SoLID Magnet Update

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Many Thanks to Eugene Chudakov, Xin Qian, Jian-Ping Chen, Whit Seay, Robin Wines, Javier Gomez, Will Oren, Rolf Ent

SoLID Collboration Meeting
2012/12

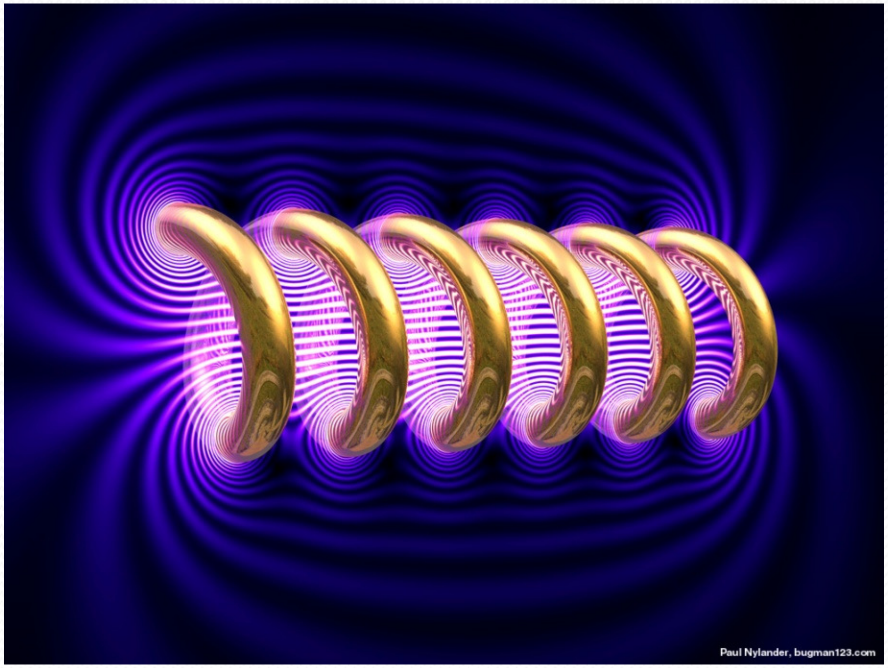
Jefferson Lab

Outline

- Requirement
- Magnet Choice
- CLEO
- BaBar
- Summary

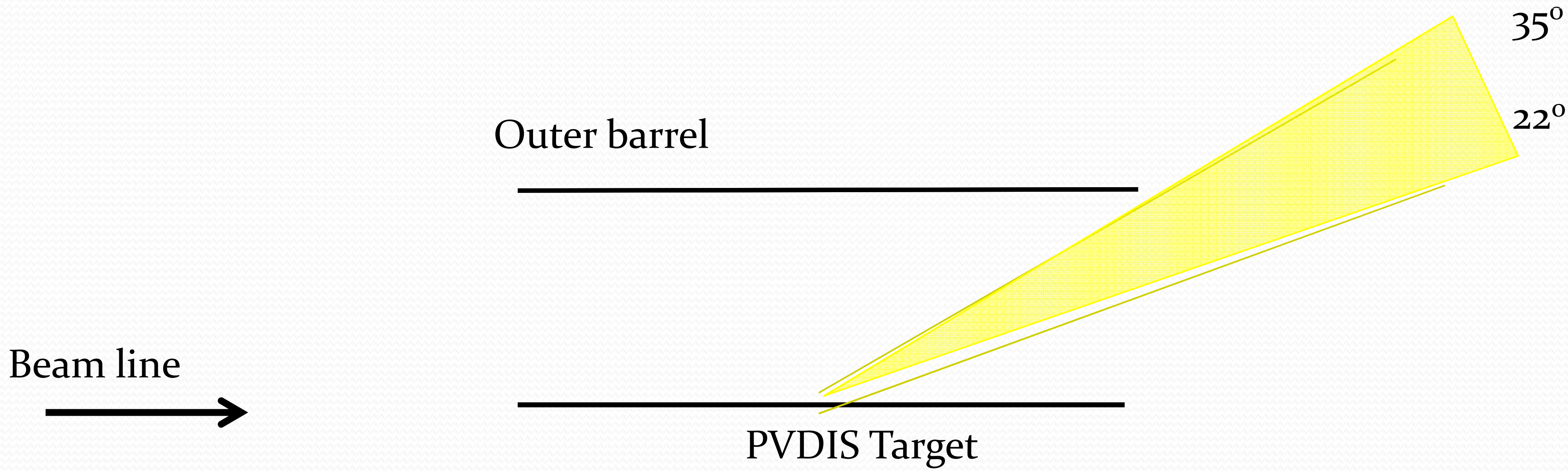
Requirement

- General
  - Large acceptance and high luminosity
  - Solenoidal magnet leaves large room for detectors and swipes away low energy background downstream.
  - **Hall A beam line height 3.05m (10 feet)**



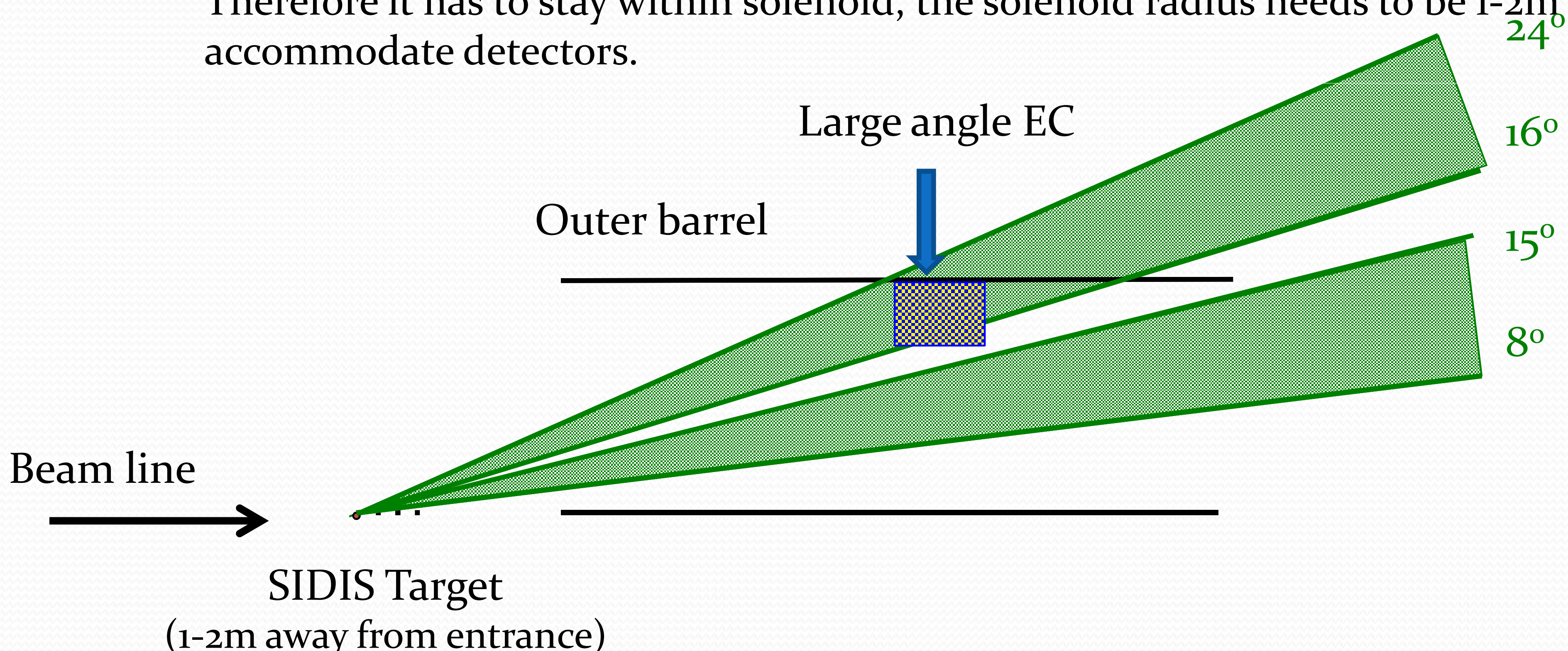
Requirement

- PVDIS (22-35^o, e^-)
  - The target can be placed within solenoid
  - Solenoid radius needs to be 1-2m. Small radius will make the target is too close to magnet exit and not enough room for baffle.
  - field > 1T to ensure enough defection of 2-6GeV with 1-2m so that baffle can be made with not too small segmentation



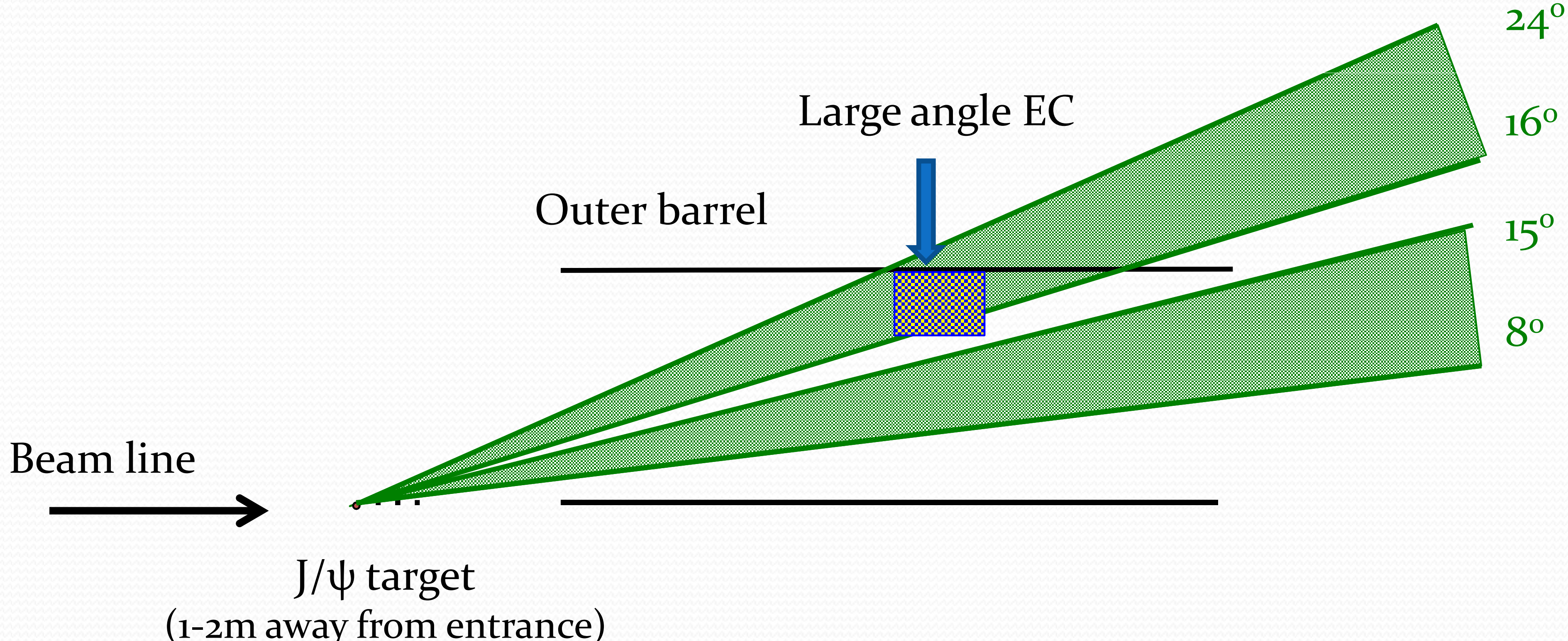
Requirement

- SIDIS (8-24^o, e^- and hadron)
  - Both polarized targets need to be outside of field and the fringe field for SIDIS-3he < 30G
  - Forward angle detectors need enough distance for tracking, Cherenkov, TOF and calorimeter. A Solenoid needs to be 3-4 m long for tracking and it can't be too long to reduce forward angle detectors acceptance and thus limit the hadron detection.
  - Large angle detectors need small distance so it won't exceed beamline height limit. Therefore it has to stay within solenoid, the solenoid radius needs to be 1-2m to accommodate detectors.



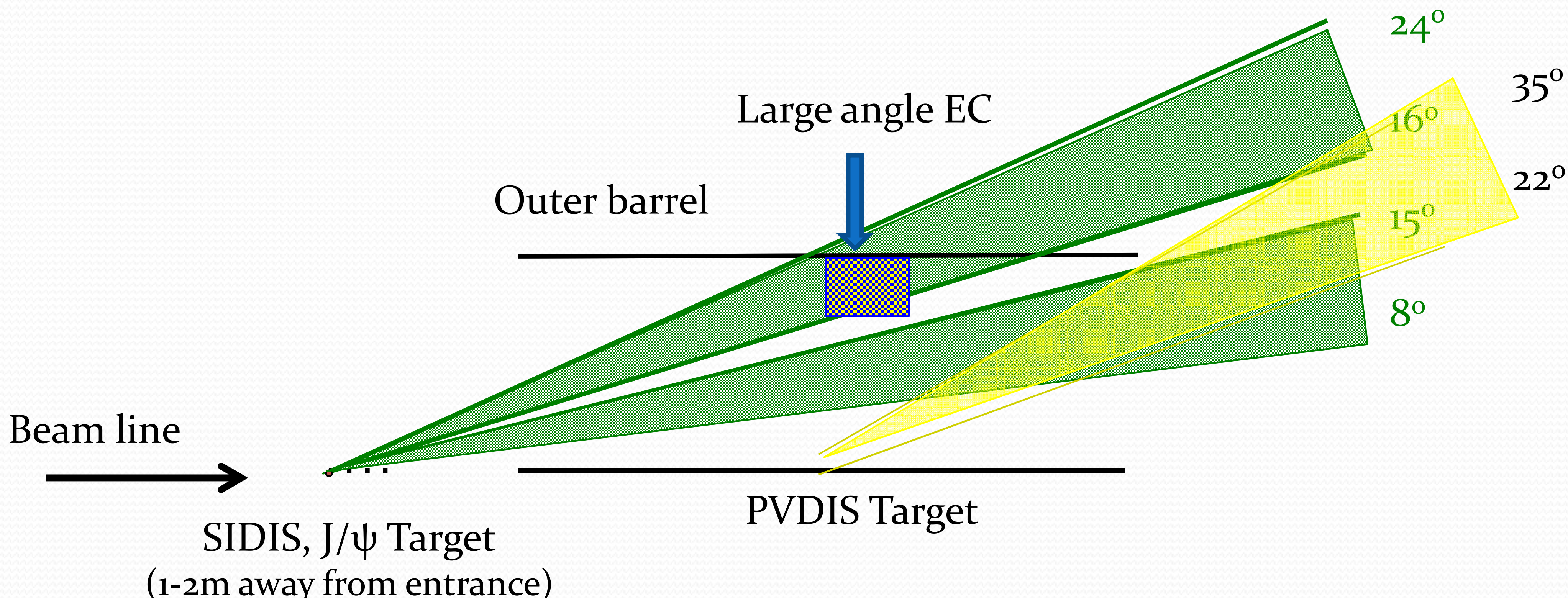
Requirement

- J/ψ (8-26°, e^-,e^+ and p)
  - Similar to SIDIS
  - Small field will help low energy scattered e- acceptance at forward angle



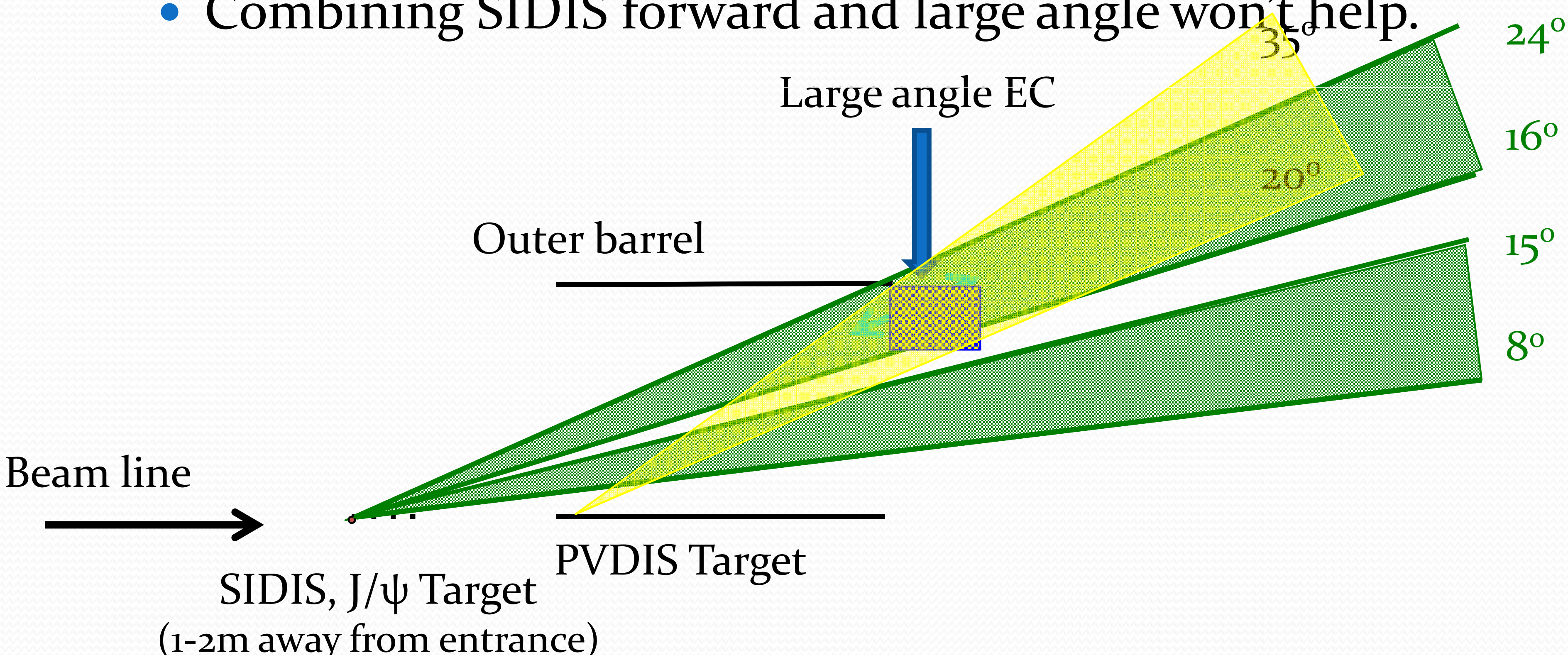
Magnet Choice

- CLEO/BaBar alike: 1.4m radius, 3.5m length
  - Large enough inner radius
  - Medium field 1.5T and medium length



Magnet Choice

- Shorter magnet: 1.4m radius, 1.75m length
  - PVDIS should be ok after move target further upstream.
  - SIDIS forward tracking need stronger field 2-3T.
  - SIDIS target needs to be further away due to larger fringe field. This in turn will reduce large angle coverage.
  - Combining SIDIS forward and large angle won't help.

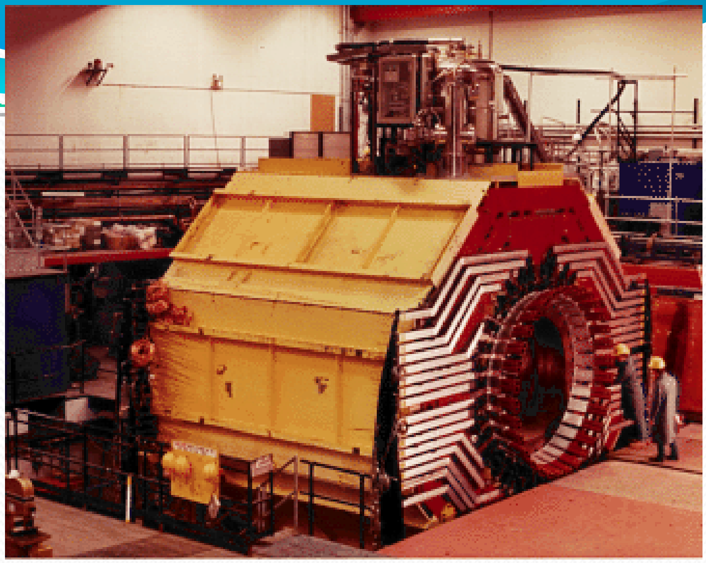


Magnet Comparison

	BaBar	CLEO	ZEUS	CDF	Glue-X	Other
Cryostat Inner Rad	142 cm	145 cm	86 cm	150 cm		Whatever we need
Length	345 cm	350cm	245cm	500 cm		
Cent Field	1.49T	1.5T	1.8T	1.47T		
Yoke Aval?	Yes	Yes	No	No		
Variation in Current density with z?	Current Density in central 50% is ½ that in end 25%	Current Density in central 50% is 1/1.04 that in end 25%	Current density 25% more current at ends	No	Yes	
Amp-Turns	5.1 M A-T	4.2 M A-T				
Available	Yes	Yes	Probably Not-- Mainz	Needs $1M repair and possible Expt at Fermilab	Perhaps	$8M??

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



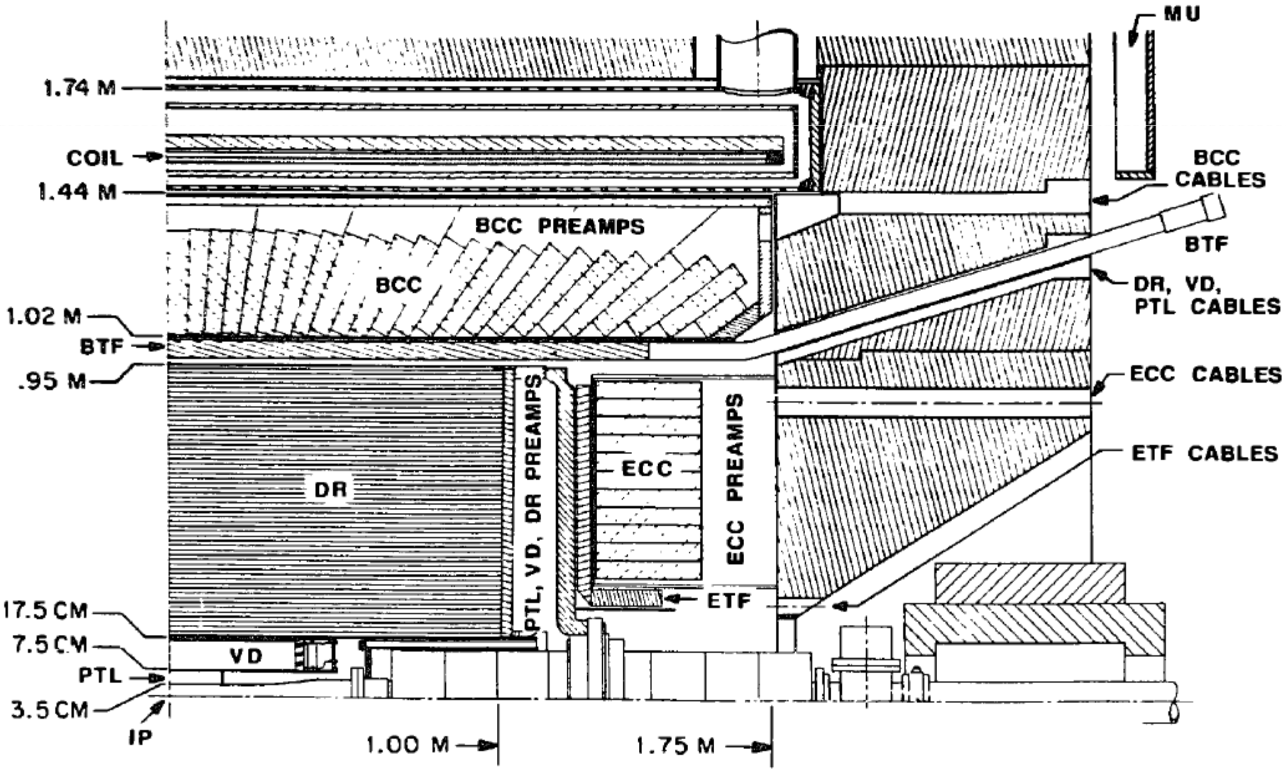
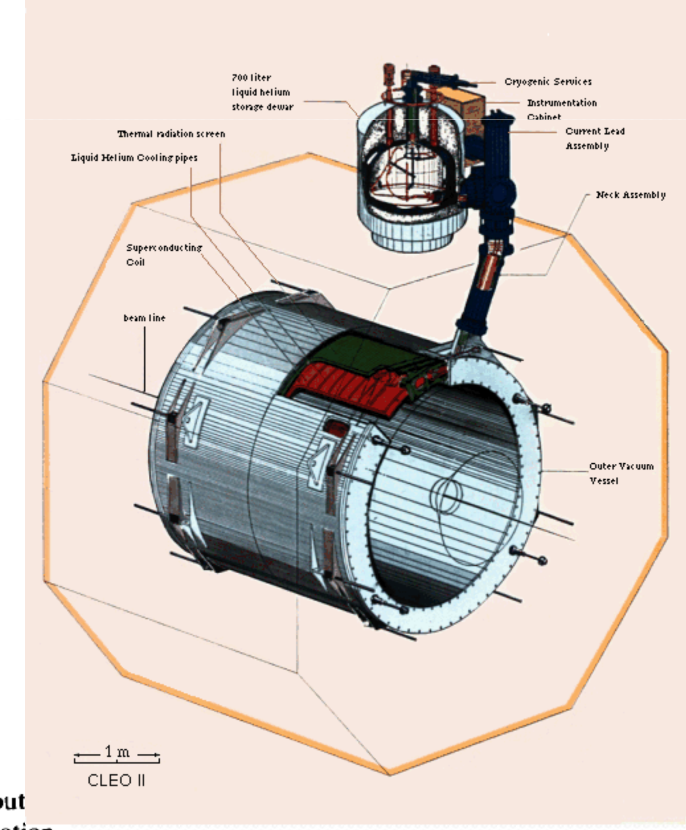
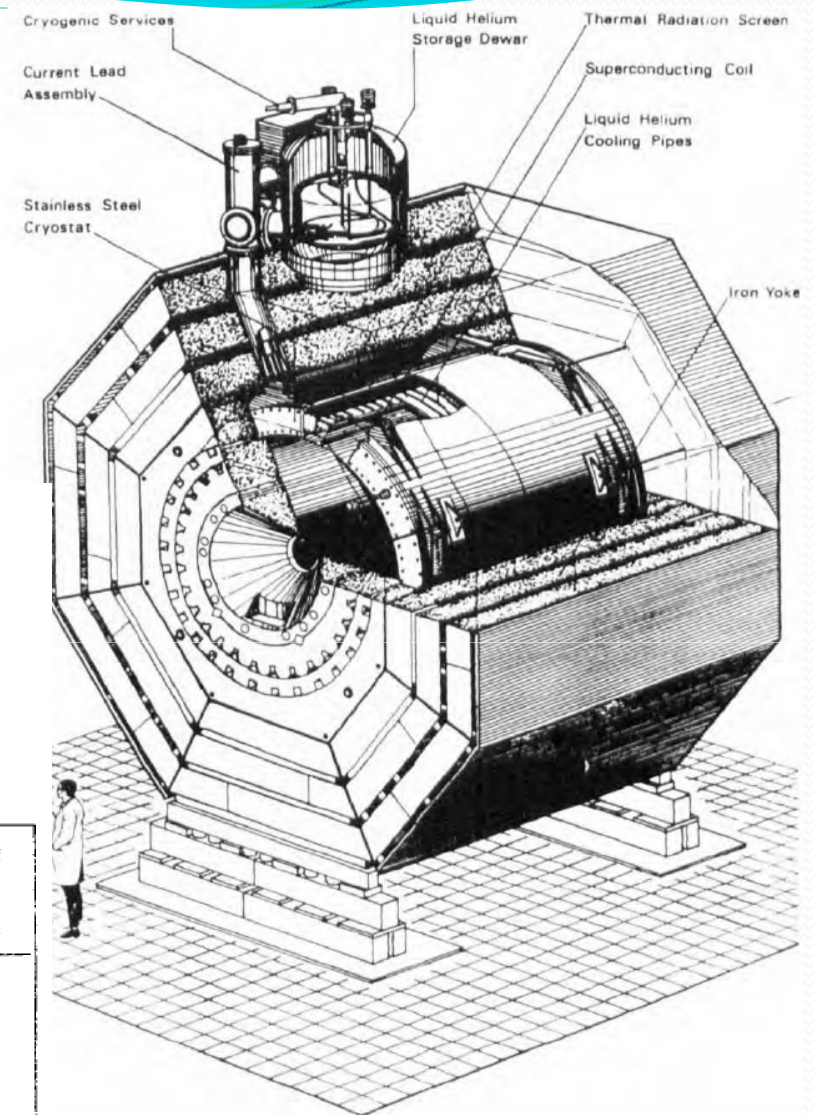


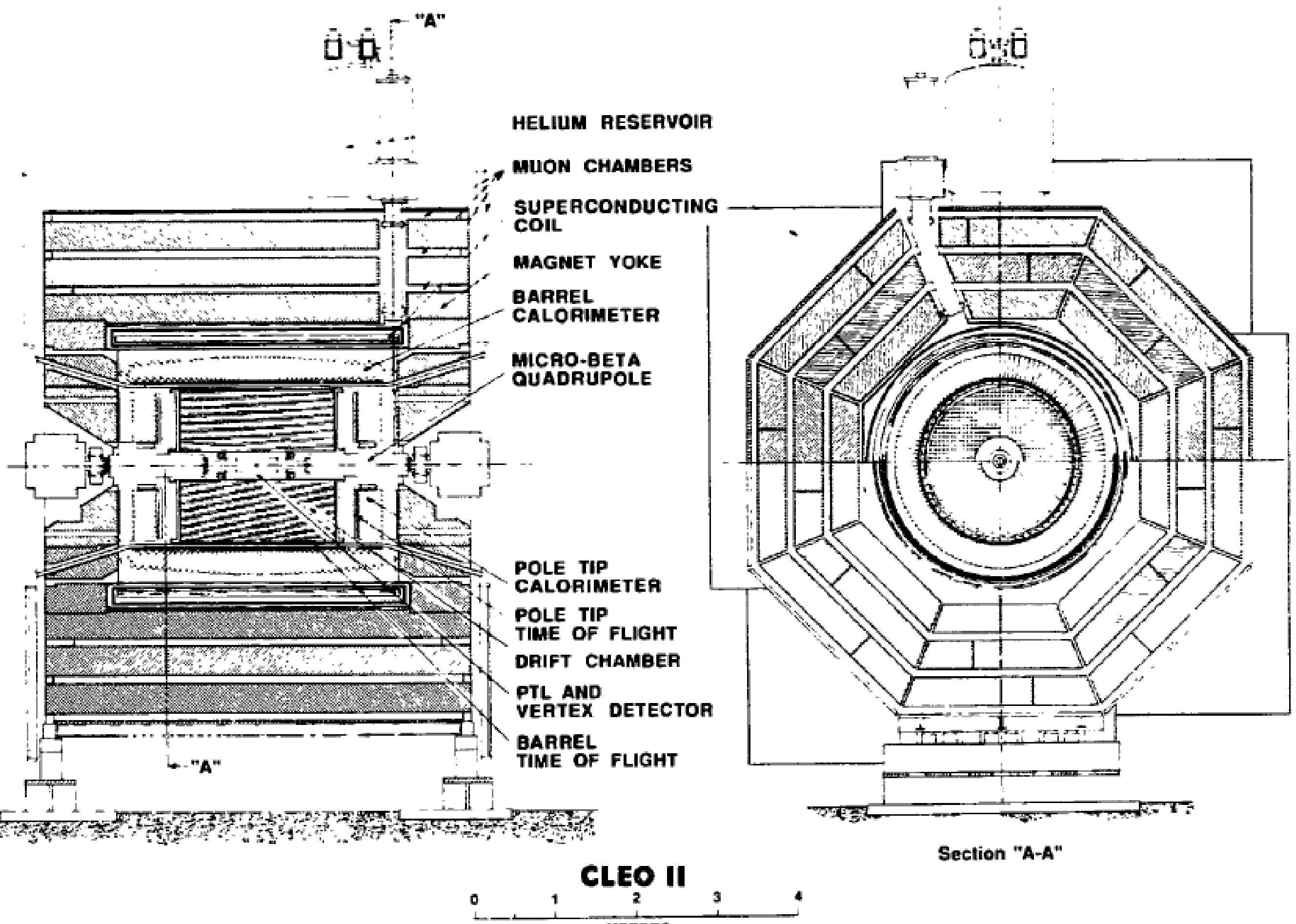
Fig. 2. Schematic Drawing of one quadrant of the CLEO II detector. The following acronyms are used – DR, VD. PTL: The out intermediate and inner drift chambers. TF, CC, MU: The time-of-flight counters, crystal calorimeter and muon identification system. Prefixes: B = barrel, E = endcap



CLEO

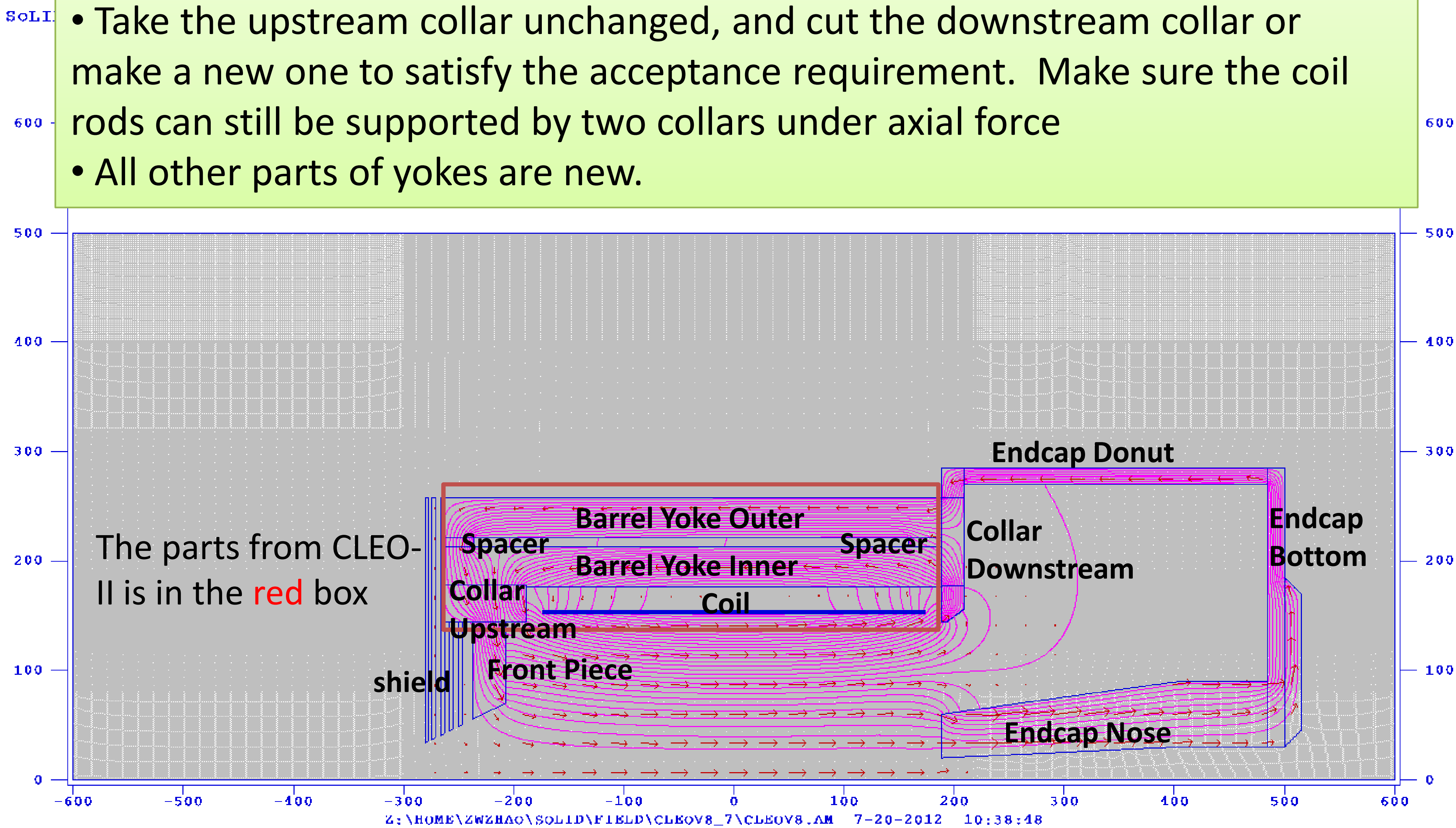
- Barrel flux return is provided by 3 layers of iron separated by spacers
- It’s in octagon
- 2 collars supports barrel irons and holding 4 coil rods in horizontal direction.





From CLEO-II to SoLID (reused parts)

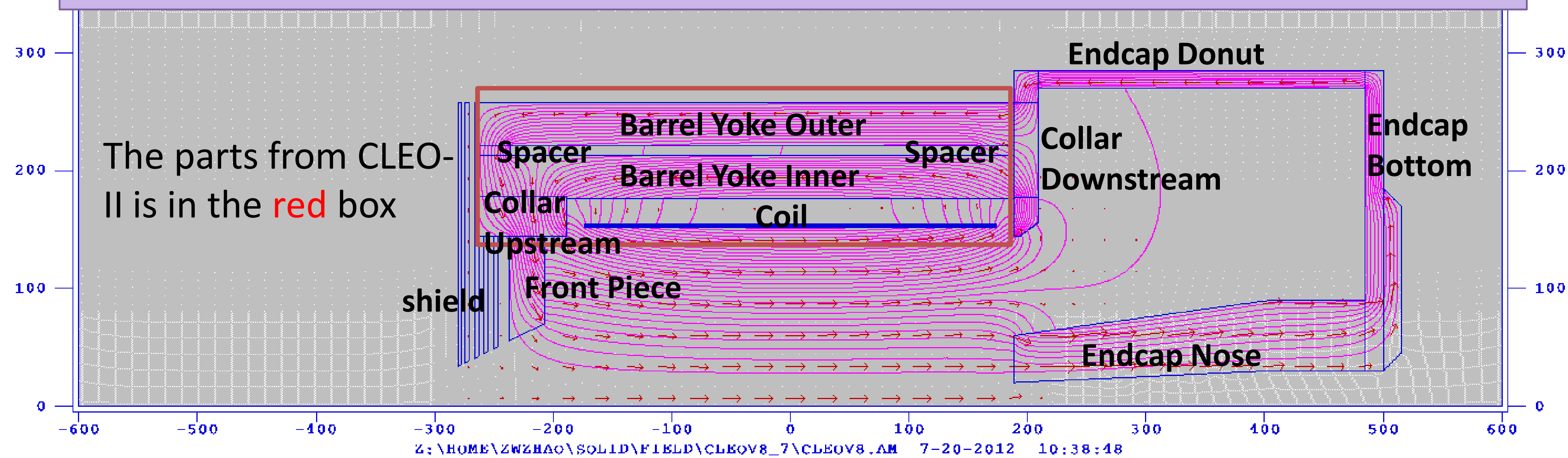
- Reuse coil and cryostat
- Take two layers of barrel yoke and spacer, keep the upstream ends unchanged, cut the downstream ends (75cm) to our need.
- Take the upstream collar unchanged, and cut the downstream collar or make a new one to satisfy the acceptance requirement. Make sure the coil rods can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



From CLEO-II to SoLID (new parts)

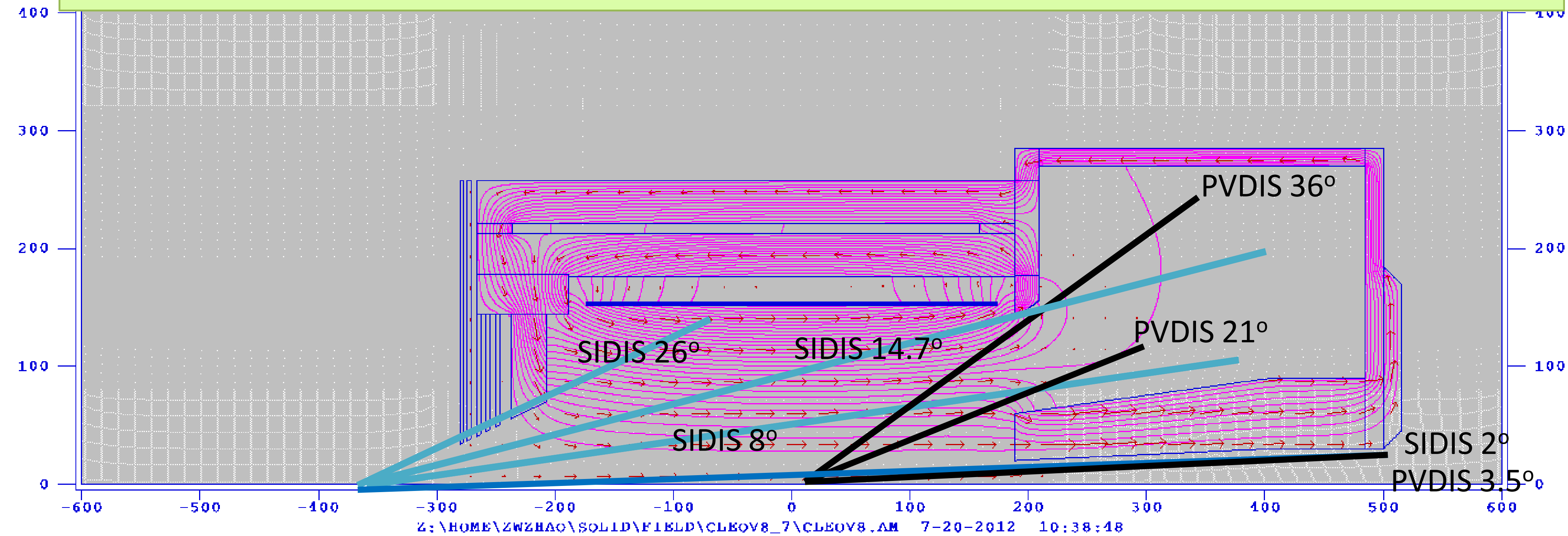
- All new parts need to be customized made.
- But it’s unclear if they will be made of newly machined iron ($6/lb) or we can get some unused CLEO-II iron machined (cost?)
- We might try to use some “stock” parts to save machining cost.

- 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.



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°



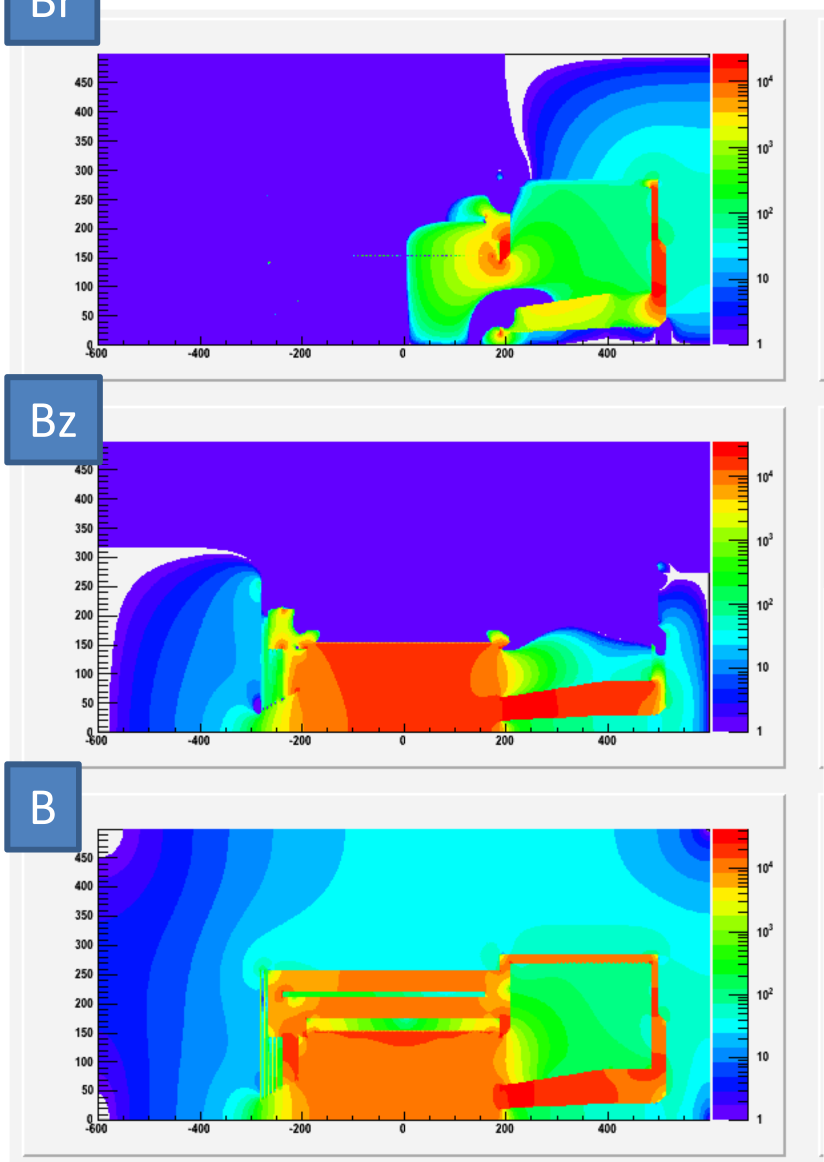
SoLID CLEO Field

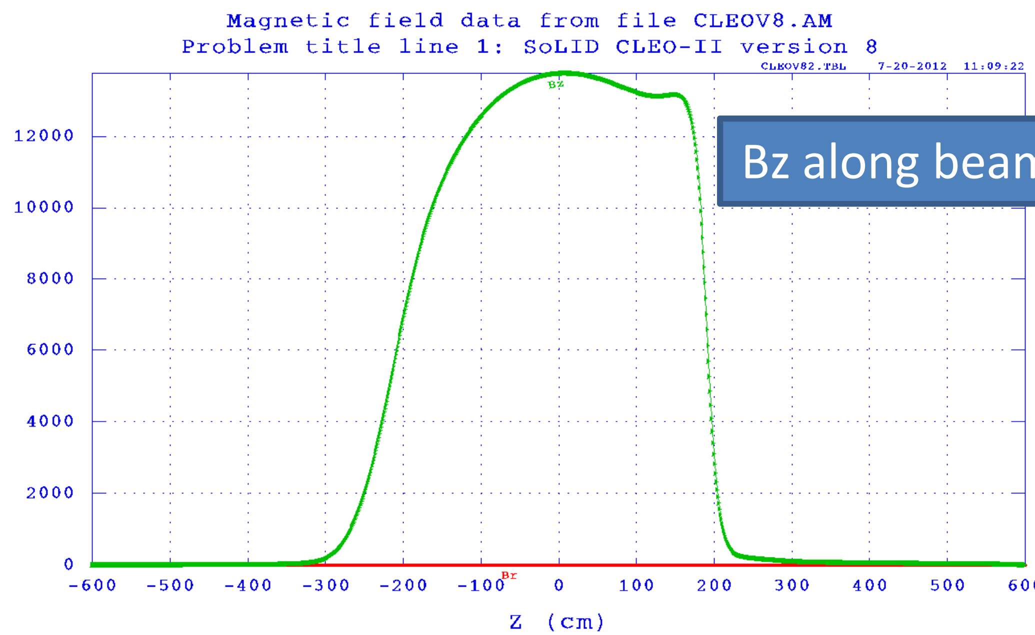
- CLEO-II can still reach 1.48T Bz
- SoLID CLEO only reaches 1.38T Bz, due to large opening and asymmetric yoke design. Unlikely CLEO-II can run higher current (?)
- The iron of the endcap nose could be saturated with >2T field.
- The radial field Br can reach a few 1000G where PVDIS GEM plane 1 and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

Br

Bz

B



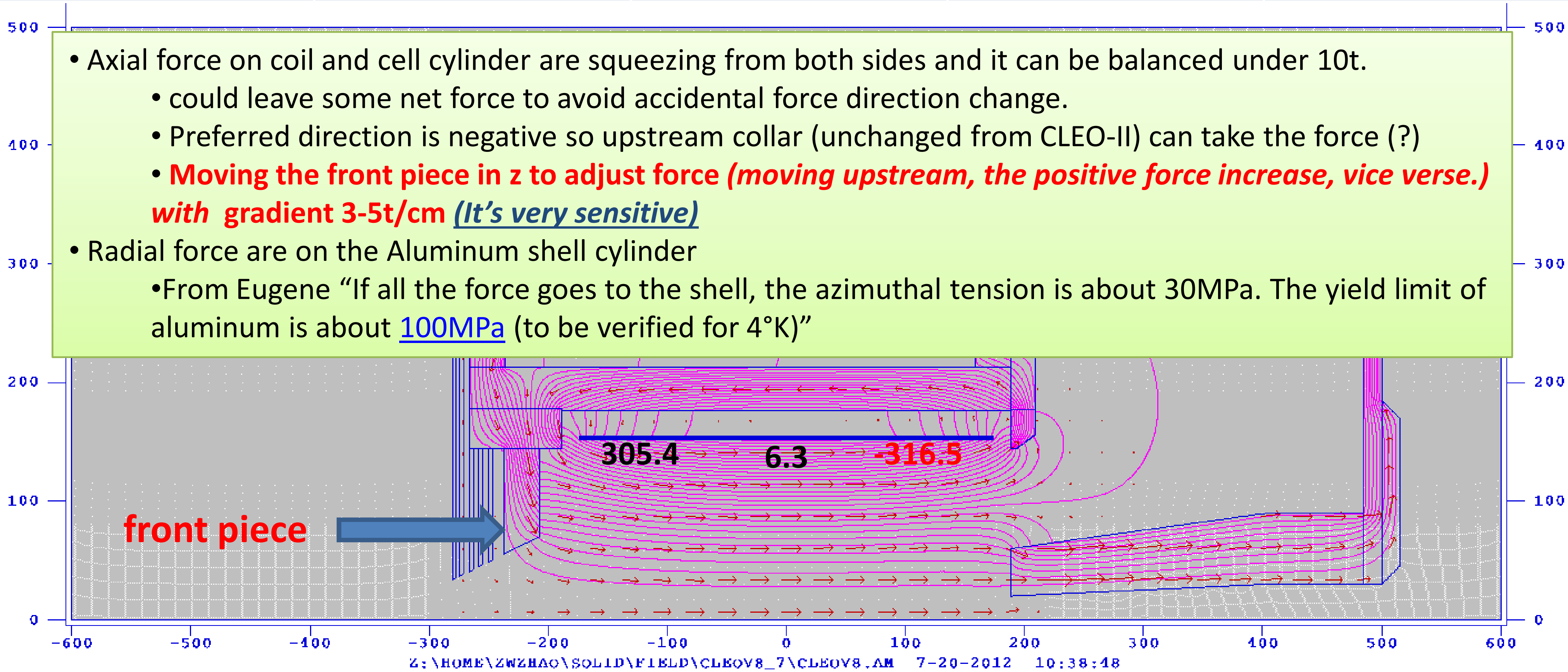


Bz along beamline

SoLID CLEO Force on coil

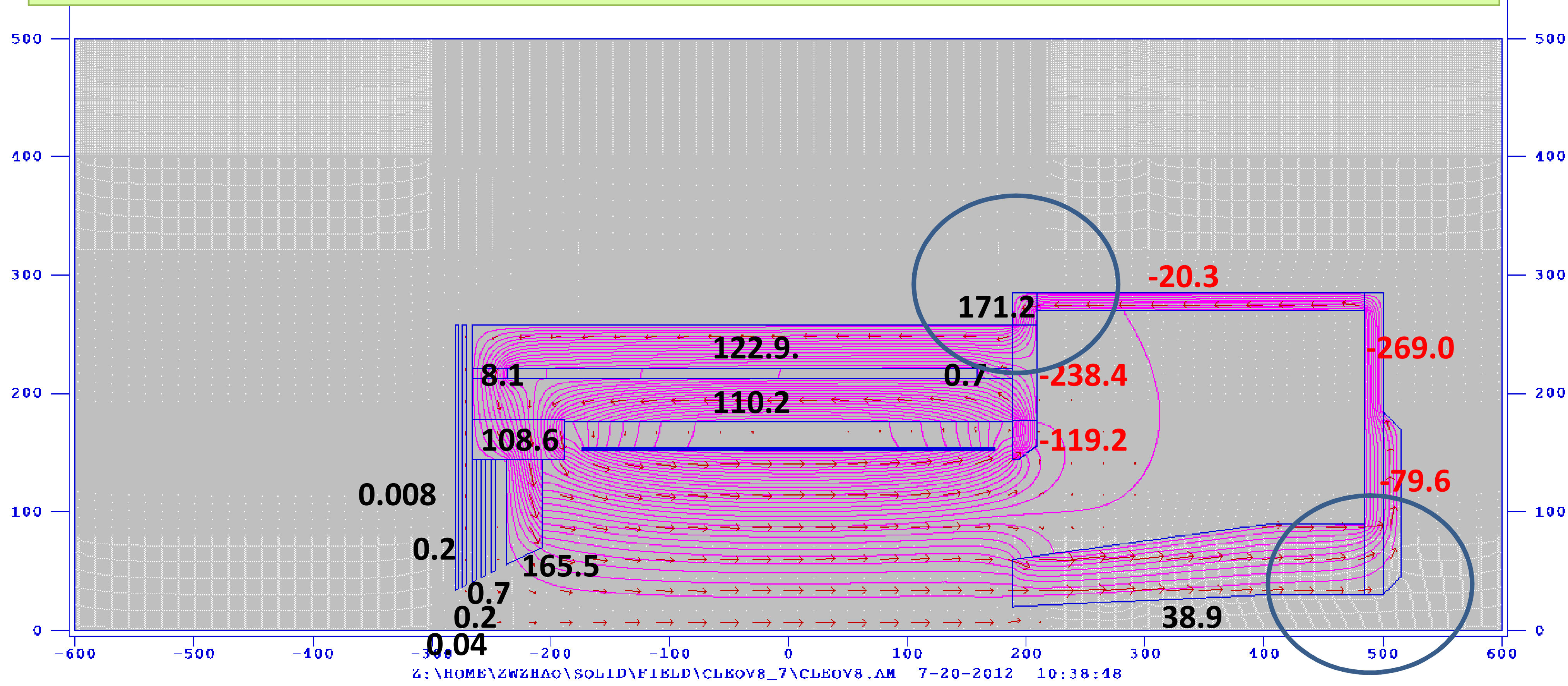
unit in t	upstream	middle	downstream	total
inner 2piFz	154.1	3.6	-159.1	-1.4
outer 2piFz	154.7	3.5	-159.6	-1.4
Total 2piFz	308.8	7.1	-318.7	-2.4
inner Fr/radian	87.9	170.2	87.2	345.3
outer Fr/radian	24.8	54.5	24.2	103.5
Total Fr/radian	112.7	224.7	111.4	448.8

- 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.

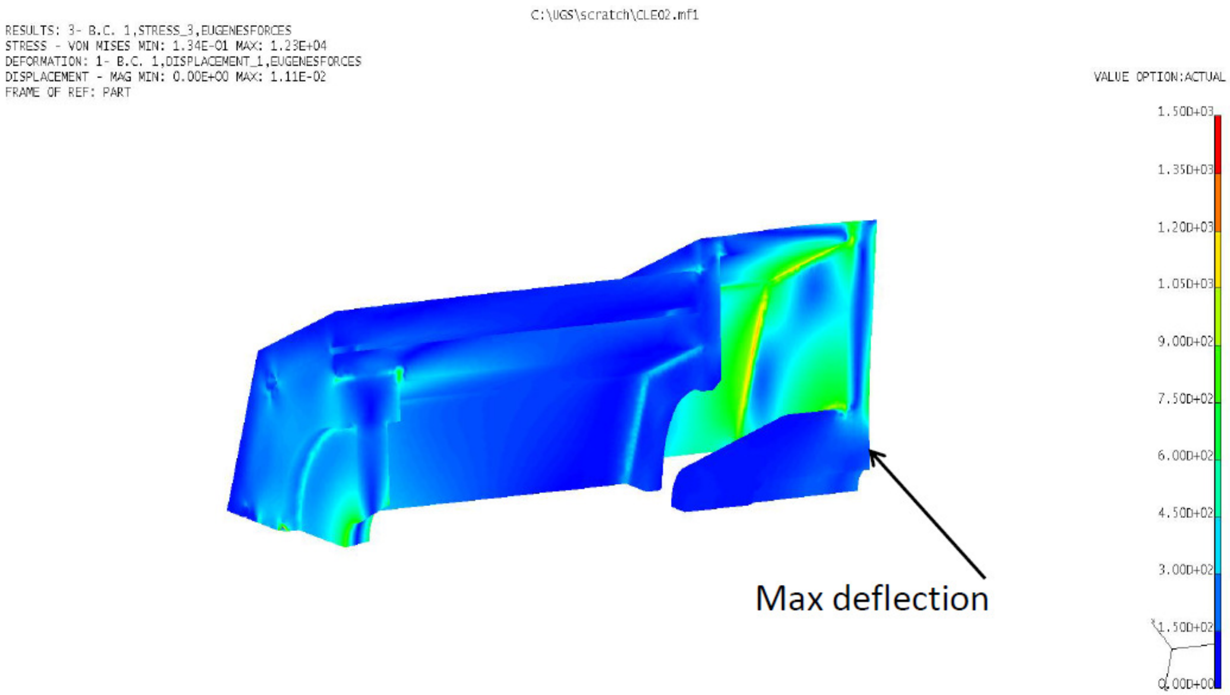


SoLID CLEO: FEA study of axial force

- Static weight are ignored for now.

Maximum Von Mises stresses on the model

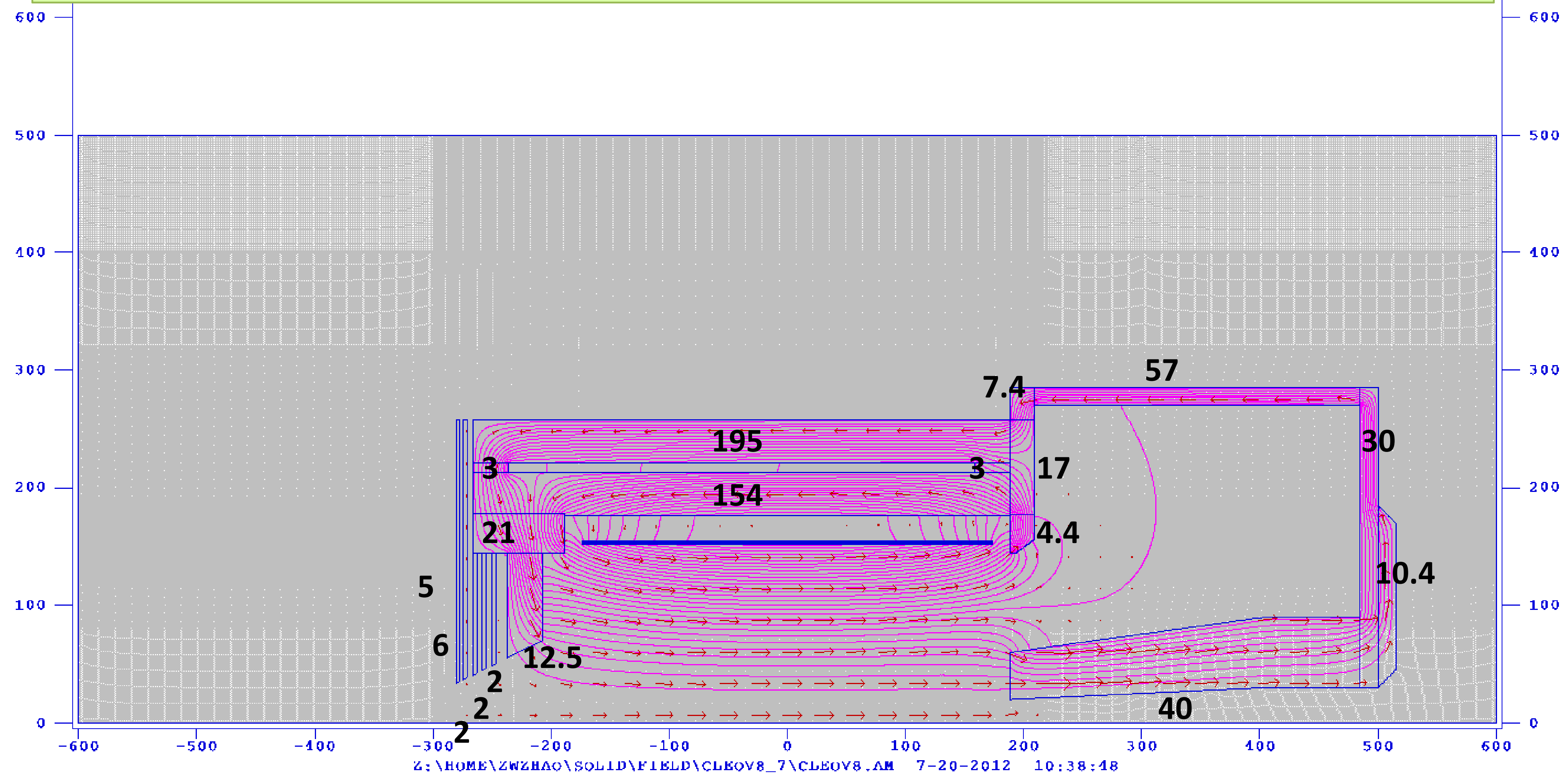
Maximum Von Mises stresses do not exceed 1500 psi. (magnetic axial forces only)
Allowable yield stress 1006 steel is 24000 psi.
Maximum deflection is 0.011" = 0.2794mm where region 15 and 16 meet.
Maximum shear was approximately 750 psi and acceptable. (not shown)



by Whit Seay

SoLID CLEO Yoke weight

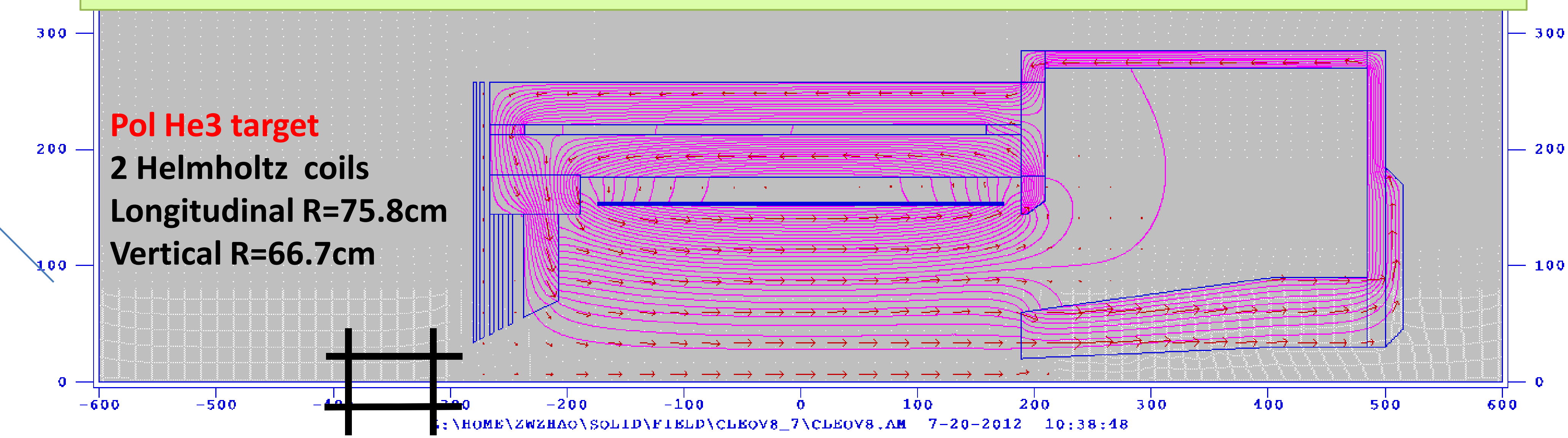
- assume steel density is 7.9g/cm3 , weight unit is in t
- material from CLEO-II 376t
- new material 200t ($2.7M if assume $6/lb machined iron)
- total 576t



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

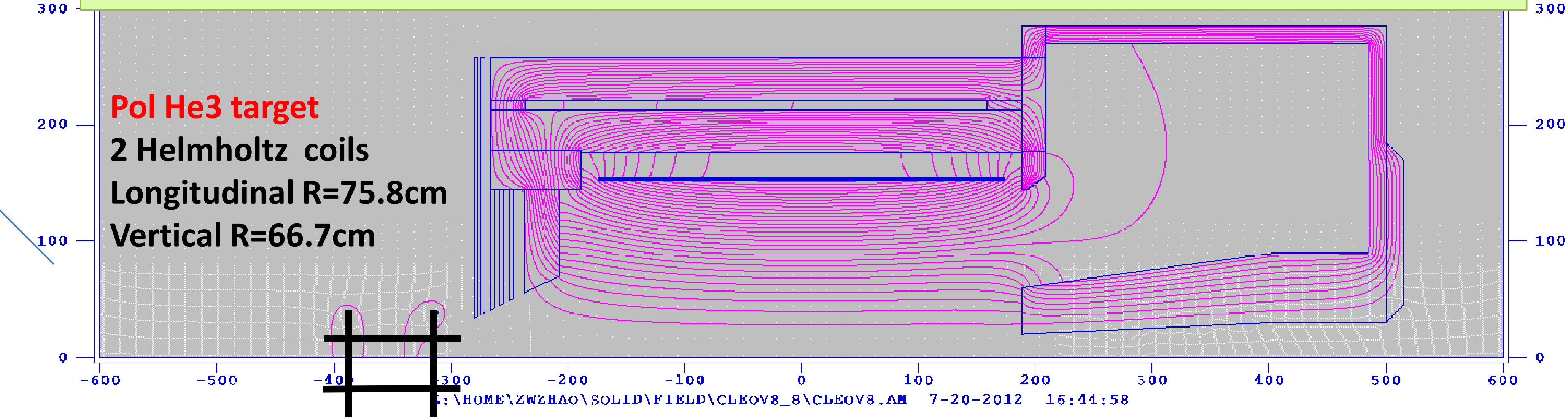
- Multilayer of iron plates and gaps have good shielding effect
- The distance between first shielding plate to the target coil is a few cm.
- pol He3 holding field is 25G and we need field gradient below 100mG/cm
- We need additional shielding or correction coil.



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

BaBar

- The magnet was built in 1990s by Ansaldo Energia in Italy
- Its setup has 9GeV e^- come from left, 3.1GeV e^+ come from right
- Yoke is in hexagon shape

	Length (mm)	Radius (mm)
Coil	3513.5	1509.8 – 1550.6
Cryo	3850	1420 -1770
Barrel flux return	3750	1820 - 3041
Side plate	3750	1902.5 – 3290.5
Support ring	328	3100 – 3728.4
Flux bar (barrel)	200	3041 - 3209
Upstream flux return	1144	1020 - 2859
Downstream flux return	1144	710/1564 - 2859
Gap plate	150	1820 - 3209
Flux bar (door)	1144	2859 - 3209

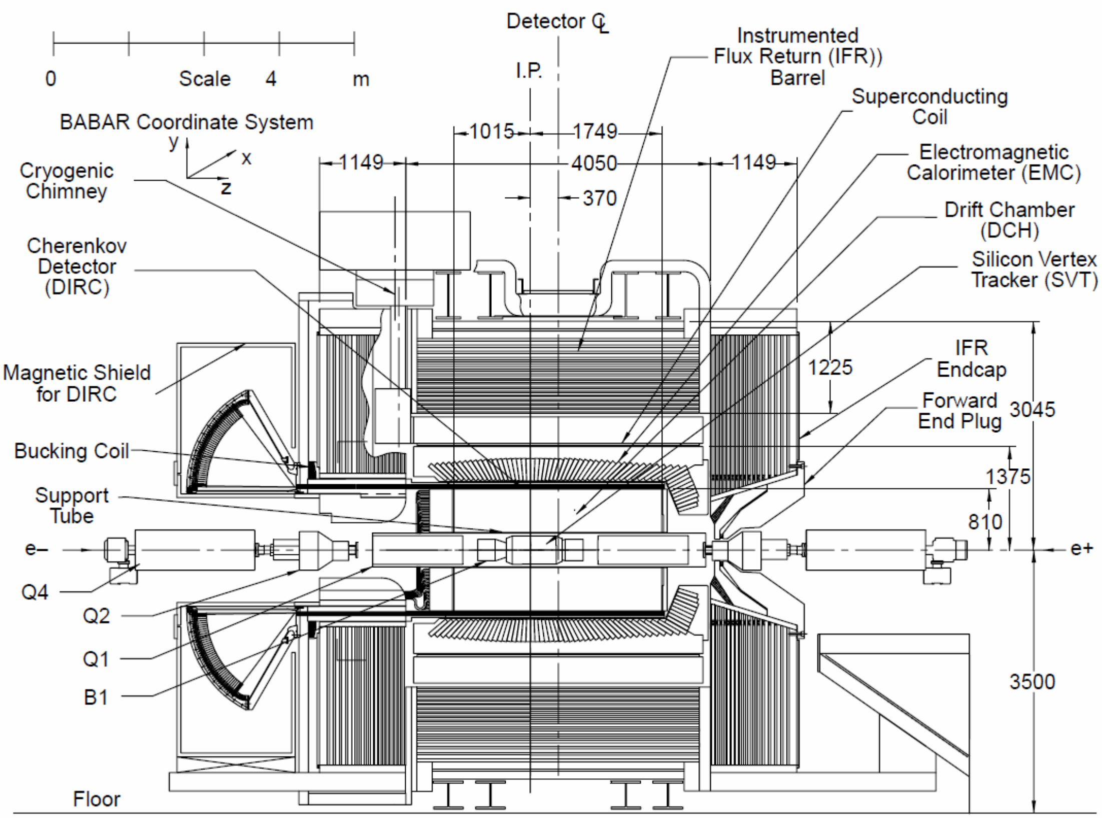


Fig. 1. BABAR detector longitudinal section.

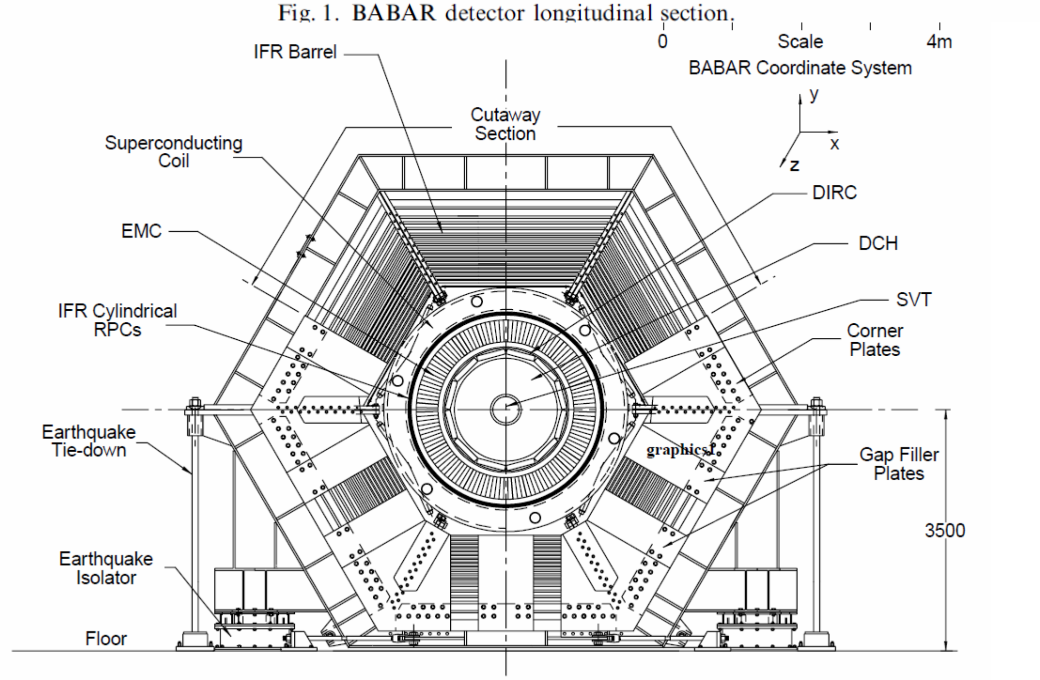


Fig. 2. BABAR detector end view.

Coil

- Radius 1509.8 – 1550.6mm
- Length 3513.5mm,
- 3 sections, middle is twice long as each of two ends.
- Turn 1067, double layer
- For 1.5T field, run with 4596A, total 4903932A. this is nominal operation current.
- For 1.58T field, run with 4826A, total 5149342A. This is tested operation current.

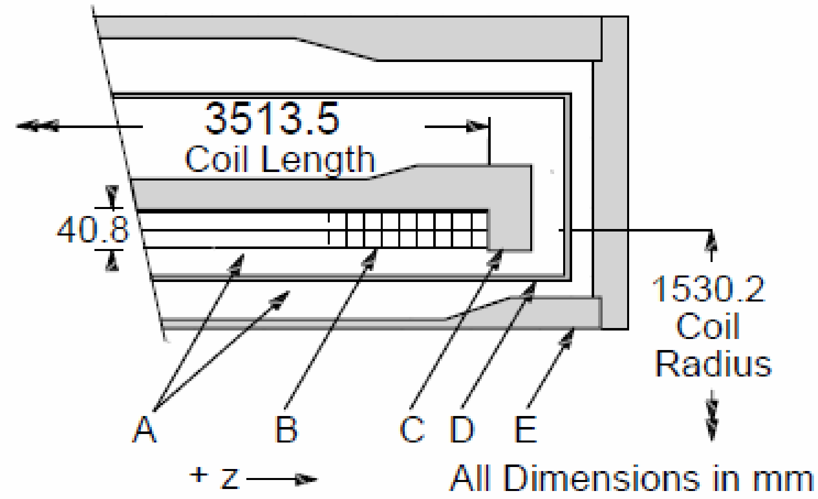


Fig. 13. A portion of cryostat assembly. The forward end is shown. Legend: (A) evacuated spaces filled with IR-reflective insulator; (B) superconducting coil (2-layers); (C) aluminum support cylinder; (D) aluminum heat shield; (E) aluminum cryostat housing.

Need more info from BaBar

- Can it run higher current?
- How is the coil supported? By the 6 poles in Cryo?

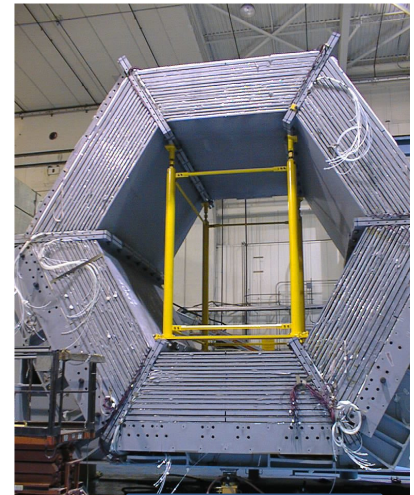
Cryo

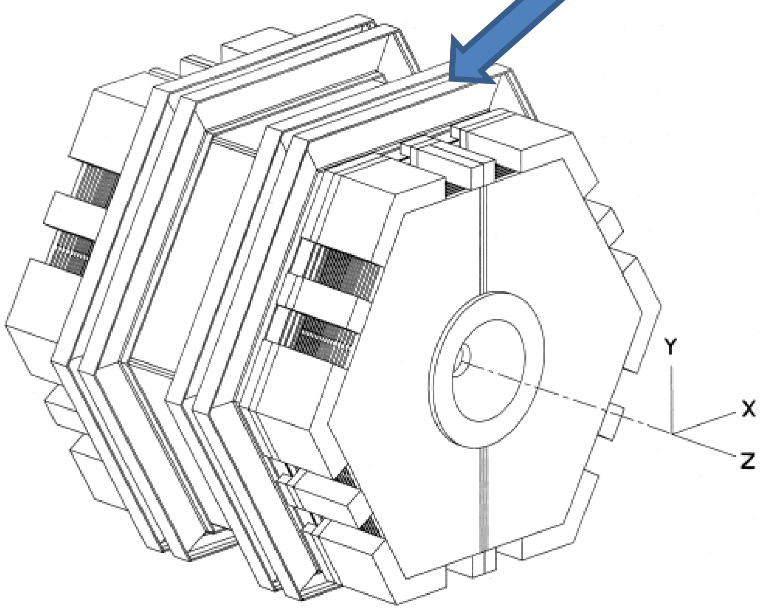
- Use thermosyphone, chimney at upstream end
- Chimney radius ***2145mm***
- Length 3850mm, ***80mm longer*** than CLEO 3870mm
- Outer radius 1770, **10mm larger** than CLEO 1760mm

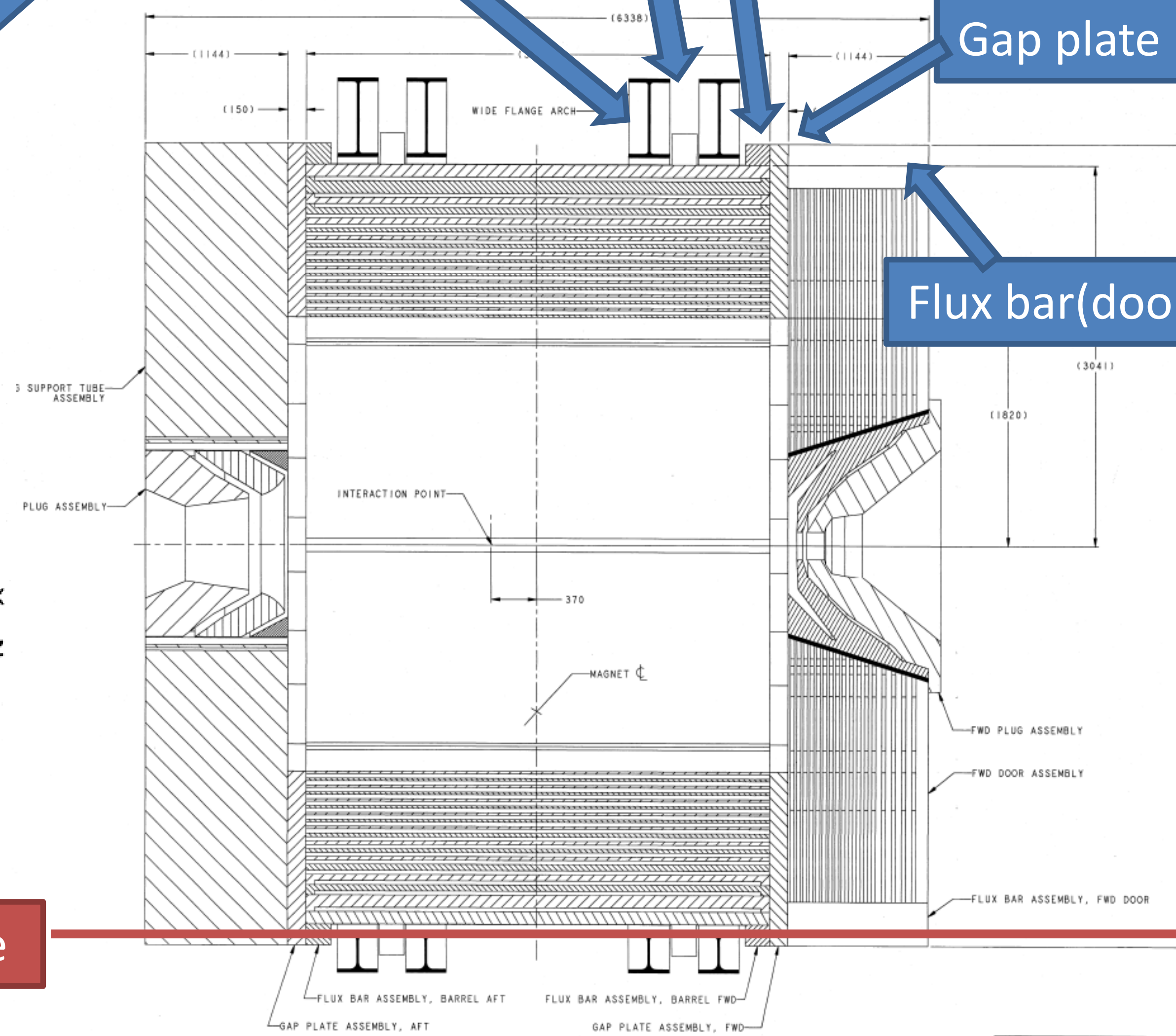
BaBar Flux return and support

Need Cut bottom to fit

- Barrel supporting ring
- End door supporting
- Remove most outer layer of barrel flux return





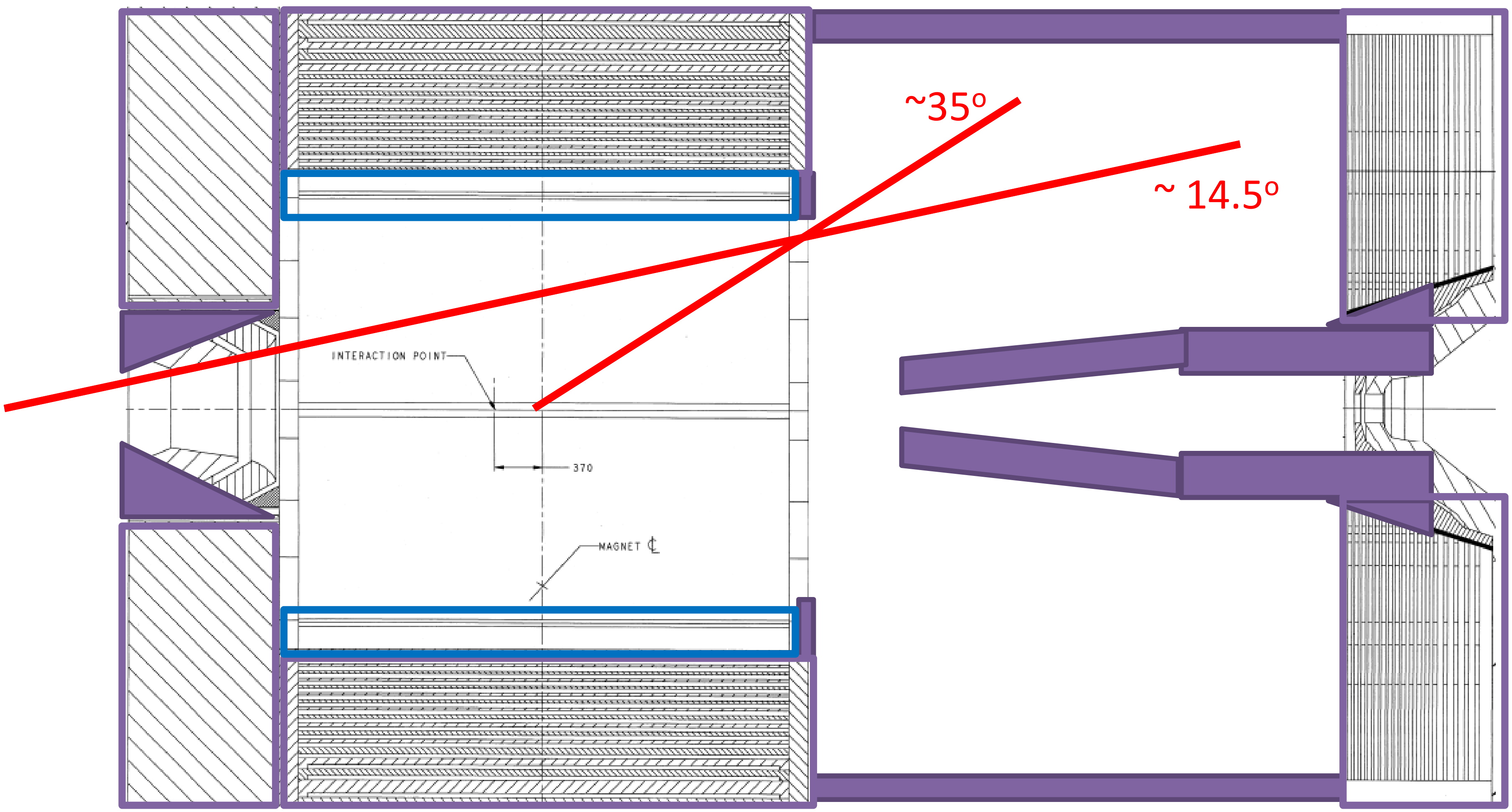


Constrain of Hall A beam line height 3048mm (10 feet)

SoLID BaBar

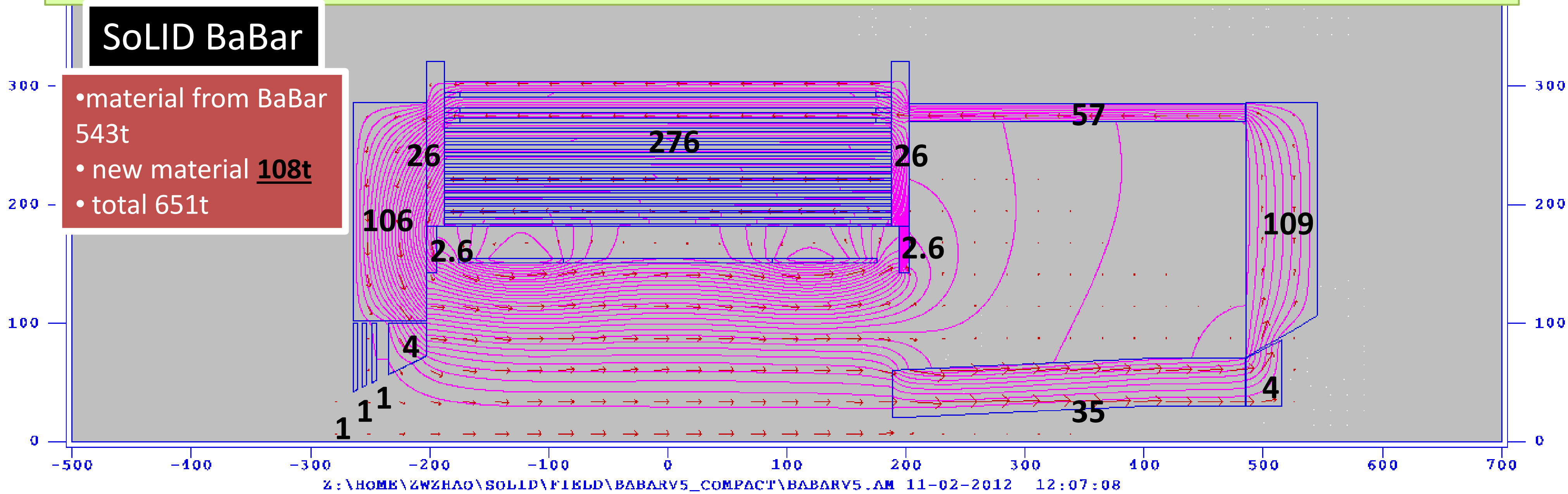
New Parts in solid color
Old parts in boxes

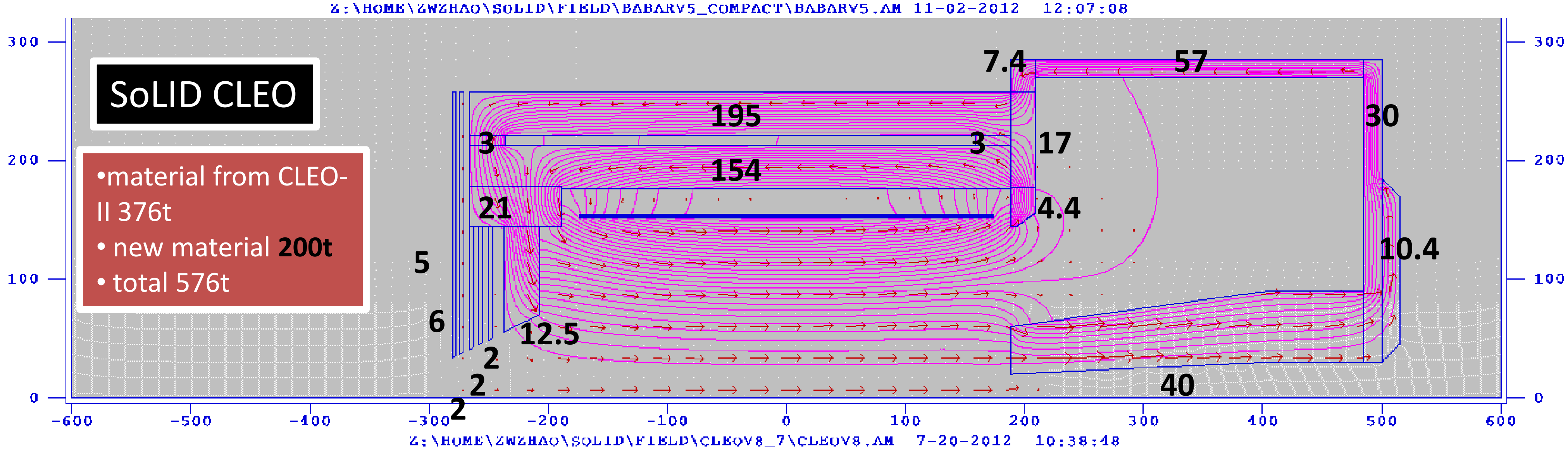
- Polar angle acceptance are similar to CLEO
- May use BaBar barrel flux return after removing the most outer layer.
- May use BaBar upstream and downstream flux return as partial SoLID front piece and endcap. How much change is needed?
- The bottom of various support structures need cut to fit Hall A beam line height



Yoke weight

- Steel density is 7.9g/cm3 , weight unit is in metric t
- SoLID BaBar could save about 92t iron. Assume machined steel cost $4.5/lb, total could save $0.9M





SoLID BaBar summary

- The initial look shows that BaBar can be used for the same physics.
- It can be improved with more input from engineering and more info from BaBar
- It could reuse more yoke than CLEO, which means potential savings.
- The modification cost could be significant though.

Summary

- Our default design is based on CLEO
- BaBar could be alternative
- Cost difference needs more input from engineering.