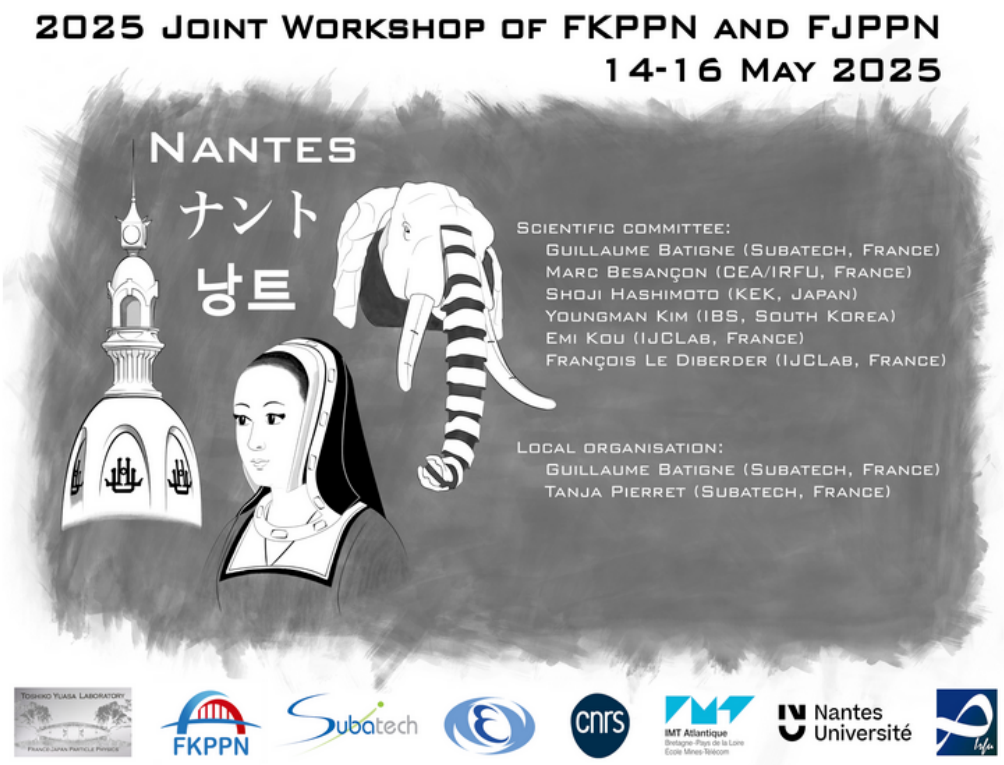
FAZIA-FKC status

Eric Bonnet (Subatech) for the FAZIA collaboration

14 May 2025



INDRA+FAZIA@GANIL#e881

FAZIA-FKC status

Outline of the presentation

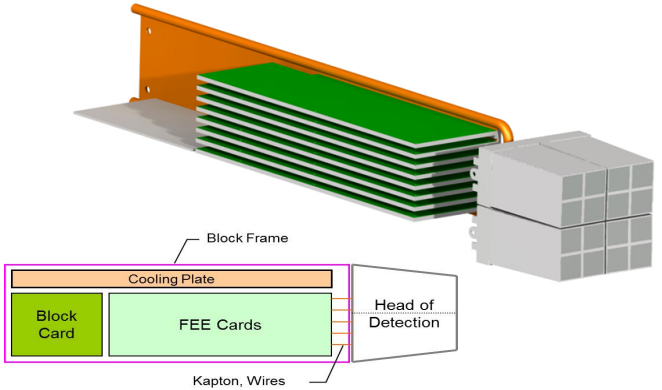
I General information on FAZIA

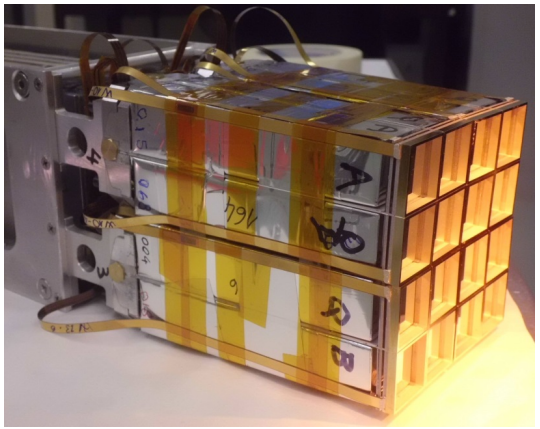
- Time line of the FAZIA device
- FAZIA block detection capabilities
- Short and mid term perspectives

II Korean activities connected to the FAZIA-FKC agreement

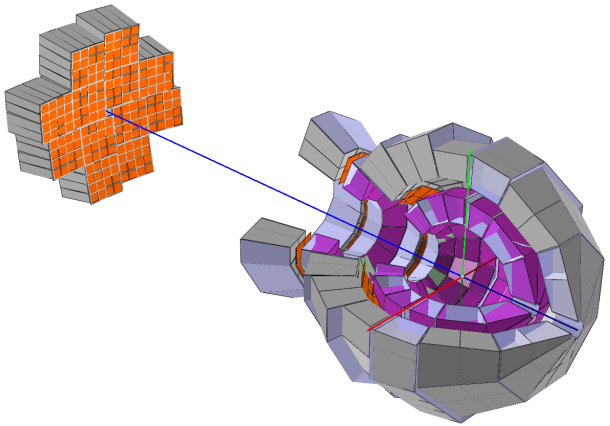
- maintain FAZIA blocks at a high level of performance, taking into account developments in electronics and detectors.
- build new FAZIA blocks for the RAON commissioning.

FAZIA, a brief history...



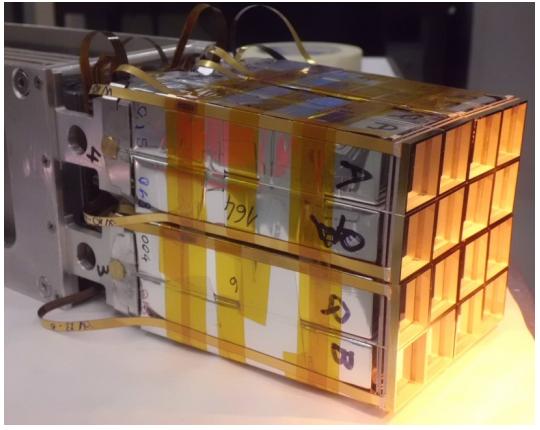


- **R&D phase** started in the early 2000's
  - High quality silicon detectors
  - Compact On-Board Digitalized electronics
  - Pulse Shape Analysis development
- **Commissioning phase**@LNS Catania (Italy) 2013-2018
  - First block was used for in-beam measurement in 2013
  - Several experiments followed until 2018, with a growing number of blocks available.
- **INDRA+FAZIA physics program**@GANIL (France) from 2019
  - 12 blocks of FAZIA in a wall configuration around the beam.
  - completed with the rings of INDRA to cover all the solid angle.

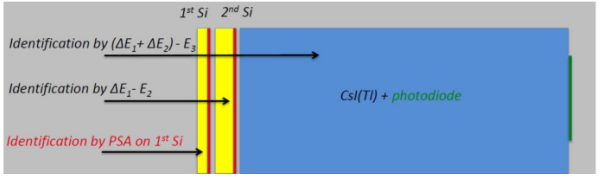


Outcome of the FAZIA R&D phase :

The FAZIA block



made of 4x4 Si+Si+CsI telescopes



- Stage 1 (300 μm silicon detector):
  - Charge: 250 Ms/s 14 bit (250 MeV full scale);
  - Charge: 100 Ms/s 14 bit (4 GeV full scale);
  - Current: 250 Ms/s 14 bit .
- Stage 2 (500 μm silicon detector):
  - Charge: 100 Ms/s 14 bit (4 GeV full scale);
  - Current: 250 Ms/s 14 bit.
- Stage 3 (10 cm CsI(Tl) + photo-diode):
  - Charge: 100 Ms/s 14 bit (4 GeV silicon-equivalent full scale).

With high identification capabilities

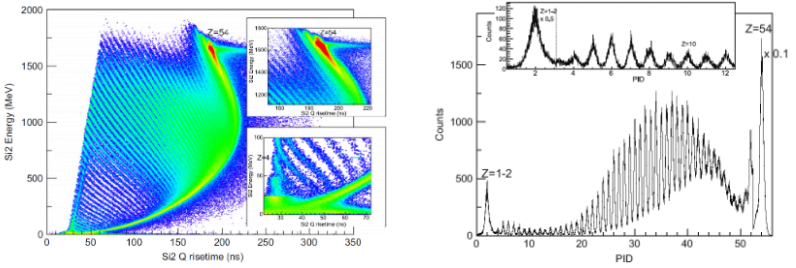


Fig. 11. (Colour on-line) Left: correlation energy *vs.* charge rise-time for nuclei stopped in the second 300 μm silicon detector. The intensity is in logarithmic scale. Right: expansions in the region of the lightest particles and in the region of the elastic scattering. From [15].

Fig. 13. Particle identification with the energy *vs.* charge rise-time technique, obtained from the linearization of fig. 11. The inset shows an expansion for the light elements. From [15].

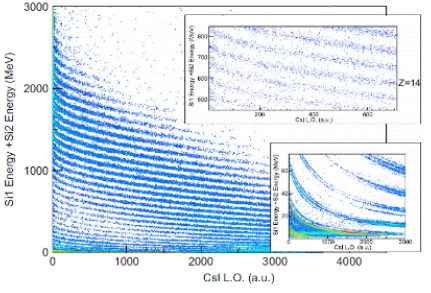


Fig. 9. (Colour on-line) ΔE-E correlation using the summed energy information (Si1+Si2) of the two 300 μm silicon detectors *vs.* the Light Output (LO) of the rear CsI. The insets present two expansions around $Z = 2$–6 and 12–16. From [15].

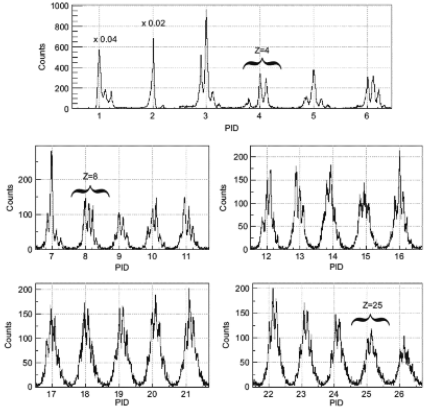


Fig. 10. Particle IDentification (PID) spectra obtained with the data of fig. 9. From [15].

For particle identification a standard linearization procedure was applied to the ΔE-E correlation of fig. 7. Then the Particle IDentification (PID) parameter was obtained

The FAZIA project in Europe: R&D phase
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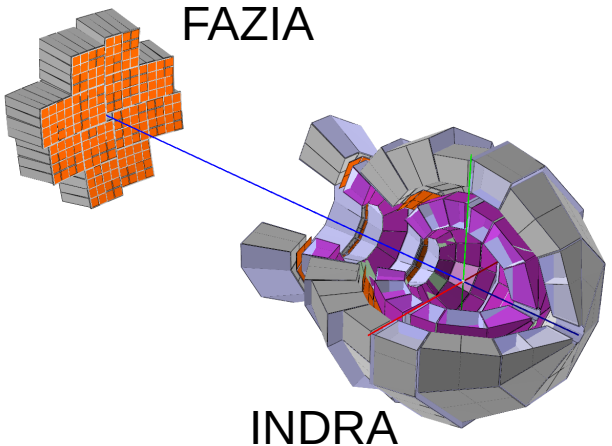
https://doi.org/10.1140/epja/i2014-14047-4

INDRA+FAZIA physics program@GANIL

At the end of the commissioning phase, the FAZIA collaboration was involved in a multi annual experimental program at GANIL coupling two multi-detectors, INDRA and FAZIA to address different physics cases :

- density dependence of the symmetry energy (EoS)
- fragmentation dynamics: spinodal instabilities and multifragmentation
- Clusterisation processes in nuclear matter



INDRA+FAZIA physics program@GANIL

- Since spring 2019, our Korean colleagues have shown their interest to participate in the experiments and join officially the FAZIA collaboration.
- This enlarged collaboration has been officially acted in September 2019 and an addendum to the FAZIA Memorandum of Understanding (MoU) (covering the GANIL experimental campaign 2018-2022) has been written and signed by the various institutions.

FAZIA, an international collaboration also focused on future radioactive ion beam (RIB) facilities

The third MoU, covering the period 2023-2027, gathers physicists from France, Italy, Korea, Poland and Spain around three main goals:

- The experimental campaign at GANIL with INDRA and FAZIA
- The construction of at least four new FAZIA blocks for the start of the RAON facility
- Developments towards RIB and collaboration with other groups/devices.

Korean activities in FAZIA

1. Upgrade of the Front-End electronic (FEE) cards of FAZIA

2. Developing partnerships in Korea for the production of high performance silicon detectors with an expertise and control on the whole process from the wafering to the sensor.

=> build at least 4 new FAZIA blocks in Korea, ready for the Raon's commissioning (in KoBRA Low-energy expt hall).

=> keep existing FAZIA blocks functional in the future, with up-to-date electronic cards and a more sustainable supply of silicon detectors.

Korean activities in FAZIA

Since 2019, the FAZIA-FKC project reinforces the collaboration and encourages exchanges between Korean and French colleagues by providing financial support for missions in both countries.

- Involved Institutes: CNRS-IN2P3, Korea University, Center for Extreme Nuclear Matters (CENuM), Inha University, Institute for Basic Science (IBS), EWHA Womans University.
- Nuclear Physics domain : dynamics and thermodynamics, equation of state and transport properties of the nuclear matter and its clustering processes.

Korean activities in FAZIA

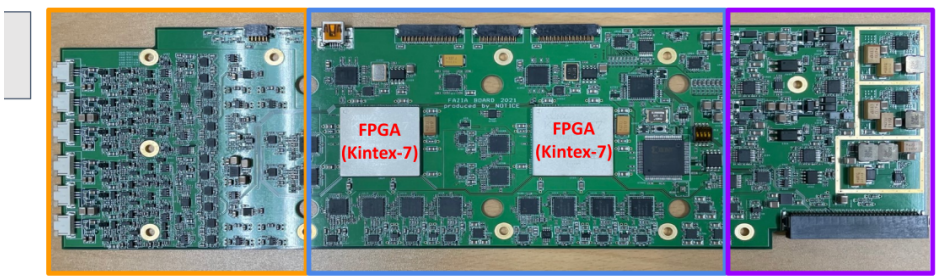
FAZIA-FKC 2025 list members

French Group			Korean Group		
Name	**Position**	**Lab./Institute**	**Name**	**Title**	**Institute**
Leader: Le Neindre Nicolas	CR	LPC Caen CNRS IN2P3 & University	**Leader: Hong Byungsik**	Professor	Korea University CENuM
Bonnet Eric	CR	Subatech CNRS IN2P3, IMTA & University	**Lee Jong-Won**	PostDoc	Korea University CENuM
Ciampi Caterina	Postdoc	GANIL	**Nam Seon Ho**	Student	Korea University CENuM
Dekhissi Ilham	Student	LPC Caen CNRS IN2P3 & University	**Park Jeonghyeok**	Student	Korea University CENuM
Frankland John	CR	GANIL	**Kweon Minjung**	Professor	Inha University
Gruyer Diego	CR	LPC Caen CNRS IN2P3 & University	**Kim Giyoung**	Student	Inha University
Lopez Olivier	DR	LPC Caen CNRS IN2P3 & University	**Jung Wonjun**	Student	Inha University
Valente Antonin	Student	LPC Caen CNRS IN2P3 & University	**Hahn Kevin Insik**	Professor	IBS
Vient Emmanuel	EC	LPC Caen CNRS IN2P3 & University	**Kim Sunji**	PostDoc	IBS

Korean activities in FAZIA

For the Front-End Electronic (FEE) part :

Realization of two prototypes FEE board for updated the next generation FAZIA electronics.
These two prototypes have been validated experimentally in 2024 and the production of the 32 FEE boards for the completion of 4 FAZIA blocks for RAON is achieved.
Discussions and tests are underway on further modifications and improvements. A new batch of 20 to 25 FAZIA FEE cards should be produced this year.



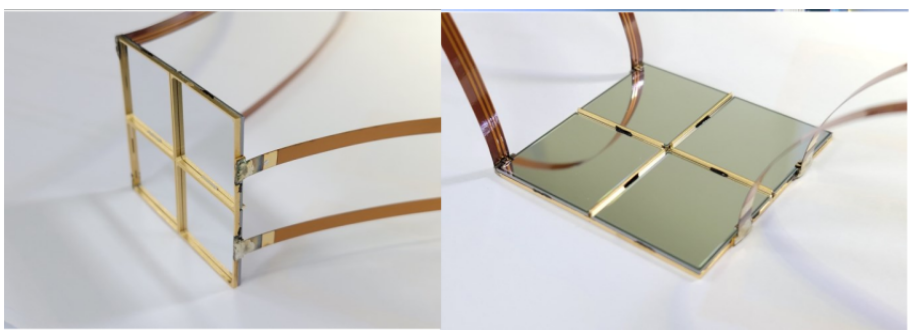
- **Analog part**:
  To amplify analog signals from the detector
- **Digital part**:
  Signal processing (analog to digital conversion)
- **Conversion part**:
  Power distribution
  Application of bias voltage

Korean activities in FAZIA

For the Silicon detector part :

Development and production of the thick silicon detectors for high energy physics experiment. Some of them have been used for INDRA-FAZIA experiments at GANIL since 2022.

Development, test and production of new silicon detectors of various thicknesses (between 100 and 750 µm)
The use of thinner silicon sensors is also being explored for lower energy physics.



Korean activities in FAZIA

Proposed experiment for the RAON PAC 2025 which will use the 4 new blocks developed and assembled in Korea.
"Exploring the Hoyle state in 12C through 20Ne+12C collisions using Si-CsI detectors"

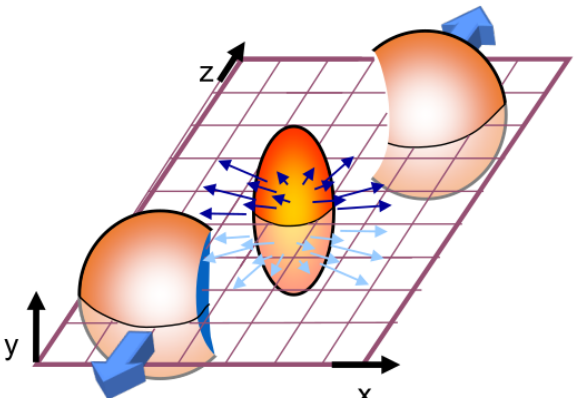
Ongoing analysis on existing INDRA/FAZIA data.
"isospin dependence of the collective flow in heavy-ion collisions"

Data sets

- INDRA: ^{129,124}Xe + ^{124,112}Sn @ 100 AMeV
- FAZIA+INDRA: ^{58,64}Ni + ^{58,64}Ni @ 32 and 52 AMeV

$$\frac{d^3N}{p_t dp_t dy d\phi} \propto 1 + 2v_1 \cos(\phi) + 2v_2 \cos(2\phi) + \ldots$$

where $\phi \equiv \phi_{meas} - \Psi_R$



Korean activities in FAZIA

The list of the anticipated Korean contribution to the FAZIA collaboration is the following:

- R&D of the thin (200 μm) and thick (300-675 μm) Si sensors.
- R&D of the front-end electronics boards and their production in Korea.
- Data analysis and articles (ex. on collective flow by a Ph.D. student).
- Building FAZIA blocks in Korea to participate in the commissioning experiments at RAON.
- Proposals for experiments during the RAON commissioning phase.

Merci Beaucoup.

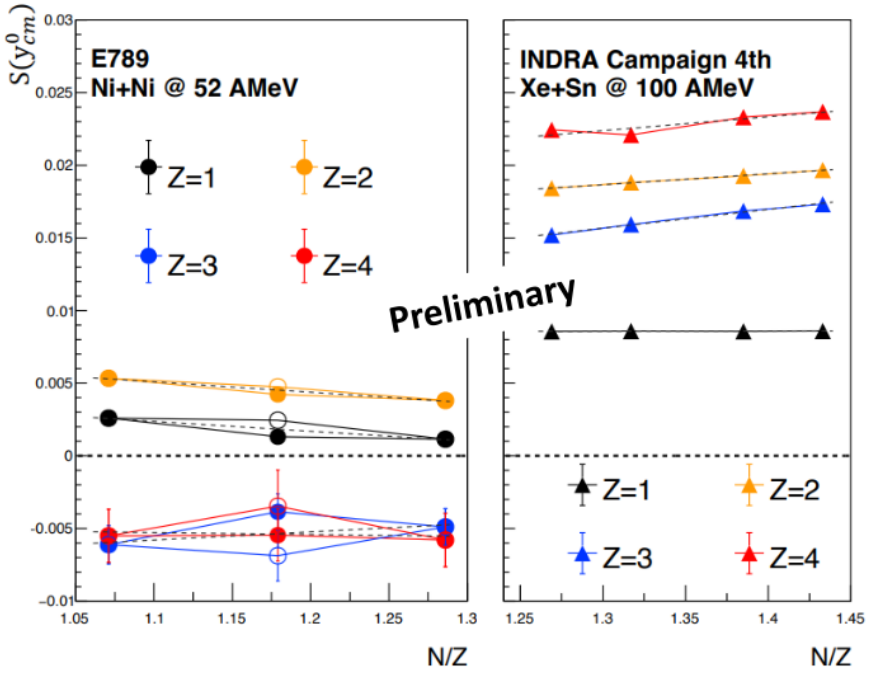
どうもありがとうございます.

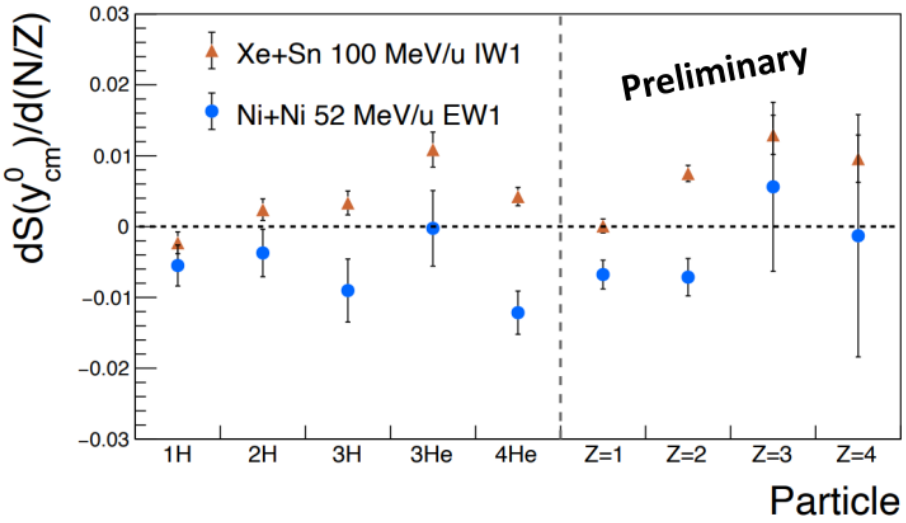
감사합니다.

Thank you very much.

BackUp Slides

Directed flow





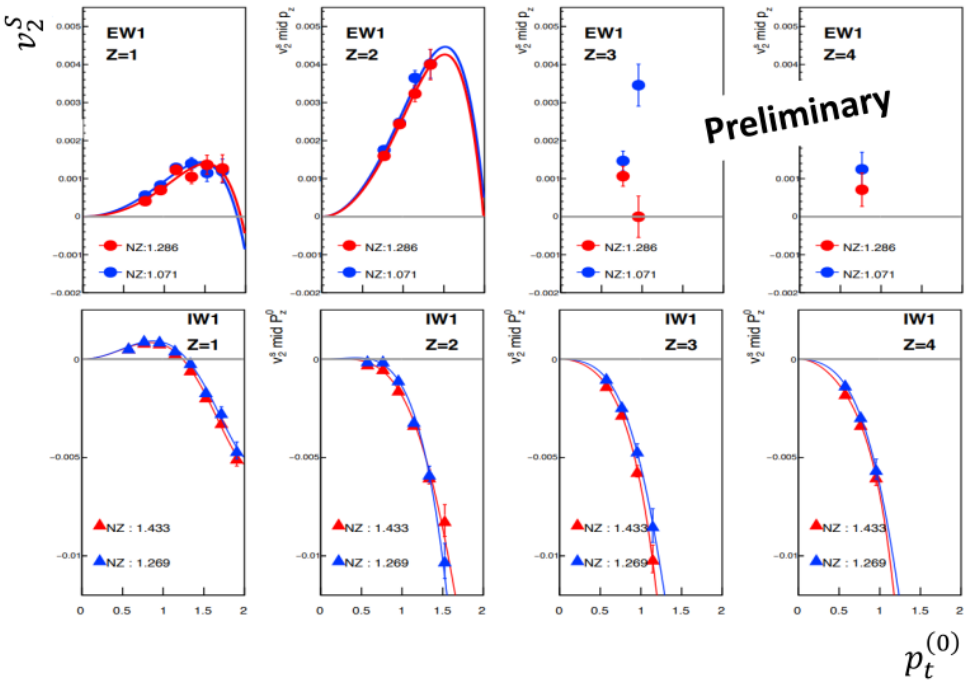
- Directed flow parameters for heavy system show larger sensitivity to the isospin composition (N/Z) of projectile and target.

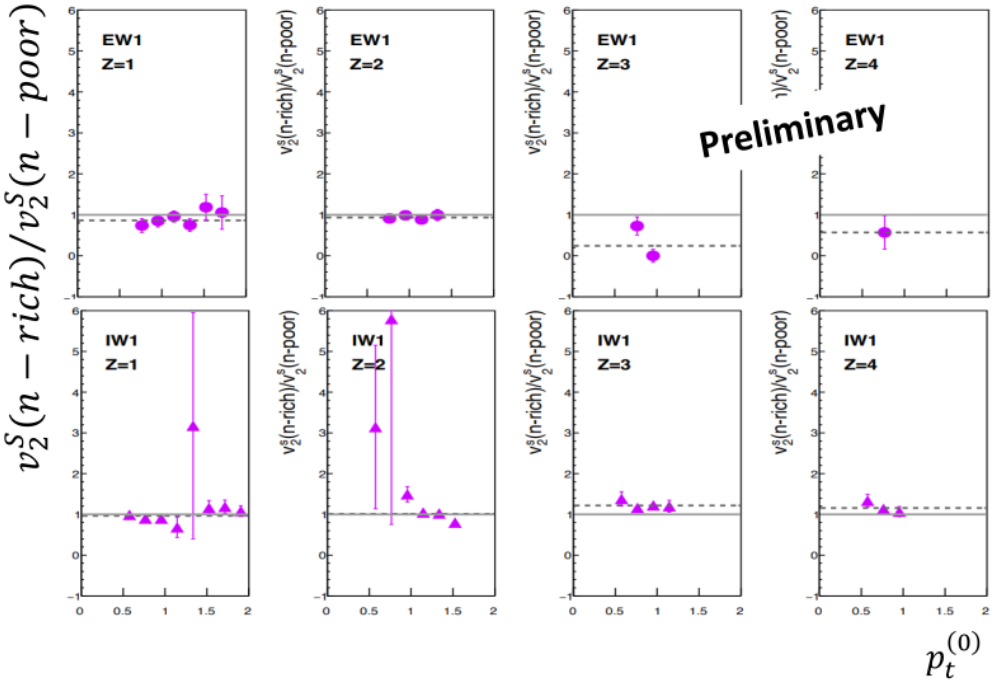
$$S(y^0_{cm}) \equiv \left. dv_1^S/dy^0_{cm} \right|_{|y^0_{cm}|<0.4}$$

$$v_1^S \equiv v_1 \cdot \left\langle p_t^{(0)} \right\rangle / \left(A_P^{1/3} + A_T^{1/3} \right)$$

$$p_t^{(0)} \equiv (p_t^{cm}/A)\,(A_P + A_T)/2p_{beam}^{cm}$$

Elliptic flow





$$v_2^S \equiv \quad v_2 \cdot \left\langle p_t^{(0)} \right\rangle / \left(A_P^{1/3} + A_T^{1/3} \right) \Big|_{|p_z^{(0)}|<0.4}$$

$$p_z^{(0)} \equiv p_z^{cm} / p_{beam}^{cm}$$

- Elliptic flow parameter does not show sensitivity to the isospin composition (N/Z) of projectile and target.

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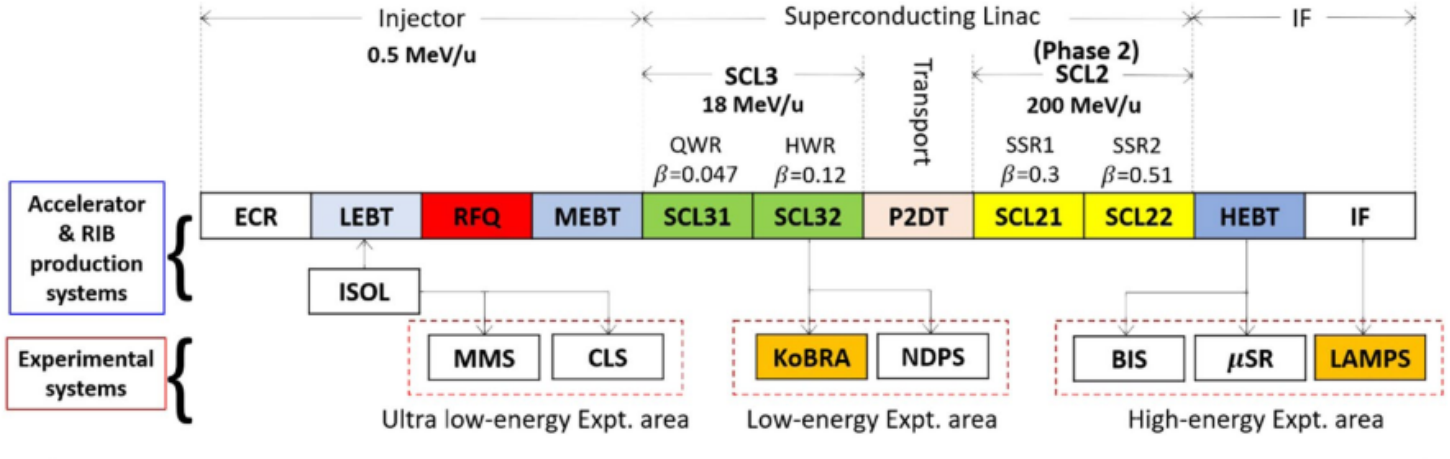
https://doi.org/10.1007/s43673-022-00074-z

AAPPS Bulletin

REVIEW ARTICLE Open Access

Status of the RAON project in Korea

Byungsik Hong*



BIS: Beam Irradiation System	**CLS**: Collinear Laser Spectroscopy	**ECR**: Electron Cyclotron Resonance
HEBT: High-Energy Beam Transport	**HWR**: Half-Wave Resonator	**IF**: In-flight Fragmentation separator
ISOL: Isotope-Separator On-Line	**KoBRA**: Korea Broad acceptance Recoil spectrometer & Apparatus	**LAMPS**: Large Acceptance Multi-Purpose Spectrometer
LEBT: Low-Energy Beam Transport	**MEBT**: Medium-Energy Beam Transport	**MMS**: Mass Measurement System
μSR: Muon Spin Relaxation	**NDPS**: Nuclear Data Production System	**P2DT**: Post-accelerator to Driver linac Transport
QWR: Quarter-Wave Resonator	**RFQ**: Radio-Frequency Quadrupole	**SCL1**: (Low-energy) SuperConducting Linac 1
SCL2: (High-energy) SuperConducting Linac 2	**SCL3**: (Low-energy) SuperConducting Linac 3	**SSR**: Single Spoke Resonator

Fig. 2 Schematic of RAON for the accelerator components, RIB production system, and beam extraction positions for seven experimental setups. The bottom table shows the full names of acronyms used in this article

Comissioning phase

Reviewing the experimental achievements of the early years of FAZIA at INFN-LNS,
Eur. Phys. J. P (2024) 139: 1134
https://doi.org/10.1140/epjp/s13360-024-05932-3

Forward A&Z, Identification Array