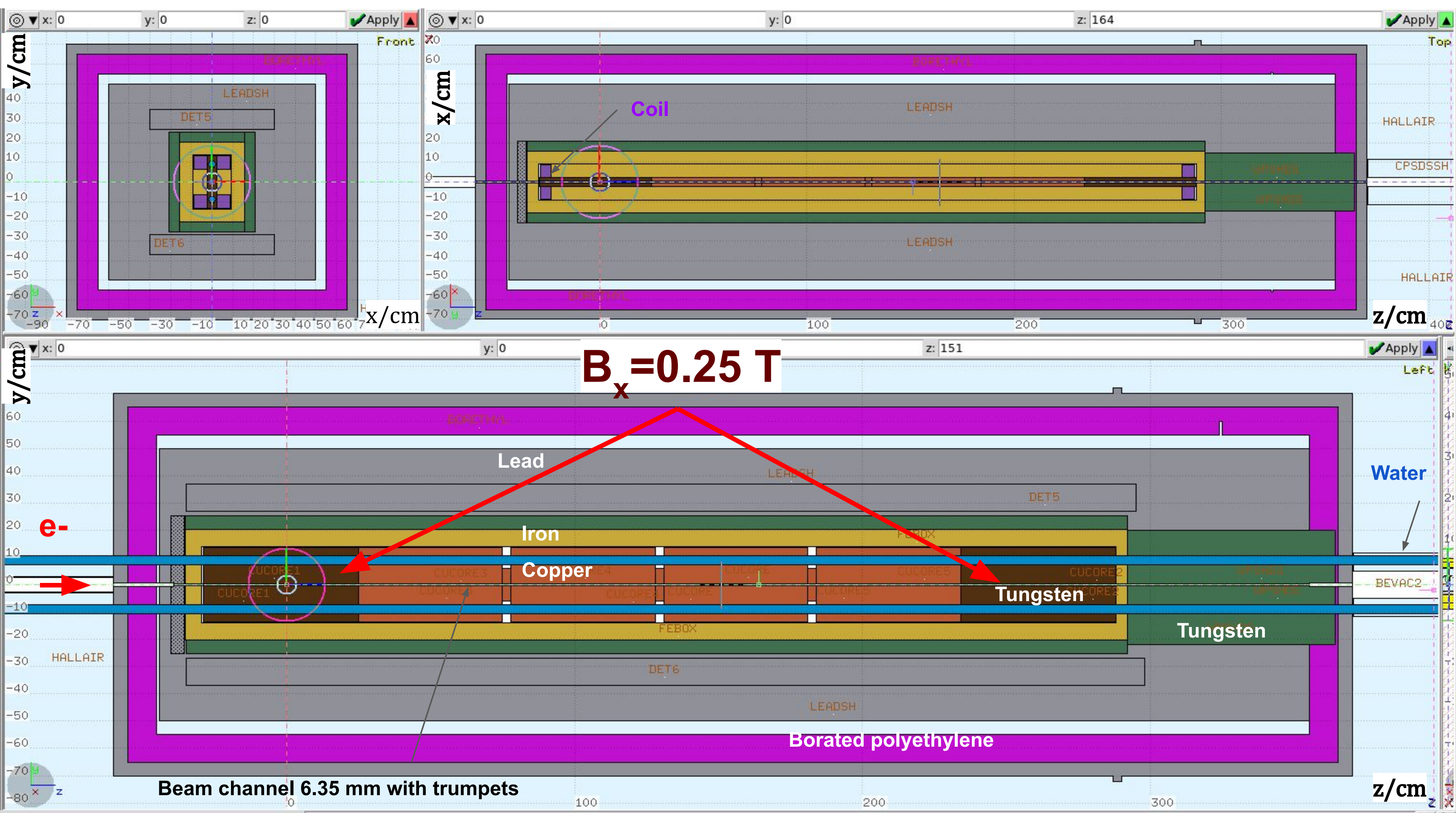
What we expect from Temperature Calculations.

1. Temperature of LEAD in baseline design -whether lead melts?
2. Temperature of Magnet Poles - need cooling?

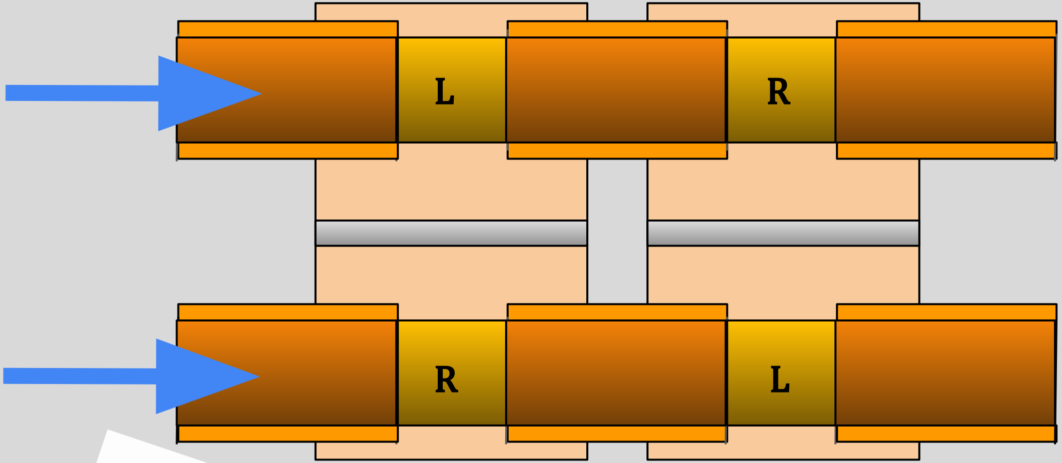
3. Temperature of LEAD on place of Tungsten? - Lower cost if not melts.
4. Temperature of Radiator at 10 W ? – need cooling ?
5. Temperature of other copper segments? Need +20 KW to cooling capacity!
6. Temperature with W-based segments without cooling ? NO need in cooling?

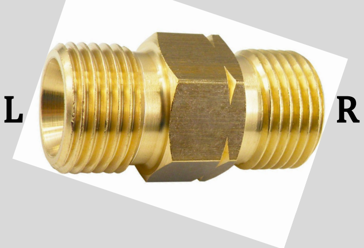
<u>Outline</u>

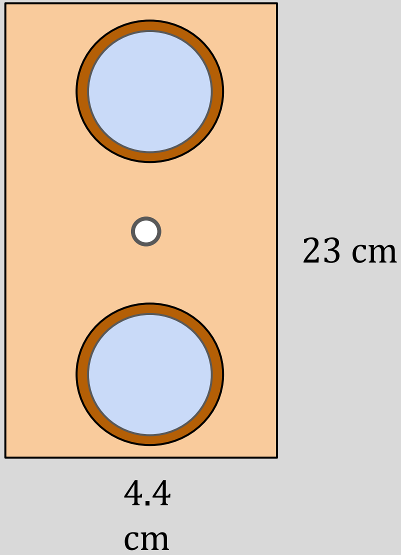
1. Design and Hot Spot Size.
2. Rastered beam.
    - Temperature.
    - Insulation lifetime.
3. Permanent Magnet.
    - Permeability Lifetime
    - Prompt Radiation.


x: 0
y: 0
z: 0
Apply
Front
y/cm
LEADSH
DET5
DET6
x/cm
z: 164
Top
x/cm
Coil
LEADSH
HALLAIR
CPSDSSH
z/cm
z: 151
Left
B_x=0.25 T
y/cm
Lead
LEADSH
DET5
Iron
FEBOX
Copper
CUCORE1
CUCORE3
CUCORE2
Tungsten
Water
BEVAC2
e-
HALLAIR
DET6
Borated polyethylene
Beam channel 6.35 mm with trumpets
z/cm

Segmented Copper Absorber. Possible solution.







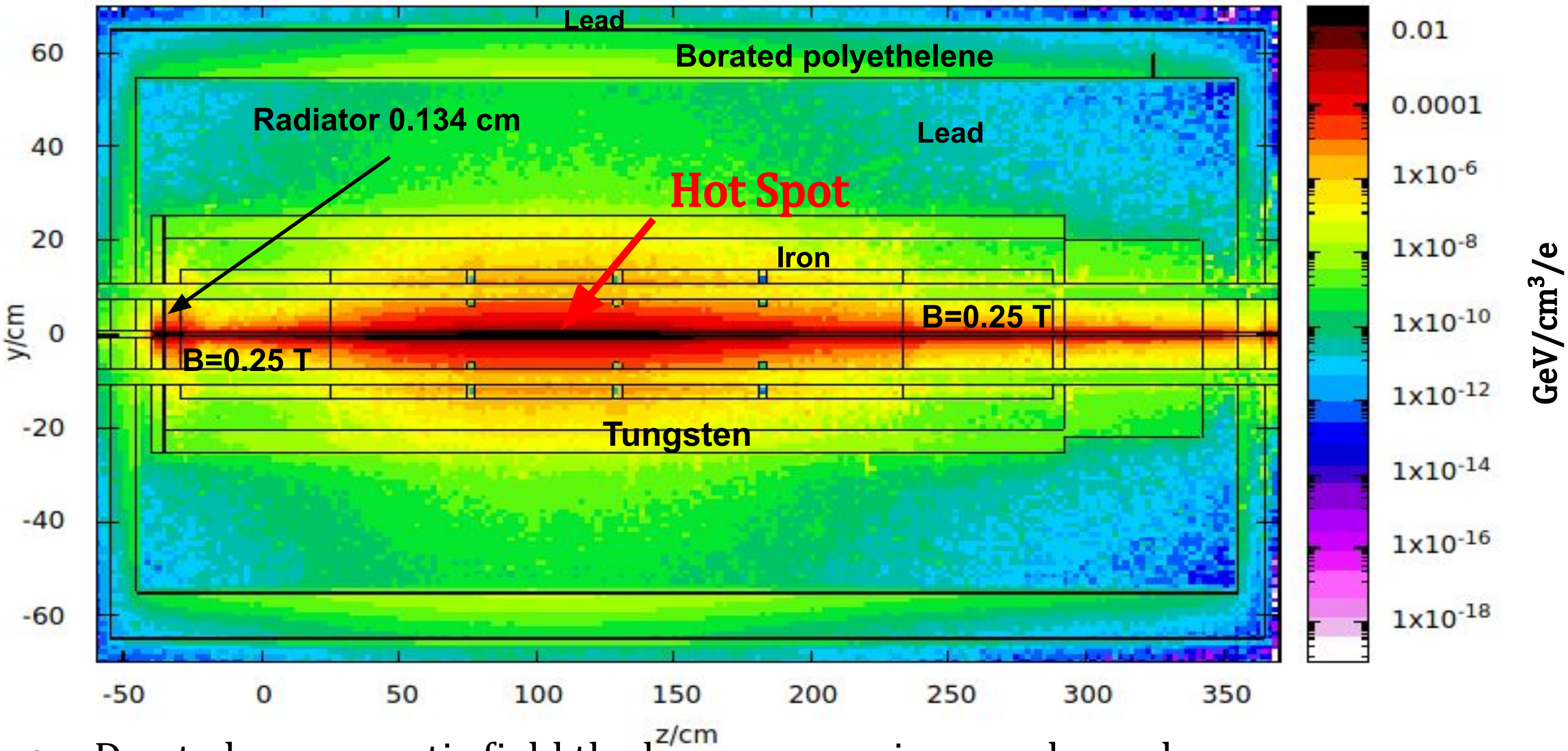
Segment 4 × 20 × 50 cm^3 with **round** beam **hole** = >avoid problem with thermal contact between parts.

Segments are connected by fittings with **left/right-**hand threads; may be soldered.

Provides direct **copper-water contact** in each segment => no interface; better cooling.

V. Baturin, ODU, Norfolk, 11/10/2022

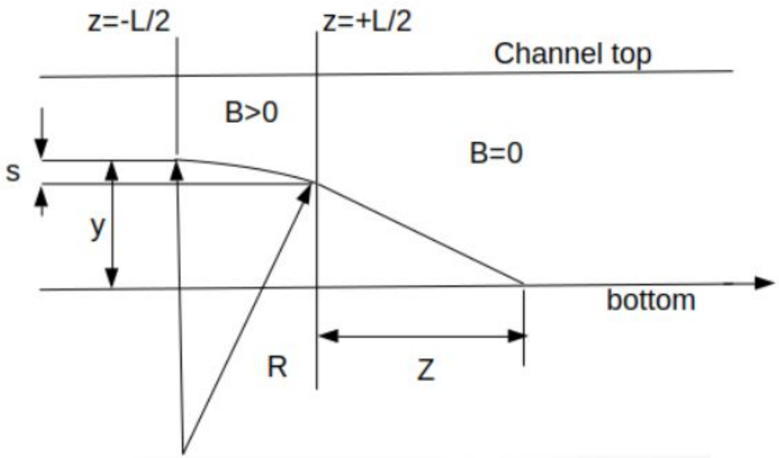
Energy Deposition in CPS .



- Due to low magnetic field the beam energy is spread over large area.
- Maximum Energy Deposition is inverse-proportional to the Hot Spot size.

Magnetic field, beam channel, and Hot Spot. Basic relations.

Effect of vacuum pipe window and of air inside CPS beam channel



From two triangles on this figure we find:

$$
\begin{aligned}
(\mathrm{R}-\mathrm{s})^2+\mathrm{L}^2=\mathrm{R}^2, \quad &=> \quad \mathrm{s}\approx\frac{\mathrm{L}^2}{2\mathrm{R}}, \\
\frac{\mathrm{L}}{\mathrm{R}-\mathrm{y}} &= \frac{\mathrm{y}-\mathrm{s}}{\mathrm{z}}, \\
\mathrm{z}\approx\frac{\mathrm{R}}{\mathrm{L}}(\mathrm{y}-\mathrm{s}) &= \frac{\mathrm{R}}{\mathrm{L}}\mathrm{y}-\frac{\mathrm{L}}{2}, \\
<\mathrm{z}'> &\approx <\mathrm{y}>\frac{\mathrm{R}}{\mathrm{L}}, \\
\mathrm{rms}(\mathrm{z}')\approx\mathrm{rms}(\mathrm{y})\frac{\mathrm{R}}{\mathrm{L}} &= <\mathrm{z}'>\frac{\mathrm{rms}(\mathrm{y})}{<\mathrm{y}>}.
\end{aligned}
$$

As z'=L_M/2 is constrained to be in the middle of Magnet we write: =>

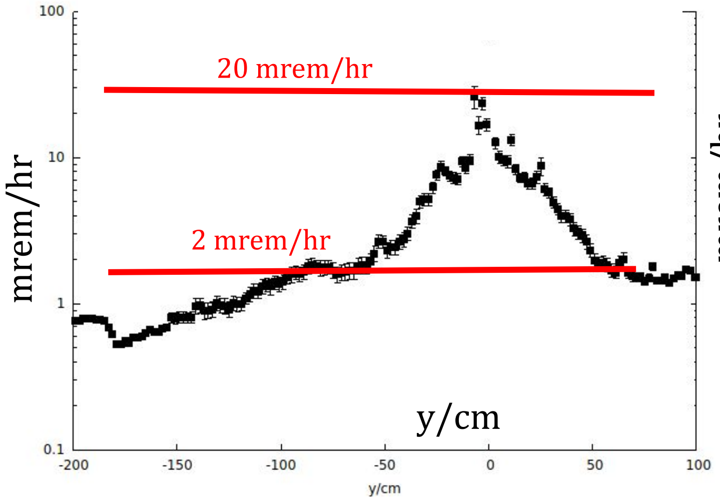
$$\mathrm{rms}(\mathrm{z}') = 2<\mathrm{z}'>\frac{\mathrm{rms}(\mathrm{y})}{\mathrm{d}} = \frac{\mathrm{L_M}}{\mathrm{d}}\mathrm{rms}(\mathrm{y})$$

- For **lower temperature** – **reduce channel** diameter "d" , **increase length** "L_M" of Magnet and increase up to rms(y) = "½d" , or constrained to be any fraction of "d".
- Then rms(z')=½L_M .
- That means if we can raster e-beam within ½ cm, then "d" may be 1 cm, etc.

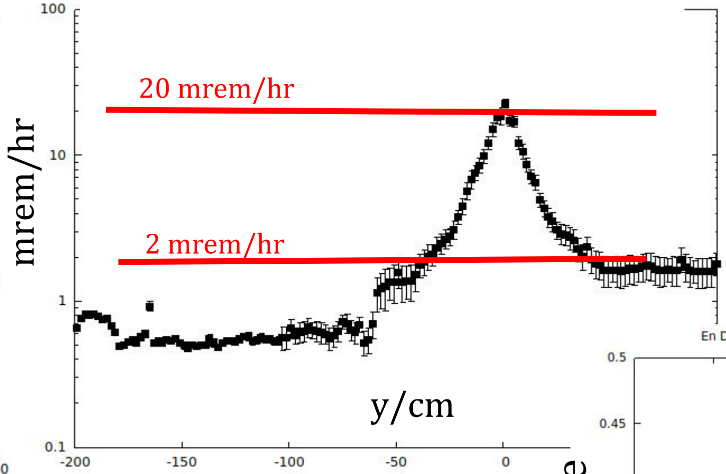
Nominal beam profile FWHM=2.5 mm.

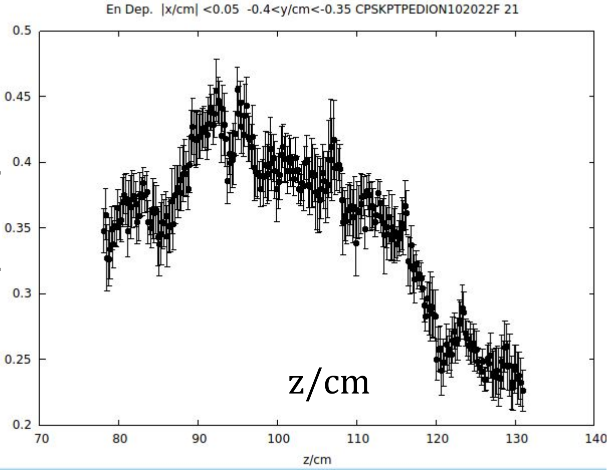
Effect of vacuum pipe window and of air inside CPS beam channel

1000+1 hr Dose Eq. Upstr. CPS side



1000+1 hr Dose Eq. Dstr. CPS side

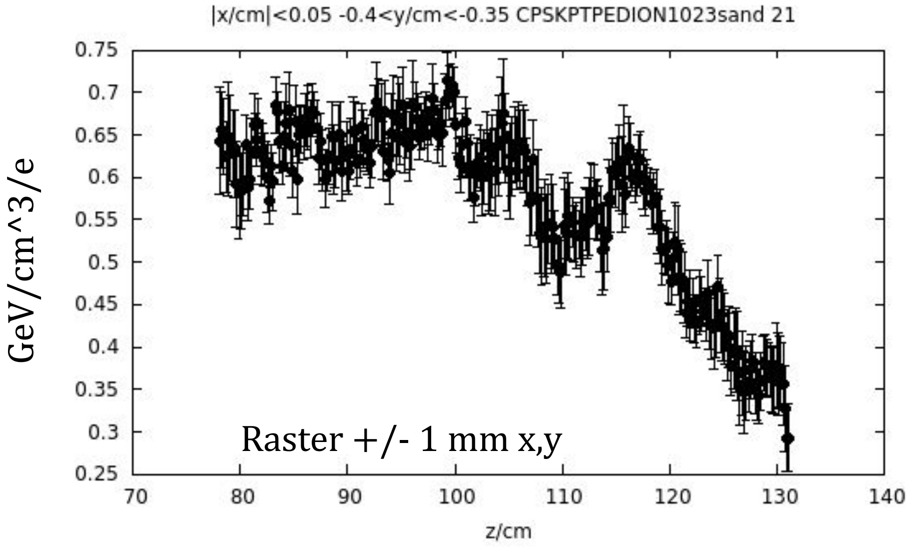




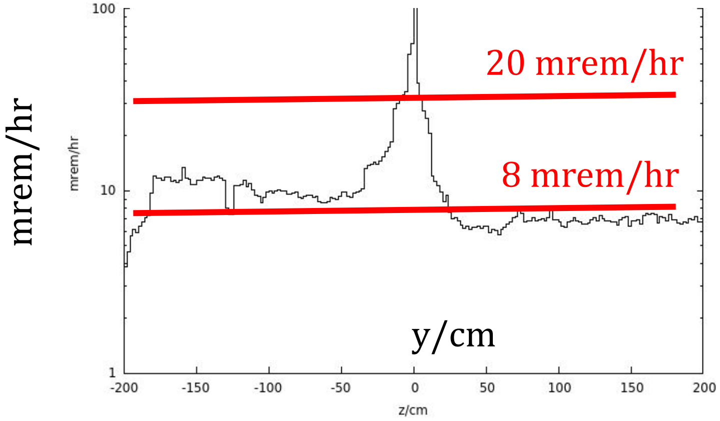
- Maximum energy deposition 0.42 GeV/cm^3/e +10 %.
- No critical change in activation.

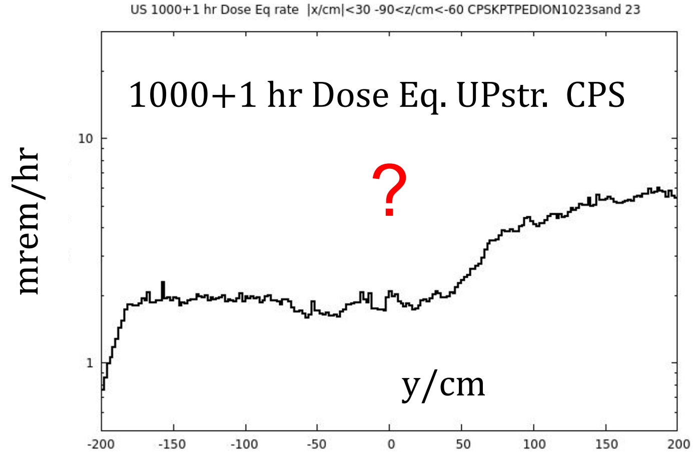
Rastered beam ±1mm in 6.35 mm channel

Energy Deposition in “hot” segment



1000+1 hr Dose Eq. Dstr. CPS

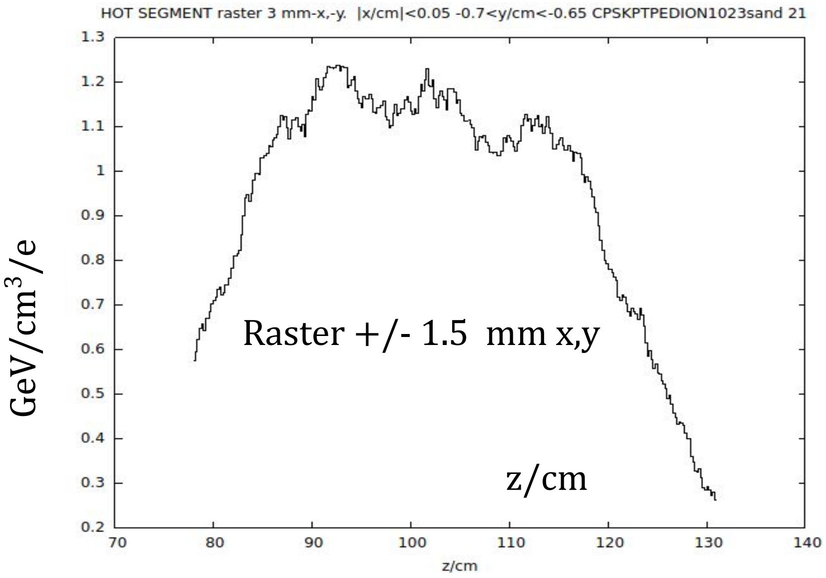


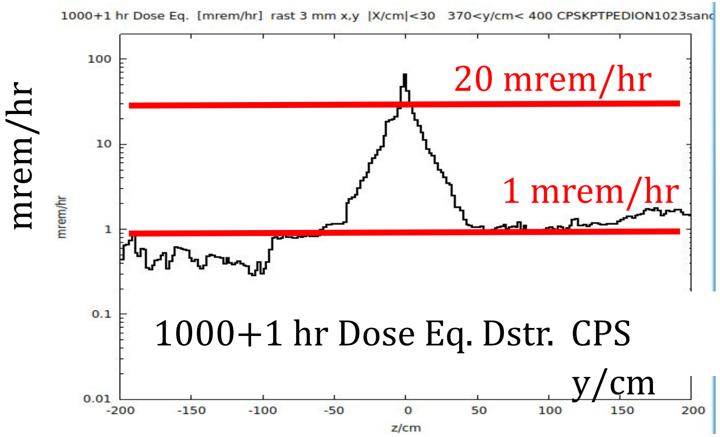


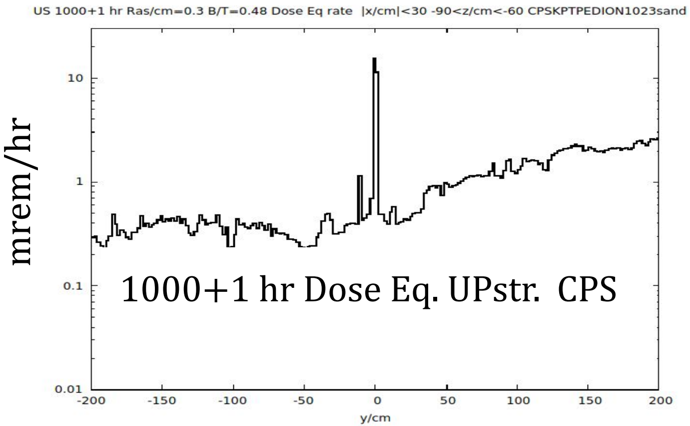
- Max. En. Dep. changes from 0.42 to 0.65 GeV/cm^3/e
- Max. downstream dose rate is 5 times higher.

Rastered beam ±1.5 mm in 12.7 mm channel

Energy Deposition in “hot” segment







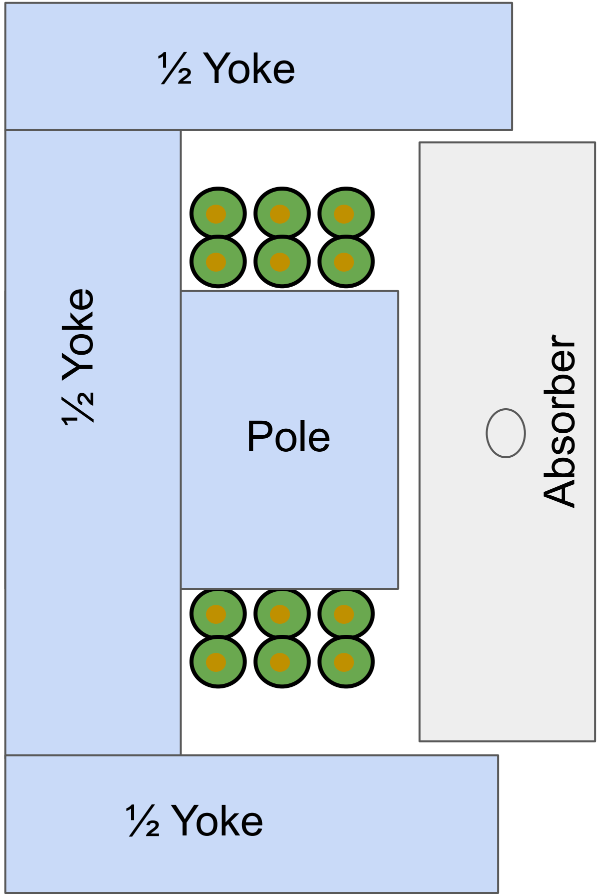
- Max. En. Dep. changes from 0.42 to **1.2 GeV/cm^3/e**
- Max. downstream dose rate is 3 times higher

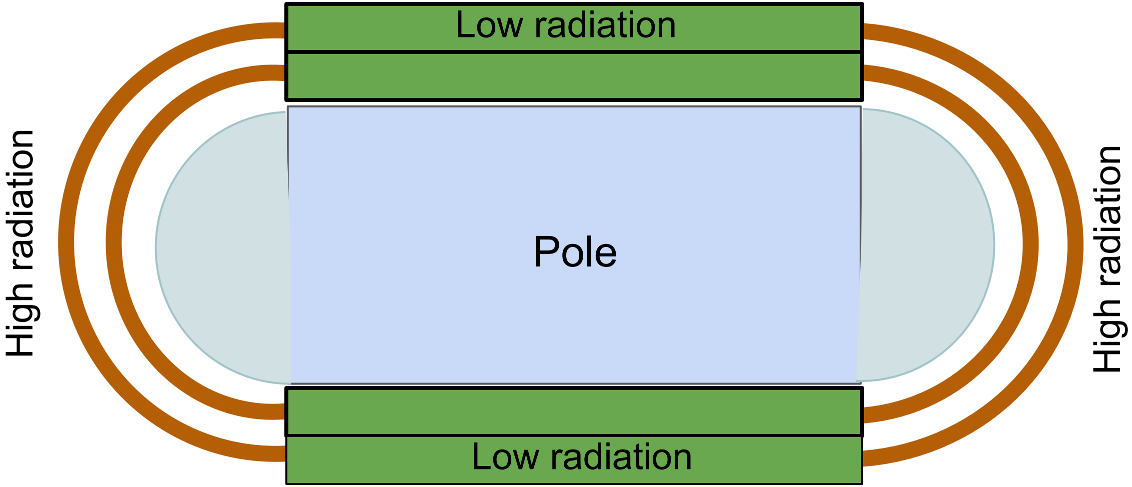
Coil design vs Radiation

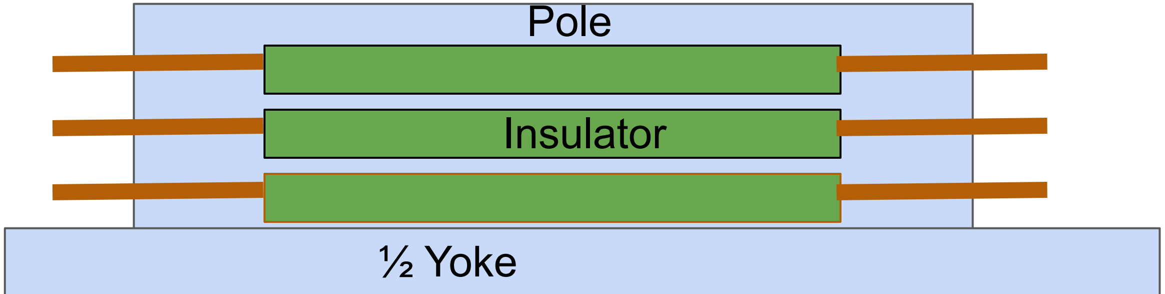
- We need ⅕ of B=1.5 T => reduces winding density with ~5 mm spacing.
- Only parallel to the beam axis portions of coils need to be insulated.
- Coil "return" portion remains "naked" – insulated by air gap.
- Ceramic spacers in between curver parts to prevent touching.

- Although "return" parts are exposed to significantly higher radiation, they do not affect the insulation lifetime.
- Only straight parts of windings to be addressed in lifetime estimations.
- Lifetime is 1160 days for kapton and 5500 days for the fiberglass material.

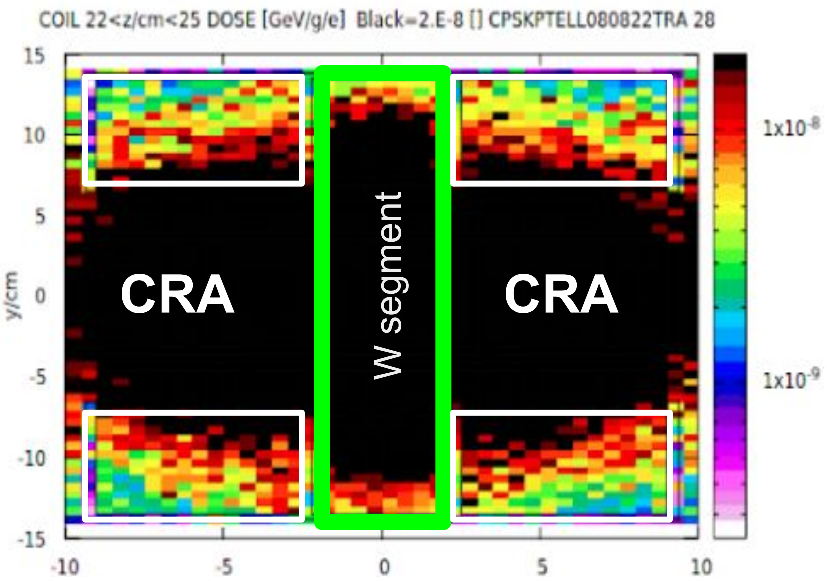
Coil design vs Radiation

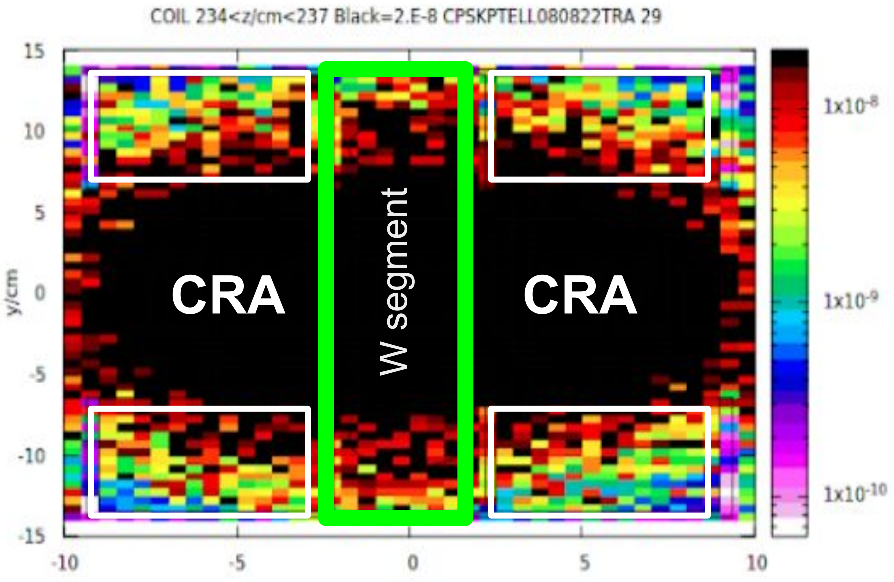






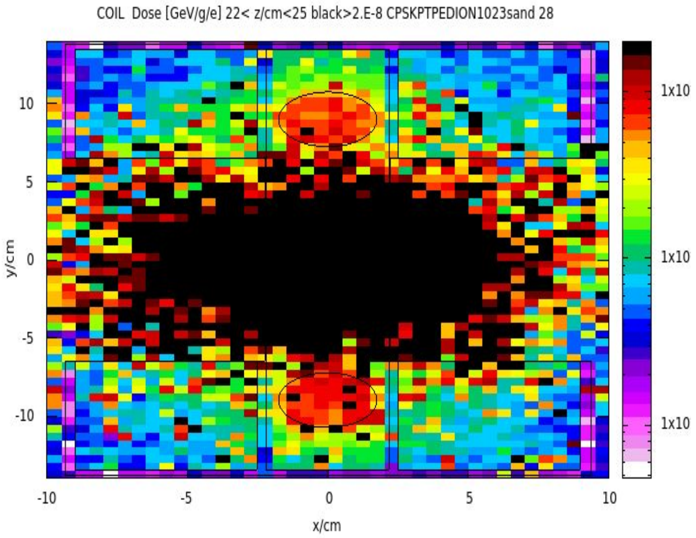
Prompt Dose in 3 cm long hot areas of two magnets. Insulation lifetime.

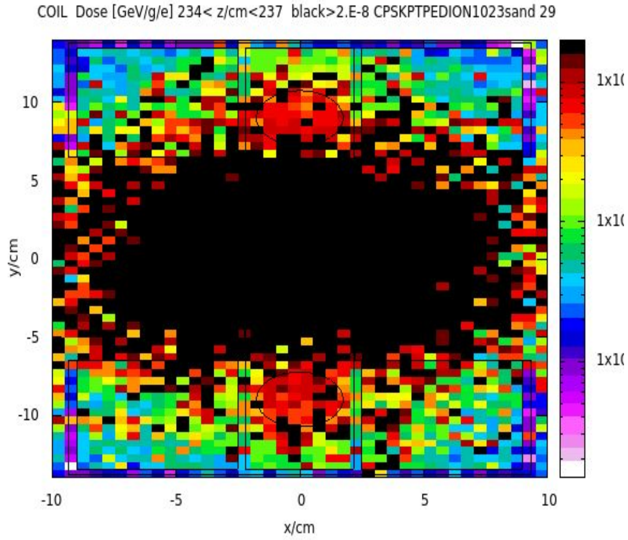




- Special design of coils: no insulation in coil “return” area (CRA) where DOse is significantly higher.
- Maximum dose 2.E-8 [GeV/g/e] = 3.2E-15 [Gy/e] ; (× 1.6E-7 Gy/(GeV/g)).
- At 5 μA beam intensity = 3.E+13 [e/s]. Dose rate = 3.2E-15 [Gy/e]×3.E+13 [e/s] ≅ **0.1 [Gy/s]**.
- Kapton withstands **1.E+7 [Gy]** => Coil **Lifetime** ~1.E+8 [s]=**1160 days** of continuous operation.
- Compare to lifetime of 3 m coil : = ~**25 days** ; ~120 days using fiberglass cloth.

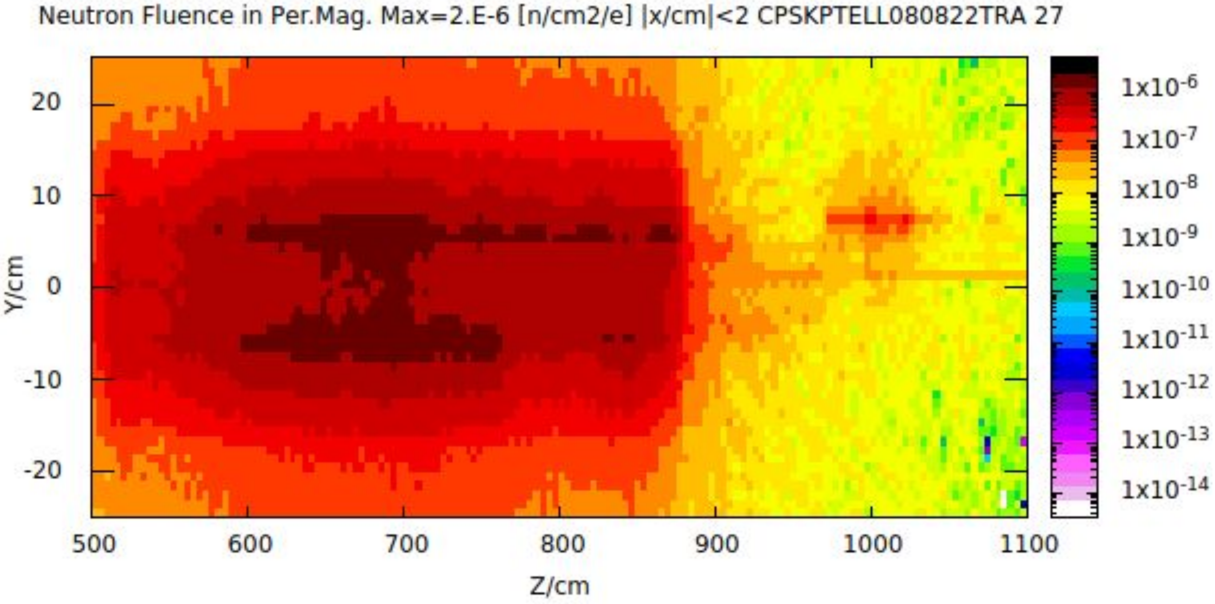
Raster 2 mm. Coil lifetime.





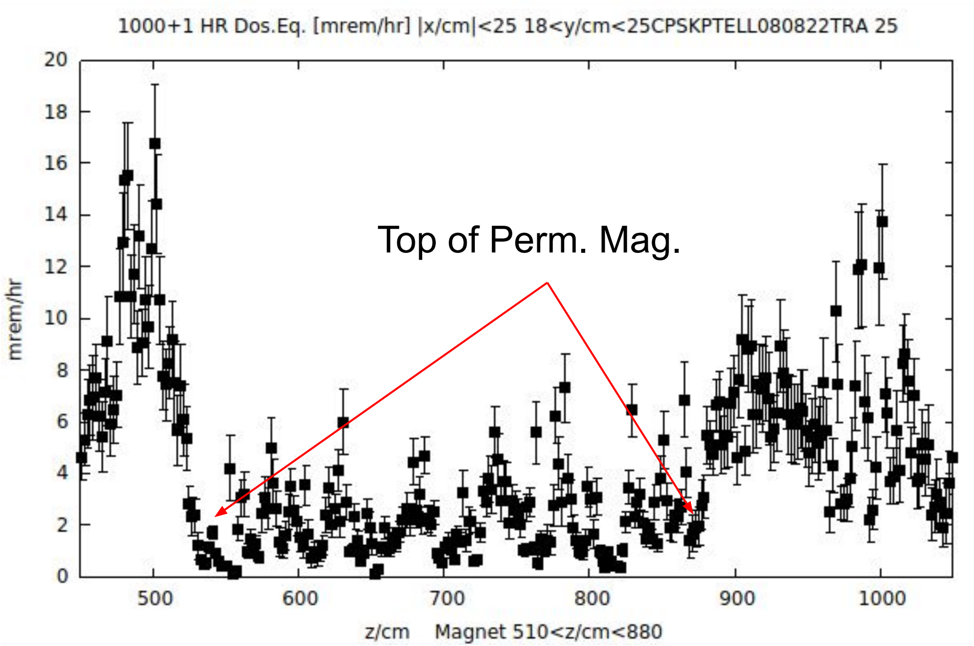
- Max. dose in coils is 2-3 times lower
- Kapton insulation lifetime 2000-3000 days.
- For twice narrower coils 20000-30000 days.
- Another factor 5 from fiber-glass based insulation

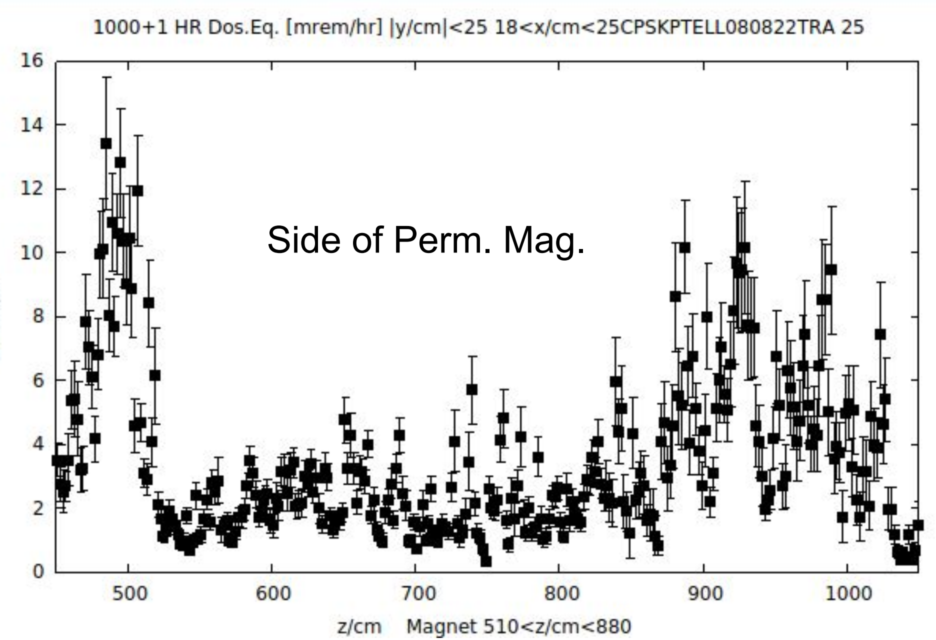
Lifetime of Beam Line Per .Mag. (Max. fluence 2.E+16 n/cm^2)



- We read Max. Fluence = 2.E-6 n/cm^2/e => 6.E+7 n/cm^2/s.
- Lifetime=(2.E+16 / 6.E+7) [s] = 3.3 E+8[s] = 10 years.

Prompt Dose Equivalent around Permanent Magnet





- Prompt Dose (mrad/hr) around Per.Mag. is 10-20 times lower.