Micromegas detectors for neutron detection and imaging

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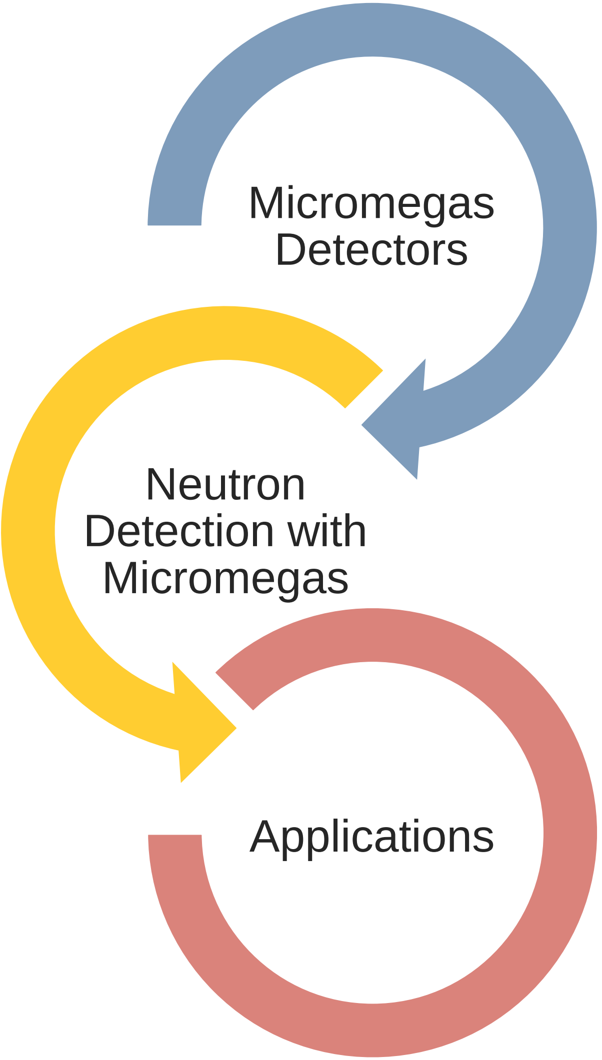
OUTLOOK



Micromegas Detectors

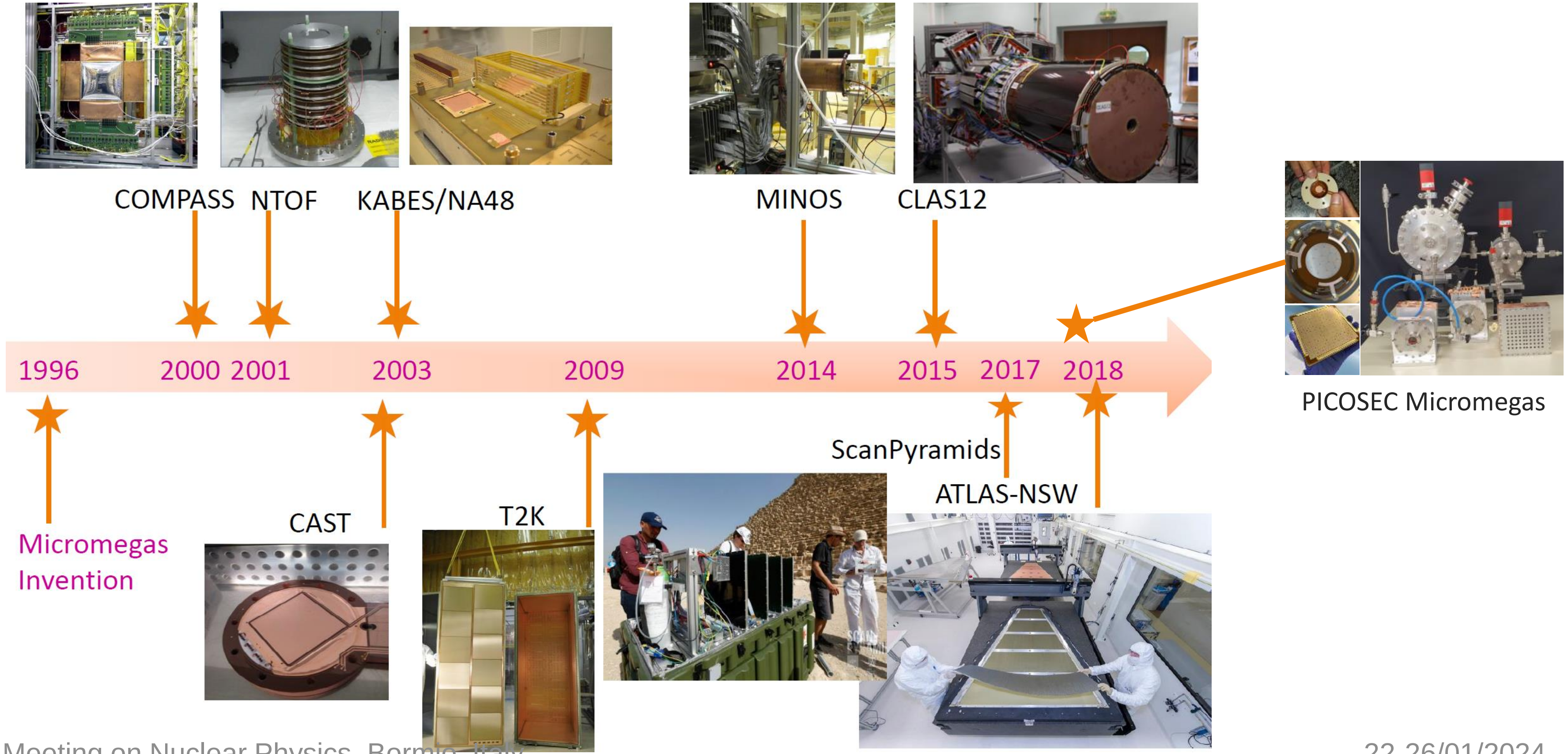
Neutron Detection with Micromegas

Applications

MICROMEGAS

Micromegas:

- *Invented in 1996 at **CEA** Saclay by I. Giomataris*
- *Micro-Pattern Gaseous Detector for **charged particles**, designed for **physics experiments***
- *Advanced characteristics: **large-area** scalability, **high rate** capabilities, **low cost**, large **dynamic range***
- *Versatility: particle tracking, TPC, imaging*



COMPASS NTOF KABES/NA48

MINOS CLAS12

1996 2000 2001 2003 2009 2014 2015 2017 2018

PICOSEC Micromegas

ScanPyramids

ATLAS-NSW

CAST

T2K

Micromegas
Invention

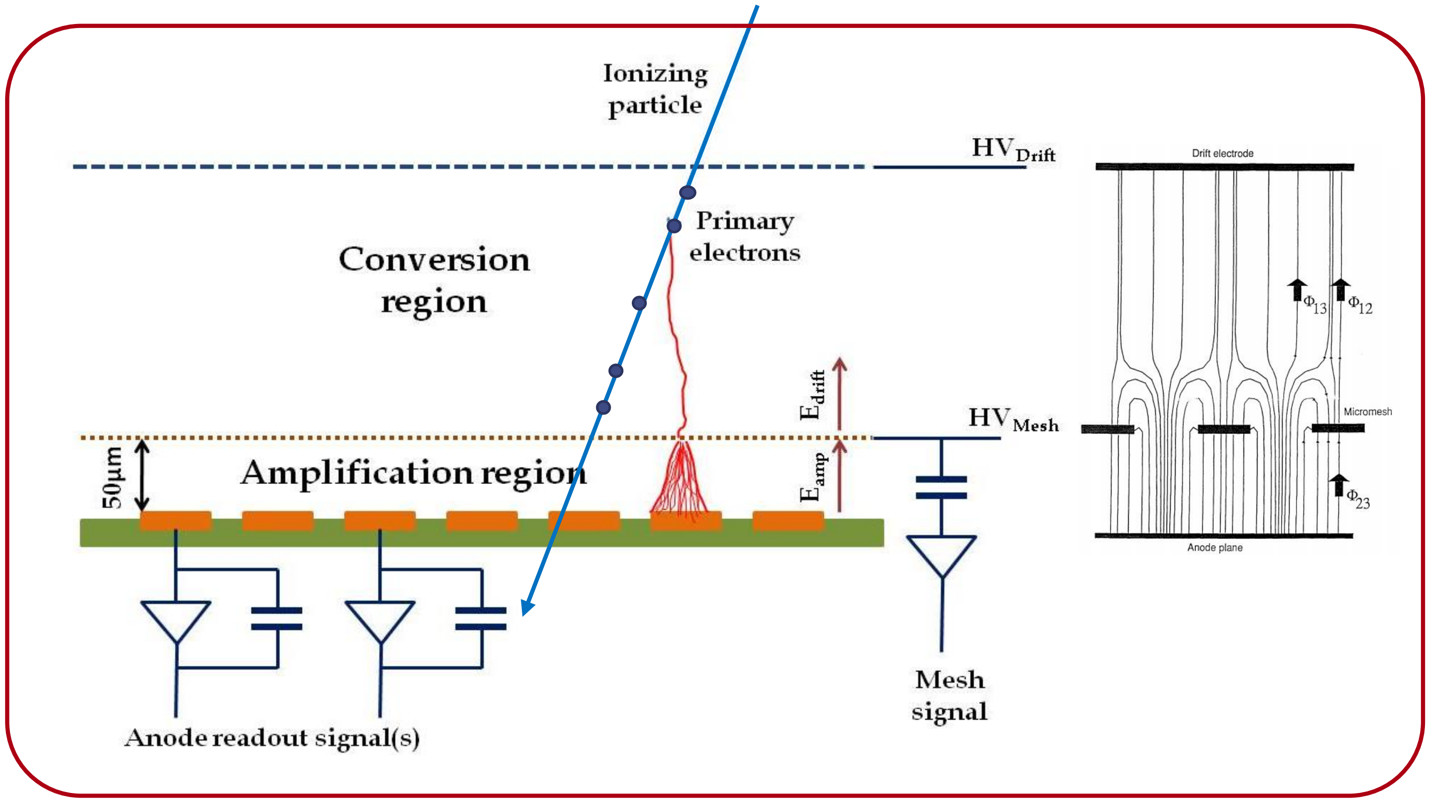
MICROMEGAS

Two-region gaseous detector separated by a *Micromesh* :

Micro-mesh type → Micromegas family

- **"Conventional"**: a micromesh stretched on a frame is placed on a readout board with the help of spacers ("pillars")
- **Bulk Micromegas**: Process to encapsulate the mesh on a readout board
- **Microbulk:** Photolithography & chemical etching of Kapton foils with Cu layers on both sides ("GEM technology").
- **Hybrid**: Micromesh placed on top of a silicon readout chip (i.e. InGrid, GridPix)
- **Piggyback**: A resistive bulk Micromegas on top of a dielectric. Decoupled readout
- ***Micro r-well (μRwell)****: a resistive Microbulk (DLC layer)*

Y. Giomataris, P. Rebourgeard, J.P. Robert and G. Charpak, *"Micromegas: A high-granularity position sensitive gaseous detector for high particle-flux environments",* Nuc. Instrum. Meth. A 376 (1996) 29



☞ *Use of converters ➔ detection of* ***neutral particles***

Neutron detection with Micromegas

Why a Micromegas for neutrons?

Motivation:

Increasing demand for neutron detectors

- ➔ Science
- ➔ Homeland security
- ➔ Industry

Higher performance demanded

^{3}*He crisis*

Advantages of Micromegas:

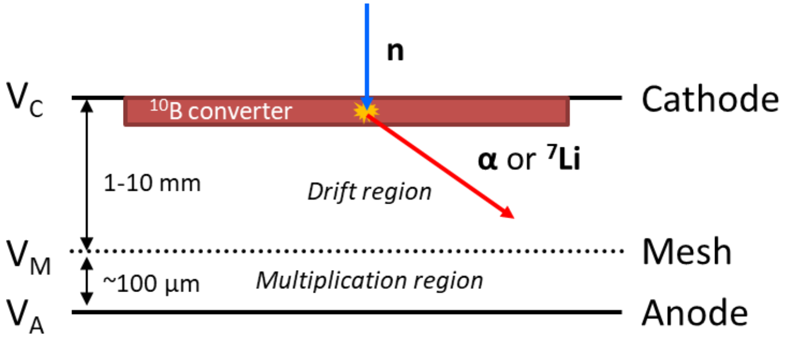
- ➢ Gaseous detector
  - ✓ Strong n/γ discrimination
  - ✓ Low material budget possible
  - ✓ Can be “transparent” to neutrons or gammas
  - ✓ Radiation hardness / robustness $>10^{16}$ p/cm^2
- ➢ High performances (gain, energy and time resolution)
- ➢ Gain homogeneity (thin amplification gap)
- ➢ Low energy threshold
- ➢ Large dynamic range of operation
- ➢ High granularity
- ➢ Fast signals / high rate capabilities $> 10^6$/cm^2/s
- ➢ Reduced ion feedback < 1%
- ➢ Simplicity / Low cost / big surface / robust
- ➢ Resistive for sparks

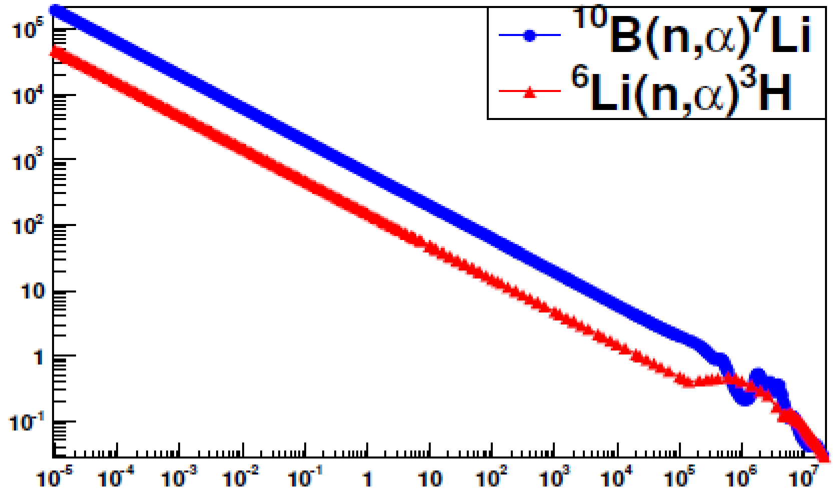
Neutron detection with Micromegas

Neutron-to-ion(s) reactions (p, α, fission, spallation …)
– *slow & fast neutrons*

- **Solid converter**: thin layers deposited on the drift or mesh electrode

  Usually (^{10}B, $^{10}B_4C$, ^{6}Li, ^{6}LiF, U, actinides…)
  - ✓ Simplified implementation
  - ✓ Excellent n/γ discrimination
  - × *Limitation on sample thickness from fragment range (strangling)*
    ⇒ limited conversion efficiency
  - × Not easy to record all fragments
  - ➢ Sample availability & handling may be complicated
- **Detector gas** (^{3}He, BF_3…)
  - ✓ Recording of all fragments
  - ✓ No fragment strangling ⇒ reaction kinematics reconstruction possible
  - ✓ No limitation on the size ⇒ high efficiency
  - × *Gas availability*
  - × Handling (highly toxic or radioactive gasses)





$^{10}B(n,\alpha) \rightarrow$ 0.0253 eV to 1 MeV
$^6Li(n,t) \rightarrow$ 0.0253 eV to 1 MeV
$^{235}U(n,f) \rightarrow$0.0253 eV, and 0.15 to 200 MeV

Neutron detection with Micromegas

Elastic scattering (ion recoils) – *fast neutrons*

- **Gas** (**H, He**) or **solid** (**paraffin etc.)**
  - ✓ Availability
  - ✗ Very low efficiency
  - ✗ Efficiency strongly depends on the applied threshold on the EDEP

Radiative capture reactions (n,γ) – slow neutrons

- ✓ High conversion efficiency (**Gd, Cd**)
- ✗ Bad n/γ discrimination
- ✗ Reduced spatial resolution

*Detector to be designed on experiment needs, **Micromegas are very adaptable!***

- *Designed based on neutron energy range expected, backgrounds, etc*
- *Counting and current modes possible*
- *Choice of the gas/quenchers important*
  - *Fast signasl : CF4, …*
  - *No hydrogen to limit recoils : CO2*
  - *Higher gains : ethane, …*
  - *Noble gases (recoil in Ar, …)*

Applications of Micromegas neutron detectors

Fundamental physics

- Neutron interaction **cross-section** measurements (n,p), (n,α)… and differential cross-sections
  - fission chambers (nTOF…) and TPCs (nTOF)
- Fission studies
  - TPCs (NIFFTE, FIDIAS…)
- Detector development
  - quenching factor studies for DM experiments (MIMAC TPC)
  - fission tagging in (n,γ) measurements (nTOF)

MMs Features

- ✓ Thin / low material budget
- ✓ ~4π coverage possible
- ✓ Simplicity / cost
- ✓ Radiation hardness
- ✓ Good energy resolution
- ✓ Good dE/dx discrimination
- ✓ Dynamic range
- ✓ High granularity

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Neutron beam diagnostics

- Beam flux monitors (nTOF, NFS, ESS)
- Beam profile monitors (nTOF, ESS)

- ✓ ~ transparent to neutrons
- ✓ Fast signals ➔ high rate
- ✓ Excellent timing (< ns)
- ✓ High granularity

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Neutron counters

- Beam Loss Monitors (ESS, Saraf, IPHI)
- Neutron detection / flux in harsh environments (i.e. nuclear reactors, medical accelerators,…)
- Neutron dosimetry during hadron therapy

- ✓ Good n/γ discrimination
- ✓ High rate capabilities
- ✓ Radiation hardness

Applications of Micromegas neutron detectors

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Fundamental physics

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✓ Radiation hardness

Neutron imaging applications

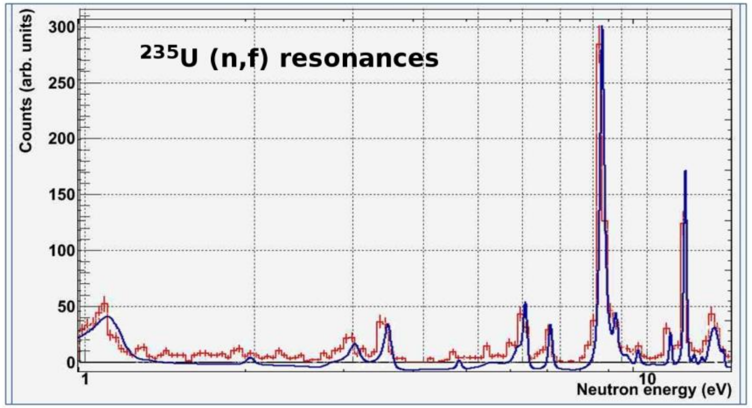
- Radiography / tomography
- Optical readout ➔ ***Real time imaging***

✓ Good n/γ discrimination
✓ High granularity
✓ Optical readout possible

APPLICATIONS

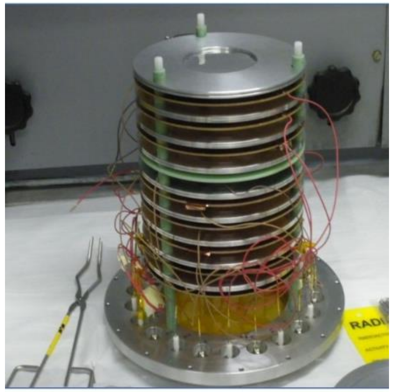
Fission X-section Measurements : nTOF

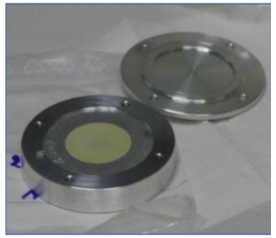
- **Good discrimination between fission fragments and α or γ particles**
- Low mass detectors
- (n,α) / (n,p) cross-section measurements also done

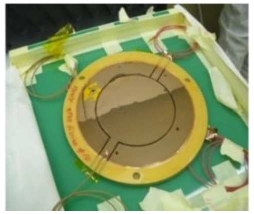


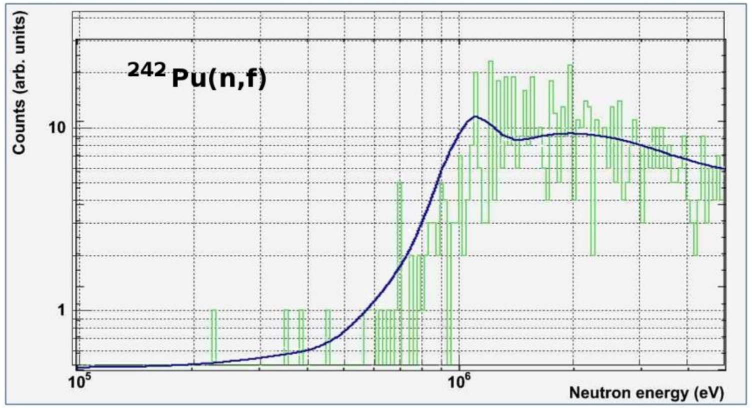
Setup for fission at n_TOF

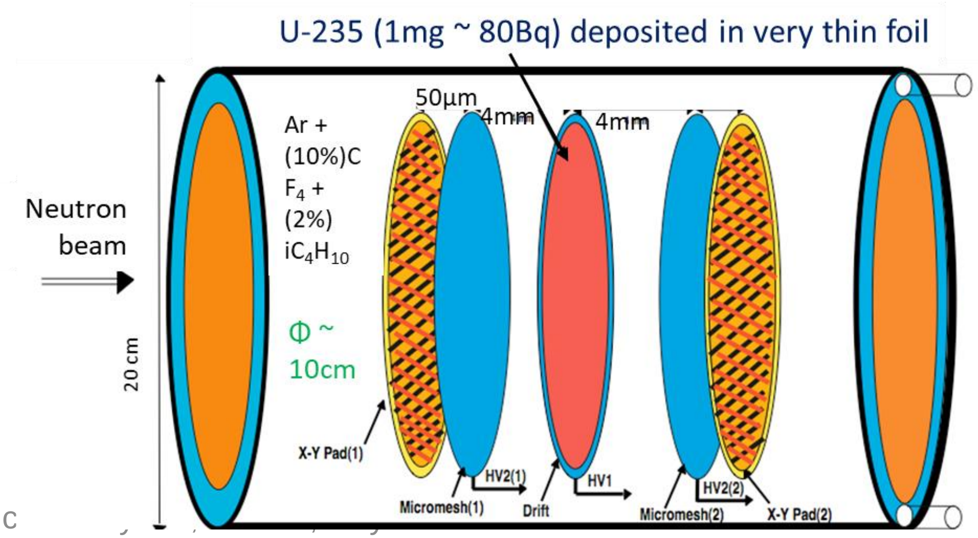
10 Microbulk Micromegas:
  ➢∅ = 10 cm
  ➢Cu(5µm)/Kap(50µm)/Cu(5µm)
Windows:∅ = 15 cm, kapton 25 µm
Gas: Ar + (10%)CF_4 + (2%) iC_4H_{10}
Samples:
  4 ^{240}**Pu**:
    •∅ = 3 cm each
    •3.5 mg each (27.3 MBq)
  4 ^{242}Pu:
    •∅ = 3 cm each
    •3.0 mg each (1.2 MBq)
  1 ^{235}U: (as ref)
    •∅ = 3 cm each
    •5.0 mg each (0.4 MBq)











Fission tagging: nTOF

The accuracy in the capture cross sections measurement of fissile isotopes is reduced due to the **large background contribution from fission reactions**

A total absorption calorimeter can be used in order to discriminate capture events using the Q_γ

- × fission γ's can have total energy close to Q_γ

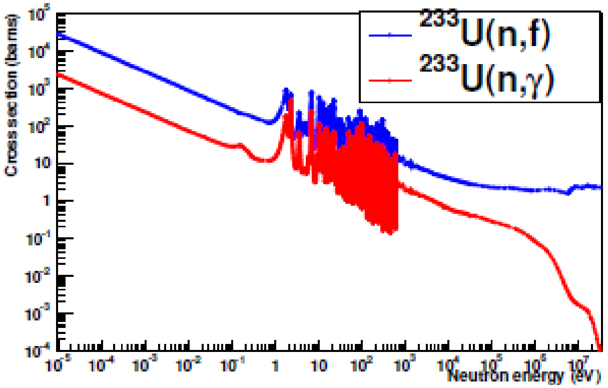
A heavy ion detector can be used to discriminate fission events.

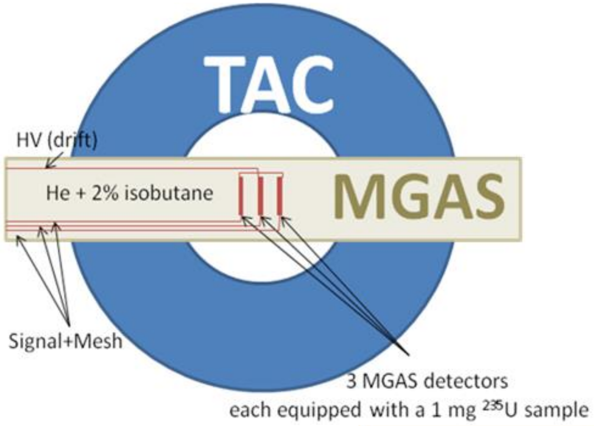
Specifications:

- ■ Low mass
- ■ Insensitive to γ's
- ■ High FFs detection efficiency
- ■ Good a to FF discrimination

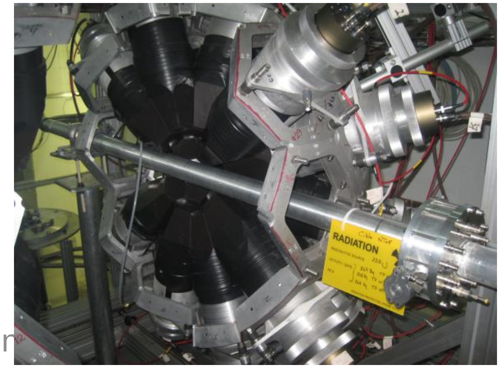
⇒ **Microbulk Micromegas**

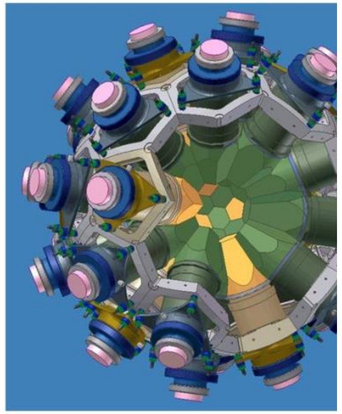
- Discrimination FF and α
- Coincidence γ and FF to estimate the background from fission events





3 MGAS detectors
each equipped with a 1 mg ^{235}U sample





Setup for fission tagging

3 Microbulks :

- ➢ ∅ = 3.5 cm
- ➢ Cu(5μm)/Kap(25μm)/Cu(5μm)

Windows:

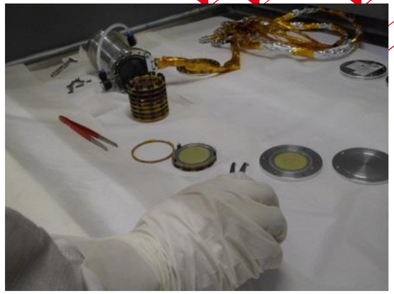
- ➢ ∅ = 7 cm
- ➢ kapton 25 μm

Gas:

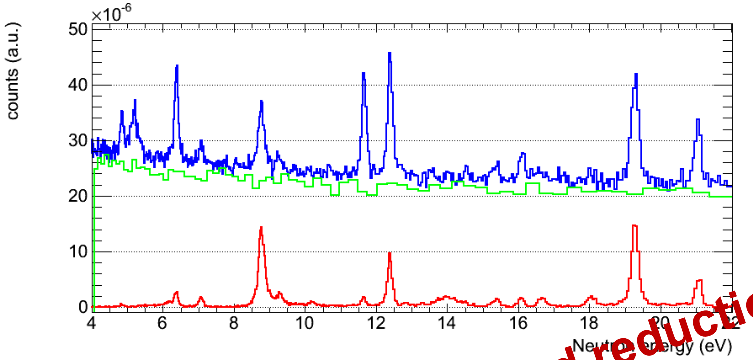
- ➢ He + (2%) iC_4H_{10}

Samples:

- ➢ 3 ^{235}Pu:
  - ∅ = 2 cm each
  - 1 mg each (27.3 MBq)

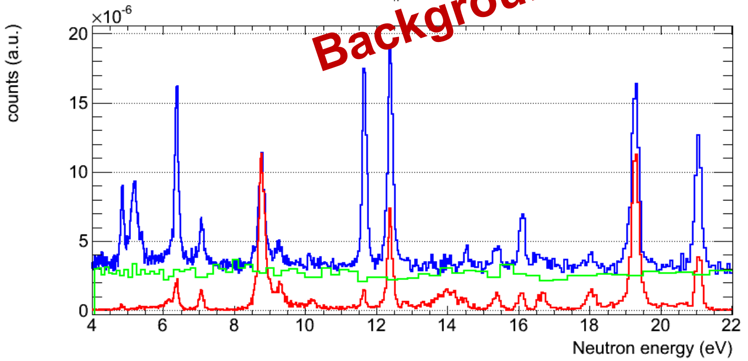


TACFTMG rate as a function of E_n , 1 MeV < E < Ehi, mult>1



Background reduction × 7

TACFTMG rate as a function of E_n , 3 MeV < E < Ehi, mult>2



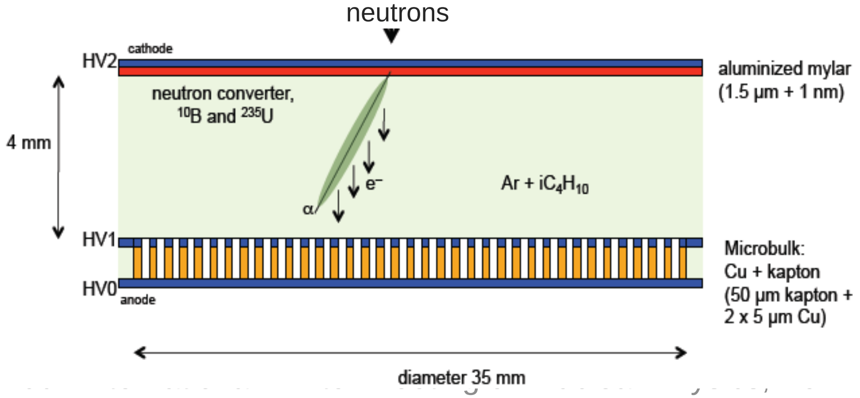
Micromegas as neutron flux monitor: nTOF

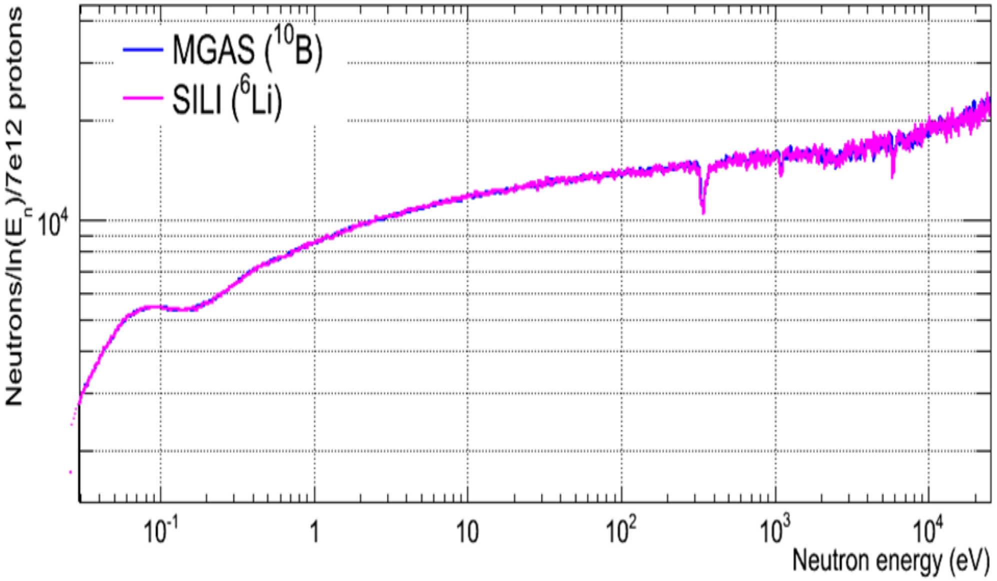
Online neutron flux monitor:

- Minimal beam perturbation
- Negligible induced background
  - Massless detectors
- Cover a wide energy range

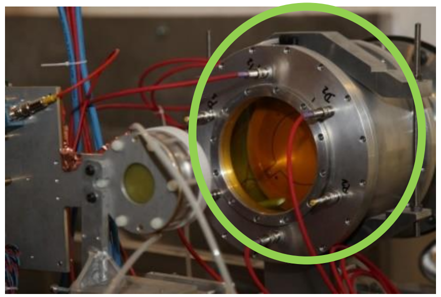
n_TOF:

- **Thin microbullks** since 2009 placed in the beam
- Equipped with appropriate convertor deposited on cathode
  - ^{10}B, ^{6}Li, ^{235}U
- Low mass & low cost
- The converter is not exposed to the avalanche



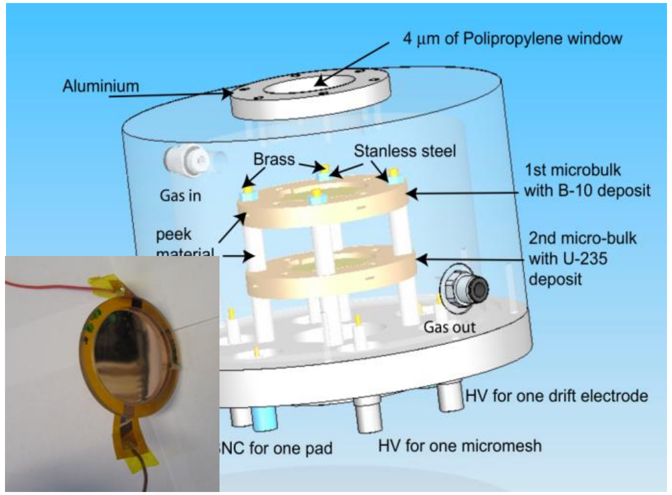


NEUTRON FLUX 2010: borated water + demineralized water as coolant & moderator, n_TOF Collaboration, Facility performance report



Φ ~ 8cm

Setup 2010

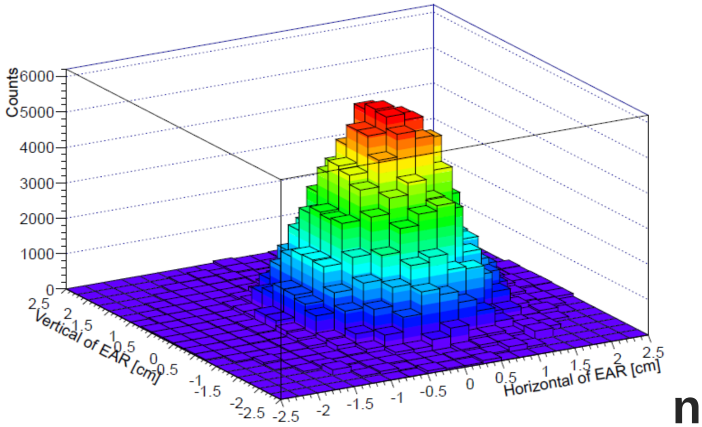


Micromegas as neutron beam profiler: nTOF

Neutron cross section measurements need an accurate knowledge of:

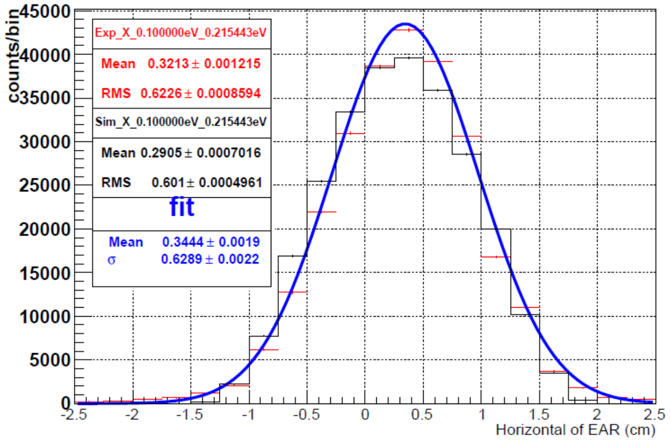
- ➢ Shape of the beam profile
  - ▪ Beam optics misalignments affect the neutron flux
- ➢ Beam intersection factor (BIF)
  - ▪ Correction factor when samples are smaller than the beam ∅
    - ▪ BIF = fraction of the number of neutrons hitting the area covered by the sample compared to the total number of neutrons in beam

- ➢ **Neutron beam profile from thermal up to ~1 MeV**
- ➢ **Experimental (almost real-time) position of the neutron beam**

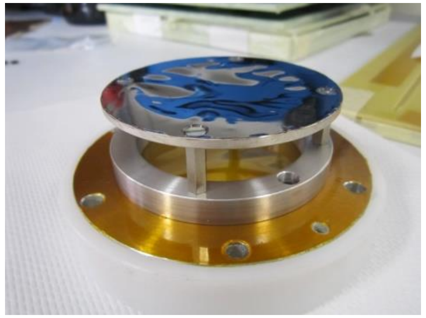


nTOF Results

F. Belloni et al. Nucl. Data Sheets 119, 2014



At n_TOF (since 2001)



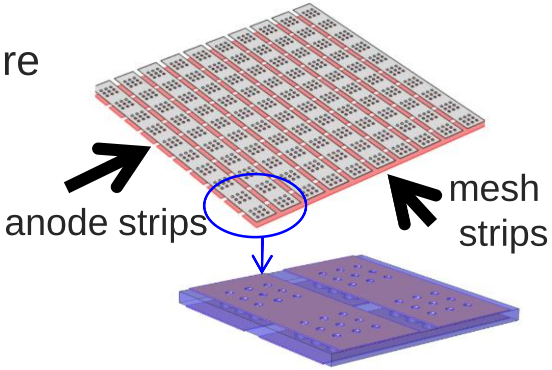
- ➢ pixelized readout with 2.5 mm pitch
- ➢ number of pixels = 77 x 4
- ➢ mesh gap = 128 μm
- ➢ drift gap = 4 mm
- ➢ window = 12.5 m kapton
- ➢ Ar + (10%)CF4 + (2%) iC4H10
- ➢ Equipped with B converter (2 μm thick)

➔ Micromegas + solid sample placed on the drift electrode

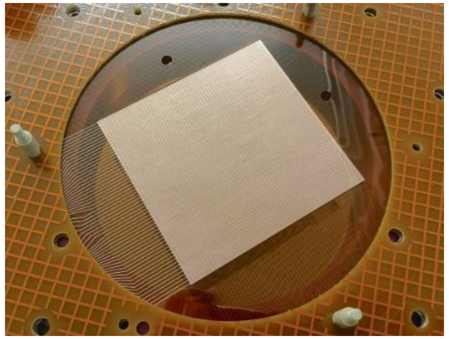
1D strips (2001) → 2D strips (2009) → pixels (2011)

A thin Micromegas 2D structure transparent to neutron beams

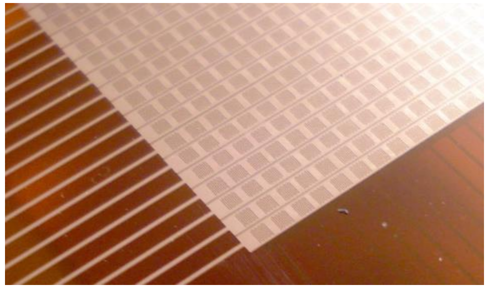
- ➢ Microbulk production simplification with a real 2D readout structure
  - Better position determination
- ➢ Mass minimization
- ➢ Large surfaces with high radiopurity possible
- ➢ Very good background rejection



Anode strips

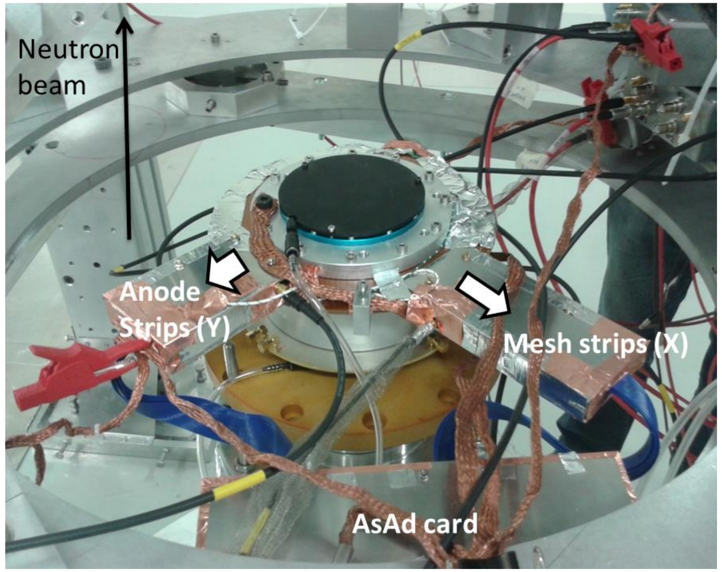


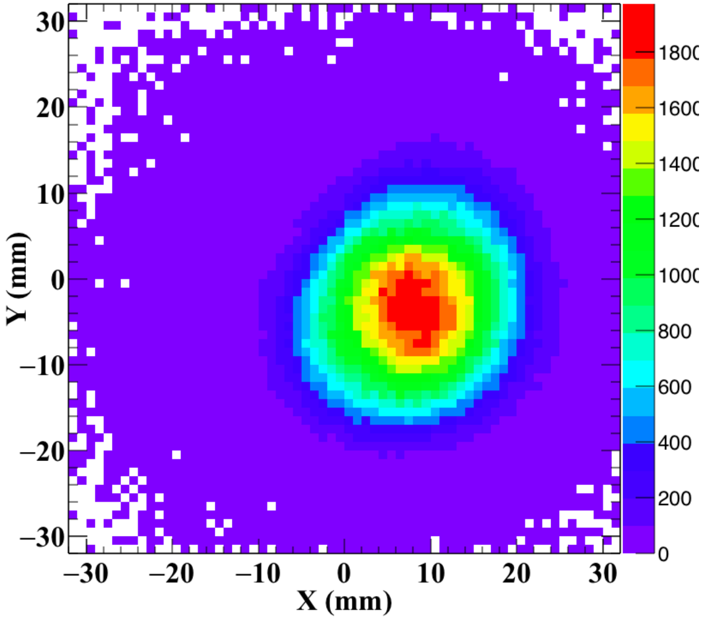
6x6 cm2



Mesh strips

- ✓ Successfully used as a neutron beam profiler at GELINA (IRMM), n_TOF (CERN), Orphee reactor (CEA/Saclay).
- ✓ Spatial resolution ~300-400 µm

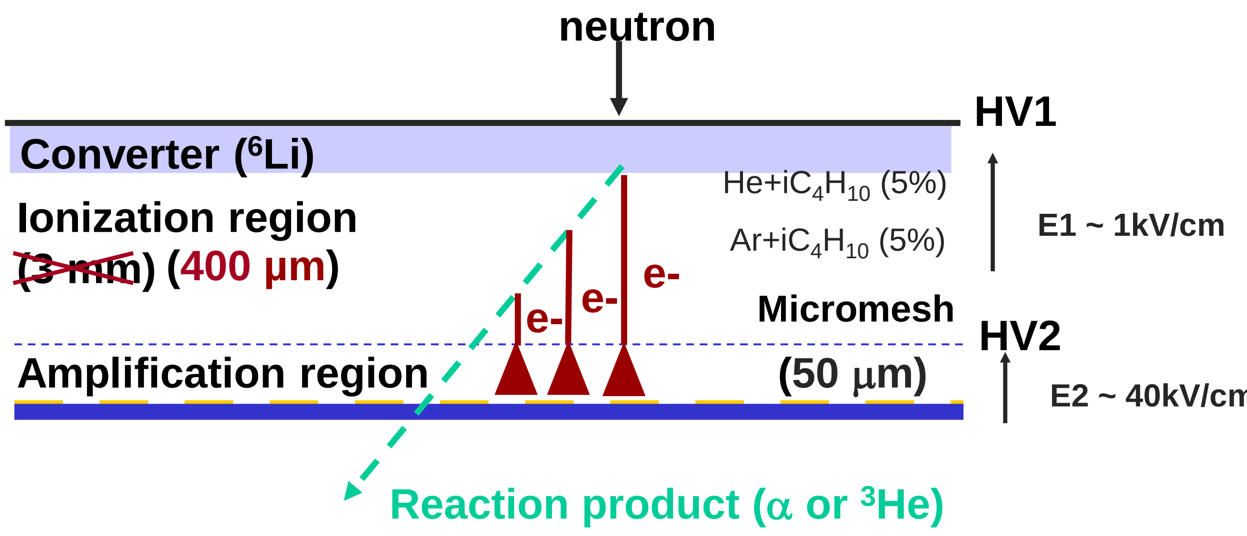




M. Diakaki et al., NIM A 903 (2018) 46–55, http://dx.doi.org/10.1016/j.nima.2018.06.019

Neutron Imaging

- Test of neutron 2D imaging and tomograhy capabilities
- Use for instance to see defects in mechanical pieces
- Use of classical converters for thermal neutron detection
- Use of a CAST-like detector
- Small drift gap and pre-amplification in the drift gap to reconstruct properly the reaction point



neutron

HV1

Converter (^{6}Li)

Ionization region

~~(3 mm~~) (400 µm)

He+iC_4H_{10} (5%)

Ar+iC_4H_{10} (5%)

E1 ~ 1kV/cm

e-

e-

e-

Micromesh

HV2

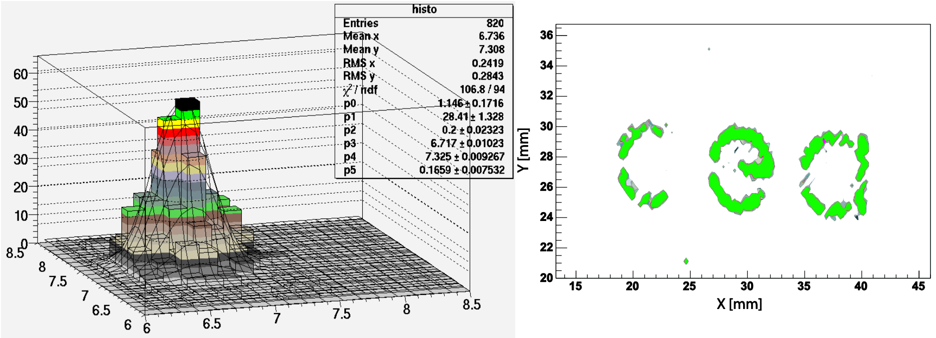
Amplification region

(50 µm)

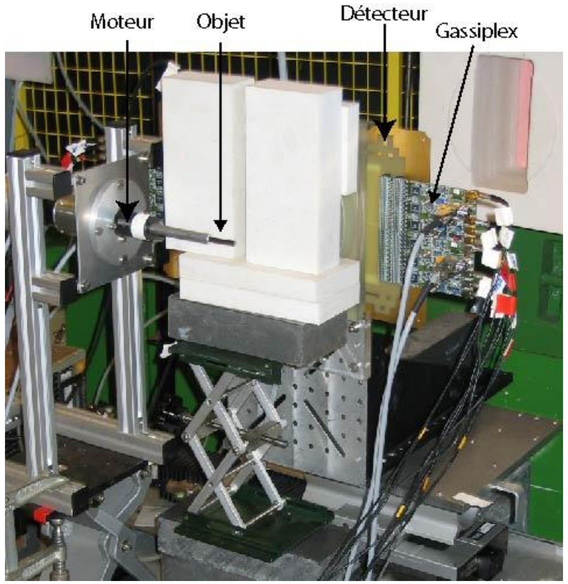
E2 ~ 40kV/cm

Reaction product (α or ^{3}He)

2D image at ORPHEE

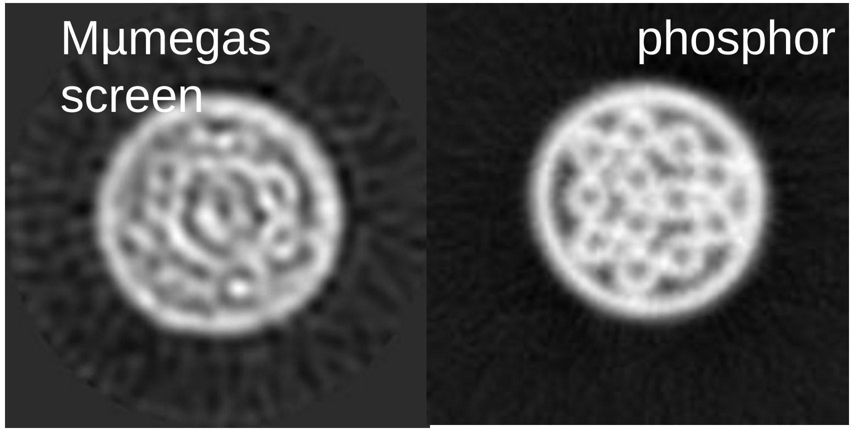


160 µm spatial resolution



Tomography at GKKS

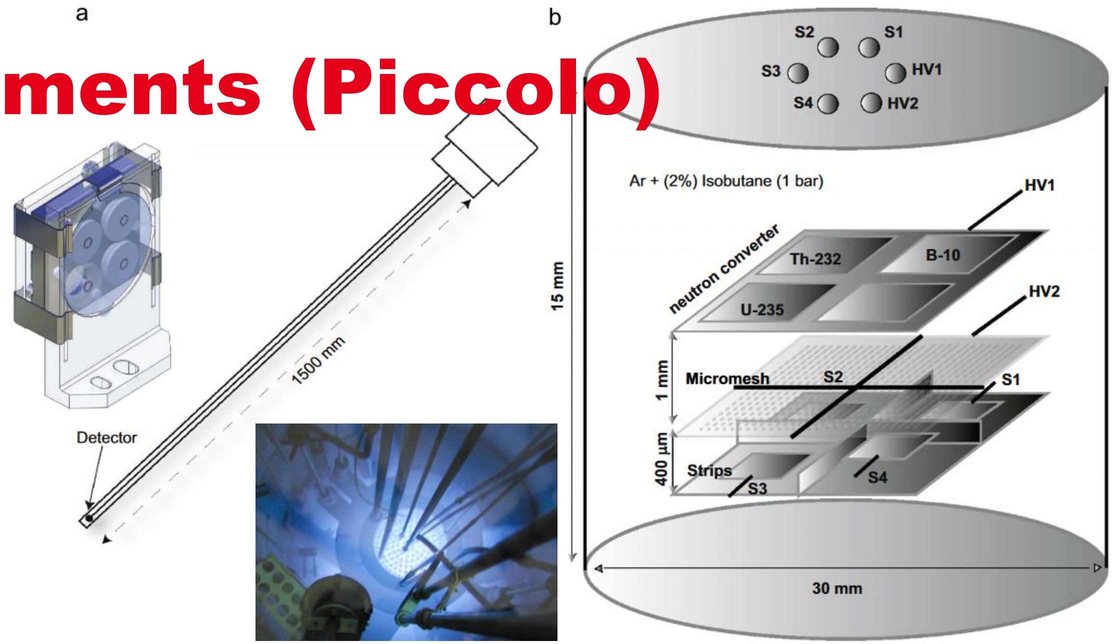
F. Jeanneau, Proc. SPIE 4785, 214 (2002)

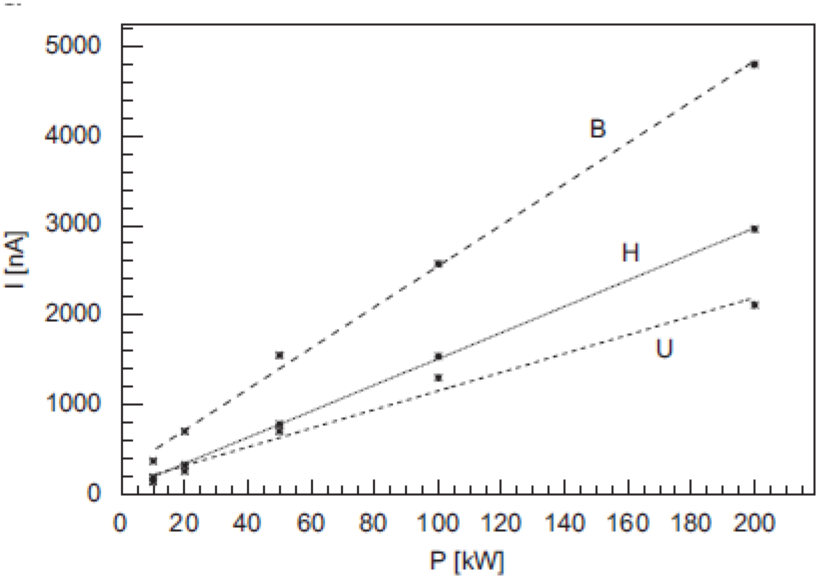


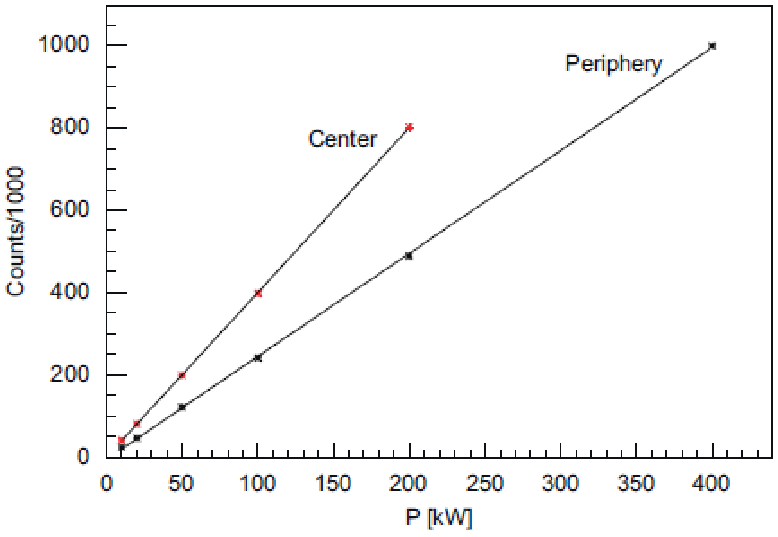
Lack of stat. put also aberration due to mesh pilars

Micromegas in harsh environments (Piccolo)

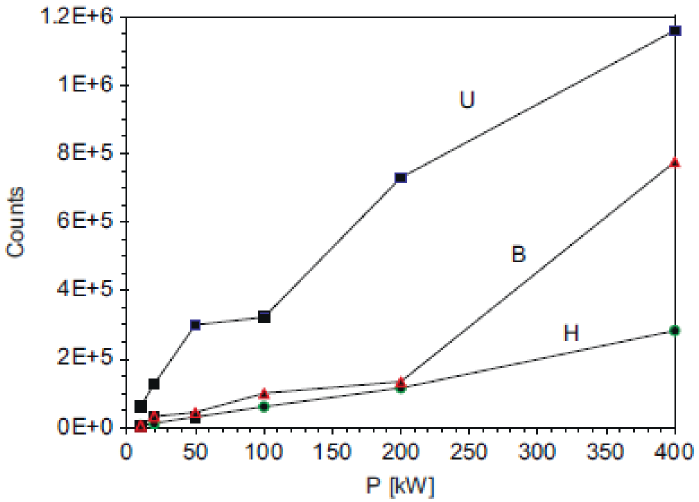
- Framework of ADS projects to monitor accurately the neutron flux
- Low gamma ray sensitivity ($10^9\ \gamma/cm^2/s$)
- 4 pads to cover various energy ranges with individual HV to adapt the gain
- Test performed at ENEA in Casaccia on a 1MW TRIGA research reactor in 2006
- Current, counting and pulse ampl. measurements
- Ar+iC4H10 (2%) in sealed mode







J. Pancin, NIM A, 592, 2008



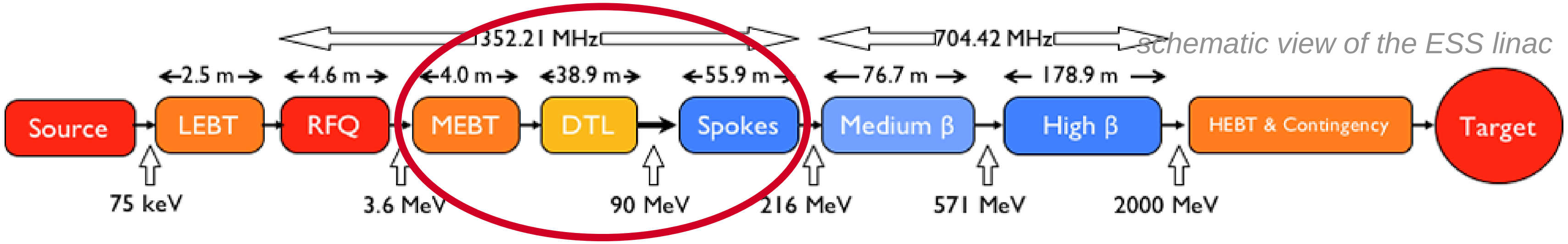
Slide courtesy of J. Pancin (IRFU, CEA GANIL)

Relatively good linearity, could merit further studies (sealed mode, electronics…)

neutron Beam Loss Monitor: nBLM-ESS

The **European Spallation Source:**

- The most powerful **neutron source**, under construction in Sweden
- Protons accelerated to 2 GeV in a **linear accelerator** (62 mA, 5 MW)
  ➔ hit on a W target to produce **neutrons**



schematic view of the ESS linac

The problem:

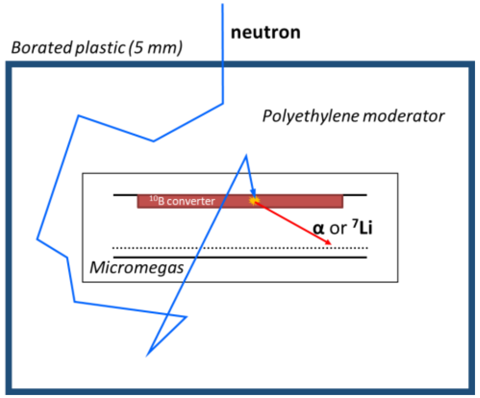
- **Accidental beam loss In high power linear accelerators:**
  Damage the accelerator ➔ *need for* ***fast alarm***
  Activate materials ➔ *monitor* ***small beam loss***
- **Monitors** for **high energy** part: ionization chambers (charged particles)
- **No solution** at the **low energy** part of the accelerator:
- Need to **detect fast neutrons** with **very large dynamic range**
  strong gamma background from RF cavities!

Proposed solution: ***nBLM (neutron Beam Loss Monitor)***

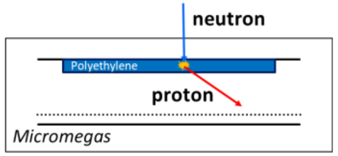
Adapt *a particle detector (****Micromegas****) for* ***beam diagnostics*** *using a combination of neutron* ***convertors*** *and* ***moderators.***
➔ *Detect* ***individual neutrons*** *(****counter****)*

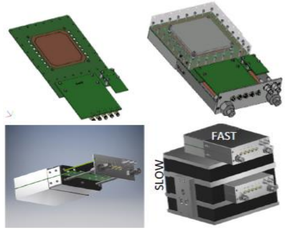
Two complementary modules

High sensitivity



Fast response





More info on nBLM:

L. Segui et al 2023 JINST 18 P01013

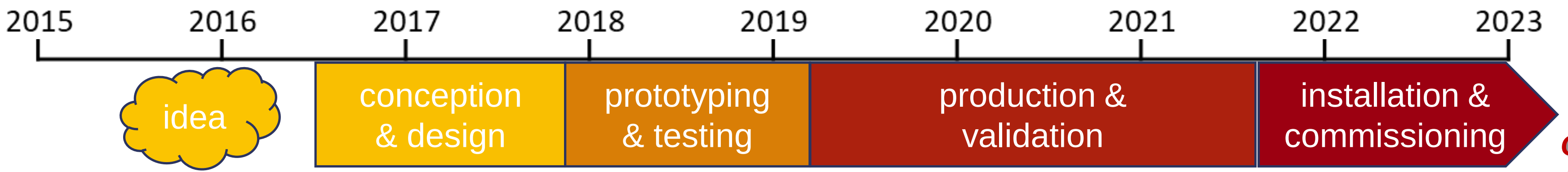
neutron Beam Loss Monitor: nBLM-ESS

The nBLM-ESS project: **in-kind contract** (Schedule AIK 7.9) between the **European Spallation Source** (ESS) & **IRFU** (CEA), part of the **French in-kind contribution** to the **ESS accelerator**

➔ Design, construction, testing and commissioning of **84 detectors** & **auxiliary subsystems**

Development & Implementation of a complete system:

- *Detectors & FEE*
- *Gas system*
- *HV & LV Control system*
- *DAQ & alarm system*



2015 2016 2017 2018 2019 2020 2021 2022 2023

idea

conception & design

prototyping & testing

production & validation

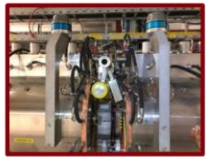
installation & commissioning

Commissioning start @ ESS: April 2022

MC40-Cyclotron
Birmingham, UK

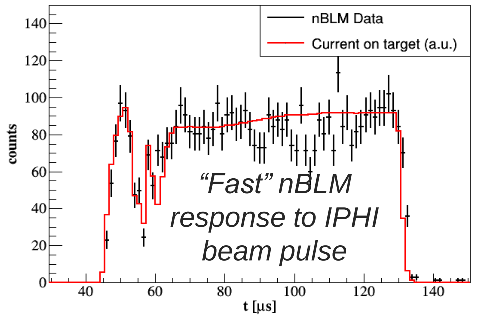
IPHI,
CEA Saclay

AMANDE IRSN,
CEA Cadarache

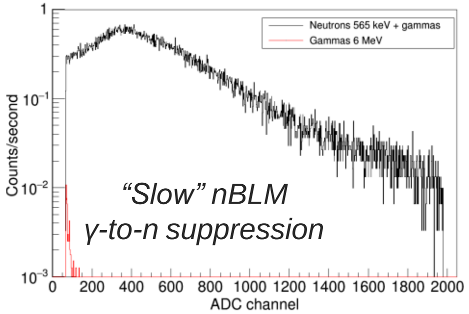


LINAC4
CERN

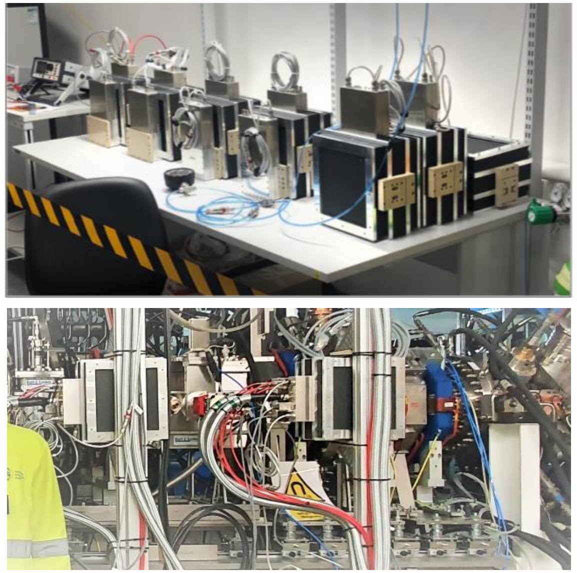
n/γ sources,
CEA Saclay



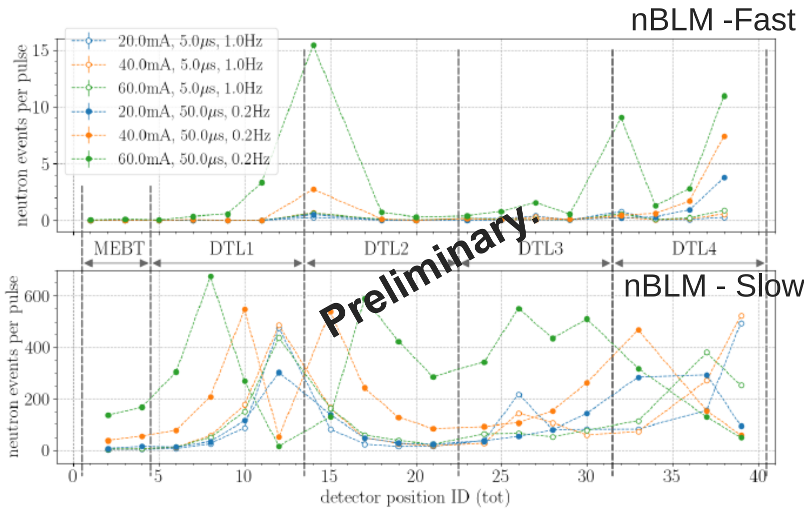
“Fast” nBLM response to IPHI beam pulse



“Slow” nBLM γ-to-n suppression



Detectors @ ESS (2021)



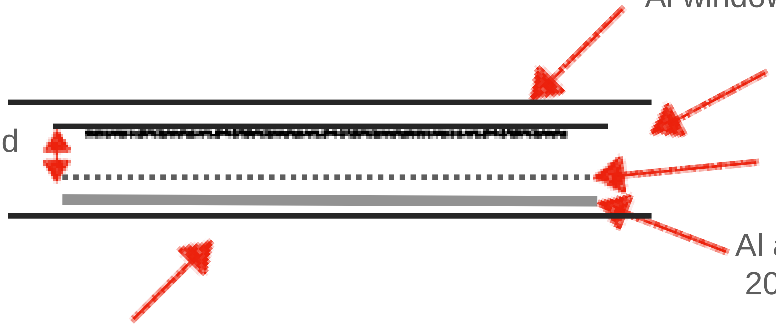
DTL4 commissioning run –results

I. Dolenc-Kittelmann, IBIC 2023, paper TU1I02

nBLM as a versatile thermal neutron monitor

Established technology used at ESS (nBLM)
Now co-developed by ESS, CEA Saclay, CERN

- Build with **low beam attenuation** materials (< 2% @ 1.8Å)
- **Very high dynamic range**
  - Single neutron to over 10^9 n·cm^{-2}s^{-1}
  - **Dual pulse & current mode** operation
- Operation with **single or multiple channels**
  - Excellent timing resolution (sub-μs)
  - High rate capability *O*(MHz)
- Vessel adapted as needed
  - **Low thickness** down to 10 mm
  - **In-vacuum** monitors
- Interchangeable electrodes for
  - variable efficiency
  - N_2 operation for minimised efficiencies (~10^{-7})
- Posibility of 1D/2D segmentation for beam profile monitoring



Al window 100 μm

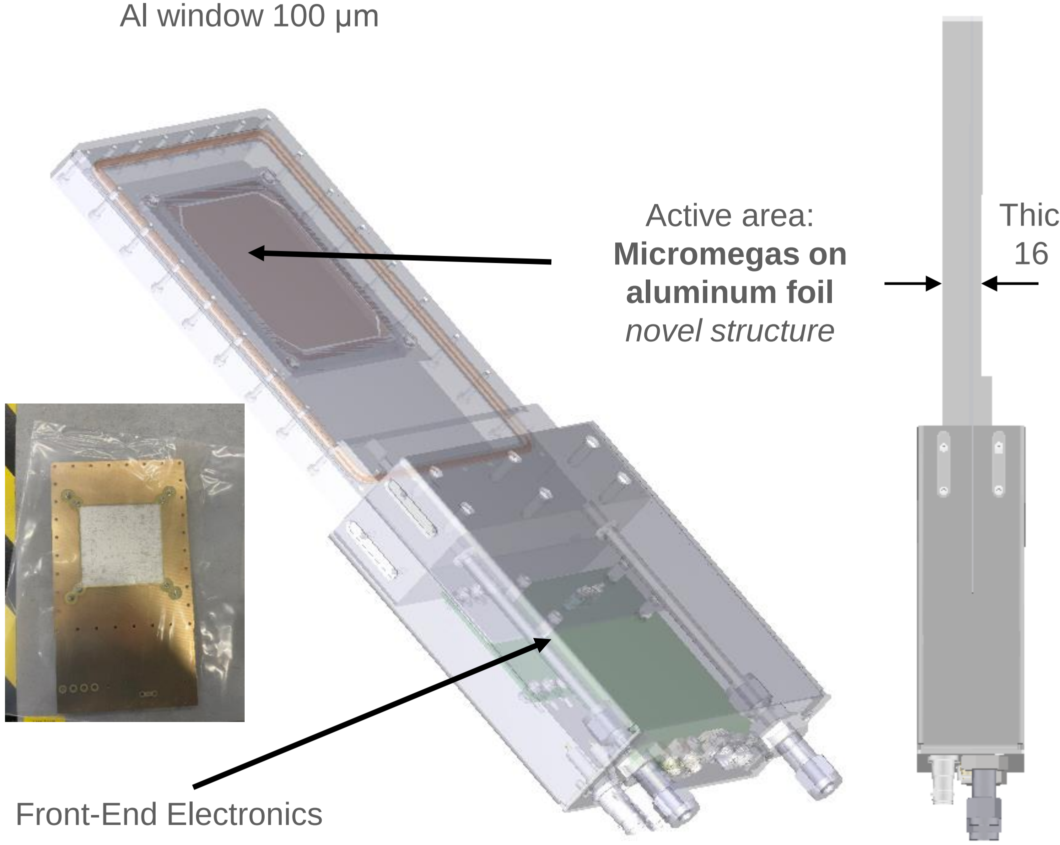
B4C coated
Al cathode 100 μm

Easily modified
with spacers

SS Mesh <20 μm

Al anode
200 μm

Al window 100 μm



Active area:
Micromegas on aluminum foil
novel structure

Thickness
16 mm

Front-End Electronics

Slide courtesy of I. Katsioulas (ESS)

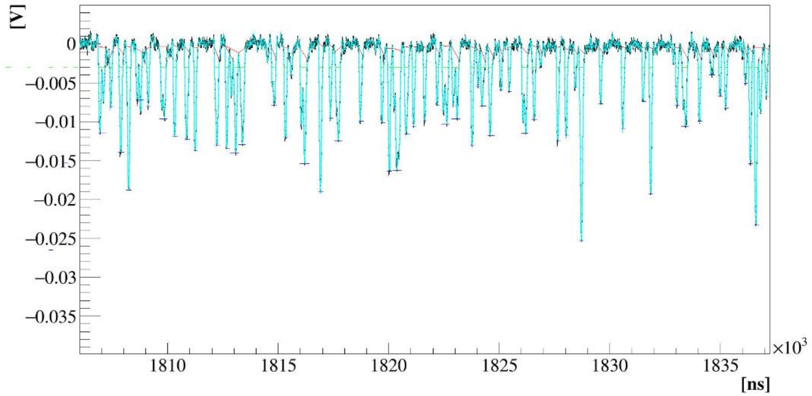
nBLM as a versatile thermal neutron monitor

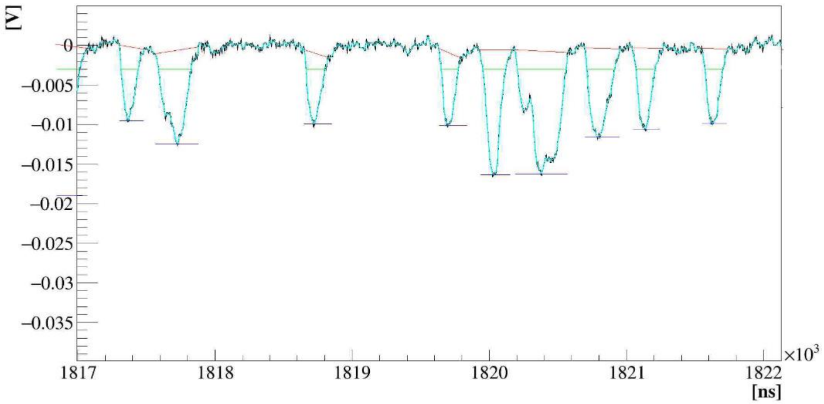
Neutron flux measurements at PSI (Dec 2023)

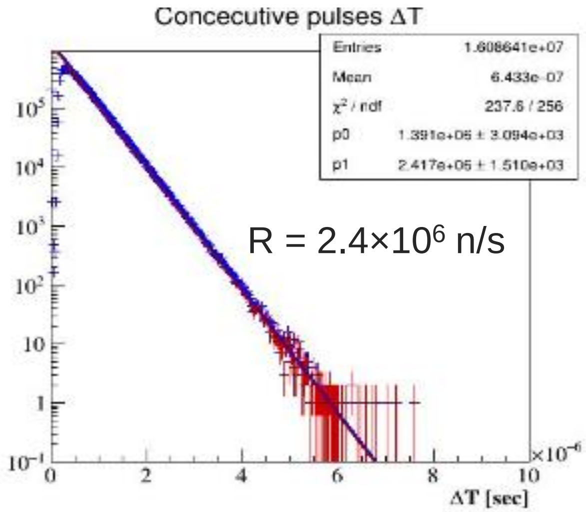
Beamline: Morpheus / SINQ,

$\lambda = 3.6\text{Å}$, **beamsize 4×6 cm^2**

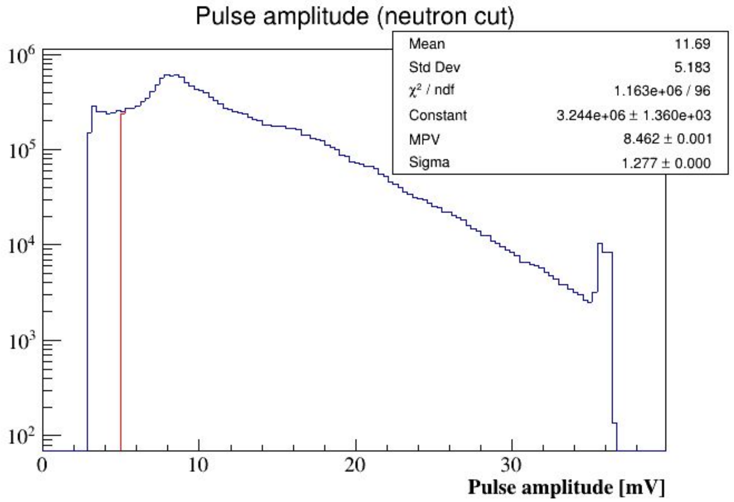
MM Gas : Ar + 10% CF$_4$

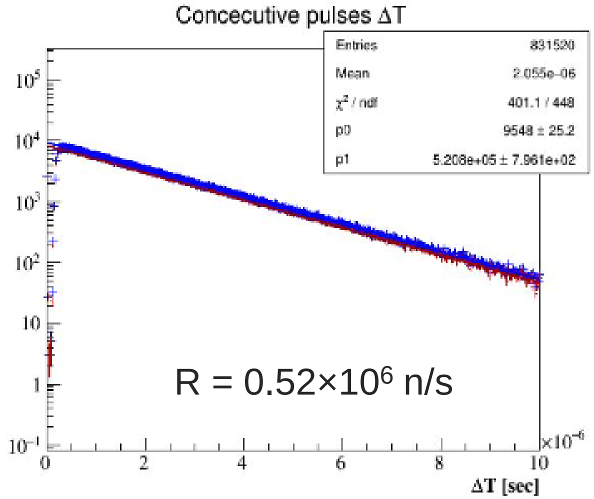




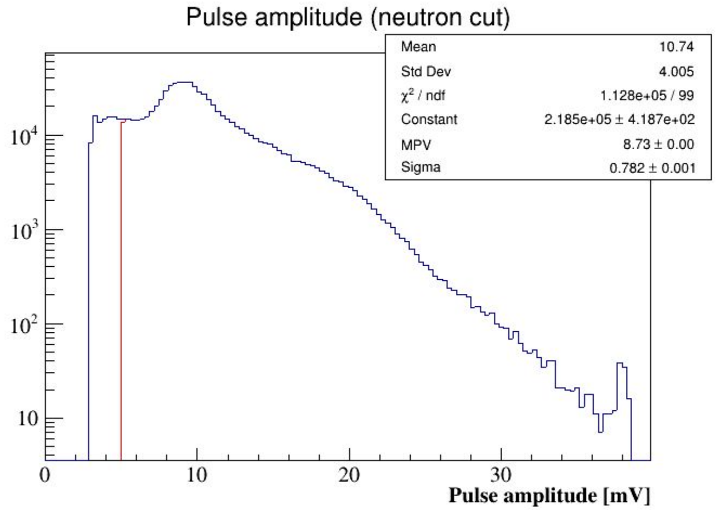


R = 2.4×10^6 n/s





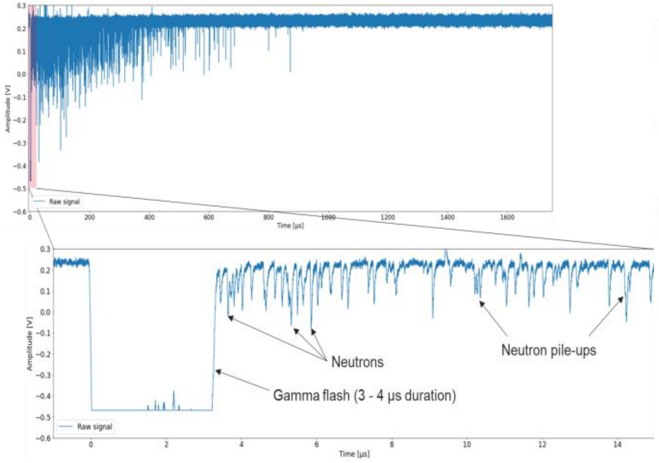
R = 0.52×10^6 n/s

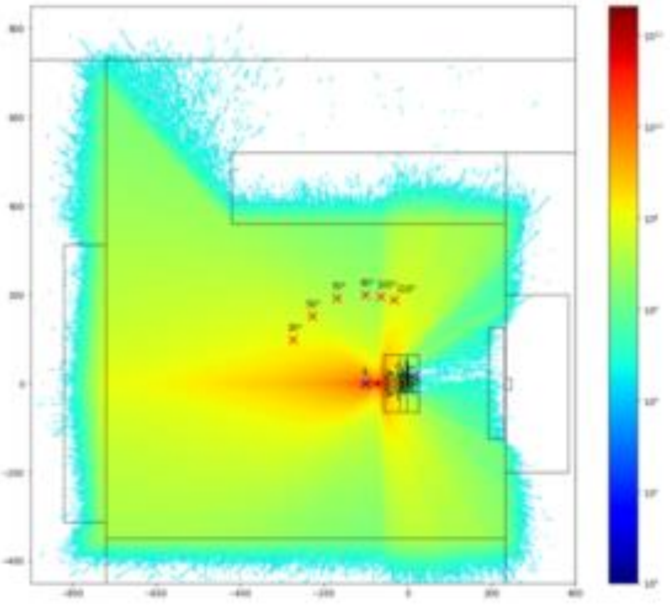


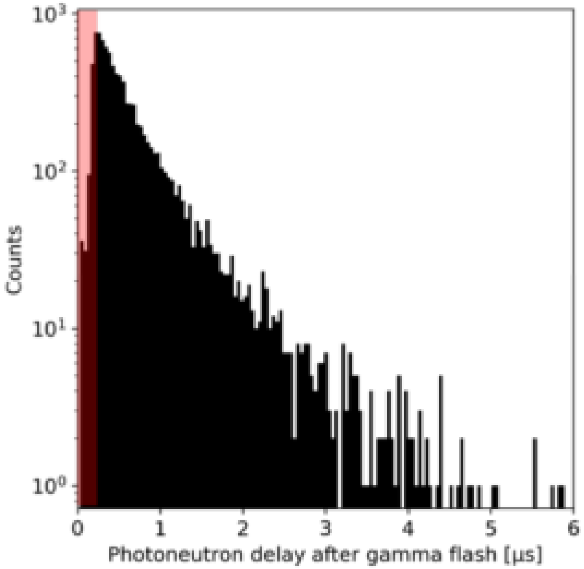
“nBLM MM” in medical accelerators

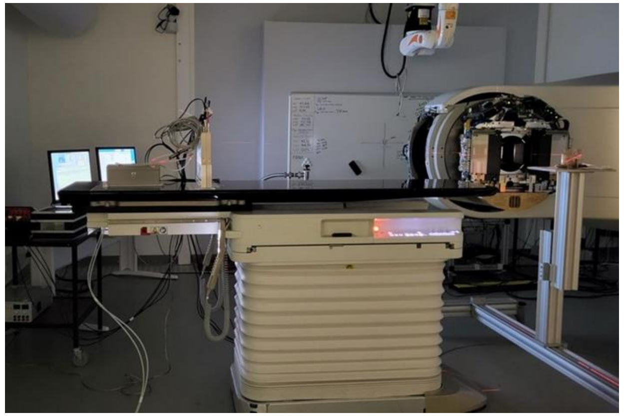
- ➢ Characterization of angular and time distributions of photo-neutrons in medical accelerator
- ➢ Neutron measurements in presence of strong “gamma flash” ➔ scintillators become blind

Varian TrueBeam





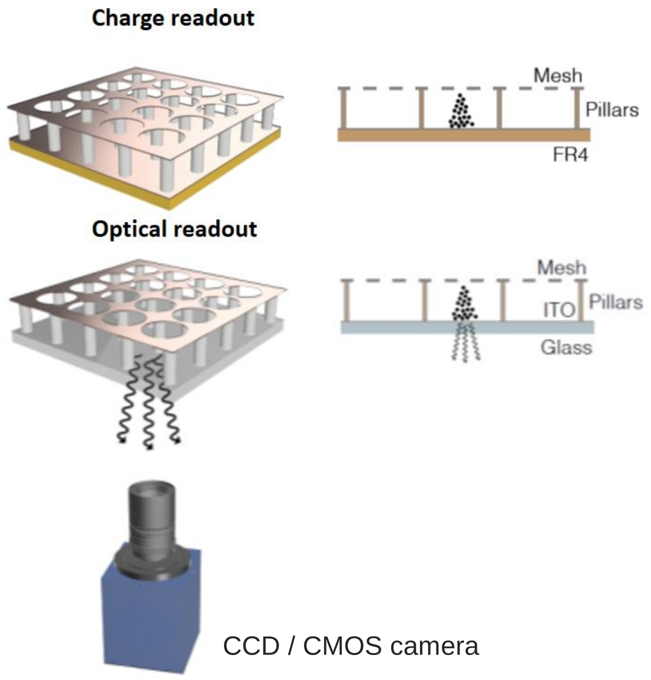




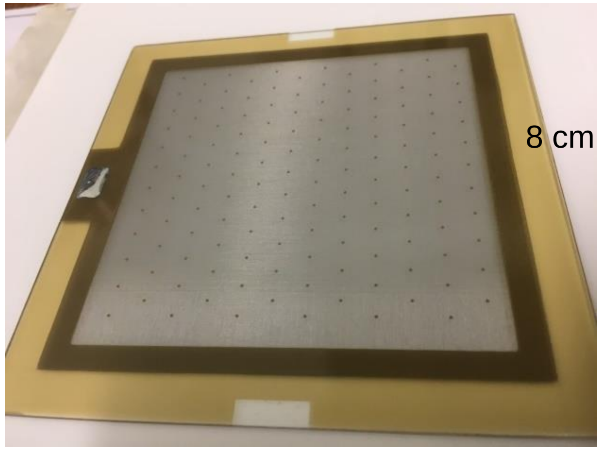
Test at **DOSEO (CEA/DRT/LIST):** 17 MeV e$^-$ beam on several targets (C, Al, Fe, W…)

Analysis by Clément Besnard-Vauterin, CEA, DRT,List

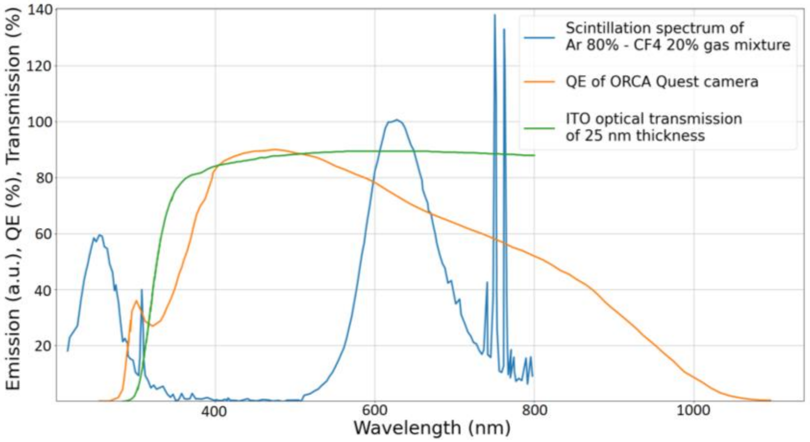
A Micromegas with optical readout



Need for specific gasses, i.e. Argon – CF4 mixtures ➔ ***scintillation light in the visible*** *during a avalanches*

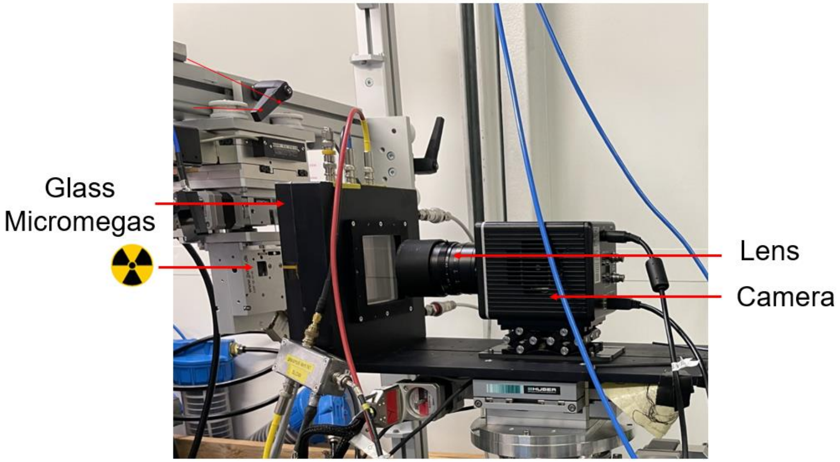


Glass Micromegas
Produced at MPGD IRFU workshop



Optical vs Charge readout

- Use of camera (**high granularity**, large number of pixels, use of lens for large field of view)
- Easy handling of the data (light intensity matrix)
- **Real-time imaging** thanks to very low data processing and light **integration approach**



Neutron imaging setup

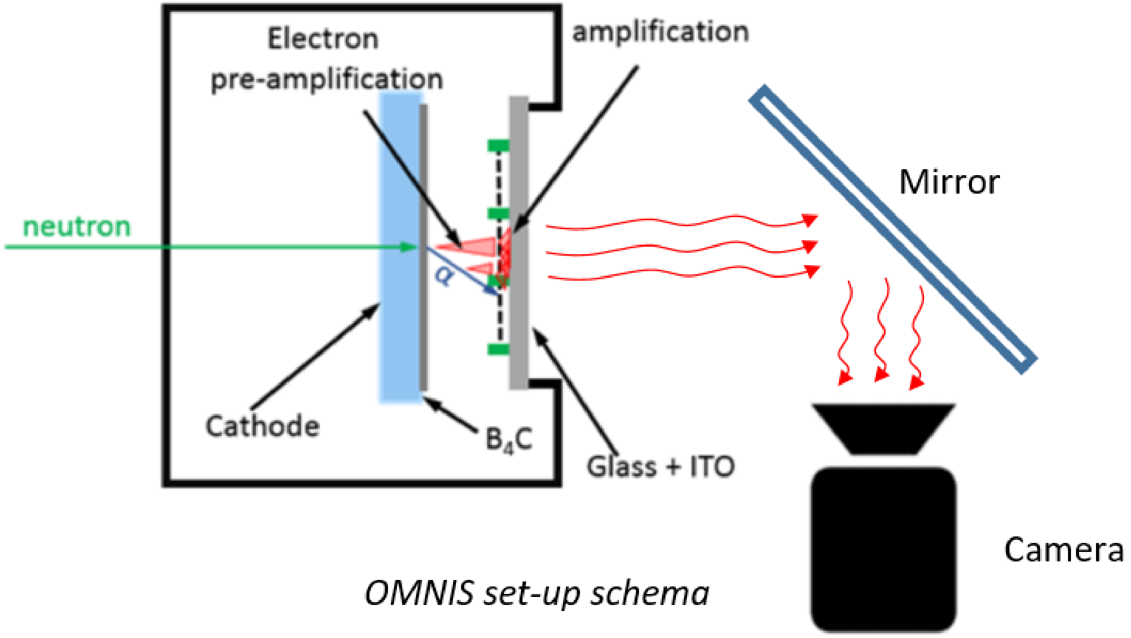
Cathode : $^{10}B_4C$ neutron-to-charge converter

Thermal neutrons absorbed by 2 µm thin $^{10}B_4C$ layer

Conversion efficiency: ~5% @ 0.01 eV

(α or Li) fragments cause strong ionisation

Limitation: fragments long range in the gas (5 mm)



OMNIS set-up schema

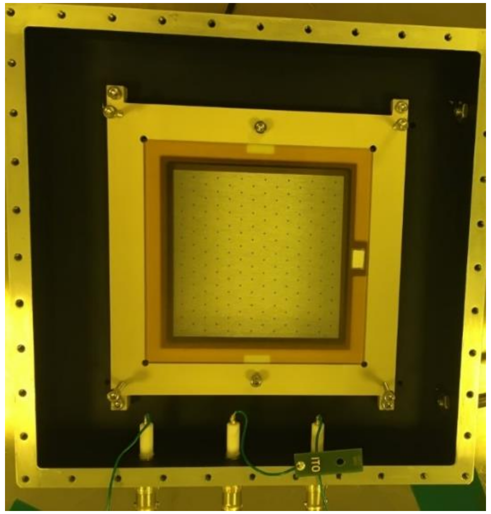
Acquisition modes:

Event-by-event: track reconstruction:

Potentially higher resolution and ɣ-to-n suppression

Integrated: real-time radiography:

Almost no data processing

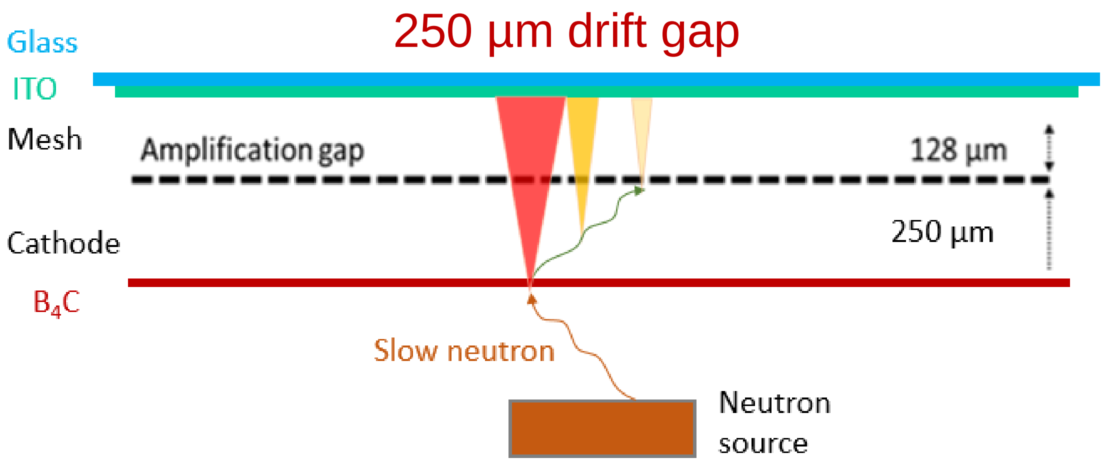


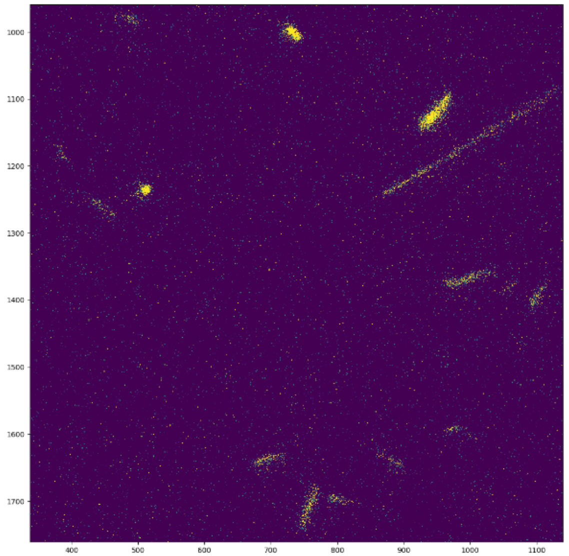
Improving the spatial resolution towards 100 µm

Problem: α-particle range ~7 mm

Our approach:

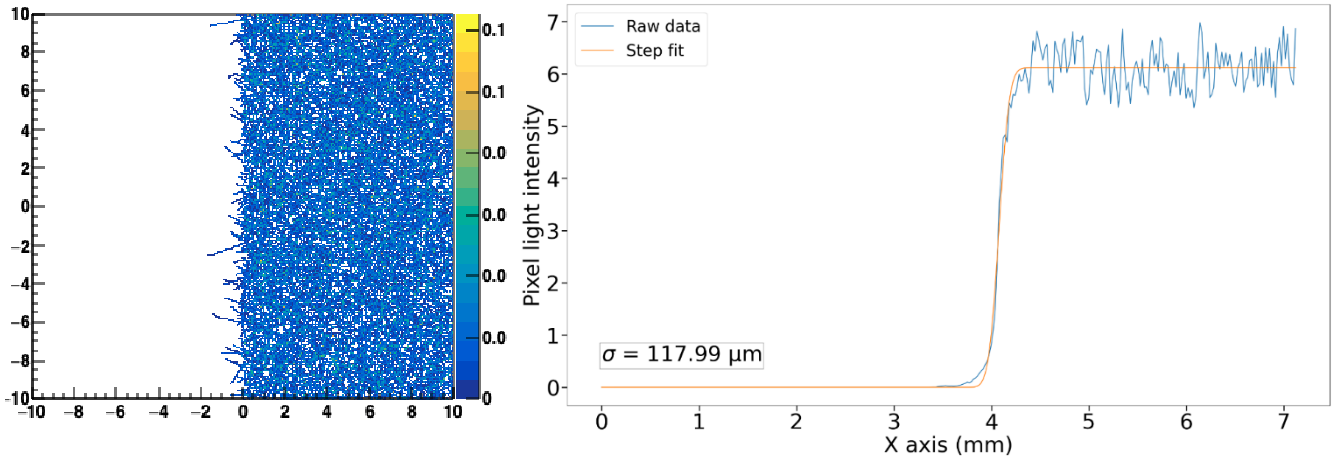
- ➢ Reduce drift gap << 1 mm
- ➢ Apply strong field for preamplification
  - ➔ Emphasize emition point
  - ➔ Planarity requirements ~ 10 µm / 10 cm!





Am-Be source – Ar/10%CF4

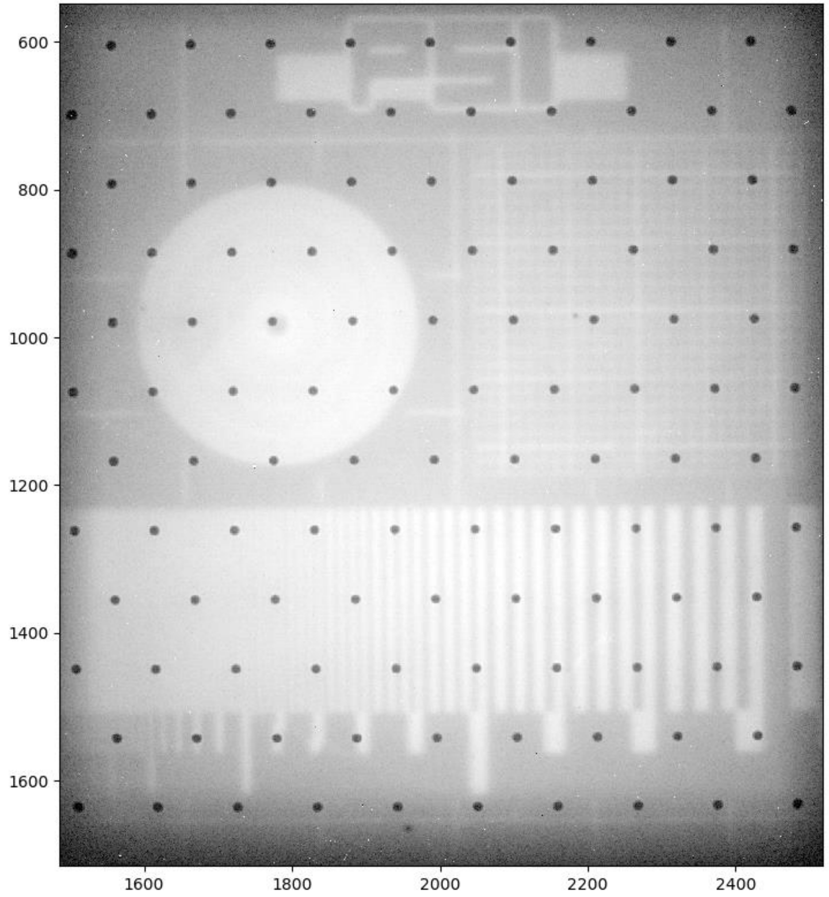
Simulated dE/dX - maxboltz



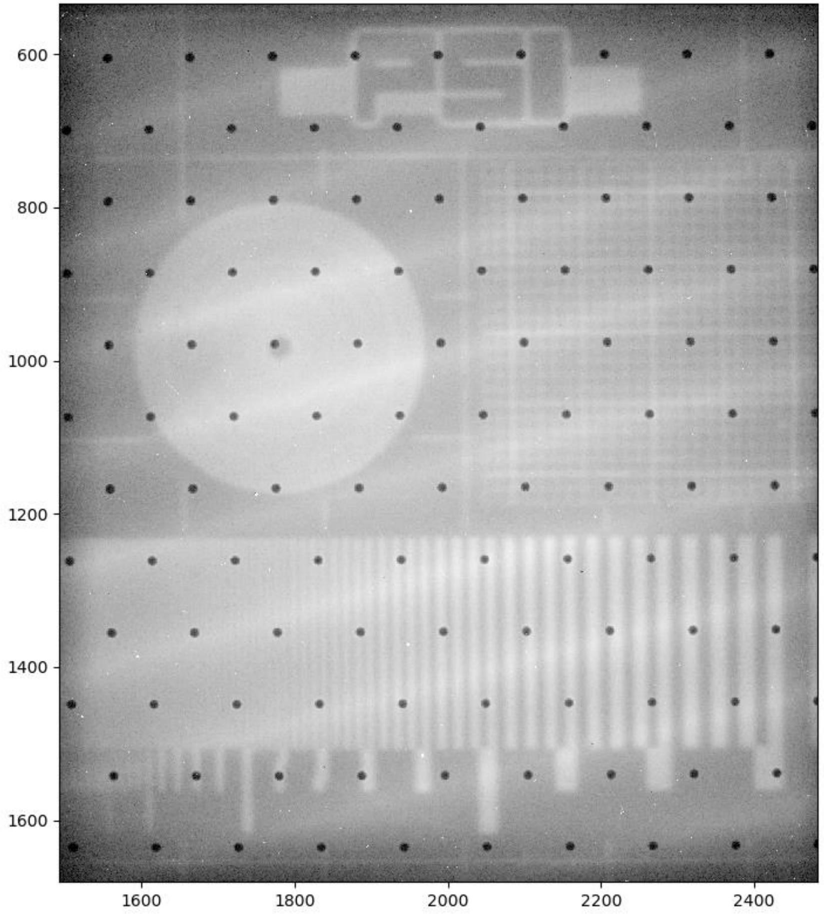
Spatial resolution measurements @ PSI

Raw images

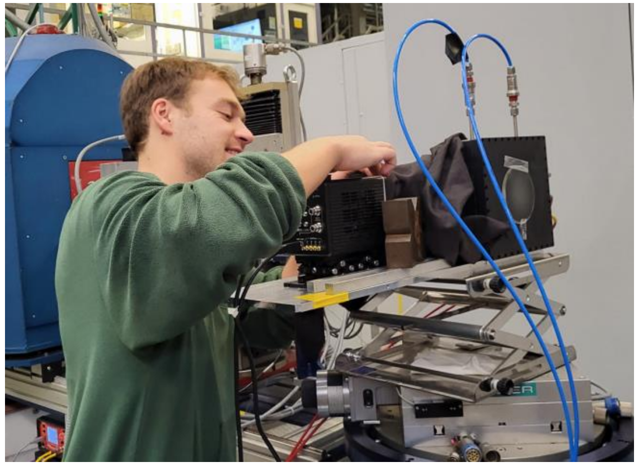
Flat cathode (1.5 µm B_4C), 6x4 cm beam, Gd mask

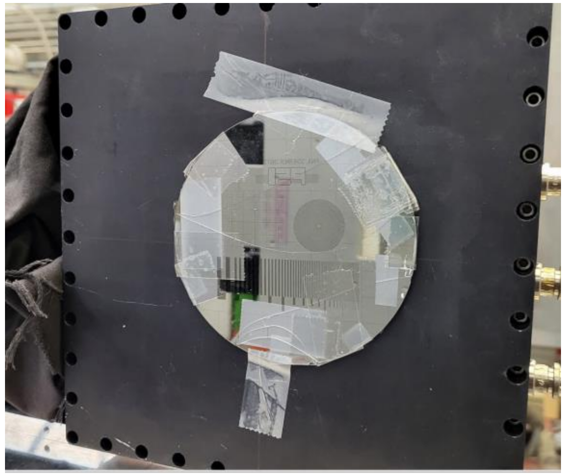


Light intensity profile with single amplification
E_{amp} = 38 kV/cm, E_{drift} = 500 V/cm, 100 s



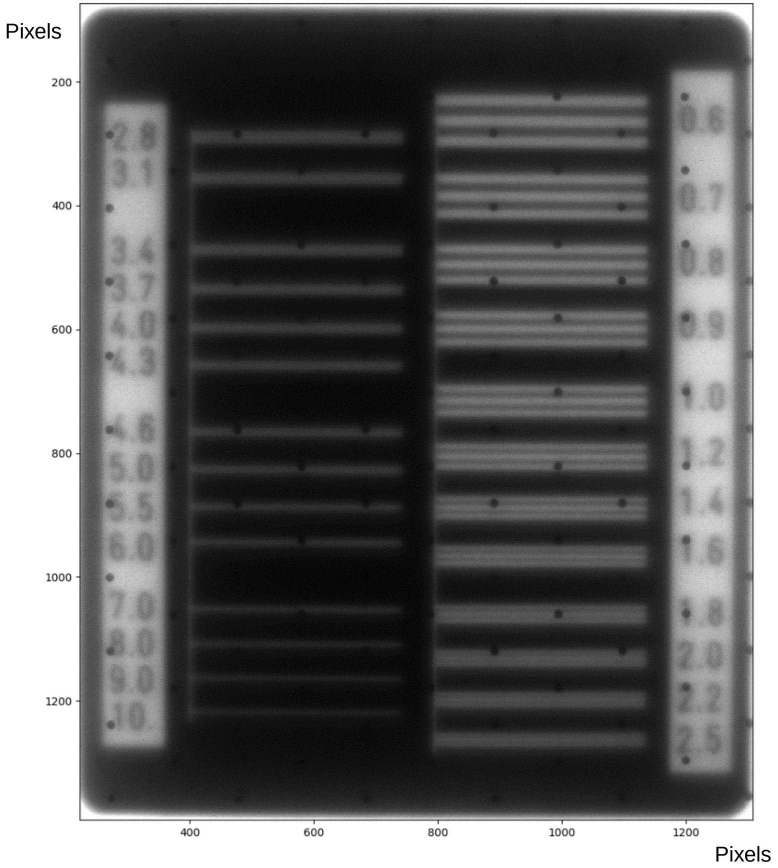
Light intensity profile with double amplification
E_{amp} = 20 kV/cm, E_{drift} = 24 kV/cm, 100 s





Deconvolution of the PSF: x-ray tests!

Deconvolution

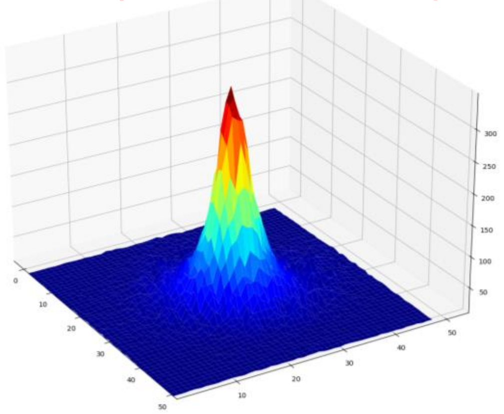


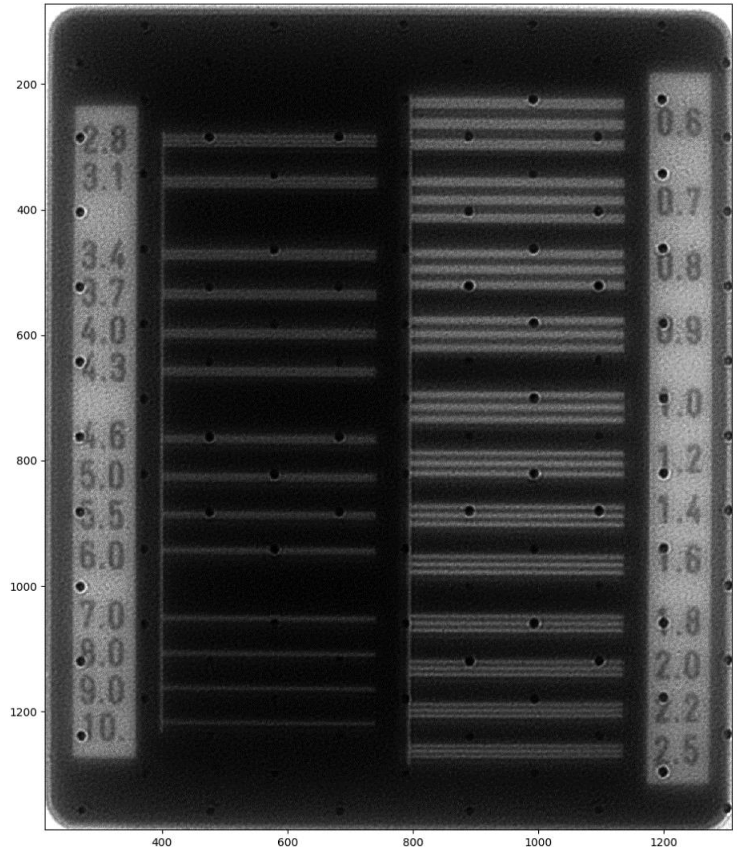
MTF (10%) : 800 µm

10 mm

Deconvolution

PSF from experimental data (σ = 280 µm)



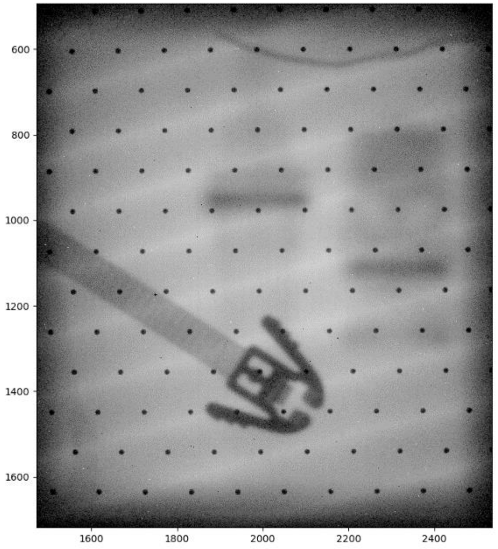


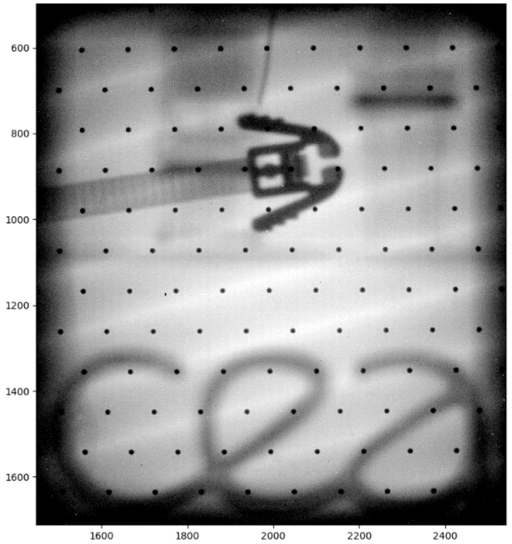
MTF (10%) : 281 µm

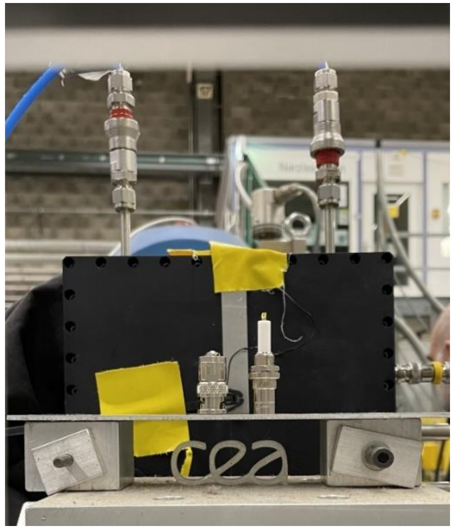
Real-time imaging of several objects

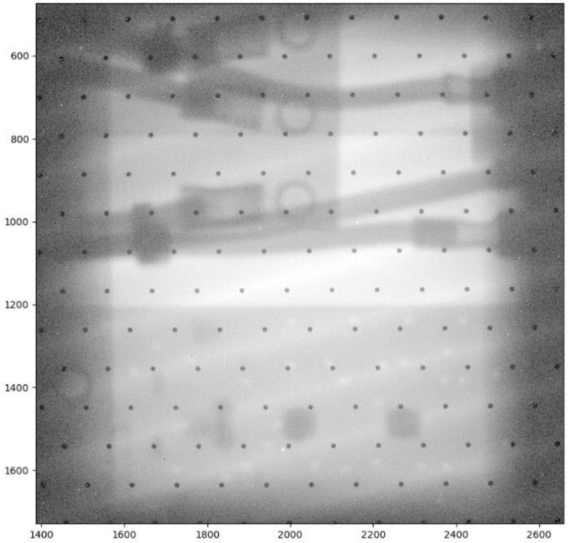
Raw images

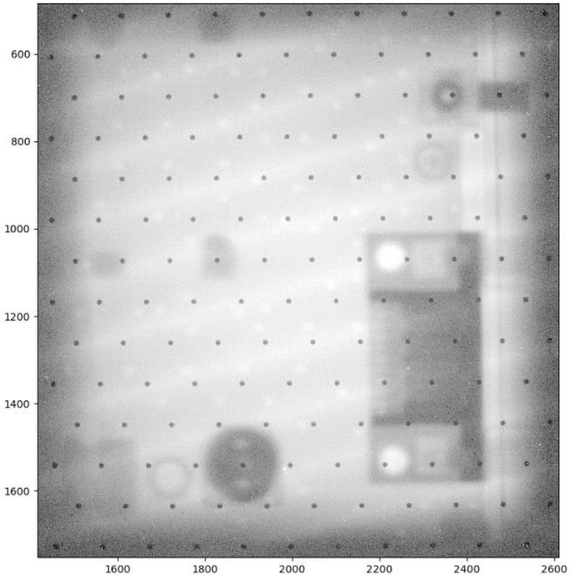
Flat cathode (1.5 µm B_4C), 6x4 cm beam



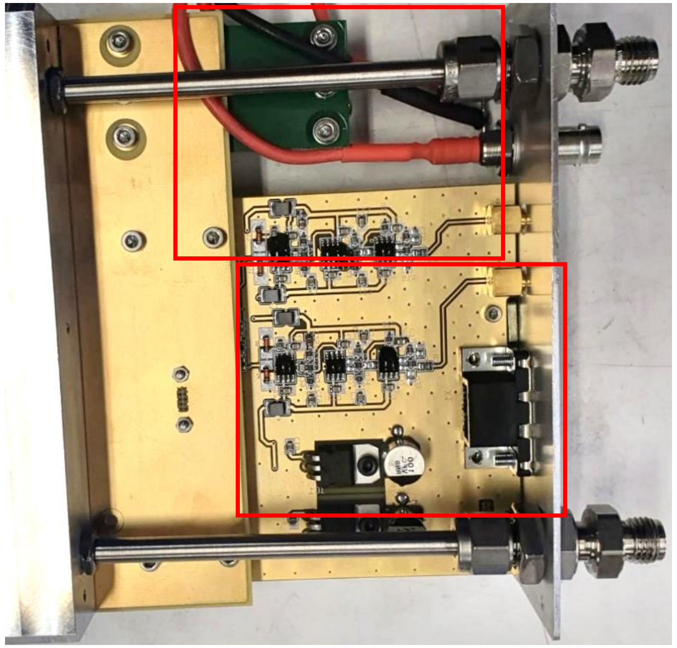








Light intensity profile with double amplification
E_{amp} = 20 kV/cm, E_{drift} = 24 kV/cm, 100 s



Conclusions

- Micromegas are Micropattern Gasseous Detectors for charged particles originally designed for HEP experiments
  - Advantages: low cost for high surface, high granularity, easy operation and robustness, excellent n/gamma discrimination, spatial, large dynamic range,…
  - Suitable also for TPC readout (2D → 3D)
- They can be adapted to detect neutrons using appropriate convertors (solid, gas,)
- Very versatile to adapt to applications from basic science
  - Neutron physics (x-section measurements)
  - Neutron beam monitoring: profile & flux monitors
- to applications beyond physics
  - Beam loss monitoring for machine protection
  - Neutron flux measurements in harsh environments
  - Real-time neutron imaging
- *Prospects: TPCs with Optical Readout (SPAD chip ➔ Arrays of avalanche photodiodes* $\sigma_t \sim 0.1$ *ns!)*

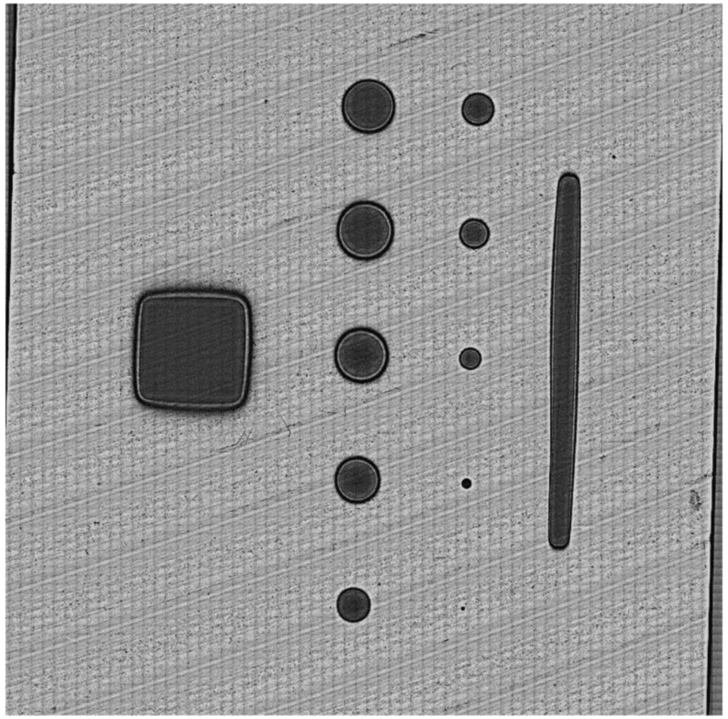
Thank you for your attention!

Spatial resolution measurements @ PSI

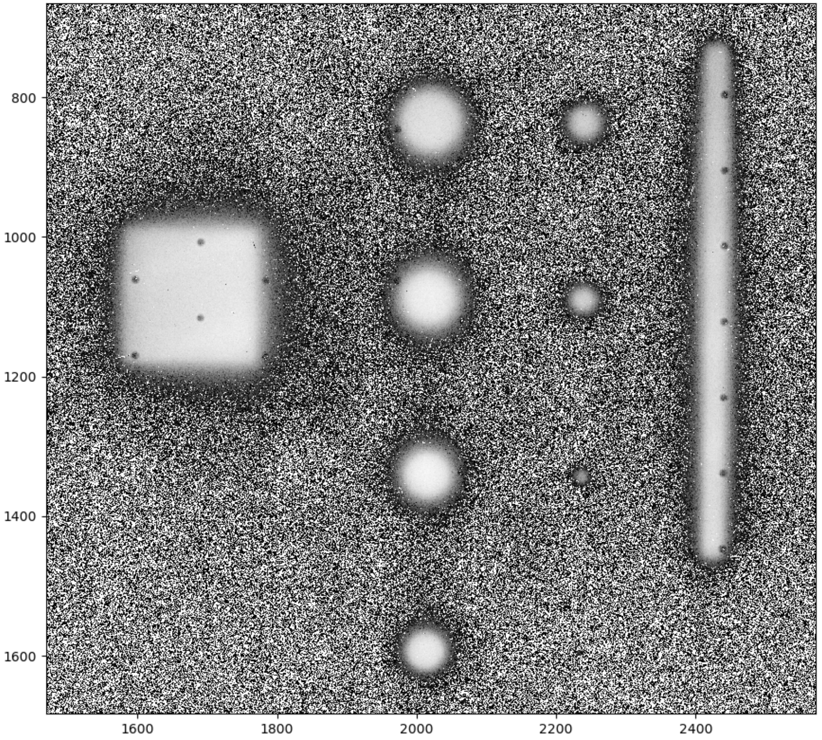
Preliminary

B_4C deposition using a mask

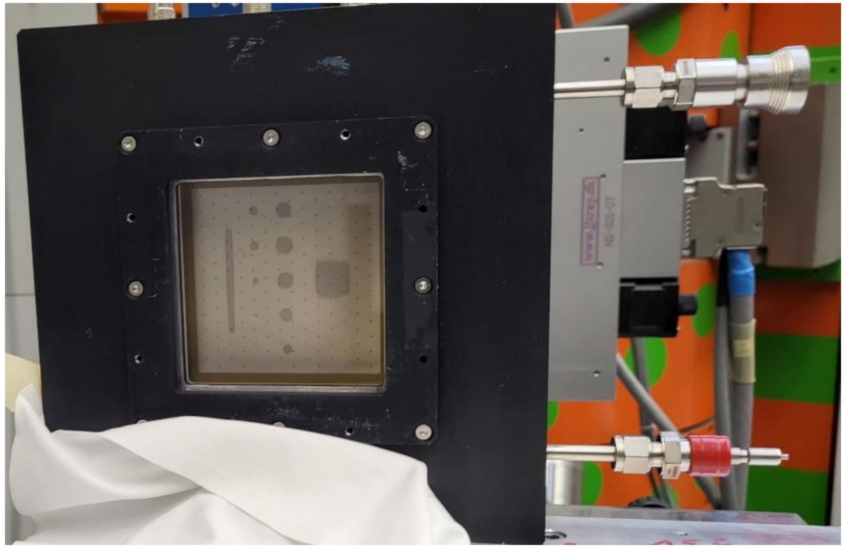
3.4 meV Neutron beam – 10 MHz – PSI Zurich – 09/12/2023



Al cathode with $^{10}B_4C$ pattern deposition



E_{amp} = 25 kV/cm, E_{drift} = 22 kV/cm, **100 s**

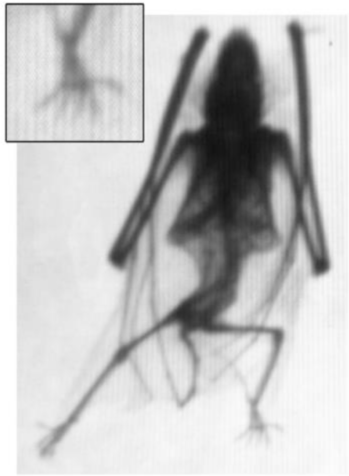


Neutron imager with visible cathode

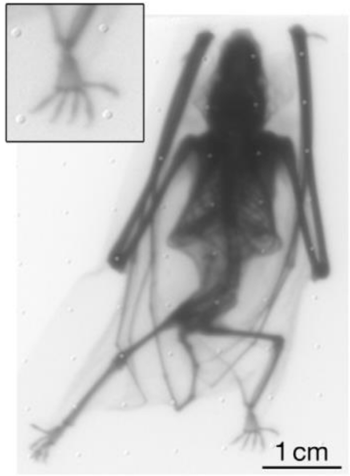
Optically read Micromegas: OMNIS/OptiMed-β

Electronic readout
GEM-based detector

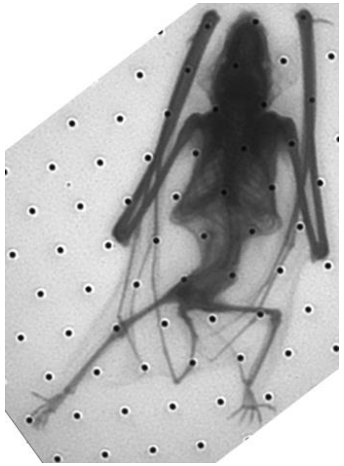
Optical readout
Triple-GEM detector



Optical readout
Glass Micromegas



Glass Micromegas, Optical
readout, deconvolution

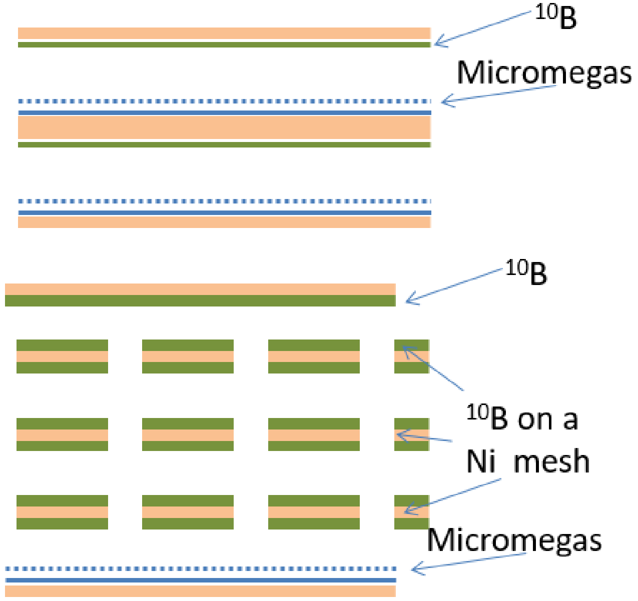


Increasing the efficiency: The multilayer concept

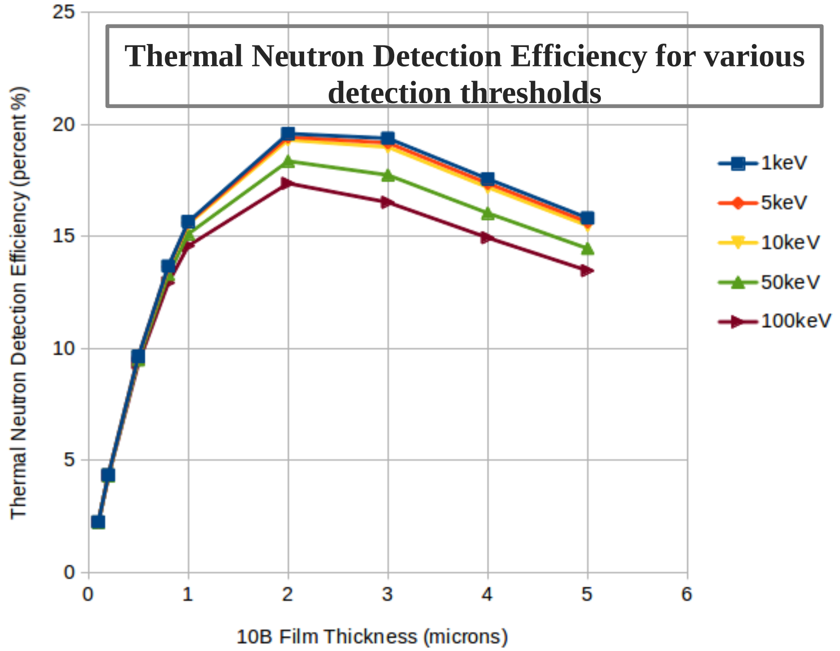
- A boron layer thicker than 1-2 µm is not efficient due to the absorption of the reaction products
- Maximum efficiency that can be achieved in this case is of the order of 5% @ 0.025 eV
- Efficiency increase with multilayers, either multi-micromegas or multiconverter
- Efficiency up to ~20%, in agreement with simulations

Tower of detector-convertor layers

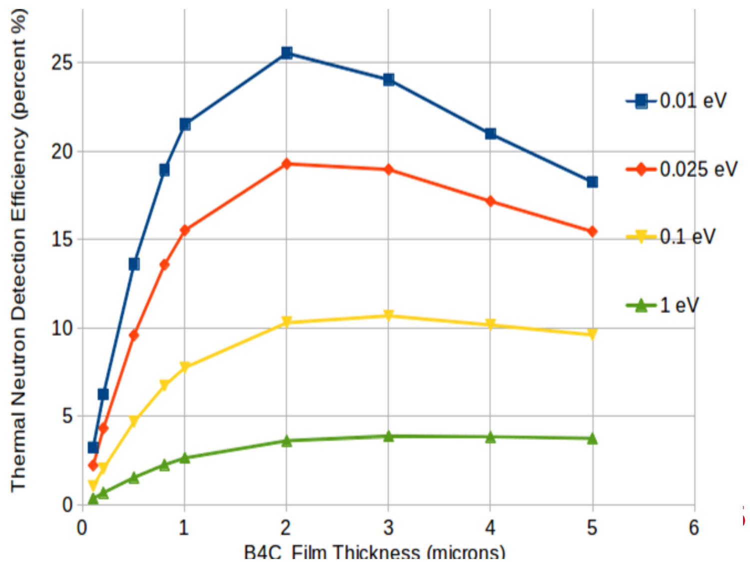
Tower of convertor layers



G. Tsiledakis et al.,JINST 12, 2017



Neutron Detection Efficiency for various neutron beam energies with detection threshold at 10 keV



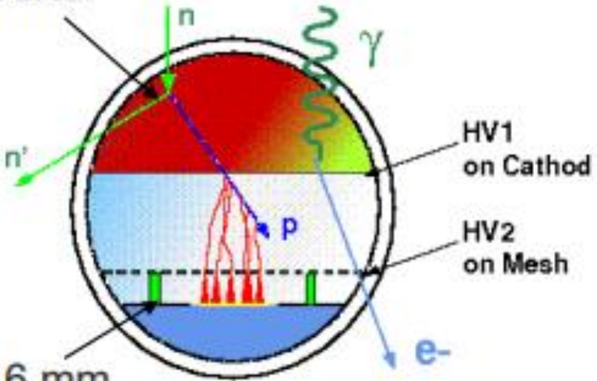
Involvement in the Work Package of the European ***FP7/NMI3*** *program (2012-2016)*
From 2016: Science & Innovation with Neutrons in Europe in 2020 → ***SINE2020***

Micromegas Concept for Laser MégaJoule & ICF Facilities

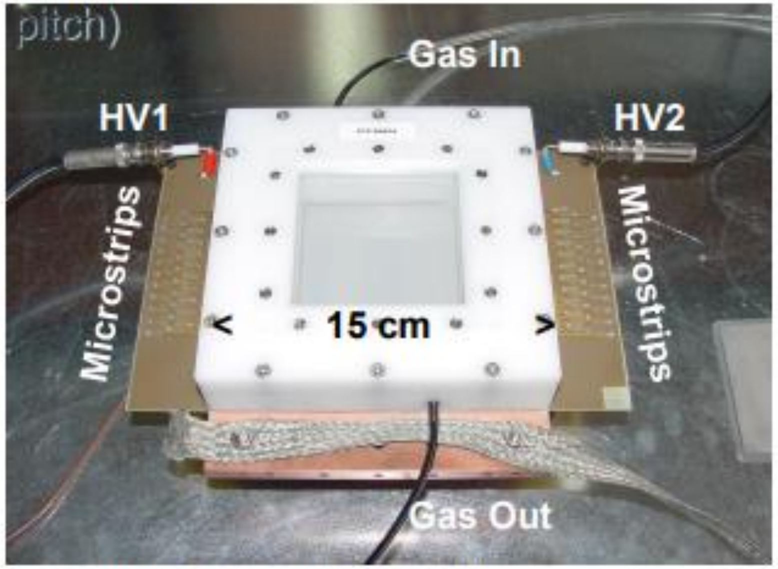
M. Houry et al., NIM,557(2006)648

The γ insensitivity of Micromégas applied to neutron spectroscopy on Inertial Confinement Fusion experiments

2mm CH_2 converter

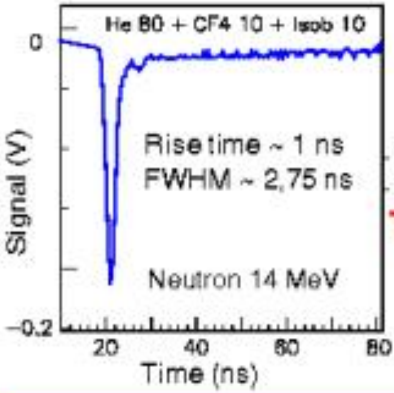


65 strips (1.6 mm pitch)



Ref: CEA/DIF/DCRE/SDE M. Houry

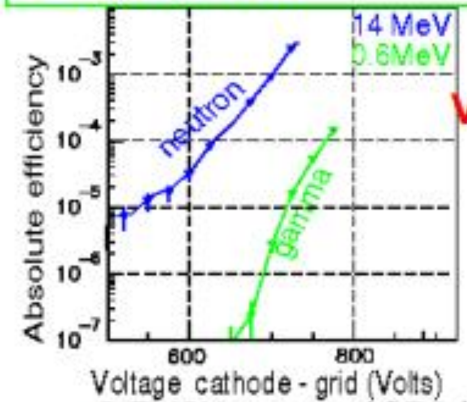
Neutron measurement by TOF in time windows of ~ 100 ns
-> Fast pulses



- Time of flight : δE/E~1%
- Low pile-up

Time response < 500 ps

Neutron measurement in a High γ Background
-> n/γ discrimination



Very good γ-rejection

Efficiency Ratio

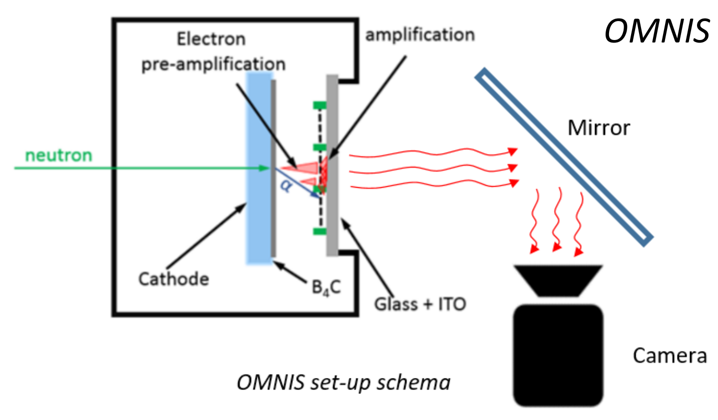
-> 10^3

DEMIN group (CEA/DIF/DCRE and DAPNIA)

Irfu Thomas.Papaevangelou@cea.fr

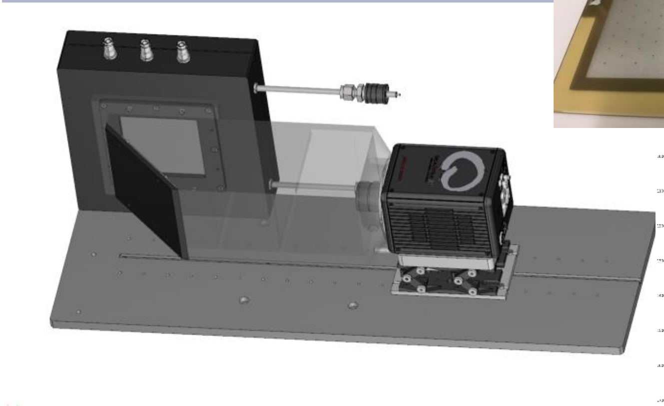
Micromeg

neutron imaging

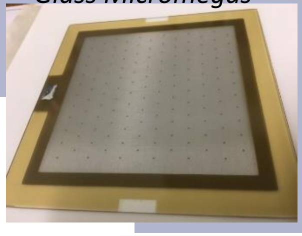


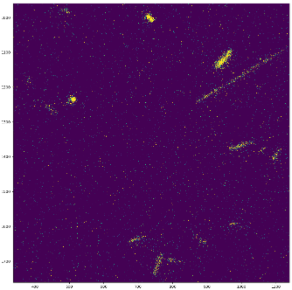
OMNIS set-up schema

OMNIS set-up scheme

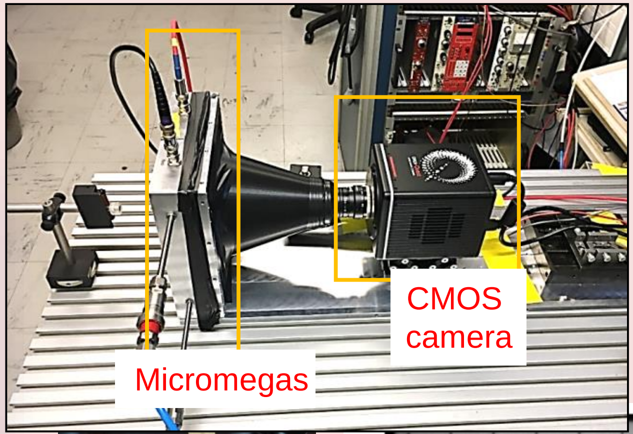


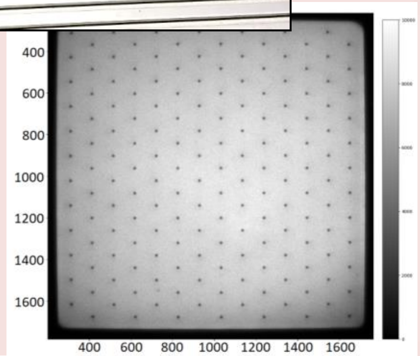
Glass Micromegas

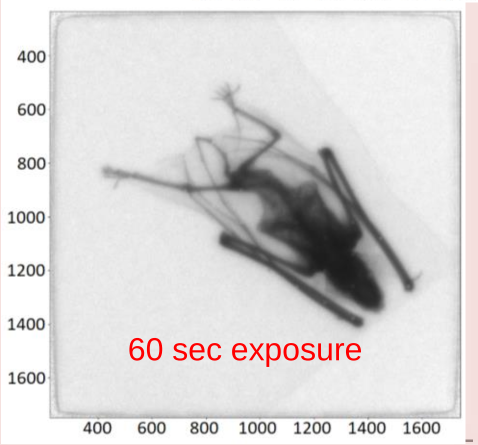




X-ray imaging

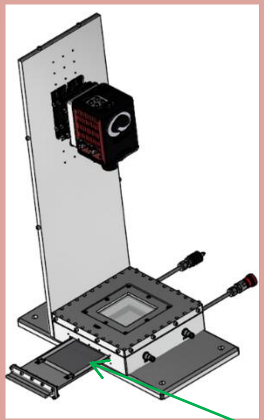


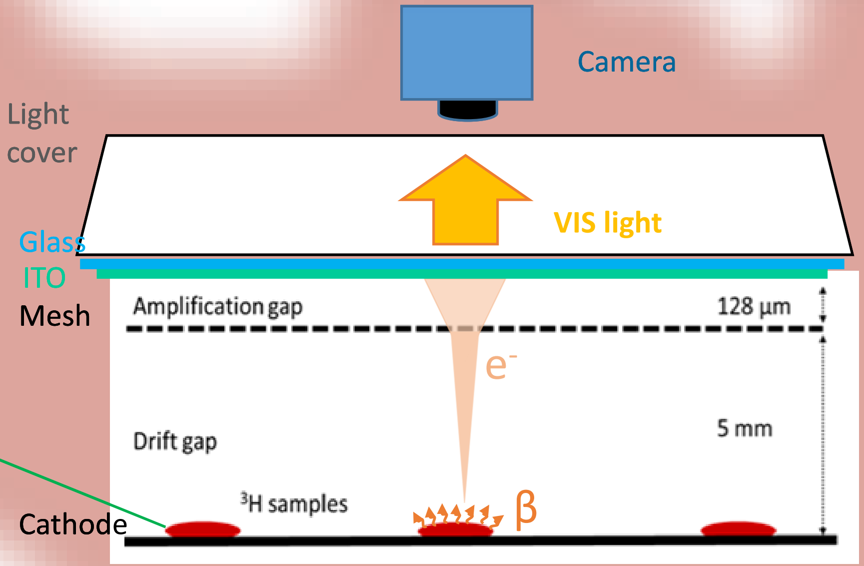




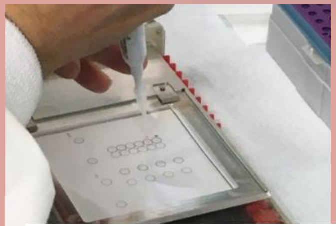
60 sec exposure

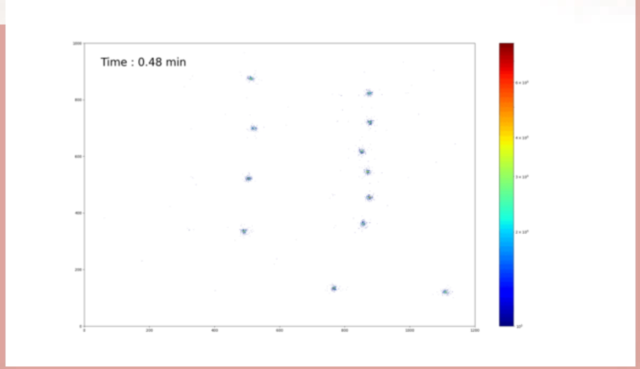
β imaging





OPTIMED-BETA set-up scheme



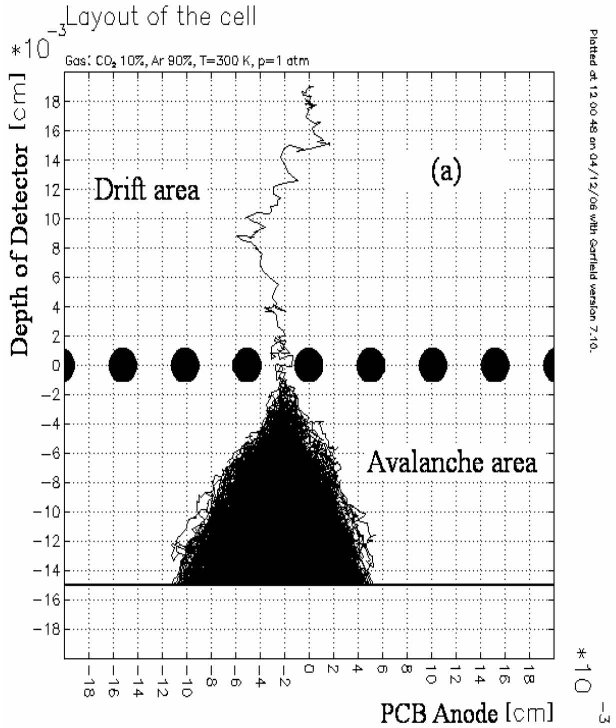


MICROMEGAS CONCEPT

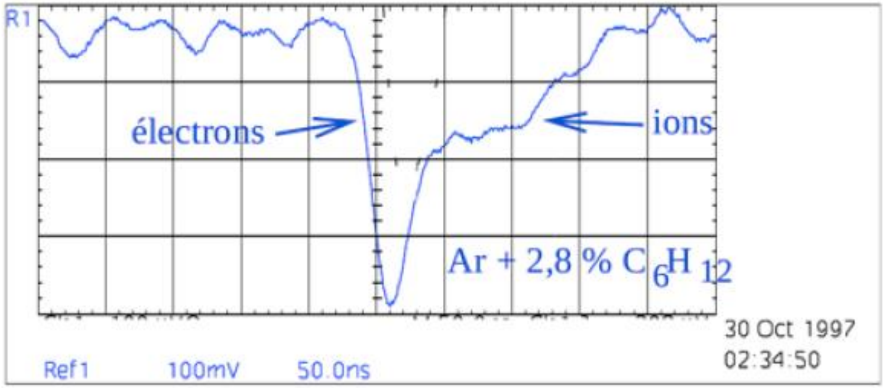
The multiplication takes place in high E field (> 20 kV/cm) between the anode and the mesh

- Thin amplification gap (64-128 µm) →
    - Small imperfections -> no gain variations
- High gain (up to 10^5 or more)
- Single stage of amplification
    - Fast signals (< 1 ns)
    - Fast ion collection
    - Short recovery time (~150 ns)

→ High-rate applications (>MHz)



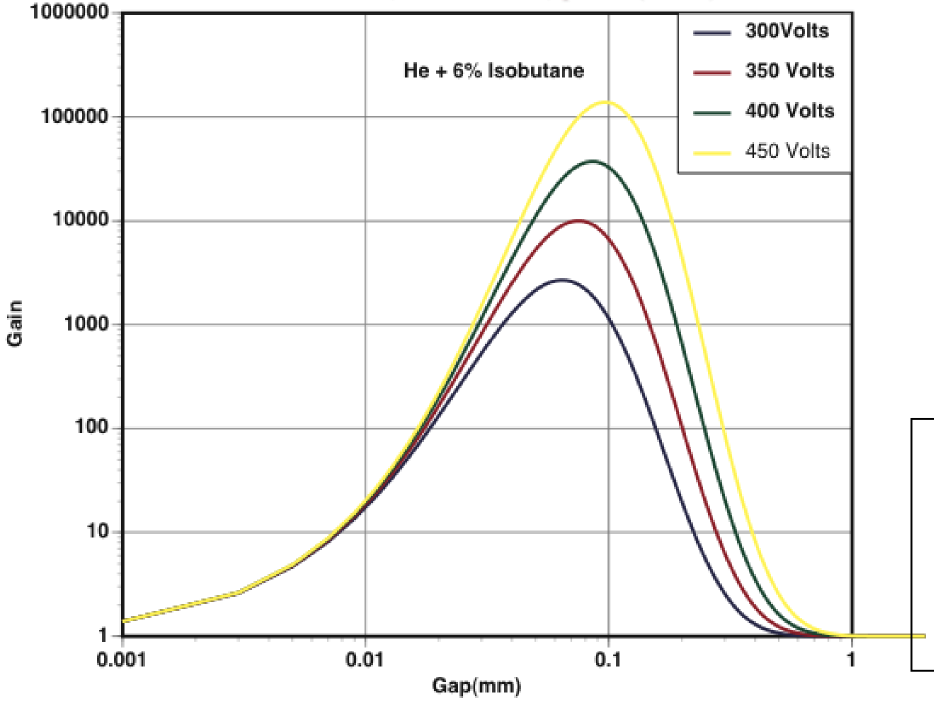
A GARFIELD simulation
of a Micromegas avalanche
(Lanzhou university)



The virtue of the small gap

Micromegas is a proportional counter!

Ref: Y. Giomataris, NIM A419, p239 (1998)



Parallel plate detector gain: $G = e^{a d}$

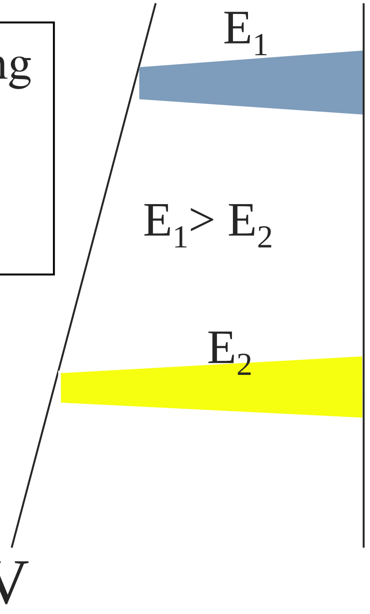
Townsend coefficient α: $\frac{\alpha}{p} = Ae^{-Bp/E} = Ae^{-Bpd/V}$

Gain variation: $\frac{\delta G}{G} = apd\left(1-\frac{Bpd}{V}\right) = apd\left(1-\frac{Bp}{E}\right)$

The gain variation is reaching

a minimum for :

d = V/Bp



Optimum gap : 30 - 100 microns

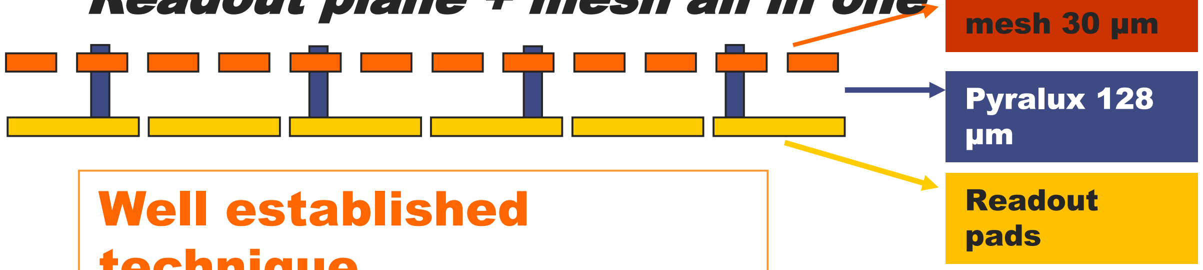
Stable gain – *non sensitive to flatness defects or temperature and pressure variation*

➔ good energy resolution

BULK MICROMEGAS TECHNOLOGY

Result of a CERN-Saclay collaboration (2004)

Readout plane + mesh all in one

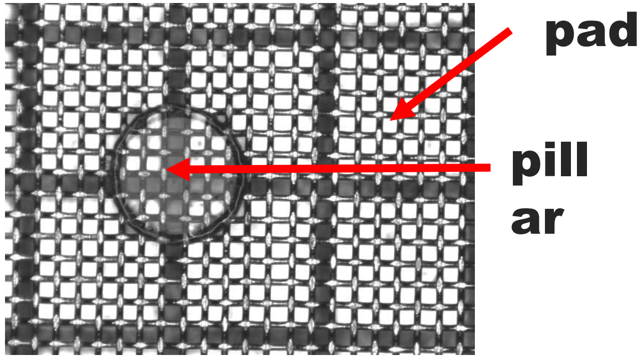


Woven Inox mesh 30 µm

Pyralux 128 µm

Readout pads

Well established technique



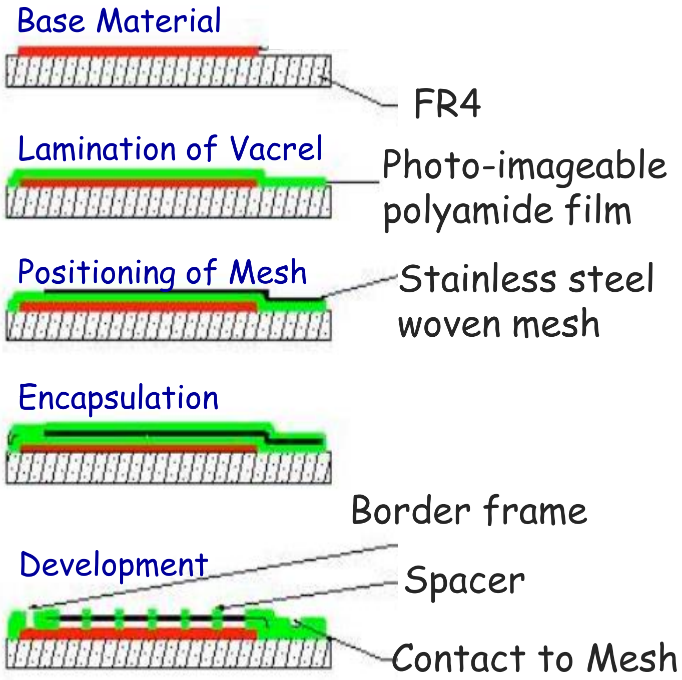
pad

pillar

I. Giomataris *et.al.*, NIM A560 (2006) 405

Motivations for using bulk Micromegas:

- The mesh is held everywhere
- Robustness (closed to dust)
- Can be segmented
- Fabrication time short and not expensive → industrialization
- Repairable
- **Large area detectors feasible and robust!**



Base Material

FR4

Lamination of Vacrel

Photo-imageable polyamide film

Positioning of Mesh

Stainless steel woven mesh

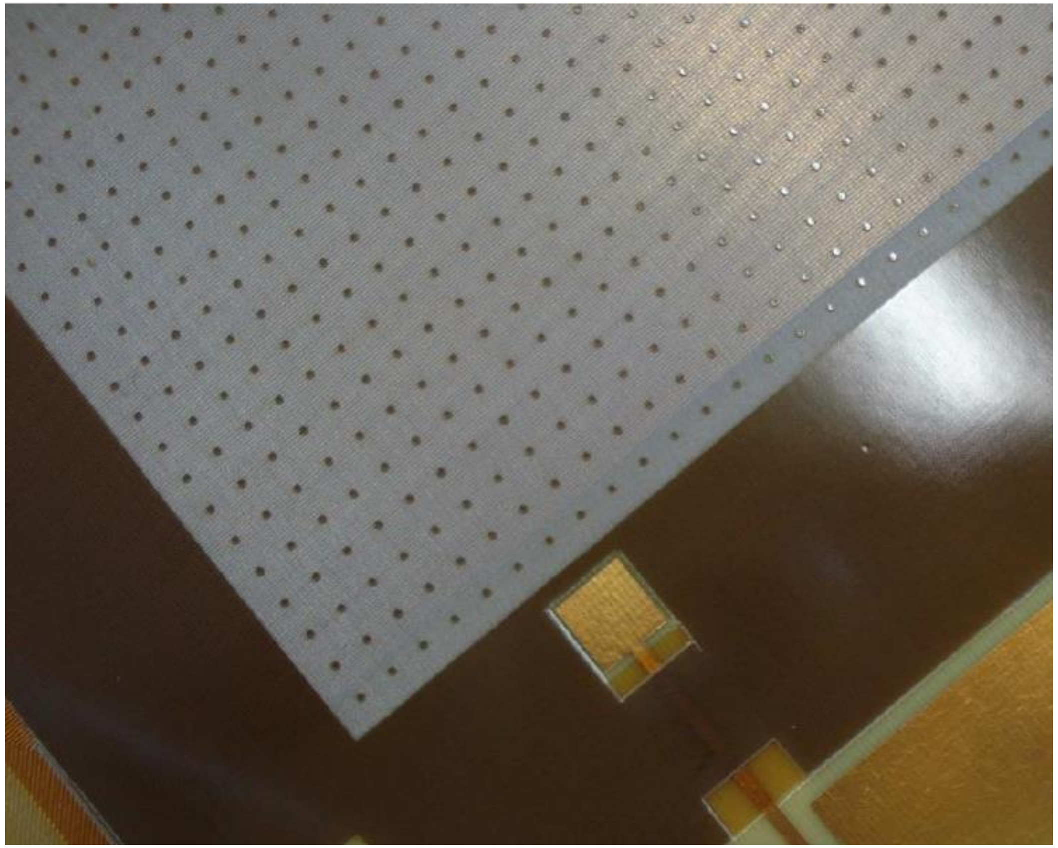
Encapsulation

Border frame

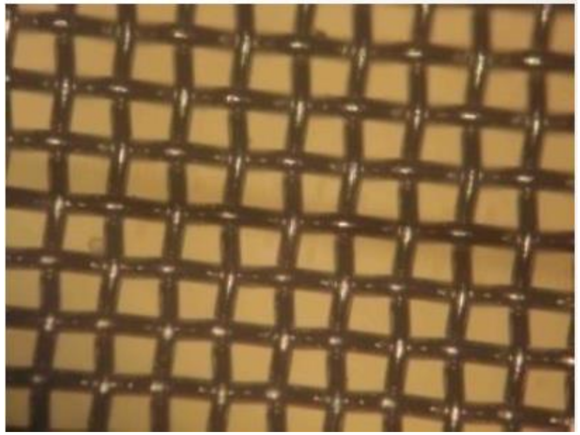
Development

Spacer

Contact to Mesh



Pillar distance on photo: 2.5 mm



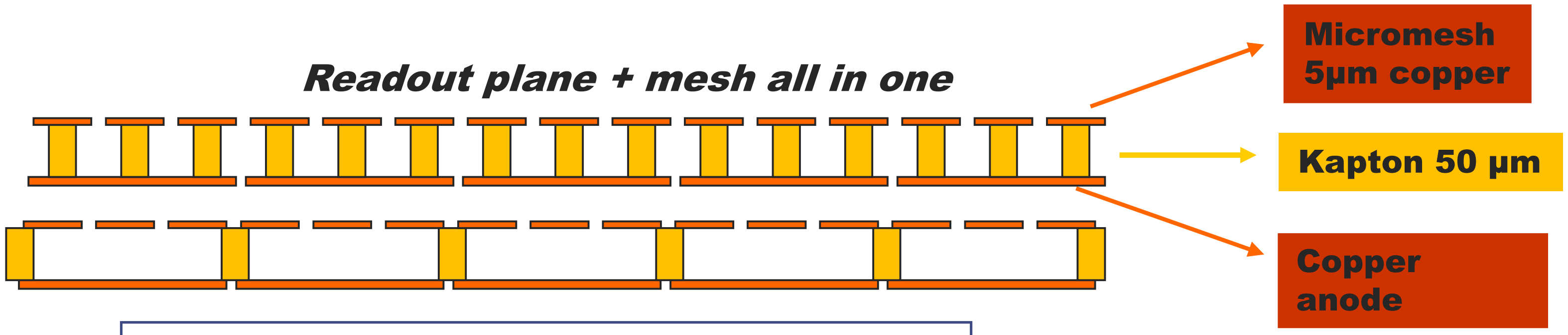
Standard configuration

- Pillars every 5 (or 10) mm
- Pillar diameter ≈350 μm
- Dead area ≈1.5 (0.4)%
- Amplification gap 128 μm
- Mesh: 325 lines/cm

Source: RD51 Electronics School, February 2014

MICROBULK MICROMEGAS TECHNOLOGY

- The pillars are constructed by chemical processing of a copper-kapton-copper foil, on which the mesh and the readout plane are attached



Readout plane + mesh all in one

Micromesh 5µm copper

Kapton 50 µm

Copper anode

S. Andriamonje et al., Journal of Instrumentation, 5, 2010

- ✓ Energy resolution (down to 10% FWHM @ 6 keV)
- ✓ Uniformity of amplification gap of few microns
- ✓ Low intrinsic background
- ✓ Low mass detector
- ✗ Higher capacity
- ✗ Fabrication process complicated
- ✗ Fragility / mesh can not be replaced