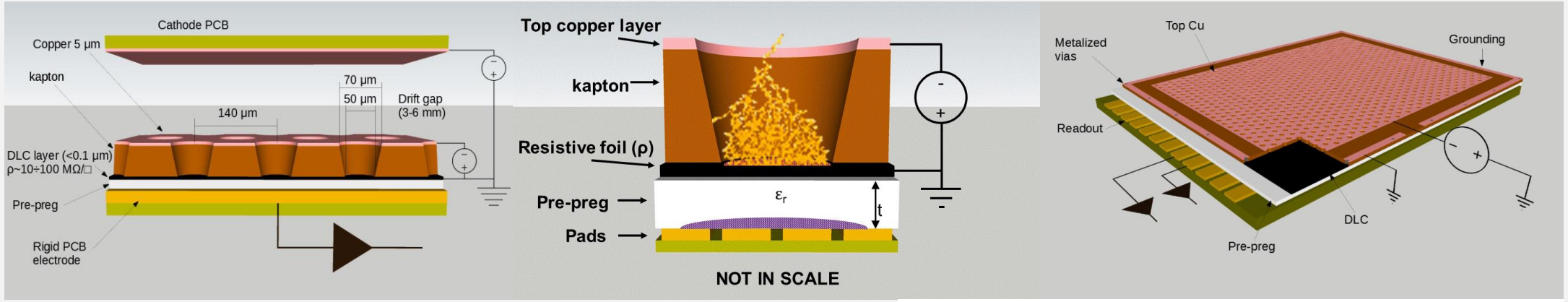
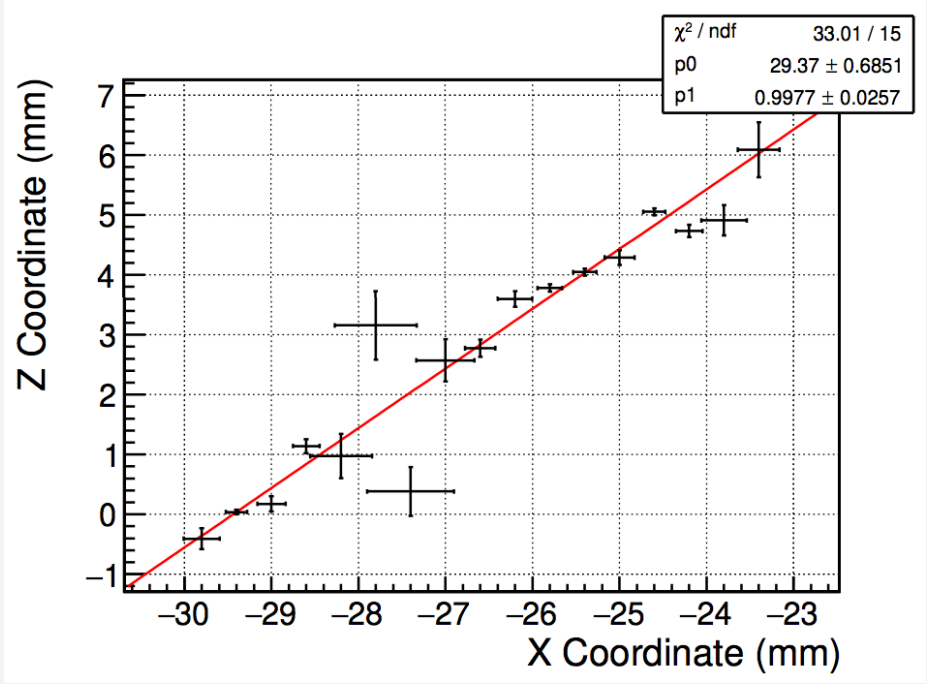
Magnetic field simulations X17 @ n_TOF

RICCARDO MUCCIOLA

uRwell detector



- uTPC with drift gap and uRwell
- Active area of 325 x 380 mm
- Ar/CF4/CO2 (60:20:20) gas mixture
- 3D track reconstruction



Performed simulations

GARFIELD

- Simulations of the uRwell detector with realistic materials and dimensions;
- Electric field generated by voltages cathode and anode
- Estimation of drift velocity in the gap
- Reconstruction of single tracks in the volume in a constant magnetic field

Geant4

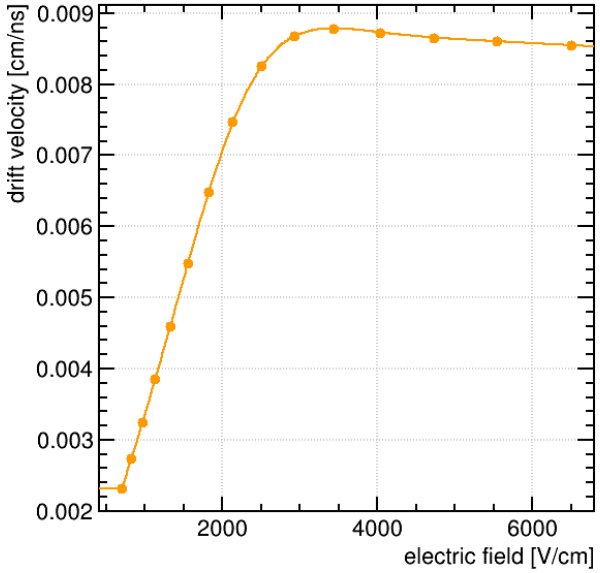
- Simulation of detectors in homogeneous magnetic field;
- Events of IPC and X17 from theory calculations;
- Realistic target and detector dimensions;
- Realistic pitch for hit reconstruction;
- Reconstruction of relevant quantities (Pt, θ, ϕ etc.).

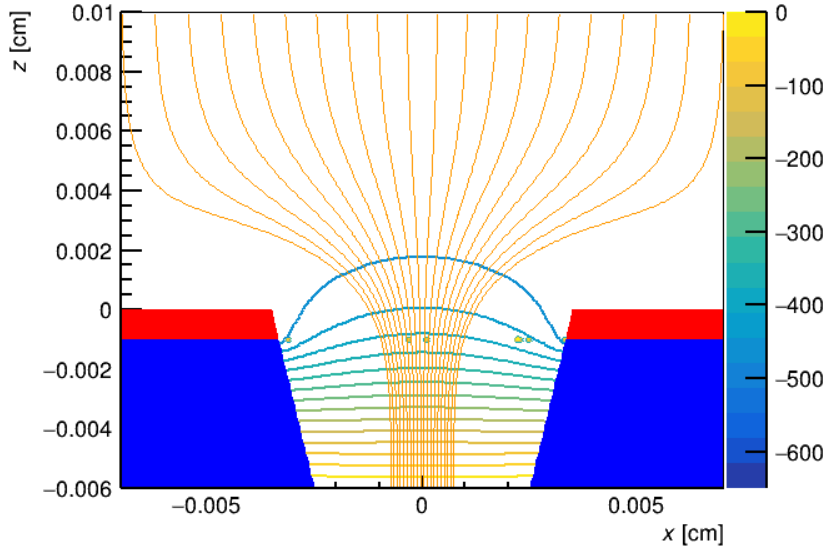
uRwell simulations - Garfield

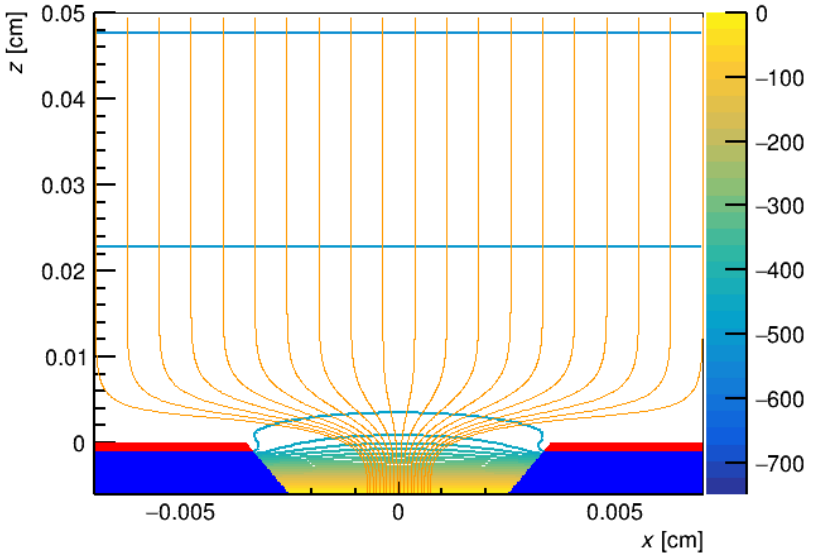
- Detectors constructed in simulation code Garfield;
- Pitch of resistive wells of 140μm in hexagonal pattern;
- Resistive and conductive layer implemented in simulation;
- 3000V were placed in the drift region while 500V were used in the wells.
- Signal of avalanche recorded only with multiplications higher than 500;
- Magnetic filed of different magnitude tested, maximum field of 500G;
- Spatial resolution of each event given by pitch of detectors, no additional effect on the resolution included in the simulation.

uRwell Simulations - Garfield

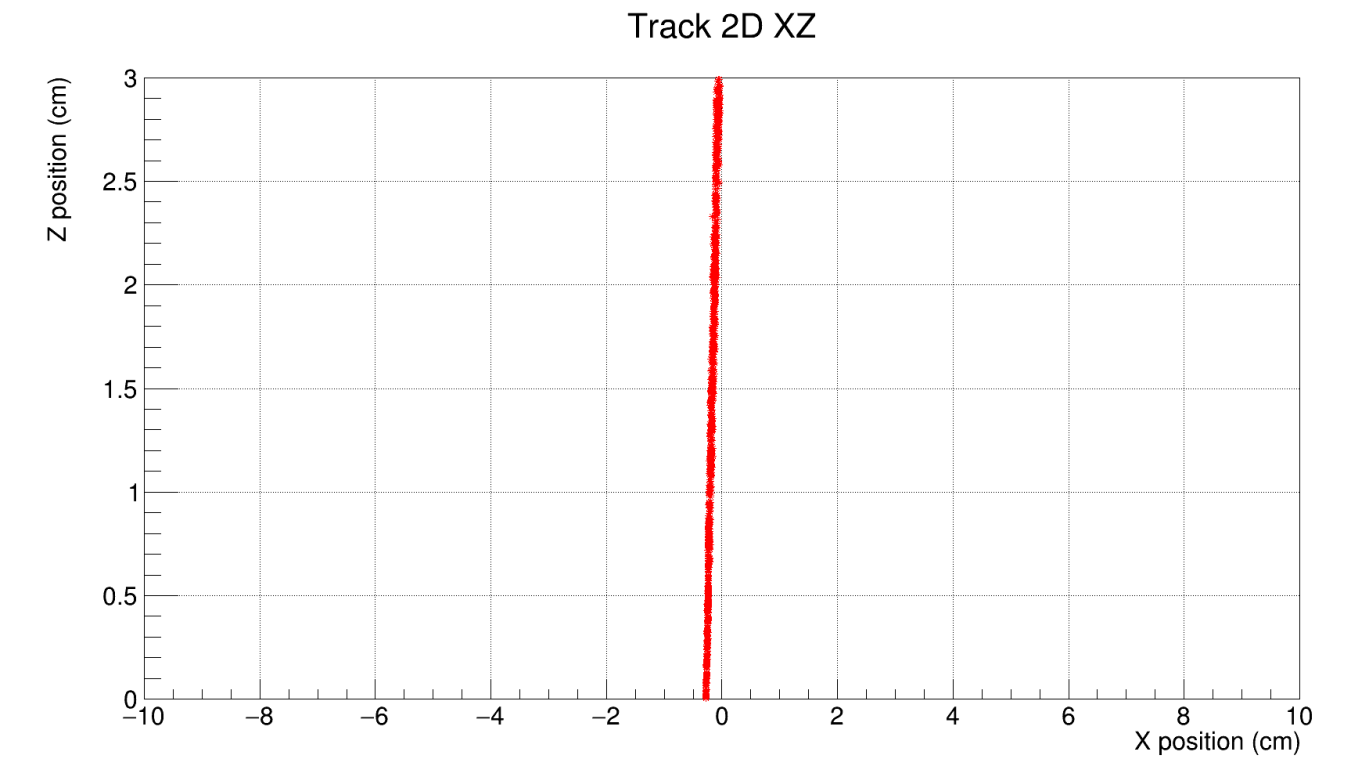
- GARFIELD simulations to study detector performances
- Ar/CO2/CF4 gas mixture simulated
- Electric field and electrons drift velocities simulated
- Track reconstruction in a constant magnetic field







Garfield tracks



- Tracks of electrons of different energies (2-18 MeV)
- Magnetic field of 500 G
- No visible curvature in the perpendicular plane

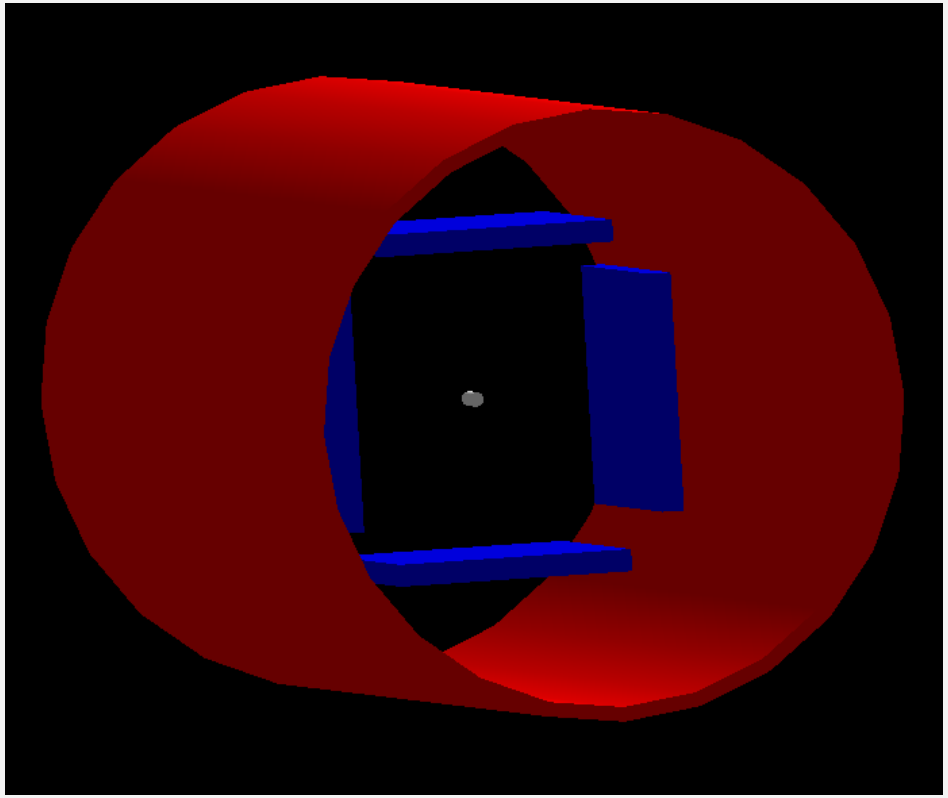
Not possible to use curvature inside a 3cm gap uRwell to obtain the energy, longer arm needed

Geant4 simulations

To study the track reconstruction capabilities of the setup we performed additional Geant4 simulations:

- Detector active volumes made only of Ar/CO2/CF4;
- Hit inside active volumes recorded using resolution given by detector pitch (1,26 mm X/Z axis and 0,74mm Y axis). All the hits are recorded in the position of the strip;
- Detectors of 325 x 380 mm with a gap of 3cm;
- Target volume is a cylinder of 2cm diameter, 4cm length, made of 1mm thick carbon;
- Events are generated from random points within target volume;
- Events of IPC and X17 decay (1/40 IPC) obtained from calculation of M. Viviani. A total of ~100k events simulated in the detector.

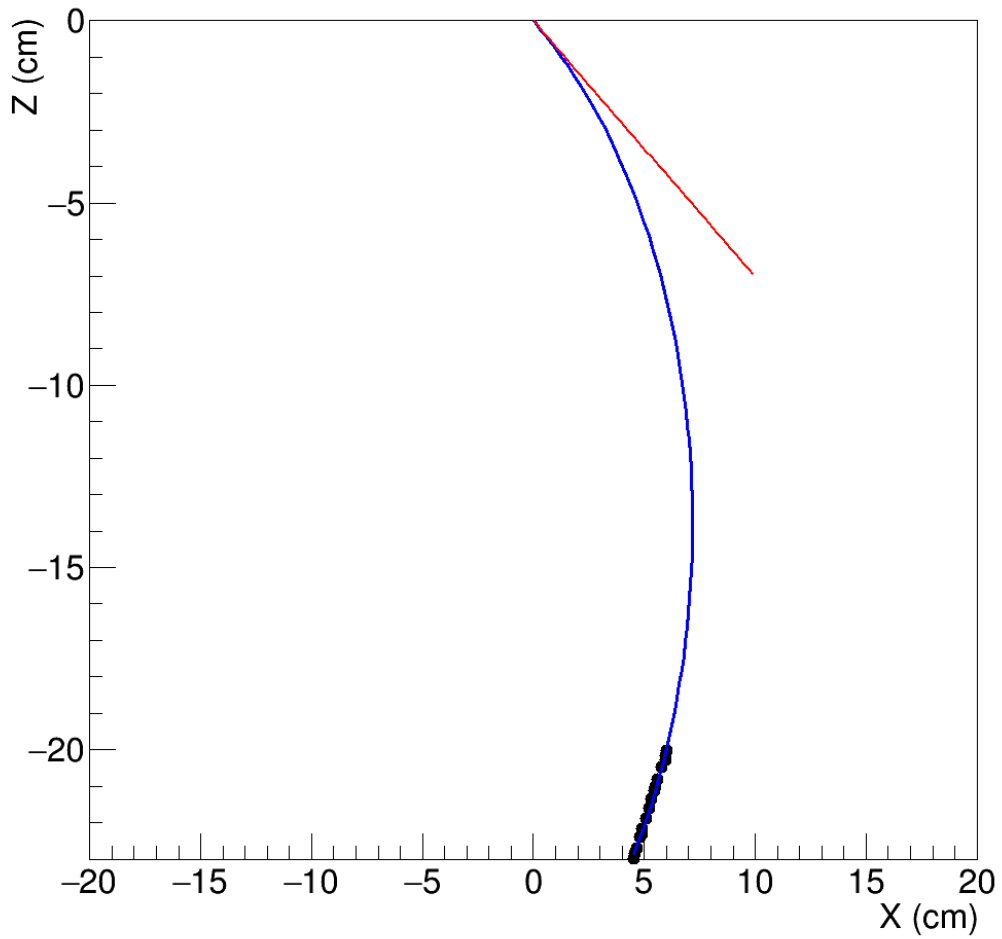
Geant4 setup



Simulations performed with Geant4 to study high number of events:

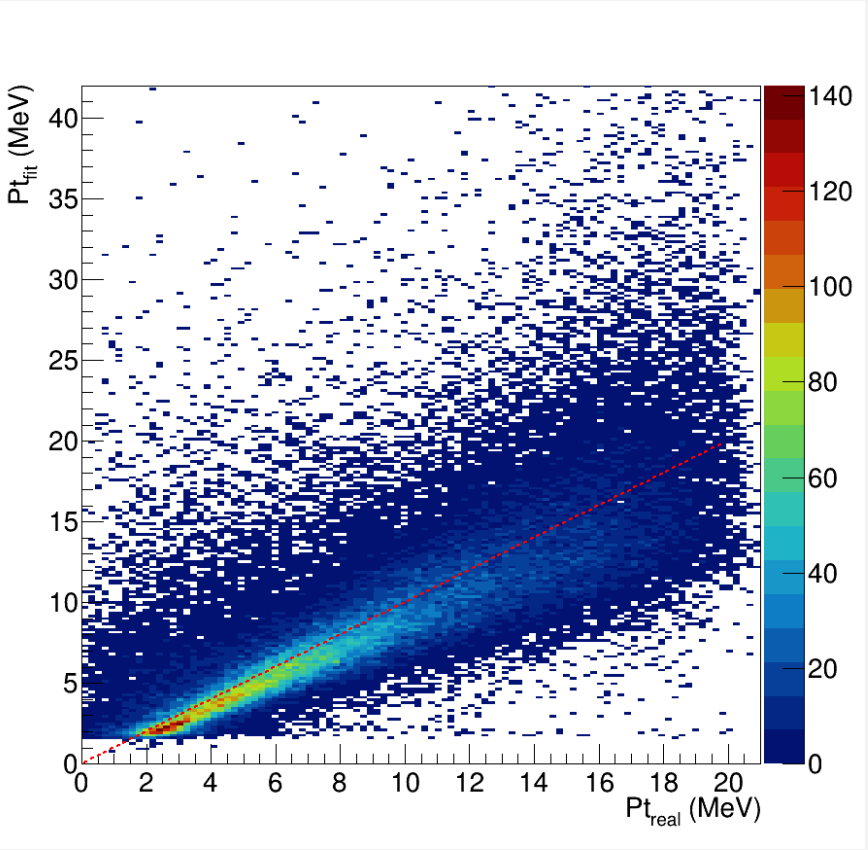
- **4 uRwell detectors,**
- **20 cm from beam,**
- **Magnetic field of 500 G parallel to beam direction.**

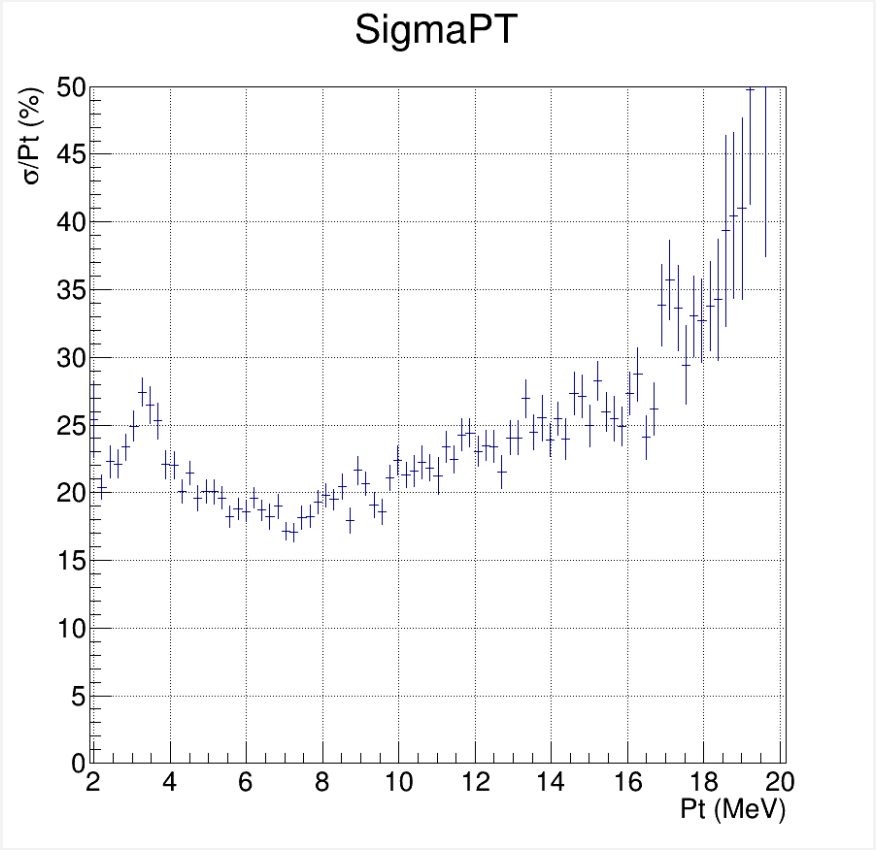
Energy reconstruction



- Assume interaction vertex at the origin;
- Fit circumference arc using straight track inside the detector gap and vertex;
- Tangent (red line) used for angle determination (see later)

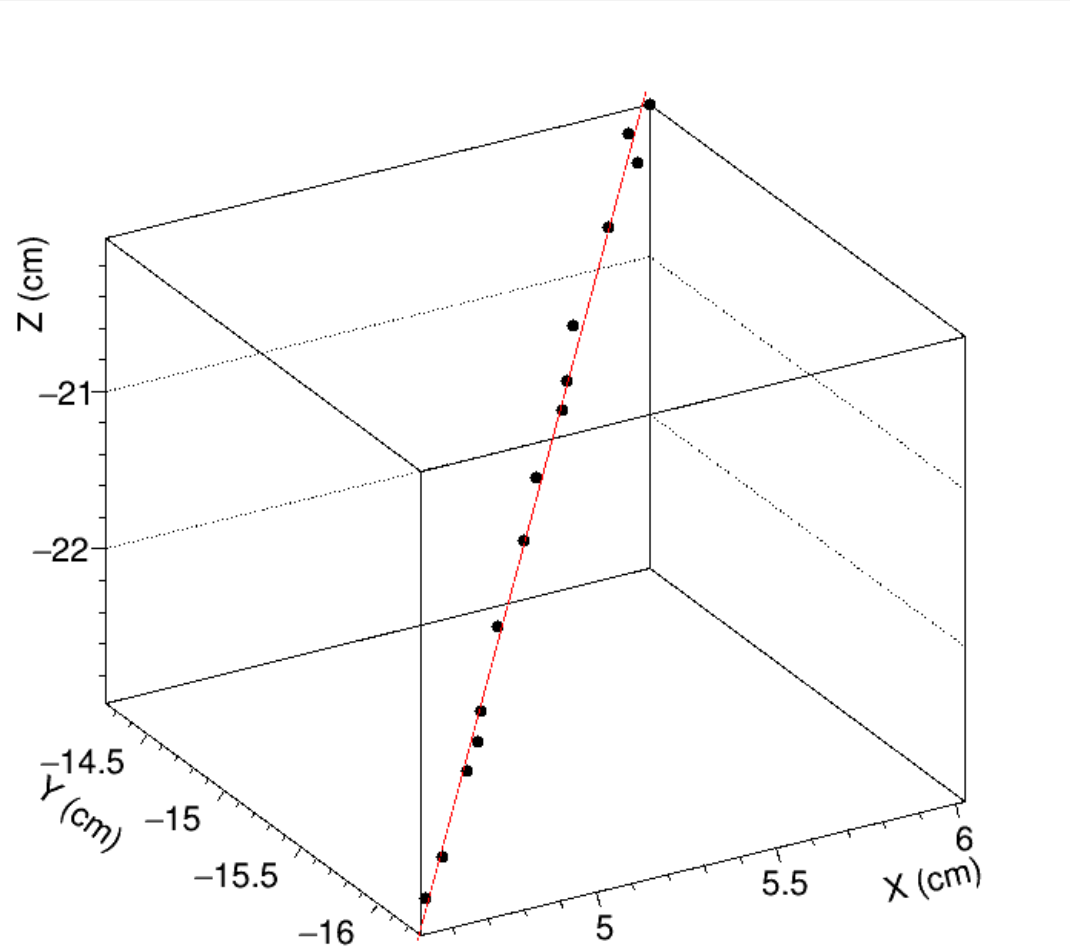
Energy reconstruction





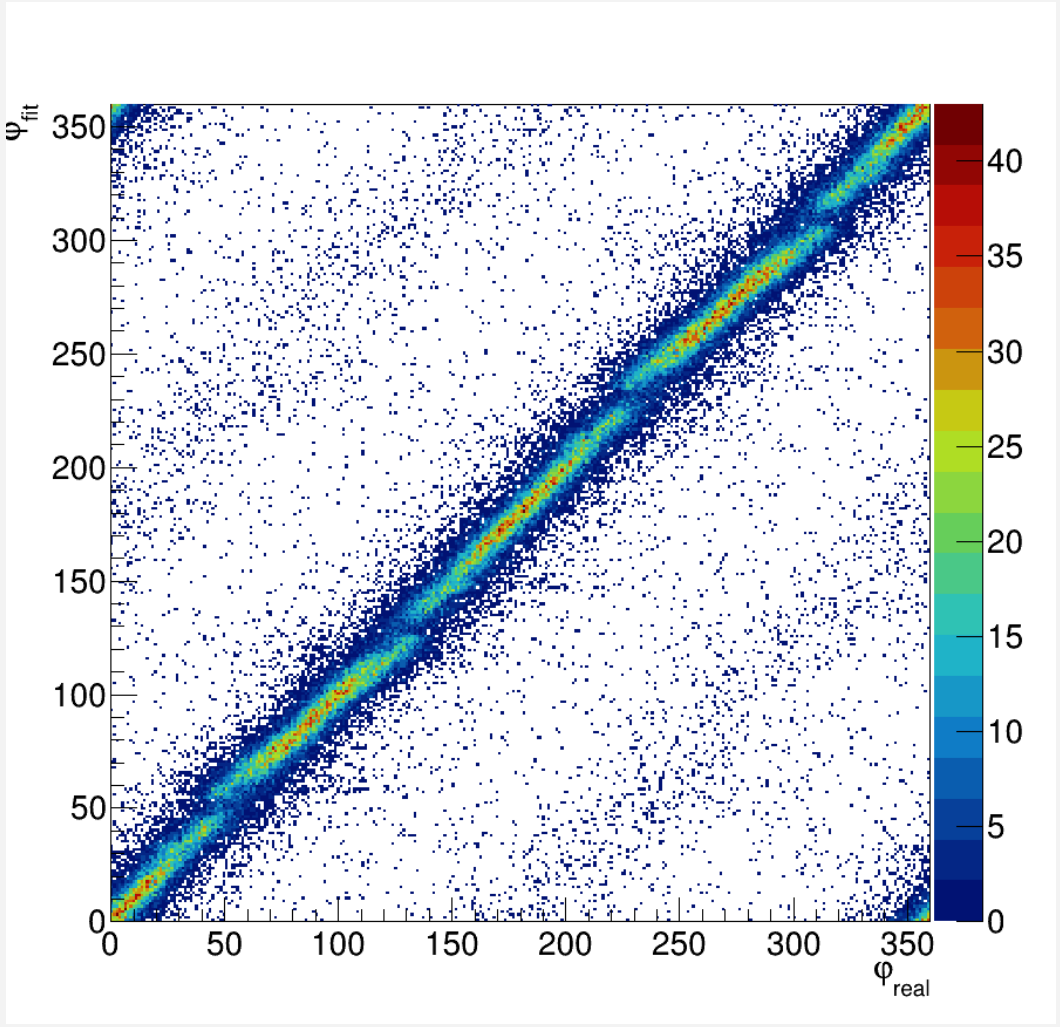
- Energy of the track reconstructed using curvature radius in magnetic field
- Resolution estimated at different energies with a gaussian fit of the projection of the 2D plot

Emission Angle Reconstruction



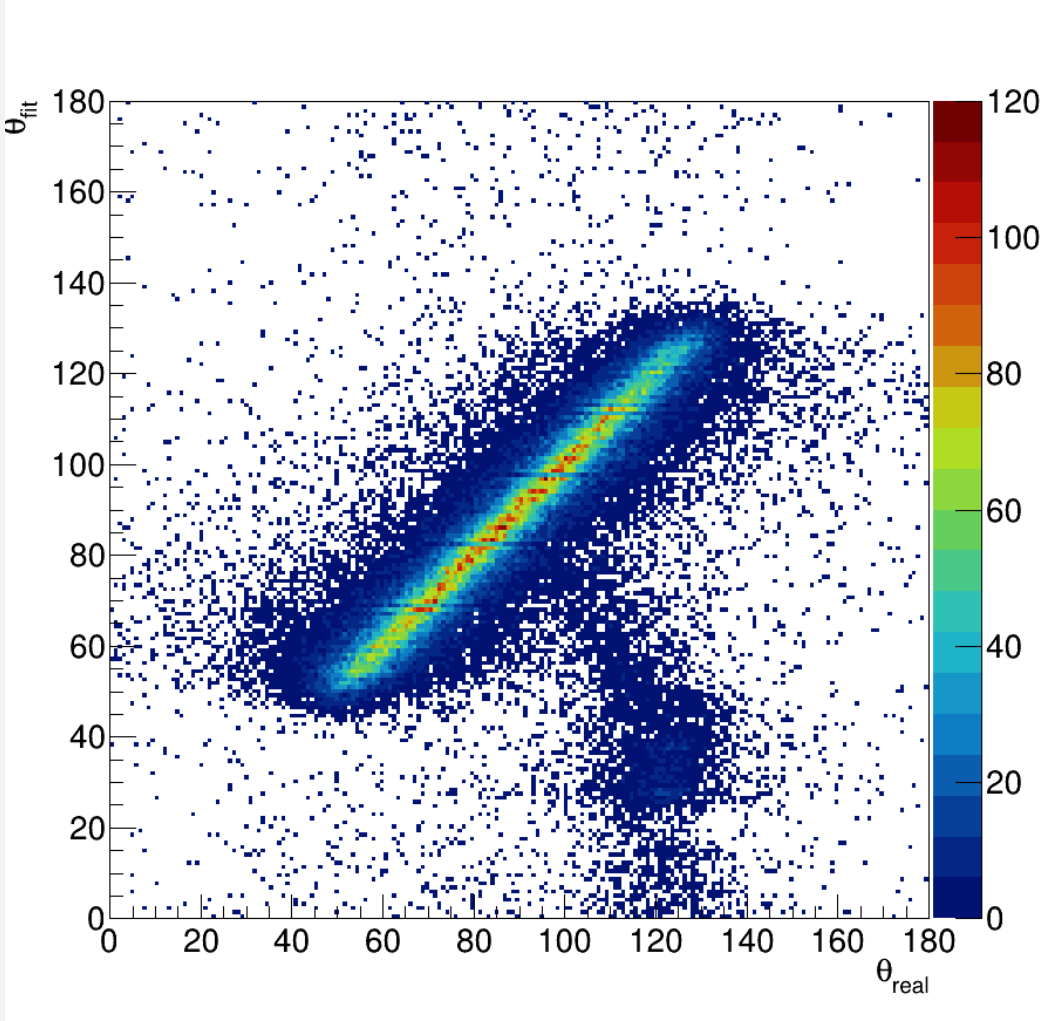
- **Theta reconstructed using linear fit of the track in 3D inside of the uRwell detecotr**
- **Phi reconstructed using tangent to circumference at emission vertex (origin of axis)**

Angles Reconstruction performance



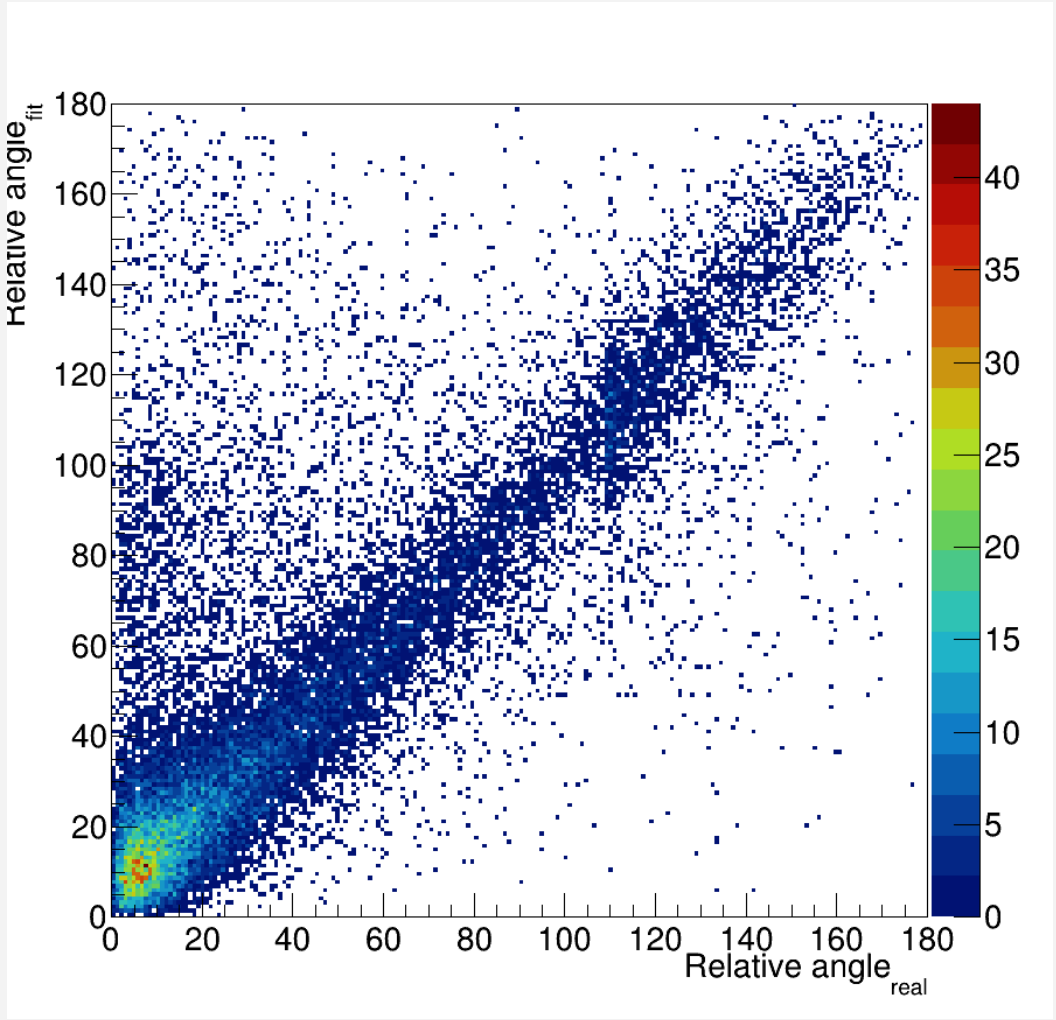
- **Comparison of reconstructed and real phi of the track**
- **Good agreement of >95% of the events, few events are reconstructed with phi shifted of 180°**

Angles Reconstruction performance



- **Comparison of reconstructed and real theta of the track**
- **Small number of tracks reconstructed with wrong angle**

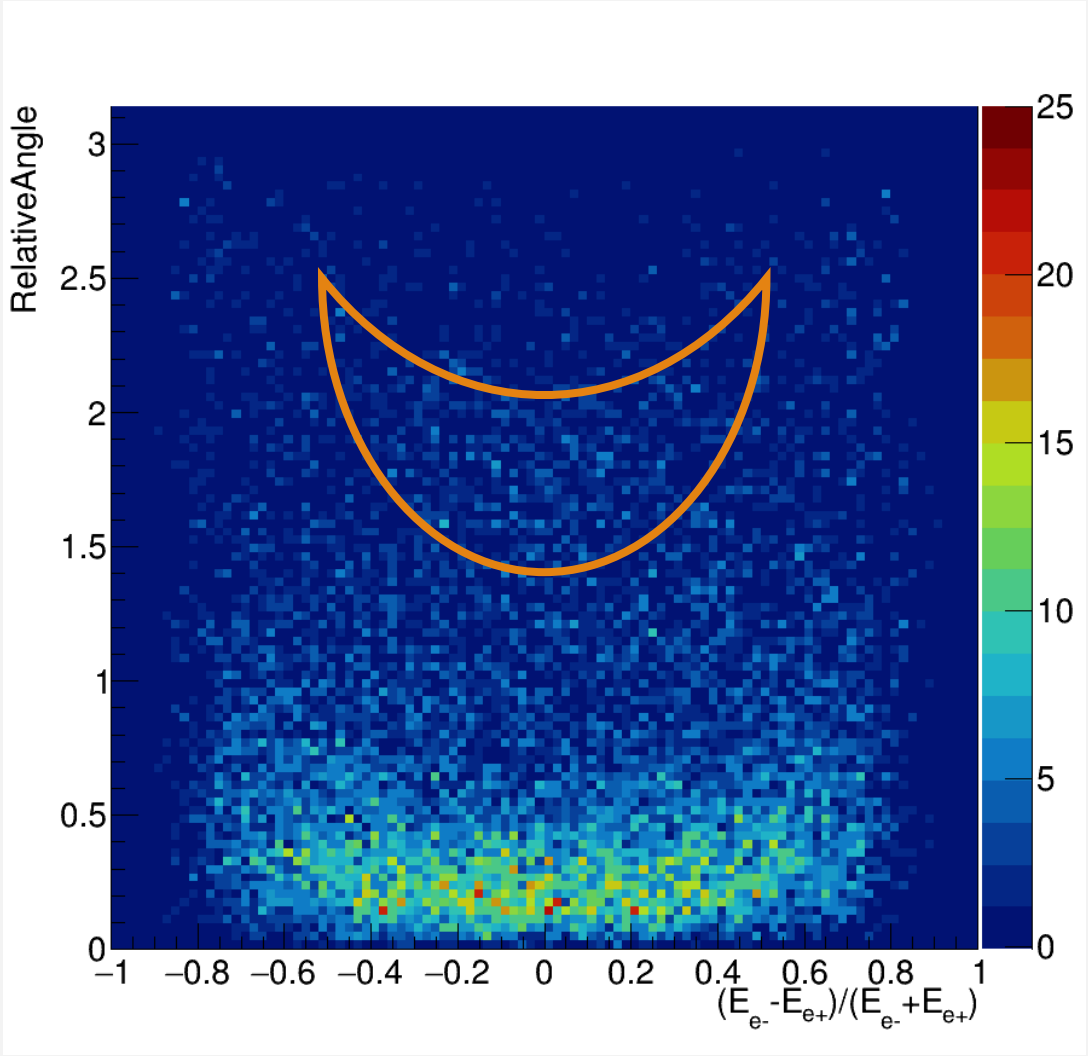
Relative angles



- Relative angle between the two reconstructed particles;
- Excess of events around 110° given by X17 signals;
- Excess reconstructed using fitted values with ~15° spread.

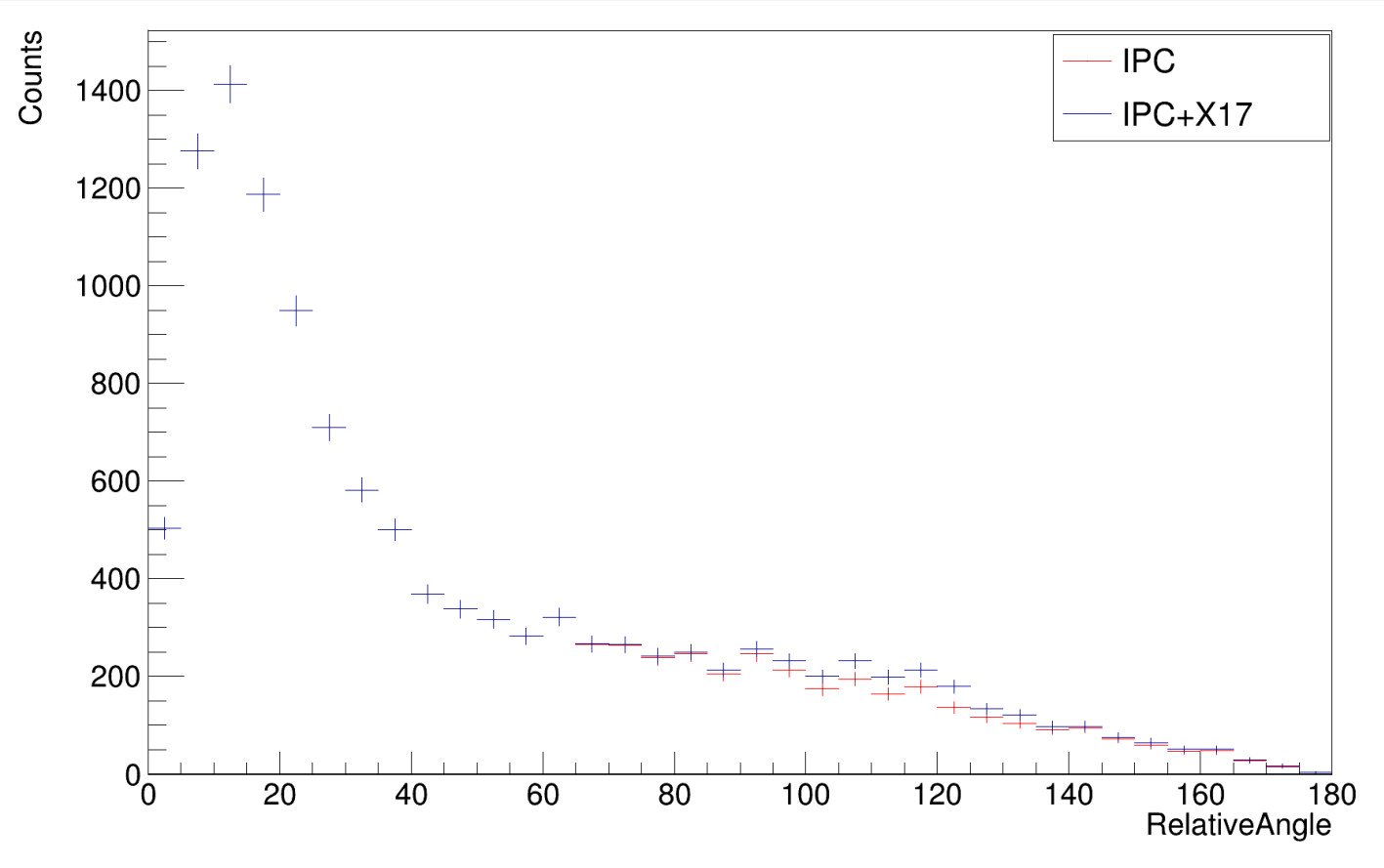
X17 events reconstruction

- **Relative angle versus e± energy asymmetry;**
- **Small excess of events at high relative angles with respect to simulation without X17 events.**



Counts versus relative angle

- **Counts as a function of relative angles between two reconstructed tracks;**
- **Comparison of counts without (red) and with (blue) X17 events (1/40 IPC);**
- **Excess visible around 110°, with a spread of ± 15°**



Conclusions

- The setup proposed for the search of the X17 boson at n_TOF has been simulated using Geant4;
- IPC and X17 realistic events have been simulated;
- Detectors placed in homogeneous magnetic field of 500G parallel to beam direction;
- The tracks were reconstructed using simulated hits in detector active volume;
- Simulations show a ~20% uncertainty on the Pt reconstruction for electrons of 4 – 15 MeV;
- The counts vs relative angle show an excess of events in the region of interest with a peak spread of ± 15° around the real value (110 °)

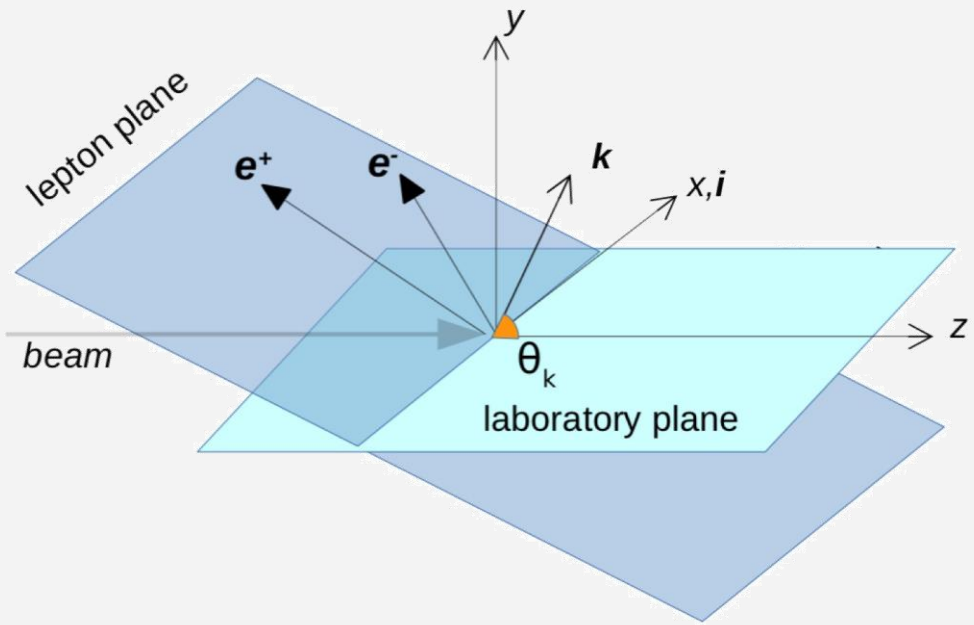
Thank you for your attention

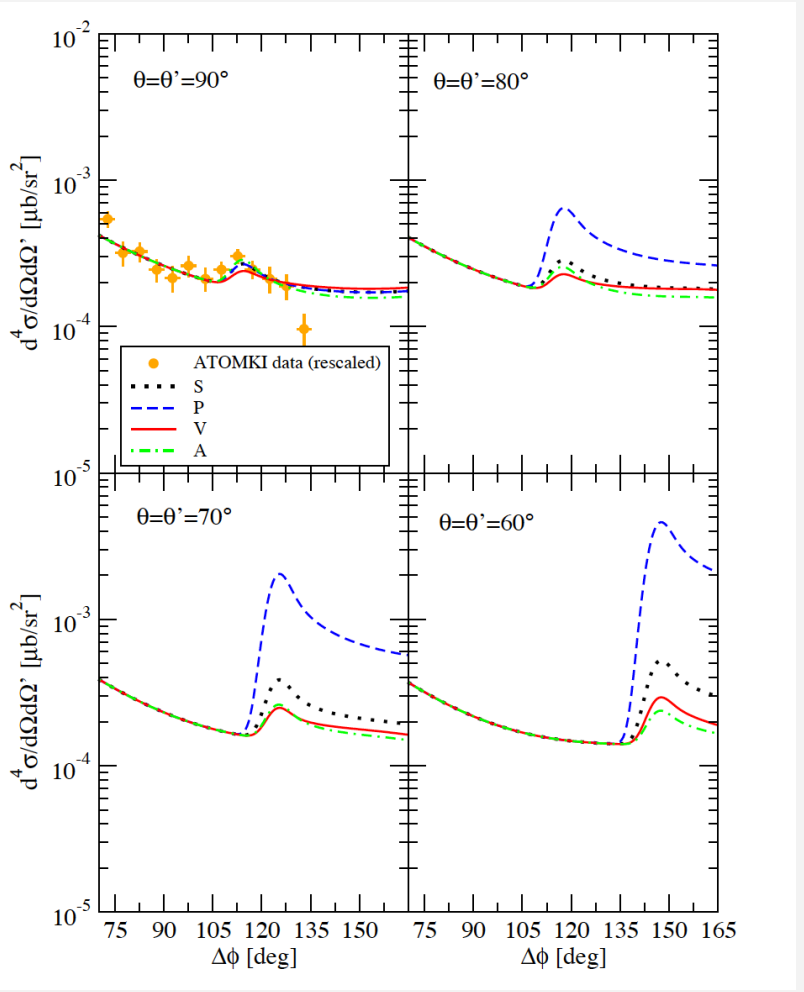
Backup

Theoretical calculations

M. Viviani et al.: PRC 105, 014001 (2022)

- Theoretical calculations for kinematical signature for different X17 boson (scalar, pseudo-scalar, vector, axial).,
- Calculation for different center-of-mass energies.





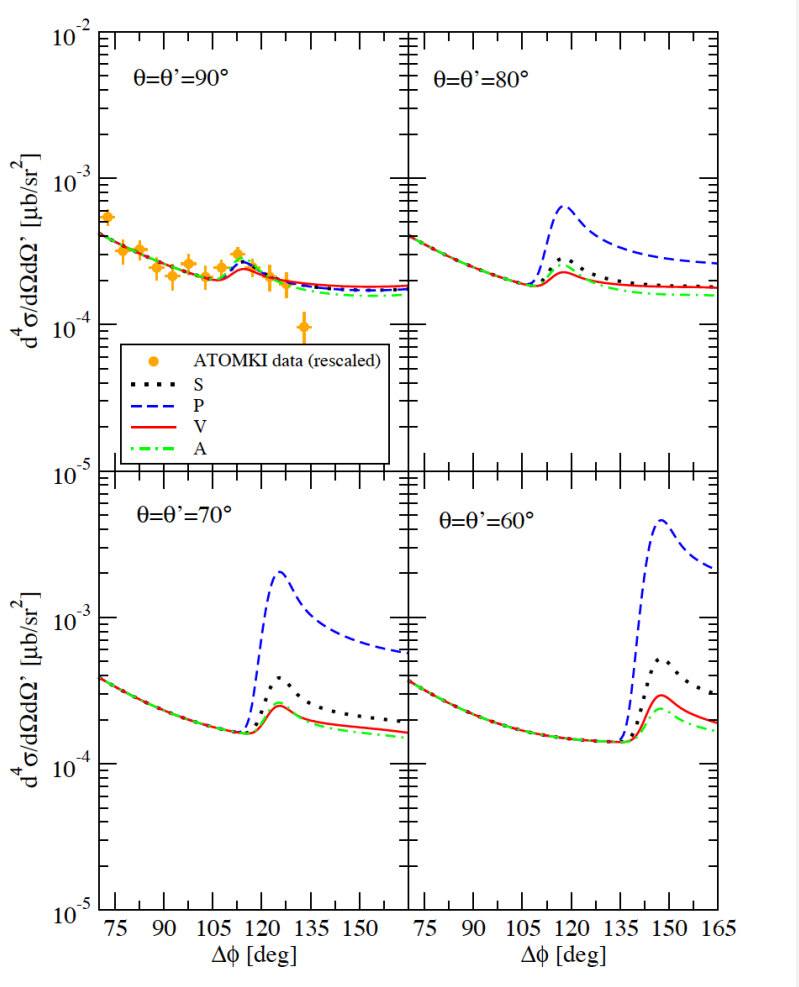
Theoretical calculations

M. Viviani et al.: PRC 105, 014001 (2022)

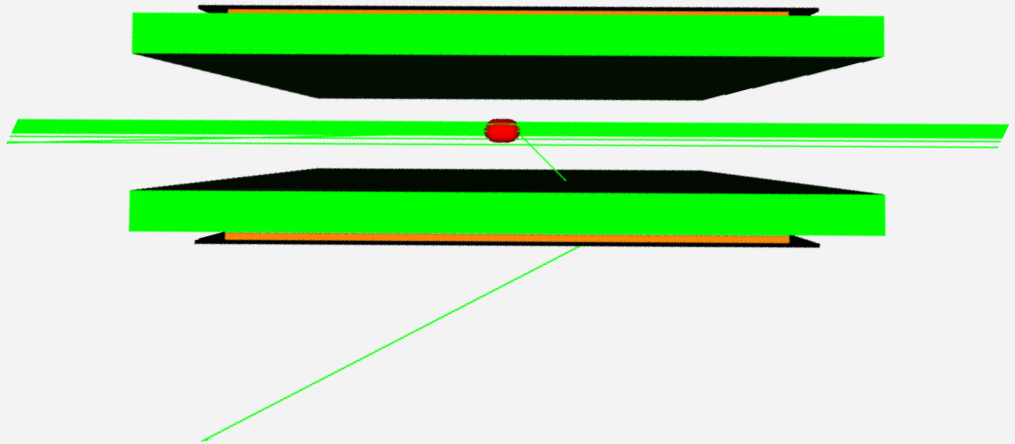
- Theoretical calculations of expected counts at different lepton plane angles,
- Calculation for different natures of the X17 boson (scalar, pseudo-scalar, vector, axial).

Wide energy range (protons and neutron beams) to explore all resonances with different J^{π}

Large detector acceptance for statistics and kinematics



Simulations



SIMULATION:

- SETUP with all used materials
- Realistic n_TOF beam
- IPC/X17 events rate (normalized to ATOMKI data)

OUTPUT:

- Acceptance/efficiency/MS
- Signal/Noise
- Detector performance
- e+e- ID and 4-momenta
- X17 invariant mass