

2022 Joint Workshop of FKPPPL and TYL/FJPPL
(Online) LS2N/University of Nantes, 16-18 May 2022

Status of FKPPPL in FAZIA

Byungsik Hong (Korea University)

and

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for

FAZIA-FKC

Korea in FAZIA: Brief history

- Before 2019:
 - The Korean group (part of LAMPS Collaboration) was designing the **Si-Csl** telescope detector for the low-energy (a few tens MeV per nucleon) nuclear collision experiments at **RAON**, which is the new radioactive-ion beam facility being built in Korea.
 - The International Advisory Committee of RAON reviewed the status of the detector development and suggested us to collaborate with **FAZIA** in Europe, because it had been operating the most advanced Si-Csl detector system for nuclear physics.
 - Therefore, to join the Collaboration, we started the discussion with some FAZIA members in several Conferences & meetings.
- In 2019
 - Even before officially joining the FAZIA Collaboration, a group of interested Korean researchers visited GANIL in May 2019 and participated in the E789 experiment.
 - Three professors ([B. Hong @ Korea Univ.](#), [M. Kweon @ Inha Univ.](#), [I. Hahn @ Ewha Womans Univ.](#)) attended the FAZIA Workshop at GANIL in September and presented the application to join the Collaboration.

Korea in FAZIA: Brief history

- Addendum of MOU for FAZIA, adding Korea with CENuM (Center for Extreme Nuclear Matters directed by B. Hong) the national representative, was signed by CENuM (Korea), INFN (Italy), CNRS/IN2P3 (France), GANIL (France), COPIN (Poland), UHU (Spain) on November 6, 2020.

ADDENDUM n. 1

to the Memorandum of Understanding for the 2018-2022 FAZIA Experimental phase

The following Institutions:

- ISTITUTO NAZIONALE DI FISICA NUCLEARE (INFN), Italy
- INSTITUT NATIONAL DE PHYSIQUE NUCLEAIRE ET DE PHYSIQUE DES PARTICULES (CNRS-IN2P3), France
- GRAND ACCELERATEUR NATIONAL D'IONS LOURDES (GANIL), France
- CONSORTIUM OF POLISH INSTITUTIONS (COPIN), Poland
- UNIVERSITY OF HUELVA (UHU), Spain

hereinafter collectively referred to as the "Institutions" of the FAZIA Collaboration

WHEREAS

- on October 2018, the Institutions forming the FAZIA Collaboration have concluded a Memorandum of Understanding of the duration of five years (2018-2022) for the purpose of operating, maintaining, developing the FAZIA detectors during the experimental phase mostly carried out at GANIL in the fields of Heavy-Ion reactions at Fermi energies.
- In accordance with the provisions foreseen in article 8 of the MoU other Institutions may join the Experiment upon execution of a written Addendum approved by the Management Board of the Collaboration.
- On September 27 2019, following a plenary collaboration meeting held at GANIL, the Management Board has discussed and approved the accession of a new Institution in the FAZIA Collaboration.

NOW, THEREFORE, IT IS AGREED AS FOLLOWS:

ARTICLE 1

The purpose of the present Addendum n. 1 is to extend the participation in the FAZIA Collaboration to the following research Institution:

- Center for Extreme Nuclear Matters (CENuM) Korea University, Seoul 02841, South Korea

It is specified that for what concerns the plans and the activity of the FAZIA MoU, the CENuM includes and coordinates members of three Korean Universities: the Korea University, the Ewha Womans University and the Inha University.

With the accession of the Korean Party, some capital and human resources are added to the Collaboration as detailed in the table attached herewith as Appendix 1.

The acceding Party agrees and accepts the full openness and availability, within the Collaboration, in exchanging ideas, designs, drawings, software and hardware solutions that are now in use and those that will be developed and put in operation during the period of the MoU.

ARTICLE 2

This Addendum n. 1 shall enter into force upon signature by the authorized representatives of the Institutions forming the FAZIA Collaboration and shall remain in effect for the period set out in the preamble and in the text of the MoU.

ARTICLE 3


The acceding Institution joining the FAZIA Collaboration under the present Addendum n. 1 and in accordance with the Collaboration rules, during the period of validity of the MoU, shall accept the terms in force.

For what not explicitly modified by the present Addendum n. 1, the terms and conditions of the MoU shall continue in full force and effect.

ARTICLE 4

The present Addendum n. 1 and its Annexes shall form an integral part of the FAZIA MoU.

For the CENuM:


Byungsik HONG
Director
Date: 06. Nov. 2020




For the INFN:


Antonio ZOCOLI
President
Date: 25 OTT. 2019




For the CNRS-IN2P3:


Reynald FAIN
Director
Date: 07.02.2020

For the GANIL:


Alahari NAVIN
Director
Date:

For the COPIN:


Marek JEZABEK
Director
Date: 12.03.2020

For the UHU:


Juan Alguacil Ojeda
Vice Chancellor for Research and Transfer
Date: 18.04.2020

- COPIN: Consortium of Polish Governmental and Public Institutions, Polish Academy of Sciences
- UHU: University of Huelva

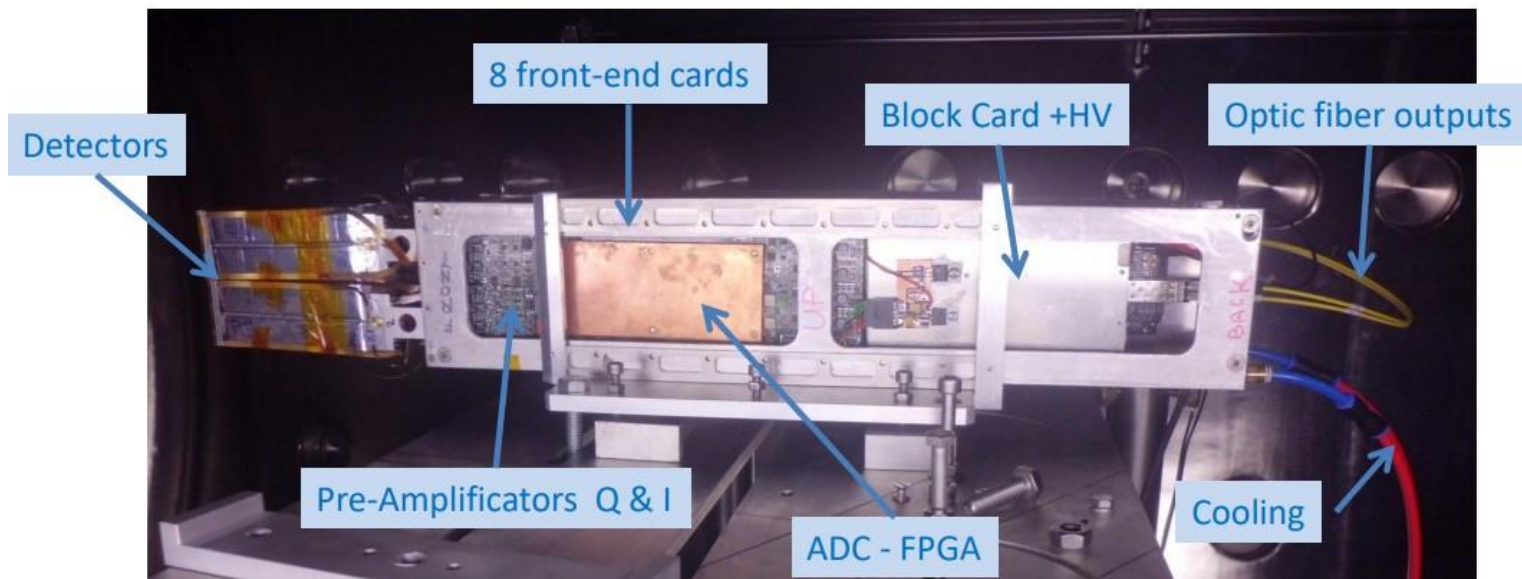
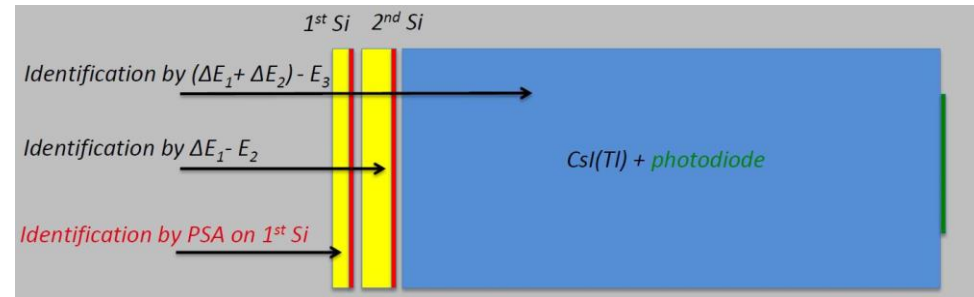
FAZIA 101

- A charged-particle detector for heavy-ion collision studies at intermediate beam energies
- Collaboration status
 - 5 countries (France, Italy, Korea, Poland, Spain)
 - ~30 physicists & ~10 students



FAZIA 101

- One FAZIA block consists of 16 Si₁+Si₂+CsI telescopes with a cross-sectional area of 2X2 cm².
 - Si₁ (nTD): 300 μm thick
 - Si₂ (nTD): 500 μm thick
 - CsI: 10 cm thick, photodiode readout
 - Dedicated digital electronics with optical fiber outputs
 - Units of 8 FEE cards are cooled under vacuum



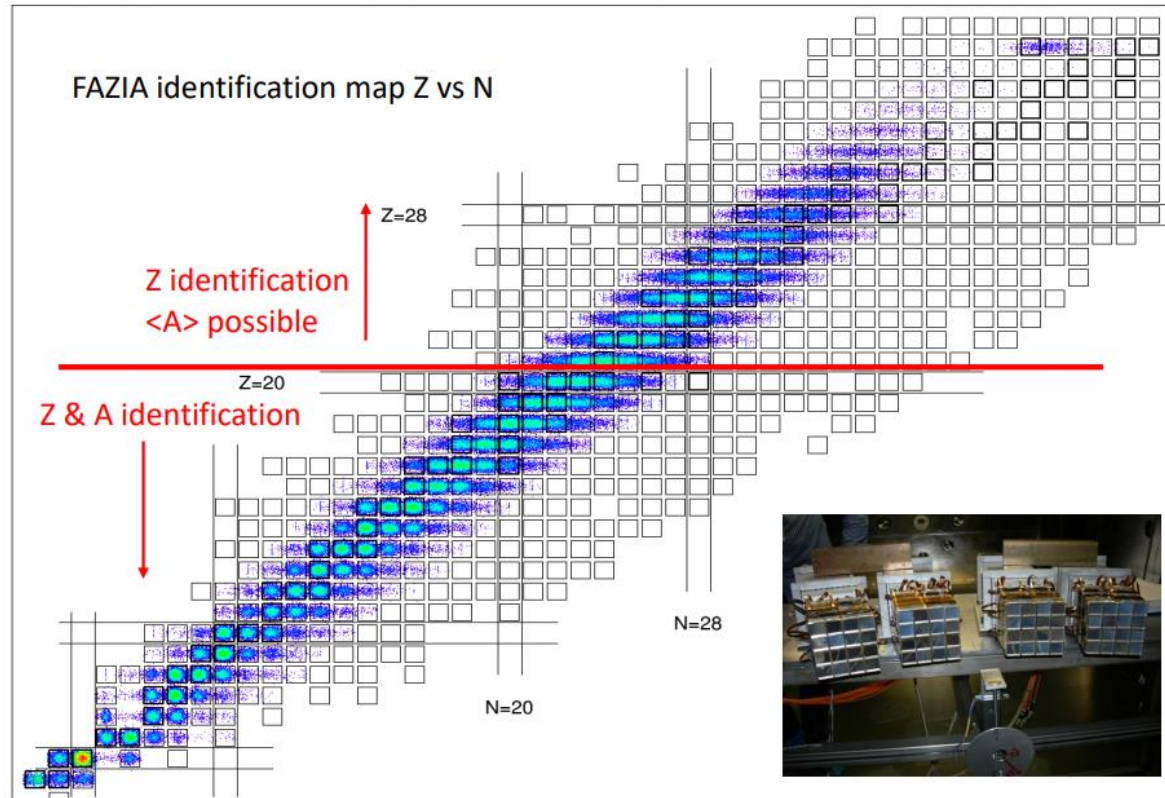
FAZIA 101

- FAZIA isotope identification map

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

The FAZIA block is the result of > 10 years of R&D into pushing the limits of the $\Delta E - E$ technique with

- highly uniform (in thickness and doping) Si detectors,
- refining Pulse-Shape Analysis (PSA) techniques for identification in a single detector,
- a dedicated on-board electronics comprising both analogue (pre-amplifier) and digital stages.



- FAZIA has a good isotopic resolution for charged particles produced in heavy-ion collisions at the beam-energy range from 15 to 100 A MeV, which is mandatory for the future radioactive ion beam experiments.

FAZIA 101

- Scientific goal
 - Detailed understanding of the nuclear Equation of State (EOS) and constraining the nuclear symmetry energy for both microscopic (nuclei) and macroscopic (neutron stars) objects
- Recent experiments
 - E789 (data taking was completed in 2019): Isospin transportation and the density dependence of the symmetry energy
 - E818 (data taking was finished at 6:00 this morning): Characteristics of the warm dense nuclear matter in low-density region
- Future
 - Extended identification capability
 - Flexible installation scheme in the limited space of vacuum chamber
 - Application of the modern technology to detectors and FEE
 - Larger acceptance: Plan to increase the number of FAZIA blocks manufactured in different locations in Europe and Korea for more comprehensive measurements, etc.

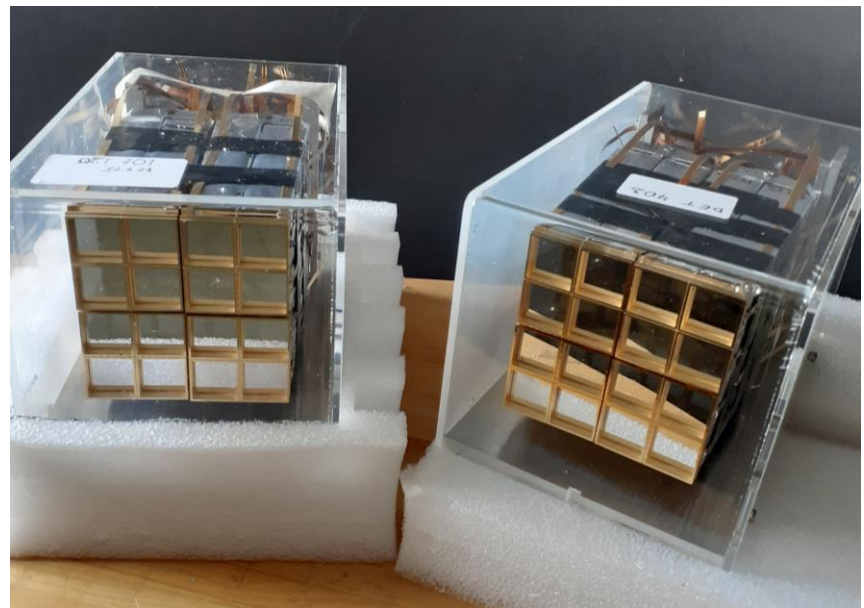
FKPPL Collaboration in FAZIA focuses on (but not limited to) the future improvement.

FKPPL in FAZIA

French group			Korean group		
Name	Position	Lab./Institute	Name	Position	Institute
Leader: Le Neindre, Nicolas	CR	LPC Caen CNRS IN2P3 & University	Leader: Hong, Byungsik	Professor	Korea University & CENuM
Bonnet, Eric	CR	Subatech Nantes CNRS IN2P3	Kweon, Minjung	Professor	Inha University & CENuM
Borderie, Bernard	Emeritus	IPNO Orsay CNRS IN2P3 & University	Park, Jonghan	PostDoc	Inha University, Korea University & CENuM
Bougault, Rémi	DR	LPC Caen CNRS IN2P3 & University	Nam, Seon Ho	Student	Korea University & CENuM
Chbihi, Abdou	DR	GANIL	Park, Jeonghyeok	Student	Korea University & CENuM
Fable, Quentin	Postdoc	L2IT Toulouse CNRS IN2P3	Kim, Giyoung	Student	Inha University & CENuM
Frankland, John	CR	GANIL	Hahn, Kevin Insik	Professor	IBS & Ewha Womans University
Genard, Tom	Student	GANIL	Kim, Sunji	PostDoc	IBS
Gruyer, Diego	CR	LPC Caen CNRS IN2P3 & University			
Lemarié, Julien	Student	GANIL			
Lopez, Olivier	DR	LPC Caen CNRS IN2P3 & University			
Rebillard, Alex	Student	LPC Caen CNRS IN2P3 & University			
Vient, Emmanuel	EC	LPC Caen CNRS IN2P3 & University			

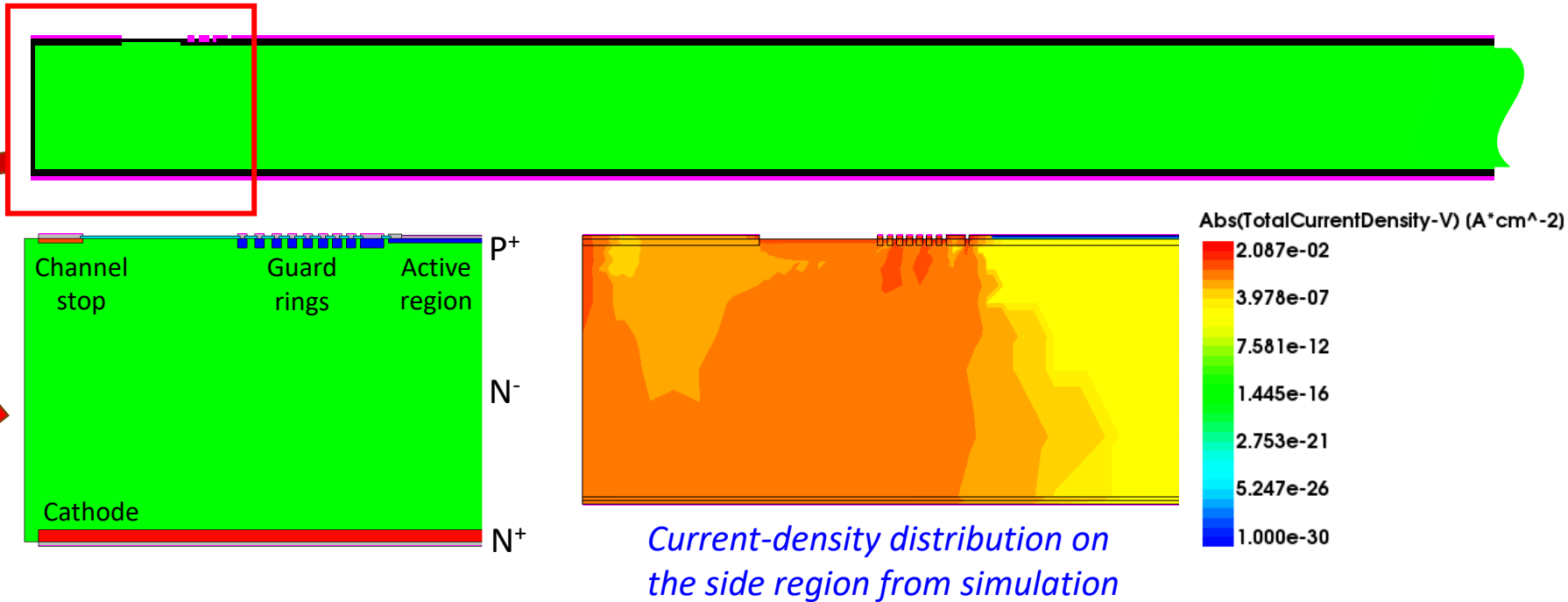
FKPPL in FAZIA

- Development of new Si detectors
 - Collaboration produced 750 μm thick detectors
 - Wafers supplied by the Korean group
 - Processed by CiS, the private company in Germany (The cost was shared by France, Italy, and Korea.)
 - Assembled by the Italian (INFN @ Florence) group
 - Installed by French (GANIL) group in the inner most modules for the beam test during the E818 experiment



FKPPL in FAZIA

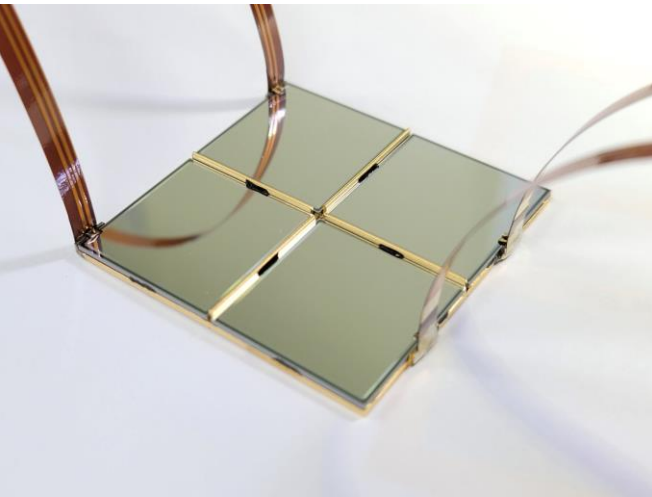
- Design and construction of the new thick Si detectors



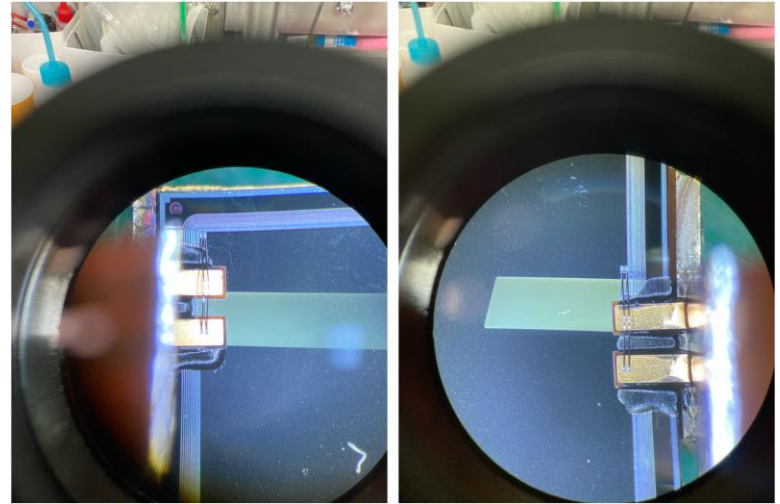
- The detailed structure, dimensions, and doping profiles are finalized by intense simulations with helps from the experts in the Dept. of Electrical Engineering.
- Low total current, $\mathcal{O}(10 \text{ nA})$, is expected in the working-voltage range.
- Si wafers will be processed at ETRI & NNFC in Korea ($750 \mu\text{m} \rightarrow 1 \text{ mm}$ thickness).
- If successful, the next step is to design and produce the $150 \mu\text{m}$ thick detectors.

FKPPL in FAZIA

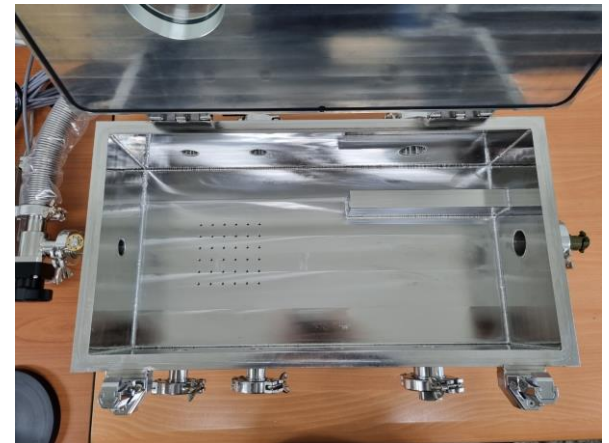
- Detector assembly
 - Chip mounting & wire-bonding



- Wire-bonding flexi-cables to the Si-chip pad
- ↓ Lab. testing system is in preparation at Inha University.



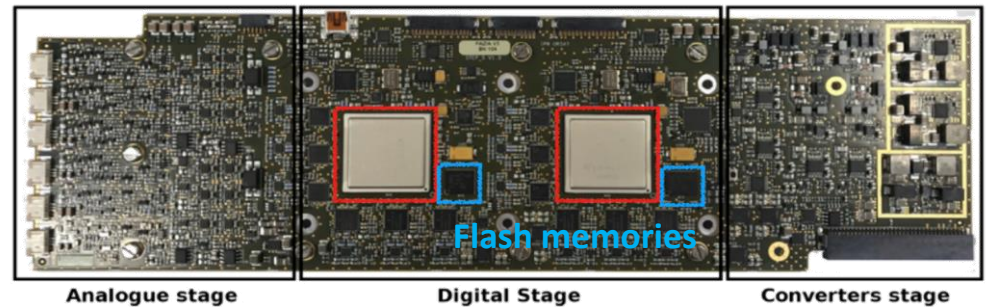
- ↑ First product of quartetto
 - Used 750 μm chips previously processed by CiS
 - Chip mounting (gluing), wire-bonding done by the Korean company (MEMSPACK)



FKPPL in FAZIA

- Development of the new FEE card
 - Two prototype FEE cards produced by the Korean company (NOTICE).
 - Original schematics were provided by the FAZIA Collaboration.
- Several changes were applied for more effective functioning.
- Some components are outdated.
 - FPGA: Virtex-5 → Kintex-7
 - Uploading method of the VHDL bit files to FPGAs : 2 flash memories → 1 flash memory & CPLD
 - + many other modifications
- Major modification of VHDL code to adopt the changes in the new prototype FEE card

FAZIA / FEE(Front-End Electronics) Old Card



The FAZIA setup. NIMA. Volume 930. 2019. Pages 27-36

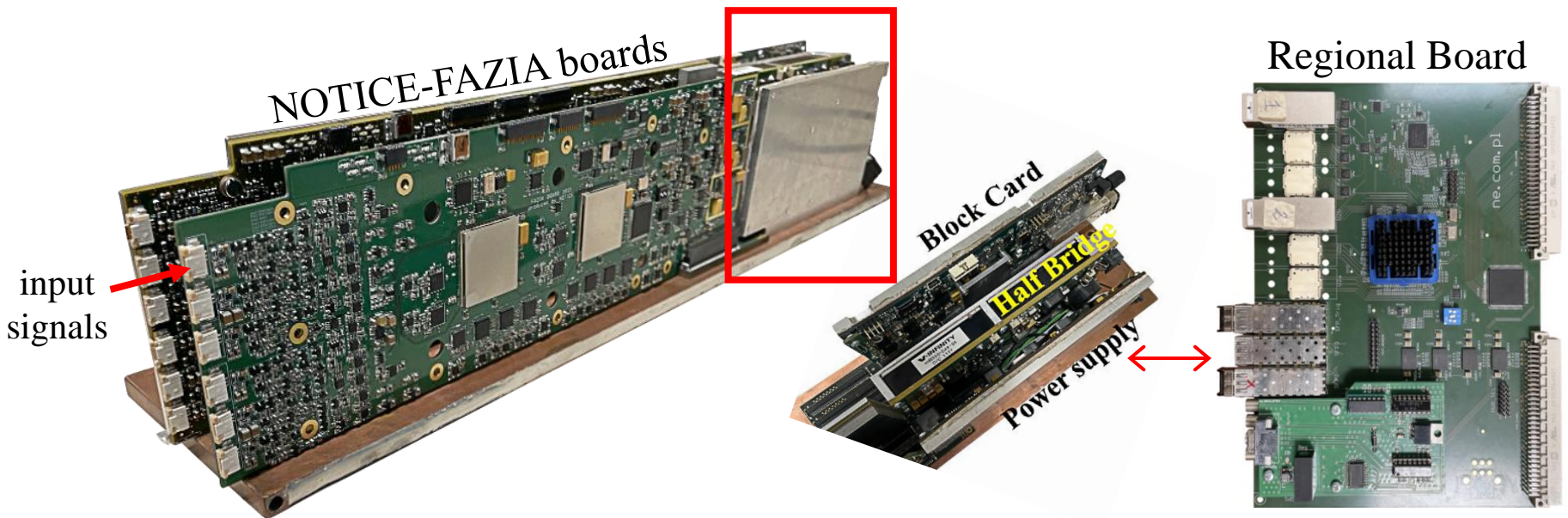


FAZIA / FEE(Front-End Electronics) new card



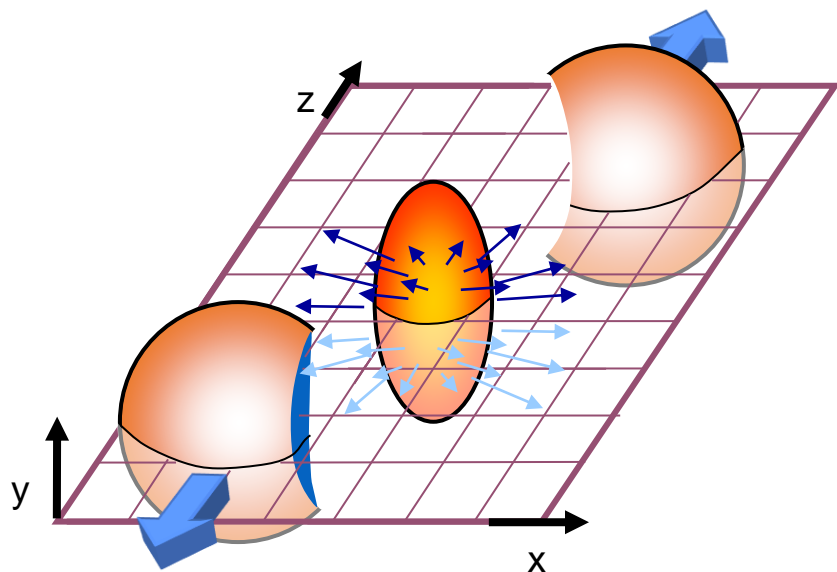
FKPPL in FAZIA

- Development of the new FEE card
 - Two prototype FEE boards were brought to GANIL on May 4 for further test.
 - New board installed on the electronics frame that contains block card, half-bridge and power supply.
 - Block card retrieves all the data from FEE and builds a partial event.
 - Block card communicates with the spare regional board, which takes care of event building.



FKPPL in FAZIA

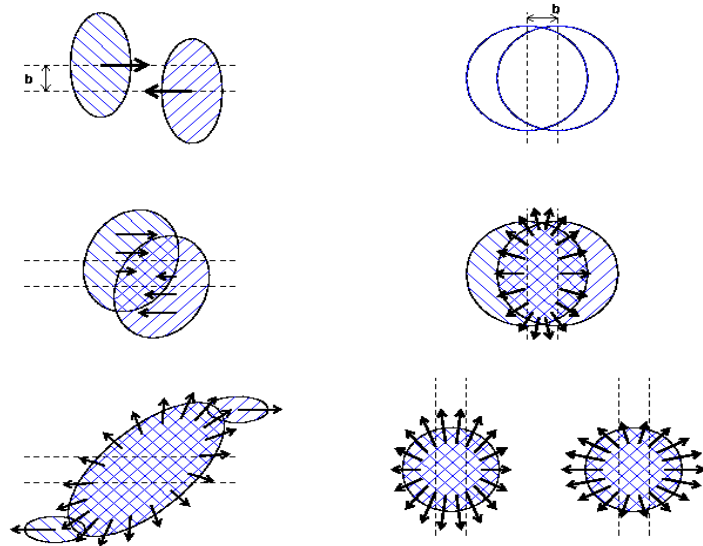
- Data analysis
 - Collective flow using the INDRA data
 - $^{129,124}\text{Xe} + ^{124,112}\text{Sn}$ @ 100 A MeV
 - $N/Z=1.43, 1.39, 1.32, 1.27$



Reaction plane

Transverse plane

time ↓



Directed (Sideward) flow

$$v_1 < 0 \quad v_1 > 0$$

$$v_1 = \langle p_x / p_t \rangle$$

Elliptic flow

$$v_2 < 0 \quad v_2 > 0$$

$$v_2 = \langle (p_x^2 - p_y^2) / p_t^2 \rangle$$

No approved results yet to show!

$$\frac{d^3 N}{p_t dp_t dy d\phi}$$

$$\propto 1 + 2v_1 \cos(\phi) + 2v_2 \cos(2\phi) + \dots$$

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

Summary

- The specific goal of FKPPPL for the FAZIA collaboration has been well defined.
- Active collaboration between Korea and Europe (France + Italy +...) is being performed on the developments of new **Si detectors** and new **FEE cards** and the **data analysis** on the collective flow of nuclear matter.
- The Korean group plans to duplicate **some FAZIA blocks in Korea with Korean technologies**. (FAZIA Collaboration will fully support this effort.)
- We will pursue the **analysis of the INDRA-FAZIA data** to understand the nuclear equation of state and symmetry energy at intermediate energies.
- **FAZIA will use the detector blocks constructed in Korea in the commissioning phase of RAON. Later, FAZIA can also use the Korean blocks for the RIB experiments not only at RAON but also at GANIL & other accelerator facilities.**
- **Because of COVID19, travel to either country was not possible for the last ~2 years. But the Korean group, finally, visited GANIL in April and May this year and participated in the E818 experiment.**
 - We will actively exchange the researchers for FAZIA for the detector developments, experiments, analyses, and meetings in the future.

The FKPPPL Collaboration in FAZIA is extremely beneficial to both sides!

Merci Beaucoup.

どうもありがとうございます。

대단히 감사합니다.

Thank you very much.