Pad-based Readout Scheme for RPC Home Security Applications

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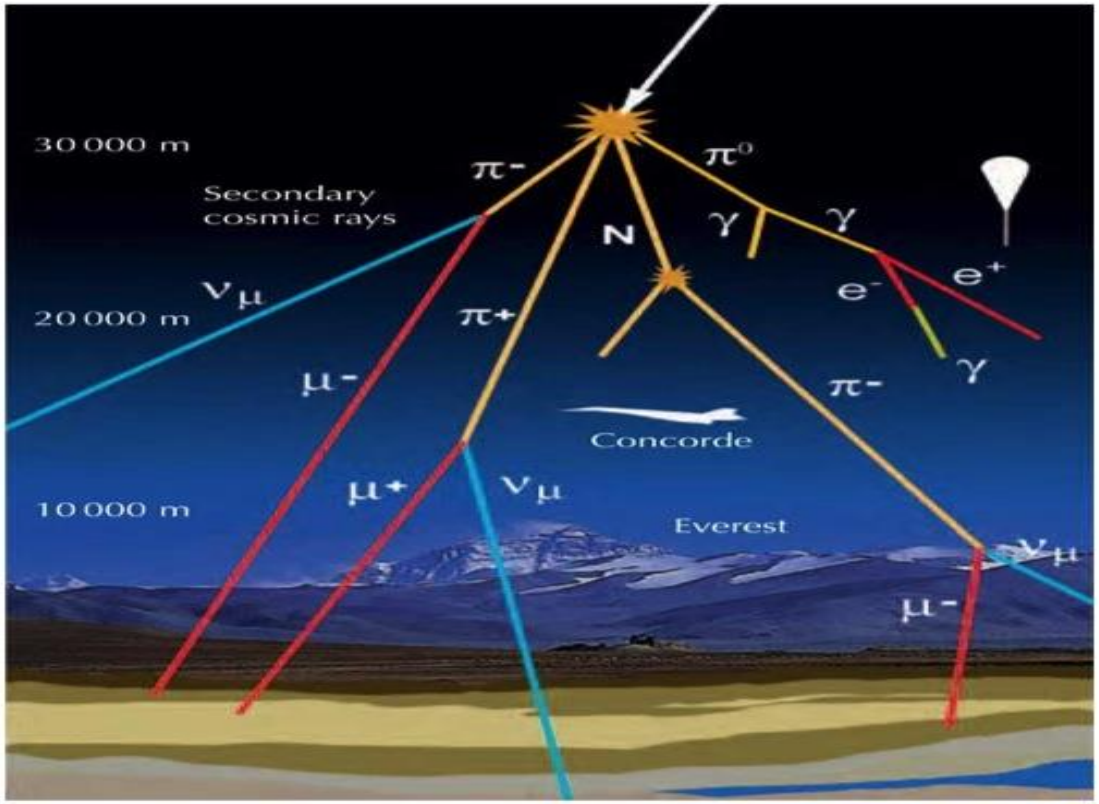
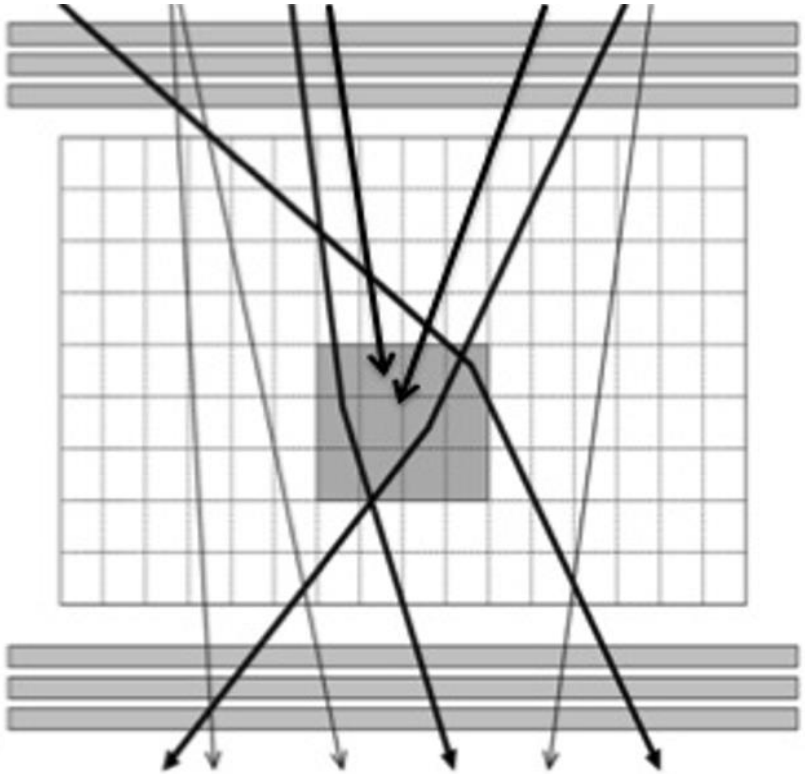
Cosmic rays



- Cosmic rays are free particle sources with no energetic cost
- Their rate is however not high (1/cm^2/min)

They are used in two ways in tomography:

- Scattering
- Absorption



$$\theta_0 = \frac{13.6\,MeV}{\beta c \rho} z \sqrt{x/X_0}(1 + 0.038 ln(x/X_0))$$

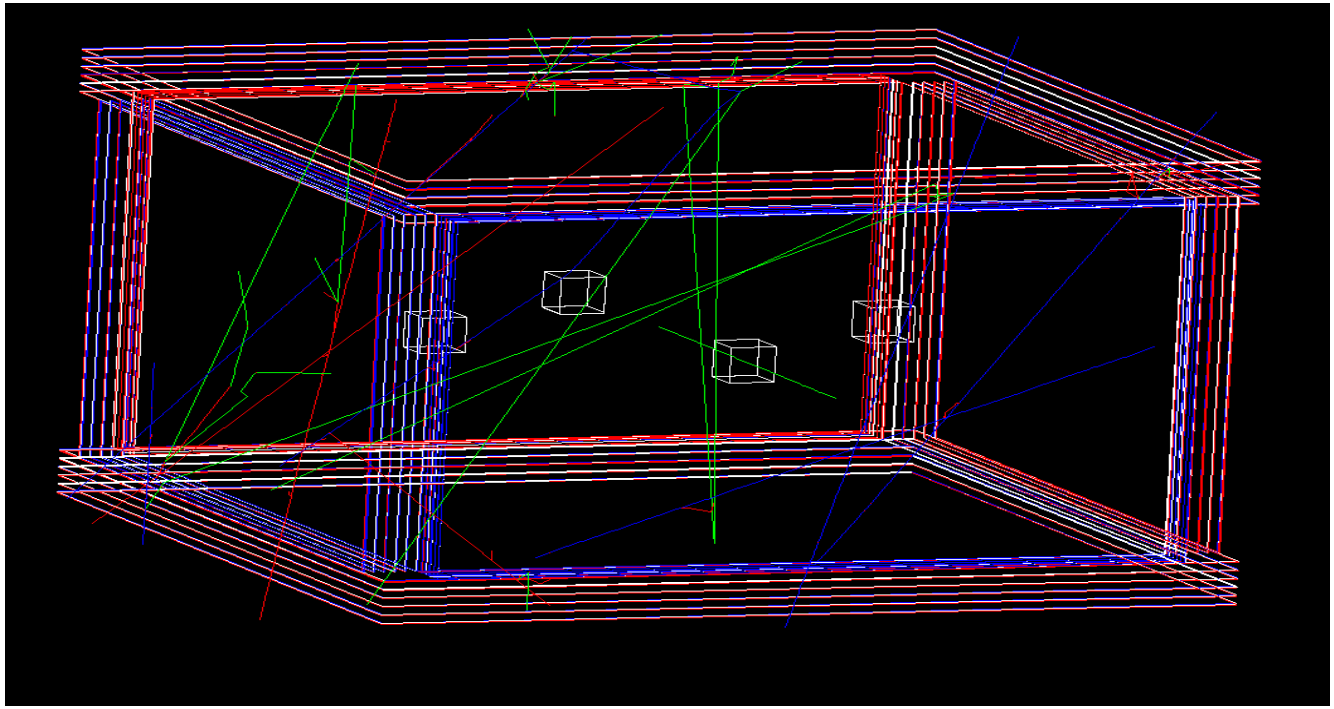
To use them efficiently we need:

- ❑ Large size to cover to compensate for the low rate
- ❑ High spatial resolution to determine the scattering angle

Simulation

In order to study the possibility to detect hidden objects we simulated, a setup of 4 sets each made of 6 RPC of 4m X 4m separated by 6 cm. sets are 4 meters apart:
two verticals and two laterals
The granularity is given by 1 cm x 1cm pads with an average multiplicity of 1.7 (similar to the one obtained in SDHCAL GRPC). An of 95% was used in this simulation.

In between 4 blocks of 30 cm X 30 cm of Al, Fe, Au and Pb are placed



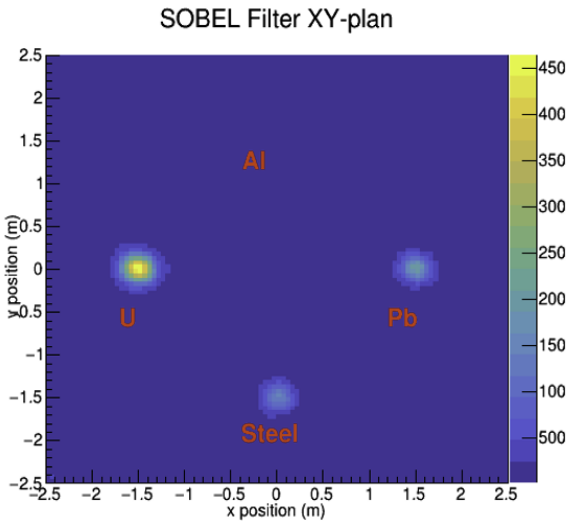
Simulation

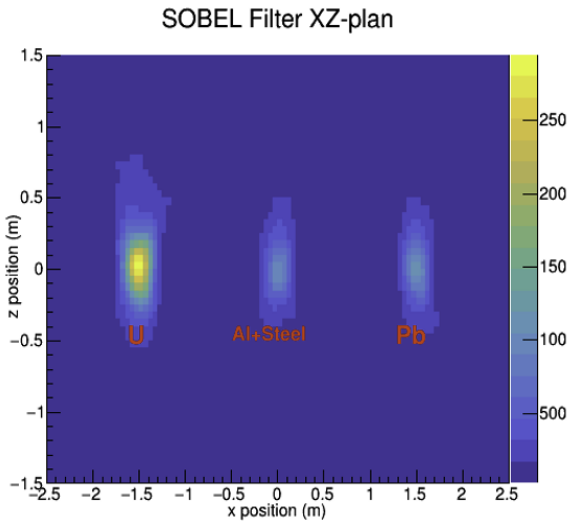
Using crossing tracks with two track segments featuring a kink ($\cos\theta < 0.98$) and taking the middle of the minimal distance between the track segments we were able to find

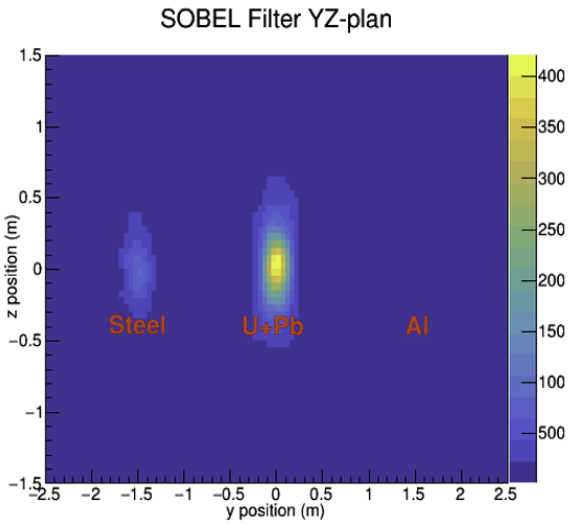
- ❑ The four objects placed between the 4 sets
- ❑ Discriminate different kinds of heavy objects

In a reasonable exposure time (less than 5 minutes)

Hu Jiangqiao
Master work







We reduce the exposure time by a factor of 2 by using the stopped tracks and applying the same technique to these track segments (two by two).

However

- Several layers of large detectors are needed to scan large containers
  → **(20 m x 4m)**

- RPC detectors are cheap but to reach the needed spatial resolution with no ghost particles we need to use pickup pads but this implies a tremendous number of electronic channels

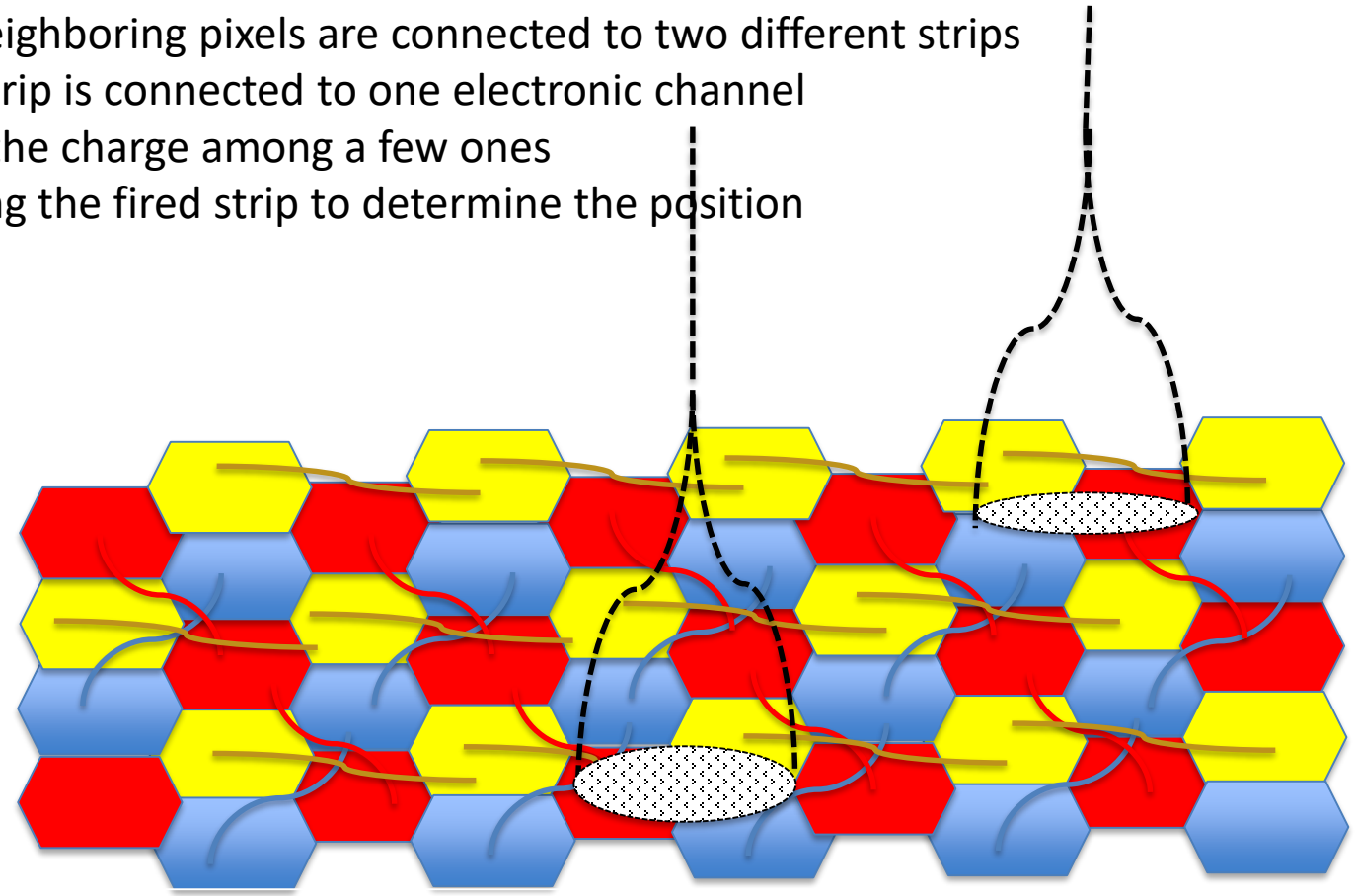
1 channel for each pick up pad (1 cm X 1 cm) --> 8 10^5 ch/layer of 20 m x 4 m
At least 3+3 layers are needed → 48 10^5 ch

We propose to keep the same granularity (with no ghosts) but reduce the number of channels by a factor of 1000 using the woven strips readout technology

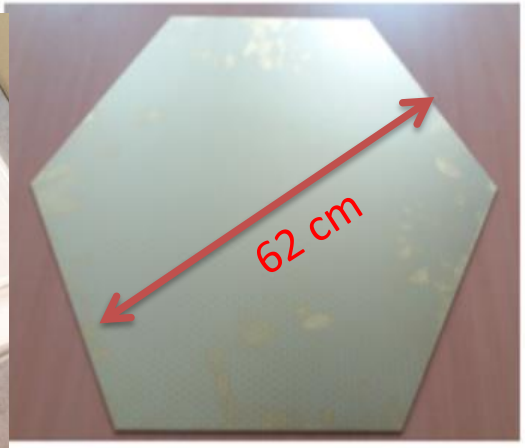
There is a solution

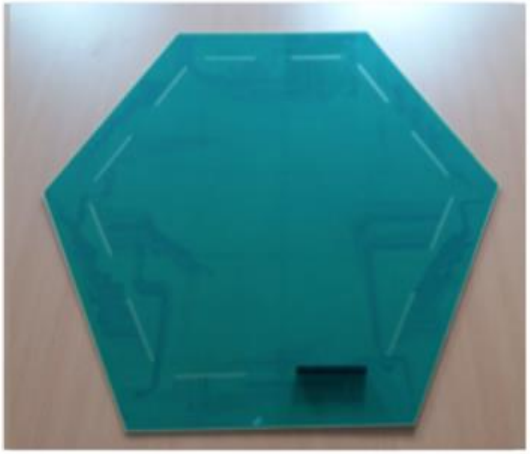
PCT/EP2018/053561

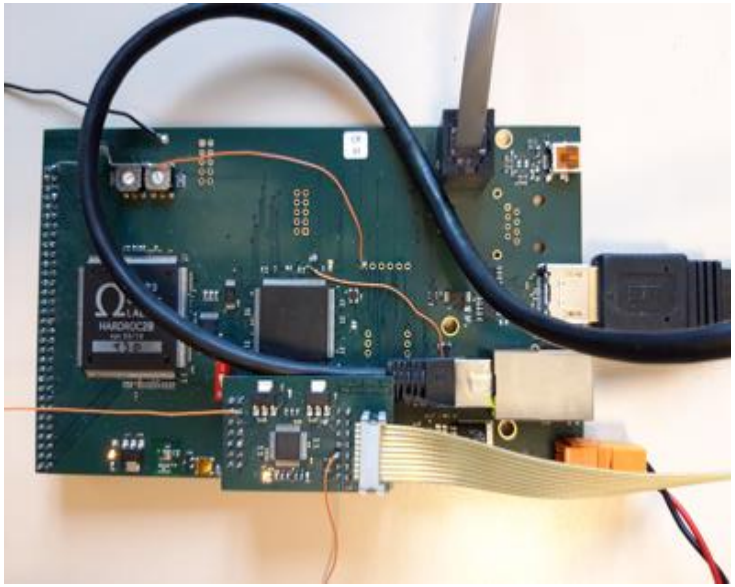
- Connect the pixels in a special way: **woven strips**
- Two neighboring pixels are connected to two different strips
- Each strip is connected to one electronic channel
- Share the charge among a few ones
- Crossing the fired strip to determine the position



NXN → 3N : Reduction of electronic channels, power consumption and occupancy





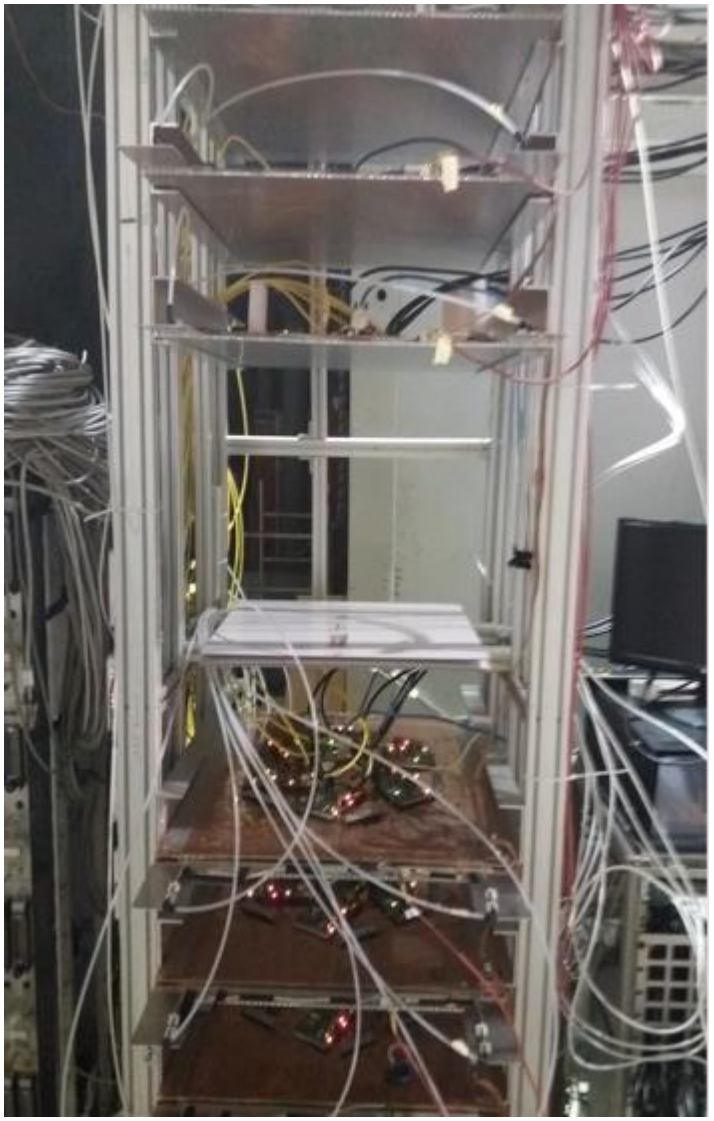


A board hosting
- One Hardroc ASIC
- One Microcontroller

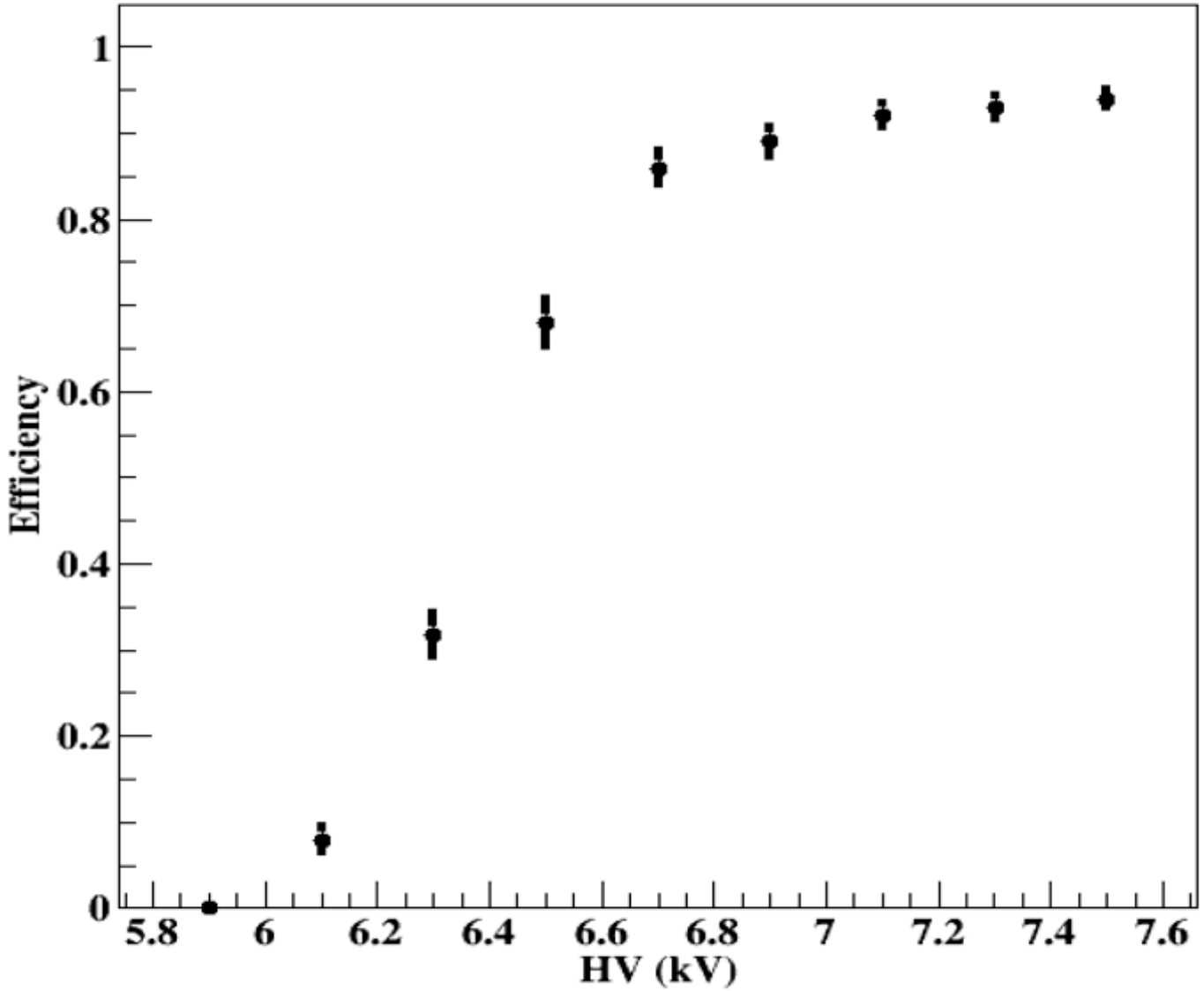
To be plugged directly on the back of the PCB, on the edge to read out 64 woven strips.

SETUP

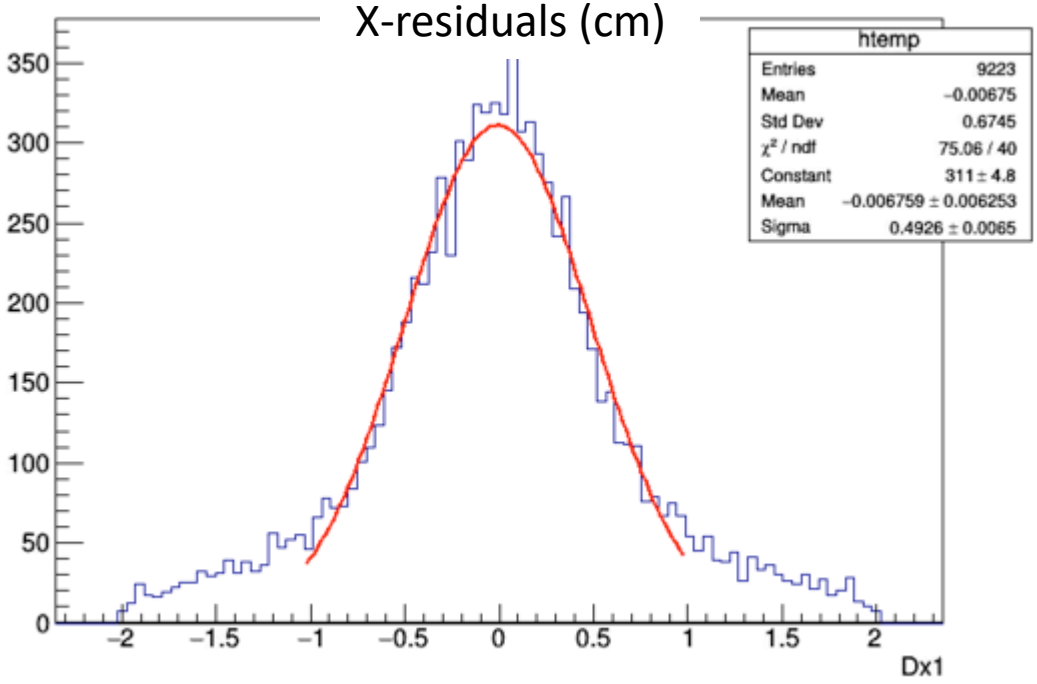
The new readout scheme was tested first using a SC-PMT and in a standalone mode.



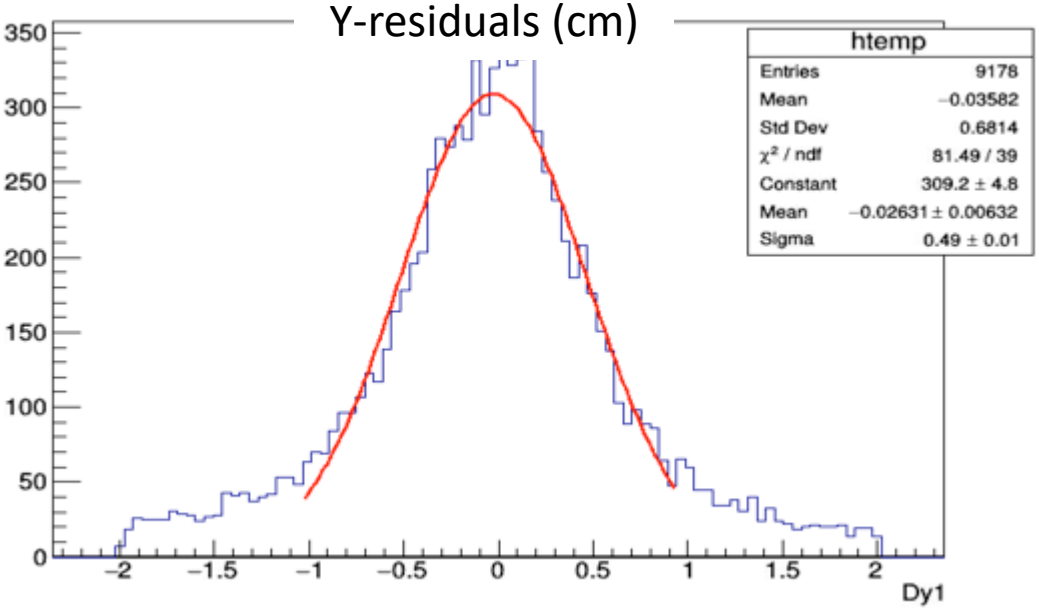
Efficiency with the new scheme



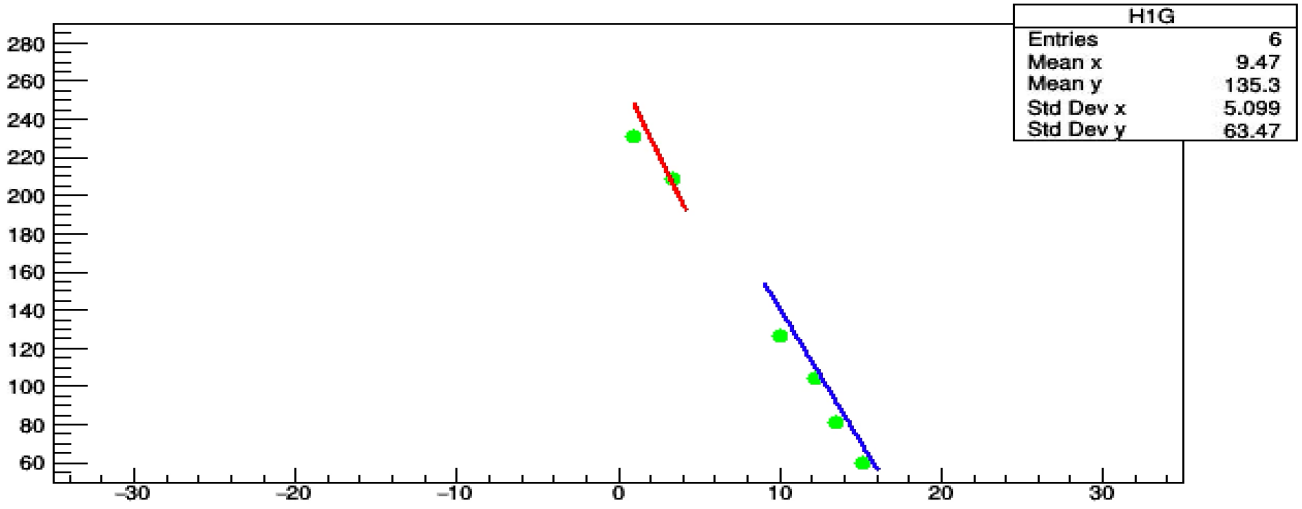
X-residuals (cm)

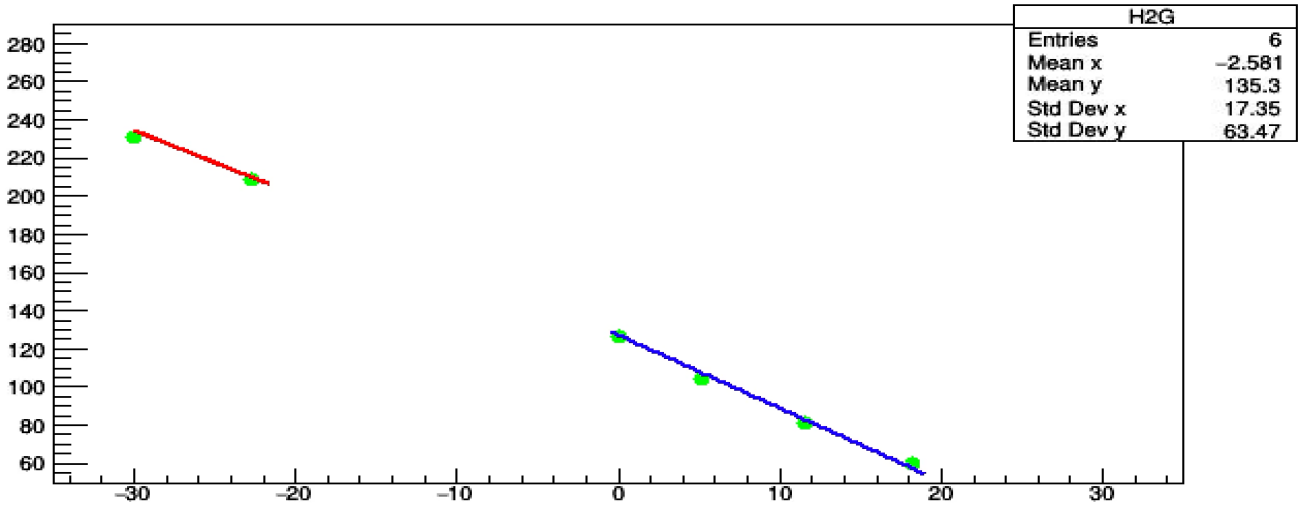


Y-residuals (cm)



Movie-Tracks



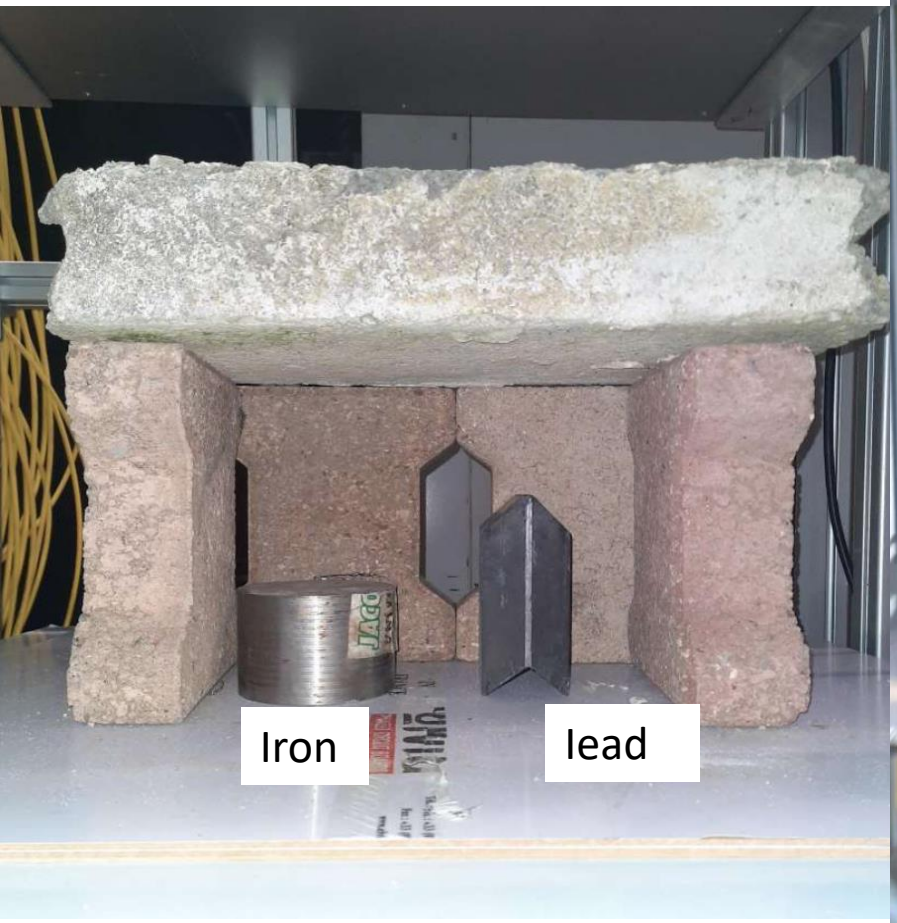


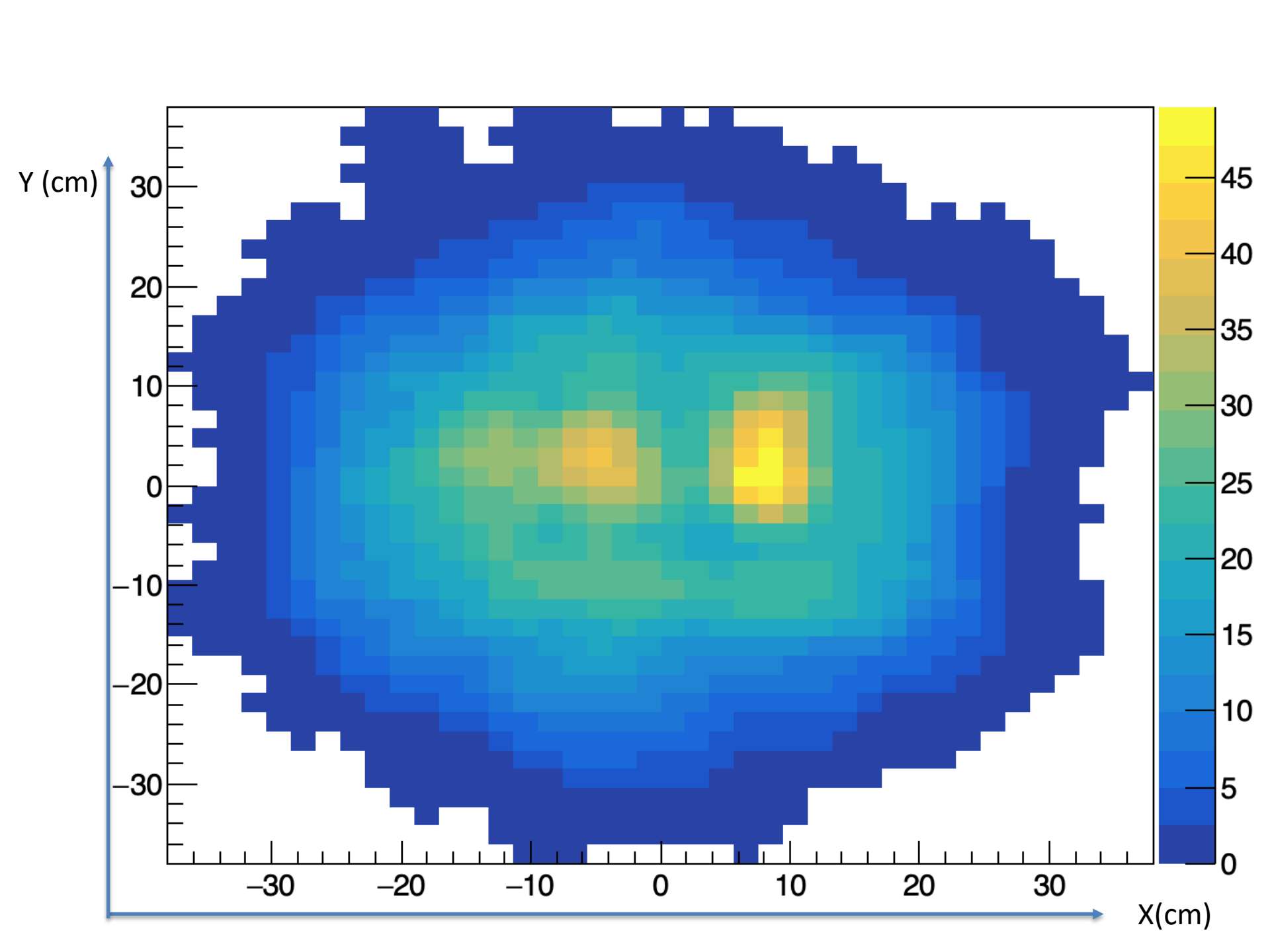
Only good track segments ($\chi^2<10$) and at least 3 hits/segment are used.
Deflection points are determined when a kink ($\cos(\theta)<0.98$) is found.

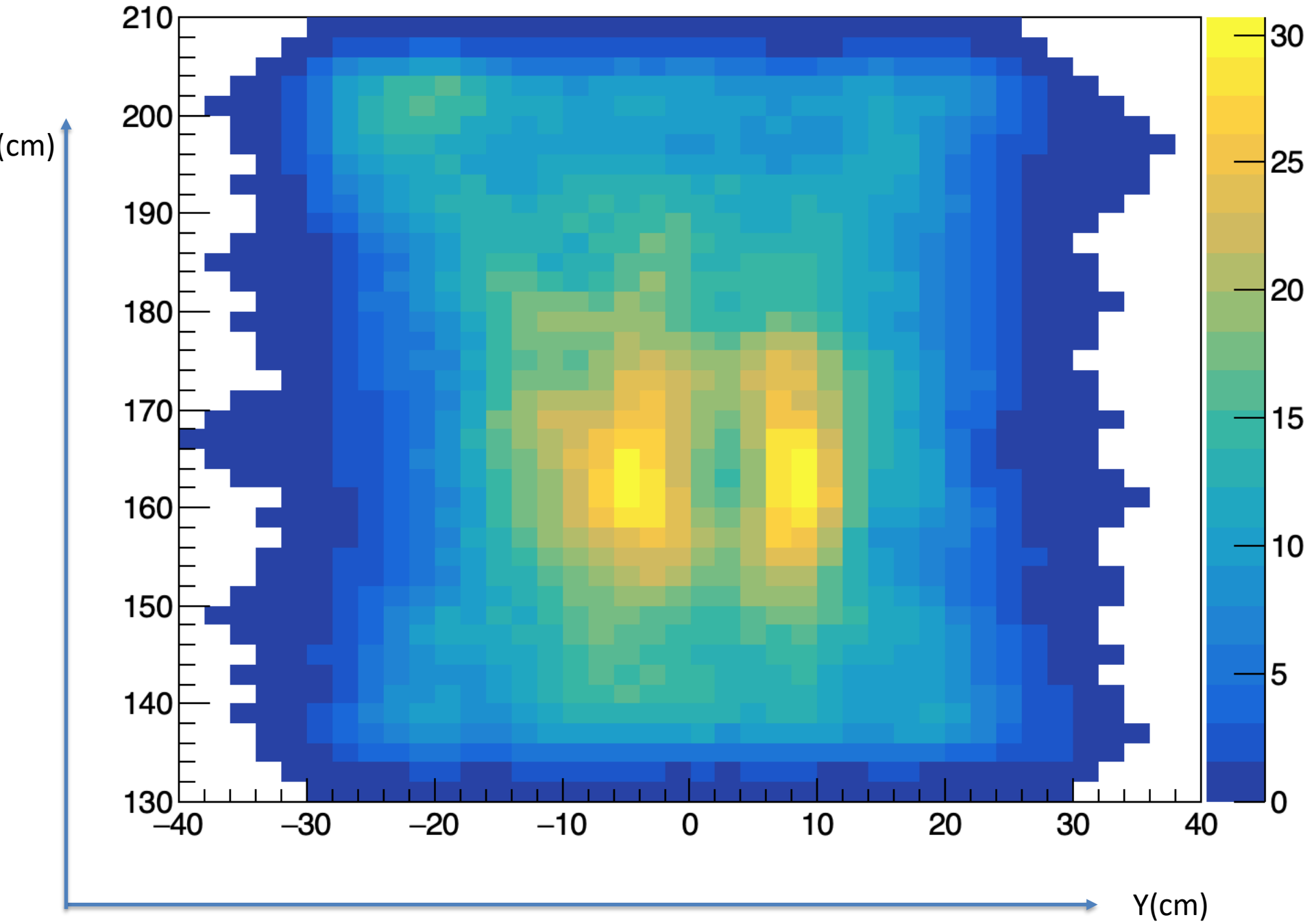
Some results

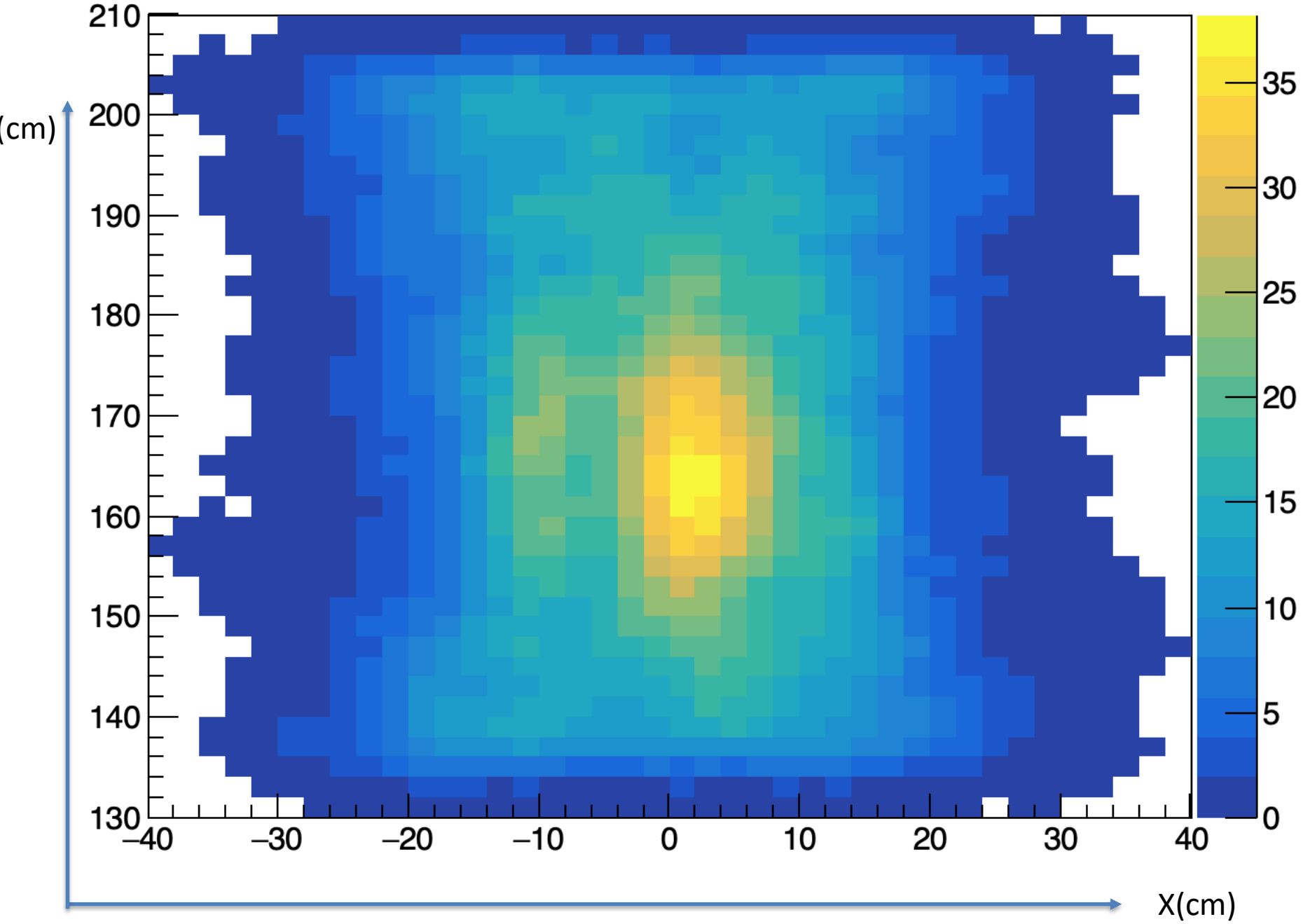
Steel cylinders shielded by thick concrete plates

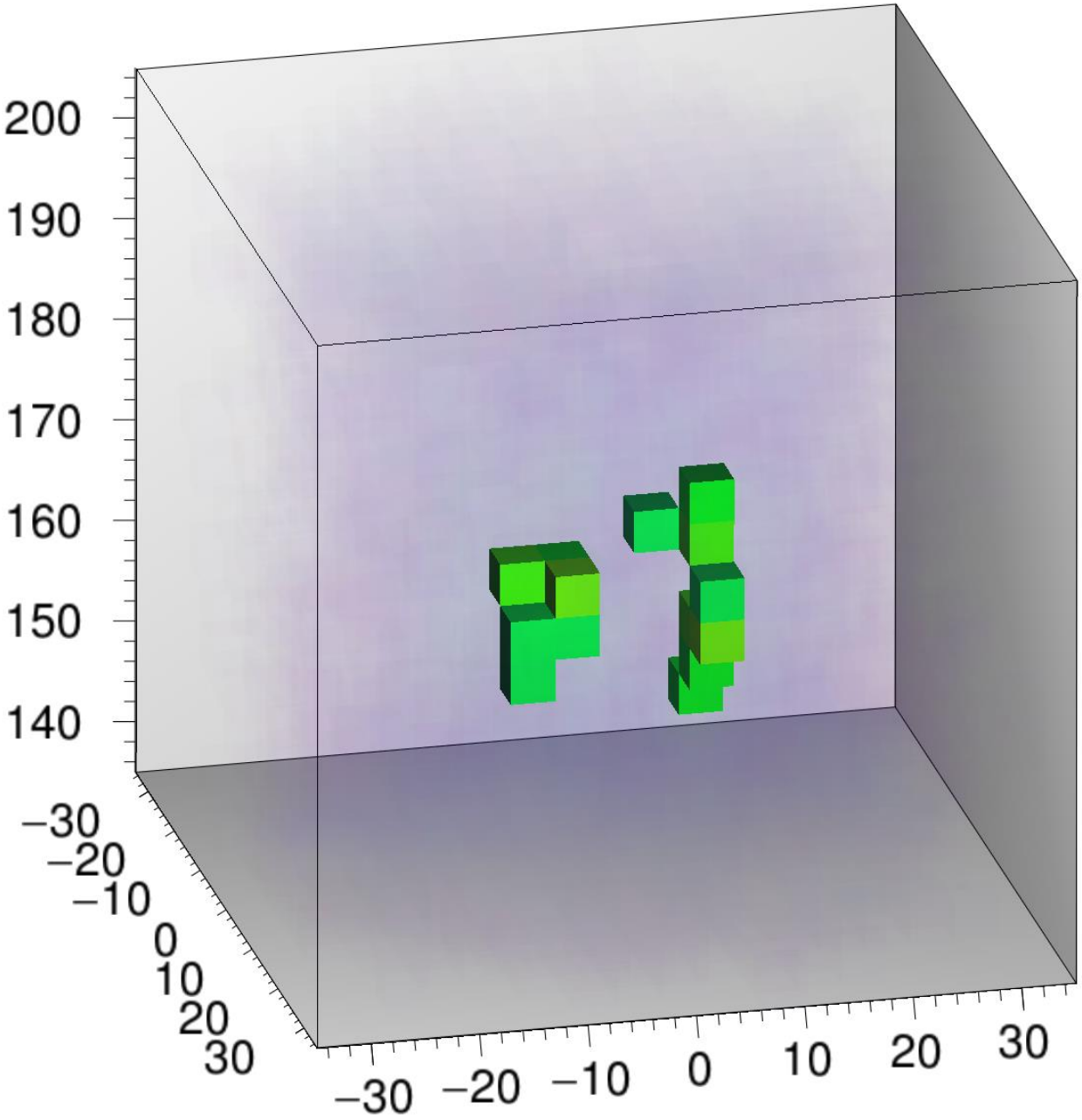
Top and laterals


Iron
lead


Y (cm)
30
20
10
0
−10
−20
−30
−30
−20
−10
0
10
20
30
X(cm)
45
40
35
30
25
20
15
10
5
0

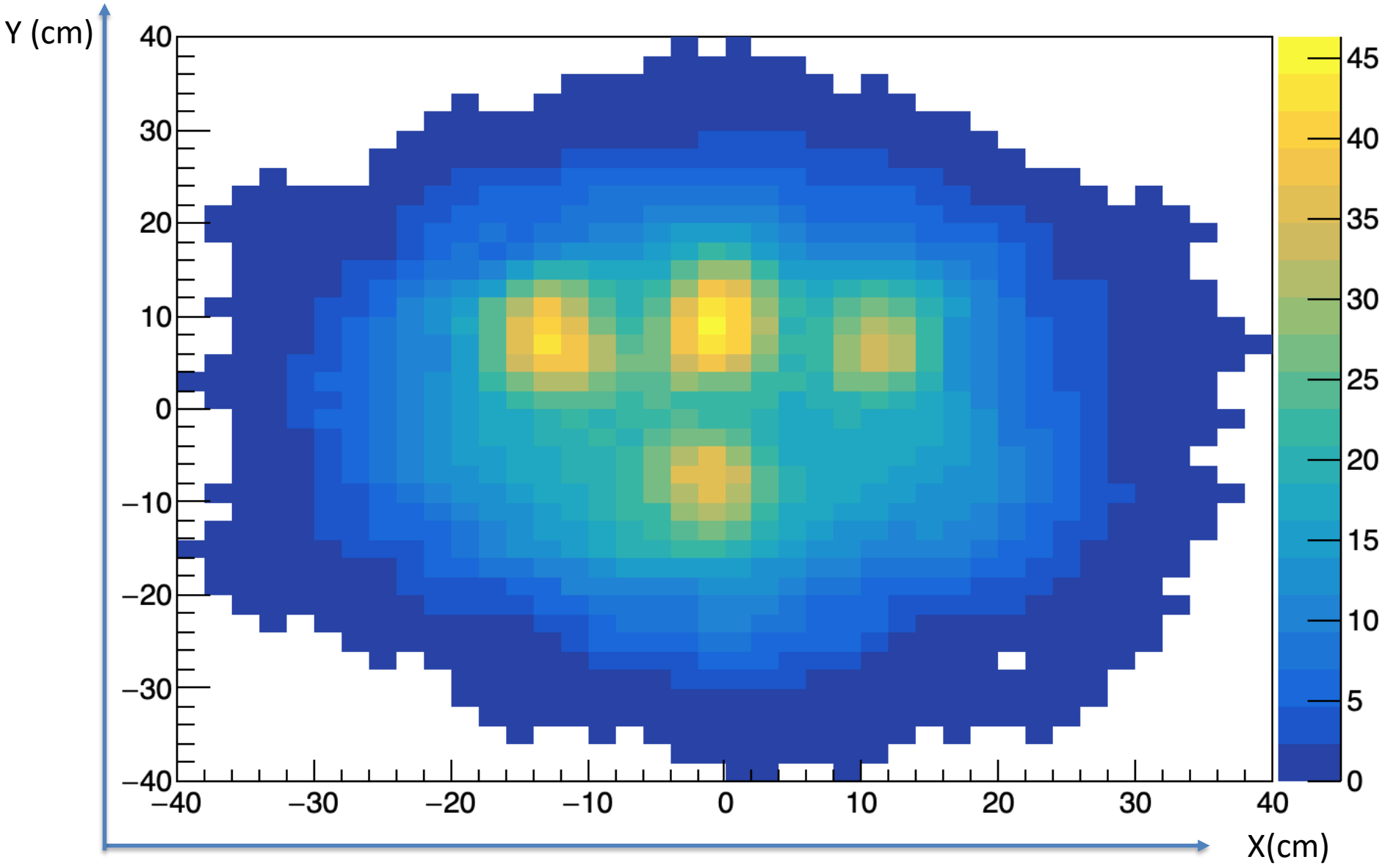

(cm)
210
200
190
180
170
160
150
140
130
–40
–30
–20
–10
0
10
20
30
40
30
25
20
15
10
5
0
Y(cm)

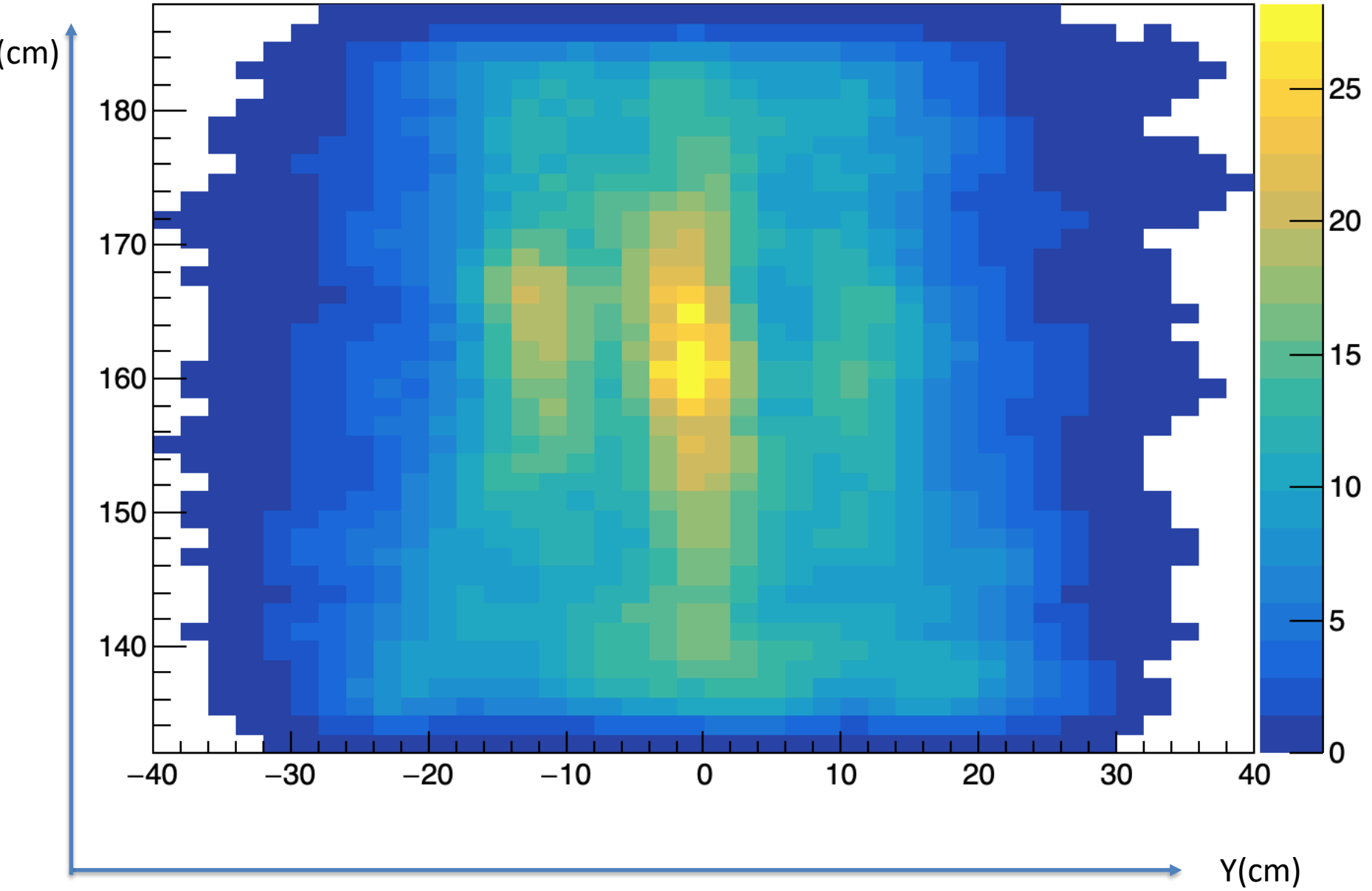

(cm)
210
200
190
180
170
160
150
140
130
−40
−30
−20
−10
0
10
20
30
40
35
30
25
20
15
10
5
0
X(cm)


200
190
180
170
160
150
140
−30
−20
−10
0
10
20
30
−30
−20
−10
0
10
20
30

Lead blocks shielded by thick concrete plates

Top


Y (cm)
40
30
20
10
0
−10
−20
−30
−40
−40
−30
−20
−10
0
10
20
30
40
X(cm)
45
40
35
30
25
20
15
10
5
0


(cm)
180
170
160
150
140
−40
−30
−20
−10
0
10
20
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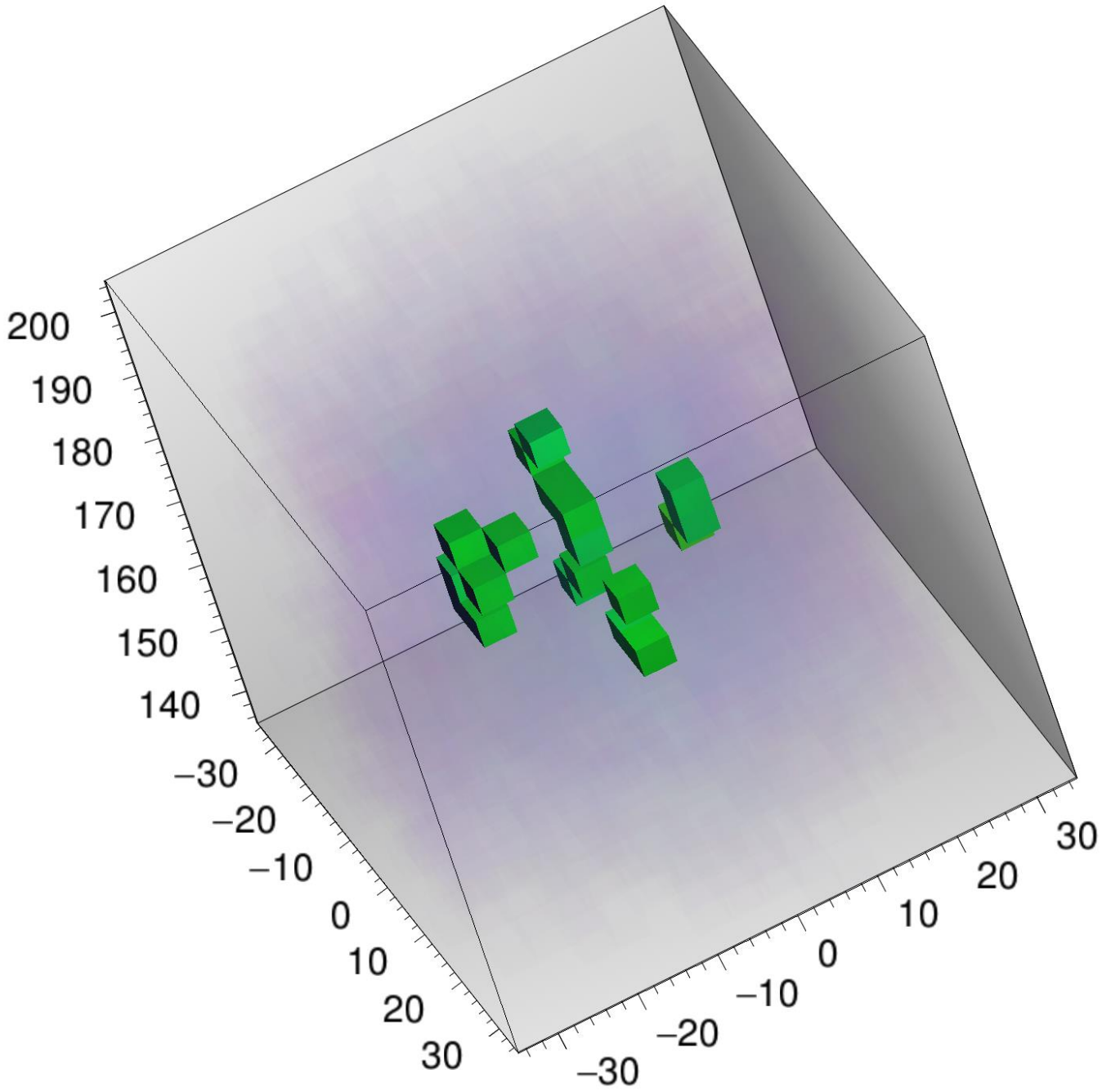
40
25
20
15
10
5
0
Y(cm)


200
190
180
170
160
150
140
−30
−20
−10
0
10
20
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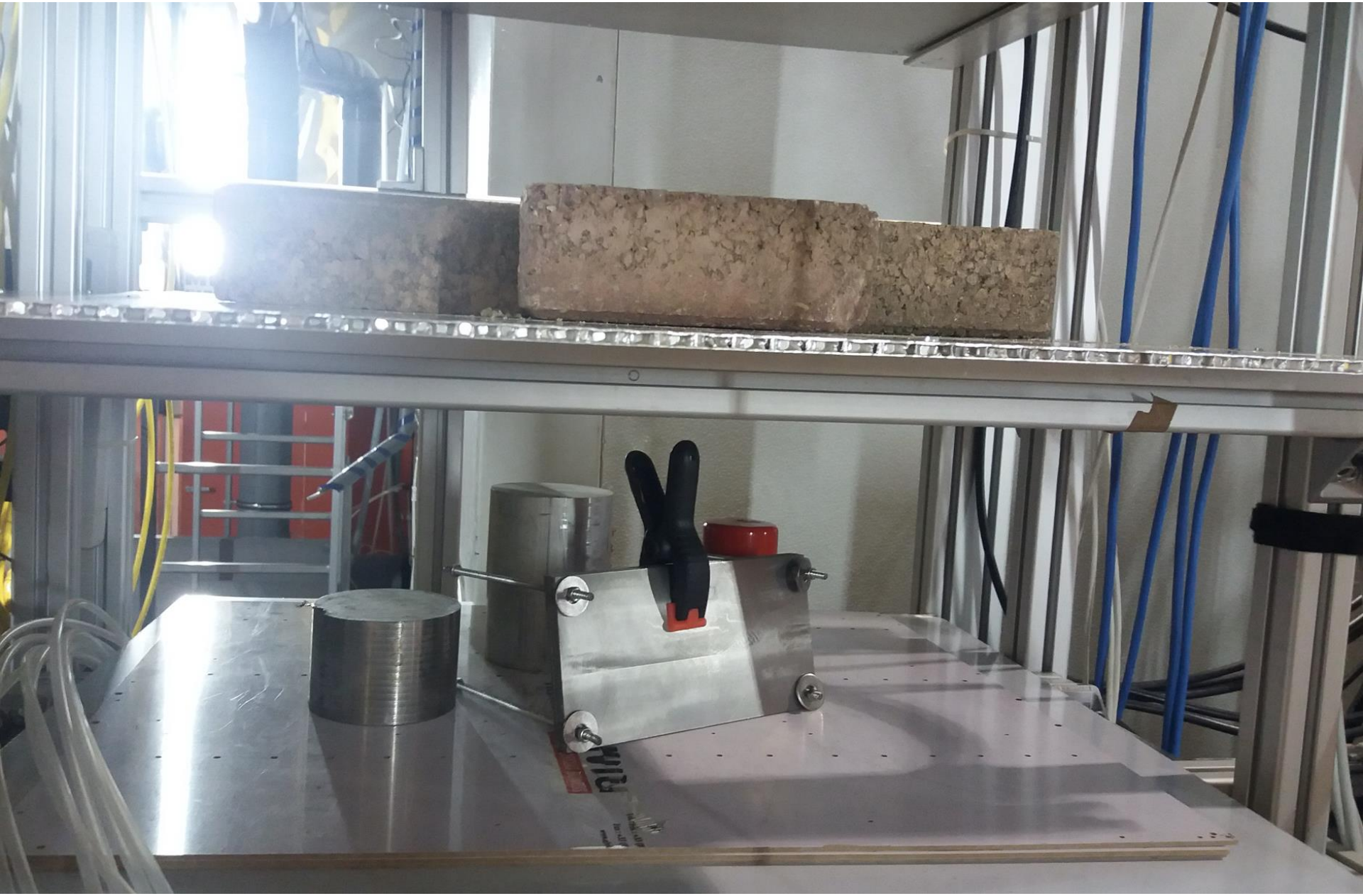
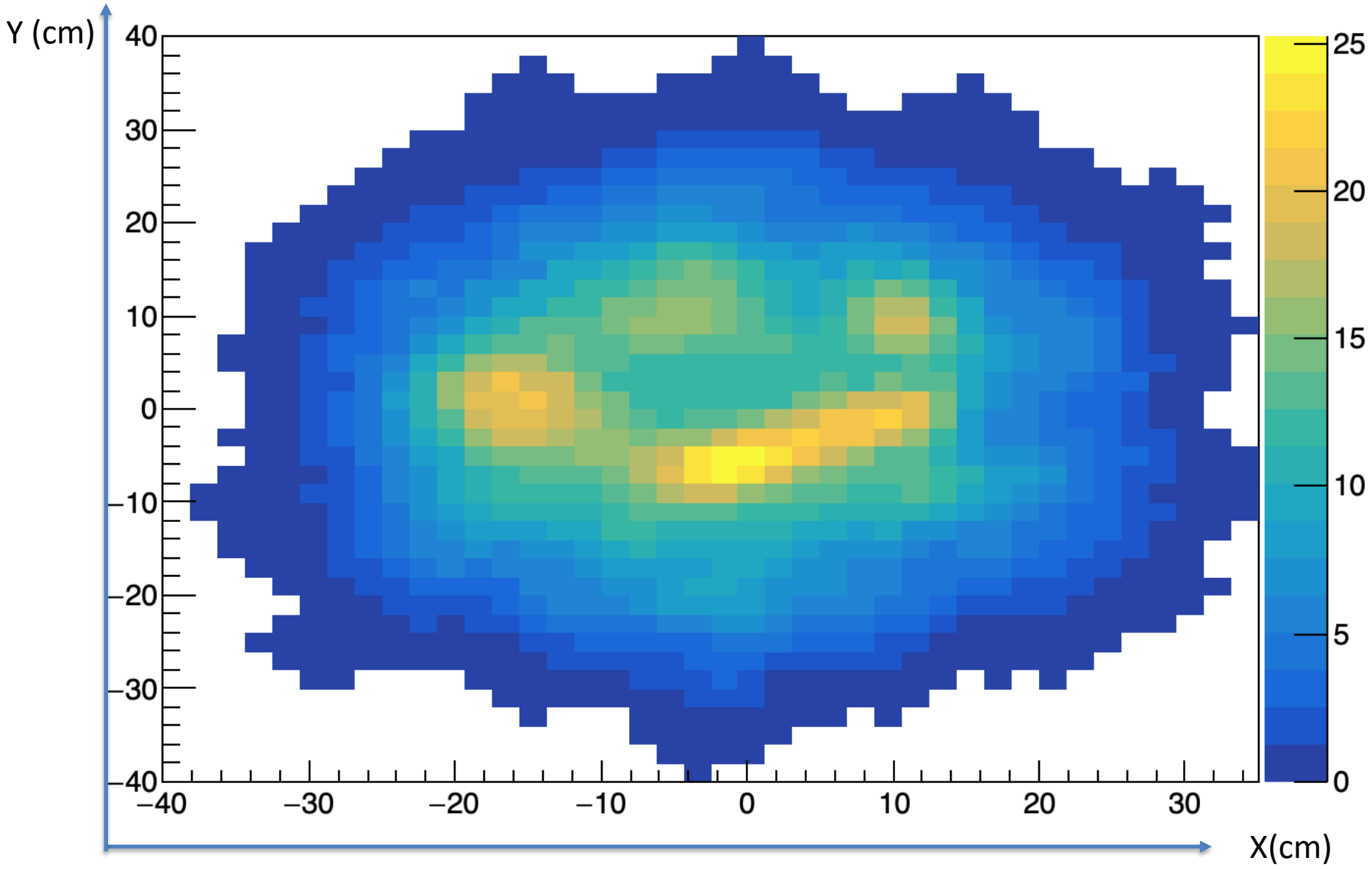
−30
−20
−10
0
10
20
30

4 kinds of elements shielded by thick concrete plates

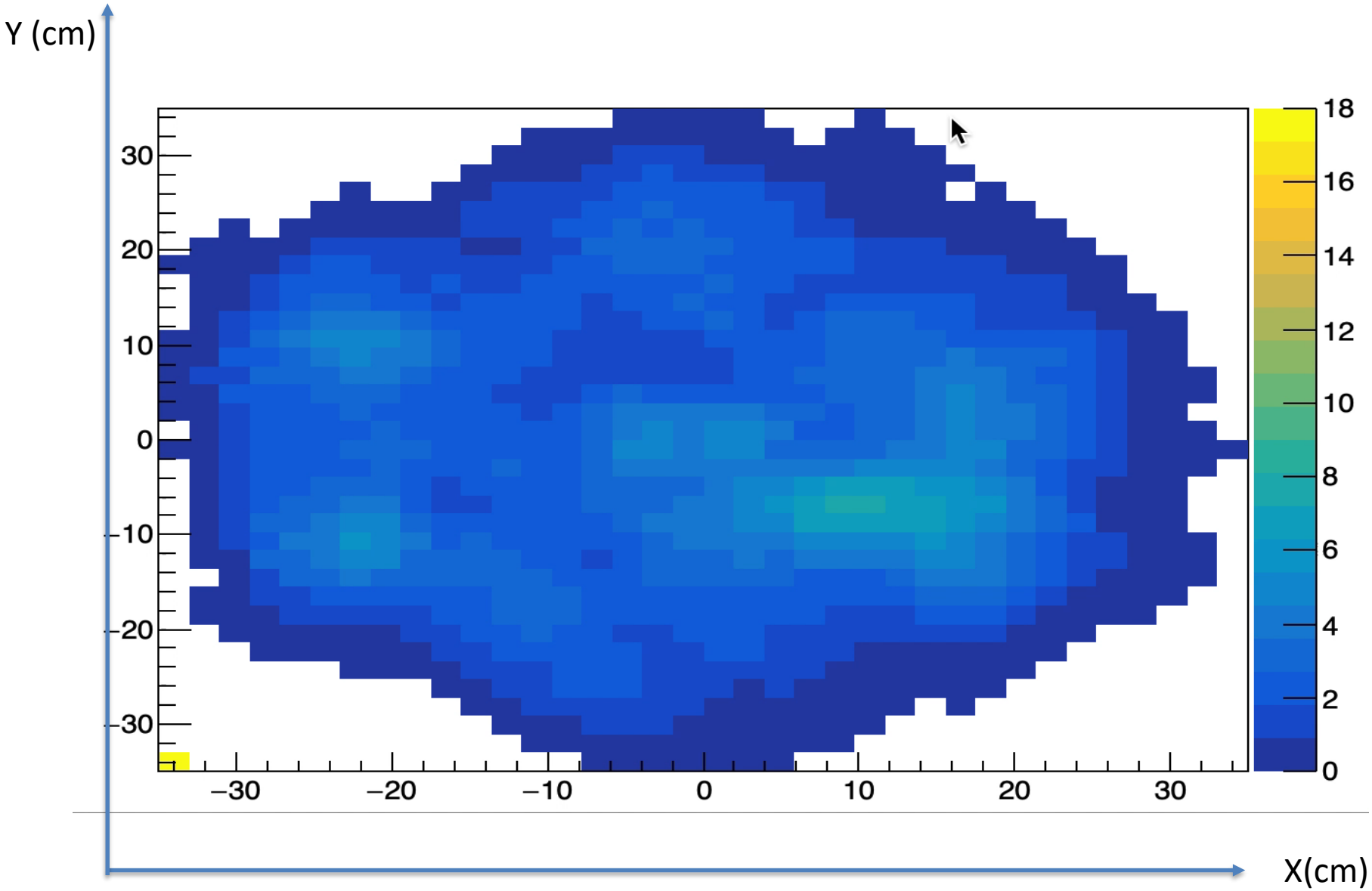
Top




Y (cm)
40
30
20
10
0
−10
−20
−30
−40
−40
−30
−20
−10
0
10
20
30
X(cm)
25
20
15
10
5
0

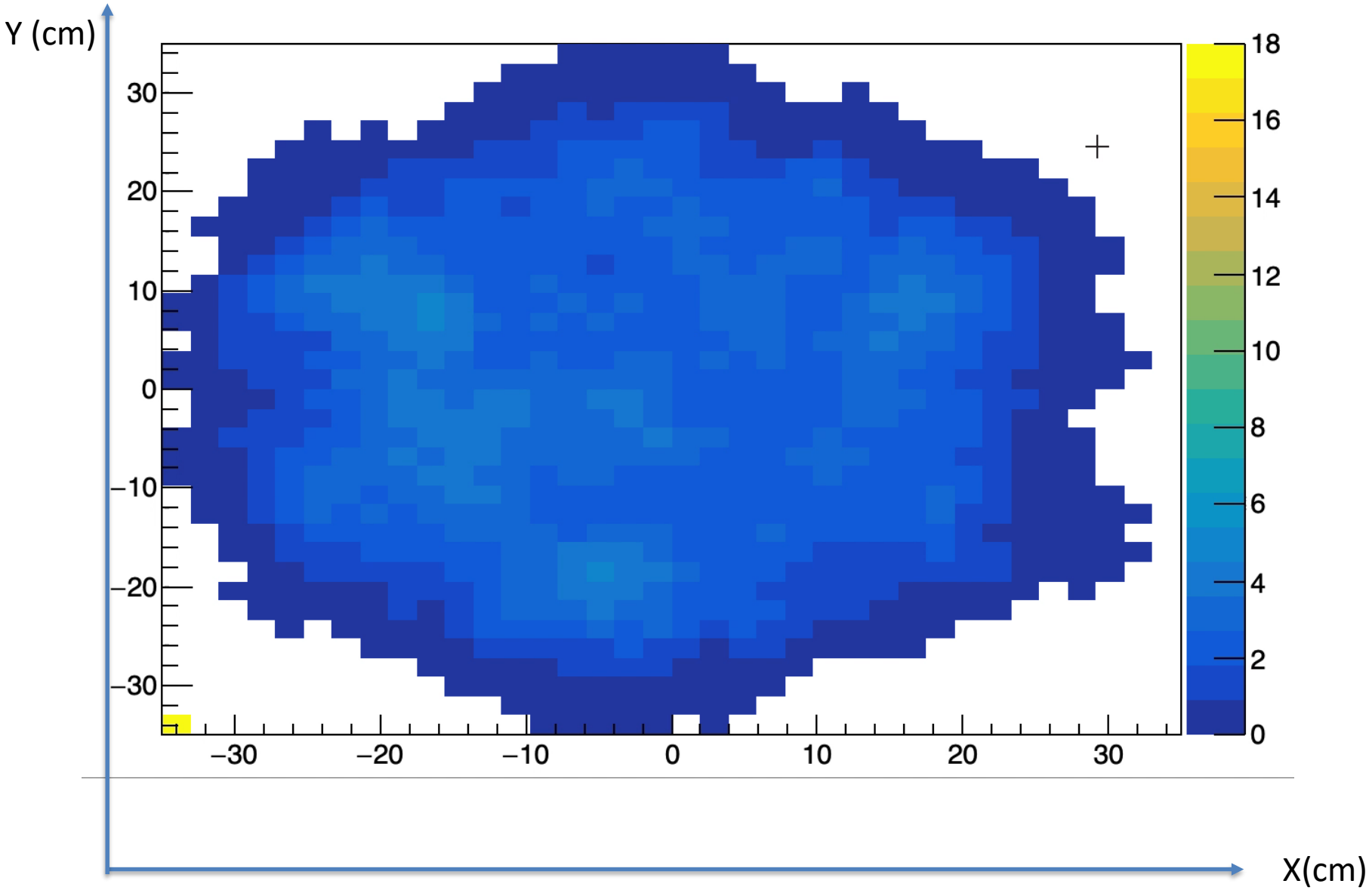
Hidden objects in concrete shielding placed at two different levels

Movie-Zscan

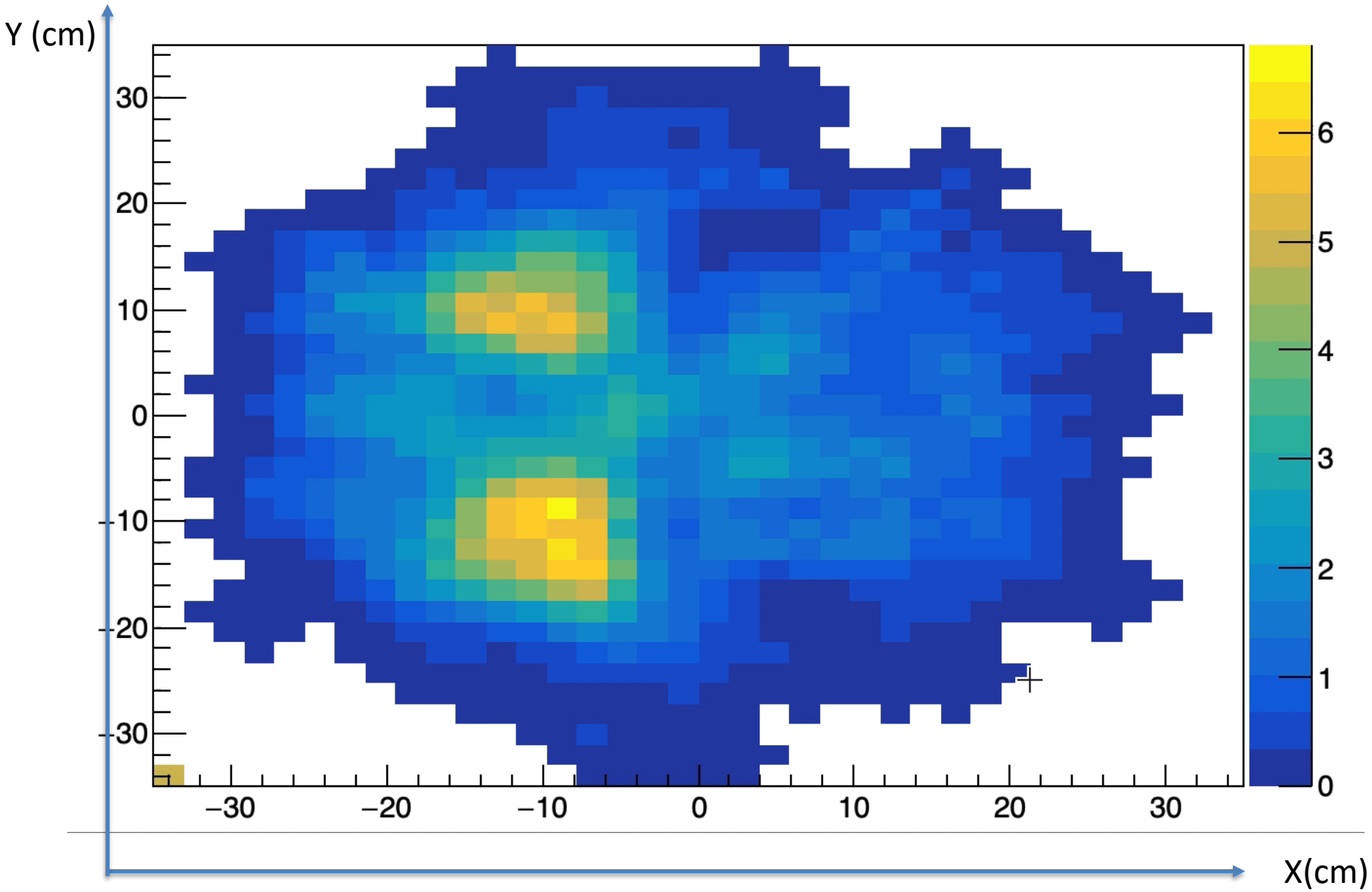


Another configuration with different kinds of objects

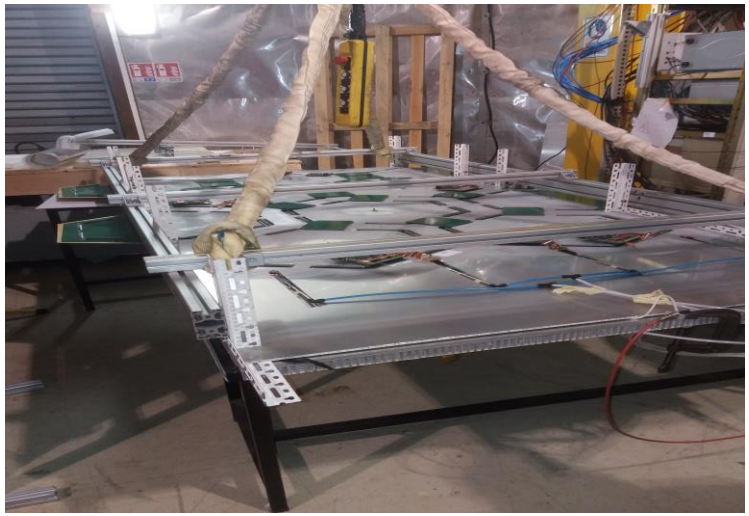
Movie-Zscan



Movie-Zscan



Next steps



- Build a few large surface RPC
- “Pave” them with 3D woven-strips PCB
- build a mechanical structure to support two sets of detectors separated by a few meters
- Test with large containers with hidden objects
- Improve the reconstruction algorithms to determine better the kink position (MLEM)
- Use time information to select momentum range of interest.

Conclusion

- RPC equipped with small pads pickup can provide a strong tool to study 3D structures
- Home security applications can take advantage of the excellent performances of RPC: efficient, robust and cost effective

- 3D woven strips readout can provide instrumentation of very large RPC at very affordable cost

- Readout electronics (developed for SDHCAL) was used but it is not adequate for this application. New readout electronics with continuous acquisition is needed.

- We intend to introduce time information to select the range of momenta of cosmic rays that provides the best information.