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SMART + GANIL coupling

How to synchronize and label events across different detectors ?

Outline

This talk is not about…

- Time-of-flight or timing measurements (TAC, etc.)
- Computing/dataflow architecture
- Acquisition software integration

But about…

- The process of assigning global (absolute) timestamps to physical events
- Hardware synchronization across different detectors
- Enabling coherent event correlation in distributed setups

From challenges to solutions: The timeline of Timestamping at GANIL

*This presentation aims to shed light on the following **key questions**:*

I. Where are we today at **GANIL** ?
  - Current **state-of-the-art** solutions and methods we use

II. What are the **main challenges** we face ?
  - Challenges that pushed us to proposed something new

III. How does the **SMART** system address future challenges ?
  - Key concepts and how it addresses our **specific requirements**

IV. How are we **deploying** it in practice ?
  - Our **phased** development and deployment strategy

V. What else ?
  - **Future questions** to solve over coffee

I. Where are we today at GANIL?

*Four representative setups to **illustrate the state-of–art** of timestamping in GANIL*

INDRA/FAZIA

- MESYTEC VME DAQ modules with **CENTRUM** (**C**lock **E**vent **N**umber **T**ransmitter **R**eceiver **U**niversal **M**odule) and TGV (**T**rigger **G**enerique **V**ME)

EXOGAM–MEDLEY–PPAC

- GANIL NUMEXO2 DAQ modules with **GTS** (**Gl**obal **T**rigger and **S**ynchronization)

ACTAR

- GET (Generic Electronics for TPCs) µTCA DAC with **MUTANT** (**MU**tiplicity, **T**rigger **AN**d **T**ime)

LISE 2024 (MUGAST/CATS/EXOGAM/ZDD)

- GANIL VXI DAQ modules with CENTRUM coupled with NUMEXO2 modules with GTS thanks to **AGAVA** (**AGA**TA **V**ME **A**dapter) & **TGV** gateway

“48-bit timestamp @ 10 ns & 32-bit event number:
The universal backbone ensuring time correlation across all systems”

II. What are the main challenges we face?

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Aging Standards (VXI)

- Maintaining aging standards like VXI is increasingly difficult

Obsolescence (TGV, AGAVA and GTS mezzanines) and Increasing Demand

- Modules such as TGV and AGAVA and GTS mezzanines are now obsolete. At the same time, our experimental needs require an ever-growing number of these modules.

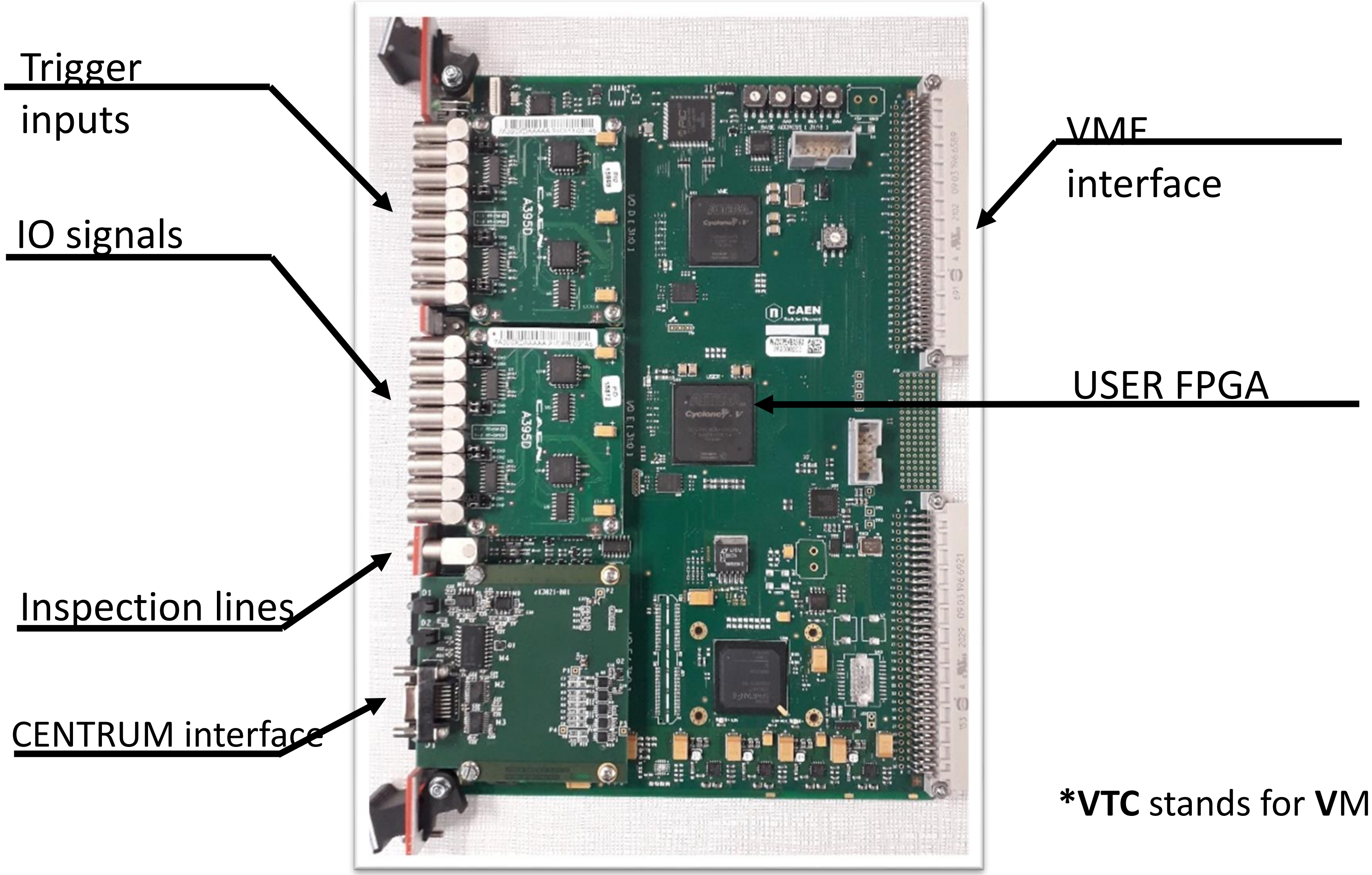
Heterogeneity and Integration Issues

- Coupling and timestamping schemes vary significantly between experiments. This drives the need for reliable gateways and interface modules.

Operational Stability and Documentation Gaps

- Ensuring the long-term stability and robustness of systems like GTS is challenging, especially given the lack of comprehensive technical documentation and support

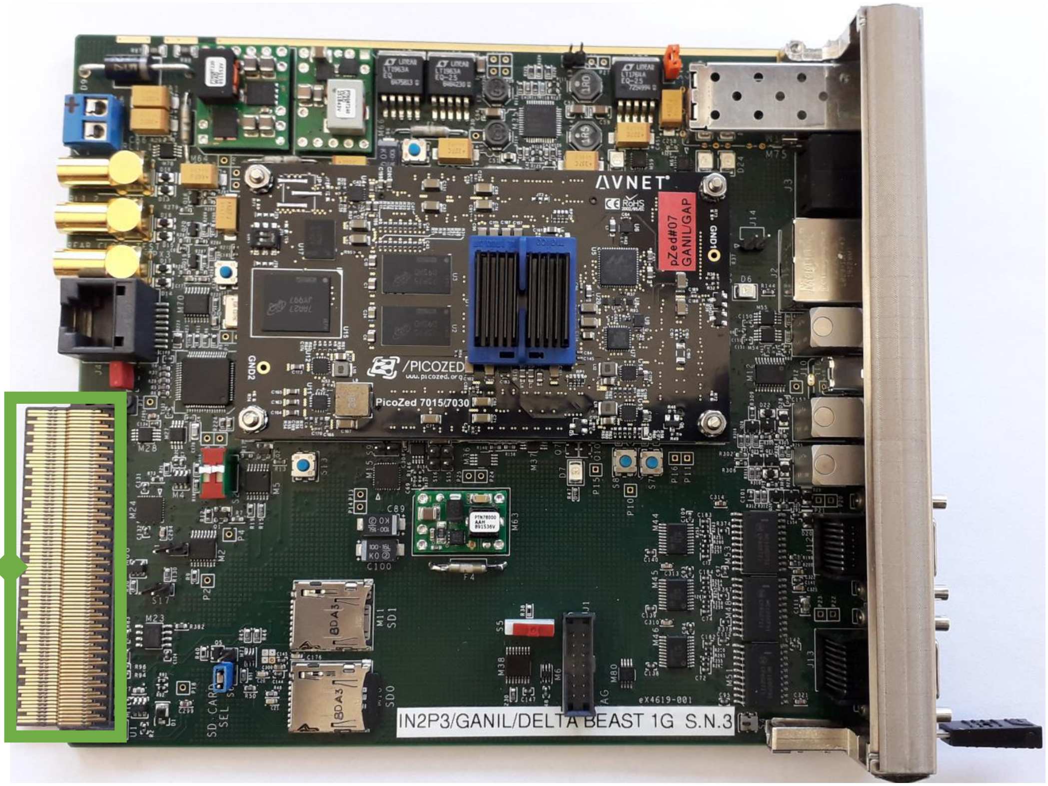
II.1. A VTC* in response of the lack of TGV

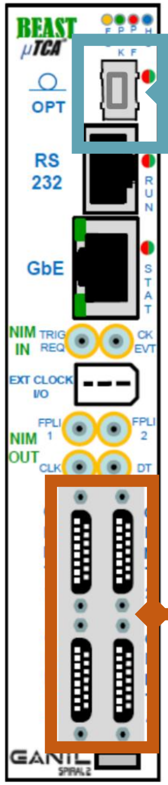


*__VTC__ stands for __V__ME __T__rigger __C__entrum

II.2. The beauty of the BEAST

SELF_SYNC mode GTS_SYNC mode MIXED_SYNC mode MUTANT_SYNC mode





Optical interface
GTS or SMART

CENTRUM interface

MUTANT
µTCA interface

II.2. The beauty of the BEAST

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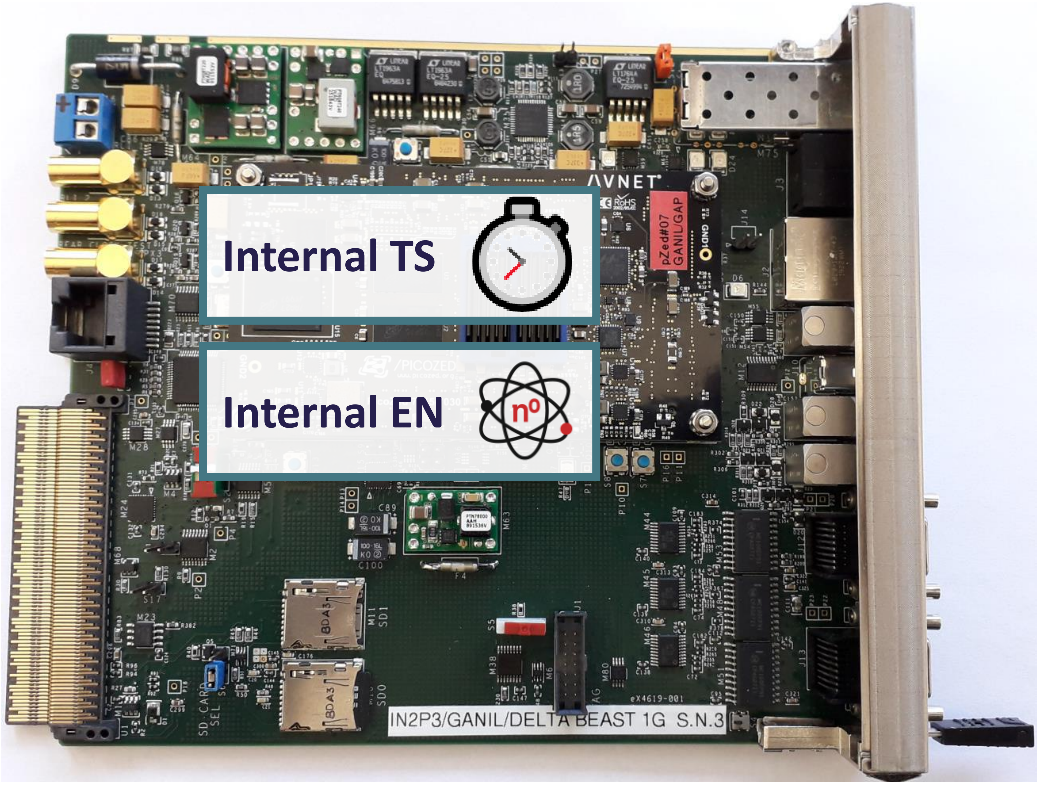
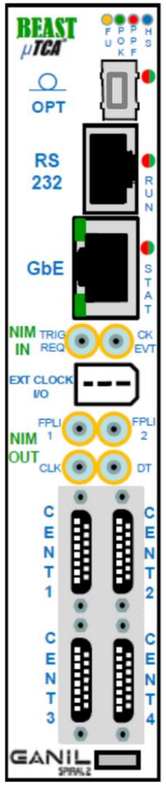


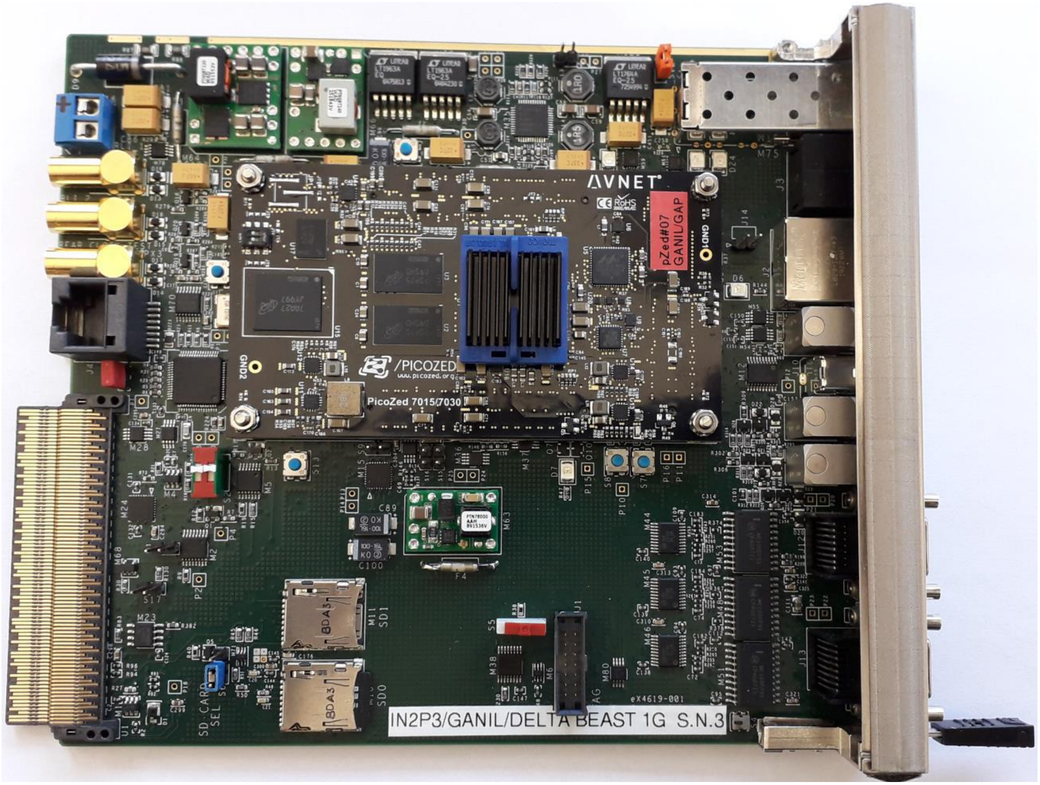


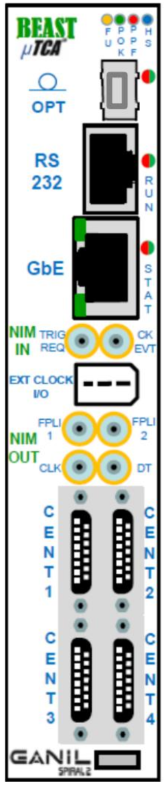
TS to CENTRUM RX

EN to CENTRUM RX

II.2. The beauty of the BEAST

SELF_SYNC mode GTS_SYNC mode MIXED_SYNC mode MUTANT_SYNC mode



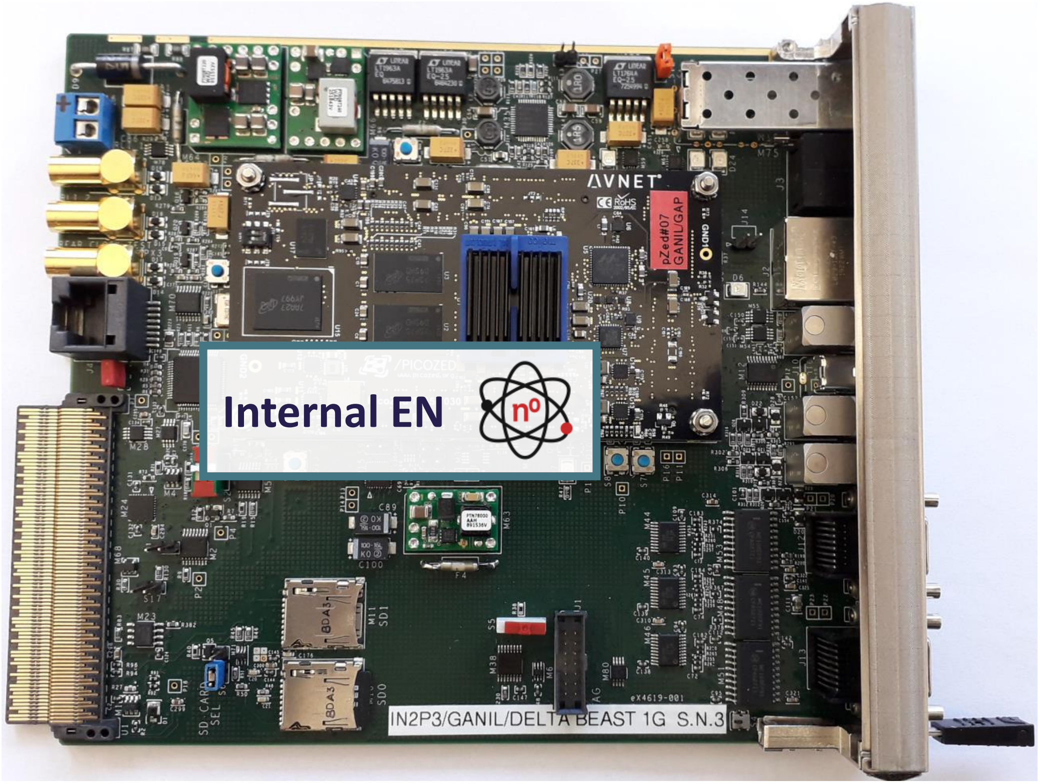


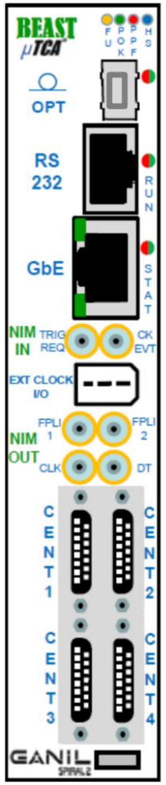
TS From GTS or SMART

TS to CENTRUM RX

II.2. The beauty of the BEAST

SELF_SYNC mode GTS_SYNC mode **MIXED_SYNC mode** MUTANT_SYNC mode





TS From GTS or SMART

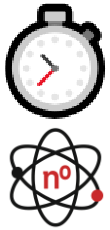
Master Trigger Input

TS to CENTRUM RX

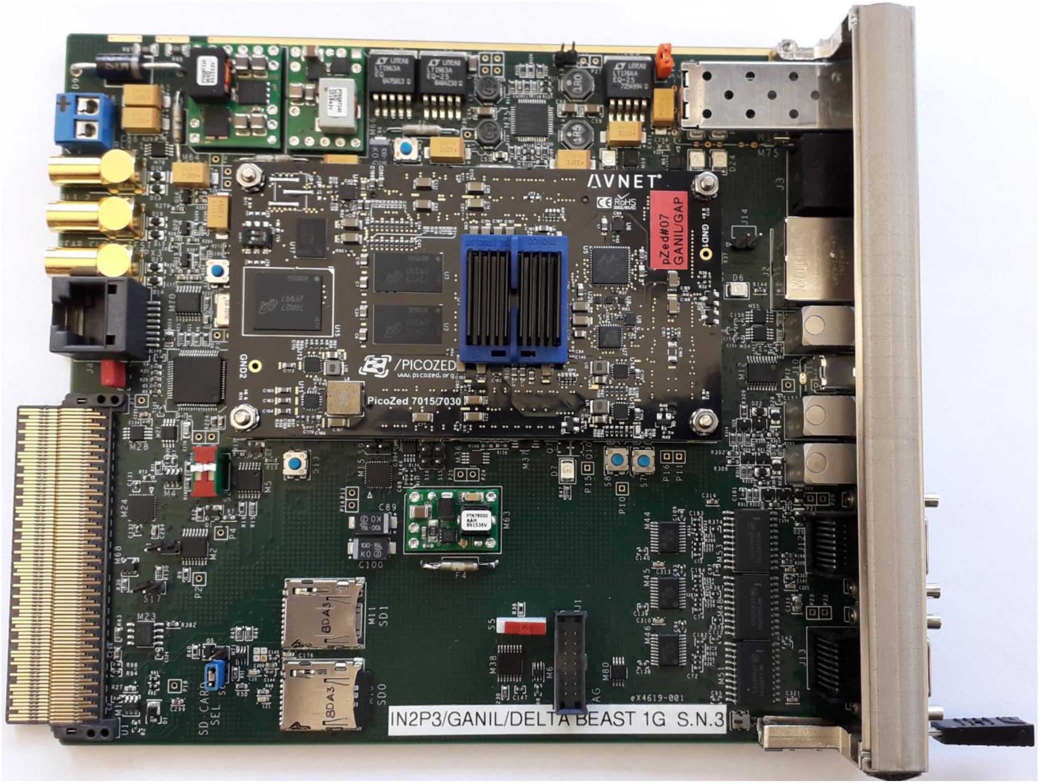
EN to CENTRUM RX

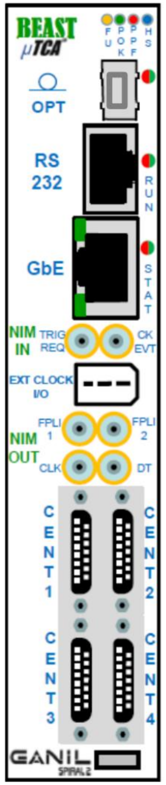
II.2. The beauty of the BEAST

SELF_SYNC mode GTS_SYNC mode MIXED_SYNC mode **MUTANT_SYNC mode**



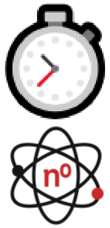
TS & EN from MUTANT





TS to CENTRUM RX

EN to CENTRUM RX



III. 1. How does the SMART system address future challenges ?

GANIL needs more GTS boards, and it’s **obsolete**

- More than **40 GTS boards** on 12 NIM Carrier on use today
- More than 20 GTS boards out of work
- **1 working GTS** mezzanine for hardware **spare**

$\Rightarrow$ SMART propose an **up to date hardware** solution

The GTS tree needs too much nodes

- For example : **13 GTS nodes** for 24 NUMEXO2 in **EXOGAM** setup

$\Rightarrow$ SMART_AMC_ROUTER node can address 15 endpoints ; **3 modules** are needed for **EXOGAM** setup

The GTS is seen at GANIL as a **black box**

=> SMART will be **developed**, **supported and documented** by GANIL local team

III. 2. The SMART project

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Sfp connectivity and **M**icrotca for **A**dvanced **R**emote **T**rigger

Phase 1 : SMART_AMC
Phase 2 : SMART_MCH
Phase 3 : SMART_TRIGGER

A minimum of 6 people in GANIL acquisition group involved in the project:

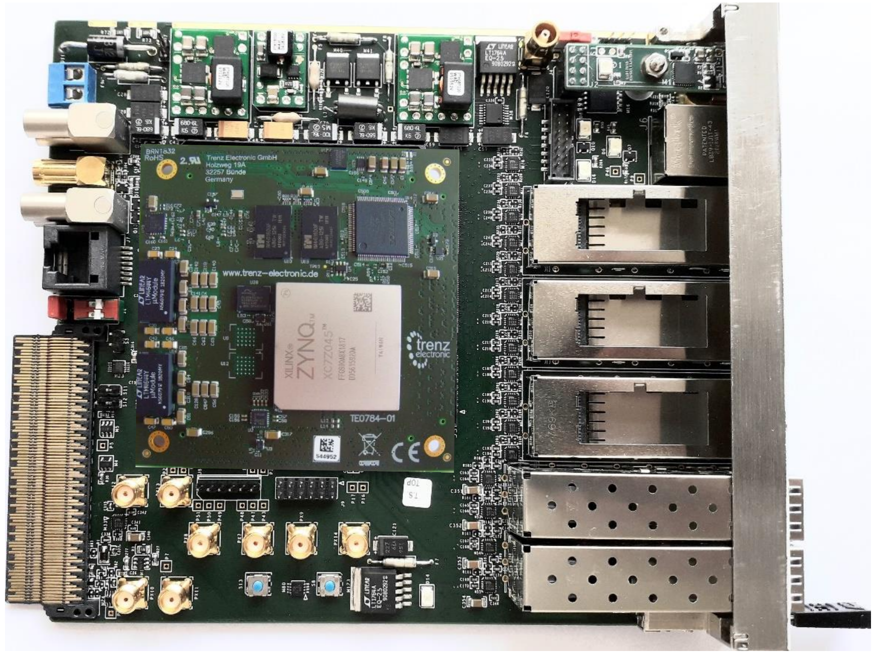
- Project leader, global architecture, firmware, software, CAD :................................. Gilles Wittwer
- PCB Routing, component ordering, manufacturing follow-up : .... Maria Blaizot
- SMART IP in NUMEXO2, SMART production tests : …….. Matthieu Bezard/Alexis Duval
- Embedded software (Linux OS, slow control, automatic alignment): ……………..….. Sébastien Coudert/Frédéric Saillant

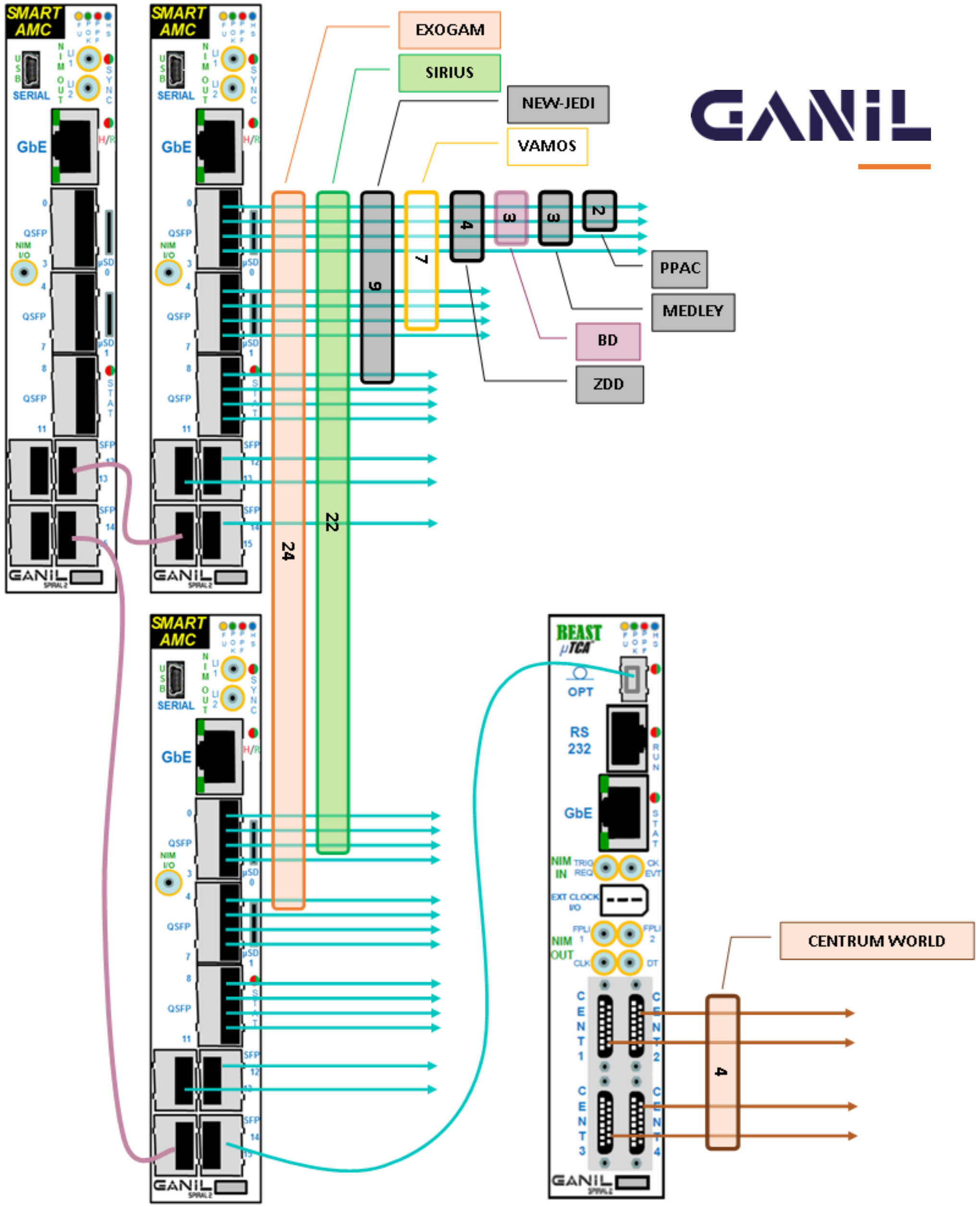
“More or less two Full-Time Employees for GANIL acquisition group”

III. 3. The SMART_AMC phase

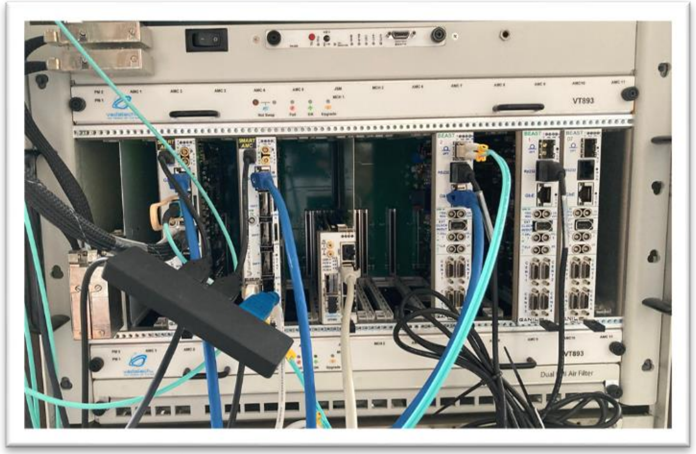
- Up to **240** digitizers or boards synchronized by **17** AMC's (1 HUB & 16 ROUTERS) housed in 2 µTCA shelves.

- **3 SMART_AMC** modules (1 HUB + 2 ROUTER) can synchronize up to **30 endpoints.** It's **equivalent to 14 GTS Mezzanines** in 5 GTS NIM Carrier





III. 4. What is on the shelf ?

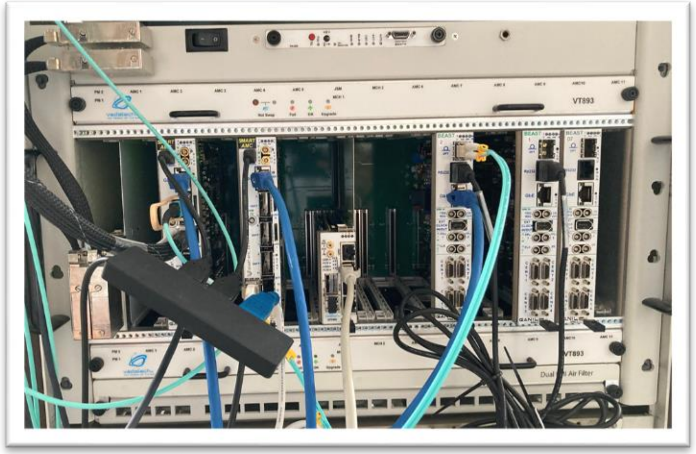




- **3 tests benches** : with in each 1 SMART_AMC HUB + 1 SMART_AMC ROUTER + up to 3 BEAST

- **26 SMART_AMC** modules ready to deploy (1st production batch)

III. 4. What is on the shelf ?

AGATA



- **3 tests benches** : with in each 1 SMART_AMC HUB + 1 SMART_AMC ROUTER + up to 3 BEAST

- **26 SMART_AMC** modules ready to deploy (1st production batch)

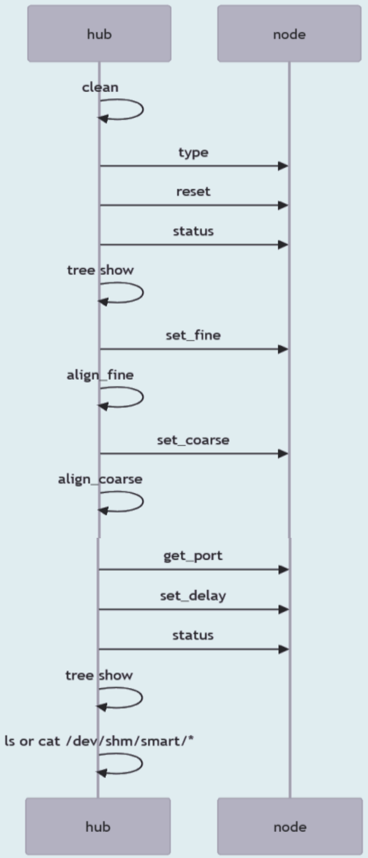
AGATA

III. 5. What is on the shelf ?

SMARTree : the alignment software

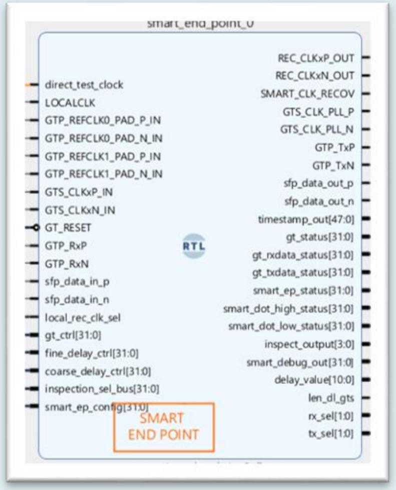
- **Autonomous system**
- Executed on SMART_AMC_HUB
- Setup via **ssh** on nodes
- Based on shell **scripts**
- POC **validated** with BEAST

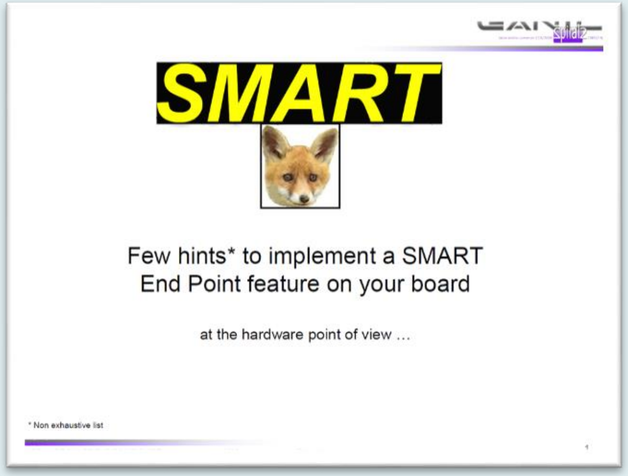
```
#!/bin/bash

#desc.: [SMART] smart discover and alignment suite
#usage: $0
#usage: $0 smart_tree.txt

version="v0.1.0"

#static port map between hub and routers
cfg=smart_tree.txt
cfg=$0

#check running on hub
if [ ! -e "/__SMART_AMC_HUB__" ]
then
  echo "error: this script should be running on SMART hub !"
  exit
fi

#clean
sudo ./clean.sh full
```



SMART_ENPOINT : the firmware

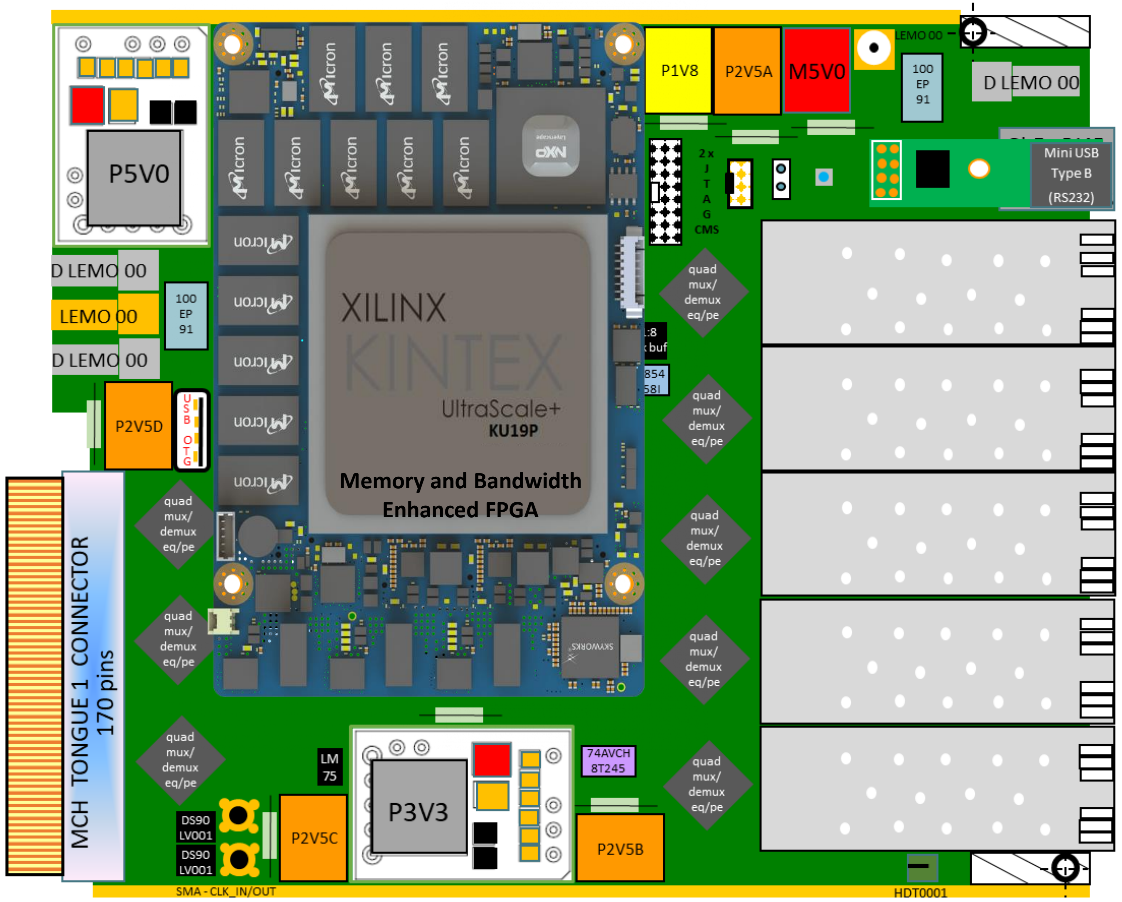
- ENDPOINT firmware IP **supported by GTA**
- **Documentation** to make implementation easier
- POC **validated** in BEAST module
- Under tests on **NUMEXO2_REA**
- On implementation on MASTER (**FASTER interface** with SMART)



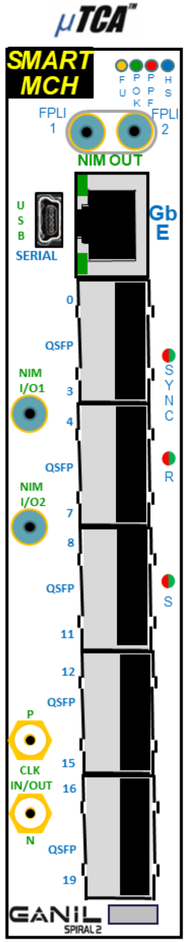


III. 6. The SMART_MCH phase

- From 240 to **480 End Points** synchronized by 32 SMART_AMC_ROUTER modules and 1 SMART_MCH housed in 3 µTCA shelves
- **SMART_TRIGGER** will be implemented in this module for AGATA needs
- **ToDo list (Q1/2026 milestone):**
  - ❑ SMART MCH prototype assembly
  - ❑ SMART MCH prototype for tests (hardware, firmware, software)
  - ❑ SMART MCH prototype to production update (schematics, routing, …)
  - ❑ SMART MCH ready to use (automatic alignment + first trigger version)



5 QSFP - 20 HUB ports



IV. How are we deploying it in practice?

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SMART_AMC deployment strategy

- **Milestone 1 :** Q3/2025 : An experimental setup with **NUMEXO2_REA**
  - Validation of the **SMARTree** software and **SMART_ENPOINT** on NUMEXO2
- **Milestone 2 :** Q3/2025 : A experimental setup with **FASTER** and NUMEXO2_REA
  - Validation of SMART_ENDPOINT in FASTER coupled with NUMEXO2 for **TAS experiment**
- **Milestone 3 :** Q1/2026 : Deploy **SMART in VAMOS-EXOGAM** setup
  - Validation of a setup with NUMEXO2 and **BEAST/VTC as gateway** towards MESYTEC VME modules
- **Milestone 4 :** Q2/2026 : Integration of SMART_ENPOINT in **AGATA PACE module**
  - Validation of the last endpoint implementation for AGATA-GRIT-VAMOS

V. What else?

This presentation hasn't covered the full scope of our ongoing work, nor all the open questions to keep exploring together:

- **SMART_TRIGGER definition for AGATA**
  - *We have to write the functional description of the Trigger for AGATA needs*
- **SMART_AMC production batch 2 & SMART_MCH production batch**
  - *We have to plan the production of SMART modules to satisfied all expressed needs*
- **SMART_ENDPOINT for MESYTEC modules**
  - *We have to see if the BEAST & VTC gateway fulfill the needs or if we have to go further*
- **Other timestamping systems (e.g., White Rabbit)**
  - *Exploring compatibility and potential integration pathways for even broader system interoperability.*

Plenty still on our plate—let's keep the discussion going!

Thank you for your attention

	SMART_AMC ROUTER	SMART_AMC HUB	SMART_MCH
PCB (14 layers)	640+150(VAT)	640+150(VAT)	~1000(estimation)
Front panel kit + Drilling + Silkscreen	20 50 70	20 50 70	20 50 70
Assembly + Passive components	850	850	900
Active components (provided)	600	600	700
SOM	2300	2600	9000
UART2USB board	120	120	120
Price/Unit (€)	**4800**	5100	**11860**