FAZIA: *prototyping a next-generation 4π detection array for reaction dynamics studies with RNBs*

Contents:

- **Heavy-ion reactions with *RNB* around *Fermi* energy as a probe of the isospin dependence of the nuclear EoS *(e.g. Symmetry Energy)***
- **Very demanding detectors are needed, in terms of A, Z identification, ToF and Energy measurements with improved transportability**

FAZIA R&D: testing and applying novel solutions

- **Charge + Current preamplifiers + Fast Analogue Pipeline**
- **Fully digital electronics for Energy, Pulse Shape Analysis and Timing**
- **Si-Si-CsI *non-standard* telescope**

FAZIA Organization and Phases

State-of-the-art dynamical simulations applied to heavy-ion collisions with exotic isospin contents **produce observables sensitive to the symmetry energy and to its dependence on density and surface effects**

(see for instance Ono et al - PRC 70 (2004), V.Baran et al – Phys.Rep. 410 (2005))

A "paradigmatic" observable: *the isotopic ratio R_{21}*

For homogeneously selected events of a given pair of reactions r_1--r_2, characterized by "different isospin contents" *(e.g. $^{124}Sn + ^{64}Ni$ -- $^{112}Sn + ^{58}Ni$)*, R_{21} is the ratio of the *experimental (or simulated) yields* $Y_{2,1}(N,Z)$ of a given isotope in the two reactions:

$$R_{21}(N,Z) = Y_2(N,Z)/ Y_1(N,Z)$$

Under somewhat general *(though still debated...)* assumptions

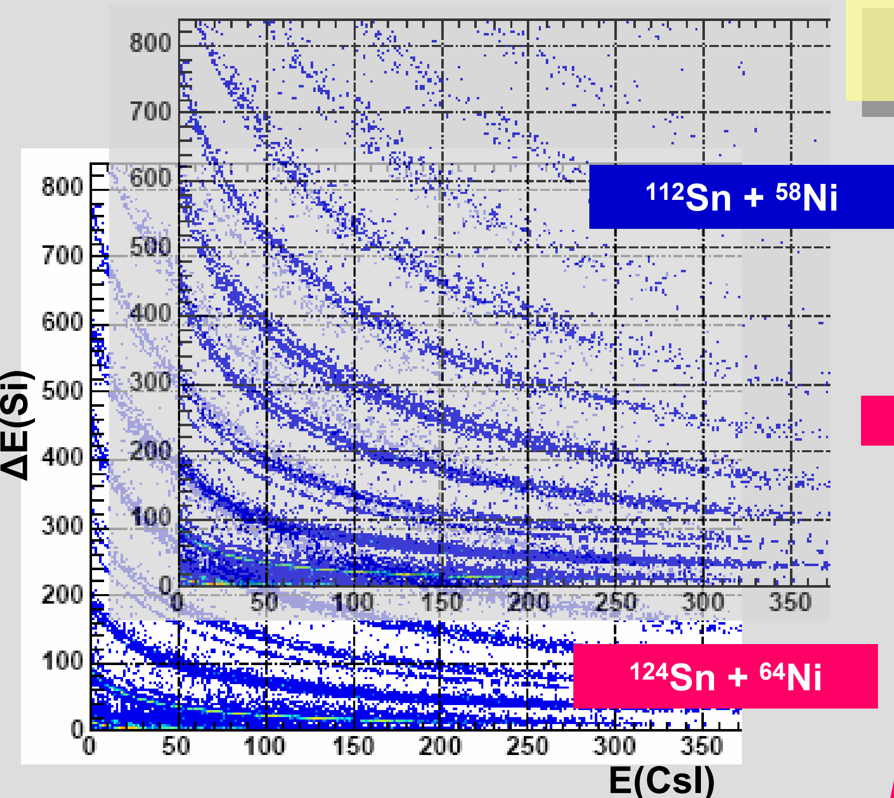
$$R_{21}(N,Z) \sim C_{sym} / T$$

with T, temperature of the selected emitting system

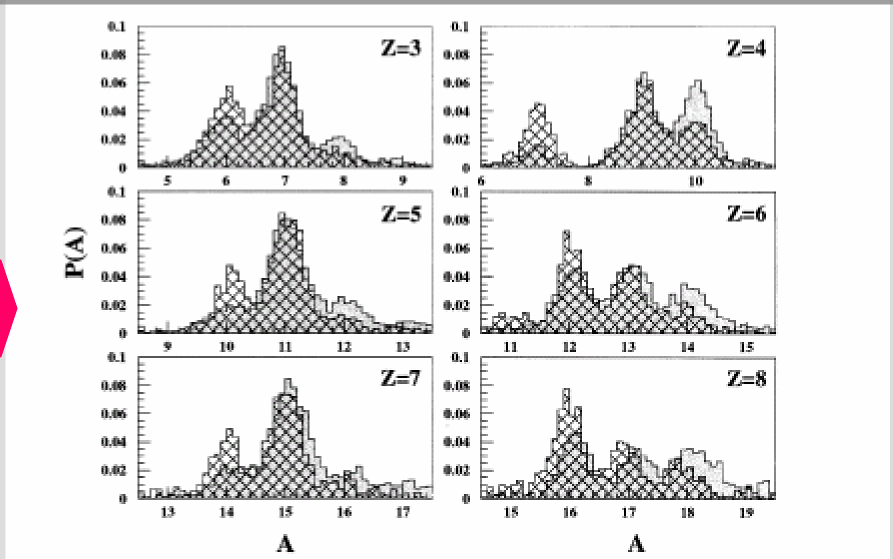
The more exotic the system, the better the sensitivity for the symmetry energy determination

The temperature T can also be extracted from the various isotope yields

How is R_{21} extracted? An example: *(Le Neindre et al (CHIMERA)– NIMA 490 (2002) 251)*



Shaded and hatched areas refer to two different reactions: $^{124}Sn + ^{64}Ni$ and $^{112}Sn + ^{58}Ni$ respectively



$$R_{21} = Y_2(N,Z)/\,Y_1(N,Z) \sim C_{sym} / T$$

Other important features (usually lacking in 4π arrays):

***Very high granularity for nuclear interferometry** (disentangle between primary and secondary fragments)*

***Reduced material (or easily removable)** for possible insertion of neutron detectors*

An updated overview of the best performing H.I. arrays (INDRA, CHIMERA, HiRA) is available here:

http://cyclotron.tamu.edu/wci3/newer/chapVI_1.pdf

None of these detectors matches all the requirements needed for a long term Physics program aimed at determining the nEoS with RNBs

The FAZIA (Four Pi Z and A Identification Array)

initiative ***(about 70 physicists from France, Italy, Poland, Spain, Rumania,Canada, India and USA)*** **was formalized to define a Physics program aimed at studying the dynamics and thermodynamics (nEoS) of H.I. reactions around *Fermi energies* with RNBs.**

A first R&D phase dedicated to studying new solutions for:

- ***Increasing the dynamic ranges of E, Z and A identification, keeping the ToF capability***
- ***Designing a transportable heavy-ion detector array: various beam energies, necessary operation at various RNB facilities***
- ***Aiming at a detector as versatile, thin and compact as possible: integration with other specialized detectors (e.g. interferometers, spectrometers), possibility of detecting neutrons***

Most of the "*FAZIANS*" ripened their expertise in the *AZ4π Franco-Italian initiative*

FAZIA: PROTOTYPING A NEXT-GENERATION 4Π DETECTION ARRAY

The prototype under study

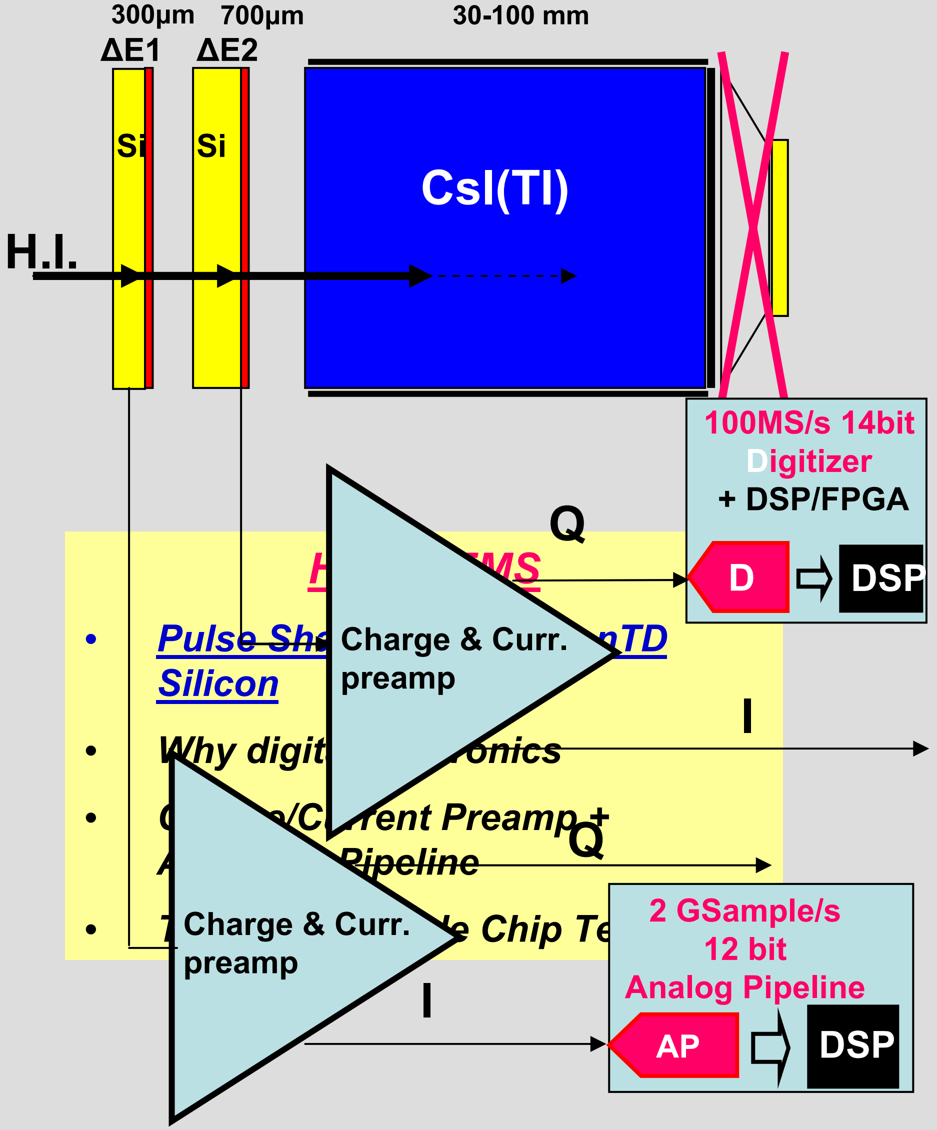
Detector and front end electronics:

Three stage ΔE-ΔE-E (Si-Si-CsI telescope)

- Pulse Shape Analysis in the first reverse-mount *nTD* Silicon detector to extract Z and A with low thresholds, also exploiting ToF
- a Silicon pair of 300μm + 500-700 μm for high-resolution standard A and Z identification
- a few cm thick CsI(Tl) for stopping more penetrating particles
- with a possible novel solution for the second ΔE-E stage
- Charge-and-Current preamplifier (PACI) for improving pulse shape analysis

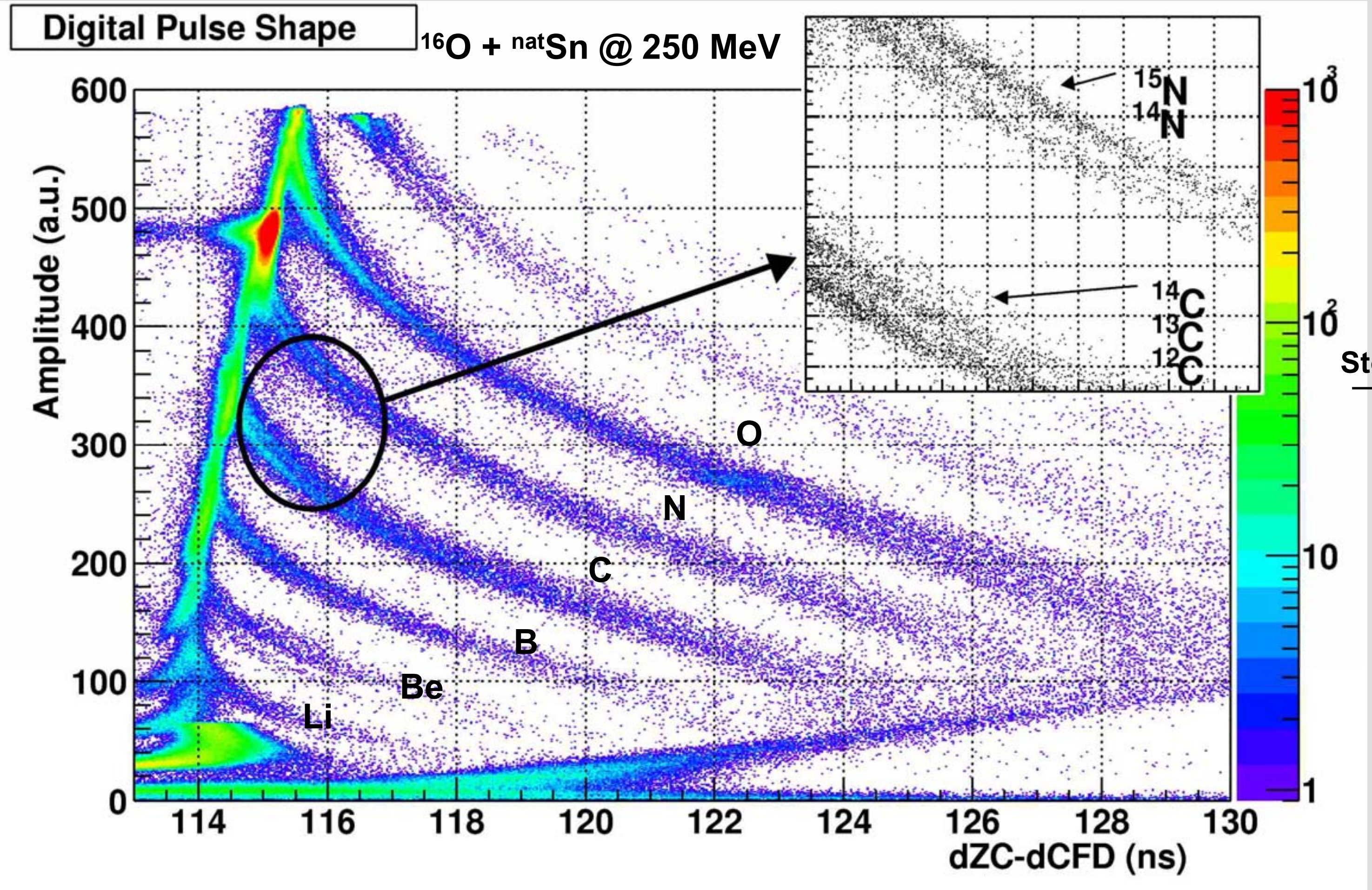
Back-end electronics:

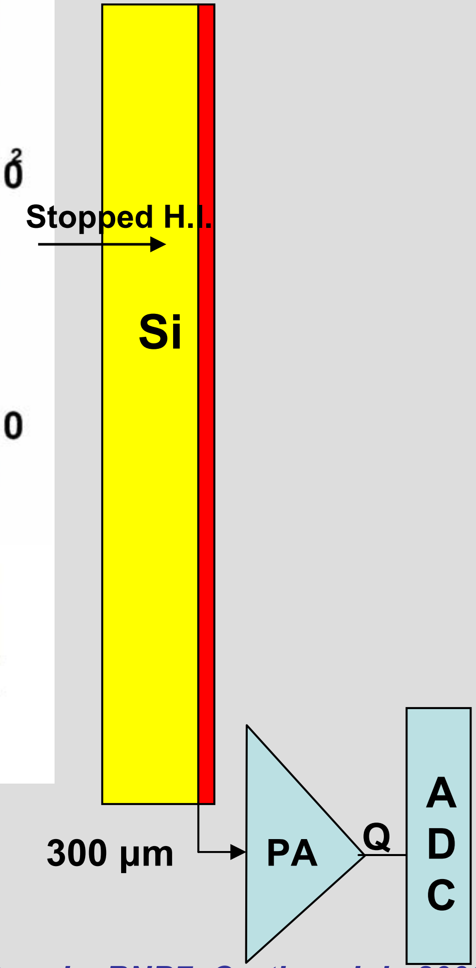
- Fully Digital Electronics for on-line signal treatment



Digital Pulse Shape analysis of *charge signal*. Particle identification of particles stopped in a "reverse mounted" Silicon detector.

L.Bardelli et al: NP A746 (2004) 272





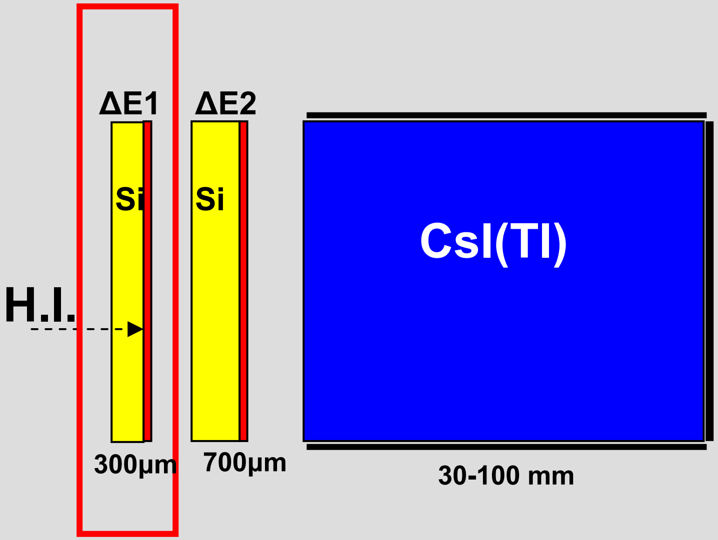
Thresholds are around 2 AMeV for Z=6. Present upper limit is around Z ≅ 20. How far can we go?

Pulse Shape Analysis of particles stopped in nTD Silicon: a promising approach to significantly lower the energy for Z (and A?) identification capability → *see E vs risetime.*

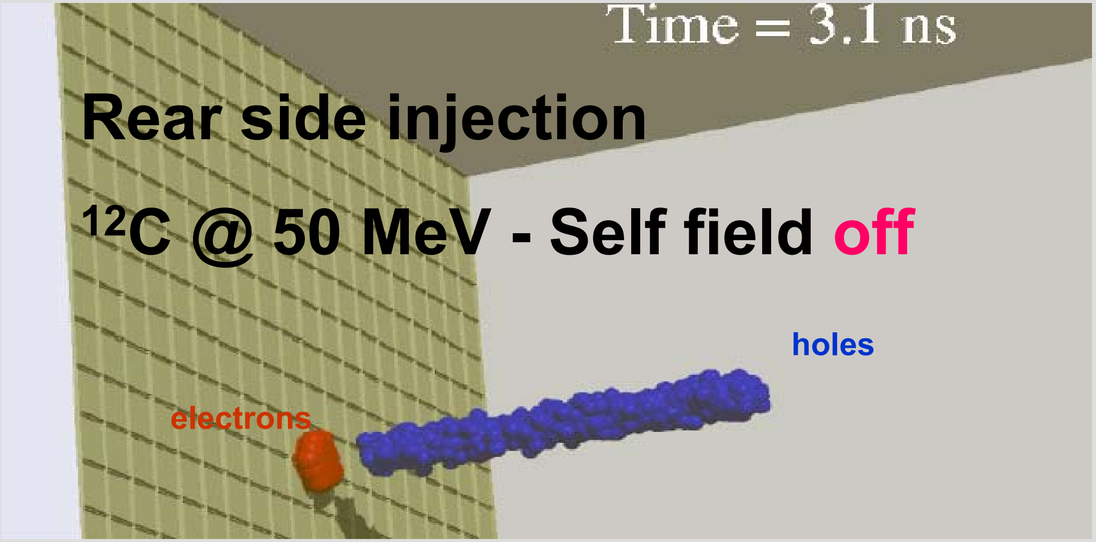
In order to improve discrimination algorithms is necessary to *understand the Physics of the "plasma delay" process.*

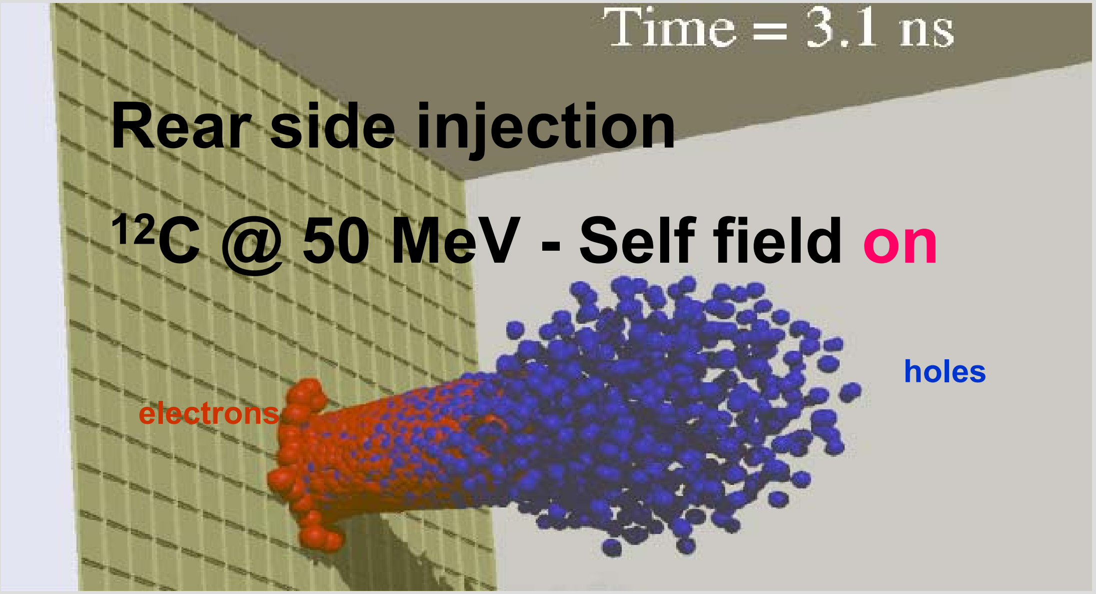
A *first-principles approach to "plasma delay": no free parameters and only the electrostatic e-h interactions in the ionization wake* are considered.

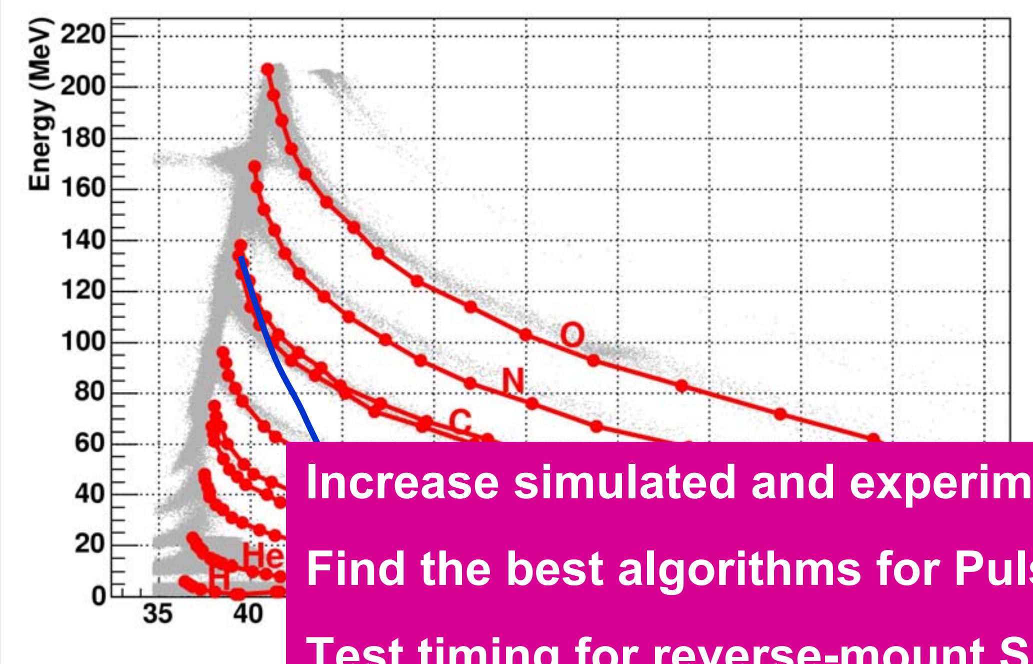
Many complications for the numerical implementation: huge number of involved elementary carriers (electrons and holes)…



Plasma effects in the ionization wake and Coulomb self-field *(Bardelli et al – in preparation)*







PSA on charge signals: exp & sim

Silicon Rear injection
Digital Pulse Shape
experiment and simulation
Experiment → *L.Bardelli et al: NP A746 (2004) 272*

L.Bardelli et
ion

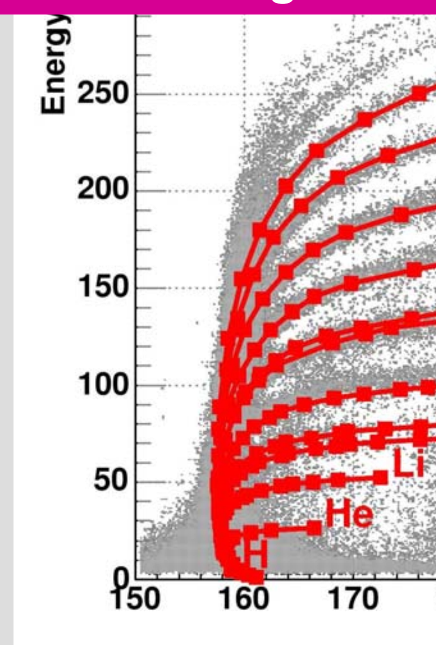
- **Increase simulated and experimental data base**
- **Find the best algorithms for Pulse shape analysis**
- **Test timing for reverse-mount Silicon**
- **Test channeling effects for higher Z**

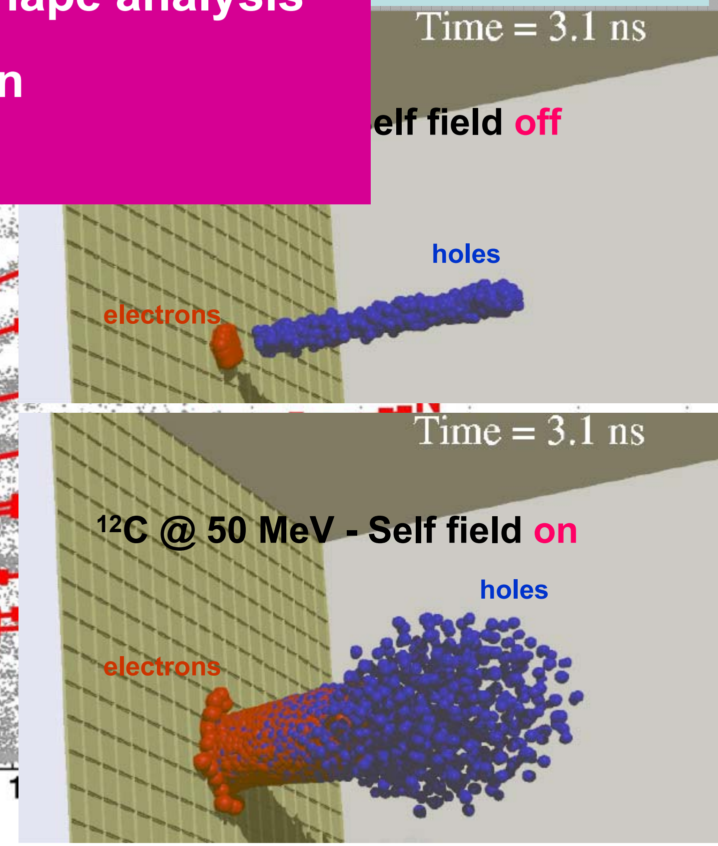
Silicon Fron
Digital Pulse Shape
experiment and
simulation

Experiment: Chimera Coll.
LNS Report 2004, 129

Simulation: → L.Bardelli et al in preparation

Tuning is under way to control numerical instabilities for higher Z ions





FAZIA: PROTOTYPING A NEXT-GENERATION 4Π DETECTION ARRAY

Some envisaged solutions for the prototypes

Detector and front end electronics:

Three stage ΔE-ΔE-E (Si-Si-CsI telescope)

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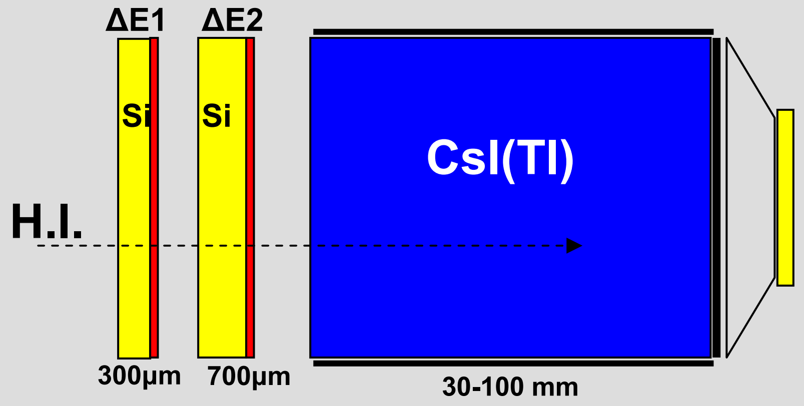


HOT ITEMS

- *Pulse Shape Analysis in nTD Silicon*
- *Why digital electronics?*
- *Charge/Current Preamp + Analogue Pipeline*
- *The Digital Single Chip Telescope*

FAZIA: PROTOTYPING A NEXT-GENERATION 4Π DETECTION ARRAY

Why digital electronics?

ur

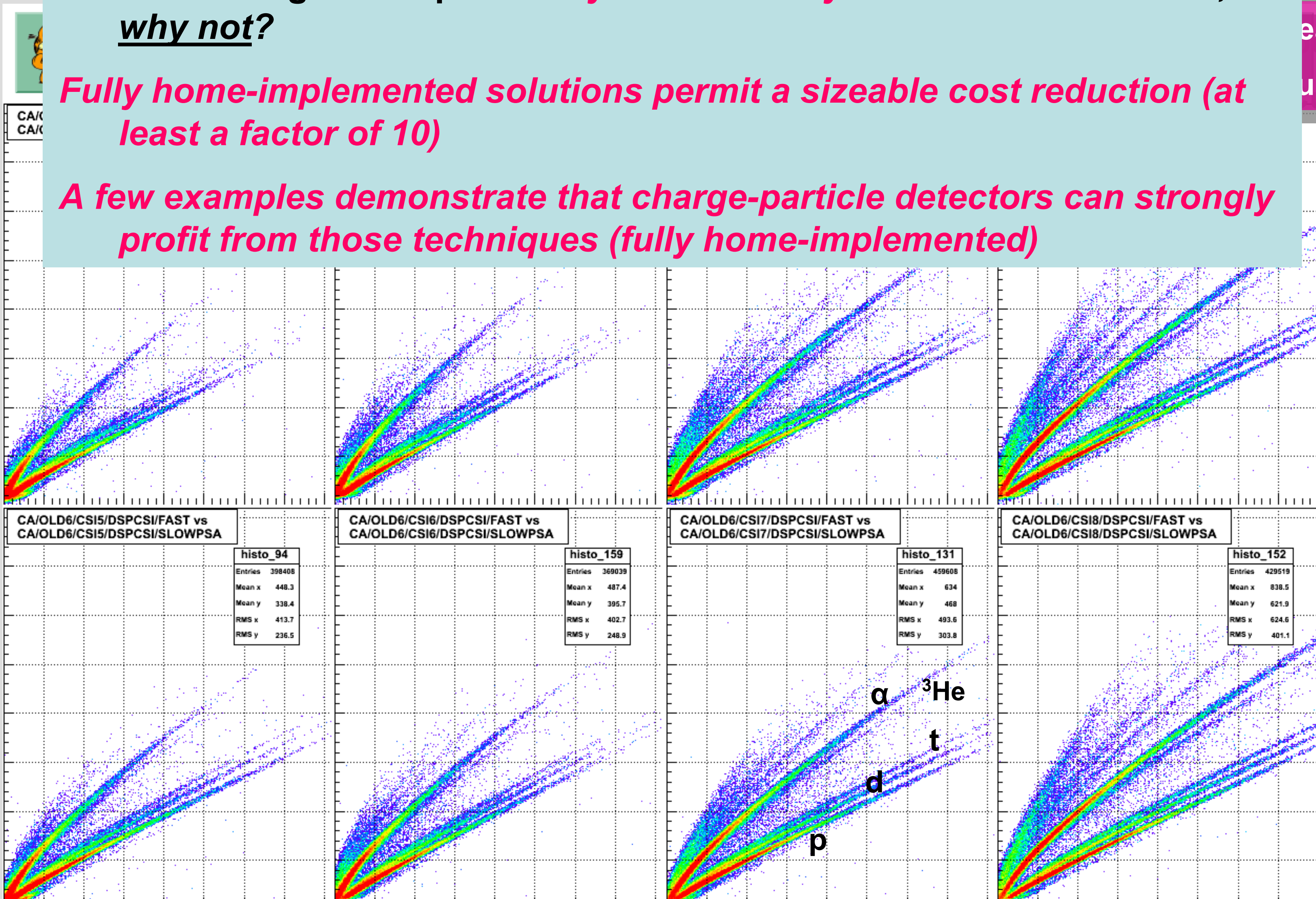
eam - LNL:

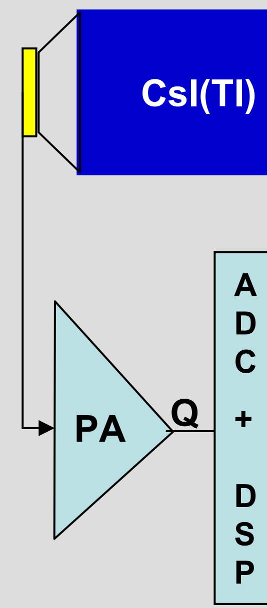
u @ 15AMeV

Once you have good control of the hardware and of the Digital Signal Processing techniques *and you can write your own DSP software*, ***why not***?

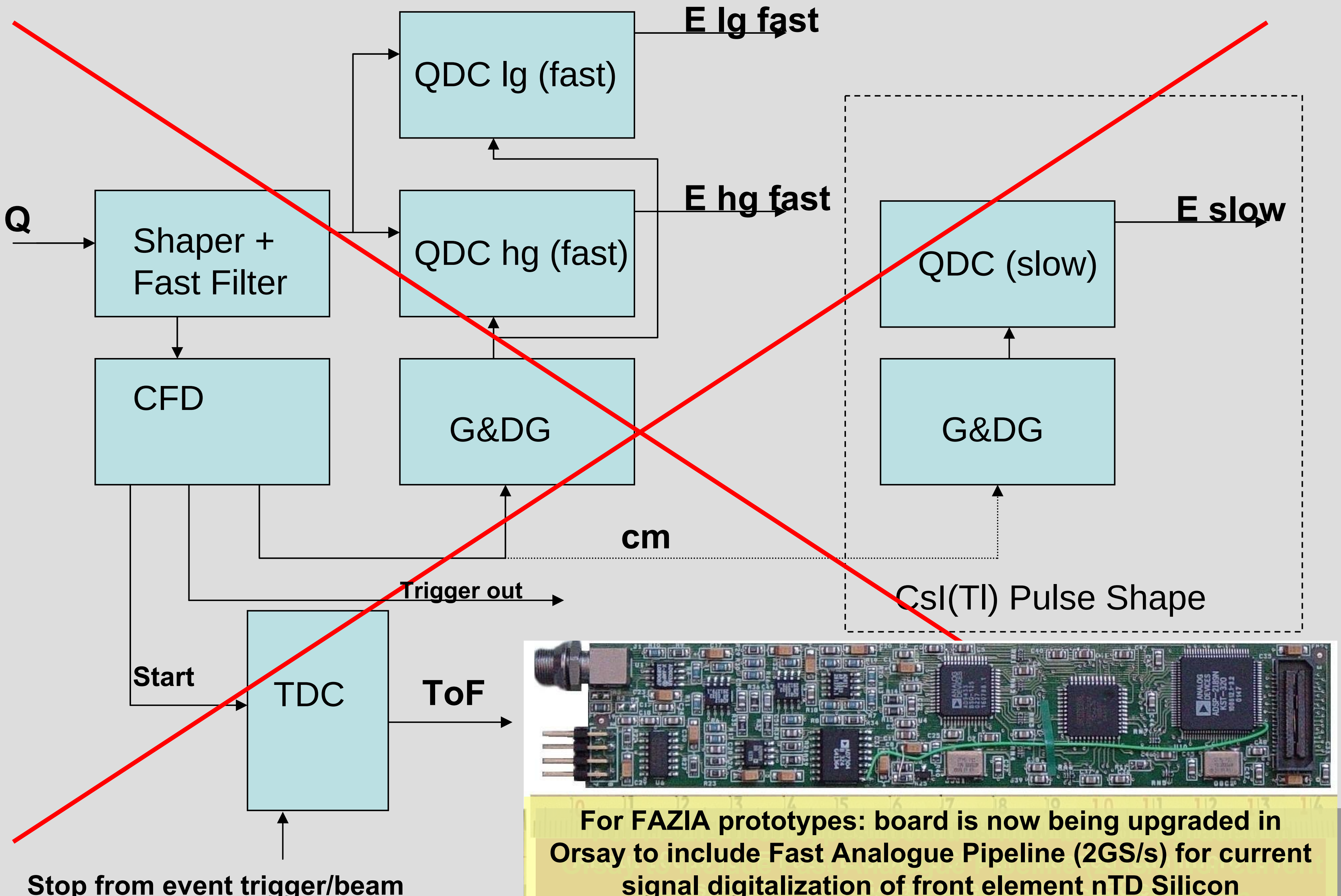
Fully home-implemented solutions permit a sizeable cost reduction (at least a factor of 10)

A few examples demonstrate that charge-particle detectors can strongly profit from those techniques (fully home-implemented)



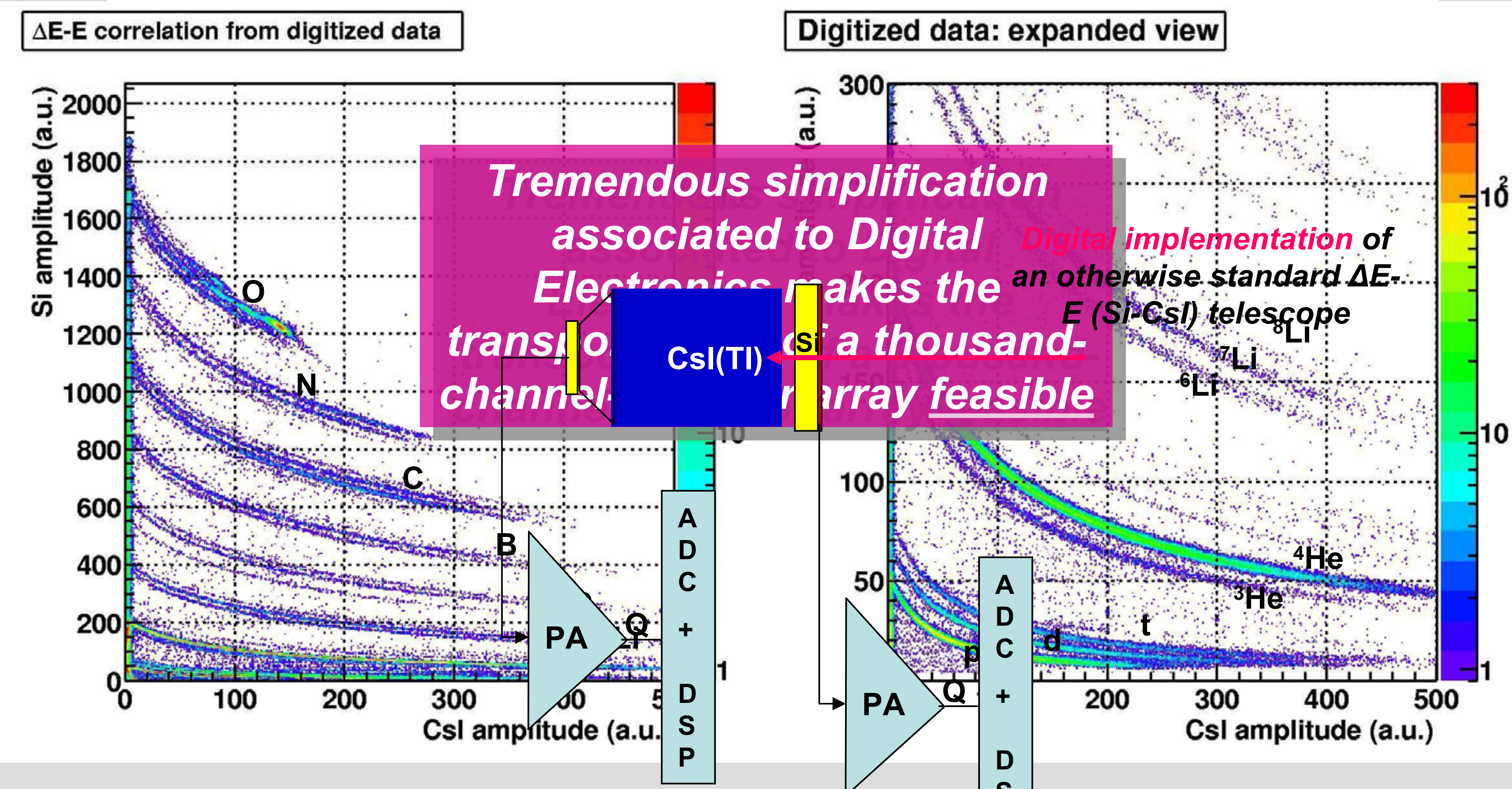


What a fast ADC + *(well programmed)* DSP/FPGA can replace



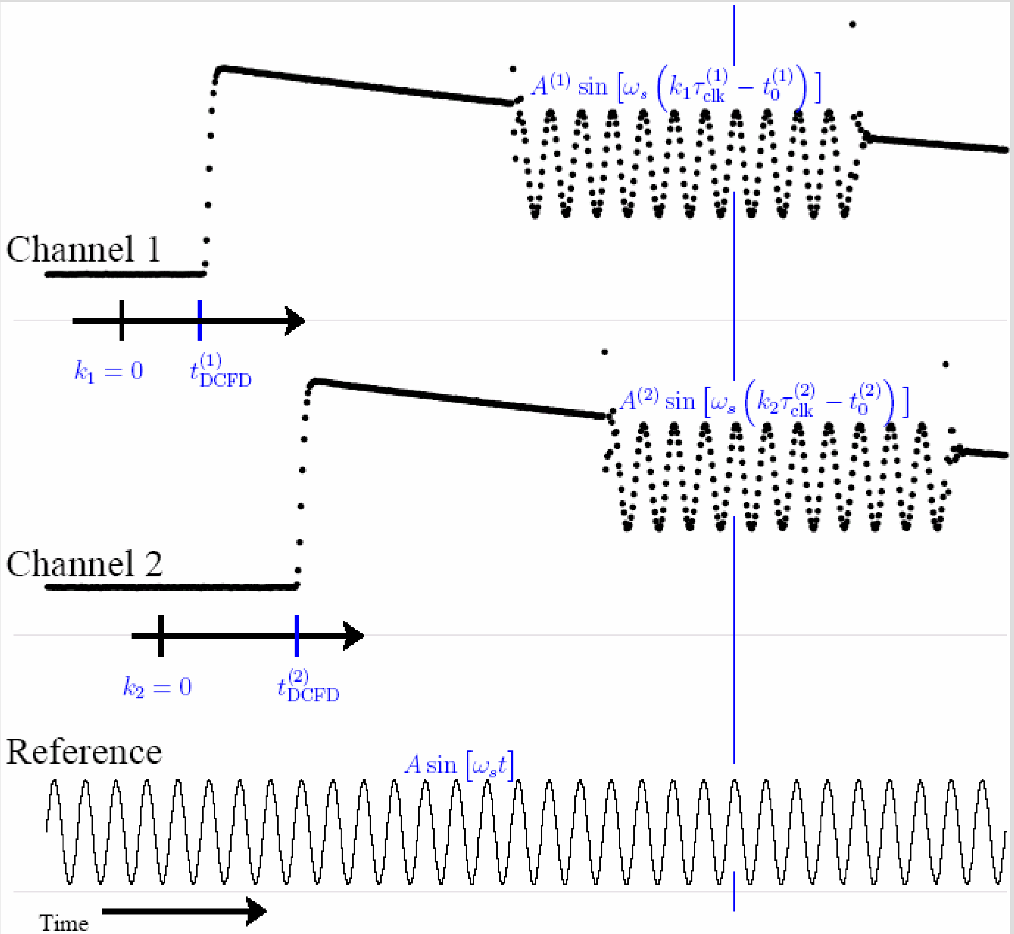
For FAZIA prototypes: board is now being upgraded in Orsay to include Fast Analogue Pipeline (2GS/s) for current signal digitalization of front element nTD Silicon

Digital Standard Si-CsI(Tl) Telescope *L.Bardelli et al:LNL Annual Report (2002)*



"Bit gain" effect: a digital chain based on a *12 bit sampling ADC at 100 MSample/s provides* amplitude measurements with the **same dynamic ranges of an analogue chain with a final** ***16 bit ADC*** *(typically implemented with the two-gain approach)*

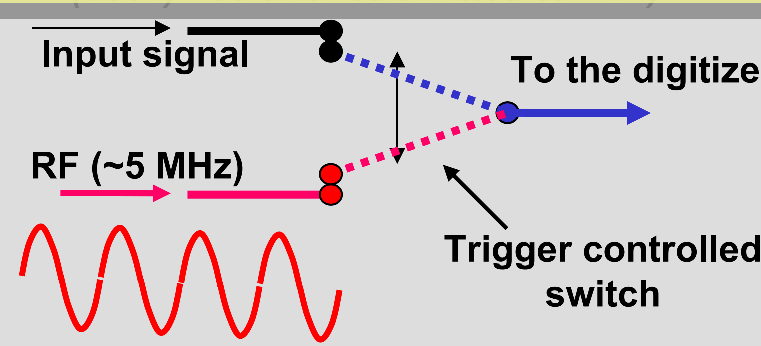
For a quantitative explanation, see 2x(*L.Bardelli and G.P. , NIMA 560 (2006)*)



Digital ToF and synchronization:

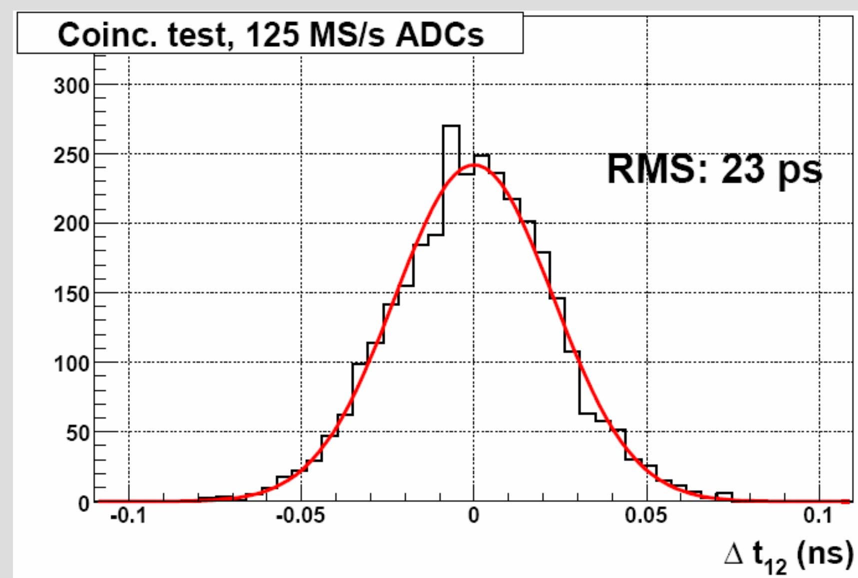
- easy operation and upgrading suggest **independently clocked digitizers**
- how to synchronize them *(at a-few-tens-of-ps level)*?

For trigger-based arrays a solution has been proposed *(L.Bardelli et al: NIM A521 (2004) 480* and *submitted to NIM)*



For Silicon detectors, by sampling with 100-200 MS/s @ 12-14 bits: *"detector-limited" timing*

Dynamic ranges for *digital timing* are expected to be similar to *analogue* implementation: *minor "bit gain" effect*



FAZIA: PROTOTYPING A NEXT-GENERATION 4Π DETECTION ARRAY

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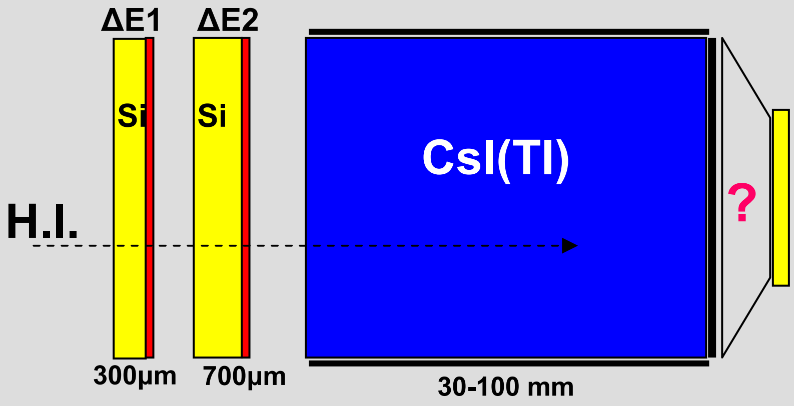

HOT ITEMS

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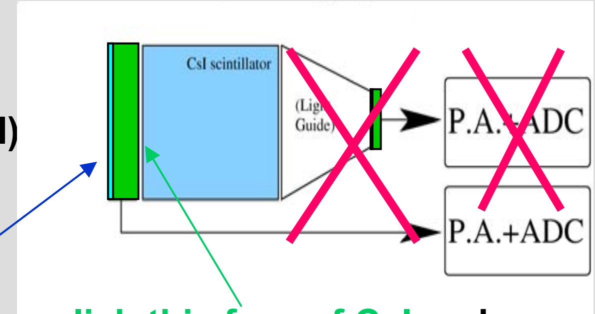
- *Why digital electronics*
- *Charge/Current Preamp + Analogue Pipeline*
- *The Digital Single Chip Telescope*

The Single Chip Telescope (SCT)

A novel, revisited telescope: "Single Chip Telescope"

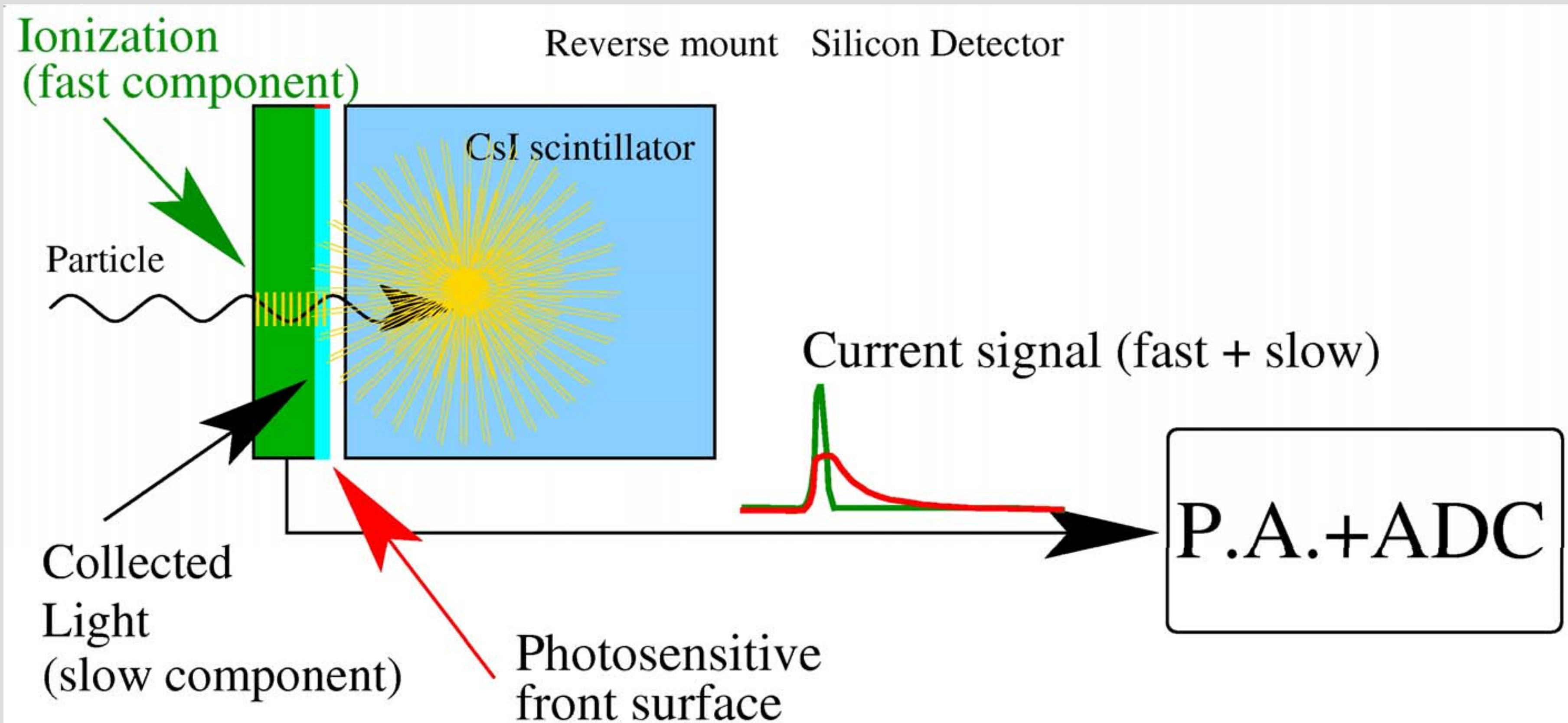
(G.Pasquali et al: NIM A301 (1991) 101)
(L.Bardelli et al: NP A746 (2004) 272)

Standard Si-CsI(Tl) telescope configuration

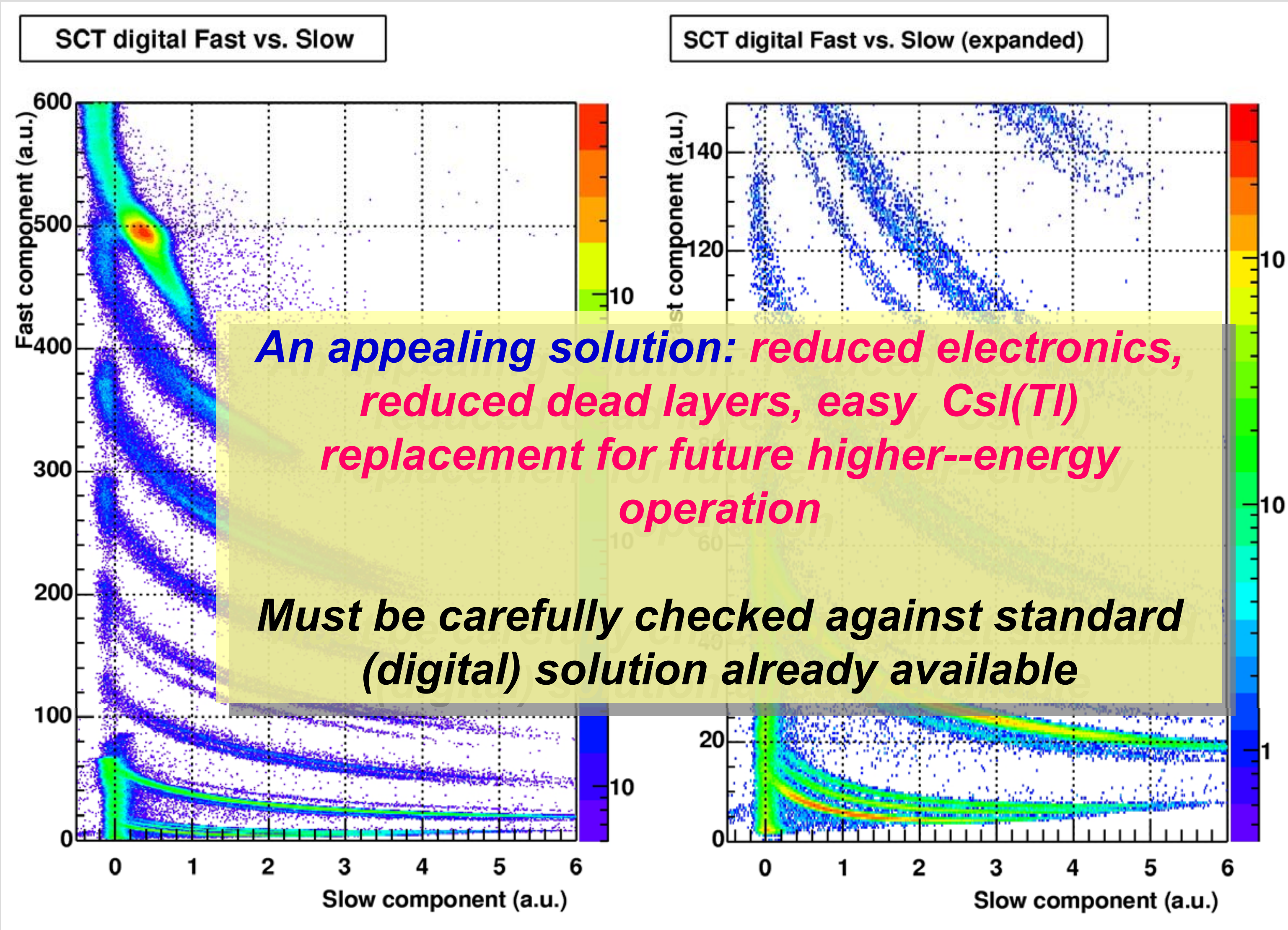


Let's flip Silicon, polish this face of CsI and throw away light guide and phodiode

The Si-CsI(Tl) SCT telescope



Fully digitized Single Chip Telescope



An appealing solution: reduced electronics, reduced dead layers, easy CsI(Tl) replacement for future higher--energy operation

Must be carefully checked against standard (digital) solution already available

RNB6

L.Bardelli et al: NP A746 (2004) 272

The three FAZIA phases

Phase I *(the present up to 2008)*:

- **Elaborate Physics cases to better pin down the final detector characteristics**
- **Test envisaged solutions and build prototypes**
- **Build a Prototype array to test *"under beam"* realistic conditions**

Phase II *(if Phase I passed, from 2008 till 2011)*:

- **build a Demonstrator, to couple with existing arrays and do Physics out of it**

Phase III *(from 2011 and up)*:

- **Build the 4π Array**

Financial support for Phase I (a MoU is in preparation):

•France: ANR + IN2P3

•Italy: INFN and (possibly) from the Ministry of University and Research

•other participating countries submit requests to national funding agencies

•total support for the three-years R&D of the order of 1.5 M€, including Prototype Array

FAZIA: presently involved Institutions and physicists
(+ an almost equal amount of engineers/technicians)

FRANCE:
- INPO (Orsay): B.Borderie, ... N.Le Neindre, ...
- GANIL: A.Chibhi, J.Frankland, J.P.Wieleczko
- LPC (Caen): R.Bougault, E.Galmichelli, O.Lopez, R.Tamain, E.Vient
- IPNL (Lyon): P.Lautesse, ...

ITALY:
- Bologna (INFN & University): M.Bruno, M.D'Agostino, F.Geraci, G.Vannini
- Firenze (INFN & University): L.Bardelli, M.Bini, G.Casini, M.Chiari, A.Nannini, A.O... A.A.Stefanini
- Catania (INFN): M.Baldo, M.Papa*, G.Politi*, G.Verde
- LNL (INFN): F.Gramegna, V.Kravchuk, A.Quaranta
- Napoli (INFN & University) ... M.Vigilante
- LNS: R.Alba*, A.Bonasera, M.Colonna, M.DiToro, D.Santonocito*

SPAIN:
- Huelva: R.Berijillos, J.L.Flores...
- Sevilla: *(HIDE collaboration)*

Eastern Europe:
- Cracow + Katowice: Tomasz Kozik + ...
- Warsaw: A.Kordyasz + ...
- Bucarest: R.Borcea, A.Buta, F.Negoita, H.Petrascu, M.Petcu, A.Raduta

CANADA:
- University of Laval – Quebec: ...

US:
- Western Michigan University: M.Famiano

INDIA: ...

FAZIA : *Four π A-Z Identification Array*

Scientific Coordinator: *G.P.*

Scientific Deputy Coordinator: *R.Bougault*

Technical Coordinator: *P.Edelbruck*

Active working groups and convernors:

- Signal Shape Analysis… *(L.Bardelli)*
- Physics cases *(G.Verde)*
- Preamplifier & front-end… *(P.Edelbruck)*
- Acquisition *(B.Carniol)*
- Semiconductor detectors… *(L.Lavergne)*
- CsI detectors *(M.Parlog)*
- Single Chip Telescope *(G.P.)*
- Detector Design and Integration (R.Bougault & M.Bruno)
- Web site *(O.Lopez)*

Recent non-scientific events are now severely jeopardizing the FAZIA collaboration, in particular the relationship between the two largest parties/teams: France and Italy….