

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

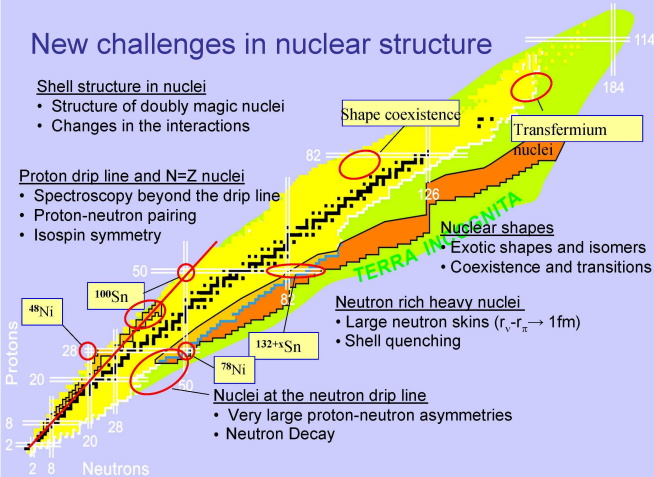
New challenges in nuclear structure

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

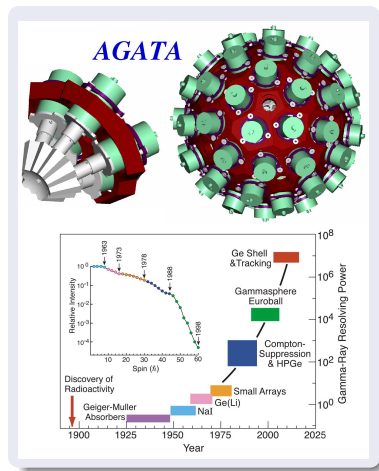
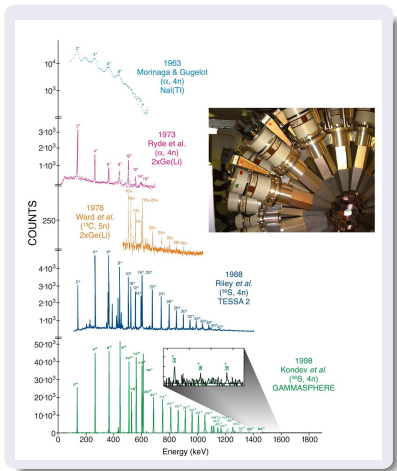
- Large neutron skins ($r_v - r_\pi \rightarrow 1\text{fm}$)
- Shell quenching

Nuclei at the neutron drip line

- Very large proton-neutron asymmetries
- Neutron Decay

Introduction

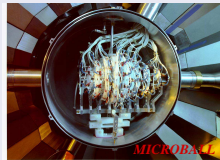
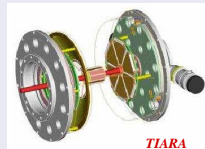
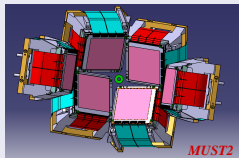
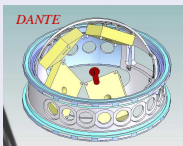
Instrumentation: γ -spectrometers



Introduction

Instrumentation: ancillaries used in conjunction with γ -spectrometers

Selectivity improvement and background reduction



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.



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Design criteria

Guidelines

- **Material** Transparency, energy resolution, properties, costs
- Particle discrimination technique
- Segmentation
- Efficiency
- Pad (or strips)
- 4π detector



Design criteria

Guidelines

- Material
- **Particle discrimination technique** $E-\Delta E$, thickness
- Segmentation
- Efficiency
- Pad (or strips)
- 4π detector



Design criteria

Guidelines

- Material
- Particle discrimination technique
- **Segmentation** Angular resolution
- Efficiency
- Pad (or strips)
- 4π detector



Design criteria

Guidelines

- Material
- Particle discrimination technique
- Segmentation
- **Efficiency** Solid angle coverage, low energy threshold
- Pad (or strips)
- 4π detector



Design criteria

Guidelines

- Material
- Particle discrimination technique
- Segmentation
- Efficiency
- **Pad (or strips)** Sizable number, heat dissipation, energy resolution
- 4π detector



Design criteria

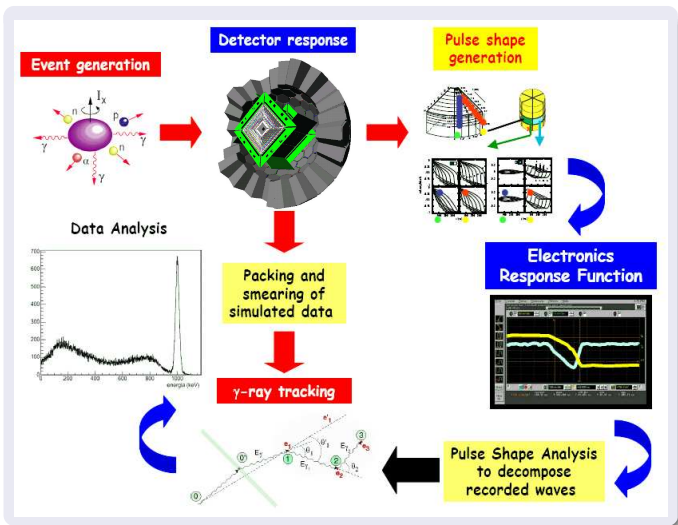
Guidelines

- Material
- Particle discrimination technique
- Segmentation
- Efficiency
- Pad (or strips)
- 4π detector Reaction kinematics



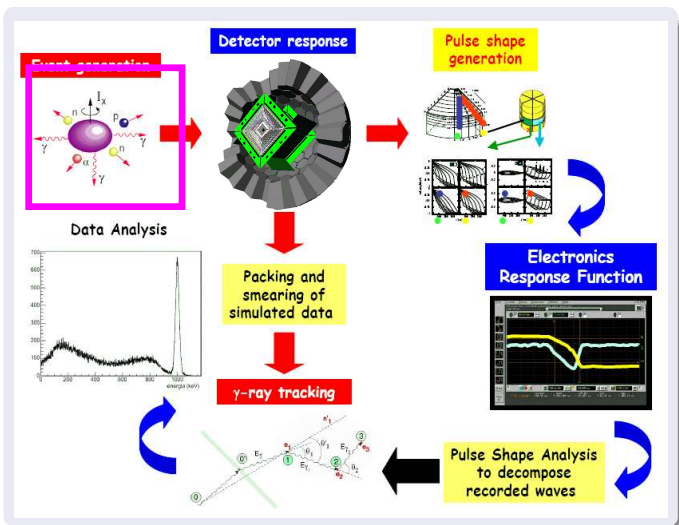
Simulation: framework

Event generator, radiation interaction, filter (PSA, tracking), data collection (matrices and spectra)



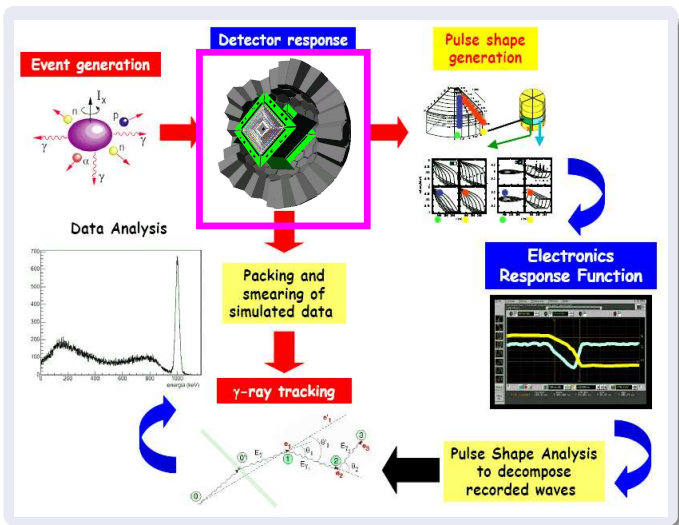
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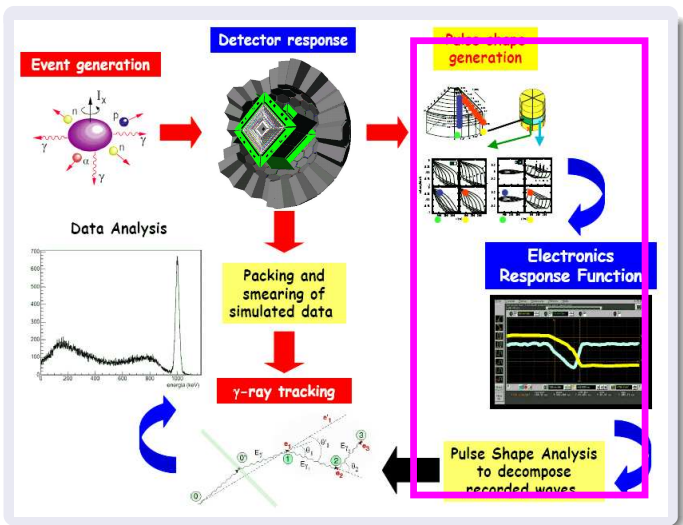
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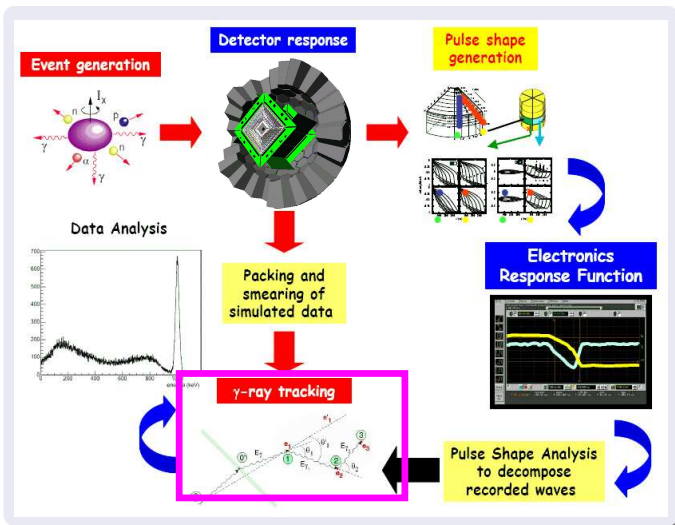
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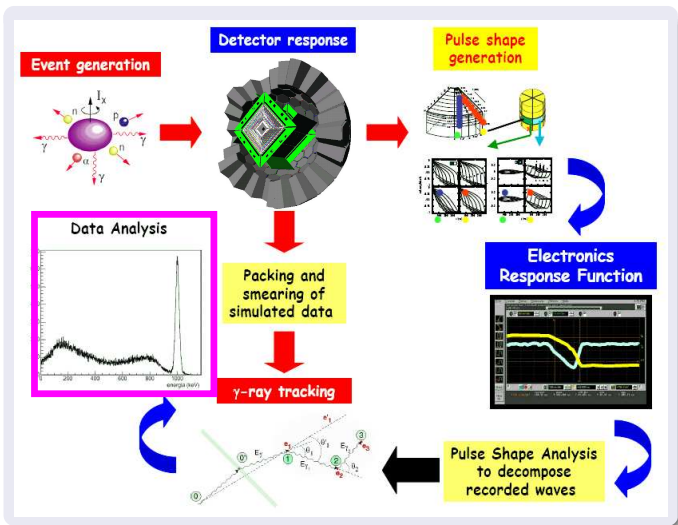
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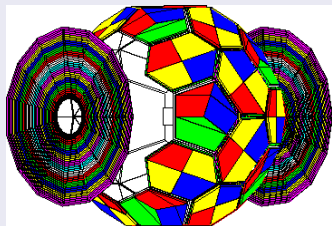


Simulation: TRACE

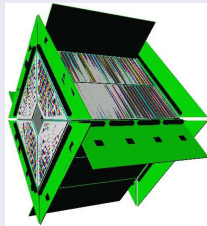
TRacking Array for light Charged particle Ejectiles

- Starting point: improvement of the EUCLIDES Si ball;
- Next steps: increase segmentation and solid angle coverage without losing in simplicity (barrel, end-caps).

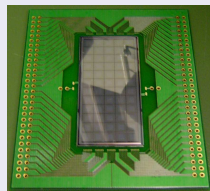
Hodoscope Euclides-like



TRACE4,6,8



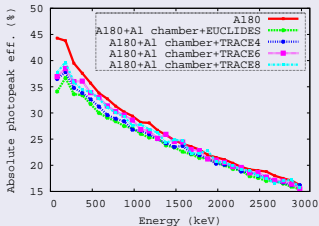
module



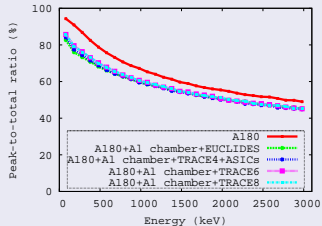
Transparency

- **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.

Absolute photopeak eff. (%)



Peak-to-total ratio (%)

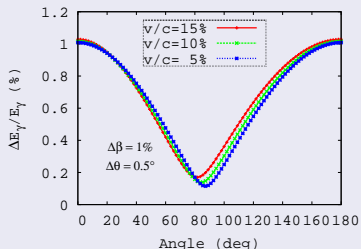
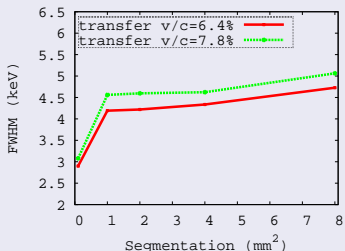


Doppler correction

TRACE8

Doppler broadening

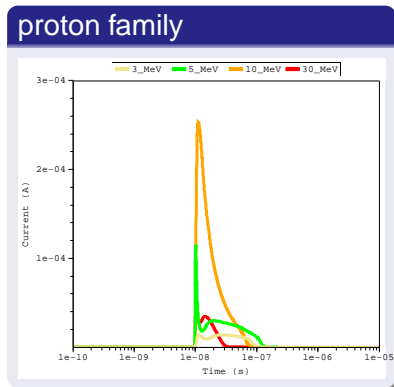
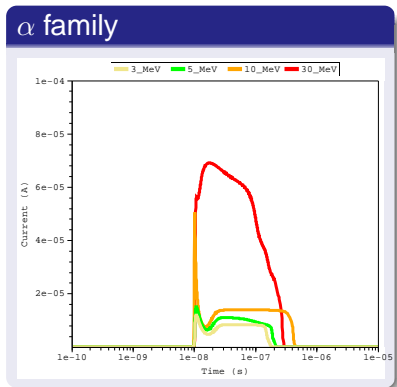
- uncertainty in the photon emission angle
- uncertainty in the recoil energy
- intrinsic detector resolution



Collecting electrodes

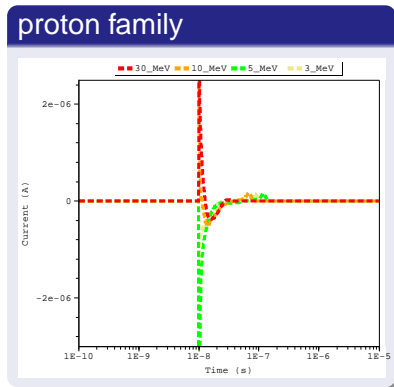
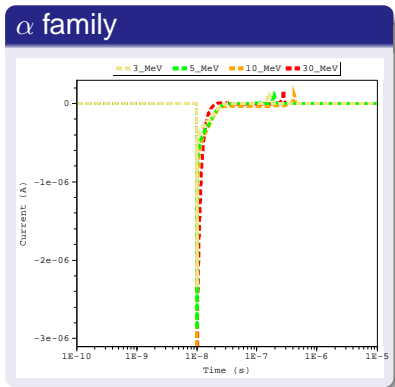
Rear side current signals as a function of the injected particles.

The particles are injected in the middle of the central pad.



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.

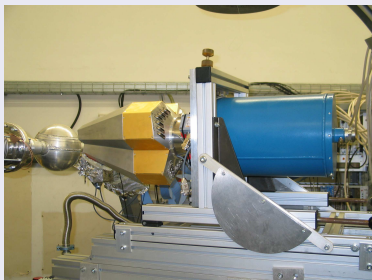


Ancillary impact

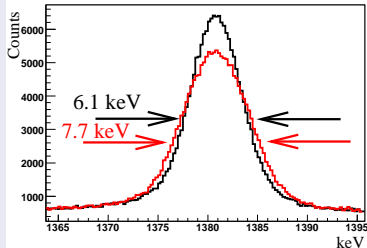
Single hit on Si, Ge cluster

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

AGATA cluster + ancillary



^{49}Ti Energy resolution

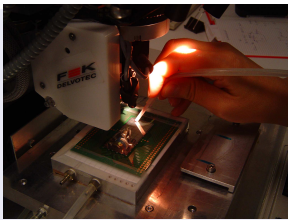
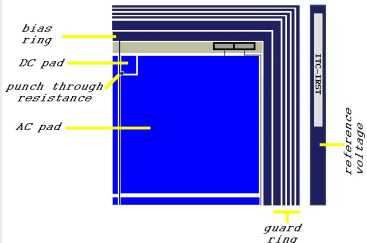


Preliminary tests: ITC-IRST detectors

300 μm , 1 mm, 1.5 mm thickness, 1x1, 2x2, 4x4 mm², low resistivity, AC coupling.

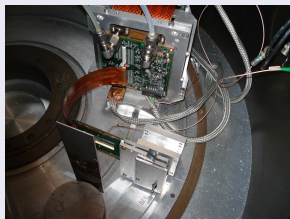
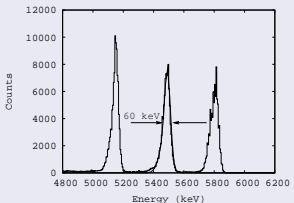
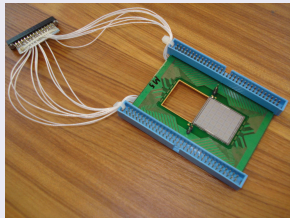
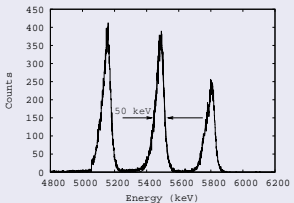
Junction side: DC, AC pad; bias and reference voltage; guard rings; "punch-through" resistance.

pad layout zoom



Preliminary tests: ITC-IRST detectors

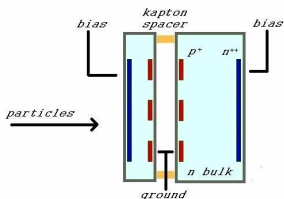
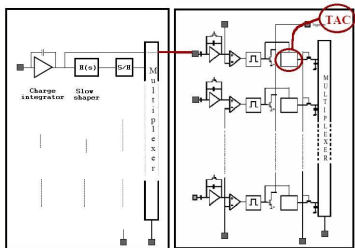
Energy resolution with modular NIM and ASIC electronics



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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