CHARACTERISATION OF THE GET ELECTRONICS FOR SI DETECTOR APPLICATIONS

A.T. LAFFOLEY
ON BEHALF OF THE ACTAR TPC COLLABORATION
OUTLINE

• Overview of ACTAR TPC project

• Description of General Electronics for TPCs (GET)

• Overview of Si performance (baseline noise, resolution, etc.)

• Investigation of system dead time
WHAT IS AN ACTIVE TARGET?

- Based on time projection chamber (TPC) concept from particle physics
  - Gas is both detector and target
  - Event-by-event reconstruction in 3D
  - High efficiency (+ low energy threshold)

- Advantages over conventional approaches

- Thin target experiments:
  - Need very high rates
  - Not feasible with exotic nuclei

- Thick target experiments:
  - Significant losses in target
  - Degraded resolution
BASIC DESIGN ASPECTS

- **Drift Region**
  - Particles ionise gas along their trajectories

- **Amplification Region**
  - Micromegas – J. Pancin et al., NIMA 735, 532 (2014)

- **Pixelated Pad Plane**
  - Very high density: 2x2 mm² (= 25 channels/cm²)
  - Total 16384 fully digitised electronics channels (GET)

- **Auxiliary Detectors**
  - Telescopes for escaping particles (Si and/or CsI walls)
  - LaBr₃ or CeBr₃ for γ rays (SpecMAT, O. Poleshchuk)
**ACTAR TPC: TIMELINE**

- 2012–2016: Research and Development
  - Building of prototype and tests
  - GET electronics development

### WP 1: Physics & Sims

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<thead>
<tr>
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<th>2014</th>
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<th>2016</th>
<th>2017</th>
<th>2018</th>
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<tbody>
<tr>
<td><strong>WP 1.1:</strong> Demonstrator Expt</td>
<td><img src="image1" alt="IPNO PAC Meeting" /></td>
<td><img src="image2" alt="GANIL in-beam test" /></td>
<td><img src="image3" alt="IPNO Demonstrator Campaign" /></td>
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**END OF PROJECT (Jan 2019)**

- **WP 1.2:** Commissioning Expt
  - ACTAR TPC LOI’s @ SPIRAL WS
  - Mount in G3
  - Experiments (E1)

- **WP 1.3:** 2p Decay Expt
  - ACTAR TPC LOI’s @ LISE WS
  - Mount at LISE
  - Experiments (E2)

- **WP 1.4:** HIE ISOLDE Expt
  - ACTAR TPC LOI’s @ ISOLDE WS
  - Setup and Installation
  - Experiments (E3)

- **GANIL PAC Meeting**
- **ISOLDE PAC Meeting**
ACTAR TPC ELECTRONICS

- Using GET (General Electronics for TPCs)
  - Wave digitiser using 512 analogue memory cells @ 100 MHz (max)
  - L0/L1/L2 trigger capabilities (external, multiplicity & higher order)
  - Zero suppression, full & partial readout for reducing data traffic
  - ANR funded project (Nov. 2009–Oct. 2013; IRFU/CEA, CENBG, GANIL, MSU)

Electronics exist and hardware is ready to use!
AGET:

- 64 input channels
- 4 fixed-pattern noise (FPN) channels
- 512 circular memory cells
- Four built-in preamplifiers with fixed gain (120 fC, 240 fC, 1 pC, 10 pC)
- Generates multiplicity signal
GET ARCHITECTURE

AsAd:
- 4 AGET/AsAd card
- 256 channels
- 12-bit ADC
CoBo:

- Up to 4 AsAd/CoBo
- 1024 channels
- Reads, reduces, and concentrates data
**MuTanT:**
- Distributes master clock
- Provides 3-level trigger system
  (L0 = external, L1 = multiplicity, L2 = software level trigger)

**μTCA Crate:**
- Up to 11 CoBos (11264 channels)
- Adjustable writing clock frequency (1–100 MHz)
- Controlled by MuTanT
ACTAR TPC DEMONSTRATOR

- 2048-channel electronics test bench
  - Two detectors with identical chamber design (GANIL and CENBG)
  - Mechanics scalable to final design (1/8 scale)
  - 12 Si detectors perpendicular to beam axis
  - 4 DSSD downstream
DSSD details

32x32 channel DSSD

Size: 6.4 cm x 6.4 cm

Thickness: 1500 μm

4 detectors = 256 channels
MAYA Si details
Size: 5 cm x 5 cm
Thickness: 700 μm
3x2 configuration per side

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DSSD CONNECTORS

N card = back strips
P card = front strips

Cable to AsAd
SAMTEC ERM8 ↔ ERM8
L1 Trigger: $M = 1$ DSSD multiplicity

Triple $\alpha$ source for DSSD calibration

$^{239}$Pu (5.15 MeV); $^{241}$Am (5.48 MeV); $^{244}$Cm (5.8 MeV)
SAMPLE DSSD SIGNALS

Gain set to 1 pC
Energy range: 17.5 MeV
Baseline noise: 25 keV
(5 ADC channels)

Extract maximum

Baseline mean & σ
Detector biased to 150 V
(300 V full depletion)
Alpha Energies

Gain = 1 pC; Range = 17.5 MeV
Comparison between GET gain settings

Gain = 1 pC; Range = 17.5 MeV

Gain = 10 pC; Range = 175 MeV
DSSD SI RESOLUTION

Resolution @ 5.1 MeV
GET: 80 keV FWHM

Gain set to 1 pC
Energy range: 17.5 MeV
Baseline noise: 25–80 keV
(5–15 ADC channels)
RECOVERY OF SATURATED SIGNALS

Experiment @ IPNO:

$^{12}\text{C}$ @ 6.6 MeV/u
He:$i\text{C}_4\text{H}_{10}$ (90%:10%) @ 1 atm

1 pC Gain = 17.5 MeV $E_{\text{range}}$
10 pC Gain = 175 MeV $E_{\text{range}}$

How to detect 20–30 MeV particles?

Saturated signal prevalence: 33% in DSSD, 7% in MAYA, 2% in Pads
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TESTING MUTANT DEAD TIME

- **Trigger:** Poisson distributed random pulser

- **Dead time:** Measured per event from MuTanT LEMO output

- **Live time:** Measured accepted trigger requests as TVal LEMO output. Ratio of trigger requests to accepted triggers gives live time
MUTANT DEAD TIME

- MUTANT dead time signal width measured with oscilloscope

To read:
- ~52 μs of overhead
- + 20.5 μs per channel read

- Dead time set only by AGET chip with most channels being read (parallelisation at AGET level)
MUTANT DEAD TIME

• MUTANT dead time signal width measured with oscilloscope

To read:
~52 μs of overhead
+ 20.5 μs per channel read

\[ P(R\tau) = 1 - e^{-R\tau} \]
where R is trigger request rate and \( \tau \) is dead time per event

• Dead time set only by AGET chip with most channels being read (parallelisation at AGET level)
\[ LT(R\tau) = 100e^{-R\tau} \]
Dead time dominated by bursting associated with 800 Mbit/s data transfer rate limit
System Live Time vs. Channels Read

Assuming a Mutant overhead of 52.5 μs and 20.5 μs to read each channel (all 512 time buckets read)
SYSTEM LIVE TIME

System Live Time vs. Channels Read

Assuming a Mutant overhead of 52.5 µs and 20.5 µs to read each channel (all 512 time buckets read)

Experiment-Dependent Parameters

<table>
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<tr>
<th>Parameter</th>
<th>Value</th>
<th>Max Value</th>
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<tbody>
<tr>
<td>Channels/AGET</td>
<td>54</td>
<td>(max 68)</td>
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<tr>
<td>Total Channels</td>
<td>400</td>
<td>(max 1088)</td>
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<tr>
<td>Trigger Delay</td>
<td>5 µs</td>
<td>(max 655.35)</td>
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<tr>
<td>Buckets Read</td>
<td>512</td>
<td>(max 512)</td>
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<tr>
<td>Trigger Rate</td>
<td>200 /s</td>
<td></td>
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<tr>
<td>Reading Frequency</td>
<td>25 MHz</td>
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<tr>
<td>Live Time</td>
<td>61.04%</td>
<td>Bursting</td>
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<tr>
<td>CoBo Data Transfer Rate</td>
<td>100.00 MB/s</td>
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CONCLUSION AND SUMMARY

• DSSD Si resolution ~**80 keV** FWHM (@ 5.1 MeV) with GET

• Energy range:
  - 120 fC – 2.5 MeV
  - 240 fC – 5 MeV
  - 1 pC – 20 MeV
  - 10 pC – 200 MeV

• Baseline noise: **25 keV** (~5 ADC channels)

• System live time can be estimated knowing:
  - Max channels read on a single AGET
  - Max channels read on a single CoBo
  - Trigger delay
  - Time buckets read per channel
  - Trigger request rate
# COLLABORATION

<table>
<thead>
<tr>
<th>GANIL</th>
<th>GANIL</th>
<th>K.U. Leuven</th>
<th>CENBG</th>
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<tr>
<td>M. Blaizot</td>
<td>P. Senecal</td>
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<td>B. Blank</td>
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<td>B. Duclos</td>
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## Students
- J.C. Yang

## Postdocs + CDD
- D. Suzuki

## Alumni *
- T. Roger

+ GET Team

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*Students, Postdocs + CDD, Alumni*
ACKNOWLEDGMENTS

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For more information:
http://pro.ganil-spiral2.eu/laboratory/detectors/actartpc