Results on the R&D of the FAZIA detectors for Nuclear (Thermo)dynamics

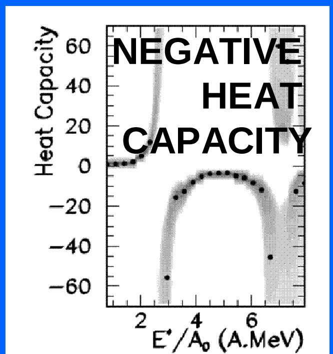
FAZIA Collaboration

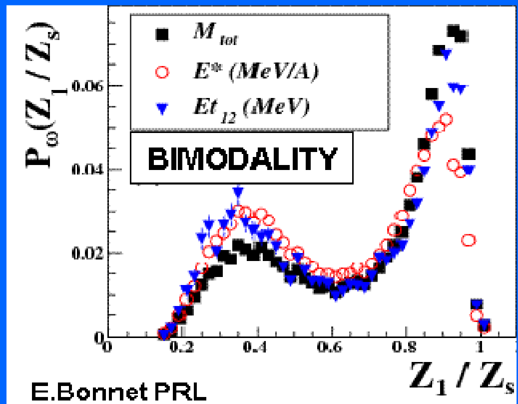
FAZIA: Scientific case

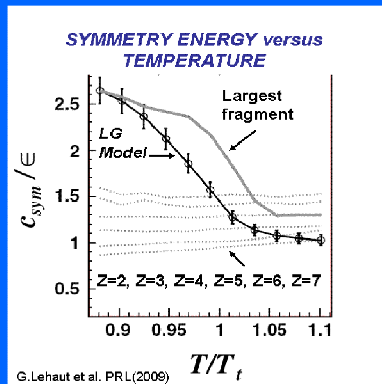
Nuclear Equation Of State N/Z dependence

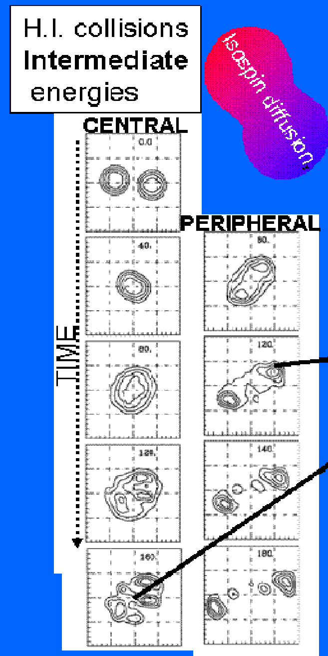
$$E(\rho, T, (N-Z)/A)$$

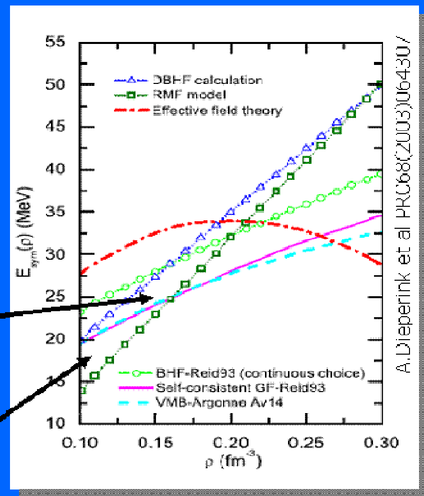
- ***Nuclear Matter first Phase Transition ("Liquid-Gas")***
- ***Nuclear level densities and Limiting temperature***
- ***Symmetry Energy (density and temperature dependence)***











NEED OF (A,Z) Identification

Spiral2 SPES exotic beams for science

GANIL, LNS, LNL

EURISOL

Spiral2

LOI 18

Letter of Intent for SPIRAL 2

Title: Dynamics & Thermodynamics of exotic nuclear

Spokesperson(s) *(max. 3 names, laboratory, e-mail - please und... one corresponding spokesperson):*

F. Gulminelli (LPC-ENSICaen, Caen, France, e-mail: gul... .in2p3.fr)
G. Poggi (INFN & University, Florence, Italy, e-mai... @fi.infn.it)
G. Verde (INFN, Catania, Italy, e-mail: giuseppe...)

GANIL contact person

J. Frankland (GANIL, Caen, France)

Collaboration *(names and labo...*

FRANCE:
IPNO (Orsay): E. Bonnet, B. Borderie, E. Galichet, N. ...
GANIL (Caen): A. Chbihi, J. Frankland, J. Moisa...
LPC-ENSICaen (Caen): S. Barlini, R. Bouga... Lehaut, O. Lopez, B. Tamain, E. Vient
IPNL (Ly...
INDIA:
VECC (C...
Banerjee, ...
ITALY:
Bologna (...
Marini, ...
Catania (...
Catania (I...
Firenze (I...
Olmi, G. Pasq... ggi, S. Piantelli, A. Stefanini
LNL (INFN): M. ...ausero, M. Degerlier, F. Gramegna, V. Kravchuk
Napoli (INFN & University): M. La Commara, A. Ordine, E. Rosato, G.Spadaccini, M. Vigilante

POLAND:
Krakow (Jagiellonian University): A. Becla, T. Kozik, Z. Sosin, A. Wieloch
Katowice (Silesian University): A. Grzeszczuk, S. Kowalski, W. Zipper
Warsaw (Warsaw University): A. Kordyasz, E. Piasecki
ROMANIA:
... M. Preda,
... Salmeron

« ... y apparatuses are available at present, the new ... al demands require a new detector system, FAZIA, ... will be indispensable in future studies at SPIRAL2… »
(...umé of general recommendations of the SAC of SPIRAL2, 2006)

NEED OF (A,Z) Identification

72 persons – 19 institutions – 8 countries

SPES exotic beams for science

Prompt collective oscillations with exotic beams

a Letter of intent for the SPES-ALPI facility

G.Casini[a], R. Alba[f], G. Baiocco[b], L. Bardelli[a], S. Barlini[a], M.Bini[a], A. Bracco[e], M. Bruno[b], F. Camera[e], S. Carboni[a], M. Ciemala[d], A. Corsi[e], M. D'Agostino[b], M. Degerlier[c], B. Fornal[f], N. Gelli[a], F. Gramegna[c], M. Kmiecik[d], V.L. Kravchuk[c], A. Maj[d], C. Maiolino[f], T. Marchi[c], K. Mazurek[d], L. Morelli[b], A. Nannini[c], A. Olmi[a], G. Pasquali[a], G. Poggi[a], D. Santonocito[f], O. Wieland[e] and M. Colonna[f], M. Di Toro[f], C. Rizzo[f]

[a] Istituto Nazionale di Fisica Nucleare, Sezione di Firenze and Dipartimento di Fisica dell'Università, Firenze, Italy

[b] Istituto Nazionale di Fisica Nucleare, Sezione di Bologna and Dipartimento d... dell'Università, Bologna, Italy

[c] Istituto Nazionale di Fisica Nucleare, Laboratori Nazionali di L...

[d] H. Niewodniczański Institute of Nuclear Physics P...

[e] Istituto Nazionale di Fisica Nucl... dell'Università, Milano, Italy

[f] Istituto Nazion...

Th... interest in using SPES radioactive beams. The physics case i... already presented by other italian groups which we refer to. This fact in... relevance of the subject and asks for the development of several SPES beams, which would allow a more detailed study of this physics thanks to the different detectors and techniques employied.

Neutron and proton transfer in dissipative collisions

G. Casini[a], G. Verde[f], + FAZIA Collaboration
and
M. Colonna[d]

[a] Istituto Nazionale di Fisica Nuclear... ...ca

[b] Istituto Nazionale ... ...a

...gnaro, Italy

...i del Sud , Catania, Italy

...ance

...Nucleare, Sezione di Catania, Italy

Abstract

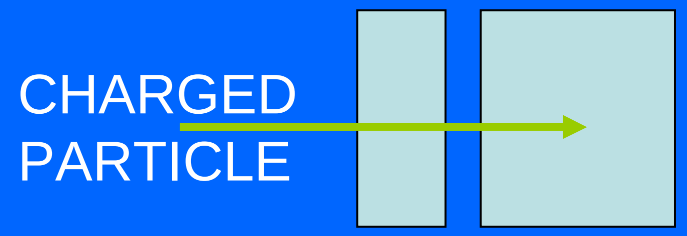
The idea of this programme is to extend to the SPES beams the investigation on reaction mechanisms at low-moderate bombarding energies till now done with stable ions, in particular focusing on the interplay of the dynamics and the sequential decay of the excited fragments produced in dissipative collisions.
At this energy regime, reactions proceed via nucleon exchanges which are mainly ruled by the mean-field whose details are rather unknown expecially in system characterized by exotic isospin contents. Very selective data are scarce so far, due to both the intrinsic difficulty of disentangling the two main sources at low energies and the limitations of the detectors till now used; we think that some knowledge can be gained with experiments with exotic (and stable) beams done with highly performing detectors and analysis techinques.

Two LOI presented by G. Casini

A and Z Identification

HEAVY-IONS COLLISIONS→IDENTIFY THE REACTION PRODUCTS

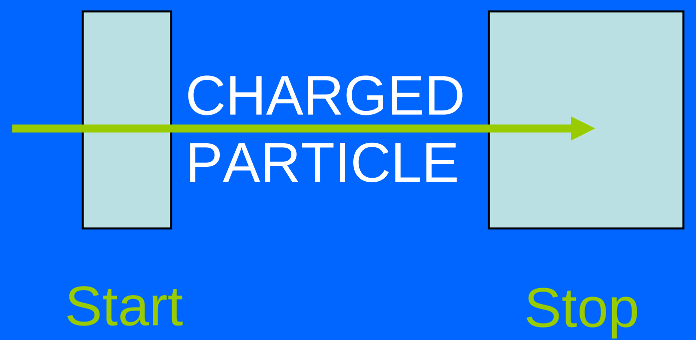
Energy is measured
Z identification
A identification (for low Z)
For particles stopped in the first DE no identification



METHOD DE/E

Energy loss = f(A,Z)

Energy is measured
Velocity is measured
A identification
For particles stopped in the first DE no Z identification



METHOD ToF

Time, long fligh path

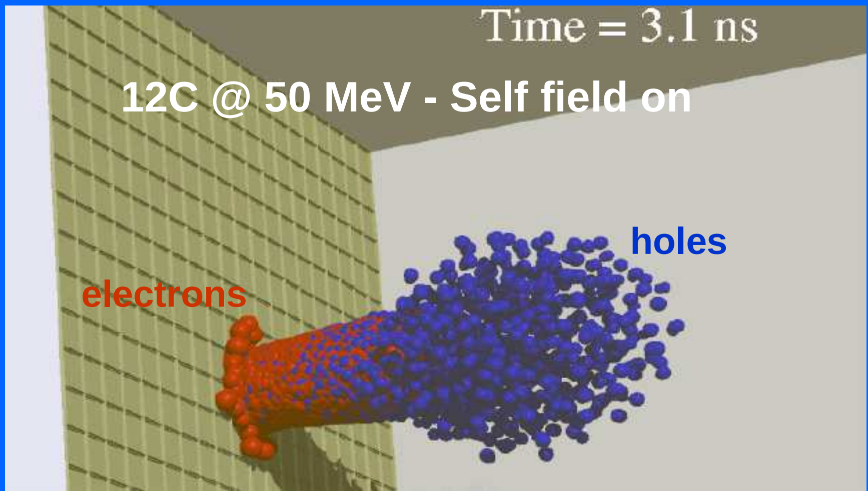
A and Z Identification

HEAVY-IONS COLLISIONS→IDENTIFY THE REACTION PRODUCTS

1) RANGE=f(E,A,Z)

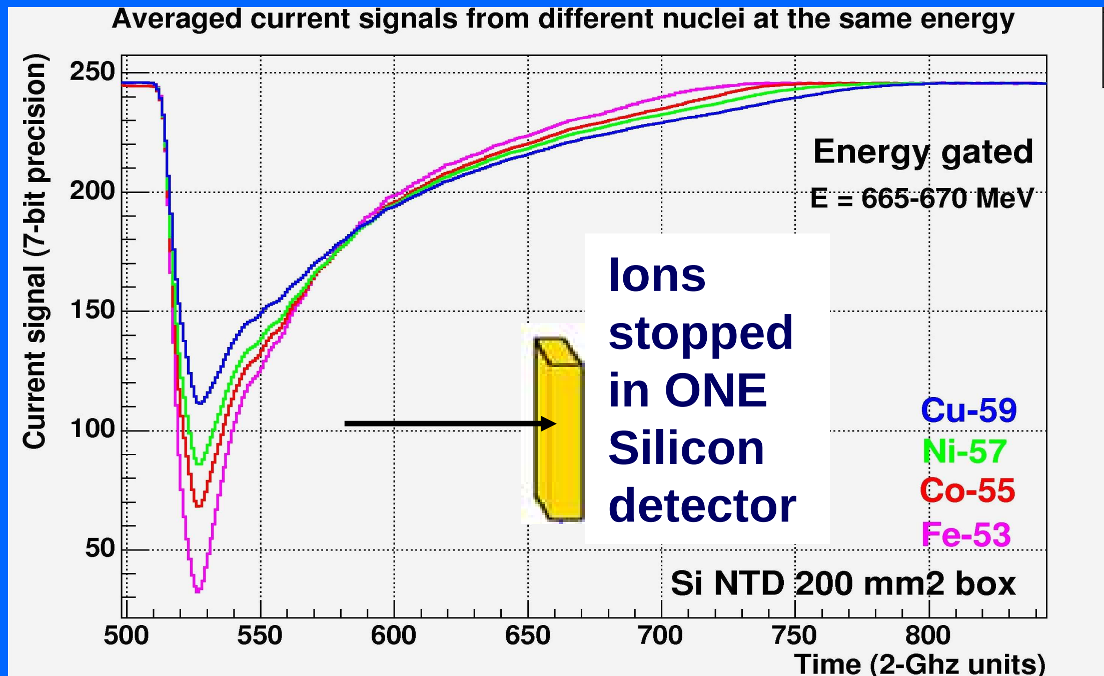
2) Plasma erosion process = f(E,A,Z)

USE THE DIGITIZED I-Q SIGNALS FOR (A,Z) IDENTIFICATION: "Pulse Shape Discrimination"



A simulated plasma column for ^{12}C @ 50 MeV

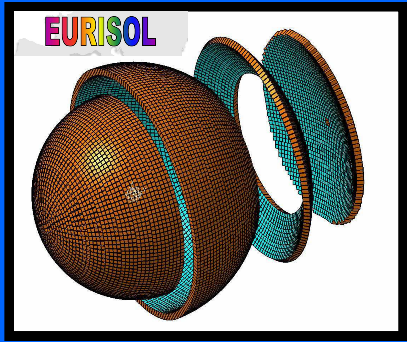
(L.Bardelli, FAZIA)



FAZIA DATA (GANIL)

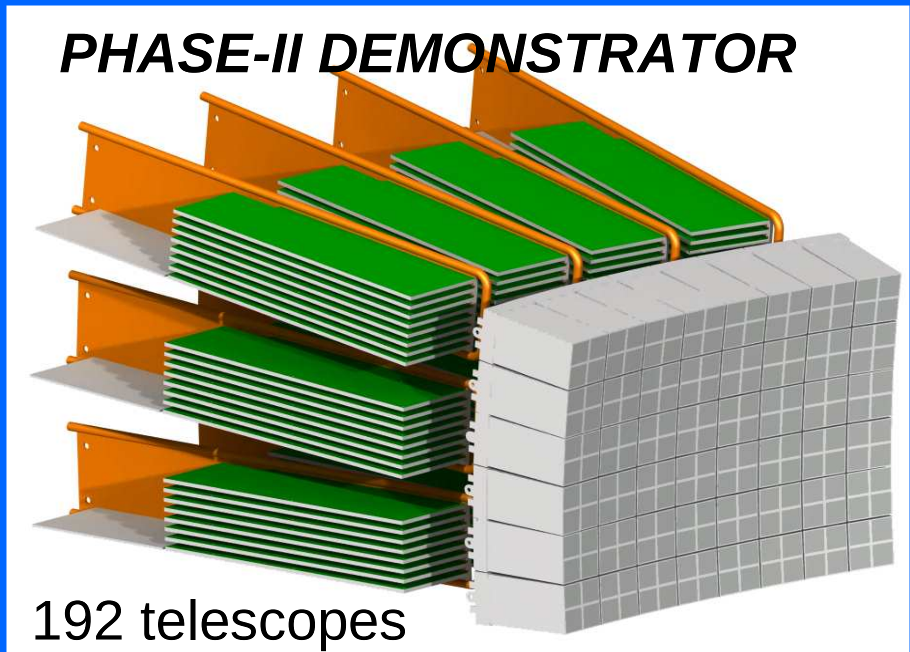
FAZIA collaboration

An R&D project supported by Spiral2PP and LEA.
It is aimed at designing a new-generation detector for charged particles, suited for Isospin Physics to be done *with n-poor and n-rich ions* at Radioactive Beam Facilities like Spiral2, SPES, Fribs (and EURISOL)



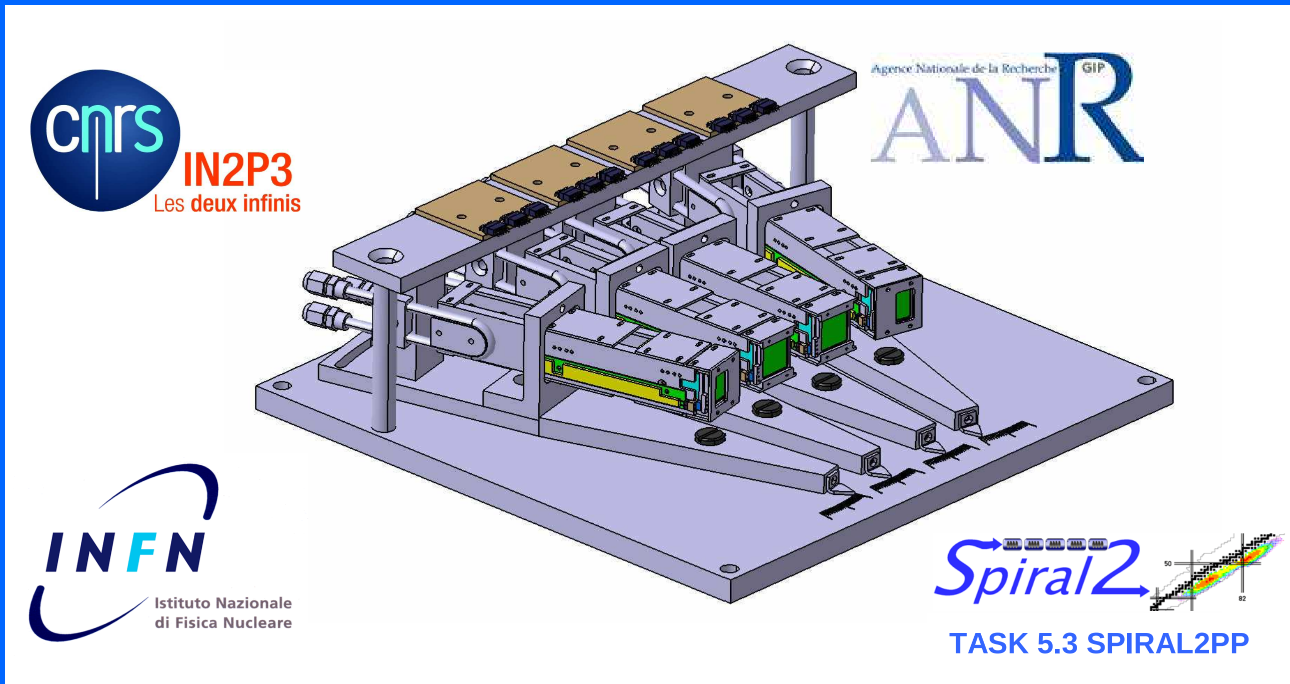
FAZIA Working Groups

1. **Modeling current signals and Pulse Shape Analysis**
2. **Physics cases**
3. **Front End Electronics**
4. **Acquisition**
5. **CsI(Tl) crystals**
6. **Single Chip Telescope**
7. **Design, Detector, Integration and Calibration**



FAZIA R&D

1) Experiments with single silicon-detector
   (Tandem-Orsay, LISE-GANIL)
2) Experiments with single silicon-detector
   & strip-detector
   (CIME/GANIL) & LNL (channeling & uniformity)
3) Prototypes (phase1)
   (LNL, LNS, Ganil)



+ nTD strip-detector

2006

GANIL-experiment

2007

LNL-experiment

2008

GANIL-experiment

2009

LNS-test

LNS-experiment

2010

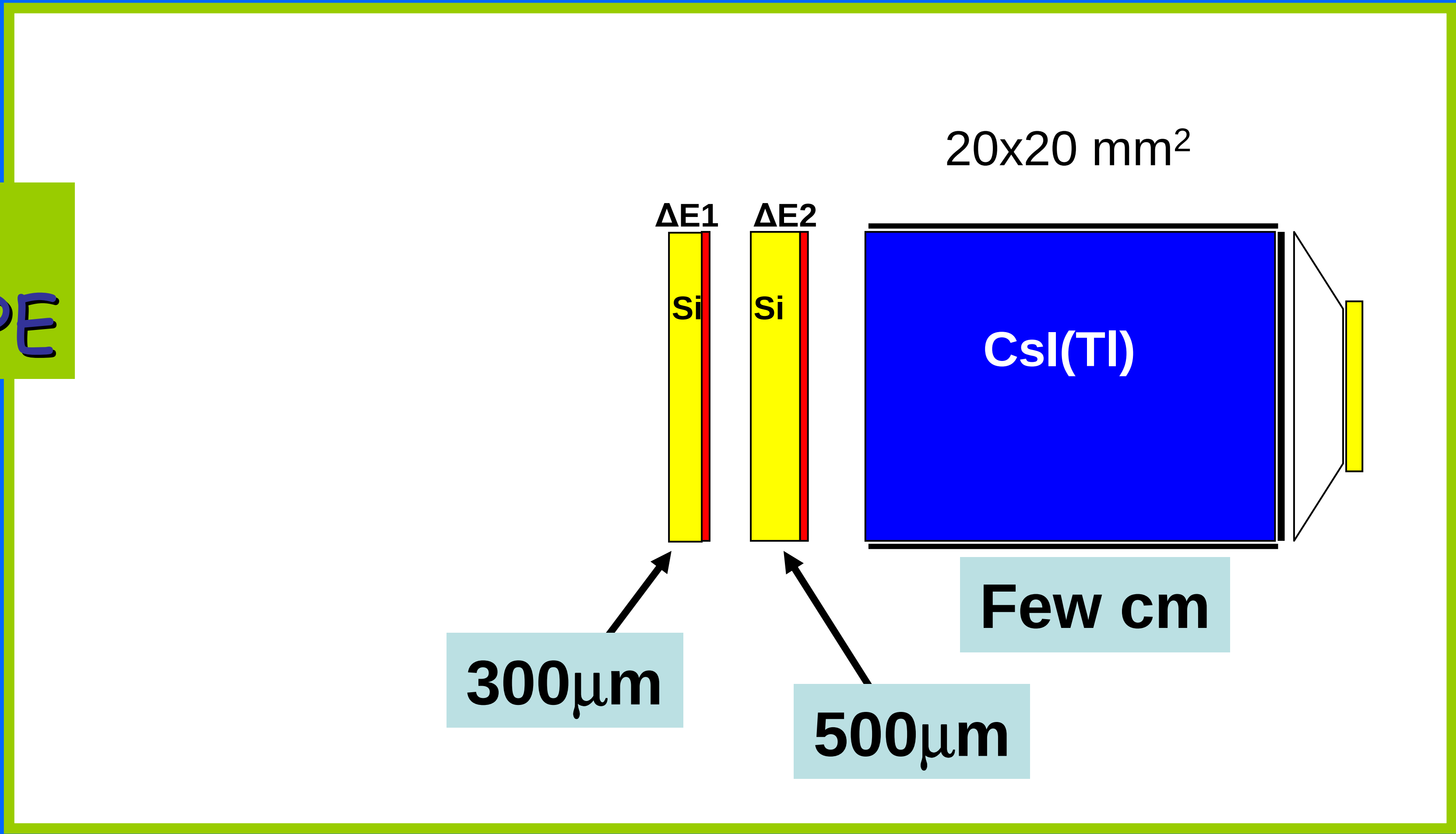
GANIL-experiment

2011

LNS-experiment

FAZIA detector

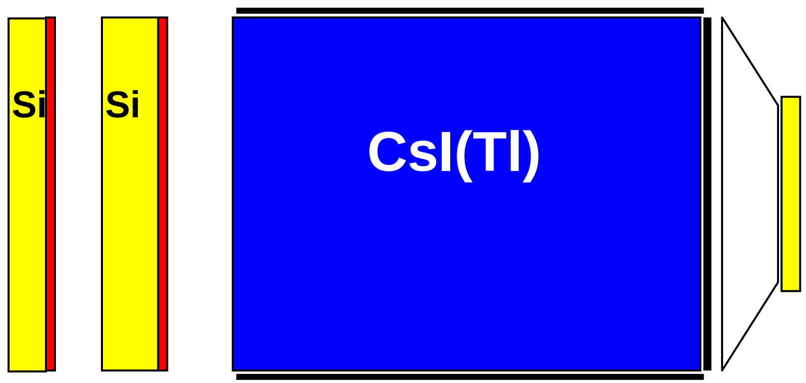
BASIC TELESCOPE

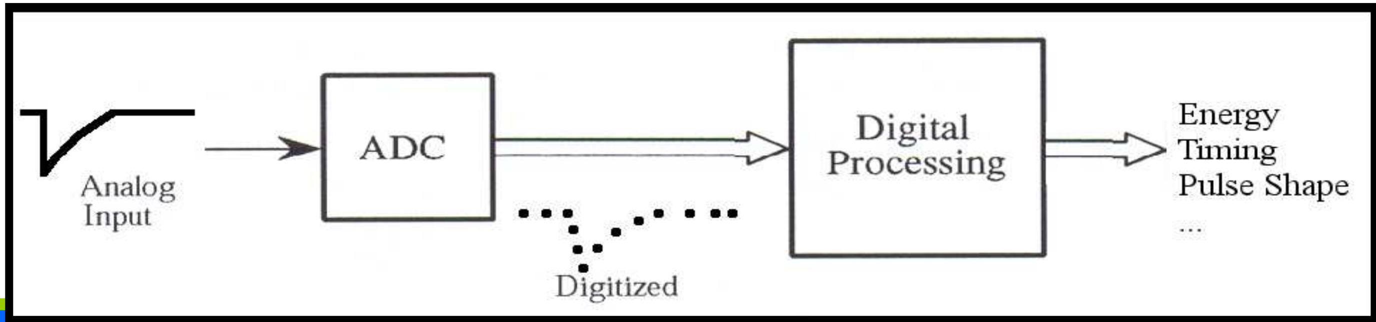


FAZIA detector

BASIC TELESCOPE

Identify ions with in one silicon detector
low id. Thresholds (digitized signals)

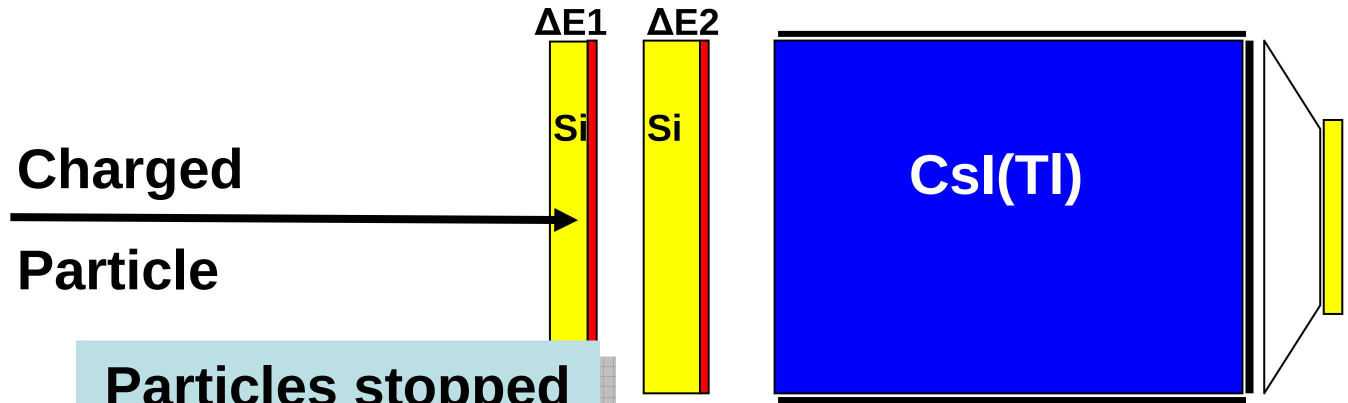




=> Special pre-amp. PACI with double outputs Q and I: *P. Edelbruck* et al. Orsay

FAZIA detector

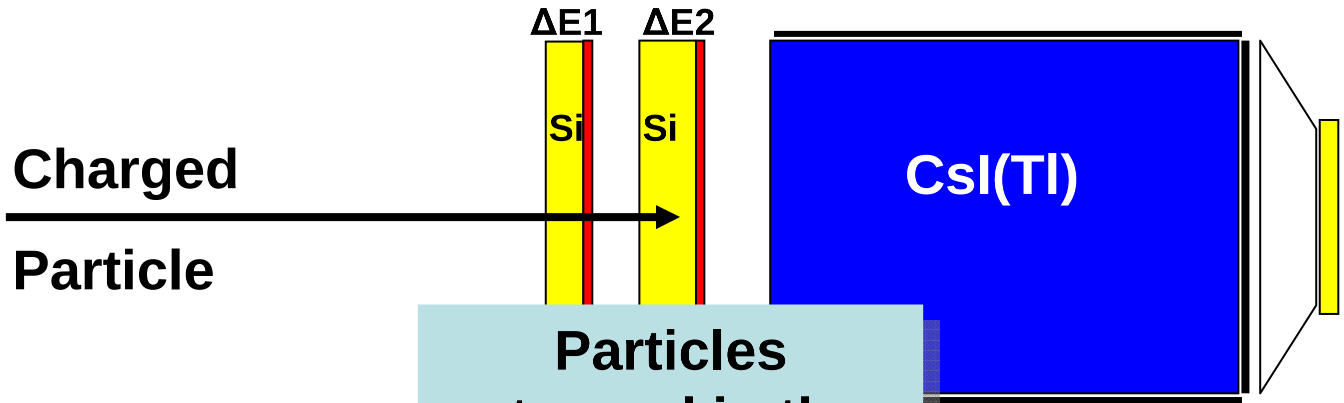
BASIC TELESCOPE



Particles stopped in the first *nTD* Silicon: Z and A identification by means of Digital Pulse Shape and Time of Flight

FAZIA detector

BASIC TELESCOPE

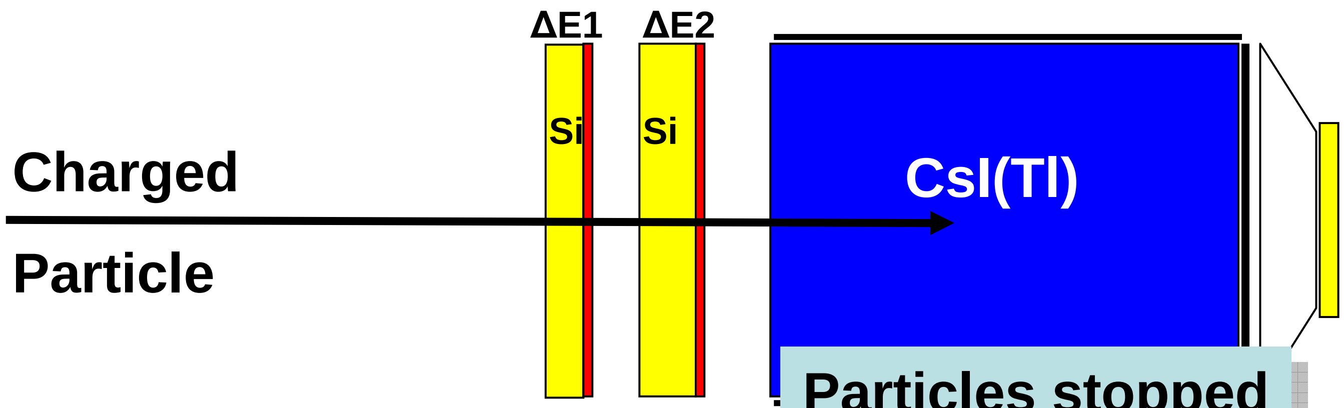


Particles stopped in the second Silicon: Z and A Digital Pulse Shape (E_2)

+redundant identification by means of ΔE_1-E_2

FAZIA detector

BASIC TELESCOPE



Particles stopped in CsI(Tl): Z and A identification by means of $\Delta E_2(+\Delta E_1)$-ECsI and Pulse Shape in CsI(Tl)

FAZIA PhaseI-R&D

RECIPE FOR HIGH QUALITY CHIPS

1 – DOPING UNIFORMITY

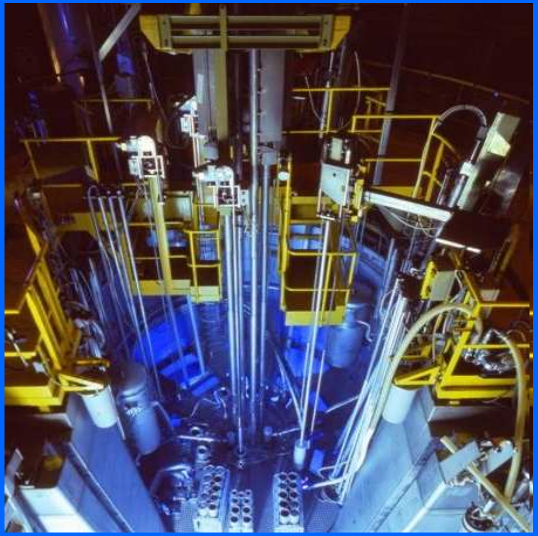
Ingot selection from the producer, controlled doping (at about ρ=3000 ohm.cm) and use of nTD technology for best uniformity

2 – AVOID (as far as possible) CHANNELING

Ingot orientation and choice of the cut along special 'random' directions (7deg to <100>); slices of 300 and 500 microns

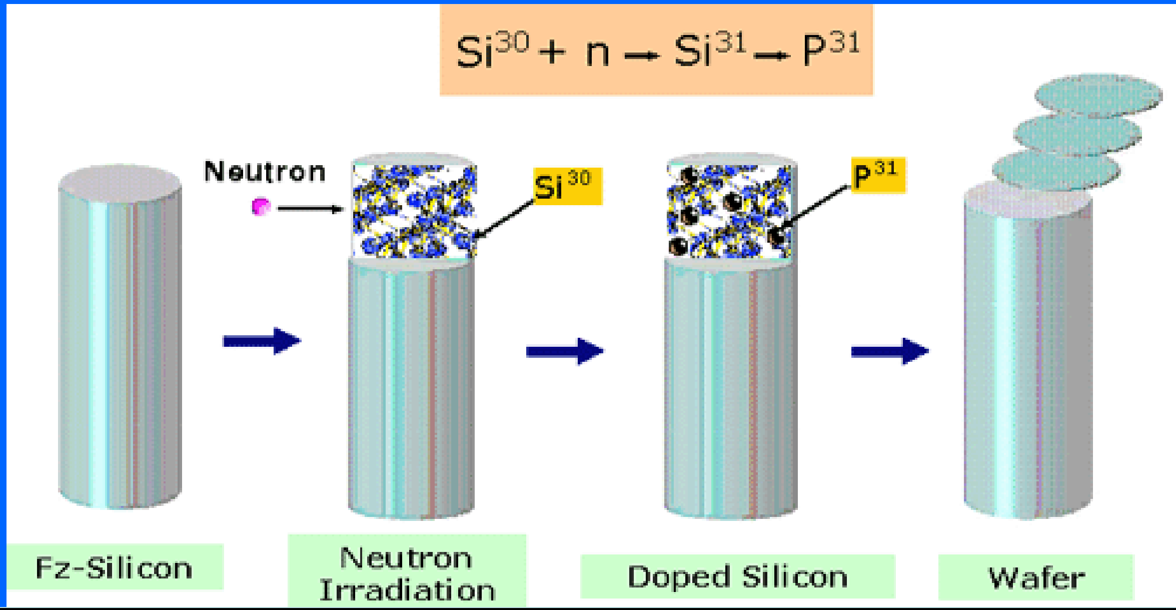
FAZIA PhaseI-R&D

DOPING UNIFORMITY



FAZIA PhaseI-R&D

Beyond ΔE-E: Z and A Identification with Pulse Shape
Doping uniformity: nTD-silicon detector



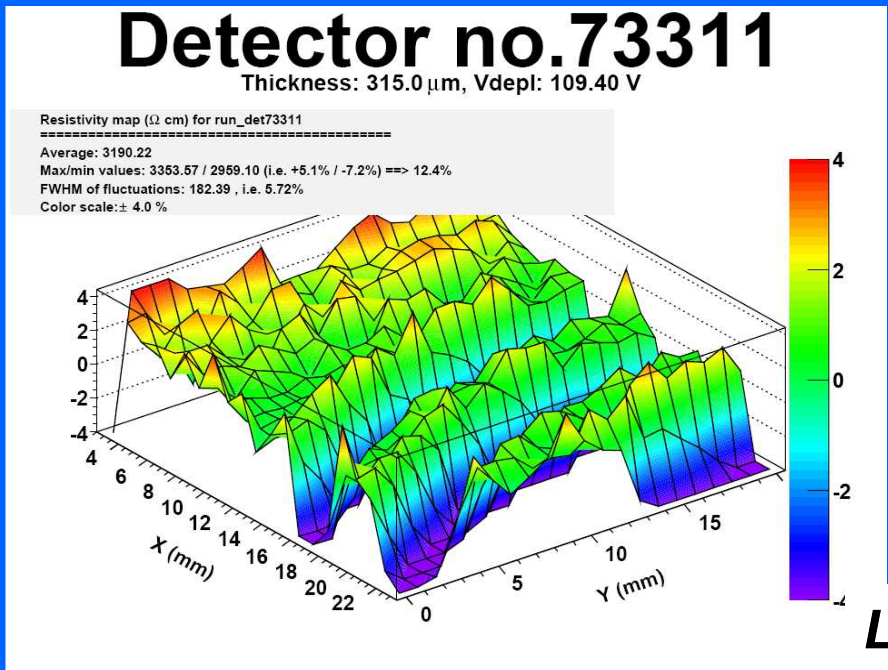
Isotope	abundance	Neutron capture	Cross section
28Si	92.3%	28Si(n,γ)29Si	0.08 b
29Si	4.7%	29Si(n,γ)30Si	0.28 b
30Si	3.1%	30Si(n,γ)31Si ⇨by beta decay (2.62 hrs)⇨ 31P	0.11 b

Regular Silicon: +/- 15% uniformity – nTD silicon: below +/- 5%

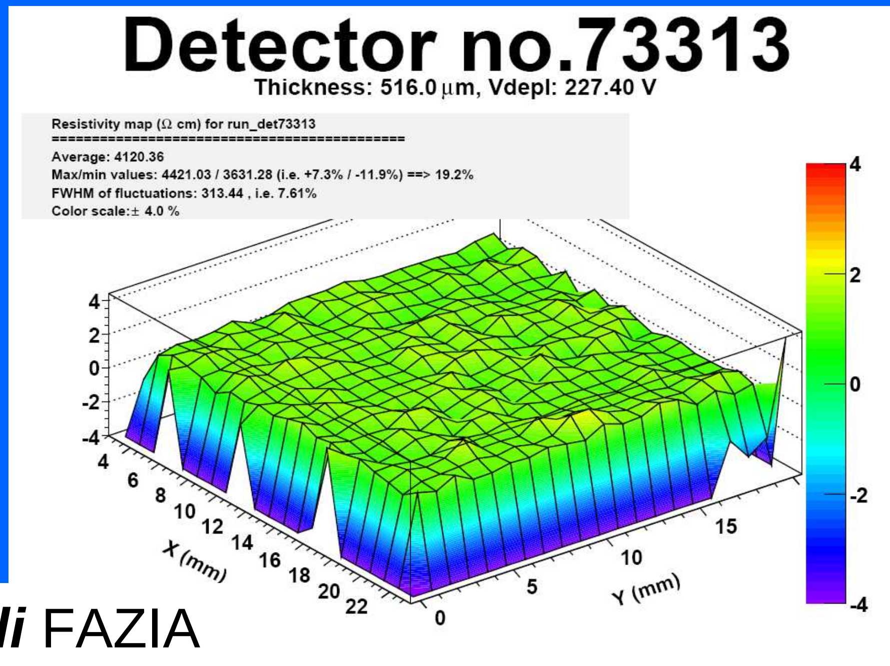
FAZIA PhaseI-R&D

non-homogeneity in the electric field inside the detector (doping) may have a severe impact over the Pulse Shape Discrimination capabilities:

A typical detector: ~9% non-uniformity



A <u>very good</u> detector: ~1% non-uniformity



L. Bardelli FAZIA

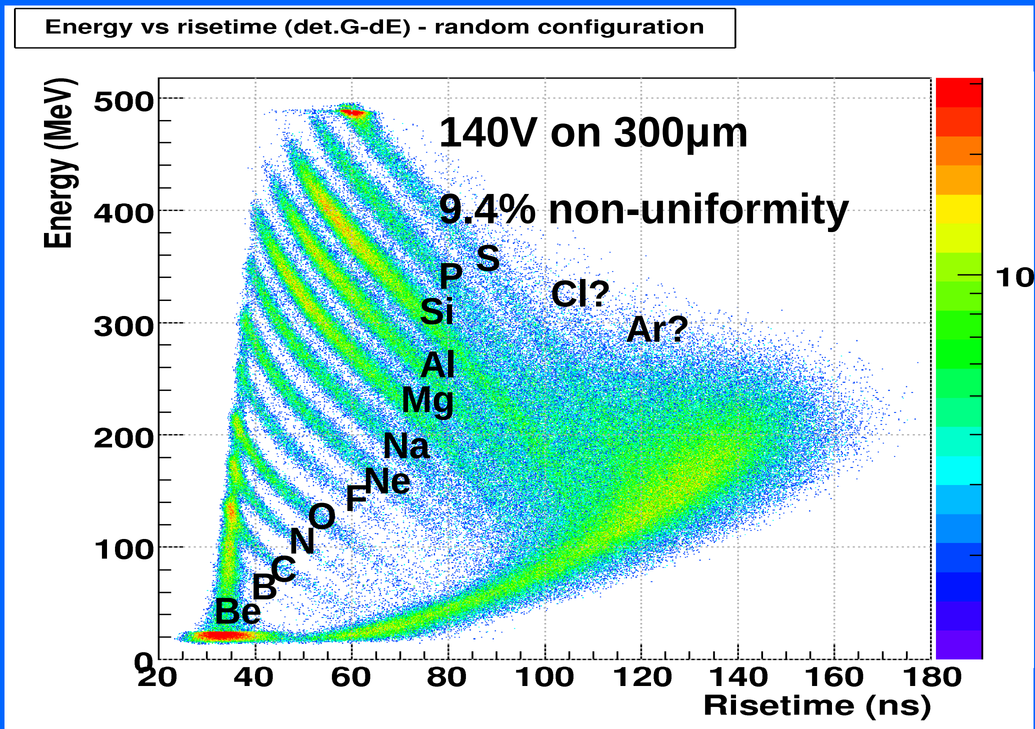
IMPROVEMENT IN DOPING UNIFORMITY

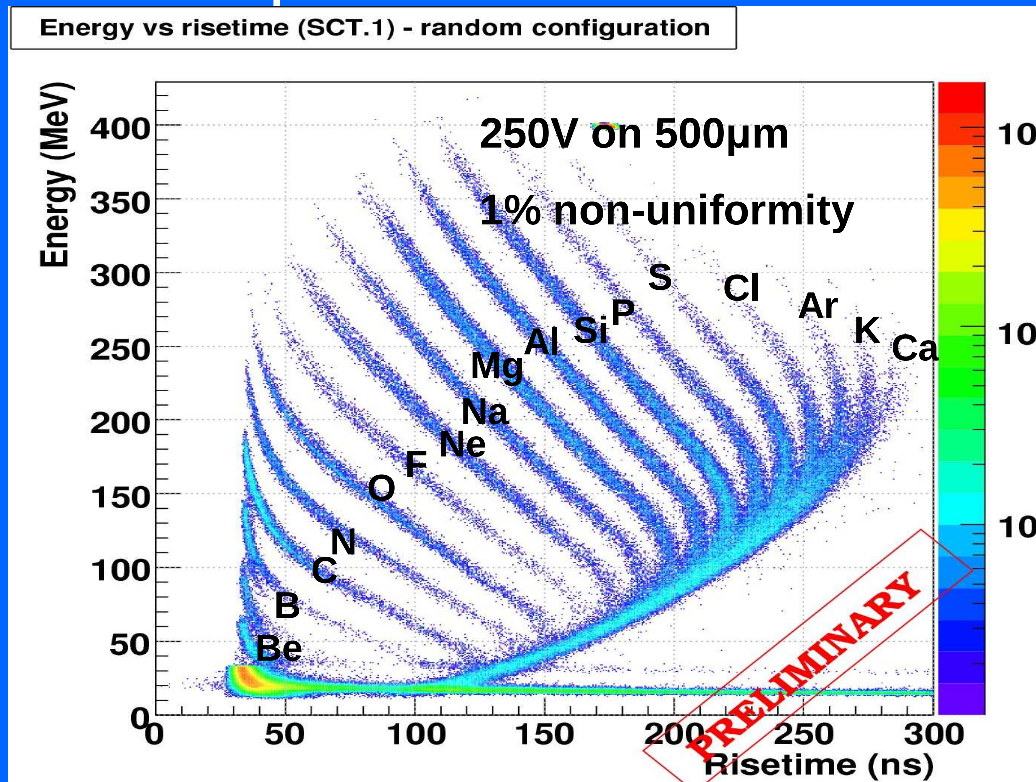
FAZIA data (INFN-Firenze)

FAZIA PhaseI-R&D

Beyond ΔE-E: Z and A Identification with Pulse Shape
Doping uniformity: nTD-silicon detector

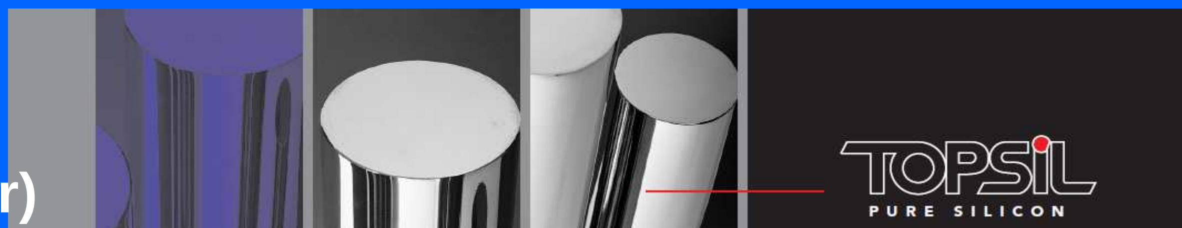
DIGITAL PULSE SHAPE on 500μm and 300μm Silicons with similar field and different doping non-uniformities: 300μm: ~ 4 GeV full scale 500μm: ~ 4 GeV full scale



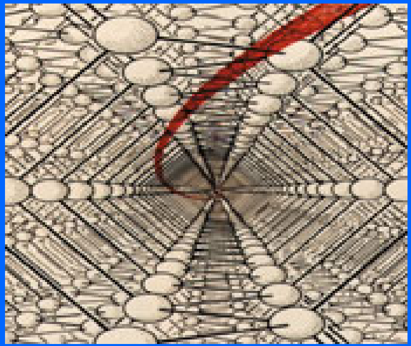


+/- 5% is not enough PSId. needs +/- 0.5%

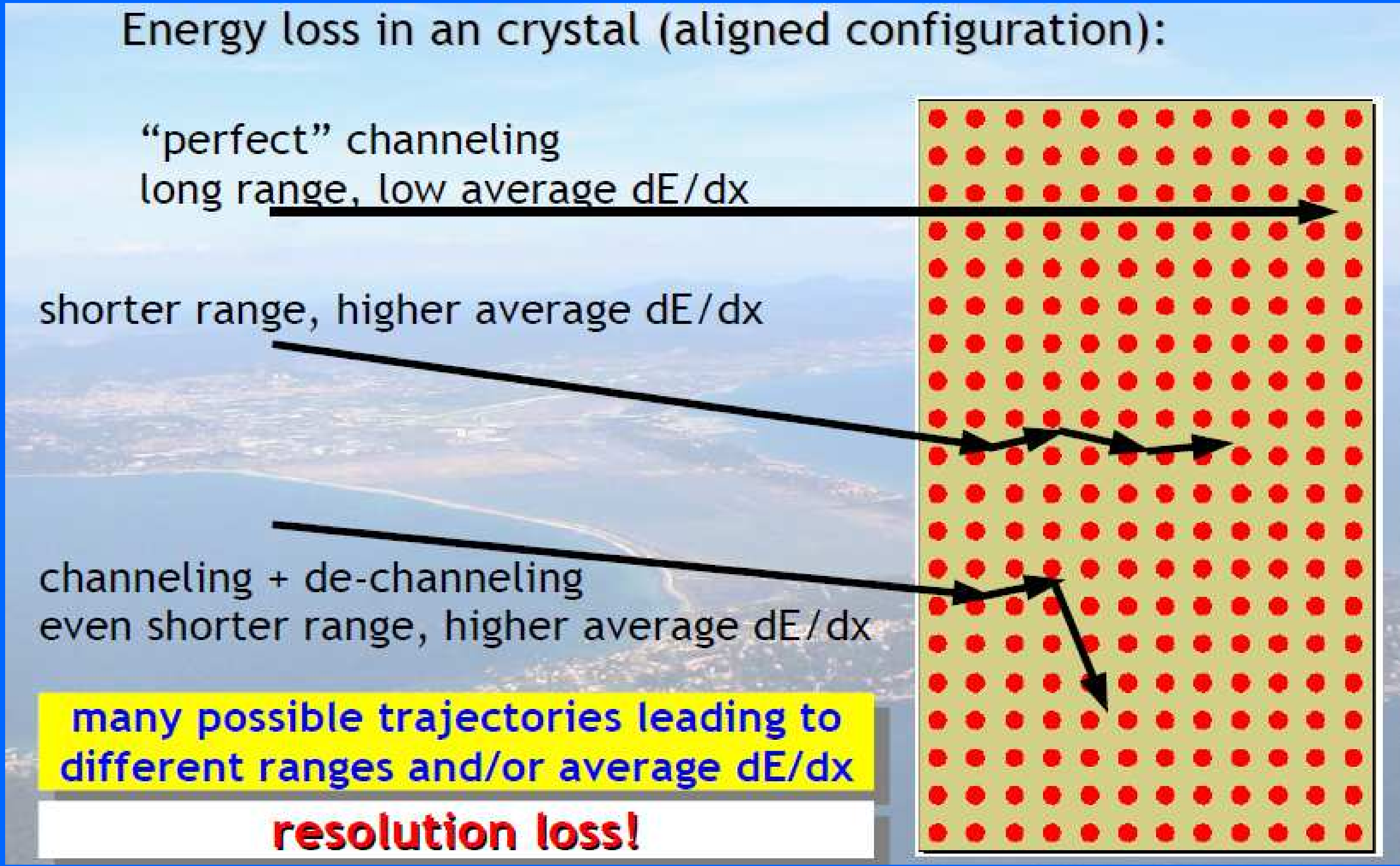
It is possible (work with manufacturer)



FAZIA PhaseI-R&D



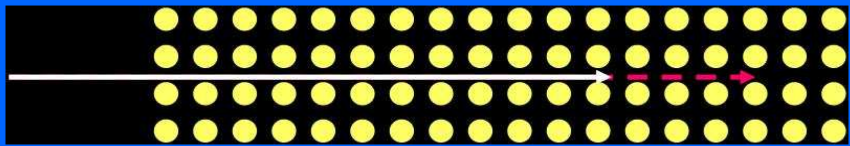
CHANNELING

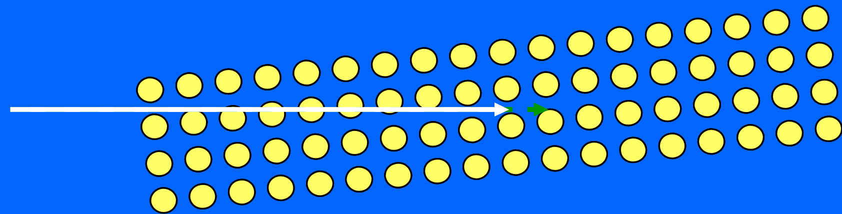


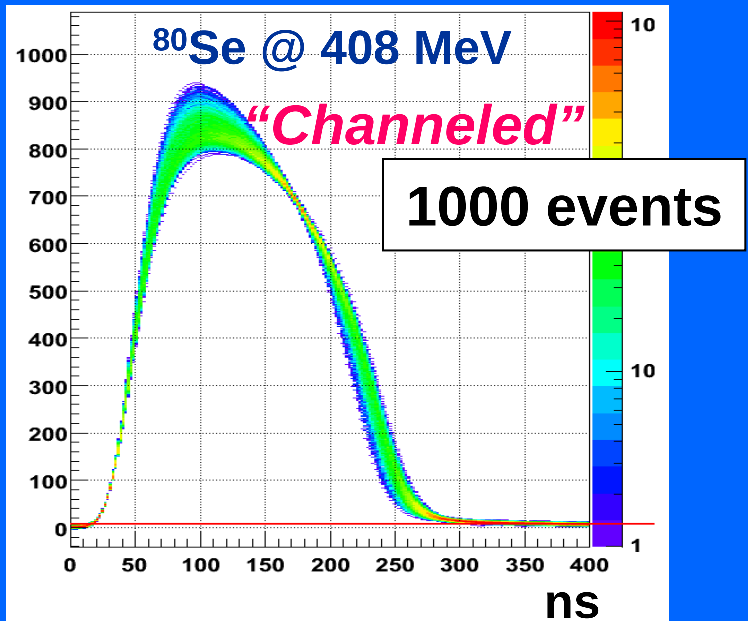
FAZIA PhaseI-R&D

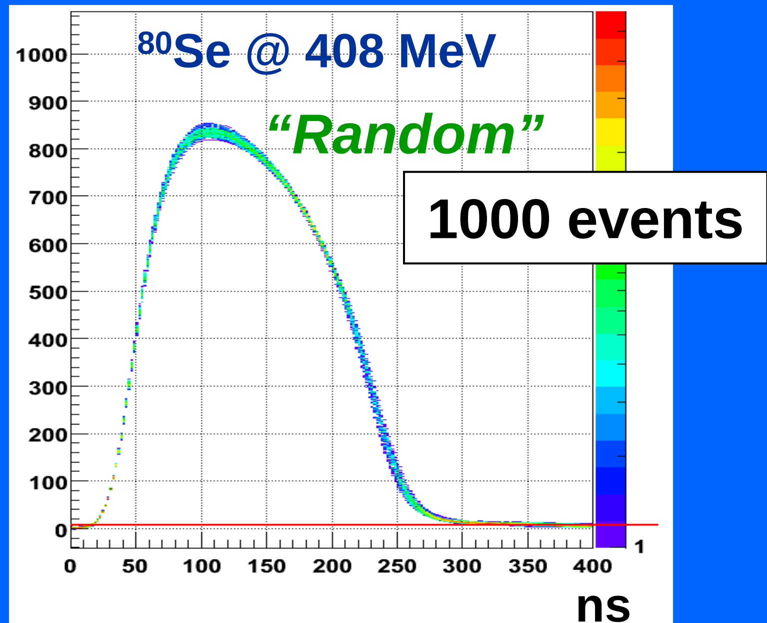
“Channeled”

“Random”





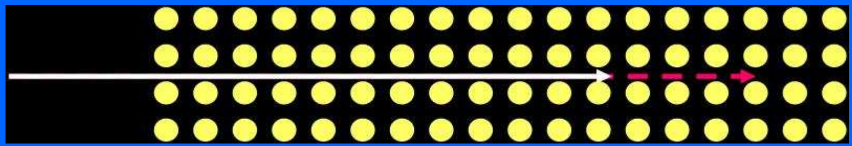


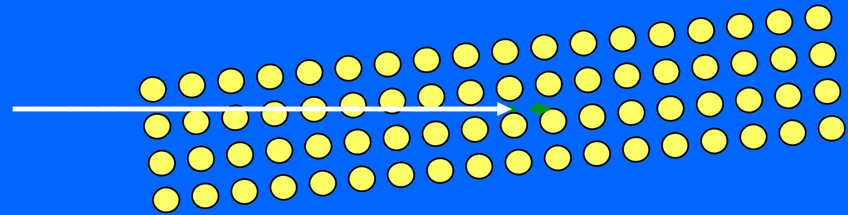


IMPROVEMENT IN SIGNAL DISPERSION

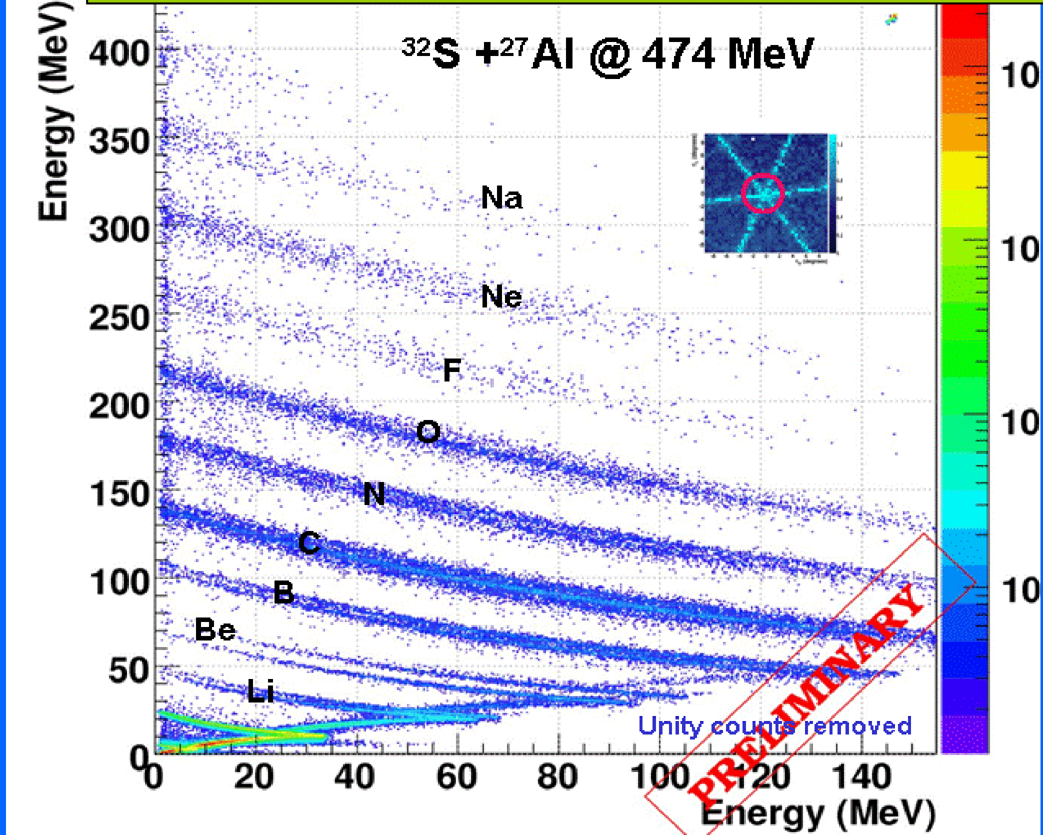
FAZIA data (LNL)

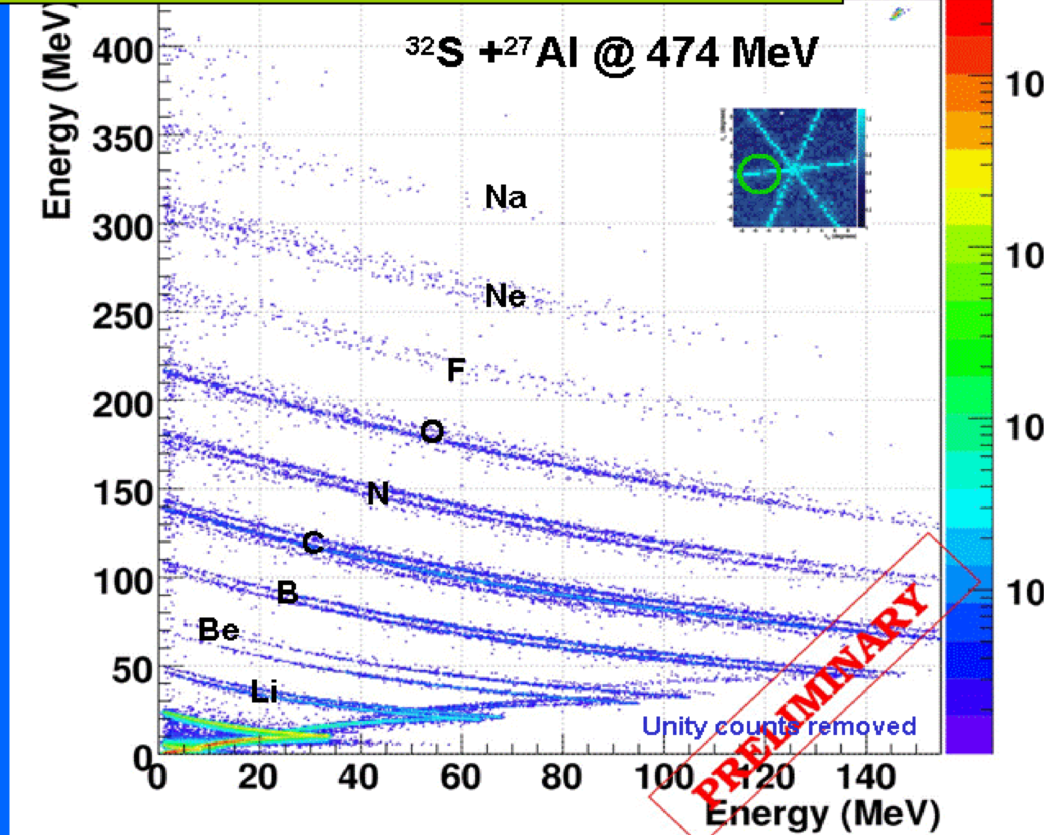
FAZIA PhaseI-R&D





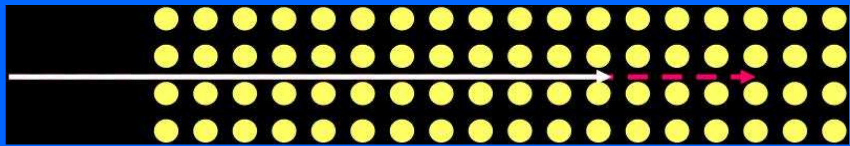
IONS IDENTIFIED WITH TWO DETECTORS: USUAL ΔE/E-plot

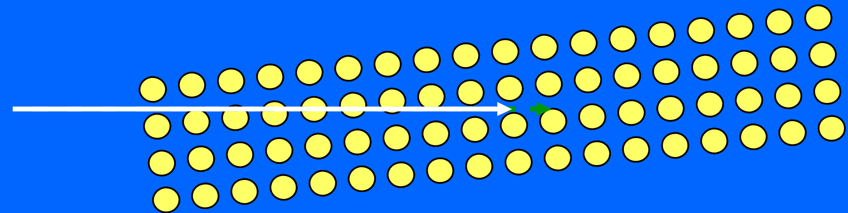




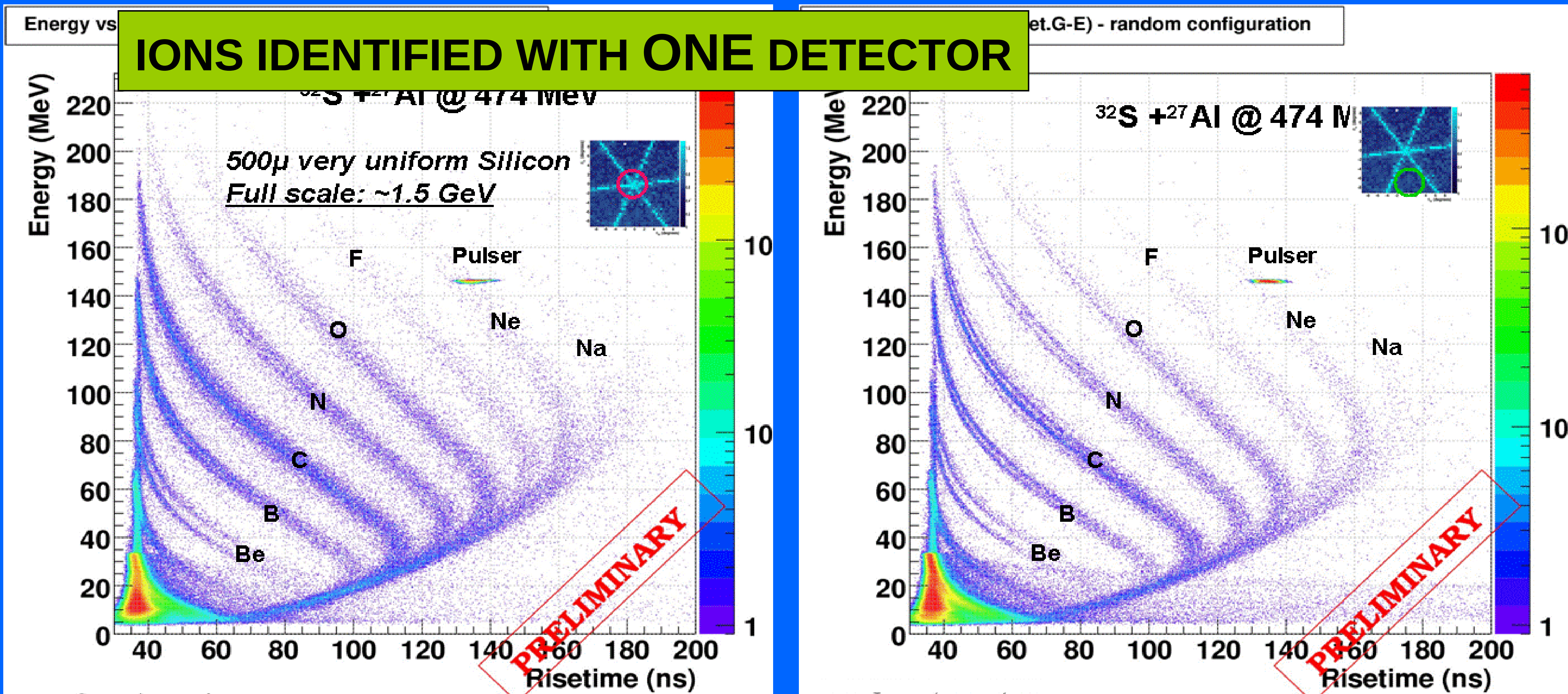
LNL-Experiment

FAZIA PhaseI-R&D



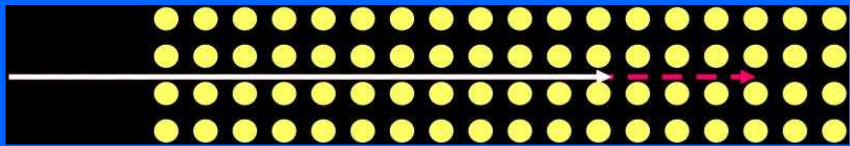


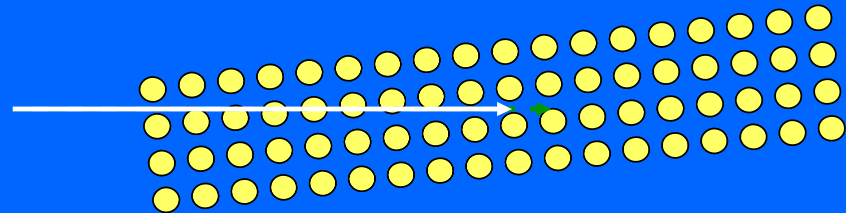
IONS IDENTIFIED WITH ONE DETECTOR



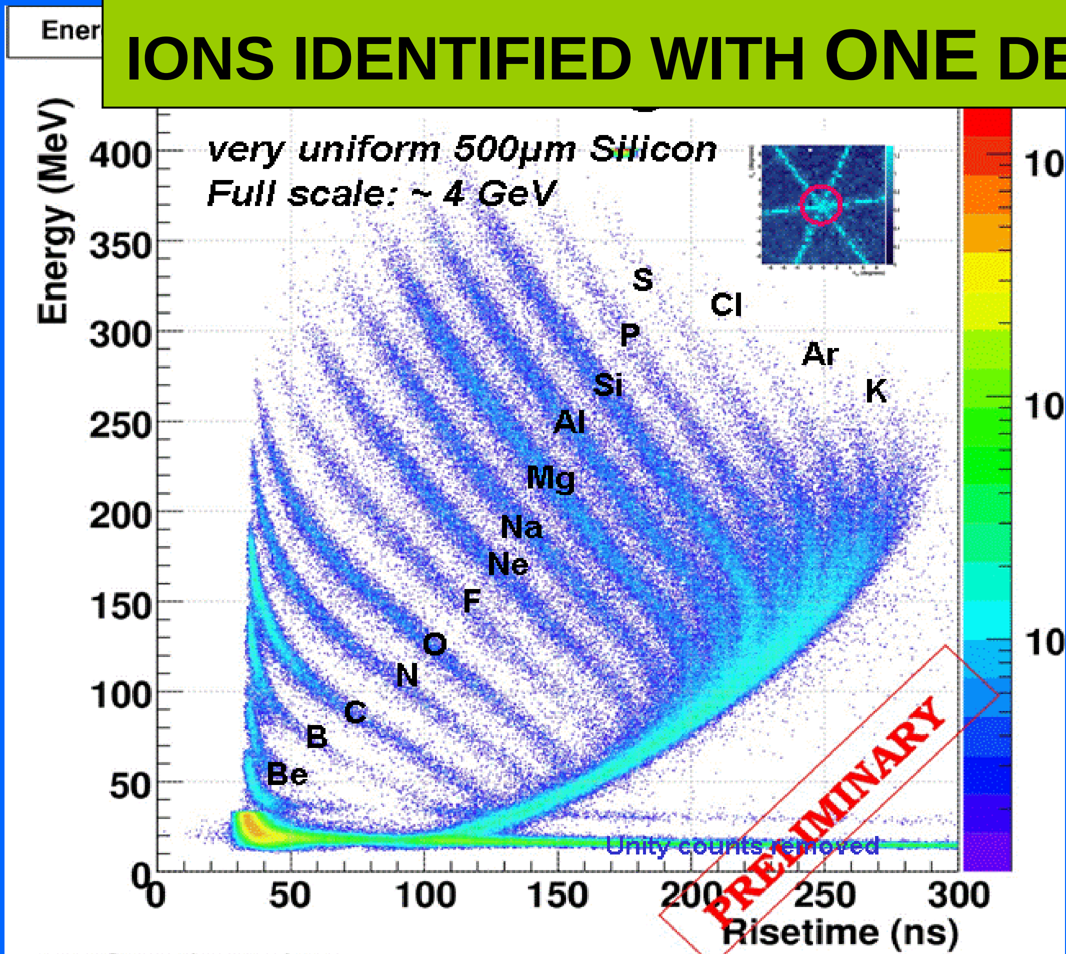
LNL-Experiment

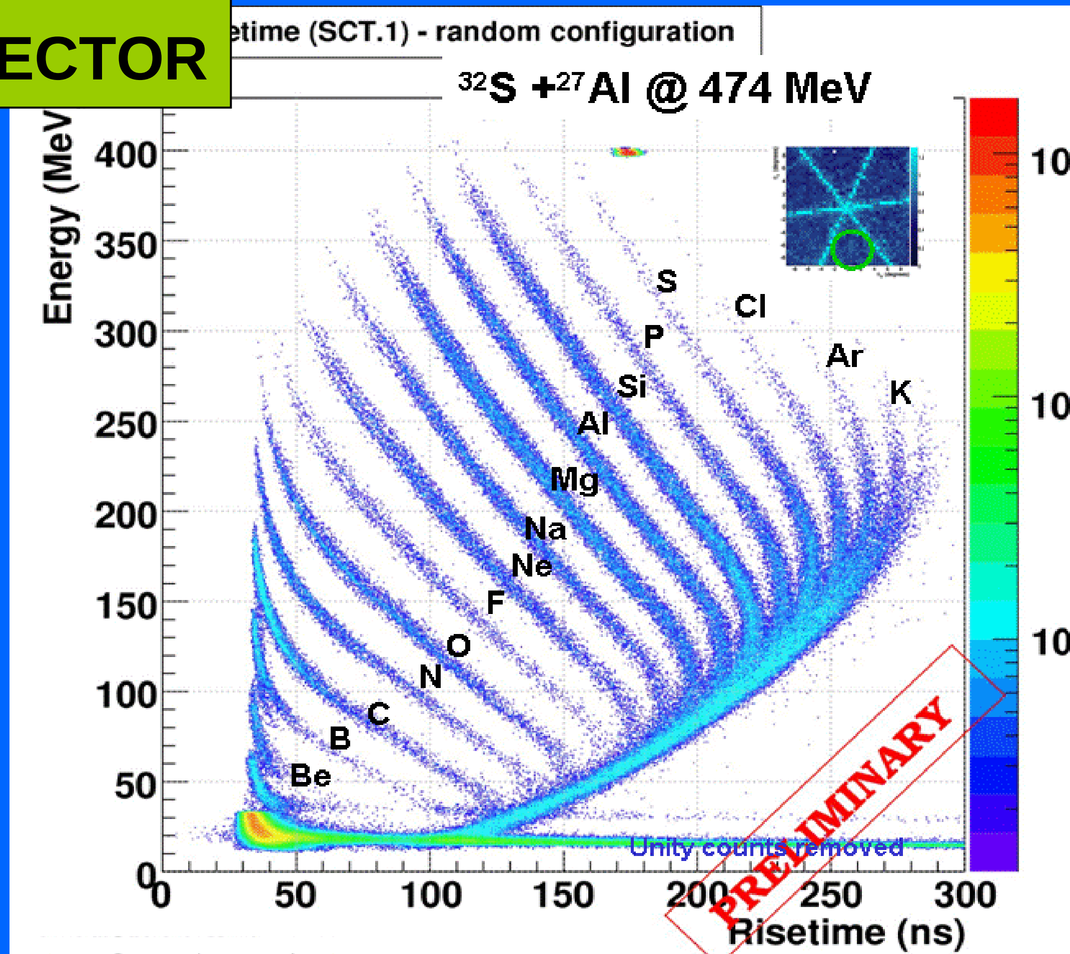
FAZIA PhaseI-R&D





IONS IDENTIFIED WITH ONE DETECTOR





LNL-Experiment

FAZIA PhaseI-R&D

RECIPE FOR HIGH QUALITY CHIPS

1 – DOPING UNIFORMITY

Ingot selection from the producer, controll... ping (at about ρ=3000 ohm.cm) and use of nT... chnology for best uniformity

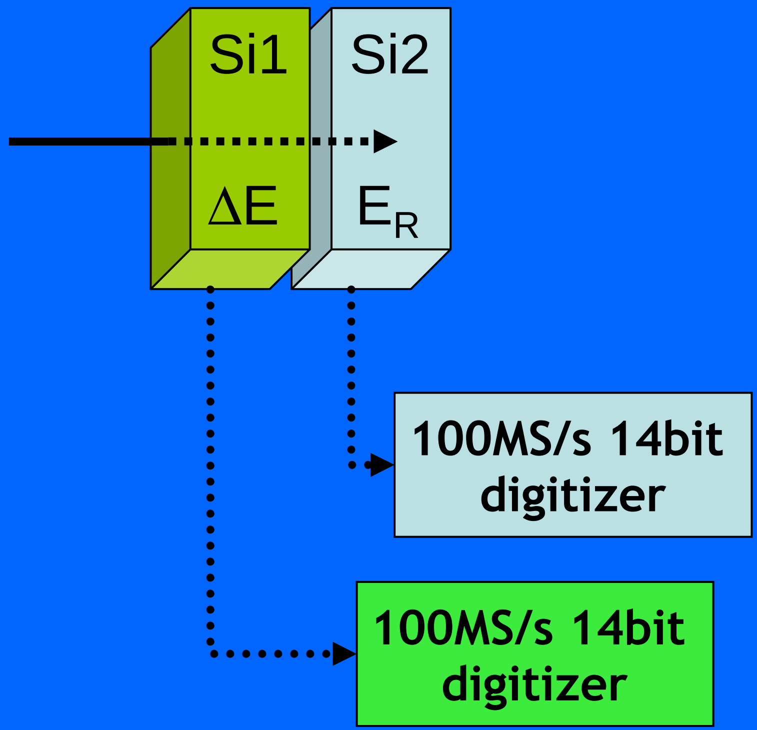
2 – AVOID CHANNELING

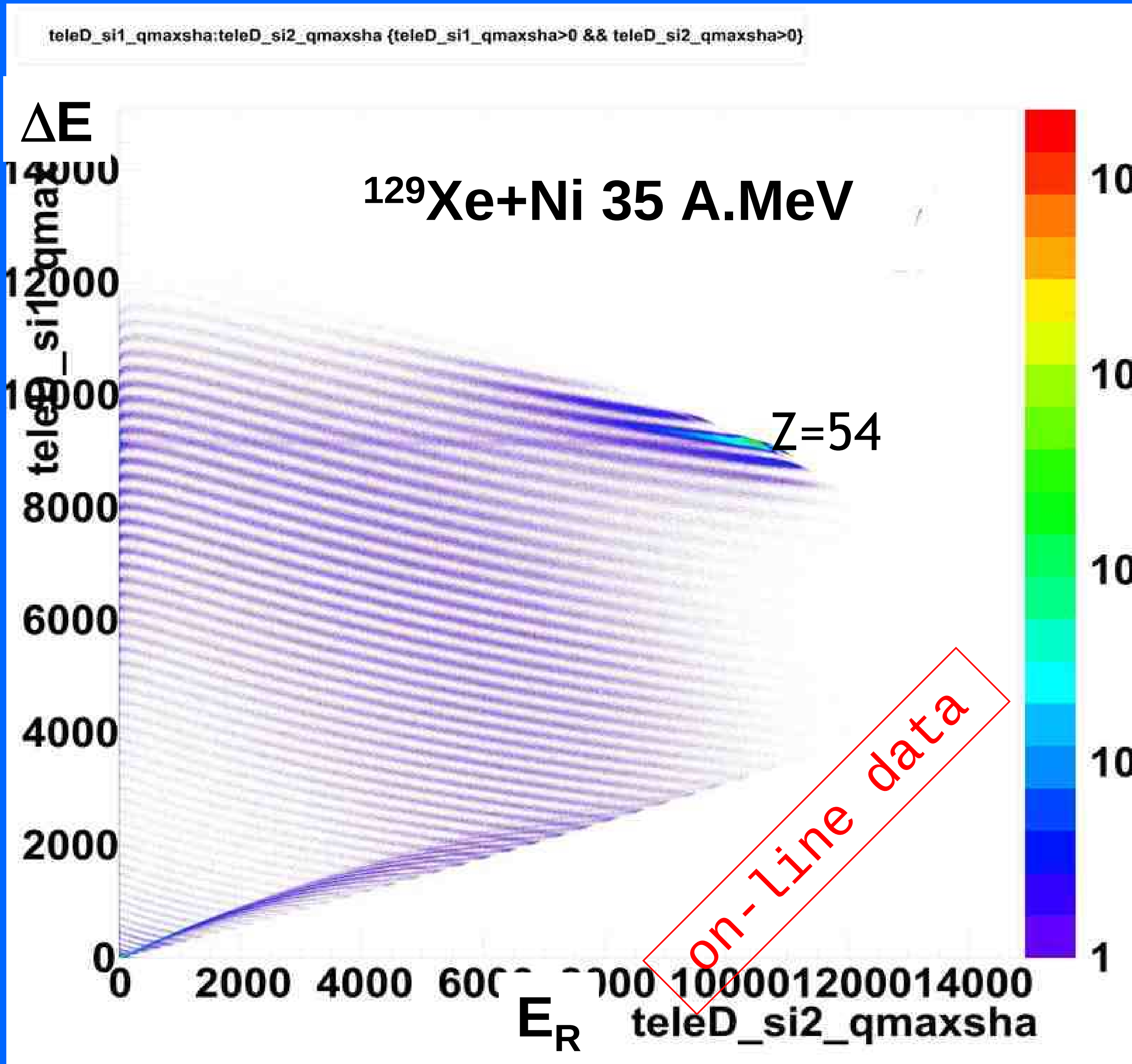
Ingot orient... nd choice of the cut along special 'random ... ections (7deg to <100>); slices of 300 and 500 mi...

IN THE FOLLOWING THE RECIPE HAS BEEN APPLIED

FAZIA PhaseI-R&D

Usual DE/E technique

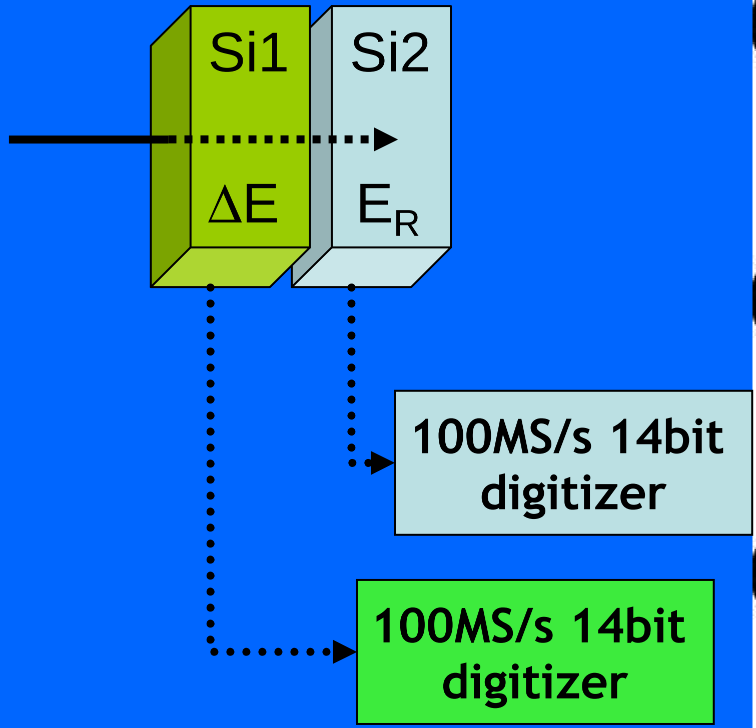




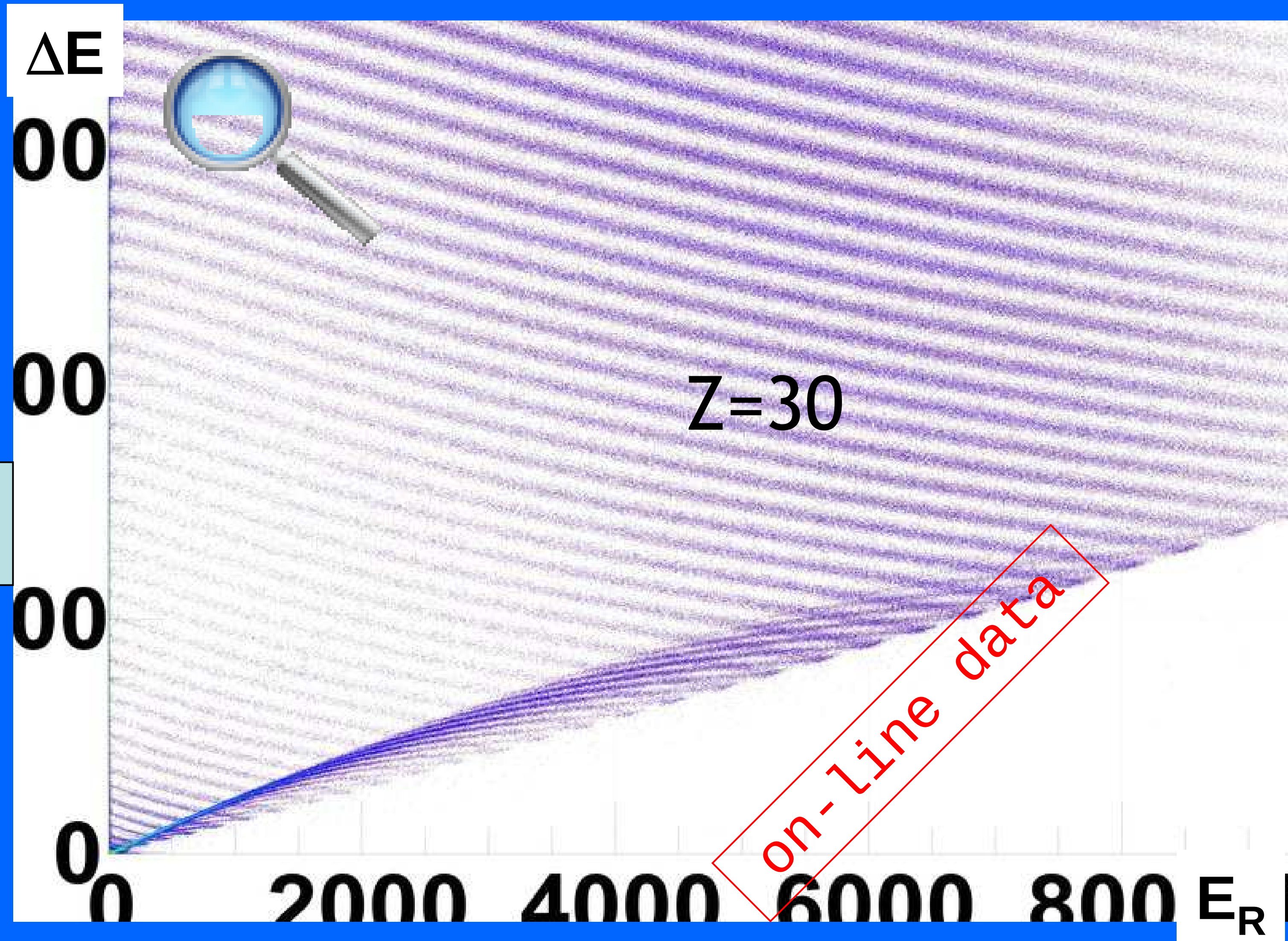
FAZIA data (LNS)

FAZIA PhaseI-R&D

Usual DE/E technique



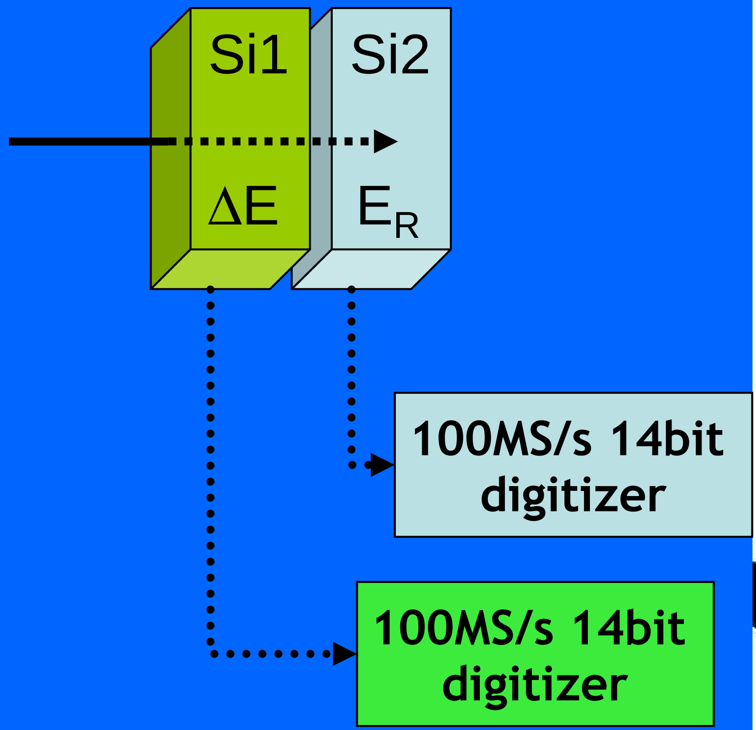
ZOOM



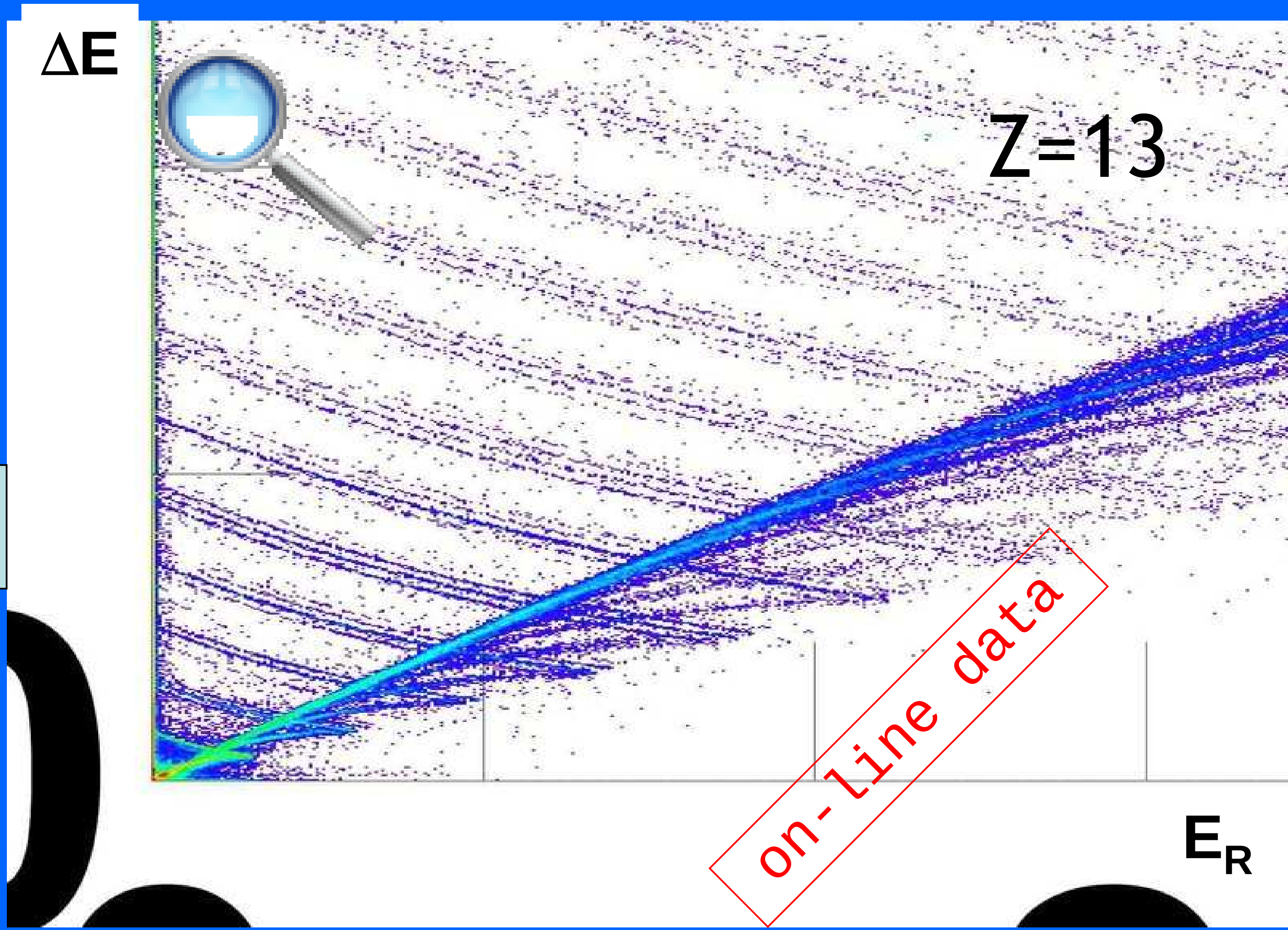
FAZIA data (LNS)

FAZIA PhaseI-R&D

Usual DE/E technique



ZOOM (again)

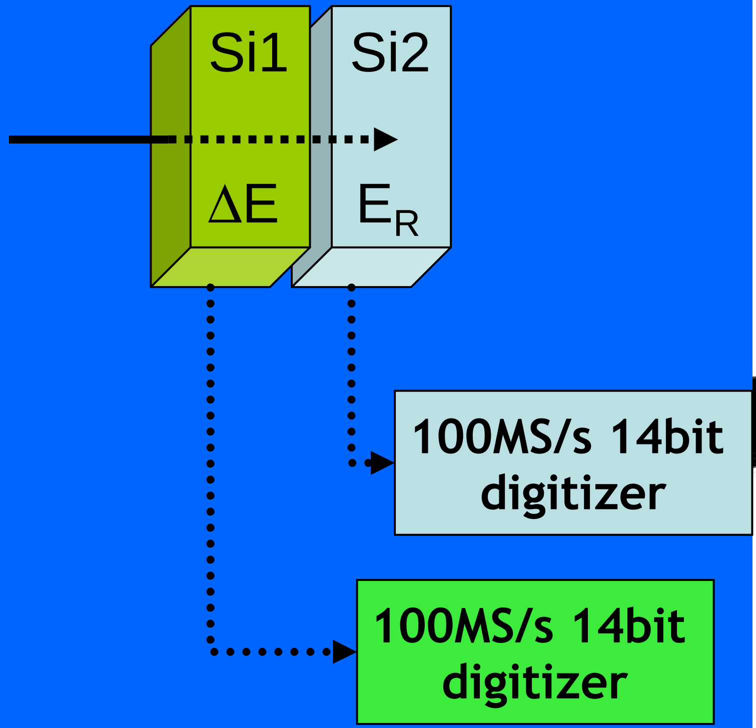


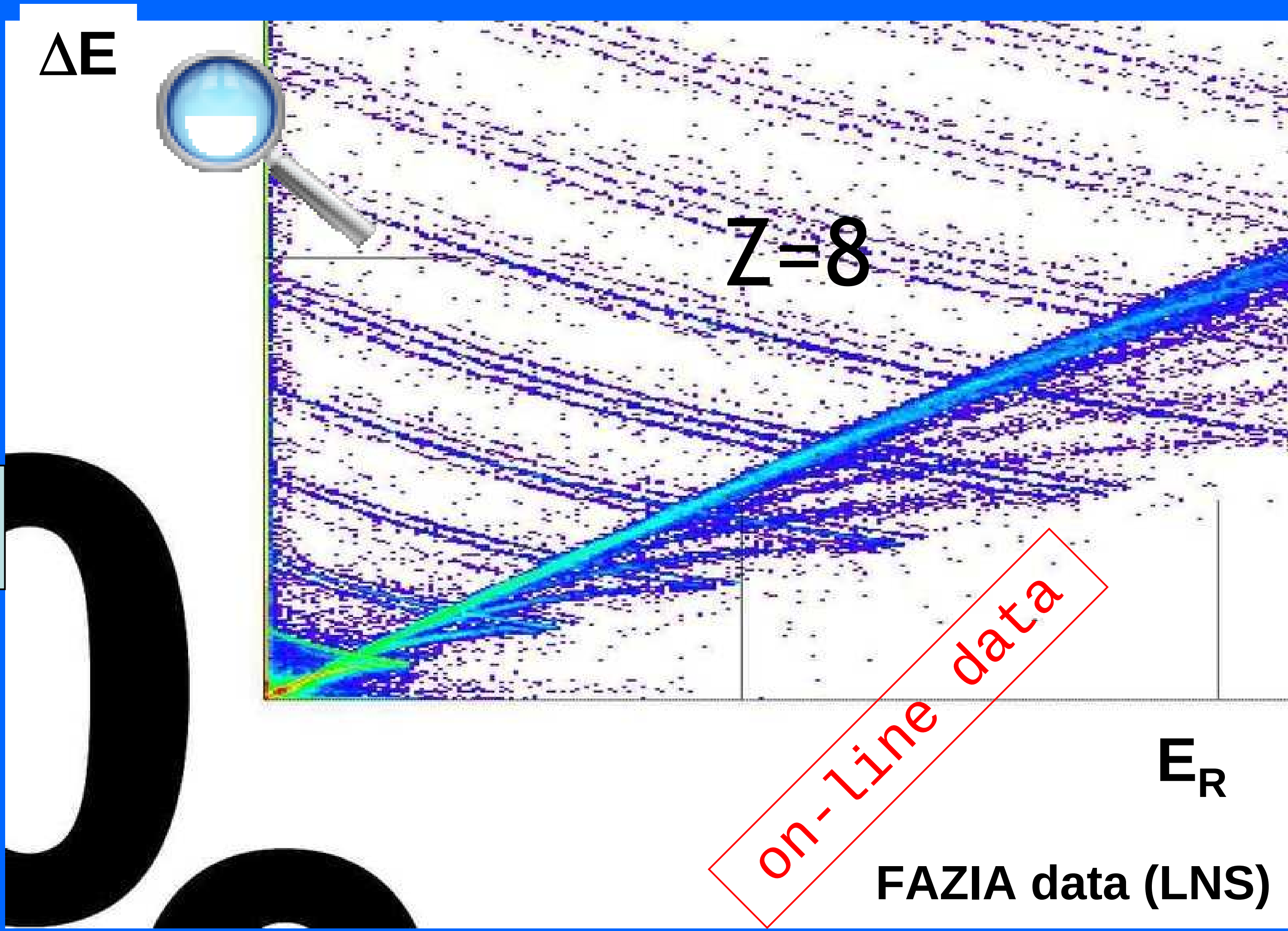
FAZIA data (LNS)

FAZIA PhaseI-R&D

Usual DE/E technique

ZOOM (again and again)



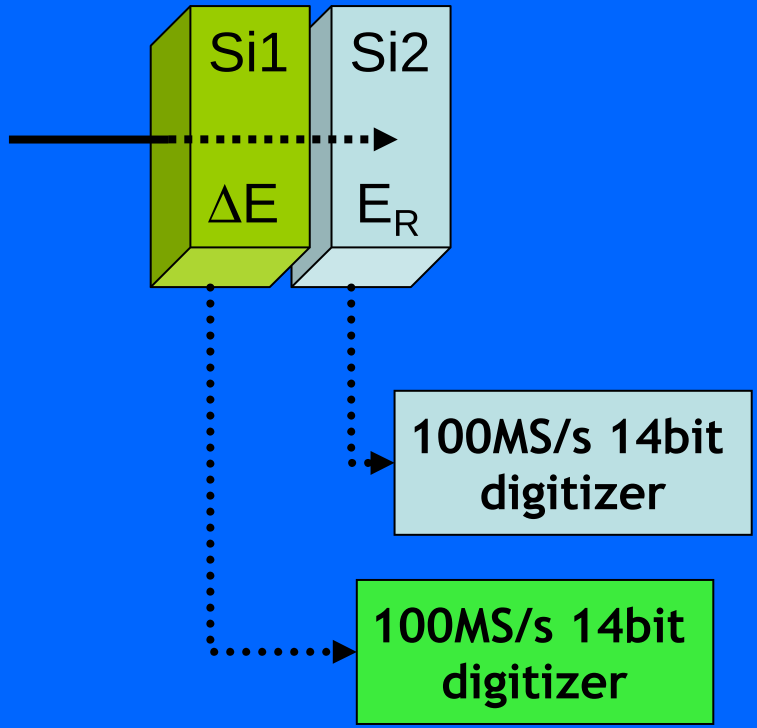


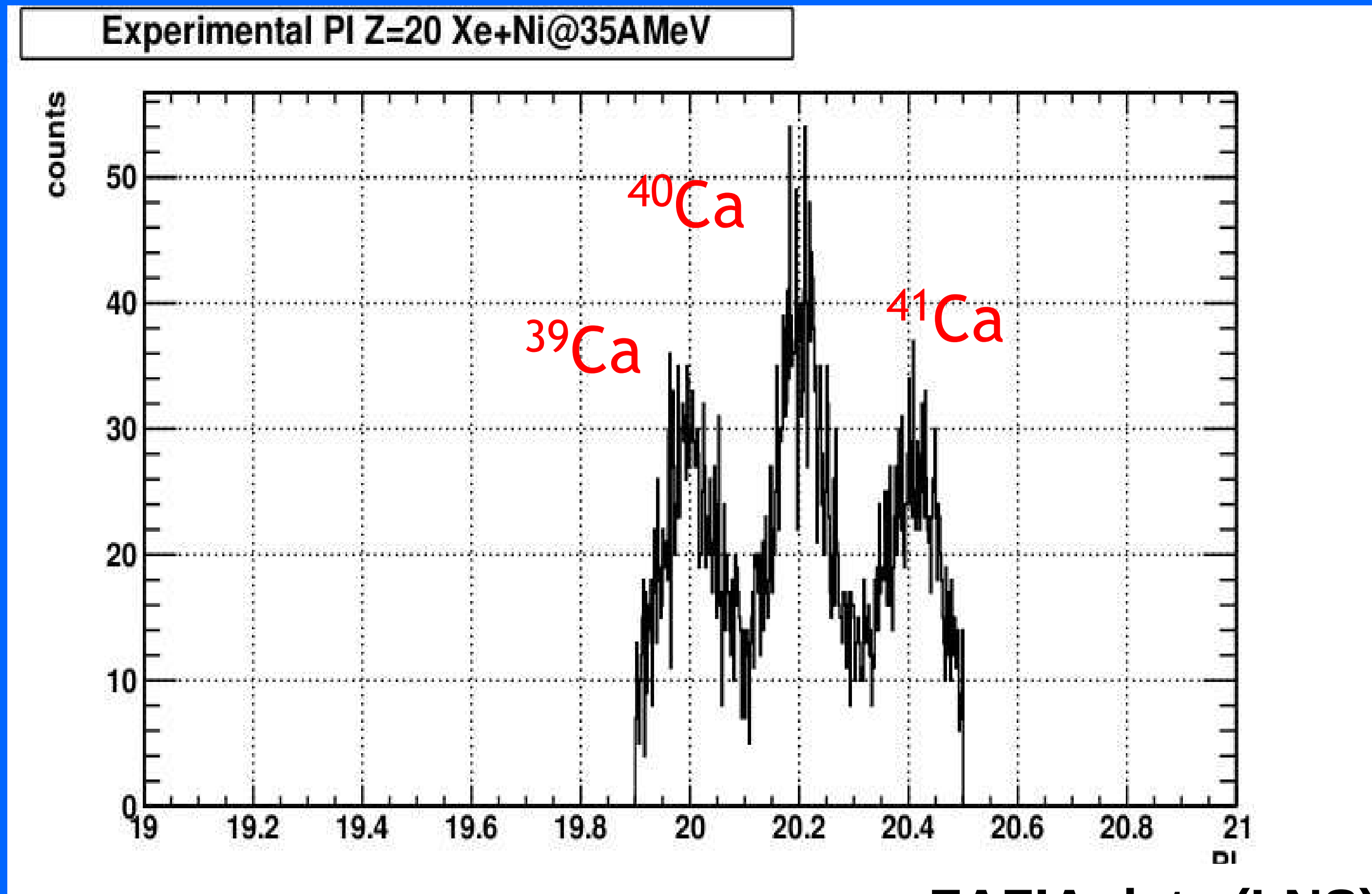
Used configuration:
isotopic identification up to Z~25 with ~5GeV full range

FAZIA PhaseI-R&D

Usual DE/E technique

Particle Identification (PID): experimental results obtained by linearizing the three higher intensity Ca isotopes – whole examined Er range (KaliVeda/INDRA program).
Unit-mass separation up to A>40 *(~50)* is observed.

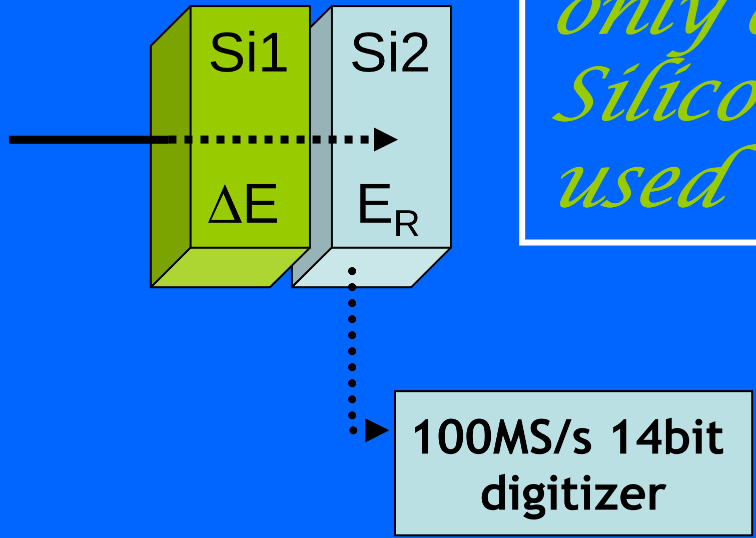




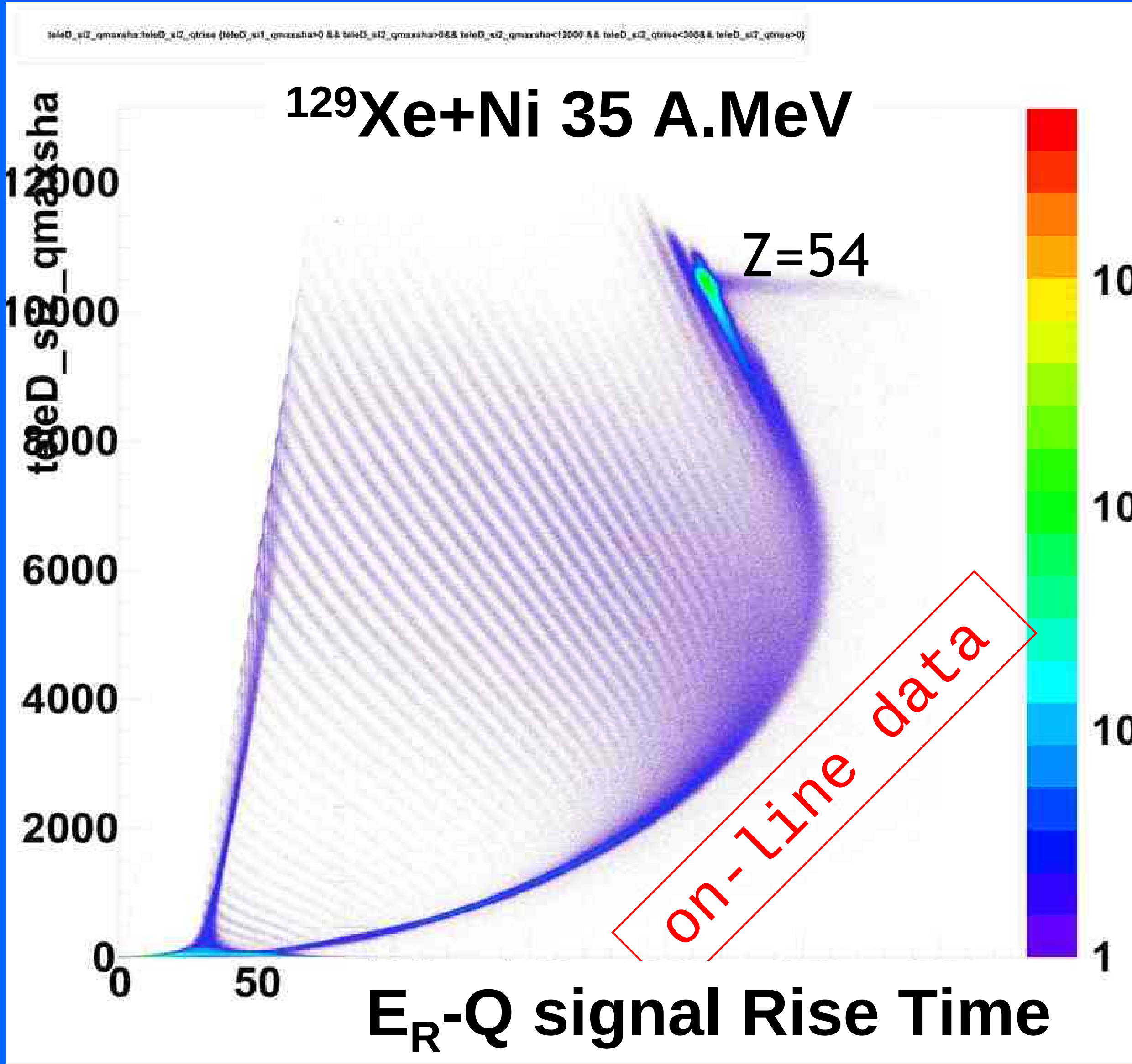
FAZIA data (LNS)

Used configuration:
isotopic identification up to Z~25 with ~5GeV full range

FAZIA PhaseI-R&D



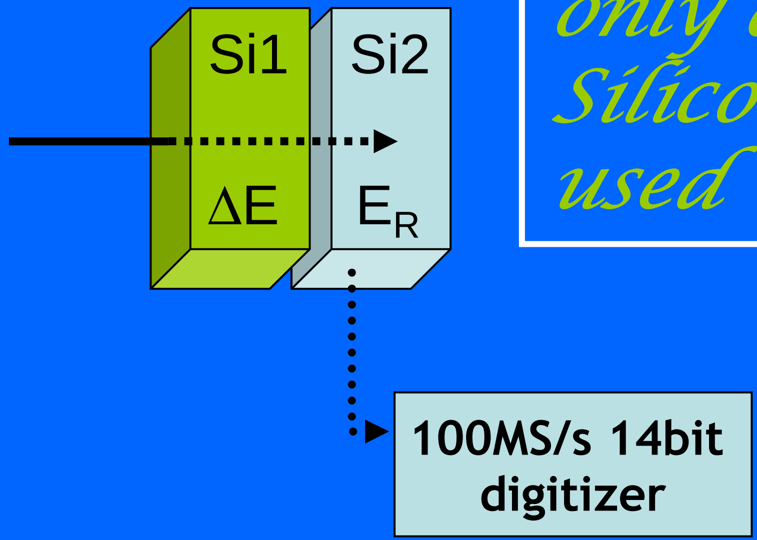
PSA: only one Silicon is used



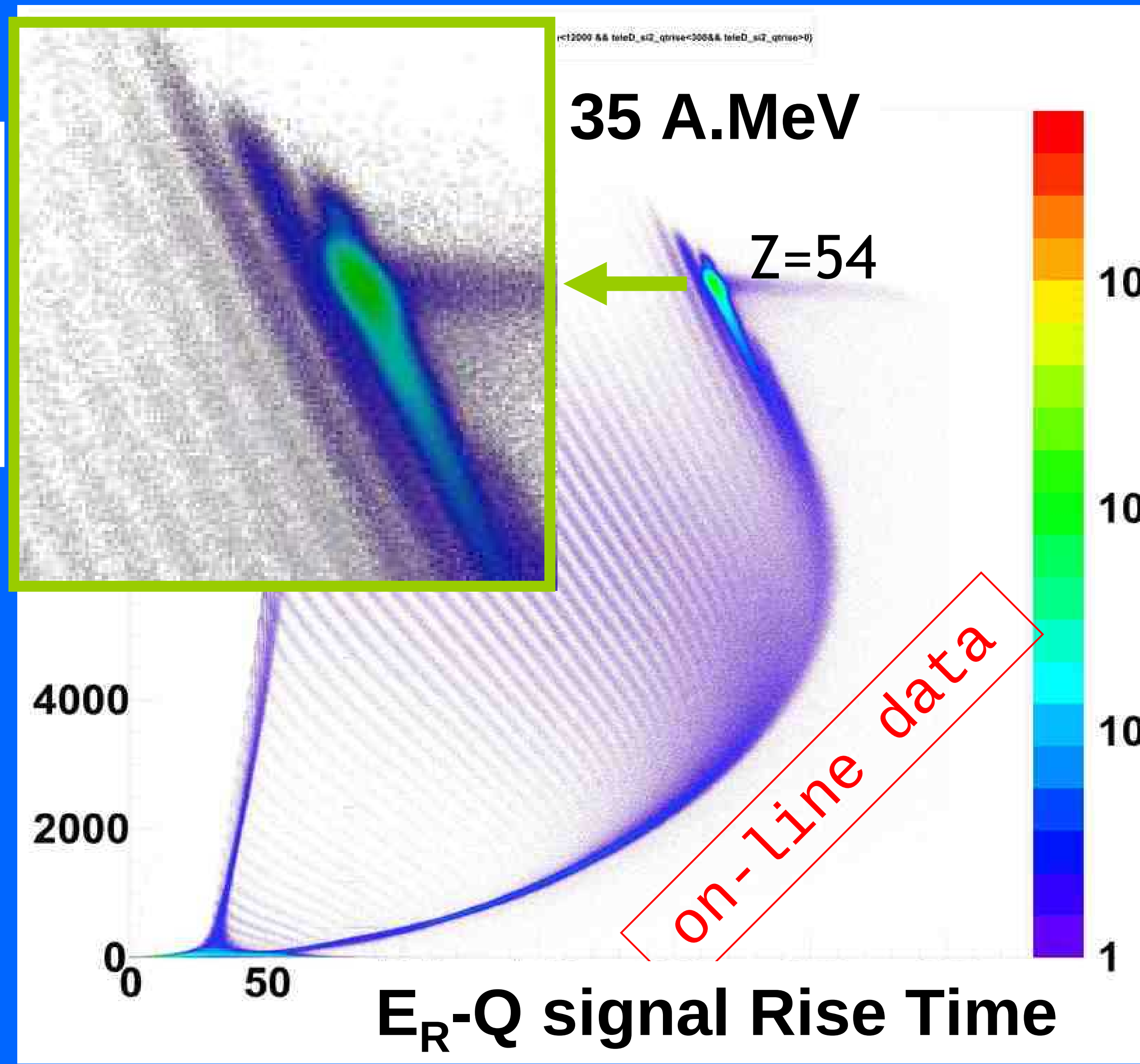
Digital PSA results:
one digitizer,
6 GeV full scale

FAZIA data (LNS)

FAZIA PhaseI-R&D



PSA: only one Silicon is used

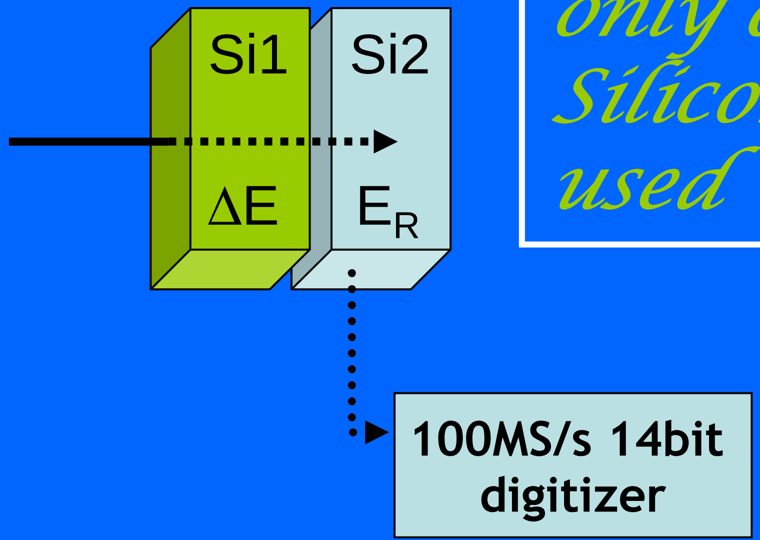


Digital PSA results:
one digitizer,
6 GeV full scale

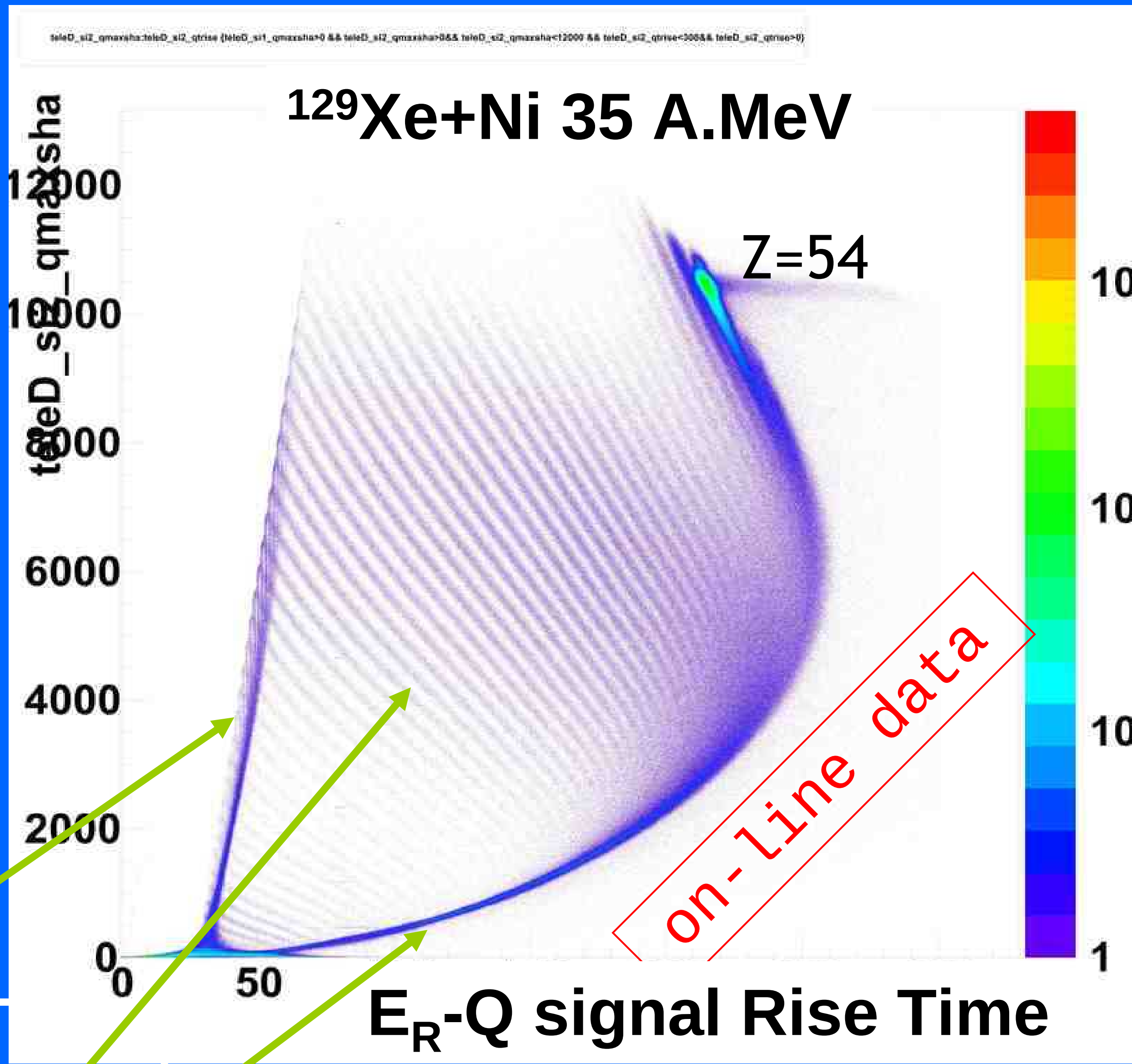
FAZIA data (LNS)

FAZIA PhaseI-R&D

PSA:
only one Silicon is used



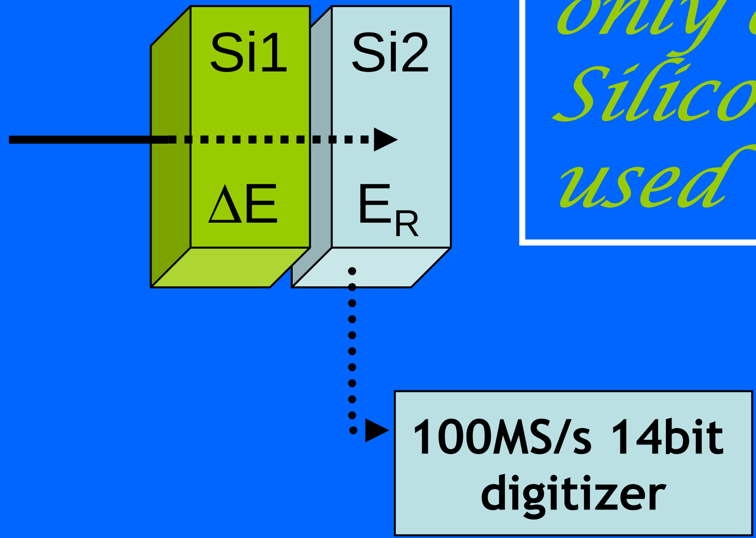
Digital PSA results:
one digitizer,
6 GeV full scale



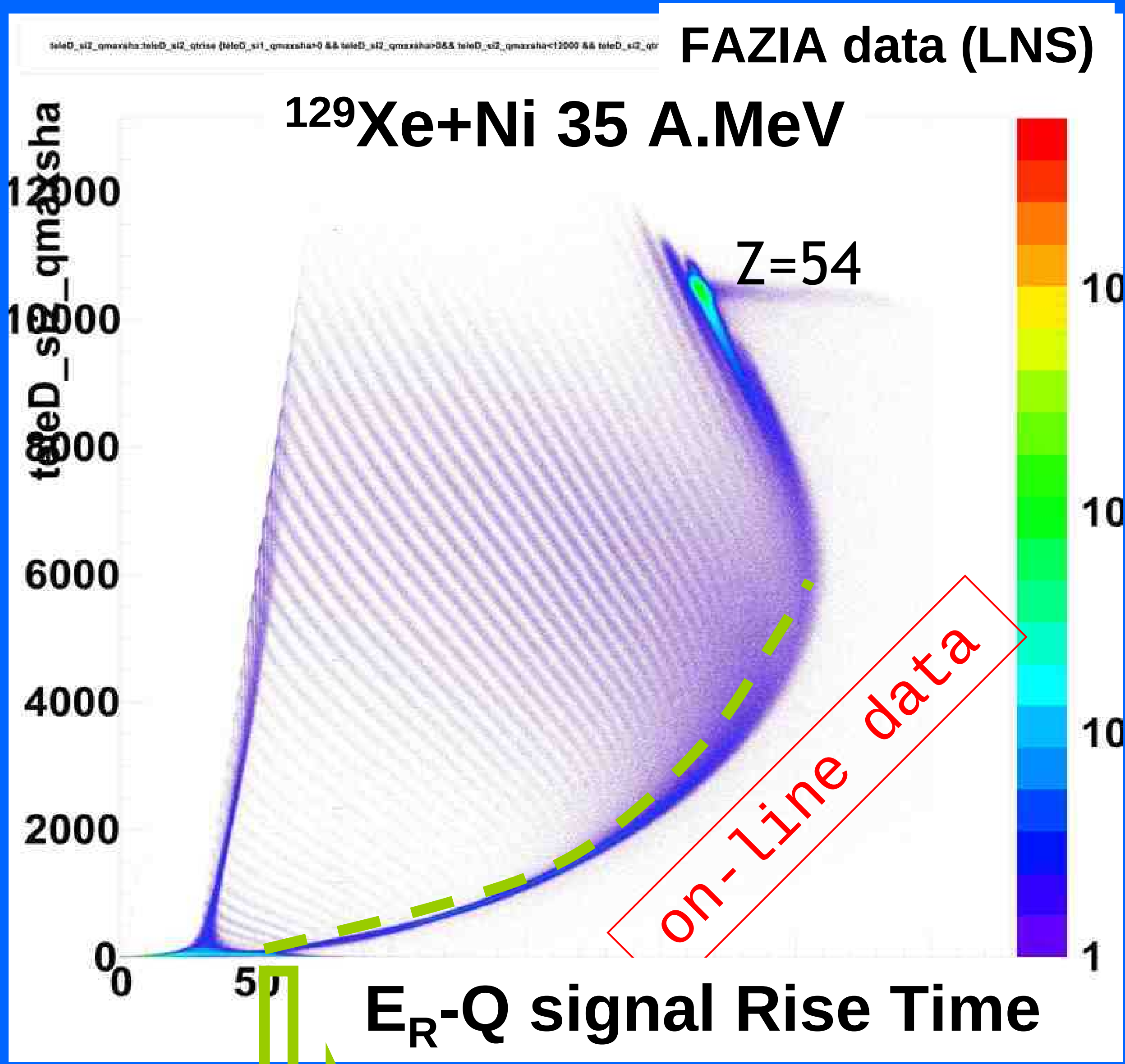
Punch-through particles
Particles identified by Silicon detector Si2
Effective threshold: about 30 µm Silicon

FAZIA data (LNS)

FAZIA PhaseI-R&D



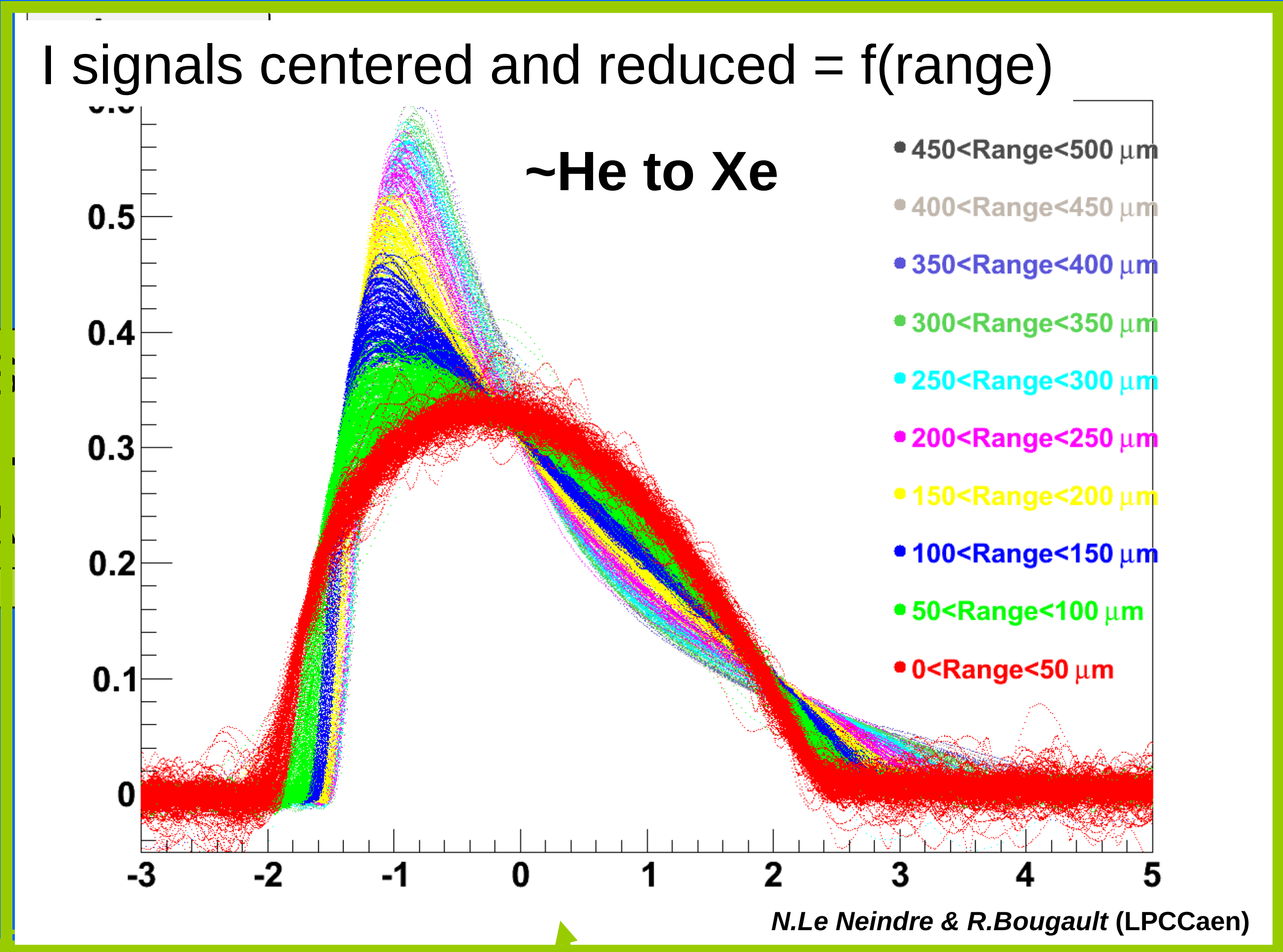
PSA:
only one Silicon is used

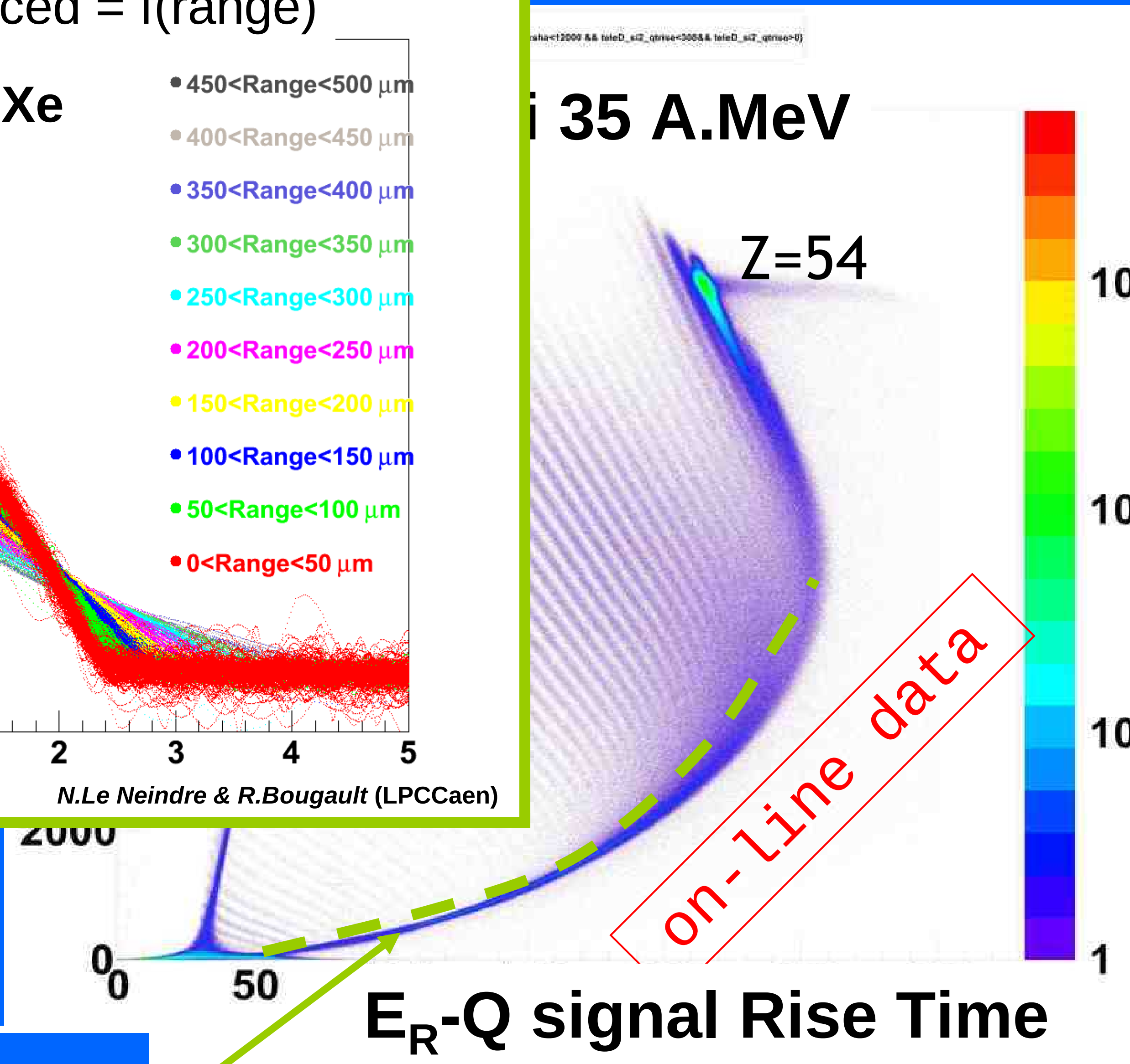


Digital PSA results:
one digitizer,
6 GeV full scale

Time of Flight

FAZIA PhaseI-R&D





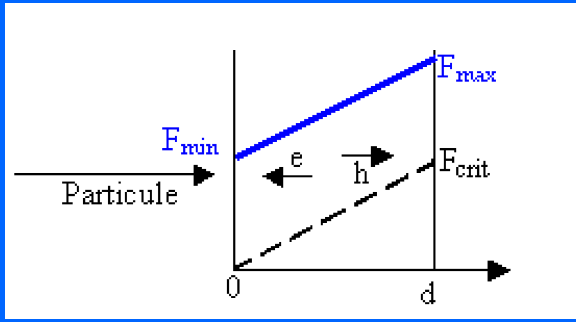
Digital PSA results:
one digitizer,
6 GeV full scale

Id. thresholds below 3-4 A.MeV

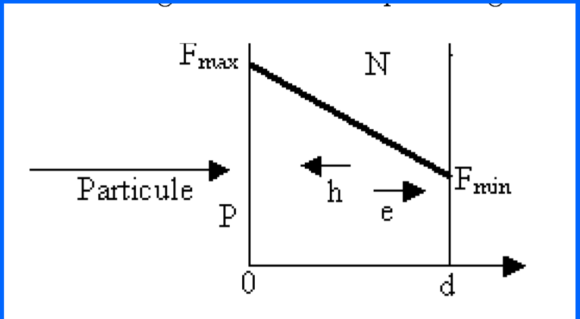
FAZIA data (LNS)

FAZIA PhaseI-R&D

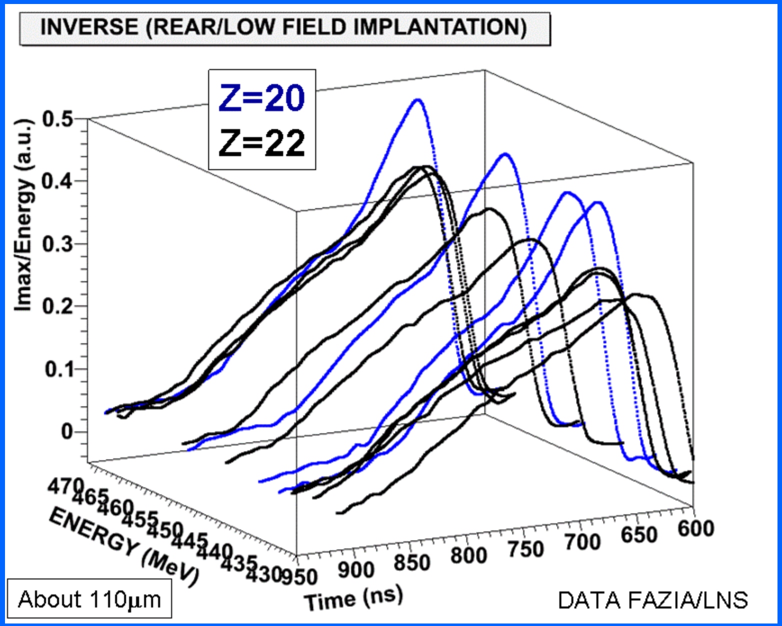
INVERSE (rear)

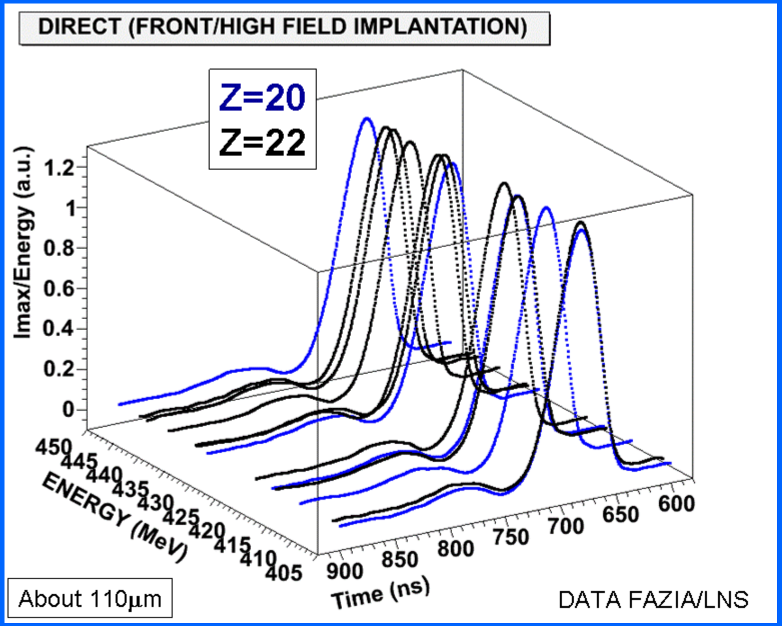


DIRECT (front)



Pulse Shape of stopped particules is different: charge-carrier mobilities of electrons and holes, different plasma-erosion times

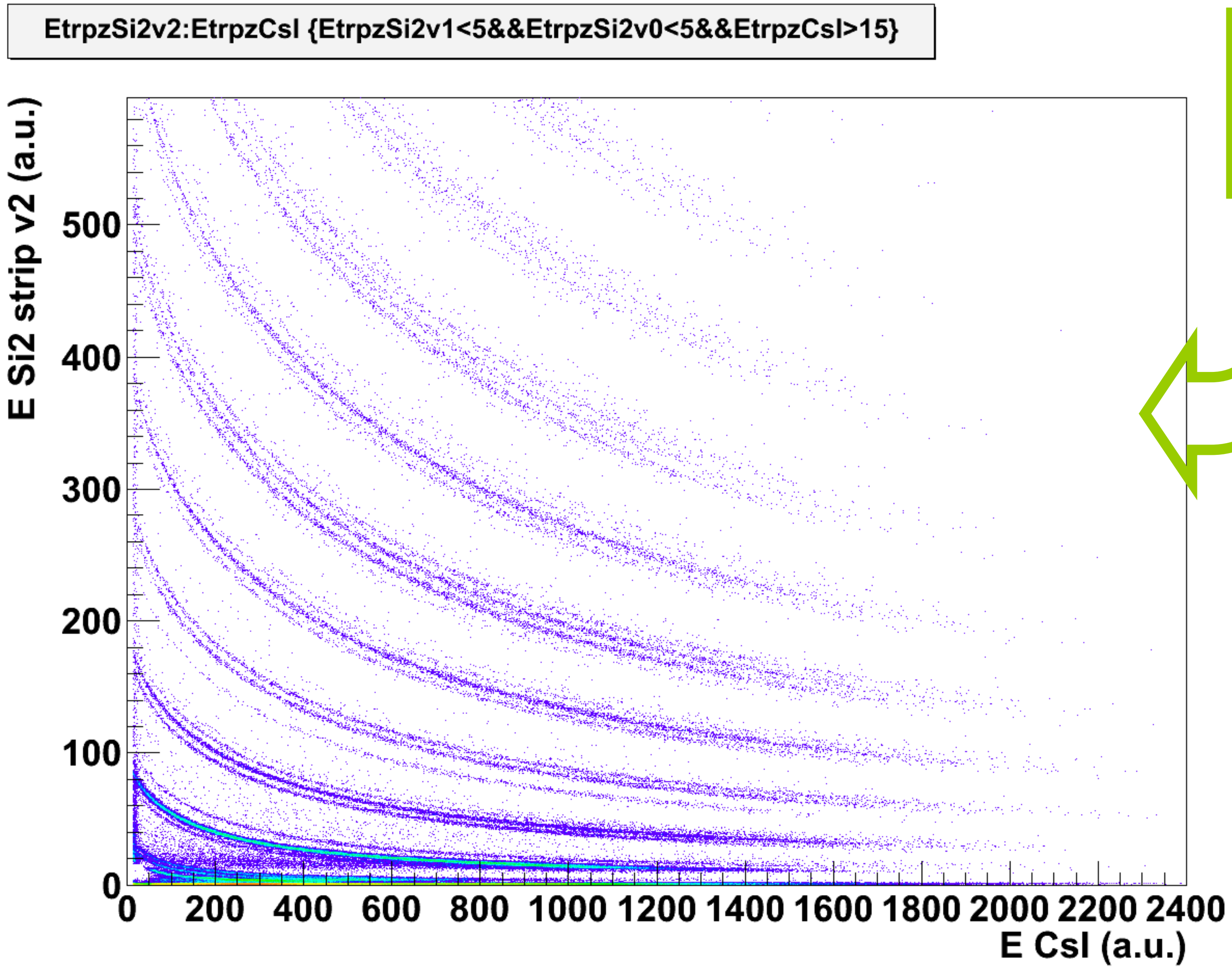




FAZIA data (LNS)

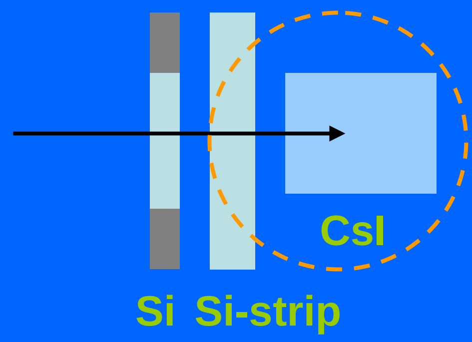
FAZIA PhaseI-R&D

nTD-silicon strip detector



same wafer as previous standard Fazia detectors but 50x50mm, 16x16strips

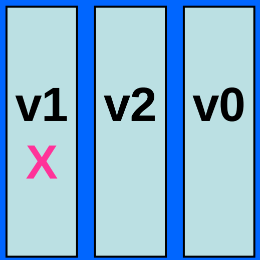
Same quality ΔE-E id. for the strips

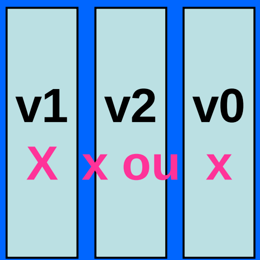


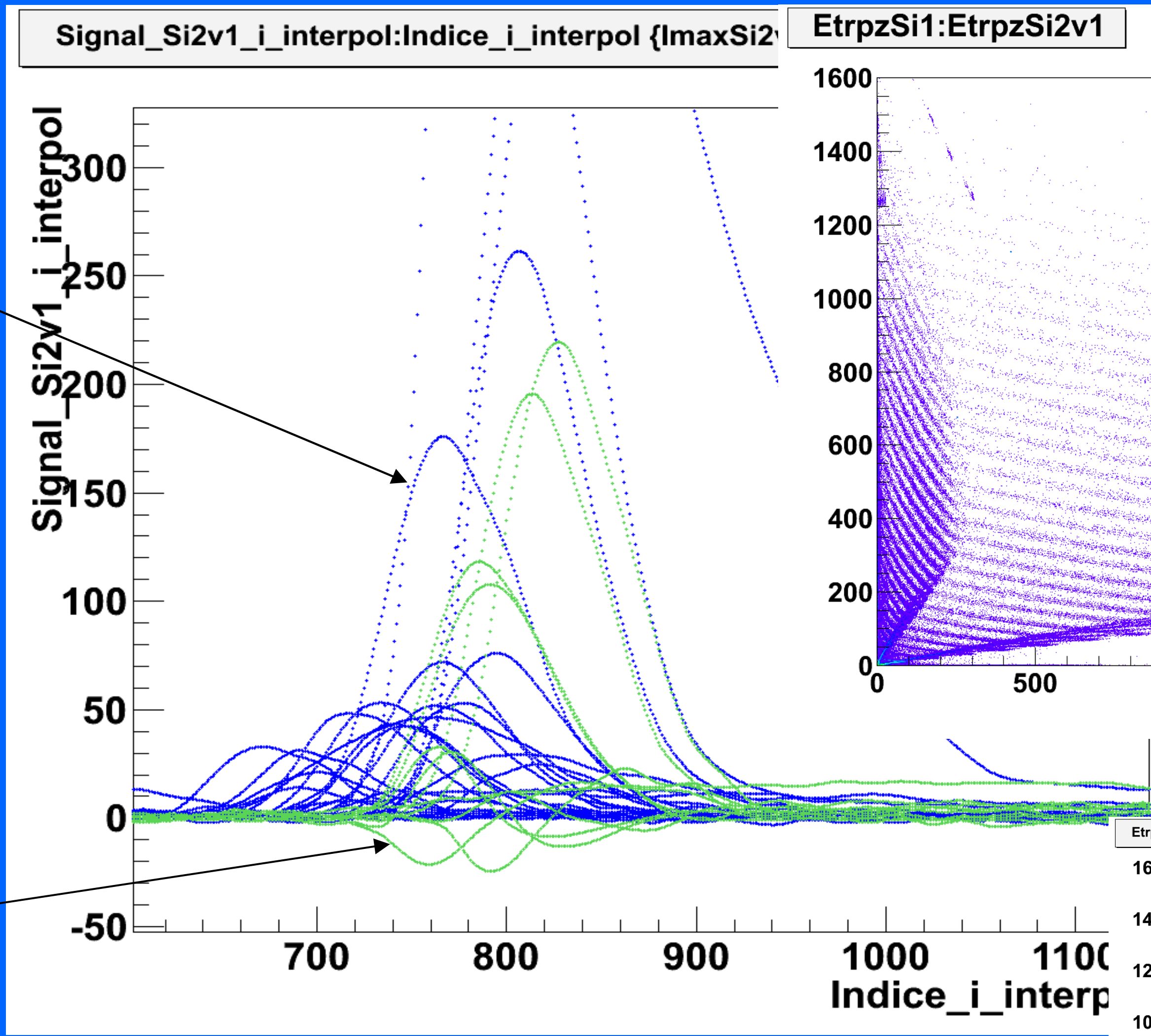
FAZIA data (Ganil)

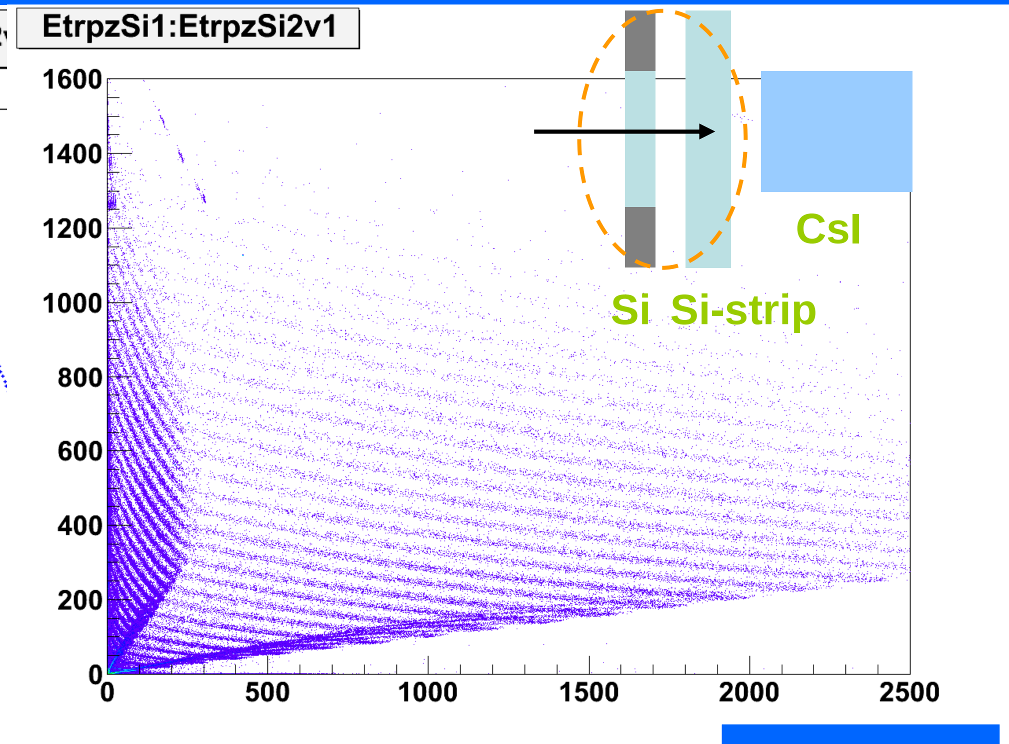
A. Chbihi et al. (Ganil)

FAZIA PhaseI-R&D

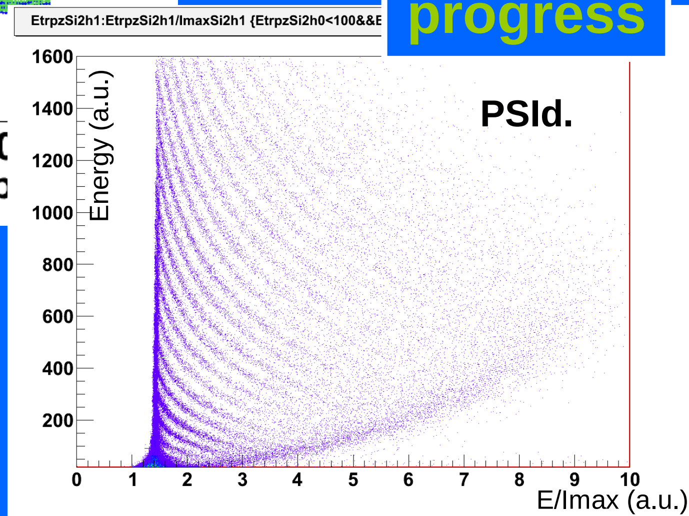








Work in progress



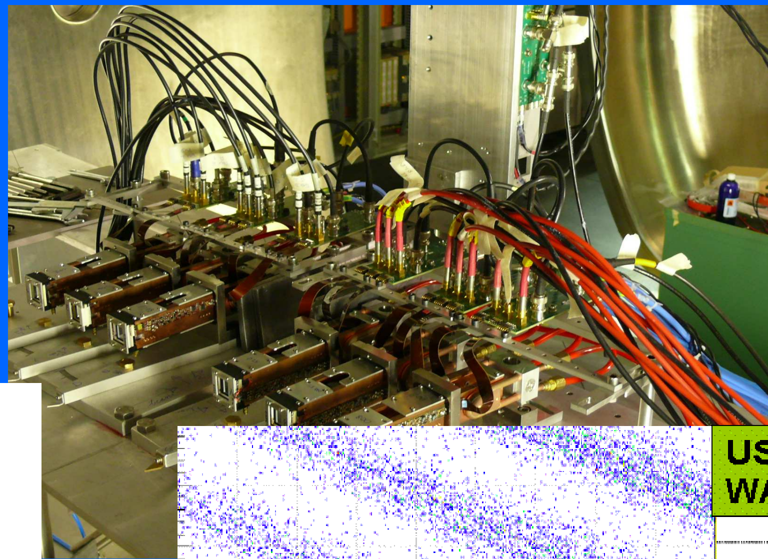
nTD-silicon strip detector

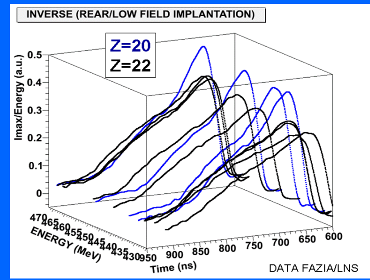
negative polarity for inter-Strip:
J. Yorkston and A.C. Schotter **NIM A 262 (1987) 353-358**

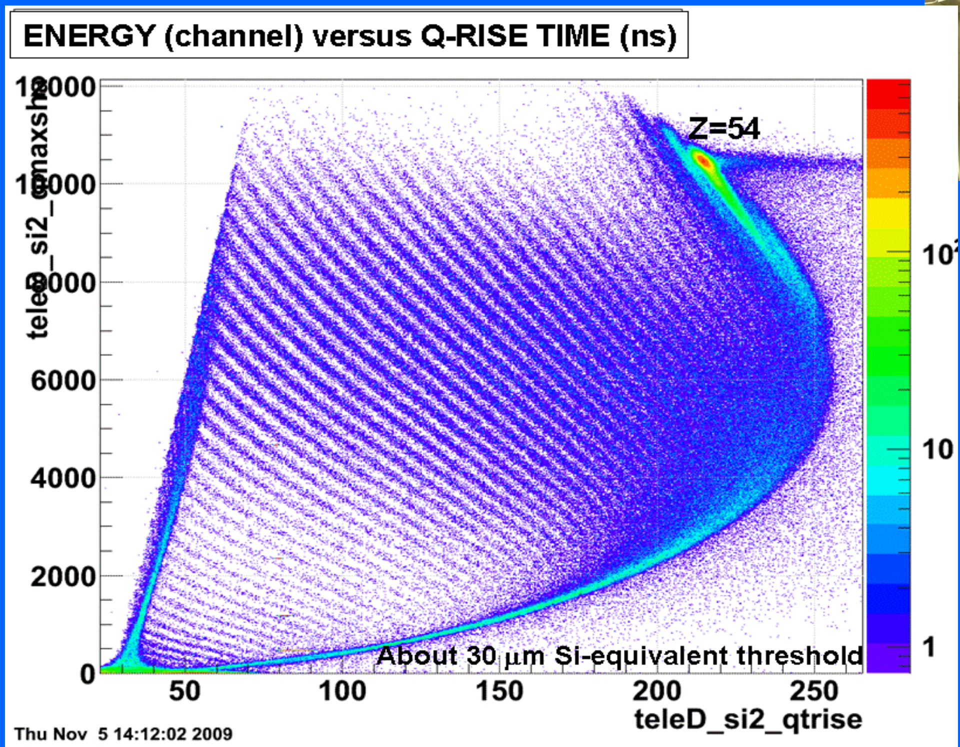
FAZIA PhaseI-R&D

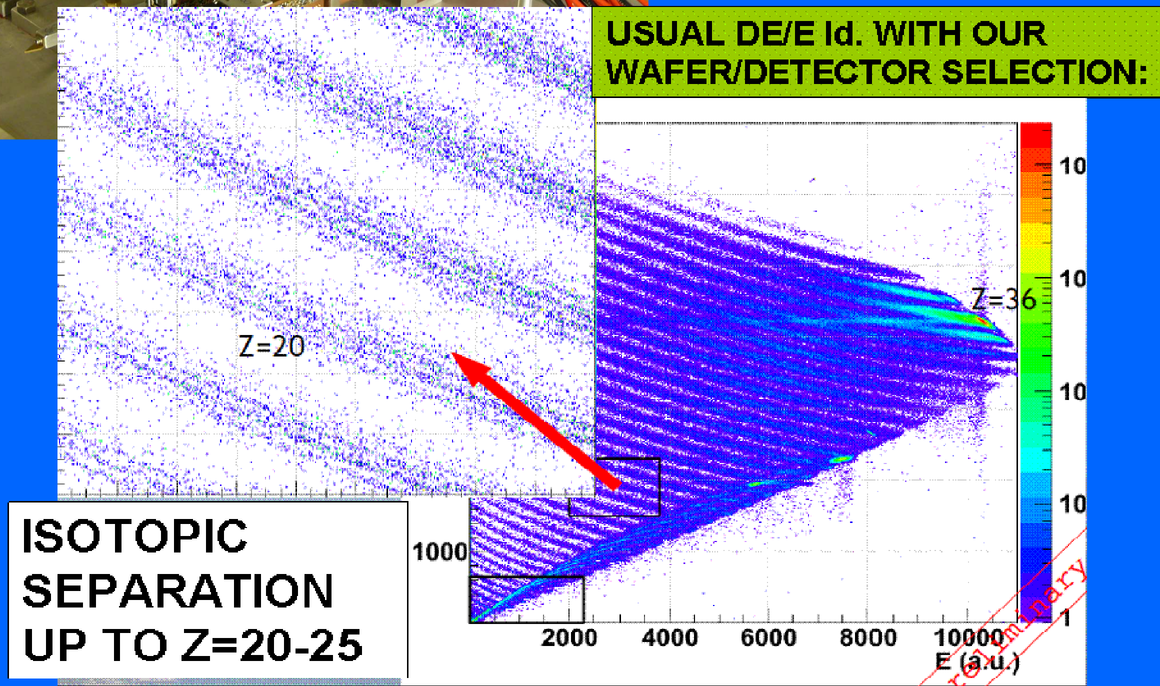
FAZIA PHASE-I prototype
R&D Experiment
(LNS-Nov. 2009)

^{129}Xe+Ni 35 A.MeV







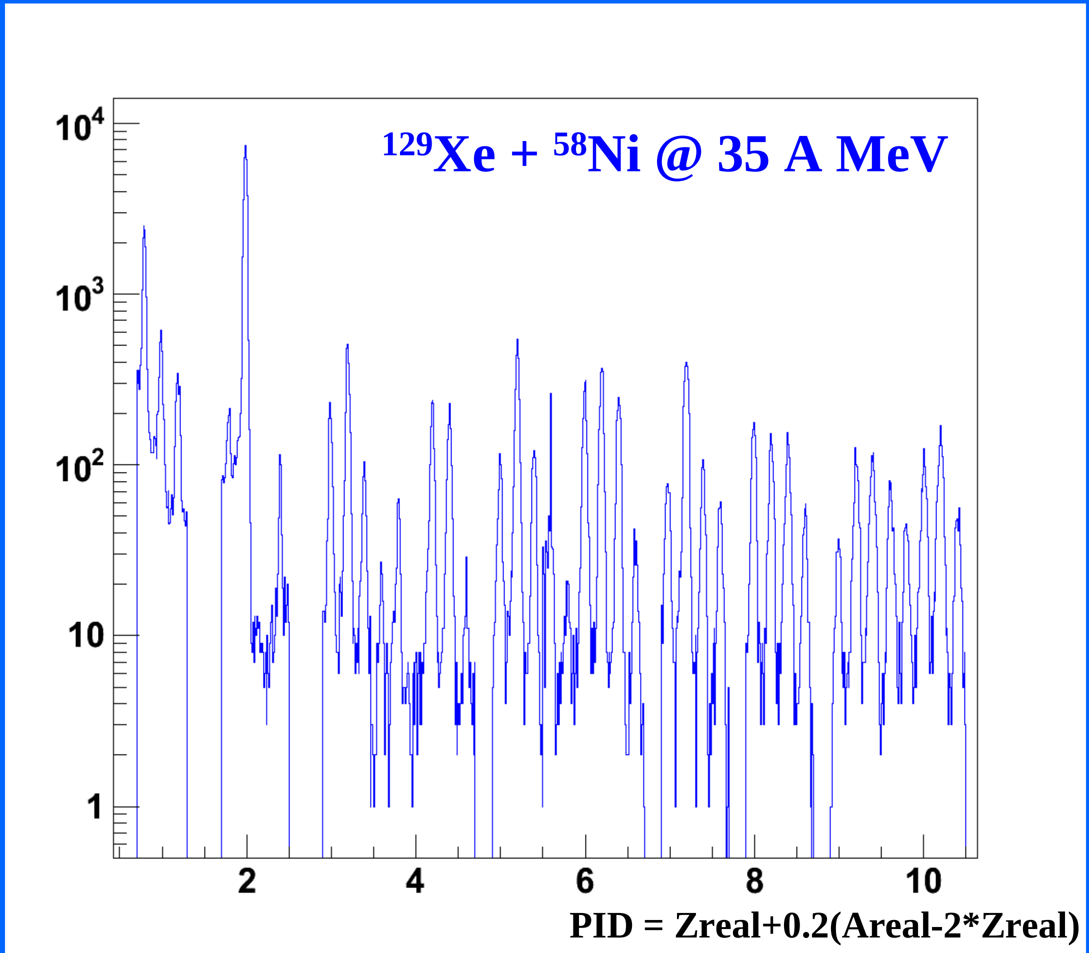


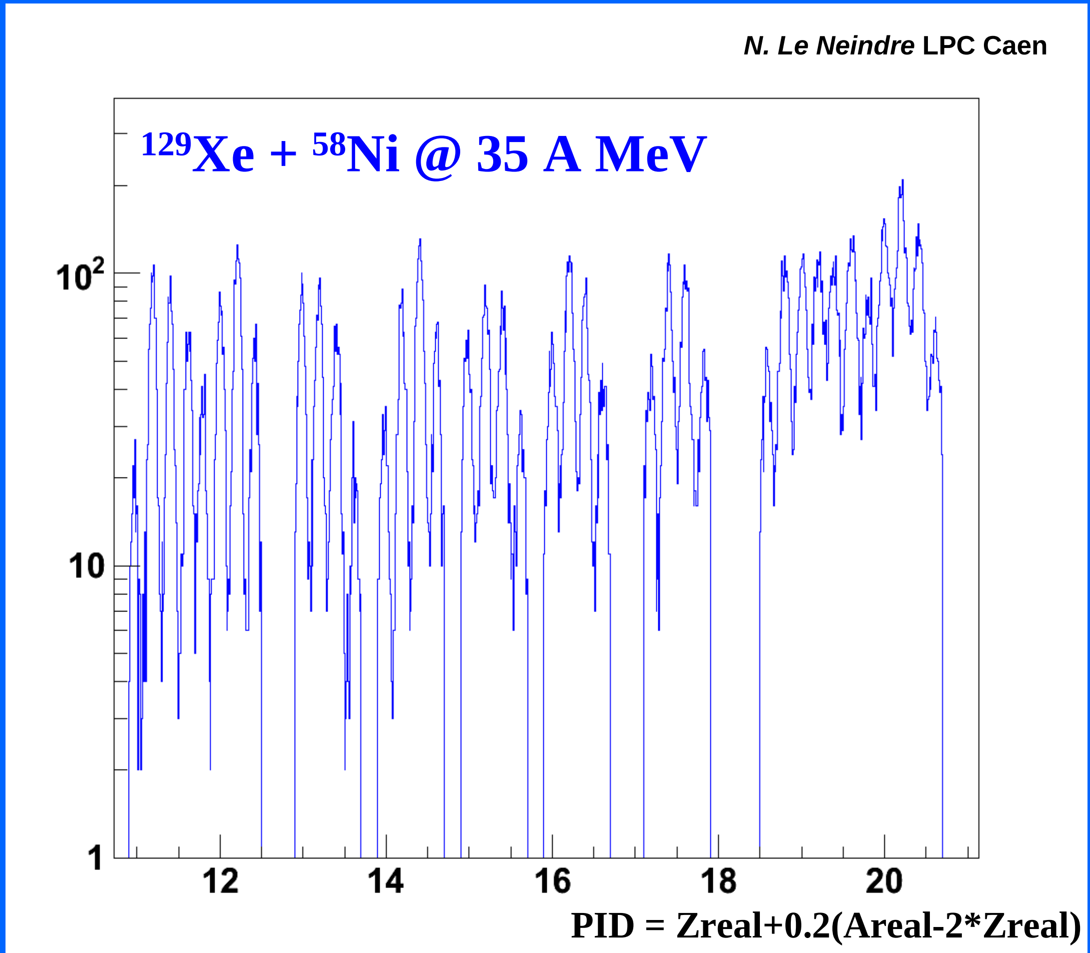
Z identification up to Z=54
with ONE detector by Pulse Shape Analysis

FAZIA PhaseI-R&D

FAZIA PHASE-I prototype
R&D Experiment
(LNS-Nov. 2009)

FAZIA ΔE-E isotopic distribution





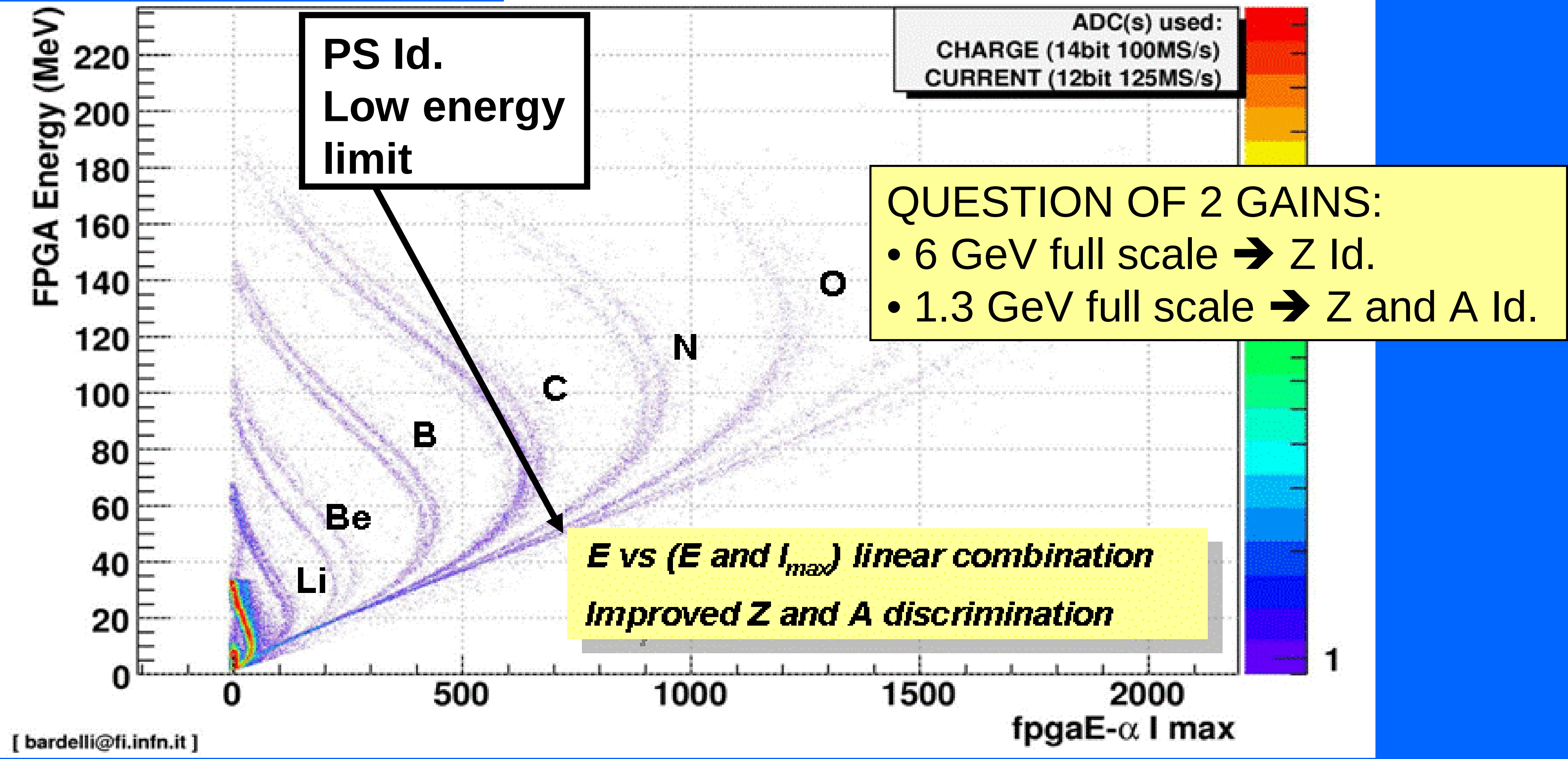
FAZIA data (LNS)

KaliVeda/INDRA program root based J. *Frankland, E. Bonnet, D. Cussol*

FAZIA PhaseI-R&D

CHARGE (14bits, 100MS/s)
CURRENT (12bits, 125MS/s)
1.3 GeV full range

IONS IDENTIFIED BY ONE DETECTOR

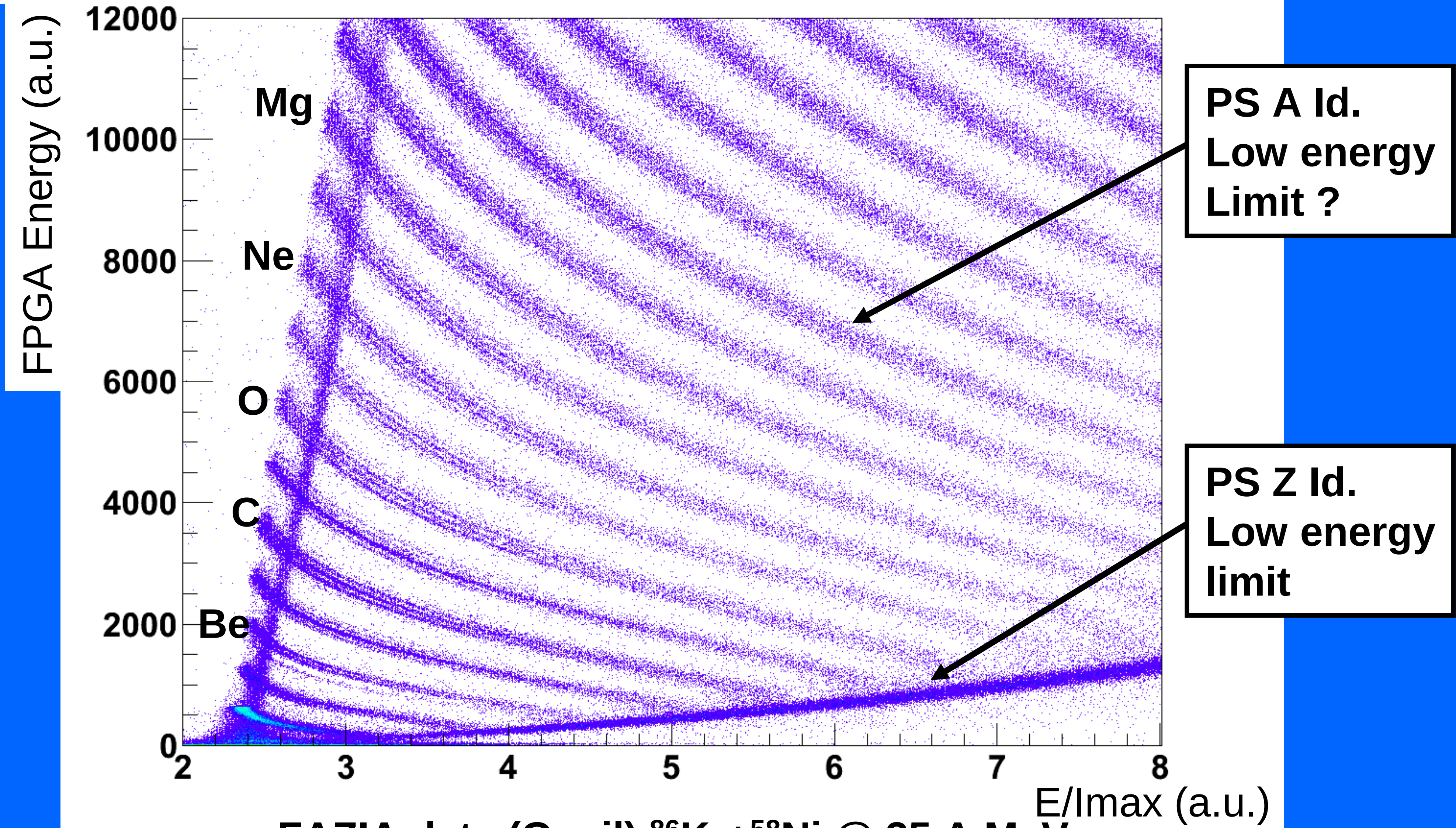


FAZIA data (LNL) $^{32}S+^{27}Al$ @ 14.8 A MeV

FAZIA PhaseI-R&D

CHARGE (14bits, 100MS/s)
CURRENT (14bits, 100MS/s)
0.7 GeV full range

IONS IDENTIFIED BY ONE DETECTOR



FAZIA data (Ganil) $^{86}Kr+^{58}Ni$ @ 35 A MeV

FAZIA demonstrator

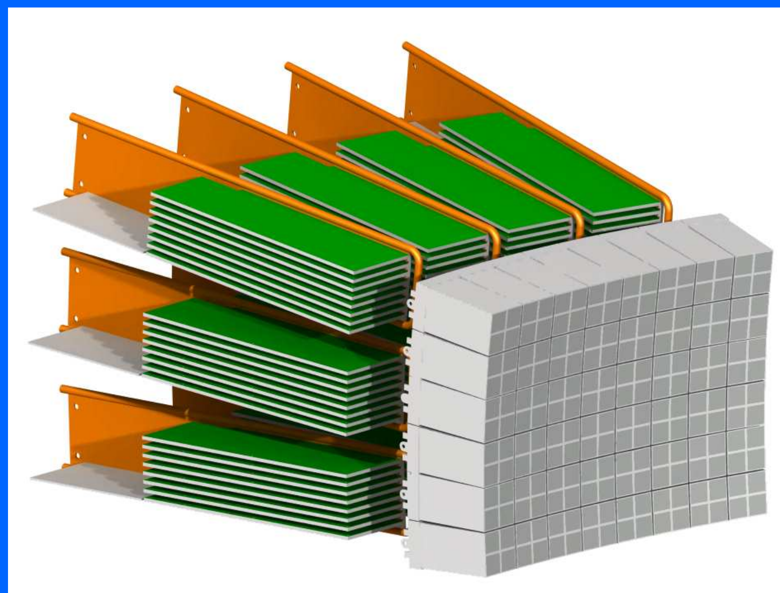
FAZIA PHASE2 “demonstrator & physics” :

• Built (2011-2013) a demonstrator of 192 telescopes Si/Si/CsI with “all” the finals (4π detector) electronics, mechanical solutions.

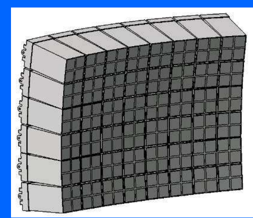
• With this demonstrator coupled to existing multi-detectors (INDRA, GARFIELD, CHIMERA,…), realize experiments (GANIL, SPIRAL2, LNL, LNS).

12 BLOCKS
48 MODULES
192 TELESCOPES Si/Si/CsI

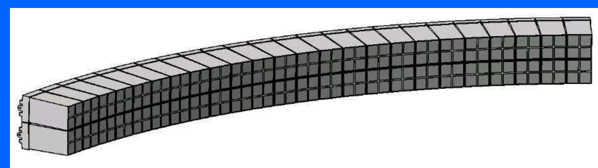
- Telescope			
Si(300µ)	- charge	250 MeV f.s.	250 Ms/s 14 bit
	- charge	4 GeV f.s	100 Ms/s 14 bit
	- current		250 Ms/s 14 bit
Si(500µ)	- charge	4 GeV f.s	100 Ms/s 14 bit
	- current		250 Ms/s 14 bit
CsI(phdiode)	- charge	4 GeV f.s	100 Ms/s 14 bit



“WALL”



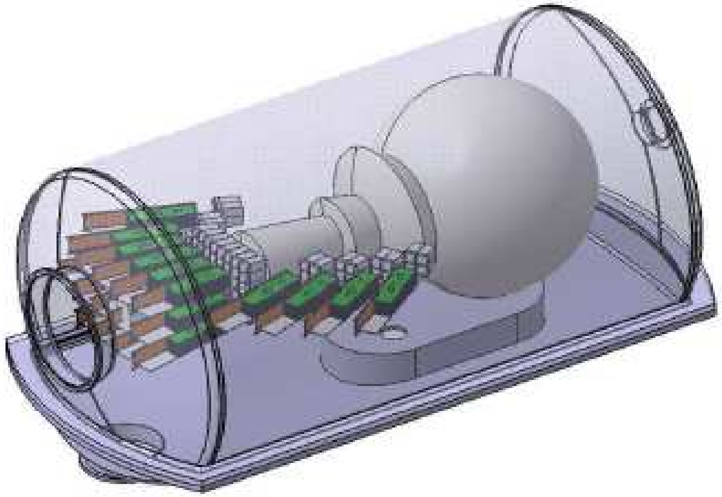
“BELT”

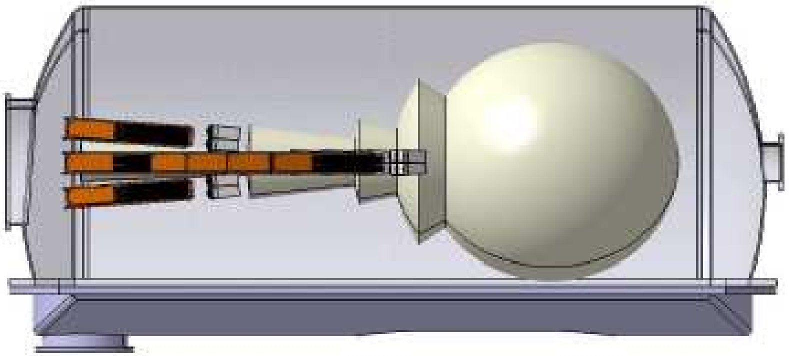


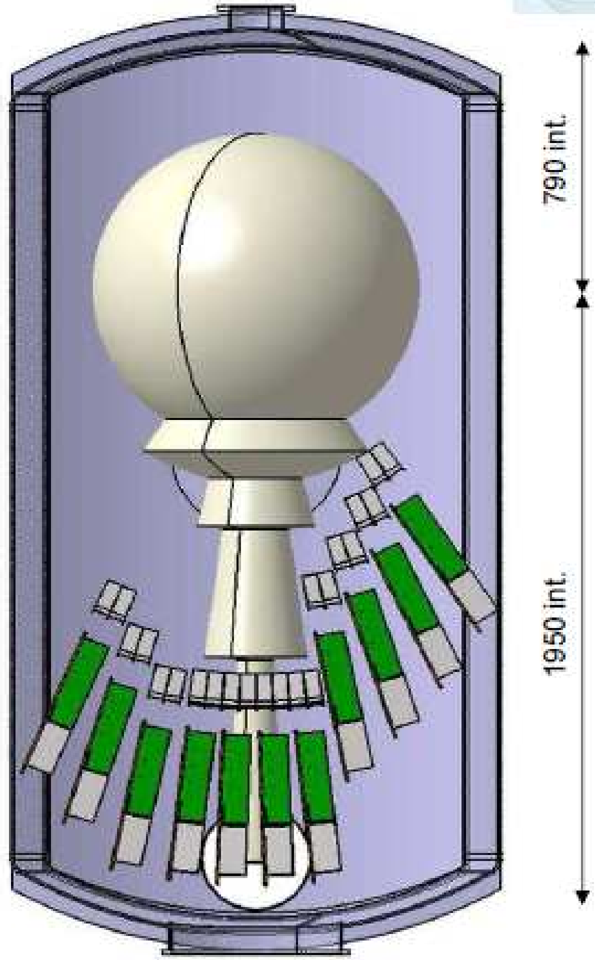
FAZIA Phase2 2011-2013

Laboratoire de Physique Corpusculaire

FAZIA – INDRA







Bloc : R600 à R1200 & Wall : R1200

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DEMONSTRATOR & PHYSICS (COUPLING WITH INDRA)