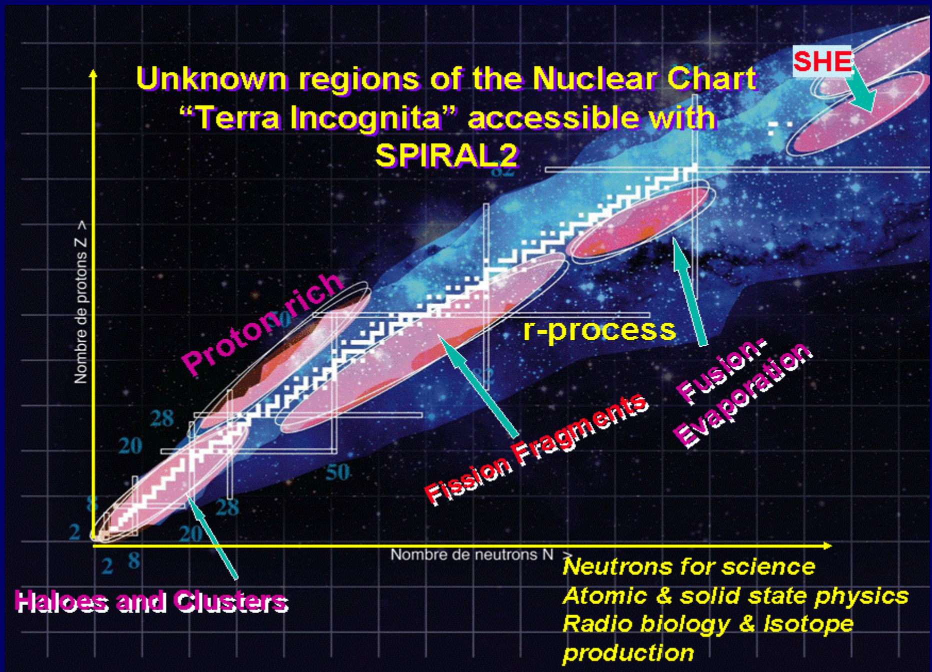
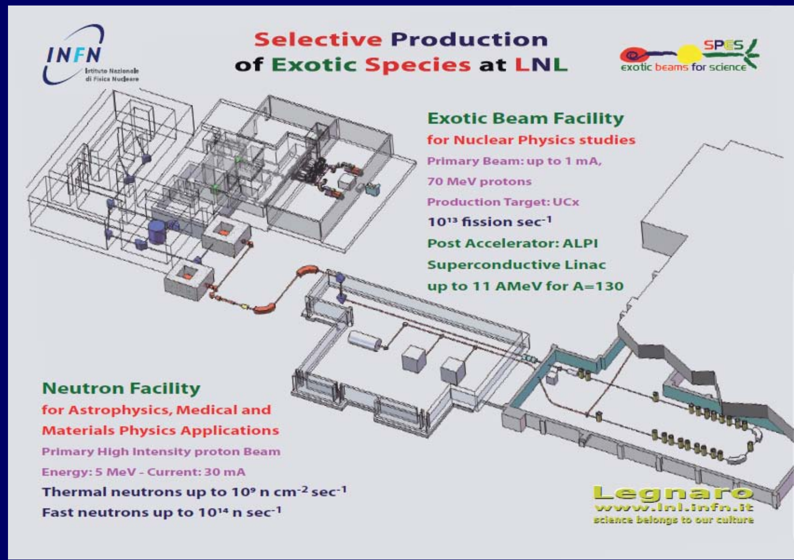
FAZIA detector for Nuclear (Thermo)Dynamics Physics using RIBs factories

from Phase1 to Phase2





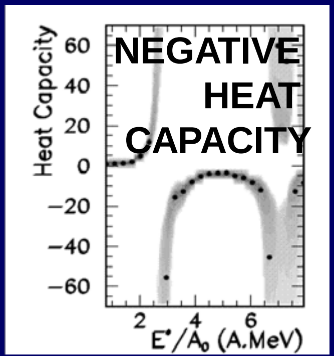
GANIL, LNS, LNL

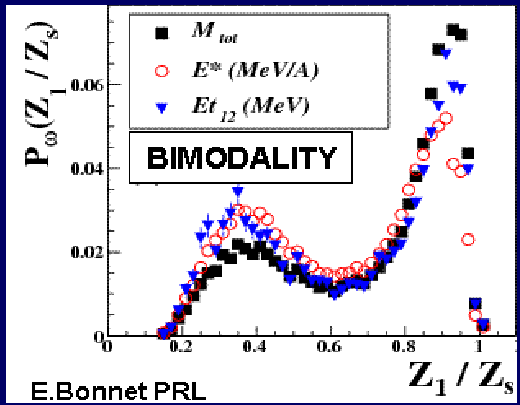
FAZIA: Scientific case

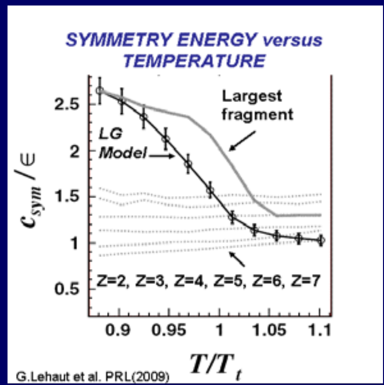
Nuclear Equation Of State N/Z dependence

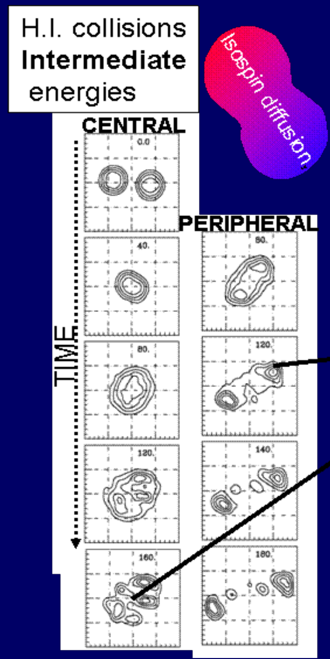
$$E(\rho, T, (N-Z)/A)$$

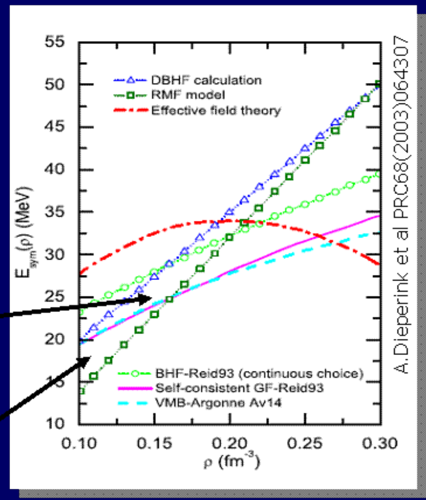
- ***Nuclear Matter first Phase Transition ("Liquid-Gas")***
- ***Nuclear level densities and Limiting temperature***
- ***Symmetry Energy (density and temperature dependence)***











NEED OF (A,Z) Identification

GANIL, LNS, LNL

LOI 18

Letter of Intent for SPIRAL 2

Title: Dynamics & Thermodynamics of exotic nuclear s

NEED OF (A,Z) Identification

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

F. Gulminelli (LPC-ENSICaen, Caen, France, e-mail: gul ... .in2p3.fr)
G. Poggi (INFN & University, Florence, Italy, e-mail ... @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. L
GANIL (Caen): A. Chbihi, J. Frankland, J. Moisan
LPC-ENSICaen (Caen): S. Barlini, R. Bougau ... Lehaut, O. Lopez, B. Tamain, E. Vient
IPNL (Lyo
INDIA:
VECC (C
Banerjee,
ITALY:
Bologna (
Marini, G
Catania (
Catania (L
Firenze (I
Olmi, G. Pasq ... ggi, S. Piantelli, A. Stefanini
LNL (INFN): M. ... usero, 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)

72 persons – 19 institutions – 8 countries

FAZIA LOI SPES

SPES-2015 FAZIA config. **1180 detectors**

Beam current: 132Sn 3.3*10^7 pps
target thickness: 0.5 mg/cm2
Reaction Xsection 3.2 barn; DIC Xsection 2.
DIC total rate: 330 Hz

2-body channel:

MC estimated eff. for QP & M>=
Request: 10^7 dissisipative e... most central impact parameters (b/b_{gr}<0.5)
Rate for wanted even... about 4.6days
(this gives 35 mil... ed elastic-Sn on the 3deg forward Telescope, 91... te)

3-body c... he split of the QP)

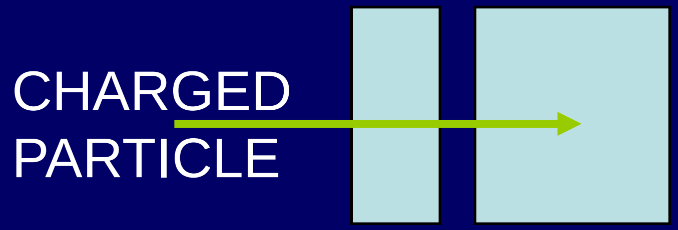
MC es... for (FF1& FF2 & M>=1 LCP): 10%
3b... assumed to be 20% of DIC
Re... he previous 10^7 binary events
Rate... 3-body events 7Hz --> 2.7 million 3body events in 4.6days

NEED OF (A,Z) Identification

A and Z Identification

HEAVY-IONS COLLISIONS→IDENTIFY THE REACTION PRODUCTS

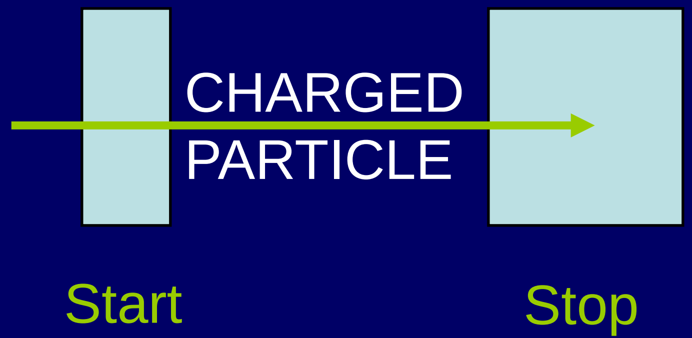
Energy is measured
Z identification
A identification (for low Z)
For particles stopped in the first DE no identification



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

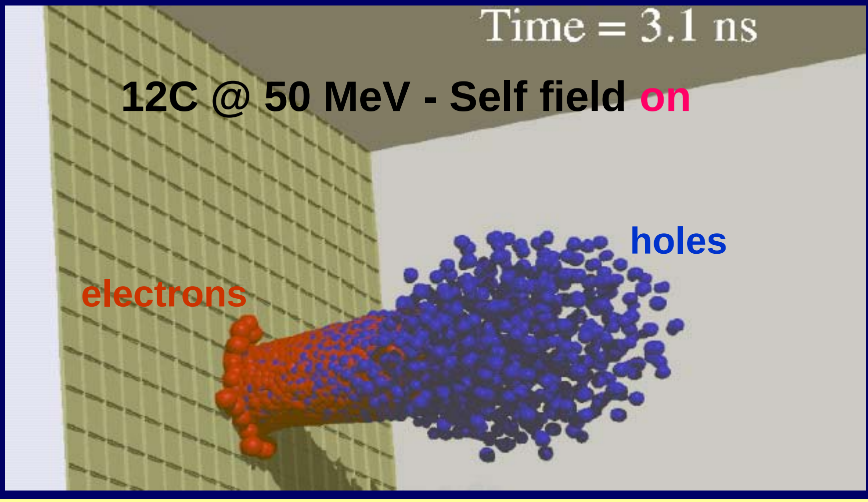
A and Z Identification

HEAVY-IONS COLLISIONS → IDENTIFY THE REACTION PRODUCTS

1) RANGE = f(A,Z)

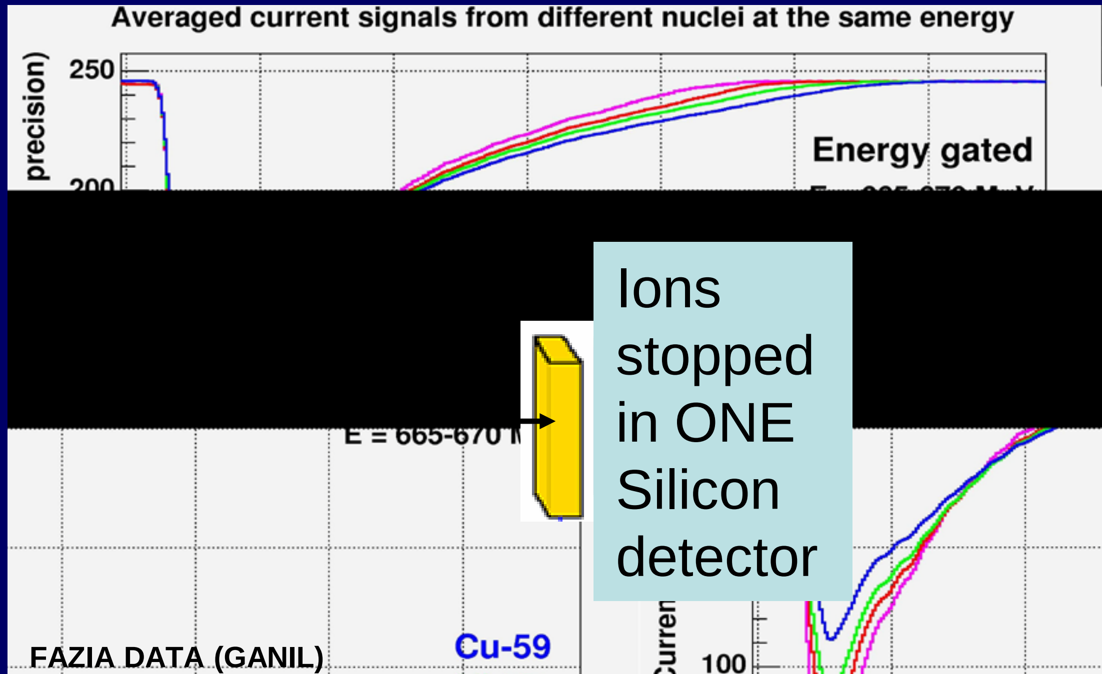
2) Plasma erosion process = f(A,Z)

USE THE ELECTRONIC SIGNAL FOR (A,Z) IDENTIFICATION: "Pulse Shape Discrimination"



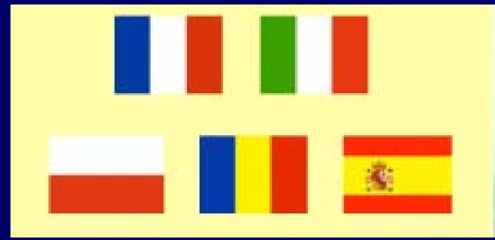
A simulated plasma column for ^{12}C @ 50 MeV

Self field on (L.Bardelli, FAZIA)



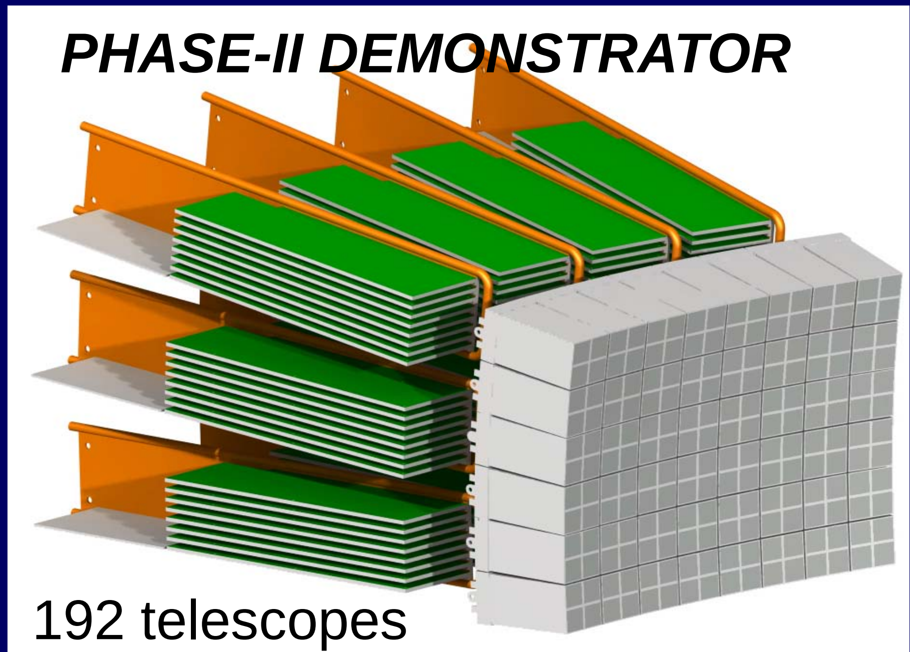
FAZIA collaboration

An R&D project supported by Spiral2PP and LEA-colliga.
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 and SPES (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

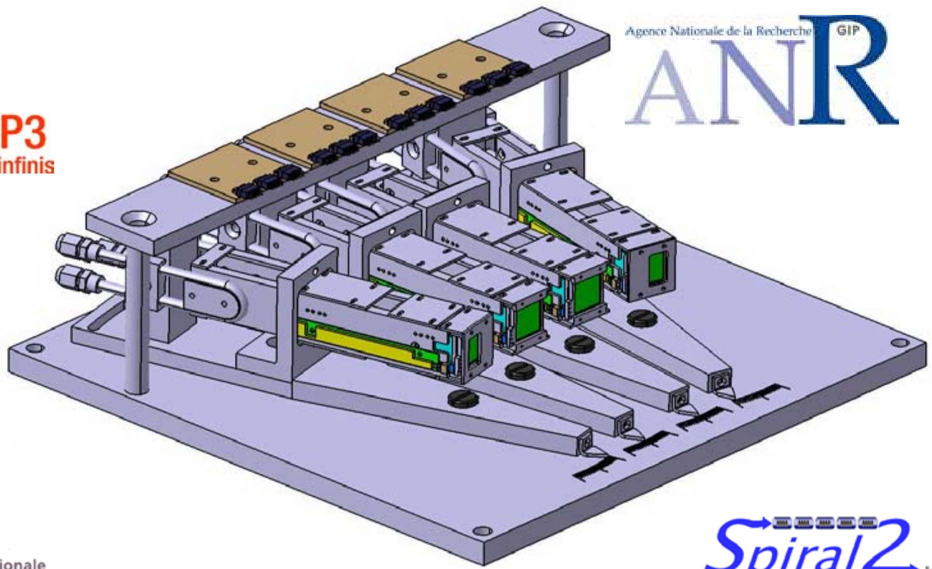
1) Experiments with single silicon-detector (Tandem-Orsay, LISE-GANIL)

Jan. 2006

2) Experiments with single silicon-detector & strip-detector (CIME/GANIL) & LNL (channeling & uniformity)

Jan. 2007

3) Prototypes (phase1)



TASK 5.3 SPIRAL2PP

+ nTD strip-detector

LNL-experiment

Jan. 2008

Jan. 2009

LNS-test

LNS-experiment

Jan. 2010

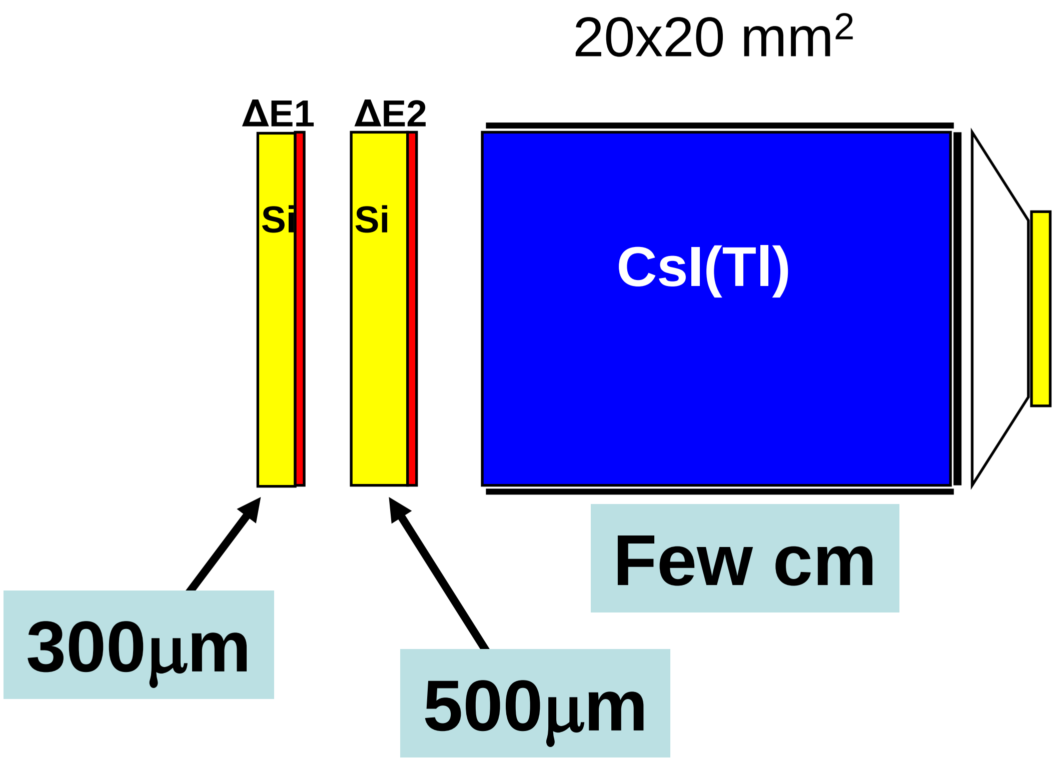
GANIL-experiment

Jan. 2011

LNS-experiment

FAZIA detector

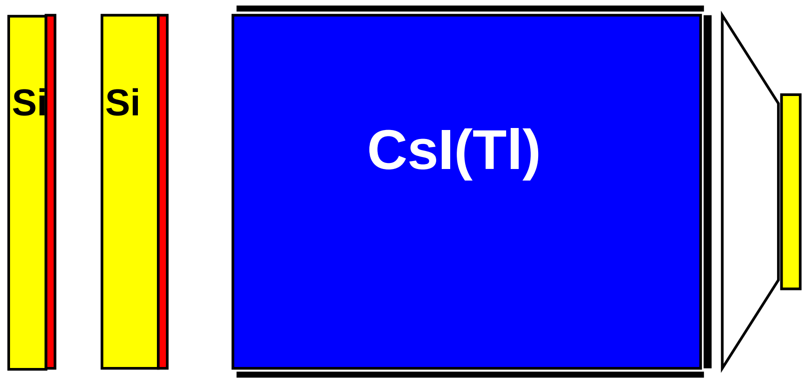
BASIC TELESCOPE

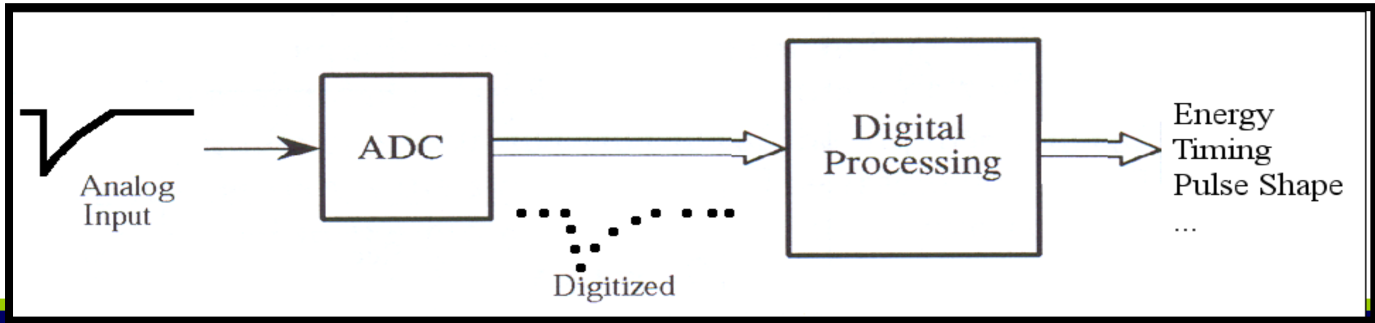


FAZIA detector

BASIC TELESCOPE

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





FAZIA PhaseI-R&D

RECIPE FOR HIGH QUALITY CHIPS

1 – DOPING UNIFORMITY

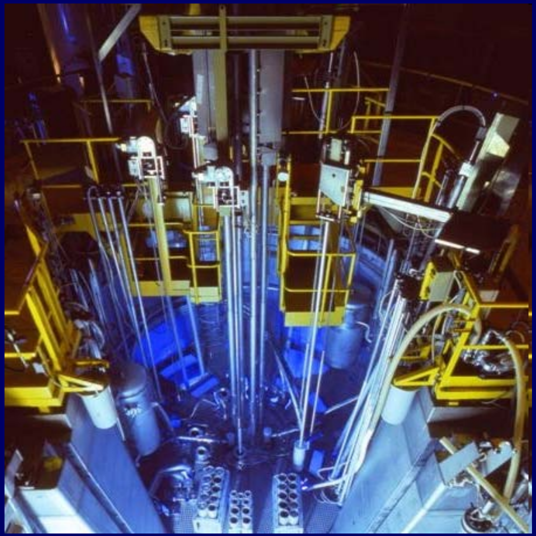
Ingot selection from the producer, controlled doping (at about ρ=3000 ohm.cm) and use of nTD technology for best uniformity (+/- 0.5 %)

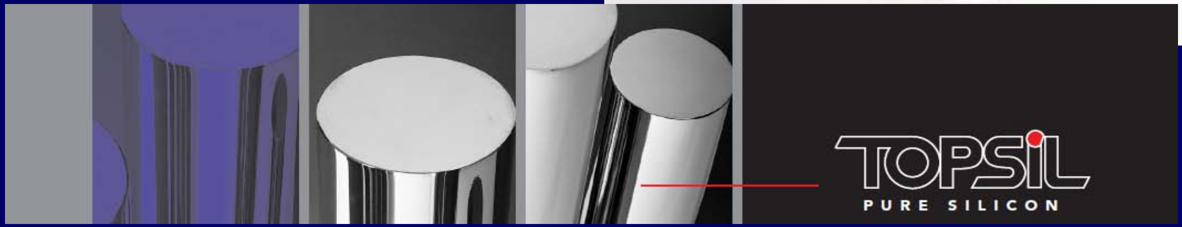
2 – AVOID (as far as possible) CHANNELING

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

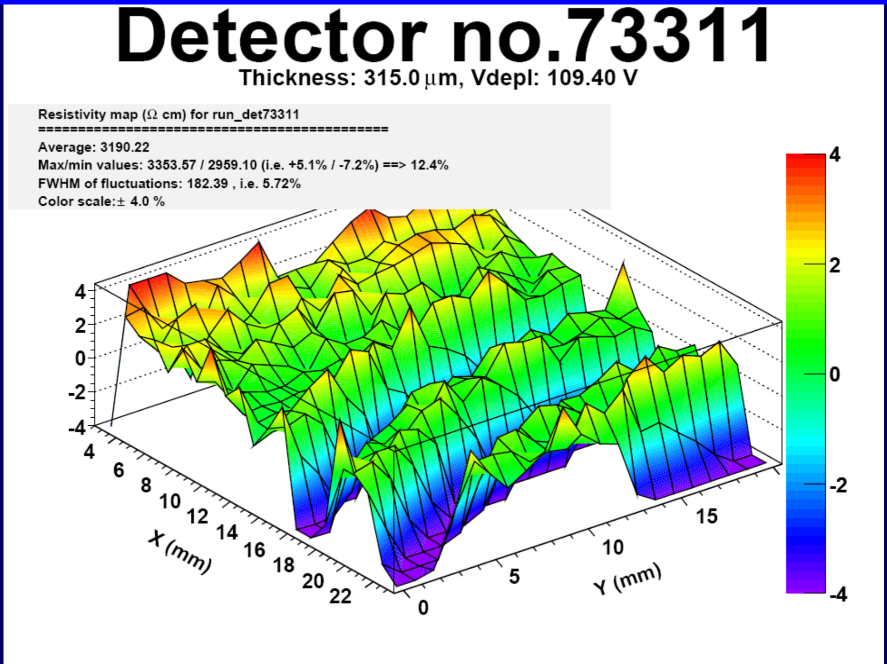




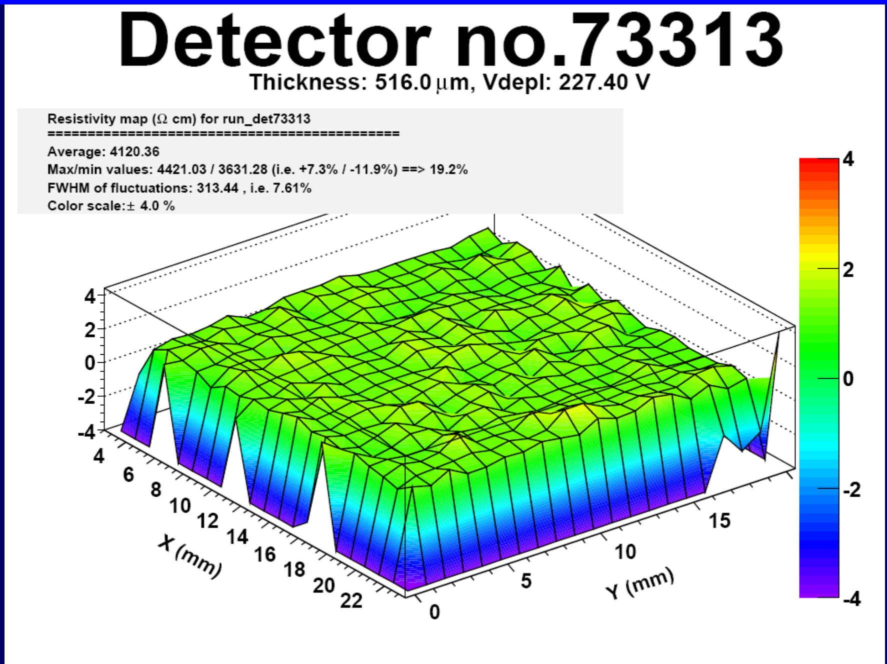
FAZIA PhaseI-R&D

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



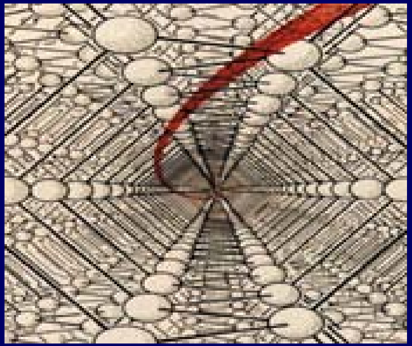
A __very good__ detector: ~1% non-uniformity



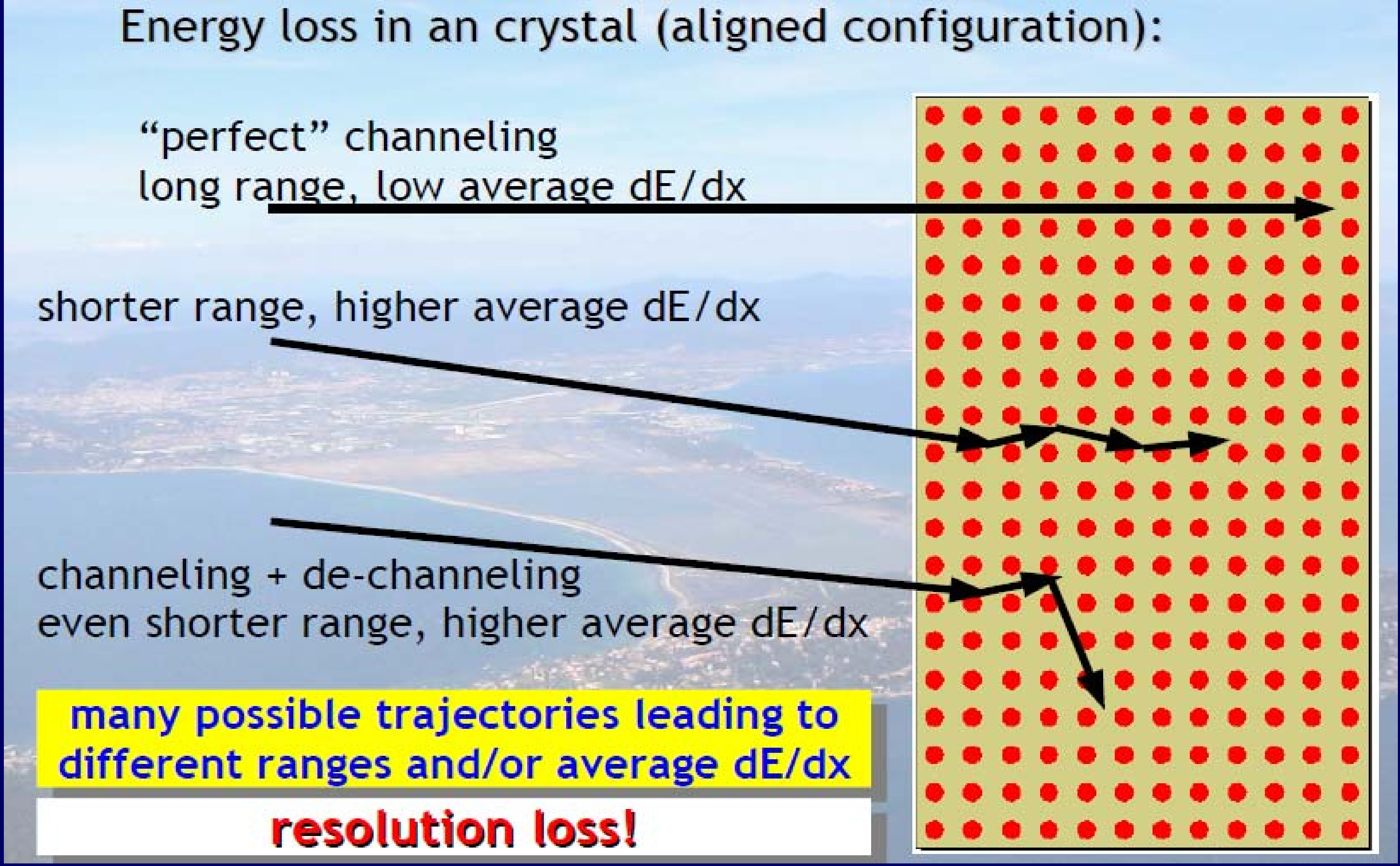
IMPROVEMENT IN DOPING UNIFORMITY

FAZIA data (INFN-Firenze)

FAZIA PhaseI-R&D



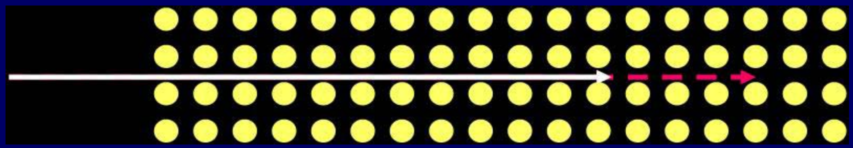
CHANNELING

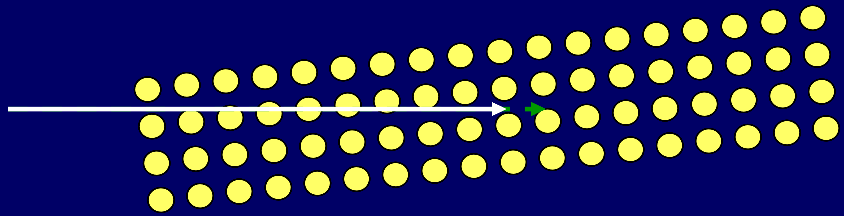


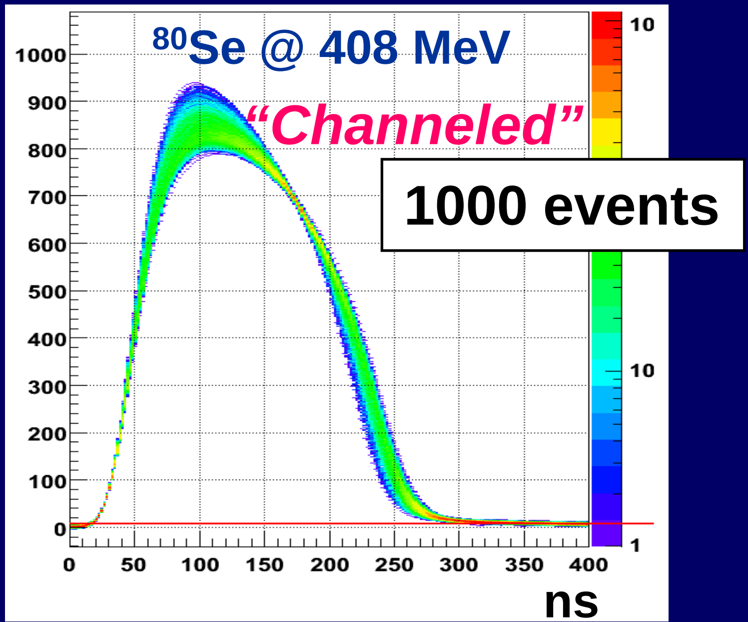
FAZIA PhaseI-R&D

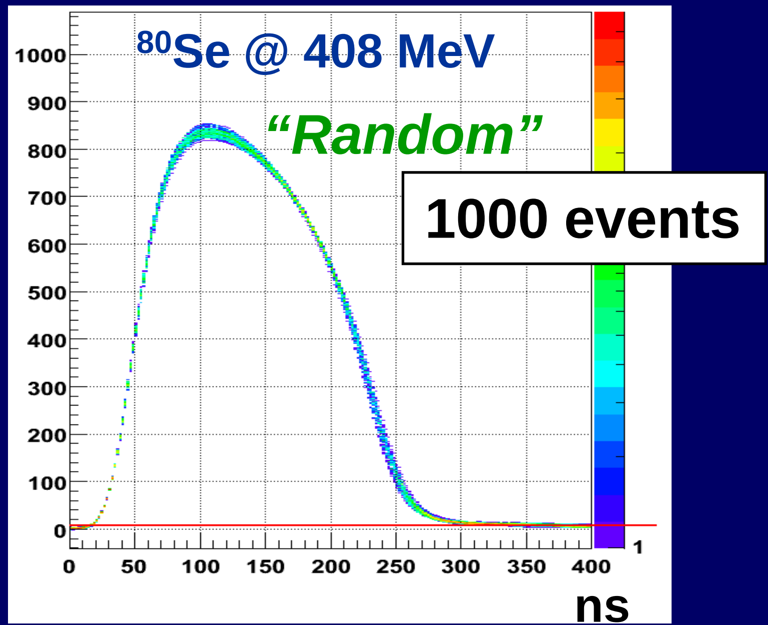
"Channeled"

"Random"









IMPROVEMENT IN SIGNAL DISPERSION

FAZIA data (LNL)

FAZIA PhaseI-R&D

RECIPE FOR HIGH QUALITY CHIPS

1 - UNIFORMITE DU DOPAGE

Ingot selection from the producer, controll… …ping (at about ρ=3000 ohm.cm) and use of nT… …chnology for best uniformity (+/- 0.5 %)

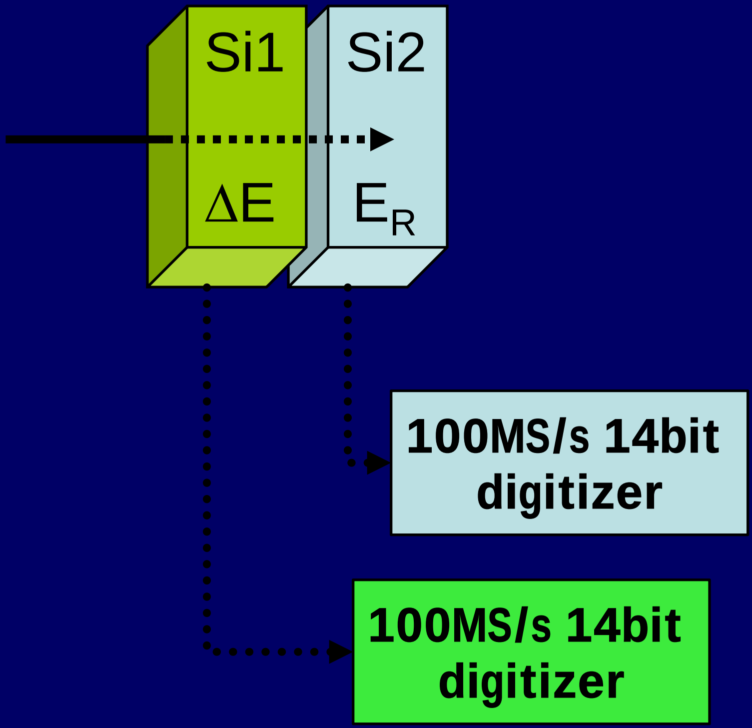
2 – EVITER AU MIEUX LA CA… …TION

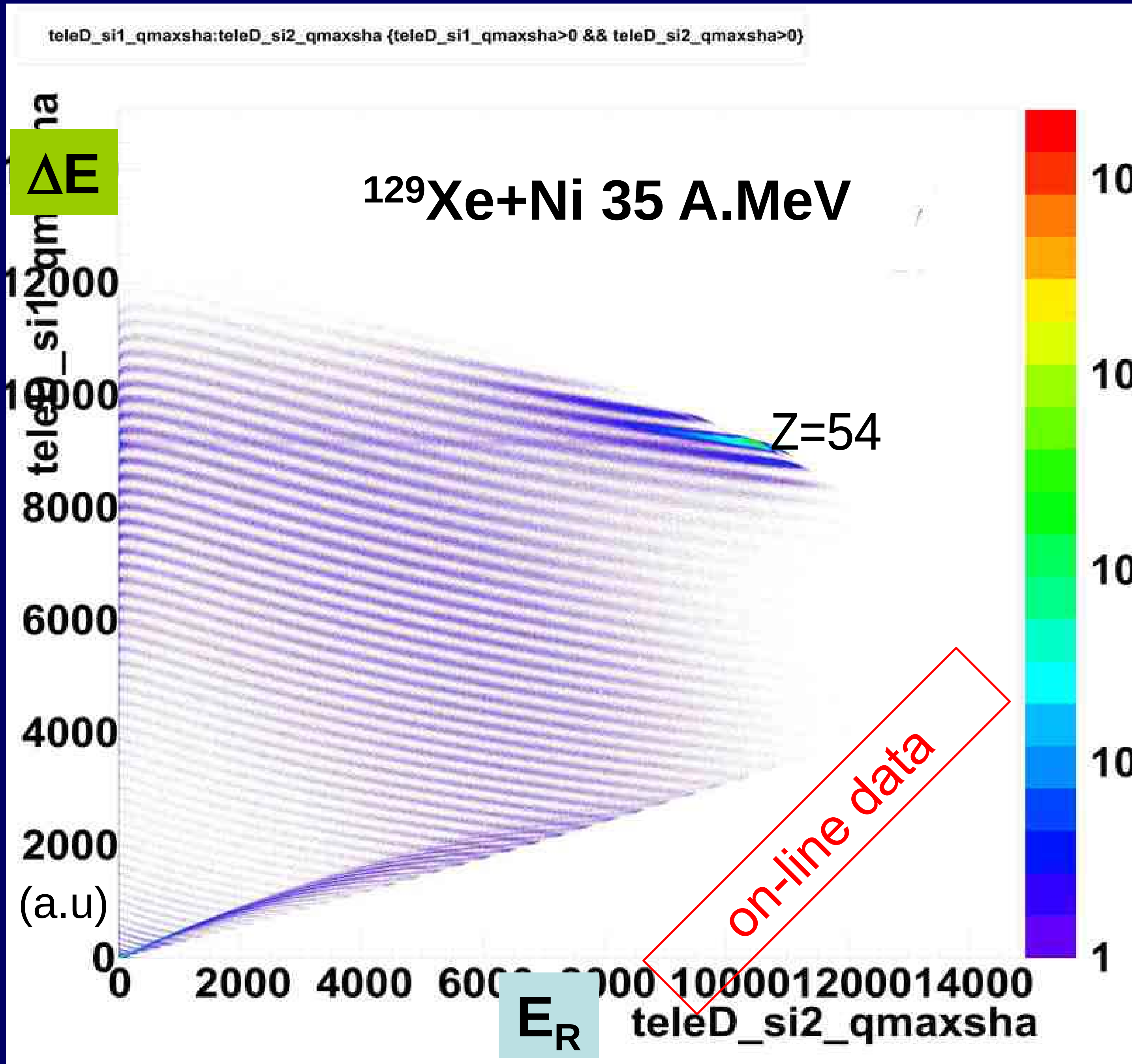
Ingot orient… …nd choice of the cut along special 'random… …ections (7deg to <100>); slices of 300 and 500 mi…

IN THE FOLLOWING THE RECIPE HAS BEEN APPLIED

FAZIA PhaseI-R&D

Usual DE/E technique

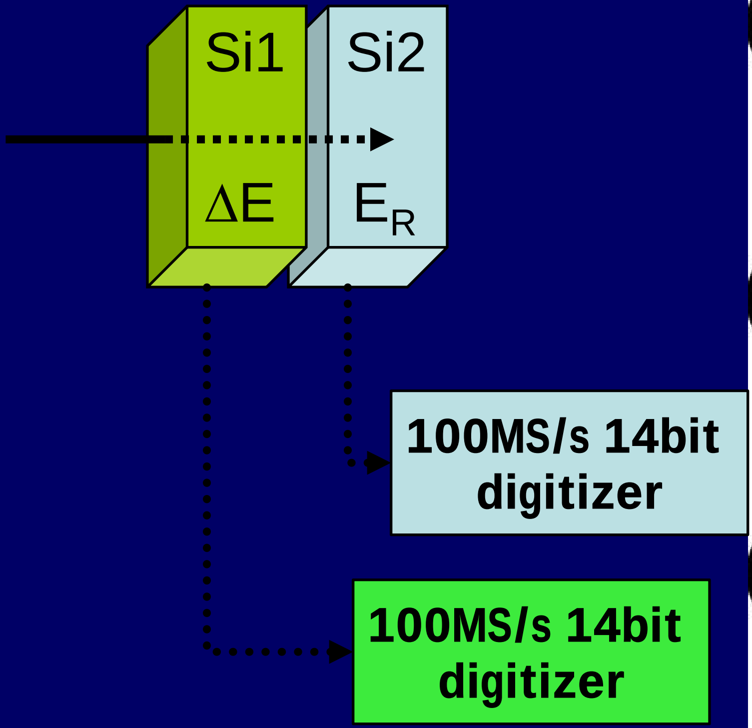




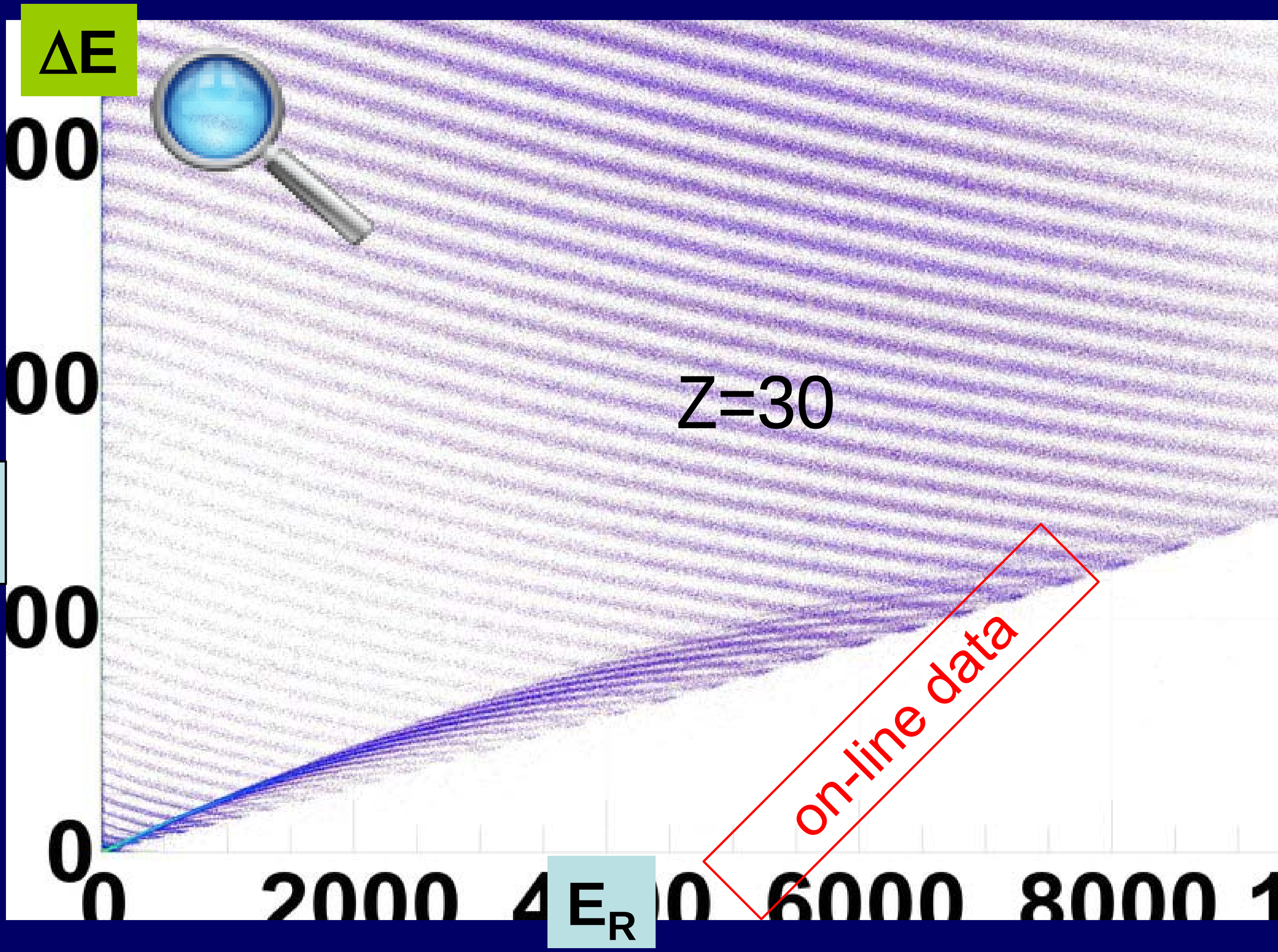
FAZIA data (LNS)

FAZIA PhaseI-R&D

Usual DE/E technique



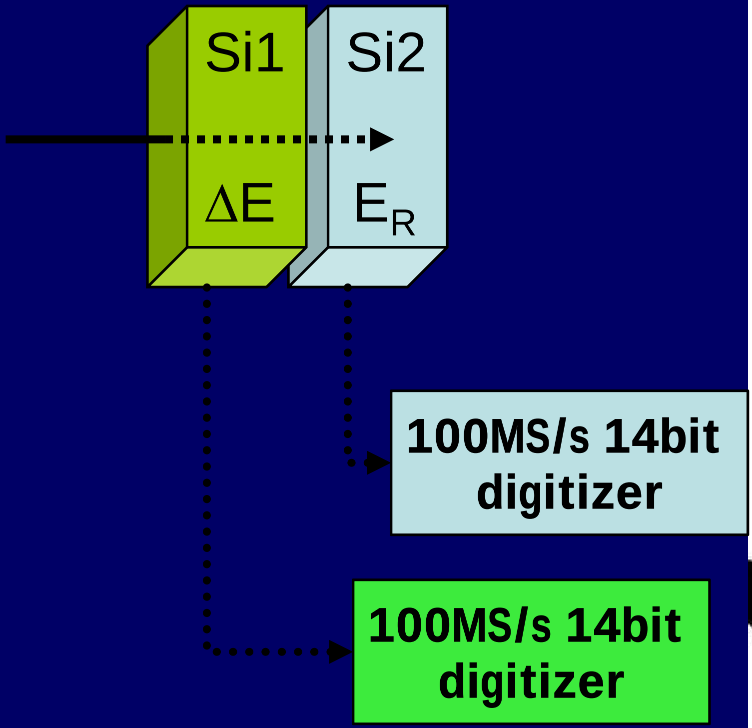
ZOOM



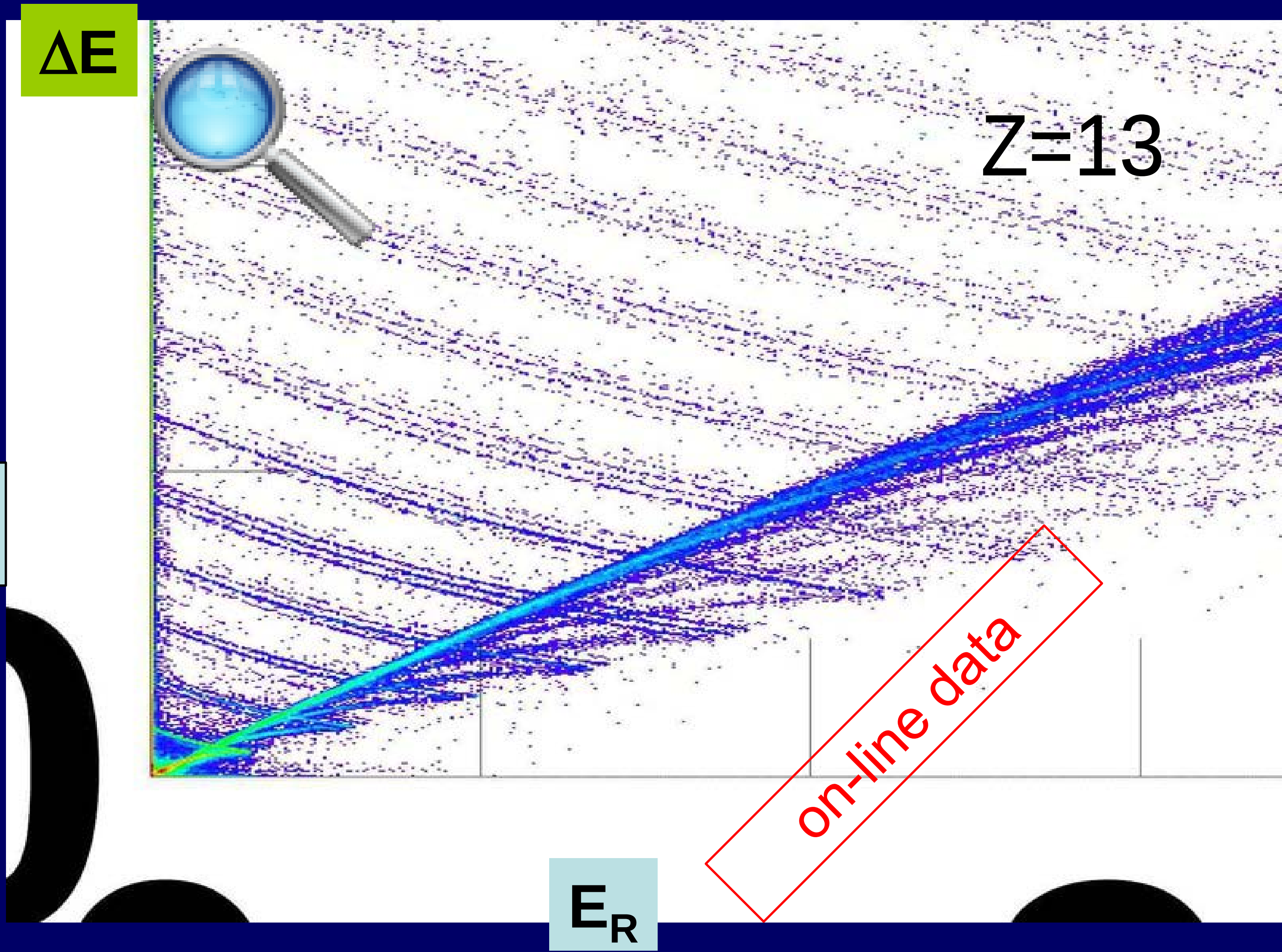
FAZIA data (LNS)

FAZIA PhaseI-R&D

Usual DE/E technique



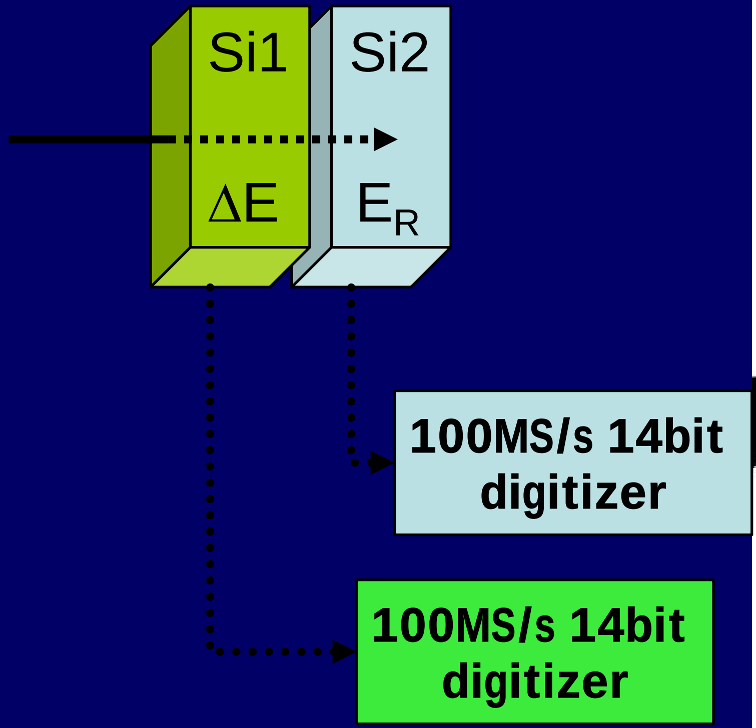
ZOOM (again)



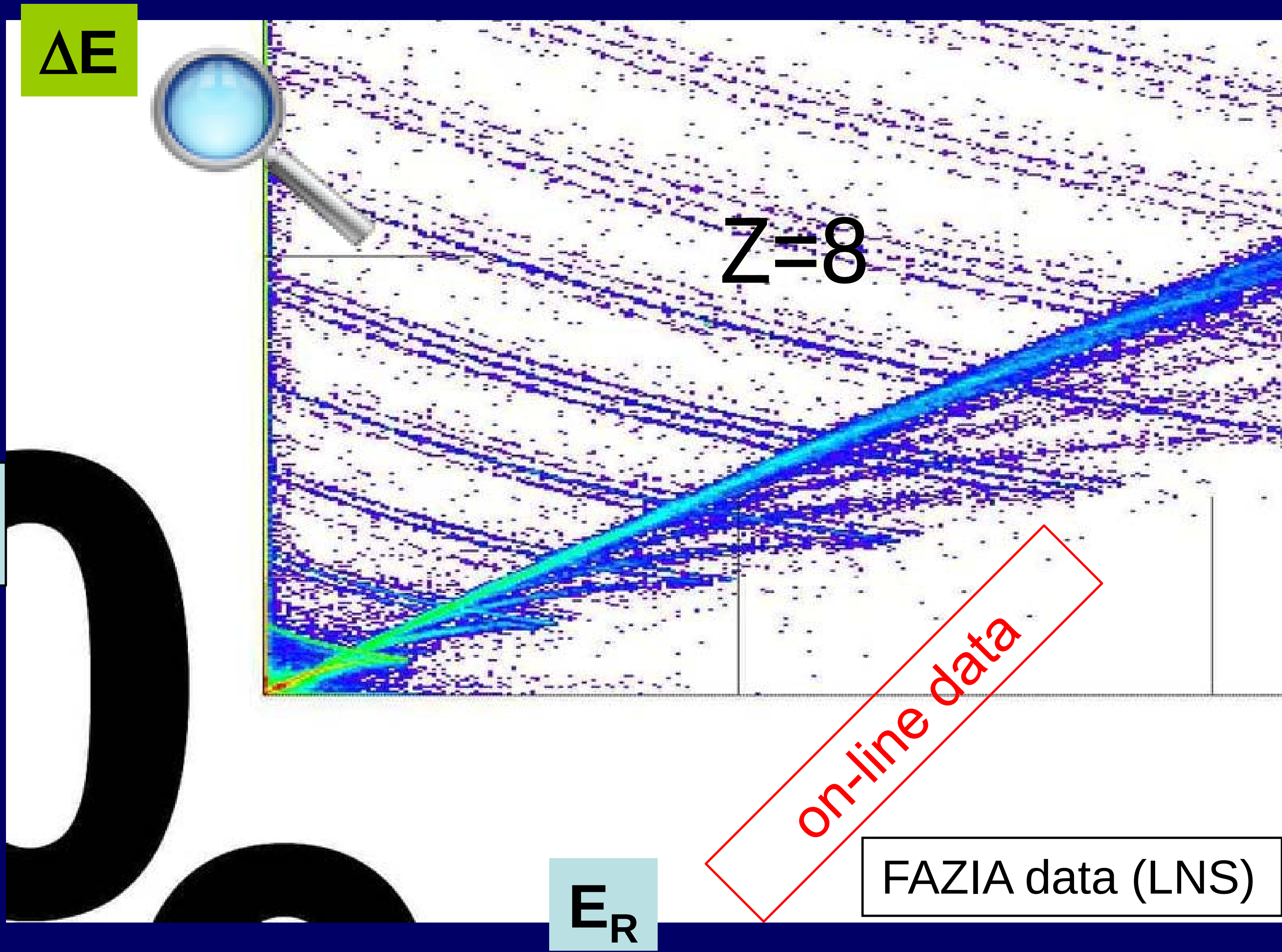
FAZIA data (LNS)

FAZIA PhaseI-R&D

Usual DE/E technique



ZOOM (again and again)

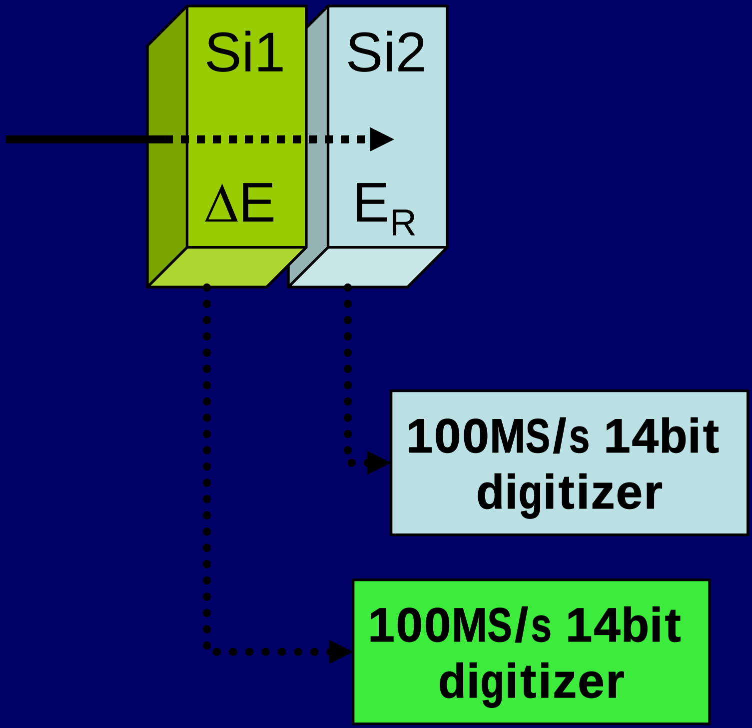


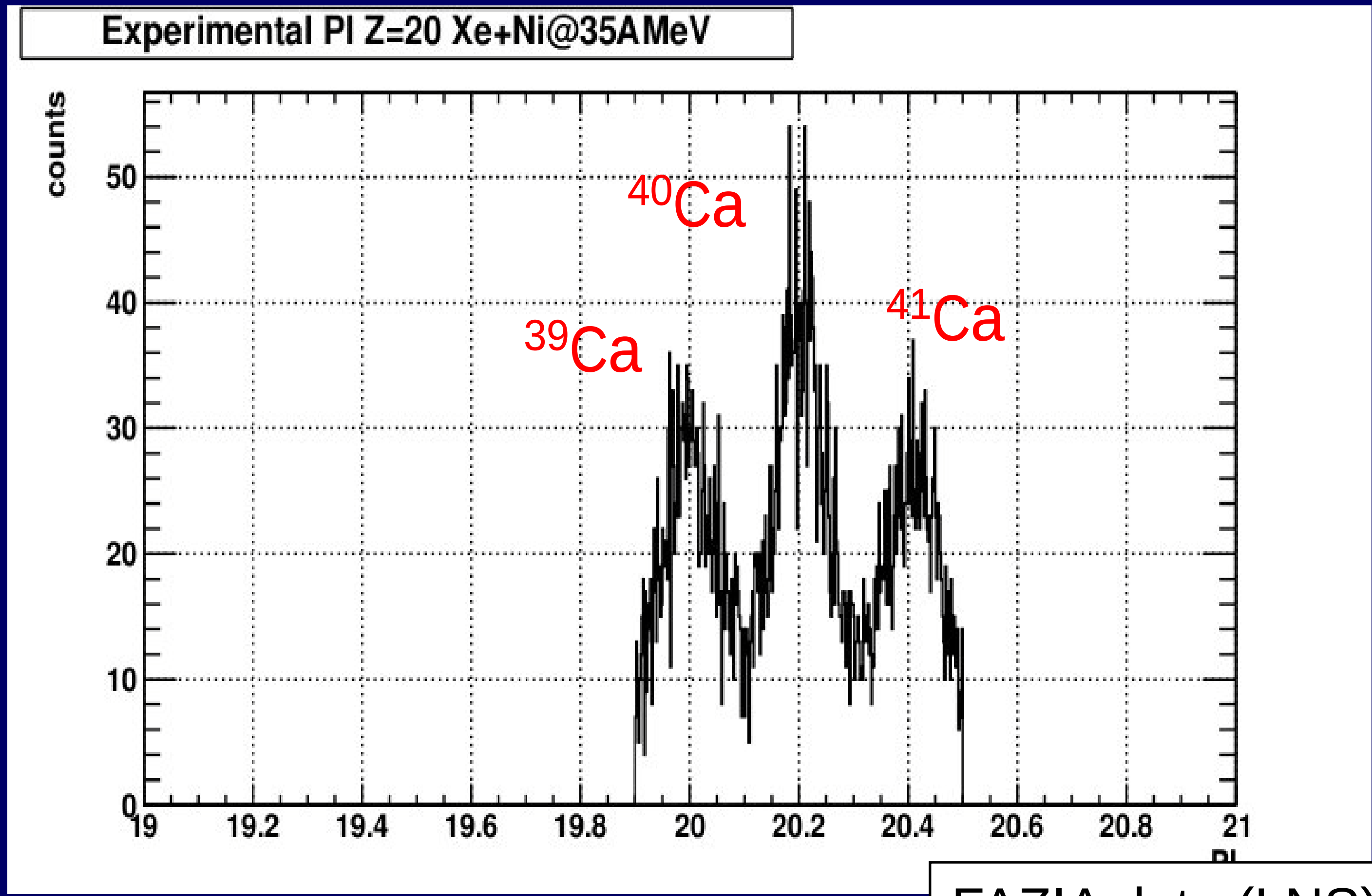
Used configuration:
isotopic identification up to Z~25 with ~5GeV full range

FAZIA PhaseI-R&D

Usual DE/E technique

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

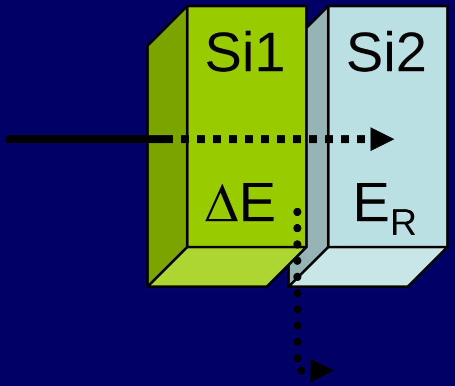




FAZIA data (LNS)

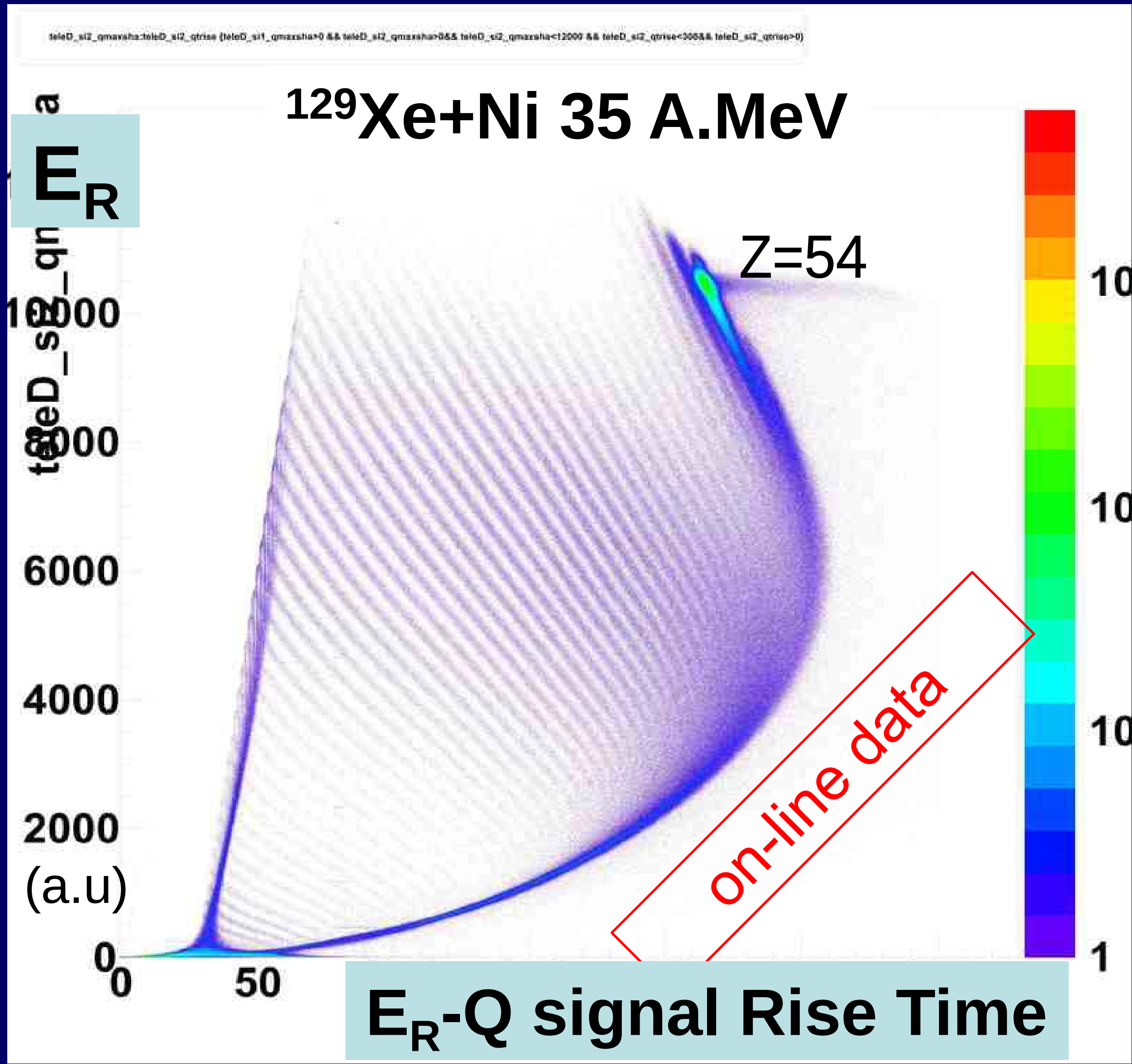
Used configuration:
isotopic identification up to Z~25 with ~5GeV full range

FAZIA PhaseI-R&D



PSA: only one Silicon is used

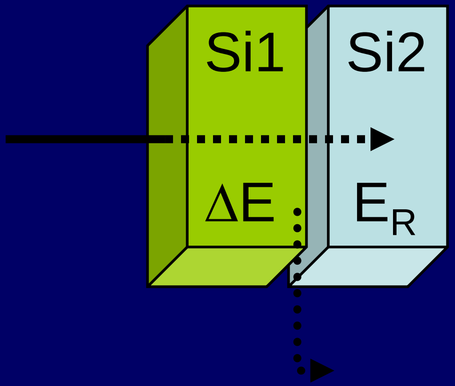
100MS/s 14bit digitizer



Digital PSA results:
one digitizer,
6 GeV full scale

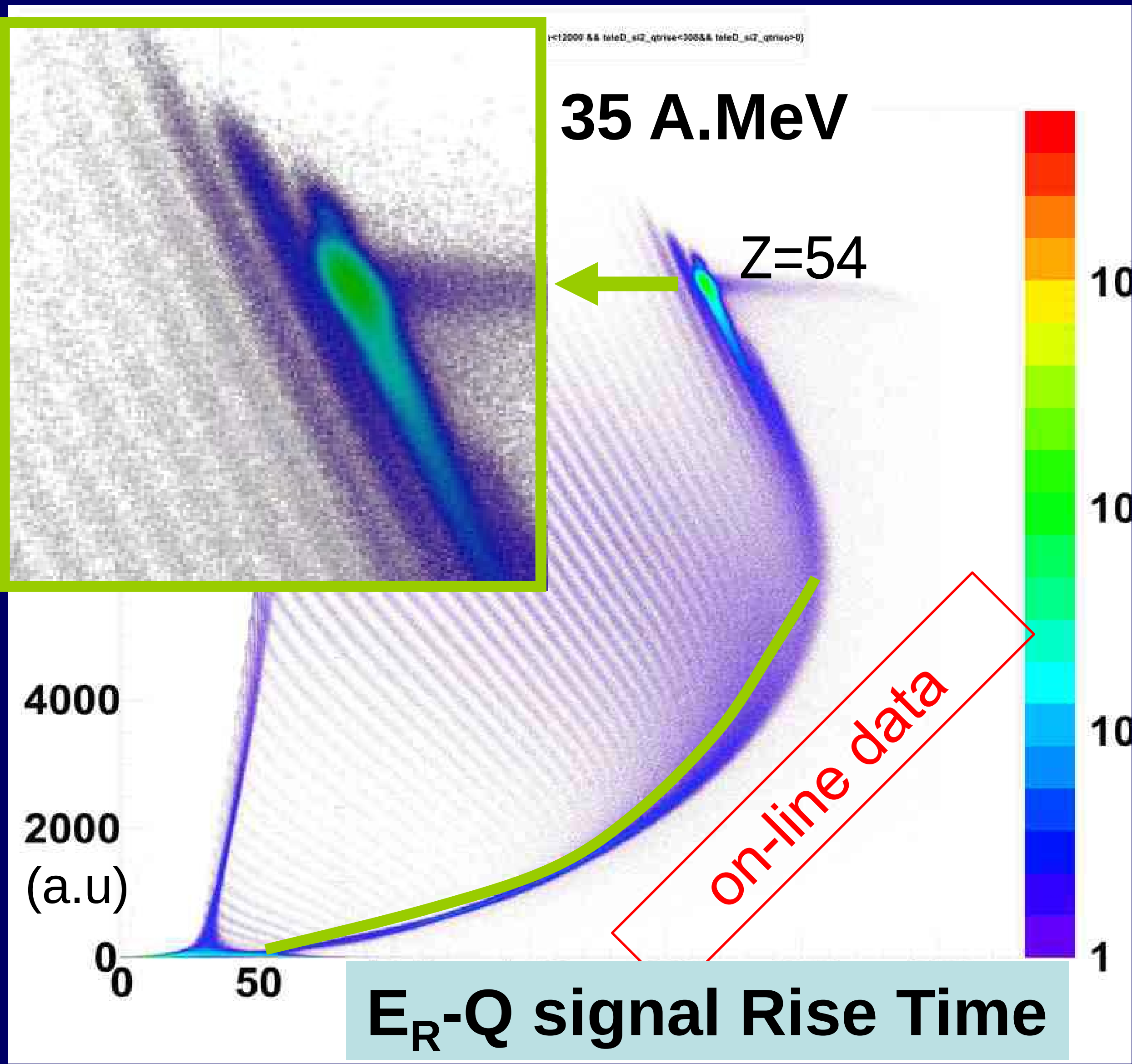
FAZIA data (LNS)

FAZIA PhaseI-R&D



PSA:
only one Silicon is used

100MS/s 14bit digitizer

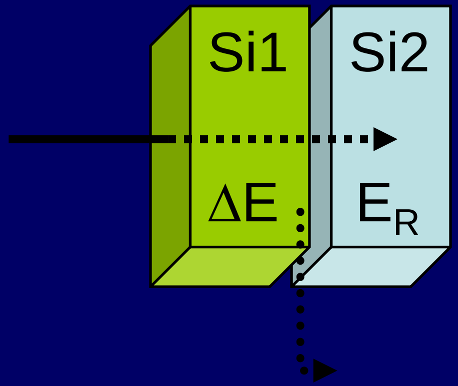


E_R-Q signal Rise Time

Digital PSA results:
one digitizer,
6 GeV full scale

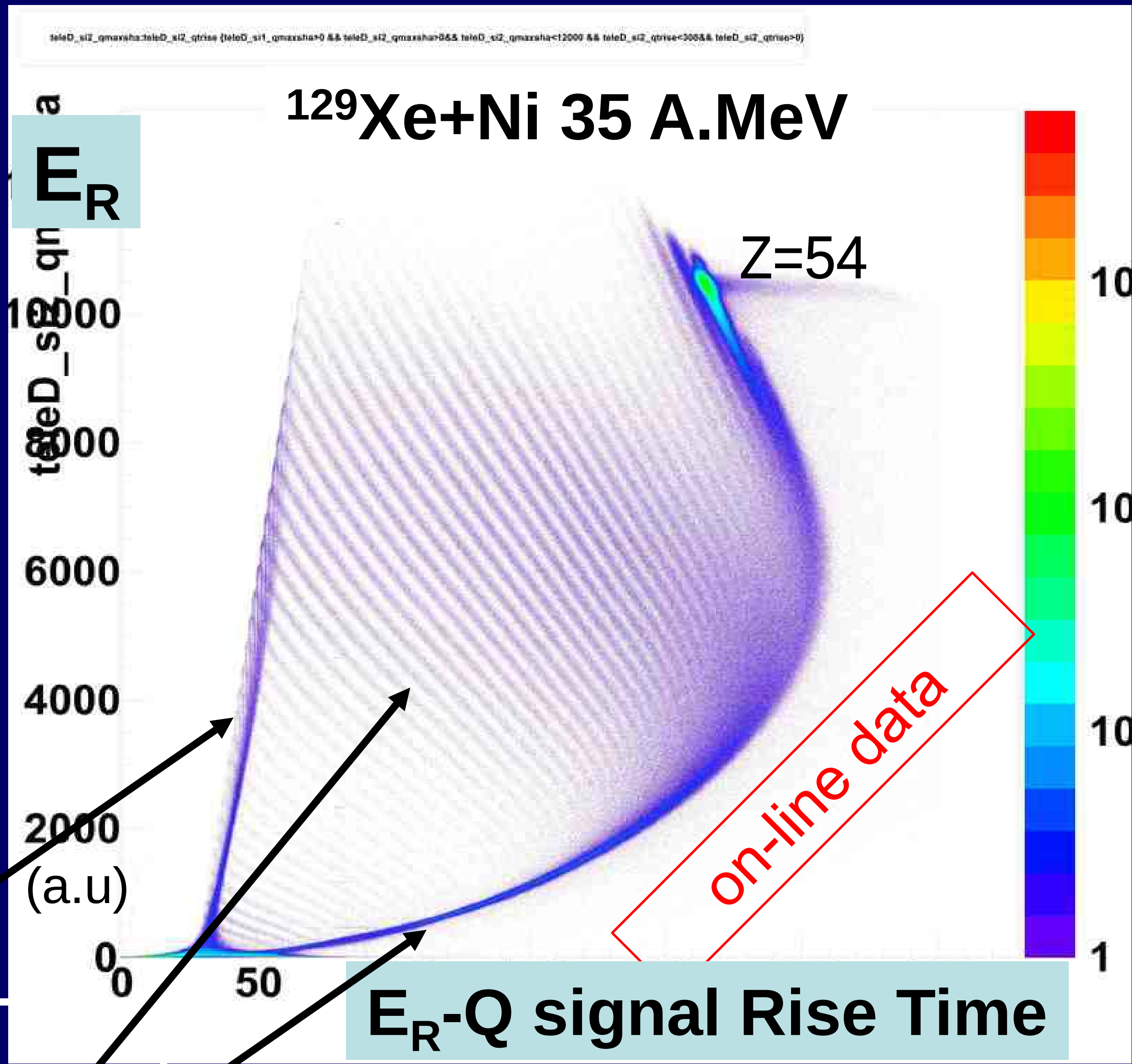
FAZIA data (LNS)

FAZIA PhaseI-R&D



PSA: only one Silicon is used

100MS/s 14bit digitizer

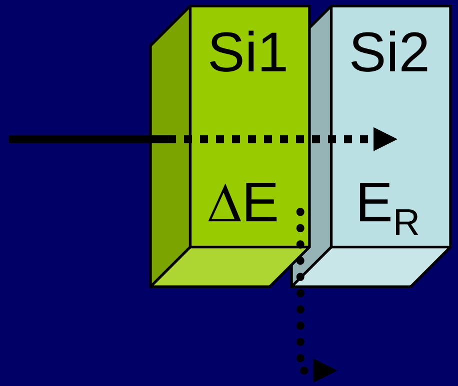


Digital PSA results:
one digitizer,
6 GeV full scale

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

FAZIA data (LNS)

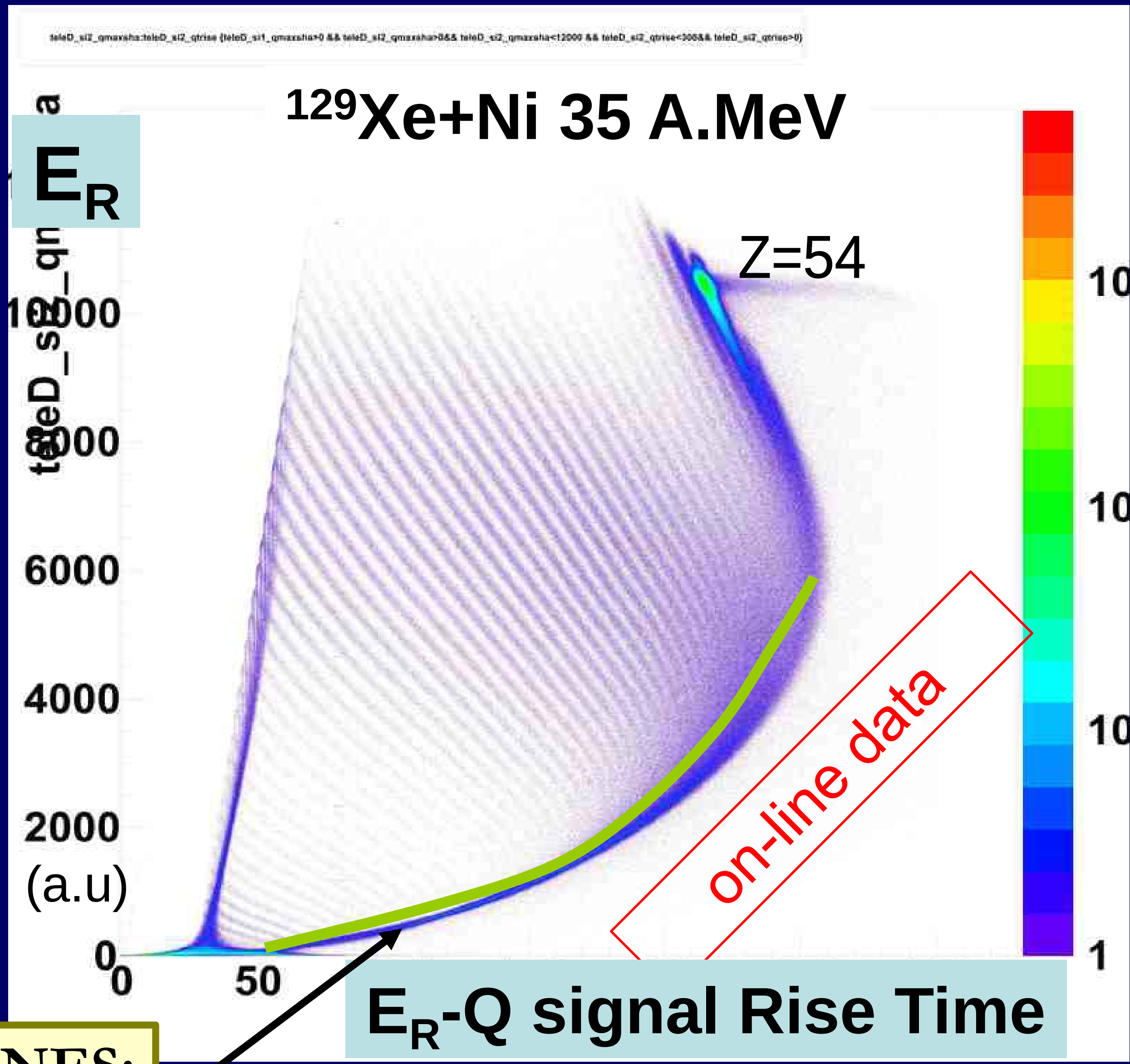
FAZIA PhaseI-R&D



PSA: only one Silicon is used

100MS/s 14bit digitizer

Digital PSA results:
one digitizer,
6 GeV full scale

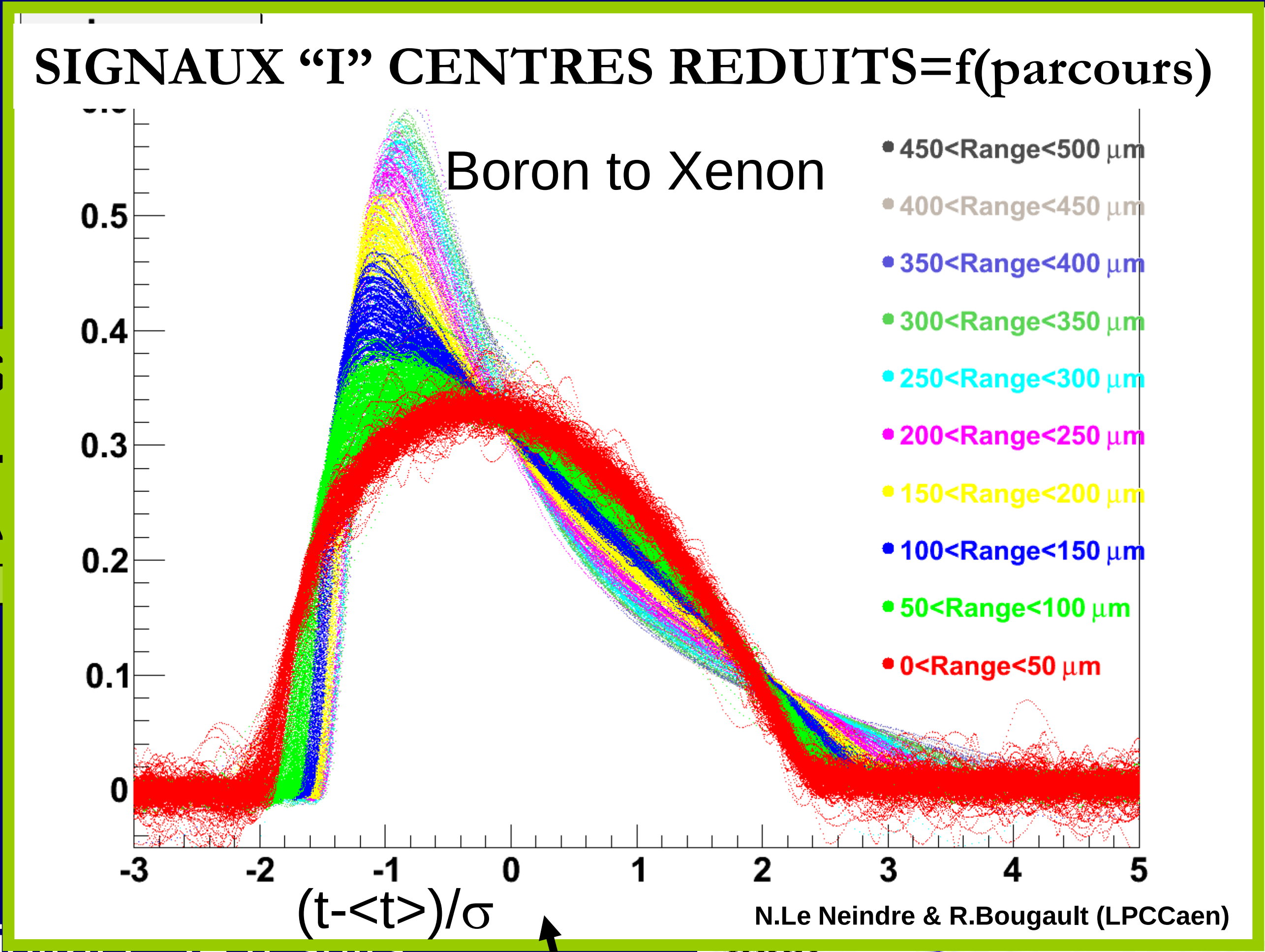


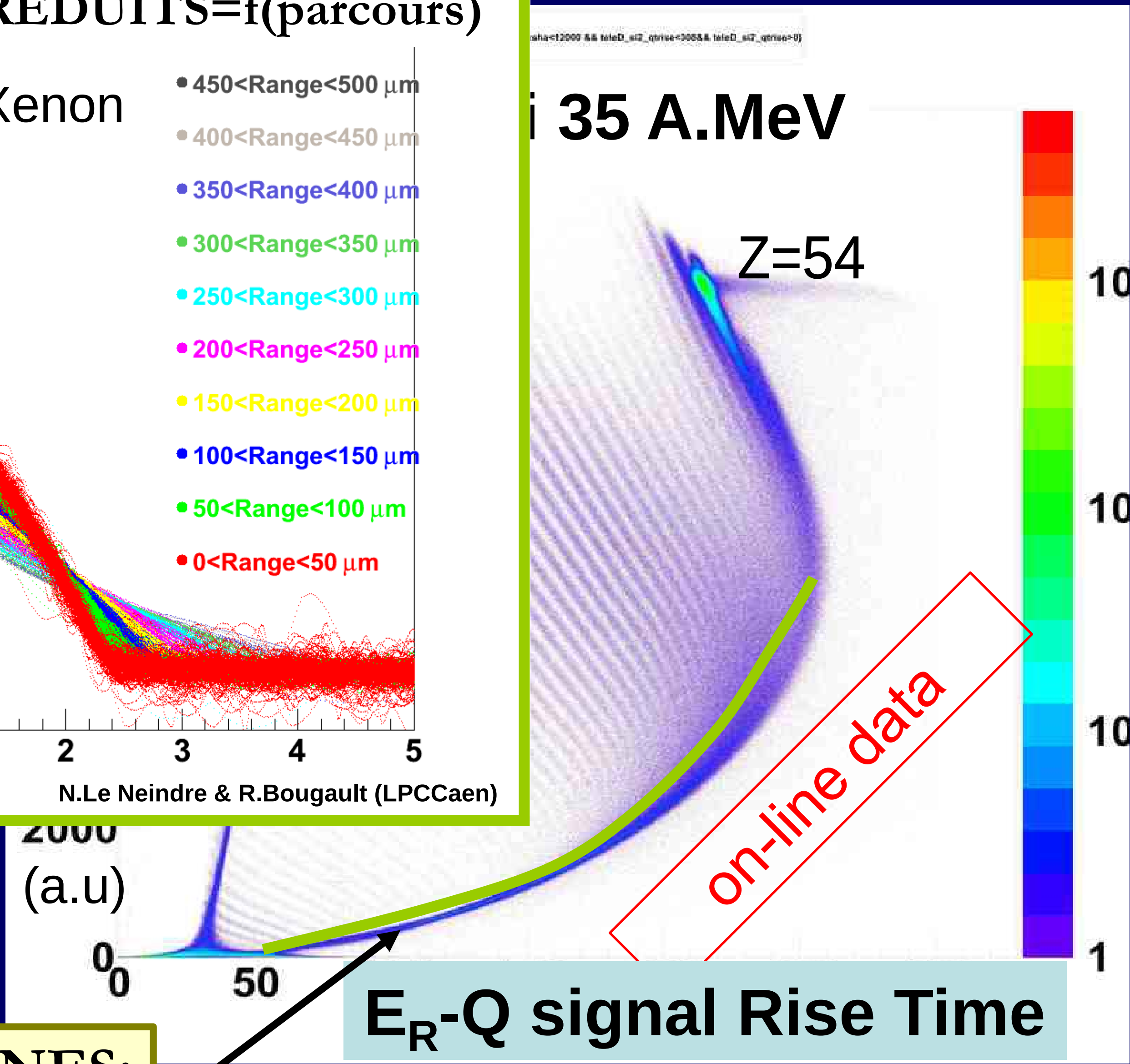
HIC SUNT LEONES:
below 3-4 A.MeV

➔ Time of Flight

FAZIA data (LNS)

FAZIA PhaseI-R&D





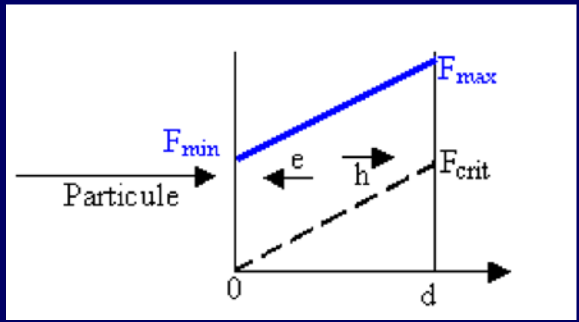
Digital PSA results:
one digitizer,
6 GeV full scale

HIC SUNT LEONES: below 3-4 A.MeV

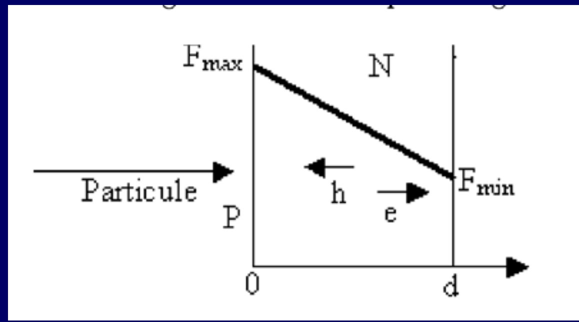
FAZIA data (LNS)

FAZIA PhaseI-R&D

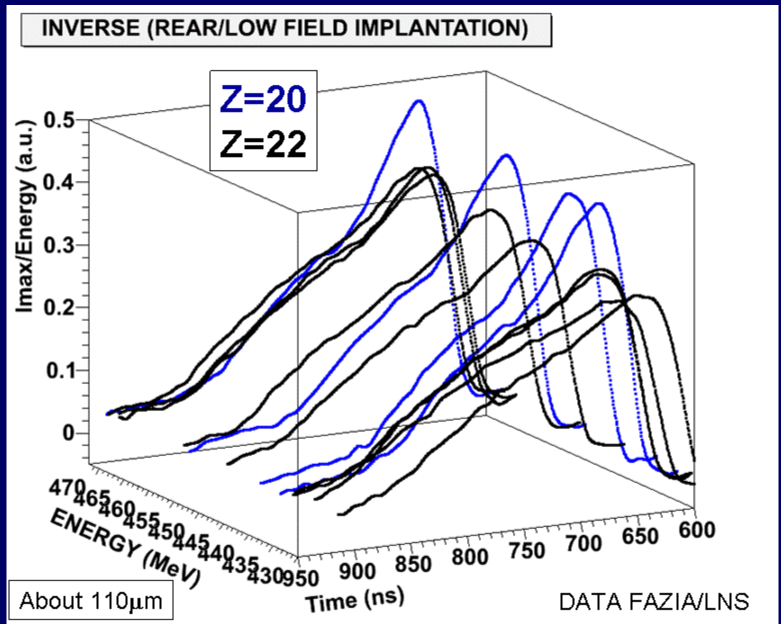
INVERSE (rear)

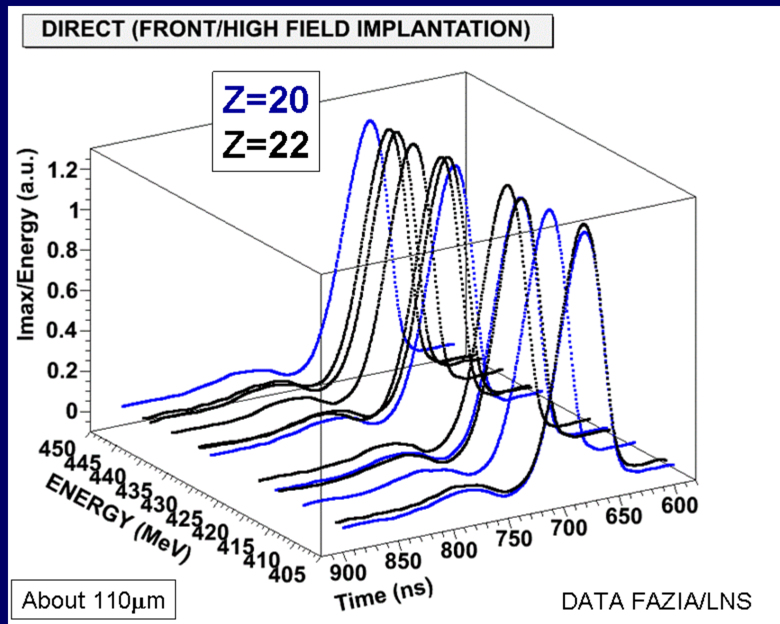


DIRECT (front)



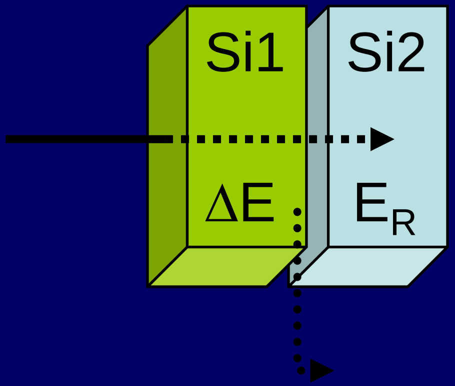
Pulse Shape of stopped particules is different: charge-carrier mobilities of electrons and holes, different plasma-erosion times





FAZIA data (LNS)

FAZIA PhaseI-R&D

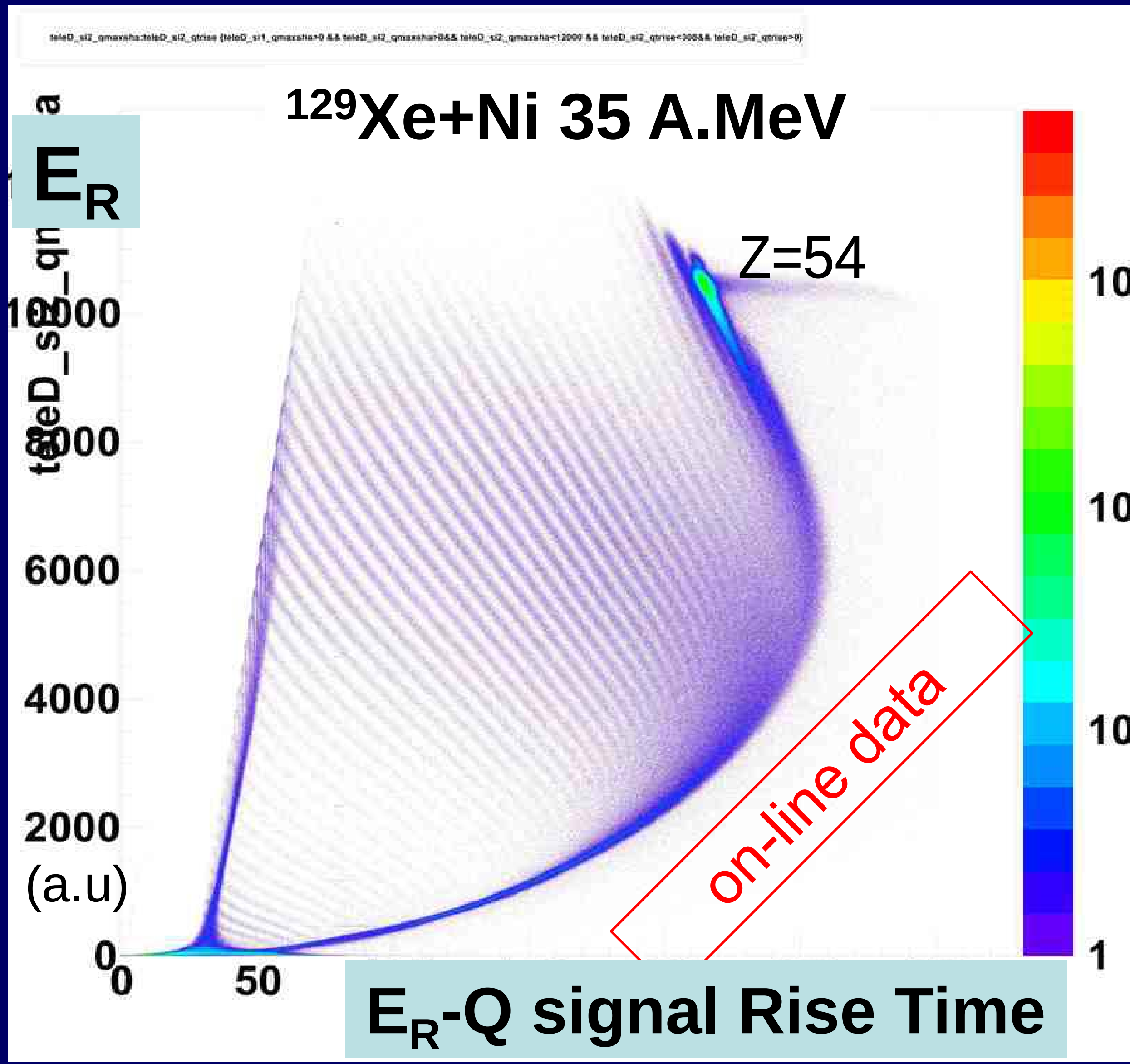


PSA: only one Silicon is used

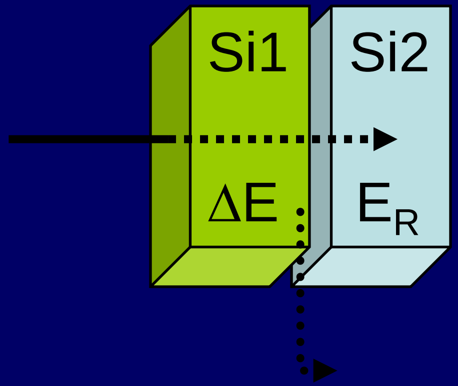
100MS/s 14bit digitizer

Digital PSA results:
one digitizer,
6 GeV full scale

FAZIA data (LNS)



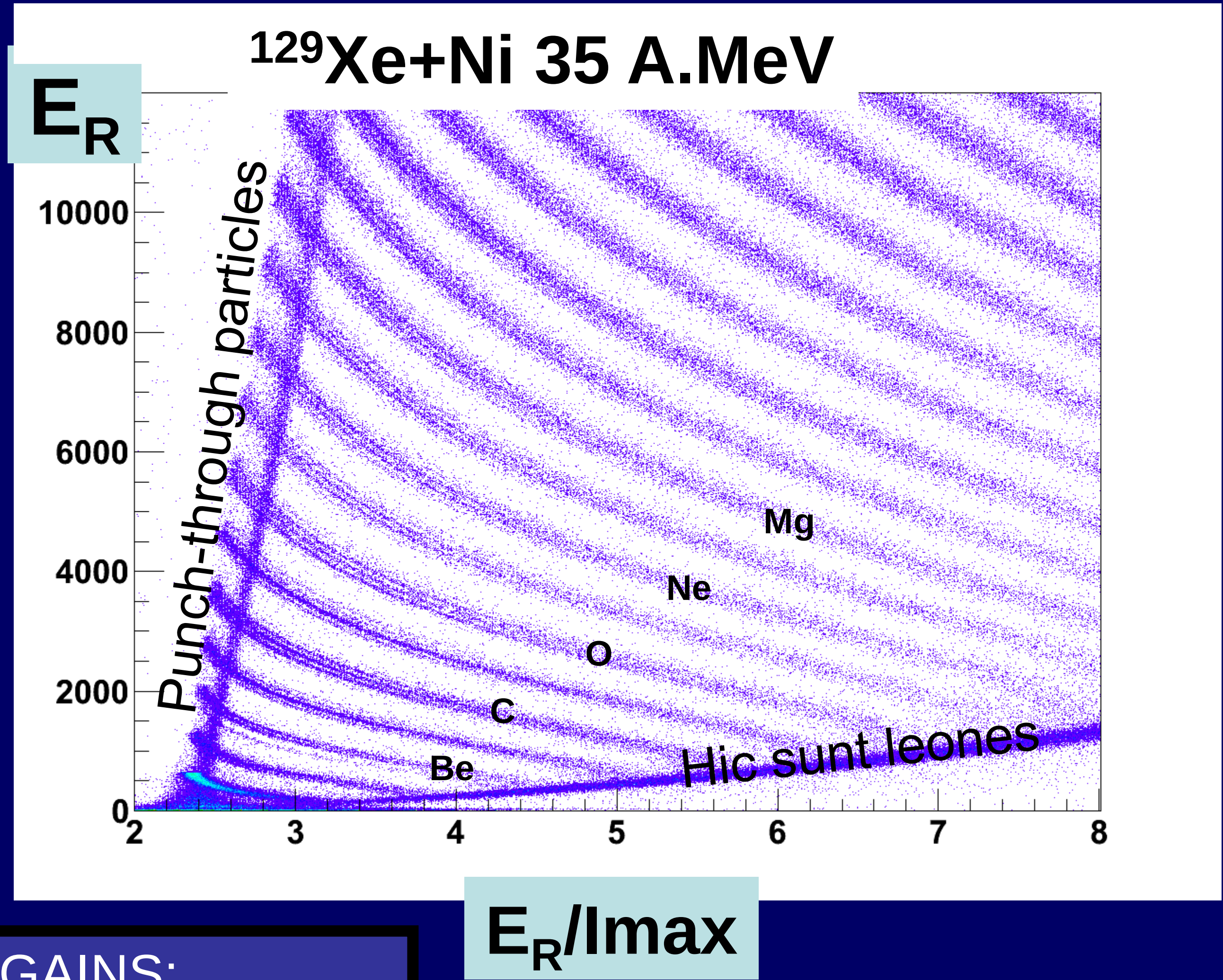
FAZIA PhaseI-R&D



PSA: only one Silicon is used

100MS/s 14bit digitizer

Digital PSA results:
one digitizer,
0.7 GeV full scale



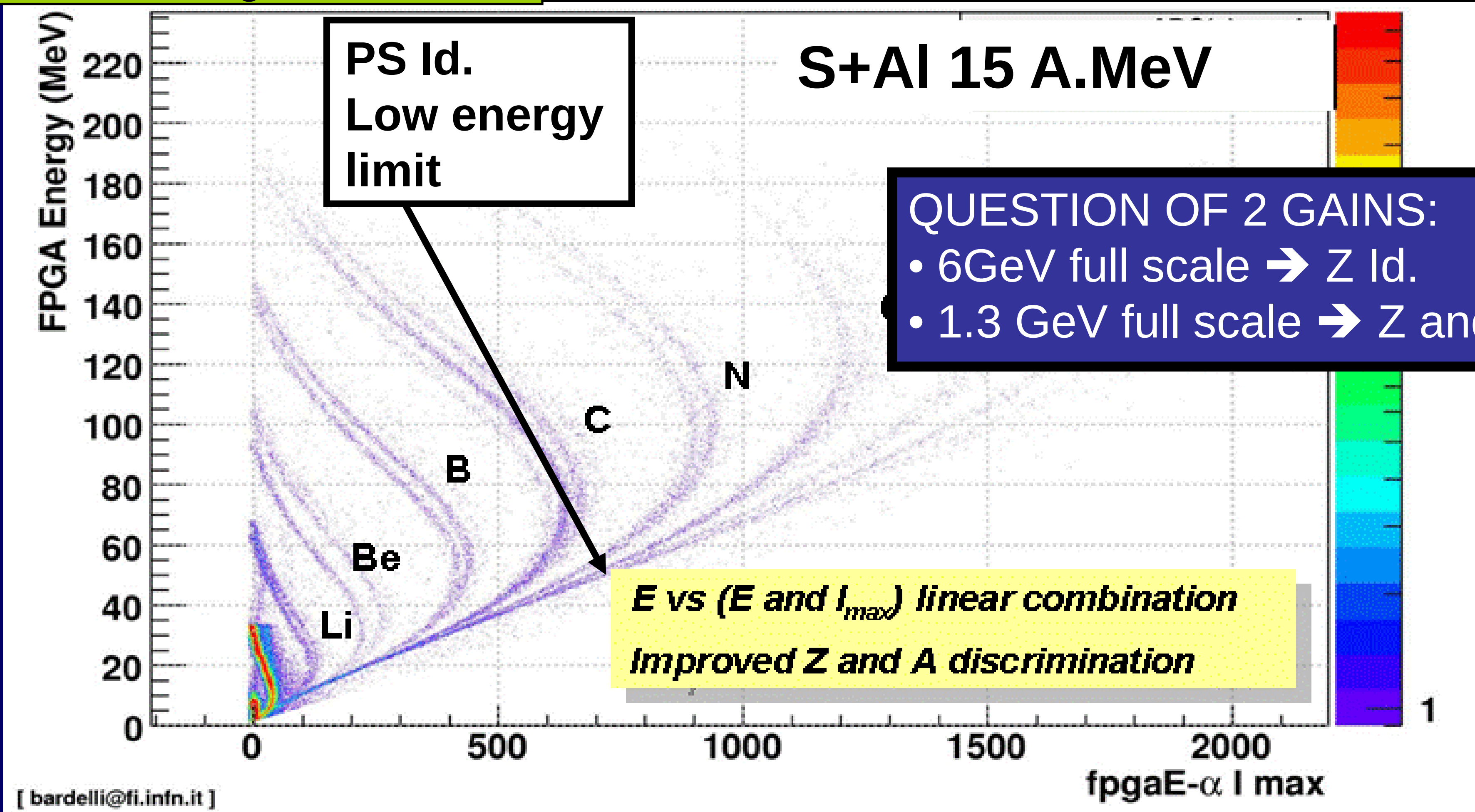
QUESTION OF 2 GAINS:
- 6GeV full scale → Z Id.
- 0.7 GeV full scale → Z and A Id.

FAZIA data (GANIL2010)

FAZIA PhaseI-R&D

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

IONS IDENTIFIED BY ONE DETECTOR



PS Id.
Low energy limit

QUESTION OF 2 GAINS:
- 6GeV full scale ➔ Z Id.
- 1.3 GeV full scale ➔ Z and A Id.

E vs (E and I_{max}) linear combination
Improved Z and A discrimination

FAZIA data (LNL)

FAZIA demonstrator

FAZIA PHASE2 “demonstrator & physics” :

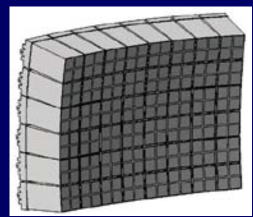
• **Built (2011-2013) a demonstrator of 192 telescopes Si/Si/CsI with “all” the finals (4π detector) electronics, mechanical solutions.**

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

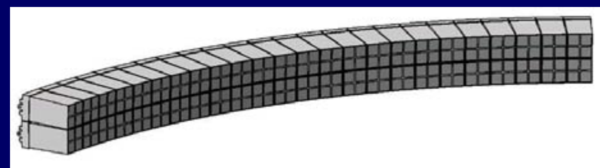
12 BLOCKS
48 MODULES
192 TELESCOPES Si/Si/CsI

- 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”



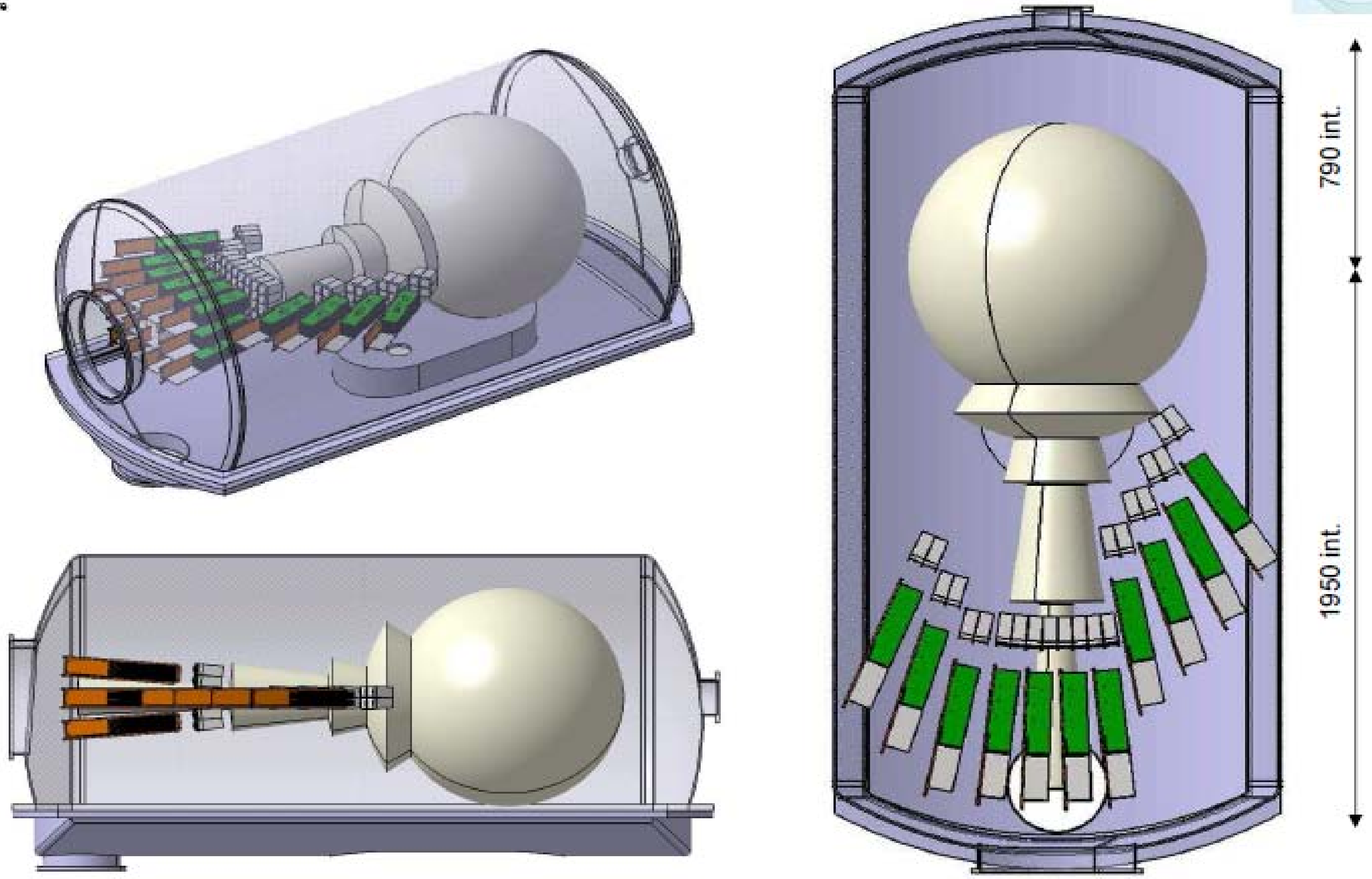
“BELT”



FAZIA Phase2

LPC CAEN
Laboratoire de Physique Corpusculaire

FAZIA – INDRA

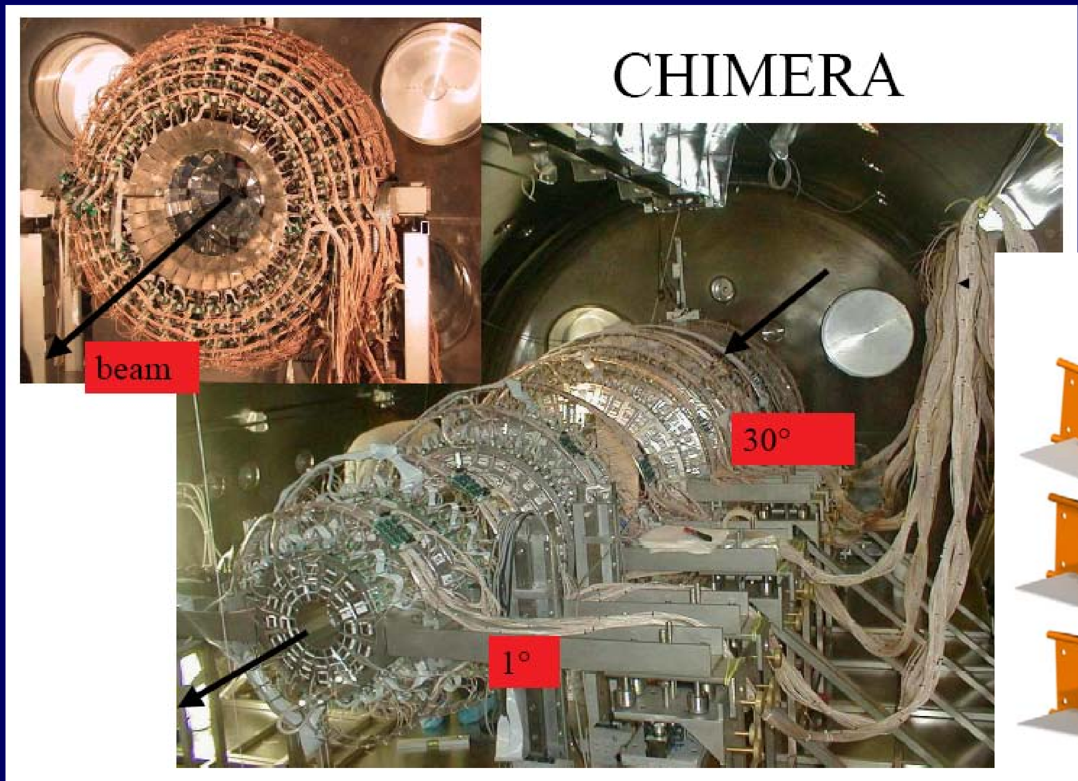


Bloc : R600 à R1200 & Wall : R1200

DEMONSTRATOR & PHYSICS (COUPLING WITH INDRA)

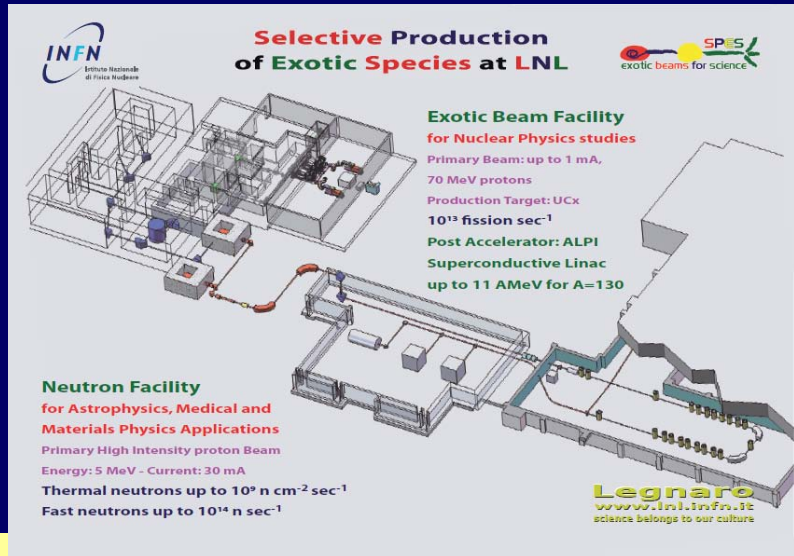
FAZIA Phase2

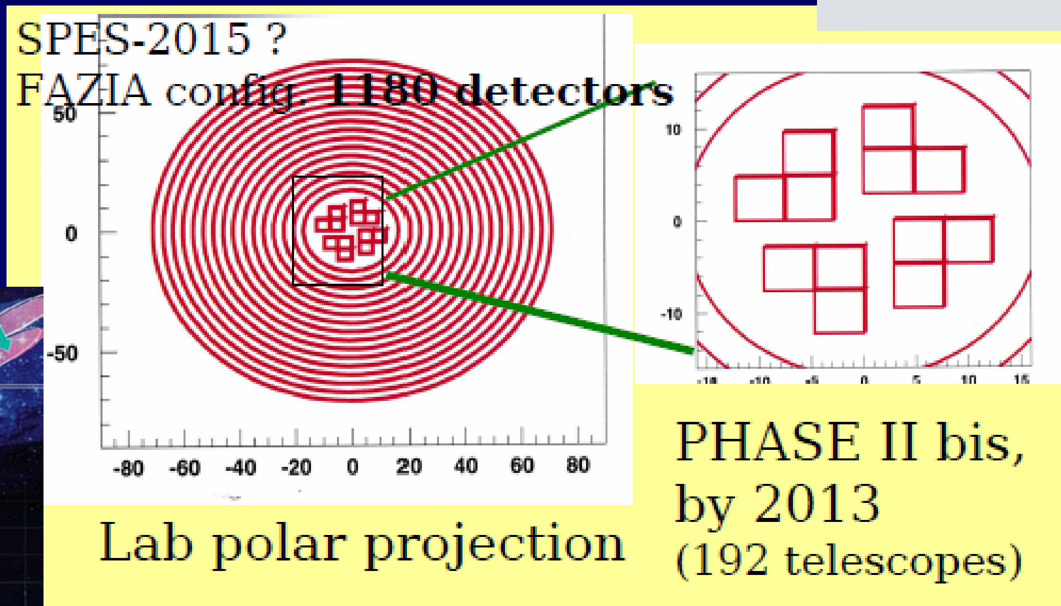
FAZIA@CHIMERA

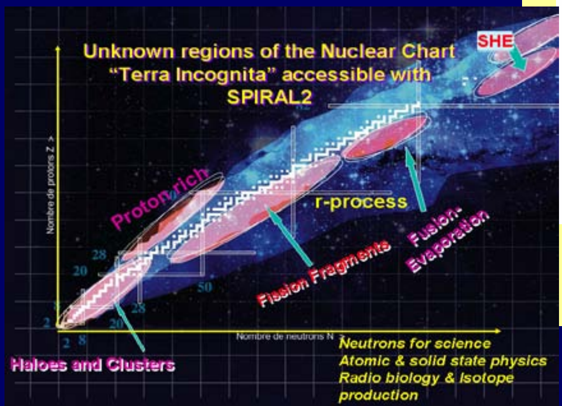


FAZIA Phase2

FAZIA@GARFIELD
… and FUTURE:







(G.Casini et al. SPES-WS)

FAZIA Phase2 2011-2013

TECHNICAL CHOICE :

Digitize as close as possible /preamplier

- Noise reduction
- Avoid signal distortion (PSA)
- Simplify signal transmission (high number of channels)

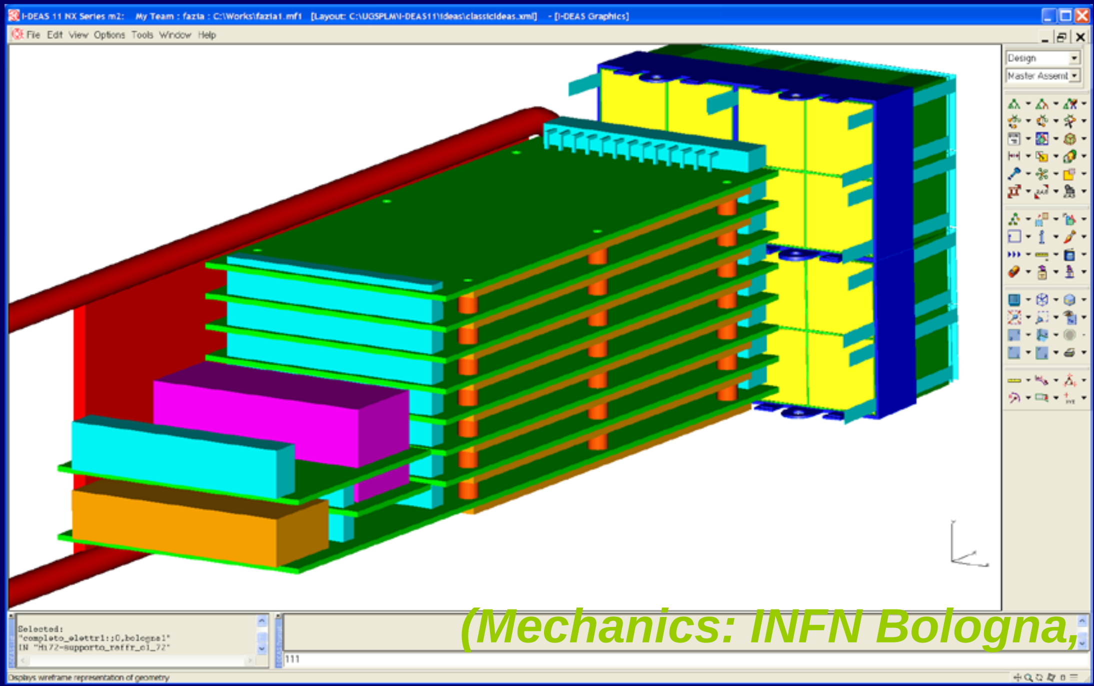
- Telescope			
Si(300µ)	- charge	250 MeV f.s.	250 Ms/s 14 bit
	- charge	4 GeV f.s	100 Ms/s 14 bit
	- current		250 Ms/s 14 bit
Si(500µ)	- charge	4 GeV f.s	100 Ms/s 14 bit
	- current		250 Ms/s 14 bit
CsI(phdiode)	- charge	4 GeV f.s	100 Ms/s 14 bit

2 gains for the first Silicium detector

FAZIA Phase2 2011-2013

TECHNICAL CHOICE :

Digitize as close as possible /preamplier



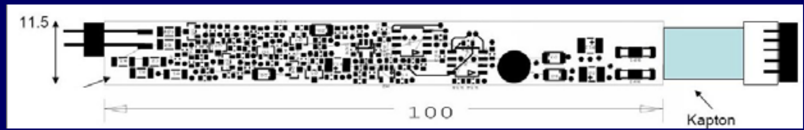
(Mechanics: INFN Bologna, Napoly and LPCCaen)

- 16 telescope “Block” structure
- 8 analog./dig. cards
- with mother board (communication , HV and “low bias”)
- 1 optic fibber per “Block” (3Gbit/s)

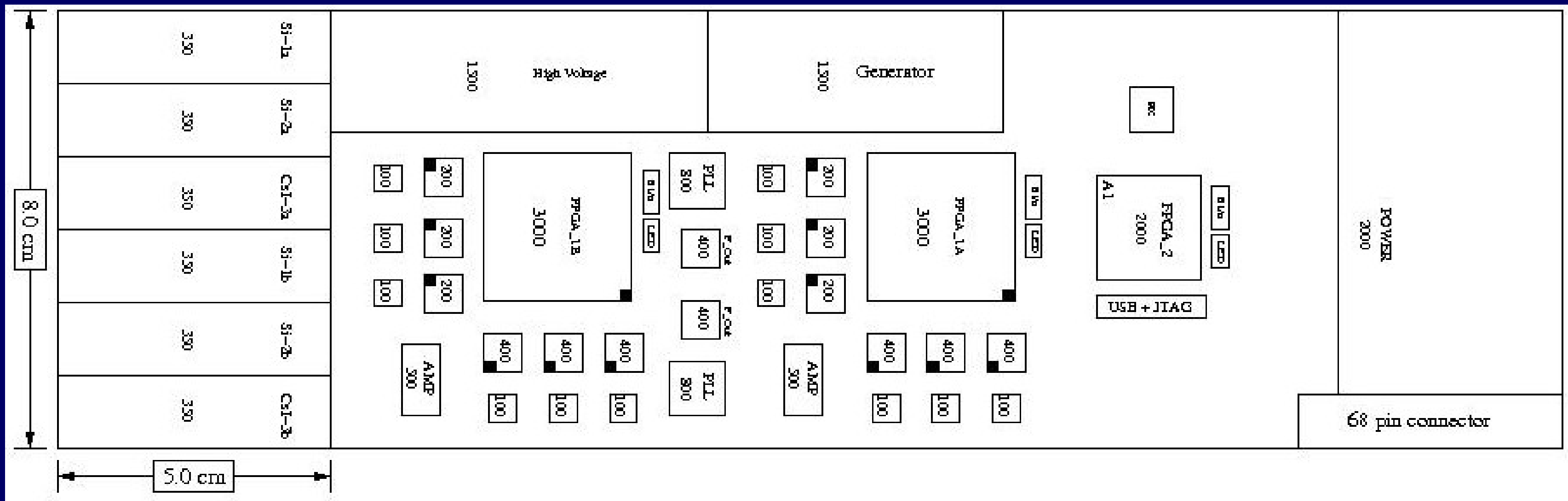
FAZIA Phase2 2011-2013

TECHNICAL CHOICE :
Digitize as close as possible /preamplier

PACI preamp.
Charge & Current



(P.Edelbruck IPNOrsay)



(Card for 2 telescopes)

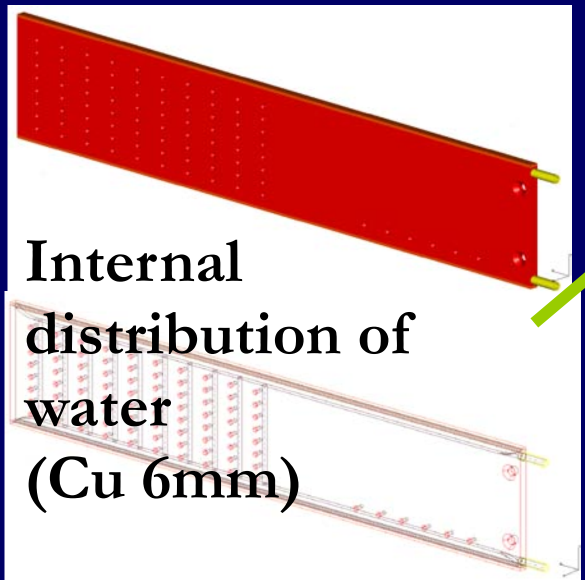
(IPNOrsay, INFN Napoly)

"Price to pay"
- 25 Watts per card
- Cooling system

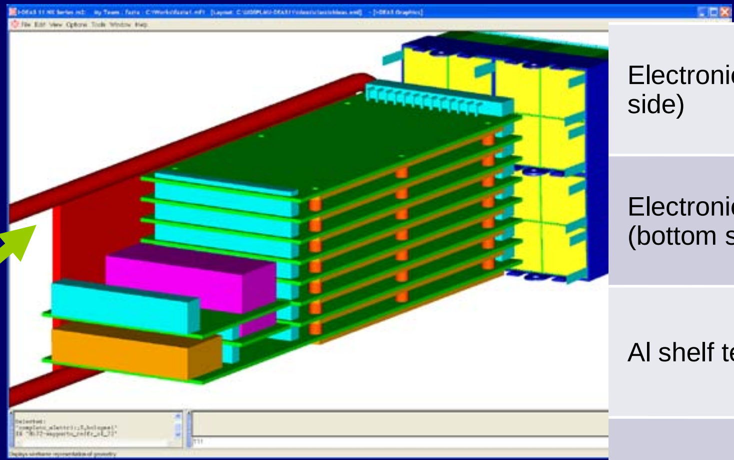
FAZIA Phase2 2011-2013

TECHNICAL CHOICE :

Digitize as close as possible /preamplier

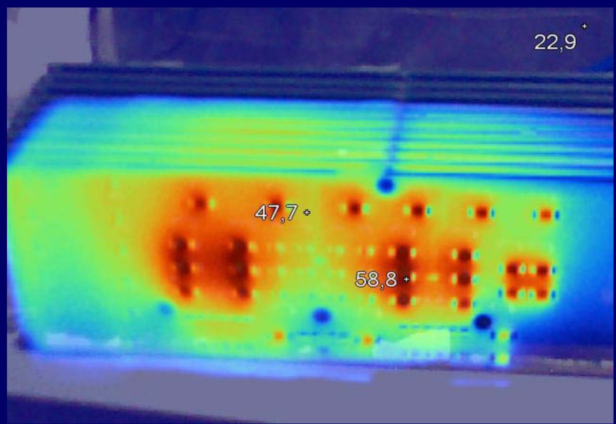


Internal distribution of water (Cu 6mm)



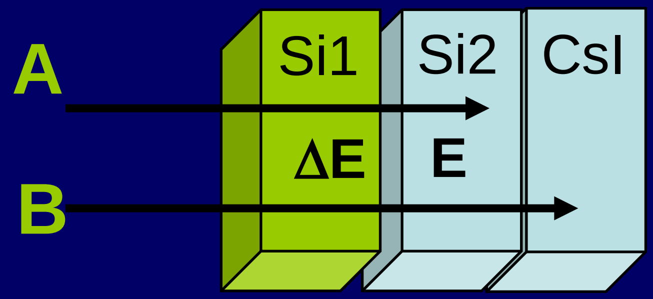
Electronic card temperature (top side)	50 °C	45 °C
Electronic card temperature (bottom side)	43 °C	40 °C
Al shelf temperature	35 °C	32 °C
Cu plate temperature	34 °C	28 °C
TESTS under vaccuum		
Outgoing water temperature	25 °C	20,1 °C
Incoming water temperature	20 °C	17,5 °C
Cooling water flow	0,5 l/m	1 l/m

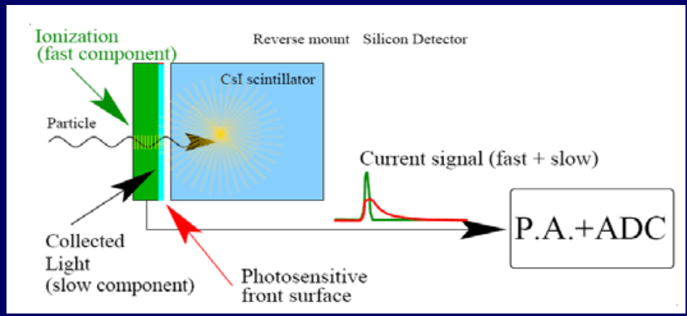
Air test : Existence
Of hot points
(improve)



(INFN Napoly)

FAZIA

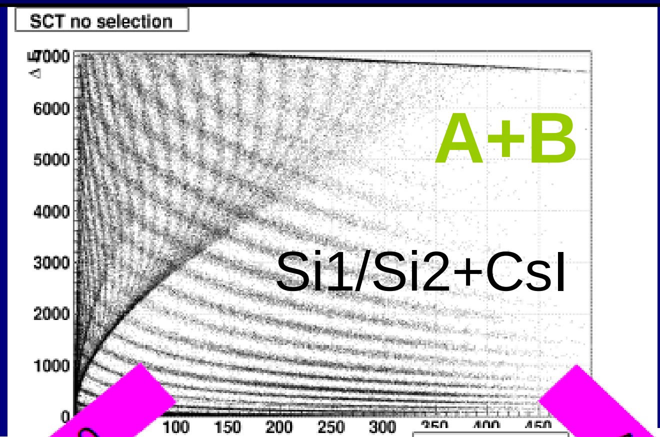


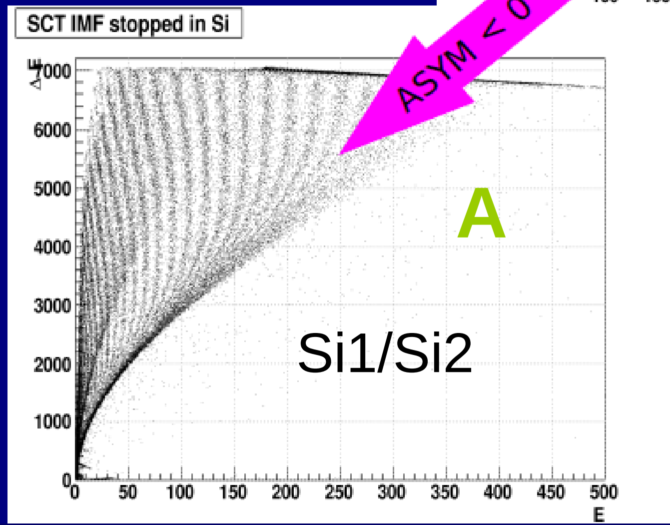


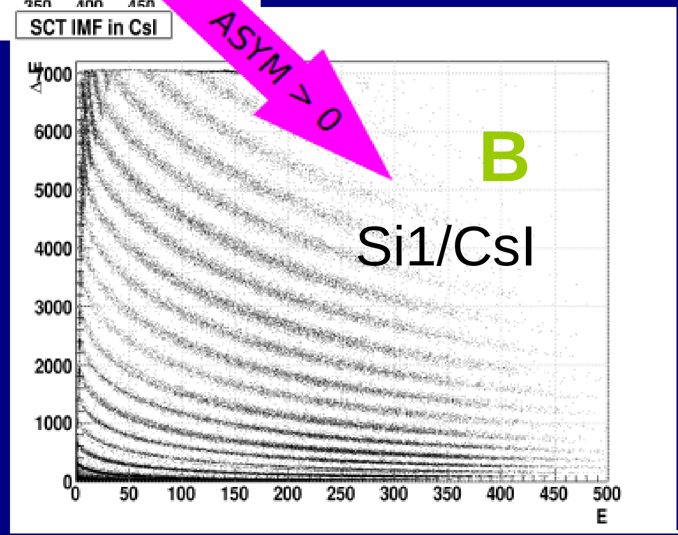
Single Chip Telescope: no photodiode

Separation algorithm using ΔE and T_{rise}

Analysis:
Particles stopped in Si are separated from those punching through (shape of leading edge).





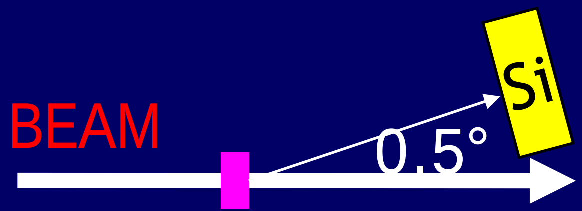


FAZIA data (LNS)
Analysis: Firenze

FAZIA: RADIATION DAMAGE

LNS (November 2009): “Radiation damage and PSA”

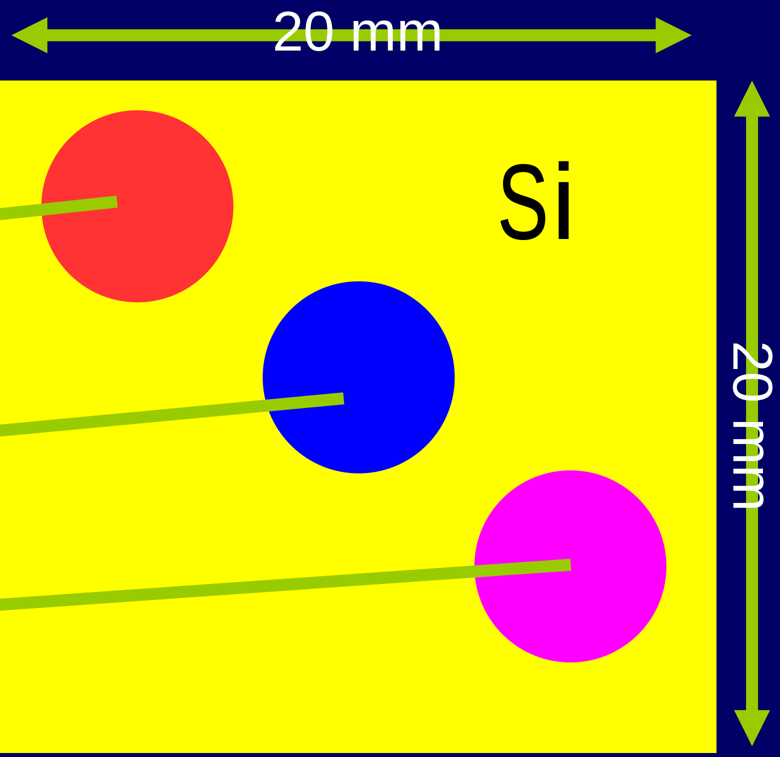
- **A 300µm detector was placed at very forward angles**
  - **Mono-energetic (elastically scattered) Xe ions of 35 MeV/n are either implanted or punching-through, depending of absorbers, in narrow zones of the <u>same</u> Silicon detector**
  - **The detector was periodically irradiated and tested, in terms of energy and risetime resolution, by moving it far from the high flux region. Only elastically scattered Xe ions are measured *(worst case)***
  - **A total fluence of 1.2×10^{9} ions/cm^2 has been experienced by the detector**



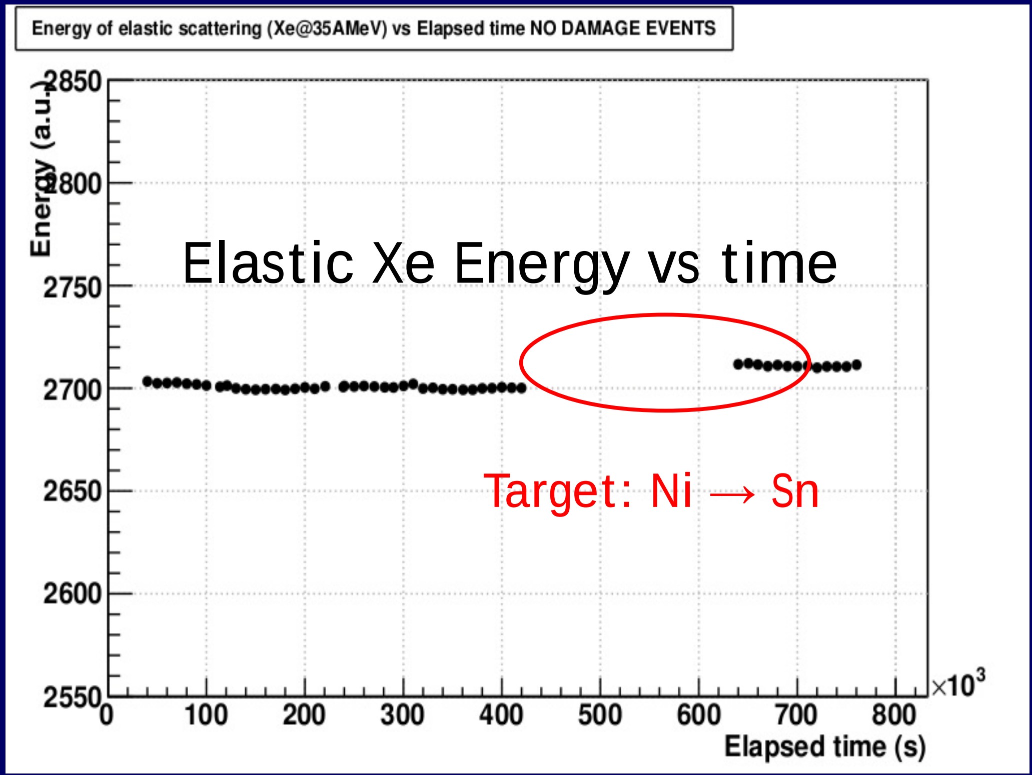
Heavy damage zone: 6×10^{8}/cm^2 implanted Xe ions

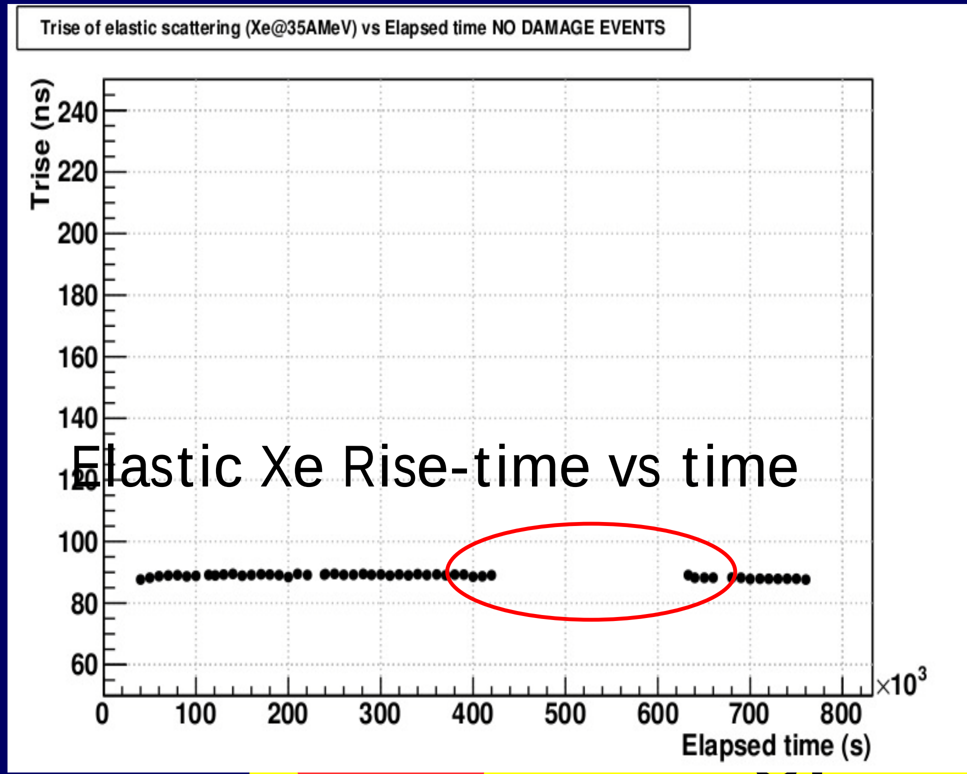
Standard irradiation zone: 2.5×10^{6}/cm^2 implanted Xe ions *(as for a real, safe experiment)*

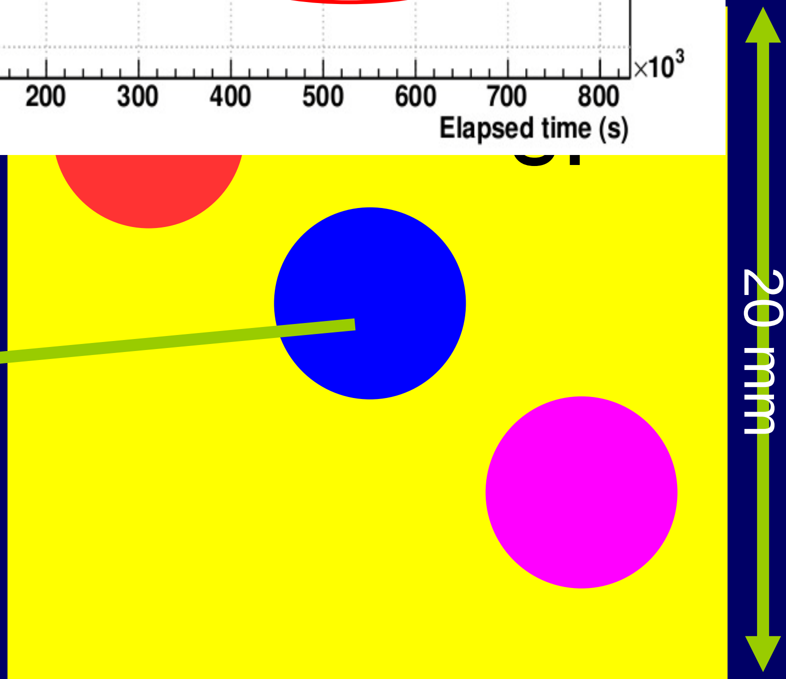
Punch-through zone: 6×10^{8}/cm^2 punching-through Xe ions



FAZIA: RADIATION DAMAGE



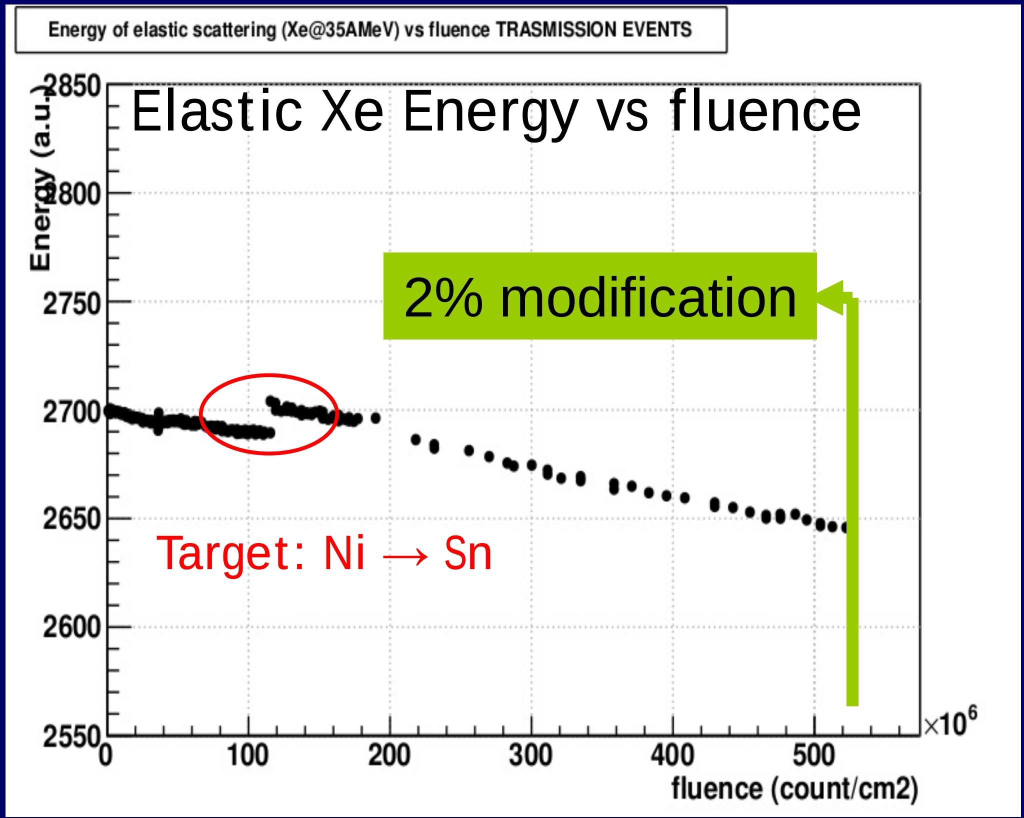


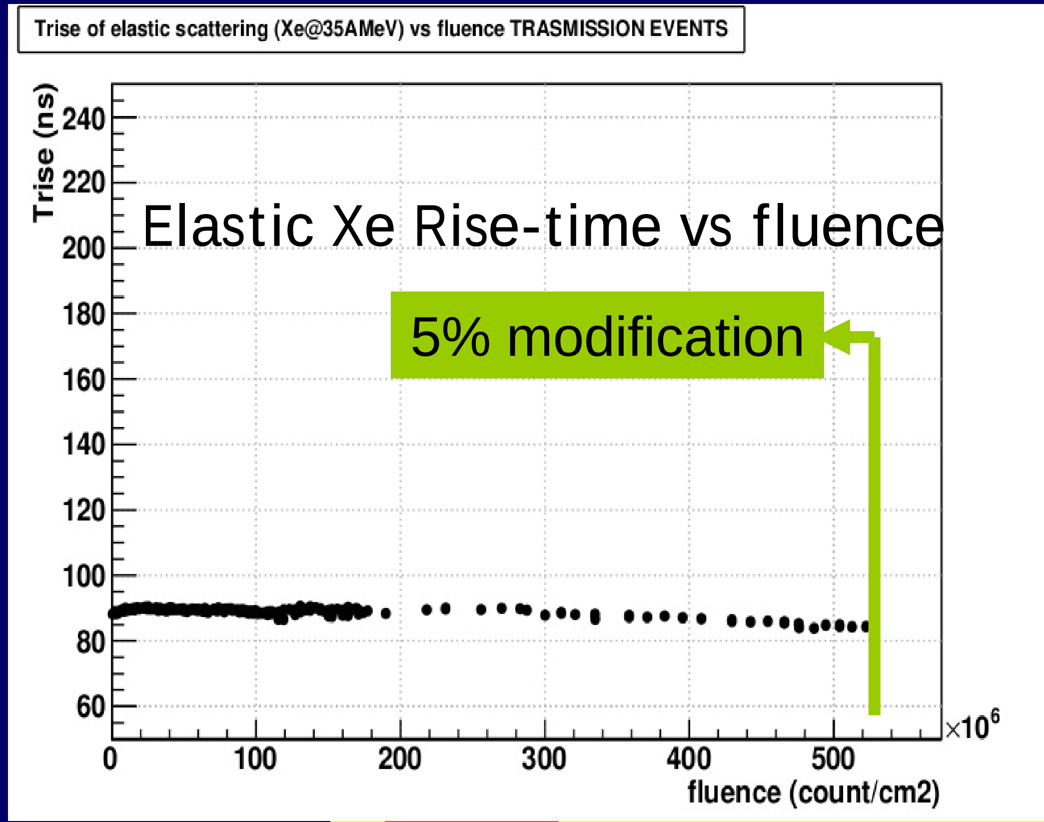


Keeping the field constant by changing the biais Voltage

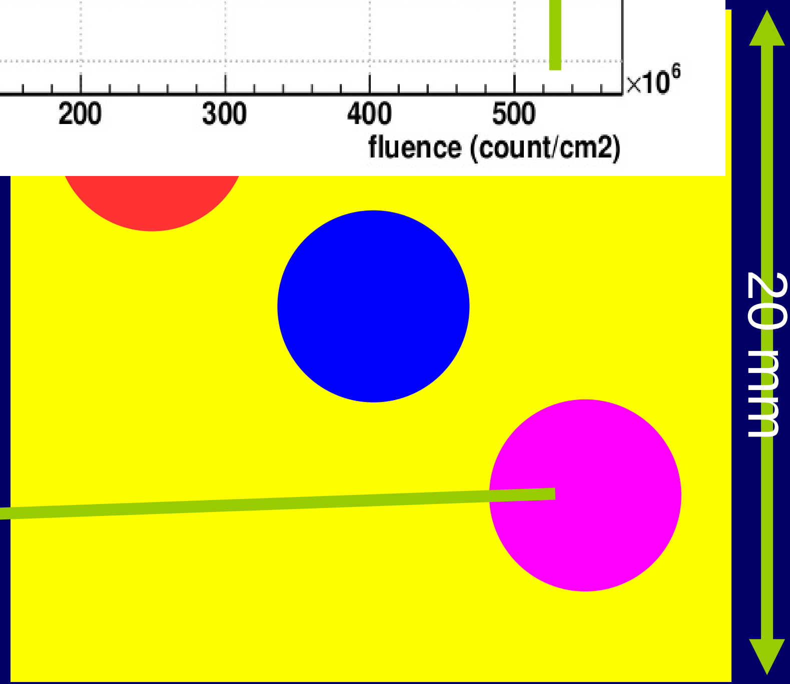
Standard irradiation zone:
$2.5 \times 10^6/cm^2$ implanted Xe ions
(as for a real, safe experiment)

FAZIA: RADIATION DAMAGE



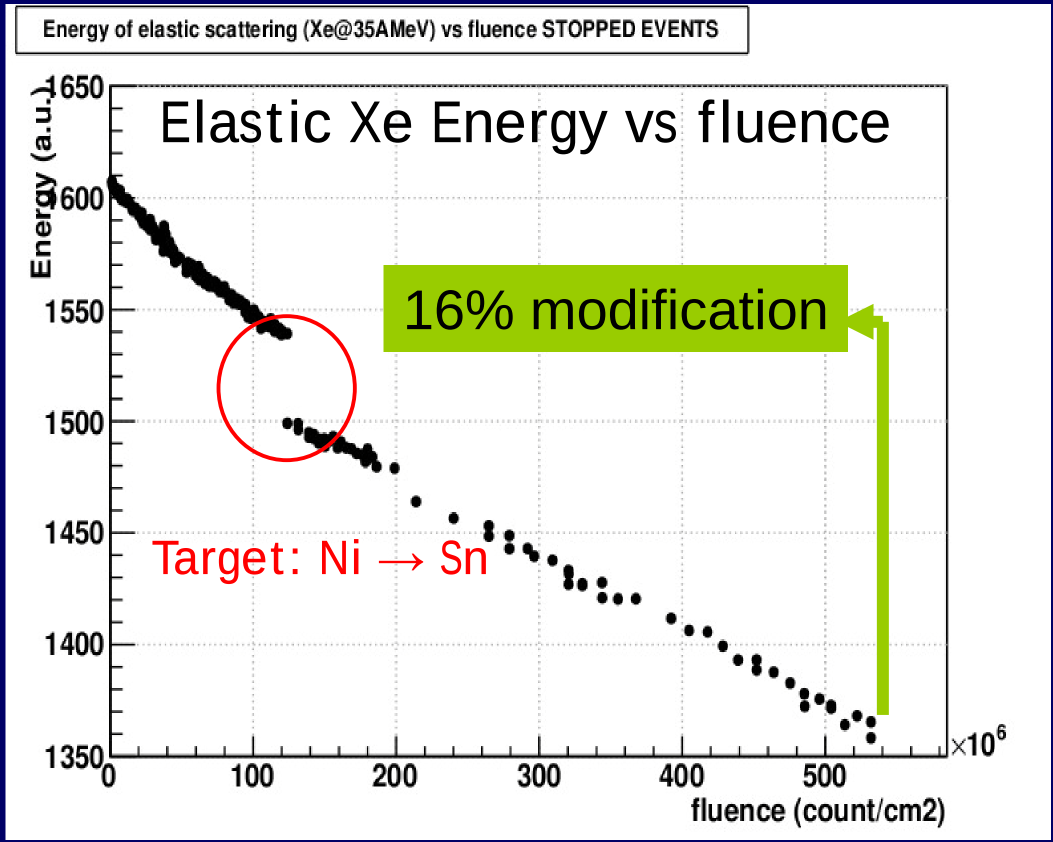


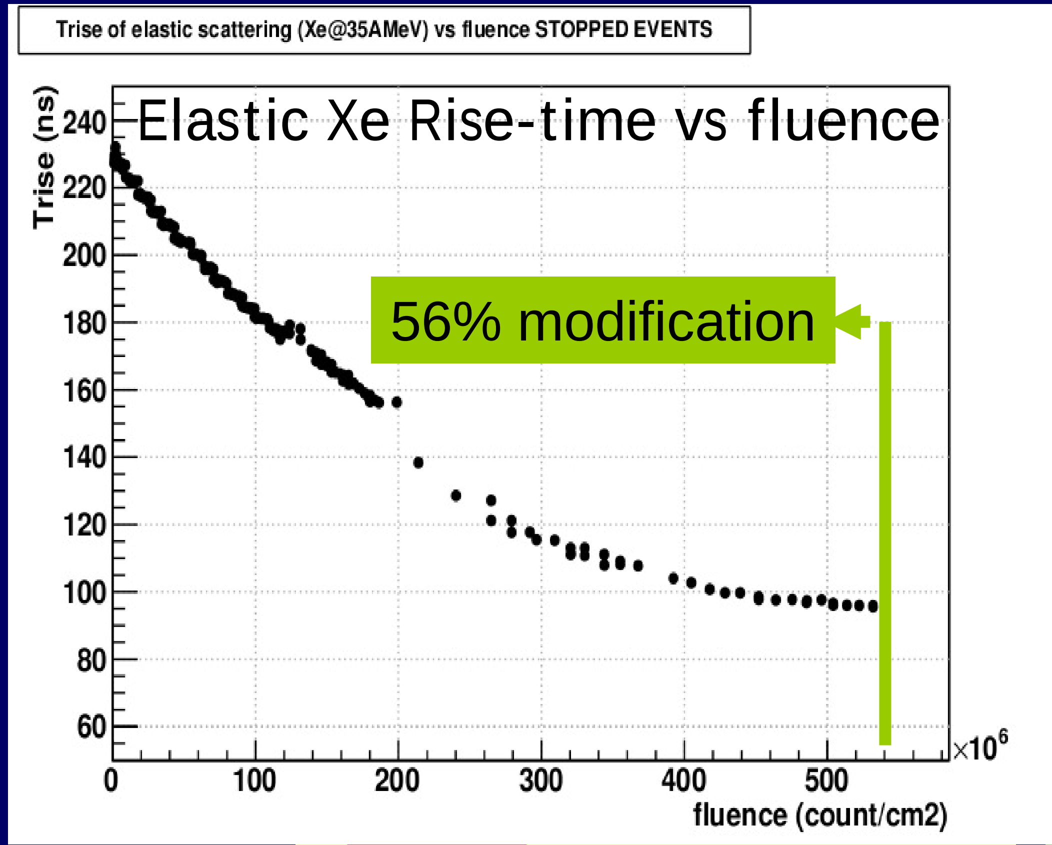
Keeping the field constant by changing the biais Voltage



Punch-through zone: $6x10^8/cm^2$ punching-through Xe ions

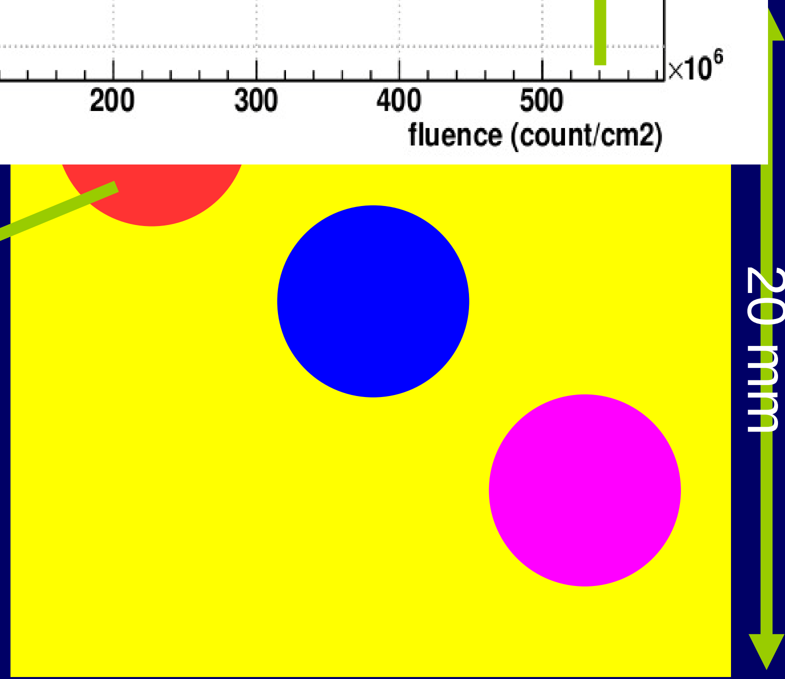
FAZIA: RADIATION DAMAGE





Keeping the field constant by changing the biais Voltage

Heavy damage zone:
$6x10^8/cm^2$ implanted Xe ions



FAZIA: RADIATION DAMAGE

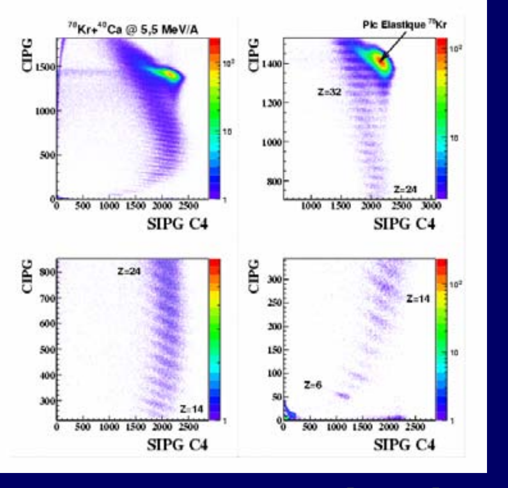
LNS (November 2009): Radiation damage and PSA

- **The average effect of the increased reverse current (associated to local damage) can be fully recovered by simply keeping the field constant**
- **No significant effect is expected for the electronic noise (below 100 keV)**
- **Local damage is mainly associated to mono-energetic implanted ions (a narrow trapping layer is created at a depth=”ion range”):**
  - **2×10^7 (Xe-like) ions per detector ($4cm^2$) is the estimated limit for full Fazia performance for the energy and PSA of the same considered ions**
  - **minor degradation is observed in zones where ions have punched-through and fluences about 10^2 times higher can be sustained**

NUCLEAR EQUATION OF STATE

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

INDRA@SPIRAL



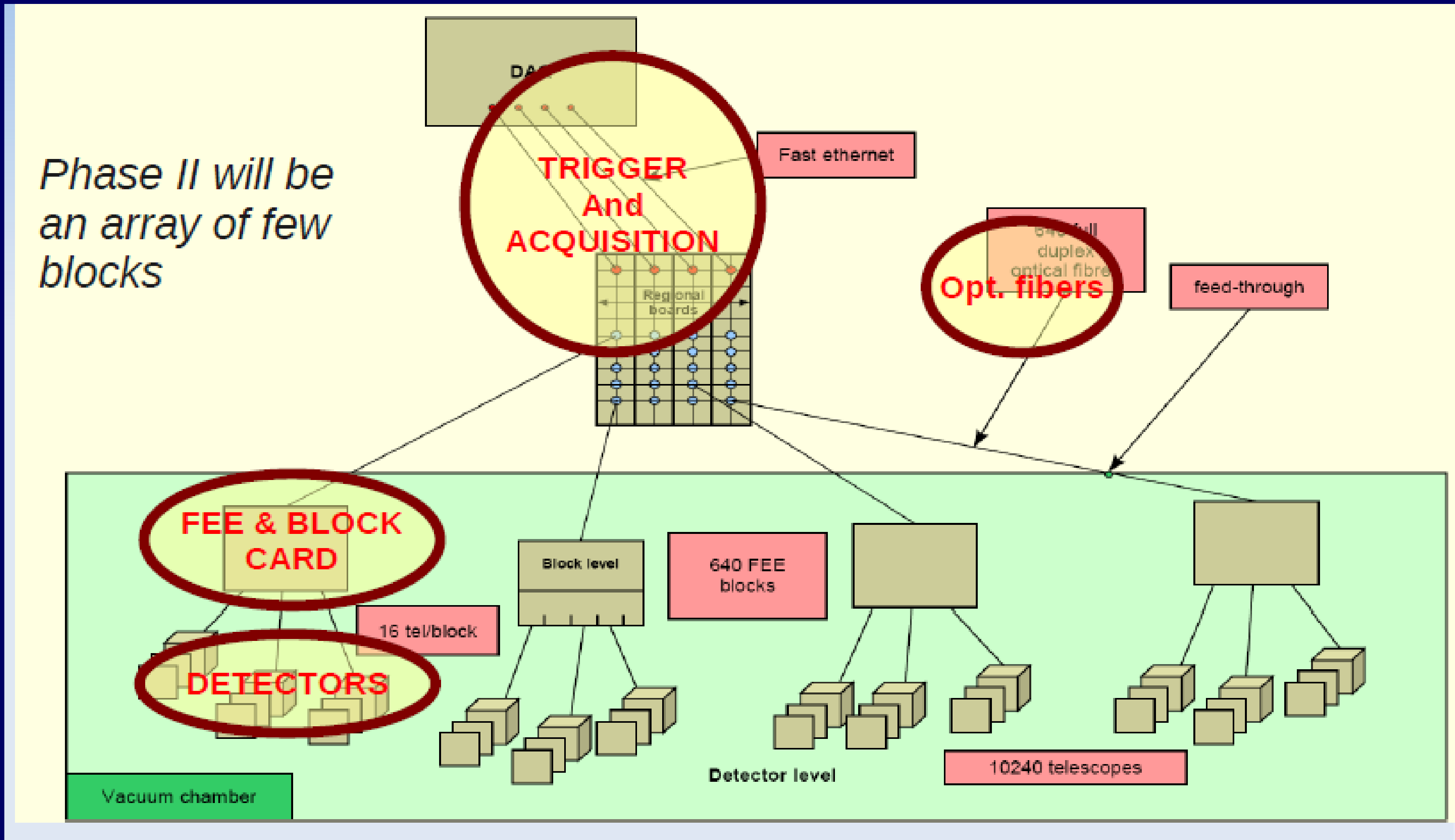
Fragment production at 5.5 A.MeV

LIQUID PHASE

Isospin physics case from SPIRAL2/SPES (liquid phase) to GANIL/LNS high energies

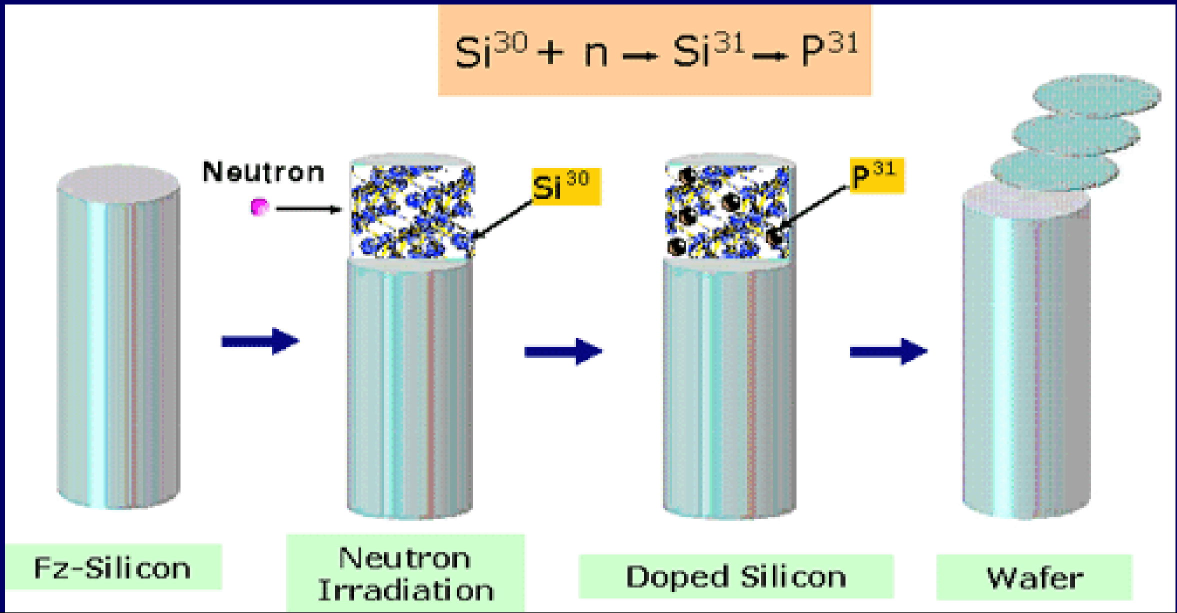
FAZIA Phase2 2011-2013

Phase2 = “répétition générale” for several 1000 of telescopes



FAZIA PhaseI-R&D

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



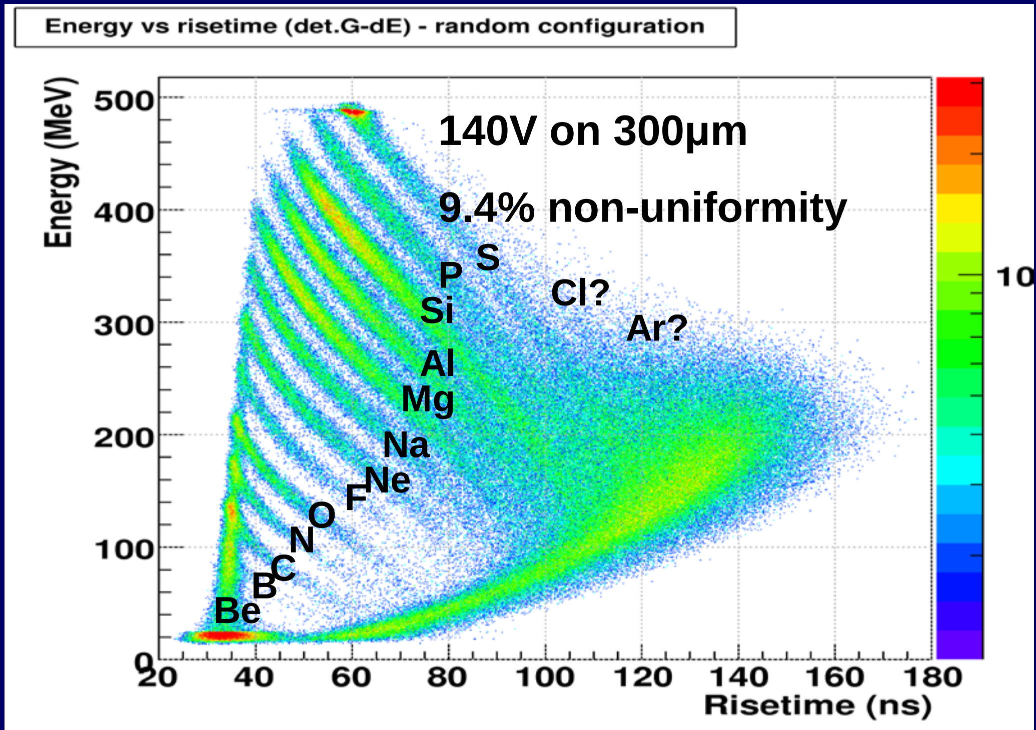
Isotope	abundance	Neutron capture	Cross section
28Si	92.3%	28Si(n,γ)29Si	0.08 b
29Si	4.7%	29Si(n,γ)30Si	0.28 b
30Si	3.1%	30Si(n,γ)31Si ⇨ by beta decay (2.62 hrs) ⇨ 31P	0.11 b

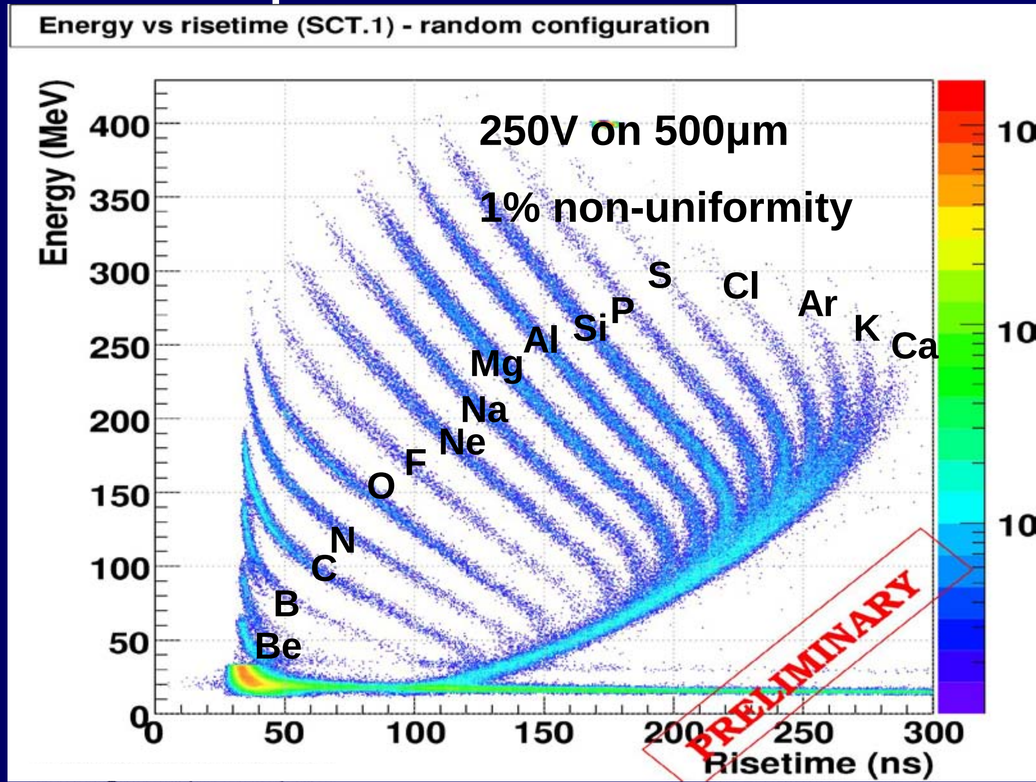
Regular Silicon: +/- 15% uniformity – “regular” nTD silicon: below +/- 5%
FAZIA nTD silicon: +/- 0.5%

FAZIA PhaseI-R&D

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

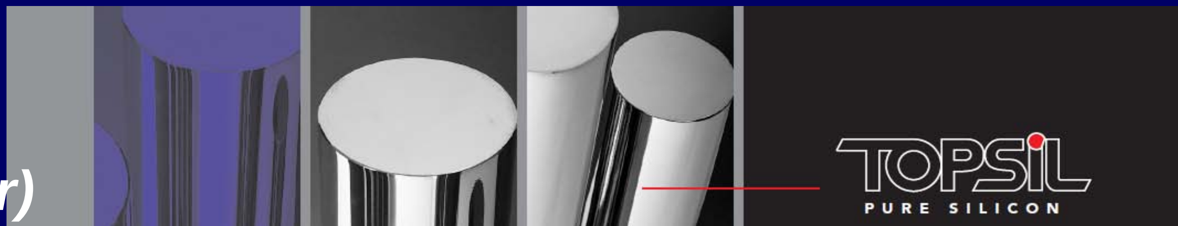
DIGITAL PULSE SHAPE on 500μm and 300μm Silicons with similar field and different doping non-uniformities: 300μm: ~ 4 GeV full scale 500μm: ~ 4 GeV full scale





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

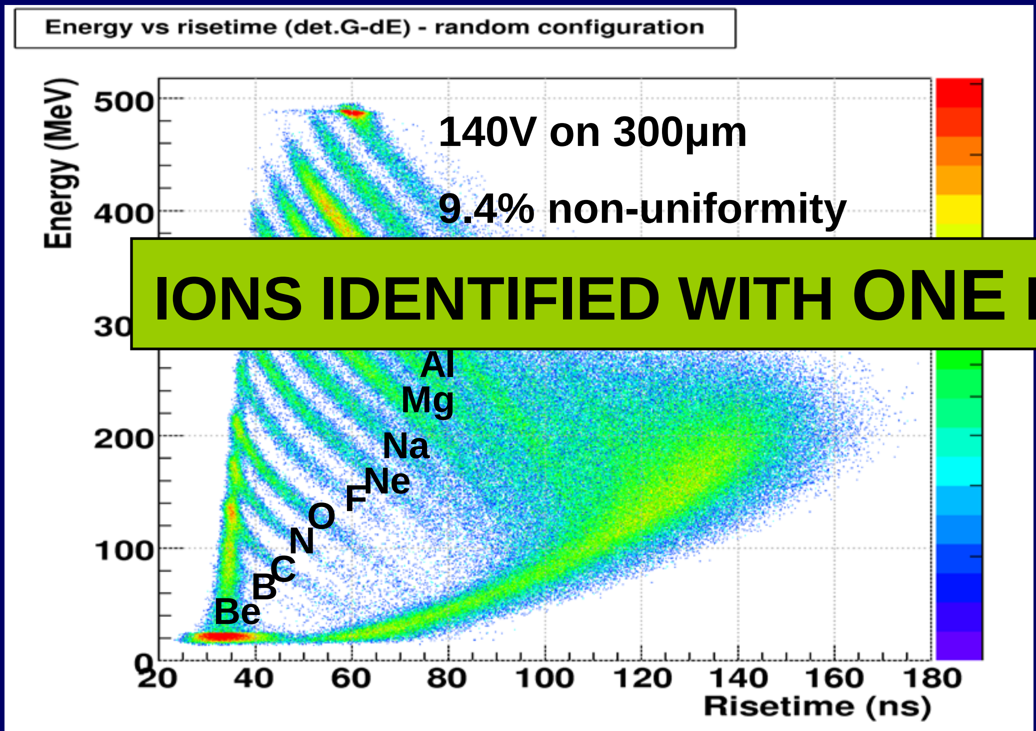
It is possible (work with manufacturer)

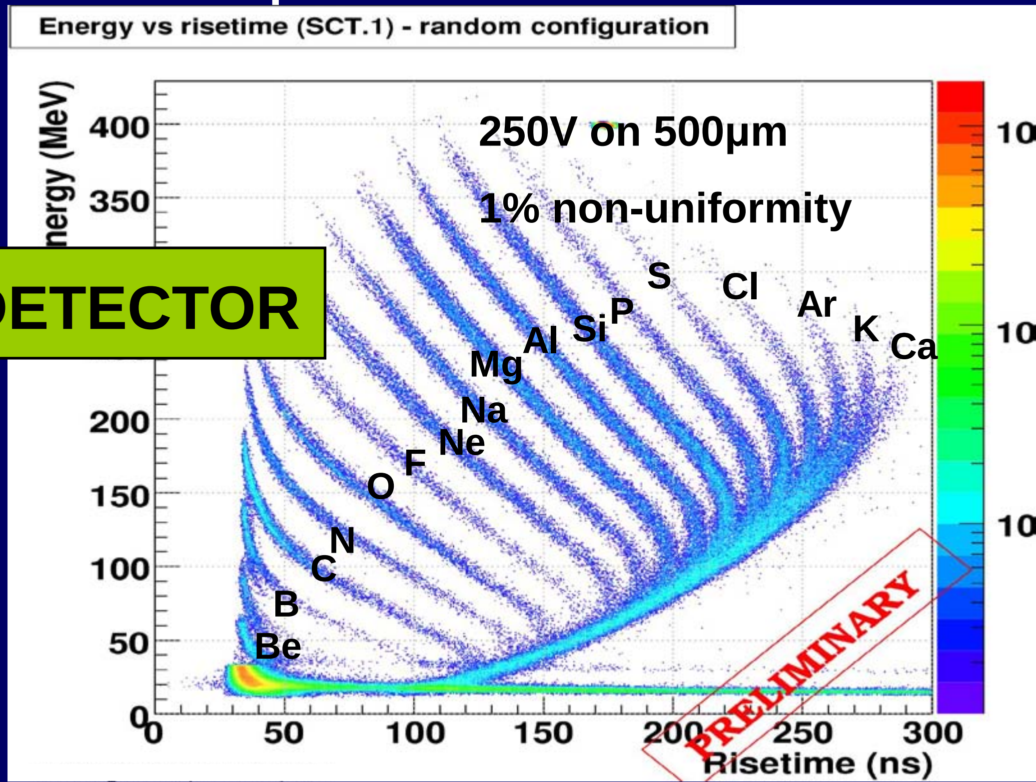


FAZIA PhaseI-R&D

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

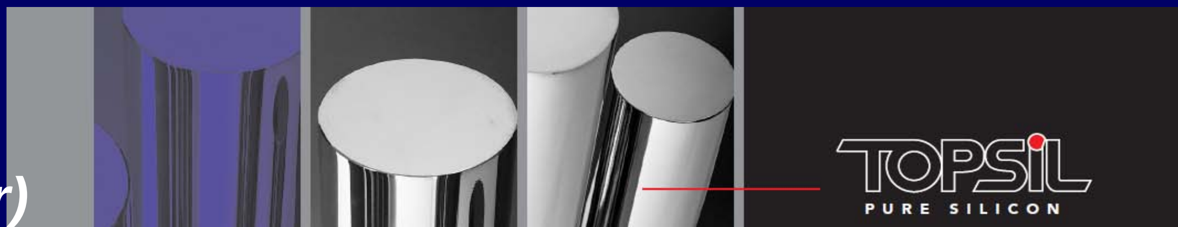




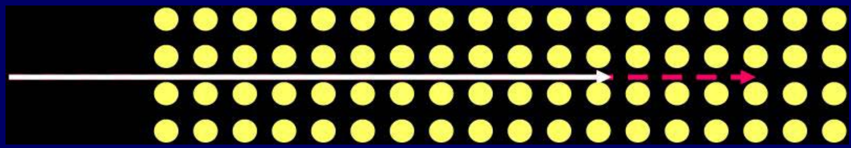
IONS IDENTIFIED WITH ONE DETECTOR

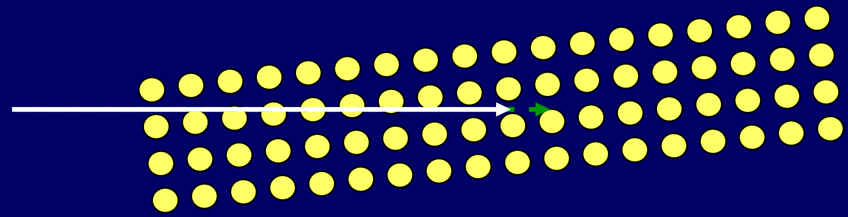
+/- 5% is not enough PSId.
needs +/- 0.5%

It is possible (work with manufacturer)

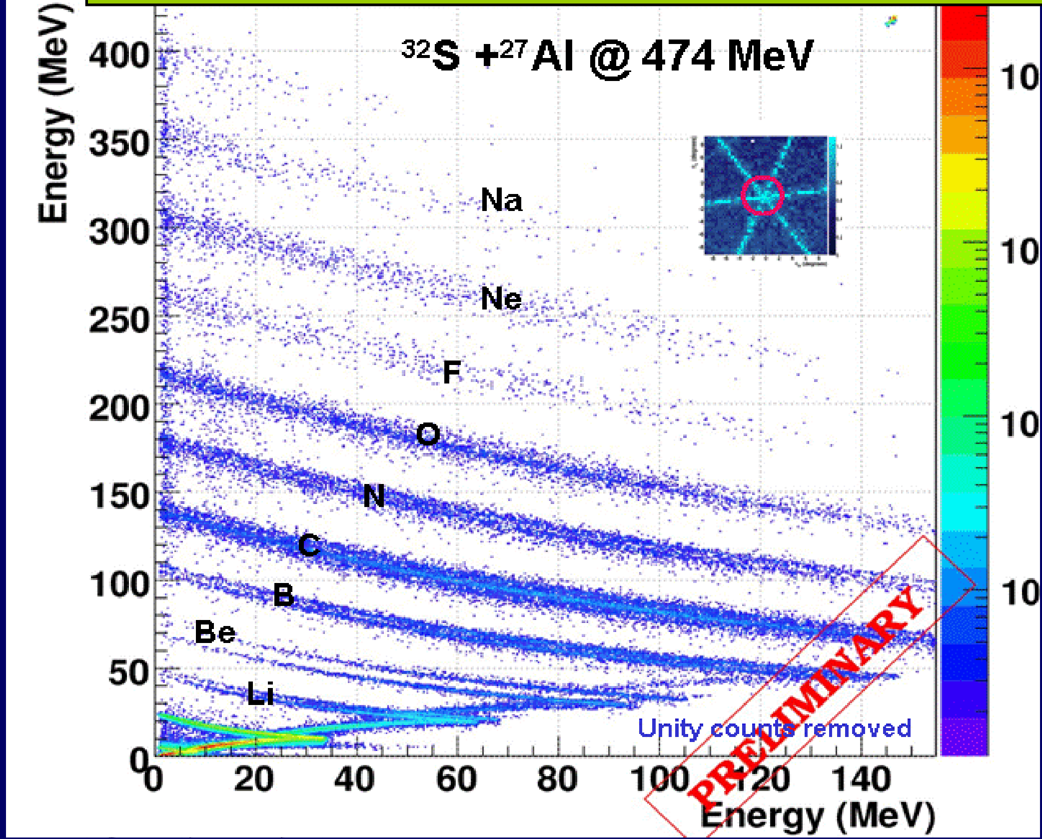


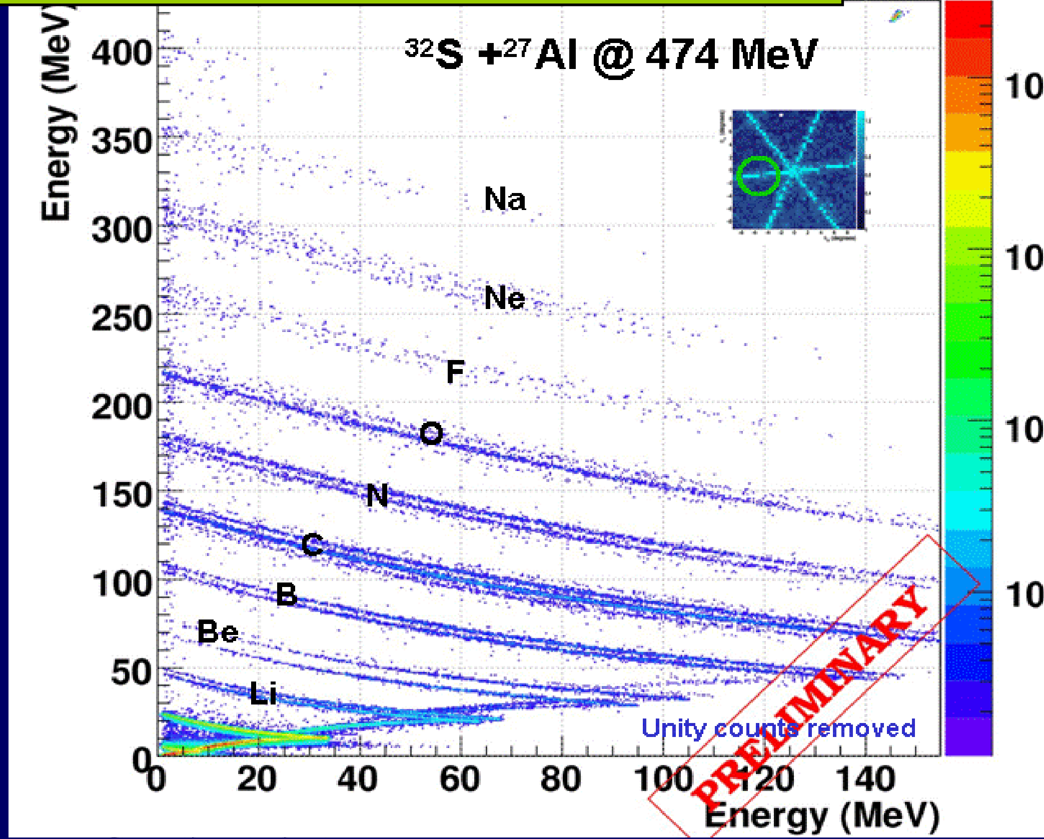
FAZIA PhaseI-R&D





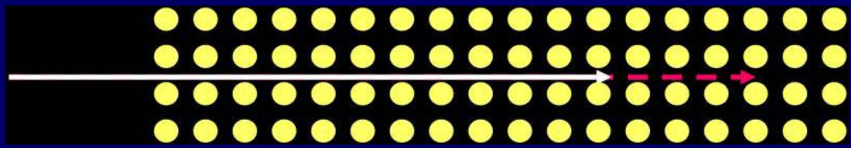
IONS IDENTIFIED WITH TWO DETECTORS: USUAL DE/E-plot

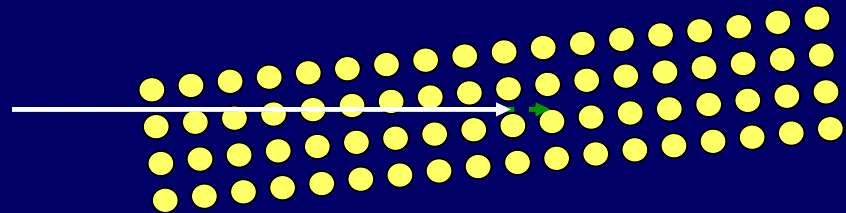




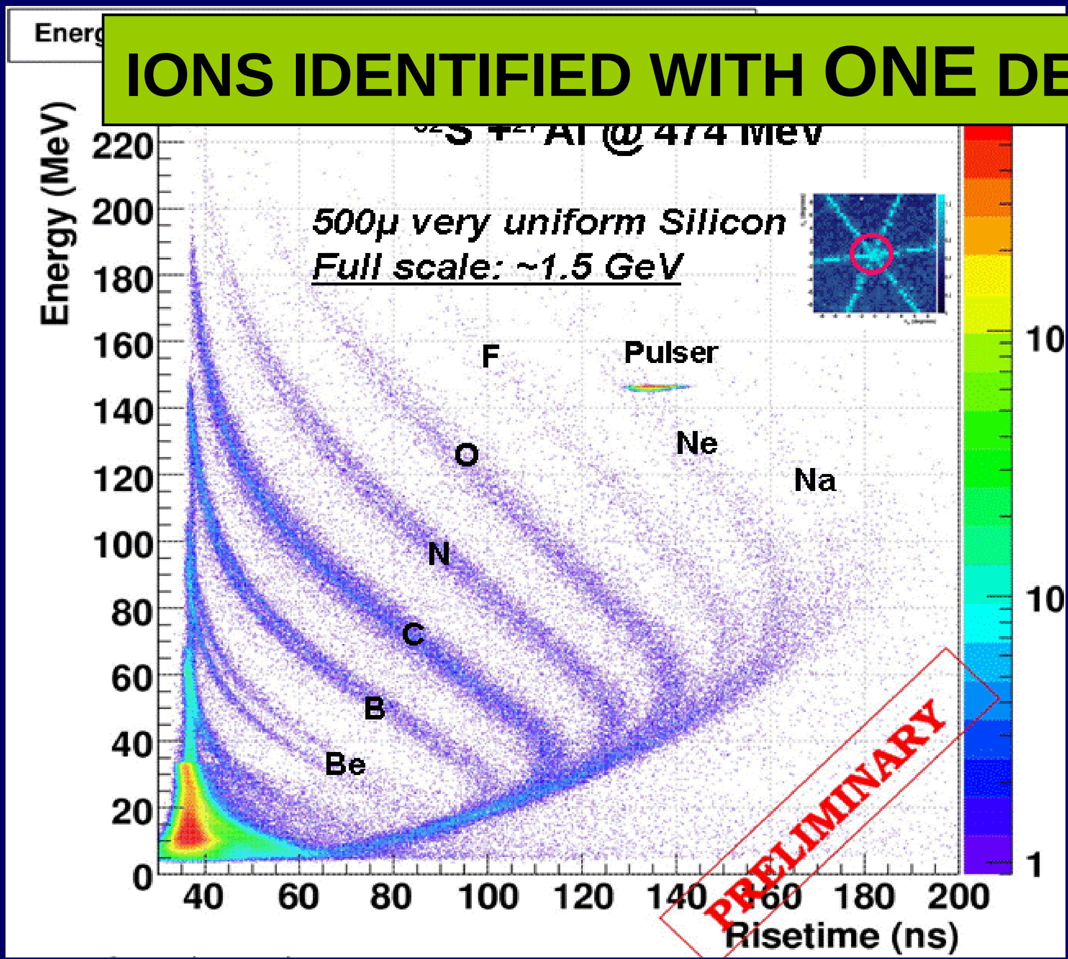
LNL-Experiment

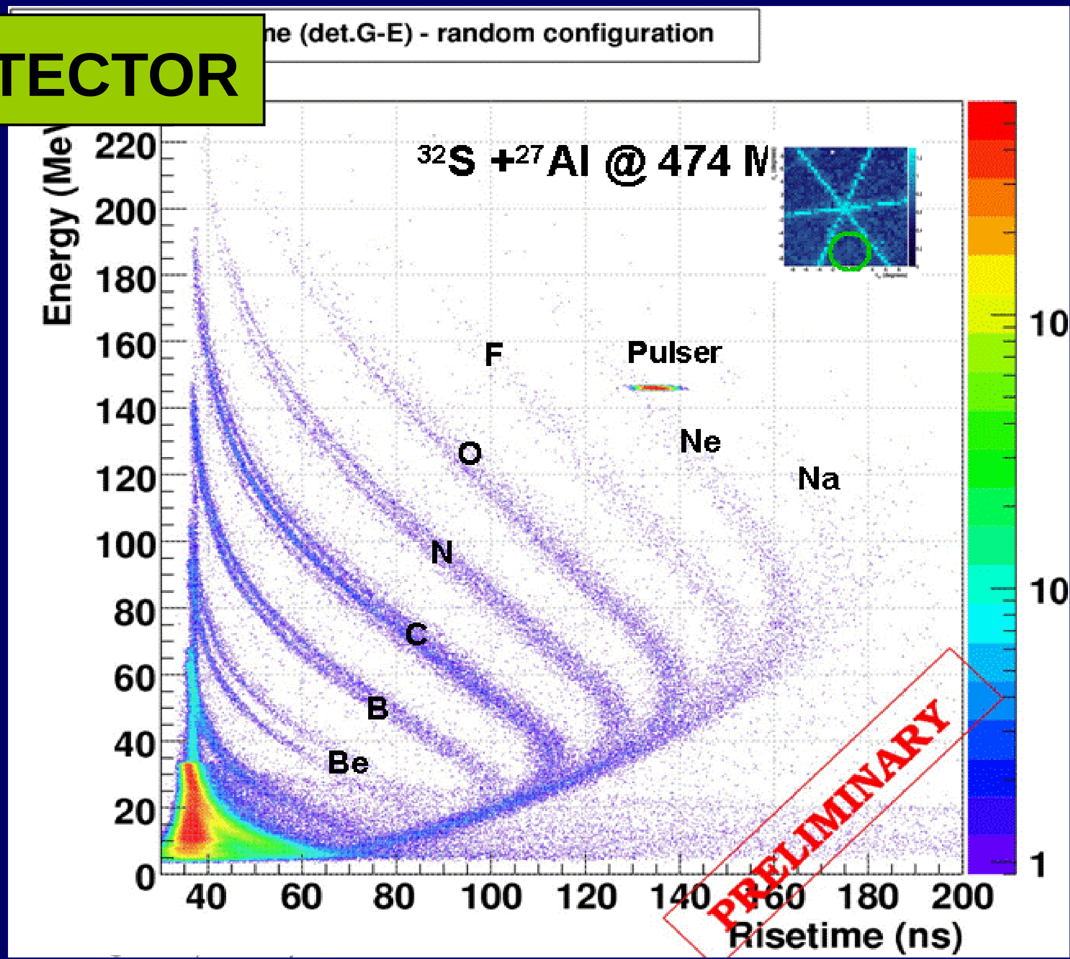
FAZIA PhaseI-R&D





IONS IDENTIFIED WITH ONE DETECTOR





LNL-Experiment