20to2T5mDL WITH RESISTIVE MAGNETS: C TARGET

ENERGY DEPOSITION STUDIES [+ COMPARISON WITH 20to2T5m]

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20to2T5m WITH RESISTIVE MAGNETS: 10 cm GAPS BETWEEN CRYOSTATS

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SC#1+2, SC#3, BeWind#1, C MODULE INNER TUBE, SHVS#1B INNER TUBE, SHVS#2 UPSTREAM FLANGE AZIMUTHAL TDPD SIMULATIONS AND C TARGET SEGMENATION FOR 0< r < 0.2 cm FOR 20to2T5mDL TARGET STATION [ICEM = 1 MODE SIMULATIONS].

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➡ **SIMULATION CODE:** mars15(2014)[USING MCNPDATA x-SECTION LIBRARIES FOR NEUTRON INTERACTIONS WITH KE < 14 MeV]

➡ **NEUTRON ENERGY CUTOFF:** 10^{-12} GeV

➡ **SHEILDING:** 60% W + 40% He [WITH STST VESSELS]

➡ **B_z (r = 0, z) :** 20 T [z = 0.0 cm] ---→ 2.0 T [z ~ 500.0 cm]

➡ **C ROD RADIUS / ANGLE:** 0.80 cm / 65 mrads (~ 3.72 degrees) [-40.0 < z < 40.0 cm]
C density ~ 1.8 g/cc { + C DUMP: 40.0 < z < 160.0 cm R = 2.4 cm }

➡ **PROTON BEAM POWER:** 4.0 MW

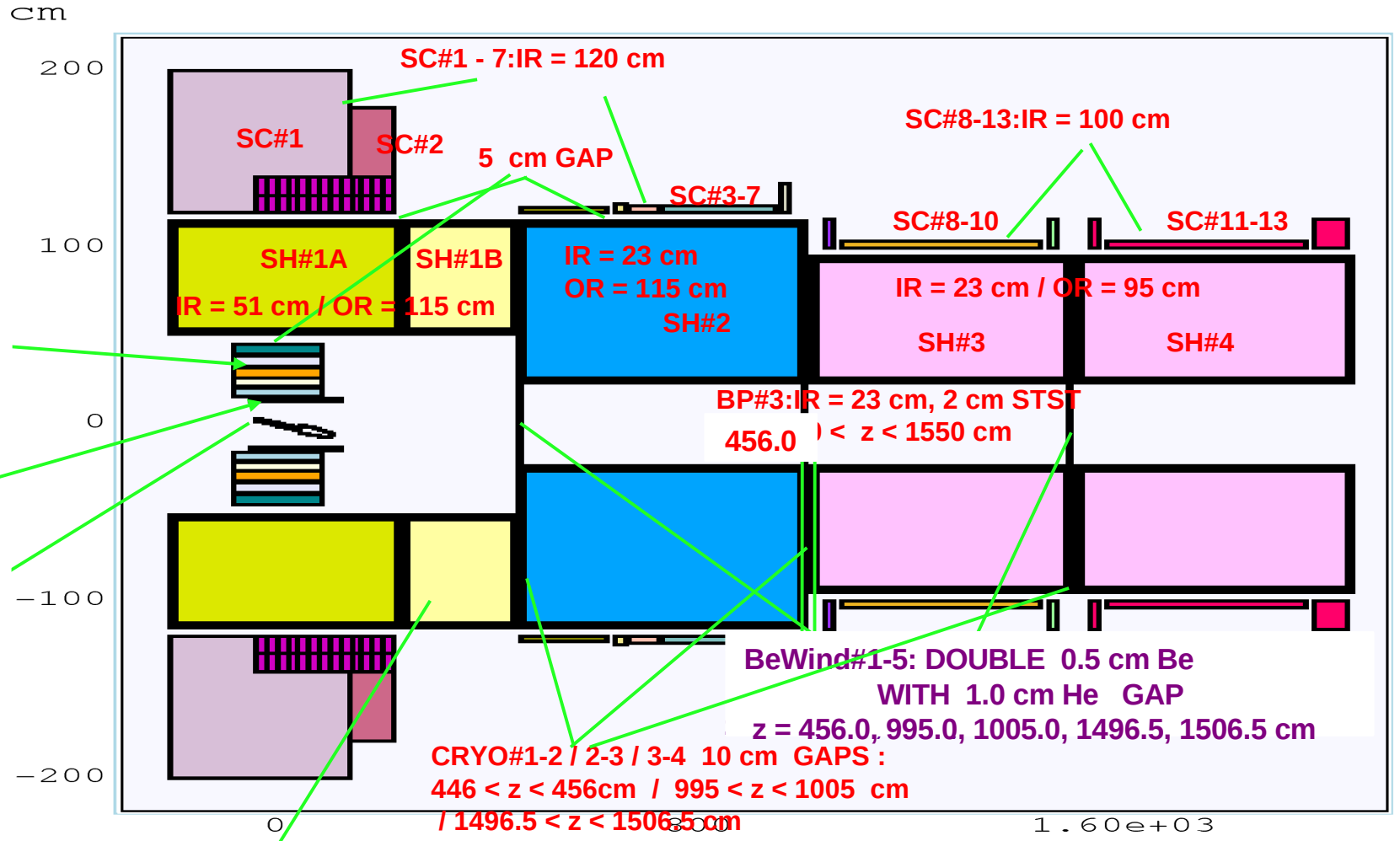
➡ **PROTON ENERGY:** E = 6.75 GeV

➡ **PROTON BEAM PROFILE :** GAUSSIAN, σ_x = 0.3268 σ_y = 0.3272 cm
[5 micron emmitance, sigma star =0.18 cm at z = 0.0 cm]

➡ **PROTON BEAM LAUNCH :** (xo, yo, zo) = (-2.32307, 5.95973, -100.0) cm
(dcxo, dcyo, dczo) = (0.039324, -0.049940, -0.997978)

➡ **EVENTS IN SIMULATIONS :** N_p = 5E6 ==> 100 (SUBDIRECT) x 5E4 (STEP: 10^-3)

20to2T5mDL: yz CROSS SECTION (x = 0.0 cm) WITH GEOMETRY DIMENSIONS / PARAMETERS.



RS#1-5: IR = 16 cm
OR = 45.86 cm
-81.45 < z < 162.42 cm

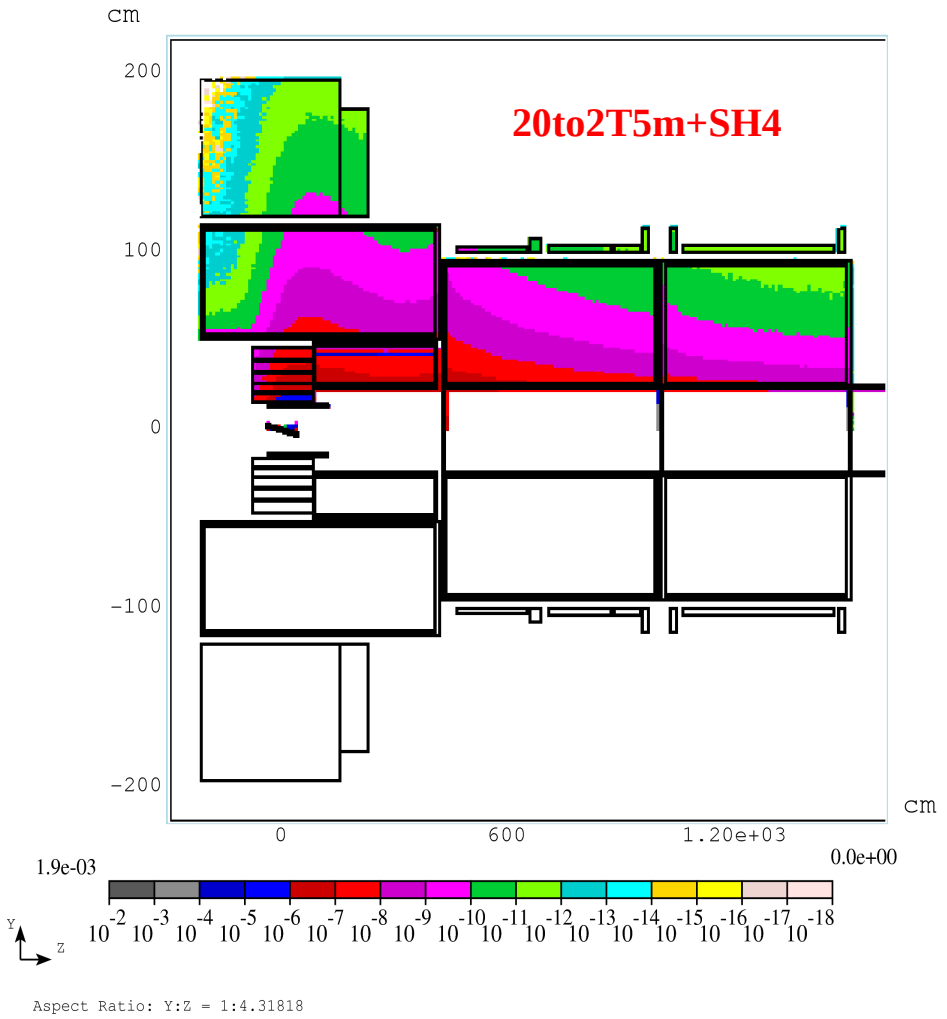
BP#1: IR = 13 cm
0.5 cm DOUBLE STST
0.5 cm He GAP
-50.0 < z < 120.0 cm

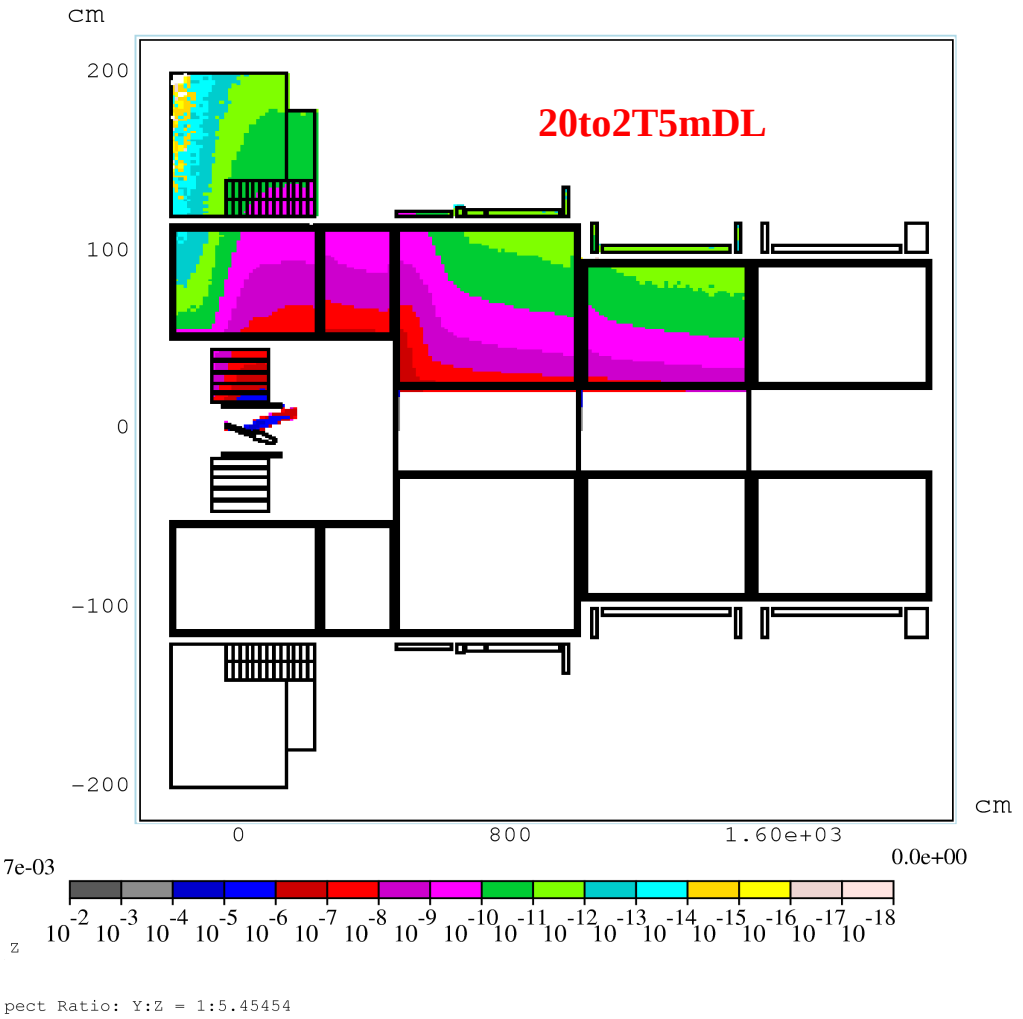
C TARGET / DUMP
-40.0 < z < 40.0 cm
R = 0.80 cm /
40.0 < z <160.0 cm
R = 2.4 cm

SH#1B (2 cm THICK TUBES, 5 cm THICK FLANGES): SEPARATE SHIELDING MODULE IN THE GAP REGION (~ 238 cm) BETWEEN SC#2 AND SC#3 TO MITIGATE STRESS FORCES IN SHVS#1

20to2T5m [LEFT] 20to2T5mDL [RIGHT]: yz CROSS SECTION (x = 0.0 cm) WITH AZIMUTHALLY AVERAGE TDPD DISTRIBUTION : LEFT TS HAS R= 0.80 cm L = 80 cm C TRGT AND NO DUMP, RIGHT TS R = 0.80 cm L = 80 cm C TRGT WITH R =2.4 cm L = 120 cm C DUMP.

COLOR SCALES ARE THE SAME FOR BOTH PLOTS

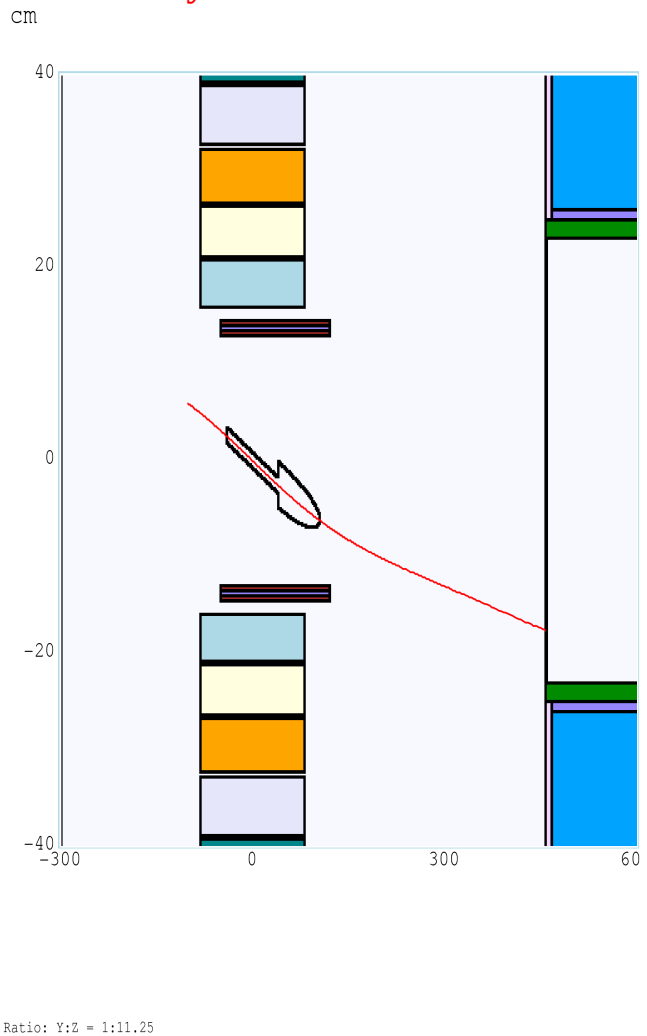




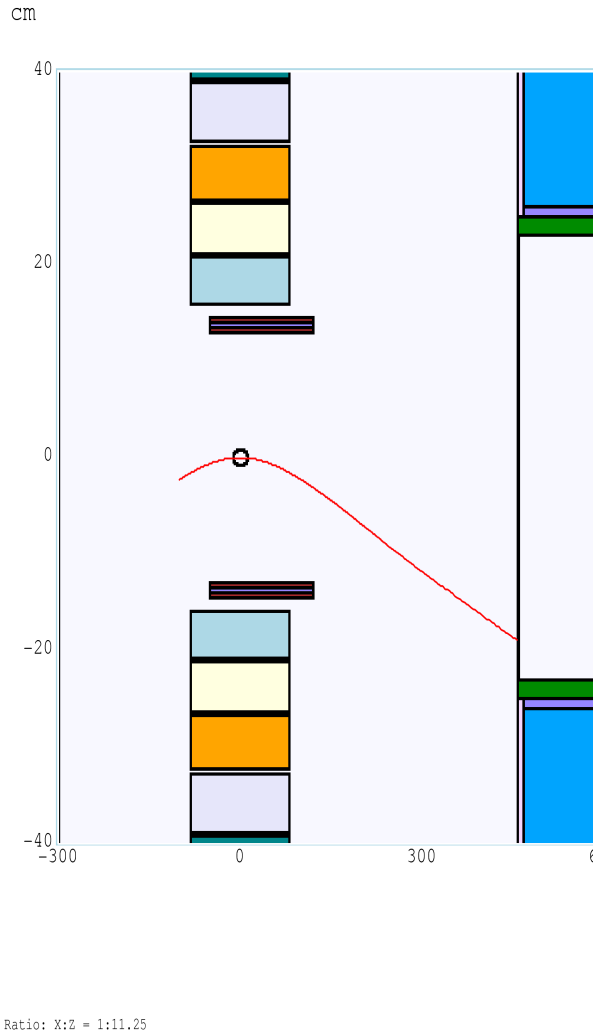
20to2T5mDL: **yz AT x = 0.0 cm (LEFT) , xz AT y = 0.0 cm (MIDDLE), xy AT z = 456.0 cm (RIGHT) CROSS SECTION WITH THE PROTON BEAM CENTROID TRAJECTORY PROJECTION WITHOUT C TARGET/DUMP AND BeWind#1. TRAJECTORY DATA SHOW THAT SOME OF BEAM PROTONS WILL END UP AT z ~ 456.0 cm BeWind#1 REGION.**

(THE PEAK TDPD OF SC#3 IS AT ~ 225-255 degrees, AS EXPECTED FROM xy PLOT)

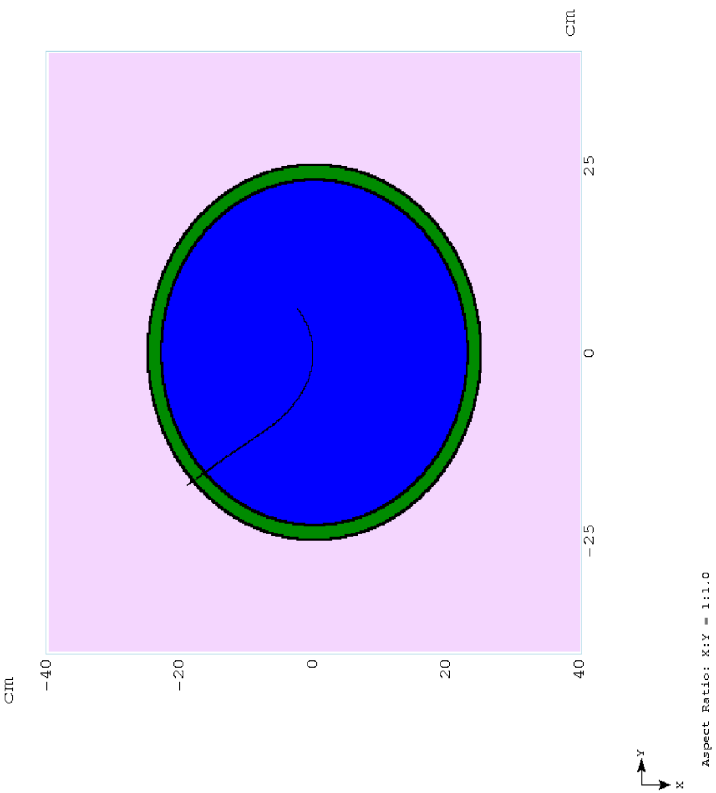
yz AT x = 0.0 cm



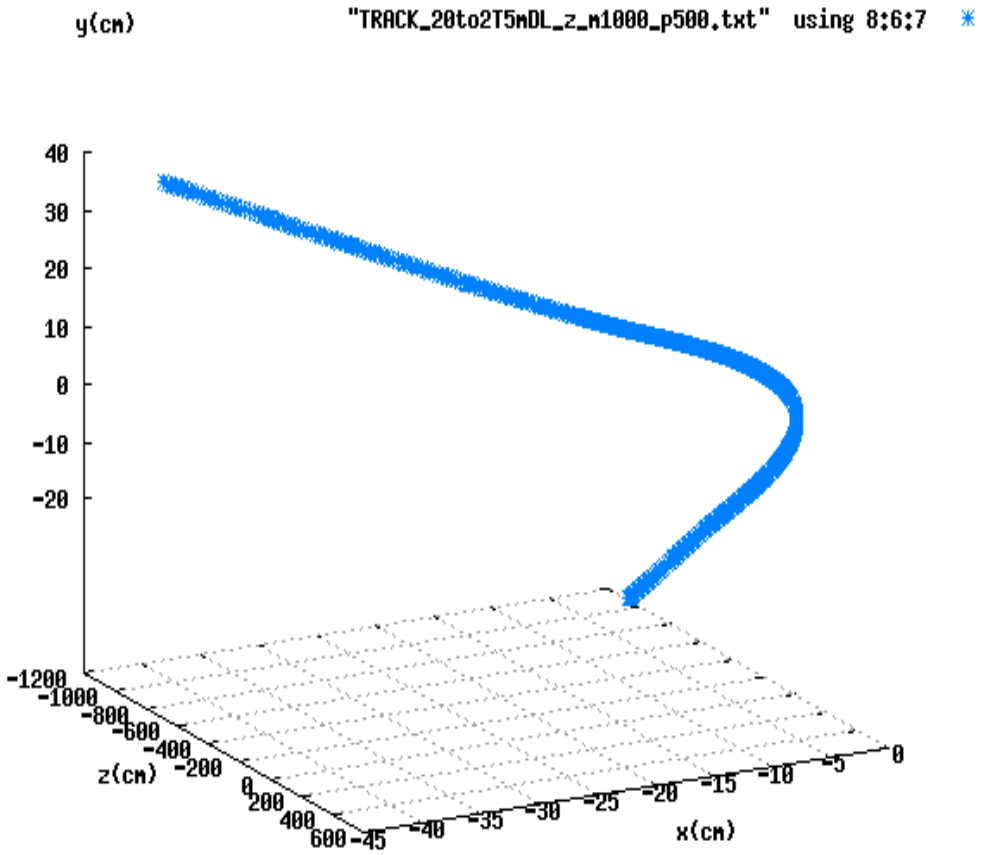
xz AT y = 0.0 cm

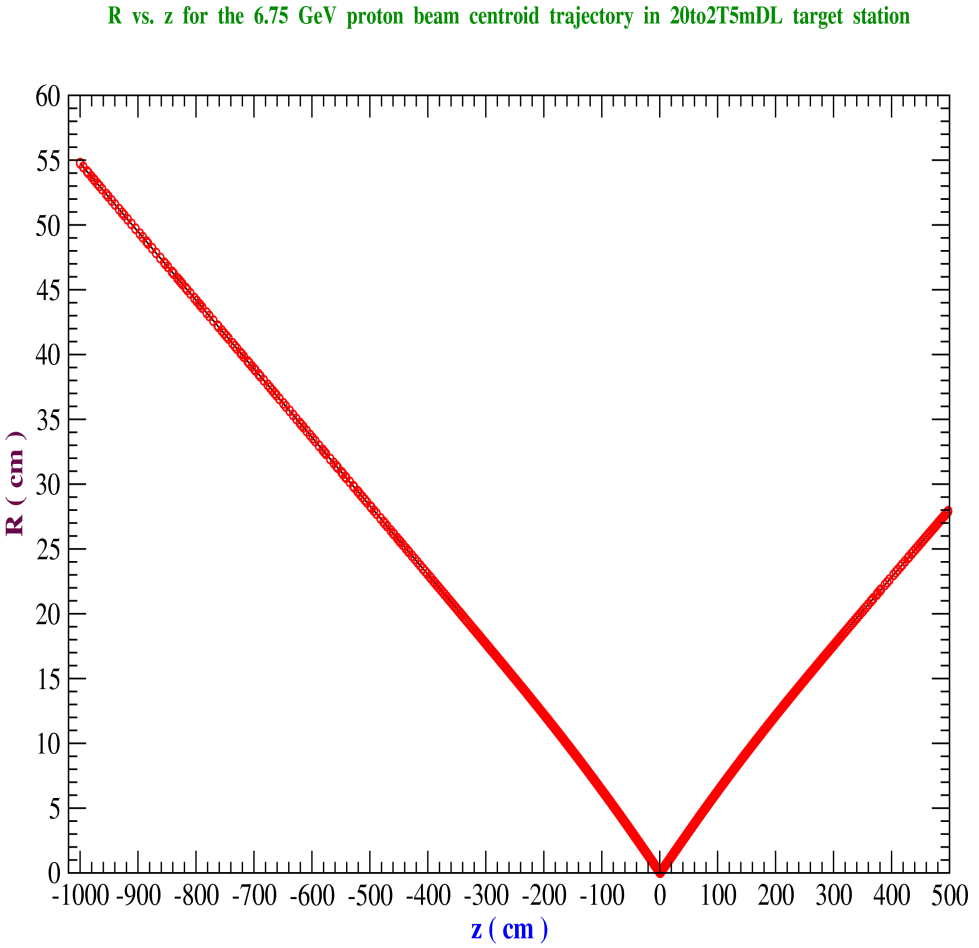


xy AT z = 456.0 cm



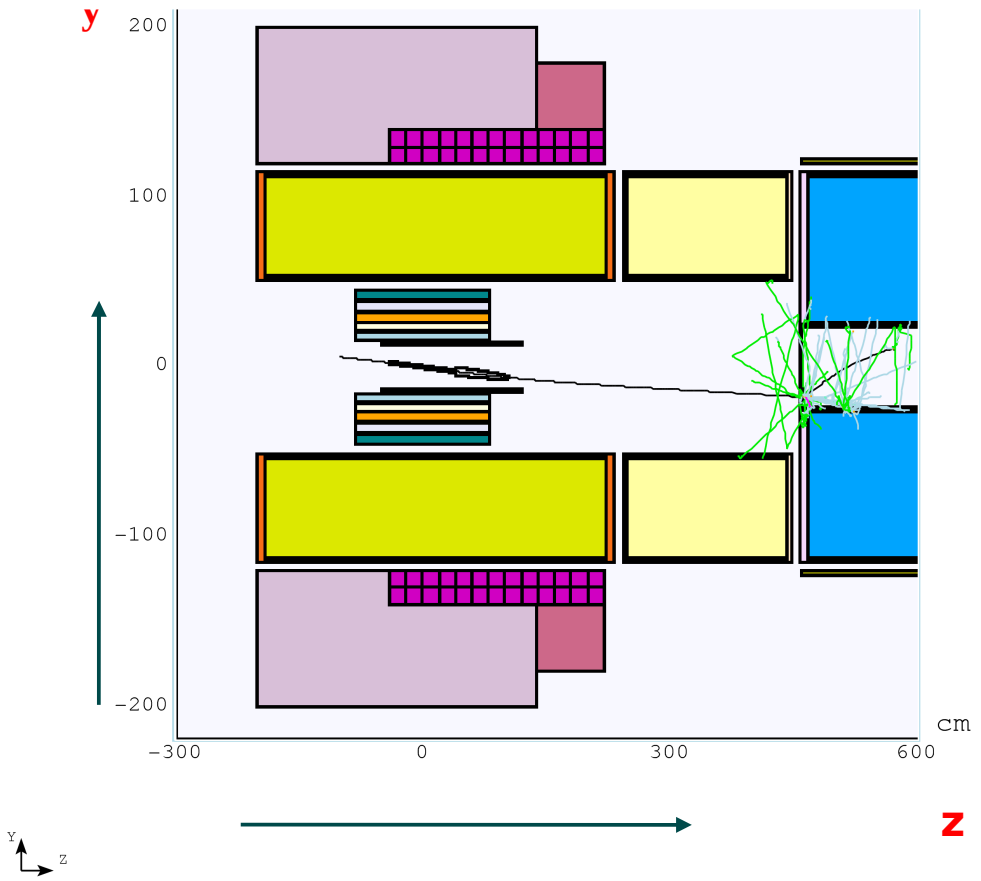
20to2T5mDL: 3D PLOT OF PROTON BEAM CENTROID TRAJECTORY (LEFT), AND RADIUS R vs. z PLOT (RIGHT). AT z ~ 456.0 cm WE ARE IN THE BeWind#1 REGION, AND FOR z > 456 AND R>23 cm WE ARE IN SH#2 REGION.

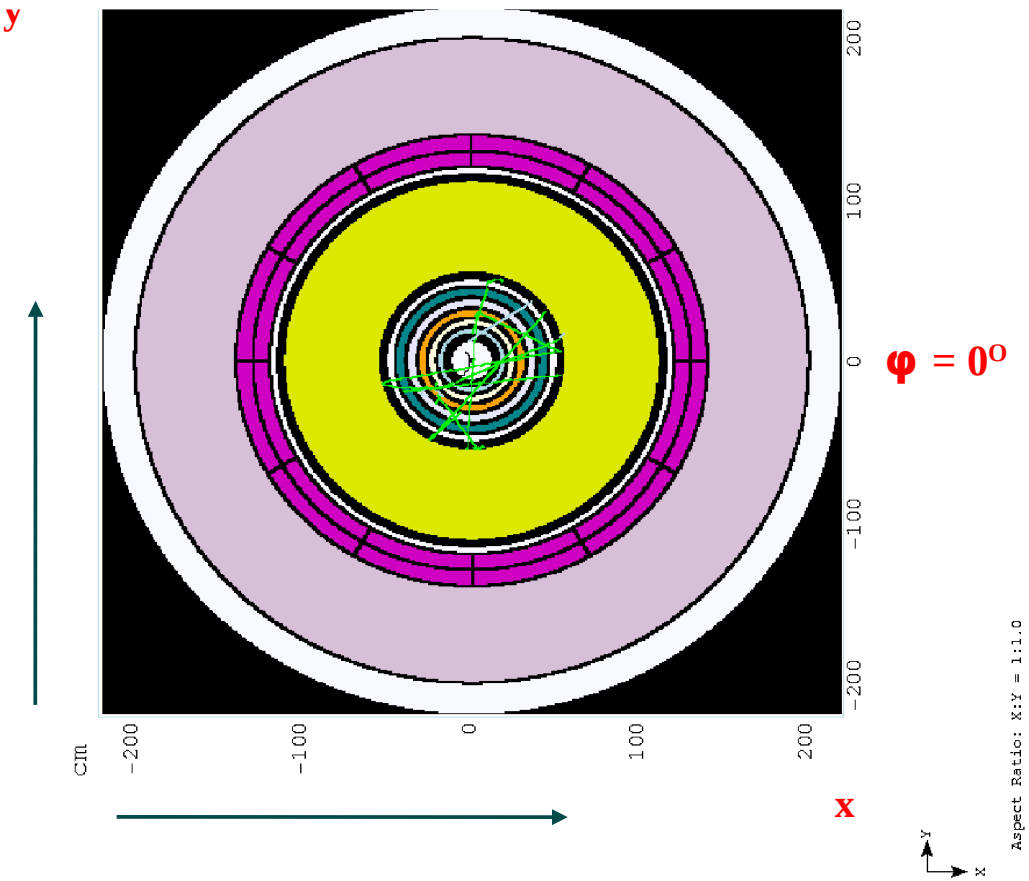




SC#1+SC#2 AZIMUTHAL TDPD DISTRIBUTION

SC#1+2 SEGMENTATION DETAILS : yz AT x = 0.0 cm [LEFT] AND xy AT z = 0.0 cm [RIGHT] CROSS SECTION.





$120.0 < r < 140.0$ cm **dr = 10.0 cm** **N_r = 2 bins**

$-41.0 < z < 219.0$ cm **dz = 20.0 cm** **N_z = 13 bins**

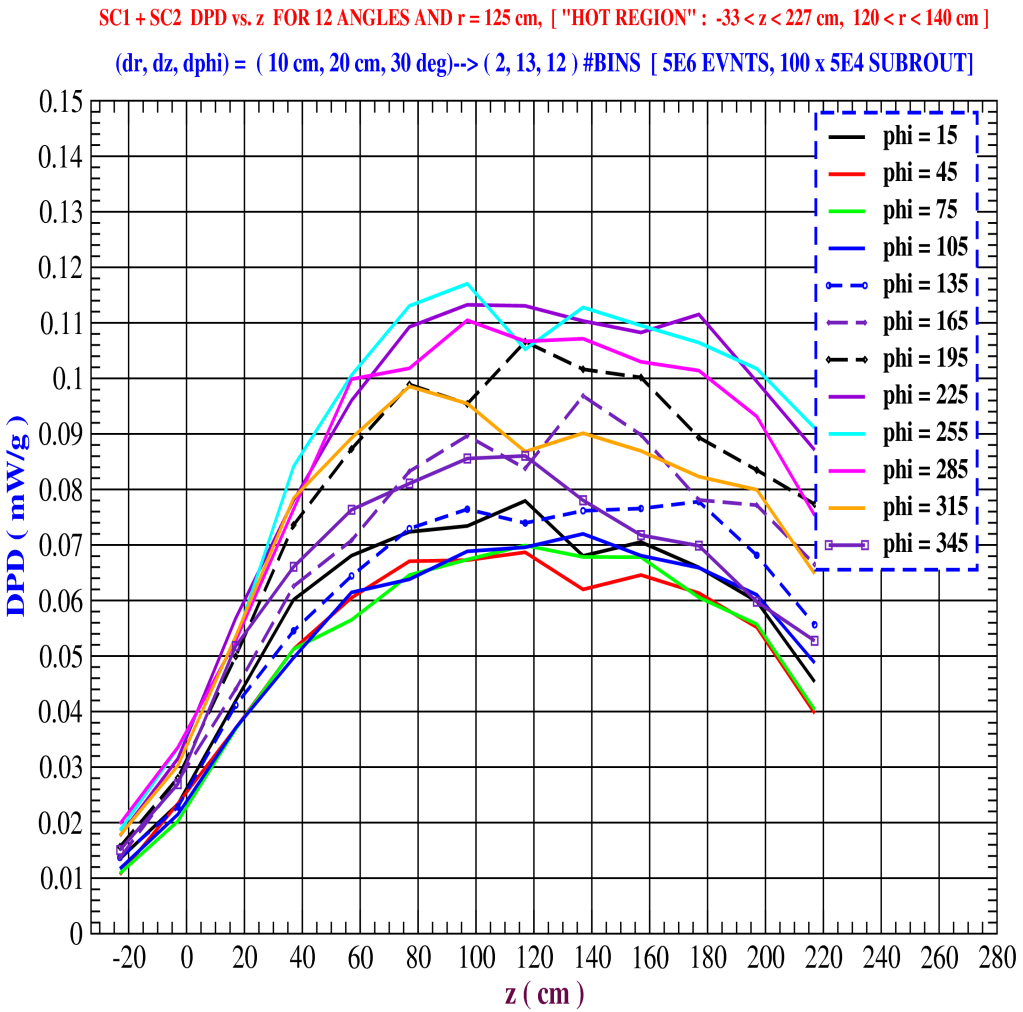
$0.0 < \varphi < 360.0$ deg. **$d\varphi$ = 30 deg.** **N_φ = 12 bins**

N_{tot} = 312 "pieces"

SC#1+2 : TDPD AZIMUTHAL DISTRIBUTION FOR 12 ANGLES.

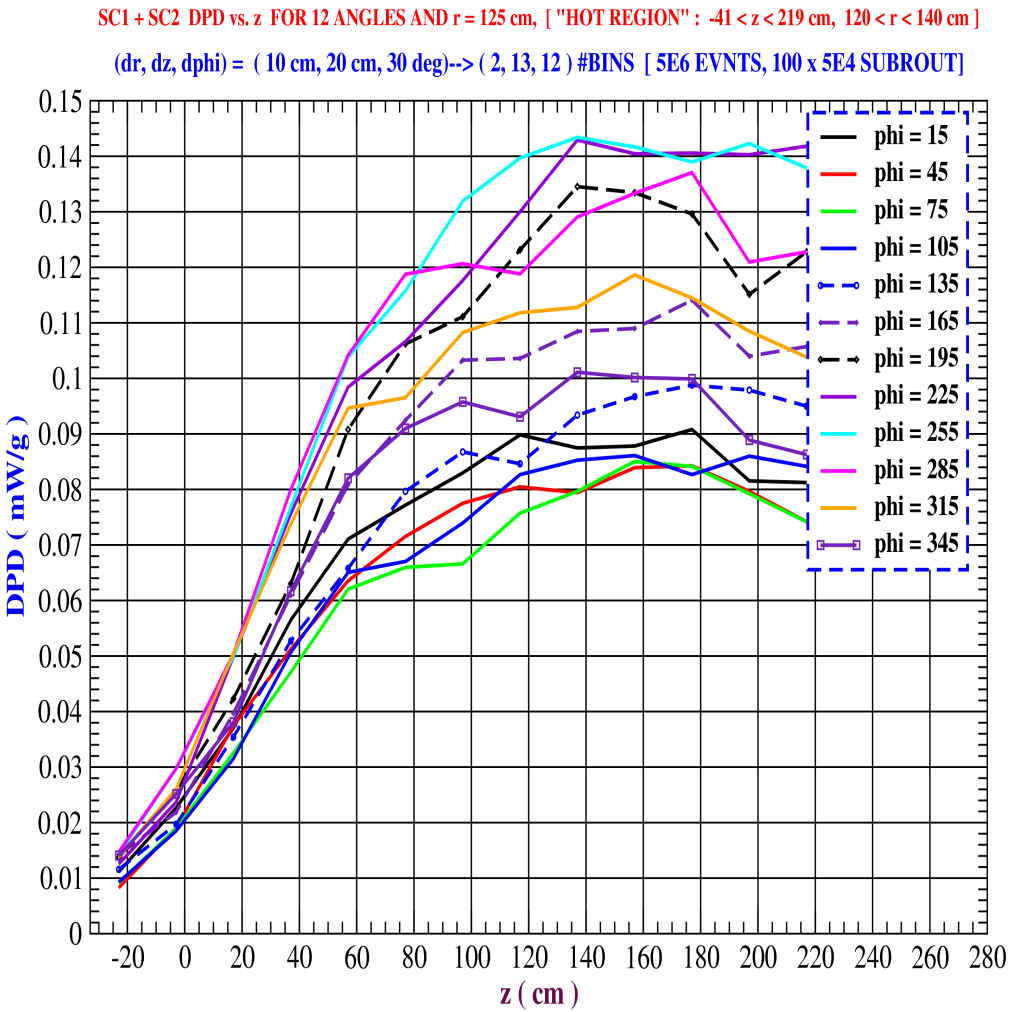
R = 125.0 cm "PIECES"

20To2T5m



PEAK: 0.12 mW/g AT (r, z, phi) = (125.0 97.0 255)

20to2T5mDL



PEAK: 0.143mW/g AT (r, z, phi) = (125.0 129.0 255)

20to2T5m TDP: 1.59 kW ("PIECES") + 1.058 kW (REST) = 2.65 kW vs. 2.63 kW (NO SEGMENTATION)

20to2T5mDL TDP: 1.89 kW ("PIECES") + 1.258 kW (REST) = 3.15 kW vs. 3.13 kW (NO SEGMENTATION)

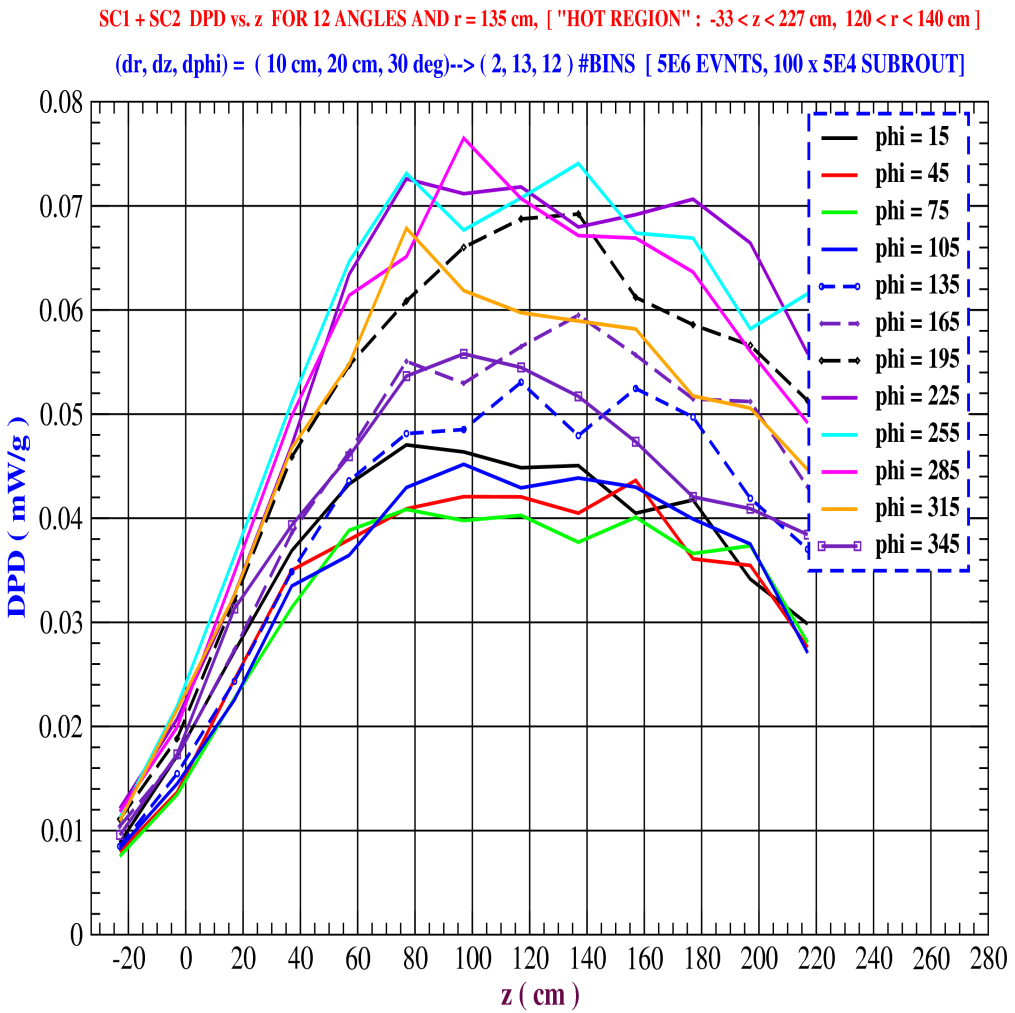
FOR THE NEW GEOMETRY AND AFTER CREATING A SEPARATE SHIELDING MODULE IN THE FIRST GAP WE HAVE A SMALL INCREASE IN THE PEAK TDPD (BY ~ 0.02 mW/g)

FOR 1-2 MW PROTON BEAM PRESENT SHIELDING PROVIDES ADEQUATE PROTECTION FOR SC#1+2

SC#1+2 : TDPD AZIMUTHAL DISTRIBUTION FOR 12 ANGLES.

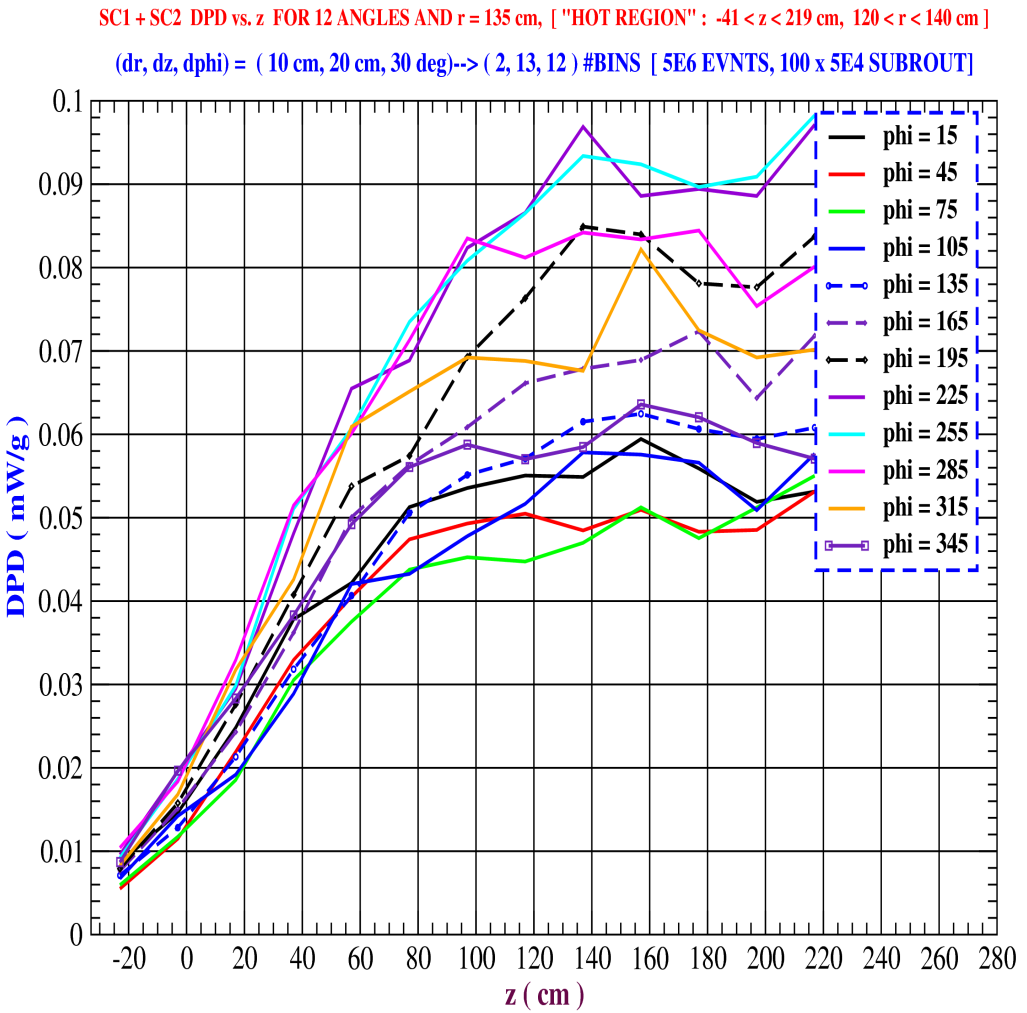
R = 135.0 cm ''PIECES

20to2T5m



PEAK: 0.076 mW/g AT (r, z, phi) = (135.0 97.0 285)

20to2T5mDL

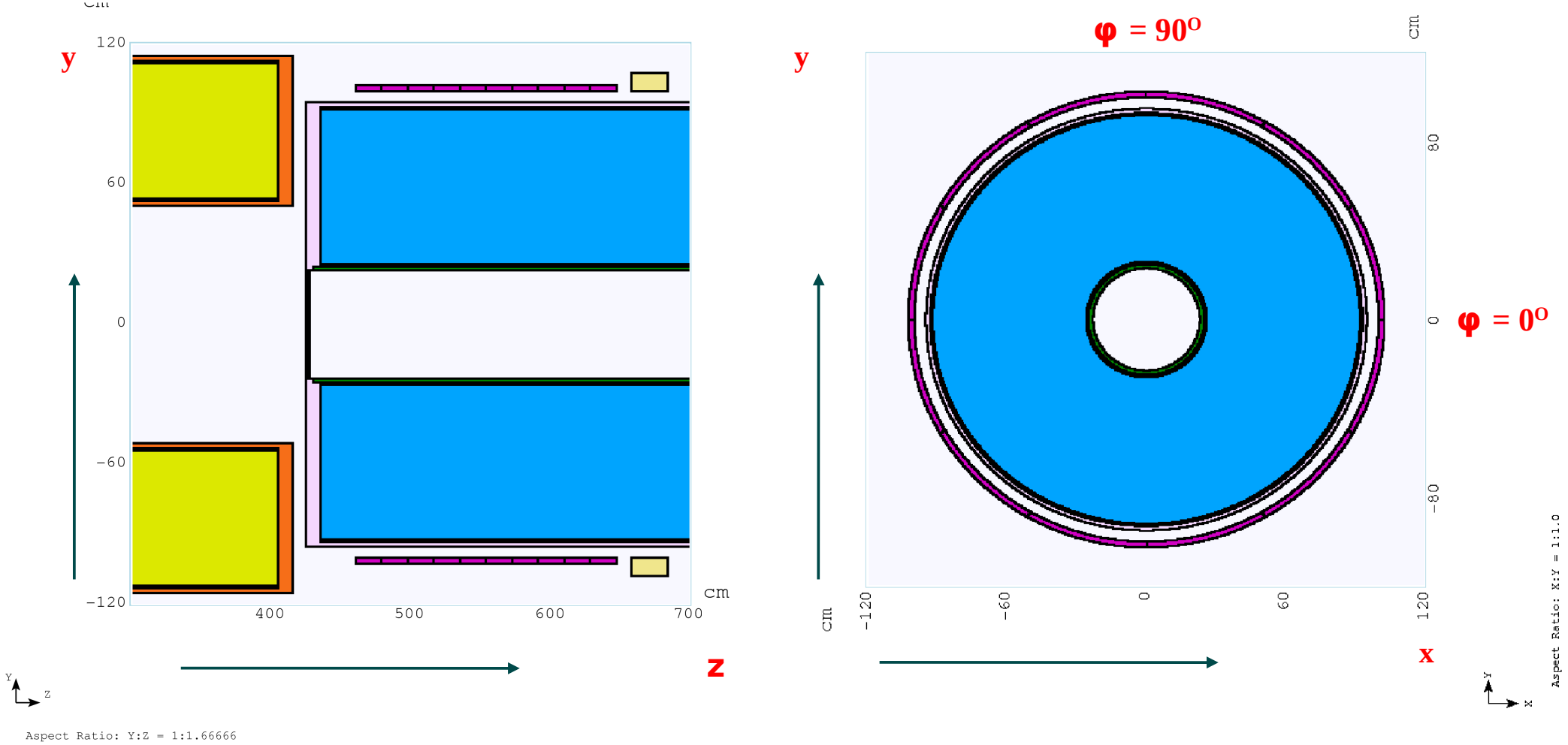


PEAK: 0.098 mW/g AT (r, z, phi) = (135.0 220.0 255)

FOR THE R= 135.0 RADIUS “PIECES” THE INCREASE IS ~ 30%

SC#3 AZIMUTHAL TDPD DISTRIBUTION

SC#3 SEGMENTATION DETAILS : yz AT x = 0.0 cm [LEFT] AND xy AT z = 540.0 cm [RIGHT] CROSS SECTION.



$120.0 < r < 123.01$ cm $dr = 3.01$ cm $N_r = 1$ bins

$458.07 < z < 621.36$ cm $dz = 16.329$ cm $N_z = 10$ bins

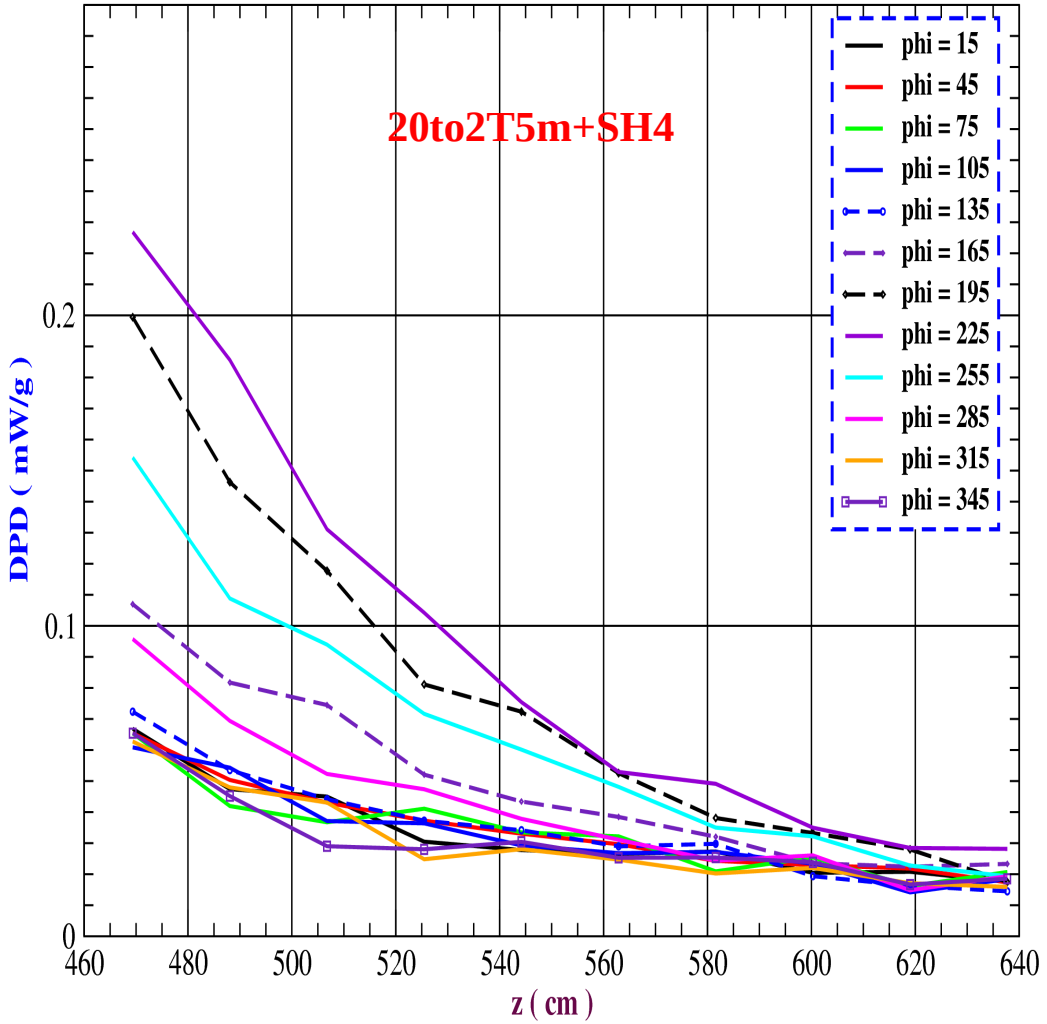
$0.0 < \varphi < 360.0$ deg. $d\varphi = 30$ deg. $N_\varphi = 12$ bins

$N_{tot} = 120$ "pieces"

SC#3 : TDPD AZIMUTHAL DISTRIBUTION FOR 12 ANGLES.
BEFORE (LEFT) AND AFTER THE INCREASE (RIGHT) OF RADIUS FROM R=100 TO R=120 cm

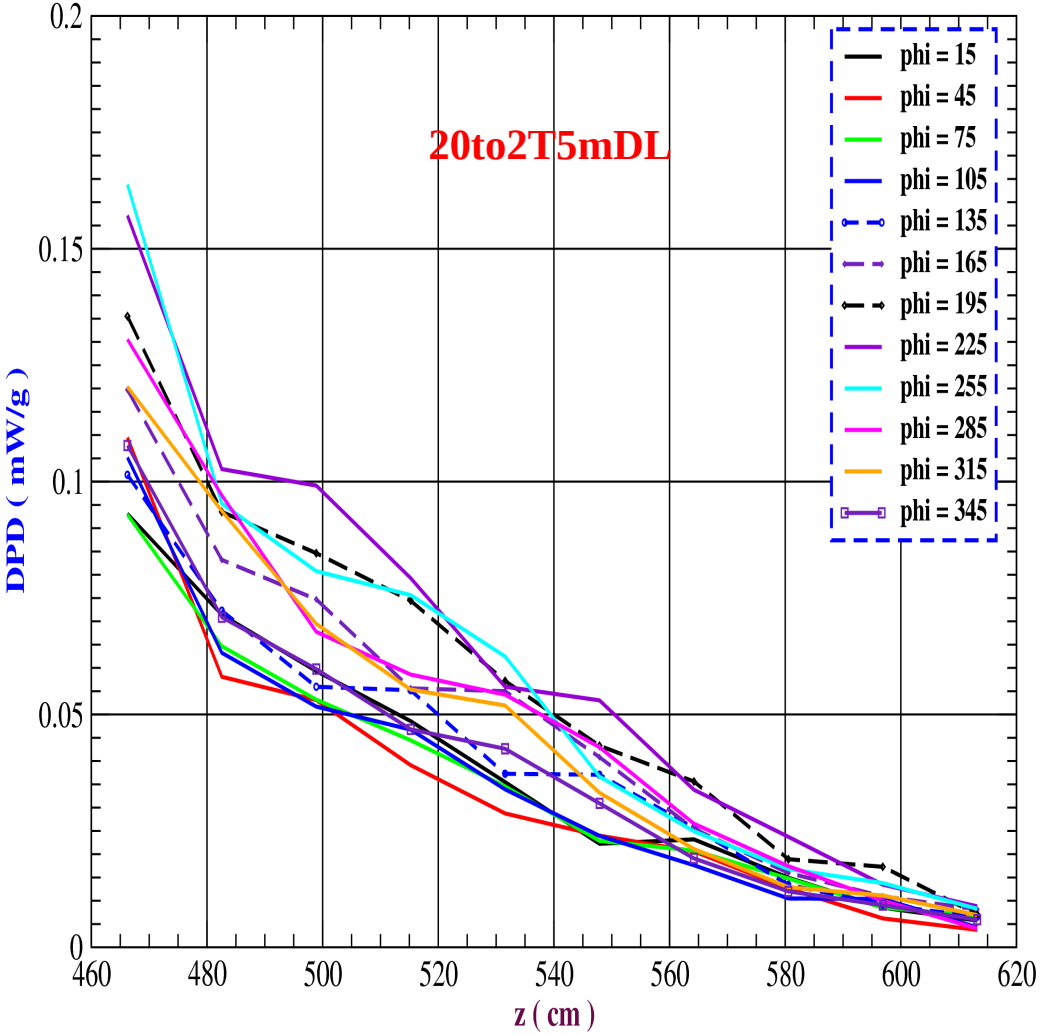
SC3 DPD vs. z FOR 12 ANGLES AND r = 101.335 cm, [460.0 < z < 647.19 cm, 100 < r < 102.67 cm] < WITH SH#4 >

(dr, dz, dphi) = (2.67 cm, 18.706 cm, 30 deg)--> (1, 10, 12) #BINS [5E6 EVNTS, 100 x 5E4 SUBROUT]



SC3 DPD vs. z FOR 12 ANGLES AND r = 121.505 cm, [458.07 < z < 621.36 cm, 120 < r < 123.01 cm]

(dr, dz, dphi) = (3.01 cm, 16.329 cm, 30 deg)--> (1, 10, 12) #BINS [5E6 EVNTS, 100 x 5E4 SUBROUT]



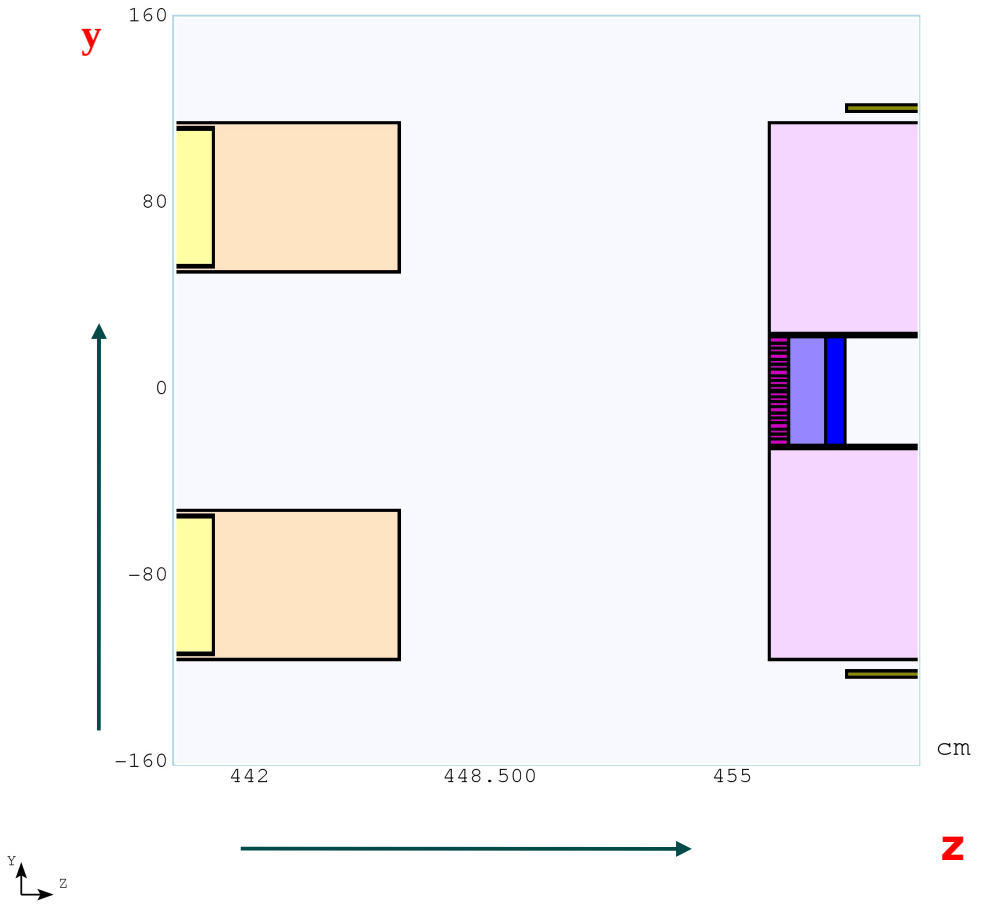
PEAK: 0.23 mW/g AT (r, z, phi) = (101.335 469.353 225)
TDP: 0.100 kW (''PIECES'') vs. 0.099 kW (NO SEGMNT)

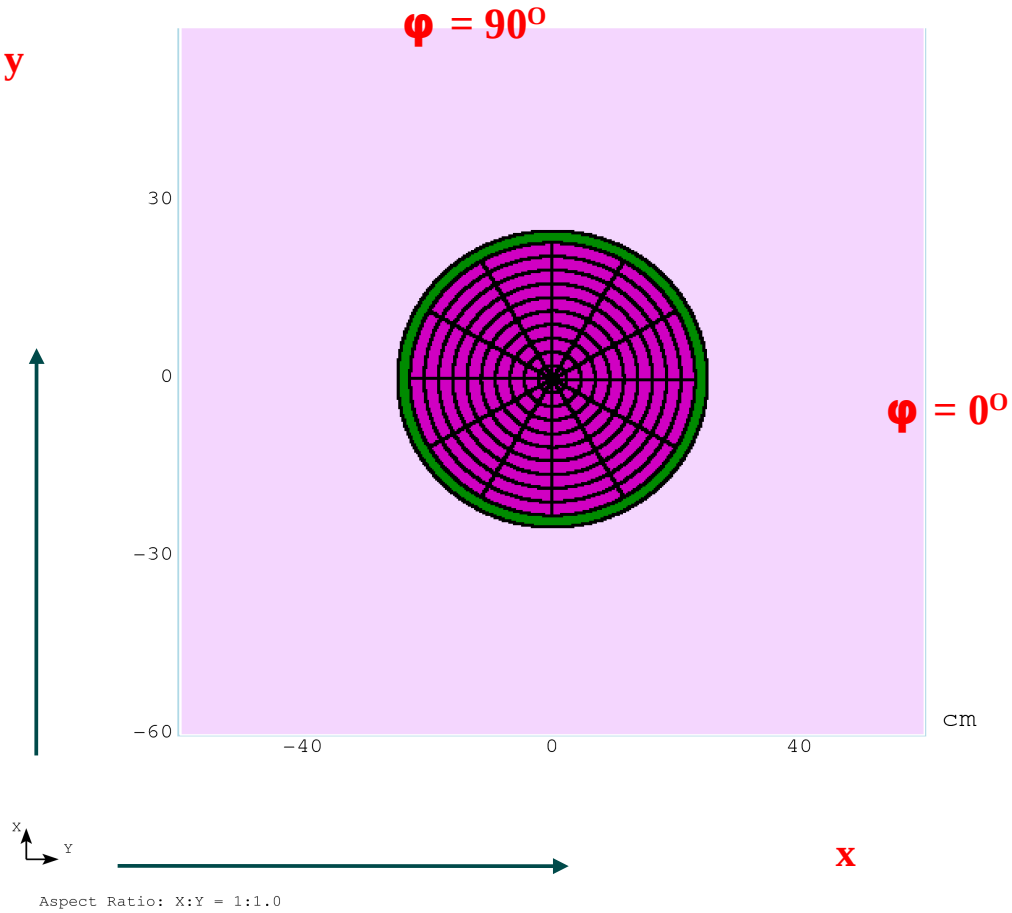
PEAK: 0.16 mW/g AT (r, z, phi) = (121.505 466.234 225)
TDP: 0.118 kW (''PIECES'') vs. 0.116 kW (NO SEGMNT)

WITH THE INCREASE OF THE RADIUS BY 20 cm THE PEAK TDPD DECREASED BY ~ 30% FOR A 4 MW BEAM.
THEREFORE FOR 1 MW IS ~ 0.04 mW/g.

BeWind#1 AZIMUTHAL TDPD DISTRIBUTION

BeWind#1 SEGMENTATION DETAILS : yz AT x = 0.0 cm [LEFT] AND xy AT z = 456.3 cm [RIGHT]
CROSS SECTIONS FOCUSED IN THE GAP#1 BeWind#1 REGION.





$0.0 < r < 23.0$ cm $dr = 2.3$ cm $N_r = 10$ bins

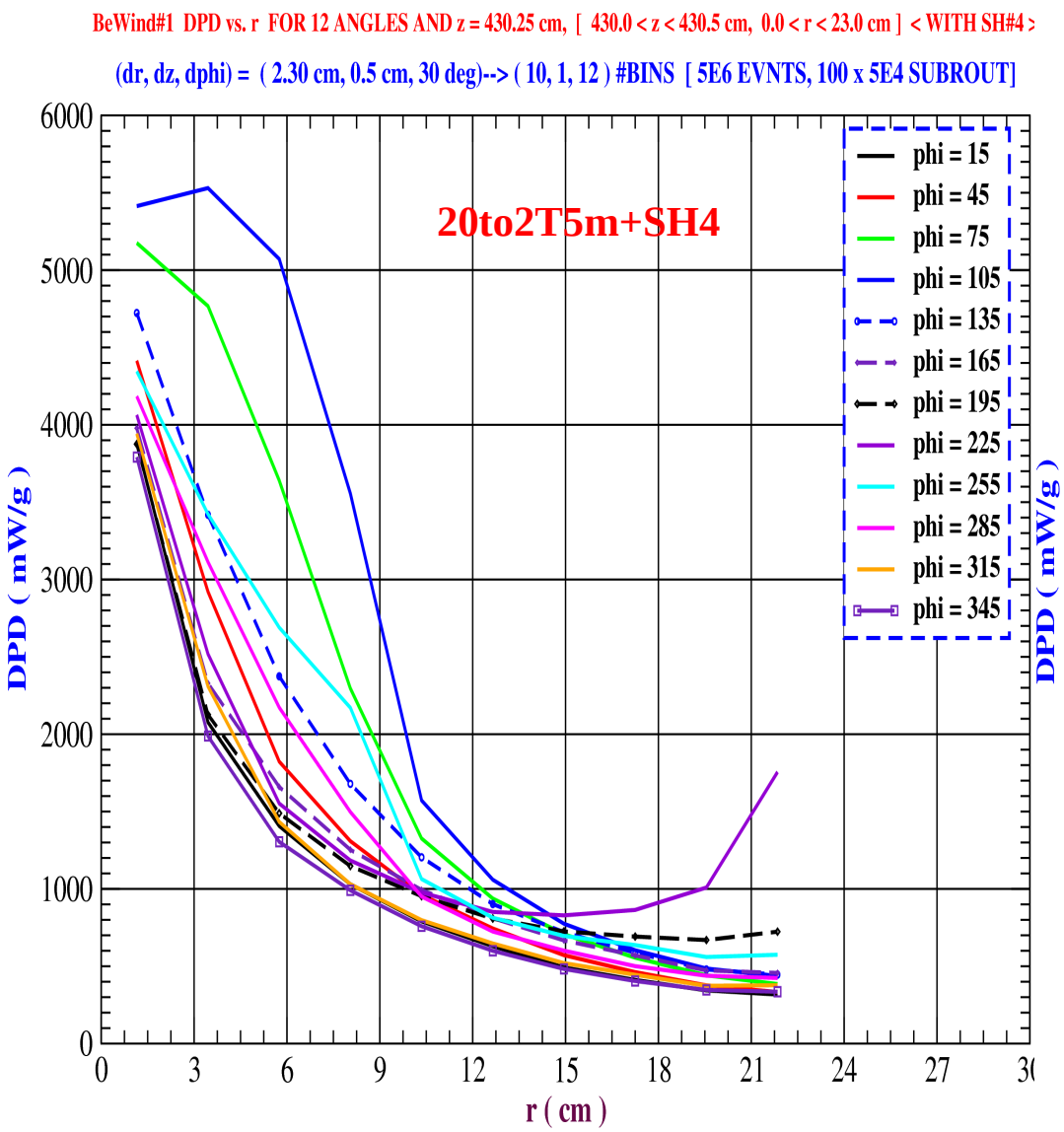
$456.0 < z < 456.5$ cm $dz = 0.5$ cm $N_z = 1$ bins

$0.0 < \varphi < 360.0$ deg. $d\varphi = 30$ deg. $N_\varphi = 12$ bins

$N_{tot} = 120$ "pieces"

BeWind#1 : TDPD AZIMUTHAL DISTRIBUTION (vs. r) FOR 12 ANGLES

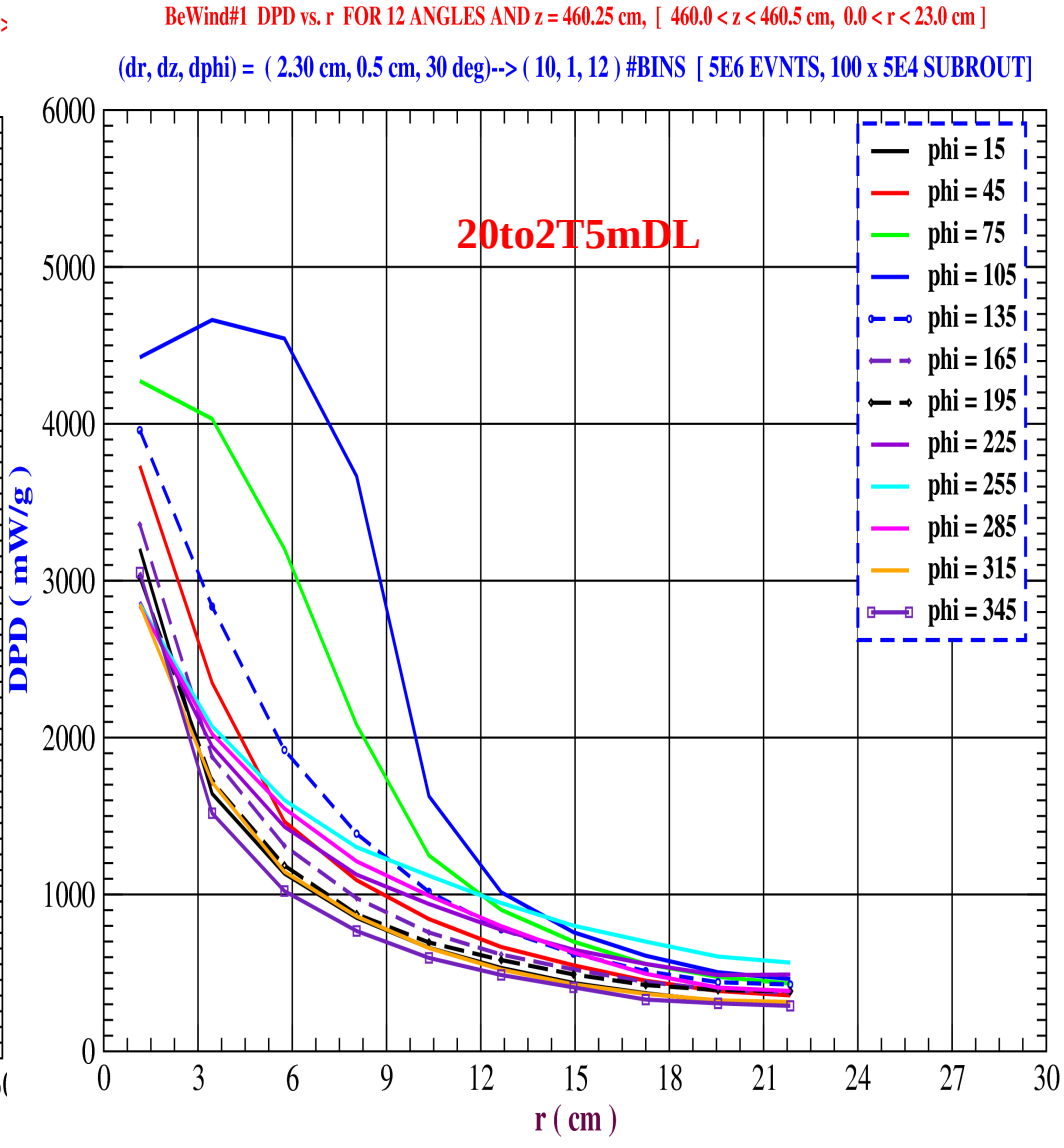
20to2T5m



PEAK: 5530.64 mW/g AT (r, z, phi) = (3.45 430.5 105)

20to2T5m TDP: 1.373 kW (''PIECES'') + 1.652 (REST) ~ 3.03 vs. 3.375 kW (NO SEGMNT)

20to2T5mDL



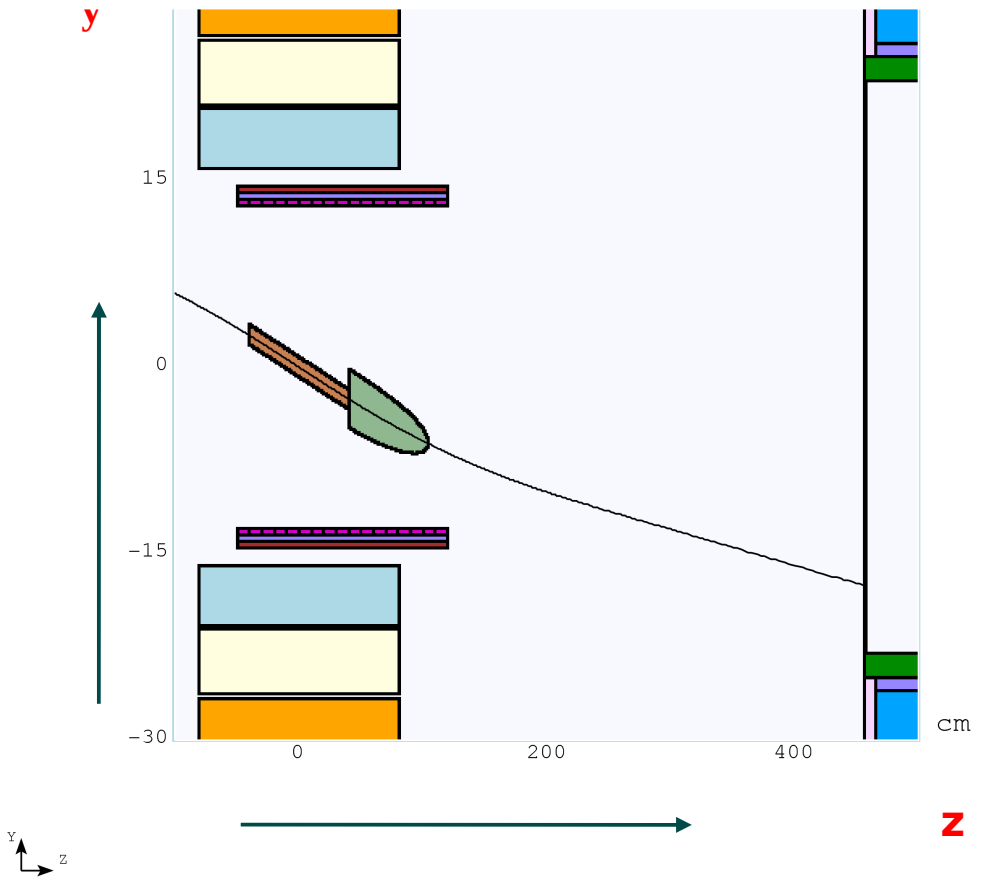
PEAK: 4661.91 mW/g AT (r, z, phi) = (3.45 460.25 105)

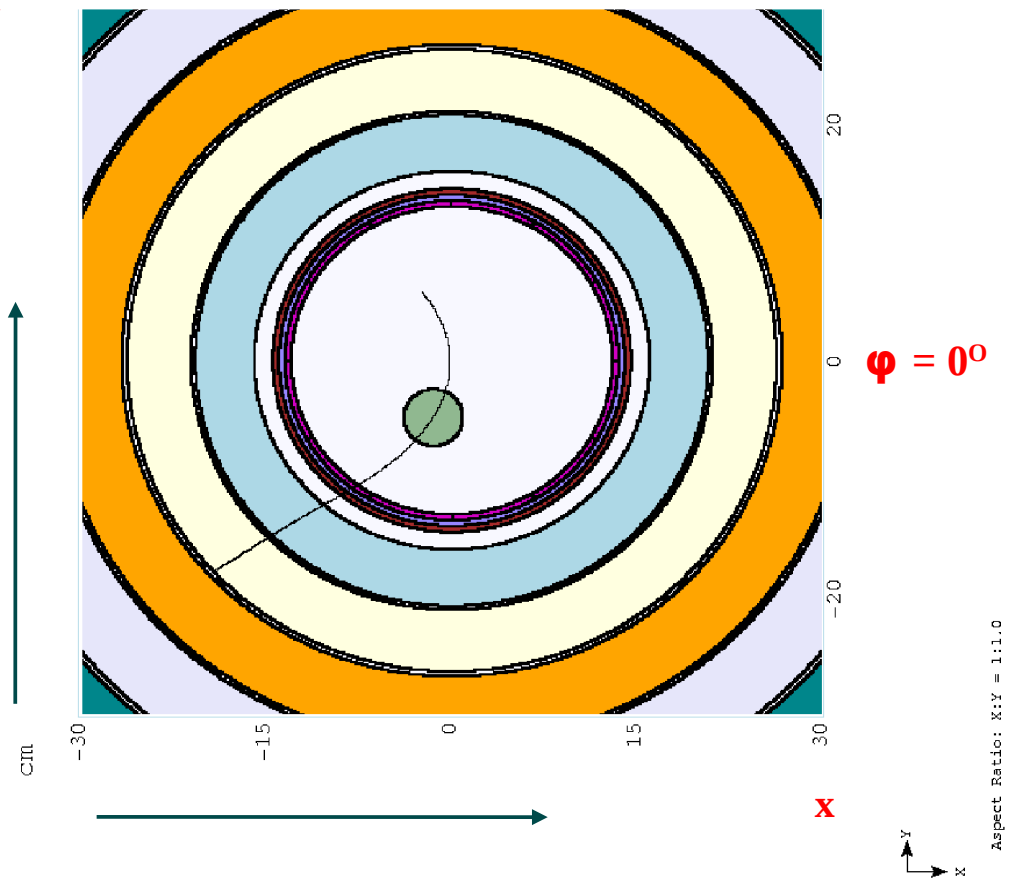
20to2T5mDL TDP: 1.147 kW (''PIECES'') + 1.153 (REST) ~ 2.3 vs. 2.6 kW (NO SEGMNT)

BeWind#1 HAS BEEN MOVED FURTHER DOWNSTREAM (FROM z = 430 TO z = 460 cm) AND THE PEAK TDPD HAS DECREASED BY 868.73 mW/g.

C TARGET VESSEL INNER TUBE AZIMUTHAL TDPD DISTRIBUTION

BP#1 SEGMENTATION DETAILS : yz AT x = 0.0 cm [LEFT] AND xy AT z = 80.0 cm [RIGHT]
CROSS SECTION WITH SEGMENTATION DETAILS OF INNER TUBE (BP#1).





φ = 0°

13.0 < r < 13.5 cm **dr = 0.5 cm** **N_r = 1 bins**

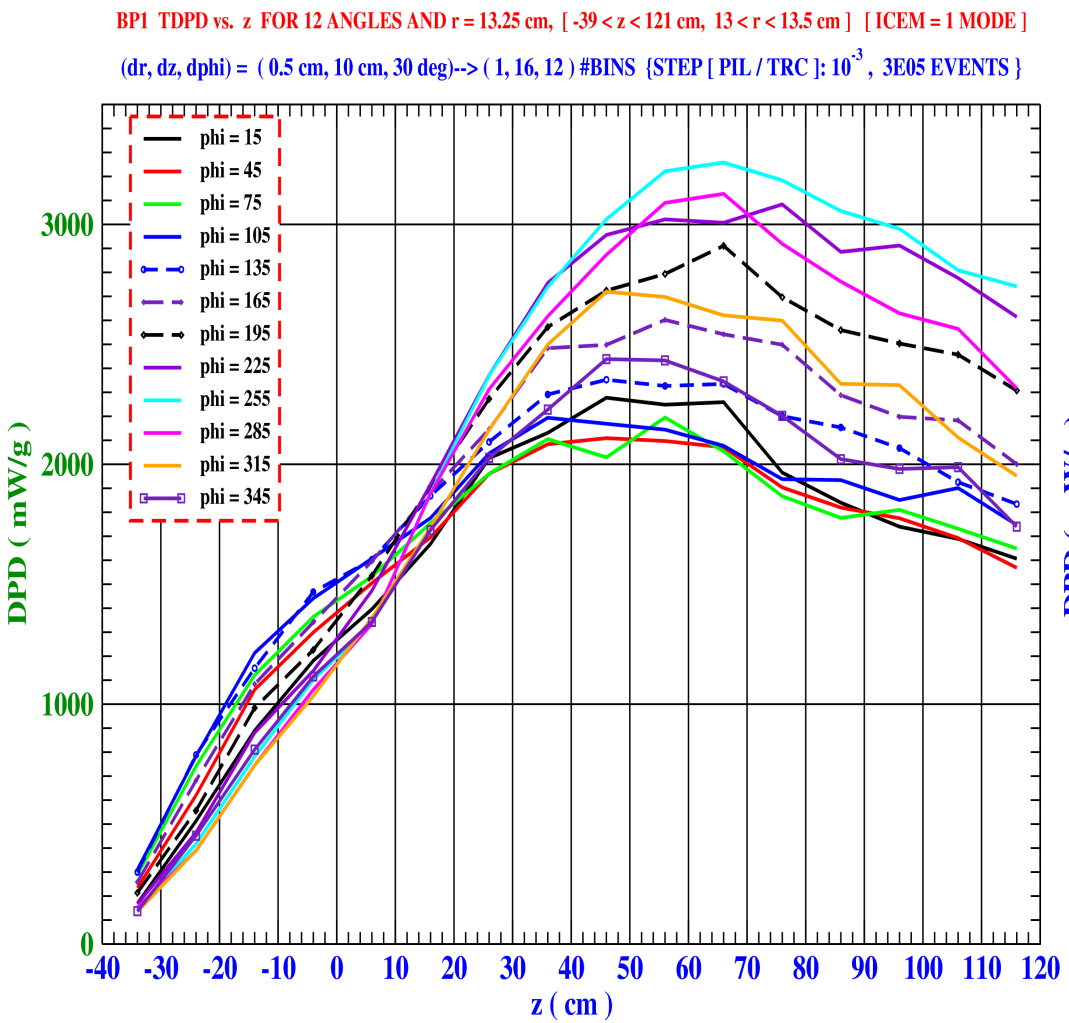
- 50.0 < z < 120.0 cm **dz = 10.0 cm** **N_z = 17 bins**

0.0 < φ < 360.0 deg. **dφ = 30 deg.** **N_φ = 12 bins**

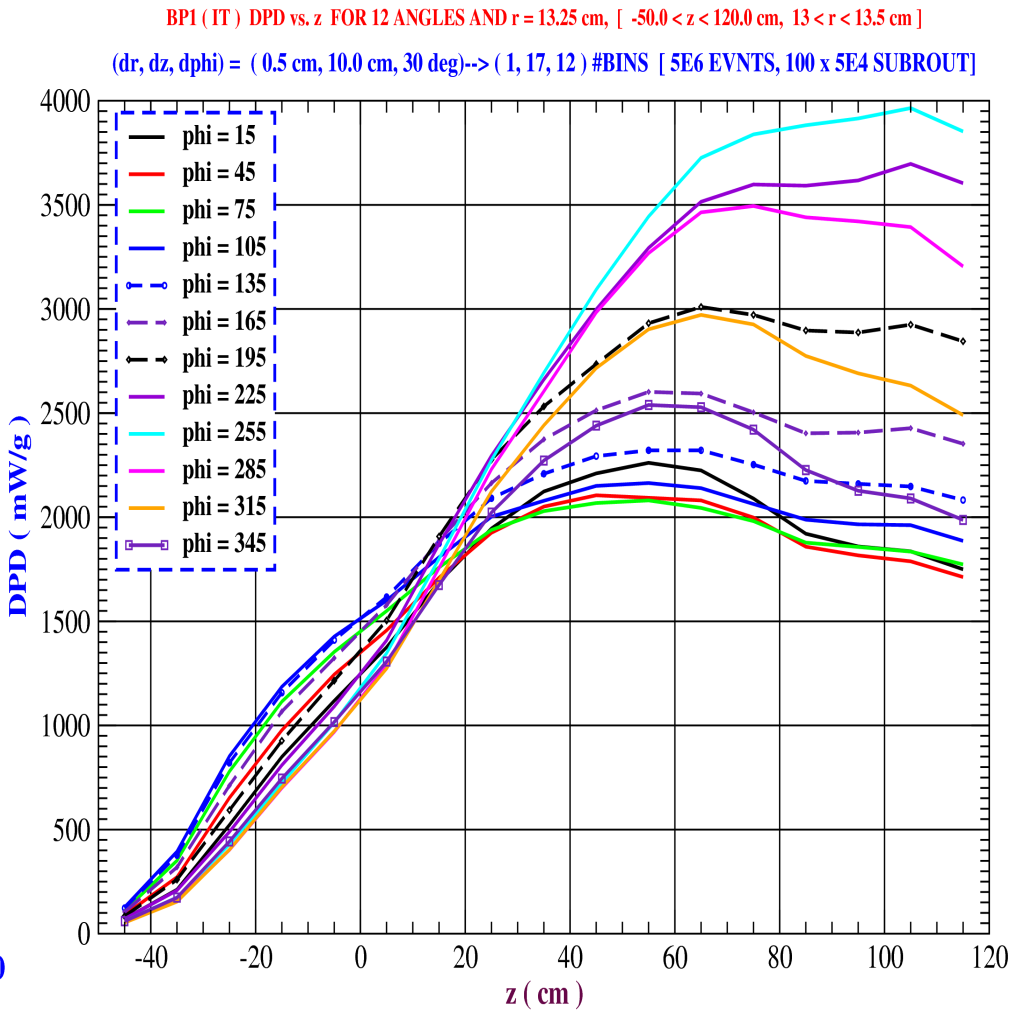
N_{tot} = 2004 "pieces"

BP#1 (C MODULE INNER TUBE): TDPD AZIMUTHAL DISTRIBUTION FOR 12 ANGLES

20to2T5m



20to2T5mDL



PEAK: 3258.06 mW/g (r, z, phi) = (13.25 66.0 255)

PEAK: 3964.43 mW/g (r, z, phi) = (13.25 105.0 255)

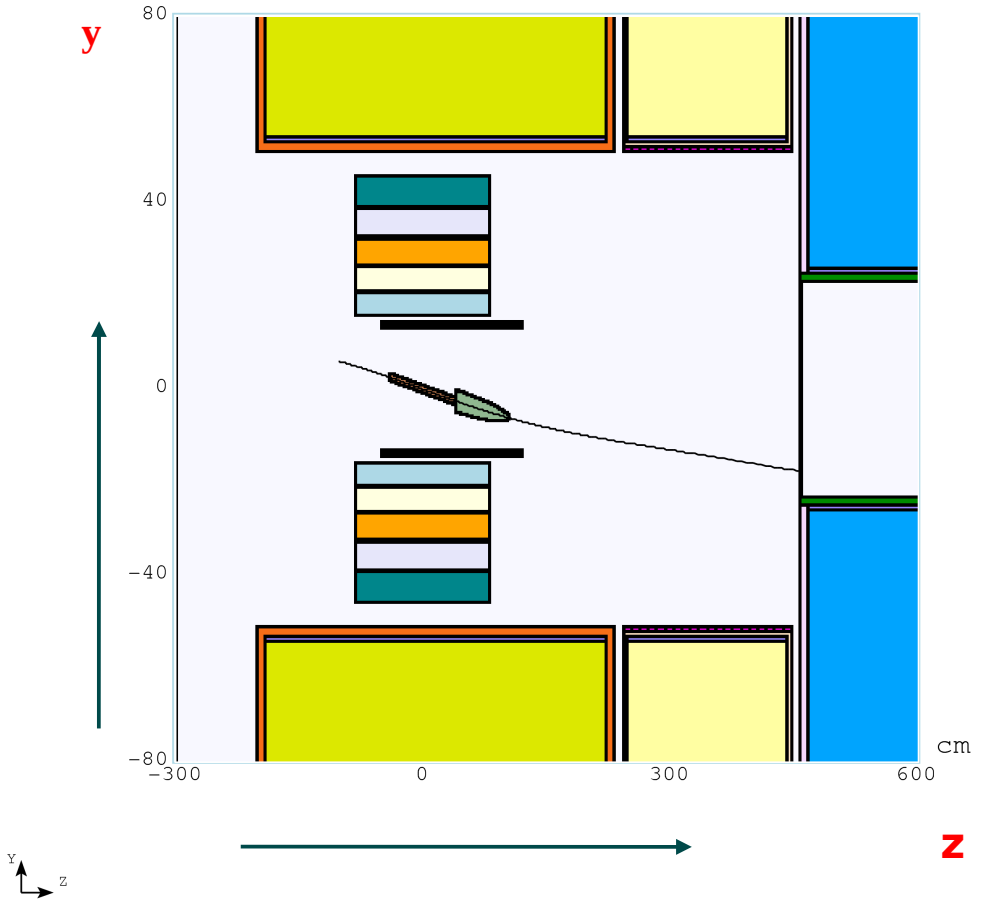
20to2T5m TDP: 97.28 kW (PIECES) vs. 114.31 kW (TUBE 2)

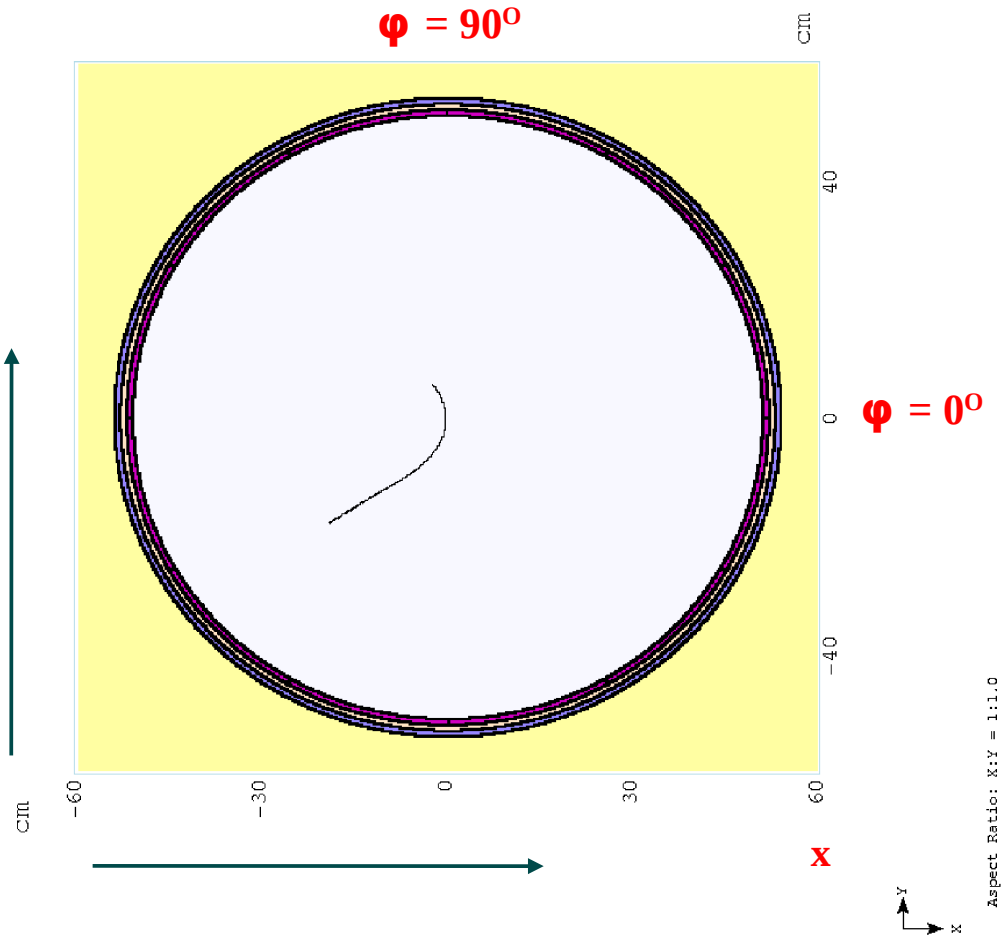
20to2T5mDL TDP: 103.66 kW (PIECES) + 117.47 (REST) = 224.13 kW vs. 240.57 kW (NO SEGM.)

PEAK IN NEW GEOMETRY IS MUCH HIGHER (+ 706.37 mW/g) TO A LARGE DEGREE DUE TO THE PRESENCE OF THE C DUMP IN THE SECOND GEOMETRY.

SHVS#1B VESSEL INNER TUBE AZIMUTHAL TDPD DISTRIBUTION

SHSV#1B INNER TUBE SEGMENTATION DETAILS : yz AT x = 0.0 cm [LEFT] AND xy AT z = 340.0 cm [RIGHT] CROSS SECTION.





51.0 < r < 52.0 cm dr = 1.0 cm N_r = 1 bins

242.0 < z < 446.0 cm dz = 10.20 cm N_z = 20 bins

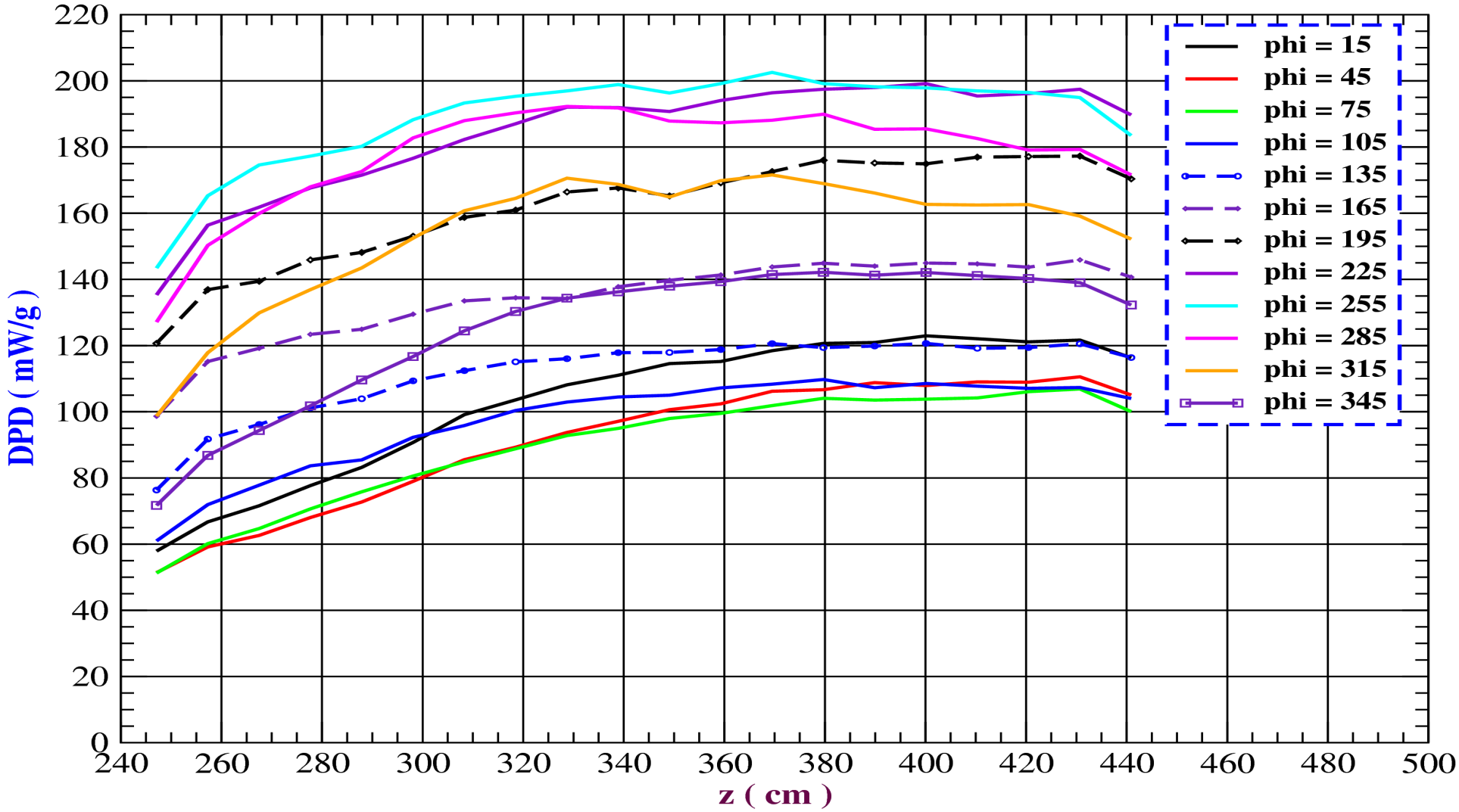
0.0 < φ < 360.0 deg. dφ = 30 deg. N_φ = 12 bins

N_{tot} = 384 "pieces"

SHVS#1B INNER TUBE : TDPD AZIMUTHAL DISTRIBUTION (vs. z) FOR 12 ANGLES.

SHVS1B (IT) DPD vs. z FOR 12 ANGLES AND r = 51.50 cm, [242.0 < z < 446.0 cm, 51 < r < 52 cm]

(dr, dz, dphi) = (1.0 cm, 10.20 cm, 30 deg)--> (1, 20, 12) #BINS [5E6 EVNTS, 100 x 5E4 SUBROUT]



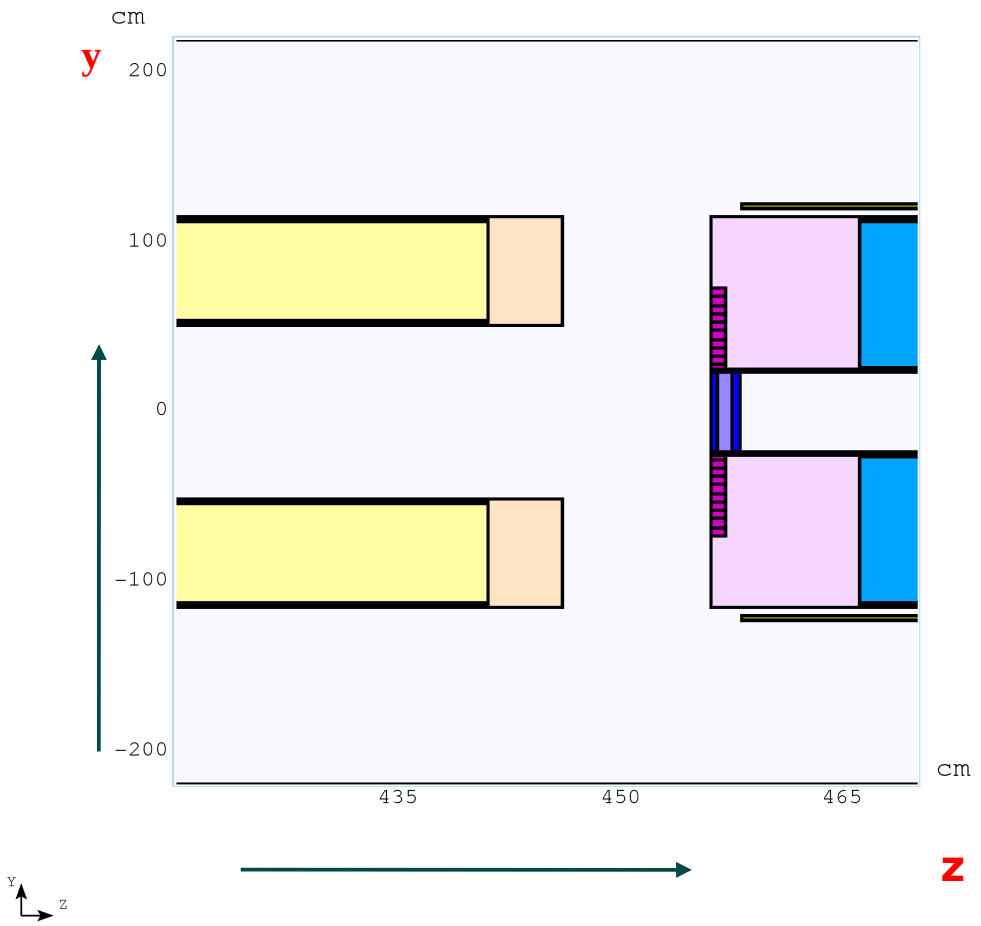
PEAK: 202.547 mW/g AT (r, z, phi) = (51.5 369.5 255)

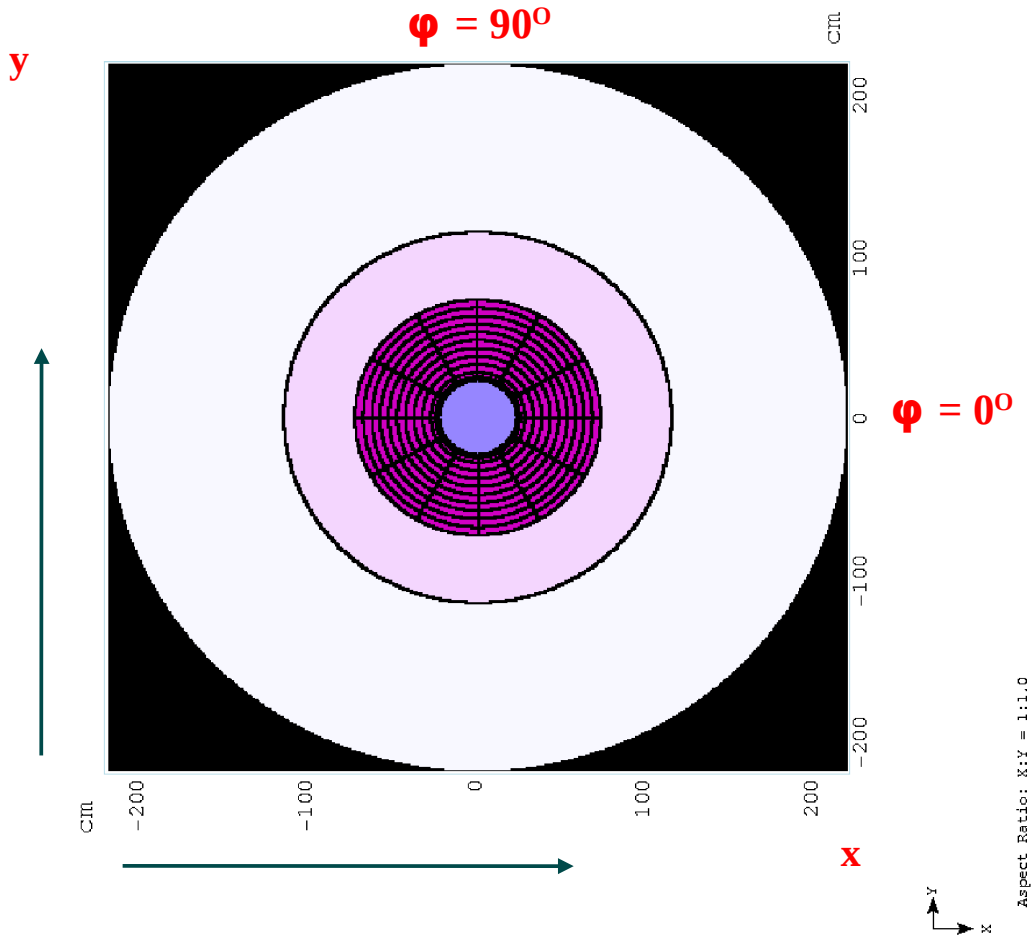
TDP: 70.54 kW ("PIECES") + 81.125 (REST) = 151.67 vs. 151.79 kW (NO SEGMNT)

PEAK TDPD SMALL AND IT APPEARS THERE ARE NO HOT SPOTS IN THE INNER TUBE OF THE VESSEL

SHVS#2 UPSTREAM FLANGE AZIMUTHAL TDPD DISTRIBUTION

SHVS#2 INNER TUBE SEGMENTATION DETAILS : yz AT x = 0.0 cm [LEFT] AND xy AT z = 456.5 cm [RIGHT] CROSS SECTION.





$23.0 < r < 73.0$ cm $dr = 5.0$ cm $N_r = 10$ bins

$456.0 < z < 457.0$ cm $dz = 1.0$ cm $N_z = 1$ bins

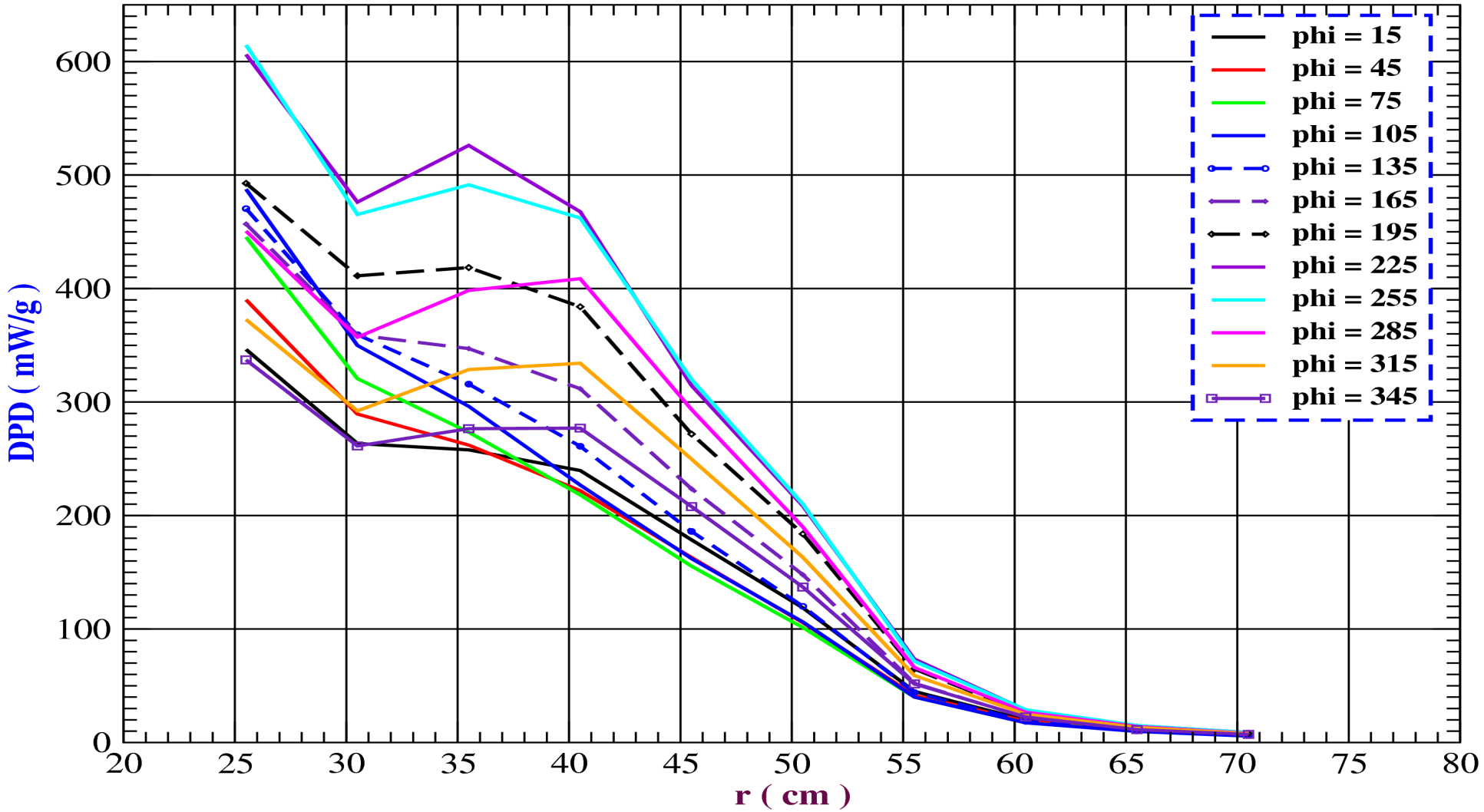
$0.0 < \varphi < 360.0$ deg. $d\varphi = 30$ deg. $N_\varphi = 12$ bins

$N_{tot} = 120$ "pieces"

SHVS#2 UPSTREAM FLANGE : TDPD AZIMUTHAL DISTRIBUTION (vs. z) FOR 12 ANGLES.

SHVS#2 UFL DPD vs. r FOR 12 ANGLES AND z = 456.5 cm, [456.0 < z < 457.0 cm, 23.0 < r < 73.0 cm]

(dr, dz, dphi) = (5.0 cm, 1.0 cm, 30 deg)--> (10, 1, 12) #BINS [5E6 EVNTS, 100 x 5E4 SUBROUT]



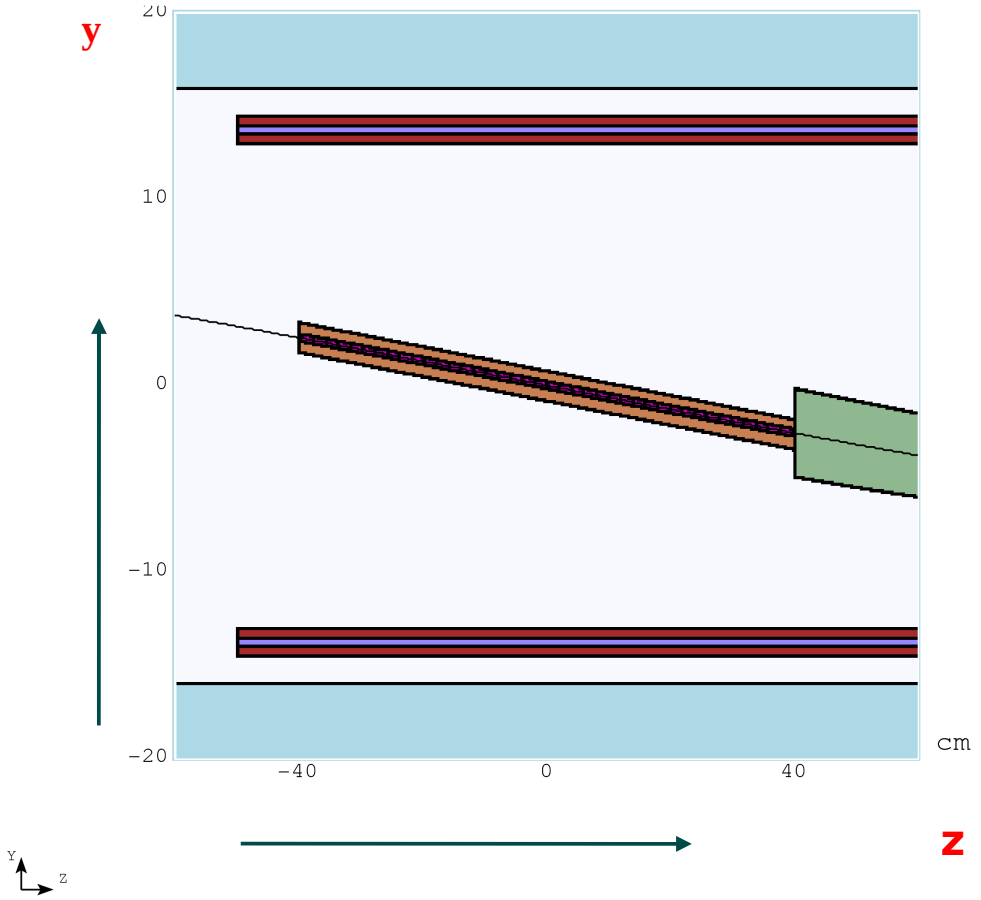
PEAK: 614.51 mW/g AT (r, z, phi) = (25.5 456.5 255)

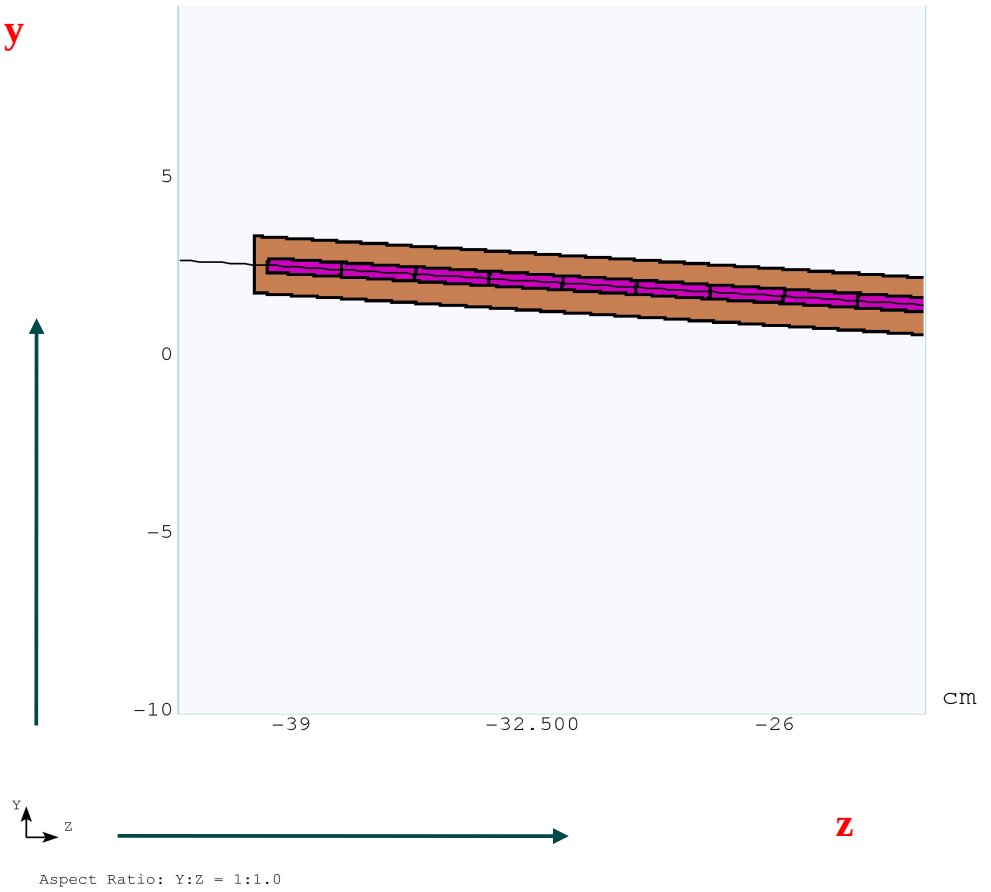
TDP: 17.70 kW ("PIECES") + 1711.92 (REST) = 189.62 vs. 188.72 kW (NO SEGMNT)

PEAK TDPD SMALL AND WE OBSERVE HOTSPOTS AT r ~ 34 - 40 cm AND FOR phi ~ 195.0 - 285.0 MAINLY DUE TO THE BEAM PROTONS WITH SMALL SCATTERING ANGLES.

C TARGET AXIAL TDP DISTRIBUTION FOR 0 < r < 0.2 cm

C TARGET 0 < r < 0.2 cm SEGMENTATION DETAILS : yz AT x = 0.0 cm [LEFT] AND yz WITH FOCUS ON THE FIRST HALF OF THE TARGET [RIGHT] CROSS SECTION.





$0.0 < r < 0.2$ cm $dr = 0.2$ cm $N_r = 1$ bins

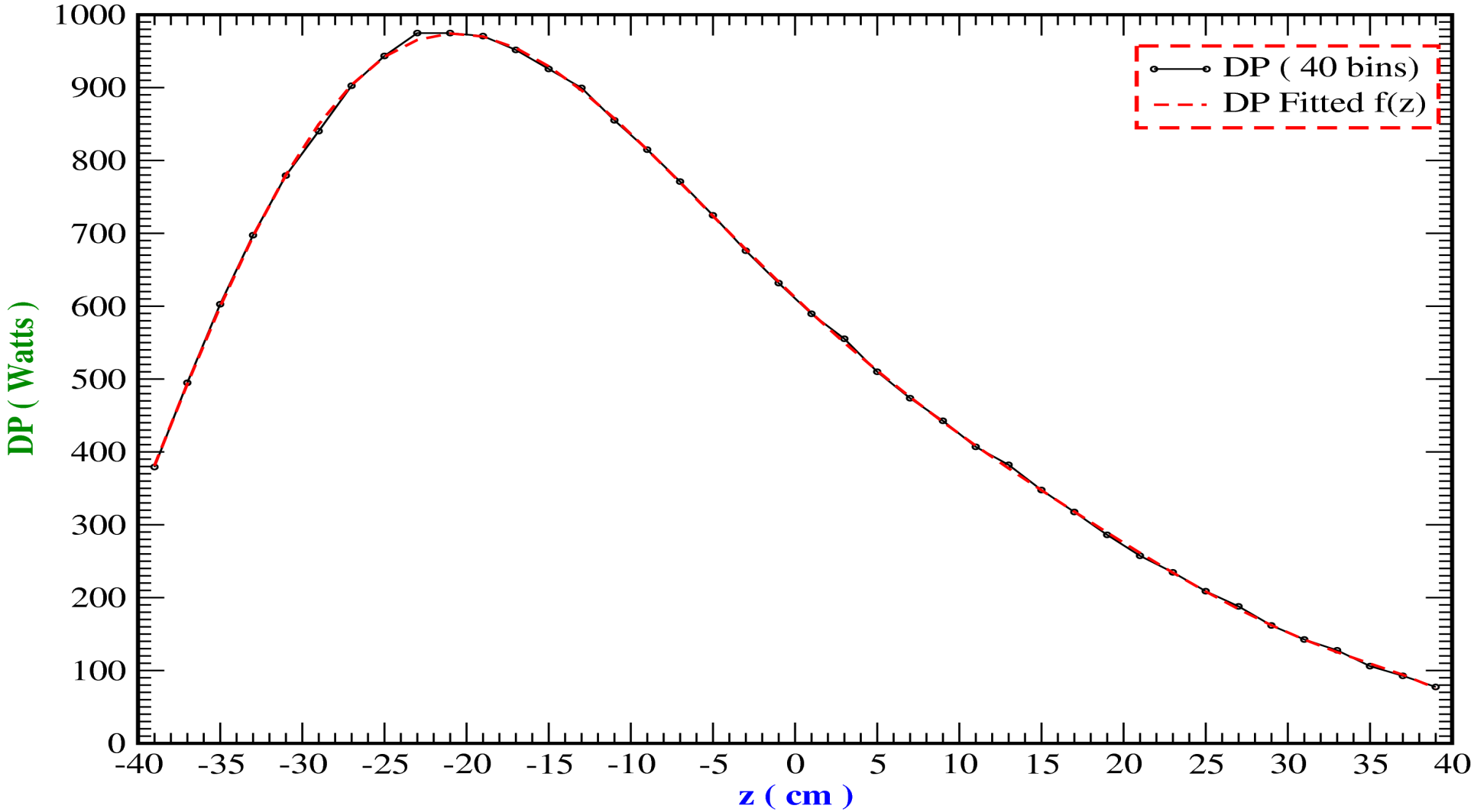
$-40.0 < z < 40.0$ cm $dz = 2.0$ cm $N_z = 40$ bins

$0.0 < \varphi < 360.0$ deg. $d\varphi = 360$ deg. $N_\varphi = 1$ bins

$N_{tot} = 40$ "pieces"

20to2T5mDL C TRGT SGNT for [0.0 < r < 0.2 cm, -40.0 < z < 40.0 cm] 1.8 g/cc density

(dr, dz, dphi) = (0.2 cm, 2.0 cm, 360.0)---> (Nr, Nz, Nphi) = (1, 40, 1) # BINS



PEAK: 974.811 Watts ~ 2154.805 W/g AT z ~ - 22 cm

(TO GET TDPD IN W/g DIVIDE WITH 0.452 g = MASS OF EACH "PIECE")

TDP: 21.72 kW (''PIECES'') + 91.08 (REST) = 112.80 vs. 112.83 kW (NO SEGMNT)

8th ORDER FITTED POLYNOMIAL FUNCTION: TDP = 611.74 - 21.426 * z+ 0.25202 * z^2 + 0.0076365 * z^3 - 0.00065839 * z^4 + 6.8115e-06 * z^5 + 2.8994e-07 * z^6 - 2.8021e-09 * z^7 - 4.9265e-11 * z^8

mars15 (2014) : ***~ 3.5 - 4 hrs FOR 5E4 EVENTS, ~ 4 - 8 hrs FOR 5E6 = 100 SUBDIRECTORY x 5E4 SIMULATIONS***
(SINCE SOMETIMES SOME SUBDIRECTORY JOBS WILL START AFTER SOME WAITING TIME) **[BOTH:MCNP, ICEM =1]**

{DING XIAOPING SET UP 3 NEW GNUMake FILES FOR mars1514 MULTIDIRECTORY JOB}

mars1514 + new Princeton cluster much faster than mars1512 + Old Princeton cluster

******* DEPOSITED POWER IN DIFFERENT PARTS OF THE TARGET STATION IN kW (Np / STEP): 5E6 / 10^{-3} *******

GEOMETRY COLOR CODE: 20to2T5m + SH4 20to2T5mDL

A) SC# 1 / 2 / 3 / 4 / 5 / 6 / 7 / 8 / 9 / 10 : 1.757 / 0.498 / 0.100 / 0.016 / 0.022 / 0.005 / 0.004 / 0.006 / 0.010 / 0.002
1.842 / 1.293 / 0.116 / 0.003 / 0.002 / 0.005 / 0.002 / 0.006 / 0.009 / 0.001
TOTAL DP SC#1-10: 2.42 / 3.29 { WITH ~ 2.36 / 3.25 kW JUST IN SC#1+2+3 }

B) DP IN RS COILS RS# 1 / 2 / 3 / 4 / 5 : 401.698 / 193.210 / 100.419 / 58.869 / 34.585
415.161 / 198.674 / 105.245 / 61.369 / 37.990
TOTAL: 788.78 / 818.44 (USING A 65% Cu + 7% H_2O +288% MgO MIXTURE WITH ~ 7.0 g/cc DENSITY)

C) DP IN SHIELDING SH# 1 / 2 / 3 / 4 : 138.047 / 490.086 / 39.557 / 682.99
(1A) 255.039 / 353.035 / 725.465 /(1B) 71.959
TOTAL : 1,350.680 / 1369.96 (~ 34 % OF 4 MW)

D) DP IN VESSELS SHVS# 1 / 2 / 3 / 4 : 18.950 / 39.59 / 2.882 / 409.625
(1A) 71.959 / 188.497 / 3.021 / (1B) 81.125
TOTAL: 471.027 / 344.603

E) DP IN C TRGT : 112.81 / 112.71 (USING 1.8 g/cc DENSITY FOR BOTH TARGET AND DUMP)
C DUMP : ------ / 74.060 (R= 2.4 cm 40.0 < z < 160 cm)

F) DP IN Be WINDOW 1 / 2 / 3 / 4 : 3.375 / 1.557 / 1.418 / 1.183
2.597 / 1.481 / 1.402 / 1.160
TOTAL: 7.532 / 6.641

G) DP IN BP# 1 / 3 : 217.063 / 284.491
240.369 / 193.791

TOTAL DP IN TARGET STATION :3,234.82/ 3,234.15

20to2T5mDL : yz CROSS SECTION (x = 0.0 cm) WITH B FIELD MAP AND CENTROID TRAJECTORY WITHOUT C TARGET / DUMP / BeWind#1 PRESENT . THE BEAM WILL REACH THE CRYO#1 UPSTREAM Be WINDOW (AT z ~ 456 cm) NEAR THE BOTTOM AREA. POWER LEAK FLOW { ENERGY FLOW = KE (p, n)+E($e^{\pm}$, $\pi^{\pm}$, π^{0}, $\mu^{\pm}$, $K^{\pm}$, γ) } .

z = - 450.0 , 2000.0 cm, R = 210.0 cm SURFACE DETECTORS].