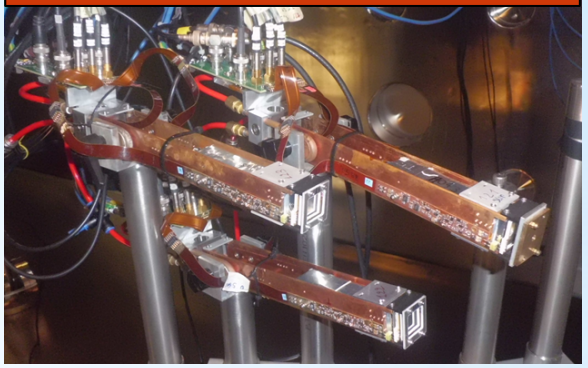
FAZIA@LNS: dal 2009 ad oggi

Ivano Lombardo for the FAZIA collaboration

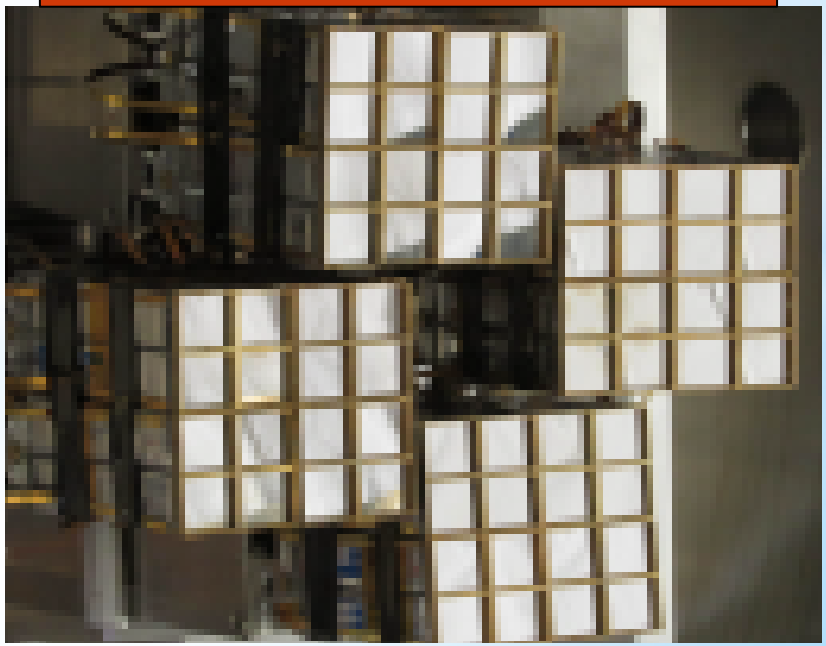
Summary

- Short introduction to the FAZIA project
- 2009-2013: R&D FAZIA
- 2014: from telescope to the block
- 2015-2018: the physics experiment
  - ISOFAZIA
  - FAZIASYM
  - FAZIACOR
  - FAZIAPRE
  - FAZIAZERO
- Future perspectives

2009-2013: R&D phase

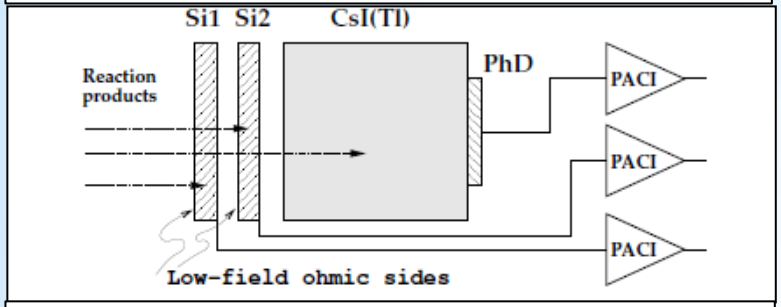


2015-2018: physics experiments



FAZIA: breve introduzione al progetto

1 telescopio di FAZIA (2x2 cm)



300 um + 500 um + 10 cm

FAZIA è inserita all'interno del gruppo NUCLEX, finanziato dalla CSNIII

INTERNATIONAL COLLABORATION

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

OBJECTIVE

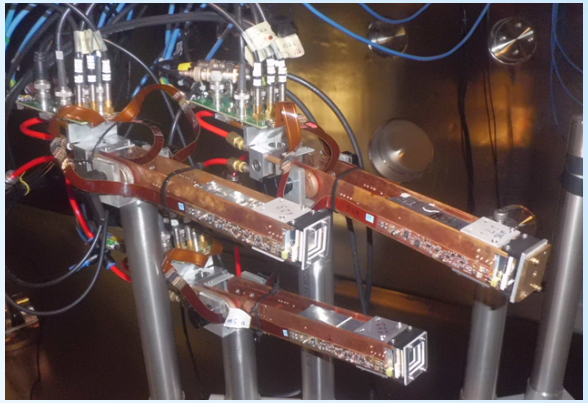
Build-up a new array with unprecedented capabilities of ion identification, with "low" energy thresholds, modular, versatile and transportable (in view of a 'spread' use in various labs)

2009-2013: The R&D phase

During this phase, we focus in the detector building in order to improve the particle identification.

The electronic was already fully digital, but not in the final configuration.

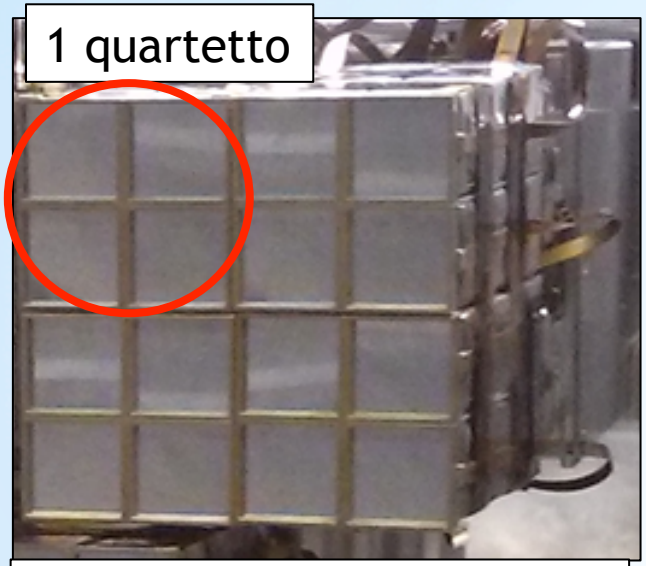
Also the mechanical mounting was not the final one.



The FAZIA R&D with LNS beam: main results

- **S.Carboni et al., NIMA664(2012),651 (Resolution obtained with PSA and ΔE-E in FAZIA telescopes)**
- **G.Pasquali et al., EPJA48(2012), 158 (Single chip telescope-CsI read out by Si2)**
- **N.LeNeindre et al., NIMA701(2013), 145 (about front vs. reverse mounting of Si)**
- **S.Barlini et al., NIMA707 (2013), 89 (about Radiation Damage)**
- **G.Pasquali et al., EPJA 50(2014), 86 (about underdepleted Si detectors)**
- **A.J.Kordyasz et al.,EPJA 51(2015), 15 (Fazia telescope with 20um silicon)**

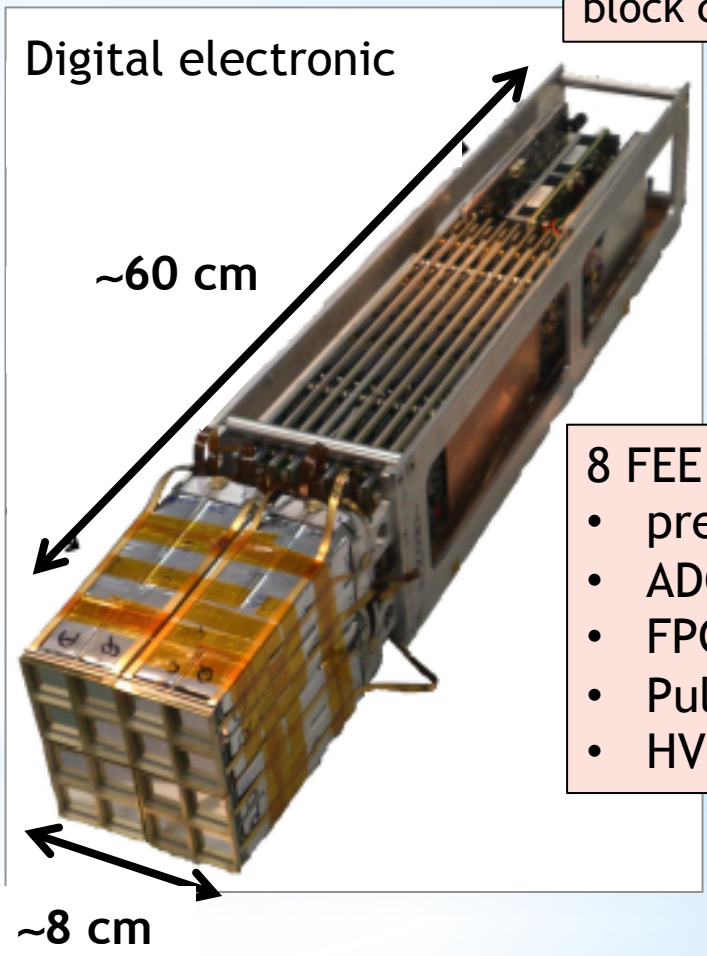
2014: From telescope to the block



1 blocco= 16 telescopes

List of the digitalized signals:

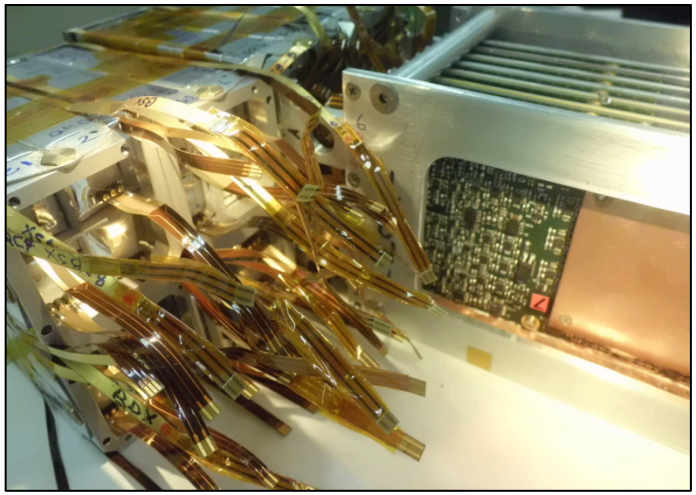
- Stage 1 (silicon 300 μm)
  - Charge 250 MeV full scale 250 Ms/s 14 bit
  - Charge 4 GeV full scale 100 Ms/s 14 bit
  - Current 250 Ms/s 14 bit
- Stage 2 (silicon 500 μm)
  - Charge 4 GeV full scale 100 Ms/s 14 bit
  - Current 250 Ms/s 14 bit
- Stage 3 (CsI + photodiode)
  - Charge 4 GeV full scale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

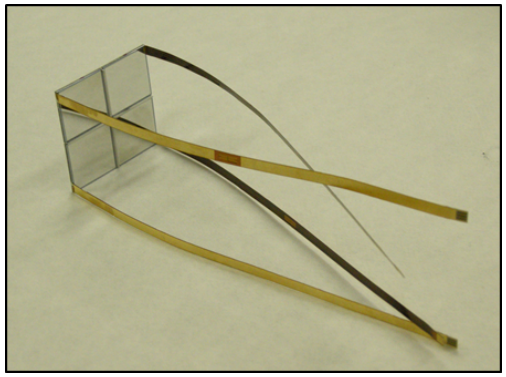


3 Cards: 2HV and 1 block card for I/O

8 FEE boards with:
- preamplifiers
- ADC
- FPGA
- Pulser
- HV detectors

2014: From telescope to the block

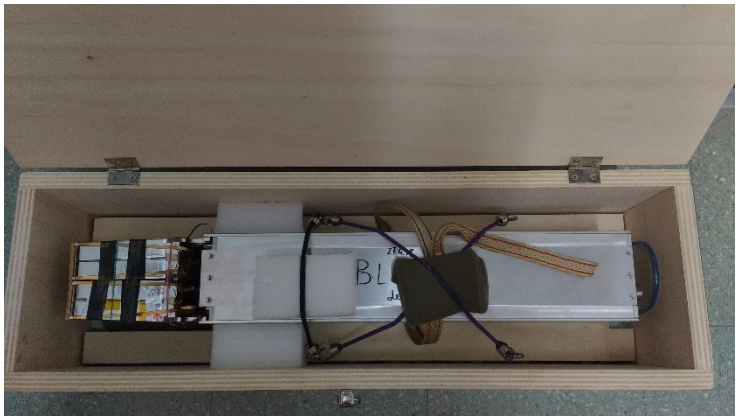


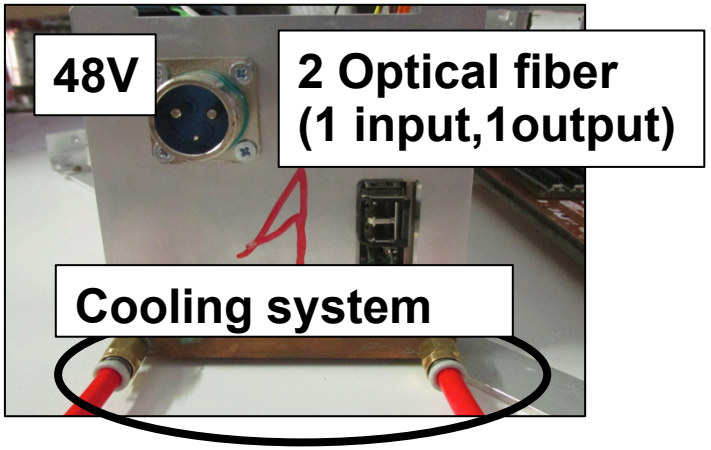


Mechanics, connection and mounting really challenging…

…but once that they were ready:

- Easy to transport
- Easy to mount and connect!





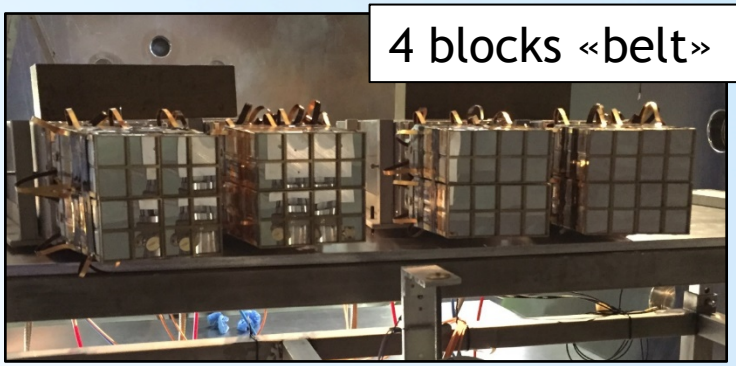
2015-2018: physics experiments

QP* decay
Isospin transport
NEoS.

2015

ISOFAZIA: $^{80}Kr+^{40,48}Ca$@35 AMeV
Tesi di dottorato di G.Pastore (UniFi) discussa a marzo 2018

FAZIASYM: $^{40,48}Ca+^{40,48}Ca$@35 AMeV
Tesi di dottorato di A.Camaiani(UniFi)

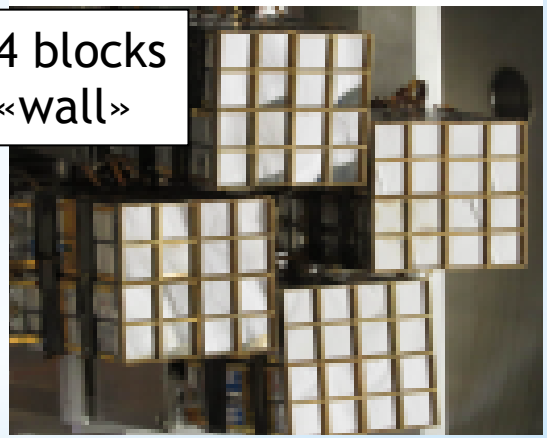


In-medium effects
Isospin vs. E_{beam}

2017

FAZIA-COR: $^{20}Ne,^{32}S+^{12}C$@25,45 AMeV

FAZIA-PRE: $^{40,48}Ca+^{12}Ca$@20,40 AMeV
Tesi di dottorato di P.Ottanelli(UniFi)

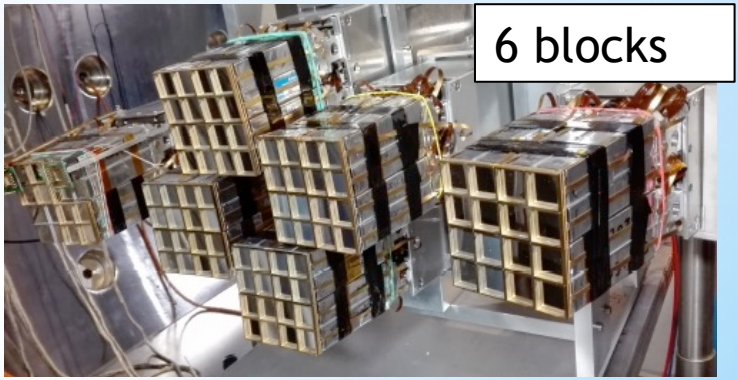


Neutron skin thickness:
Misura di test

2018

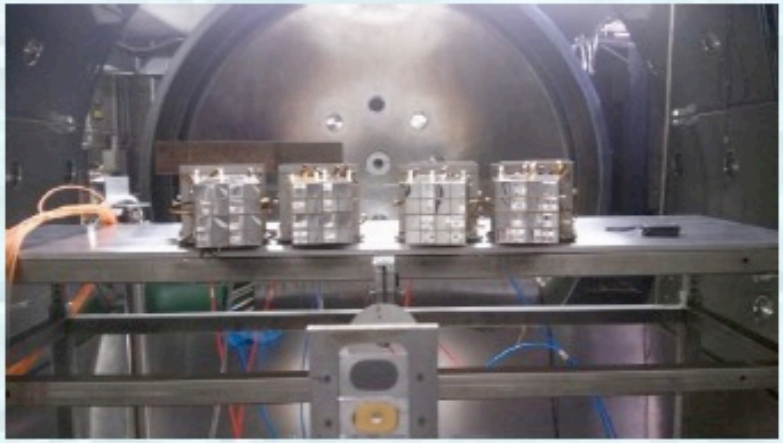
FAZIA-PRE: Recupero parte misura

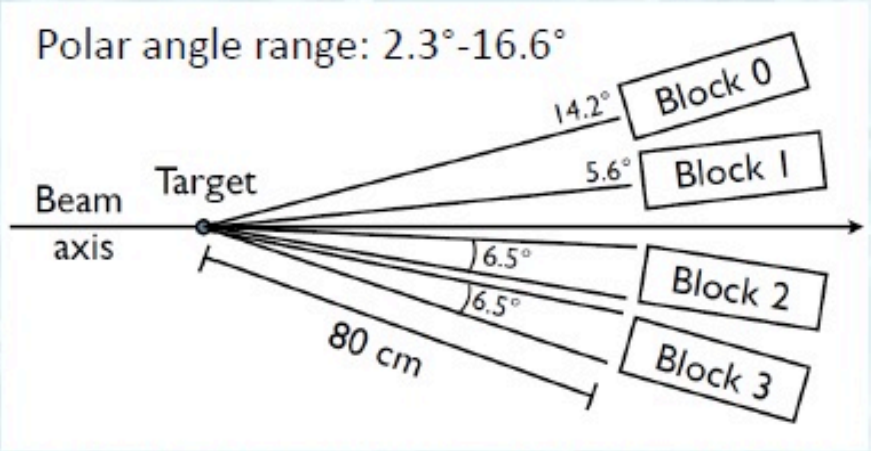
FAZIA-ZERO: $^{12}C+^{12}C$@62 AMeV
Collaborazione con Università di Beihang



2015: ISOFAZIA

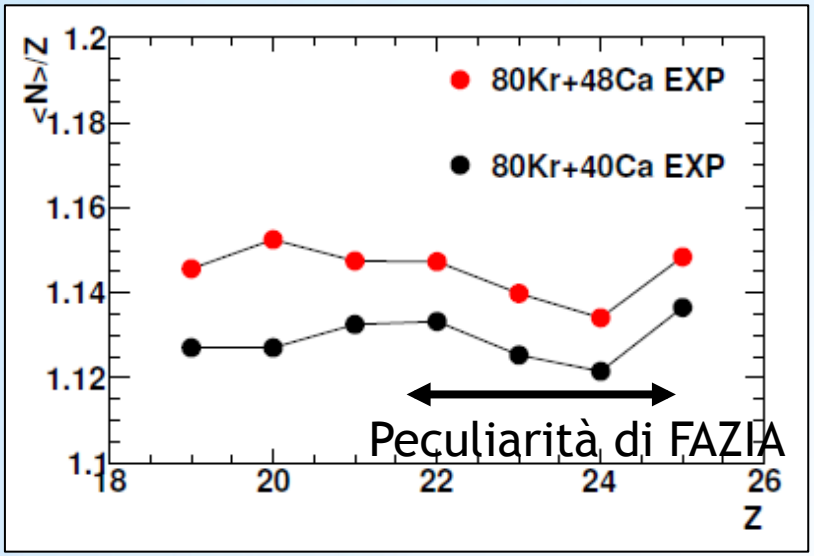
- ISOFAZIA was the first physics experiment performed by the FAZIA Collaboration after the R&D phase (June 2015, INFN – LNS Catania)
- **Systems:** $^{80}Kr+^{40,48}Ca$ @ 35AMeV (N/Z_{proj}=1.22 N/Z_{40Ca}=1.00 N/Z_{48Ca}=1.40)
- **Goals:**
  - Study of the isospin transport phenomena and comparison with transport models (in particular AMD by A.Ono) to gain information on the symmetry energy term of the EOS
  - Study of the QP fission (A and Z of both fission fragments) to investigate the time scale of the process
- **Setup:** 4 complete blocks (64 detectors) in belt configuration





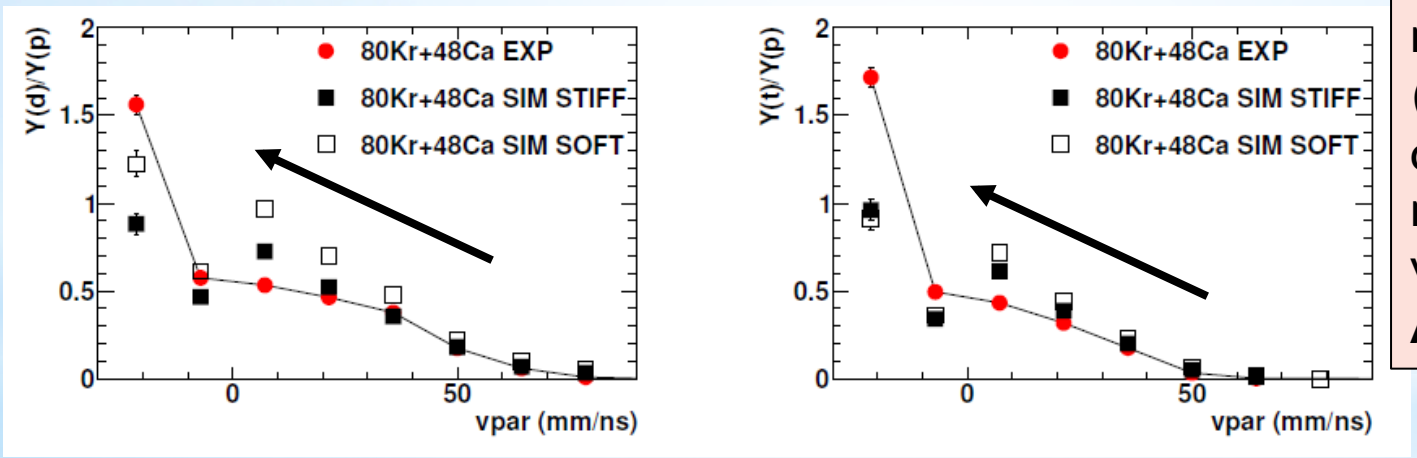
- The data analysis was the subject of the PhD Thesis of G. Pastore (Univ. di Firenze, 2017)

ISOFAZIA: isospin transport effects



Evidenza di un arricchimento del contenuto di neutroni del QP nell'interazione con il target neutron rich (**ISOSPIN DIFFUSION**)

Avvicinandosi alle emissioni da mid-velocity (neck emission), il contenuto in neutroni aumenta (**ISOSPIN DRIFT**). Il confronto con il modello spinge verso una NEoS **Asy-Stiff**



AMD (Antisymmetrized Molecular Dynamics)

A.Ono et al., PRC59, 853(1999)

+

GEMINI++

R.J.Charity et al., PRC82, 014610(2010)

+

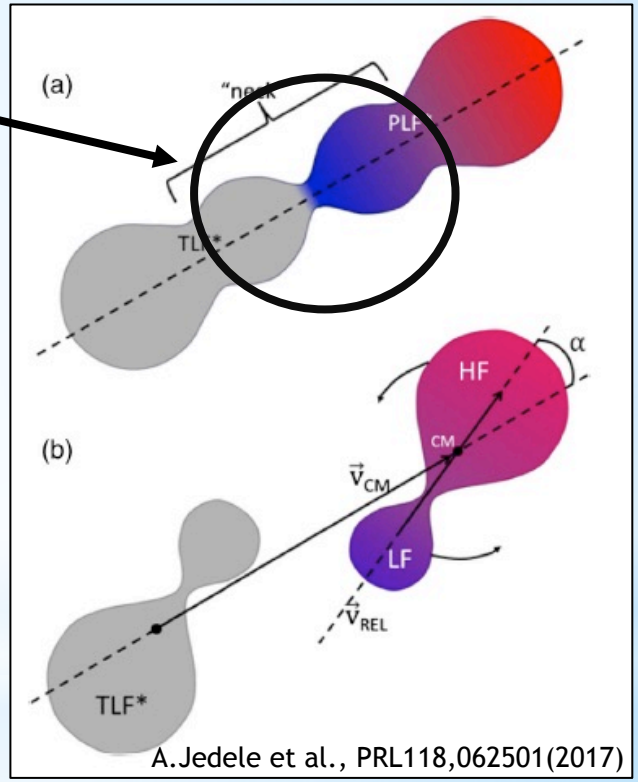
Filtro sperimentale (geometria, risoluzione, selezioni sperimentali)

ISOFAZIA: study of QP disintegration

- Diverse tecniche per lo studio del QP decay [1,2,3]
- Nuova tecnica → tempi di equilibrazione dell'isospin [4,5]

Copertura angolare sui prodotti del QP e risoluzione isotopica permettono lo studio dell'isospin dei due frammenti HF ed LF in funzione dell'angolo α [3,4]

Arricchimento di neutroni nella zona del neck (ISOSPIN DRIFT)



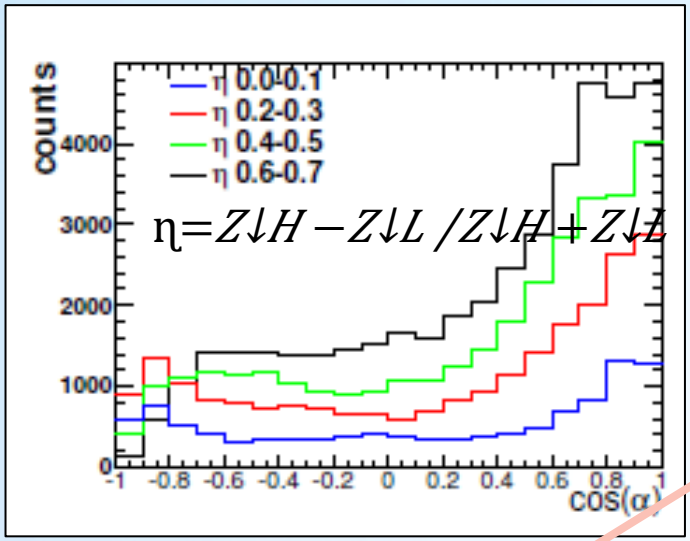
A.Jedele et al., PRL118,062501(2017)

$\alpha = \arccos(\vec{v}_{CM} \cdot \vec{v}_{rel} / |\vec{v}_{CM}| |\vec{v}_{rel}|)$

Più tardi avviene la separazione, maggiore è la possibilità di raggiungere l'equilibrio di isospin

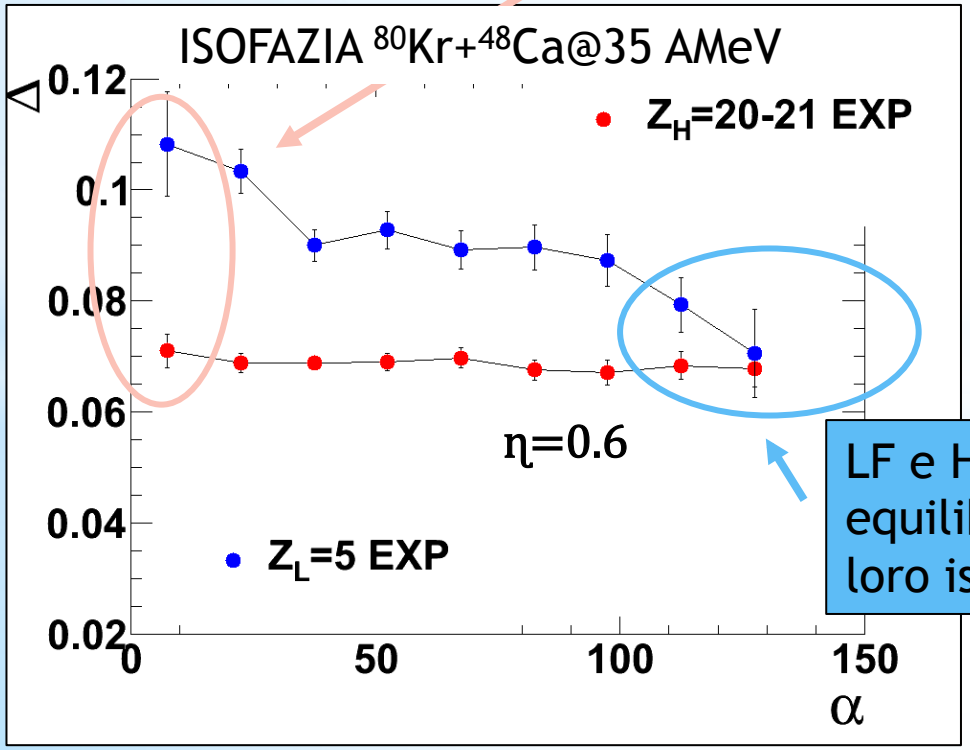
[1] E. De Filippo et al, PRC 71 (2005) 064604 and 044602
[2] J. Colin et al, PRC 67 (2003) 064603
[3] S. Hudan et al PRC 86 (2012) 021603
[4] A. Jedele et al PRL 118 (2017) 062501
[5] A. Rodriguez Manso et al PRC 95 (2017) 044604

ISOFAZIA: study of QP disintegration

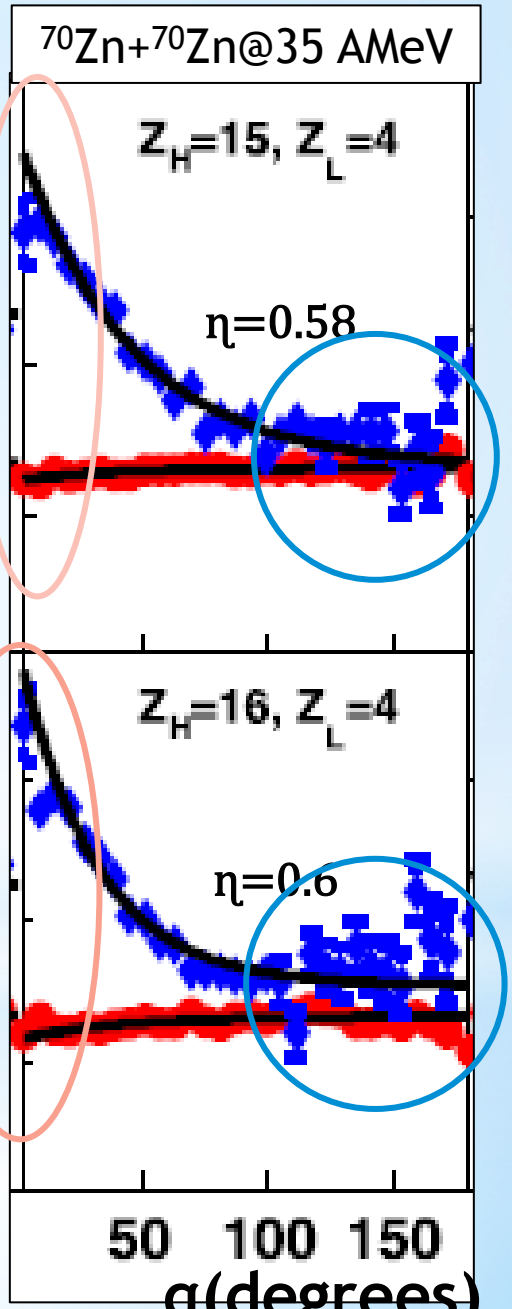


Per tempi brevi, LF che proviene dalla parte del QP più vicina al neck, mantiene il suo più alto contenuto di neutroni

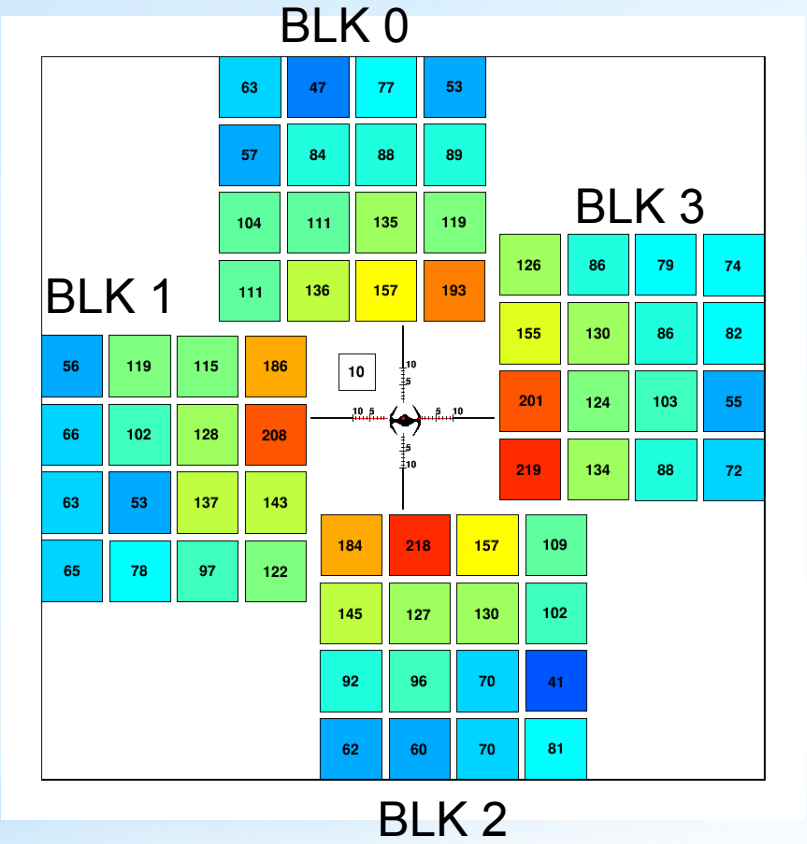
$$\Delta = < \frac{N-Z}{A} >$$



LF e HF equilibrano il loro isospin.



2015: FAZIASYM



At the Laboratori Nazionali del Sud:

- **$^{40}Ca+^{40}Ca$**
- $^{40}Ca+^{48}Ca$
- **$^{48}Ca+^{40}Ca$**
- **$^{48}Ca+^{48}Ca$**

@ 35 MeV/u

Geometry:

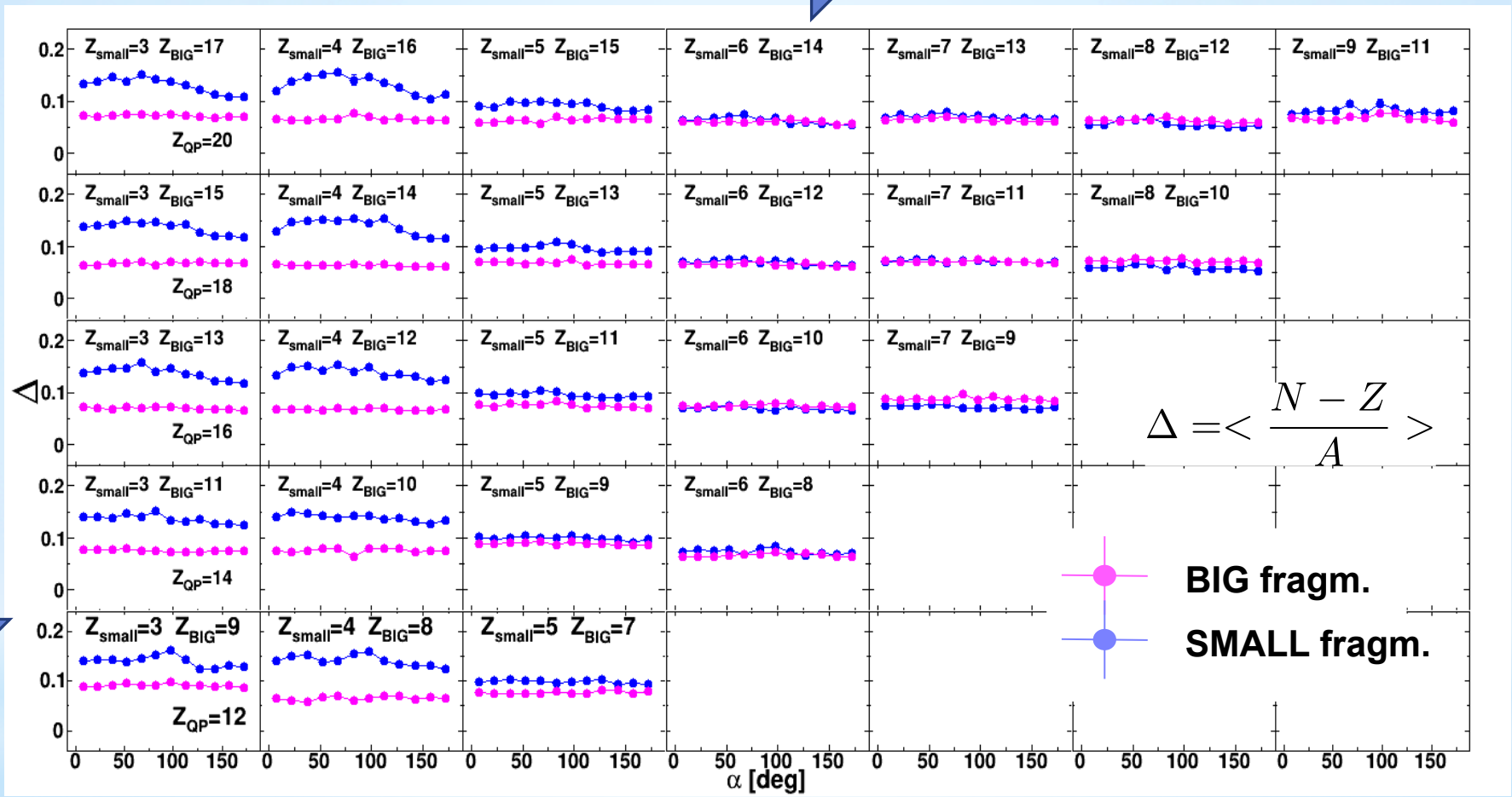
- 4 blocks located around the beam axis and 80 cm far from the target
- Covered polar angles in the lab frame:
  - $\Theta_{min} = 2°$
  - $\Theta_{max} = 8°$

FAZIASYM: QP disintegration

$^{48}Ca+^{48}Ca$ @ 35 A.MeV

Increasing Symmetry

Dissipation



For each class of events with a fixed dissipation:

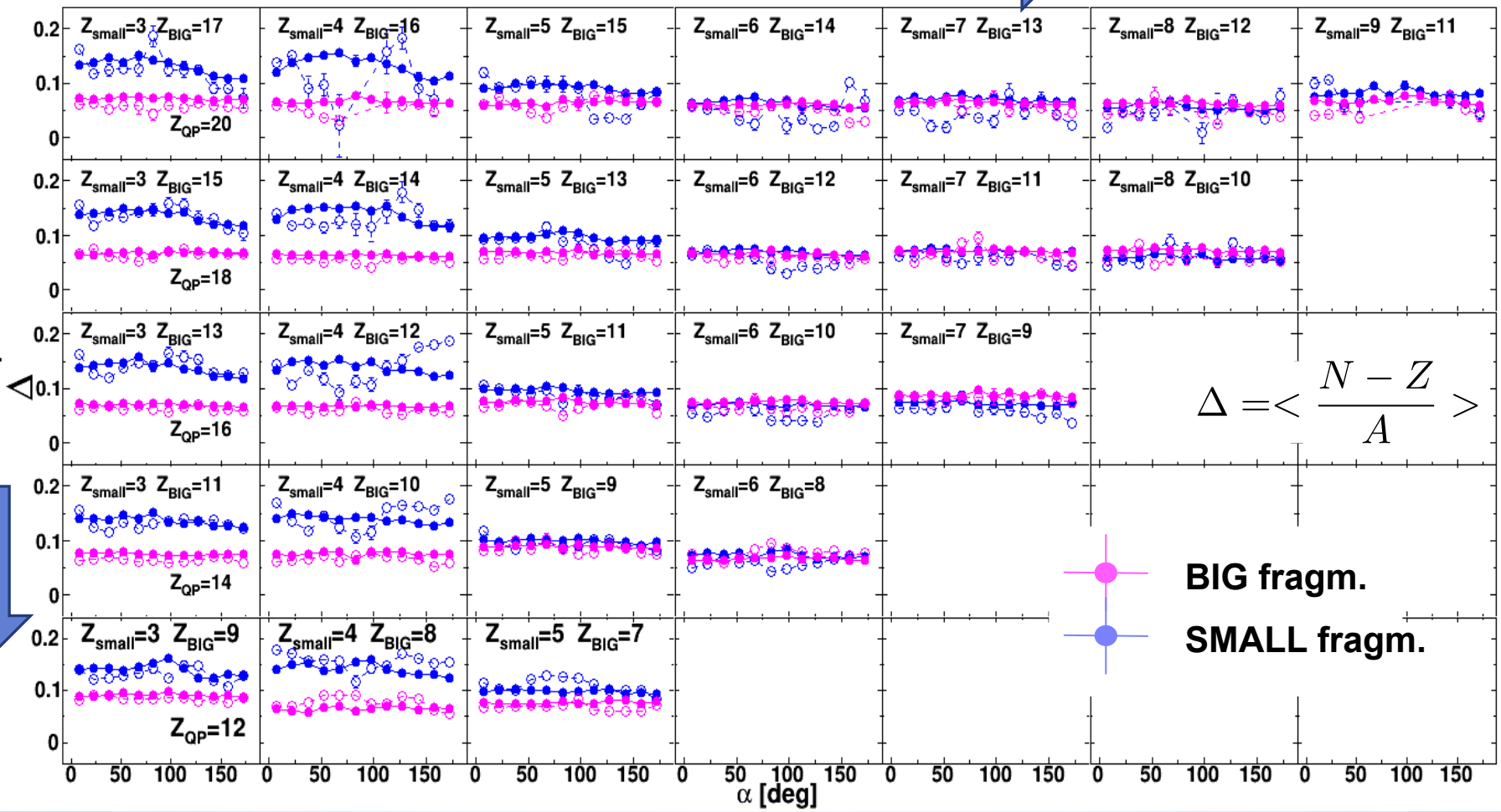
- equilibration is visible when the symmetry increases
- **No signals of Δ evolution** as **α angle *increases***, while it was seen in $^{70}Zn+^{70}Zn$ at 35 A. MeV!!!

FAZIASYM: comparison with AMD

$^{48}Ca+^{48}Ca$ @ 35 A.MeV

Increasing Symmetry

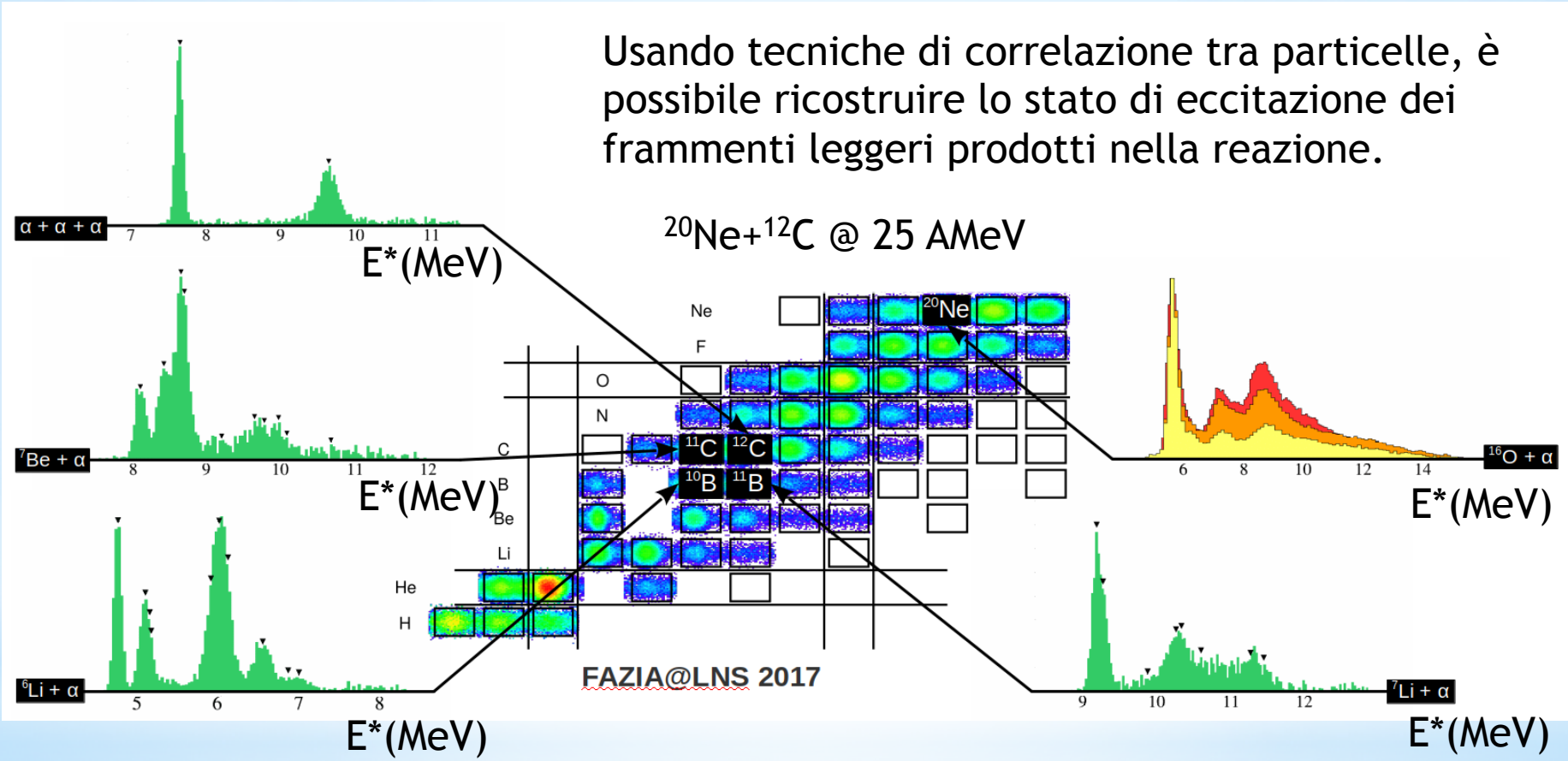
Dissipation



- Except for statistical fluctuations, **the AMD predictions are globally in agreement with the exp. results**
- Except for a reduction in the statistics, the geometry effects do not change too much the main trends of the figure: **the Δ gap is preserved, and even AMD does not predict a clear evolution of Δ as a function of α → analysis in progress!**

2017 FAZIA-COR: $^{20}Ne, ^{32}S + ^{12}C$@25,45 AMeV

Invariant mass method

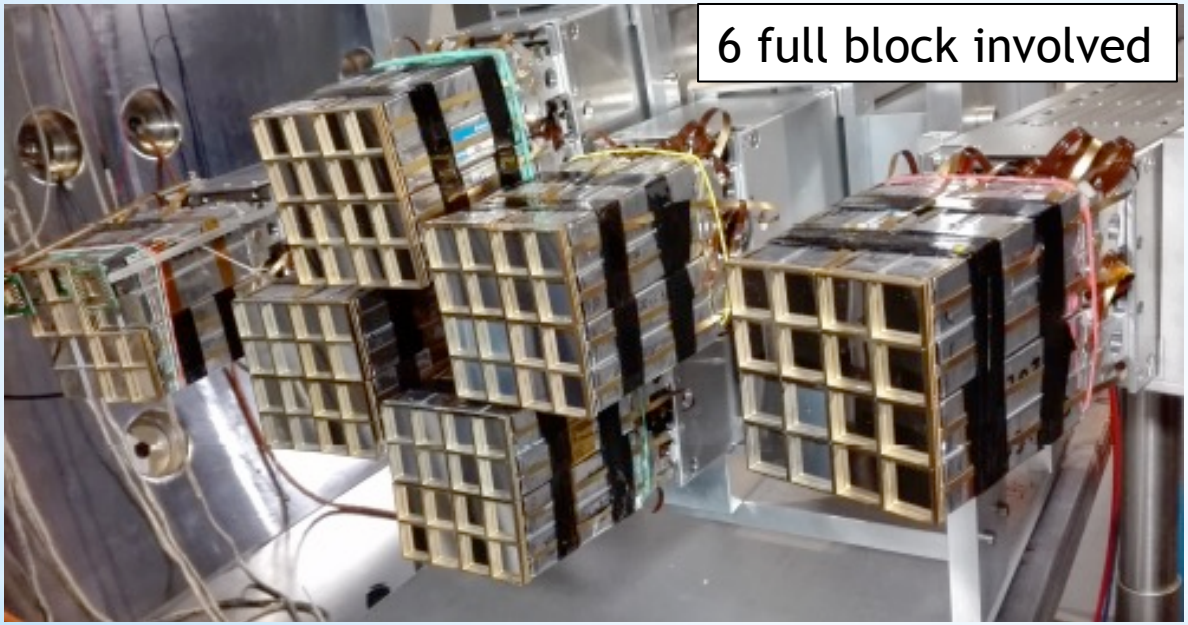


- Studio del decadimento di stati risonanti in volo
- Studio di fenomeni di clusterizzazione alfa

2017-2018 FAZIAPRE: $^{40,48}Ca+^{12}C$@20,40 AMeV

- Investigating of the persistence, with bombarding energy, of the neutron content of QP formed in semiperipheral collisions at Fermi energies.

- Ph.D thesys of P.Ottanelli (Unifi)

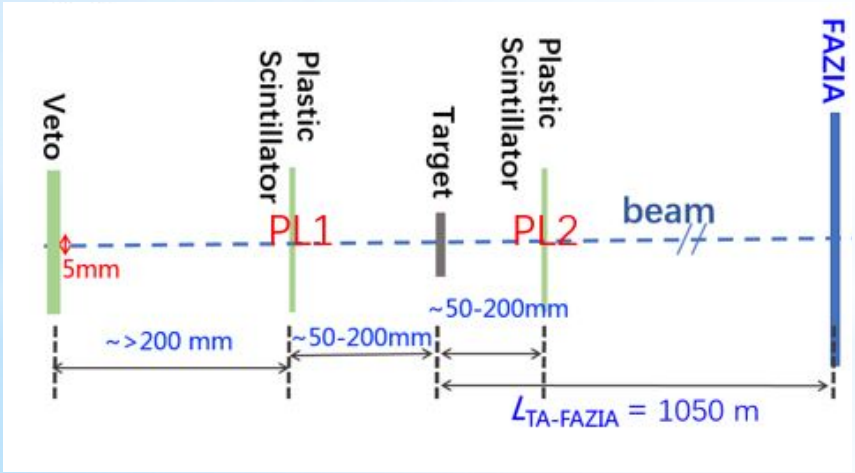


…calibration work in progress!!

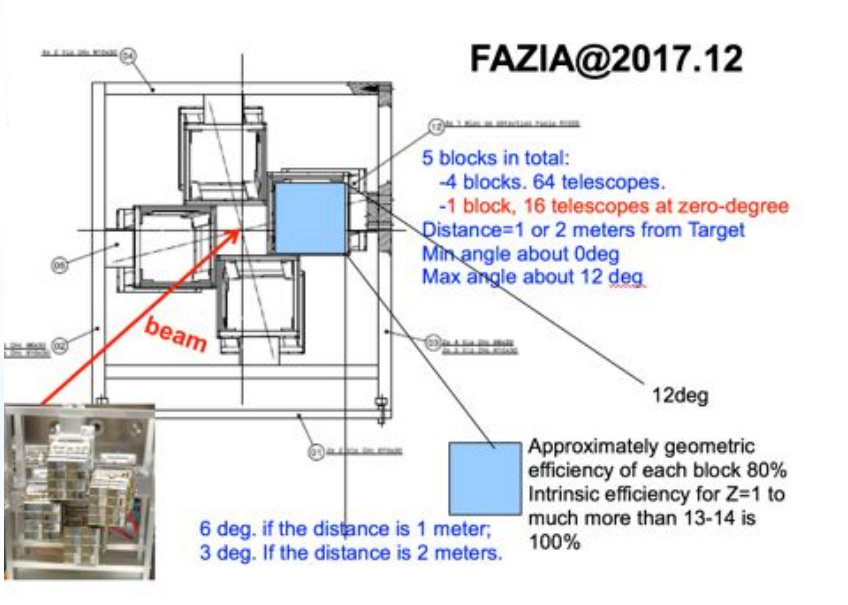
2018 FAZIAZERO: $^{12}C+^{12}C$@55 AMeV

International collaboration with Tanihata group (Beihang University)

- Precise cross-section and ***charge-changing cross-section data*** at intermediate energies → ***neutron skin thickness*** of neutron-rich isotopes (FR Glauber model)
- The ***high isotopic resolution*** of the FAZIA detector → can do it!
- $^{12}C+^{12}C$ and **^{12}C+proton** cross sections at 50-70 MeV/u → benchmark systems
- Future → **RIBs** !



PL1 and PL2 in the FAZIA FEE!!



…analysis from Beihang group in progress!!

FAZIA: progetti futuri 2019-2022

MOU 2018

Italia, Francia,
Polonia e Spagna

- 12 blocchi di FAZIA saranno montati e resteranno a GANIL per realizzare una campagna di misure FAZIA+INDRA
- 4 blocchi di FAZIA sono da considerarsi come «spare», utilizzabili in altri laboratori per altre misure non in coincidenza con la presa dati a GANIL

INFN
INPC, Caen, Francia
GANIL, Caen, Francia
IPNO, Orsay, Francia
COPIN, Polonia
UHU, Huelva, Spagna

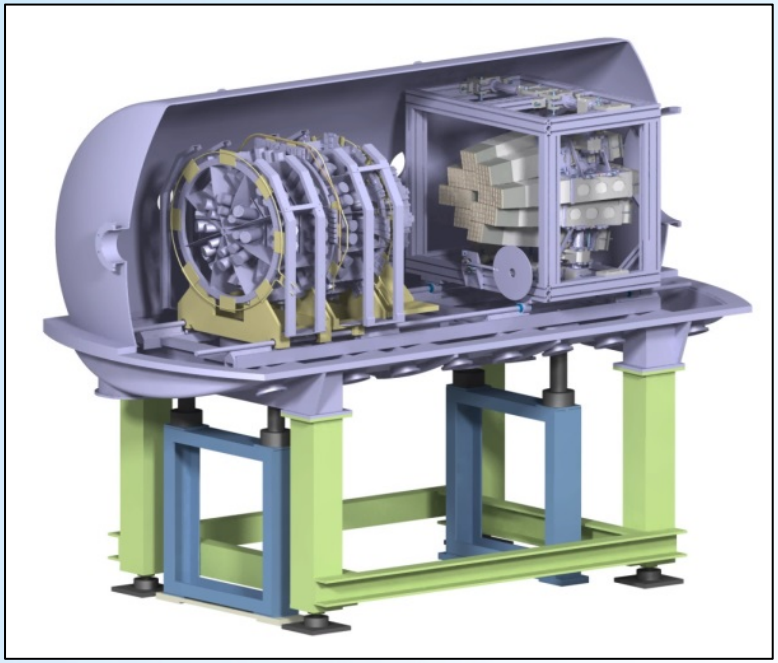
Esplicito riferimento al possibile utilizzo FAZIA@SPES

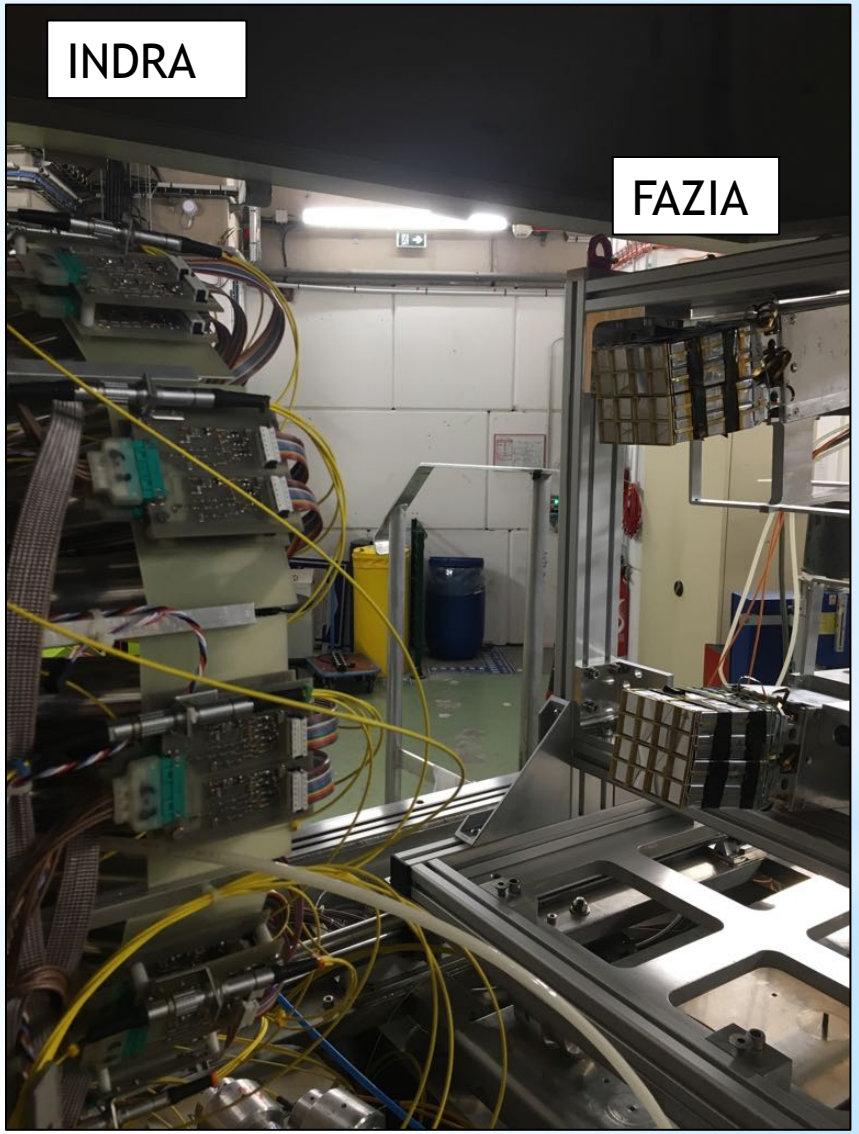
*"FAZIA is designed in such a way that it is easily movable; it can be reconfigured and coupled to other apparatuses in order to permit a very rich scientific program exploiting various stable and radioactive beams, with the complementary campaigns at several research facilities: GANIL/SPIRAL/SPIRAL2 in Caen, LNS/FRIBS in Catania, LNL/ALPI/**SPES** in Legnaro and EURISOL."*

Finanziamento per sviluppi del FEE e rivelatori per esperimenti di fisica a basse energie

FAZIA: future perspectives

2019-2022 FAZIA+INDRA@GANIL





June 2018

2019: 42.5 BTU approved

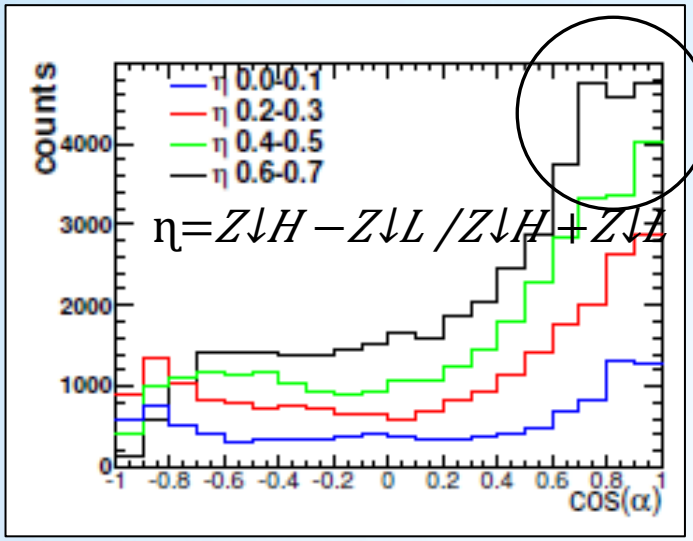
^{58,64}Ni+^{58,64}Ni @32 and 52 A.MeV

Stima dei parametri L_{sym} e K_{sym} dello sviluppo in serie della parte iso-vettoriale della NEoS.

Thank you for the attention!

BACK SLIDES

ISOFAZIA : fissione del QP

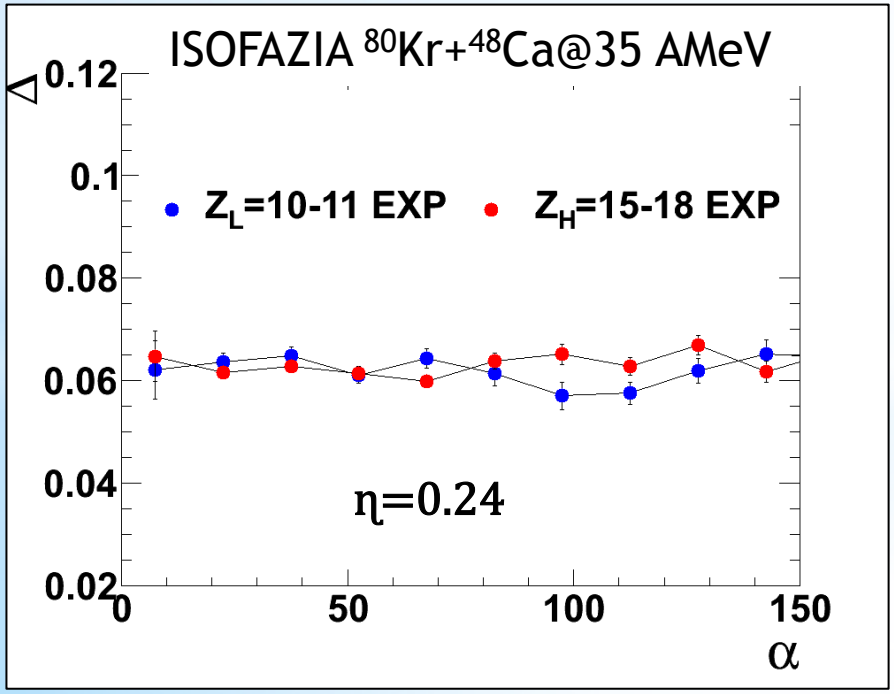


Fissioni asimmetriche corrispondono a η maggiori per le quali è favorita la configurazione di separazione allineata.

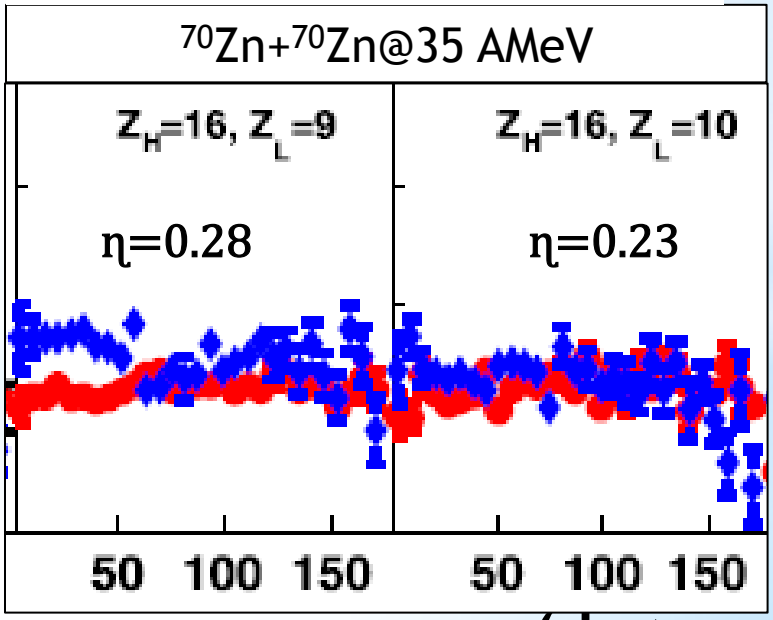
Per fissioni simmetriche, si può arrivare ad una completa equilibrazione dell'isospin tra i due frammenti. L'angolo α perde di significato

$\Delta = \langle N - Z / A \rangle$

Variabile sensibile all'isospin

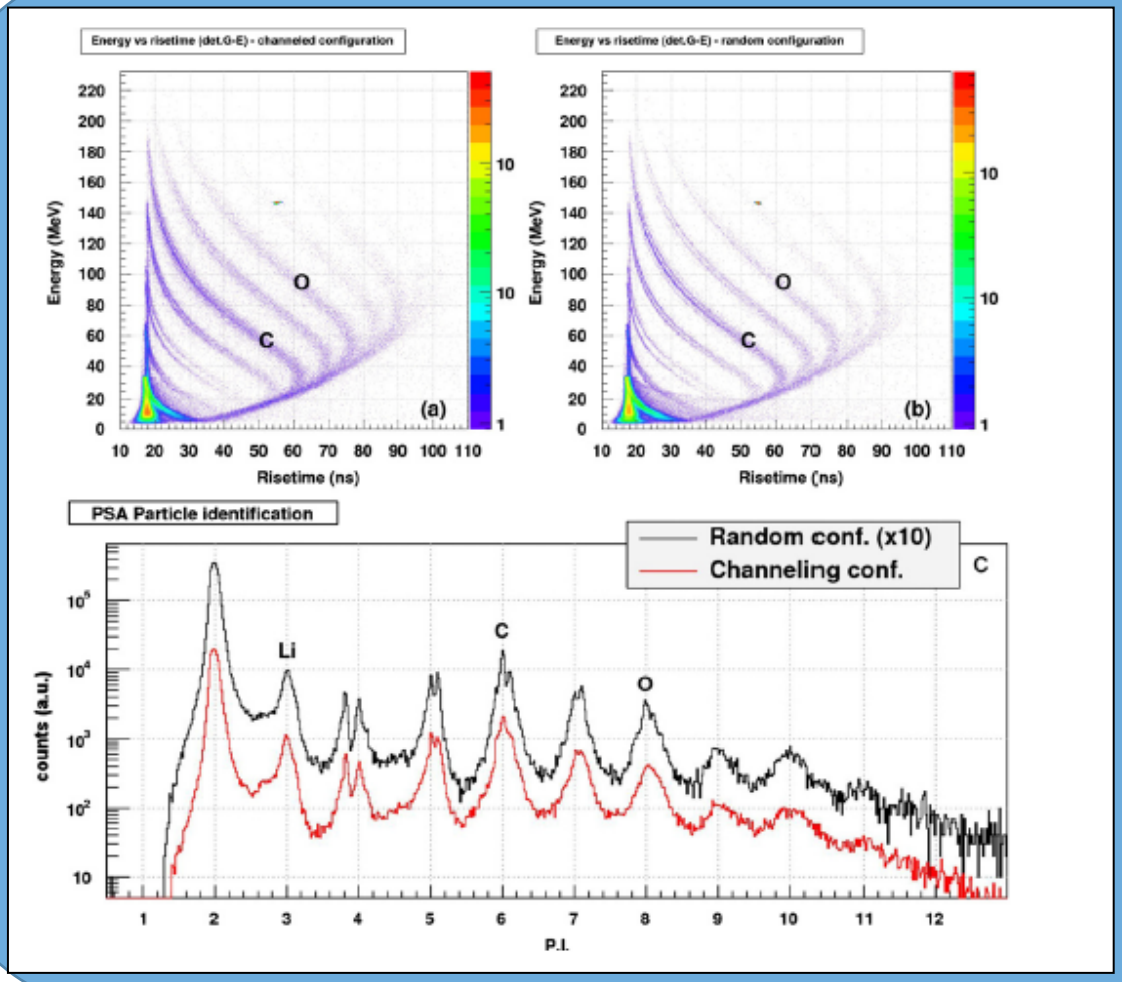


A.Rodriguez Manso et al., PRC95,044604(2017)

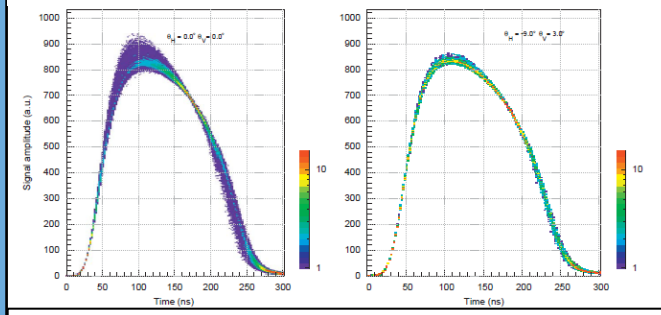


The R&D phases: the FAZIA "recipe"

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



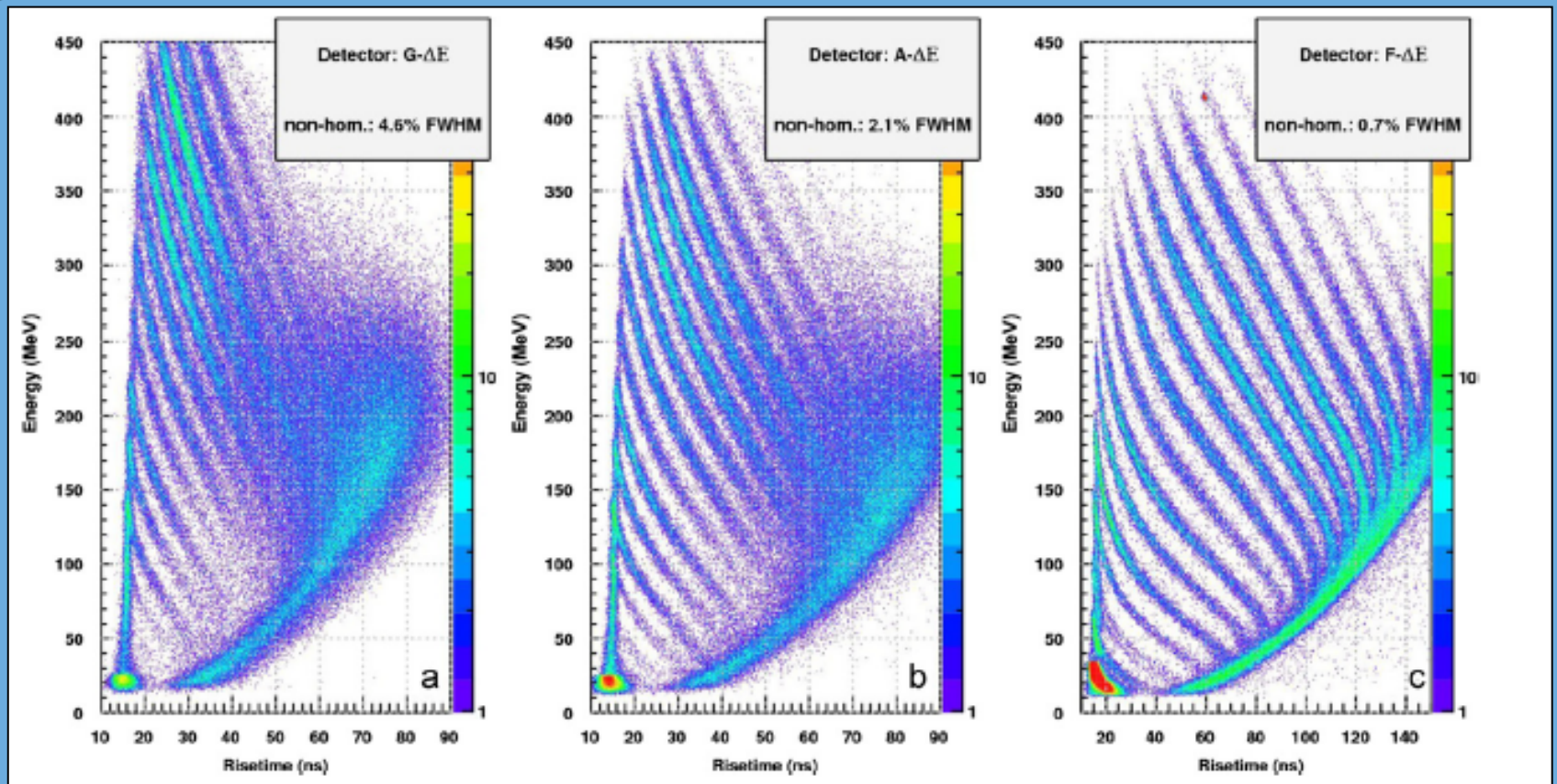
Channeling Conf. **Random Conf.**



^{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%)

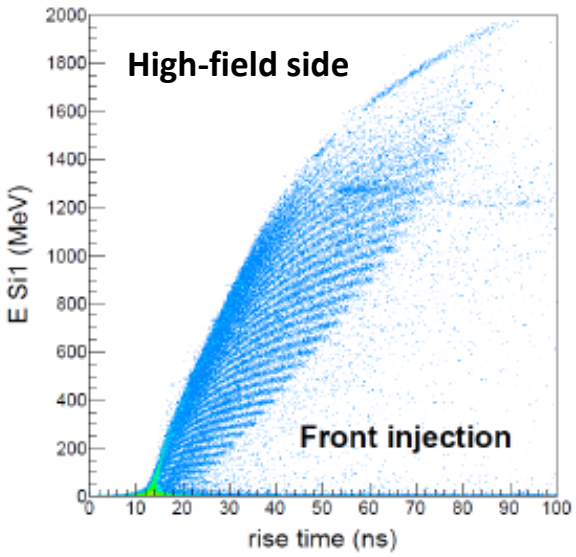


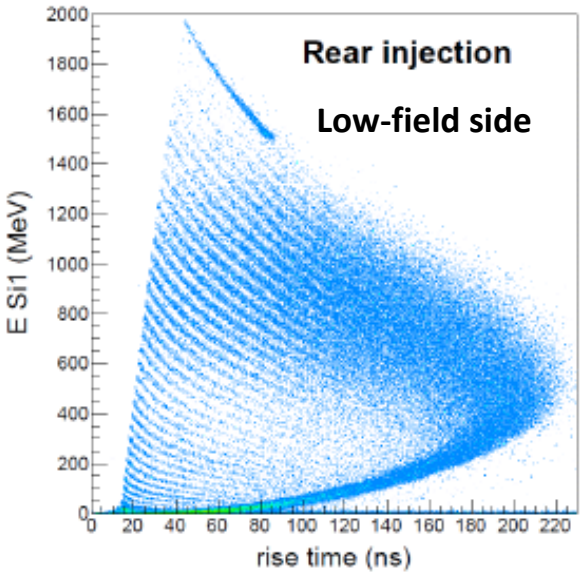
Effect of different doping homogeneity on Energy vs Charge rise-time PSA

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.

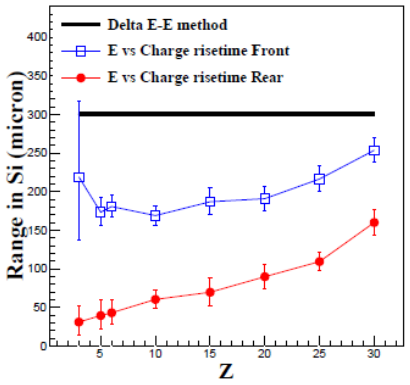
No difference in ΔE-E, but very different behavior in PSA!!





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%)
- Reverse mounting configuration of Silicon detectors: the particles enter from the low-field side.
- Selection of Silicon detectors with good planarity and parallelism of front and rear sides (high thickness uniformity)

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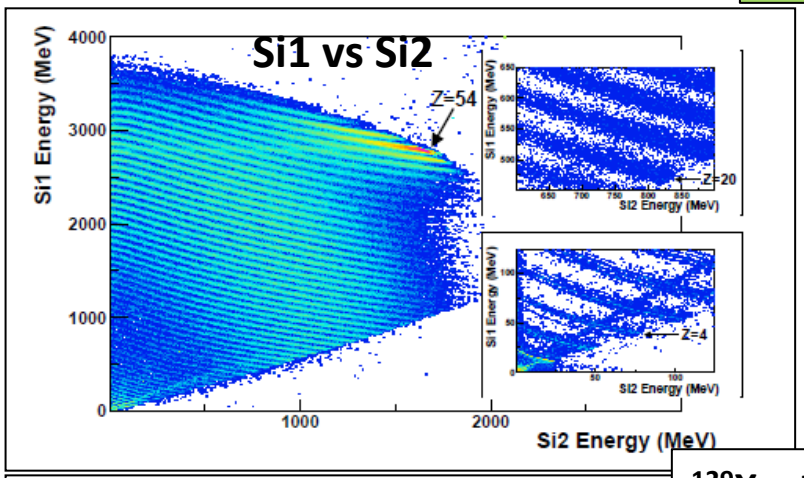
Main results published on

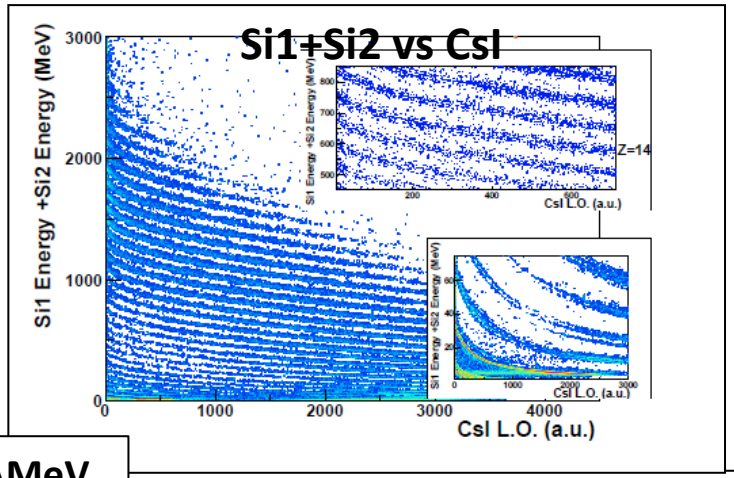
S.Barlini at al., Nucl.Instr.and Meth. A600 (2009), 644
L.Bardelli et al., Nucl.Instr.and Meth. A605 (2009), 353
L.Bardelli et al., Nucl.Instr.and Meth. A654 (2011), 272
S.Carboni et al., Nucl.Instr.and Meth. A664 (2012), 251
G.Pasquali et al., Europ. Phys. J. A48, (2012), 158
N.Le Neindre et al., Nucl.Instr.and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

Attention to the radiation damage!

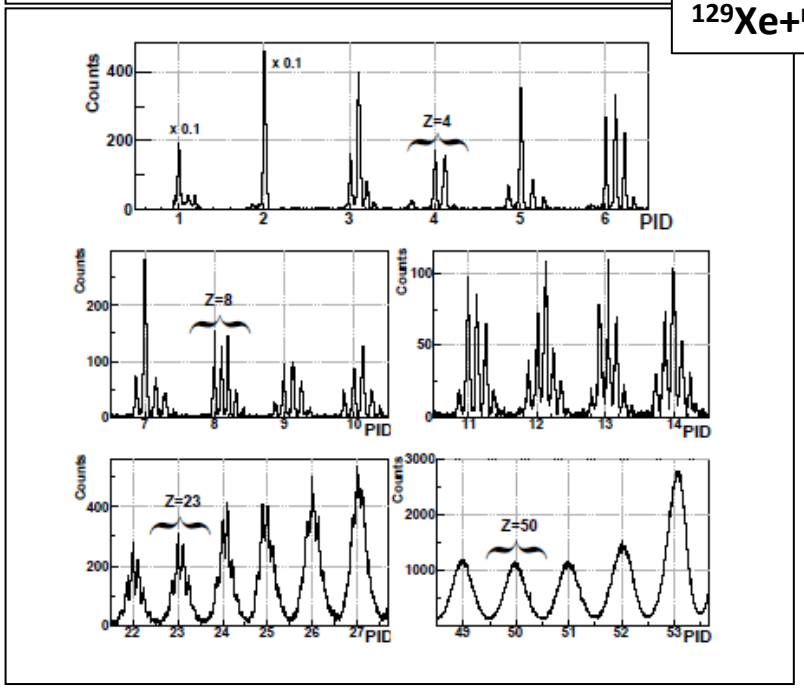
The R&D phases: the main results.

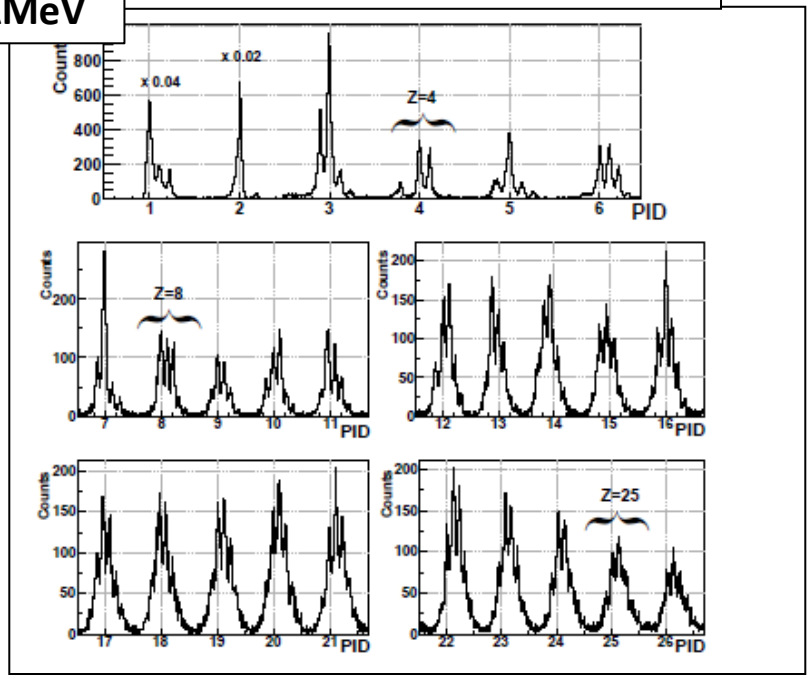
ΔE-E technique





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

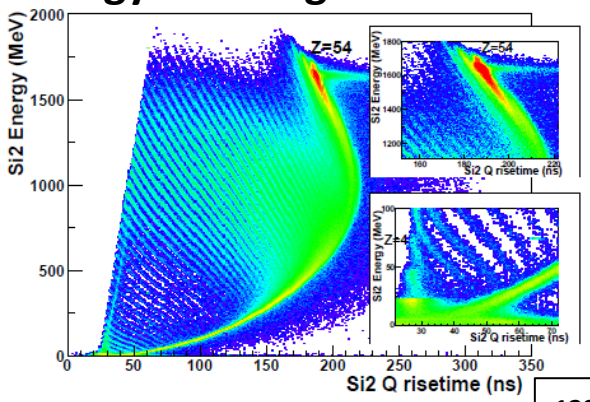




The R&D phases: main results.

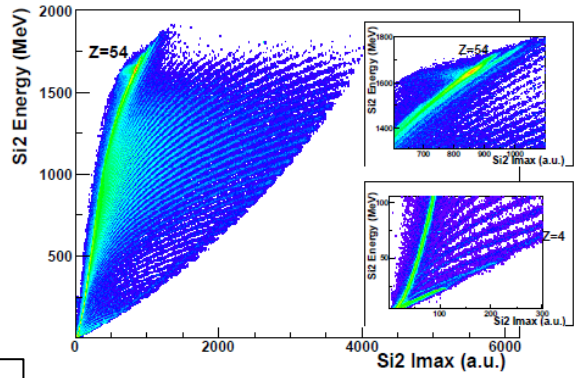
PSA technique

Energy vs Charge rise-time



~2 GeV range

Energy vs Current maximum



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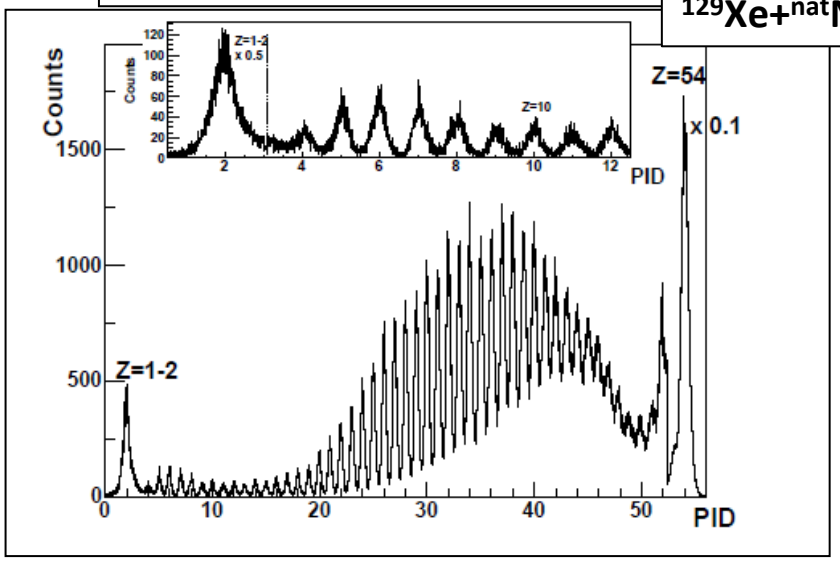
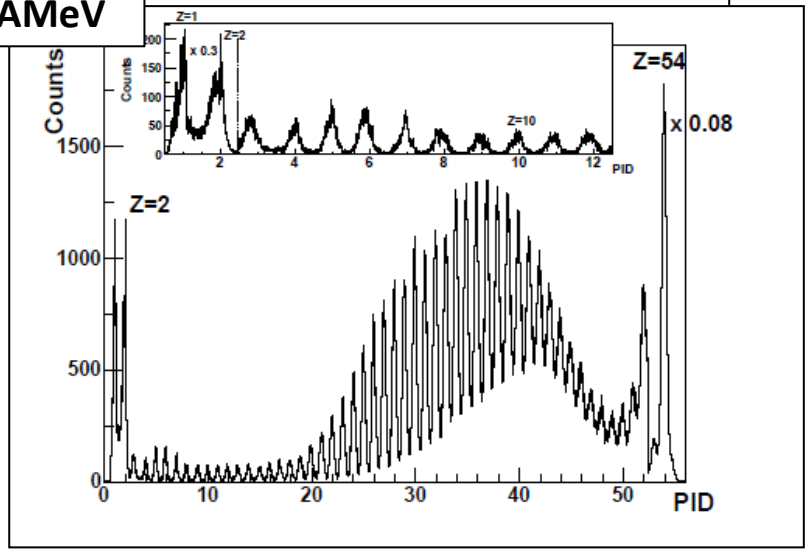
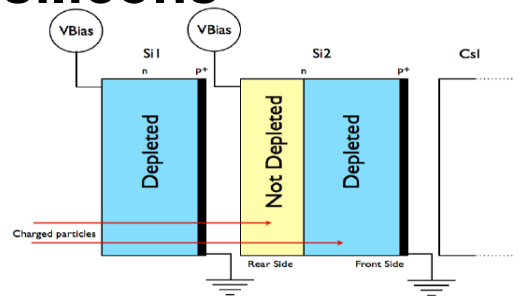




With a higher gain (as in LNL test showed in previous slide), we can see also some masses!

The R&D phases: main results.

Behavior of partially depleted silicons



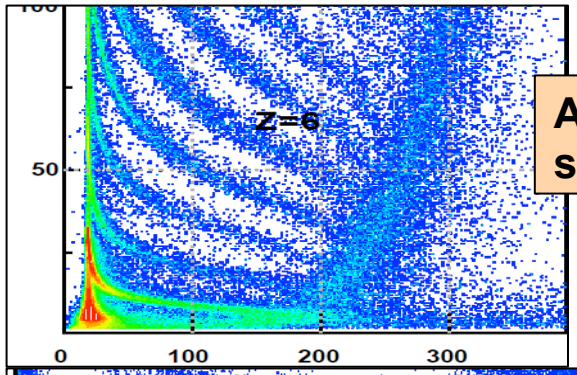
290V full depletion V i.e.
500 μm active layer

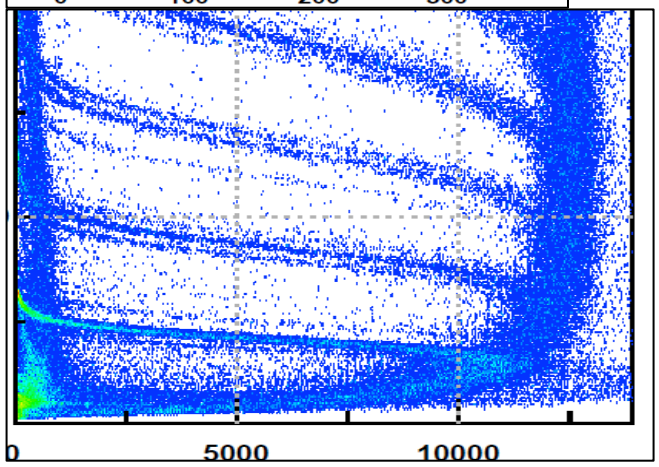
Several voltage steps...

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

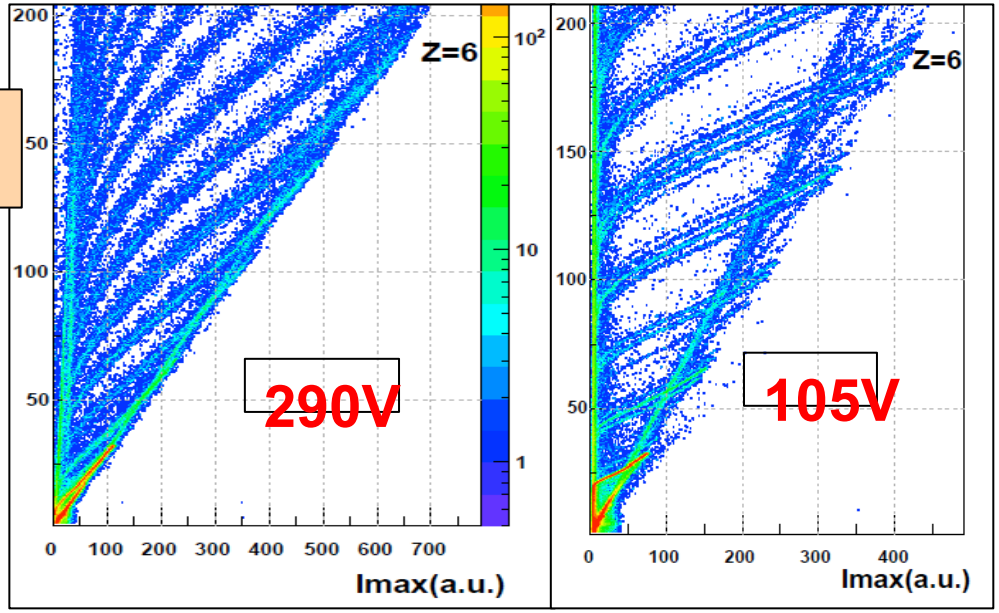
G.Pasquali et al., EPJA to be submitted

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