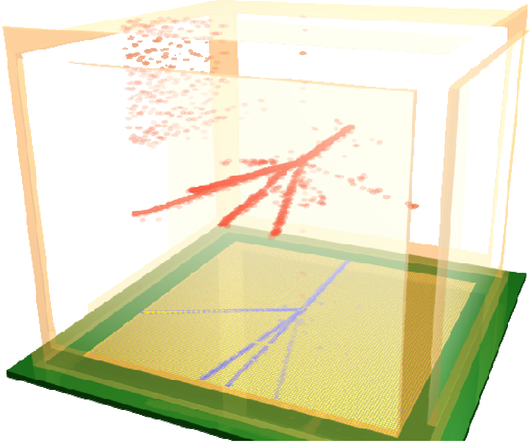
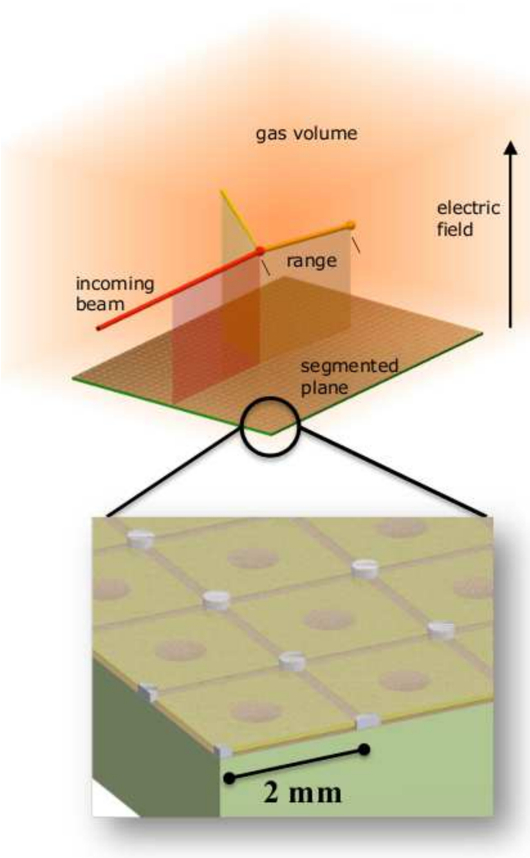
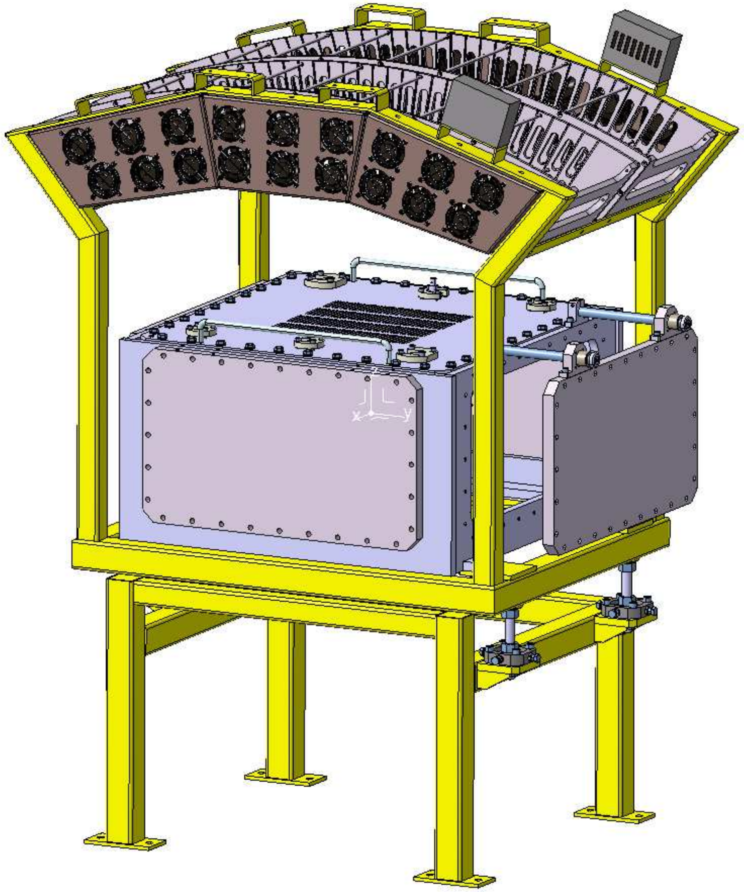
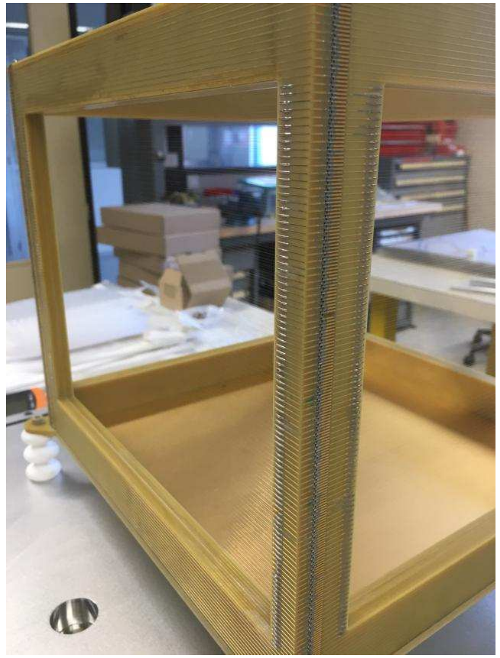
laboratoire commun CEA/DRF CNRS/IN2P3

ACTAR TPC



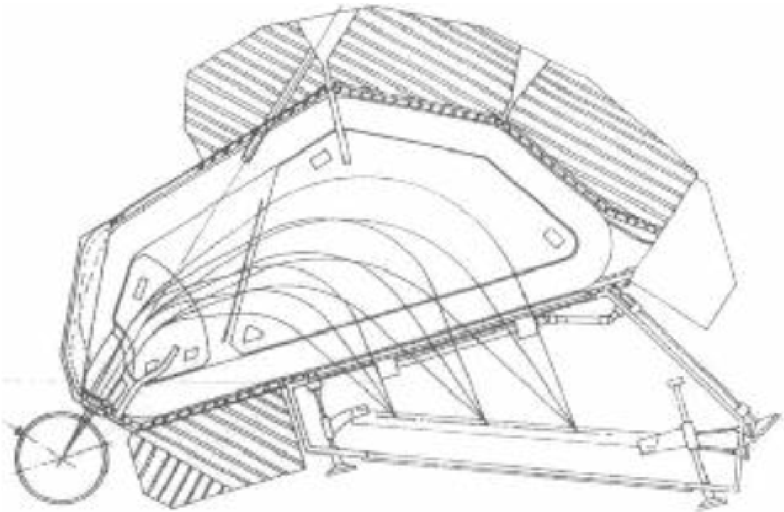


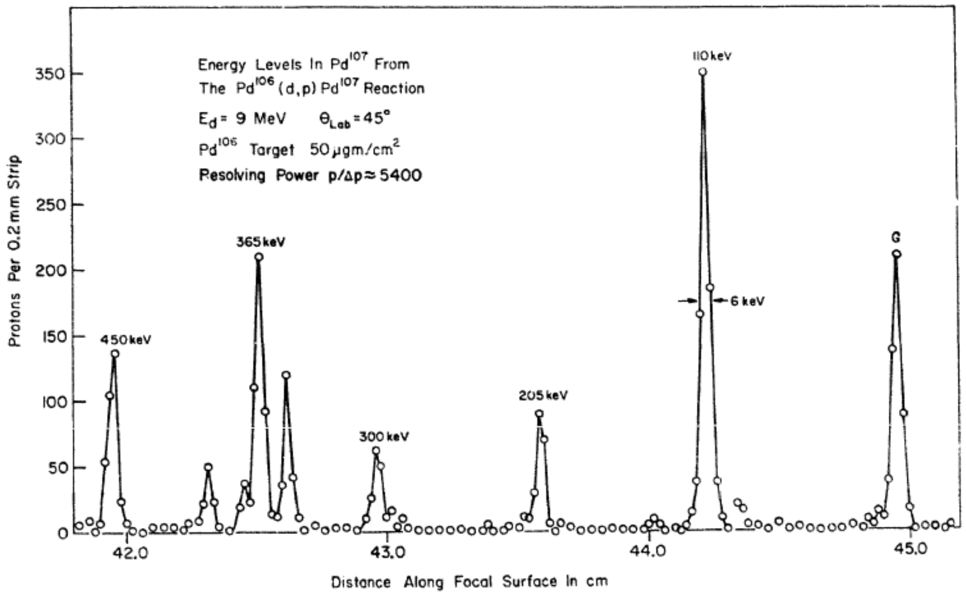




Past: structure of nuclei close to stability in direct kinematics, use of magnetic spectrograph

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

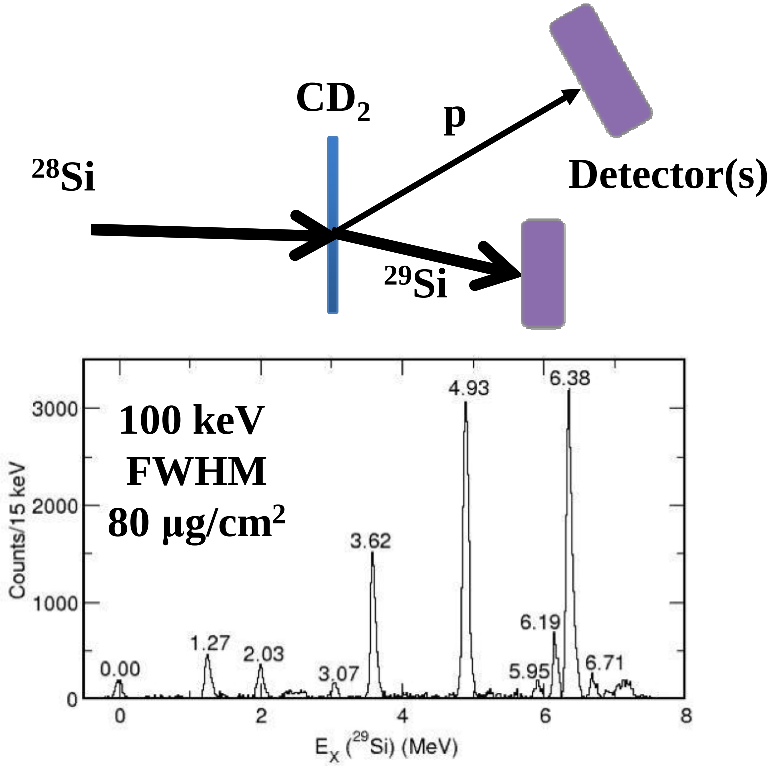




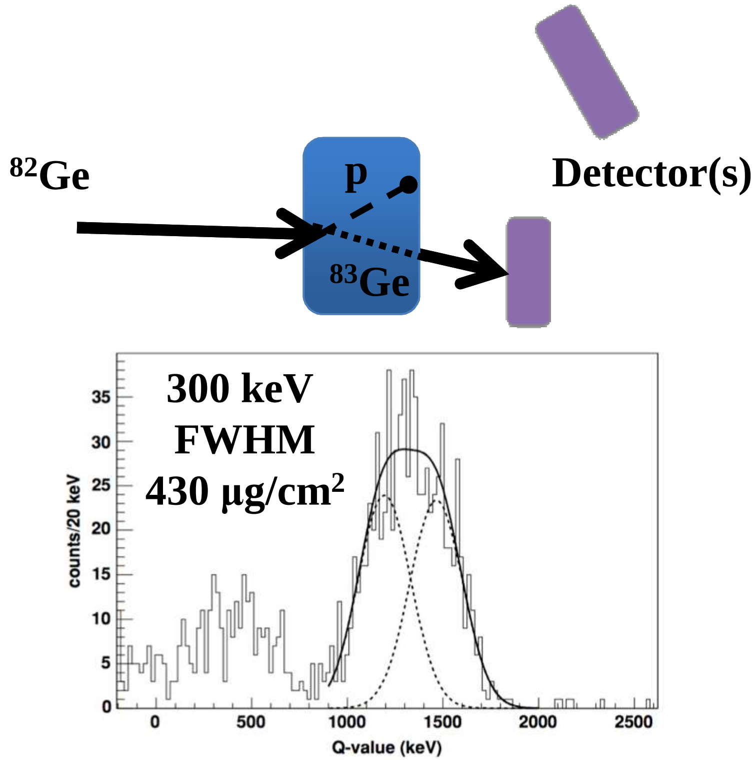
J.E. Spencer and H.A. Enge, NIM ***49,*** *181 (1967)*

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)*

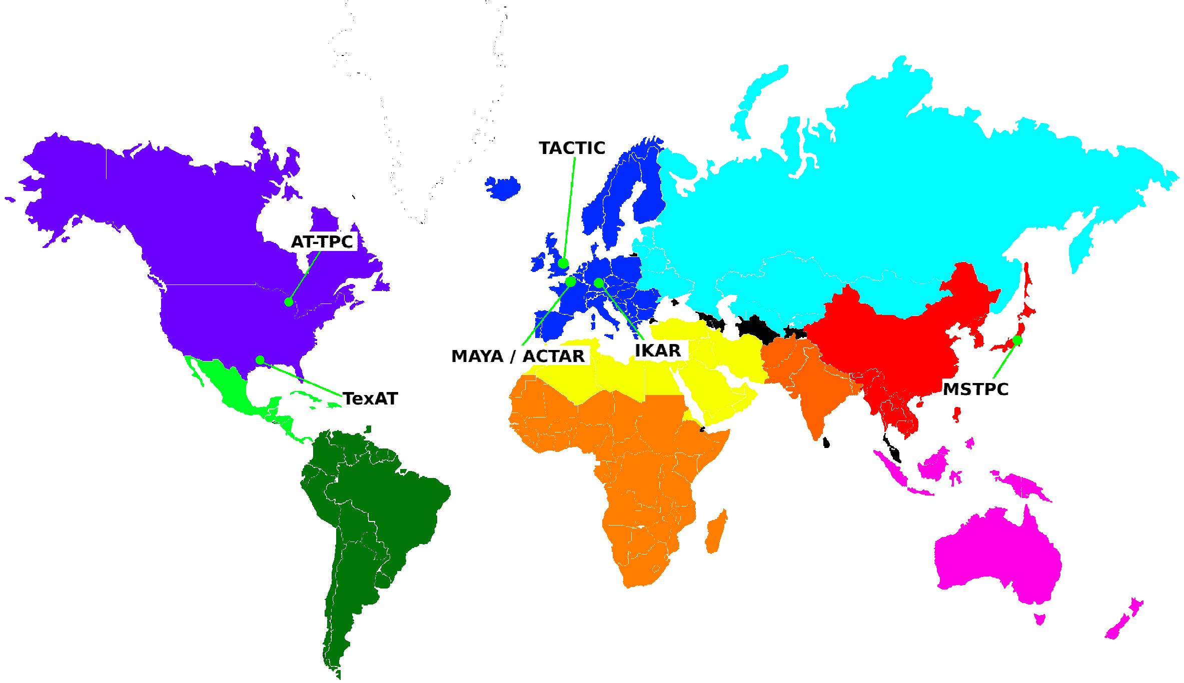
Need thick targets *and* excellent resolution

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

➔ 1st difficulty: the choice of the gas is driven by the physics, not by its properties!



- ✓ 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, …

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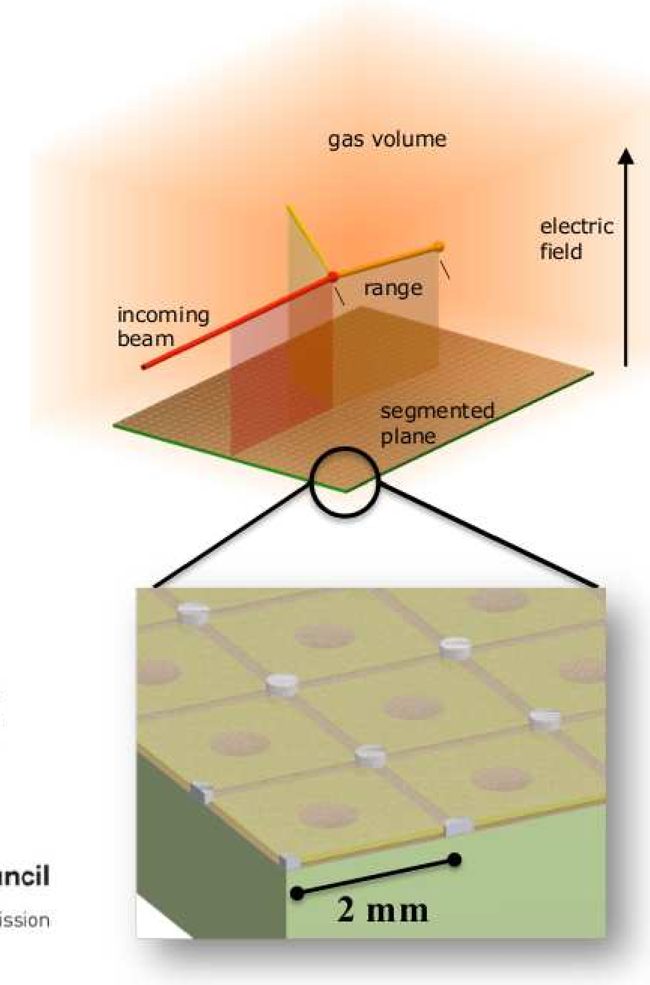


➔ 2nd difficulty: LARGE variety of experiments, involving "high energy" light particles and "low energy" heavy ions: LARGE detection dynamics required!

ACTAR TPC : Design

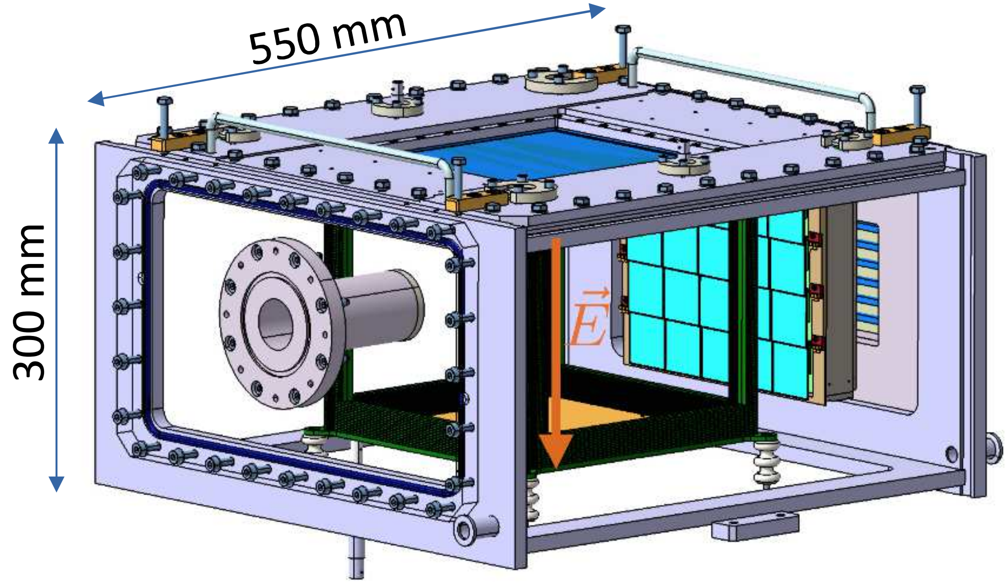
✓ Drift region: principle

- Transparent to particles on 4 sides

→ Wire field cage

- Homogeneous vertical drift electric field

→ Double wire field cage: 2 mm/1 mm pitch



✓ Amplification region: principle

- Bulk Micromegas (CERN PCB workshop)
- Local gain reduction via pad polarization

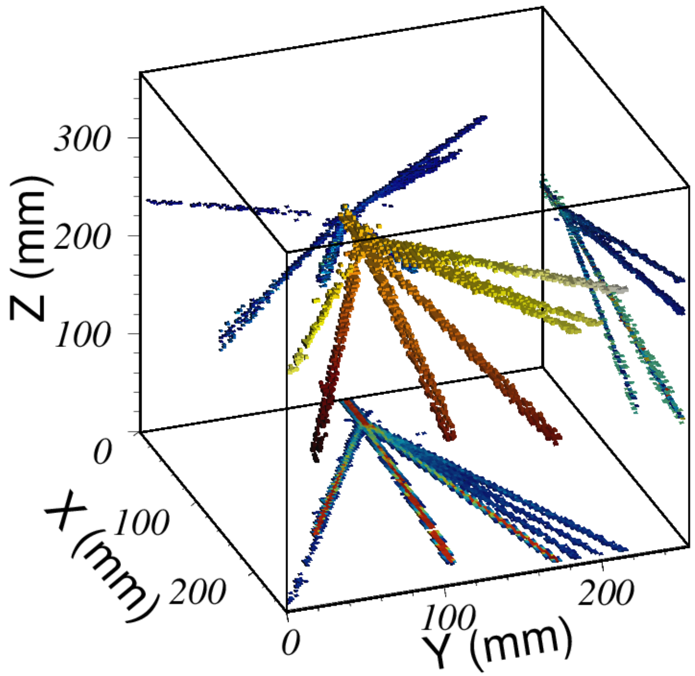
✓ Segmented pad plane

- Micromegas

→ transverse multiplicity ≈ electron straggling: 2x2 mm^2 pads

- 16384 pads with very high density: challenge!

→ Two solutions investigated



✓ Electronics: GET

GET electronics:

- 512 samples ADC readout depth x 16384 pads

→ volume sampling in 8 Mega voxel

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

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}

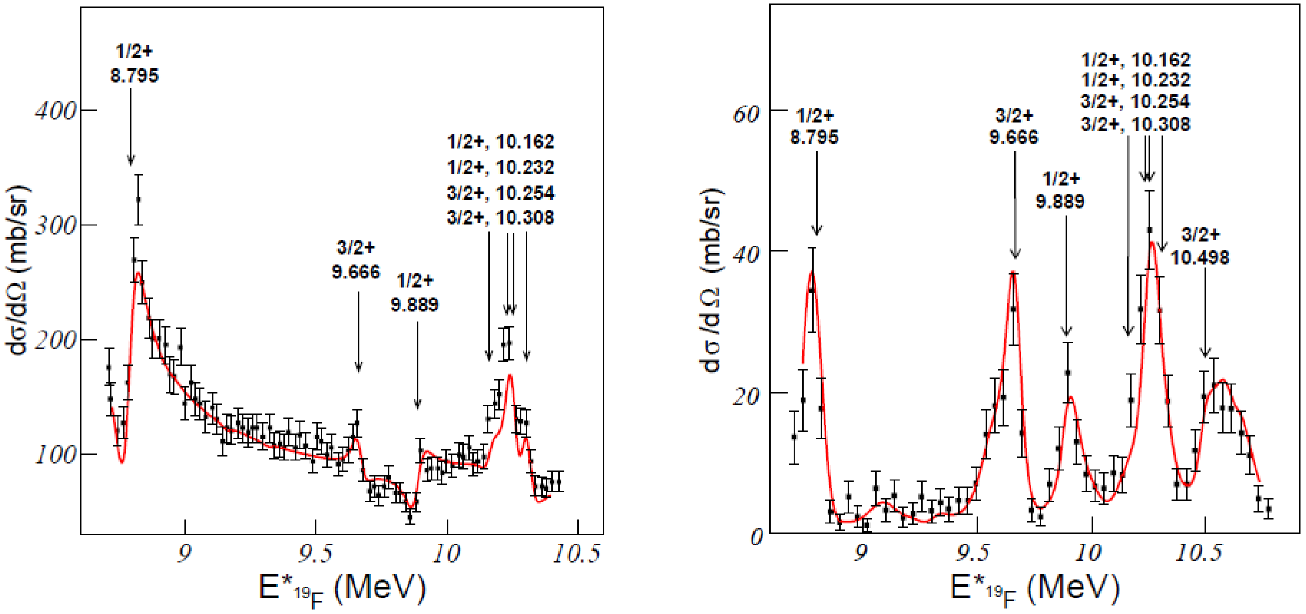
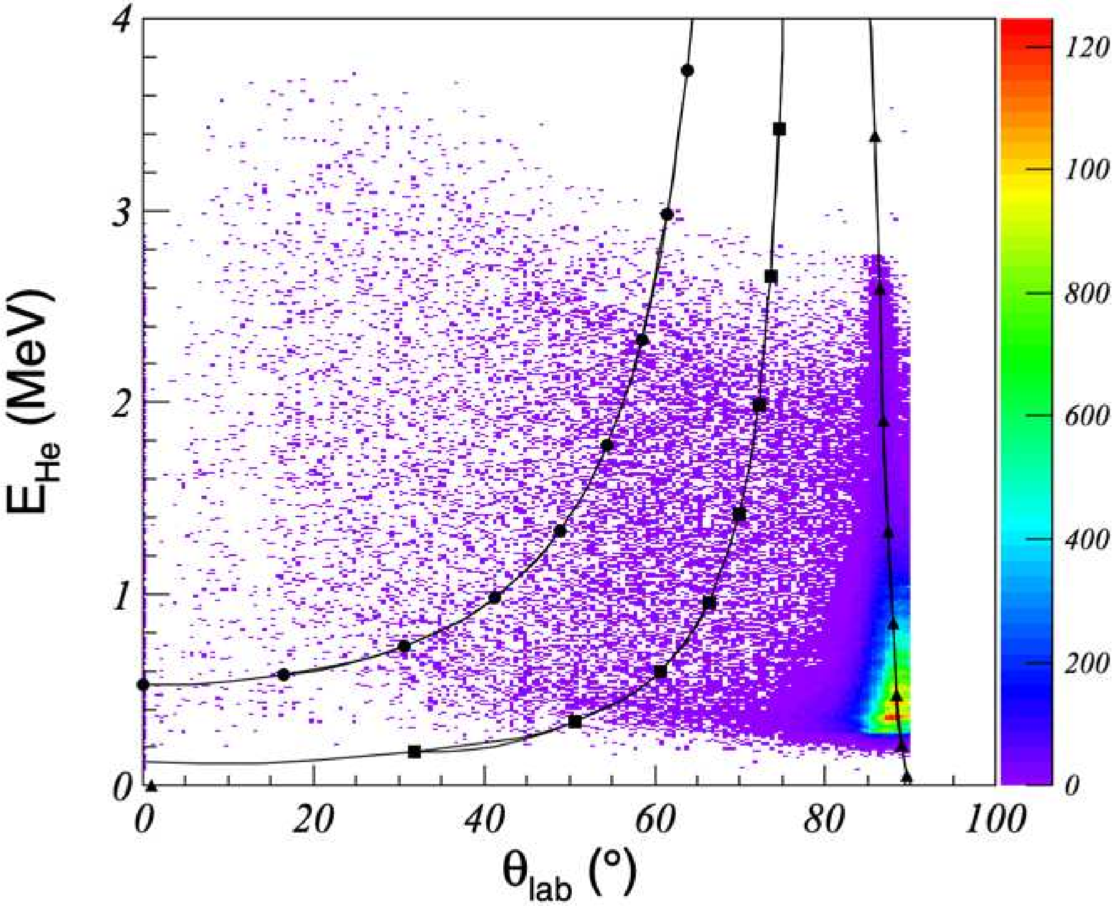


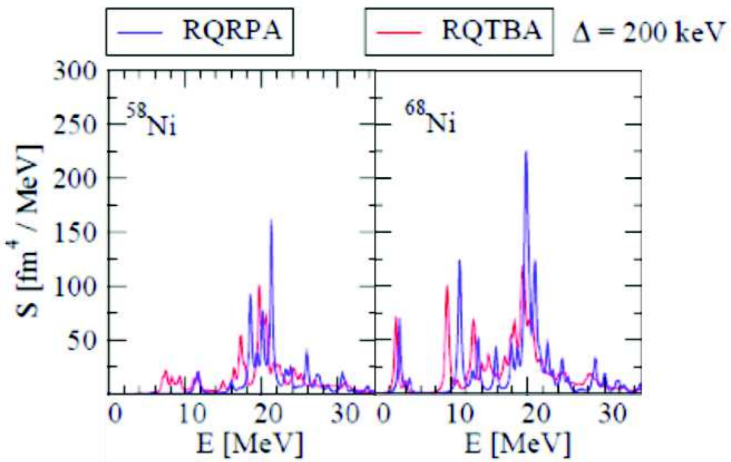
Figure 7: Excitation energy of ^{19}F from the (p,p) channel on the left and from the (p,α) channel on the right projected for $\theta_{cm} = (160 \pm 5)^{\circ}$. The black dots with statistical uncertainties are the experimental points and the red curve is the result of the R-matrix calculation convoluted 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%)





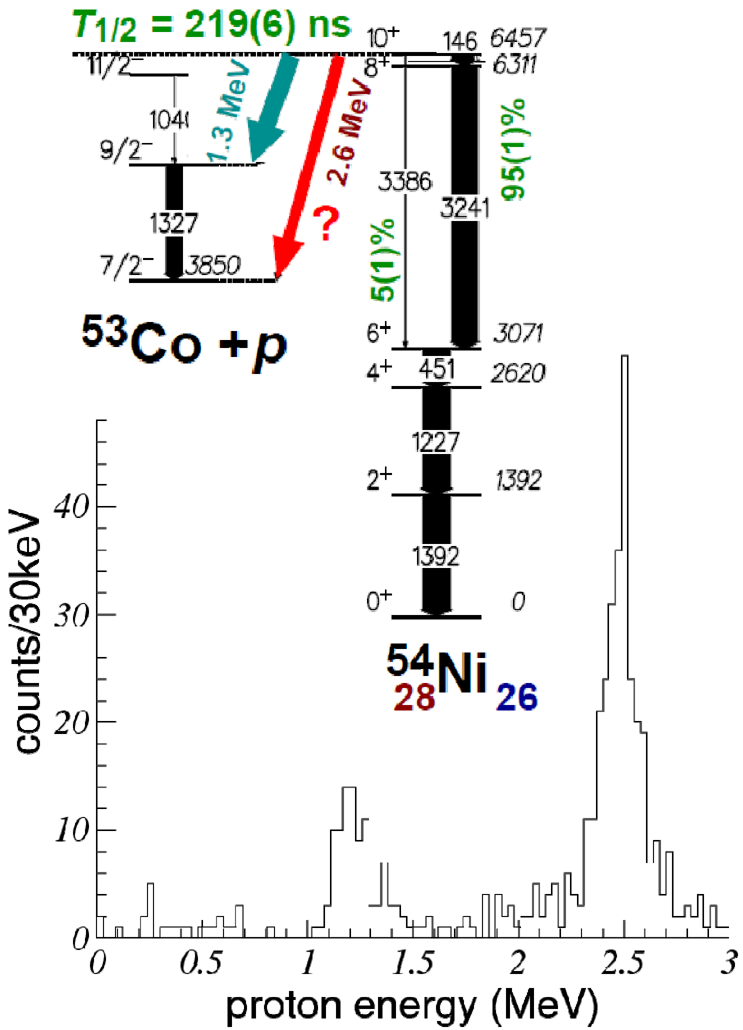
Courtesy B. Mauss & M. Vandebrouck

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

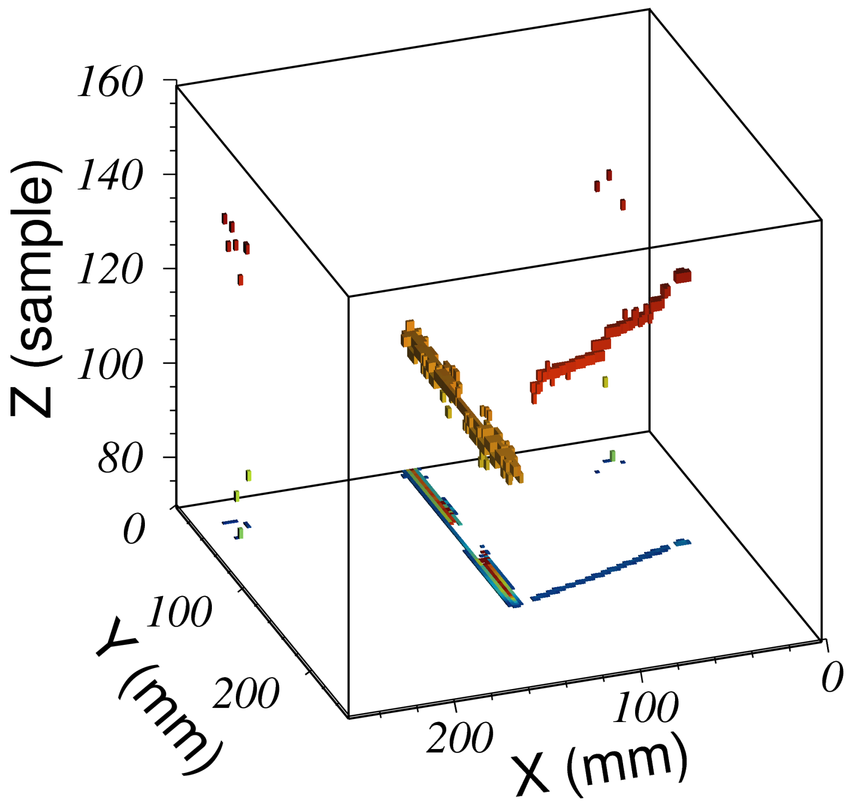
ACTAR TPC : First experiments

✓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%)



Courtesy B. Mauss



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

ACTAR TPC : Prospectives

✓ 100% working pad plane: 1st deliverable (2020)

✓ Mask for high intensity / heavy beams

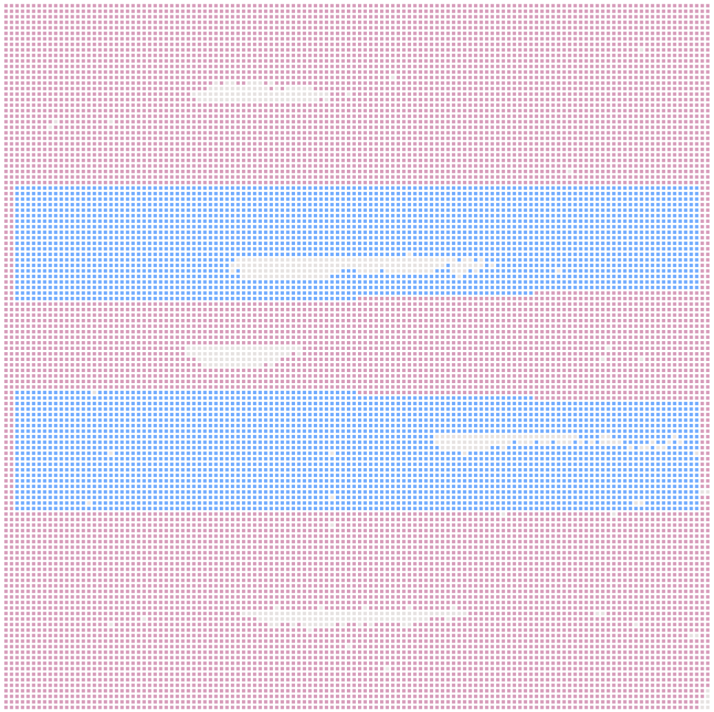
✓ Amplification system for pure gases

✓ Recirculation system for rare gases

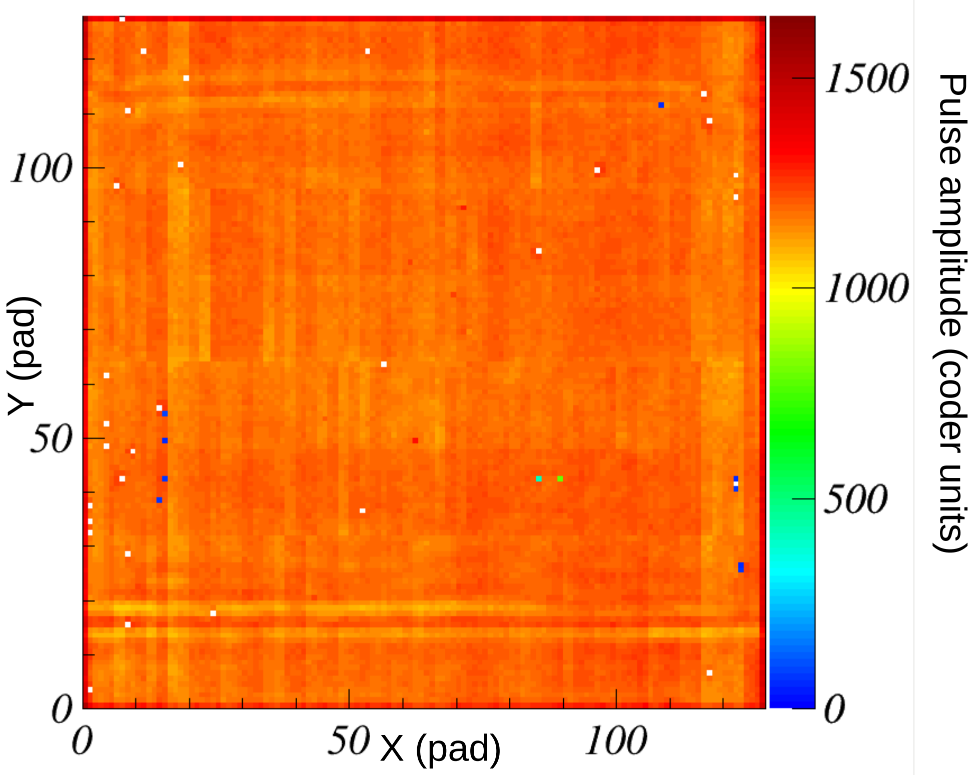
ACTAR TPC : Prospectives

✓ 100% working pad plane: 1st deliverable (2020)

2019 version: about 400 pads grounded



2020 version: >99.9% functional pads

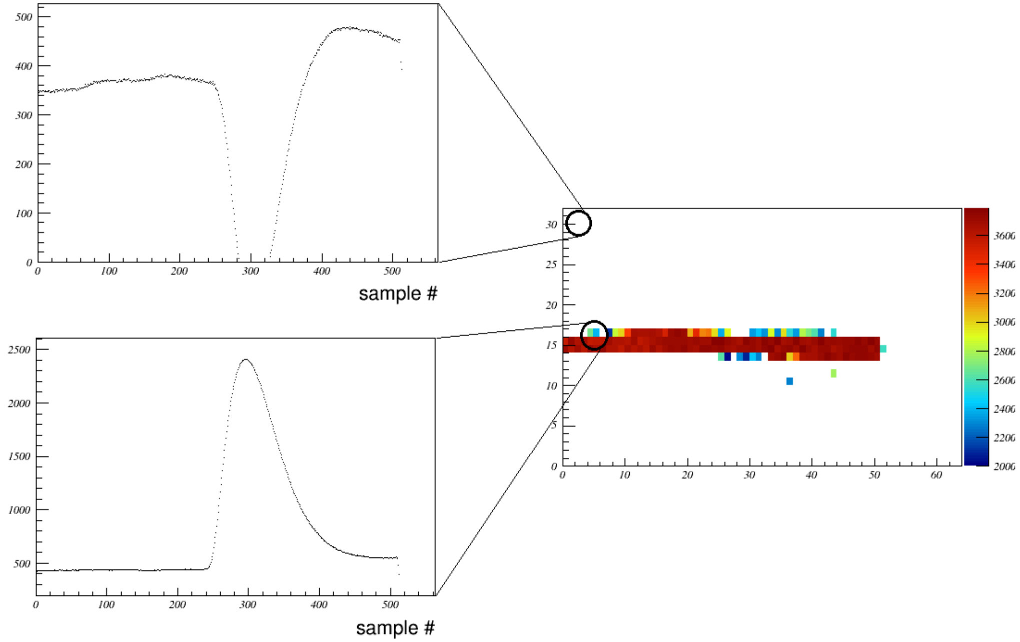


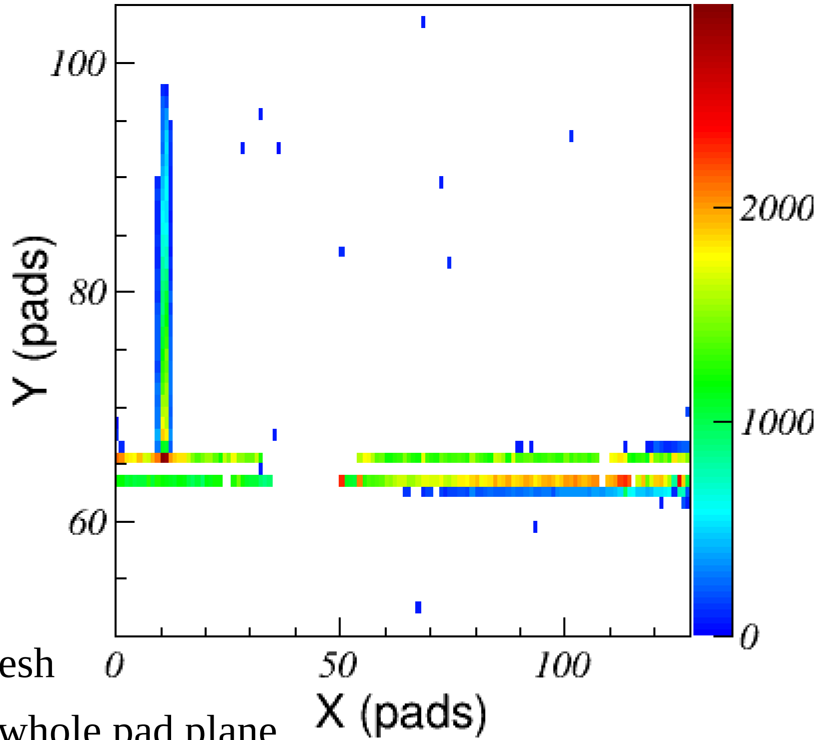
ACTAR TPC : Prospectives

✓ Mask for high intensity / heavy beams

✓ The GET preamp has a decay time constant of ~ 50 µs
→ No way to recover the preamp saturation: simply loose the signal

✓ The use of micromegas creates capacitive coupling problems
→ Possibility to correct at low rate
→ induces (important) noise at high rate, kills the small signals if the energy deposit is too important





→ Strong energy deposit or high gain ⇔ current peak on the mesh
⇔ signal induced on the whole pad plane

ACTAR TPC : Prospectives

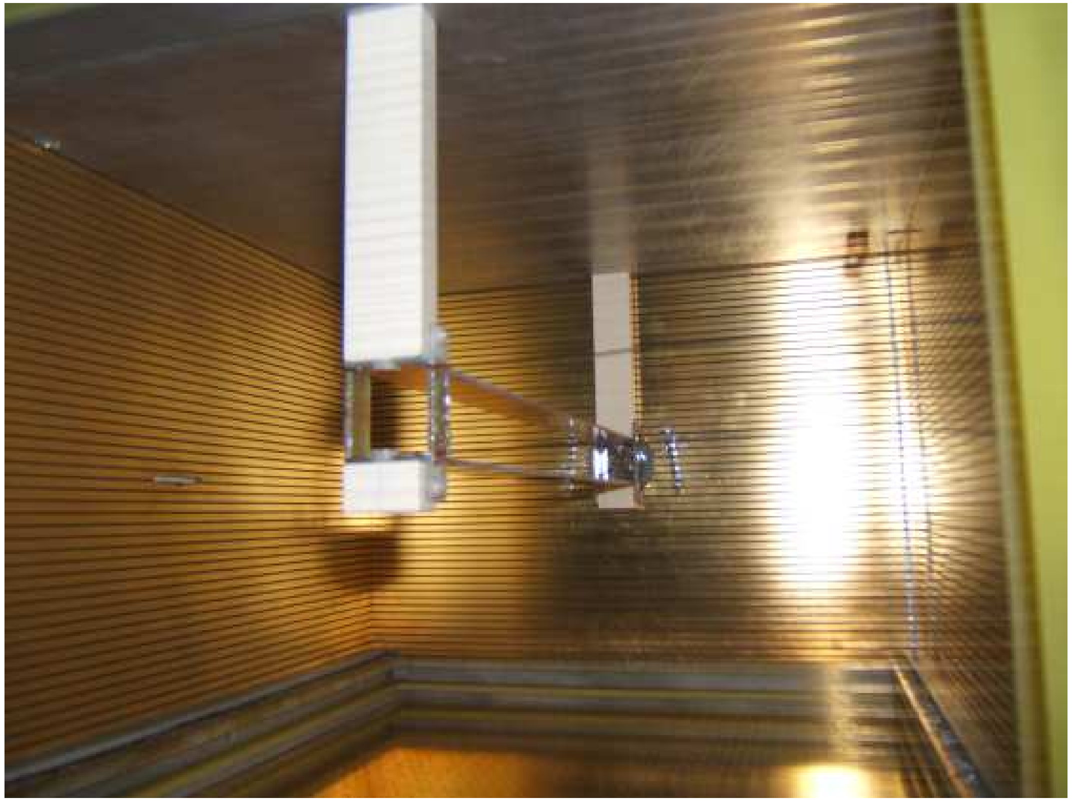
✓ Mask for high intensity / heavy beams

➔ Electrostatic mask for field screening

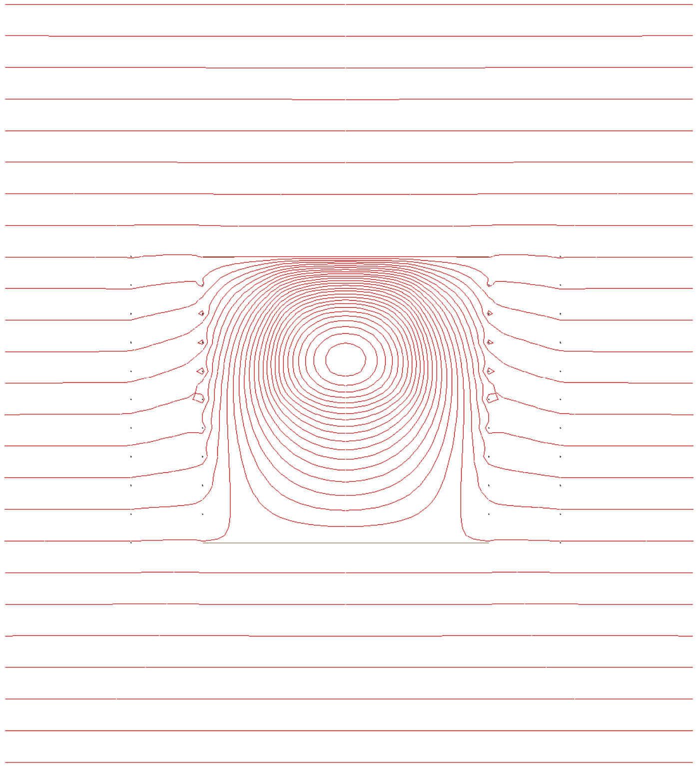
mask with double wire planes

space charge density 140 pC/cm3

→ Equivalent: 10^6 Hz of ^{136}Xe @ 7A MeV in 100 mbar iC_4H_{10}



C. Rodriguez et al., NIM A**768**, 179 (2014)

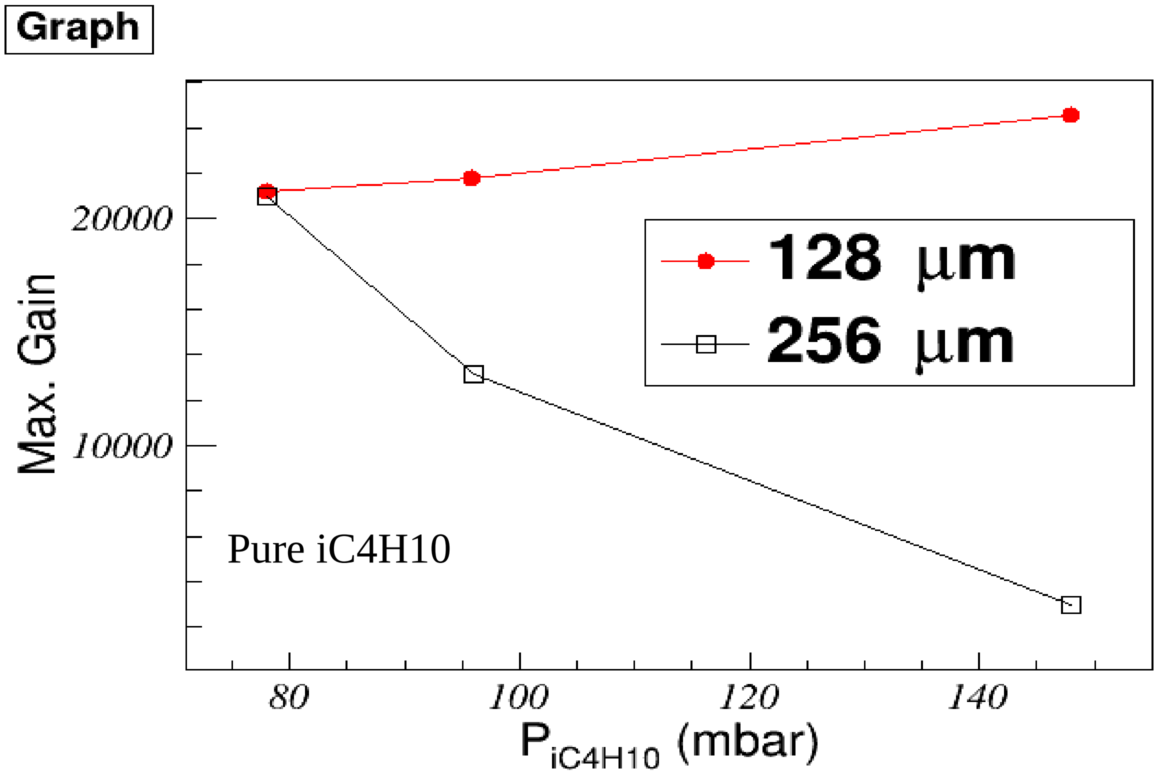


Simulations: R. Revenko (GANIL)

ACTAR TPC : Prospectives

✓ Amplification system for pure gases

✓ The micromegas gap can be adapted to “low pressure” in the TPC, e.g. down to few tenth of mbar of isobutane.



✓ 220 µm gap suited for low-pressure isobutane
✓ 128 µm gap needed for P>150 mbar

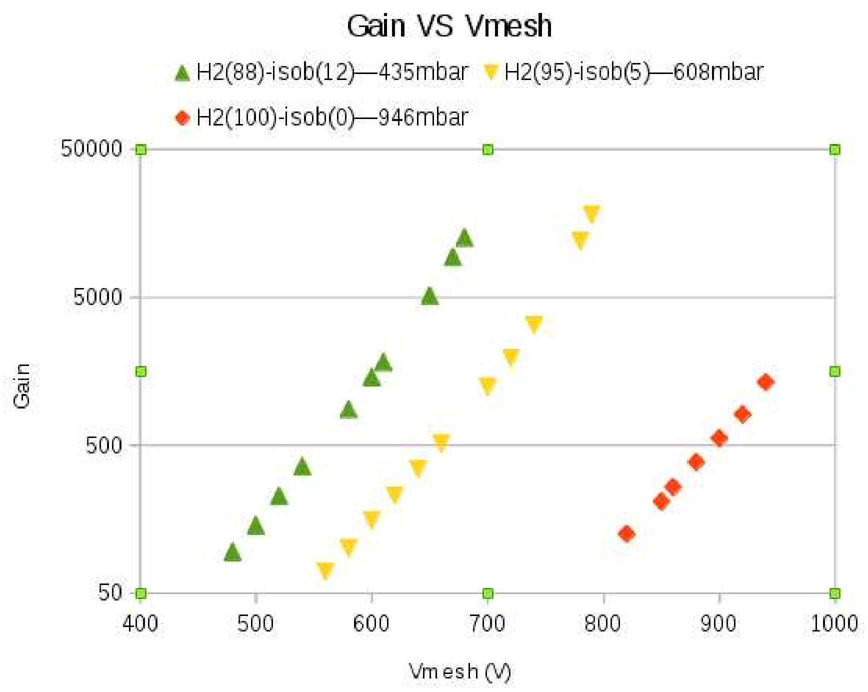
ACTAR TPC : Prospectives

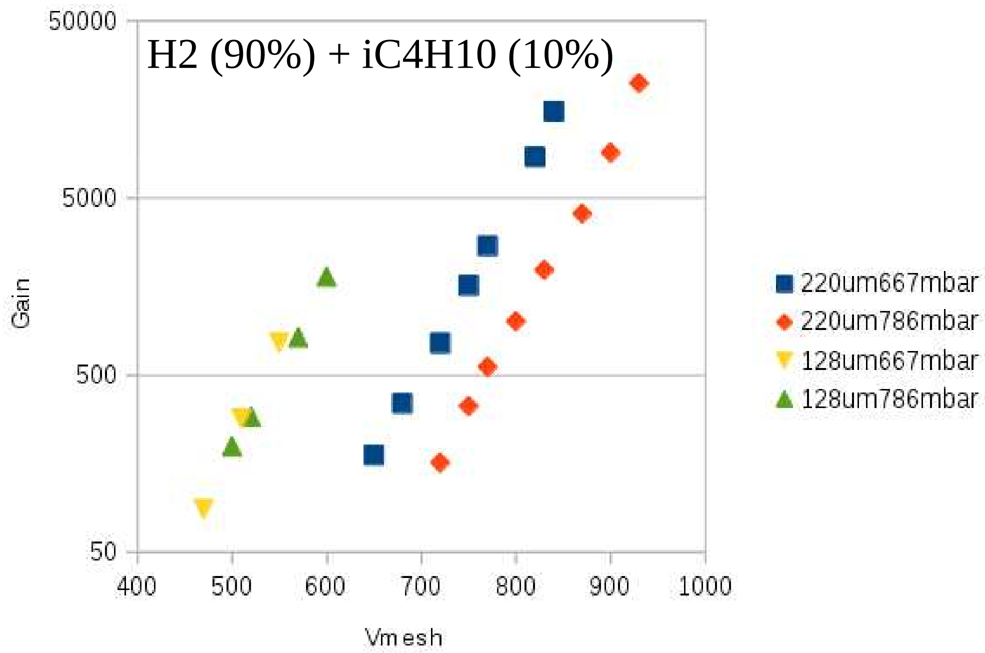
✓ Amplification system for pure gases

✓ The micromegas gap can be adapted to "low pressure" in the TPC, e.g. down to few tenth of mbar of isobutane.

✓ However, the gain with pure monoatomic or diatomic gases remains too small

→ Need to quench the gas:





✓ 220 μm gap better suited for "high"-pressure gas mixes

ACTAR TPC : Prospectives

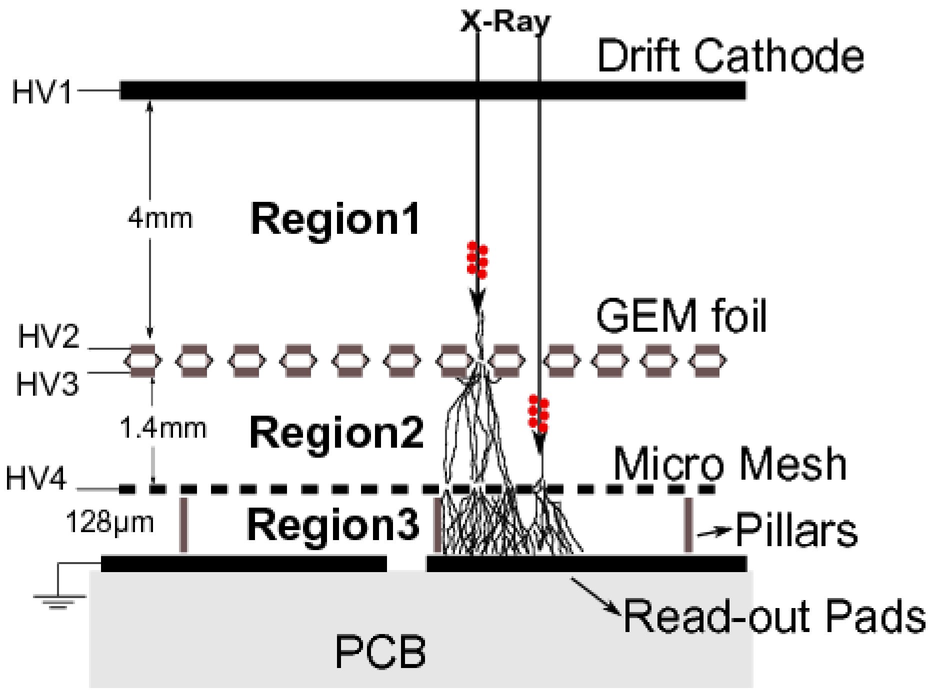
✓ Amplification system for pure gases

✓ The micromegas gap can be adapted to "low pressure" in the TPC, e.g. down to few tenth of mbar of isobutane.

✓ However, the gain with pure monoatomic or diatomic gases remains too small

→ Need to quench the gas

→ OR use a hybrid amplification system, e.g. micromegas + GEM



Yu-Lian Zhang, Chin. Phys. C38, 046001 (2014)

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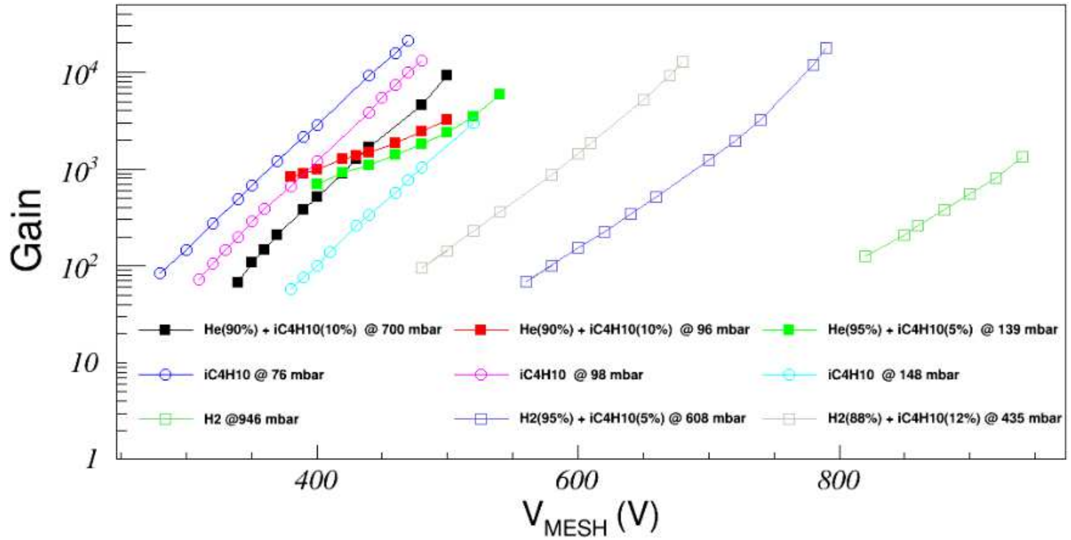
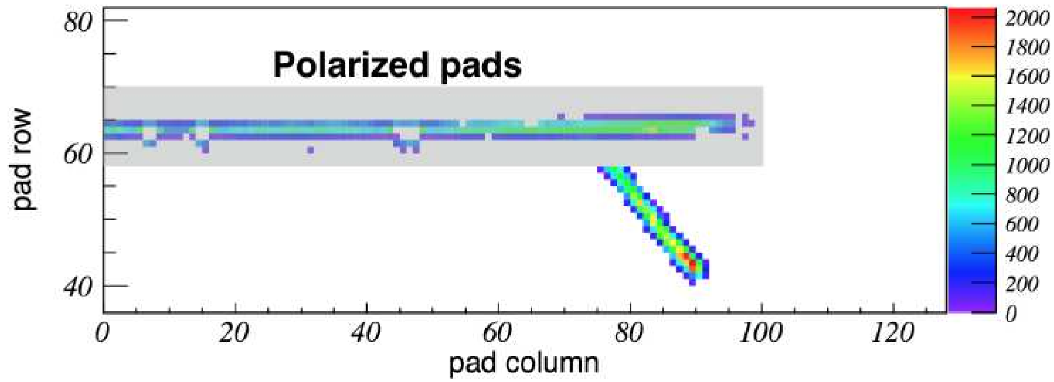
The research leading to these results have received funding from the European Research Council under the European Union's Seventh Framework Program (FP7/2007-2013)/ERC grant agreement n° 335593.

ACTAR TPC : Design

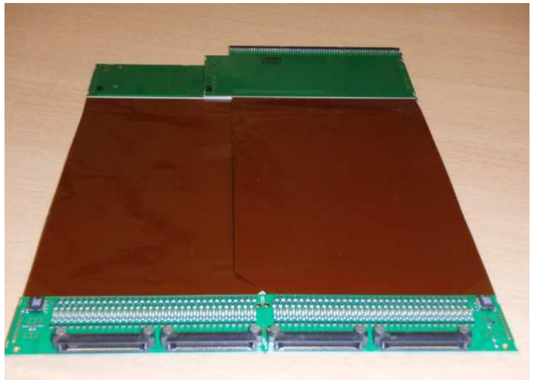
- ✓ Drift region
- ✓ Amplification region: principle
  - Micro Pattern Gaseous Detectors: bulk micromegas (CERN PCB workshop)
  - Operate at P = 75 mbar – 1 bar: gap = 220 µm
  - Local gain reduction via pad polarization

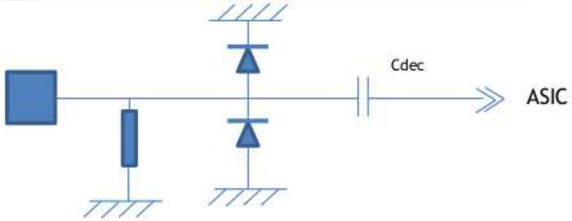


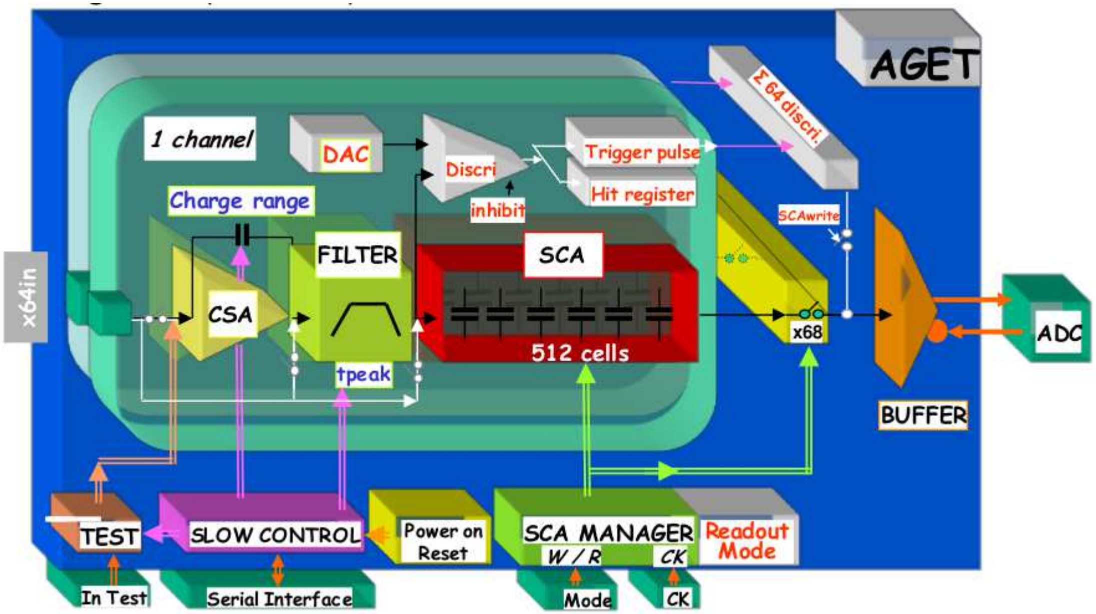


ACTAR TPC : Design

- ✓ Drift region
- ✓ Amplification region: principle
- ✓ Segmented pad plane
- ✓ 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)

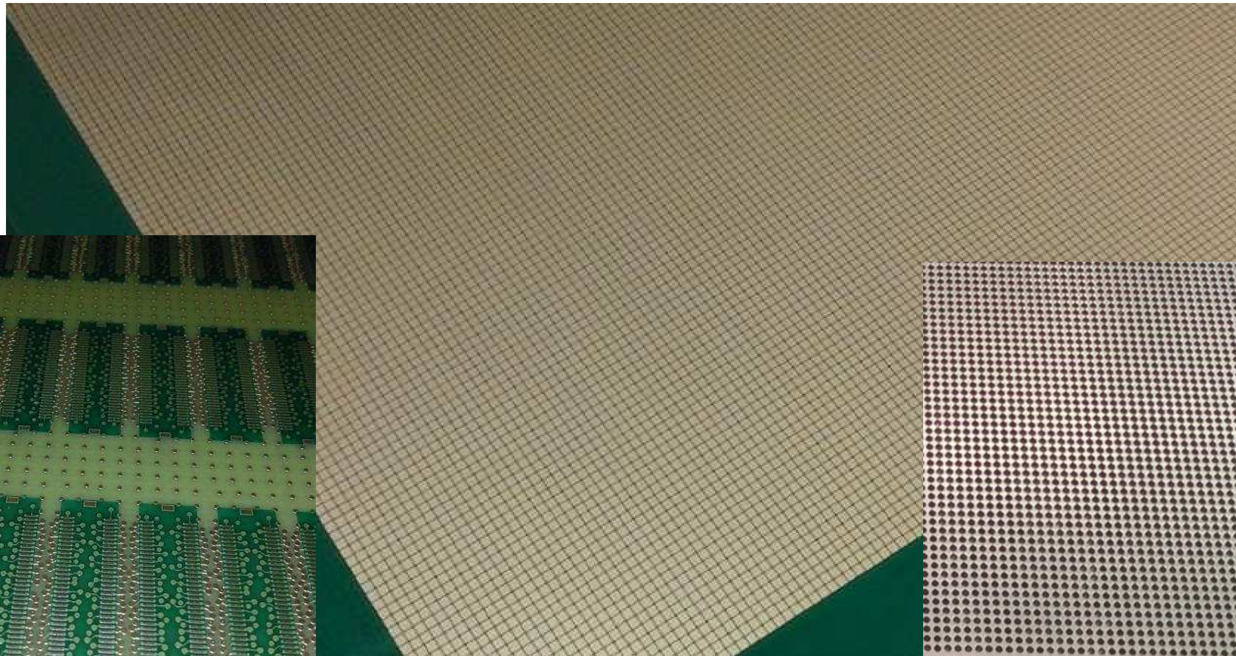
ACTAR TPC : Design

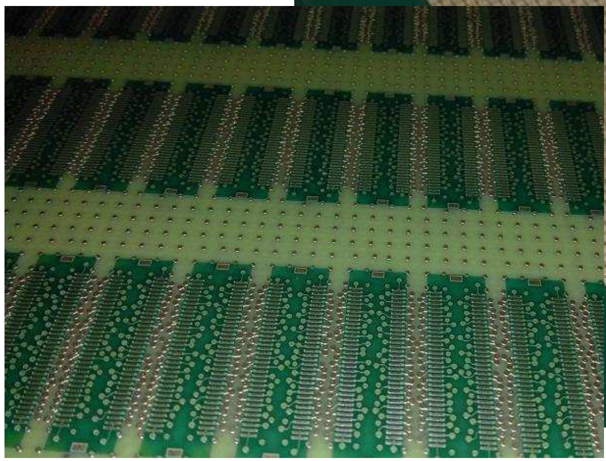
✓ Drift region

✓ Amplification region: principle

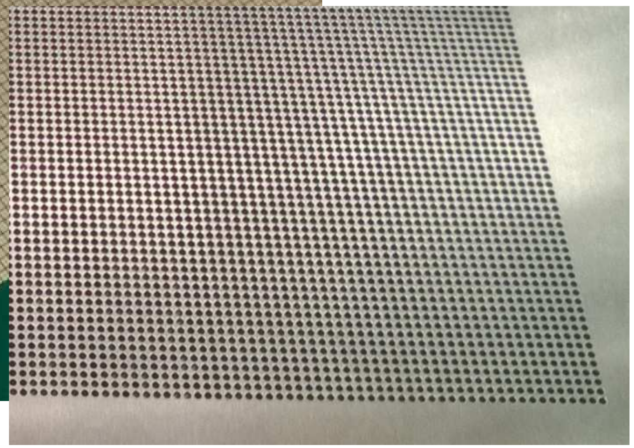
✓ Segmented pad plane

- Micromegas (CERN PCB WS) → transverse multiplicity ≈ electron straggling: 2x2 mm^2 pads
- 16384 pads with very high density: connectics challenge!





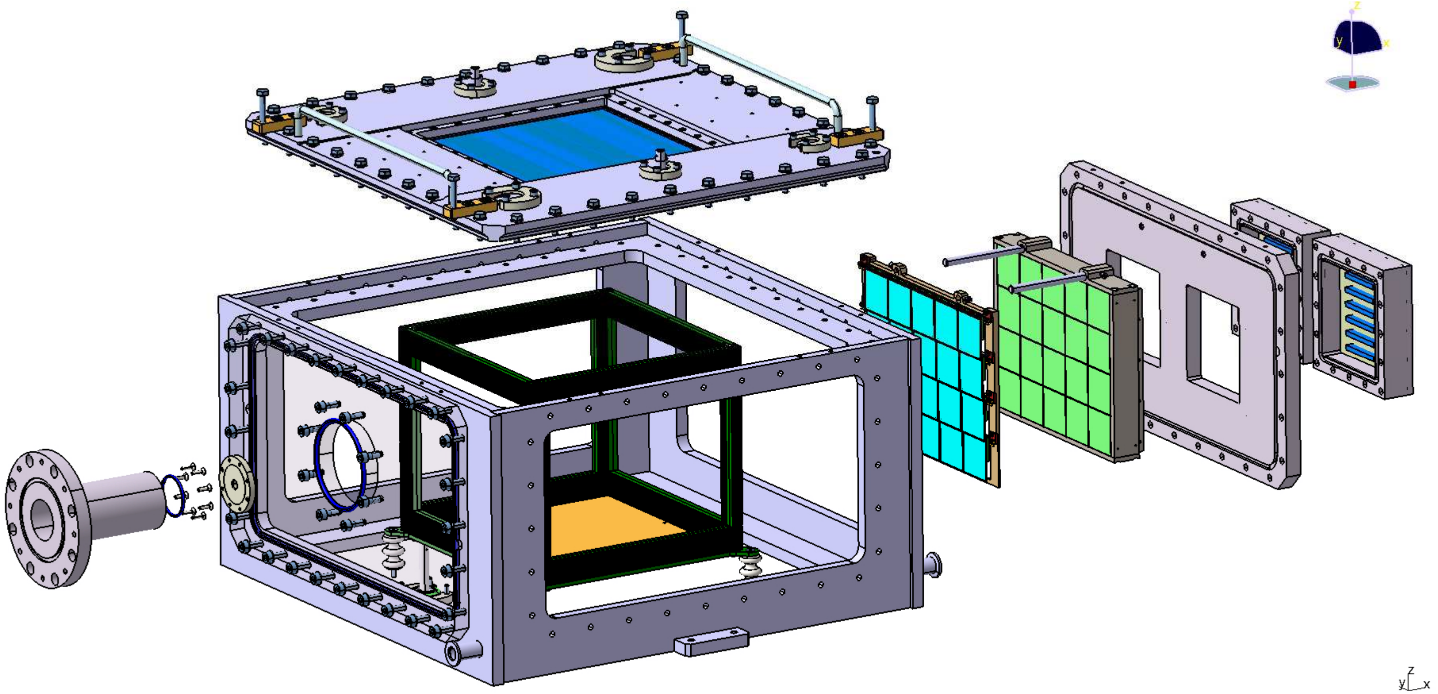
Multi-layer PCB routing solution :
P. Gangnant/M. Blaizot-GANIL
JST Connectors, 0.5 mm pitch



FAKIR solution : J. Pibernat-CENBG

ACTAR TPC : Design

- ✓ Drift region
- ✓ Amplification region: principle
- ✓ Segmented pad plane
- ✓ Electronics
- ✓ Auxiliary detectors
  - Already equipped with Si/CsI telescopes on 1 side
  - Configurable flange design: can be adapted to many other detectors



ACTAR TPC : Design