The TRACE spectrometer at SPES

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Dipartimento di Fisica e Astronomia - INFN Padova

SPES one-day Workshop
Probing Fundamental Symmetries and Interactions by low energy excitation with RIBs
Feb. 1, 2018

Project and collaboration

Goals of the **TR**acking **A**rray for light **C**harged **E**jectiles (TRACE) project:

- High efficiency and high resolution
- High counting rate capabilities
- Light charged particles and ions identification

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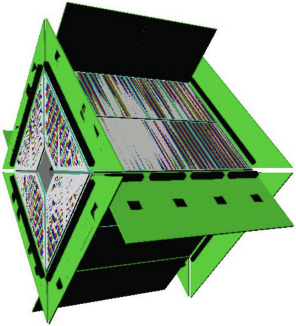

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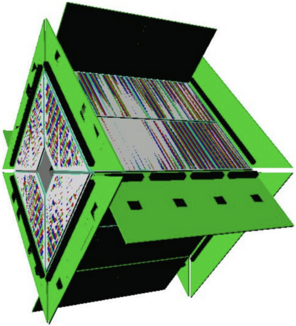

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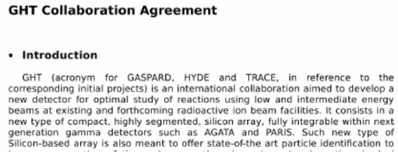
$\Longrightarrow$ **The GHT collaboration**



GHT Collaboration Agreement

- **Introduction**

GHT (acronym for GASPARD, HYDE and TRACE, in reference to the corresponding initial projects) is an international collaboration aimed to develop a new detector for optimal study of reactions using low and intermediate energy beams at existing and forthcoming radioactive ion beam facilities. It consists in a new type of compact, highly segmented, silicon array, fully integrable within next generation gamma detectors such as AGATA and PARIS. Such new type of Silicon-based array is also meant to offer state-of-the art particle identification to

A new versatile 4π silicon array

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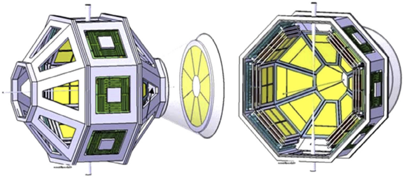

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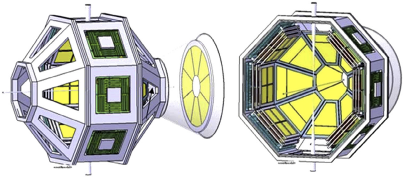

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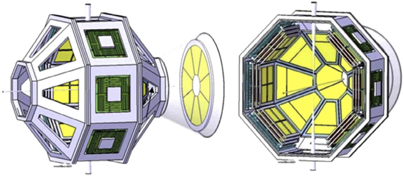

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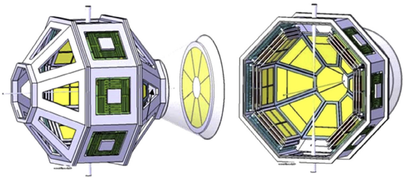

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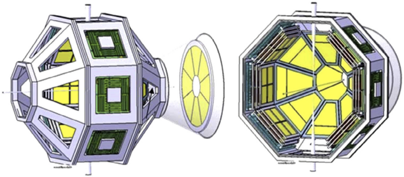

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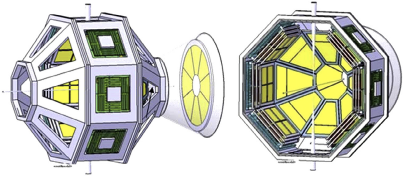

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- Data acquisition system and integration with other arrays

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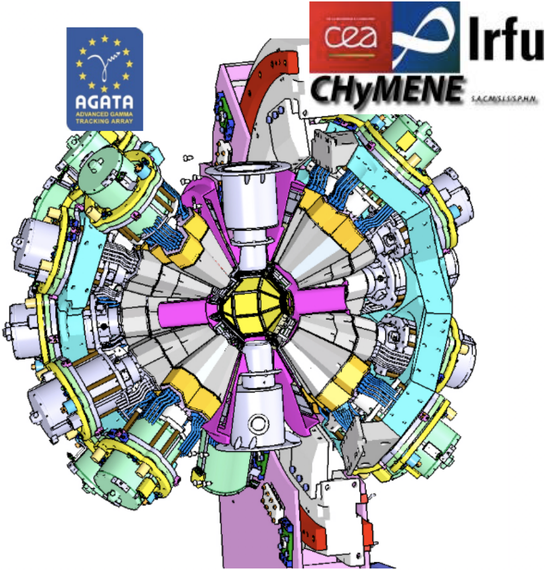

Silicon detectors development

- Large surface detectors with new geometries

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Silicon detectors development

MICRON SEMICONDUCTOR LIMITED

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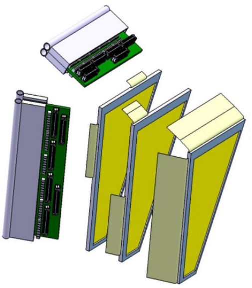
  - Thin (500 μm) and thick (1.5 mm)
  - Kapton connectors at 90°
  - Thin frames



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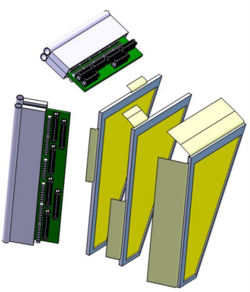

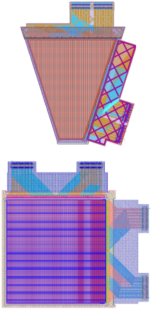

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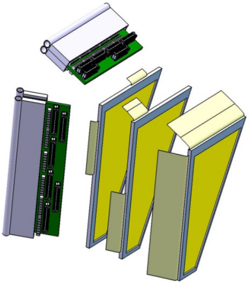
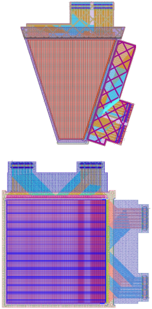
  - Highly uniform detectors
  - neutron transmuted silicon detectors
  - reverse-mount





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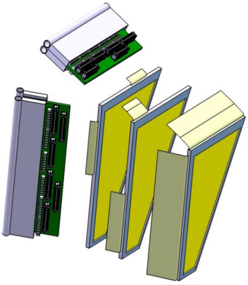
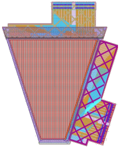
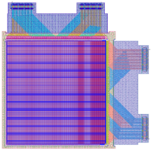
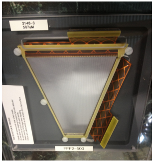




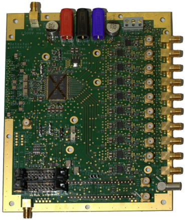




Developments on the electronic

Two **preamplifier** solutions are being investigated:

- Current and charge output (IPN Orsay): iPACI



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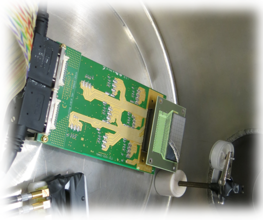

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Intermediate stage between preams and digitizers: **PLAS** (R.Aliaga, A.Gadea)

Input:

- Different polarity and signal range
- Sampling at 200 MS/s
- Common Trigger Request signal
- **32 inputs with independent trigger**

Output:

- Generates timestamp for pulses
- Synchronizable with each other and/or GTS
- Low noise (11.5 ENOB spec)
- **Single differential output**

R.J. Aliaga et al., NIM A 800 (2015)

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Possible **digitizers**: NUMEXO2

- 200 MS/s digitizers
- Compatible with AGATA/GALILEO GTS system
- Compatible with the new Trigger Processor
- Customization possible at the firmware level

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What can be done with TRACE?

Design and detectors of GASPARD-TRACE arrays:

- Elastic and inelastic scattering
- Transfer reaction with very light targets (d, ^{3,4}He, ...)
- Cluster transfer / Incomplete fusion with weakly bound ions (^{6,7}Li, ^{9}Be)
- Multi-nucleon transfer with light ions
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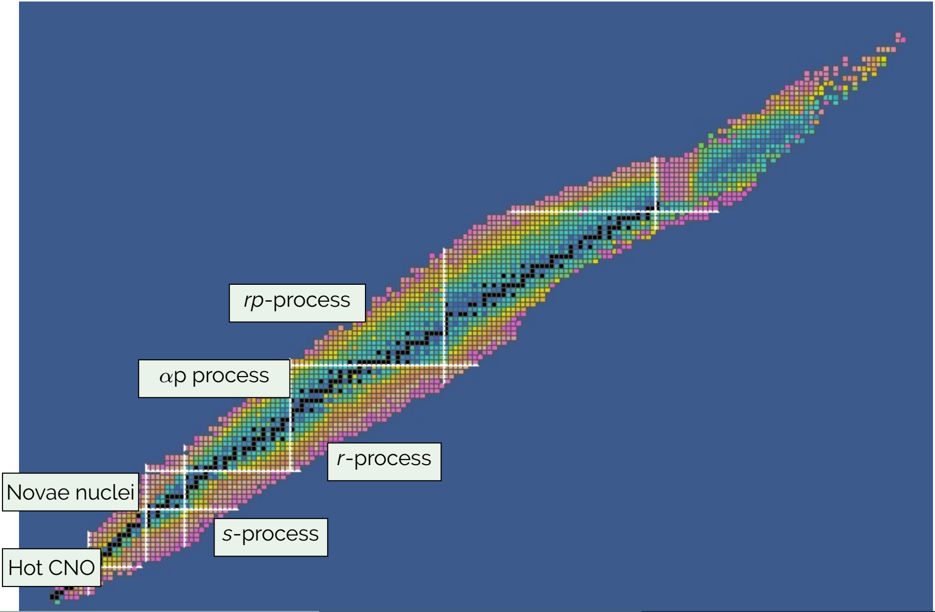
SPES beams are well suited for direct reaction studies:
Energy, intensity, emittance, purity

Direct reaction studies with TRACE



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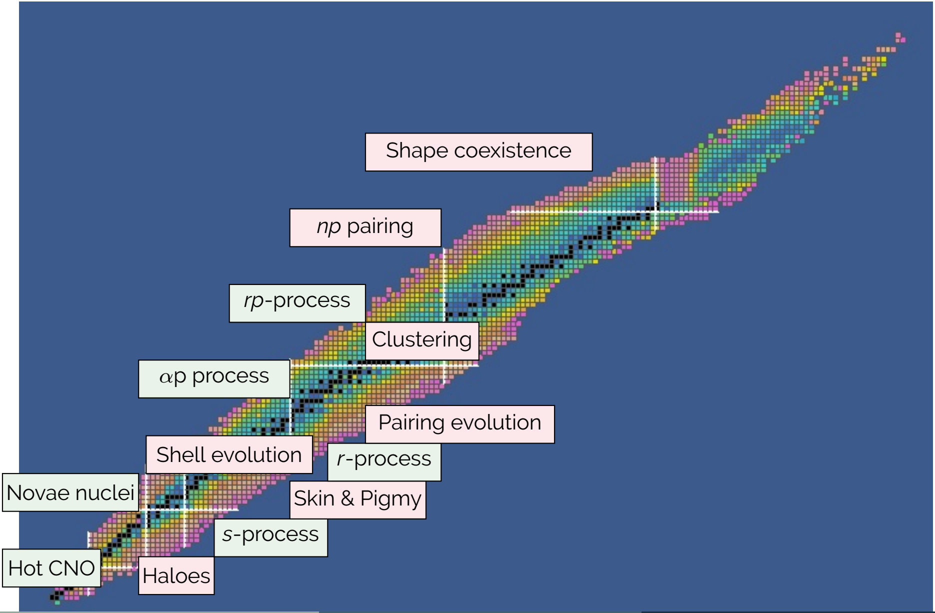
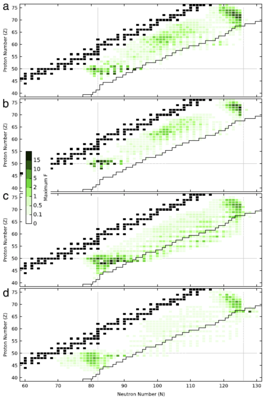


LoI for r-process studies at SPES using transfer reactions

S. .D. Pain et al.



Prog. Part. Nucl. Phys. **86** (2016) 86.

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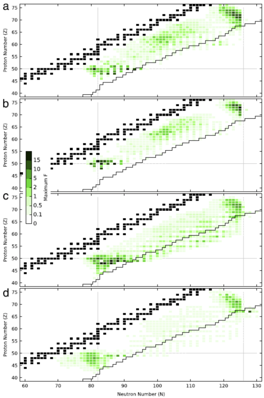

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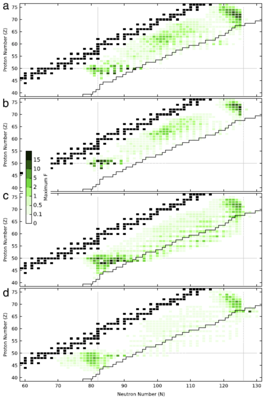

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- SPES beams have excellent overlap with r-process nuclides of interest for n capture
- Transfer reactions can provide input (energies, quantum numbers and spectroscopic factors) to calculations of direct and resonant neutron capture cross sections
- Recent advances in surrogate reaction theory

TABLE I: Example experiments that could be performed with projected Phase 1 beams from SPES. In each case, data from the (d,p), (d,t) and (d,^{3}He) reactions could be acquired simultaneously. In the case of experiments motivated primarily by constraining n-capture cross sections, the (d,p) reaction of foremost interest, but data on pickup reactions would also be acquired in such a measurement.

Beam	Projected intensity	Reactions	Primary motivation
^{80,81}Ge	8×10^4	(d,t) (d,^{3}He)	structure
^{81}Ge	1×10^4	(d,p) (d,t) (d,^{3}He)	n-capture
^{78,80,81}Ga	8×10^4, 1.5×10^4, 3.5×10^3	(d,p) (d,t) (d,^{3}He)	n-capture
^{84}Se	7×10^4	(d,t) (d,^{3}He)	structure
^{129,131}Sn	8.7×10^6, 1.7×10^6	(d,p) (d,t) (d,^{3}He)	n-capture
^{130}Sn	4×10^6	(d,t) (d,^{3}He)	structure
^{132}Sb	9×10^5	(d,p) (d,t) (d,^{3}He)	structure
^{134}Sb	1.5×10^4	(d,p) (d,t) (d,^{3}He)	n-capture
^{132,134,136,138}Te	2×10^7, 5.8×10^6, 2.7×10^5, 1.1×10^4	(d,p) (d,t) (d,^{3}He)	structure, n-capture
^{137}Xe	4×10^4	(d,p) (d,t) (d,^{3}He)	n-capture
^{138,140,142}Xe	5.6×10^6, 3.4×10^5, 1.8×10^4	(d,p) (d,t) (d,^{3}He)	structure, n-capture

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- SPES beams have excellent overlap with r-process nuclides of interest for n capture
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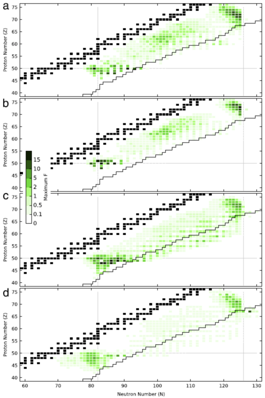
- Recent advances in surrogate reaction theory
- Final r-process abundances are sensitive to neutron-capture cross sections during freeze-out



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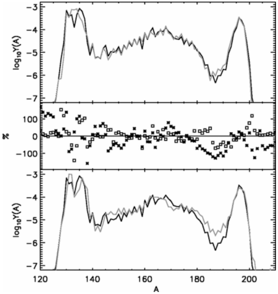


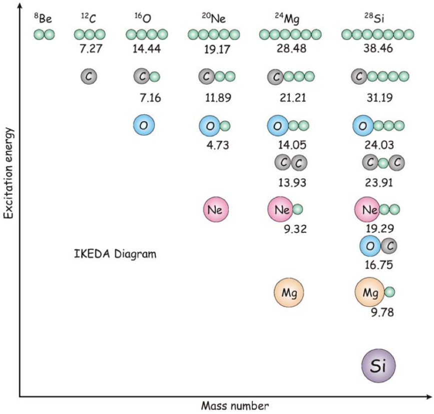
Phys. Rev. C **79** (2009) 045809

Nuclear Astrophysics studies with SPES

- **β-decay station and associated detectors** (see talk of A. Gottardo)
  - Measurement of the decay characteristics of nuclei around $A = 90$ relevant to the r-process nucleosynthesis [T. Kurtukian-Nieto et al.]
  - LoIs for measurements at SPES on β-decay properties of nuclei belonging to the s-process path [S. Cristallo et al.]
  - Study of beta-decay properties of neutron-rich isotopes approaching the r-process path [D. Testov et al.]

- **Reaction studies with TRACE**
  - LoIs transfer reaction measurements at SPES for r-process nucleosynthesis [S.D. Pain et al.]
  - Measurement of astrophysical relevant reactions induced by α, protons and neutrons at the Gamow peak using the Trojan Horse method [M.La Cognata. et al.]
  - Direct Reactions at SPES: Shell Evolution and Nuclear Astrophysics around $Z \sim 50$ and $N \sim 82$ [D. Mengoni et al.]
  - Measurements at SPES of n-capture cross sections on radioactive nuclei interesting for s-process nucleosynthesis [O. Trippella et al.]

Colletive modes in nuclei



Clustering is a phenomenon existing at all scales:

- Strongly bound cluster: α

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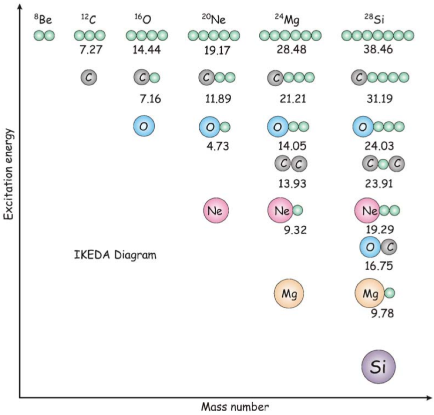

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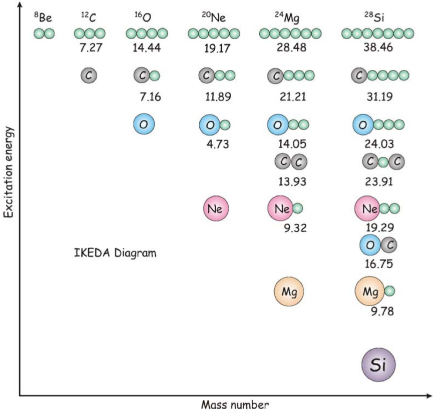

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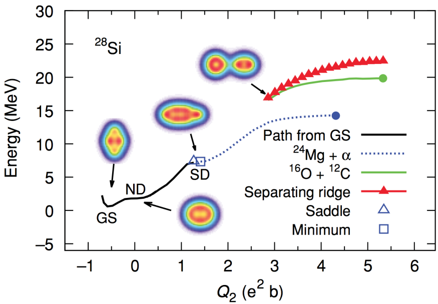

Phys. Rev. C **83** (2011) 054319

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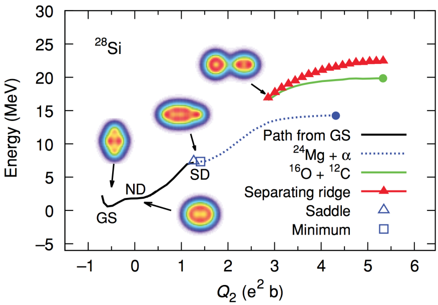

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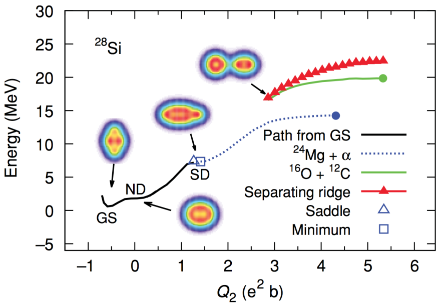
How to study these states:

- Cluster transfer reaction (^{6}Li,d), (^{7}Li,t), ...
- Breakup into the clusters
- Cluster decay
- ...

Colletive modes in nuclei



Phys. Rev. C **83** (2011) 054319

Clustering is a phenomenon existing at all scales:

- Strongly bound cluster: α
- Appearance of cluster states ⇔ Separation threshold
- Hoyle state in ^{12}C
- Smooth transition between ND and cluster states

How to study these states:

- Cluster transfer reaction (^{6}Li,d), (^{7}Li,t), ...
- Breakup into the clusters
- Cluster decay
- ...

SPES LOI: Search for deformed oblate structures in ^{96}Y by γ-spectroscopy and cluster transfer reactions with a ^{95}Sr SPES beam.
B. Fornal, S. Leoni ...

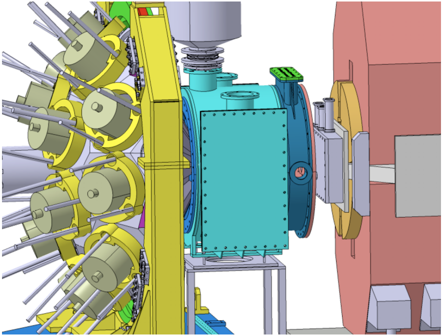
MUGAST+AGATA @ GANIL + SPIRAL1 beams

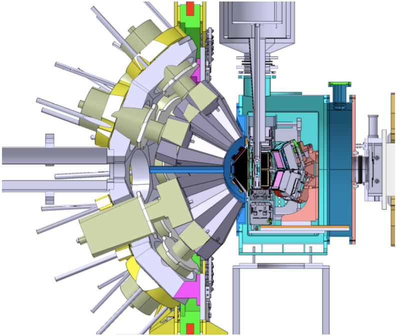
The MUGAST array:

- 5 GASPARD trapezoidal detectors backward
- 2 TRACE square DSSSD around 90 degrees
- 4 MUST2 telescopes forward

The physics campaign:

- Shell-evolution far from stability
- Shape-coexistence
- Reaction dynamics
- Nuclear astrophysics
- ...





Possible experimental campaign in 2019

Letters of intent for the MUGAST campaign

- **Shell structure evolution & deformation:**
  - Mapping of neutron orbitals around $N = 28$ — F.Flavigny, O.Sorlin et al.
  - Oblate driving force in n-deficient nuclei above ^{56}Ni — A.Goasduff, D.Mengoni, et al.
  - Shape transition along and across $N = 28$ — L.Fortunato, D.Mengoni et al.
  - Interplay of single-part and collective structures in ^{46}Ca — S.Leoni et al.
  - Shell evolution toward the island of inversion — A.Matta, W.Catford, N.Orr, et al.
  - Island of Inversion and shape coexistence in ^{30,31}Mg — B.Fernandez-Dominguez et al.
  - ^{75}Kr: Shape coexistence in characterization in light Kr — A.Matta, W.Catford, N.Orr, et al
- **Neutron-proton pairing:**
  - *np*-pairing in *fp*-shell — M. Assié et al.
- **Astrophysics:**
  - Breakout from hot CNO to *rp*-process — C.Diget et al.
  - Explosive H-burning in Novae — N. de Séréville, F. Hammache et al.
  - *s*-process ^{79}Se(n,γ) — G.de Angelis et al.
  - *s*-process ^{60}Fe(n,γ) — A.Matta, W.Catford, N.Orr, et al.
- **Reaction dynamics:**
  - Space-time characterization of emitting sources in HI collisions — G. Verde, et al.

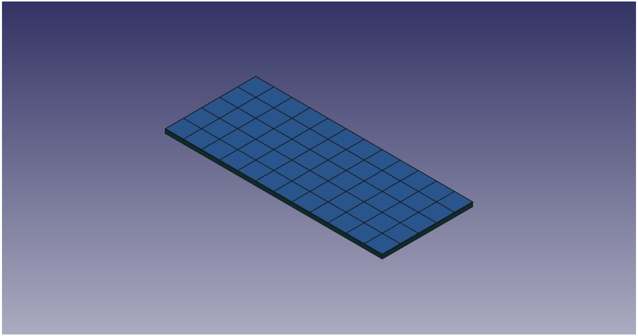
protoTRACE+GALILEO @ LNL

The protoTRACE array:

- 8 segmented TRACE prototypes
- Barrel/cube configuration
- GALILEO digitizers @ 100 MS/s

The physics campaign:

- Shell-evolution near the stability
- Shape-coexistence
- Exotic structures in nuclei



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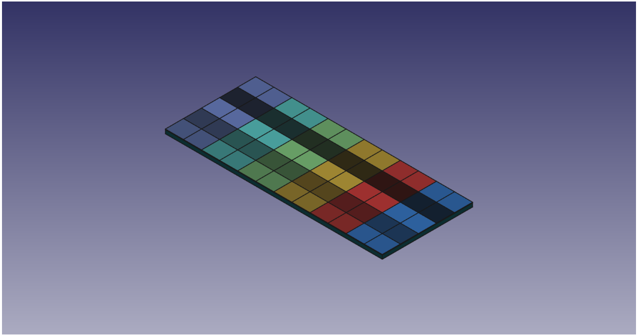

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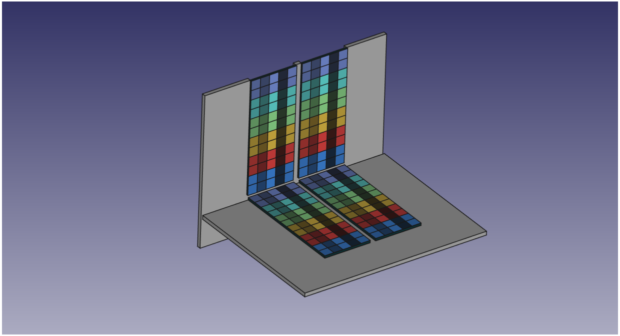

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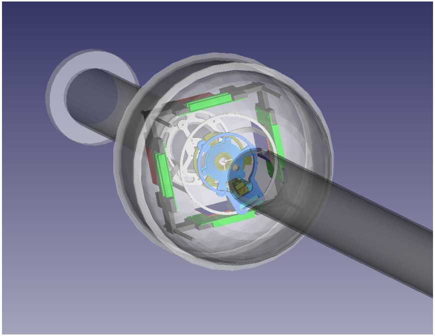

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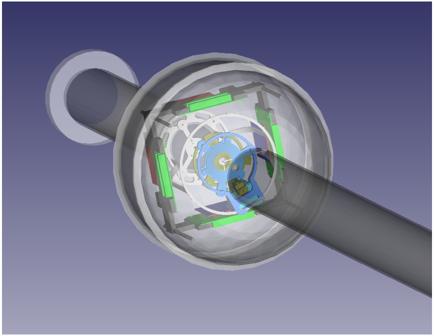
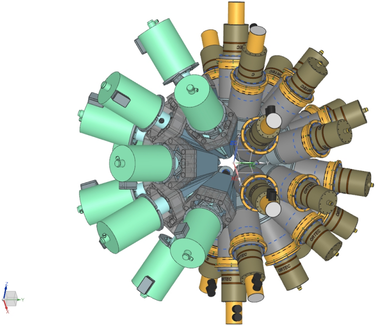
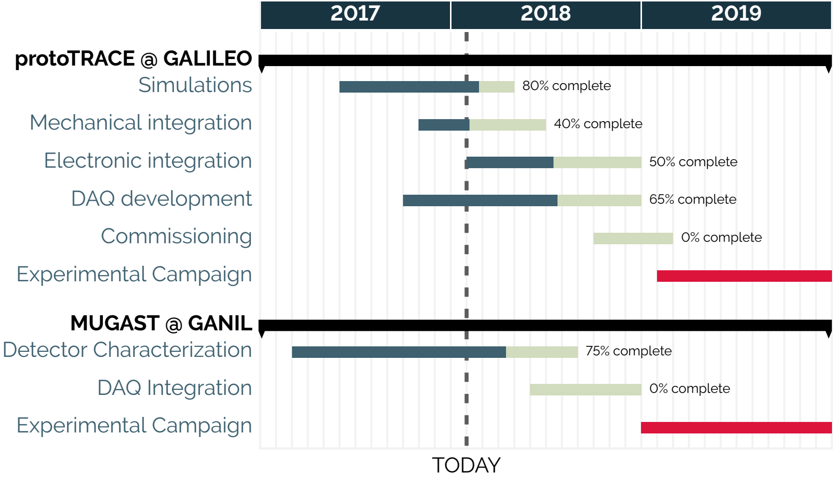




Timeline


2017
2018
2019
protoTRACE @ GALILEO
Simulations
80% complete
Mechanical integration
40% complete
Electronic integration
50% complete
DAQ development
65% complete
Commissioning
0% complete
Experimental Campaign
MUGAST @ GANIL
Detector Characterization
75% complete
DAQ Integration
0% complete
Experimental Campaign
TODAY

THANK YOU FOR YOUR ATTENTION