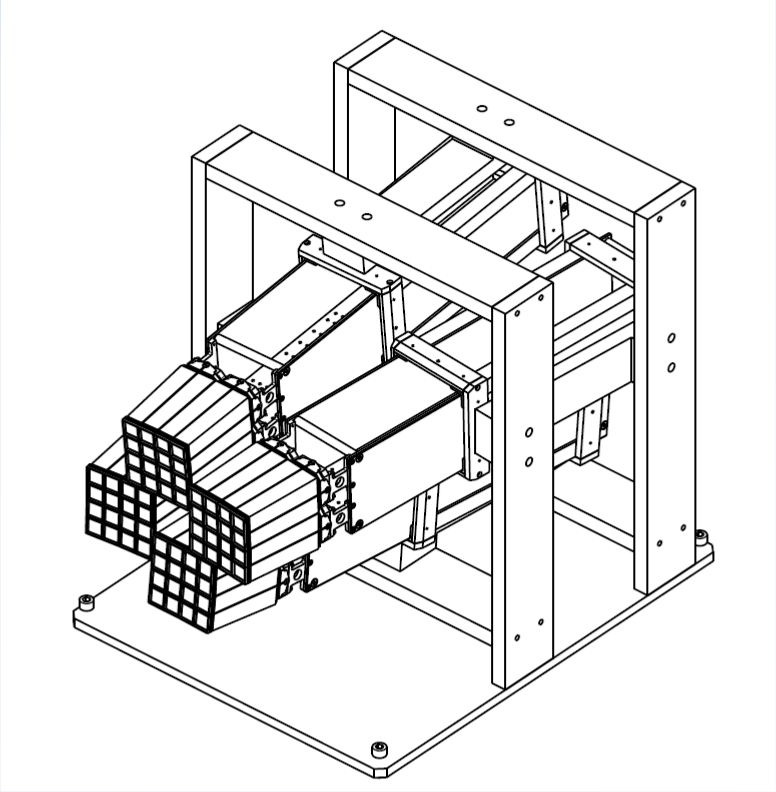
Fazia: a new versatile detector device for isospin physics

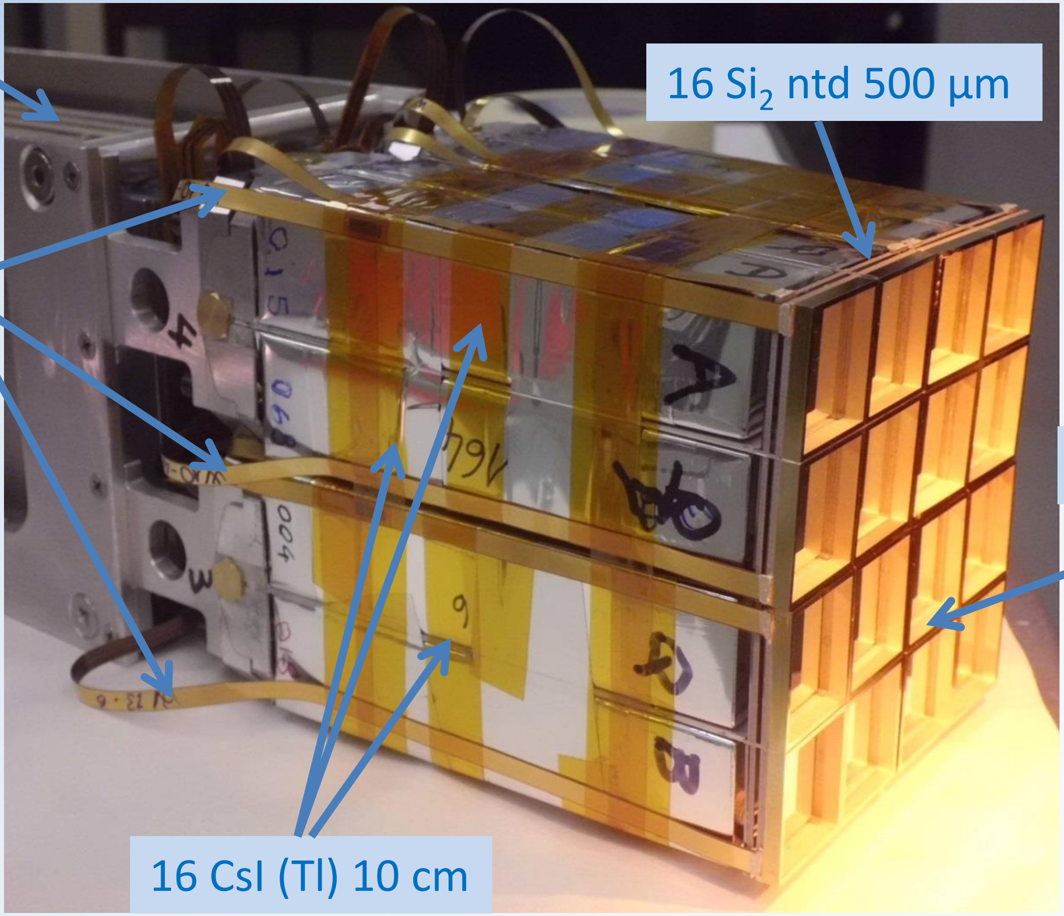
Scientific program in the following years



FaziaSym experimental
set-up December 2015

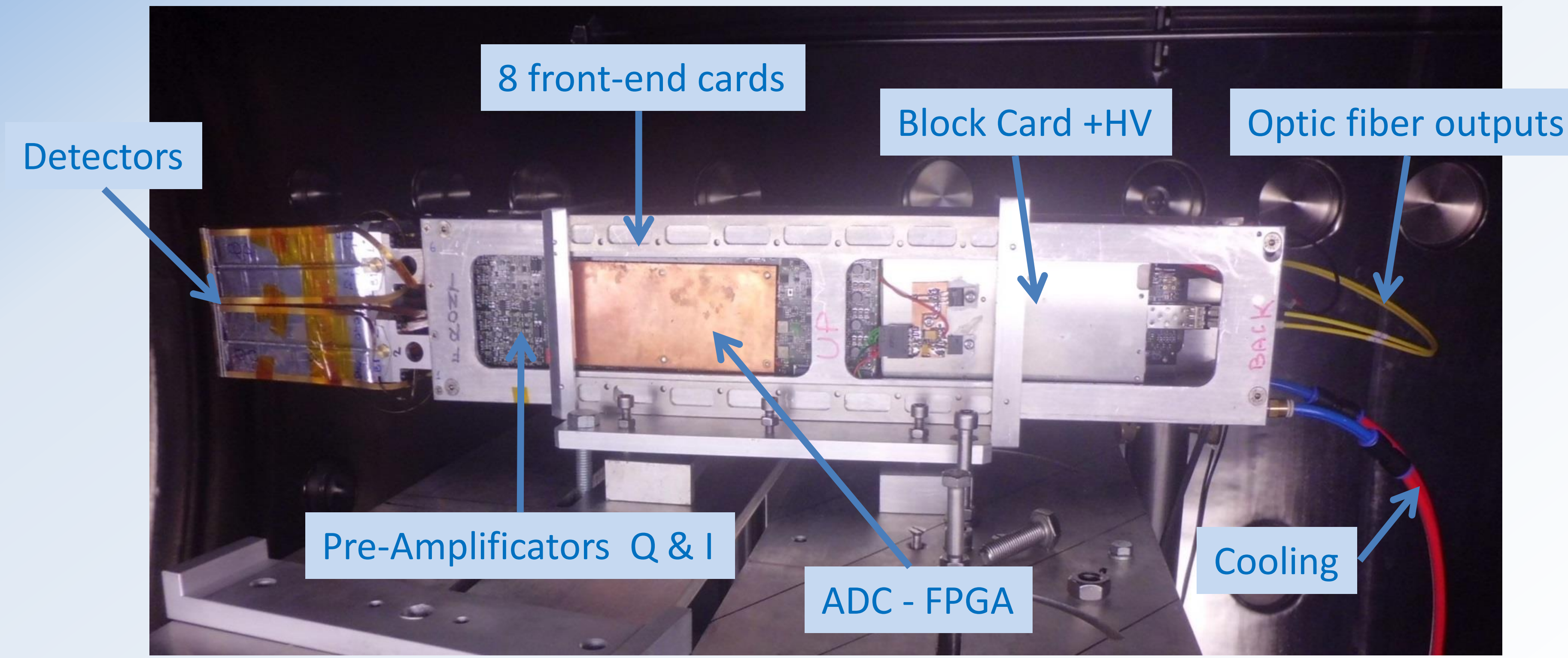
FAZIA

One Fazia block is 16 telescopes Si_1-Si_2-CsI 20x20 mm^2



One Fazia Block:

- 16 telescopes Si(ntd 300µm)-Si(ntd 500µm)-CsI (10 cm)
- Digital electronic, optic fiber outputs
- 8 front end cards cooled under vacuum (integrated power supply PA and detectors)
- Si (300 µm) Charge 250 MeV full scale 250 Ms/s 14 bits
  Charge 4 GeV full scale 100 Ms/s 14 bits
  Current 250 Ms/s 14 bits
- Si (500 µm) Charge 4 GeV full scale 100 Ms/s 14 bits
  Current 250 Ms/s 14 bits
- CsI(photodiode) Charge 4 GeV full scale 100 Ms/s 14 bits



Fazia goals:

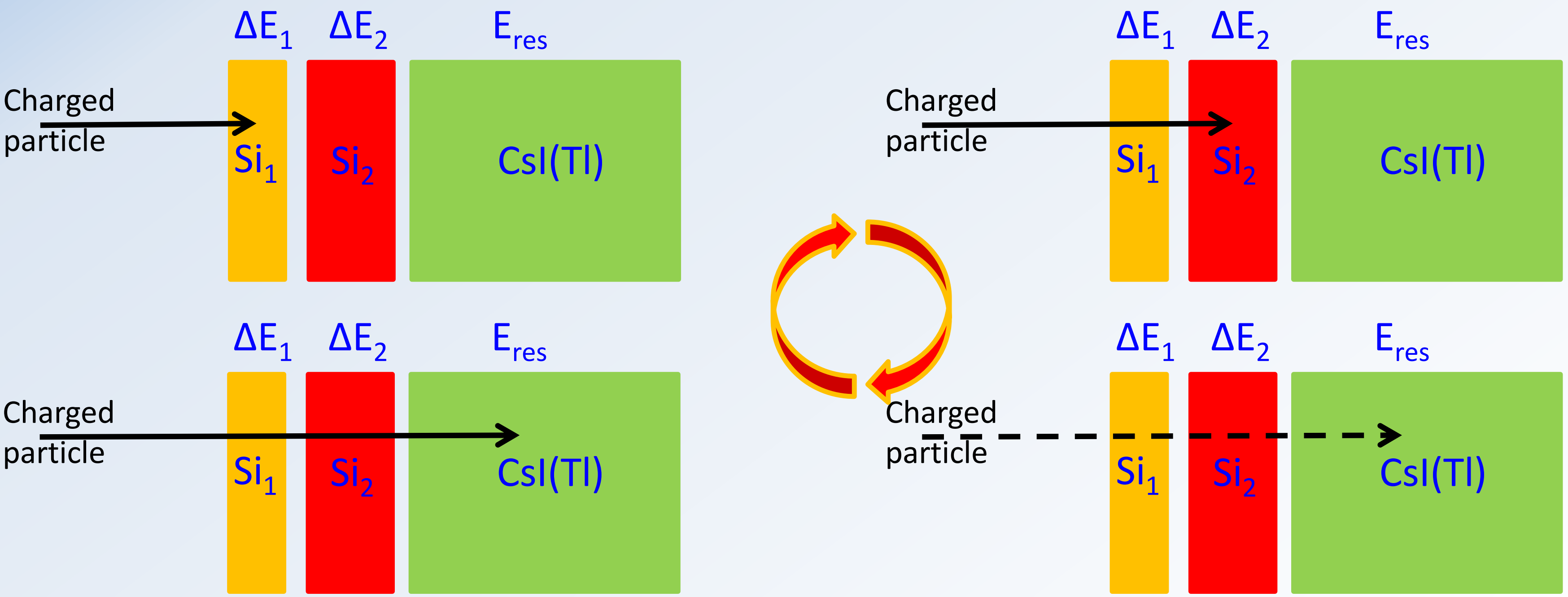
improving Z and A identification on a large scale for isospin physics

- nTD silicon detectors: better homogeneity (≈1%) for better response
- Ingot orientation and cut along special “random” crystal directions to avoid channelling

⇒ Better results on standard ΔE-E technique: mass identification A≈45-50

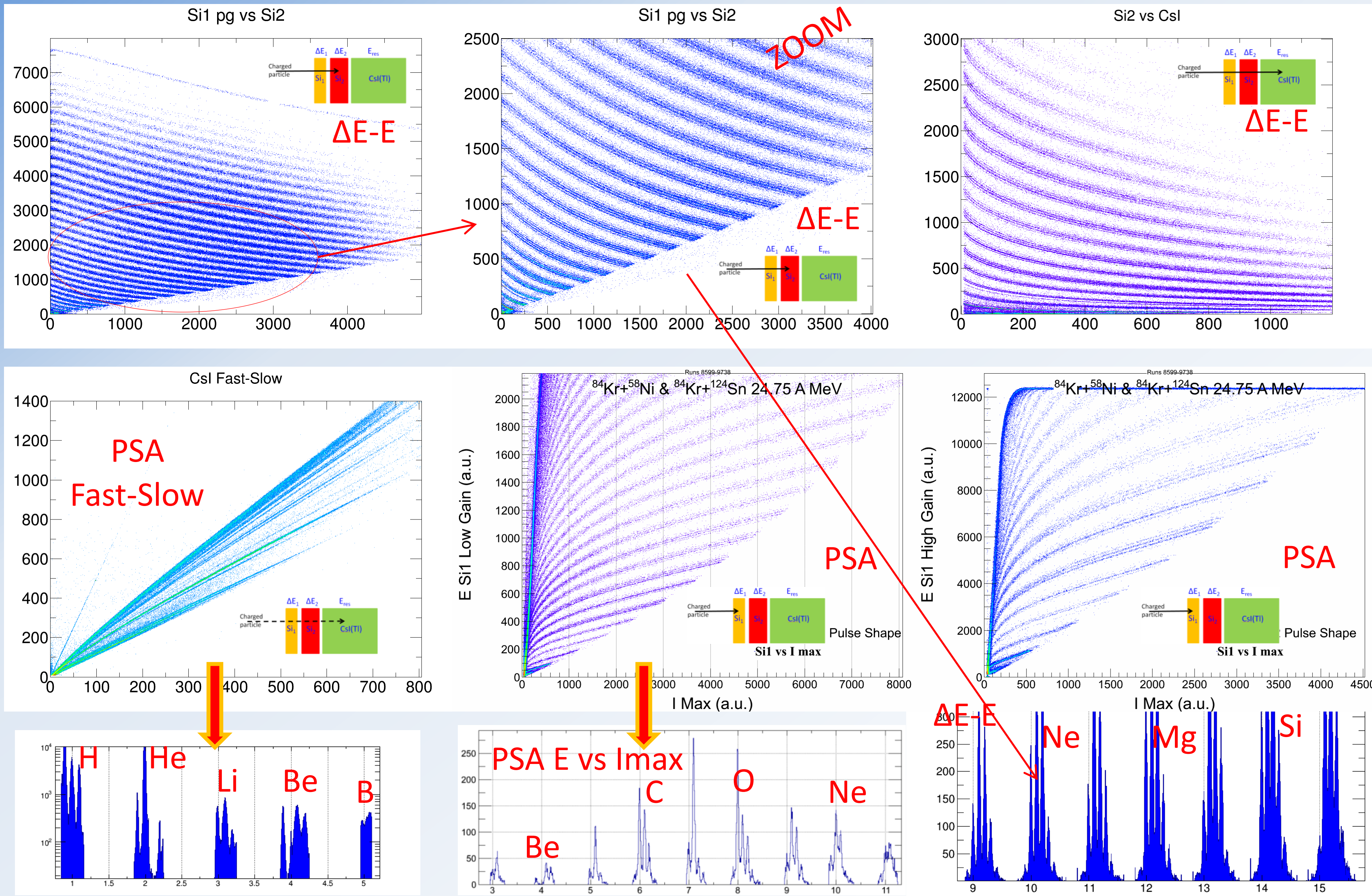
- Digital sampling of all full Si signals (Q and I)
- Pulse shape analysis on a single signal (ΔE) to lower the thresholds

⇒ No limit so far on Z, A≈25 for stopped particles



Isospin transport in heavy ion collisions at Fermi energies

$^{80}Kr+^{40-48}Ca$ @ 35 A MeV IsoFazia experiment, June 2015, LNS Catania



Fazia scientific program in the next following years

- Isospin transport in heavy ion collisions at Fermi energies (LNS Catania)
- Isotopic cross section measurements in the $^{40,48}Ca+^{40}Ca$ systems at E/A = 35 MeV (LNS Catania)

Approved

- Exploring in-medium structure with particle-particle correlations in heavy-ion collisions (LNS Catania)
- Isospin transport versus neutron pre-equilibrium in medium-light systems (LNS Catania)

Approved

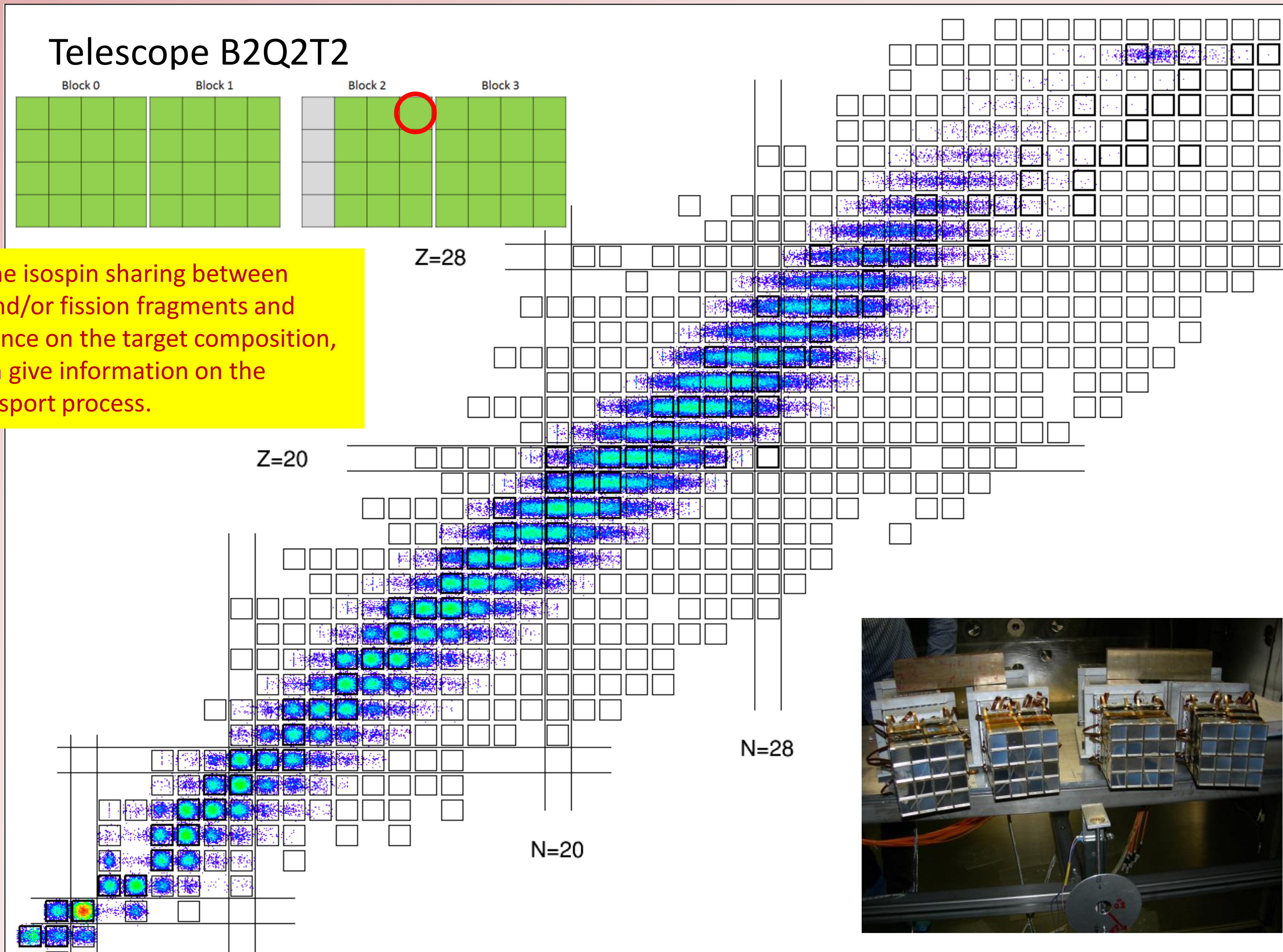
- N/Z dependence in dissipative collisions: from evaporation toward vaporization (Ganil)
- Characterization of neutron signal in Si-CsI telescope and measurement of the absolute neutron detection efficiency (Ganil-NFS)

Approved

- The role of the Isospin in the formation and decay of excited nuclei (Ganil-Spiral2)
- Transport Properties of Isospin Asymmetric Nuclear Matter (Ganil-Spiral2)
- Neutron and proton transfer in dissipative collisions (SPES-Alpi)
- Prompt collective oscillations with exotic beams (SPES-Alpi)

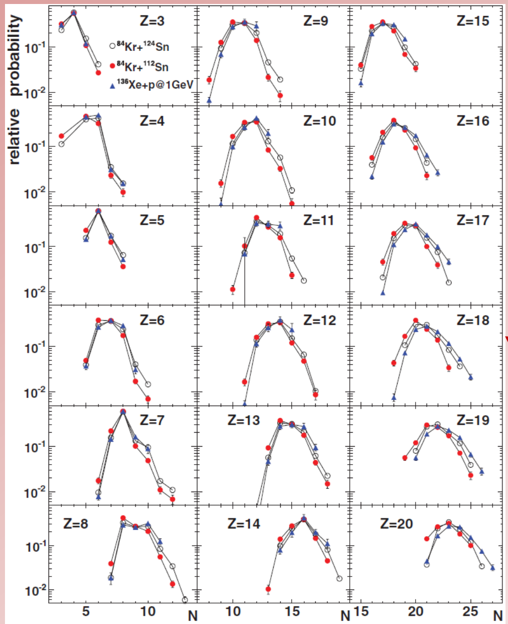
Isospin transport in heavy ion collisions at Fermi energies

$^{80}Kr + ^{40\text{-}48}Ca$ @ 35 A MeV IsoFazia experiment, June 2015, LNS Catania

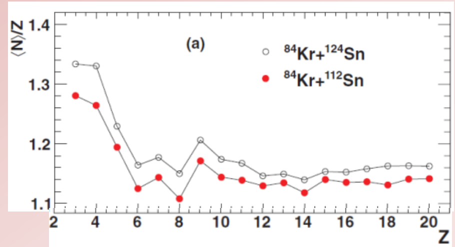


Access to the isospin sharing between QP decay and/or fission fragments and its dependence on the target composition, and this can give information on the isospin transport process.

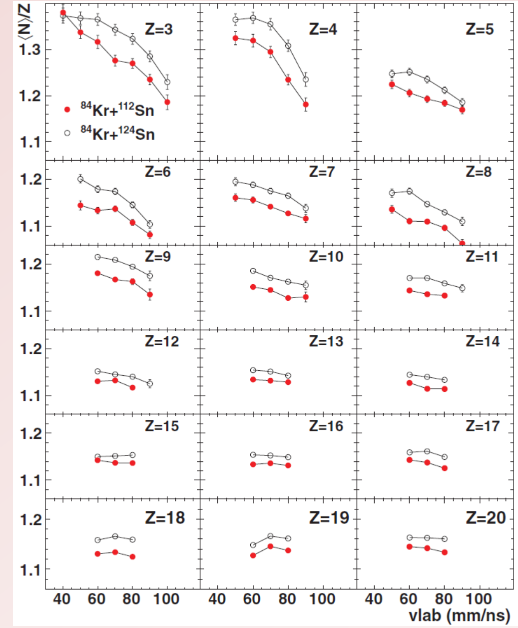
Same projectile with different isotopes for the target



Isotopic distributions

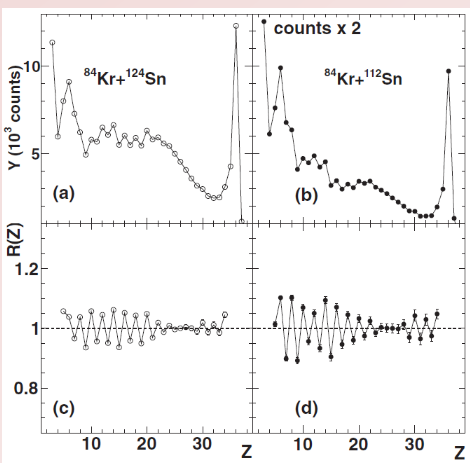


Isospin diffusion effects
≠ <N>/Z for the reactions

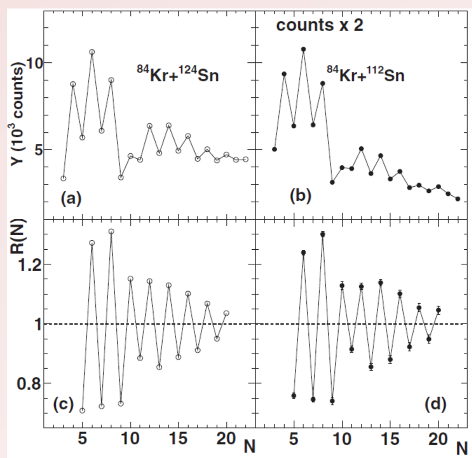


Isospin drift in the diluted region of the neck emission?
<N>/Z depends of velocity for light particles but not the heaviest ones

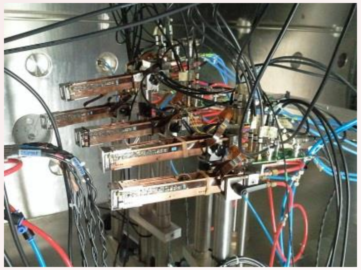
First Fazia results with prototype telescopes at LNS Catania during the R&D phase



Higher staggering in Z for neutron poor system



Higher staggering in N compare to the Z one



These effects are not well understood and they deserve more investigations. They will strongly benefit from the future radioactive beams and high resolution detectors

Following the first results obtained with one telescope

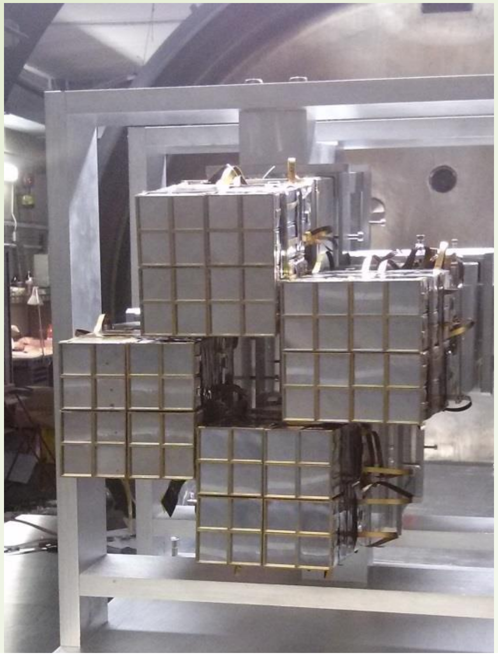
Barlini et al., Physical Review C 87, 054607 (2013)

Piantelli et al., Physical Review C 88, 064607 (2013)

Isotopic cross section measurements in the $^{40,48}Ca+^{40}Ca$ systems at E/A = 35 MeV

$^{40-48}Ca+^{40-48}Ca$ @ 35 A MeV FaziaSym experiment, December 2015, LNS Catania

Complementary with an already Performed experiment with Indra multidetector and Vamos spectrometer at Ganil



benchmark for the future FAZIA+INDRA experiments using GANIL and SPIRAL beams

Such measurements would allow us

1) to complete the investigation of the secondary decay reconstructing the primary fragments via correlation technique specially for PLF which will decay in the forward direction.

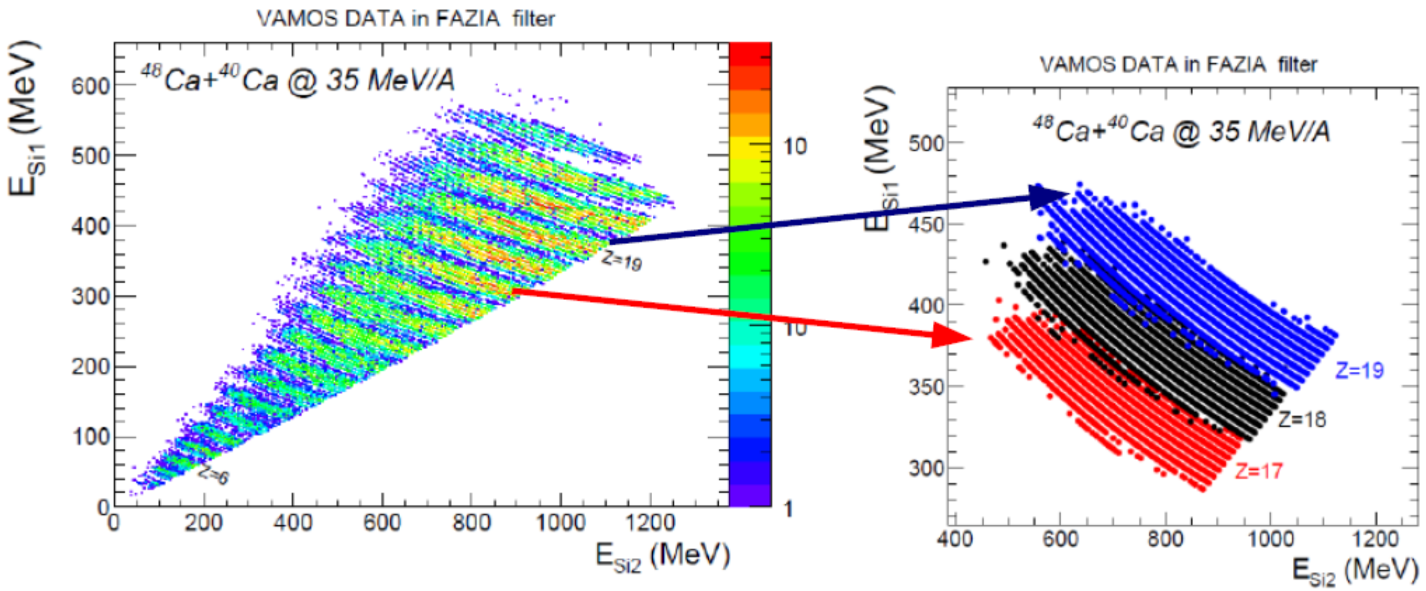
2) to measure the absolute cross sections for each isotope resolved by the FAZIA telescopes. This would allow us to cross check the normalization done in the INDRA-VAMOS experiment. To perform such measurement we will need a continuous measurement of the beam intensity (faraday cup of the CICLOPE chamber and a dedicated Si-Si streaming telescope).

3) to compare the achievable mass resolution of the FAZIA telescopes to the VAMOS spectrometer one. This would allow us to evaluate possible limitations/advantages introduced by the use of the FAZIA detectors in the investigation of the symmetry energy.

Isotopic cross section measurements in the $^{40,48}Ca+^{40}Ca$ systems at E/A = 35 MeV

From Eric Bonnet's presentation Legnaro, May 26-28, 2014

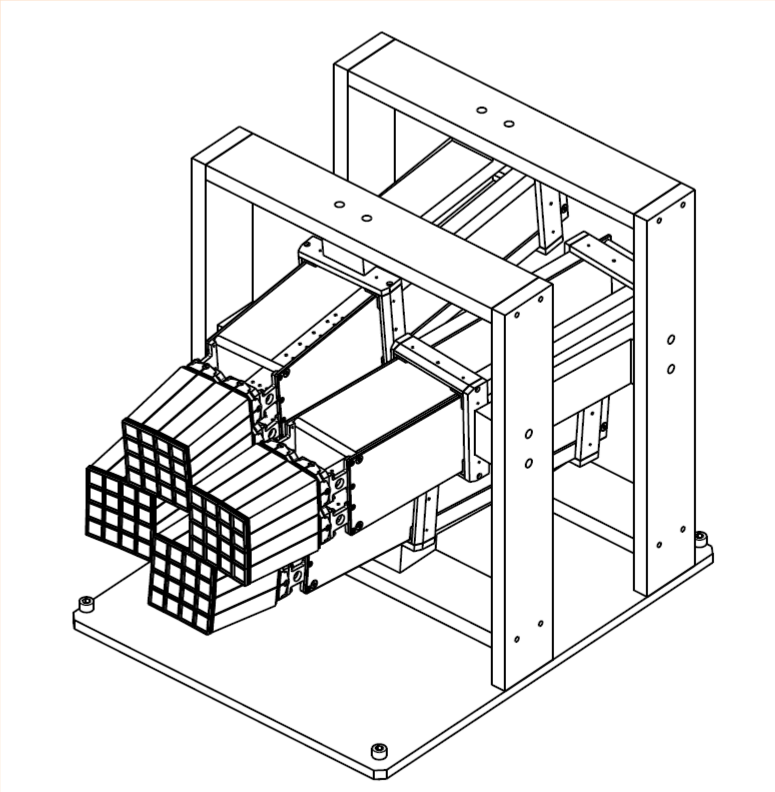
Broad isotopic distributions are expected using 48Ca n-rich beam leading to overlapping of A lines of two neighbor Z



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

Exploring in-medium structure with particle-particle correlations in heavy-ion collisions

$^{32\text{-}36}S+^{12}C$ @ 25-50 A MeV FaziaCor experiment, submitted to last LNS PAC

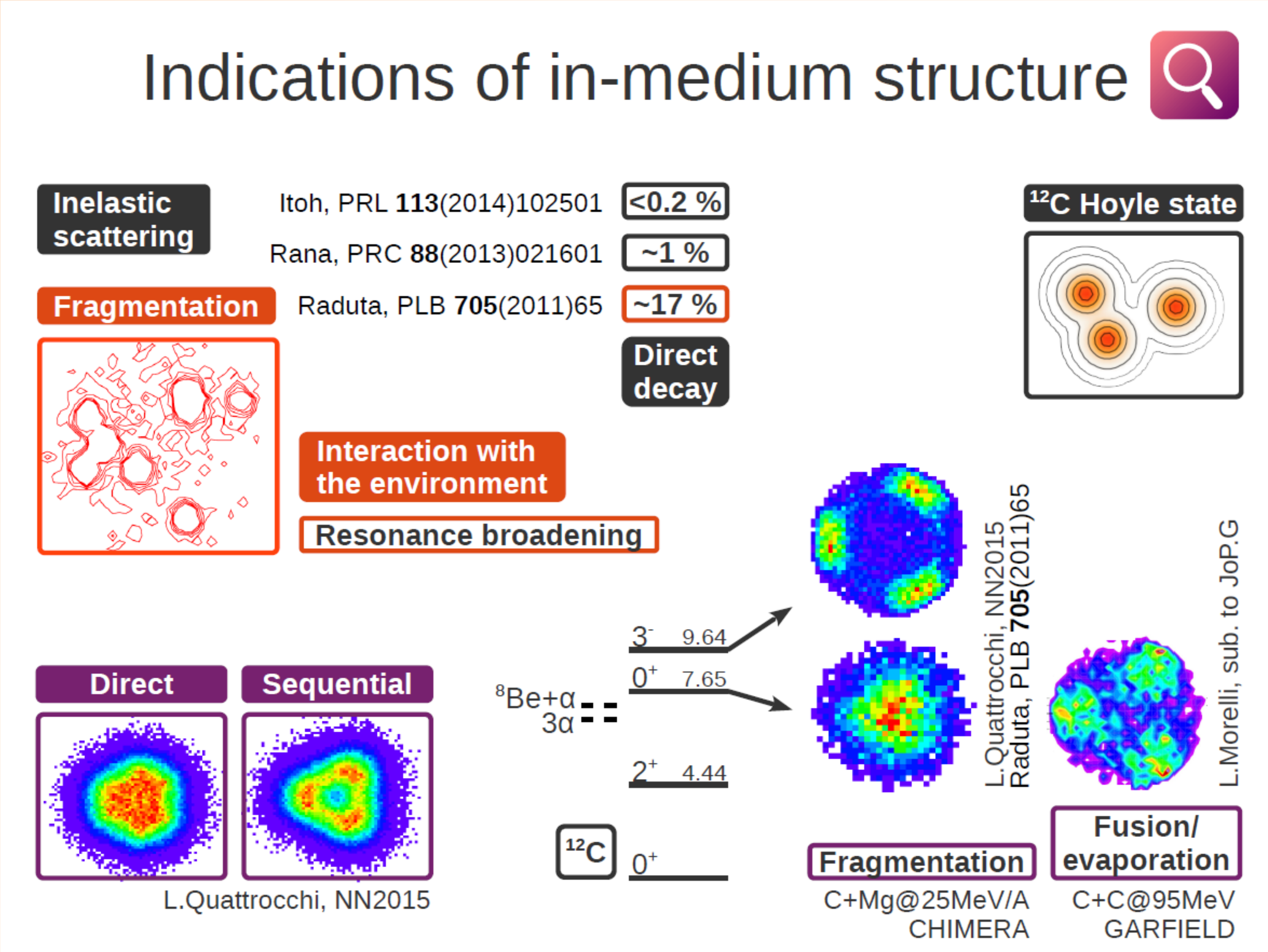


just approved

Heavy-ion collisions allow exploring the nuclear equation of state (EoS) under laboratory controlled conditions. In such complex dynamical systems particle-particle correlations probe dynamics and thermodynamics of hot nuclear systems. Moreover, correlations can also be used as a spectroscopic tool.

Exploring in-medium structure with particle-particle correlations in heavy-ion collisions

From Diego Gruyer's presentation LNS PAC, November 16, 2015



Exploring in-medium structure with particle-particle correlations in heavy-ion collisions

From Diego Gruyer's presentation LNS PAC, November 16, 2015

^{12}N, ^{10}B, and ^{12}C particle decay

^{12}N : resonance width

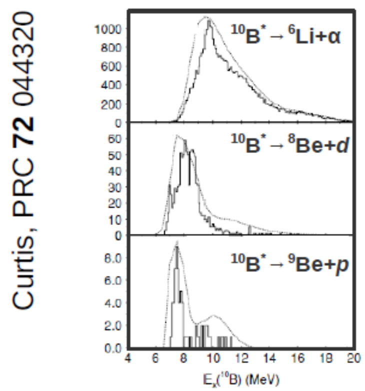
^{12}N → ^{11}C + *p* (-0.6MeV)

7400(1200) keV
6400(1200)
5348(180)
4140(825)
3558(220)
3132(220)
2439(68)
1800(750)
960(<20)
601(Sp)
0

All excited states are above Sp

^{10}B : branching ratios

^{10}B → ^{6}Li + α (-4.5MeV)
^{10}B → ^{8}Be + *d* (-6.0MeV)
^{10}B → ^{9}Be + *p* (-6.5MeV)

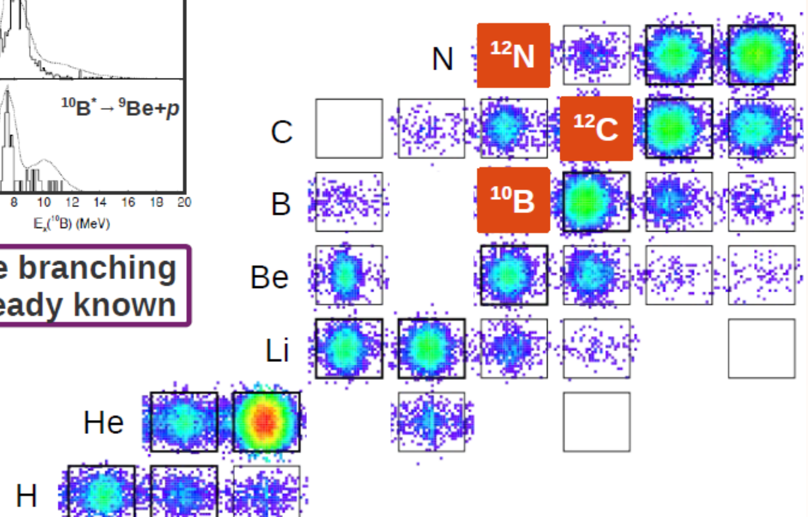


Some branching ratios already known

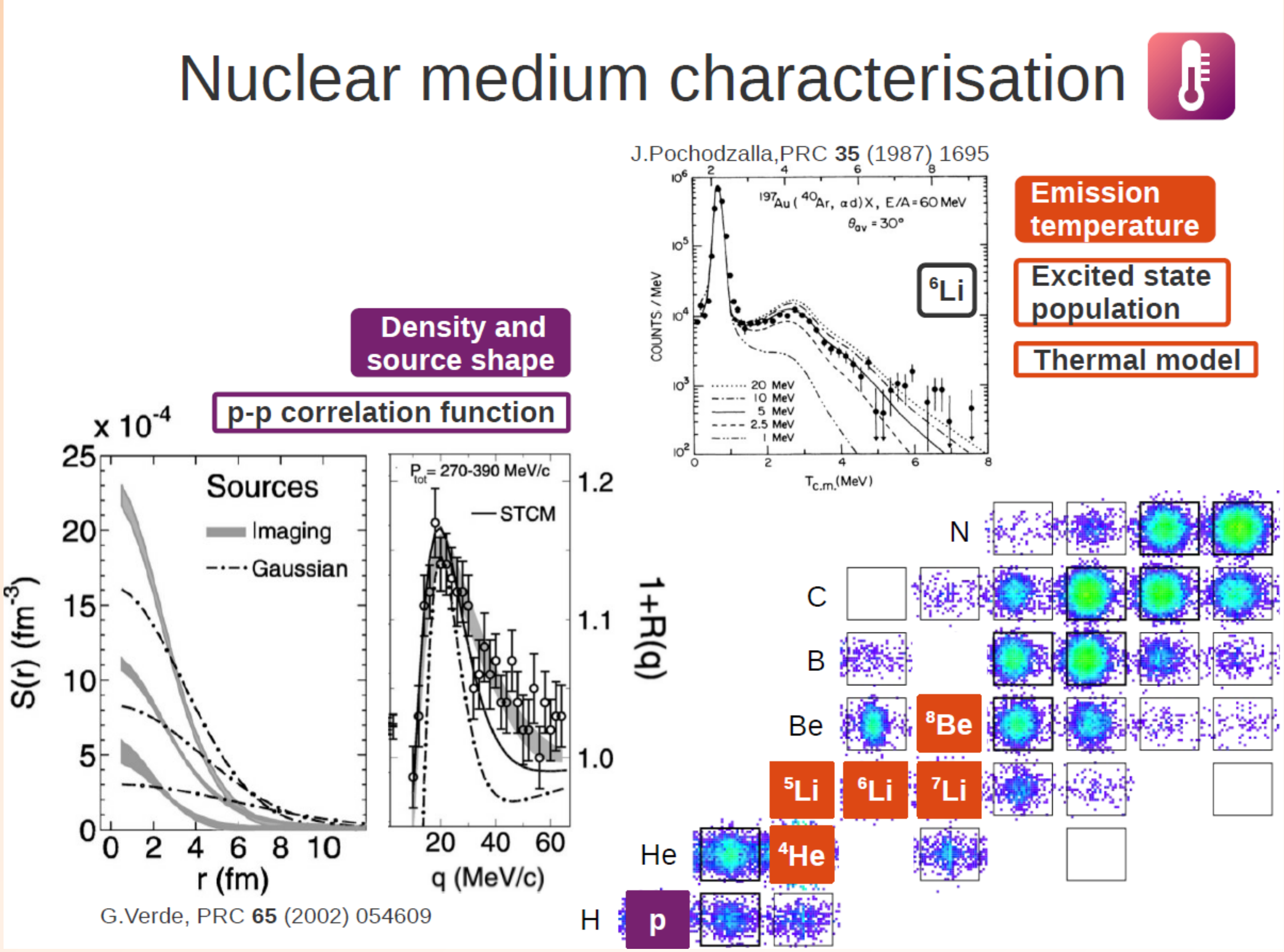
^{12}C : direct decay %

^{12}C → ^{8}Be + α (-7.4MeV)
^{12}C → 3α (-7.3MeV)

Itoh *et al.* **<0.2 %**
Rana *et al.* **~1 %**
Raduta *et al.* **~17 %**

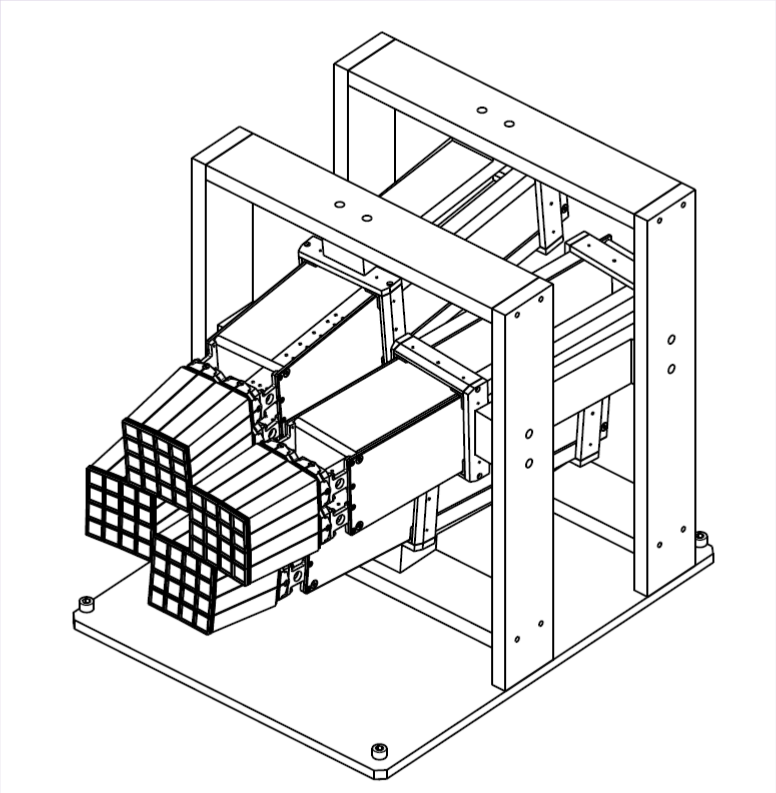


From Diego Gruyer's presentation LNS PAC, November 16, 2015



Isospin transport versus neutron pre-equilibrium in medium-light systems

$^{40-48}Ca+^{40-48}Ca$ @ 25-35-45 A MeV FaziaIsoPre experiment, submitted to last LNS PAC

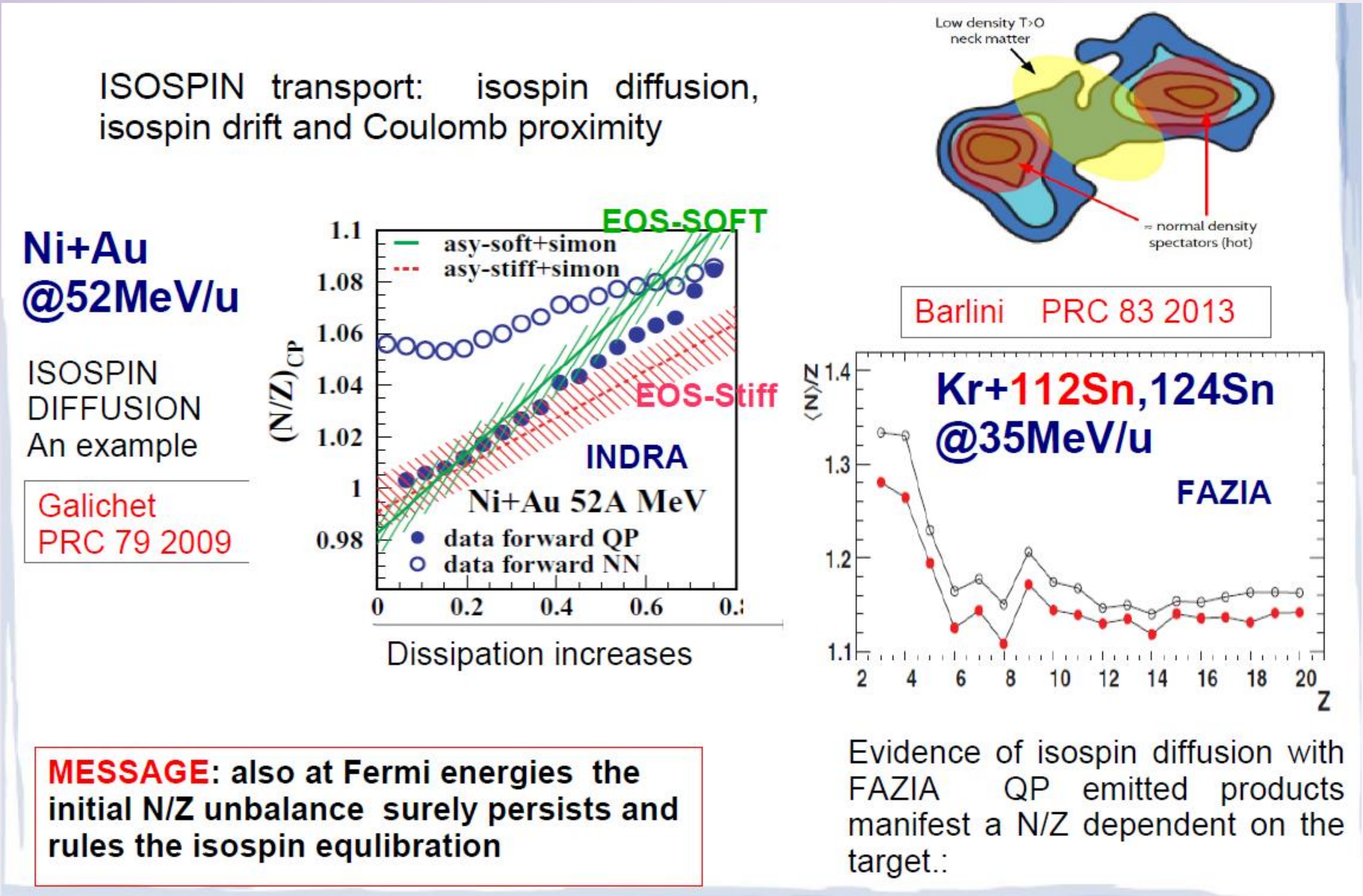


Not yet approved

for a given system, one expects that the number of neutrons participating to the isospin transport during the interaction depend on the entrance channel relative velocity. Indeed, with increasing bombarding energy, a larger number of free neutrons can be fastly removed by the system.

Isospin transport versus neutron pre-equilibrium in medium-light systems

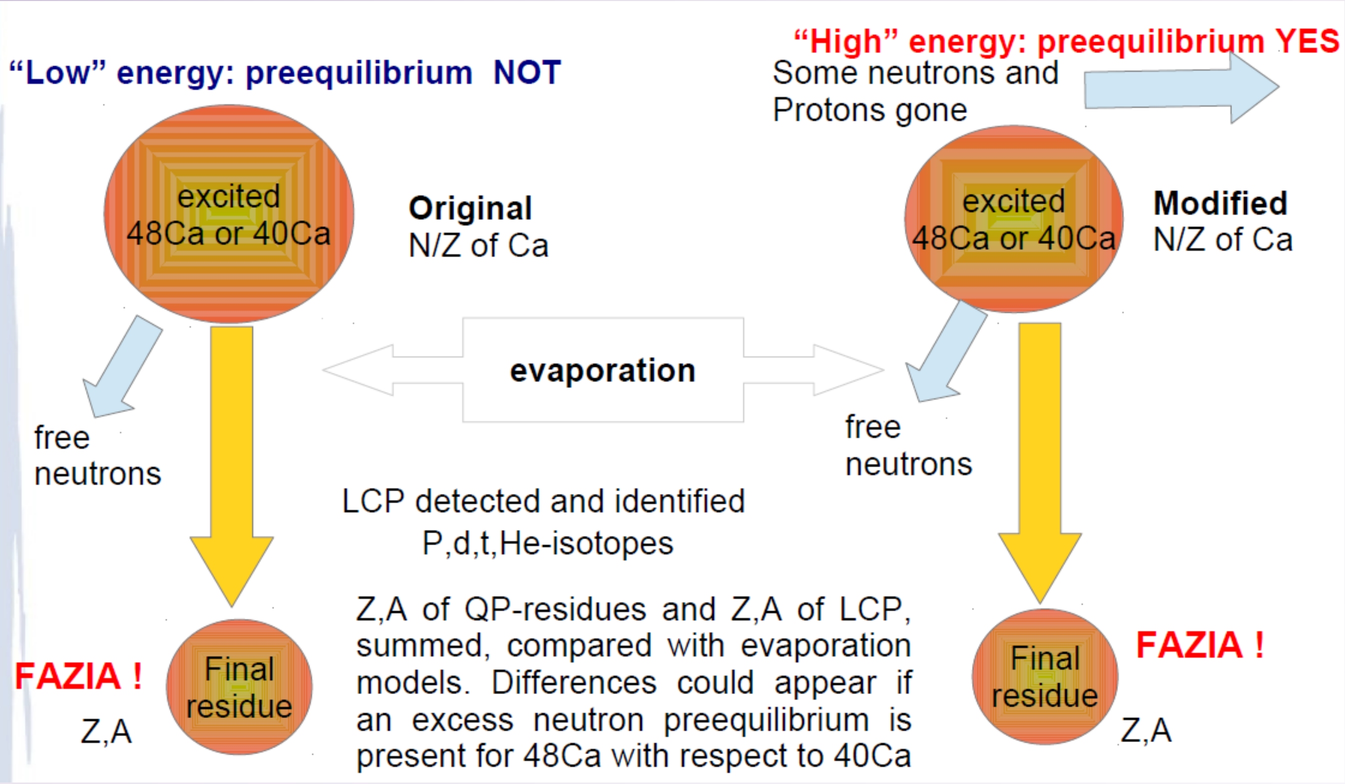
From Giovanni Casini's presentation LNS PAC, November 16, 2015



Preequilibrium vs. isospin diffusion/drift

Isospin transport versus neutron pre-equilibrium in medium-light systems

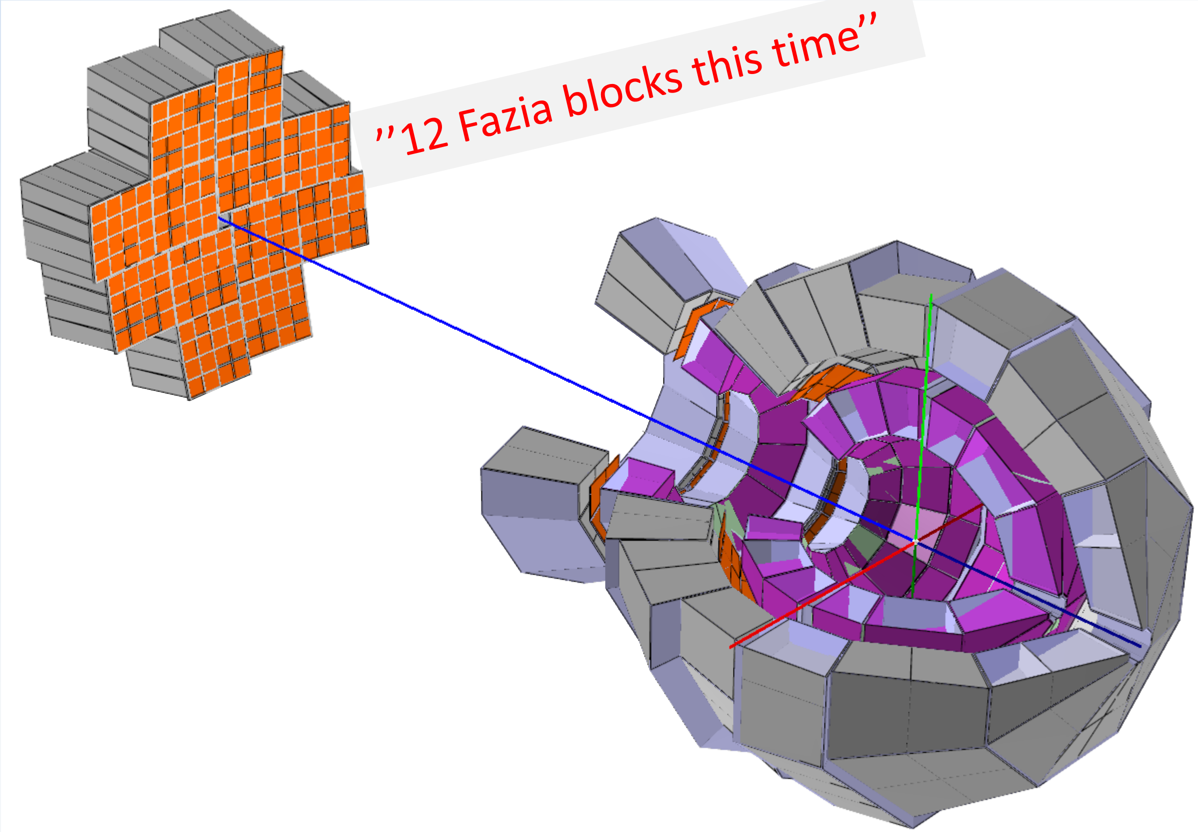
From Giovanni Casini's presentation LNS PAC, November 16, 2015



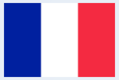
QP reconstruction and properties in ^{40,48}Ca+C @ 25, 35 and 45 A MeV

N/Z dependence in dissipative collisions: from evaporation toward vaporization

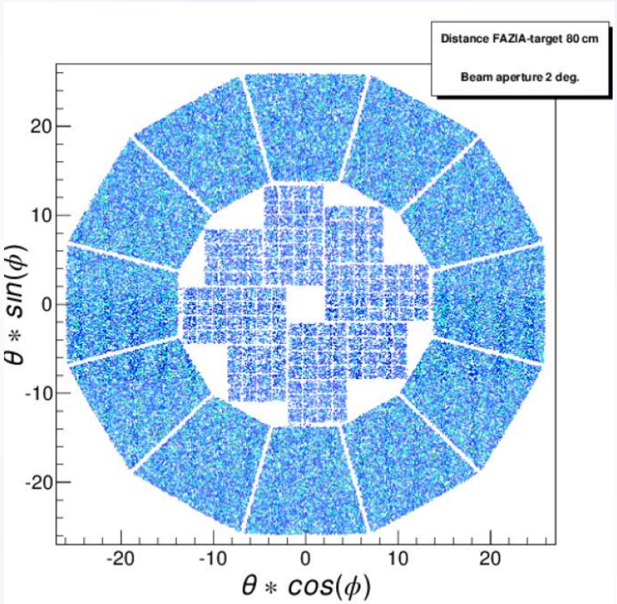
One LoI at Ganil PAC in April 2014, approved and then by the Ganil scientific council too (autumn 2014)



"12 Fazia blocks this time"



Indra+Fazia coupling @ Ganil

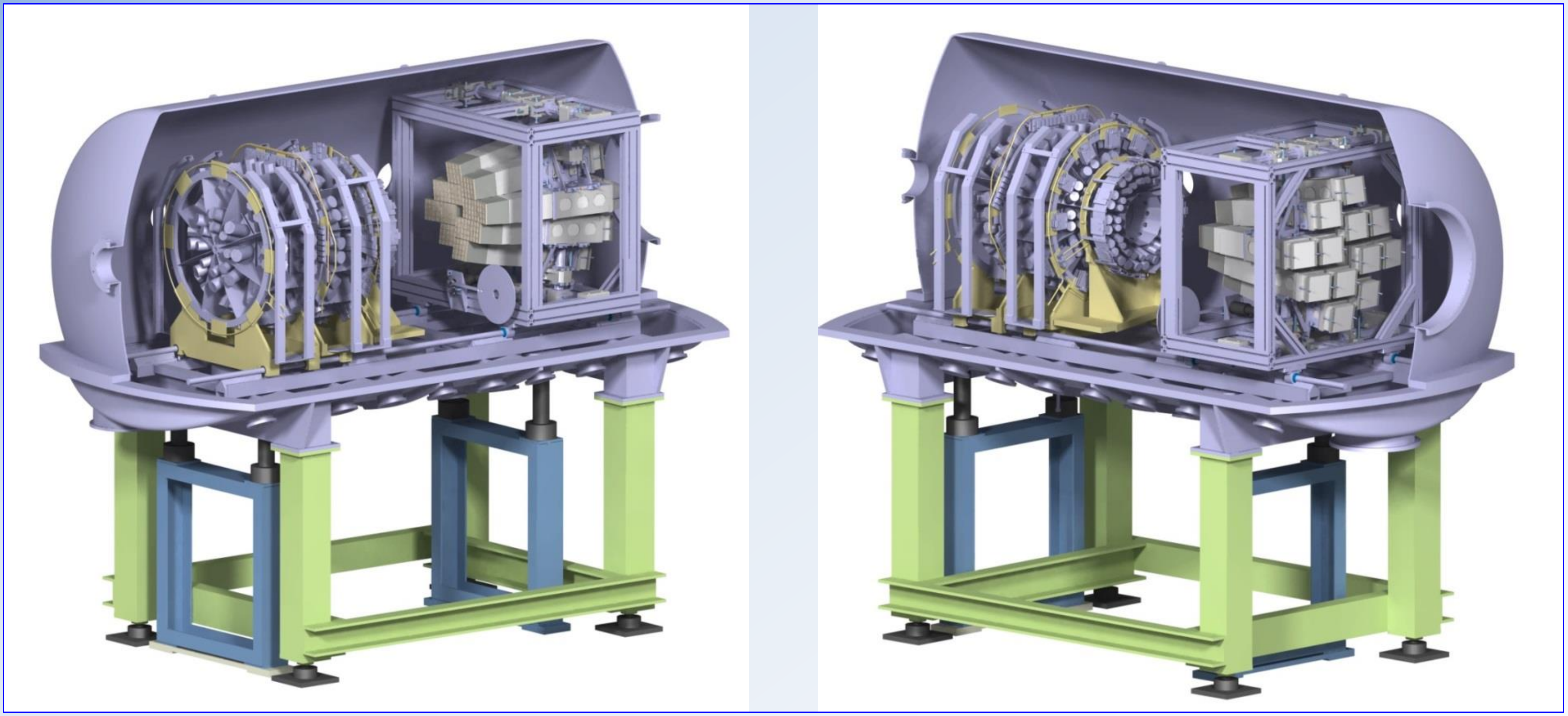


(b) FAZIA is 80cm from the target

To be ready in 2017 when CSS2 beams (high E) will be again available

Coupling Indra+Fazia at Ganil

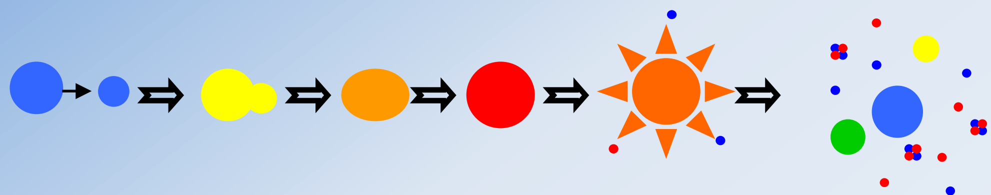
Indra vacuum chamber at Ganil

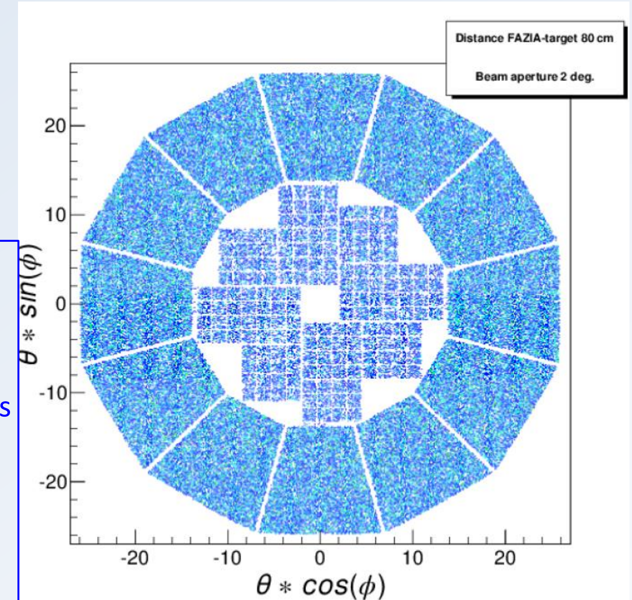


But for this purpose we need to remove the Indra ring number n°1-2-3-4-5 (2°-13,8°)

N/Z dependence in dissipative collisions: from evaporation toward vaporization

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





(b) FAZIA is 80cm from the target

Evaporation	Multifragmentation	Vaporization
Decay chain	Flow and Stopping	Clusters yields in nucleon gas
Level density parameters Fission barriers viscosity	n-n cross section Effective masses incompressibility	In medium nuclear data Cluster-gas interaction

E*, impact parameter

- Bring constraints on nuclear EoS at sub saturation densities and finite T for isospin (N/Z) between 1 and 1,5
- Provide high quality data and results from the Indra-Fazia campaigns to ask funding to increase the number of Fazia blocks: towards x.π

Indra+Fazia at Ganil-2017

As a first step we plan a campaign of measurements at Ganil from the end of 2016 – 2017 (LoI at Ganil-PAC April 3-4 2014)

Postponed!

- $^{17-23}$Ne + ^{9}Be @ 12 A MeV (Spiral1-Cime)

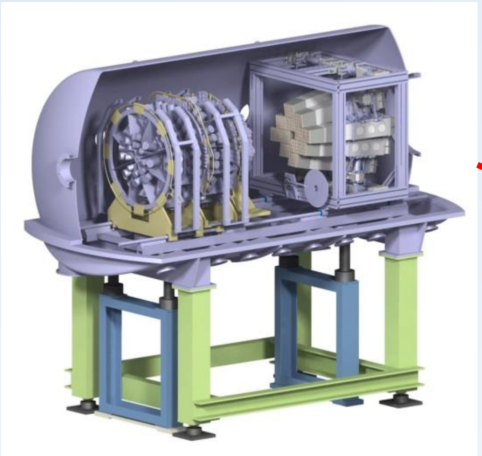
  Fusion-evaporation, level density measurements (Indra-Vamos continuation program)

- $^{40-48}$Ca + ^{40}Ca @35-65 A MeV (Ganil-CSS2)

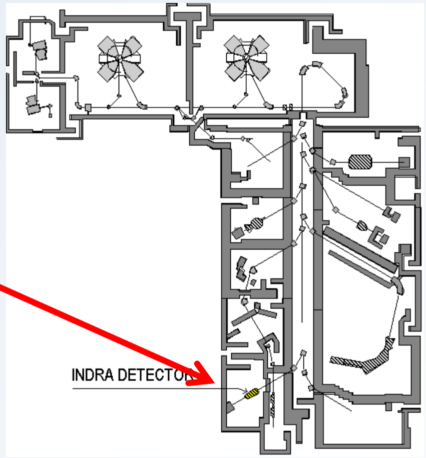
  Isospin migration with density effects (distillation), vaporization

- ^{124,129,136}Xe + $^{40-48}$Ca @ 25-50 A MeV (Ganil-CSS1+CSS2)

  fission time, chronometry, radial expansion (with the help of the mass resolution)



D5



Ganil 2017

Indra+Fazia Ganil-Spiral2 202?

Second step: use of Spiral2 beams at Ganil (see Fazia LoI)
Between E/A = 5 MeV and maximum beam energy

- *Limiting temperature in hot N/Z asymmetric nuclear systems*
- *N/Z dependence of nuclear level densities*
- *Two and multi-particle correlation studies and validity of statistical theories*
- *Accessing the nuclear symmetry energy from fragment isotopic distributions*
- *Studies with dissipative peripheral collisions and probes of the symmetry energy*

- Medium mass systems:
  ^{78}Zn + ^{64}Ni, ^{94}Kr + ^{50}Ti, ^{96}Sr + ^{48}Ca, ^{72}Kr + ^{50}Ti

- Heavier mass systems:
  $^{114\text{-}145}$Xe + ^{40,48}Ca, ^{122}Cd + ^{58}Ni, ^{90}Kr + ^{90}Zr

Spiral2 !!!

- Same mass but different N/Z
  ^{72,78}Kr + ^{28}Si and ^{74,80}Zn + ^{26}Mg

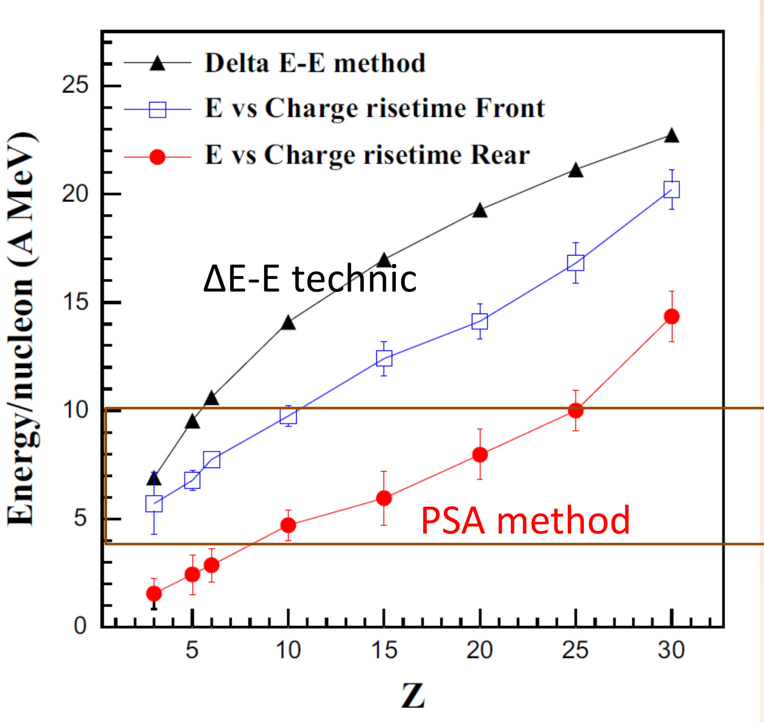
- Comparison with SMF calculation (neck fragmentation and three body break-up)
  ^{112,132}Sn + ^{58,64}Ni @ 10 A MeV

Fazia collaboration in SPES physics program (low energy beams)

Many members of Fazia are part of the LoI presented at SPES workshop:

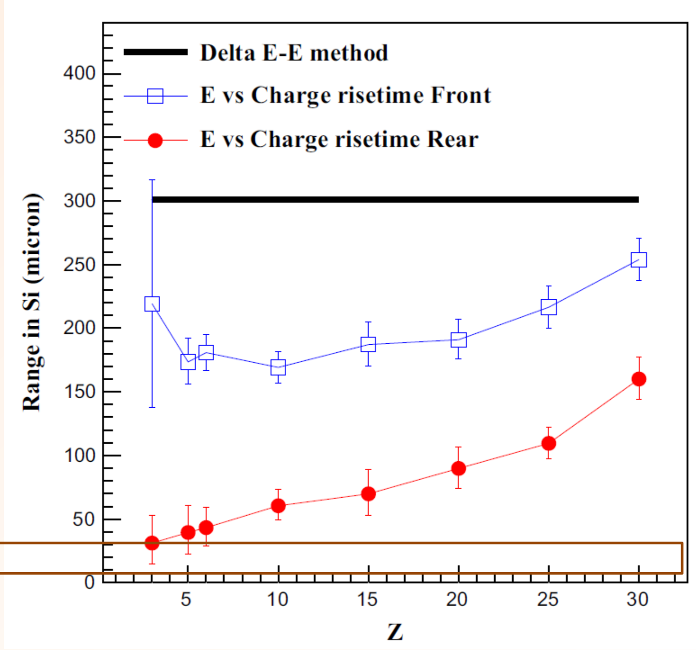
- *G. Politi et al.* Isospin dependence of compound nucleus formation and decay
- *S. Barlini et al.* Prompt collective oscillations with exotic beams
- *L. Morelli et al.* Projectile and compound nucleus decay with light beams provided by SPES
- *T. Marchi et al.* Preequilibrium emission: a tool to study dynamic effects and clustering structure in exotic nuclei
- *G. Casini et al.* Isospin dynamics and thermodynamics in n-rich heavy ion induced reactions

Low energy ion beams: SPES, Spiral2



E thresholds for Si-300 µm thickness:
ΔE-E and PSA Identification technics

Dedicated developments are necessary to use Fazia blocks at low E (Spes, Spiral 2)



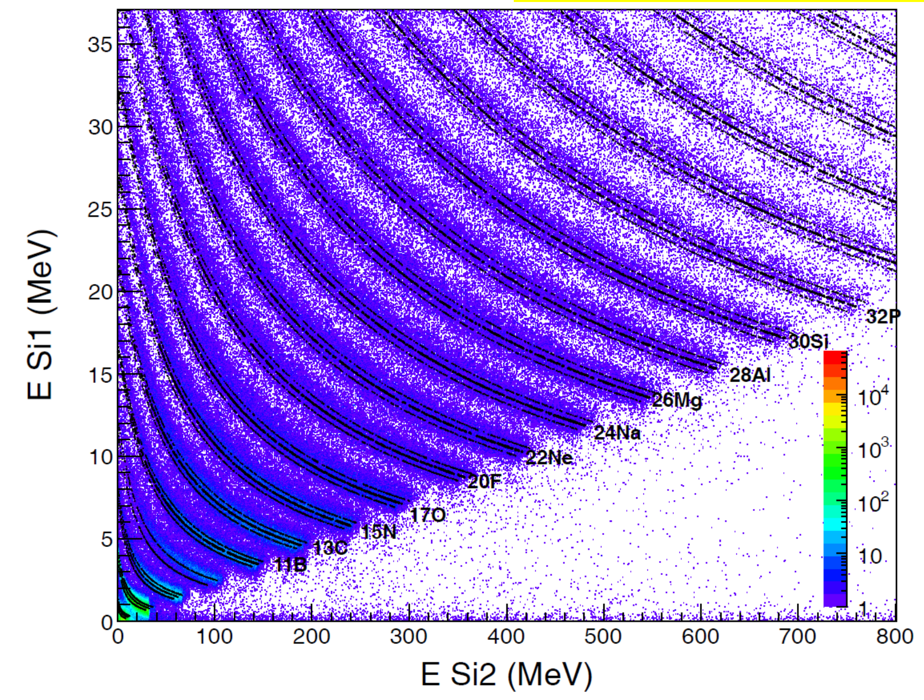
Small Si thickness <30 µm

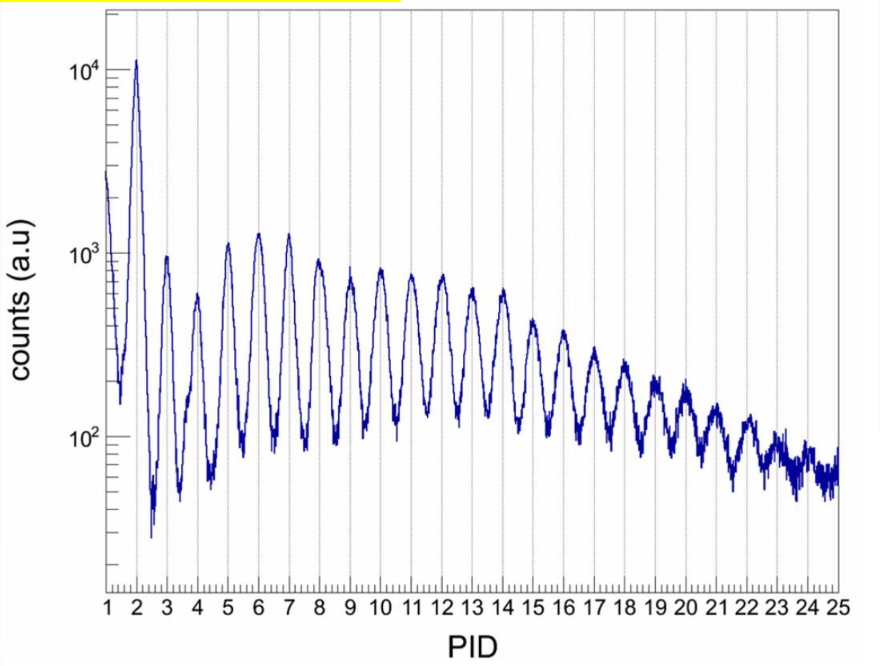
Low energy ion beams: SPES, Spiral2

Lowering the Z identification thresholds: Two options

- Ionisation chamber
- Very thin silicon detectors as first layer < 30 µm

Telescope Si1 (21 µm) –Si2 (510 µm)-CsI





"Low temperature technology of thin silicon ion Implanted epitaxial detectors"
Kordyasz et al. Eur. Phys. Journal A (2015) 51:15

European facilities time scale and Fazia program

Stable Ion Beams: LNS, LNL, Ganil
Low E-RIB (p-rich): Spiral 1 (& 1+)

Low E-RIB (n-rich):
SPES-Spiral2 or LISE

High E-RIB (n-rich):
Eurisol

2015

Fazia 4blocks@LNS

Today

2016-2017

Fazia 4blocks@LNS
measurements @ NFS
commissioning @ Ganil

202?

Garfield+Fazia
Fazia-1π
Lise:Fazia+γ detectors

203?

Fazia-4π
Lets dream

Indra-Fazia 12 Blocks @ Ganil

Existing 4π devices

Chimera
Garfield
Indra

To be maintained and upgraded (electronics)

High intensity ion beams: LNS Catania

- Exotic beams obtained by fragmentation (rare isotopes)
- Low cross section phenomena
- Exotic nuclei
- Clusters
- Exotic shapes?

If any interesting idea, join the team!

The FAZIA Collaboration

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