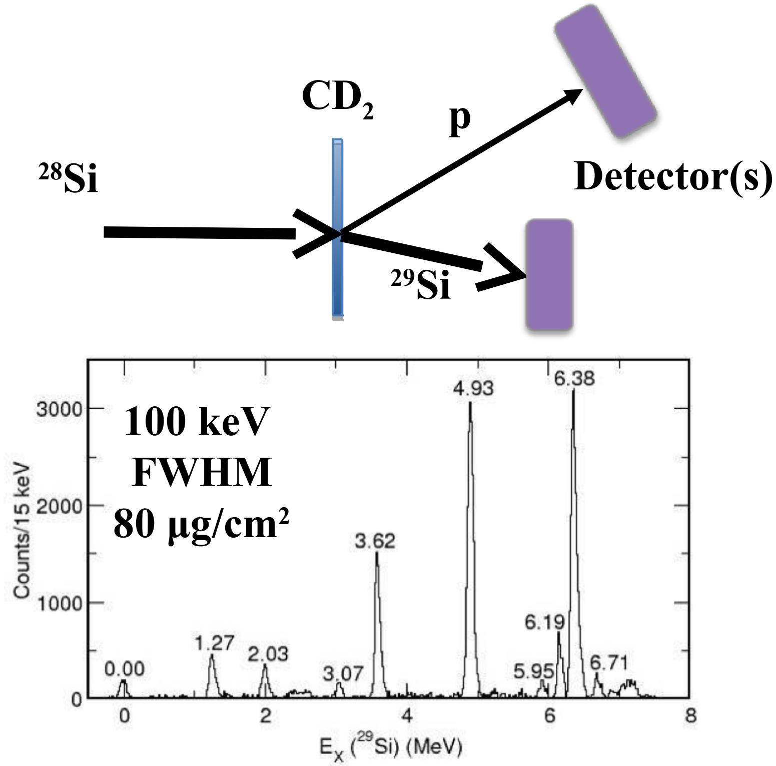
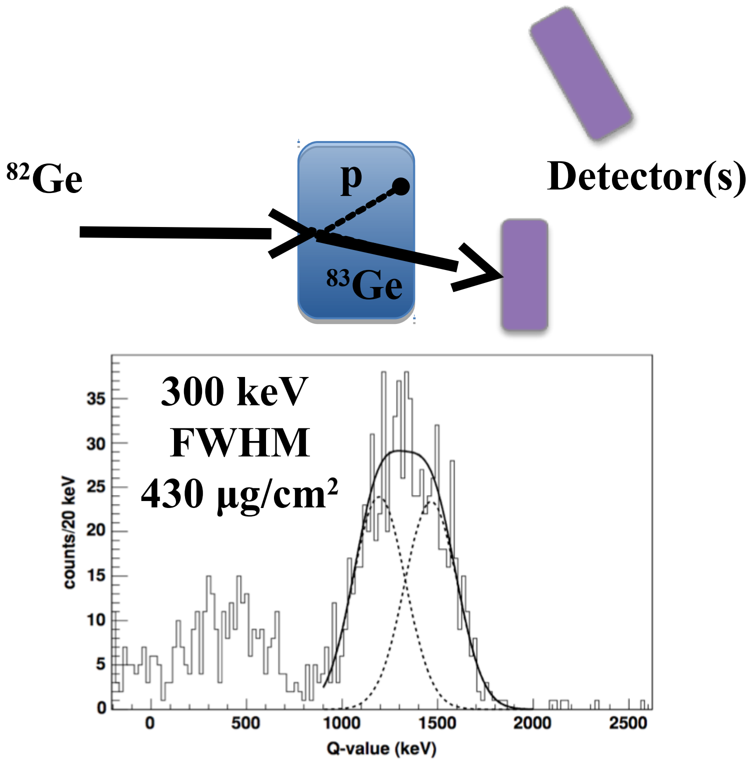
ACTAR TPC: an active target and time projection chamber for nuclear physics

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)*



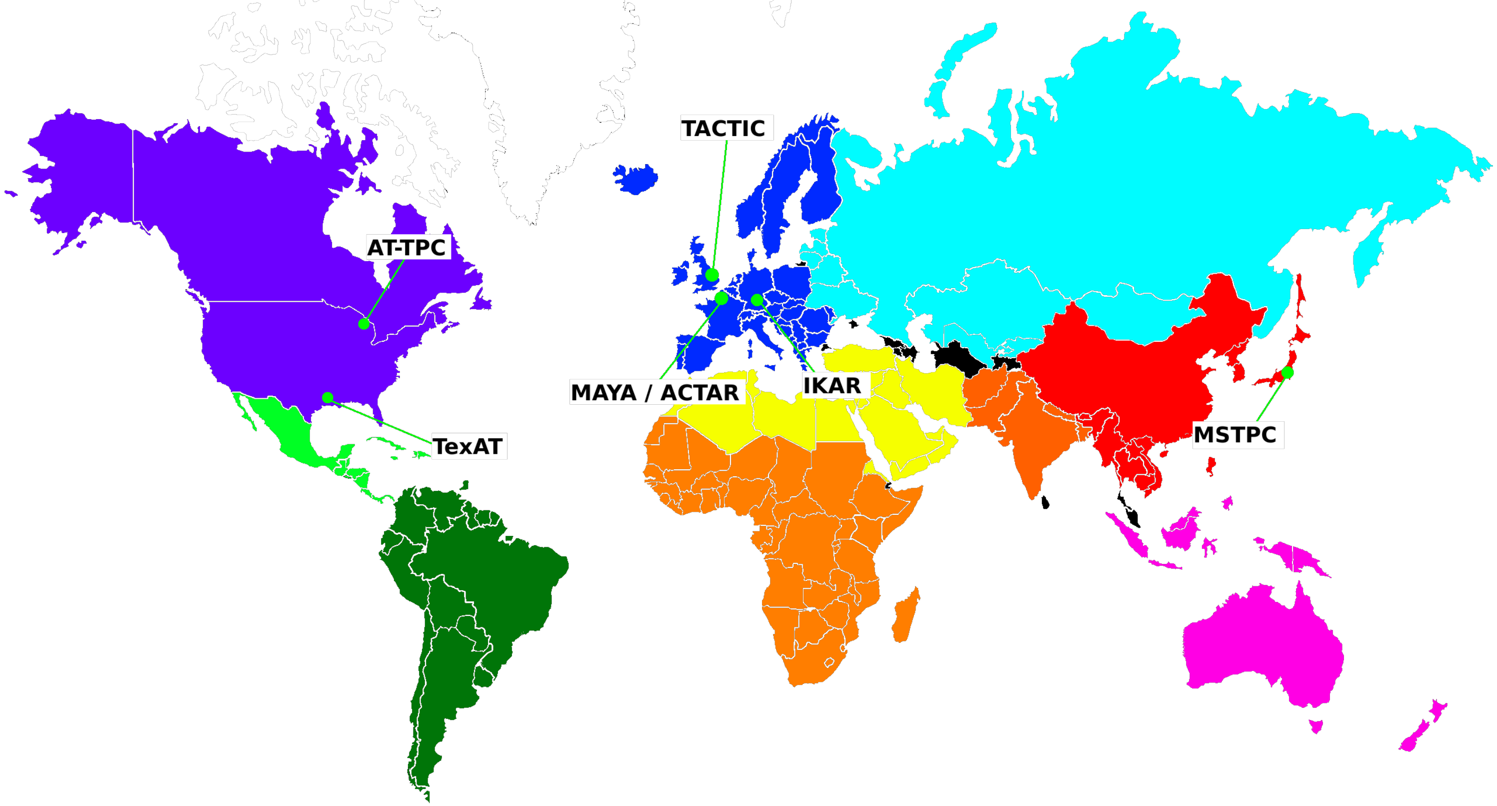
J.S. Thomas et al., PRC ***71,*** *012302 (2005)*

Need thick targets *and* excellent resolution

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

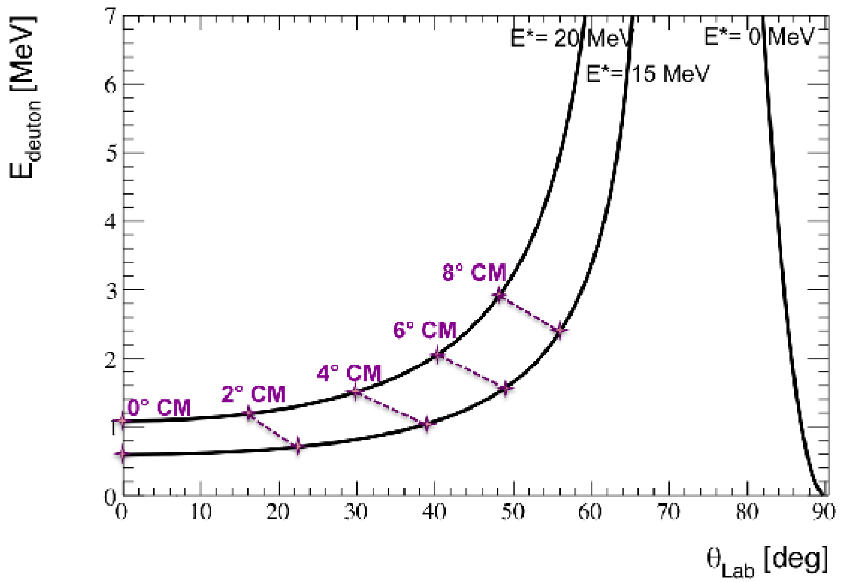
Active target: (Gaseous) detector in which the atoms of the gas are used as a target



When should active targets be used?

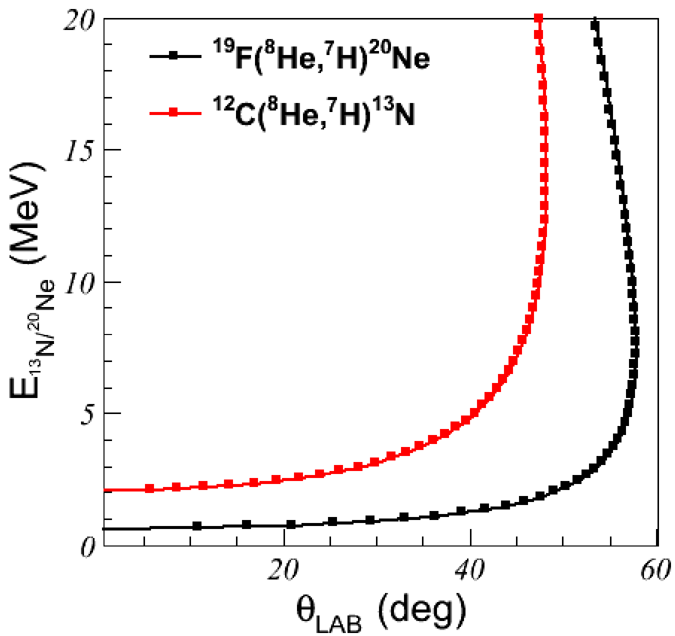
- Reactions with very negative Q-value in inverse kinematics
  → recoil stops inside the target

^{68}Ni(d,d') @ 50*A* MeV → GMR
Q ≈ -15 MeV

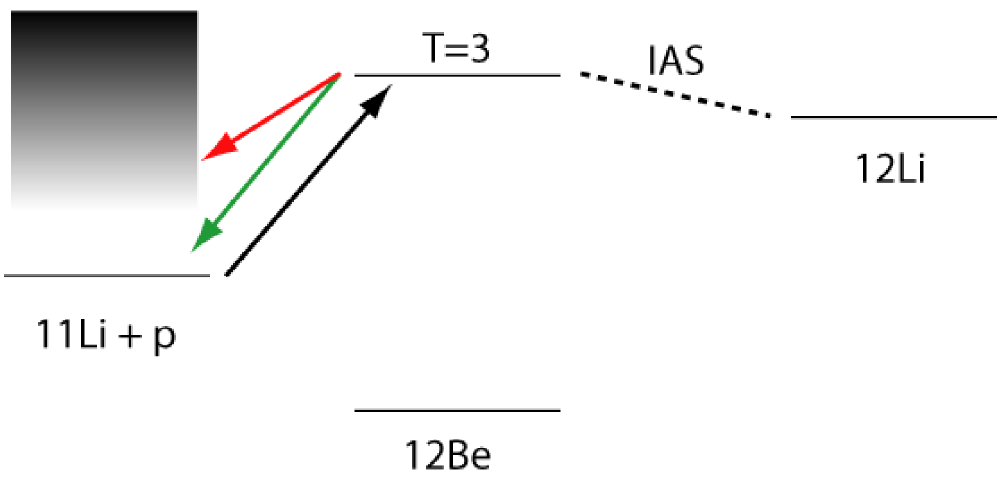


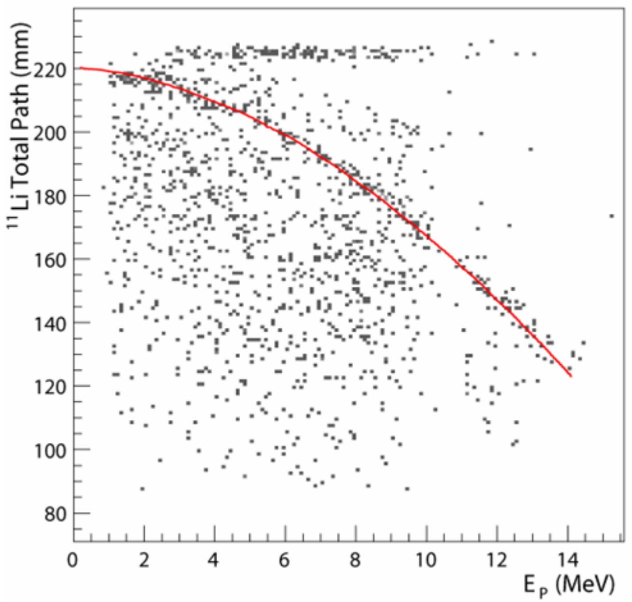
M. Vandebrouck, PhD thesis, Université Paris-Sud XI (2013)

^{8}He(^{19}F,^{20}Ne)^{7}H @ 15*A* MeV
Q ≈ -13 MeV



- Reactions with very negative Q-value in inverse kinematics
  → recoil stops inside the target
- Study of excitation functions
  → thick target, need to differentiate the reaction channels





T. Roger, PhD thesis, Université de Caen (2009)

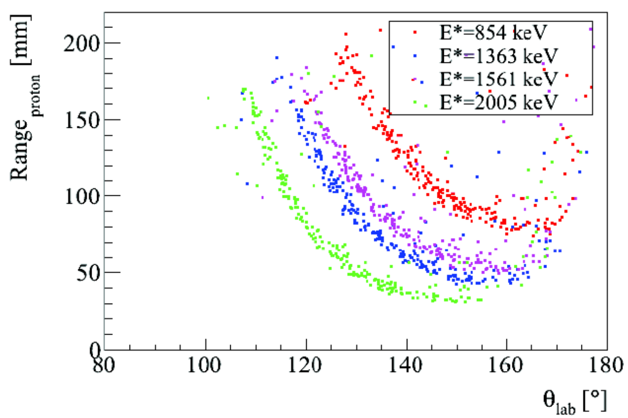
- Reactions with very negative Q-value in inverse kinematics
  → recoil stops inside the target
- Study of excitation functions
  → thick target, need to differentiate the reaction channels
- Reactions with very low intensity beams
  → thick target, possibly no ^{12}C contamination

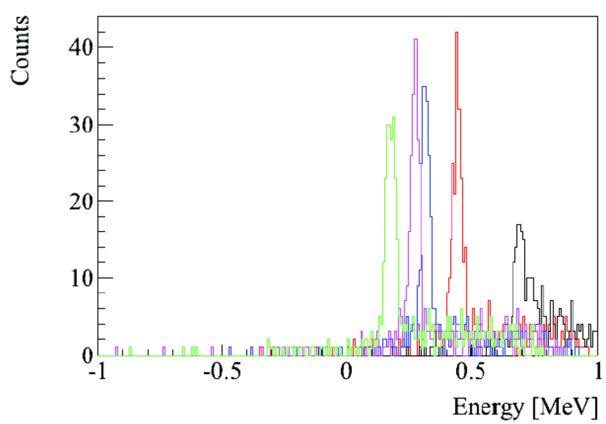
Example: $^{132}Sn(d,p)$ reaction

→ For the same energy loss in the target, about 3x more deutons in D_2 gas than in solid CD_2 target

→ Vertexing: possibility to increase the target thickness without loss of resolution

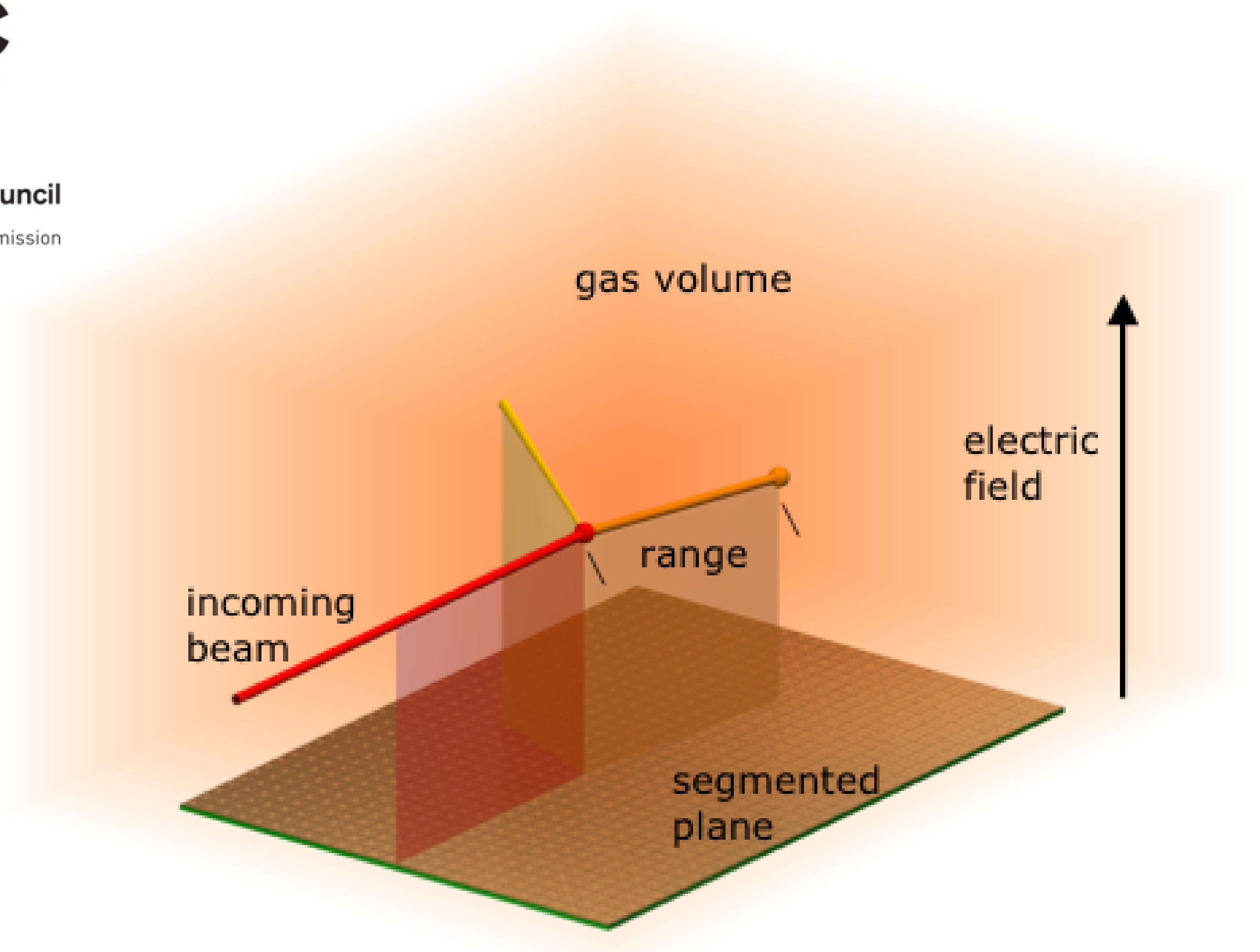
→ Overall gain of D_2 gaseous target: factor up to 100!





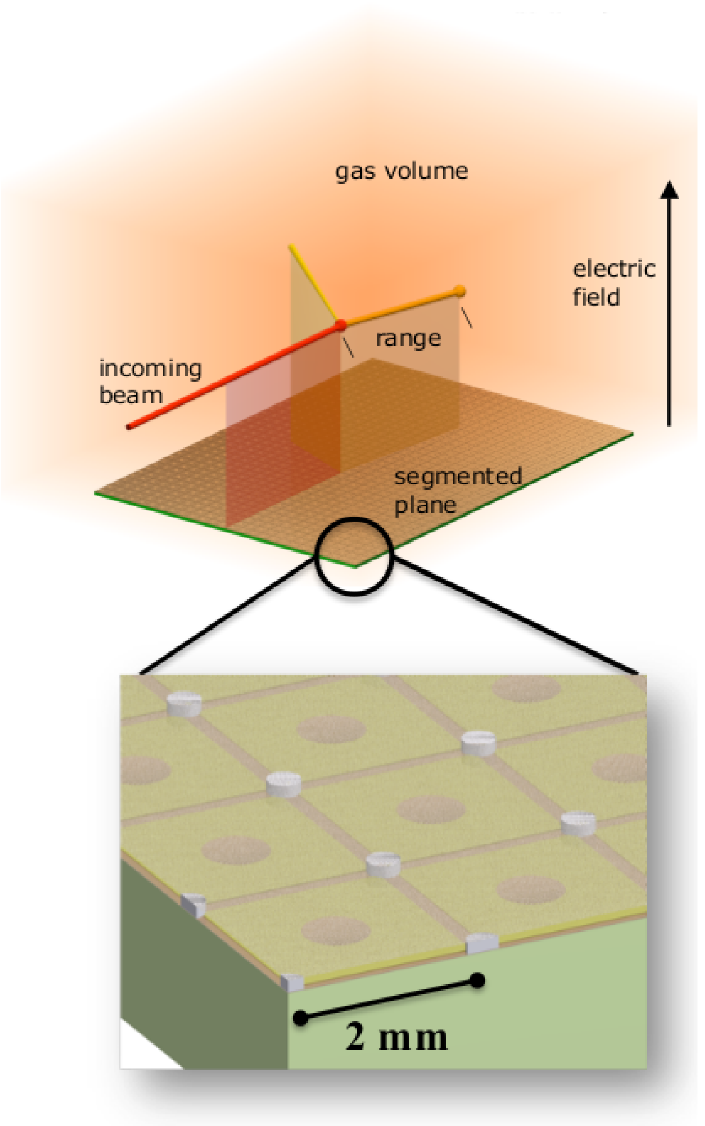
ACTARsim report: http://pro.ganil-spiral2.eu/spiral2/instrumentation/actar-tpc/actarsim-2013-report/view

European Research Council
Established by the European Commission



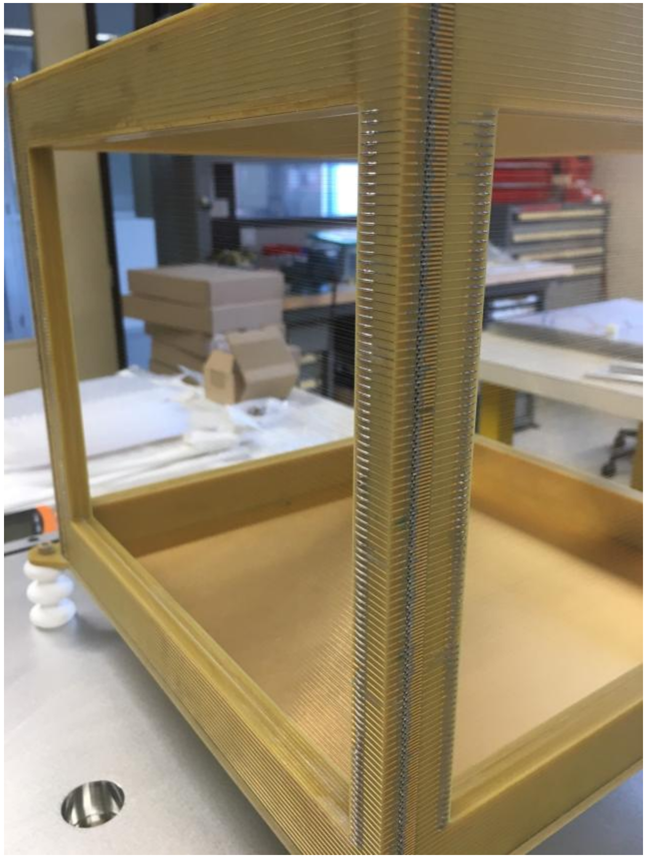
ACTAR TPC: Detector design

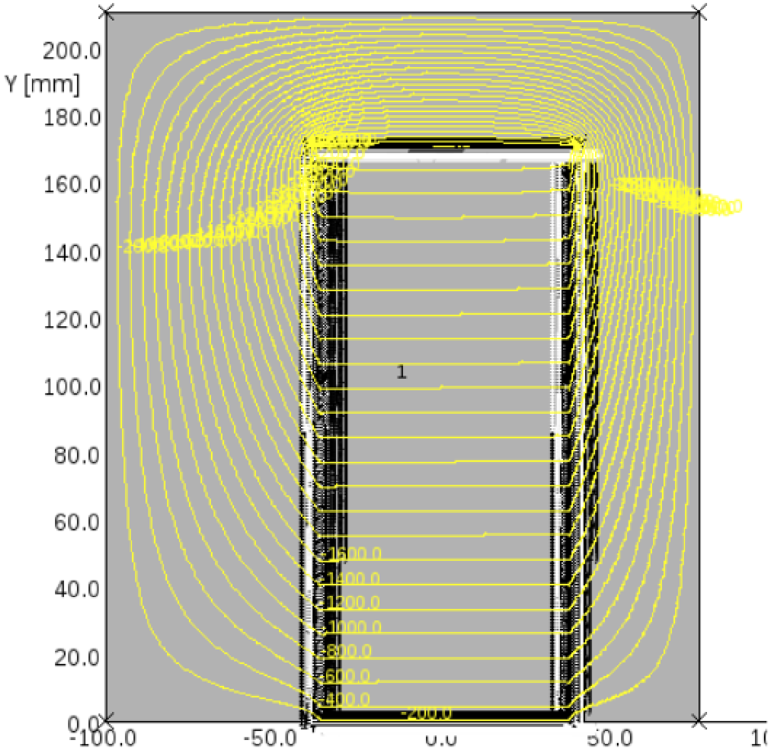
- Drift region:
  - → Demonstrator: 1 mm pitch single wire field cage
  - → Final chamber: double wire field cage
- Amplification region:
  - → Micromegas, 220 µm gap: OK for low pressure
  - → Fast timing, robust, cost effective
- Segmented pad plane:
  - → Very high density: 2x2 mm² (= 25 channels/cm²)
  - → Total 16348 electronics channels, digitized (GET system)
- Auxiliary detectors:
  - → Telescopes for escaping particles (Si+Si or Si+CsI)
  - → $LaBr_3$ or $CeBr_3$ for γ rays (SpecMAT ERC – R. Raabe)

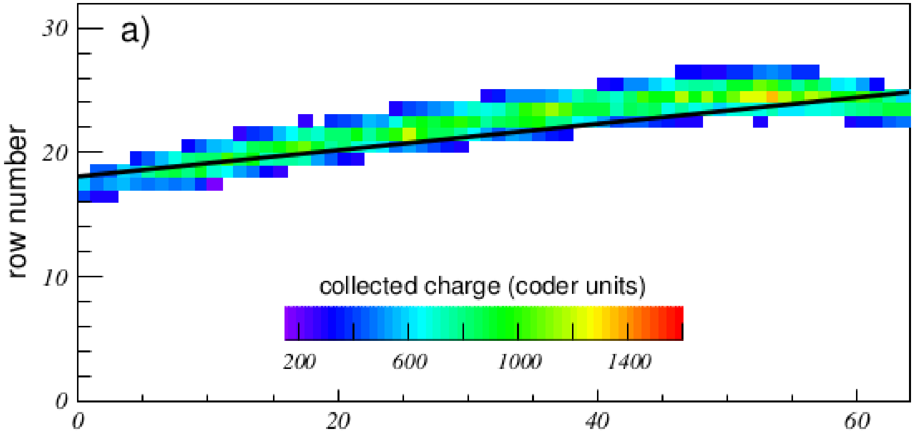


ACTAR TPC: Field cage

- Field cage:
  - → Needs to be transparent to particles: wires
  - → Horizontal electric field between the field cage and the walls leaks in the drift region: deformed trajectories
  - → Add a second wire plane to reduce this effect

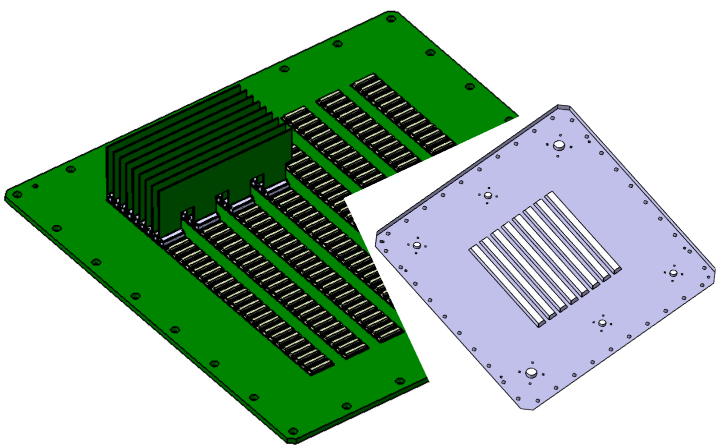




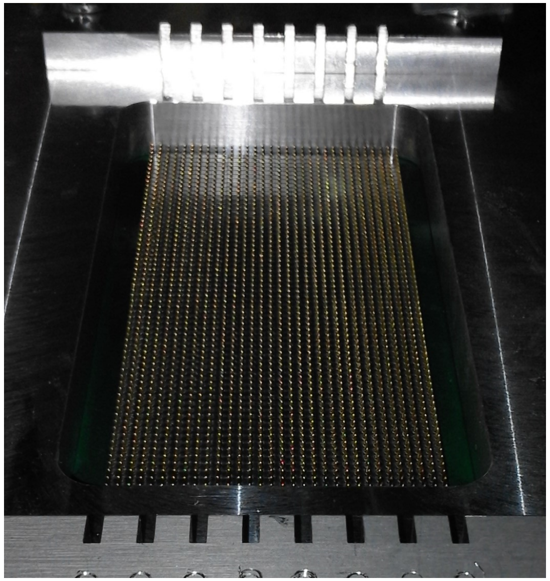


ACTAR TPC: Detection plane

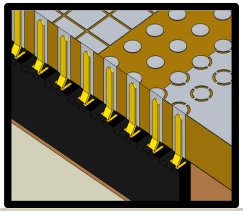
- Detection plane:
  - → 128 x 128 pads, 2 mm side
  - → Challenge to connect 16384 electronic channels on a surface of 25x25 cm^2 that serves as interface with outside (must sustain 1 bar differential pressure)
  - → 2 solutions investigated (and built)

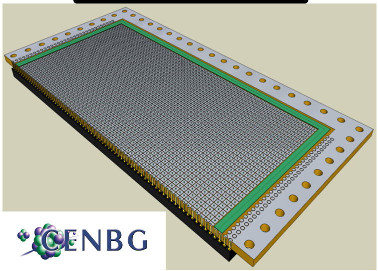


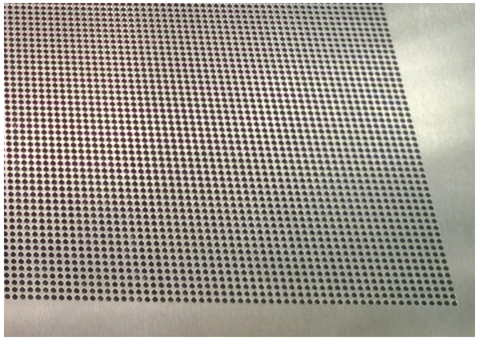
Multi-layer PCB routing solution :
P. Gangnant/M. Blaizot-GANIL
JST Connectors, 0.5 mm pitch



FAKIR solution :
J. Pibernat-CENBG



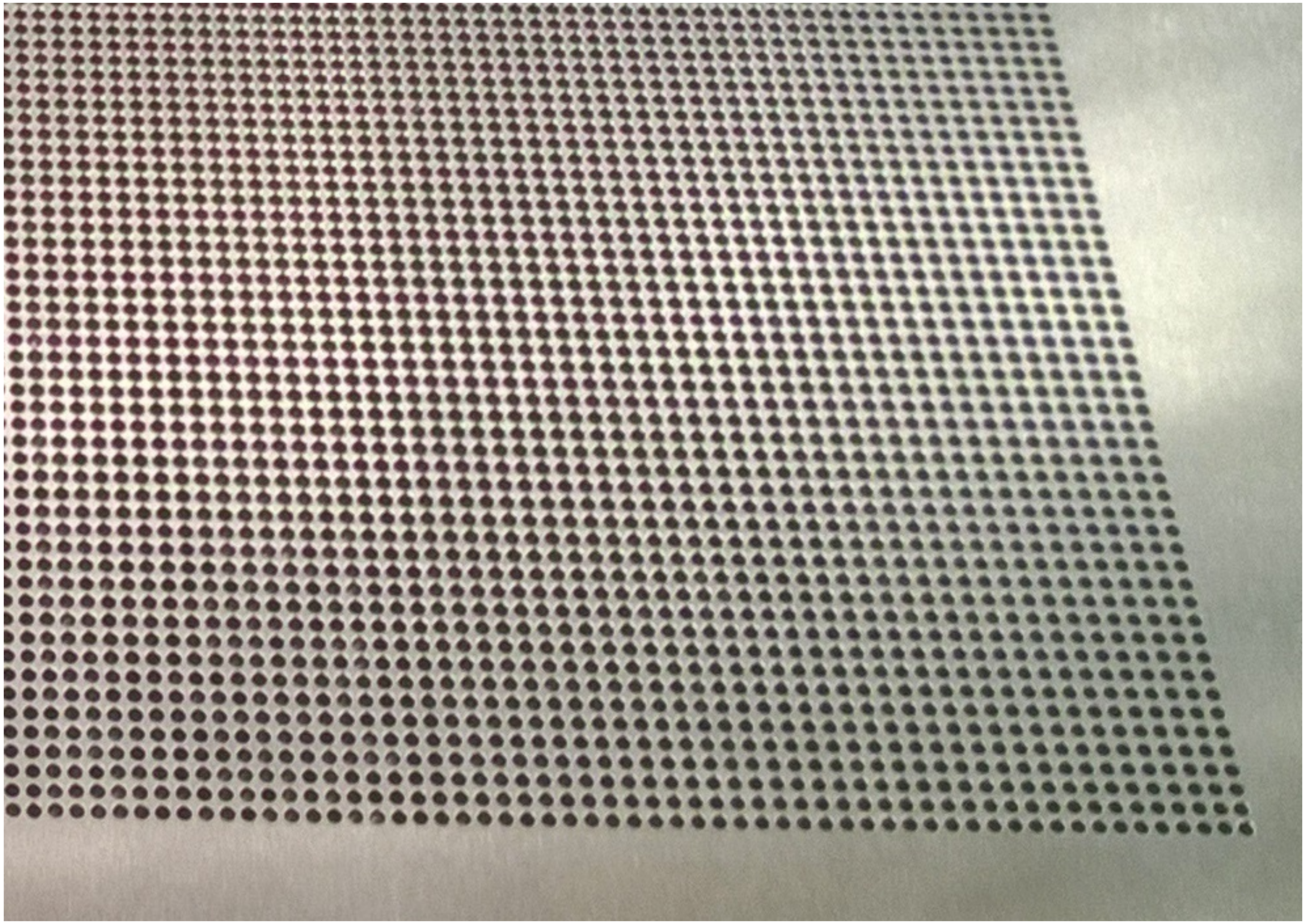




- Detection plane: FAKIR, many steps before bulking the micromegas
  - the metal plate is drilled to obtain 1.5 mm diameter holes every 2 mm on the whole surface that will contain pads;
  - a 30 μm layer of copper is deposited on the plate (in order to fix the PCB layers);
  - the holes are filled with an epoxy resin, that is used to insulate the pads connection from the metal core;
  - the PCB layers (25 μm Krempel adhesive, 75 μm polyimide and 18 μm copper) are added on both sides of the plate;
  - the resulting stack is drilled again, at a diameter of 1 mm, inside the holes previously filled with resin;
  - the pads (and ground ring around the active area) are etched on both sides of the plane;
  - the copper surfaces (pads, ring) and the holes are metallized (20 to 30 μm);
  - a protection solder mask is applied around the pads;
  - the connectors with pins every 2 mm are inserted and wave soldered (this part of the process has been realized by an external company, FEDD company [12]);
  - final grinding and polishing are applied;

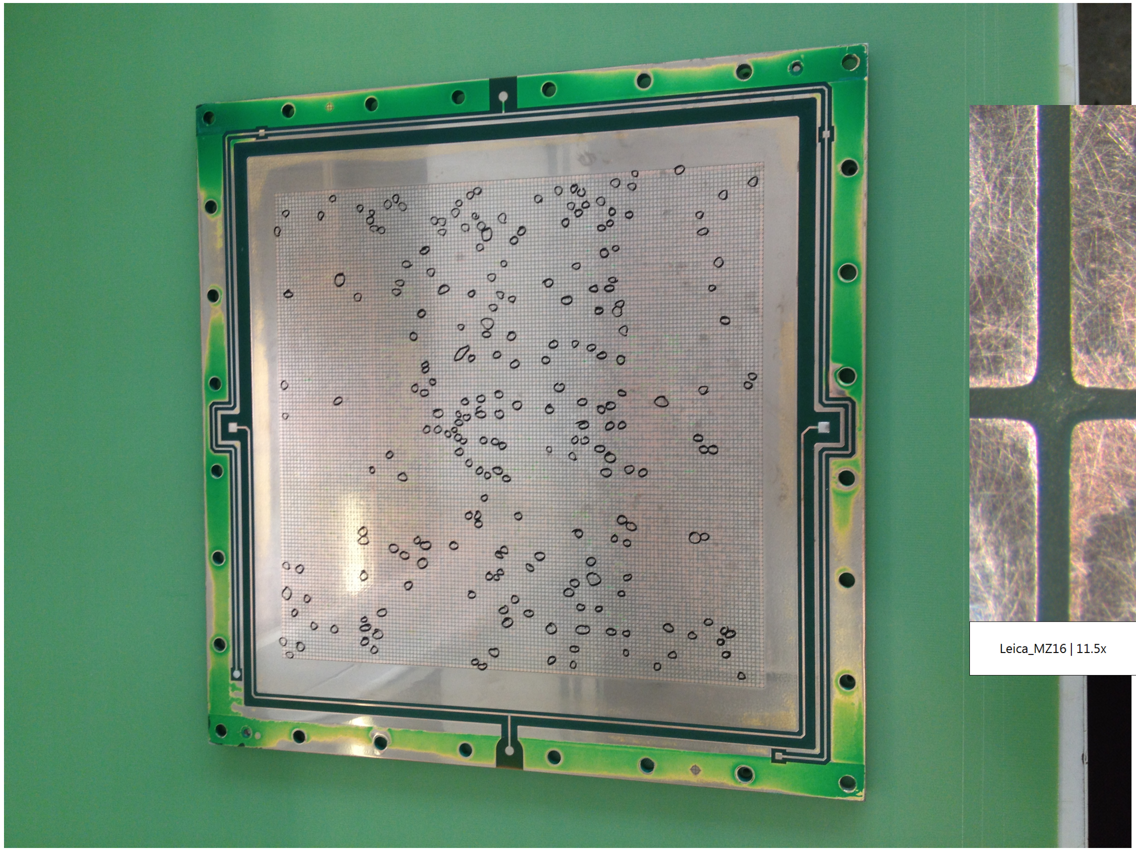
J. Giovinazzo et al., submitted to NIM A

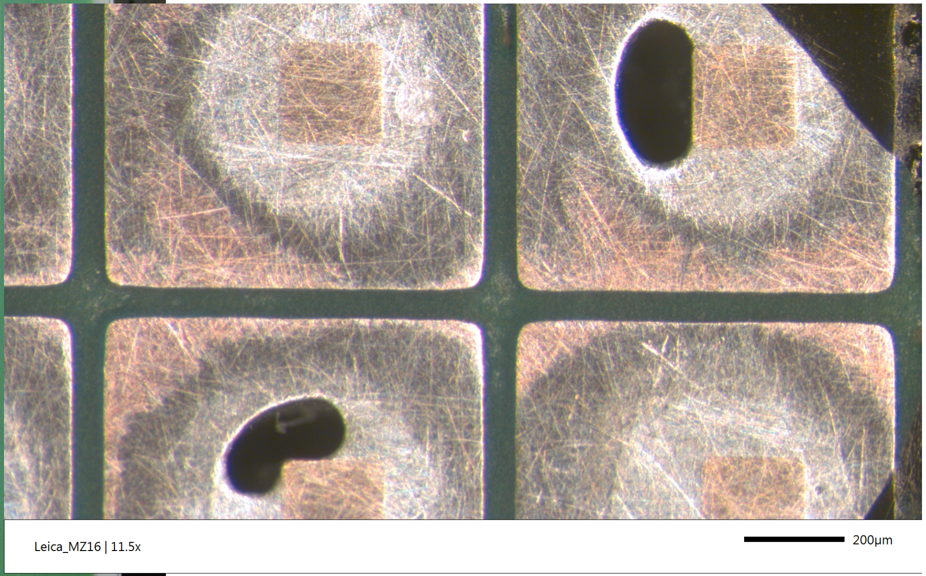
- Detection plane: FAKIR



7 mm thick stainless steal plate drilled with 16384 holes,
1.5 mm diameter, 2 mm pitch

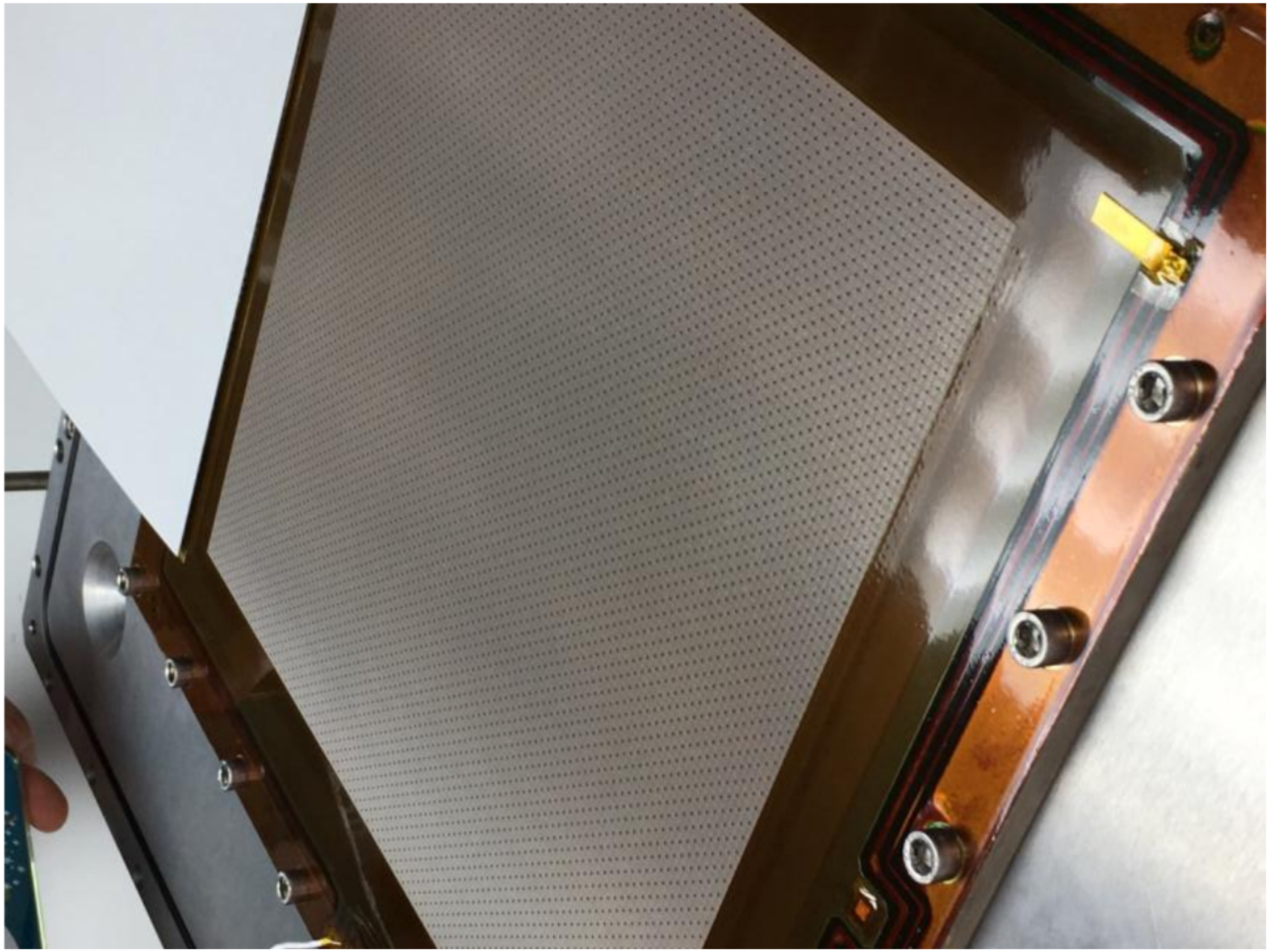
- Detection plane: FAKIR





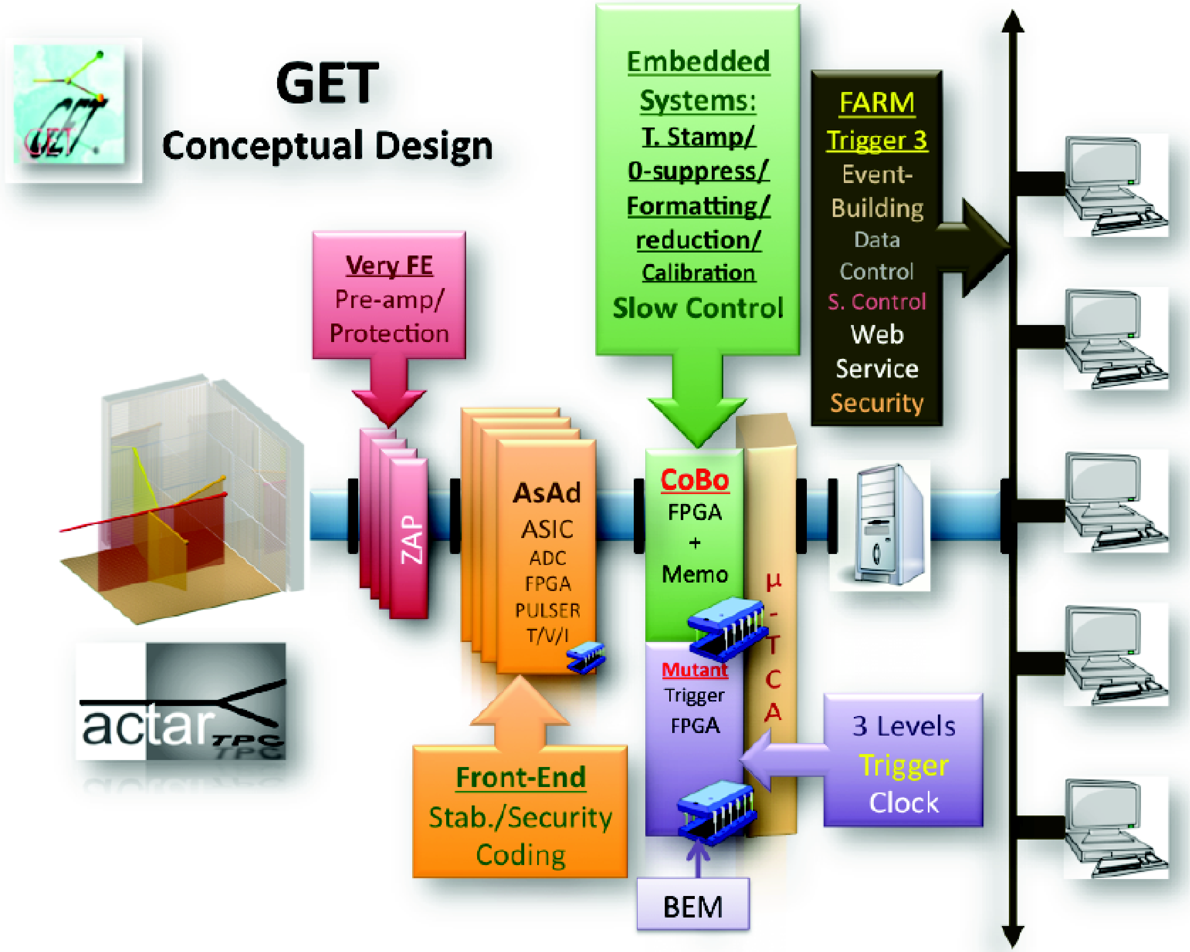
Pad plane surface after grinding step (last step before bulking)

- Detection plane: FAKIR



Pad plane with 220 μm micromegas bulk

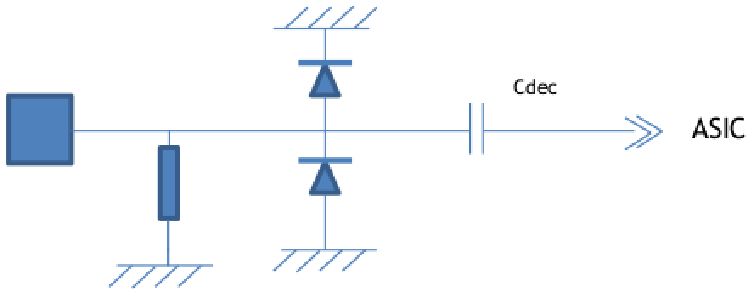
❑ Electronics: GET

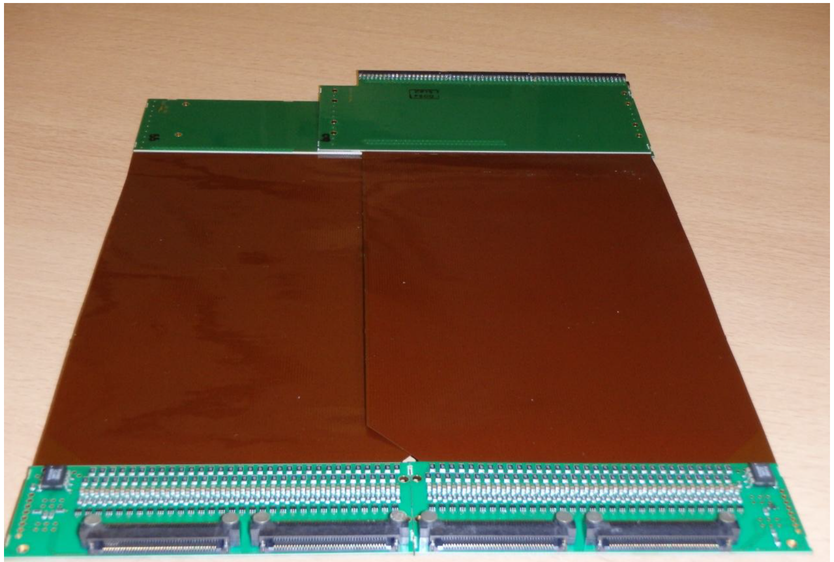


E.C. Pollaco et al., Physics Procedia ***37,*** *1799 (2012)*

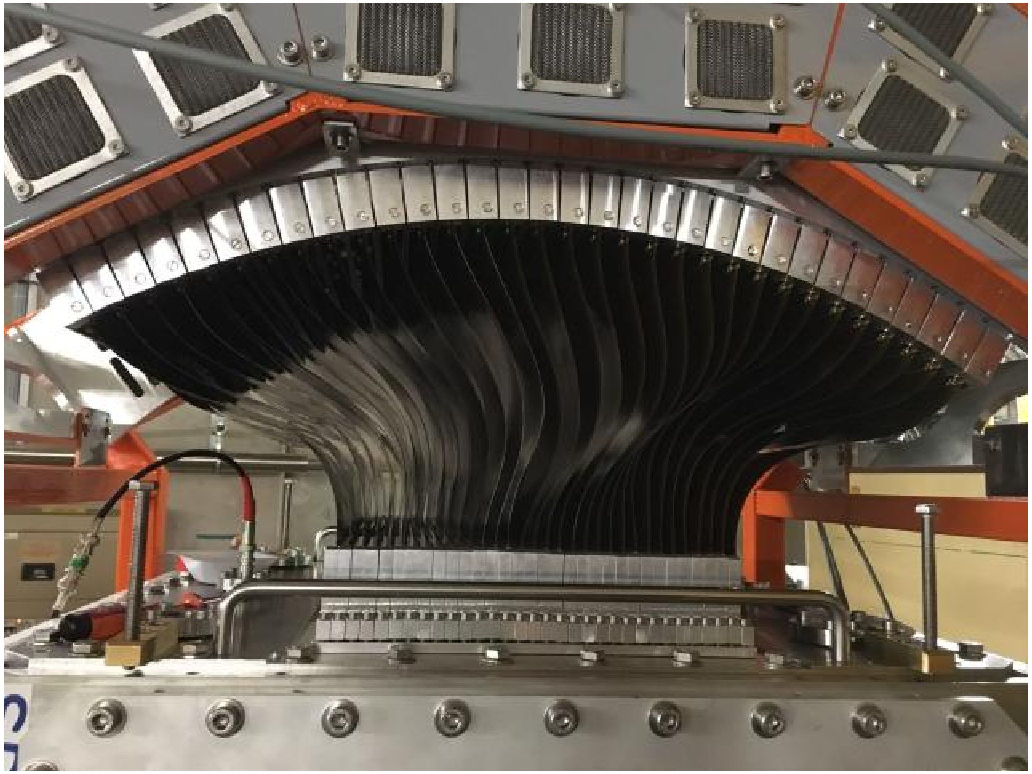
Electronics: GET

→ Very front end sparking protection circuit





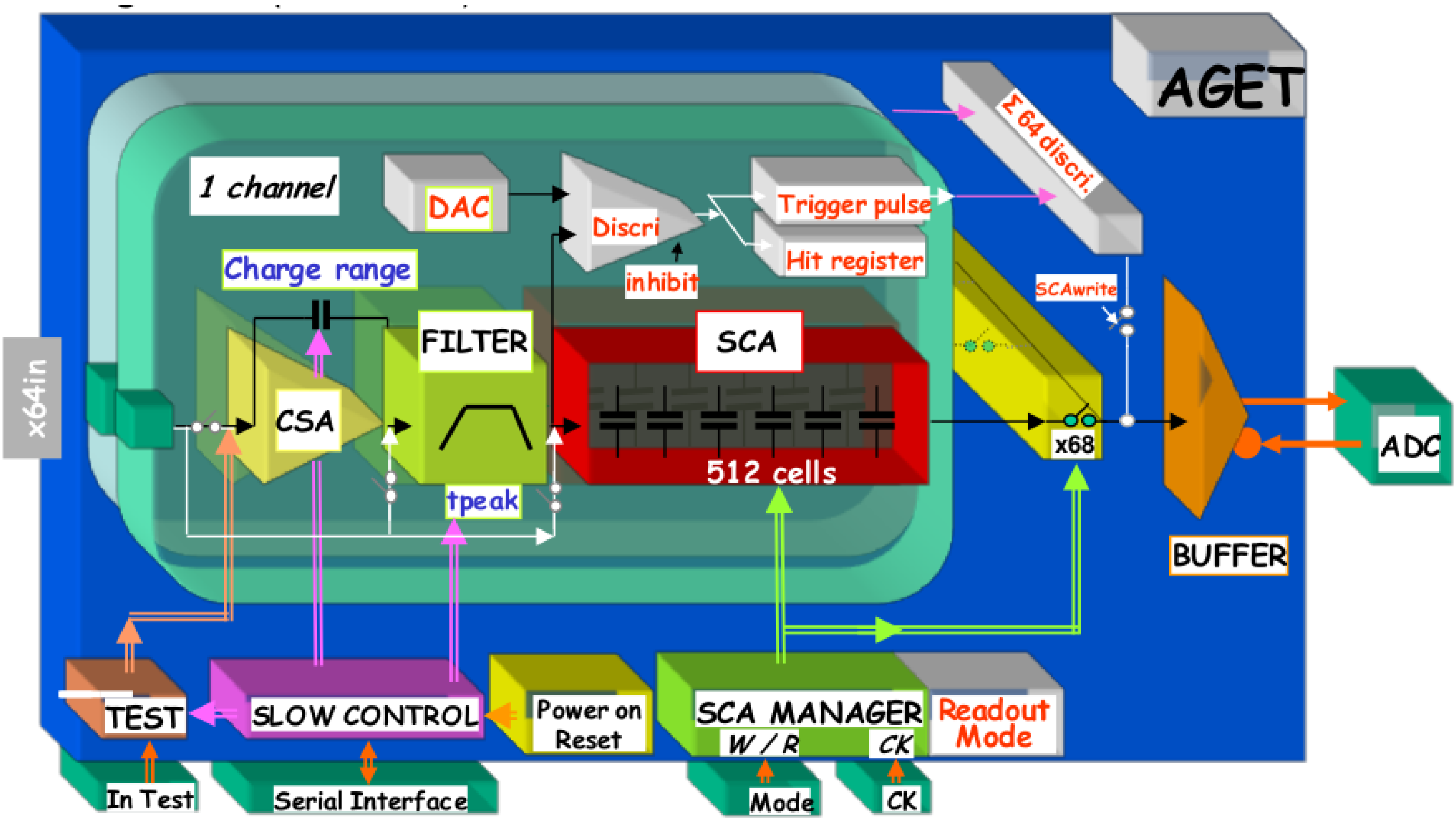
2x128 channel ZAP boards designed at CENBG



Electronics: GET

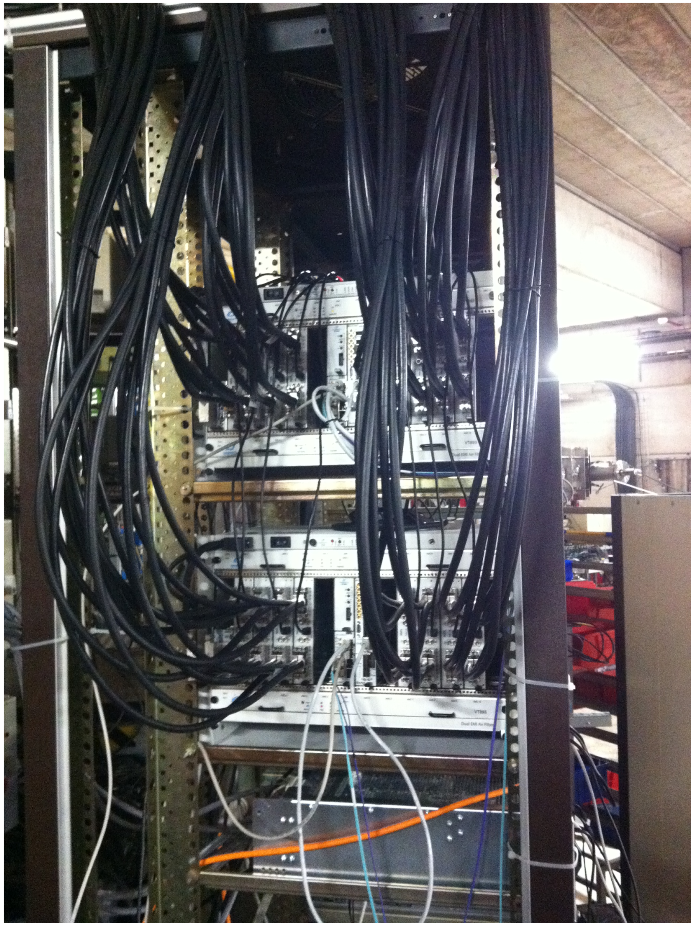
→ Very front end sparking protection circuit

→ ASIC and ADC boards (AsAd)

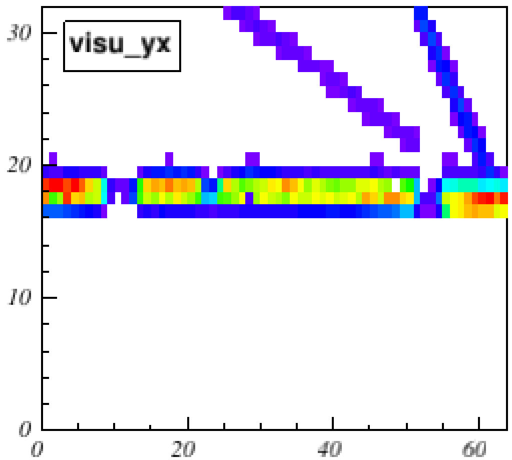


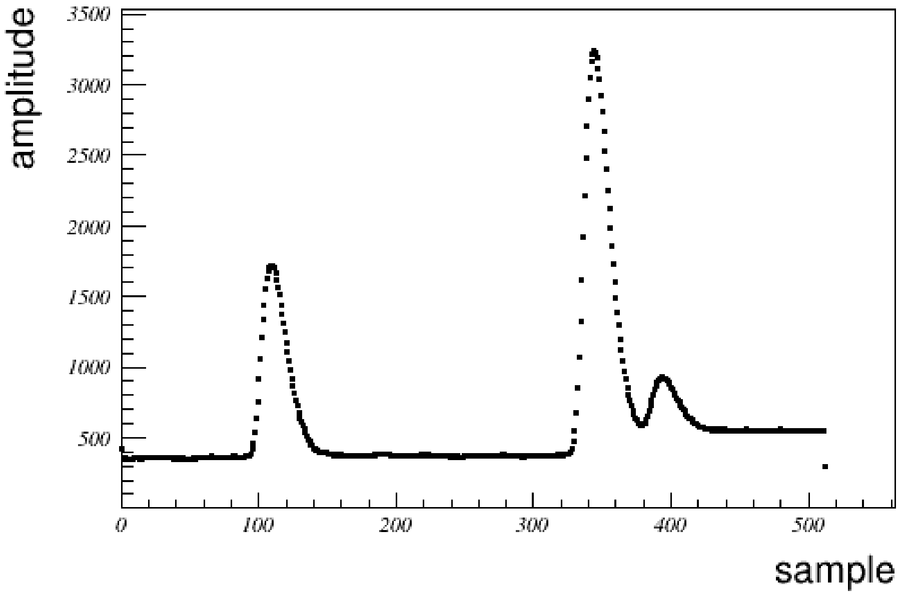
Electronics: GET

- → Very front end sparking protection circuit
- → ASIC and ADC boards (AsAd)
- → Concentration boards and Trigger module (CoBo & MuTant)



Electronics: GET
- → Very front end sparking protection circuit
- → ASIC and ADC boards (AsAd)
- → Concentration boards and Trigger module (CoBo & MuTant)
- → Each channel equipped with 512 samples ADC readout depth: 8 Mega Voxels in total





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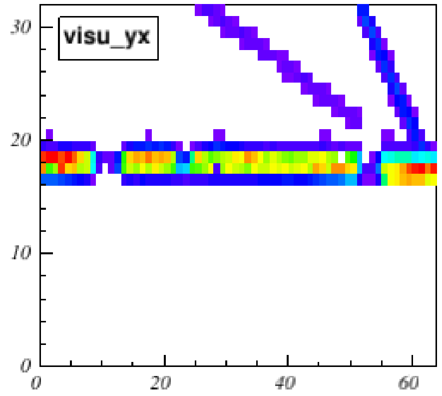
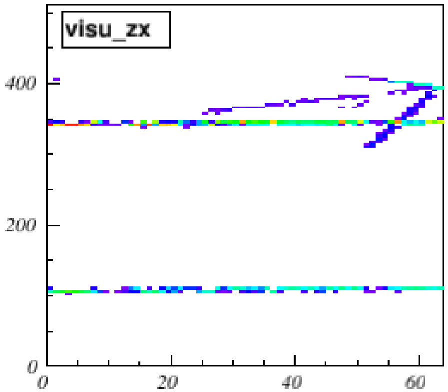
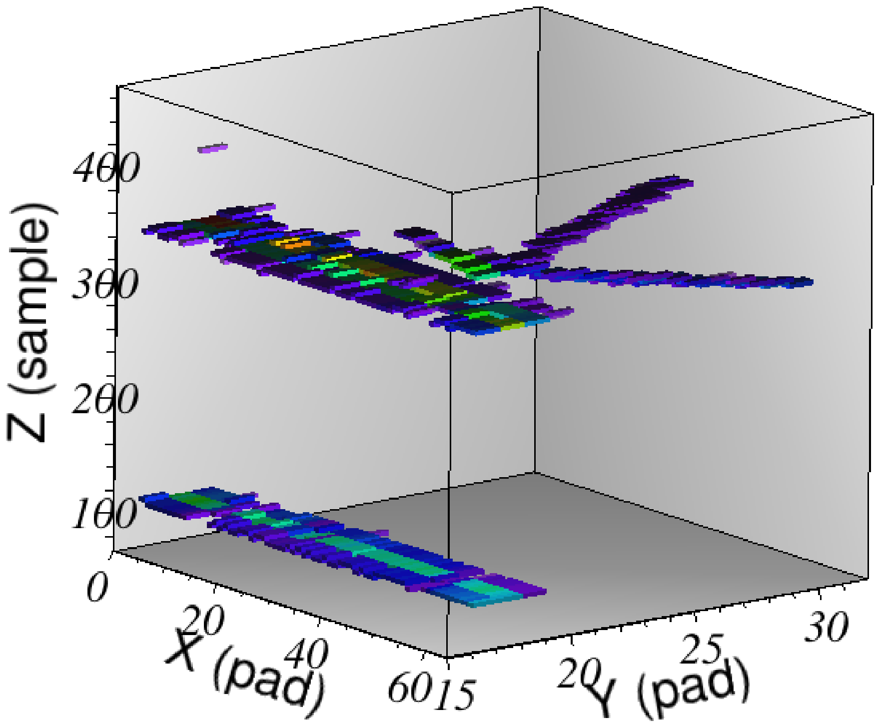
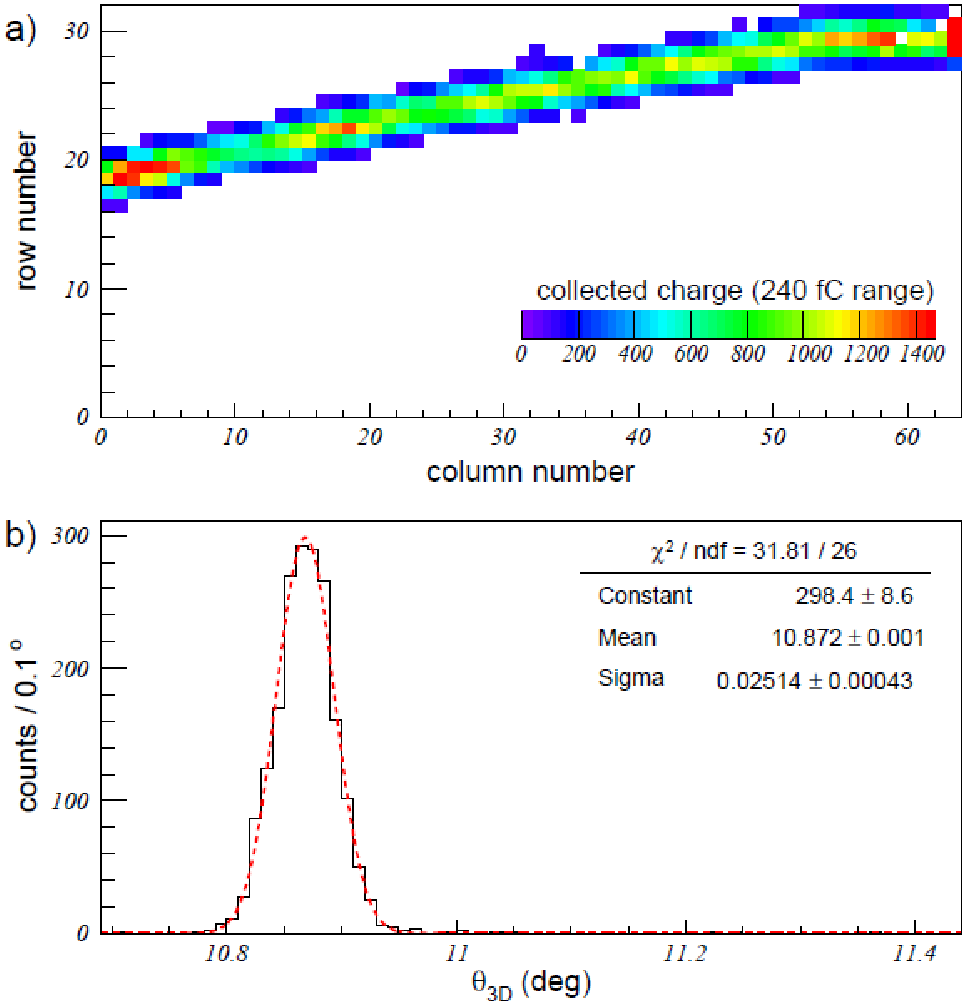




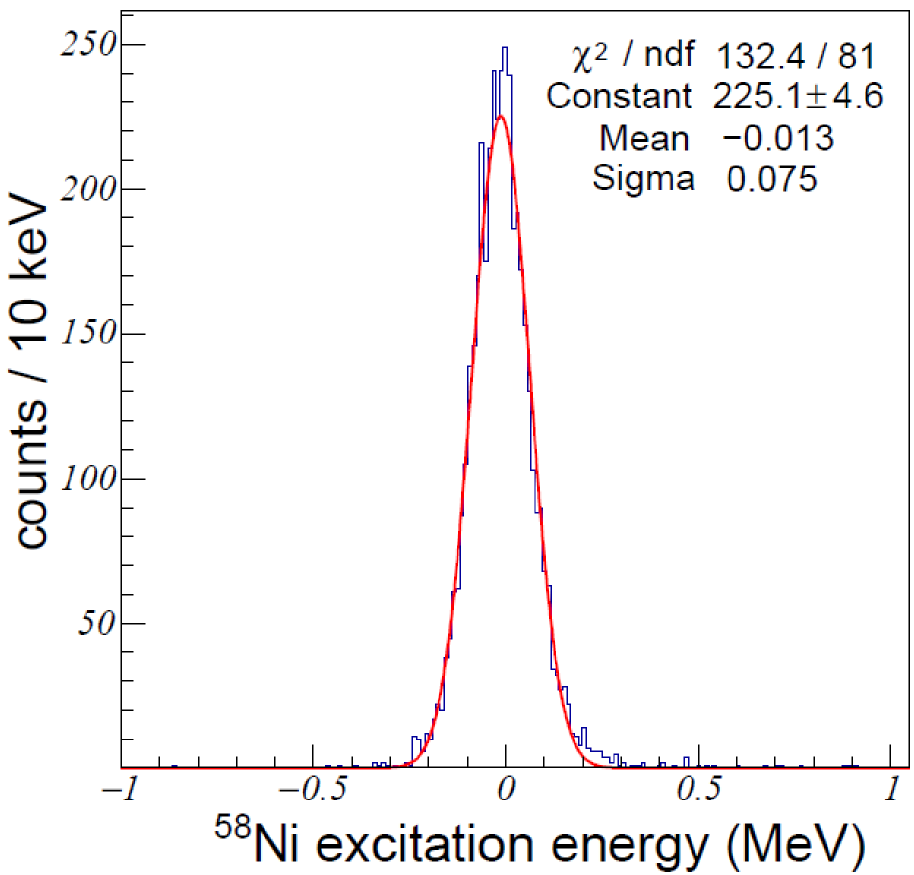


Detector performances with the 64x32 pads demonstrator:
→ Angular resolution tested with a laser (no straggling)



3D angular resolution: 0.06° FWHM
→ dominated by the straggling

Detector performances with the 64x32 pads demonstrator:
- → Angular resolution tested with a laser (no straggling)
- → Excitation energy resolution tested with ^{58}Ni(p,p) @ Elab = 3A MeV → ~ 0 MeV

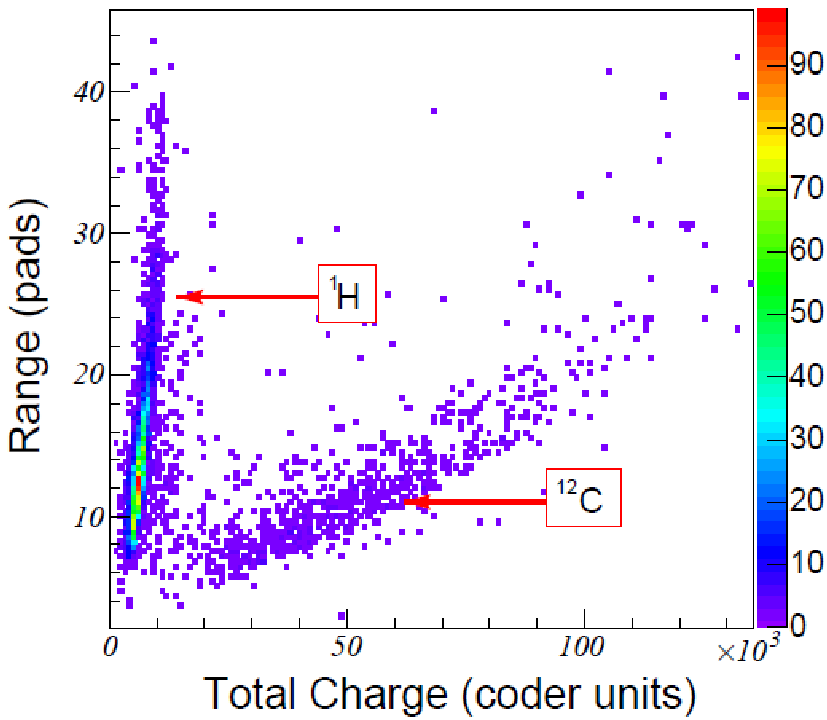


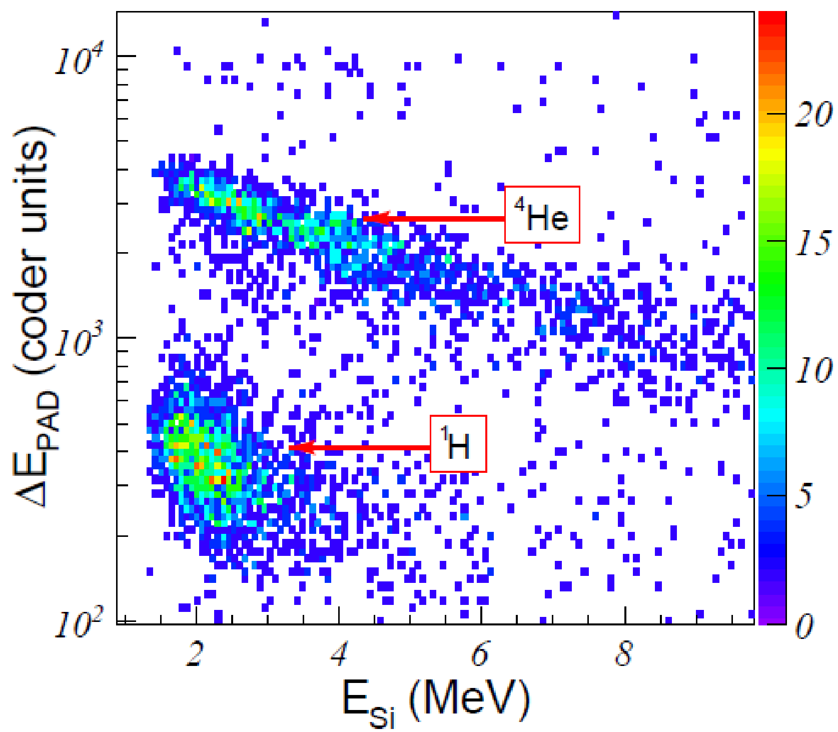
E* determined with proton angle and energy (range)
→ ~ 175 keV FWHM

B. Mauss, PhD thesis - GANIL

Detector performances with the 64x32 pads demonstrator:

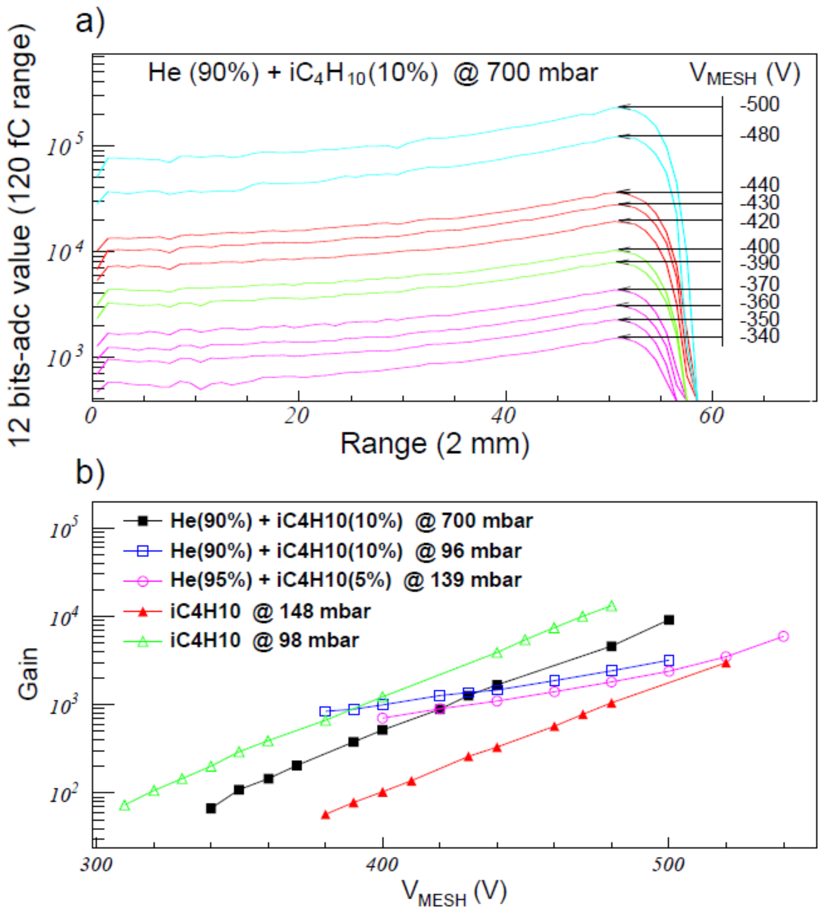
- → Angular resolution tested with a laser (no straggling)
- → Excitation energy resolution tested with 58Ni(p,p) @ Elab = 3A MeV → ~ 0 MeV
- → PID capabilities (room for improvement)





B. Mauss, PhD thesis - GANIL

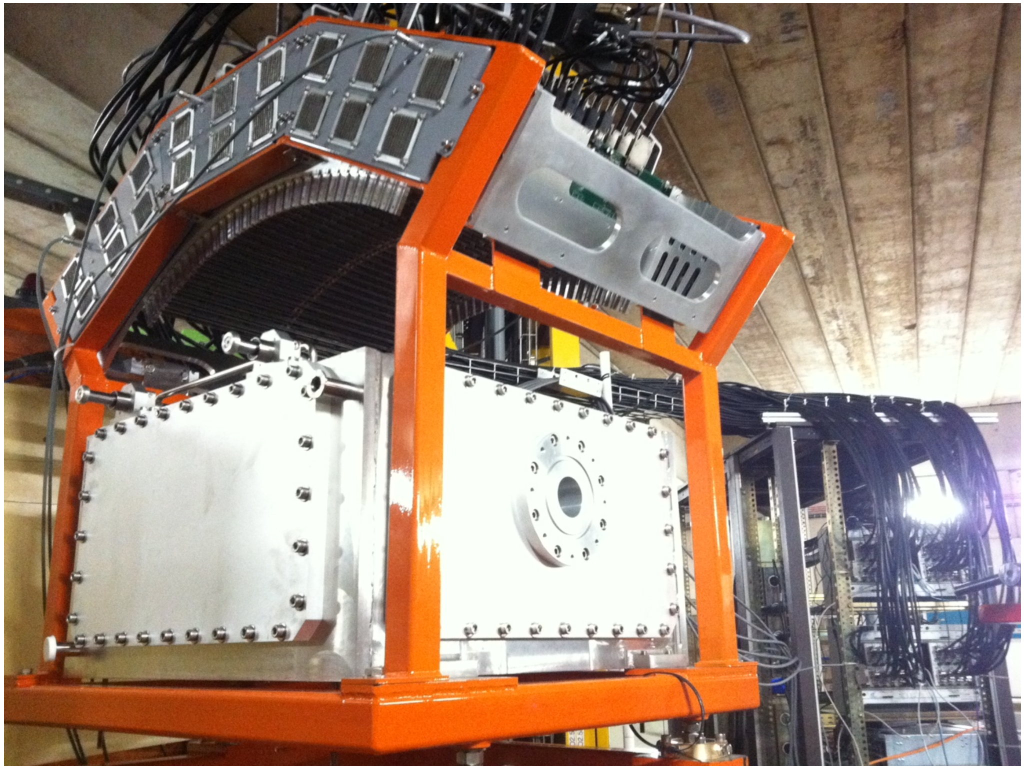
Detector performances with the 64x32 pads demonstrator:
- → Angular resolution tested with a laser (no straggling)
- → Excitation energy resolution tested with ^{58}Ni(p,p) @ Elab = 3A MeV → ~ 0 MeV
- → PID capabilities (room for improvement)
- → Detection limits: gain curves can be measured for any gas foreseen to be used

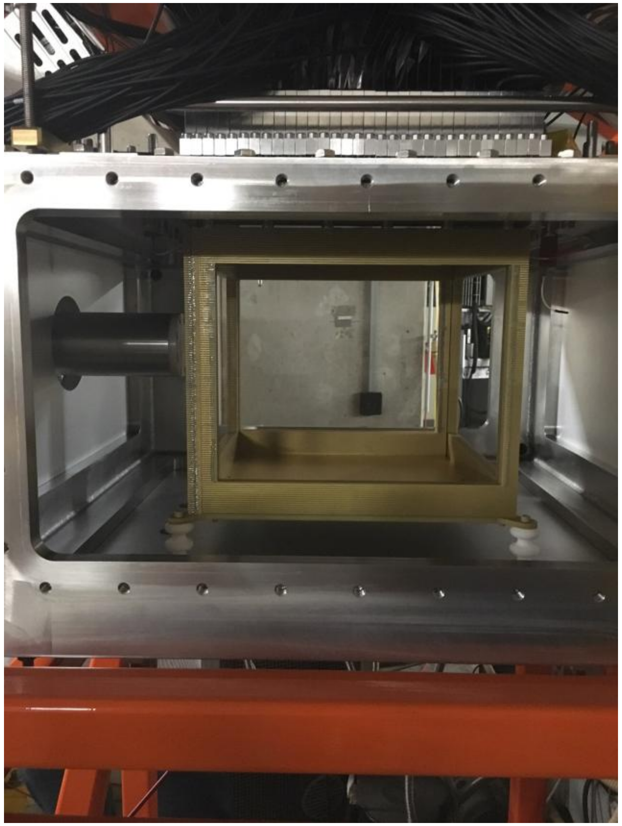


For most "classic" gas mixtures, single electron detection can be achieved

Status of the detector today:

- → Mounted on the G3 beam line
- → All electronics plugged (~ 5% failure, connexion problems that will be solved next week)
- → Field cage successfully mounted and polarized
- → First tests in alpha source next week
- → Commissioning planned for Nov. 20th: $^{18}O(p,p)$ resonant scattering reaction

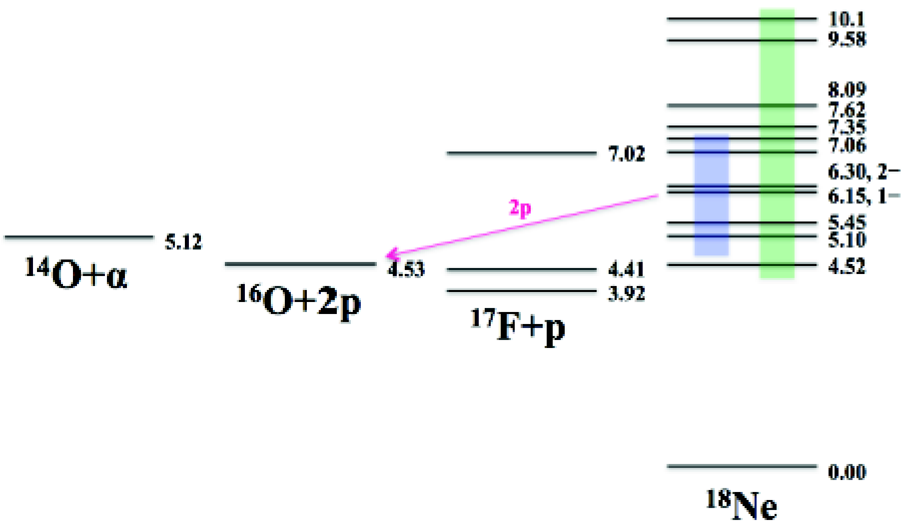




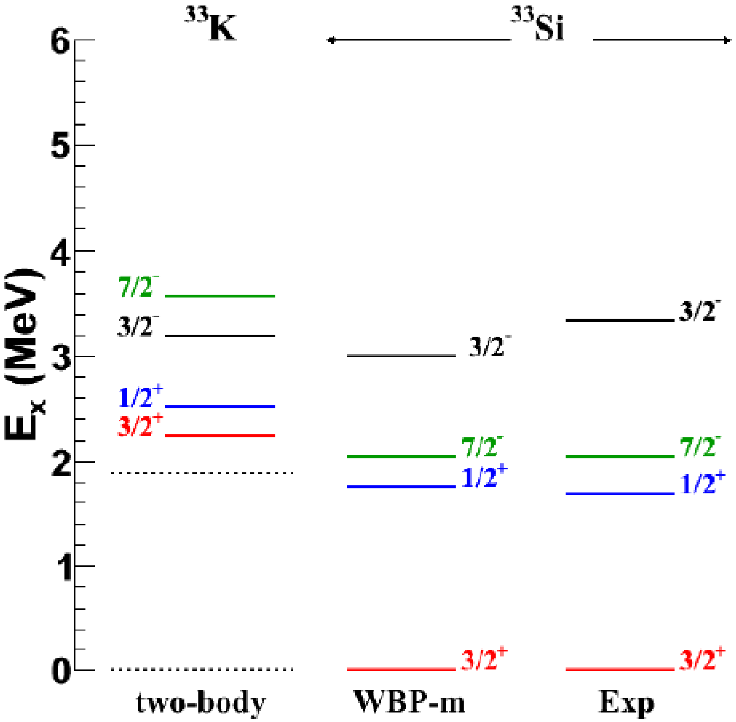
Planned experiments (2018 - 2019)

→ Resonant scattering with ^{17}F and ^{32}Ar on proton: SPIRAL1 beams

Resonant proton scattering on ^{17}F and 2p emission from excited states in ^{18}Ne (G.F. Grinyer – GANIL / U.Regina)



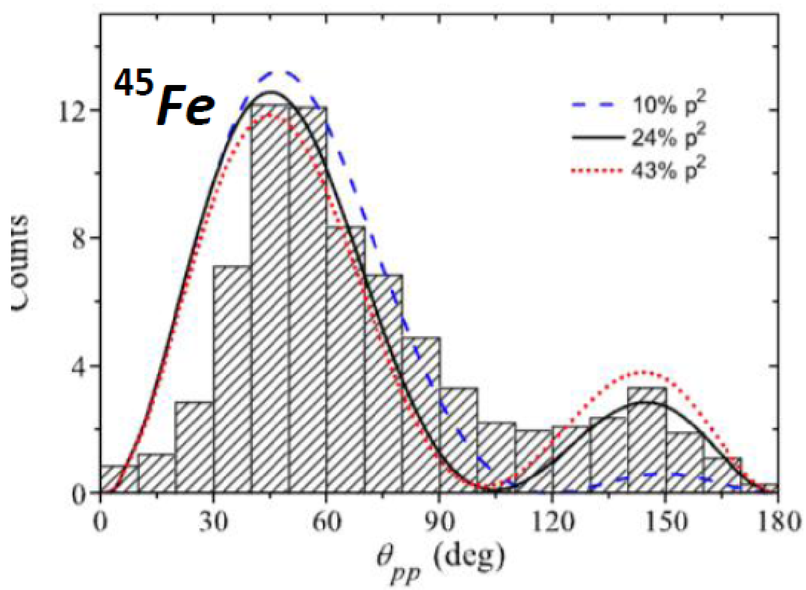
Spectroscopy of ^{33}K: (B. Fernandez-Dominguez - USC)



Planned experiments (2018 - 2019)

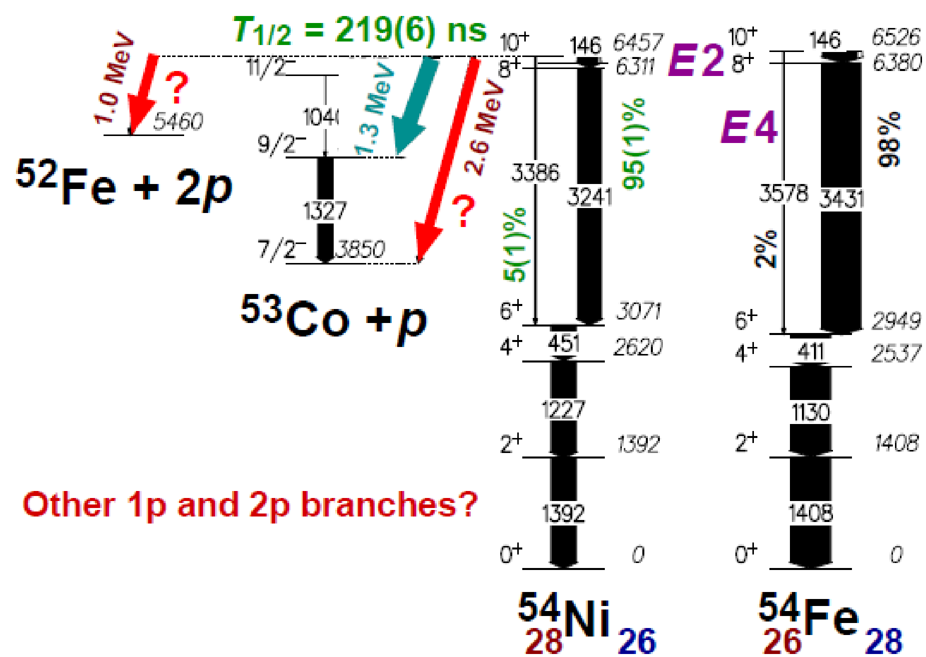
- → Resonant scattering with ^{17}F and ^{32}Ar on proton: SPIRAL1 beams
- → Proton decay studies of ^{48}Ni and ^{54}Ni: LISE fragmentation beams – TPC mode

Study of proton-proton correlations in the two-proton radioactivity of ^{48}Ni or ^{54}Zn
(J. Giovinazzo - CENBG)



K. Miernik et al., EPJA 42, 431 (2009)

Proton-decay branches from the 10+ isomer in ^{54}Ni
(D. Rudolph – Lund University)



CONCLUSION

Technical choice (wire field cage, 2x2 mm^2 pads, micromegas) validated with the demonstrator
- → Angular resolution: limited by the straggling (for tracks length > 1 cm)
- → Range resolution: better than 1 mm
- → High gain reached: detection of single ionization electrons
- → Multiparticle tracking possible

Final detector fully mounted but:
- → Few connectics problems (need to check the connexions one by one)
- → Still some firmware problems on the CoBo boards (bit flip problems). MSU is working on it
- → Solutions to these problems are known

Future physics program will start in 2018
- → 4 experiments accepted at GANIL
- → 5 proposal received for the next PAC
- → ACTAR TPC pre-PAC meeting will be organized before the 2018 PAC.


Workshop on Active Targets
and Time Projection Chambers
for High-intensity and Heavy-ion beams
in Nuclear Physics
Second GDS Topical Meeting
16-19 January 2018. Santiago de Compostela, Spain
• Physics with Gas Detections Systems (GDS)
• Active Target and TPCs: ongoing and forthcoming projects
• Experiments with high-intensity and heavy-ion beams
• Gas properties for high-intensity and heavy-ion beams
• Ancillary detectors for high-intensity and heavy-ion beams
• Simulations and electronics for GDS
Information and registration:
https://indico.in2p3.fr/event/16443/
ENSAR2
GDS
GANIL
USC
IPN
INFN
KU LEUVEN
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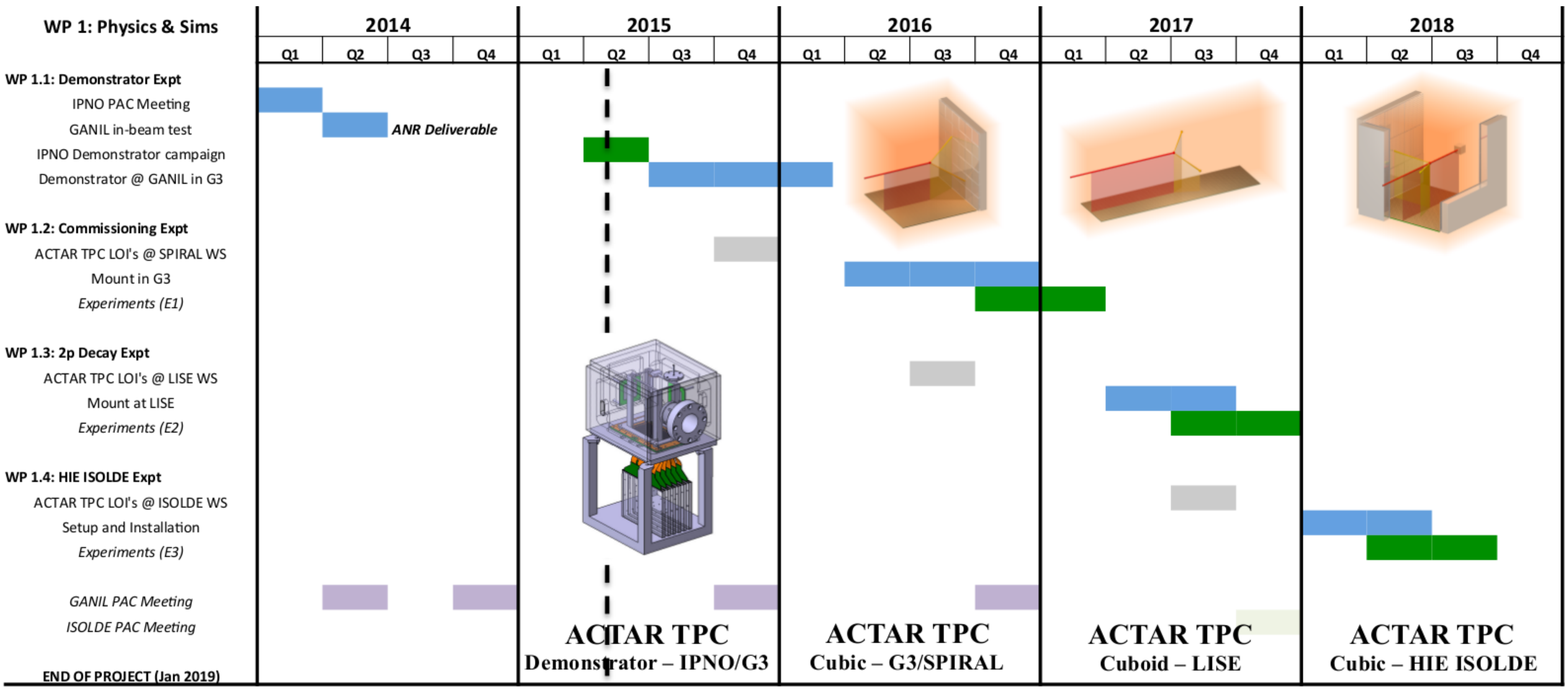
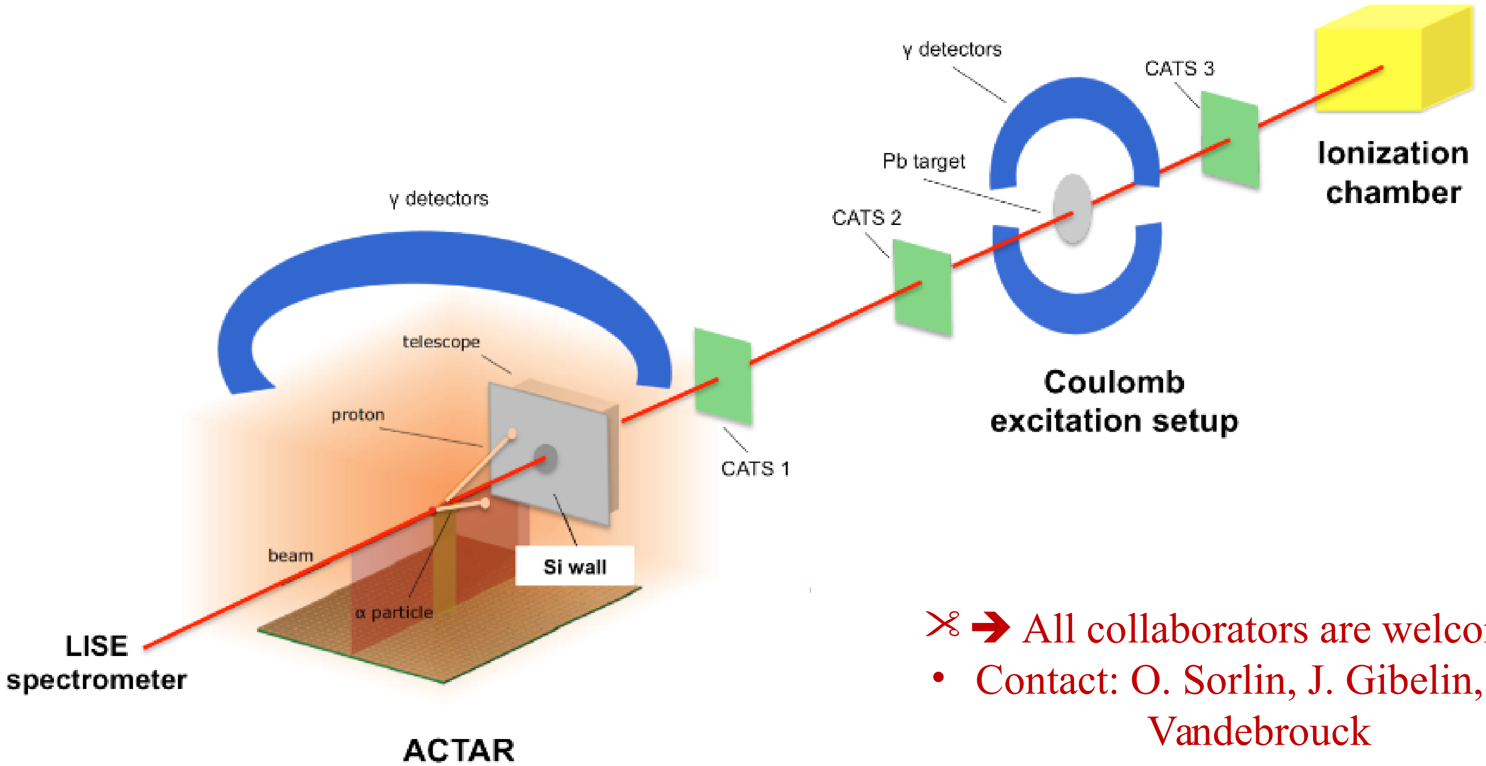
ACTAR TPC: ERC planning

- ACTAR TPC ERC Project Planning
- → Experiments at GANIL/G3 (2016/2017), GANIL/LISE (2017), HIE-ISOLDE (2018)
- → Demonstrator experiments at IPNO (July 2015)



- Document on the exploitation of LISE in the horizon of 5 years currently written
  - → Working groups constituted: shell evolution, collective modes, nuclear astrophysics…
  - → Presentation at the next GANIL SAC in October

- Preliminary conclusions of the "collective modes" working group:
  - → Possibility to combine ACTAR TPC and "classic" solid target + Château de Cristal setup
  - → Study (α,α') or (p,p') and (γ*,γ) at the same time!



→ All collaborators are welcome!
- Contact: O. Sorlin, J. Gibelin, M. Vandebrouck

MAYA / ACTAR TPC collaboration

GANIL	K.U. Leuven	IPNO	CENBG	USC
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G.Fremont	F.Renzi	A.Maroni		B.Fernández
J.Goupil	S.Sambi	G.Noel		
G.F.Grinyer		J.Peyre	**CEA/IRFU**	
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L.Legeard		P.Rosier	A.Gillibert	
C.Maugeais	**GANIL**	D.Suzuki	E.C.Pollacco	
J.Pancin	K.Turzo	T.Zerguerras	P.Sizun	
D.Perez-Loureiro*	M.Vandebrouck			
C.Porte*	V.Vandevoorde			
B.Raine	G.Voltolini			
T.Roger	G.Wittwer			
F.Saillant				
C.Spitaels				
L.Suen*				

Students   Postdocs   *Alumni