TRACE ancillary: a highly-segmented silicon-pad detector for light charged particles emitted in direct nuclear reactions

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Outline

1. Introduction

2. TRACE simulation and design
   - Estimations, simulation and performances evaluation
   - Signals induced in silicon

3. Experimental tests
   - In beam test: silicon ancillary coupled to the AGATA cluster
   - Detector & electronics (NIM, ASIC) tests

4. Conclusion
Introduction

New challenges in nuclear structure

Shell structure in nuclei
- Structure of doubly magic nuclei
- Changes in the interactions

Proton drip line and N=Z nuclei
- Spectroscopy beyond the drip line
- Proton-neutron pairing
- Isospin symmetry

Shape coexistence

Transfermium nuclei

Nuclear shapes
- Exotic shapes and isomers
  - Coexistence and transitions

Neutron rich heavy nuclei
- Large neutron skins \( (r_{\gamma}-r_{\pi} \rightarrow 1\text{fm}) \)
- Shell quenching

Nuclei at the neutron drip line
- Very large proton-neutron asymmetries
- Neutron Decay
Introduction

Instrumentation: $\gamma$-spectrometers
Introduction
Instrumentation: ancillaries used in conjunction with $\gamma$-spectrometers

Selectivity improvement and background reduction

DANTE
MUST2
TIARA
PRISMA
EUCLIDES
MICROBALL
Introduction

Suitable reactions

Direct nuclear reactions

in inverse kinematics to measure the angle of the recoiling light particle.

... Fusion-evaporation reactions

to measure energy and angle of the recoiling light particle with ancillary detectors coupled with gamma arrays.
Suitable reactions

Direct nuclear reactions in inverse kinematics to measure the angle of the recoiling light particle.

... Fusion-evaporation reactions to measure energy and angle of the recoiling light particle with ancillary detectors coupled with gamma arrays.
Design criteria

Guidelines

- **Material**  Transparency, energy resolution, properties, costs
- Particle discrimination technique
- Segmentation
- Efficiency
- Pad (or strips)
- $4\pi$ detector
Design criteria

Guidelines

- Material
- Particle discrimination technique \( E-\Delta E, \text{ thickness} \)
- Segmentation
- Efficiency
- Pad (or strips)
- \( 4\pi \) detector
Design criteria

Guidelines

- Material
- Particle discrimination technique
- **Segmentation** Angular resolution
- Efficiency
- Pad (or strips)
- \(4\pi\) detector
Design criteria

**Guidelines**

- Material
- Particle discrimination technique
- Segmentation
- **Efficiency** Solid angle coverage, low energy threshold
- Pad (or strips)
- $4\pi$ detector
Trace simulation and design

Experimental tests

Conclusion

Summary

Acknowledgements

Design criteria

Guidelines

- Material
- Particle discrimination technique
- Segmentation
- Efficiency
- Pad (or strips) - Sizable number, heat dissipation, energy resolution
- $4\pi$ detector
Design criteria

Guidelines

- Material
- Particle discrimination technique
- Segmentation
- Efficiency
- Pad (or strips)

$4\pi$ detector Reaction kinematics
Simulation: framework
Event generator, radiation interaction, filter (PSA, tracking), data collection (matrices and spectra)
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Simulation: framework
Event generator, radiation interaction, filter (PSA, tracking), data collection (matrices and spectra)
Starting point: improvement of the EUCLIDES Si ball;
Next steps: increase segmentation and solid angle coverage without losing in simplicity (barrel, end-caps).
Transparency

- **Full-energy eff.** probability to detect the total energy of any emitted photon individually
- **Peak-to-total ratio**: the ratio of full energy efficiency to the total interaction efficiency.
Doppler correction

TRACE8

Doppler broadening

- uncertainty in the photon emission angle
- uncertainty in the recoil energy
- intrinsic detector resolution

![Graph 1: FWHM vs Segmentation](image1)

- Transfer v/c = 6.4%
- Transfer v/c = 7.8%

![Graph 2: ∆Eγ/EG vs Angle](image2)

- ∆β = 1%
- ∆θ = 0.5°
Collecting electrodes
Rear side current signals as a function of the injected particles.
The particles are injected in the middle of the central pad.

α family

Proton family
Neighbour electrodes
Rear side, bipolar transient signals as a function of the injected particles.
The particles are injected in the middle of the central pad.
Ancillary impact
Single hit on Si, Ge cluster

- Silicon center, PSA on Ge detector
- Full information on the DSSSD, PSA on Ge detector

AGATA cluster + ancillary

49Ti Energy resolution

6.1 keV
7.7 keV
Preliminary tests: ITC-IRST detectors

300 $\mu$m, 1 mm, 1.5 mm thickness, 1x1, 2x2, 4x4 mm$^2$, low resistivity, AC coupling.

Junction side: DC, AC pad; bias and reference voltage; guard rings; “punch-through” resistance.
Preliminary tests: ITC-IRST detectors
Energy resolution with modular NIM and ASIC electronics
Conclusion

Telescope Prototype

- ASIC: quasi-parallel energy-time cycle;
- Telescope prototype closely resembles the traditional Si telescope;
- TRACE prototype key features: Si-pad technology, integrated electronics, high segmentation, PSA...
Summary

- Simple estimations
- Geometry simulation
- PSA simulation
- Ancillary impact
- Si and electronics test

⇒ telescope specifications and possible prototype.

Future perspectives:
- PSA test
- In beam test
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