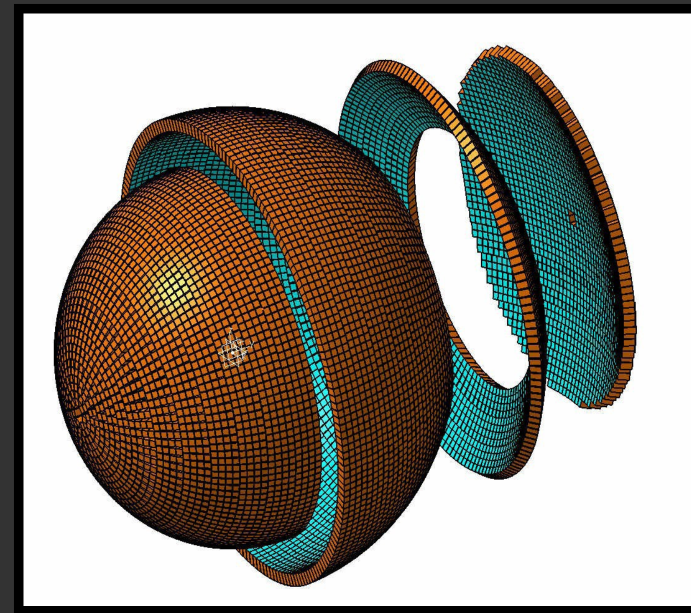
A case study in nuclear physics: the FAZIA project

Giacomo Poggi
(for the FAZIA Collaboration)

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, SPES and FAIR
The main partners are INFN and CNRS (~90 members)

The Organization:

Physics Coordinators R. Bougault, G.P.
Technical Coordinator P. Edelbruck

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

FAZIA project

Phase I (mainly performed within Spiral2 PP)

Check if possible to:

- *Lower the energy thresholds with Pulse Shape Analysis (PSA)*
- *Find the very limit of the PSA technique in terms of Z and A identification*
- *Identify and develop the digital electronics / digital signal processing needed*
- *Design of the final mechanics for vacuum operation of FEE*

Phase I is concluded with the signature of the MoU between INFN, CNRS, GANIL, COPIN and IFIN-HH. Now we are in:

Phase II

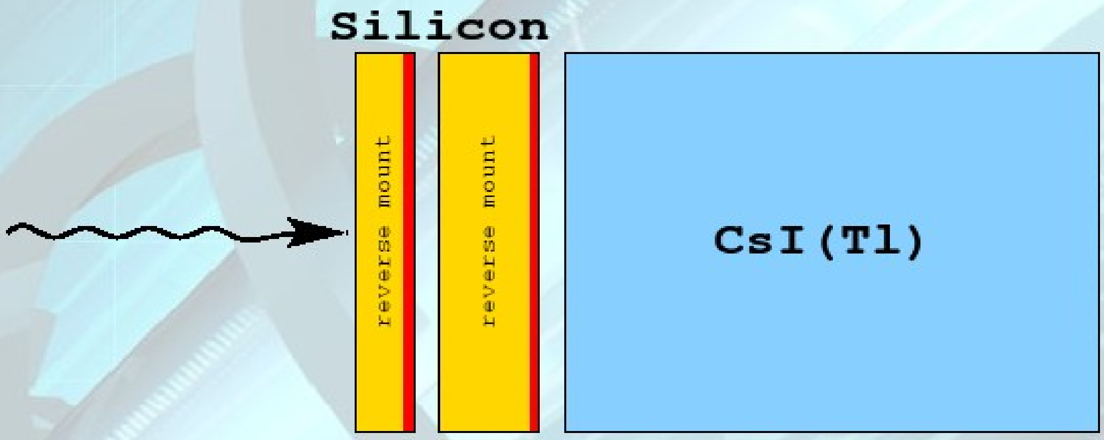
It is in order to convince the Agencies to fund the project.

The most efficient way is to

- *Build the Demonstrator (just started)*
  - *--See the contributions from A.Boiano and G.Tortone to this meeting about the FEE electronics*

FAZIA project: the basic element

Two NTD silicon and one CsI(Tl) detectors:



Characteristics: *(other solutions are also being investigated. . .)*

First Si (ΔE) NTD, 300 μm thickness, reverse mount

Second Si (E) NTD, 500/700 μm thickness, reverse mount

CsI(Tl) Few cm thick, depending on beam energy

Area Current prototypes: 20×20 mm^2

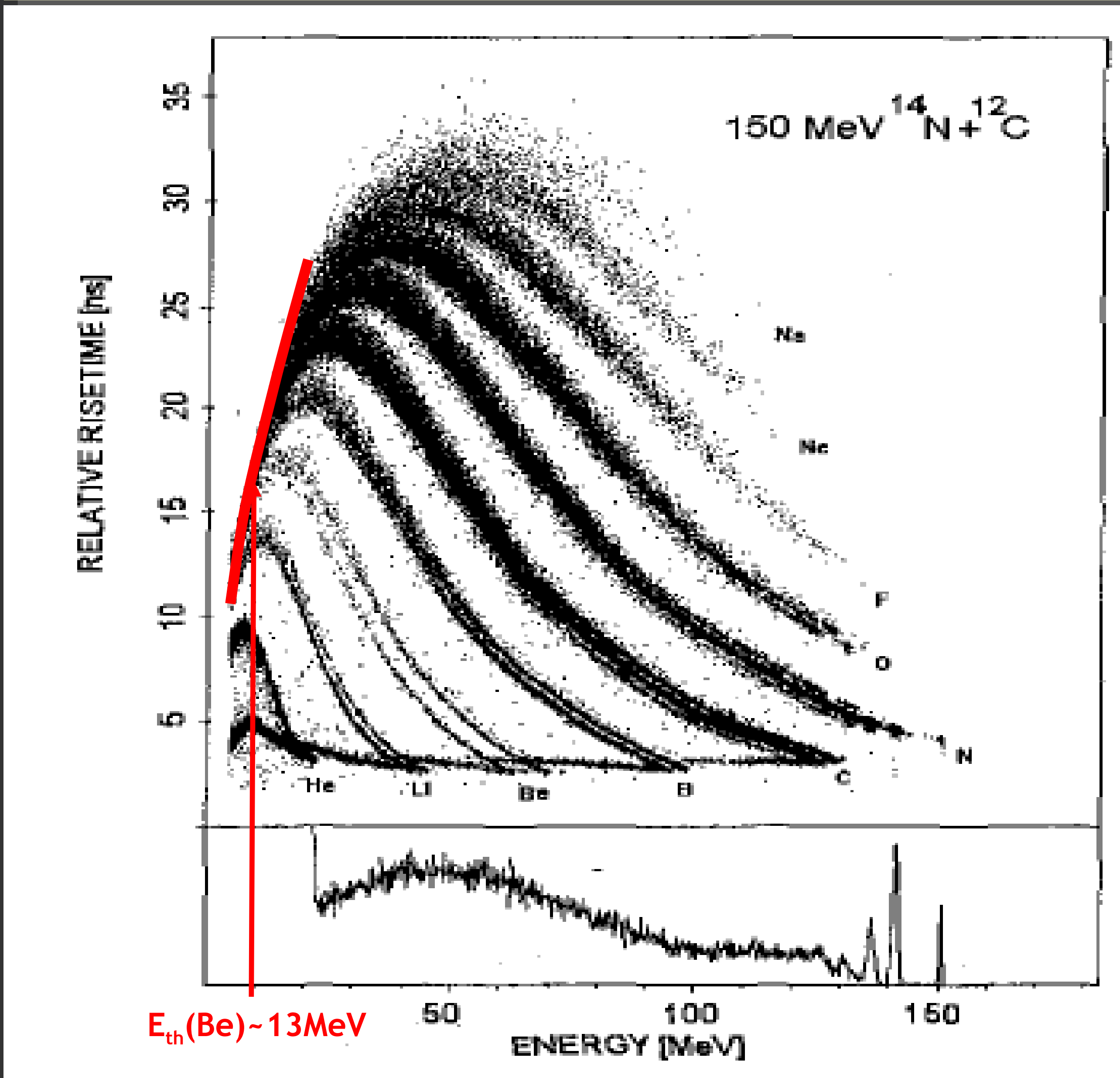
The basic detection block: Si-Si-CsI(Tl) triple telescope, with original and innovative solutions:

- **Digital Pulse Shape Analysis (PSA) for A and Z discrimination of particles stopped in the first Silicon**
- **Second Silicon acting *also* as a photodiode *(at backward angles)***
- **Fully digital implementation**

FAZIA project: the basic element

Pulse Shape Analysis in Silicon (the experts are kindly asked to forgive me):
The time dependence ("shape") of the charge or current signal associated to particles of the same energy stopped in the Silicon <u>does depend</u> on their atomic and mass numbers, because of the different ionization profile along the track. Signal formation (Ramo's theorem) is different and preserves the signature of the stopped particle. Pioneer work on the right side, by Mutterer et al. For a reverse-mounted Silicon detector.
Energy vs rise-time (charge)

Mutterer et al IEEE TNS 47 (2000) 756



Phase I of the FAZIA project

Phase I: known issues, potential problems and needed solutions

- *~10^4 dynamic range of energies (from MeV up to a few GeV)*
- *Good electronic energy resolution (a few tens of keV for a-particles at 5.5 MeV to be on the safe side)*
- *Ideally, sub-ns timing for PSA and ToF*

Therefore R&D was needed for the electronics / digital signal processing side:

- *Full digital implementation expected to*
  - *guarantee the necessary flexibility for PSA, but new algorithms must be implemented in order to exploit that flexibility*
  - *provide a significant "bit gain" and dynamic range improvement, but how much?*

Digital timing techniques were promising, but how much do we loose (or gain) with respect to analogue techniques?

Even more important, addressing the issues of the detector (Si) side:

- *Known irreproducibility in the published PSA results, but why?*
- *Importance of Silicon doping uniformity, but how uniform is to be the Silicon material?*
- *An irreducible limit to PSA and DE-E due to straggling must exist, but what is this limit?*

Phase I of the FAZIA project

Hardware development:

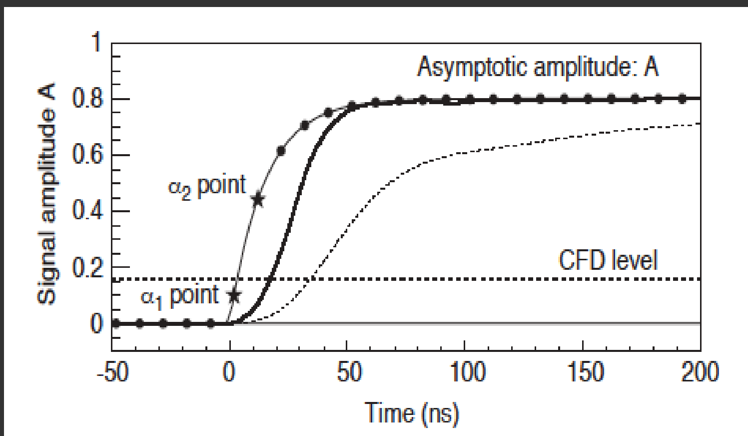
- *Preamplifiers (charge and current) have been built by IPNO-Orsay (**H.Hamrita et al: NIMA A531 (2004) 607**)*
- *FEE digital electronics has been built by IPNO-Orsay, also exploiting the expertise gained by INFN-Florence within Fiasco and Garfield Collaboration (L.Bardelli et al: NIMA 491 (2002) 244 and G.Pasquali et al : NIMA 570 (2007) 126)*
- *Basically the FEE of Phase I consists of custom built 100MSample/s, 14bit digitizers (IPNO-Orsay)*

Digital Signal processing characterization and pulse shape study:

- *Quantitative study of digital timing, as a function of preamplifier and digitizer characteristics (L.Bardelli et al, NIMA 521 (2004) 480)*
- *Quantitative study of the effect of digital signal processing on resolutions, dynamic ranges and "bit-gain" (Two companion papers of L.Bardelli and G.P, NIMA 560 (2006) 517 and NIMA 560 (2006) 534)*
- *Digital Pulse Shape algorithms have been developed (S.Barlini et al NIMA 600 (2009) 644) and others are under way (see the very end of this talk)*
- *Studies on the pulse shape formation (L.Bardelli – unpublished; M.Parlog et al, NIM A 613 (2010) 290; H.Hamrita et al, NIM A 642 (2011) 59)*

Digital Signal Processing - I

• *Quantitative study of digital timing, as a function of preamplifier and digitizer characteristics* *(L.Bardelli et al, NIMA 521 (2004) 480)*

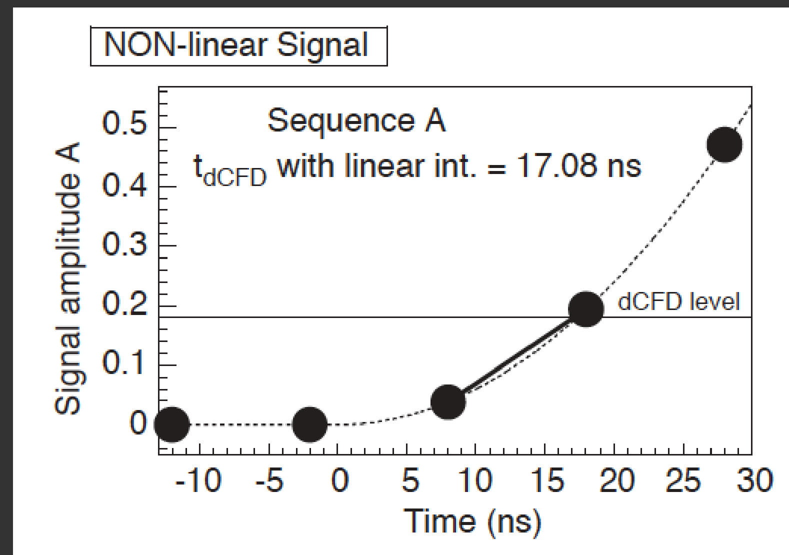


The implementation of Digital timing basically consists of making an interpolation between two samples

$$\sigma_{\mathrm{dCFD}} \leqslant \sigma_{\mathrm{e+q}} \left[\left| \frac{\mathrm{d}S}{\mathrm{d}t} \right|_{t_{\mathrm{dCFD}}} \right]^{-1}$$

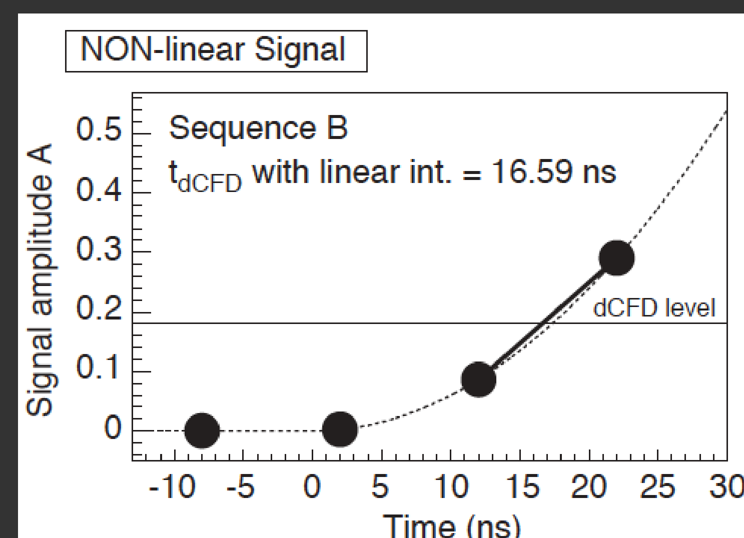
$$\sigma^2_{\mathrm{e+q}} = \sigma^2_{\mathrm{e}} + \frac{1}{12 \times 4^{\mathrm{ENOB}}}$$

In order to evaluate the timing uncertainty, the additional error from quantization is to be considered



Linear interpolation critically depends on the phase of the sampling clock with respect to the signal

Higher order interpolation solves the problem. Cubic interpolation is a quite good solution



Digital Signal Processing - I

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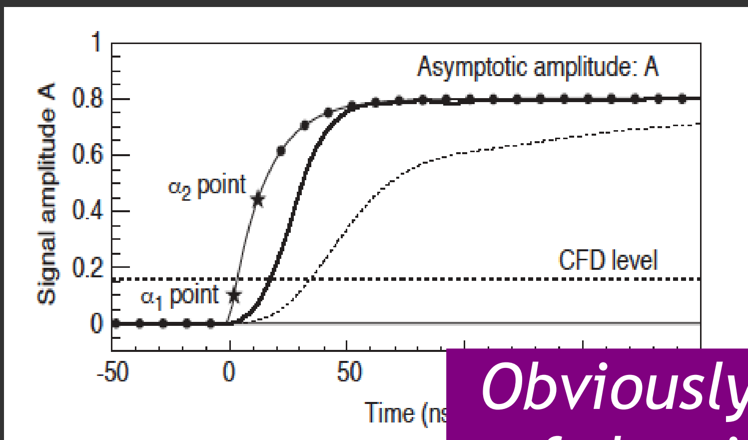

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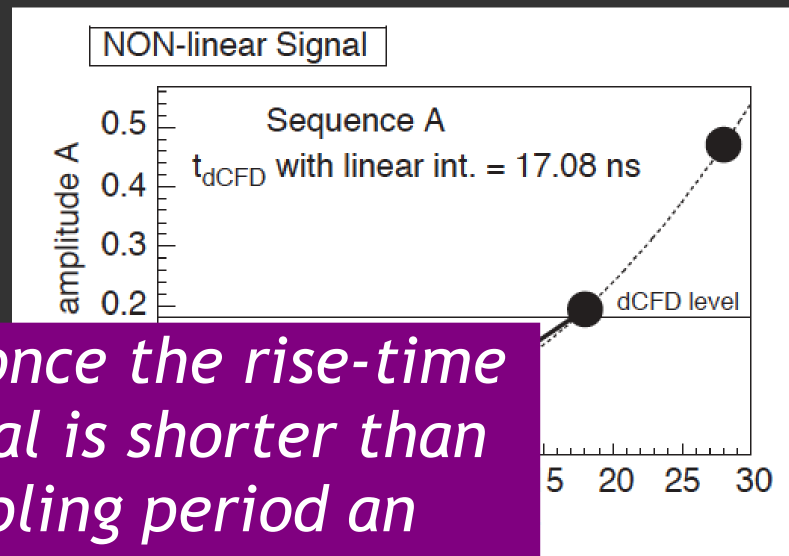

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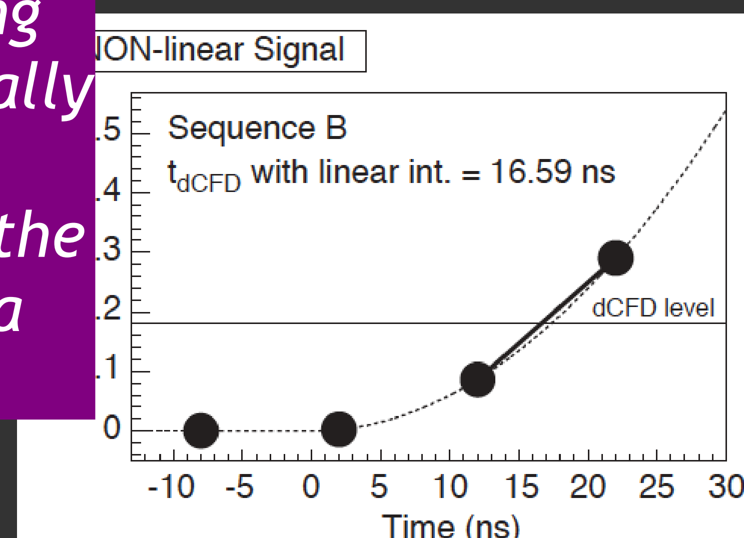


Obviously, once the rise-time of the signal is shorter than the sampling period an uncertainty of the sampling period itself is present: usually the presence of the antialiasing filter prevents the system to face with such a condition

Digital Signal Processing - I

•*Quantitative study of digital timing, as a function of preamplifier and digitizer characteristics* *(L.Bardelli et al, NIMA 521 (2004) 480)*

The effect on timing is studied, as a function of the ADC parameters: effective number of bits (enob) and sampling rates. The figure shows that a trade-off exists between enob and sampling rate, the second one often determining the quality of the result. Cubic interpolation has been demonstrated to perform better than any other approach. It is better than sync (how about Nyquist?)

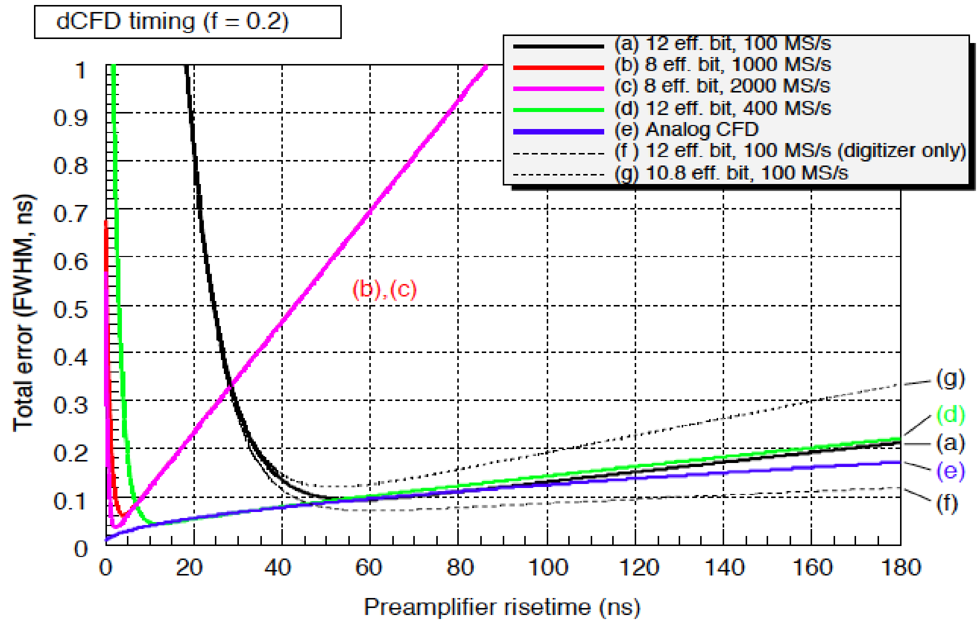


Fig. 4. Total error on digital Constant Fraction timing ($f = 0.2$) performed by various digital sampling systems (continuous lines labeled from a through d). Data corresponding to a standard analog CFD signal treatment are also shown (continuous line e). For one of the digitizers (100 MSample/s-12 bit) the contribution due to digitization only is separately presented (dashed line f). The dotted curve g refers to the digitizer used in our tests. The simulation has been performed using realistic signals of half full range amplitude ($A = 0.5$).

With signal rise-time of the order of 40 ns, 10.8 enob, 100MSample/s ADC dCFD with cubic interpolation provides a time resolution as good as ideal, analogue CFD.
The figure show how the resolution changes with signal and ADC parameters. Results are obtained by realistic simulations.

Digital Signal Processing - I

•*Quantitative study of digital timing, as a function of preamplifier and digitizer characteristics* *(L.Bardelli et al, NIMA 521 (2004) 480)*

Walk of the dCFD is studied and quite good figure have been obtained, e.g. > 125 ps for a dynamic range of 250

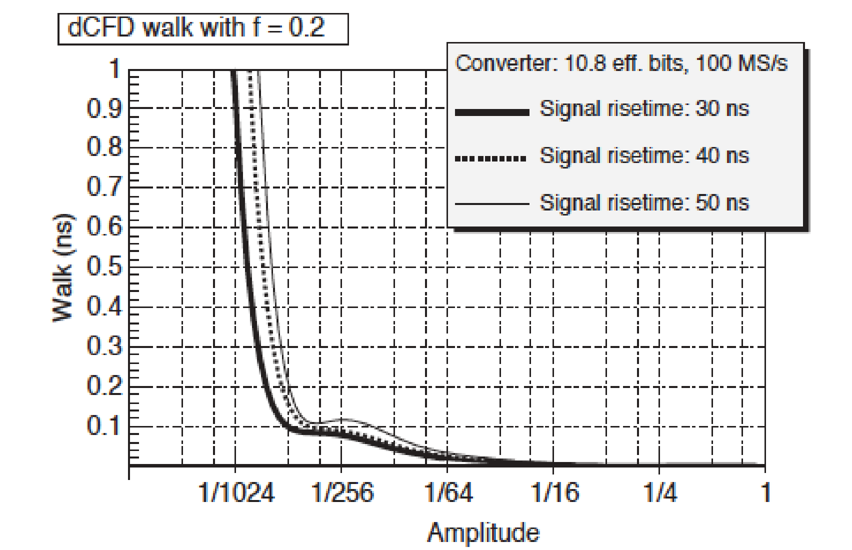


Fig. 5. dCFD walk for a 100 MSample/s, 10.8 eff. bits converter and fraction $f = 0.2$ as a function of signal amplitude A. Note the logarithmic horizontal axis. The three curves correspond to different risetimes (10–90%) of the input signal. For this converter the signal risetime value $t_r = 50$ ns corresponds roughly to the minimum of curve g in Fig. 3.

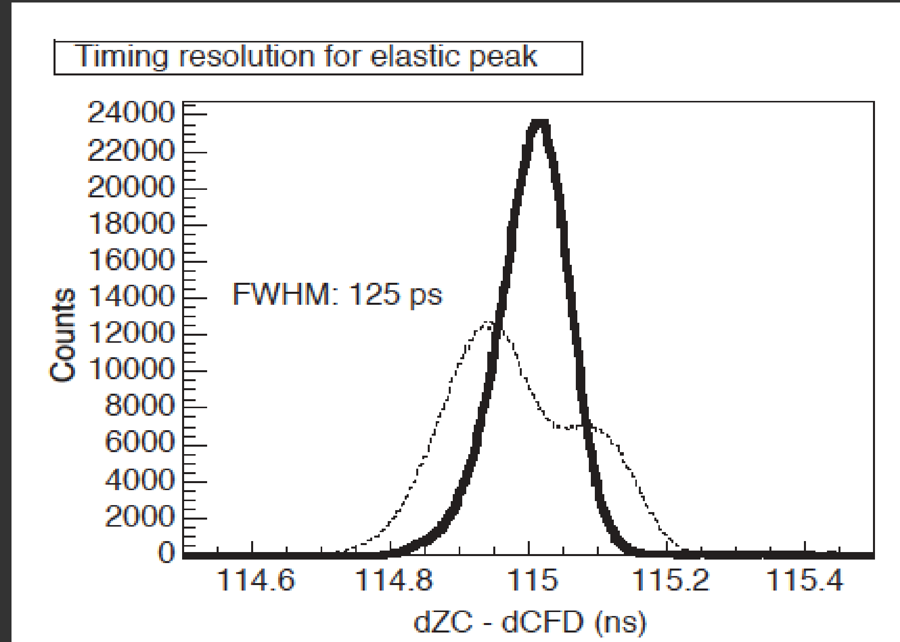


Fig. 8. Full line: dZC-dCFD time spectrum (see text) for the elastic peak as obtained with the digital sampling system as in Fig. 7 and cubic interpolation. Dashed line: the same quantity obtained using linear interpolation: note the strongly non-Gaussian shape of the peak and the worse resolution.

The most important point: experimental results confirm the calculation: 125 FWHW is obtained for a 50ns rise-time, 250MeV of ^{16}O, using a cubic interpolated dCFD implemented with a 100MSample/s, 10.8 enob ADC.

Digital Signal Processing - I

•*Quantitative study of digital timing, as a function of preamplifier and digitizer characteristics* *(L.Bardelli et al, NIMA 521 (2004) 480)*

Obviously, digital treatment of the data cannot remove the intrinsic 1/Amplitude behavior of the resolution. *<u>Moreover, true-life conditions very often introduce other sources of resolution deterioration,</u>* *as we will see later, when addressing the detector characteristics.*
An example of an overall time resolution obtained in the "early days" (pre-FAZIA) of DPSA analysis is shown in the figure.

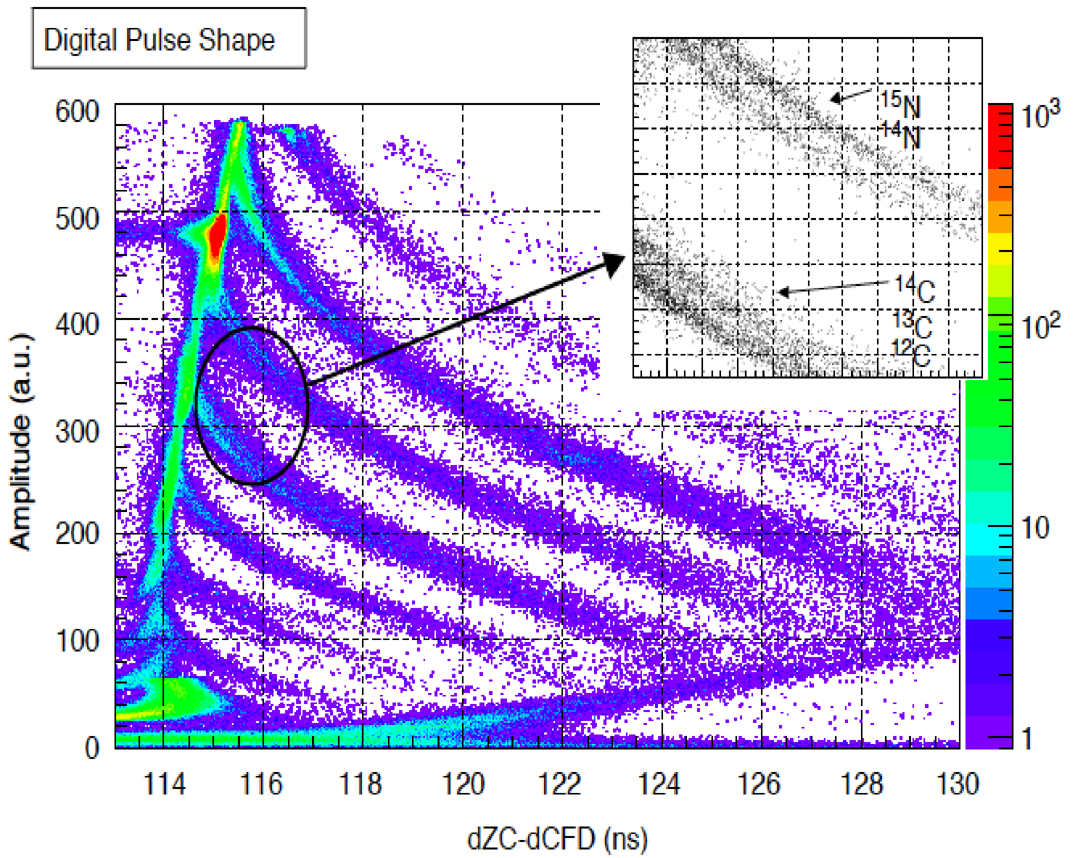
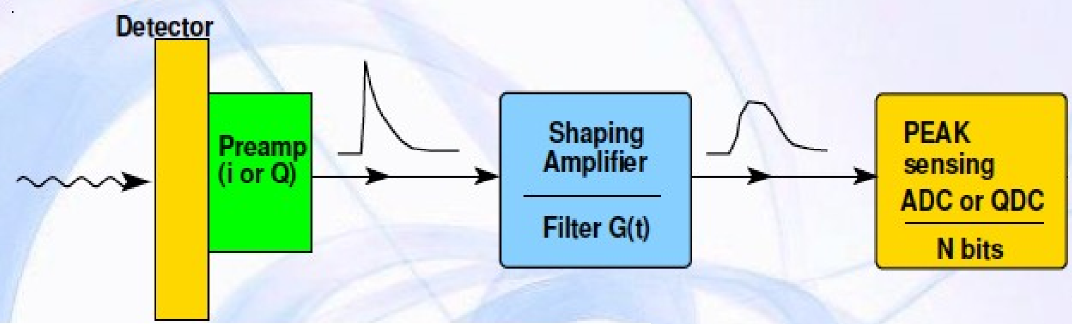


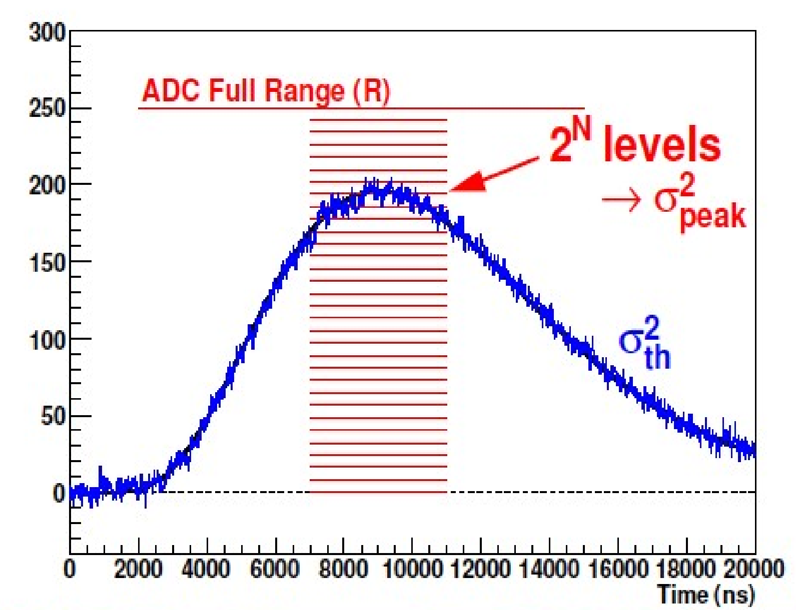
Fig. 9. Digitally determined Amplitude vs. dZC-dCFD time correlation: charge identification is apparent. In the inset: detail of the isotope separation of carbon and nitrogen. Data have been obtained with the electronic chain of Fig. 7.

Digital Signal Processing - II

Quantitative study of the effect of digital signal processing on resolutions, dynamic ranges and "bit-gain" *(Two companion papers of L.Bardelli and G.P., NIMA 560 (2006) 517 and NIMA 560 (2006) 534)*

A typical analogue system, ending with a single value sensing ADC. In order to exploit the maximum theoretical resolution available in the continuum (either limited by electronics or by detector Physics) an infinite number of bits would be required (obvious).





$$\sigma^2_{exp} = \sigma^2_{th} + \sigma^2_{peak}$$

$$\sigma^2_{peak} = \frac{R^2}{12}\frac{1}{4^N}$$ Quantization error

PEAK-sense contribution to the resolution, *assuming otherwise perfect ADC*:

$$\frac{\sigma^2_{exp}}{\sigma^2_{th}} = 1 + \frac{9}{12}\cdot\left(\frac{R}{3\sigma_{th}}\right)^2\frac{1}{4^N}$$

INDRA Silicon: R=5 GeV, N=16: $\sigma_{peak} \rightarrow$ 60 keV FWHM

Digital Signal Processing - II

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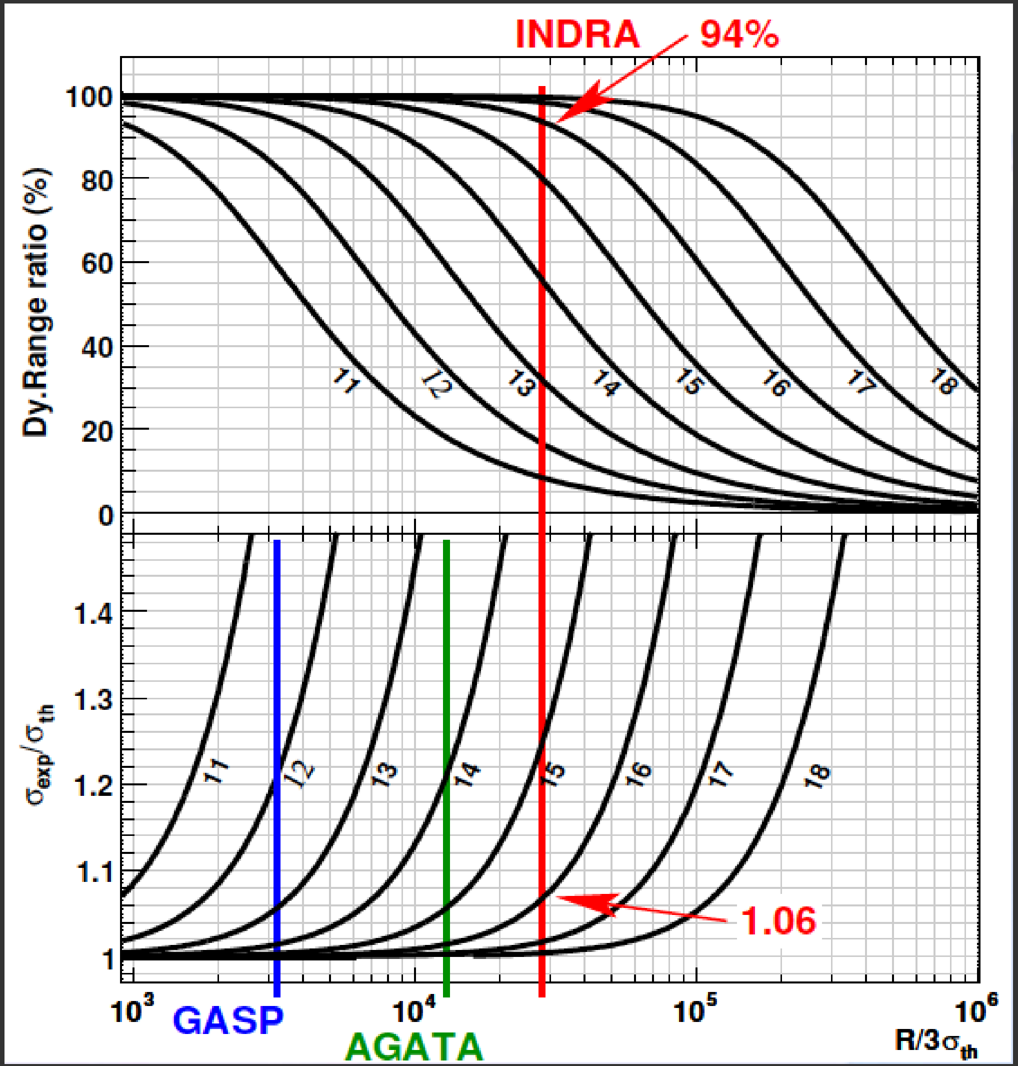
The theoretical Dynamic range for the quantity of interest (e.g. energy) can be defined as the ratio between the range R to be covered and 3 times the theoretical standard deviation at low measured values - minimum measurable value over the noise (infinite numerical resolution):

$$DyR_{th} = R/(3\cdot\sigma_{th})$$

Because of the quantization error the experimentally available Dynamic range is decreased:

$$DyR_{exp} = DyR_{th}\cdot\sigma_{th}/\sigma_{exp}$$

by a factor depending of the number of bits of the single value sensing ADC. The larger N, the smaller the decrease. In order to take into account the ADC noise, N is the ENOB.
In practice a <u>two-gain approach is normally used to get the needed effective number of bits</u> over the used range R. Typical value N=16 for a DyR higher than 10^4



Digital Signal Processing - II

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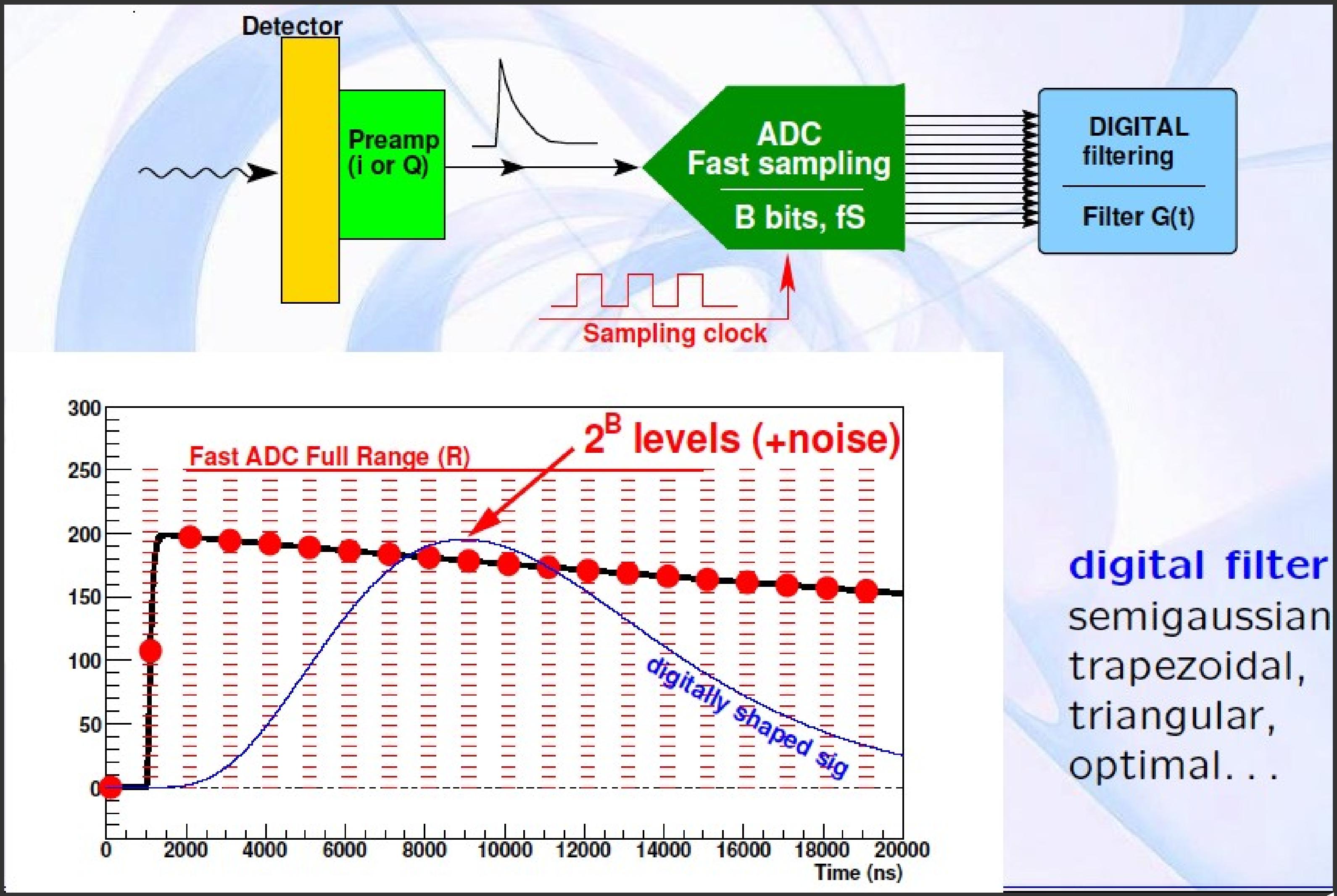
A not-so-naïf question arises:
How do energy measurements performed by digital processing of the preamplifier output using a B-bit, f_s sampling rate ADC compare with the standard analogue shaping and single value N-bit ADC detection?

- *What do we gain or loose using the digital approach?*



Digital Signal Processing - II

Quantitative study of the effect of digital signal processing on resolutions, dynamic ranges and "bit-gain" *(Two companion papers of L.Bardelli and G.P., NIMA 560 (2006) 517 and NIMA 560 (2006) 534)*

Sampling frequency "f_S" Limits the bandwidth of the system

Number of bits "B" quantization level

Effective number of bits "ENOB" Real ADCs have thermal noise,. . .
ENOB gives the ADC noise performances in terms of an equivalent "ideal" ADC:

$$\sigma^2_{\mathrm{ADC}} = (quantization) + (thermal\ noise, \ldots) = \frac{R^2}{12}\left[\frac{1}{4^{\mathrm{B}}} + \sigma^2_{noise}\right] = \frac{\mathbf{R^2}}{\mathbf{12}} \cdot \frac{\mathbf{1}}{\mathbf{4^{ENOB}}}$$

Taking into account the ADC characteristics (sampling rate, noise as described by the effective number of bits ENOB), the electronic noise of the preamplifier output and the applied digital filter G, one gets an expression for the final resolution.

- "Theoretical" shaped output resolution due to detec.+preamp. *(the same as analogue-shaped output)*:

$$\sigma^2_{\mathrm{th}} = b \cdot k_G^2 + A$$

where b is the preamp's white-noise component and:

$$\text{Delta-Noise Index} = (k_G)^2 = \frac{1}{2}\int_{-\infty}^{T_{\mathrm{M}}} [G(T_{\mathrm{M}} - t)]^2\, \mathrm{d}t \qquad T_{\mathrm{M}} = \text{measuring time}$$

- the white digitizer noise is added and one obtains:

$$\sigma^2_{\mathrm{exp}} = (b + b_{\mathrm{ADC}}) \cdot k_G^2 + A$$

Digital Signal Processing - II

Quantitative study of the effect of digital signal processing on resolutions, dynamic ranges and "bit-gain" *(Two companion papers of L.Bardelli and G.P., NIMA 560 (2006) 517 and NIMA 560 (2006) 534)*

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$$\sigma^2_{\mathrm{ADC}} = (quantization) + (thermal\ noise, \ldots)$$
$$= \frac{R^2}{12}\left[\frac{1}{4^{\mathrm{B}}} + \sigma^2_{noise}\right]$$
$$\boldsymbol{R^2} \quad 1$$

Taking int
the ADC
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output an
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amp.

time

$$\sigma^2_{\mathrm{exp}} = (b + b_{\mathrm{ADC}}) \cdot k^2_G + A$$

b_{ADC} is well described as a white noise

$$\sigma^2_{ADC} = b_{ADC} \cdot f_S/2$$

if a proper antialiasing is present the integral over the BW correspond to multiplication of the spectral density by the Nyquist frequency = $f_S/2$

Digital Signal Processing - II

Quantitative study of the effect of digital signal processing on resolutions, dynamic ranges and "bit-gain" *(Two companion papers of L.Bardelli and G.P., NIMA 560 (2006) 517 and NIMA 560 (2006) 534)*

The final expression for the experimental resolution can be put in a form which permits to directly compare the "digital" result with the "standard" or "analogue" counterpart.

These results have been extended to consider the problem of the baseline stability and clock jitter

$$\frac{\sigma^2_{\mathrm{exp}}}{\sigma^2_{\mathrm{th}}} = 1 + \frac{9}{12}\left(\frac{R}{3\sigma_{\mathrm{th}}}\right)^2 \cdot \frac{1}{4^{\mathrm{PSENOB}}}$$

$$\mathrm{PSENOB} = \mathrm{ENOB} + \frac{1}{2}\log_2\left(\frac{f_S}{k_G^2}\right) - \frac{1}{2}$$

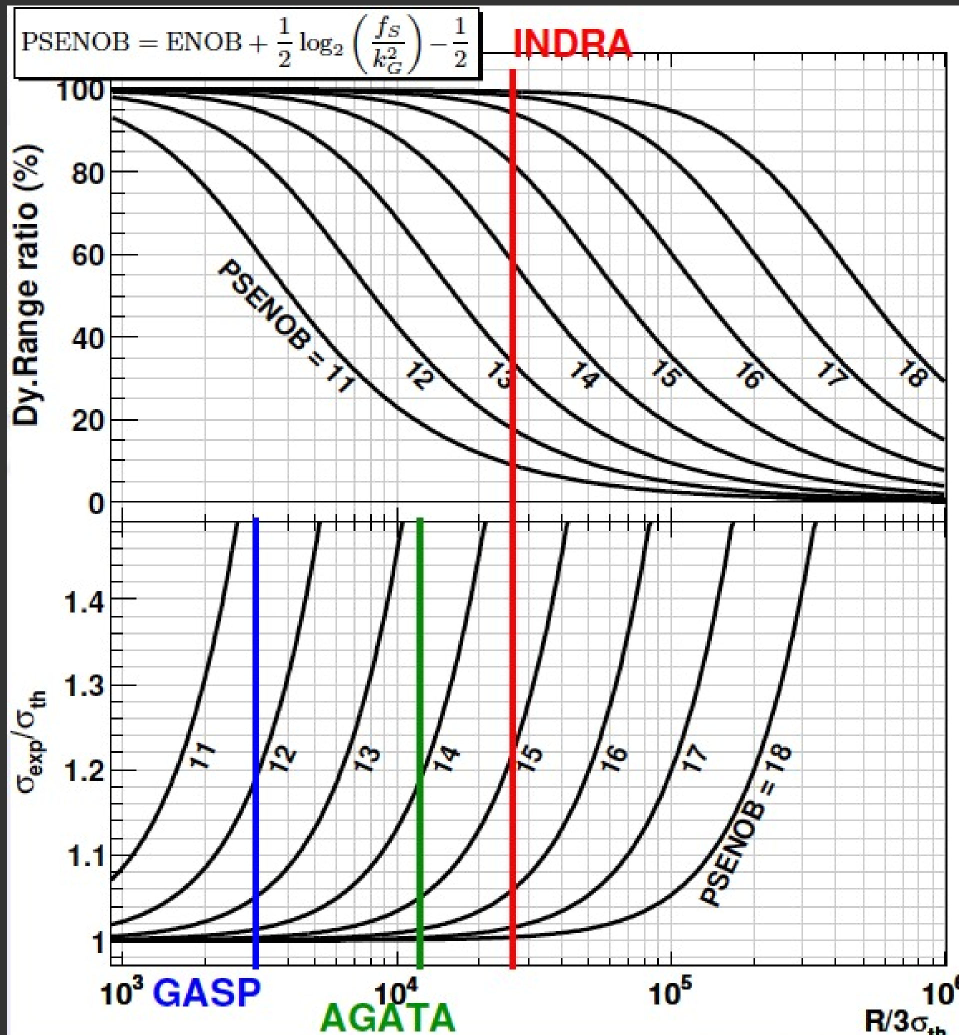
Peak-**S**ensing-**E**quivalent **N**umber **o**f **B**its

- depends on ADC ENOB *(as expected, the higher the better)*
- depends logarithmically on f_S *(as expected, the higher the better)*
- depends on the used filter G by means of k_G *(not so obvious)*. In typical high-resolution applications, the filter G is tuned so that $k_G^2 \sim 1/\tau_C$, with $\tau_C \sim 2 \div 7\mu$s (the detector noise corner time)
- *the quantity f_S/k_G^2 measures the effective number of points used by the filter to shape the signal*
- *a fast sampling ADC performs the same as a Peak-sensing ADC with PSENOB bits*

Digital Signal Processing - II

Quantitative study of the effect of digital signal processing on resolutions, dynamic ranges and "bit-gain" *(Two companion papers of L.Bardelli and G.P., NIMA 560 (2006) 517 and NIMA 560 (2006) 534)*

The Table shows the PSENOB that one can get for various ADC parameters and a given noise corner time τ_c
Basing on these results we designed a single gain FEE of FAZIA covering the full range of 5 GeV preserving the energy resolution basically determined by the irreducible energy resolution due to detector and straggling
(see next part of the talk -timing deserves a different discussion)



Numerical examples:

ENOB	B	f_S (MS/s)	PSENOB
12.0	14	100	16.2
10.0	12	400	15.3
10.8	12	100	15.0
10.0	12	200	14.7
7.0	8	2000	13.4
12.0	14	400	17.2

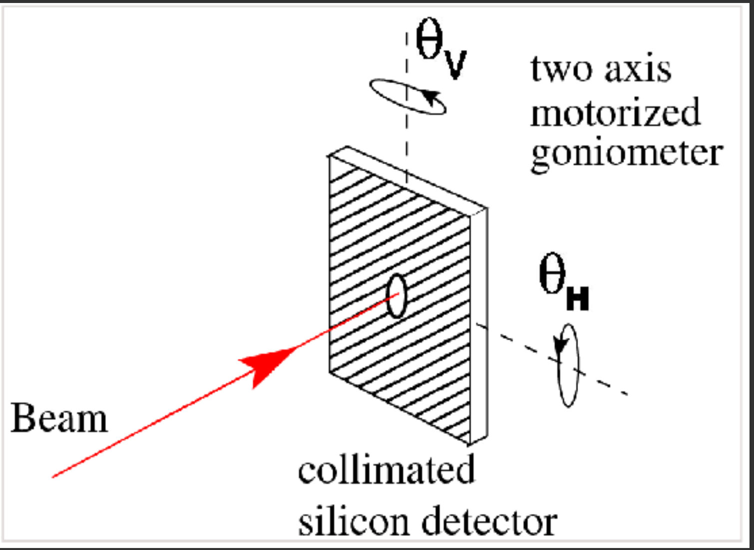
(assuming $\tau_C = 5\mu s$)

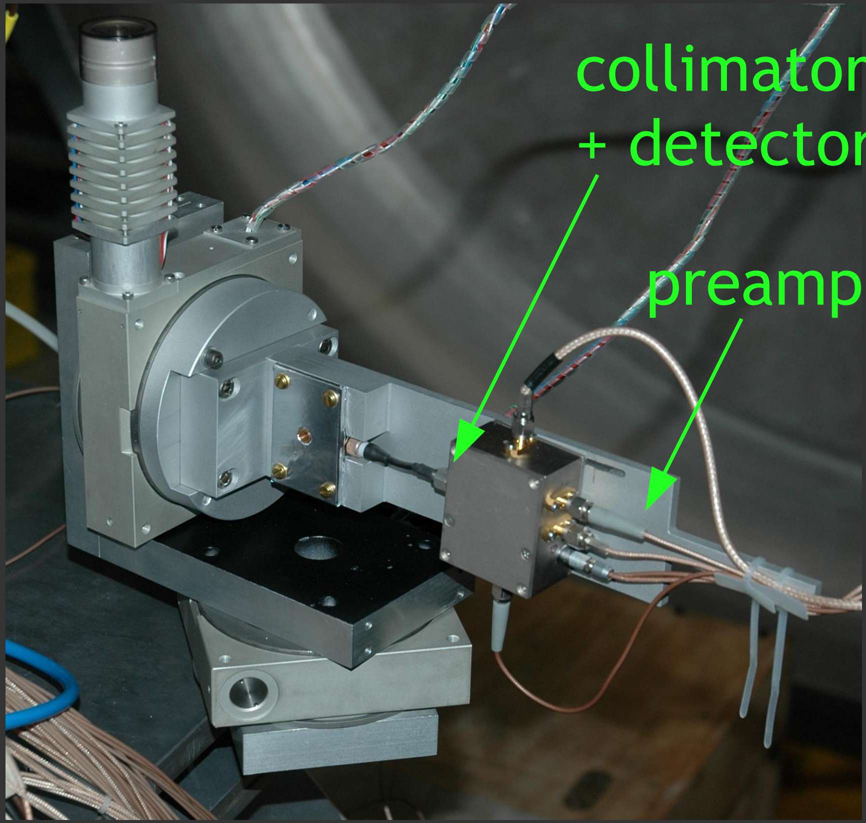
Giacomo Poggi

Detector optimization: avoiding channeling

Quantitative study of the effect of "channeling" on the Pulse Shape discrimination (L.Bardelli et al, NIMA 605 (2009) 353 and L.Bardelli et al, NIMA 654 (2011) 272)

The main part f the irreproducibility observed by various groups – including FAZIA in its earliest days- has been finally connected, by FAZIA itself, to "channeling effects" in the Silicon crystal.
The key experiment consisted of studying the shape of current and charge signals of a Silicon detector irradiated with monochromatic ions as a function of the relative orientation of the ions with respect to crystal axes



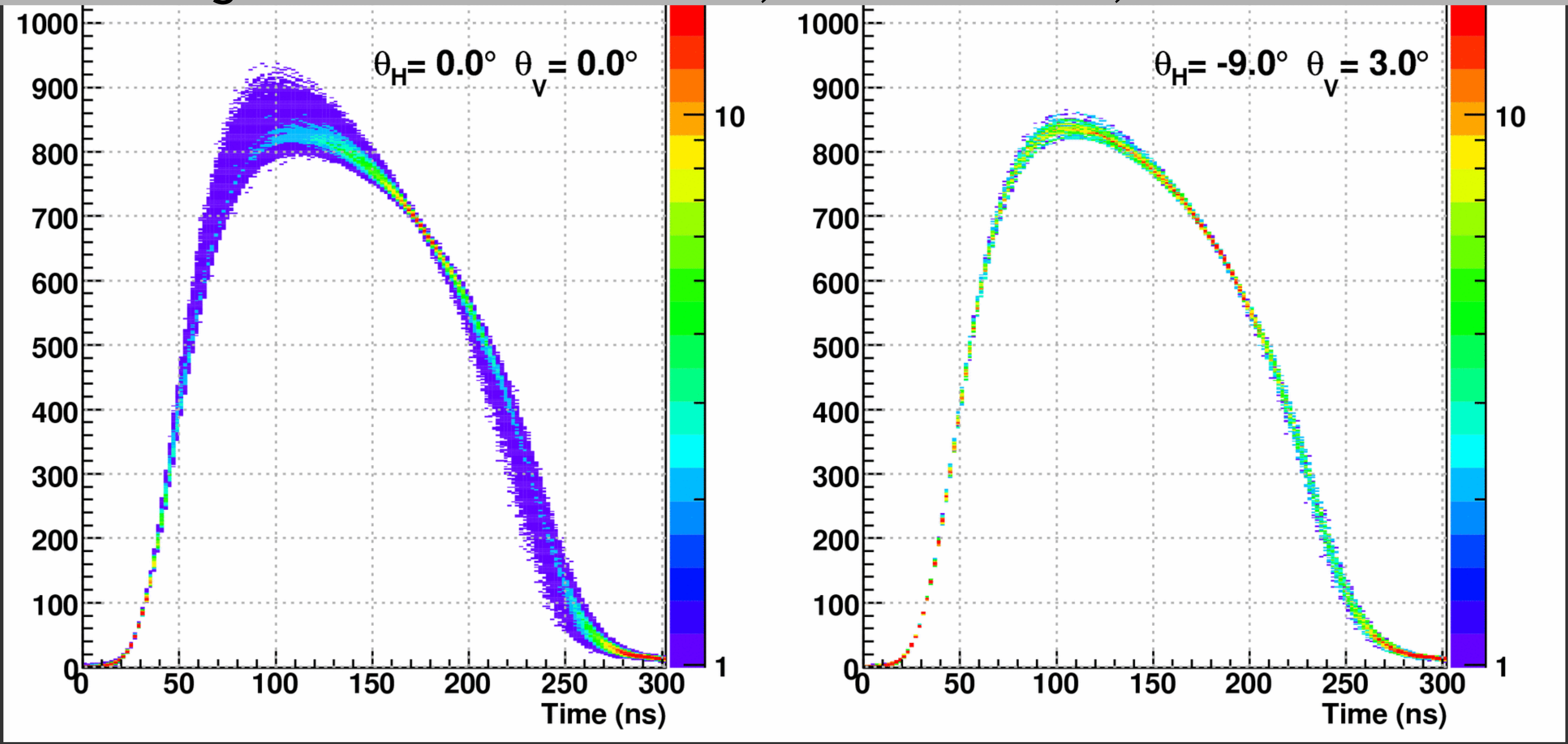


Measuring the detector response at various tilt angles by using a motorized support (with remote control) using a FAST SAMPLING ADCs (12bit, 125 MS/s) - G.Pasquali et al, NIM A 570 (2007) 126

Detector optimization: avoiding channeling

Quantitative study of the effect of "channeling" on the Pulse Shape discrimination *(L.Bardelli et al, NIMA 605 (2009) 353 and L.Bardelli et al, NIMA 654 (2011) 272)*

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



standard detector mounting (normal to direction of incoming particles)

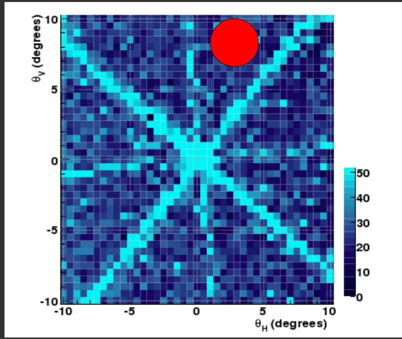
Properly tilted detector: Significant reduction of signal dispersion!

Detector optimization: avoiding channeling

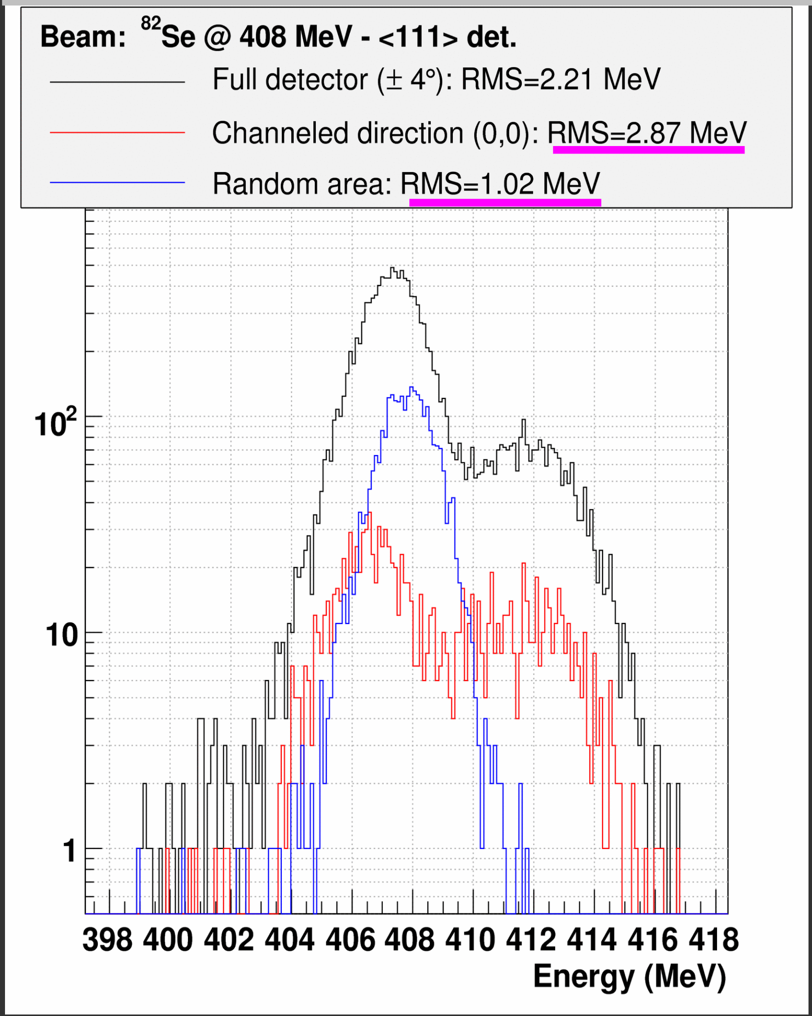
Quantitative study of the effect of "channeling" on the Pulse Shape discrimination *(L.Bardelli et al, NIMA 605 (2009) 353 and L.Bardelli et al, NIMA 654 (2011) 272)*

Energy and rise-time resolution significantly improves once the impinging direction of the ion is far from any crystal axis: even by about a factor of three for both quantities!

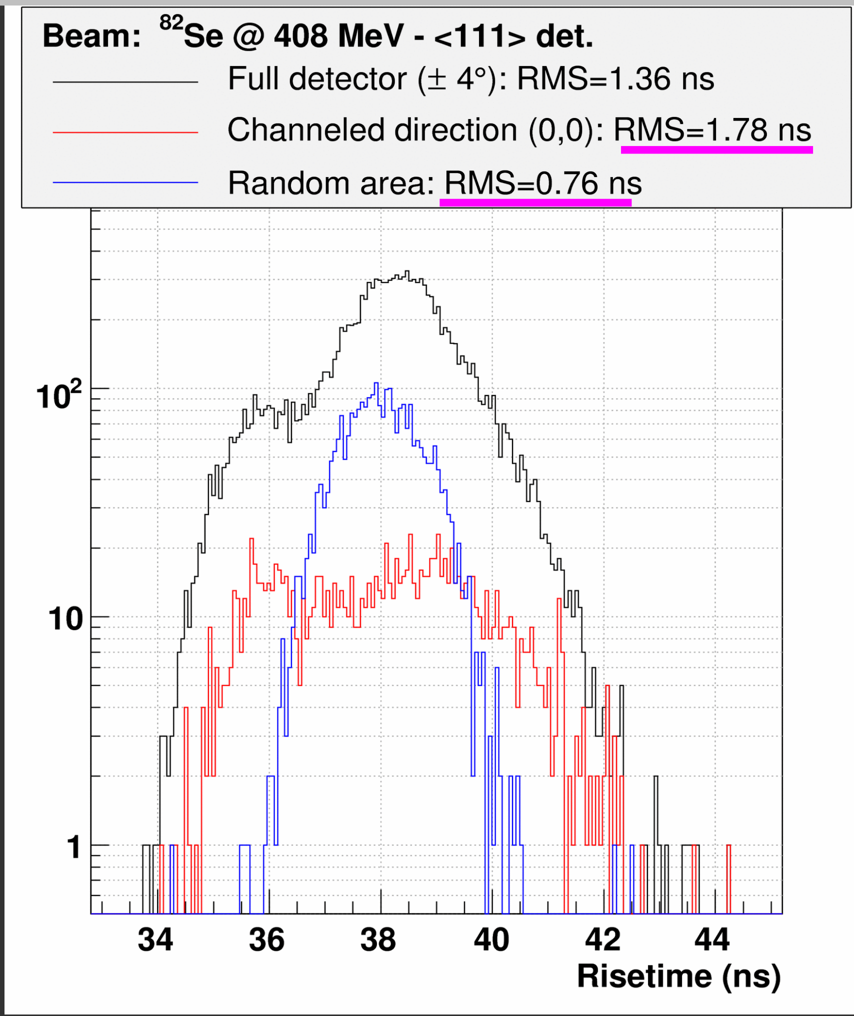
Timing does depend on crystal orientation!



Energy and Risetime resolution for a <111> detector:



ENERGY

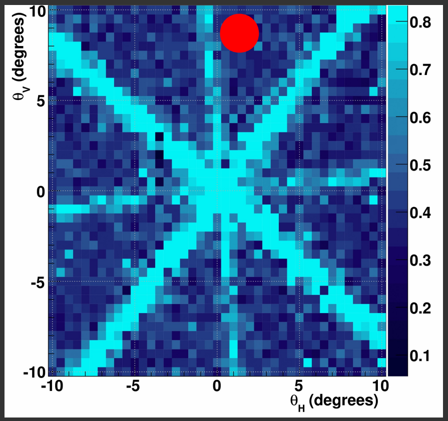


RISETIME

Detector optimization: avoiding channeling

Quantitative study of the effect of "channeling" on the Pulse Shape discrimination (L.Bardelli et al, NIMA 605 (2009) 353 and L.Bardelli et al, NIMA 654 (2011) 272)

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 (as usual in these days) the only solution is to tilt it (unpractical for a 4π device...)
2) we asked TOPSIL to cut uniform nTD Silicon <100> wafers along the properly identified directions ("random-cut")

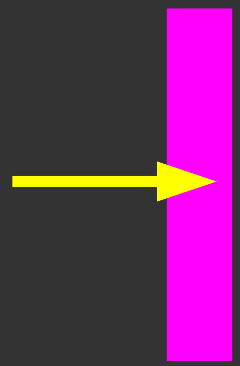
FBK/IRST (Trento) produced Silicon detectors out of "random-cut" (i.e. channeling free) wafers; Silicon material was the high-doping-uniformity nTD Silicon manufactured by TOPSIL. These detectors were used during a two-step Experiment at LNS (July-November 2009)

Detector optimization: avoiding channeling

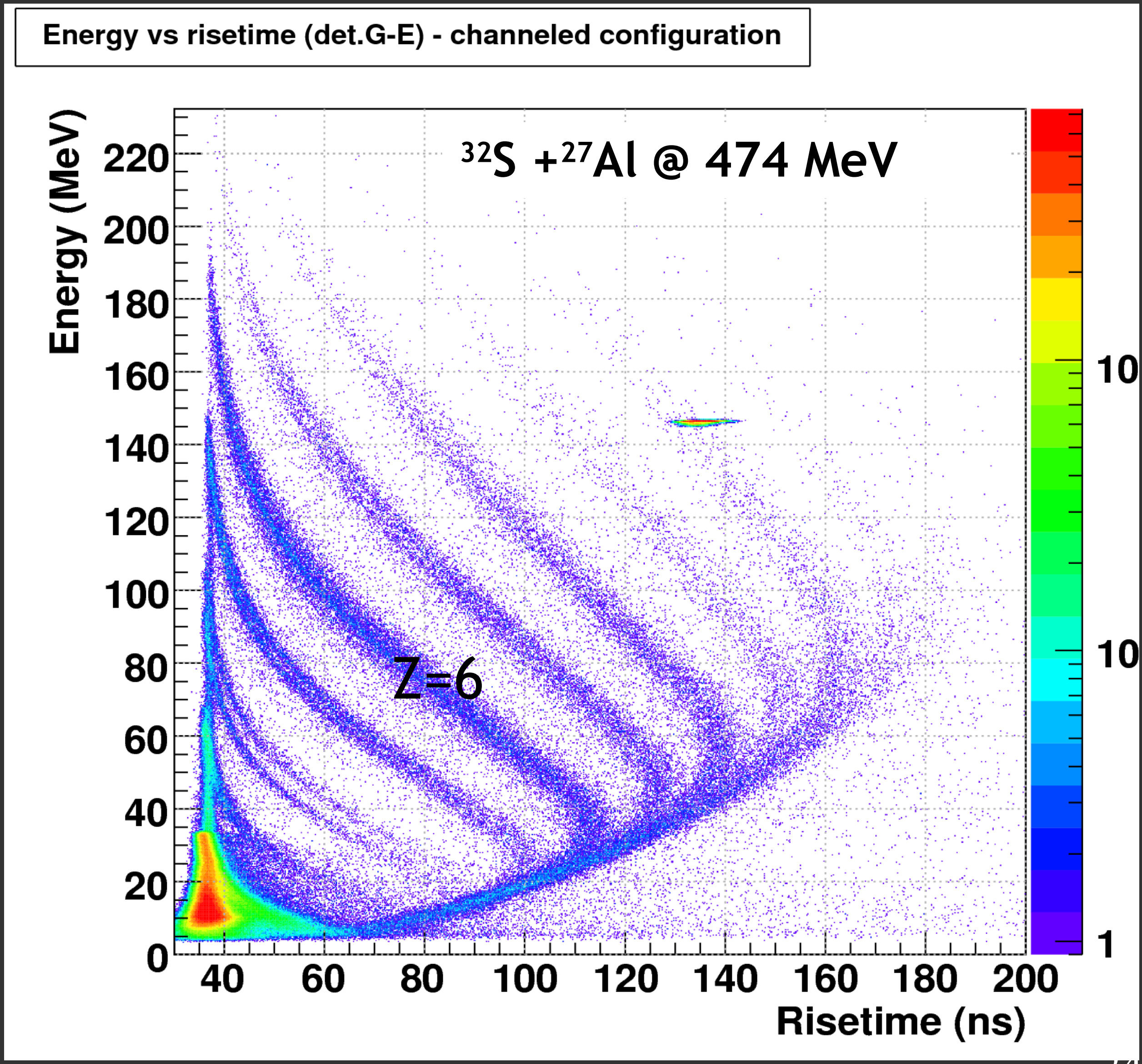
Quantitative study of the effect of "channeling" on the Pulse Shape discrimination *(L.Bardelli et al, NIMA 605 (2009) 353 and L.Bardelli et al, NIMA 654 (2011) 272)*

500 um detector
~1% non-uniformity

"with" channeling
(normal incidence)



14 bit, 100 MS/s digitizer
1.3 GeV full range



Detector optimization: avoiding channeling

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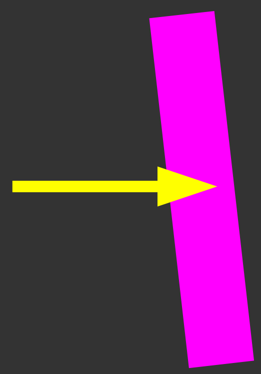
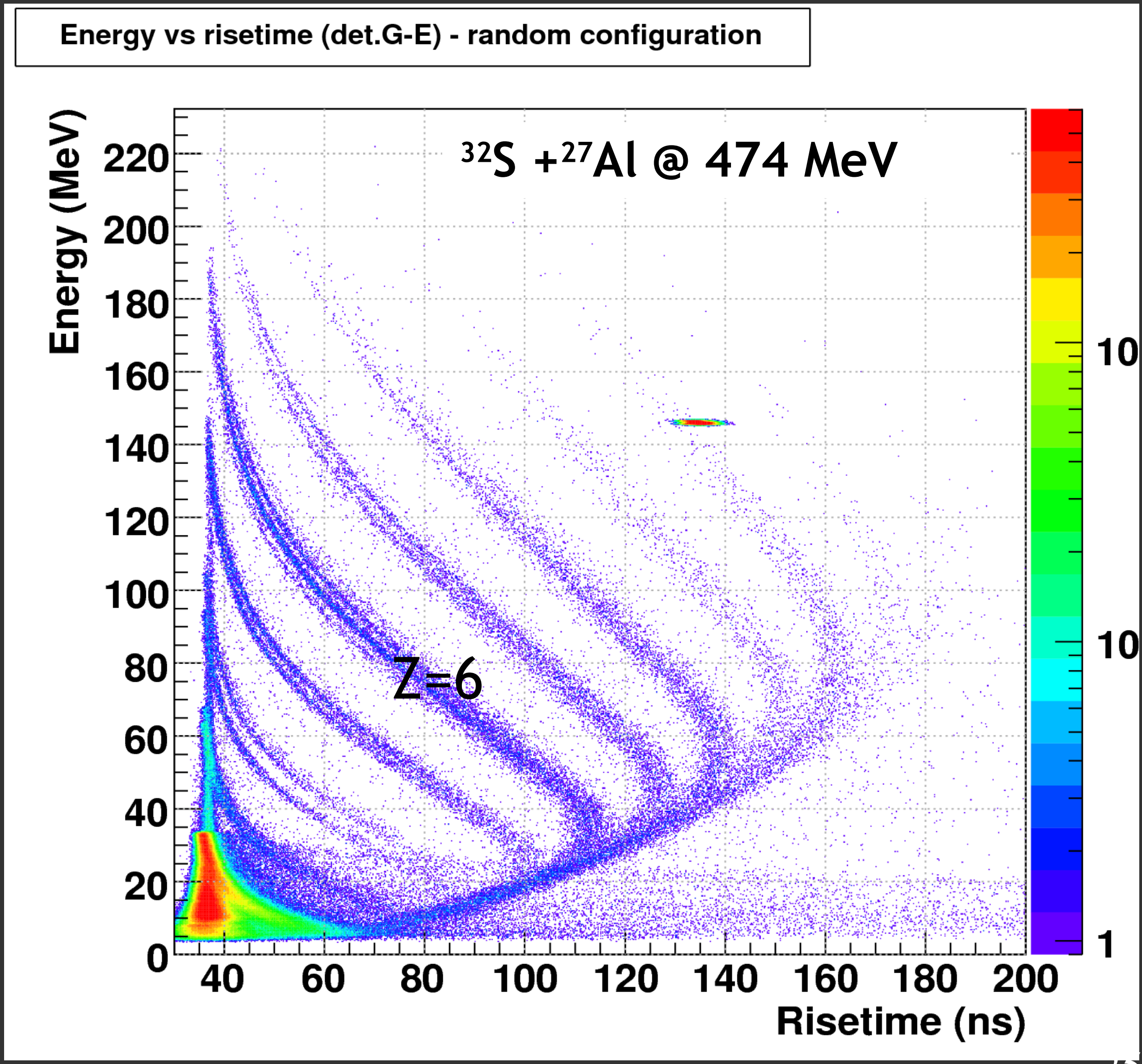
500 um detector
~1% non-uniformity

"without" channeling
(a few deg tilting)



14 bit, 100 MS/s digitizer
1.3 GeV full range



Detector optimization: avoiding channeling

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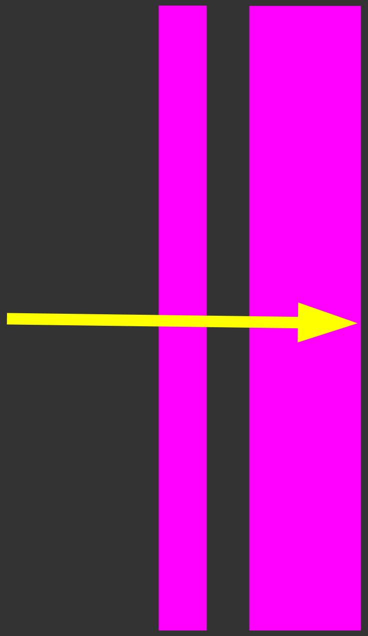
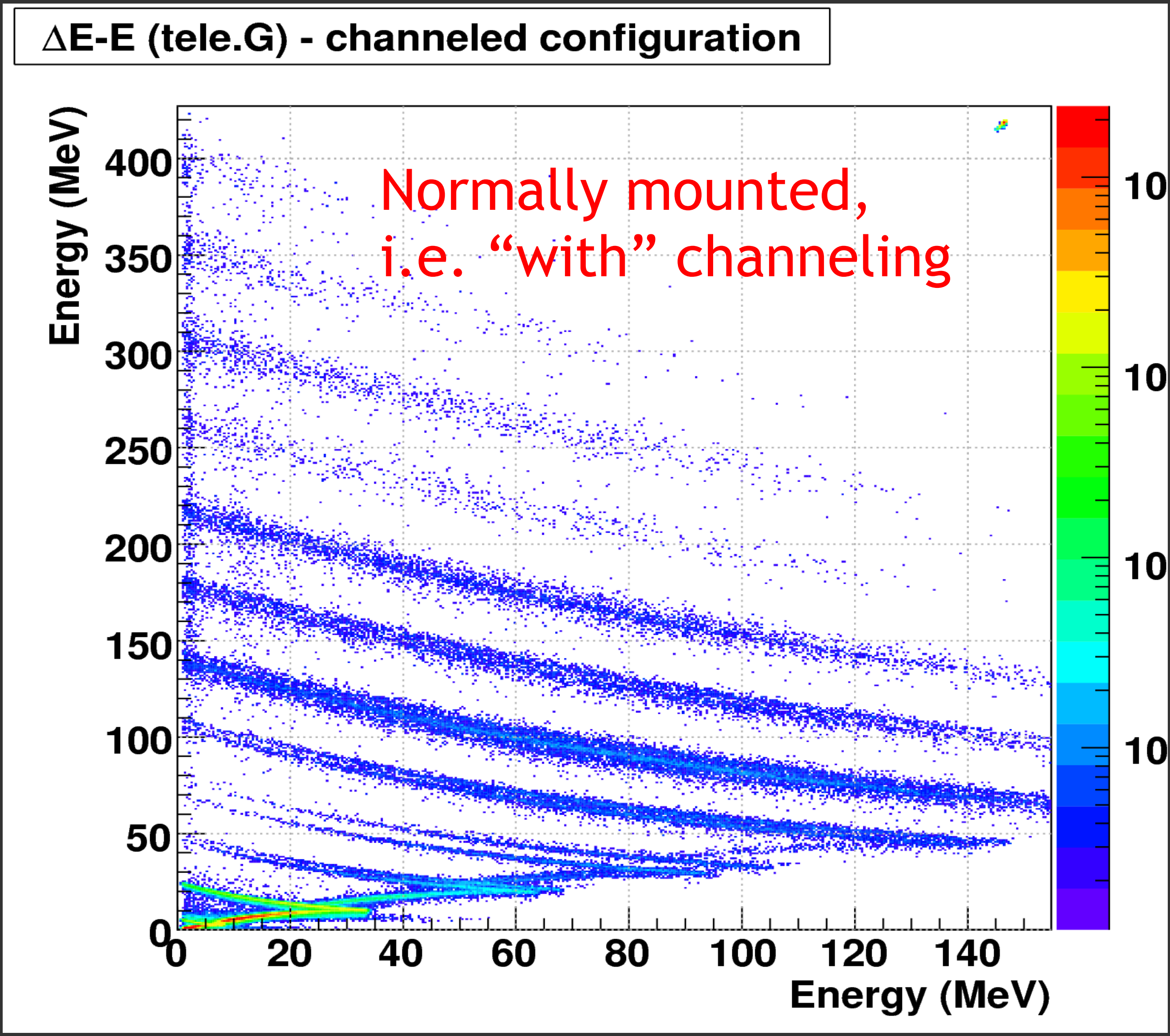
The standard DE-E technique also takes advantage of removing channeling





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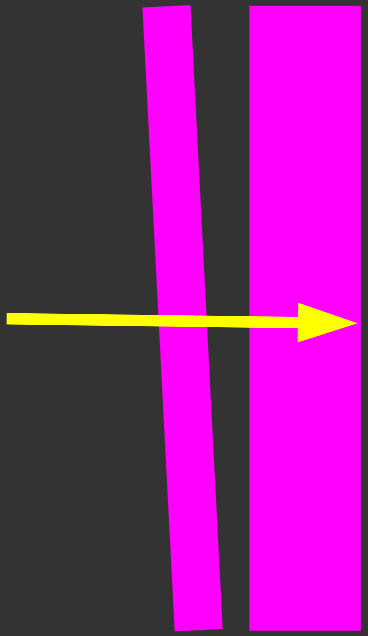
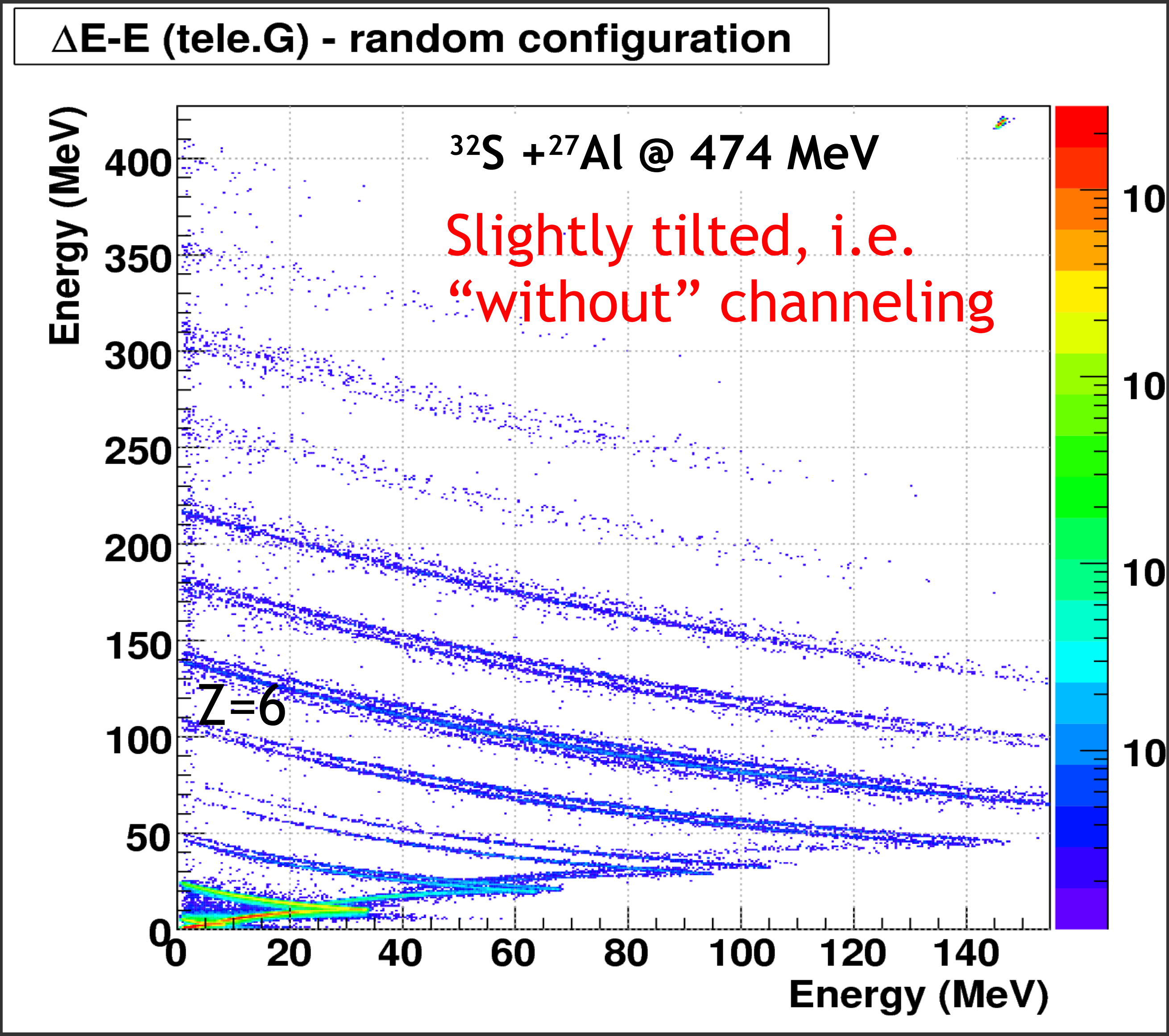




Detector optimization: doping uniformity

Quantitative study of the effect of doping non-uniformity on the Pulse Shape discrimination *(L.Bardelli et al, NIMA 602 (2009) 501)*

Silicon Doping uniformity is necessary to ensure a homogeneous electric field across the detector area.

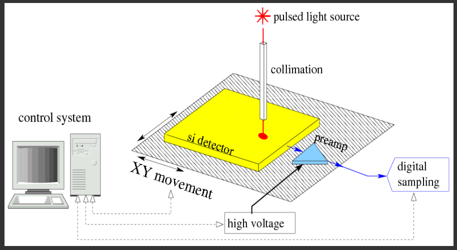
How uniform is to be the Silicon doping?

Presently available techniques are not able to provide the necessary information neither for the Silicon ingot, nor for the wafers.

Once the geometrical thickness of the detector is known, the depletion voltage provides a direct measurement of the average (over surface and depth) material resistivity

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

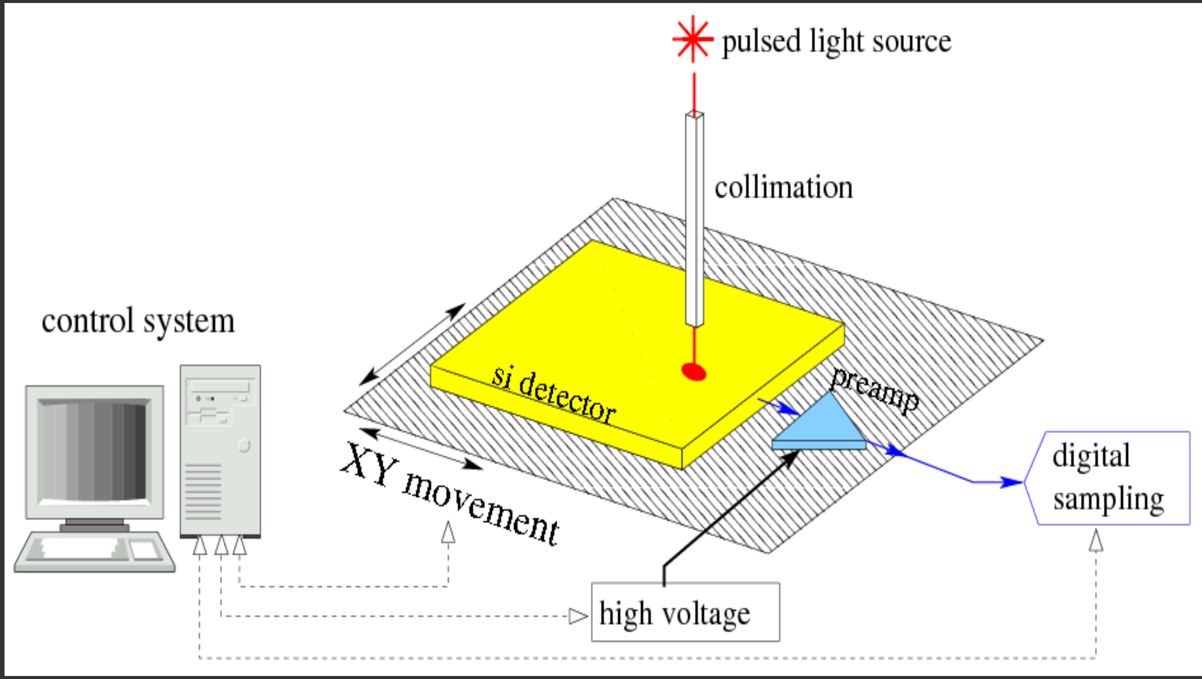
Is it possible to measure the local value of resistivity? Yes, with a variation of the Transient Current Technique

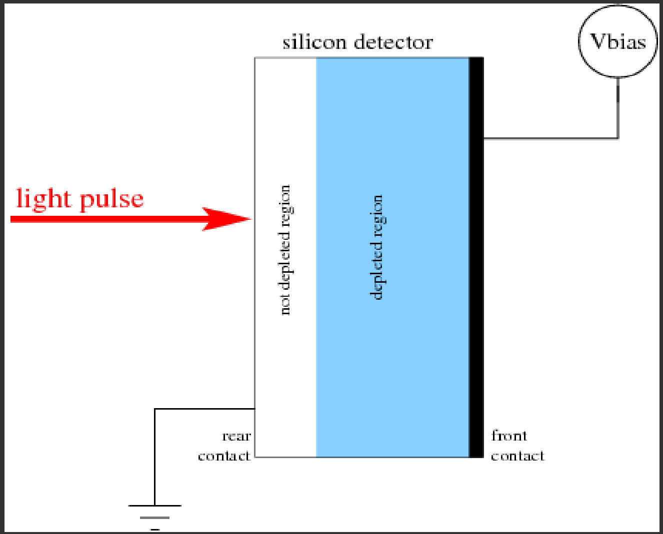


Detector optimization: doping uniformity

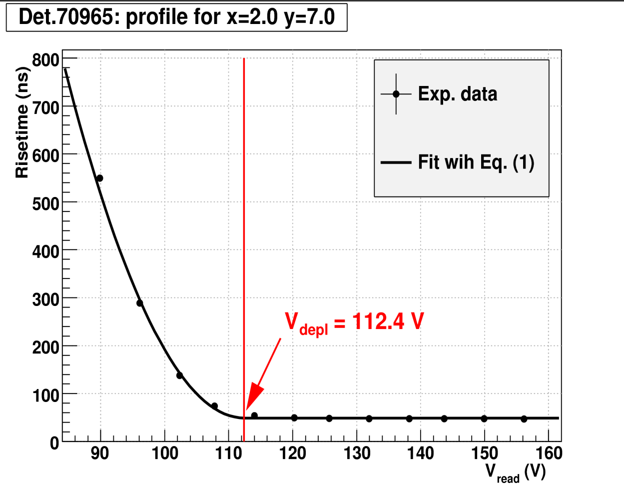
Quantitative study of the effect of doping non-uniformity on the Pulse Shape discrimination *(L.Bardelli et al, NIMA 602 (2009) 501)*

- The detector is mounted on a XY movement.
- A point-like sub-ns Light pulse irradiates the ohmic side (partly transparent)
- Shapes are collected with a digitized as function of applied voltage and position
- Both the XY support and the HV are computer controlled.





For each XY position on the detector we can build an "Average rise-time" vs "V_{bias}" plot and finally fit the LOCAL V_{depl}, i.e. the resistivity



Detector optimization: doping uniformity

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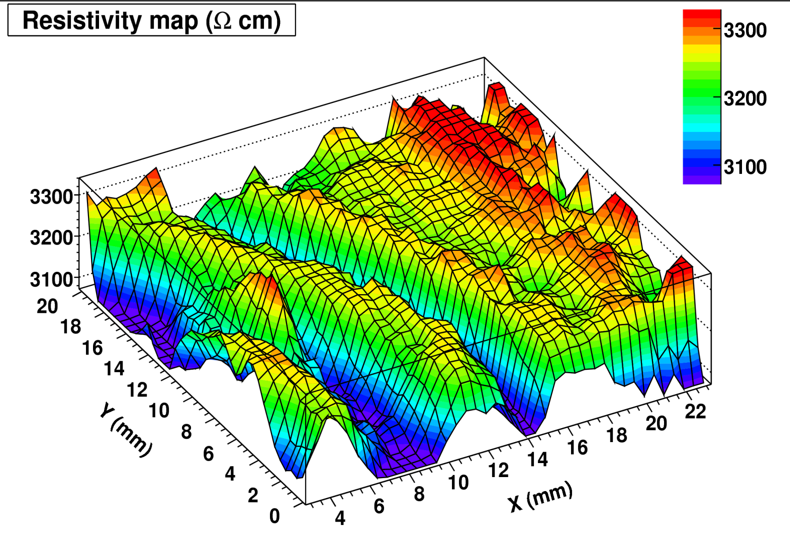
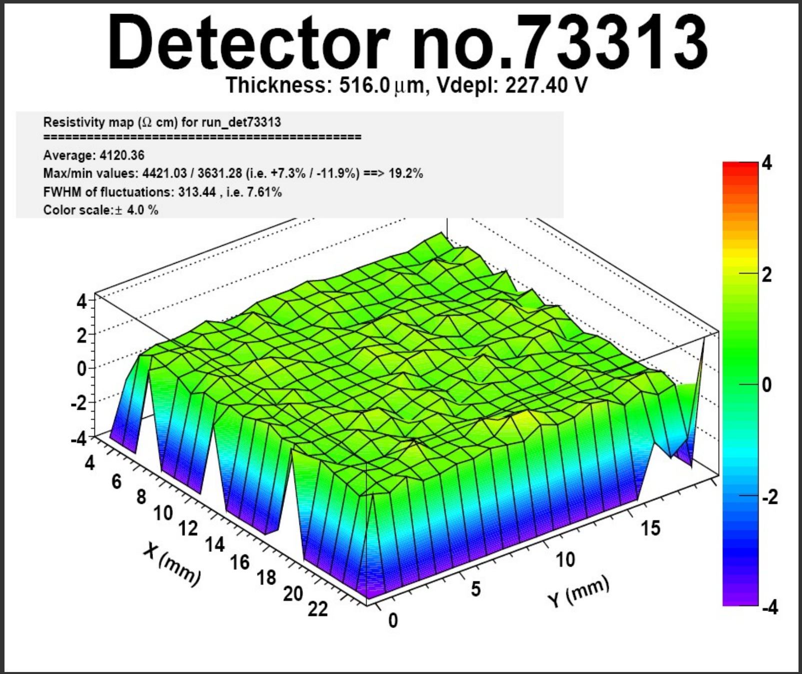
Resistivity 2-D maps are build, with the needed accuracy. FZ detectors, high resistivity Silicon normally provides poor uniformity. Neutron transmuted Silicon can be much better; not necessarily, indeed



A "standard-uniformity" i.e. 9% nTD Silicon detector, not apt to Pulse Shape Analysis



A "good-uniformity" NTD detector (better than 1%), very well apt to Pulse Shape Analysis.

Final nTD Silicon uniformity depends on the resistivity and uniformity of the original FZ Silicon.
Easy to obtain low-resistivity and high-uniformity nTd Silicon. The opposite is much more difficult

Detector optimization: doping uniformity

Quantitative study of the effect of doping non-uniformity on the Pulse Shape discrimination *(L.Bardelli et al, NIMA 602 (2009) 501)*

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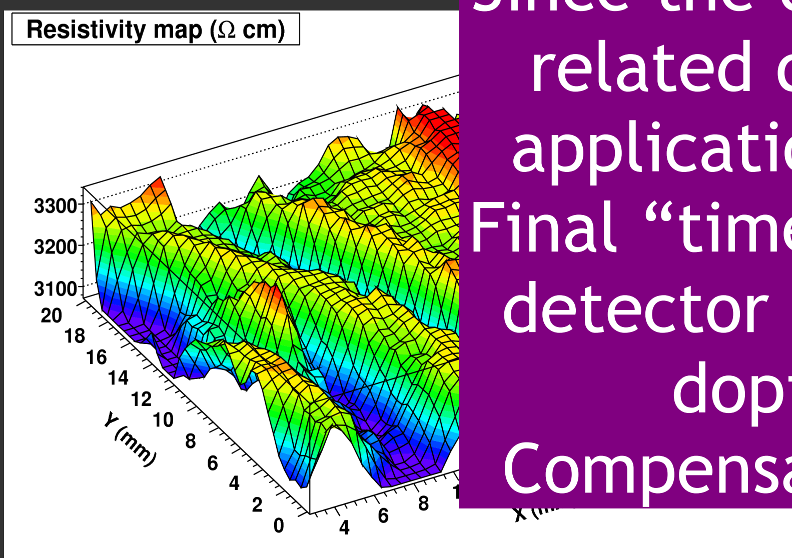
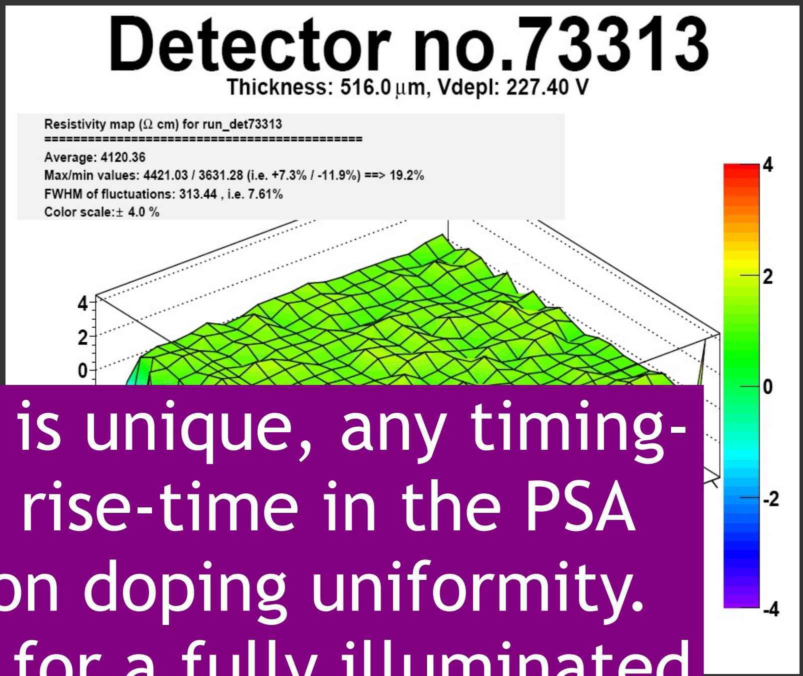


A "standard-uniformity" i.e. 9% nTD Silicon detector, <u>not apt to Pulse Shape Analysis</u>



(better ... ape

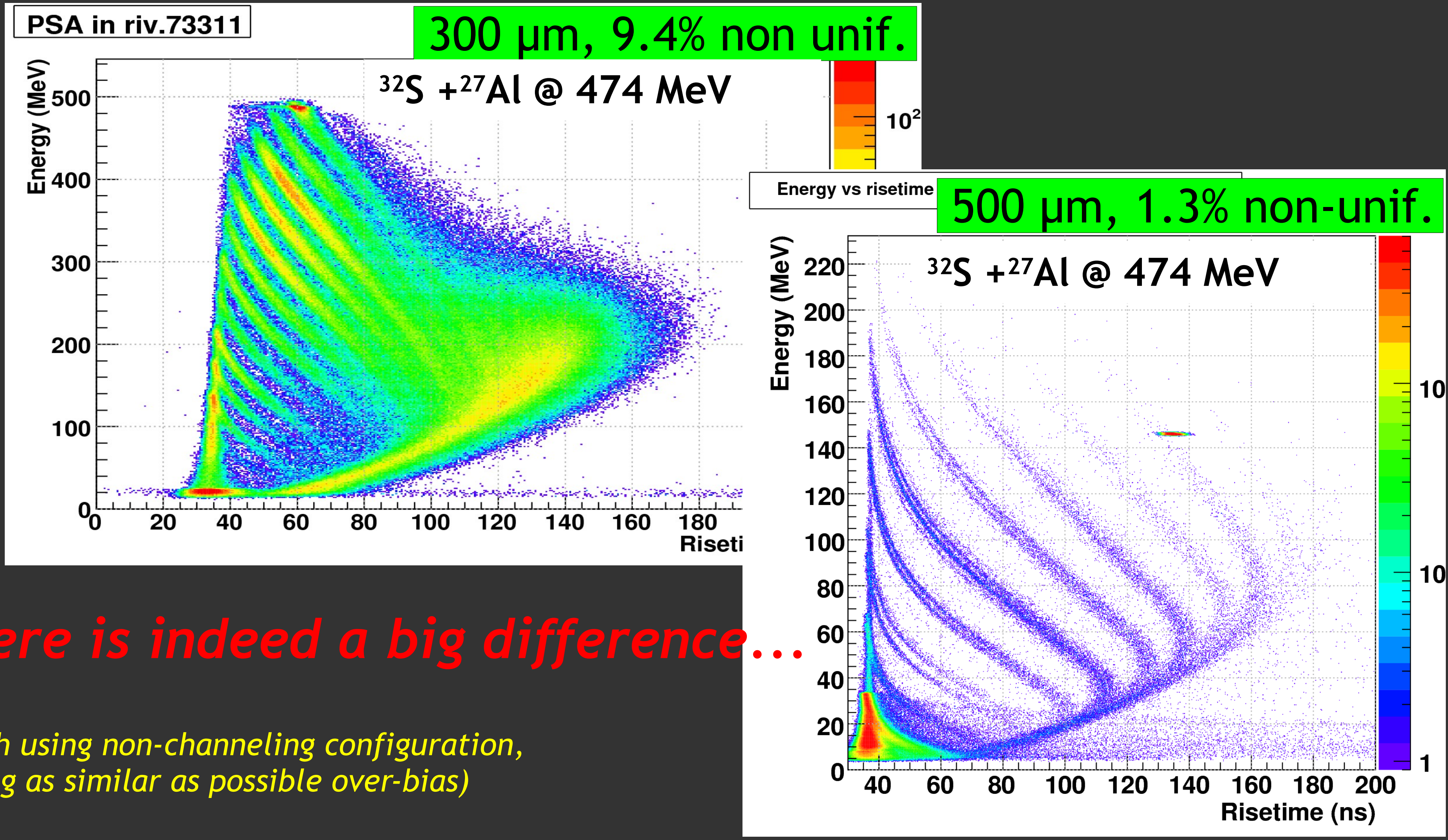
Since the detector bias is unique, any timing-related quantity (like rise-time in the PSA application) depends on doping uniformity. Final "time" resolution for a fully illuminated detector is impaired by the variation of the doping across the detector area. Compensation requires significant overbias

...ds on the resistivity and uniformity of the original FZ Silicon.

Easy to obtain low-resistivity and high-uniformity nTd Silicon. <u>The opposite is much more difficult</u>

Detector optimization: doping uniformity

Quantitative study of the effect of doping non-uniformity on the Pulse Shape discrimination *(L.Bardelli et al, NIMA 602 (2009) 501)*



There is indeed a big difference…

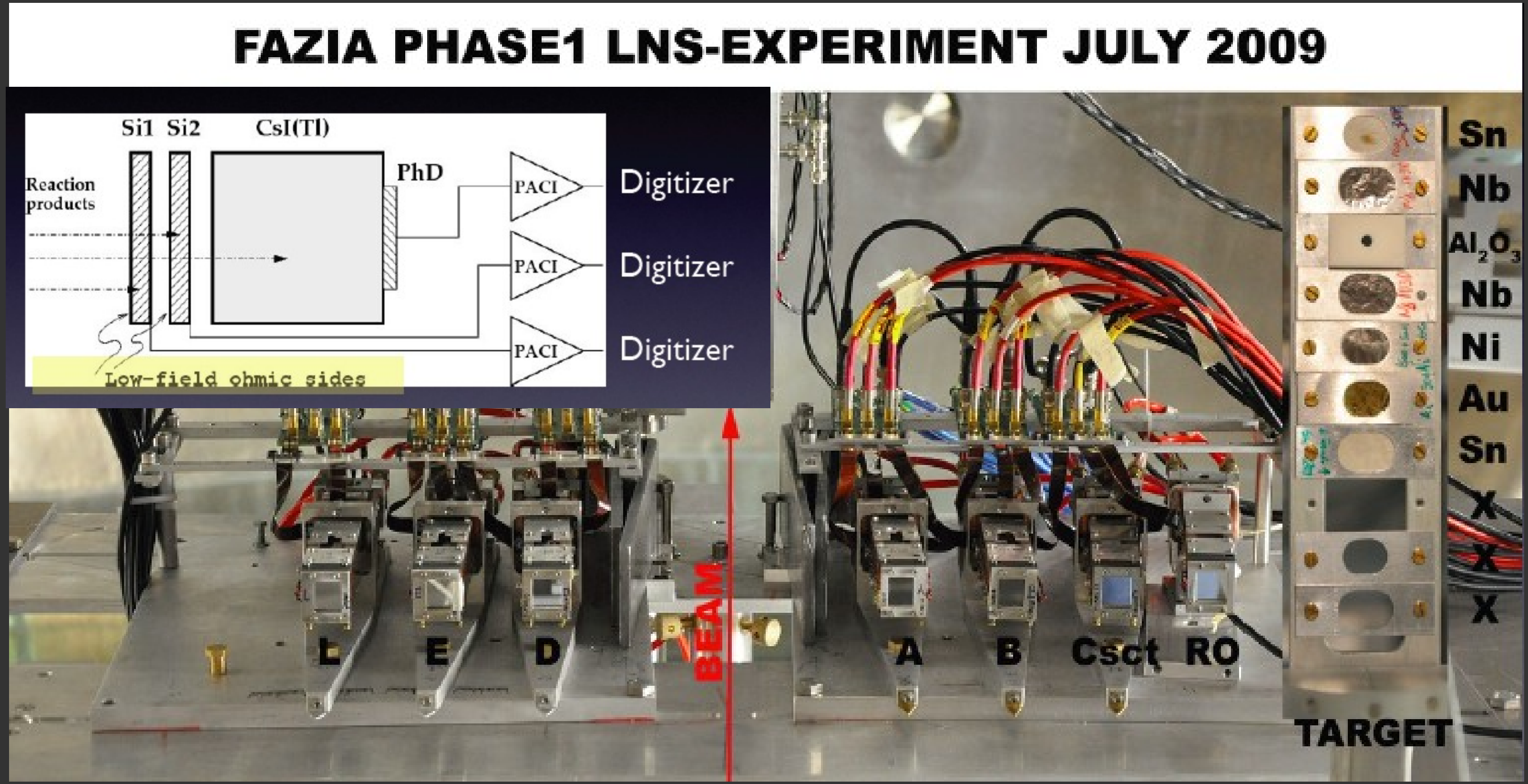
(both using non-channeling configuration, using as similar as possible over-bias)

Present Detector performance

Recently at LNS an experiment showed the present available performance of our detectors *(S.Carboni et al, NIMA – available on line)*

The experiment consisted of detecting the reaction products of the
$^{84}Kr + ^{nat}Ni$ and $^{129}Xe + ^{nat}Ni$ @ 35MeV/n
with our final FAZIA telescopes (highly uniform and "properly cut" to avoid channeling)

Tests have shown very good performance both for the standard DE-E and PSA methods. Both methods benefit from the absence of any channeling effect and the optimal signal treatment



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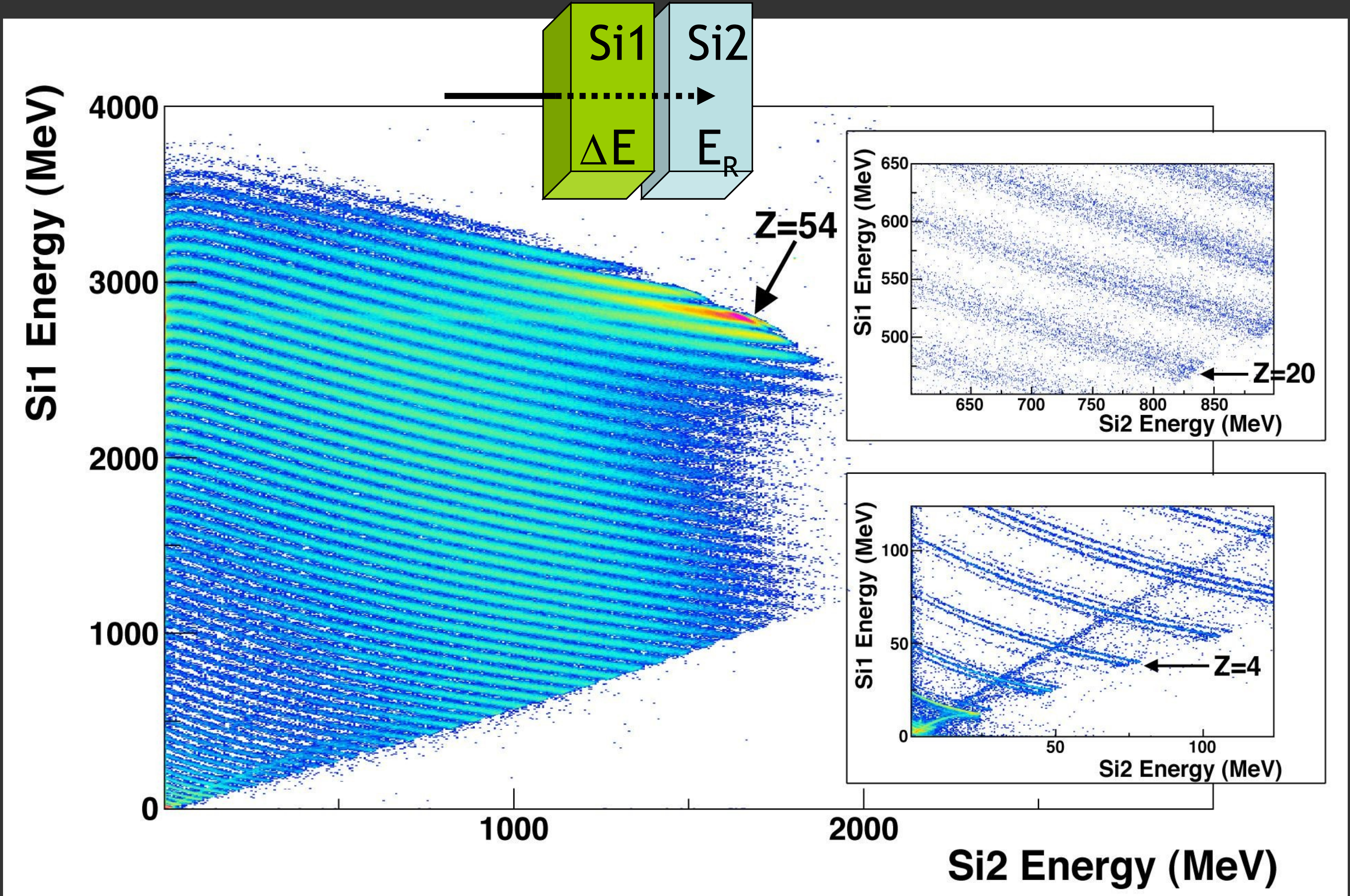
Full range of 5 GeV and 3 GeV for Si1 and Si2 resp. Digital shaping permits, as anticipated, very high dynamic energy range, using a single gain



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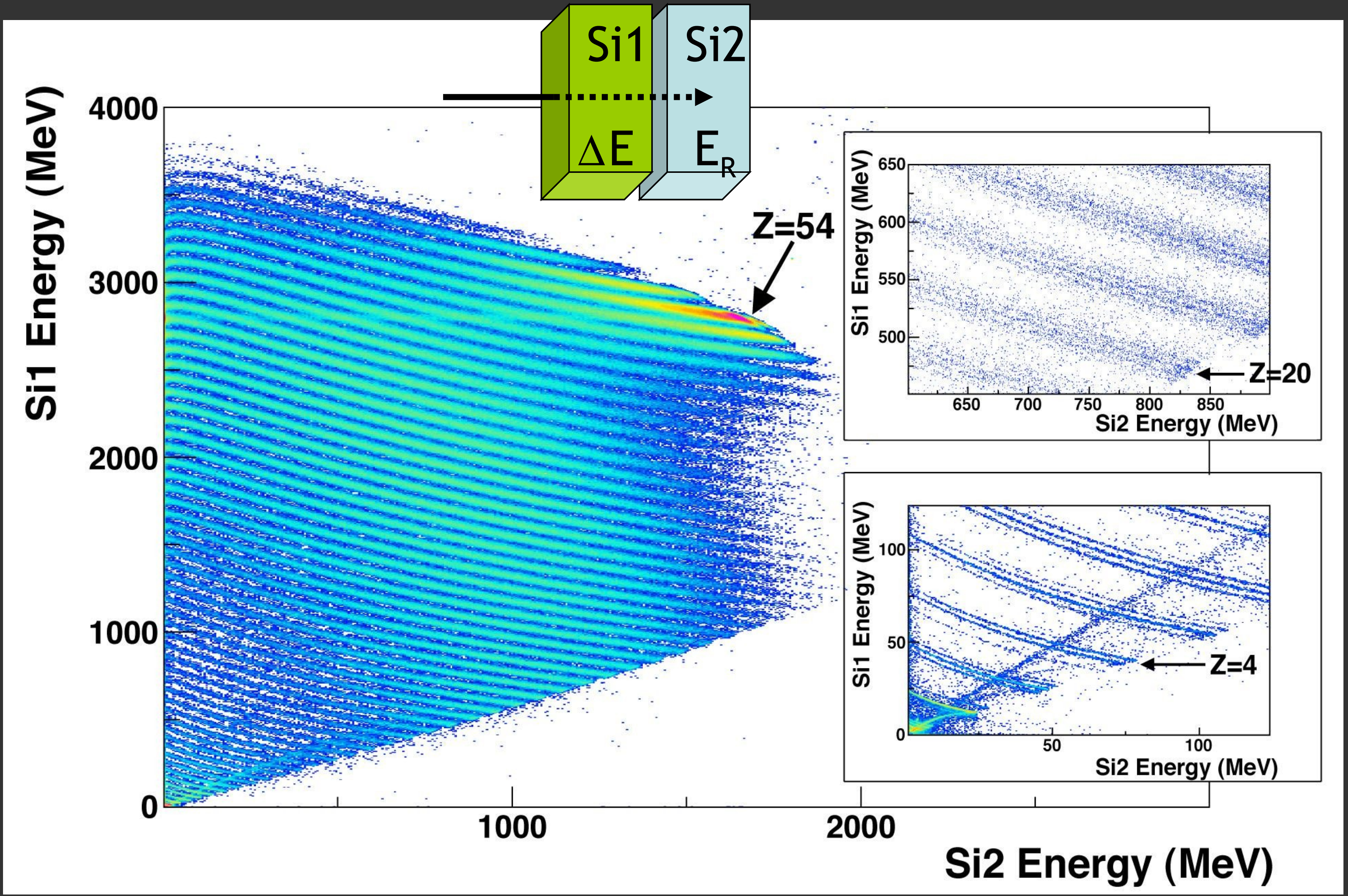

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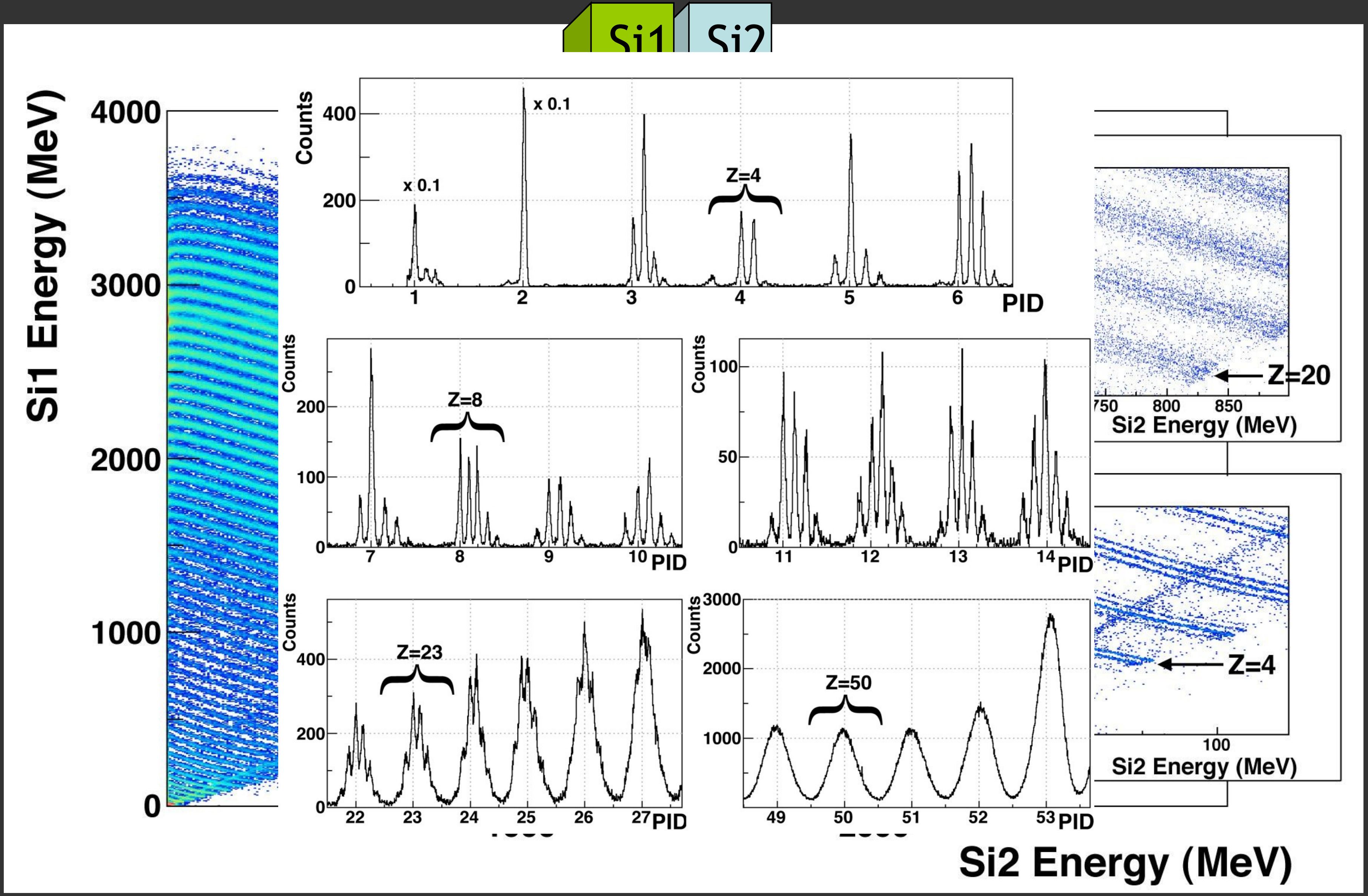
Good isotopic separation (0.7 FoM) up to Z=25-26. Very close to the estimated limit due to irreducible energy straggling. Thanks to the absence of channeling



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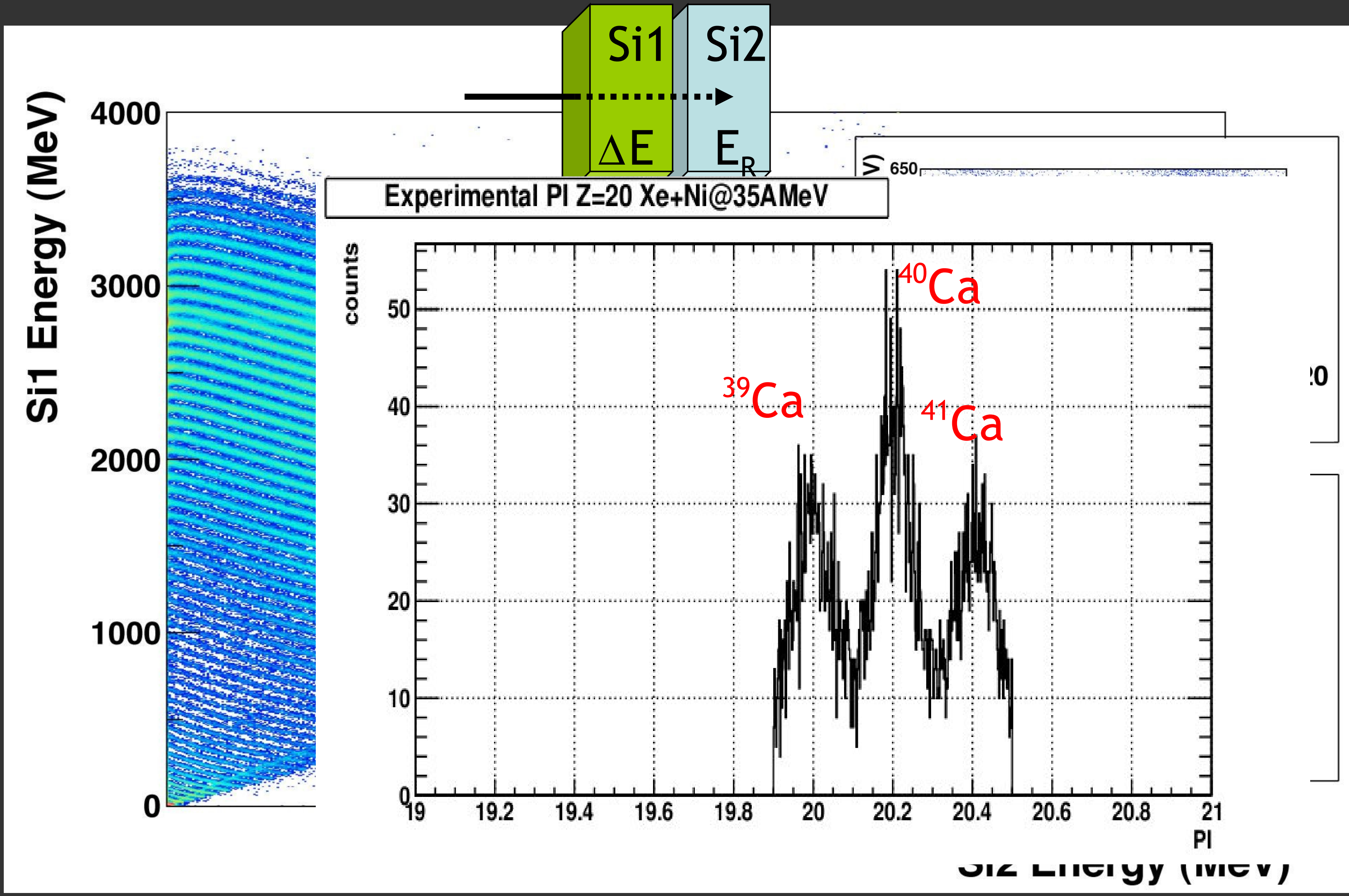

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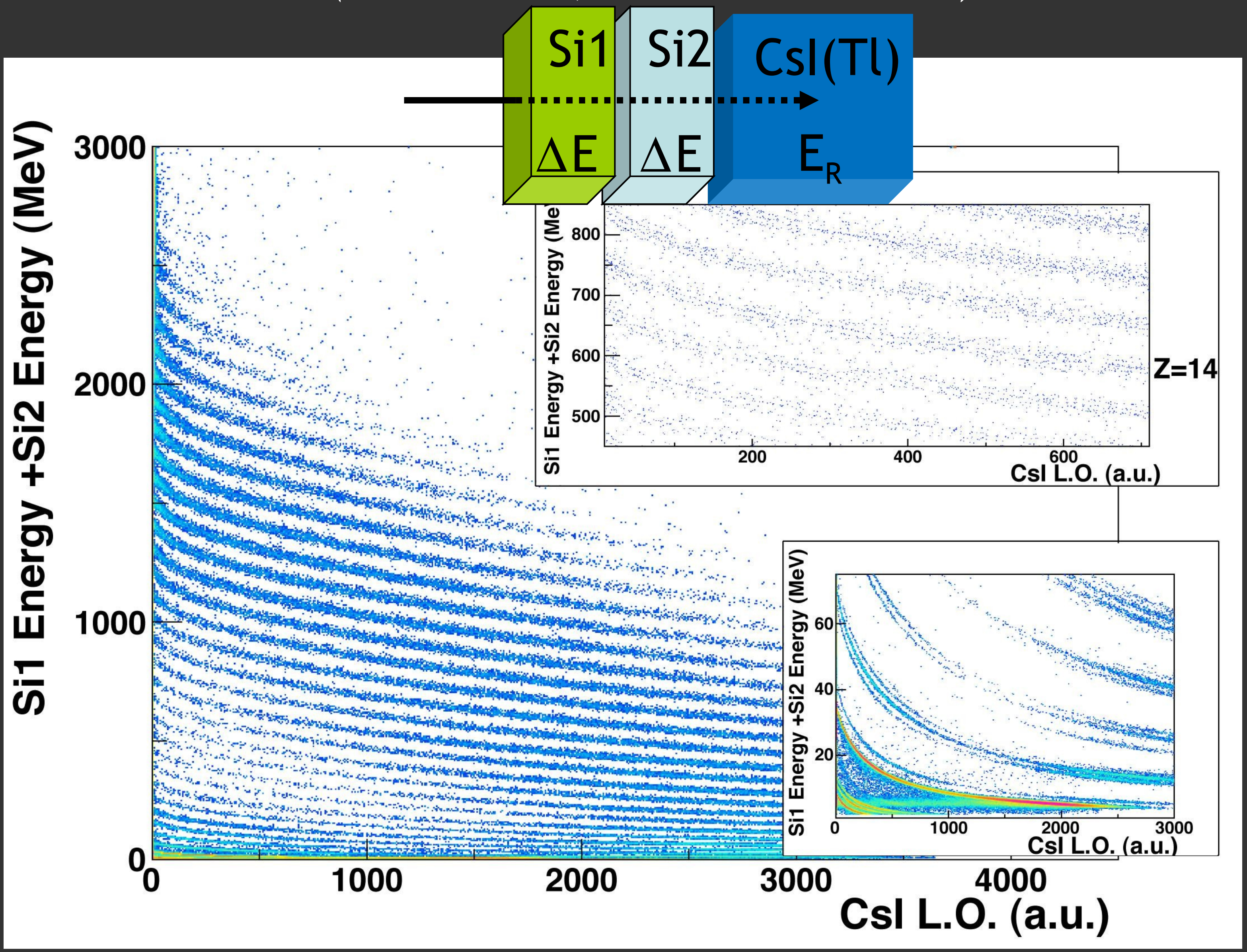
Recently at LNS an experiment showed the present available performance of our detectors *(S.Carboni et al, NIMA – available on line)*

Correlation between the sum of the energies deposited in the two Si detectors versus the CsI(Tl) light output. Very good isotopic separation is obtained, up to Z=25



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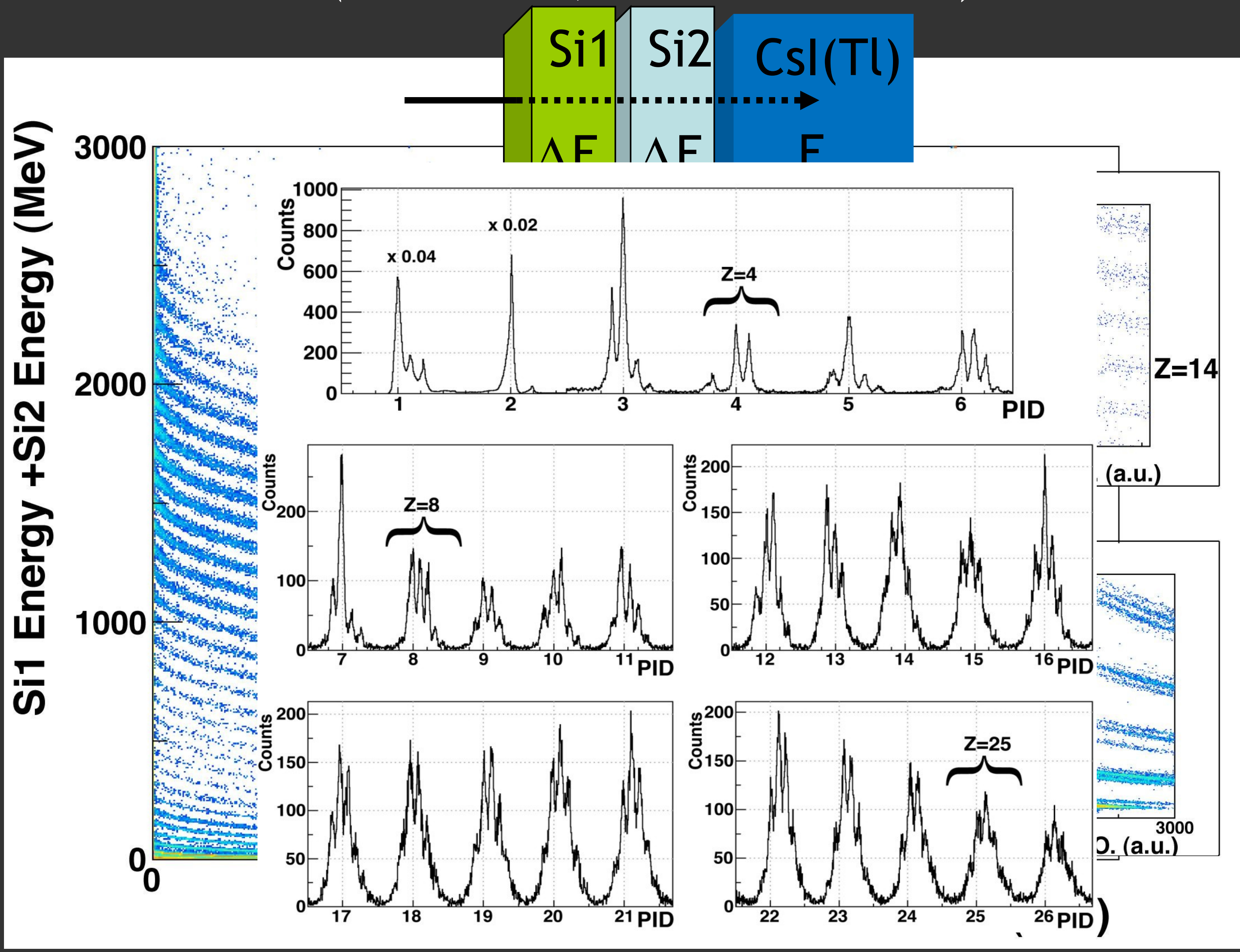

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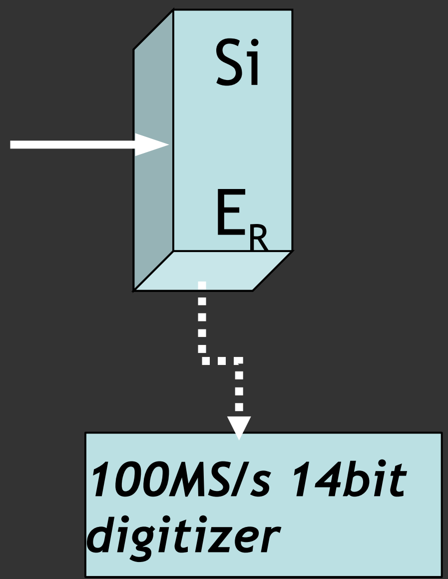

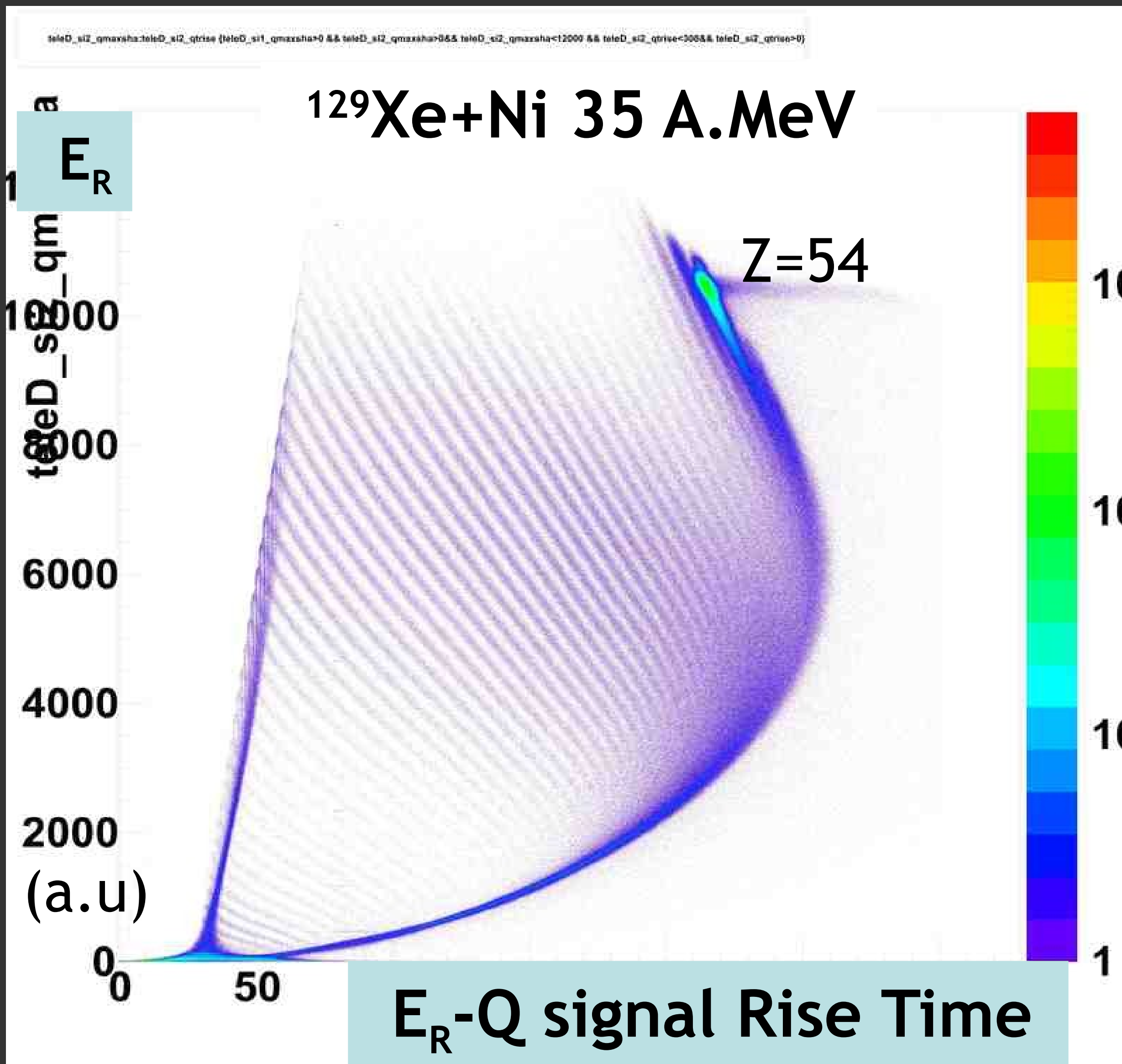

Digital PSA results:
one digitizer,
6 GeV full scale

FAZIA data (LNS)

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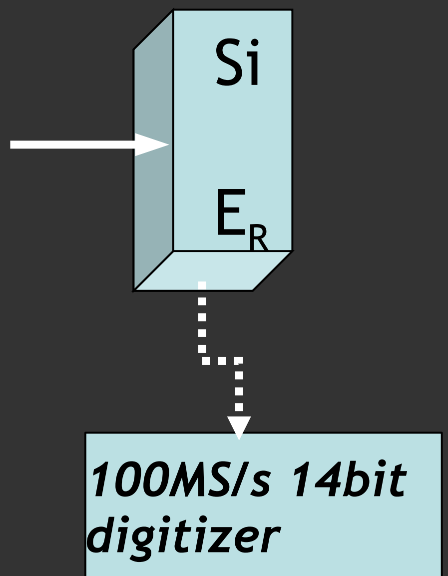

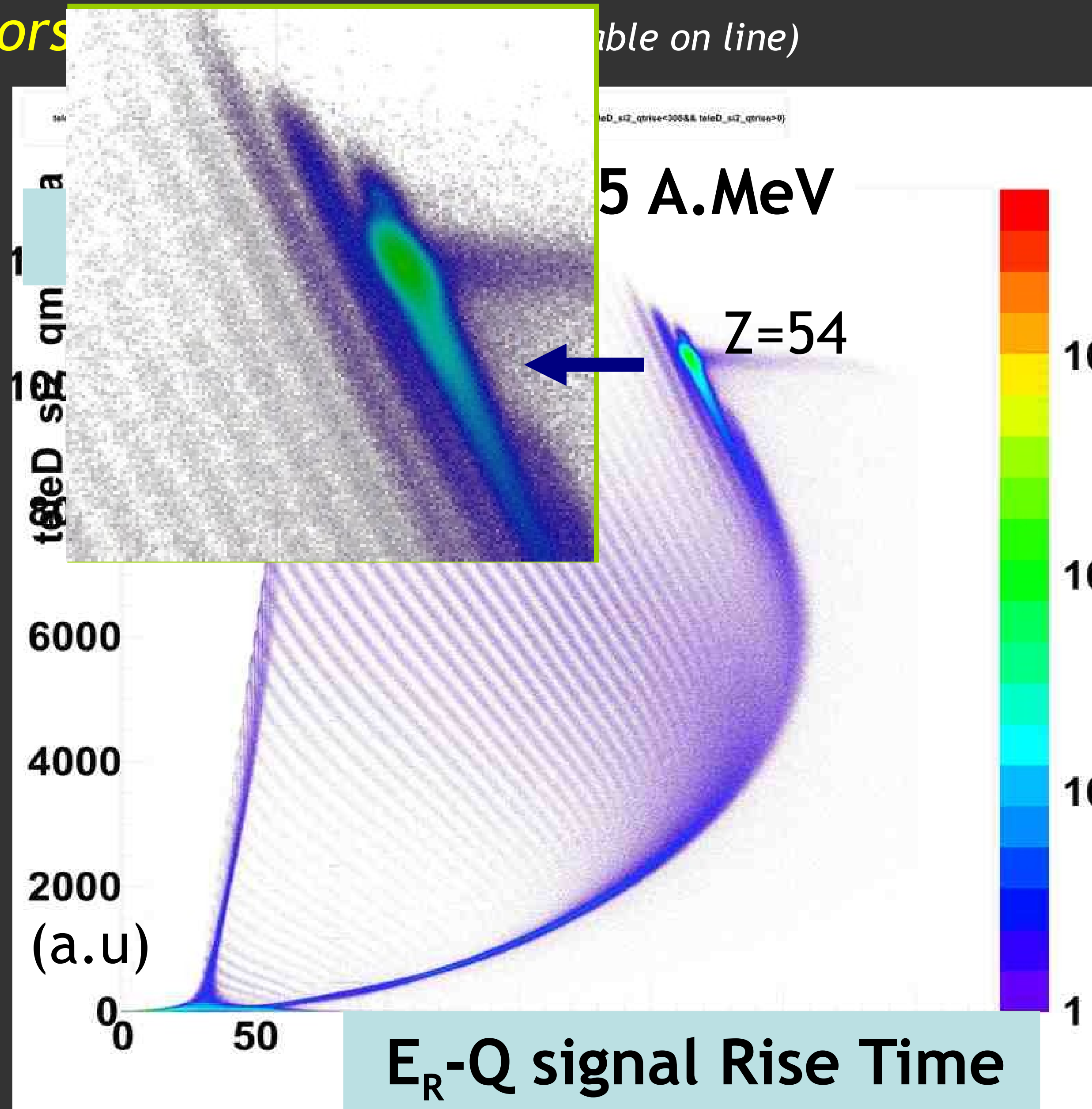

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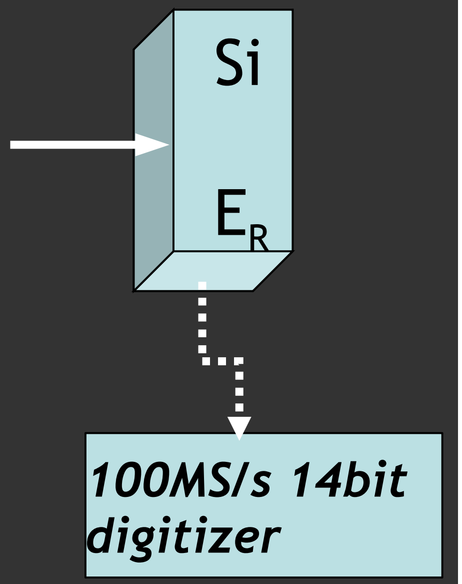

Digital PSA results:
one digitizer,
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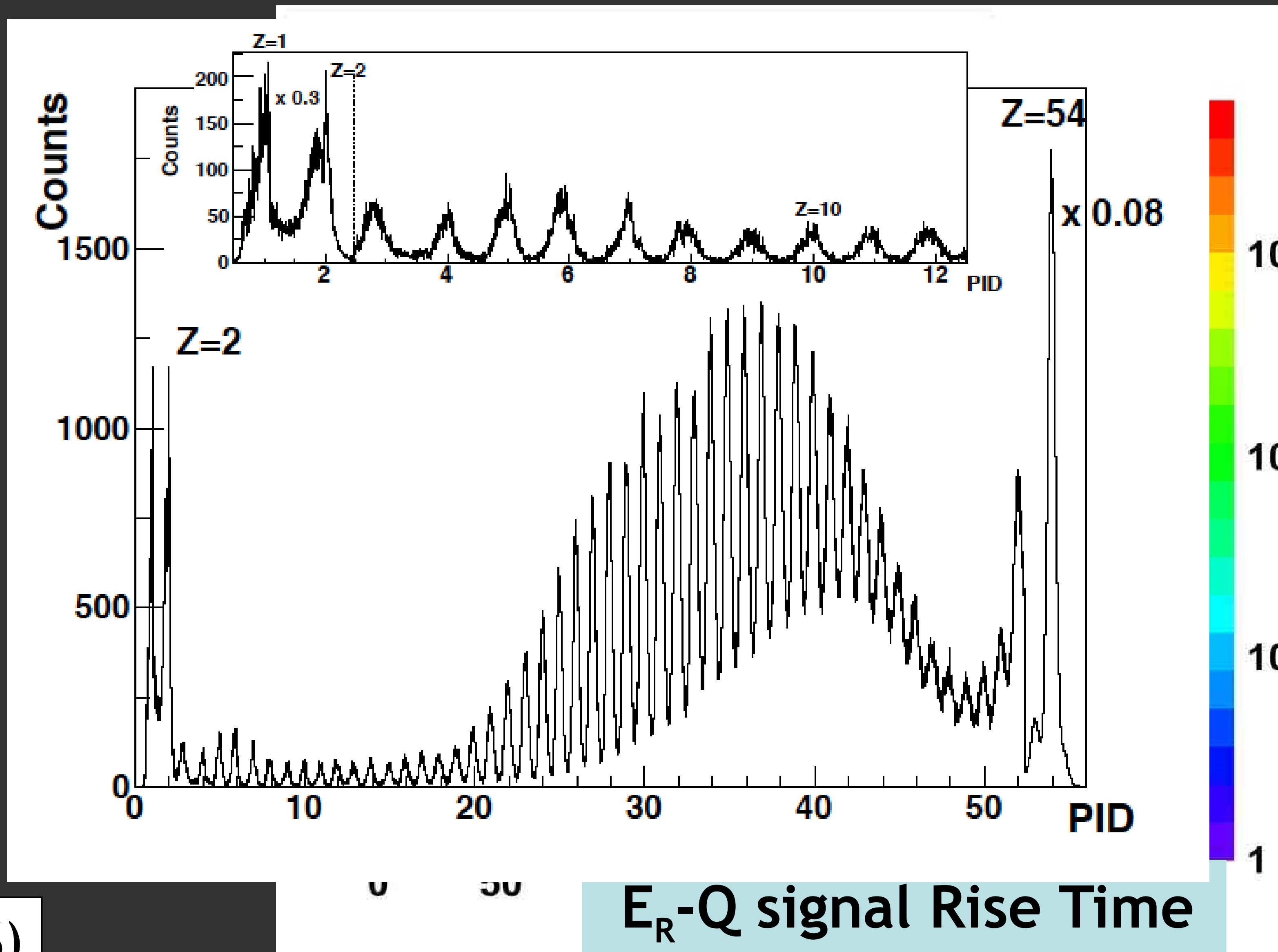
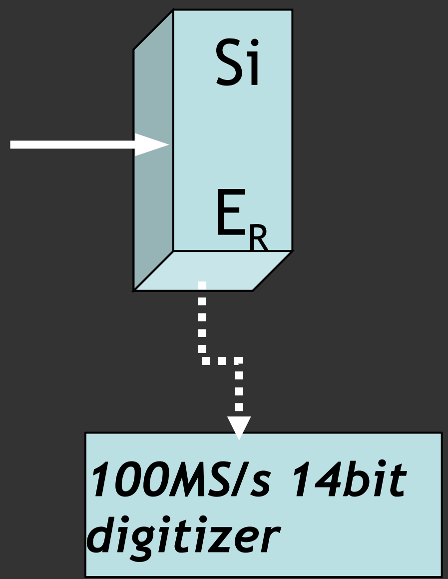


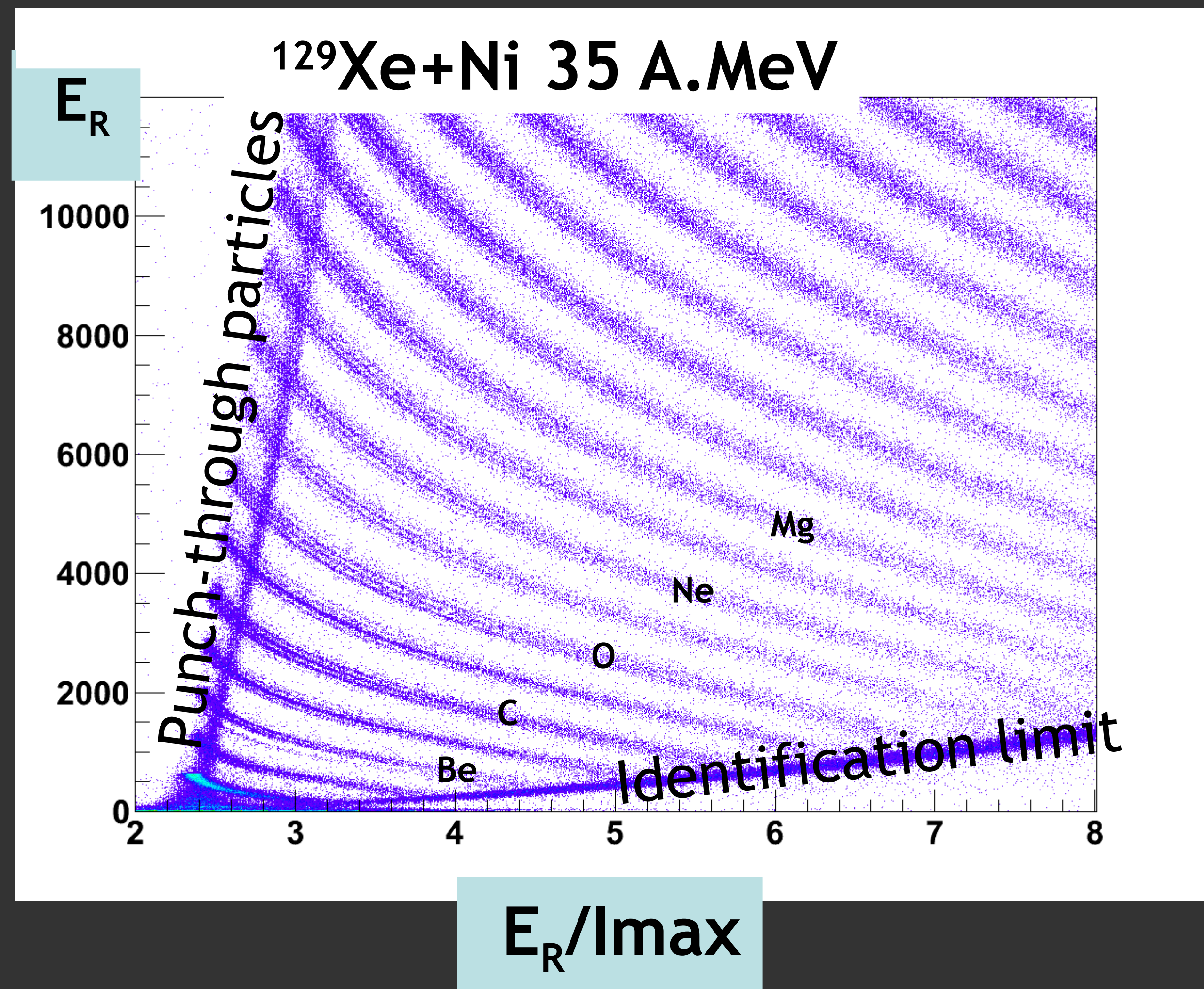
FAZIA data (LNS)

Present Detector performance

Recently at LNS an experiment showed the present available performance of our detectors *(S.Carboni et al, NIMA – available on line)*

Another, quite promising, approach for Pulse Shape identification using the maximum of the current signal



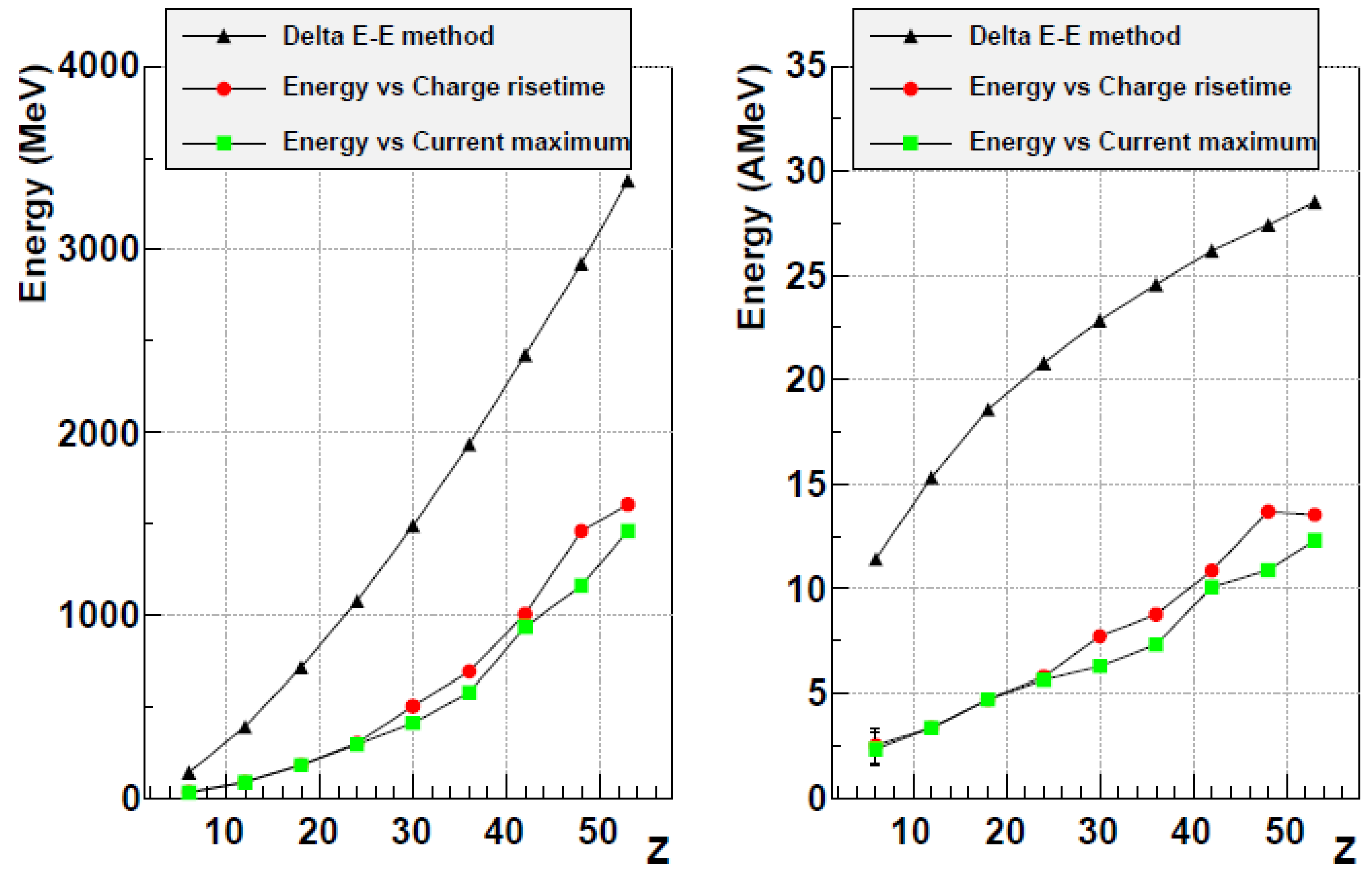


Digital PSA results:
one digitizer,
0.7 GeV full scale
Please note that a higher gain provides a sizable advantage once timing - as in pulse shape- is concerned

Present Detector performance

Recently at LNS an experiment showed the present available performance of our detectors (S.Carboni et al, NIMA – available on line)

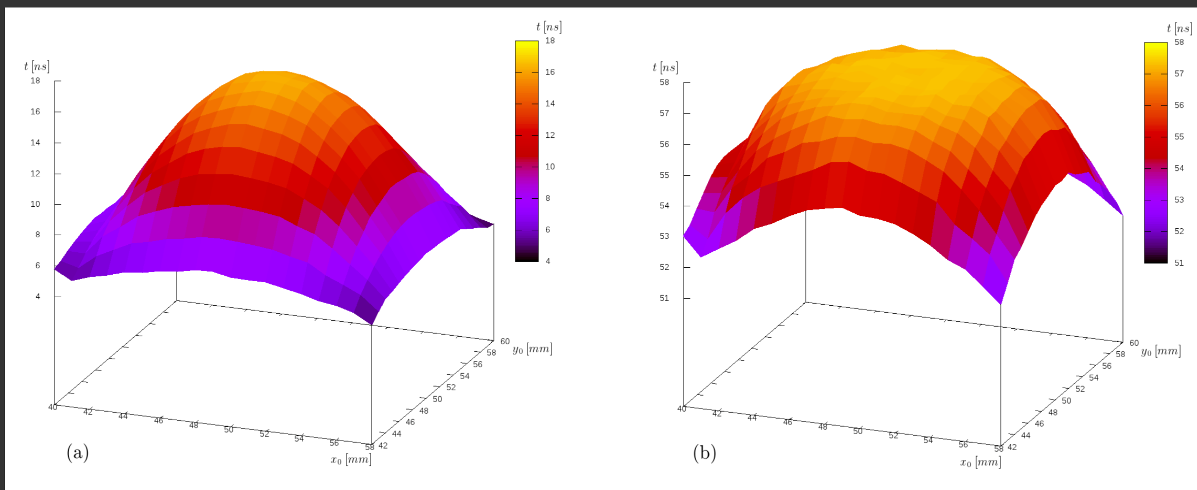
The energy thresholds for particle identification. Sizable improvement with respect to DE-E method (comparison with 300µm Si). Atomic number is identified for penetrations from 30 to 80 µm, depending on Z



Detector optimization: other issues

Further issues have been addressed and solved about Silicon detectors:

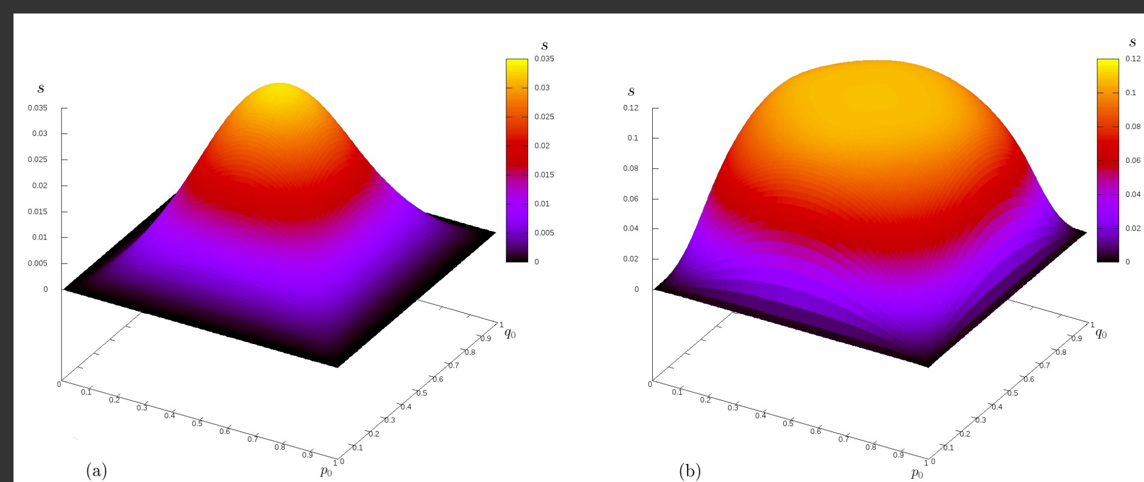
- *Reduction of sheet resistance, necessary to remove any position dependence of the timing*



Experimental distribution of delay (left) and rise-time (right) as a function of the impact point. Data have been collected using light point-like, sub-ns Q-switched laser pulses (first production detectors). Variations in the ns region are measured

---

Calculated distribution of delay (left) and rise-time (right) as a function of the impact point. Calculations have been done by analytic solution (S.Valdré – Diploma Thesis 2009).
20-30 nm Aluminum deposition is necessary to confine any position dependence to a < 100 ps level



Present Detector performance

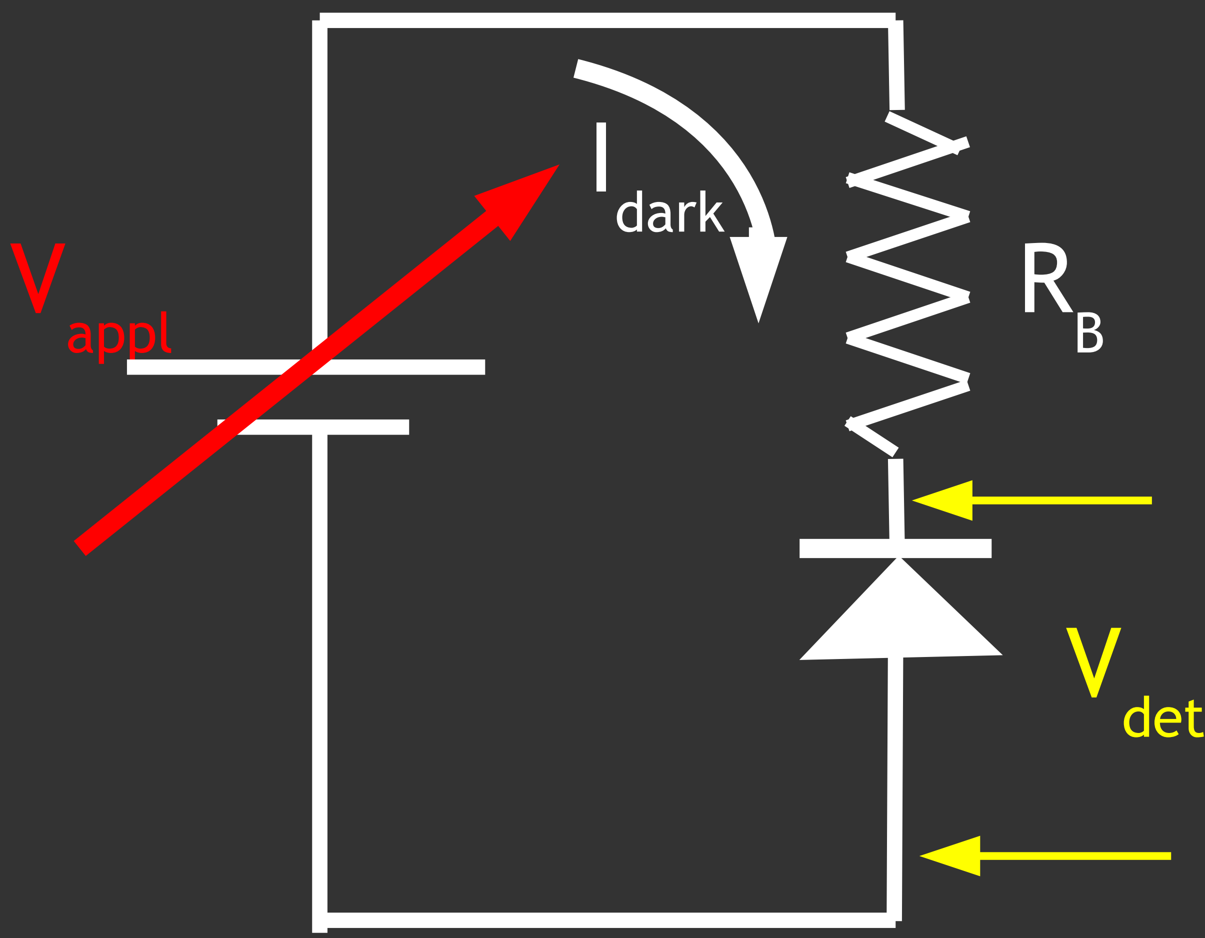
Further issues have been addressed and solved about Silicon detectors:

- *Reduction of sheet resistance, necessary to remove any position dependence of the timing*

Two weeks ago at LNS an experiment showed that the present metallization applied by FBK to our detectors (25 nm Al – according to the recipe of S.Valdré) of both electrodes guarantees sub-ns timing performances over the full area of the detector while maintaining the necessary semi-transparency for the doping uniformity tests.
The estimate of S.Valdré was fully correct. We better publish his results...

Detector optimization: other issues

Do not forget basic principles. Careful control of the applied voltage to the detector is mandatory: electric field must be constant as a function of time to ~1% or better for PSA applications.



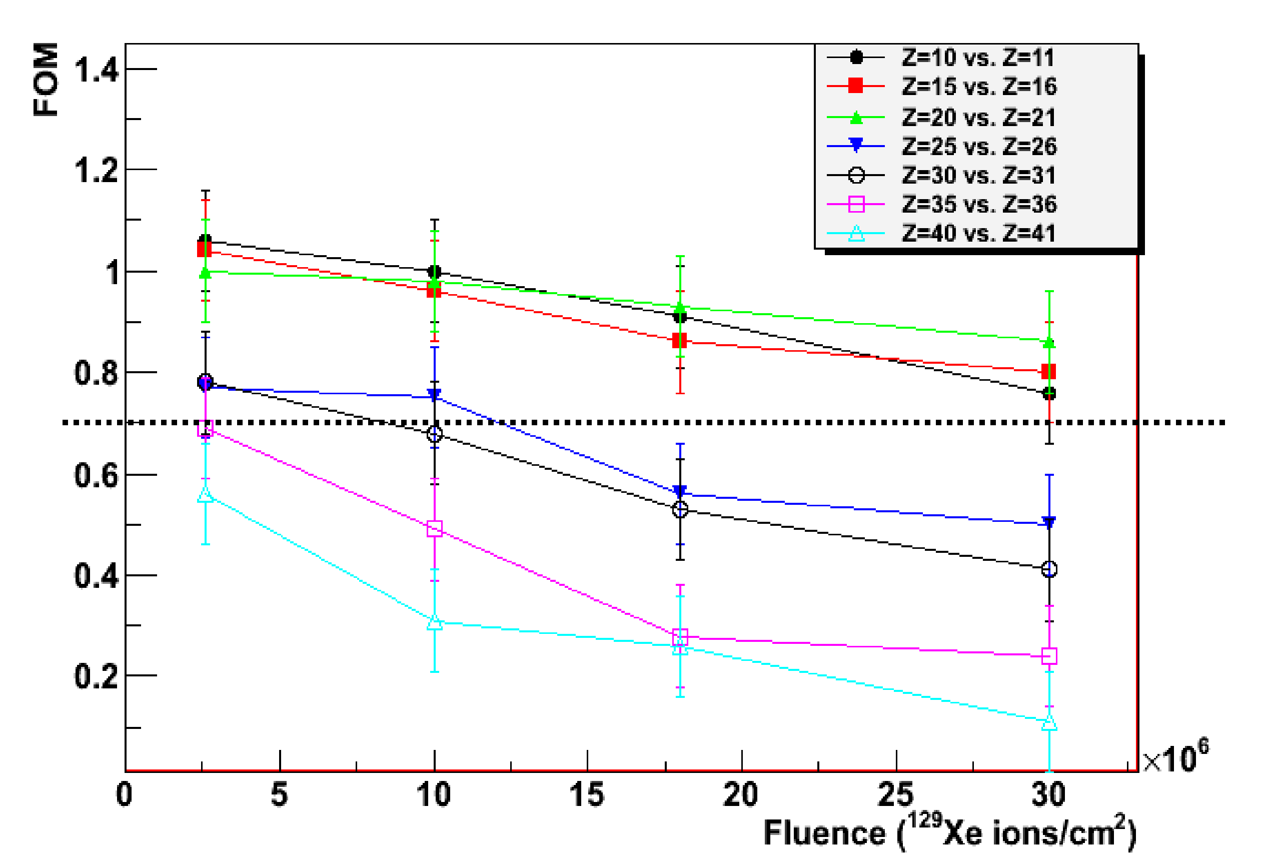
If I_{dark} changes (normally increases) V_{appl} is modified in order to compensate for the voltage drop on the bias resistor R_b -- normally a high value for reducing the electronic noise.

<u>All our bias systems are provided with an automatic control to keep V_{det} constant to well within 1%.</u>

<u>It is indeed very important</u>

Radiation Damage and PSA

Radiation damage effects on pulse shape has been studied. A paper from S.Barlini et al will be shortly submitted for publication

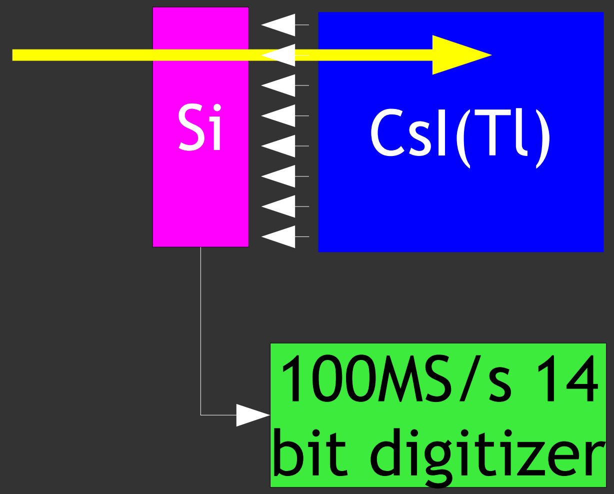


Detector exposed to a high flux of elastically scattered Xenon ions

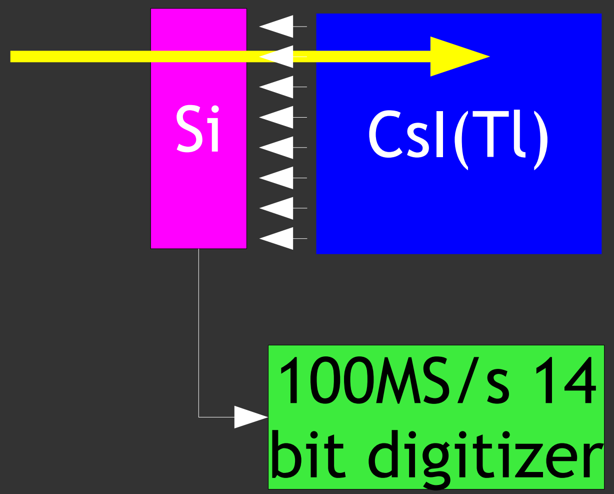
The final conclusion: in order to keep the optimal performance level of PSA in Silicon for the highest examined Z values, the fluence of <u>heavy implanted ion</u> in the detector has to be kept to a value lower than about few 10^7/cm^2 (S.Barlini et al, to be published)

The fancy "Single Chip" solution

From an our old idea, implemented with analogue electronics (G.Pasquali et al, NIM A 301 (1991) 101): a reverse mounted Silicon detector can act both as a ionization detector and as a photodiode.
Analogue implementation required two different shaping constants in order to separate the ionization and the fluorescence components.
Digital shaping looks much more promising and suited to the purpose....

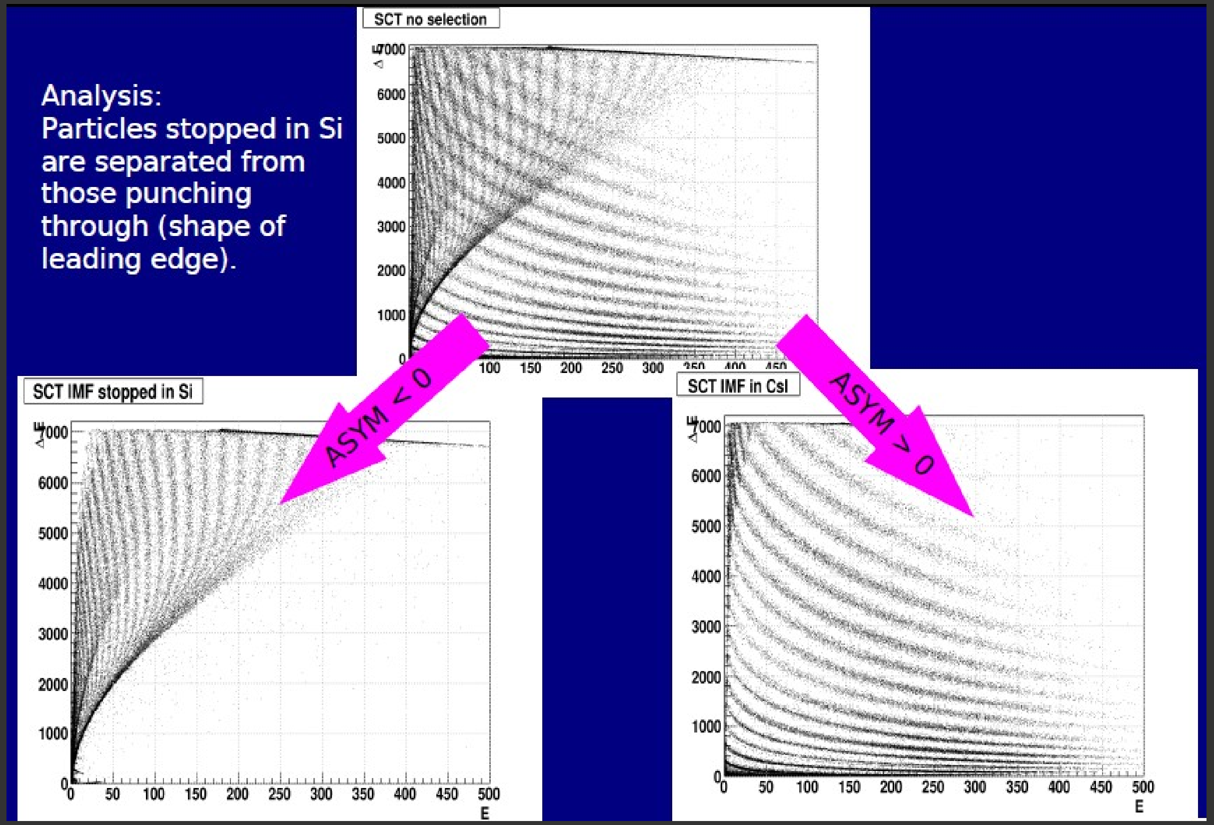


The fancy "Single Chip" solution



Some sophisticated digital processing is necessary for disentangling the ionization and fluorescence components (G.Pasquali, to be published)

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



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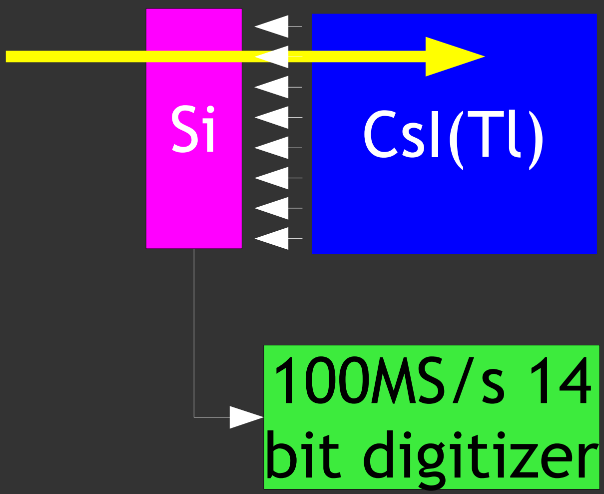
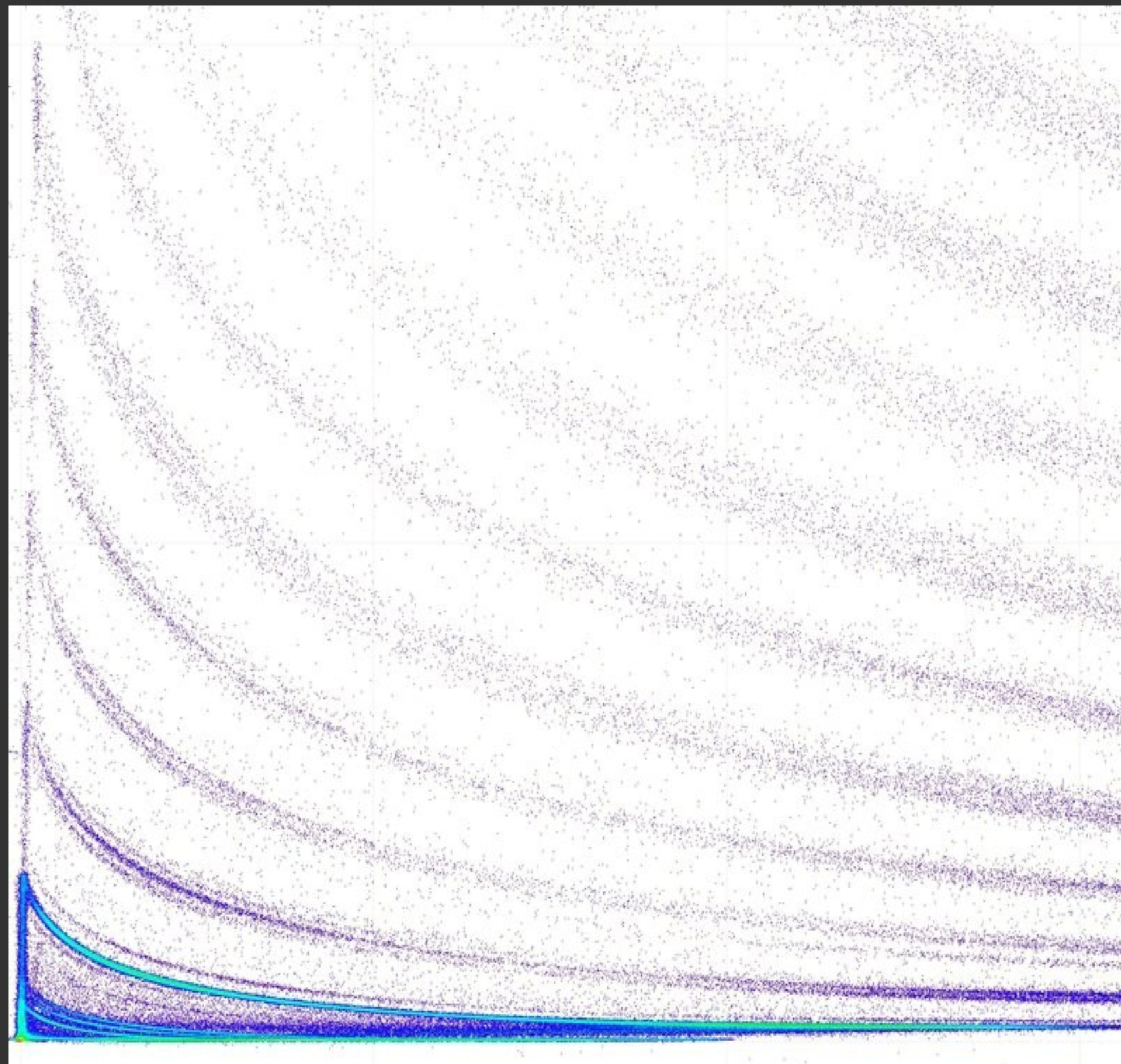


Single chip telescope: 1 readout channel for two detectors + digital signal processing. Results are quite similar to standard operation. The solution appears very well apt to backward angles



FAZIA demonstrator
(2011-2015)

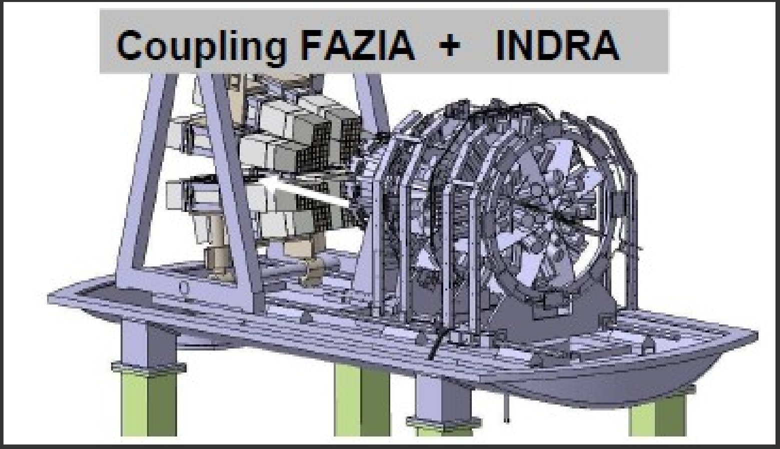
FAZIA PHASE2 “demonstrator & physics” :

• **Build a demonstrator with 192 telescopes Si/Si/CsI with “all” the final (4π detector) electronics and mechanical solutions.**

• **With this demonstrator coupled to existing multi-detectors (INDRA will be the first one), run experiments (GANIL, SPIRAL2, LNL/SPES, LNS).**

12 BLOCKS
48 MODULES
192 TELESCOPES Si/Si/CsI

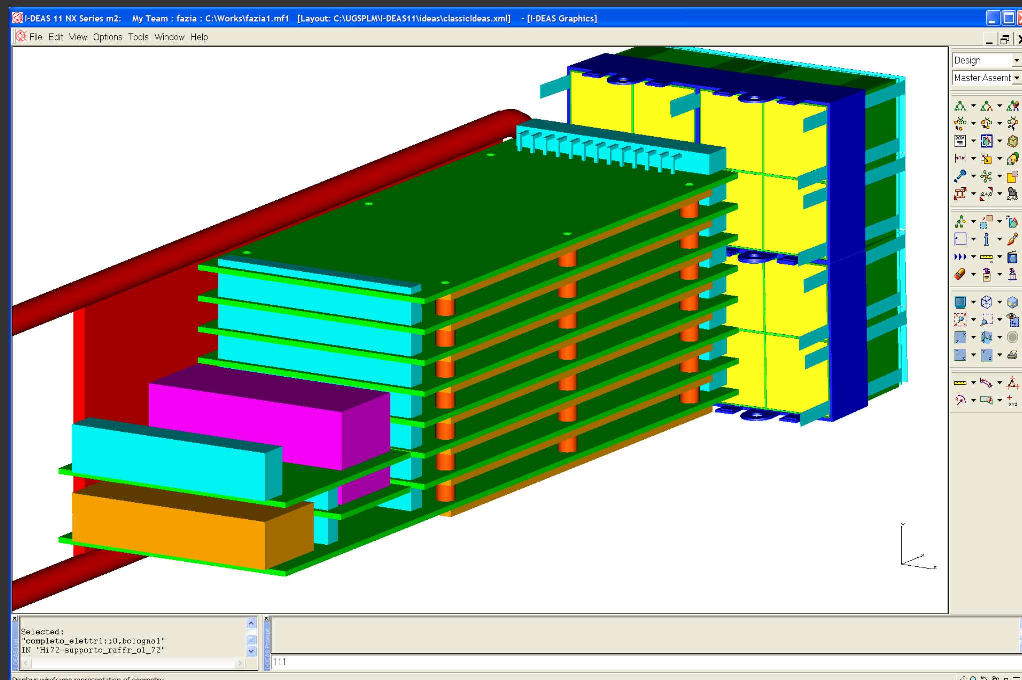
- Telescope			
Si(300μ)	- charge	250 MeV f.s.	250 Ms/s 14 bit
	- charge	4 GeV f.s	100 Ms/s 14 bit
	- current		250 Ms/s 14 bit
Si(500μ)	- charge	4 GeV f.s	100 Ms/s 14 bit
	- current		250 Ms/s 14 bit
CsI(phdiode)	- charge	4 GeV f.s	100 Ms/s 14 bit



FAZIA Phase2 demonstrator

TECHNICAL CHOICE :

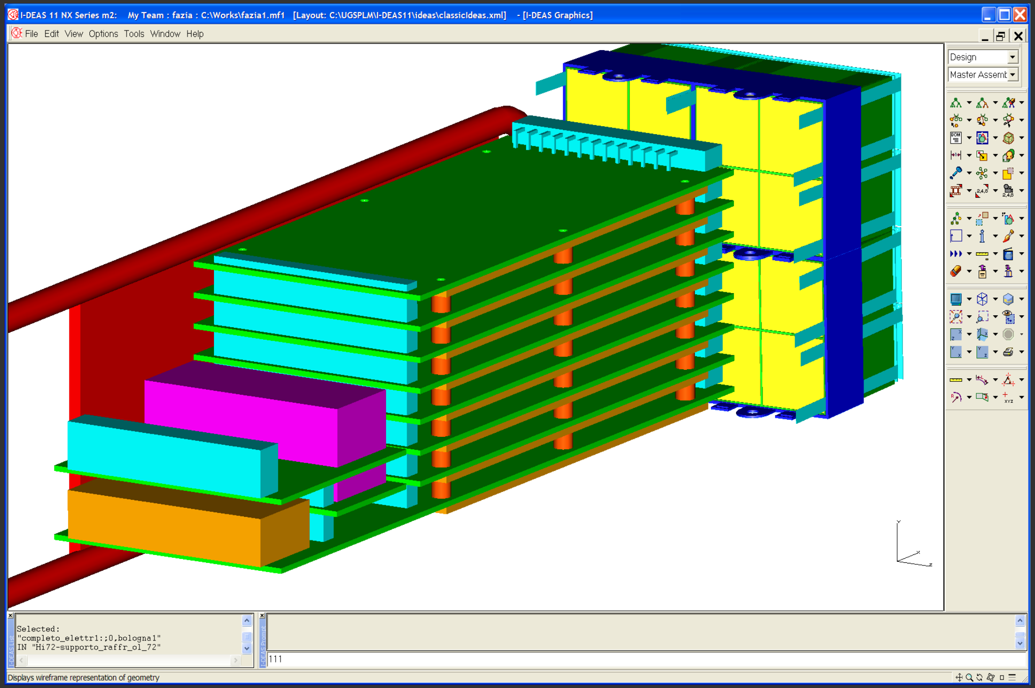
Digitize as close as possible /preamplifier



- 16 telescope “Block” structure
- 8 analog./dig. cards
- with mother board (communication , HV and “low bias”)
- 1 optical fiber per “Block” (3Gbit/s)
- Necessity of under vacuum operation for the FEE!

FAZIA Phase2 demonstrator

TECHNICAL CHOICE :
Digitize as close as possible /preamplifier



The main subgroups involved are

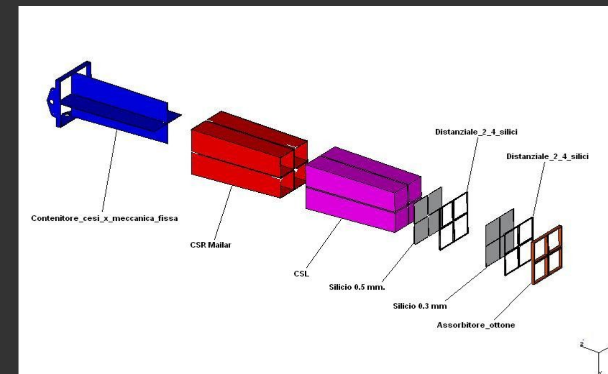
- Orsay: FEE
- Napoli: Data Transmission, Acquisition, Cooling and Mechanics
  (see the contributions to this Workshop by A.Boiano and G.Tortone)
- LPC: Mechanics (including coupling with INDRA)
- Bologna: Mechanics

FAZIA Phase2-demonstrator

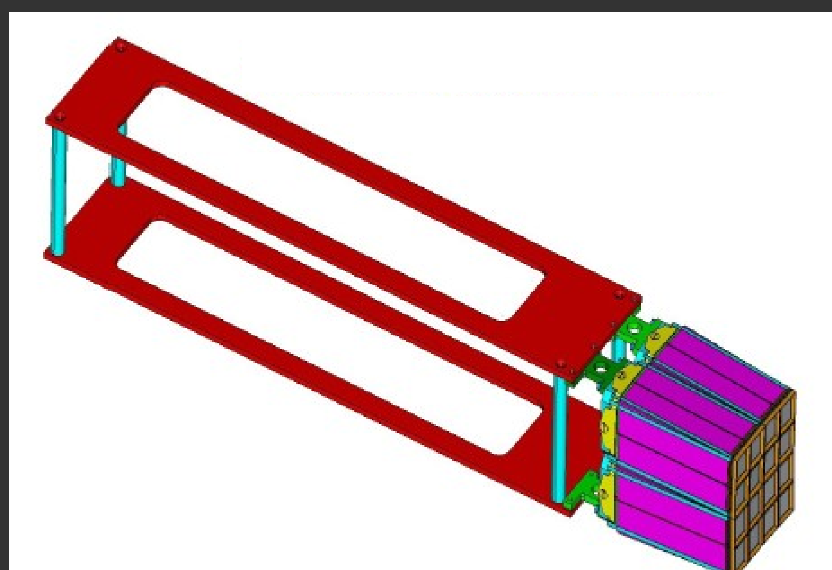
MILESTONE 2012

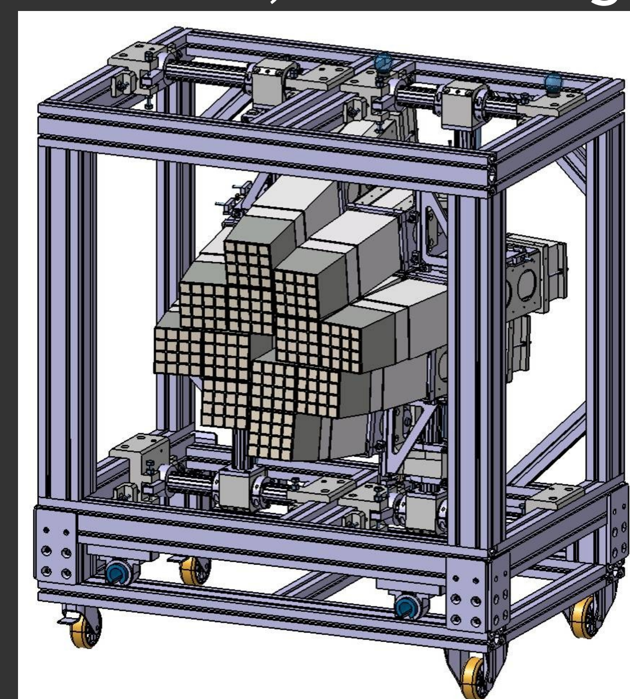
1 Block of telescopes for ½ 2012

- Mechanics for the telescopes
- Backplane for 8 FEE (each 6 channels)
- Cooling system
- Block card with opt. fibber
- Regional level and DAQ architecture and Trigger.



M.Guerzoni, INFN-Bologna





Y.Merrer, LPCCaen

FAZIA Phase2-demonstrator

As witness: the Parties have caused this Memorandum of Understanding to be duly signed by the undersigned authorized representatives in separate signature pages, the day and year first above written.

ISTITUTO NAZIONALE DI FISICA NUCLEARE (INFN)

Date: 30 GIU. 2011

Signature: 31 AOUT 2011

Name: Roberto PETRONZIO

Titles: President

8. **Signatures**

As witness: the Parties have caused this Memorandum of Understanding to be duly signed by the undersigned authorized representatives in separate signature pages, the day and year first above written.

INSTITUT NATIONAL DE PHYSIQUE NUCLEAIRE ET DE PHYSIQUE DES PARTICULES / CNRS (IN2P3)

Date: 31 AOUT 2011

Signature:

Name: Jacques MARTINO

Titles: Director

As witness: the Parties have caused this Memorandum of Understanding to be duly signed by the undersigned authorized representatives in separate signature pages, the day and year first above written.

GRAND ACCELERATEUR NATIONAL D'IONS LOURDS (GANIL)

Date: 5 Septembre 2011.

Signature:

Name: Sydney GALES

Titles: Director

As witness: the Parties have caused this Memorandum of Understanding to be duly signed by the undersigned authorized representatives in separate signature pages, the day and year first above written.

CONSORTIUM OF POLISH GOVERNMENTAL AND PUBLIC INSTITUTIONS (COPIN)

Date:

Signature:

Name: Marek JEŻABEK

Titles: Director

As witness: the Parties have caused this Memorandum of Understanding to be duly signed by the undersigned authorized representatives in separate signature pages, the day and year first above written.

INSTITUTUL NATIONAL DE CERCETARE -DEZVOLTARE PENTRU FIZICA SI INGINERIE NUCLEARA "HORIA HULUBEI" (IFIN-HH)

Date:

Signature:

Name: Nicolae Victor ZAMFIR

Titles: Director General

MOU signed by all the partners: INFN, CNRS, GANIL, COPIN (Poland), IFIN-HH (Rumania)