Study of Reconstruction Precision of Double Beta Decay Vertex for SuperNEMO Demonstrator

Miroslav Macko

Comenius University in Bratislava,
IEAP CTU in Prague,
Université de Bordeaux

Supervisors: Fabrice Piquemal, Ivan Štekl

2.6.2017, Prague, MEDEX´17 meeting

Presentation plan

- SuperNEMO and Falaise
- Precision of vertex resolution
- RMS and FWHM method
- Results
- Conclusions

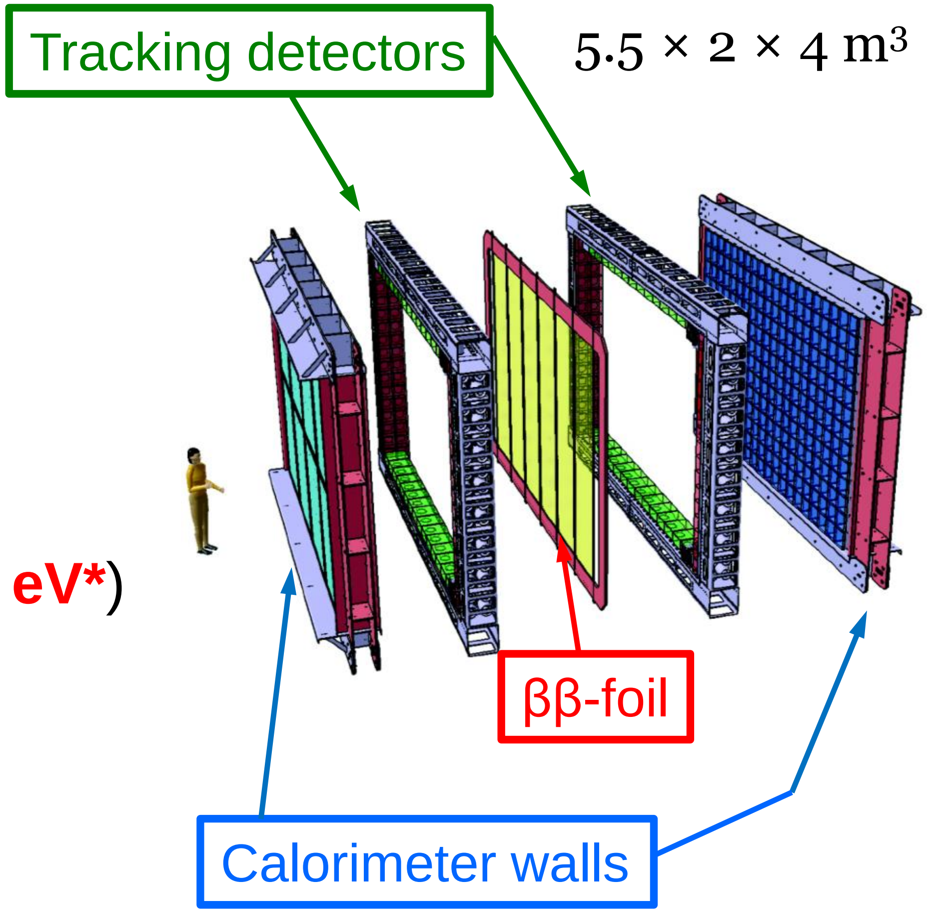
SuperNEMO and Falaise

SuperNEMO experiment

- Modular geometry (20 modules)
- Planned start: **2017**
- Placed in **LSM** (Modane, FRA)
- Studied isotope: **^{82}Se**

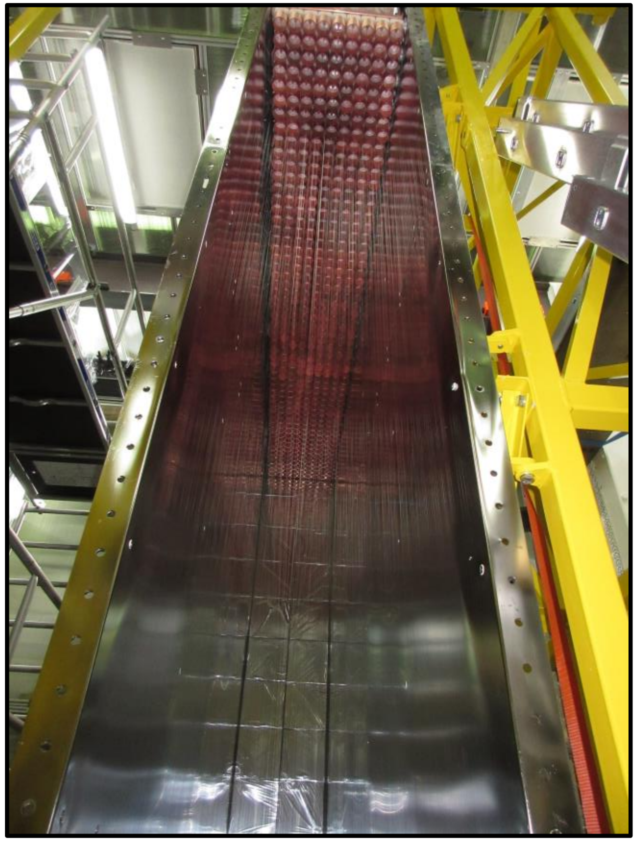
- 7 kg of isotope (**100+ kg***)
- $0\nu\beta\beta$: $T_{1/2} > 6\text{x}10^{24}$ yr (**10^{26} yr***).
- Limit $m_{\beta\beta}$: 0,2-0,4 eV (**0,04 -0,11 eV***)

* Full SuperNEMO design = 20 modules

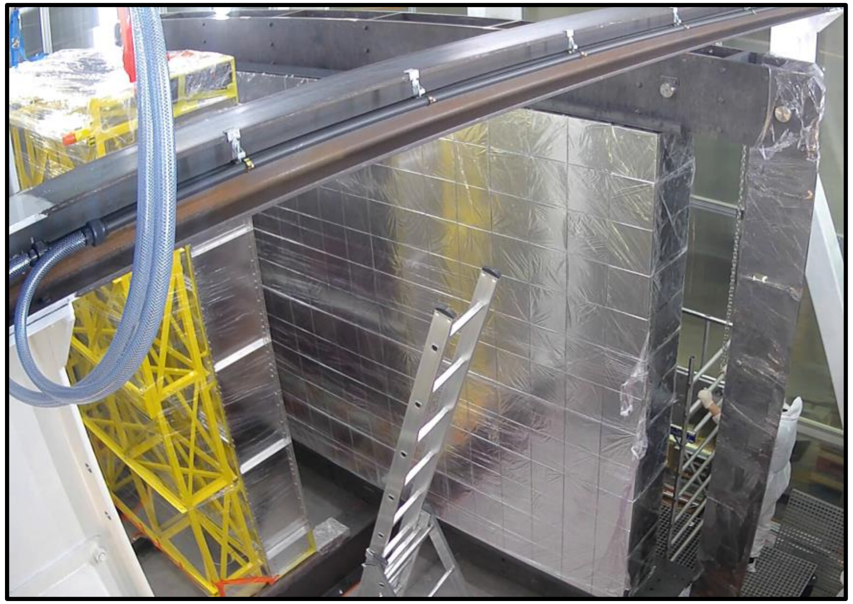


Photos of SuperNEMO demonstrator

Tracker



Calorimeter wall

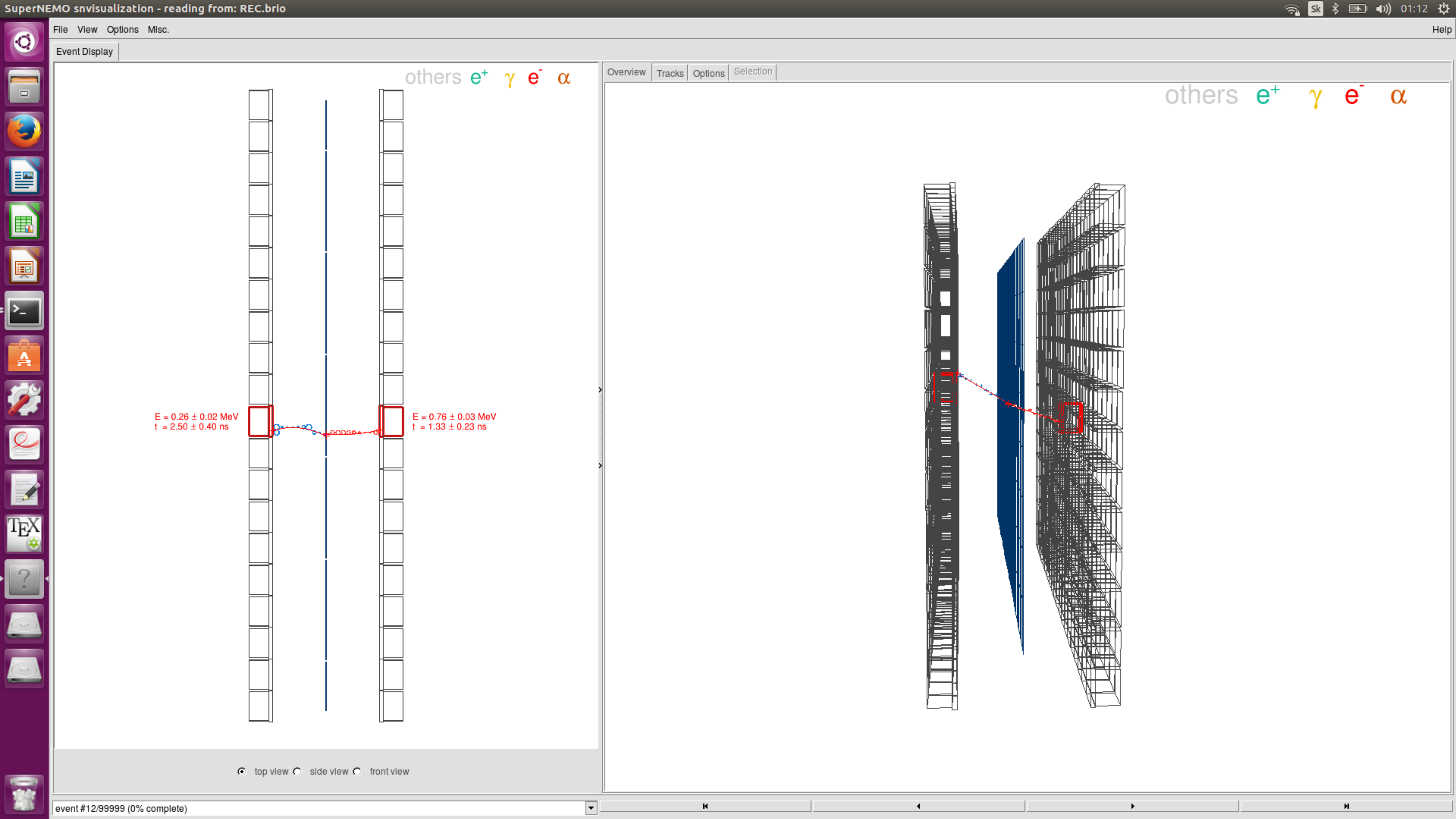


Clean tent from outside

Falaise

- Software package developed by **SuperNEMO software group**
- Based on **Geant4**
- **flsimulate, flreconstruct, flvisualize**
- **simulation** -> **mock calibration** -> **user module**

- Includes **full geometry of module**


SuperNEMO snvisualization - reading from: REC.brio
01:12
File
View
Options
Misc.
Help
Event Display
others e+ γ e- α
E = 0.26 ± 0.02 MeV
t = 2.50 ± 0.40 ns
E = 0.76 ± 0.03 MeV
t = 1.33 ± 0.23 ns
top view
side view
front view
event #12/99999 (0% complete)
Overview
Tracks
Options
Selection
others e+ γ e- α

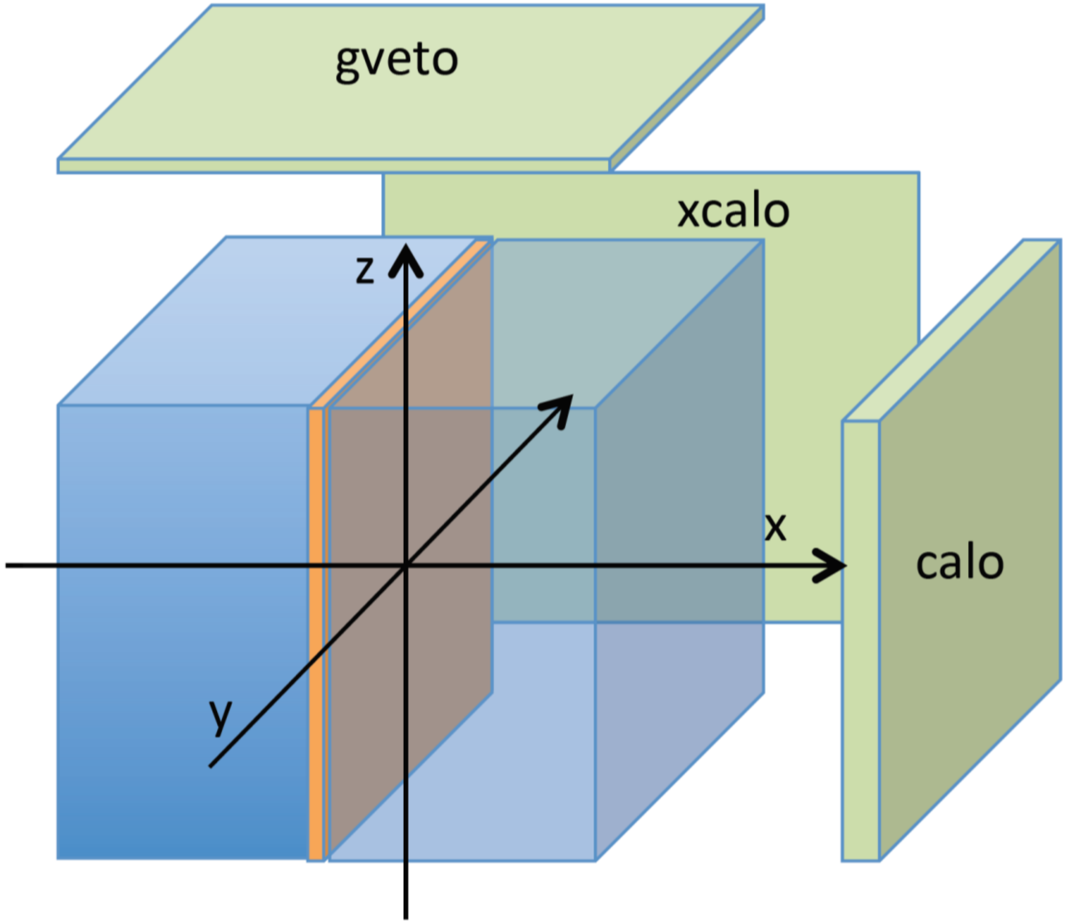
Precision of vertex reconstruction

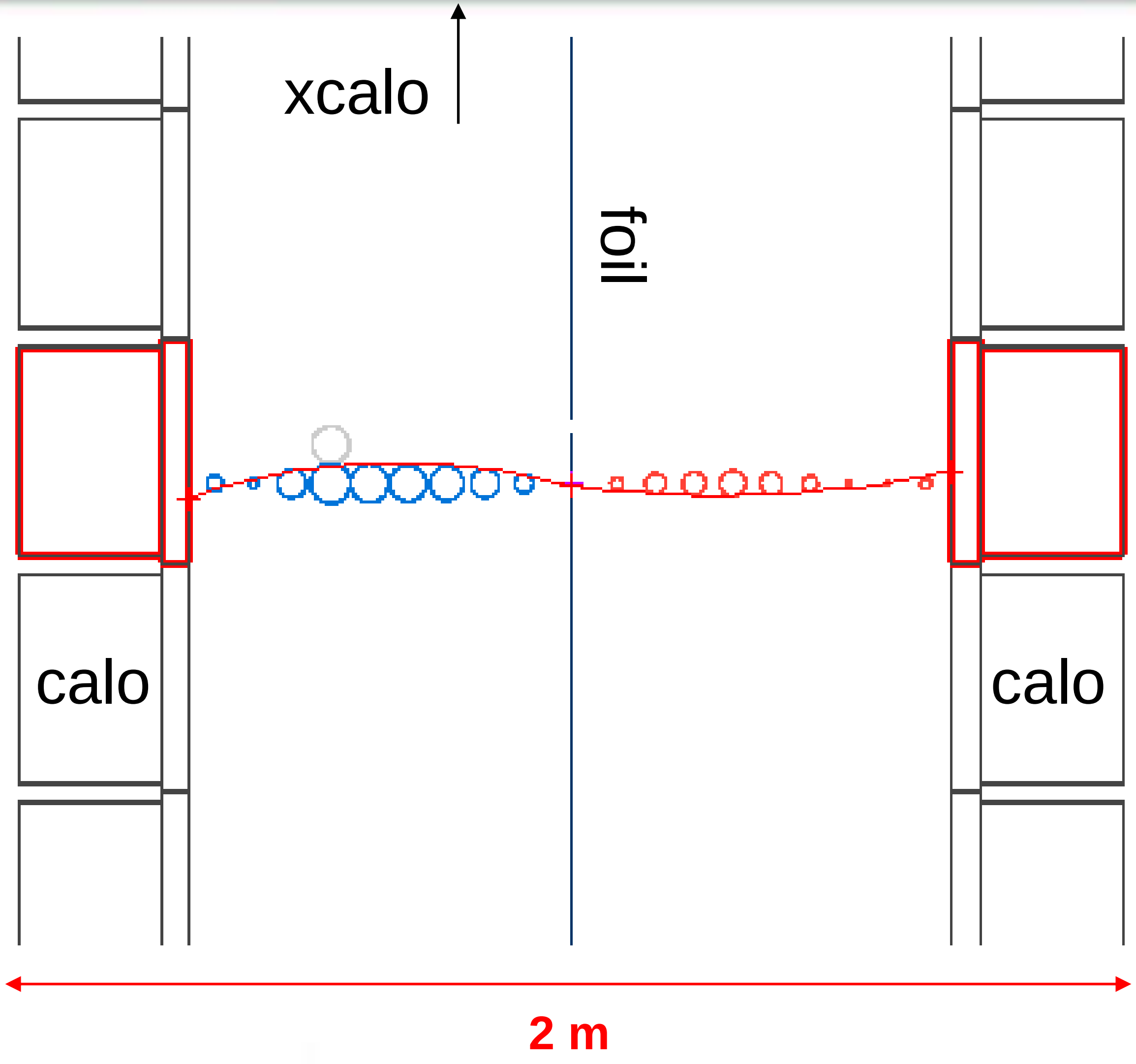
CAT & filtration criteria

- **CAT** (Cellular Automaton Tracker) is a **reconstruction algorithm** for electron tracks for SuperNEMO.
- In optimal case there are **two** electron **tracks**, each with one **vertex on foil** and one **vertex on calorimeter.**
- In simulated set of events we look only for **„nicely looking events“.**
- What are **my criteria** for „nice looking event“?
  - *2 calorimeter hits*
  - *2 associated calorimeter hits*
  - *2 foil vertices*
  - *2 reconstructed particles*
  - *2 negatively charged particles*

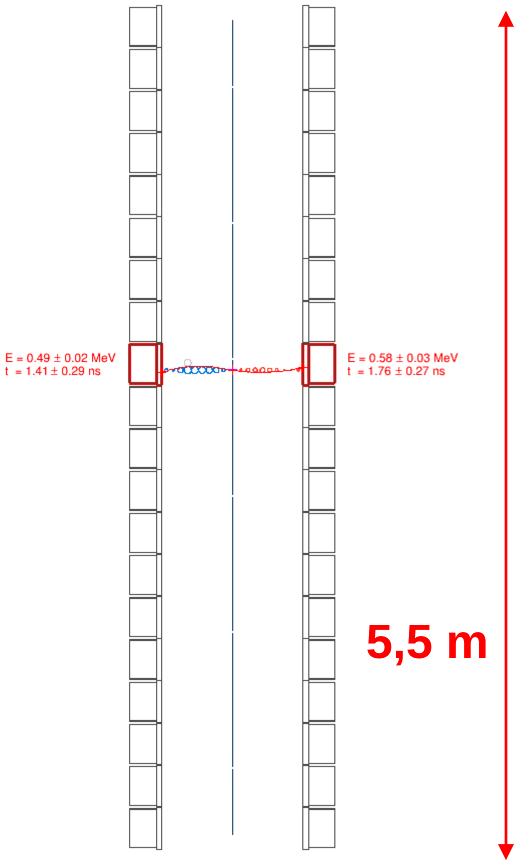
- Only if event fullfiled **all of the criteria** it was **kept** by pre-filter.
- In case of 2νββ only roughly **10,4 %** of events are kept.

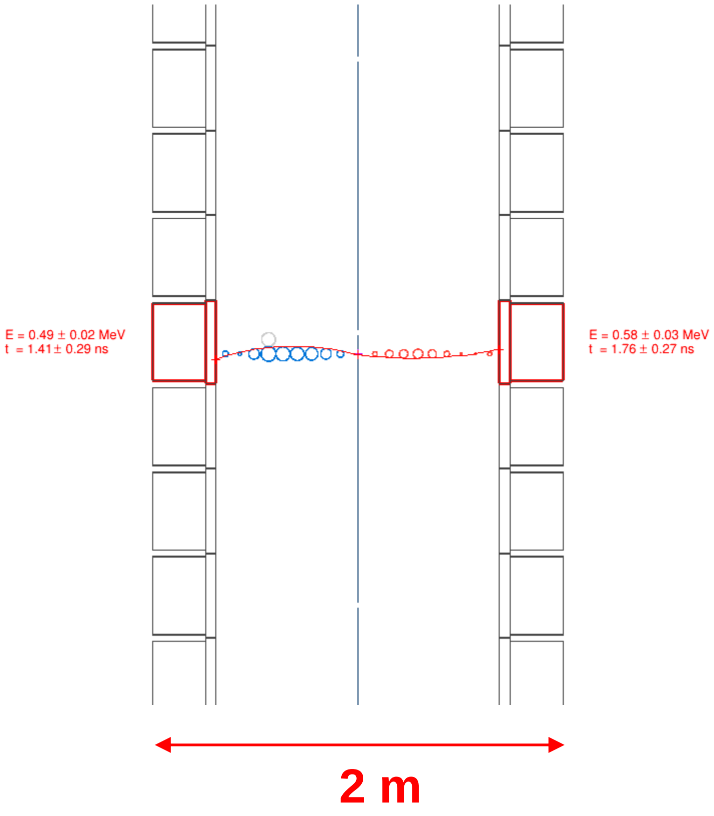
SuperNEMO module coordinate system

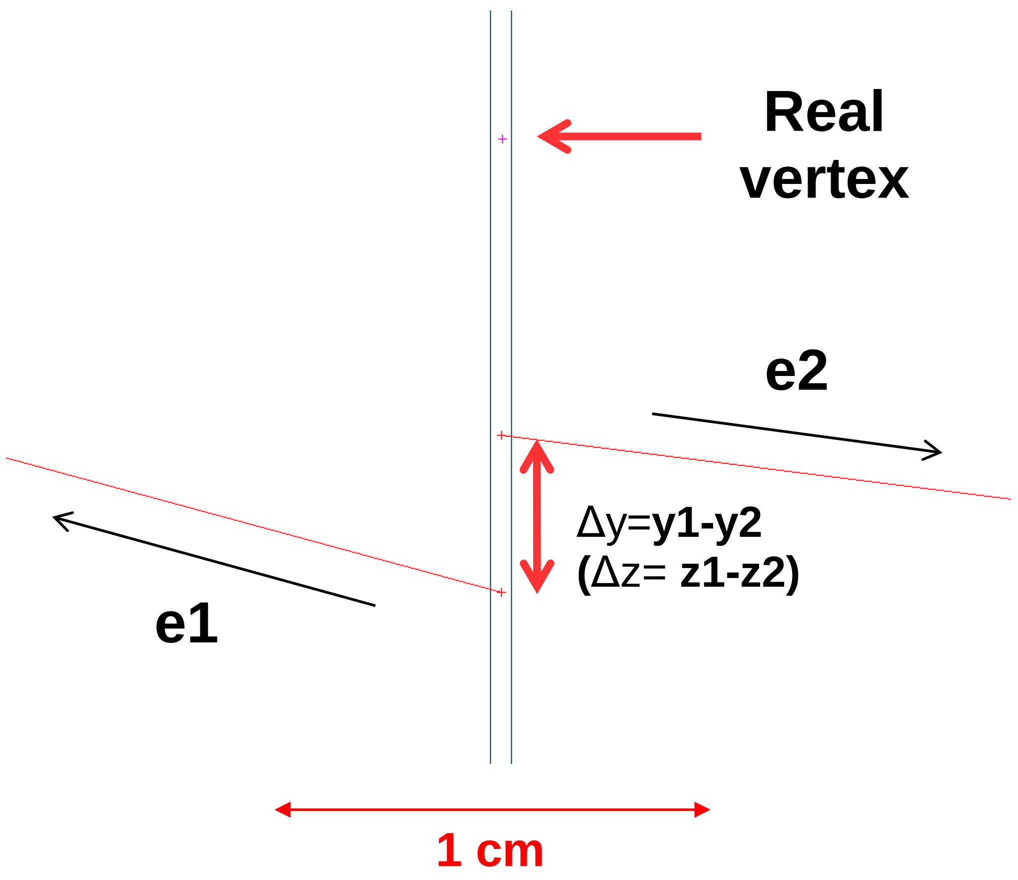




Description of the problem

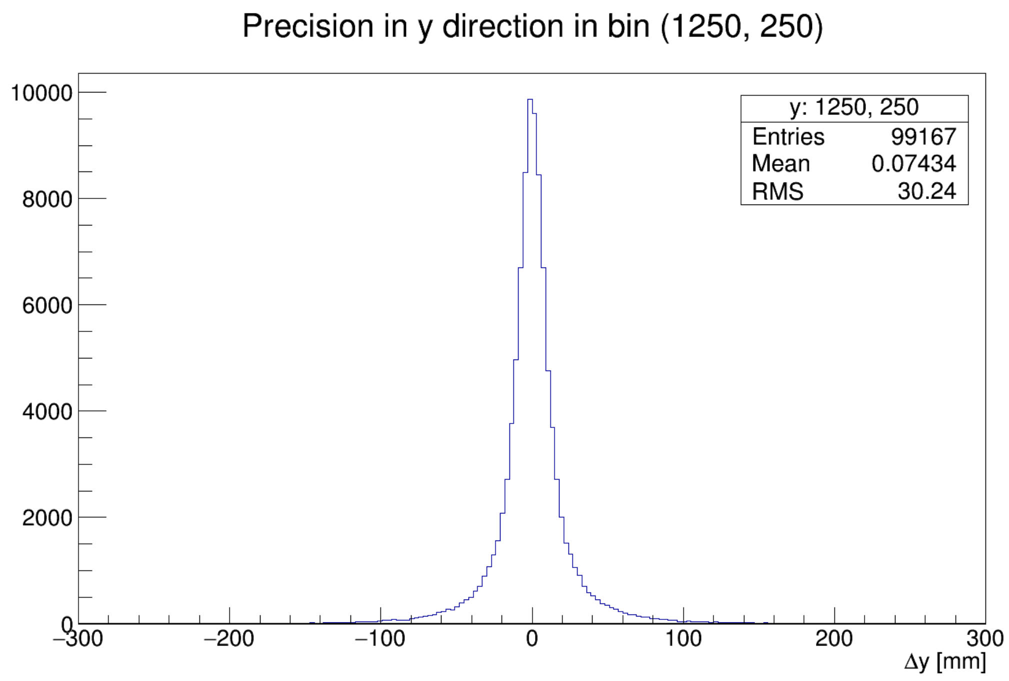


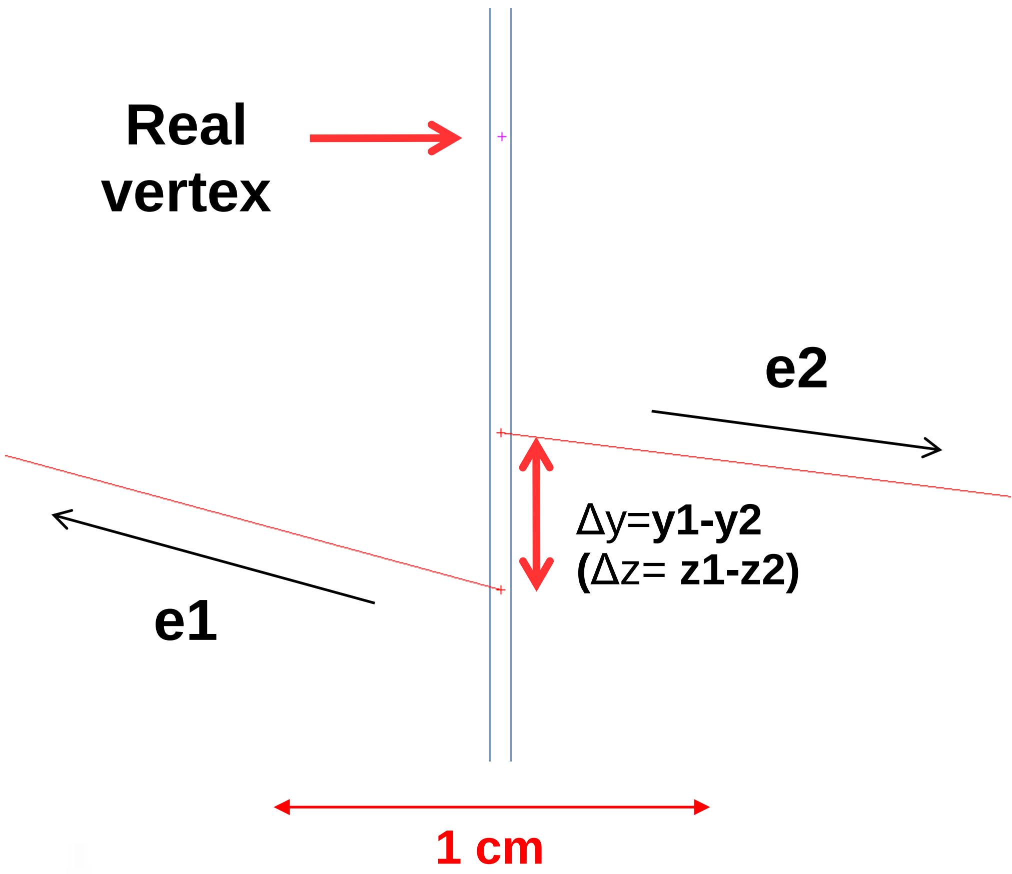




Δy and Δz values

- Main interest of my work is the **precision of foil vertex** reconstruction by CAT.
- In ideal case vertices **should be at the same point, they are not** (experimental uncertainities)**.**
- **Δy and Δz** values were calculated for every event after pre-filtration.
- They form **two statistical sets** with some distribution and standard deviation.





RMS and FWHM method

Methodology

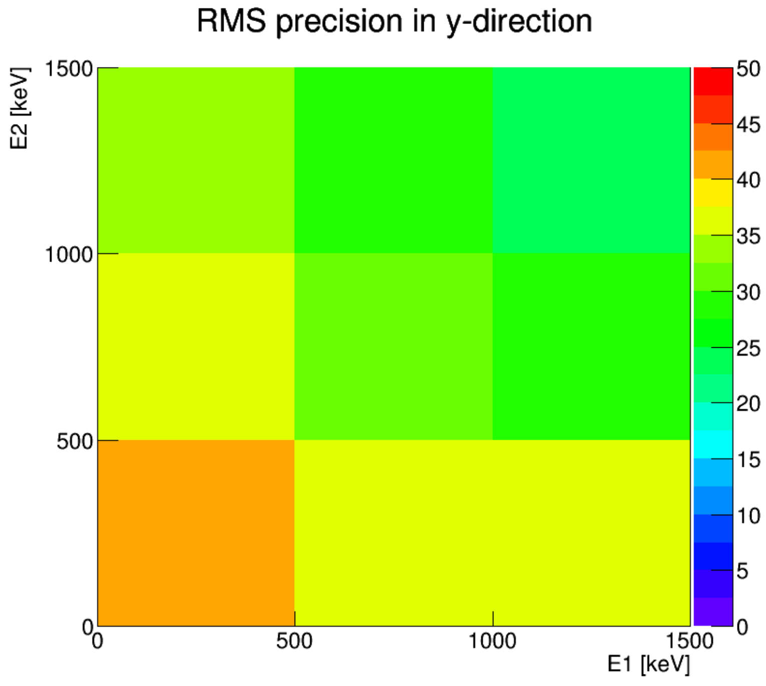
- „RMS“ ($\sqrt{<\Delta y^2> - <\Delta y>^2}$) of this distribution = **„RMS precision“**
- Condition: $|\mathbf{\Delta y}|, |\mathbf{\Delta z}| < \mathbf{300\ mm}$

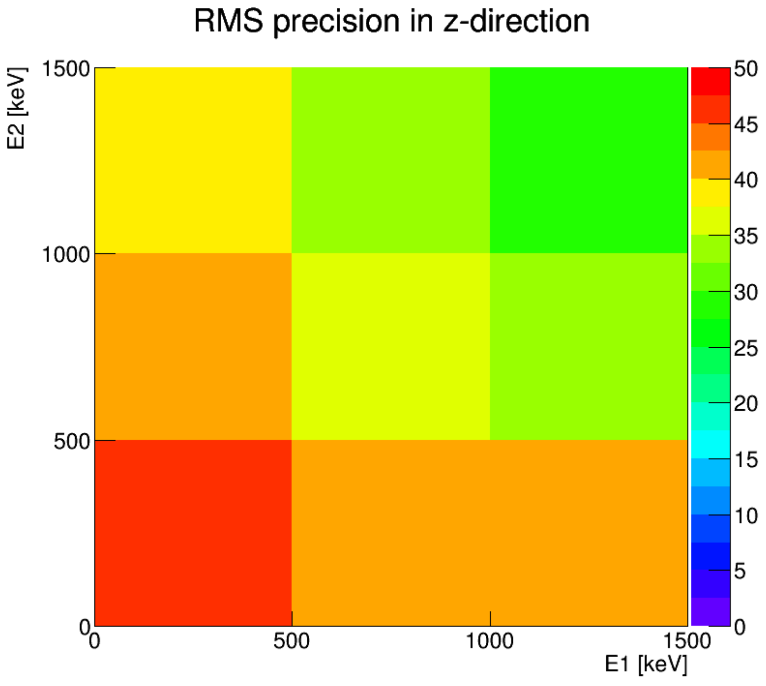
- Fitting and extraction of FWHM = **„FWHM precision“**

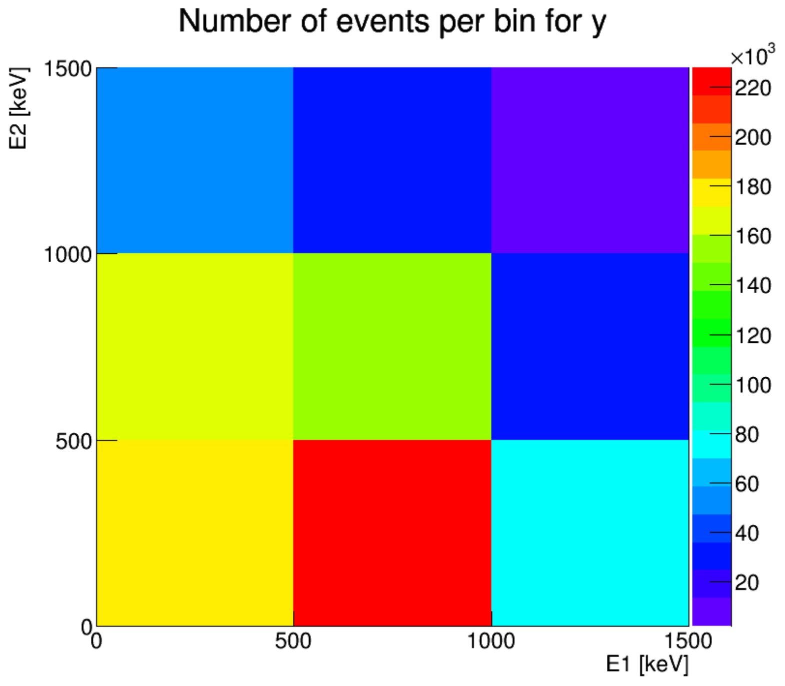
- Aim was to study precision **in dependence on electron energy and magnetic field**.
- Before calculation of precision of Δy and Δz I categorized events into **2D bins** depending on **energy of individual electrons**.
- I calculated **both precisions (RMS and FWHM) for every bin**.
- **Upper limit** on single electron energy was chosen to **1500 keV**.
- I used two types of binning 3x3 and 10x10.

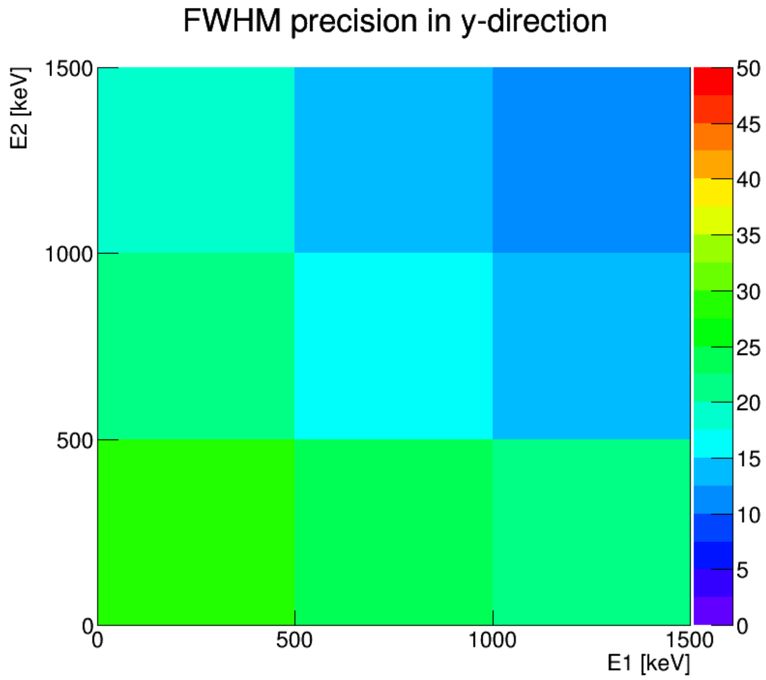
- Values for magnetic field were chosen as follows: **0G, 5G, 10G, 15G, 20G, 25G, 30G, 60G**.
- I generated **2.4×10^7 events** of **2νββ of ^{82}Se** with Falaise for **each data set** of different value of magnetic field.

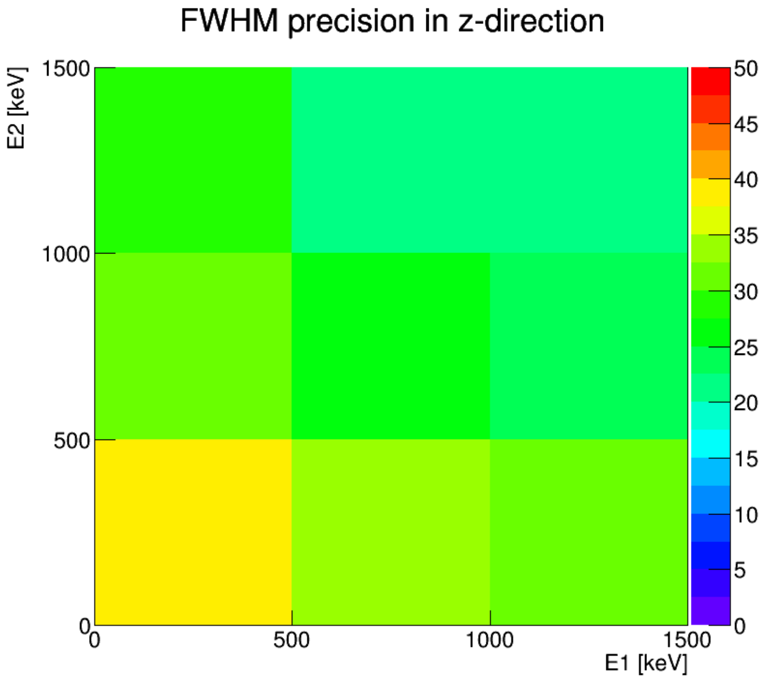
3x3-binning results







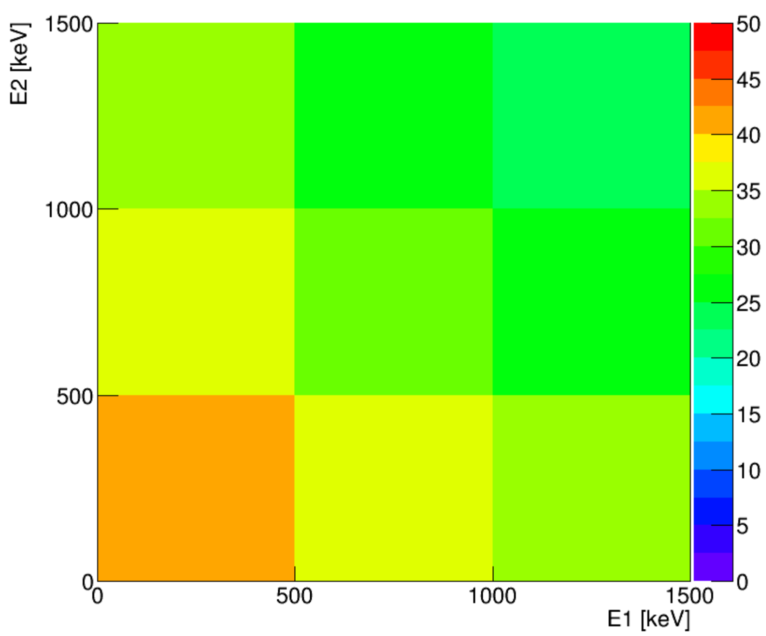




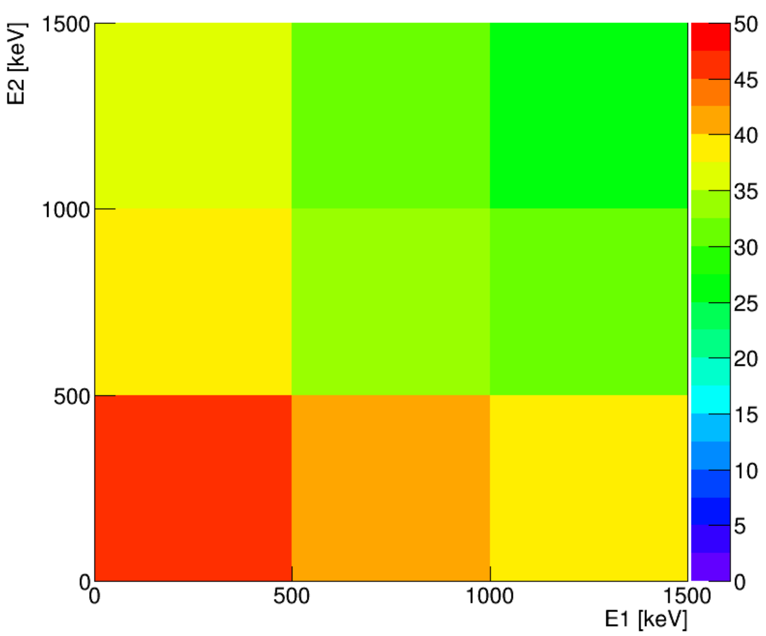
0 G

Precision **[mm]**

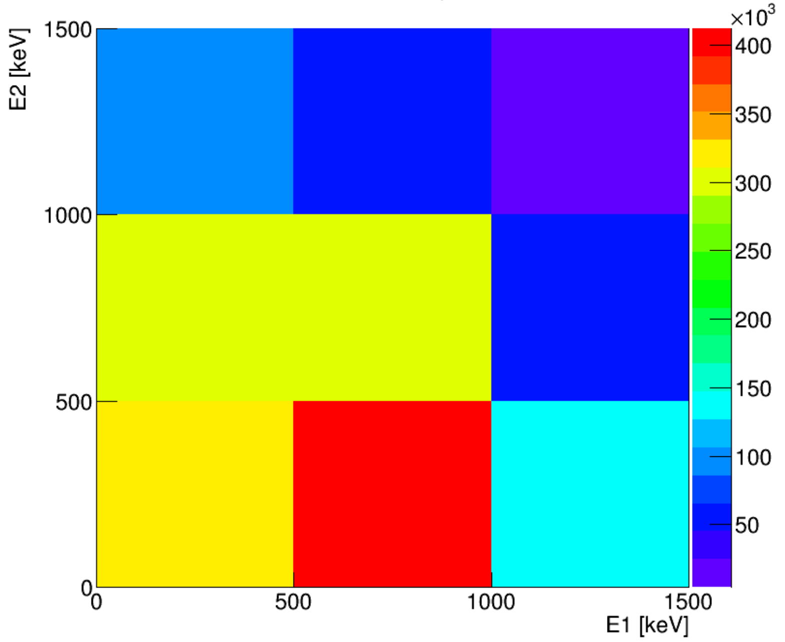
RMS precision in y-direction



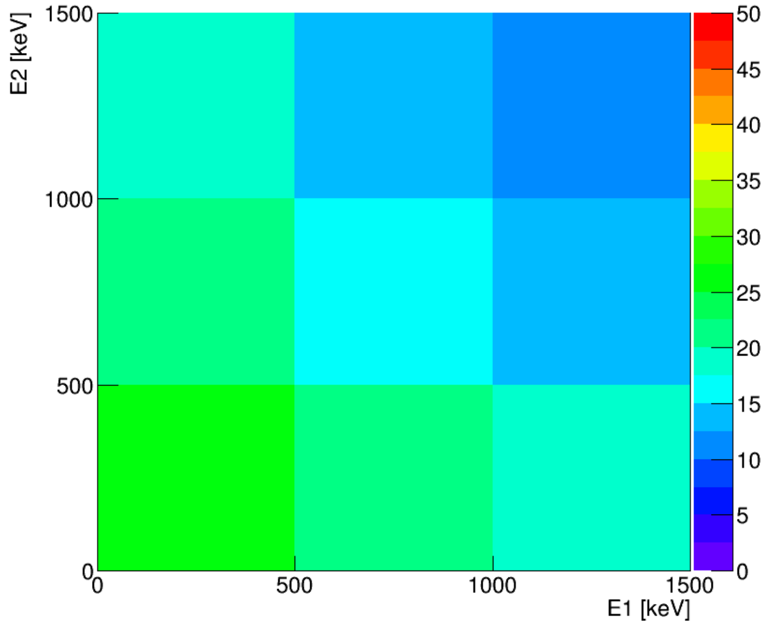
RMS precision in z-direction



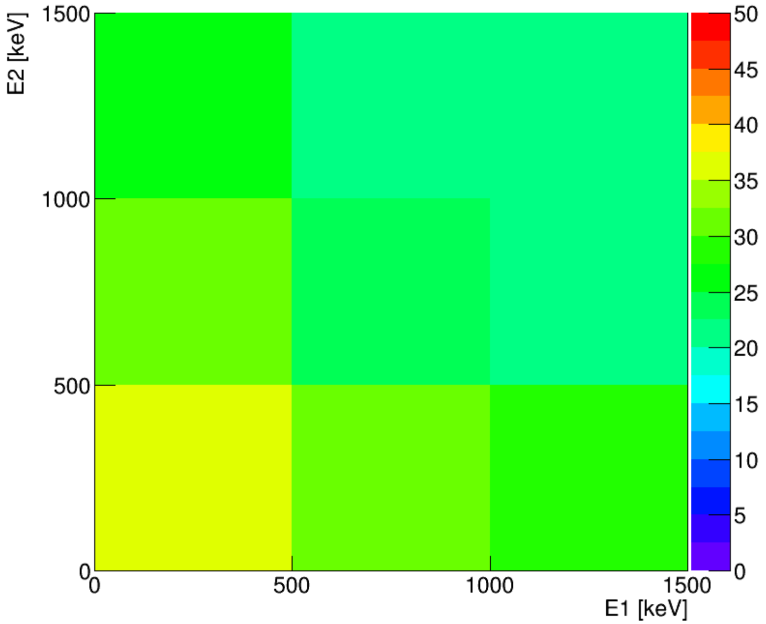
Number of events per bin for y



FWHM precision in y-direction

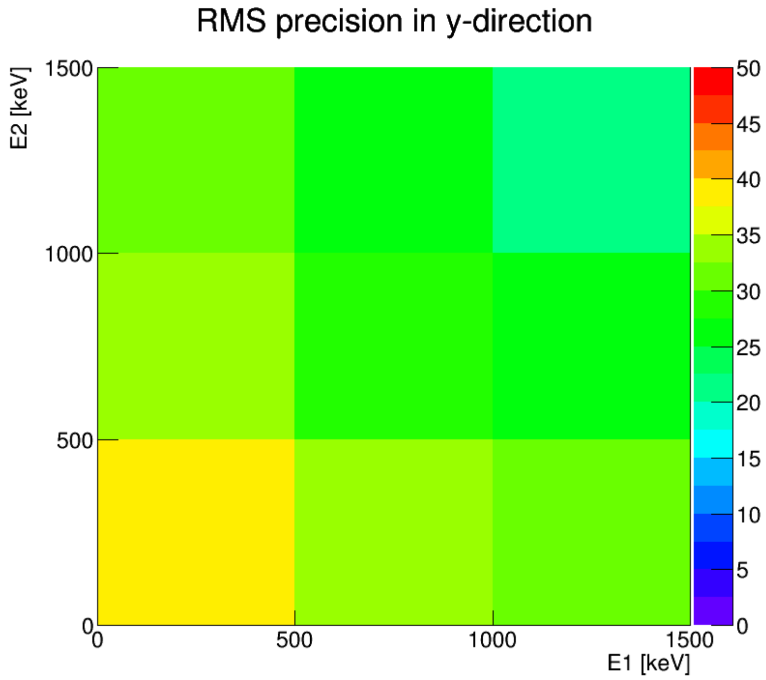


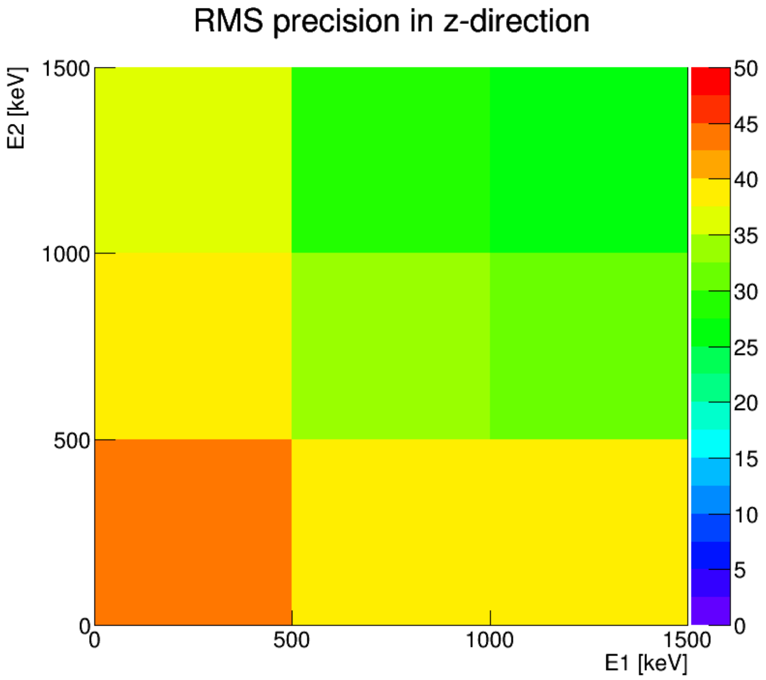
FWHM precision in z-direction

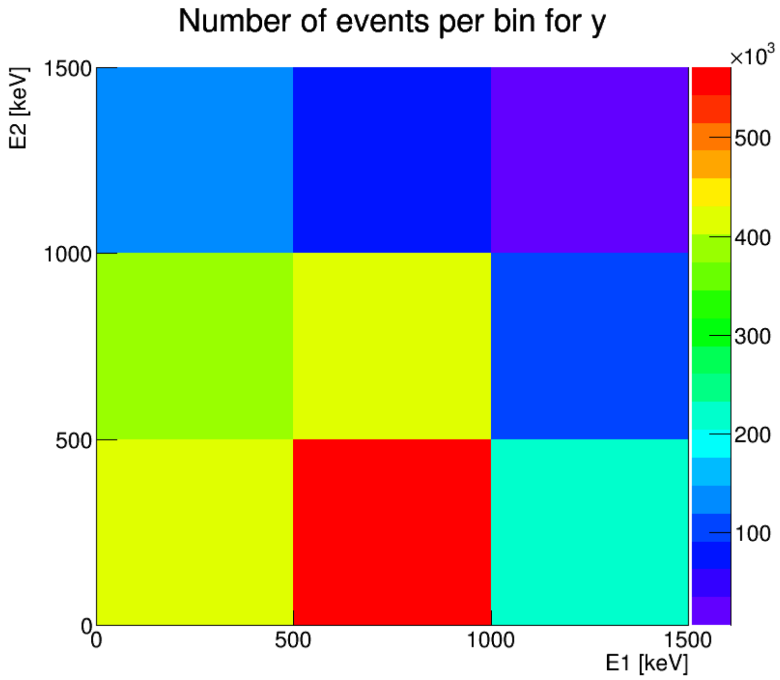


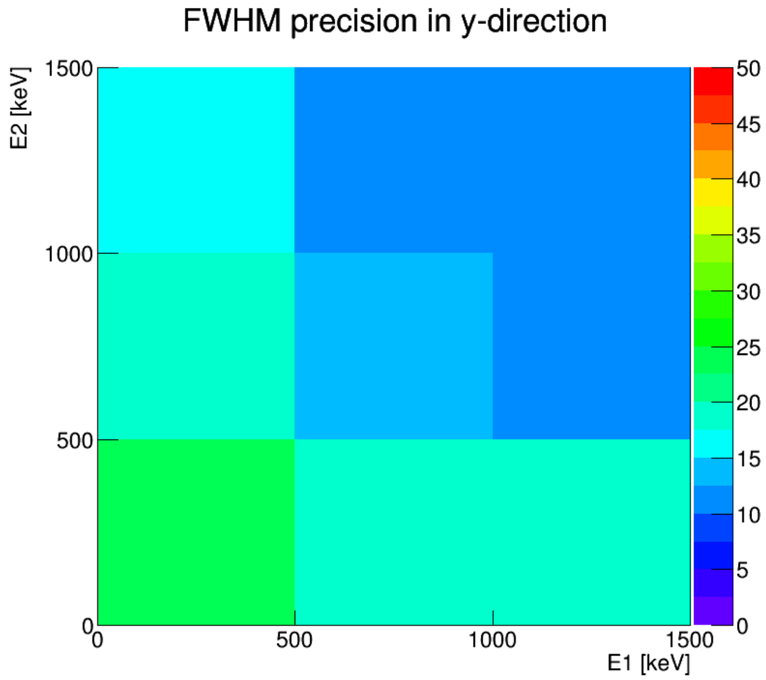
5 G

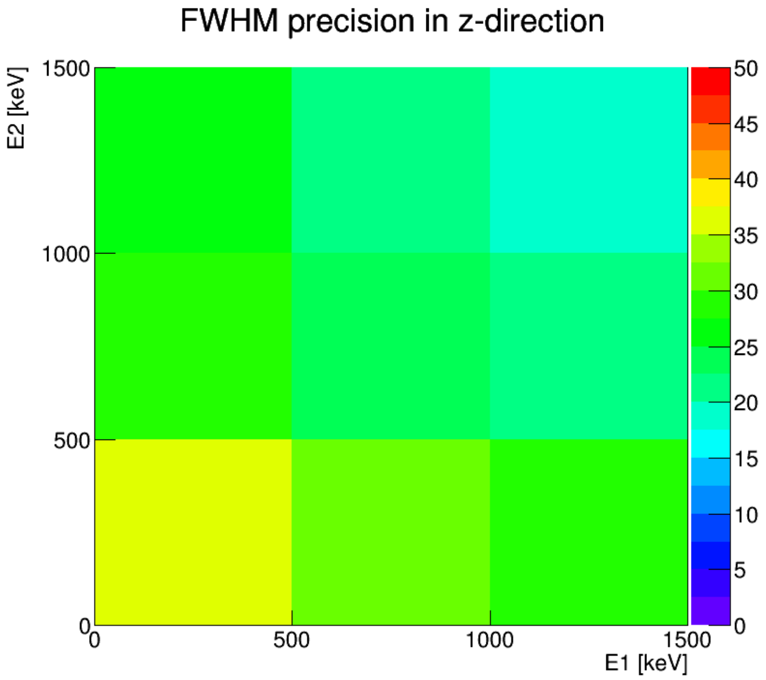
Precision **[mm]**





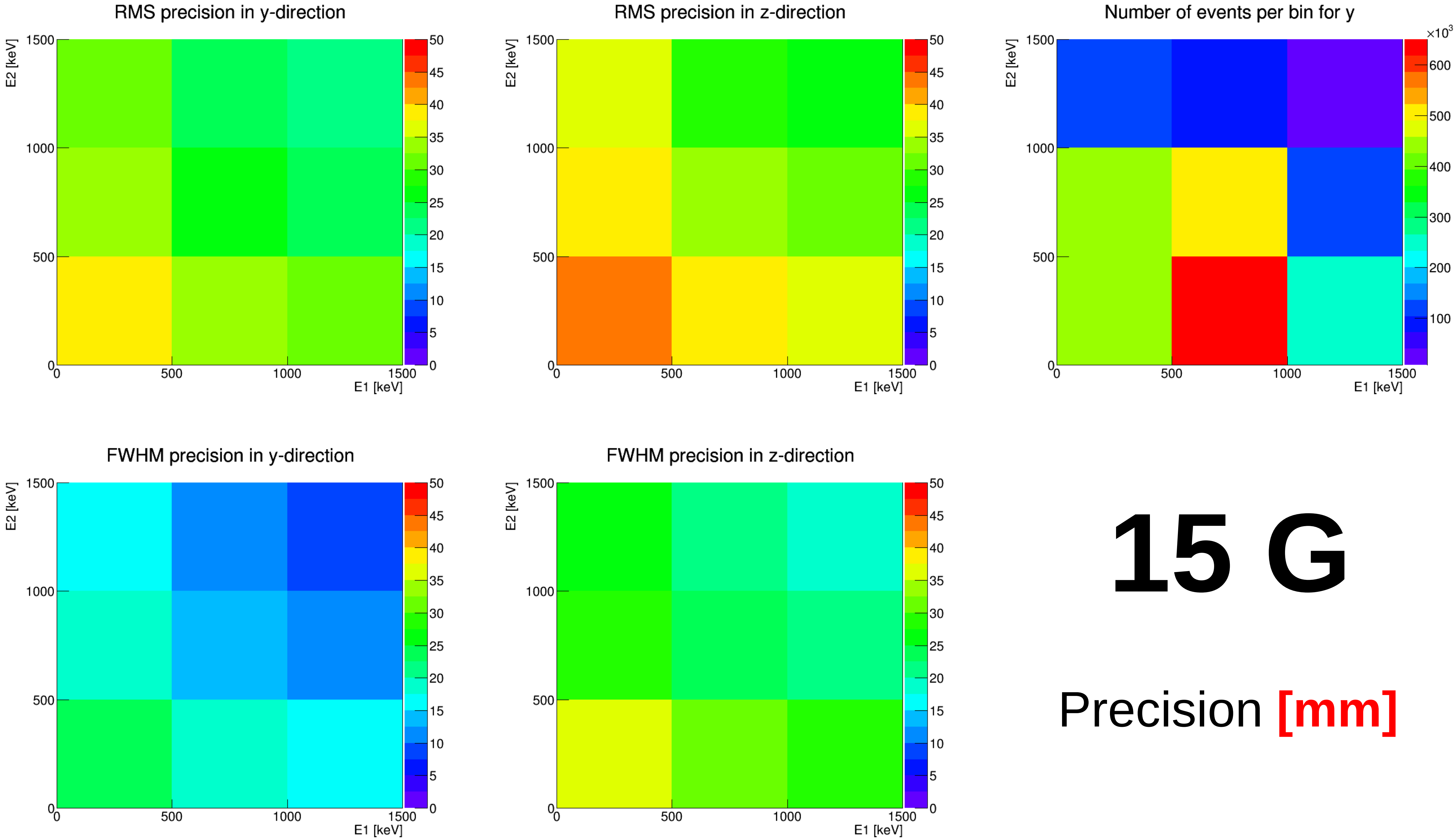






10 G

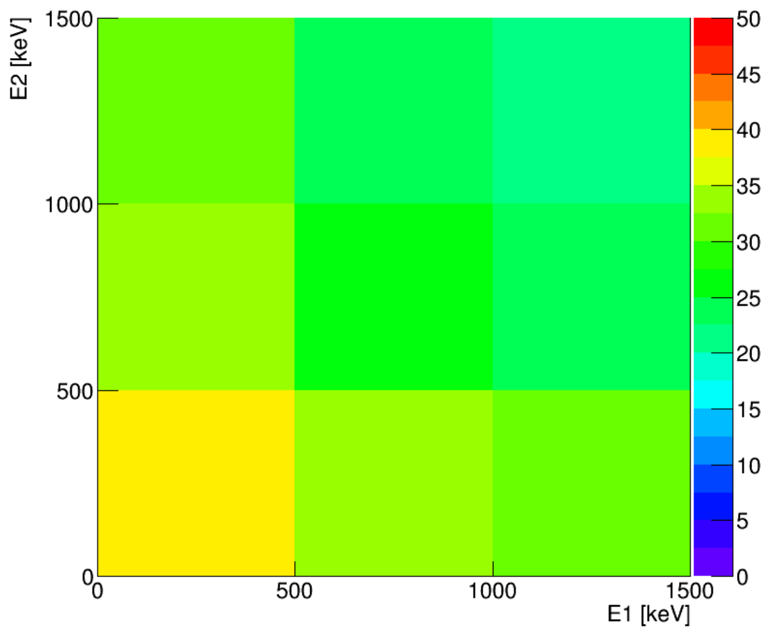
Precision **[mm]**



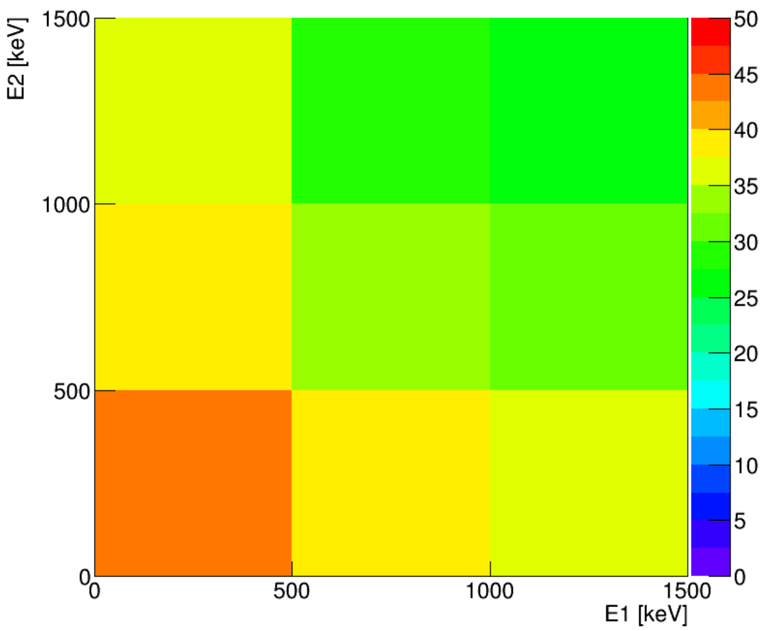
15 G

Precision [mm]

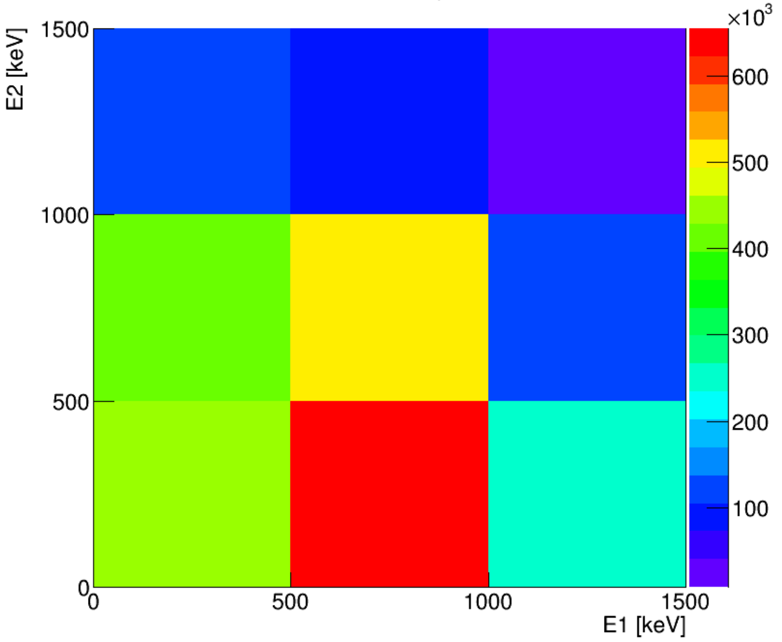
RMS precision in y-direction



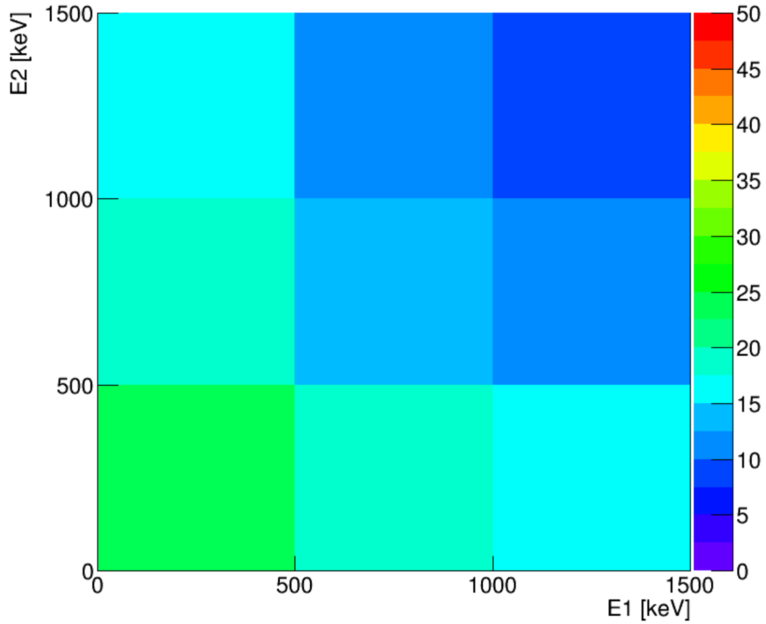
RMS precision in z-direction



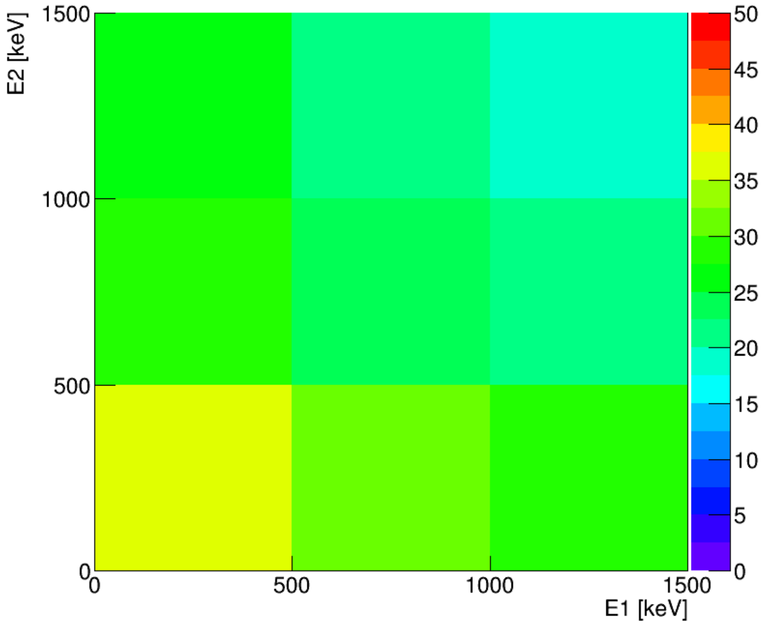
Number of events per bin for y



FWHM precision in y-direction



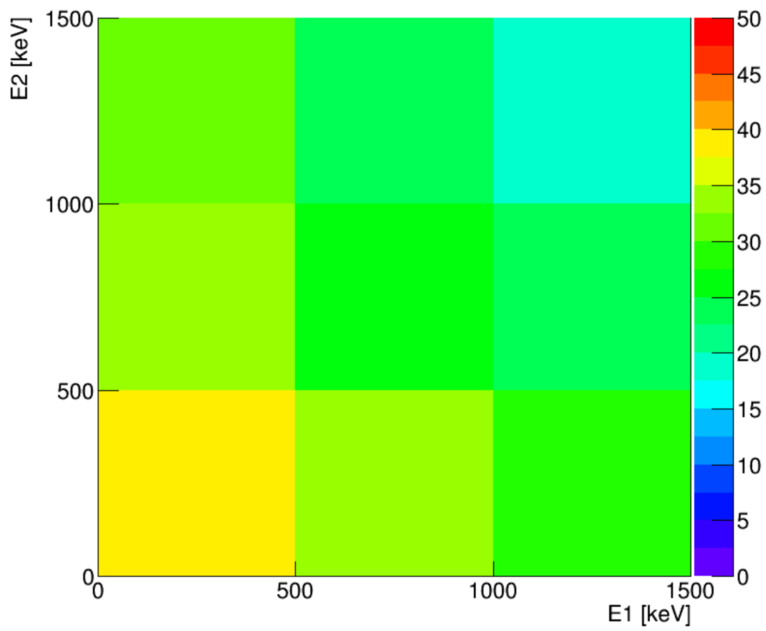
FWHM precision in z-direction



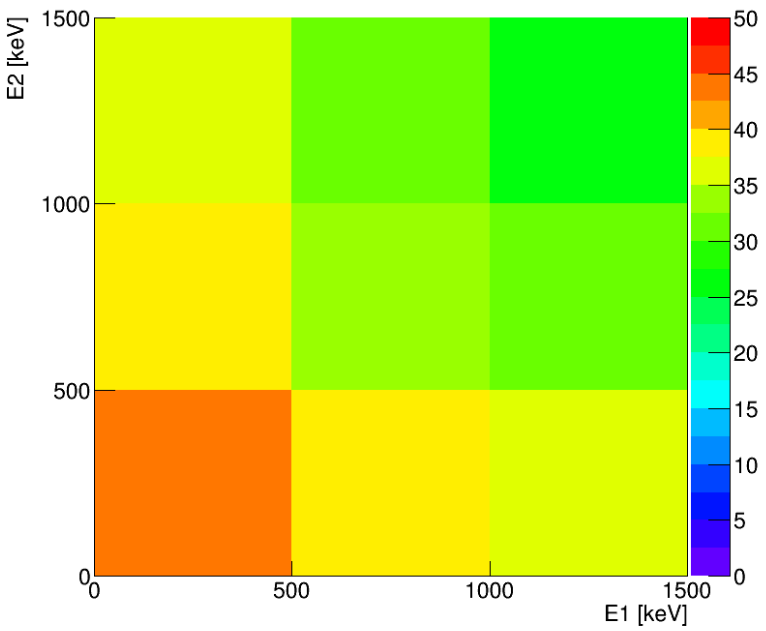
20 G

Precision **[mm]**

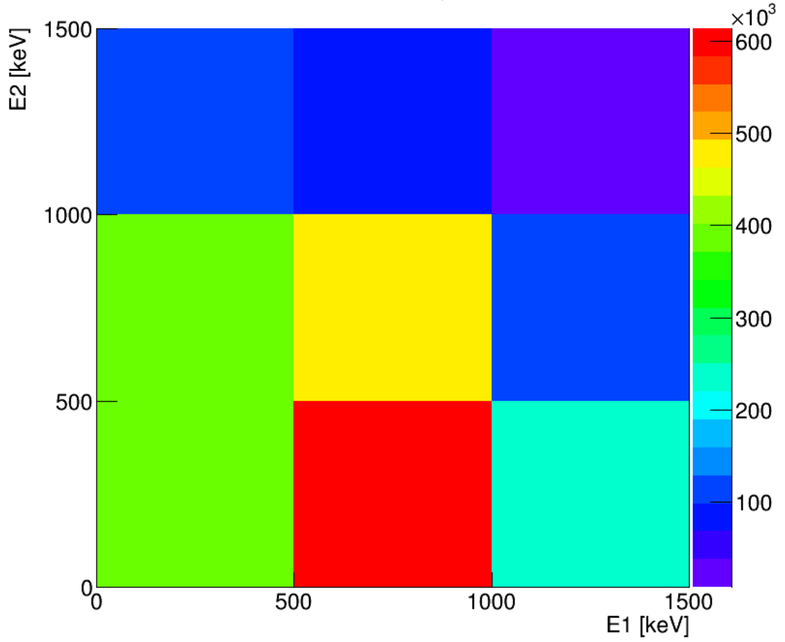
RMS precision in y-direction



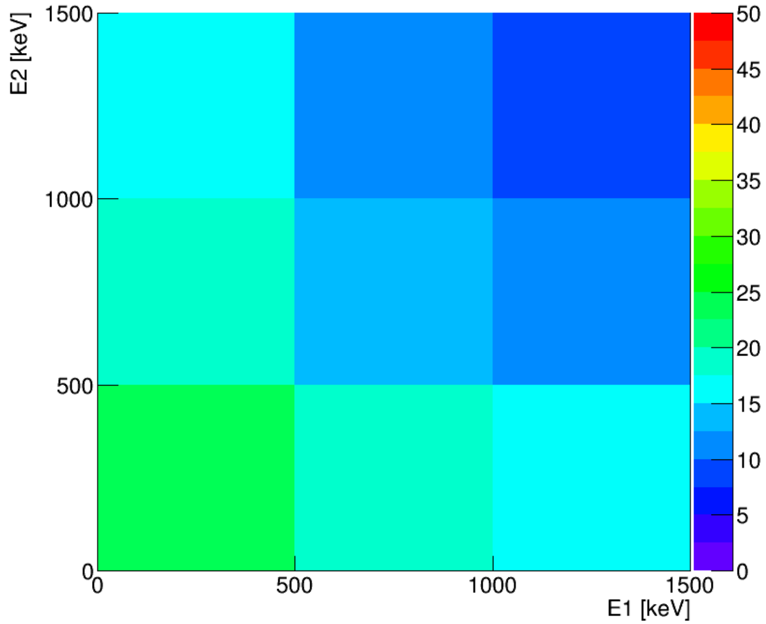
RMS precision in z-direction



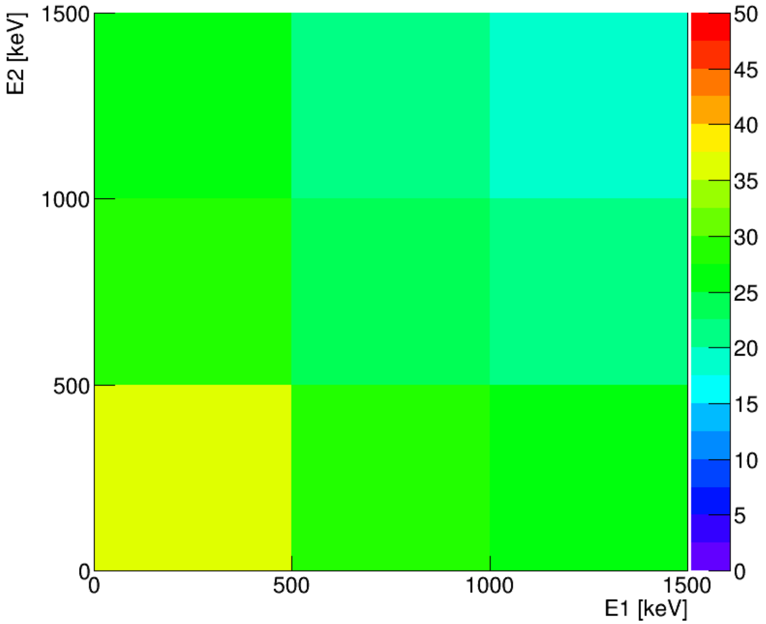
Number of events per bin for y



FWHM precision in y-direction

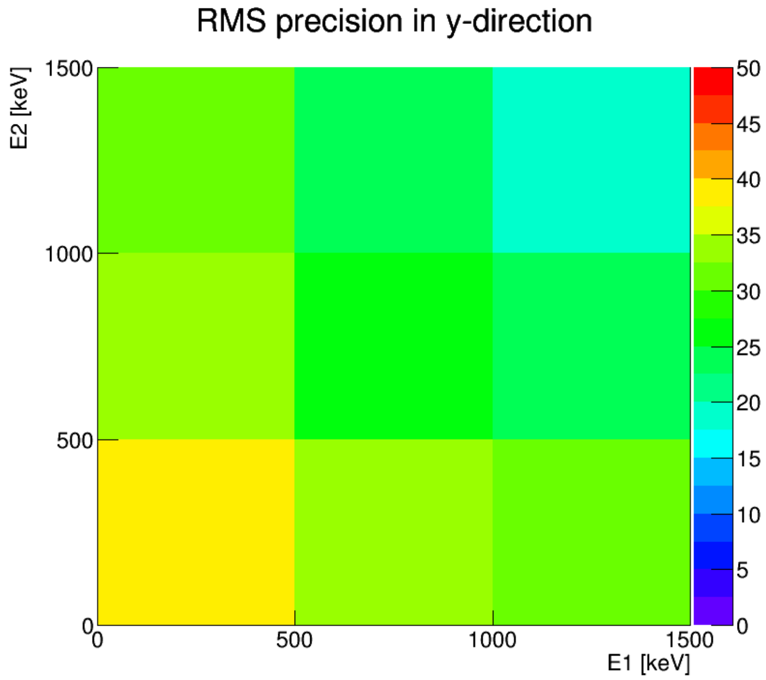


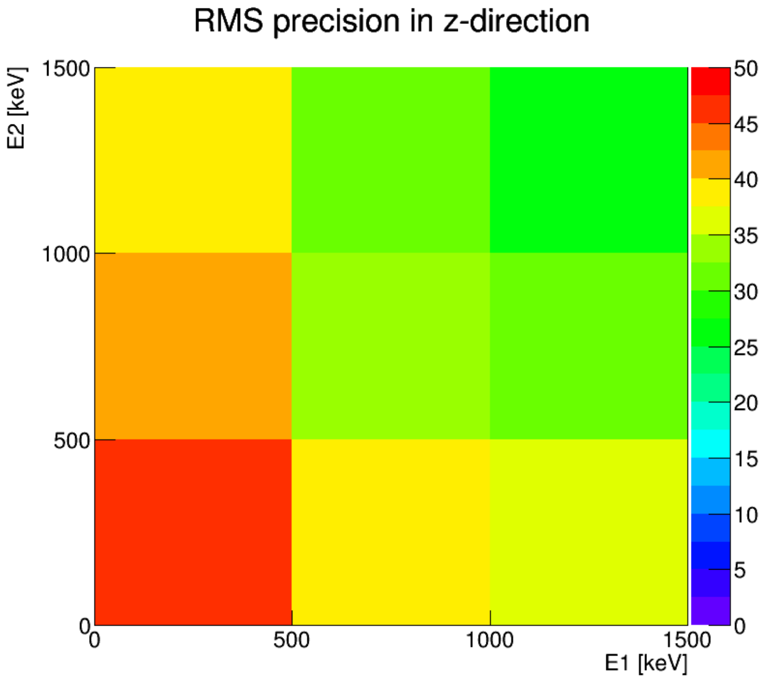
FWHM precision in z-direction

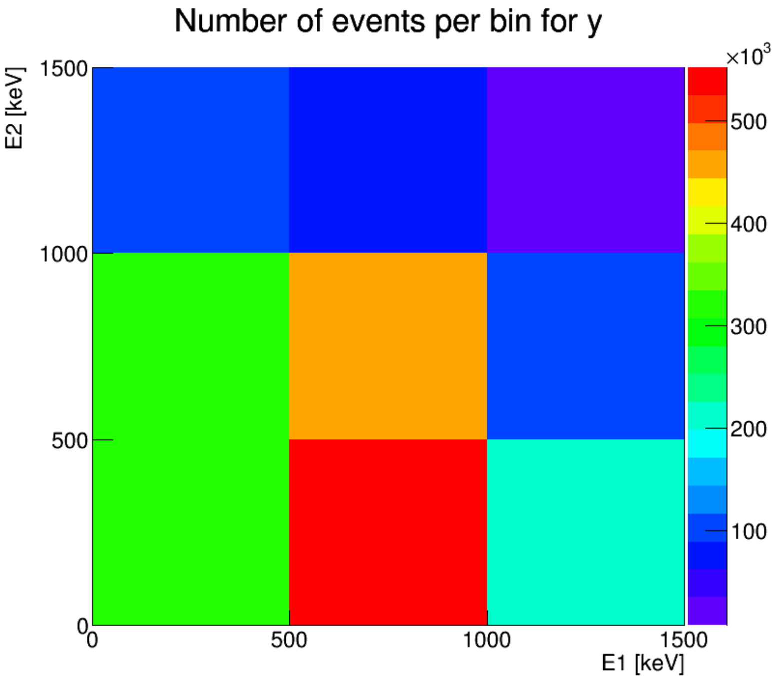


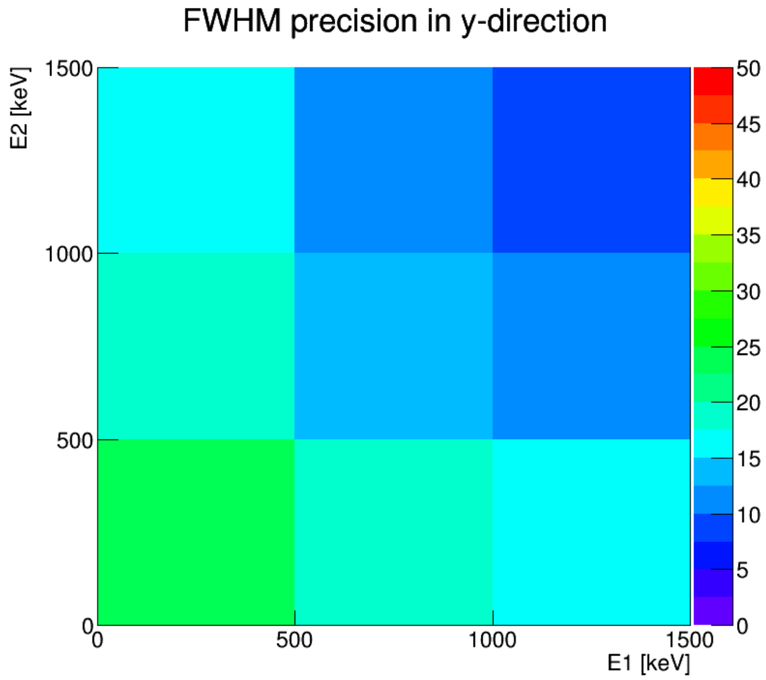
25 G

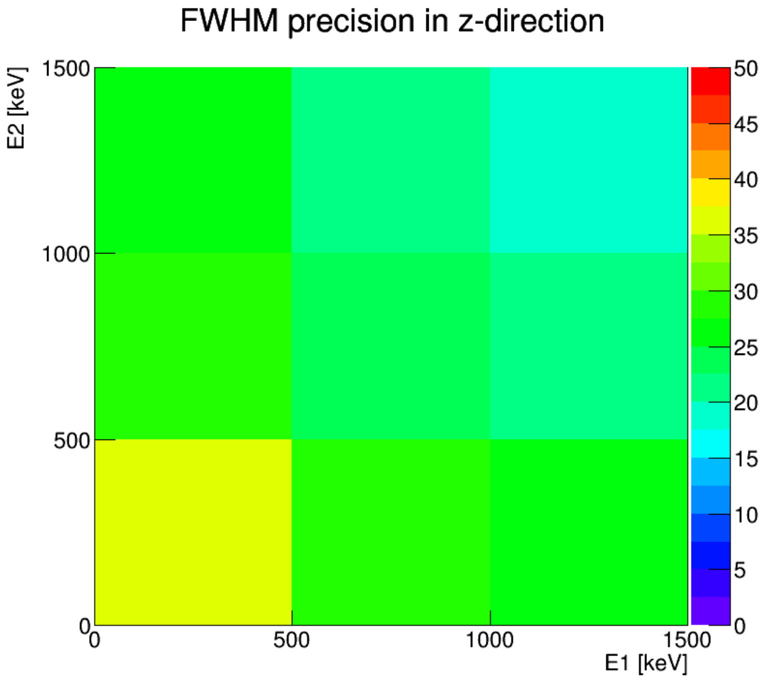
Precision **[mm]**





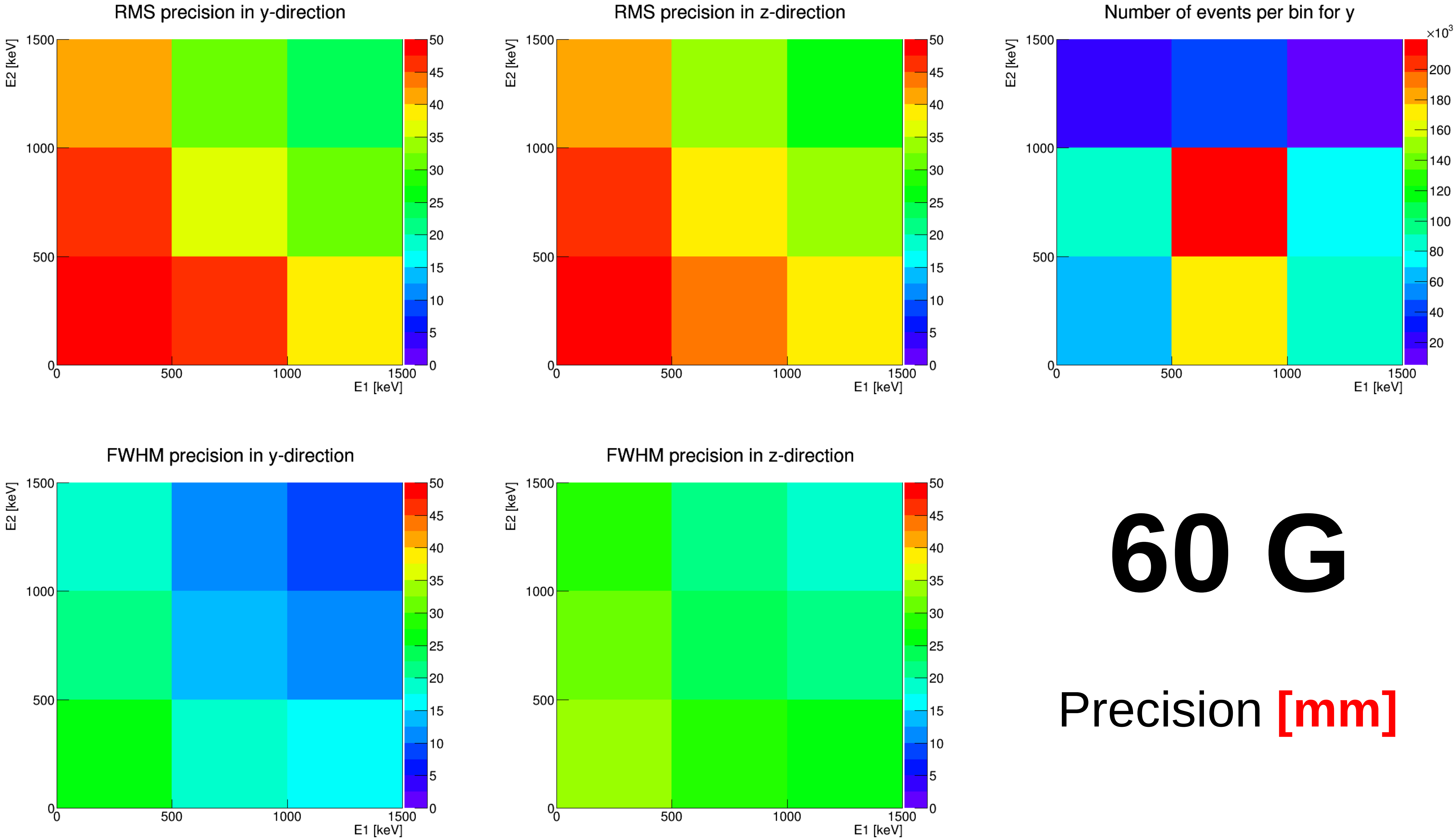






30 G

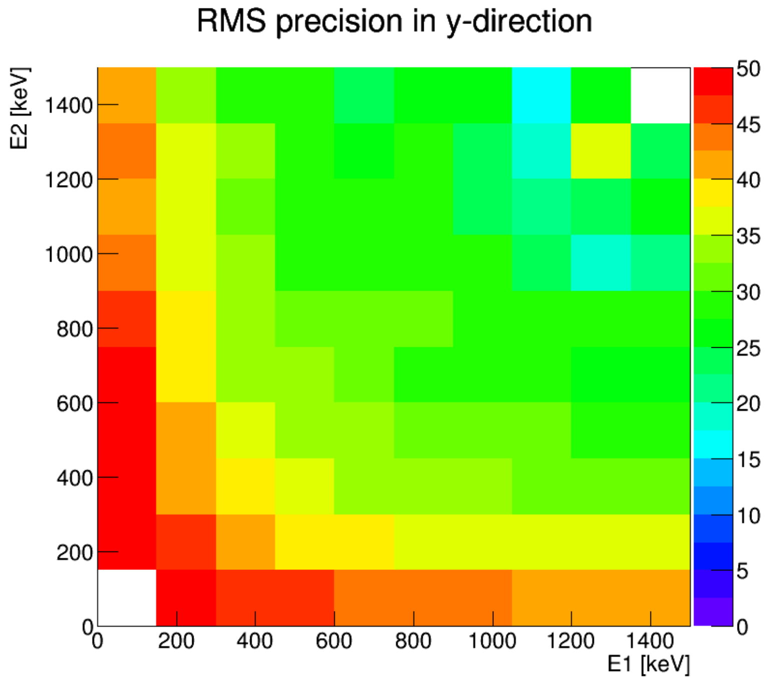
Precision **[mm]**

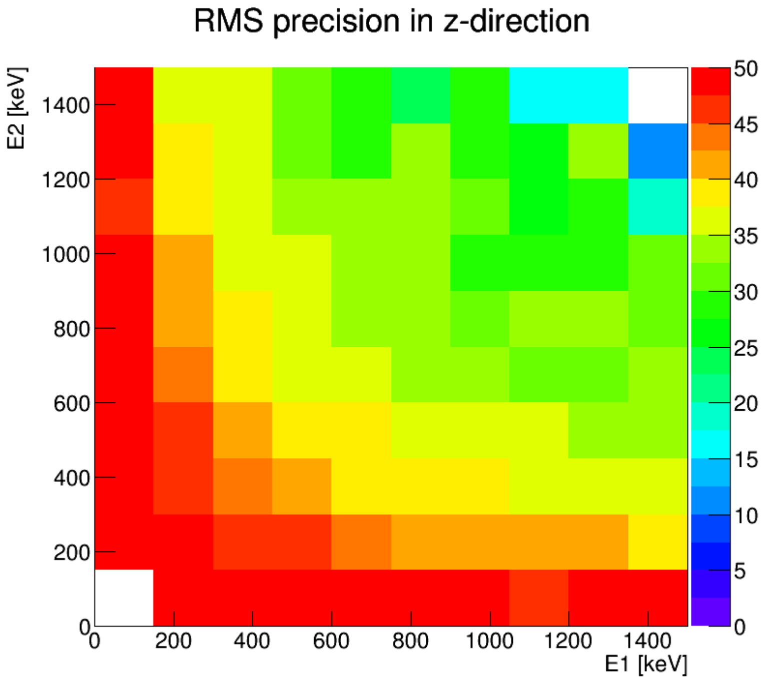


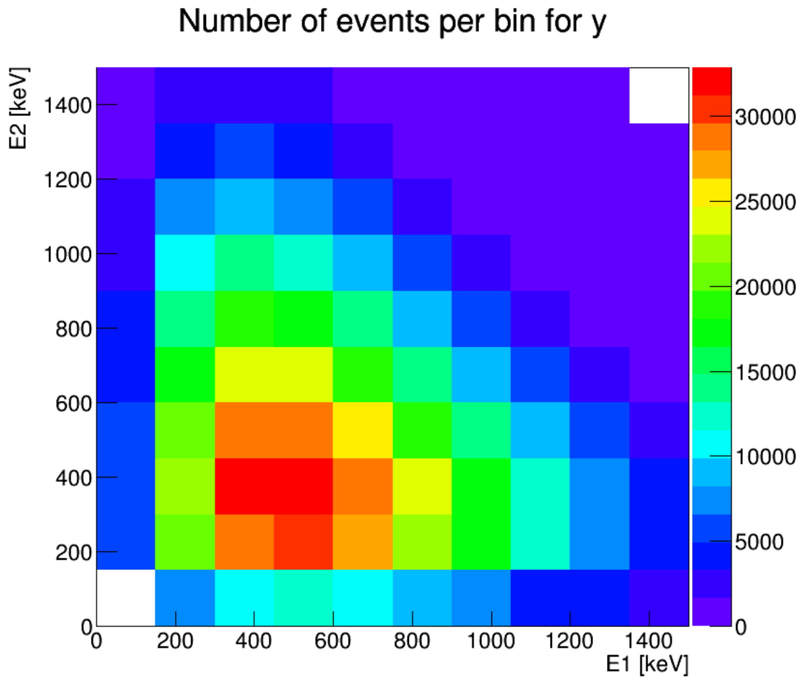
60 G

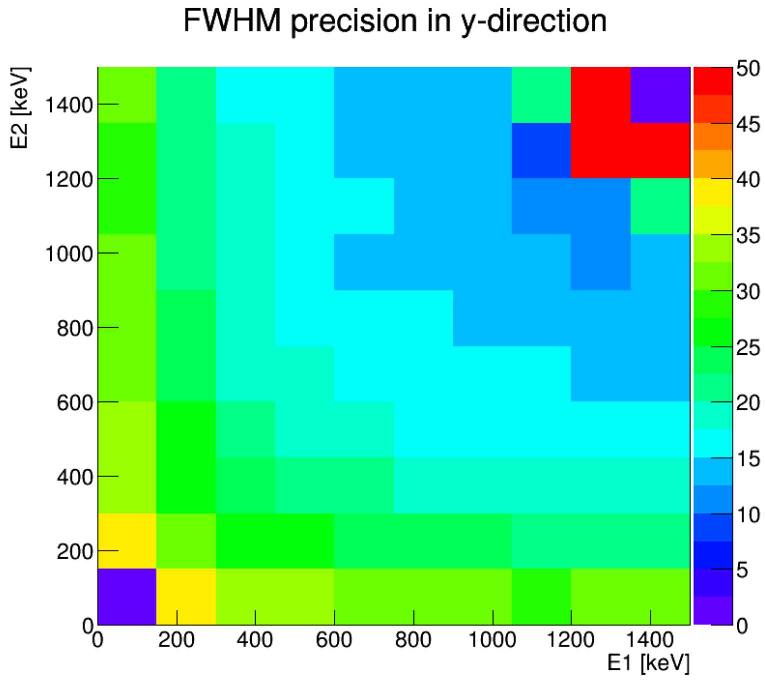
Precision [mm]

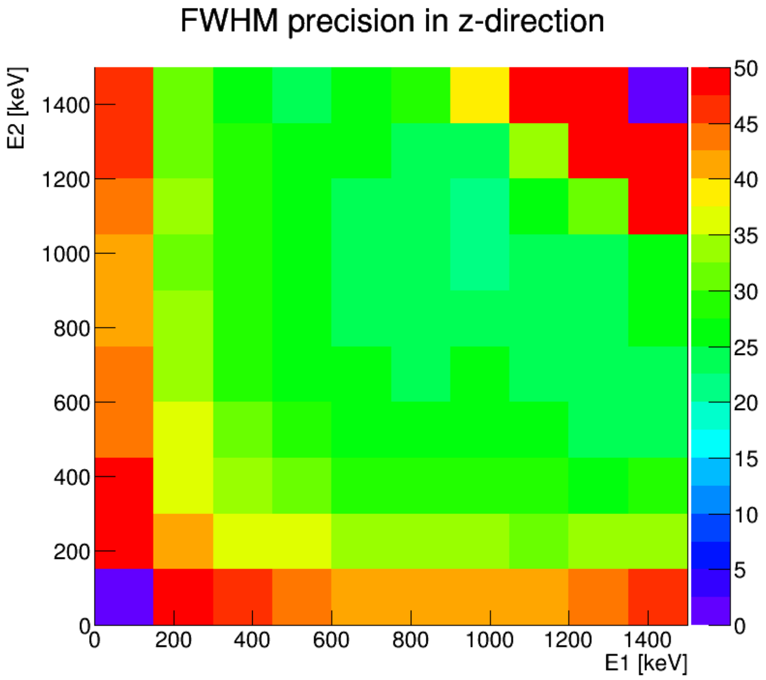
10x10-binning results





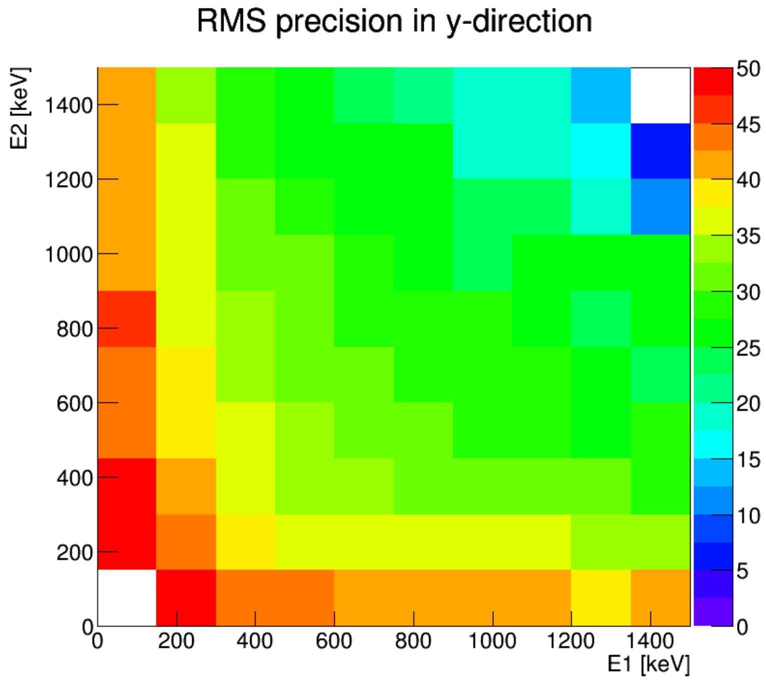


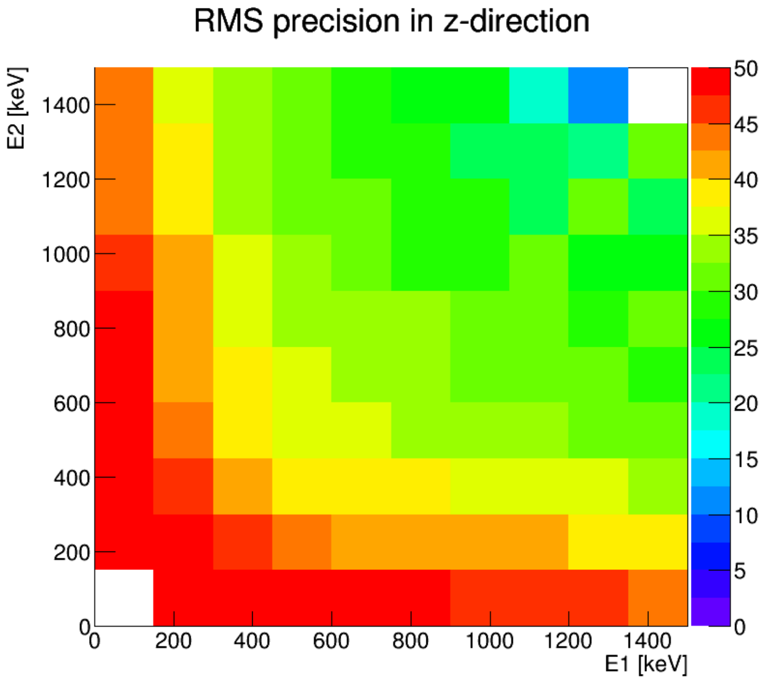


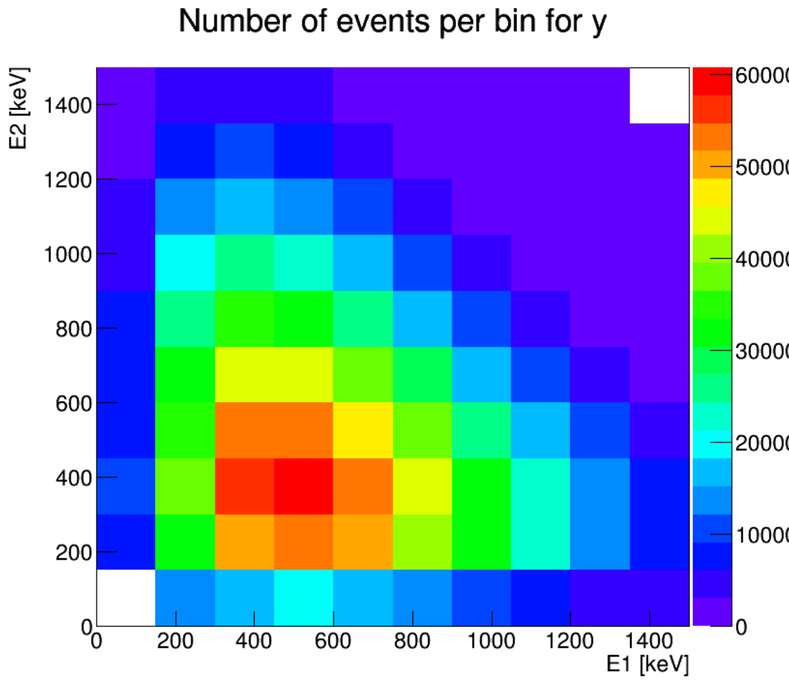


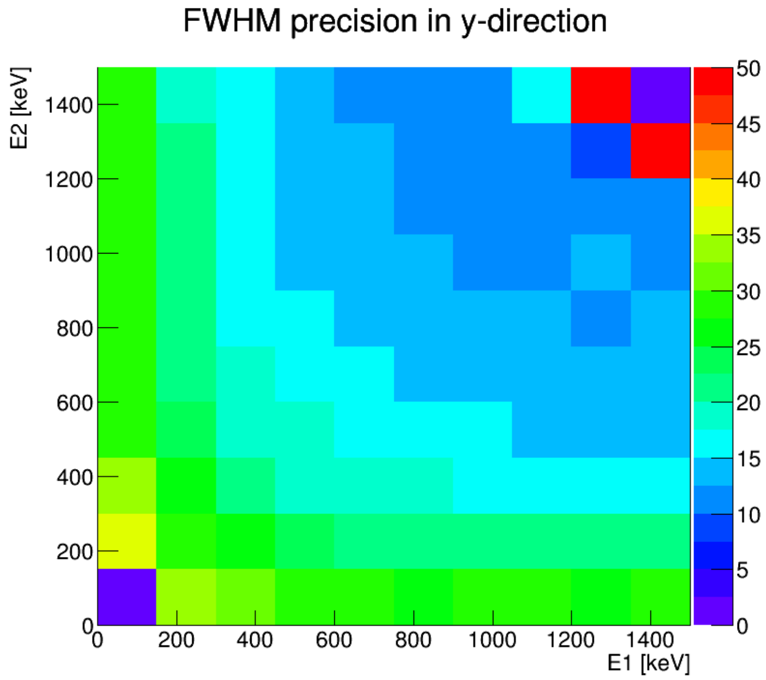
0 G

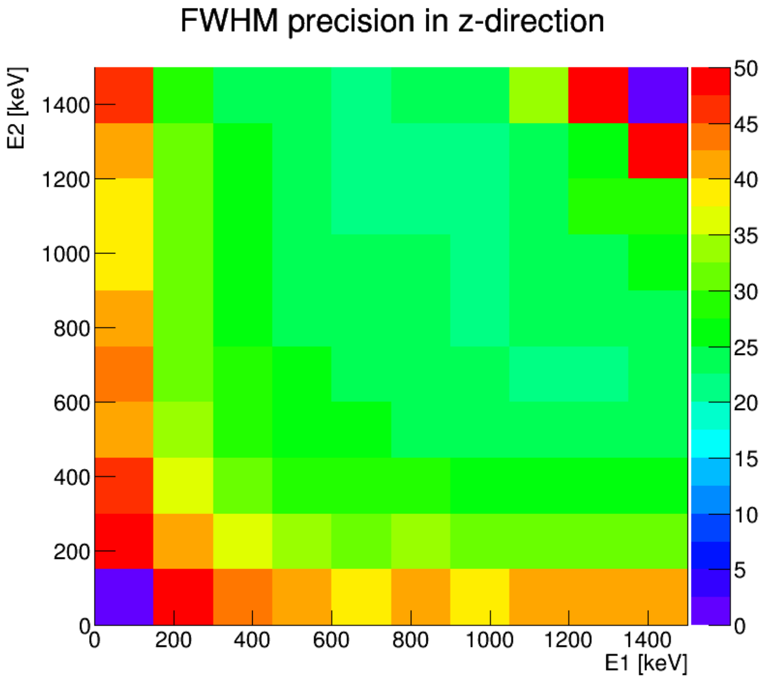
Precision [mm]





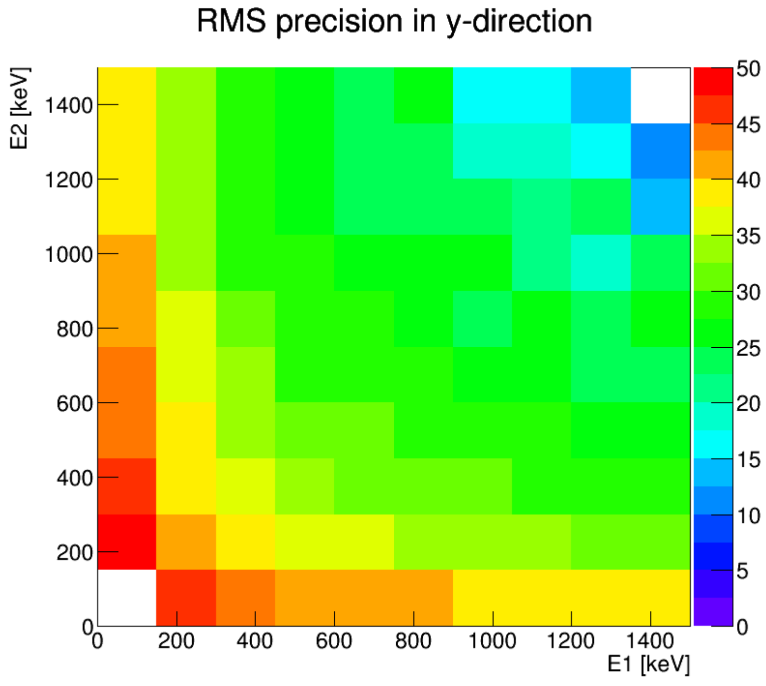


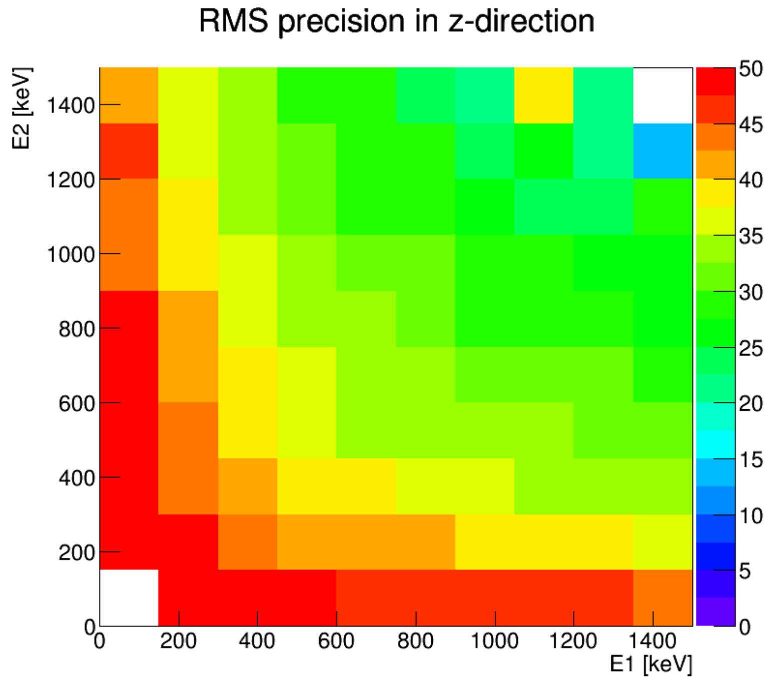


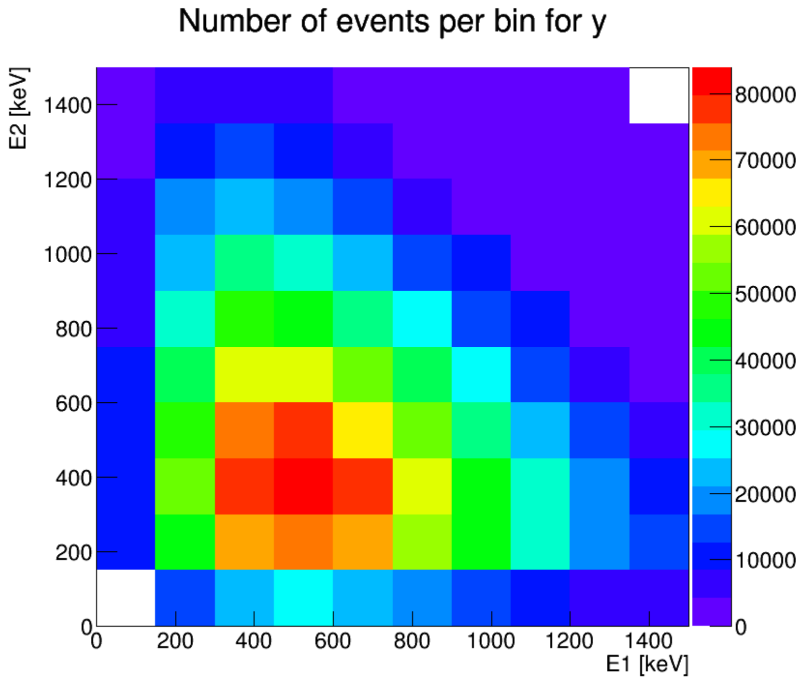


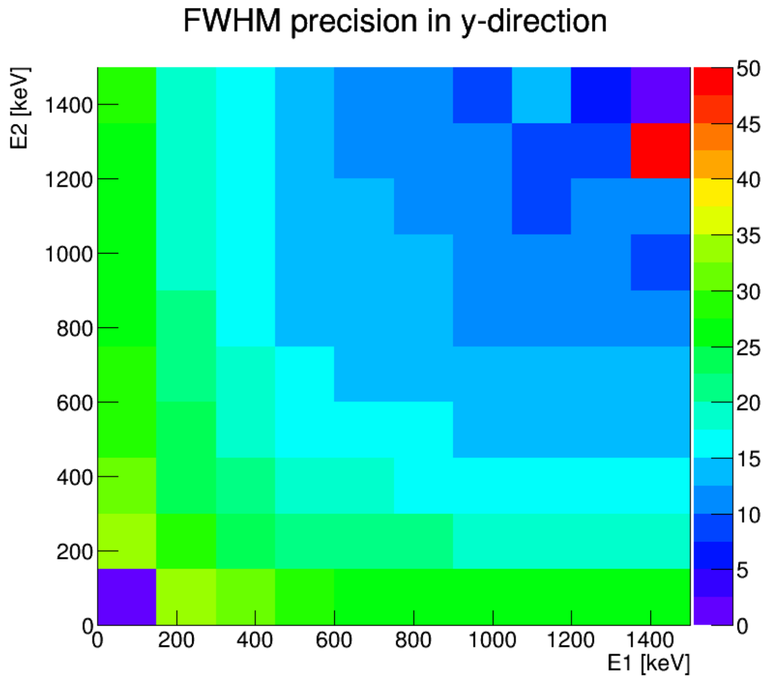
5 G

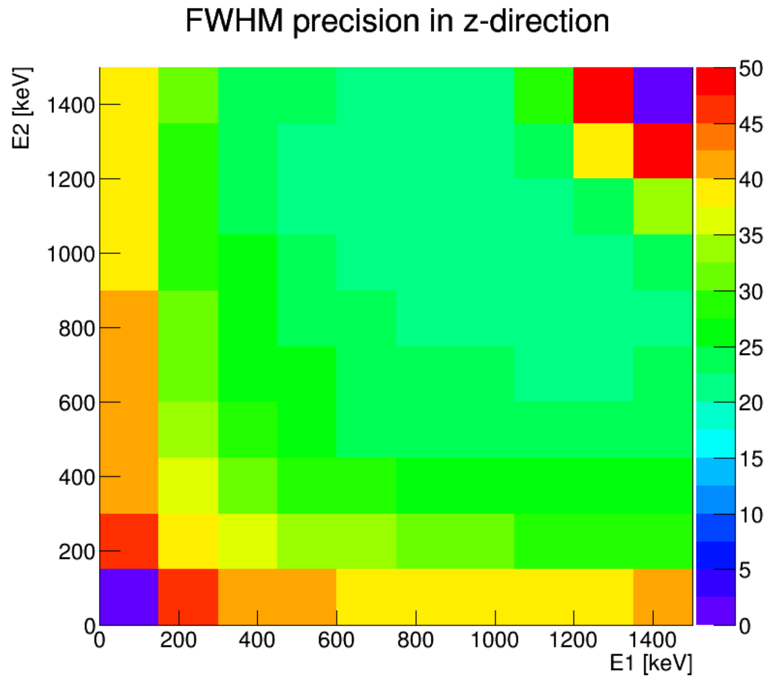
Precision **[mm]**





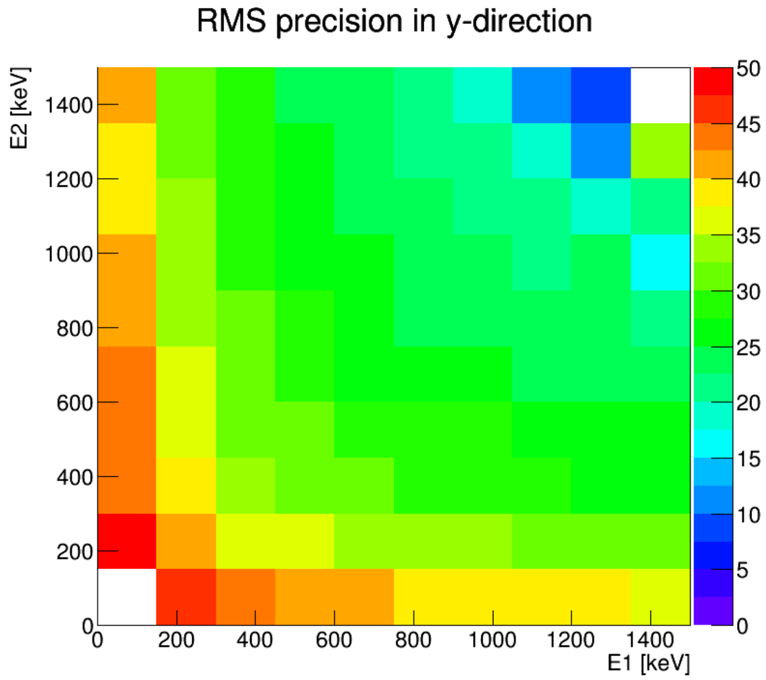


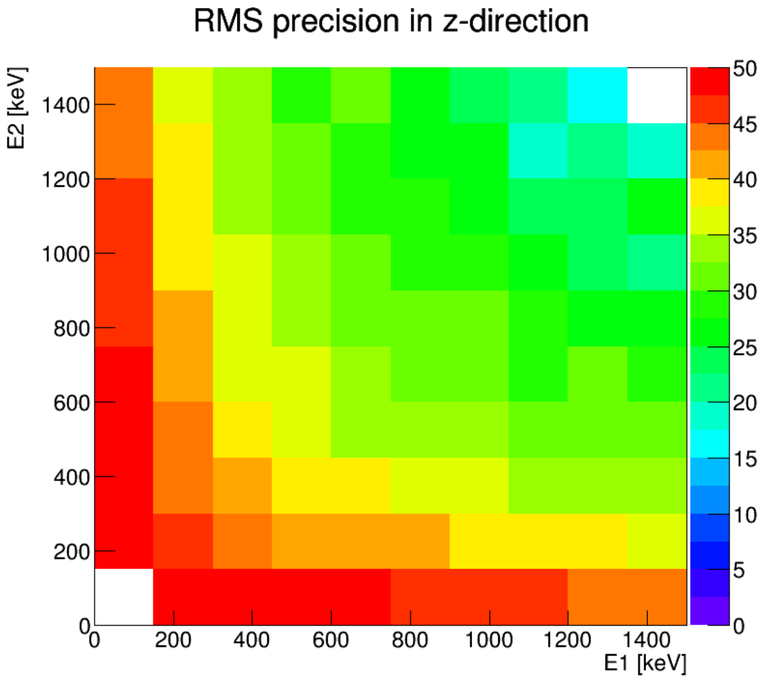


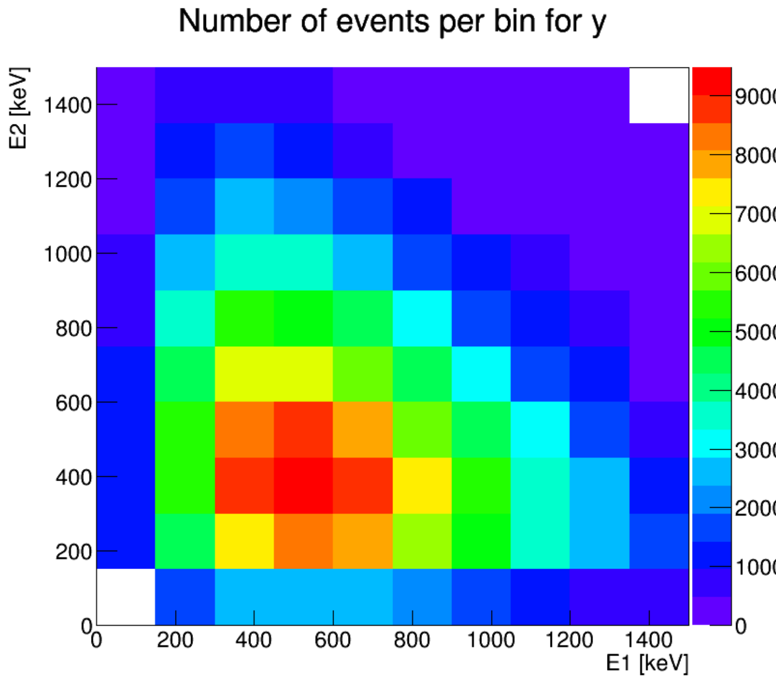


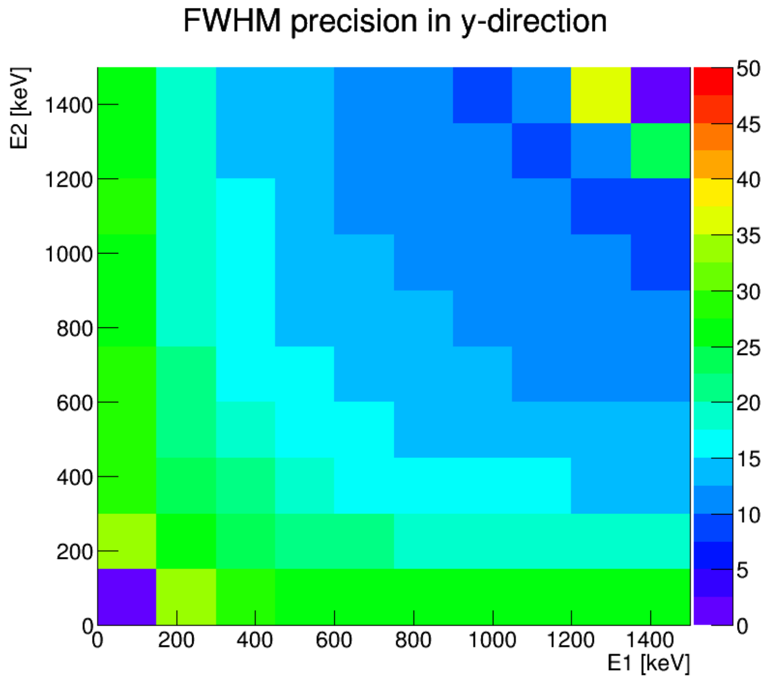
10 G

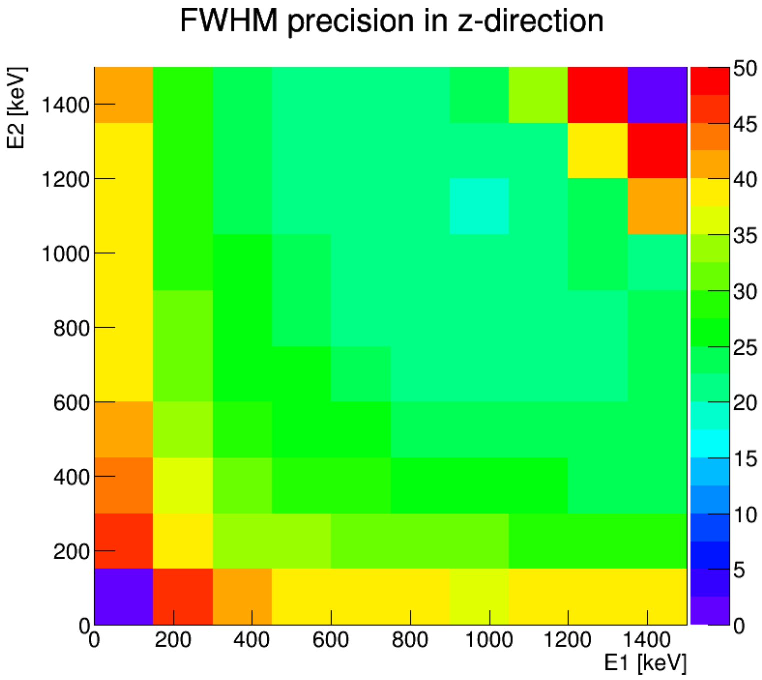
Precision **[mm]**







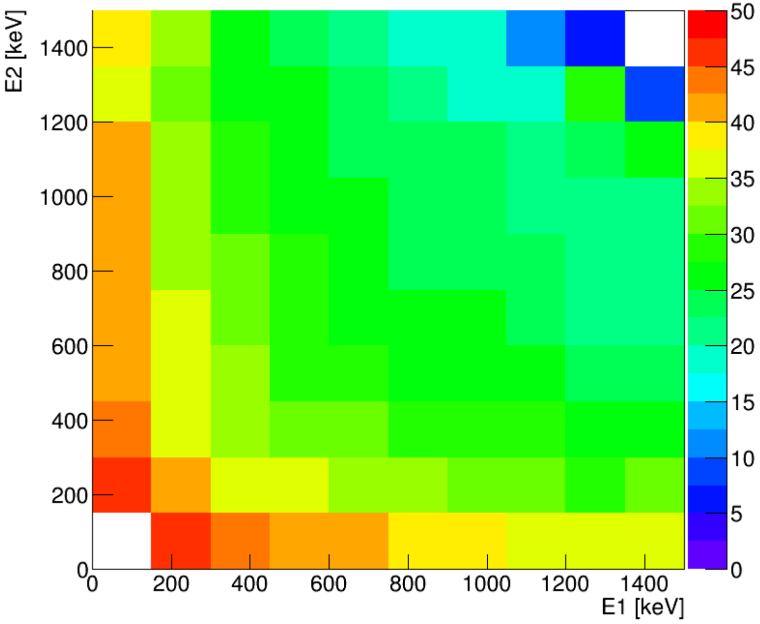




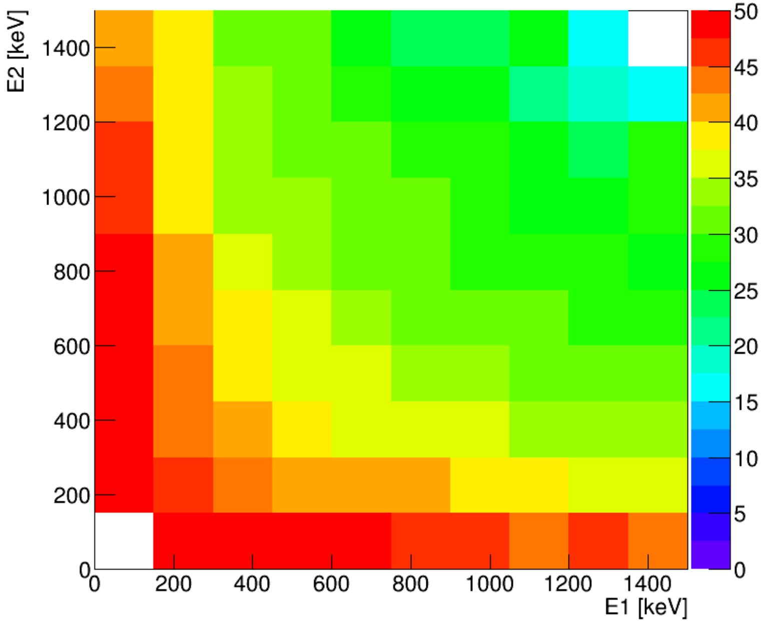
15 G

Precision **[mm]**

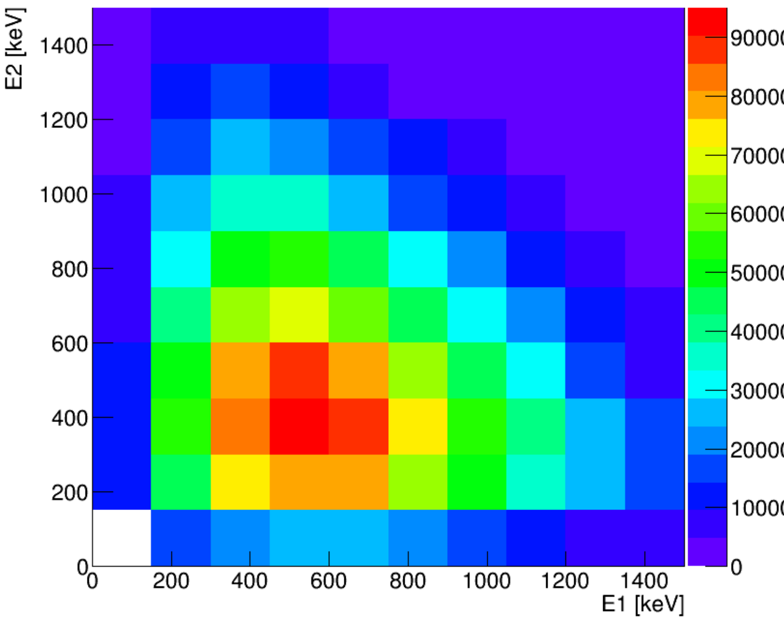
RMS precision in y-direction



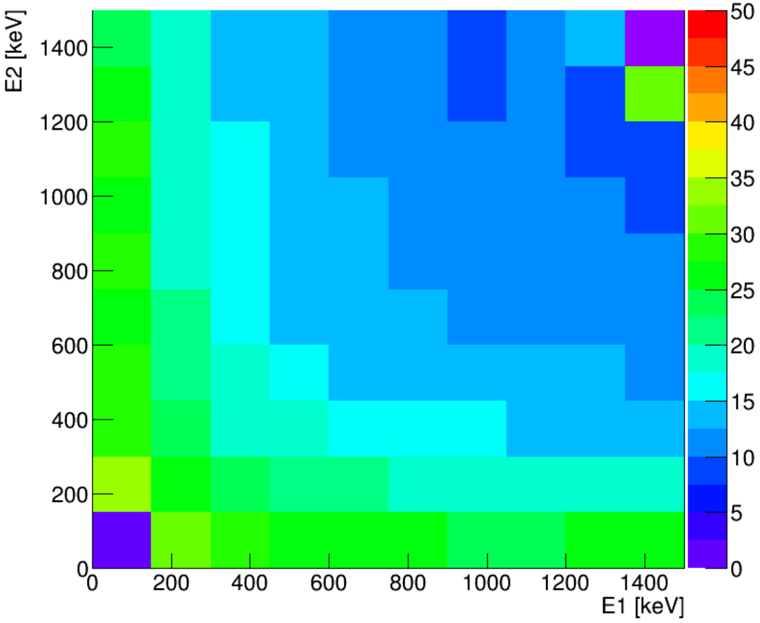
RMS precision in z-direction



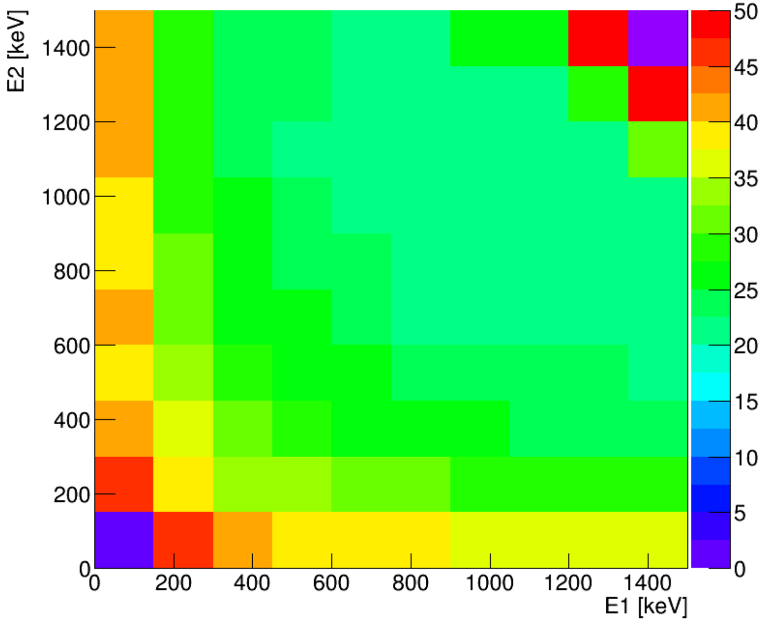
Number of events per bin for y



FWHM precision in y-direction

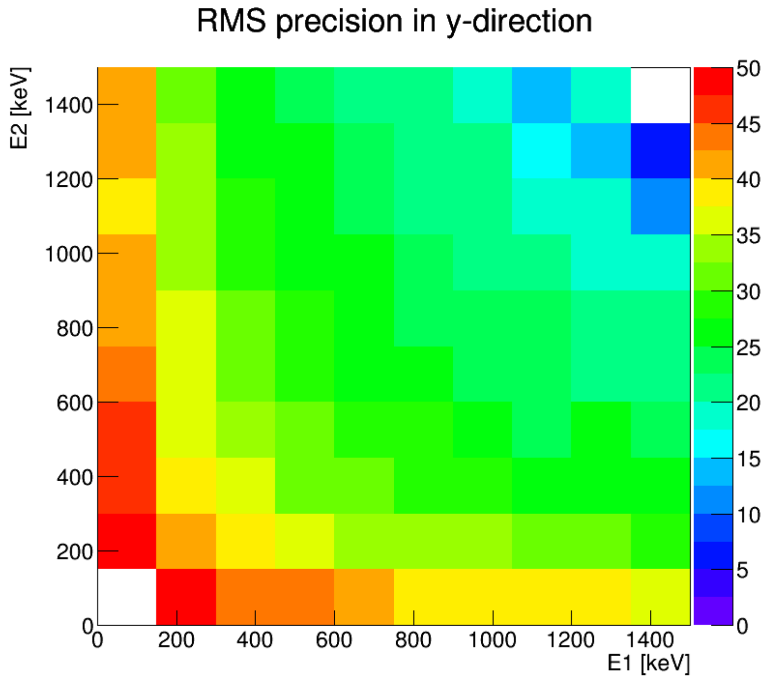


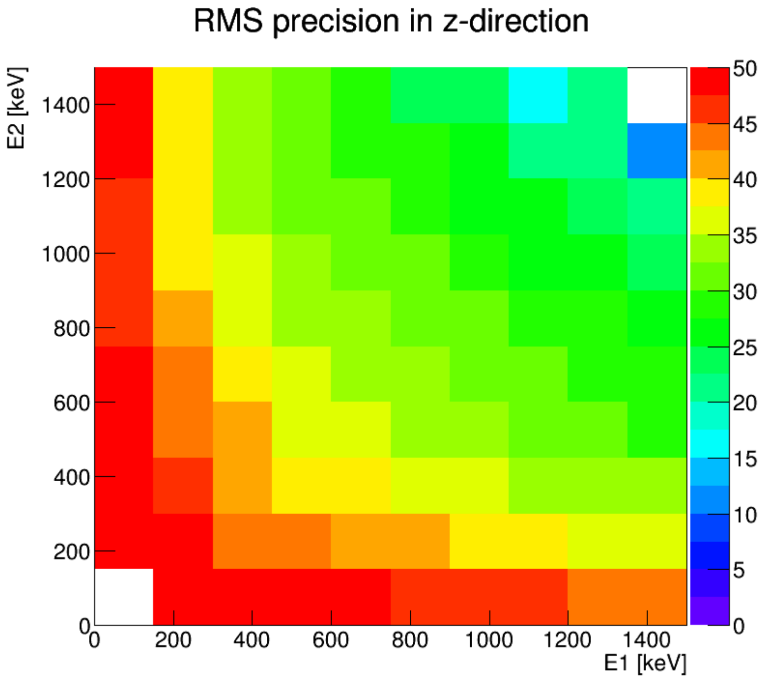
FWHM precision in z-direction

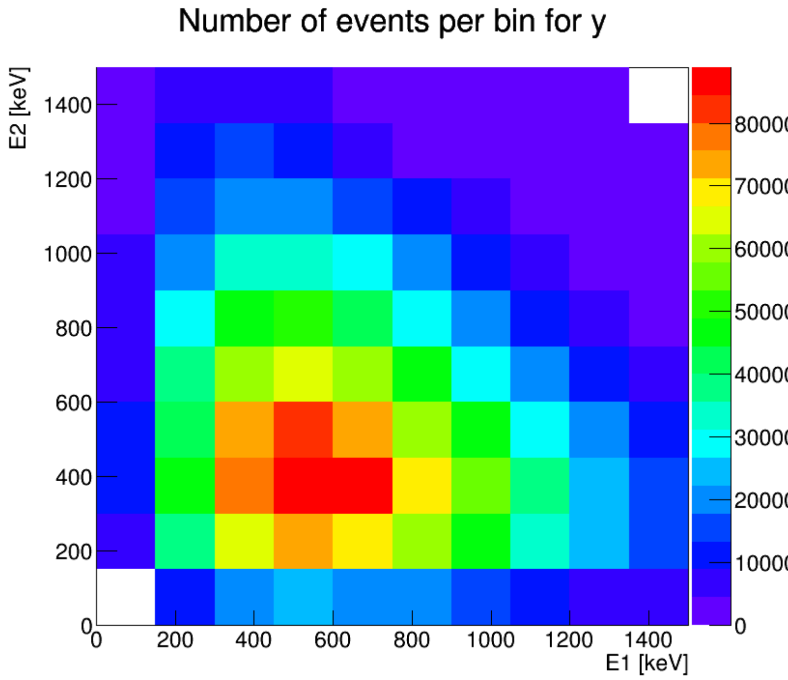


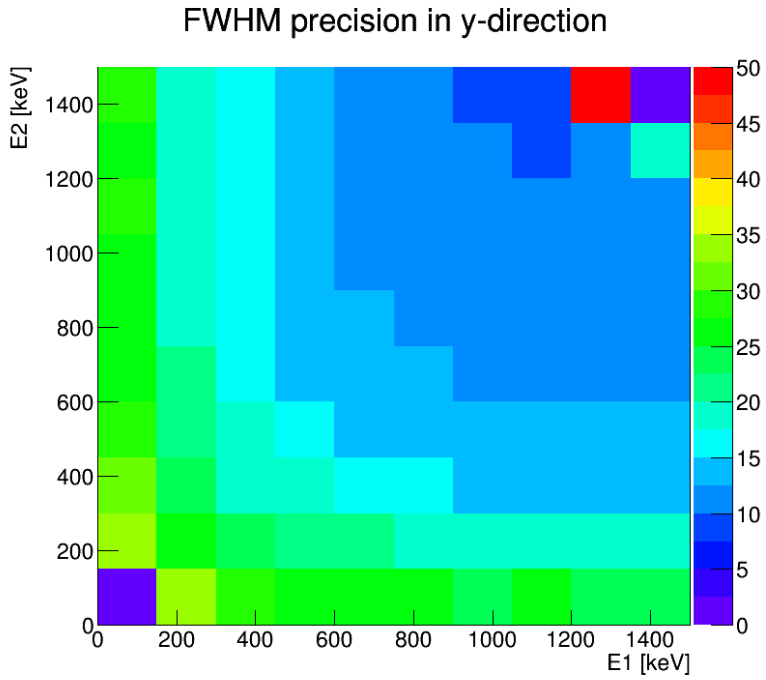
20 G

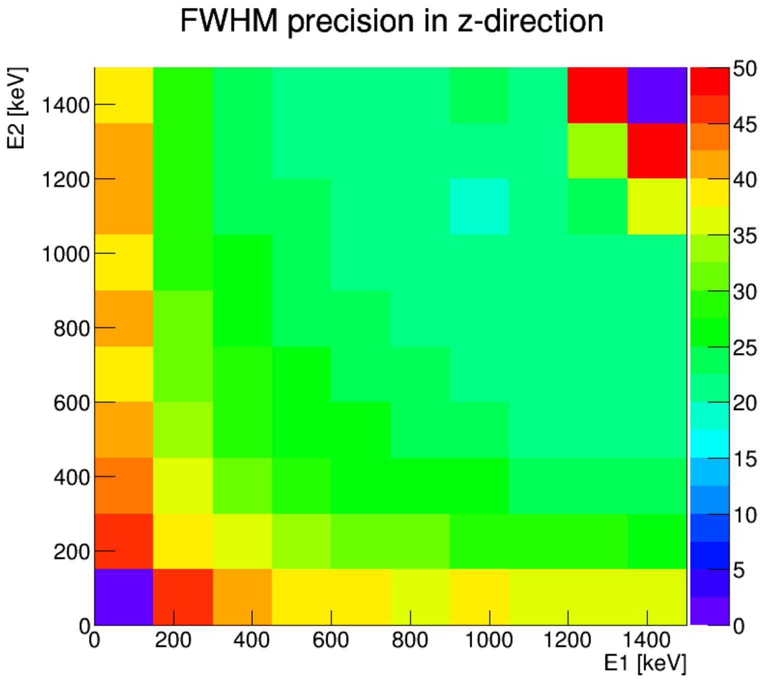
Precision **[mm]**







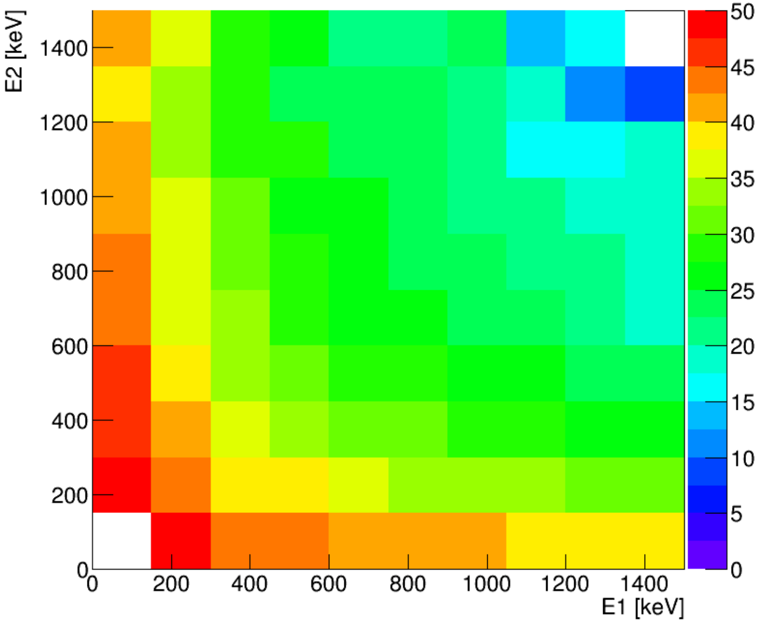




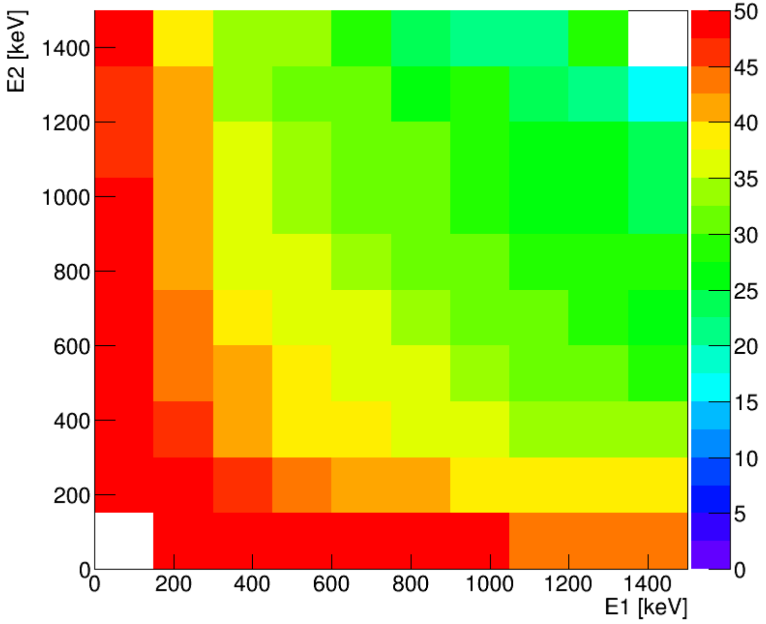
25 G

Precision [mm]

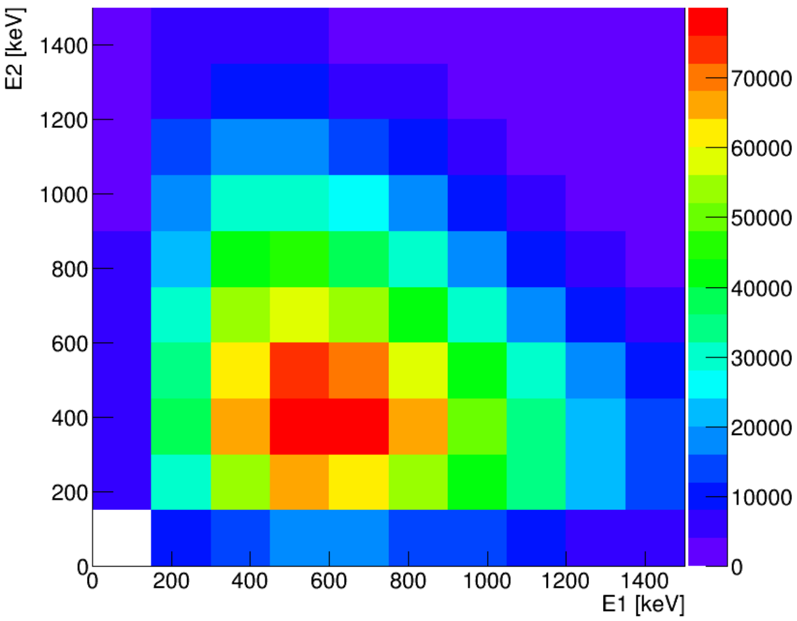
RMS precision in y-direction



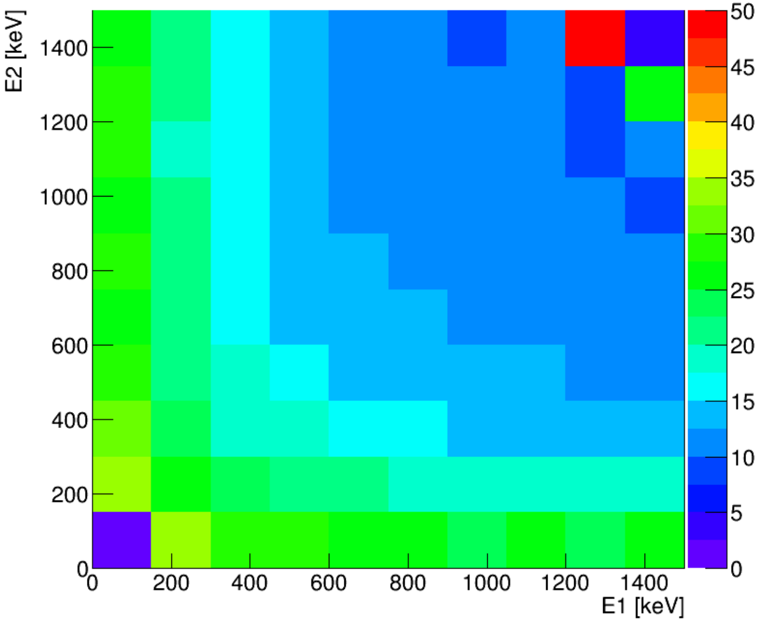
RMS precision in z-direction



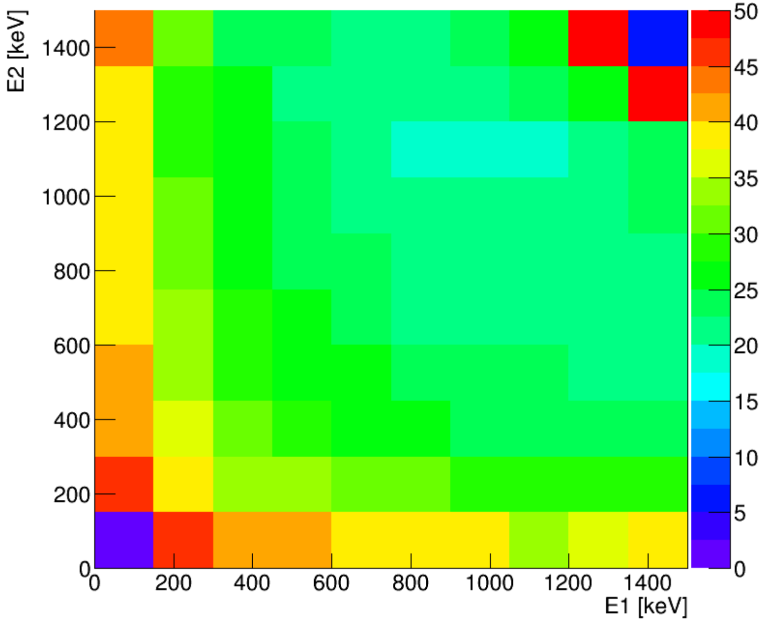
Number of events per bin for y



FWHM precision in y-direction

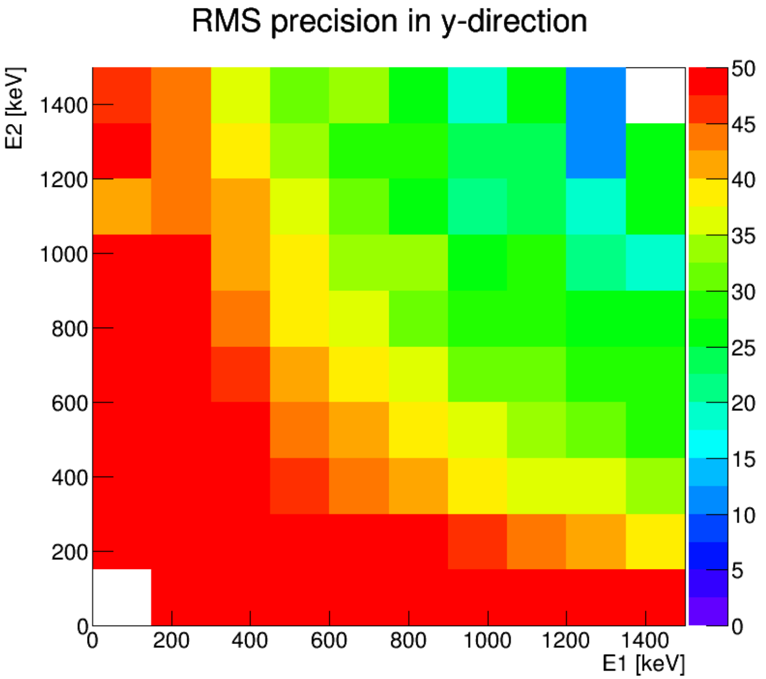


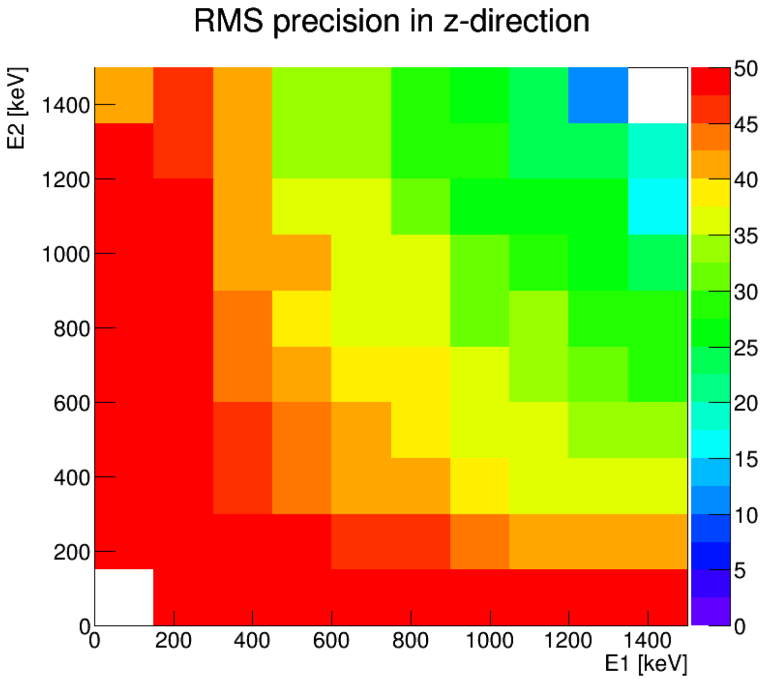
FWHM precision in z-direction

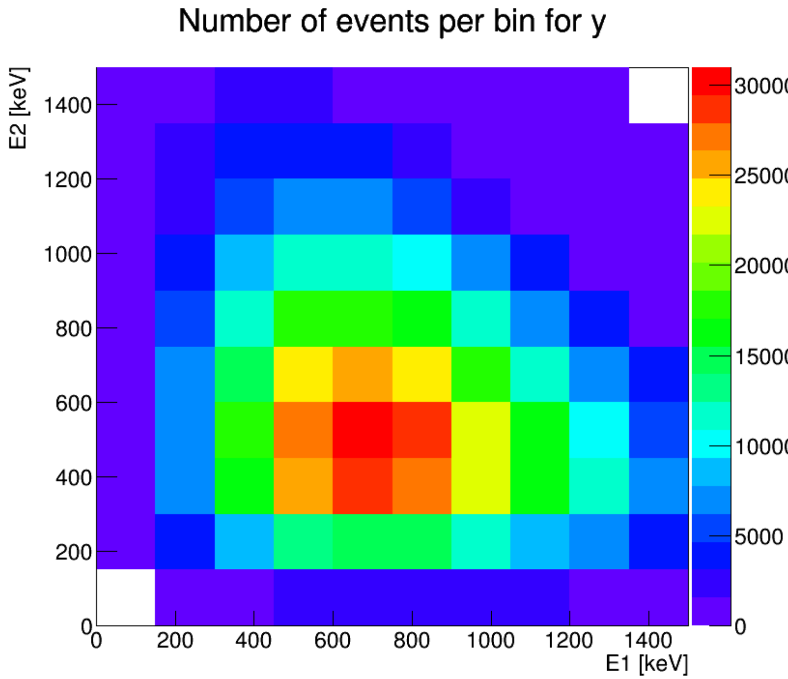


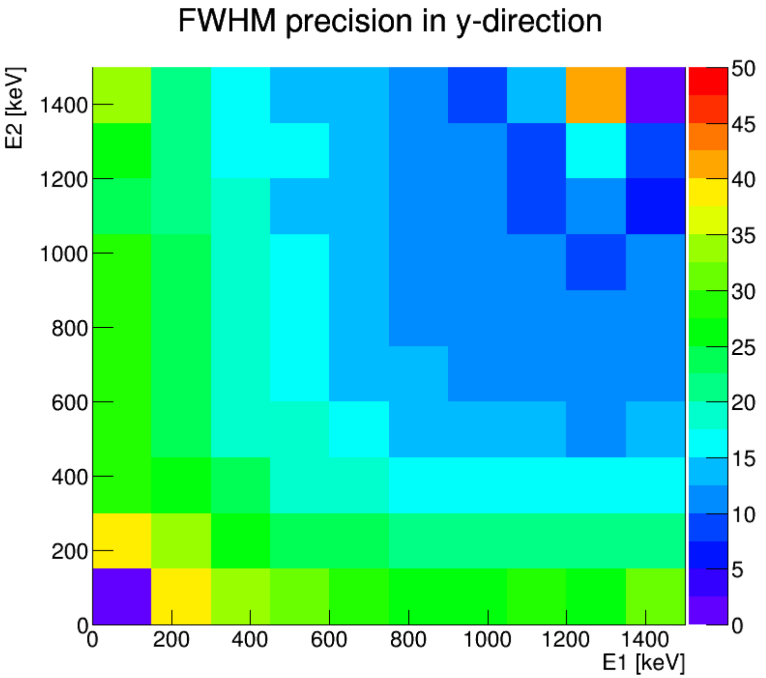
30 G

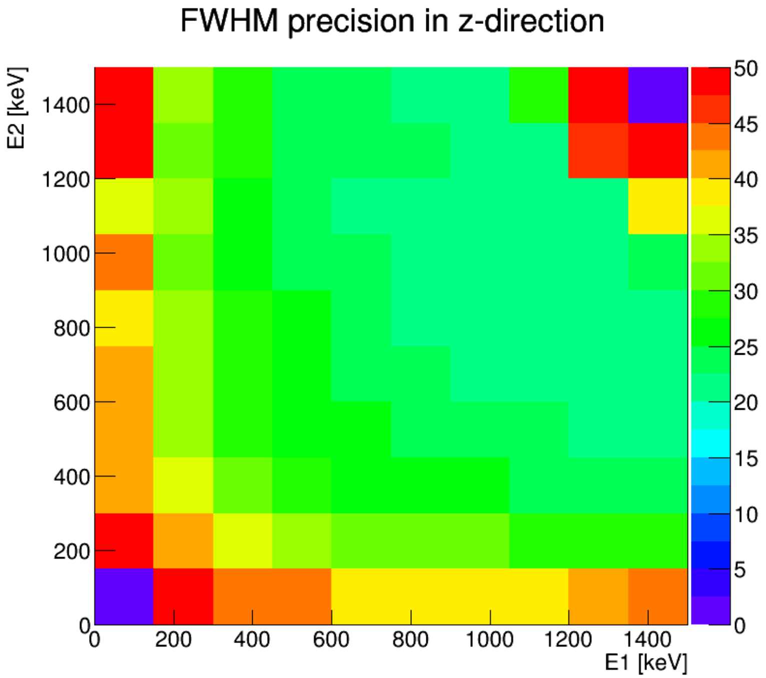
Precision **[mm]**









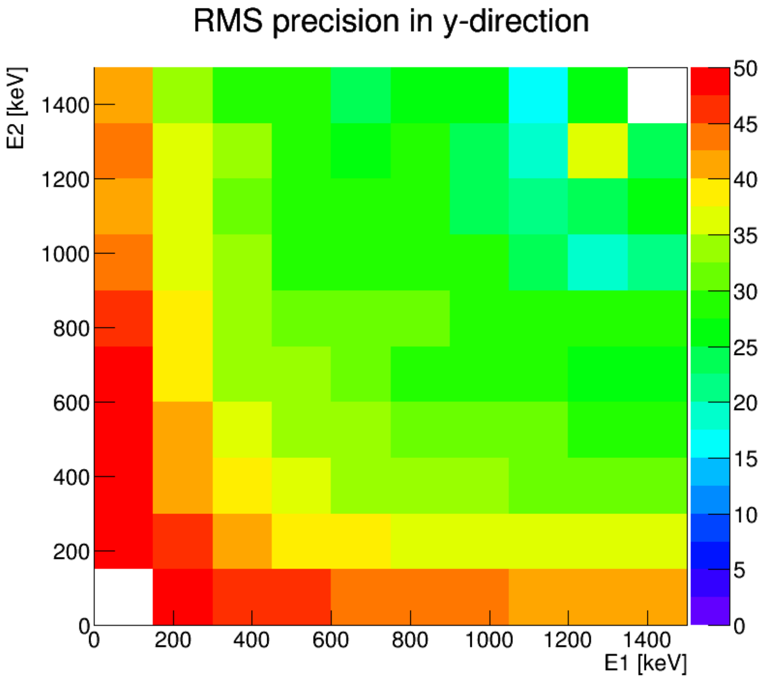


60 G

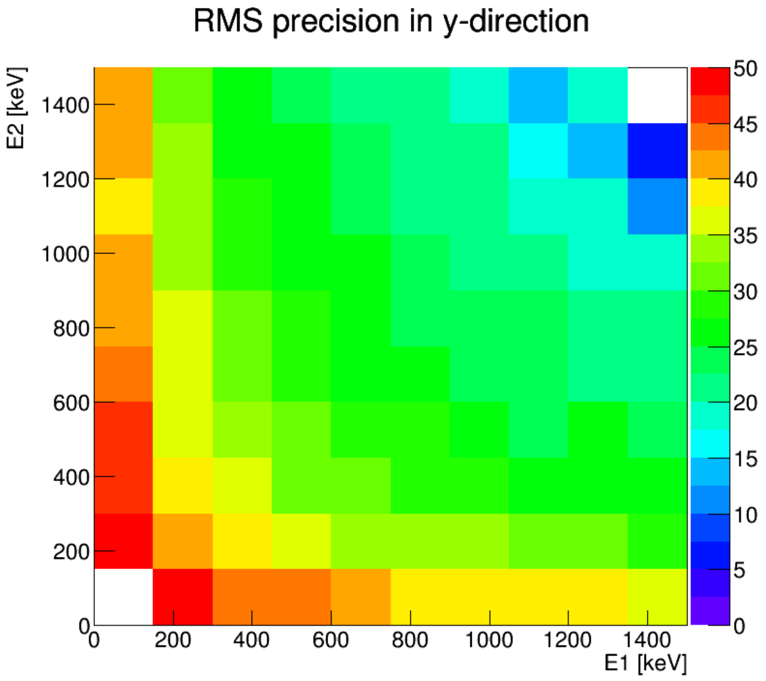
Precision [mm]

Precision is **worse** for **lower energies**
Precision is the best in the region of **15G – 25G**

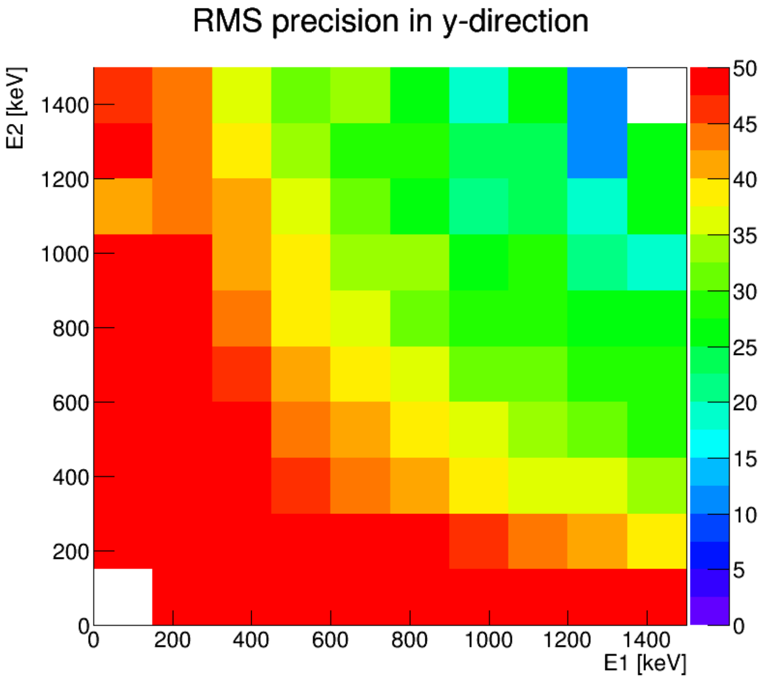
Precision **[mm]**



0 G



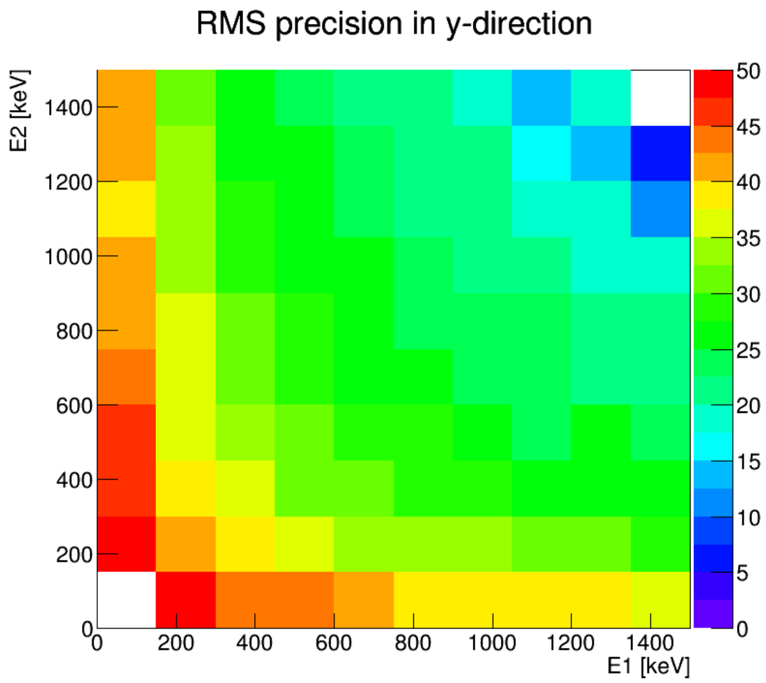
25 G



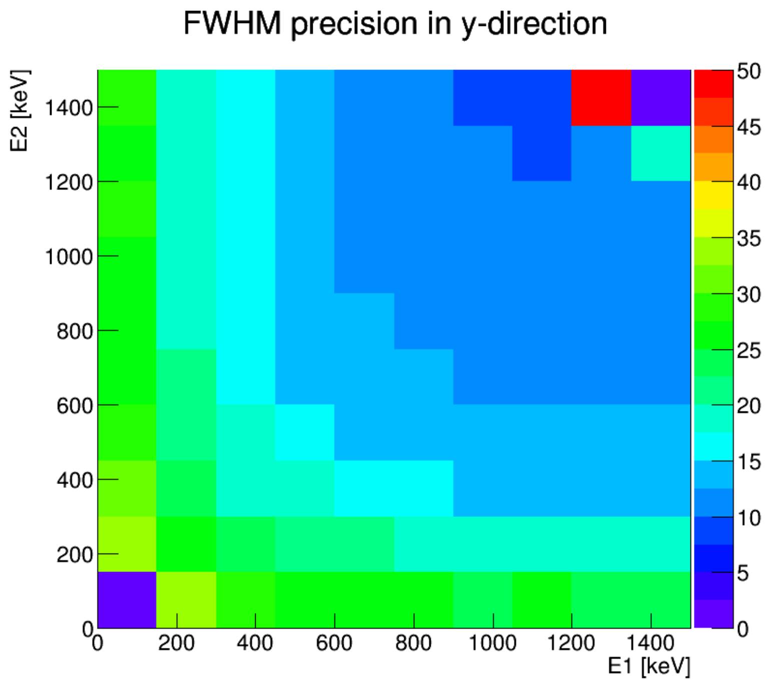
60 G

Precision **[mm]**
e^- energies **[keV]**

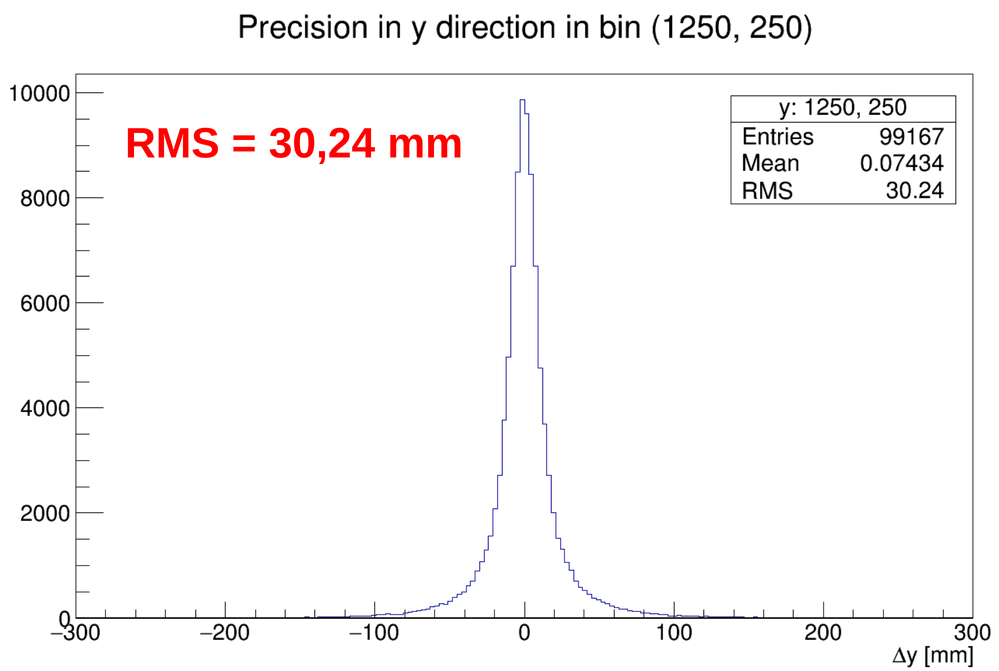
RMS **is sensitive** to limits of Δy (Δz)!
RMS precision is in general **worse than FWHM** precision

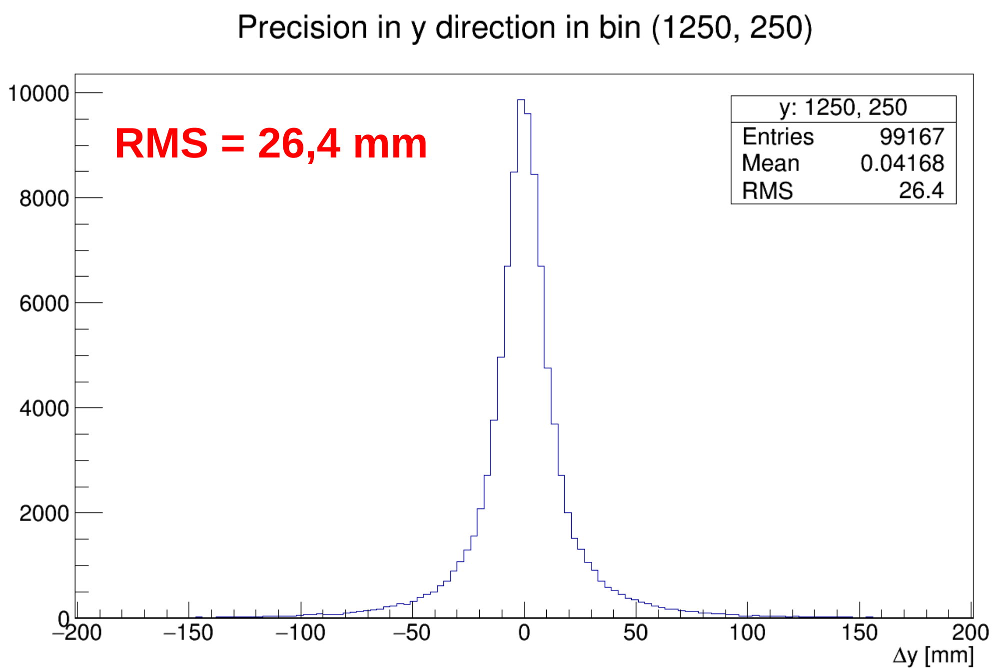


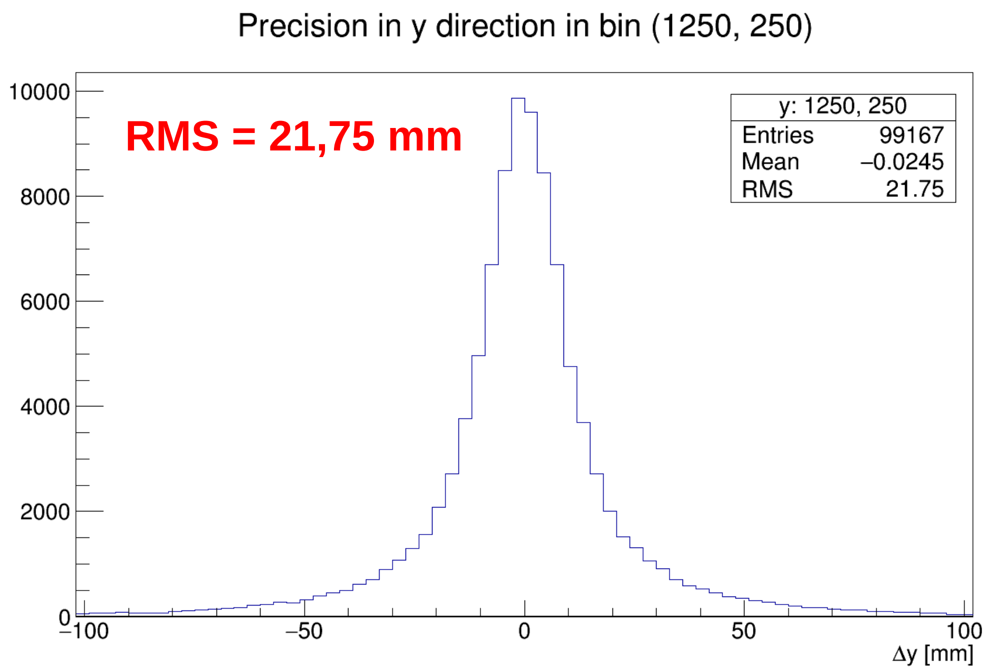
25 G

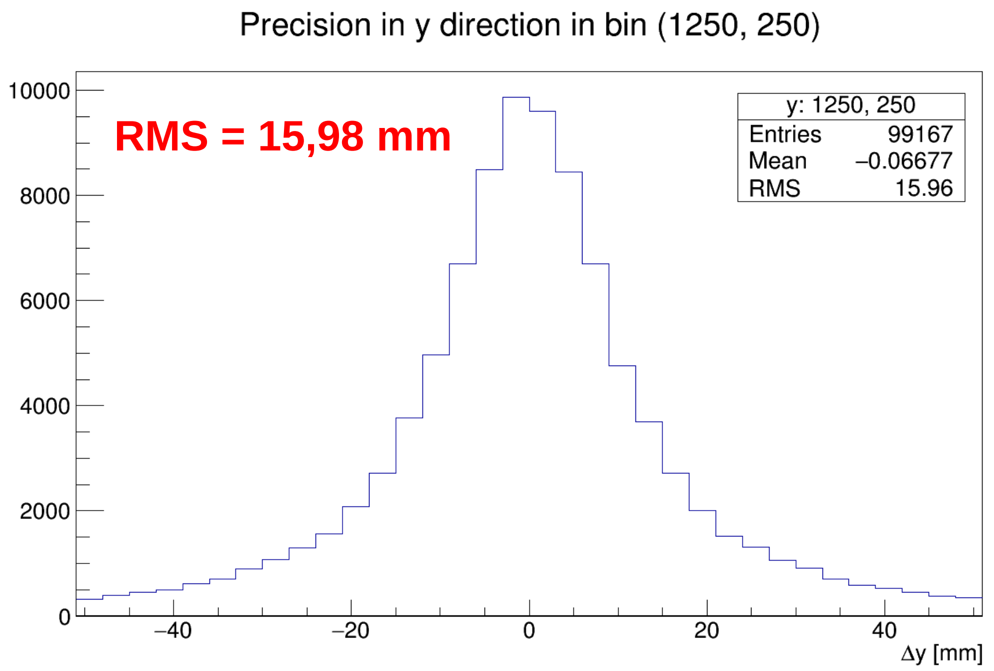


25 G


Precision in y direction in bin (1250, 250)
RMS = 30,24 mm
y: 1250, 250
Entries 99167
Mean 0.07434
RMS 30.24
Δy [mm]


Precision in y direction in bin (1250, 250)
RMS = 26,4 mm
y: 1250, 250
Entries 99167
Mean 0.04168
RMS 26.4
Δy [mm]


Precision in y direction in bin (1250, 250)
RMS = 21,75 mm
y: 1250, 250
Entries 99167
Mean −0.0245
RMS 21.75
Δy [mm]


Precision in y direction in bin (1250, 250)
RMS = 15,98 mm
y: 1250, 250
Entries 99167
Mean −0.06677
RMS 15.96
Δy [mm]

Conclusions

- The best invariant method to evaluate precision is **fitting**.
- The precision using **FWHM** method is changing **negligibly with magnetic field**.
- **RMS** method can be used in case **upper and lower limit** is given.
- RMS From **0G to 20G** precision **get better** and **towards 60G** it **drops** again.
- Future work: To study dependence **on the angle between electrons**.

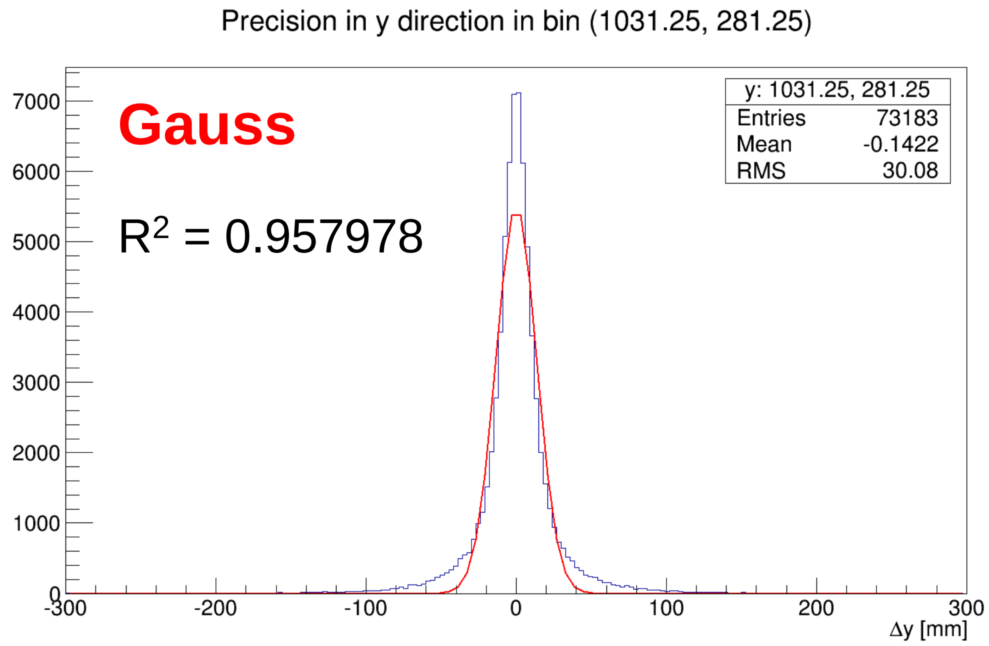
Thanks for attention!

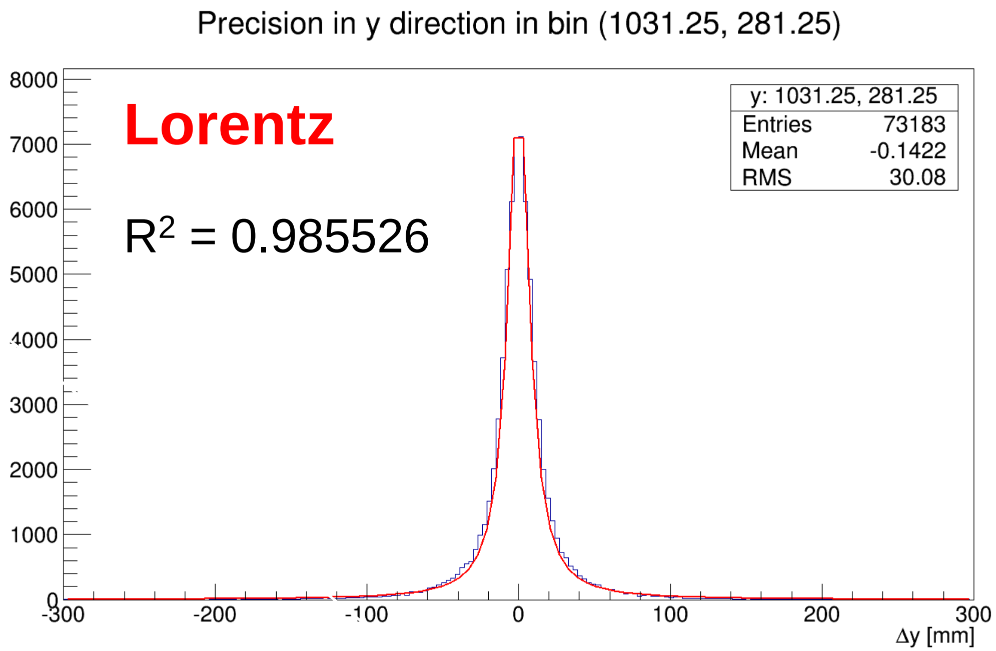
Backup

Gauss vs. Lorentz

- Fitting is not so dependend on the distribution tails as RMS.
- **Lorentzian fit** seems to describe datasets more suitably.
- FWHM = 2γ => **FWHM precision**.

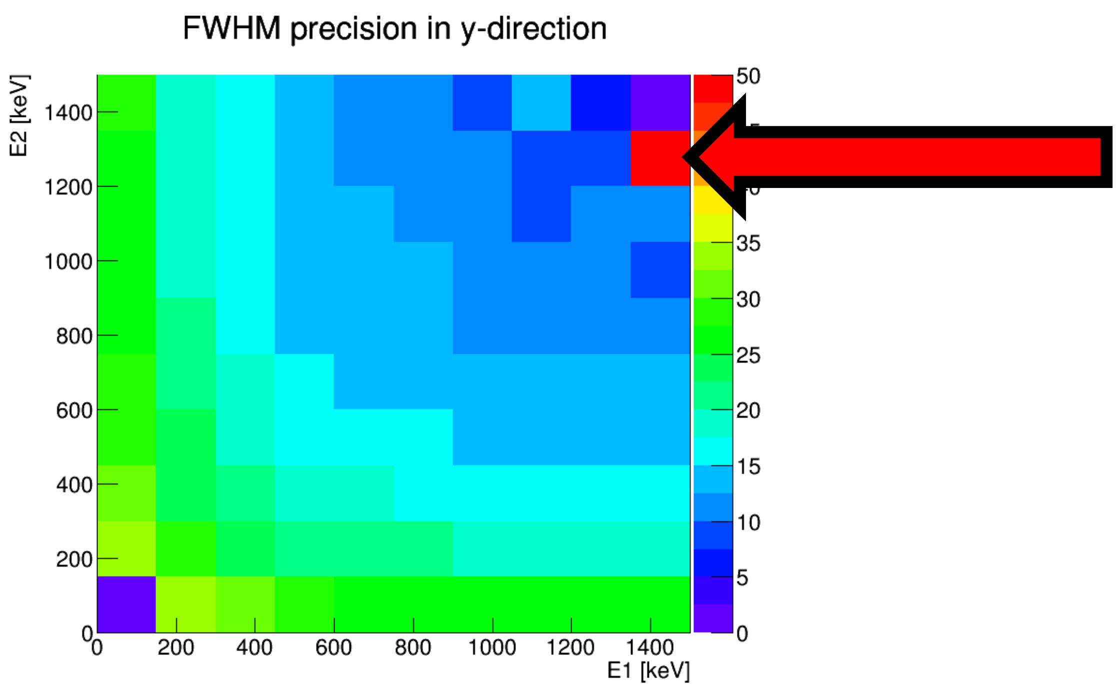
$$f(x) = \frac{A}{x^2 + \gamma^2}$$



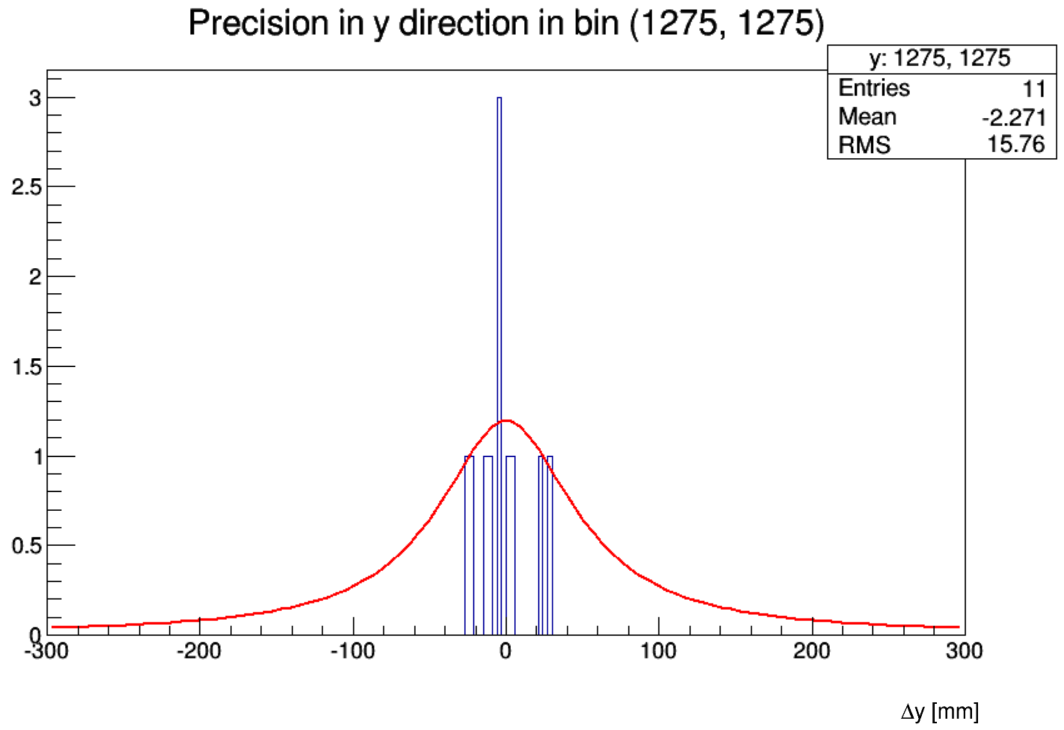


Error bins in FWHM method

Red bins – small statistics – fit is imprecise



10 G



Electron scattering in source foil