# INDRA-FAZIA E884 experiment status

Caterina Ciampi

12/03/2025

The study of the ternary reaction channel, i.e. QP breakup, could provide some interesting insight on the most dynamical features of a HIC, related to the interplay of different **isospin transport phenomena**.

# Physics motivation

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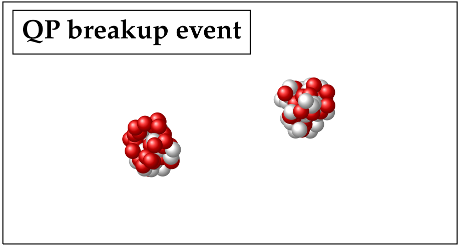

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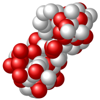

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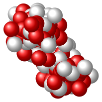

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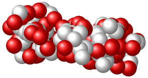

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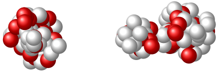

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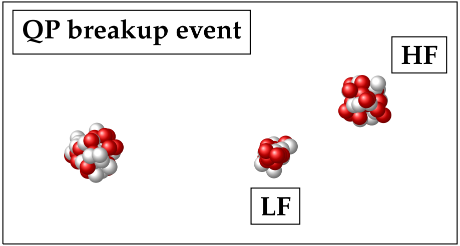

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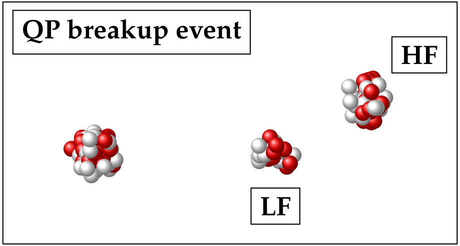


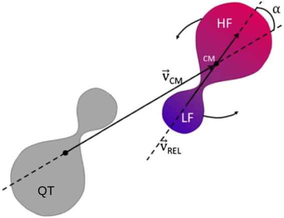


- *Isospin drift:* neutron enrichment of the neck, i.e. the light fragment (LF) side
- *Isospin diffusion:* internal equilibration occurring inside the QP* prior to the split
- $\alpha$ angle between the QP-QT separation axis and the fission axis can been used as a "clock" for the breakup timescale (*equilibration chronometry*)
  → A. Jedele *et al.*, Phys. Rev. Lett. 118, 062501 (2017)

# Physics motivation

## Isospin equilibration rate in different systems

A. Rodriguez-Manso *et al.*, Phys. Rev. C 95, 044604 (2017):
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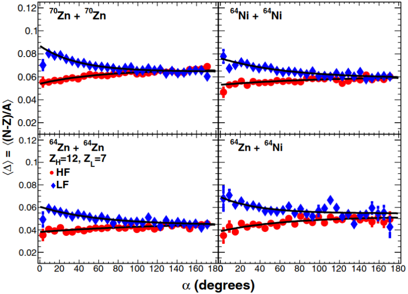

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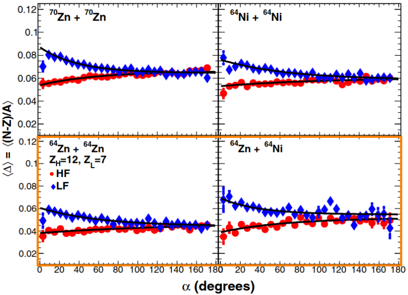
- both the initial and equilibrium composition $\langle\Delta\rangle_{LF}$ are affected by the neutron richness of the target



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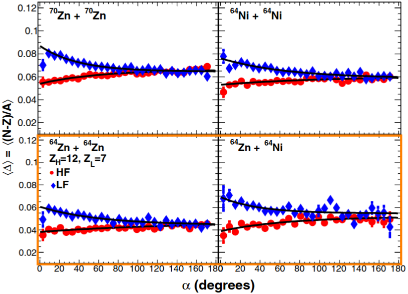
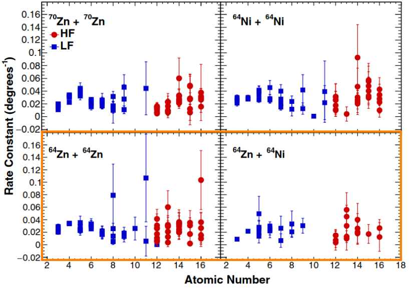
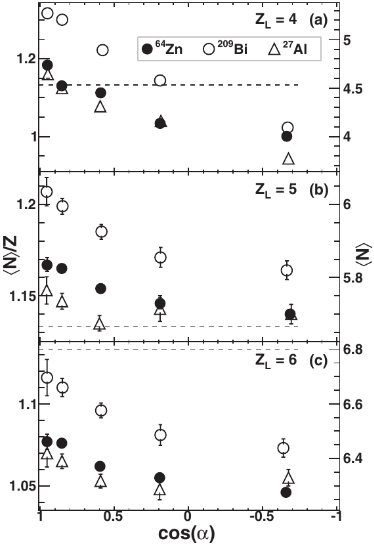



Two reactions with same projectile ($^{64}$Zn) on different targets ($^{64}$Zn and $^{64}$Ni):

- both the initial and equilibrium composition $\langle\Delta\rangle_{LF}$ are affected by the neutron richness of the target
- the isospin equilibration rate constants seem to be independent of the system

→ *Such rate can be expected to depend on the details of the NEoS, and not on the composition of the system or the chemical potentials involved*



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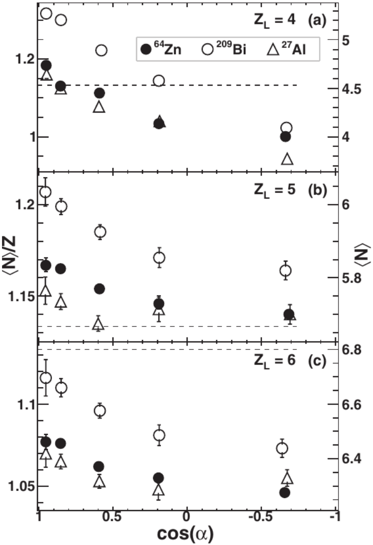


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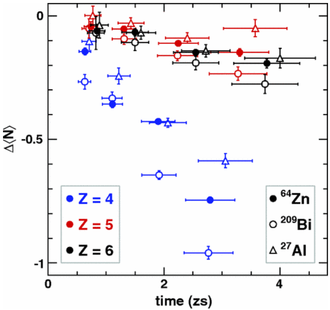
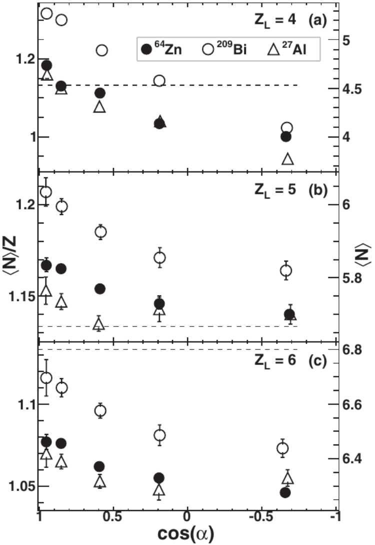
- both the LF composition **and its isospin equilibration rate** depend on the system



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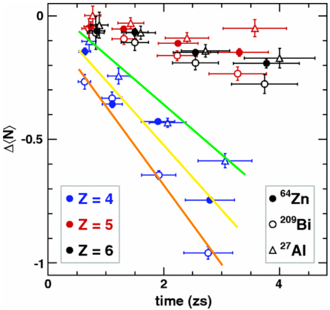
  → *interpreted as a consequence of the different isospin gradient inside the QP**



Study the evolution towards equilibration in three systems, using the same projectile on three targets with strongly different size and composition:

**Beam energy: 35 MeV/nucleon**

- $^{70}$Zn ($N/Z$ = 1.33) + $^{27}$Al ($N/Z$ = 1.07)
- $^{70}$Zn ($N/Z$ = 1.33) + $^{70}$Zn ($N/Z$ = 1.33)
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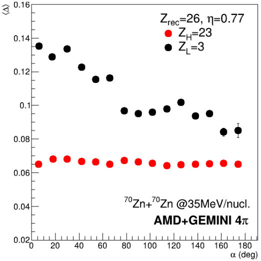
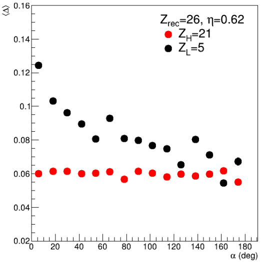



- $^{70}$Zn+$^{70}$Zn at 35 MeV/nucl. as reference symmetric system allows for the direct comparison with literature (Phys. Rev. C 95, 044604 (2017))



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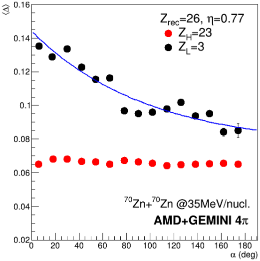


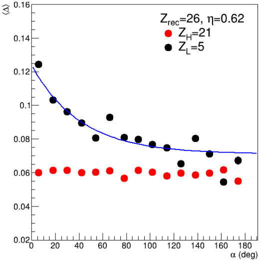

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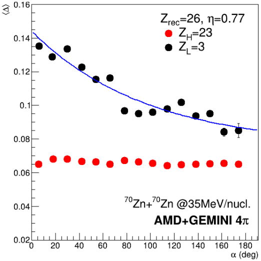
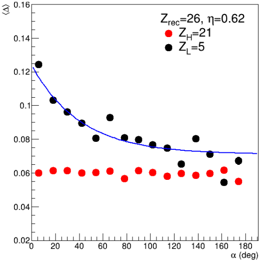
- Asymmetric systems → different neutron reservoir provided by targets, different isospin imbalance inside QP*



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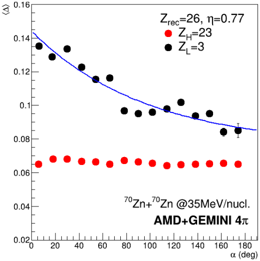
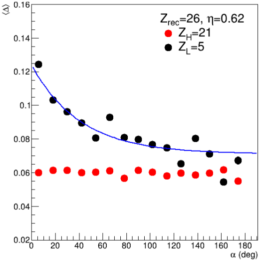
- Asymmetric systems → different neutron reservoir provided by targets, different isospin imbalance inside QP*

*The aim is to see to what extent the evolution towards isospin equilibration inside the deformed QP* before its breakup depends on the preceding step of the reaction.*

AMD: A. Ono et al., Phys. Rev. Lett. 68, 2898 (1992)
BUU: S. Mallik et al., J. Phys. G: Nucl. Part. Phys. 49 015102 (2022)



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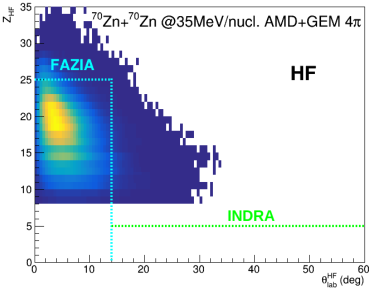


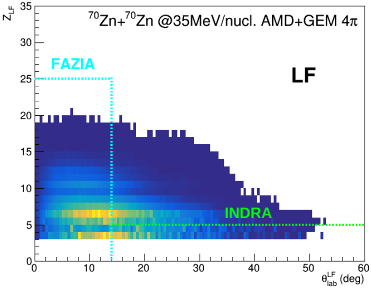


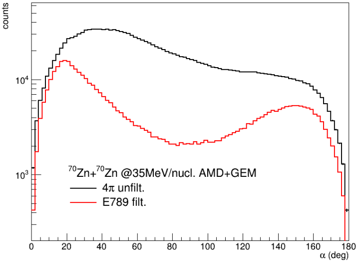

# Proposed experiment

## INDRA-FAZIA: recent upgrades and expected performances

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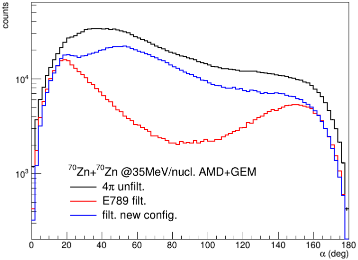
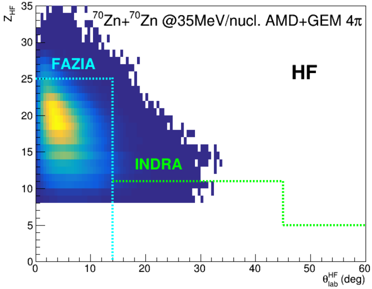
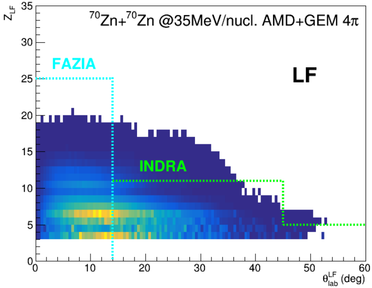
- previously, INDRA could provide mass identification only up to $Z \sim 4$
  → no QP breakups with $\alpha \sim 90°$ and large $v_{rel}$
- after the electronics upgrade, the mass ident. capability has been extended up to $Z \sim 10$ (J. D. Frankland et al., Nuovo Cim. C 45, 43 (2022))
  → recover the majority of transverse breakups, with LF emitted at larger $\theta_{lab}$




- further improvements: new INDRA Si detectors, Rutherford monitor

| Beam | Beam Energy | Schedule | Intensity | Target | UTs request |
|---|---|---|---|---|---|
| $^{70}$Zn | 35 MeV/nucleon | 30 May - 8 June | $10^8$ pps | $^{27}$Al<br>$^{70}$Zn<br>$^{209}$Bi | 8 UTs<br>8 UTs<br>8 UTs |
| $^{12}$C | 8.75 MeV/nucleon<br>13.75 MeV/nucleon<br>35 MeV/nucleon | 13 April<br>12 - 13 April<br>16 - 17 June | $10^8$ pps | $^{197}$Au | 2 UTs<br>2 UTs<br>2 UTs |
| | | | | **Total** | **30 UTs** |

- The beam time request is 8 UTs for each one of the three systems: $^{70}$Zn + $^{27}$Al, $^{70}$Zn, $^{209}$Bi at 35 MeV/nucleon $\rightarrow \approx 2.5 \times 10^6$ QP breakup events

# Beam planning

## Summary of the beam schedule for E884_23

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- The beam time request is 8 UTs for each one of the three systems: $^{70}$Zn + $^{27}$Al, $^{70}$Zn, $^{209}$Bi at 35 MeV/nucleon → ≈ $2.5 \times 10^6$ QP breakup events
- Three $^{12}$C beams for calibration for both experiments:
  → their schedule is not optimal. We will have some additional beam of $^{129}$Xe at 50 MeV/nucl. (applications) before E881 (~9-10 april) and after E884 (~21 june)

# Beam/target status

## Isotope supply

**Beam:** $^{70}$Zn (0.6% natural abundance)

Rare isotope, extremely hard to find especially in *solid form* (required for the source).
We received the 300 mg needed for the beam in December 2024.

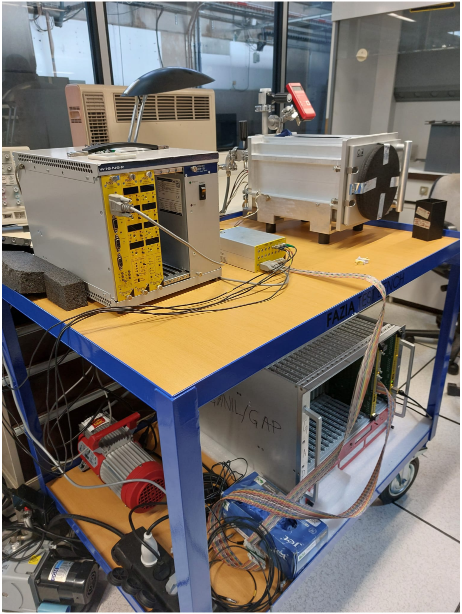
**Target:** $^{70}$Zn
Some of the $^{70}$Zn *powder* already available at GANIL will be used to produce the targets.
Self supporting Zn targets already manufactured last year.

**Target:** $^{27}$Al
Will be produced in GANIL, relatively easy to manufacture.

**Target:** $^{209}$Bi (100% natural abundance)
Will be produced both at GANIL (not sure they can do it self supporting) and at LNS, Catania.

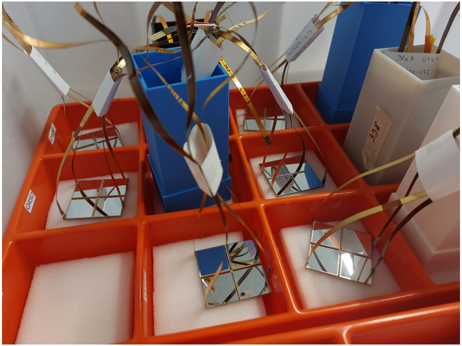
# FAZIA status

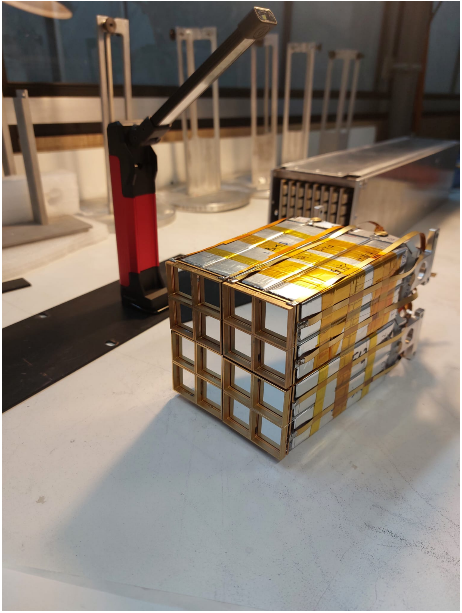
## New test bench for the single detectors




A new test bench has been realized, in order to test all detectors *before* mounting them on the FAZIA electronics.

The detector tests have been completed recently and the best Si detectors have been selected.

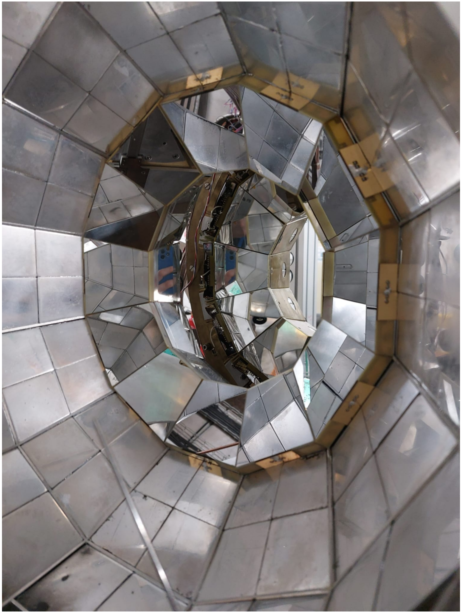




New FAZIA detection blocks have been reassembled and mounted on the electronics

- 300 $\mu$m-750 $\mu$m configuration for blocks 0-3
- 300 $\mu$m-500 $\mu$m configuration for blocks 4-11

More details on the tests and obtained performances will be given by Ilham Dekhissi in her presentation.



**Si detectors**:

- rings 6-7: all 150 $\mu$m Si replaced with 300 $\mu$m Si *before E818*
- rings 8-9: new 300 $\mu$m Si, replaced in 2023 and tested in July and September 2024

**CsI detectors**:

- some CsI detectors have been re-glued to their respective PMT

**Preamplifiers**:

- Preamplifiers for Si in rings 6-7 have been replaced to adapt the range to expected deposited energies (based on filtered simulations)

# Rutherford Monitor

A “new entry” of the setup

Four small (∅ = 1 cm) plastic scintillators placed downstream the setup at very small polar angles for cross section normalization.
Introduced in INDRA’s acquisition for counting (common dead time).

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Introduced in INDRA's acquisition for counting (common dead time).

Tested in July 2024 with the old head.
New head recently manufactured (adapted for smaller $\theta$)