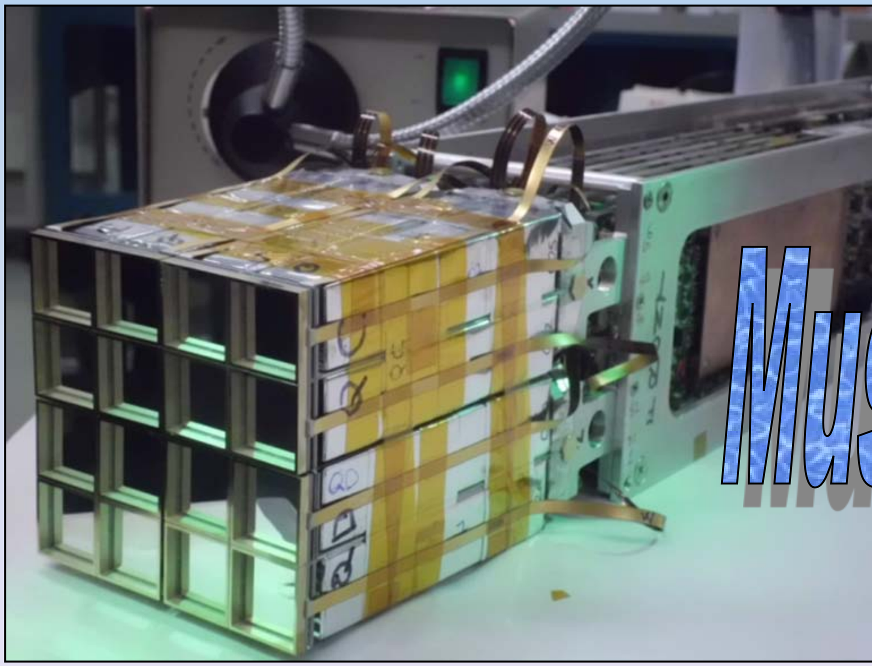
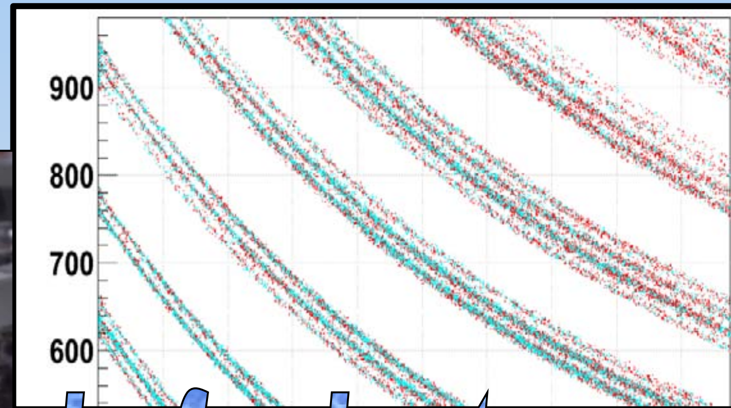
FAZIA: a new detector for charged particles.
Developments and first results on isospin sensitive observables.

S. Barlini for the FAZIA collaboration





Music for isotopes

Four-π A Z Identification Array

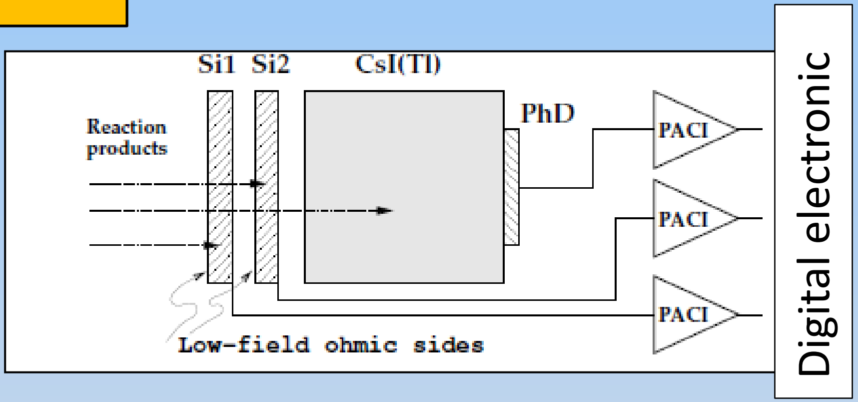
LNS -User Meeting - 2 Dicember 2014

Contents:

- The FAZIA project: a brief introduction
- The R&D phases on detectors (2005-2012)
  - The "FAZIA recipe"
  - The main results
- The Demonstrator (2012-2015)
  - Introduction
  - Some details about the "block"
- The experiments with FAZIA: first results and future prospective
  - Isospin transport
  - Staggering
  - Approved experiments
  - Future prospective

The FAZIA project: a brief introduction.

FAZIA is a new array for charged particles based on a three stages telescope Si (300 µm) + Si (500 µm) + CsI (Tl) (10 cm) with a completely digital electronic.



INTERNATIONAL COLLABORATION

Countries: Italy, France, Poland, Romania (+support from Spain)
People: about 30 physicists + engineers + technicians

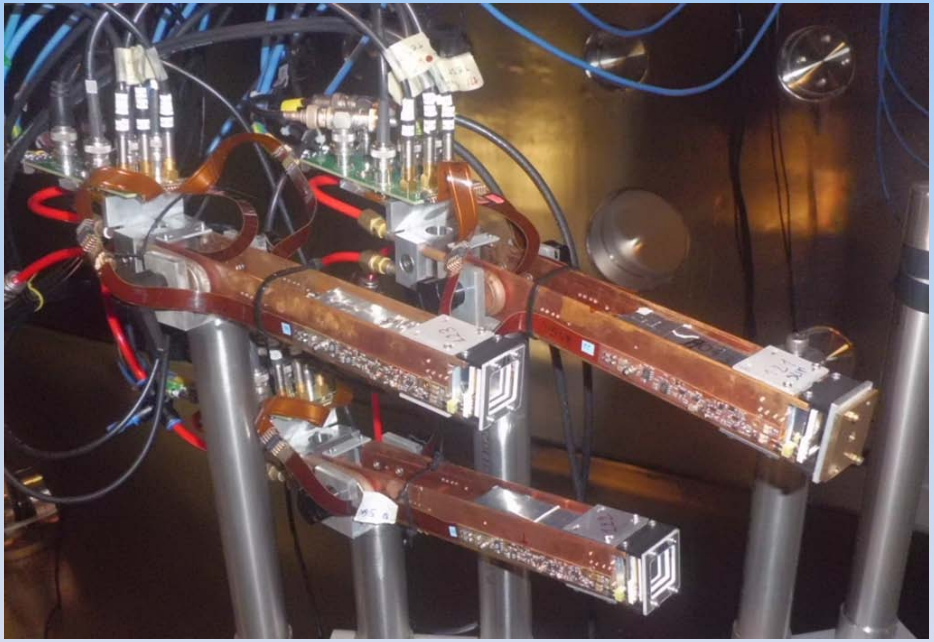
OBJECTIVE

Build-up a new array with unprecedented capabilities of ion identification, with "low" energy thresholds, modular, versatile and transportable (in view of a 'spread' use in various labs)

MAIN PHASES

- R&D on detectors and electronics (2005-2012)
- *construction of a Demonstrator (2012-2015)*
- experiments with stable and unstable heavy-ion beams (>2014)

The R&D phases



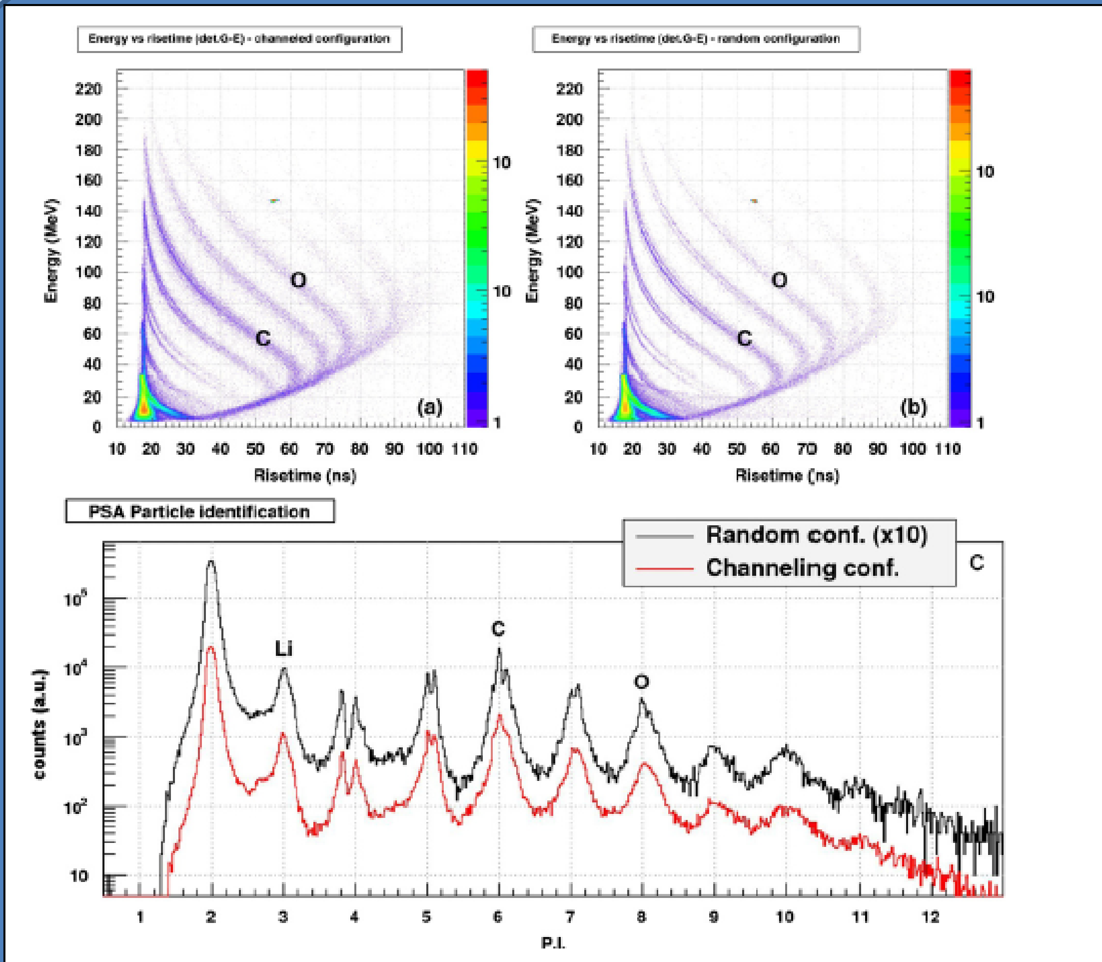
During this phase, we focus in the detector building in order to improve the particle identification. The electronic was always digital, but not in the final configuration. Also the mechanical mounting is not the final one.

-Many test in different laboratories (LNS, GANIL. LNL)
-PACI: preamplifier with **charge and current outputs**
-Digital electronic cards outside scattering chamber with:

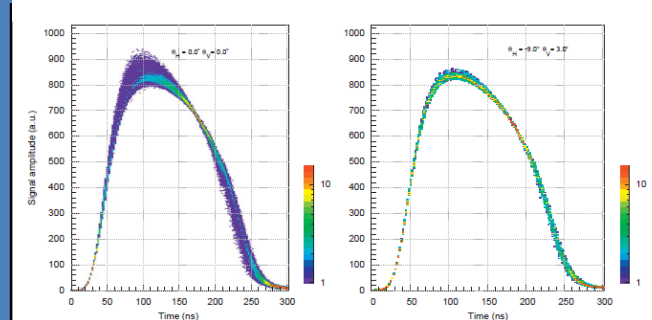
- Fast sampling ADC's (100MS/s@14bit for Si,125MS/s@12bit for CsI)
- Powerful computation unit, FPGA
- accurate Base Line (BL) estimation (pre-trigger 2-4μs)
- large memory depth (typical 16 μs, BL + signal)

The R&D phases: the FAZIA "recipe"

- "Random" cut of the Silicon wafers tilted with respect to the major crystal direction



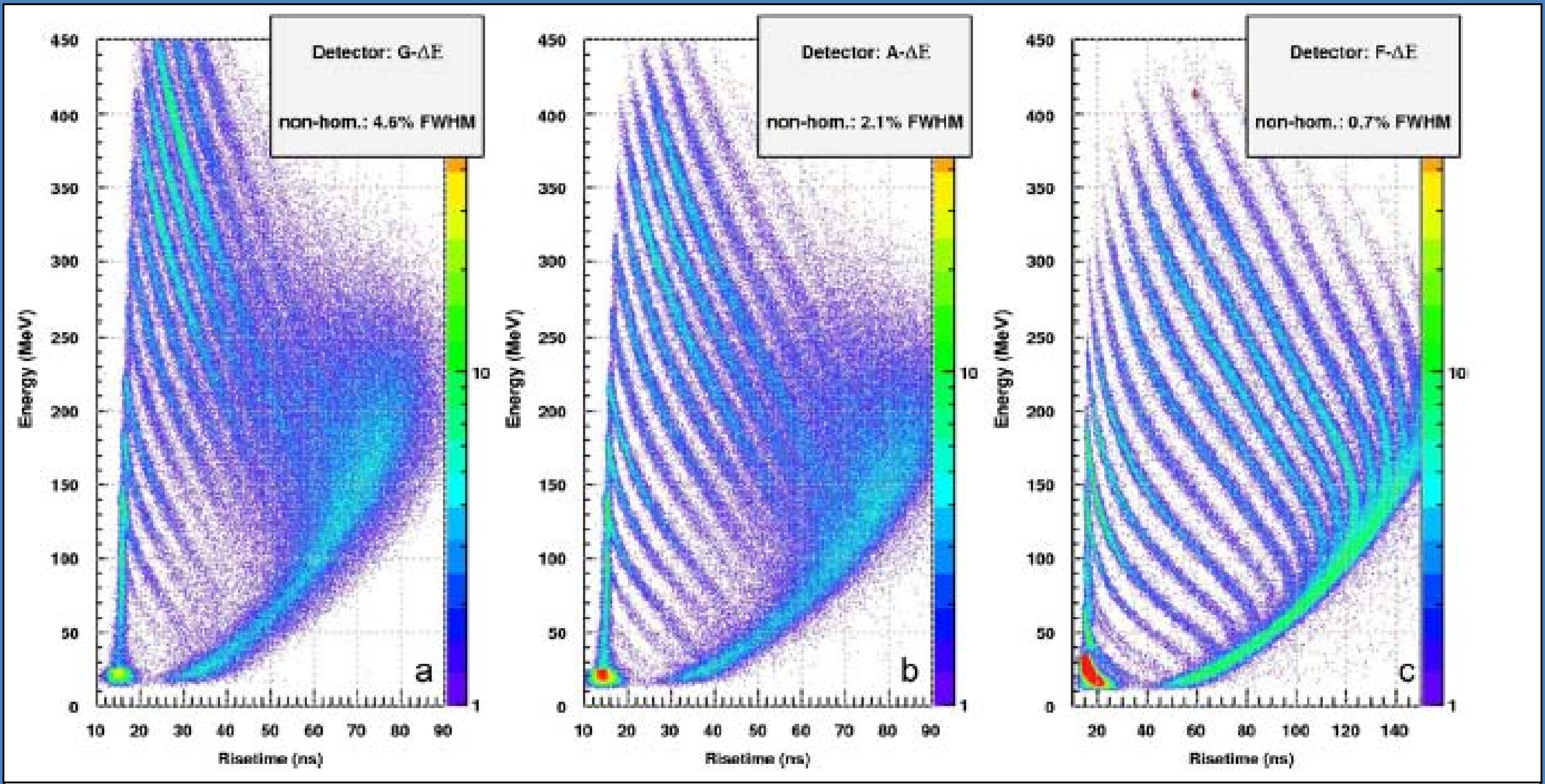
Channeling Conf. **Random Conf.**



^{80}Se@408MeV current signals in the two different configurations

The R&D phases: the FAZIA “recipe”

- "Random" cut of the Silicon wafers tilted with respect to the major crystal direction
- Usage of nTD Silicon detectors with good dopant homogeneity (1-3%)

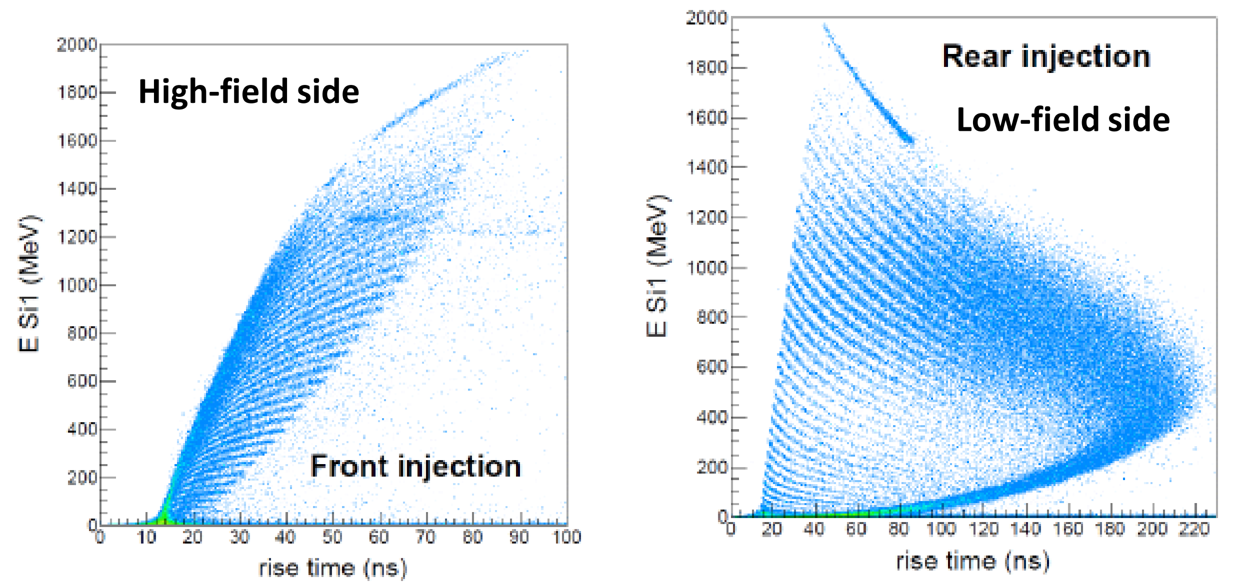


Effect of different doping homogeneity on Energy vs Charge rise-time PSA

The R&D phases: the FAZIA “recipe”

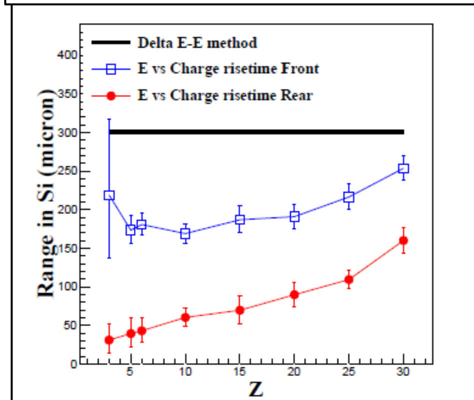
- "Random" cut of the Silicon wafers tilted with respect to the major crystal direction
- Usage of nTD Silicon detectors with good dopant homogeneity (1-3%)
- Reverse mounting configuration of Silicon detectors: the particles enter from the low-field side.

No difference in ΔE-E, but very different behavior in PSA!!



Same detector, used both in front than rear injection

Energy threshold



The difference is not only qualitative, but quantitative!!

The R&D phases: the FAZIA “recipe”

- "Random" cut of the Silicon wafers tilted with respect to the major crystal direction
- Usage of nTD Silicon detectors with good dopant homogeneity (1-3%)
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Main results published on

S.Barlini at al., Nucl.Instr.and Meth. A600 (2009), 644
L.Bardelli et al., Nucl.Instr.and Meth. A605 (2009), 353
L.Bardelli et al., Nucl.Instr.and Meth. A654 (2011), 272
S.Carboni et al., Nucl.Instr.and Meth. A664 (2012), 251
G.Pasquali et al., Europ. Phys. J. A48, (2012), 158
N.Le Neindre et al., Nucl.Instr.and Meth. A701(2013), 145
S.Barlini et al., Nucl.Instr.and Meth. A707(2013), 89

Attention to the radiation damage!

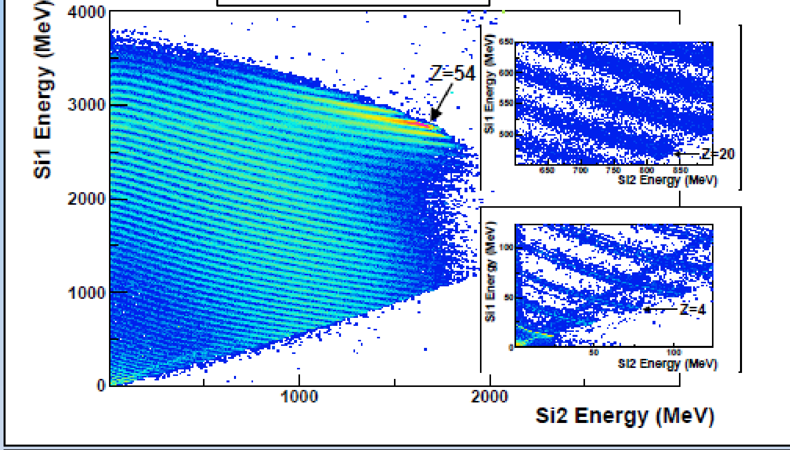
The R&D phases main results: the Isotopic resolution

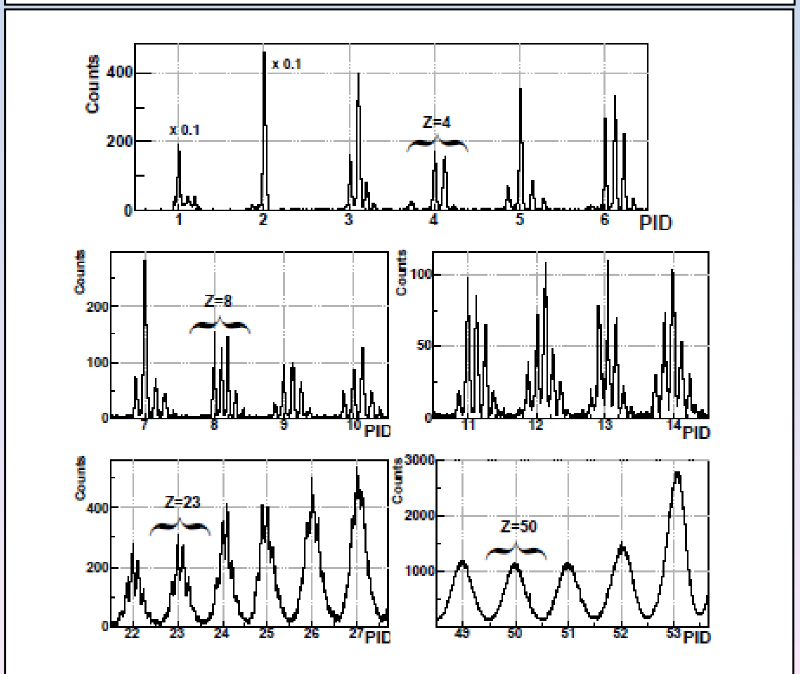
$^{129}Xe+^{nat}Ni$@35AMeV

ΔE-E technique

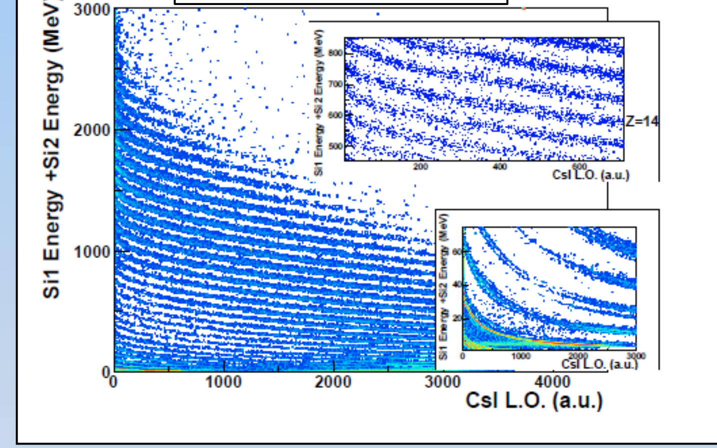
$$\frac{dE}{dx} \propto \frac{Z^2 A}{E}$$

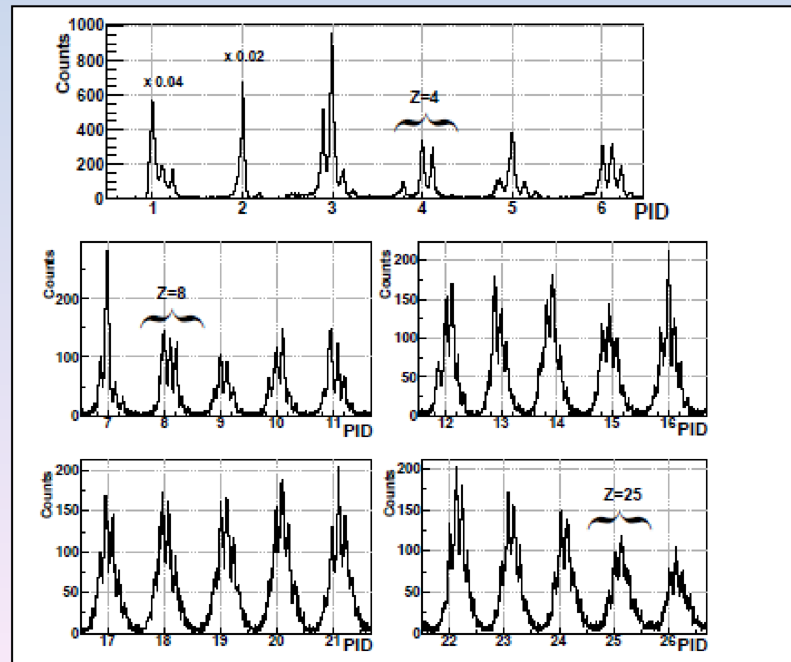
Si1 vs Si2





Si1+Si2 vs CsI

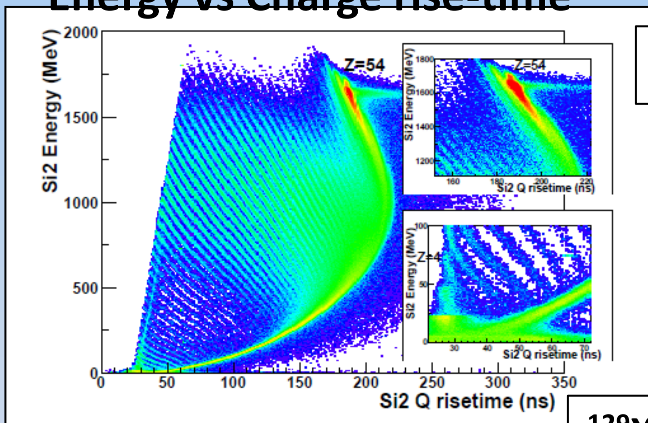




The R&D phases main results: PSA identification

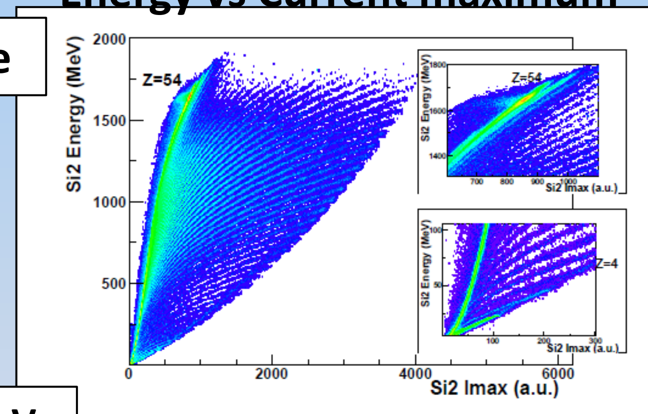
PSA technique

Energy vs Charge rise-time

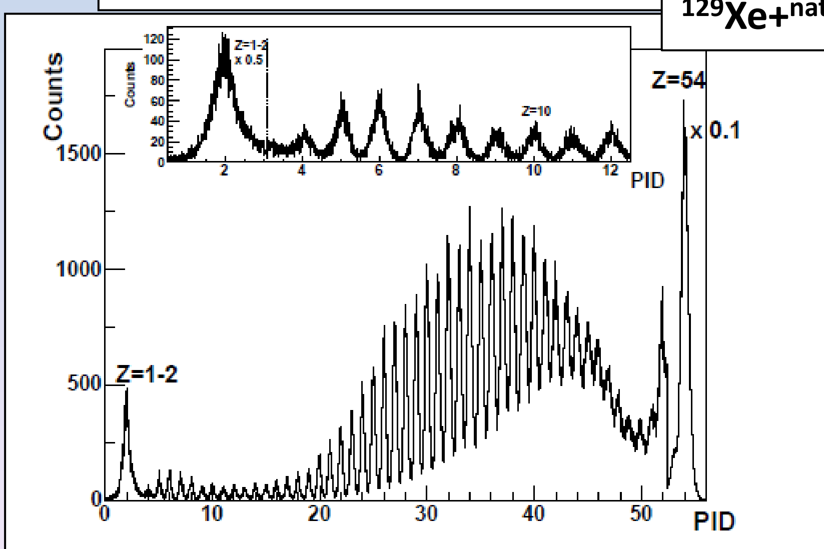


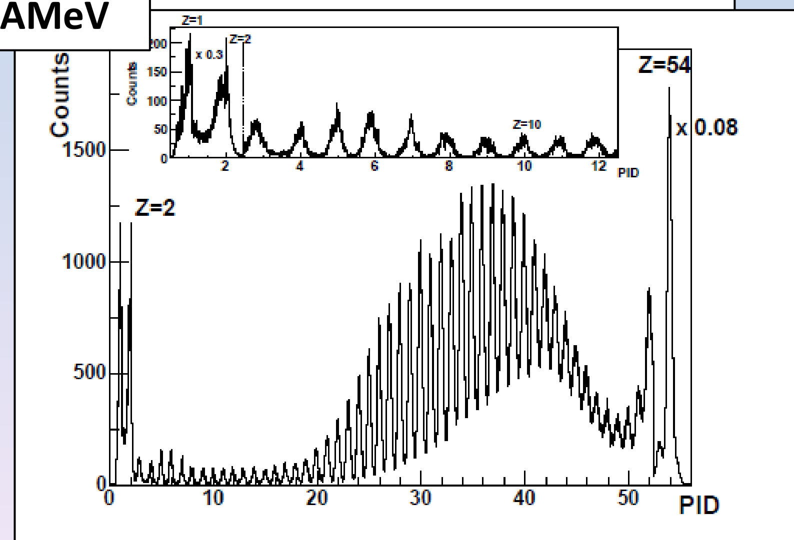
~2 GeV range

Energy vs Current maximum



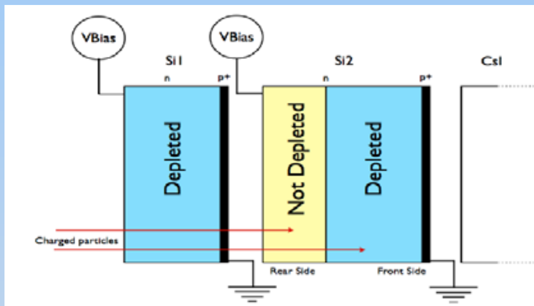
$^{129}Xe+^{nat}Ni$@35AMeV





With a higher gain (as in LNL test showed in previous slide), we can see also some masses!

The R&D phases main results: Behavior of partially depleted silicons



290V full depletion V i.e.
500 μm active layer

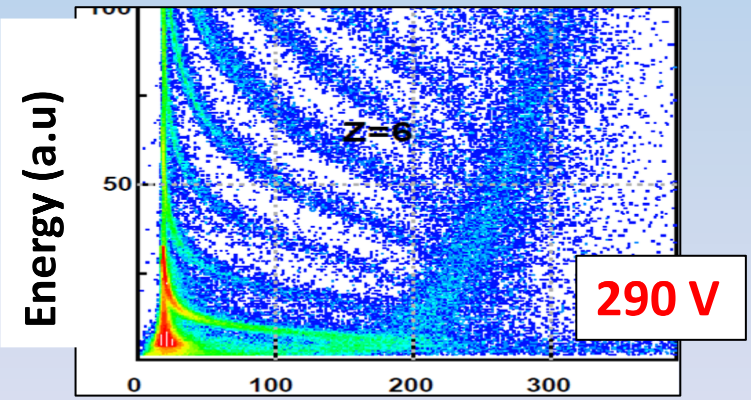
Several voltage steps...

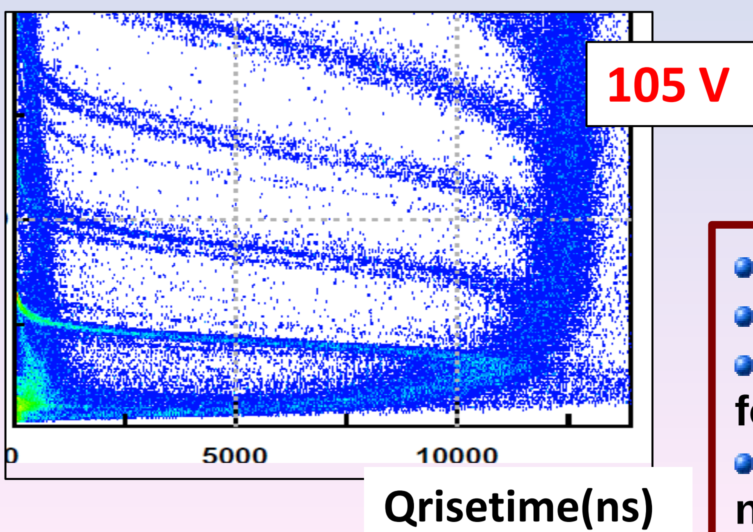
105V bias voltage i.e.
300 μm active layer

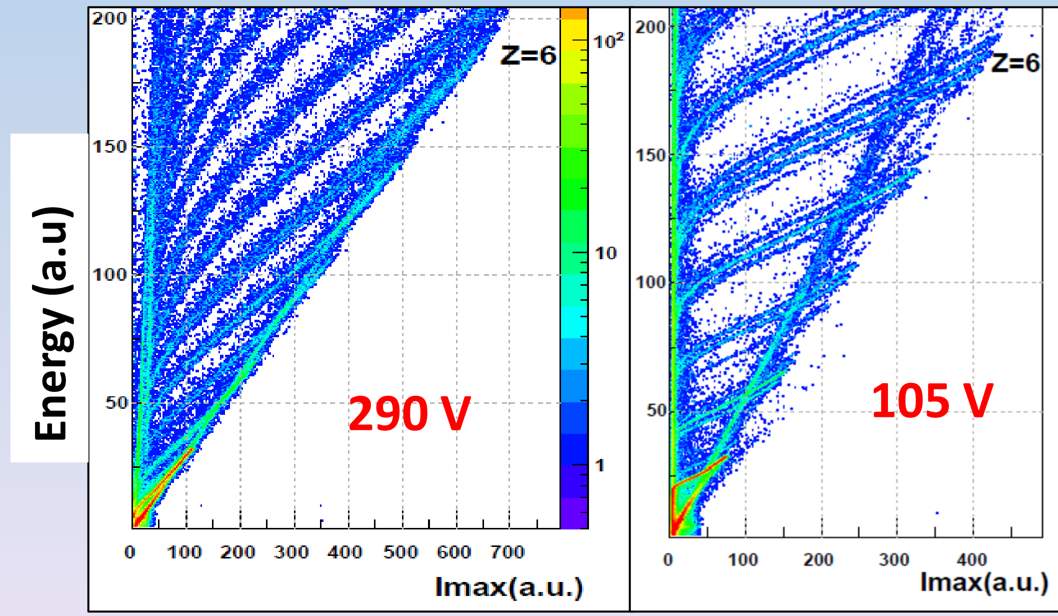
G.Pasquali et al., EPJ A50 (2014), p.1

Isotopic separation Improves !

All ions stopped in Si2



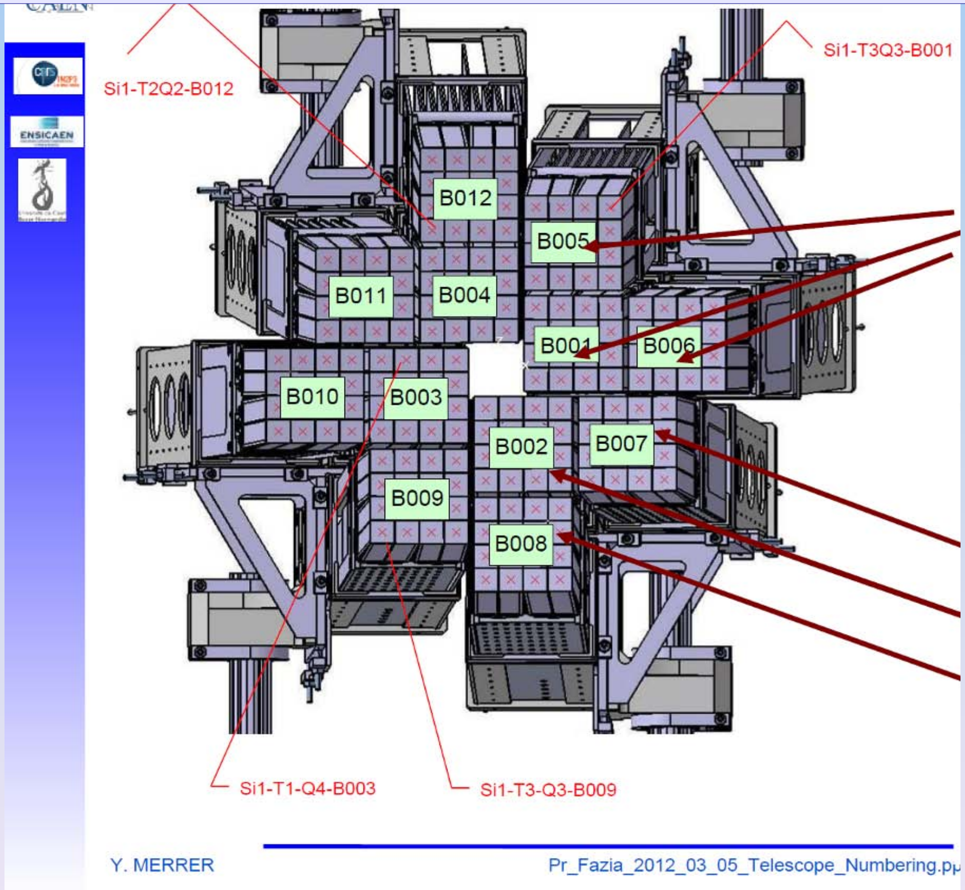




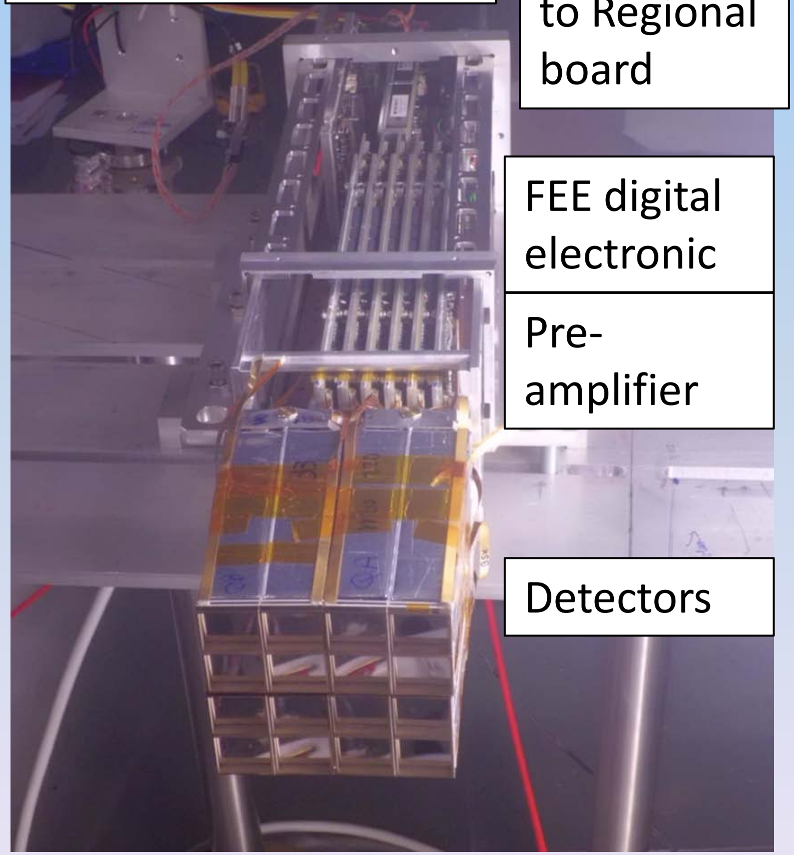
- Masses very well separated at 105V
- Current max better than Qrisetime
- Thresholds for charge identification higher than for full depletion
- Problem: calibration energy for ions stopped in the not depleted region

The Demonstrator (2012-2015): introduction

A possible final setup for 12 blocks.
Coverage from about 3 to 14 degree (@1m from target)



A single BLOCK



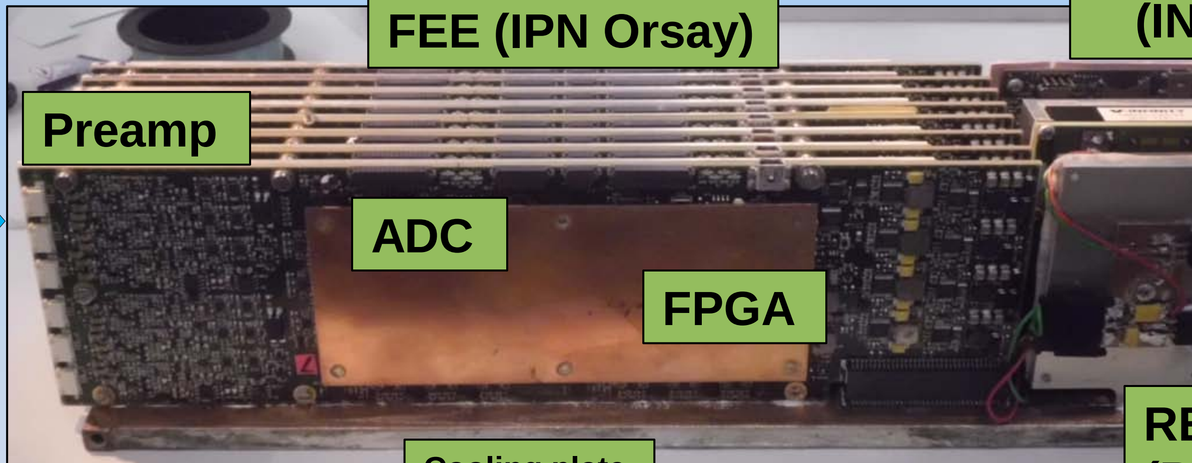
Block: the elementary structure formed by 4x4 telescopes (Si-300um + Si-500um +CsI).
The FEE is mounted behind the detectors under vacuum!

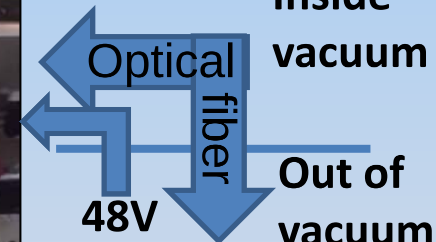
A single block: some details

Under vacuum operation: 25W/board

BLOCK CARD + HV card (INFN Napoli)

detectors





REGIONAL CARD (Polish project)
Global trigger (validation)

ACQ

Server

Slow controls

Slow controls

Different client

List of the digitalized signals:

"Low range"
"High range"

- Stage 1 (silicon 300 µm)
  - Charge 250 MeV full scale 250 Ms/s 14 bit
  - Charge 4 GeV full scale 100 Ms/s 14 bit
  - Current 250 Ms/s 14 bit
- Stage 2 (silicon 500 µm)
  - Charge 4 GeV full scale 100 Ms/s 14 bit
  - Current 250 Ms/s 14 bit
- Stage 3 (CsI + photodiode)
  - Charge 4 GeV full scale 100 Ms/s 14 bit

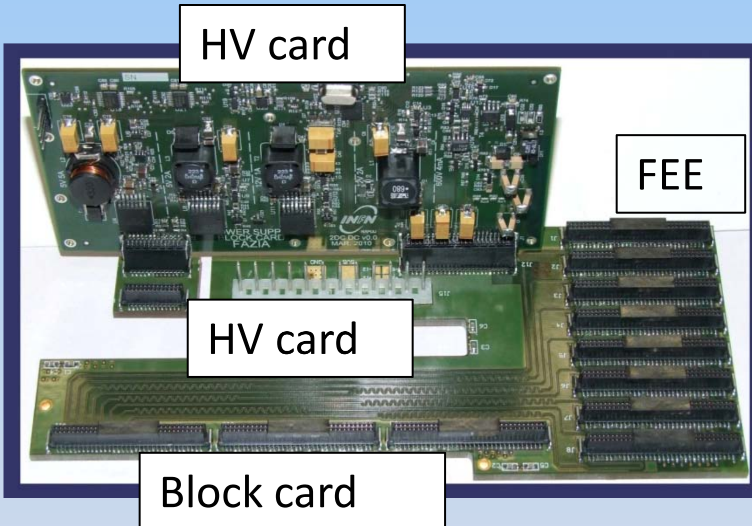
Embedded FEE Logics

- Local trigger
- Memories & buffers
- Input/output

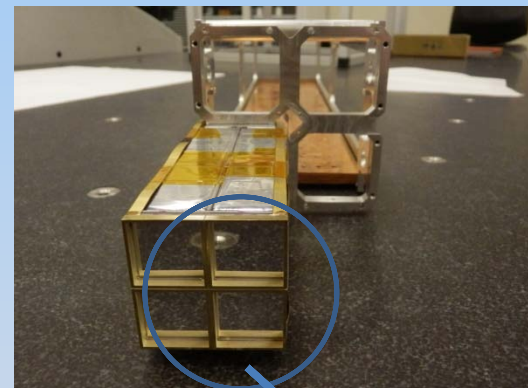
Embedded FEE functions

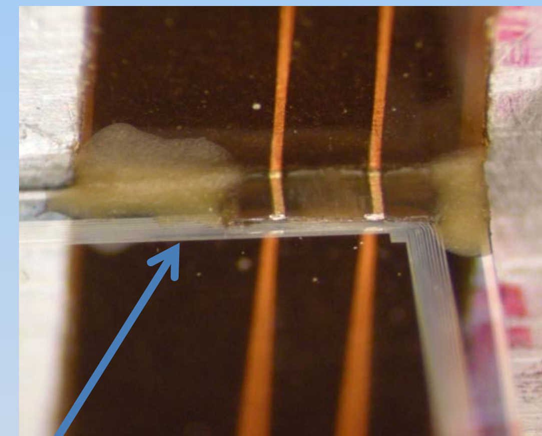
- Pulser to all channels
- Generation, Si-HV monitoring

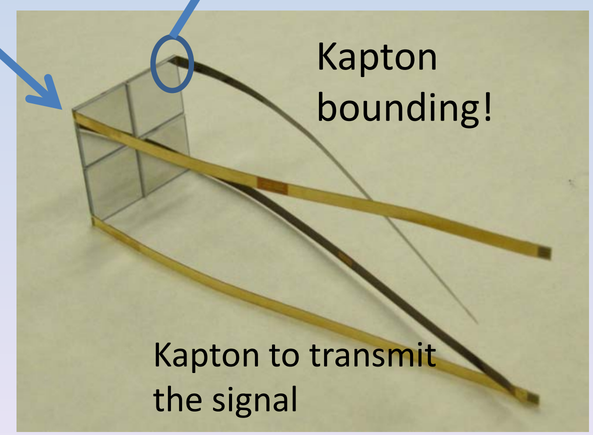
A single block: some details



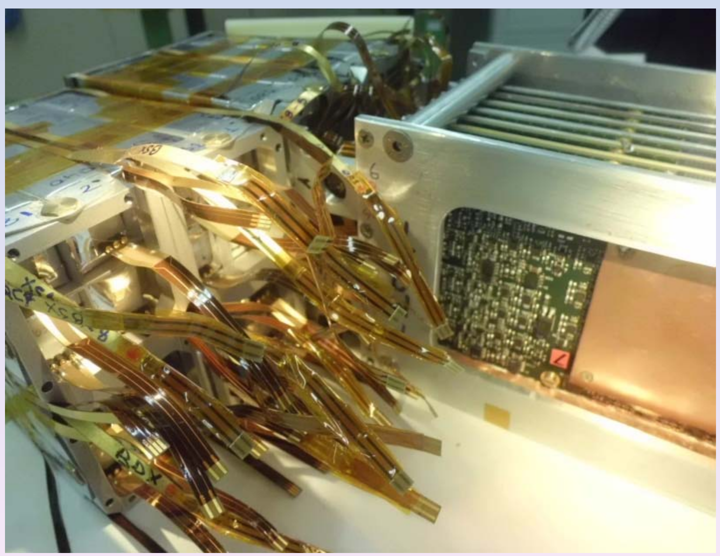
The mechanical mounting and bus connection







Many detectors …
many Kapton to
be connected!!



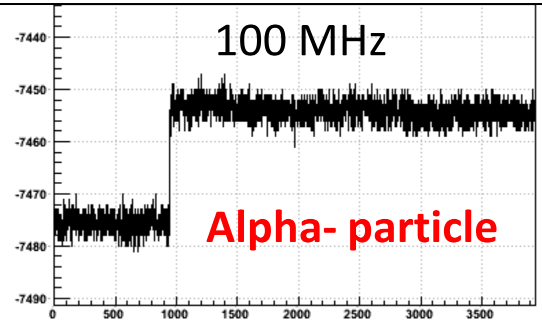
FIRST TEST UNDER BEAM FROM 10-13th DECEMBER @LNS!

The Block: first “real” test (with 2 blocks)

LAST WEEK RESULTS

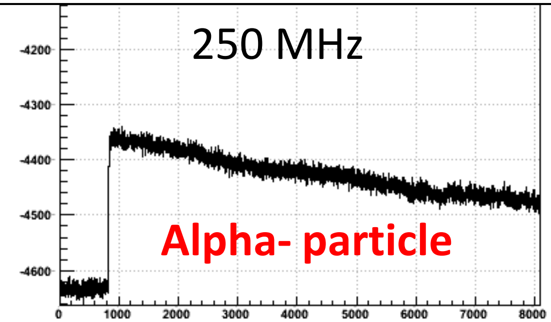
Same Pre-amplifier

fQH1- Si1 High Range (4GeV)



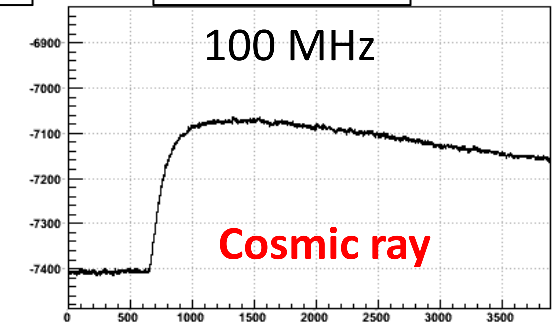
Pre-ampli output divided by 4

fQL1- Si1 Low Range (350MeV)



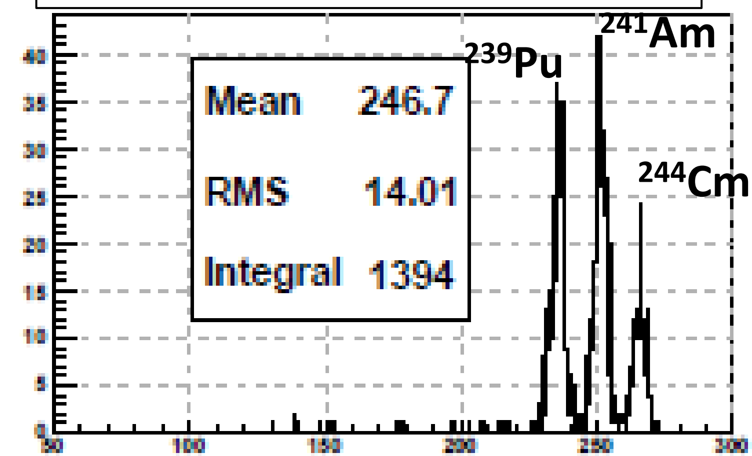
Pre-ampli multiplied by 3

fQ3- CsI



Alpha test with a 3 peak source

fQL1- Si1 Low Range (350MeV)



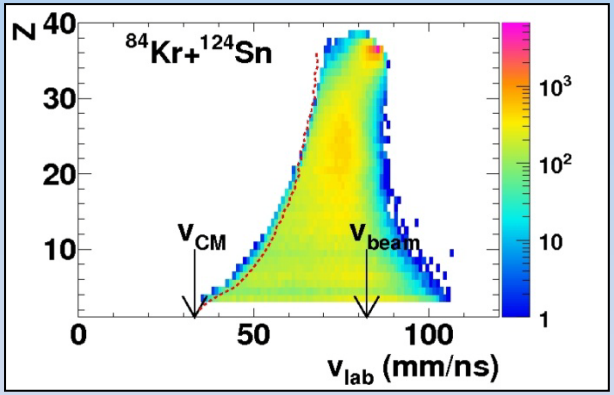
This results is very interesting because the range of the fQL1 signal is around 350MeV, but this is obtained starting from THE SAME pre-amplifier of fQH1. In other words, this result is obtained from a 4GeV pre-amplifier, using a different “electronic” gain.

The experiments with FAZIA: ISOSPIN TRANSPORT

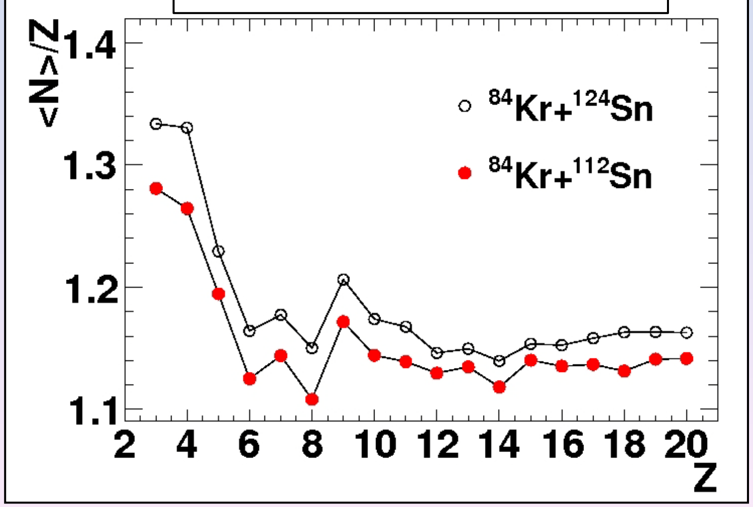
^{84}Kr + ^{112,124}Sn@35AMeV

Only one telescope of FAZIA with R&D configuration between θ=4.8° and 6° (grazing 4.1° and 4.0°)

S.Barlini et al., PRC 87 (2013), 054607

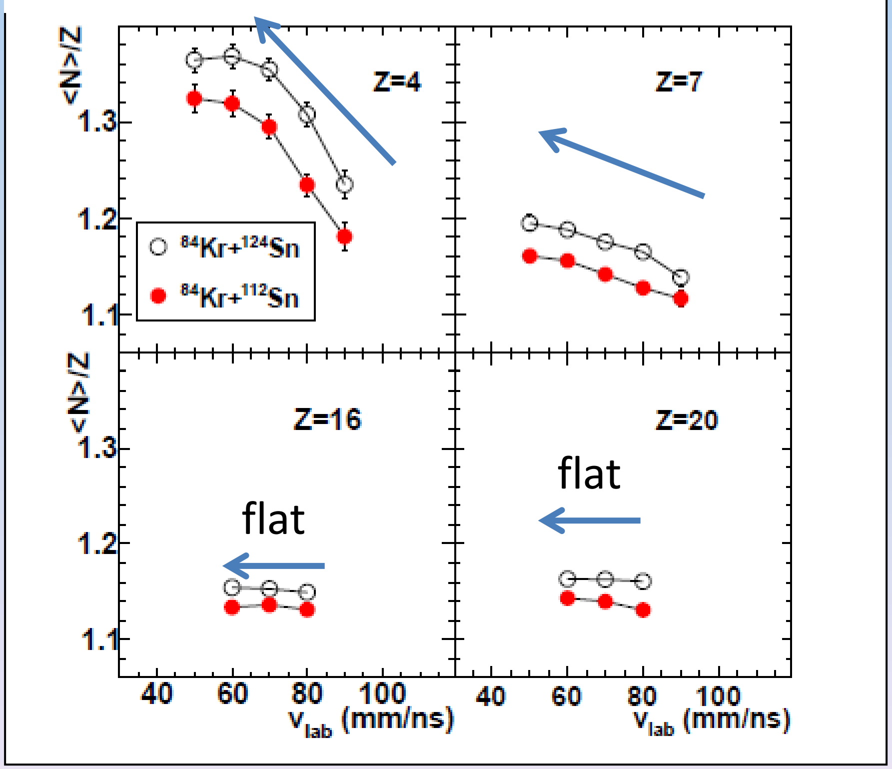


ISOSPIN DIFFUSION



ISOSPIN DRIFT

Mid-velocity



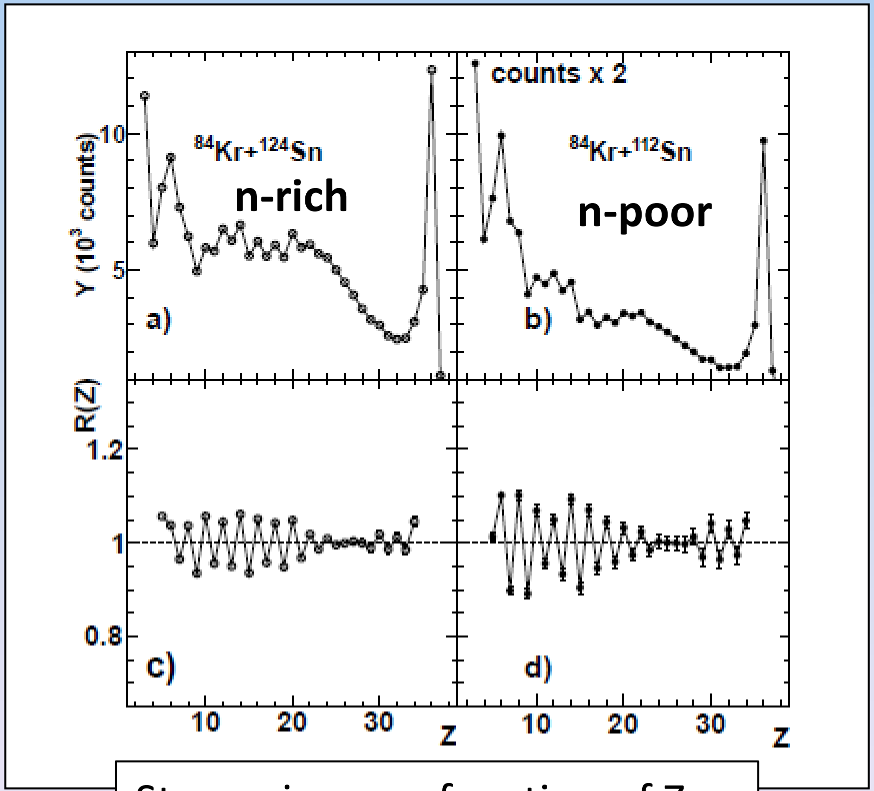
A few examples at comparable energies:
Yang PRC60(1999)
Lombardo PRC82(2010), JmodPE 20(2011), PRC84(2011);
DeFilippo PRC86(2012);
Galichet PRC80 (2009);
Brown PRC87 (2013)

The experiments with FAZIA: STAGGERING

^{84}Kr + ^{112,124}Sn@35AMeV

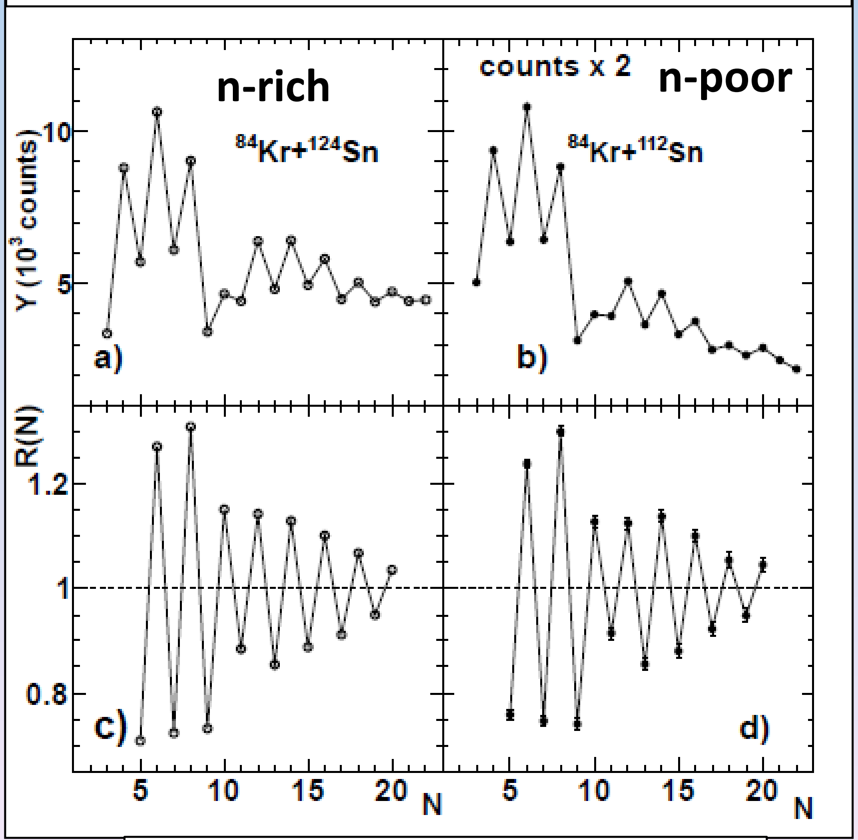
Only one telescope of FAZIA with R&D configuration between θ=4.8° and 6° (grazing 4.1° and 4.0°)

S.Piantelli et al., PRC 88, 064607 (2013)



Staggering as a function of Z

Thanks to the very good mass resolution, we can explore also this!



Staggering as a function of N

A few examples from literature:

M. V. Ricciardi, NPA 733, 299 (2004).
P. Napolitani, PRCC 76, 064609 (2007)
I. Lombardo, PRC84, 024613 (2011).
G. Casini, PRC 86, 011602 (2012).
M.D'Agostino, NPA875 (2012) 139

The experiments with FAZIA: approved experiments

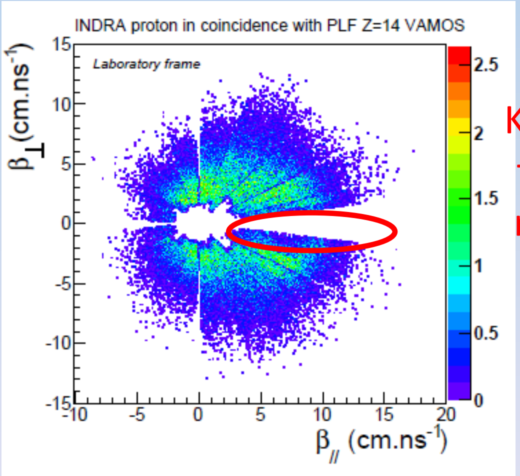
2015: 4 (to 6) FAZIA blocks in a stand-alone configuration. Partial covering of forward angles up to about 15 degrees

MAIN PHYSICS: QP features, QP fragmentation cross section

Two experiments already ***APPROVED by LNS-PAC:***

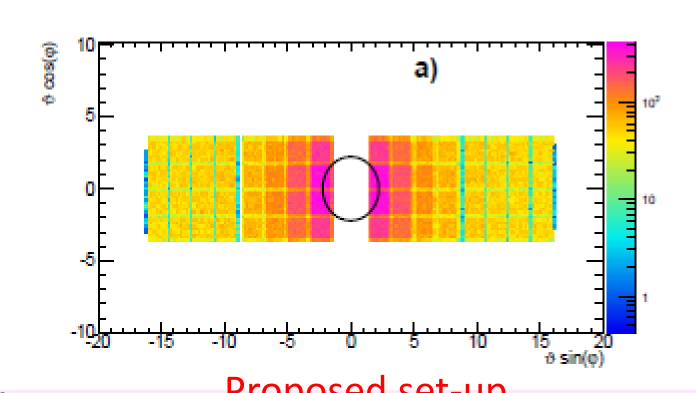
^{40,48}Ca+^{40,48}Ca at 35AMeV to refine VAMOS-INDRA data and to accurately determine fragment cross sections

Signers (47) and affiliations (16)



Kinematic cut due to single particle mode in VAMOS

^{78}Kr+^{46,50}Ti at 35AMeV in reverse kinematics, to investigate the role of isospin diffusion on QP sequential fission



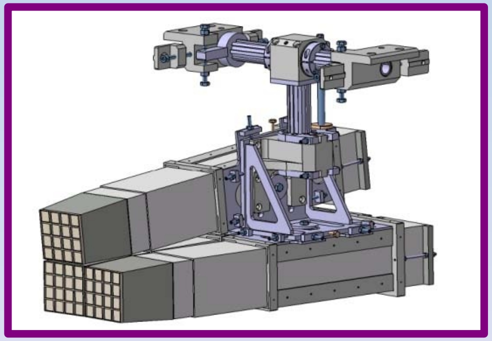
Proposed set-up

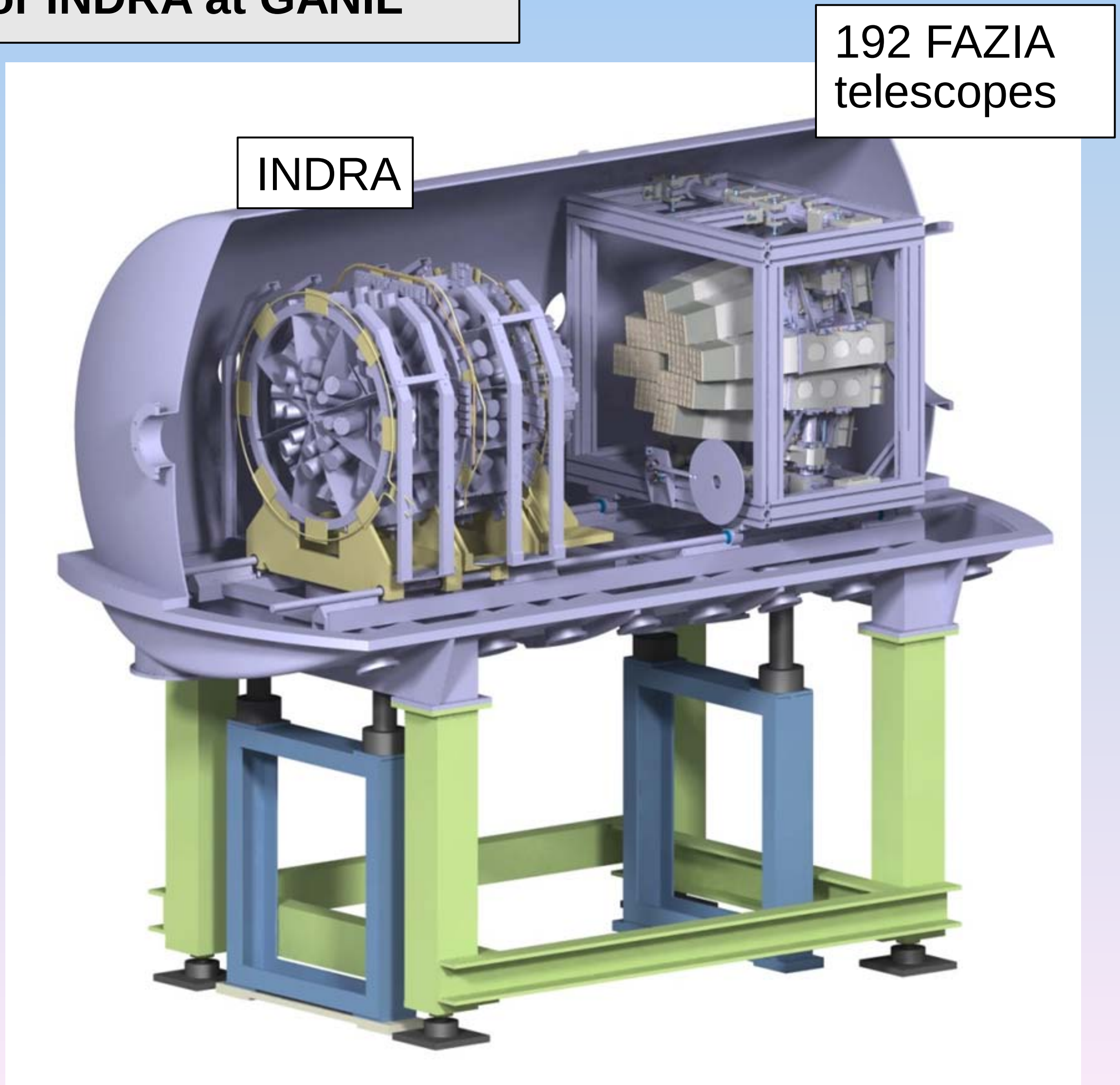
The experiments with FAZIA: future perspective

>2015:

FAZIA and the multidetector INDRA at GANIL

3-block supporting arm





…but also to LNS, LNL with stable and exotic beams!

CONCLUSIONS:

- Many fragments are produced in heavy ions collisions, with wide range of energy and sizes and coming from several sources
- The identification of these fragments in A,Z with low thresholds and over wide solid angles is needed to next exploration of EOS and of role of Symmetry Energy in excited systems

- FAZIA is building a new medium-size array of telescopes with unprecedented capabilities in terms of ion identification

- Specific recipes and solutions for production and use of Si detectors has been proposed and tested with success

- Pulse shape analysis and fast sampling electronics are employed

- RIBs (besides stable energetic beams) will be useful to explore reaction dynamics far from stability

The FAZIA project in Europe: R&D phase

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