A new high granularity Silicon Array for future reaction studies

D. Beaumel,
IPN Orsay
**Direct reactions**

*A great tool to investigate Exotic Nuclei and astrophysics processes*

Case of **transfer reactions**:

- d transfer
- p transfer
- np pairing
- rp process
- n transfer
- r-process
- 2n transfer
- 1(2)-nucleon transfer
- Cluster transfer
- 1(2)-nucleon transfer
- Haloes, Clusters
- Skin, Pygmys
- Shell Evolution
- Pairing changes

**Good energy regime**: few MeV/u → few tenths of MeV/u

**Methodology**:

Radioactive Ion Beam → Light target (H, He...)

Detect the recoil particle with high accuracy

Silicon technology
Landscape of Si detectors for DR studies

Light Beams

1997

MUST
coll.: IPN, CEA-Saclay, DAM

Cooling
Connectors
Preamplifiers
Detectors

2007

MUST2
coll.: IPN, CEA-Saclay, GANIL

Cooling
Connectors
Preamplifiers
Detectors

Fission fragments

2017~

GASPARD
coll.: IPN, INFN, BARC
Irfu, Huelva, STFC, Surrey, GANIL

Cooling
Connectors
Preamplifiers
Detectors

Particle spectroscopy

$E_x$ resolution: $\sim 500$keV

Particle-Gamma Spectroscopy

$E_x$ resol.: $\sim 5$keV
(AGATA case)
A new Si array for reaction studies

4π, fully integrable in PARIS/AGATA/EXOGAM2

“GASPARD-TRACE” design

Layers of Silicon
- 300(500) μm DSSD pitch < 1mm
- 1(or 2) x [1.5 mm DSSD pitch~1mm]
2 main shapes : square & trapezoid, large area

Electronics:
- ~ 10000 channels (Digital)
- high transparency to γ-rays
- Big integration challenge

Other features:
- State of the art for PID Pulse Shape Discrimination
- Special targets (pure H,D)
- Portable device
Collaboration

- IPN Orsay, CEA Saclay, GANIL, LPC Caen (France)
- INFN Univ. of Padova, INFN-LNL Legnaro, INFN Univ. of Milano (Italy).
- Univ. of Huelva, Univ. of Santiago de Compostella, Univ. of Valencia (Spain)
- Univ. of Surrey, STFC Daresbury (UK)
- BARC, Mumbai (India).
GASPARD-TRACE collaboration agreement

Under elaboration (D. Mengoni, DB)

Goal: converge towards a common portable device to be used at

2 phases scheme:

- 2015-2017: (full) Si prototypes developments, Electronics dev. and full definition, TDR
- 2017 ~ 2019?: Construction

GHT Collaboration Agreement

1. 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 improve separation of the various reaction channels and reduce the physical background. Native integration of special targets such as the pure
R&D on Pulse Shape Discrimination with DSSD

Goal: establish the method for light particles and highly segmented detectors

- Effect of segmentation
- Lower E threshold for each particle?
- Minimum sampling frequency (Digital elec)
- n-side or p-side?
- Filters (e.g. Haar wavelets transform, ...)
- Other possible observable: Rise time?
- Radiation damage
- ....

Detector:
- 500 um nTD DSSD
  BB13 design of MSL
- 8° cut
- 128X+128Y
- pitch<500um
- special package
  90° kapton readout
  high density connectors
  test experiments at the IPNO tandem
Test experiment at IPNO tandem
Reaction:
$^7\text{Li} + ^{12}\text{C} @ 35 \text{ MeV}$

PSD for $Z=1$ particles

$\Delta E$ 40um nTD 100um PAD

$\Delta E$ 40um nTD 500um PAD

8 PACIs 32mV/MeV

5 MATACQ (20 ch) 1GHz

GANIL DAQ (~10Hz)

Beam $^7\text{Li}$

4p 4n

PSD for $Z=1$ particles

$\Delta E$ 40um nTD 100um PAD

$\Delta E$ 40um nTD 500um PAD

40um 500um 128X+128Y strips BB13

Preamps : PACI gain ~32 mV/MeV

Digitizers : 5 MATACQ - 1GHz sampling

GANIL DAQ : 20 digital channels 10Hz

Test experiment at IPNO tandem
Reaction:
$^7\text{Li} + ^{12}\text{C} @ 35 \text{ MeV}$

PSD for $Z=1$ particles
Reaction: $^7\text{Li} + ^{12}\text{C}$ at 35 MeV

Discrimination achieved down to $E < 2.5$ MeV

M. Assié et al., EPJA(2015)
For Z=1, p, d, t:
- Discrimination down to 2.5 MeV for 300V
- Amplitude of current signal sufficient @ 300V

⇒ Analog electronics? Peak finder?

⇒ The sampling rate should be higher than 200MHz

- Effect of bias: best compromise is 300V
- Effect of P and N-side: lower threshold on P-side
- Other observables and Filters (Haar wavelets)
- Effect of sampling frequency: loss of discrimination below 250MHz

M. Assié et al., EPJA(2015)
Reaction: $(d, ^3\text{He})$ on mylar @ 26 MeV

- $^3\text{He}/^4\text{He}$ discrimination
- Test of analog peak finder on current

$\Delta E - E$ with 40um detector

Digitalization (N and P coincidence)

$\Delta E$ detector for PID

PSD for $Z=2$ particles

(IPNO tandem)

40um

500um nTD

PAD 500um

4n 4p

8 PACIs 32mV/MeV

Peak finder

Wavecatcher (48 ch)

1GHz (1028 points)

Wavecatcher DAQ 80/s

4p 4n

Good $^3\text{He}/^4\text{He}$ separation

preliminary
Silicon developments

Silicon detectors plan (short term):
- 1st layer (trapez.): 2 prototypes ordered (Micron) in 2013 (IPNO)
- 1st layer (square): 2 prototypes ordered (Micron) in 2014 (INFN-Padova)
- 2nd layer (thick square) & 2nd layer (thick trapez): BARC-IPNO

Specifications
- large area, 6” wafers, nTD, 500um thick
- 128X+128Y (pitch~700 um)
- <100> random cut (8deg)
- Thin frame / Kapton readout at 90deg /High density connectors

Test bench
Test of uniformity In resistivity
Leakage current /strip, capacitance/strip, interstrip resistance

Trapezoid under commissioning
Trapezoid DSSD prototype

Received  June 23, 2015
ELECTRONICS
Integration of electronics
FEE architecture (preliminary)
ASIC internal architecture
iPACI

IPACI: 9-channel integrated Charge and Current output preamplifier

Status:
- ASIC and Testbench available, test starting soon

To do next:
- ASIC qualification via test input
- Coupling with a detector (June/15)
- Possibly ASIC redesign
- Design slow shaper
1-Channel performance (simulated!)

**Charge Output**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy max (Si)</td>
<td>50 MeV</td>
</tr>
<tr>
<td>Charge signal swing (50 MeV)</td>
<td>1.6V single ended</td>
</tr>
<tr>
<td>Charge gain</td>
<td>32mV/MeV</td>
</tr>
</tbody>
</table>
| Equivalent noise charge (Input-refered, FWHM) | 7 keV  
830 e- Si |
| Charge resolution                            | 12.8 bits ENOB         |
| Charge non-linearity                         | < 2%                   |
| Charge output recovery time                  | 100μs                  |

**Current Output**

**System data**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technology</td>
<td>AMS 0.35μm BICMOS</td>
</tr>
<tr>
<td>Supply</td>
<td>3.3V</td>
</tr>
<tr>
<td>Detector's input capacitance</td>
<td>Compatible with [10pF .. 40pF] range</td>
</tr>
<tr>
<td>Compensation cap</td>
<td>Digitally tuneable within [0.5pF .. 2.25pF], step 0.25pF</td>
</tr>
<tr>
<td>Current consumption</td>
<td>12mA (40mW) / Channel</td>
</tr>
</tbody>
</table>
| Size                                          | 220 x 100μm (PACI block)  
+ 130 x 70μm (Buffer ch)  
+ 130 x 70μm (Buffer cu) |
System providing continuous extrusion of $^1\text{H}$ or $^2\text{H}$ through a rectangular extruder nozzle defining the target-film thickness

- Hydrogen target in a solid phase near triple point
  $s\text{H}_2 \sim 17$ K
- Thickness 50 – 200 µm
- No window - C free
- Continuous flow in vacuum
  2-10mm/sec
- Compatible with particle detection

CHyMENE collaboration:
- CEA/IRFU Saclay
  *project coordinator: A. Gillibert*
- IPN Orsay
- CEA/DAM Bruyères

Grant from French ANR ~550k€
CHyMENE - Design
CHyMENE - Status

- Now being commissioned
  Test under beam beg. of 2016
- Further tests of thin ribbon production needed
  (Nozzle material, geometry, surface treatment, …)
- Need implement system for thickness measurement presently: $\alpha$-source+SD
2014:
- DSSD prototypes development
- Thick Si proto develop.
- Bench for DSSD & thick Si

2015:
- Test experiments
- Data analysis
- PACI preamp ASIC

2016:
- Signal processing / simulations
- FEE developments
- Mechanical design

2017 - 2019:
- Production DSSD/ Si thick
- Mechan. & electronics
- Full array
- TDR

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Detectors

R&D PSD

Mechanics Elec.
MUGAST
(MUST2 - GASPARD – TRACE)

Implementing an intermediate configuration

- GASPARD-TRACE prototypes
  + few MUST2 telescopes
- One-layer philosophy (VAMOS)
- CHYMENE
- MUST2 electronics with new connectics

100 k€, 2 years (start : 2017)

To perform high resolution reaction studies using
  - AGATA@ VAMOS
  - The new SPIRAL1 beams

In particular stripping reactions e.g. \((d,p)\)
MUGAST
(MUST2 - GASPARD – TRACE)

Efficiency of AGATA $1\pi \sim 8\%$
Reaction studies using the MUGAST+AGATA setup at VAMOS

Letter of Intent to the AGATA collaboration

D. Beaumel, IPN Orsay
D. Mengoni, University and INFN Padova

1. Introduction

The GASPARD and TRACE high granularity Silicon arrays have been natively designed for optimal integration in new generation gamma detectors such as AGATA with the aim of performing high-resolution reaction studies. Indeed, the coupling to AGATA allows a very large gain in excitation energy resolution, in comparison with the case where the excitation energy is deduced from the recoil charged-particle measurement. The GASPARD and TRACE collaboration are now converging to build such new-generation Si ensemble in common, with a timeline of 2019-20 for completion of the final 4π array, ready for the emerging ISOL facilities, like SPES and SPIRAL1. A view of such ultimate GASPARD-TRACE setup sitting inside AGATA is shown in Fig.1.
MUGAST with EXOGAM & PARIS

« MUGAST » configuration = MUST2 + GASPARD (trapeze) +TRACE (square)
available for AGATA campaign at GANIL (2017)
read by MUST2 electronics (MUFEE+MUVI)

Possible gamma detector’s configurations :
- 6 PARIS clusters (if available)
- 6 EXOGAM
Thank you