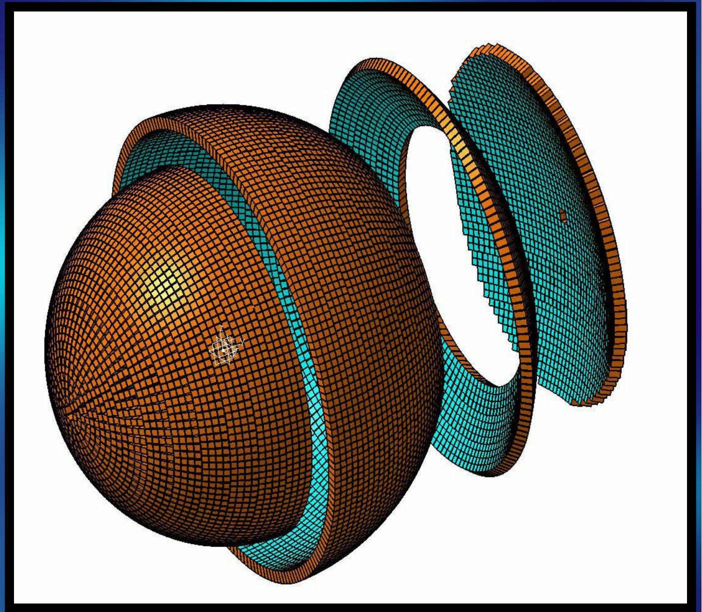
Il rivelatore FAZIA

Giacomo Poggi

FAZIA Project

FAZIA (Four π A and Z Identification Array)



An R&D project supported by Spiral2PP and LEA.
The goal: to design and build a new-generation detector for charged particles, suited for Isospin Physics to be done at Radioactive Beam Facilities like Spiral2 and SPES.
The main partners are INFN and CNRS (~90 members)

The Organization:
- Physics Coordinators G. P., R. Bougault
- Technical Coordinator P. Edelbruck
- Project management board
- 9 Working groups:

L.Bardelli, Coordinator of WG1 on Pulse Shape

WEB site: http://fazia.in2p3.fr

FAZIA Project

Heavy-ion reactions at *Fermi* energies with exotic beams permit to study the symmetry energy term of the nuclear Equation of State, for density and temperature different from equilibrium, under controlled laboratory conditions

Nuclear Equation of State for infinite nuclear matter and Symmetry Energy:

$$E(\rho,T,I)/A = E(\rho,T,0)/A + C_{sym}(\rho,T)\cdot I^2$$

$I = (N-Z)/A$

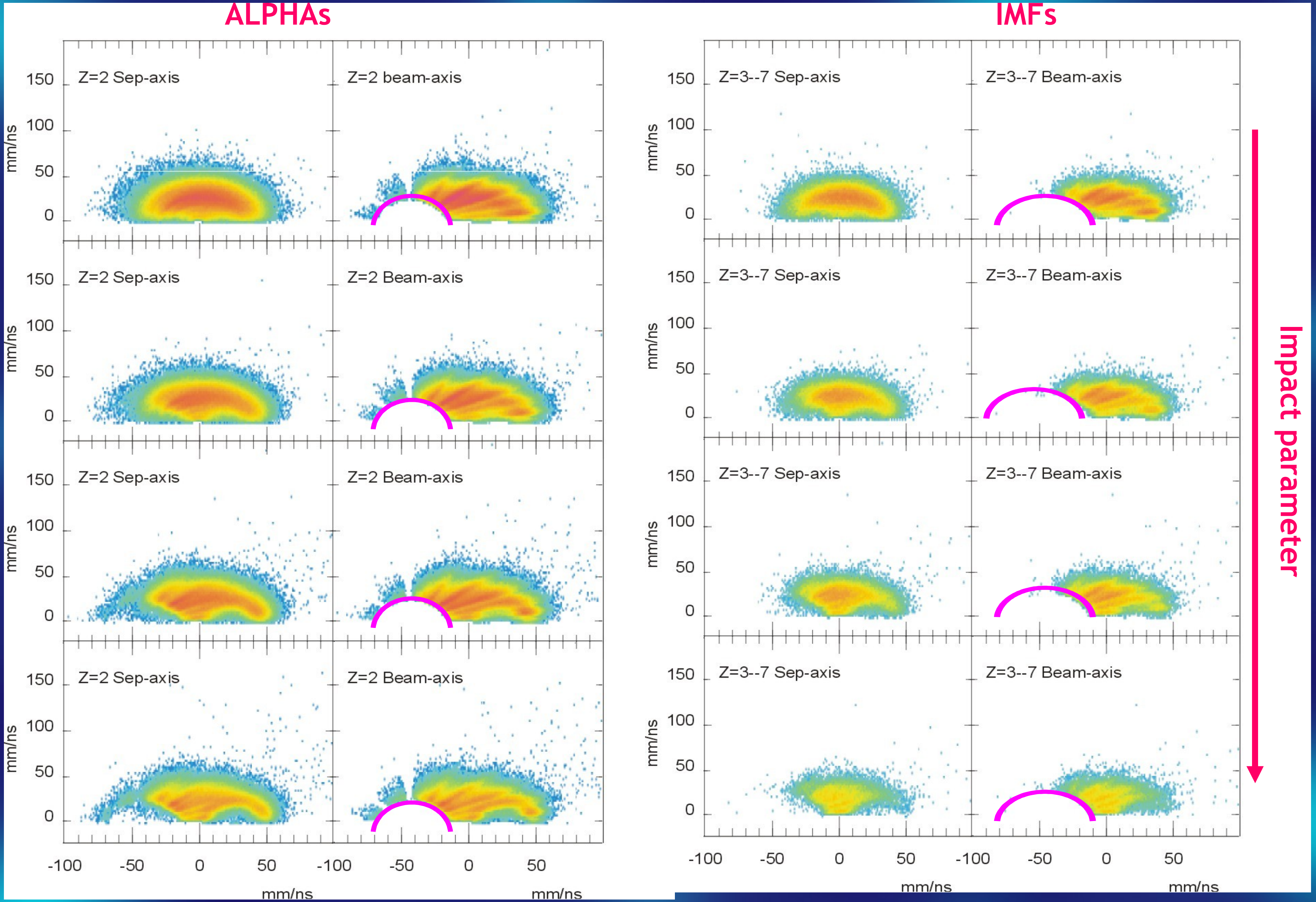
$C_{sym}(\rho_0,0) = a_4 = a_{symm}$ of the Weizsäcker Mass Formula

$C_{sym}(\rho,T)$ *for finite systems may also contain a surface dependent term*

As an example, the dependence of Symmetry energy on density and temperature might explain the properties of neutron stars, with special reference to "solid" structures of the crust

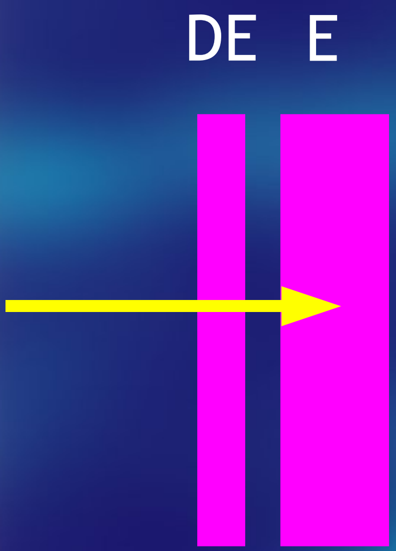
V_{perp}-V_{par} Plots (rapidity plot)

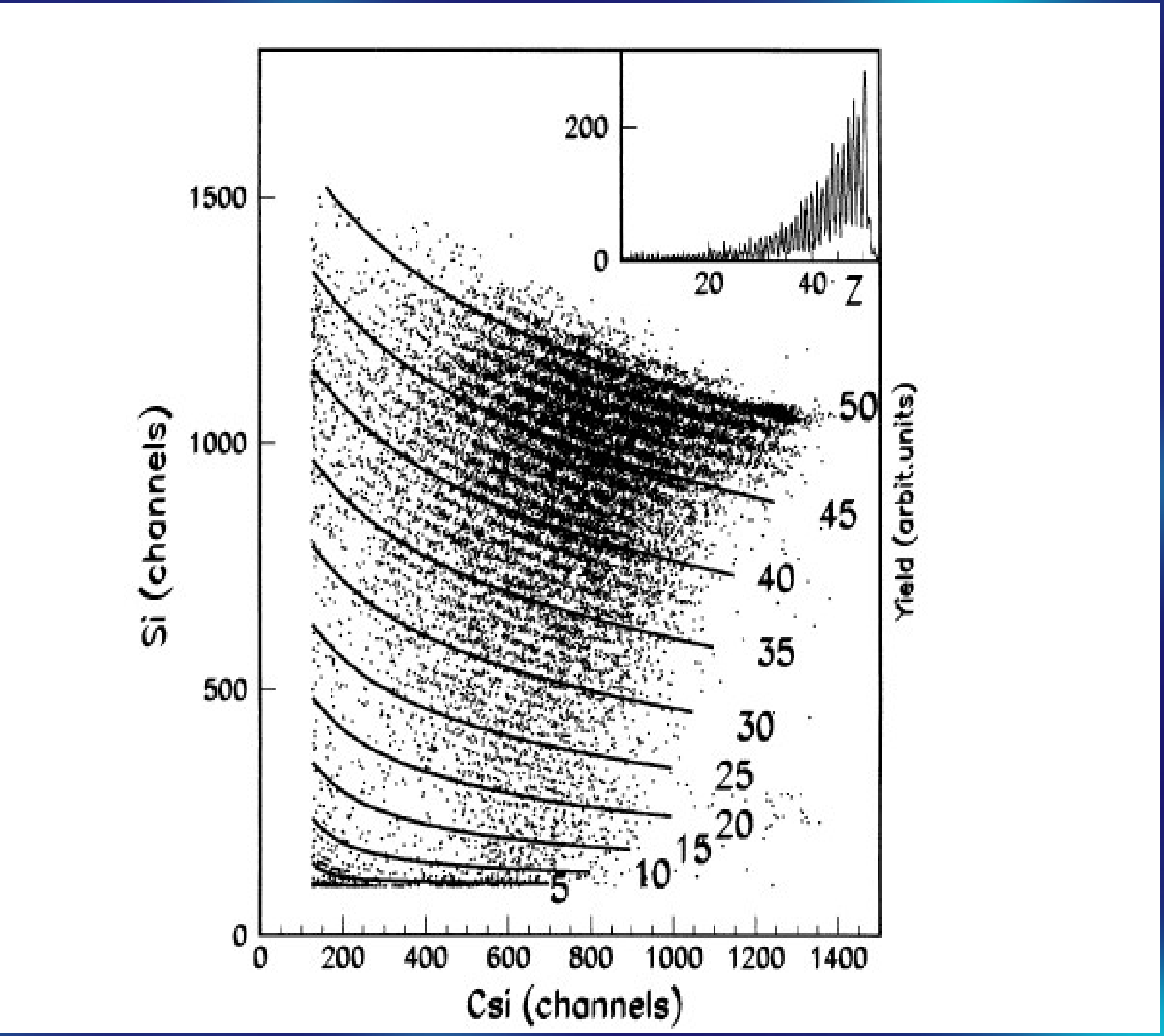
Where we are now



FAZIA project

The present status of the art for DE-E identification (Chimera at LNS
NIMA 490 (2002) 251-262)

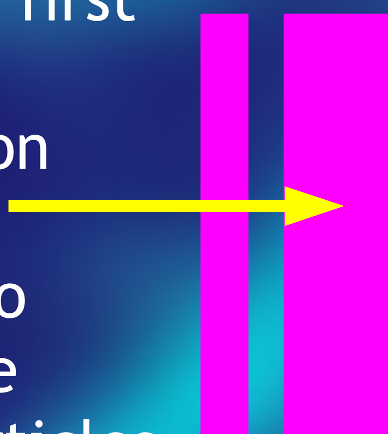




FAZIA project

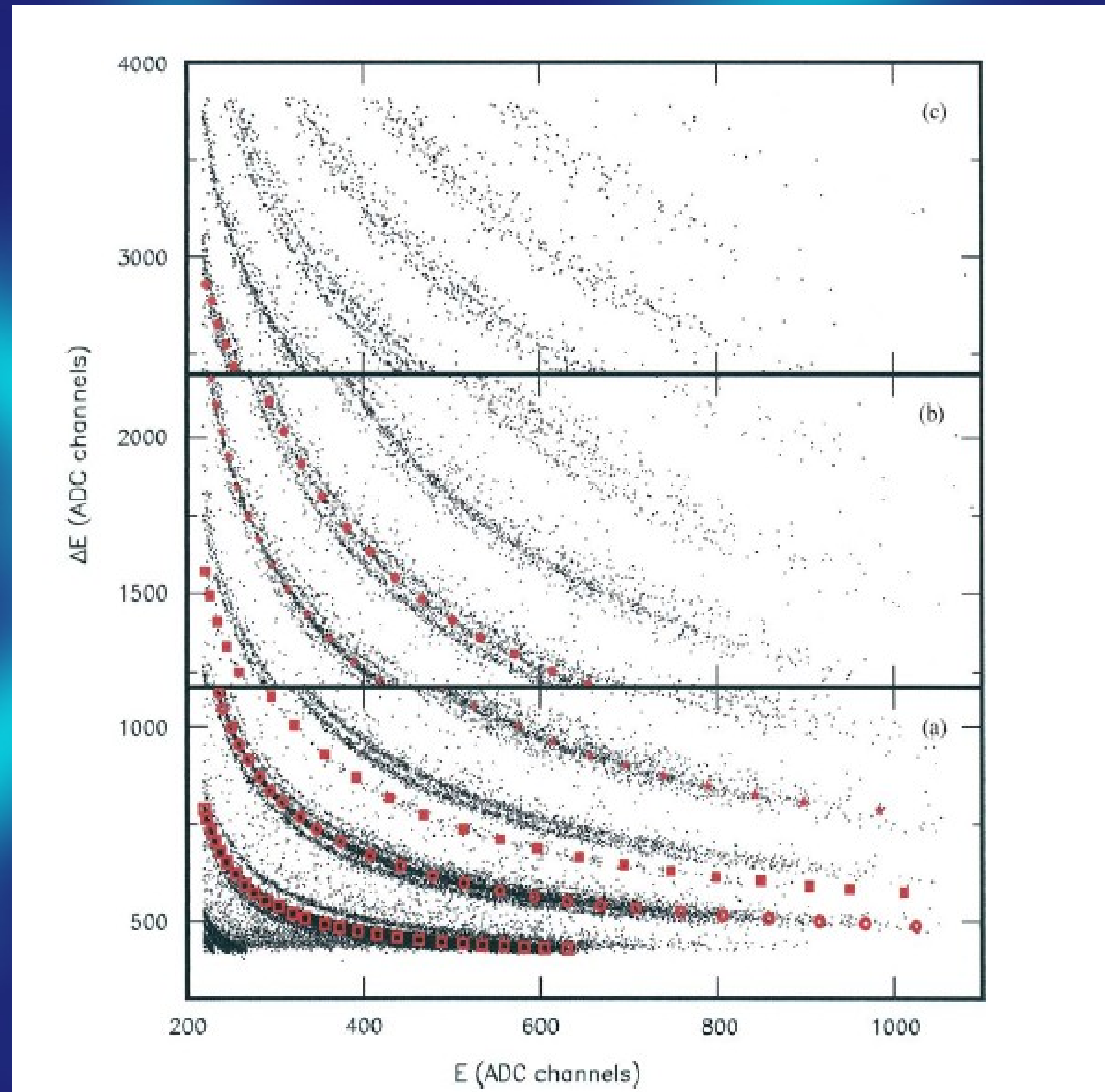
The present status of the art for DE-E identification (Chimera at LNS NIMA 490 (2002) 251-262)

Energy thresholds are too high: ions have to punch-through the first Silicon for identification

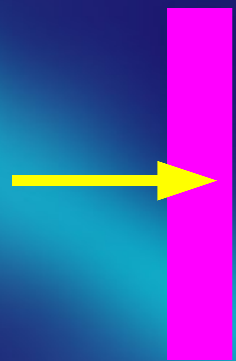


Necessary to discriminate stopped particles

How to do it?



Pulse Shape in Silicon



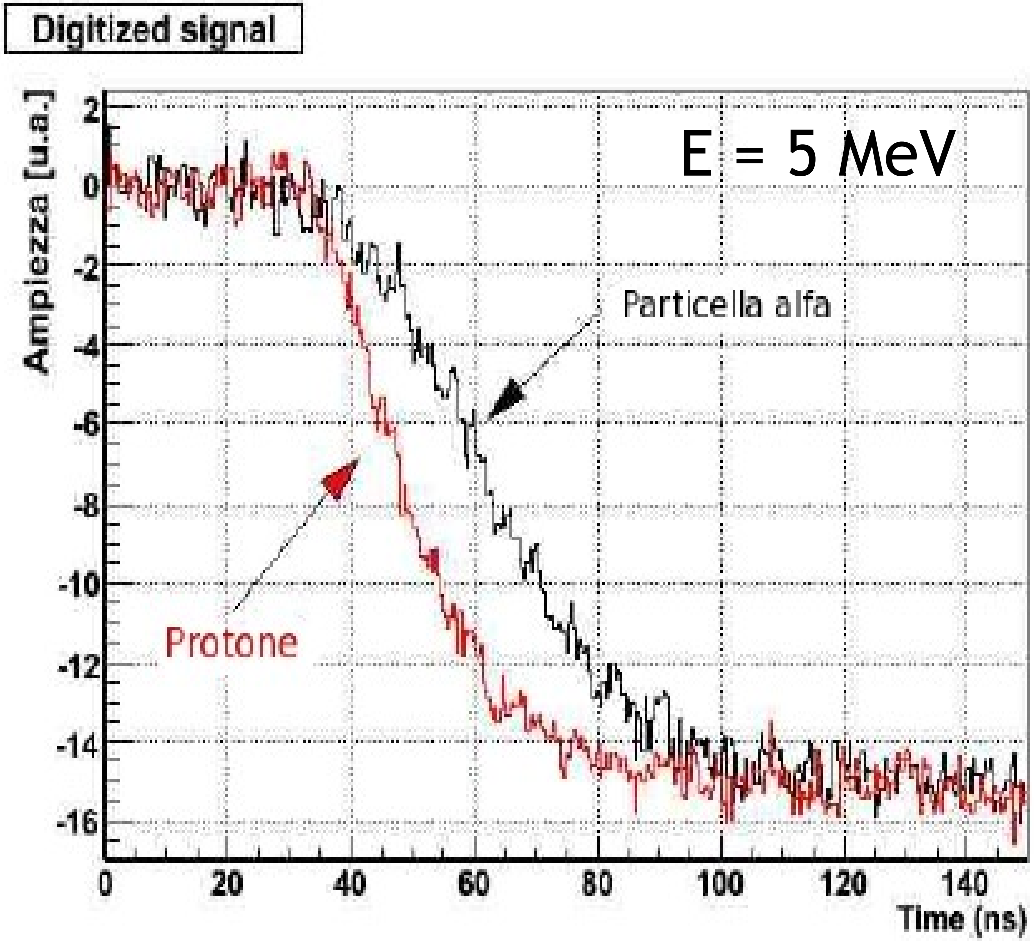
Why Pulse Shape in Silicon is possible?

Stopped particles with the same energy, different Z and A have different ranges

Signal time-evolution depends on the electric field along the ionization wake, i.e. on the range

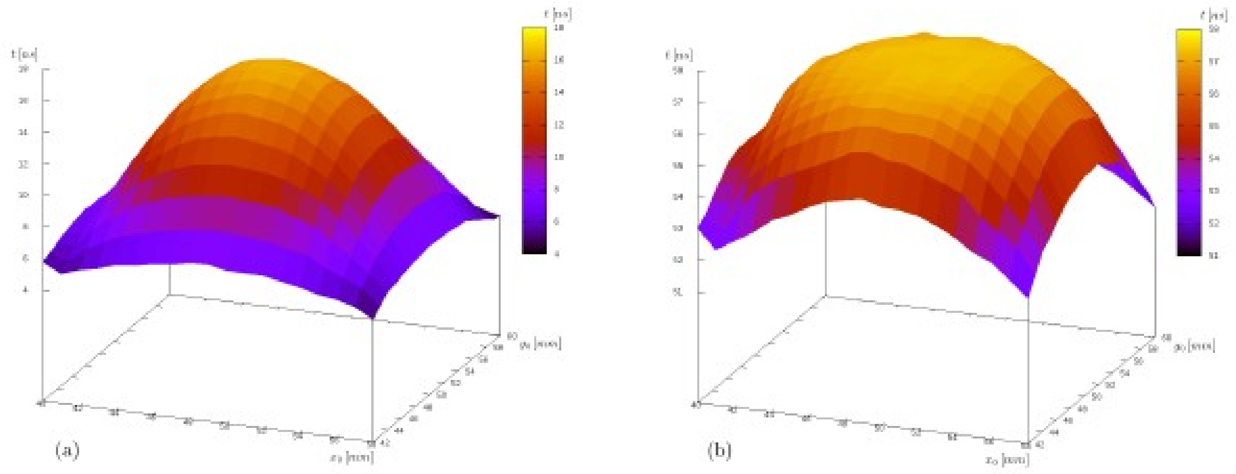
Plasma erosion time also depends on the local field intensity and increases with the e-h local density

L.Salvestrini: tesi triennale in preparazione



Pulse Shape in Silicon

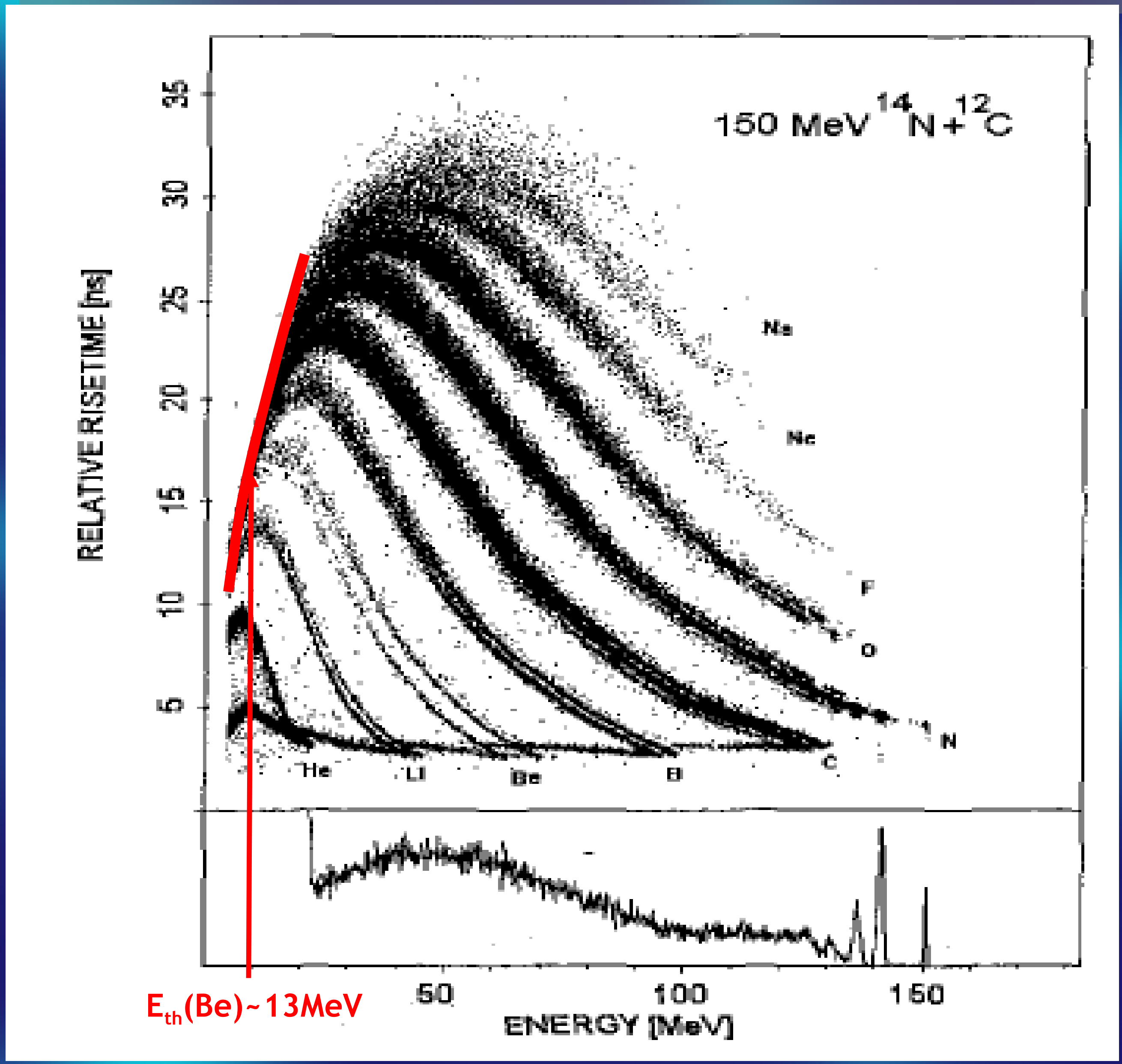
S.Valdré: tesi triennale dic 2009



La tecnica richiede cura particolare nel trattamento dei Silici: per esempio abbattimento della resistenza di strato dei lati giunzione e ohmico.
Nella figura è riportata la dipendenza dal punto di impatto del ritardo del segnale e del suo tempo di salita in caso di resistenza di strato non "curata"

Pulse Shape in Silicon

Mutterer et al IEEE TNS 47 (2000) 756



<u>Energy vs rise-time of charge signals</u> permits identification of stopped particles

In the figure the best known result available in the literature is shown (before FAZIA...)

PSA in Silicon – the status of the art before FAZIA

Available data about PSA in Silicon were characterized by strong irreproducibilities

The necessary (analog) electronics was very demanding and was indeed limiting the real applicability of the method

Pulse Shape in Silicon

Non dirò niente degli sviluppi di tecniche digitali (hardware e software) che sono stati condotti dal gruppo negli ultimi anni in stretta collaborazione con IPN-Orsay *(L.Bardelli, M.Bini, R.Ciaranfi, G.Pasquali + P.Edelbruck)*

Molti dei risultati che mi appresto a mostrare non sarebbero stati possibili senza questi avanzamenti

FAZIA è un dispositivo realizzato integralmente con tecniche digitali, ad eccezione dei preamplificatori di carica

Detector characterization:

CHANNELING

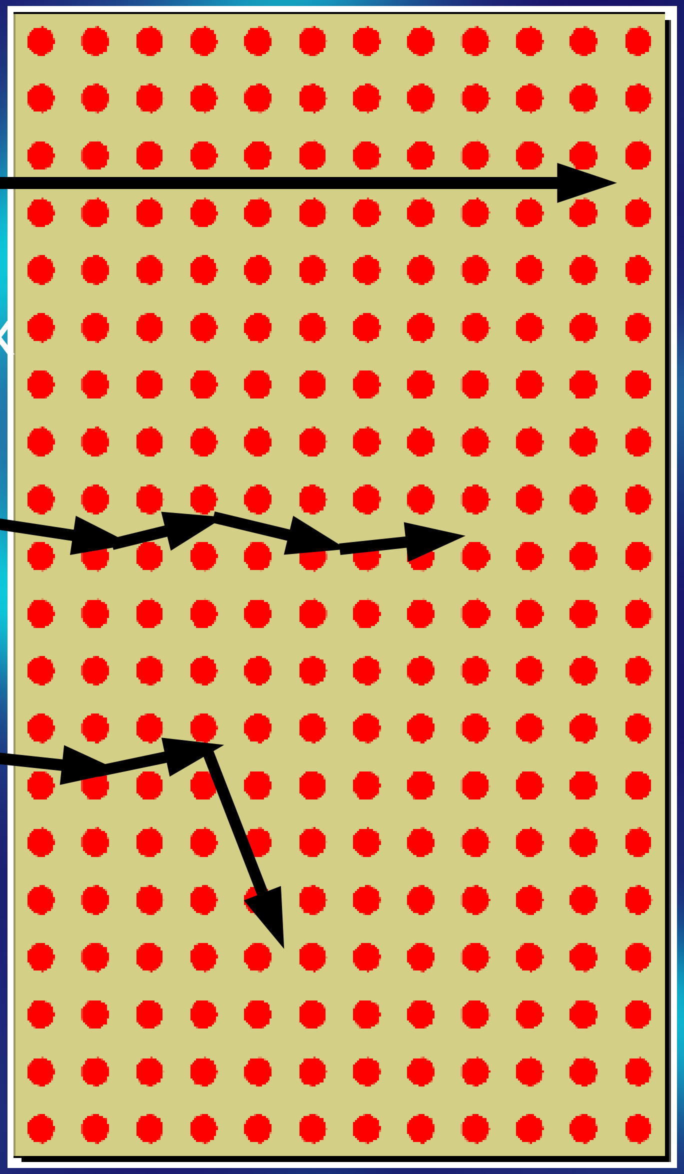
Channeling

Energy loss in an crystal (aligned configuration):

“perfect” channeling: long range, low average dE/dx

Channeled ion: slightly higher average dE/dx

channeling + de-channeling
even shorter range, higher average dE/dx

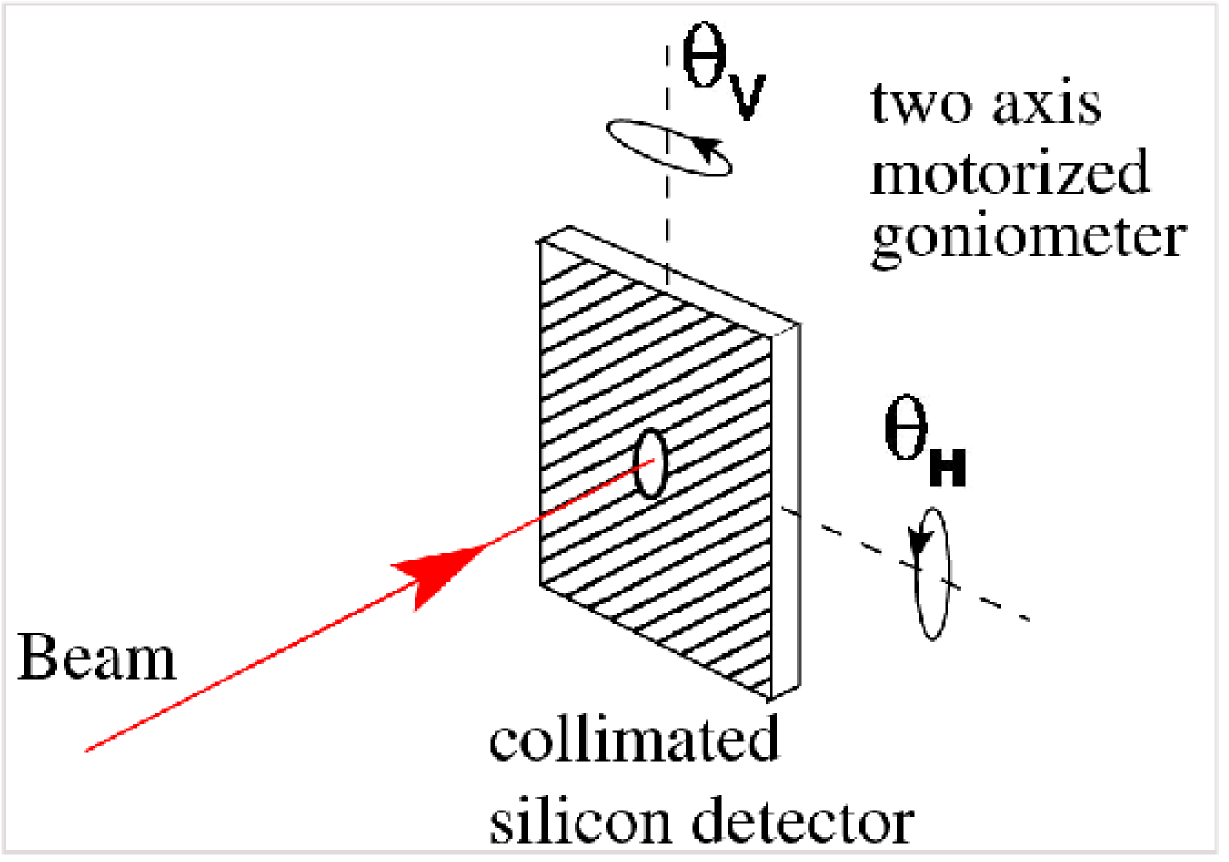


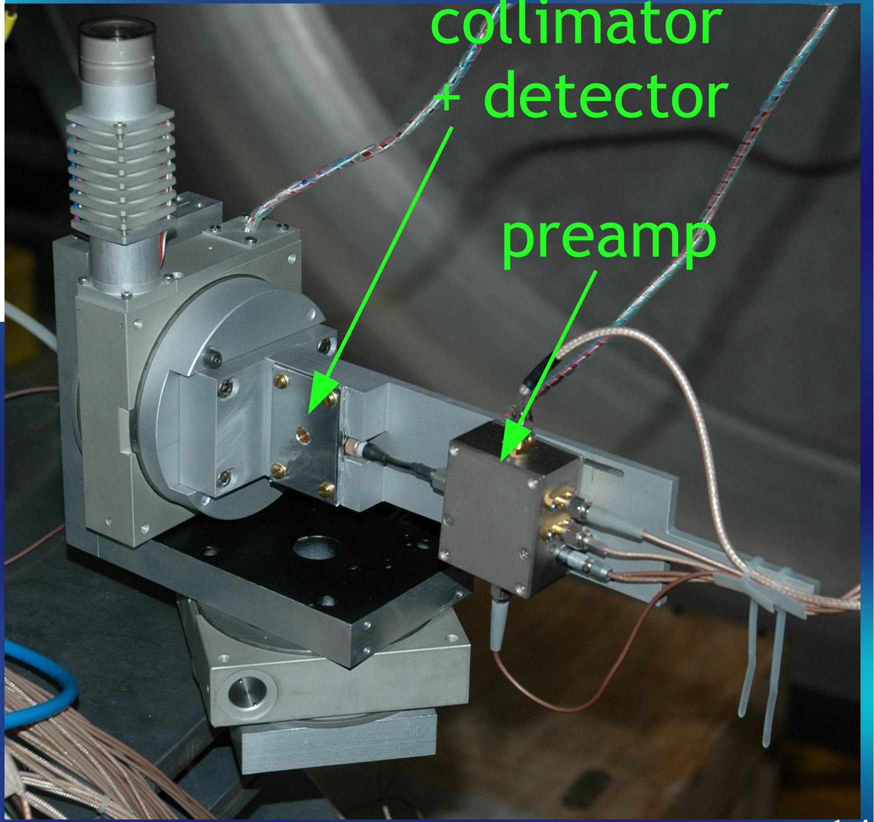
many possible trajectories leading to different ranges and/or average dE/dx

Pulse shape resolution loss!

Experimental setup

L.Bardelli et al, NIM A605 (2009) 353





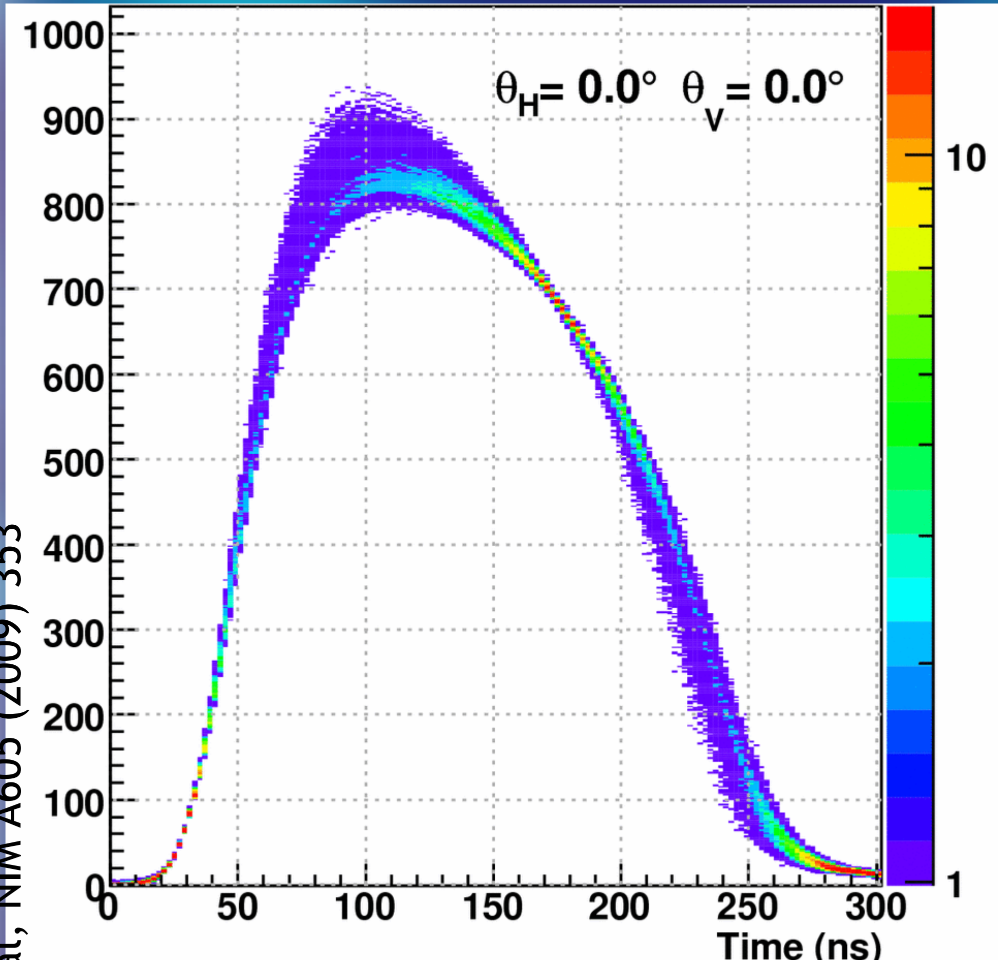
Measure the detector response at various tilt angles by using a motorized support (with remote control) using

FAST SAMPLING ADCs (12bit, 125 MS/s

INFN-Fi digitizer: G.Pasquali et al, NIM A 570 (2007)

Signal shapes

Current signals for a ^{80}Se @ 410MeV, <100> detector, 1000 events:



12 bit - 125 MS/s data (INFN-Fi card)

L.Bardelli et al, NIM A605 (2009) 353

standard detector mounting

(normal to direction of incoming particles)

Signal shapes

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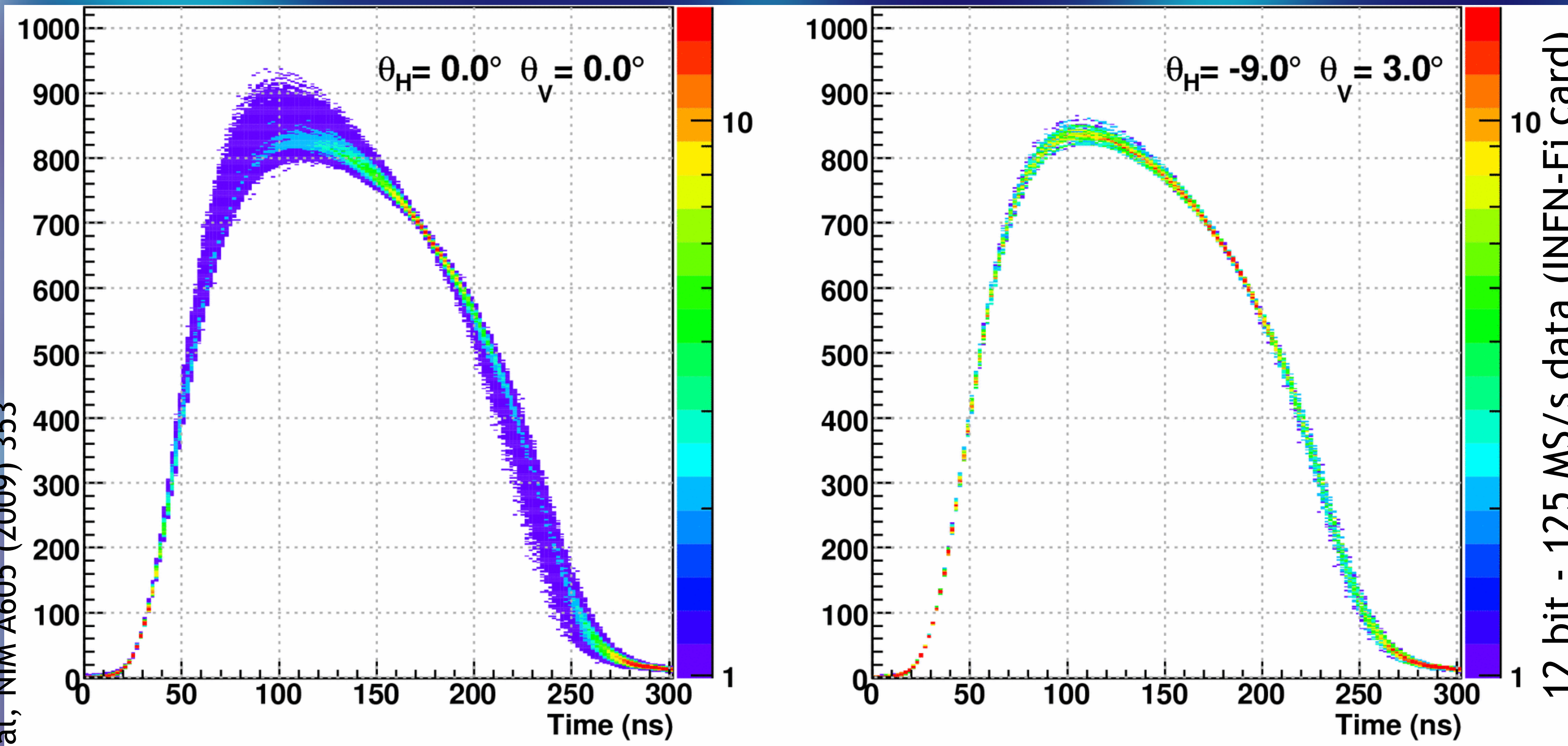


standard detector mounting
(normal to direction of incoming particles)

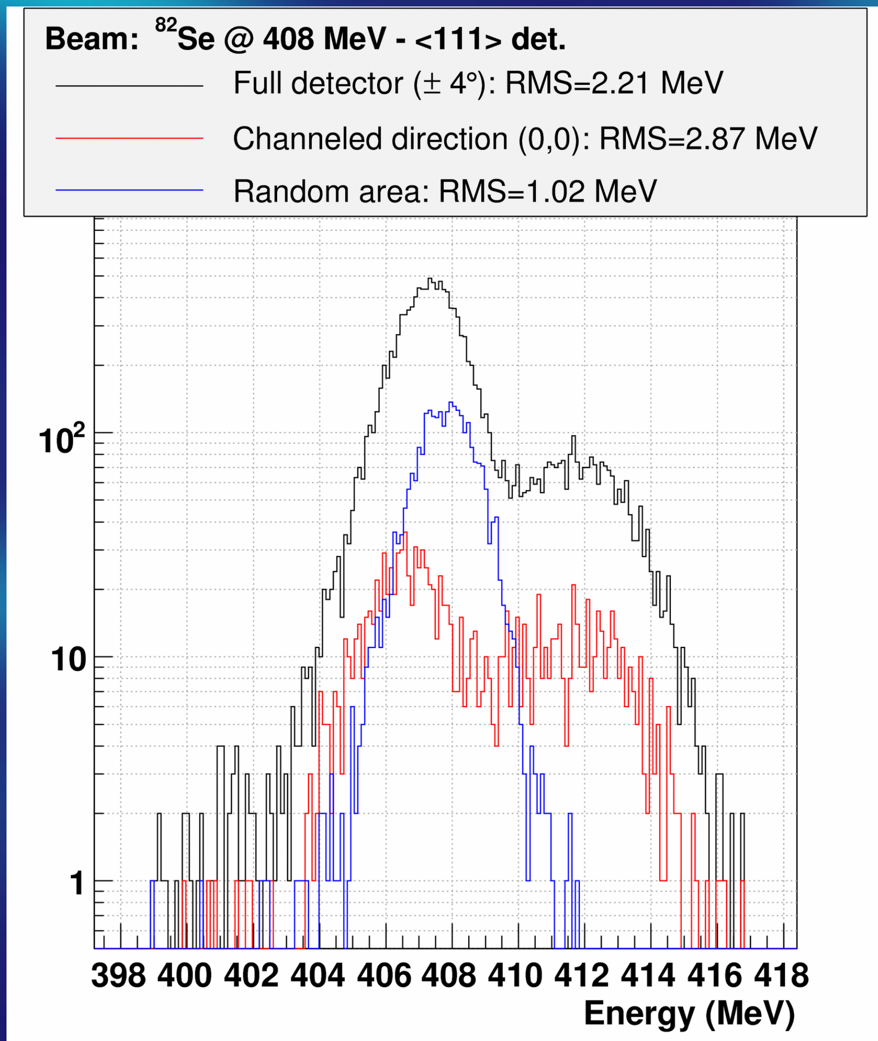
tilted detector

Note the reduction of the signal fluctuations

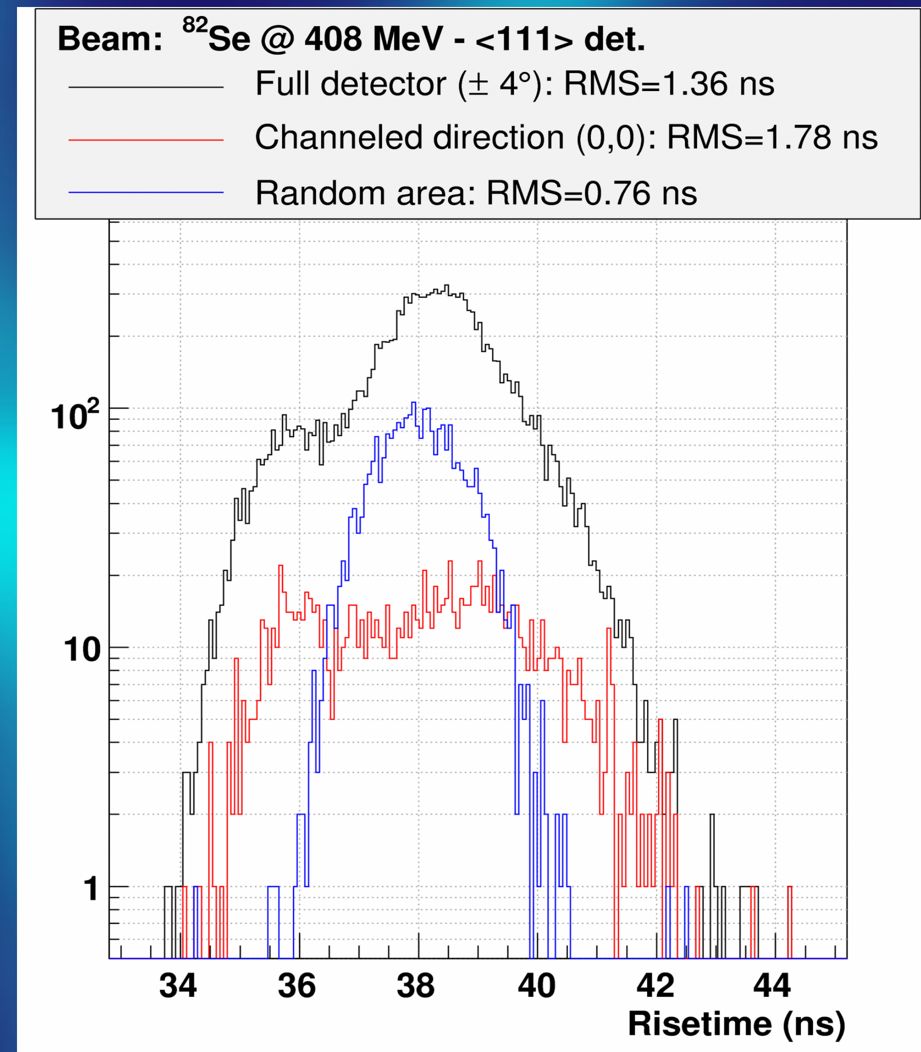
L.Bardelli et al, NIM A605 (2009) 353

Energy/timing resolution

Resolution for a <111> detector:



ENERGY



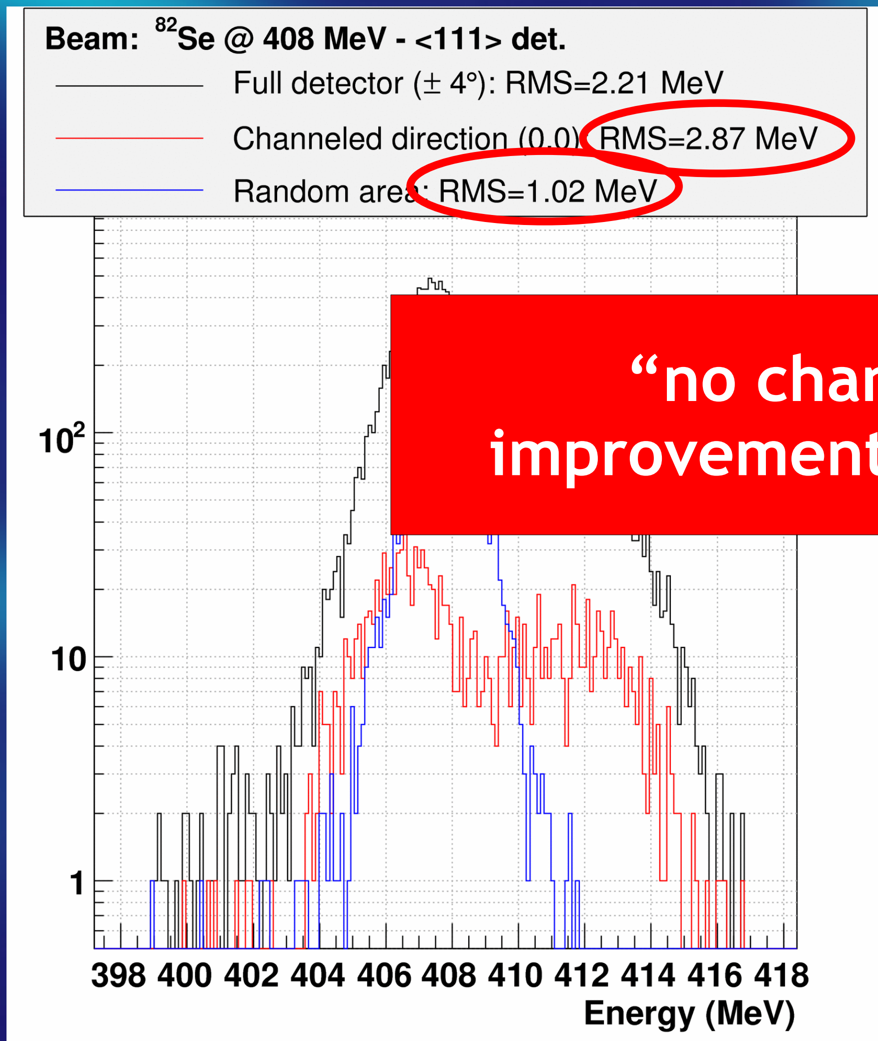
RISETIME

12 bit - 125 MS/s data (INFN-Fi card)

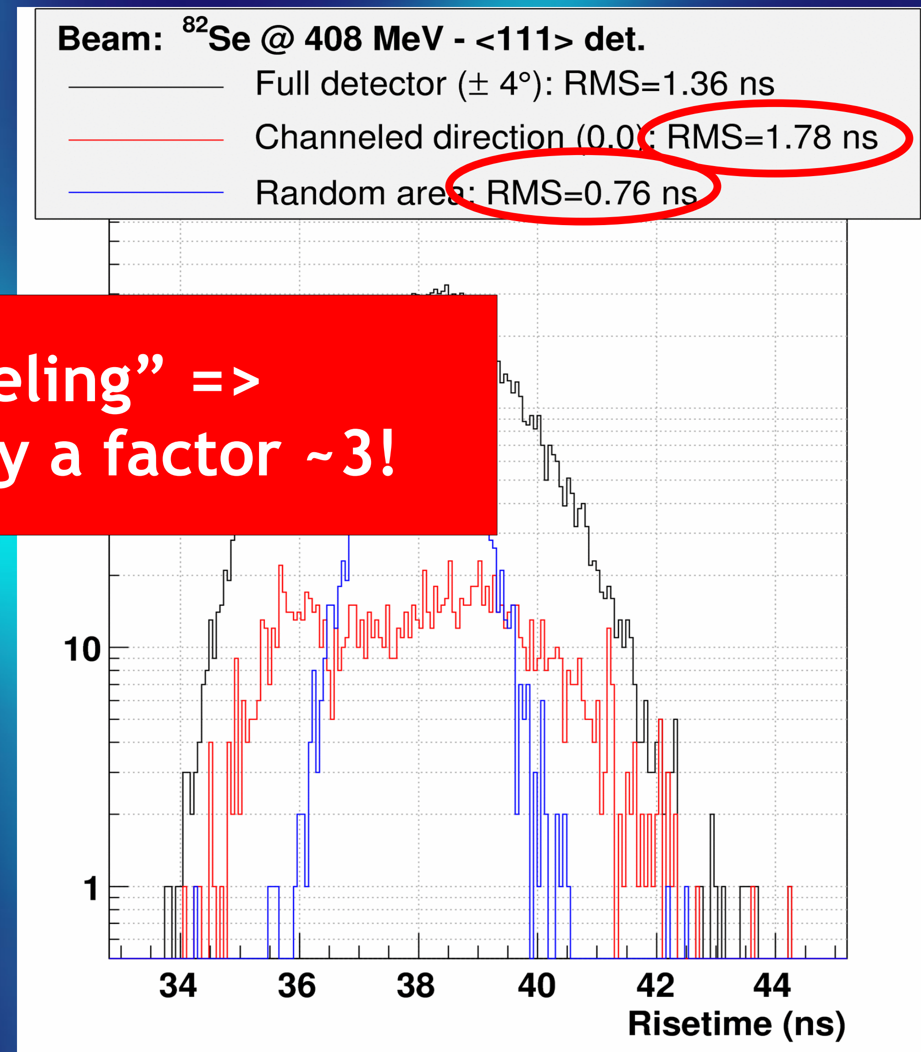
L.Bardelli et al, NIM A605 (2009) 353

Energy/timing resolution

Resolution for a <111> detector:



ENERGY



RISETIME

“no channeling” => improvement by a factor ~3!

L.Bardelli et al, NIM A605 (2009) 353

12 bit - 125 MS/s data (INFN-Fi card)

Map of exp. signal fluctuation ↔ Crystal structure

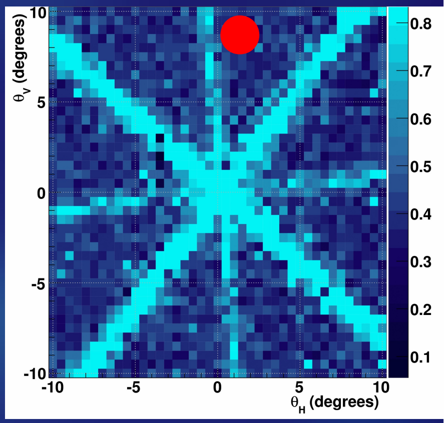
Dark zones: minimum variance
Light zones: maximum variance

How to “avoid” channeling

Channeling effects must be avoided in order to obtain the highest discrimination in PSA applications.

How can we avoid these effects?

1) if the detector is cut along a <111> or <100> axis, the only solution is to tilt it (unpractical for a 4π device...)
2) we can ask manufactures to build detectors from silicon wafers having a special cut *(“random-cut”)*



FBK/IRST (Trento) produced Silicon detectors out of “random-cut” (i.e. channeling free) wafers; Silicon material was the high-doping-uniformity nTD Silicon manufactured by TOPSIL. These detectors were used during a two-step Experiment at LNS (July-November 2009)

the angle covered by the detector must be small (rule of thumb: < ±2°)

Detector characterization:

DOPING UNIFORMITY

Doping uniformity

It is well known that any non-uniformity in the electric field inside the detector may have a severe impact over the PSA discrimination capabilities:

Two closely connected issues:

- is it possible to measure the resistivity (i.e. doping) uniformity of our detectors? (non destructive is better.......)
- *is it possible to get very uniformly-doped high-resistivity Silicon?*

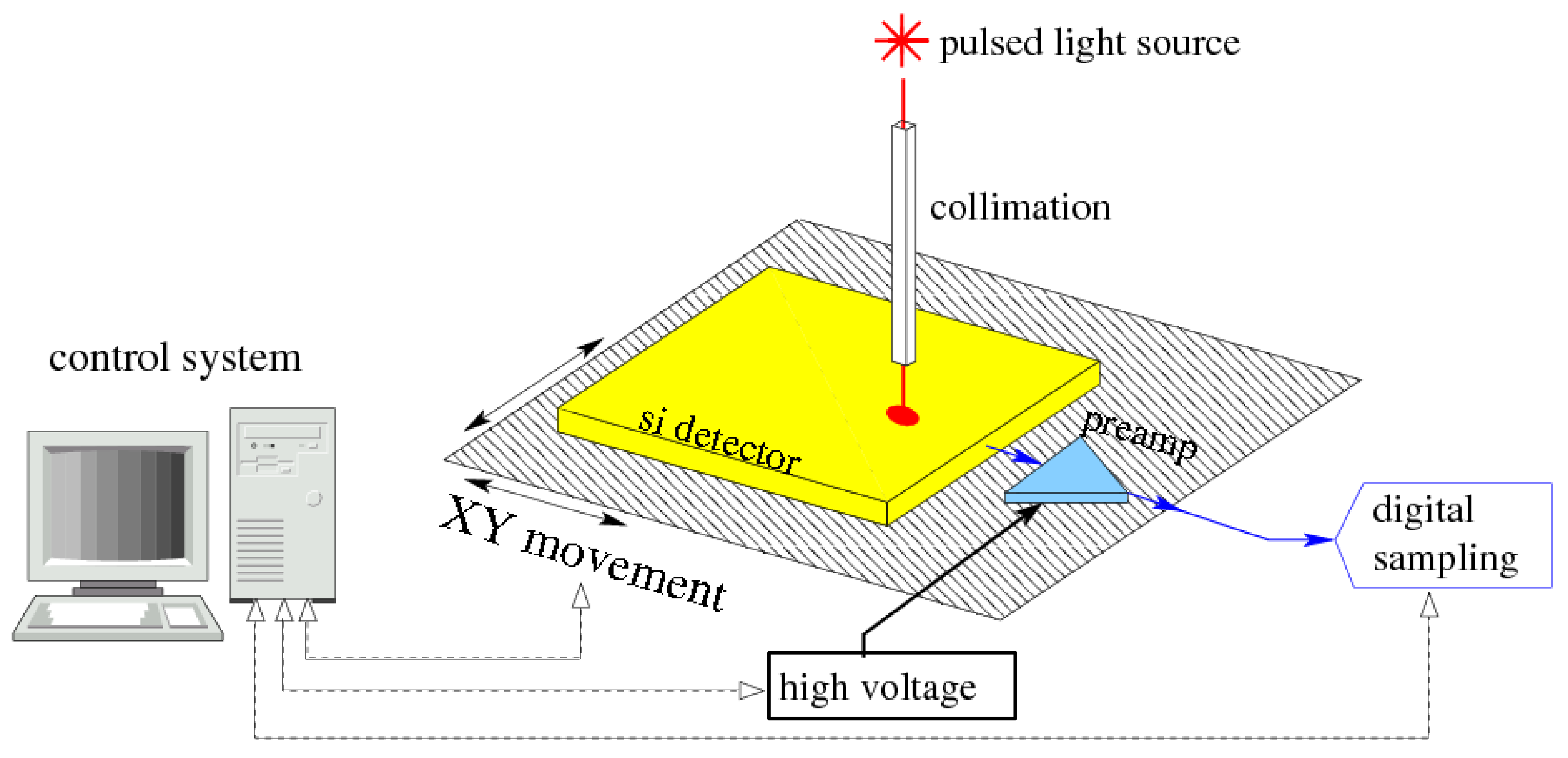
Issue n.1: measuring uniformity

Once the detector thickness is known, the depletion voltage provides a direct measurement of the material resistivity:

$$\rho = \frac{\mathrm{th}^2}{2\, V_D\, \epsilon_R\, \mu}$$

Depletion voltage measurements are routinely performed with C-V plots.

The method



L.Bardelli et al, NIM A602 (2009) 501

The detector is mounted on a XY movement.

Both the XY support and the HV are computer controlled.

Shapes are collected with a digitizer ("*Florence DSP card*")

The method

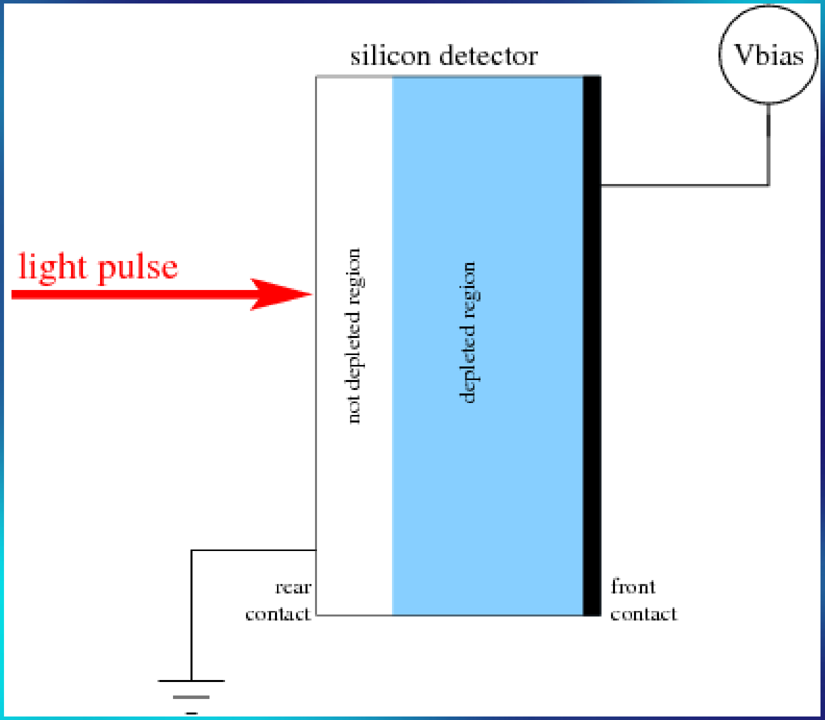
1) The collimated laser pulse enters the detector in the low field zone *(Q-switch sub-ns laser)*

2) Shapes are collected for various applied voltages and various XY positions.

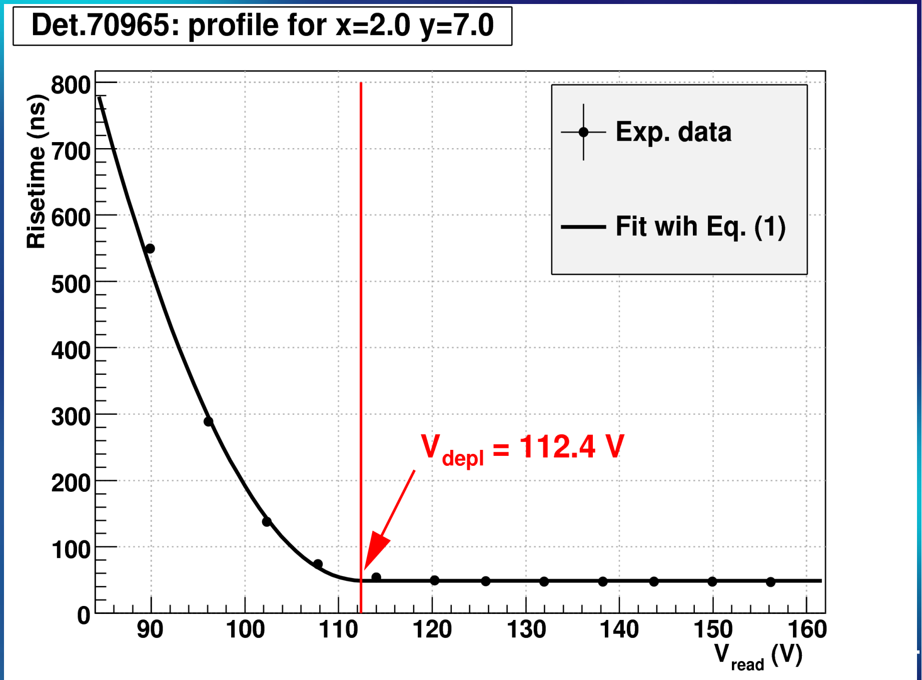
3) XY and $V_{applied}$ scans of the detector are performed

4) For each XY position on the detector we can build an "Average risetime" vs "Vapplied" plot

5) ... and fit the <u>LOCAL</u> V_{depl}

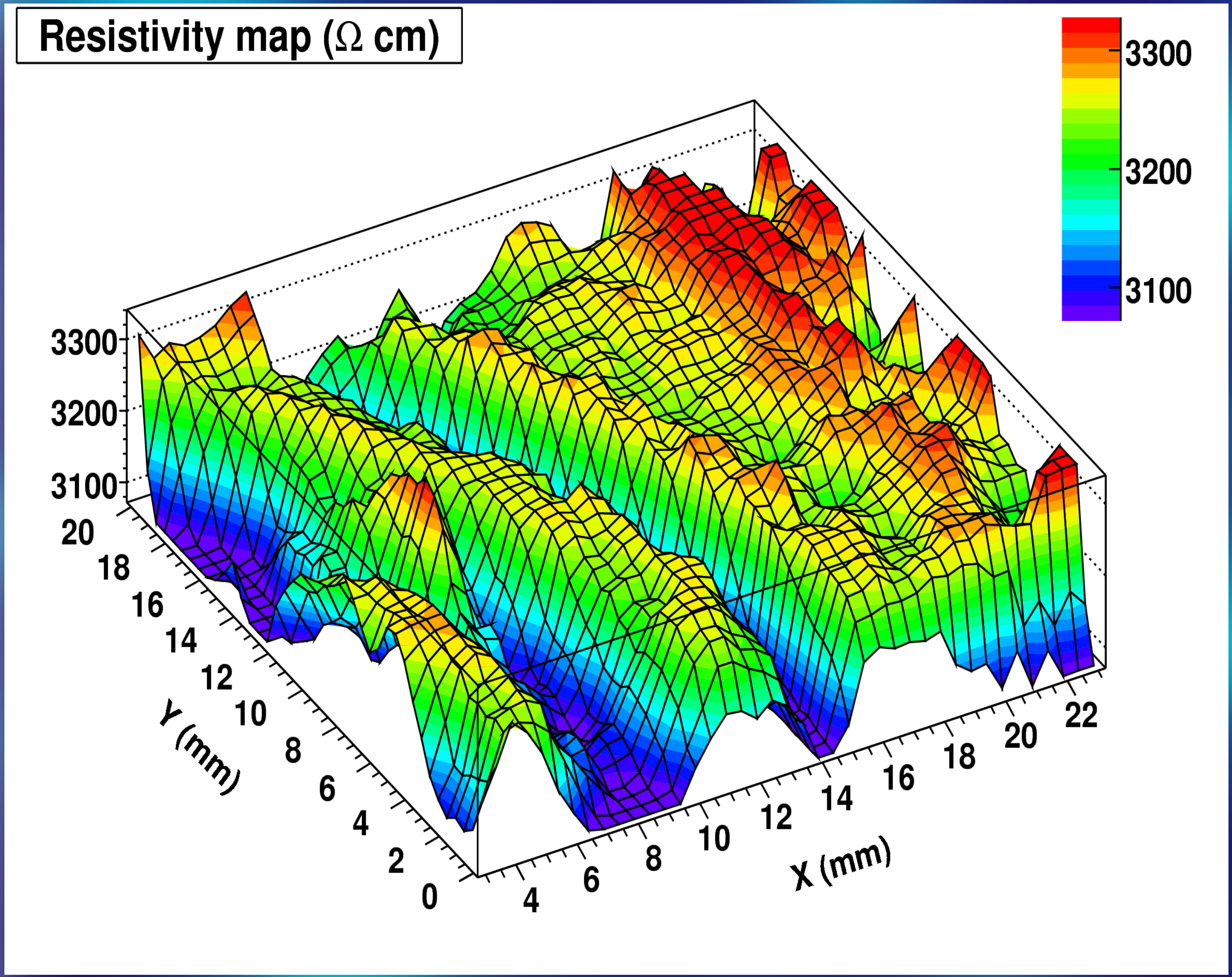


L.Bardelli et al, NIM A602 (2009) 501



Resistivity plot

... and finally we can build a 2D resistivity plot:

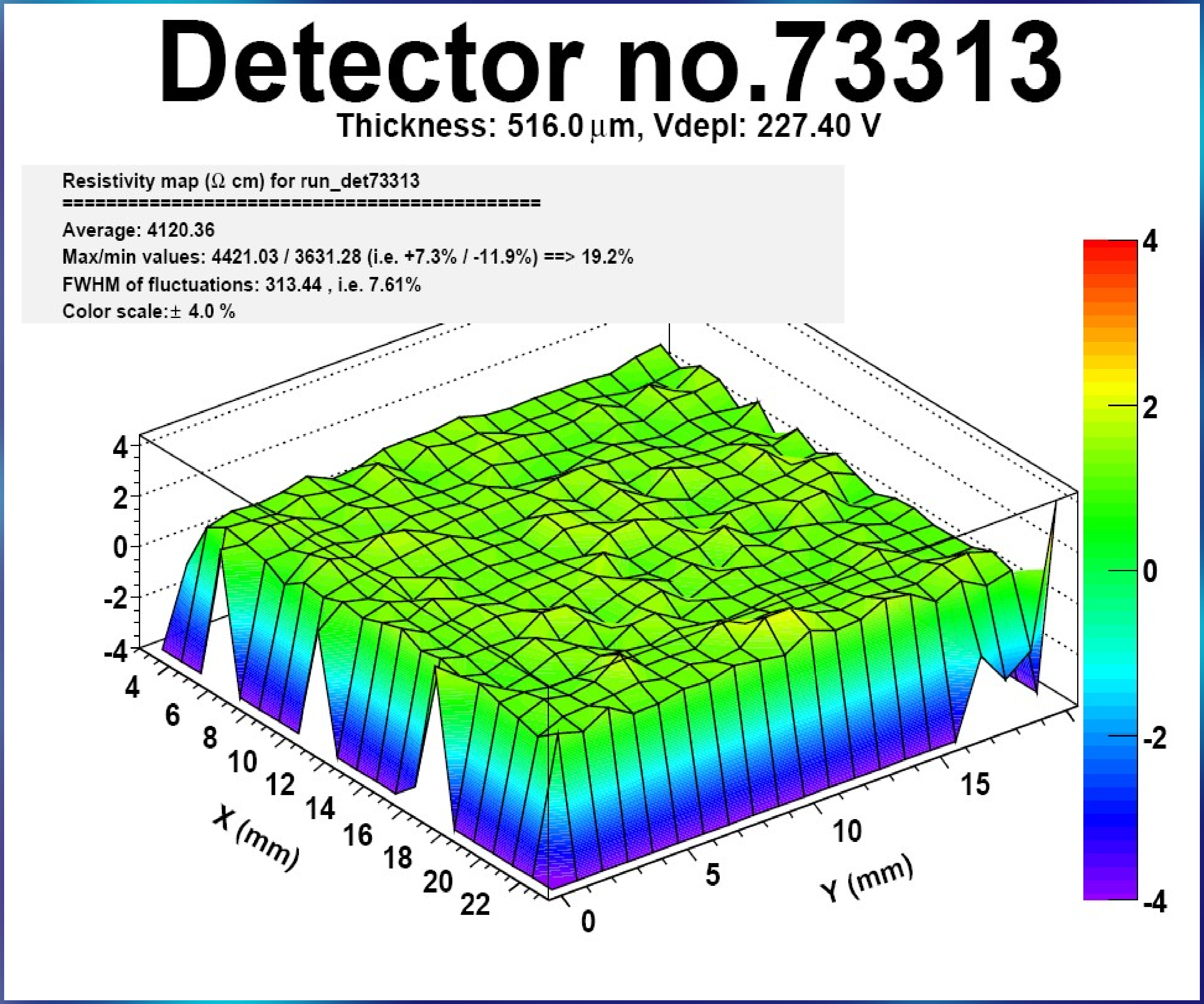


a "standard-uniformity" i.e. 9% detector, *not apt to Pulse Shape Analysis*

L.Bardelli et al, NIM A602 (2009) 501

Resistivity plot

... and finally we can build a 2D resistivity plot:



a "good-uniformity" detector (better than 1%), *well apt to Pulse Shape Analysis*

L.Bardelli et al, NIM A602 (2009) 501

EXPERIMENTS

LNL '07: using “light” ions, low energy

Highly uniform detectors selected, but

final, “random-cut” detectors not yet available, thus -->

poor-man channeling reduction (detector tilting)

some very promising results already seen

LNS '09: using “heavy” ions, higher energy

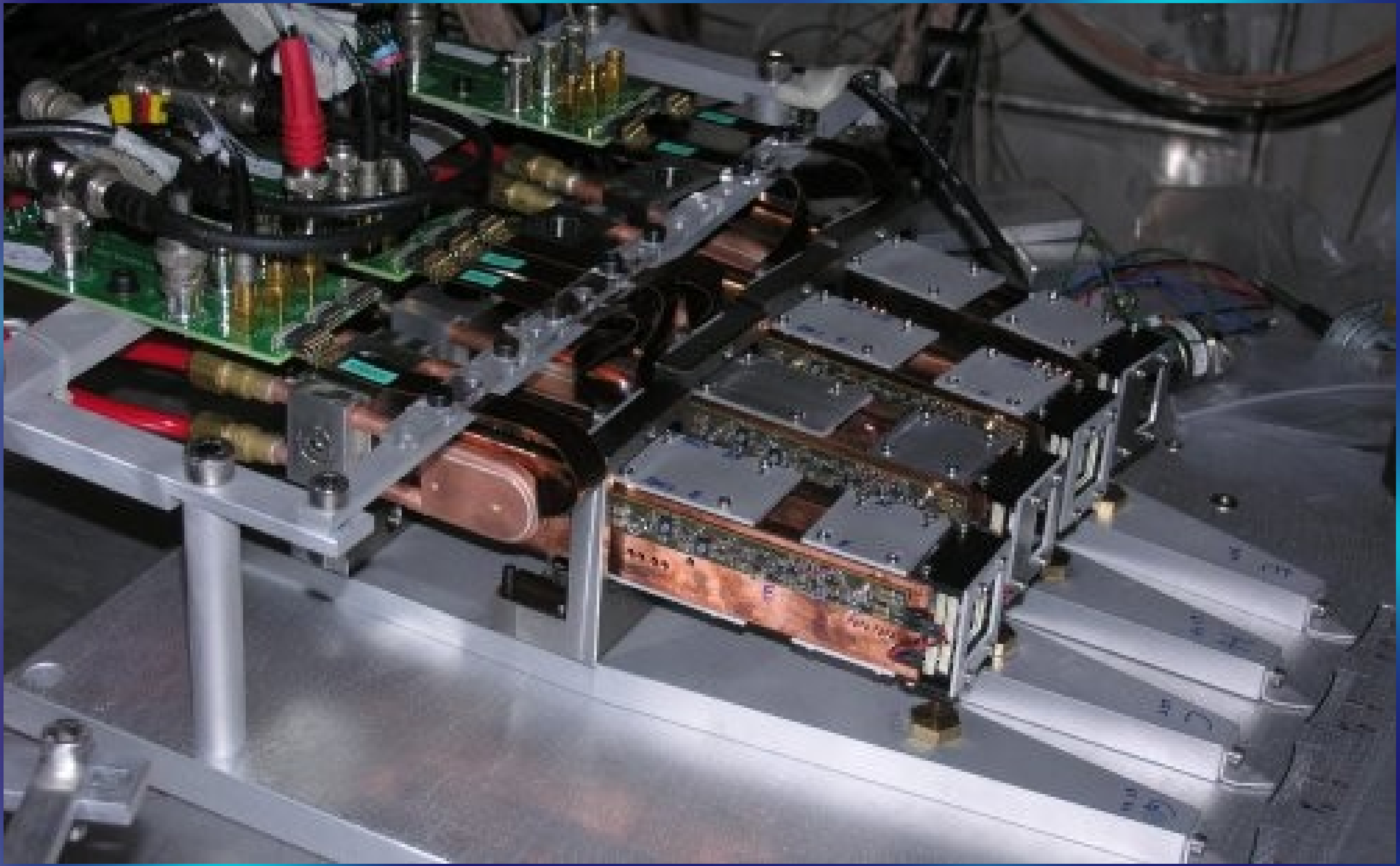
Final high-grade detectors available

Did they work as expected?

Are we able to finally answer the key-question about the identification limit?

FAZIA tests

December 2007: experimental run in LNL (^{32}S + ^{27}Al @ MeV/n) to test the performances of our detectors and first prototype of the final FEE



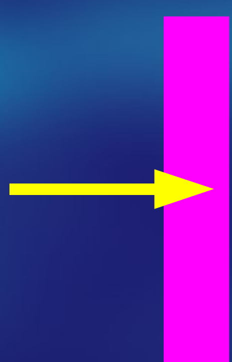
Several Si-Si or Si-CsI telescopes in various configurations and different readouts...

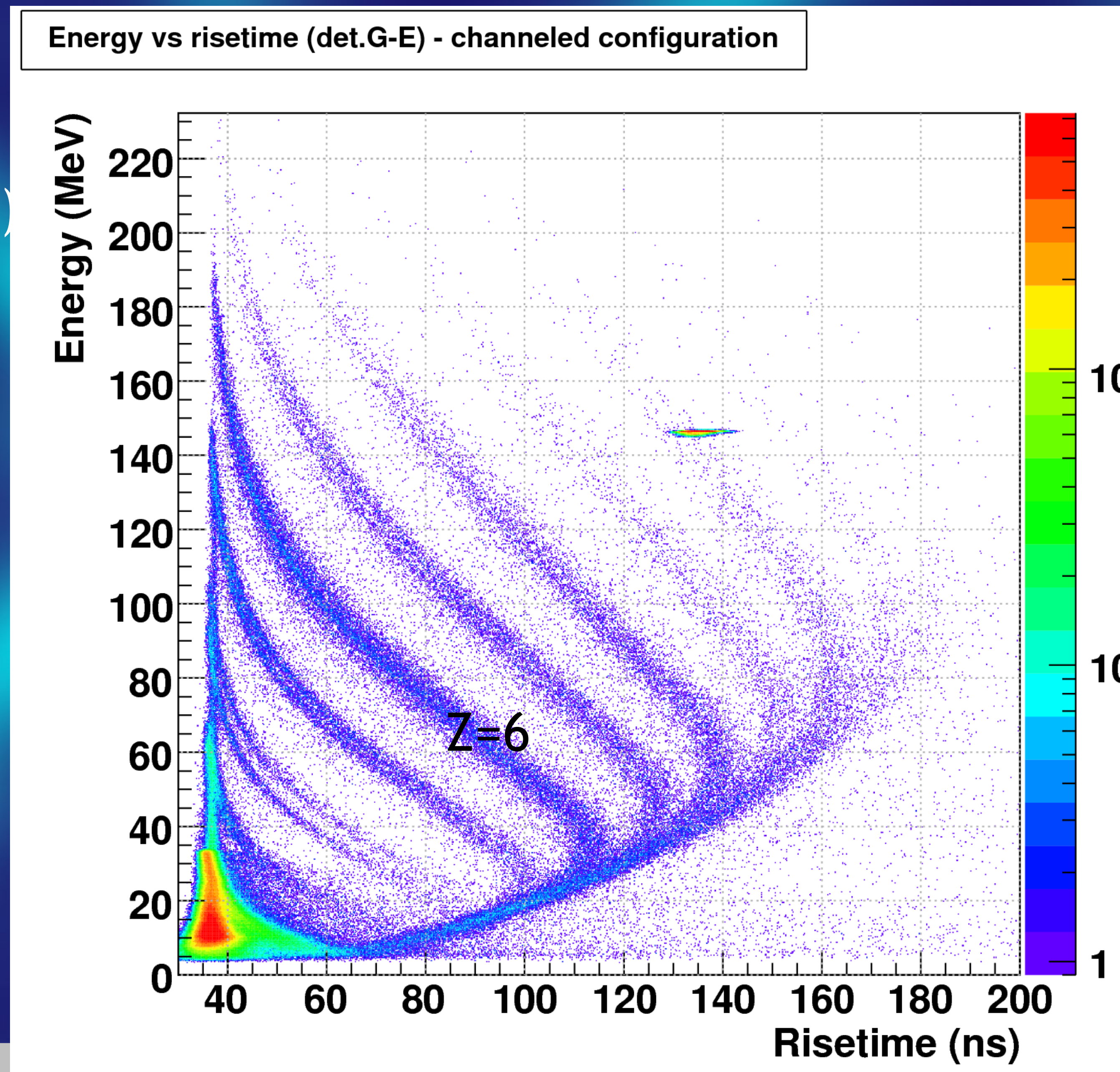
Channeling and uniformity

Digital PSA:

500 um detector
1.5% non-uniformity (BEST)

"with" channeling





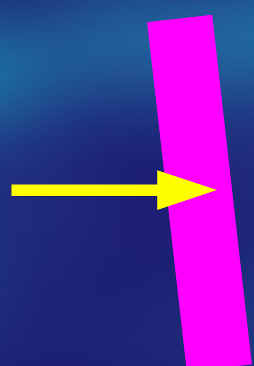
Channeling and uniformity

Digital PSA:

500 um detector
1.5% non-uniformity (BEST

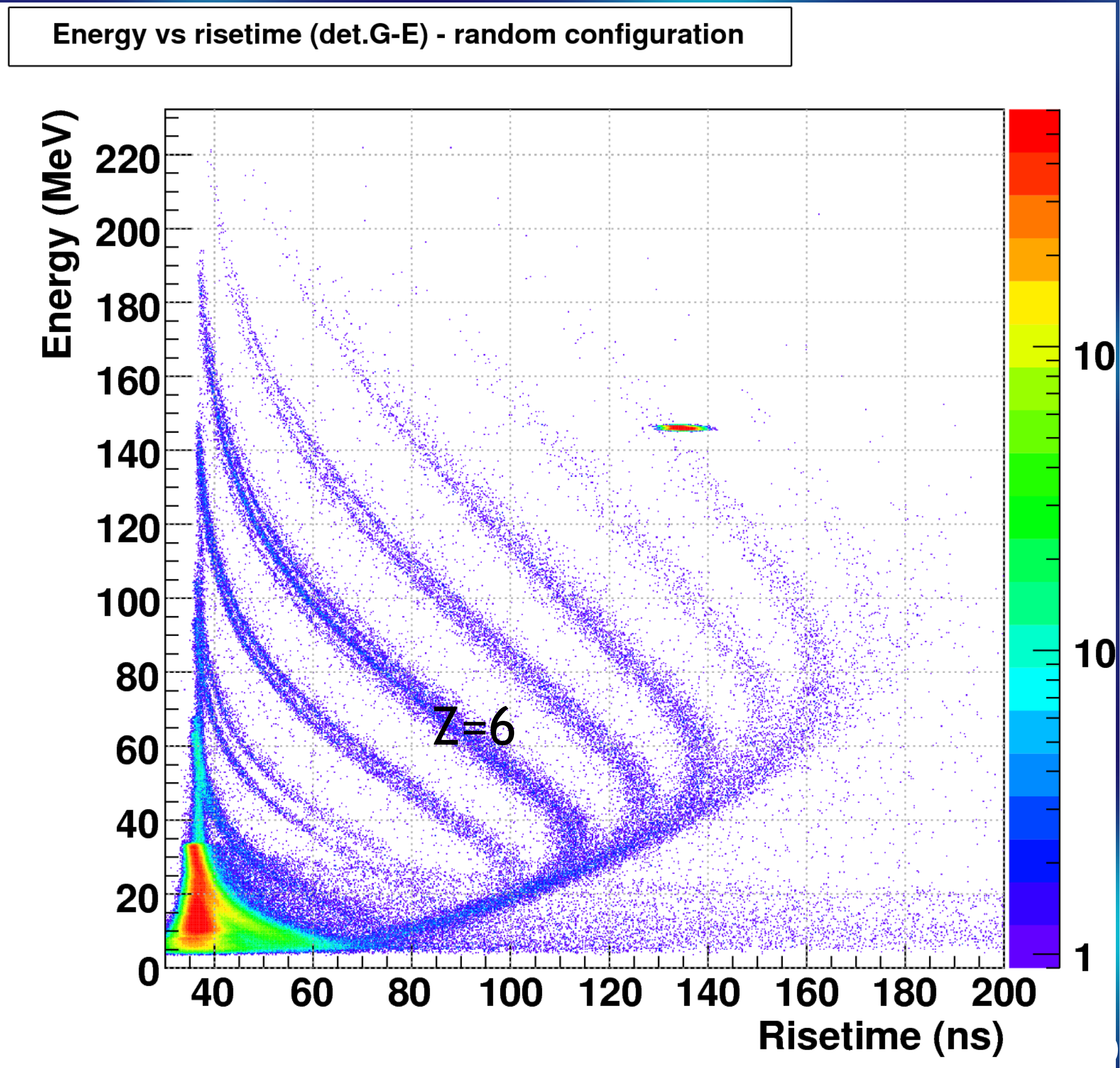
"without" channeling
(a few deg tilting)

(BEST



14 bit, 100 MS/s
digitizer

1.3 GeV full range

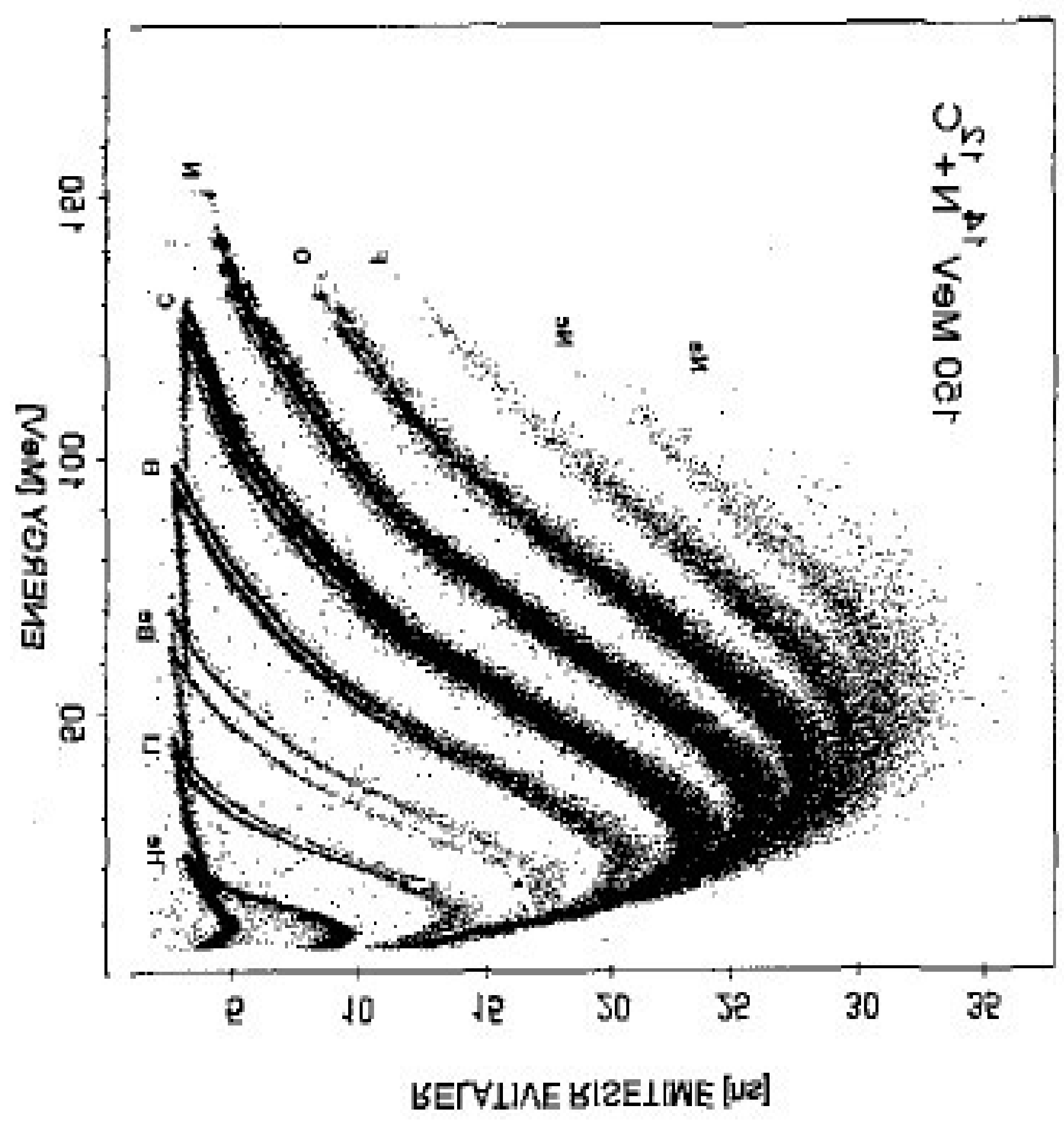


Channeling and uniformity

We found the way to reproduce the almost "unique" result present in the literature (obtained with a significantly smaller detector)

The major contribution to observed irreproducibility has been identified

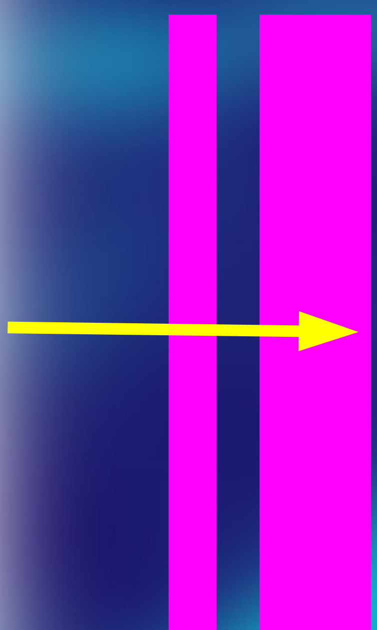
Mutterer et al IEEE TNS 47 (2000) 756

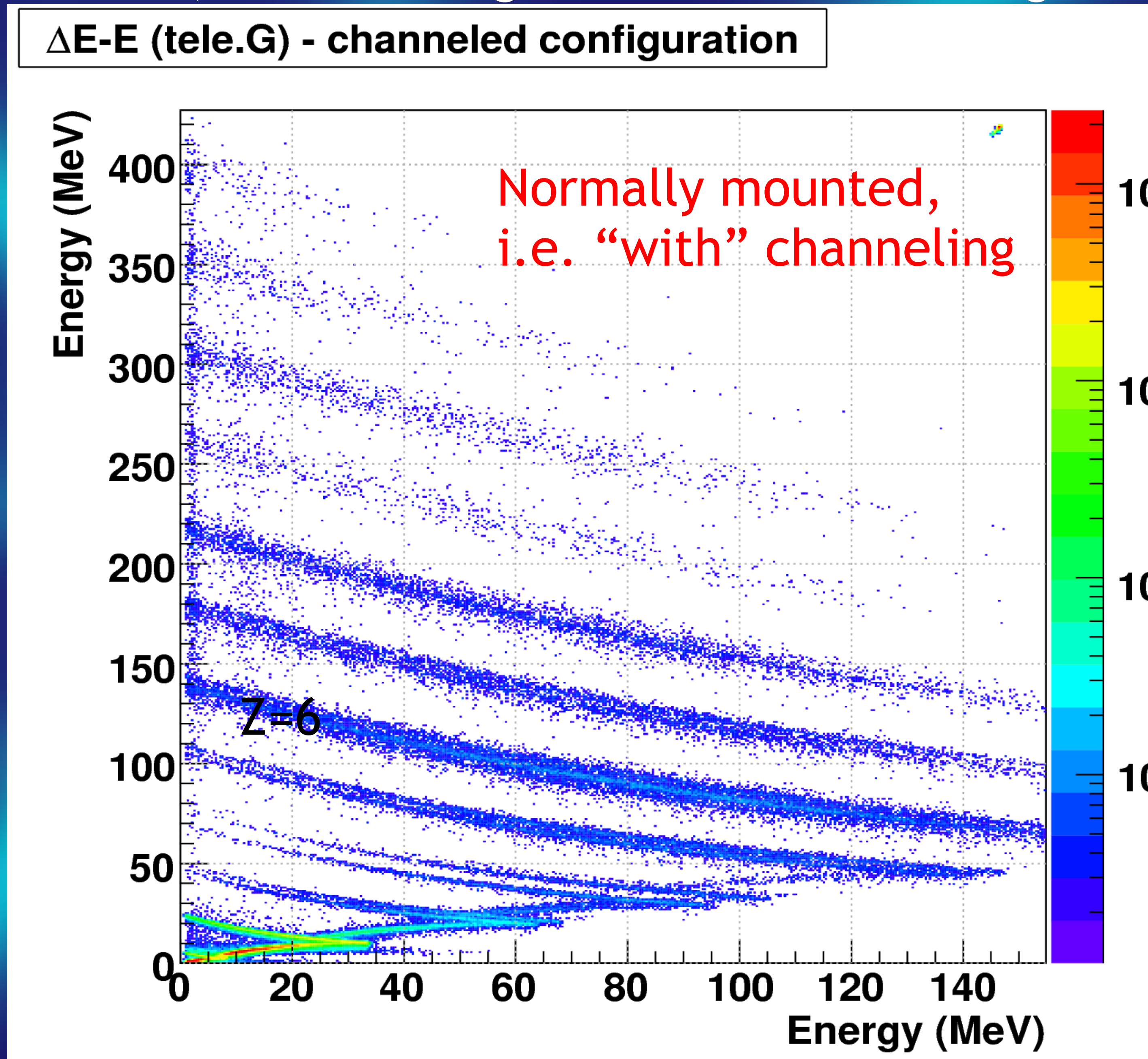


Channeling effects in ΔE-E

14bit, 100 MS/s digitizer 4.2 GeV full range in ΔE

The standard DE-E technique also takes advantage of channeling removal

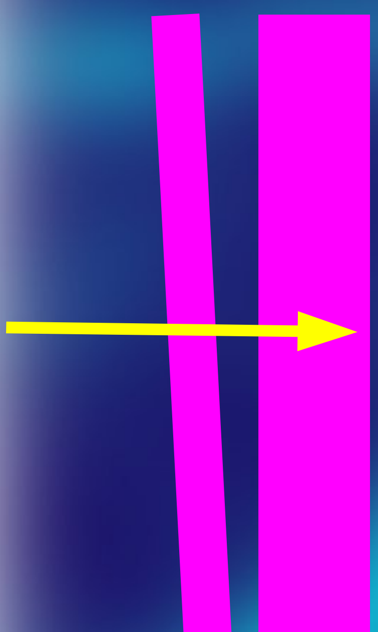


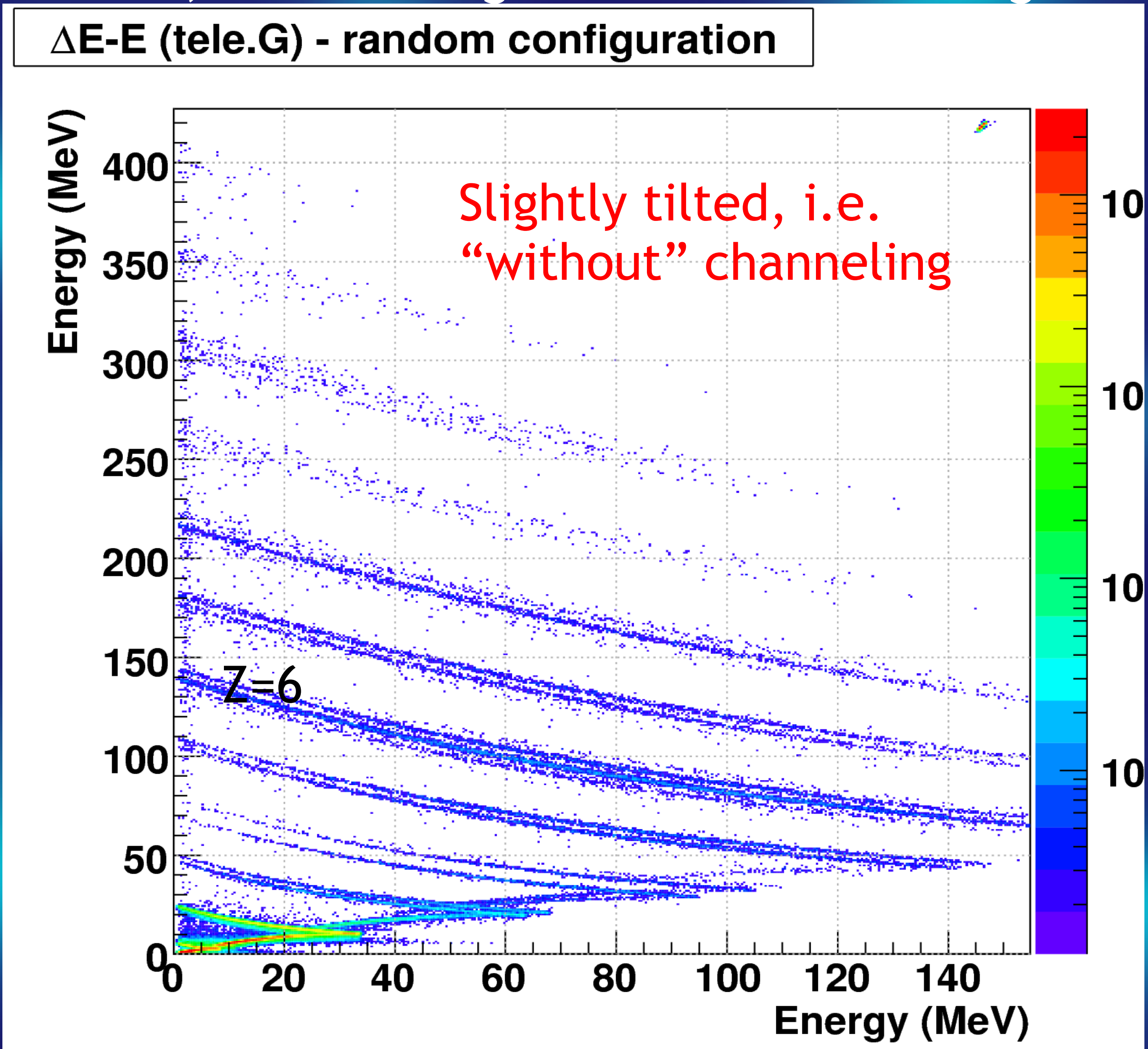


Channeling effects in ΔE-E

14bit, 100 MS/s digitizer 4.2 GeV full range in ΔE

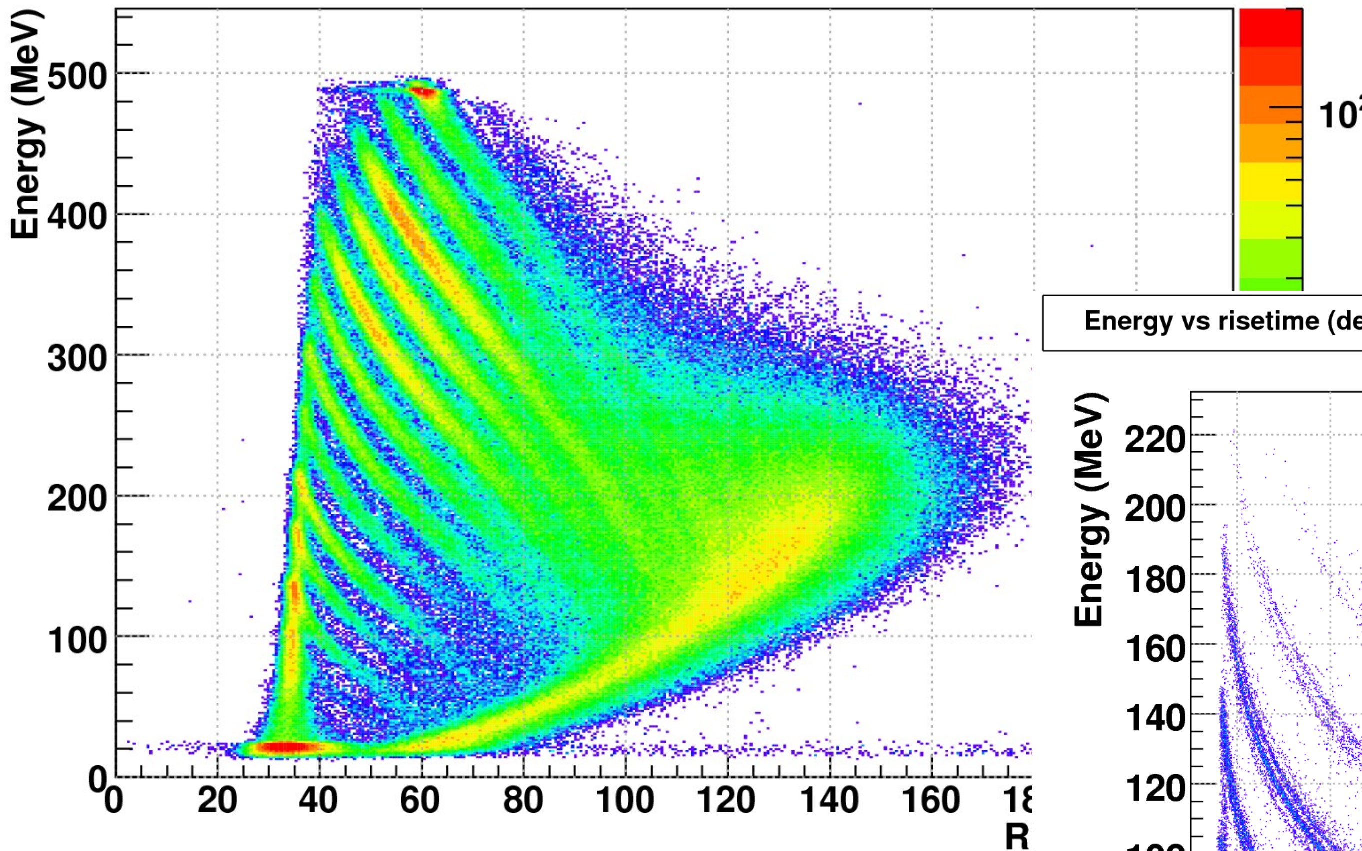
Also standard DE-E technique takes strong advantage of channeling removal





Doping uniformity

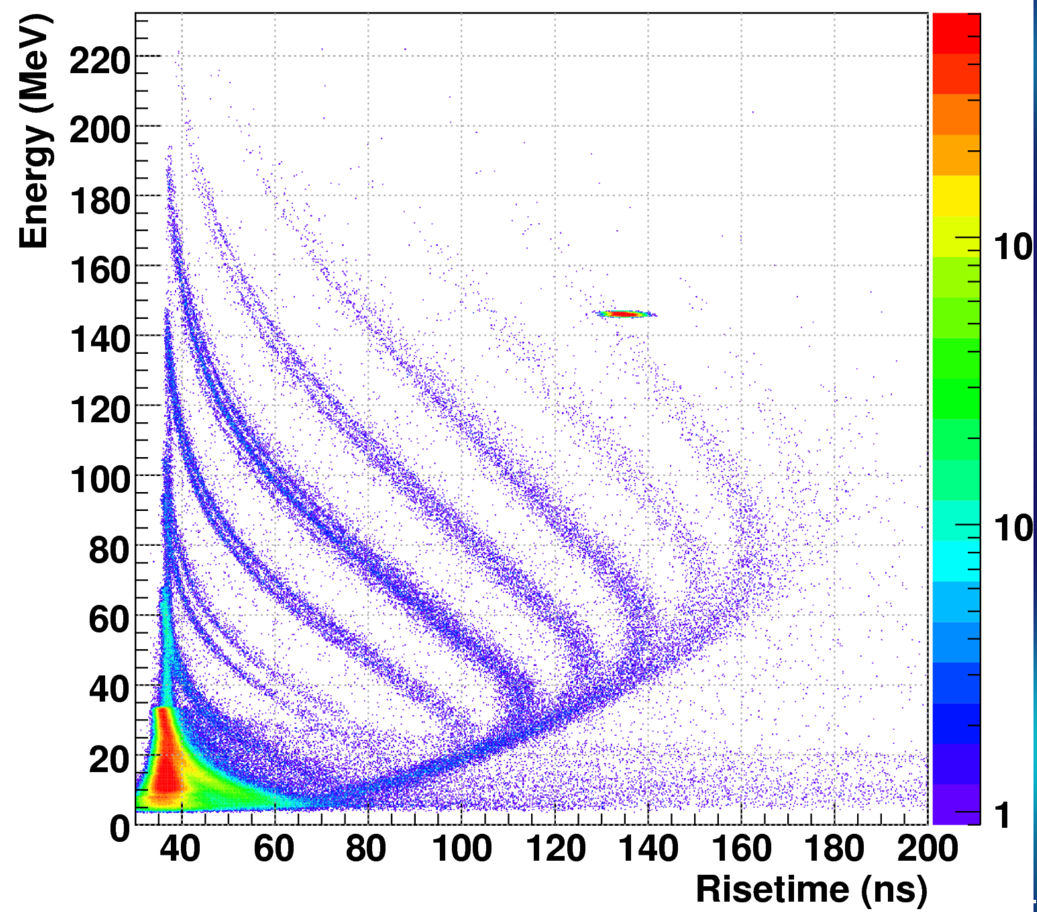
PSA in riv.73311



300 μm, 9.4% non hom.

500 μm, 1.3% non-hom.

Energy vs risetime (det.G-E) - random configuration



Digital PSA:

There is a difference...

(both using non-channeling configuration,
using as similar as possible overbias)

Experiment in LNS to study:

- Verify the performance of FAZIA-grade Silicon detectors

  ("random cut", very high doping *and* thickness uniformity)

- PSA for heavier ions, higher energies

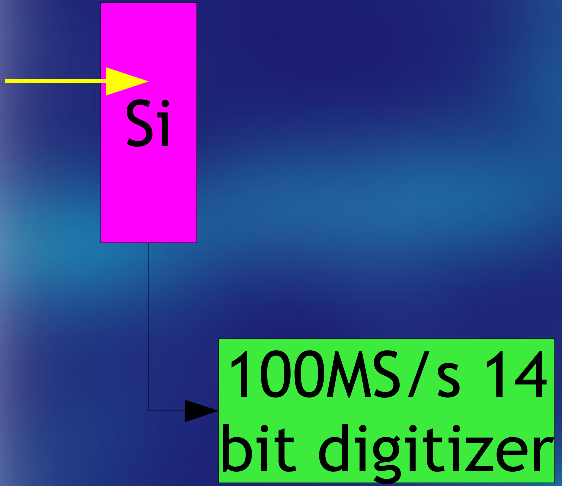
- PSA for rear-side and front-side injection

LNS Nov '09: PSA

Digital PSA results:

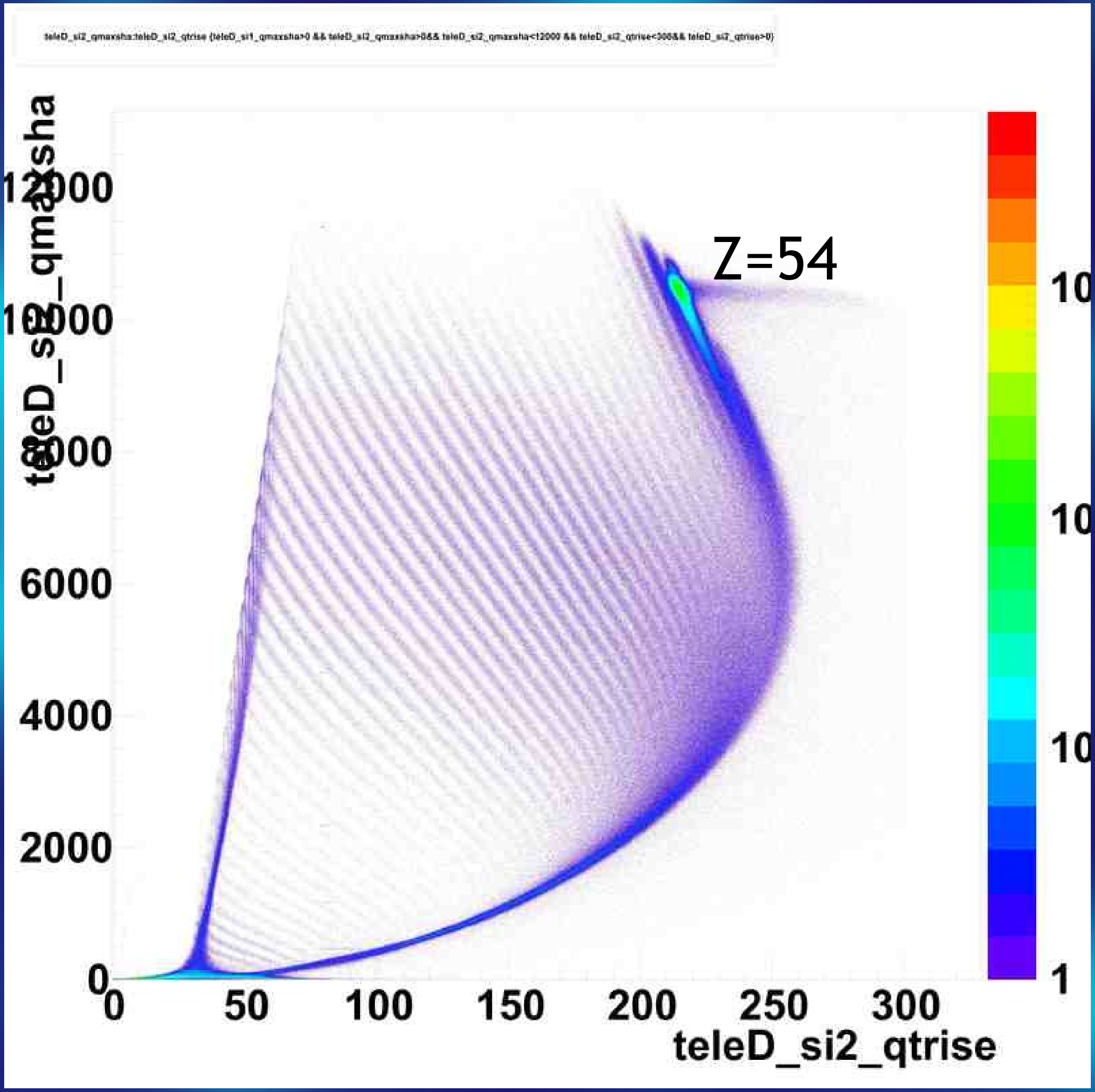
one digitizer,

6 GeV full scale



Particles stopped in one single Silicon. Effective threshold: about 30 μm Silicon

$^{129}Xe + ^{58}Ni$ @ 35 MeV/n

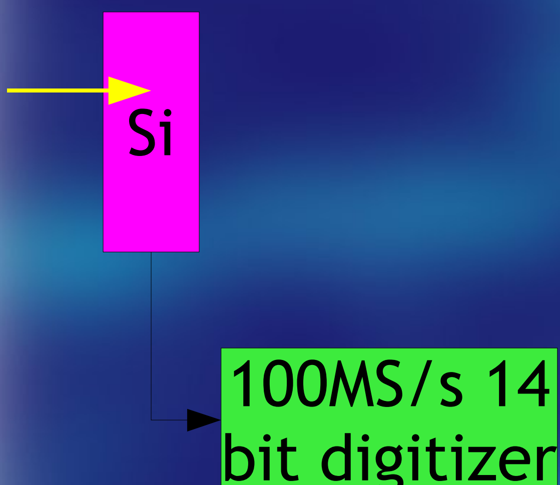


LNS Nov '09: PSA

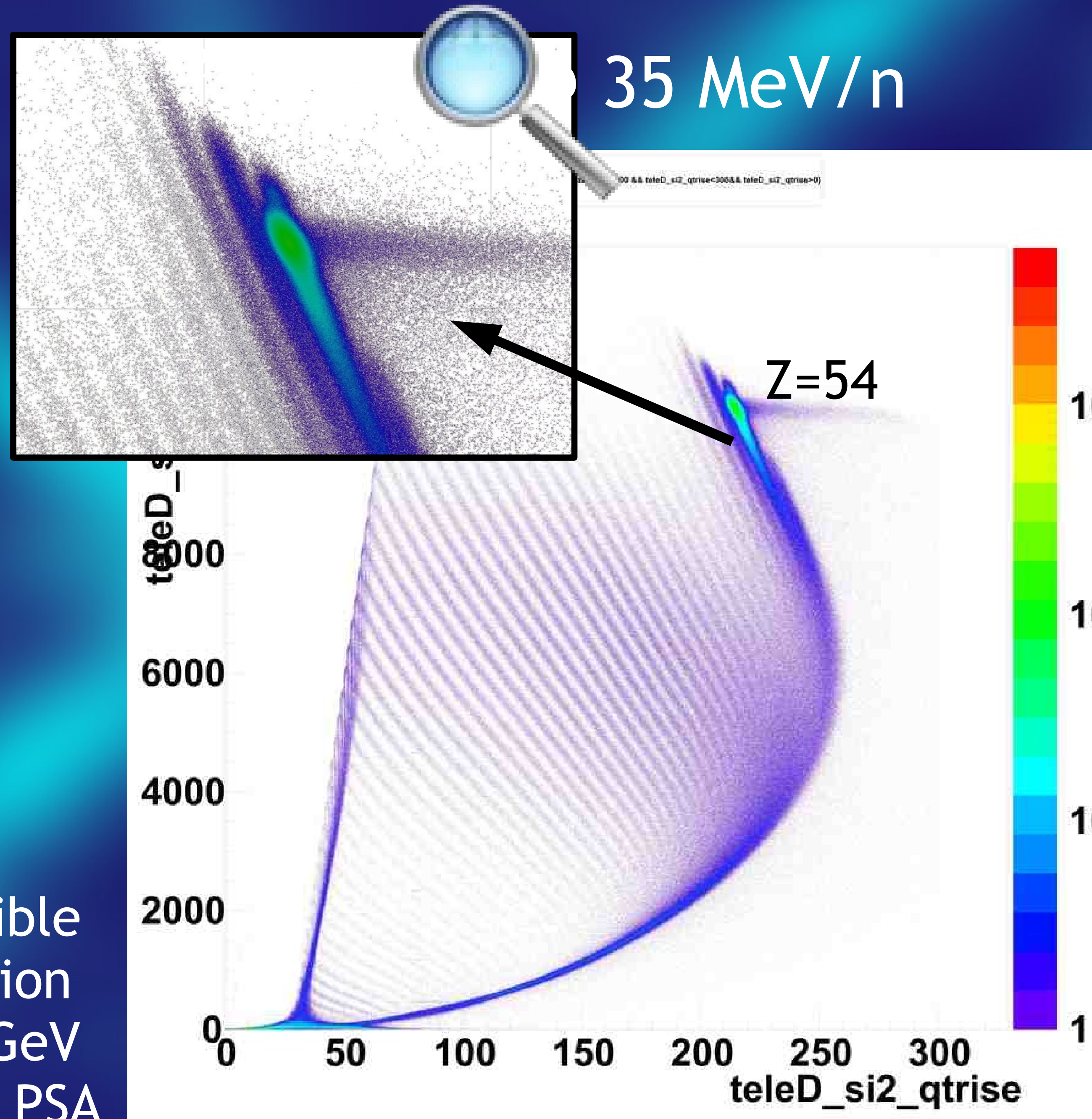
Digital PSA results:

one digitizer,

6 GeV full scale

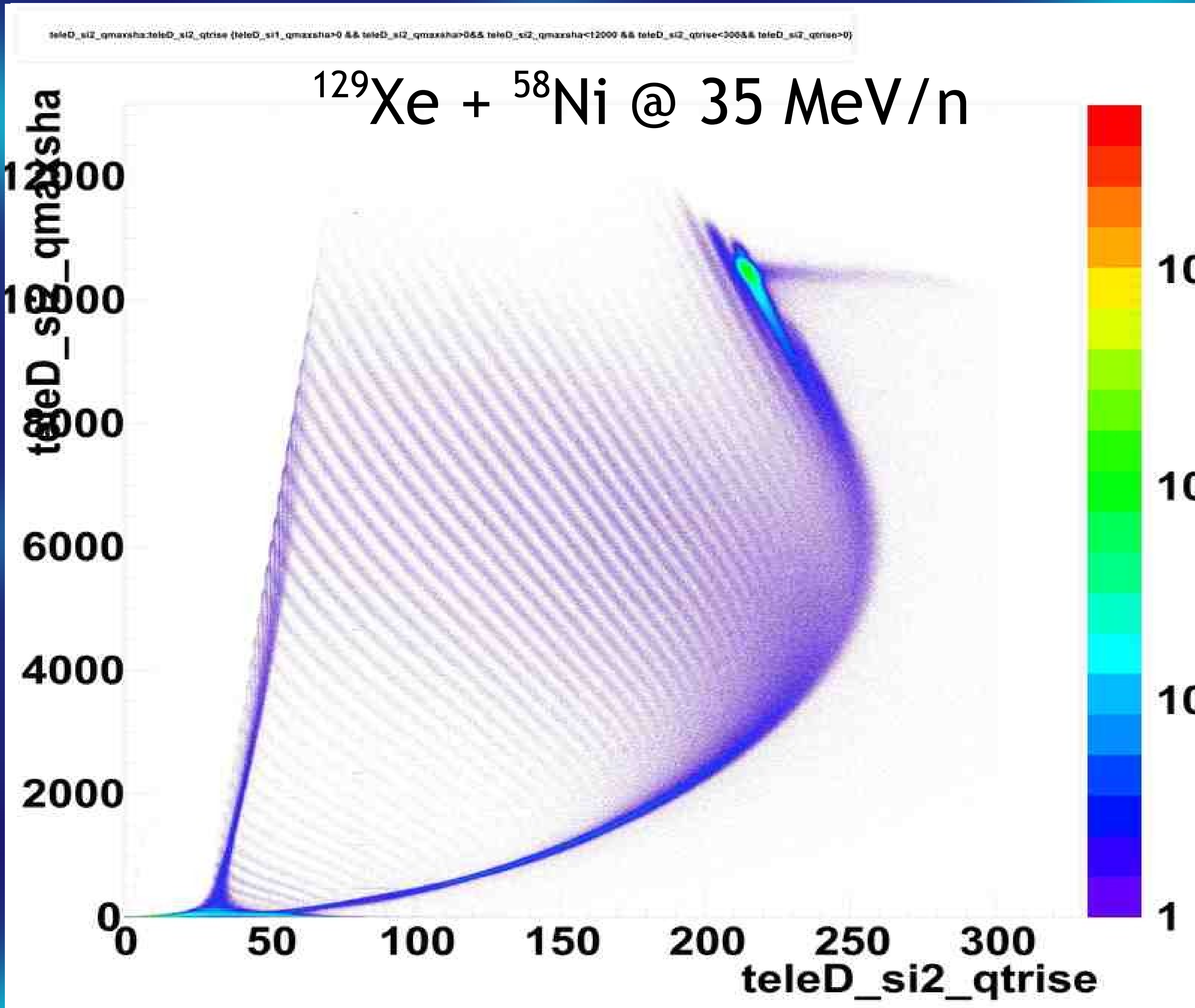


35 MeV/n



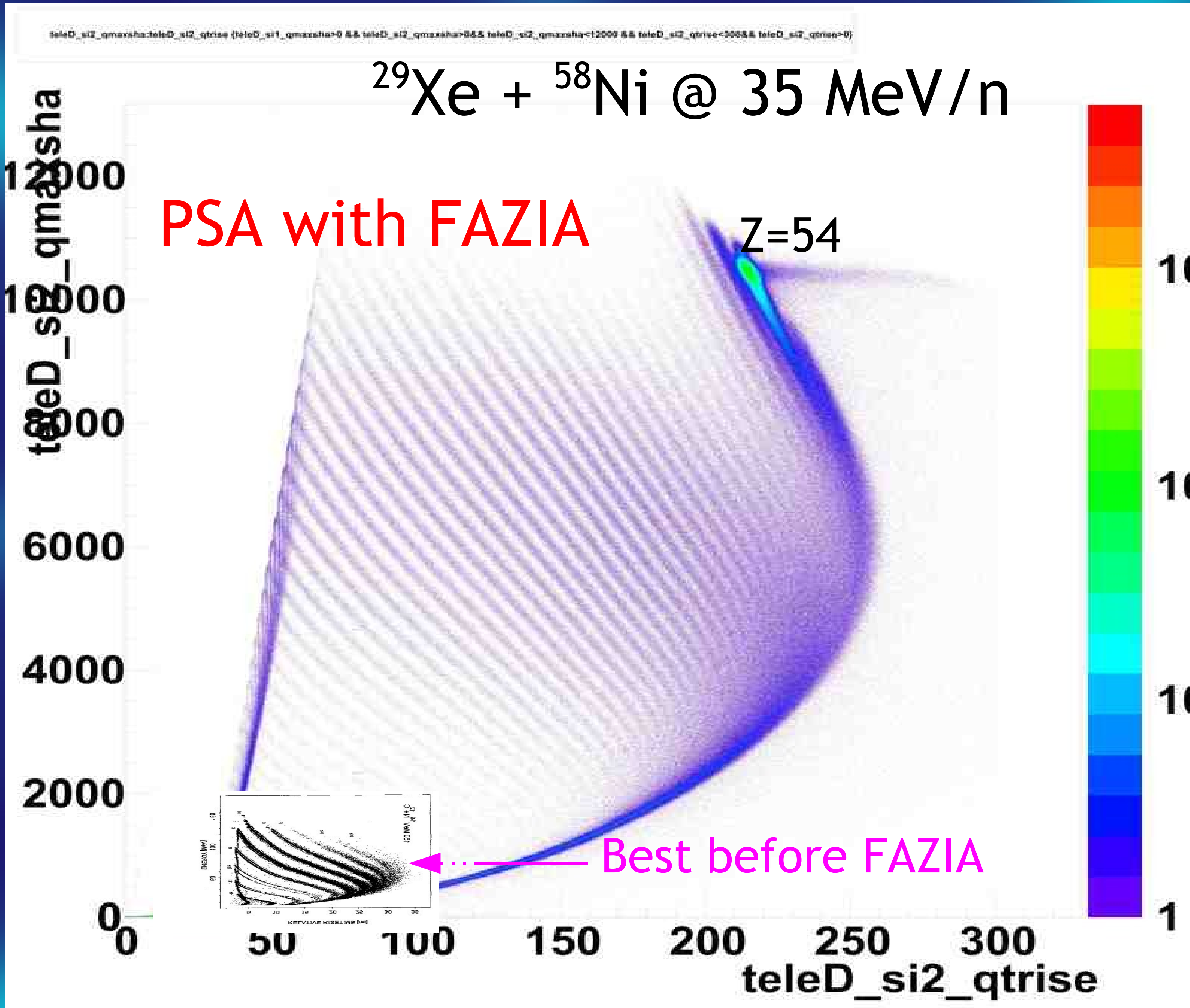
6 GeV full scale is responsible
For not resolving A resolution
Observed in LNL with 1.6 GeV
Two ADC's will be used for PSA

LNS Nov '09: PSA



Si

LNS Nov '09: PSA



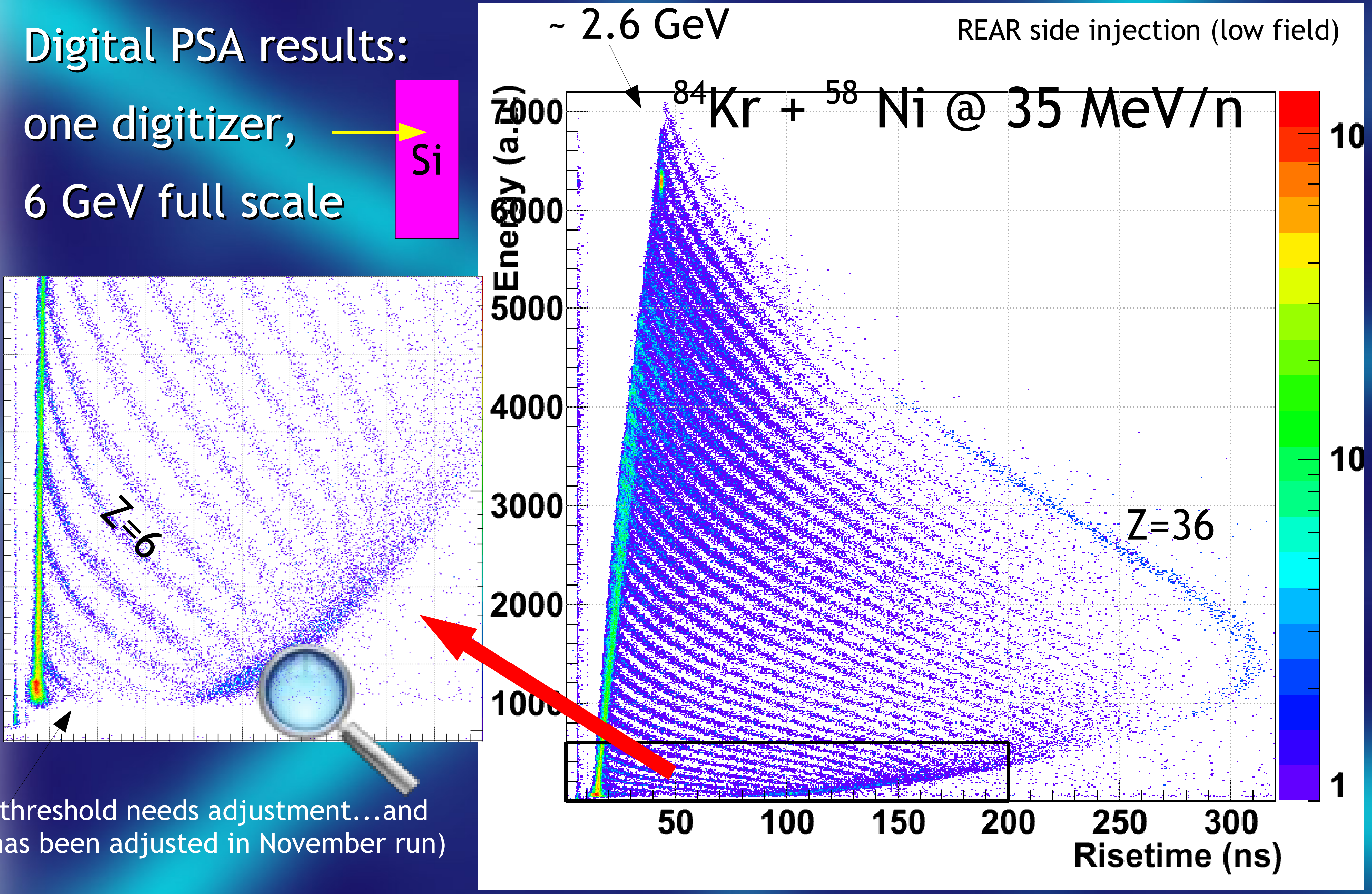
Si

LNS July '09: PSA

Digital PSA results:

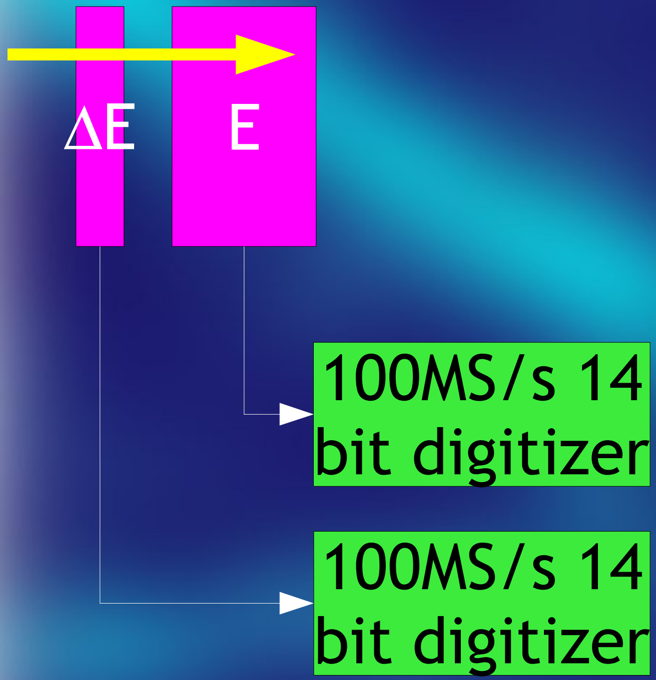
one digitizer,

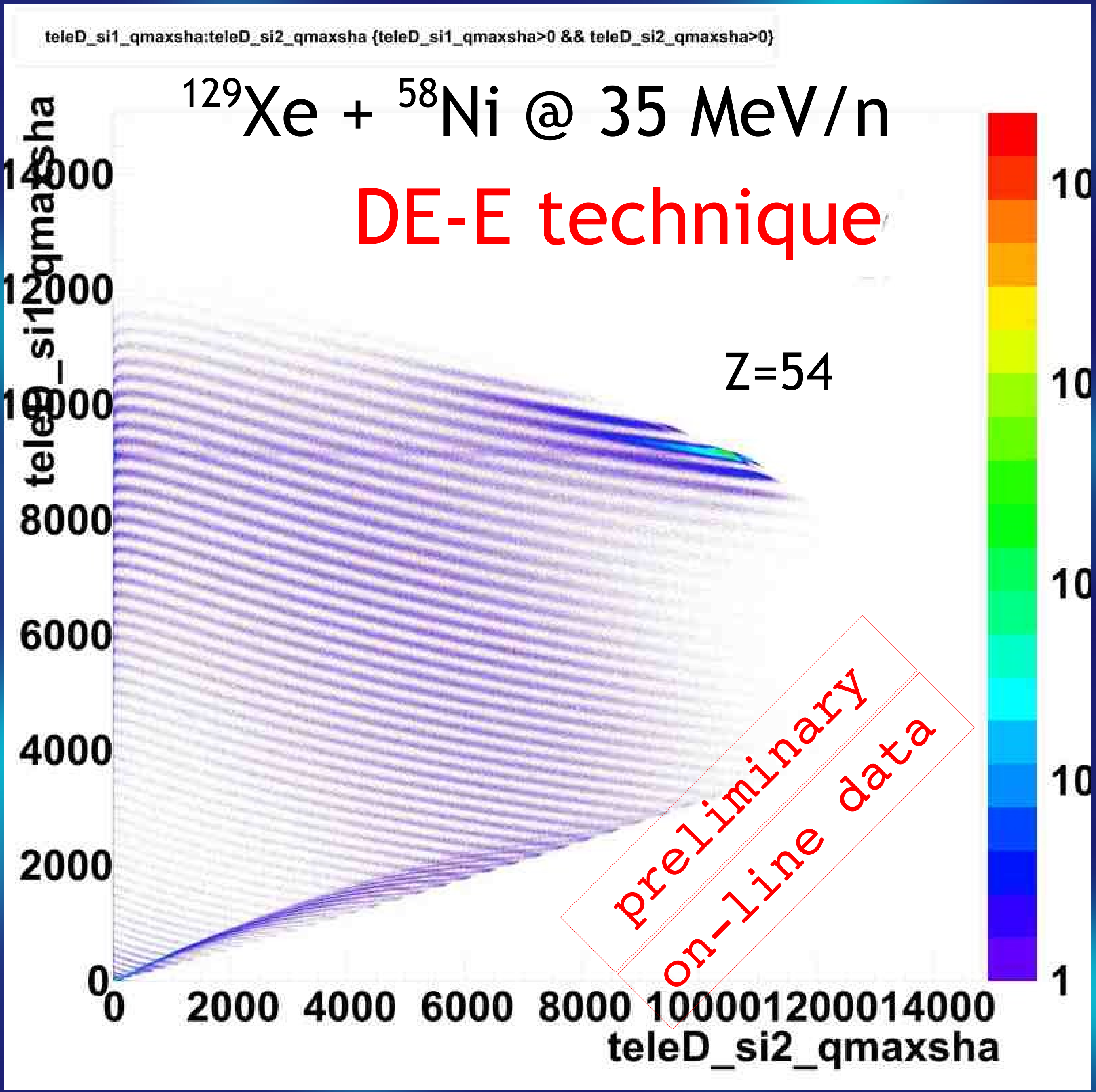
6 GeV full scale



(threshold needs adjustment...and has been adjusted in November run)

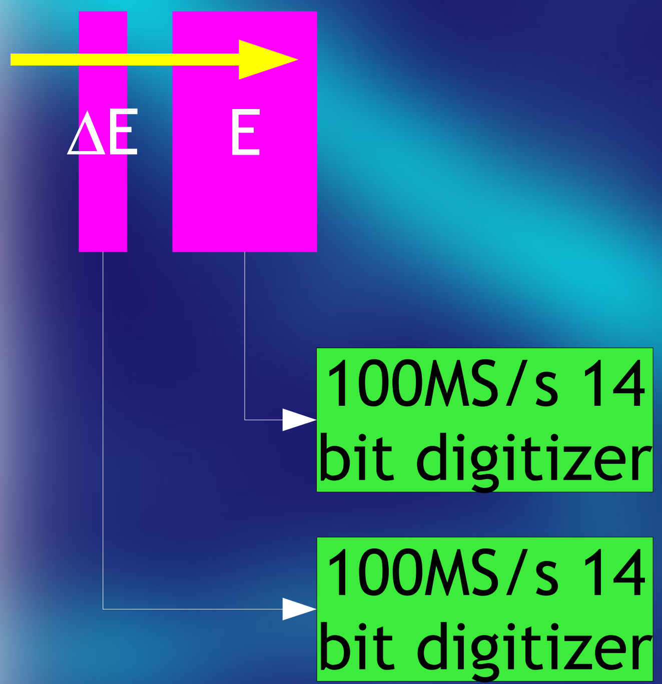
LNS Nov '09: DE-E

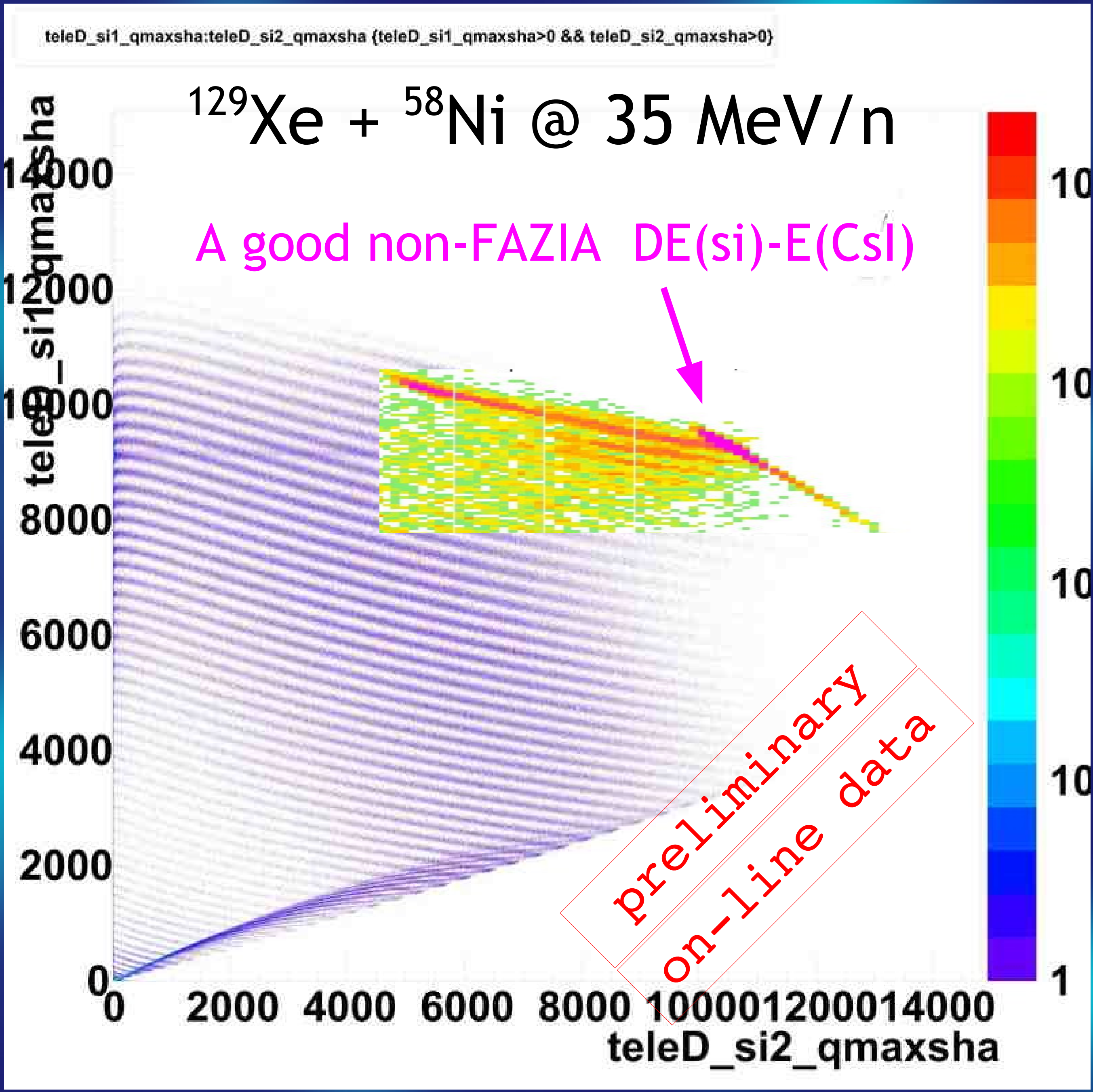




Used configuration:
Isotopic identification up to Z~25 with ~5GeV
Full range

LNS Nov '09: DE-E





Used configuration:
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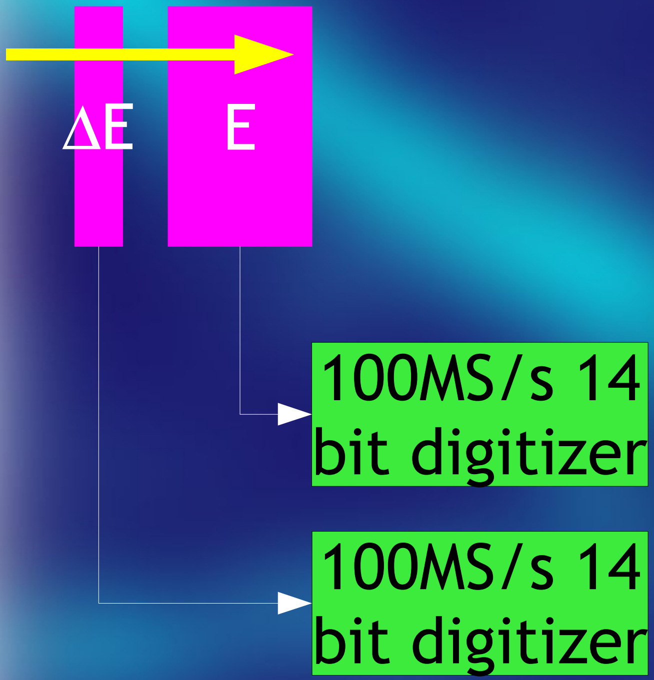
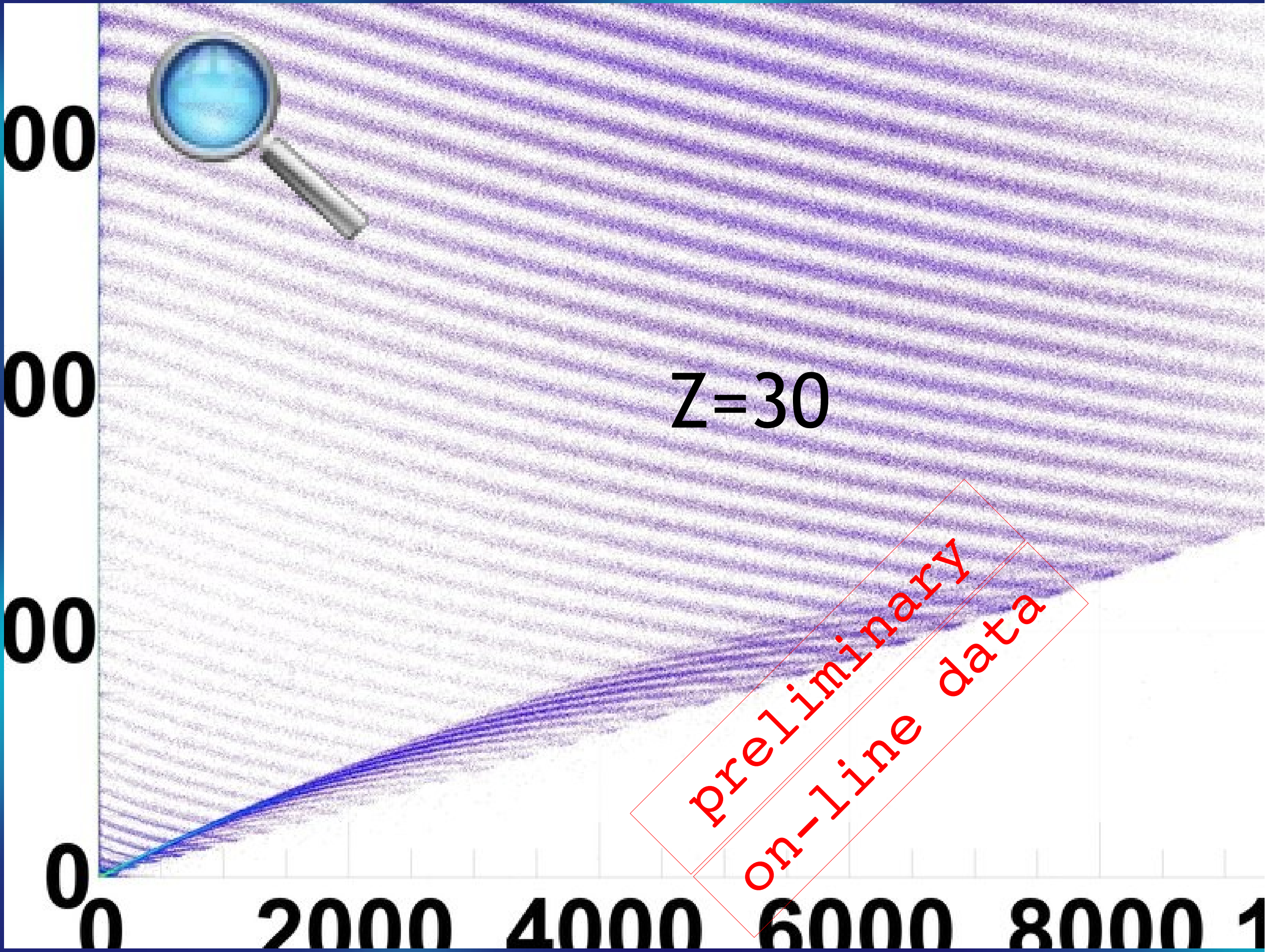
Full range

LNS Nov '09: DE-E

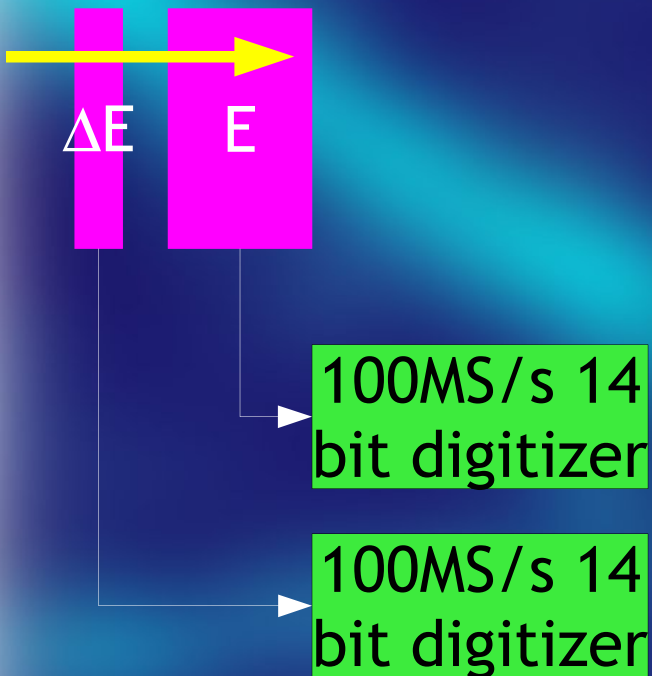


Let's “zoom” the image:

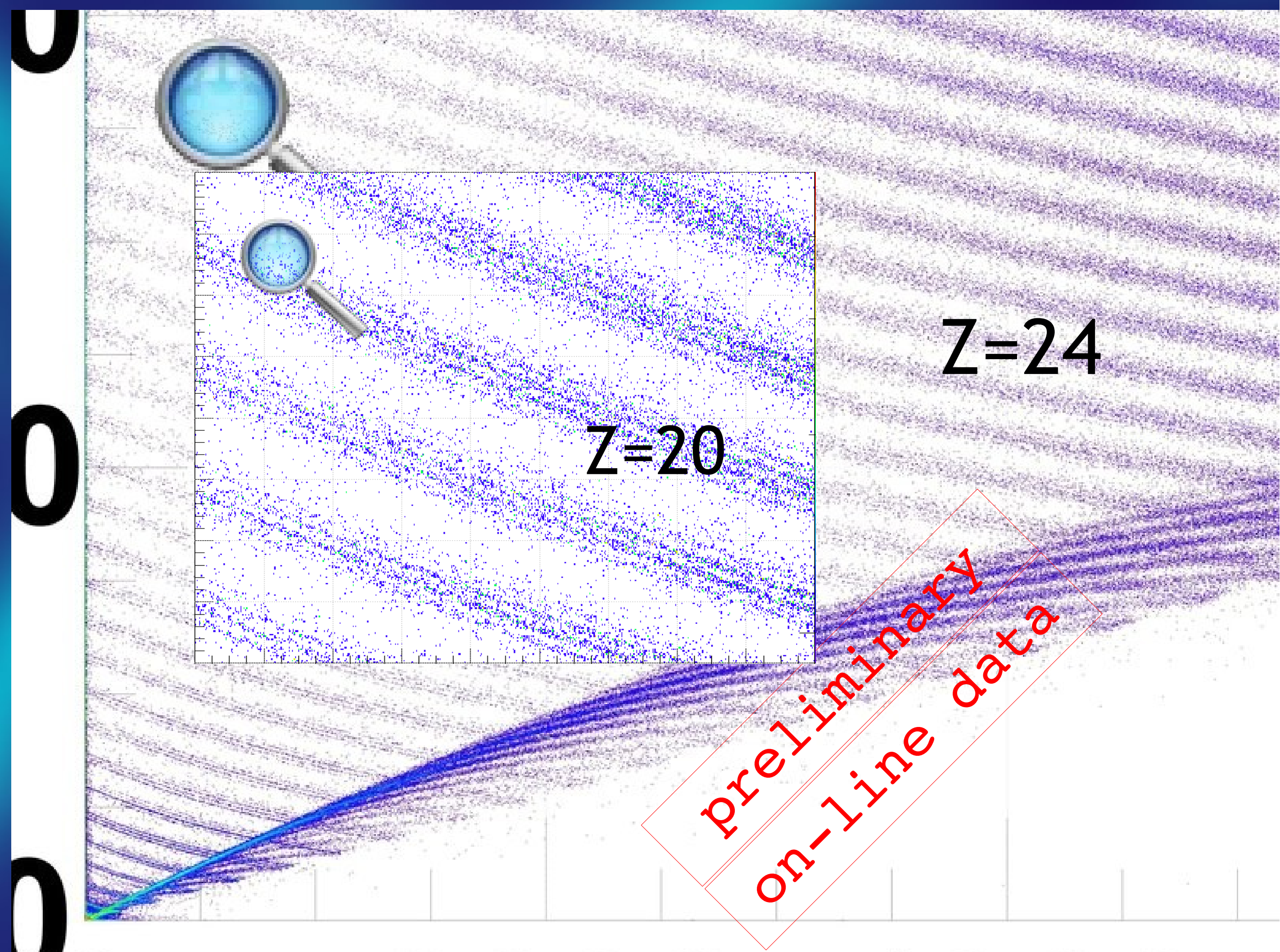


Used configuration:
Isotopic identification up to Z~25 with ~5GeV
Full range

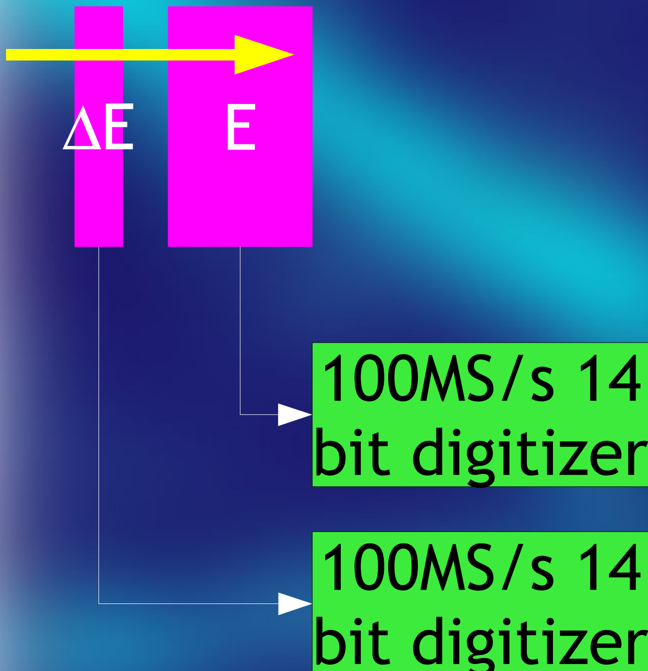
LNS Nov '09: DE-E



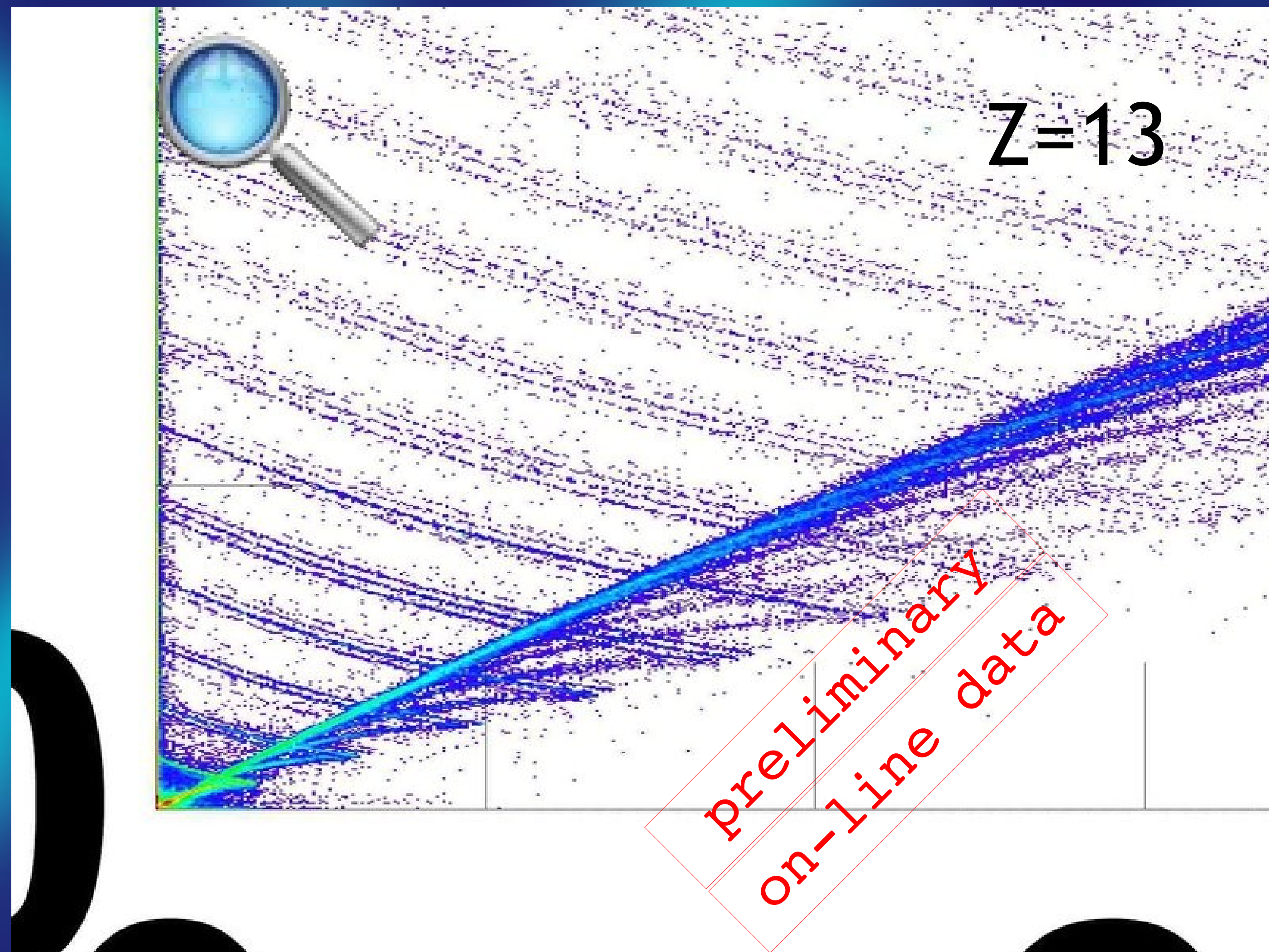
Let's “zoom” the image (2):



Used configuration:
Isotopic identification up to Z~25 with ~5GeV Full range

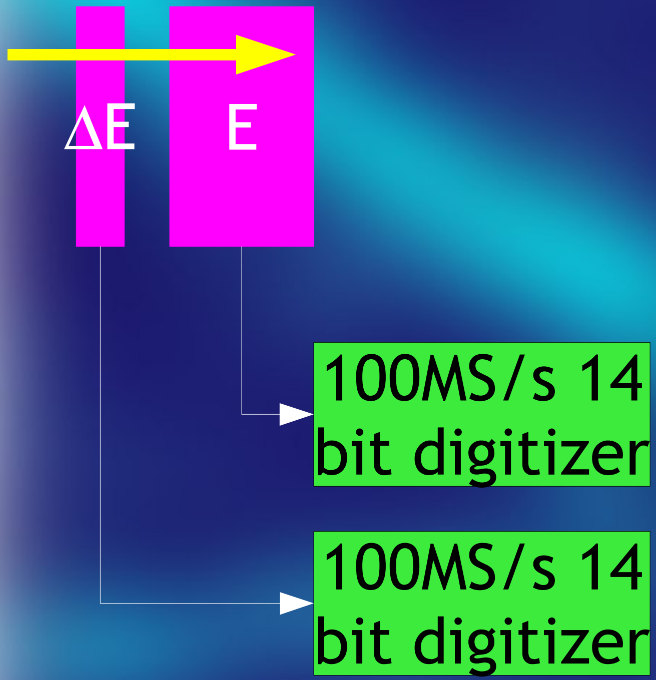


Let's “zoom” the image (3):

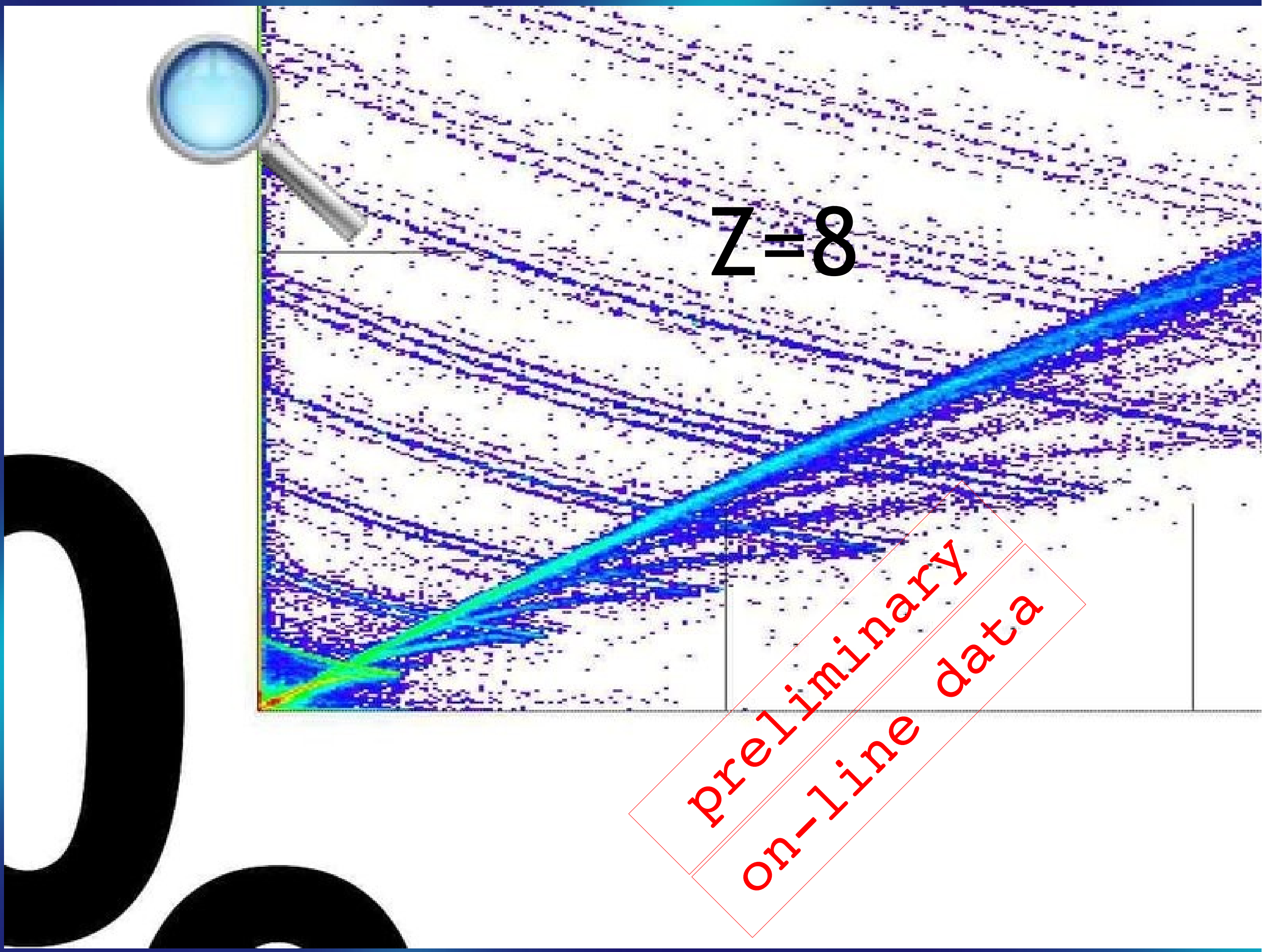


Used configuration:
Isotopic identification up to Z~25 with ~5GeV
Full range

LNS Nov '09: DE-E



Let's "zoom" the image (4):

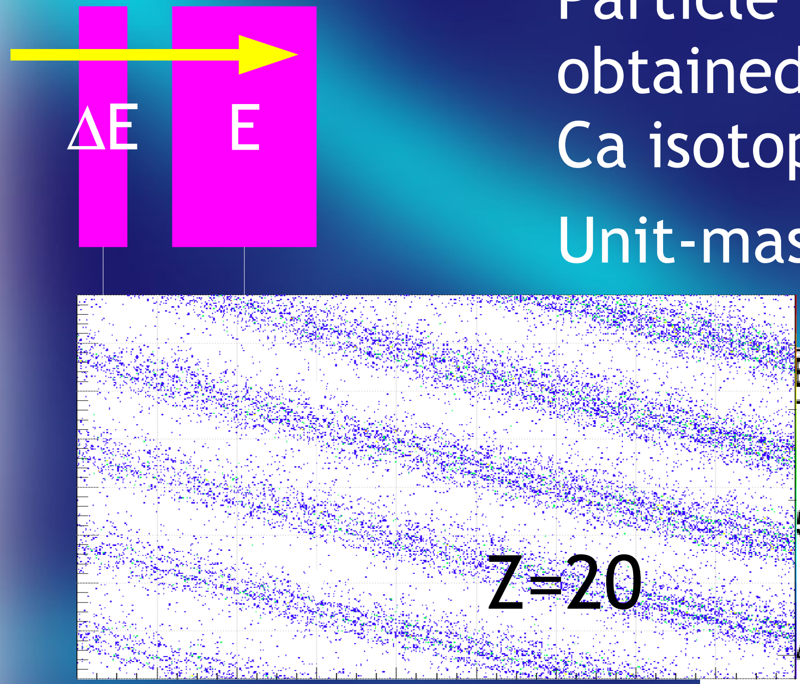


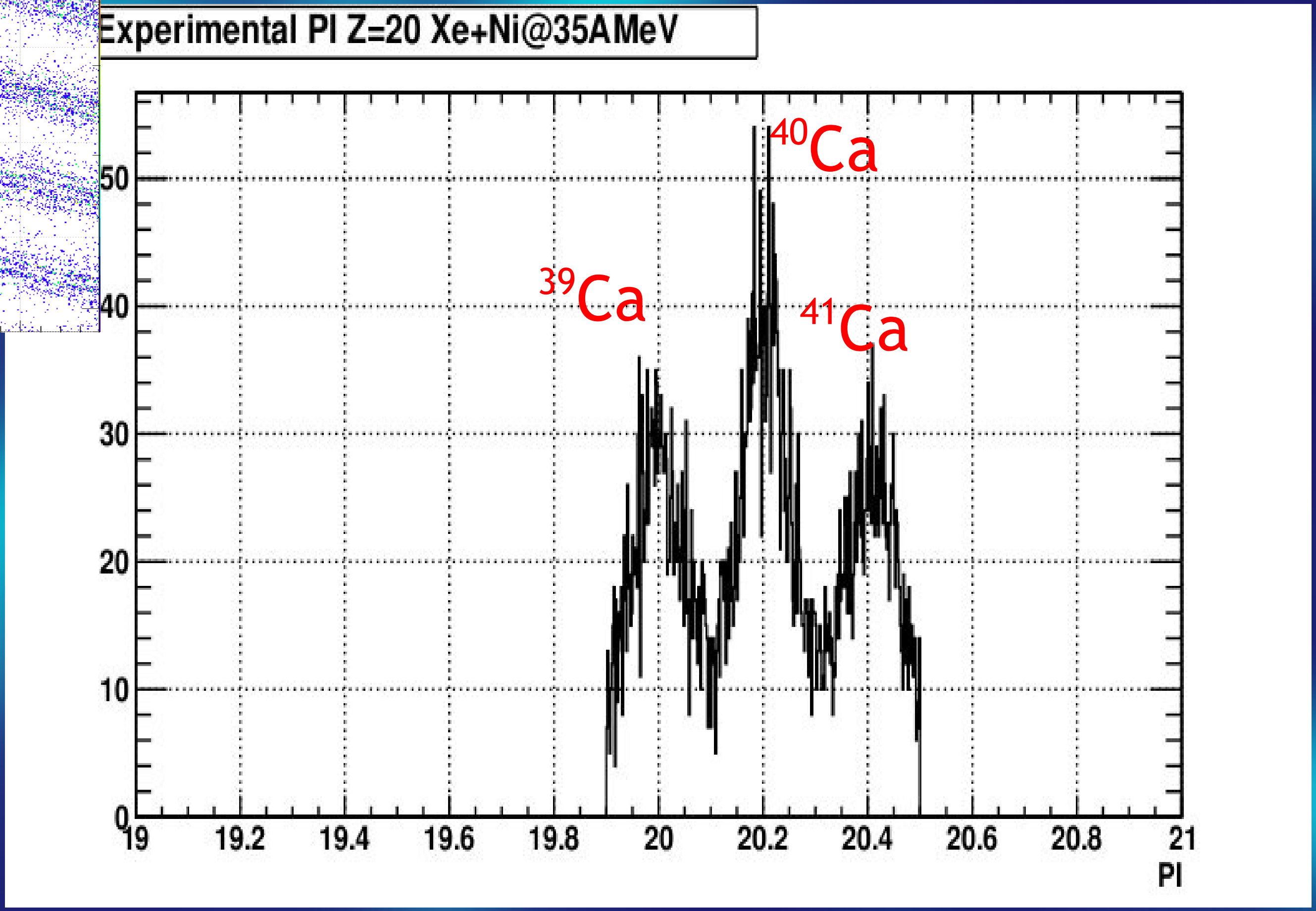
Used configuration:
Isotopic identification up to Z~25 with ~5GeV
Full range

LNS Nov '09: DE-E

Particle Identification (PID): experimental results obtained by linearizing the three higher intensity Ca isotopes – whole examined E_{res} range.

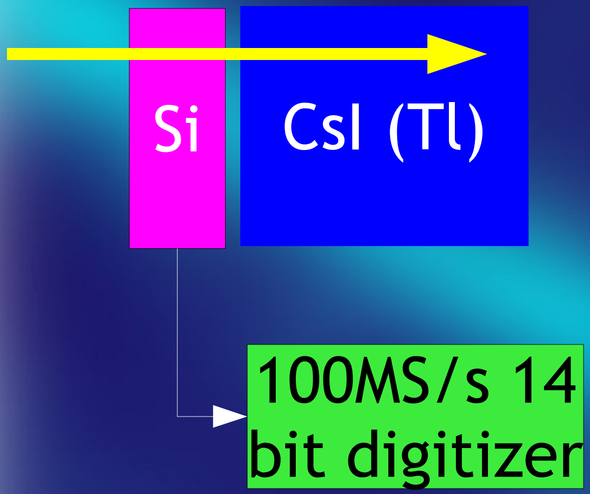
Unit-mass separation up to A>40 *(~50)* is observed



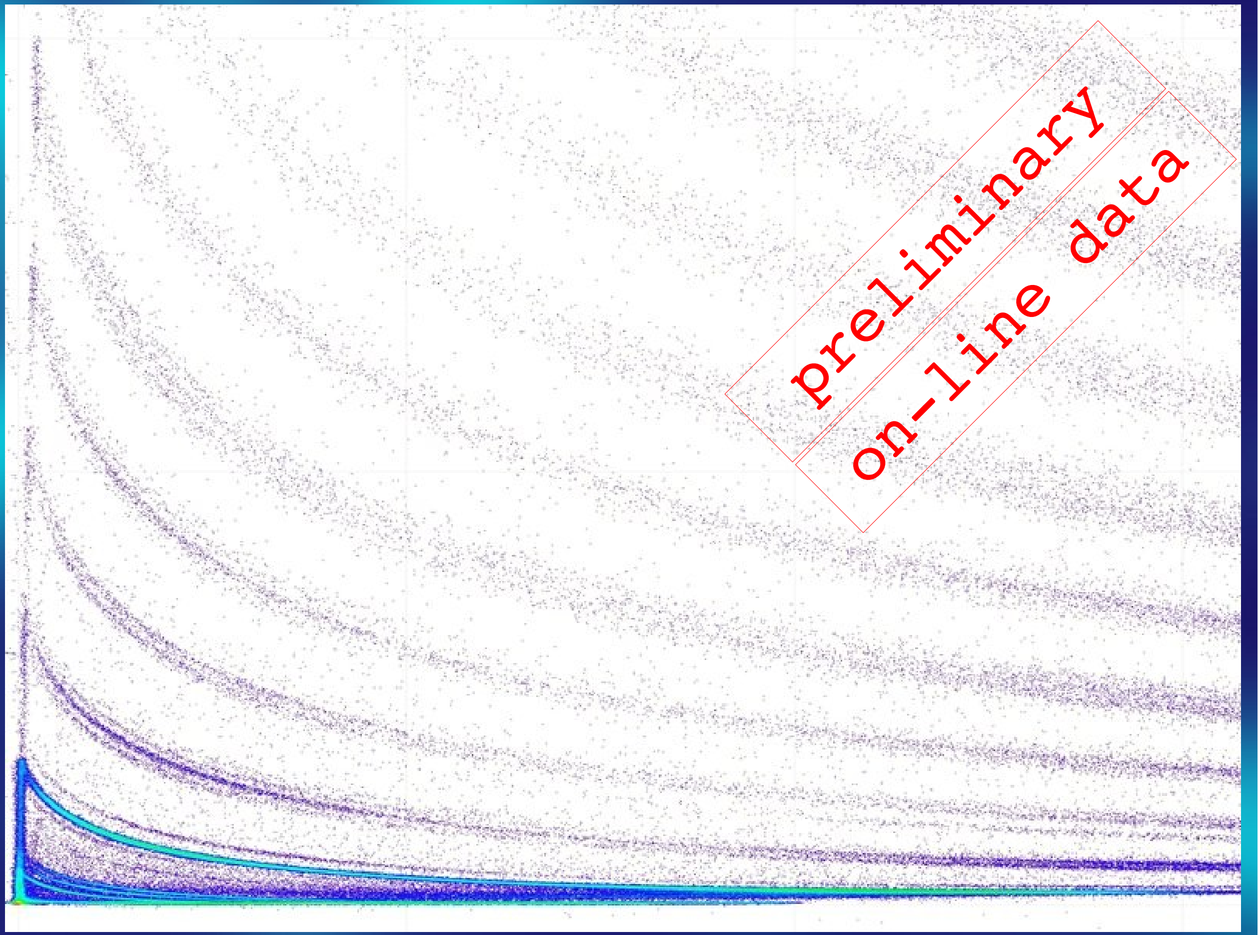


Used configuration:
Isotopic identification up to Z~25 with ~5GeV
Full range
Exp. PID: N.Le Neindre

LNS Nov '09: SCT



Single chip telescope: 1 readout channel for two detectors + digital signal processing



Ready for FAZIA phase II

Given the achieved identification performances in Phase 1 (R&D) ...

- FAZIA is starting its Phase 2:
  - Implementation of compact modules having 16 telescopes Si-Si-CsI with very low dead space
  - Complete digital signal processing
  - *Custom electronics operating under vacuum*
  - Build few-hundred telescopes (10-14 modules)
  - Couple them to existing 4π devices (INDRA, GARFIELD, CHIMERA, ...) and start selected Physics cases with FAZIA
- Support from EU (SPIRAL2-GANIL) + III CSN - LEA

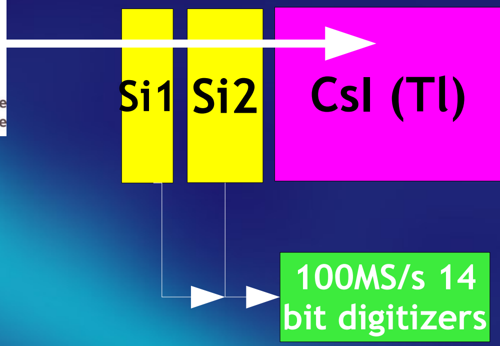
Ready for FAZIA phase II

- FAZIA is starting its Phase II
- Gli impegni maggiori:
  - Meccanica: principalmente INFN-Bologna e Napoli, LPC Caen
  - Elettronica: principalmente INFN-Napoli e IPN-Orsay
  - Silicon Detectors R&D: INFN-Firenze in stretto contatto con TOPSIL e FBK (Trento) – Convenzione FBK-INFN
  - CsI(Tl) R&D
  - Sviluppo algoritmi digitali
  - Silicon detector microbonding: fondamentale il supporto di E.Scarlini

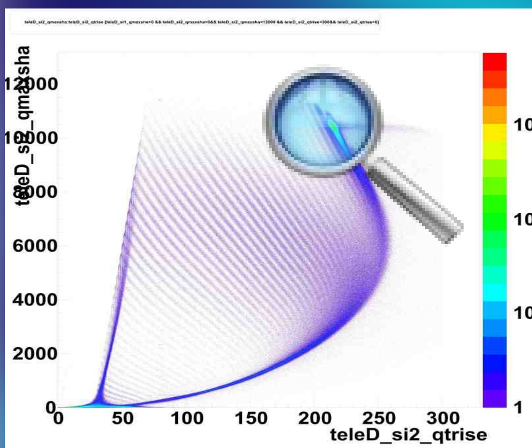
Ready for FAZIA phase II

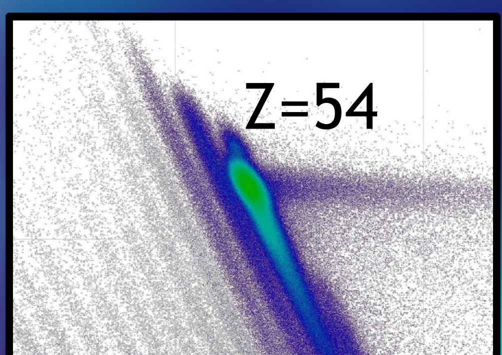
- **Ricercatori/tecnologi fiorentini impegnati (2010):**
  - L.Bardelli (art.23 EU-INFN), S.Barlini (Assegnista), M.Bini, G.Casini, A.Olmi, G.Pasquali, G.P., A.Stefanini + L.Carraresi per le misure al LABEC
  - S.Carboni (Dottorando)
  - S.Valdré, L.Salvestrini (tesi triennali completate)
  - E.Scarlini (I Gruppo)
- **Impegno strutture fiorentine**
  - Camera bianca per microbonding
  - Officina meccanica, principalmente per attrezzatura bonding (1-2 mese . uomo)
  - Servizio elettronica, al momento non coinvolto (INFN-Napoli + IPN Orsay)

FAZIA phase I



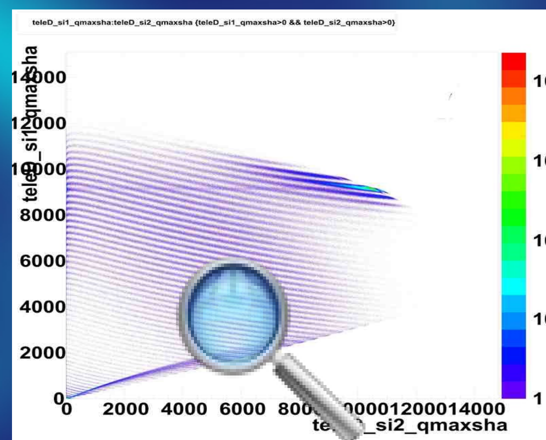
Si1: DIGITAL PSA

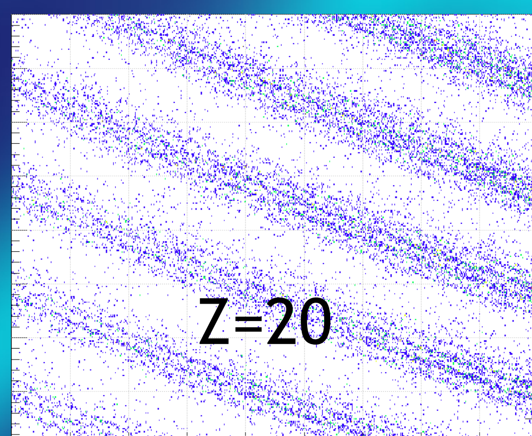




Unprecedented full Z discrimination of stopped particles. No apparent limit for Z up to Z=54. A separation observed for A~20.

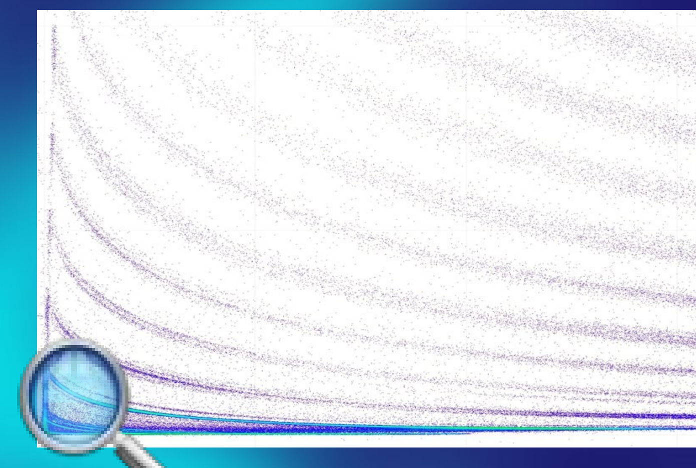
Si1-Si2: DE-E

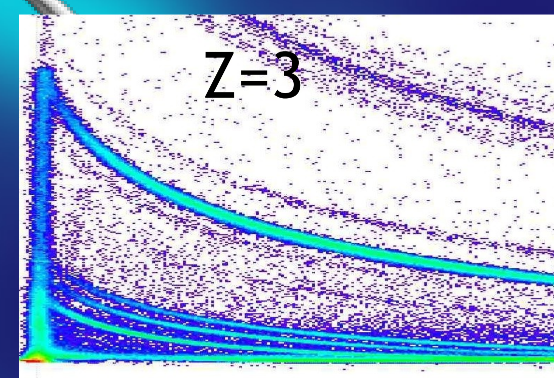




Basically straggling-limited DE-E discrimination (Z and A) is obtained. Mass discrimination up to about A=50

Si2: Single Chip Telescope





SCT solution: no needs for an additional light sensor. The second Silicon acts also as a photodiode, fully exploiting CsI(Tl) performances. Digital PSA is used to discriminate the ionization and fluorescence components

FINE

FINE

FAZIA project

The present status of the art for DE-E identification Si-Si (NIMROD-ISiS detector NIMA A 604 (2009) 578-583)