ACTAR TPC

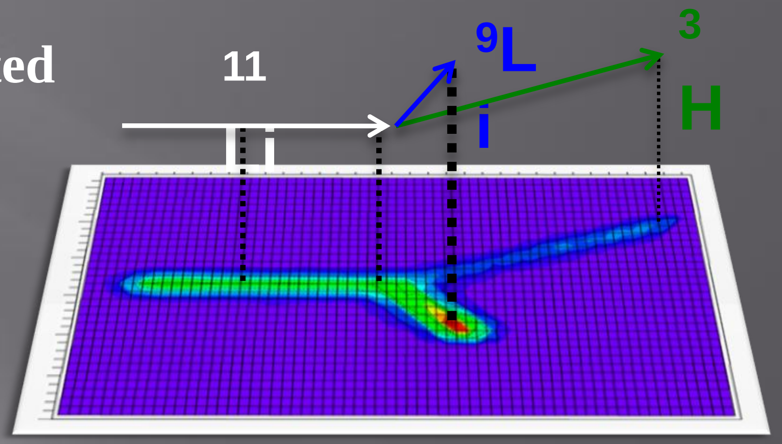
➢ Active targets and physics motivation
➢ ACTAR TPC prototype: Demonstrator GANIL/IPNO/CENBG
➢ Development of the final system: mechanics, anode, field cage…
➢ Technical perspectives

J. Pancin
On behalf of the ACTAR-TPC collaboration

Active targets and TPC

- Based on TPC concept from particle physics

- The **Gas is also the target (not always adapted for detection)**: IKAR, CENBG TPC, MAYA…
- **Advantages vs thick target:**
  - ➢Energy loss like a thin target
  - ➢Trajectory reconstruction in 3D
  - ➢ High efficiency (gas thickness…)
  - ➢ Low beam intensity
  - ➢ Low energy threshold
  - ➢ Direct study on beam energy dependance



- **Nuclear physics interest:**

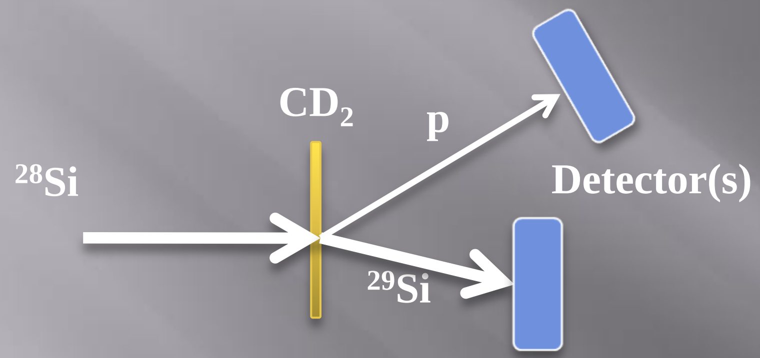
- Structure/reaction dynamics of unstable nuclei
- Weakly-bound many-body systems
- Nucleosynthesis
- Resonant reactions
- Exotic decays…

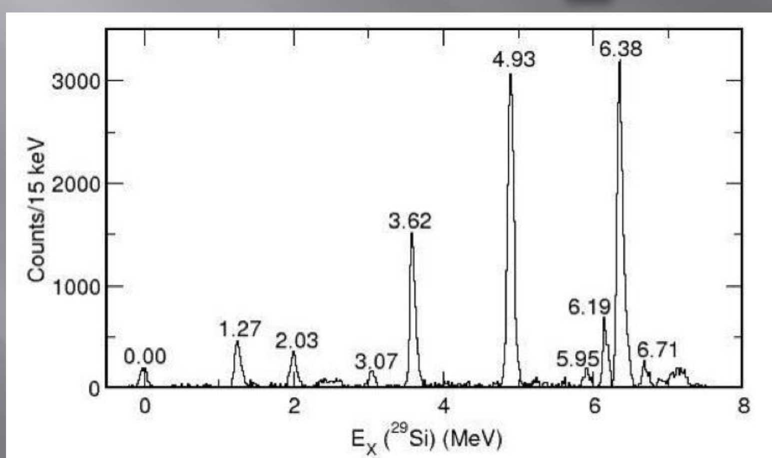
Accepted Experiment GANIL:

- ***Resonant proton elastic scattering on ^{17}F and 2p-decay of excited ^{18}N (GF. Grinyer et al.)***
- ***Spectroscopy of the unbound proton rich nucleus ^{33}K (B. Fernandez et al.)***
- ***Study of p-p correlation in 2p radioactivity of ^{54}Zn and ^{48}Ni with ACTAR TPC***

Conventional Techniques

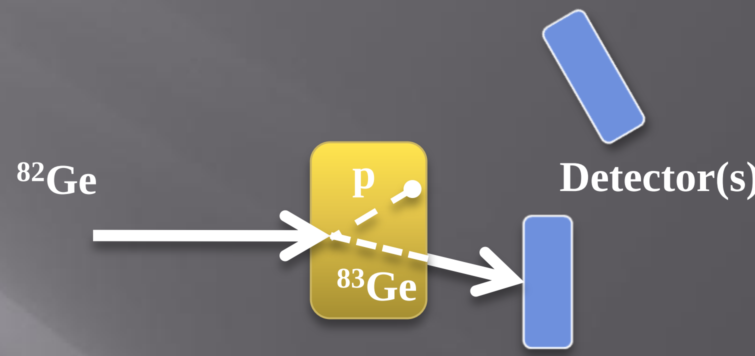
- Thin target experiments:
  Need very high rates, not exotic nuclei

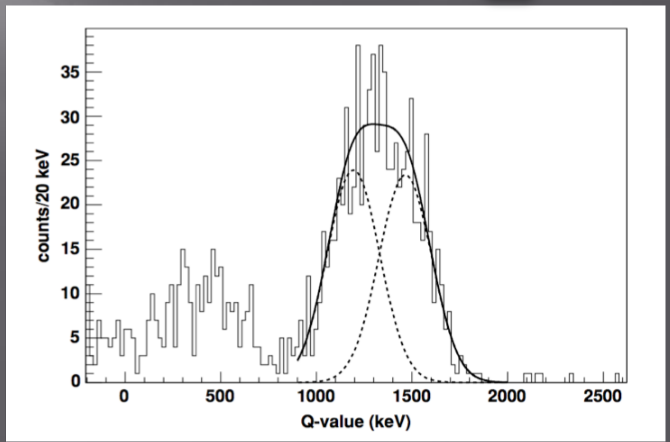




*J.C.Lighthall *et al.* Nucl. Instrum. Meth. A **622** 97 (2010)

- Thick target experiments:
  Significant losses in the target itself





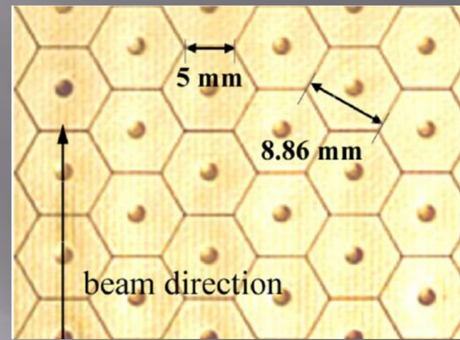
*J.S.Thomas *et al.* Physical Review C **71** 012302(R) (2005)

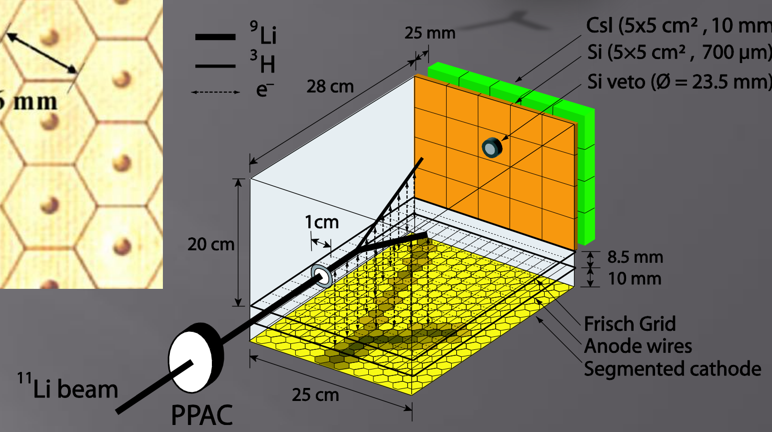
Need thick targets *and* excellent resolution

MAYA @GANIL

Operational since 2003

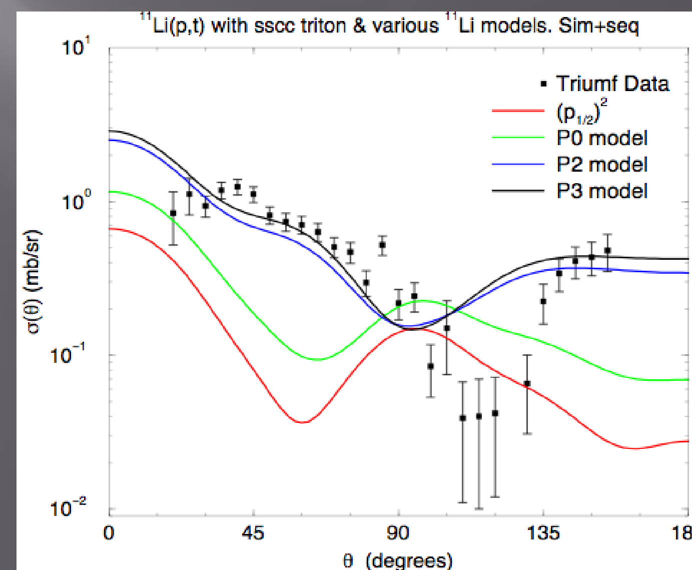
- Wire chamber
- Gassiplex electronics
- Si/CsI wall
- 8 mm hexagonal pads





C.E. Demonchy et al., Nucl. Instrum. and Meth. A 583 (2007) 341

Beam/Energy [MeV/u]	Date	Reaction	Gas	Mixture [%]	Pressure [mbar]
^{8}He @ 3.9	2003	^{8}He(p,p')	C_4H_{10}	100	1000
^{8}He @ 3.5	2003	^{8}He(p,d)^{7}He	C_4H_{10}	100	525
^{25,26}F @ 50.0	2004	^{25}F(d,^{3}He)^{24}O	D_2	100	2200
^{56}Ni @ 50.0	2005	^{56}Ni(d,d')	D_2	100	1050
^{8}He @ 15.4	2005	^{8}He(^{12}C,^{13}N)^{7}H	C_4H_{10}	100	30
^{11}Li @ 3.6	2006	^{11}Li(p,d)^{10}Li	C_4H_{10}	100	150
		^{11}Li(p,t)^{9}Li	C_4H_{10}	100	664
^{6}He @ 3.5	2007	^{6}He(p,n)^{6}Li	C_4H_{10}	100	107
^{68}Ni @ 50.0	2010	^{68}Ni(d,d')	D_2	100	1040
		^{68}Ni(α,α')	He + CF_4	98/2	500
^{56}Ni @ 50.0	2011	^{56}Ni(α,α')	He + CF_4	98/2	1200
^{8}He @ 15.4	2011	^{8}He(^{19}F,^{20}Ne)^{7}H	He + CF_4	10/90	175
^{12}Be @ 3.0	2012	^{12}Be(p,p')	C_4H_{10}	100	100

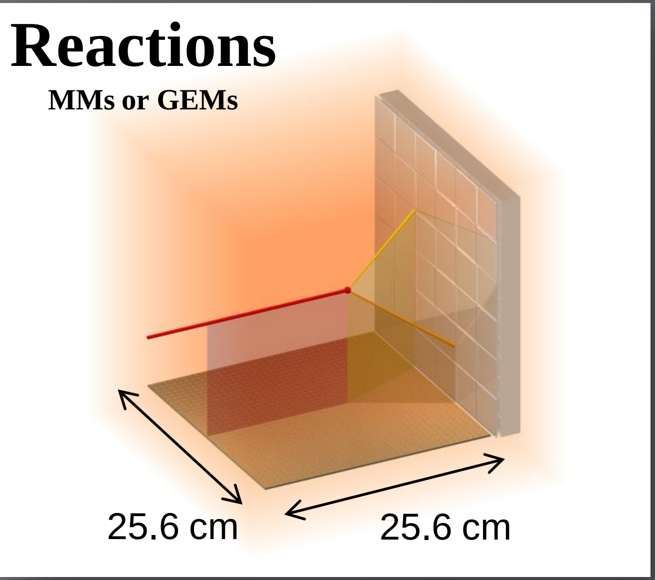


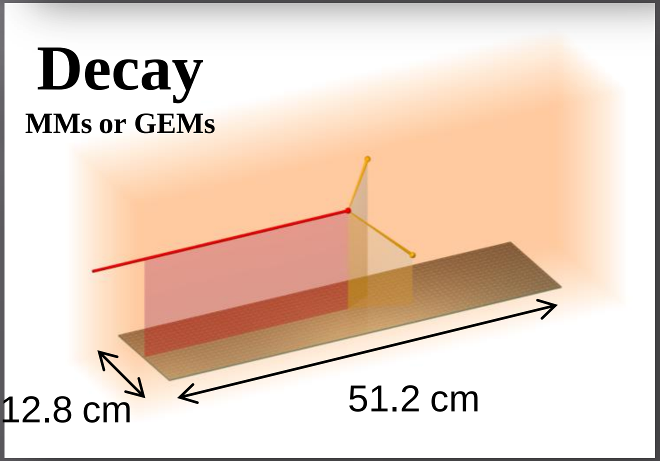
I. Tanihata *et al.*, Phys. Rev. Lett. **100**, 192502 (2008)

Next Generation: ACTAR TPC

- **What has to be improved :**
  - Counting rates
  - Multi-particules
  - Low energy threshold
  - Spatial resolution (angular and range)
  - Reconstruction efficiency (granularity+Si walls)
  - New electronics (16k channels)
  - Energy dynamics (pad polarisation or electrostatic mask)

Different physical geometries: Reaction and decay





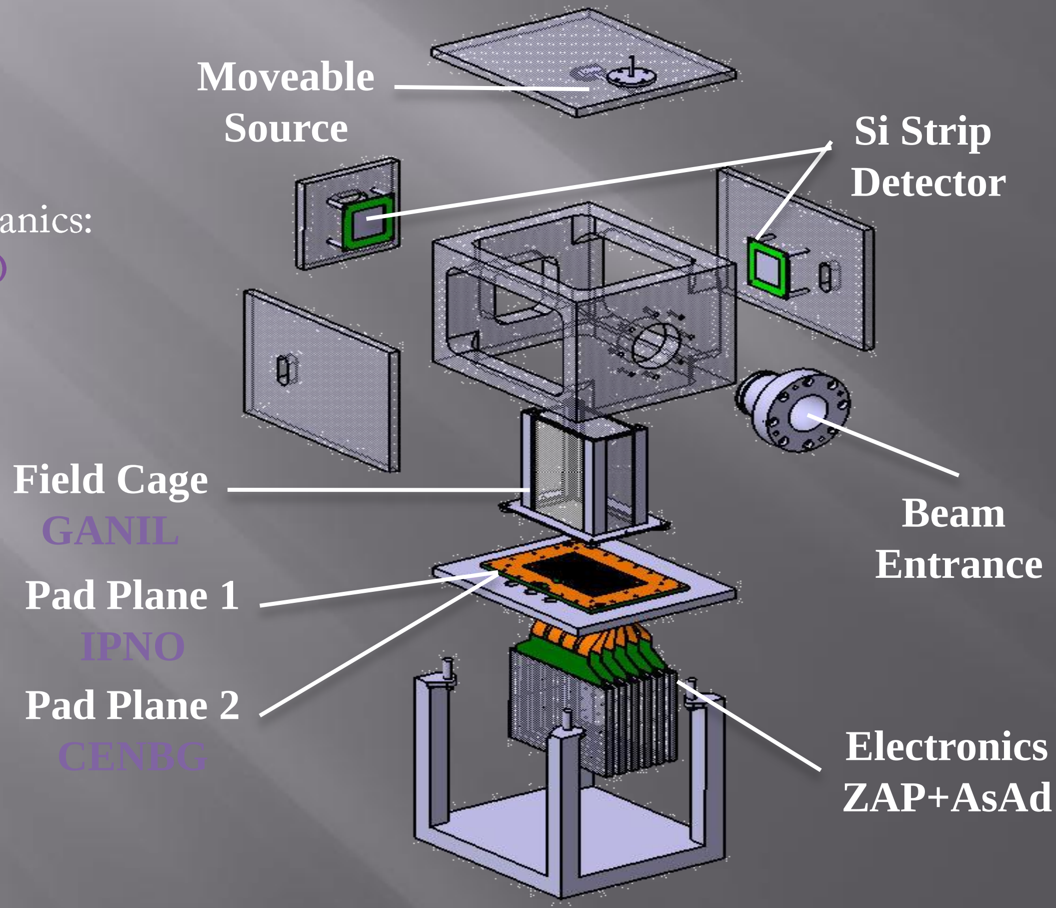
- Specifications of final detector
  - Micromegas/ GEM (~650 cm^2, pad size 2×2 mm^2)
  - GET (General Electronics for TPC's) for 16,384 channel:
- 2012 - 2016 Research and Development
  - Tests of prototype detector (Micromegas & GEM)
  - Building of demonstrator and tests
  - Physics simulations (ACTARsim)
  - GET electronics development
  - ERC grant for G.F. Grinyer and ACTAR TPC (fév. 2013)

ACTAR-TPC demonstrator

Need for a 2k channels detector to address different questions (≈12×7 cm^2):

- Mechanical solution for the pad plane
- Field cage
- Source & beam tests with GET electronics

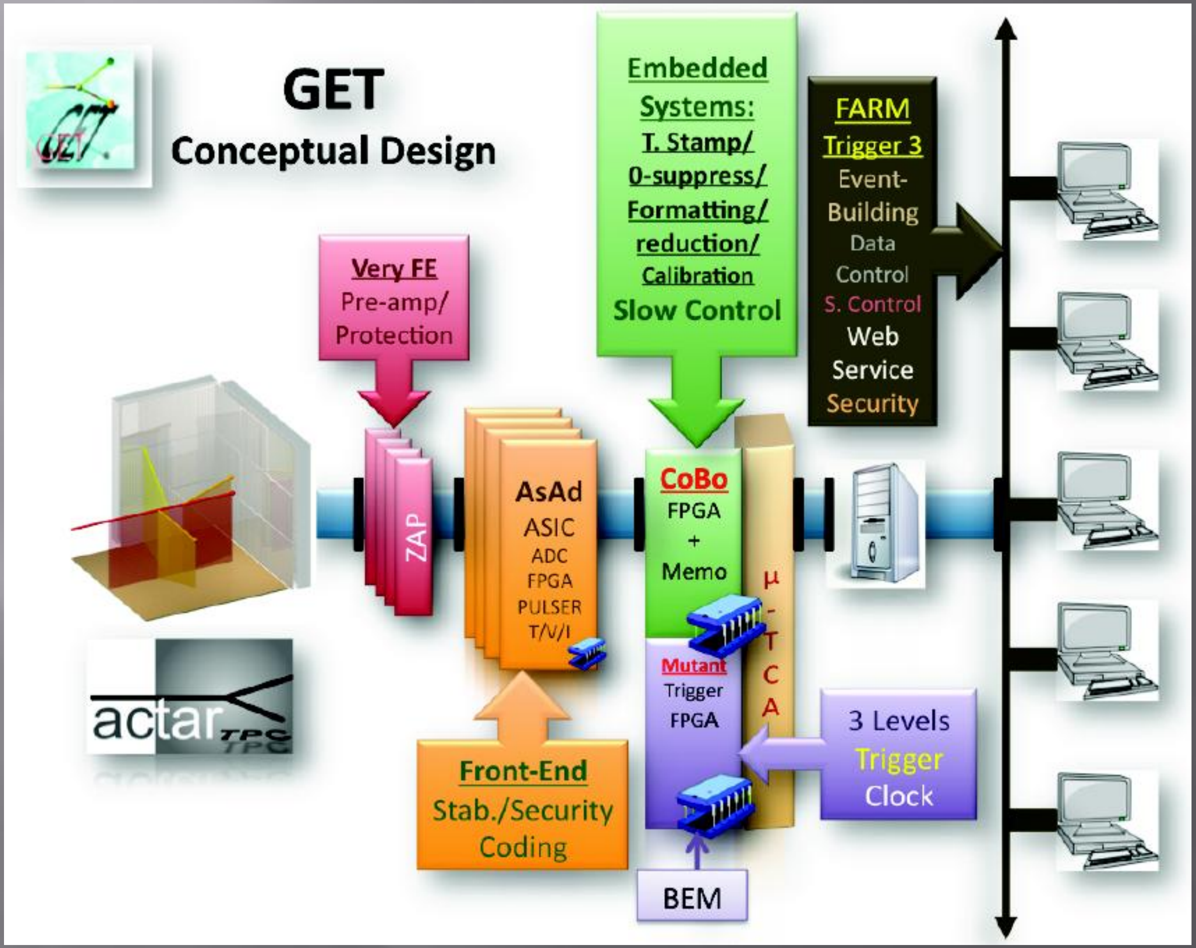
Mechanics:
IPNO



ACTAR TPC Electronics

Use GET electronics: Wave-digitizer using 511 analogue memory cells @ 100 MHz max
Internal/self trigger and zero suppression for reducing data traffic

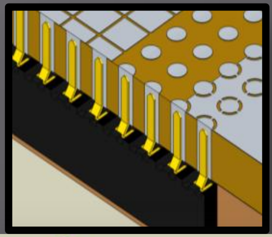
ANR Funded Project (Nov. 2009 − Oct. 2013; IRFU/CEA, CENBG, GANIL, MSU)

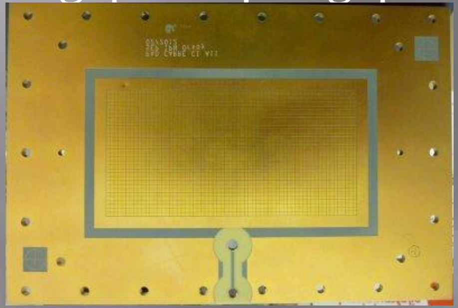


E.C. Pollaco et al., Physics Procedia 37, 1799 (2012)

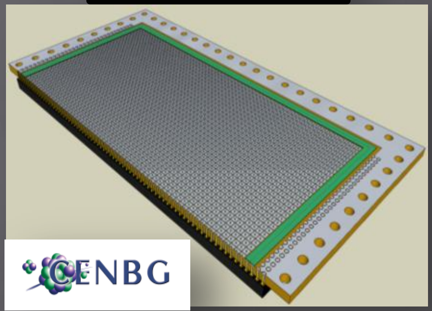
Demonstrator pad planes

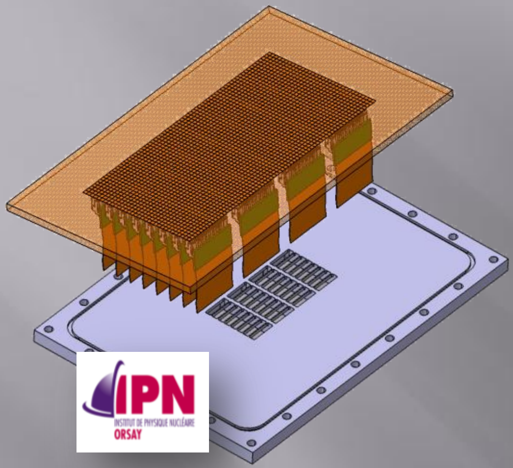
- Gas/air interface (vacuum resistant, no leaks…)
- 2048 2×2 mm² pixels and 16384 for the final detector
- Connectics just behind the pad plane to minimize rounting time, pad plane size and capacitance
- Micromegas of 220 μm gap/110 μm gap

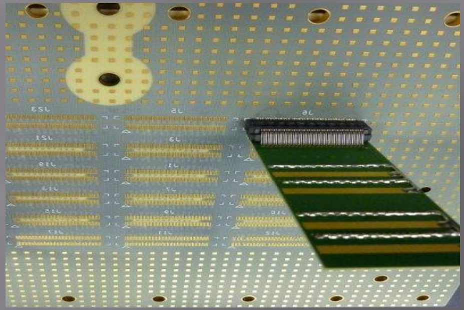


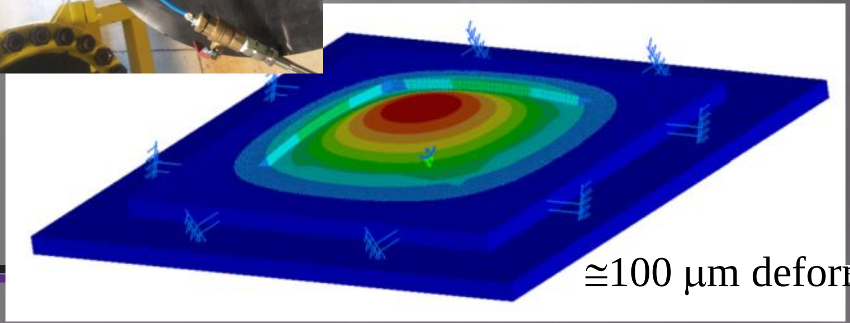


2 solutions studied

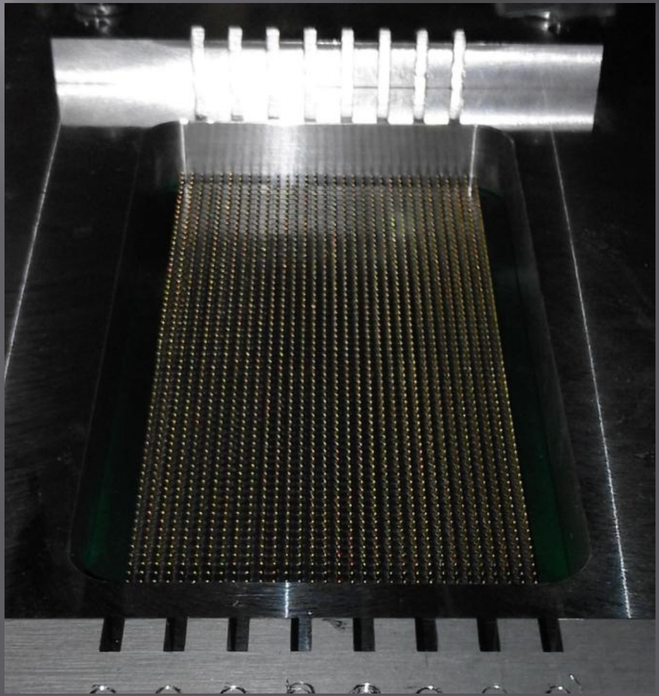








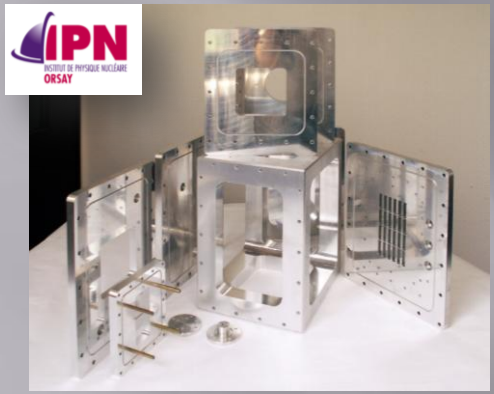
≅100 μm deformation

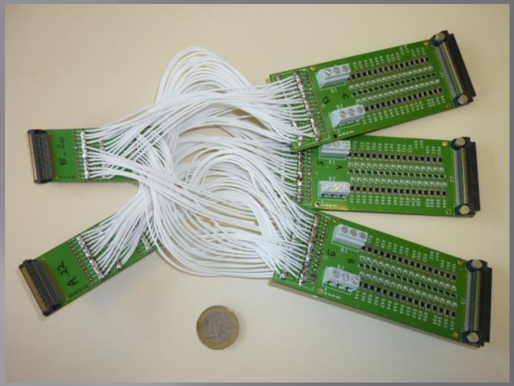


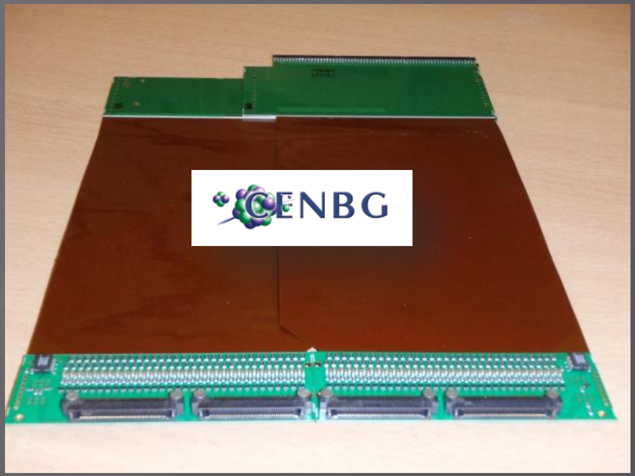
Made at CERN

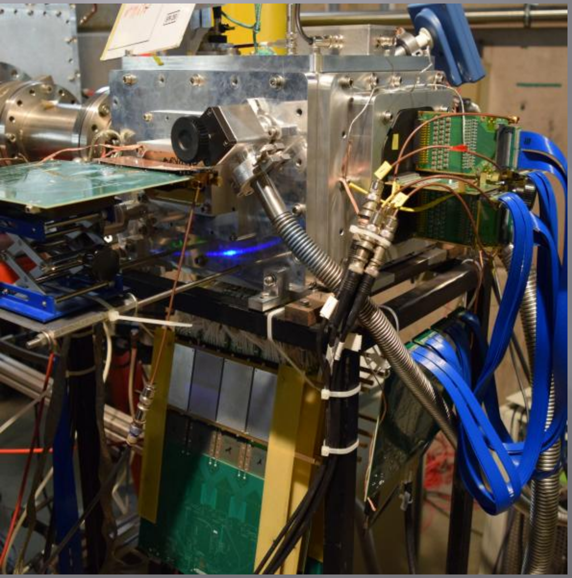
Courtesy of P.Rosier (IPNO) & J.Pibernat (CENBG)

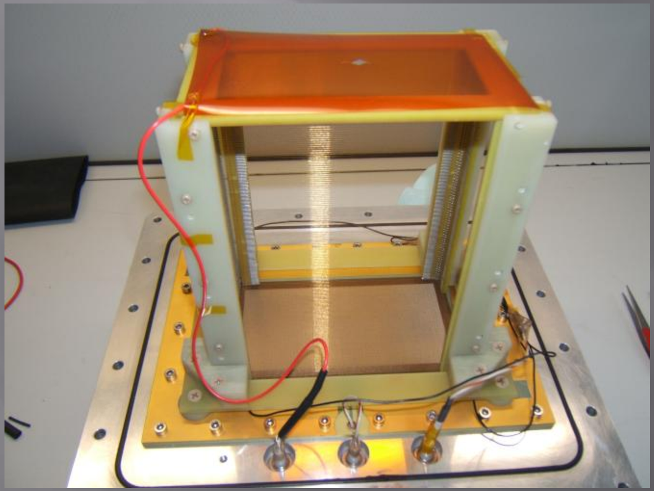
ACTAR TPC Demonstrator images









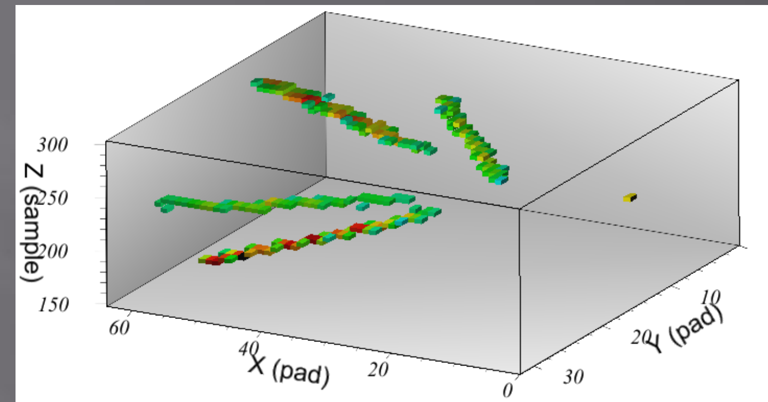


First tests and experiments

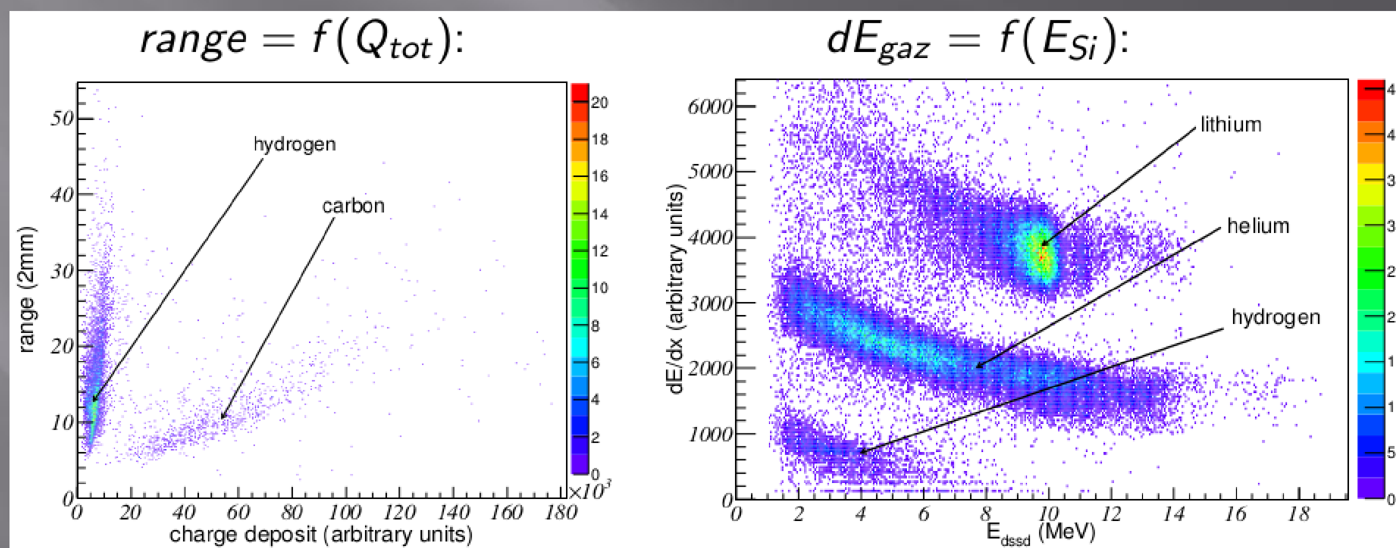
2 experiments at ALTO@Orsay in 2015:

- Study of cluster states in ^{10}B through ^{6}Li on ^{4}He gas target
- Hoyle state in ^{12}C through ^{12}C on ^{4}He gas target

2 beam tests at GANIL in 2016 with ^{58}Ni and ^{24}Mg at 5MeV/n in pure iC_4H_{10} et 100 mbar and $He+iC_4H_{10}$(10%) at 200 mbar respectively



Still under analysis



^{58}Ni on an iC_4H_{10} target.

^{6}Li on an ^{4}He target.

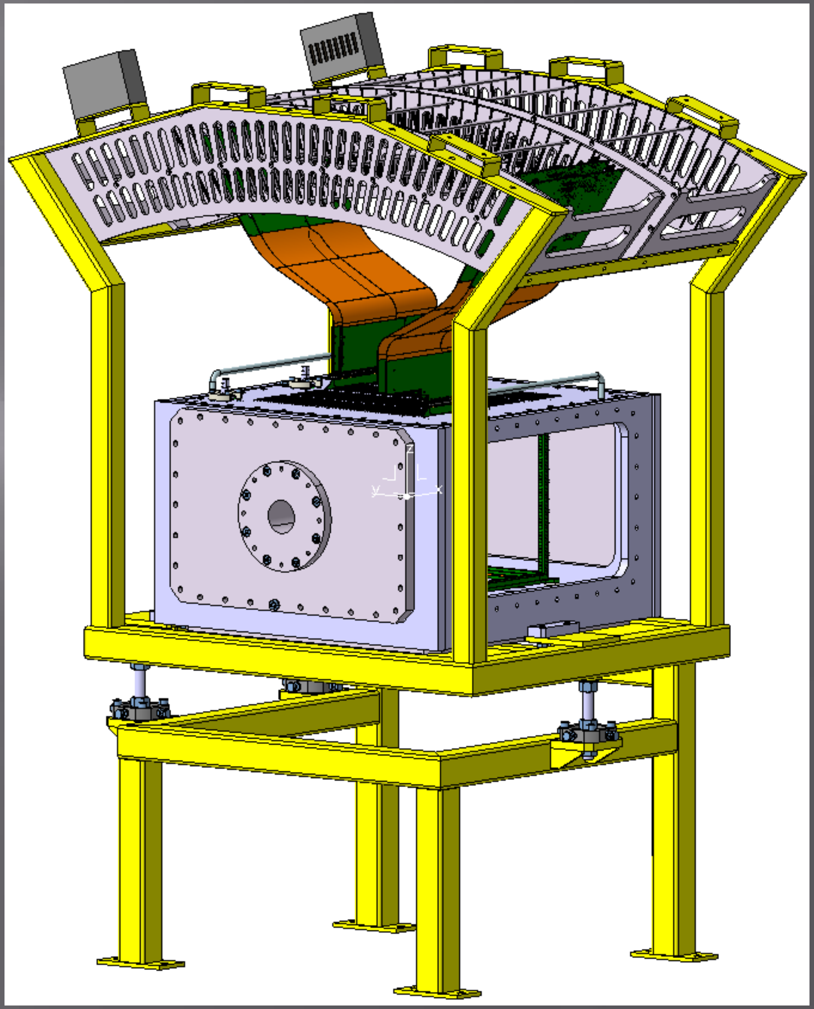
Courtesy B. Mauss (GANIL)

ACTAR TPC final design

- To be ready mid-2017

- Vaccum chamber and flanges
- Feedthroughs; high voltage, vacuum, source…
- Electronic rack for Asad cards
- Chassis
- Entrance window
- Drift cage
- Anode routing
- Calibration procedures

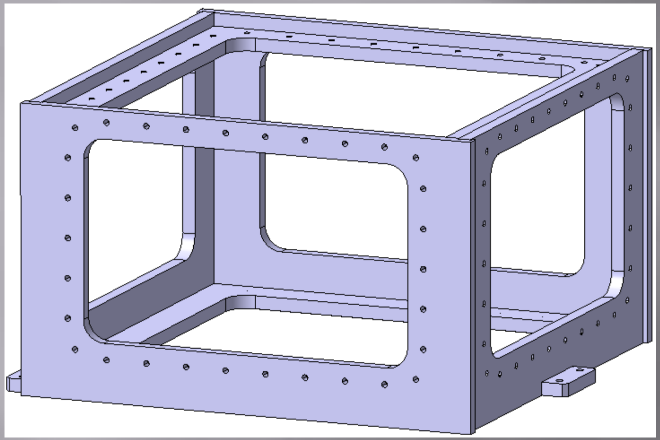
…



On the courtesy of P. Gangnant

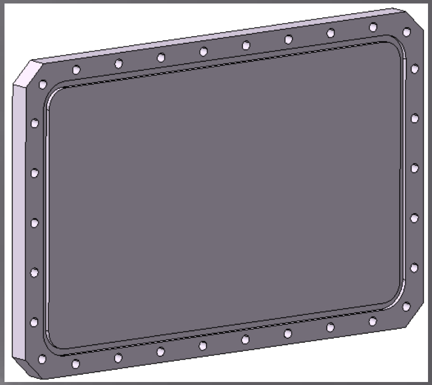
ACTAR TPC CHAMBER

- *Stainless steel machined welded frame (+/-1 bar)*
- *2 Identical opening on the top and bottom*
- *4 Identical opening on the sides (same flanges)*

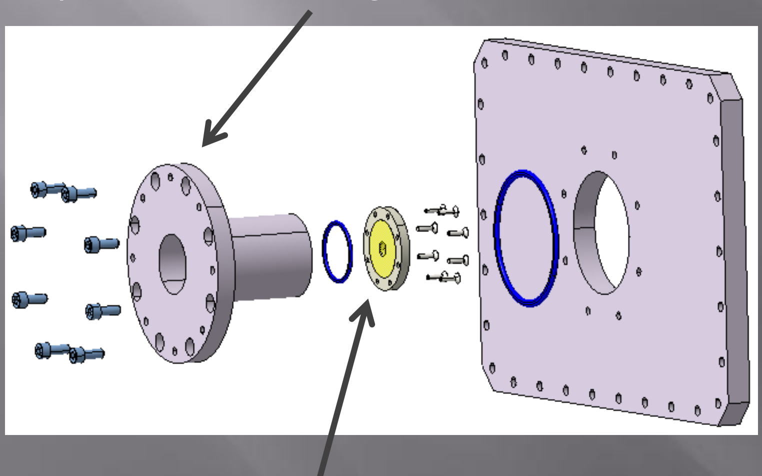


SIDE FLANGES:

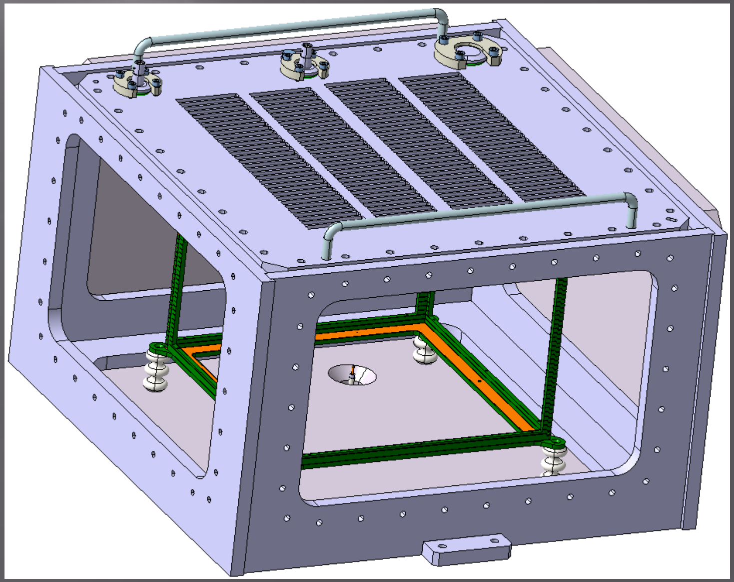
- *20 mm thickness*
- *Will be used for Silicon wall, gas feedthrough, source holders,…*



Adaptor beam line/flange ISO-F DN100



window: mylar…



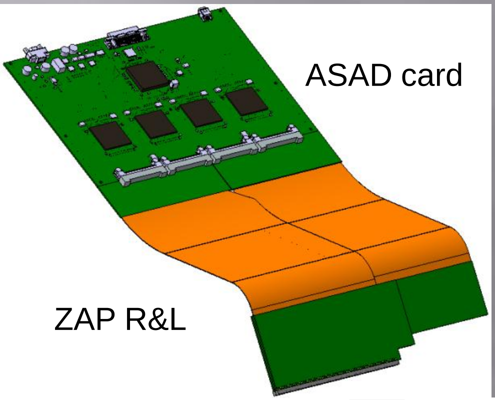
ACTAR TPC: ELECTRONICS RACK AND CHASSIS

ASAD RACK:

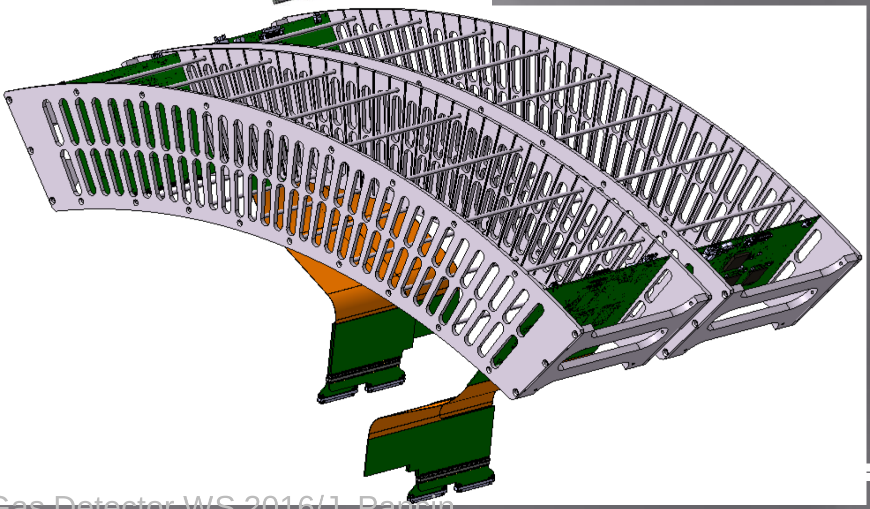
- *2x Parallel raws of 32 ASAD cards*
- *ASAD cards are arranged in semi-circular shape to use same ZAP lenght*
- *Eventually 2x32 Adapter cards between Zap and Anode PCB*

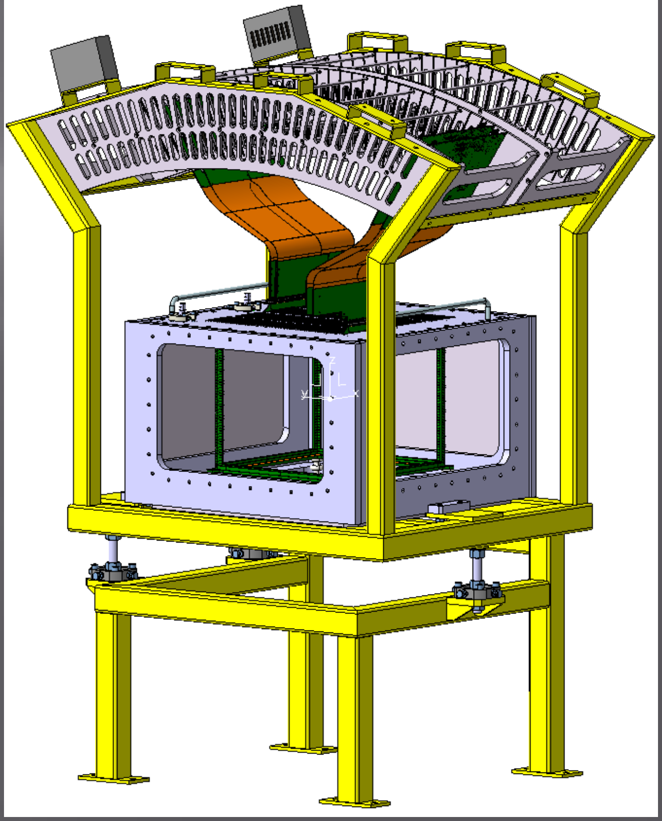
CHASSIS:

- *Steel machine welded frame*
- *2 Parts: 1 fixed on the floor and 1 ajustable +/5mm on XYZ axis*
- *The ajustable part supports : ACTAR, ASAD rack, vent. cooling, and low voltage distribution*

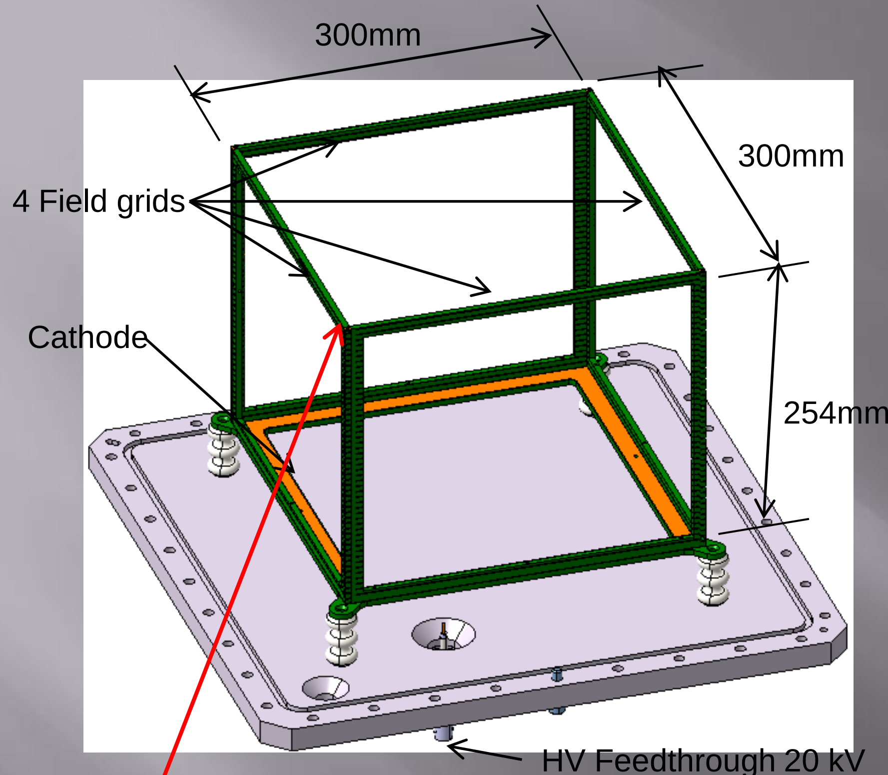


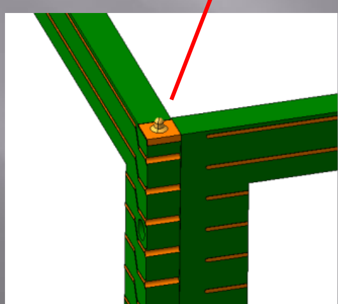
CENBG (J.Pibernat and Co)

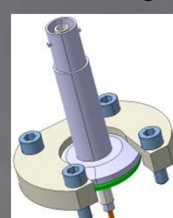




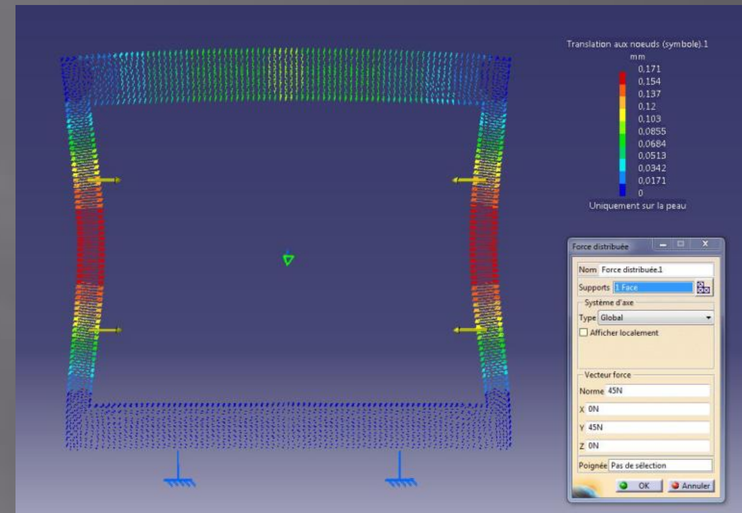
ACTAR TPC DRIFT CAGE (1)

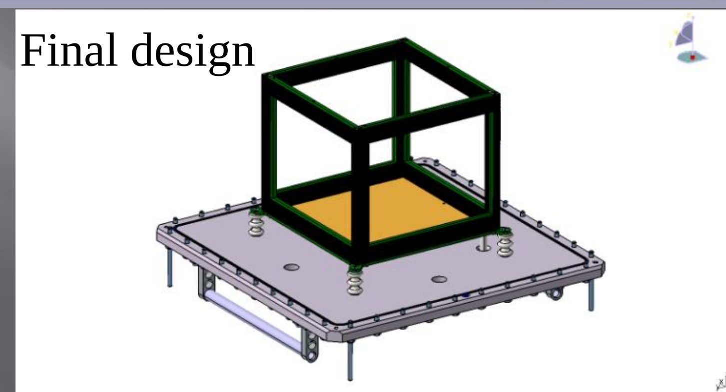






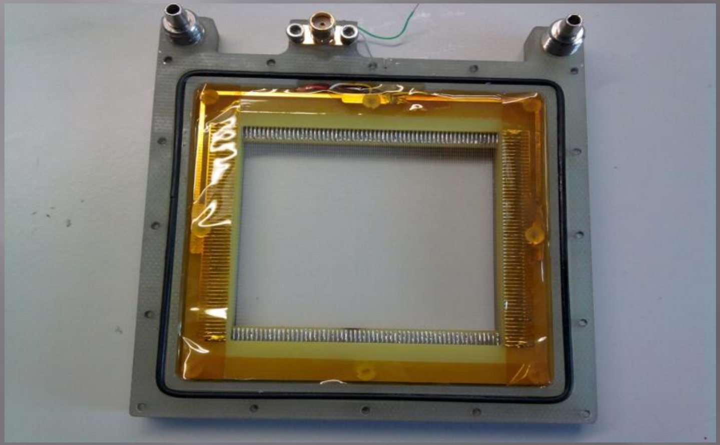
ZOOM Gold touch point:
On each grid , output voltage 0.5kv,
In contact with the Anode PCB

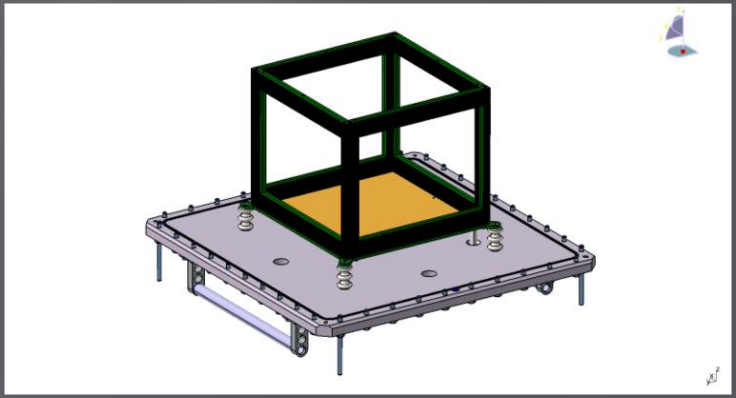




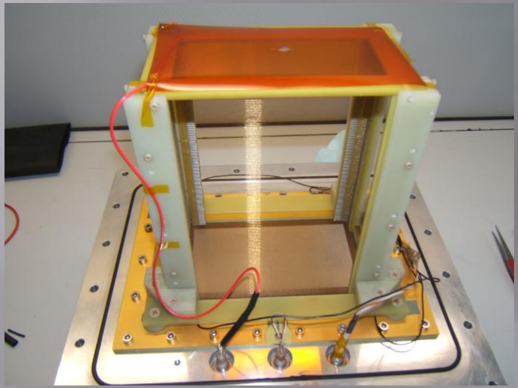
- *Dark zone minimized*
- *4 identical field grids*
- *Mechanically independant of the Anode*
- *No wire to plug*
- *Ancillary detectors position*
- *Corona ring*

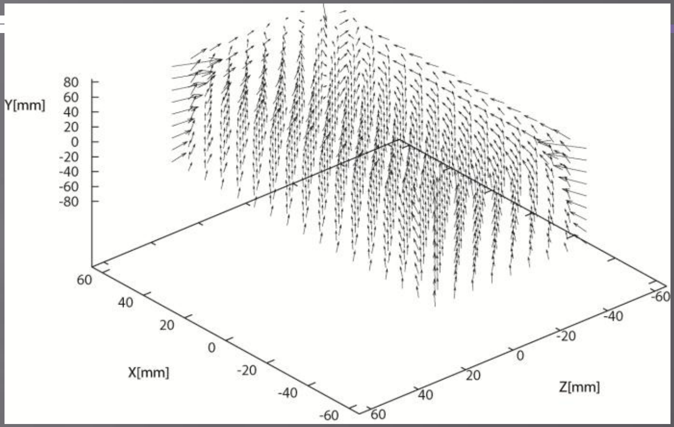
Thin wire integration

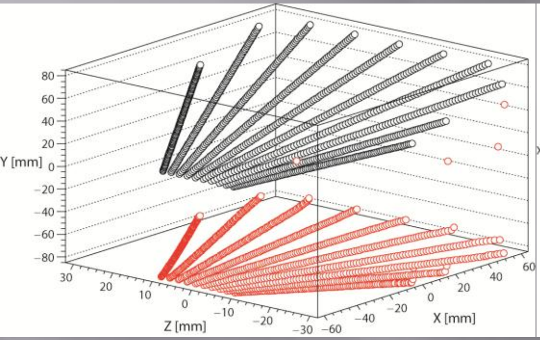


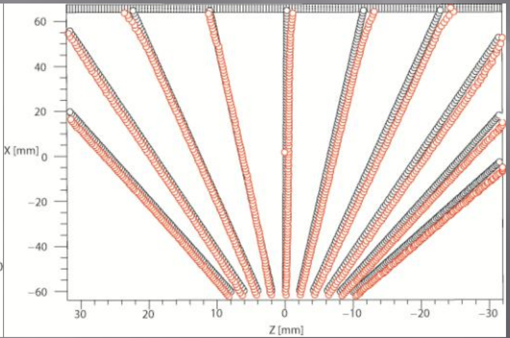


ACTAR TPC DRIFT CAGE (2)
ELECTROSTATIC SIMULATIONS

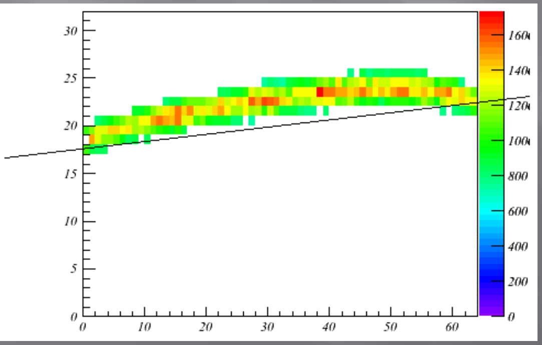


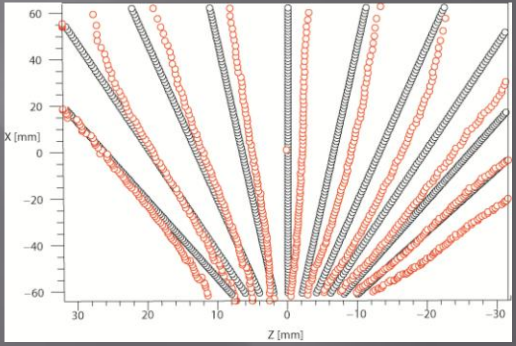


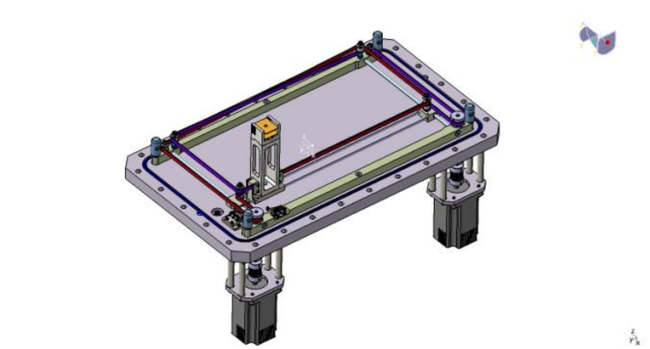




- Electrostatic simulations performed with SIMION, GARFIELD and OPERA in agreement with math. calculations
- Some effects are correctly reproduced
- Transversal elec. field ×5 to reproduce all effects
- Tests performed showed that a double grid 1mm/2mm pitch should be enough



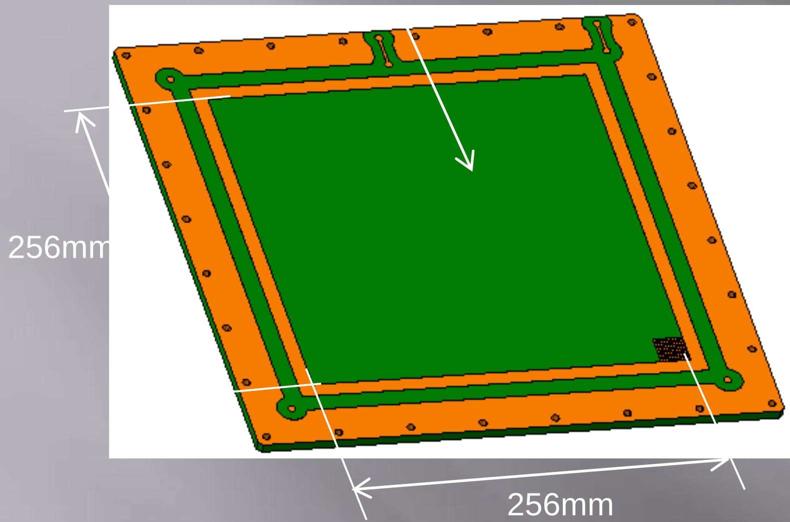




X,Y source table

ACTAR TPC ANODE (1)

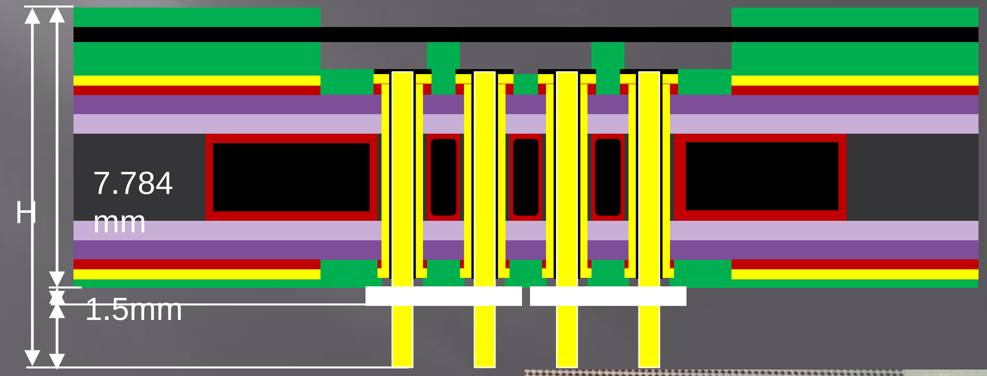
128x128 Pads 2x2mm area

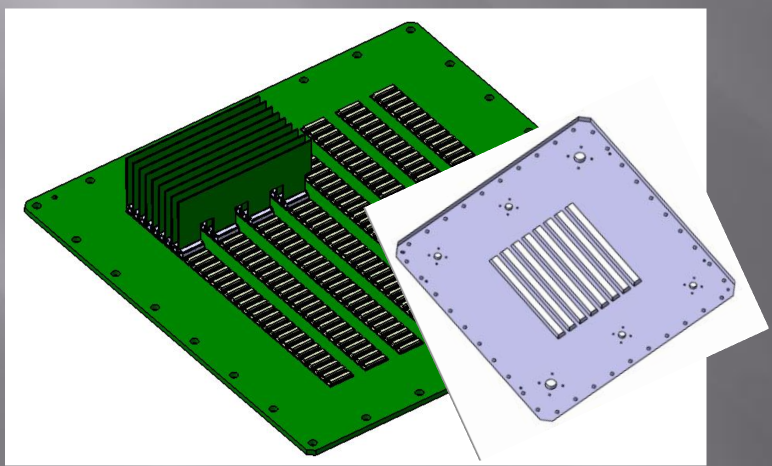


- Minimize capacitance
- Simplify the routing
- Minimize deformations and keep planeity
- Integrate the 16384 GET channels on the pad planes

We have kept the 2 solutions

J. Pibernat-CENBG

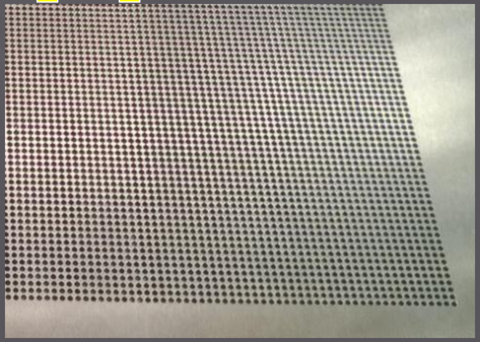




P. Gangnant/M. Blaizot-GANIL

Connecteurs JST au pas de 0.5 mm

Currently integrated at CERN



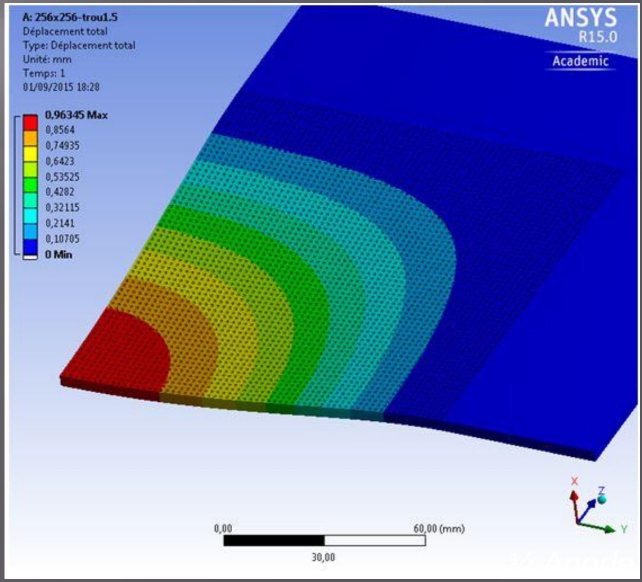
CENBG Technical Proposal :

ACTAR Anode type CENBG
Metallic frame is integrated in the anode : one part metallic frame « filled » with epoxy)

Mechanical Simulation by Matthieu MICHEL (GANIL)
=> to check for deformation of the part for different thickness and material

For stainless steel 7mm thickness:
0.15mm deformation for 1000mbar pressure

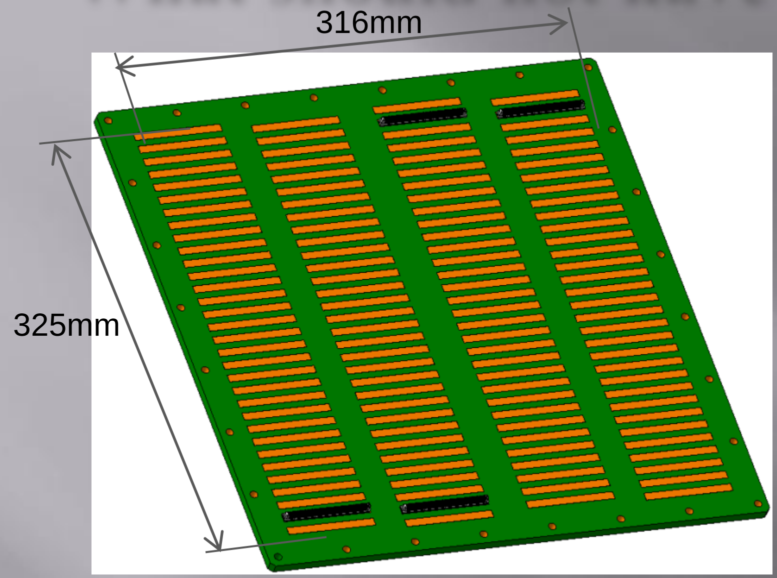
	Aluminium	Inox
Epaisseur 3.8	2.7	1
Epaisseur 5	1.2	0.42
Epaisseur 6	0.7	0.25
Epaisseur 7	0.43	0.15



PCB

ACTAR TPC ANODE (3)

What should not have be done…

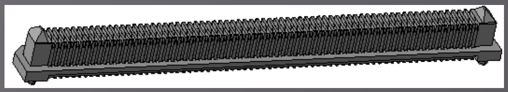


4x32 raws of connectors

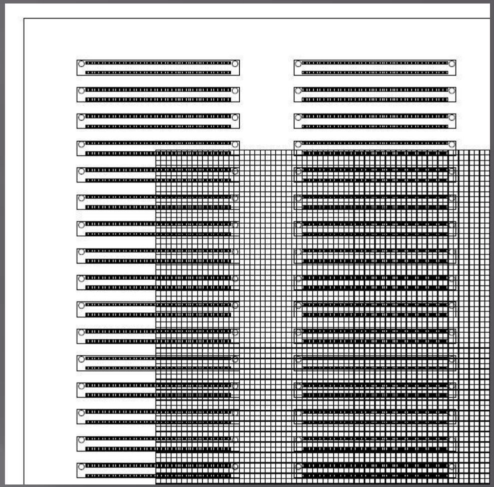
*Located on a **bigger area** than the pads area*

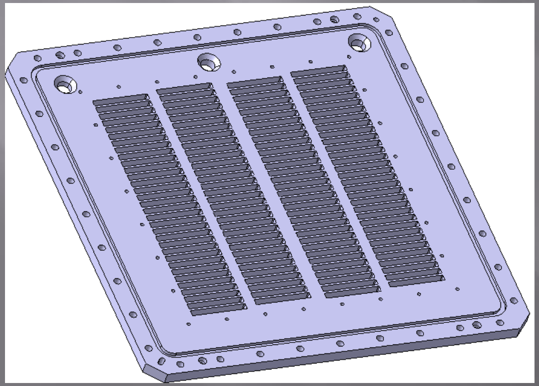
To place all connectros and sustain pressure diff.

CONNECTORS SAMTEC ERM8/ERF8



Pitch: 0.8mm, Contacts

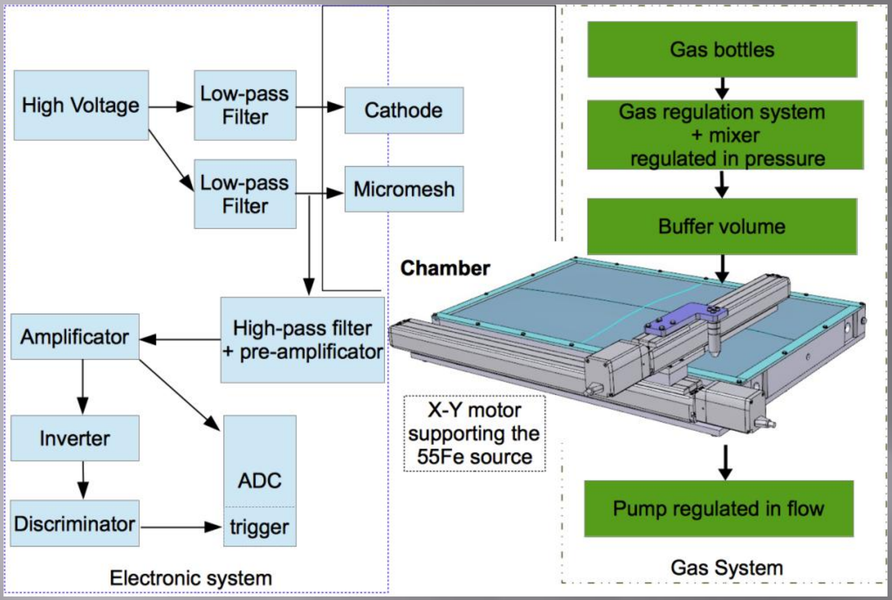


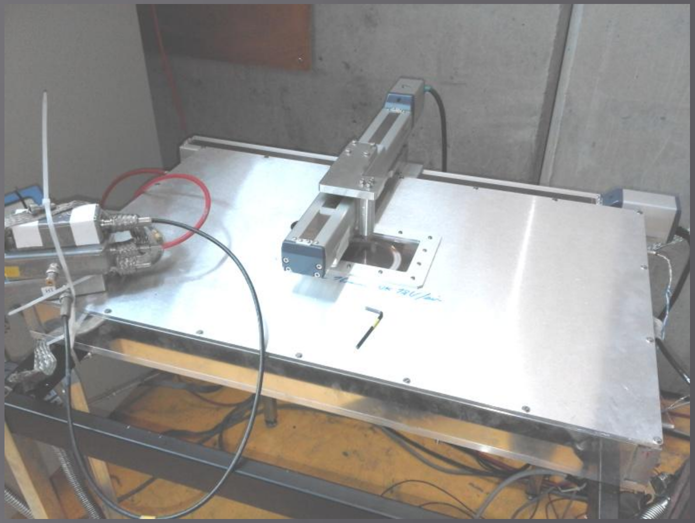


Actar Anode type IPNO-GANIL, realized by Maria BLAIZOT (GANIL)

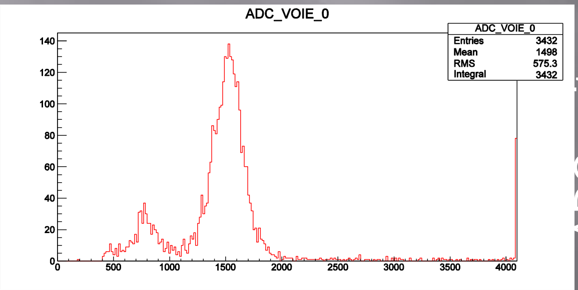
- *20 Layers (9 ground and 11 signals)*
- *Between 4.5mm &6.4mm thickness*
- *A nightmare to design (pads routing all different)*
- *NOT FEASIBLE…*

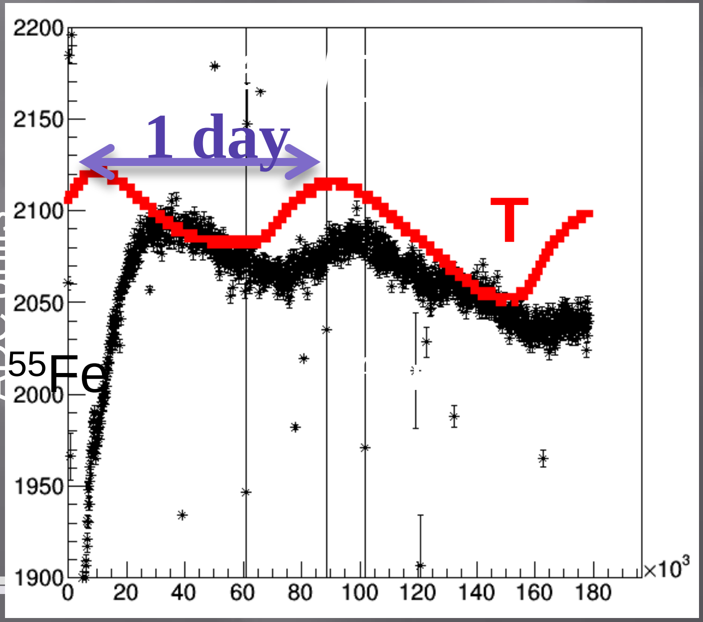
MICROMEGAS calibration





The design fits with the size of the final detectors



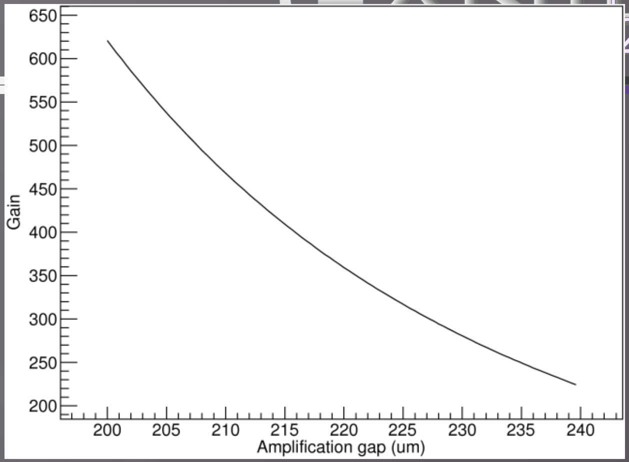


≅ 2 days for 1024 channels

No simple stability correction

⇒ Relative calibration

Micromegas calibration



Parallel plate approx. + MAGBOLTZ to calculate α coef.

Gain ∝ exp(α × d)

α the 1st Townsend coef

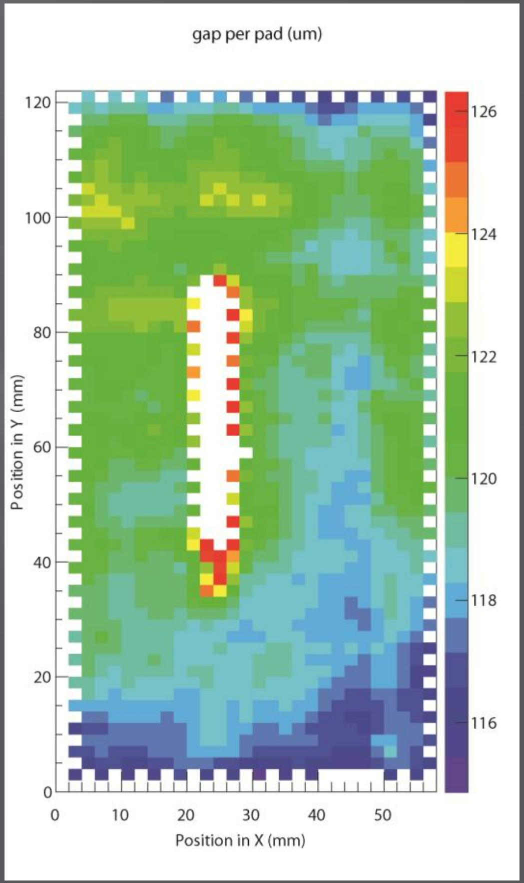
d the gap

All pad responses aligned with ref. pad

Ref. pad aligned to MAGBOLTZ gain with d_{ref}

Calculation of d_{pad} to fit local gain variation

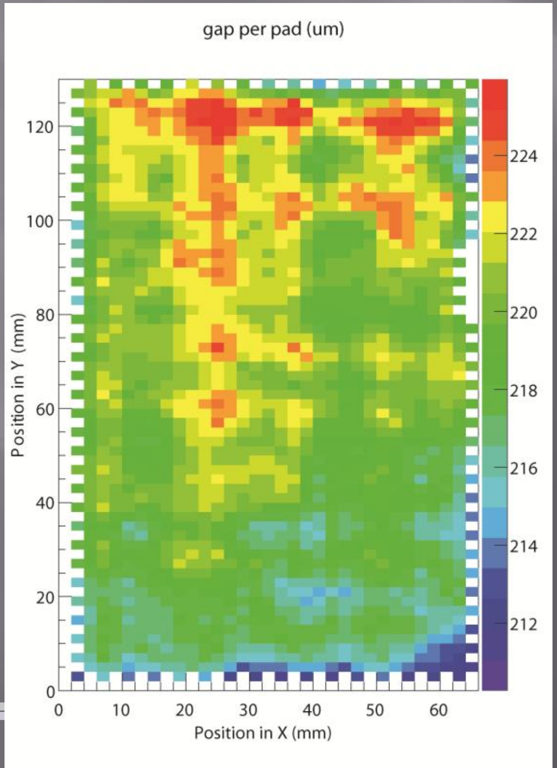
CENBG detector



Demonstrator pad plane

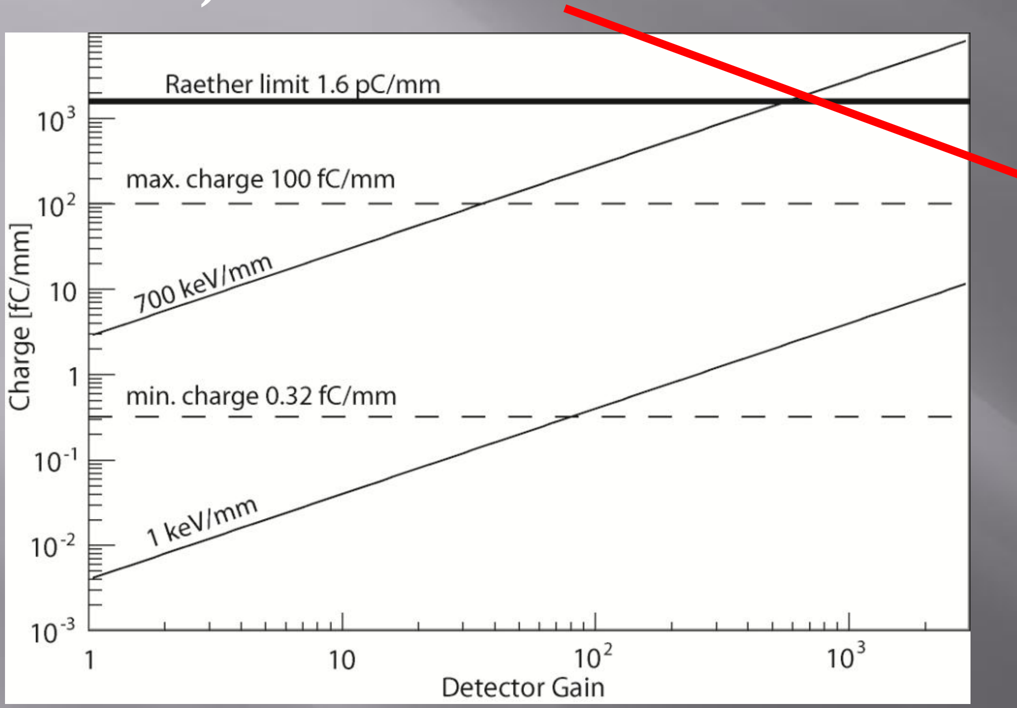
Δd ≅ +/-2.5%

ΔG ≅ +/-5%



Dynamical range (1)

Experiments with wide range of energy loss: d$E \propto z^2/v^2$ (^{80}Zn(d,p)^{81}Zn for instance):



- Dynamical range <200 due to electronics
- Raether limit 10^6-10^7 e^-/mm
- Gain degradation
- Capacitive coupling (mesh/pad)

❑ Masking completely the beam with a metallic foil over the pads or a gating grid (E. Pollacco et a/NIMA723(2013))

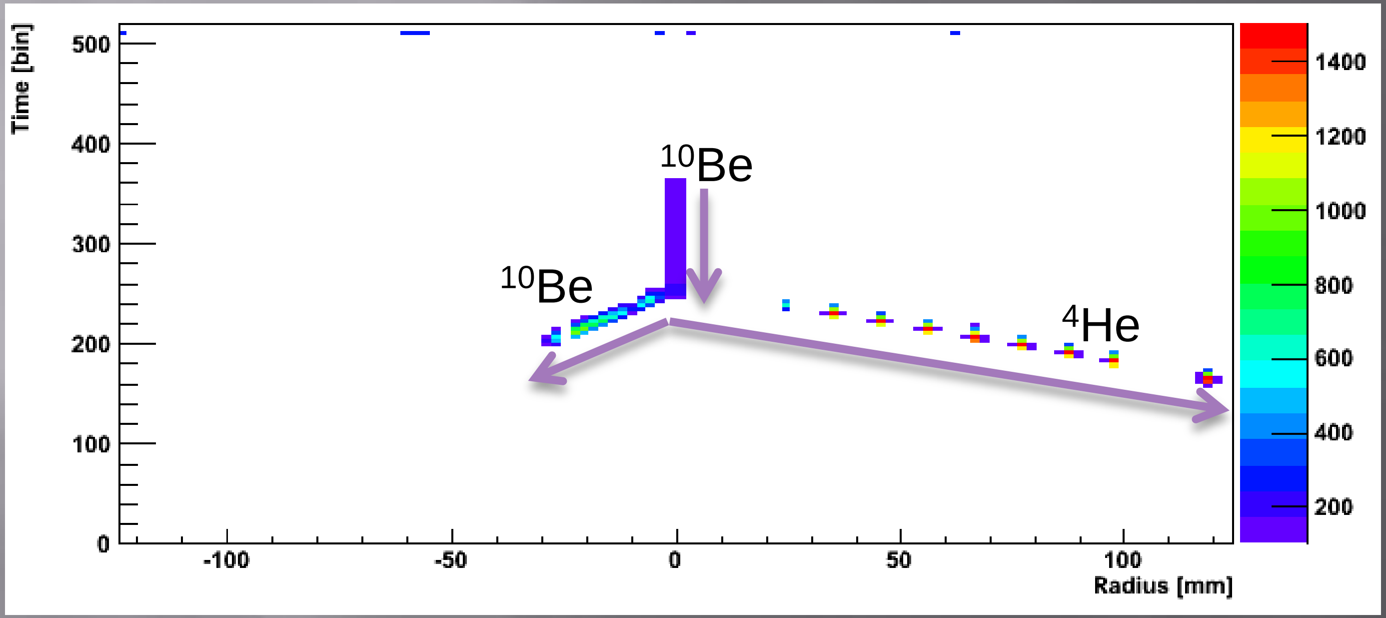
❑ Decrease the gain below the beam by pad biasing

❑ Use a tuneable mask to lower the amount of ionization electrons created by the beam

❑ Use of adaptable charge dynamics on the electronics

Dynamical range (2)

- Example of pad biasing in AT-TPC

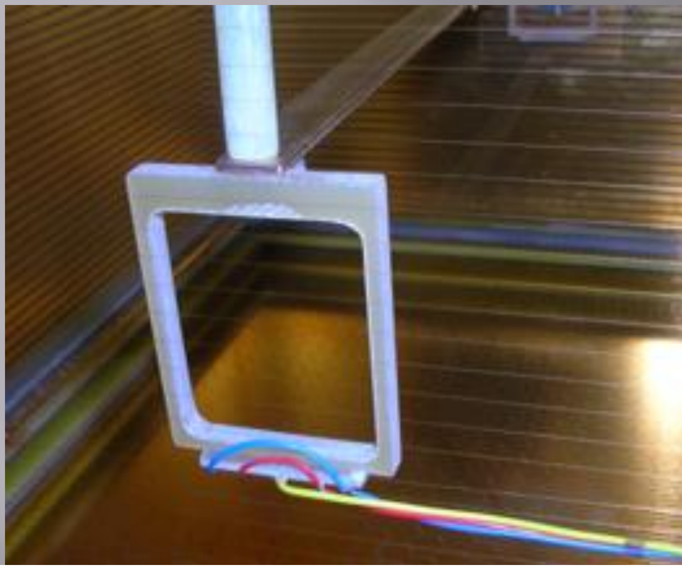


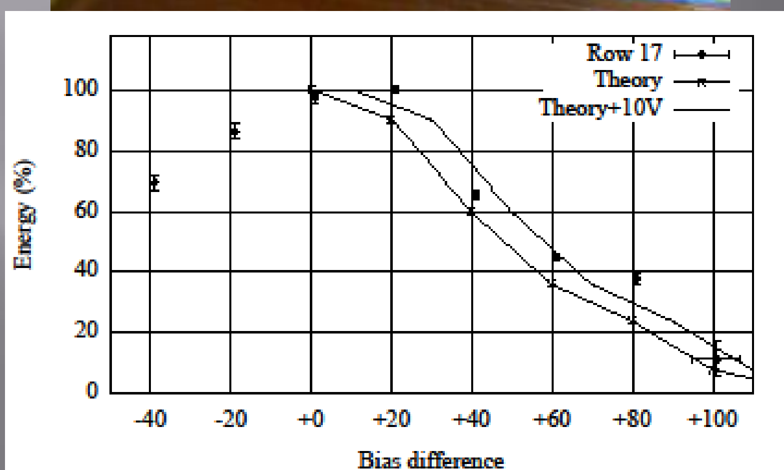
D. Suzuki *et al.*, NIM A 660, 64 (2011)

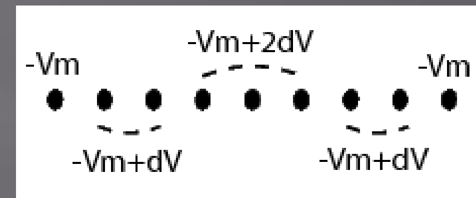
- Low gain strips: (θ, TKE) for ^{10}Be / low-energy ^{4}He
- High gain strips every five anode pads: θ for ^{4}He
- Pad biasing on ACTAR TPC central pads through ZAP cards

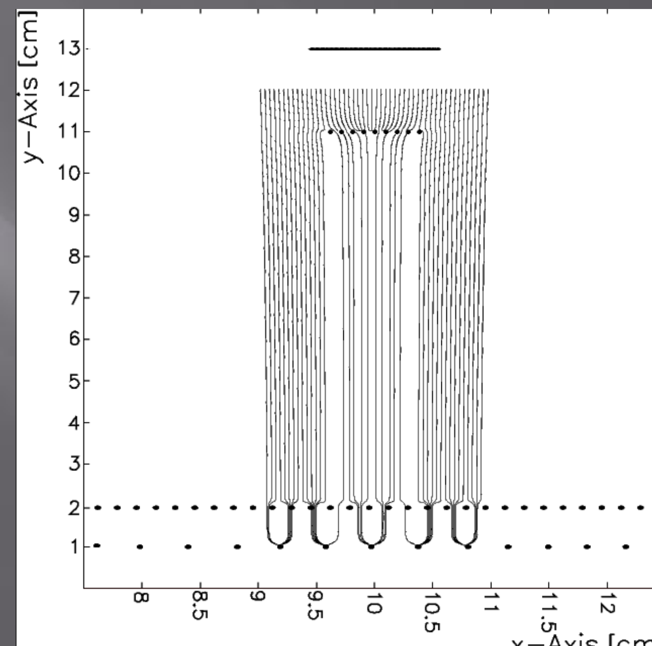
Dynamical range (3)

- Tuneable mask below the beam, factor ×10 on dynamical range





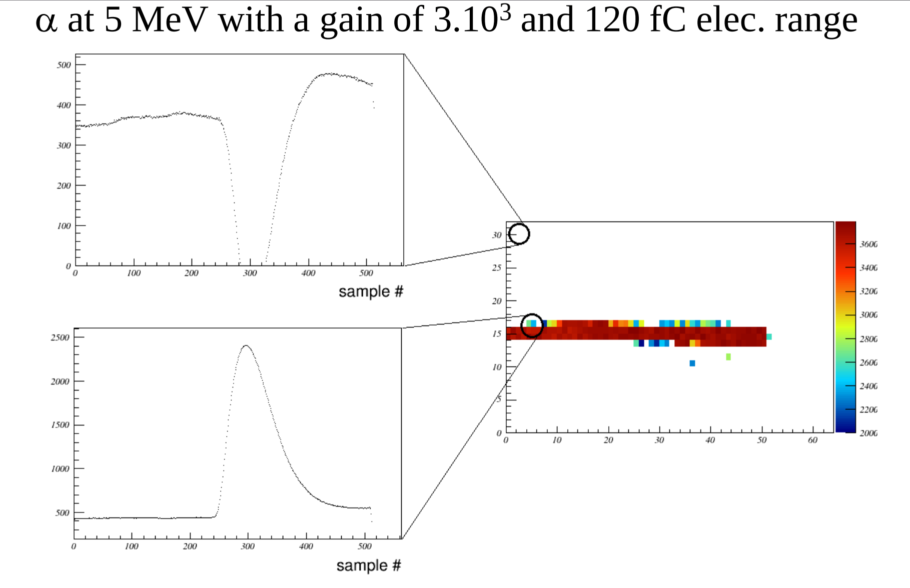




J. Pancin et al., JINST 7, P01006 (2012)

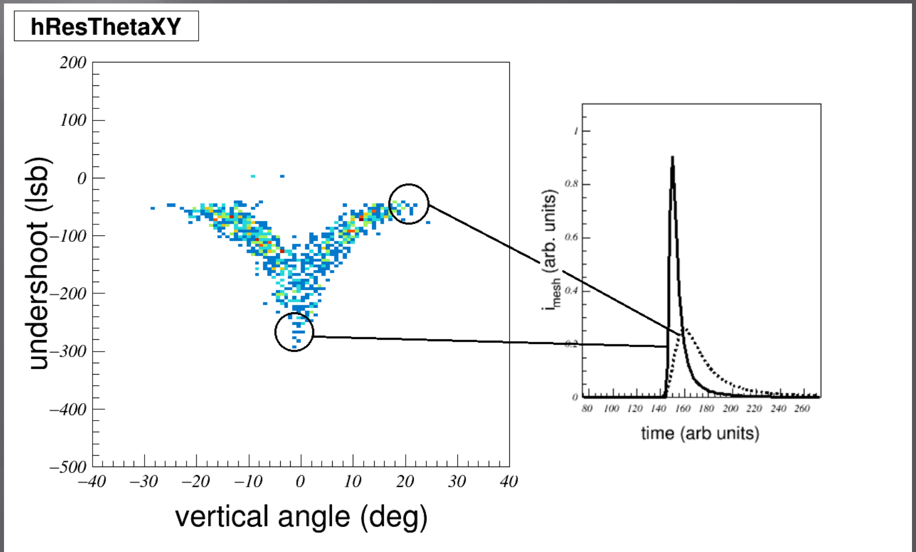
Used for ^{68}Ni(α,α') in 2011 in MAYA (M. Vandebrouck et al.,PRL113 (2014))

Dynamical range (4)

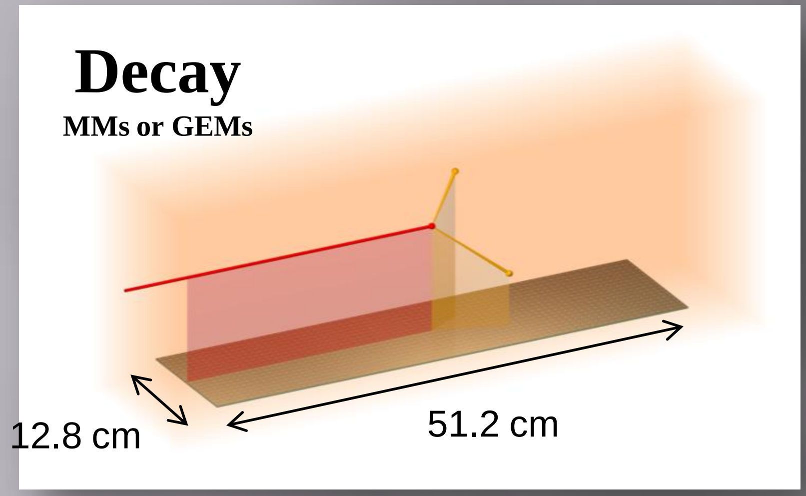


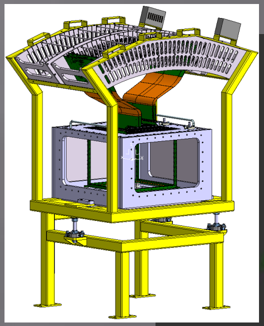
Capacitive coupling due to the mesh/pad capacitance:

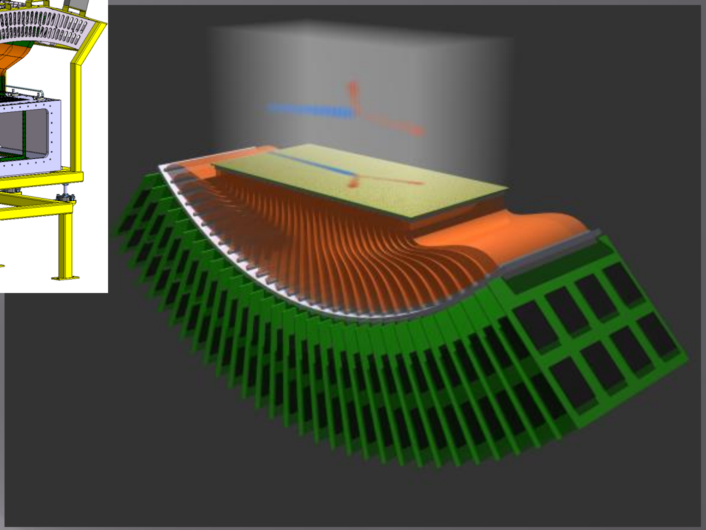
- Overshoot due to strong energy deposit
- Partial readout (thresh.)
- Can be seen with alphas
- Use of masks
- Or GEMs…(decay exp.)



ACTAR TPC Decay chamber







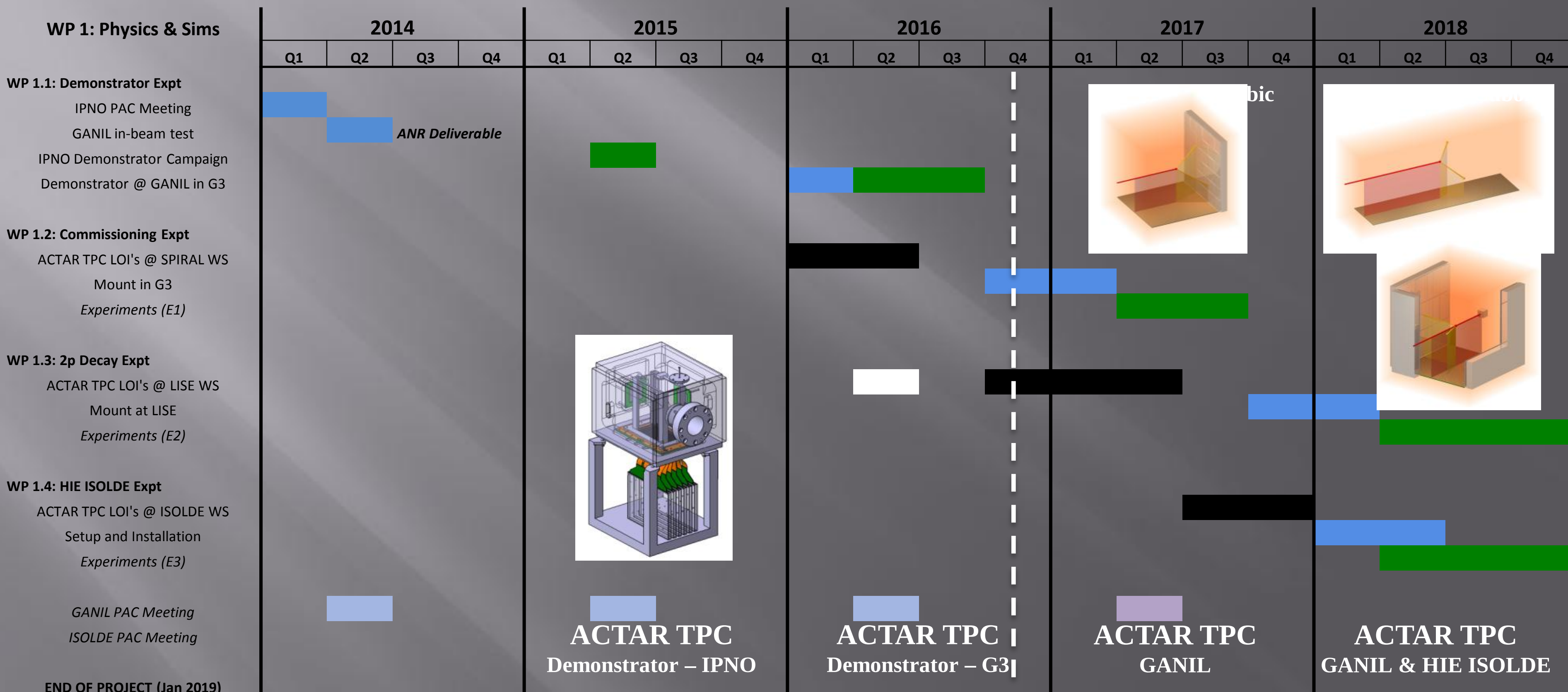
J. Giovinazzo
CENBG

- No auxilliary detector
- Increase implantation length and decrease pressure (low energy protons…)
- Same electronics
- Re-design all the detector (chassis, elec. rack, chamber…)
- Field cage (no transparency needed…)
- Strong issue on the anode (size…)
- To be designed in the forthcoming monthes (CENBG, GANIL)

ACTAR TPC Project Timeline

ERC Project Planning

- Experiments in G3/SPIRAL (2017), LISE (2018), HIE-ISOLDE (2018)

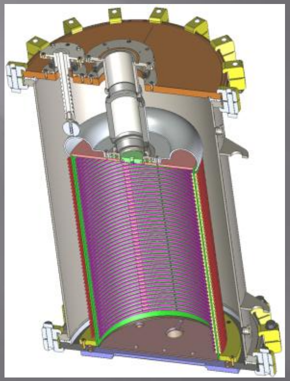


To conclude…

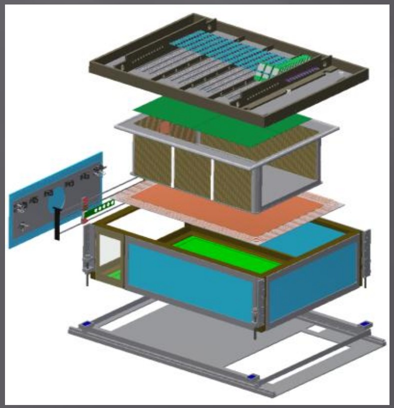
- **ACTAR TPC Demonstrator**
  - Detector tested at GANIL
  - Beam tests and 2 experiments already performed
- **ACTAR final detector**
  - Should be fully mounted for spring 2016
  - First experiments accepted
- **ACTAR decay chamber**
  - To be designed in 2017

- **Other projects around the world:**

AT-TPC @ NSCL



SAMURAÏ-TPC @ RIKEN



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- For more information: http://pro.ganil-spiral2.eu/laboratory/detectors/actartpc