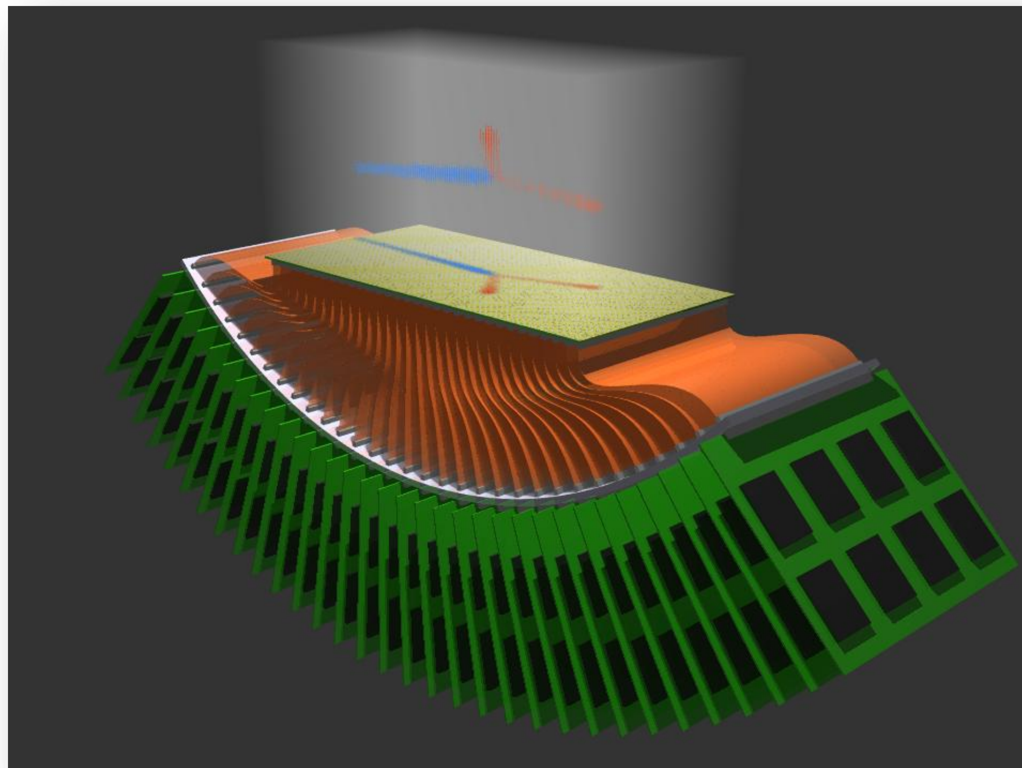
Status of developments for ACTAR TPC

J. Giovinazzo - CENBG
and the ACTAR TPC collaboration

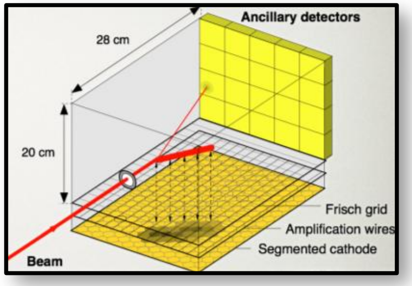
- ▷ **what is ACTAR TPC**
- ▷ **GET electronics**
- ▷ **collection plane R&D**
- ▷ **tests results**



RD51 mini-week – CERN – 6-9 june 2016

What is ACTAR TPC ?

time projection chambers for (fundamental) nuclear physics

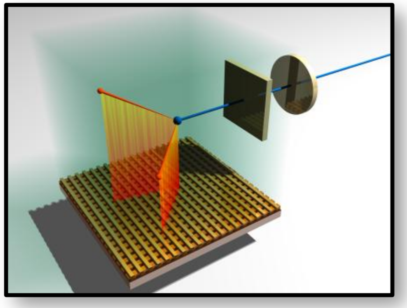


MAYA

(GANIL and coll.)

nuclear reactions

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

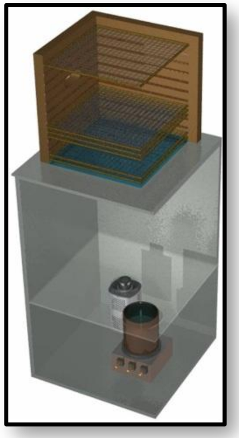


CENBG TPC

ions stopping and decay

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

image Warsaw coll.



Optical TPC
(Warsaw)

ions stopping and decay

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

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

actar TPC

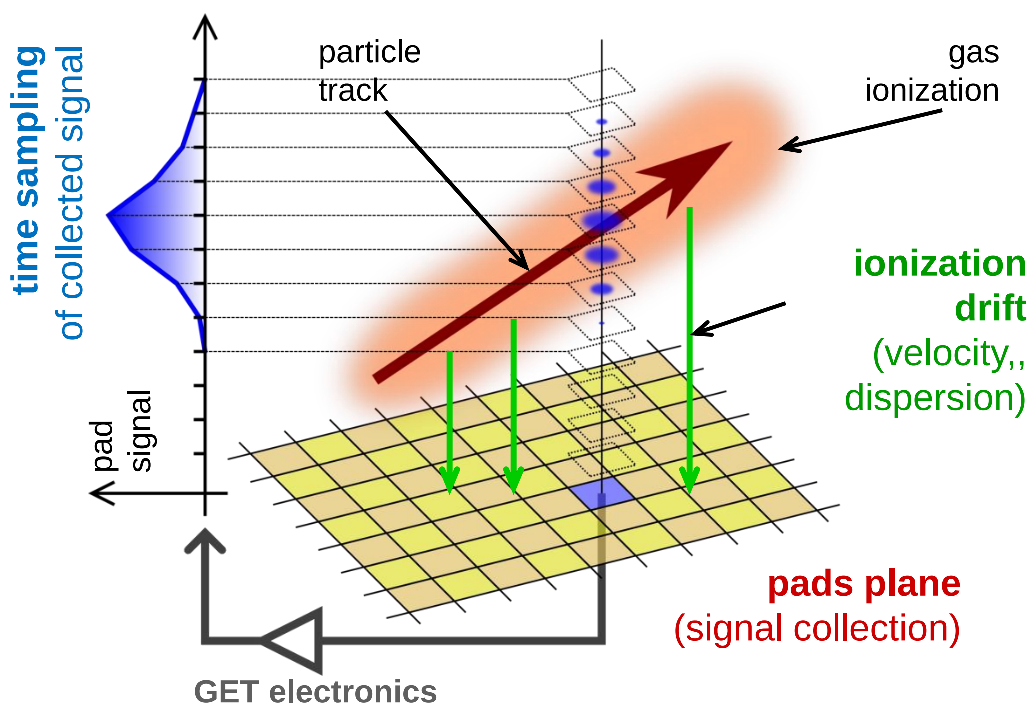
GANIL, CENBG, IPNO (F)
Leuven (B), Santiago de C. (S)

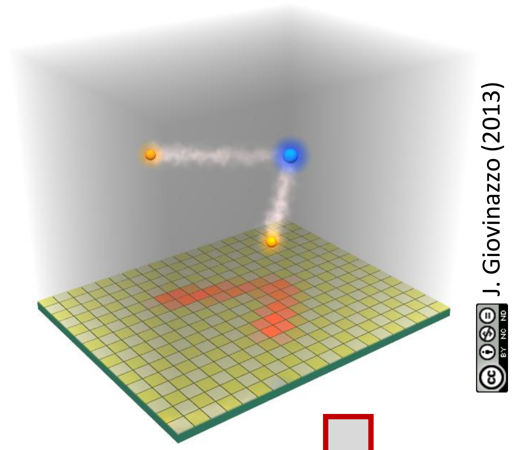
see also talk from E. Pollacco

ACTAR TPC principles: full 3D + energy

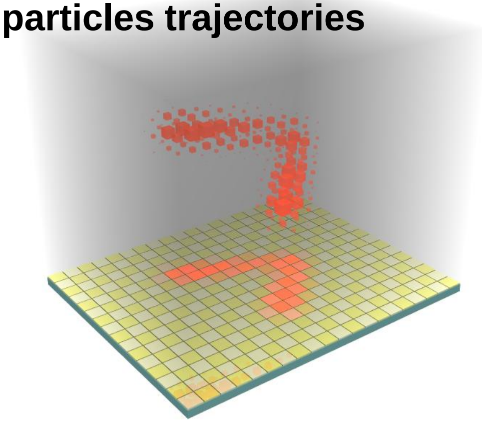
pads plane (signal collection)	TPC principle	time sampling of signal
2D digitization	$z \Leftrightarrow t$	3D digitization

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





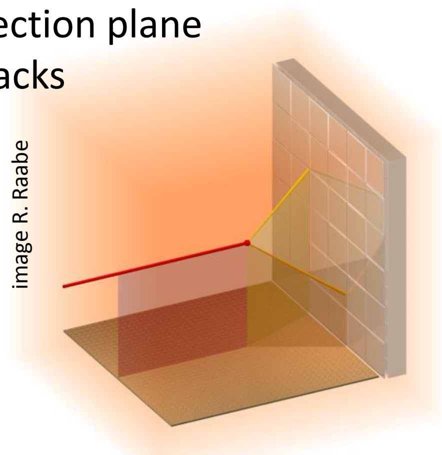
3D reconstruction of ionizations charges along the particles trajectories



ACTAR TPC: 1 development, 2 detectors

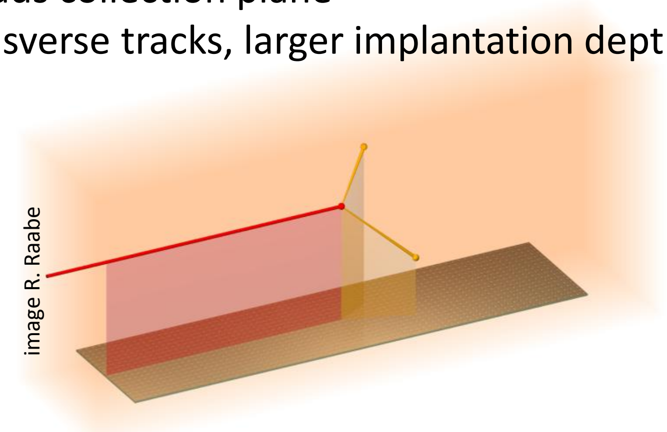
"reaction" chamber

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, 2x2 mm^2
2 geometries

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

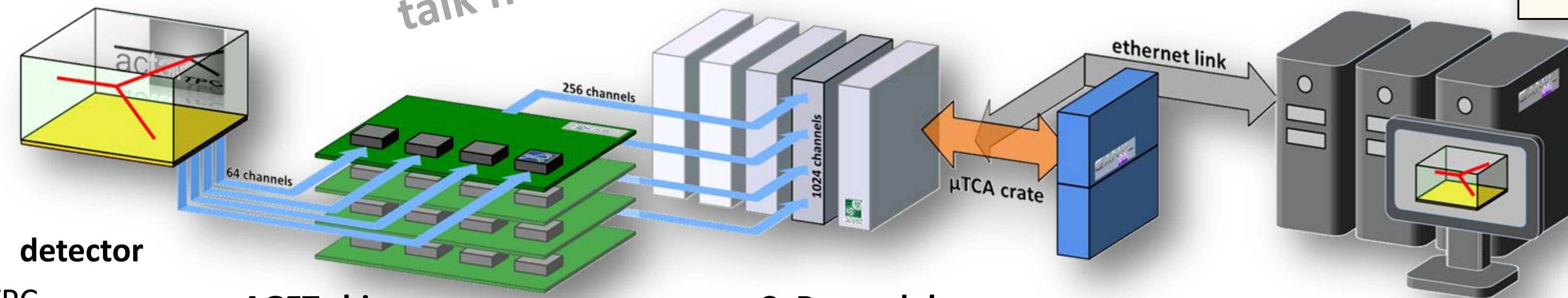
→ decay chamber: Region
pad plane R&D
(J. Giovinazzo, CENBG)

GET electronics
technical solution
for channels readout

GET electronics

IRFU, CENBG, GANIL, MSU
ANR 2011-2015

talk from E. Pollacco...



detector
TPC
16384 pads

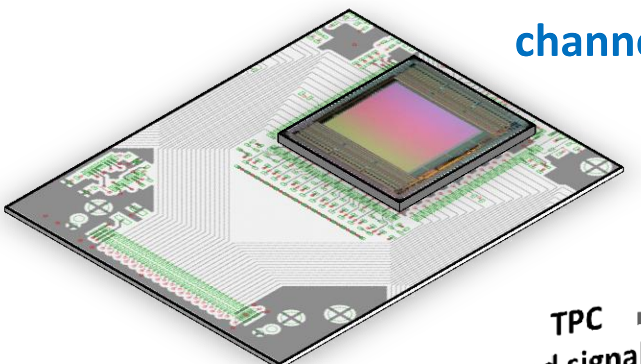
AGET chip
64 channels
signal processing
(CSA + shaper),
analog memory,
discriminator

AsAd board
4 chips
(+ config.)
signal & mult.
coding (ADC)

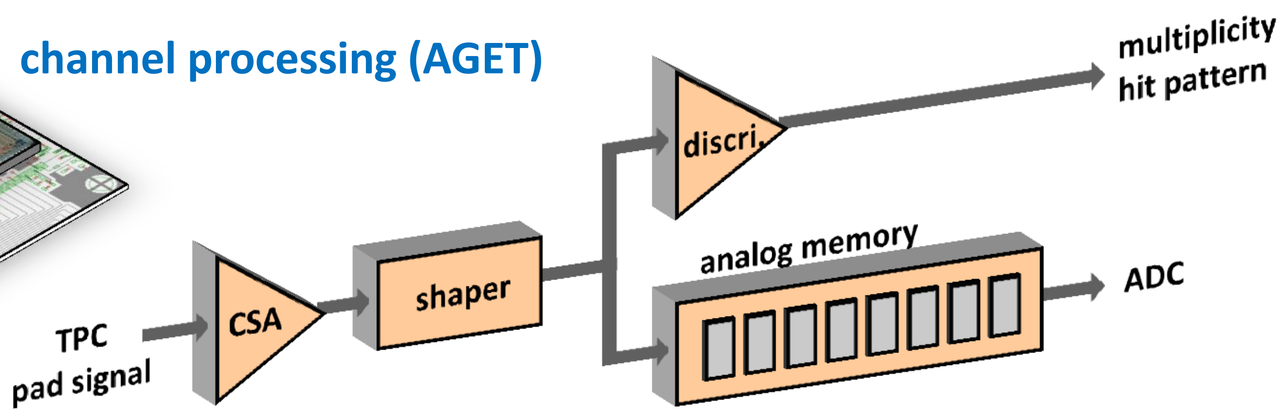
CoBo module
4 AsAd boards
digital data
management

MuTAnT
clock distrib.,
trigger management
(3 levels)

control / acquisition



channel processing (AGET)



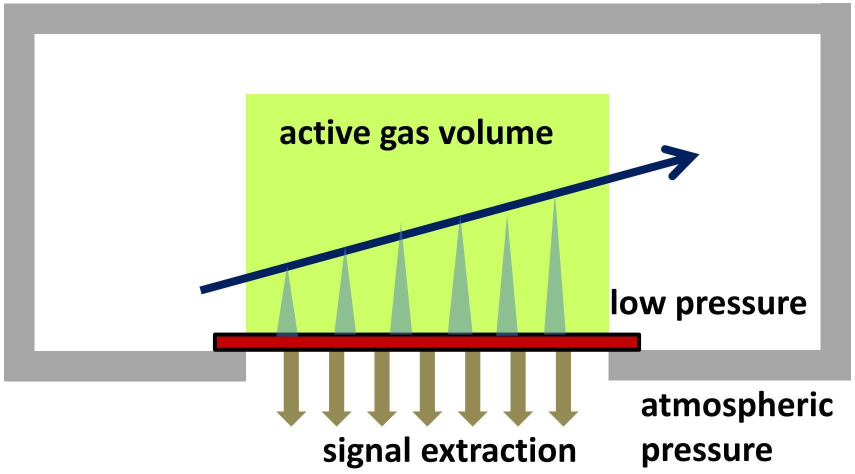
collection pad plane: 2 demonstrators prototypes

signal amplification: "***micromegas***"

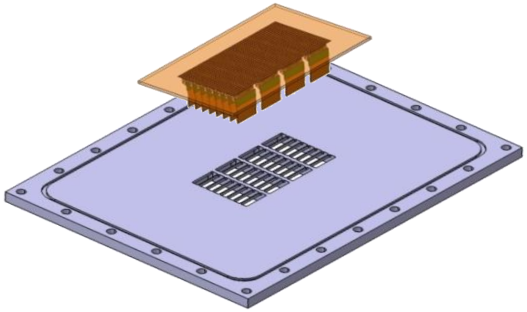
various constraints

→ **pads density**
signal extraction through the plane

→ **mechanical**
sealing, deformation



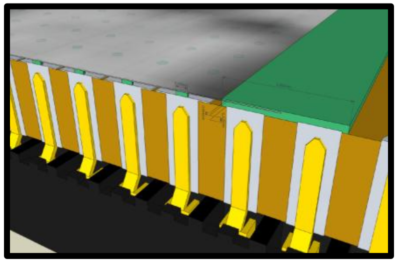
"standard" option (GANIL / IPNO)
standard PCB, small connectors for signal extraction through flange holes



☺ known technology

☹ fragile (connectors), signal routing

"CENBG" option
direct connection through PCB
reinforced PCB (metal core)



☺ conceptually extremely simple

☹ mechanical constraints
complex realization process
feasibility and response to be tested

“FAKIR” pad plane

original proposition:

CENBG (J. Pibernat)

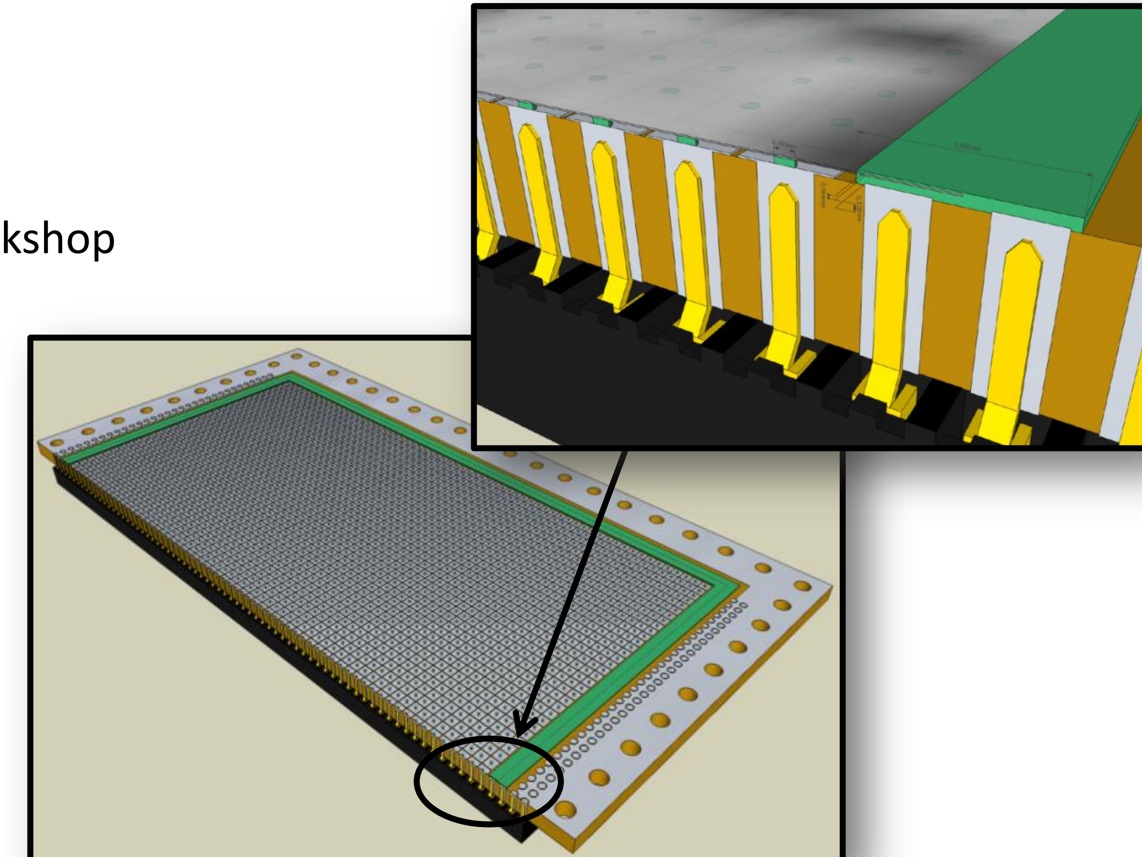
realization:

collaboration CERN PCB workshop
(R. de Oliveira)

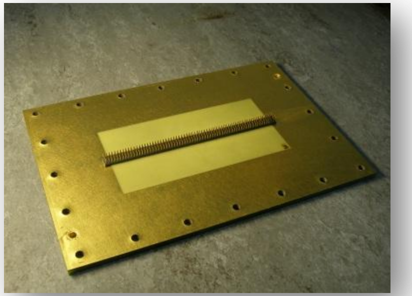
principle:

metal-core PCB (Alu-HR)

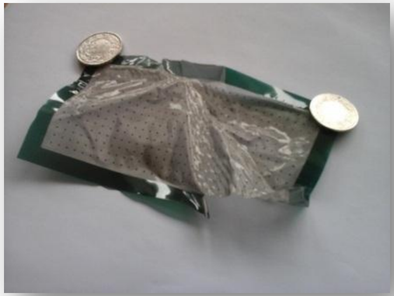
- metal plate drilling
- holes isolation (resin)
- PCB layers
- drilling & metallization
- connectors soldering
- micromegas



"FAKIR" pad plane prototypes

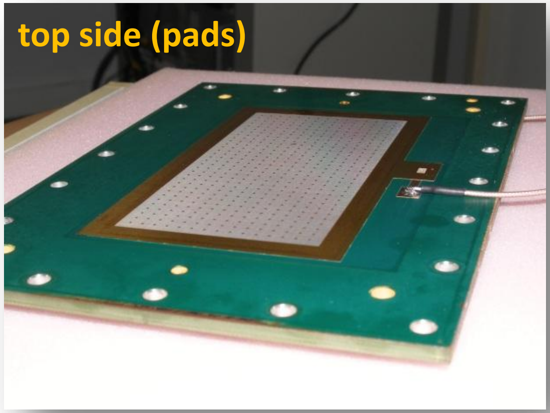


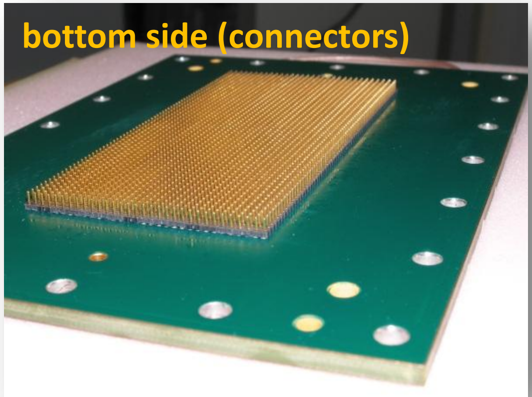
1st prototype: feasibility test (limited pads number)
coll. CERN / R de Oliveira
PCB realization issues
soldering issues

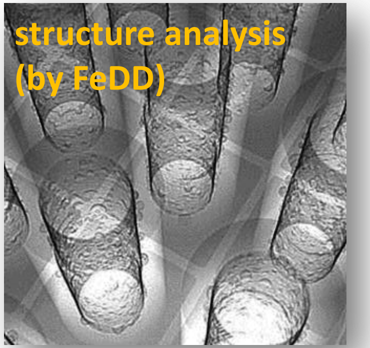


2nd prototype: response characterization
coll. CERN / R de Oliveira
problems with micromegas

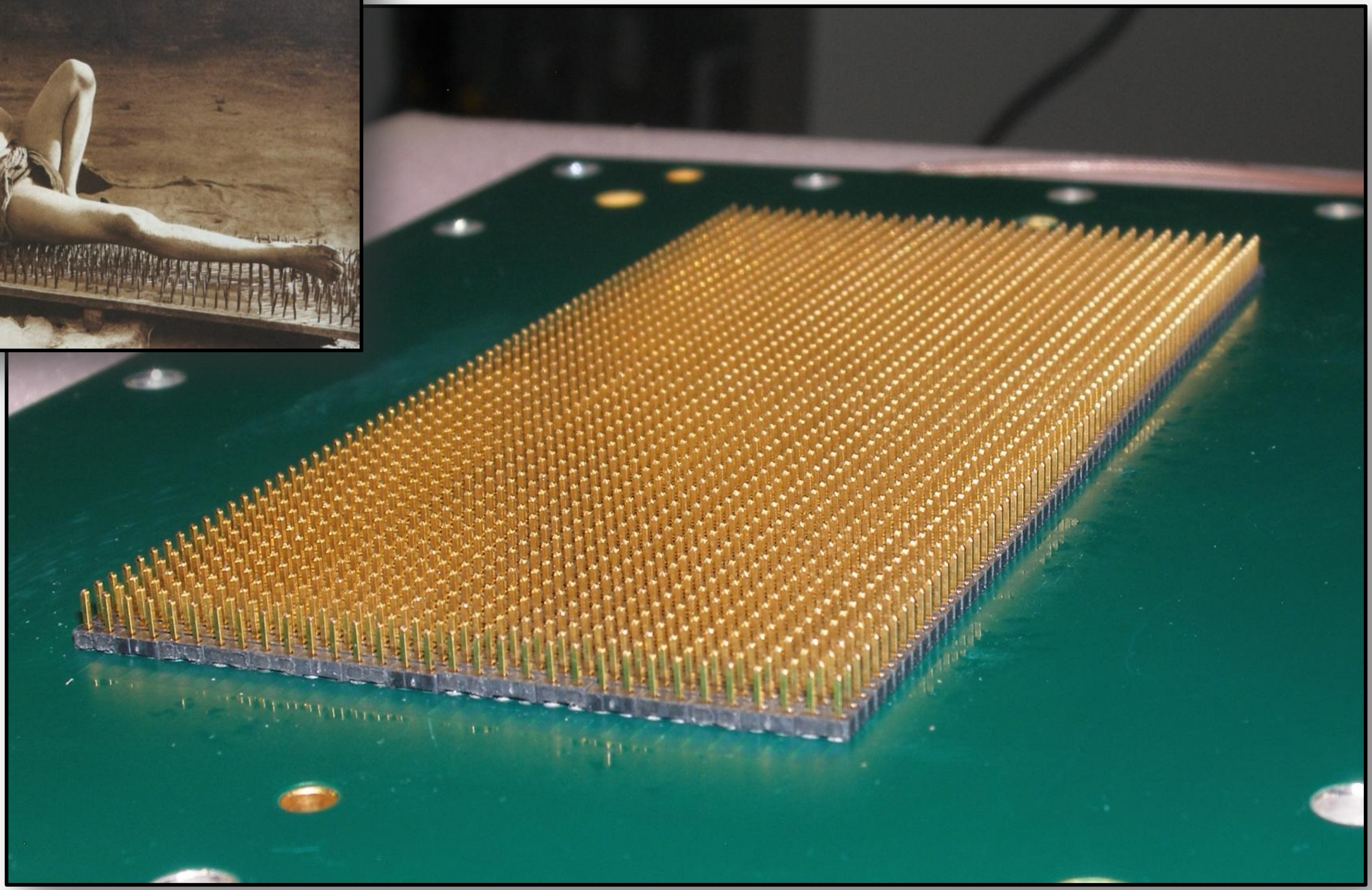
3nd prototype: ACTAR TPCdemonstrator equipment
coll. CERN / R de Oliveira (PCB + micromegas)
& FeDD company (connectors soldering)



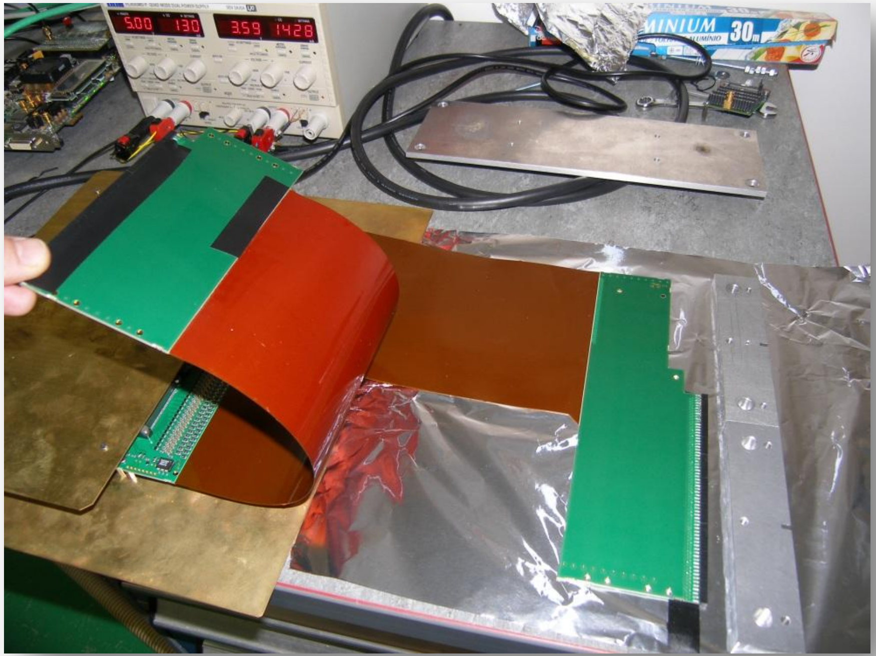




why "FAKIR" ?



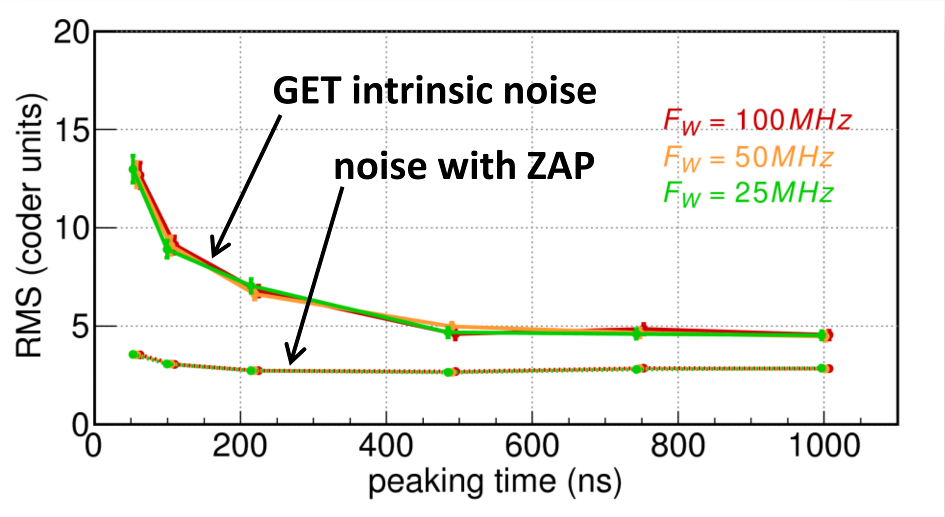
ZAP connectors: flex design



signal readout
- limited noise (capacitor)
- shielding

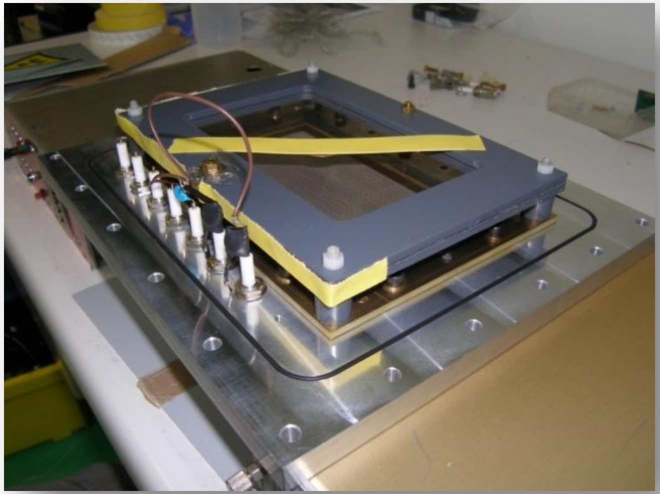
electronics channels protection

noise from ZAP



design for both final chambers
- 1 x 64 AsAd boards (decay)
- 2 x 32 AsAd boards (reaction)

test setup (collection plane): ^{55}Fe X ray source

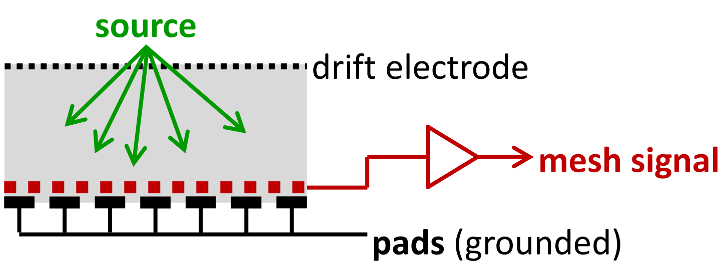


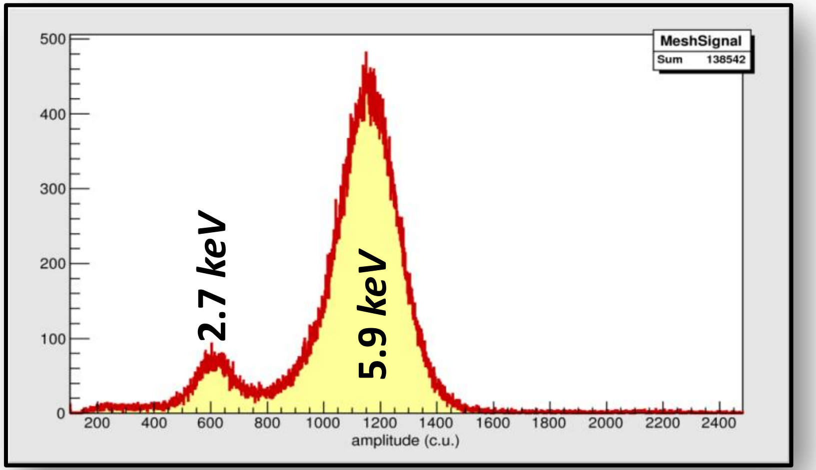
drift volume thickness: **2.5 *cm***

HV_{mesh} = **–570** *V*

HV_{drift} = **–1000** *V*

P10 gas ($Ar\text{-}CH_4$), 1 atm



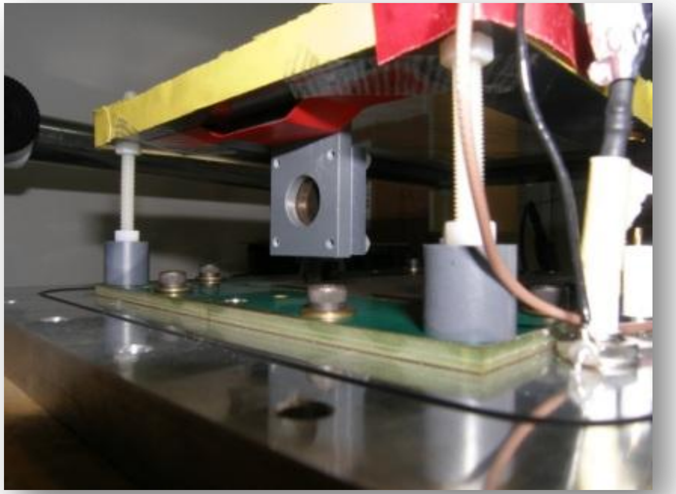


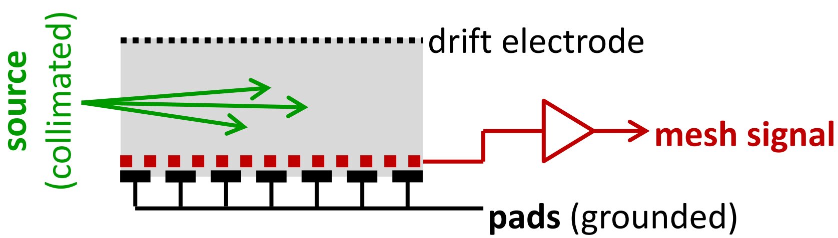
pad plane resolution (FWHM)

@ **6** *keV*: **~22 %**

non collimated source → includes the pads collection variations

test setup (collection plane): 3-alpha source



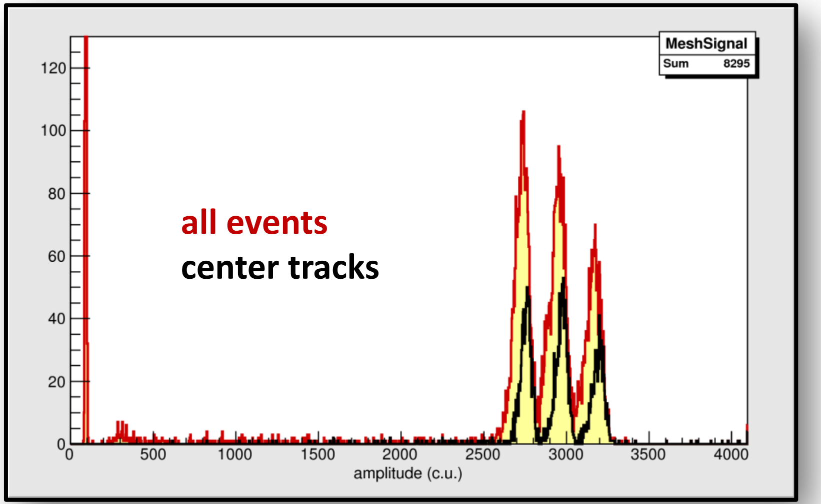


drift volume thickness: **5.0 *cm***

$HV_{mesh} = -370\ V$

$HV_{drift} = -1500\ V$

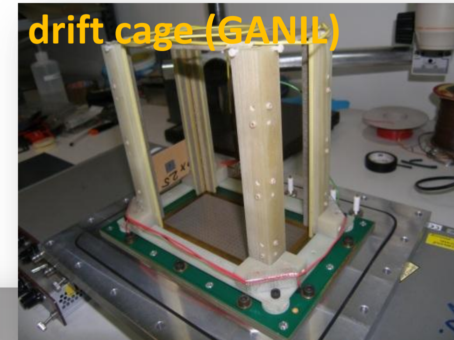
P10 gas (Ar-CH_4), 1 atm

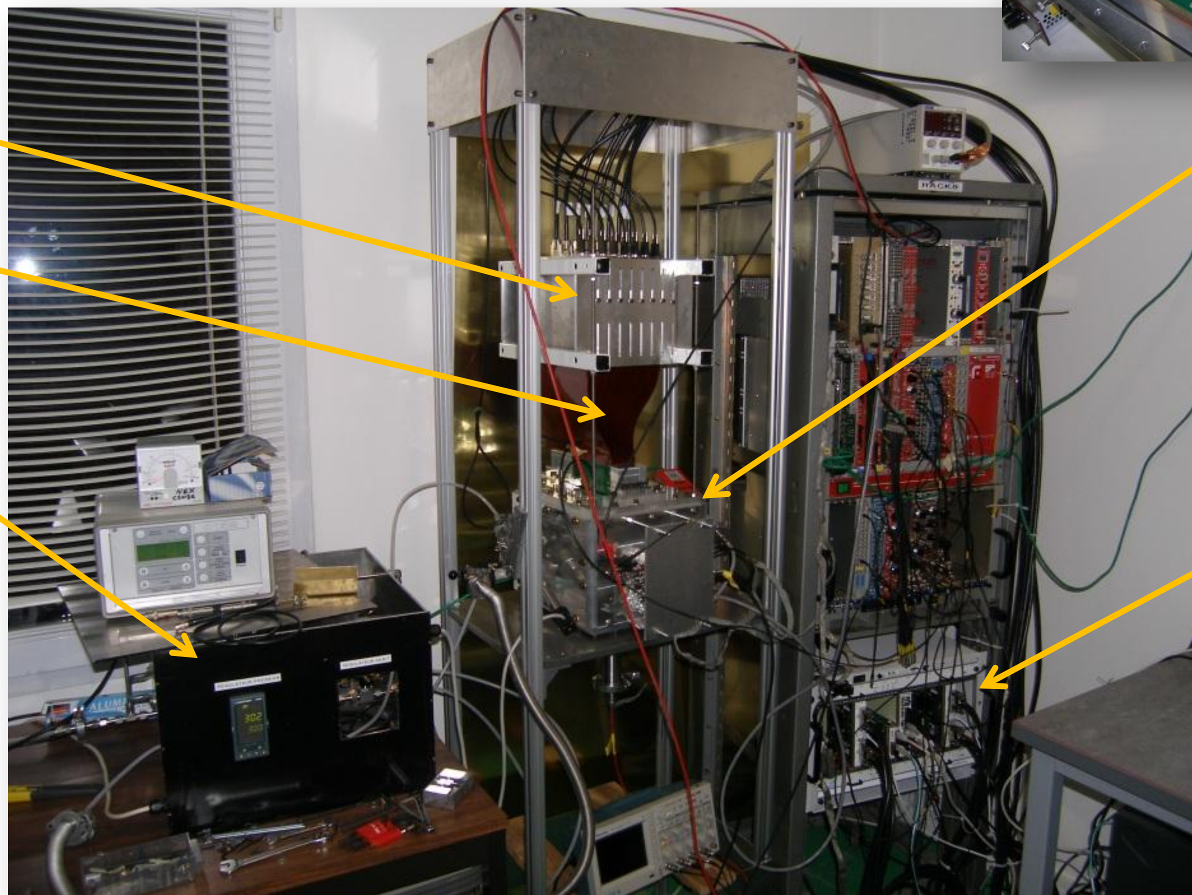


includes the pads gain inhomogeneity

ACTAR TPC demonstrator (CENBG version)

full electronics (march 2016) → 2048 pads signal





8 AsAd boards

ZAP

gas control

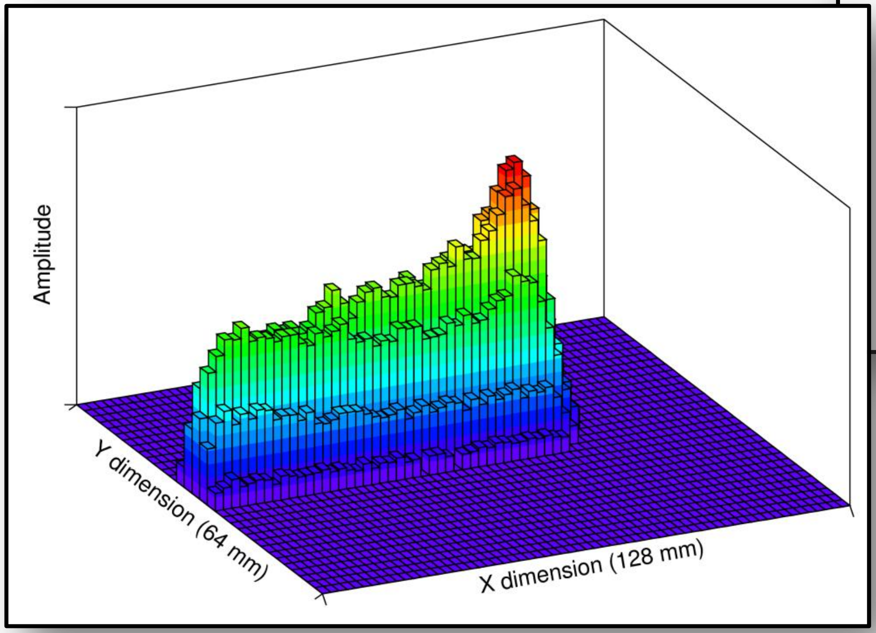
demonstrator chamber

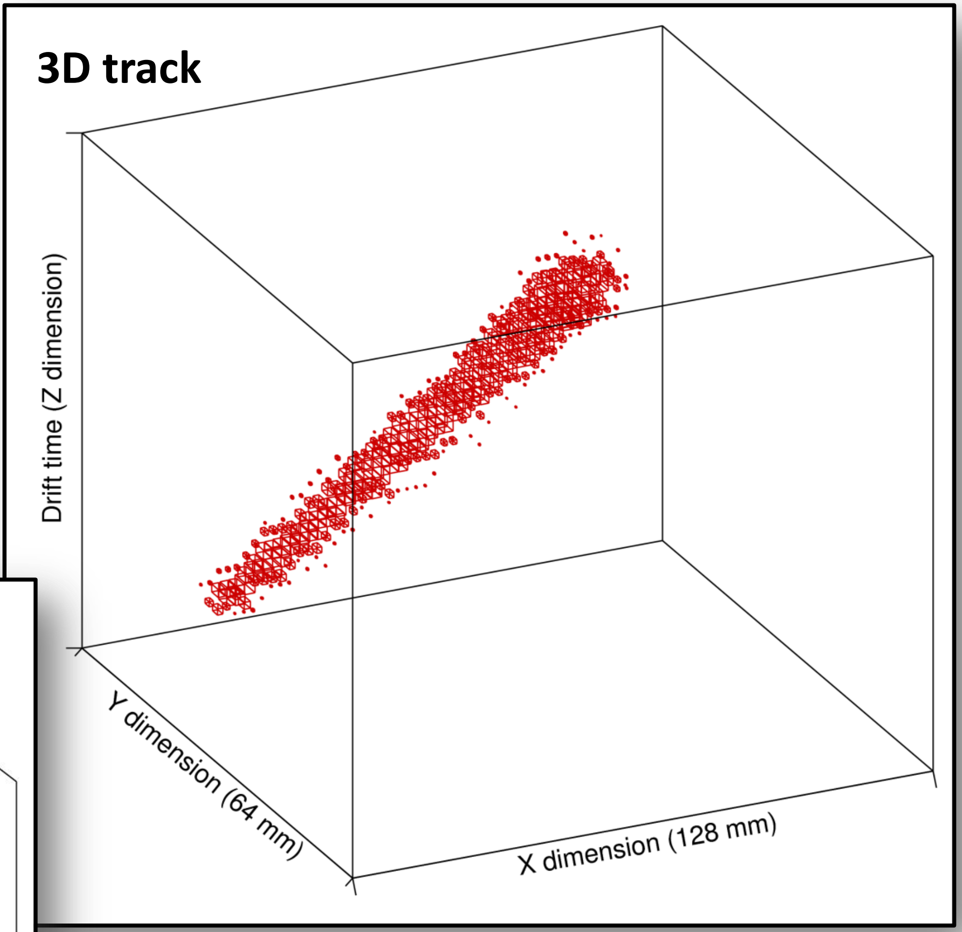
µTCA crate
CoBo modules

3D tracks + signal amplitude

single track:
alpha particle, 45° angle

X-Y energy deposit: Bragg peak

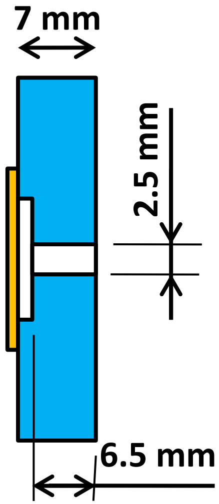


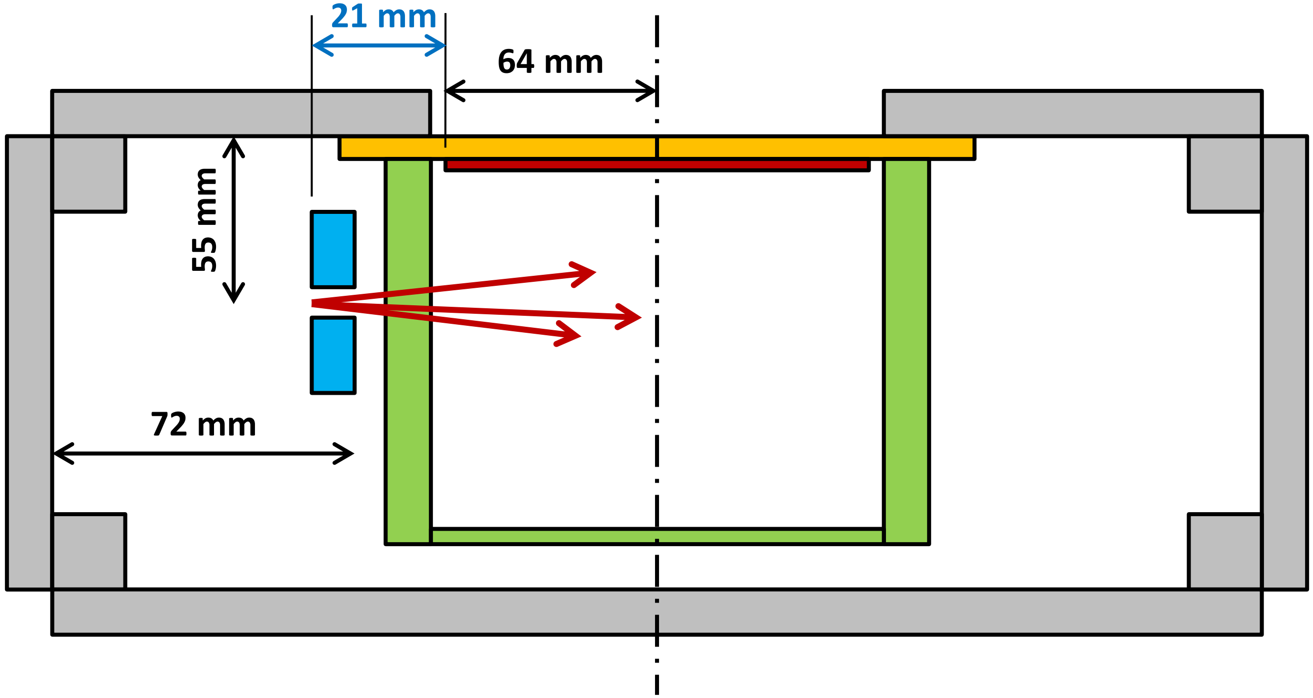


P10 gas (Ar-CH_4), 400 *mbar*

ACTAR TPC demonstrator tests (alpha source)

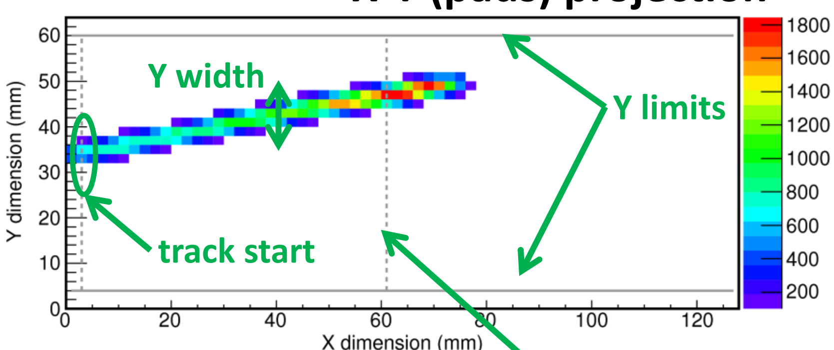
collimated (roughly)
3-alpha source
(5~6 *MeV*)



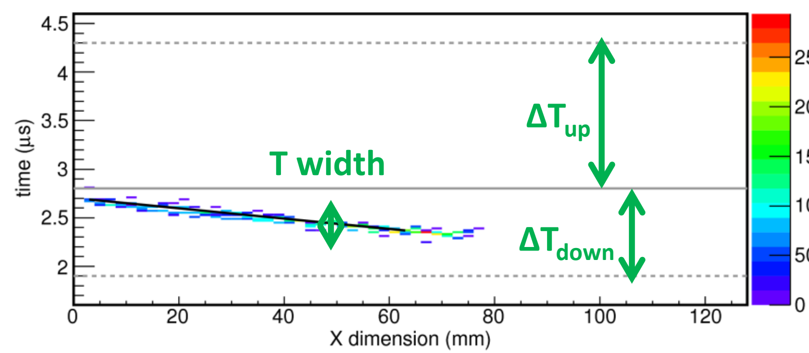


tracks selection

X-Y (pads) projection

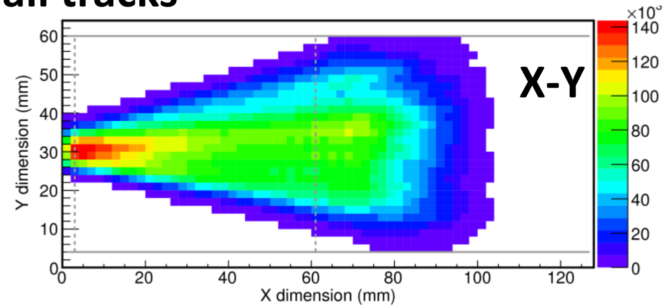


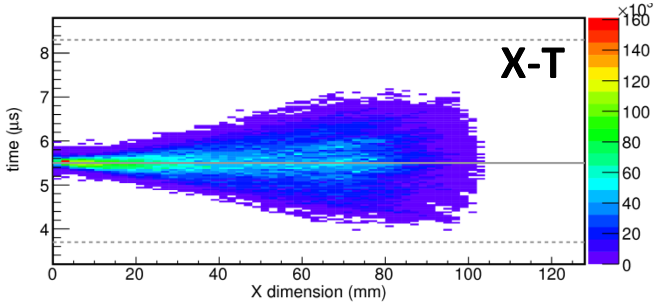
drift time



first characterization: energy resolution

all tracks





Energy resolution @ 5-6 *MeV*

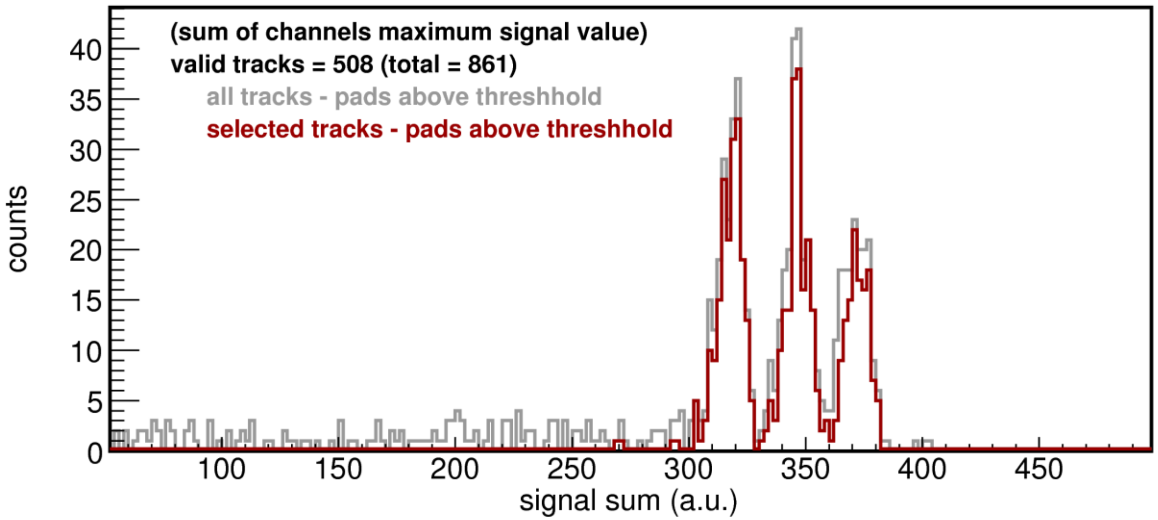
measured: **130 ~ 150 *keV***

effective: **105 ~ 135 *keV***

→ correction of intrinsic energy deposit before active volume (estimated from Geant4 simulations)

→ good resolution for a gas detector (silicon → 25 *keV*)

very preliminary analysis algorithms !!!



first characterization: drift velocity & tracks length

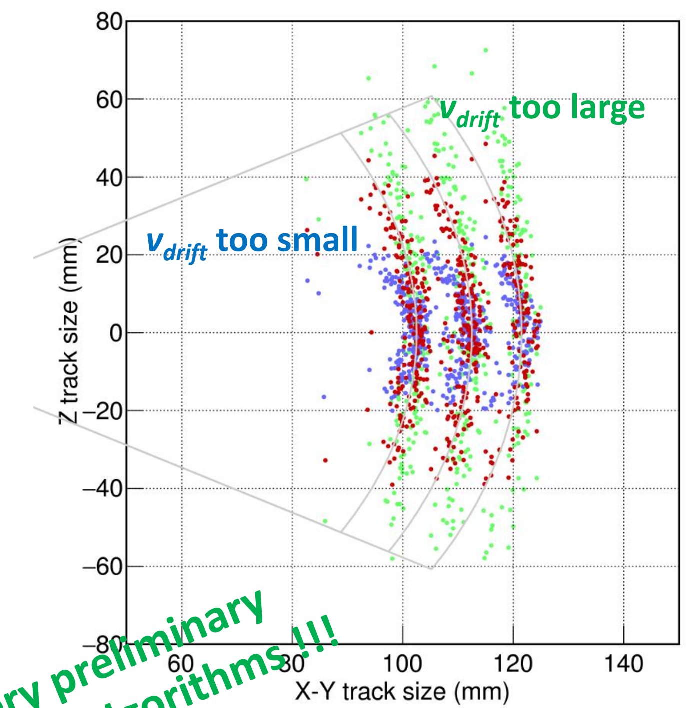
tracks fitting Bragg peak shape (simulation)
+ **energy** & **scale** parameters
track **start** & **stop** + signal **dispersion**

from tracks fit:

$$L_{XY} = \sqrt{\Delta X^2 + \Delta Y^2}$$
$$\Delta Z = v_{drift} \cdot \Delta T$$

total length: $L = \sqrt{\Delta X^2 + \Delta Y^2 + (v_{drift} \cdot \Delta T)^2}$

→ minimization of track length distribution **FWHM** for the 3 alpha components

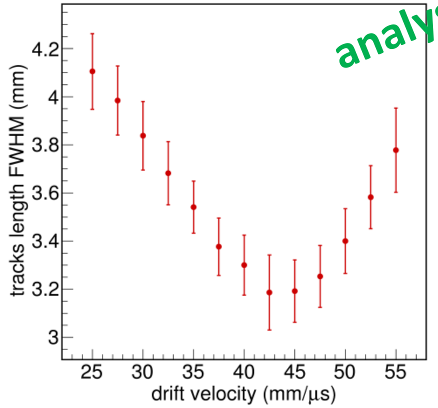


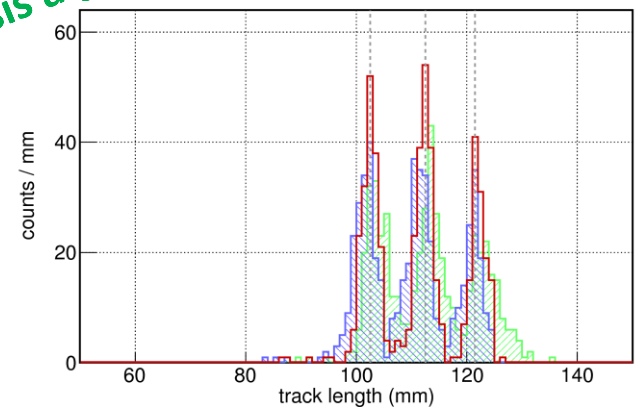
very preliminary analysis algorithms !!!

track length precision

→ simple line trajectory
→ σ_L ~ **3.2** ***mm*** (**σ_L / *L*** ~ 3%)

(to be compared with intrinsic distribution of alpha particles from simulations **~3.4** ***mm***)





Summary

collection pad plane

- → **feasibility & robustness ok**
  (several connectors insertions and extractions)
- → **resolution @ 6 keV ~ 22 %**
- → **foreseen option for final detectors**
- → some issues still to be addressed (induced cross-talk signals,…)

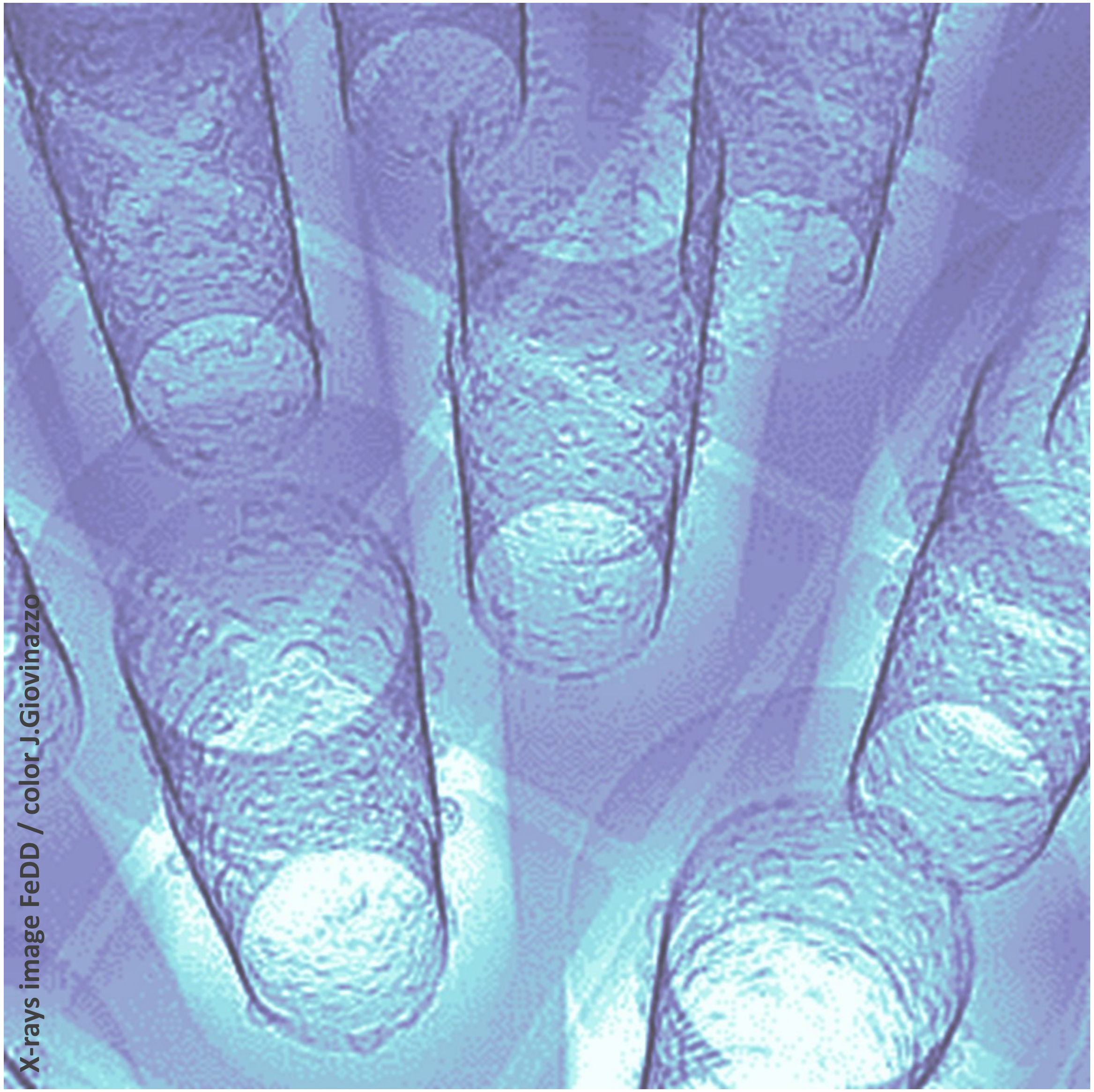
ZAP connectors

- → **noise comparable to standard connectors options**
- → **almost no additional noise from detector coupling**

pads signals / full electronics

- → **3-alpha test: resolution OK / tracking OK**
- → analysis algorithms to be developed
  (signal processing, tracking)
- → tests with ^{55}***Fe*** X-rays to be done (source not yet available)

ACTAR TPC demonstrator proof of concept is done !



thank you for your attention…