# DEVELOPMENT OF A LOW MASS/LOW BACKGROUND REAL XY-MICROMEGAS DETECTOR FOR NEUTRON BEAM PROFILING

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SPhN, 20/7/2015

# OUTLINE

- Motivation (n_TOF collaboration)
- Detector & electronics setup description
- Development & testing
- Results & future work

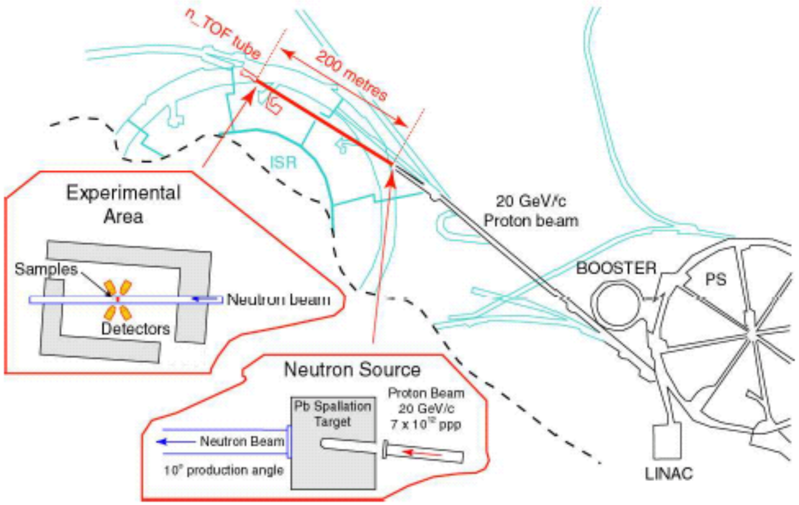
# THE n_TOF COLLABORATION

- ➢ Started before 2000, >100 participants, 37 institutes (Europe, India, Japan …)

**Goal:** Provide high accuracy data on useful parameters of neutron induced reactions for:
- Nuclear Technology
- Nuclear Astrophysics
- Medical Physics
- Fundamental Nuclear Physics

- ➢ Experiments performed at the **n_TOF (neutron Time-Of-Flight) facility** * at CERN.

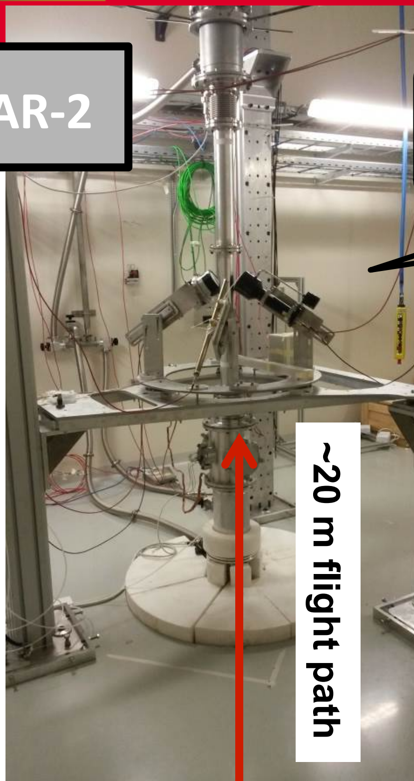
**Reaction yields measured at n_TOF:**
- Fission: (n,f) - actinides
- Capture: (n,g) – medium-mass nuclei to actinides
- Charged particle: (n,cp)




- ➢ Active participation of SPhN.

* C Rubbia et al., A High Resolution Spallation Driven Facility at the CERN-PS to measure Neutron Cross Sections in the Interval from 1 eV to 250 MeV, CERN/LHC/98-02(EET) 1998.

# THE n_TOF FACILITY (CERN)




**Neutron beam at EAR-2**
Flux:~$10^7$ neutrons/pulse
Energy resolution: $10^{-3}$ *(at 1eV)*<ΔE/E<$10^{-2}$ *(at 1MeV)*

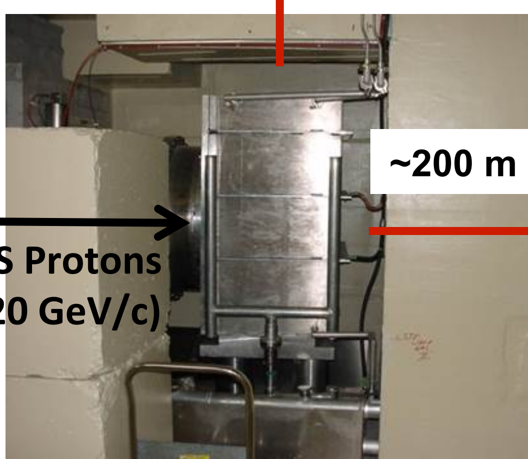
**Main features**

1. Proton beam from PS accelerator: **20 GeV/c**
2. Proton Intensity: **$7\times10^{12}$ppp**
3. White neutron beam: **0.025 eV-1 GeV.**
4. Neutron energy: **Time-Of-Flight technique**
5. 7ns width proton pulse with <0.8 Hz

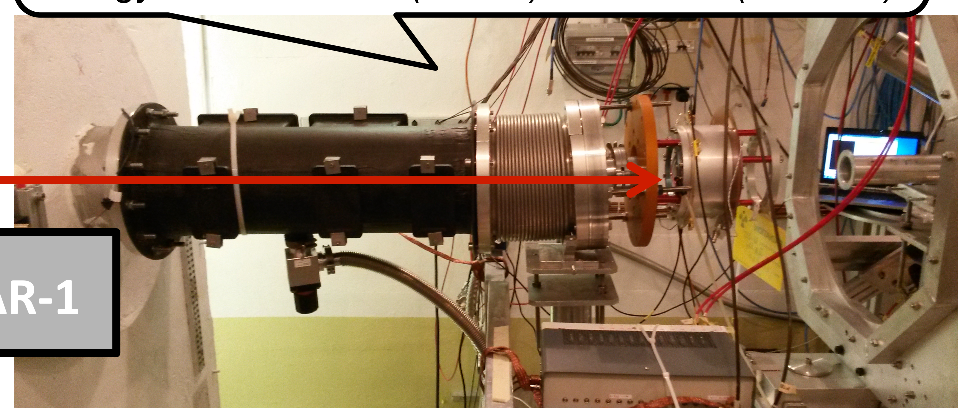
⇒ No overlapping of sequential neutron pulses.

6. High instantaneous flux in Δt~ms:

=> Maximization of signal-to-bgr ratio.




**Neutron beam at EAR-1**
Flux: ~$7\times10^5$ neutrons/pulse
Energy resolution: $10^{-4}$ *(at 1eV)*<ΔE/E<$10^{-2}$ *(at 1GeV)*

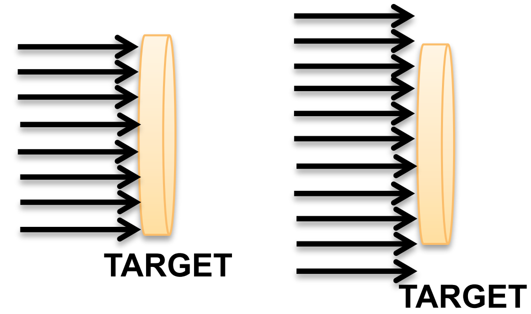


# NEUTRON BEAM MONITOR + PROFILER

Accurate neutron reaction yield measurements require:

- **Neutron fluence/Beam interception factor**

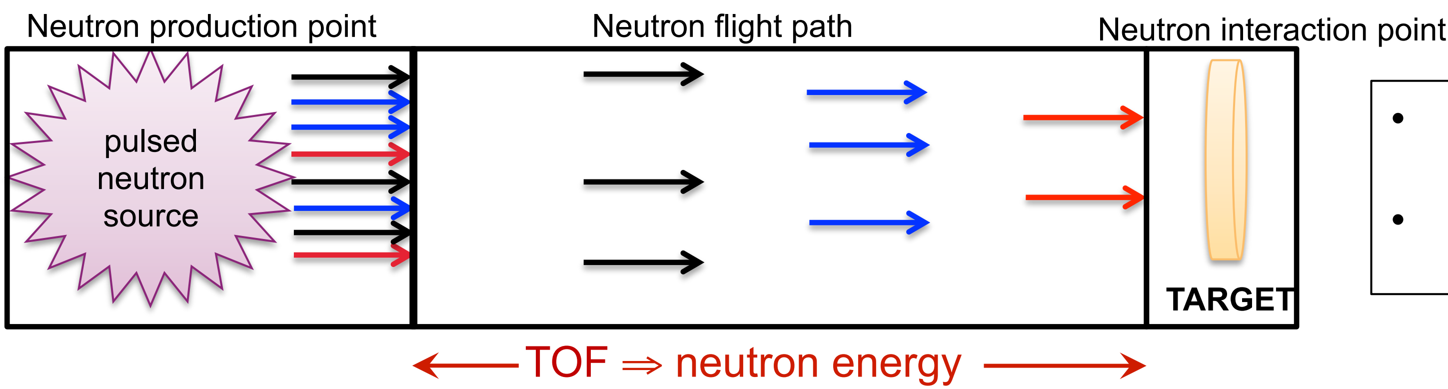
Number/fraction of neutrons hitting the area covered by the sample.




- **Shape of the beam profile**

Beam optics misalignment => Beam fluence variations.

For **non-monoenergetic** neutron sources:




- n_TOF facility (CERN) (thermal-GeV)
- GELINA (IRMM) (1meV-20MeV)

=>***Dependence of profile on the neutron energy***

**DETECTION SYSTEM:**

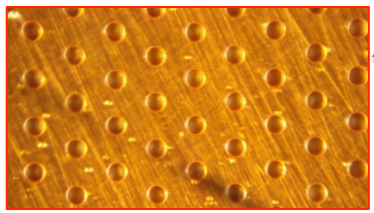
- Quasi-online neutron flux monitor + beam profiler as well
- LOW MASS: Minimal perturbation of the neutron beam / Minimal induced background: (not to disturb the main experiment)

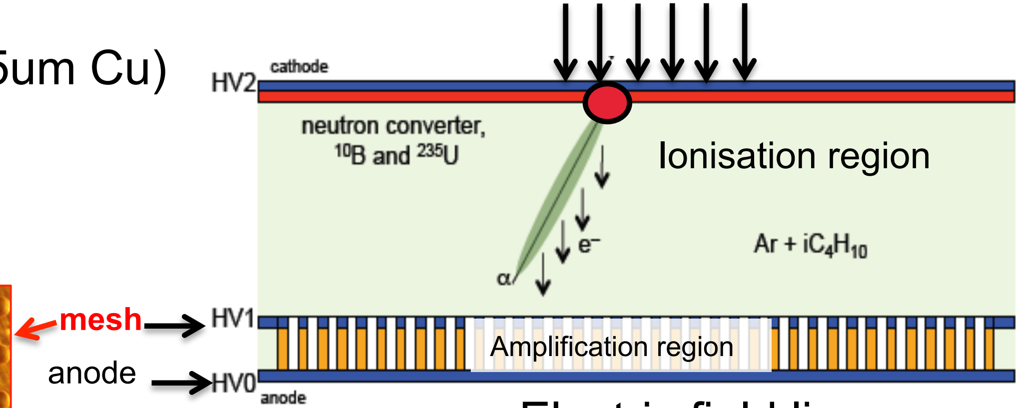
# MICROMEGAS DETECTORS FOR BEAM MONITORING

- **Neutron beam flux:** mainly **MicroMegas** detectors (IRFU)

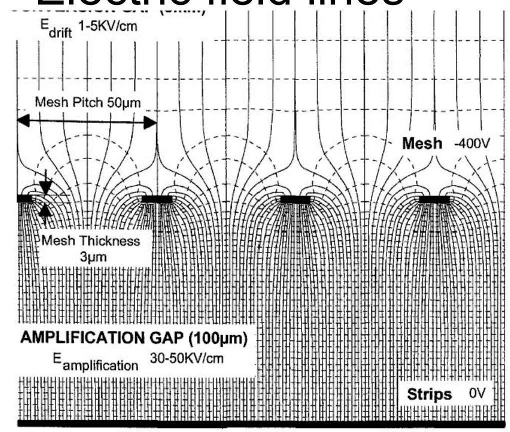
  Microbulk technology:

1. Low mass (5um Cu - 50um kapton - 5um Cu)
2. High radiopurity
3. Low cost
4. Robustness and radiation hardness.






Electric field lines




➢ Solid **neutron converters** with standard neutron induced reactions=>Detection of **charged particles**

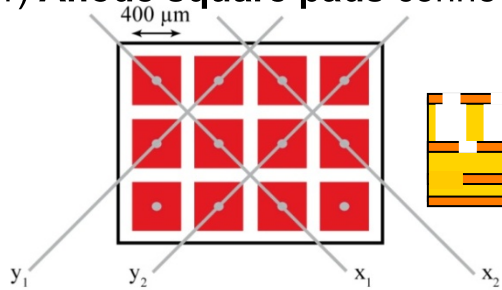
1. $^{10}B(n,a)$ **$E_n$** : 0.025eV – 1MeV
2. $^{6}Li(n,t)$ **$E_n$** : 0.025eV – 1MeV
3. $^{235}U(n,f)$ **$E_n$** : 0.025 eV & 150 keV – 200MeV

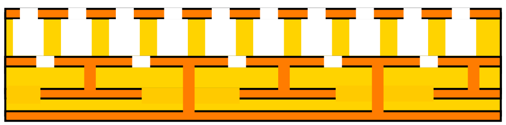
- **Neutron beam profile:** =>Bulk micromegas with Segmented or pixelised anodes.
  =>OR other type detectors: SiMon2D, Gafchromic, Timepix, GEM.

# SEGMENTED MESH MICROBULK DEVELOPMENT

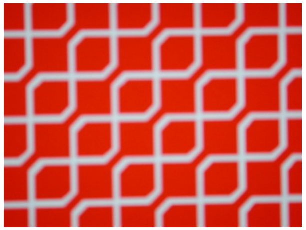
## Previous existing 2D MicroMegas at n_TOF

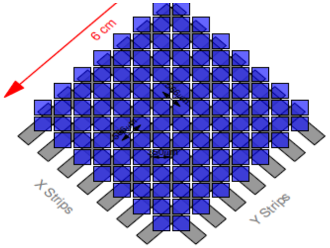
1) **Anode square pads** connected through 2 extra layers.



2) **Anode pads/strips** connected through 1 extra layer.





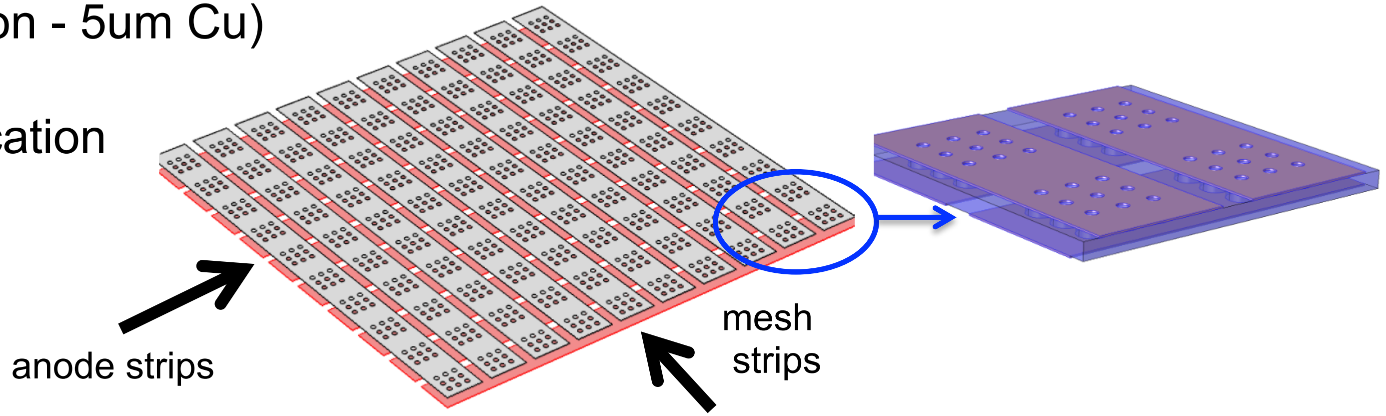

*« A low mass microbulk with real XY structure »,Th. Geralis, RD51 Common Fund Project*
*« Transparent XY-MicroMegas neutron beam profiler », F. Gunsing, P2IO Project*

**Segmented mesh microbulk:**

1) No extra layers
(5um Cu - 50um kapton - 5um Cu)

2) Production simplification

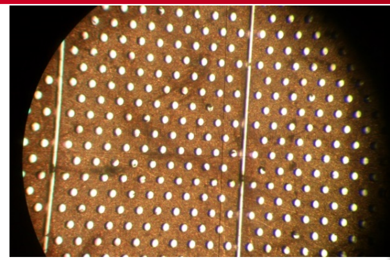
3) Real X-Y structure



# PROTOTYPE EVOLUTION

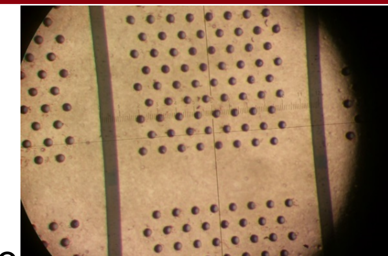
## First batch:

- ✗ Problems during etching due to holes topology.
- ✗ Many strips in short circuit.



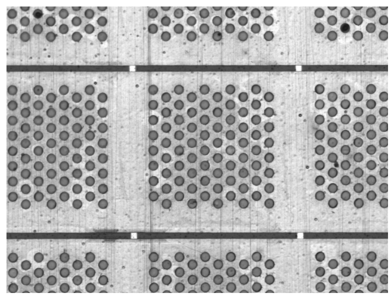
## Second batch

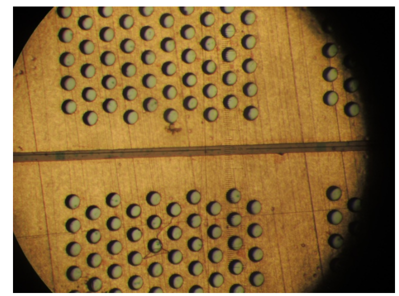
- ■ Etching OK with the new topology
- ■ All detectors working
- ✗ Bad energy resolution due to large gaps (~150 μm)



## Third batch

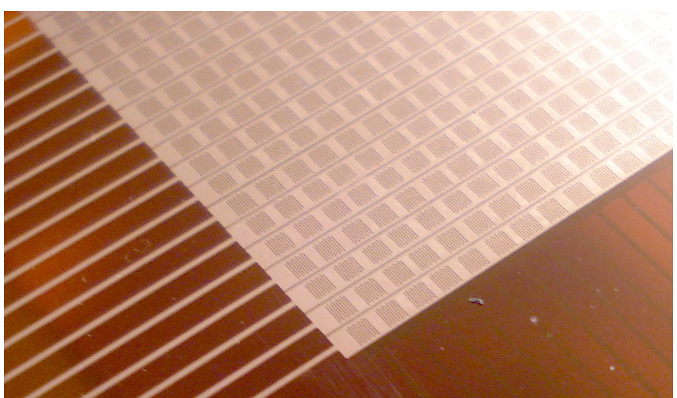
- ■ Holes ∅ 60/50 μm
- ■ Gaps reduced to 35 μm
- ■ Energy resolution OK!

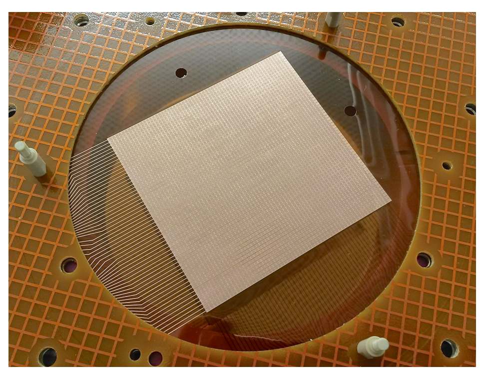


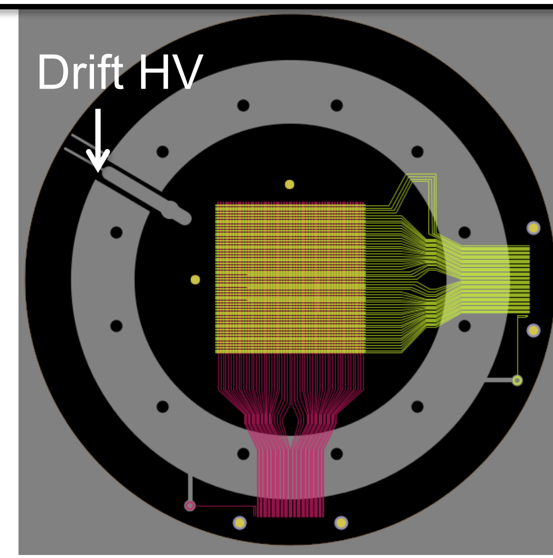


**The first TWO detectors produced:**

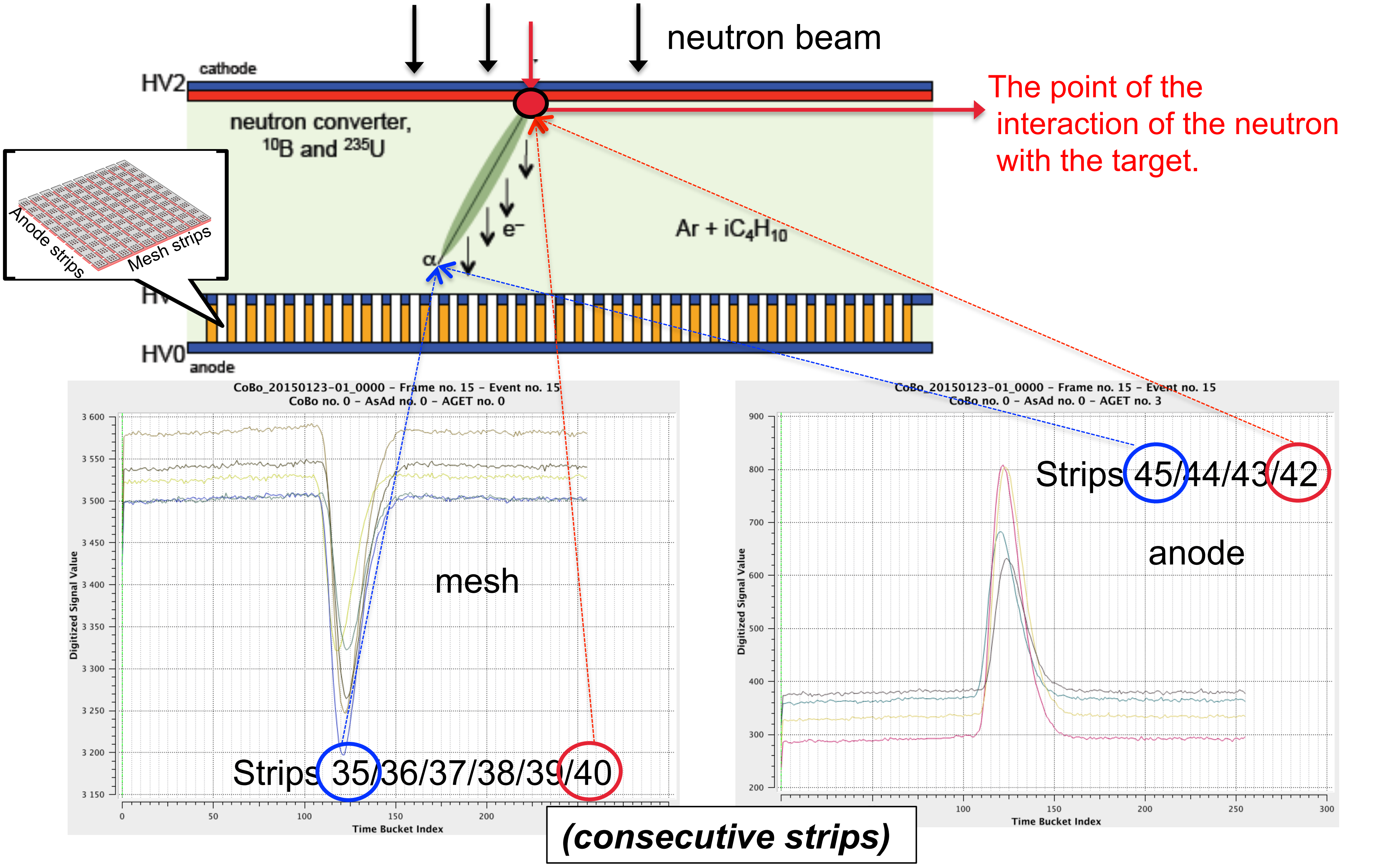
- 58 x 59 strips on a 6 x 6cm$^2$ area (**1mm** thickness)
- Mesh hole:~ 60μm / Pitch: 100 μm.







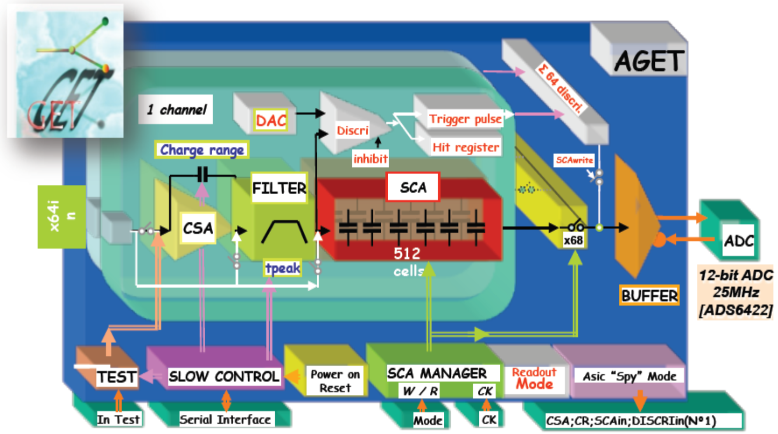
# NEUTRON BEAM PROFILE EXTRACTION



# ELECTRONICS

***Challenge:*** *No global trigger signal + timing difference between strips.*

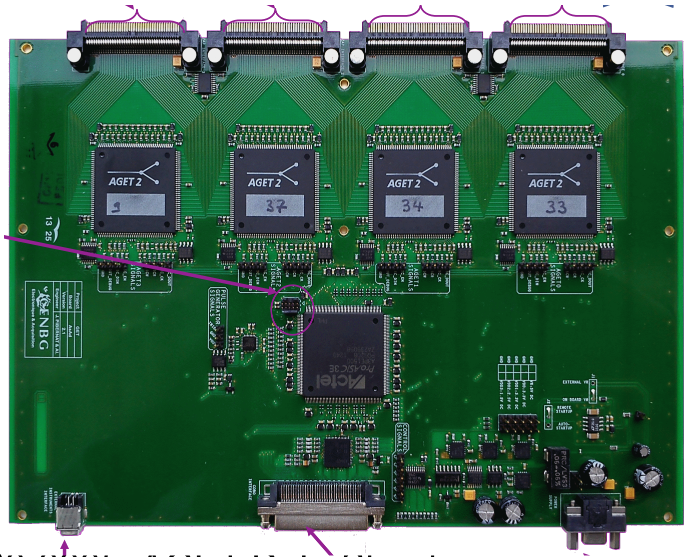
=> **AGET electronics* + Reduced CoBo configuration**




- **Auto trigger**: discriminator and threshold
- 64 analog channels /chip.
- Multiplicity signal: analog OR of 6discriminators
- Address of the hitted channels
- SCA readout mode (all/hitted/selected channels)

- Max sampling rate: 100 MHz.
- 16 peaking time values: 50 ns-1us.
- 4 charge ranges/channel: 120fC/ 240fC/ 1pC/ 10 pC.

**AsAd card:**
4 AGET chips

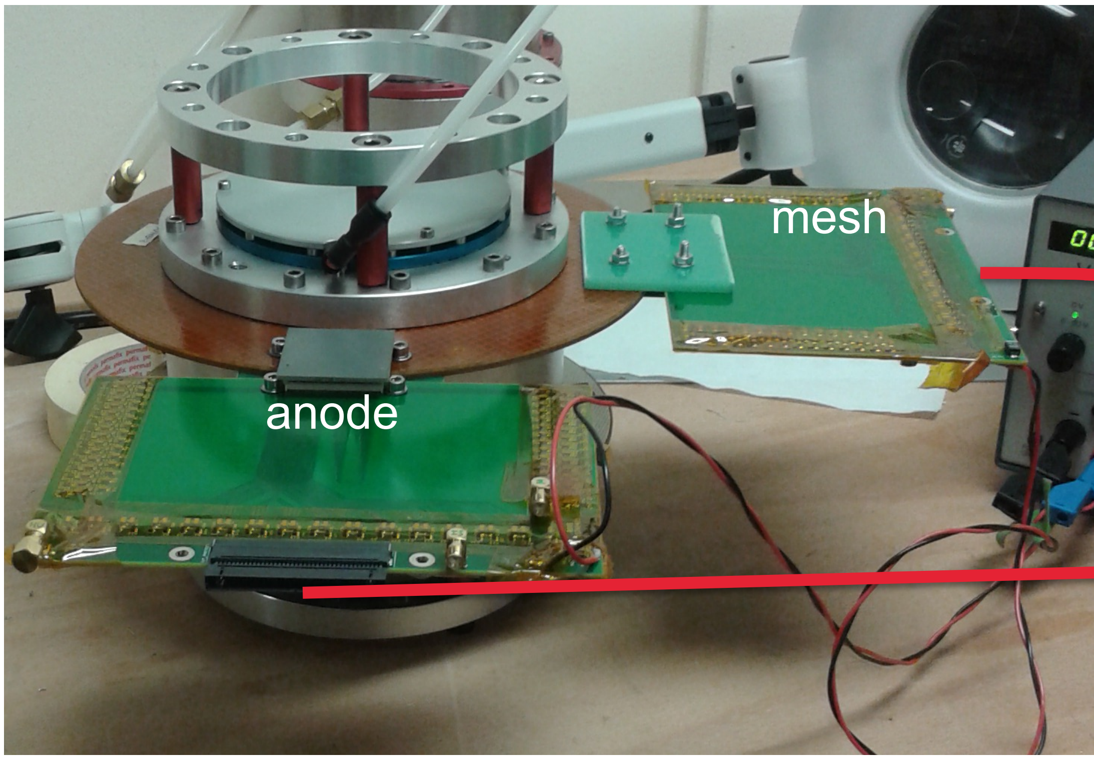


*GET, General electronics for TPC, ANR proposal / GET-QA-000-0005, AGET Data Sheet.

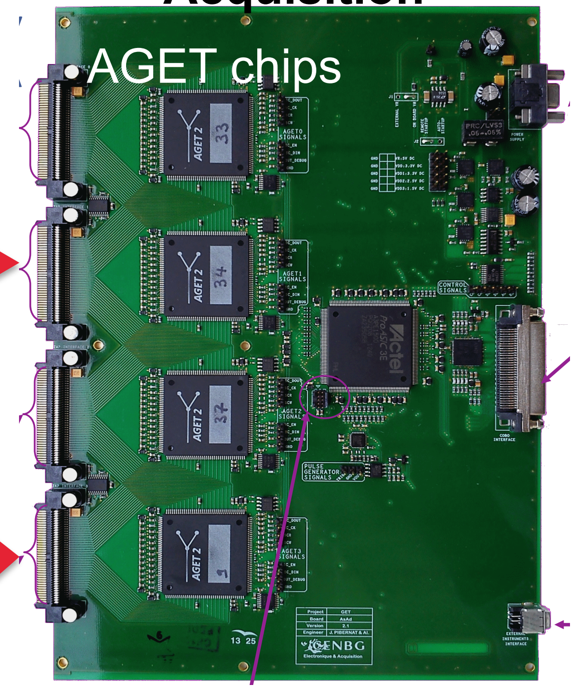
# FRONT-END CARDS SETUP

**Front end electronics**:

1) Protection diodes
2) take the signal from the strips (mesh+anode)
3) distribute the HV (mesh)
4) take the sum signal (recorded with conventional electronics)=>neutron flux




**Acquisition**



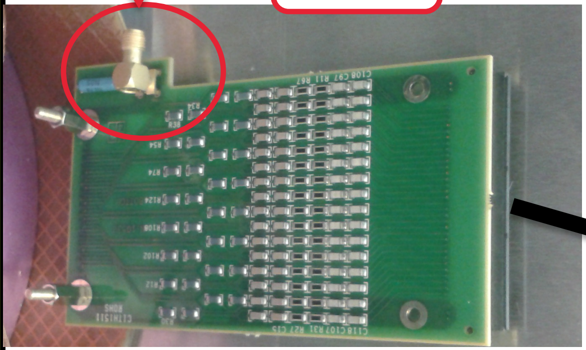

*FIRST VERSION: problems: missing strips, wrong routing, noise from low voltage supply module*

# NEW FRONT END CARDS

DETECTOR

MESH STRIPS

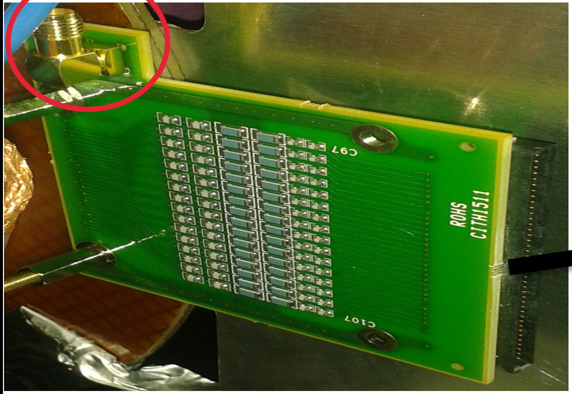
HV in



HV distribution + strip signals

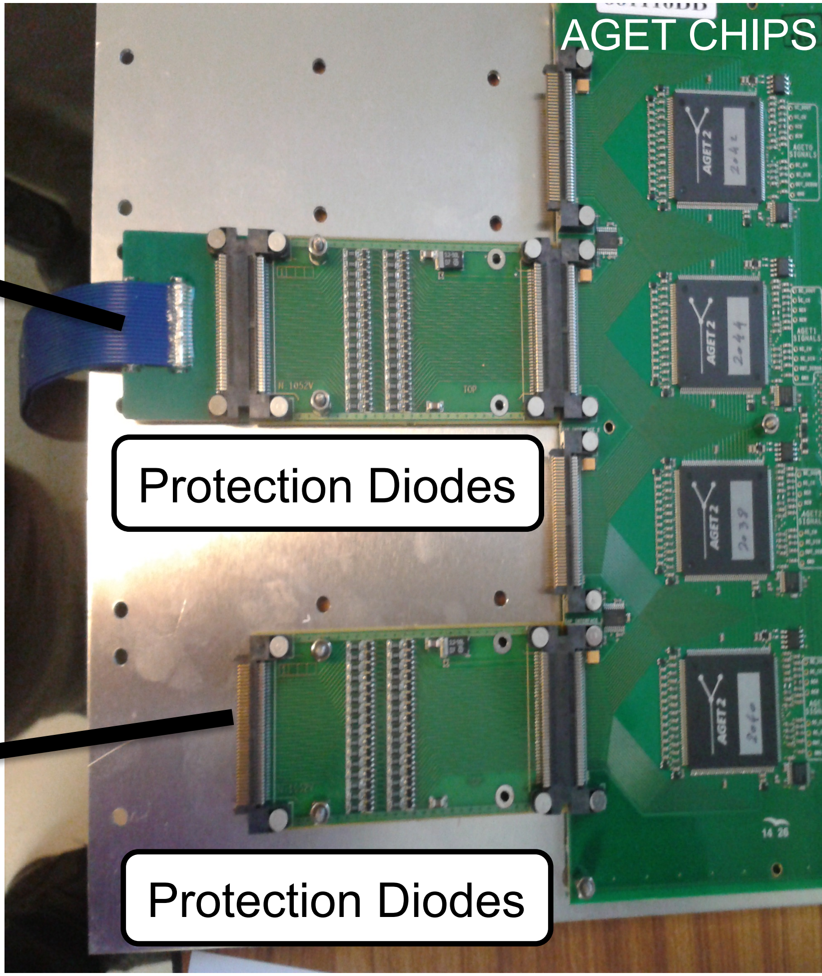
ANODE STRIPS

Sum signal to conventional electronics



Strip signals+Sum signal

AGET CHIPS



Protection Diodes

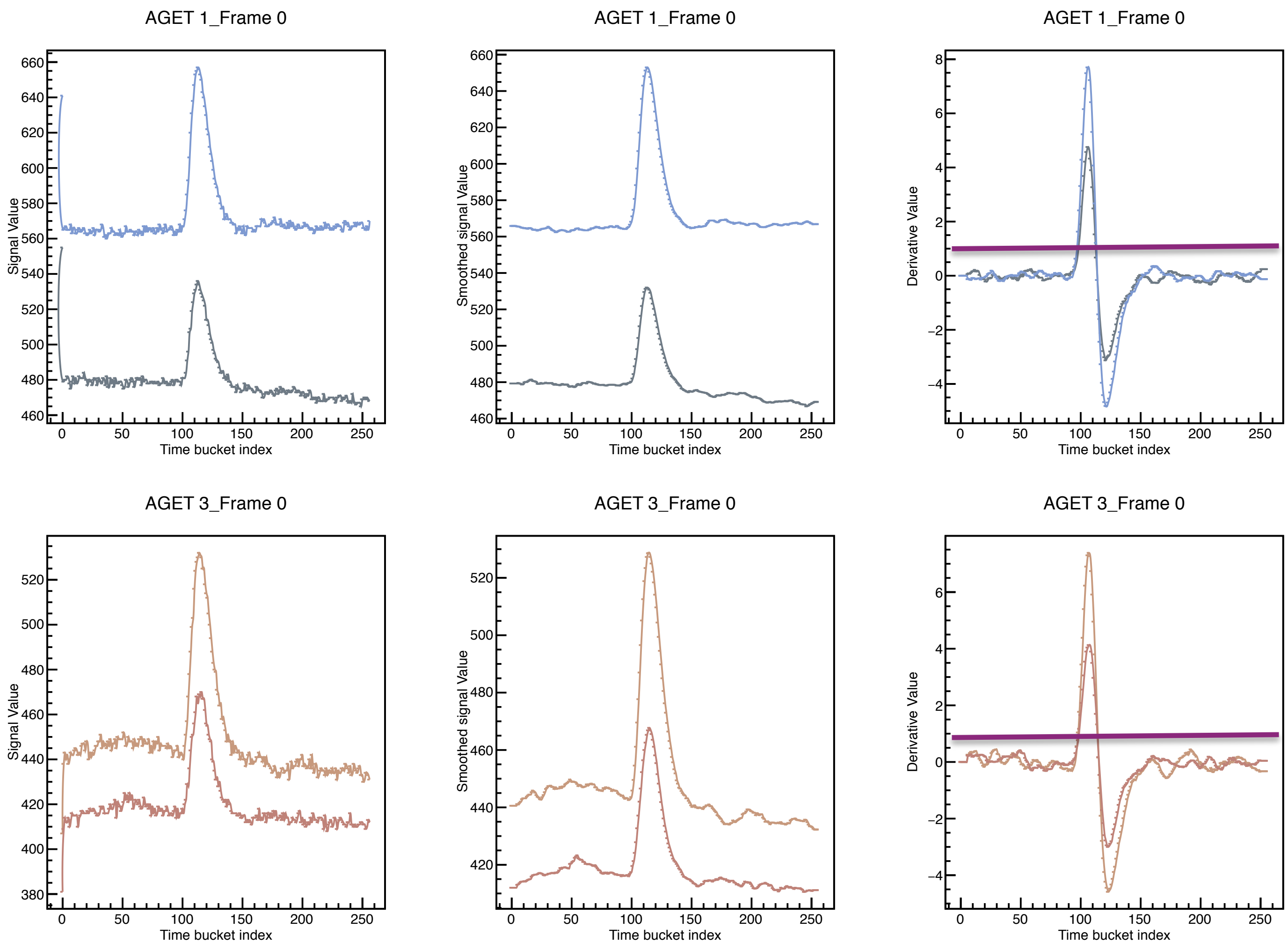
Protection Diodes

# SIGNAL ANALYSIS

Initial pulses | Smoothed pulses | Derivative pulses

MESH

ANODE

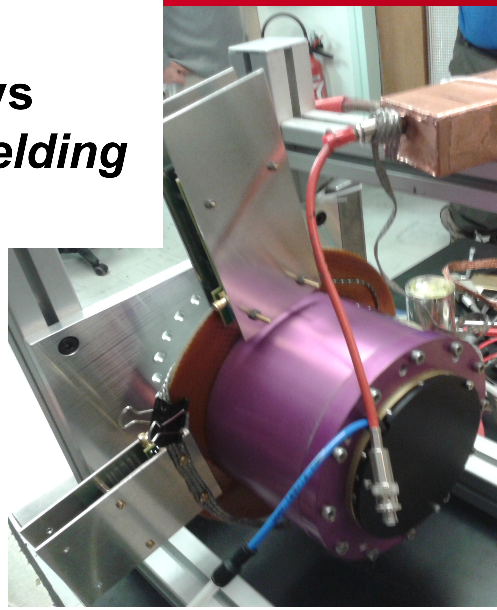


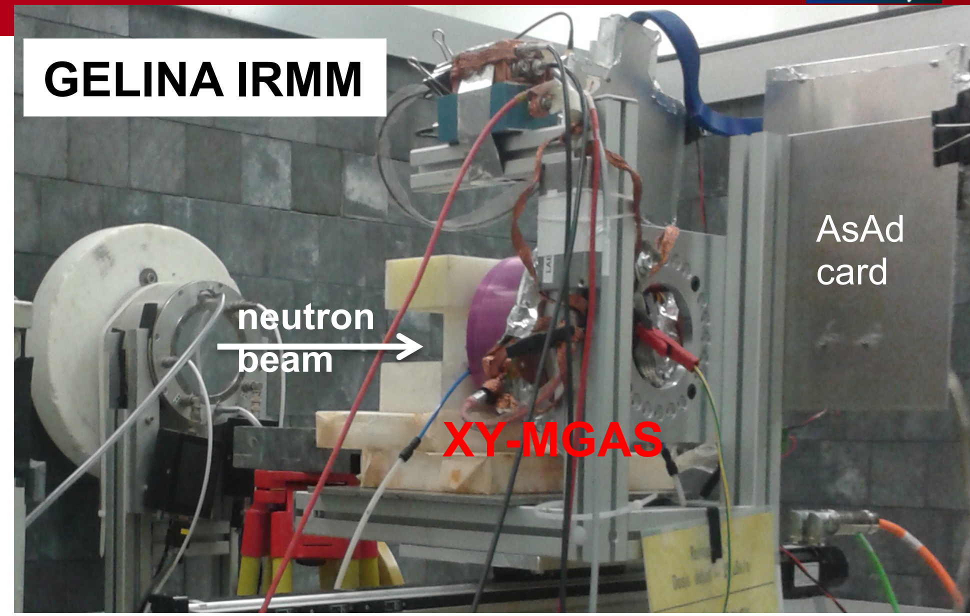

**CONDITION:**
If **both** mesh and anode had at least one strip with signal.

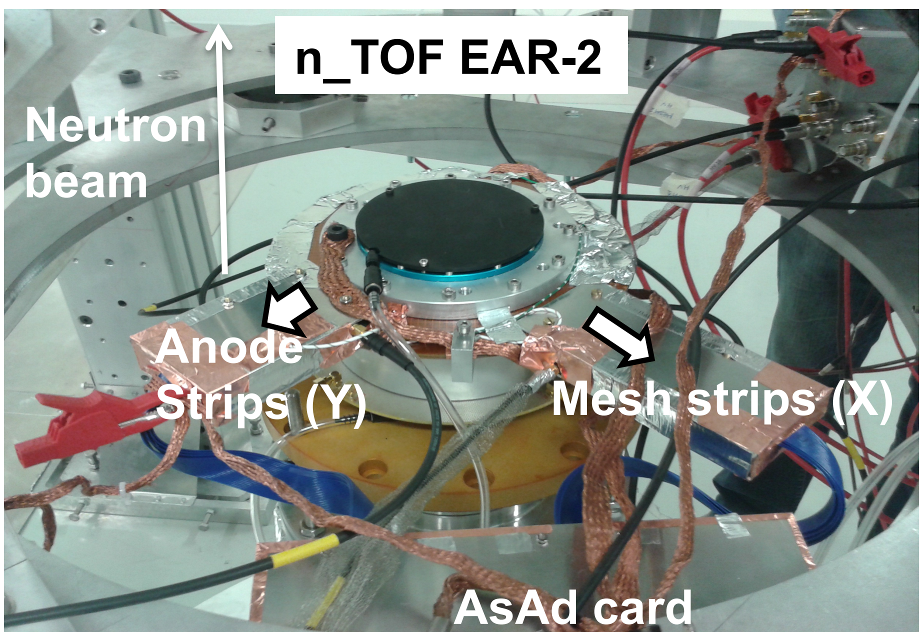
**Peak** useful parameters are stored (**Amplitude**, **Peak position**, TOT etc)
**Event** useful information is stored (Time of event, multiplicities etc)

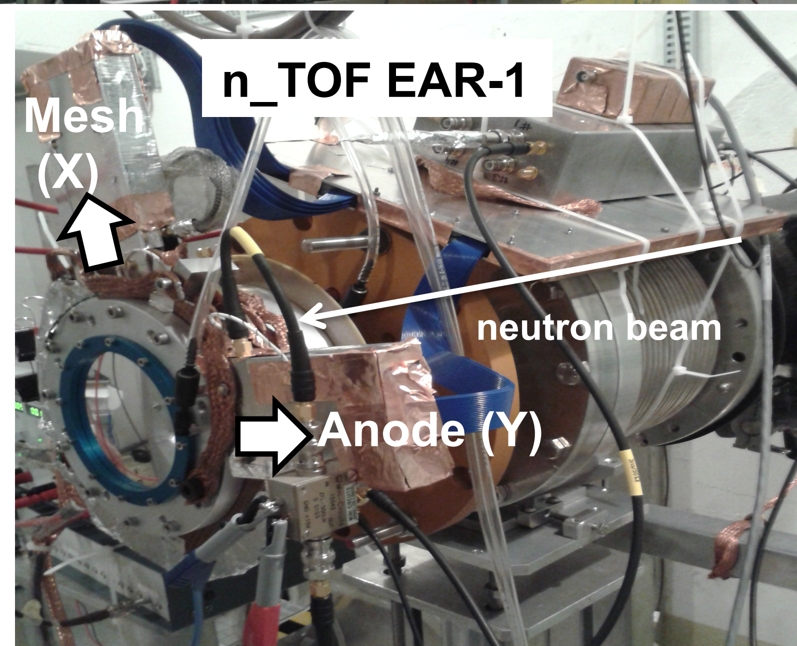
# DETECTOR SETUP MOUNTED AND TESTED AT:

**SEDI Saclay:**
**Tests with X-rays**
***Grounding+shielding essential***



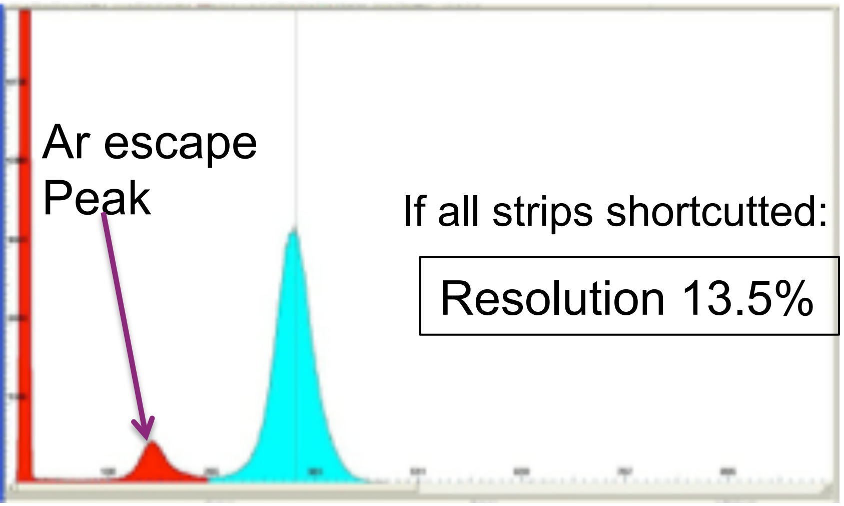


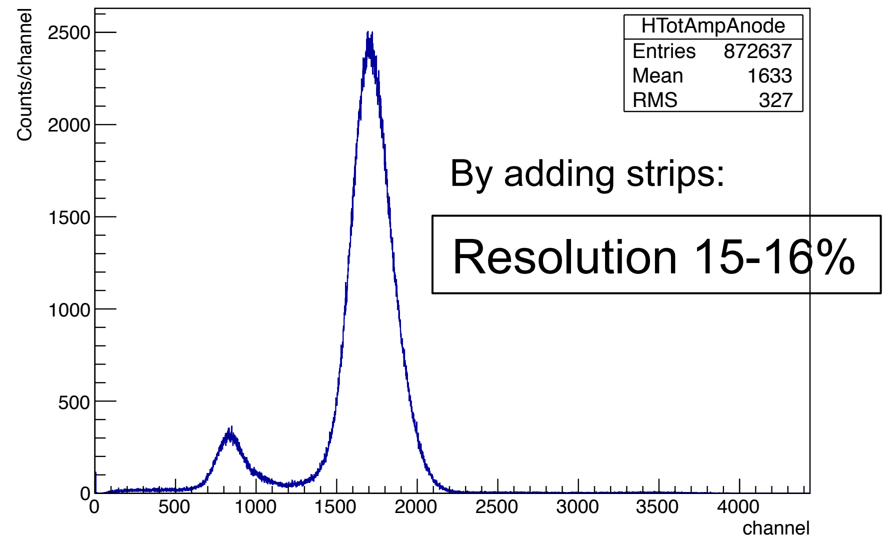



# DETECTOR PERFORMANCE TESTS WITH Xrays AT SEDI (1)

**X-ray source** : $^{57}Fe$ / **Gas**: Ar (95%), $C_4H_{10}$ (5%)

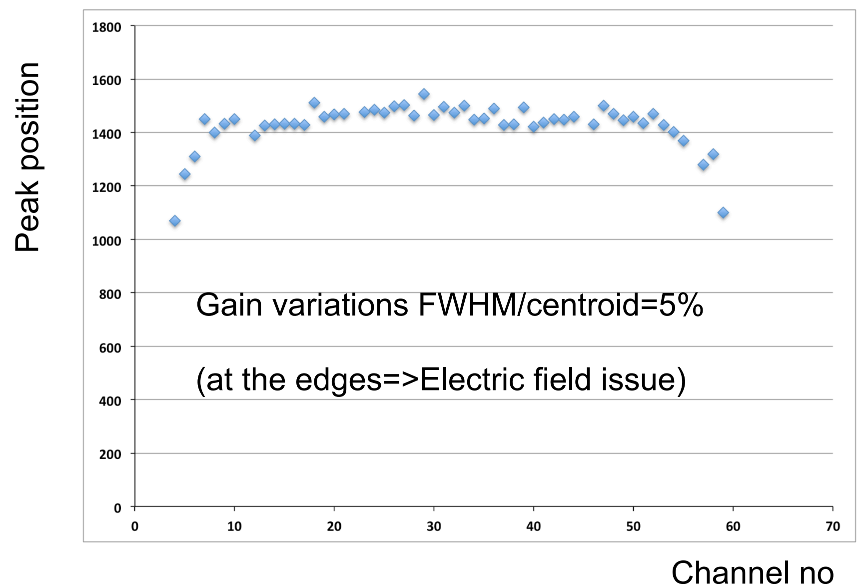



- No stripped microbulk at good transparency: ~11%.

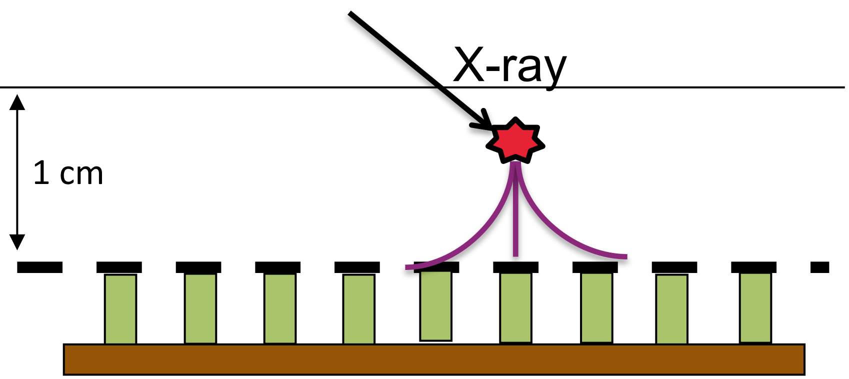
Possible reasons:

- Additional electronic noise
- Strips not crossing DAQ threshold
- Gain variations among strip response

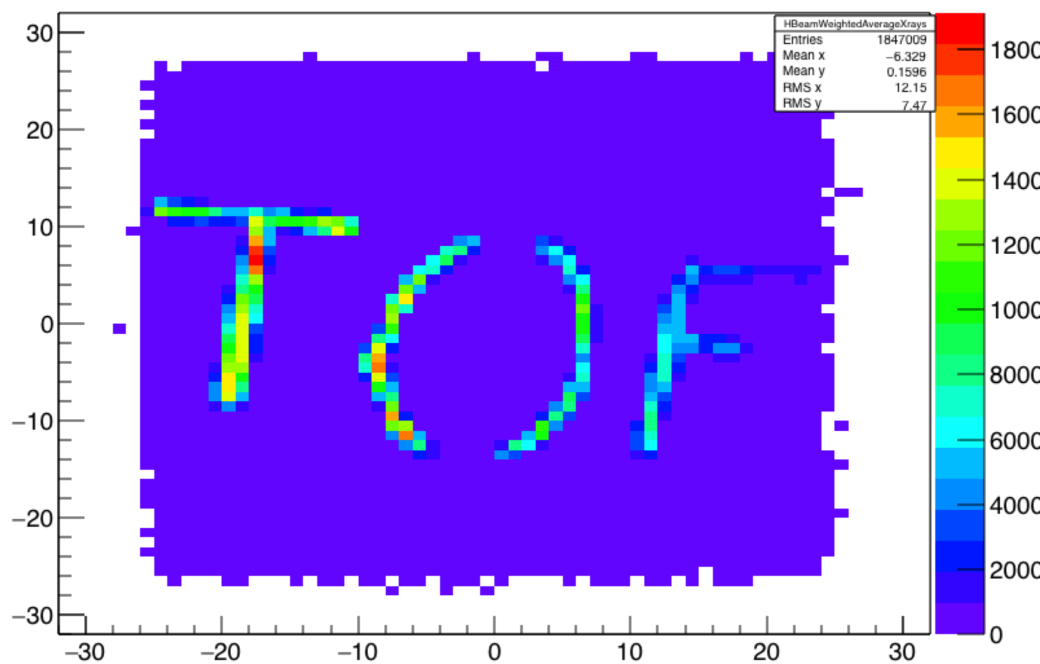


# TESTS WITH Xrays AT SEDI (2)

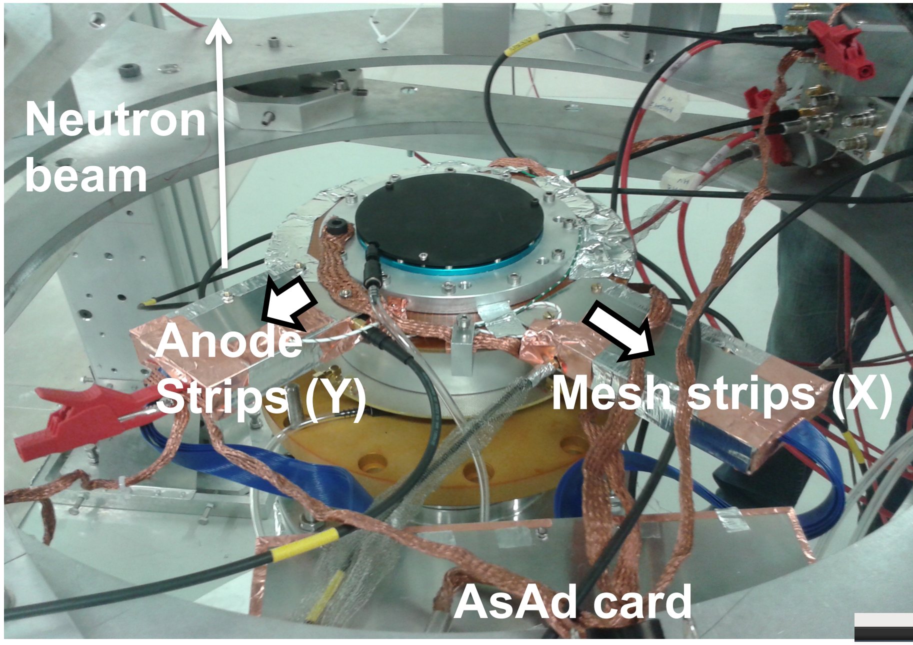

- $^{55}Fe$ X-ray source .
- 10 ns/time bucket/240fC gain
- Ar (95%)-$C_4H_{10}$ (5%)




Beam image (weighted average track)

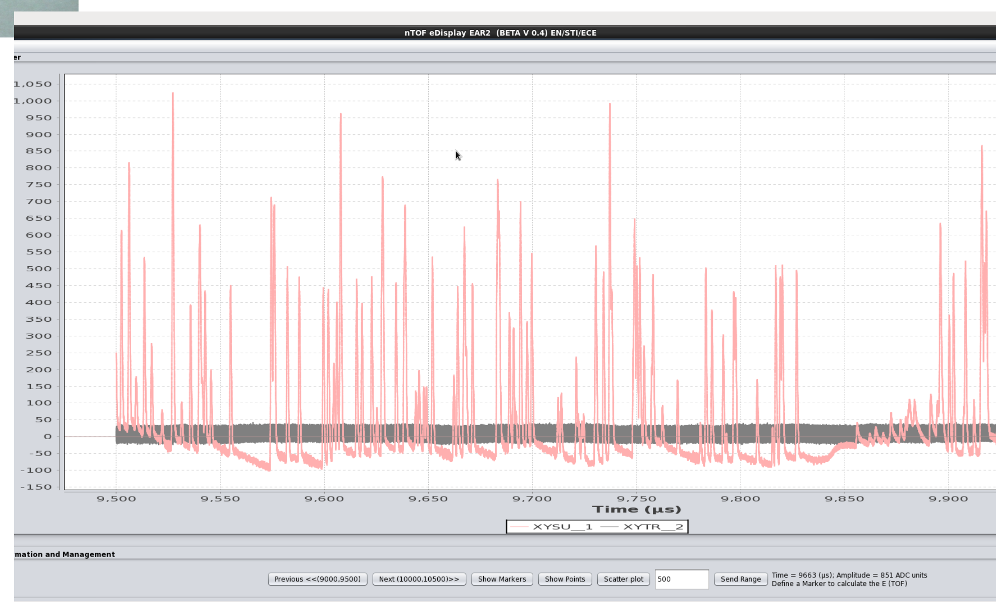


# TESTS WITH NEUTRON BEAM
# n_TOF EAR-2




- $^{6}$LiF target, 91.8µg/cm$^2$
- $V_m$=310 V / $V_d$ =750 V.
- Gas: Ar(88%) / $CF_4$(10%) / $C_4H_{10}$(2%)

- Through n_TOF DAQ:
  1) Trigger signal
  2) **Sum signal**

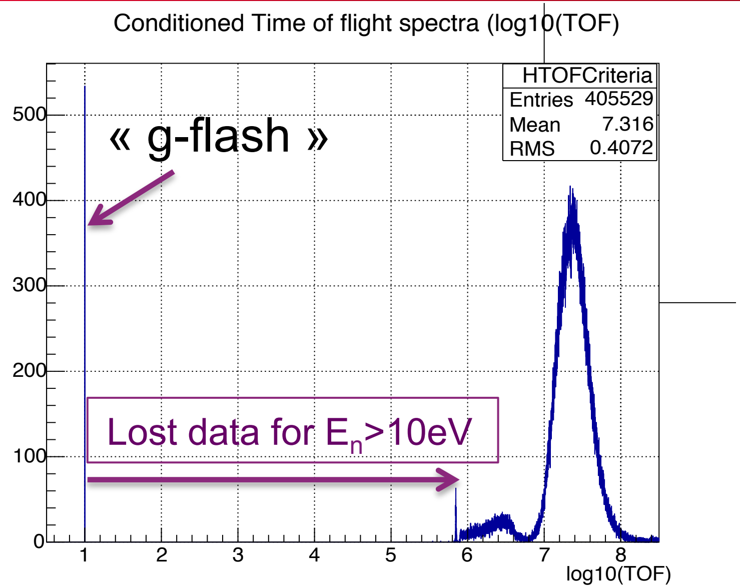


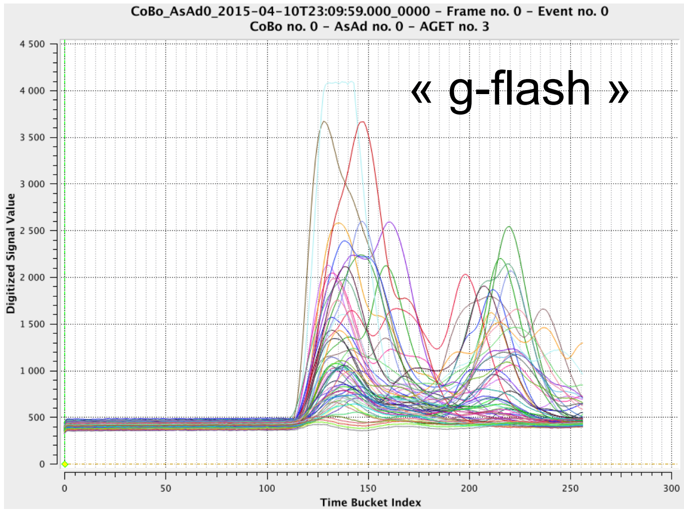

Saturated for ms or very noisy, **ongoing activity**

ORTEC preamp, (high gain)

# SOME RESULTS

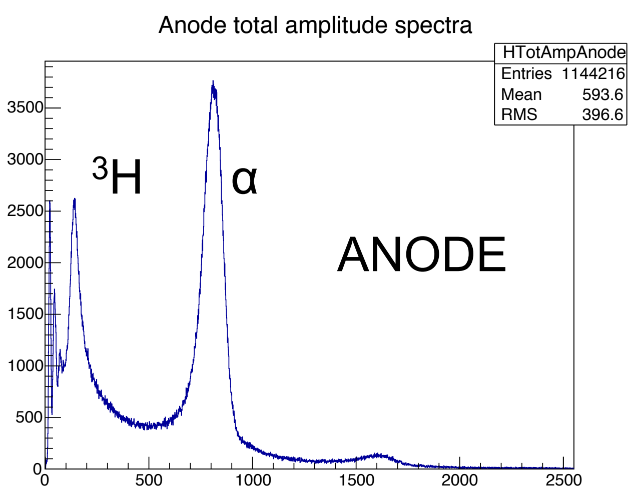
## 1) Dead time:

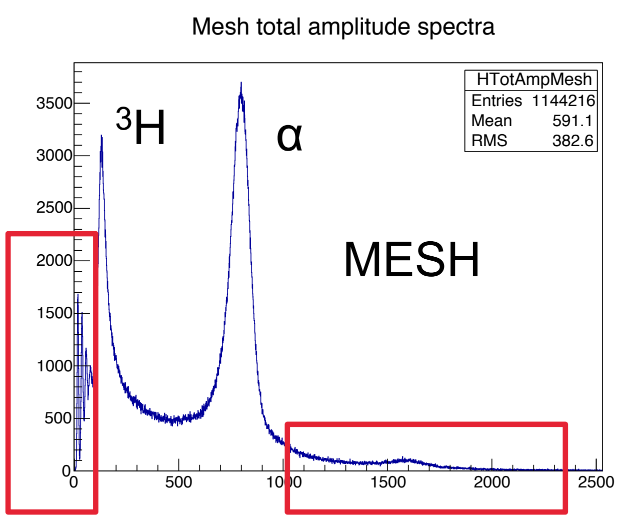



…ongoing activity

## 2) Total Amplitude histogram:



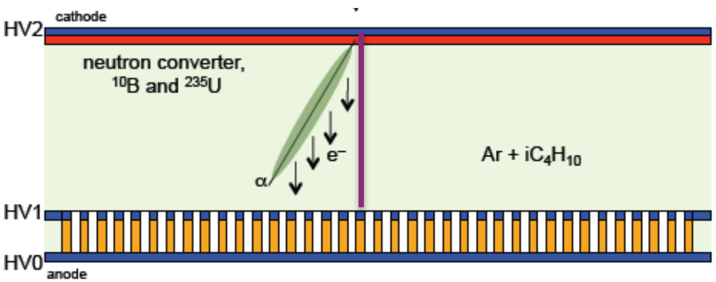



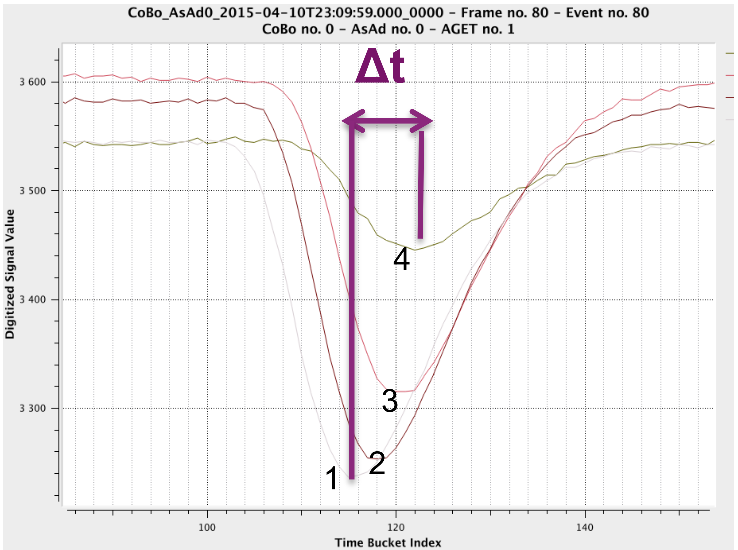

- Good energy resolution, (Similar for mesh+anode)
- Pile-up.
- Low energy deposition events.

# EVENT SELECTION CRITERIA FOR BEAM PROFILE (1)

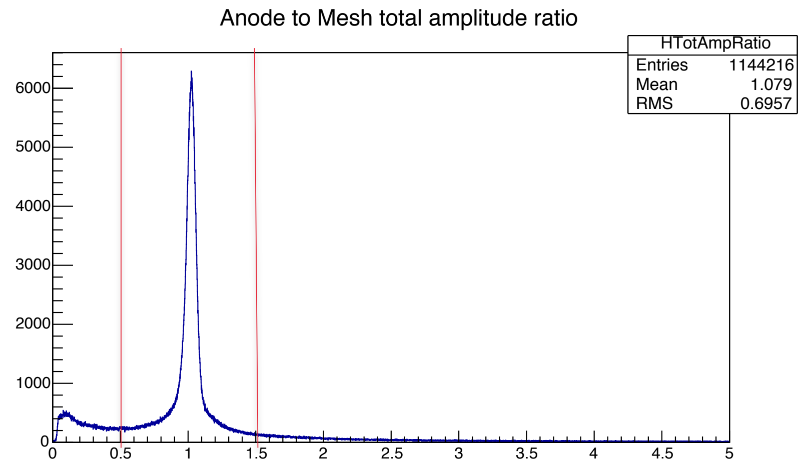
## Criterion 1:
## Δt <= (drift distance)/(e⁻ drift velocity)

From each event + for each dimension we calculate the time difference between first and last strip hit (**Δt**)

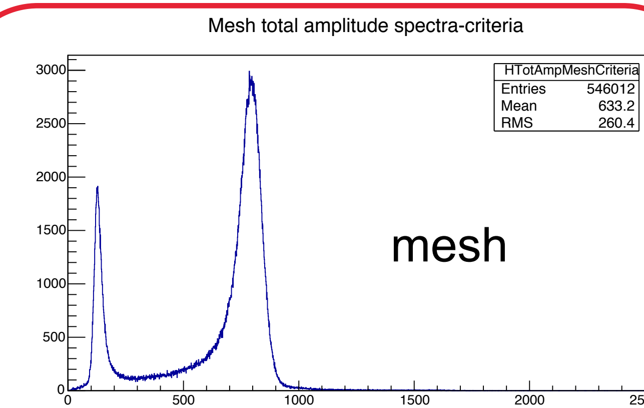



## Criterion 2: 0.5 < tot amp ratio<1.5

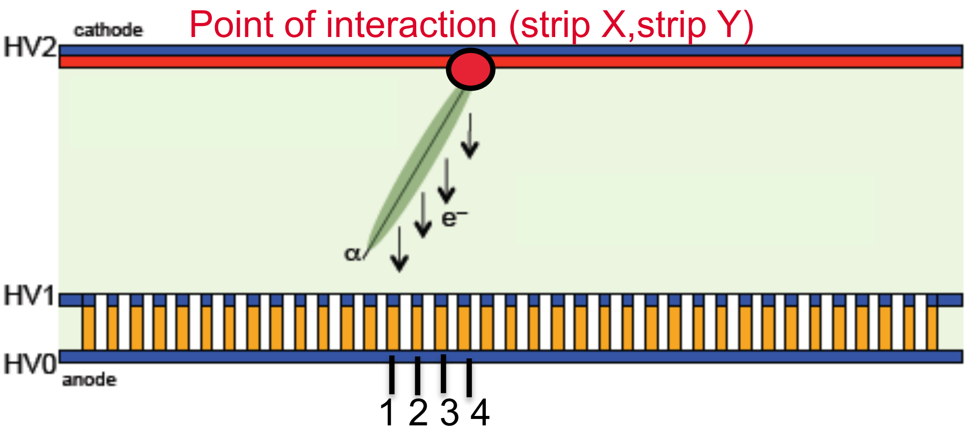



Final total amplitude hist much cleaner:

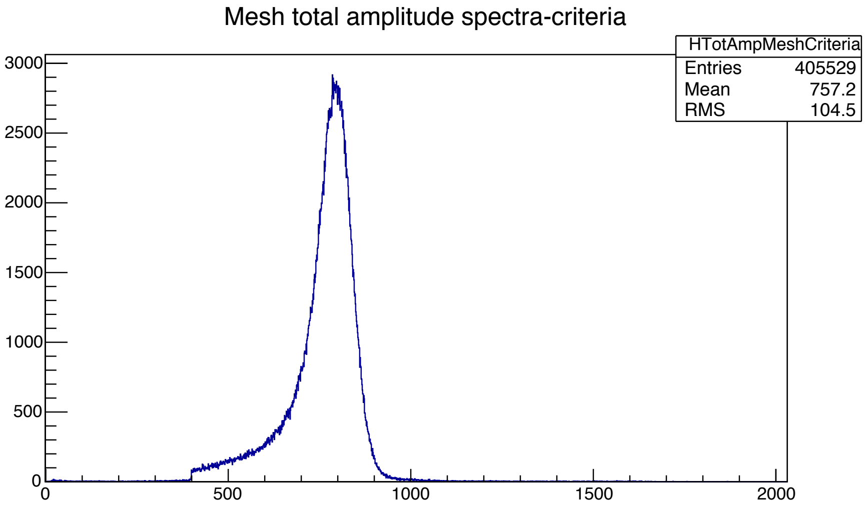


# EVENT SELECTION CRITERIA FOR BEAM PROFILE (2)

**Criterion 3: strips hit have to be consecutive**

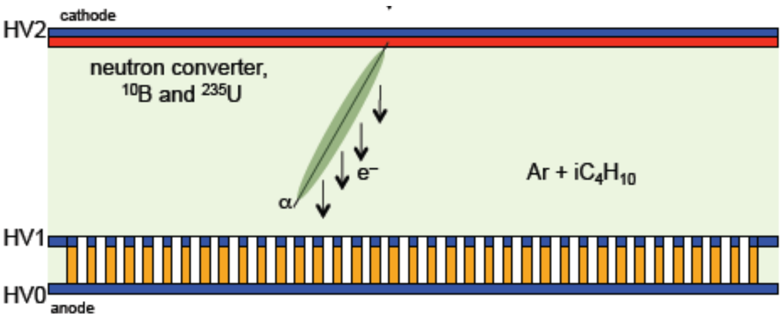



**Criterion 4: Only alphas**

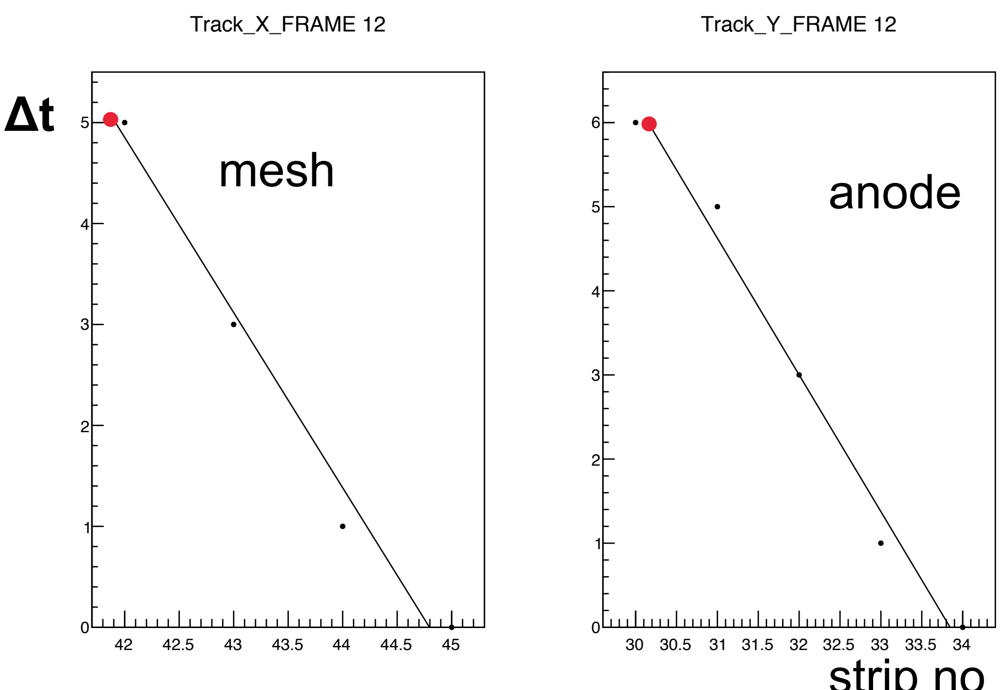


# TOWARDS THE BEAM PROFILE

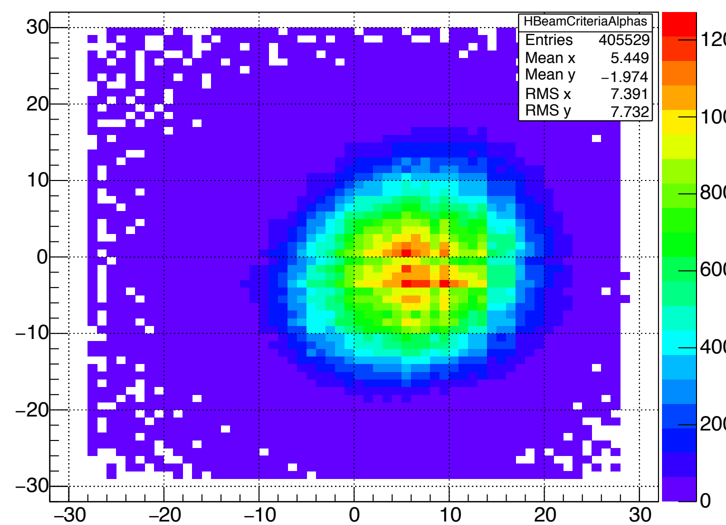
1) Taking the last strip that gave signal:

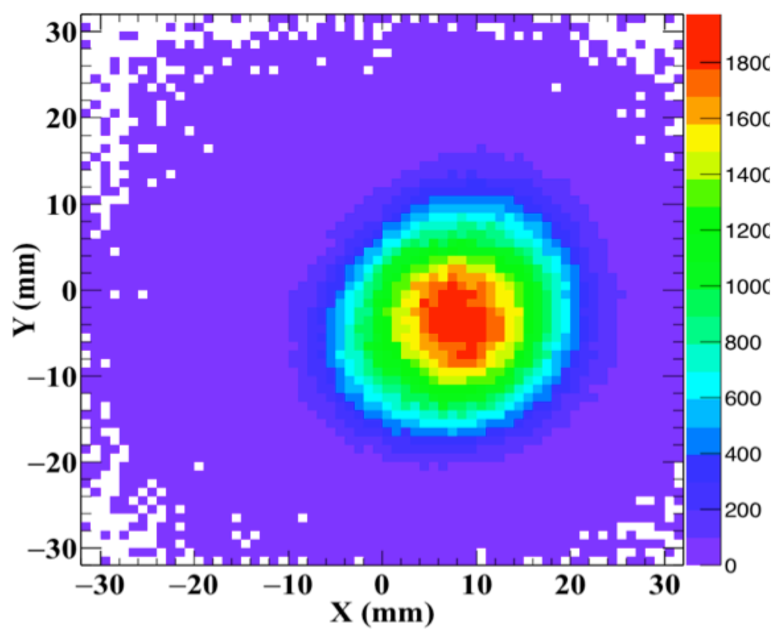



2) Particle track fitting=>BETTER PROFILE:

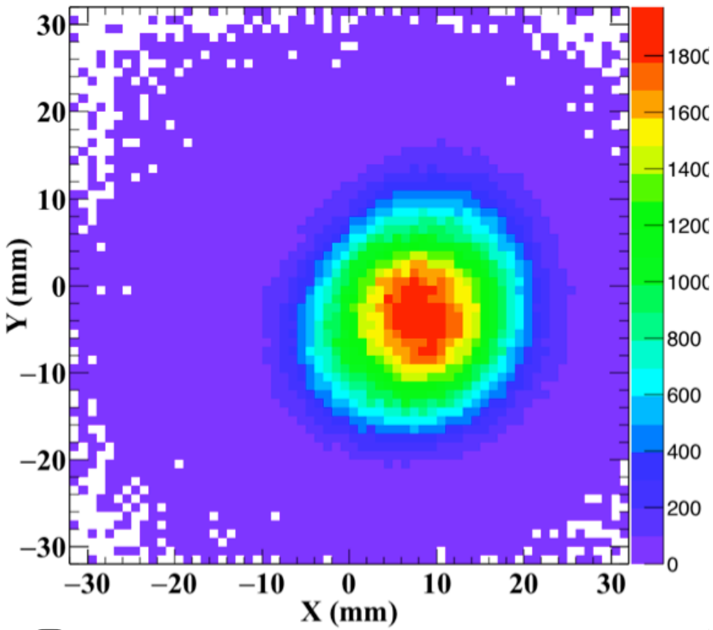



Beam image (criterias applied)

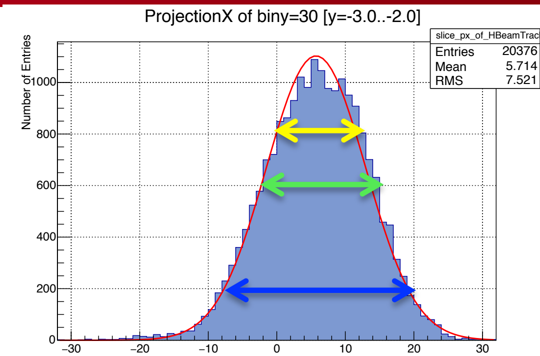


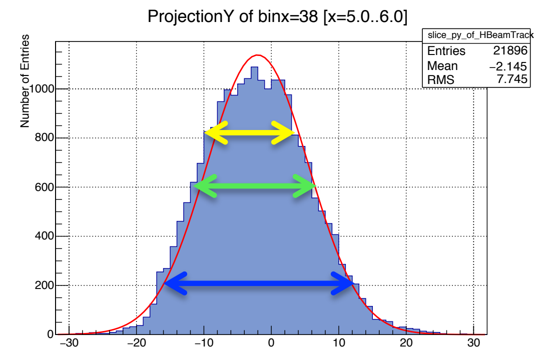
# BEAM PROFILE RESULTS EAR-2




Neutron beam $E_n$<10 eV




Radius **X:**
7 mm
8.2 mm
13.8 mm

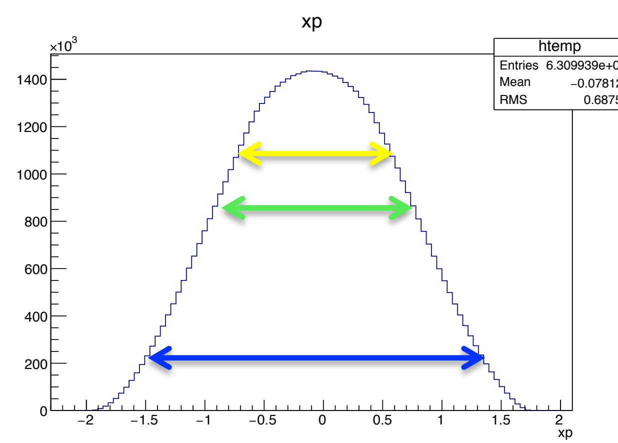



Radius **Y:**
7 mm
8.2 mm
16.5 mm

- Offset: 6.3 mm (X)
  -2.3 mm (Y)

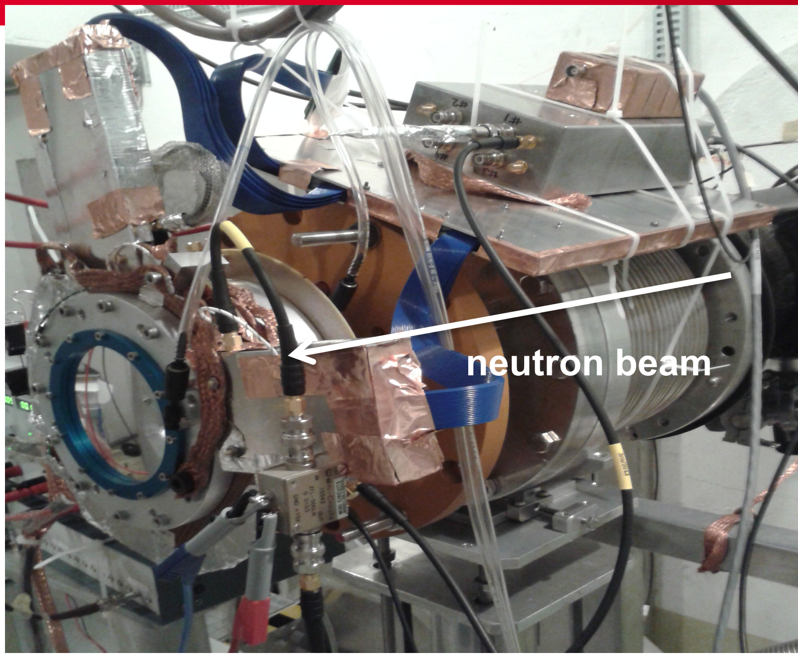
*Detector chamber displacement*

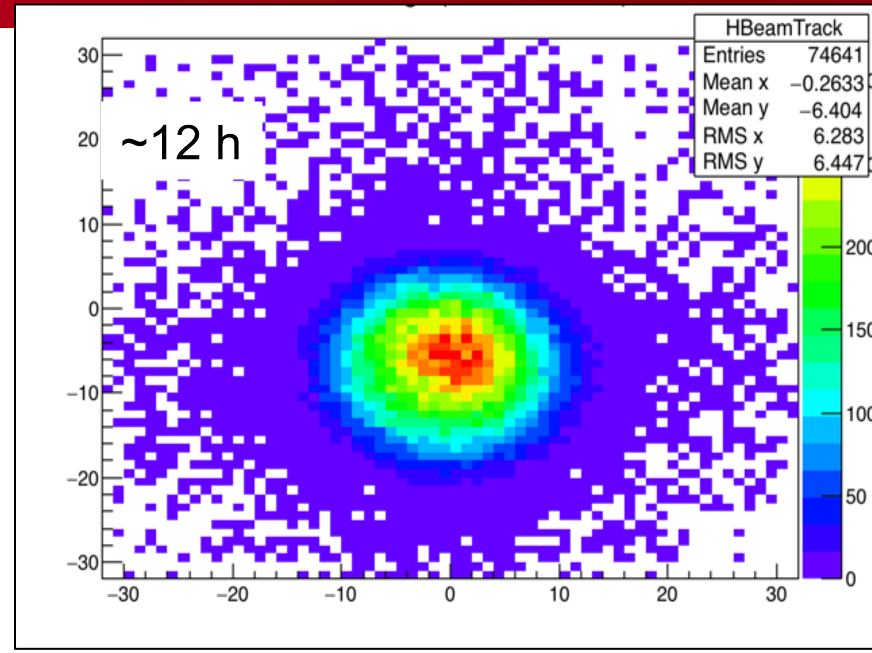
FLUKA simulations:
(C. Massimi)




Radius:
7 mm
9 mm
13.9 mm

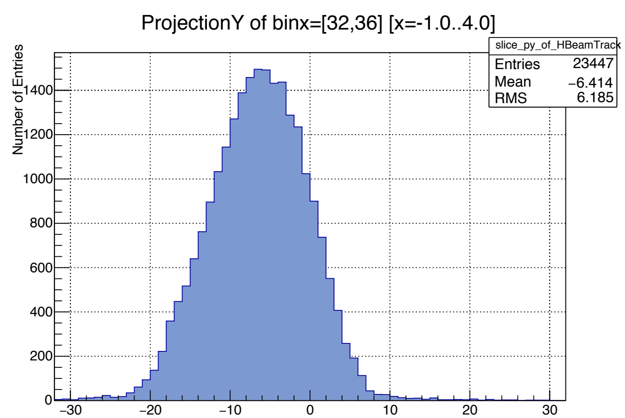
# n_TOF EAR_1 (~200 m)



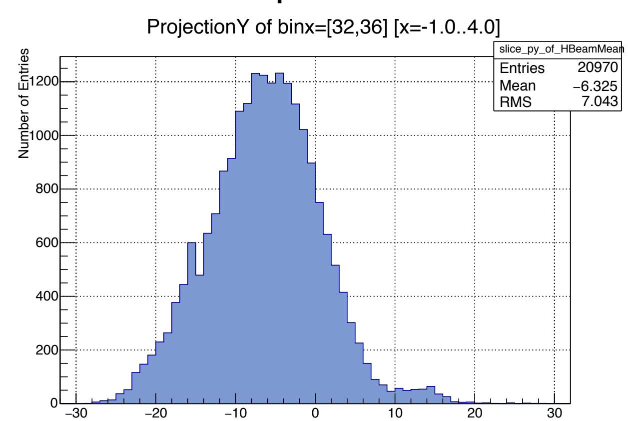




- $^{6}$LiF target, 91.8µg/cm$^{2}$
- $V_m$=-320 V / $V_d$ =-750 V.
- Gas: Ar(88%) / $CF_4$(10%) / $C_4H_{10}$(2%)

- Sum signal
- Dead time




« Mean strip from the track »



# OUTLOOK –FUTURE PERSPECTIVES

- XYMGAS neutron beam profiler in operational mode.

The electronics were improved / Dead time + Sum signal (neutron counting)
Will stay permanently in-beam at n_TOF.

- 2nd detector has worse resolution (~19%): differences in the production (missing holes+bigger gap)

- Further improvements in the design of the detector for the next production, based on the tests performed is foreseen.

- Complete characterisation of the detector at the nuclear reactor Orphee, CEA-Saclay (spatial resolution  etc).

- Challenging physics measurements will be investigated with this detector (neutron induced charged particle reactions, angular distributions, axion searches, neutrinoless double beta decay etc)

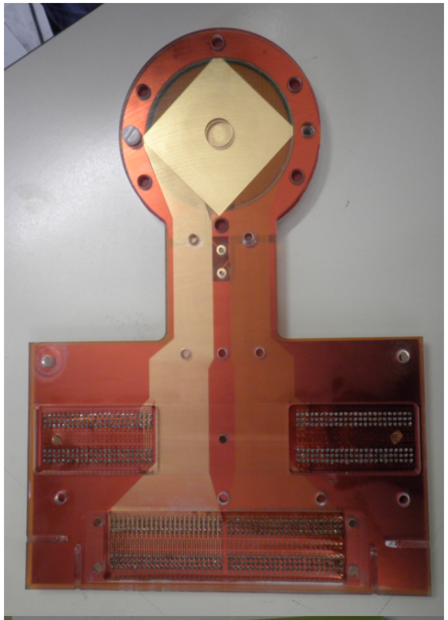
…………...Thank you…………….

# EXTRA SLIDES

# PREVIOUS BEAM PROFILERS AT N_TOF

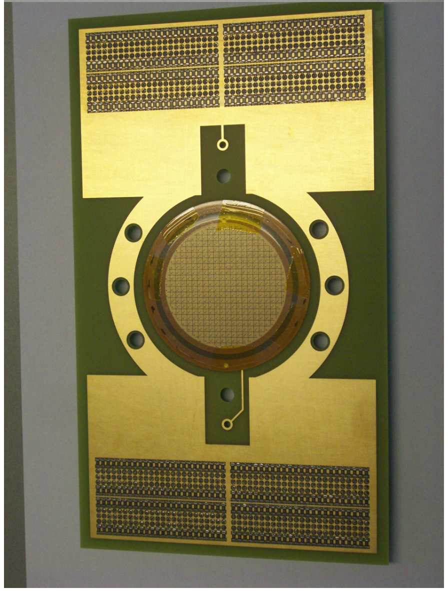
***First detector:***
***bulk on a CAST microbulk prototype!***

- 6x6 cm$^2$ (2x106 strips, 0.5 mm pitch)
- drift gap = 4 mm
- converter: $^{10}B_4C$ enriched in $^{10}B$, 2 μm
- Ar + (10%)CF4 + (2%) iC4H10
- XYMM electronics: GASIPLEX coupled to ACQIRIS FADC



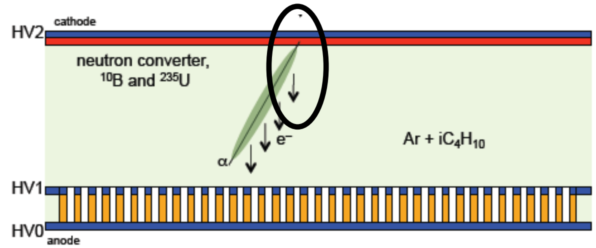
***Detector (2012):***
***pixelized bulk***

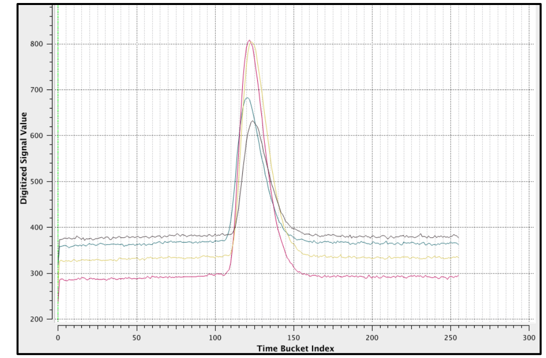
- pixelized readout with 2.5 mm pitch
- number of pixels = 77 x 4
- mesh gap = 128 μm
- drift gap = 4 mm
- window = 12.5 m kapton
- Ar + (10%)CF4 + (2%) iC4H10
- Equipped with B converter (2 μm thick)



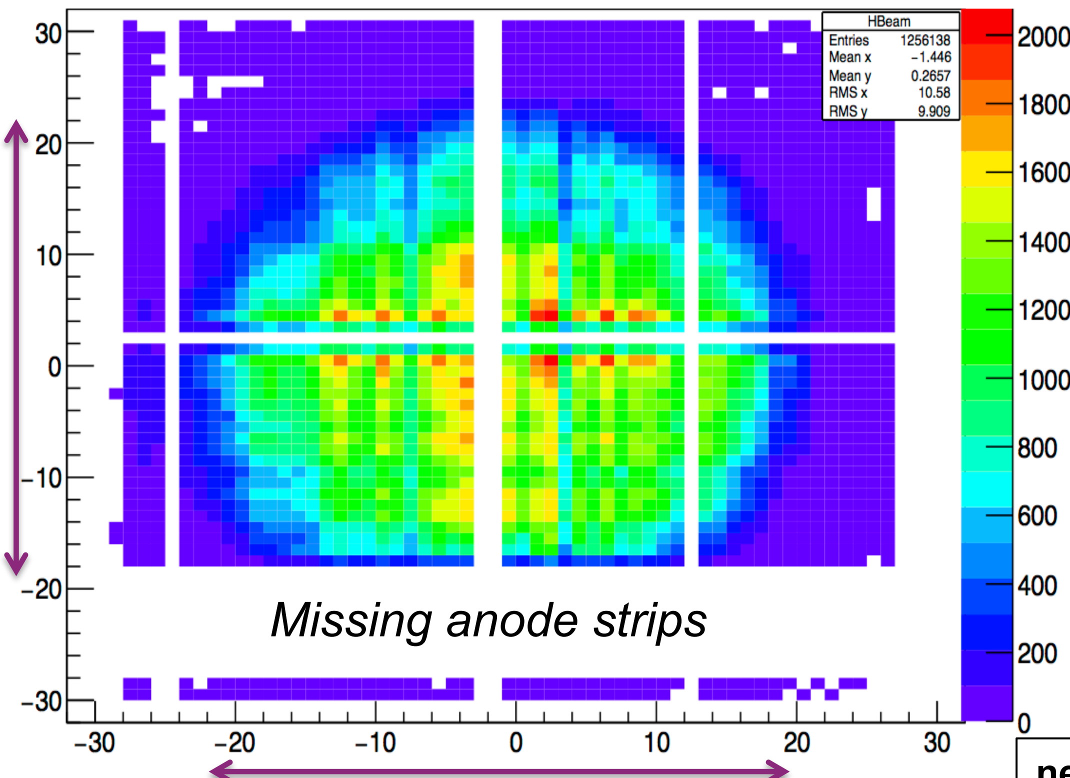
# GELINA TESTS
# NEUTRON BEAM WITHOUT ABSORBER (I)

Reconstruction taking the latest strip with signal that passed the threshold.



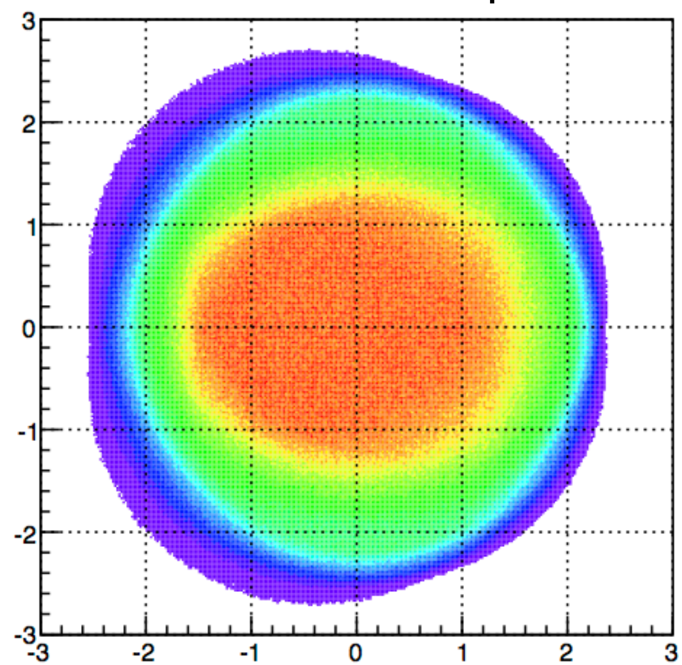




Experimental beam profile



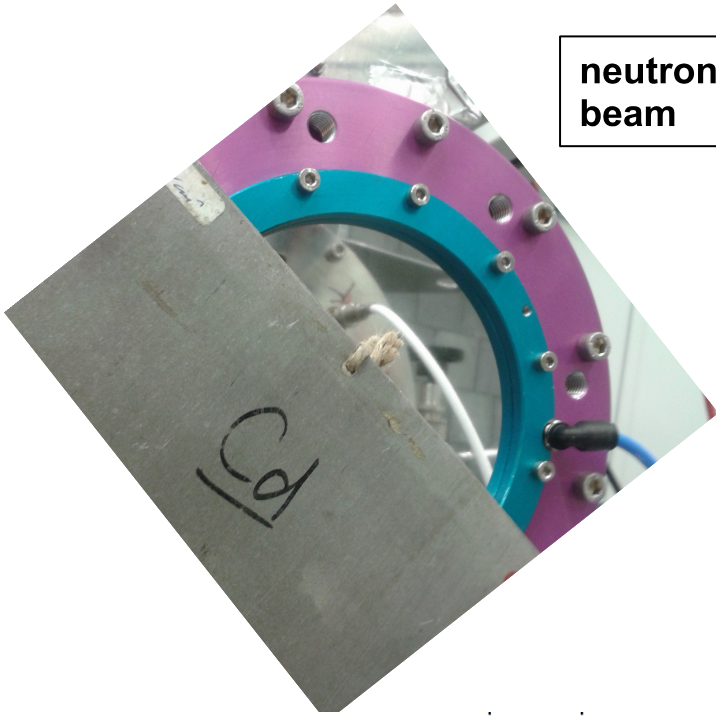

d~4 cm

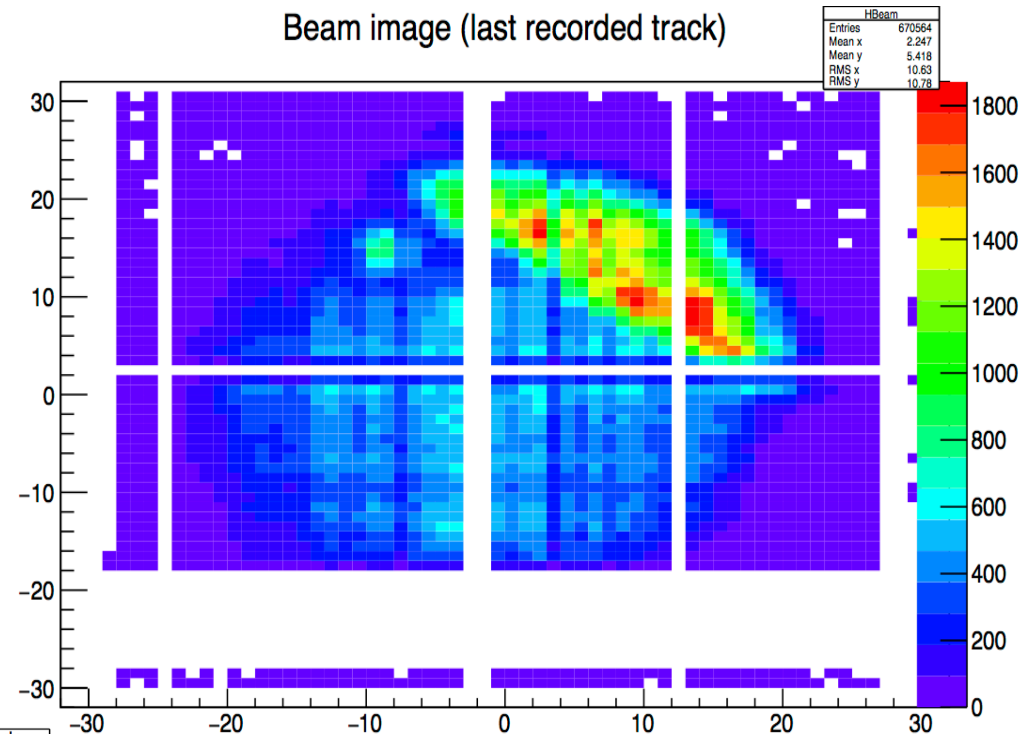
Simulated beam profile

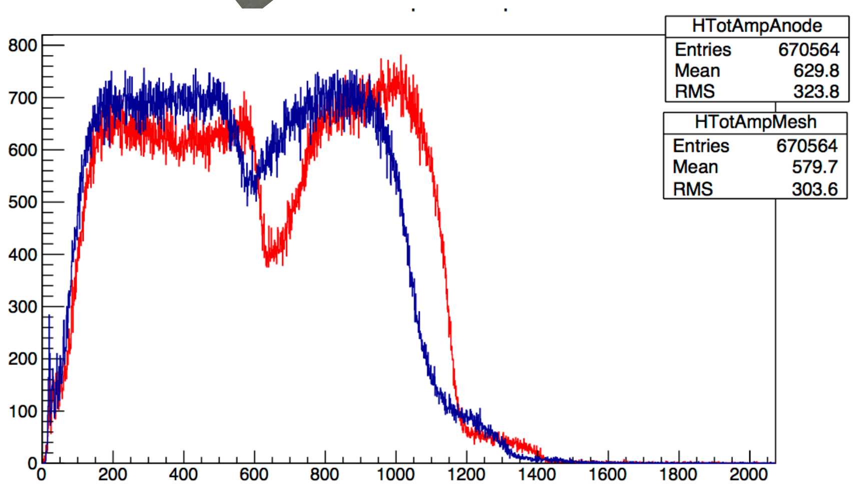


**neutron beam** ✖

# GELINA TESTS
# CD FOIL COVERING PART OF THE DETECTOR (II)



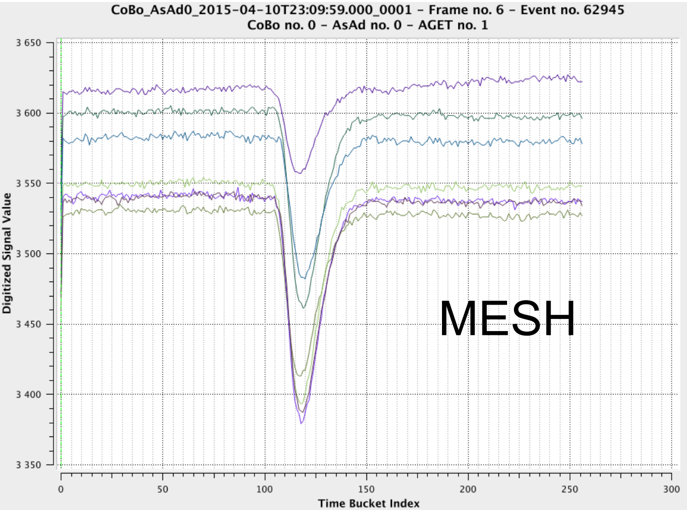



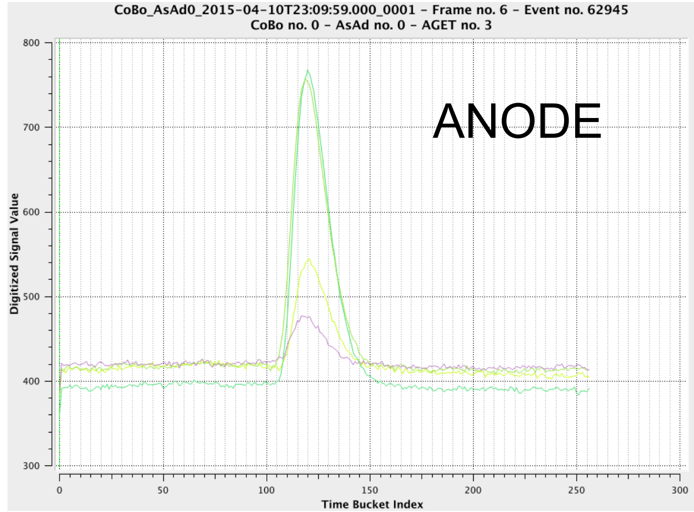

**Total amplitude distribution**

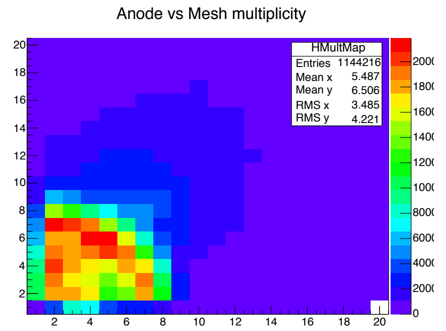
**Red:** anode strips

**Blue:** mesh strips

# DETECTOR SIGNALS IN EAR-2



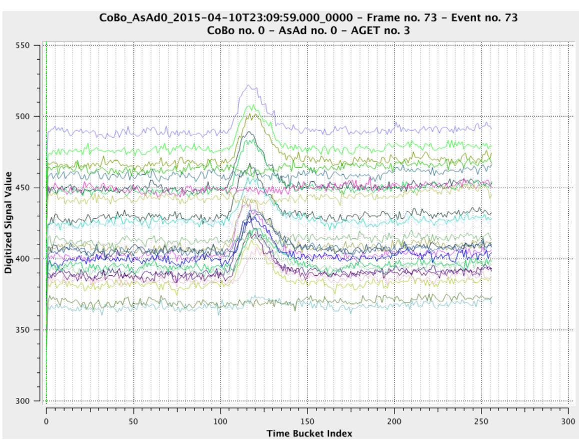



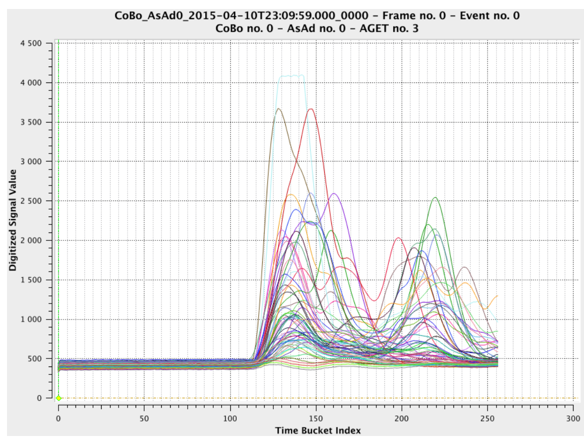

~2-7 strips hit per event for each dimension

*=>Clear signals generally free from the noise*

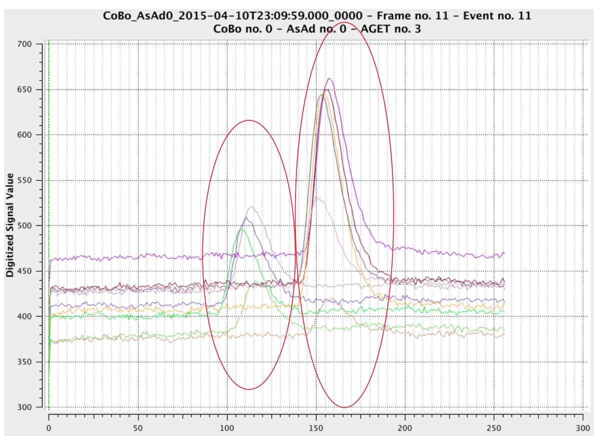
gamma-flash:gammas




gamma-flash:charged part.




PILE-UP




Sample very thick

# DEAD TIME- EAR-2