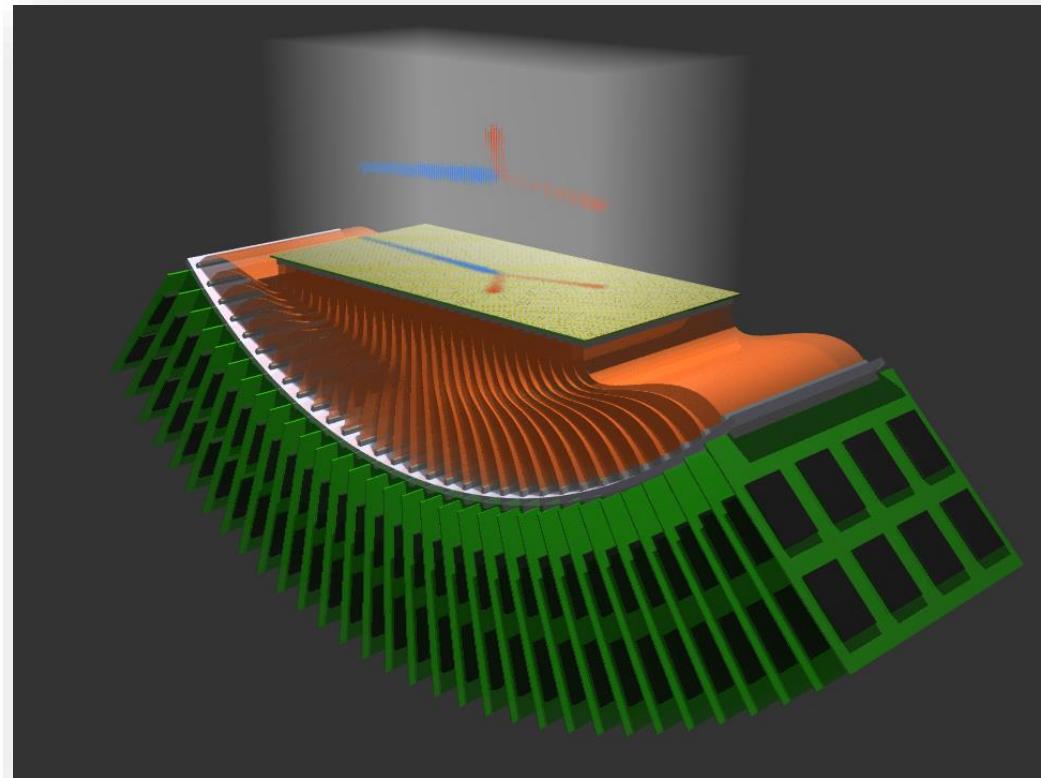


- ▷ what is ACTAR TPC
- ▷ General design
- ▷ Characterization
- ▷ Status

ACTAR TPC

a versatile instrument for nuclear physics

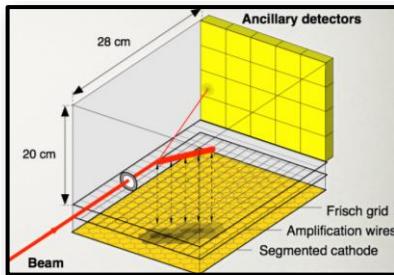
J. Giovinazzo - CENBG
and the ACTAR TPC collaboration



J. Giovinazzo (2013)

birth of ACTAR TPC

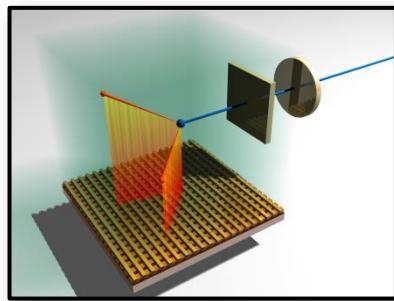
time projection chambers for (fundamental) nuclear physics



(GANIL and coll.)

nuclear
reactions

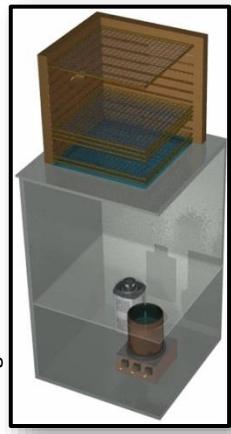
pads (hex): 2D proj.
wires: drift time



CENBG TPC

ions stopping
and decay

X-Y strips
energy & time:
2x 1D proj.



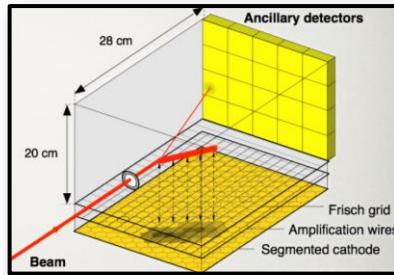
Optical TPC
(Warsaw)

ions stopping
and decay

CCD cam.: 2D proj.
PM + sampling:
global time dist.

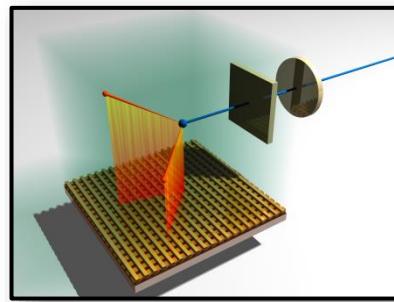
birth of ACTAR TPC

time projection chambers for (fundamental) nuclear physics



(GANIL and coll.)
nuclear
reactions

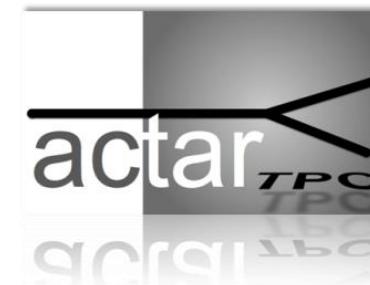
pads (hex): 2D proj.
wires: drift time



CENBG TPC
ions stopping
and decay

X-Y strips
energy & time:
2x 1D proj.

development of a new TPC
for a large (nuclear) physics case

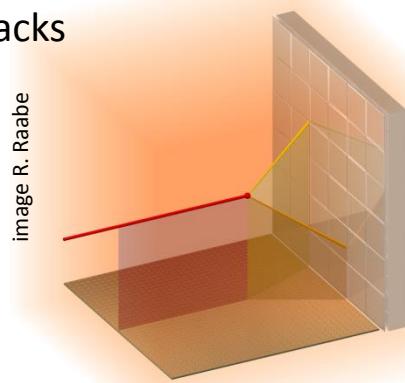


GANIL, CENBG, IPNO (F)
Leuven (B), Santiago de C. (S)

1 development, 2 detectors

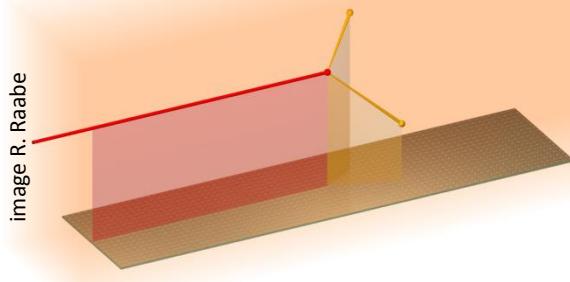
“reaction” chamber

128x128 pads collection plane
large transverse tracks



“decay” chamber

256x64 pads collection plane
short transverse tracks, larger implantation depth



shared design and technology

16384 pads, $2 \times 2 \text{ mm}^2$
2 geometries

→ main funding: ERC
(J.F. Grinyer, GANIL)



→ decay chamber: Region
pad plane R&D
(J. Giovinazzo, CENBG)



GET electronics

technical solution
for channels readout



2014 - 2018

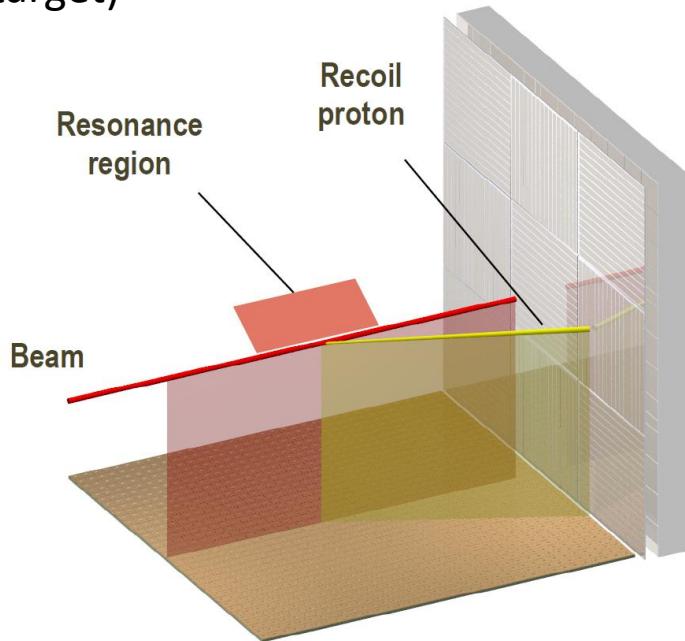
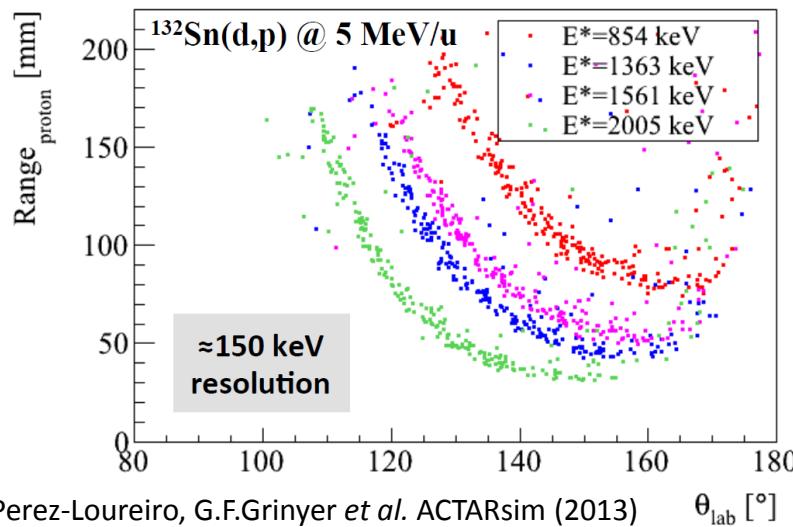
2011 - 2016

physics opportunities: Active Target

Active Target: excellent tool for inverse kinematics reactions studies
many advantages / traditional approaches (solid target)

unbound resonances, highly excited states

- thick target
- vertex measurement / particles tracking
- good energy resolution
- large angular acceptance
- low background (selected target gas)
- ...



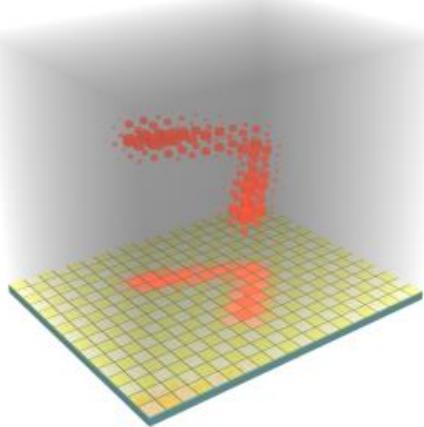
transfer and charge exchange reactions

- thick target, higher count rate
- detect low energy particles (protons)
- good energy resolution
- ...

physics opportunities: exotic decay modes

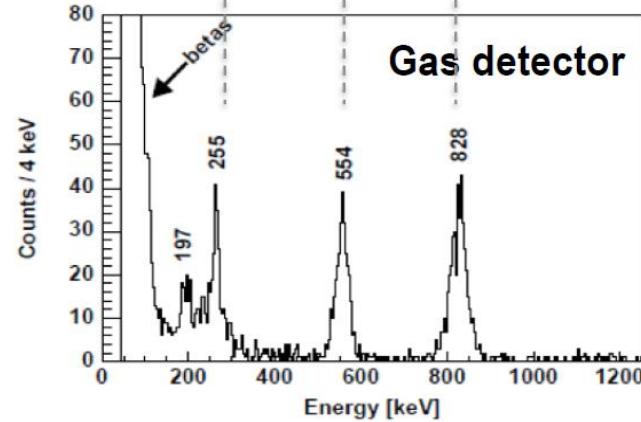
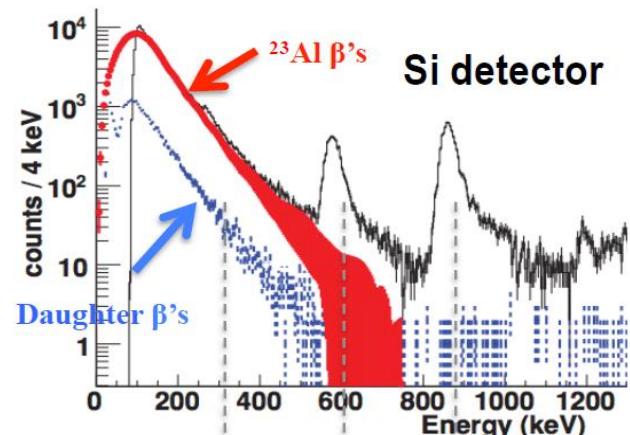
beta-delayed particle(s) emission

- detect low energy protons / no beta background (nuclear astrophysics)
- multi-particle decay (β -2p, β -3p)
- rare particles decay (^6He : β - $\alpha\delta$, ^9C : β -p2 α)



2-proton radioactivity

- tracking: angular and energy correlations
- only access to decay mechanism & structure



particle(s) decay of excited states

- decay channel selectivity
- i.e.: $^{12}\text{C}^* \rightarrow 3^\alpha$ (Hoyle state)

A. Saastamoinen *et al.* PRC 83, 045808 (2011)
E.C. Pollacco *et al.* NIM A 723, 102 (2013)

a 4D detector: tracking + energy

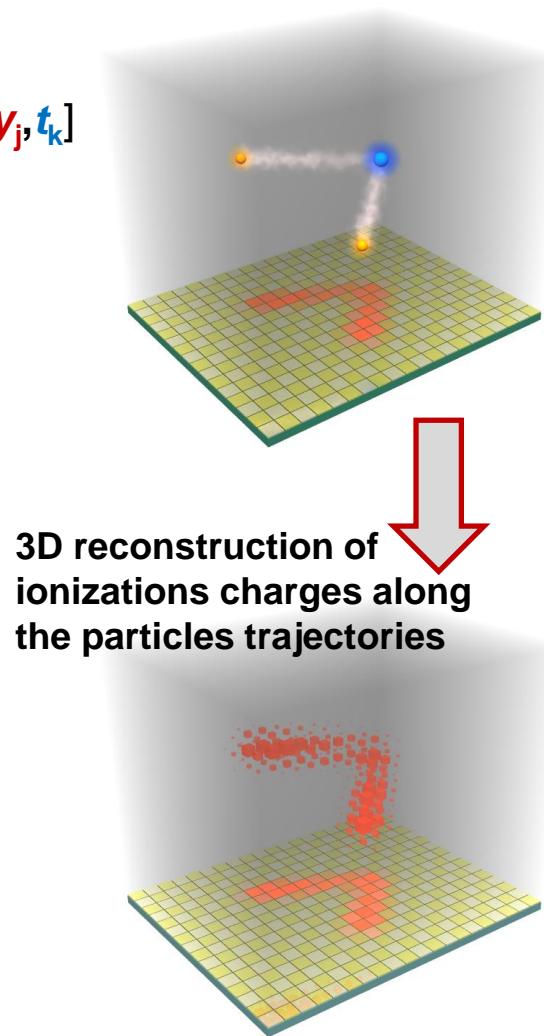
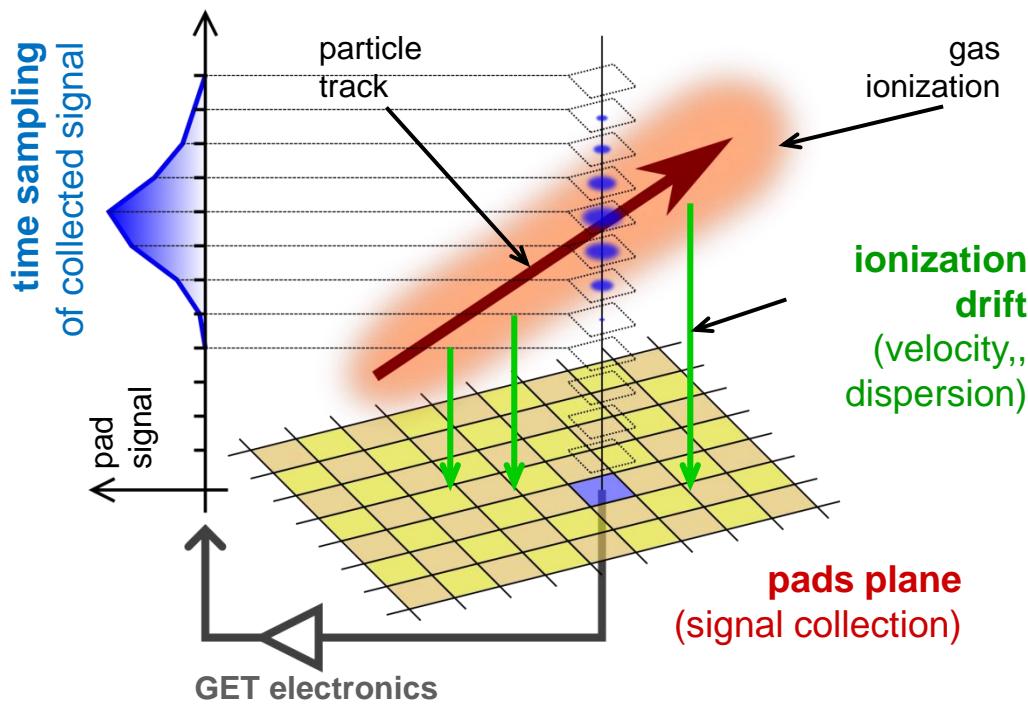
pads plane
(signal collection)
2D digitization

TPC principle

$$z \Leftrightarrow t$$

time sampling
of signal
3D digitization

$$\Delta E(x, y, z) \Leftrightarrow \Delta E[x_i, y_j](z) \Leftrightarrow \Delta E[x_i, y_j](t) \Leftrightarrow \Delta E[x_i, y_j, t_k]$$



ACTAR TPC global design

- active volume (drift region)
- collection plane (pads) & amplification
- electronics
- additional detectors

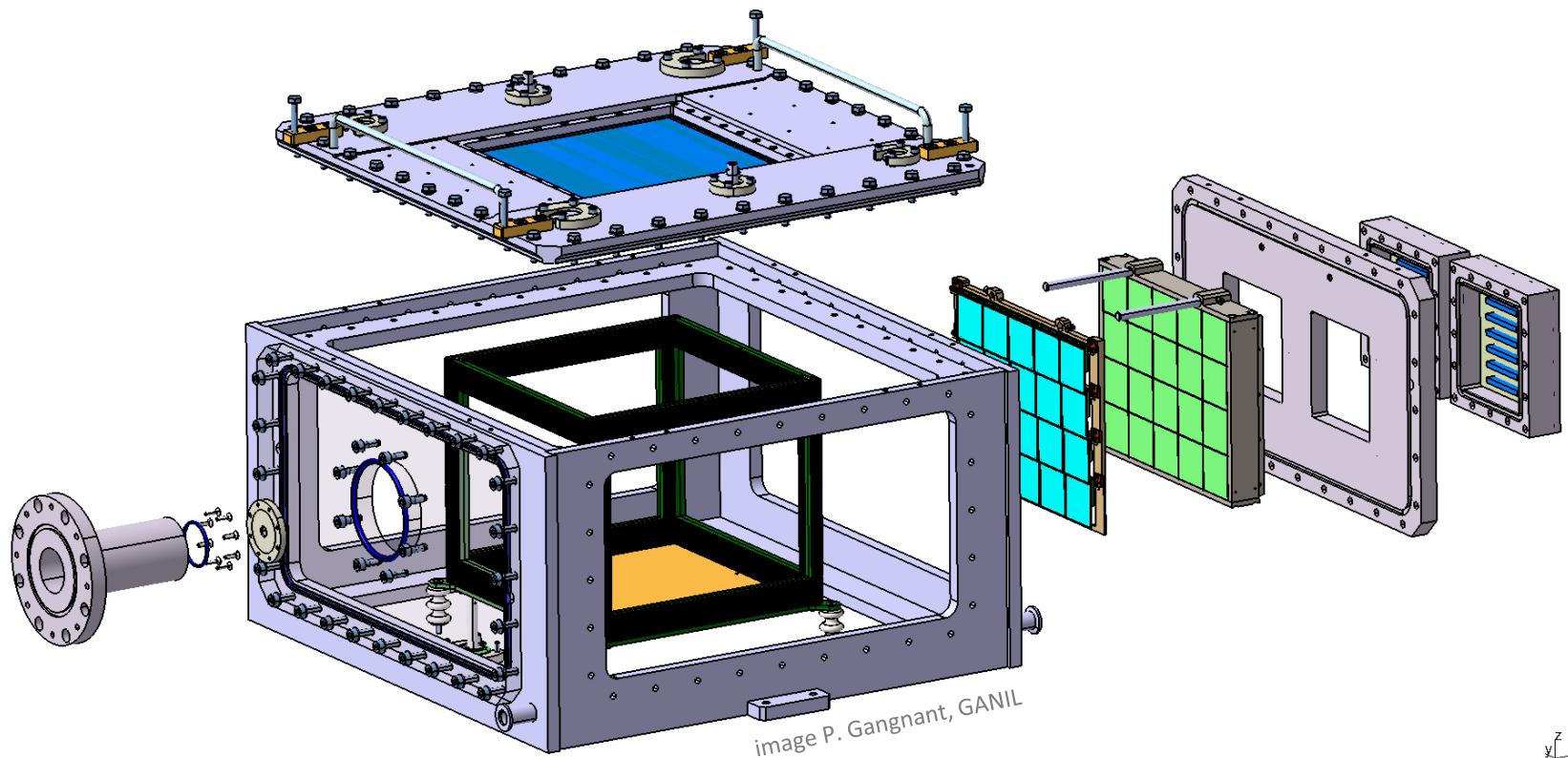


image P. Gangnanz, GANIL

ACTAR TPC design: auxiliary detectors

TPC chambers designed to include additional (side) detectors

- tracking of particles escaping the drift region
(reaction studies and active target mode)
- additional position and energy information
(used also for commissioning)

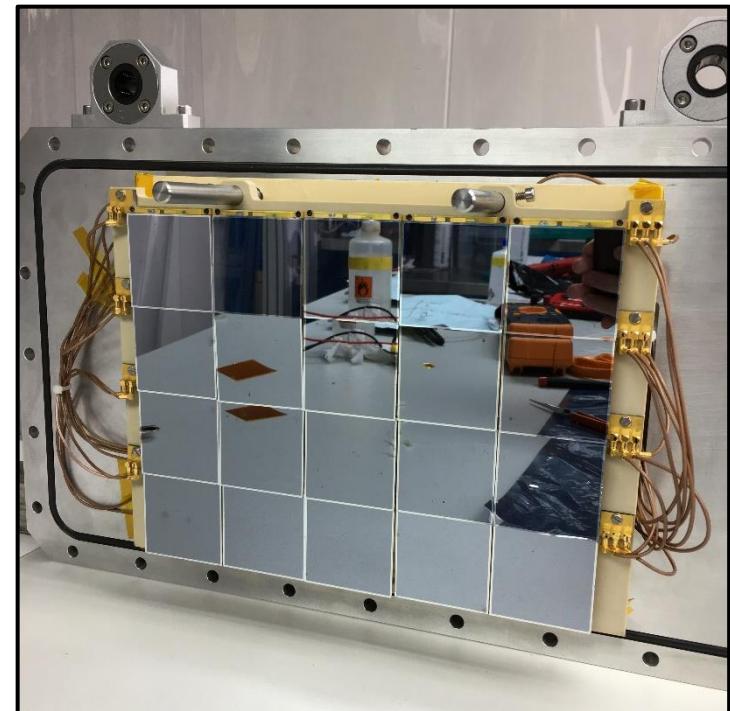
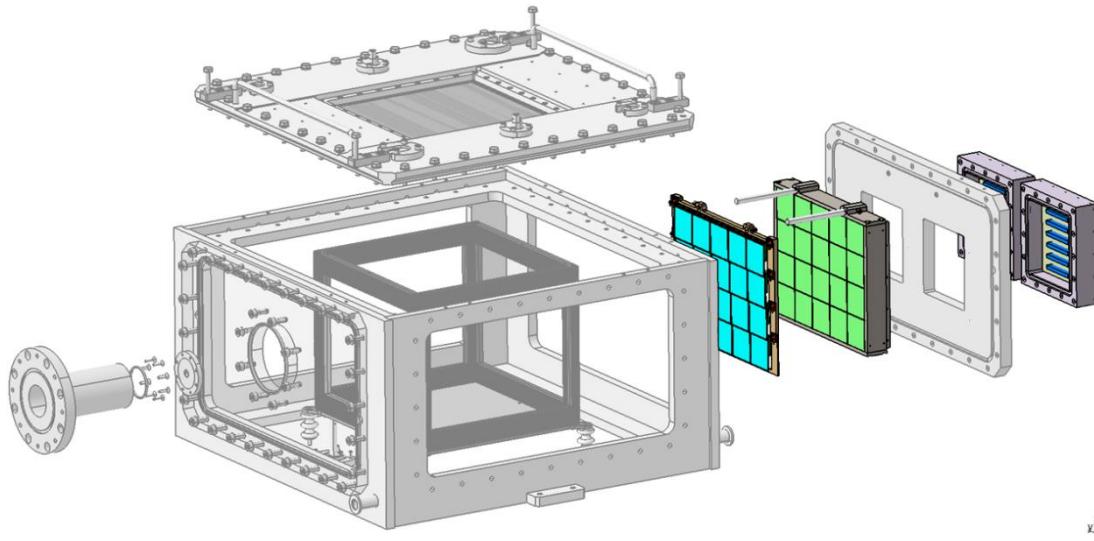


photo GANIL (2017)

ACTAR TPC design: active volume & drift cage

active volume & drift cage

electric field uniformity
transparent to particles

→ double wires frames

- 1 and 2 mm pitch (inside/outside)
- 98 % transparency

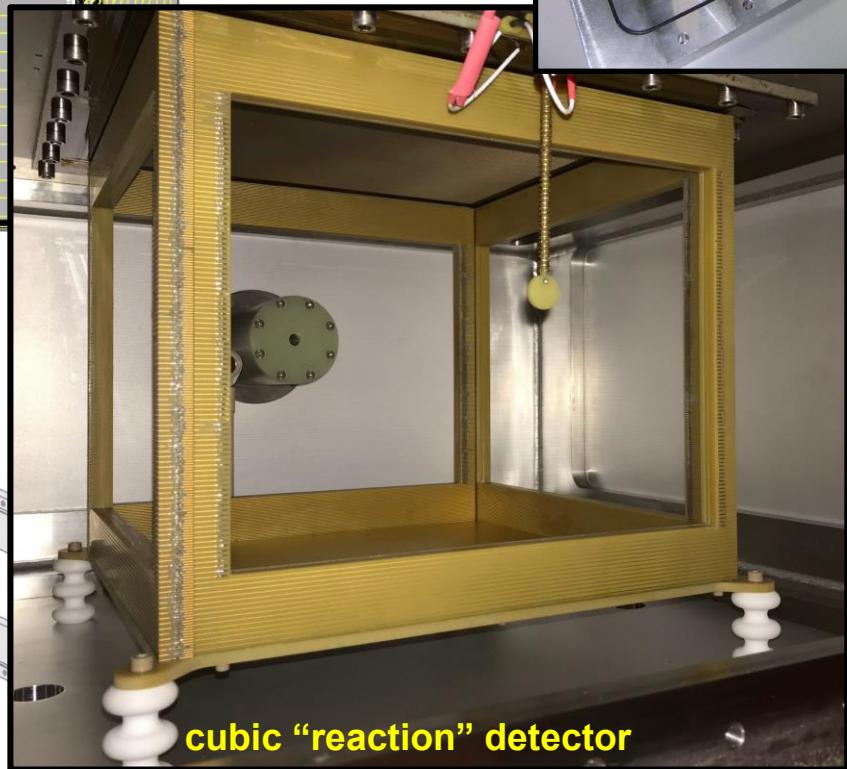
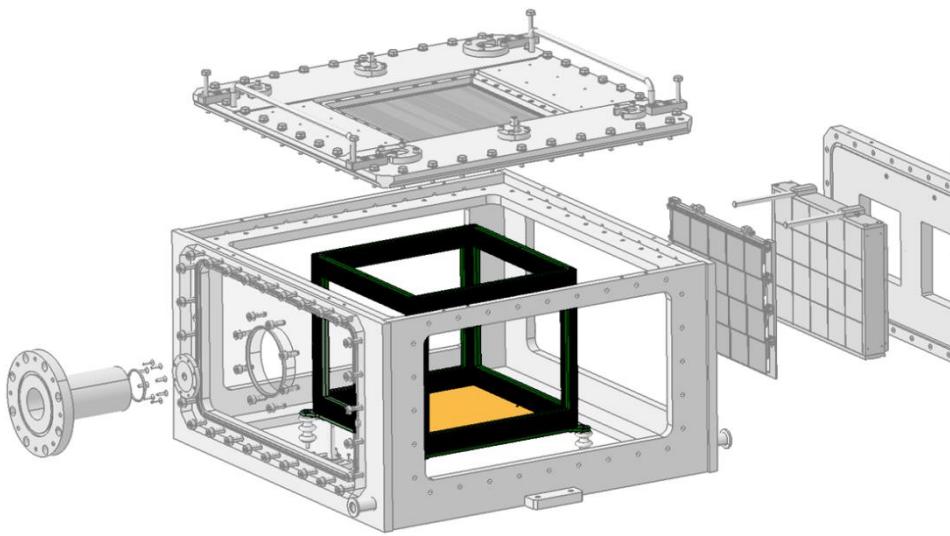
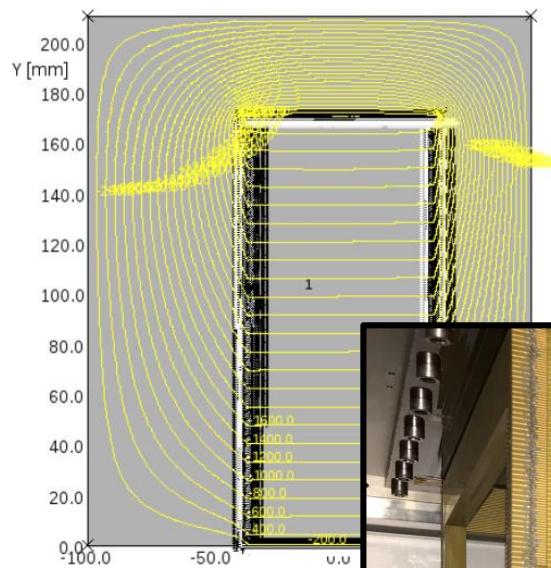


photo O. Poleshchuk (2017)

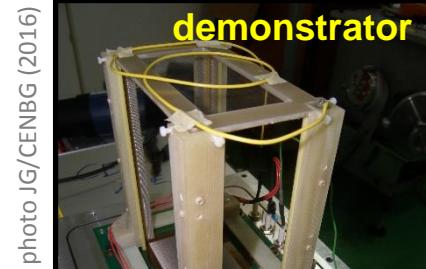


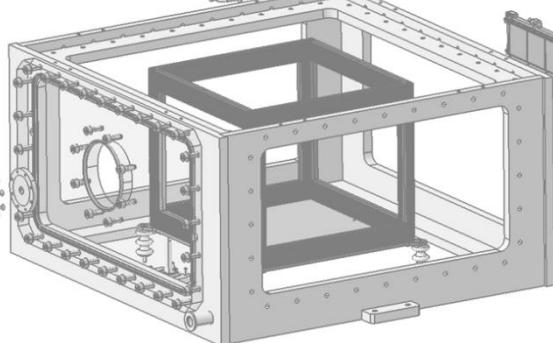
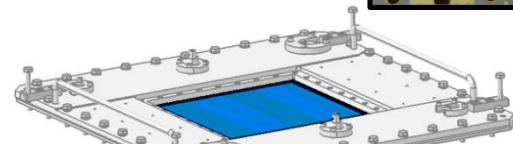
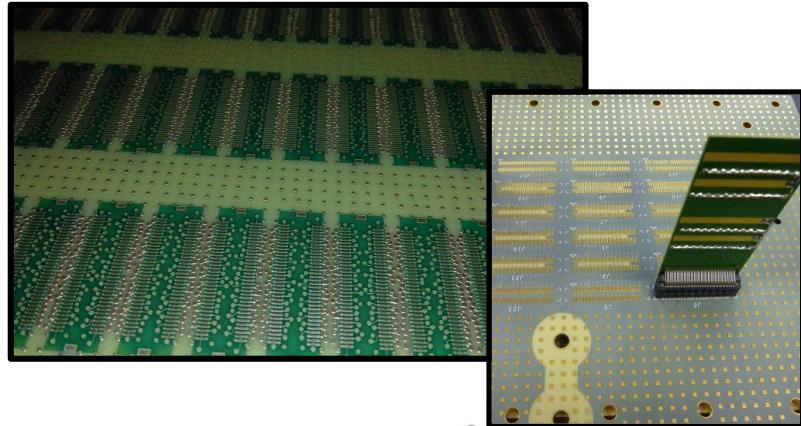
photo JG/CENBG (2016)

GANIL **Spiral2** **design**
laboratoire commun CEA/DRF CNRS/IN2P3

ACTAR TPC design: collection (pads) plane

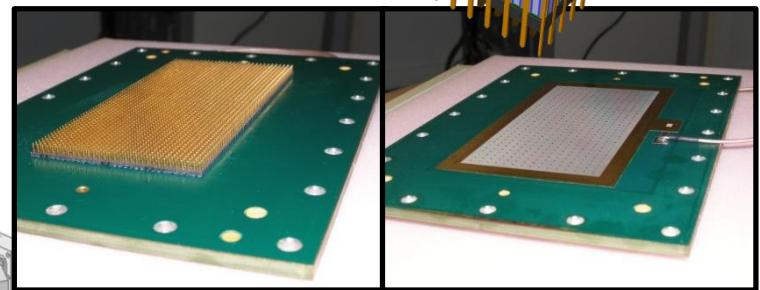
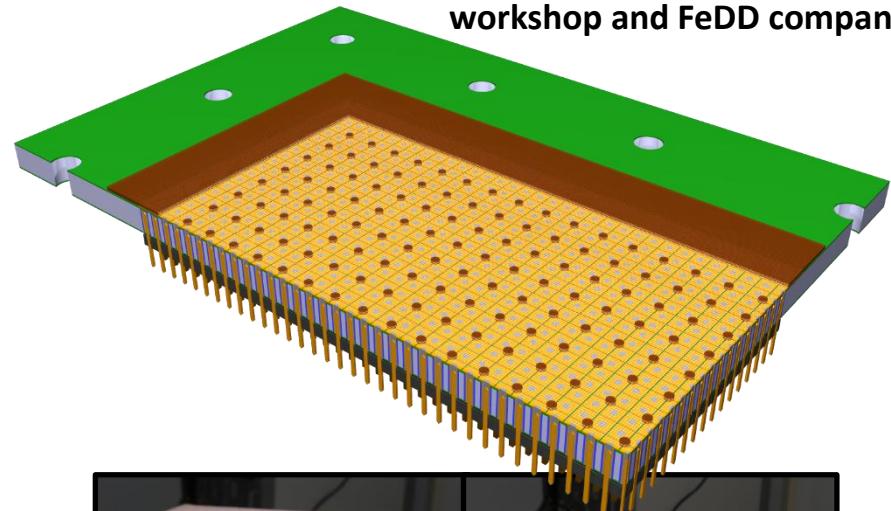
high density of pads
mechanical constraints

multi-layer PCB (GANIL version)



metal-core PCB
(CENBG version)

developed with CERN PCB
workshop and FeDD company



both tested on demonstrators

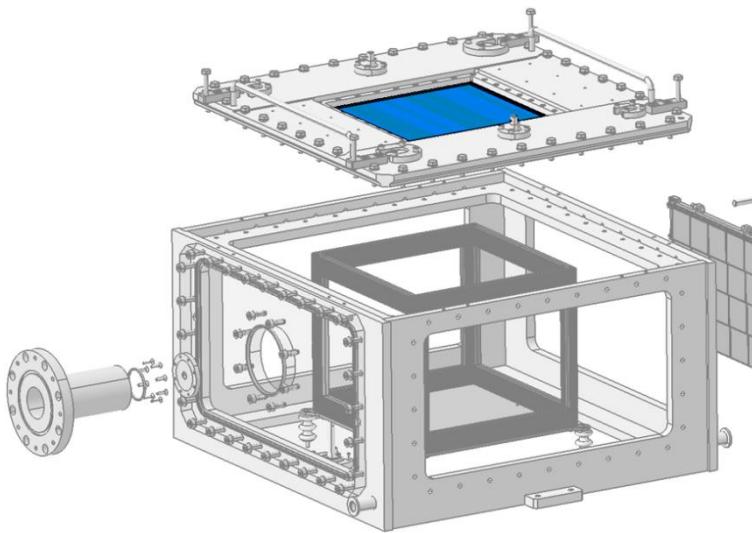
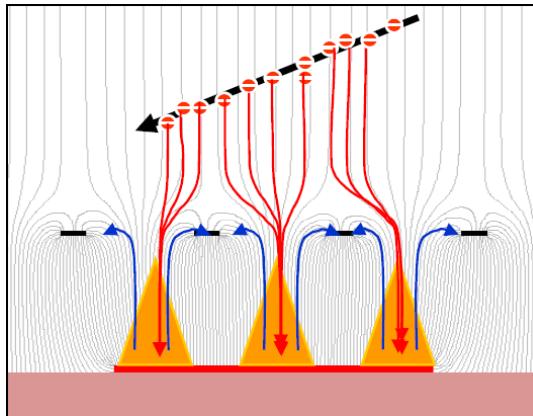
→ affects the connection to
readout electronics

$\frac{z}{x}$

ACTAR TPC design: signal amplification

bulk micromegas
(CERN)

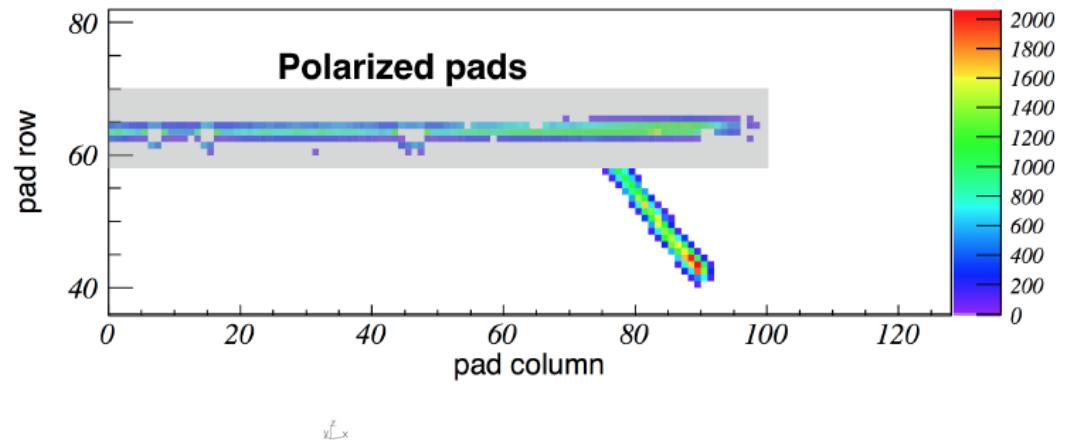
possible use of GEMs



selected pads polarization

- local reduction of the gain
- “active target” mode:
 - high intensity beam
 - few interactions

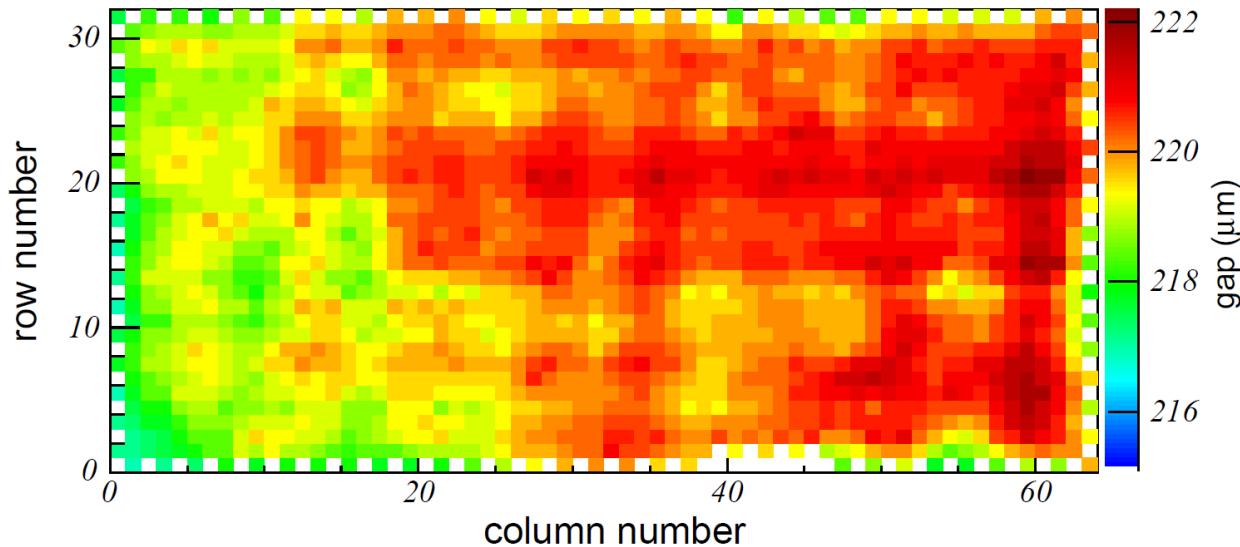
→ avoid saturation



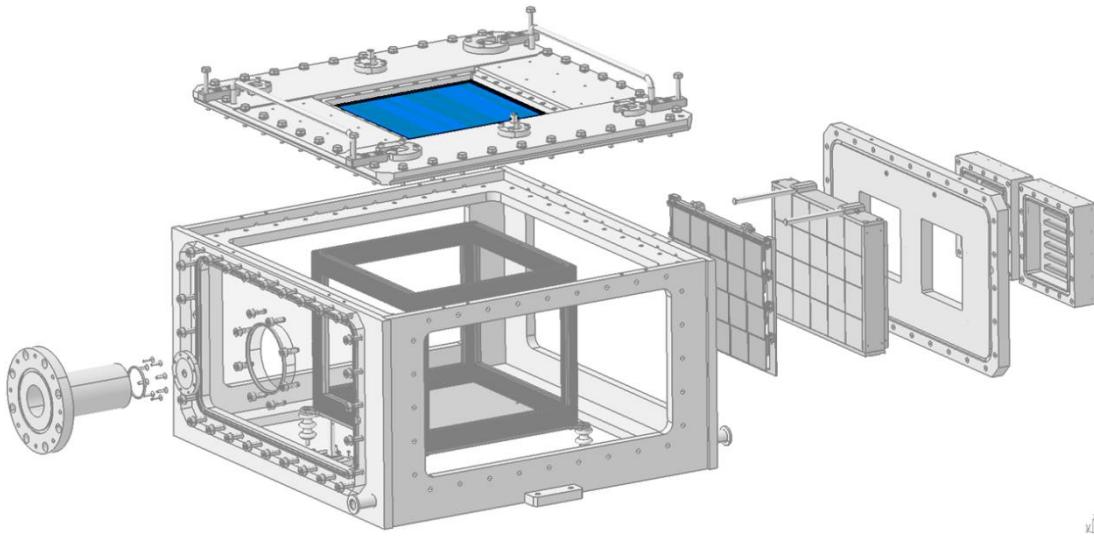
ACTAR TPC design: amplification

detector scan with collimated X-ray source (^{55}Fe)

GANIL scanning table



T. Roger et al., NIM A 895 (2018)



effective calibration

- scan
- electronics chains gain matching

ZAP connectors: signal extraction and sparks protection

connectors for multi-layer PCB

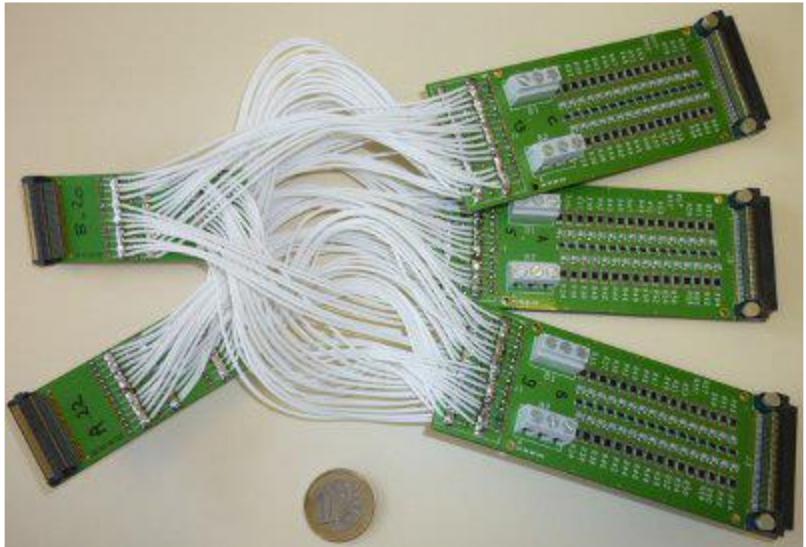


photo GANIL (2015)

with μ -coax cables

problem for 16384 pads...

**comparable noise
(test measurements)**

connectors for metal-core PCB

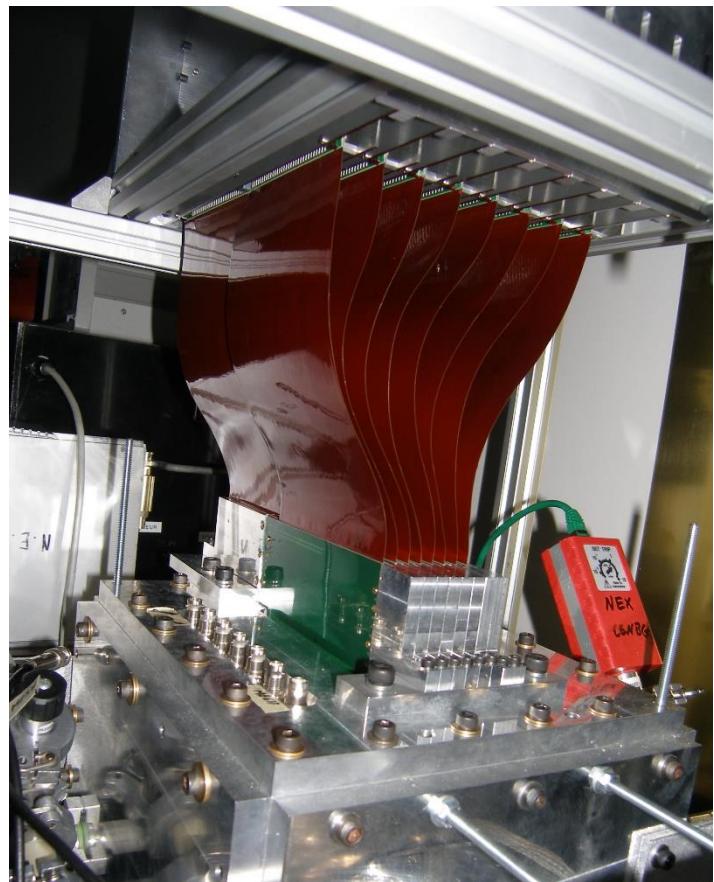


photo JG/CENBG (2016)

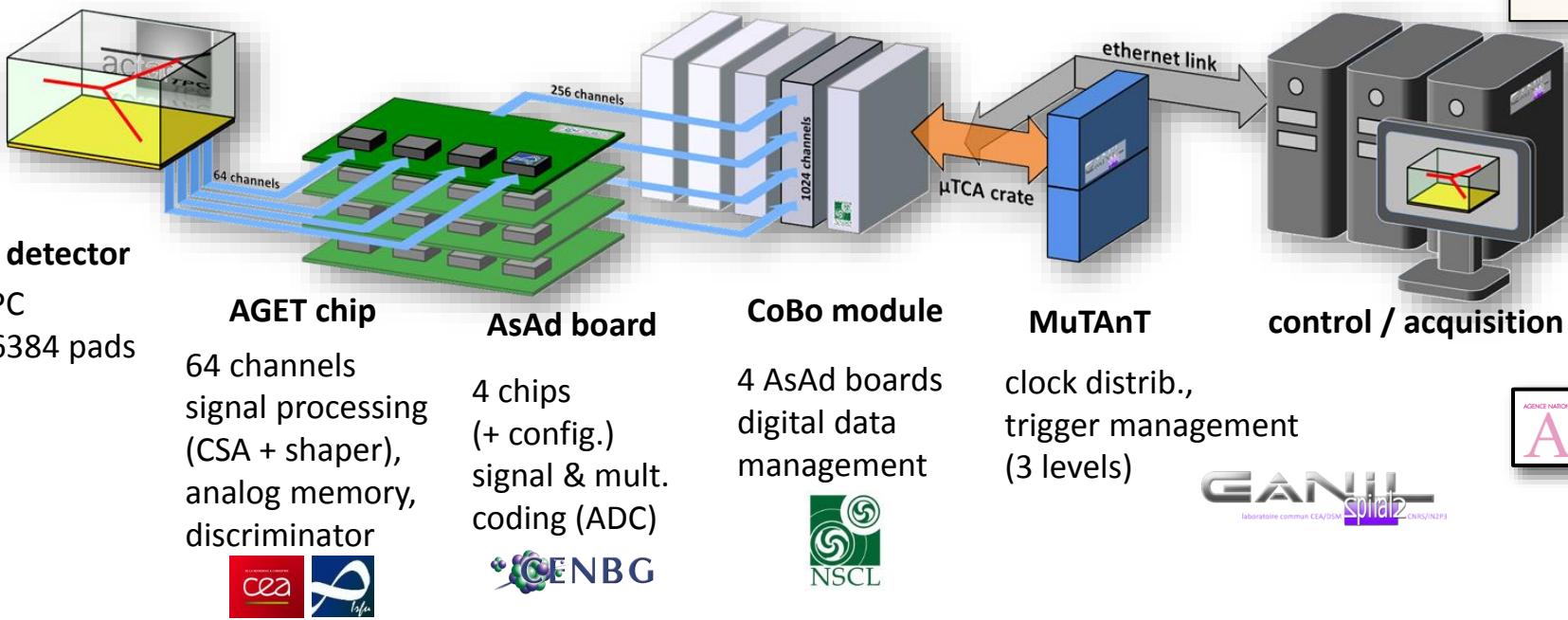
with flex (shielded) PCB

readout electronics

IRFU, CENBG,
GANIL, MSU
ANR 2011-2015



image JG / CENBG (2015)

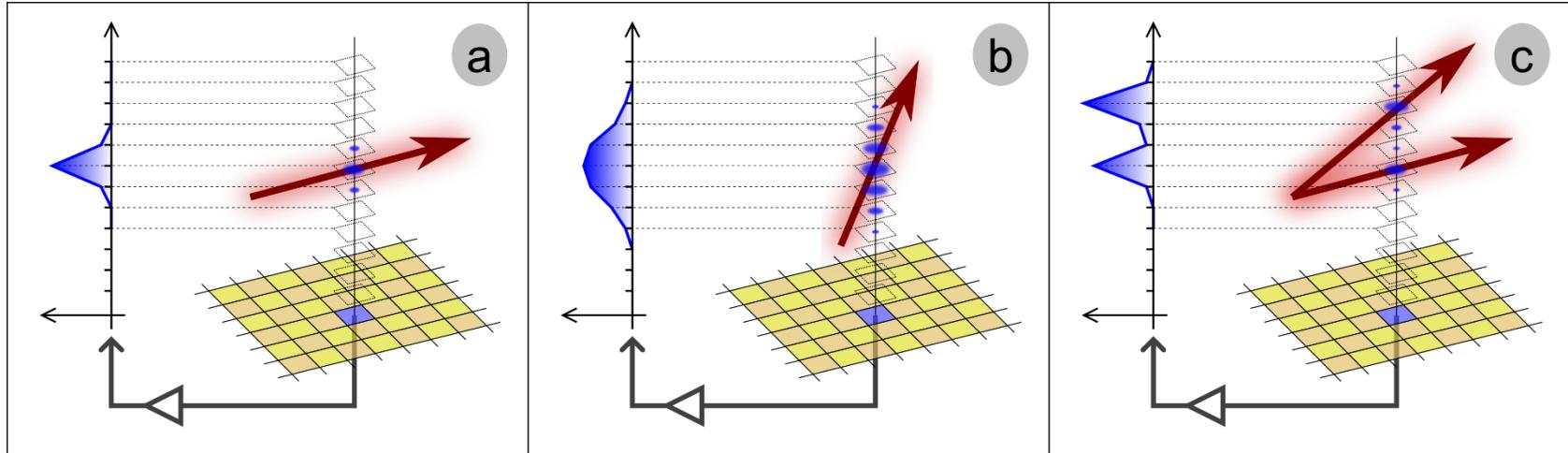


for each channel:

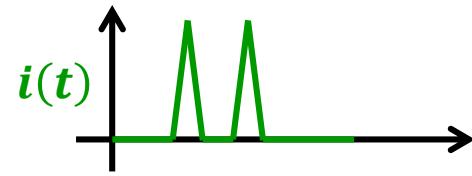
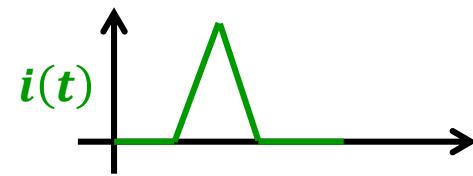
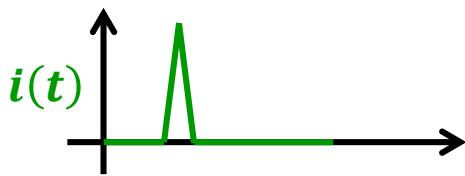
time sampling (max. 512, freq. 1-100 MHz): analog mem. + ADC
discriminator → internal multiplicity trigger

designed to handle 1 kHz count rate for 10% of channels hit (~1600 channels)

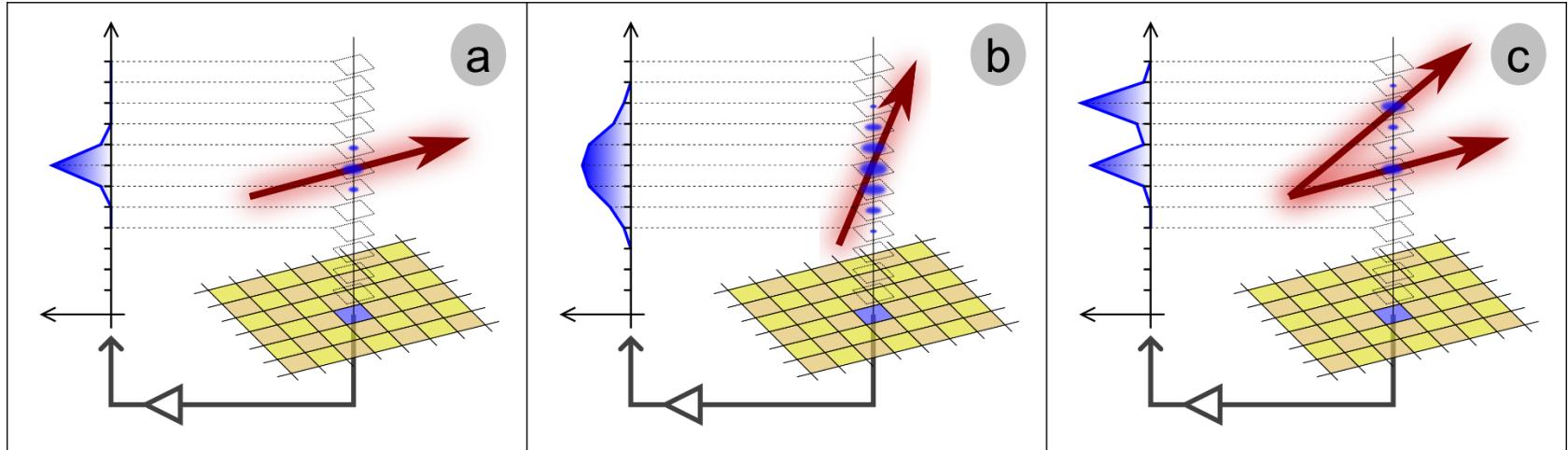
readout electronics: 3D charge reconstruction ?



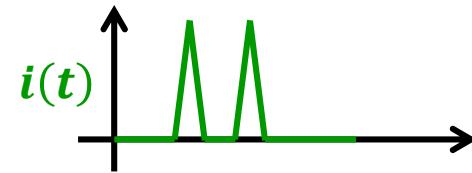
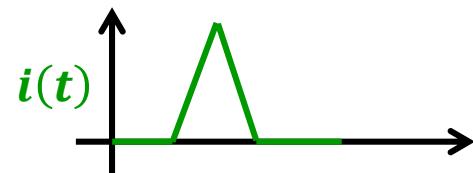
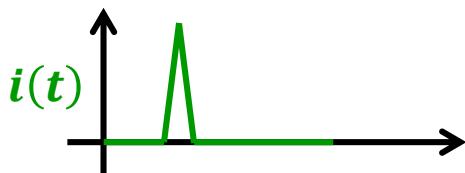
charge deposit on a single pad



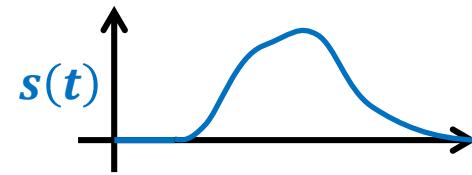
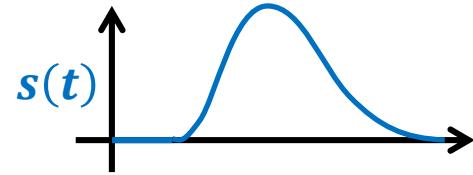
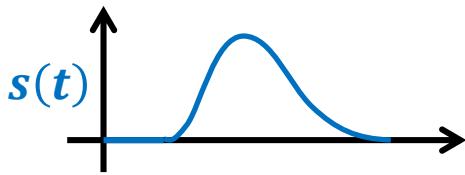
readout electronics: 3D charge reconstruction ?



charge deposit on a single pad

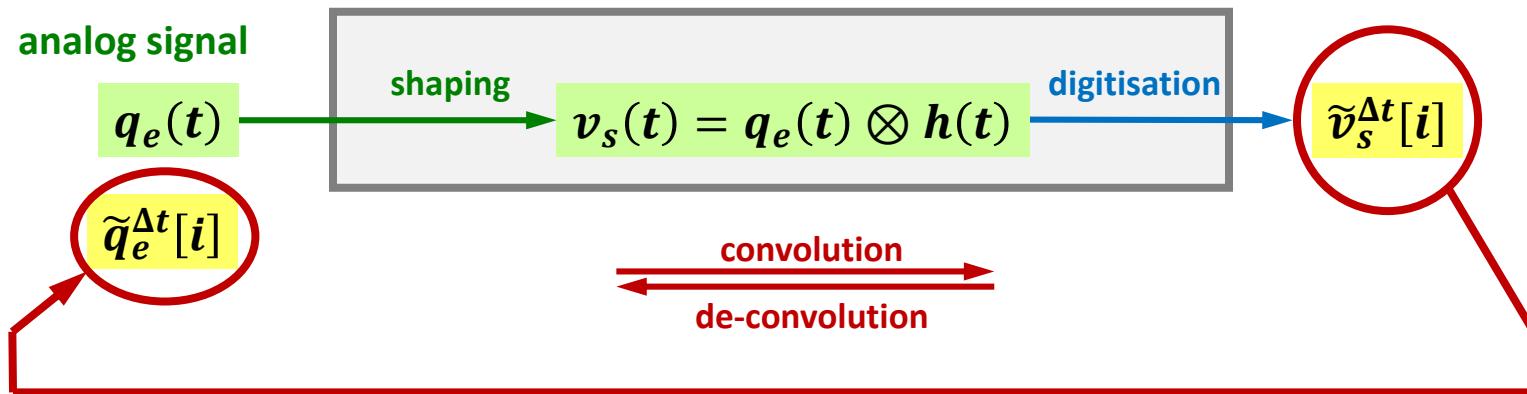
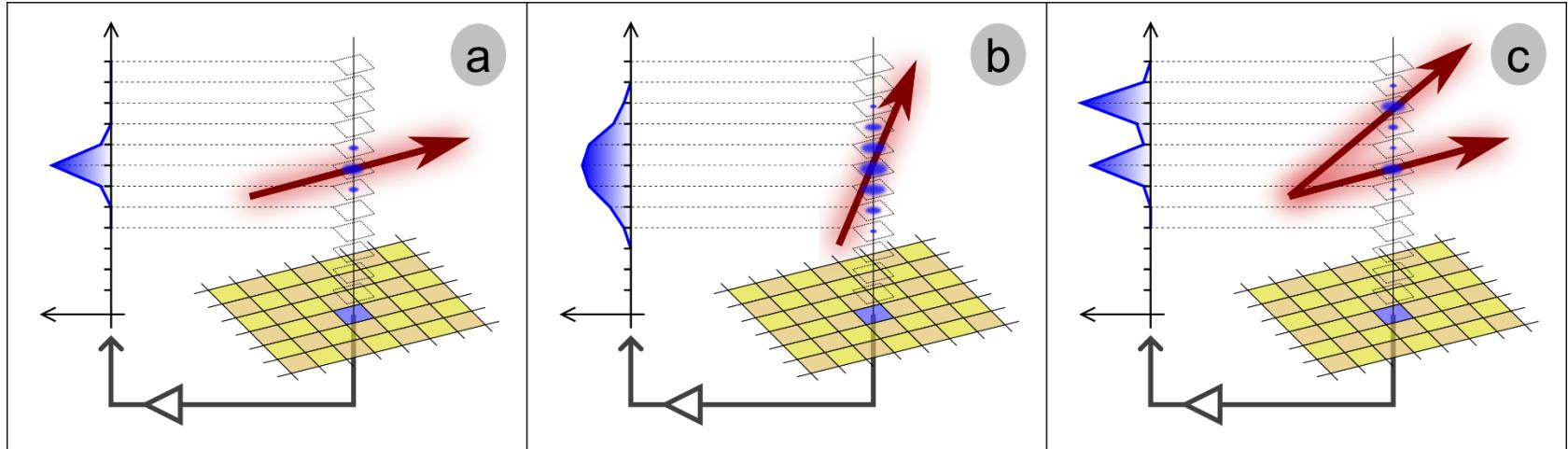


sampled signal after CSA and shaper... (based on AFTER chip for T2K)



information is “washed out” by **AGet shaping**

readout electronics: input signal reconstruction

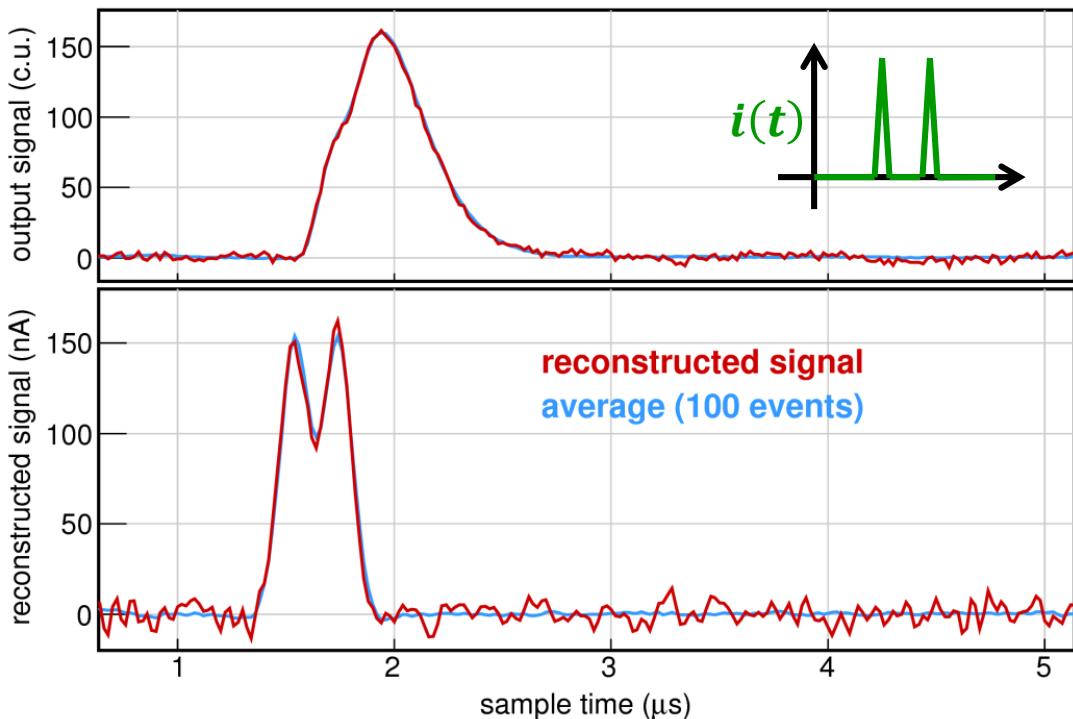
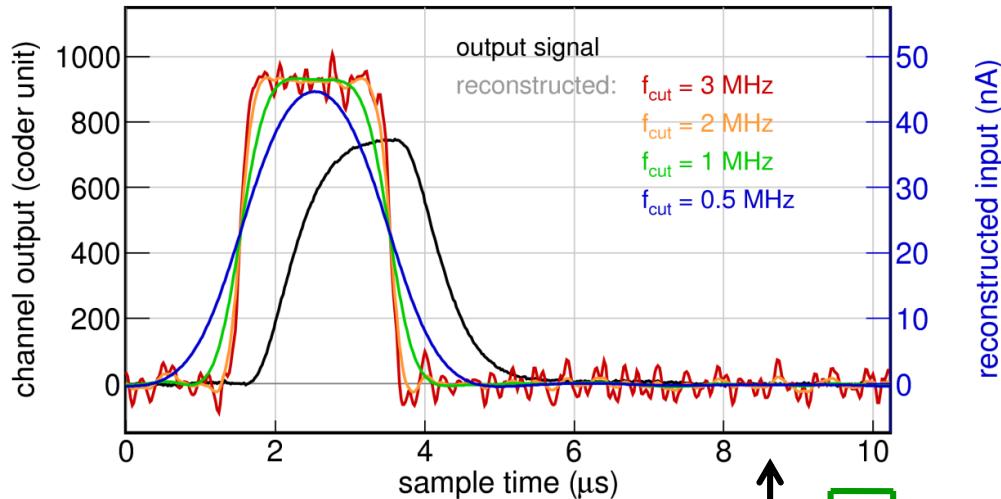


de-convolution requires each channel response function
use of FFT – need for filtering

readout electronics: input signal reconstruction

GET electronics test-bench
tested with pulse generator

- empirical response function
- filtering: noise vs distortion



charge precision $\sim 1\%$

time resolution

$\sim 60\text{ ns}$ for $F_w = 100\text{ MHz}$

$\sim 100\text{ ns}$ for $F_w = 50\text{ MHz}$

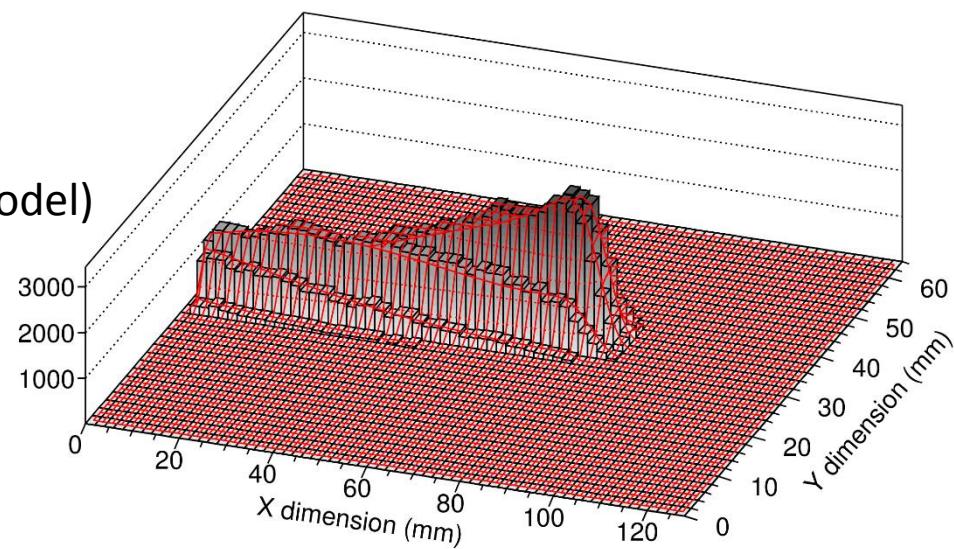
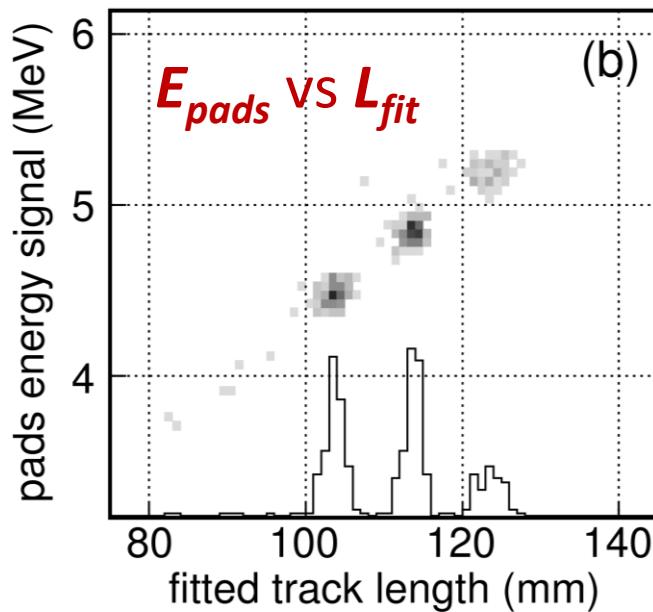
timing precision $\sim 1\text{ ns}$

stopped tracks reconstruction

3-alpha source tests

2D projection of Bragg peak:

- energy deposit along track (Bragg peak model)
- X & Y dispersion
- no time (Z) distribution of signal



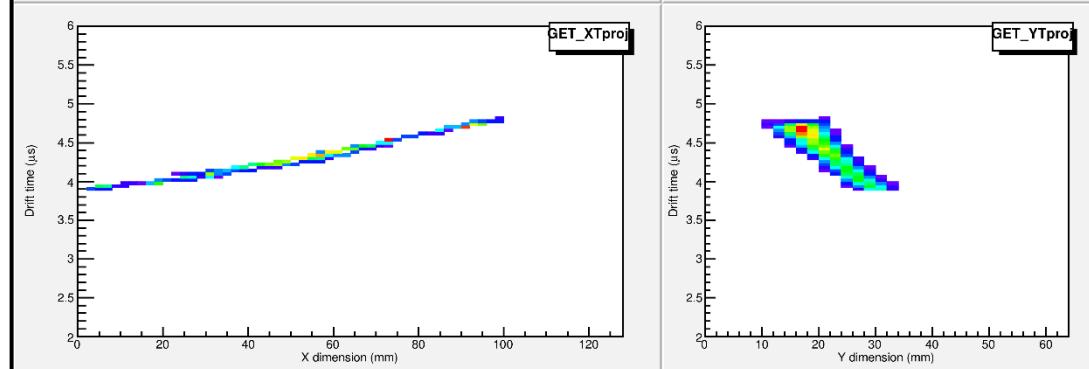
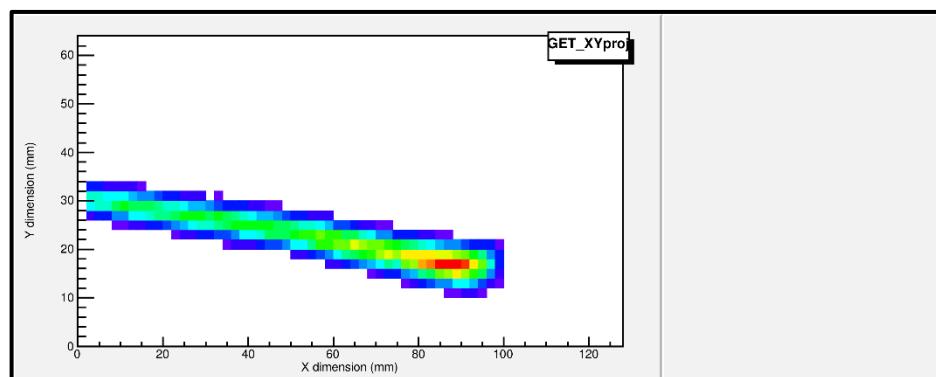
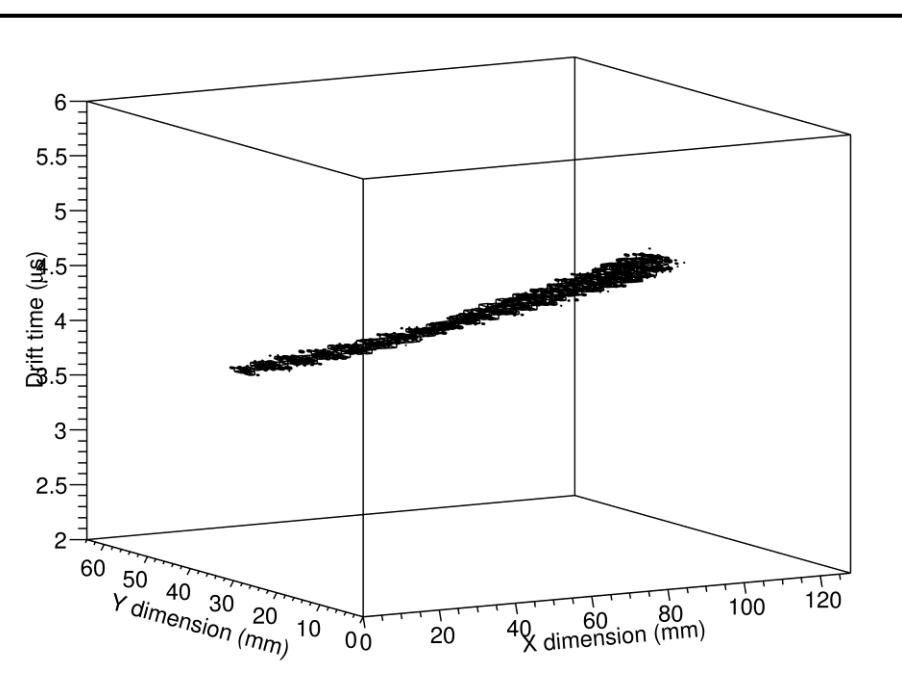
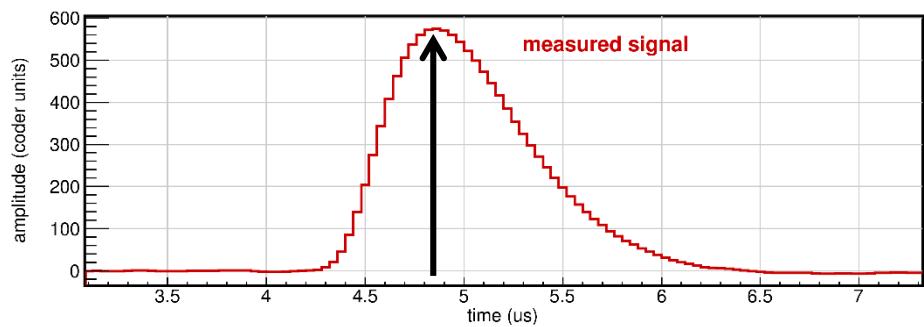
independent precision of
energy estimate (pads signal)
& track length (fit)

energy resolution: $\sigma_E^{pads} \sim 100 \text{ keV}$

fitted length dispersion: $\sigma_L^{rec} \sim 3.2 \text{ mm}$
(particles dispersion from simulation)

⇒ no improvement expected from correlation

2D+T signal reconstruction



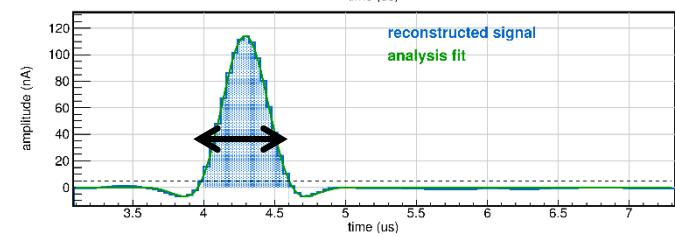
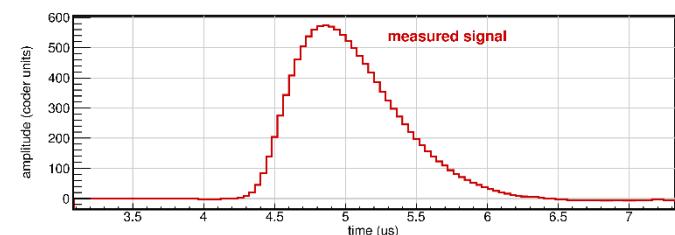
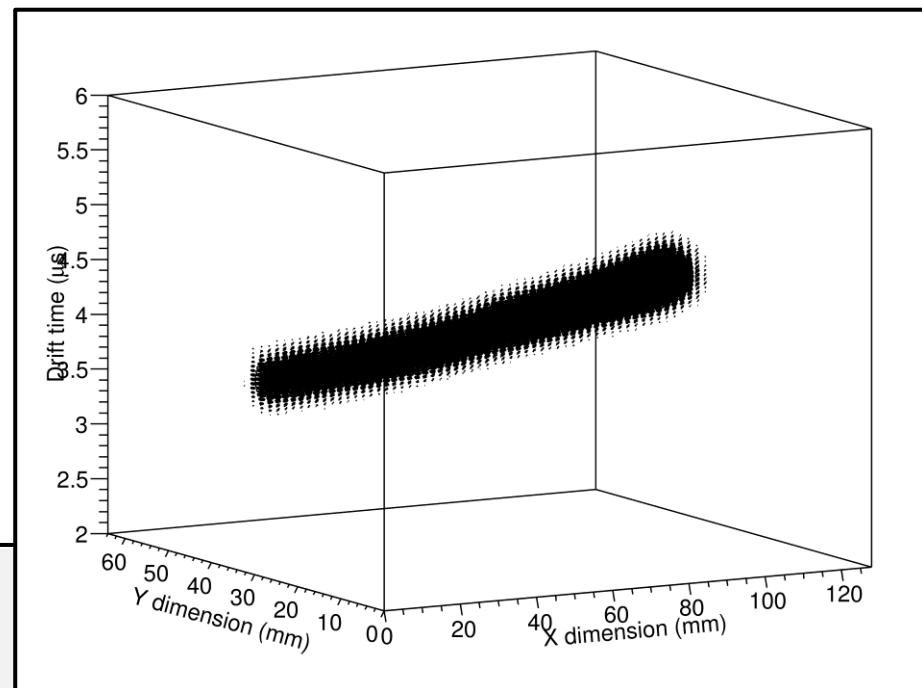
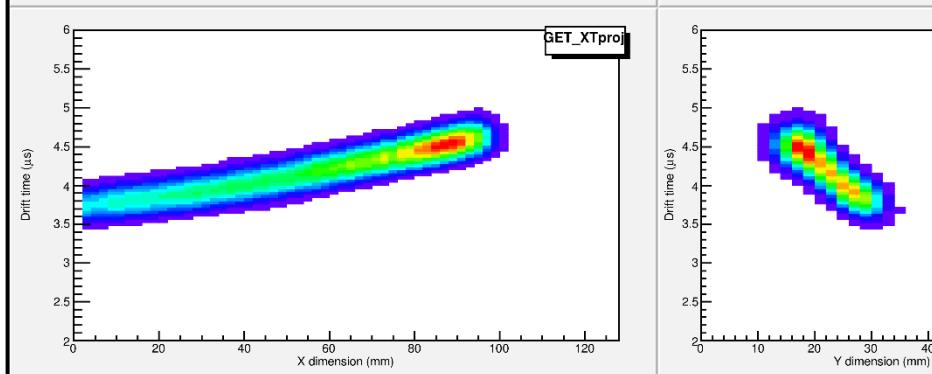
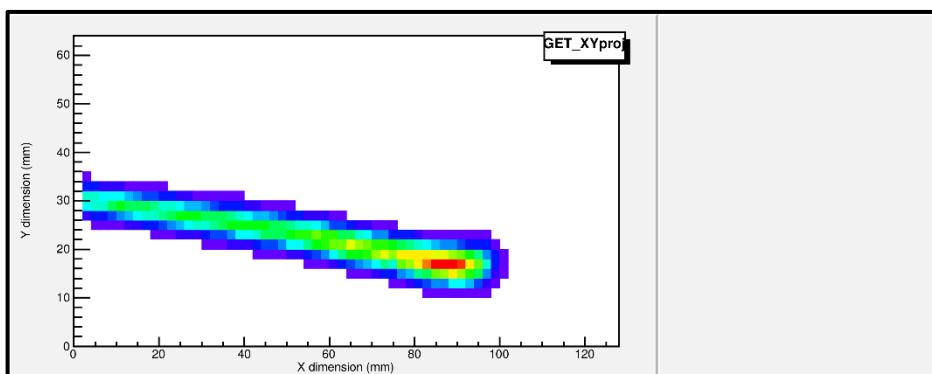
**single T info / pad
(max. signal of CFD algo)
→ no Z charge distribution**

full 3D charge reconstruction

with response function de-convolution
→ effective Z charge distribution

energy resolution from rec. signal
equiv. to output signal

(3D tracking analysis not yet performed)



beam commissioning

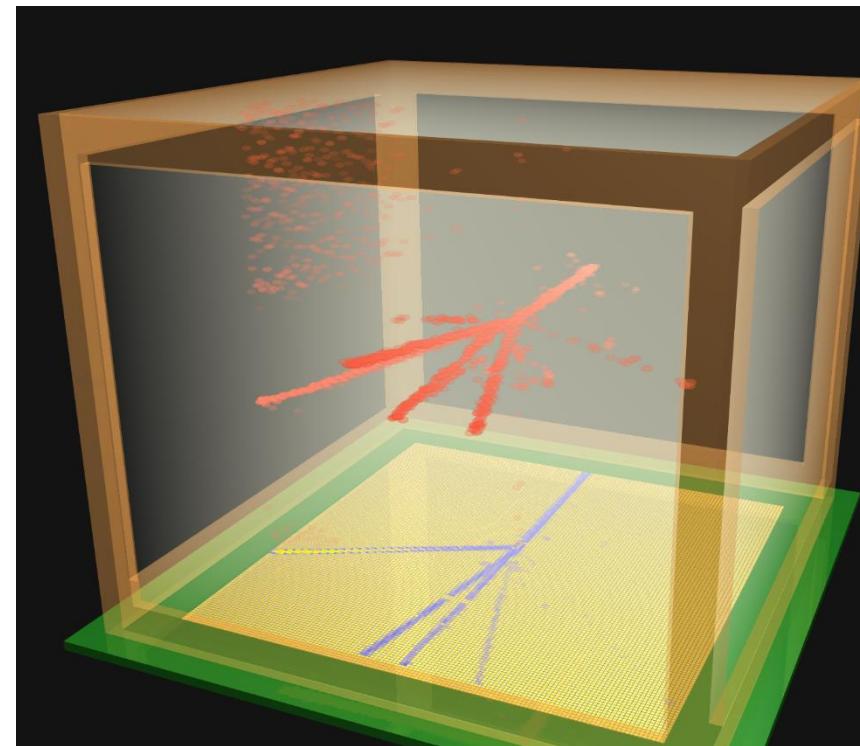
tests @ GANIL

(11/2017 & 04/2018)

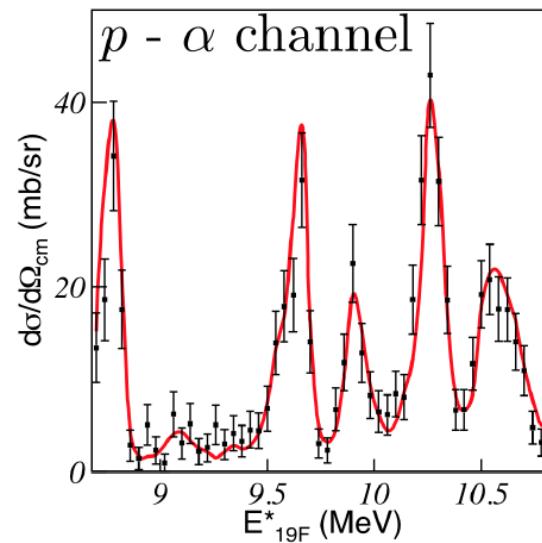
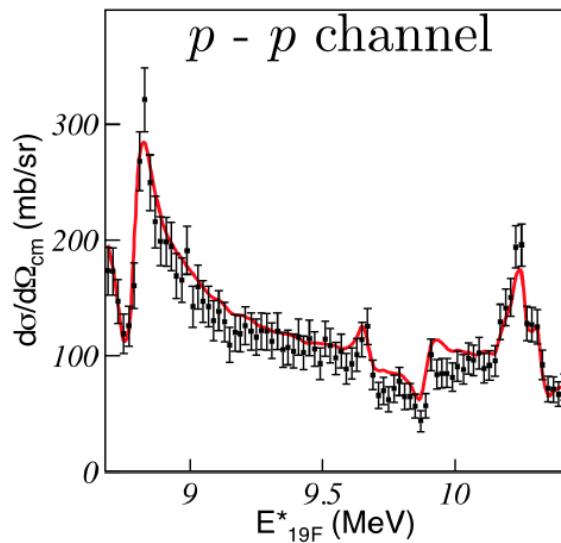
Commissioning of the
128x128 pads full detector

$^{18}O(p,p)$ and $^{18}O(p,\alpha)$ excitation functions

- reaction kinematics
- part. tracks & energy
- absolute cross section



© J. Giovinazzo (2017)



B. Mauss, PhD thesis (GANIL)

ACTAR TPC project 2018 summary



GET electronics development

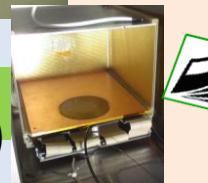


debugging

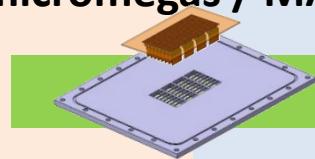
signal analysis



GANIL design tests
(micromegas / MAYA)



tracking and data analysis developments

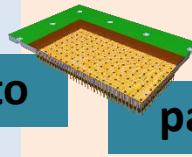


GANIL demonstrator



metal-core
PCB

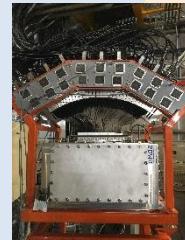
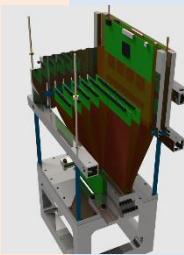
test proto



pad plane proto



CENBG demonstrator



“reaction” detector

“decay” detector

ACTAR TPC construction funding



2012

2013

2014

2015

2016

2017

2018



ACTAR TPC current status

(almost) ready for experiments

7 experiments accepted by PACs

9 more proposals

many letters of intent...

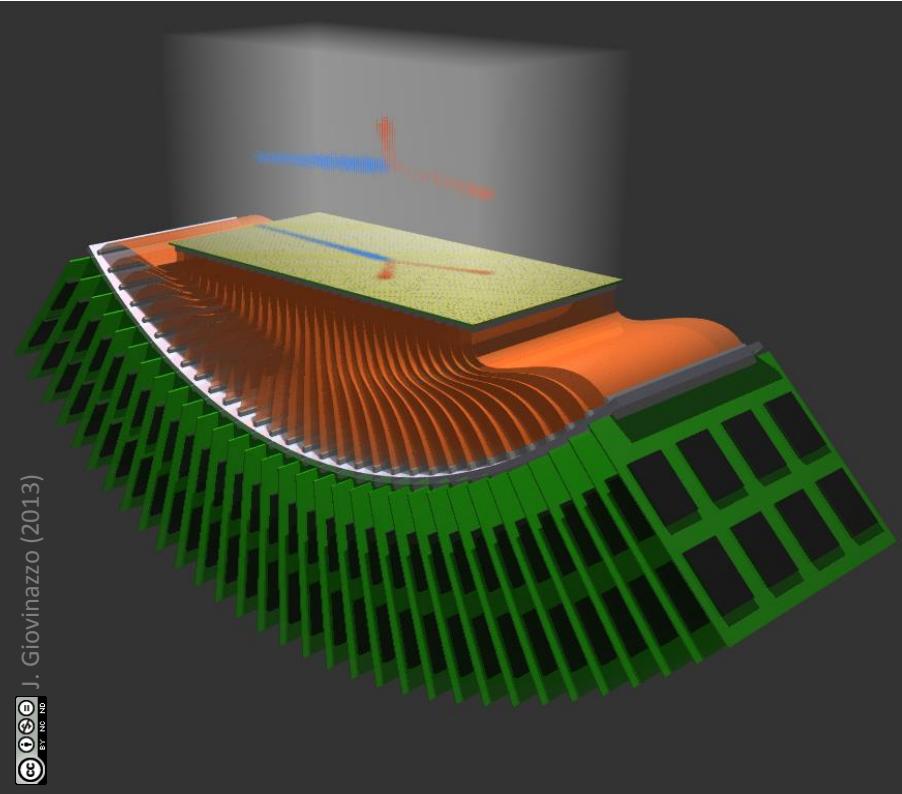
several facilities

- first exp. @ GANIL (France), RIKEN (Japan), ISOLDE (CERN / Switzerland)
- opportunities @ TRIUMF (Canada), GSI/FAIR (Germany)

still to be considered...

process for (metal-core) pad plane to be secured
(with CERN PCB workshop)

few problems with GET electronics in specific modes



J. Giovinazzo (2013)



from 2012 schematic view...

... to 2018 detector

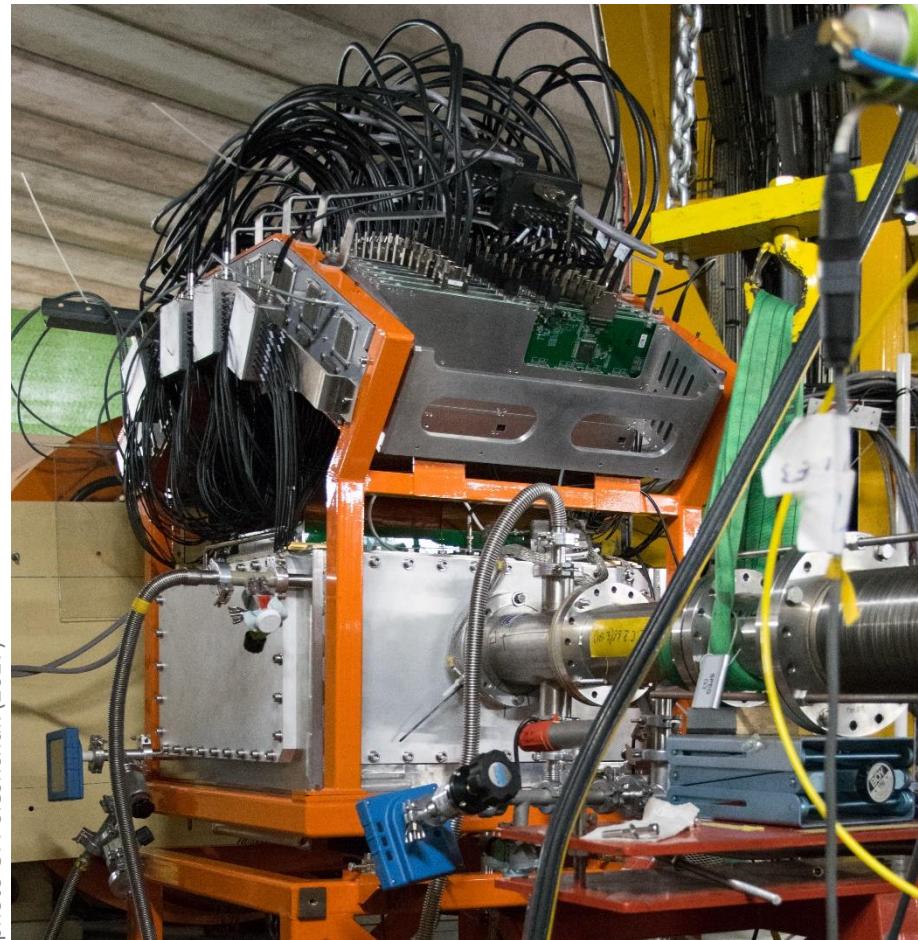


photo O. Poleshchuk (2017)