Fazia

Forward A and Z
Identification Array

Designed for
isotopic discrimination
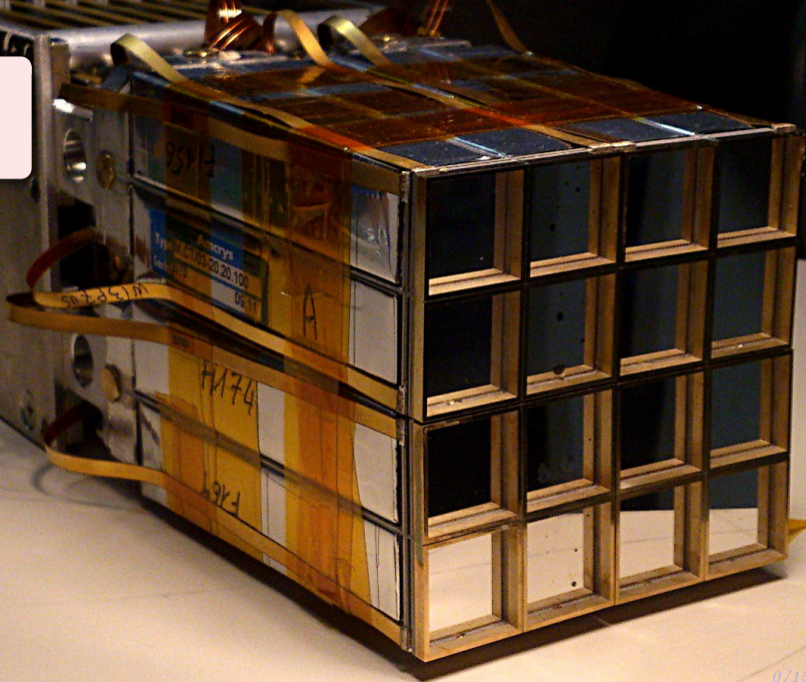up to $Z \sim 25$

FAZIA

Forward A and Z
Identification Array

Designed for
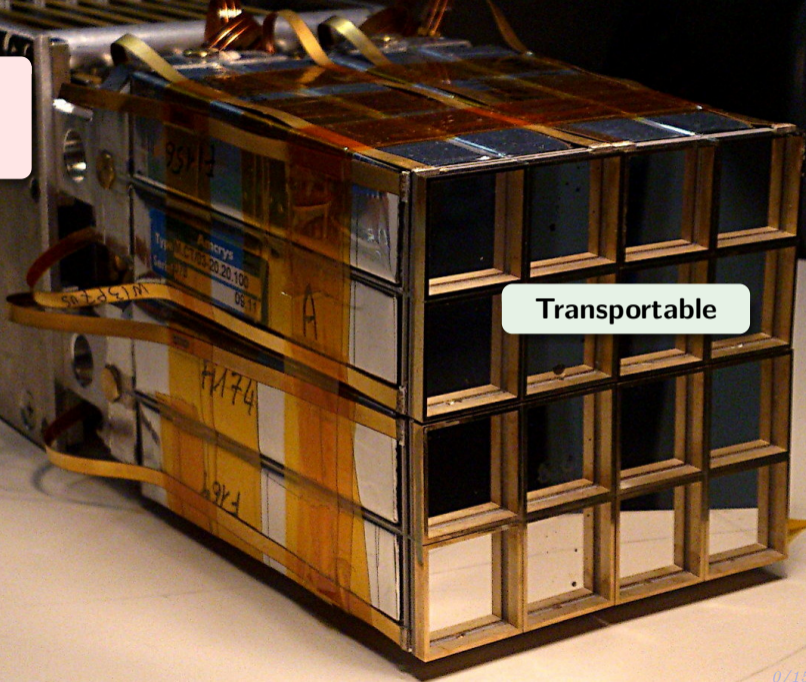**isotopic discrimination**
up to $Z \sim 25$

Transportable

FAZIA

Forward A and Z
Identification Array

Designed for **isotopic discrimination** up to $Z \sim 25$

Transportable

Modular

FAZIA

Forward A and Z Identification Array

Designed for
isotopic discrimination
up to $Z \sim 25$

Transportable

Modular

Couplable

FAZIA

Forward A and Z
Identification Array

FAZIA
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INDRA-FAZIA coupling
○○○○○○○○○○

Future at FRIB
○○○
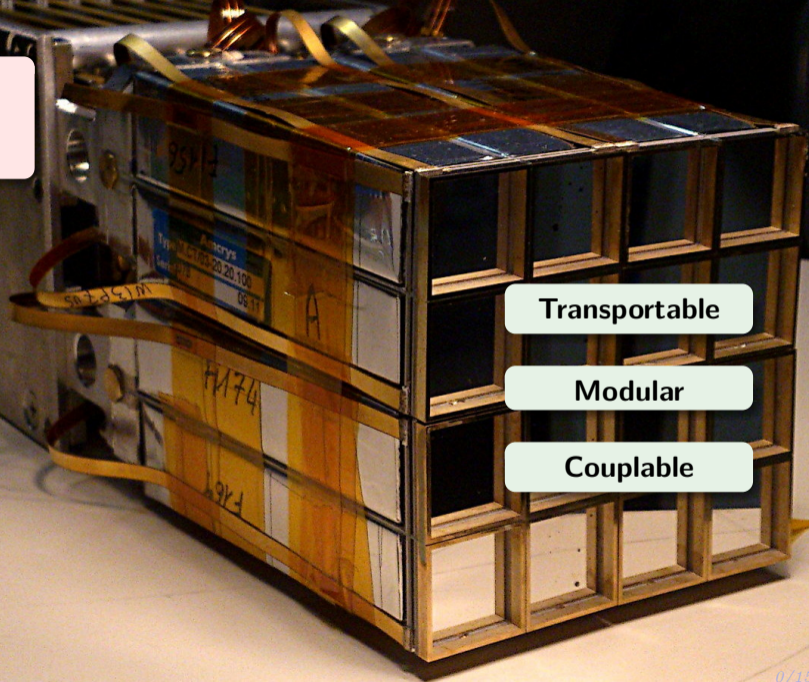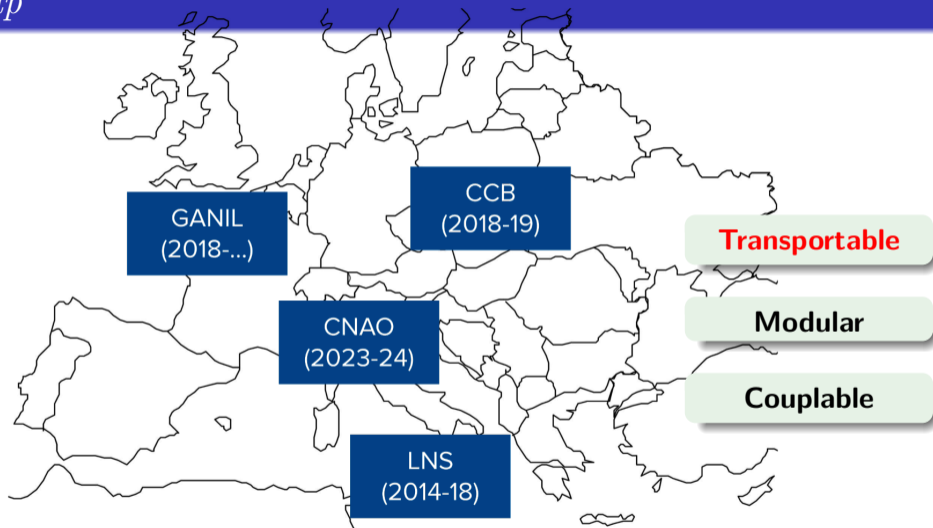
FAZIA setup

Laboratories where FAZIA measured so far

FAZIA
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INDRA-FAZIA coupling
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Future at FRIB
○○○

FAZIA setup

Transportable

Modular

Couplable

INFN-LNS (Italy)
$2014 - 2015$

FAZIA
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INDRA-FAZIA coupling
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Future at FRIB
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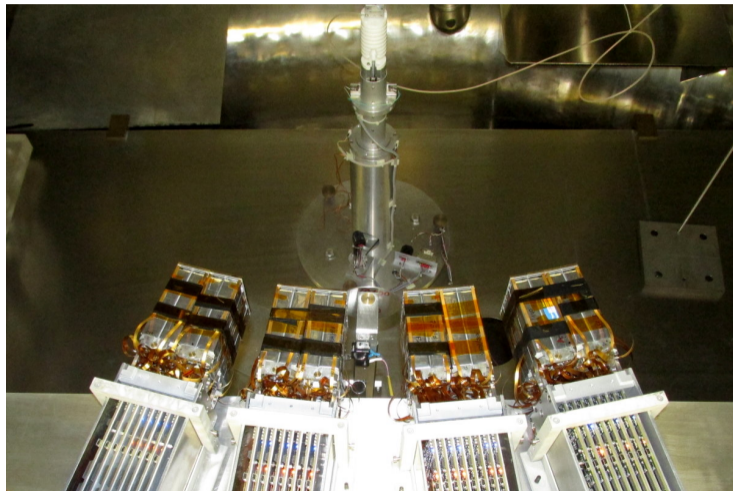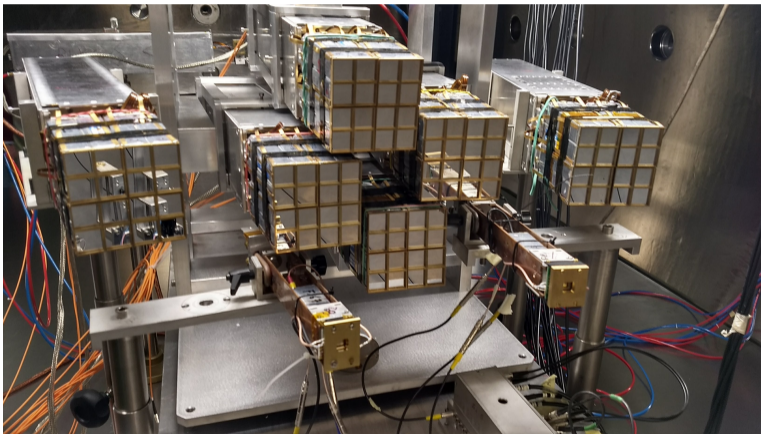
FAZIA setup

INFN-LNS (Italy)
2016 − 2018

FAZIA
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INDRA-FAZIA coupling
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Future at FRIB
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FAZIA setup

GANIL (France)
2018 – today

FAZIA
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INDRA-FAZIA coupling
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Future at FRIB
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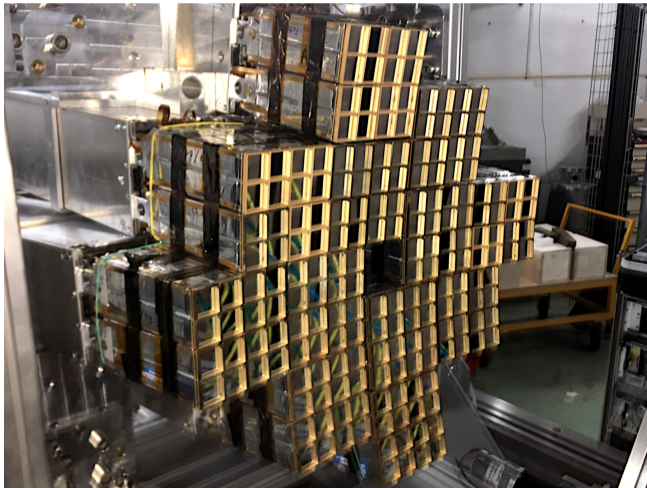
FAZIA setup

GANIL (France)
2018 − today

Transportable

Modular

Couplable

FAZIA
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INDRA-FAZIA coupling
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Future at FRIB
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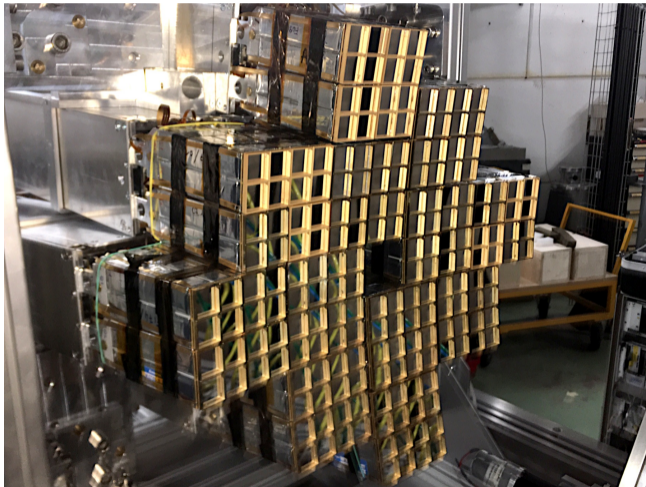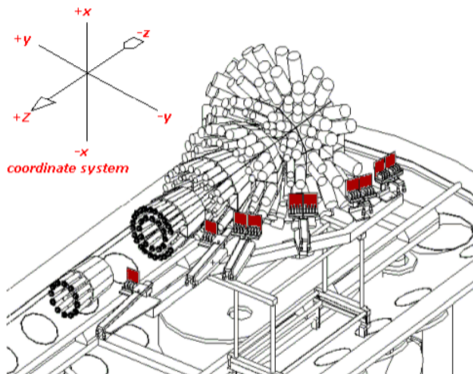
INDRA setup

Original configuration (1992-2016)

- 90% of the solid angle covered
- 17 telescope rings (8-24 sectors per ring)
  - ring 1: IC + plastic scintillators
  - rings 2-9: IC-Si-CsI telescopes
  - rings 10-17: IC-CsI telescopes

J. Pouthas *et al*, Nucl. Instr. and Meth. A 357 (418), 1995

FAZIA
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INDRA-FAZIA coupling
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Future at FRIB
○○○

INDRA setup

Present configuration (2017-today)

- FAZIA at forward angles!
- 12 telescope rings (8-24 sectors per ring)
  - rings 1-5: removed!
  - rings 6-9: IC-Si-CsI telescopes
  - rings 10-17: IC-CsI telescopes

INDRA setup

FAZIA
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INDRA-FAZIA coupling
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Future at FRIB
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Regional board

FAZIA
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INDRA-FAZIA coupling
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Future at FRIB
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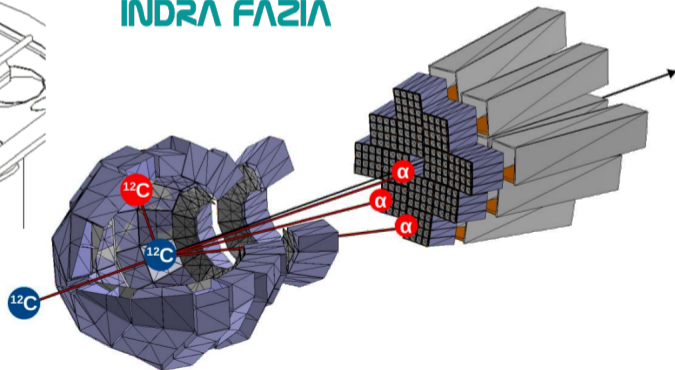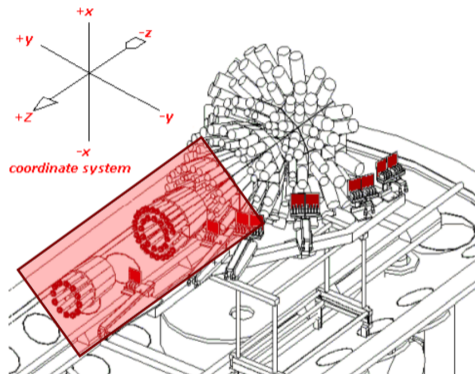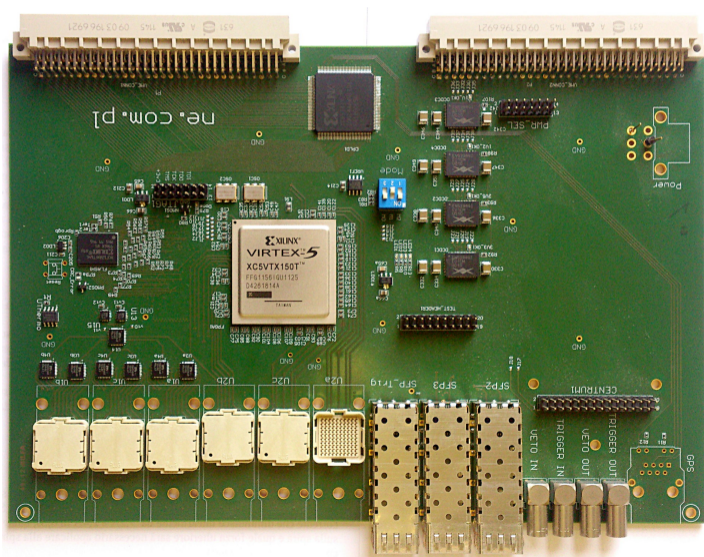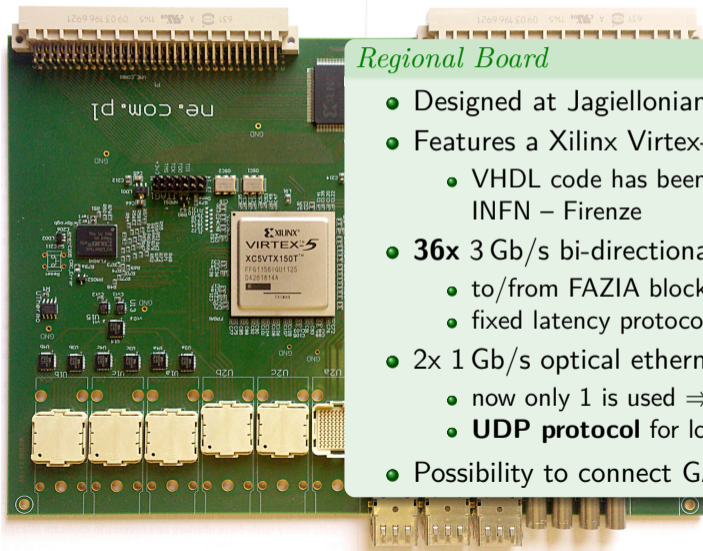
Regional board

Regional Board

- Designed at Jagiellonian University, Krakow
- Features a Xilinx Virtex-5 FPGA
  - VHDL code has been written mainly at INFN – Napoli and INFN – Firenze
- **36x** 3 Gb/s bi-directional optical links
  - to/from FAZIA blocks
  - fixed latency protocol
- 2x 1 Gb/s optical ethernet links (1000Base-SX)
  - now only 1 is used ⇒ room for transmission speed increase
  - **UDP protocol** for low-latency transfer
- Possibility to connect GANIL **CENTRUM** module

FAZIA
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INDRA-FAZIA coupling
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Future at FRIB
○○○

Regional board

Regional Board tasks

- **Slow control** management of all the electronics
    - data transmission and slow control use the same optical fibre
- **Trigger board**:
    - multiple majority logic for trigger validation
    - trigger scaling by a settable factor
    - asynchronous or master/slave trigger operation (for coupling)
- **Event building** from data coming from all the blocks
    - it may add the CENTRUM timestamp to each event
- **Transmission** of acquired data to servers
    - maximum speed achieved: $\sim 80\,\mathrm{MB/s}$ ($\sim 640\,\mathrm{Mb/s}$)

FAZIA
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INDRA-FAZIA coupling
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Future at FRIB
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Regional board

> ### Regional Board recend upgrades
>
> - **2015** Multi-IP data sending interface
> - **2015** Improved slow control state machine
>   (multiple clients simultaneously allowed)
> - **2016** CENTRUM interface
> - **2017** New TAG data format
> - **2018** Pt100 probe reading for temperature measurements
> - **2022 trigger/veto signal synchronization with slow control registers**
> - **2025** FRIB clock acquisition and timestamp storage in data flow

FAZIA
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INDRA-FAZIA coupling
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Future at FRIB
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Trigger and veto delay adjustment
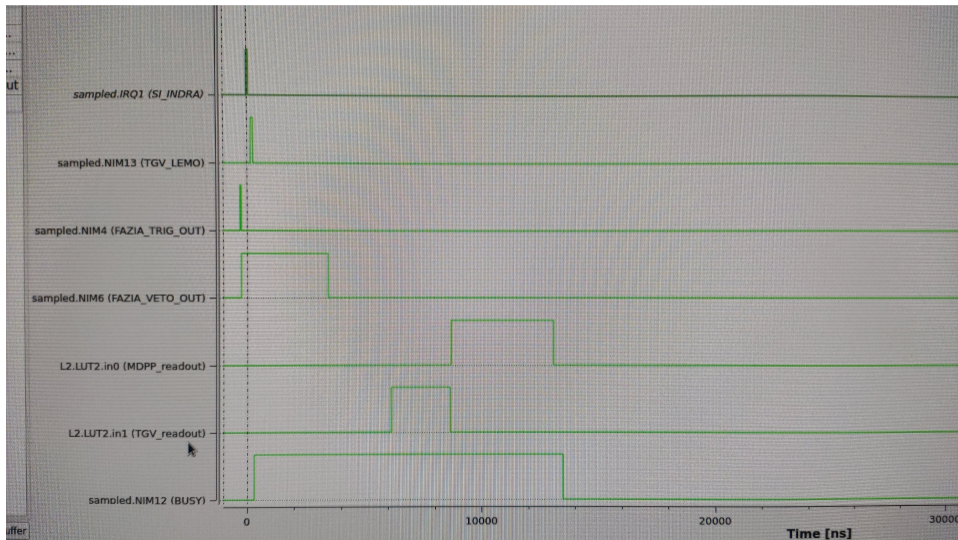
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INDRA-FAZIA coupling
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Future at FRIB
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Coupling with other apparatuses

FAZIA – INDRA coupling

FAZIA modularity makes coupling easy:

- CENTRUM[1] modules could be used for coupling
- FAZIA – INDRA coupled since 2018!

---

[1]developed at GANIL, Caen

Coupling with other apparatuses

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Trigger

- Master/slave (common dead time)
- **Asynchronous mode
  (keeping common dead time)**

---

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Coupling with other apparatuses

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- Master/slave (common dead time)
- **Asynchronous mode (keeping common dead time)**

CENTRUM operation

1. **Validation received** from one or both detectors
2. **Timestamp given** to both detectors

---

[1]developed at GANIL, Caen

FAZIA
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INDRA-FAZIA coupling
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Future at FRIB
○○○

Coupling with other apparatuses

FAZIA – INDRA coupling

FAZIA modularity makes coupling easy:

- CENTRUM[1] modules could be used for coupling
- FAZIA – INDRA coupled since 2018!
- data merging using NARVAL[2]

Trigger

- Master/slave (common dead time)
- **Asynchronous mode
  (keeping common dead time)**

CENTRUM operation

1. **Validation received**
   from one or both detectors
2. **Timestamp given**
   to both detectors

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[1] developed at GANIL, Caen
[2] developed at IPN, Orsay
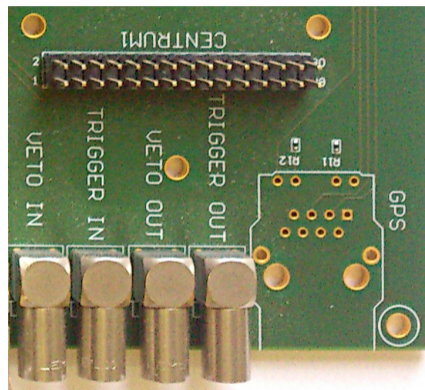
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INDRA-FAZIA coupling
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Future at FRIB
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Trigger coupling (preserving common dead time)

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INDRA-FAZIA coupling
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Future at FRIB
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Trigger coupling (preserving common dead time)

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INDRA-FAZIA coupling
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Future at FRIB
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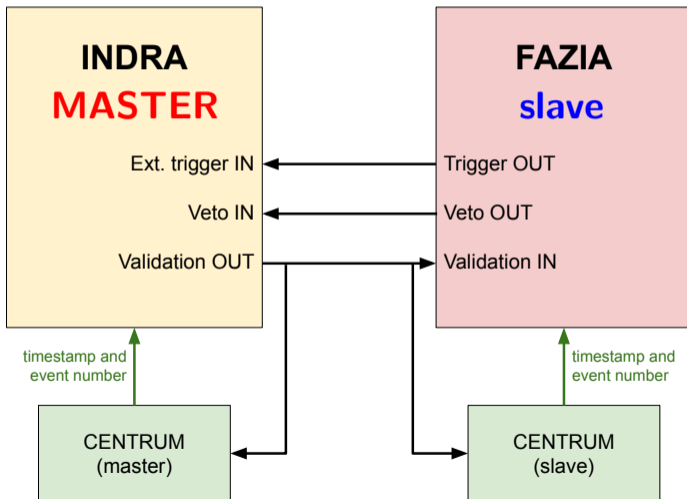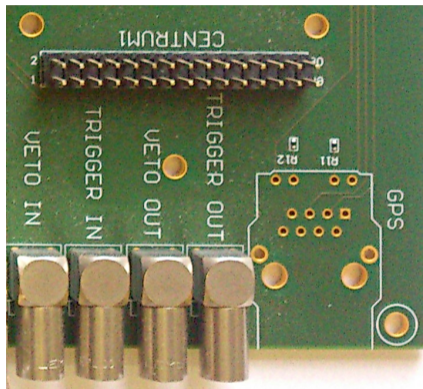
Trigger coupling (preserving common dead time)
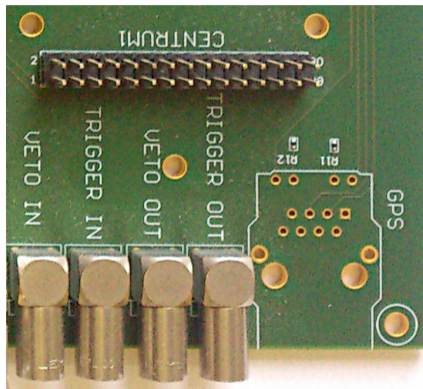
Asynchronous triggering

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INDRA-FAZIA coupling
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Future at FRIB
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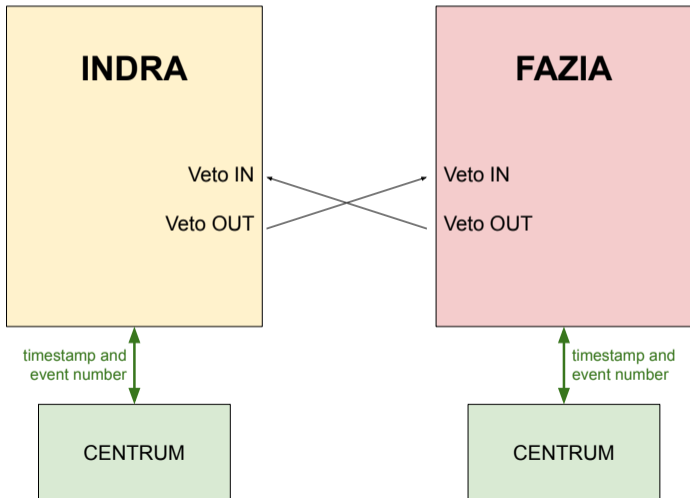
Data merging with NARVAL

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INDRA-FAZIA coupling
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Future at FRIB
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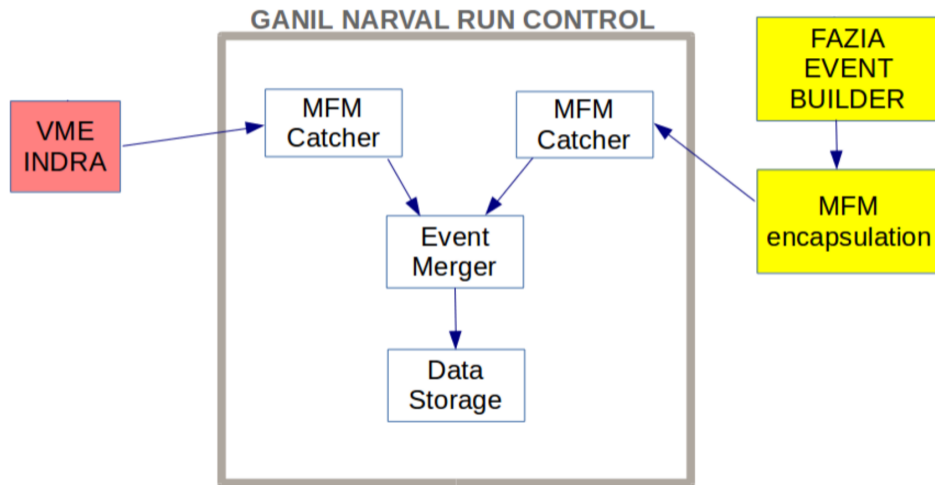
Acquisition and monitoring

Acquisition system

- Developed at INFN – Napoli
- Finite State Machine logic
- Multi-thread and **multi-machine**
    - controller sends machine IP addresses to regional board
    - regional board stores IP addresses inside a list
    - each event is sent to a different PC of the list sequentially
- Data merged and written to a data server.
- Monitoring software receives **live data** from the acquisition
- Data transfer between machines via **ZeroMQ** protocol
- NARVAL frame encapsulation implemented

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INDRA-FAZIA coupling
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Future at FRIB
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Acquisition and monitoring

Acquisition and monitoring

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INDRA-FAZIA coupling
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Future at FRIB
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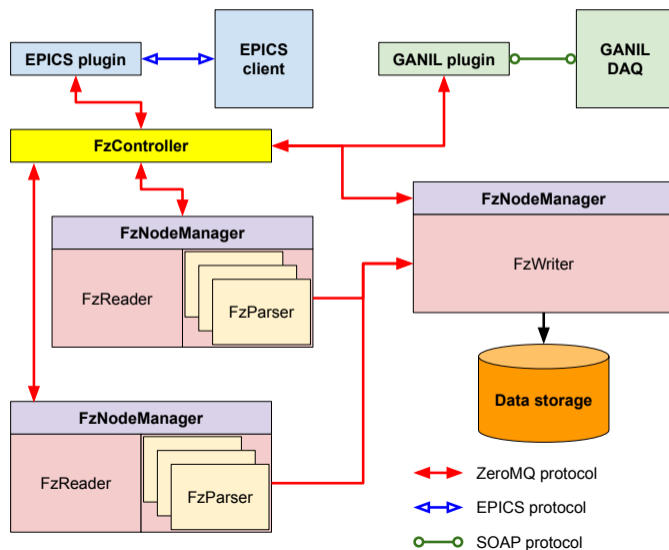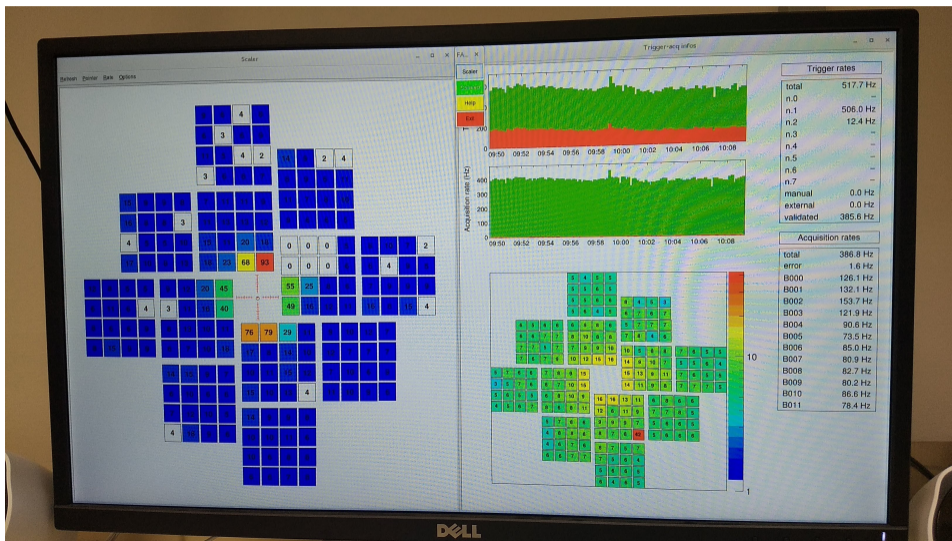
Acquisition and monitoring

High level graphical interfaces
developed at GANIL and LPC

fazia-ecc
- fazia-gui
- fazia-monitor
- . . .

fazia-visu
- fazia-viewer
- fazia-oscillo
- fazia-scaler
- . . .

FAZIA
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INDRA-FAZIA coupling
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Future at FRIB
ooo
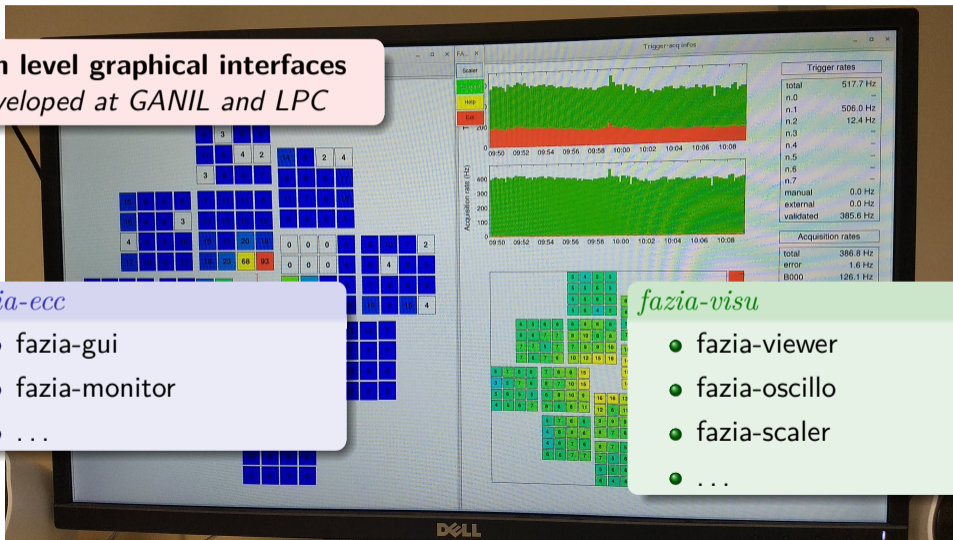
Testing and quick analysis

> **Low level command-line utilities**
> *developed at INFN-Firenze*

fz-acqui Very simple acquisition to ROOT

fz-meter Simple trigger monitoring

fz-scaler Single block scaler

fz-test Complete FEE testing and calibration suite

fz-thresholds Threshold tuning tool

fz-tree .pb to ROOT tree converter

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https://baltig.infn.it/valdre/fz-utils

FAZIA
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INDRA-FAZIA coupling
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Future at FRIB
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FAZIA now

Present status

- FAZIA is a general purpose, modular and flexible apparatus
- almost full solid angular coverage achieved with INDRA+FAZIA coupling
- setup designed for **Fermi energies** (15–50 AMeV)

FAZIA
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INDRA-FAZIA coupling
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Future at FRIB
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FAZIA now

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- setup designed for **Fermi energies** (15–50 AMeV)

Future at GANIL

There are still many physics cases to be explored

2 experiments performed in 2025!

1 experiment approved for 2026/27!

FAZIA
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INDRA-FAZIA coupling
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Future at FRIB
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FAZIA future

Future challenges

Collaboration is planning to measure at higher energies (FRIB @ MSU) to explore the supra-saturation regime of the nuclear matter. We are considering many alternatives:

FAZIA
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INDRA-FAZIA coupling
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Future at FRIB
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FAZIA future

Future challenges

Collaboration is planning to measure at higher energies (FRIB @ MSU) to explore the supra-saturation regime of the nuclear matter. We are considering many alternatives:

- **Thicker** sensors with the same FAZIA electronics

FAZIA
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INDRA-FAZIA coupling
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Future at FRIB
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Collaboration is planning to measure at higher energies (FRIB @ MSU) to explore the supra-saturation regime of the nuclear matter. We are considering many alternatives:

- **Thicker** sensors with the same FAZIA electronics
- **New block** design with the same FAZIA acquisition protocols

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INDRA-FAZIA coupling
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Future at FRIB
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- **Full re-design** of the apparatus based on the FAZIA expertise

FAZIA
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INDRA-FAZIA coupling
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Future at FRIB
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FAZIA future

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Collaboration is planning to measure at higher energies (FRIB @ MSU) to explore the supra-saturation regime of the nuclear matter. We are considering many alternatives:

- **Thicker** sensors with the same FAZIA electronics
- **New block** design with the same FAZIA acquisition protocols
- **Full re-design** of the apparatus based on the FAZIA expertise

FAZIA technology will be fundamental for the future developments

FAZIA @ 23058

- As a first test, FAZIA will measure at FRIB coupled with other apparatuses
- We started a 2-weekly technical meeting cycle to prepare the setup

Mechanics

- The scattering chamber is too small to host FAZIA
- A "nose" will be build to host a FAZIA block at 80 cm distance from target

DAQ and electronics

- FRIB DAQ experts received the full description of the FAZIA data flow protocol
- FAZIA data will be merged with other setups and handled by FRIB
- independent acquisition to store FAZIA data in the old format?

FAZIA
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INDRA-FAZIA coupling
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Future at FRIB
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- FAZIA data will be merged with other setups and handled by FRIB
- independent acquisition to store FAZIA data in the old format?
- Successful FAZIA@FRIB coupling test in October!

FAZIA
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INDRA-FAZIA coupling
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Future at FRIB
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FAZIA@FRIB

FRIB DAQ coupling

- Common dead time by trigger coupling
- Timestamp (TS) generated from external clock
- TS reset is provided to all the coupled devices
- TS written in data flow
- FRIB DAQ extracts TS to merge data

FAZIA
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INDRA-FAZIA coupling
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Future at FRIB
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FAZIA@FRIB

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- **Common dead time by trigger coupling**
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FRIB veto signal in FAZIA for **common dead time**

FAZIA
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INDRA-FAZIA coupling
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Future at FRIB
ooo

FAZIA@FRIB

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Timestamp **clock** and **reset** signals are sampled by ReBo and written in data flow

FRIB veto signal in FAZIA for **common dead time**

FAZIA
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INDRA-FAZIA coupling
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Future at FRIB
○○●

FAZIA@FRIB

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FRIB veto signal in FAZIA for **common dead time**

Timestamp coherency **verified!**

FAZIA
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INDRA-FAZIA coupling
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Future at FRIB
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FAZIA@FRIB

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  to all the coupled devices
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  to merge data

FRIB veto signal in FAZIA
for **common dead time**

Extra details from FRIB side
in the talk by **G. Cerizza**
at the NUSDAF meeting

Timestamp **clock** and
reset signals are sampled
by ReBo and written
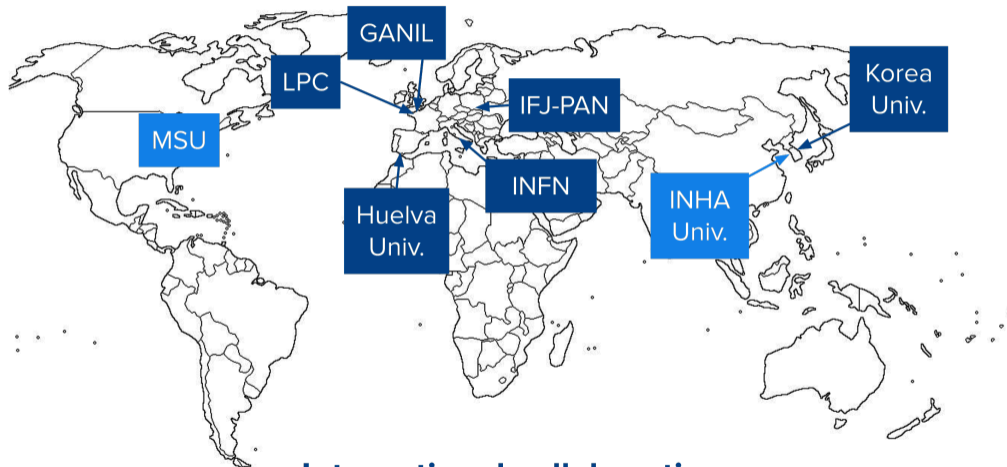in data flow

Timestamp coherency
verified!

Thanks for your attention

Backup slides

FAZIA collaboration

**International collaborations
in FAZIA MoU or FAZIA related**

The FAZIA telescope

The telescope stages

1. 300 μm reverse-mounted Si detector;
2. 500 μm reverse-mounted Si detector;
3. 10 cm CsI(Tl) cristal read by a photodiode.

The FAZIA telescope

The telescope stages

1. 300 µm reverse-mounted Si detector;
2. 500 µm reverse-mounted Si detector;
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The FAZIA telescope

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The FAZIA telescope

The telescope stages

1. 300 μm reverse-mounted Si detector;
2. 500 μm reverse-mounted Si detector;
3. 10 cm CsI(Tl) cristal read by a photodiode.

   To achieve the best possible energy resolution and A and Z identification Si detectors come from a nTD ingot cut at random angle to avoid channeling effects.

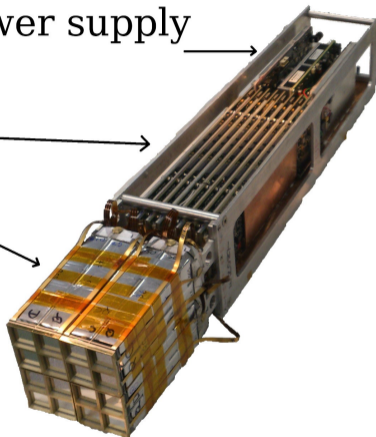R. Bougault *et al.*, Eur. Phys. J. A **50**, 47 (2014)

The FAZIA block

Block card, power supply and half bridge

FEE cards

Detectors

Transportable

Modular

Couplable

16 telescopes, together with **front-end electronics**, form a **block** operating in **vacuum**.

FAZIA front-end electronics

- Analogue chain: charge preamplifiers and anti-aliasing filters
- Signals are immediately digitized with **14-bit** ADCs:
    - on-line processed on FPGAs
    - energy resolution is better than 1 %
      from 5 MeV to 4 GeV

S. Valdré *et al*, Nucl. Instr. and Meth. A 930 (27), 2019

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- common clock distribution for **synchronous** sampling

S. Valdré *et al*, Nucl. Instr. and Meth. A 930 (27), 2019

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$\Downarrow$

- Compactness and modularity
- Very good isotopic discrimination capabilities
- Thresholds ($\lesssim 10$ MeV/u) suited for Fermi energies

S. Valdré *et al*, Nucl. Instr. and Meth. A 930 (27), 2019

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S. Valdré *et al*, Nucl. Instr. and Meth. A 930 (27), 2019