Energy Deposition in

Dummy Septum Blade
Beam Screen Window
Dummy Septum Tank
Vacuum Chamber of MMU15

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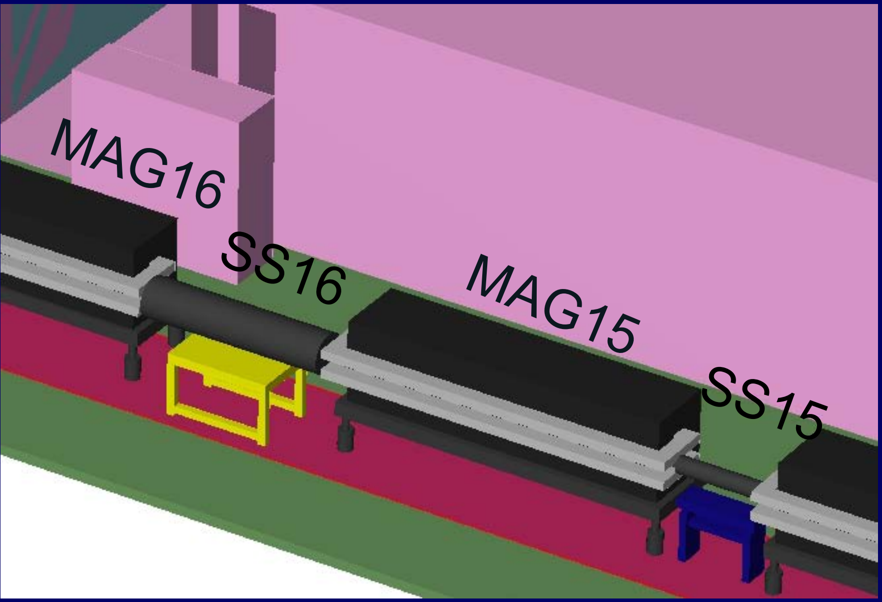
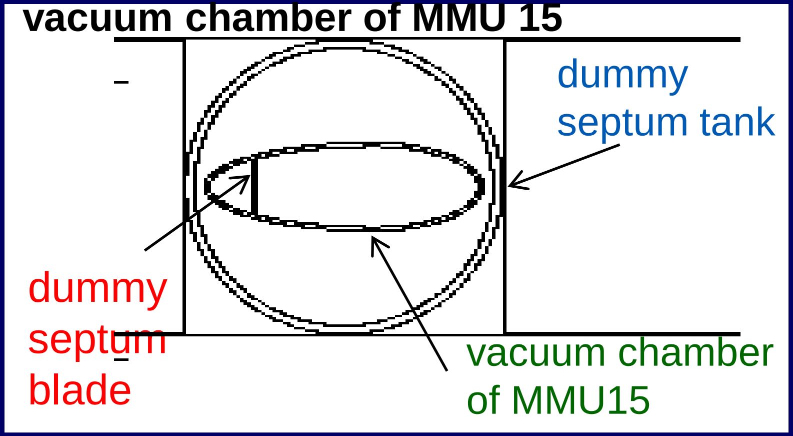
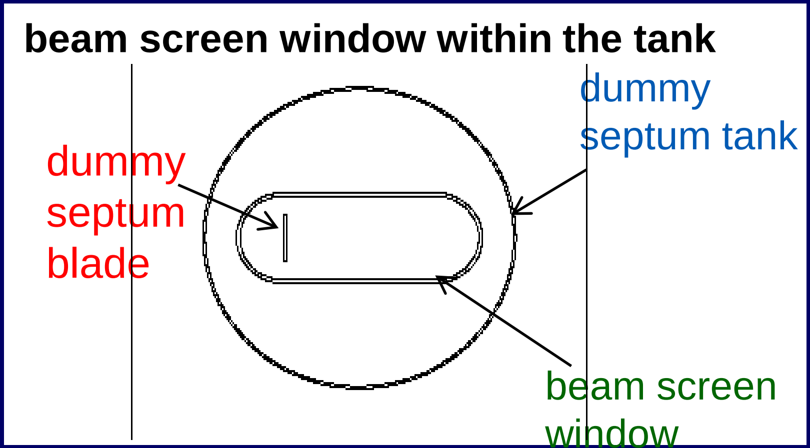
PS Straight Section 15 with Dummy Septum



Old – cut in transverse plane within the SS15 section



New – cut in transverse plane within the SS15 section

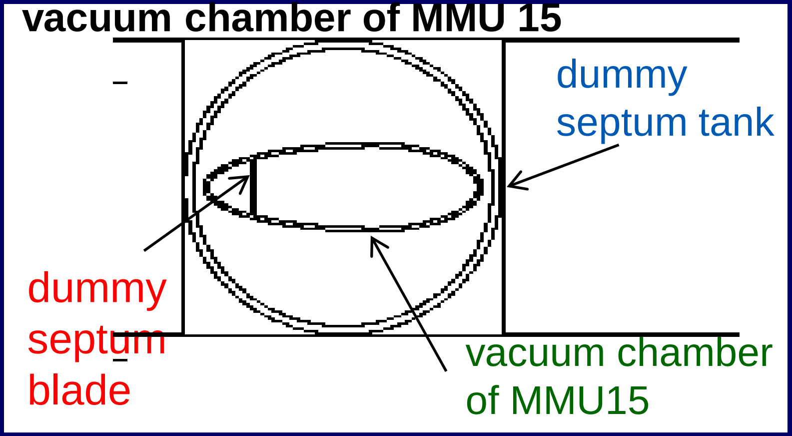


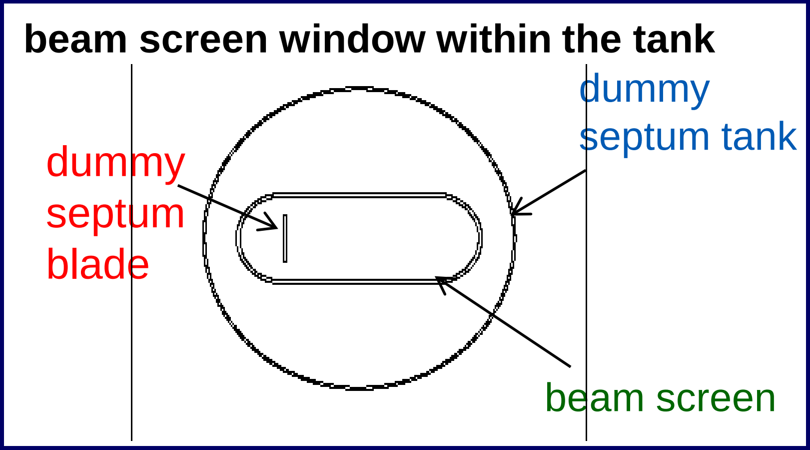
dummy septum blade : length 40cm, thickness 3mm, height 3.88 cm; material options: tungsten, copper, GlidCop

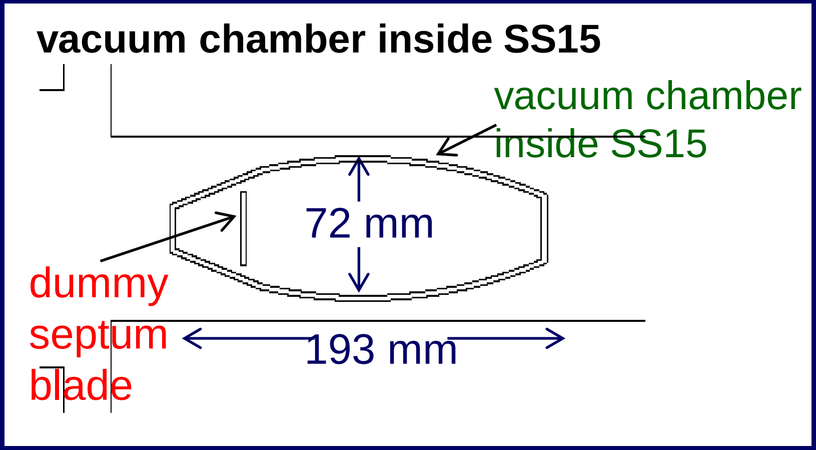
dummy septum tank : cylindrical shape, R_i=12.5cm, R_o=12.7 cm, wall thickness 2 mm, length 104 cm; material: stainless steel 316 LN

beam screen window: circumference 48.7 cm, wall thickness 3 mm, length 104 cm; material: stainless steel 316 LN (density ρ/2 to account for the holes)

FLUKA Geometry of the beam tubes and beam screen window







volume of the vacuum chamber of MMU15:
V=12.06 cm^2×length

wall thickness in all cases 3mm

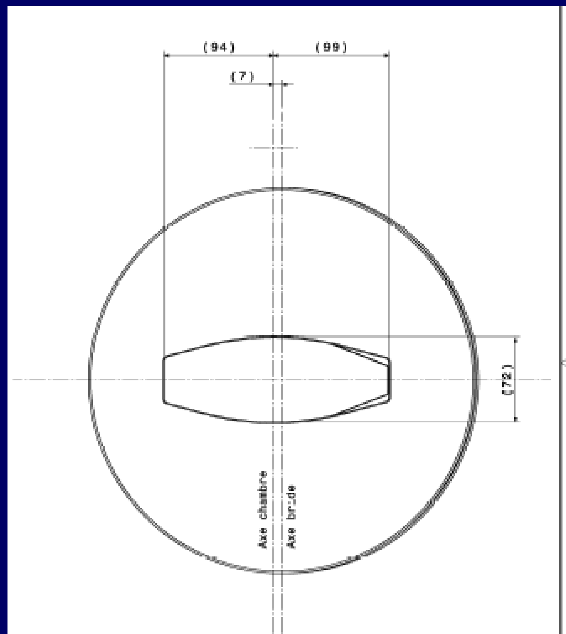
volume of the beam screen window:
V=14.3 cm^2×length

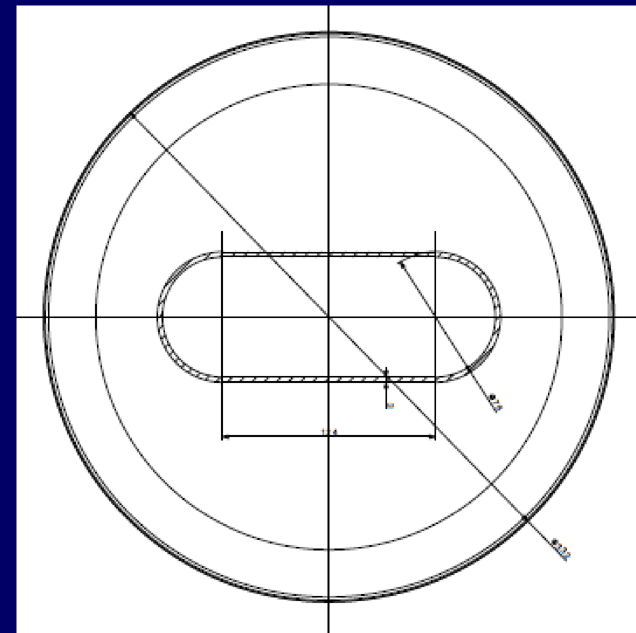
~15% higher volume of the present vacuum chamber in SS15 compared to that of the beam screen – hardly any difference in energy deposition

volume of the vacuum chamber of SS15:
V=16.7 cm^2×length

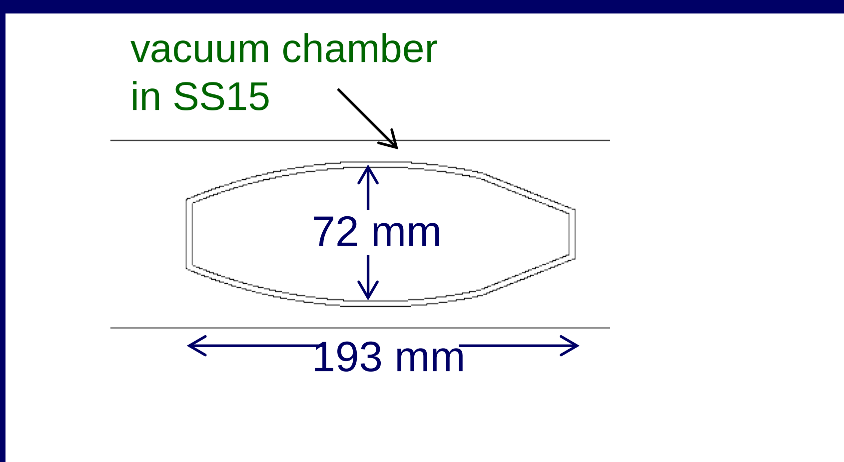
shape of the beam screen window allows increasing the height of the blade

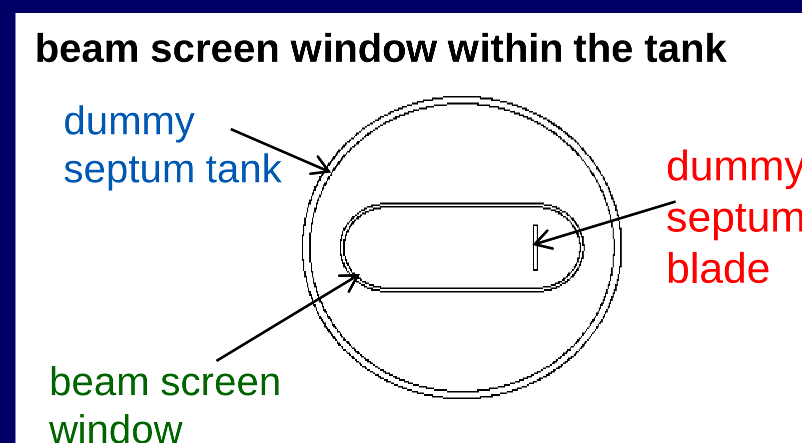
Vacuum Chamber of MMU15 and Beam Screen Window technical drawings



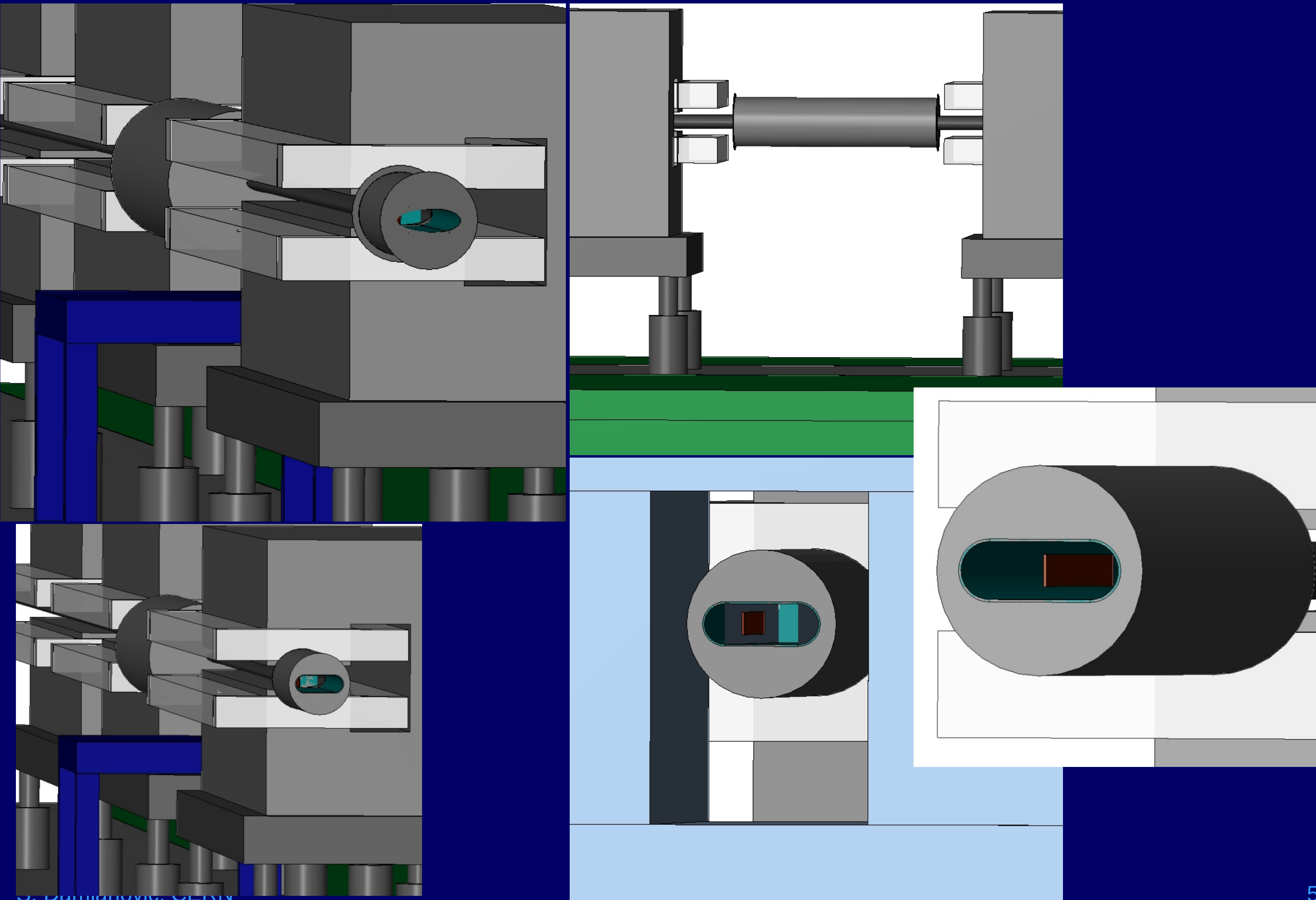


FLUKA





Dummy Septum Tank with Beam Screen Window and Dummy Blade



Assumptions for the simulations

- proton beam of p=14 GeV/c

- beam loss intensity: 1.0×10^{11} p/s (~1% of the primary intensity 1×10^{13} p/s)

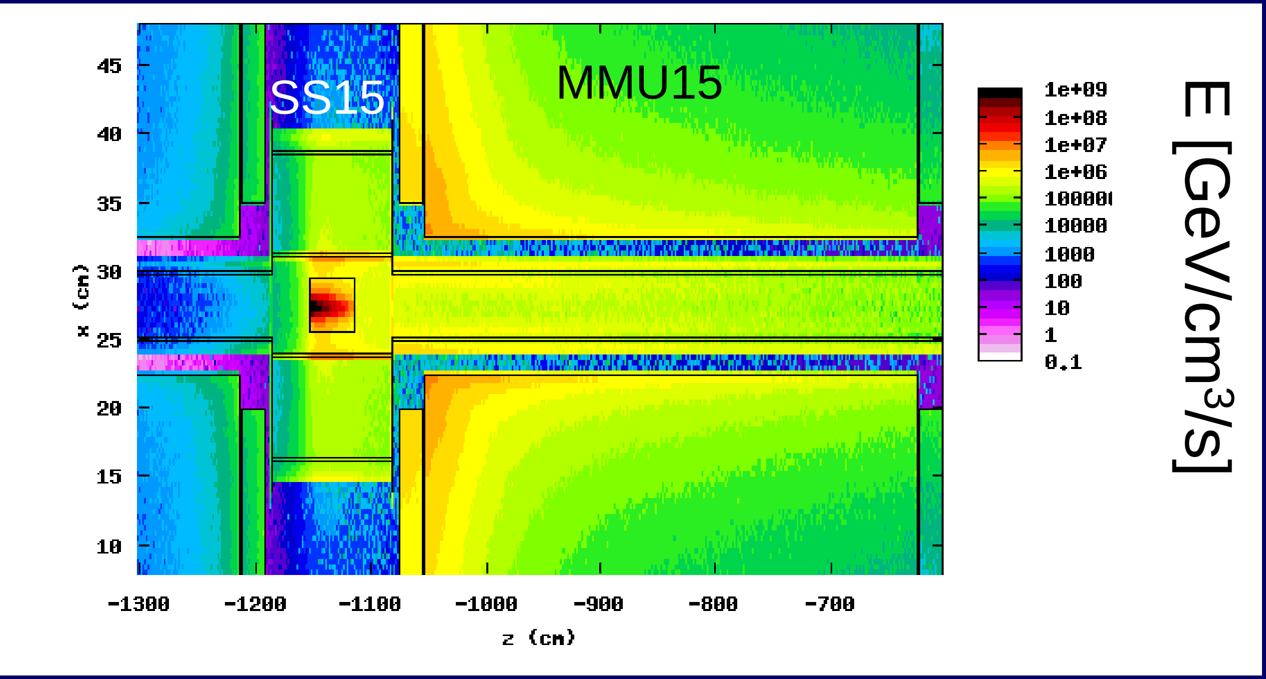
- source: dummy septum with distributed impact points

  along the beam direction (z) at the start of the blade

  Gaussian distribution in the vertical direction (x) with σ_x =2.5 mm centered in the middle plane

  uniform distribution in the horizontal direction (y) over 3mm thickness of the blade

Energy Deposition in the SS15 and along the MMU15



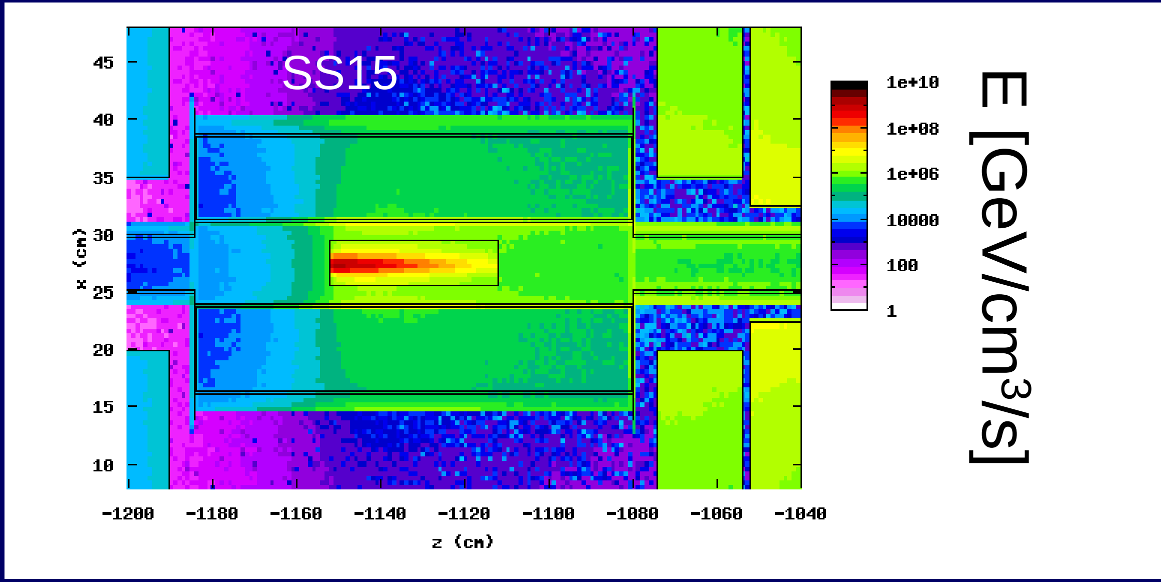
beam loss rate
10^{11} p/s

For qualitative illustration: projection into the x–z plane (x height, z beam direction)

enlarged SS15 region

Energy deposition extracted individually for:

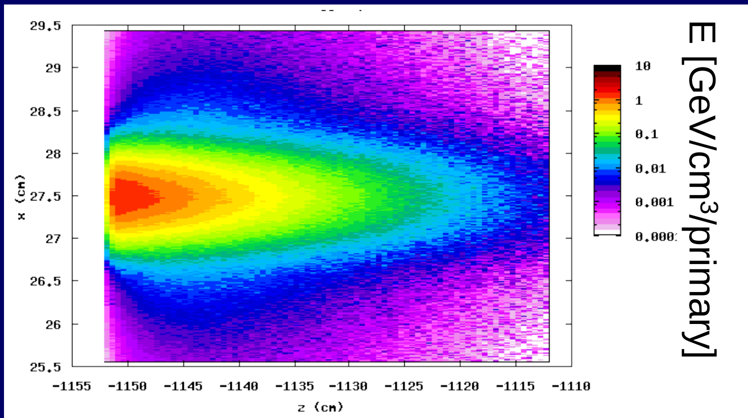
1) dummy septum blade
2) beam screen window
3) dummy septum tank
4) vacuum chamber of the magnet unit 15

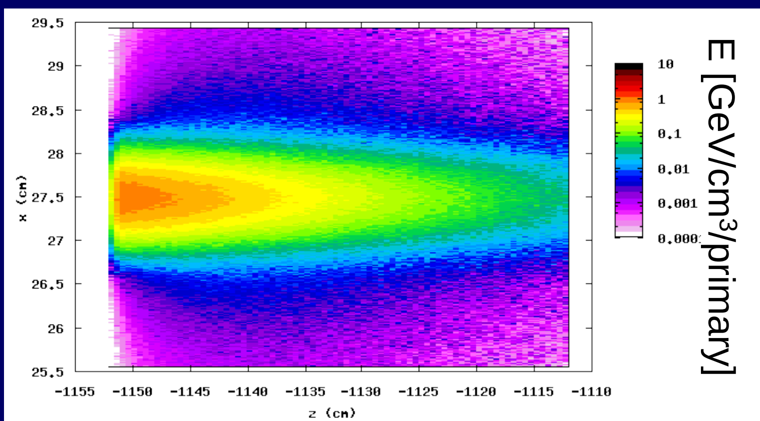


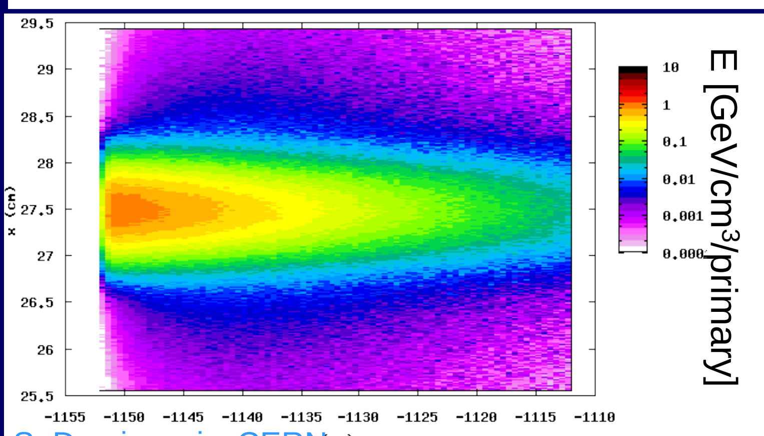
Dummy Septum Blade

three different material options:
tungsten, copper, GlidCop Al-15

Energy deposition in the dummy septum blade for different materials







Projections of deposited energy E [GeV/cm^3/primary] into the x-z plane, averaged over the blade thickness Δy=3mm (x height, z beam direction, y lateral)

W - blade

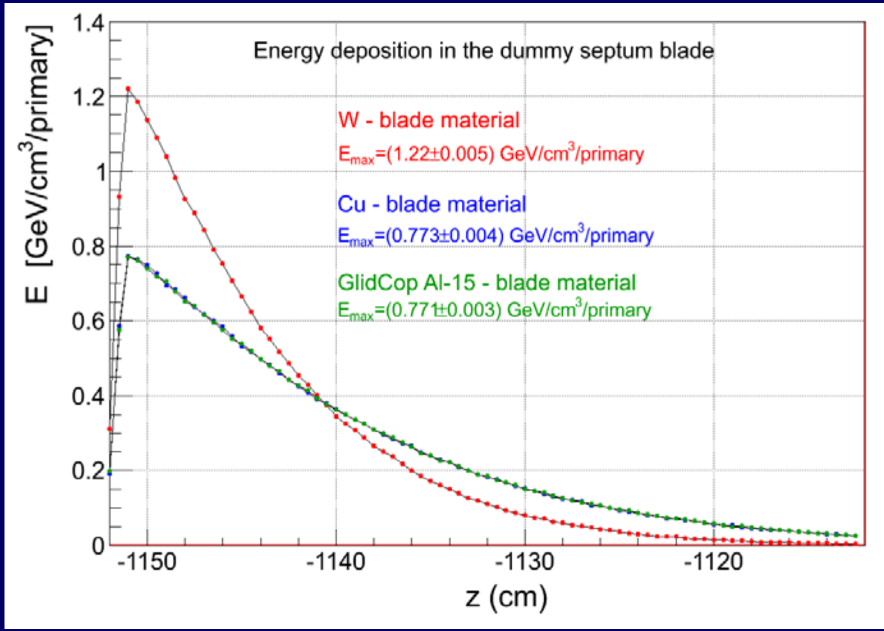
Cu - blade

GlidCop Al-15 - blade

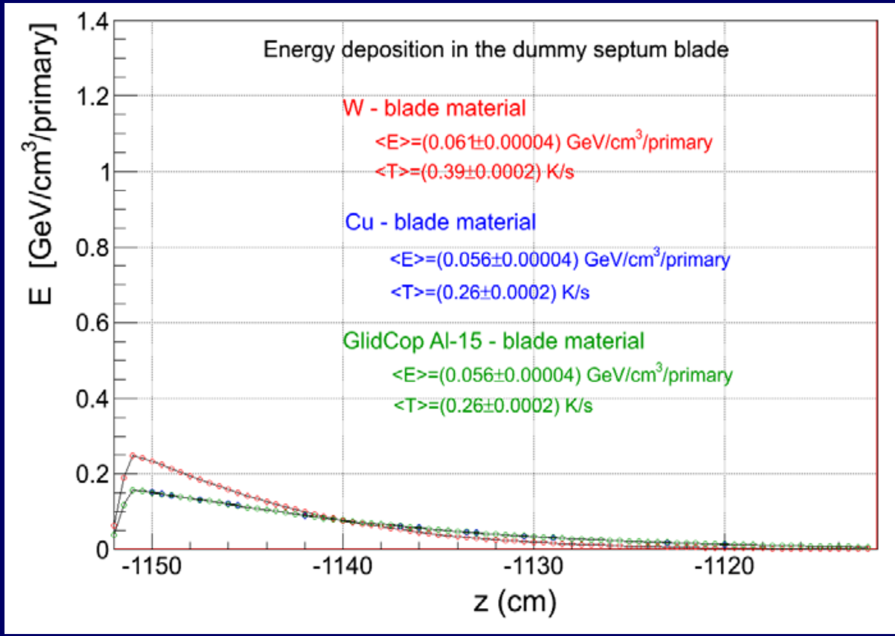
- maximum energy deposition for $-\sigma_x < x < +\sigma_x$
- hardly any difference between Cu and GlidCop Al-15

Energy deposition in the dummy septum blade for different materials

Energy Deposition vs. z averaged over $\pm 1\sigma_x$



Energy Deposition vs. z averaged over x



Material	Maximum Energy Deposition [GeV/cm^3/primary]	Average Energy Deposition (also over z) [GeV/cm^3/primary]
blade – W	1.22	0.06
blade – Cu	0.77	0.056
blade - GlidCop Al-15	0.77	0.056

- Maximum values larger by factors of 15-20 than the average values
- Energy deposition the same inside the Cu and GlidCop blade
- Maximum energy deposition highest for W, average values the same for all 3 materials

Base assumptions for the temperature simulation:

- Specific heat capacity
- Complete thermal isolation

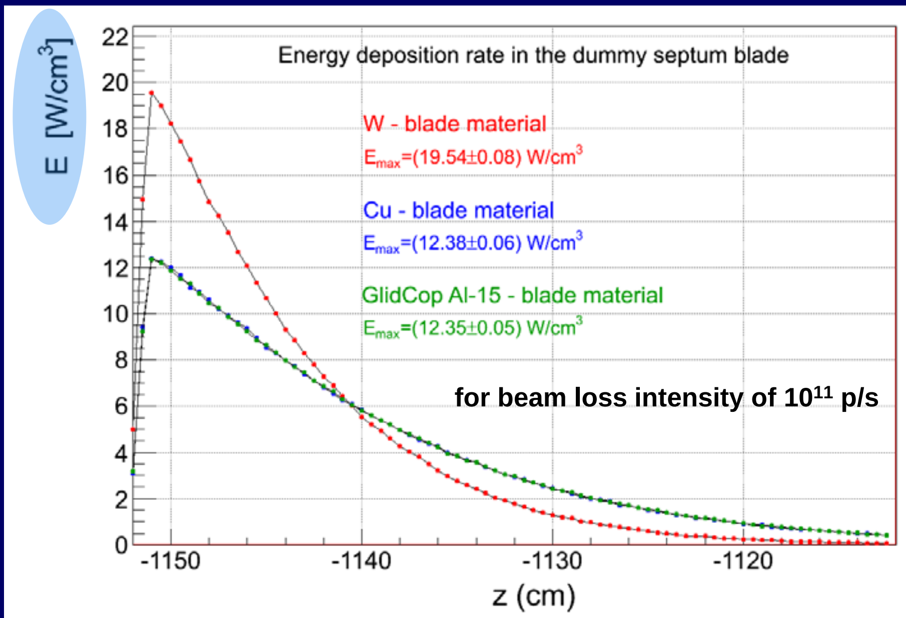
Material Properties:

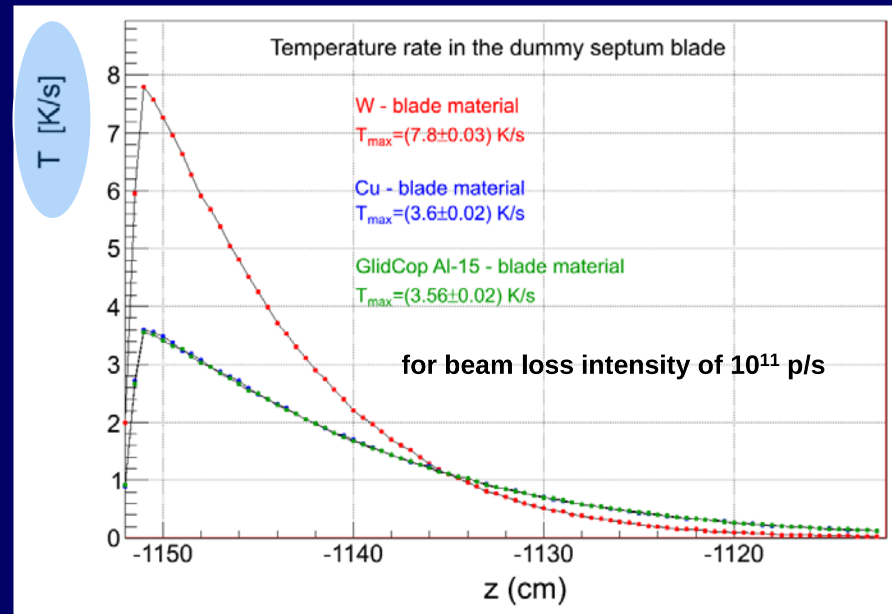
blade material	specific heat capacity [J/kg·K]	thermal conductivity [W/m·K] @293K	ρ [g/cm³]	λ_{inel} [cm]
W	130	164	19.3	15.3
Cu	385	401	8.96	10
GlidCop Al-15	390	365	8.90	10

Hardly any difference in material properties for Cu and GlidCop Al-15
→ same energy deposition, same temperature and same nuclear interaction probabilities

Energy Deposition Rate and Temperature Rate in the dummy septum blade for beam loss intensity of 10^{11} p/s

1-dim projection along the blade length (z), averaged over $\pm 1\sigma_x$ in x and over the 3mm thickness (y)





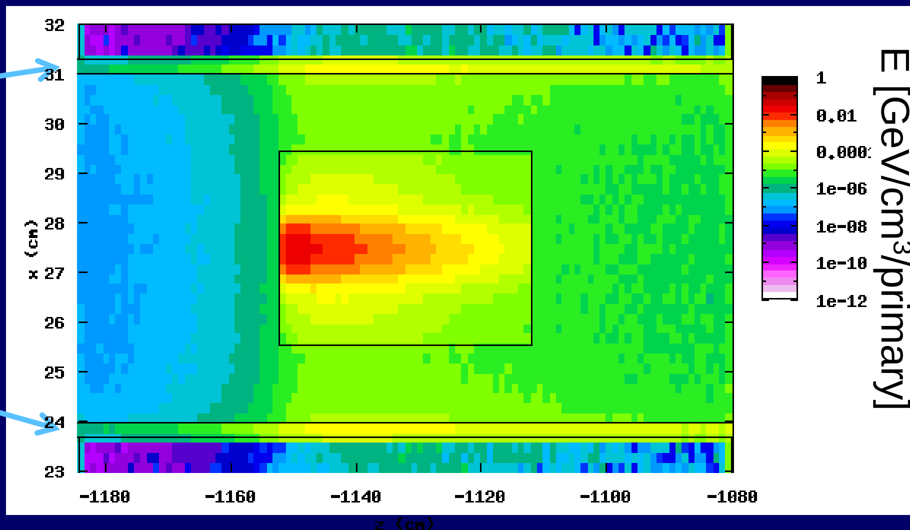
Material	Maximum Energy Deposition Rate [W/cm³]	Average (x,y,z) Energy Deposition Rate [W/cm³]	Maximum Temperature Rate [K/s]	Average(x,y,z) Temperature Rate [K/s]
blade – W	19.6	0.99	7.8	0.39
blade – Cu	12.4	0.90	3.6	0.26
blade - GlidCop Al-15	12.4	0.90	3.6	0.26

Temperature rate the same for Cu and GlidCop Al-15

Beam Screen Window

Energy Deposition in the Material of the Beam Screen Window

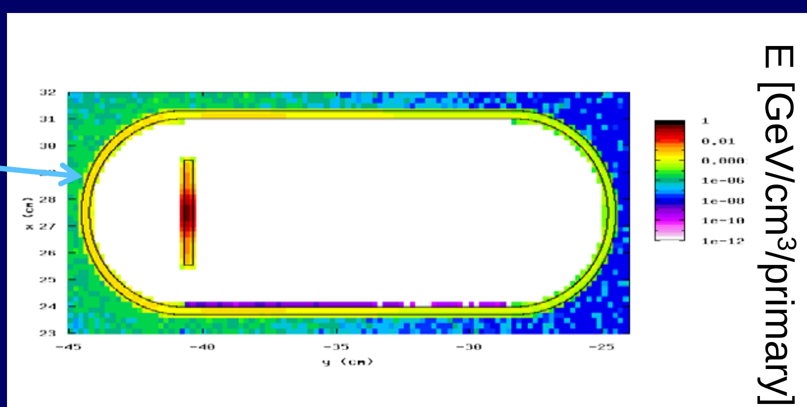
beam screen



2-dimensional projection of Energy Deposition [GeV/cm^3/primary] in the x-z plane, averaged over -44<y<-24 cm

maximum energy values for -1147<z<-1114 cm

beam screen window



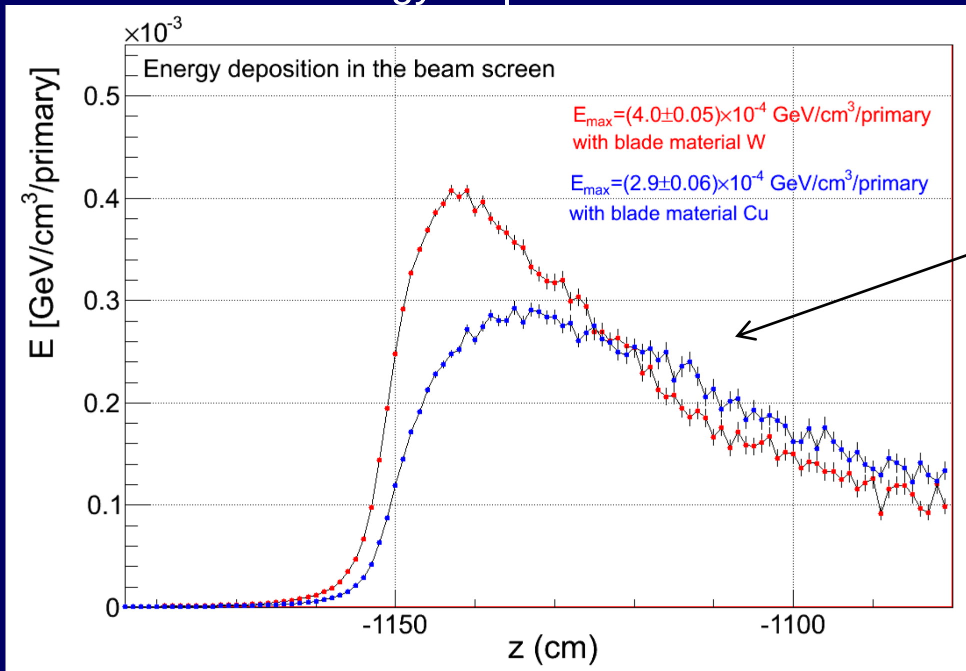
2-dimensional projection of Energy Deposition [GeV/cm^3/primary] in the x-y plane, averaged over -1147 <z< -1114 cm

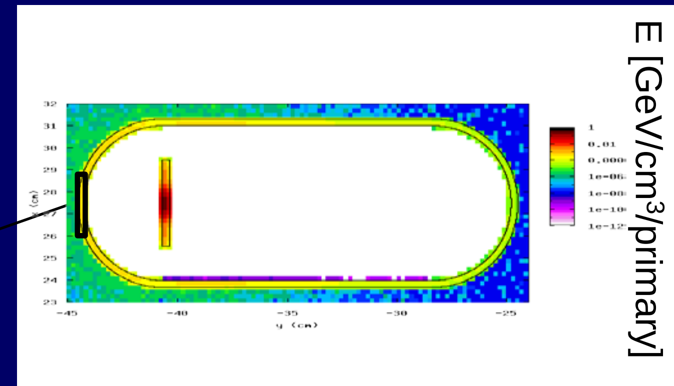
azimuthal asymmetry in the energy deposition:

variation in the medium plane by a factor of 10 between left and right

Energy deposition in the beam screen window

Maximum Energy Deposition



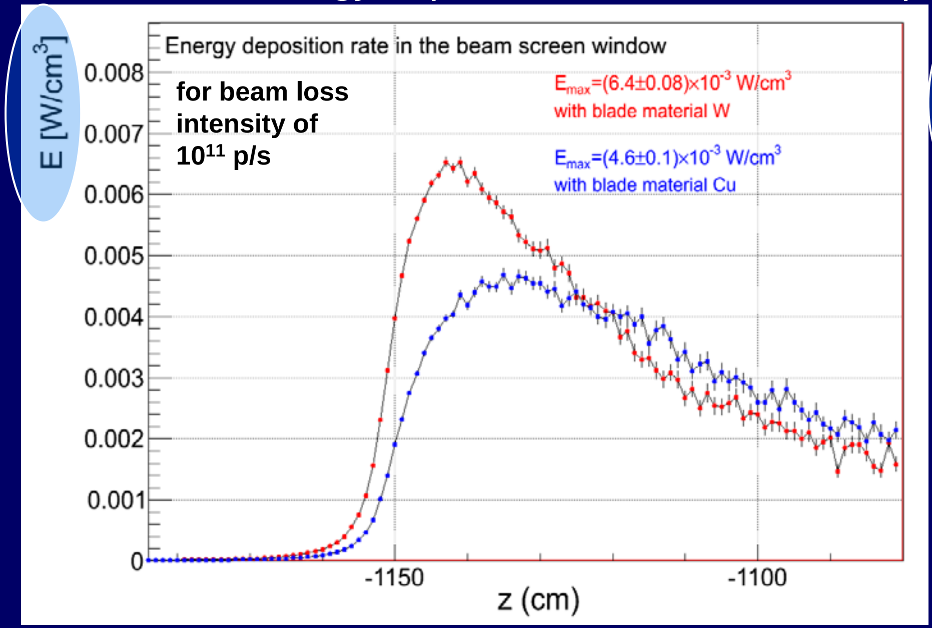


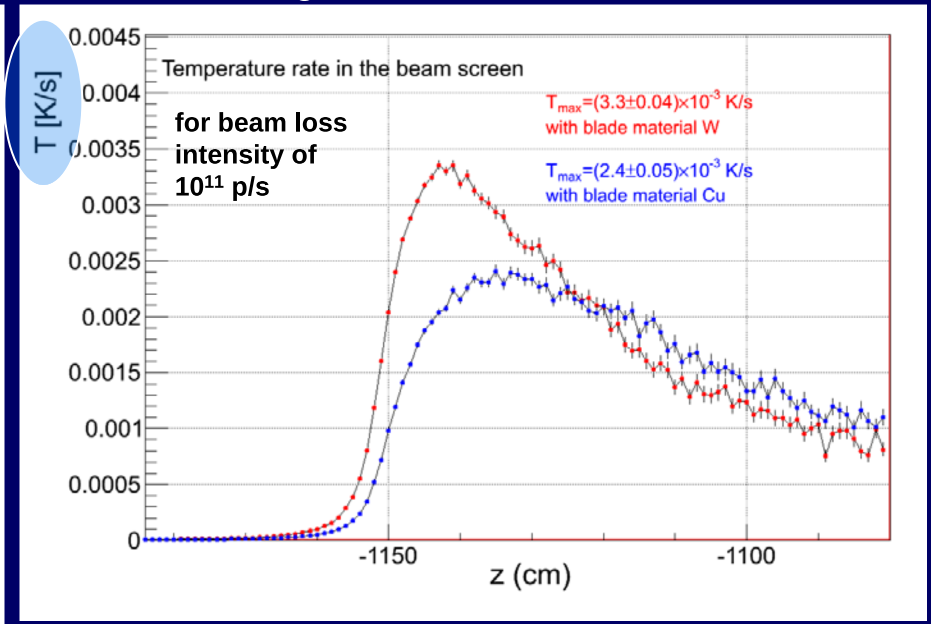
Material	Maximum Energy Deposition [GeV/cm^3/primary]	Average (x,y,z) Energy Deposition [GeV/cm^3/primary]
beam screen window (blade - W)	4.0×10^{-4}	1.2×10^{-4}
beam screen window (blade-Cu/GlidCop Al-15)	2.9×10^{-4}	1.1×10^{-4}

- Maximum values larger by about a factor of 3 compared to the average values
- Maximum energy deposition in the beam screen window slightly higher for the W blade, average values the same for all three blade material choices

Energy Deposition Rate and Temperature Rate in the beam screen window for beam loss intensity of 10^{11} p/s

Maximum energy deposition rate and max. temperature rate along the beam screen window



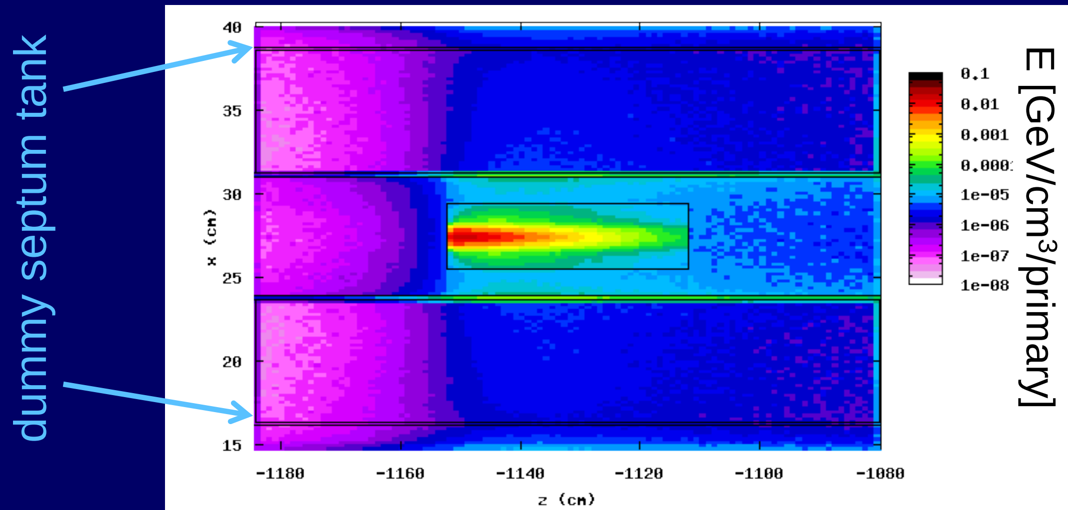


Material	Maximum Energy Deposition Rate [W/cm^3]	Average (x,y,z) Energy Deposition Rate [W/cm^3]	Maximum Temperature Rate [K/s]	Average (x,y,z) Temperature Rate [K/s]
beam screen window (blade W)	6.4×10^{-3}	1.92×10^{-3}	3.3×10^{-3}	9.9×10^{-4}
beam screen window (blade Cu/GlidCop)	4.6×10^{-3}	1.76×10^{-3}	2.4×10^{-3}	9.0×10^{-4}

Slightly higher rates in the beam screen for the W blade

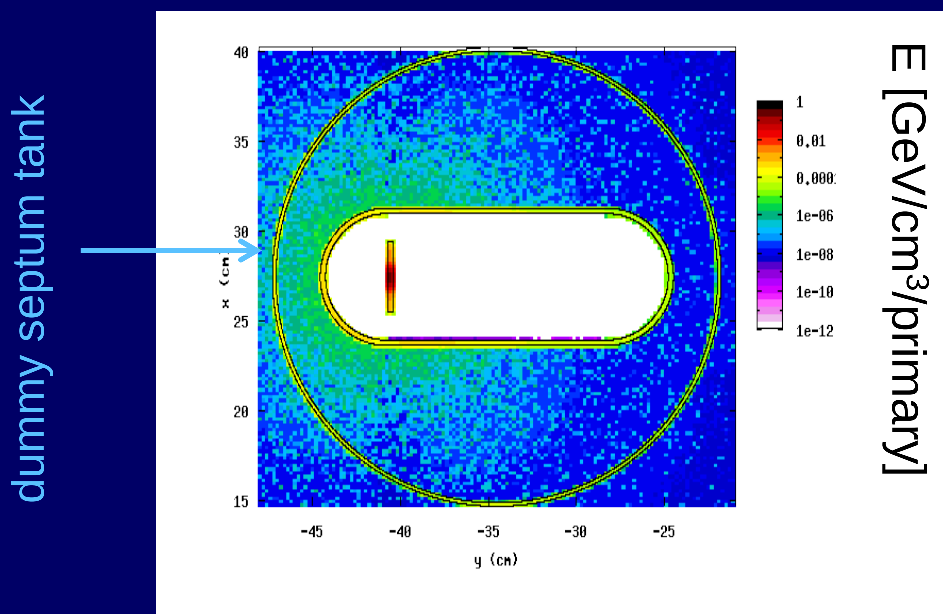
Dummy Septum Tank

Energy deposition in the material of the dummy septum tank



2-dimensional projection of Energy Deposition [GeV/cm^3/primary] in the x-z plane, averaged over $y = \pm R_{tank}$

maximum energy values for -1147<z<-1114 cm



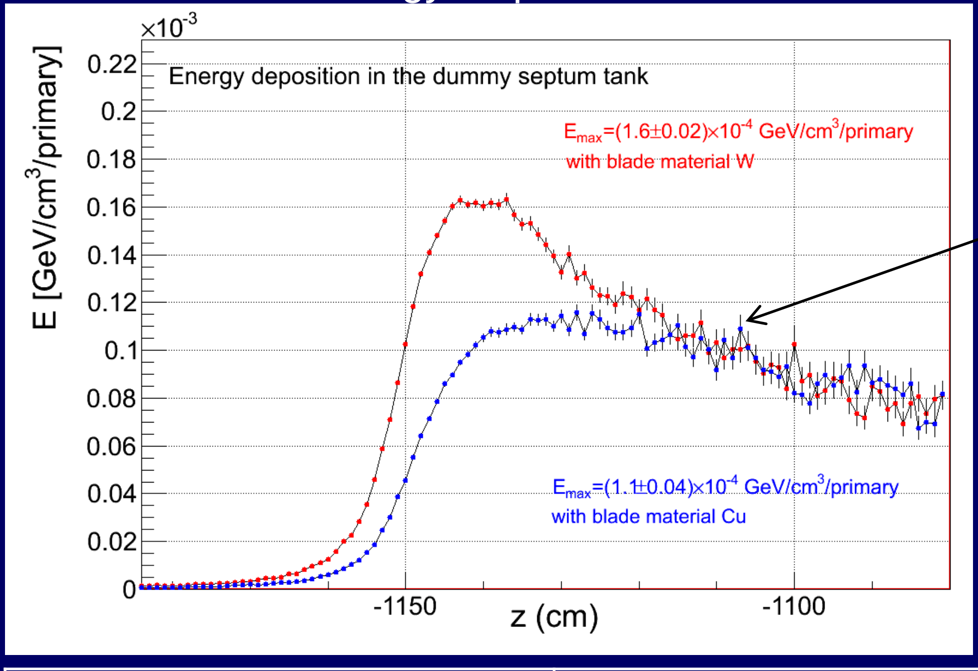
2-dimensional projection of Energy Deposition [GeV/cm^3/primary] in the x-y plane, averaged over -1147 <z< -1114 cm

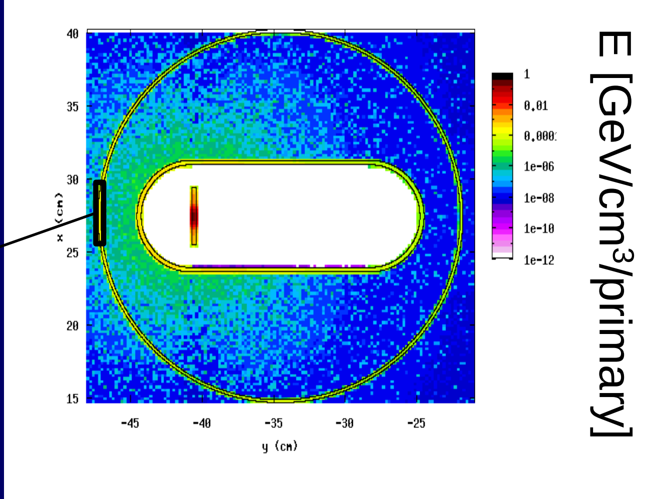
azimuthal asymmetry in the energy deposition:

variation in the medium plane by a factor of 6 between left and right

Energy deposition in the dummy septum tank

Maximum Energy Deposition



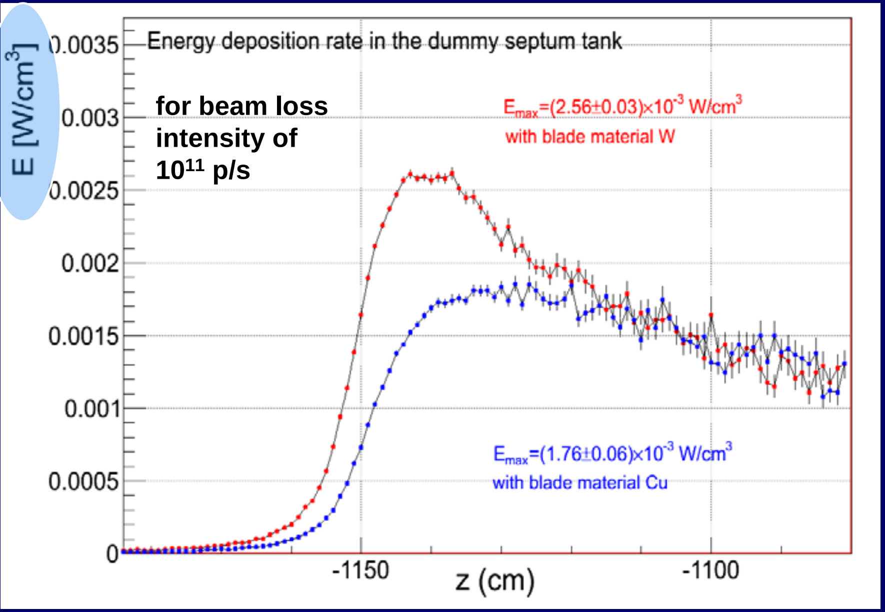


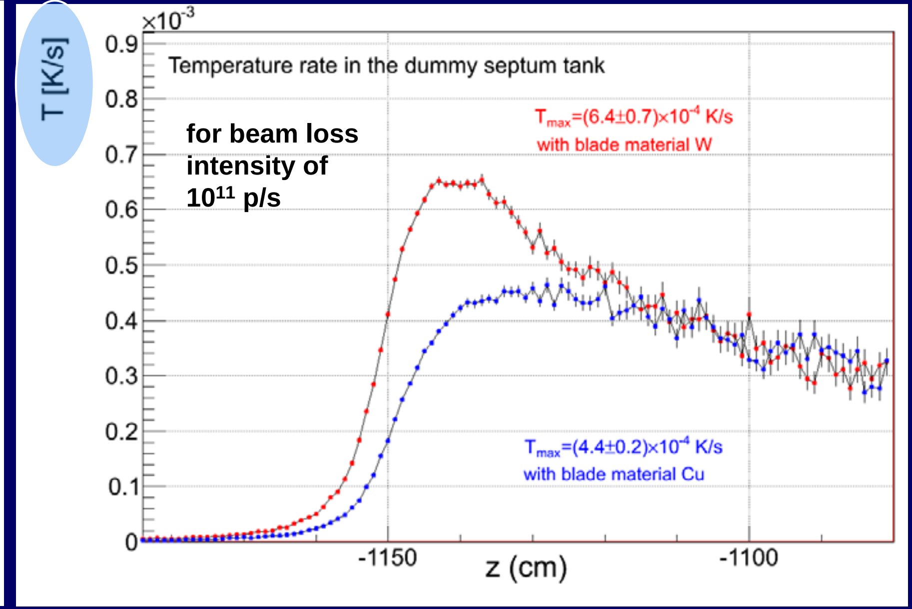
Material	Maximum Energy Deposition [GeV/cm^3/primary]	Average (x,y,z) Energy Deposition [GeV/cm^3/primary]
dummy septum tank (blade W)	1.6×10^{-4}	6.5×10^{-5}
dummy septum tank (blade Cu/GlidCop Al-15)	1.1×10^{-4}	5.45×10^{-5}

- Maximum values larger by factors of 2-2.5 compared to the average values
- Maximum energy deposition in the dummy septum tank slightly higher for the W blade

Energy Deposition Rate and Temperature Rate in the dummy septum tank for beam loss intensity of 10^{11} p/s

Maximum energy deposition rate and max. temperature rate along the dummy septum tank



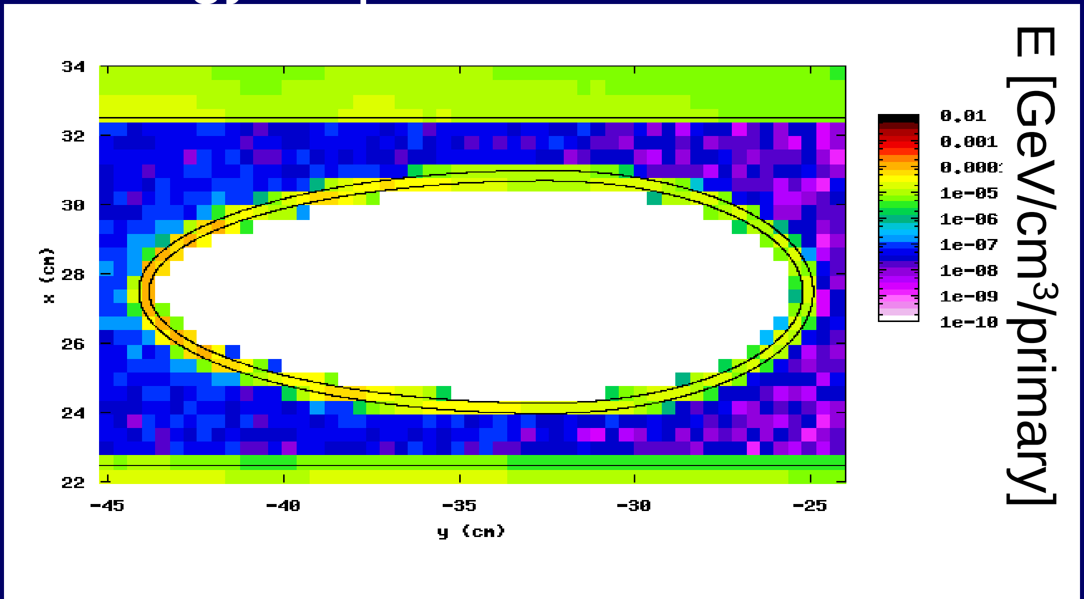


Material	Maximum Energy Deposition Rate [W/cm³]	Average (x,y,z) Energy Deposition Rate [W/cm³]	Maximum Temperature Rate [K/s]	Average (x,y,z) Temperature Rate [K/s]
dummy septum tank (blade W)	2.56×10^{-3}	1.04×10^{-3}	6.4×10^{-4}	2.6×10^{-4}
dummy septum tank (blade - Cu/GlidCop)	1.76×10^{-3}	8.73×10^{-4}	4.4×10^{-4}	2.2×10^{-4}

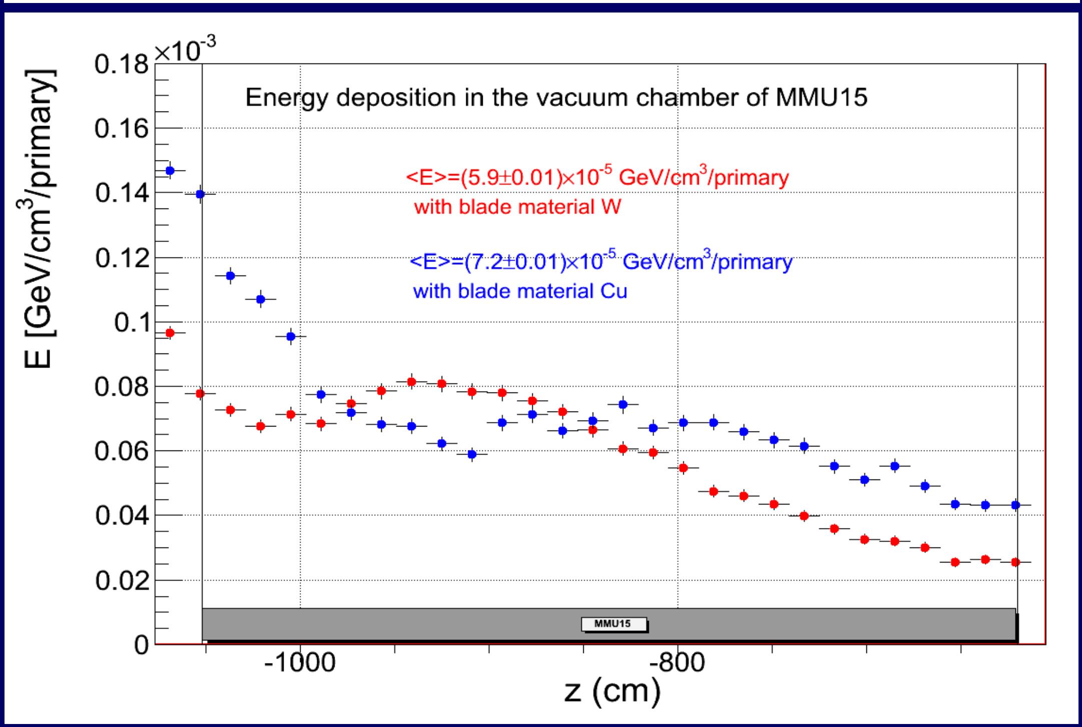
Slightly higher rates in the dummy septum tank for the W blade

Vacuum Chamber of the MMU15

Energy Deposition in the vacuum chamber of the MMU15



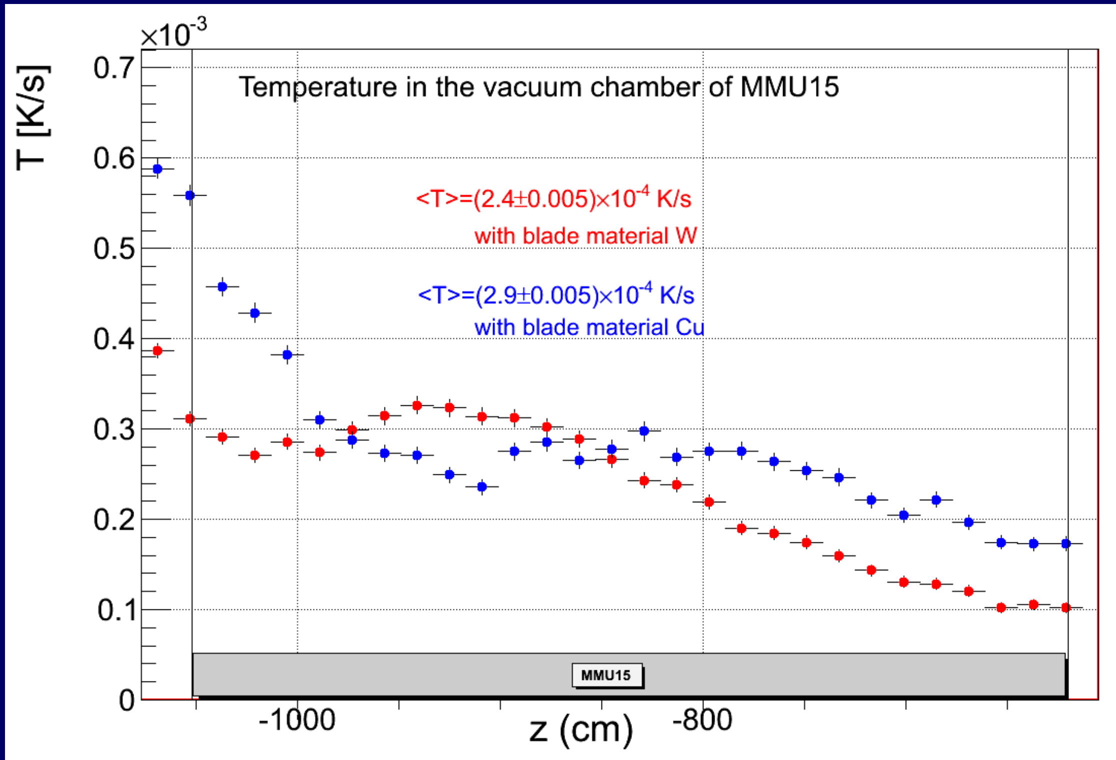
2-dimensional projection of E [GeV/cm^3/primary] in the x-y plane, averaged over -1080 <z< -800 cm



1-dim projections of the energy deposition along MMU15 (z), averaged over the azimuth

Maximum and average values of the deposited energy slightly higher for the Cu blade

Temperature Rate in the vacuum chamber of the MMU15

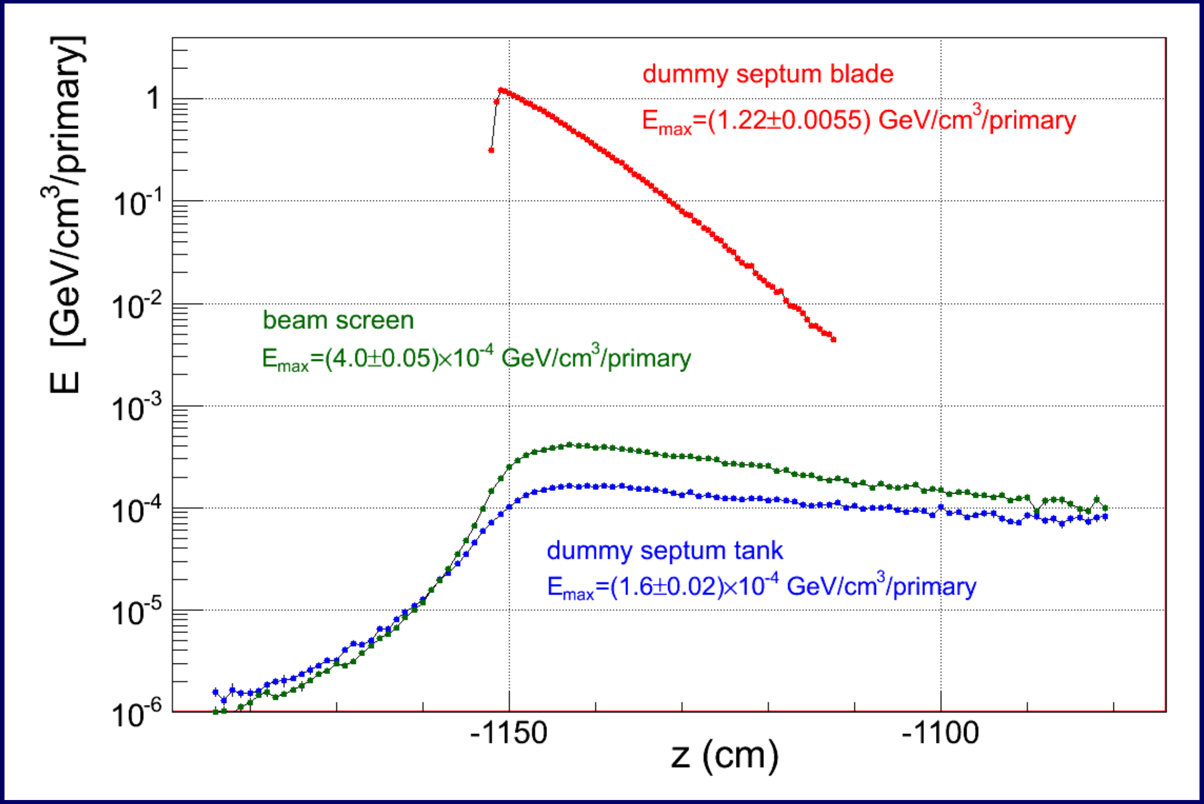


1-dim projections of temperature rate along the MMU15 length (z), averaged over the azimuth

Maximum and average values of the temperature rates slightly higher for the Cu blade

Material	Average (x,y,z) Energy Deposition [GeV/cm^3/primary]	Average (x,y,z) Energy Deposition Rate [W/cm^3]	Average (x,y,z) Temperature Rate [K/s]
vacuum chamber of MMU15 (for W blade)	5.9×10^{-5}	9.5×10^{-4}	2.4×10^{-4}
vacuum chamber of MMU15 (for Cu/GlidCop blade)	7.2×10^{-5}	1.15×10^{-3}	2.9×10^{-4}

Comparison of Maximum Energy Deposition



Maximum energy deposition higher by factors of 3000 and 7700 inside the dummy septum blade compared to the beam screen window and the dummy septum tank, resp.

Comparison of Average Energy Deposition and Average Temperature rates

beam loss intensity of 10^{11} p/s

Material	Average Energy [GeV/cm^3/primary]	Average Energy Rate [W/cm^3]	Average Temperature Rate [K/s]
dummy septum blade (W)	0.06	0.99	0.39
beam screen window	1.2×10^{-4}	1.9×10^{-3}	3.3×10^{-3}
dummy septum tank	6.5×10^{-5}	1.04×10^{-3}	2.6×10^{-4}
vacuum chamber of the magnet unit 15	5.9×10^{-5}	9.5×10^{-4}	2.4×10^{-4}

Average energy deposition rate higher by factors of 500, 900 and 1000 inside the dummy septum blade compared to the beam screen window, the dummy septum tank and the vacuum chamber of the MMU15, resp.