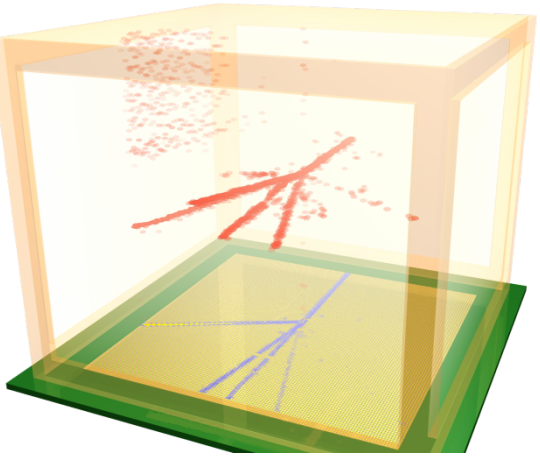
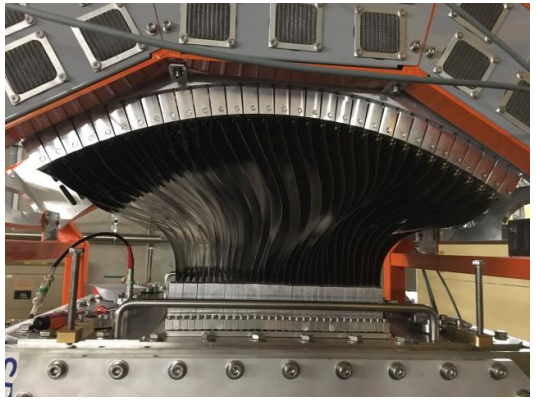
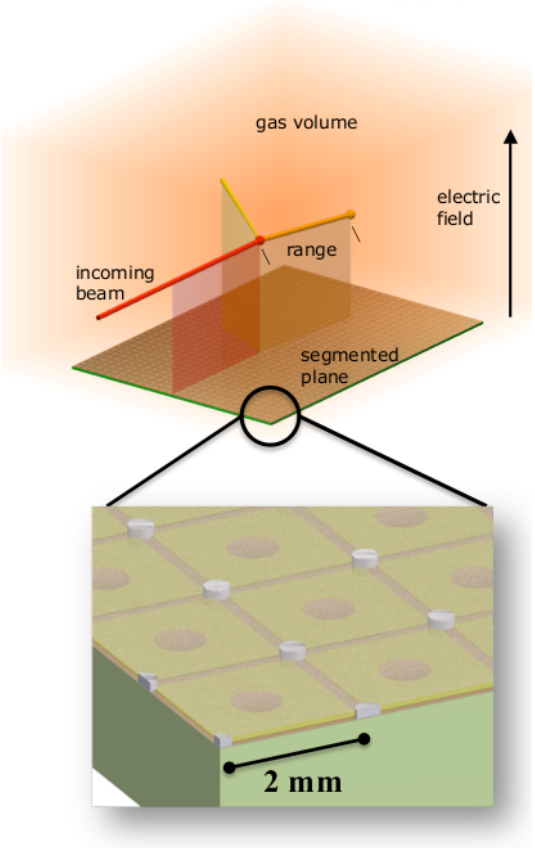
GANIL spiral2
laboratoire commun CEA/DRF CNRS/IN2P3

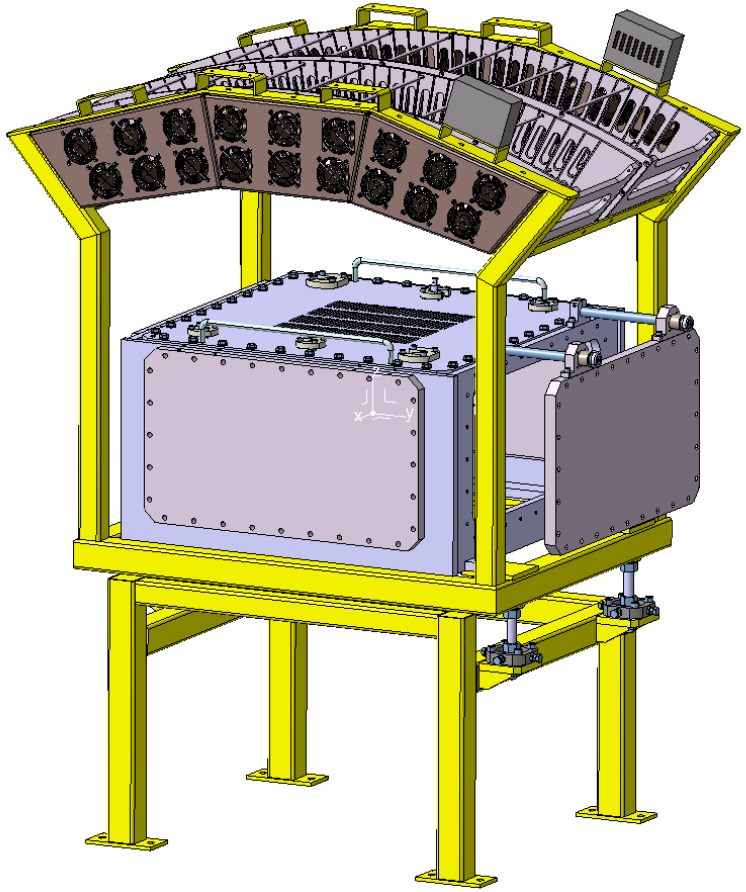
actar TPC

ACTAR TPC



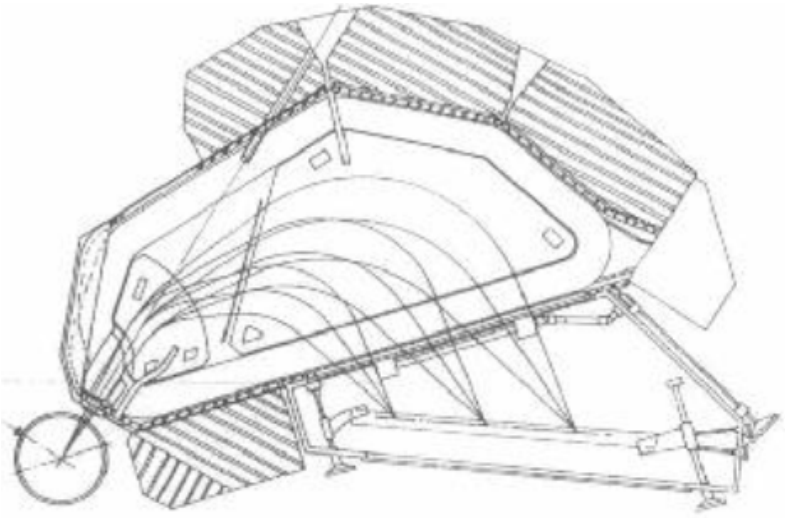


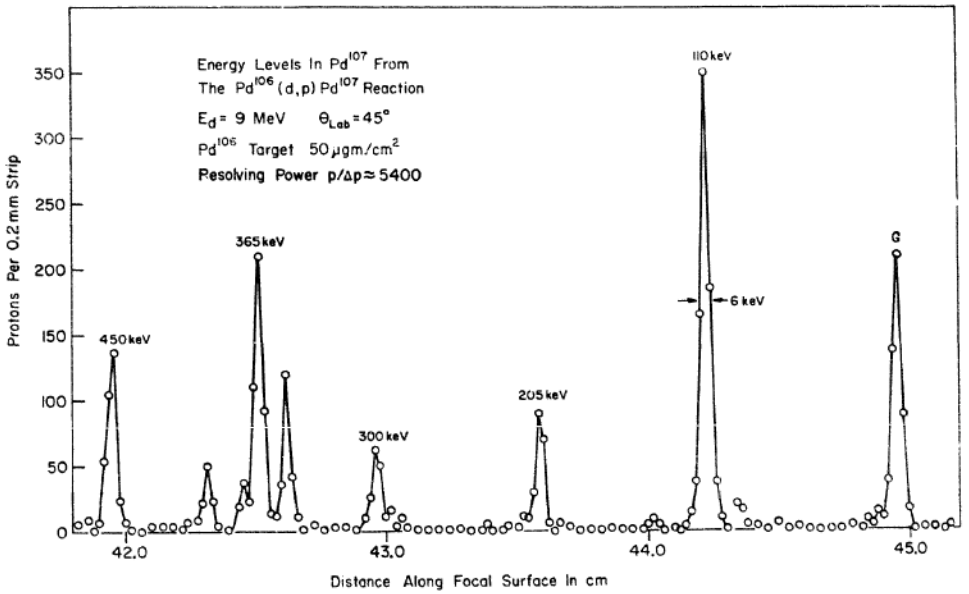




Past: structure of nuclei close to stability in direct kinematics, use of magnetic spectrograph

- Good resolution (few keV)
- High beam intensity
- Stuck with stable isotopes from which a target can be made

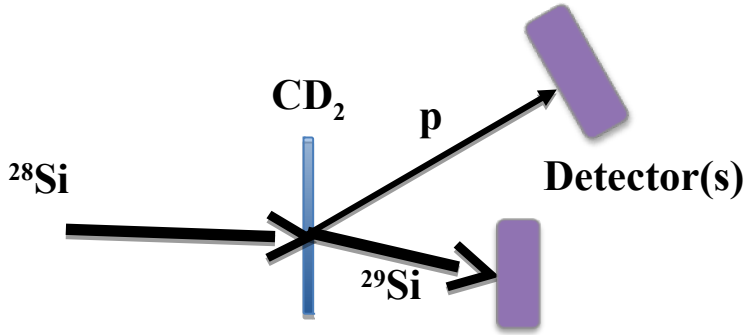


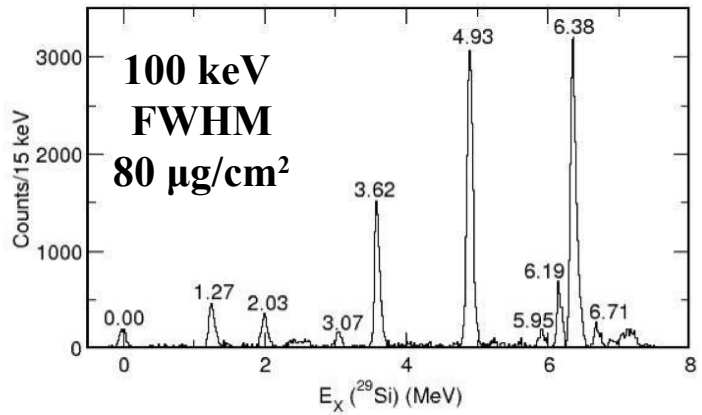


J.E. Spencer and H.A. Enge, NIM ***49,*** *181 (1967)*

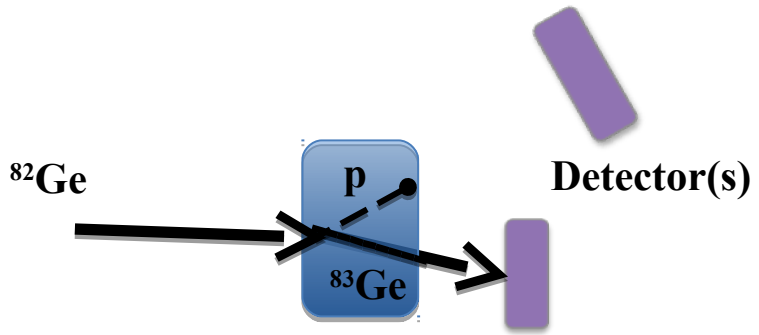
Now: structure of exotic nuclei in inverse kinematics

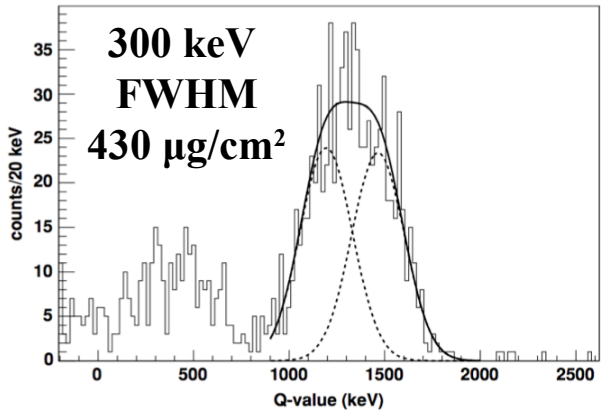
- Study of nuclei with short half-life
- Low beam intensity
- Resolution strongly depends on target thickness





*J.C.Lighthall et al., NIM A **622** 97 (2010)*





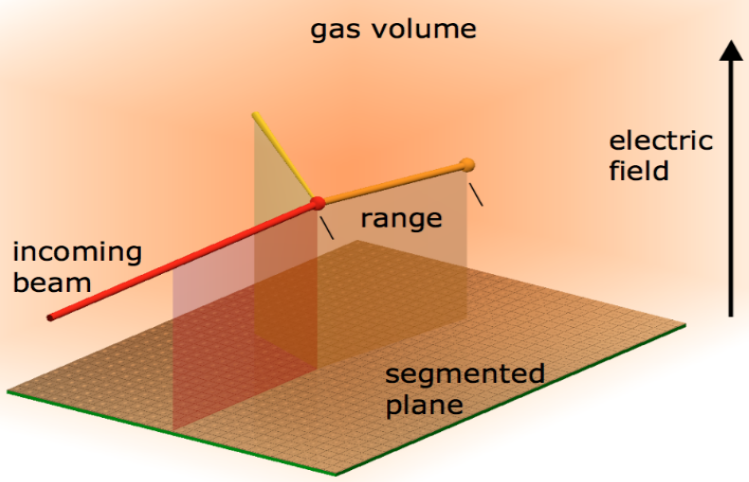
*J.S. Thomas et al., PRC **71,** 012302 (2005)*

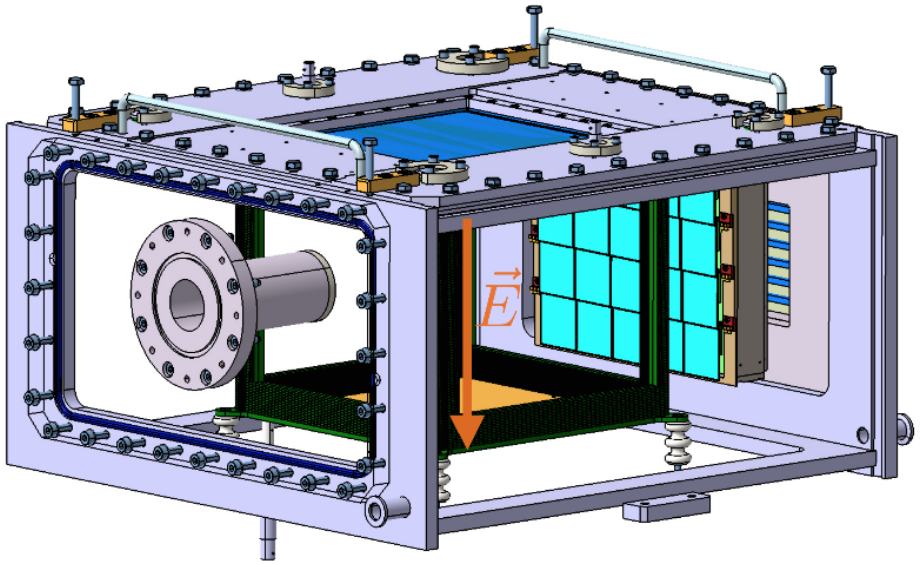
Need thick targets *and* excellent resolution

Now: ACTIVE TARGETS

- Study of nuclei with short half-life, produced with small intensity
- Use of thick target without loss of resolution
- Detection of very low energy recoils

Active target: (Gaseous) detector in which the atoms of the gas are used as a target



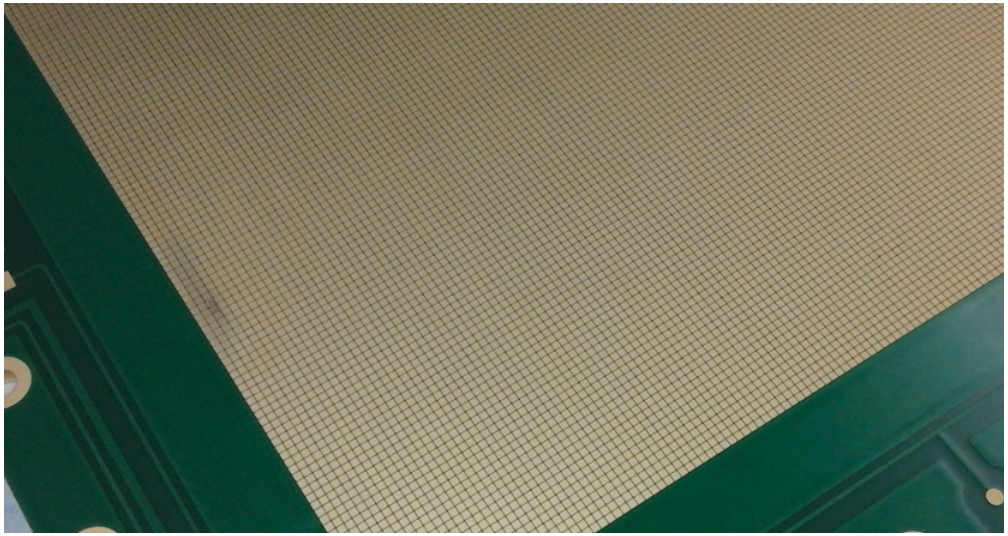


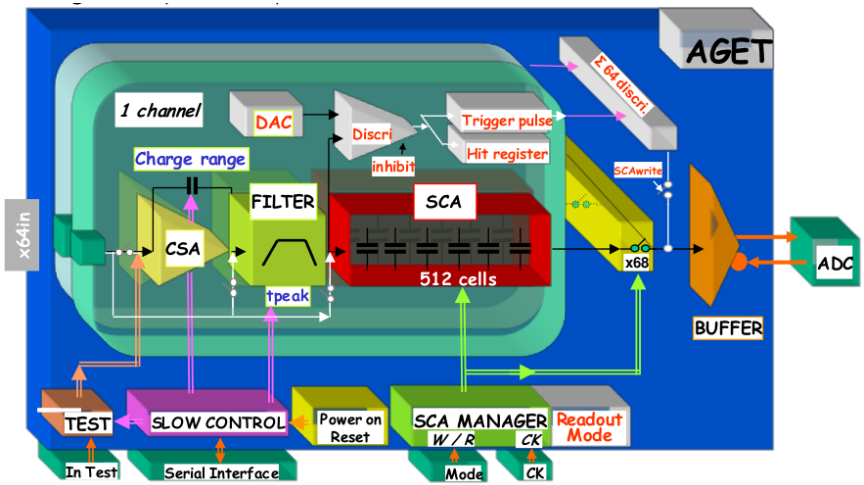
ACTAR TPC : Design

- ✓ Segmented pad plane
  - Micromegas (CERN PCB WS) → transverse multiplicity ≈ electron straggling: 2x2 mm^2 pads
  - 16384 pads with very high density: connectics challenge!
- ✓ Electronics
  - Very front end sparking protection circuit: ZAP boards
  - Pads equipped with GET electronics:

    → 512 samples ADC readout depth x 16384 pads = **volume sampling in 8 Mega voxels**

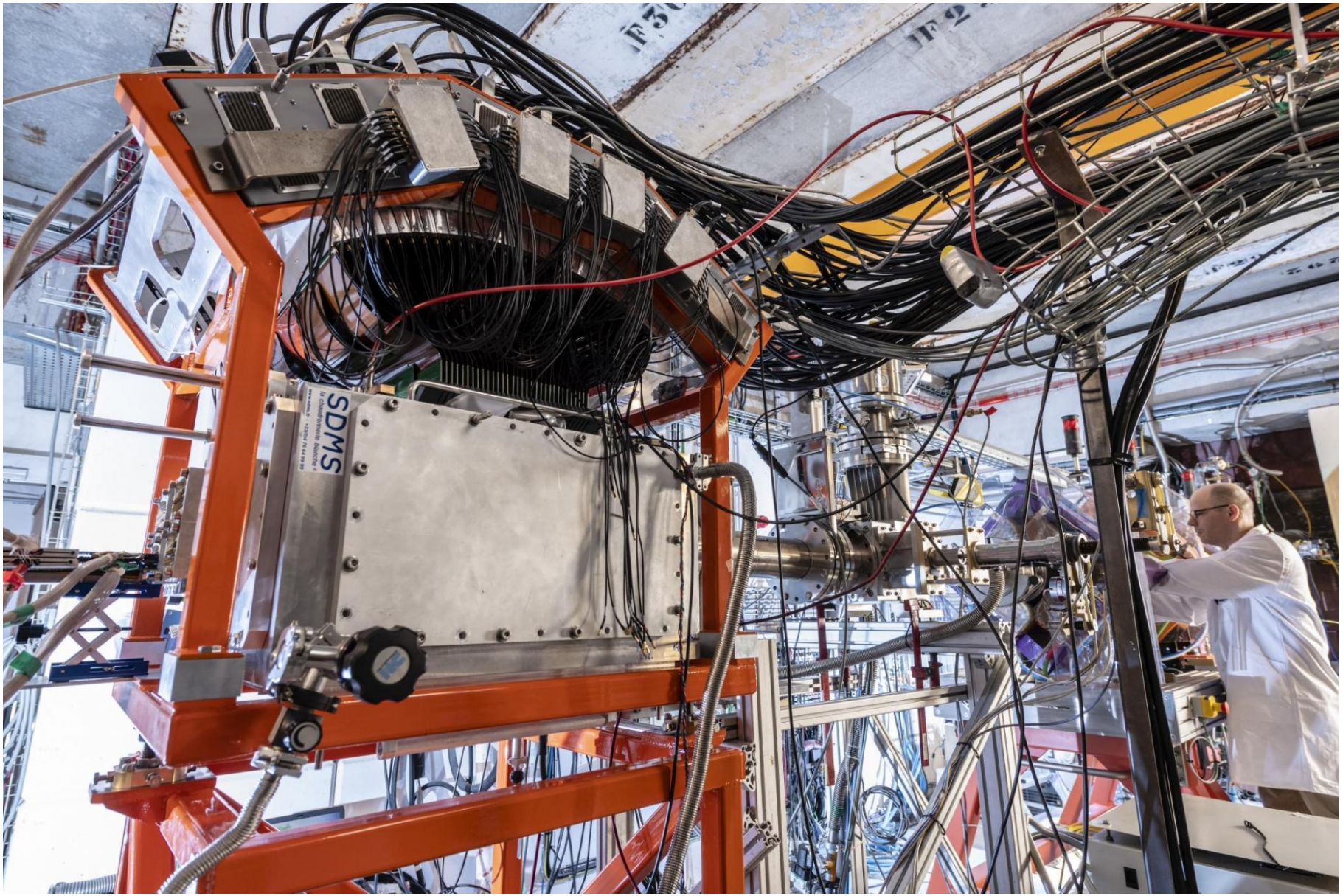
→ adjustable gain, peaking time, individual trigger: pad per pad





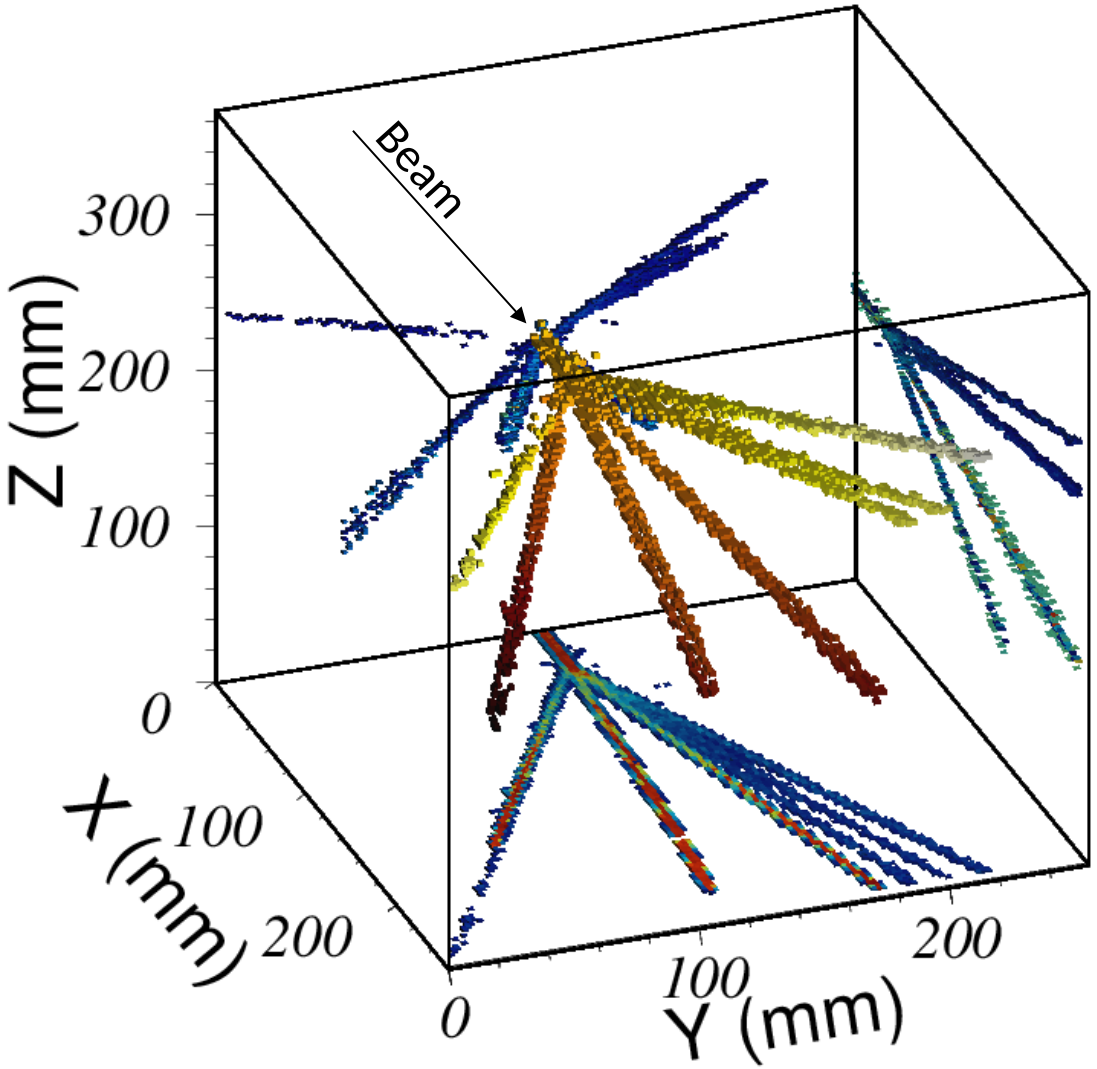
E.C. Pollacco et al., NIM A887, 81 (2018)

ACTAR TPC : Design



ACTAR TPC : Design

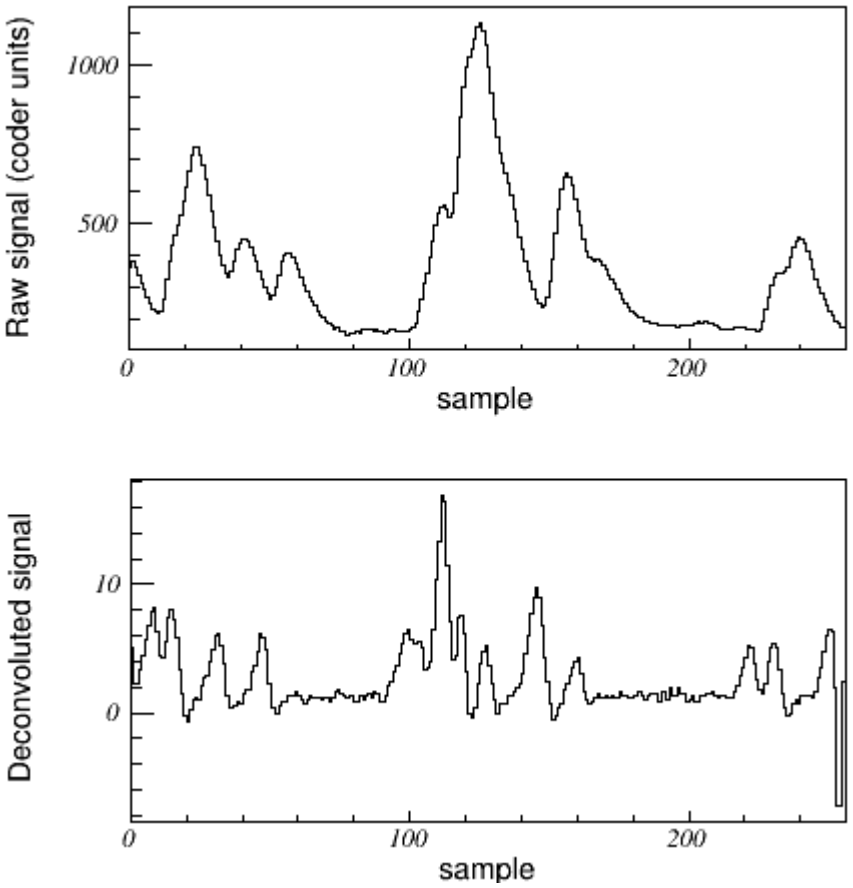
^{18}O (beam) + ^{12}C (iC_4H_{10} target gas)



ACTAR TPC : Data analysis

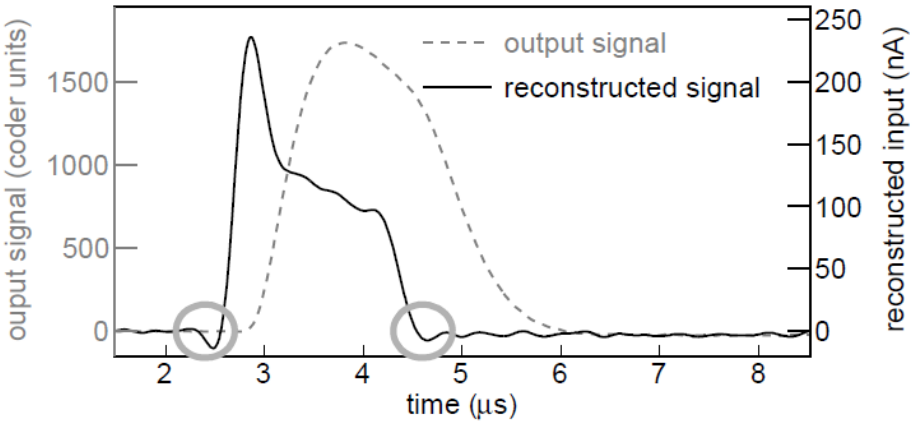
✓ 1st step: extraction of the voxel information: Z (time) and associated charge
→ peak-sensing procedure might not be sufficient: deconvolution of the shaped signal is needed

Pileup



Central pads, beam intensity: 4.10^4 Hz

Vertical tracks

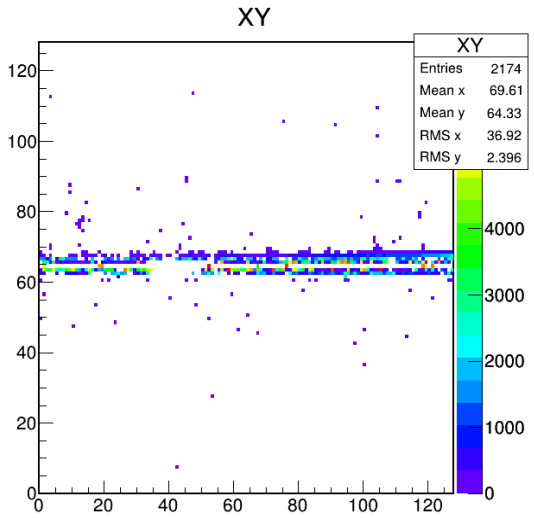


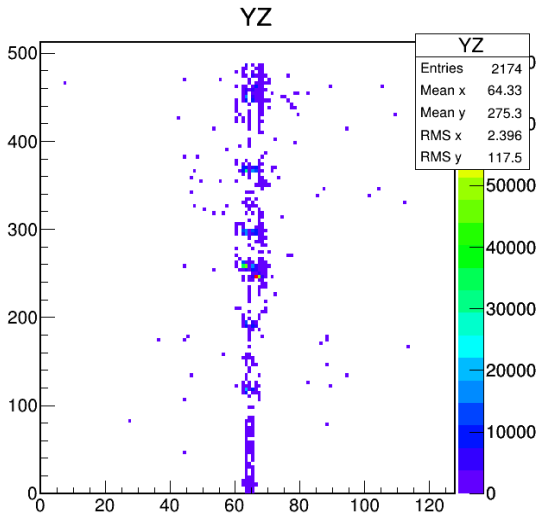
vertical track: Z-dimension can't be described by a single value

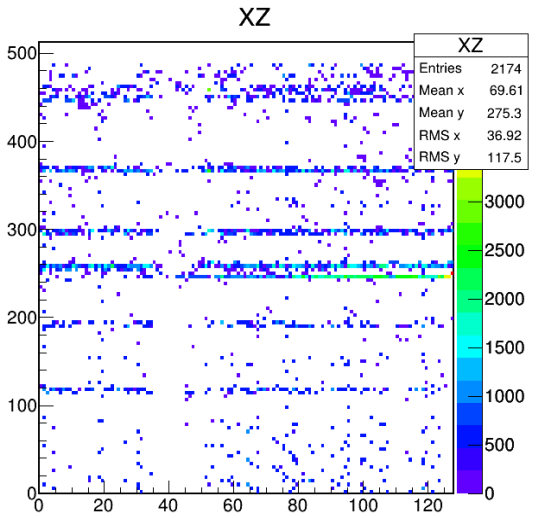
Figure: J. Giovinazzo, submitted to NIMA (2019)

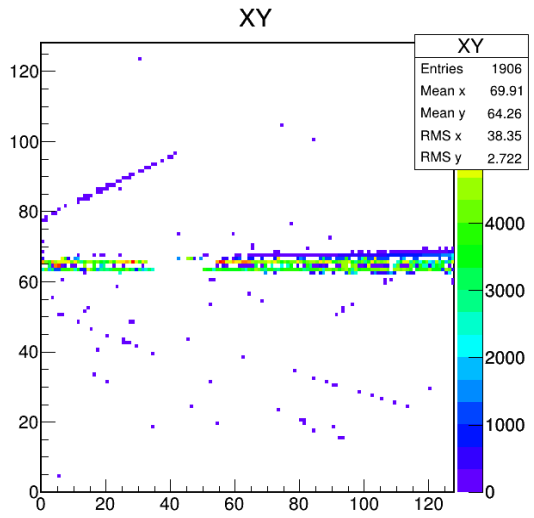
ACTAR TPC : Particle tracking

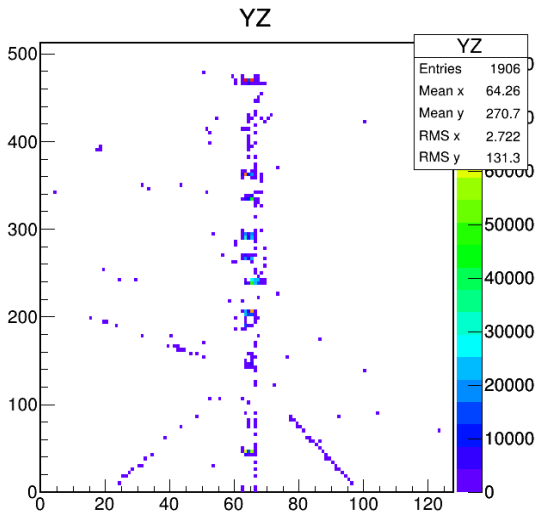
- ✓ Primary goal: counting particles

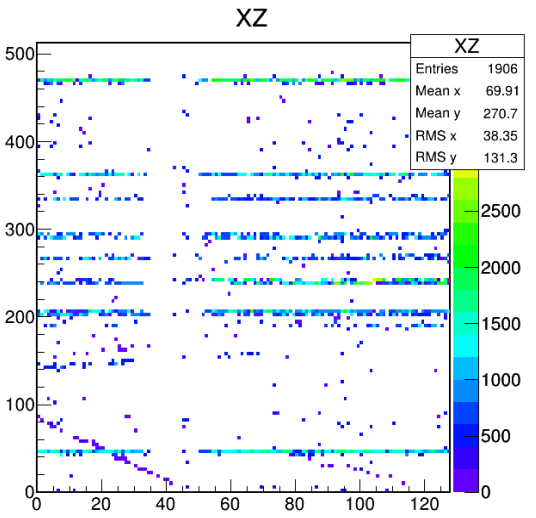






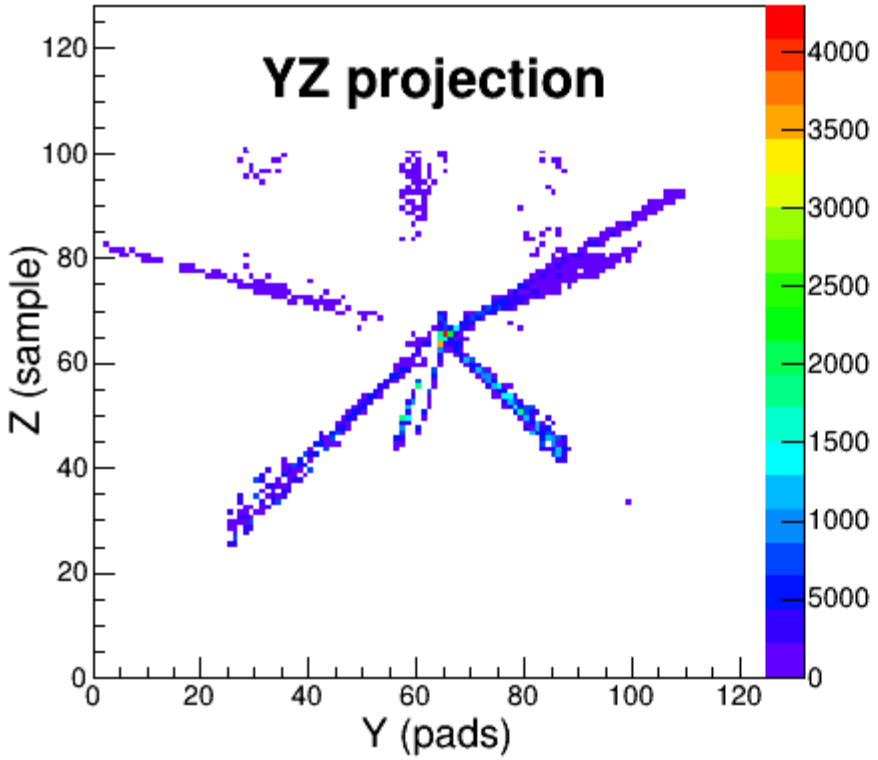


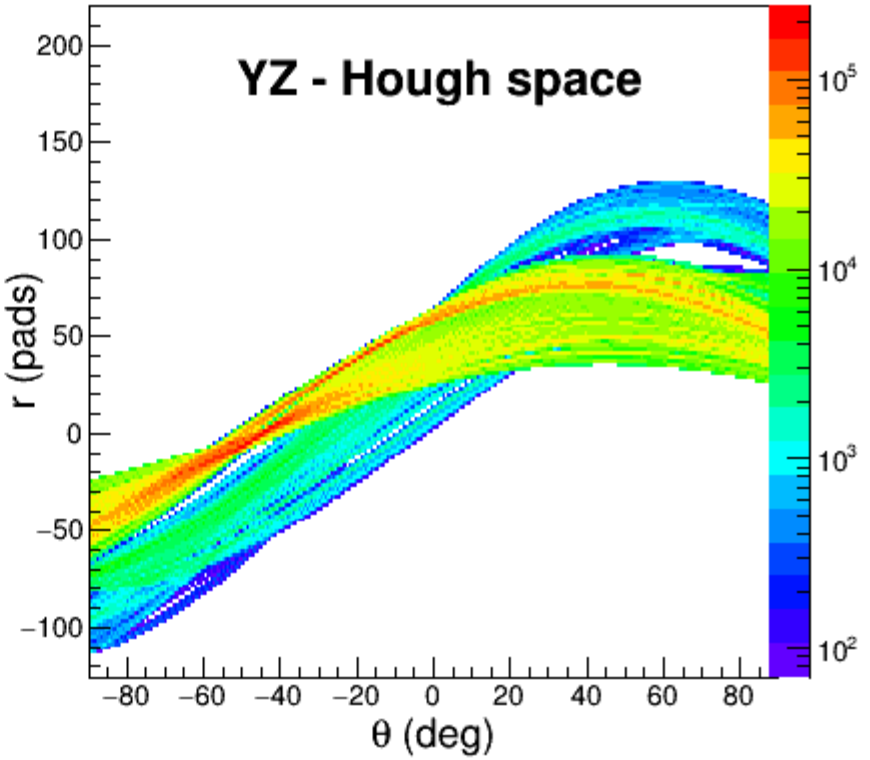




Commercial tracking algorithm

- ✓ Hough transform : r = y*cos(t) + z*sin(t) (in 2D)

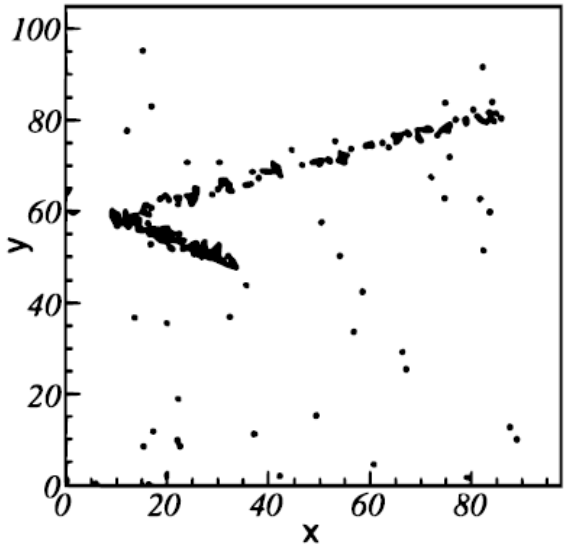


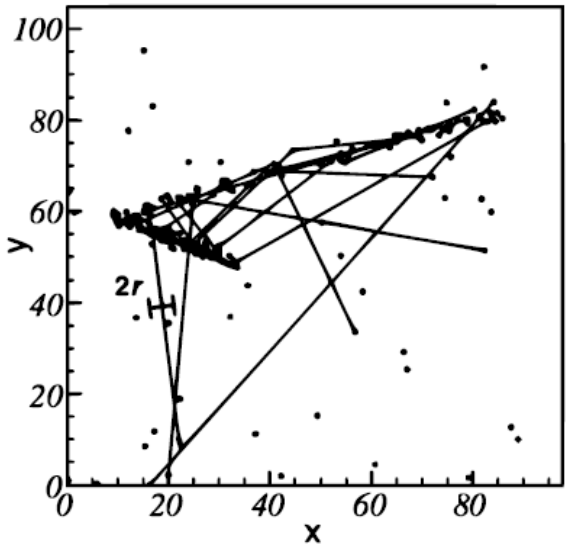


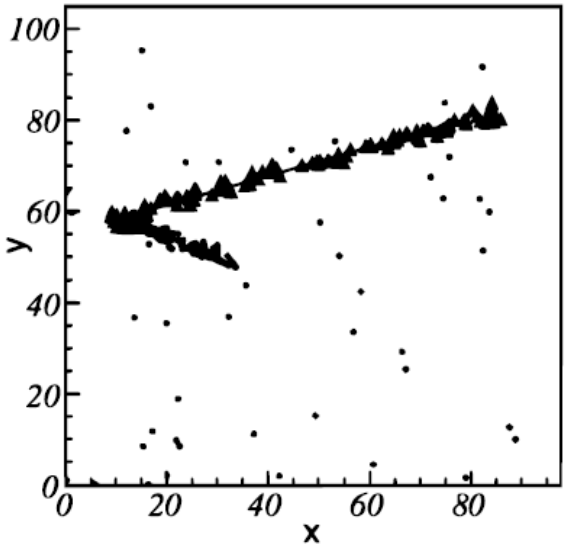
- ✓ Requires to find the local maxima on a 2D spectrum (for 2D tracks)
  → use of 6D histograms for 3D tracks!
  → not very efficient!

Commercial tracking algorithm

✓ RANdom Sample Consensus (RANSAC):





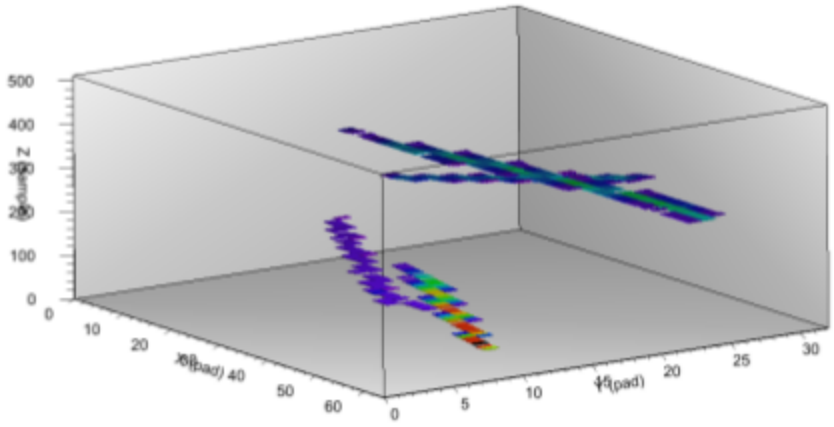


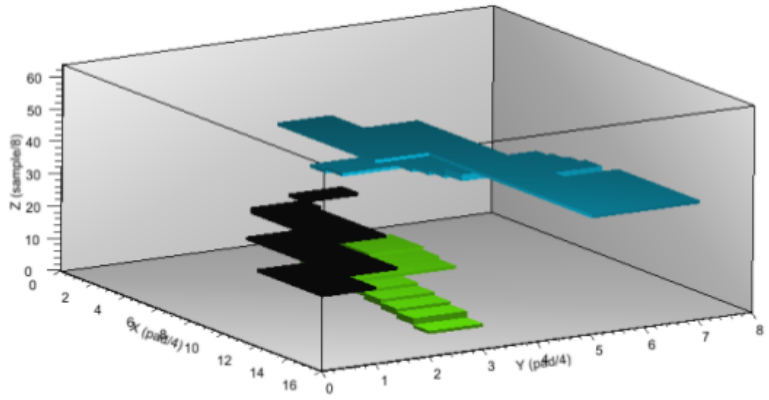
✓ Failure probability: decreases with the number of trials… while computing time increases.

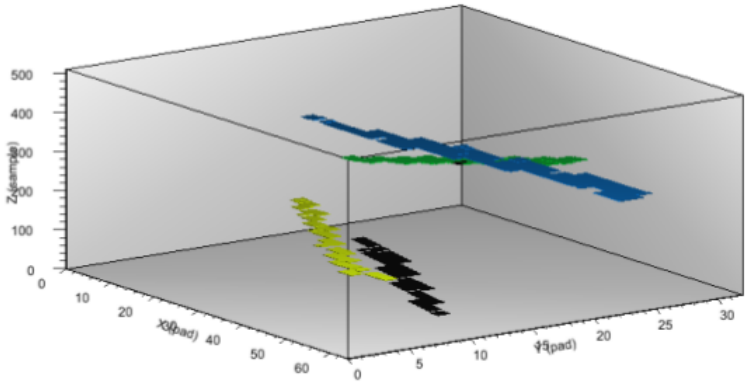
✘ Need to prioritize the "goodness" criterion: number of also-inliners or chi2??

Home-made tracking algorithm

- ✓ Cluster method (B. Mauss PhD thesis):



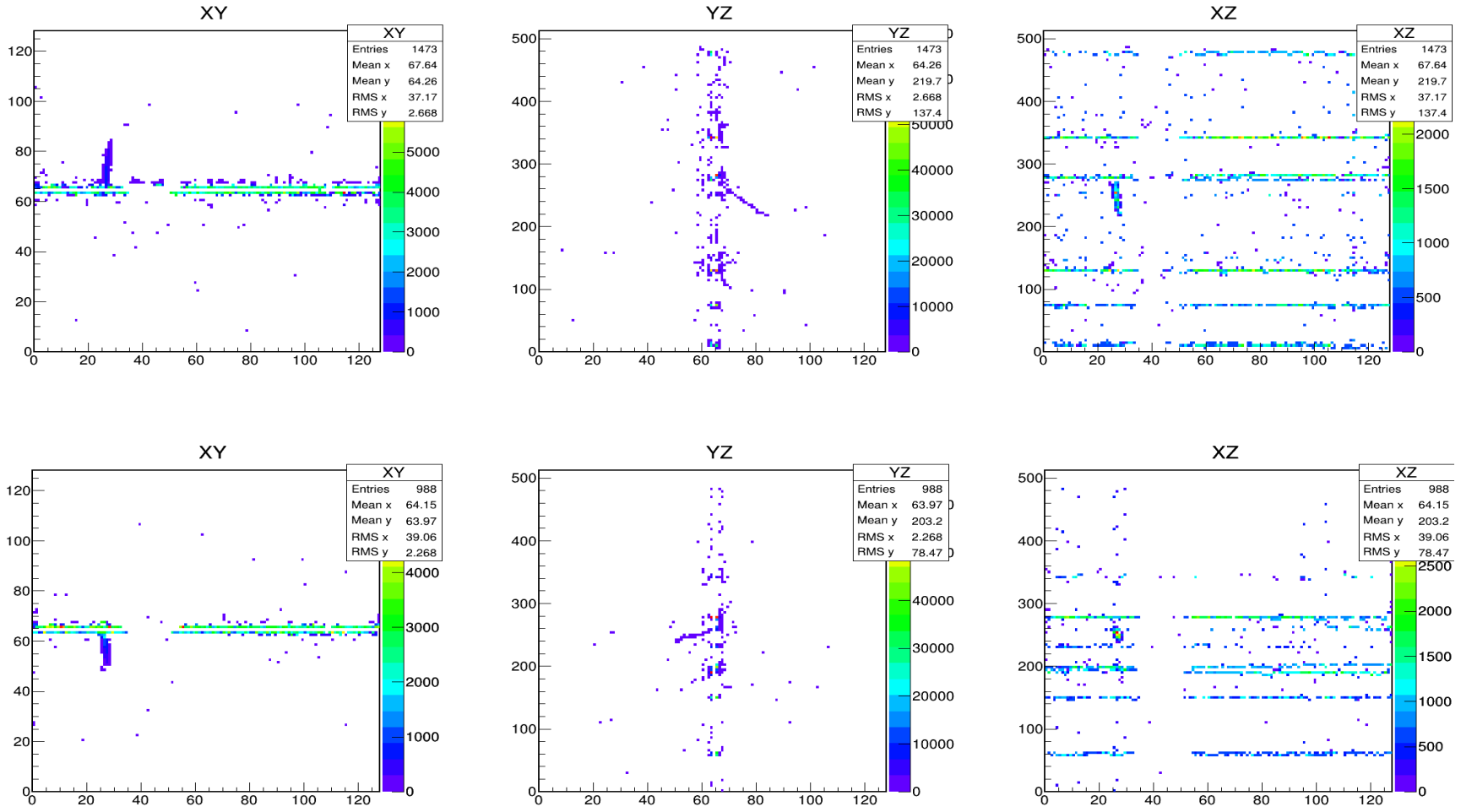




- ✓ Use continuity condition: simple and quite fast!
  - ✘ But not universal...

ACTAR TPC : Particle tracking

- ✓ Primary goal: counting particles



ACTAR TPC : Particle tracking

- ✓ → Large variety of tracks with properties that depend on the type of experiment
  - large/thin, long/short tracks: hard to find a universal tracking algorithm
  - (quite) large amount of data (about 3 TB/day)

European Research Council

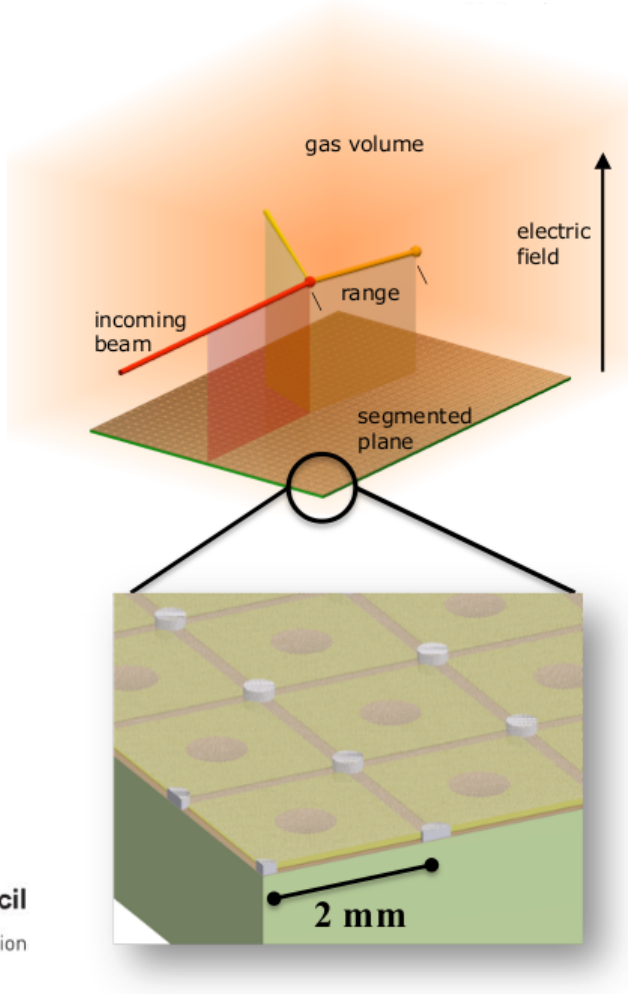
Established by the European Commission

The research leading to these results have received funding from the European Research Council under the European Union's Seventh Framework Program (FP7/2007-2013)/ERC grant agreement n° 335593.

ACTAR TPC : Particle tracking

- ✓ Primary goal: counting particles

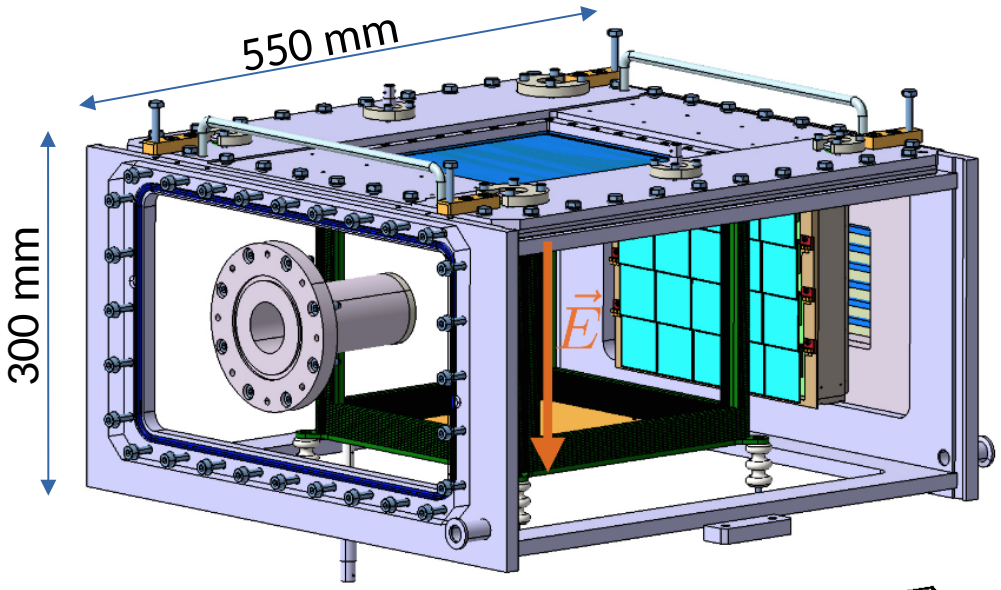
- ✓ Gas-filled active target and time projection chamber
  - Gas = detector AND target
  - Vertexing = resolution similar to thin solid target
  - High effective thickness = up to 10^3 higher
- ✓ Major advantages over conventional approaches
  - Detection efficiency close to 4π
  - Detection of low energy recoils (that stop inside the target)
  - Event-by-event 3D reconstruction
  - Compact, portable and versatile detector
- ✓ Physics programs
  - Resonant scattering
  - Inelastic scattering and giant resonances
  - Transfer reactions
  - Rare and exotic decays (2p, β2p, …)
  - Transfer-induced fission, …

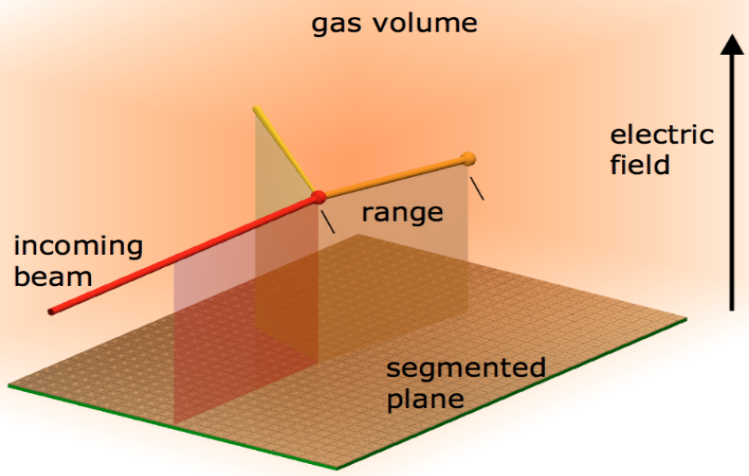


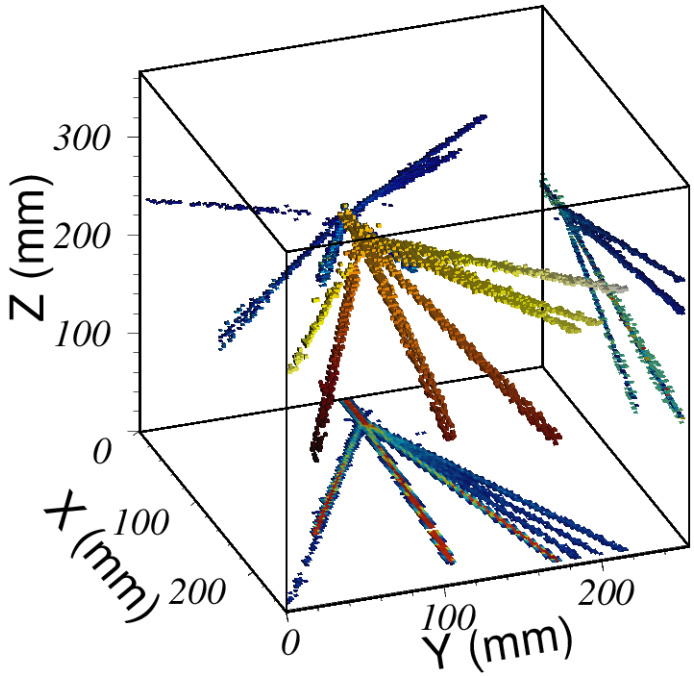
European Research Council
Established by the European Commission

ACTAR TPC : Design

- ✓ Drift region
- ✓ Amplification region
- ✓ Segmented pad plane
- ✓ Electronics
- ✓ Auxiliary detectors

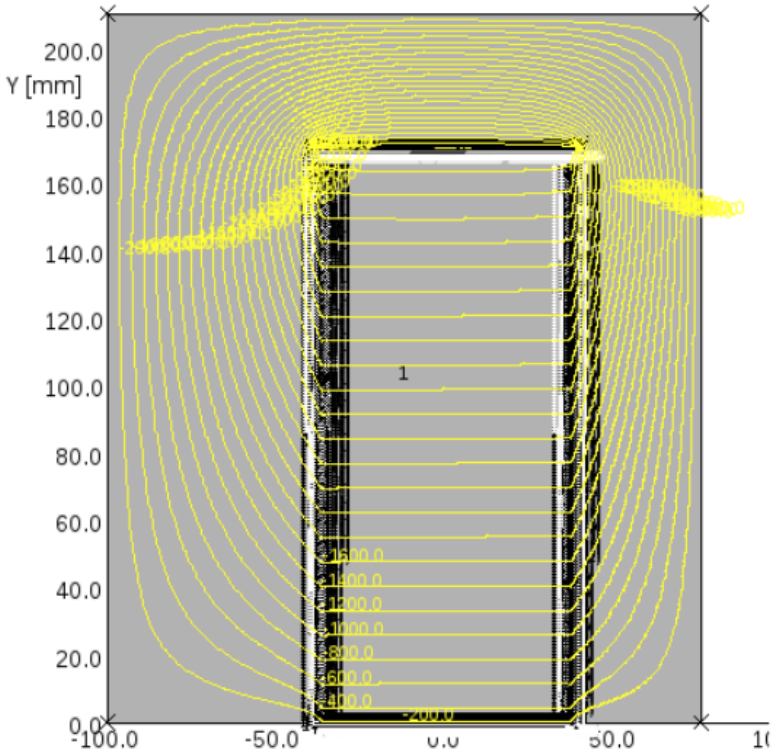


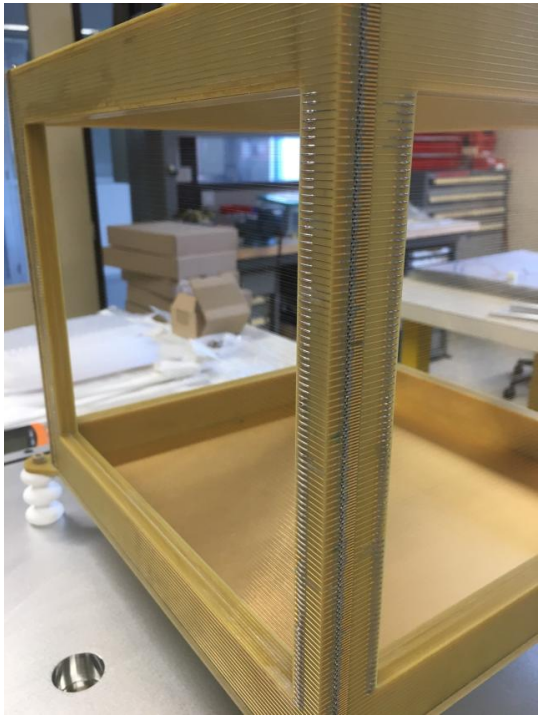




ACTAR TPC : Design

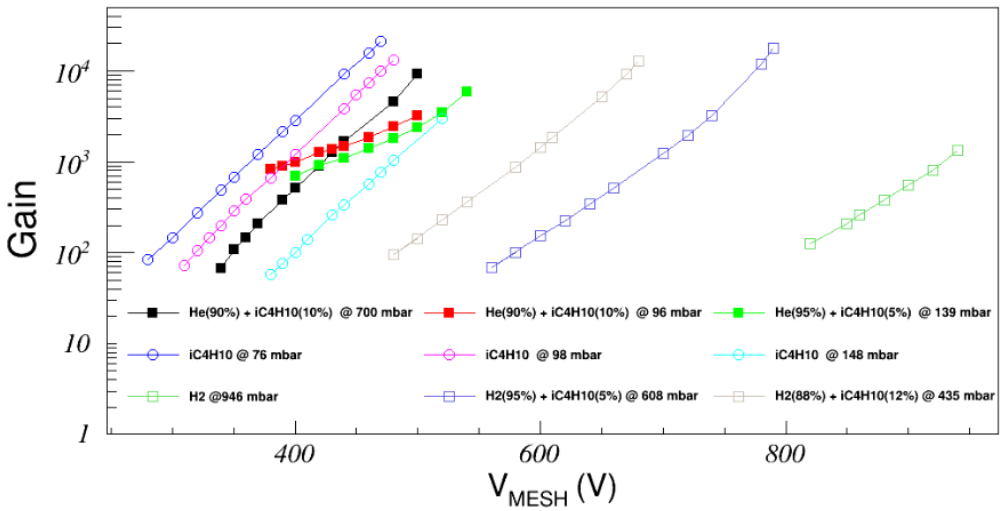
- ✓ Drift region: principle
  - Particles ionize the gas along their trajectories
  - Ionization electrons drift to pad plane under a homogeneous electric field
  - Transparent to particles on 4 sides
    → Wire field cage
  - Homogeneous vertical drift electric field
    → Double wire field cage: 2 mm pitch (outside), 1 mm pitch (inside)
    → Optical transparency = 98 %

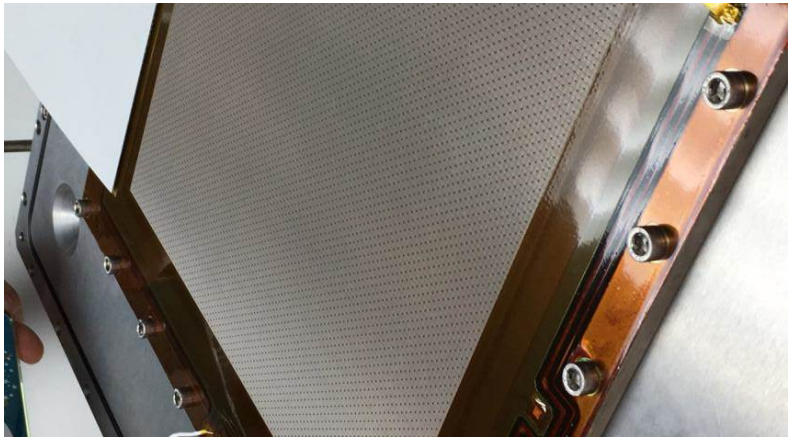


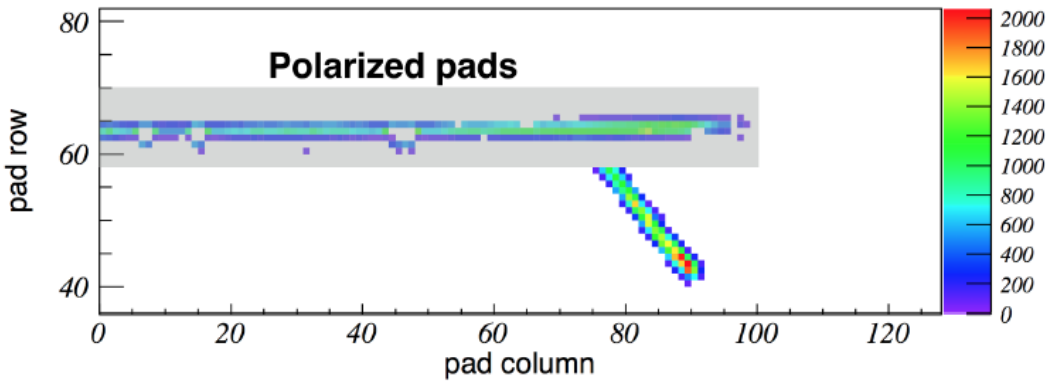


ACTAR TPC : Design

- ✓ Drift region
- ✓ Amplification region: principle
  - Micro Pattern Gaseous Detectors: bulk micromegas (CERN PCB workshop)
  - Operate at P = 75 mbar – 1 bar: gap = 220 µm
  - Local gain reduction via pad polarization

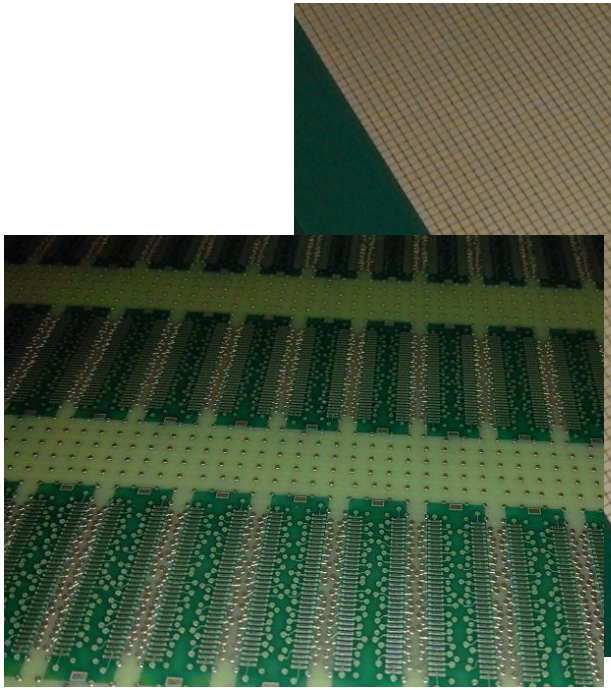




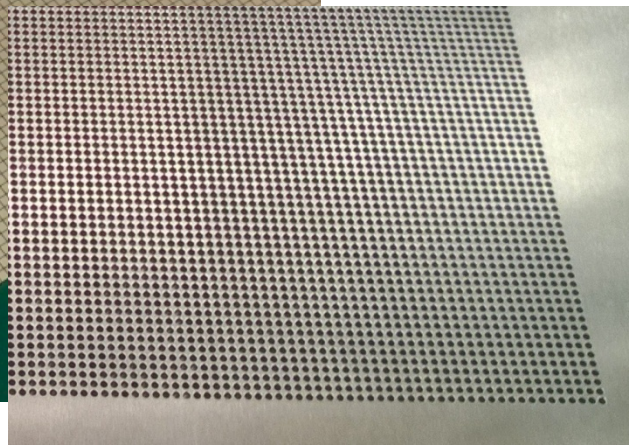


ACTAR TPC : Design

- ✓ Drift region
- ✓ Amplification region: principle
- ✓ Segmented pad plane
  - Micromegas (CERN PCB WS) → transverse multiplicity ≈ electron straggling: 2x2 mm^2 pads
  - 16384 pads with very high density: connectics challenge!



Multi-layer PCB routing solution :
P. Gangnant/M. Blaizot-GANIL
JST Connectors, 0.5 mm pitch



FAKIR solution : J. Pibernat-CENBG

ACTAR TPC : Commissioning

✓Commissioning of the 128x128 pad full detector

^{18}O(p,p) and ^{18}O(p,α) excitation functions: → 3.2*A* MeV ^{18}O beam in 100 mbar iC_4H_{10}

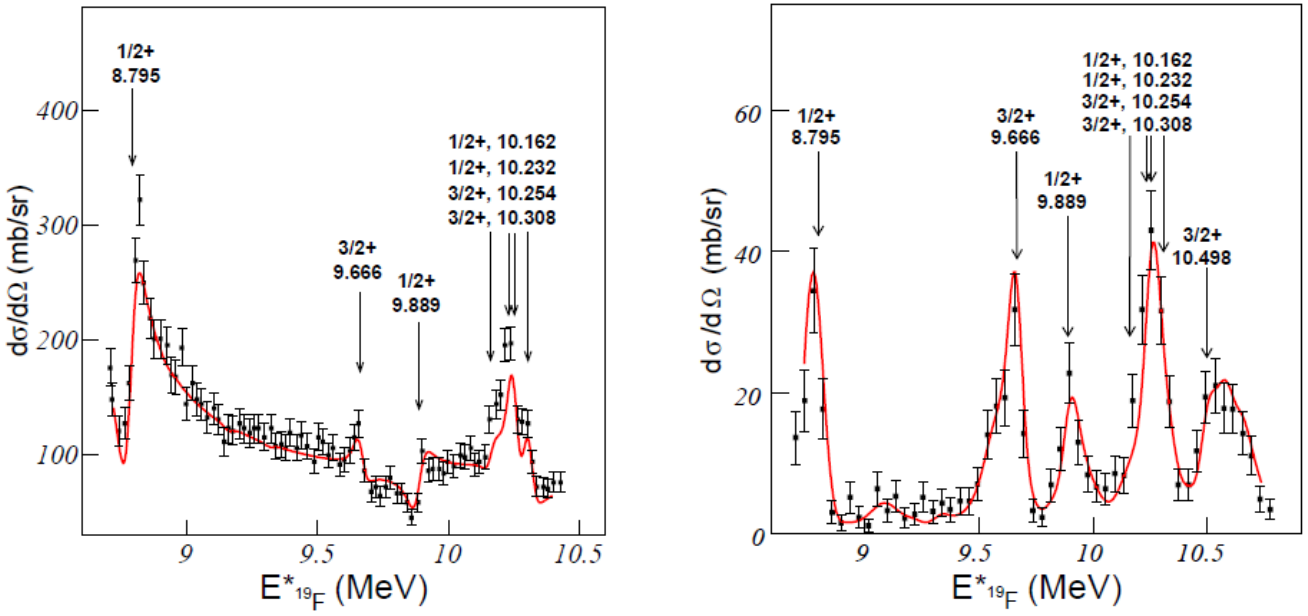


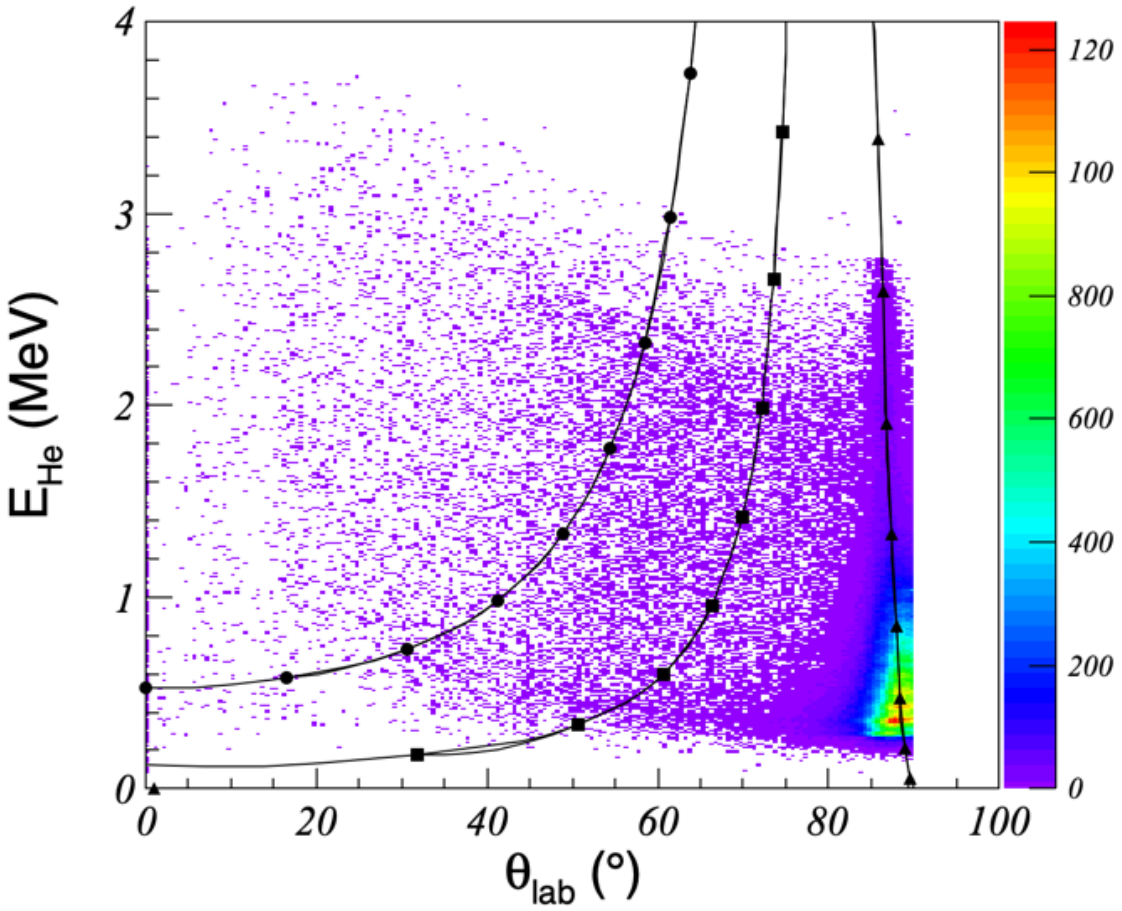
Figure 7: Excitation energy of ^{19}F from the (p,p) channel on the left and from the (p,α) channel on the right projected for $\theta_{cm} = (160 \pm 5)°$. The black dots with statistical uncertainties are the experimental points and the red curve is the result of the R-matrix calculation convoluted with a Gaussian function that was fit the data (see text for details). Resolutions were found to be 38(3) keV FWHM and 54(9) keV FWHM, respectively.

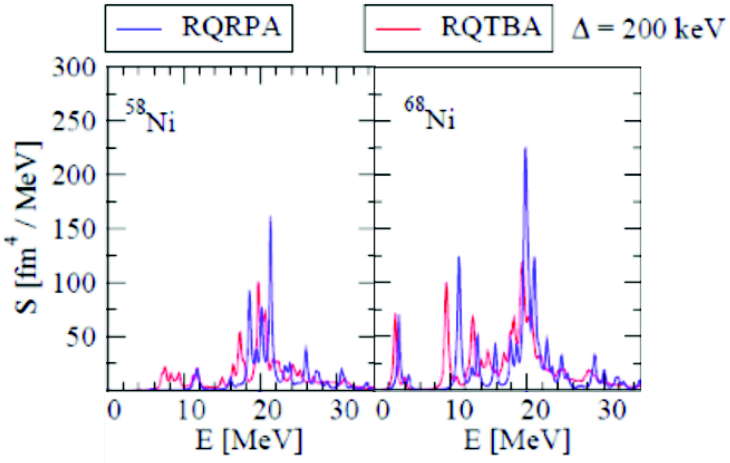
B. Mauss, et al., submitted to NIM A

ACTAR TPC : First experiments

✓ Study of the Giant Monopole Resonance in the Ni chain (April 2019)

^{58,68}Ni(α,α') : → 49*A* MeV ^{58,68}Ni beams in 400 mbar He(98%) + CF_4(2%)





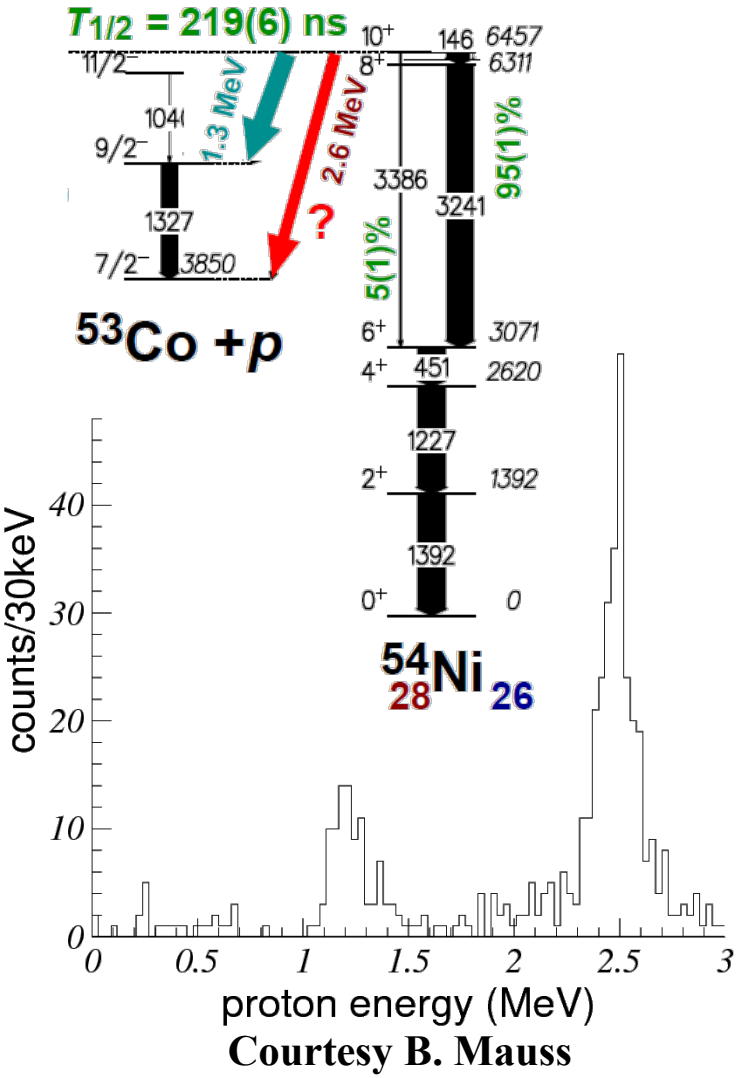
- ✓ **Helium gas**
- ✓ **50 kHz beam**
- ✓ **Observation of 200 keV α**

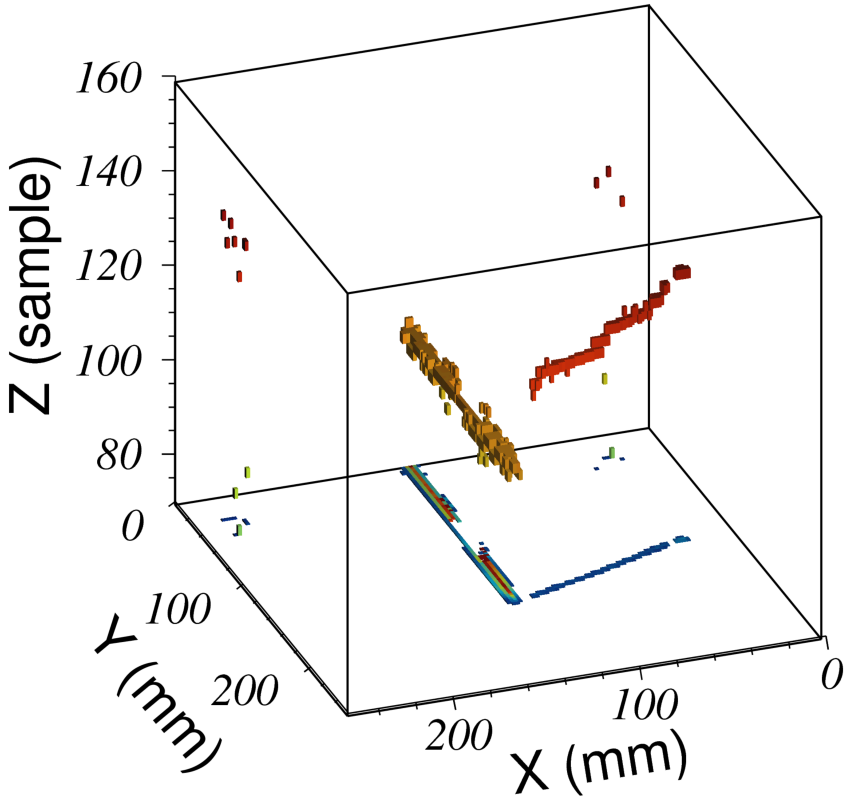
Courtesy B. Mauss & M. Vandebrouck

ACTAR TPC : First experiments

✓ Proton-decay branches from the 10^+ isomer in ^{54}Ni (May 2019)

^{54}Ni implantation – proton decay: → 10*A* MeV ^{54}Ni beam in 900 mbar Ar(95%) + CF_4(5%)





- ✓ **Implantation of fragmentation beam**
- ✓ **Simultaneous observation of Ni track (6 MeV/pad) and proton tracks (60 keV/pad)**