French-Korean Collaboration for FAZIA experiment

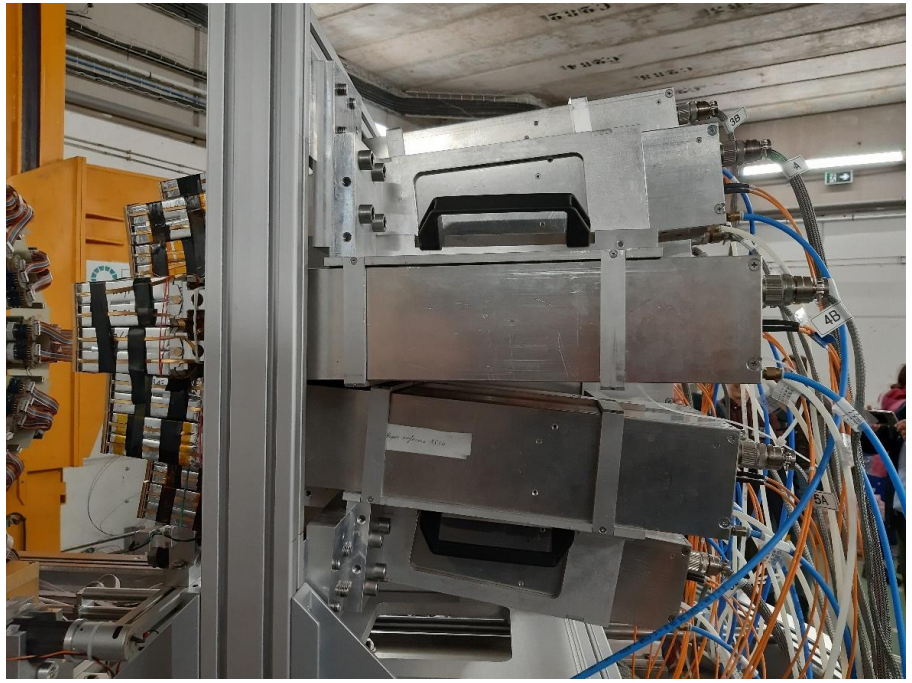
Byungsik Hong (Korea University)
&
Nicolas Le Neindre (LPC Caen)
for
FKPPN-FAZIA-FKC

Brief history of French-Korean Collaboration

- Before 2019:
  - The Korean group (part of LAMPS Collaboration) was designing the Si-CsI telescope 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.
    - For RAON the stage 1 for low-energy facility was completed, and R&D of the superconducting cavities for high-energy facility is in progress.
  - The International Advisory Committee of RAON reviewed the status of the detector development and recommended to collaborate with FAZIA in Europe, because FAZIA had been operating the most advanced Si-CsI detector system for nuclear physics.
  - We started the discussion with some FAZIA members to join the Collaboration in various meetings.
- In 2019
  - A group of Korean researchers visited GANIL in May and participated in the FAZIA experiment (E789).
  - Three professors (B. Hong @ Korea Univ., M. Kweon @ Inha Univ., I. Hahn @ Ewha Womans Univ.) attended the FAZIA Workshop at GANIL in September 2019 and presented the application to officially join the Collaboration.
- MoU
  - The Center for Extreme Nuclear Matters (CENuM), representing the whole Korean group, signed on the MoU in 2020.
  - A new MoU was signed for 2023-2027.

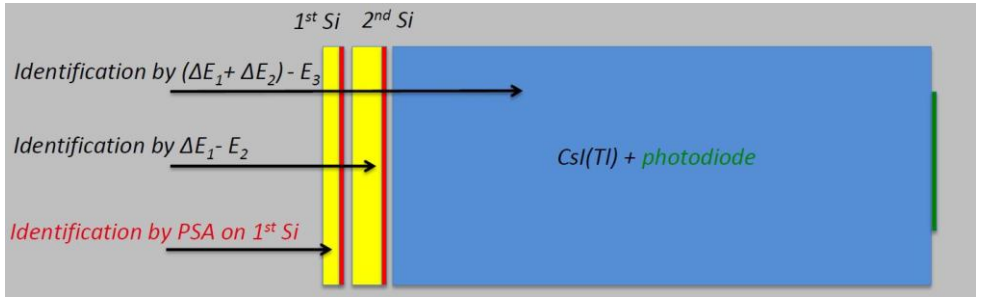
Introduction to FAZIA

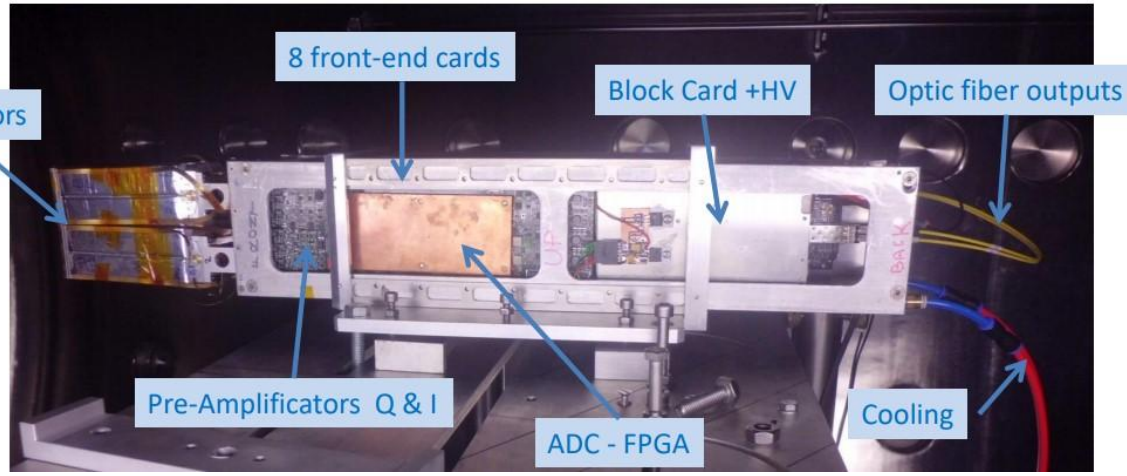
- FAZIA detector system
  - Charged-particle detector system for heavy-ion collisions at intermediate beam energies
  - Presently located at GANIL
- Collaboration status
  - 5 countries (France, Italy, Korea, Poland, Spain)
  - ~30 physicists & ~10 students

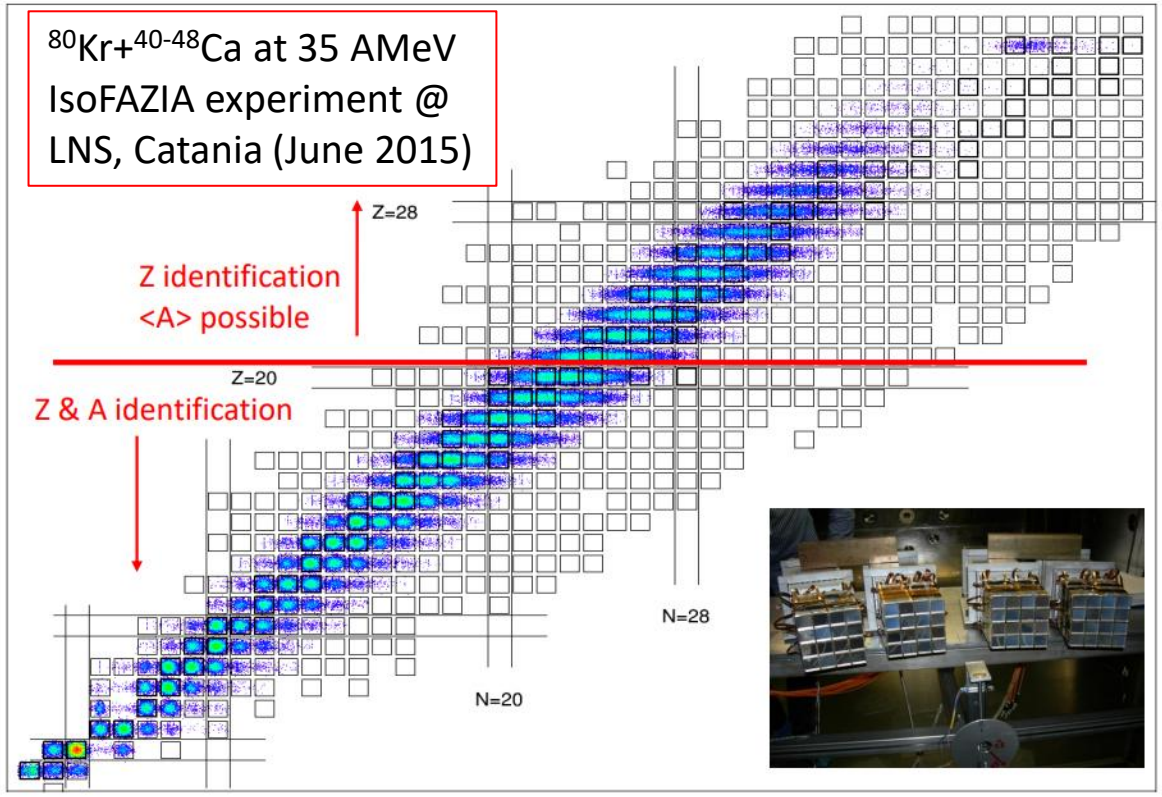


Introduction to FAZIA

- One FAZIA block consists of 16 Si_1+Si_2+CsI telescopes (Area of each telescope: 2X2 cm^2)
  - Present configuration: Si_1(nTD) 300 μm thick, Si_2(nTD) 500 μm thick, CsI 10 cm thick (PD readout)
  - Refining Pulse-Shape Analysis (PSA) techniques for identification in a single detector
  - Excellent isotopic resolution for charged particles in heavy-ion collisions at the beam-energy range from 15 to 100 AMeV, which is mandatory for the radioactive ion beam experiments.

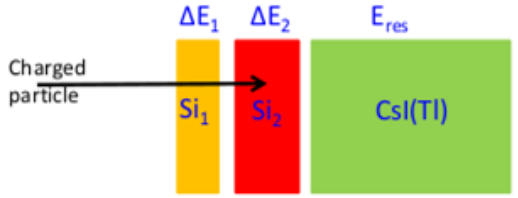


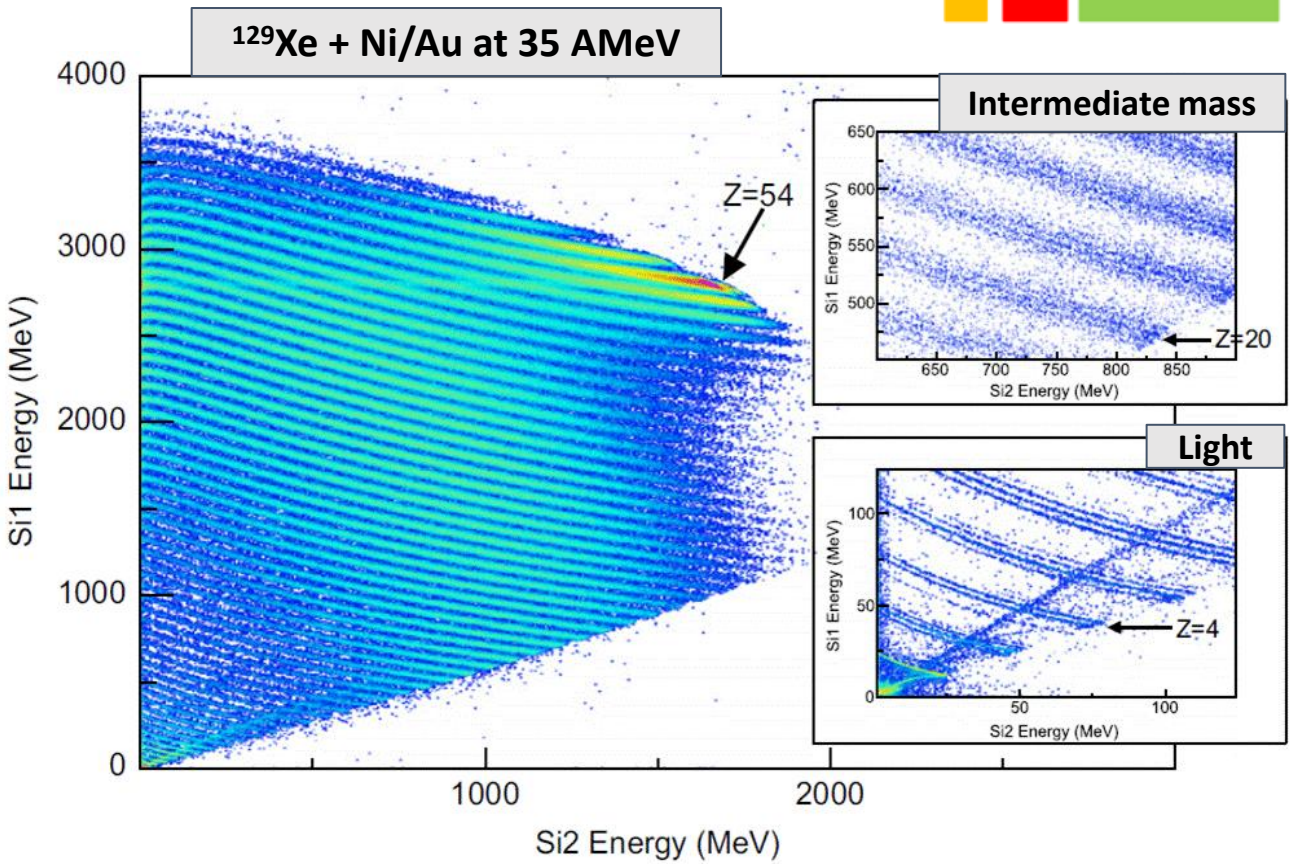


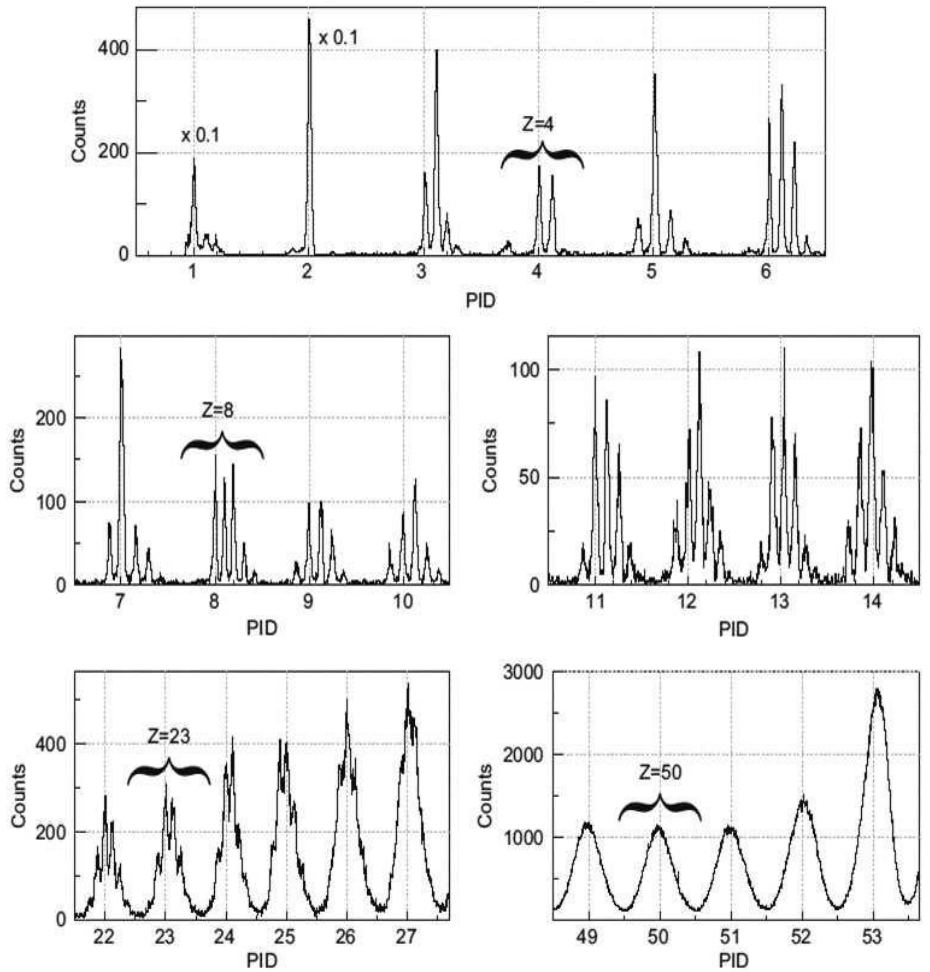


Introduction to FAZIA

- PID: EPJA 50, 47 (2014)







- Mass discrimination up to $Z\sim23$ and charge identification up to $Z\sim54$

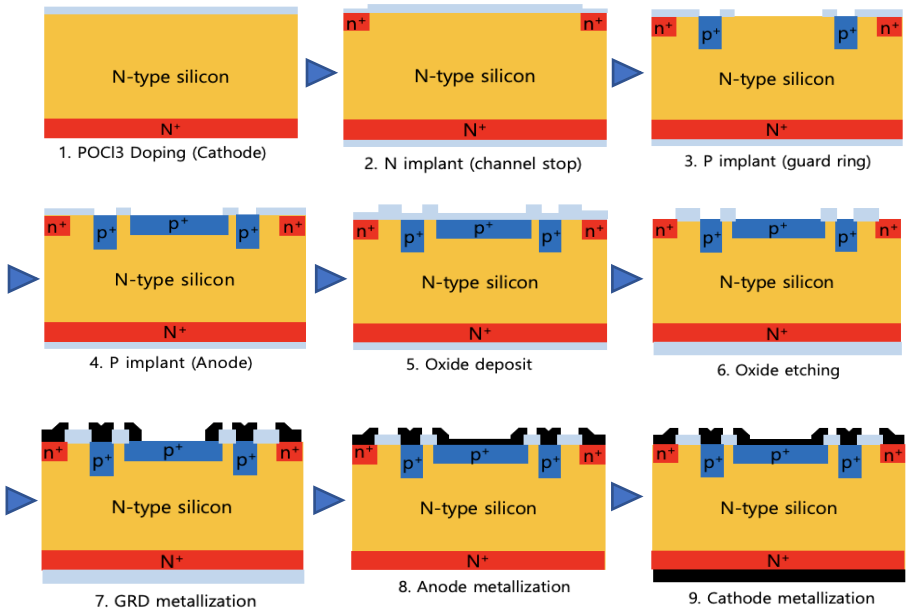
Introduction to FAZIA

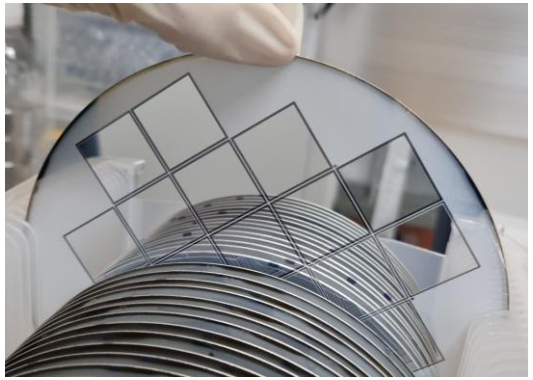
- Scientific goal
  - Detailed understanding of the nuclear Equation of State (EOS) and symmetry energy for both microscopic (nuclei) and macroscopic (neutron stars) objects

- Plan in terms of the detector development
  - Extension of the applicable beam energy range using thinner and thicker Si sensors
  - Application of the modern technology to the next generation detectors and FEE cards
  - Manufacturing more FAZIA blocks in Korea, especially, for the experiments at RAON
  - (Long-term future project) Exploration of the flexible installation scheme in the limited space of vacuum chamber

Development of Si sensors

Part of the Si sensor process flow





Wafer processing (by ETRI)

Thinning (by TRinno Tech) & dicing (by MEMSPACK)

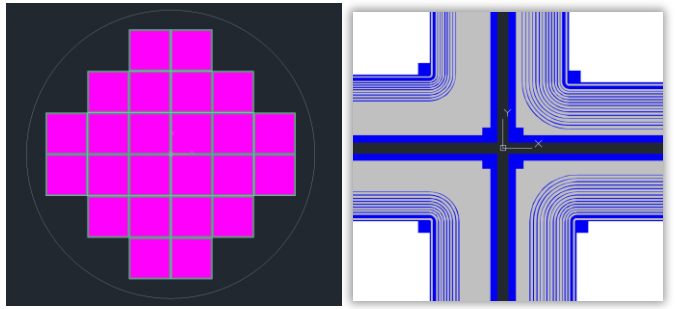
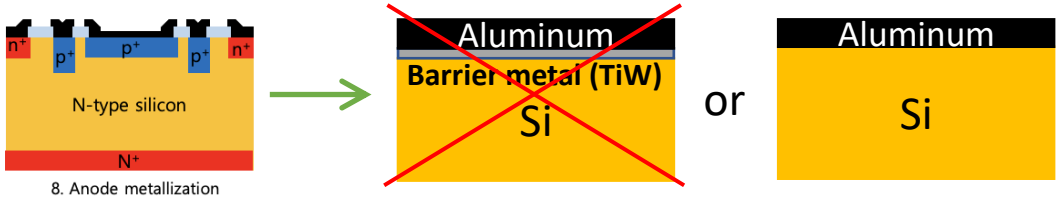
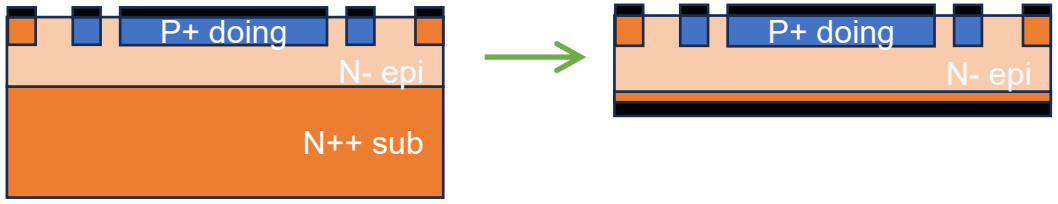


Photo mask (by MicroImage): Tested various guard ring patterns & different sensor designs

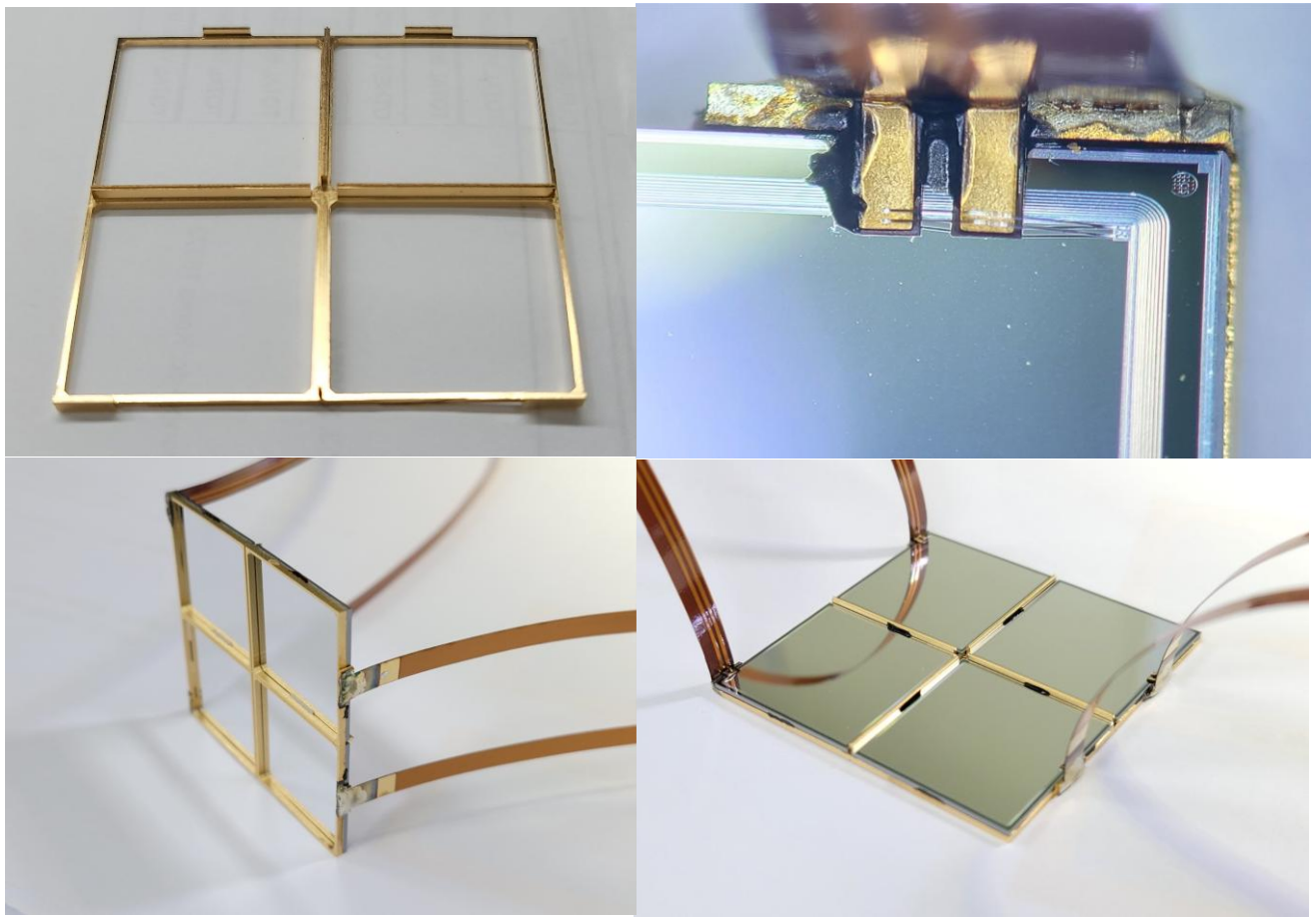
Barrier metal effect for thick (750 µm) sensors



Thinning of epitaxial wafer for thin (115 µm) sensors

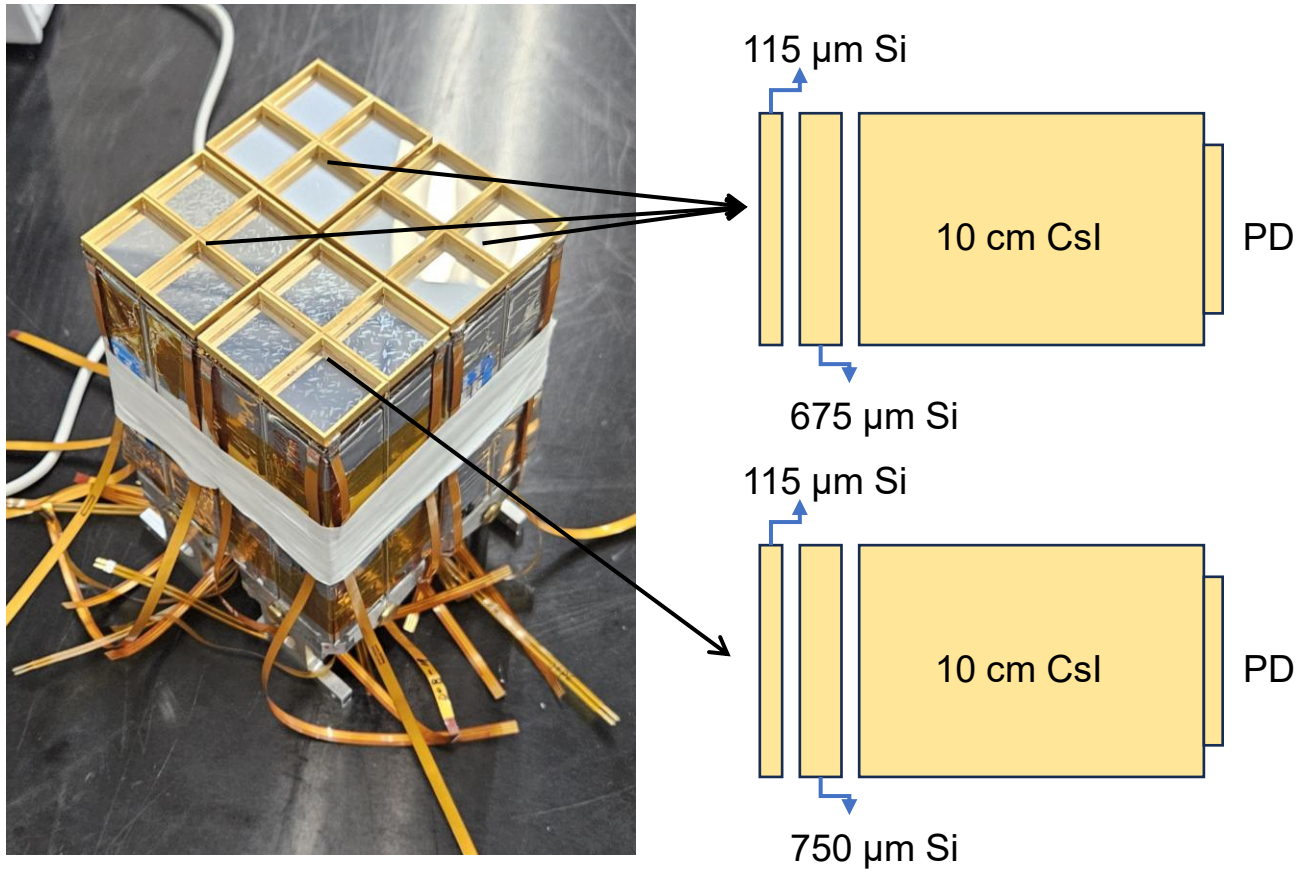


Assembly



- Chip assembly for a quartetto
  - Four chips are mounted in one quartetto frame.
  - Backside of the sensor is connected to ground.
  - Wire-bonding connection to apply the reverse-bias voltage to the sensors
  - Assembly was carried out in collaboration with MEMSPACK, a local company in Korea.

Assembly



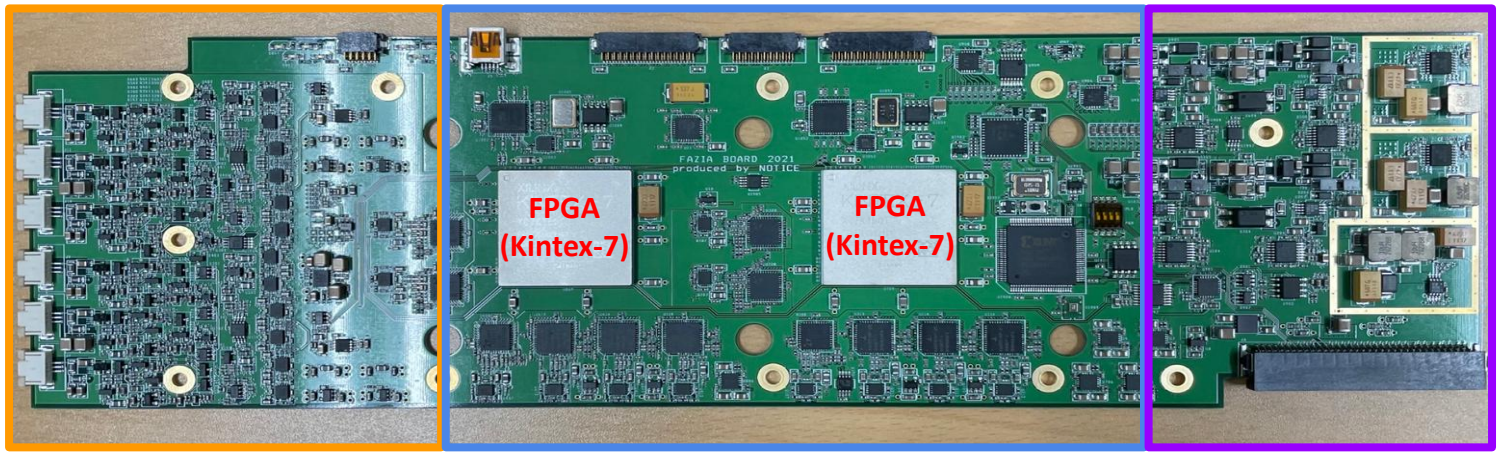
Quartetto assembly

- Four quartettos are assembled into a block detector.
- Si sensors
  - Si_1 :
    t = 115 μm, V_{bias} = 65 V
  - Si_2 (3 quartettos) :
    t = 675 μm, V_{bias} = 190 V
  - Si_2 (1 quartetto) :
    t = 750 μm, V_{bias} = 400 V
  - Energy resolution: ~0.6% (in junction side)
- CsI
  - Supplied by INFN-Firenze
  - Energy resolution: ~10% measured by stand-alone setup using ^{241}Am source

New front-end electronics cards

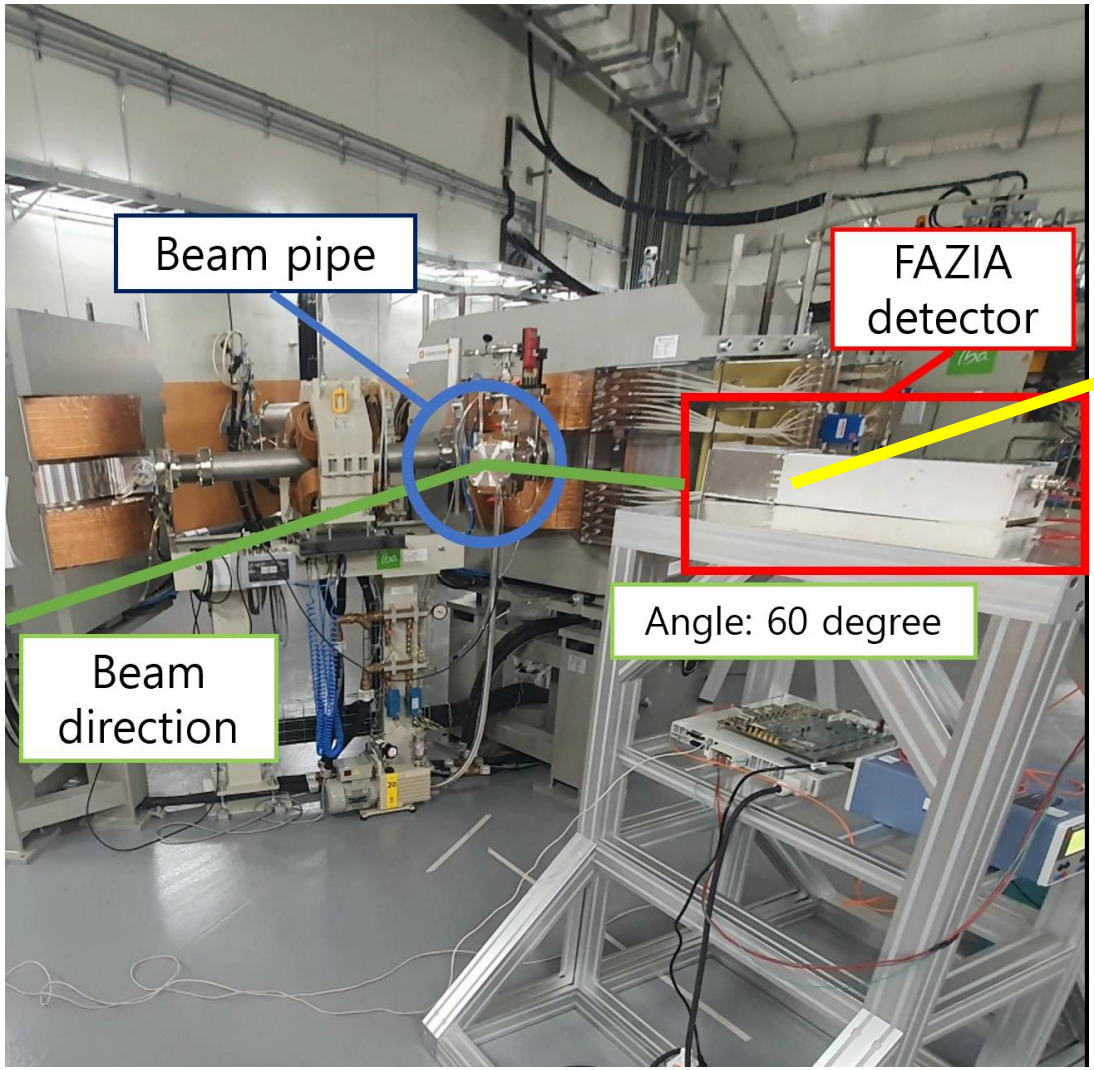
- New FEE cards development in collaboration with NOTICE, a local vendor
  - We started with the original schematics for the FEE design provided by FAZIA.
  - Out-of-dated digital parts are replaced, e.g., Vertex-5 → KINTEX-7 for FPGA.
  - Development of the new VHDL firmware for new FPGA chips
  - Two prototype FEE cards were tested their performance at GANIL and INFN-Firenze.
  - They were also tested with beams at CNAO, Italy in 2024, which validated for further production.
  - Total 55 FEE cards, which must be enough for four blocks, were manufactured.

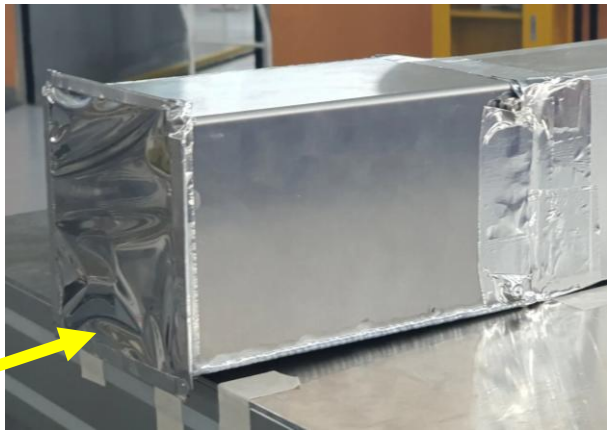
Prototype FEE card

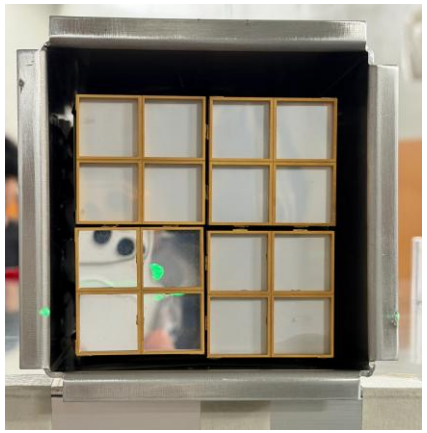


- **Analog part**:
  To amplify analog signals from the detector
- **Digital part**:
  Signal processing (analog to digital conversion)
- **Conversion part**:
  Power distribution
  Application of bias voltage

Proton beam test at RAON



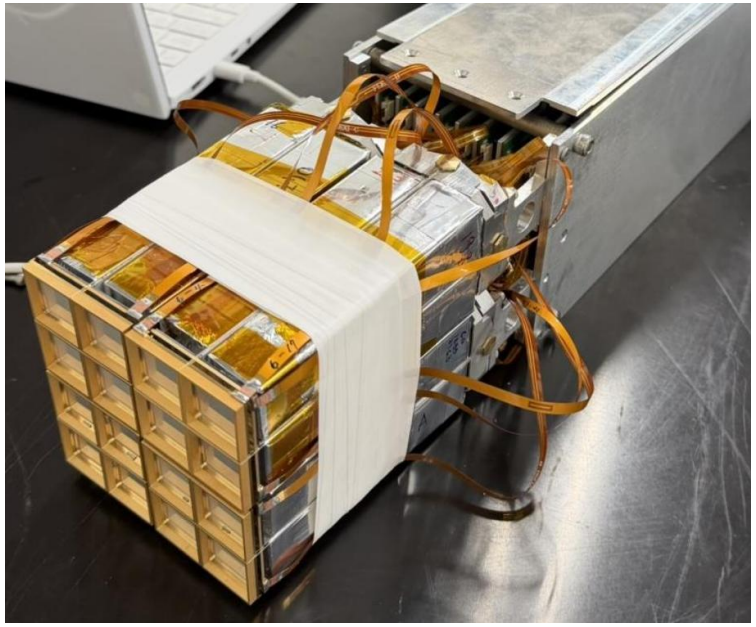


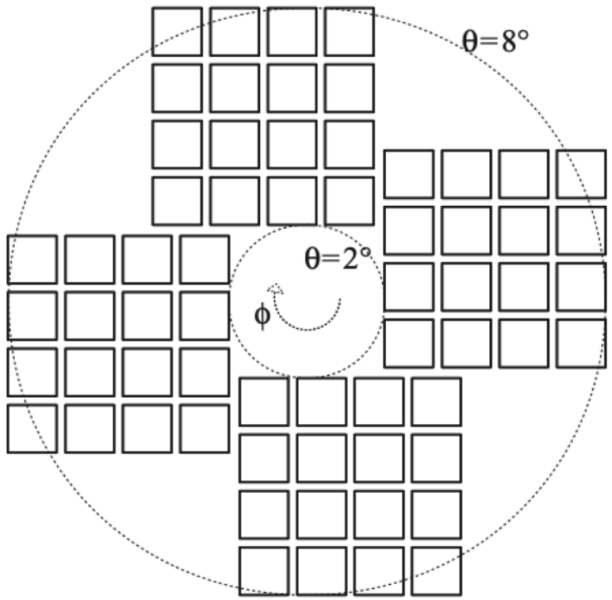


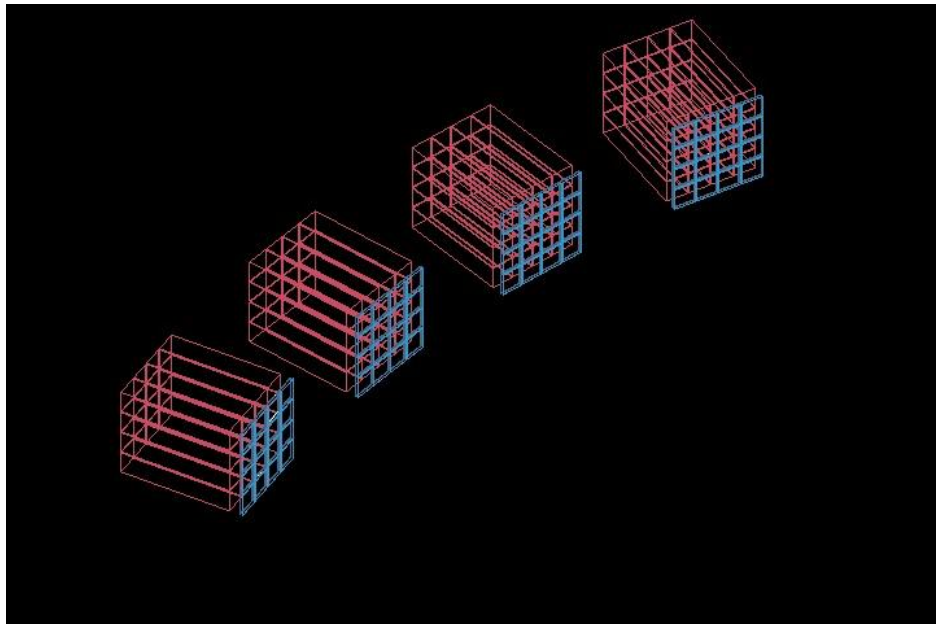
- The first FAZIA block built in Korea was tested using the proton beams at RAON.
- Beamtime: 10 - 11 February 2026
- Beam energy: 40 ~ 70 MeV (10 MeV step)
- Beam current: 30 nA
  - The minimum beam current for stable operation of cyclotron was ~10^{14} pps, but we asked to decreased the intensity as low as possible not to risk the detector.
  - Event rate: ~250 events/s

Future

- [ ] Construction of total 4 blocks by the end of this year
- [ ] Another test with protons beams at RAON is scheduled in 21-22 Sep. 2026.
- [ ] Next step is to test the FAZIA blocks produced in Korea using the ion beams
- [ ] Finally, we would like to have some physics runs at RAON and GANIL.







Summary

- The French-Korean Collaboration is well underway in FAZIA.
  - We have produced the prototype Si sensors with the thickness of 115, 675 and 750 μm and tested them with source.
  - We have successfully developed the new front-end electronics card and produced total 55 of them.
  - The performance test of the first K-FAZIA block was done using the proton beams at RAON: The data analysis is in progress.
- Plan for 2026-2027
  - Construction of three additional FAZIA blocks in Korea
  - Finishing the analysis for the first beam test
  - Second beam test of the K-FAZIA blocks at RAON in September 2026
  - Publication of the data analysis results for collective flow