# Power Deposition in the Open Midplane Dipole

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**Muon Collider 2011**

**June 27-July 1, 2011 --- Telluride**

# OUTLINE

- Parameters
- Power Deposition with Varied Vacuum Gaps
- Power Deposition of Real Field with Flux Return vs. Artificial Uniform Field
- Power Deposition with Collimator and Liner
- Conclusions

# Muon Collider

- Muon: E=750 GeV
- Circumference: 2500 m
- Transverse: $25\pi$ mm.mrad
- Momentum acceptance: $\pm 1.2\%$
- $2 \times 10^{12}$ muons/bunch
- 15 Hz repetition rate
- 1000 turns

# Ring Dipoles

- $P_0$=750 GeV/c
- $B\rho \cong 3.3356 \times P$=2502 Tm
- $B_0$=10 T, l=6 m
- $\theta$=0.3Bl [Tm]/P [GeV/c]=24 mrad or 1.375 deg

# Muon Decay

- The number of muons is $N_0 = \mathbf{2 \times 10^{12}}$ at t=0.
- The muon circulating time per turn is $8.3 \times 10^{-6}$ sec. In 1000 turns <u>$8.3 \times 10^{-3}$ sec</u>.

  (Muon life time at 750GeV is <u>$15.6 \times 10^{-3}$ sec</u>)
- The decays per meter per second is $\mathbf{5 \times 10^{9}}$.

  $15 \times 2 \times 10^{12} \times [1\text{-}\exp(-8.3 \times 10^{-3})/(15.6 \times 10^{-3})]/2500 = 5 \times 10^{9}$.

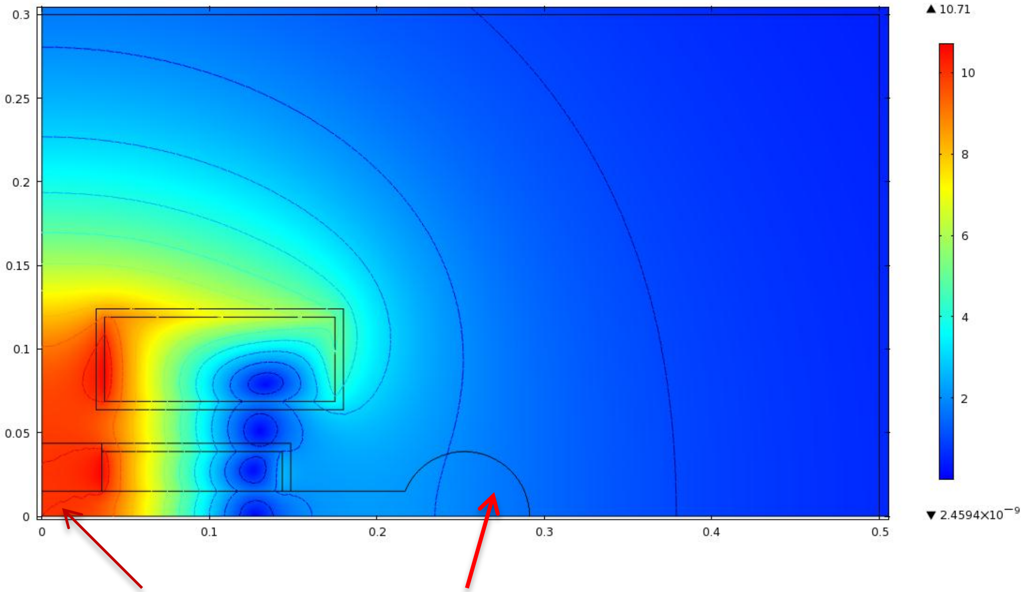
# Heat Load

- The dynamic heat load from muon decay is about **0.2 kW/m** for each charge state, mostly in the horizontal plane and inner side of the storage ring.
- The energy is deposited via electromagnetic showers induced by high-energy decay electrons as well as synchrotron radiation

# Heat Load II

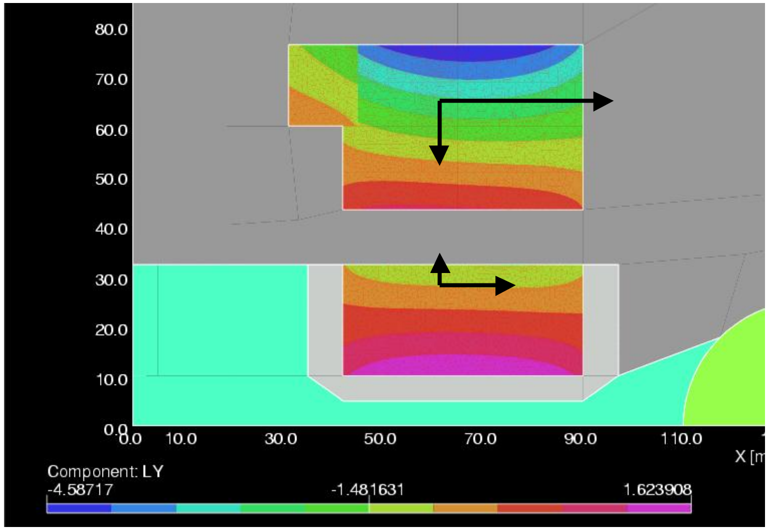
- Taking into the account the Carnot ratio and a typical refrigeration efficiency, then **for each 1% of the decay energy** deposited into the cold ($4^0$K)mass, **4.5MW of wall plug power** will be required for heat removal.
- At the FNAL Collider Ring Magnet Workshop **1%** energy flow into the cold mass was considered to be a reasonable target goal

# The OMD Principle




**Beam** **Absorber**

**Upper-right quadrant X-section showing an outboard and in inboard coil**

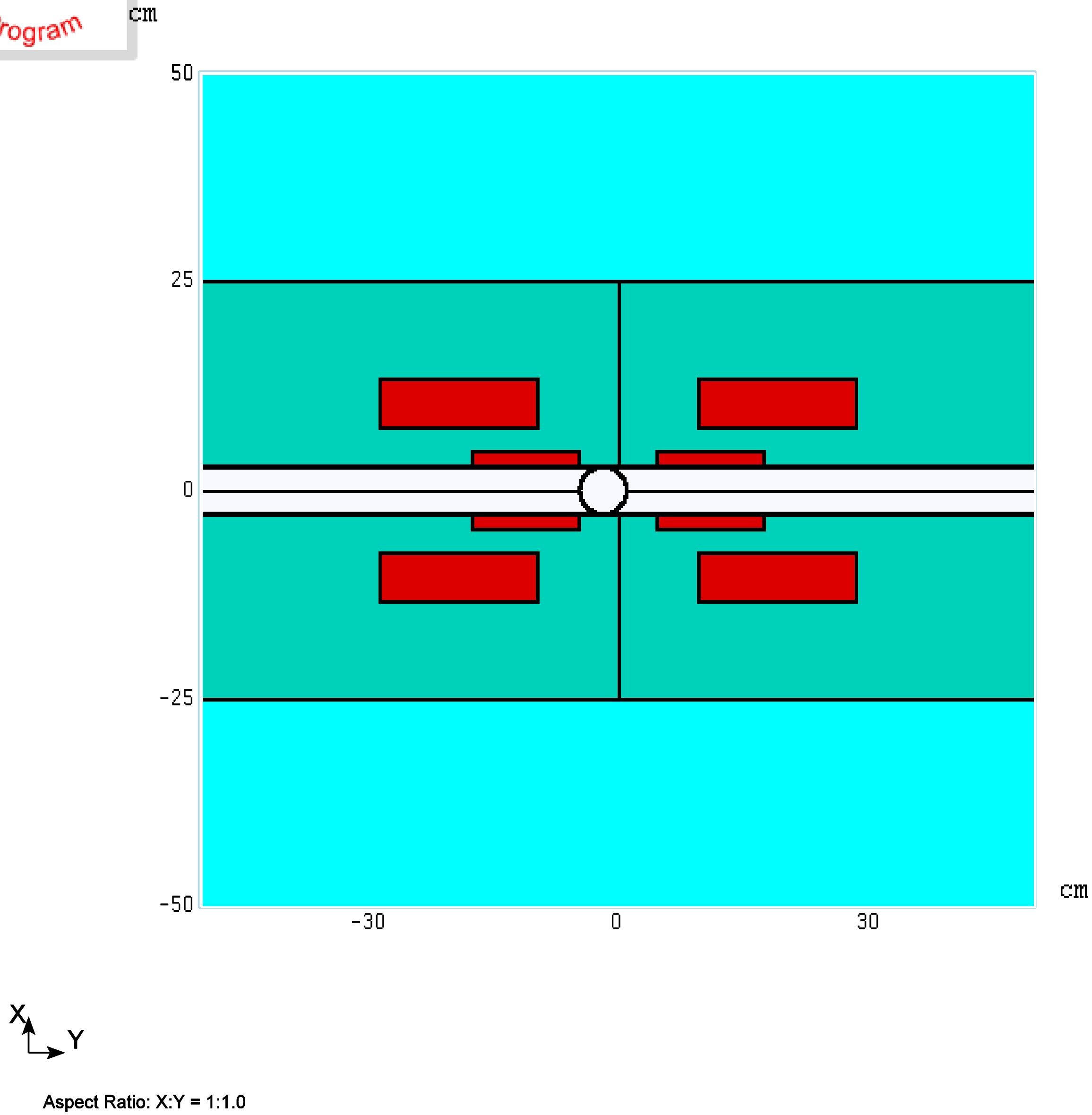



**Schematic showing the forces on the Outboard and Inboard coils**

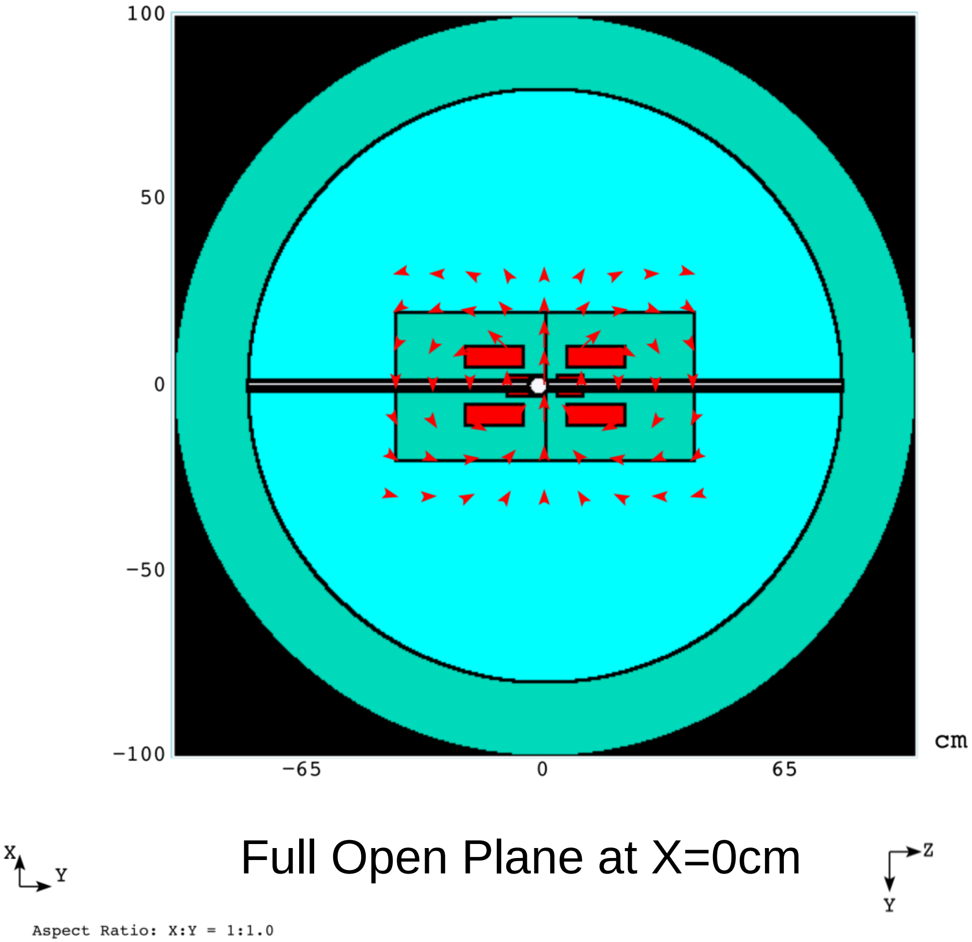
# The OMD Model


**R. Gupta (BNL)**
**B. Weggel(PBL)**

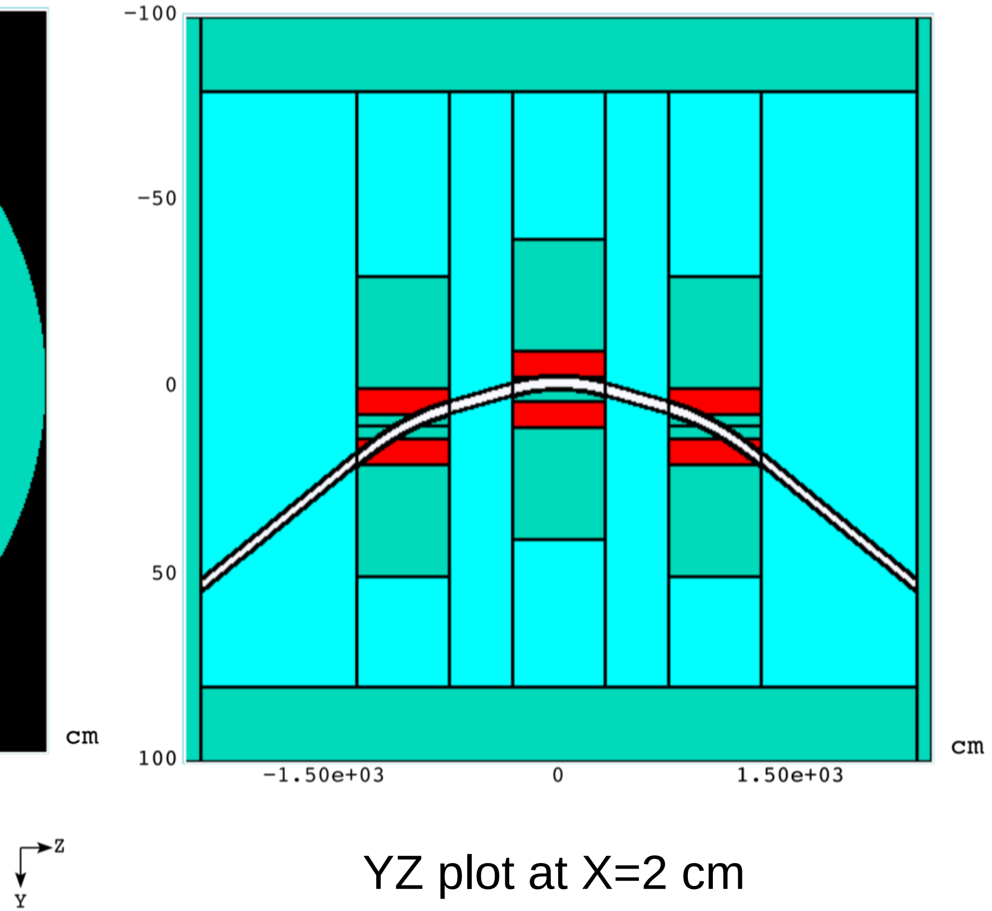

**6cm gap**



# Triple Dipole Model w/o Collimators




Full Open Plane at X=0cm



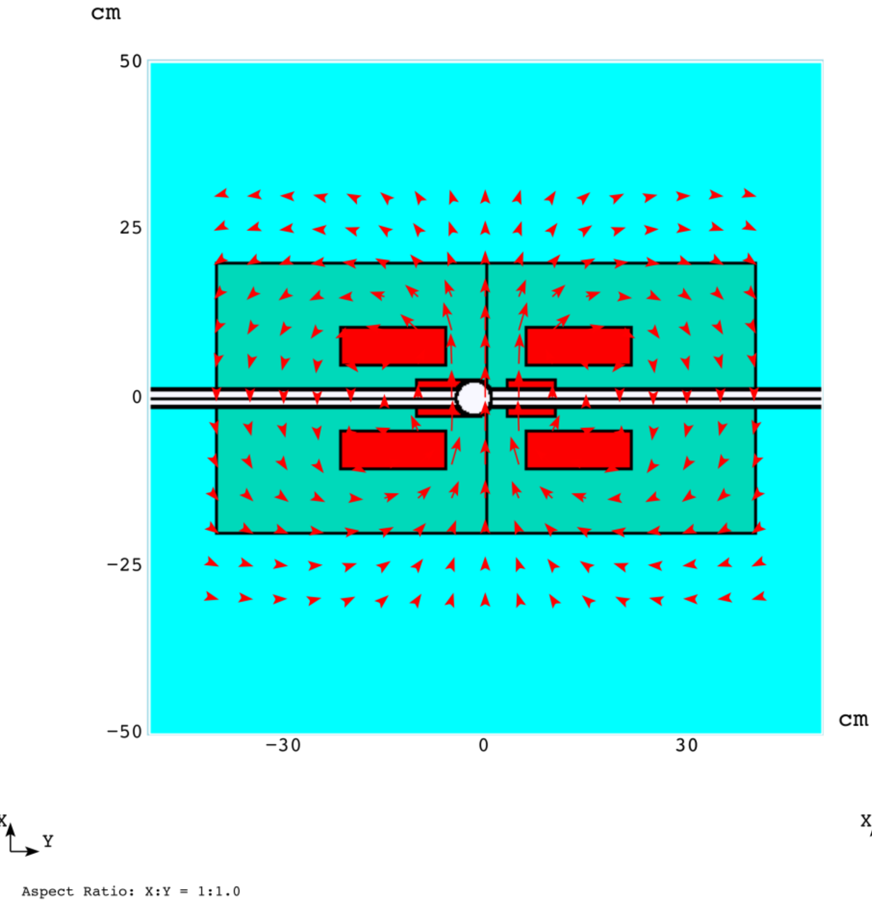

YZ plot at X=2 cm

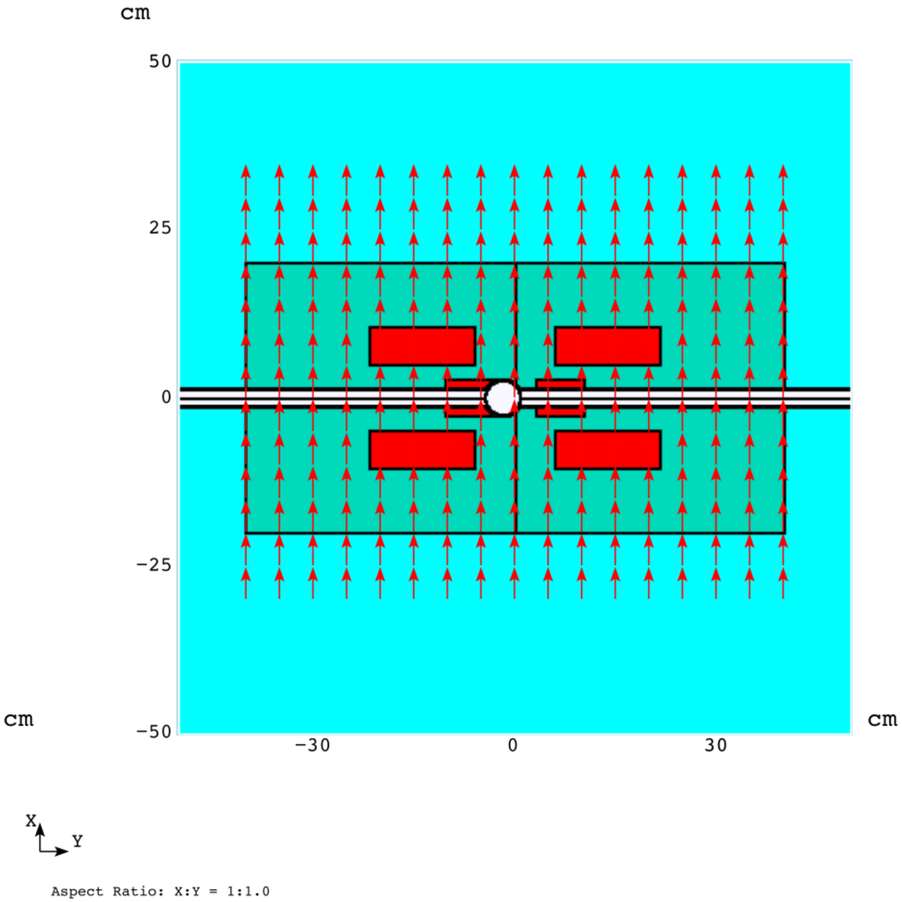
# Power Deposition with Varied Magnetic Gap

(in percent of the total power of 6 kW)

| Geometry and fieldmap | Coil + Iron | STST vacuum chamber | Other |
|---|---|---|---|
| 30 mm magnetic gap<br>(Full vacuum gap of 26 mm) | 3.43% | 14.67% | 81.9% |
| 60 mm magnetic gap<br>(Full vacuum gap of 56 mm) | 0.53% | 5.4% | 94.07% |
| 100 mm magnetic gap<br>(Full vacuum gap of 96 mm) | 0.002% | 0.973% | 99.025% |

# Real field with Flux Return vs. Artificial Uniform field



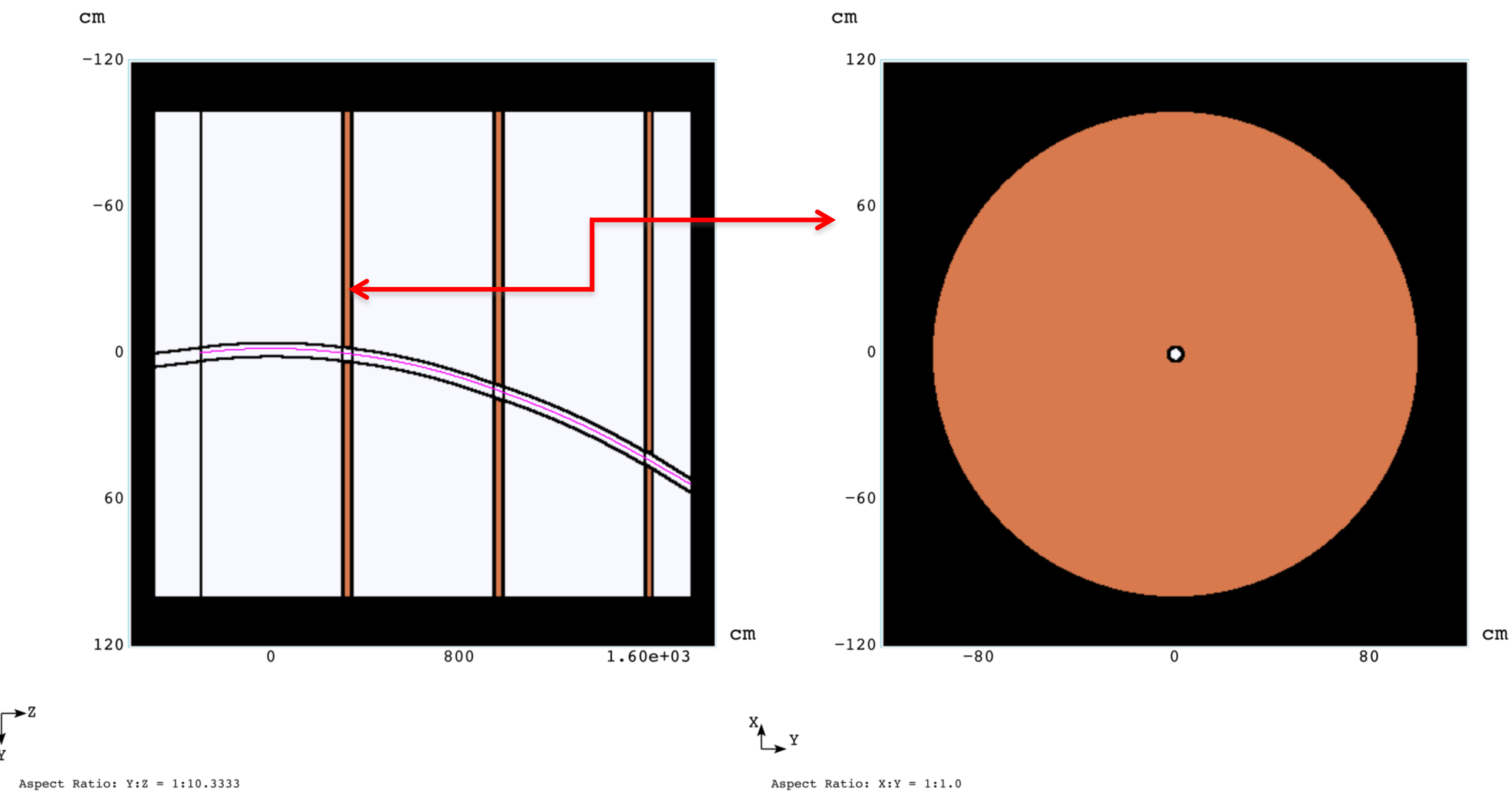



# Power Deposition

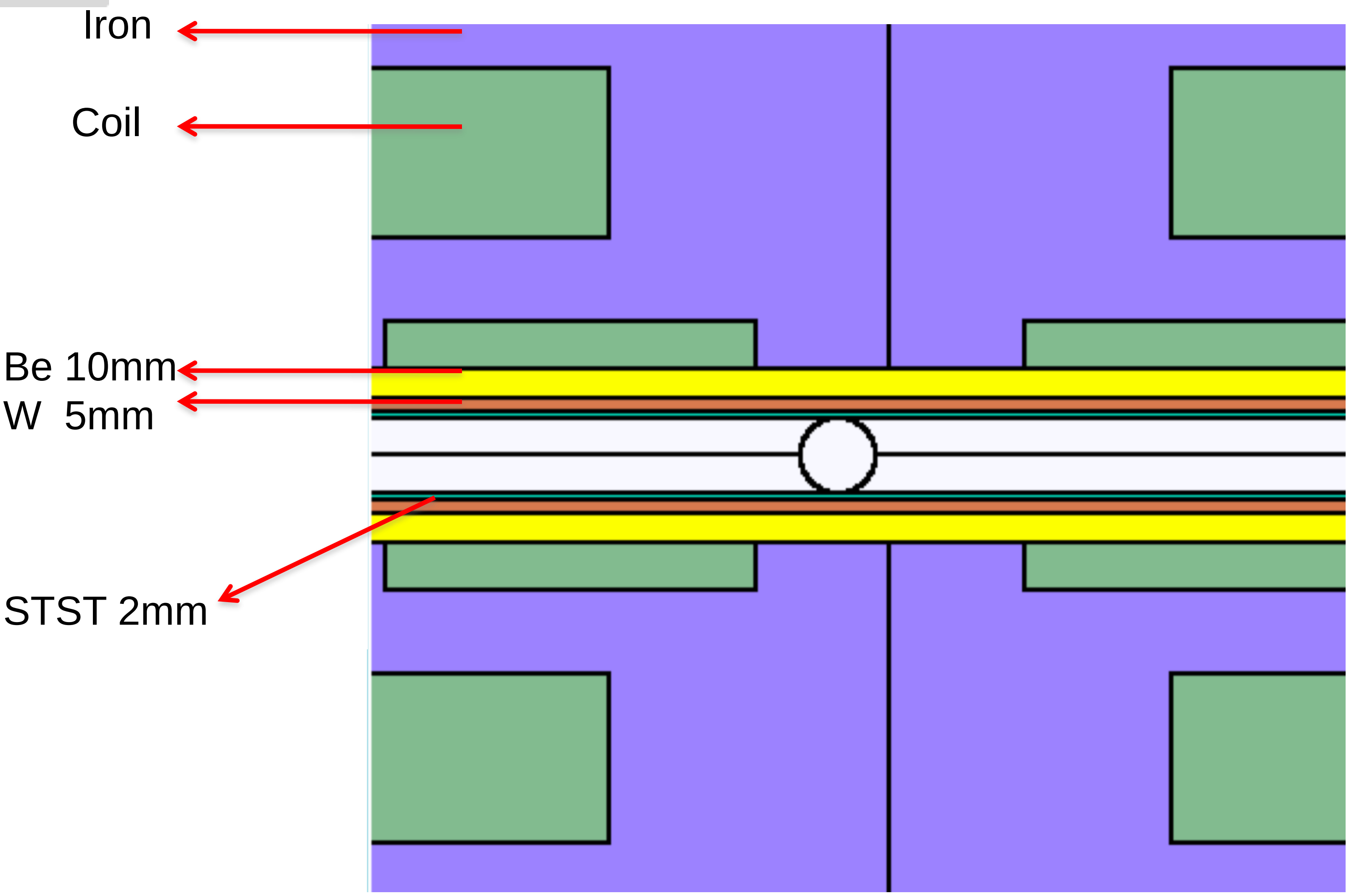
## (Real Field with Flux Return vs. Artificial Uniform Field)
## (in percent of the total power)

| Geometry and field map with 30 mm magnetic gap (Full vacuum gap of 26 mm) | Coil + Iron + STST vacuum chamber | Other |
|---|---|---|
| Real Field with Flux Return | 18.1% | 81.9% |
| Artificial Uniform Field | 1.3% | 98.7% |

# New Triple Dipole Model with Collimator (2.6cm aperture)



# Dipole with Liner



# Power Deposition with Collimator and Liner in a Triple Dipole Model

- Geometry and field map with 60 mm magnetic gap.
- The liner is 10 mm thick thermal insulation (Be) and 5 mm thick Tungsten on each side.
- The full vacuum gap is 26 mm.
- Muons decay in the 6 m beam path inside the $1^{st}$ dipole.

# Power Deposition without Liner and Collimator

| | | Power (W) | Percent of total (%) |
|---|---|---|---|
| Dipole (Coil+Iron) | 1st | 2.175 | |
| | 2nd | 25.855 | |
| | 3rd | 10.428 | |
| | sum | 38.458 | 3.315 |
| STST vacuum chamber | | 51.59 | 4.445 |
| Total "Visible" | | 1160.16 | |

# Power Deposition with Liner and Collimator

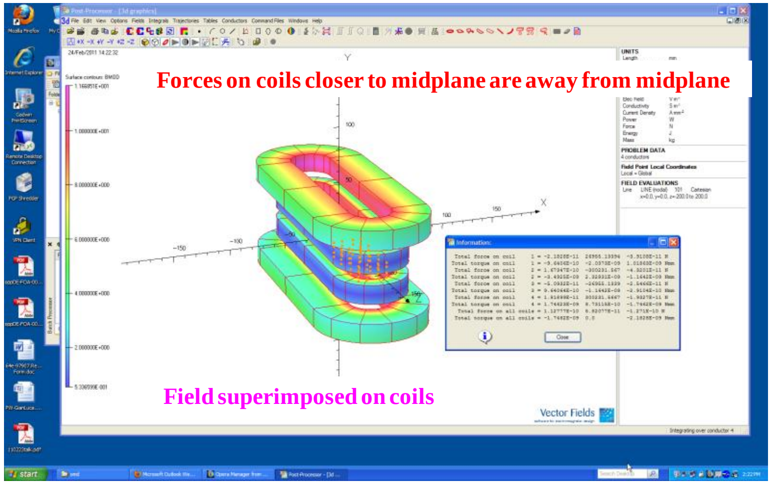
| | | Power (W) | Percent of total (%) |
|---|---|---|---|
| Dipole (Coil+Iron) | 1st | 1.168 | |
| | 2nd | 3.689 | |
| | 3rd | 0.047 | |
| | sum | 4.904 | 0.43 |
| Collimator | 1st | 828.9 | 72.25 |
| | 2nd | 244.73 | 21.33 |
| | 3rd | 5.04 | 0.44 |
| | sum | 1073.63 | 94.0 |
| STST vacuum chamber | | 48.63 | 4.2 |
| Liner (Be+W) | | 9.82 | 0.9 |
| Total "Visible" | | 1147.29 | |

# Conclusion

- The flux return of the OMD dipole field is responsible for directing some energy flow into the cold mass of the dipole
- This can be mitigated by increasing the magnetic gap of the dipole
- A 6cm magnetic gap appears to be adequate to restrict to a tolerable level the energy flow into the cold mass of the dipoles

# Open Midplane Dipole Proof-of-Principle

## PBL/BNL Phase 2 SBIR Proposal




The goal is to provide a test of the design principles of an OMD

The design incorporates key cold-mass components—$Nb_3Sn$ coils, support structure, iron yoke & space to accommodate a warm absorber.