The FAZIA project : Status and perspectives

Eric Bonnet (GANIL)
For the FAZIA collaboration

SPES exotic beams for science

SPES 2014

Second International Workshop

26th- 28th May, 2014

Laboratori Nazionali di Legnaro (Padova), Italy

European facilities time-scale

SIB: GANIL, LNS, LNL
LE-RIB (p-rich) : SPIRAL

Now, 2014

4π apparatus
CHIMERA
INDRA
GARFIELD

European facilities time-scale

SIB: GANIL, LNS, LNL
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LE-RIB (n-rich)
SPES
SPIRAL2

Now, 2014 2015-2017 202?

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LE-RIB (n-rich)
SPES
SPIRAL2

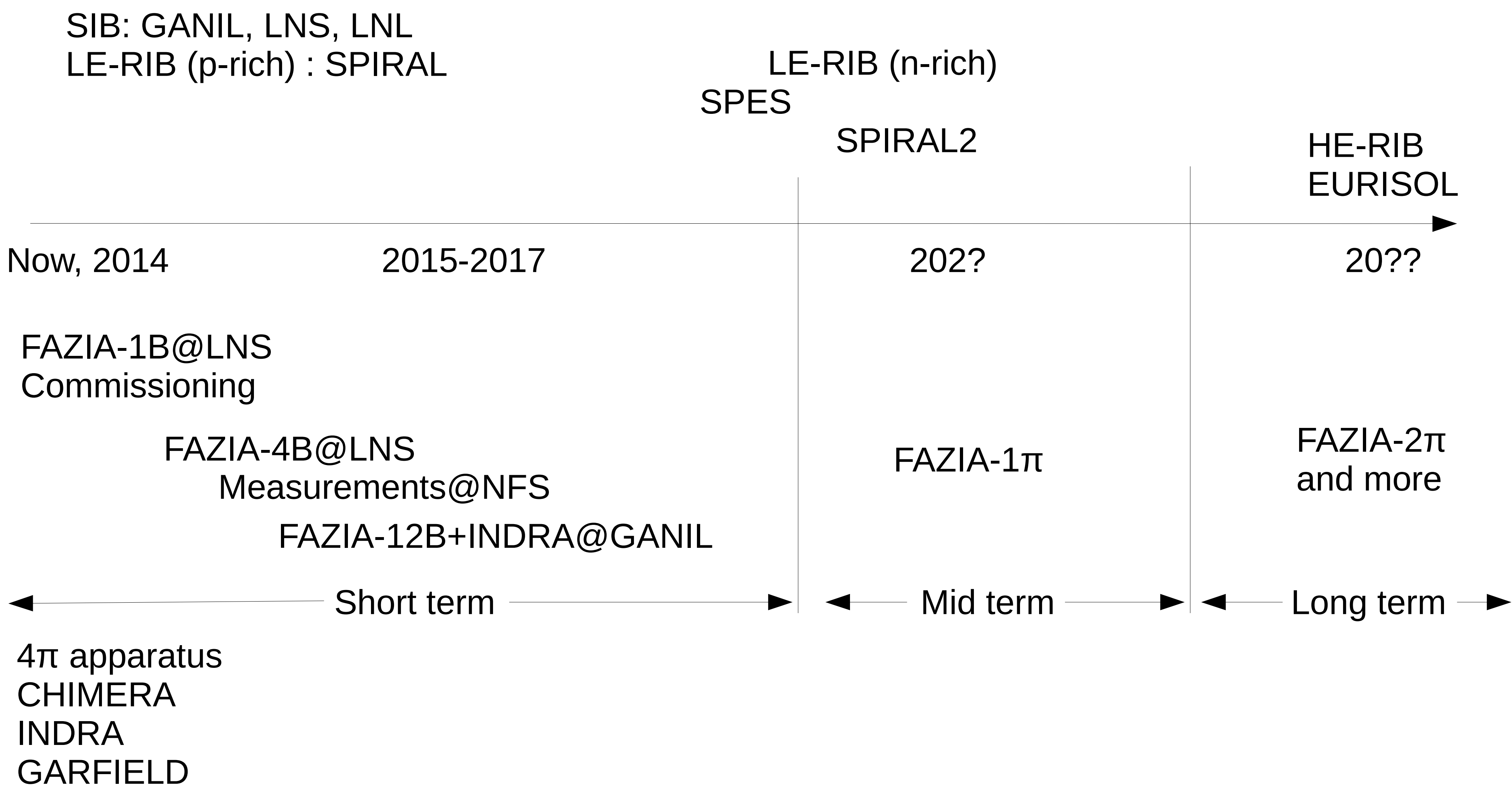
HE-RIB
EURISOL

Now, 2014 | 2015-2017 | 202? | 20??

Short term | Mid term | Long term

4π apparatus
CHIMERA
INDRA
GARFIELD

European facilities time-scale and FAZIA program



European facilities time-scale and FAZIA program

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HE-RIB
EURISOL

Now, 2014

2015-2017

202?

20??

FAZIA-1B@LNS
Commissioning

FAZIA-4B@LNS
Measurements@NFS

FAZIA-12B+INDRA@GANIL

FAZIA-1π

FAZIA-2π
and more

Short term

Mid term

Long term

4π apparatus
CHIMERA
INDRA
GARFIELD

To be maintained and upgraded

FAZIA R&D phase

- R&D first focused on the good recipe for silicon detectors :
  - Neutron Transmutation Doping of Silicon (nTD)
  - Cut on tilted axis
  - Uniformity
- Testing single telescopes with different configurations and readout
  - Digitalization
  - Rear/front mounting
  - Standard/single chip
  - Continuous monitoring of the high voltage
- R&D is almost complete, details and used figures can be found in this paper :

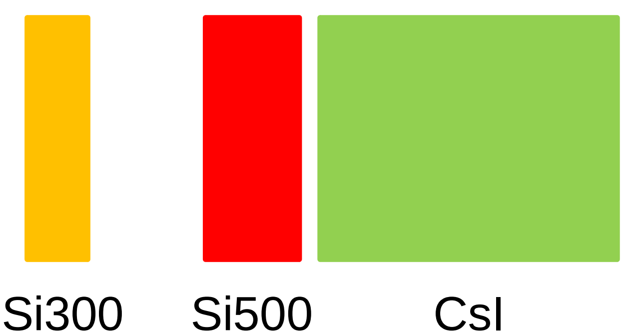
  “The FAZIA project in Europe: R&D phase”, EPJ A (2014) 50: 47 which compile 15 publications on technical aspects of detection and electronics and also physics.

Final design for FAZIA telescope

- 20x20 mm² Si(300µ)-Si(500µ)-CsI(Tl)(10cm)+photodiode

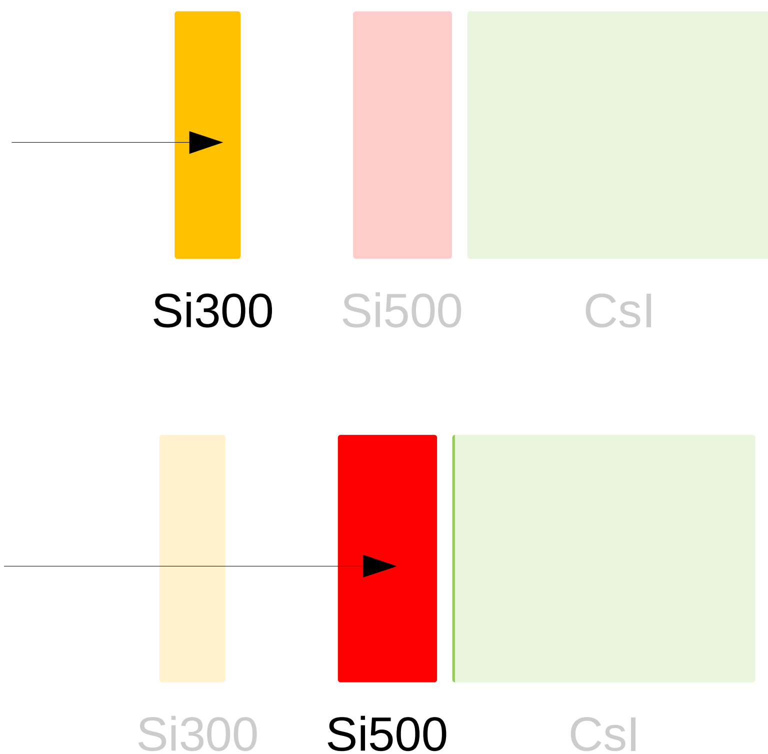
- Stage 1 (300 µm silicon detector):
    Charge: 250 Ms/s 14 bit (250MeV full scale)
    Charge: 100 Ms/s 14 bit (4 GeV full scale)
    Current: 250 Ms/s 14bit

  Stage 2 (500 µm silicon detector):
    - Charge: 100 Ms/s 14 bit (4 GeV full scale)
    - Current: 250 Ms/s 14bit
- Stage 3 (10 cm CsI(Tl) + photo-diode):
    - Charge: 100 Ms/s 14 bit (4 GeV silicon-equivalent full scale)



Identification capabilities of FAZIA telescope

Considering the signal of one particle stopping in a silicon detector and applying PSA on its digitalized signal ...



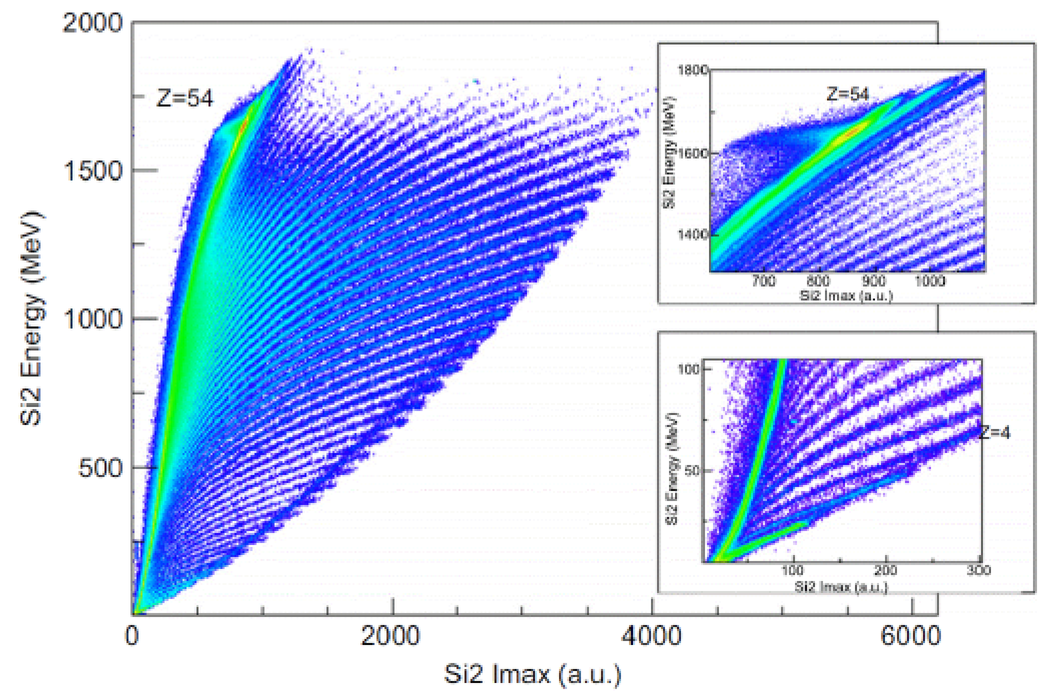
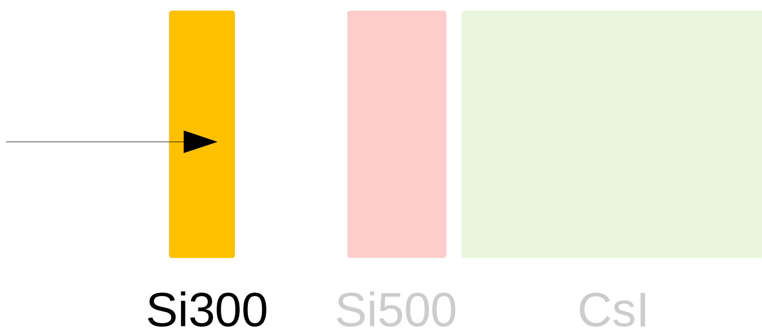


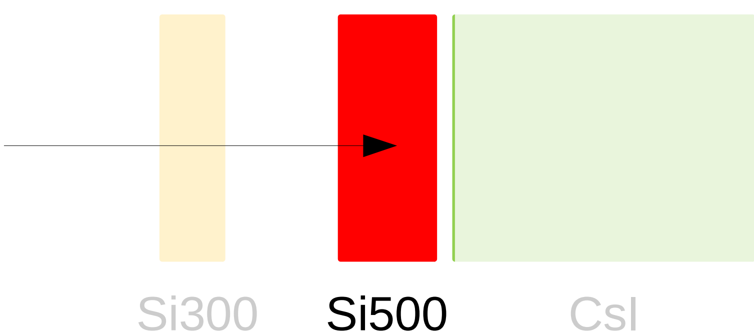
Fig. 12. (Colour on-line) Same as fig. 11, but for the correlation energy *vs.* current maximum. From [15].

Correlation between
Energy and Current maximum

Identification capabilities of FAZIA telescope

Considering the signal of one particle stopping in a silicon detector and applying PSA on its digitalized signal
Z-identification until the projectile (here Xe) is performed





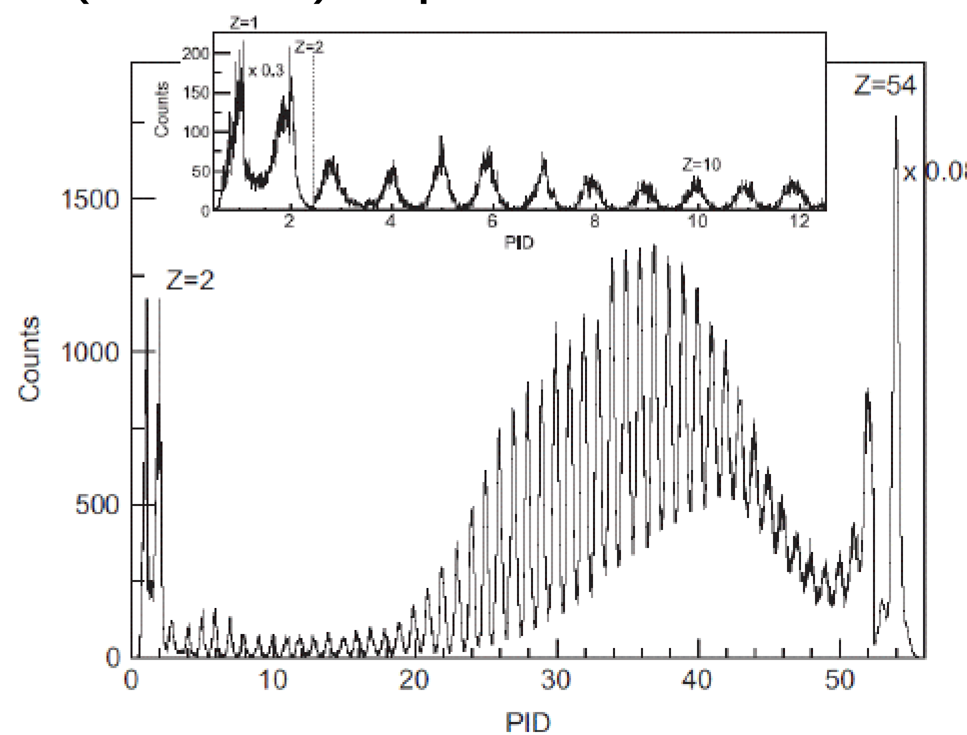
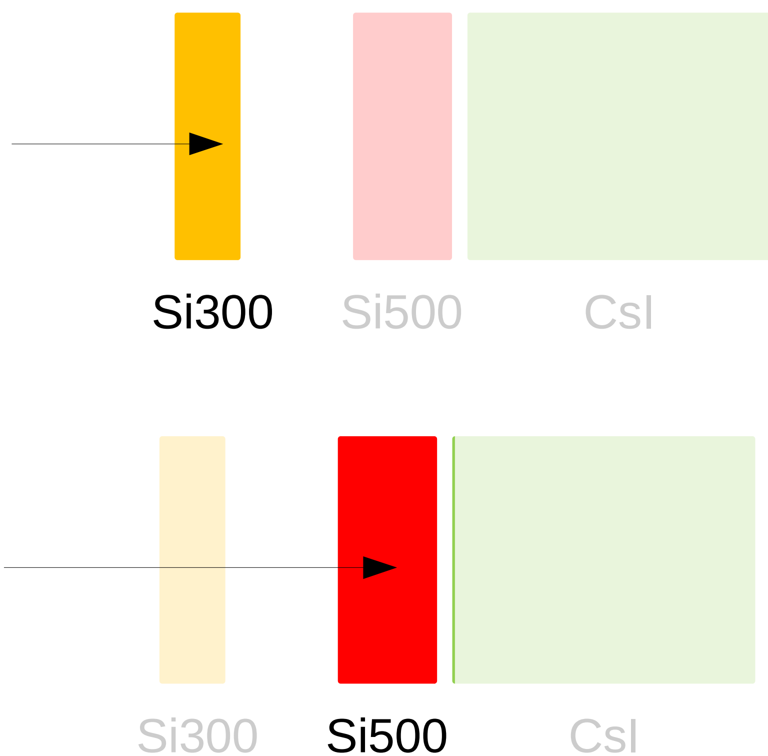


Fig. 14. Particle identification with the energy *vs.* current maximum technique, obtained from the linearization of fig. 12. The inset shows an expansion for the light elements. From [15].

Identification capabilities of FAZIA telescope

Considering the signal of one particle stopping in a silicon detector and applying PSA on its digitalized signal with higher gain A&Z-identification up to A=20 is performed



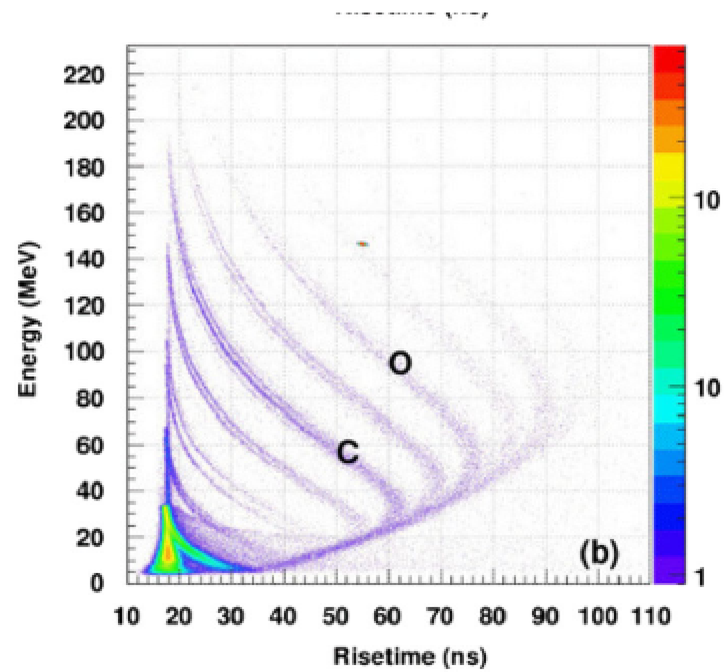
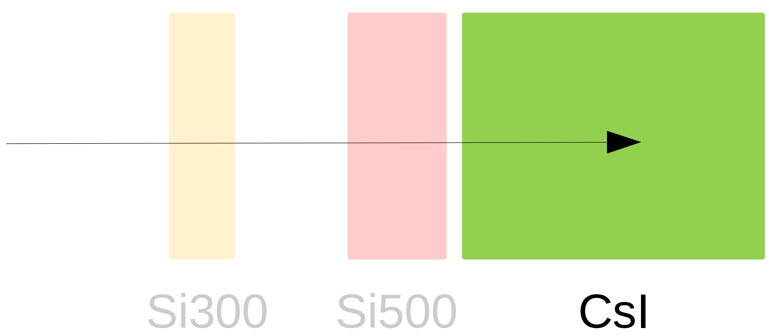
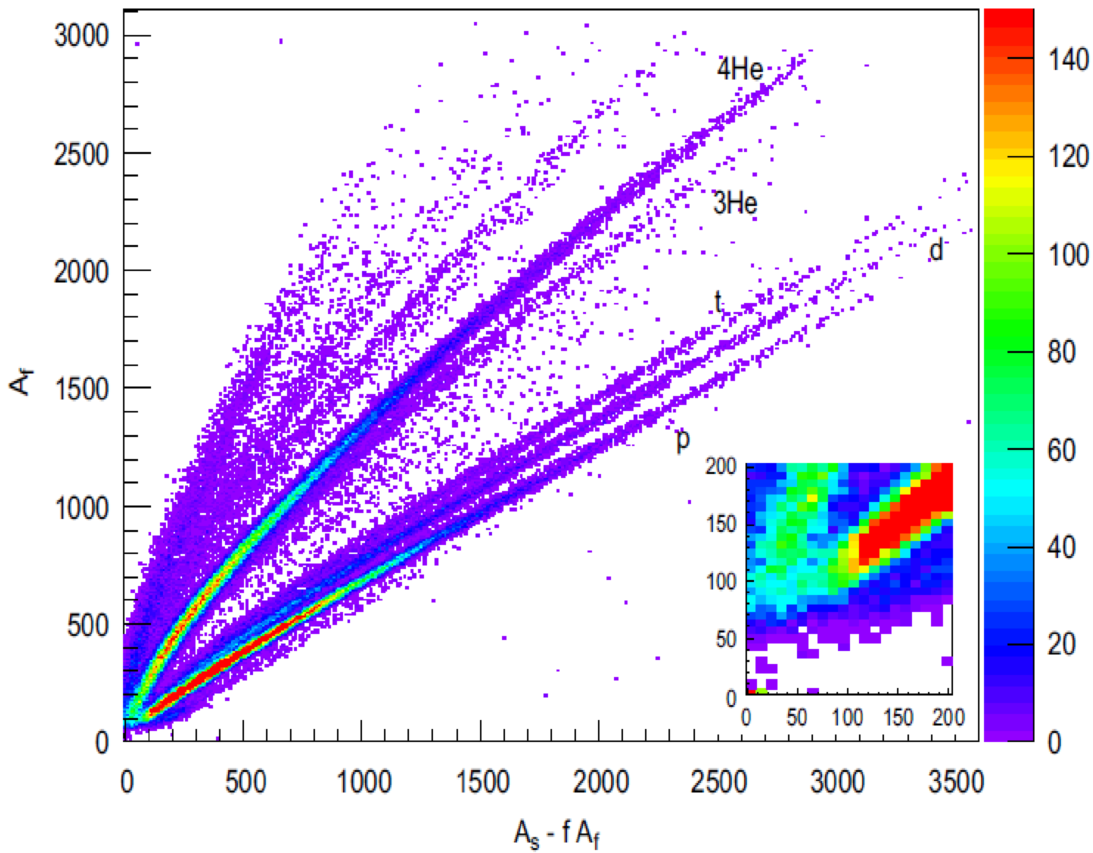


Fig. 6. (Colour on-line) PSA identification via energy *vs.* charge rise-time plots obtained with the detector in channeled (a) and random (b) configuration. From [18].

Identification capabilities of FAZIA telescope

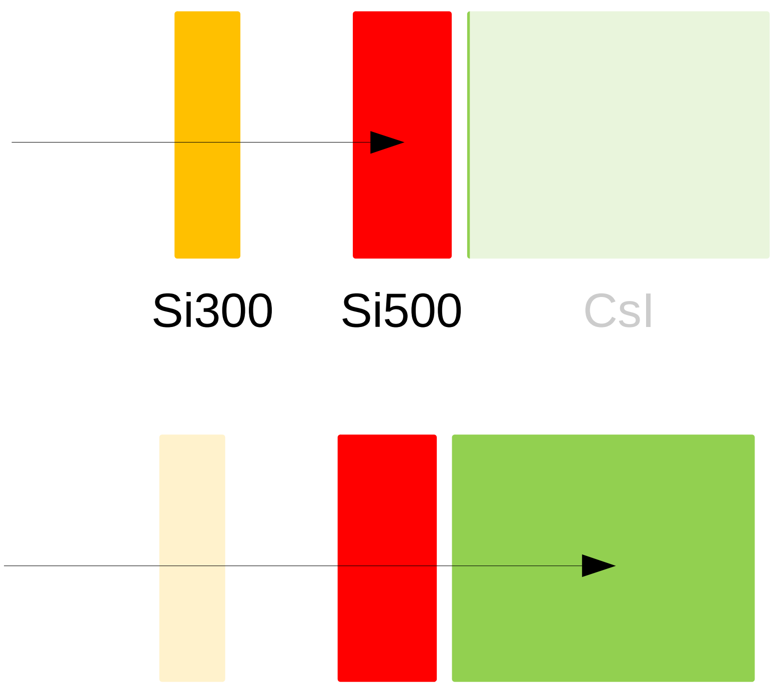
Considering the signal of one particle stopping in a CsI scintillator and applying PSA on its digitalized signal
A&Z-identification up to A~15 is also performed





Identification capabilities of FAZIA telescope

Considering the standard ΔE-E method for particle punching through one detector and stopped in the following ...



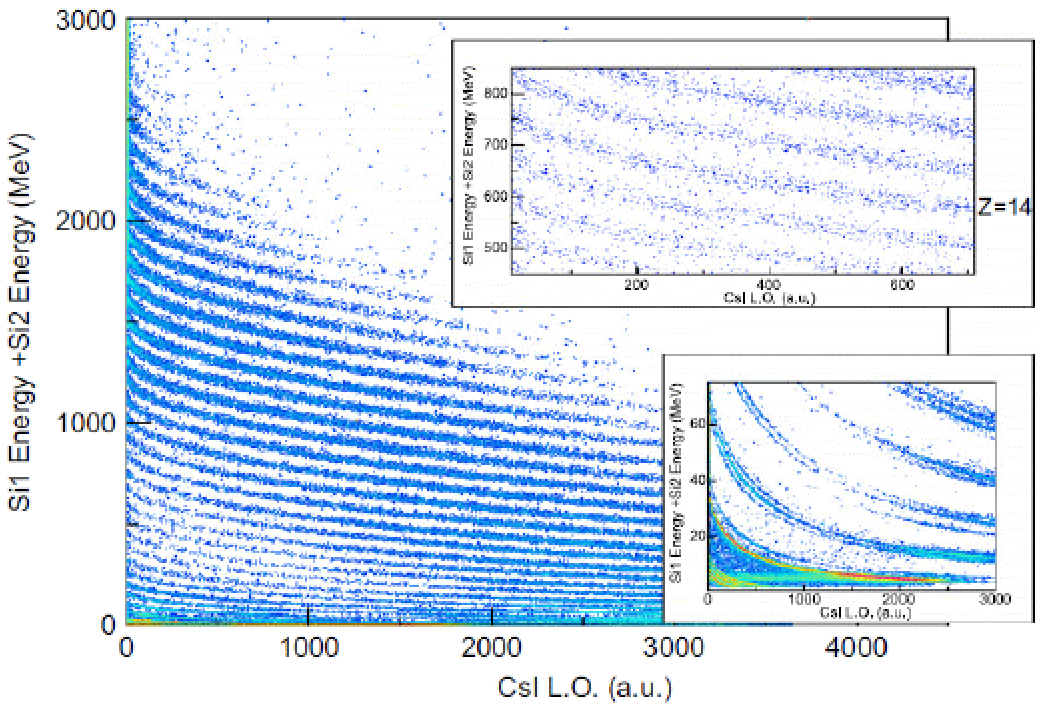


Fig. 9. (Colour on-line) ΔE-E correlation using the summed energy information (Si1+Si2) of the two 300 μm silicon detectors *vs.* the Light Output (LO) of the rear CsI. The insets present two expansions around $Z = 2$–6 and 12–16. From [15].

Identification capabilities of FAZIA telescope

Considering the standard ΔE-E method for particle punching through one detector and stopped in the following

Z&A-identification is achieved up to Ca

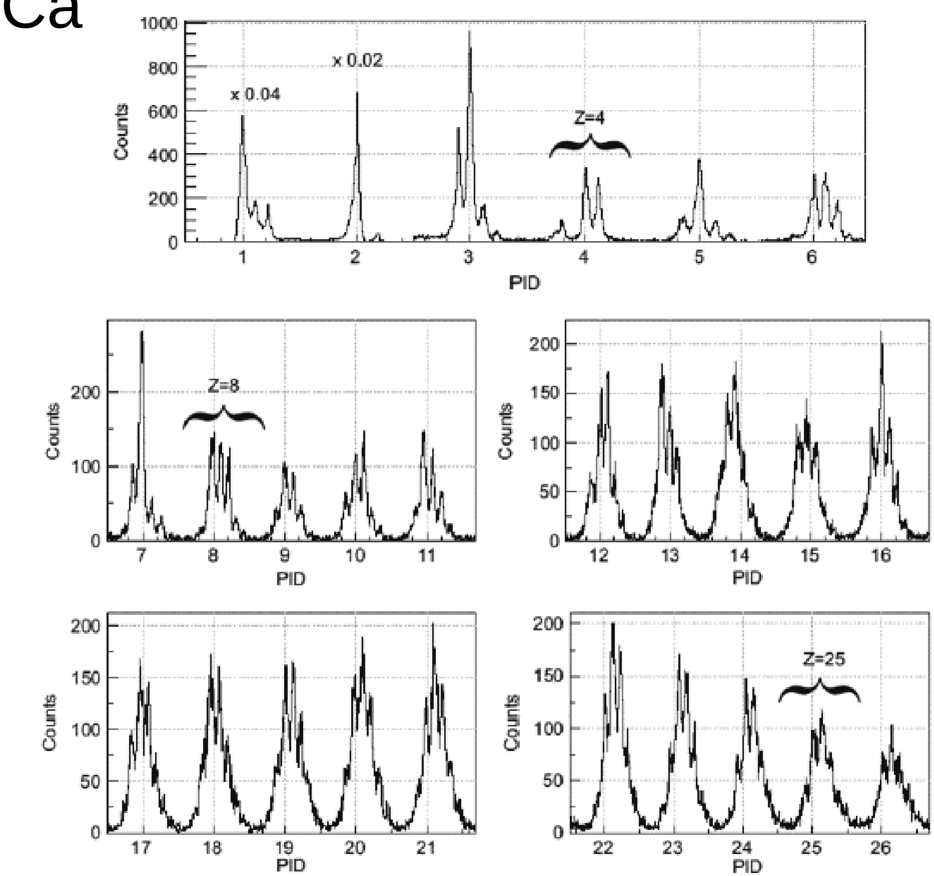
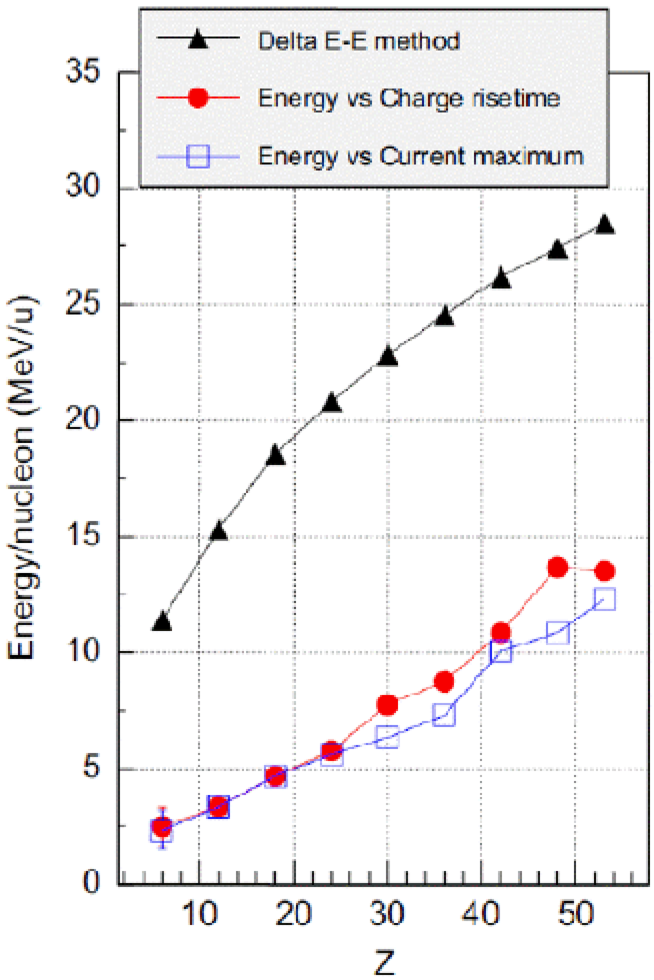
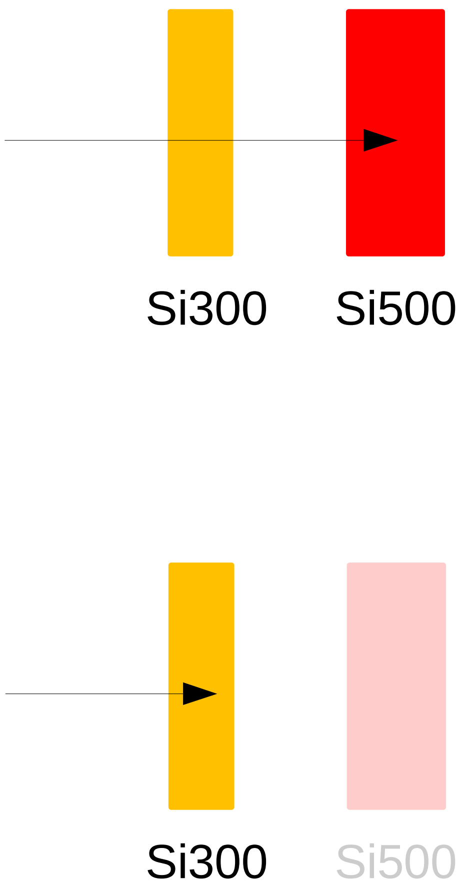


Fig. 10. Particle IDentification (PID) spectra obtained with the data of fig. 9. From [15].

Z-Identification threshold of PSA



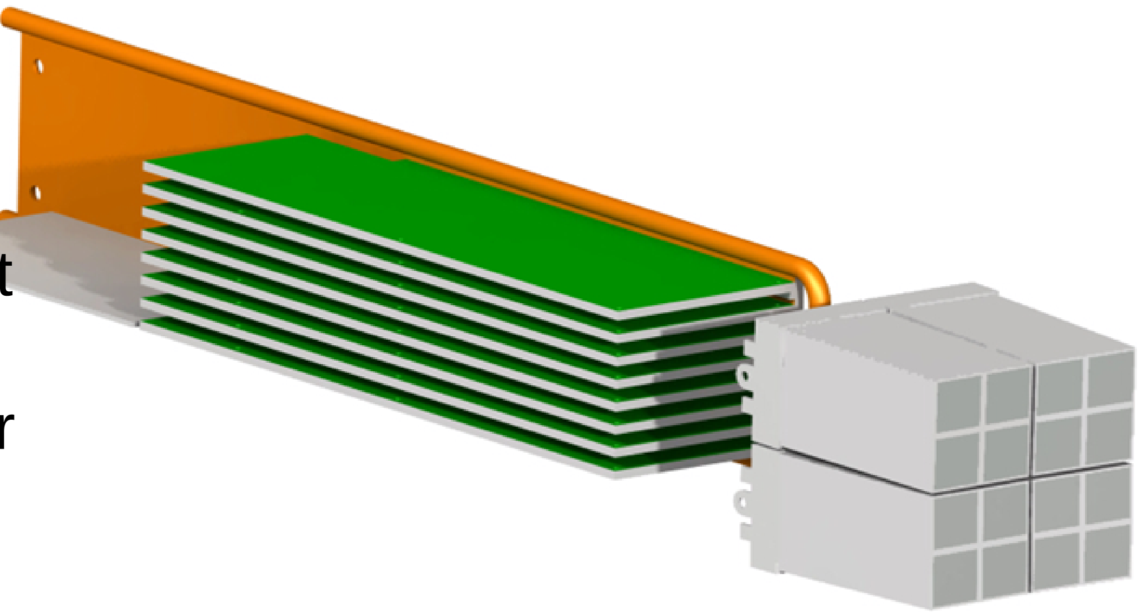


This threshold up to 15 MeV/A for Xe nuclei is not crucial
in experiments at the Fermi energy domain (20-100 MeV/A)

1 telescope … 2 PRC

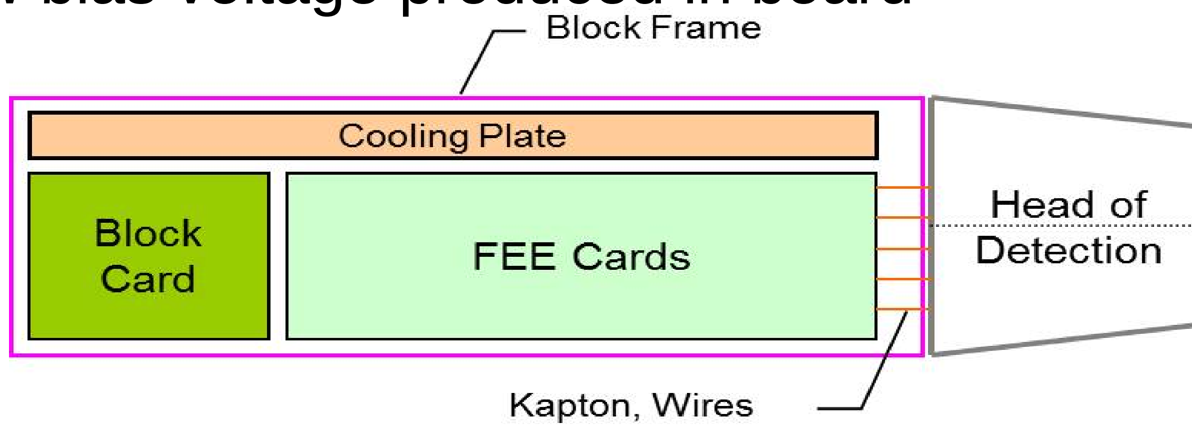
- “Isospin transport in ^{84}Kr+^{112,124}Sn collisions at Fermi energies”, S. Barlini et al. Phys. Rev. C 87, 054607 (2013)
- “N and Z odd-even staggering in Kr+Sn collisions at Fermi energies”, S. Piantelli et al. Phys. Rev. C 88, 064607 (2013)

Next step : FAZIA block(s)

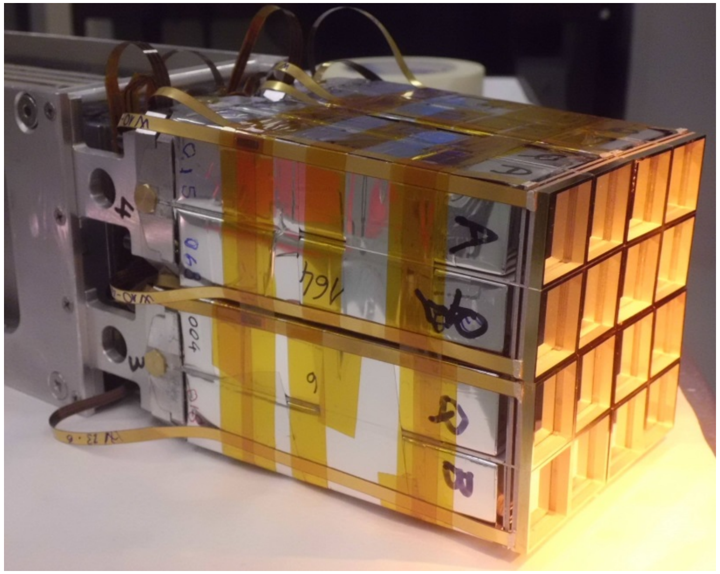


1 block=16 telescopes,
placed between 0.80
and 1.20 meter from the target

Q and I low noise pre-amplifier
8 FFE cards
+ 1 block card
+ cooling plate and mechanical support all in vacuum
+1 power supply card
    High (up to 400V) and low bias voltage produced in board



Commissioning of one block

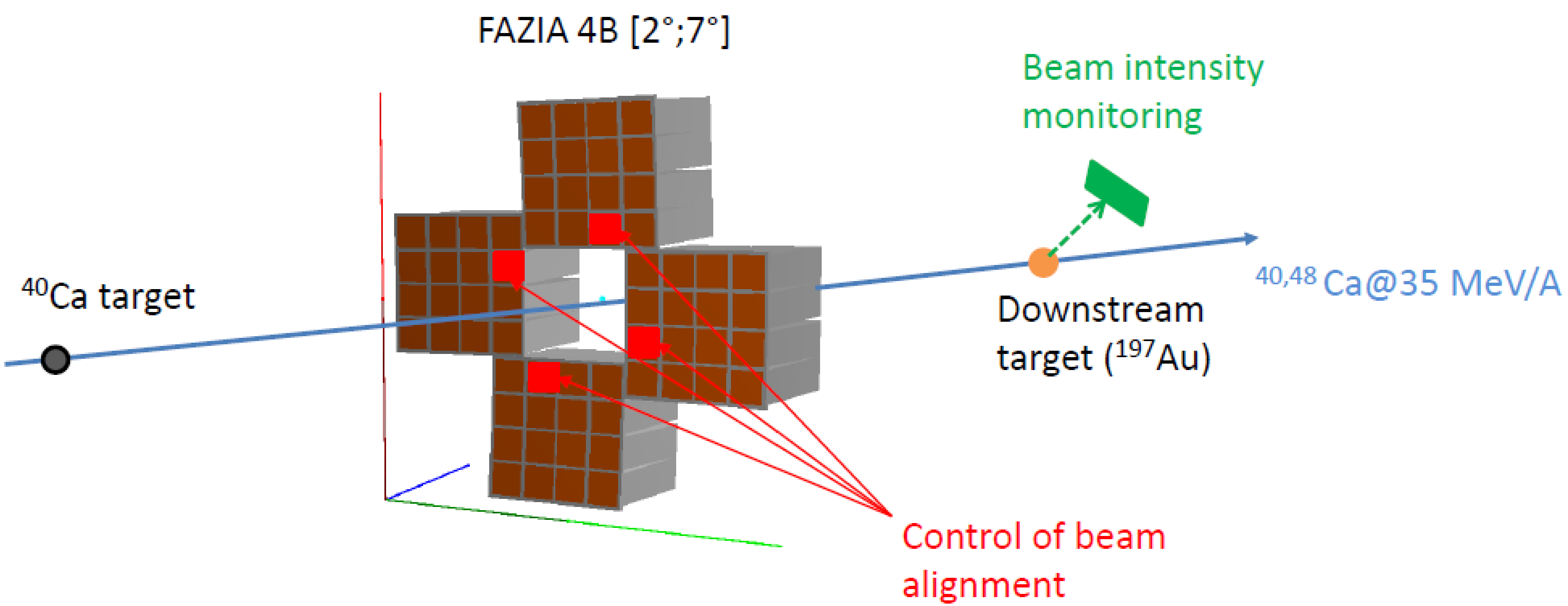


- Final test of the electronics
  - Improve the HV control
  - Reduce noise on the electronic chain
  - Electro-Magnetic Compatibility, Shielding
- Test TOF capabilities
- Acquisition, Monitoring, On-Line analysis

- Should be scheduled in the second part of this year at LNS

FAZIA-4B experiments at LNS

- Isospin cross section measurements of fragments
- Isospin transport in heavy ion collisions (plane configuration)

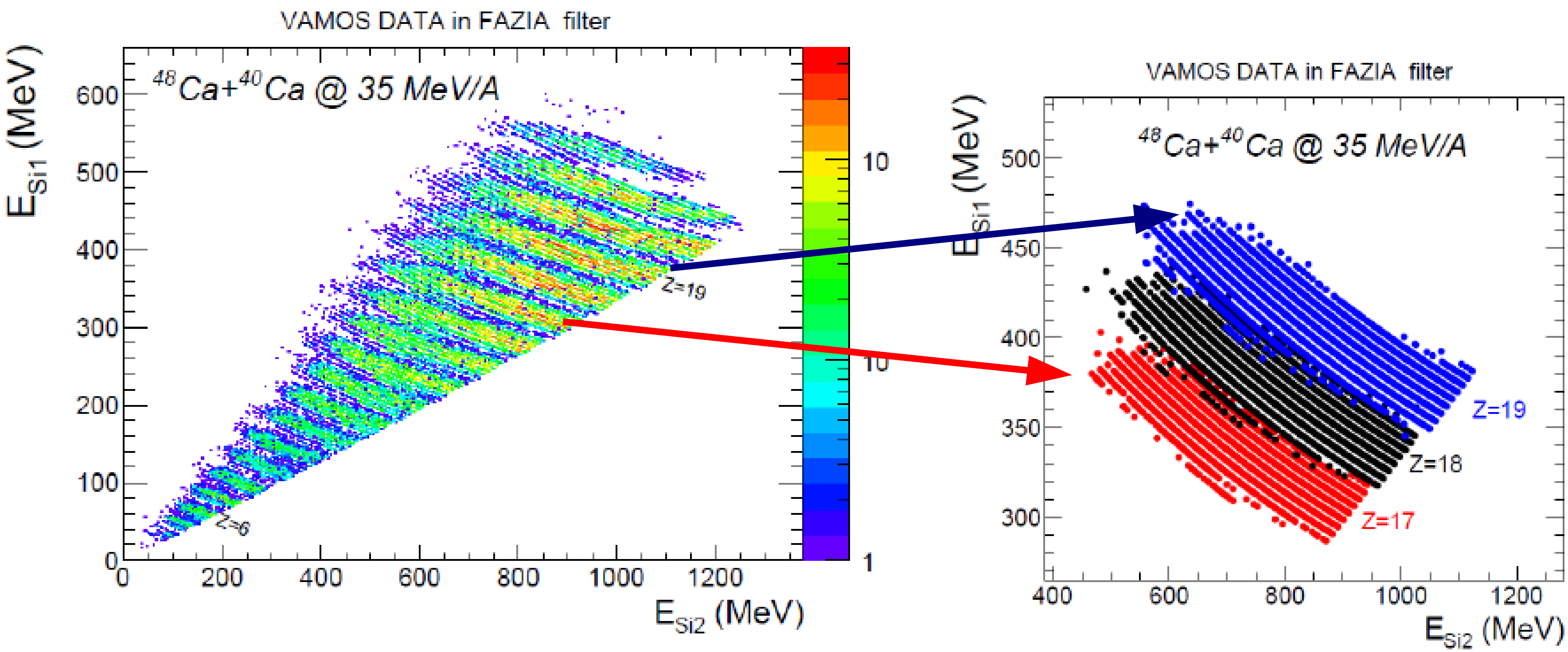


Schematic view of wall configuration

Scheduled for next year

FAZIA-4B experiments at LNS

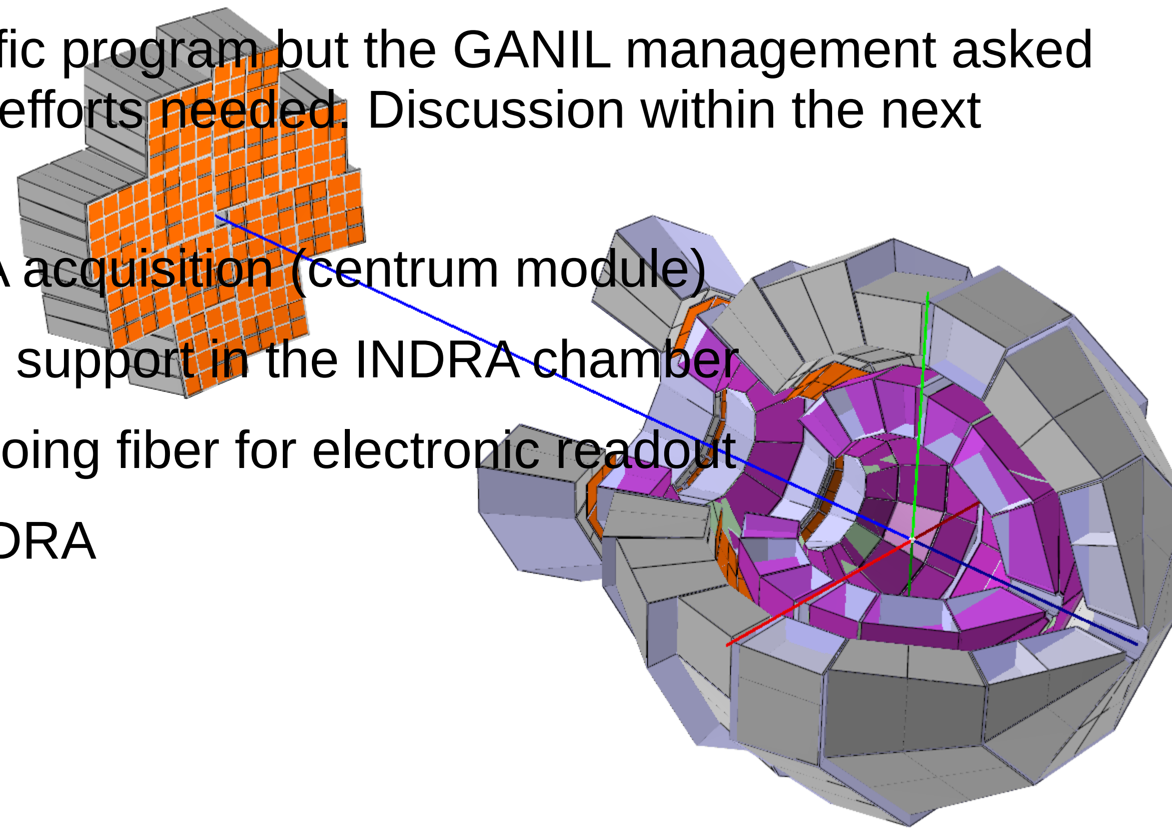
Broad isotopic distributions are expected using 48Ca n-rich beam leading to overlapping of A lines of two neighbor Z



Test the redundancy between PSA Z-identification and ΔE-E Z&A-identification.

FAZIA-12B+INDRA campaign @GANIL

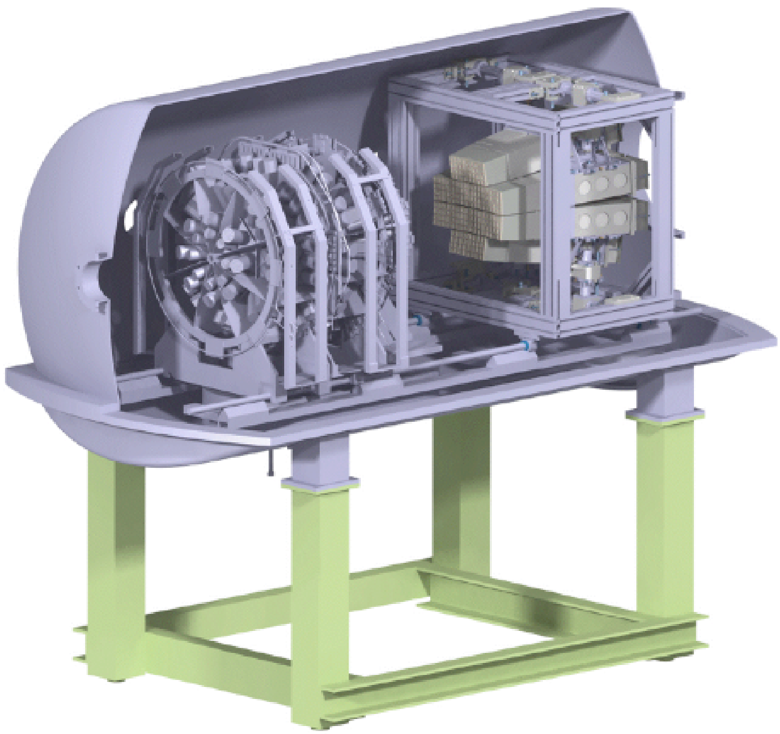
- One LoI submitted to the last GANIL PAC in April14 : “N/Z dependence of the dynamics in dissipative collisions, from evaporation towards vaporization”
- The PAC approved the scientific program but the GANIL management asked clarifications concerning local efforts needed. Discussion within the next scientific council of GANIL
  - Merging GANIL and FAZIA acquisition (centrum module)
  - Improve the solidity of ring support in the INDRA chamber
  - Cooling of FAZIA and outgoing fiber for electronic readout
  - Ionization chambers of INDRA

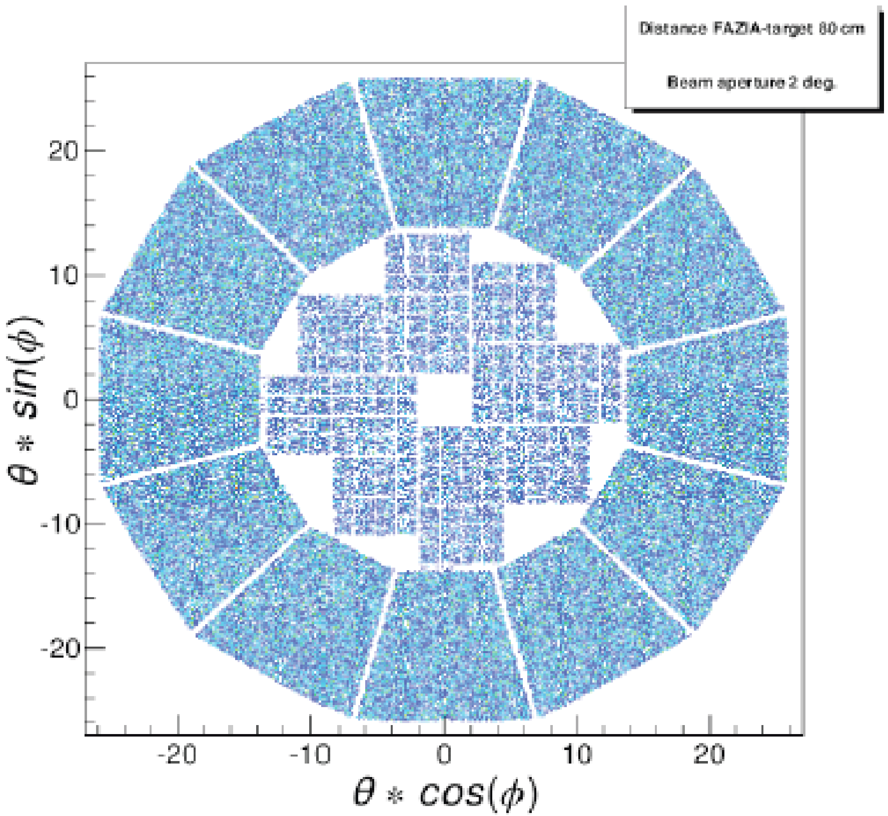


- 12 blocks should be ready in the end of 2016 when CSS2 beams (high energy beams) will be available.

N/Z dependence of the dynamics in dissipative collisions, from evaporation towards vaporization

^{40,48}Ca and ^{124,129,136}Xe beams between 35 and 88 MeV/A
Isotopic resolution for products in the angular range [2°,14°] covered by FAZIA
Improved angular resolution around (polar resolution [1°-1.4°])





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Evaporation | Multifragmentation | Vaporization

Decay chain | Flow and Stopping | Cluster Yields in nucleon gas

Level density parameter
Fission barrier
Viscosity

N-N cross section
Effective mass
Incompressibiilty

“In medium” nuclear data shift
Cluster-Gas interaction

- Bring constraints on Nuclear Equation of state at sub-saturation densities and finite temperatures for isospin (N/Z) between 1.0 and 1.5.
- Provide high quality data and results from the INDRA-FAZIA campaign to ask fundings to increase the number of FAZIA blocks.

Waiting for EURISOL

- FAZIA blocks and telescopes are designed to make experiments with stable and exotic beam in the Fermi energy domain (20-100 MeV/A)
  - Equation of state at T>0, rho<rho0 with isospin degree of freedom
  - Phase transition and related signatures
- FAZIA telescope prototypes demonstrated the capabilities and now we plan to use the FAZIA demonstrator to start such scientific program.
    - Commissioning of one block (LNS)
    - 2 accepted experiment for FAZIA-4B (LNS)
    - FAZIA-12B+INDRA campaign at GANIL
- Start to think about the integration of large number of blocks (connection, mechanics, shielding,cooling …)

European facilities time-scale and FAZIA program

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LE-RIB (p-rich) : SPIRAL

LE-RIB (n-rich)
SPES
SPIRAL2

HE-RIB
EURISOL

Now, 2014 | 2015-2017 | 202? | 20??

FAZIA-1B@LNS
Commissioning

FAZIA-4B@LNS
Measurements@NFS
FAZIA-12B+INDRA@GANIL

FAZIA-1π

FAZIA-2π
and more

Short term | Mid term | Long term

4π apparatus
CHIMERA
INDRA
GARFIELD

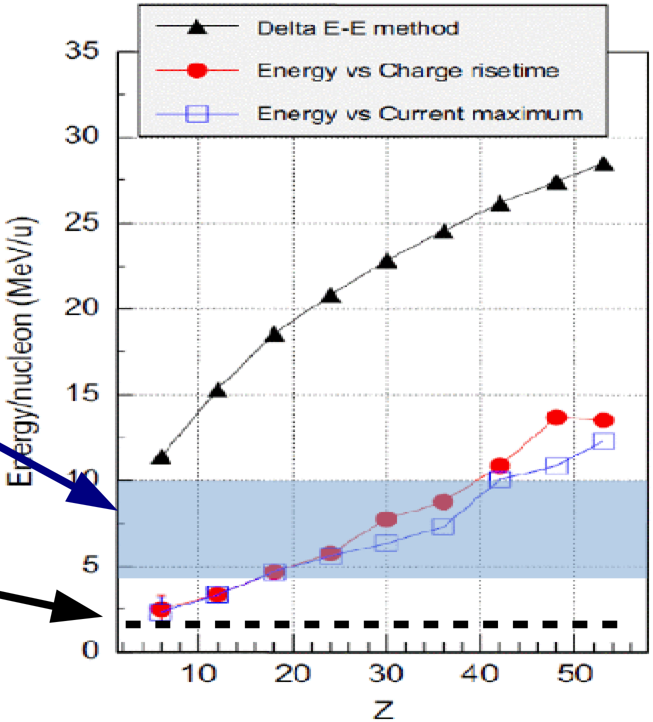
To be maintained and upgraded

Mid term :
LE-RIB : SPES, SPIRAL2

- As mentioned before the present design of FAZIA telescope implies high energy threshold for Z-identification.
- For path in the Silicon detector lower than 30 µm (for a C) to 100 µm (for a Xe), no discrimination is possible using PSA.
- Dedicated development has to be done to use FAZIA blocks at SPES energies (5-10 MeV/A)

SPES and SPIRAL2
beam energy range

Threshold needed to perform
experiments with LE-RIB (1 MeV/A)



Lower the Z-identification threshold

- Two options are possible, both consist in replacing the first detection stage Si(300μ) by :
  - Ionization chamber (IC) : experienced with it, thanks to the use of INDRA and GARFIELD. It's working with threshold around 1 MeV/A
  - Very thin Silicon thickness lower than 30 μm leading to threshold around 1.5-2 MeV/A

Low-Energy solution 1 : IC

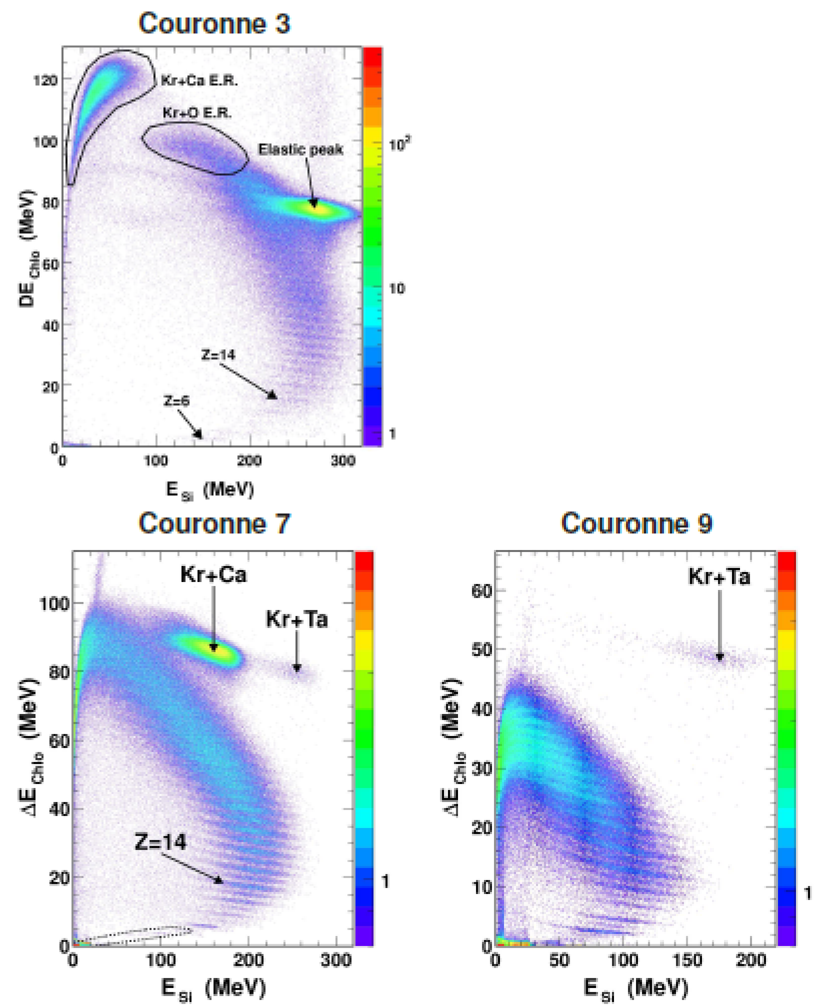


FIG. 3.10: *Exemple de matrices d'identification, pour les couronnes 3, 5, 7, 9, combinant l'énergie déposée dans la chambre d'ionisation (axe vertical) et dans le détecteur silicium (axe horizontal) pour les fragments produits dans la réaction ^{78}Kr+^{40}Ca à 5.5 AMeV.*

Thanks to the low energy threshold of Ionization chamber, on one IC-Si map, one can identify :

- Evaporation residues region
- Charge of lighter products :
  - Fission Fragments
  - Quasi-projectiles

^{78,82}Kr+^{40}Ca@5.5MeV/A INDRA@GANIL
G. Ademard Thesis, GANIL, 2011

Low-Energy solution 1 : IC

32S+40Ca@17MeV/A (LNL)

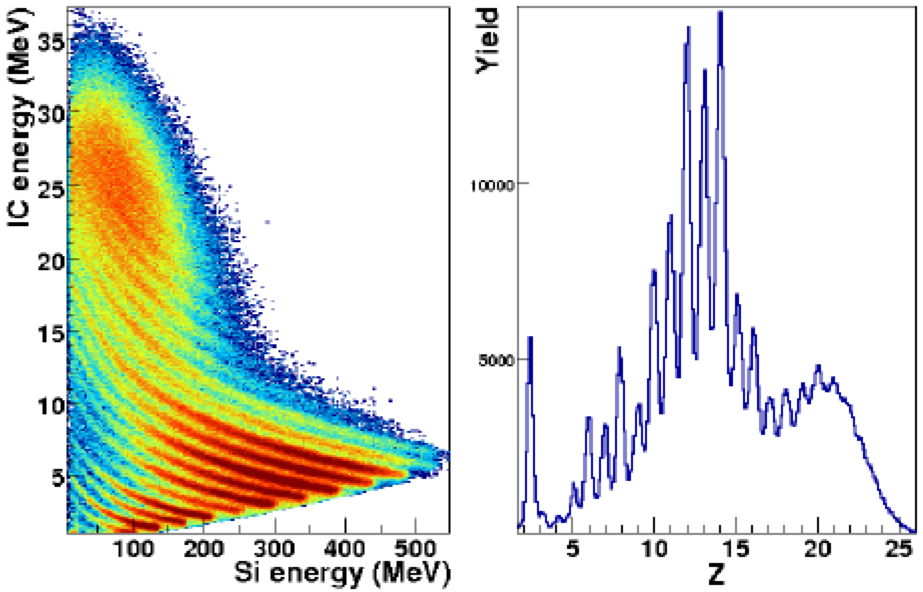


Fig. 13. *(Color online) Left panel: ΔE - E correlation "IC vs silicon" for the reaction ^{32}S + ^{40}Ca at 17 MeV/u at $\theta \approx 8°$. The line which extends to the largest silicon energy corresponds to ^{32}S ions. Right panel: PID for the same data. The $Z = 2$ distribution is slightly shifted from the right value since the procedure is optimized for greater Z values.*

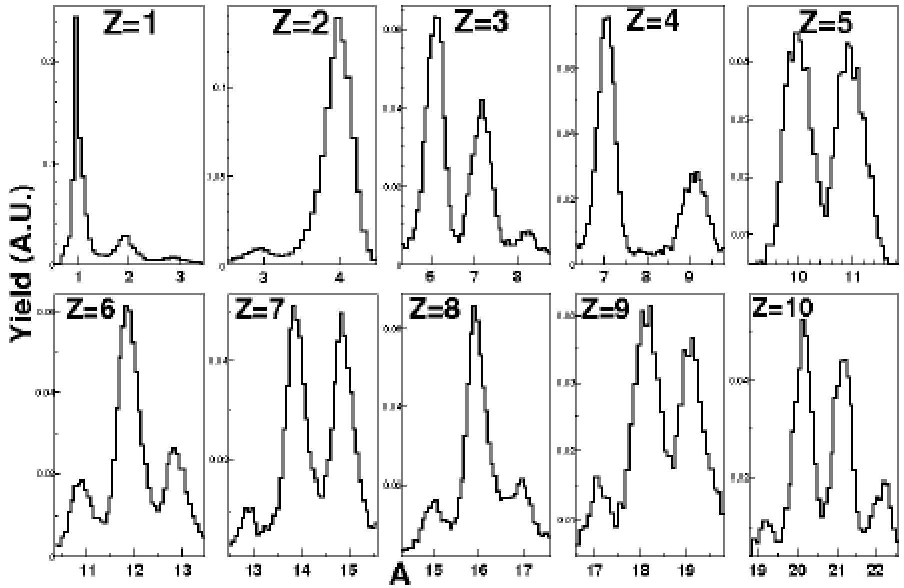


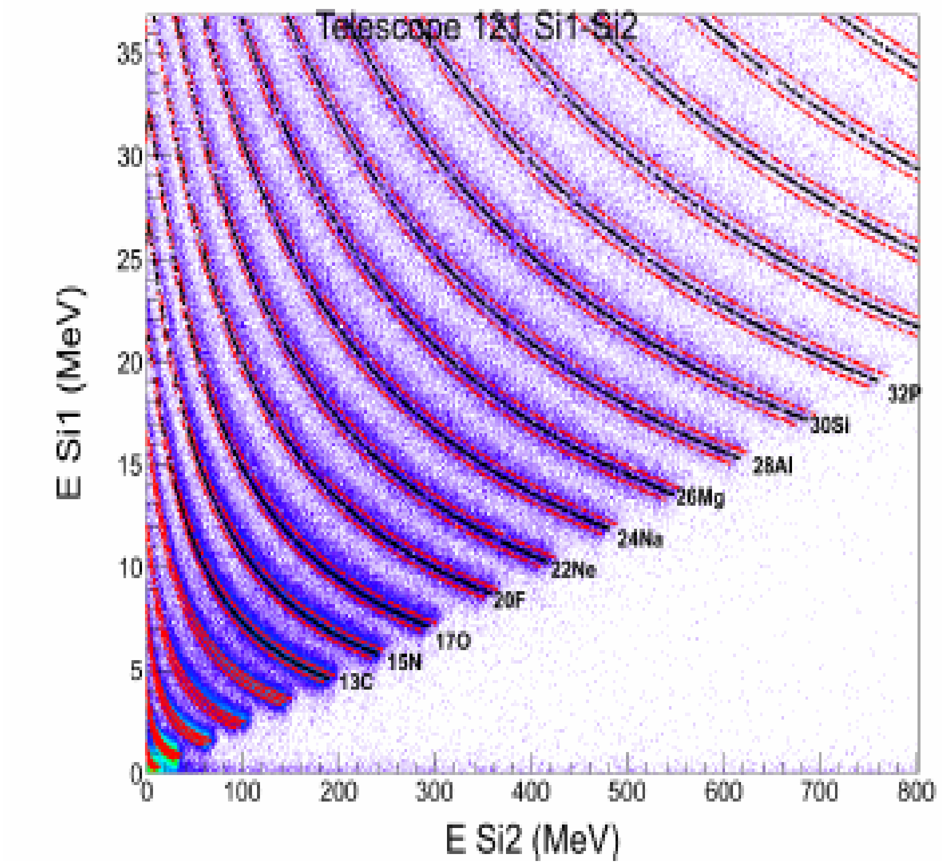
Fig. 15. *Mass identification with the procedure described in Ref. [40].*

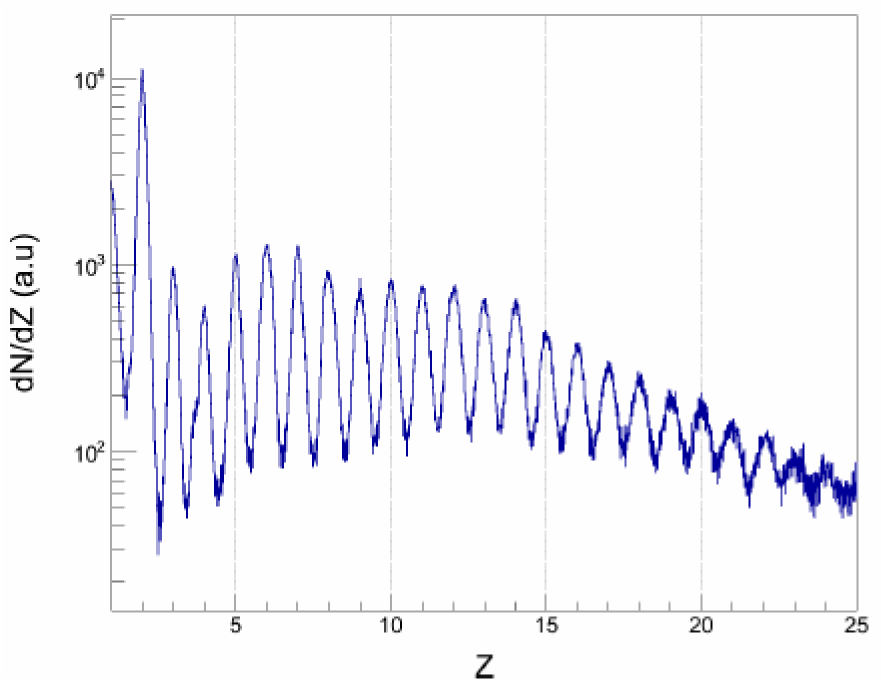
Similar threshold and Z-identification with the ring counter of GARFIELD

EPJ A (2013) 49: 128

Low-Energy solution 2 : Thin Si

- Preliminary results for Si(20µm)-Si(500µm) identification map are encouraging





"Low Temperature Technology of thin silicon ion implanted epitaxial detectors" A. J. Kordyasz et al, in preparation

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  - Ionization chamber (IC) : experienced with it, thanks to the use of INDRA and GARFIELD. It's working with threshold around 1 MeV/A
  - Very thin Silicon thickness lower than 30 µm leading to threshold around 1.5-2 MeV/A
- The collaboration has to look deeper into details on the implication of changing the first stage of detection specially concerning :
  - Mechanics and Electronics

FAZIA collaboration in SPES physics program

- Many members of the FAZIA collaboration are part of the LoI presented during this workshop :
  - G. Politi et al, *Isospin dependence of compound nucleus formation and decay.*
  - S. Barlini et al, *Prompt collective oscillations with exotic beams.*
  - L. Morelli et al, *Projectile and Compound Nucleus Decay with light beams provided by SPES*
  - T. Marchi et al, *Preequilibrium emission: a tool to study dynamic effects and clustering structure in exotic nuclei*
  - G. Casini et al, *Isospin dynamics and thermodynamics in n-rich heavy-ion induced reactions*
- The collaboration is certainly open for possible synergies with other apparatuses.

The FAZIA Collaboration

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