Status of the FAZIA project

Olivier LOPEZ (LPC Caen)

On behalf of the FAZIA Collaboration

ASY-EOS 2015,

International Workshop on Symmetry Energy and Reaction Mechanisms,

Piazza Armerina, Sicily (I) , March 3-6, 2015

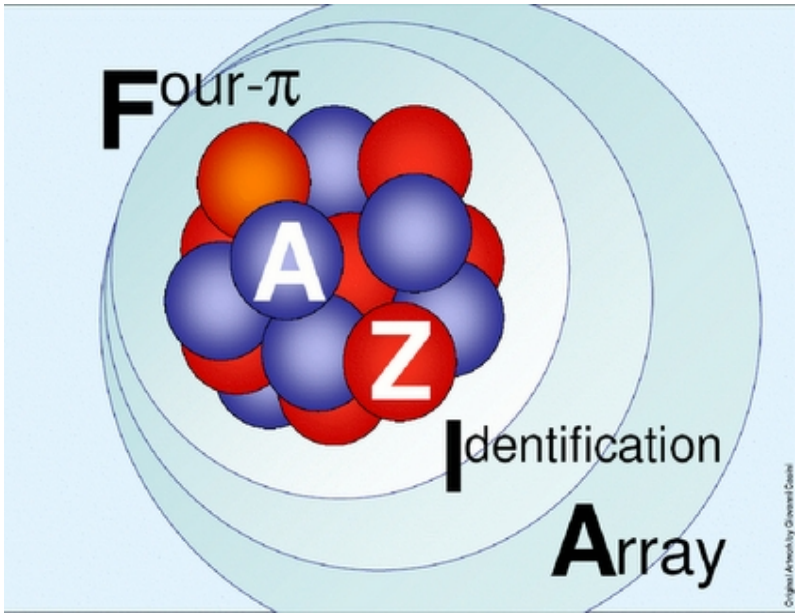
Why measuring the masses ?

- Phase transitions/calorimetry : better estimation for **primary fragments**
- Multifragmentation : **radial flow**, **spinodal decomposition**
- *EOS* : **symmetry energy** determination (*isoscaling*, *A*-distributions)
- Dynamical effects : better determination of the **neck emission** isospin content

Going further : *Z,A*-identification with 4π array

- **Digital Electronics** and **Sampling**: Pulse Shape Analysis (algorithms)
- **State-of-the-art Detection** strategy : *Si-Si-CsI* telescopes with **uniform resistivity** for the *Si (nTD)* and ***Tl* concentration** for *CsI(Tl)*
- **Next-gen trigger** : multi-level mode (Mult, Energy)
- **Integrated Electronics : FEE Cards (***PACI*, *FPGA,HV monitor*)
- **Automated calibration procedures** : Digital Signal Processing

FAZIA Project



http://fazia.in2p3.fr

FAZIA collaboration

- **35** physicists incl. PHD students and Post-Docs, **10** engineers and technicians
- involve **15** institutes from Europe : France, Italy, Spain, Poland, Romania

The FAZIA project in Europe: R&D phase

R. Bougault[1], G. Poggi[2,3], S. Barlini[2,3], B. Borderie[4], G. Casini[3], A. Chbihi[5], N. Le Neindre[1], M. Pârlog[1,6], G. Pasquali[2,3], S. Piantelli[3], Z. Sosin[7], G. Ademard[4], R. Alba[8], L. Bardelli[2,3], M. Bini[2,3], A. Boiano[12], M. Boisjoli[5], E. Bonnet[5], R. Borcea[6], B. Bougard[1], G. Brulin[4], M. Bruno[13], S. Carboni[2,3], M. Cinausero[10], L. Ciolacu[6], I. Cruceru[6], M. Cruceru[6], M. Degerlier[11], P. Desrues[1], J.A. Dueñas[9], P. Edelbruck[4], M. Falorsi[2], J.D. Frankland[5], E. Galichet[4,18], K. Gasior[15], F. Gramegna[10], D. Gruyer[5], A. Grzeszczuk[15], M. Guerzoni[14], H. Hamrita[4], C. Huss[4], M. Kajetanowicz[7], K. Korcyl[17], A. Kordyasz[16], T. Kozik[7], P. Kulig[7], L. Lavergne[4], E. Legouée[1], O. Lopez[1], J. Łukasik[17], C. Maiolino[8], T. Marchi[10], P. Marini[5], I. Martel[9], Y. Merrer[1], L. Morelli[13], F. Negoita[6], A. Olmi[3], A. Ordine[12], C. Pain[1], M. Pałka[7], P. Pawłowski[17], M. Petcu[6], H. Petrascu[6], E. Piasecki[16], E. Rauly[4], M.F. Rivet[4], E. Rosato[12], E. Scarlini[2], F. Salomon[4], D. Santonocito[8], V. Seredov[4], S. Serra[14], D. Sierpowski[7], G. Spadaccini[12], C. Spitaels[5], A.A. Stefanini[2,3], G. Tobia[3], G. Tortone[12], T. Twaróg[7], S. Valdré[2,3], E. Vient[1], M. Vigilante[12], E. Wanlin[4], A. Wieloch[7], and W. Zipper[15]

FAZIA Collaboration

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[9] Departamento de Fisica Aplicada, FCCEE Universidad de Huelva, 21071 Huelva, Spain.
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[12] Dipartimento di Fisica, Università di Napoli "Federico II" and INFN, Sezione di Napoli, Compl. Un. Monte S.Angelo - ed. 6, 80126 Napoli, Italy.
[13] Dipartimento di Fisica ed Astronomia, Università di Bologna and INFN, Sezione di Bologna, Via Irnerio 46, I-40126 Bologna, Italy.
[14] INFN, Sezione di Bologna, Viale berti pichat 6/2, I-40127 Bologna, Italy.
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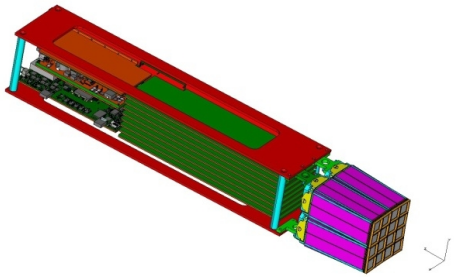
[17] Institute of Nuclear Physics PAN, ul. Radzikowskiego 152, 31-342 Krakw, Poland.
[18] Conservatoire National des Arts et Métiers, F-75141 Paris cedex 03, France.

Details can be found *in* R. Bougault et al. (FAZIA Coll.), Eur. Phys. J. A **50**, 47 (2014)

FAZIA milestones

- **Phase 0** (2001-2006) : **Telescope** *Si-Si-CsI* validation (*PICS*/AZ4π)

FAZIA milestones



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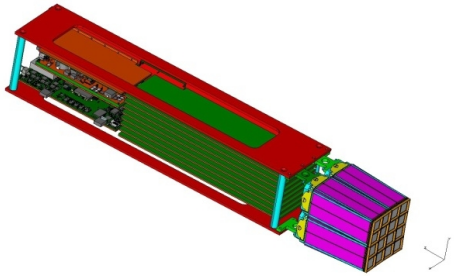

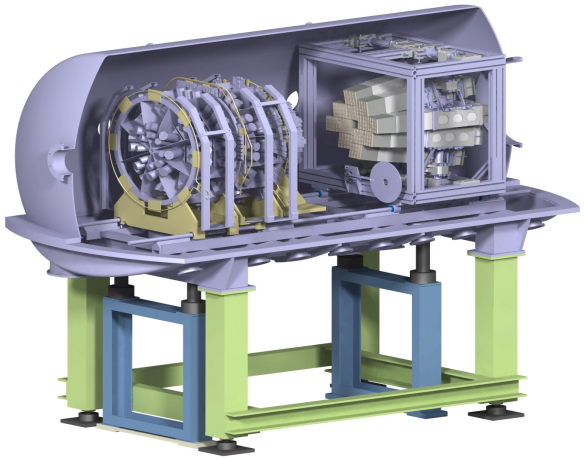

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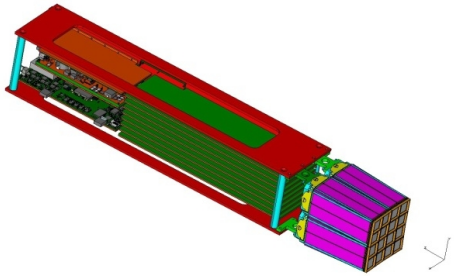
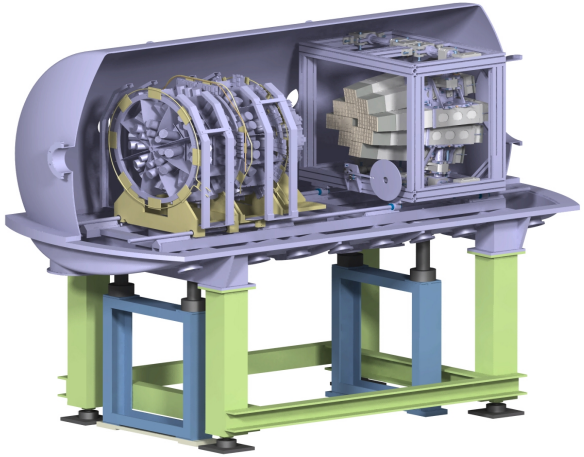
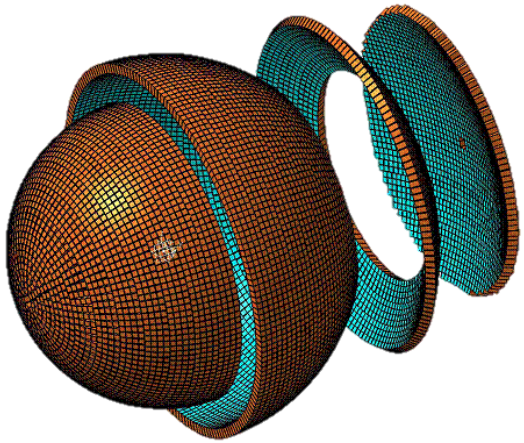
Commissioning : 2016+ (LNS/GANIL/SPIRAL1/SPES)

FAZIA milestones







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- **Phase 3** (2020+) : FAZIA array towards *x*π coverage (20-50B)

FAZIA Phase 1

Achievements toward the Block design

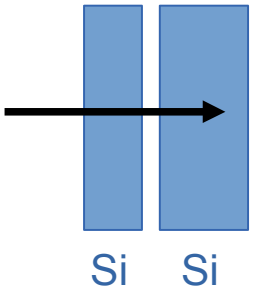
FAZIA improvements for *Z,A* identification

Improving the standard identification performances is due to:

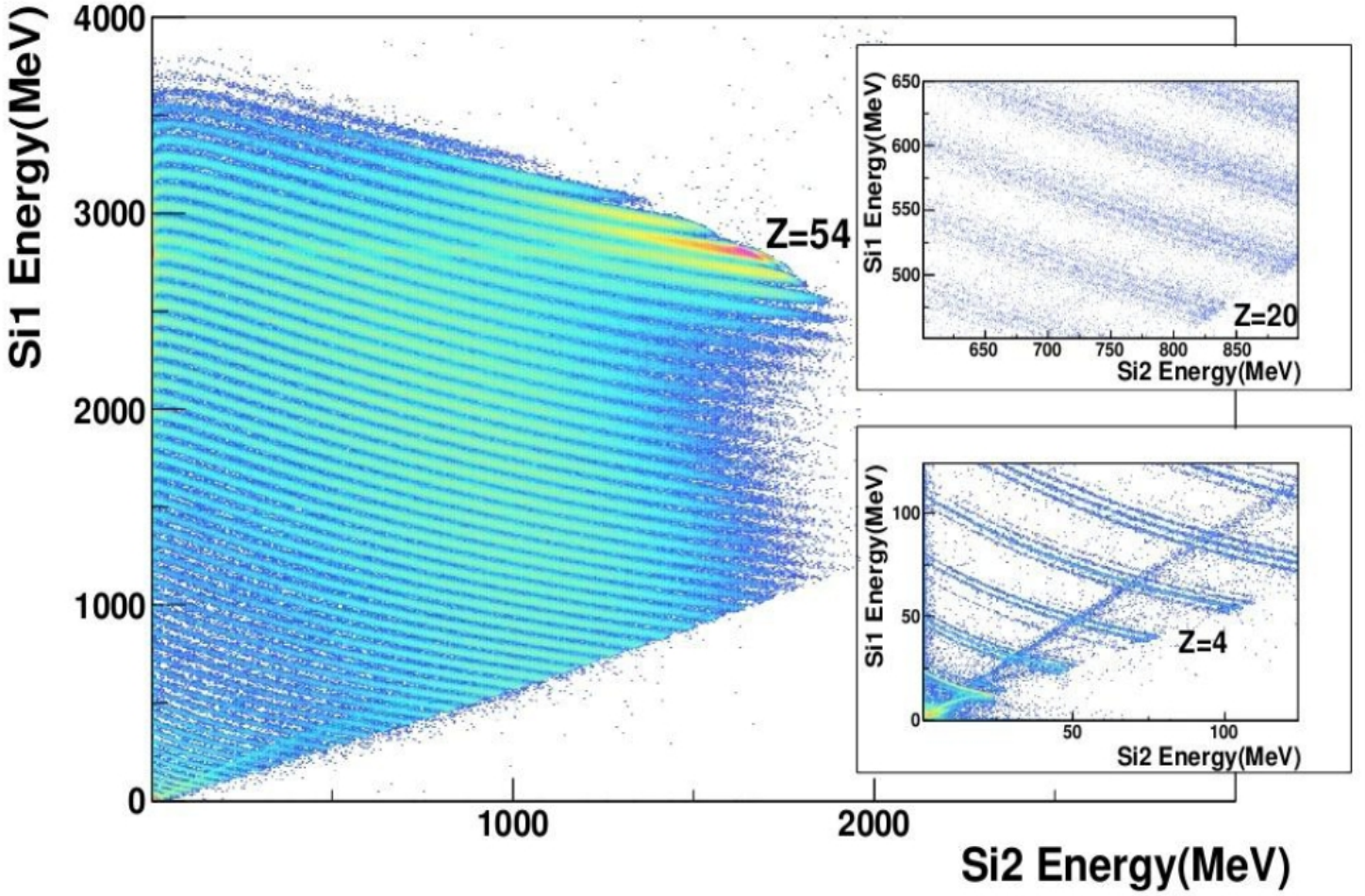
- **nTD** silicon detectors with **random cut** (uniformity 1-3%),
- **Reverse mounting :** low *E* entrance on rear (ohmic) side,
- **Digital Electronics** (PSA) : sampling 14 bits @ *100-250Mhz* , custom preamp *Q* and *I*

R. Bougault et al. (FAZIA Coll.), Eur. Phys. J. A **50**, 47 (2014)

FAZIA Phase 1 : *ΔE-E* identification



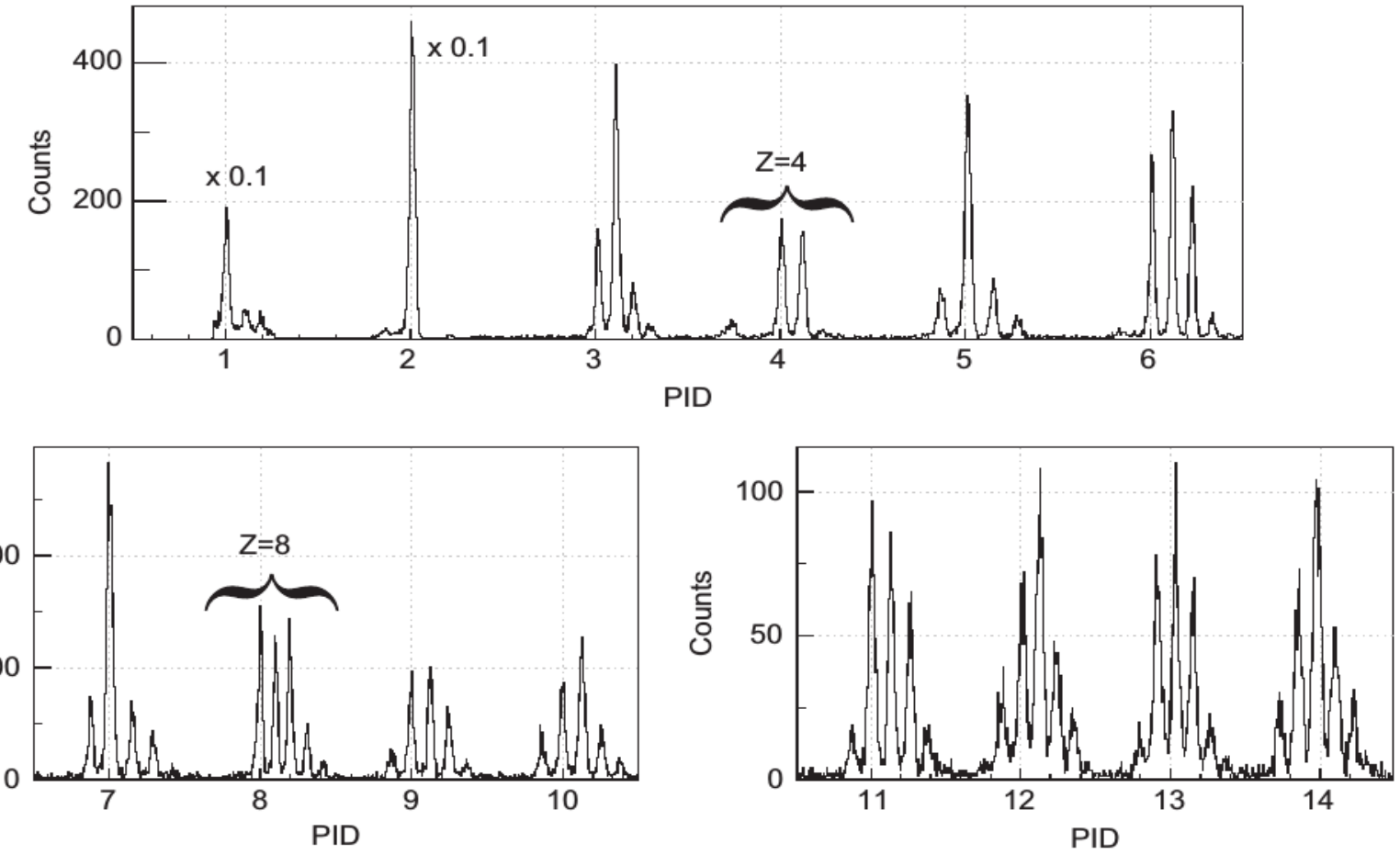
Some results at the end of phase 1: ΔE(Si1) – E (Si2)



S.Carboni et al., NIMA 664 (2012) 251 **Energy = max of shaped signal (trapezoidal filter)**

FAZIA improvements for *ΔE-E* identification

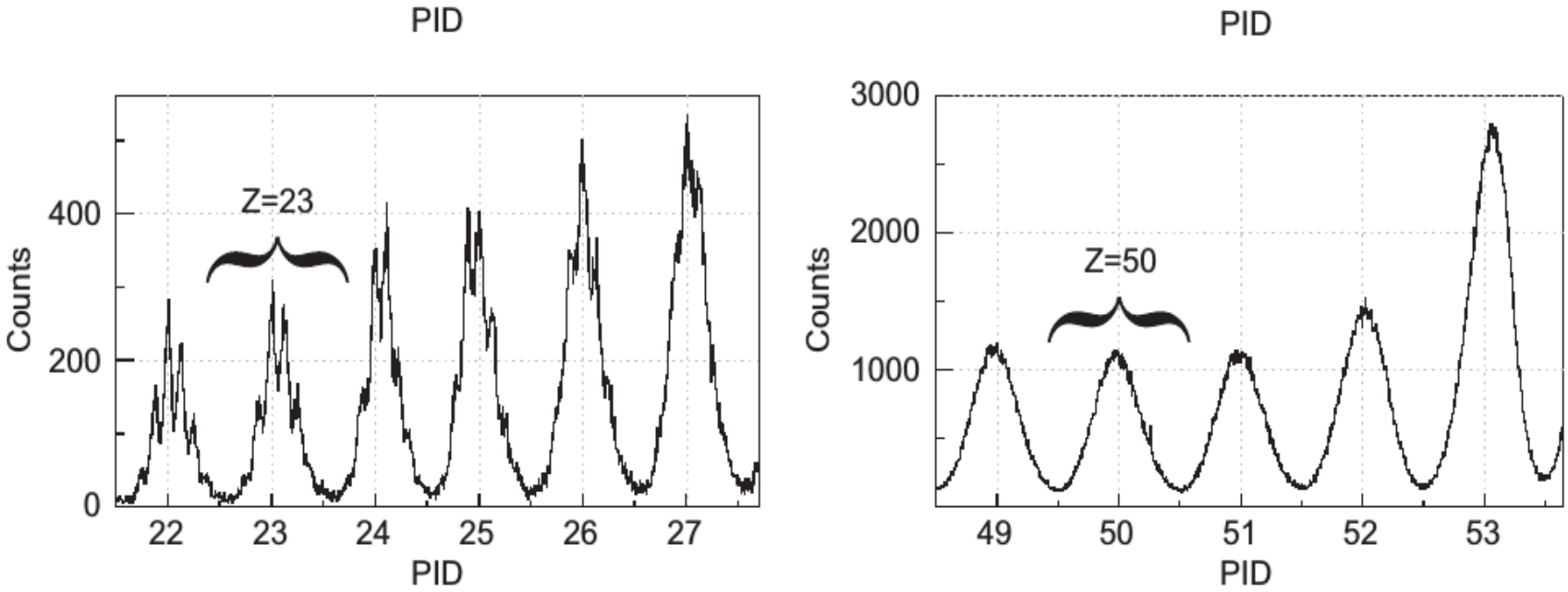
Improving **standard *E-ΔE*** identification method …



S. Carboni, NIM A **664** (2012)

FAZIA improvements for *ΔE-E* identification

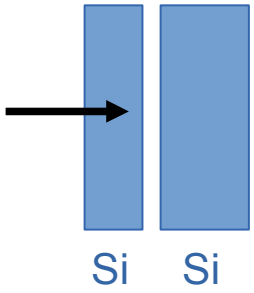
Improving **standard *E-ΔE*** identification method … up to **Z≈25** !



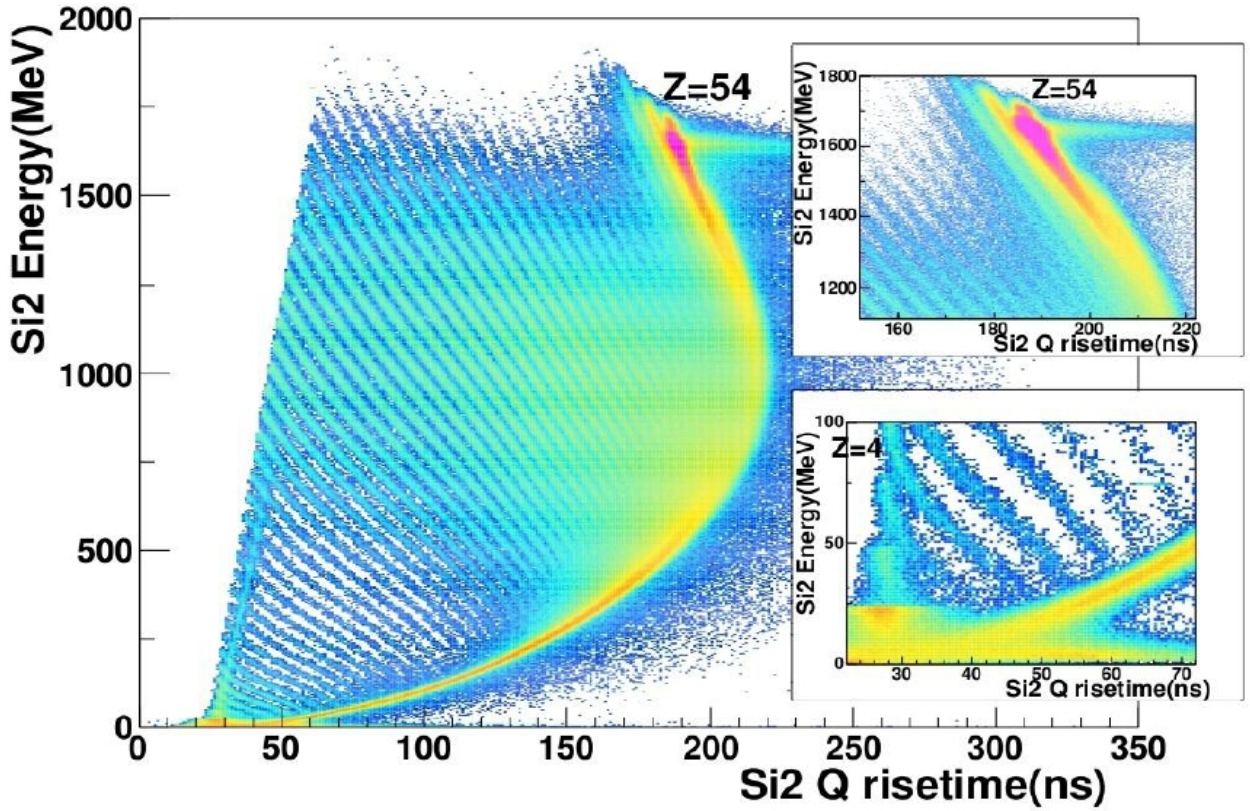
➢ Same quality results obtained with *Si-CsI*, with *A* identification up to Z≈22

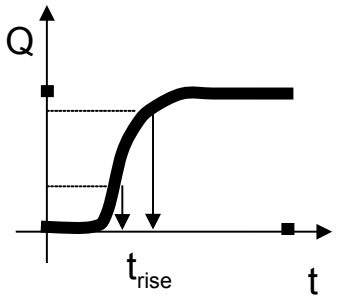
S. Carboni, NIM A **664** (2012)

FAZIA Phase 1 : Pulse Shape Analysis



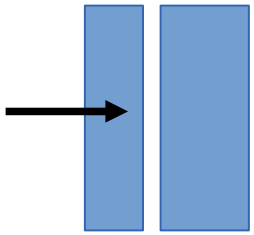
Some results at the end of phase 1:
Pulse Shape Analysis from E – Charge Rise Time





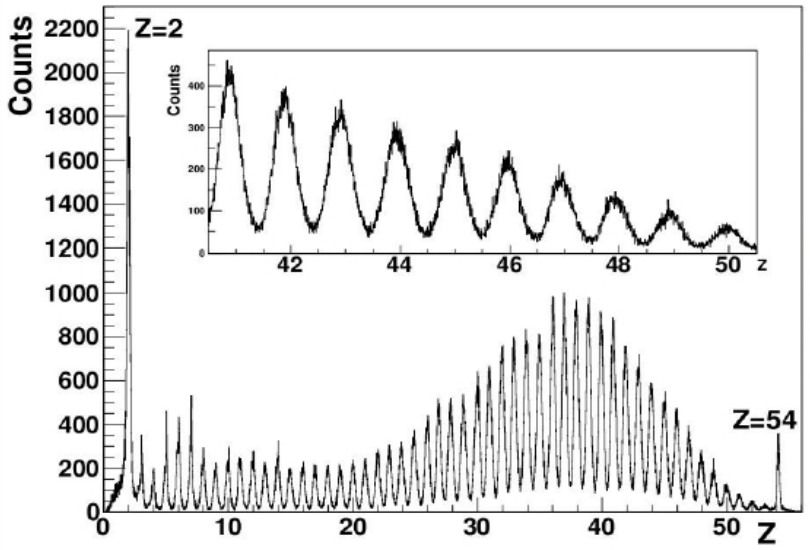
S.Carboni et al., NIMA 664 (2012) 251

FAZIA Phase 1 : Pulse Shape Analysis

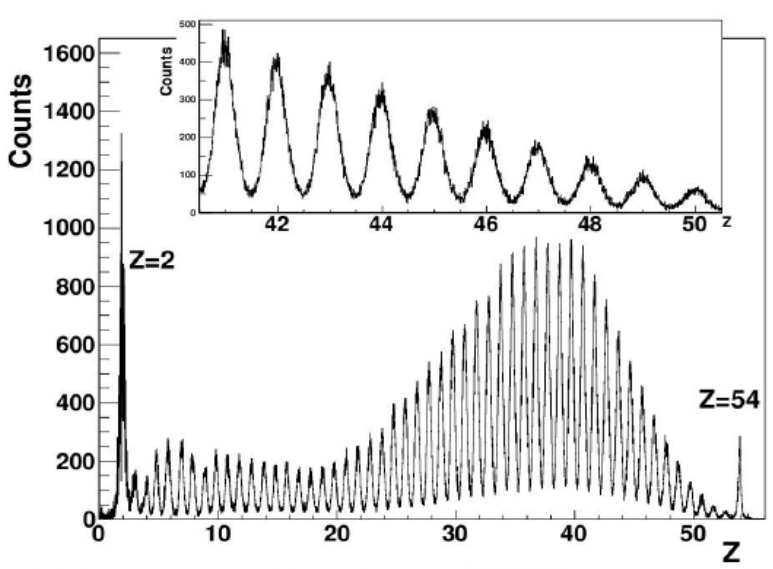


Some results at the end of phase 1:
Particle Identification from Pulse Shape Analysis

Energy vs. charge rise time



Energy vs. maximum of current signal

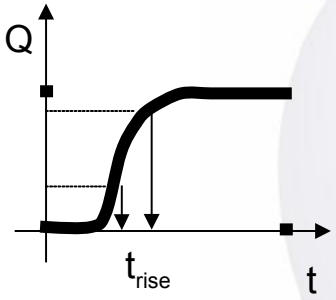


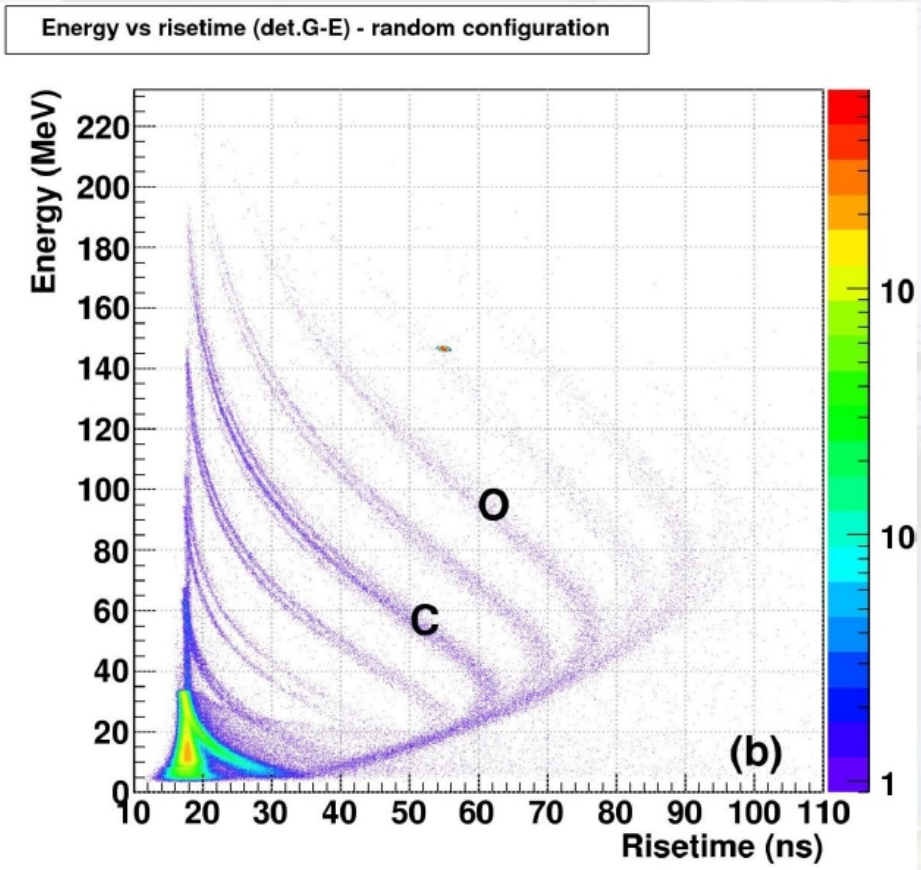
➢ *Z* identification can be achieved in the **first Silicon** detector

S.Carboni et al., NIMA 664 (2012) 251

FAZIA Phase 1 : Pulse Shape Anaysis

Some results at the end of phase 1: Mass resolution from Pulse Shape Analysis Energy vs. charge rise time





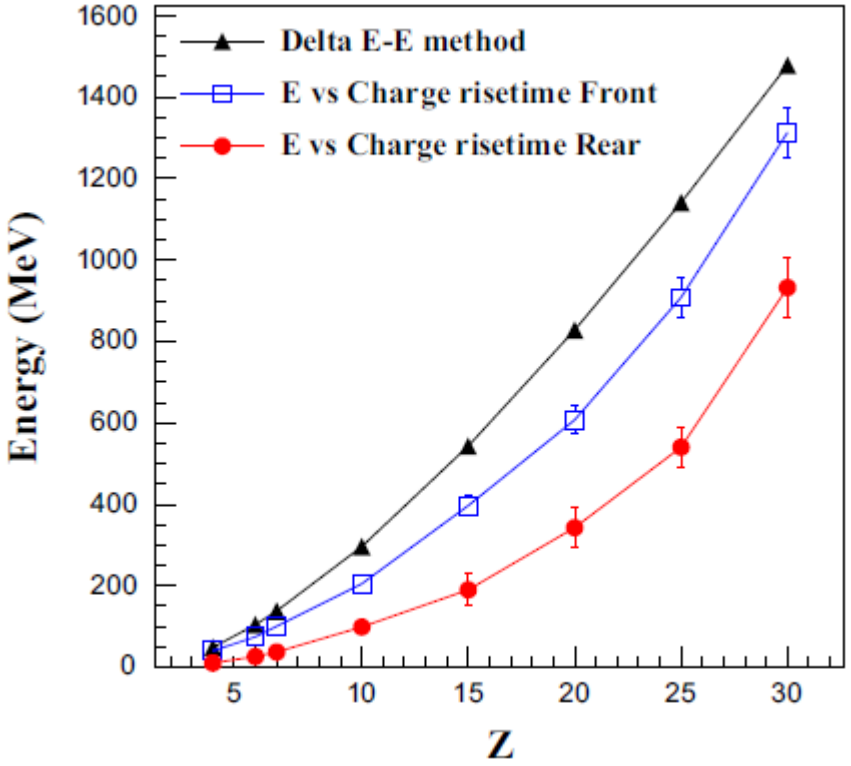
High gain
^{32}S beam@473MeV

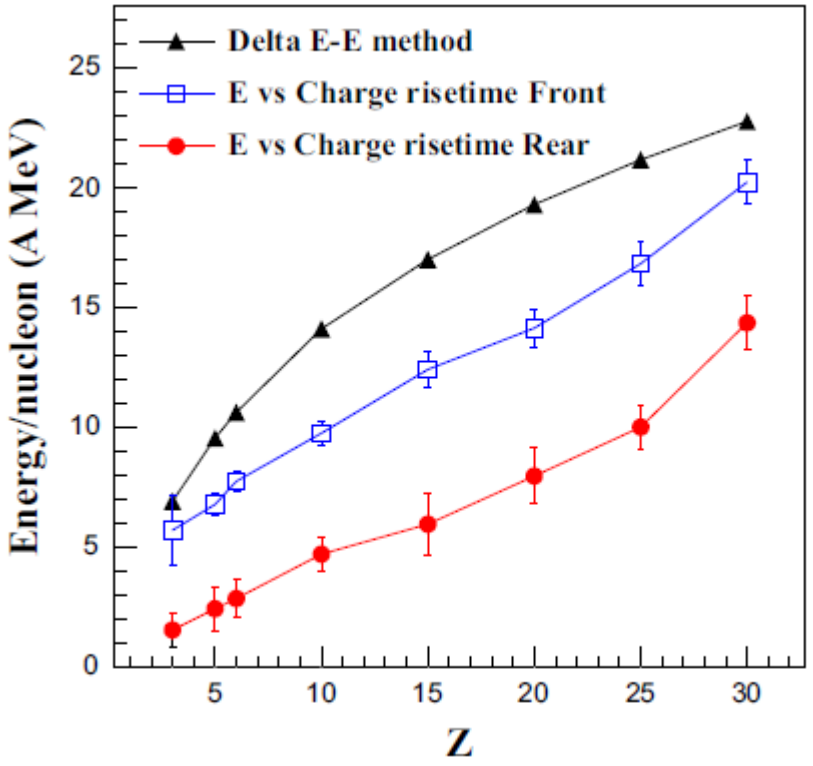
L.Bardelli et al., NIMA 654 (2011) 272

➢ Isotopic identification for **Z=3-8**

FAZIA phase 1 : *ID* thresholds (*Z*)

N. Le Neindre *et al.*, NIM A 701(2013) 145–152



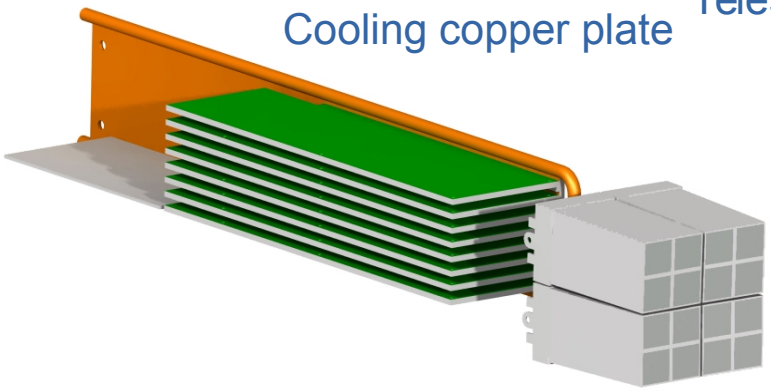


- **Pulse Shape Analysis** lowers significantly the Z (and A) thresholds
- **Rear-side** injection (low Electric Field entrance) is preferred

FAZIA Phase 2

From the block to the Demonstrator

FAZIA Phase 2 : Block structure



Telescope : Si(300µm) – Si(500µm) – CsI (10cm)

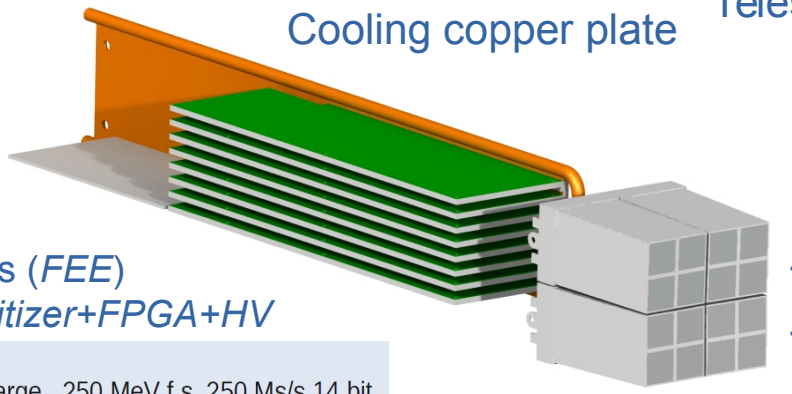
1 block : 16 telescopes, 8 *FEE* cards

1 block : ~100x100x650 mm

FAZIA Phase 2 : Block structure

Cooling copper plate

Telescope : Si(300µm) – Si(500µm) – CsI (10cm)

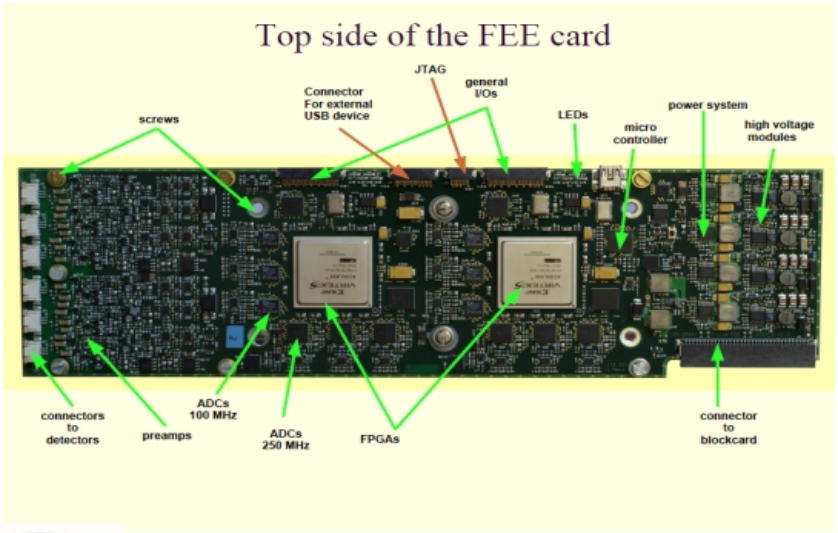


FEE Cards (*FEE*)
PACI+Digitizer+FPGA+HV

1 block : 16 telescopes, 8 *FEE* cards

1 block : ~100x100x650 mm

- 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



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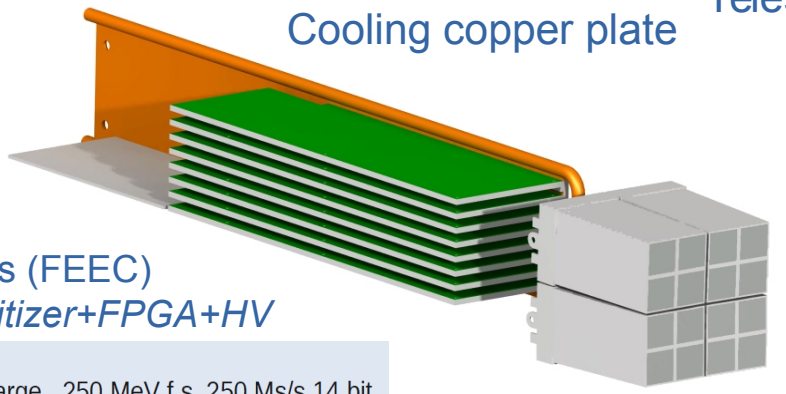

FEE Cards (FEEC)
PACI+Digitizer+FPGA+HV

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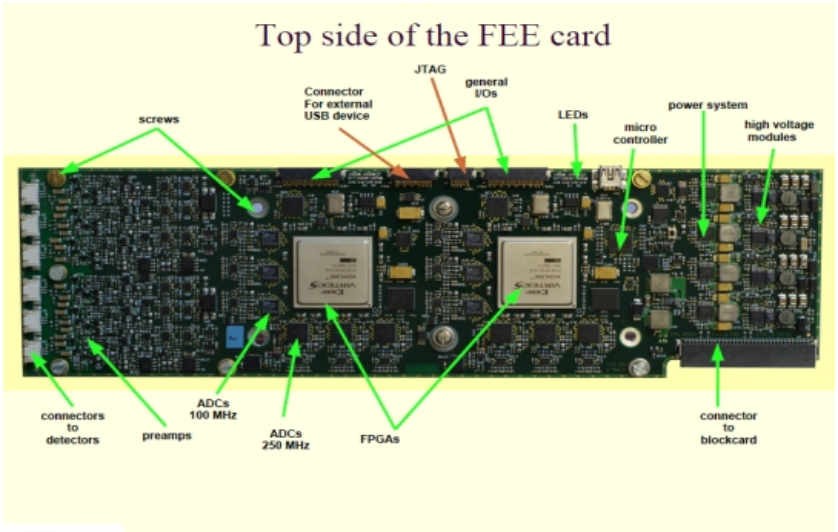
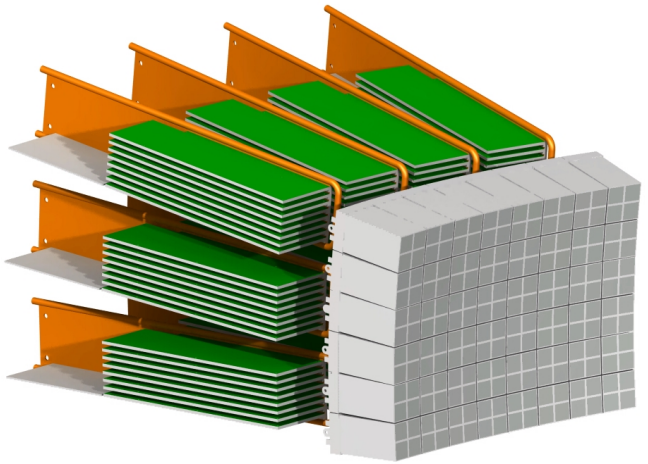
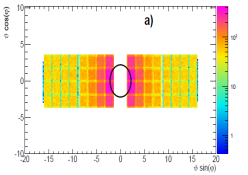


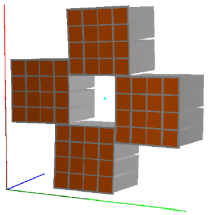
Demonstrator : « Wall » configuration



12 blocks : 192 telescopes, 96 *FEE*

Timeline for FAZIA experiments





2015 : 2 accepted experiments at LNS Catania (4 blocks)

- **IsoFAZIA** : *Isospin transport at Fermi energy for ^{78}Kr +^{46}Ti and ^{78}Kr +^{50}Ti at 35A MeV*,
  spoke persons : S. Piantelli and **N. Le Neindre**
- **FAZIAsym** : *Isotopic cross section measurements in the ^{40,48}Ca+^{40,48}Ca systems at 35A MeV*
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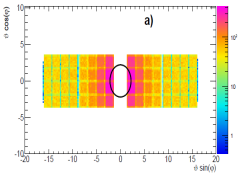

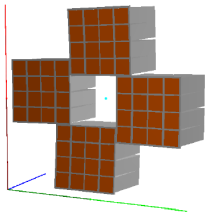

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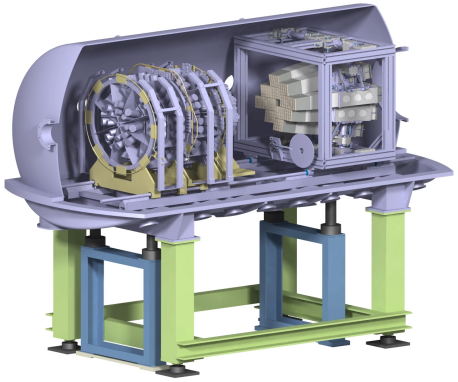
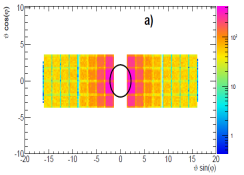
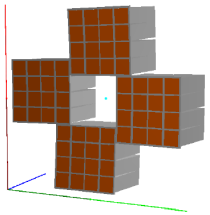
2017+ : INDRA-FAZIA(12 Blocks) coupling @ GANIL



- **GANIL** : ^{124,136}Xe at *25A-50A* MeV : Symmetry energy and EOS
- **SPIRAL** : ^{14,15,19,20}O + ^{12,13}C/^{7,9}Be : statistical .vs. cluster decay
- **LISE :** coupling with γ + strip detectors, beams ^{22}Ne up to ^{70}Ni @ 25-60A M

Timeline for FAZIA experiments

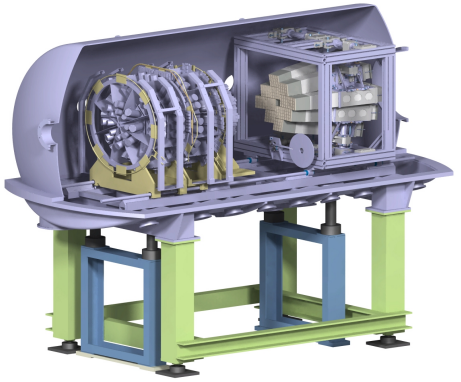




2015 : 2 accepted experiments at LNS Catania (4 blocks)

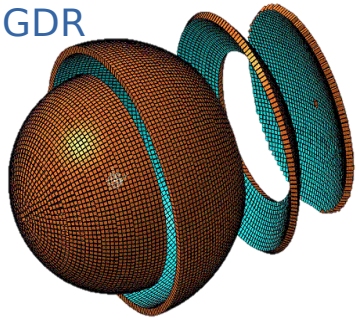
- **IsoFAZIA** : *Isospin transport at Fermi energy for ^{78}Kr +^{46}Ti and ^{78}Kr +^{50}Ti at 35A MeV*,
  spoke persons : S. Piantelli and **N. Le Neindre**
- **FAZIAsym** : *Isotopic cross section measurements in the ^{40,48}Ca+^{40,48}Ca systems at 35A MeV*
  spoke person : E. Bonnet

2017+ : INDRA-FAZIA(12 Blocks) coupling @ GANIL



- **GANIL** : ^{124,136}Xe at *25A-50A* MeV : Symmetry energy and EOS
- **SPIRAL** : ^{14,15,19,20}O + ^{12,13}C/^{7,9}Be : statistical .vs. cluster decay
- **LISE :** coupling with γ + strip detectors, beams ^{22}Ne up to ^{70}Ni @ 25-60A M

2020-2025? : FAZIA (12+) + GARFIELD + γ detectors @ LNL



- **LNL/SPES** : *QP* studies Ca-Ni-Kr-Xe, E<11A MeV : Dyn. Dipole Resonance, GDR
- **LNL/SPES** : Light systems *Si+C*, *Be+C*, cluster emission, E<15A MeV

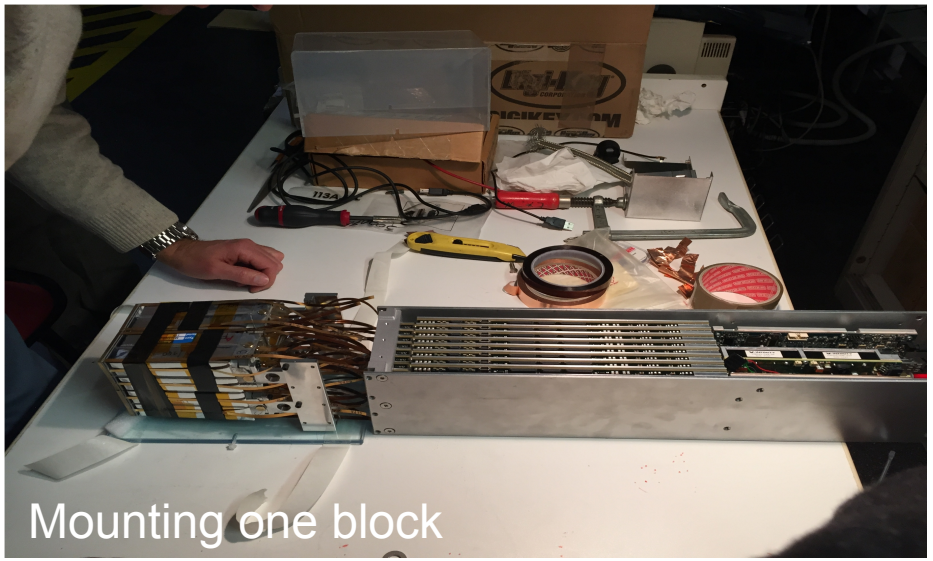
2025?? : FAZIA xπ (20-50B) ?

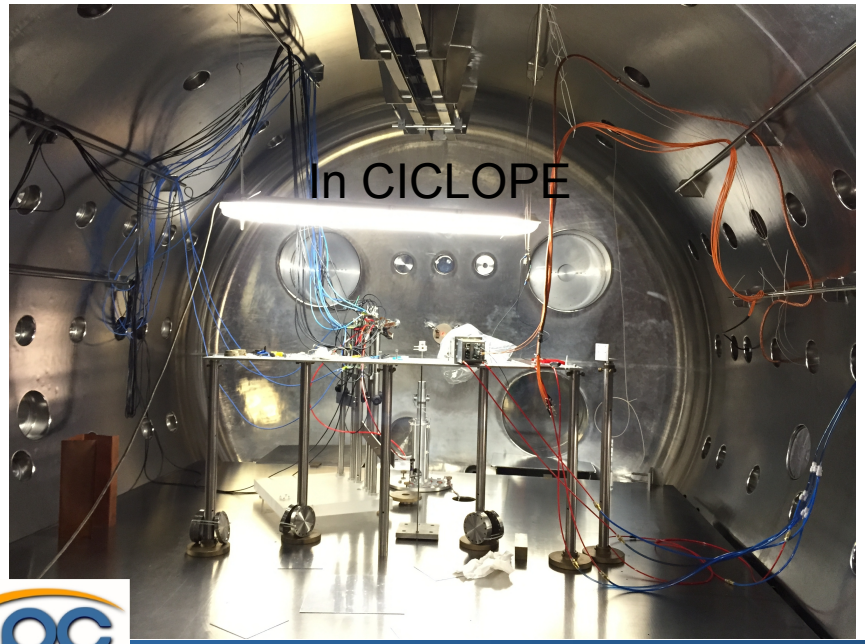
- EURISOL/SP2-PA : Fermi domain (30-100A MeV)

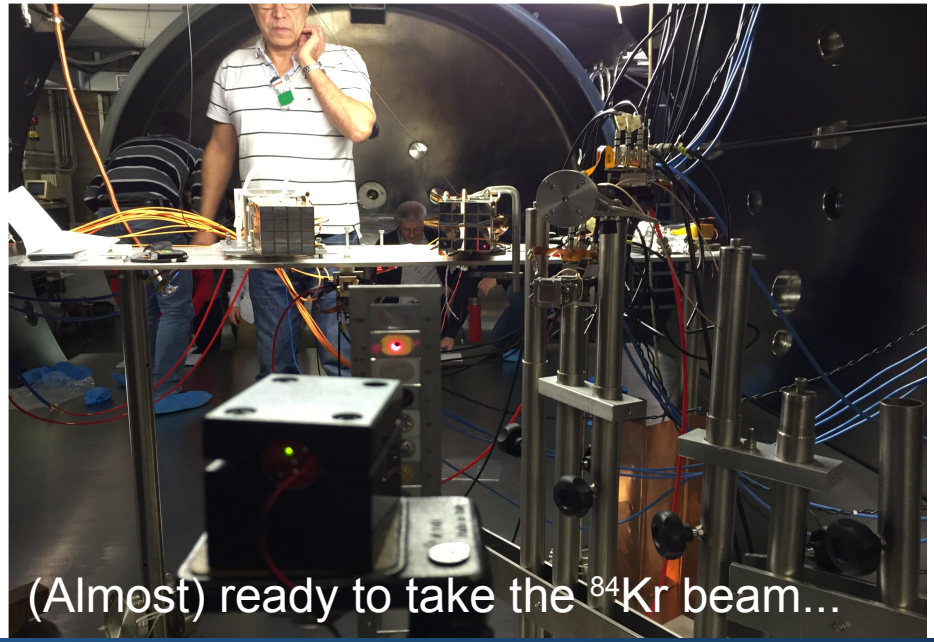
Latest news from FAZIA

FAZIA Block commissioning @ LNS Dec., 10-13 2014

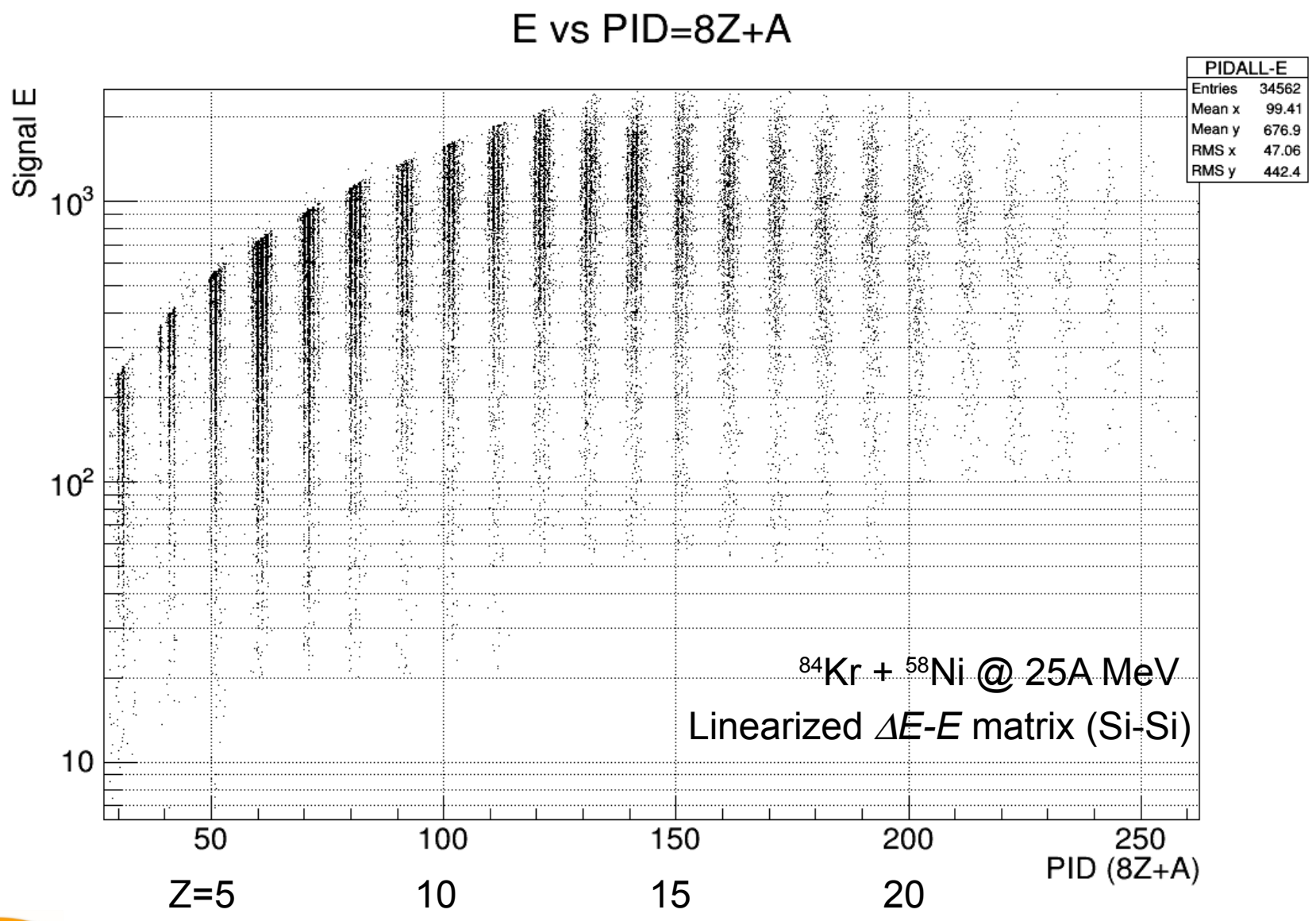

8 FEE cards ready to be assembled


Mounting one block

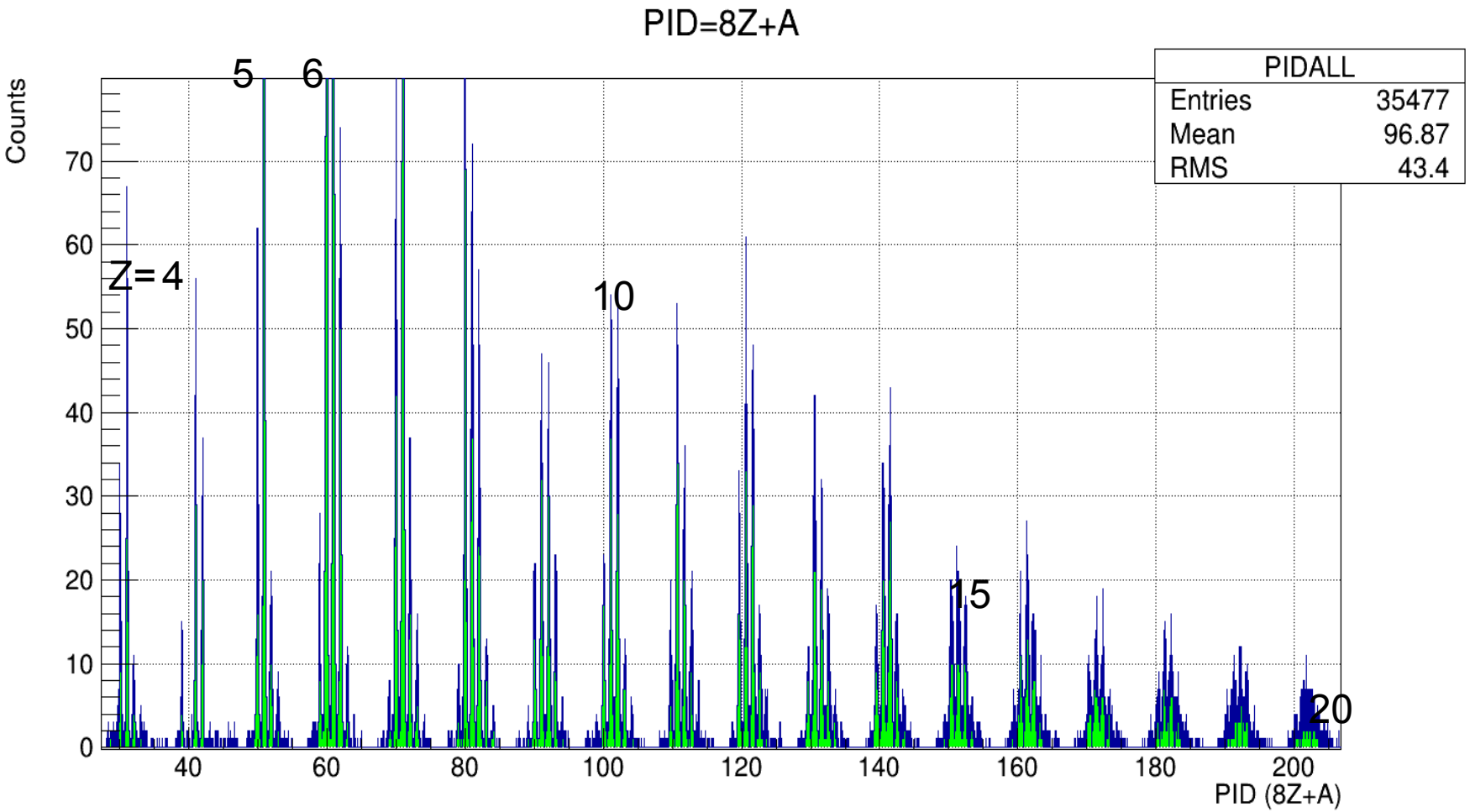

In CICLOPE


(Almost) ready to take the ^{84}Kr beam...

FAZIA Block commissioning @ LNS Dec. 2014

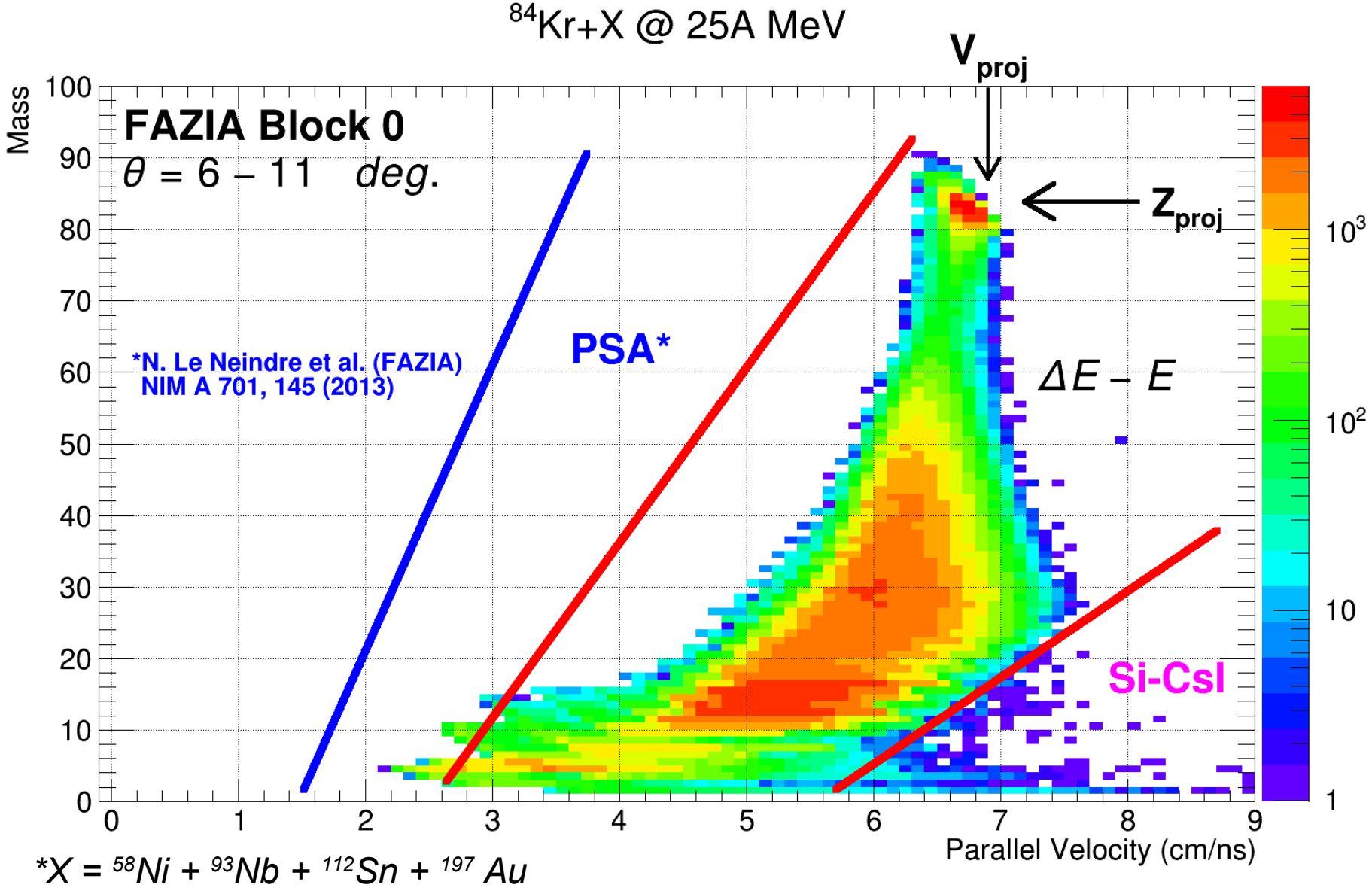


FAZIA Block commissioning @ LNS Dec. 2014



- Masses are resolved up to ***Z≈22,***
- Extrapolation to **Z=36** within *2-3 uma* uncertainty

FAZIA Block commissioning @ LNS Dec. 2014



(Not) The End

The FAZIA project in Europe: R&D phase

R. Bougault[1], G. Poggi[2,3], S. Barlini[2,3], B. Borderie[4], G. Casini[3], A. Chbihi[5], N. Le Neindre[1], M. Pârlog[1,6], G. Pasquali[2,3], S. Piantelli[3], Z. Sosin[7], G. Ademard[4], R. Alba[8], L. Bardelli[2,3], M. Bini[2,3], A. Boiano[12], M. Boisjoli[5], E. Bonnet[5], R. Borcea[6], B. Bougard[1], G. Brulin[4], M. Bruno[13], S. Carboni[2,3], M. Cinausero[10], L. Ciolacu[6], I. Cruceru[6], M. Cruceru[6], M. Degerlier[11], P. Desrues[1], J.A. Dueñas[9], P. Edelbruck[4], M. Falorsi[2], J.D. Frankland[5], E. Galichet[4,18], K. Gasior[15], F. Gramegna[10], D. Gruyer[5], A. Grzeszczuk[15], M. Guerzoni[14], H. Hamrita[4], C. Huss[4], M. Kajetanowicz[7], K. Korcyl[17], A. Kordyasz[16], T. Kozik[7], P. Kulig[7], L. Lavergne[4], E. Legouée[1], O. Lopez[1], J. Łukasik[17], C. Maiolino[8], T. Marchi[10], P. Marini[5], I. Martel[9], Y. Merrer[1], L. Morelli[13], F. Negoita[6], A. Olmi[3], A. Ordine[12], C. Pain[1], M. Pałka[7], P. Pawłowski[17], M. Petcu[6], H. Petrascu[6], E. Piasecki[16], E. Rauly[4], M.F. Rivet[4], E. Rosato[12], E. Scarlini[2], F. Salomon[4], D. Santonocito[8], V. Seredov[4], S. Serra[14], D. Sierpowski[7], G. Spadaccini[12], C. Spitaels[5], A.A. Stefanini[2,3], G. Tobia[3], G. Tortone[12], T. Twaróg[7], S. Valdré[2,3], E. Vient[1], M. Vigilante[12], E. Wanlin[4], A. Wieloch[7], and W. Zipper[15]

FAZIA Collaboration

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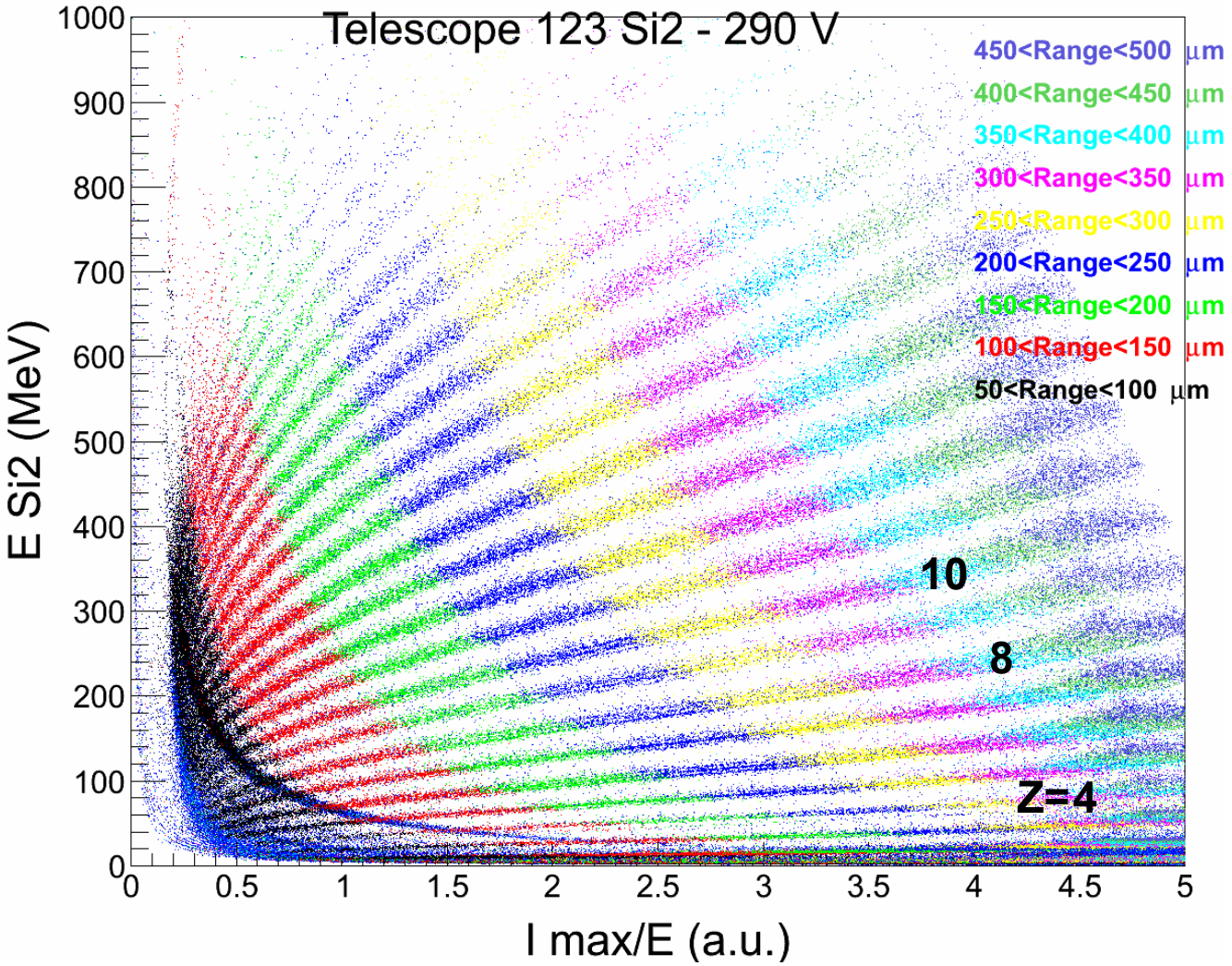
[18] Conservatoire National des Arts et Métiers, F-75141 Paris cedex 03, France.

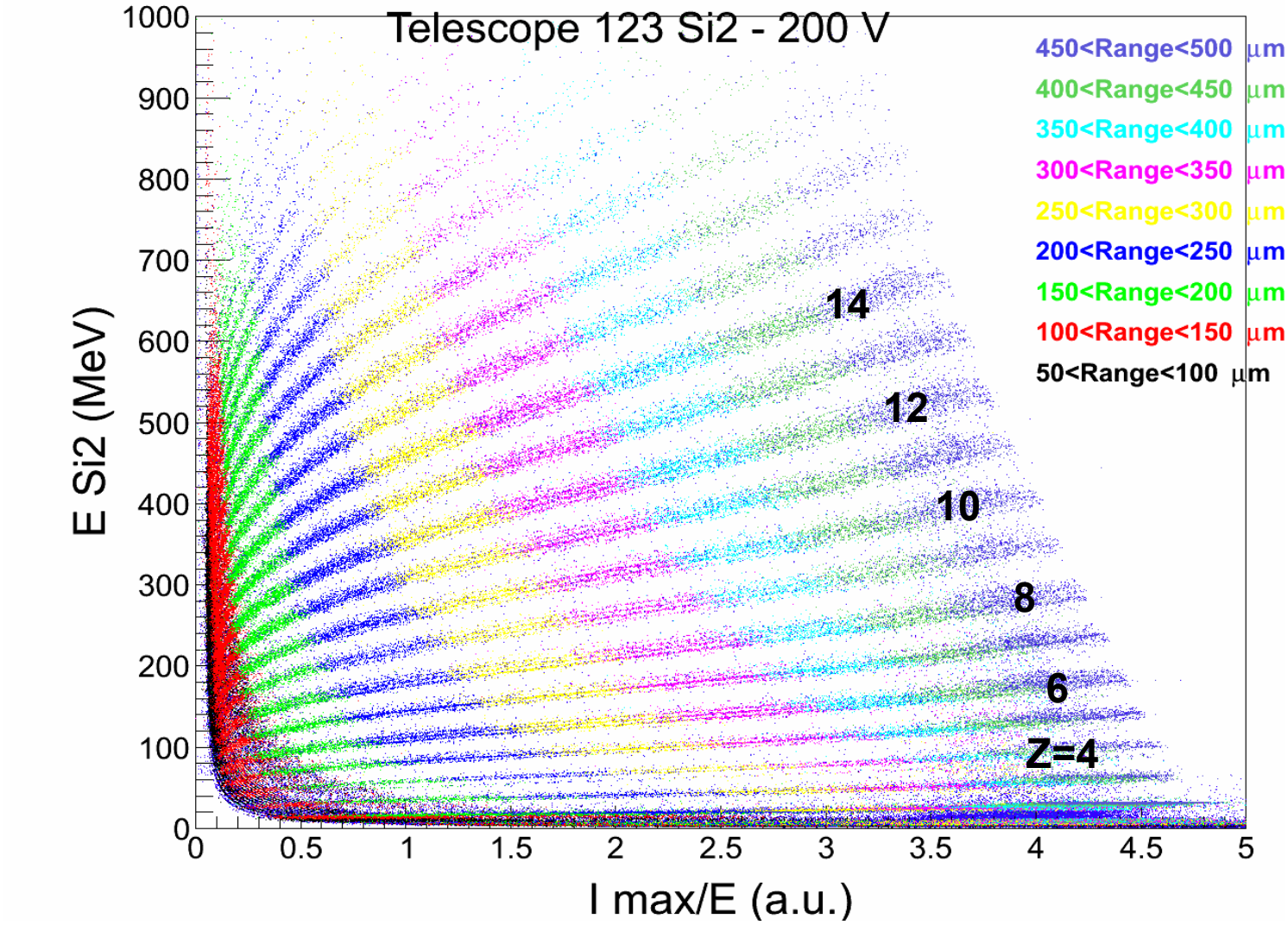
Improvement : lowering the depletion voltage

Full depletion voltage : 290V



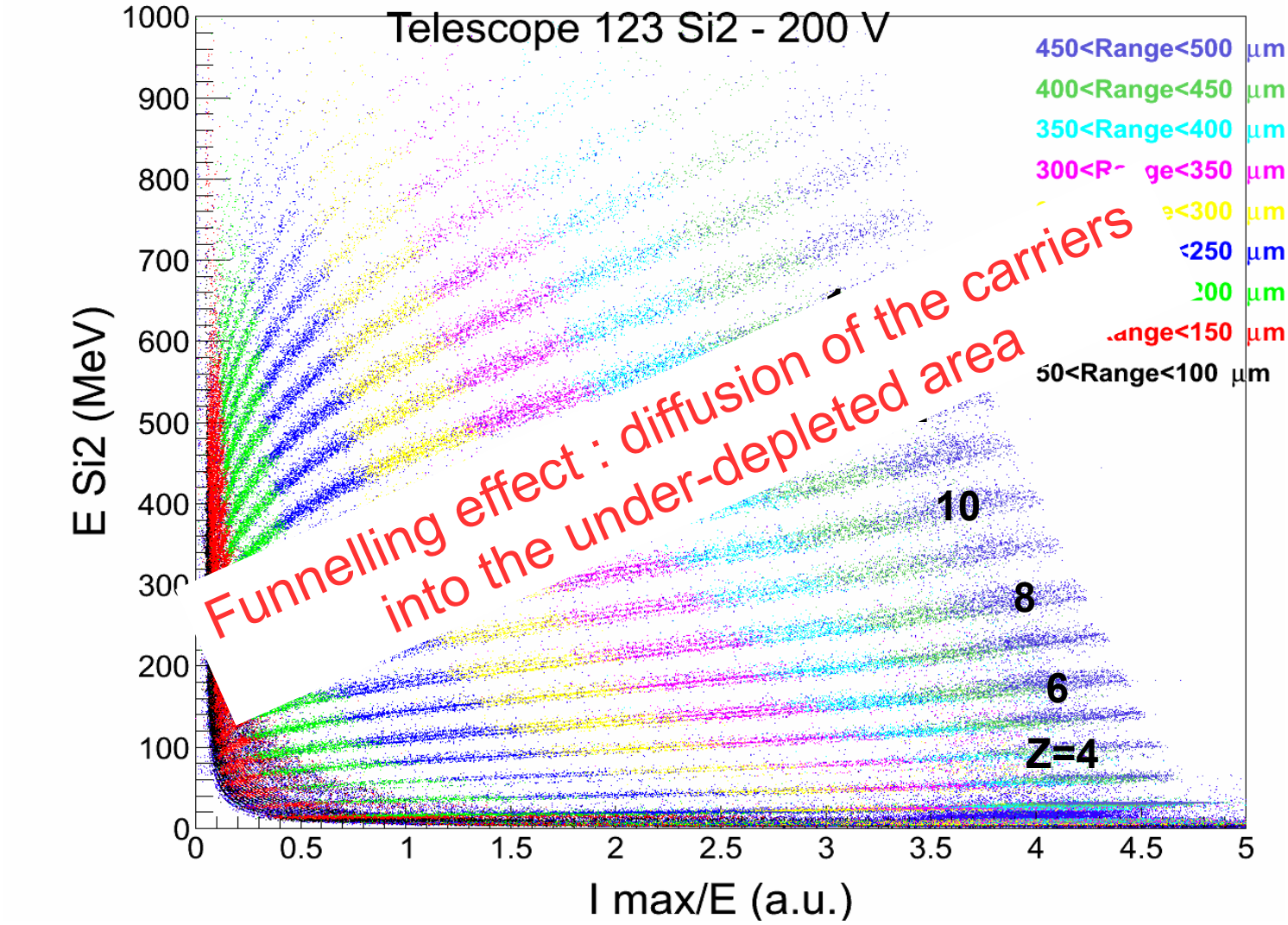
➢ Z resolution OK, isotopic resolution for **Z≈3-9 for range>200µm**

Improvement for PSA : funnelling



➢ Isotopic resolution for **Z≈3-14** for range**>350 µm**

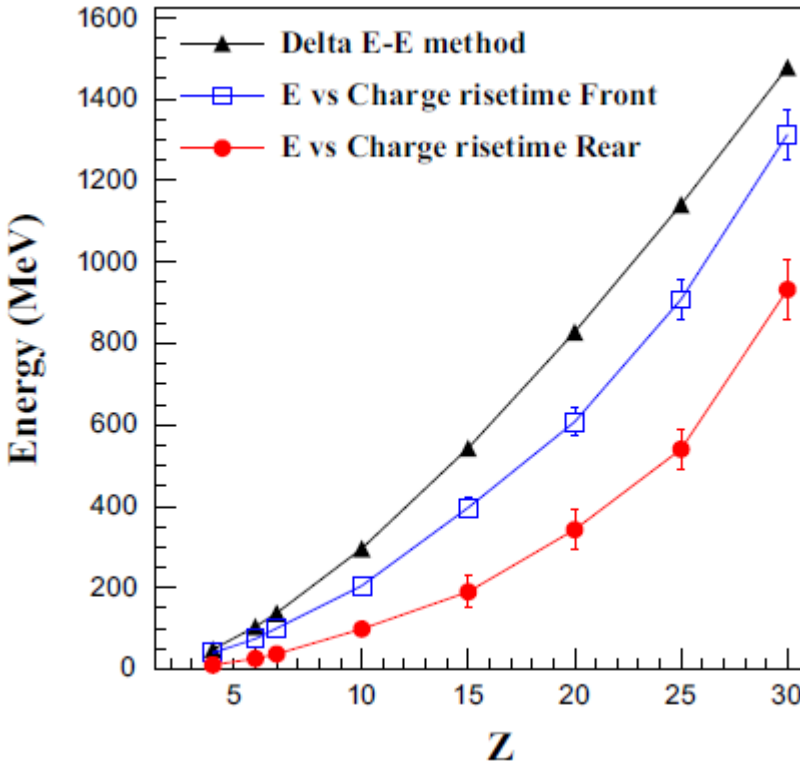
Improvement for PSA : depletion voltage

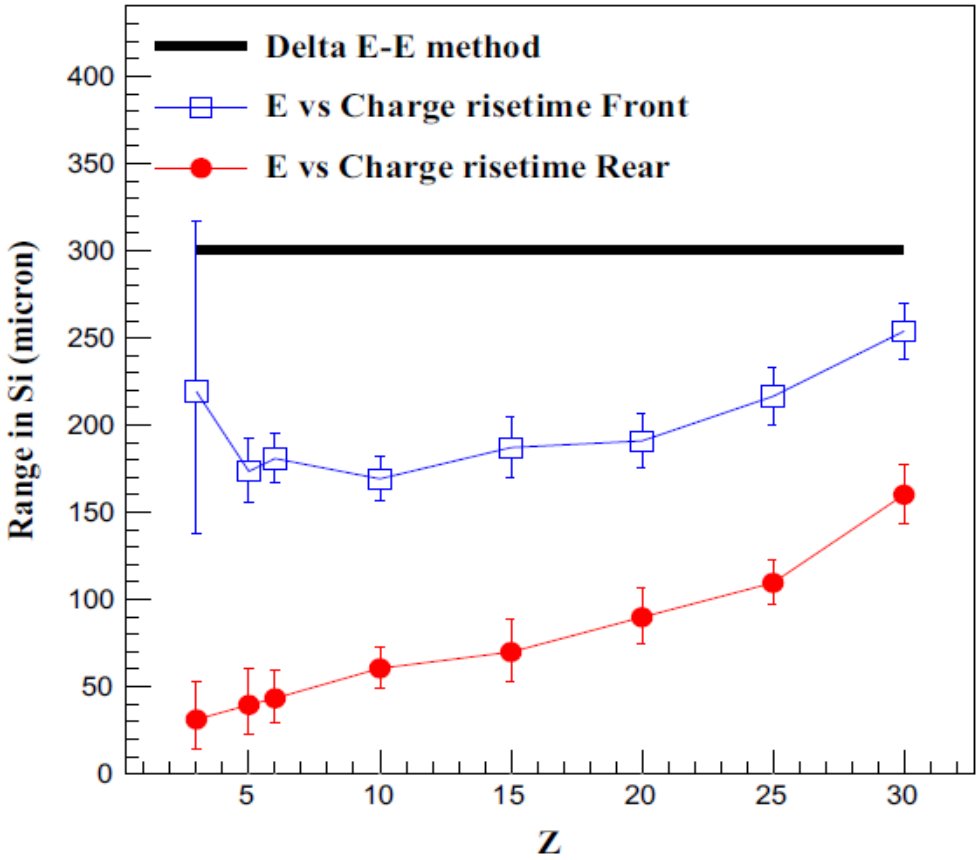


➢ Isotopic resolution for **Z≈3-14** for range**>350 µm**

FAZIA phase 1 : *ID* thresholds (*Z*)

N. Le Neindre *et al.*, NIM A 701(2013) 145–152





- **Pulse Shape Analysis** lowers significantly the Z (and A) thresholds
- **Rear-side** injection (low Electric Field entrance) is preferred
- **« dead » area** in Silicon is between ***30*** and ***150 µm*** for ***Z=30***

Physics Motivations

➢ Dynamics of heavy ion collisions

- **Reaction mechanisms** and **transport properties**
  - Deep Inelastic, neck emission, **multifragmentation**
  - **Isospin diffusion**, nuclear **stopping**, **particle flows**
  - **In-medium** properties *: NN* mean free path and cross section

- Link to the ***EOS***
  - **Compressibility** (radial/elliptic flows)
  - **Symmetry energy** for asymetric NM

➢ Thermodynamics of (hot) nuclear matter

- **Nuclear matter** in **proto-neutron stars**
  - **bulk** properties vs **finite size** effects (surface, coulomb, nuclei)

- **Phase transitions** for **strongly correlated** systems
  - Phase diagram : **Liquid-Gas** phase transitions, **first/second order**
  - **Temperature/Density/Isospin** dependence