



# L'utilisation des détecteurs semi-conducteurs au LPC Caen

*Marian PARLOG*

Reseau semi-conducteurs IN2P3  
LPNHE – Paris – le 21 novembre 2012





--- utilisation

--- development

# Laboratoire de physique corpusculaire:

## I. Physique nucléaire:

- Structure nucléaire: Ge, diamants pc
- Dynamique et thermodynamique nucléaire: Si
- Théorie et phénoménologie

## II. Intéractions fondamentales et nature du neutrino: Si -> $\beta$

## III. Recherches interdisciplinaires

- Aval du cycle électronucléaire: télescope Si  
(diamants sc) -> n via convertisseur d(t, $\alpha$ )n
- Applications industrielles et médicales

## IV. Activités techniques et administratives

- Service instrumentation: détecteurs + acq FASTER

# Low Intensity Diamond Detector Beam Profiler

**Goal:** beam ( $Z = 1 - 92$ ) profilers (1 mm, ~90%) for – SPIRAL2, EURISOL, SPARC... & focal plane of the associated spectrometers;

- Advantages: radiation hard ( $1 - 10^7$  pps), wide range (1 MeV – 1 GeV),  $t_r \sim 1$  ns

## **Synthetic diamond: CVD**

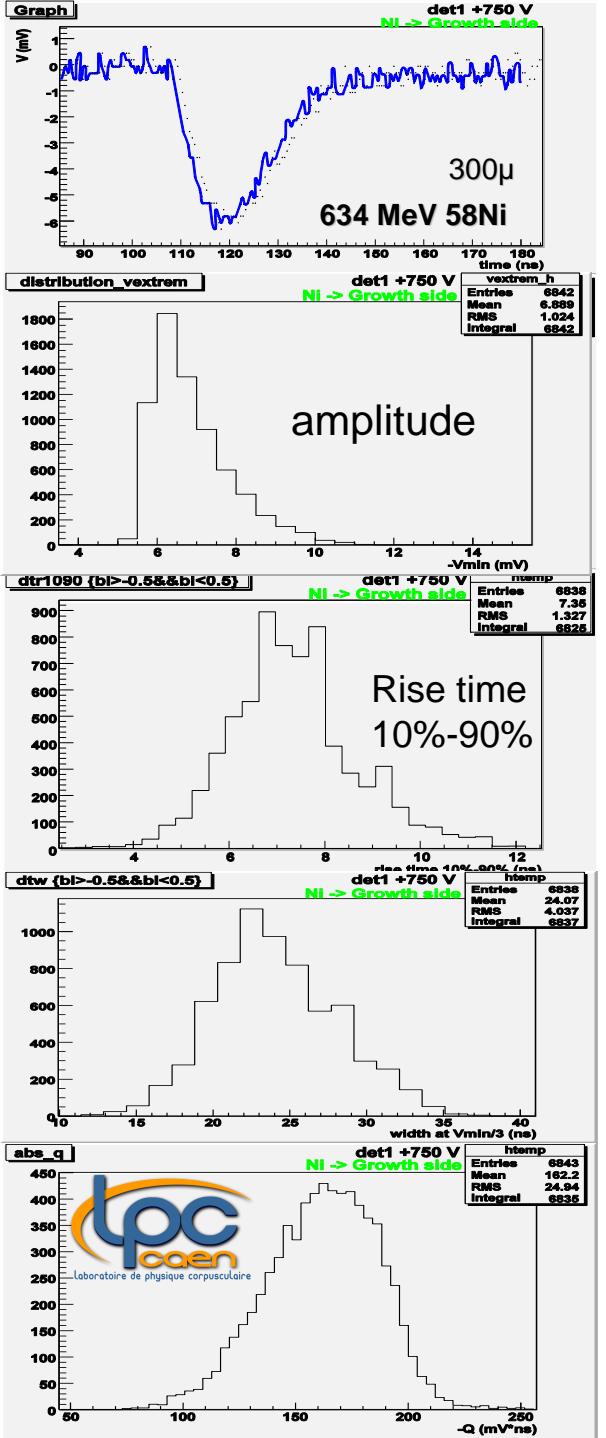
- Single-crystal and (large) polycrystalline (**Nucleation and Growth sides**) sensors
- Response and charge collection =  $f(\text{material quality \& thickness, ion } Z\&E, U)$

## **Non-segmented detectors:**

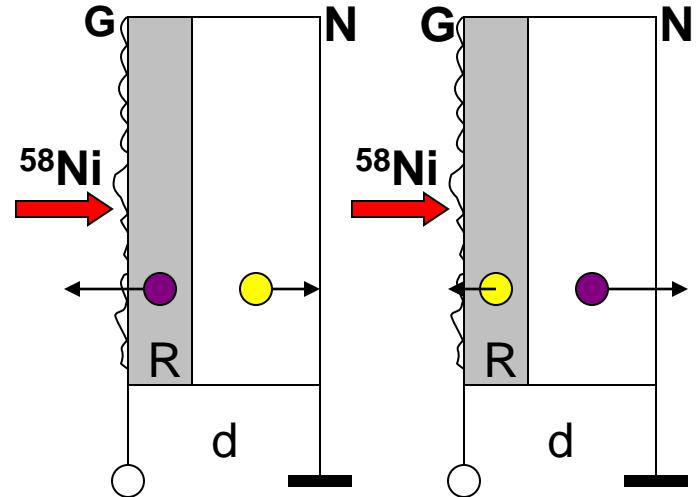
- Construction at LPC and tests at GSI (classical electronics) and GANIL (sampling)
- Stability of the signal in time; pulse shape analysis (PSA)

## **Double-sided multi-strip detectors:**

- construction at LPC and tests at GANIL (PSA); *analysis in progress*



d - thickness; R – range: R<<d



+750V

$0 \leq S_e \leq R$

$d-R \leq S_h \leq d$

-750V

$0 \leq S_h \leq R$

$d-R \leq S_e \leq d$

**favorable**

$S_e$  – drift électrons –



$S_h$  – drift holes +



**Not-segmented detectors:**

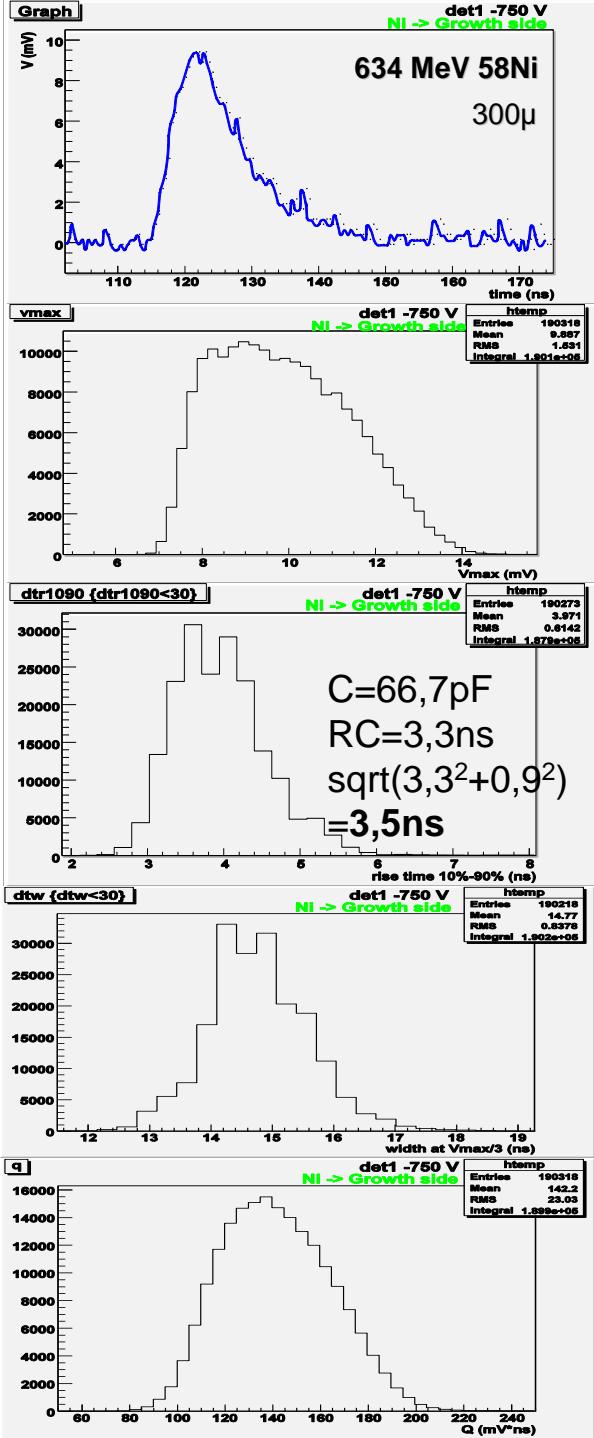
- Proba<sub>trapping h</sub> > Proba<sub>trapping e</sub>

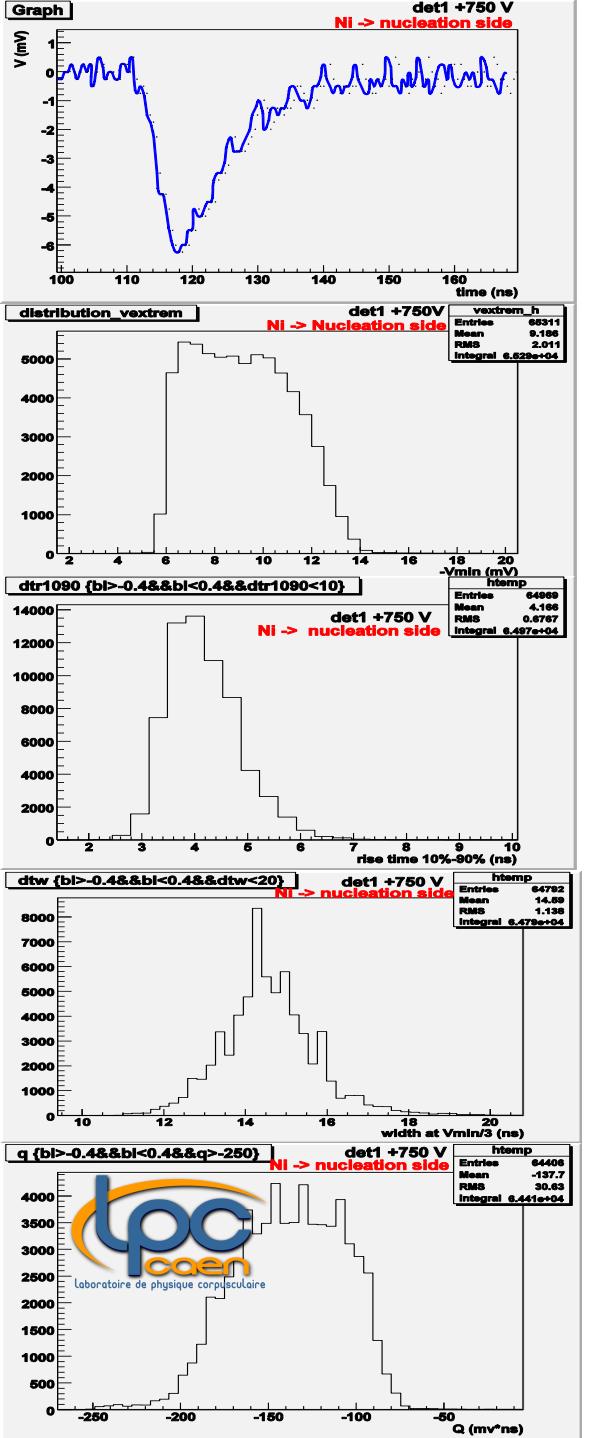
-  $S_h < S_e$  – favorable

$$E = 2.5V/\mu$$

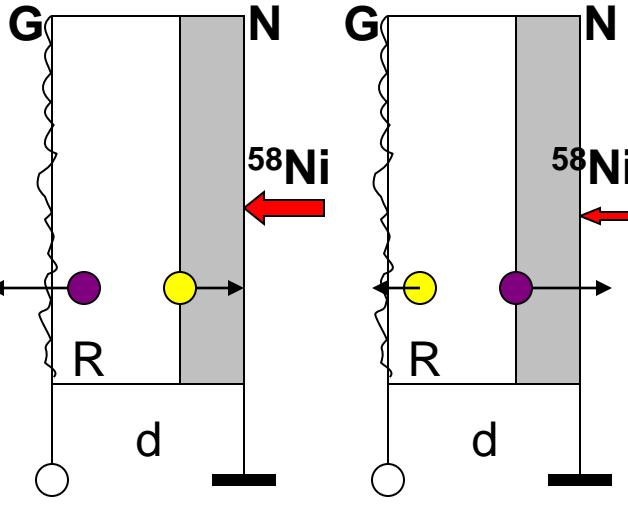
- d adequate to R

GANIL – SME:  $\sim 10^4$  pps





d - thickness; R – range: R<<d



$S_e$  – drift électrons -



$S_h$  – drift holes +



**Not-segmented detectors:**

- Proba<sub>trapping</sub>  $h >$  Proba<sub>trapping</sub>  $e$

-  $S_h < S_e$  – favorable

$$E=2,5V/\mu$$

- d adequate to R

GANIL – SME:  $\sim 10^4$  pps

**Table:** Synthetic results concerning the shape of the signal induced by **634 MeV  $^{58}\text{Ni}$**  ions, having a **range of  $\sim 60 \mu\text{m}$**  in a uni-strip diamond detector **P1N ELA of 300  $\mu\text{m}$**  at **E = 2,5 V/ $\mu$** .

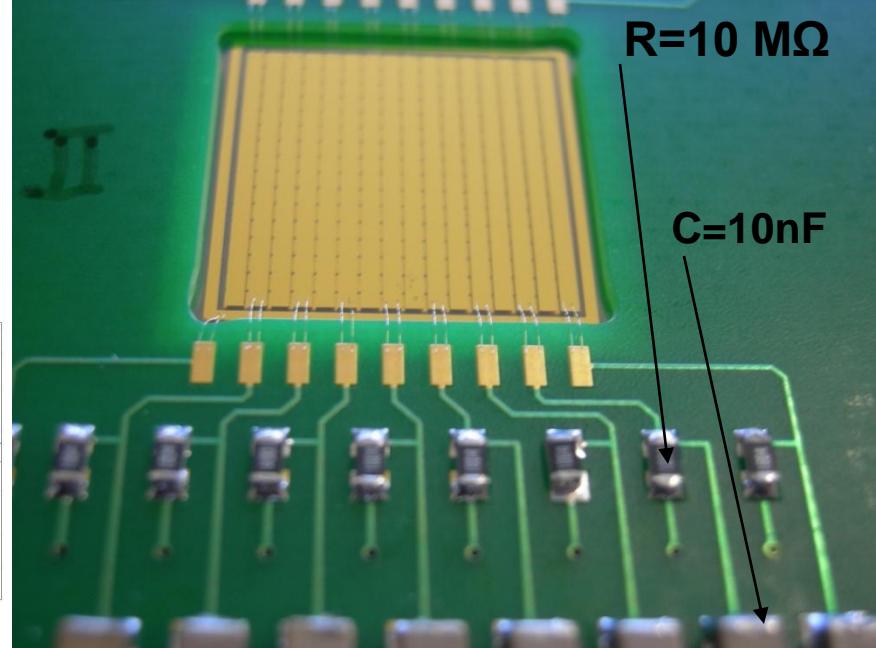
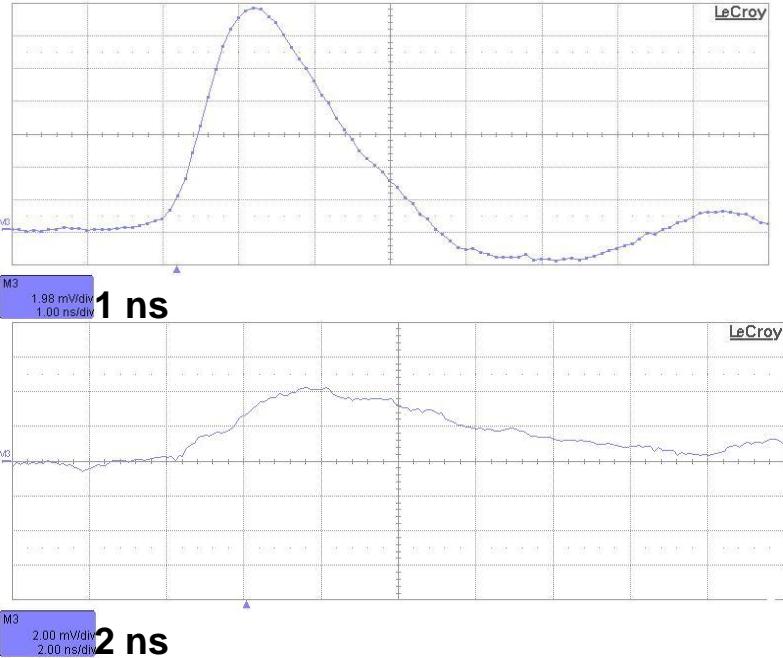
irradiated face	G face U (V) long tranzit	$\langle V_{\text{extrem}} \rangle$ (mV)	Rms V (mV)	$\langle Q \rangle$ (mV*ns)	Rms Q (mV*ns)	tr (ns)	rms tr (ns)	$\langle w_{1/3} \rangle$ (ns)	Rms w (ns)
G	+750 holes	6.9	1.0	162	25	7.4	1.3	24.1	4.0
G	-750 electrons	9.9	1.5	142	23	4.0	0.61	14.8	0.84
N	+750 electrons	9.2	2.0	138	31	4.2	0.68	14.6	1.1
N	-750 holes	8.8	1.2	166	21	6.1	1.1	19.8	2.8

**When the range of the ion is much shorter then the detector thickness**, so that the lengths of the distances of drift of the two types of carriers in their path to the electrode that will collect them are different, **the voltage has to be chosen in such a way that the holes have the shortest drift road**, regardless of the irradiated face. The signal amplitude will be greater and the signals will be shorter, being characterized by a faster rise time and a shorter duration.

Det III:

5.5 MeV  $\alpha$

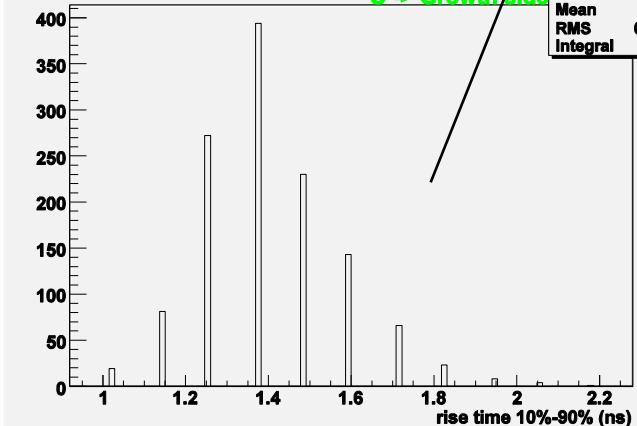
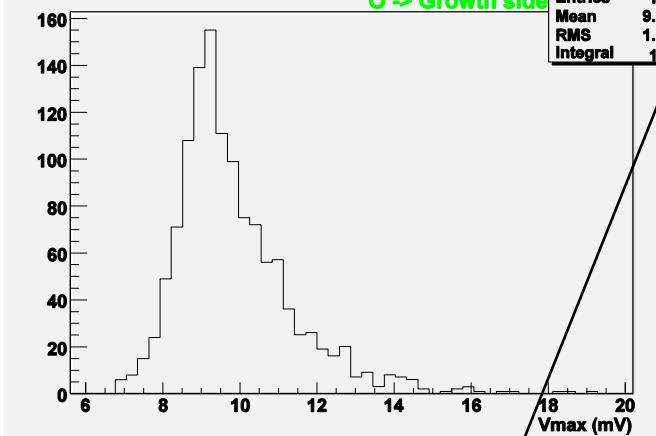
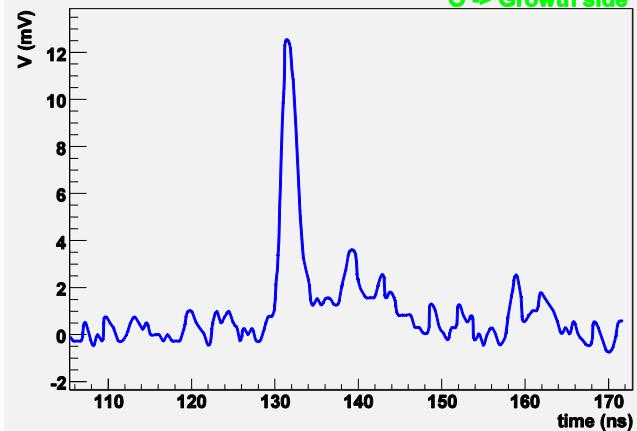
PRL:  
developped  
at LPC



**Table 3.** the multi-strip detectors built at LCP; a) and b) are the 2 faces

Detecteur	P2 - Type	Densité (g/cm <sup>3</sup> )	Epaisseur ( $\mu\text{m}$ )	Surface active (mm x mm)	Nombre de pistes
I	ELS	2.9	565	16 x 16	a) 16 b) 16
II	ELP	3.4	575	16 x 16	a) 16 b) 16
III	ELS	2.9	240	20 x 20	a) 1 b) 20
IV	ELP	3.4	350	20 x 20	a) 20 b) 20

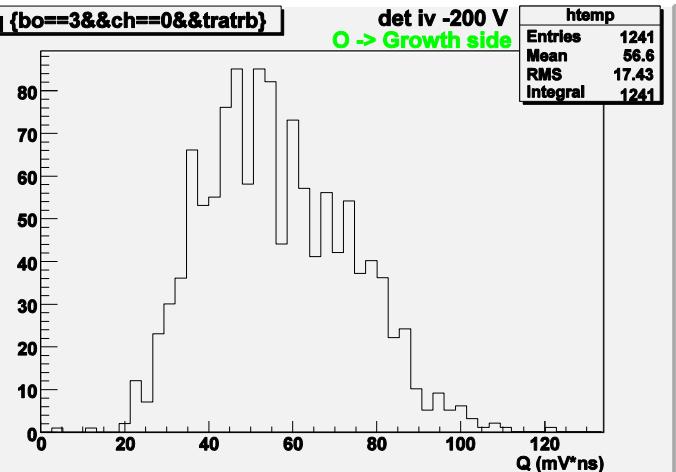
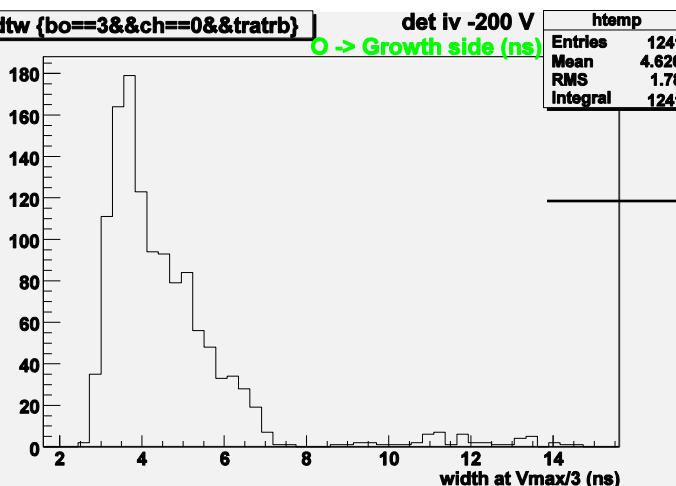




**Det iv ELP, 350  $\mu$ , -200 V,  
E=0.6V/ $\mu$  board 3, channel 0;  
O → Growth side: 13.7 AMeV**

S=18mm<sup>2</sup>; C=2,57 pF RC=0,13ns

Matacq -> 0,9 ns



Calculated  
Eeff < 0,25 V/ $\mu$

Acquisition:  
**MATACQ – VME**  
**(400 MHz BW;**  
**2GHz sampling) –**  
**12 channels**  
- oscillo LeCroy  
**64Xi (600 MHz BW;**  
**10Gs/s) –**  
**4 channels**

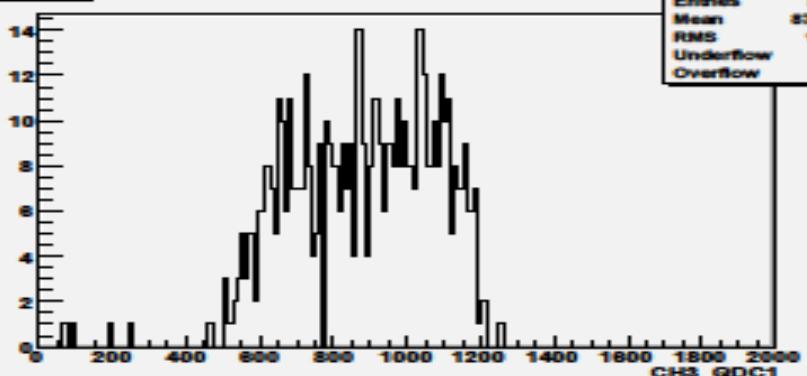
# Det\_8x8\_pistes (ELS - 300μm);

Réseau semi-cond, LPNHE, Paris 21/11/2012 Marian PARLOG

Piste4\_4\_-750V\_nuclear

HV = -750 V on Nucleation; source α on Growth, PRL1, FASTER

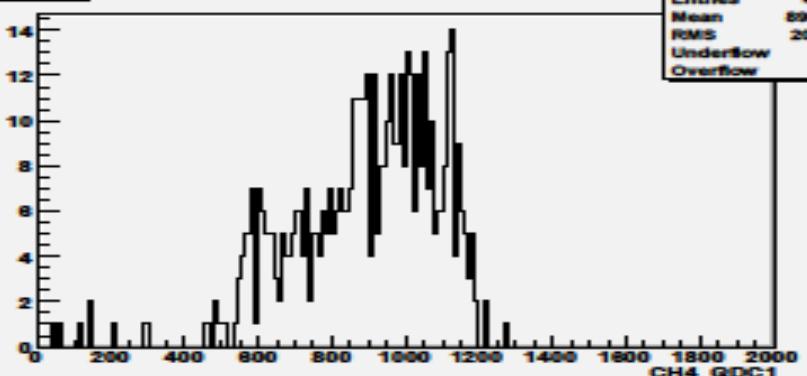
CH3\_Q1



CH3\_Q1

Entries 531  
Mean 877.1  
RMS 197  
Underflow 1  
Overflow 0

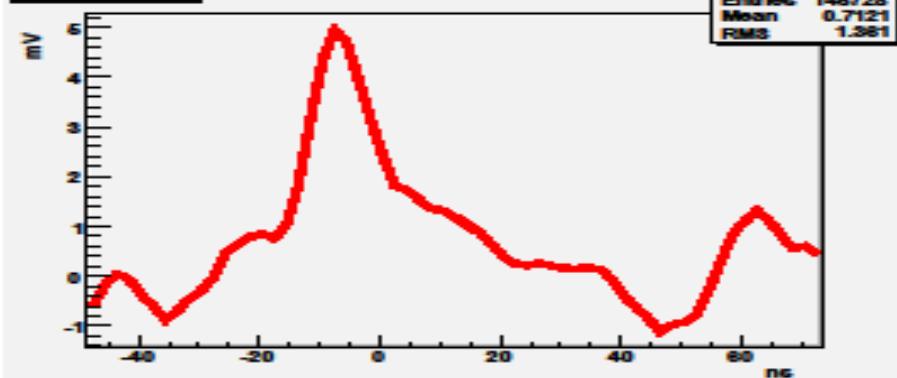
CH4\_Q1



CH4\_Q1

Entries 473  
Mean 890.9  
RMS 201.1  
Underflow 1  
Overflow 0

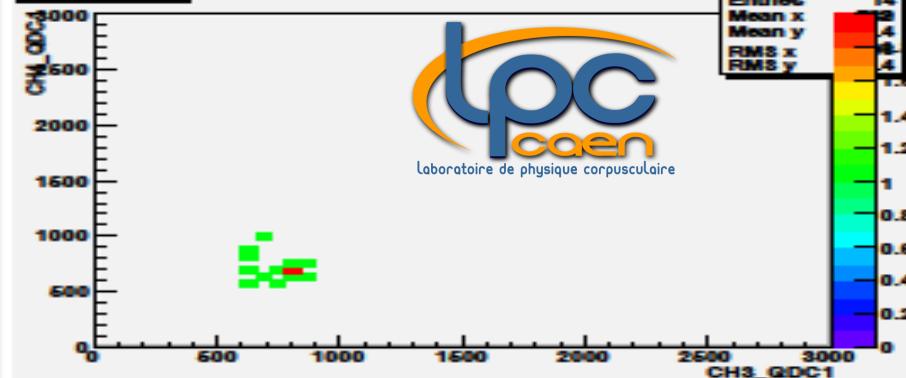
CH4\_Oscillo



CH4\_Oscillo

Entries 146728  
Mean 0.7121  
RMS 1.361

CH3\_QDC1



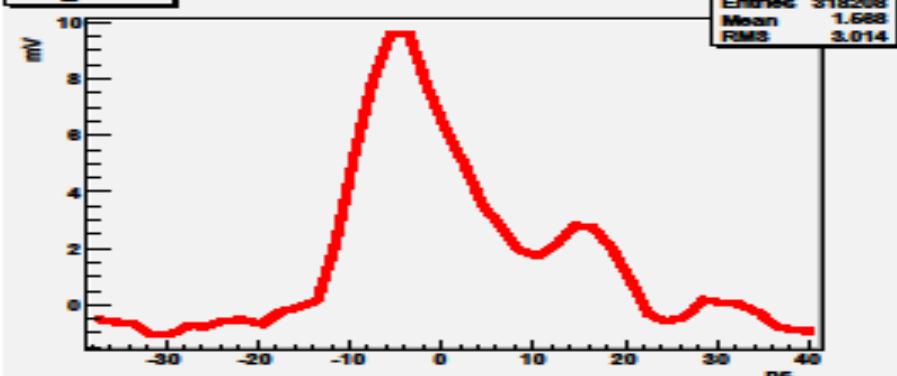
correlation

Entries 146728  
Mean x 0.7121  
Mean y 0.7121  
RMS x 1.361  
RMS y 1.361



Laboratoire de physique corpusculaire

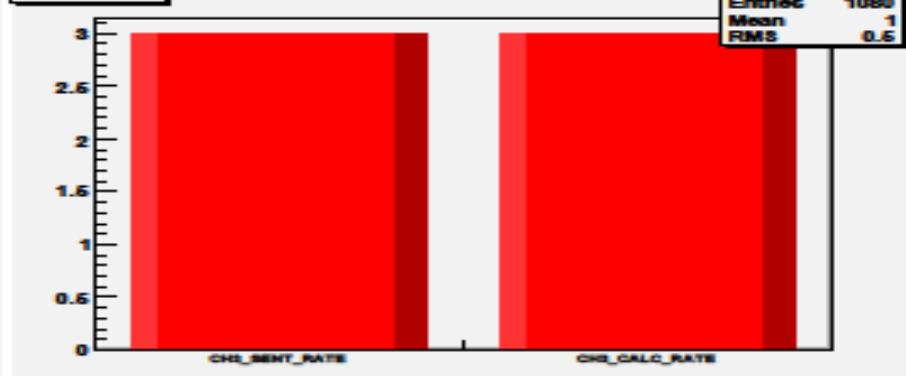
CH3\_Oscillo



CH3\_Oscillo

Entries 318208  
Mean 1.568  
RMS 3.014

CURRENTS COUNTS

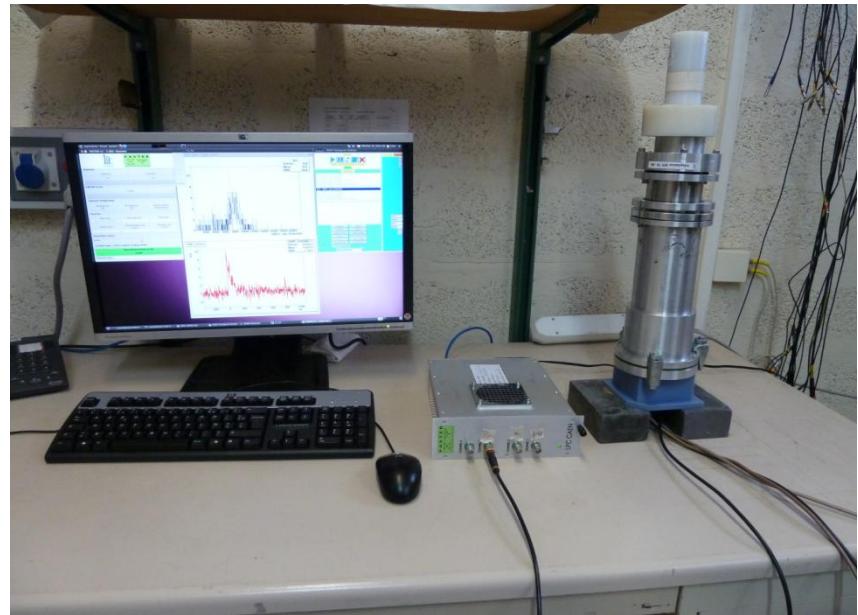
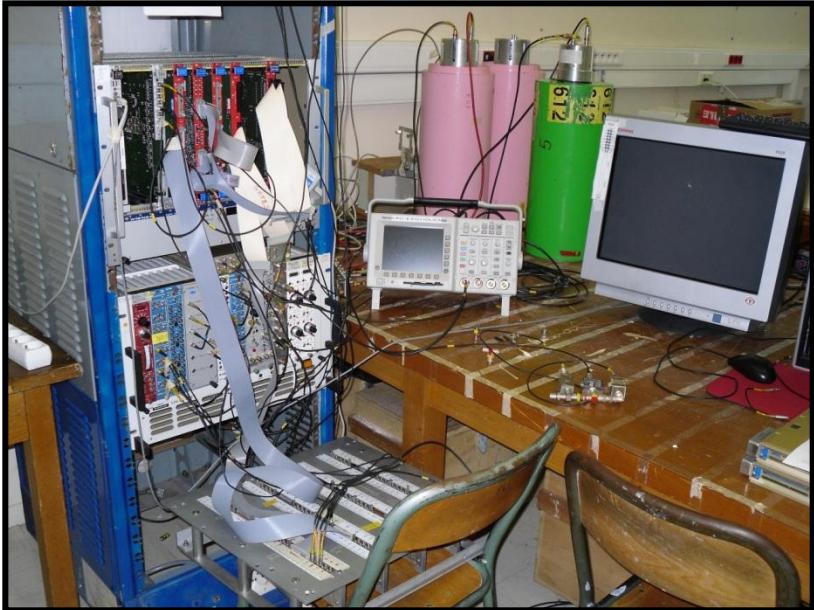


CH3\_COUNTERS

Entries 1080  
Mean 1  
RMS 0.6

# FASTER

Fast Acquisition SysTem for nuclEar Research



## Objectifs:

- L' objectif de FASTER est de concevoir une plateforme de développement d' acquisition numérique modulaire avec les contraintes suivantes.
  - Générique, adaptable, extensible
  - 1 à quelques centaines détecteurs
  - Utiliser au maximum les nouveaux standards
  - Plusieurs niveaux de décision
  - Temps réel et distribution d'horloge simplifiée



### 3 Cartes mères développées

- Syroco\_V2
- NIM
- AMC

### 3 Fonctions de mesures développées

- QDC-TDC<sub>HR</sub>
- ADC-TDC
- Synchro RF

### 2 Cartes filles de conversion analogique→digital:

- CARAS : rapide, adaptée aux fonctions QDC, TDC, synchro RF, ADC
- MOSAHR : grande dynamique, adaptée à la spectroscopie haute résolution (ADC)

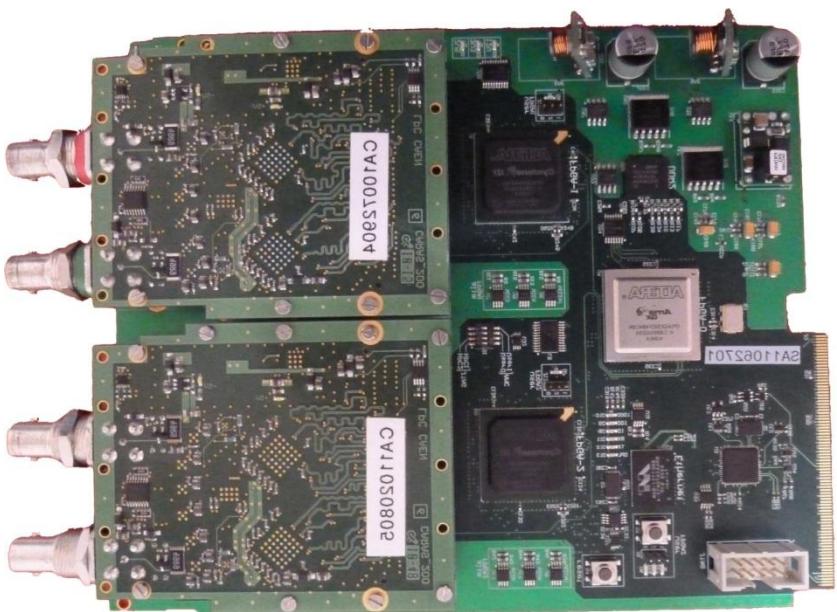
# FASTER

## BILAN

- Utilisé dans plusieurs configurations
- Qualité des mesures
- Performances élevées

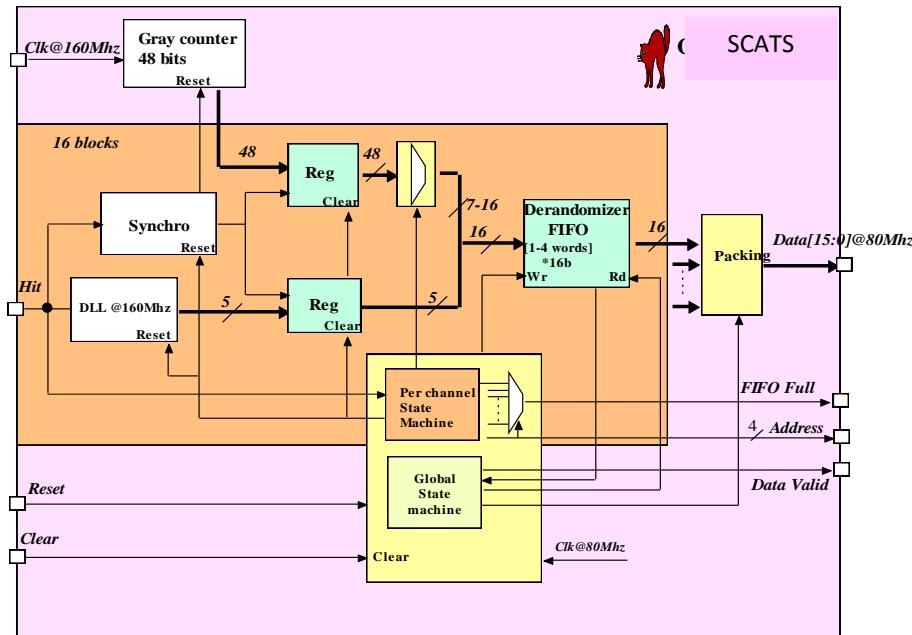
## FUTUR

- Développer des aspects dynamiques du modèle
- Augmentation des performances
- Développement de nouveaux modules
- Peut répondre aux besoins de NFS, DESIR.

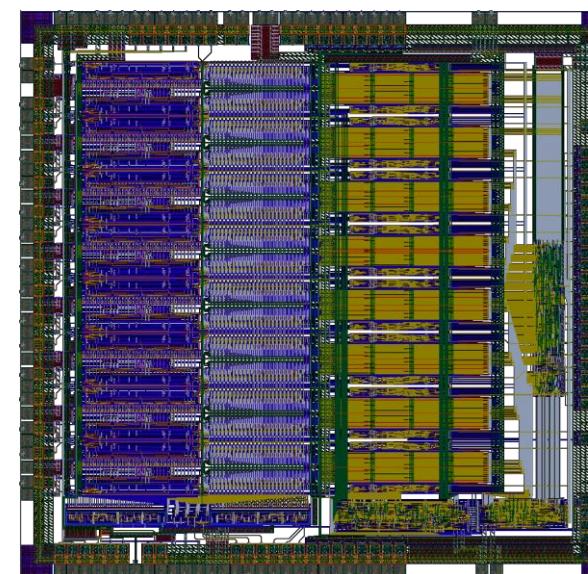


# Micro électronique

## Marquage en temps des événements



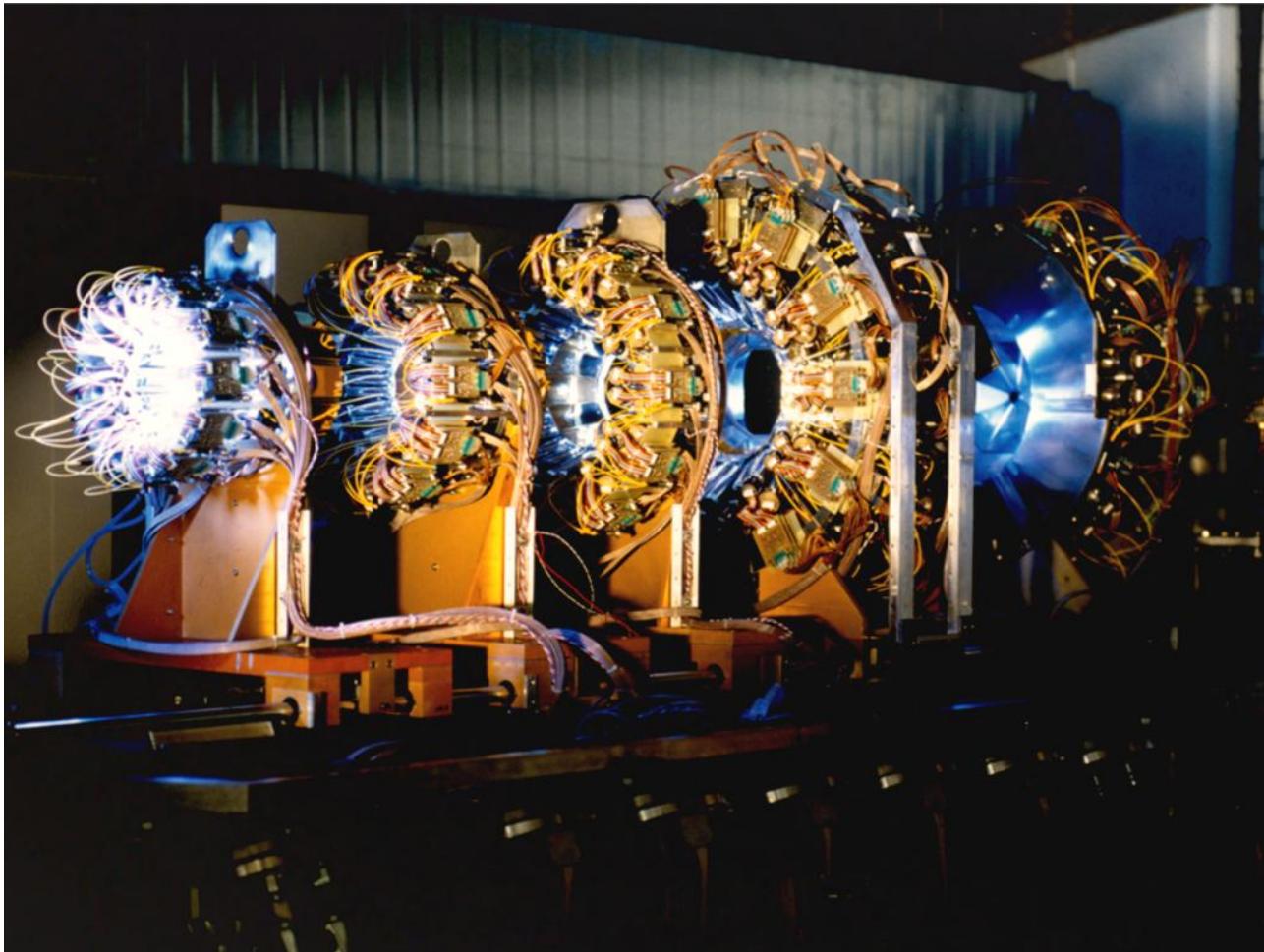
- Technologie CMOS  $0.35\mu\text{m}$
- 16 voies indépendantes
- Pas de quantification 195 ps
- Résolution < 70 ps RMS
- Dynamique : 48 bits @ 160 MHz
- FIFO (8 mots de 32 bits) / voie
- lecture des données @ 80 MHz



SCATS (Sixteen Channel Absolute Time Stamper)  
To be used by our 50 X 50 diamond  
BEAM PROFILER

Développement d'un nouveau marqueur de  
temps pour l'expérience SuperB

# INDRA Collaboration



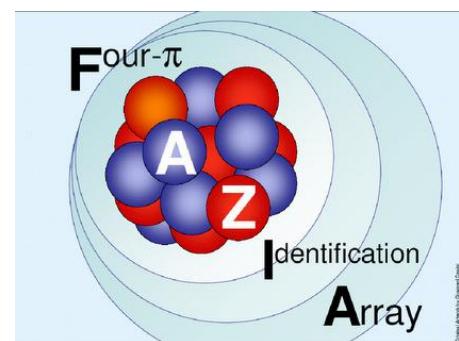
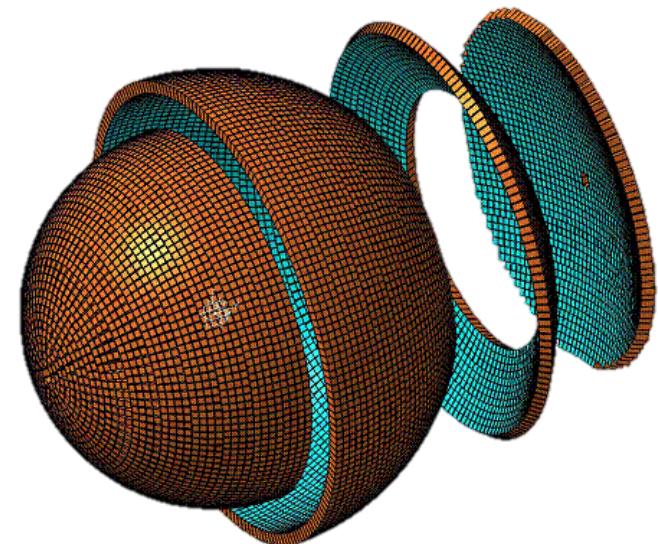
Multidétecteur INDRA : INstrument de Détection avec Résolution Accrue  
(GANIL/IPN Orsay/LPC Caen/INFN Naples/Université LAVAL)

## Spécifications :

- 336 telescopes Chlo-(Si-PIPS)-CsI (1200 channels)
- 90%  $4\pi$
- High gain VXI Electronics
- E dynamics : 1A-100A MeV
- Z,A Identification for Z=1-4 (CsI)
- Z Identification for Z=1-92 (Si-CsI)
- Low Detection thresholds :  $E = 1A$  MeV

# Going further : A-identification with $4\pi$ array

- **Digital electronics and sampling :**  
Pulse shape analysis (algorithms)
- **State-of-the-art detection strategy :**  
Si-Si-CsI telescopes (Si with uniform resistivity - NTD)
- **$4\pi$  acceptance with high granularity :** 10,000 cells
- **Next-gen trigger :** multi-level mode
- **Integrated electronics :** ASICS
- **Automatic calibration procedures :**  
Digital Signal Processing



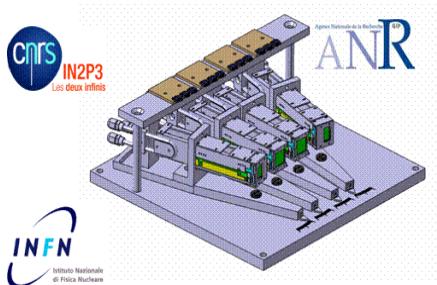
# FAZIA

France, Italy, Poland, Romania

## PHASE1 (2003-2011) [R&D]

(A,Z) identification

Pulse Shape & DE/E & ToF  
(11 articles + 1 submitted)



## NUCLEAR EQUATION of STATE E( $\rho$ , (N-Z)/A, T)

GANIL:  $^{40,48}\text{Ca}$ @35 A.MeV

SPIRAL:  $^{14,15,19,20}\text{O}$ @14 A.MeV

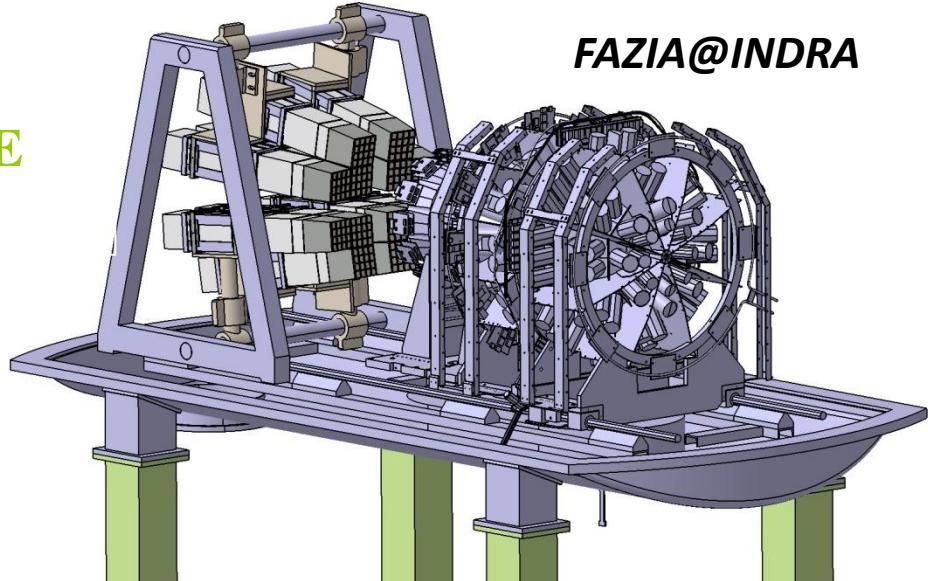
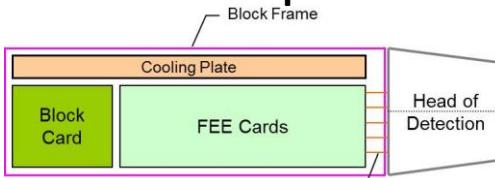
SPIRAL2:  $^{94}\text{Kr}, ^{92}\text{Kr}$ @8 A.MeV

SPES:  $^{132}\text{Sn}, ^{142}\text{Cs}$ @10 A.MeV

## PHASE2 (2012-2015) [MoU-demonstrator]

192 telescopes Si(300 $\mu\text{m}$ )/Si(500 $\mu\text{m}$ )/CsI(10cm)

Blocks of 16 (20x20mm<sup>2</sup>) telescopes with in-vacuum FEE  
(digitized signals for Pulse Shape identification)



FAZIA@INDRA

$$L = a_G \left[ \int_0^{E_\delta} \frac{1}{a_R S_e(E)} \ln \left( 1 - \frac{a_R S_e(E)}{1 + a_n S_n(E) + a_R S_e(E)} \right)^{-1} \frac{dE}{1 + \frac{S_n(E)}{S_e(E)}} \right.$$

$$+ \int_{E_\delta}^{E_0} \frac{1}{a_R S_e(E)} \ln \left( 1 - \frac{(1 - \mathcal{F}(E)) a_R S_e(E)}{1 + a_n S_n(E) + a_R S_e(E)} \right)^{-1} \frac{dE}{1 + \frac{S_n(E)}{S_e(E)}}$$

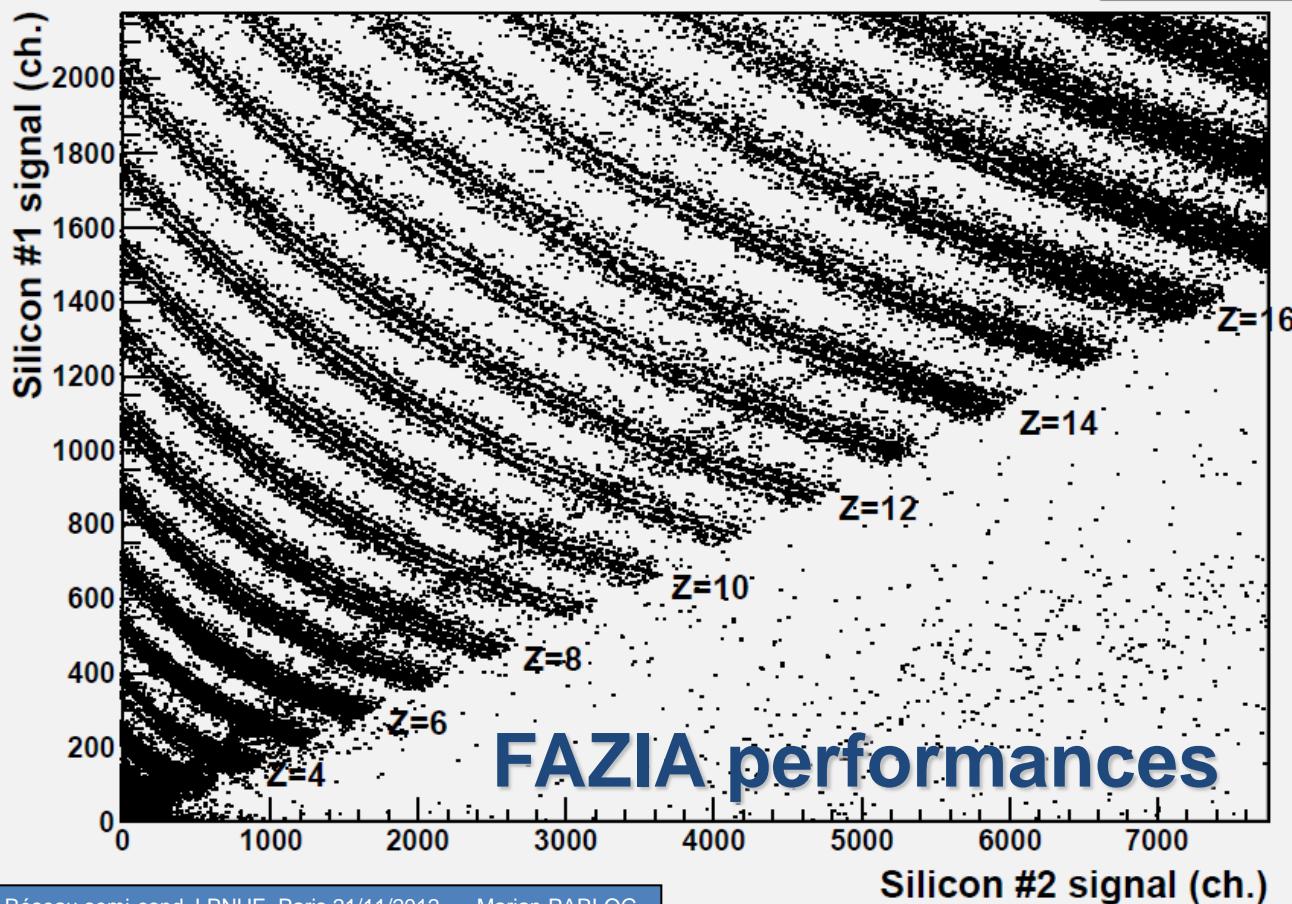
$$\left. + \int_{E_\delta}^{E_0} \frac{\mathcal{F}(E) dE}{1 + \frac{S_n(E)}{S_e(E)}} \right]$$



FAZIA Telescope A : Silicon-Silicon

Si-Si

h2  
Entries 3244012



Conseil Scientifique LPC Caen,  
13/11/12 Olivier LOPEZ

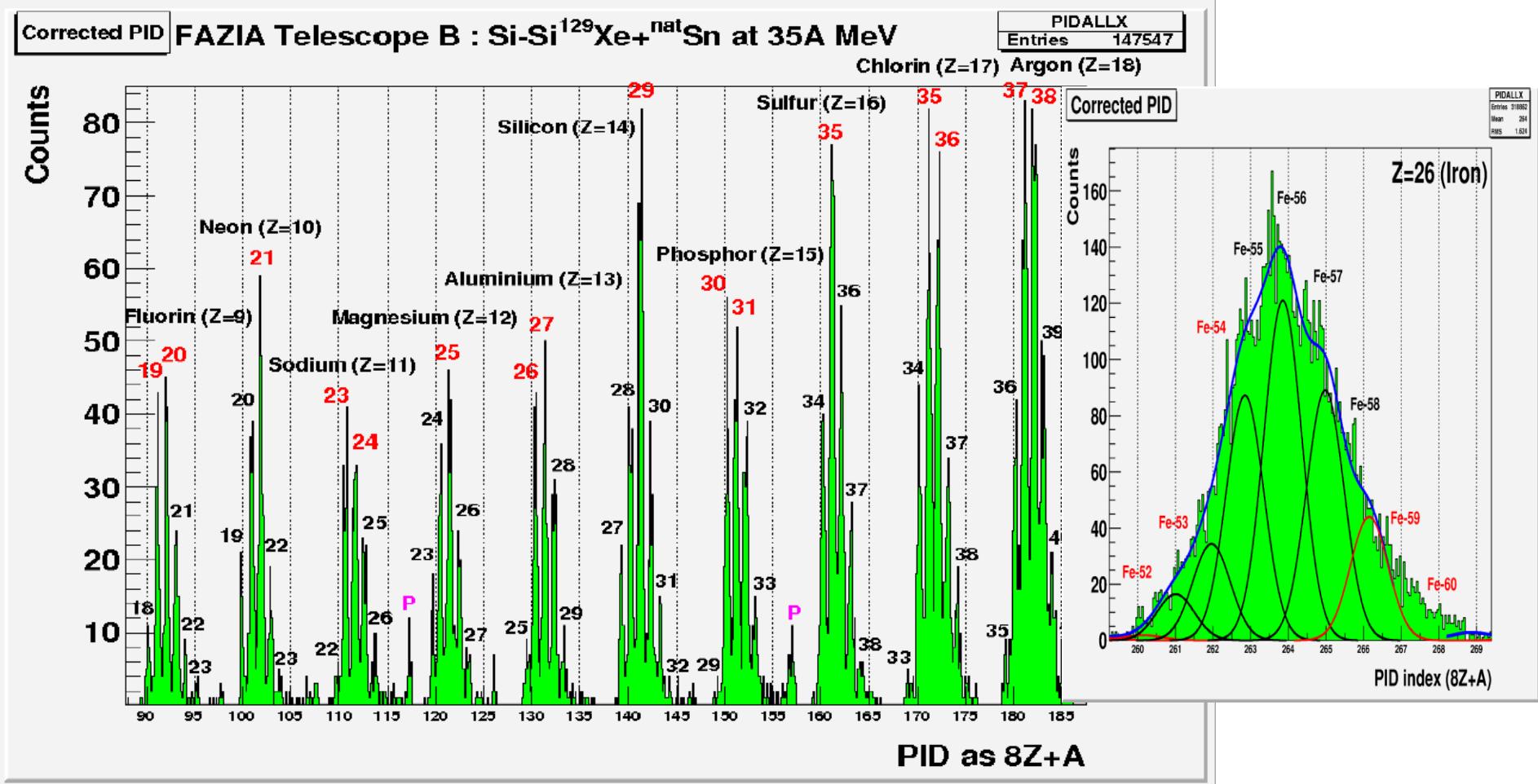
Si-CsI functional

Improving  
standard E- $\Delta$ E  
identification  
method

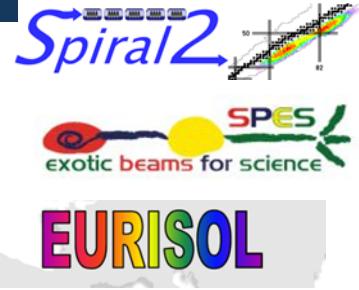
CsI Light and  
Silicon Signal  
with  $\delta$ -rays

# FAZIA performances

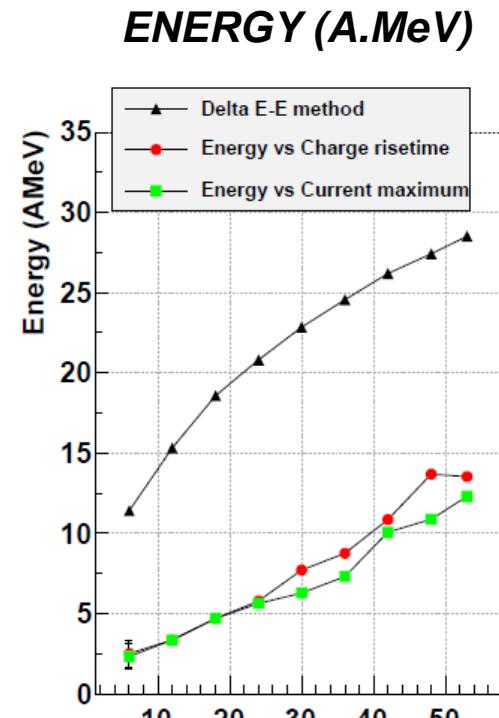
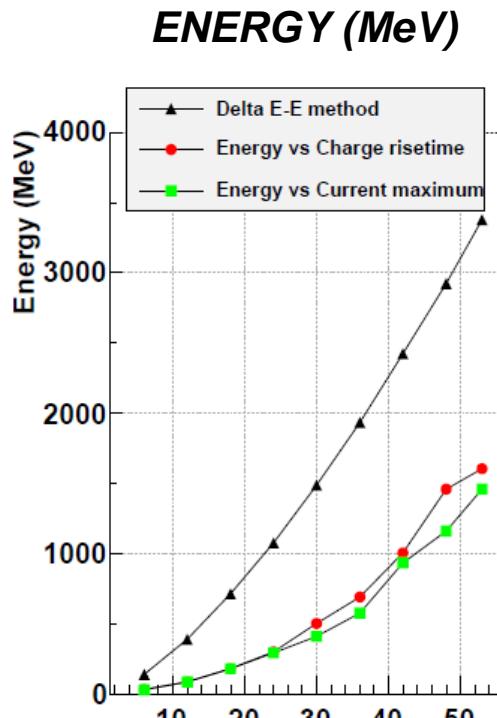
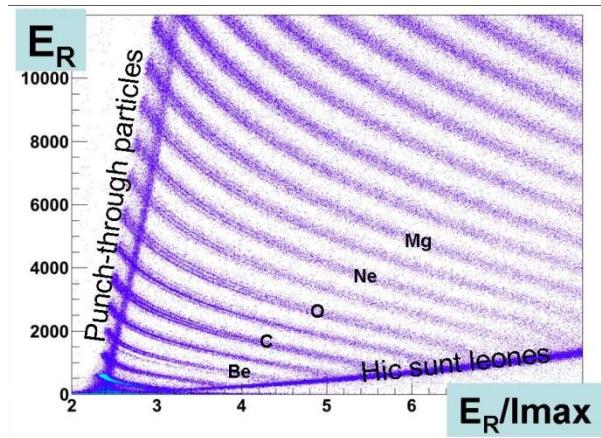
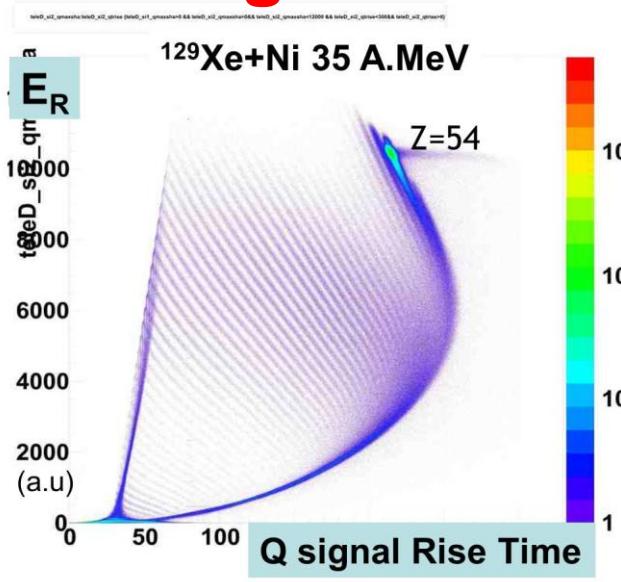
Improving standard E- $\Delta E$  identification method up to Z=20-30 !



# FAZIA performances



## Si: digital Pulse Shape Identification High quality Si-chips



N. Le Neindre *et al.*, accepted for publication NIM A

**Z Id. Thresholds**