MIMACFASTn
fast neutron detection

FAST NEUTRON SPECTROSCOPY WITH MIMAC-FASTn : A mobile and directional fast neutron spectrometer 10 keV up to more than 200 MeV

80 years of building new worlds through knowledge

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(Université Grenoble-Alpes -CNRS/IN2P3)

CONTEXT OF MIMAC-FASTn : a valorisation project

Root of the project : MIMAC

Instrumentation dedicated to directional dark matter detection

Valorisation in a fast neutron spectrometer

1 Collaboration with IRSN/LMDN

Laboratory of Neutron Metrology and Dosimetry

Since 2010

2 Fundings by :

Enigmass Labex,
« Prematuration » of CNRS,
SATT/LINKSIUM (« maturation »)

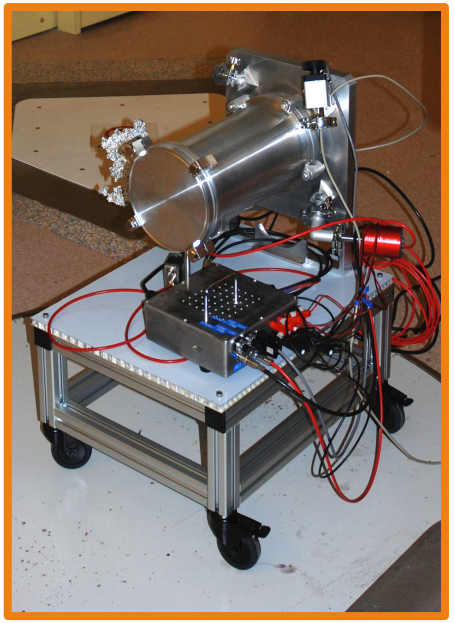
Since September 2014

Specificity of MIMAC-FASTn

NOT JUST NEUTRON COUNTING !

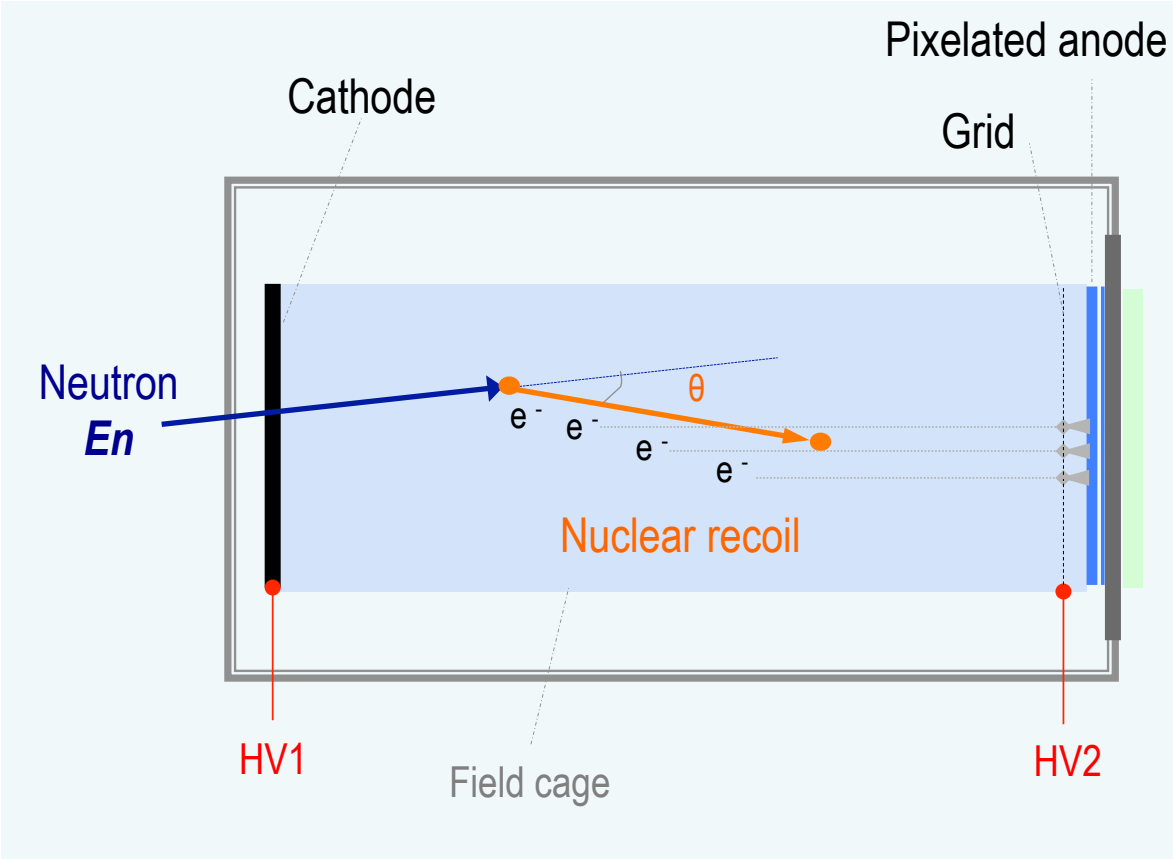
A 3D DETECTION

NO MODERATION
no ^{3}He or ^{6}Li

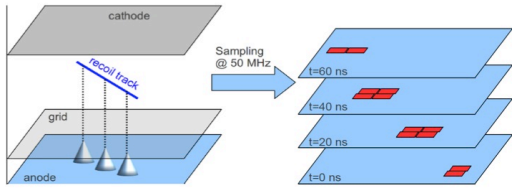


ADJUSTABLE RANGE :
[10 keV ; 200 MeV]

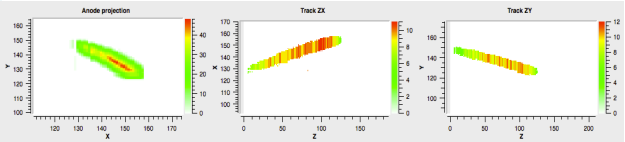
MIMAC-FASTn operation principle



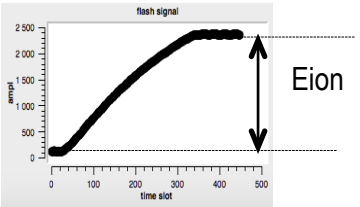
25 ns sampling :



3D recoil track → θ



Energy deposited in ionization :



From **θ**, **E_{ion}**, and the **IQF**,

*we get the neutron energy **En***

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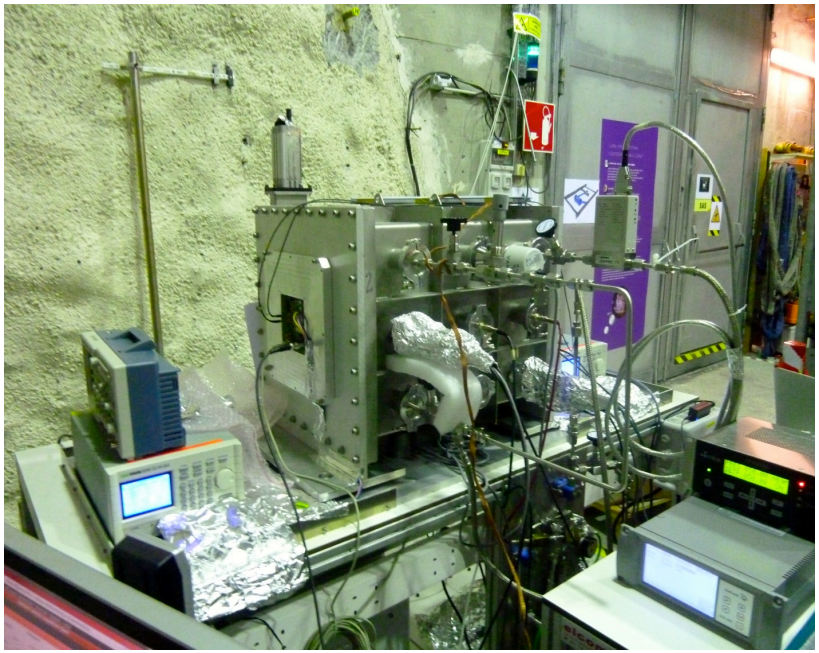
Valorisation of MIMAC-FASTn

MIMAC (Modane)



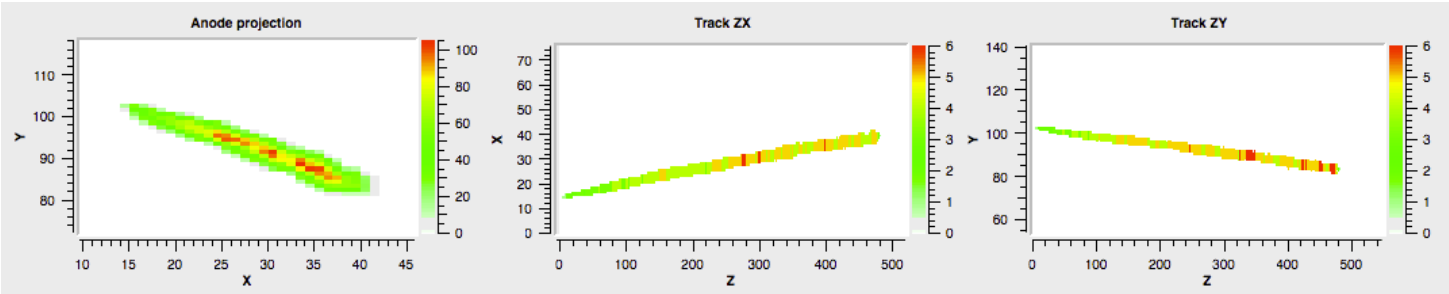
MIMAC-FASTn

^{4}He nuclear recoil / electron discrimination

A ^{4}He nuclear recoil track

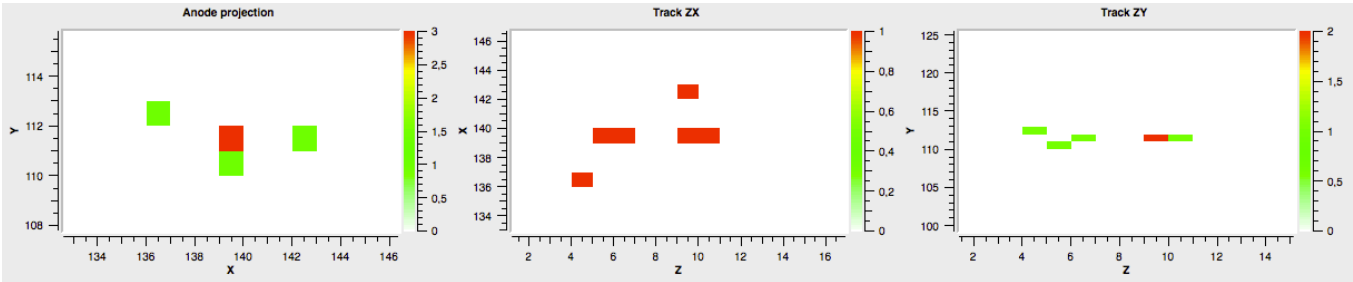
2.9 MeV kinetic

Measurements at CERF facility
(CERN high energy Reference Field)



A muon track

90 keV



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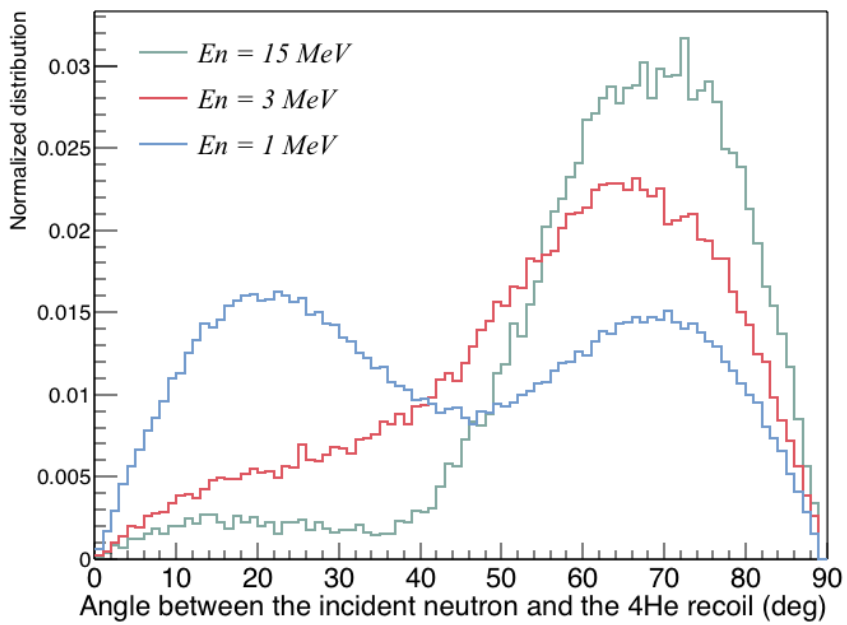
Specificity for high neutron energies, above 5 MeV

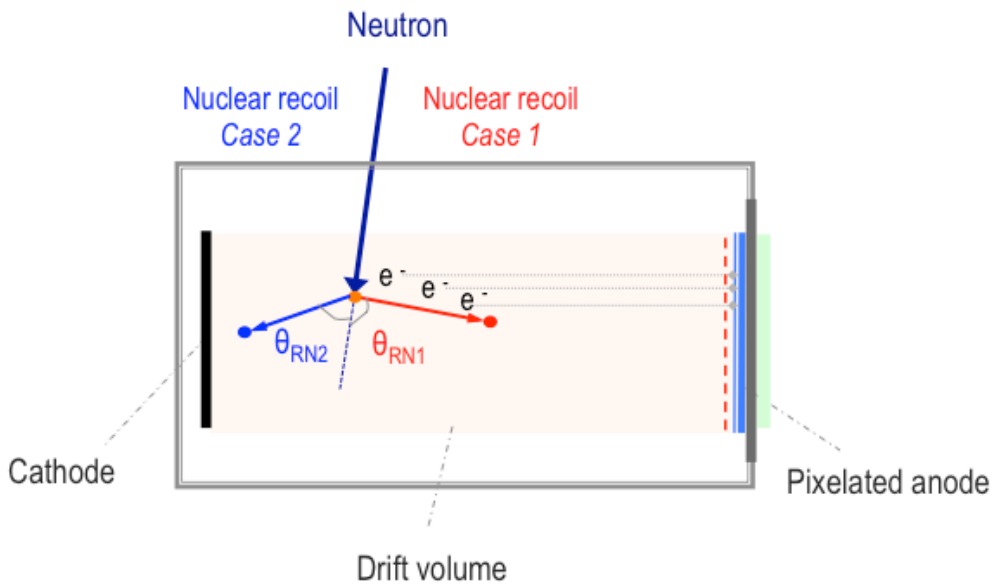
GEANT4 simulation

Angular distributions of ^{4}He recoils, resulting from elastic diffusions with neutrons :



Read-out strategy patented for high energy neutron spectroscopy

Measurement configuration above 5 MeV :
perpendicular to the detector axis



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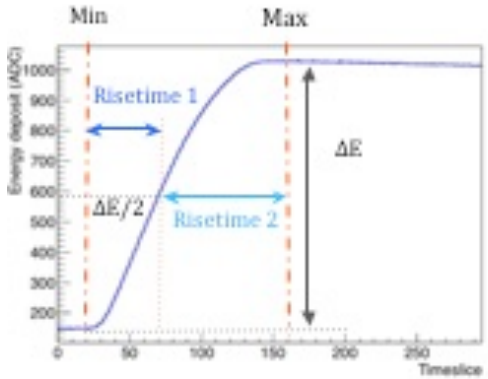
Direction of ^{4}He recoil tracks : head-tail signature

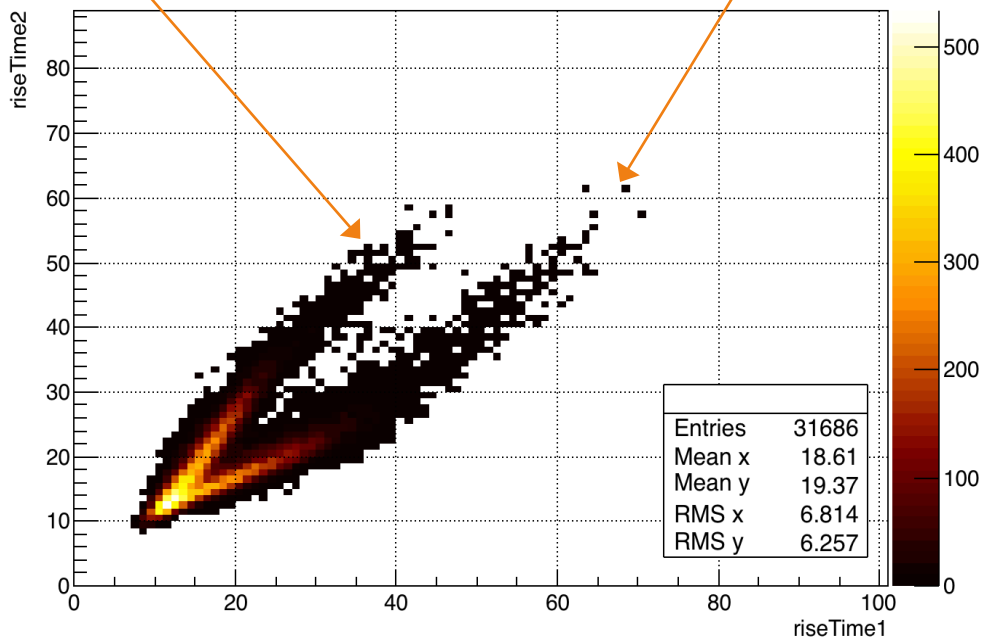
Detector perpendicular to the beam direction

1 Cathode direction

2 Anode direction

Analysis from the charge deposit profile on the grid :





The track direction is essential for the definition of the interaction point

IRSN /AMANDE (Cadarache)

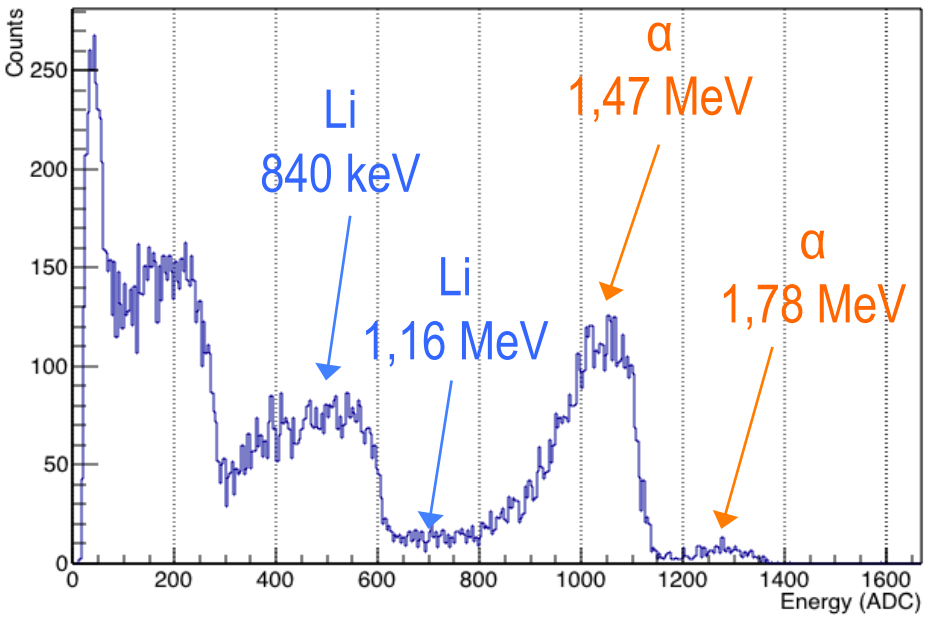
^{3}H(p(3357 keV),n)

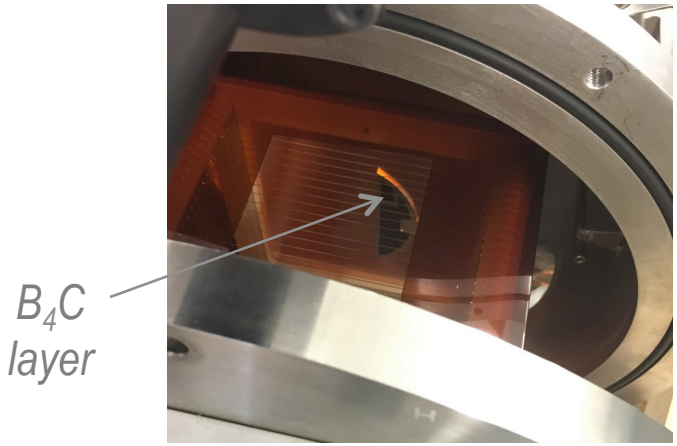
Monoenergetic neutrons of 2.5 MeV

MIMACFAST n fast neutron detection

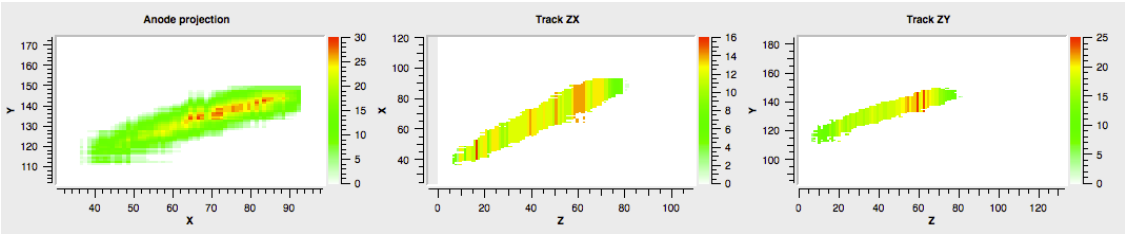
Energy calibration of the Flash-ADC

Detection of α and ^{7}Li, resulting from thermal neutron capture on a **B_4C layer**

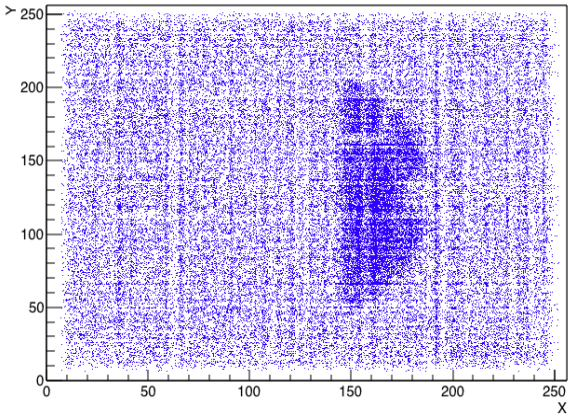




Alpha track



Anode projection : track start



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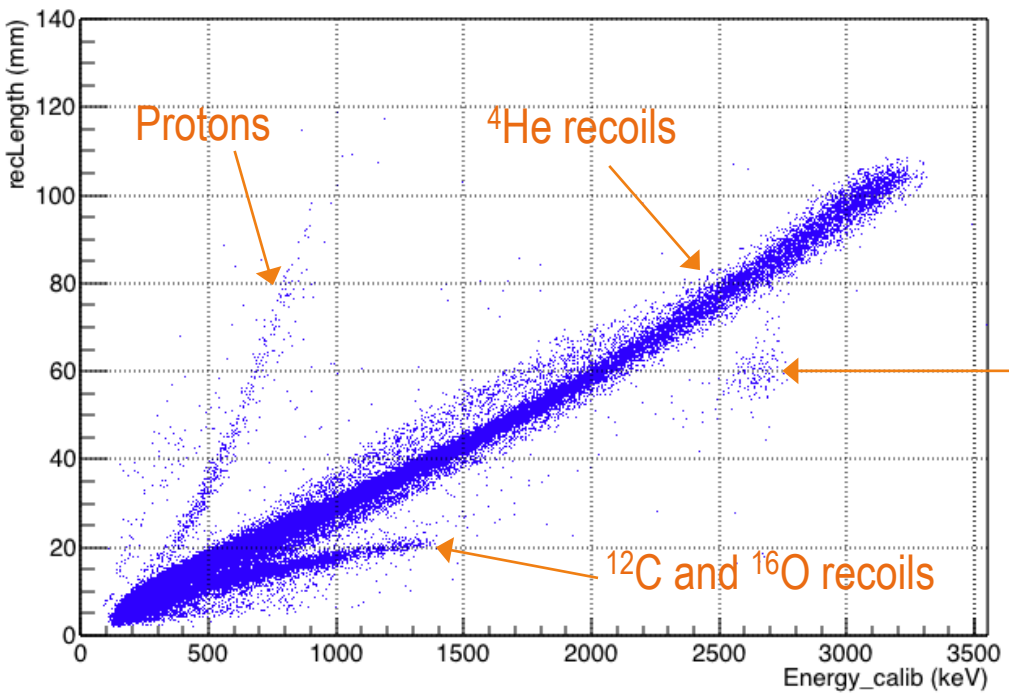
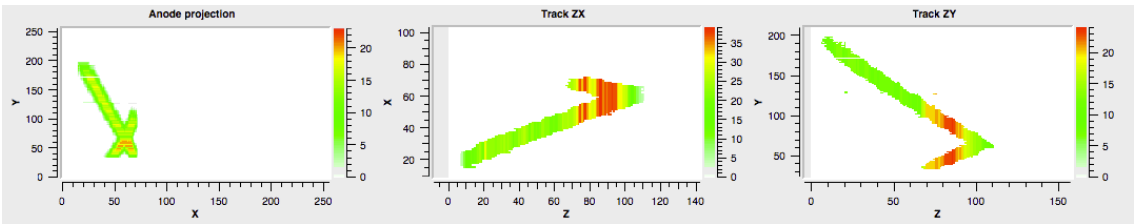
Selection of ^{4}He nuclear recoils : D(d(1.8 MeV),n)

Discrimination from protons, ^{12}C, ^{16}O, and (n,α) reactions



700 mbar He/CO_2 (5%)

^{16}O(n,α)^{13}C



IRSN /AMANDE (Cadarache)

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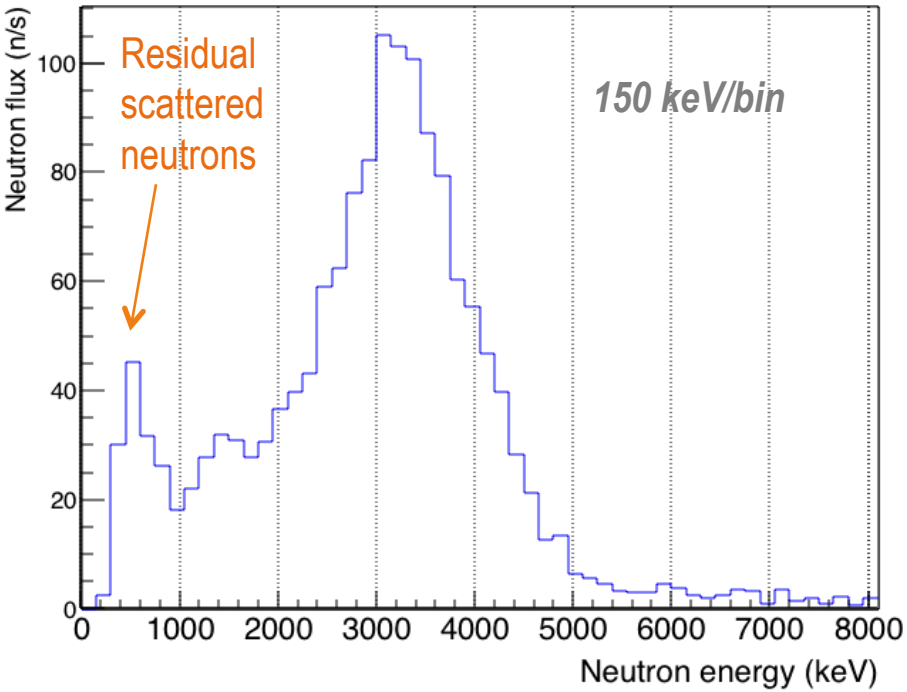
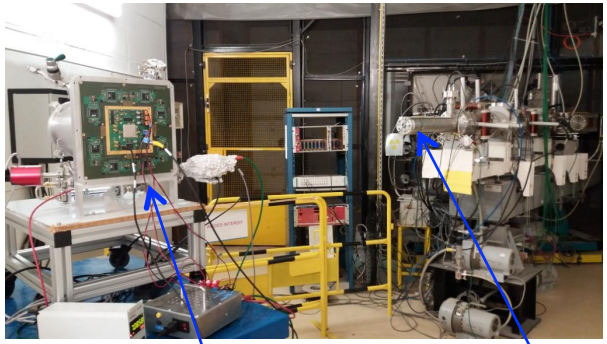
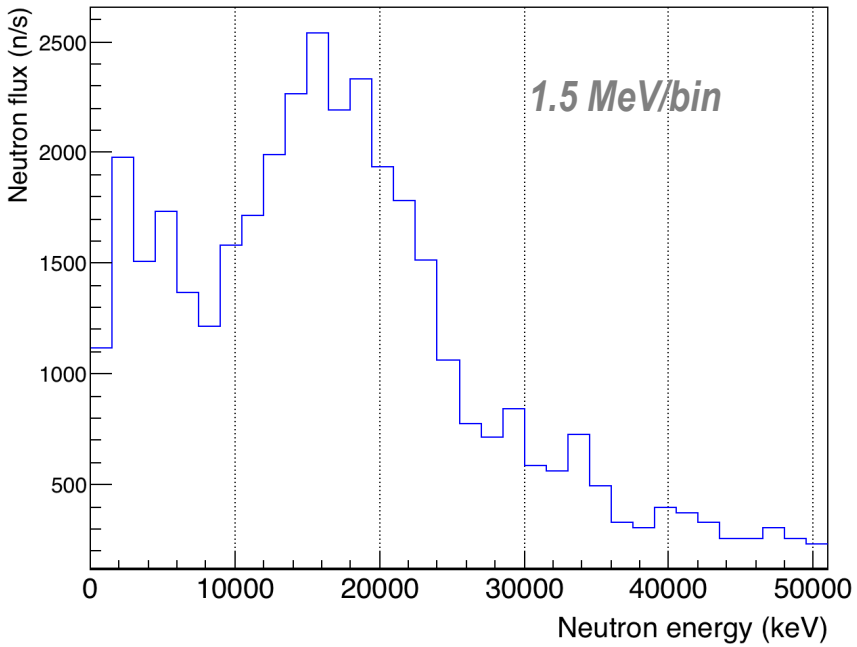
Monoenergetic measurement with neutrons of 3.1 MeV and 15 MeV on GENEPI (LPSC)

D(d(220 keV),n)
Parallel configuration





T(d(220 keV),n)
Perpendicular configuration



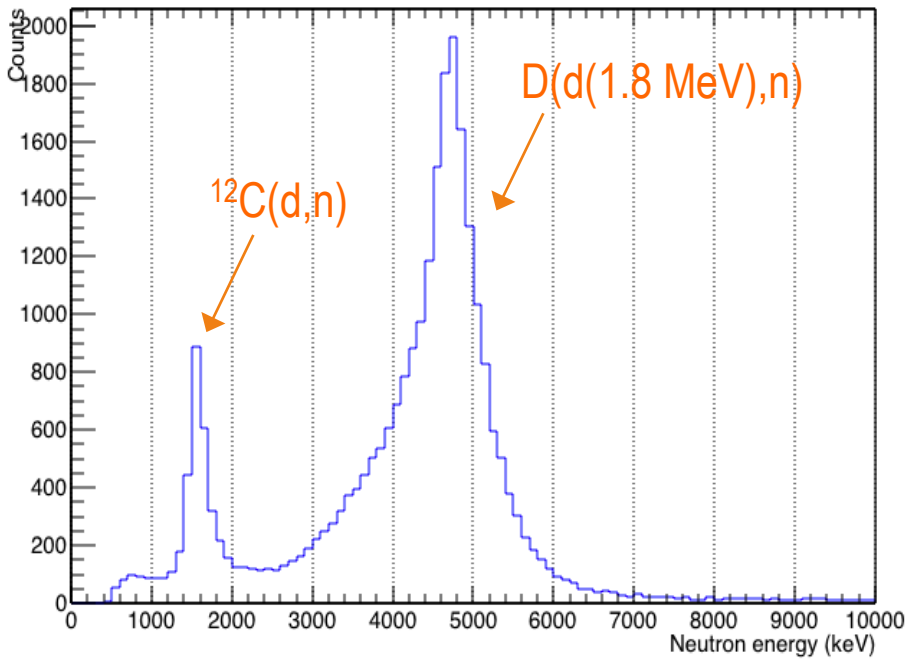
700 mbar He/CO_2 (5%)

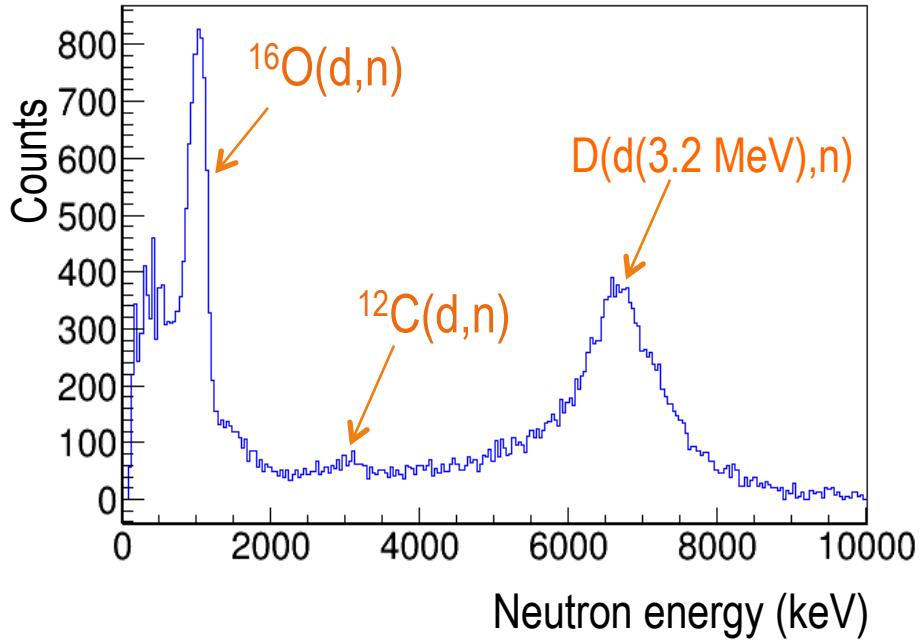
Paper to be submitted

Monoenergetic measurements : detection of target pollution

D(d(1.8 MeV,n) : neutrons of 5 MeV

D(d(3.2 MeV,n) : neutrons of 6.5 MeV





NPL /(UK)

IRSN / AMANDE (Cadarache)

700 mbar He/CO_2 (5%)

Paper to be submitted

MIMACFAST n fast neutron detection

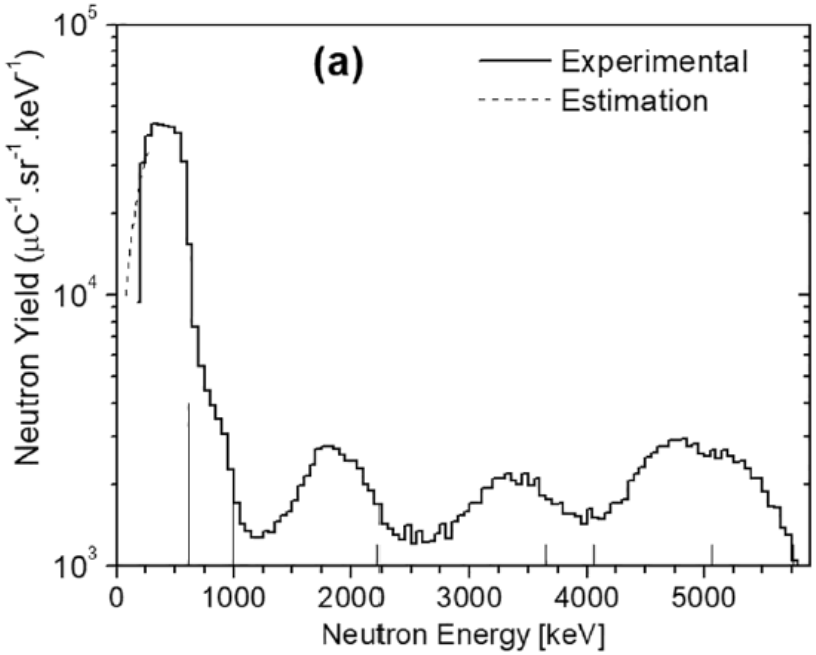
Polyenergetic measurement with 9Be(d(1.45 MeV),n)

Angular distribution

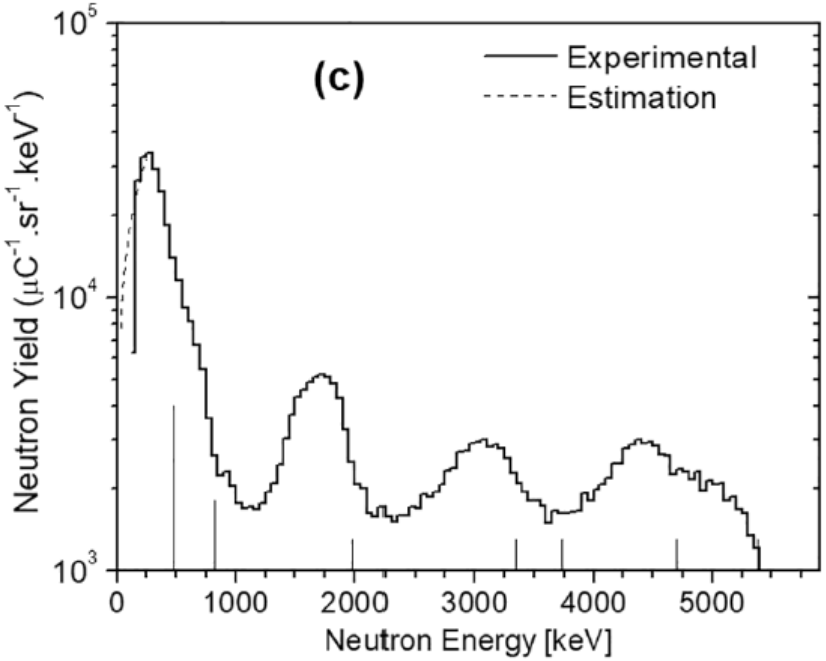
INFN LNL
(Legnaro - Italy)

700 mbar
He/CO_2 (5%)

Spectrum measured at **0 deg**



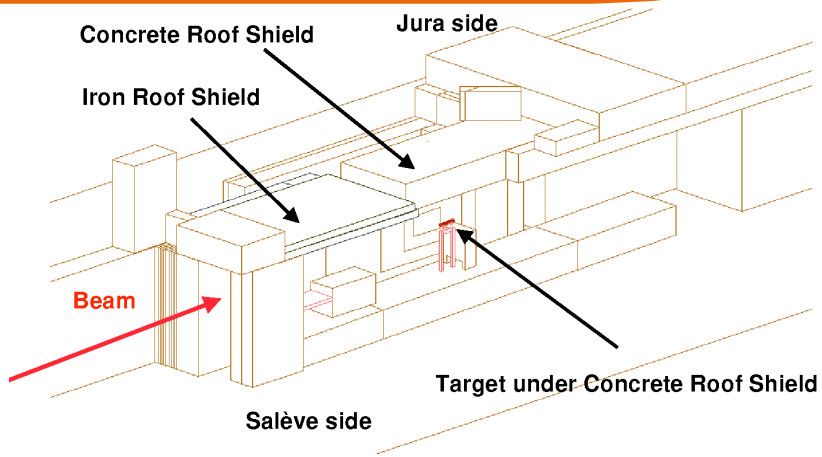
Spectrum measured at **60 deg**



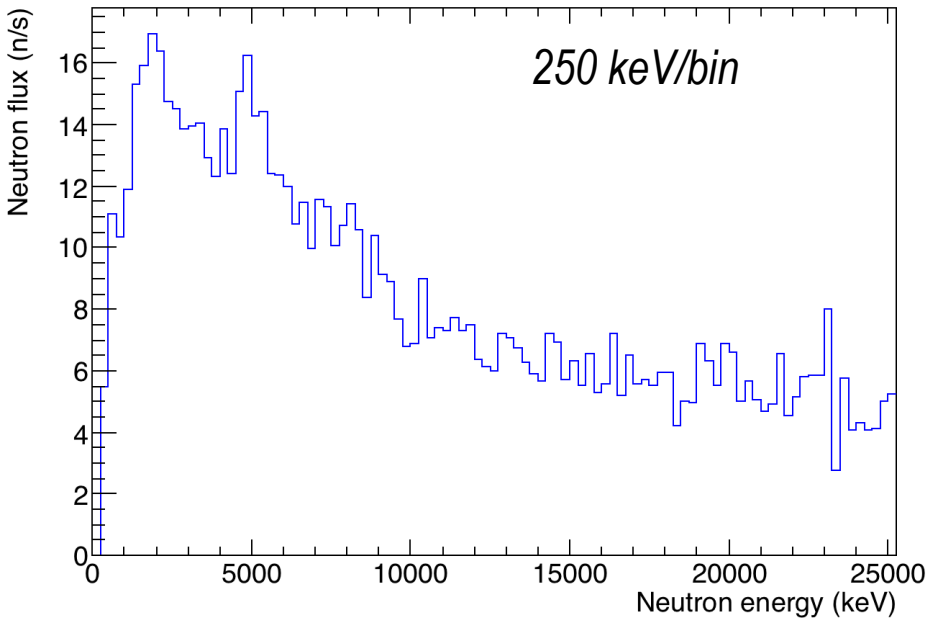
M.E. Capoulat, N.Sauzet *et al.*
« Neutron spectrometry of the $^{9}Be(d(1.45\ MeV),n)^{10}B$ reaction for accelerator-based BNCT »
NIM B, vol. 445, pp. 57-62, 2019

Exploration up to 200 MeV : measurement at CERF

Perpendicular configuration



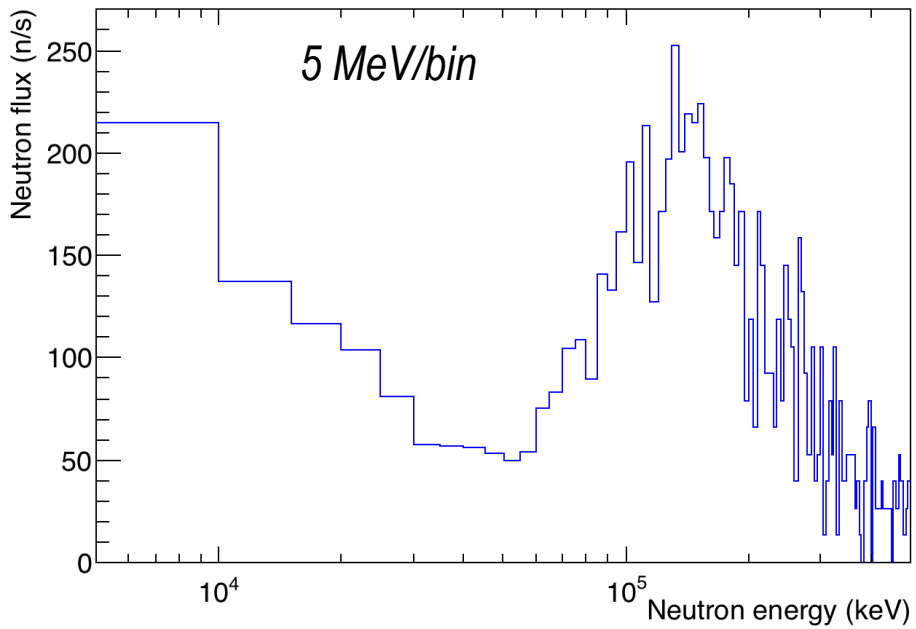
Below 25 MeV :



1.2 bars
He/CO_2 (5%)

Preliminary results

Above 10 MeV :



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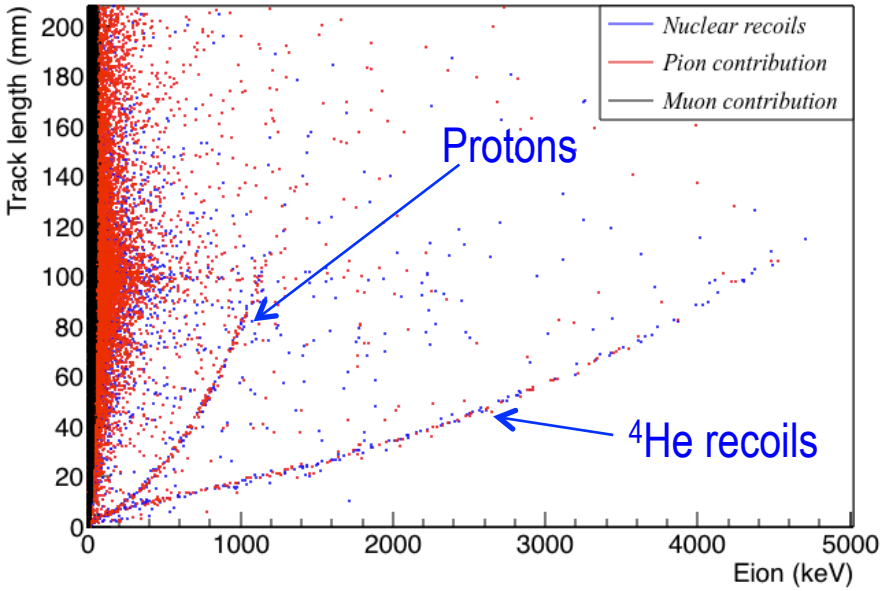
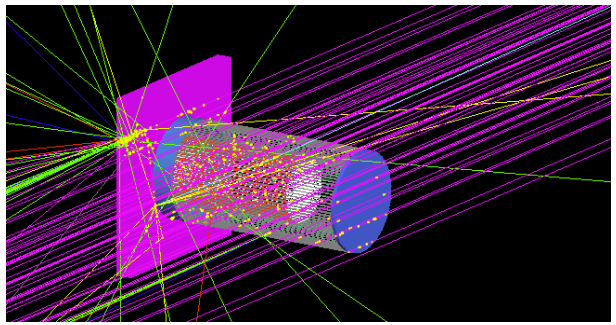
Exploration up to 200 MeV : measurement at CERF
Discrimination of muons and pions

1 GEANT4 simulation

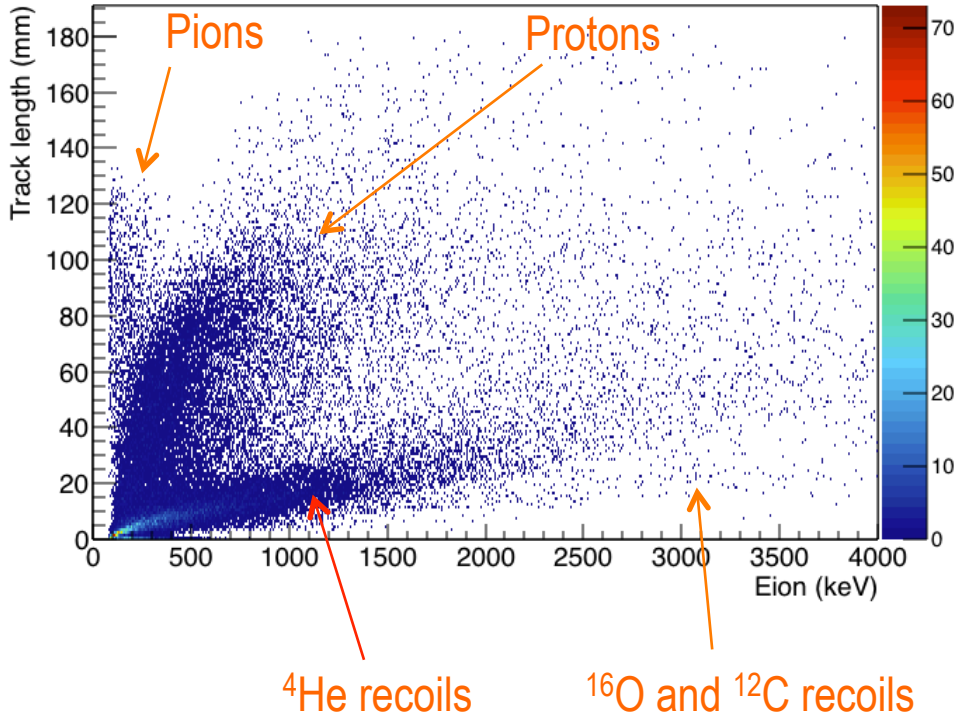
CERF facility (neutrons, muons, pions)





2 Measurement with Mimac-FastN

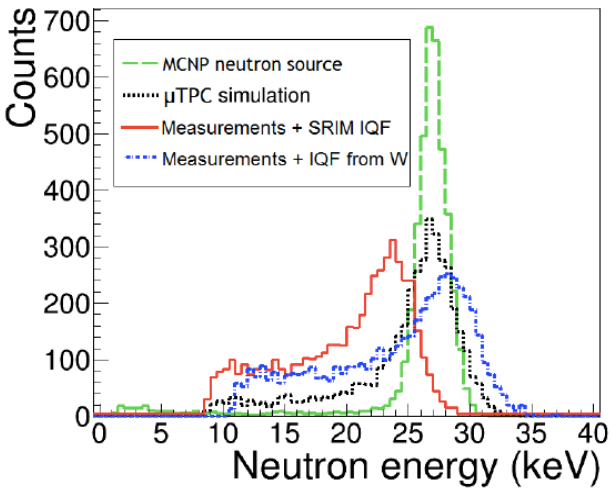
CERF facility : ^{63}Cu(p(120 GeV),n)

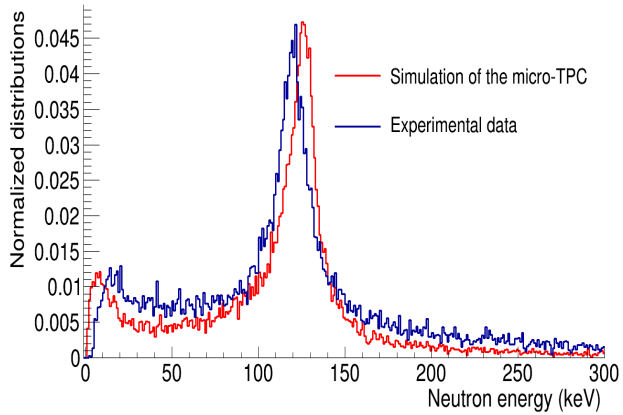


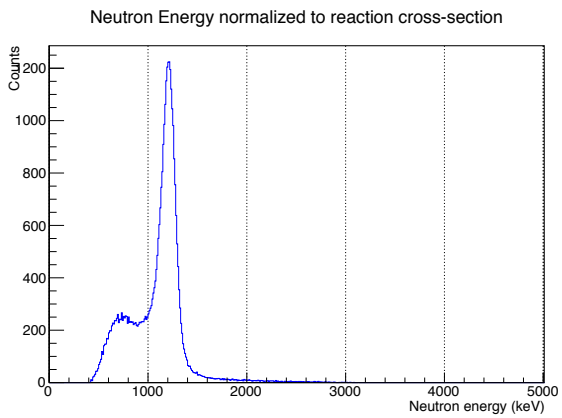
MIMACFASTn fast neutron detection

A large energy adjustable range

50% C_4H_{10} 50% CHF_3 30 mbar	60% C_4H_{10} 40% CHF_3 50 mbar	95% ^4He 5% CO_2 700 mbar
E_n=27 keV	***E_n=127 keV***	***E_n=1.2 MeV***







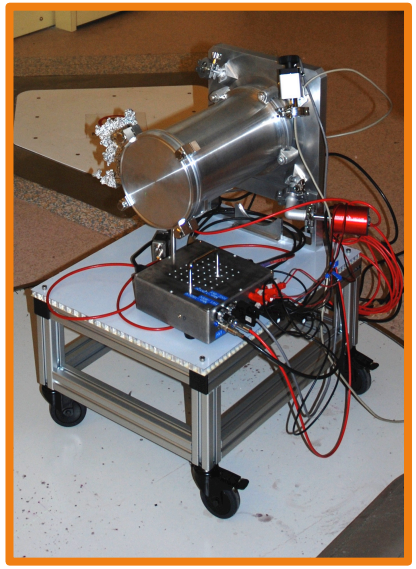
D. Maire *et al.*
« Neutron energy reconstruction and fluence determination at 27 keV with the LNE-IRSN-MIMAC µ-TPC recoil detector »
IEEE Transactions on Nuclear Science, 63(3) : 1934-1941, June 2016

D. Maire *et al.*
« First measurement of a 127 KeV neutron field with a µ-TPC spectrometer »
Nuclear Science, IEEE Transactions, 61(2014) 2090

Paper to be submitted

Conclusion

A NEW NEUTRON SPECTROMETER
WITH A LARGE ADJUSTABLE RANGE



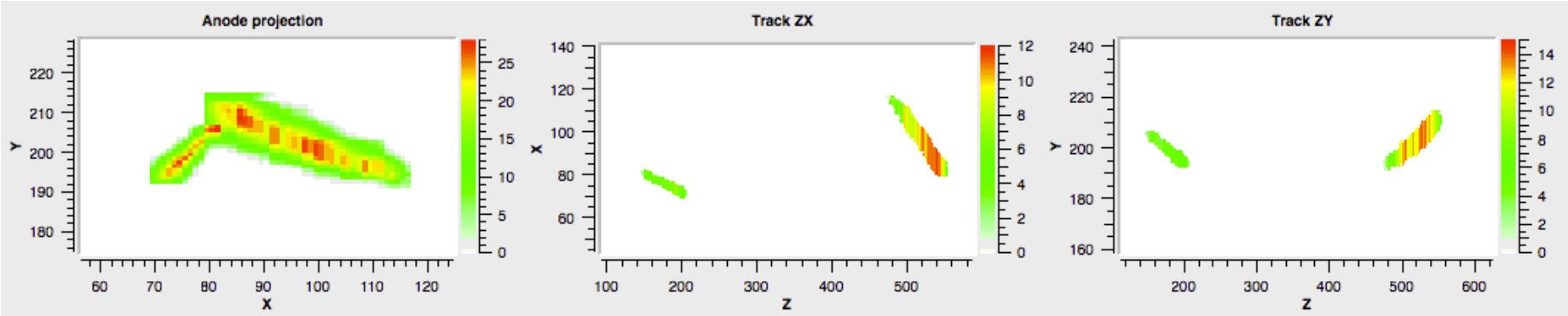
A MOBILE DEVICE,
WITH A COMPETITIVE ENERGY RESOLUTION

OPENING TO
NEW MEASUREMENTS AND APPLICATION FIELDS

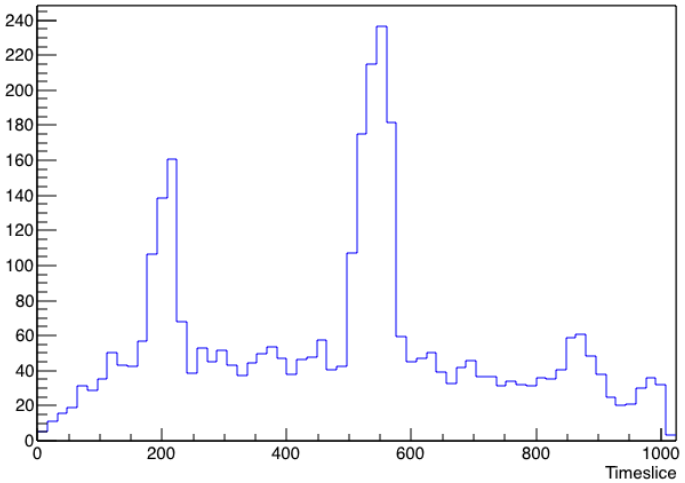
BACK-UP SLIDES

In high neutron flux, in a window of 25 microseconds

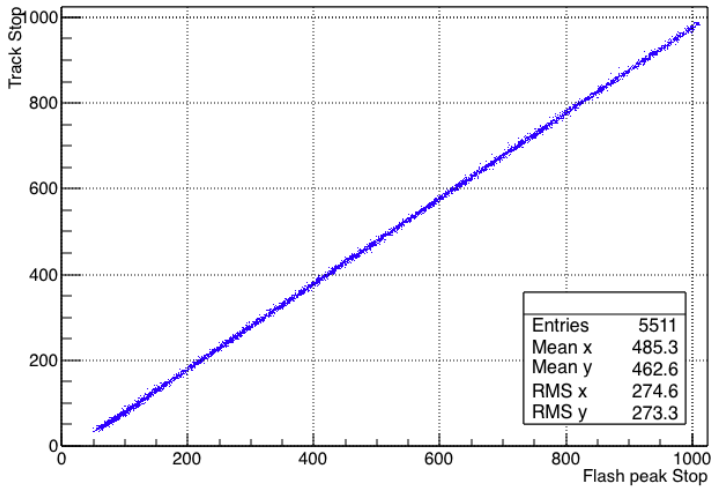
Multiple ^{4}He recoil tracks :



Flash profile derivative



Flash ADC – anode synchronization



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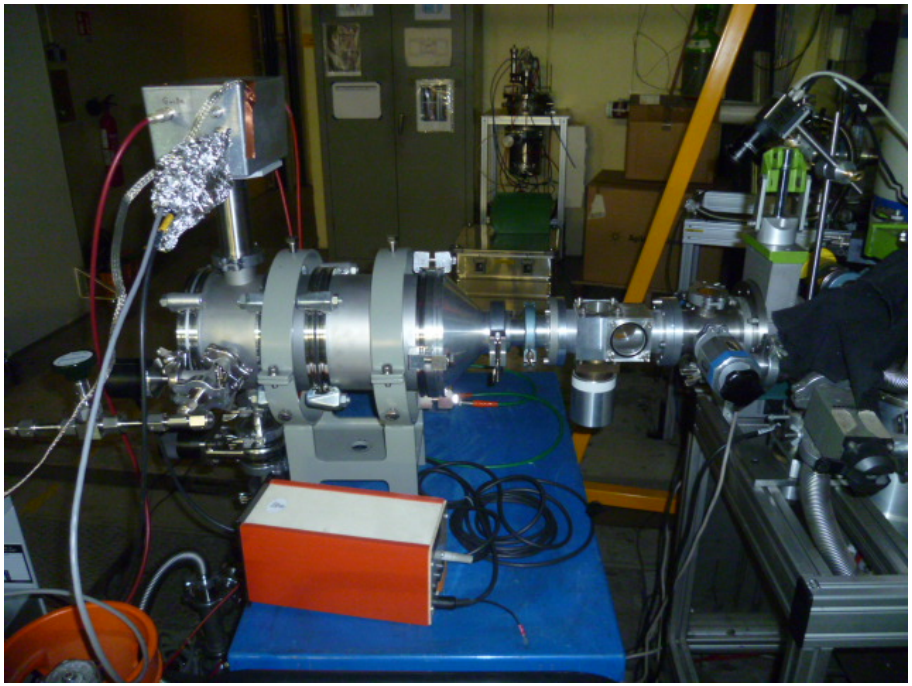
Ionization quenching factor measure of ^{4}He

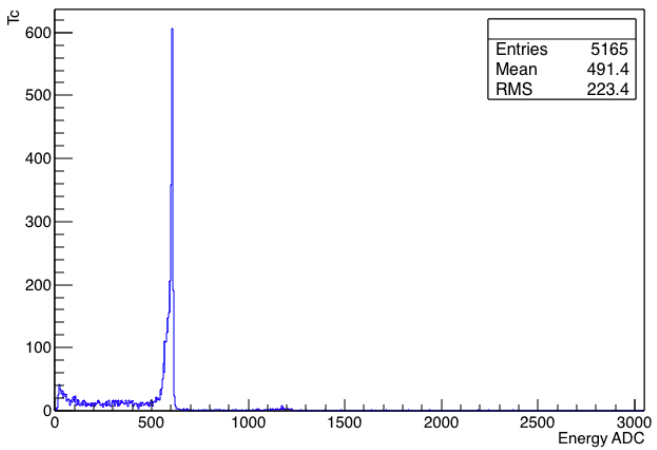
An IQF measure relative to protons



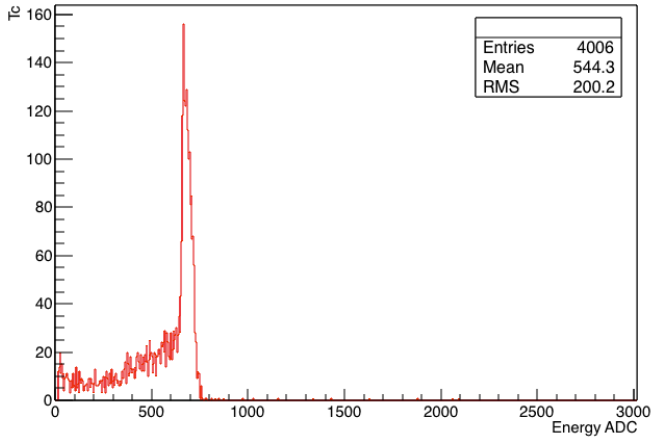
IPNL beam line coupled to a drift space of 25 cm and a 512 µm Micromegas through a 1 µm hole interface

Mixture of $^4He/CO_2$ 700 mbar

1 MeV kinetic alpha



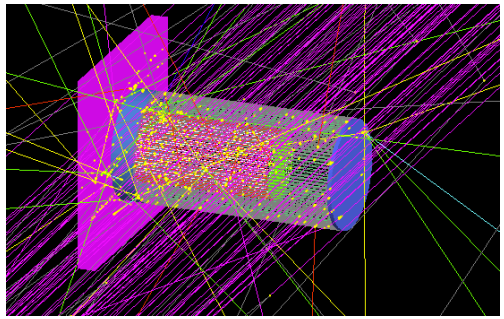
1 MeV kinetic proton



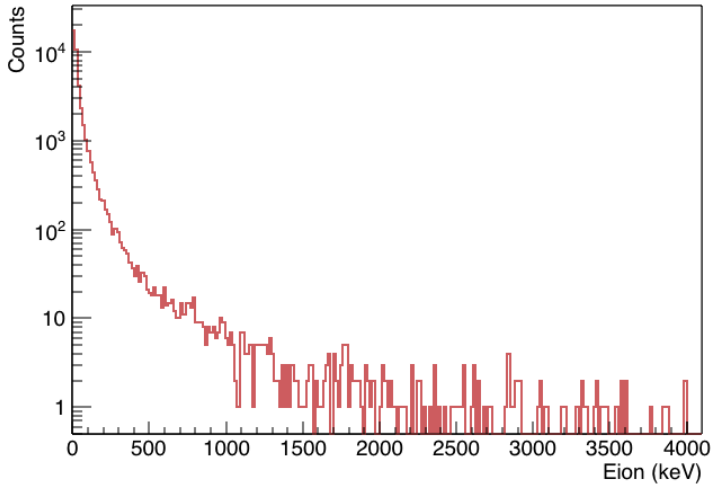
MIMACFASTn fast neutron detection

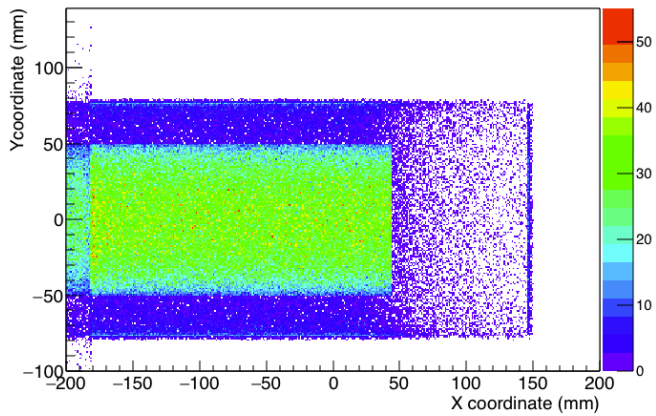
PIONS INTERACTIONS WITH MIMAC-FASTn

GEANT4 simulation

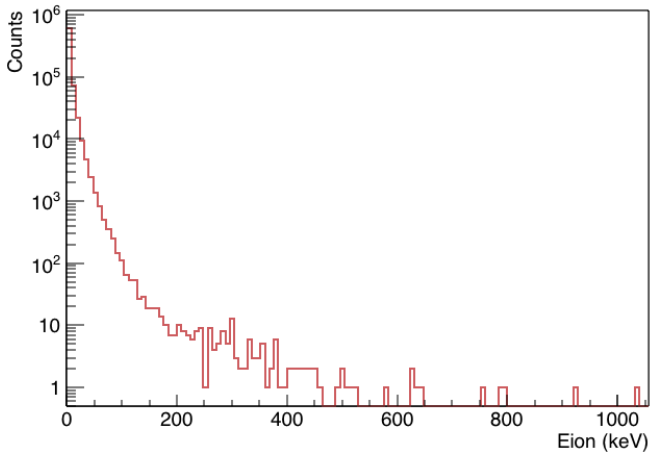


Energy deposited in ionization by 1.10^7 pions of 200 MeV, through protons and alpha particles :





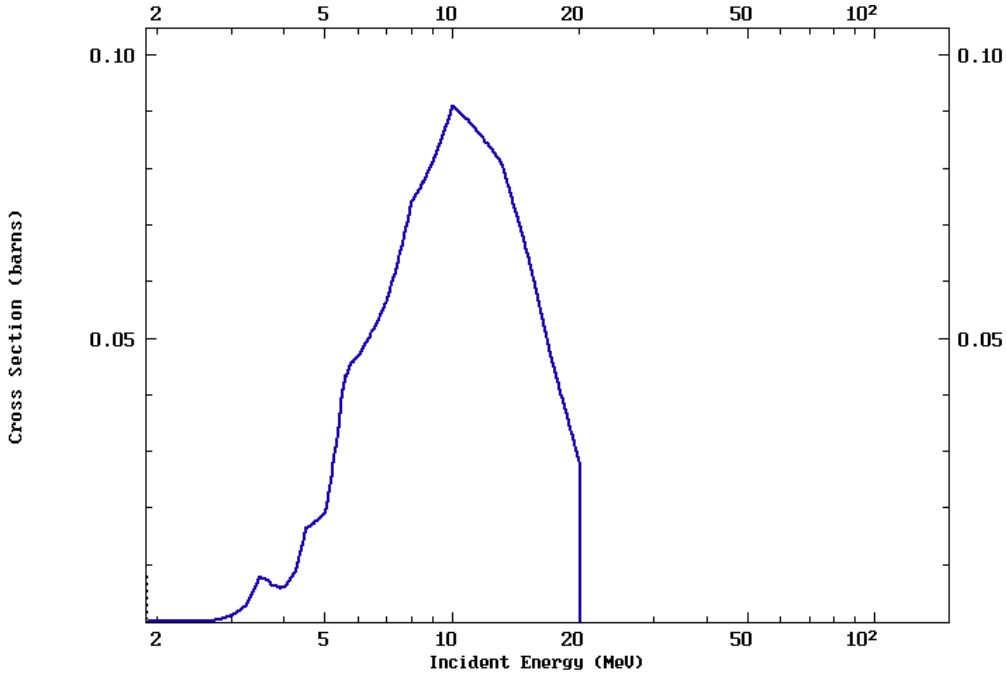
Energy deposited in ionization by 1.10^7 pions of 200 MeV, through electrons:



MIMACFASTn fast neutron detection

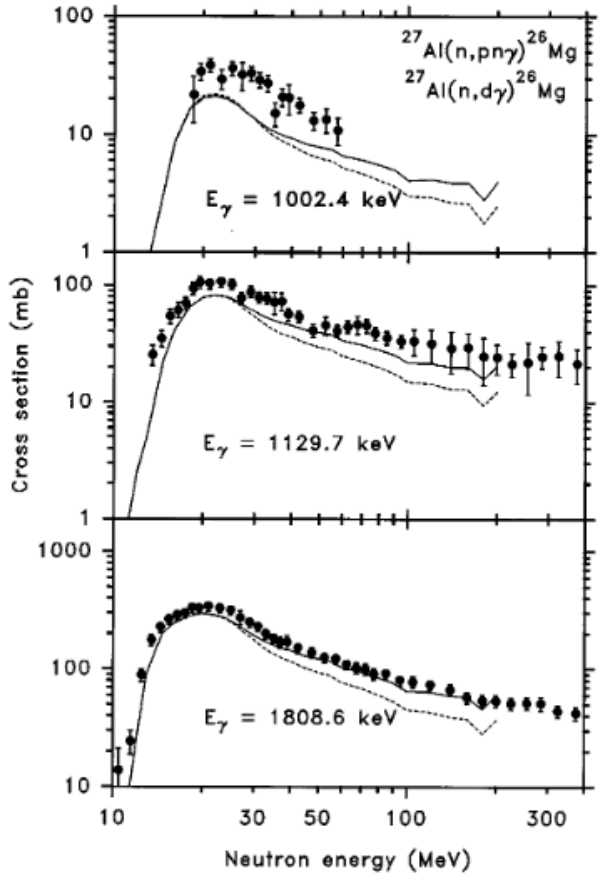
PROTONS ORIGIN AT CERF

Cross-section of $^{27}Al(n,p)$:



ENDF/B-VIII.0

Most probable inelastic reaction induced by neutrons of 70 MeV on ^{27}Al : $^{27}Al(n,pn\gamma)$



Pavlik *et al*. « $^{27}Al(n,x\gamma)$ reactions for neutron energies from 3 to 400 MeV », PhysRevC vol.57 , 1998

MIMACFAST n
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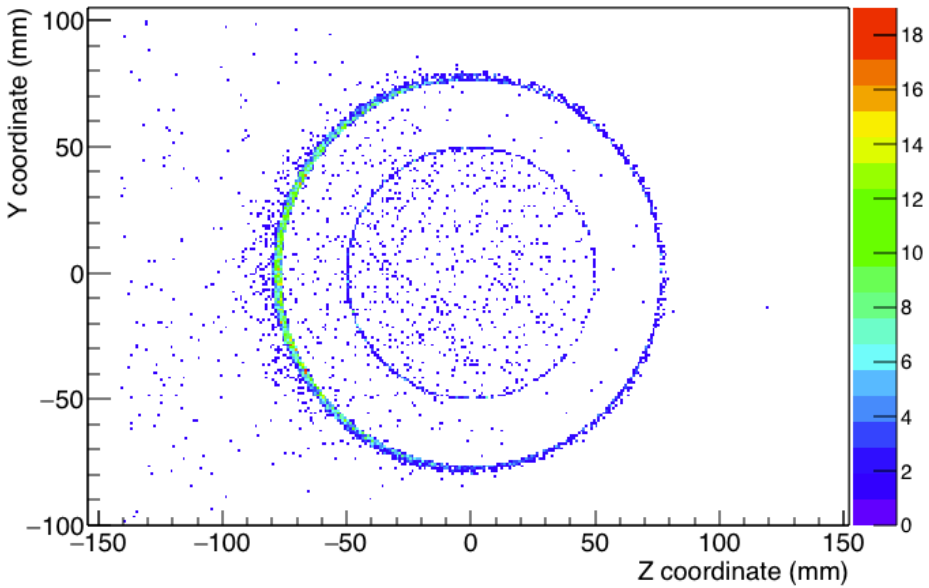
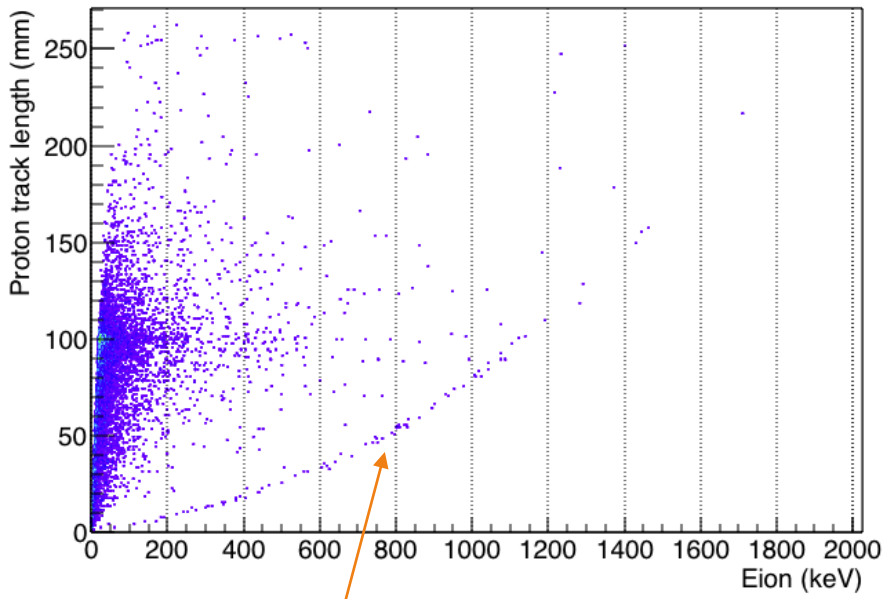
PROTONS ORIGIN : inelastic reactions of 70 MeV neutrons on 27Al

GEANT4 simulation

Protons induced by inelastic reactions of 70 MeV neutrons on Mimac-FastN aluminium structure (thickness of 3 mm) :



Proton track length = f(Eion)



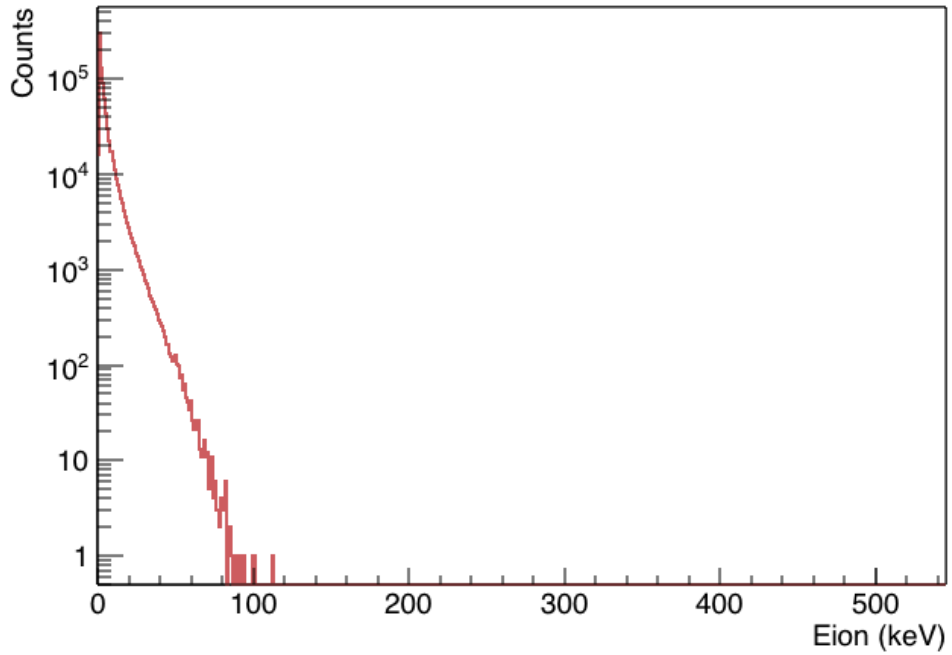
Protons that deposit all their energy in the gaseous active volume

MIMACFAST n
fast neutron detection

MUON DISCRIMINATION WITH MIMAC-FASTn AT CERF

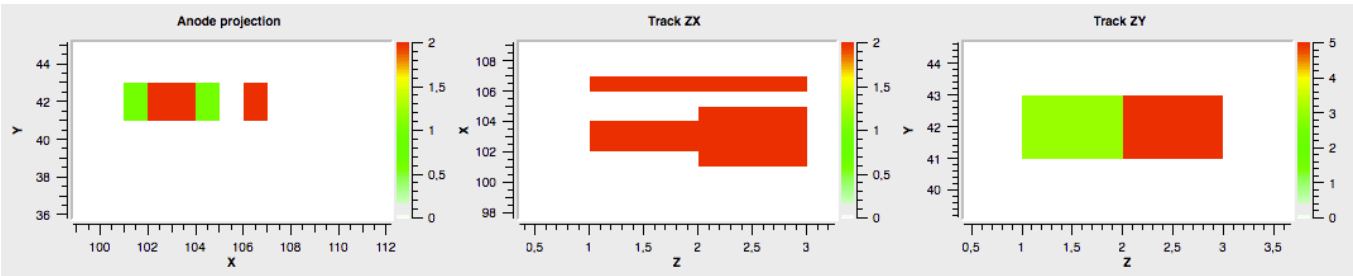
GEANT4 simulation

Energy deposited in ionization by 1.10^7 muons of 100 MeV :



Measurement with Mimac-FastN

A 90 keV muon track

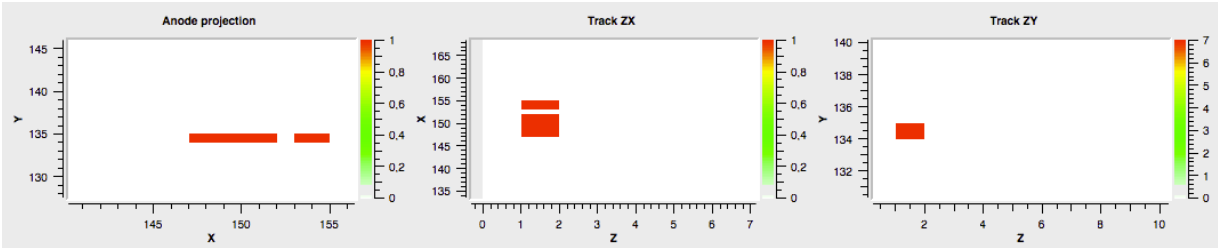


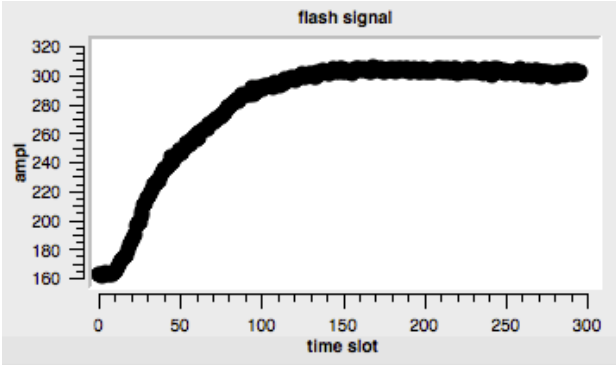
- Very few muons detected, because they lose at maximum 100 keV in the gaseous volume
- Ionization energy threshold = 60 keV

MIMACFASTn fast neutron detection

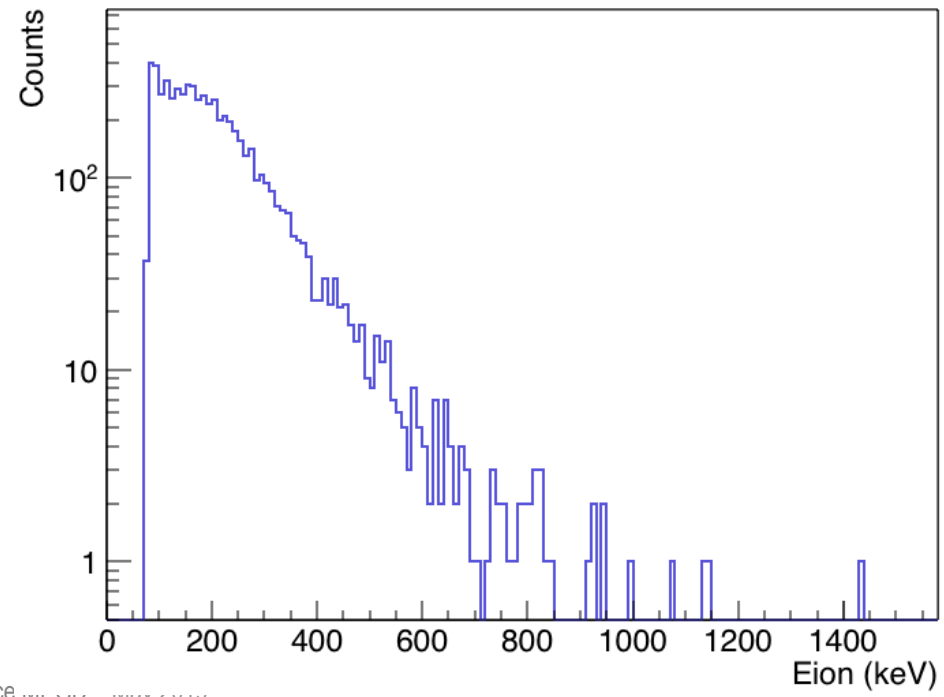
PION DISCRIMINATION WITH MIMAC-FASTn AT CERF

A 162 keV pion track and charge profile :





Pion ionization energy spectrum :



10 % of the events detected with tracks

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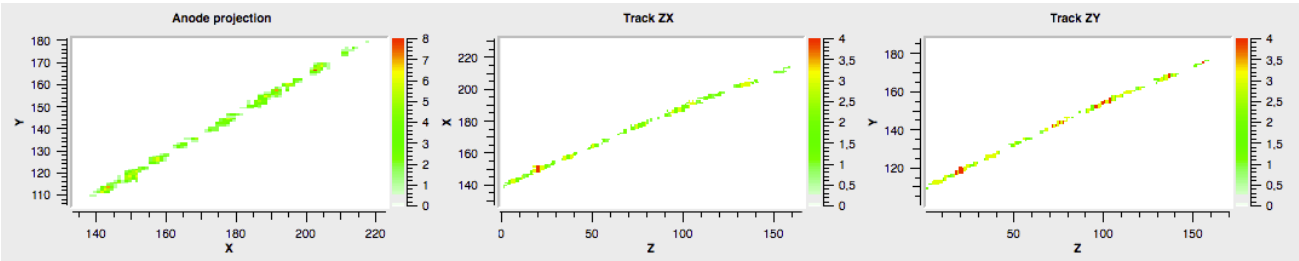
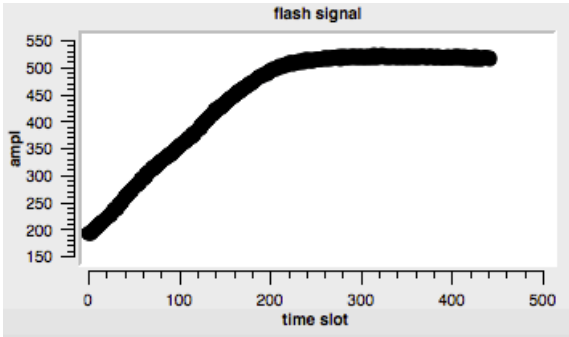
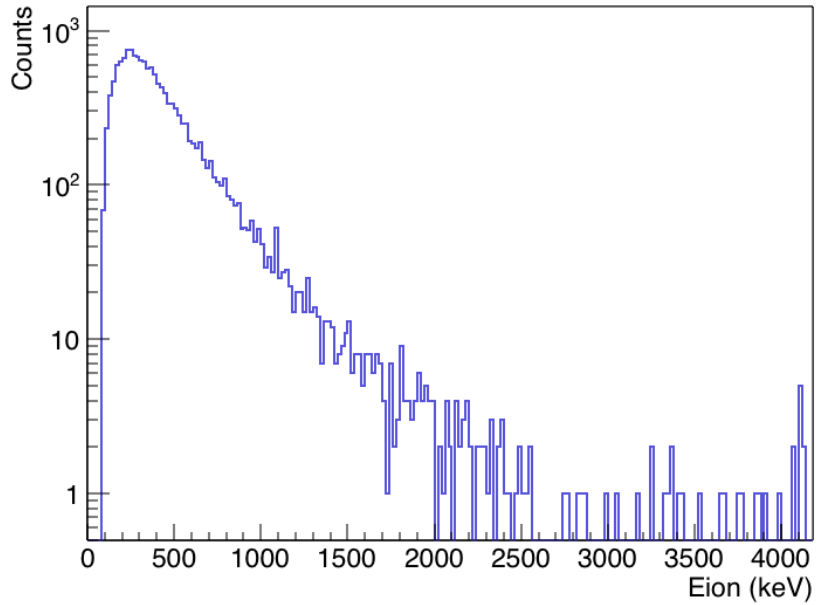
PROTON DISCRIMINATION WITH MIMAC-FASTn AT CERF

A 356 keV proton track and charge profile :

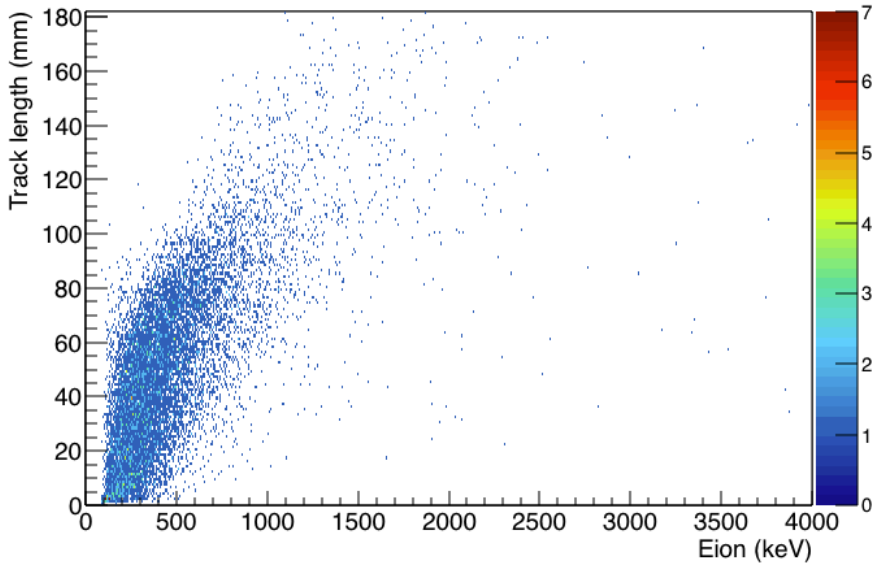




Proton ionization energy spectrum :



Proton track length=f(Eion) :



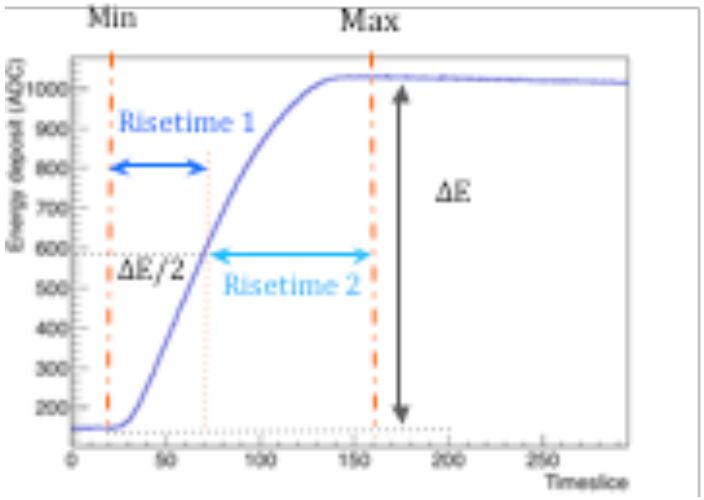
25 % of the events detected with tracks are protons

MIMACFASTn fast neutron detection

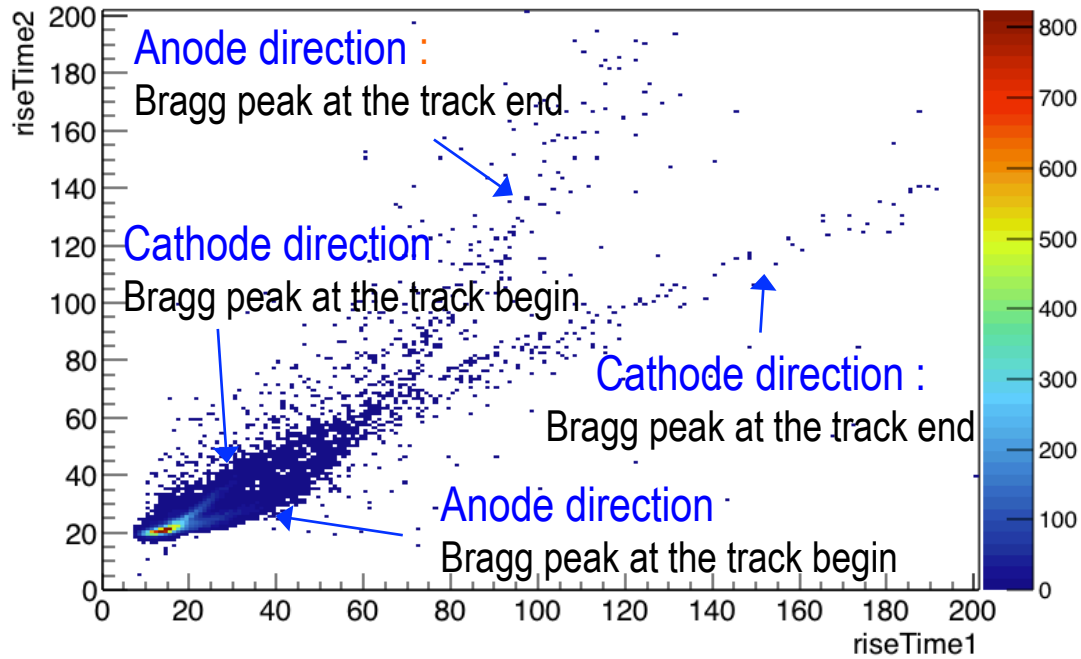
TRACKS DIRECTION : ANODE OR CATHODE

HEAD-TAIL OF THE ^{4}HE TRACKS AT CERF

Flash profile :



Risetime 2 = f(risetime 1) :



The track direction is essential for the definition of the interaction point

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