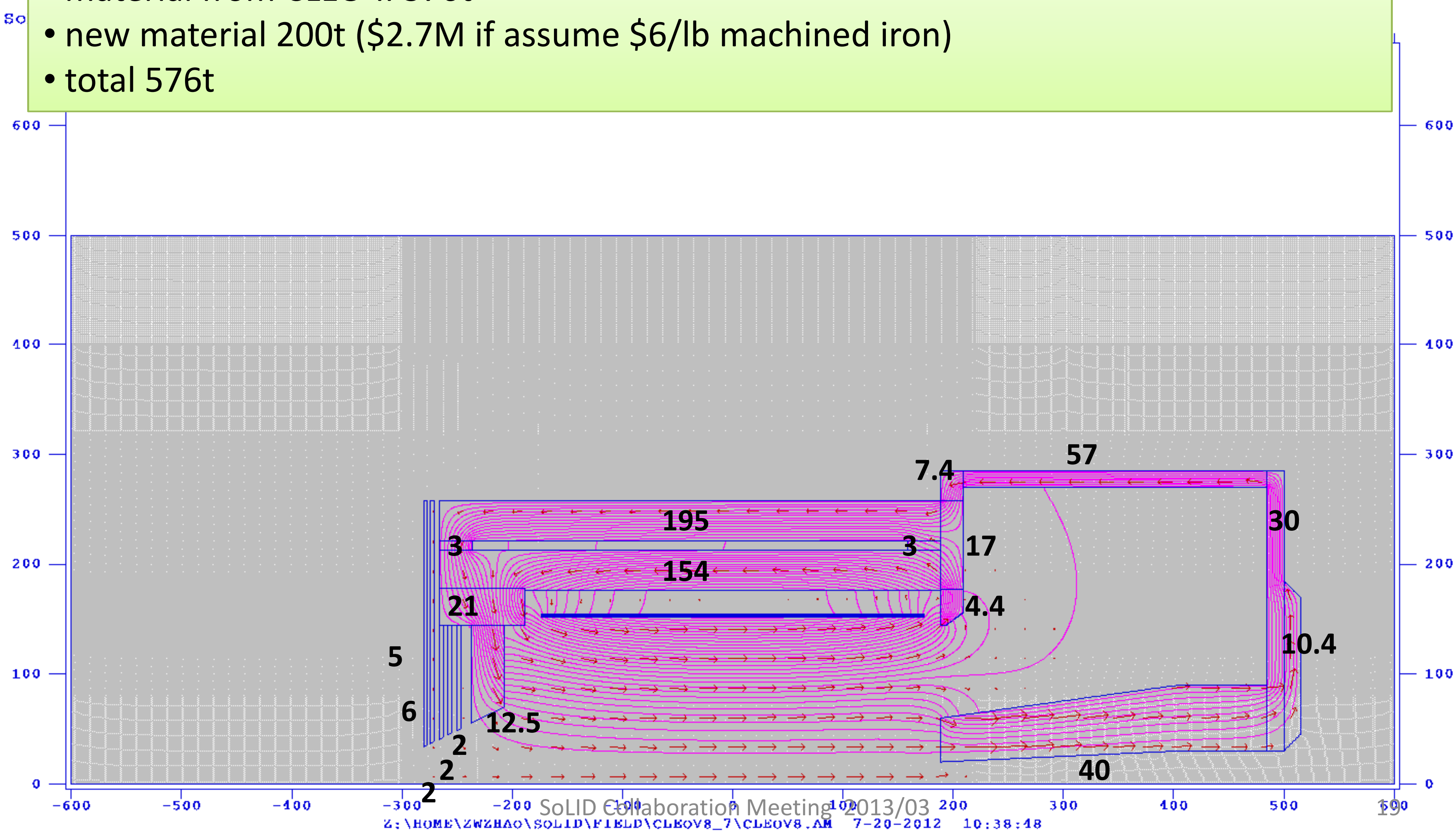
Maximum Von Mises stresses do not exceed 1500 psi. (magnetic axial forces only)
Allowable yield stress 1006 steel is 24000 psi.
Maximum deflection is 0.011” = 0.2794mm where region 15 and 16 meet.
Maximum shear was approximately 750 psi and acceptable. (not shown)




by Whit Seay

# SoLID CLEO Yoke weight

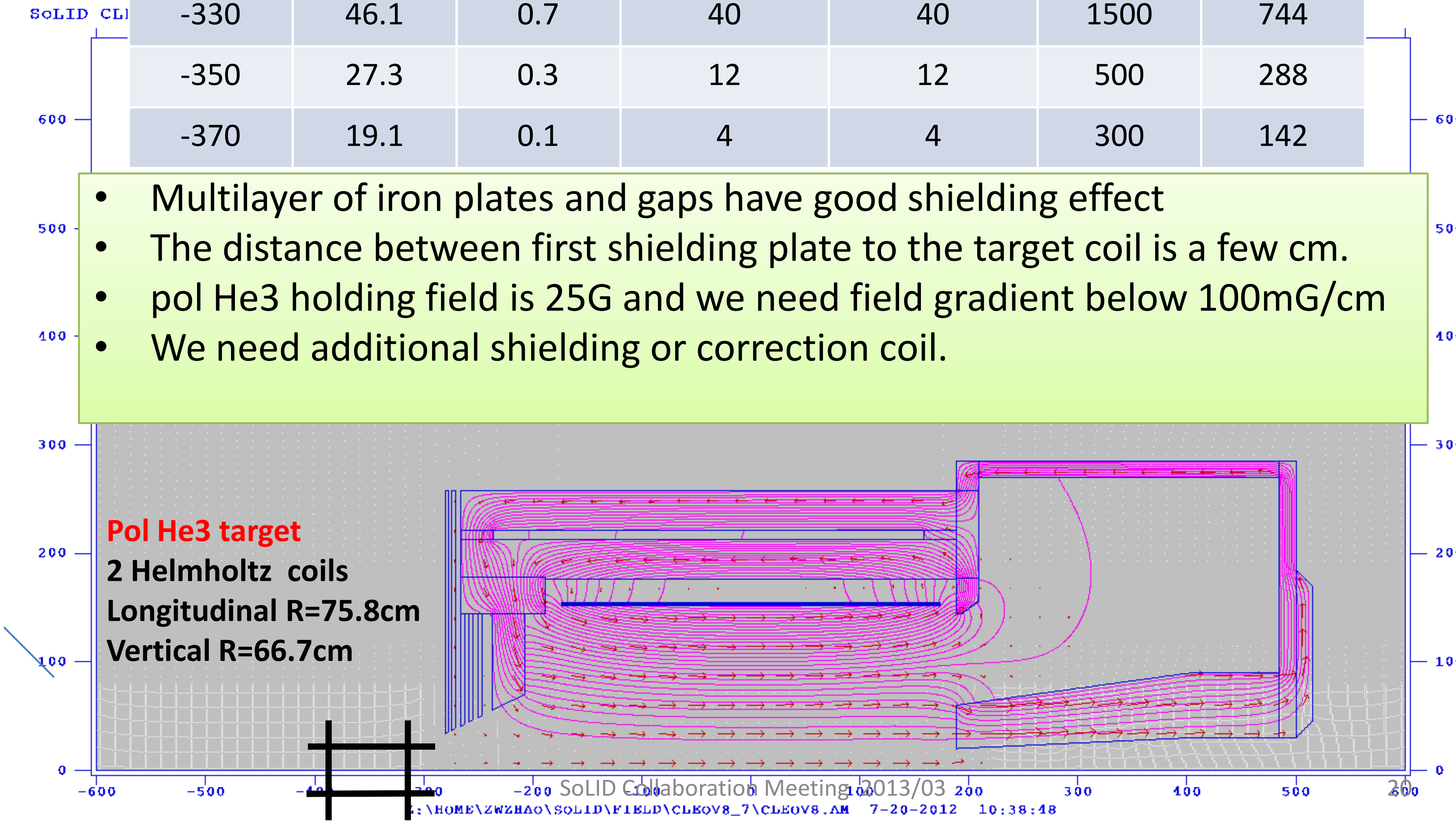
- assume steel density is 7.9g/cm3 , weight unit is in t
- material from CLEO-II 376t
- new material 200t ($2.7M if assume $6/lb machined iron)
- total 576t



# SoLID CLEO: Fringe field at SIDIS pol He3 target location

| Z (cm) | Bz(G) | Br(G) | dBz/dr (mG/cm) | dBr/dz (mG/cm) | dBz/dz (mG/cm) | dBr/dr (mG/cm) |
|---|---|---|---|---|---|---|
| -330 | 46.1 | 0.7 | 40 | 40 | 1500 | 744 |
| -350 | 27.3 | 0.3 | 12 | 12 | 500 | 288 |
| -370 | 19.1 | 0.1 | 4 | 4 | 300 | 142 |

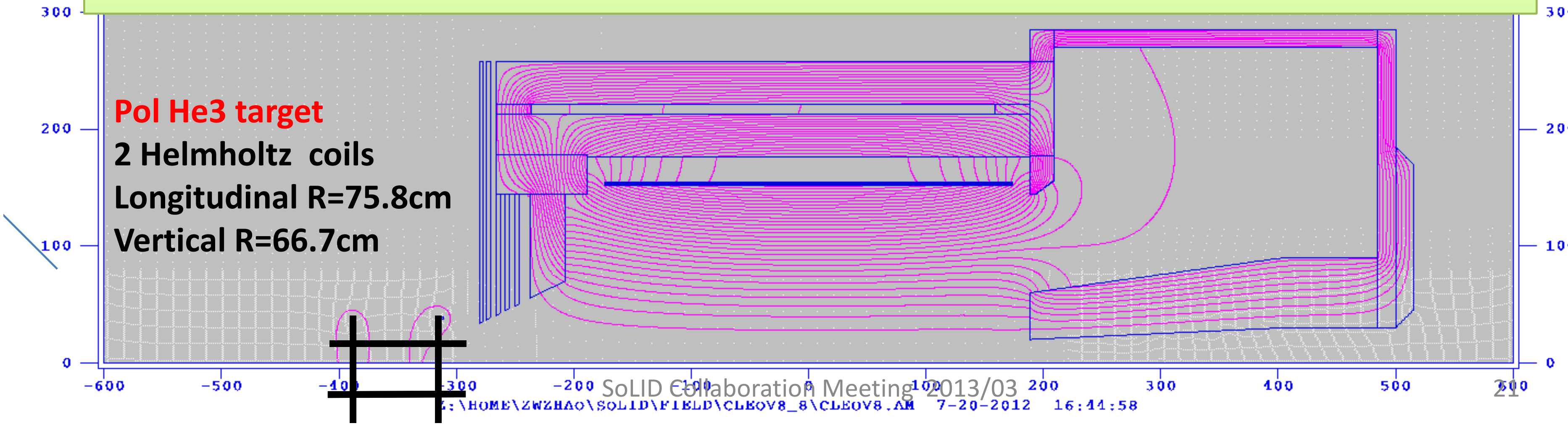
- Multilayer of iron plates and gaps have good shielding effect
- The distance between first shielding plate to the target coil is a few cm.
- pol He3 holding field is 25G and we need field gradient below 100mG/cm
- We need additional shielding or correction coil.



# SoLID CLEO: Fringe field at SIDIS pol He3 target location (with correction coil)

| Z (cm) | Bz(G) | Br(G) | dBz/dr (mG/cm) | dBr/dz (mG/cm) | dBz/dz (mG/cm) | dBr/dr (mG/cm) |
|---|---|---|---|---|---|---|
| -330 | -0.4 | 0.11 | 42 | 42 | 170 | -106 |
| -350 | 1.6 | 0.05 | 7 | 7 | -100 | 54 |
| -370 | 0.8 | 0.08 | 4 | 4 | 164 | -81 |

- Add a pair correction coil at the same position of longitudinal coil with current -3465A and -645A
- No effect on the force on solenoid coil
- Both field and field gradient are reduced
- It can be tweaked further and there can be other ideas.



# SoLID CLEO summary

- We have a preliminary design
- It can be improved with more input from engineering
- Some barrel yoke are reused, no problem to fit with Hall A beamline height.

Study by Eugene Chudukov

*https://userweb.jlab.org/~gen/jlab12gev/cleo_mag*