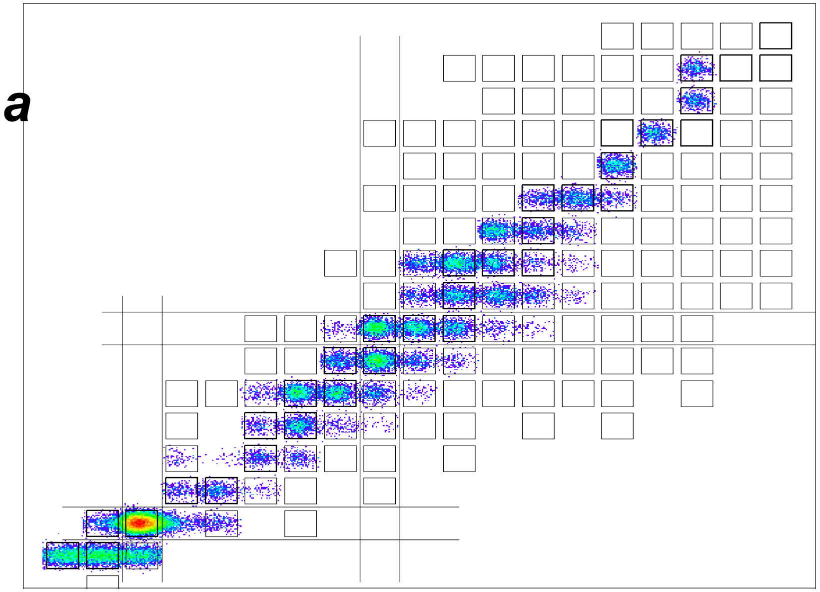
Recent results and programs of the Fazia collaboration

Taking pictures of the nuclide chart at a nanosecond scale after production



Giovanni Casini
INFN Firenze

NUSYM15 Krakow, 29 june- 2 july 2015

contents

- ➔**Motivation and brief history**
- ➔**Main results of the prototype phase**
- ➔**The challenge of the Demonstrator: top performance for a large-scale device**
- ➔**First experiments just started (@LNS)**
- ➔**Future Plans**
- ➔**Conclusions**

A brief history

Four-π A and Z Identification Array

- **Born in 2006: design a multidetector for Heavy-ion reactions with challenging objectives:**

- **Solid-state detectors for an "easy" operation**
- **Wide ranges of Z, A, E of ions from 10-100MeV/u nuclear collisions**
- **Z and A separation with 'low' thresholds to meet the requirements of experiments at the ongoing ISOL european facilities (SPES, Spiral2)**

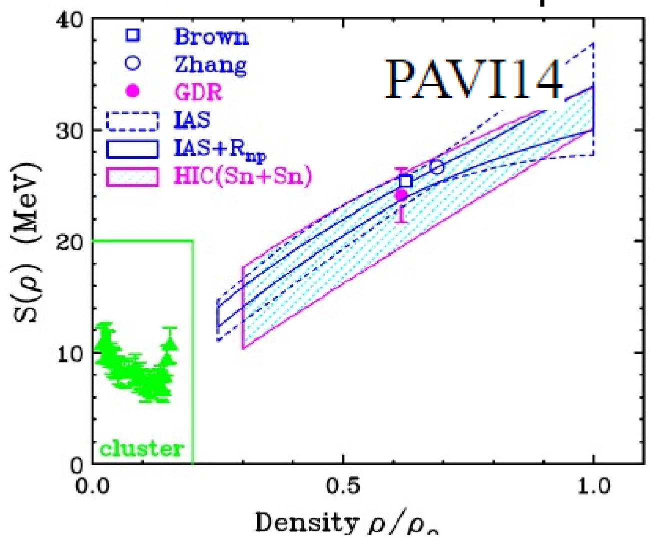
Institutions (2015)

INFN (Firenze, Napoli, LNL, LNS, Bologna, Padova), Italy
LPC, IN2P3-CNRS,ENSICAEN, Universite' de Caen, GANIL, France
CEA/DSM-CNRS, IPN Orsay, Universite' Paris-Sud XI, France
Dipartimento di Fisica Università di Firenze, Italy
Dipartimento di Fisica Università di Bologna, Italy
Dipartimento di Fisica Università Federico II Napoli, Italy
Jagellonian University, Institute of Nuclear Physics IFJ-Pan, Krakow, Poland
Heavy Ion Lab., Warsaw University, Warsaw, Poland

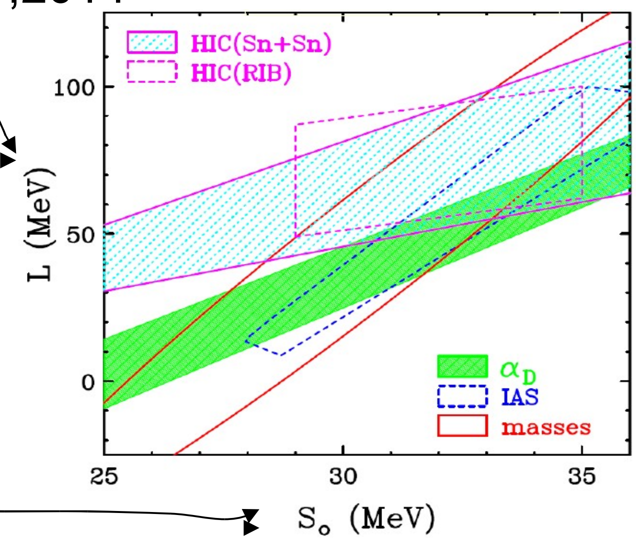
Main motivation

What about Esym far from normal conditions?

Adapted from B.Tsang PAVI14 july,2014



$$S(\rho) = S_o + \frac{L}{3}\left(\frac{\rho_B - \rho_0}{\rho_0}\right) + \dots$$



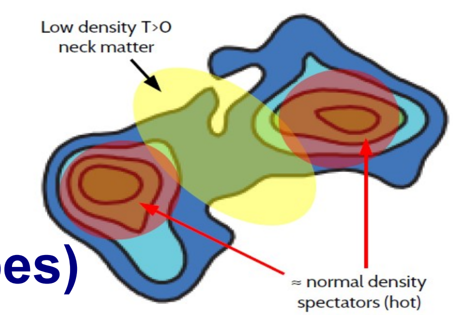
Heavy-Ion Collisions manifest processes/environments affected by E_{sym}

- **Isospin diffusion/equilibration**
- **Features of low density regions (peripheral reactions, neck zone, skin effects)**
- **Cluster formation**
- **n/p and mirror nuclei ratios**

… and more:

- **e.g. Dynamical dipole and pygmy resonances (gamma probes)**

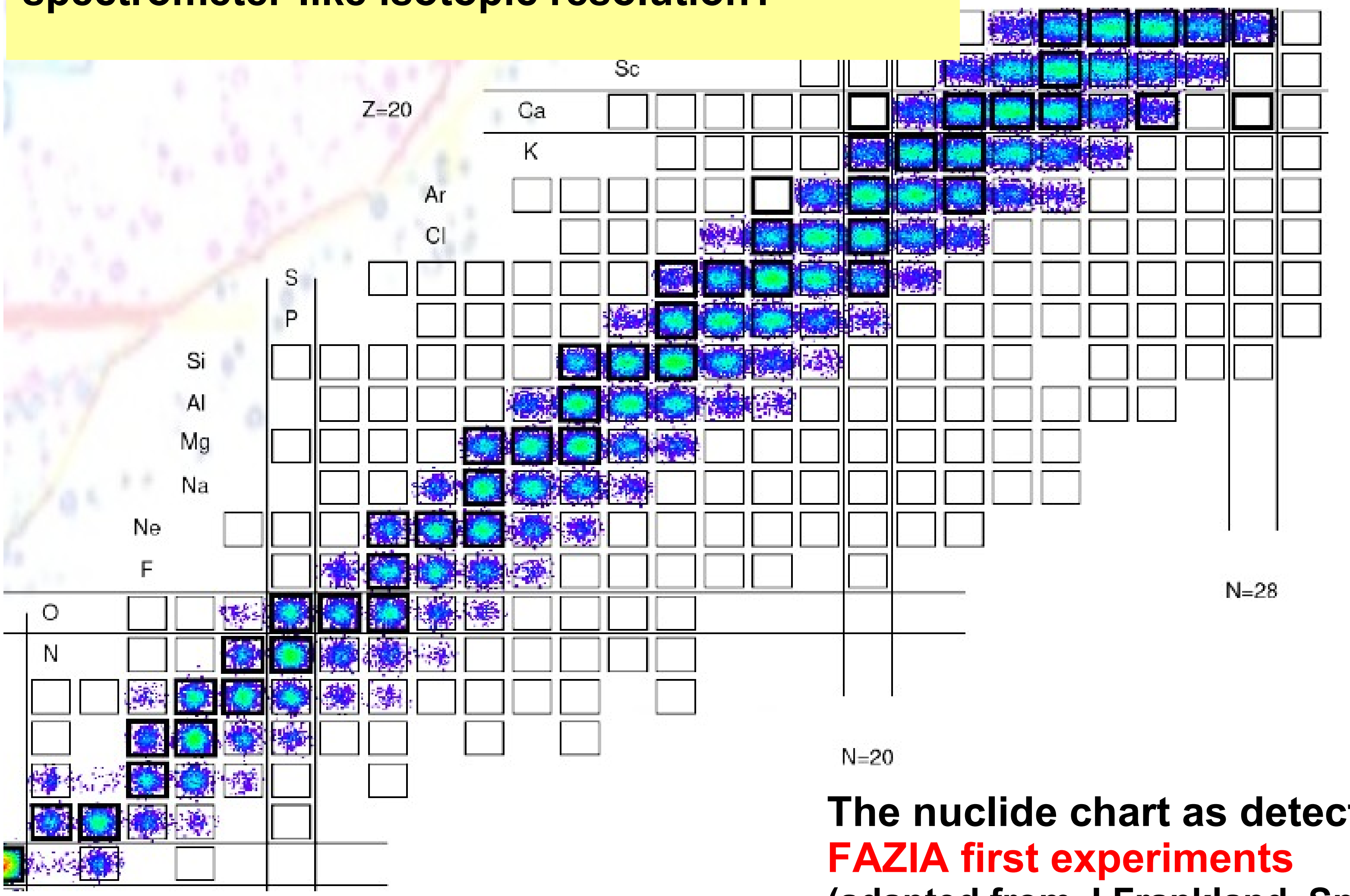
Typical times 100-180fm/s



We are learning much in this NUSYM15: many EOS! I

A brief history

Can we build a "large" acceptance device with spectrometer-like isotopic resolution?

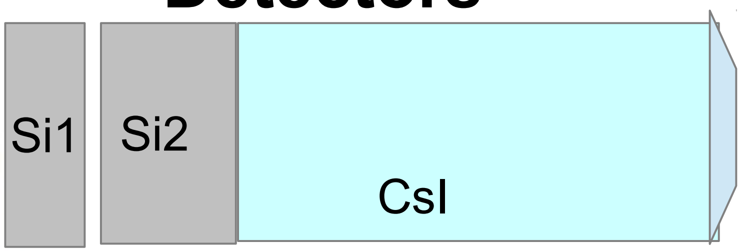


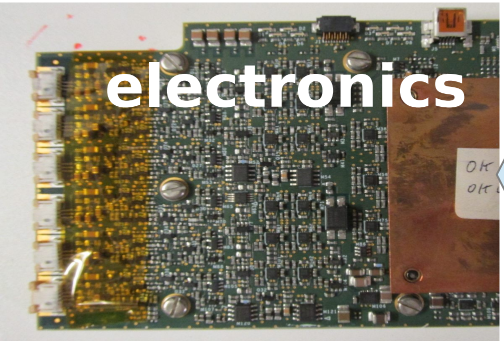
The nuclide chart as detected in FAZIA first experiments (adapted from J.Frankland, Spiral2 week, 2014)

A brief history

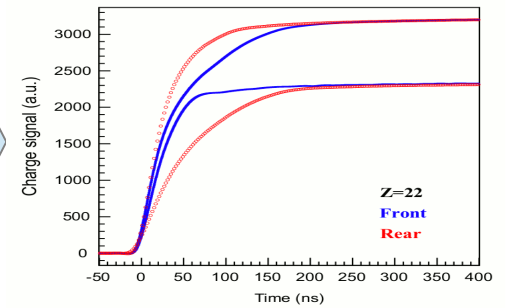
R&D phase on detectors, electronics and identification techniques

Detectors





identification



Basic detector module:

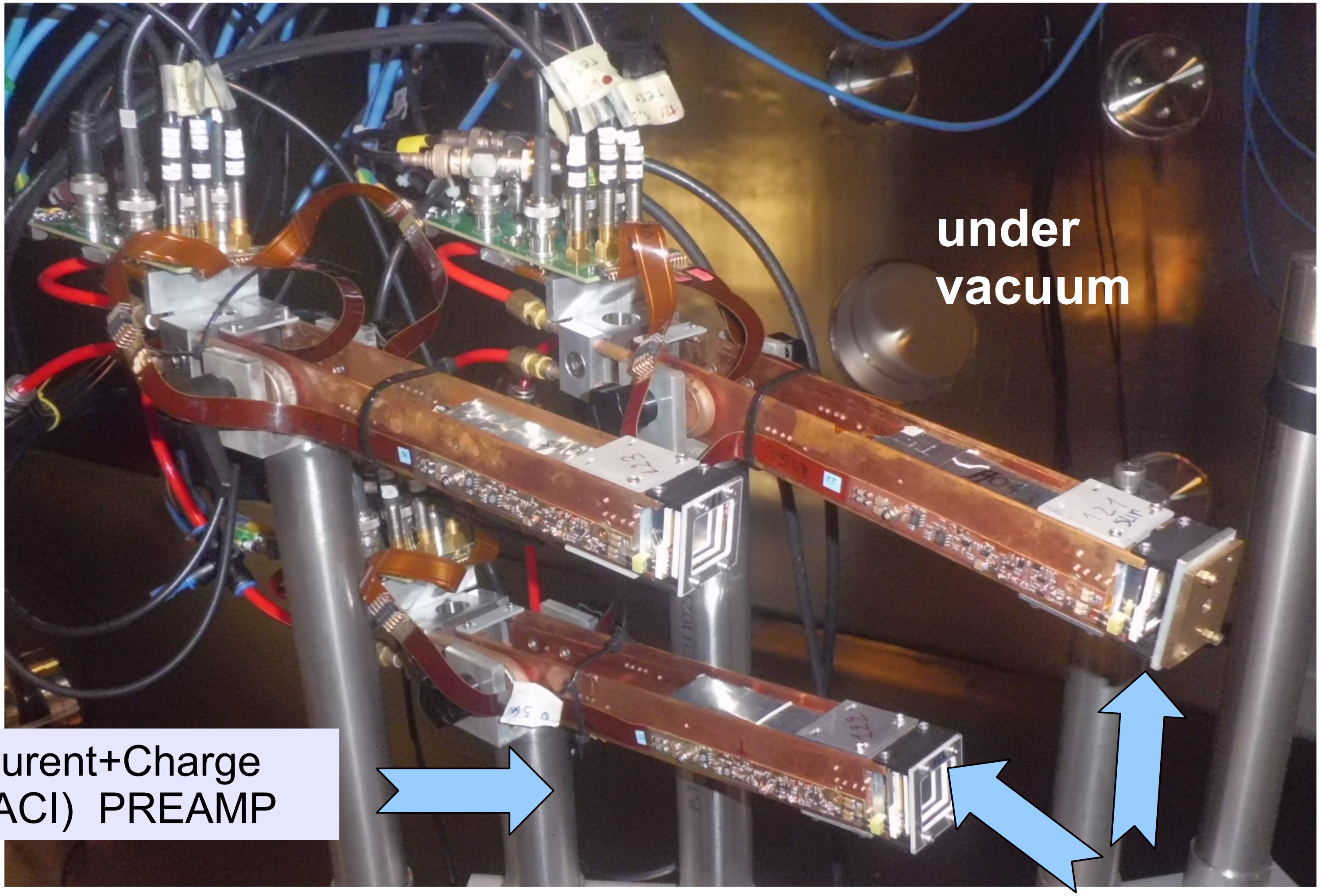
Si-Si-CsI(Tl) telescope 20x20 mm^2 Si (300μm)– Si (500μm) – CsI (10 cm) (with photodiode readout)

Fully equipped with fast digital electronics in order to best exploit Pulse Shape Analysis

the prototypes

Sampling ADC's
and DSP/FPGA

In air



Cuurent+Charge
(PACI) PREAMP

single telescopes; various choices were time by time checked under beam

Main topics about the prototypes

As for Silicons:

- Front vs. Rear injection for PSA and ΔE-E techniques
- Thikness uniformity of ΔE layer (1 micron)
- Channeling effects
- Doping homogeneity and PSA (nTD type Si-bulk)
- Bias voltage constancy
- Metal deposition (sheet resistance)

As for CsI(Tl):

Wrapping material choice

Stringent requirement on the Tl doping homogeneity

Custom Photodiode production (maximize active area)

As for Electronics:

- New low-noise Charge-Current preamplifiers (vacuum);
- Digital sampling cards with fast sampling ADC (air)
- Current and charge signals sampled/stored for the quest of the best Pulse shape algorithms

Published results from the prototypes

L.Bardelli et al., NIMA 491 (2002) 244 (digital sampling in scintillators)

H.Hamrita et al., NIMA 531 (2004) 607 (Charge and Current preamp.)

L.Bardelli et al., NIMA 521 (2004) 480 (time measurements via digital sampling techniques)

L.Bardelli et al., NIMA 560(2006) 524 (about digital sampling technique)

G.Pasquali et al., NIMA 570 (2007) 126 (Si signals analysis by means of a DSP)

L.Bardelli et al., NIMA 572 (2007) 882 (timing synchronization)

S.Barlini et al., NIMA 600 (2009) 644 (PSA from current signal)

L.Bardelli et al., NIMA 602 (2009) 501 (measurement of the resistivity of Si detectors by means of a pulsed UV-laser)

L.Bardelli et al., NIMA 605 (2009) 353 (channeling in Si and PSA)

L.Bardelli et al., NIMA 654 (2011) 272 (PSA technique; E-rise time vs. E-Imax)

S. Carboni et al., NIM A 664 (2012) 651 (results on PSA and ΔE-E with FAZIA telescopes)

G.Pasquali et al., EPJA 48 (2012) 158 (single chip telescope – CsI read out by Si2)

N.LeNeindre et al., NIMA 701 (2013) 145 (front vs. reverse mounting of Si)

S.Barlini et al., NIMA 707 (2013) 89 (radiation damage and PSA)

G.Pasquali et al., EPJA 50 (2014) 86 (PSA in partially depleted Si detectors)

R.Bougault et al., EPJA 50 (2014) 47 (review summary paper)

A.Kordjasz et al., EPJA 51 (2015) 15 (ΔE-E with epitaxial thin FAZIA-like detectors)

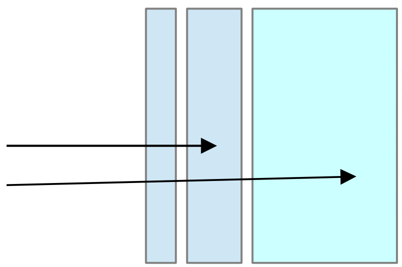
Main results from the prototypes

----> Refer to the various papers for details

Identification techniques

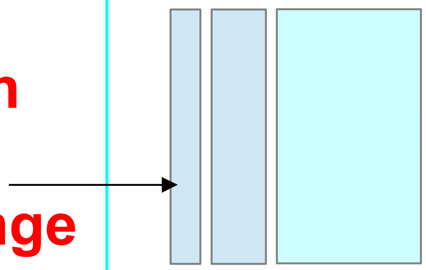
ΔE –E : particles punching-through at least the first 300 μm Si layer

– full Z identification (at least Z=56);
– A identification up to Z around 23



Pulse Shape Analysis : particles stopped in the first Si

– full Z identification (with a Z-dependent min. range in Si (>30 μm))
– A identification up to Z=15 (with a Z-dependent range (>150 μm))

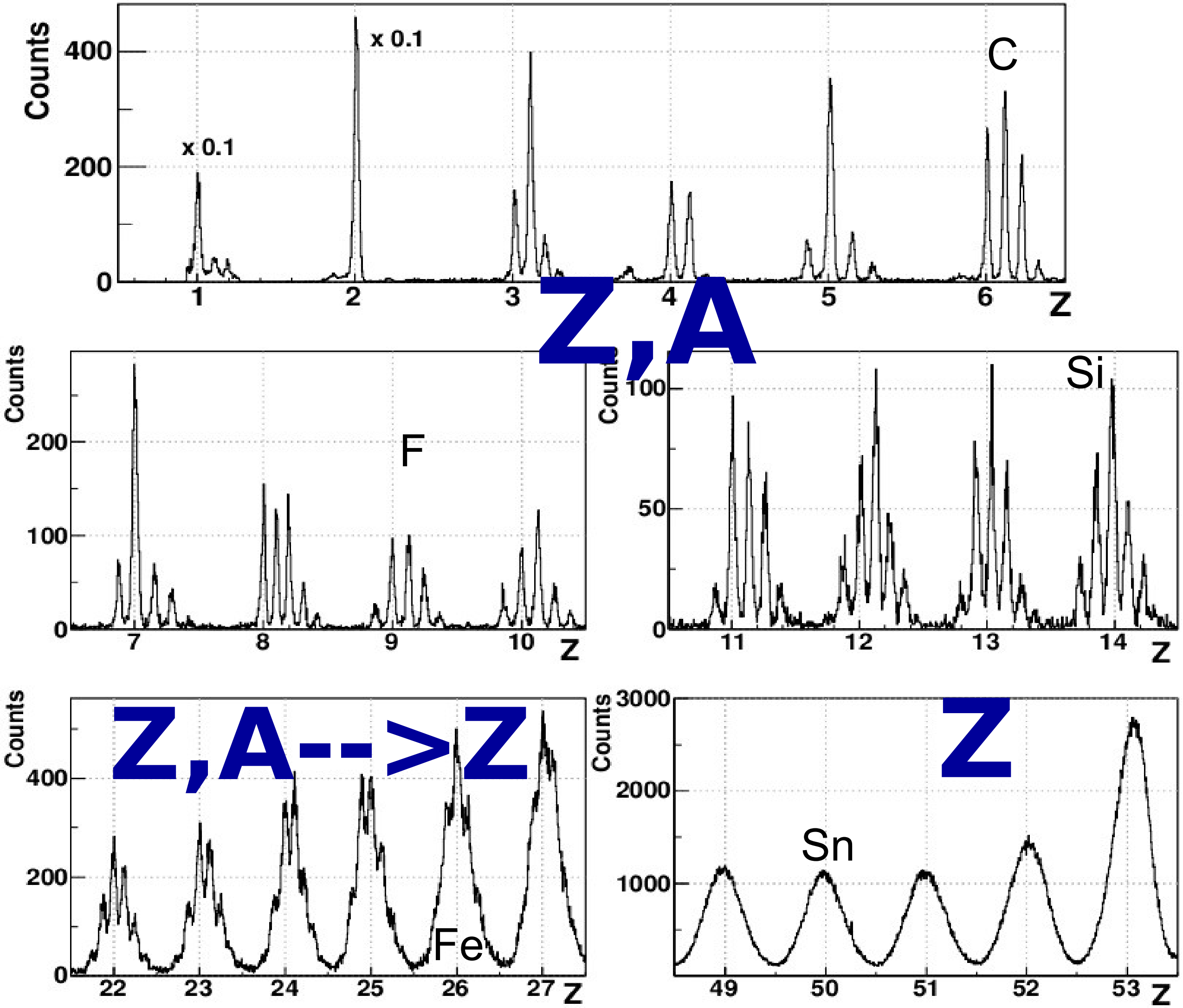


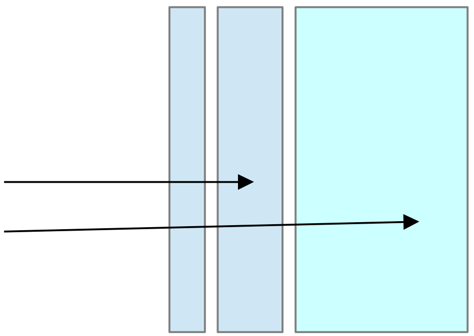
Decisive importance of DIGITAL ELECTRONICS to optimize PSA and shaping parameters

Main results from the prototypes

PI from ΔE-E

Carboni NIM A 2012

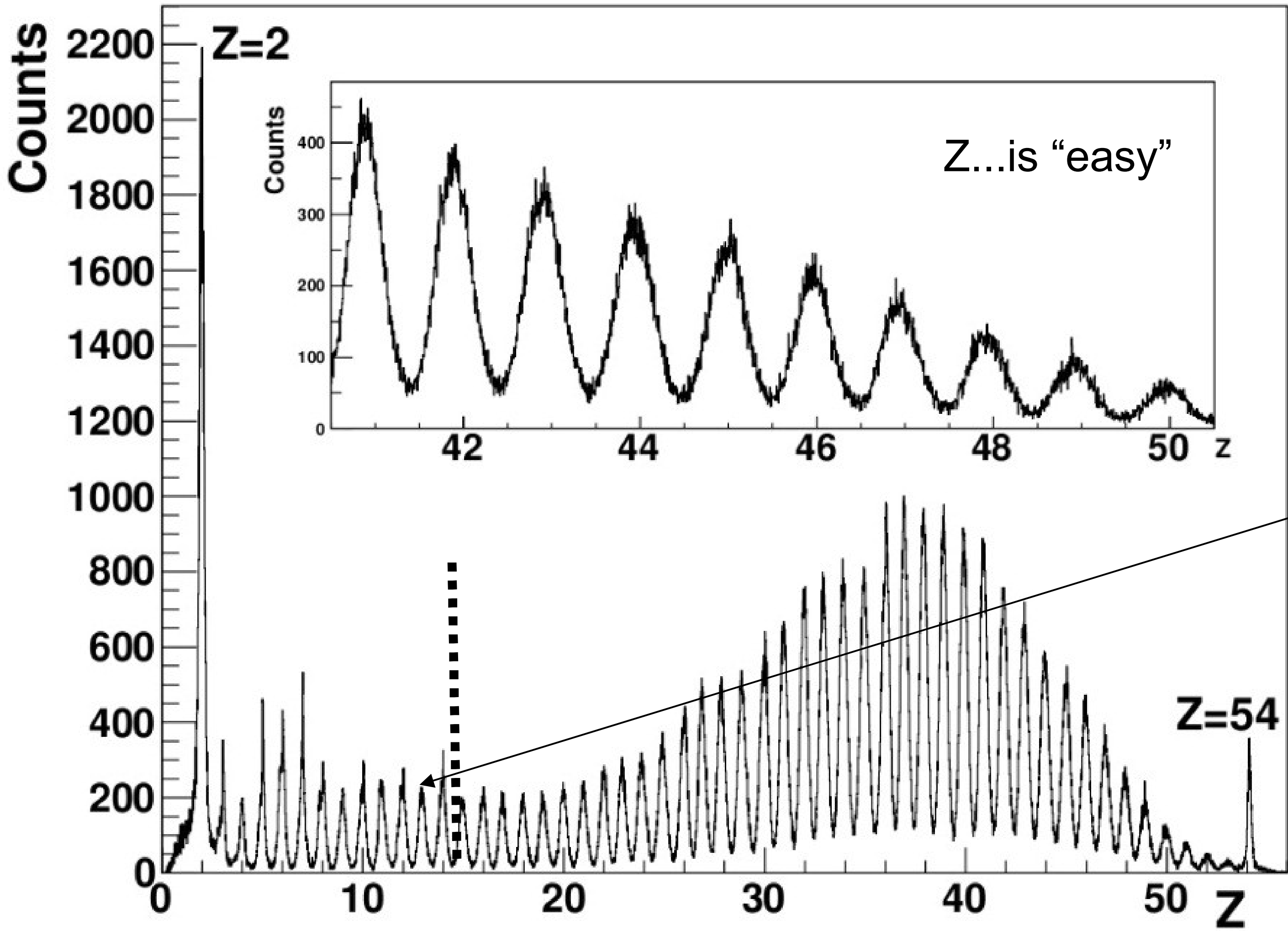


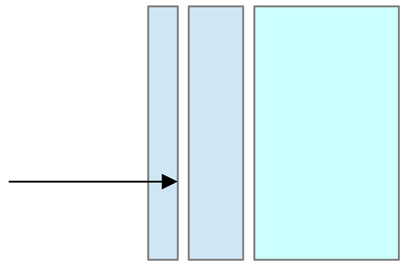


REFERENCE
Isotopes up to:
INDRA Z=4
CHIMERA Z=8-9
FIRST Z=14

Main results from the prototypes

PI from PSA (E vs. Qrisetime)





Carboni NIM A 2012

A identification - up to Z=14/15 (with a A-dependent range (>150µm))

N.LeNeindre NIM A 2013

This needs high quality detectors and controlled operation during exps

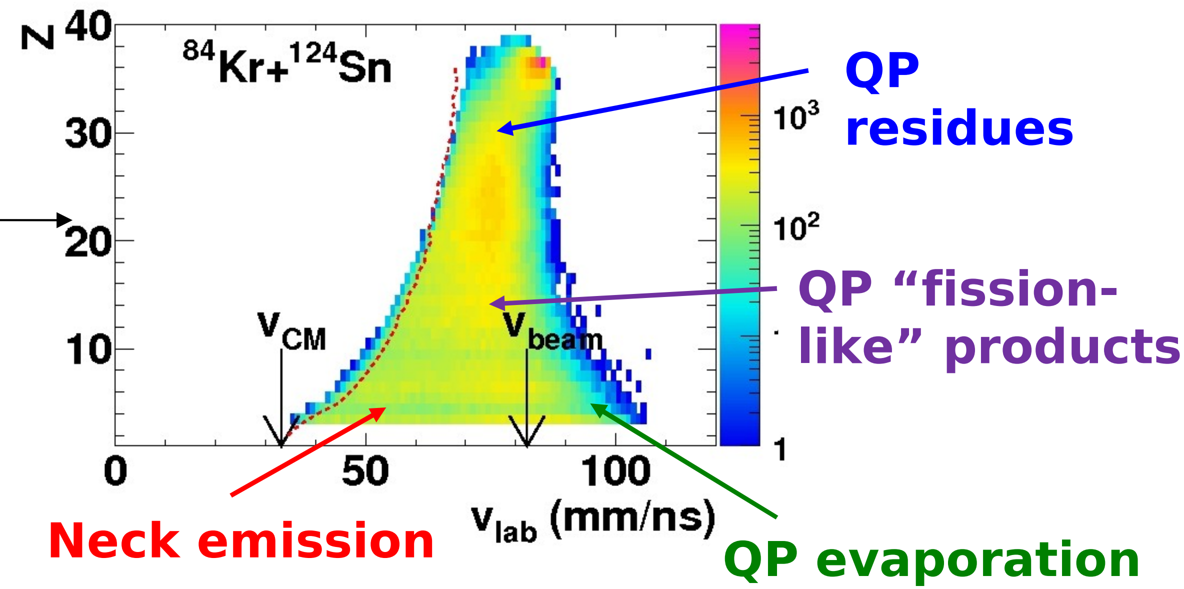
Starting physics with FAZIA

Inclusive experiment at LNS with a few telescopes in order to:

- **confirm isospin phenomena (diffusion and drift) observed by several measurements**
- **demonstrating the capability of FAZIA Telescopes for isospin and EOS studies**

84Kr+ 112,124Sn 35MeV/u

Isotopic distribution accessible up to Z around 20

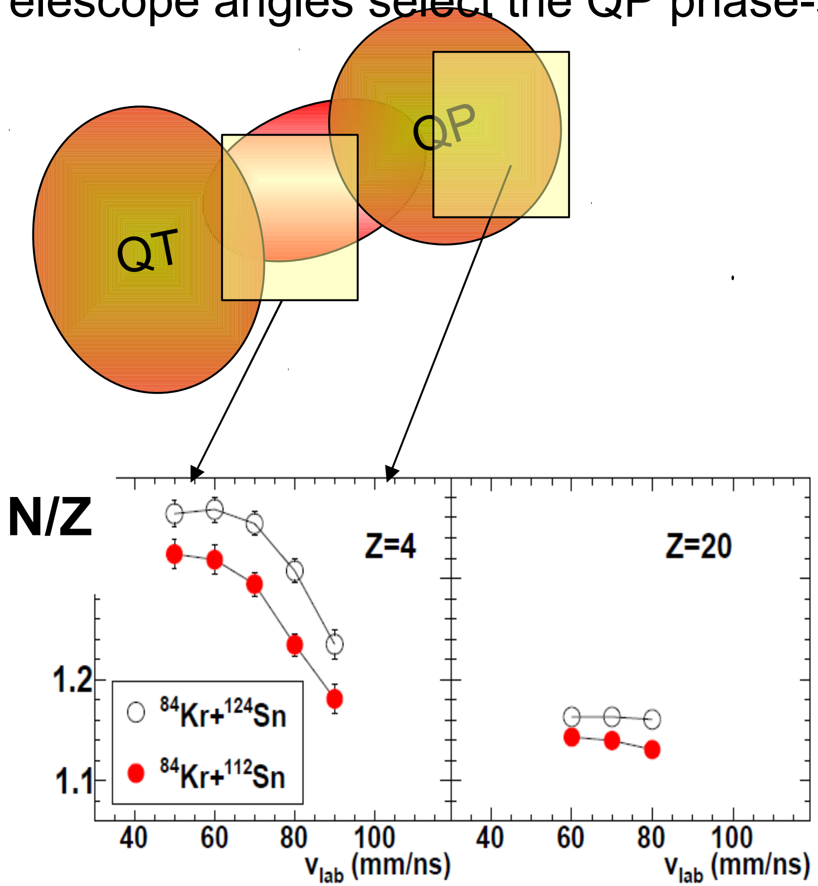


Similar to others, e.g: DeFilippo PRC 71 (2005), PRC 86 (2012)
Thèriault PRC 74 (2006)
Brown PRC 87 (2013)

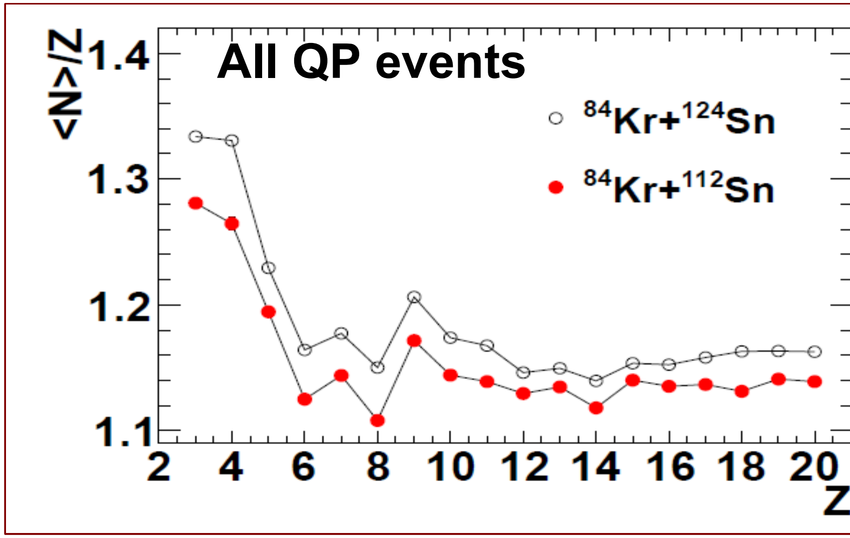
Starting physics with FAZIA

84Kr+ 112,124Sn 35MeV/u Barlini et al C 87, 054607 (2013)

Telescope angles select the QP phase-space



midvelocity forward



OBSERVATIONS

1) isospin diffusion between QP and QT (target effect)
2) for IMF neutron content increases from QP to midvelocity (two origins of IMF)
3) the N/Z of bigger fragments is about constant vs. velocity (QP fission-like)

Similar to others, e.g: DeFilippo PRC 71 (2005), PRC 86 (2012)
Thèriault PRC 74 (2006)
Brown PRC 87 (2013)

From prototypes to Demonstrator

- **Beyond detectors: the electronics and the data-flow stages have been built according to the final FAZIA design**

Electronics: ***A BIG CHALLENGE!***

From low-density separated electronics:

FEE (vacuum) + digital sampling & HV (air)

to high-density complete electronics featuring:

FEE-ADC-FPGA-HV boards for under vacuum operation

Slow-controls, triggering, regulations, Data-Flow and DAQ:

Innovative solutions based on optical-link cards, ancillary boards (under vacuum) embedding all functions, data transfer protocols compatible with future coupling with GANIL Narval center

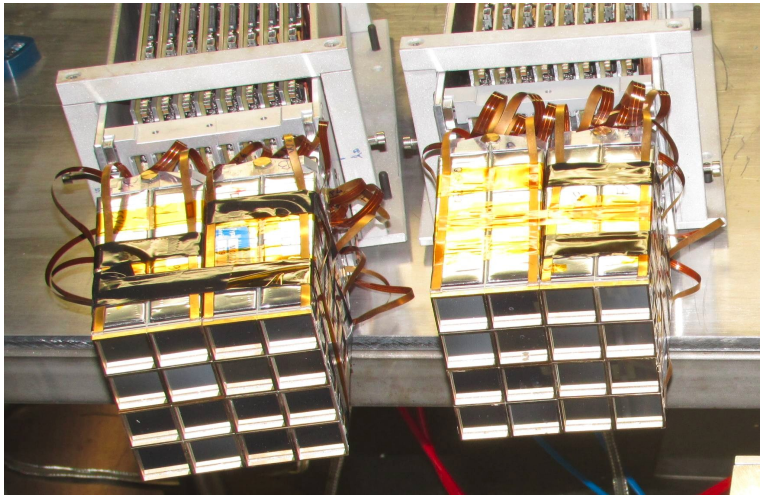
project developed by IPN-Orsay and INFN-Na

From prototypes to Demonstrator

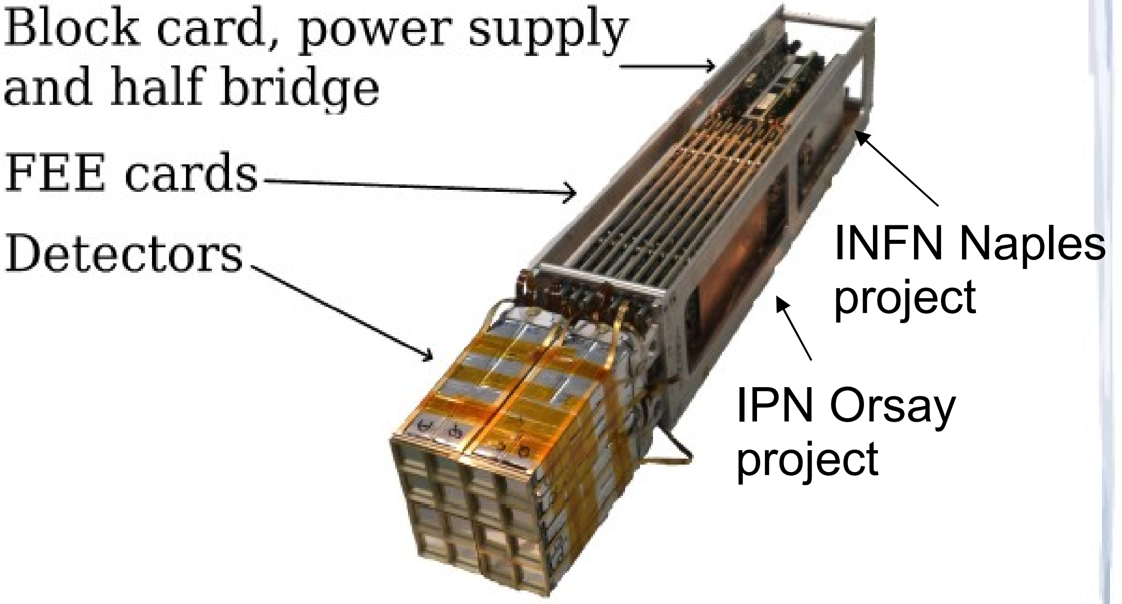
Demonstrator :
made of 12 BLOCKS, complete of the entire functional parts

Each **BLOCK**

16 Telescopes (48 channels)
8 FEE multilayer cards, each serving 6 channels (2 Teles.)
3 central control cards: BLOCK CARD, HALF BRIDGE, POWER SUPPLY CARD
1 Copper plate with internal tunnels for liquid cooling circulation



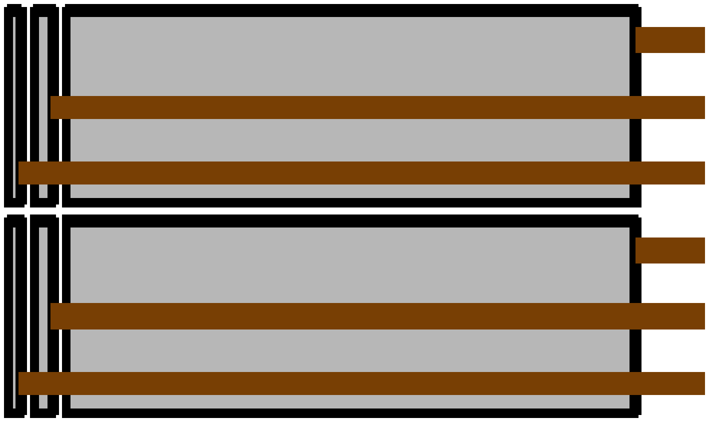
FAZIA BLOCKS



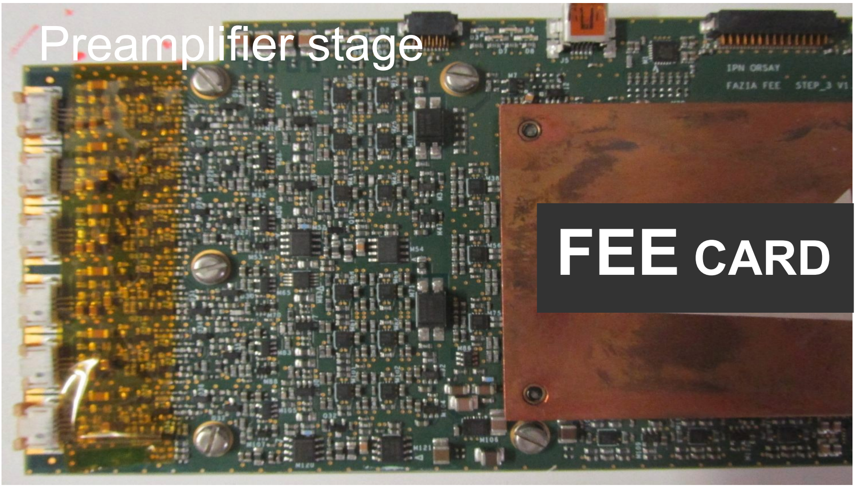
Around 300 W per block !!

From prototypes to Demonstrator

Front-End Electronics CARDS



6x kapton strips



F.Salomon and P.Edelbruck IPN Orsay

6x2 Fast SAMPLING ADC's to handle preamp outputs

2 FPGA (one for telescope) extract on-line information from waveforms

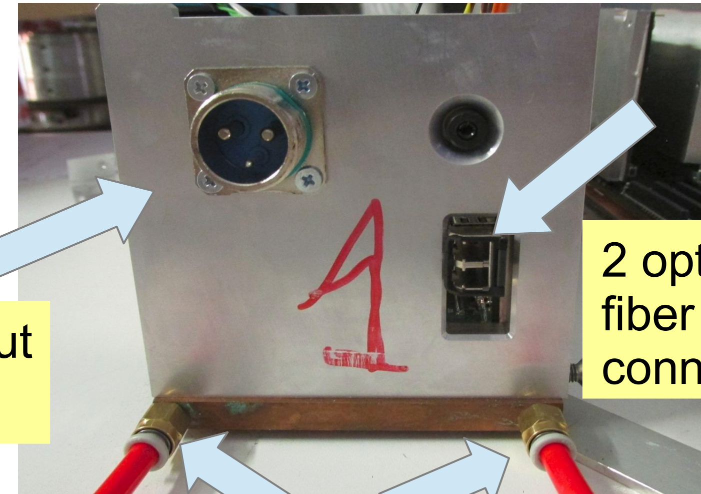
Si1
- 100 MHz, 14 bit (4 GeV full scale) [Si1 high range charge signal (QH1)]
- 250 MHz, 14 bit (250 MeV full scale) [Si1 low range charge signal (QL1)]
- 250 MHz, 14 bit [Si1 current signal (I1)]

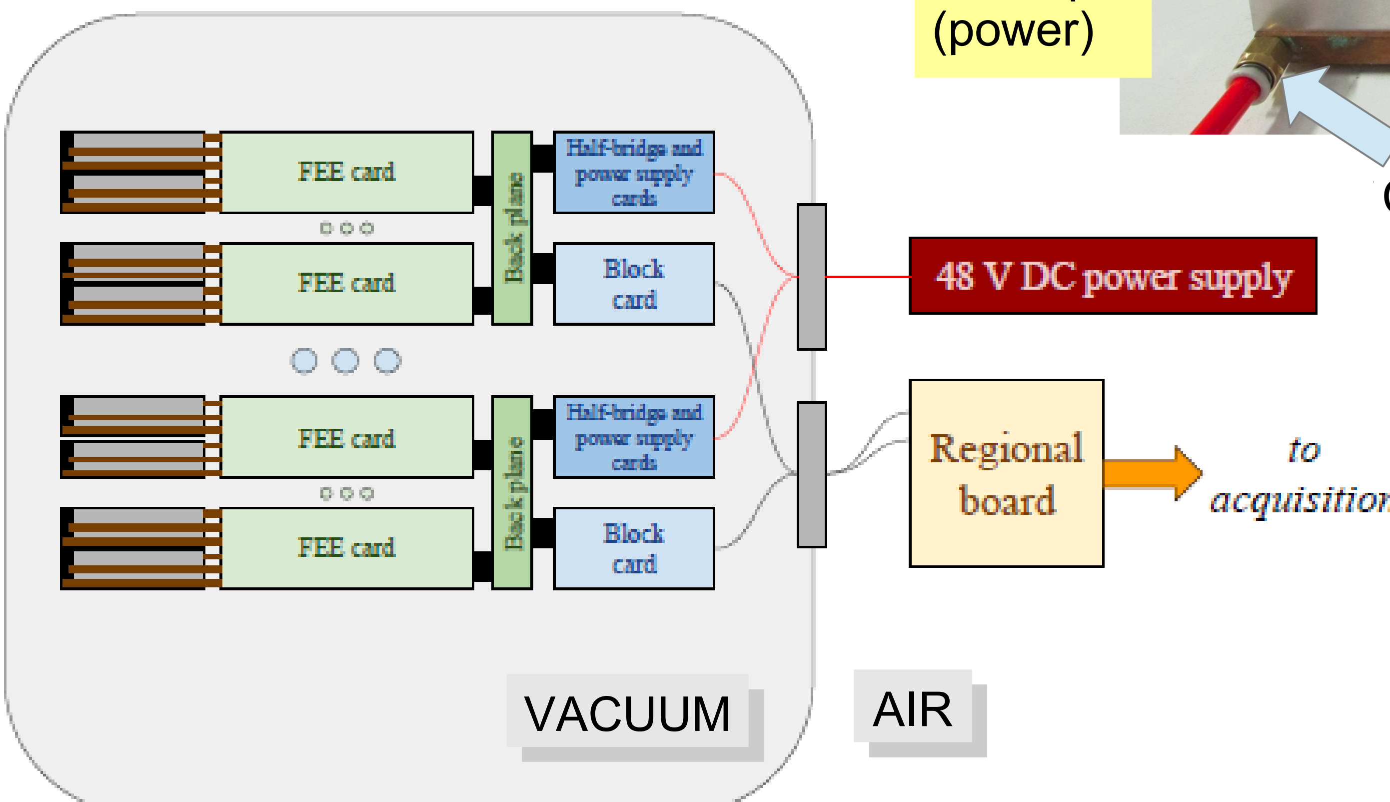
Si2
- 100 MHz, 14 bit (4 GeV full scale) [Si2 charge signal (Q2)]
- 250 MHz, 14 bit [Si2 current signal (I2)]

CsI
- 100 MHz, 14 bit (0.5GeV Si-equiv. full scale) [CsI(Tl) charge signal (Q3)]

From prototypes to Demonstrator

Complexity inside, simplicity outside!





Only three I/O ways

1) **Liquid cooling tubes**
2) **48V power supply (copper wires)**
3) **I/O optical fibers**

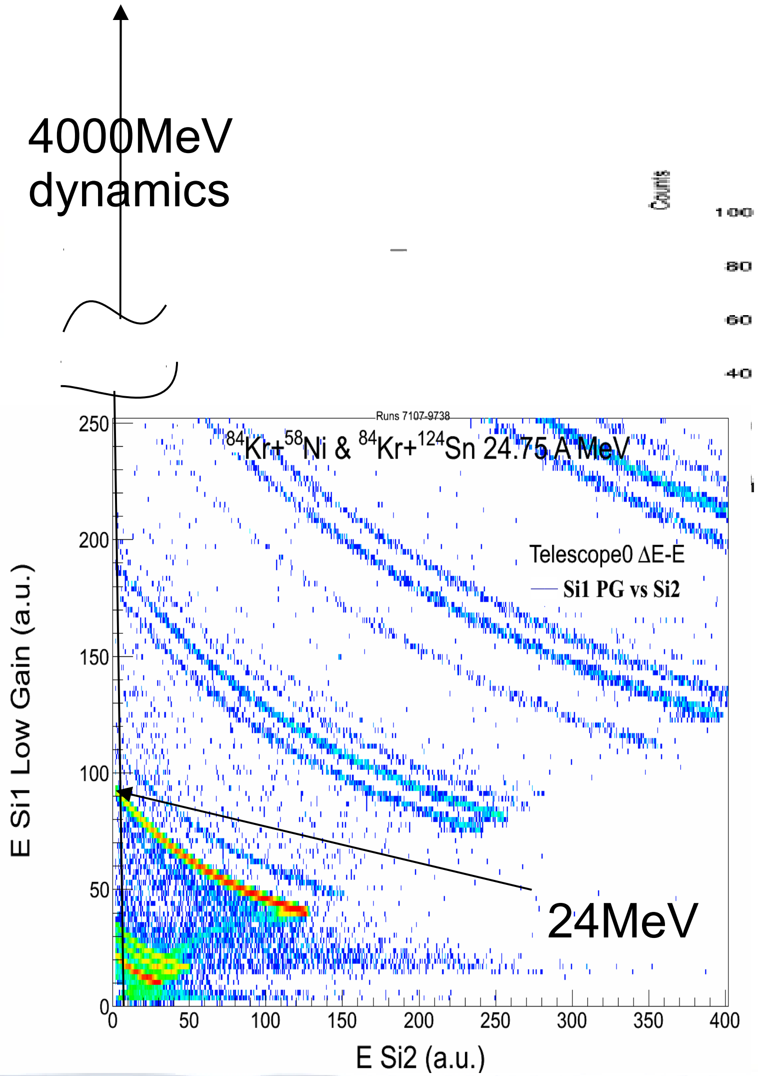
The Commissioning@LNS

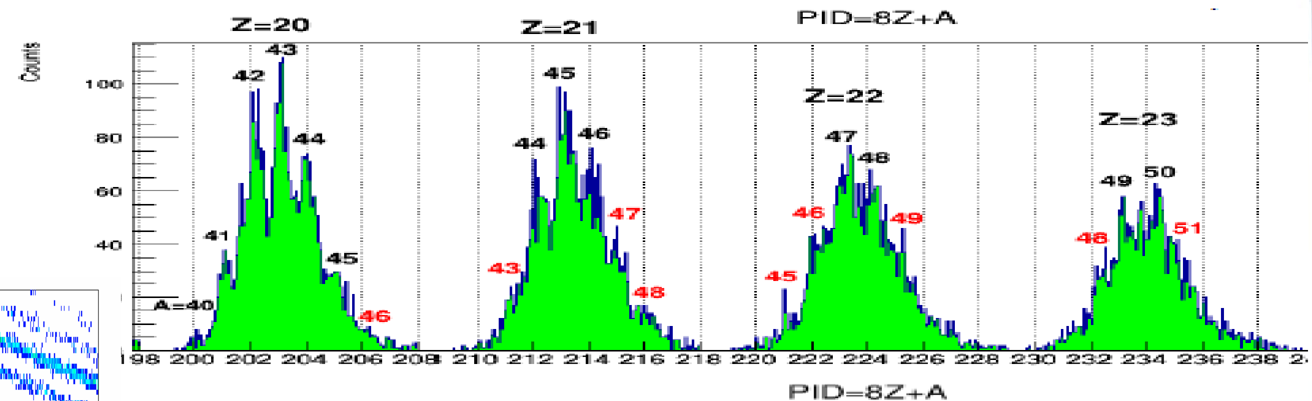
Extend "excellence" to a telescope set in the final configuration

- Two blocks were ready to be tested
- Troubles with one of the two (communication problems) during the 3-day test run
- As a result ony one block tested (16 telescopes)

DEC 2014

84Kr beams at 24.75 AMeV



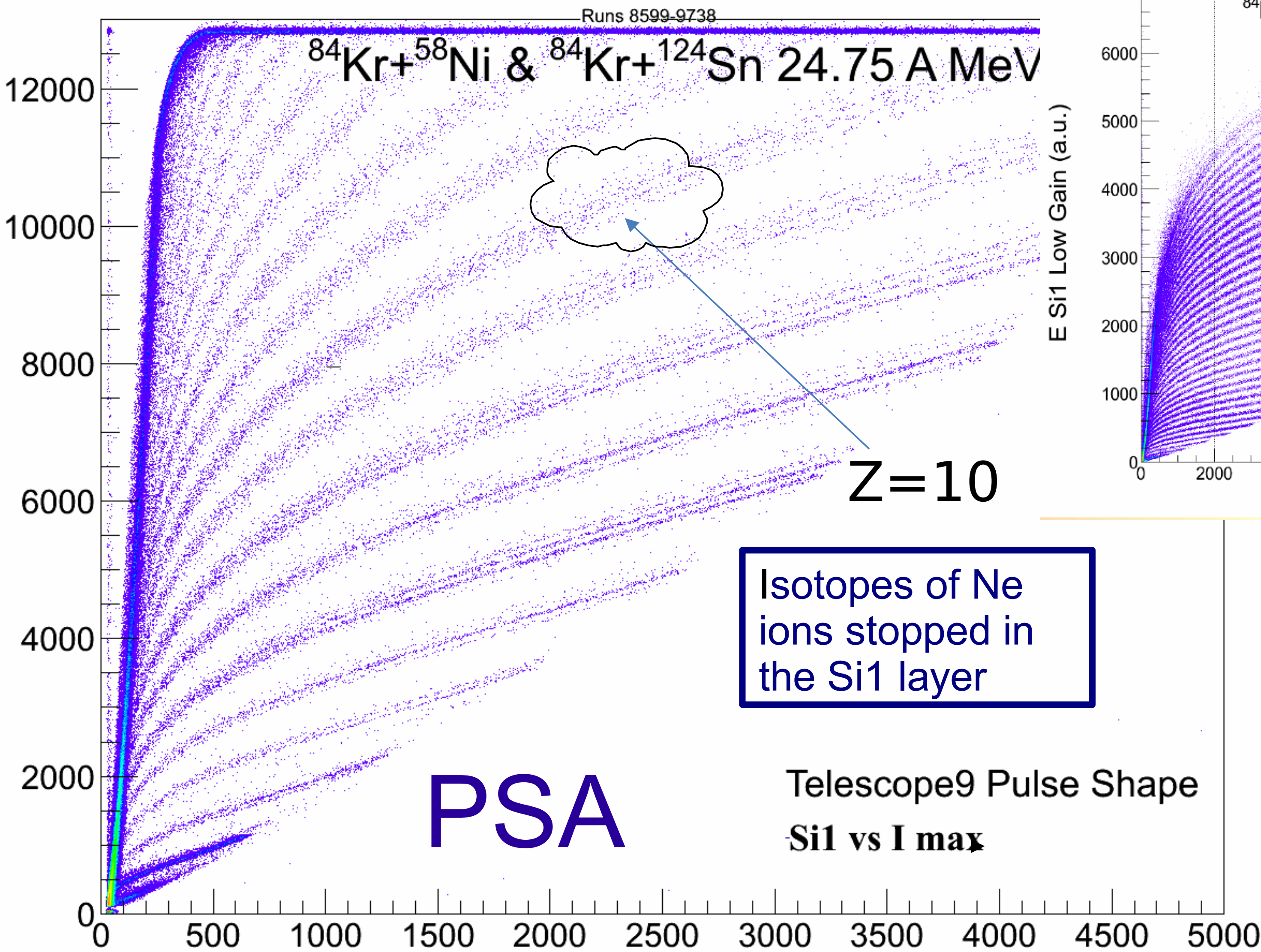


good results:

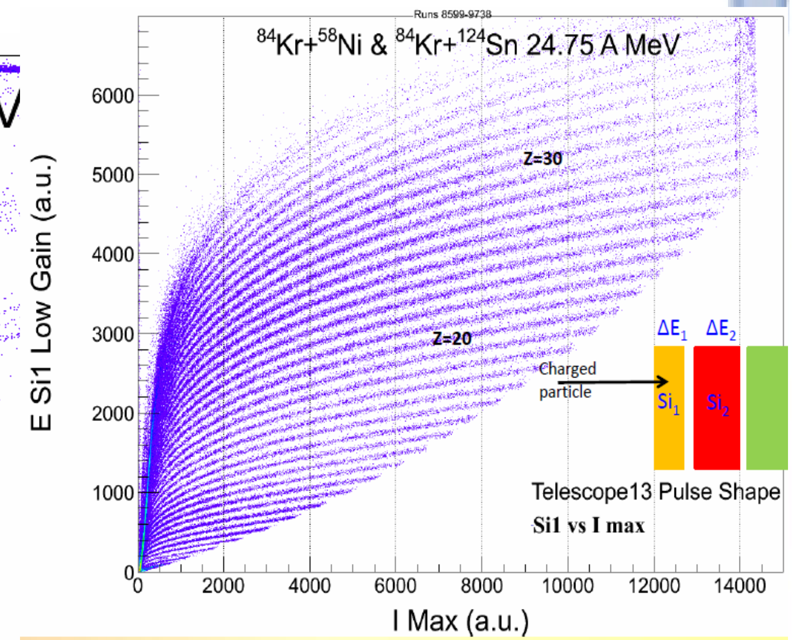
- **ΔE-E: isotopic separation of ion up to Z=21-22**
- **LCP are identified even in the LowGain scale (4GeV range)**
- **PSA: there are good news...**

The Commissioning

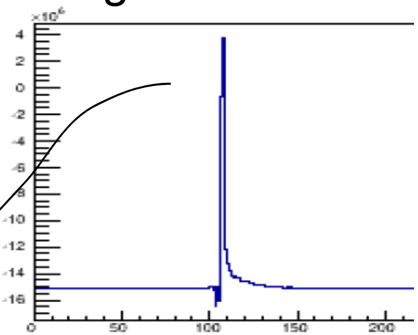
Silicon 300micron E HIGH GAIN



Maximum of the current signal



Digitized current



The IsoFAZIA experiment

BLOCKS mounted in belt configuration from 3.6° to 17.8°

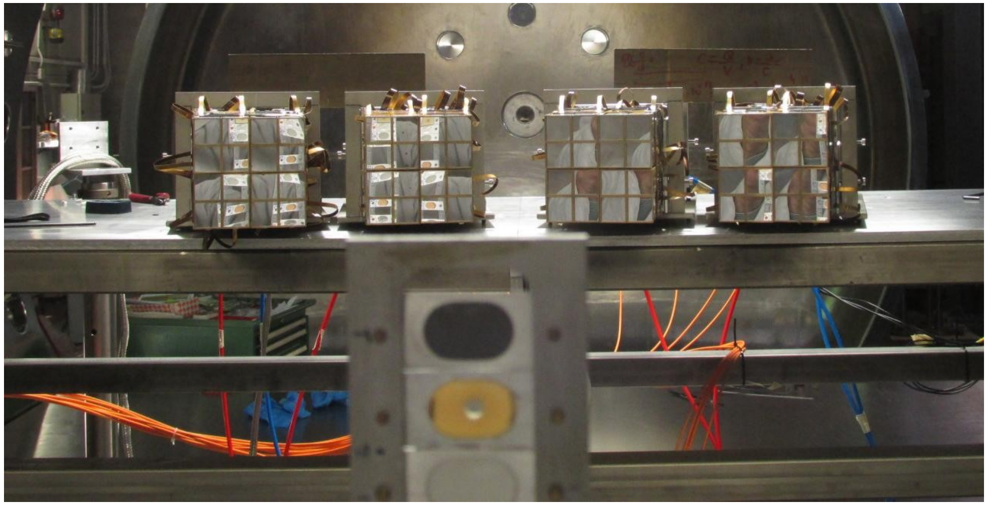
80Kr+40,48Ca; 35AMeV

LNS Catania

PROJECTILE N/Z=1.22

TARGET N/Z=1 (40Ca) or 1.4 (48Ca)

4 complete FAZIA blocks



Goals

Extension of the study of the isospin transport performed by FAZIA and many others (MSU, WU, CHIMERA, INDRA, TEXAS A&M, others...) to the QP fission channel

Centrality selection by means of the Zbiggest - vlab correlation

Identifying light fragments coming from the neck

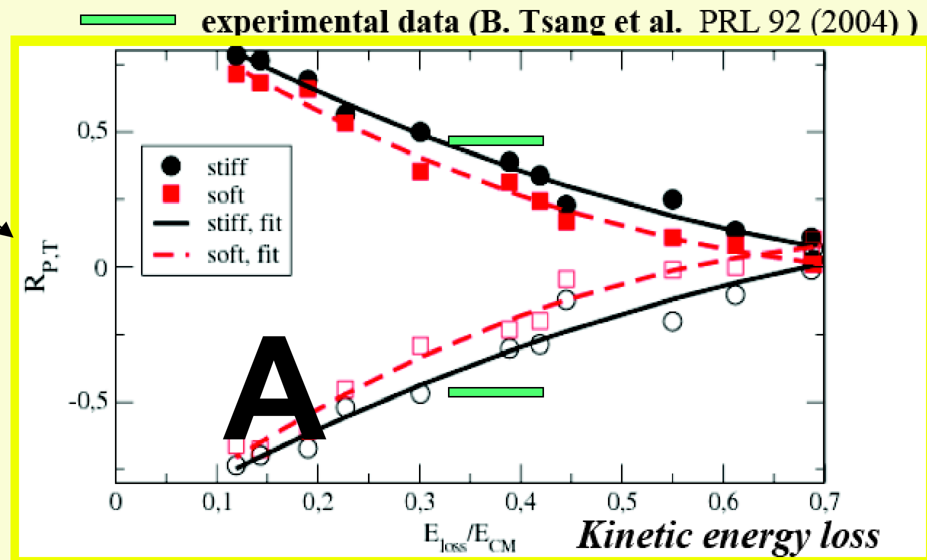
Measuring the isotopic composition of both fission fragments

Comparison with transport models (e.g. **SMF** V.Baran et al., NPA 730 (2004) 329, **AMD** A.Ono, PRC 59 (1999) 853)

IsoFAZIA experiment: the basic idea

Imbalance Ratio

Estimator of the relaxation of the isospin diffusion process

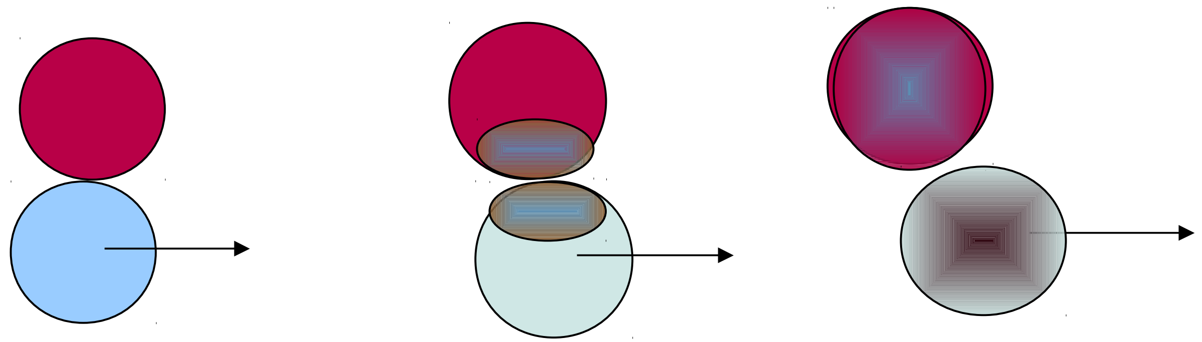


Sn + Sn 50AMeV

Scale of centrality and reaction times

Rizzo, Colonna, Baran, Di Toro, Pfabe, Wolter, PRC72(2005) and arXiv:0711.3761, accepted in NPA

A



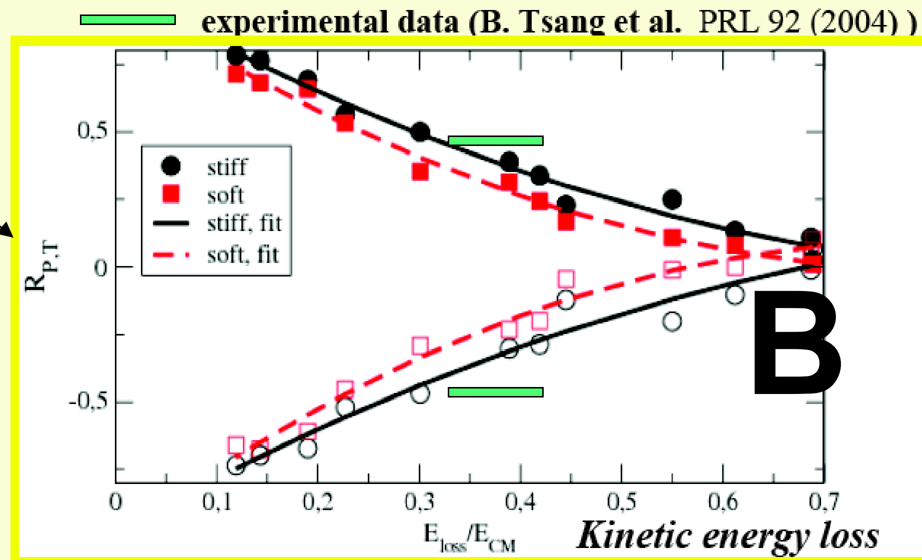
Peripheral collisions
Fast interaction
Reduced n-p exchanges

EXP: detect QP (Z) and ejected LCP (Z,A)

IsoFAZIA experiment: the basic idea

Imbalance Ratio

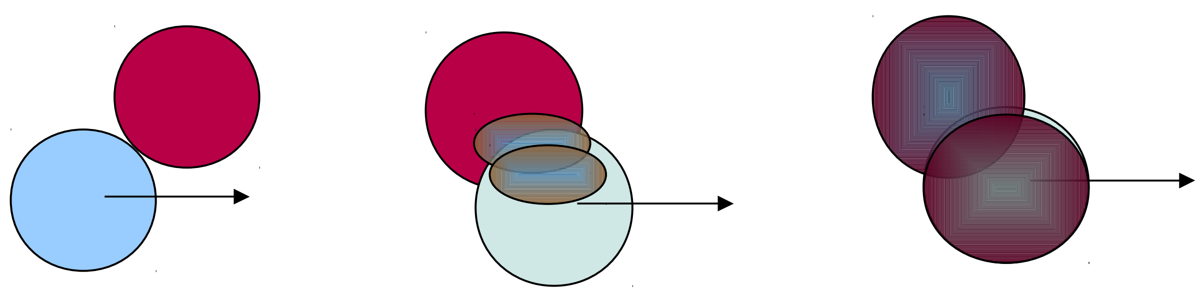
Estimator of the relaxation of the isospin diffusion process



Scale of centrality and reaction times

Rizzo, Colonna, Baran, Di Toro, Pfabe, Wolter, PRC72(2005) and arXiv:0711.3761, accepted in NPA

B



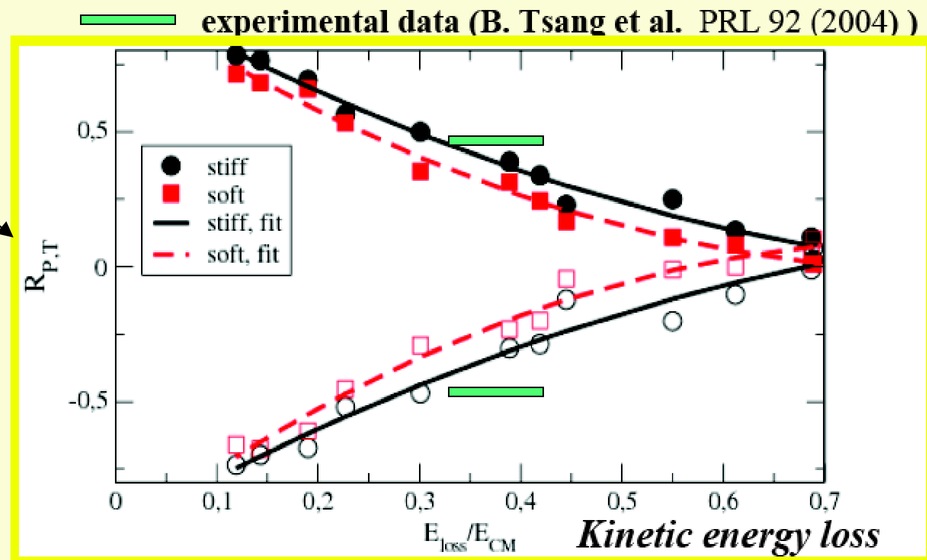
semi-central collisions
Violent and longer interaction
Many n-p exchanges

EXP: detect QP (Z) and ejected LCP (Z,A)

IsoFAZIA experiment: the basic idea

Imbalance Ratio

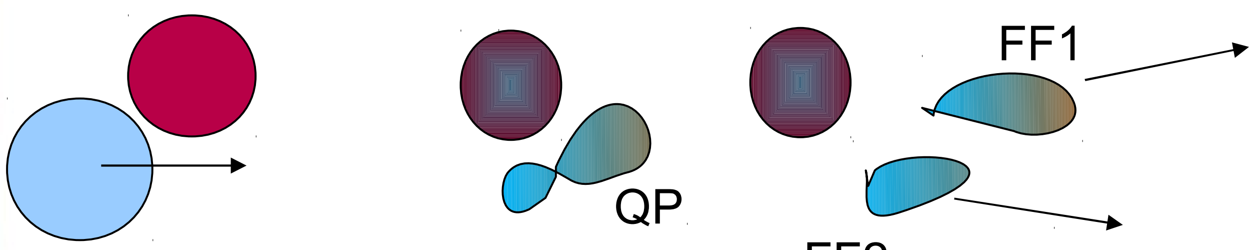
Estimator of the relaxation of the isospin diffusion process



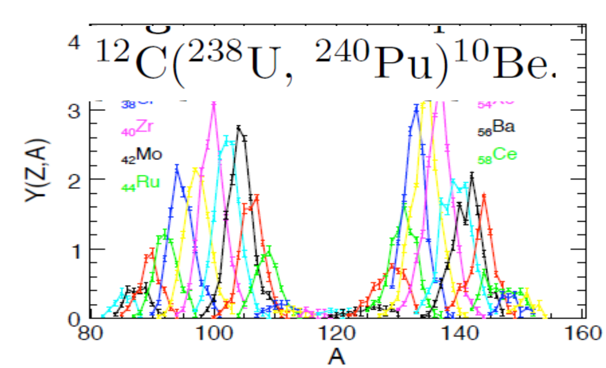
Scale of centrality and reaction times

Rizzo, Colonna, Baran, Di Toro, Pfabe, Wolter, PRC72(2005) and arXiv:0711.3761, accepted in NPA

40,48Ca



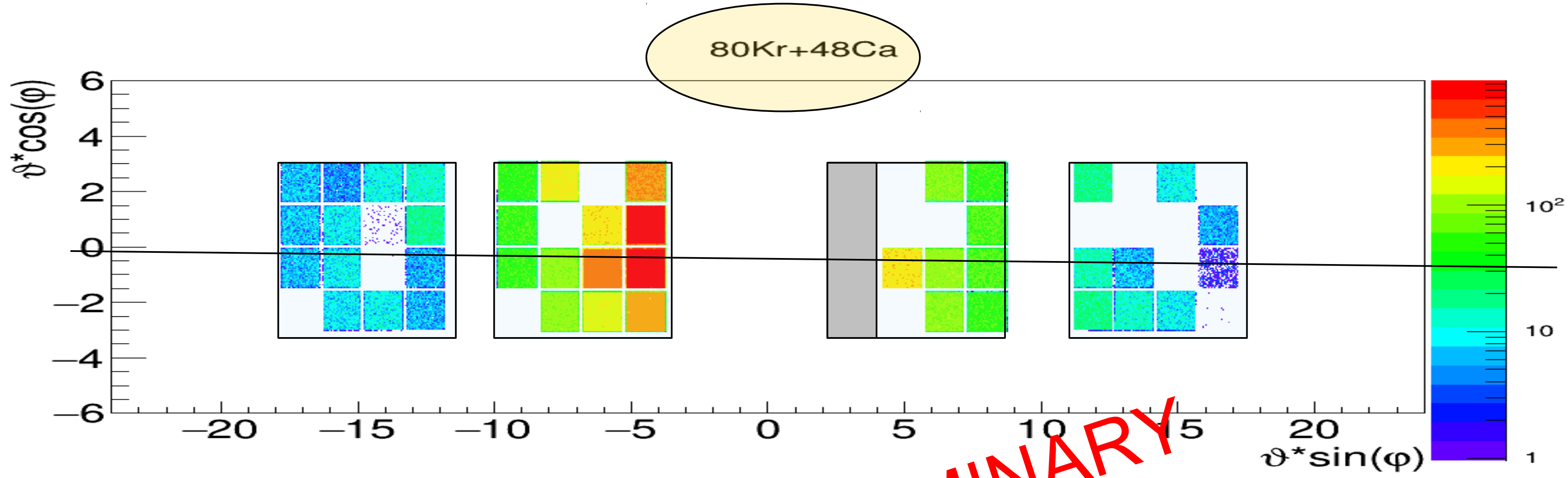
80Kr



Similar to
Farget JoP 420, 2013
Vamos at GANIL

EXP: to study the QP 'fission' channel measuring Z,A of coincident FF by varying N/Z of the target

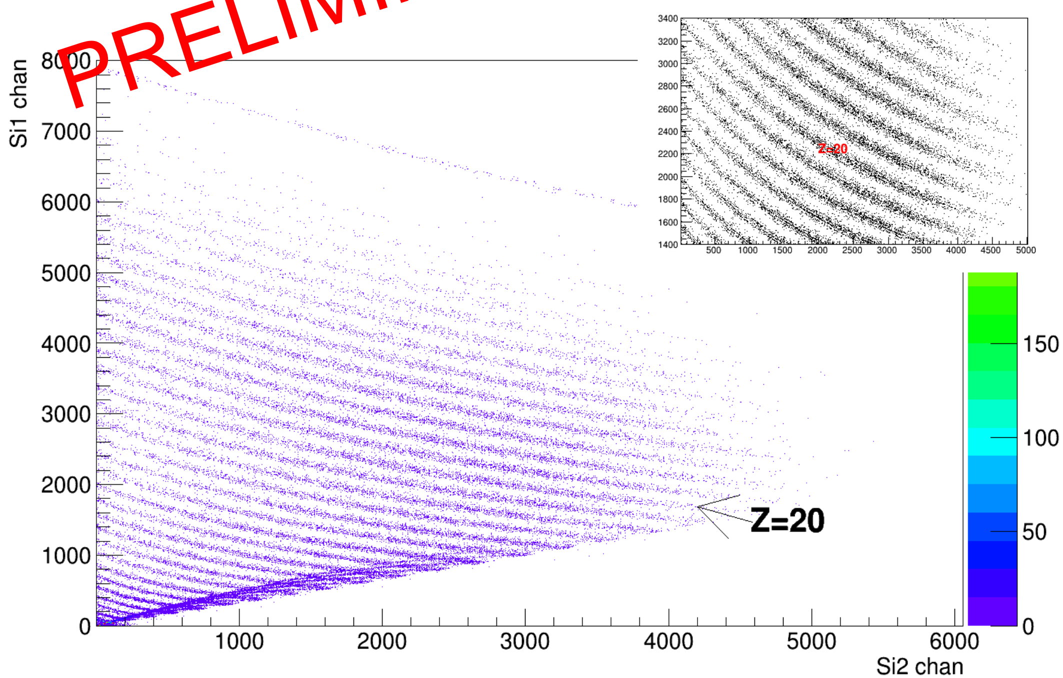
The IsoFAZIA experiment



Experiment at LNS-Catania
4-16 june 2015

The quality of the identification is comparable to the results obtained during the R&D phase with the prototype telescopes

ANALYSIS JUST STARTED



The FAZIASym experiment

Completion of the INDRA+VAMOS exp. @ GANIL (2007) 40,48Ca+40Ca at 35AMeV

VAMOS EXPERIMENT
Objectives:

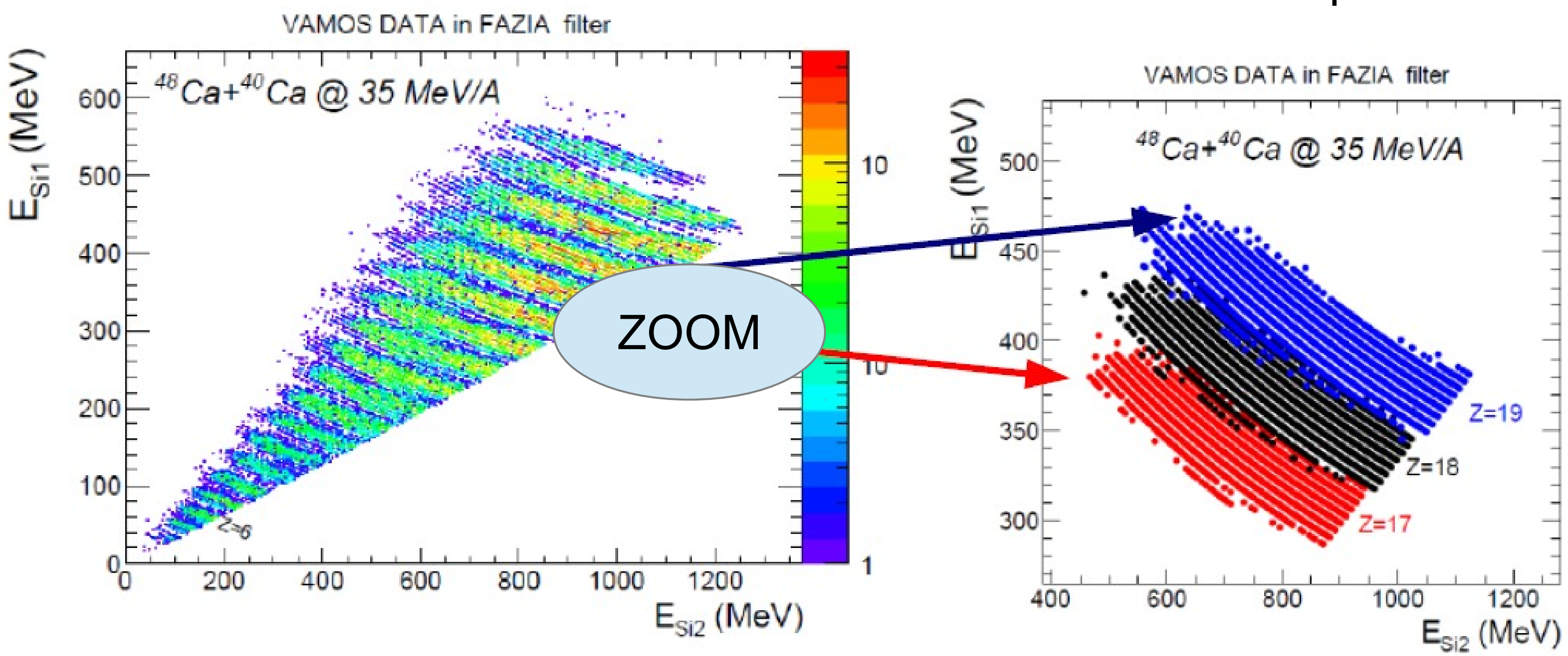
- Absolute isotopic cross section measurement
- Influence of secondary deexcitation

Some limitations have been found:

- LCP not detected at foward angles
- Scarce efficiency of VAMOS for Z<15
- Difficult measurement of absolute cross section

INDRA-VAMOS data filtered with FAZIA telescopes

Move to FAZIA

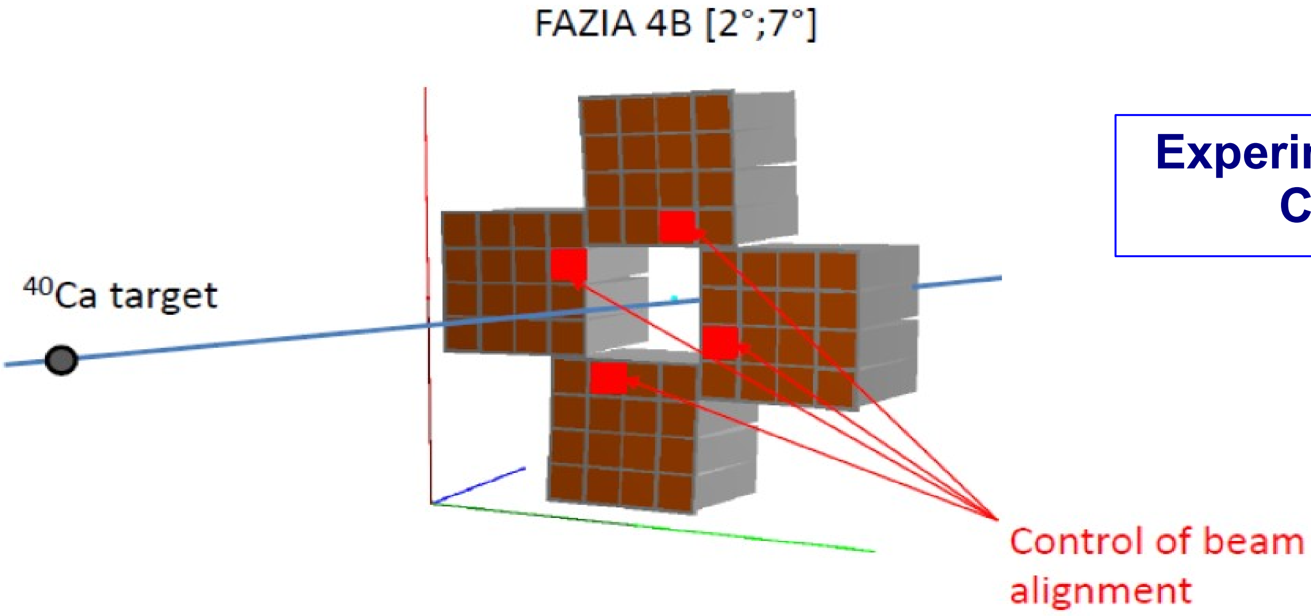


The FAZIASym experiment

40,48Ca+40Ca at 35AMeV

Main goals

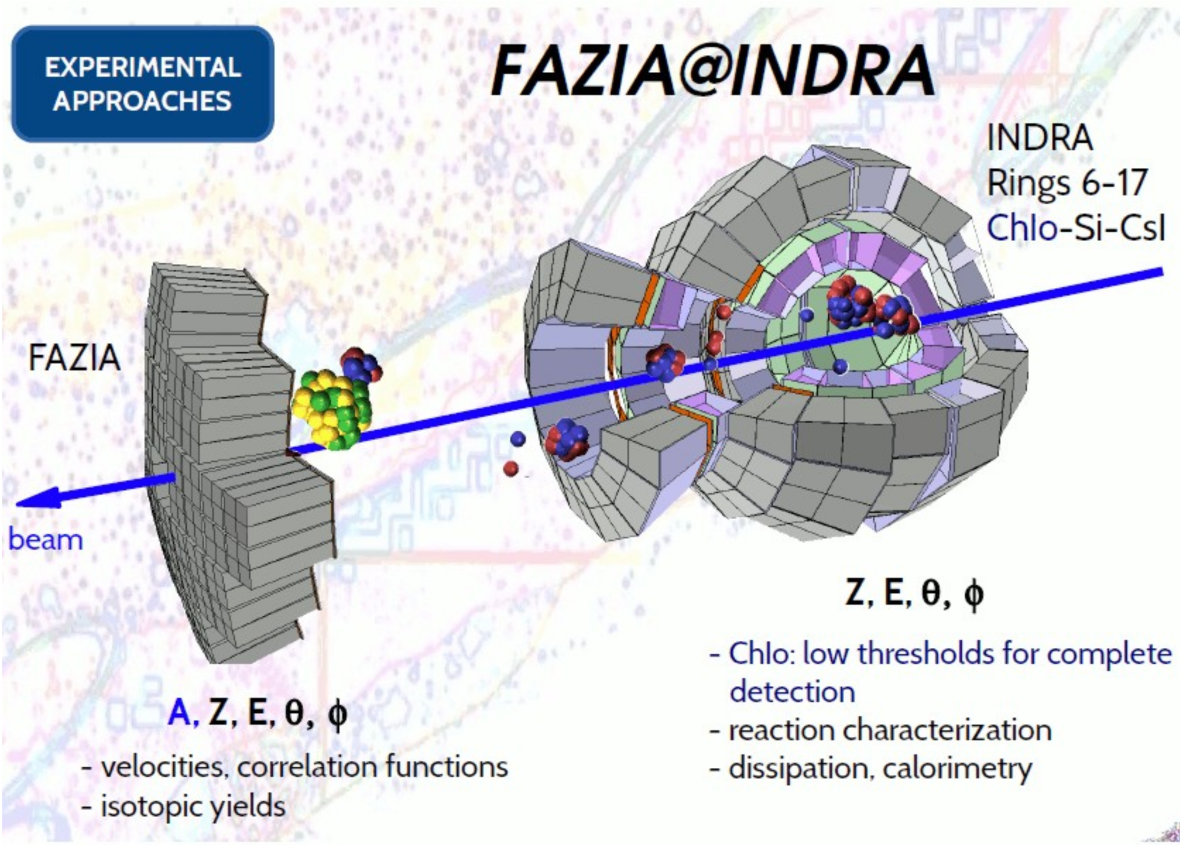
- Isotopic cross section measurements Up to QP
- Exclusive detection in the angular range [2°,7°]



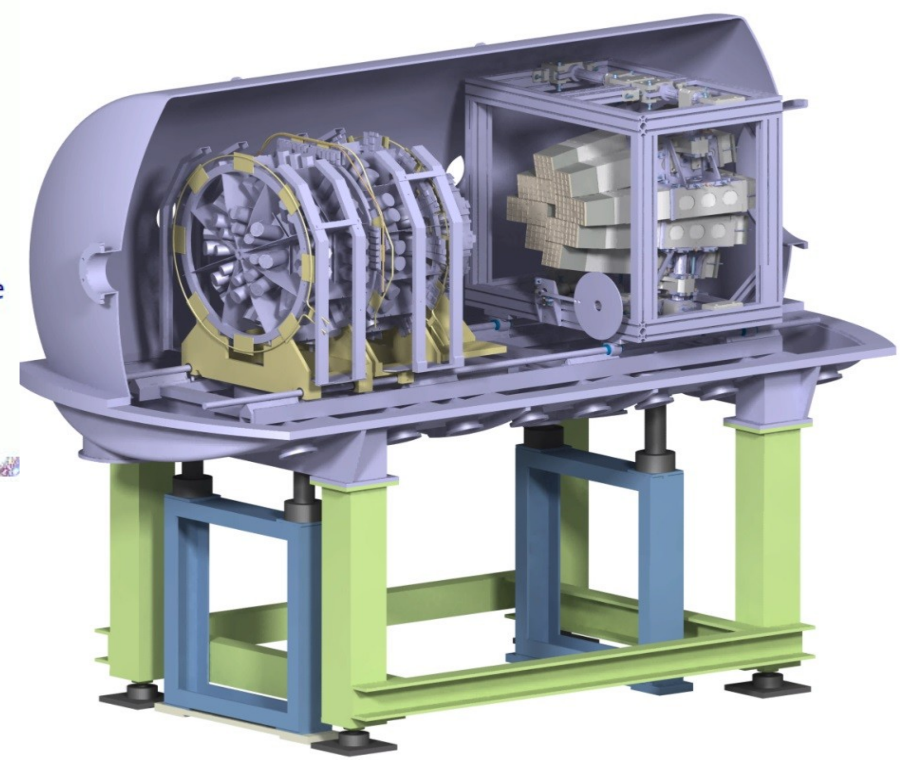
Experiment planned at LNS-Catania end 2015

Four blocks as in the ISOFAZIA experiment already done.

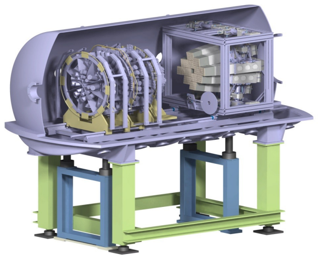
Medium term plans (>2016): Demonstrator (12 blocks) + INDRA @GANIL



CSS2 will return to operation; stable beams between Ca and Xe (E=40-80MeV/u)



- Light UNSTABLE BEAMS from LISE



The Physics cases of FAZIA (12 blocks) + INDRA @GANIL

- Radial flow in central collisions of 124,129,136Xe+40,48Ca 30 to 50 AMeV
  Compare with existing systematics and explore isospin

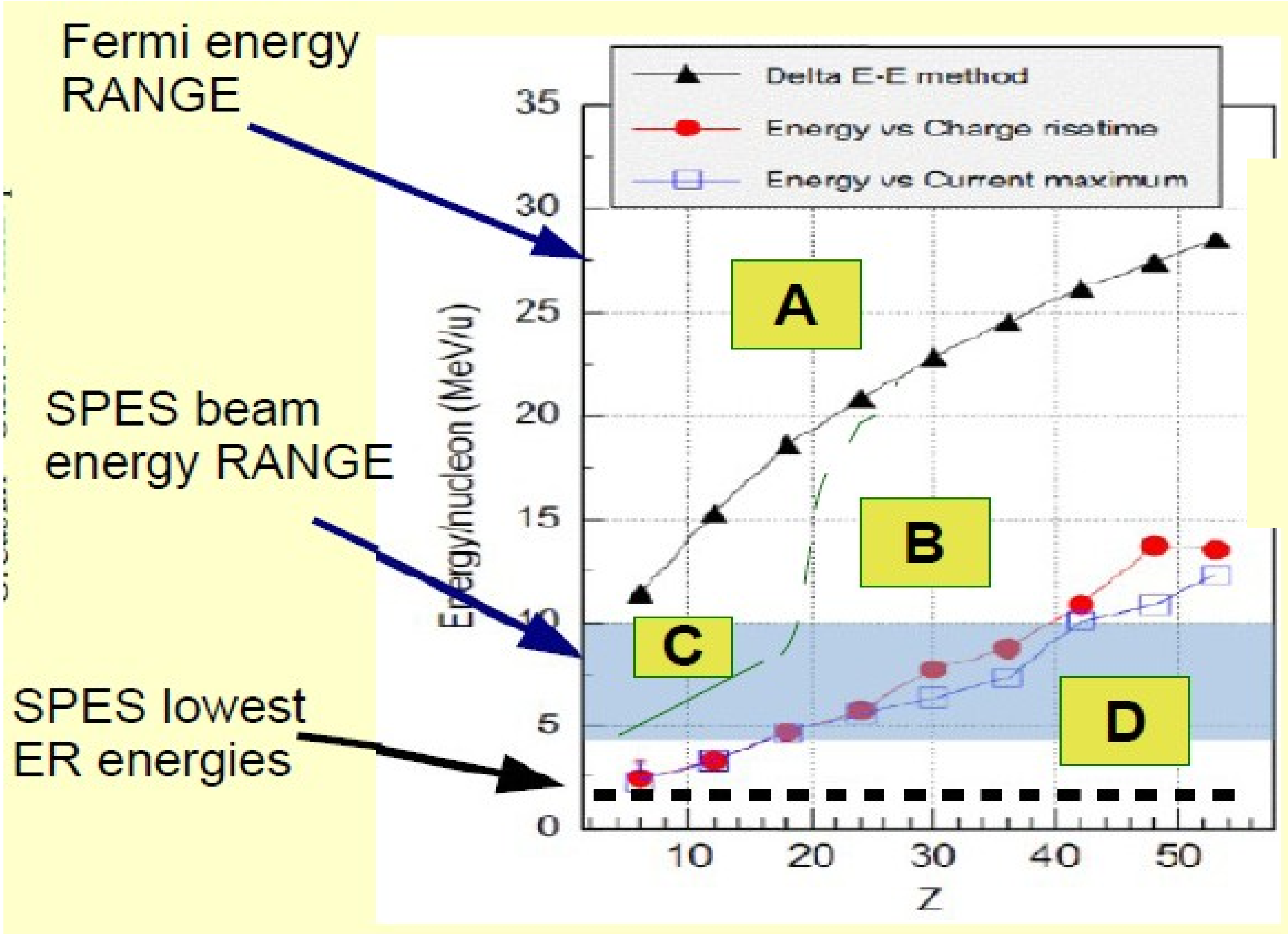
- Isospin transport in semiperipheral collisions 124,129,136Xe+40,48Ca 30 to 50 AMeV
  Extend studies at higher fragments; comparisons with AMD and SMF

- From multifragmentation to vaporization of medium-mass systems in Ca+Ca reactions 50 to 90 AMeV
  Clusters at high T and low densities; Esym from the isotopic distribution of the biggest fragment

- Decay chain reconstruction of light systems 40,48Ca+12C at 35AMeV
  Detect Z,A of all species coming from QP decay; Z,A yield staggering and tracing back decay step with multiparticle correlations

Long term plans (>2019):
FAZIA (12 blocks) + X @SPES (and Spiral2)

FAZIA very good for Fermi energy domain but what about n-rich ISOL Beams?



A	Unlimited Z A up to Z=23-25
B	Unlimited Z
C	A up to Z=13-14
D	No identification

Long term plans (>2019):
Fazia (12 blocks) + X @ SPES

Improve particle identification AND/OR reduce energy thresholds

ΔE-E method: thinner stages

- Gas stage: lower thresholds but more complications (e.g. INDRA)

- Solid state: very thin Silicon, lower thresholds; technical limits

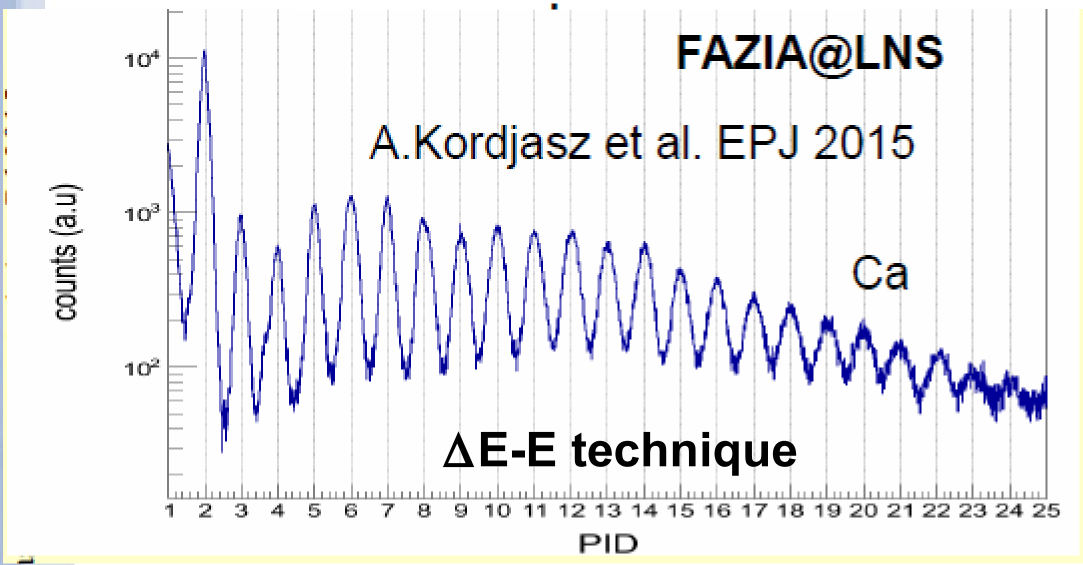
PSA

G.Pasquali et al., EPJA 50 (2014)

Exploring partially depleted Silicon diodes

Long term plans (>2019): Fazia (12 blocks) + X @ SPES

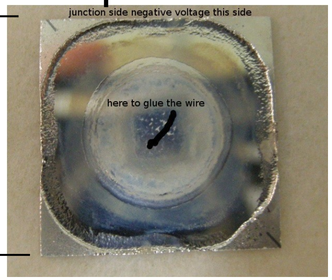
Si(20µm)-Si(500µm)



- Use very thin and "large" square FAZIA-custom detectors as a first Silicon stage.
- Encouraging pioneering test so far

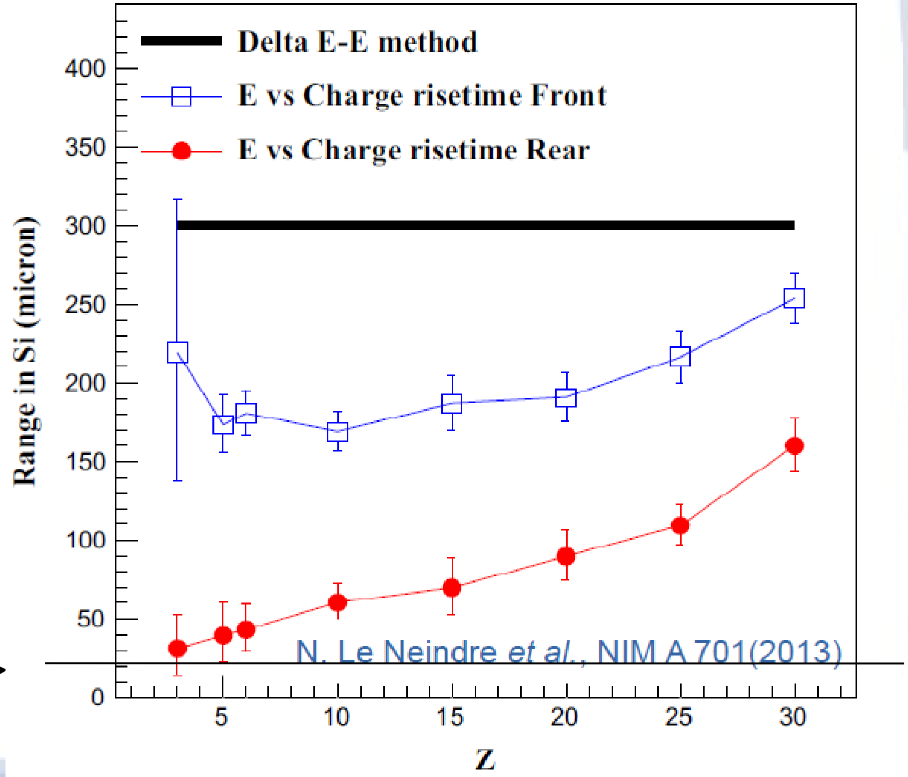
Z-identification with thresholds as low as 1.1MeV for protons and 2MeV/u for Mn ions.

epitaxial



20mm

21µm thick



Conclusions

- Commissioning (dec2014) showed that extending to 'hundreds' scale the very good perfomance of the single telescopes is feasible
- The experimental phase of FAZIA started at LNS one month ago with 4 blocks (64 telescopes): ISOFAZIA experiment.
- Next experiment 40,48Ca+40,48Ca expected next autumn again with 4 blocks (LNS, Catania)
- 2016-2019 @ GANIL and physics using FAZIA-INDRA. Stable beams and exotic light beams from LISE
- >2019 the SPES challenge (thresholds, radiation hardness...)

FAZIA welcomes all partnerships in common technological efforts and towards agreed experiments

FAZIA people, 2015

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FAZIA is indebted with **Elio Rosato** (Naples) and **MarieFrance Rivet** (Orsay) who have given so a strong contribution to the project and to us