Imaging of the cylindrical Phantom with the J-PET tomograph

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3rd Symposium on Positron Emission Tomography

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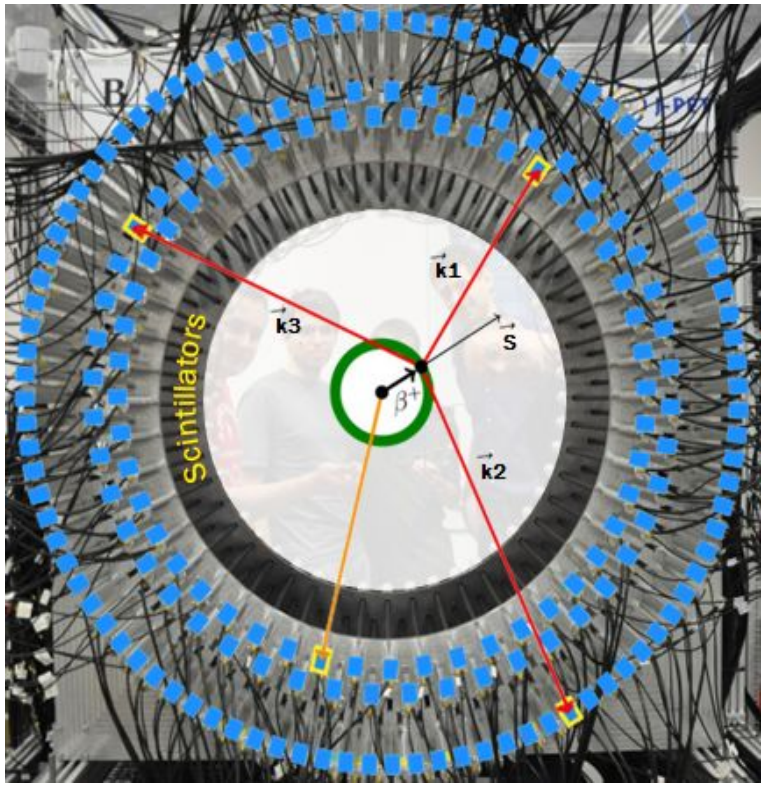
outline

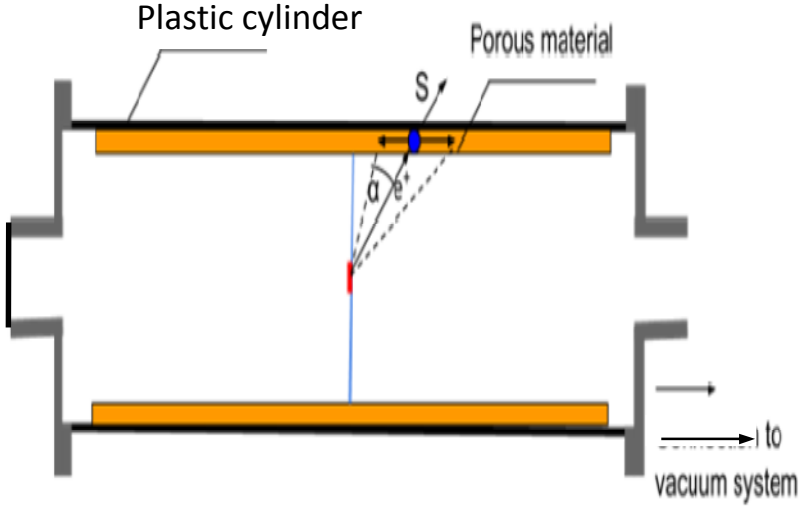
1- Determination the annihilation points (2-gamma).

2- The Imaging of the cylindrical chambers (preliminary results).

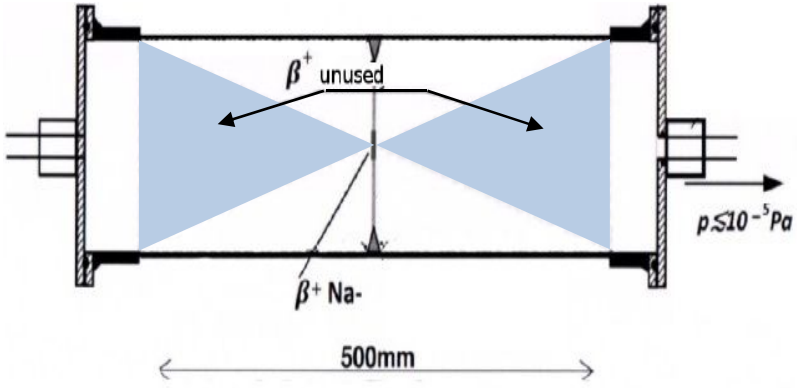
3- The o-Ps decay planes determination for Run-3 & Run-6 data .

The annihilation chamber s(Run-6) & (Run-3)



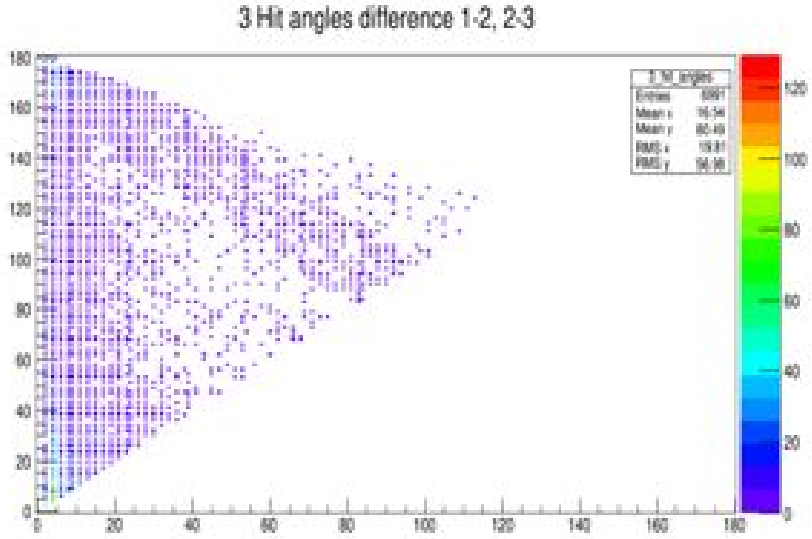


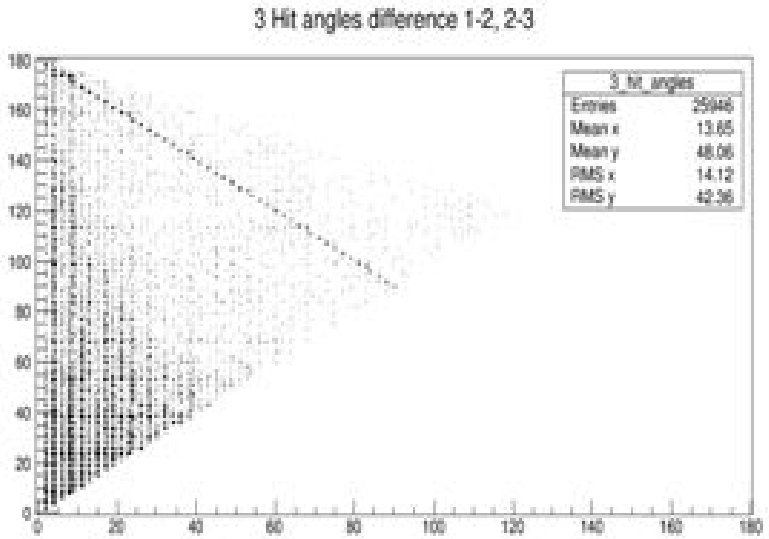
Scheme of Run-6 large annihilation chamber.

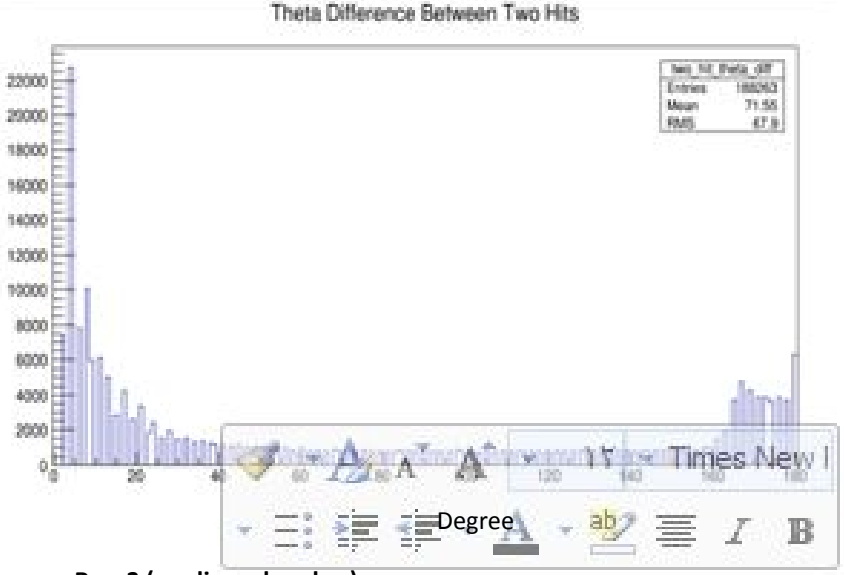


Scheme of Run-3 medium annihilation chamber.

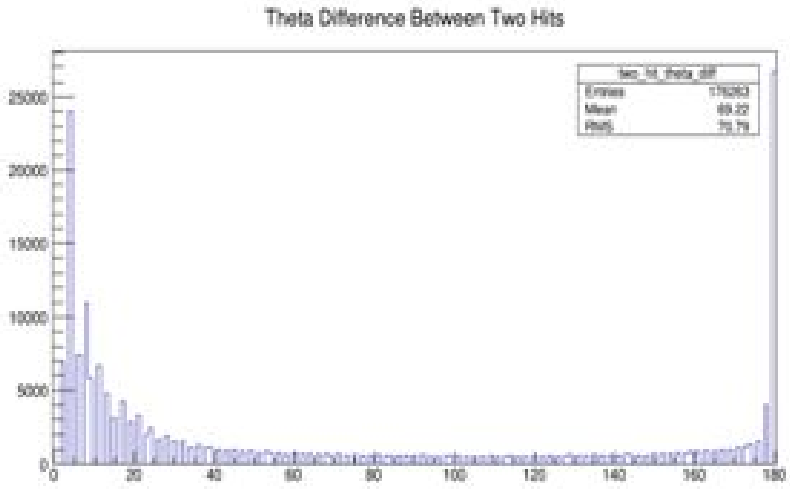
In the case of run-3 , the Na22 located inside the aluminum chamber, positrons may annihilate with electrons without" forming meta-stable positronium, through " direct and pick-off" and 3 –photons annihilation 1/370 ratio to that of 2-photon.





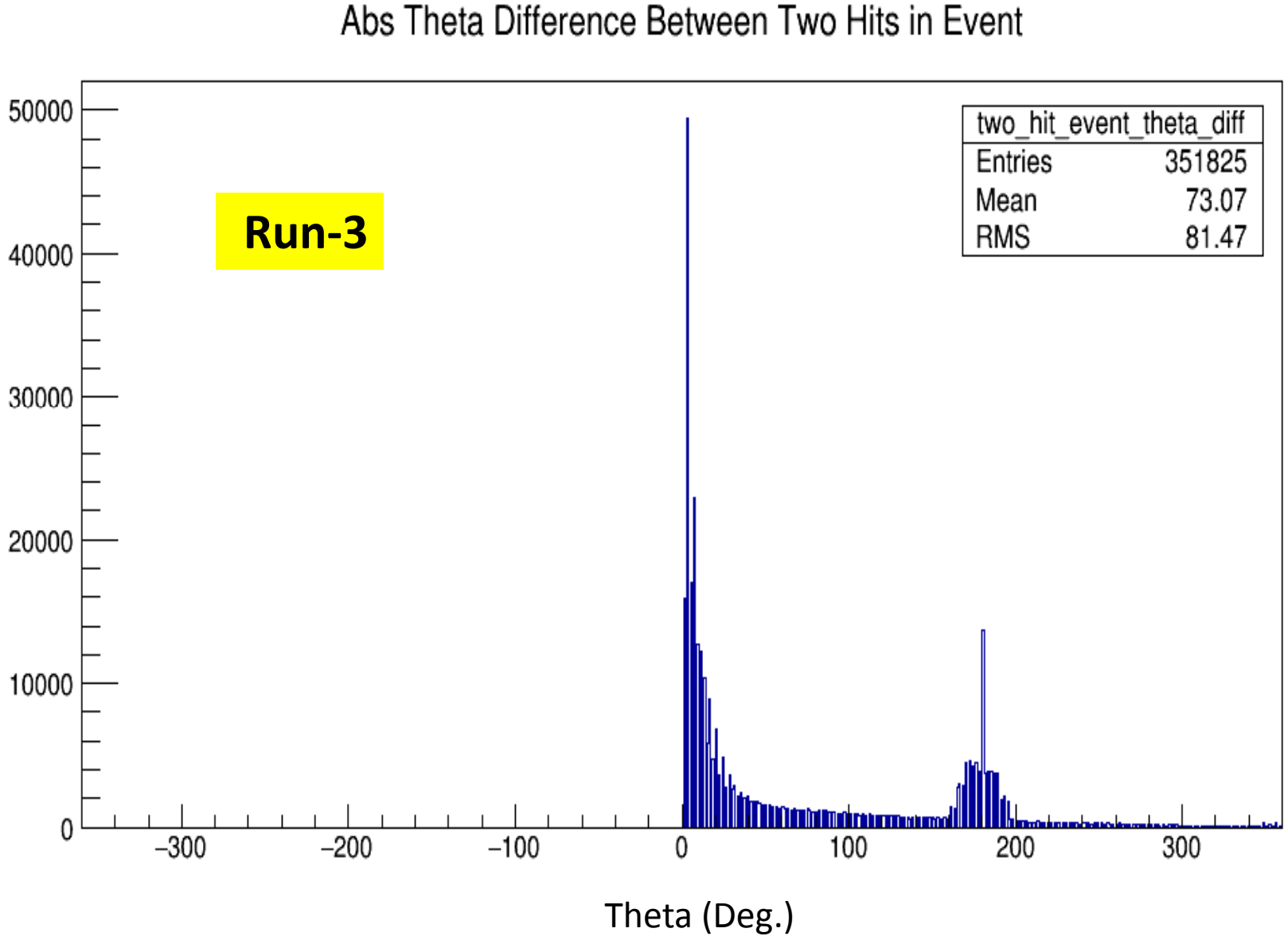


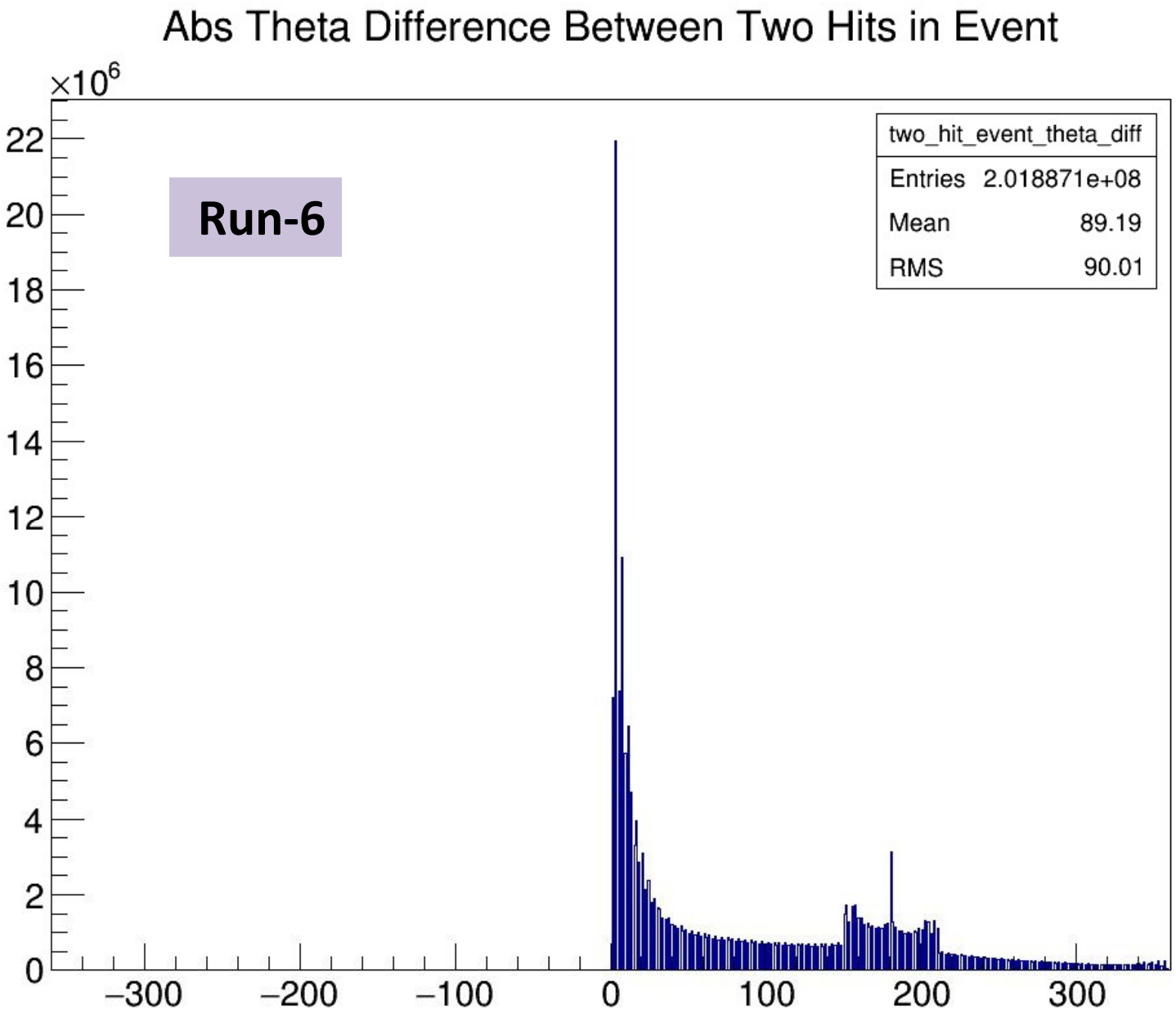
Run-3 (medium chamber)

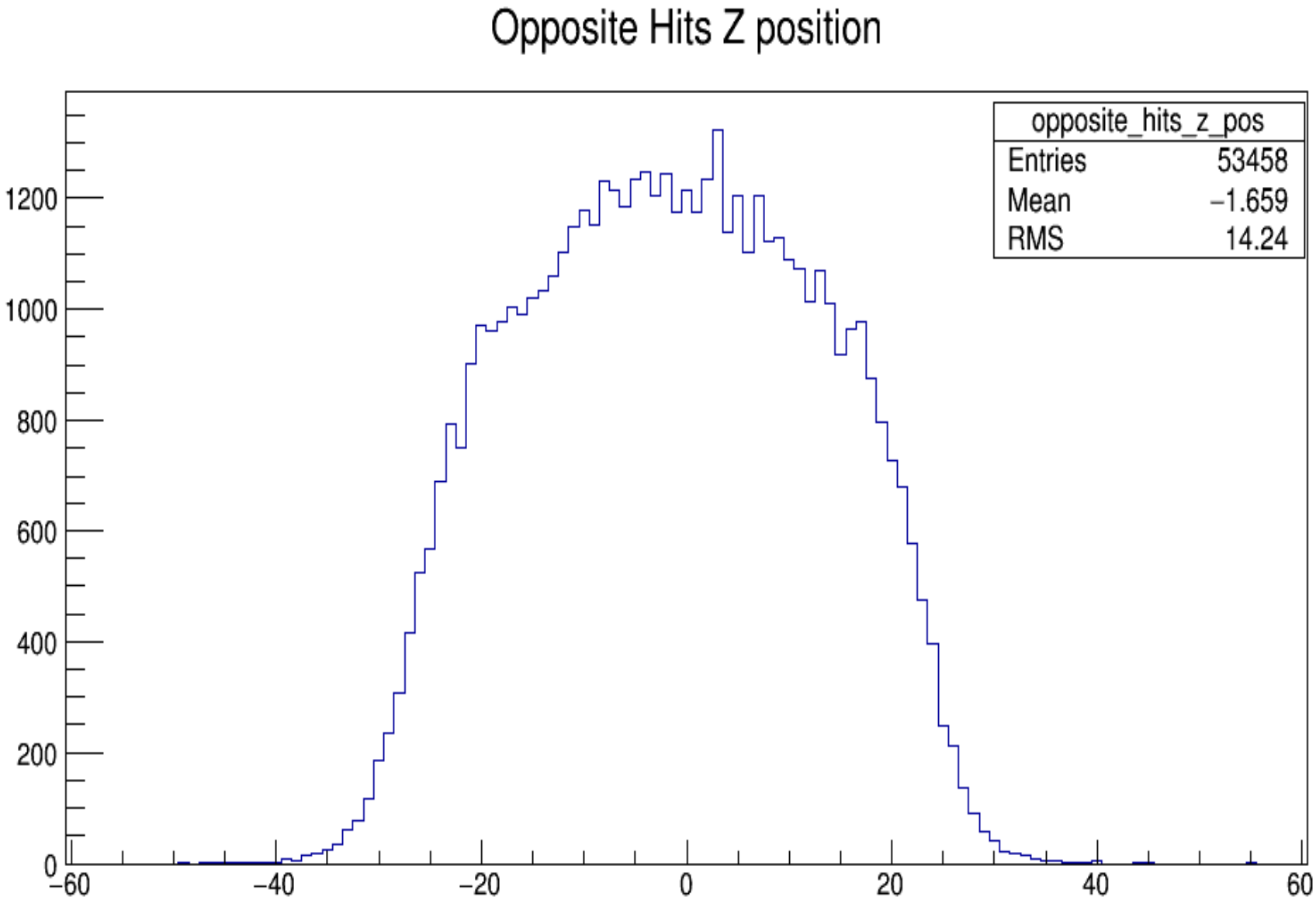


Run-2 (small chamber)

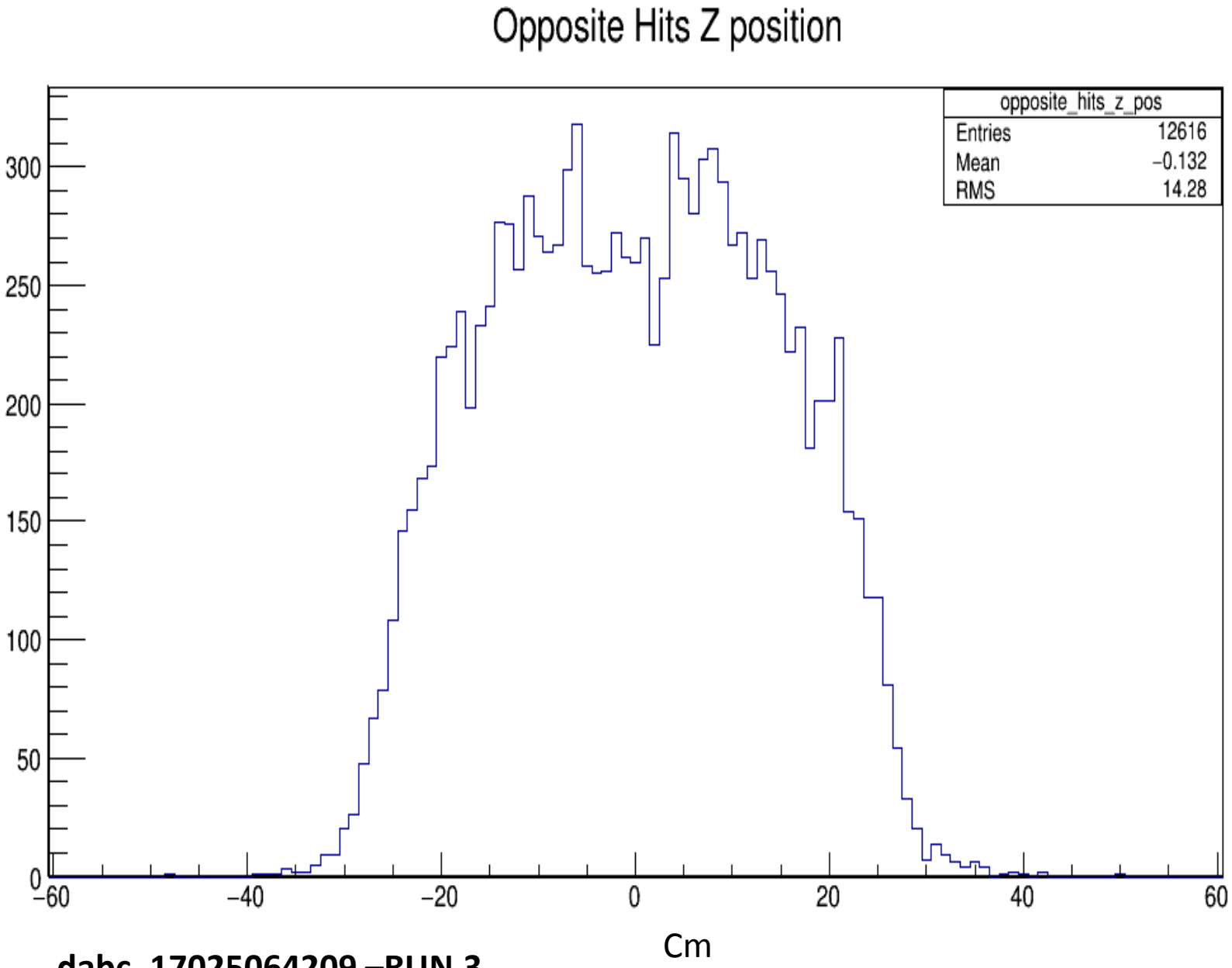
RUN-3, dabc_17025064209




Abs Theta Difference Between Two Hits in Event
×10^6
Run-6
two_hit_event_theta_diff
Entries 2.018871e+08
Mean 89.19
RMS 90.01
22
20
18
16
14
12
10
8
6
4
2
0
−300
−200
−100
0
100
200
300

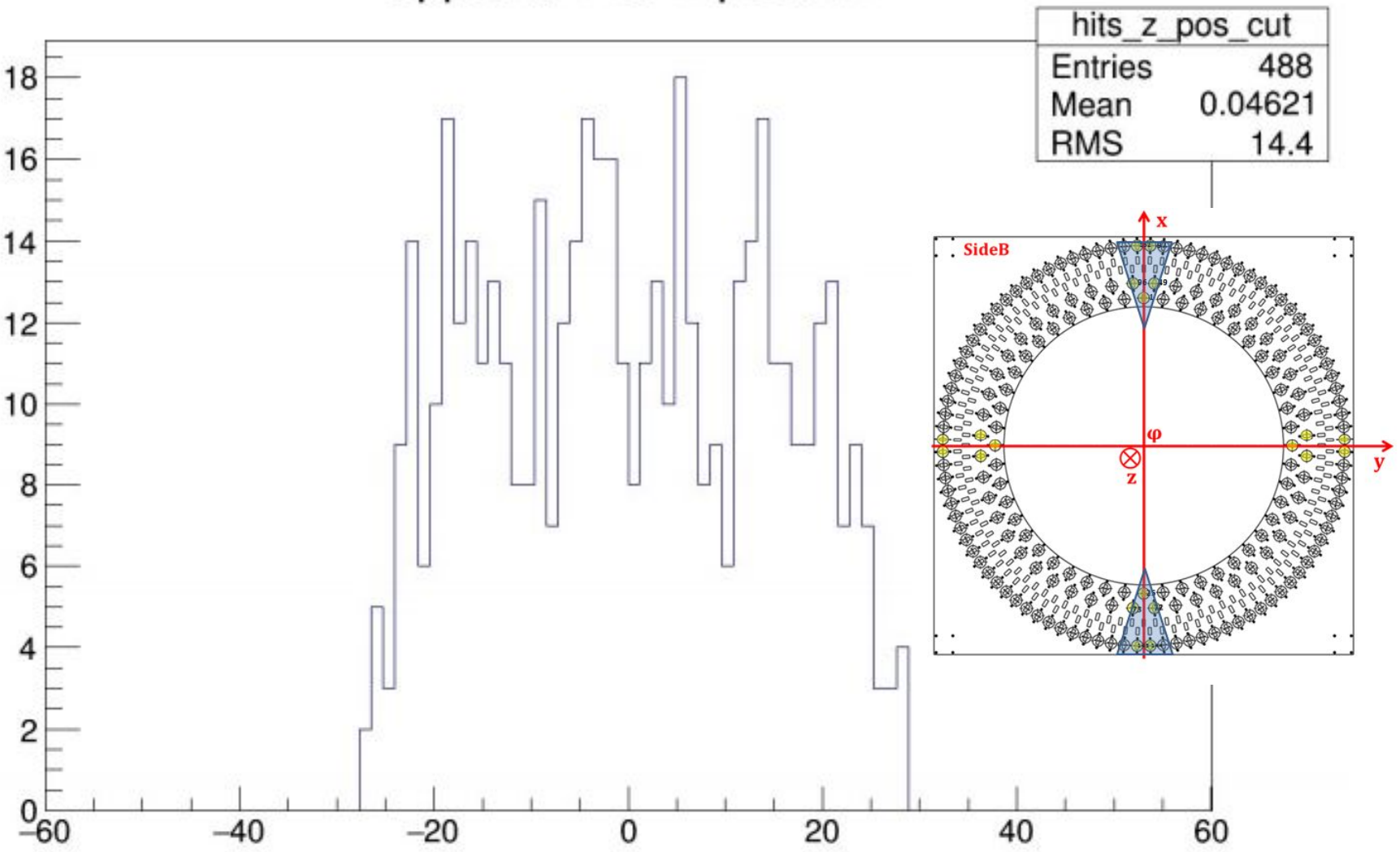


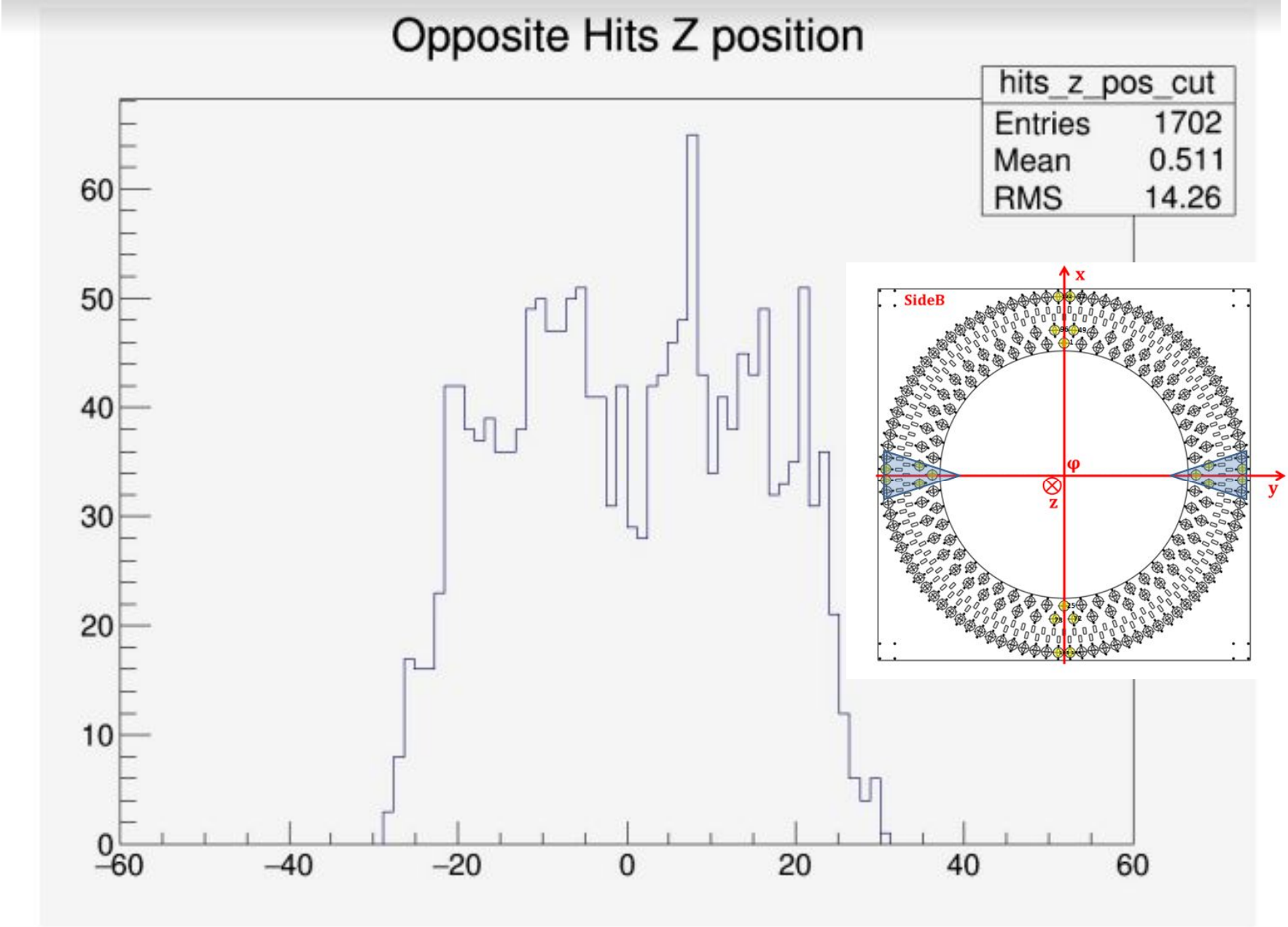
dabc_16303175304.hld, RUN-2



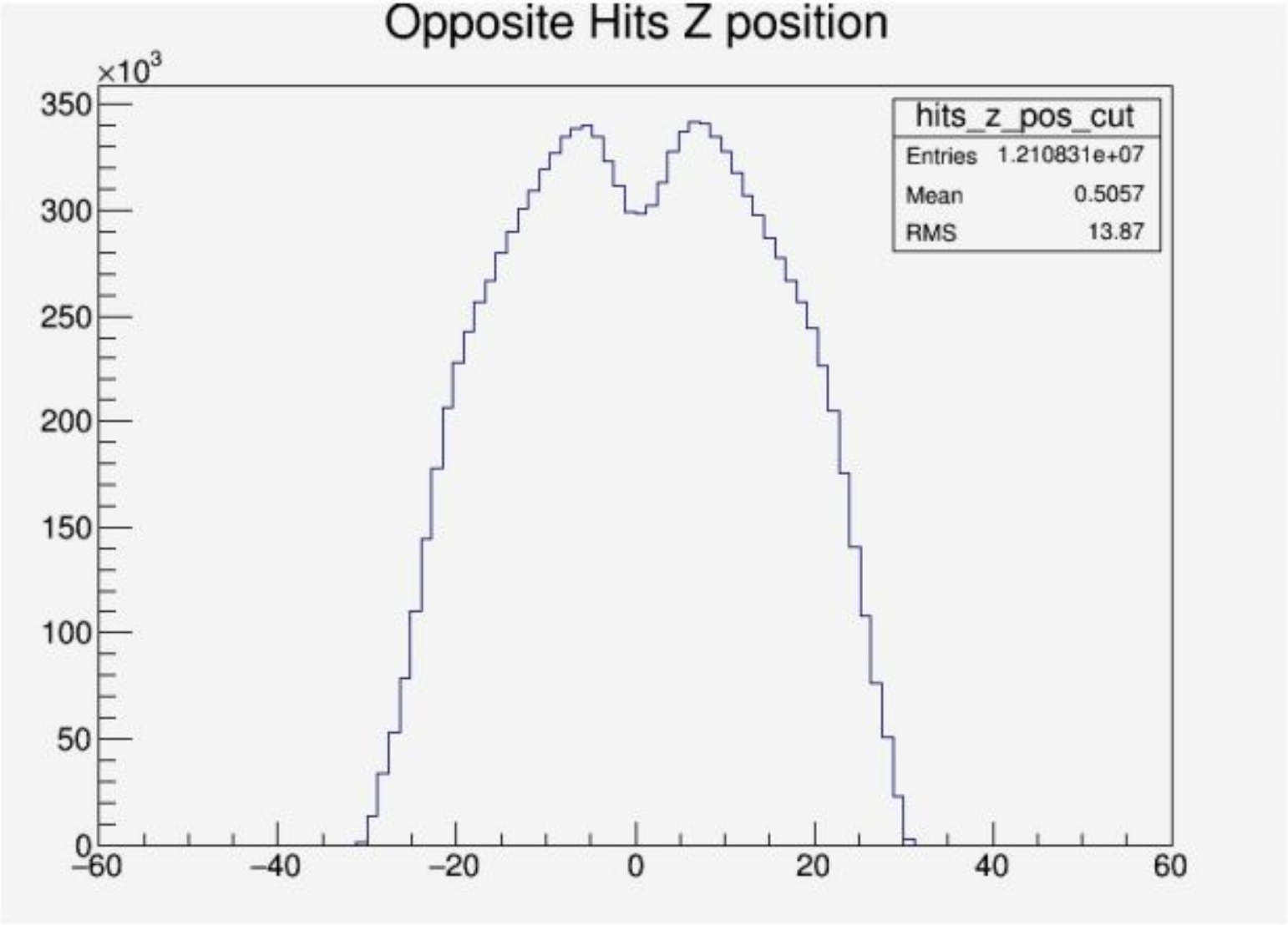
dabc_17025064209 –RUN.3

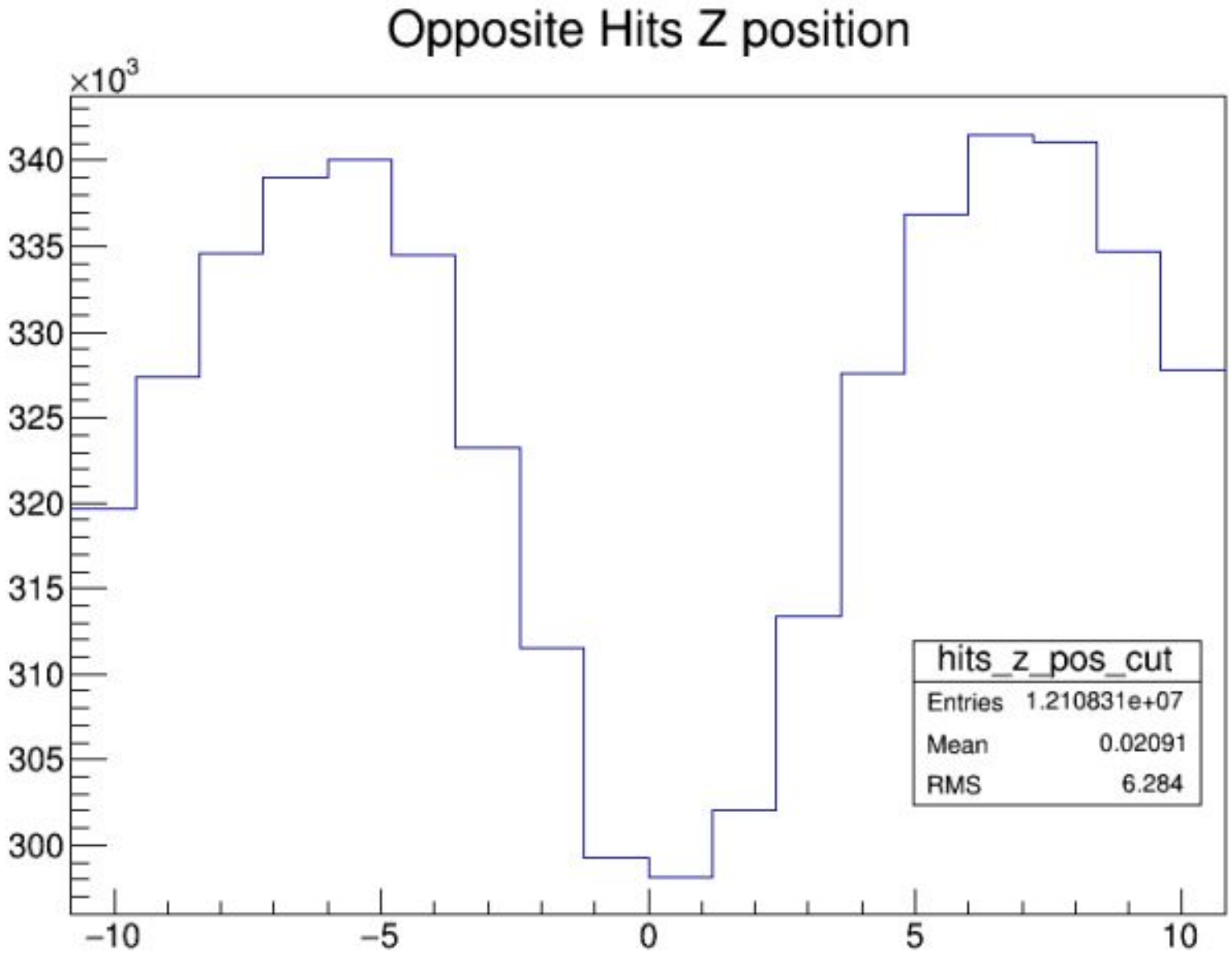
Opposite Hits Z position

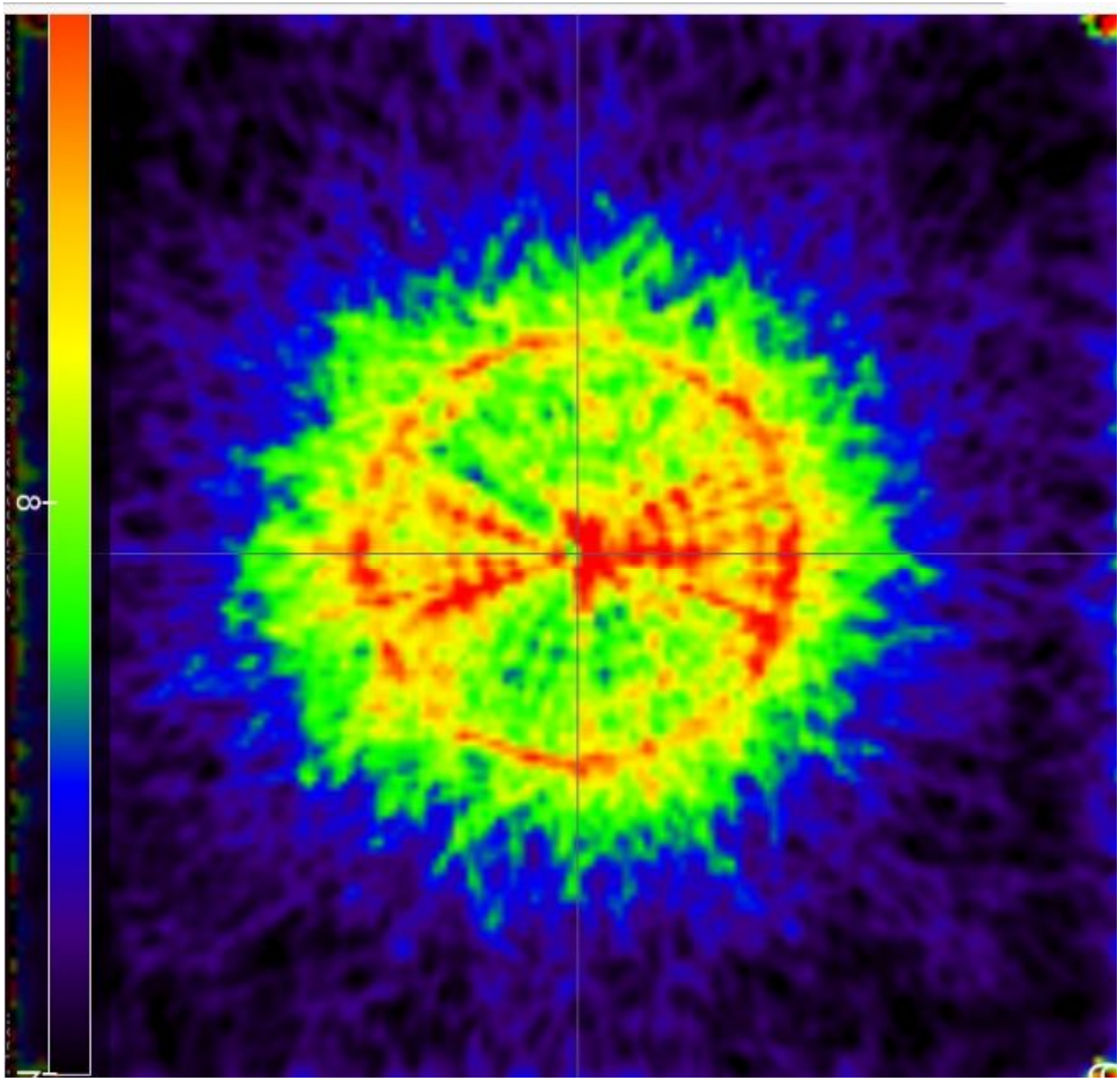


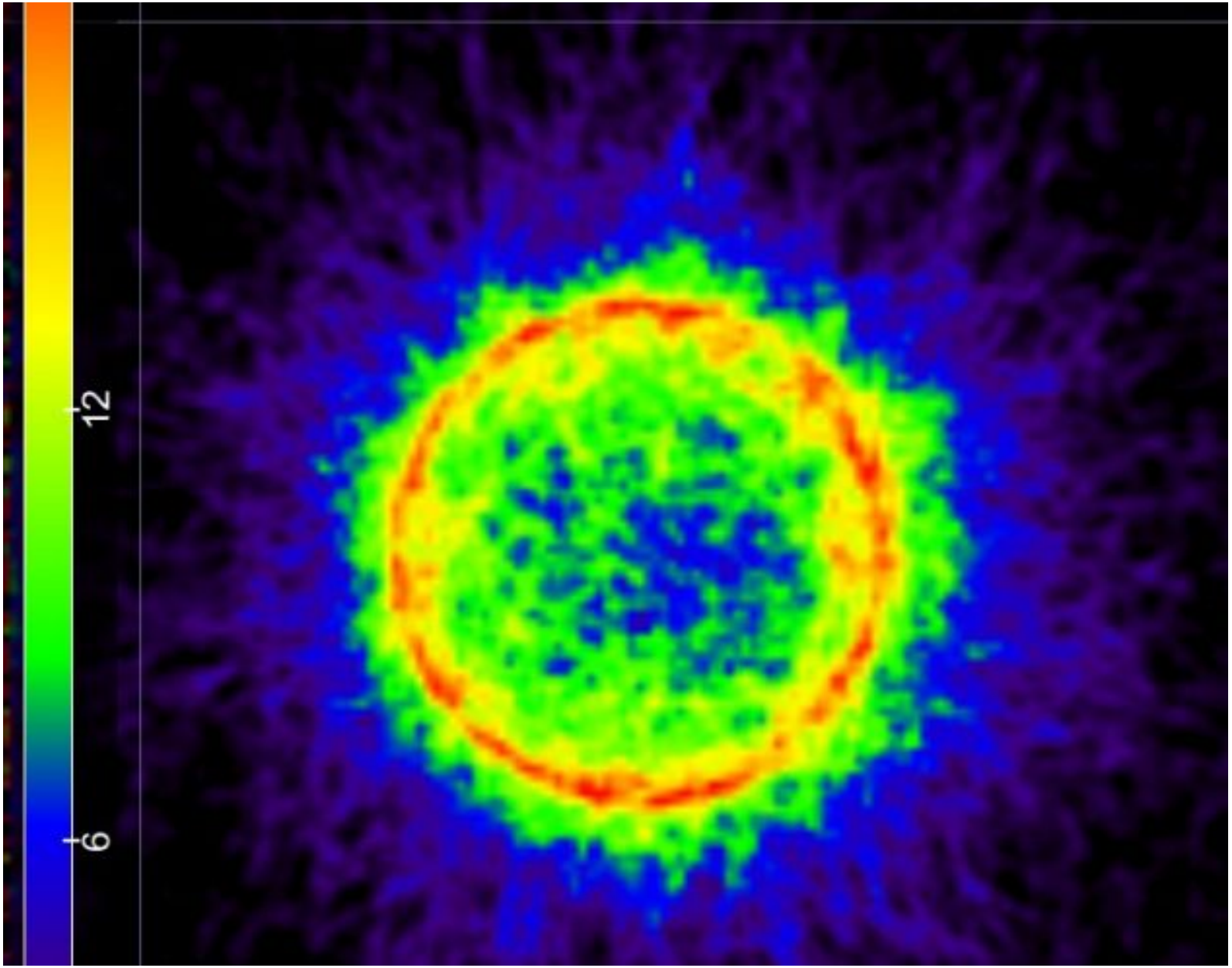

Opposite Hits Z position
hits_z_pos_cut
Entries 1702
Mean 0.511
RMS 14.26
60
50
40
30
20
10
0
−60
−40
−20
0
20
40
60
SideB
x
φ
z
y

Run-6


Opposite Hits Z position
×10^3
350
300
250
200
150
100
50
0
−60
−40
−20
0
20
40
60
hits_z_pos_cut
Entries 1.210831e+07
Mean 0.5057
RMS 13.87

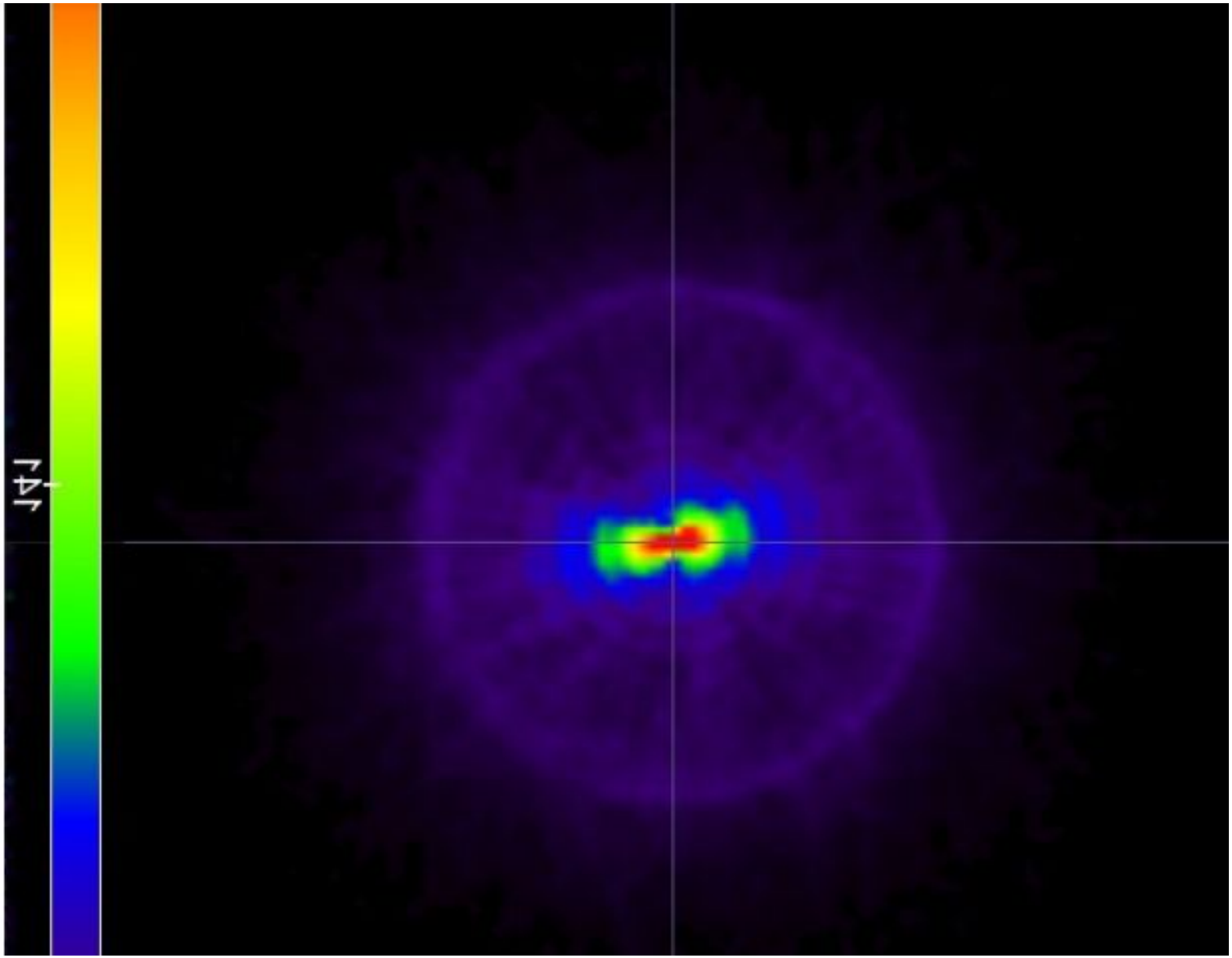

Opposite Hits Z position
×10^3
340
335
330
325
320
315
310
305
300
−10
−5
0
5
10
hits_z_pos_cut
Entries 1.210831e+07
Mean 0.02091
RMS 6.284



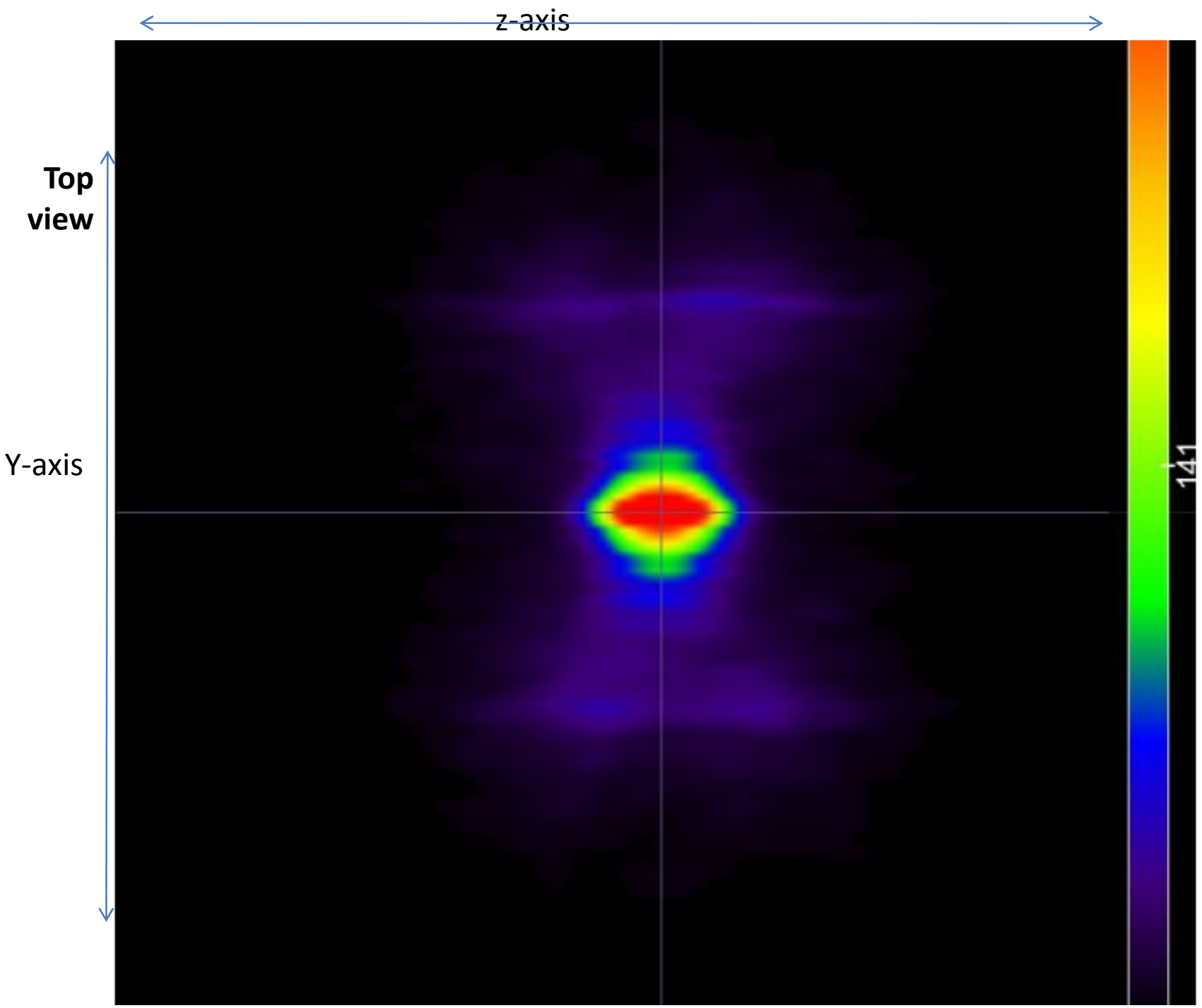


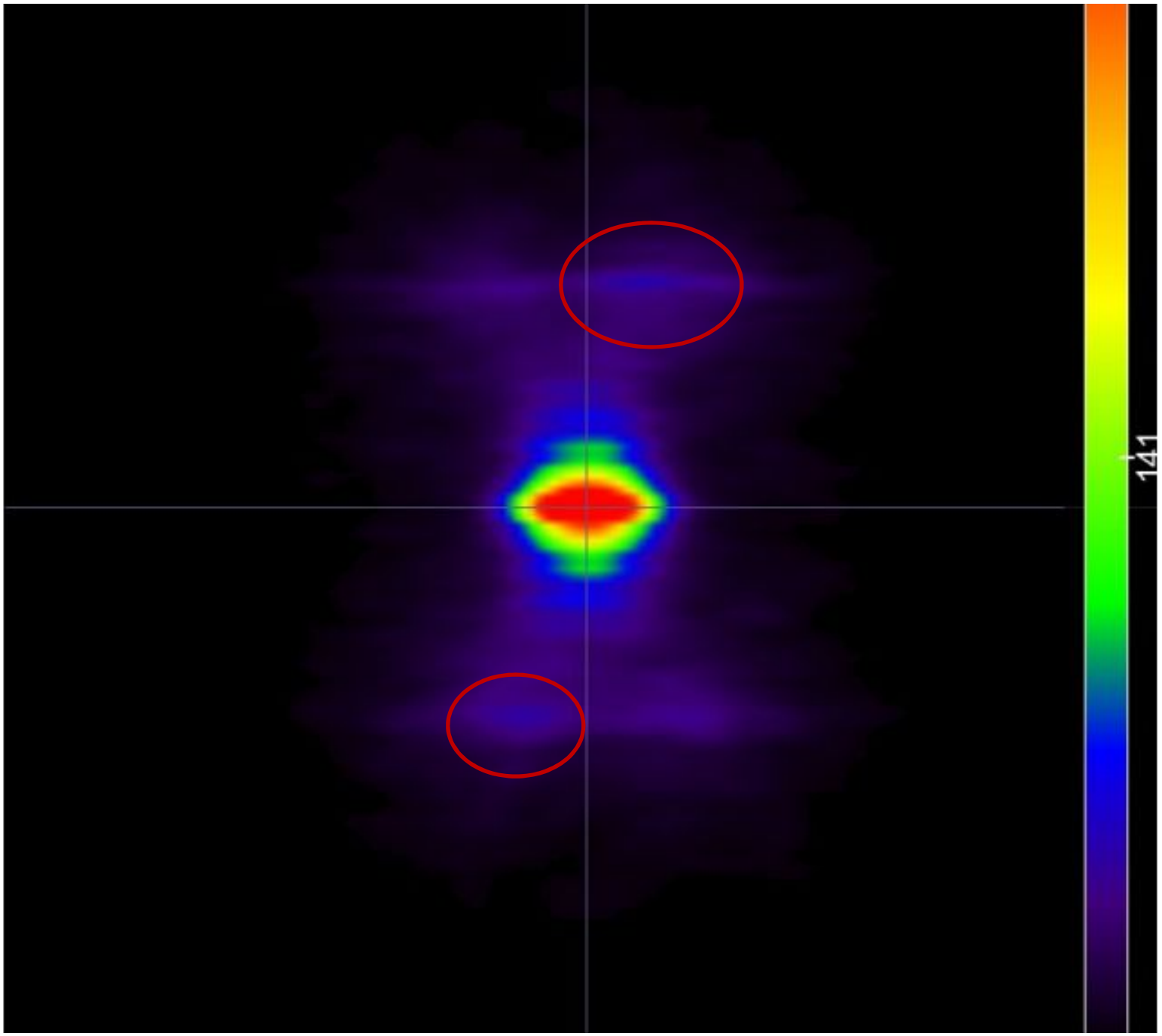
●Z=±5 cm along z-axis also removed from data, in order to get red of central part

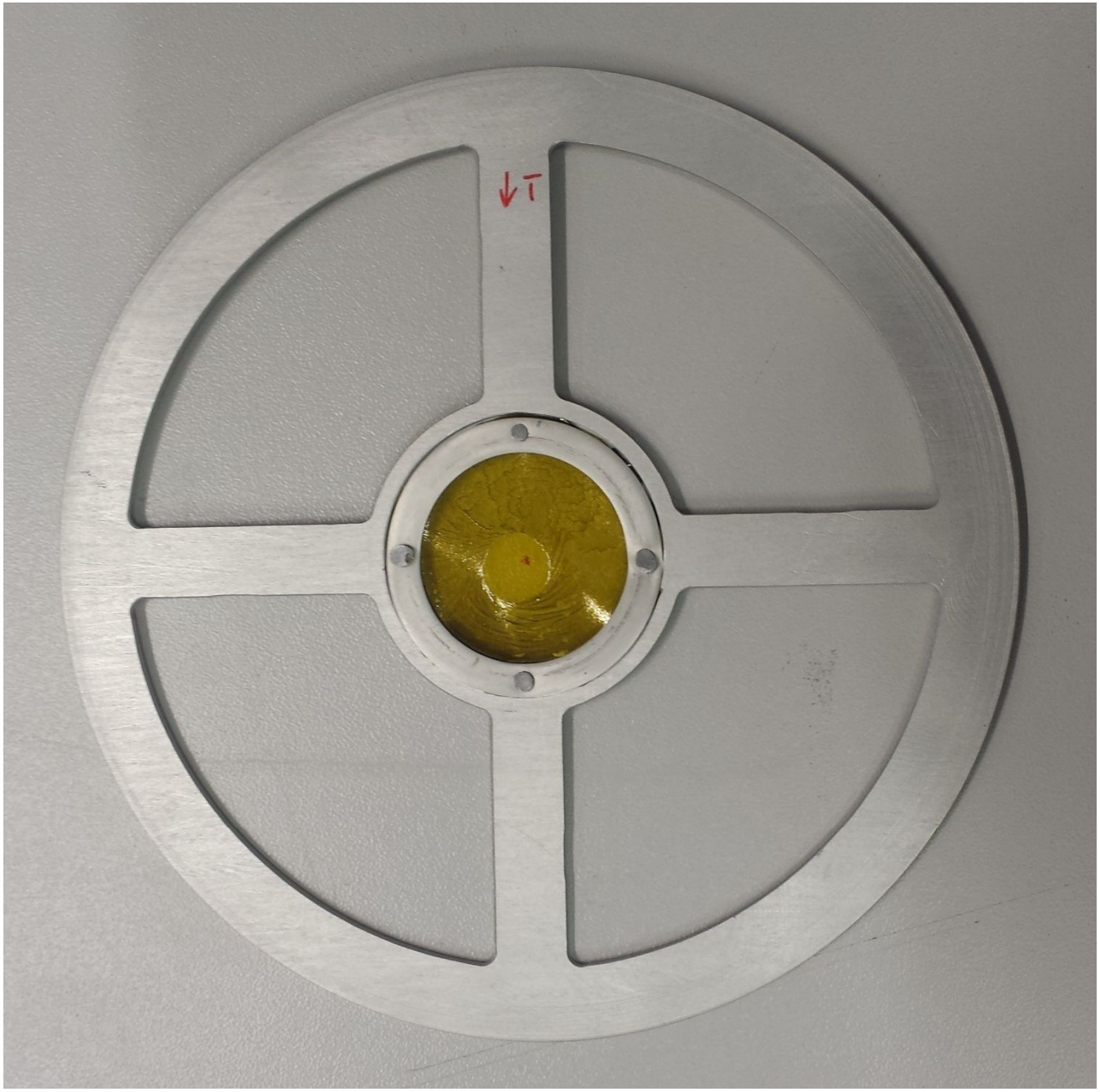
x-axis

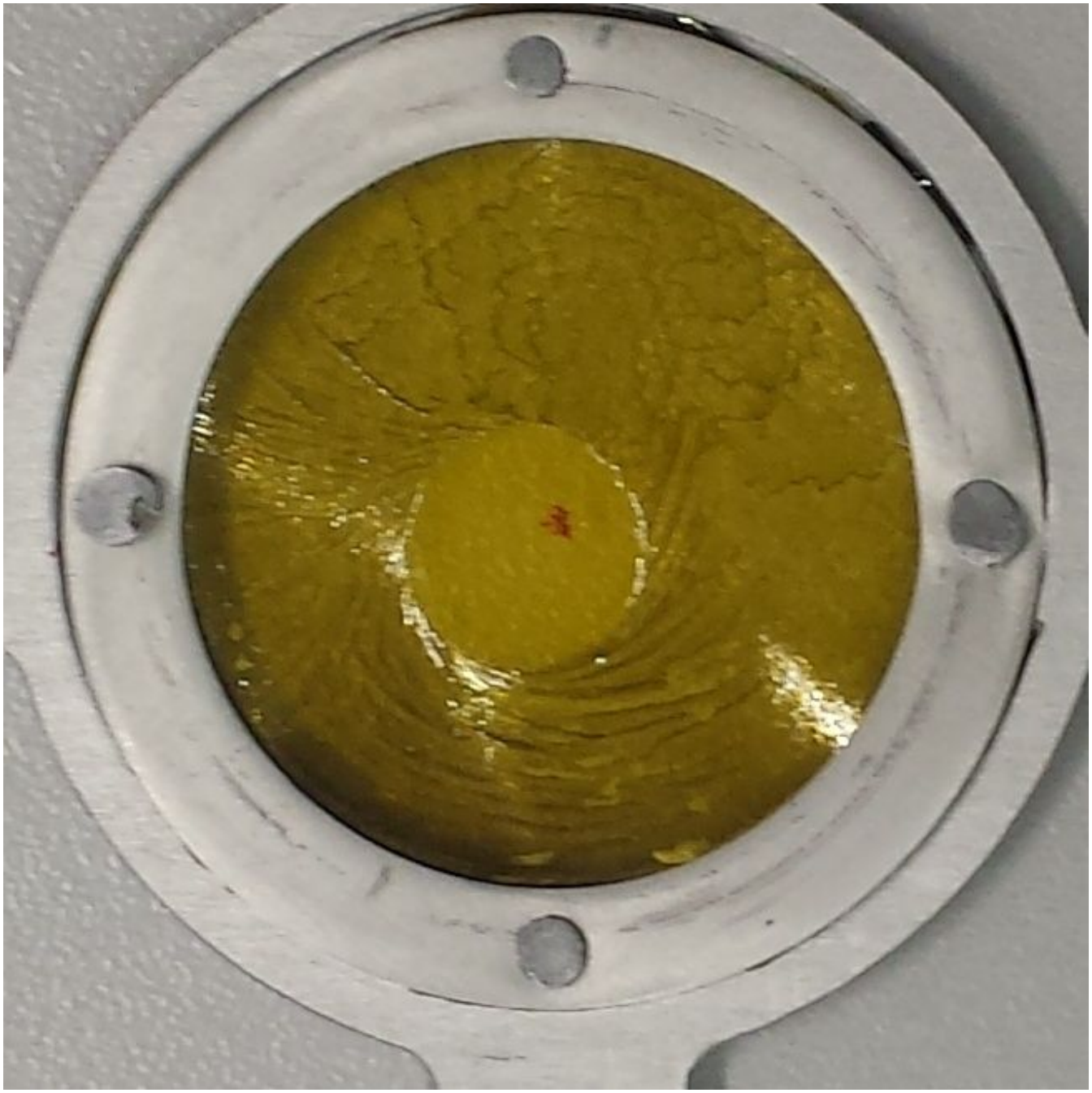


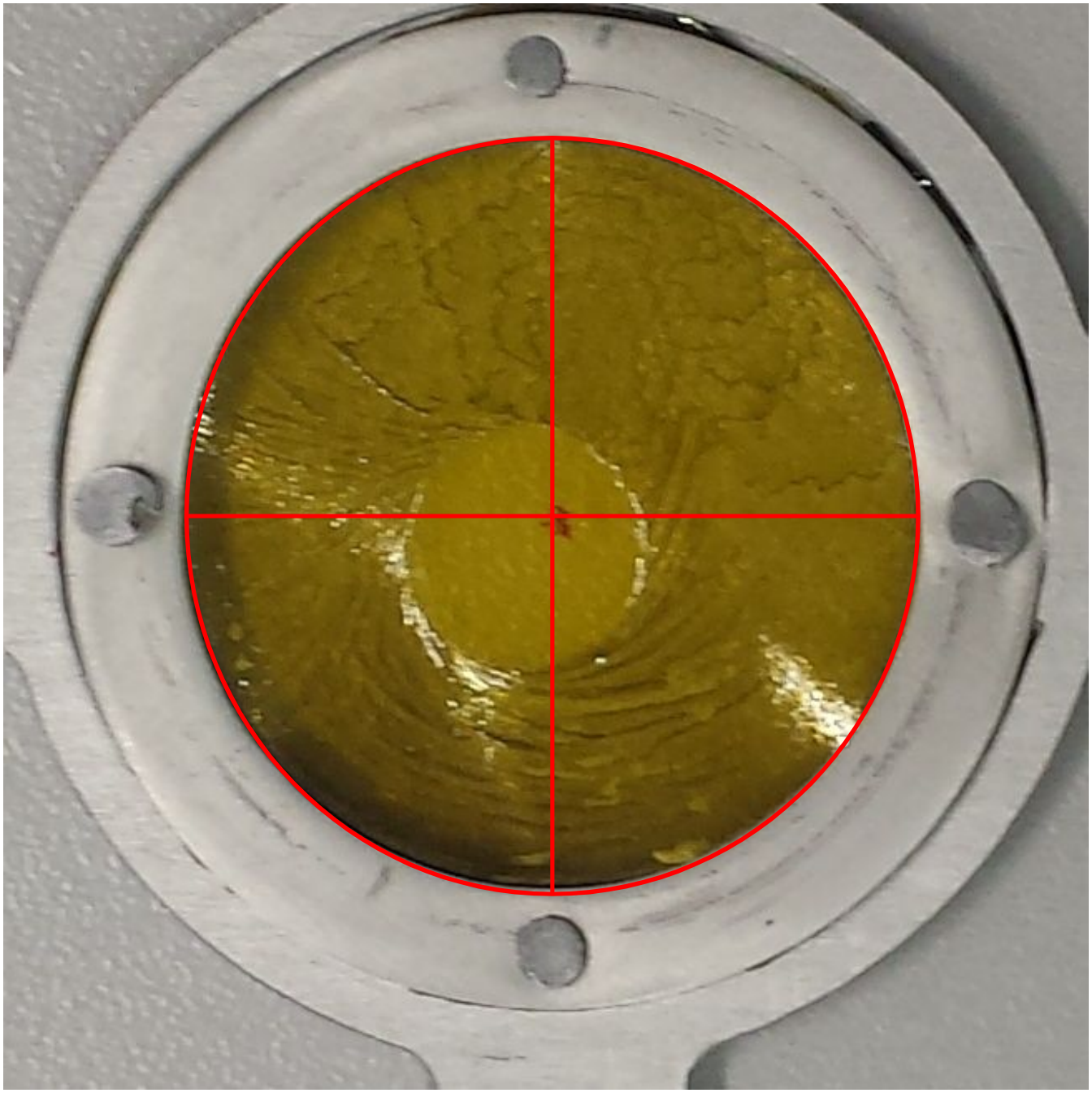
Y-axis

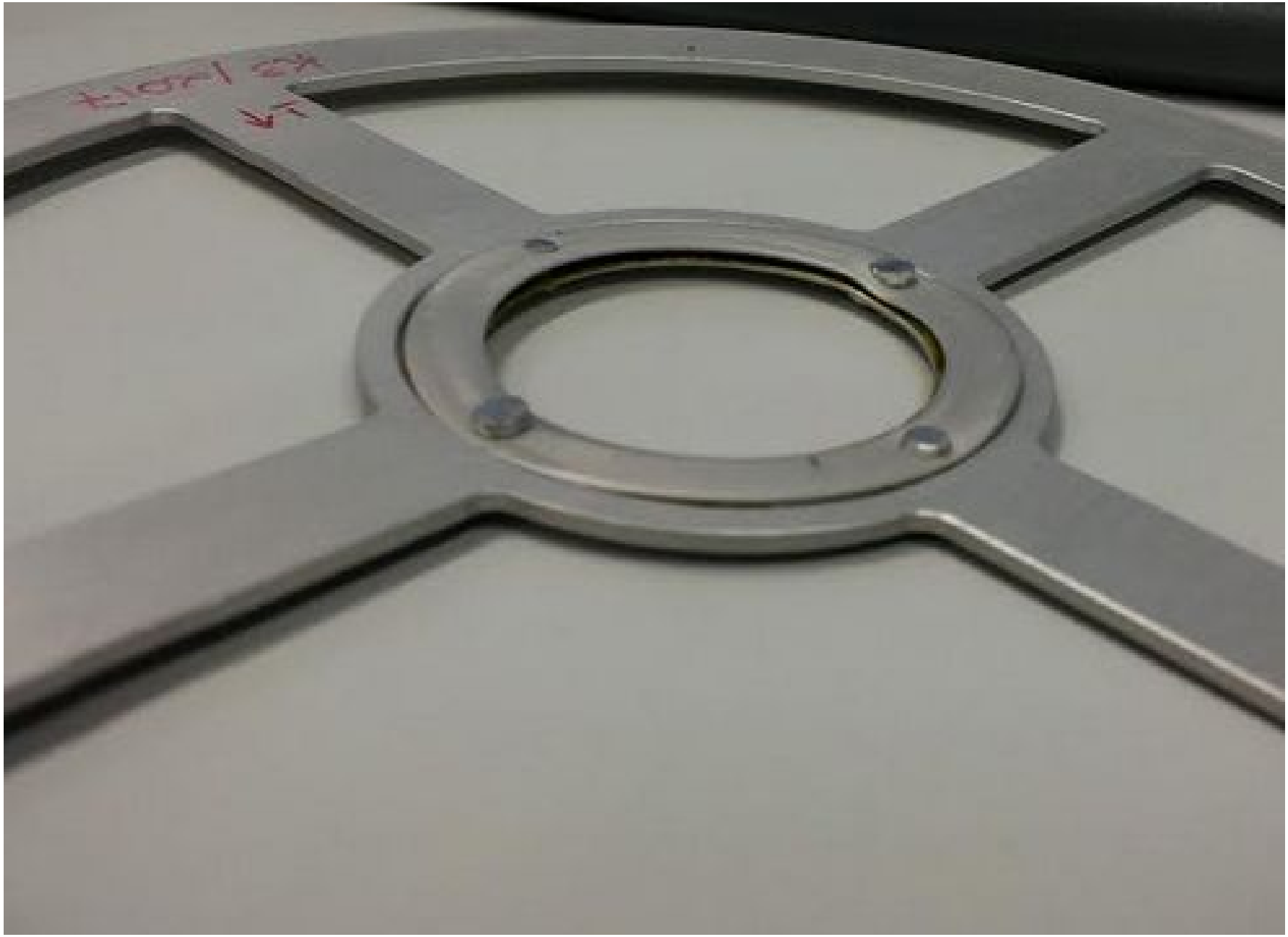

z-axis
Top view
Y-axis
141


141


↓T







Data selection criteria

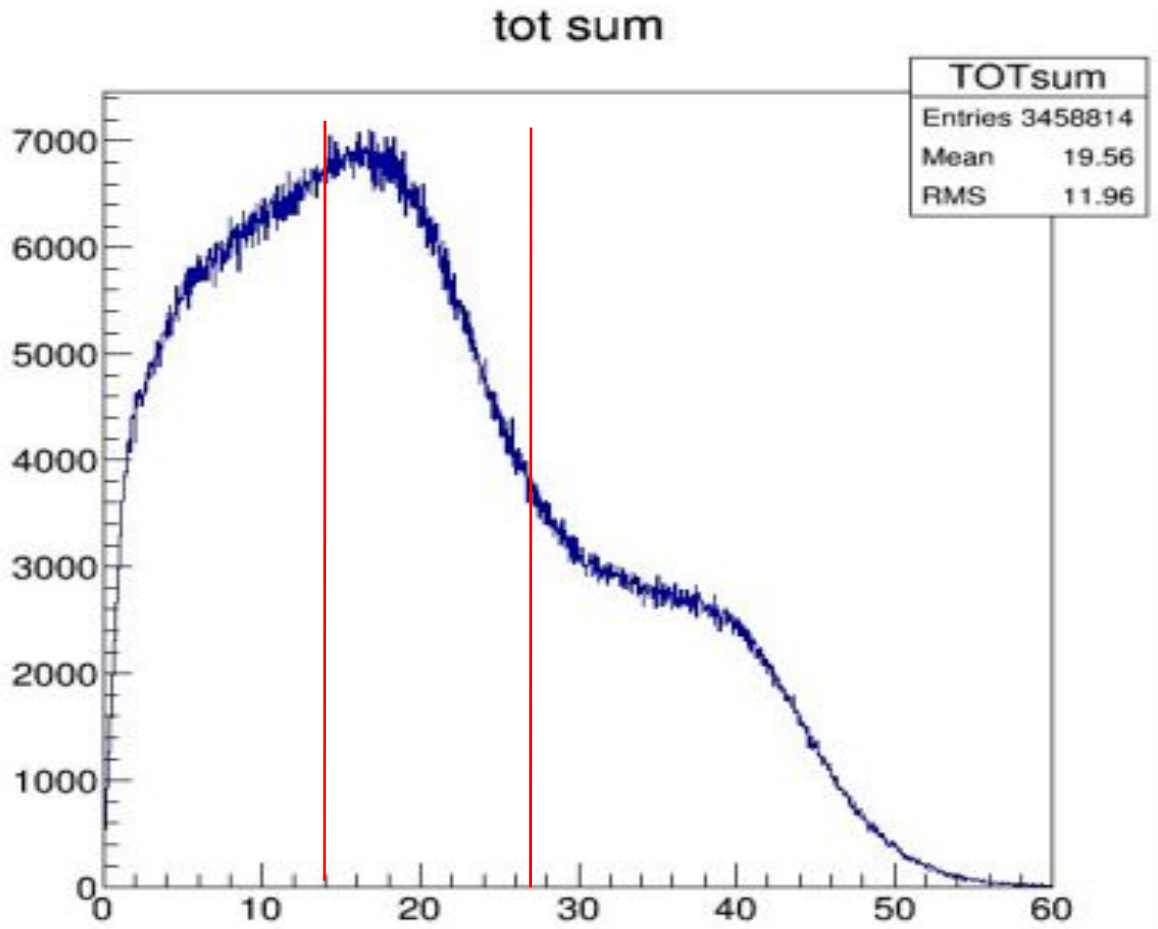
Applied cuts:

- **Select only 2 hits events.**

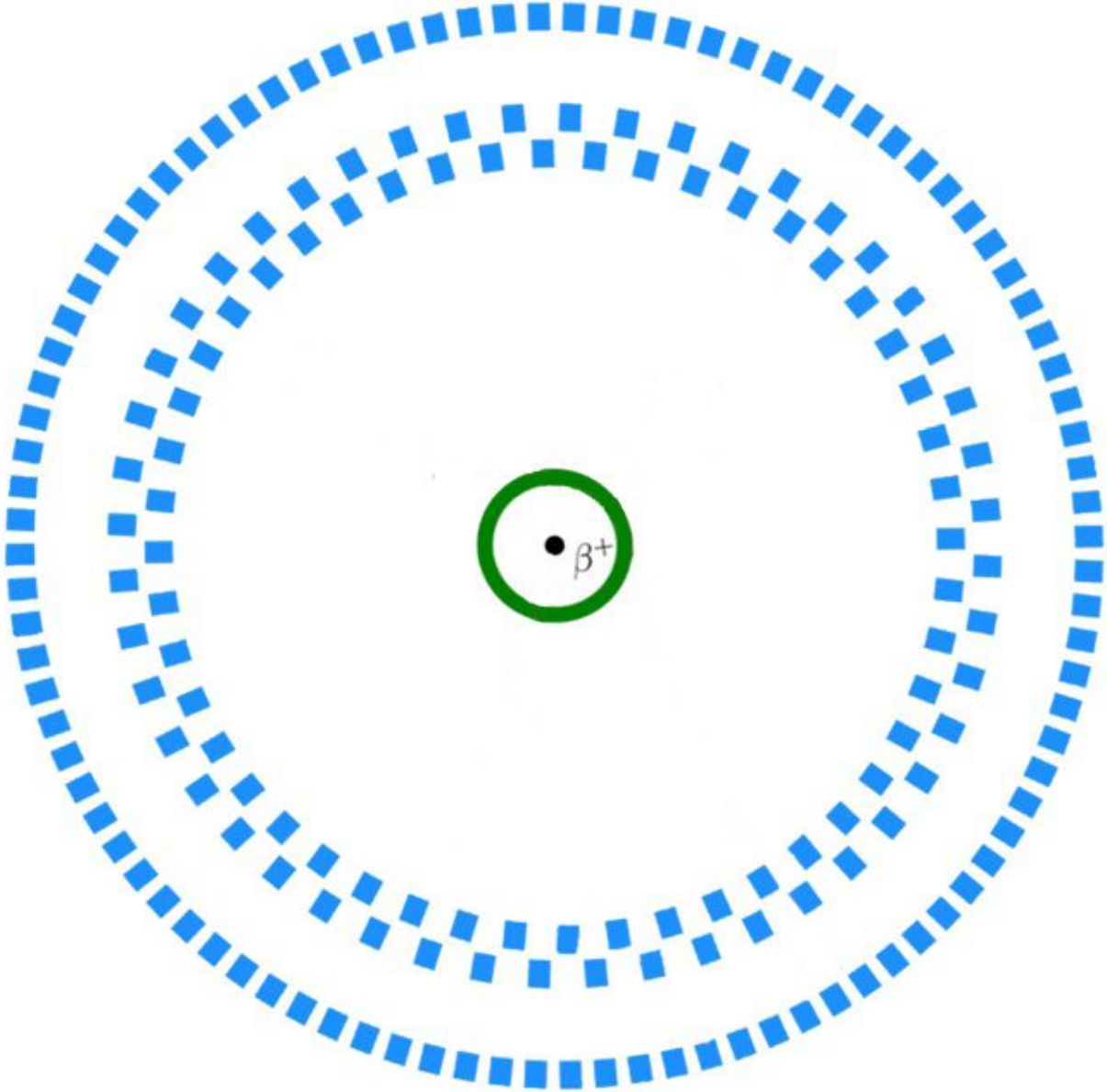
- **Specific range of the angles between two hits has been chosen.**
  The range of angles between 2 hits greater than 160.7 and smaller than 199.2.

- **Absolute value of Z coefficient < 23 cm (z coordinate of place of interaction of γ with scintillator in range ± 23cm).**

- **No TOT calibration => cuts applied to raw TOTs (ToT=14 to 27).**

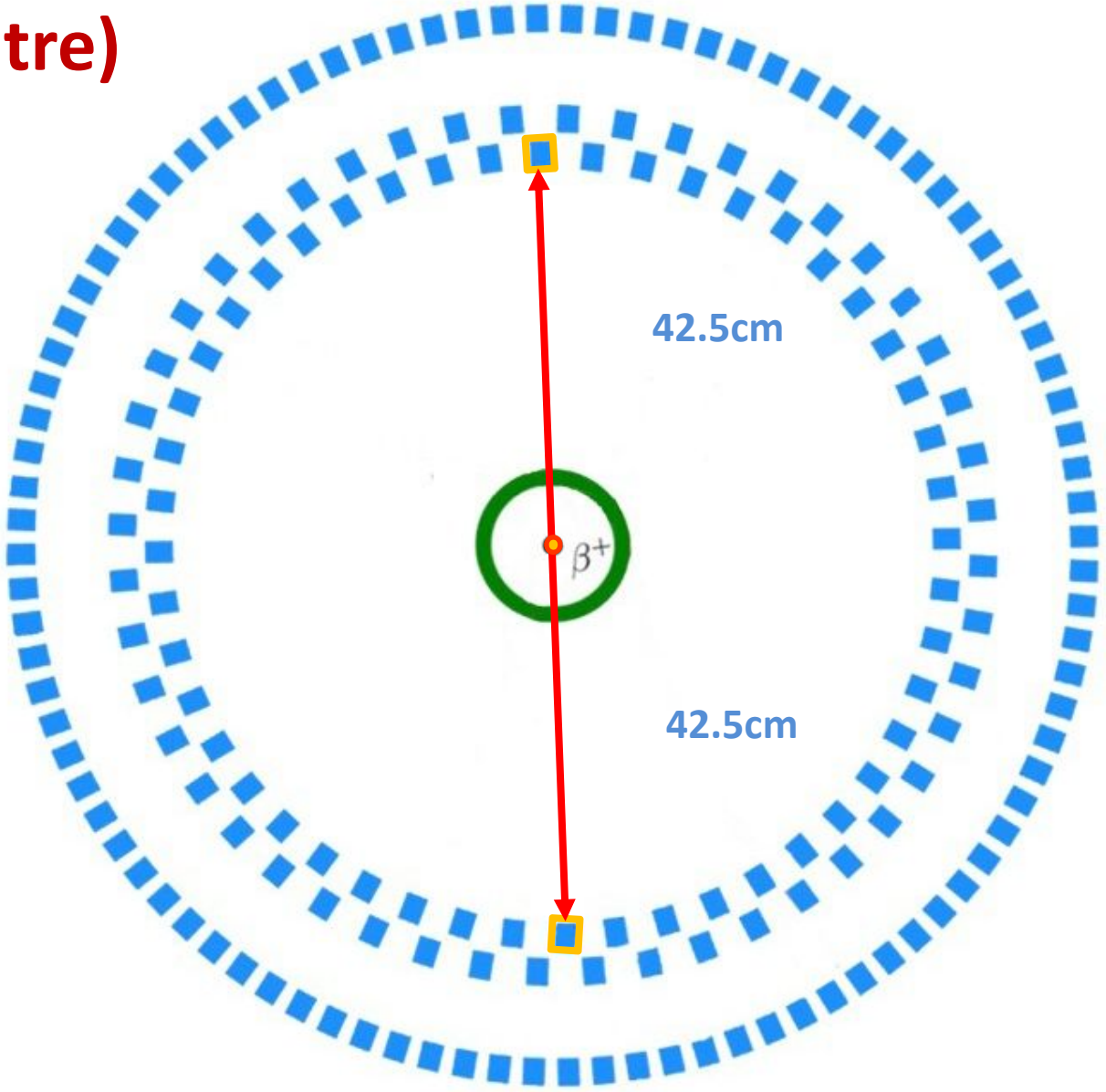


TOTs (ToT=14 to 27)


β^+

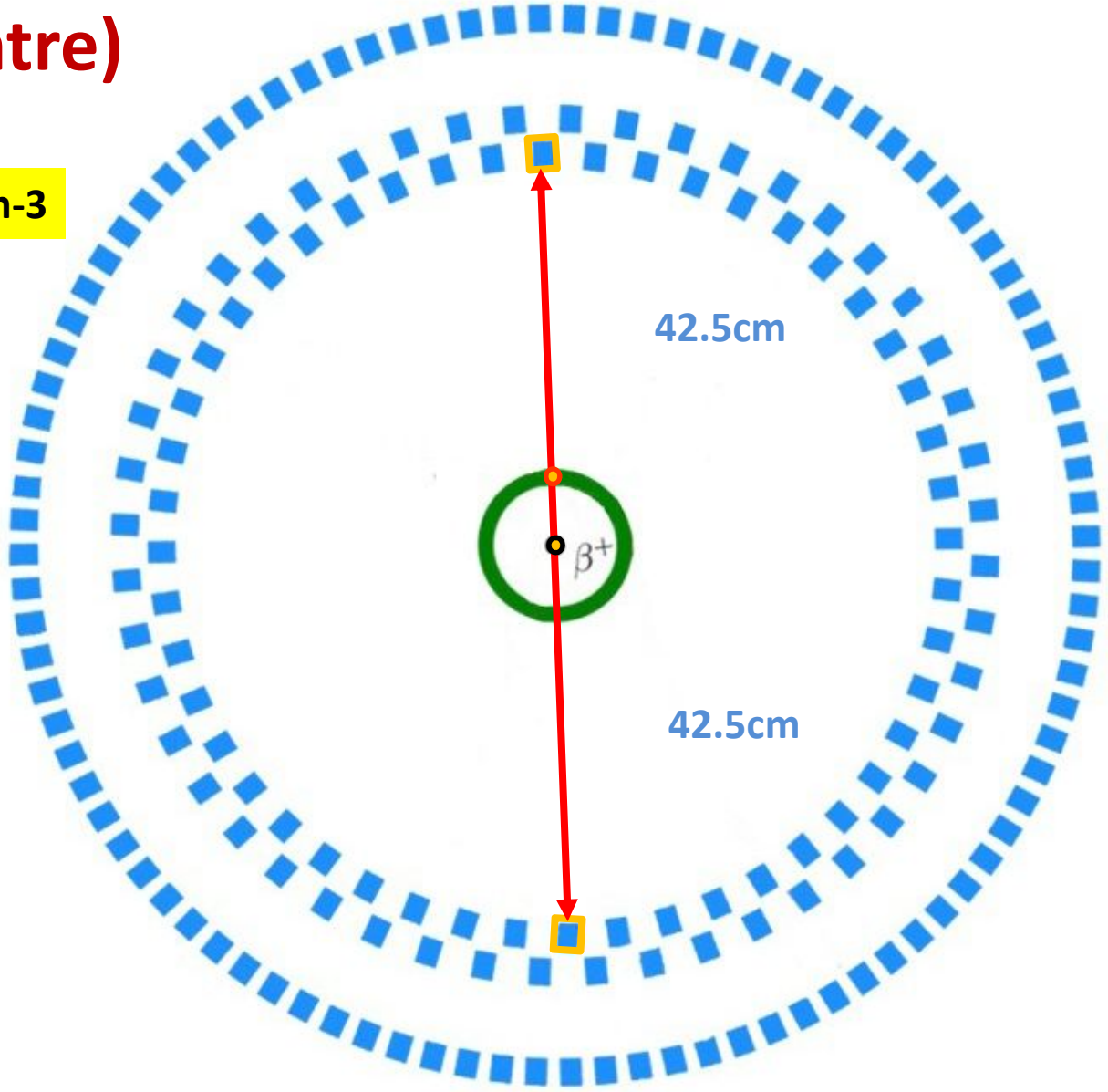
The two hit's angle calculations (annihillation at the centre)

Run-3



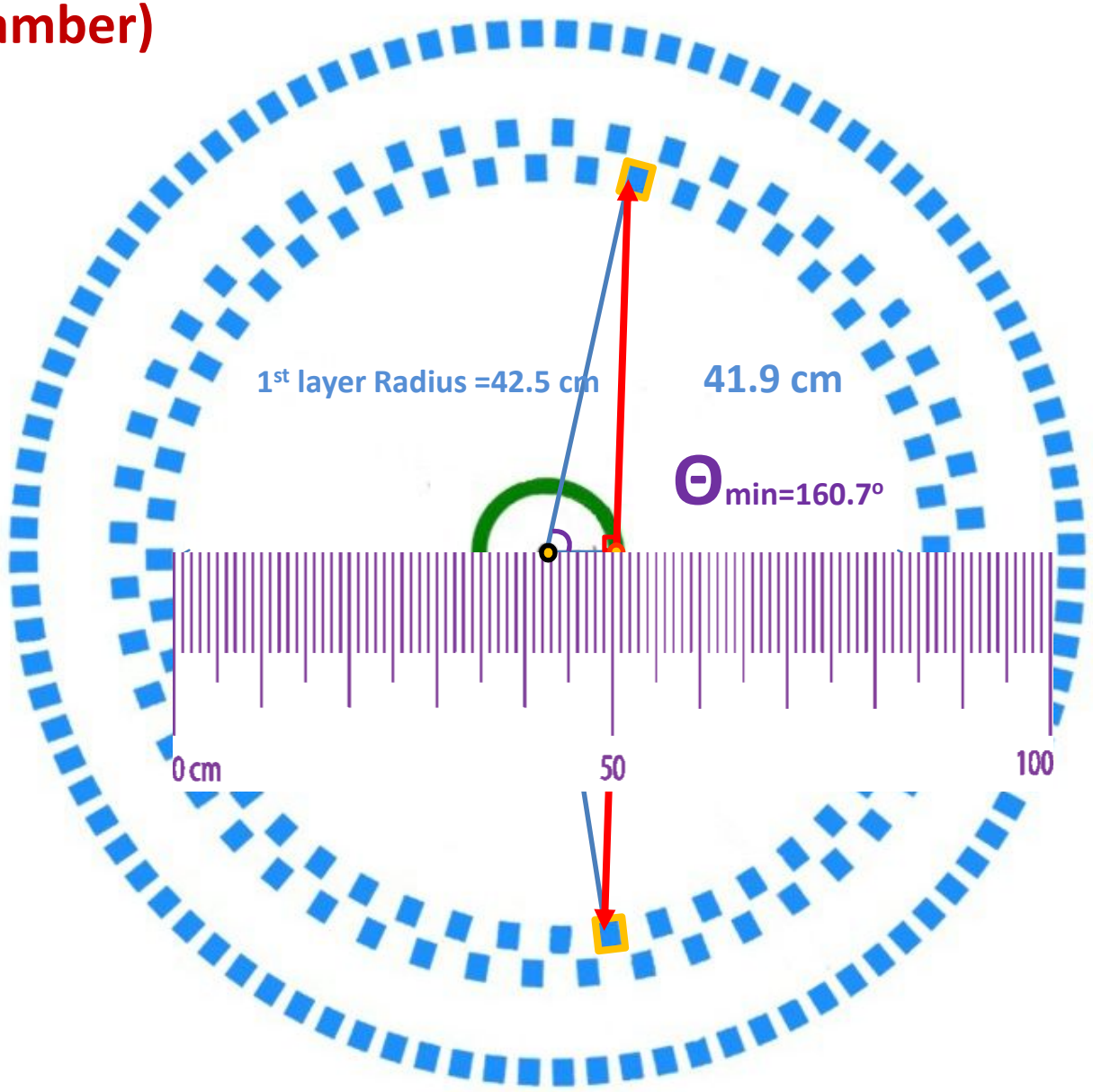
The two hit's angle calculations (annihillation at the centre)

Run-3



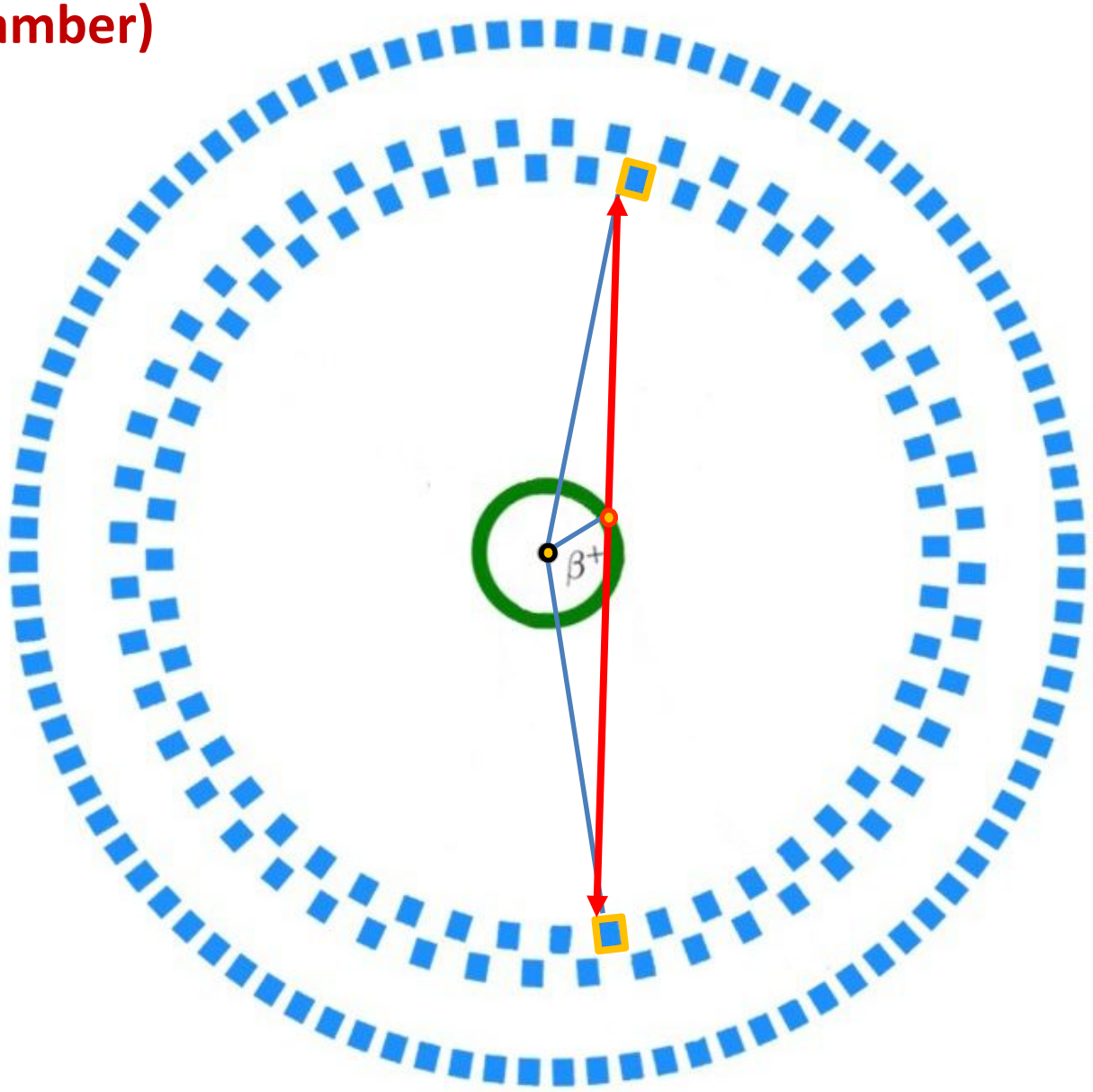
The two hit's angle calculations (annihillation point at the wall of the chamber)

Run-3



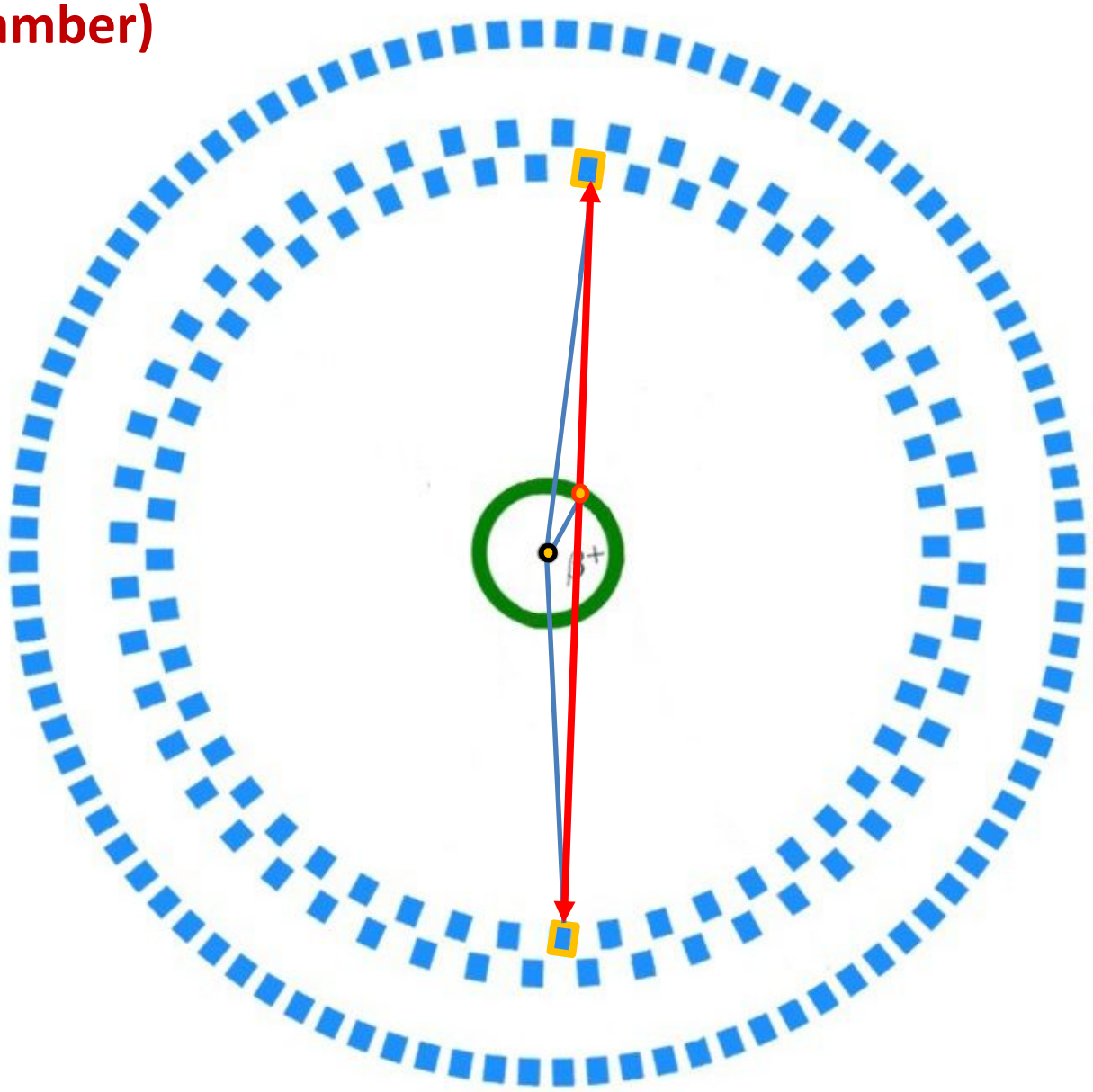
The two hit's angle calculations (annihillation point at the wall of the chamber)

Run-3



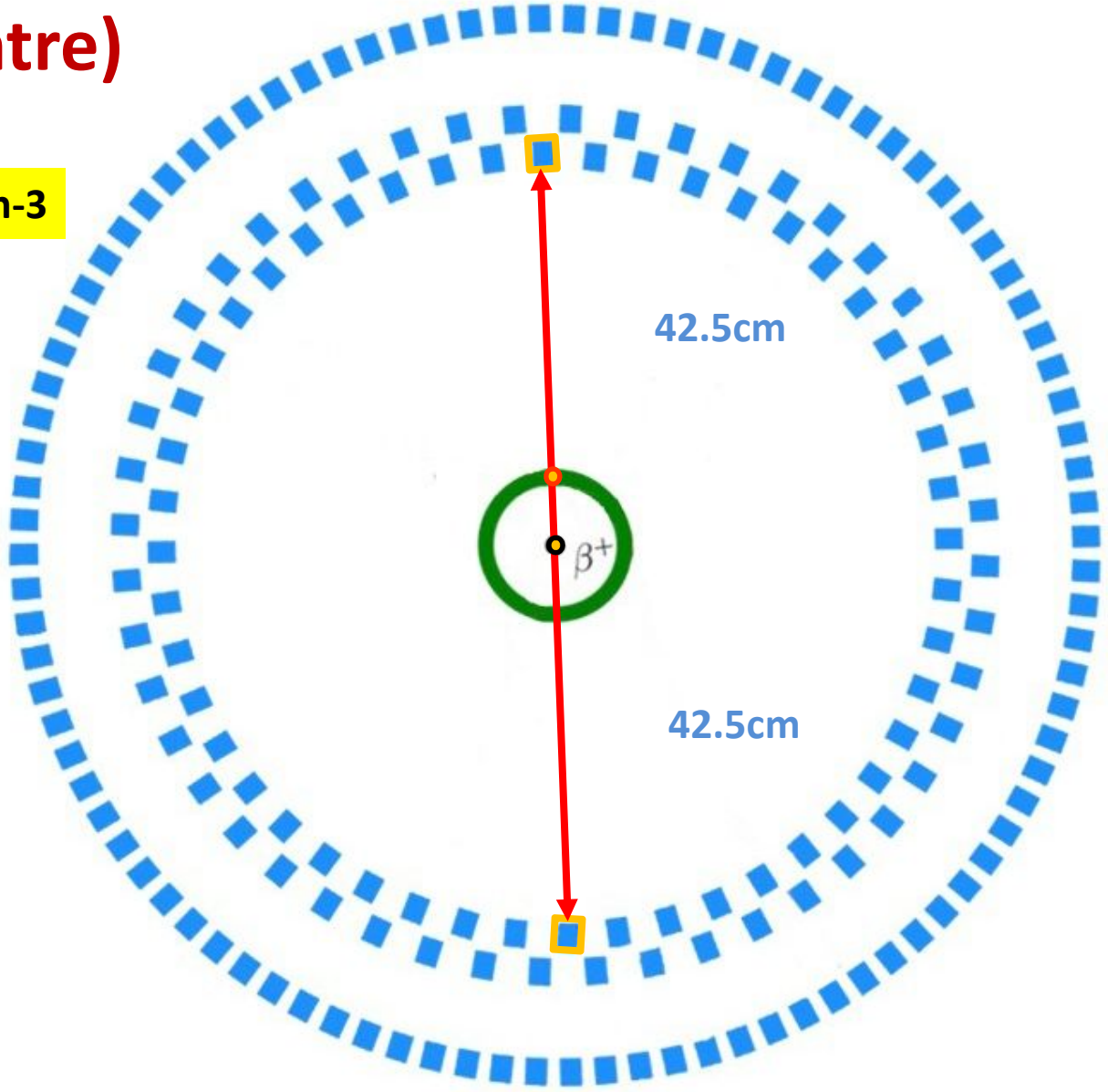
The two hit's angle calculations (annihillation point at the wall of the chamber)

Run-3



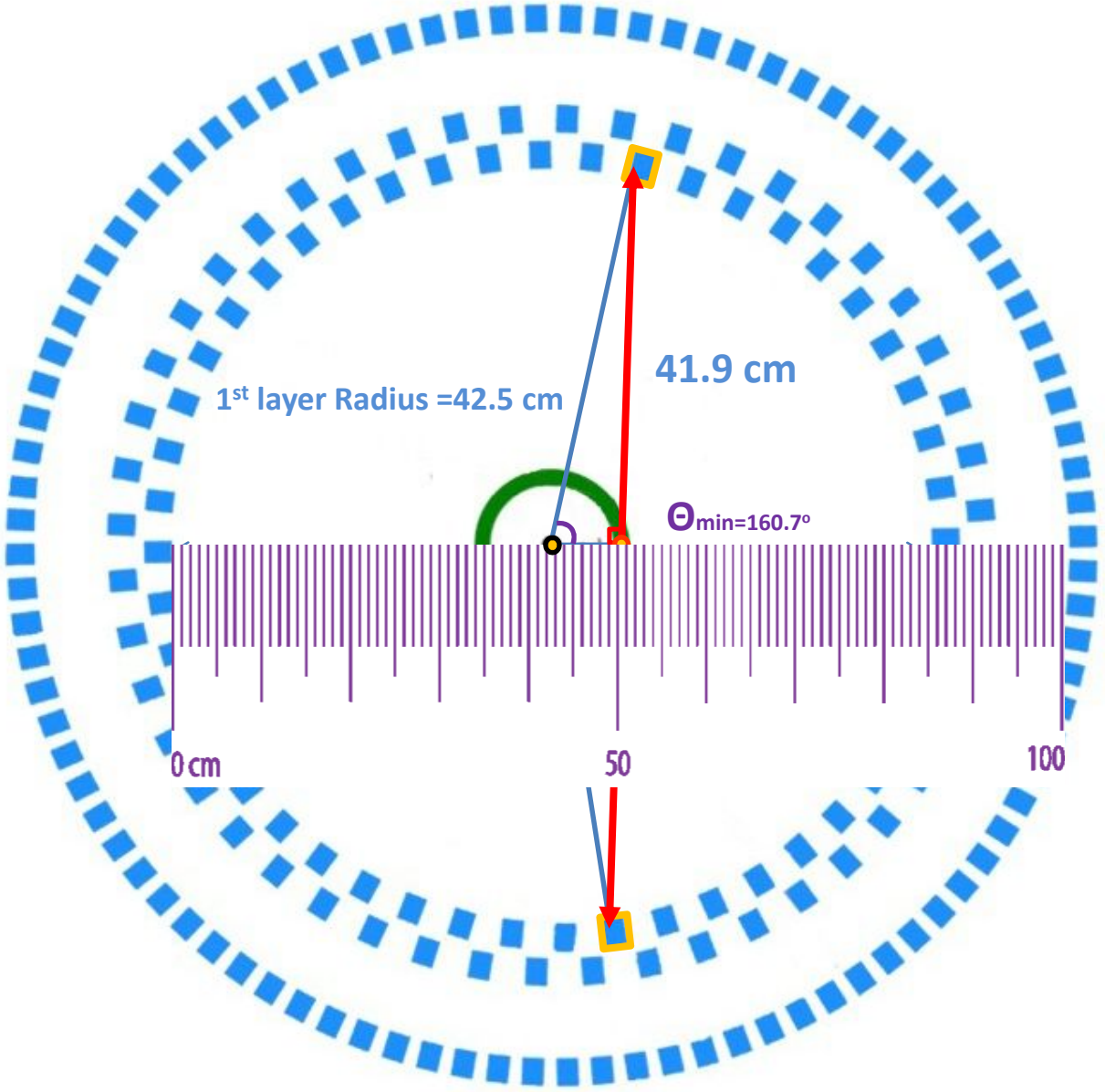
The two hit's angle calculations (annihillation at the centre)

Run-3

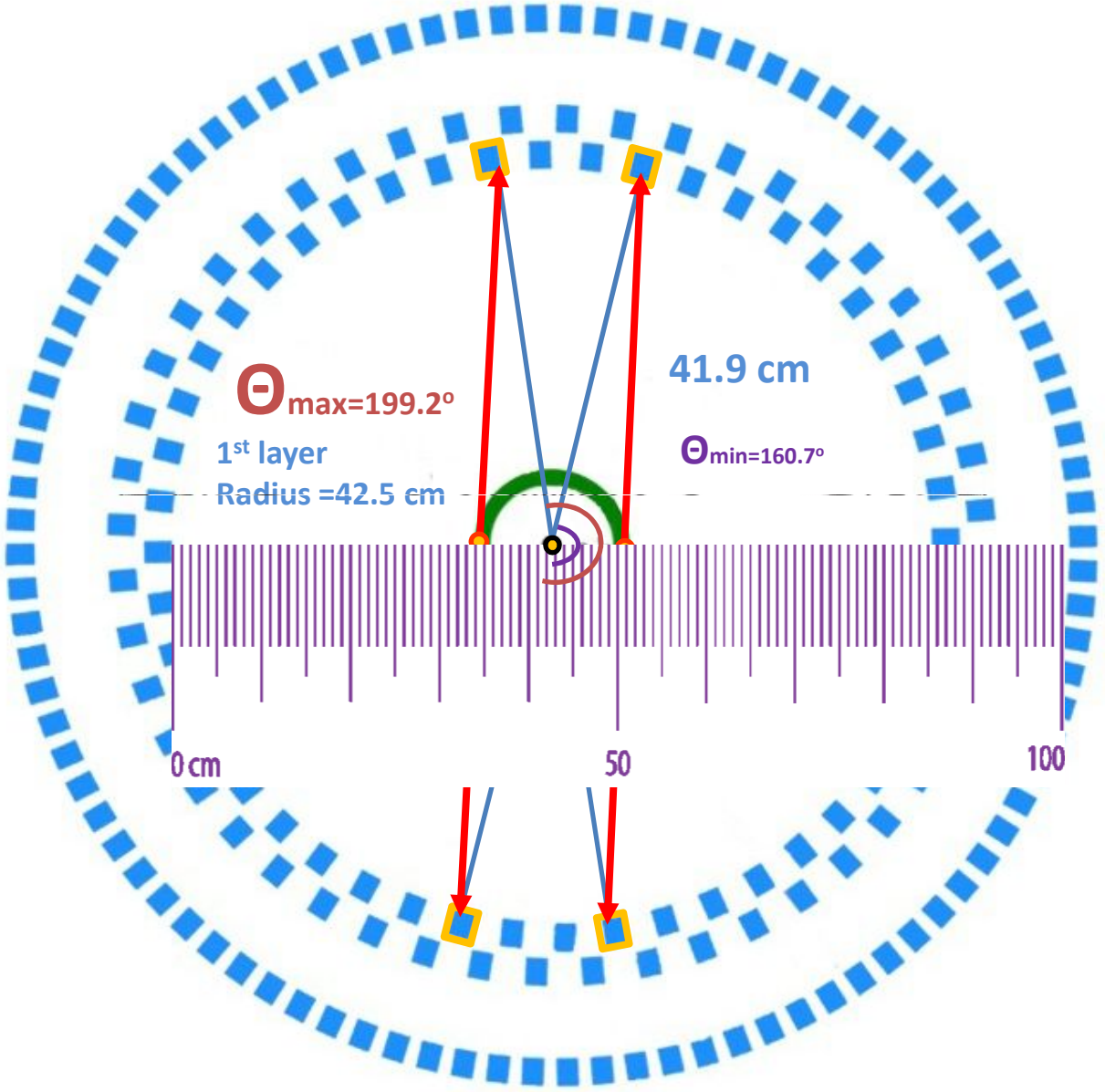


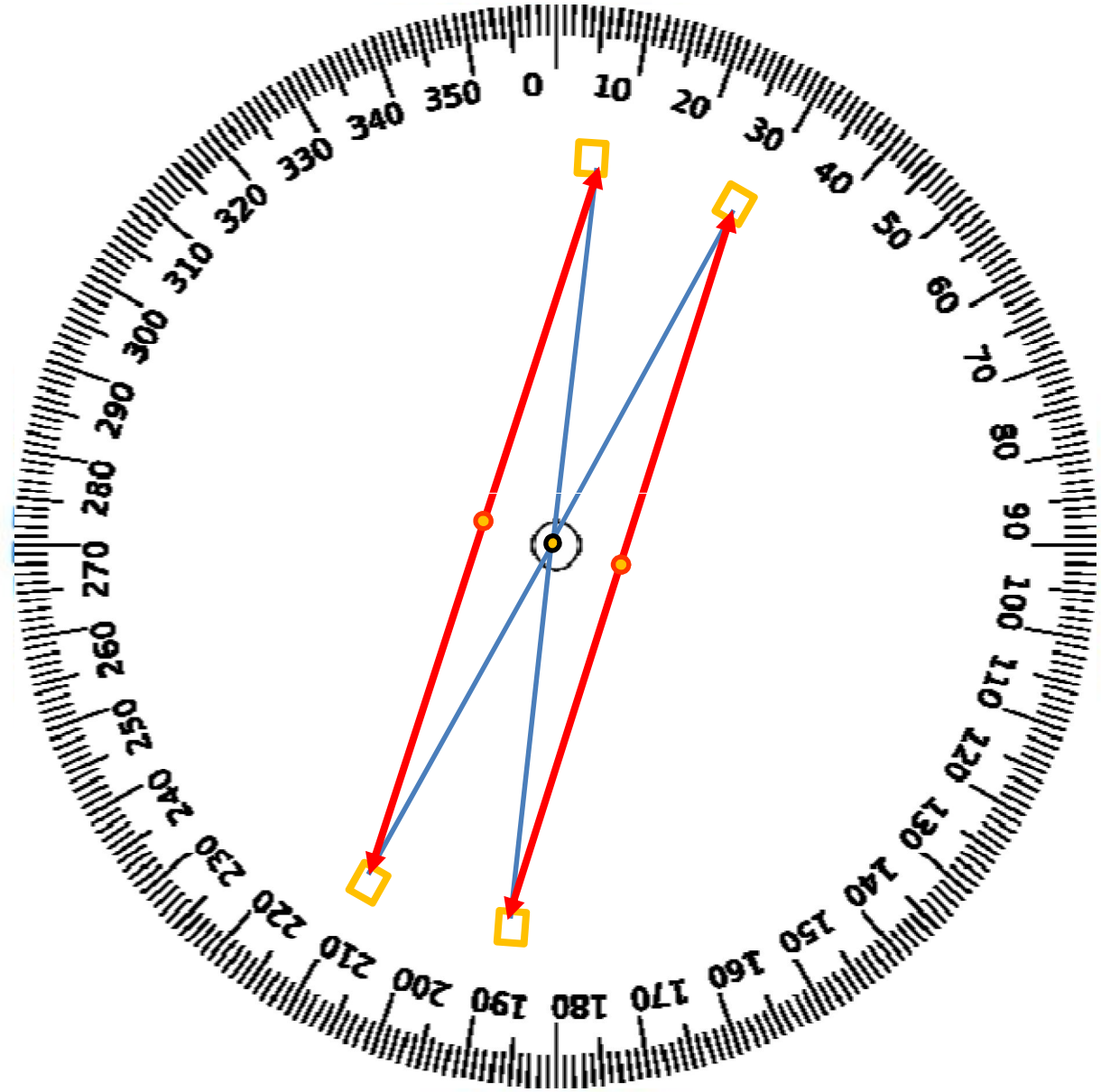
1st layer Radius =42.5 cm

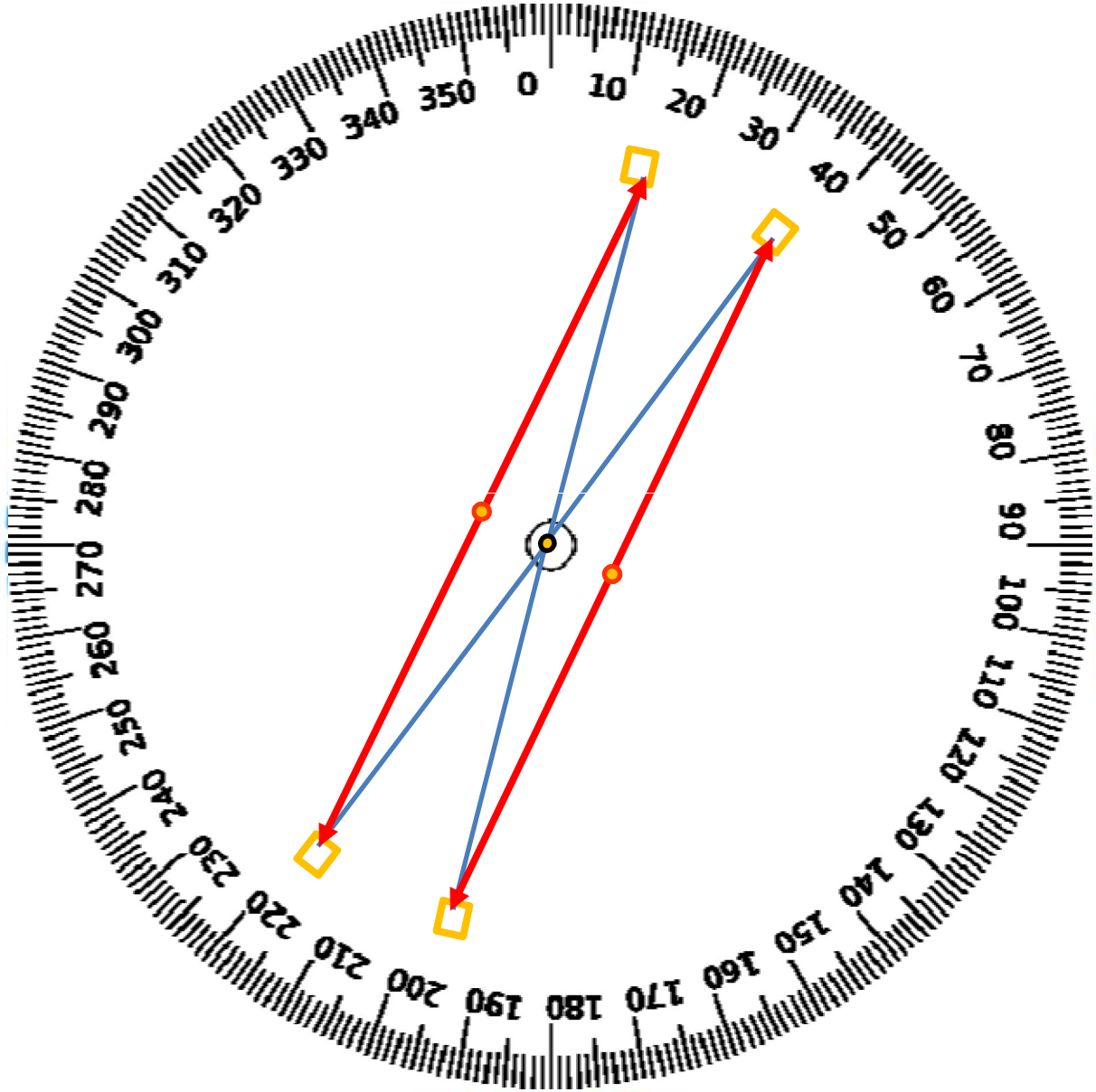
Run-3

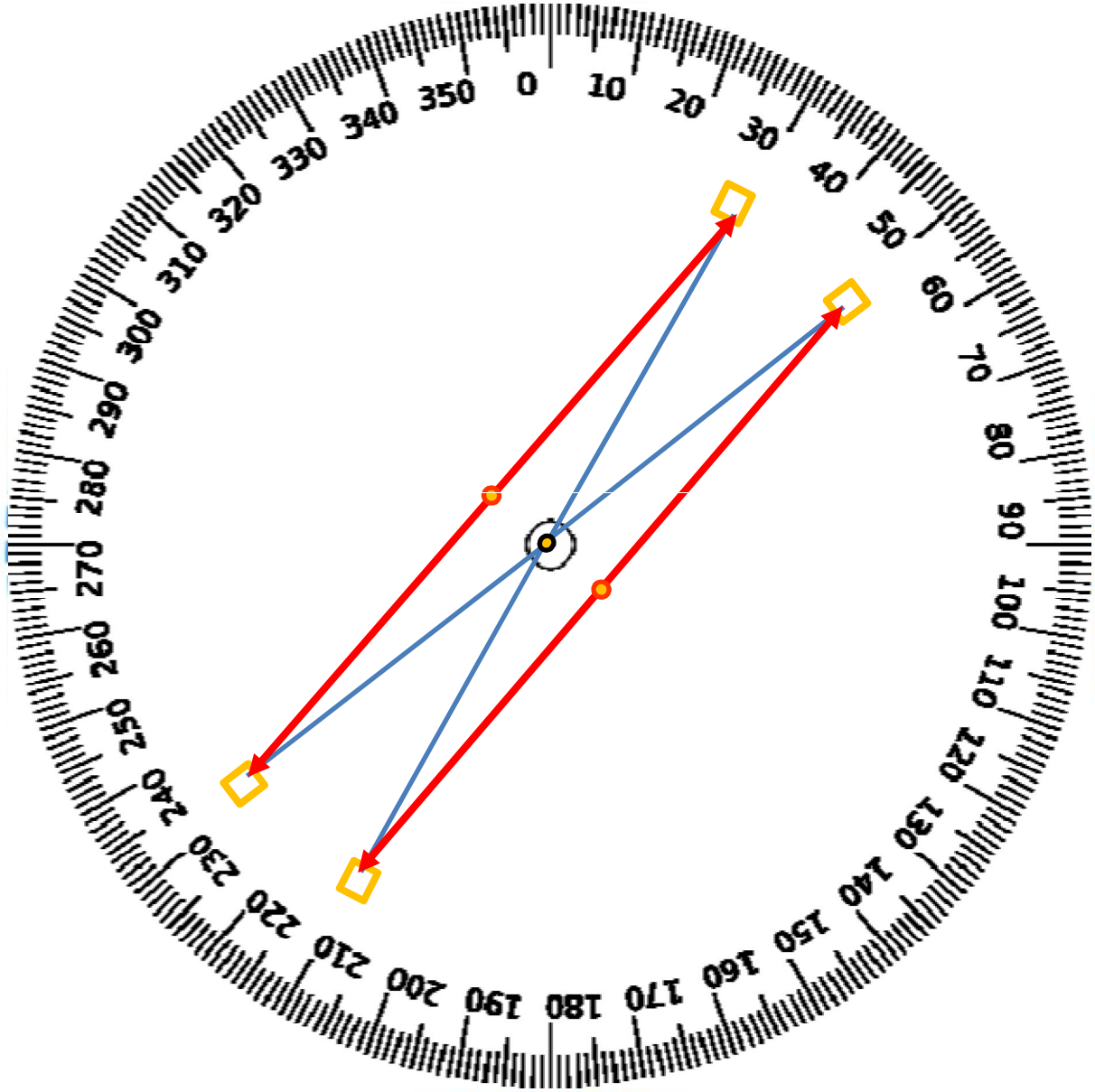


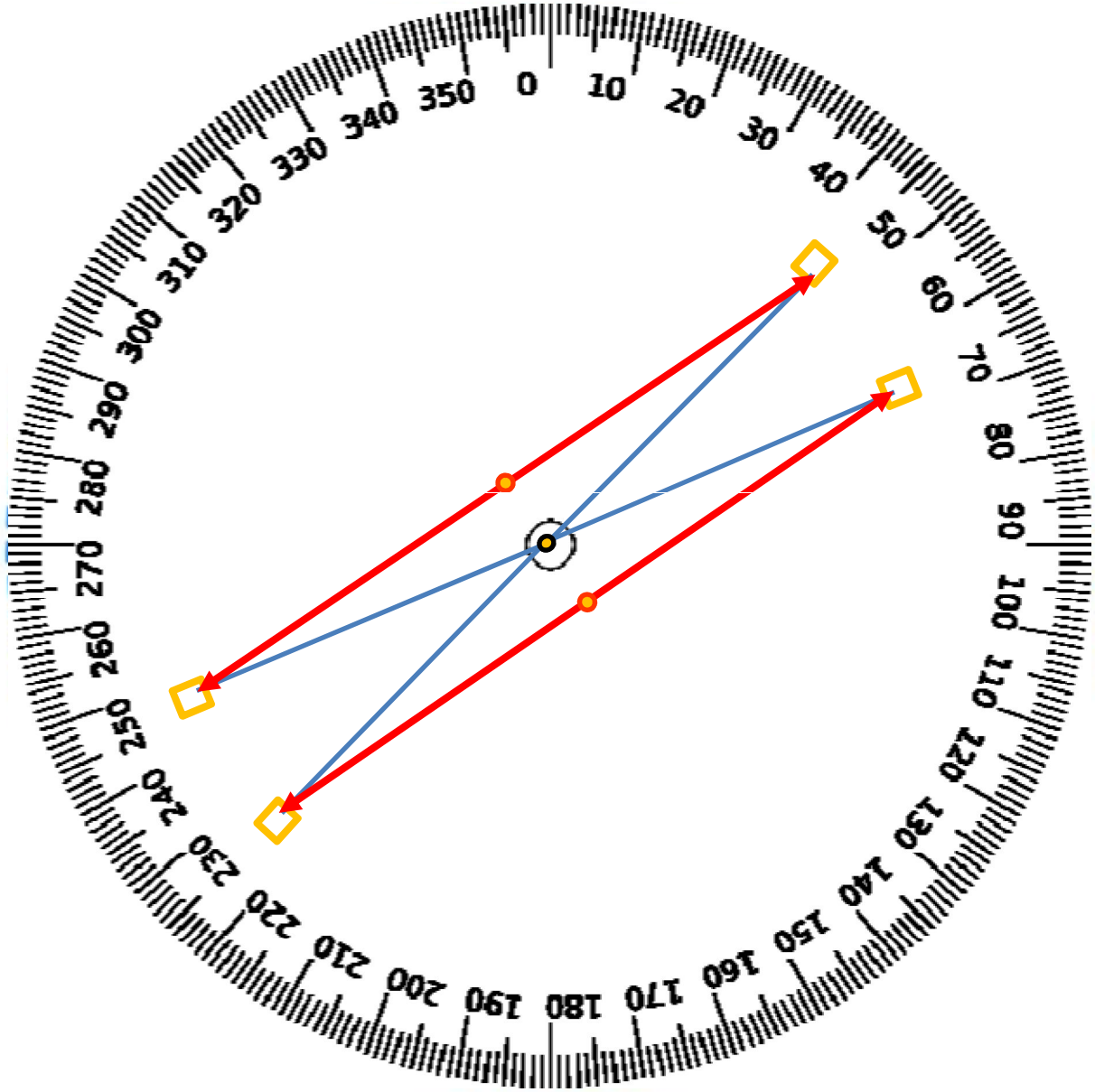
Run-3

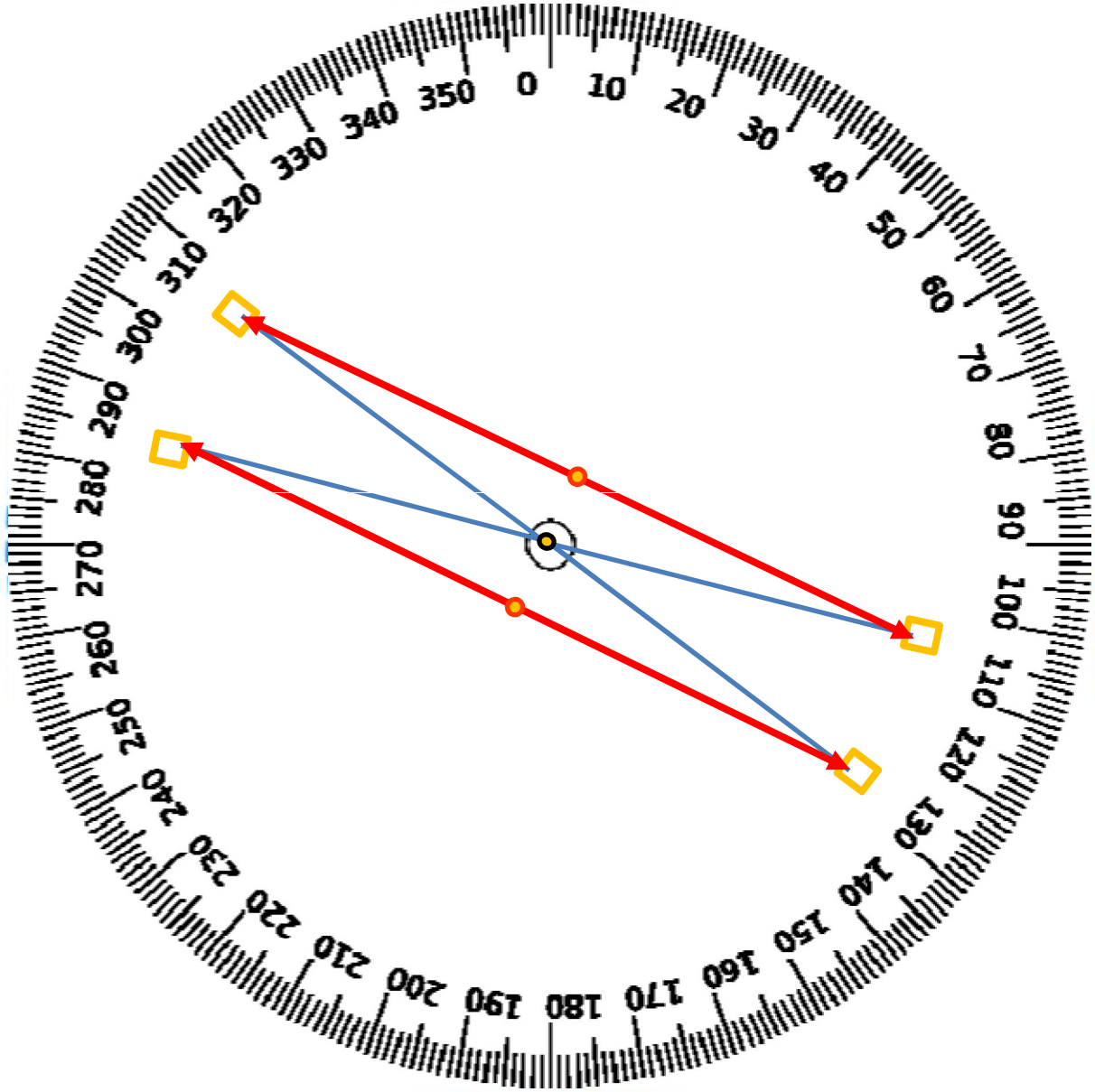



0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
210
220
230
240
250
260
270
280
290
300
310
320
330
340
350


0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
210
220
230
240
250
260
270
280
290
300
310
320
330
340
350

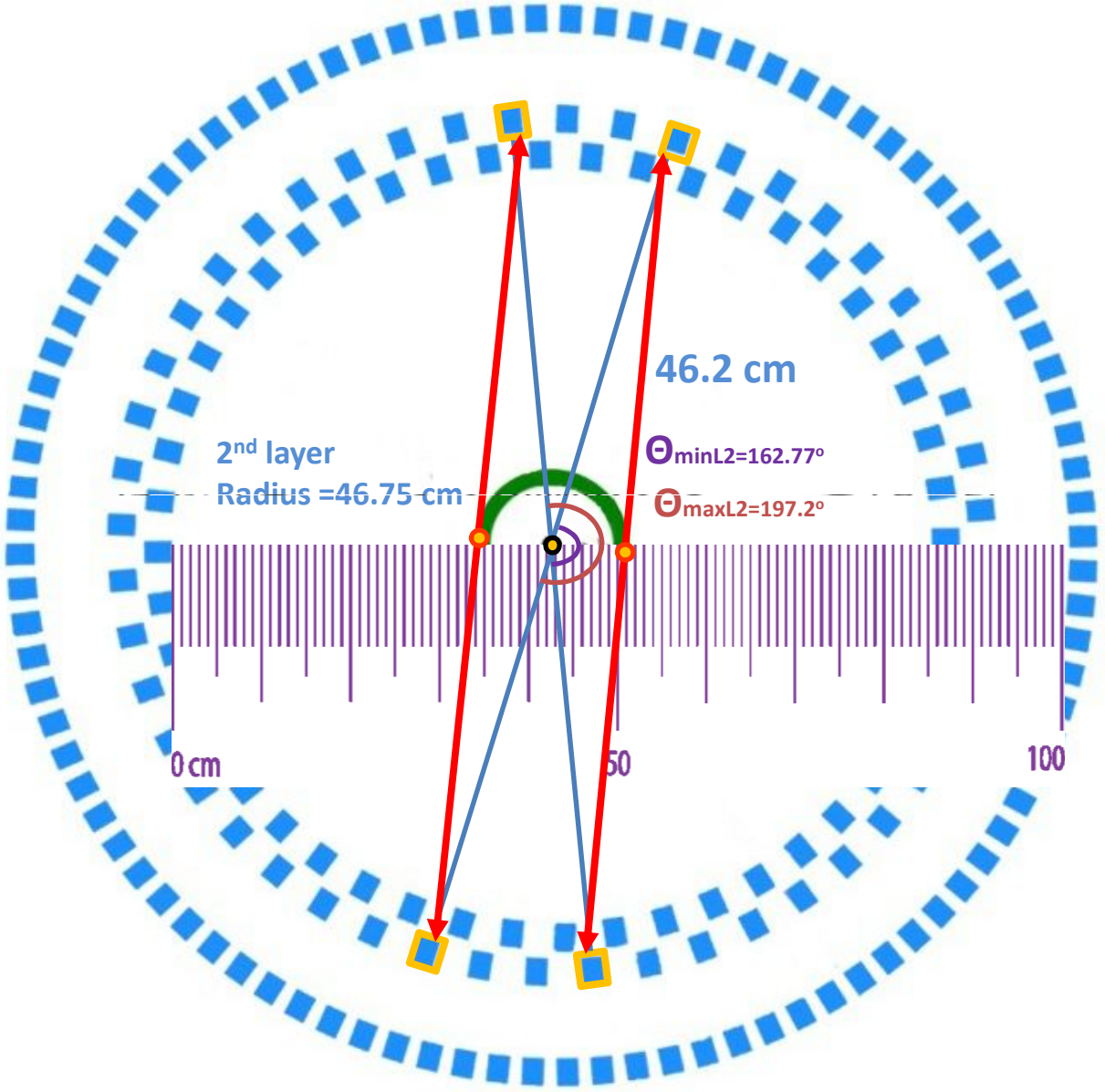

0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
210
220
230
240
250
260
270
280
290
300
310
320
330
340
350


0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
210
220
230
240
250
260
270
280
290
300
310
320
330
340
350


0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
210
220
230
240
250
260
270
280
290
300
310
320
330
340
350

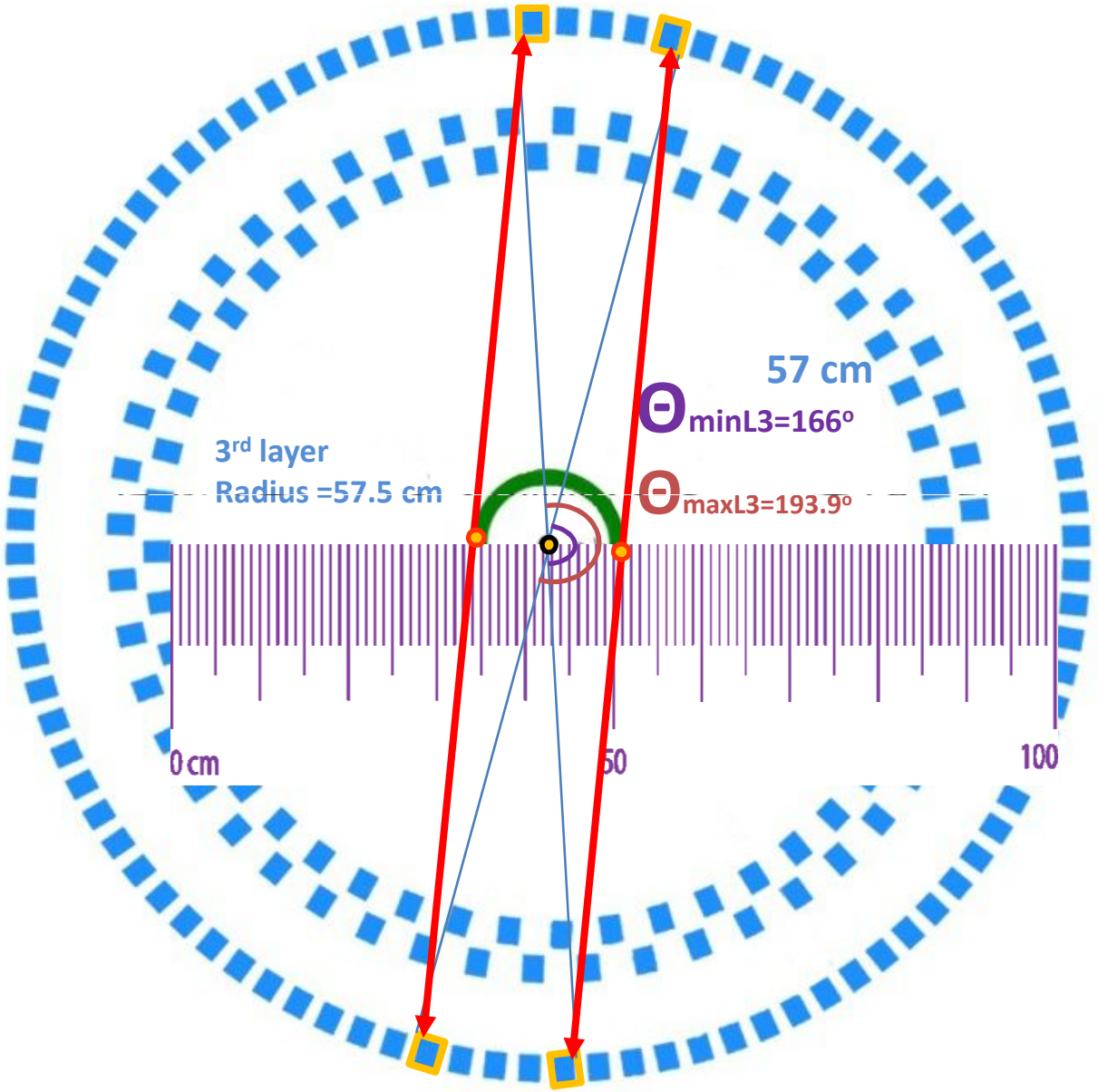
2nd layer

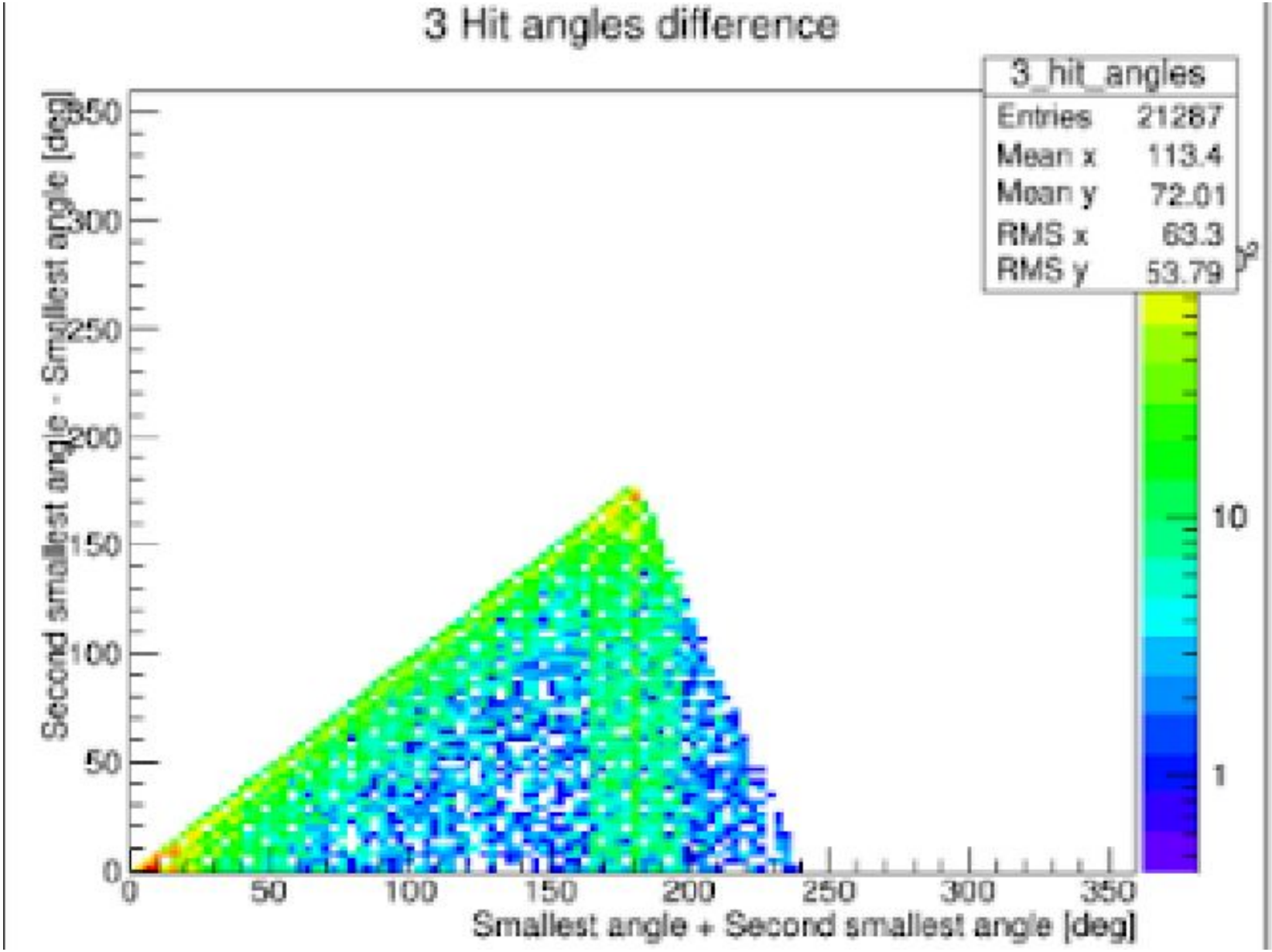
Run-3

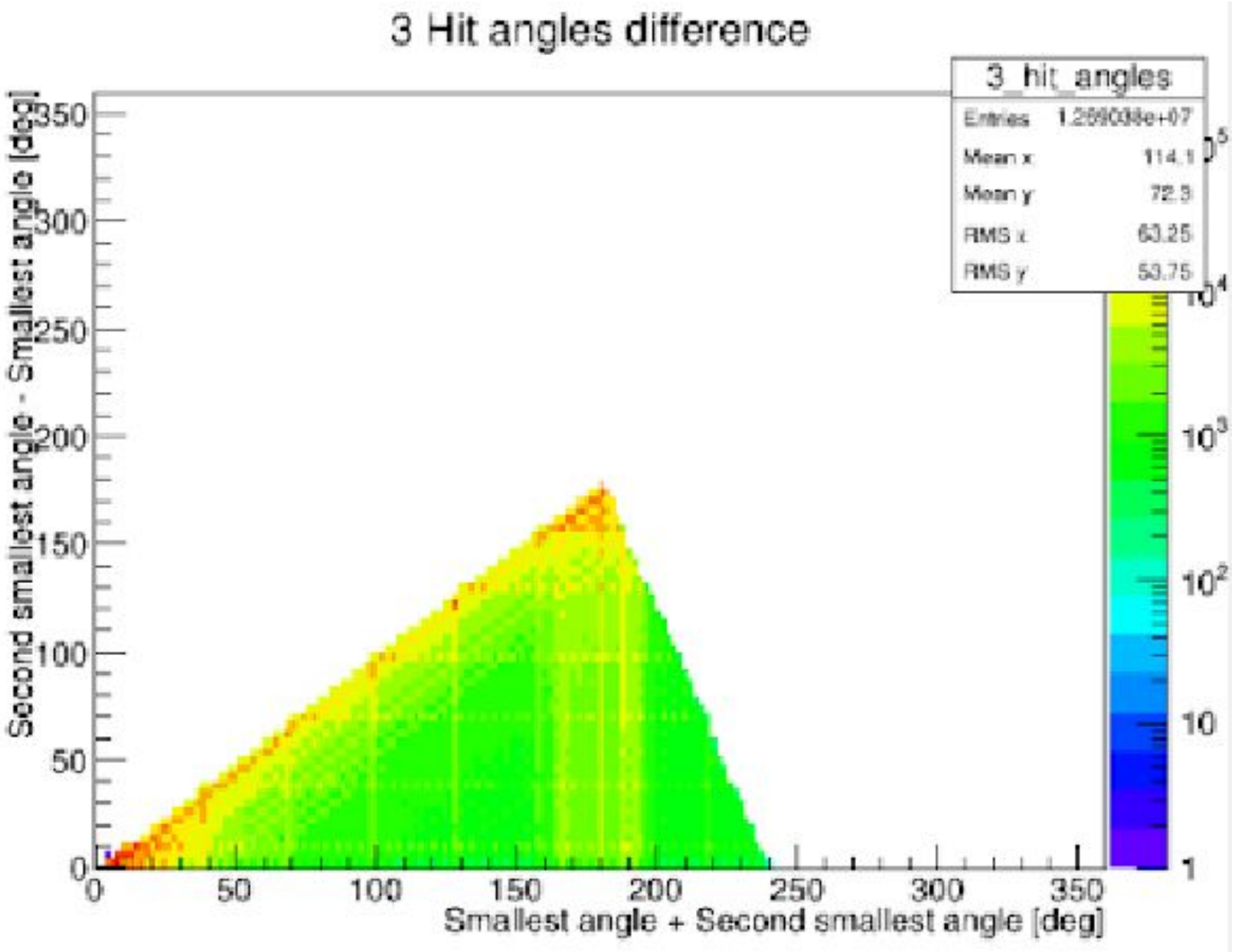


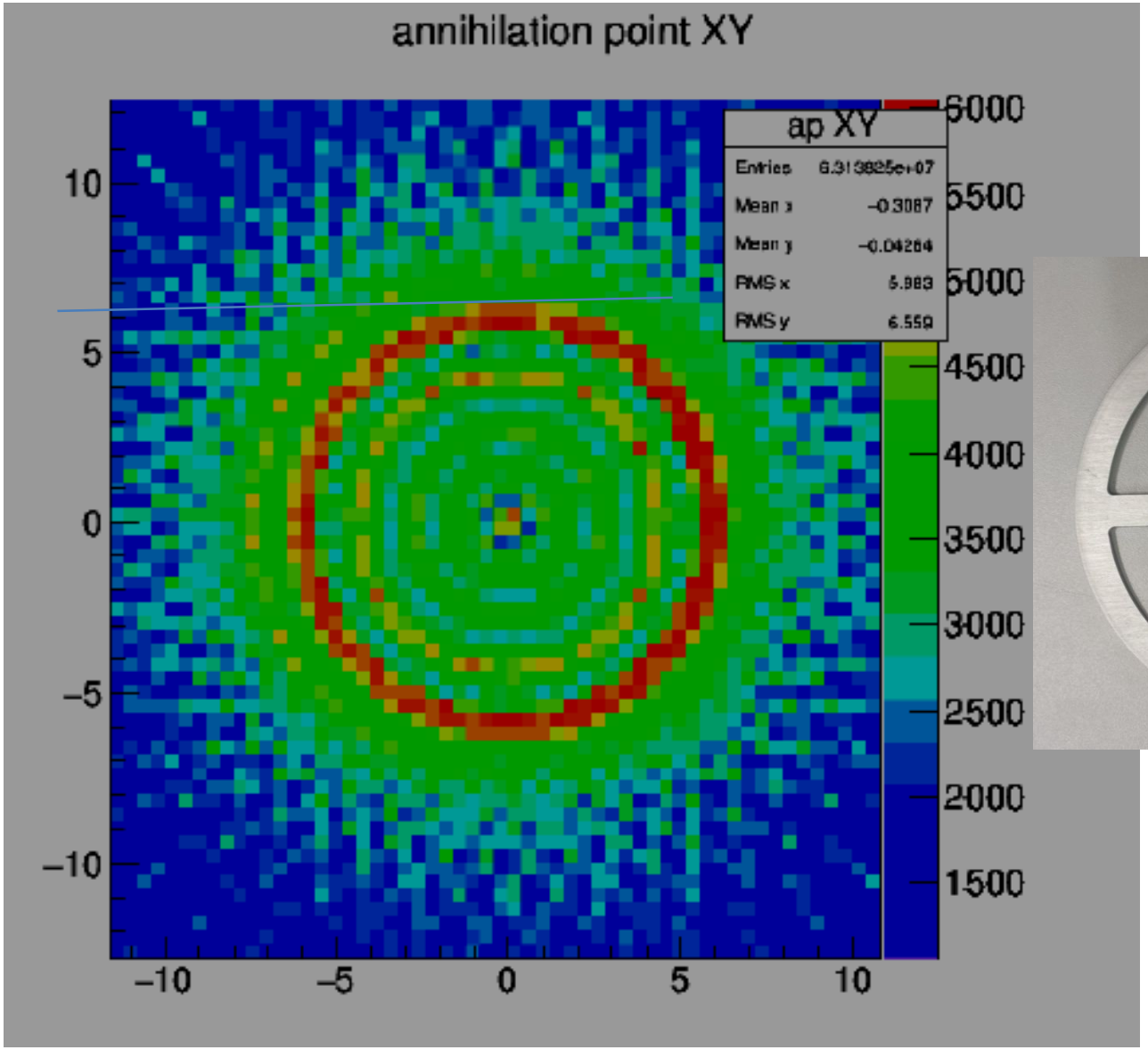
3rd layer

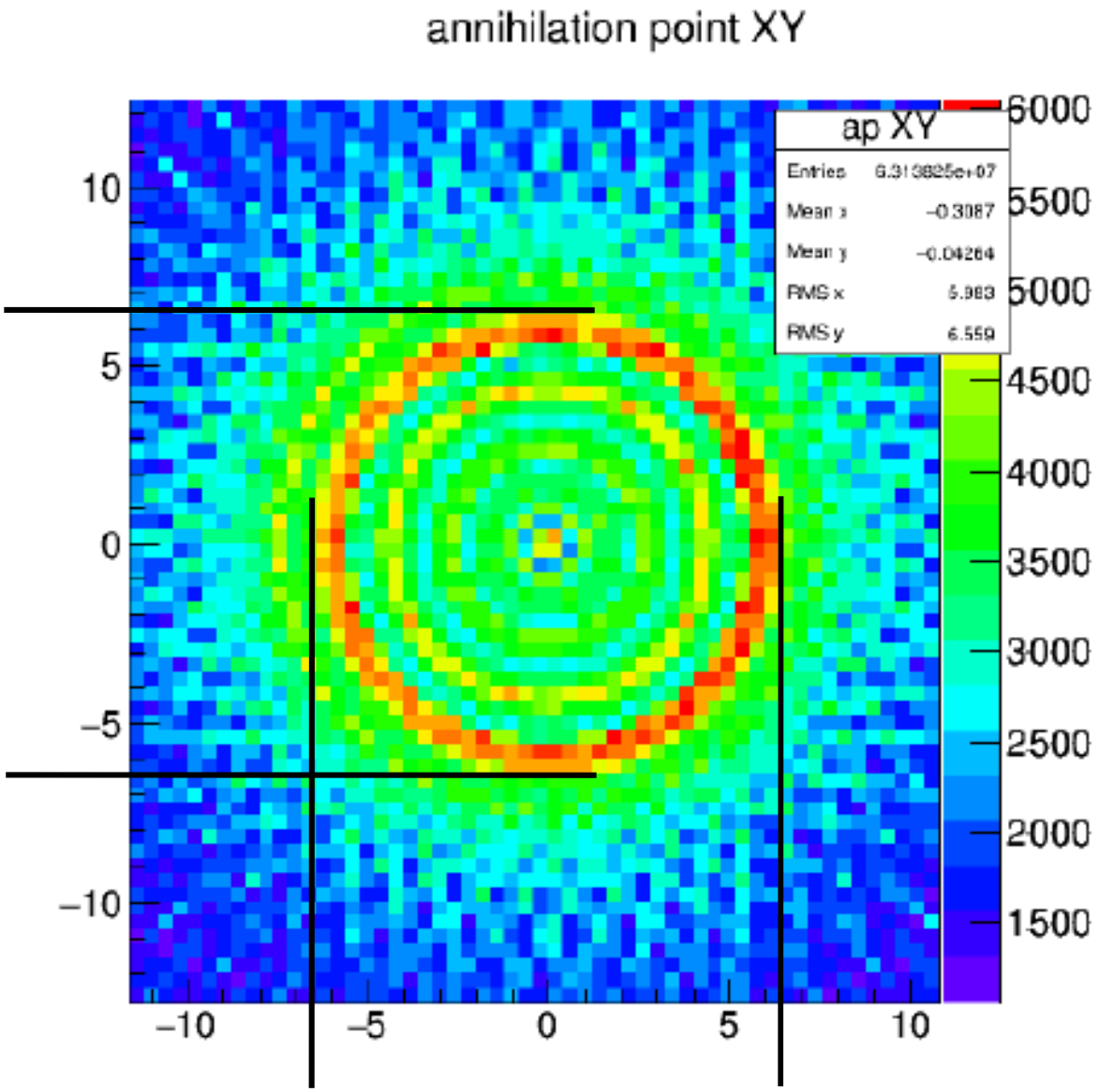
Run-3

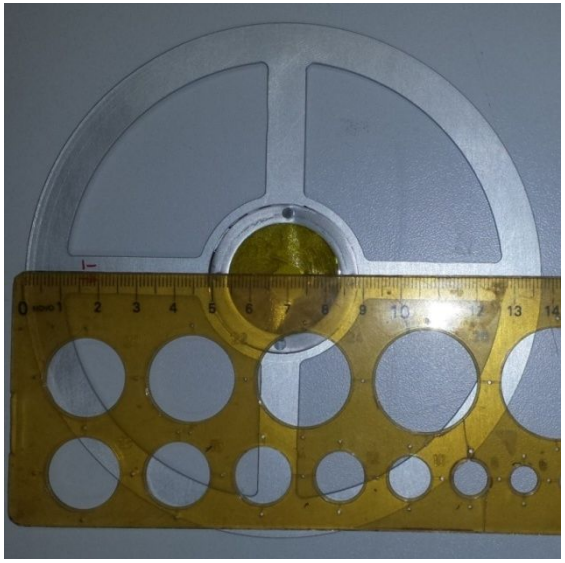



3 Hit angles difference
3_hit_angles
Entries 21287
Mean x 113.4
Mean y 72.01
RMS x 63.3
RMS y 53.79
Second smallest angle - Smallest angle [deg]
Smallest angle + Second smallest angle [deg]
0
50
100
150
200
250
300
350
10
1

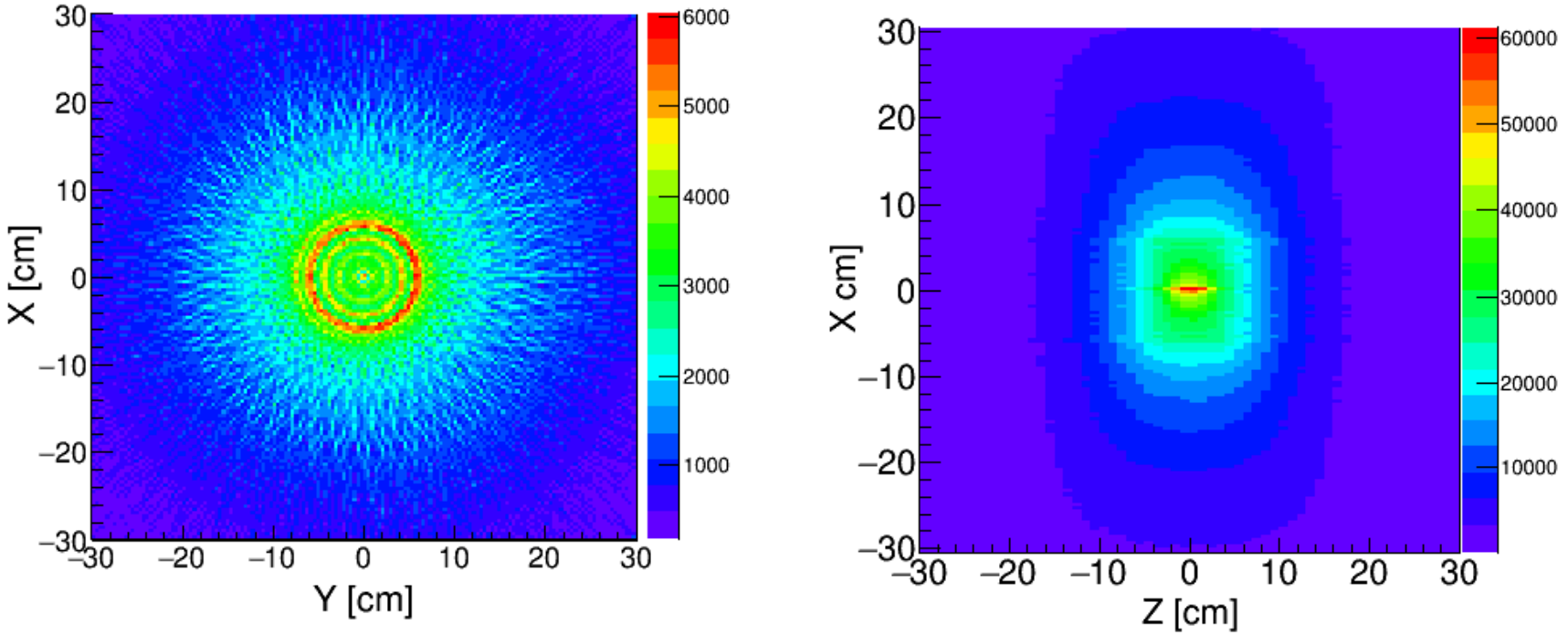

3 Hit angles difference
3_hit_angles
Entries 1.269038e+07
Mean x 114.1
Mean y 72.3
RMS x 63.25
RMS y 53.75
Second smallest angle - Smallest angle [deg]
Smallest angle + Second smallest angle [deg]
0
50
100
150
200
250
300
350
1
10
10^2
10^3
10^4
10^5


annihilation point XY
ap XY
Entries 6.313825e+07
Mean x -0.3087
Mean y -0.04264
RMS x 5.983
RMS y 6.559
10
5
0
−5
−10
−10
−5
0
5
10
6000
5500
5000
4500
4000
3500
3000
2500
2000
1500





Diameter =13.6 cm



The tomographic image of the annihilation target cylinder obtained using Ps →2ɣ annihilations used as a benchmark for the 3 annihilation reconstruction studies. Left (xy view) transverse view, |z| > 5 cm and right (zx view) side view.

Data selection criteria

Run-6 Data

Applied cuts:

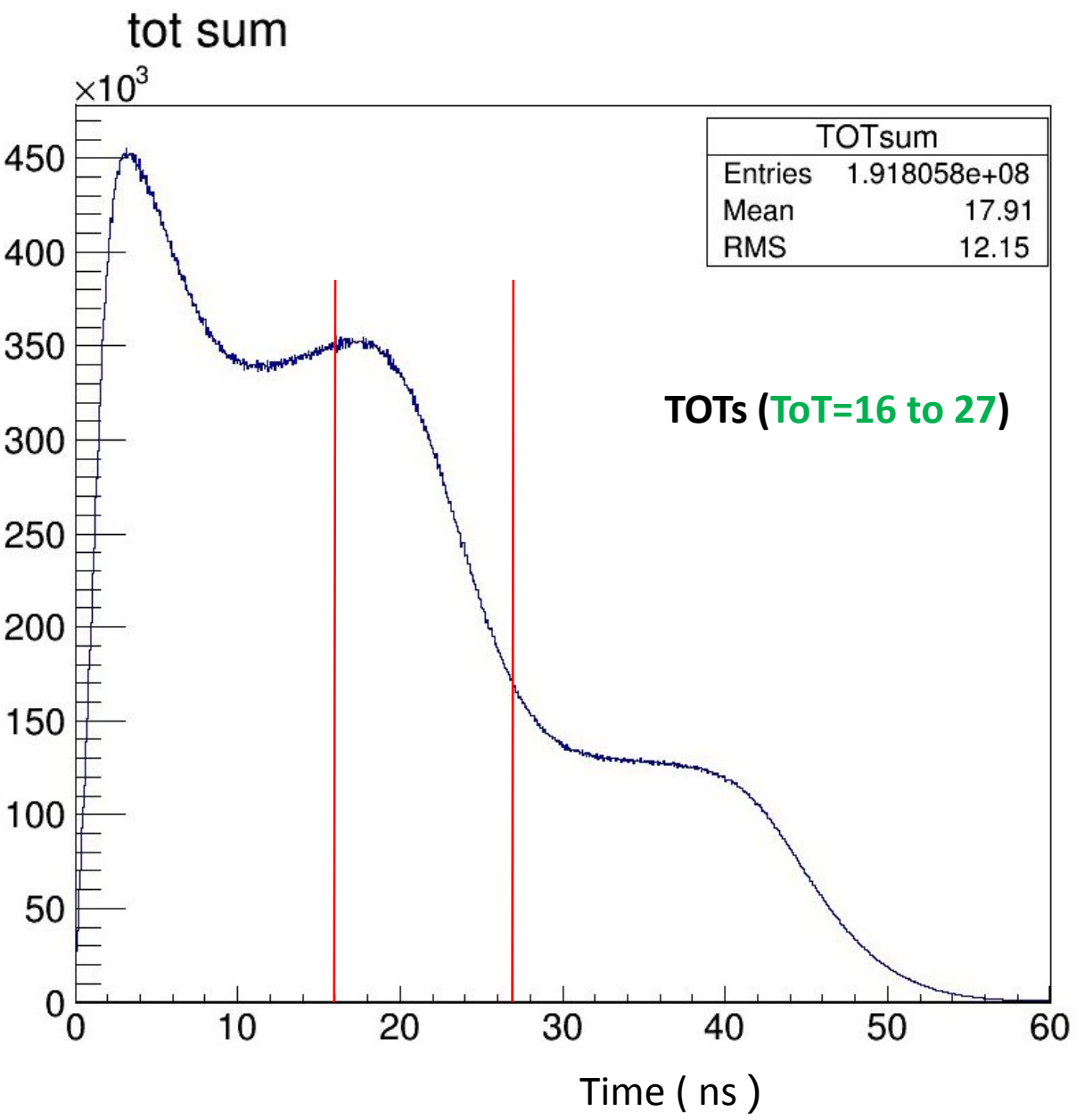
- **Select only 2 hits events.**

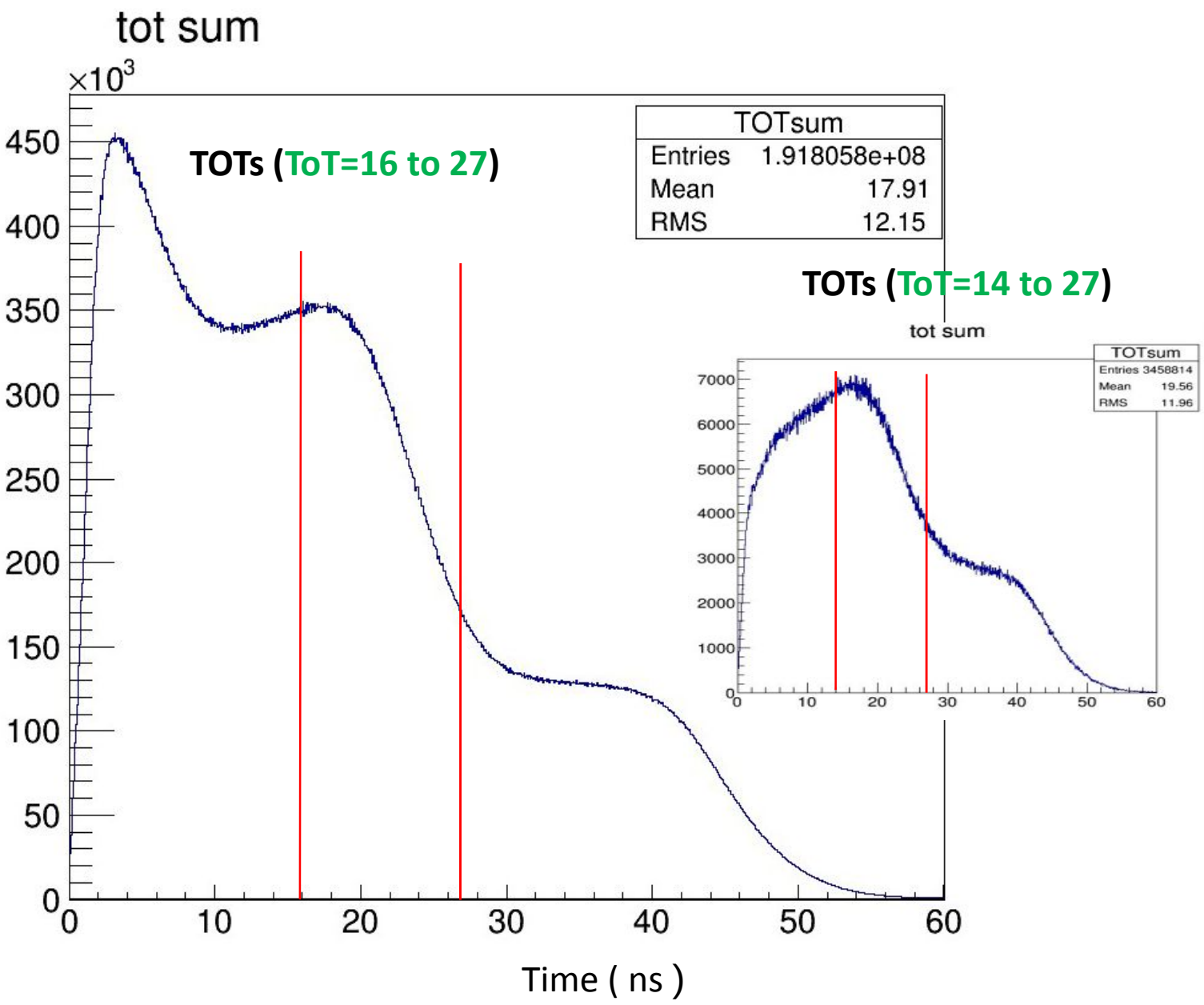
- **Specific range of the angles between two hits has been chosen.**
  The range of angles between 2 hits greater than 147and smaller than 212.

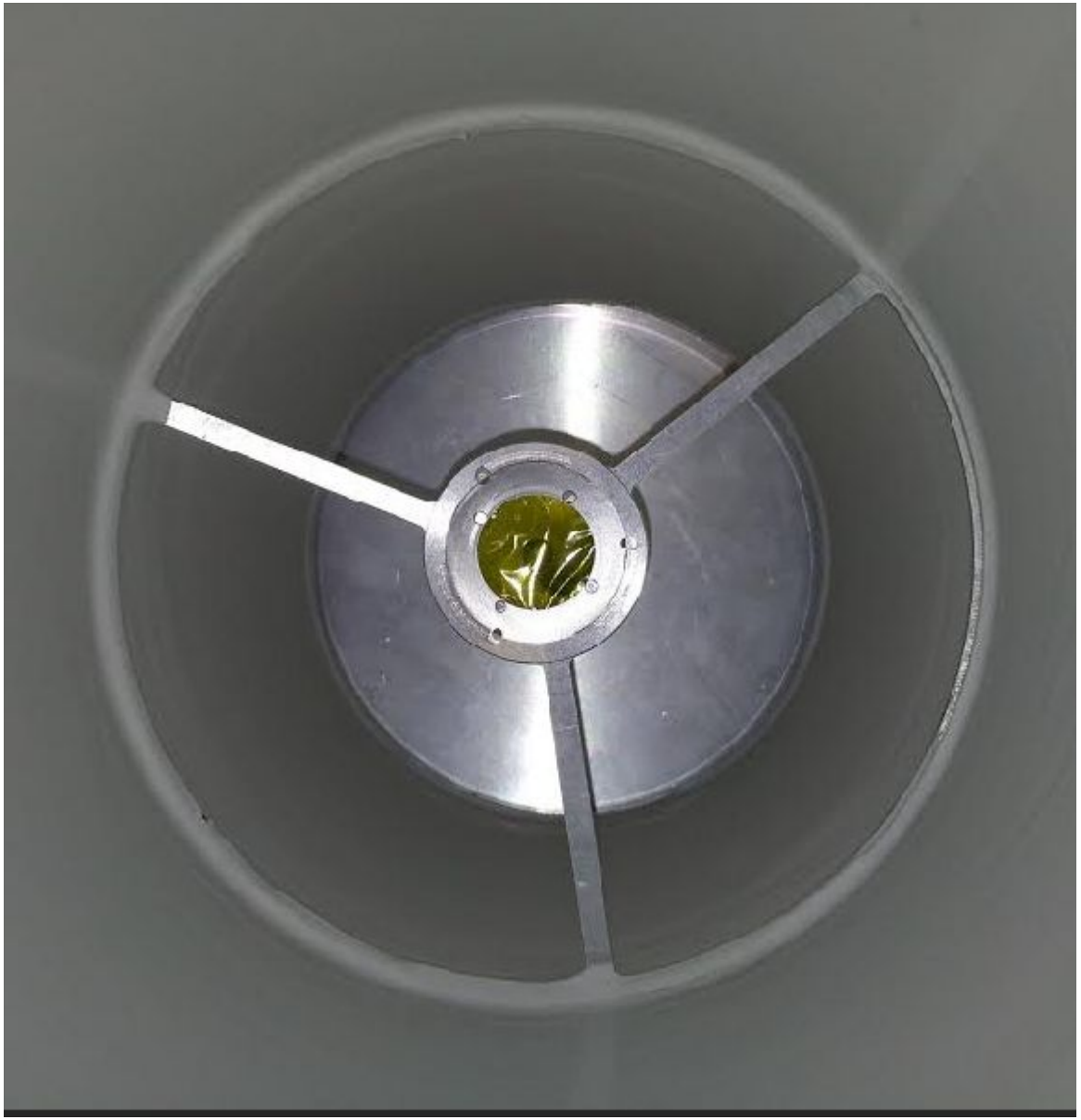
- **Absolute value of Z coefficient < 23 cm (z coordinate of place of interaction of γ with scintillator in range ± 23cm).**

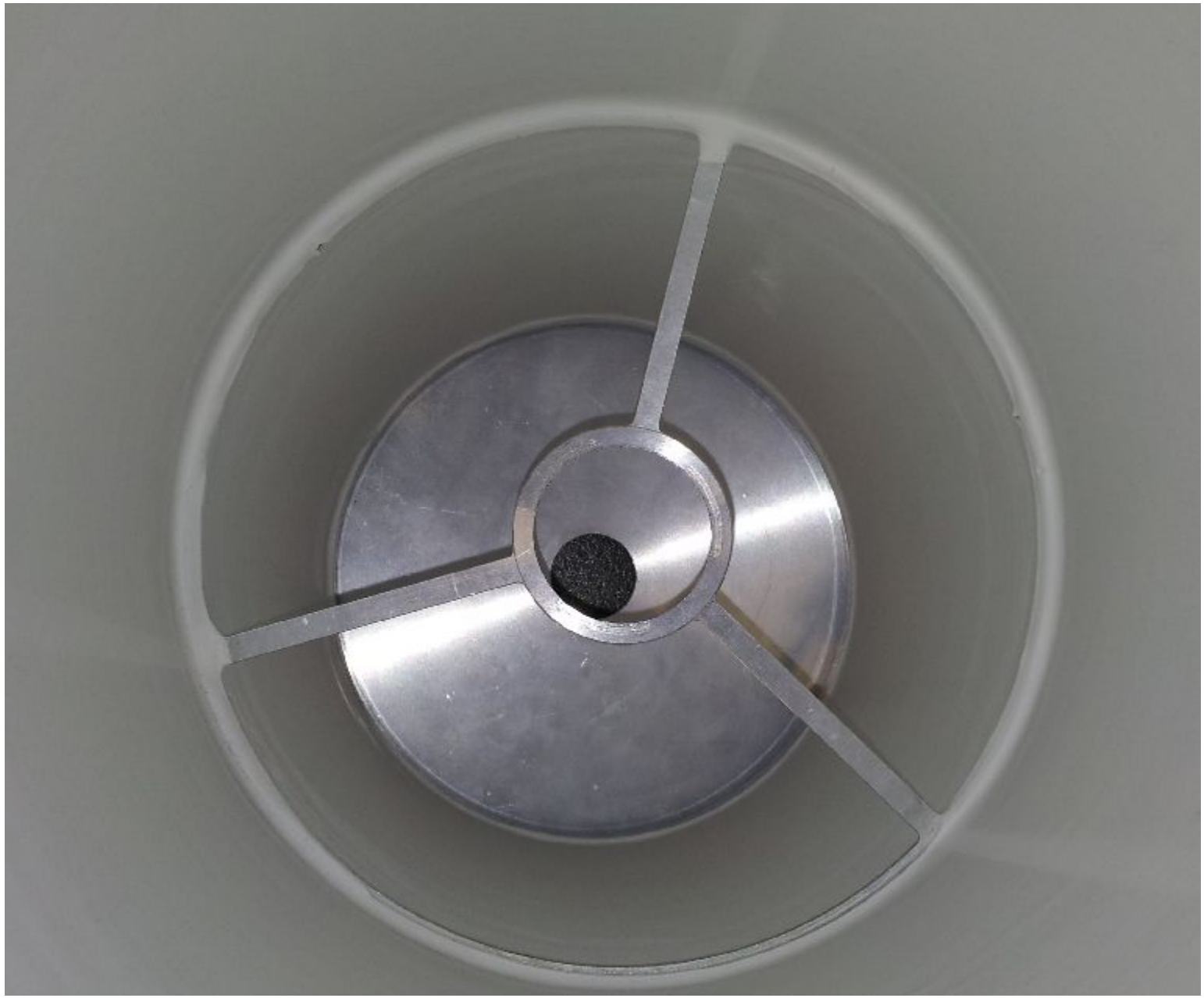
- **No TOT calibration => cuts applied to raw TOTs (ToT=16 to 27).**

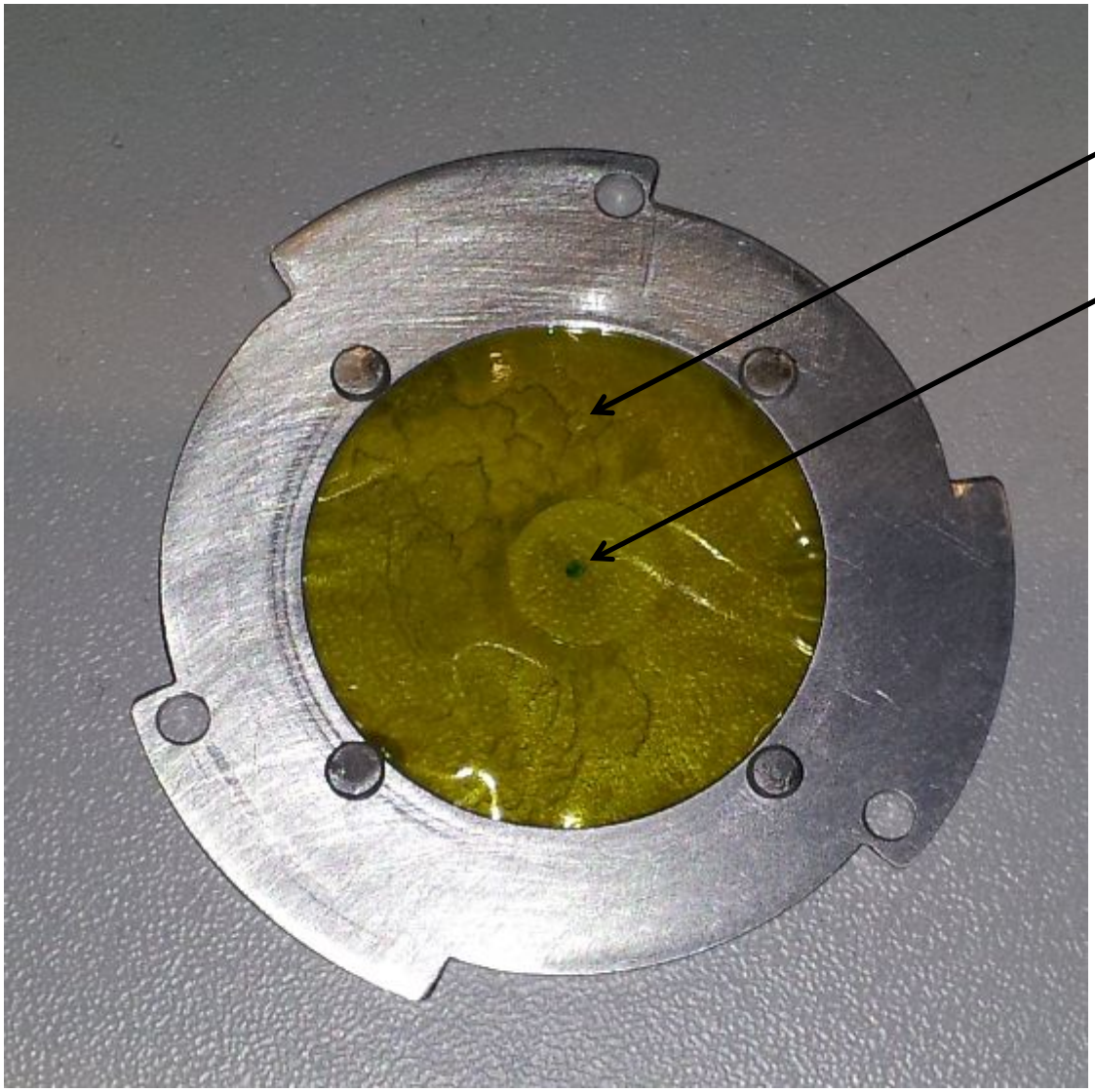
- **Z=± 5 cm along z-axis also removed from data.**


tot sum
×10^3
TOTsum
Entries 1.918058e+08
Mean 17.91
RMS 12.15
TOTs (ToT=16 to 27)
450
400
350
300
250
200
150
100
50
0
0
10
20
30
40
50
60
Time (ns)

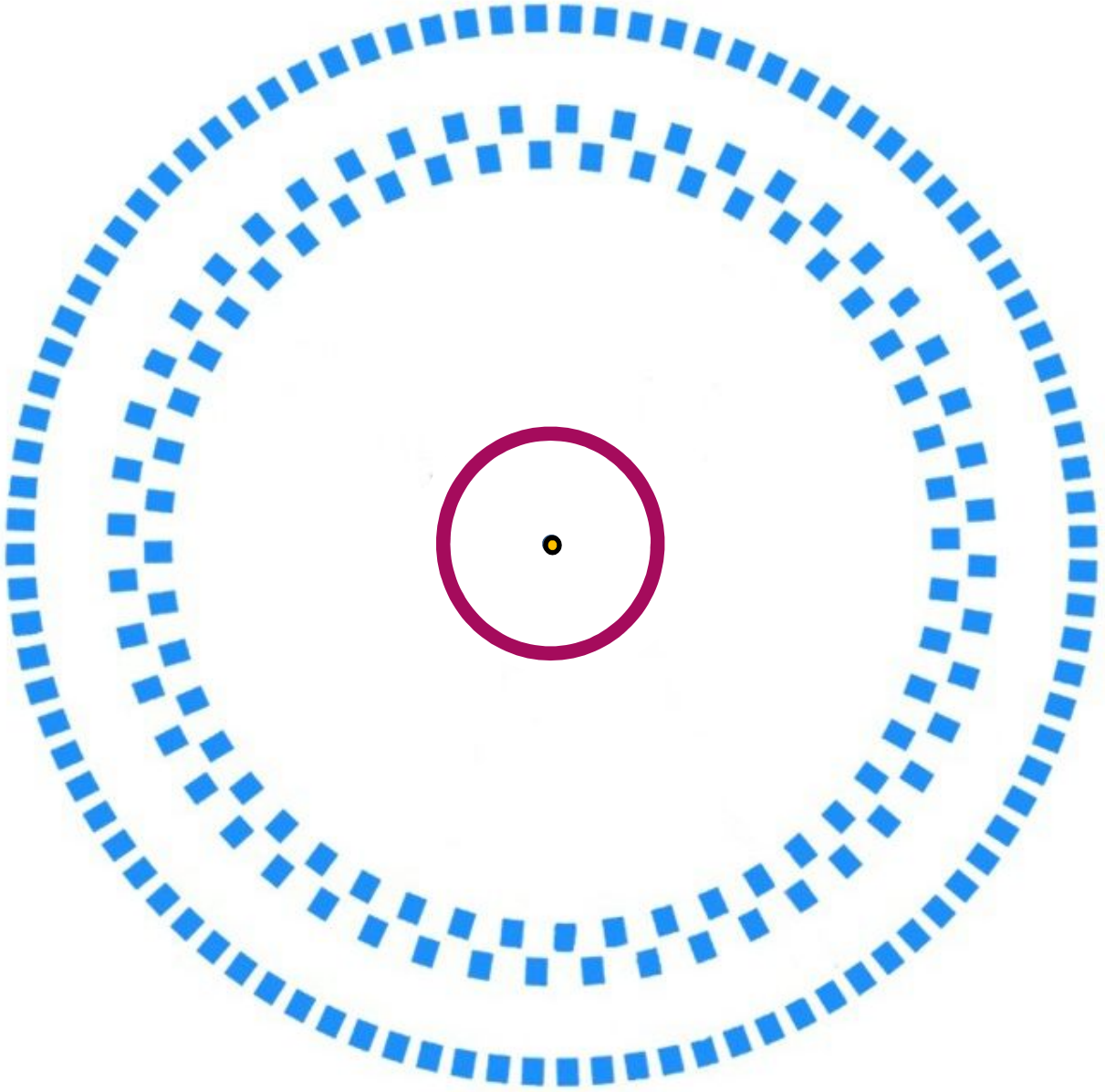

tot sum
×10^3
TOTs (ToT=16 to 27)
TOTsum
Entries 1.918058e+08
Mean 17.91
RMS 12.15
TOTs (ToT=14 to 27)
tot sum
TOTsum
Entries 3458814
Mean 19.56
RMS 11.96
Time (ns)





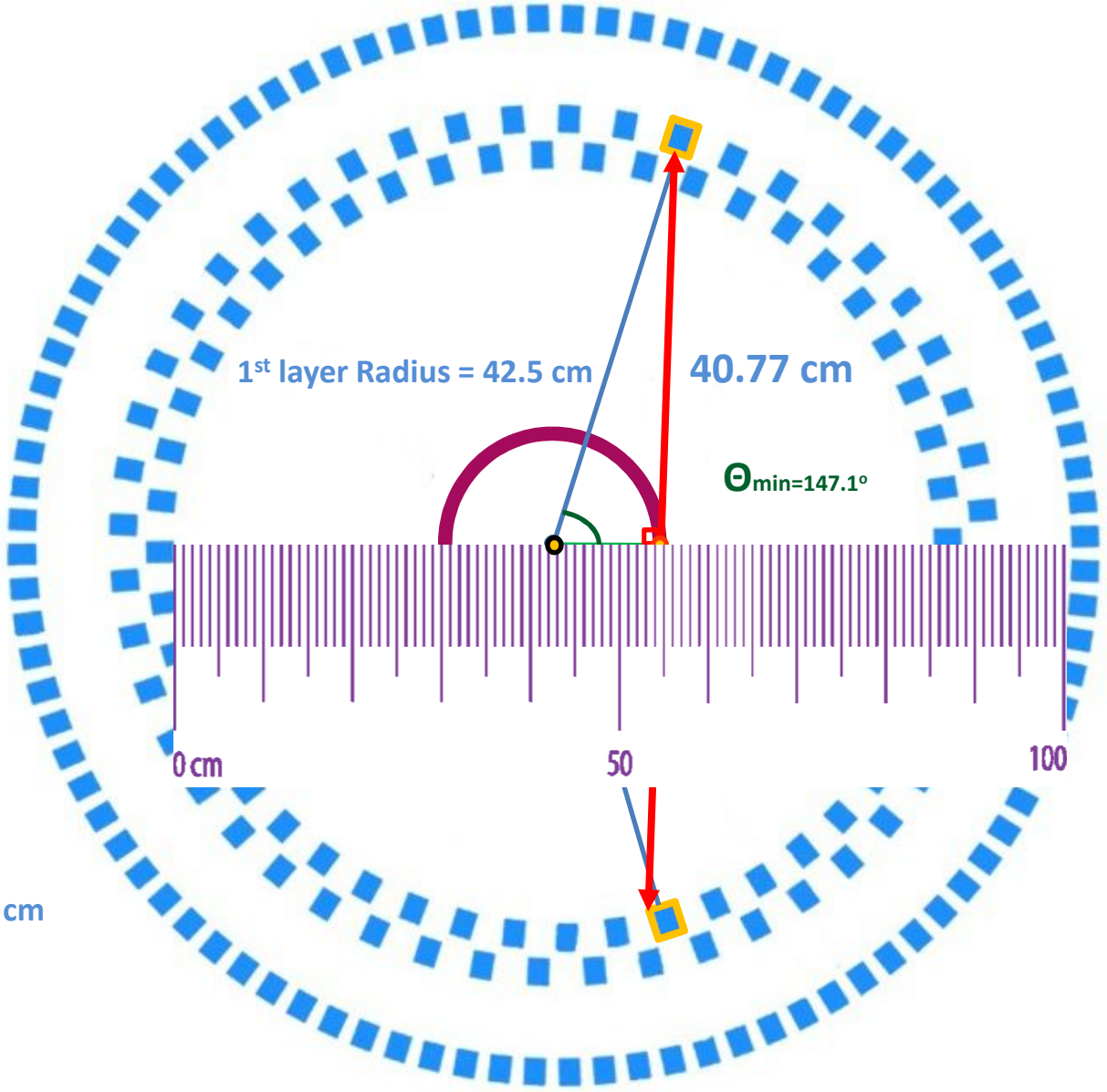

kapton foil
Radioactive source

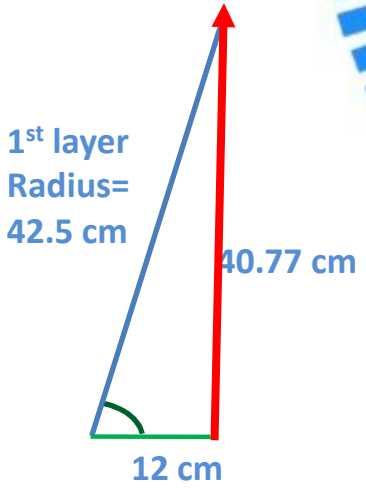
Run-6



1st layer Radius = 42.5 cm

Run-6

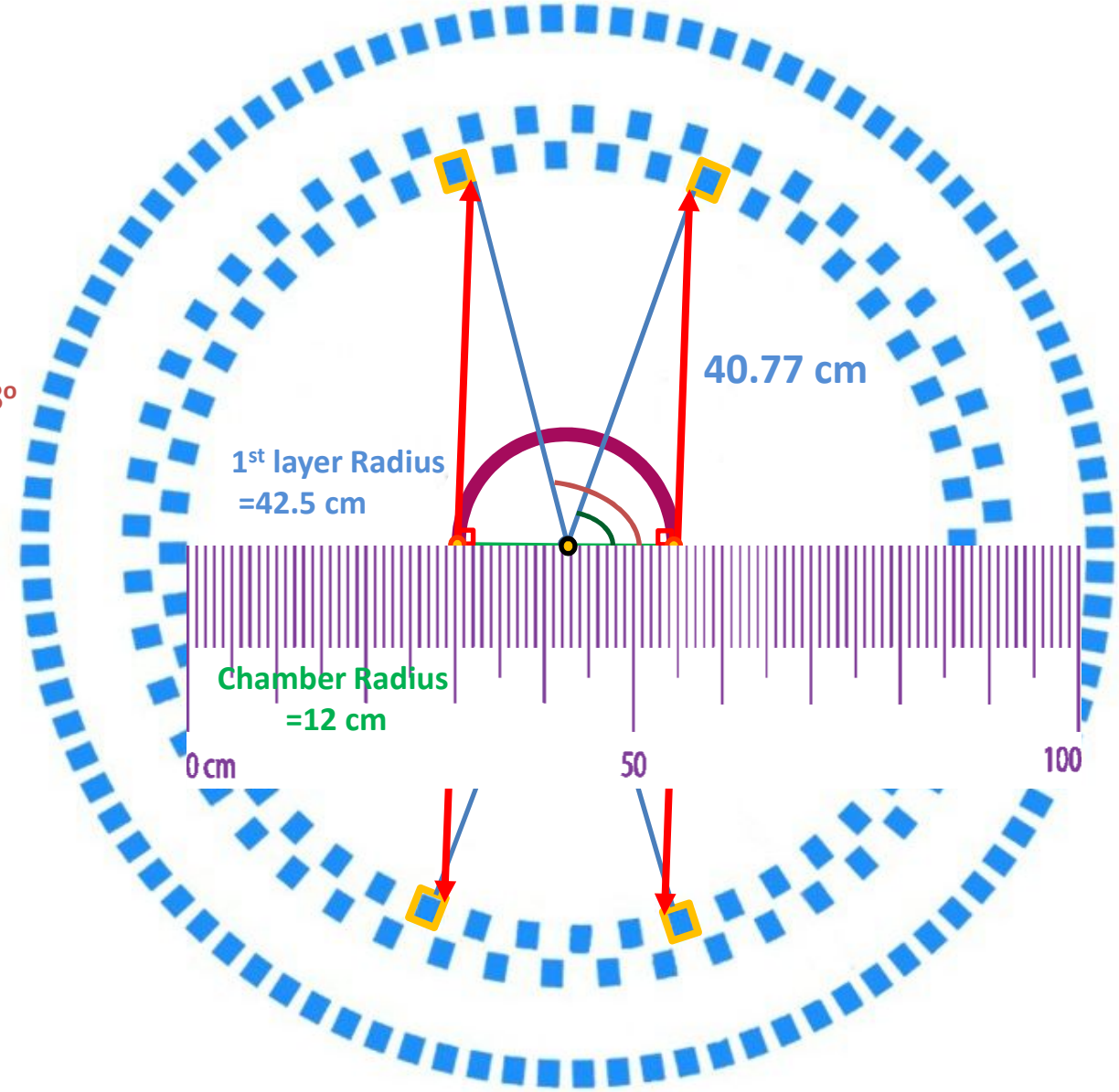




1st layer

Run-6

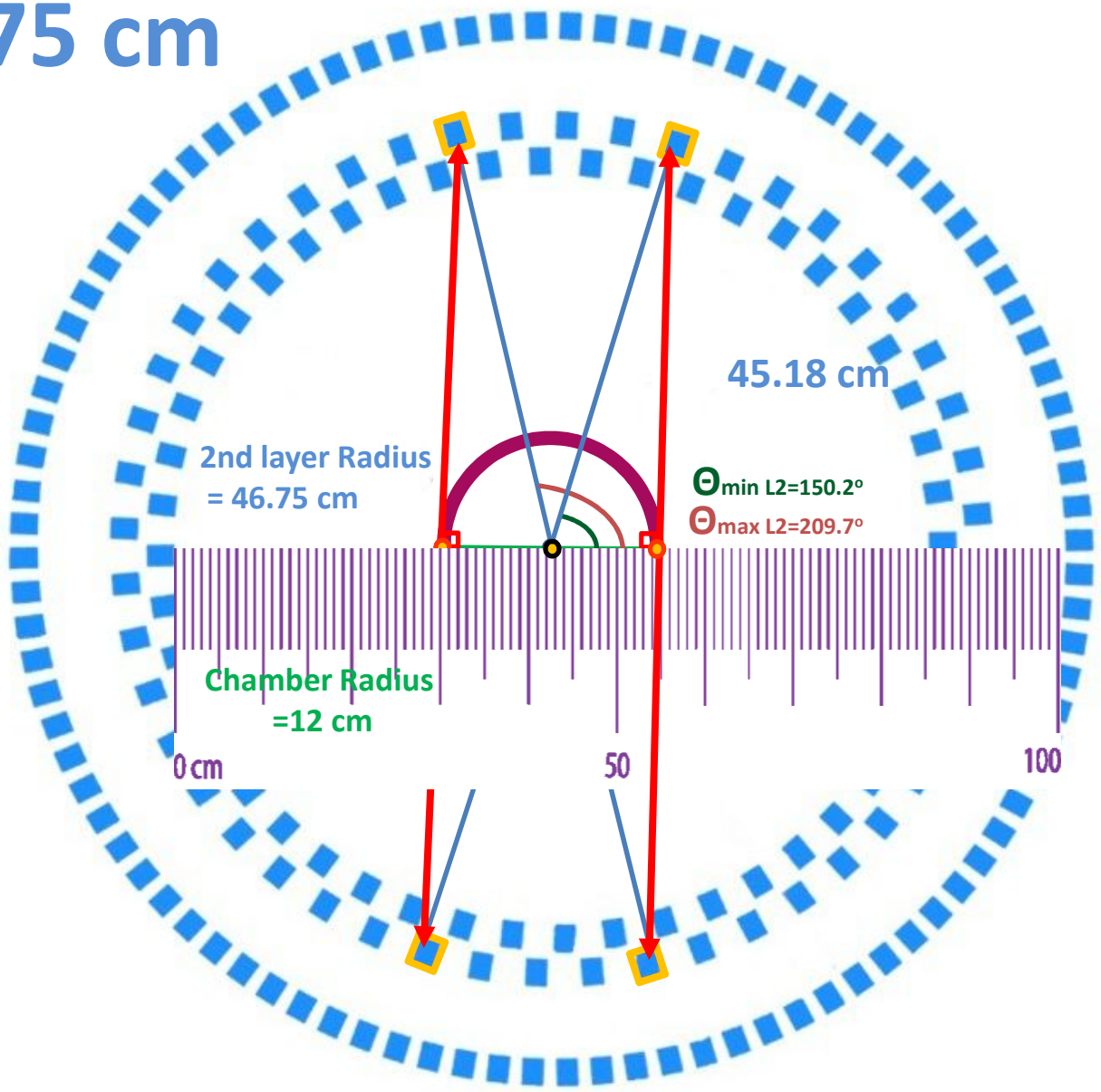
$\Theta_{max}=212.8^{o}$



$\Theta_{min}=147.1^{o}$

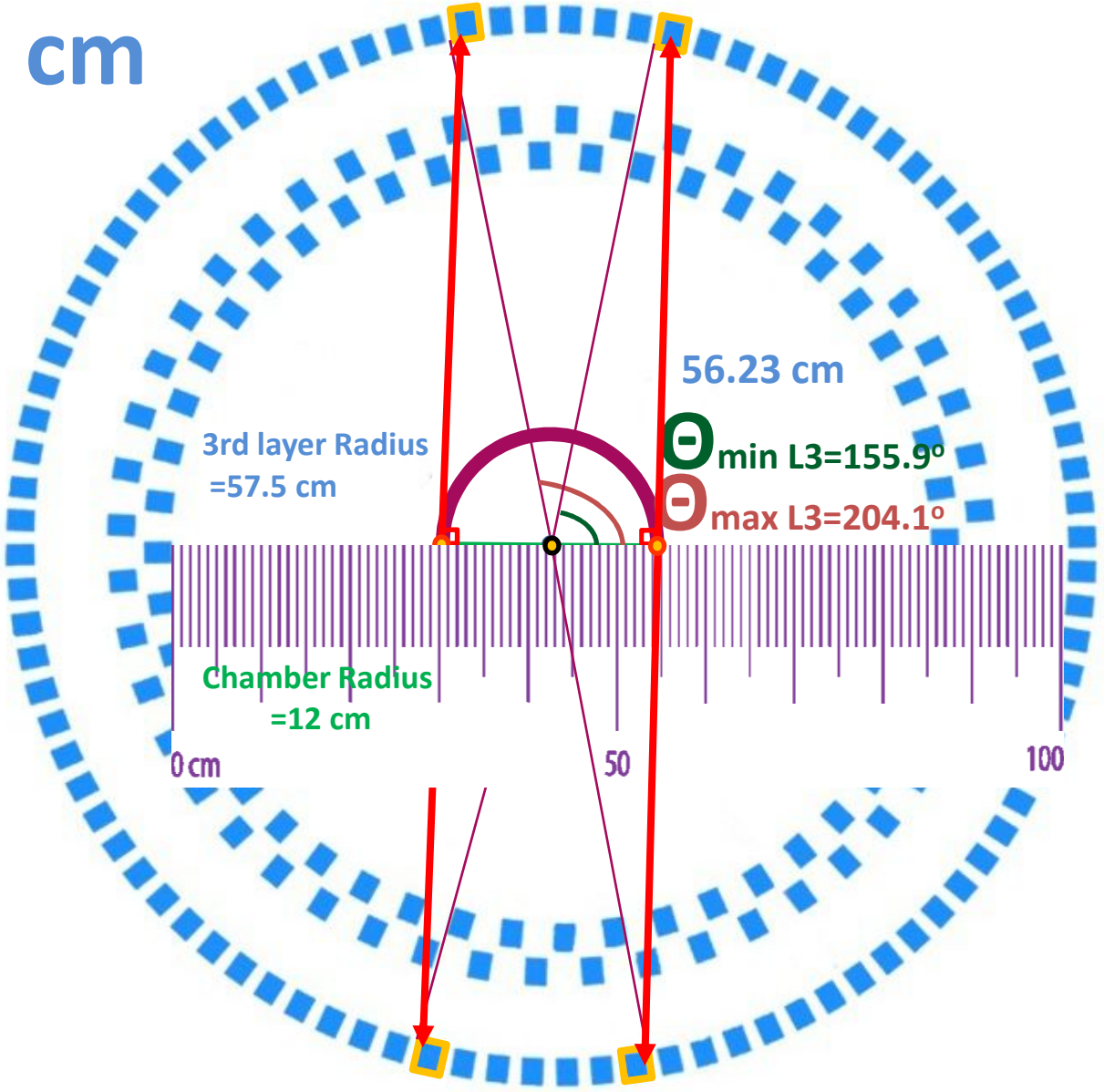
2nd layer Radius
= 46.75 cm

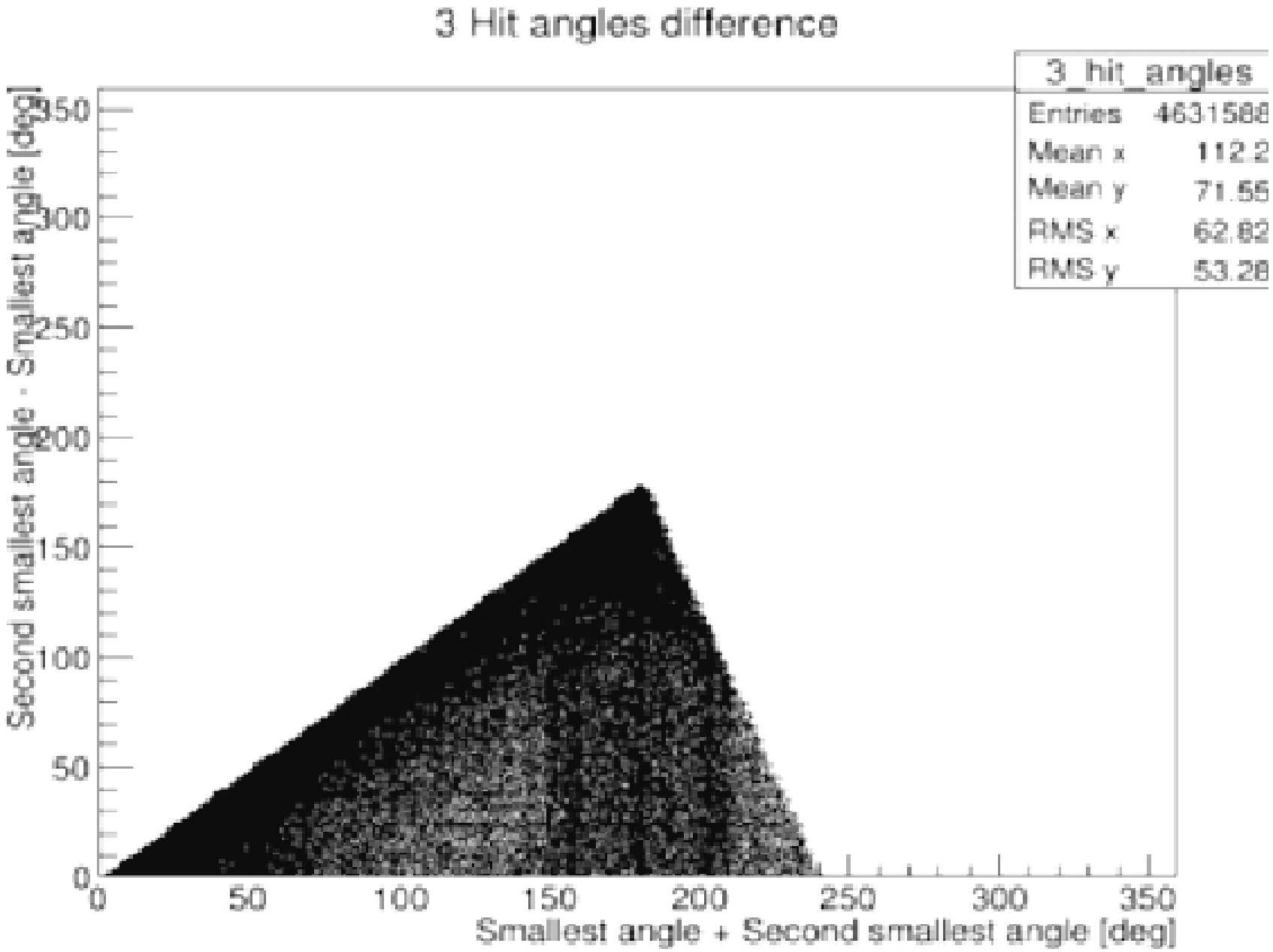
Run-6

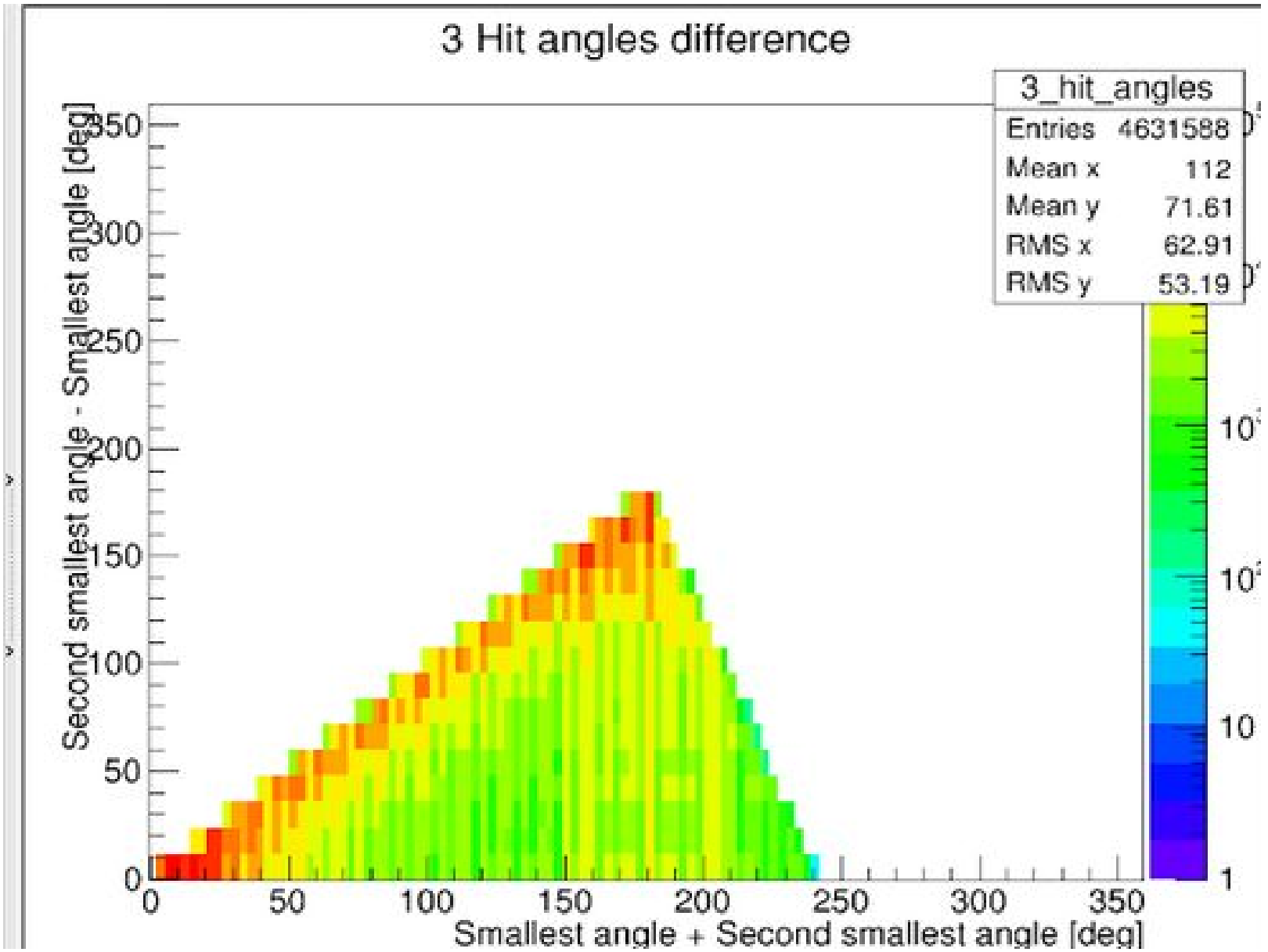


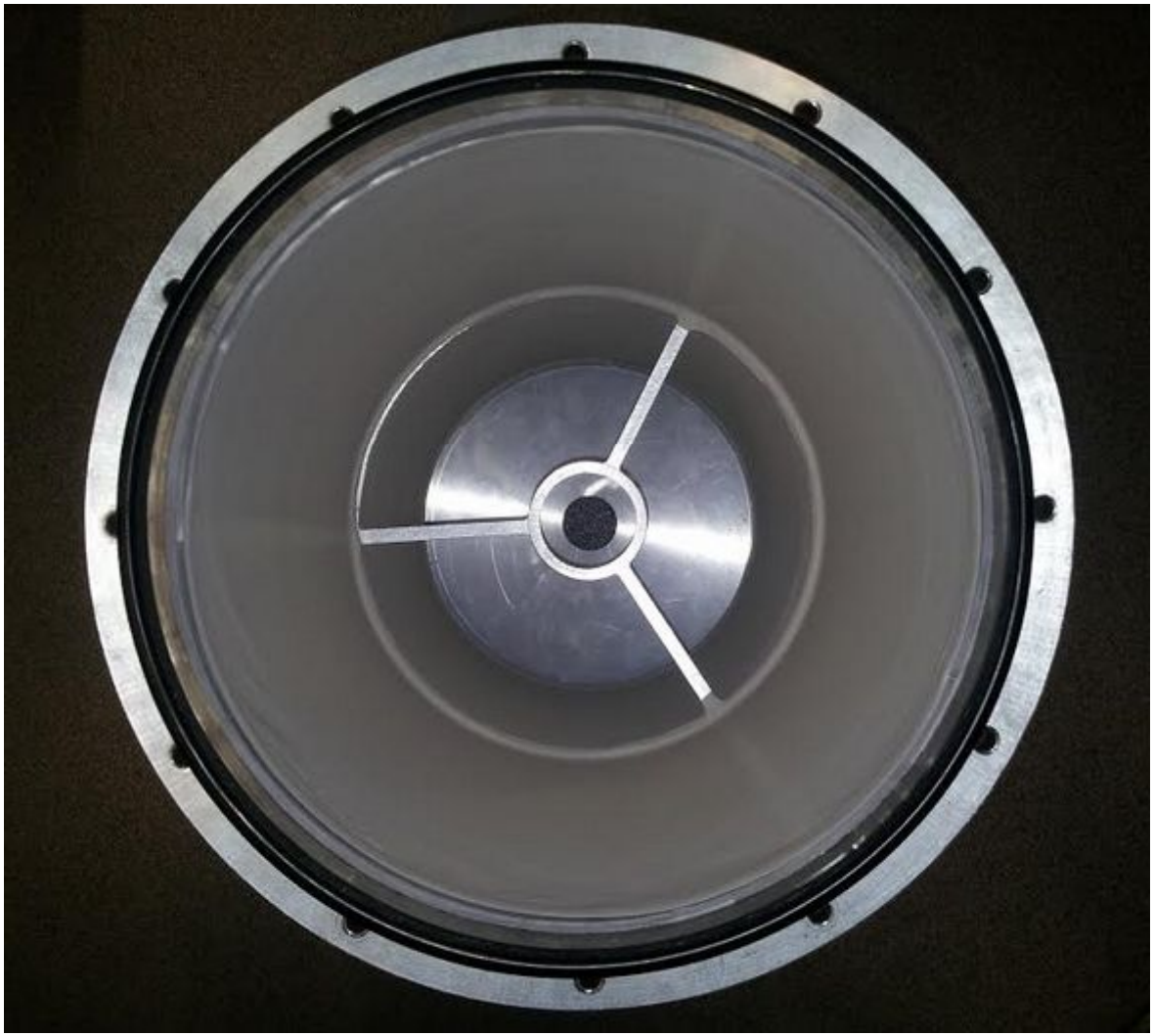
3rd layer Radius =57.5 cm

Run-6

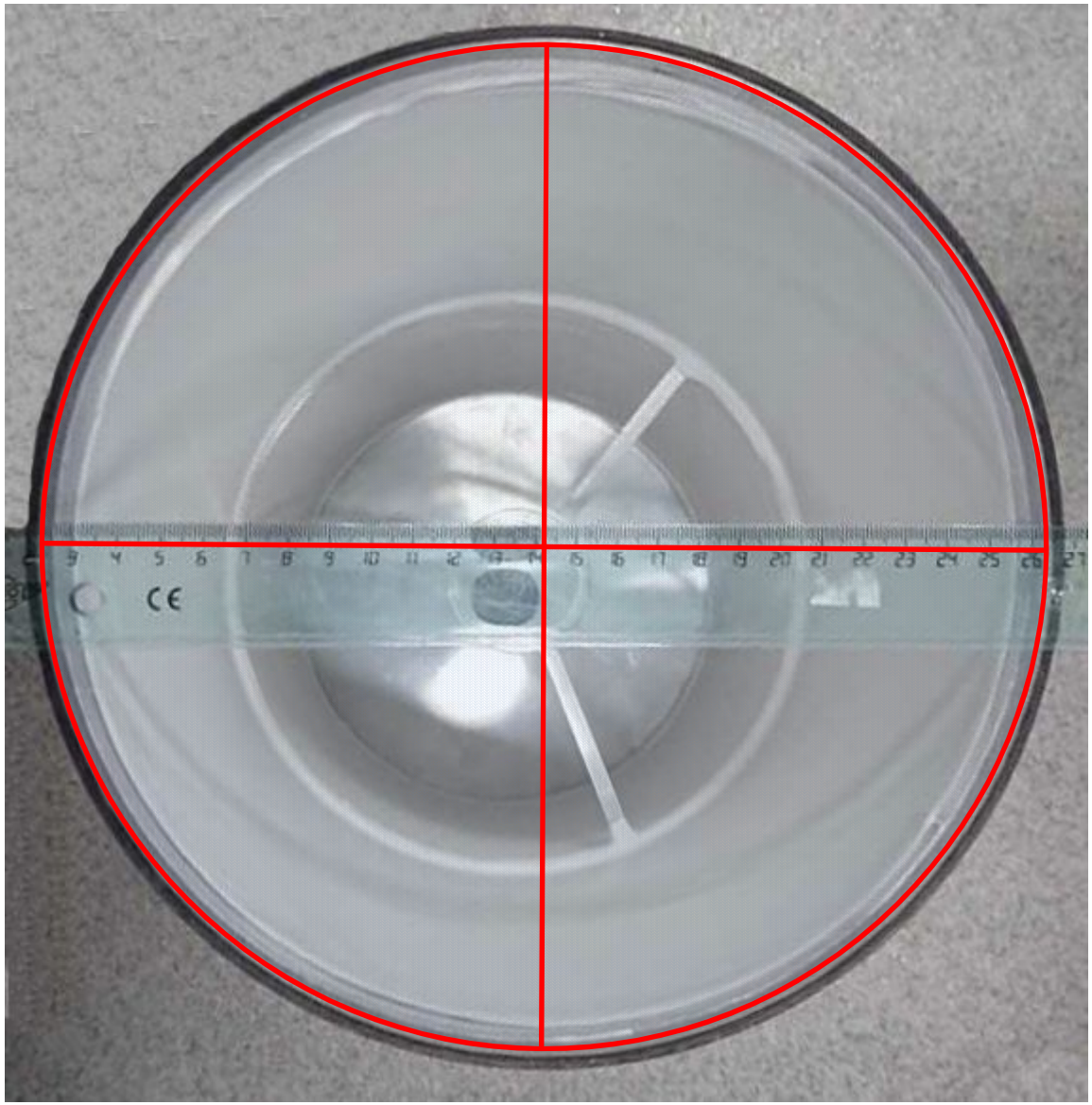



3 Hit angles difference
3_hit_angles
Entries 4631588
Mean x 112.2
Mean y 71.55
RMS x 62.82
RMS y 53.28
Second smallest angle - Smallest angle [deg]
Smallest angle + Second smallest angle [deg]
0
50
100
150
200
250
300
350

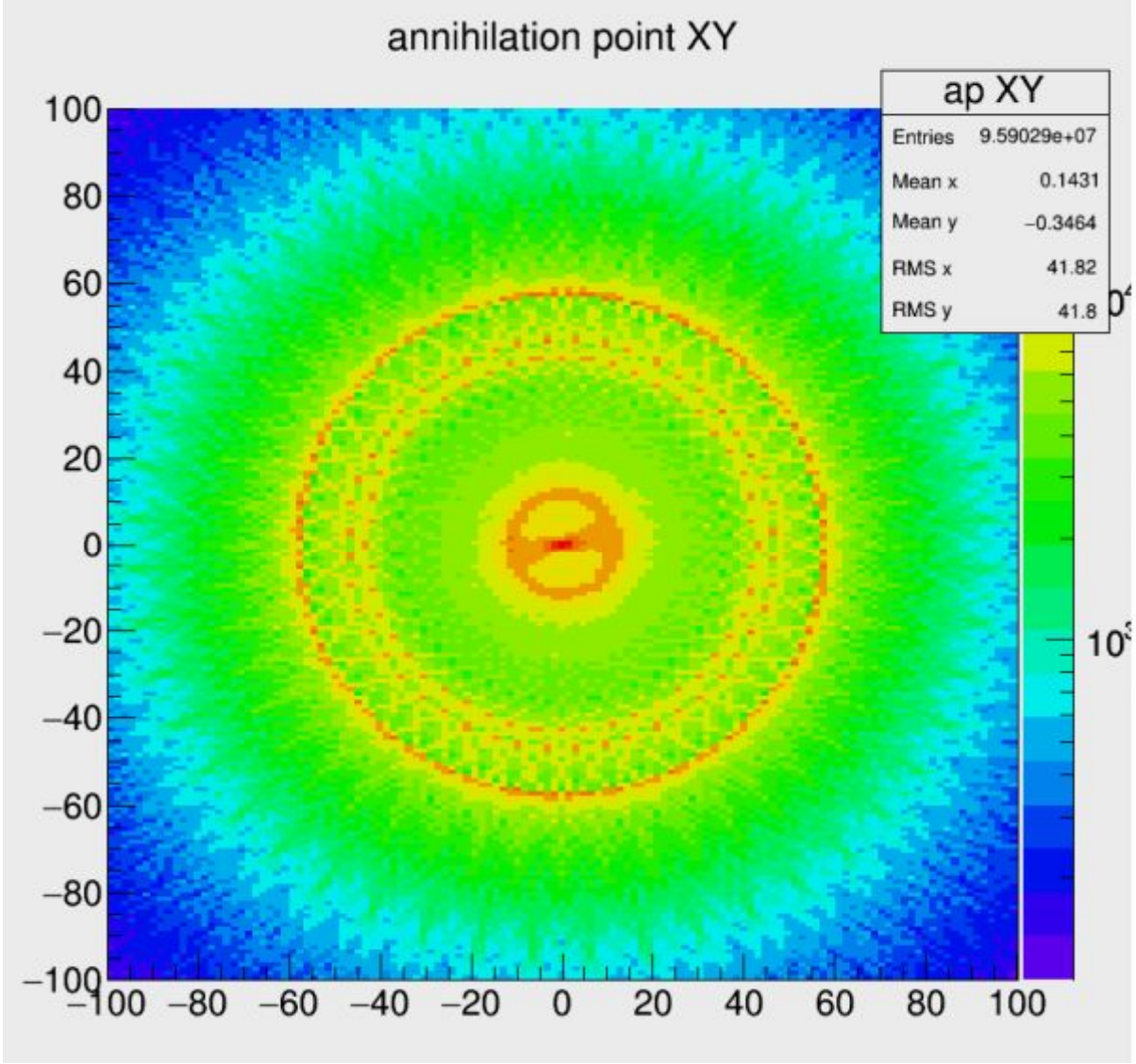

3 Hit angles difference
3_hit_angles
Entries 4631588
Mean x 112
Mean y 71.61
RMS x 62.91
RMS y 53.19
Second smallest angle - Smallest angle [deg]
Smallest angle + Second smallest angle [deg]
0
50
100
150
200
250
300
350
1
10



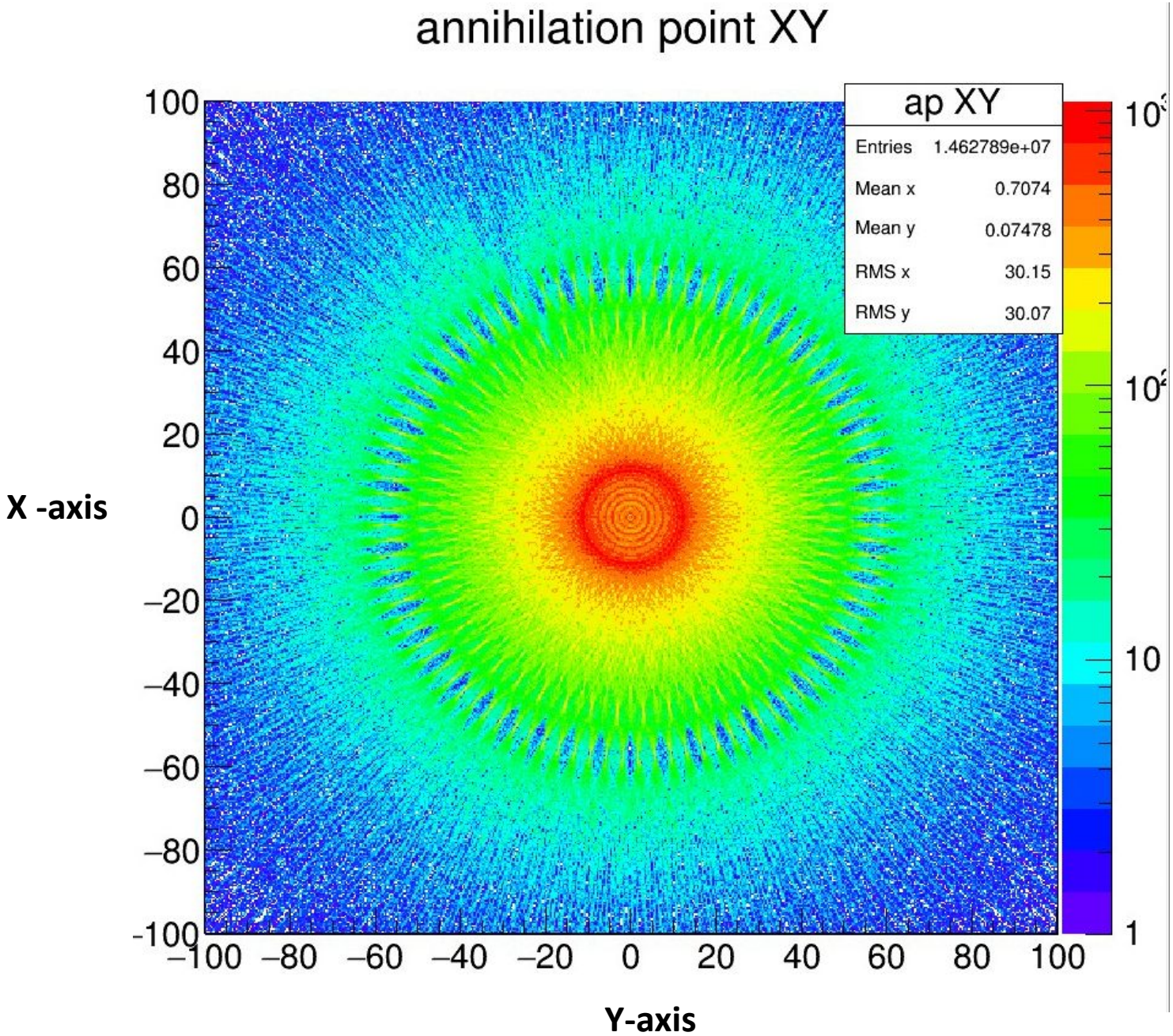
Large chamber diameter=24 cm



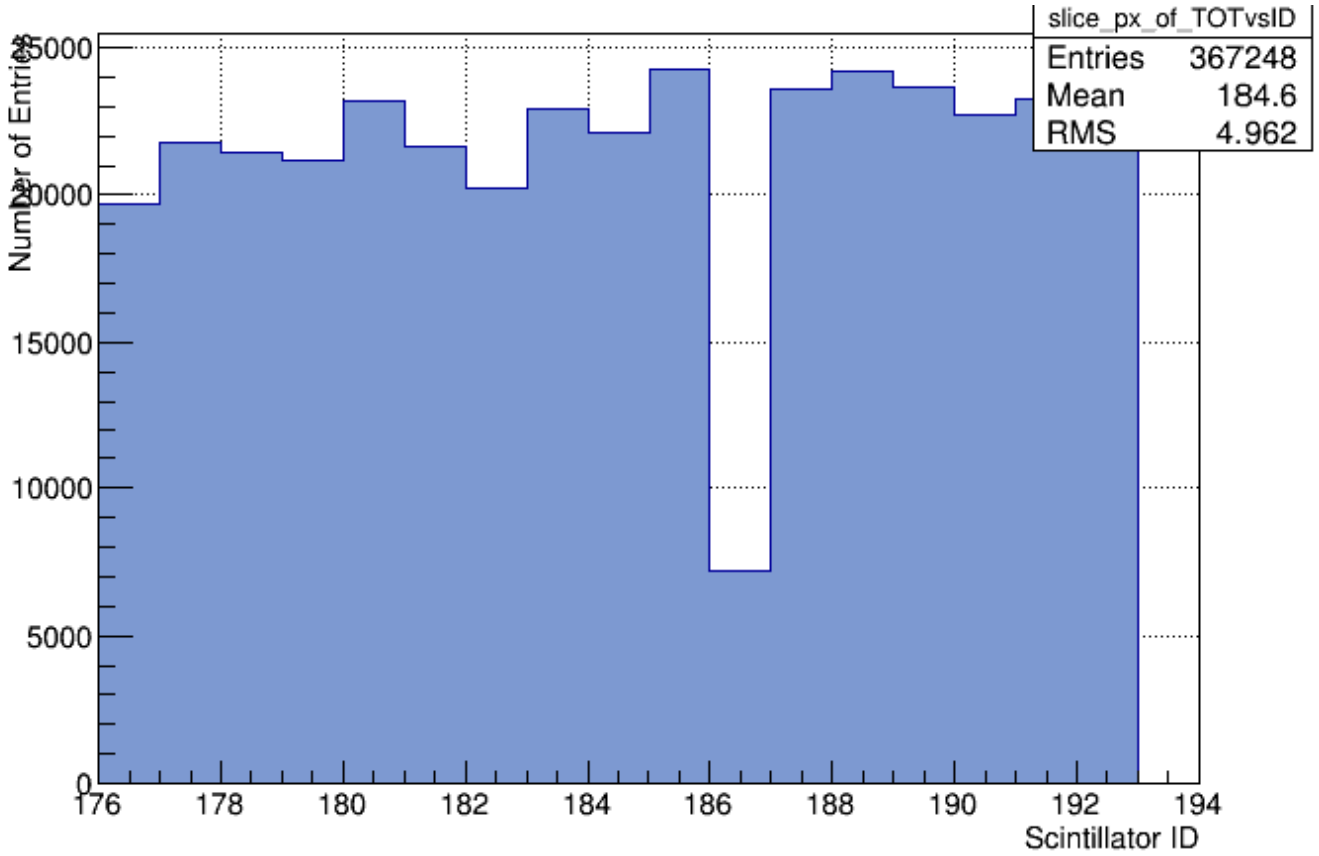
X -axis


annihilation point XY
ap XY
Entries 9.59029e+07
Mean x 0.1431
Mean y −0.3464
RMS x 41.82
RMS y 41.8
100
80
60
40
20
0
−20
−40
−60
−80
−100
−100 −80 −60 −40 −20 0 20 40 60 80 100

Y-axis

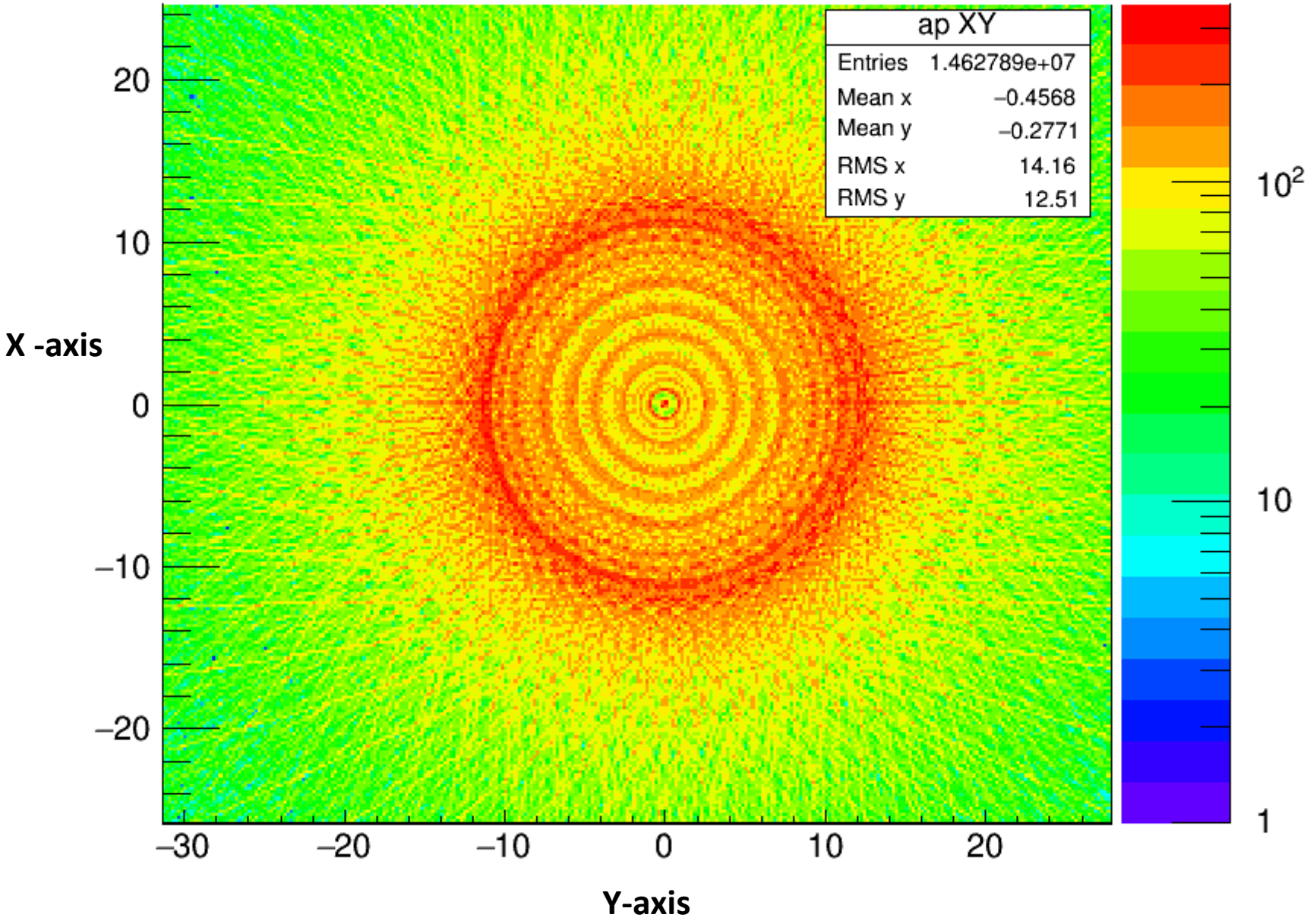

annihilation point XY
ap XY
Entries 1.462789e+07
Mean x 0.7074
Mean y 0.07478
RMS x 30.15
RMS y 30.07
100
80
60
40
20
0
−20
−40
−60
−80
-100
−100 −80 −60 −40 −20 0 20 40 60 80 100
10
1
X -axis
Y-axis

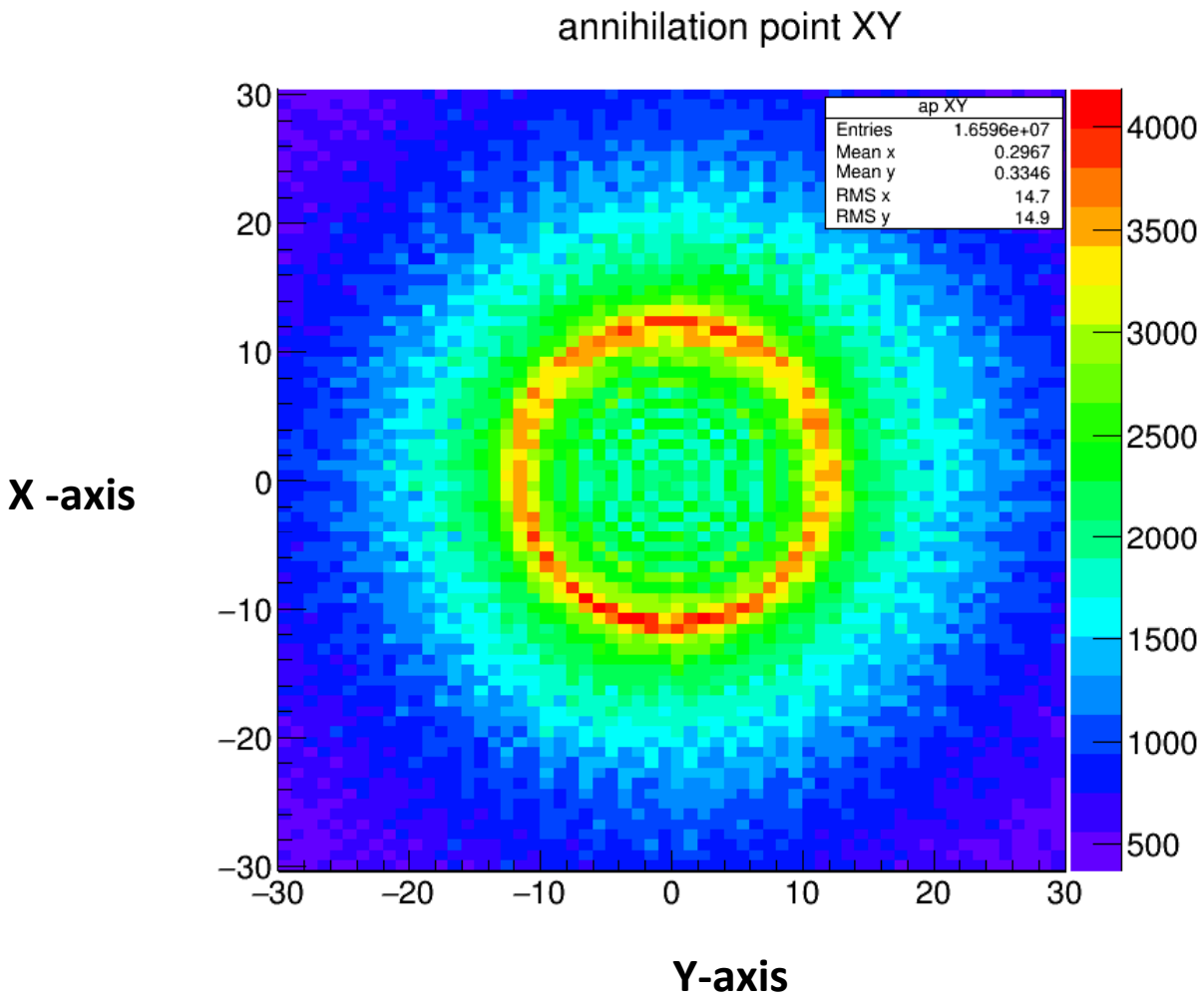
The projection



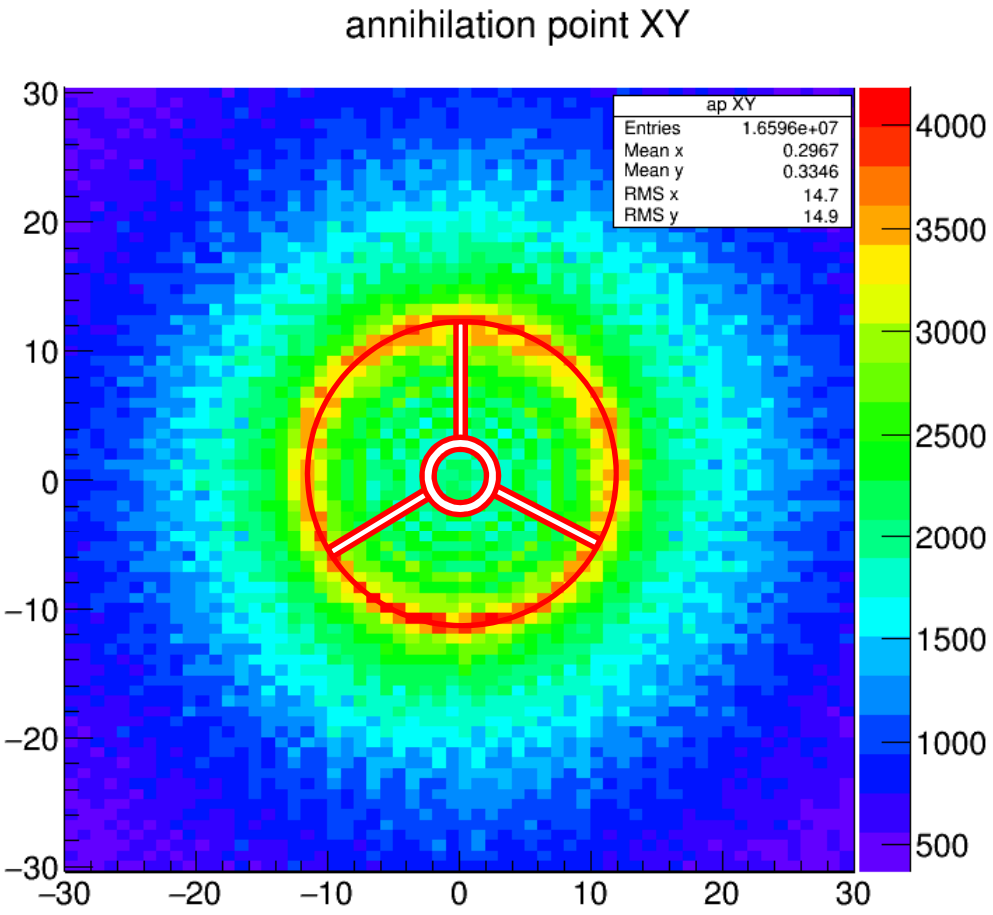
186

annihilation point XY





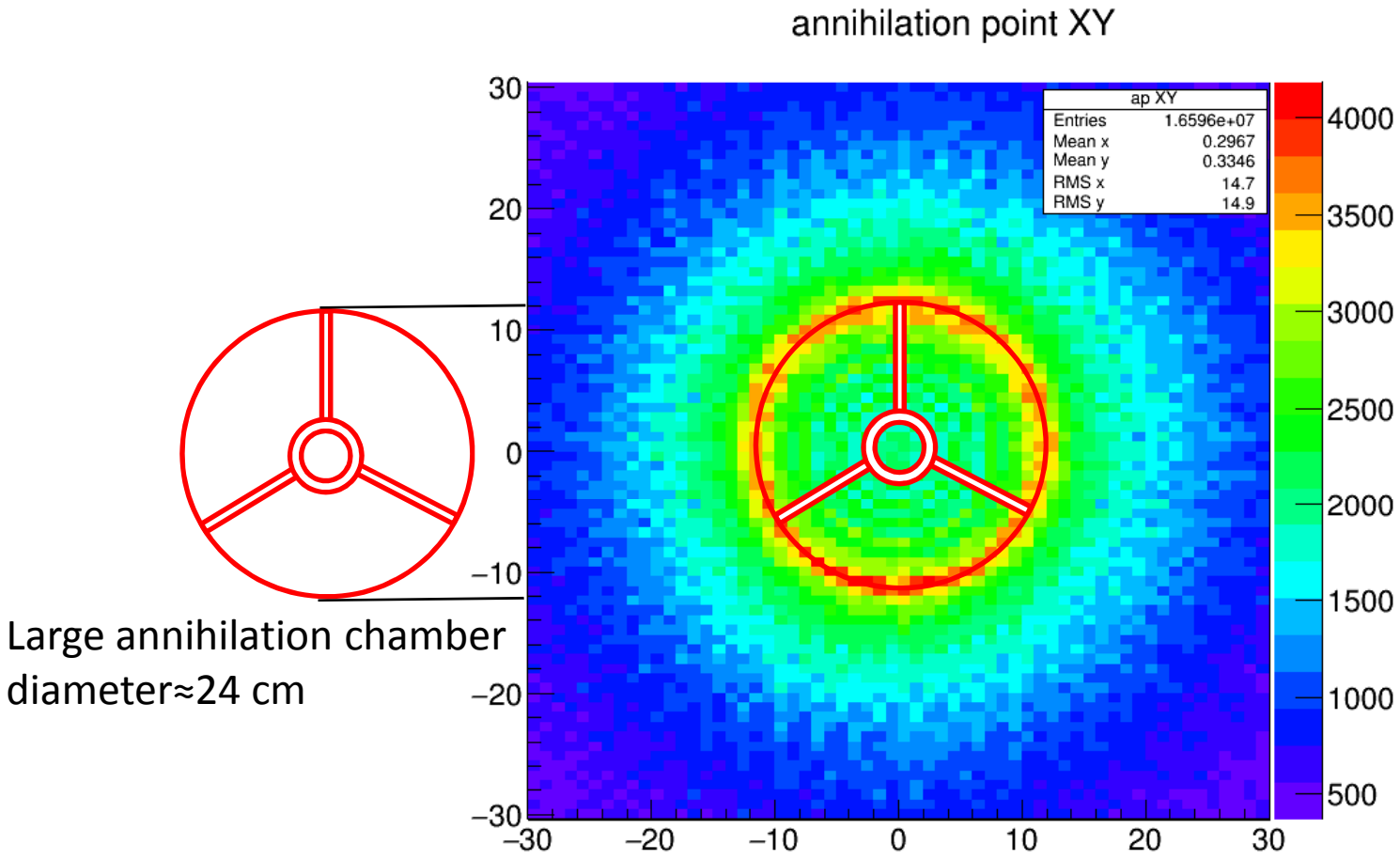
The tomographic image of the annihilation target cylinder (Run-6) obtained using Ps →2ɣ annihilations (xy view) transverse view, |z| > 5 cm



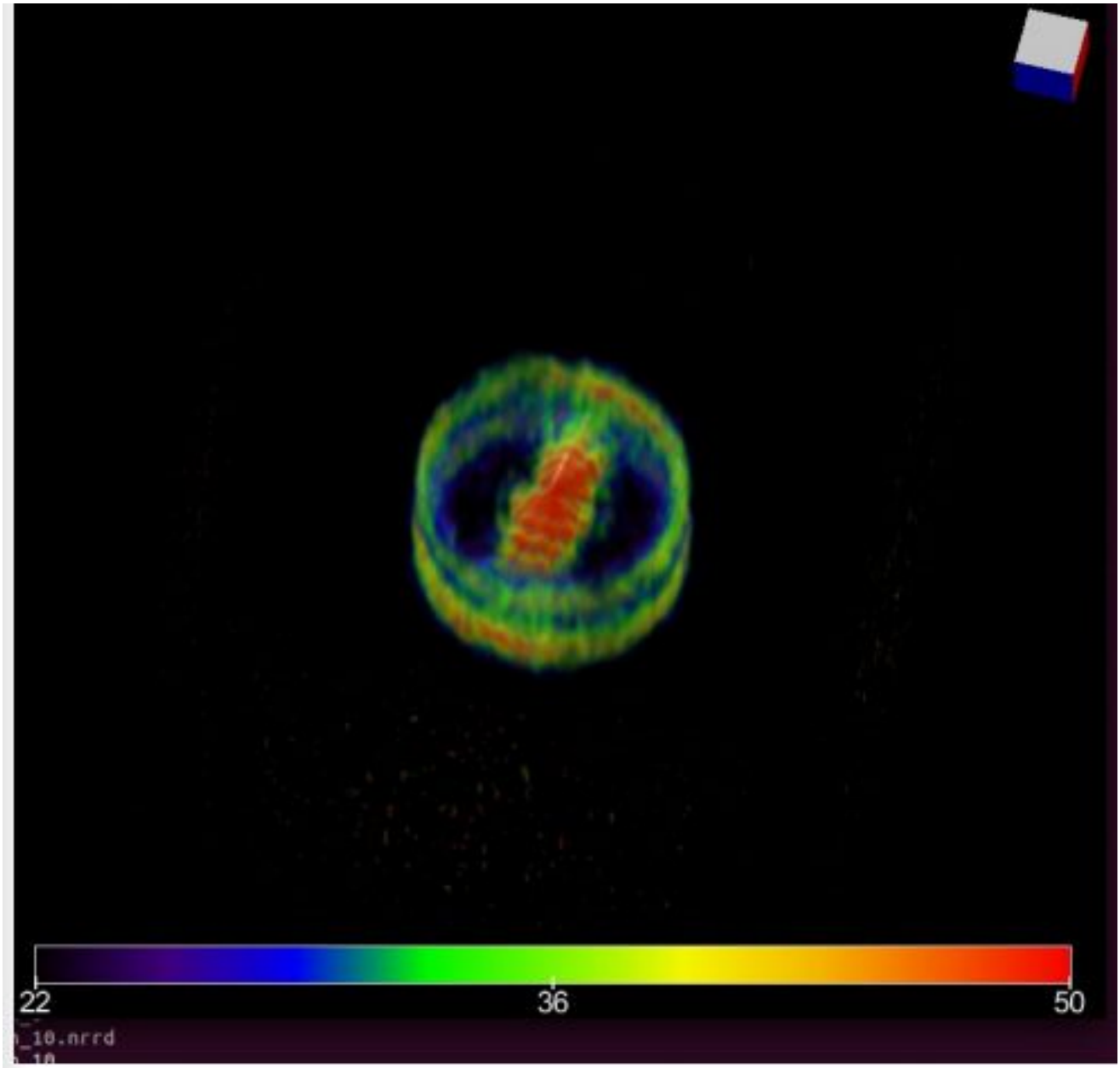
X -axis

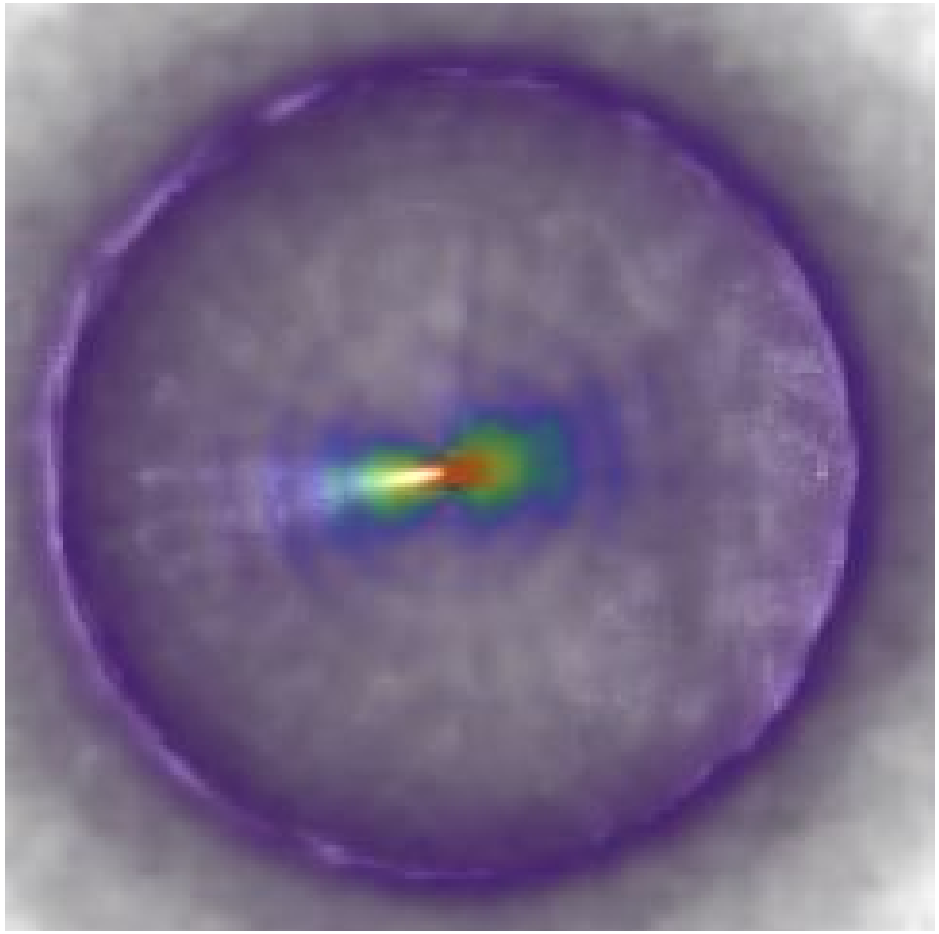
Y-axis

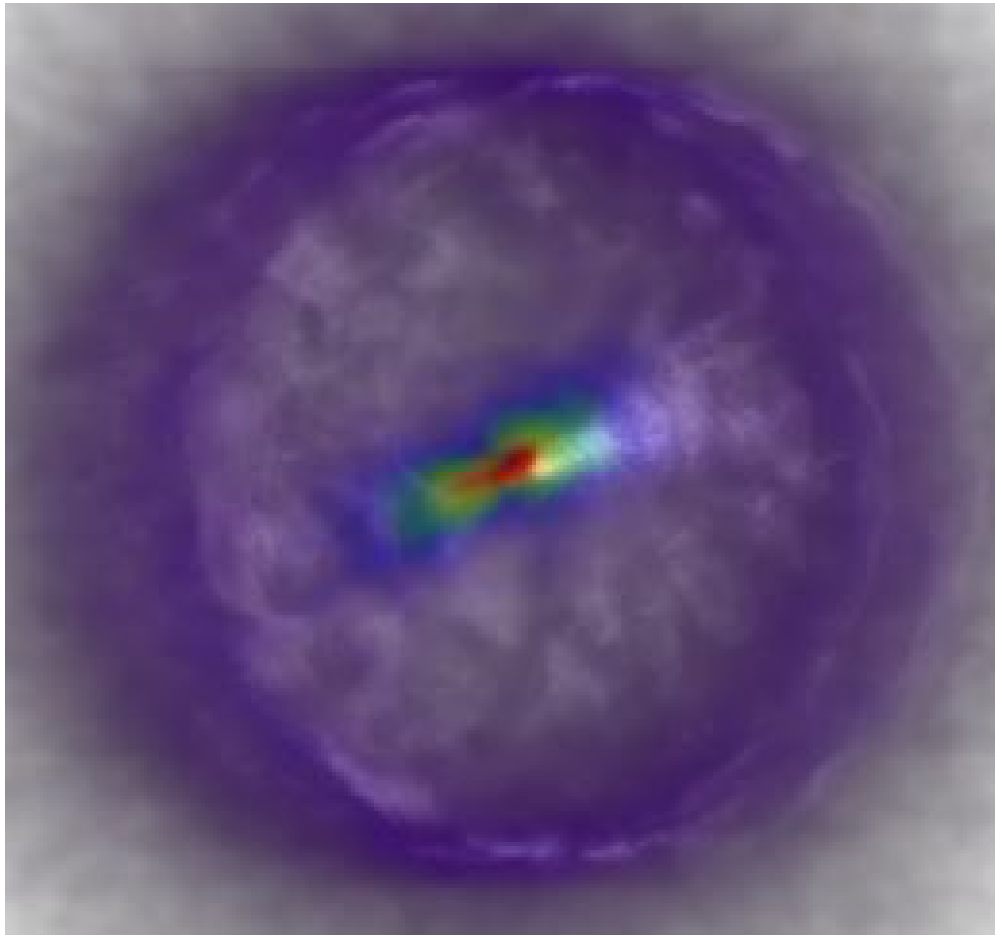
The tomographic image of the annihilation target cylinder obtained using Ps →2ɣ annihilations (xy view) transverse view, |z| > 5 cm

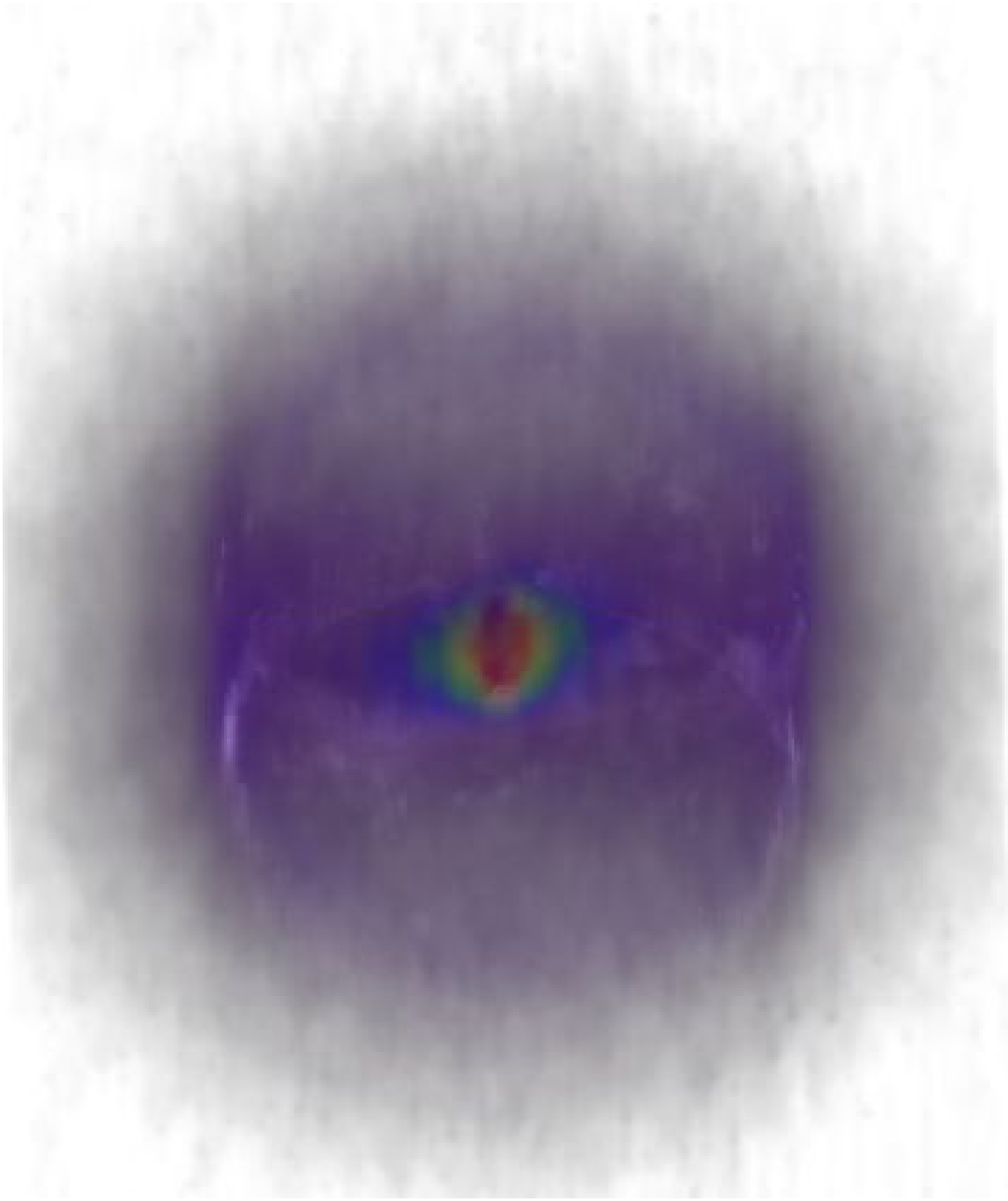


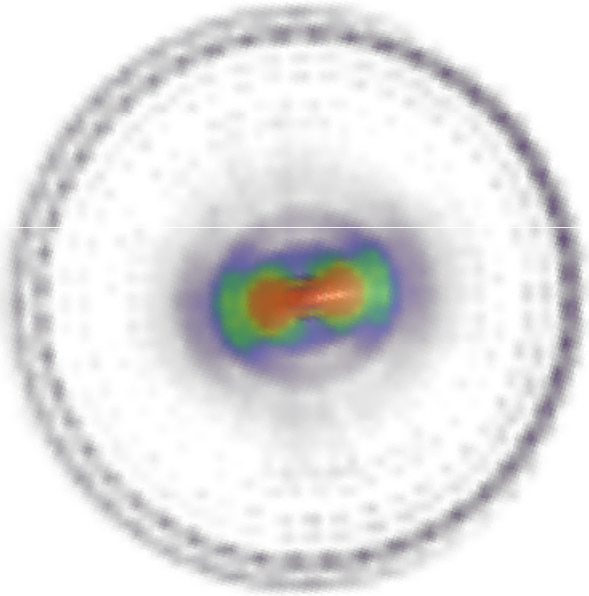
The tomographic image of the annihilation target cylinder obtained using Ps →2ɣ annihilations (xy view) transverse view, |z| > 5 cm

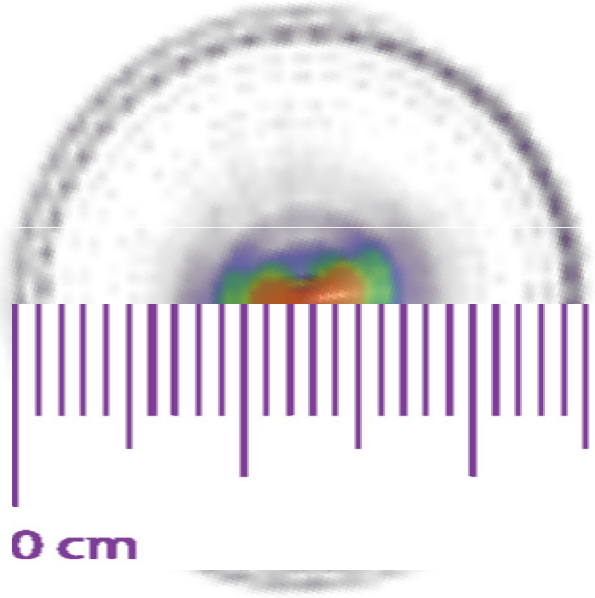

22
36
50
_10.nrrd

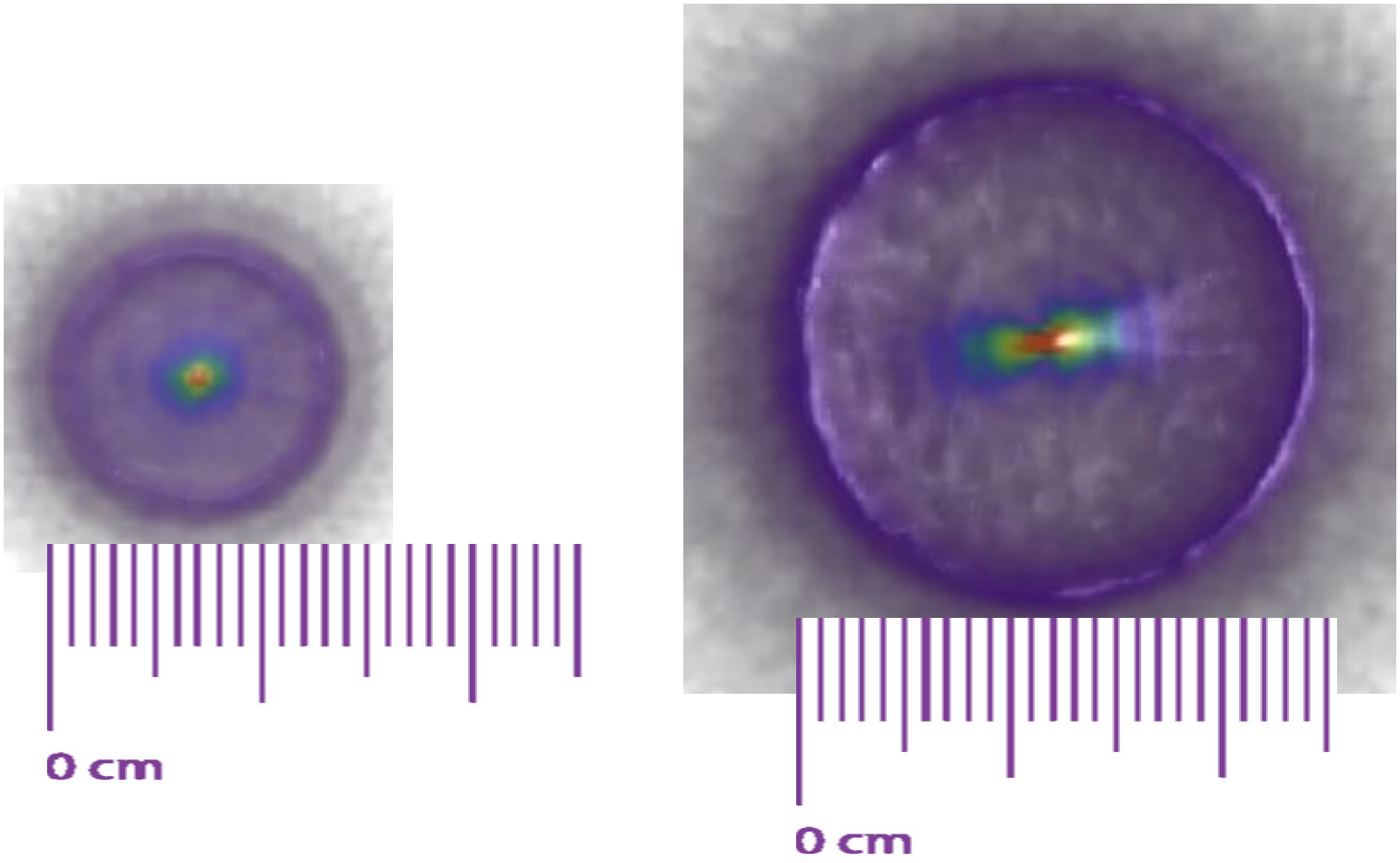


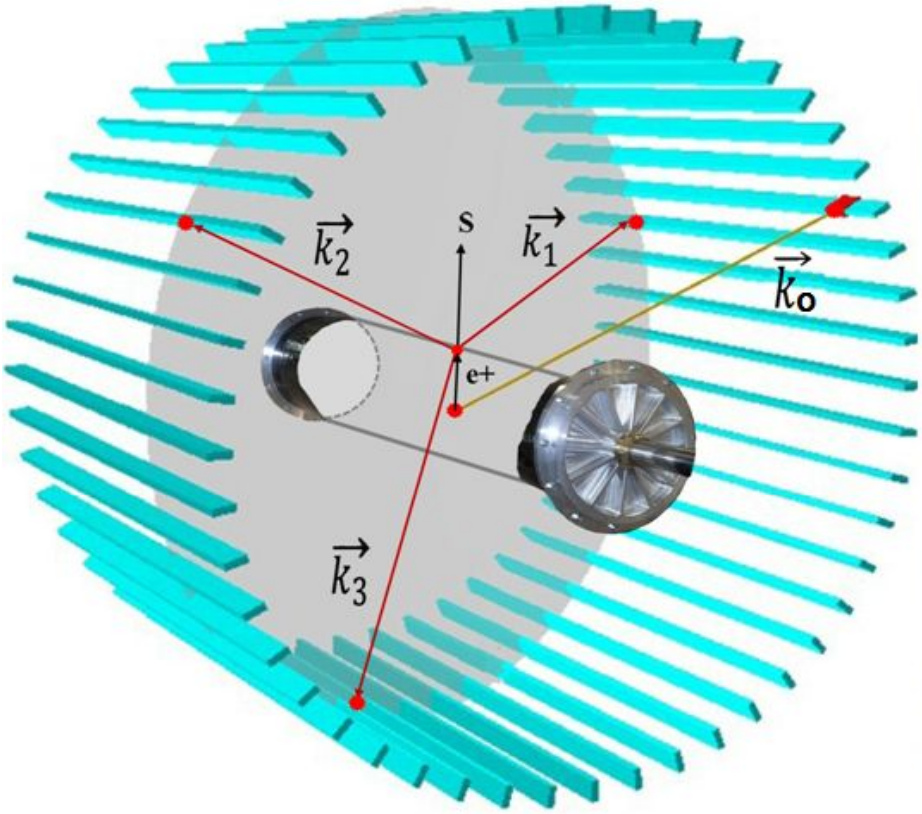


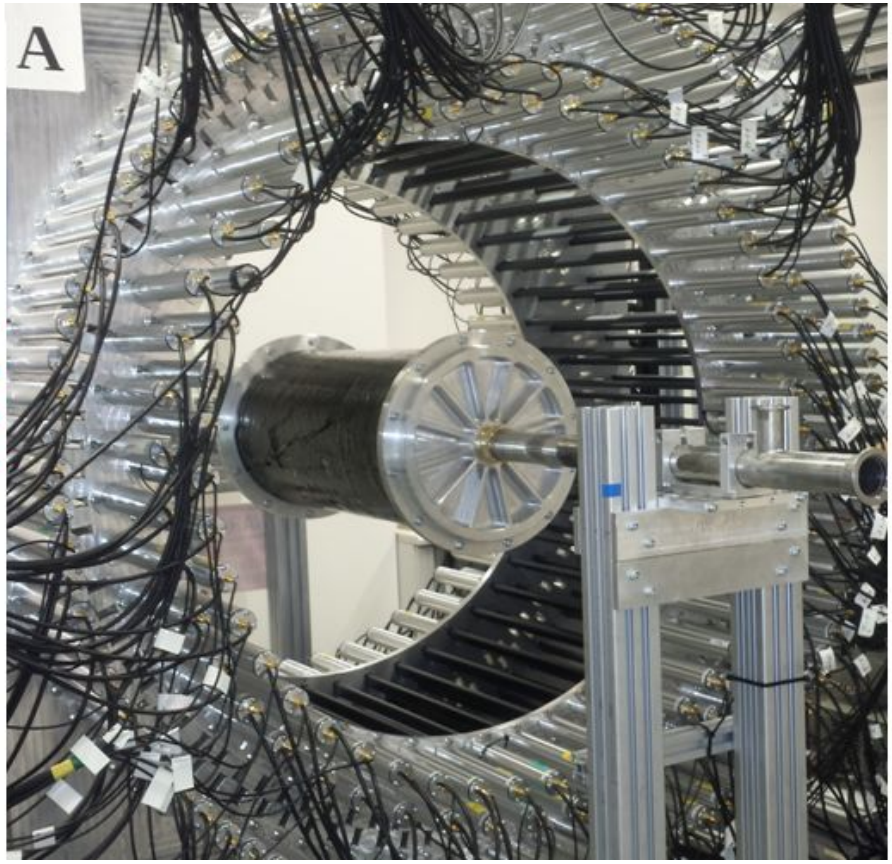




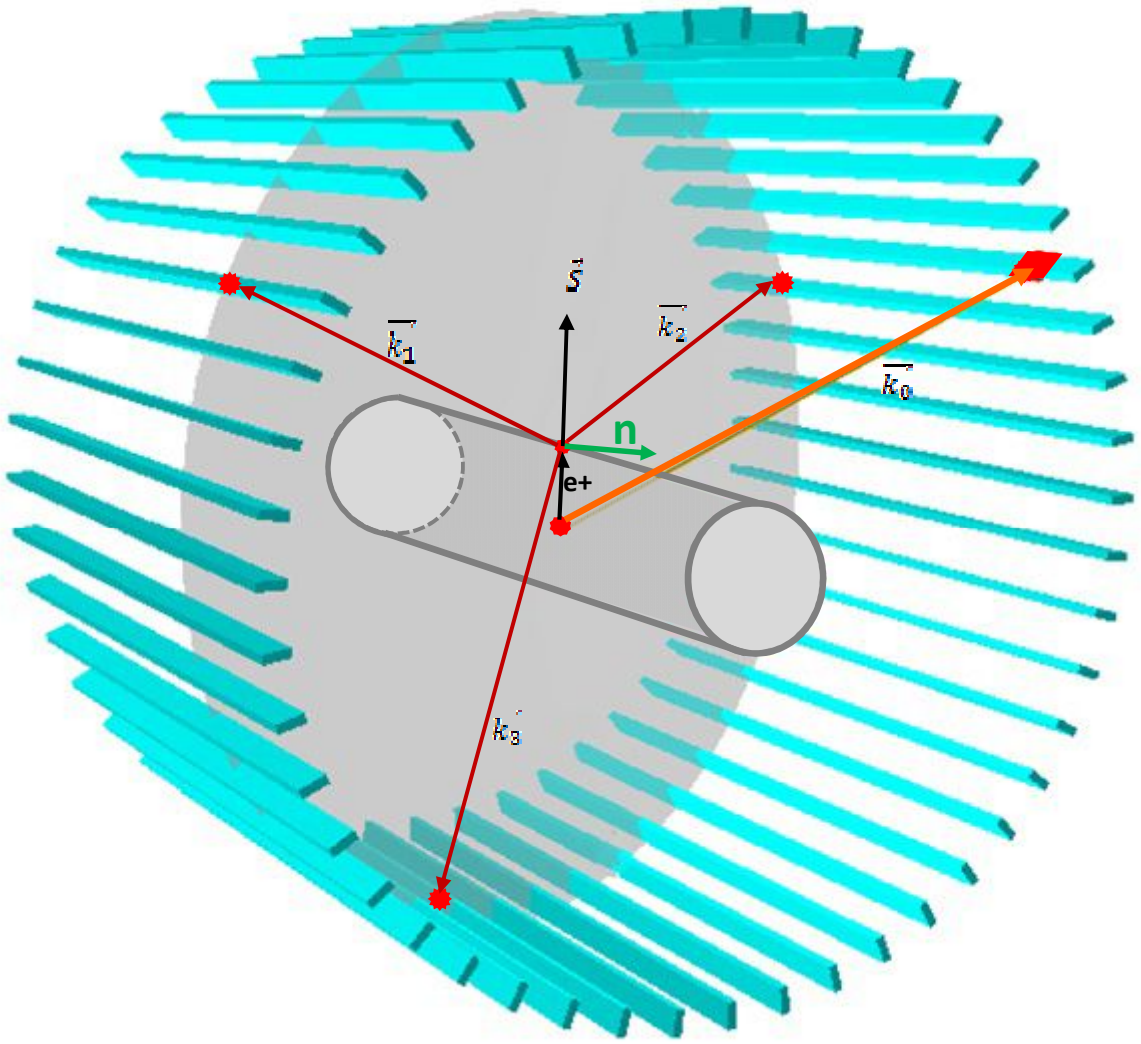

0 cm


0 cm
0 cm

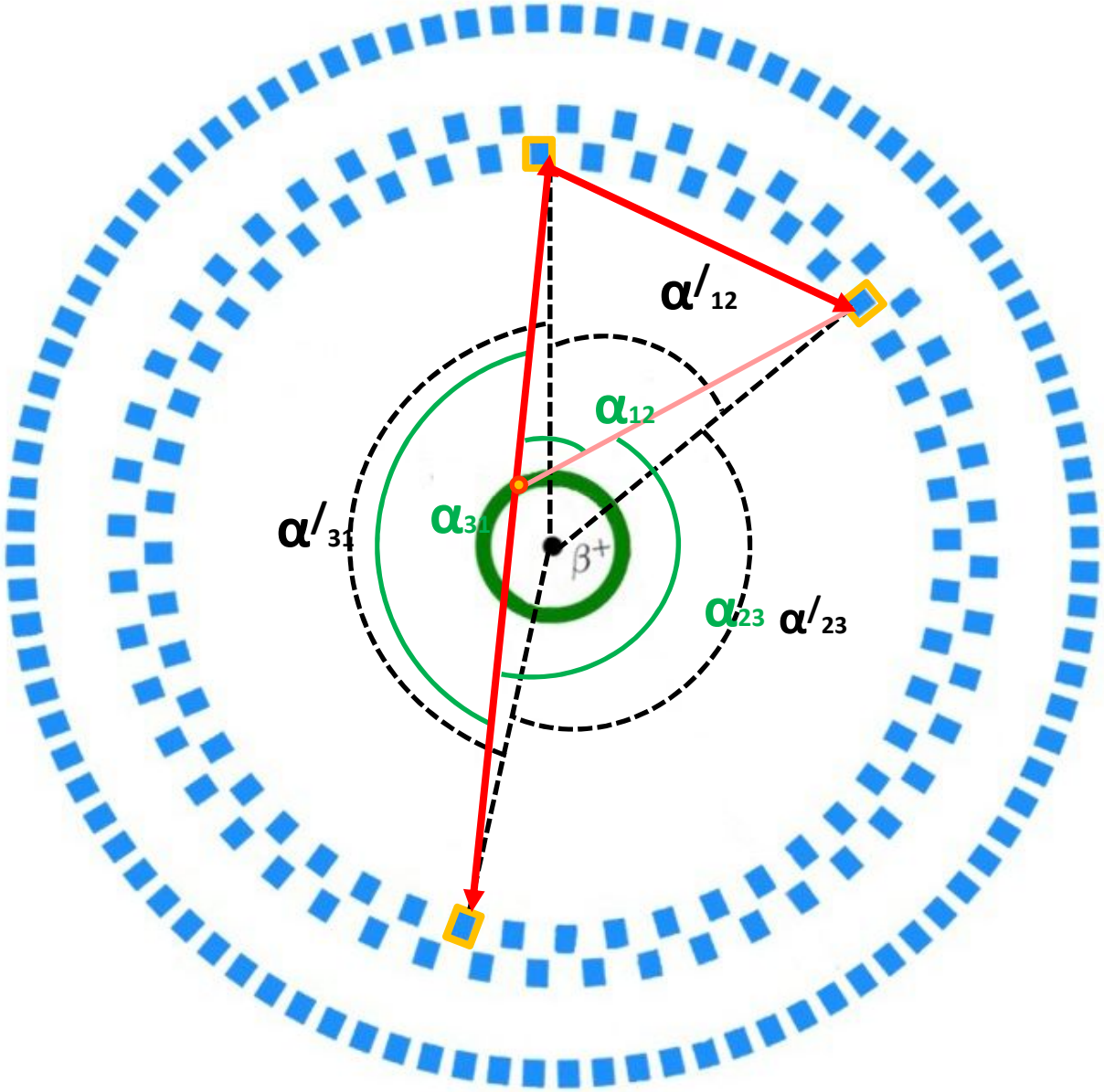


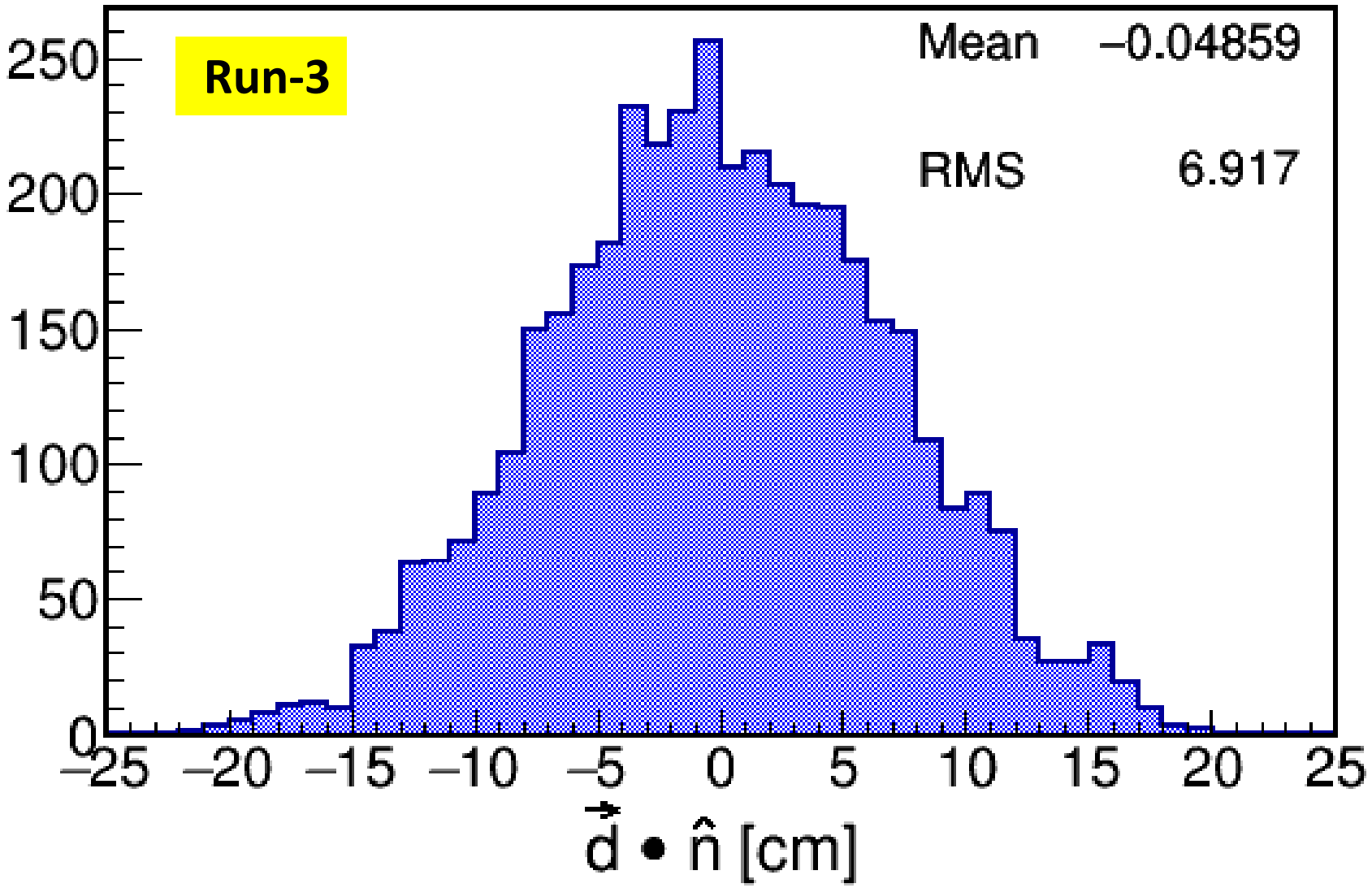


Determination the distribution of the reconstructed origin decay points of 3 annihilation events & the distance between the iso center of J-PET and the 3γ decay planes

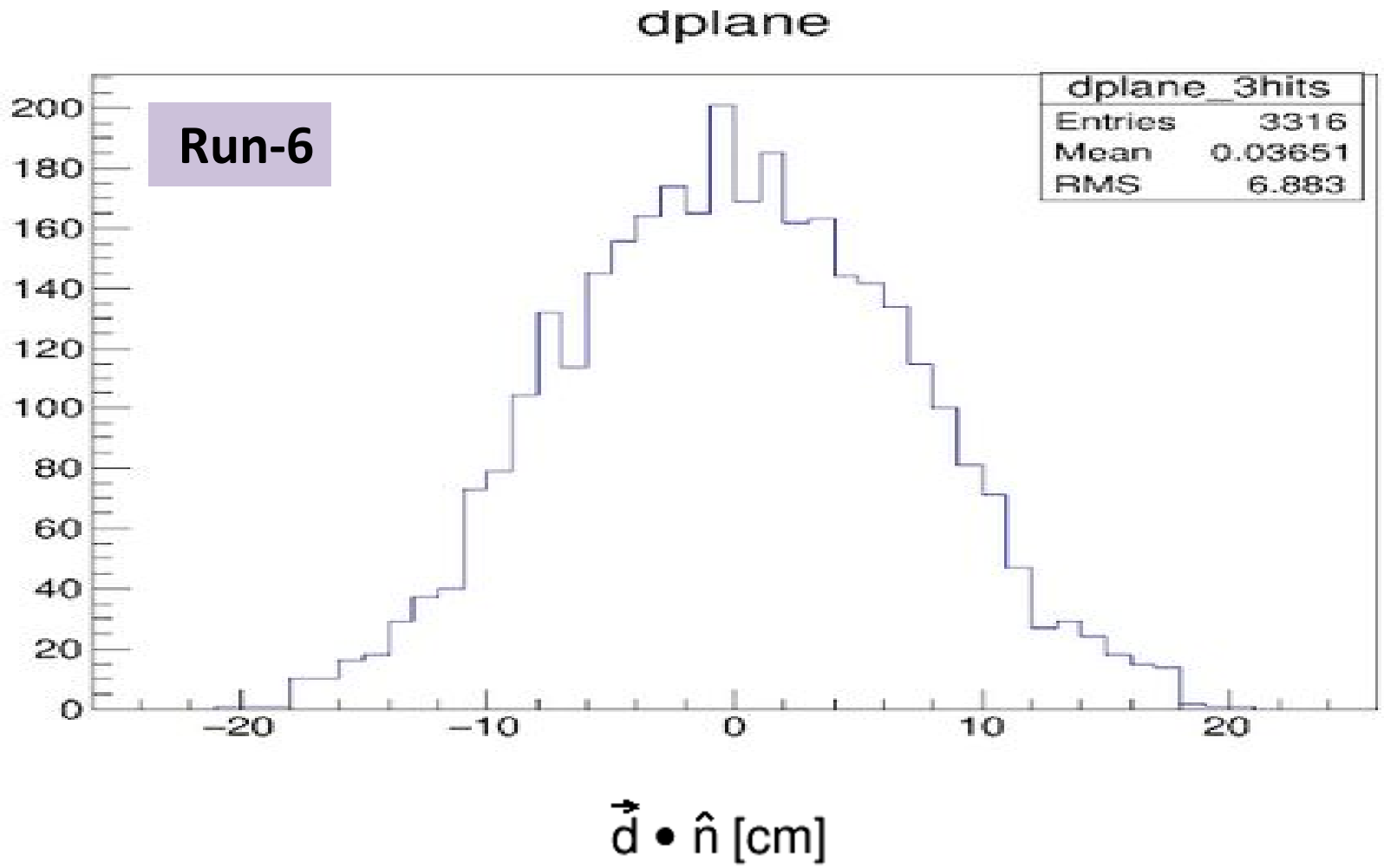

$\vec{S}$
$\overrightarrow{k_1}$
$\overrightarrow{k_2}$
$\overrightarrow{k_0}$
n
e+
$\overrightarrow{k_3}$

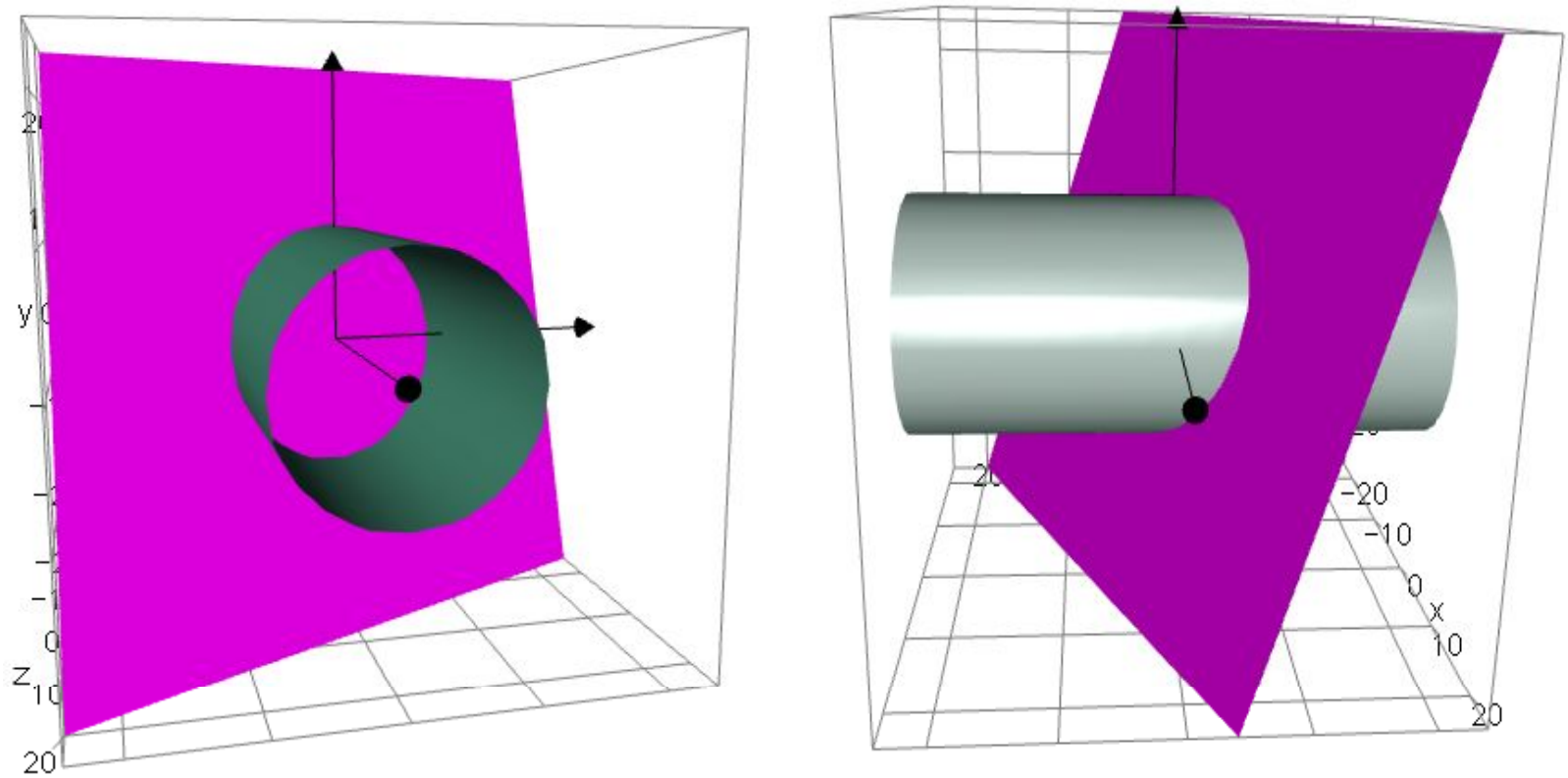
case of 2 gamma +scattering and 3 gammas



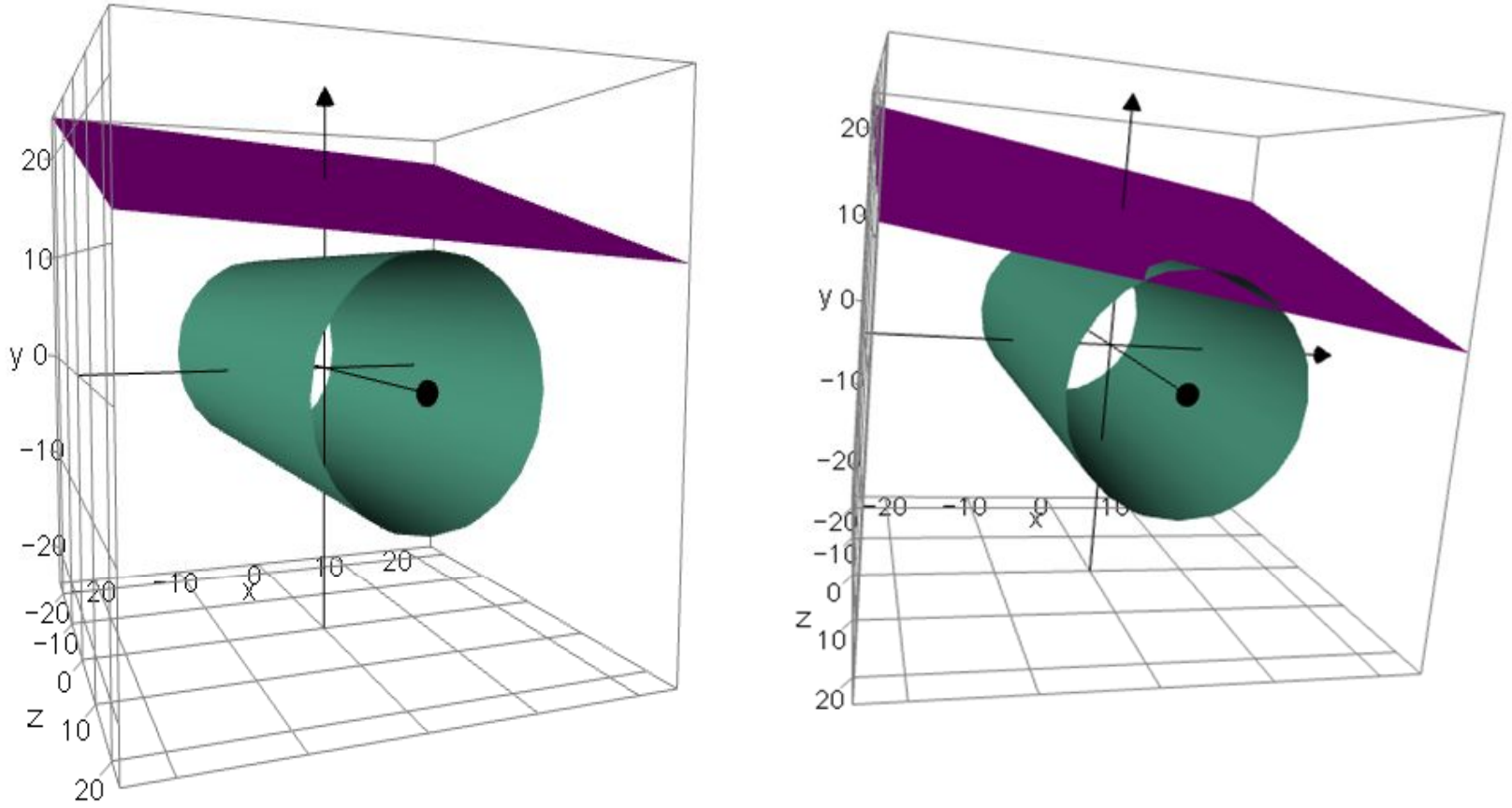


The shortest distances (the projection to the normal of the plane) between the o-Ps decay planes and the center of the J-PET which can be calculated via the projection to the normal of the decay plane.

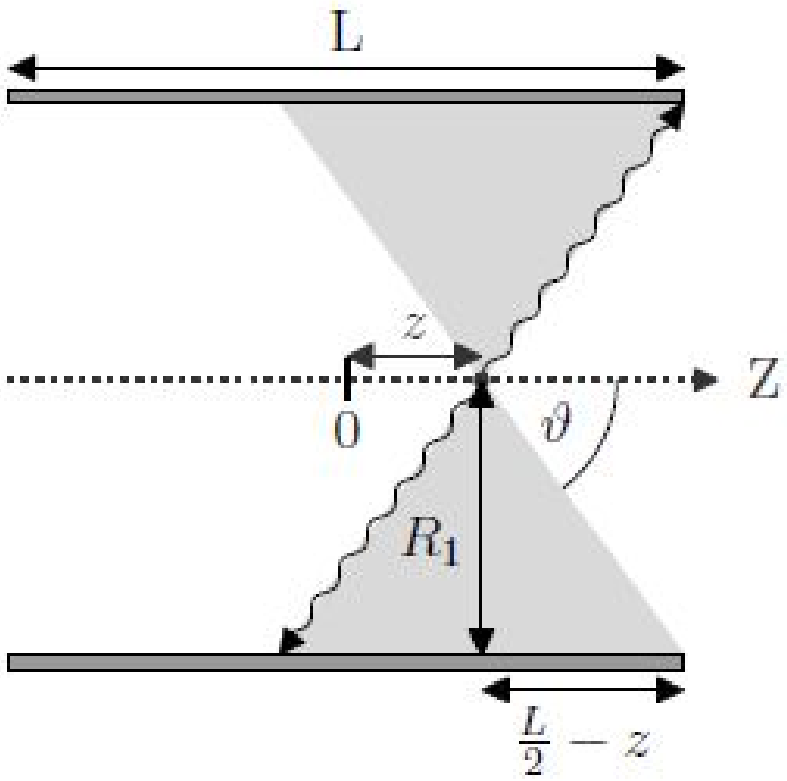

dplane
Run-6
dplane_3hits
Entries 3316
Mean 0.03651
RMS 6.883
200
180
160
140
120
100
80
60
40
20
0
−20
−10
0
10
20
$\vec{d} \bullet \hat{n}$ [cm]



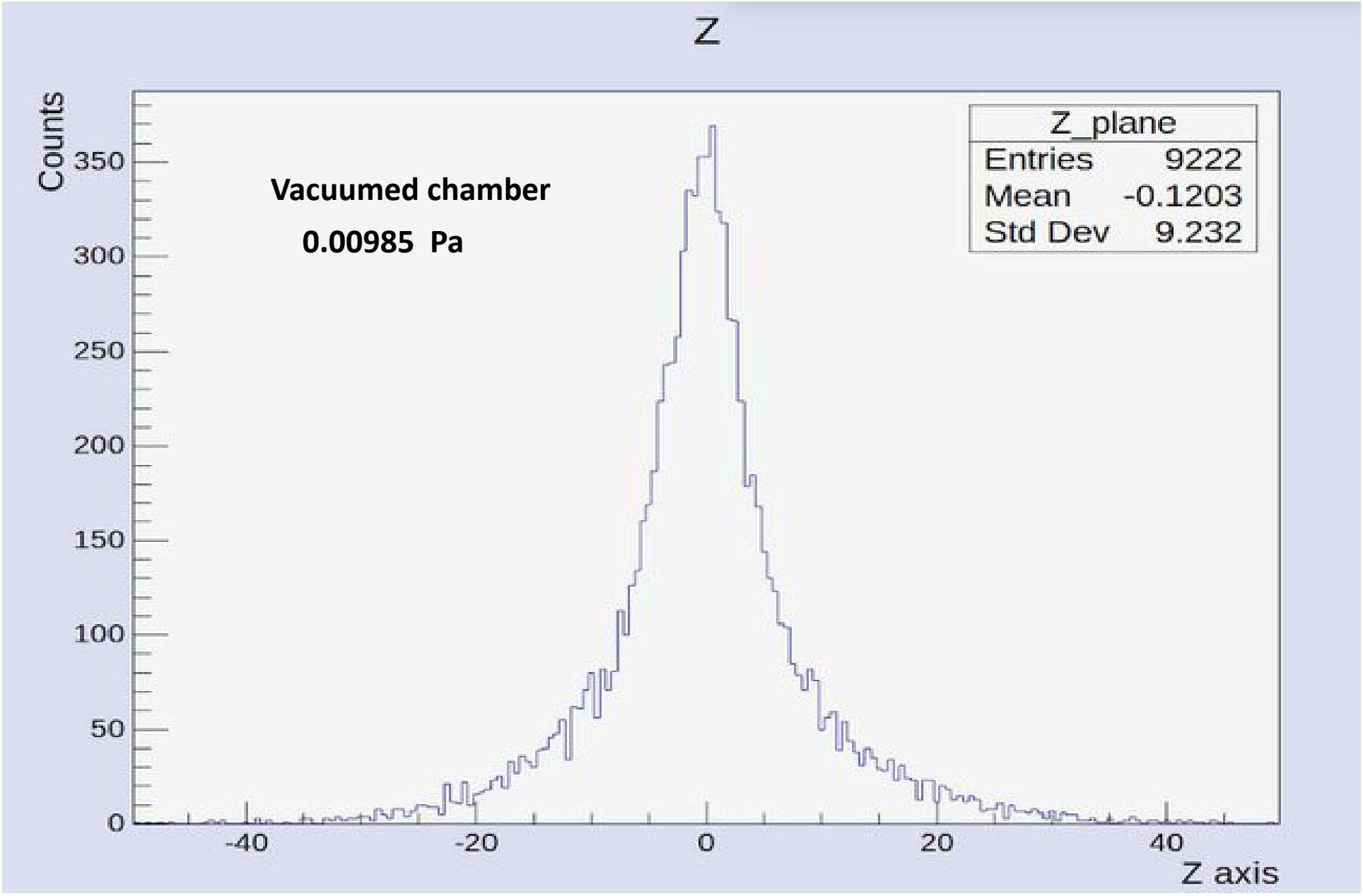
The annihilation plane for Ps decay point at the wall of the annihilation chamber. left (xy view) and Right (zx view).

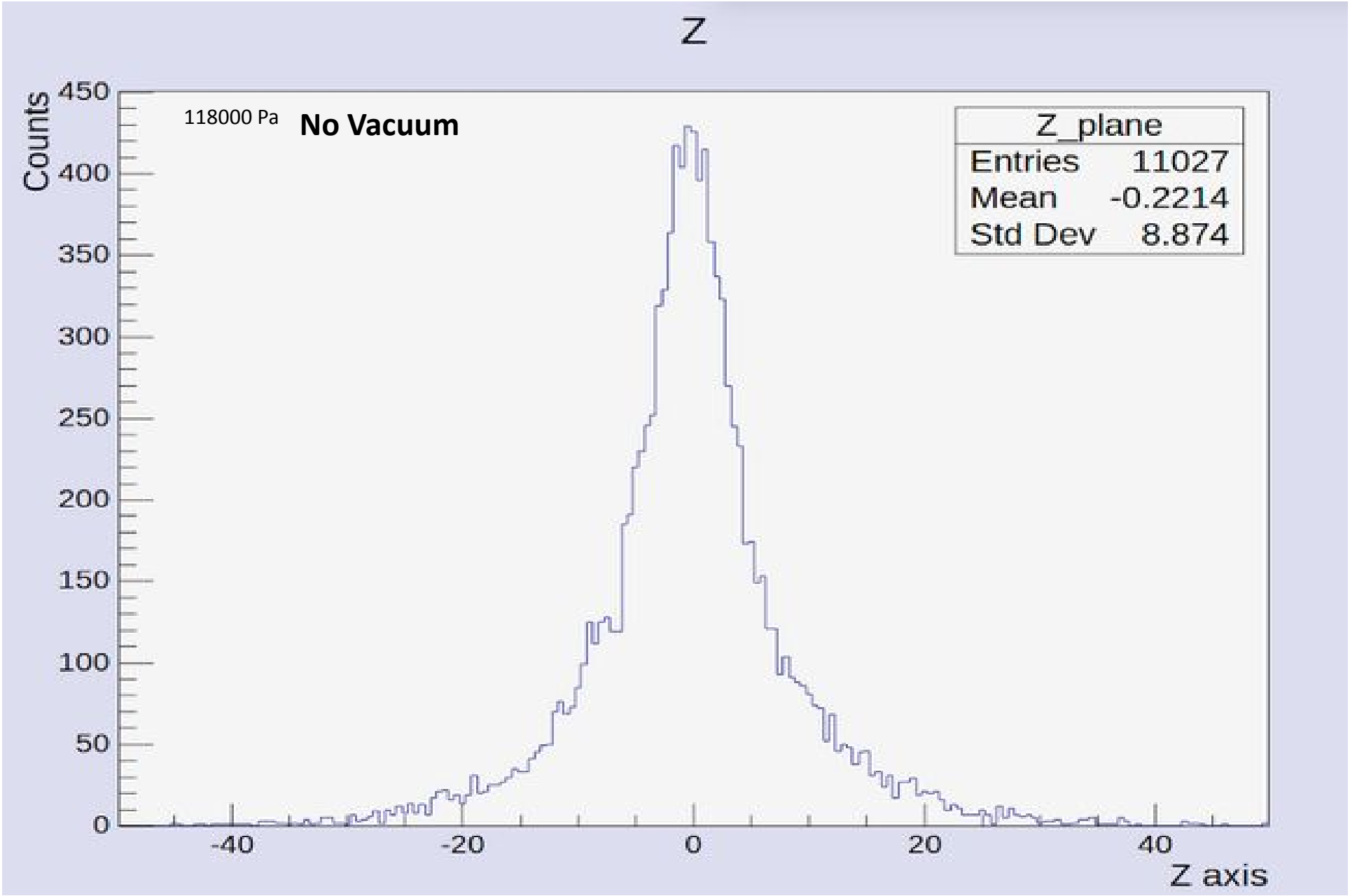


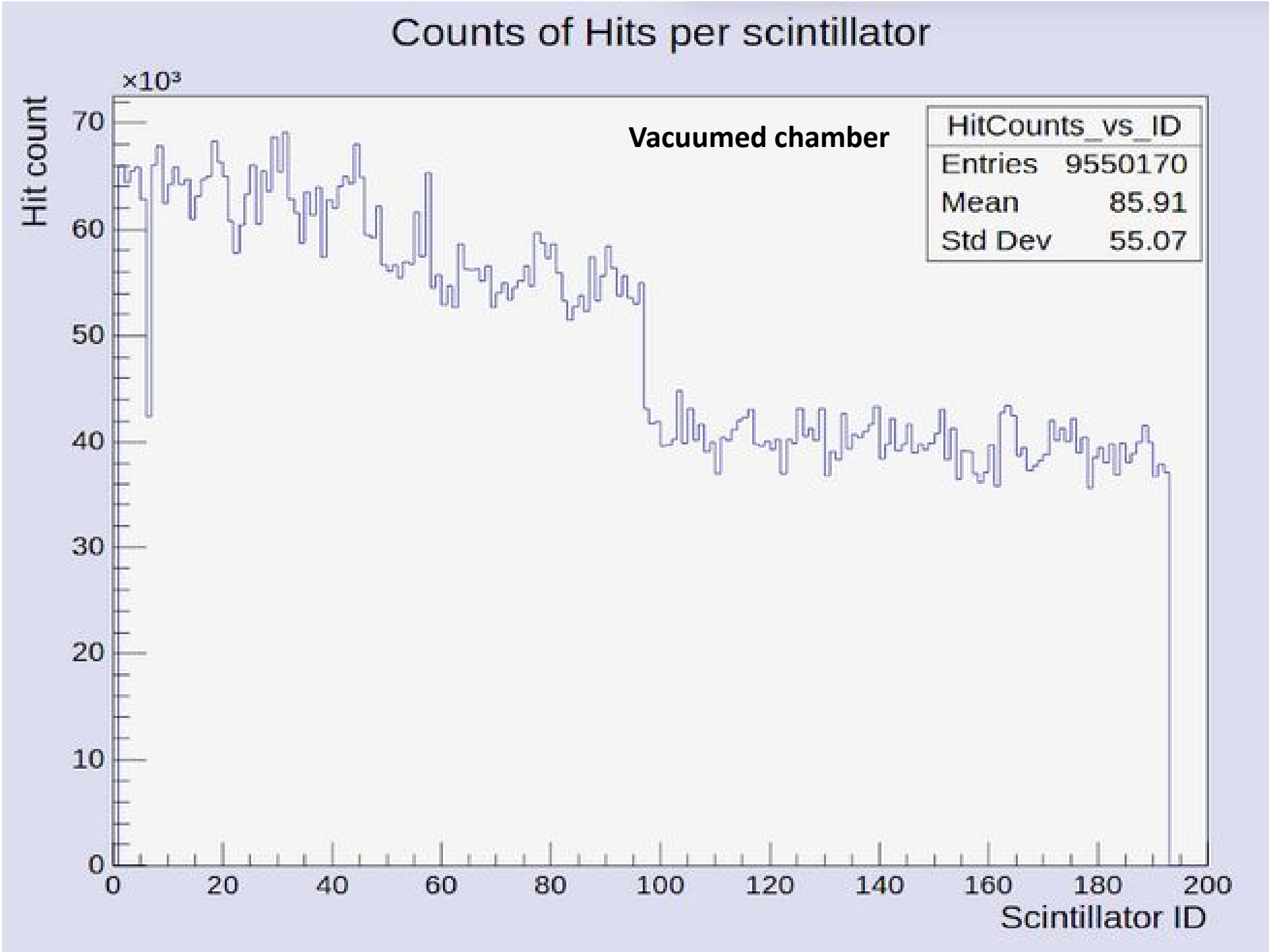
The annihilation planes for two different accidental coincidences.

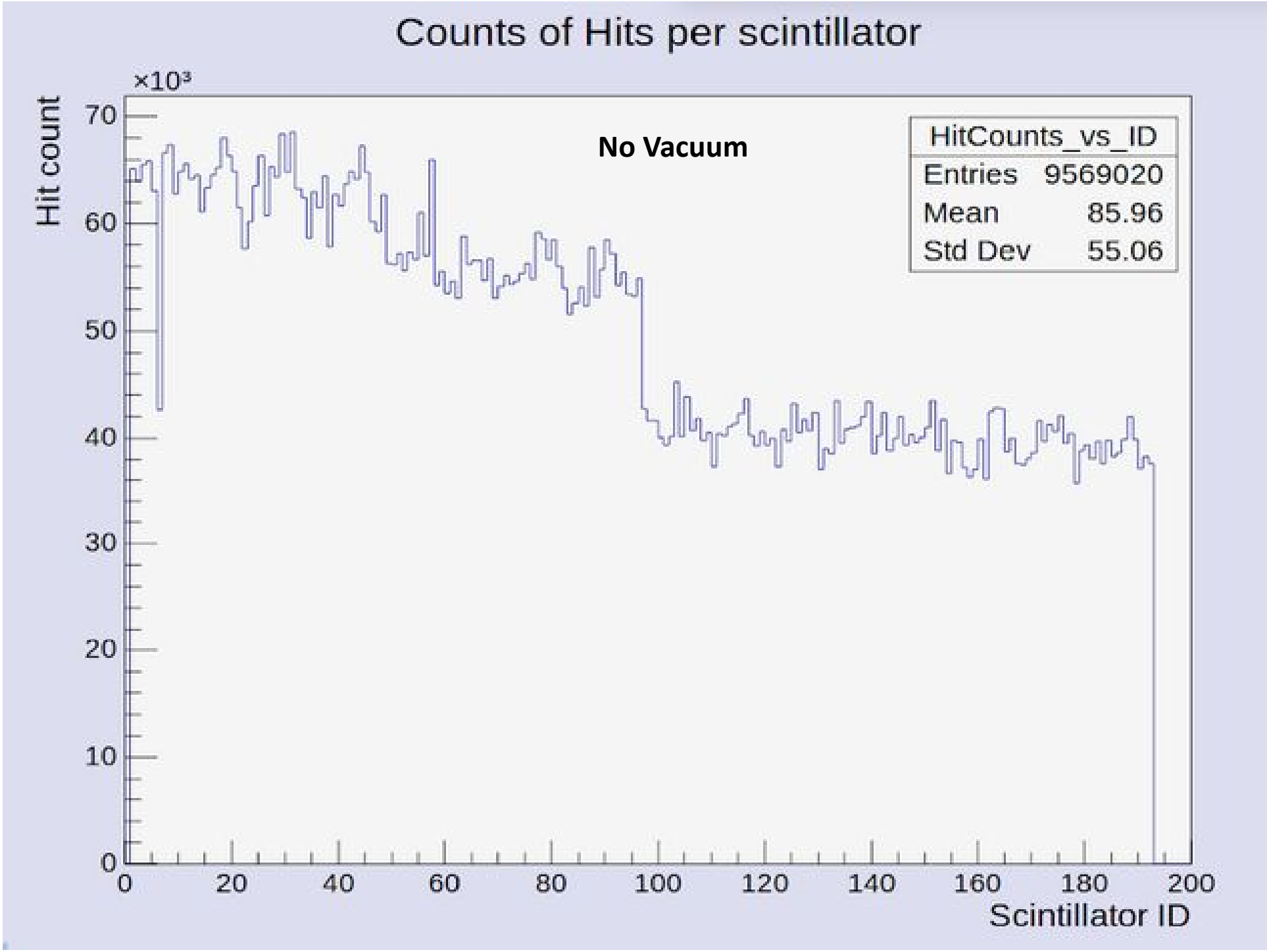


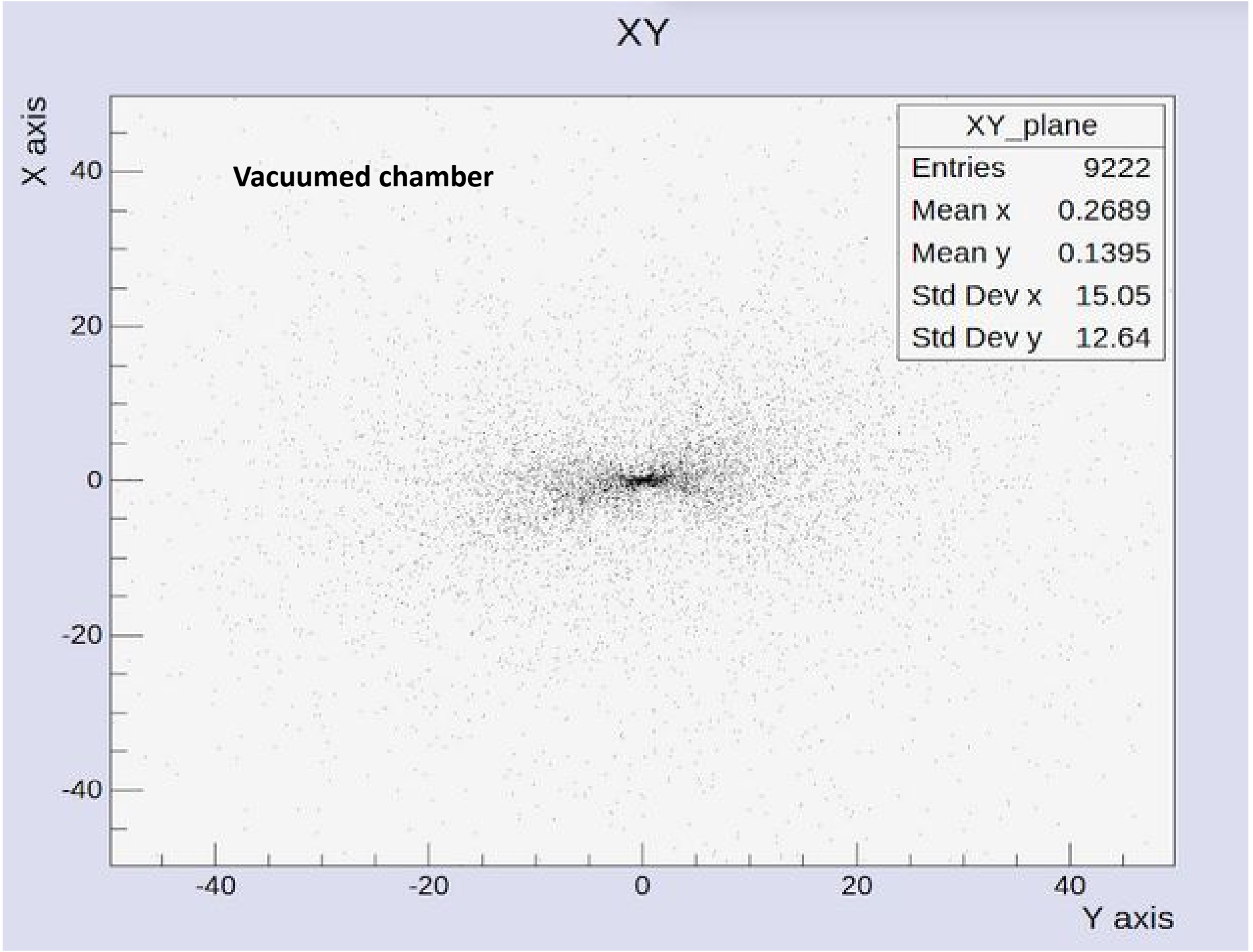
Schematic presentation of the geometrical acceptance limits on reconstruction of 2 annihilations along the z axis of the detector. Shaded region denotes the volume in which emitted e+e- pairs may be detected. (A.Gajos,2018) PhD thesis , UJ.

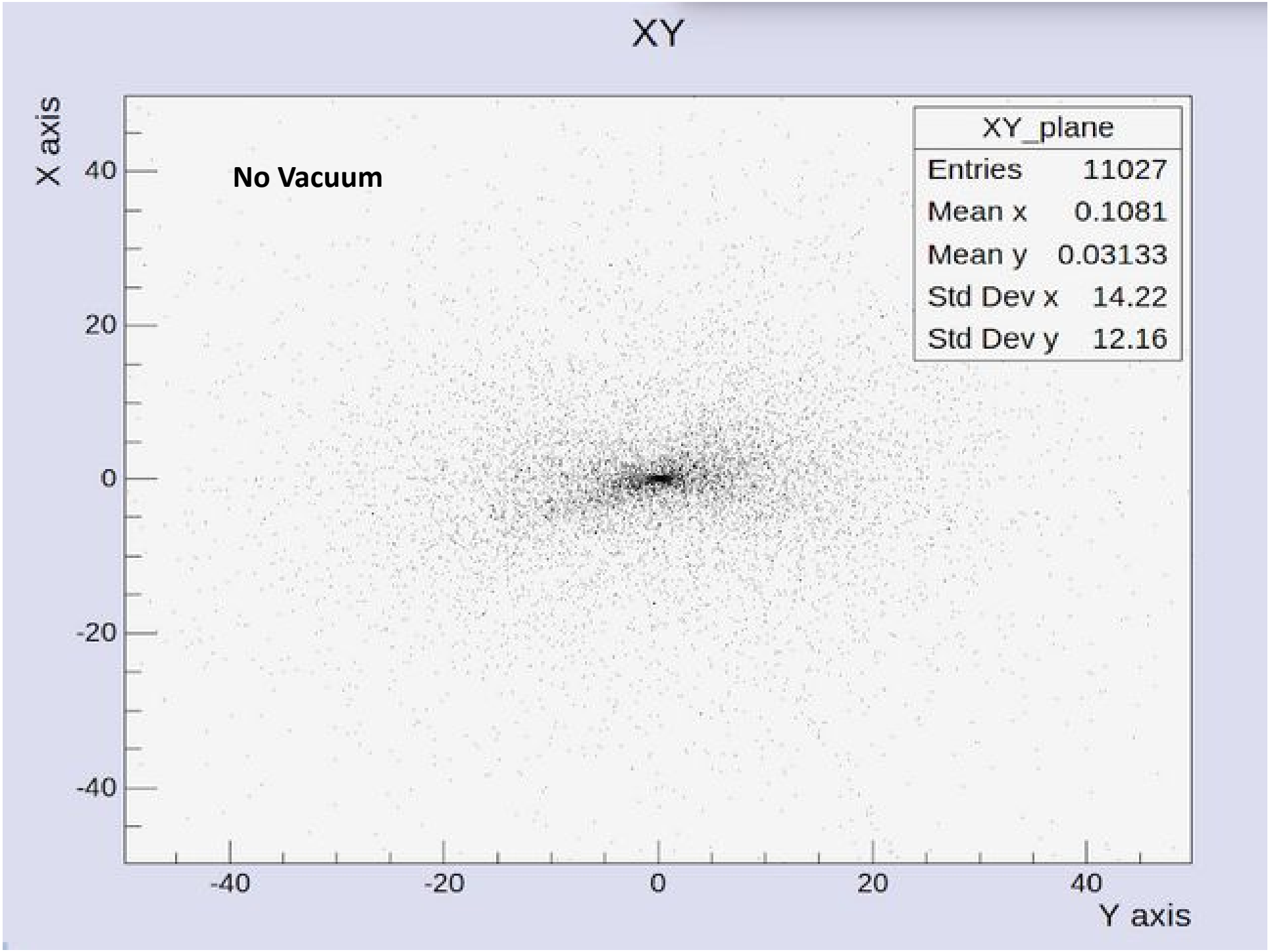

Z
Counts
350
300
250
200
150
100
50
0
-40
-20
0
20
40
Z axis
Z_plane
Entries 9222
Mean -0.1203
Std Dev 9.232
Vacuumed chamber
0.00985 Pa

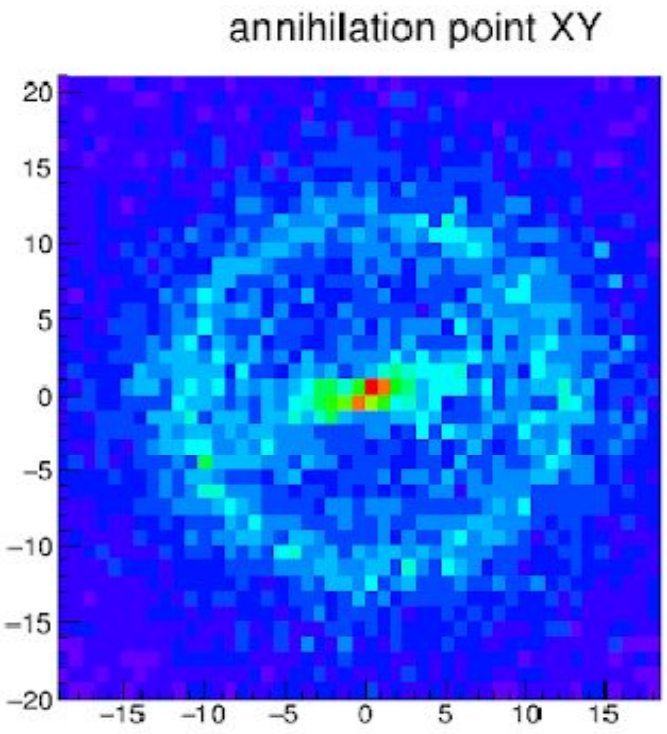

Z
118000 Pa
No Vacuum
Z_plane
Entries 11027
Mean -0.2214
Std Dev 8.874
Counts
450
400
350
300
250
200
150
100
50
0
-40
-20
0
20
40
Z axis


Counts of Hits per scintillator
Vacuumed chamber
HitCounts_vs_ID
Entries 9550170
Mean 85.91
Std Dev 55.07
Hit count
×10³
70
60
50
40
30
20
10
0
0
20
40
60
80
100
120
140
160
180
200
Scintillator ID

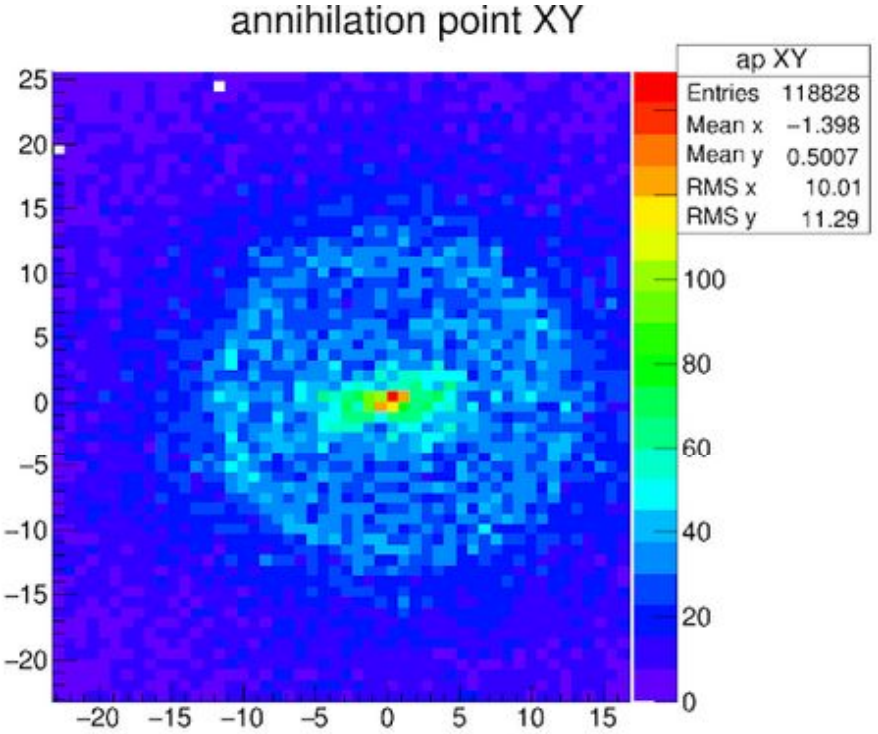

Counts of Hits per scintillator
No Vacuum
HitCounts_vs_ID
Entries 9569020
Mean 85.96
Std Dev 55.06
Hit count
×10³
70
60
50
40
30
20
10
0
0
20
40
60
80
100
120
140
160
180
200
Scintillator ID


XY
X axis
Y axis
Vacuumed chamber
XY_plane
Entries 9222
Mean x 0.2689
Mean y 0.1395
Std Dev x 15.05
Std Dev y 12.64
40
20
0
-20
-40
-40
-20
0
20
40


XY
X axis
Y axis
No Vacuum
XY_plane
Entries 11027
Mean x 0.1081
Mean y 0.03133
Std Dev x 14.22
Std Dev y 12.16
40
20
0
-20
-40
-40
-20
0
20
40



Vacuumed chamber



No Vacuum

Summary

- The o-Ps decay reconstruction method based on trilateration, intended for reconstructing the decay vertex which, in turn, allows us to estimate the positron momentum direction and spin direction of the positron / o-Ps for the needs of discrete symmetry tests in o-Ps decays .

- Use MLEM with the J-PET data we are able to have a topographic image of the chamber phantom with in 20 sec of data gathering.


Thank you for your attention