AGATA Project Phase 2: Towards 4π

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on behalf the AGATA Collaboration

3rd GRETA/GRETINA – AGATA Workshop
2nd – 4th October 2019

IFIC INSTITUT DE FÍSICA CORPUSCULAR

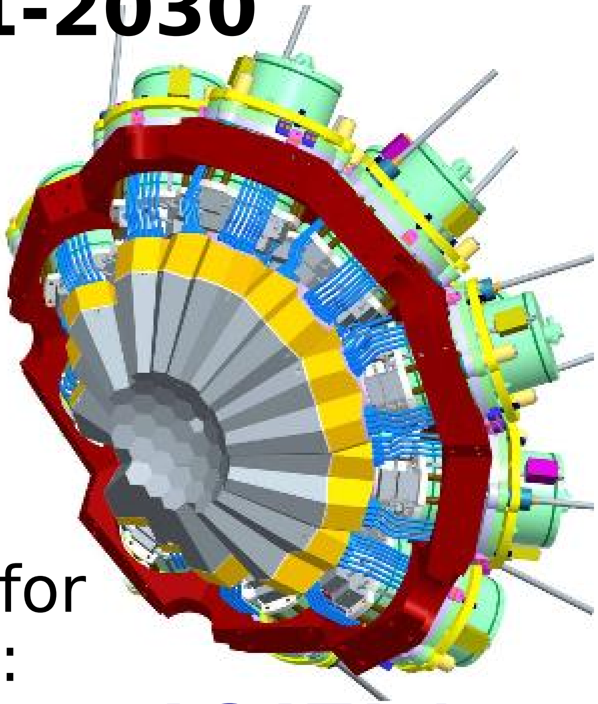
CSIC CONSEJO SUPERIOR DE INVESTIGACIONES CIENTÍFICAS

AGATA ADVANCED GAMMA TRACKING ARRAY

From AGATA Phase 1 to AGATA 4π

2009-2020 → 2021-2030

- **Phase 1 of AGATA (>1π)→ 60 crystals**
- **MoU ongoing, ~90 % achieved, Extended until 2020**
- **60 crystal set-up at LNL in 2021**



AGATA 1π

- **AGATA 4π: Project Definition**
- Improving mobility and compatibility for the host labs. Foreseen Hosting Labs: FAIR/NUSTAR, GANIL/SPIRAL, HIE-ISOLDE, JYFL, LNL/SPES
- Sustainable growth of the AGATA subsystems from 60 to 180 Detectors.
- Achieving full Tracking Performance and optimizing the Position sensitivity.
- Improving performance of subsystems FEBEE, DAQ, etc.

Detector Module & Cryostat

48 AGATA capsules procured

A001 – A016 Delivered,

B001 – B016 Delivered, B010 repairing

C001 – C016 Delivered, C001 repairing

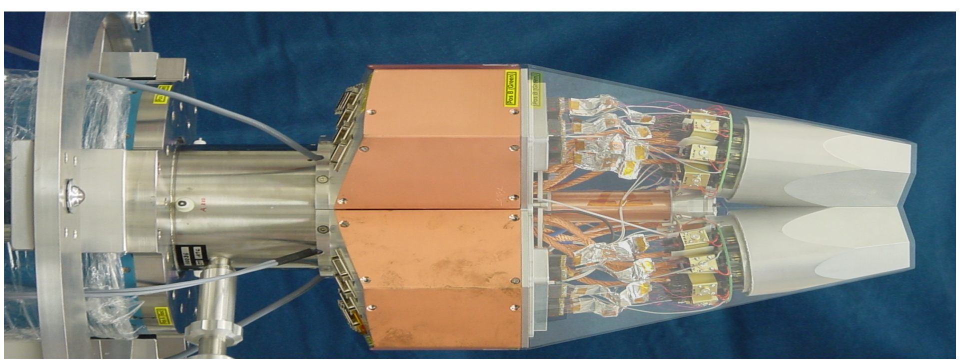
6 Capsules being ordered in 2019 by Hungary and UK

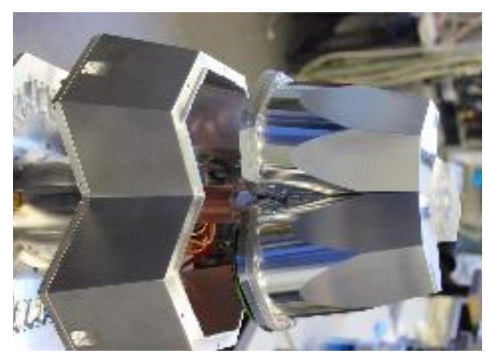
Foreseen modifications to improve the reliability of the cryostats:

- New feedthroughs: consist of gold-plated contact pins in insulators of aluminium-oxide ceramic.
- Improved vacuum getter material and positioning

Potential difficulties due to obsolete electronic components and maintenance of the preamps is anticipated.

- Obsolete field effect transistor FET BF862 no longer produced.
- The same is true for the liquid nitrogen fill level meter.



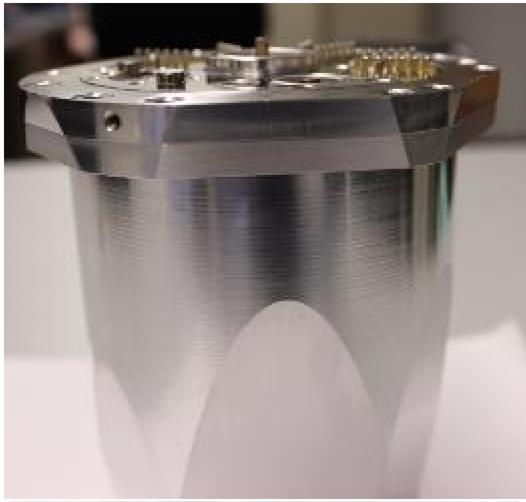


IKP-Köln, Uni. Liverpool, CEA IRFU-Saclay, GANIL, IPHC-Strasbourg

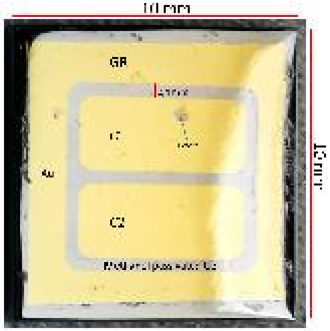
Detector Developments

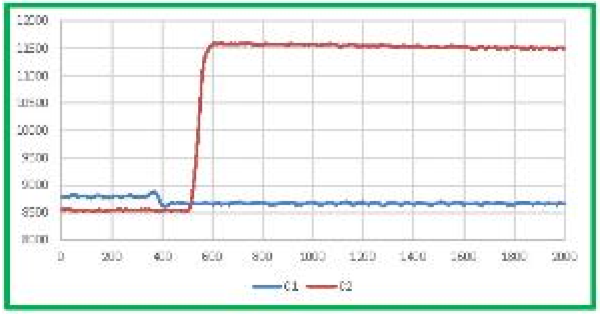
New Encapsulation, R&D on Ge detector

- A new encapsulation development has been performed at IKP-Cologne in collaboration with Mirion/Canberra.
- The design of the new capsule allows to reuse it. Fully compatible with previous ones. Mounting of crystal in capsule can be done now at Mirion →faster and safer.

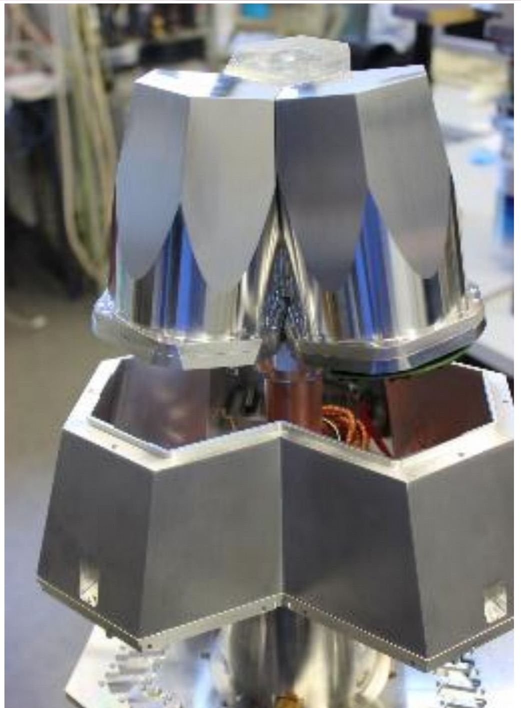


- ENSAR2 JRA2 – PSeGe R&D on Position-Sensitive Germanium Detectors for Nuclear Structure and Applications: task 1 and 3
  - Task 1: New technologies on passivation and segmentation (INFN, IKP-Cologne):
  - Task 3: R&D on segmented p-type coaxial detectors (IFIC, INFN, Uni. Padova)



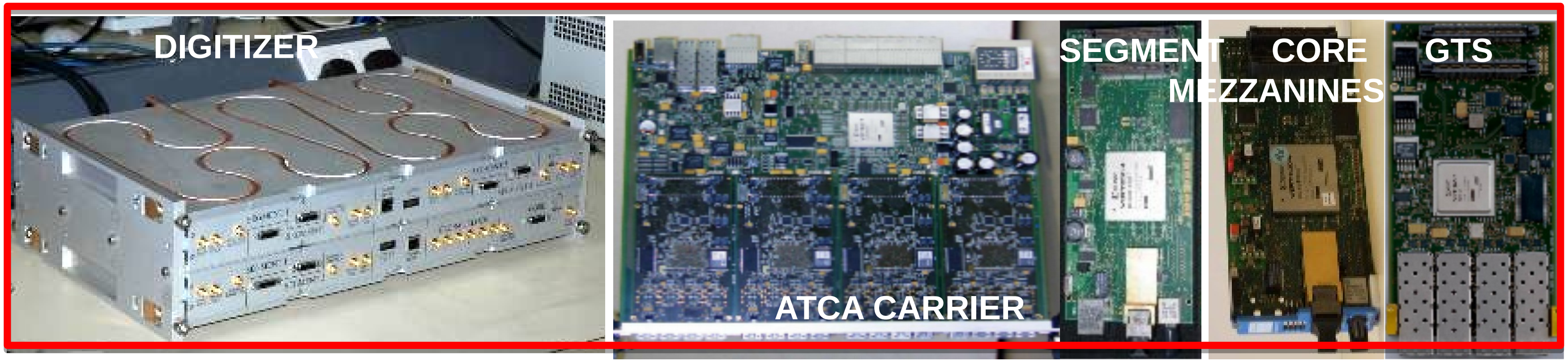


2mm thick
p-type HP-Ge
prototype.
Gap 0.4mm
next 0.2 mm

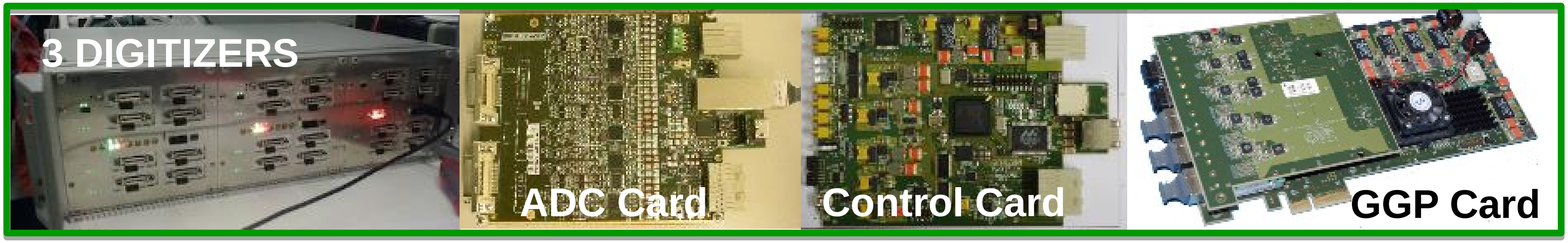


IKP-Köln, INFN-LNL, Uni. Padova, IFIC, Uni.Liverpool, IPHC, Mirion

AGATA Electronics Phase 0



AGATA Electronics Phase 1



Goal: to instrument 45 Channels

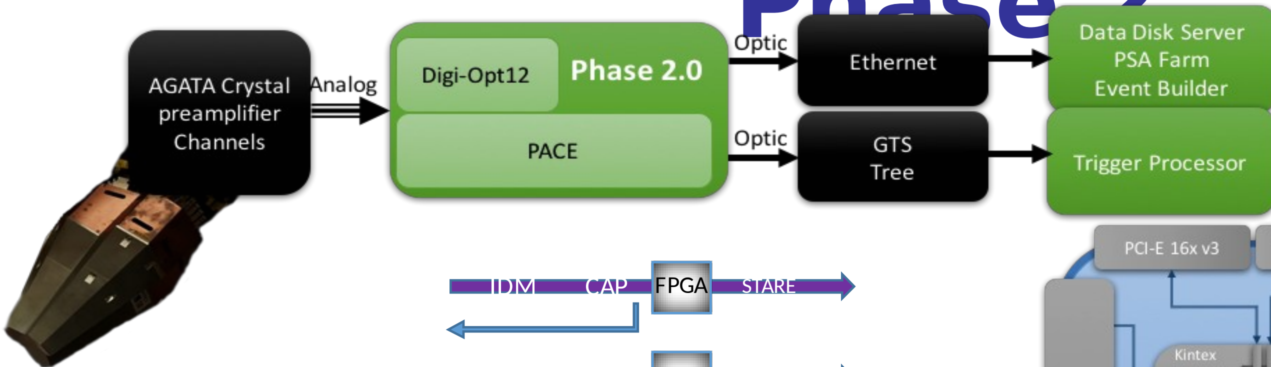
Both require optical fibre connection between Digitizer and Pre-processing

Both use largely obsolete components

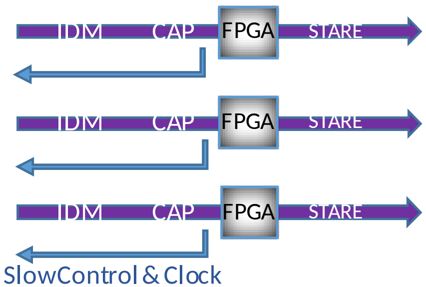
IPHC Strasbourg Uni.Liverpool STFC Daresbury IPNO, CSNSM-Orsay INFN-Padova

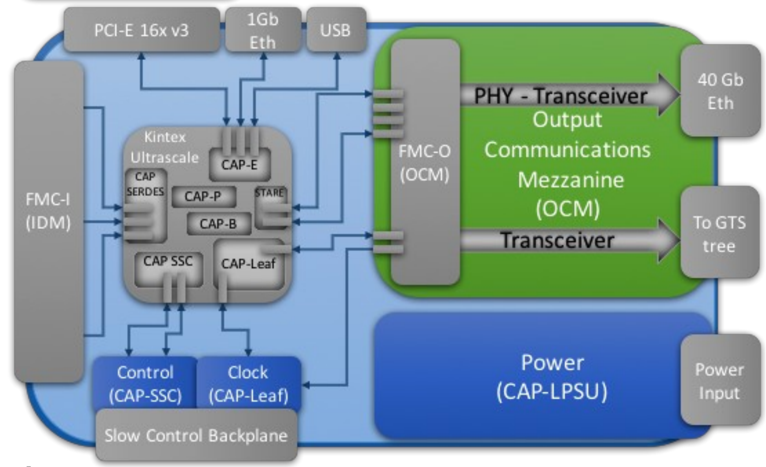
INFN-Milano INFN-Padova INFN-LNL IFIC-Valencia ETSE-Uni-Valencia

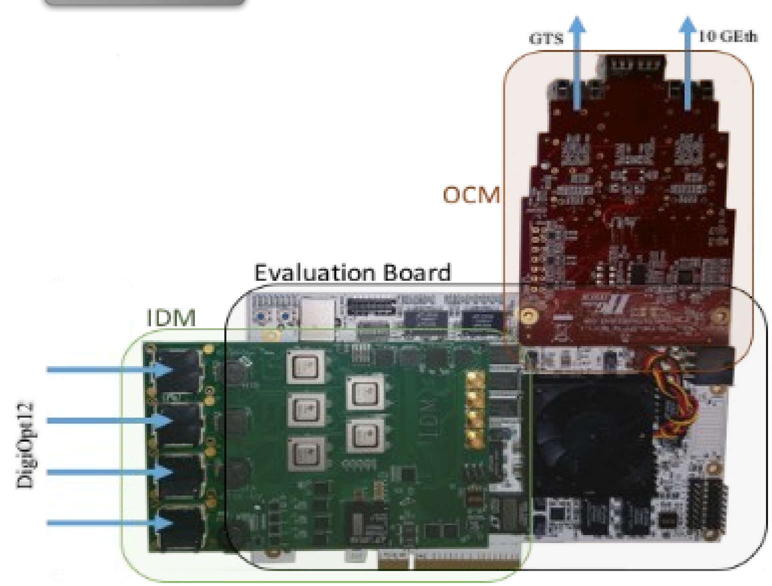
R&D on Electronics for the Phase 2



Higher processing capability.
Ethernet readout.





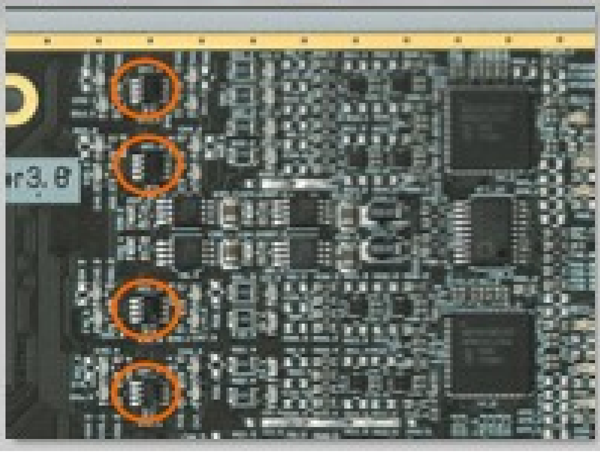


- Electronics R&D, aiming for a higher processing capability and Ethernet readout.
- DIGITIZER based on DIGIOPT12 (INFN-Milano) Improved Differential linearity (Sliding Scale).
- Pre-processing being tested on a Virtex Kintex or Zinq Ultraescale. SoM based solutions
- Optimized Input Data Module (IDM), Ethernet readout module (STARE) and GTS interface
- Firmware aiming to improve the triggering, processing and read-out capabilities.
- Inspection and monitoring information for diagnostic with a friendly GUI

INFN-Milano, CSNSM-Orsay, IPHC-Strasbourg, STFC-Daresbury, IFIC & ETSE-Valencia

DIGIOPT12 Digitizer

New opamps for analog signal conditioning

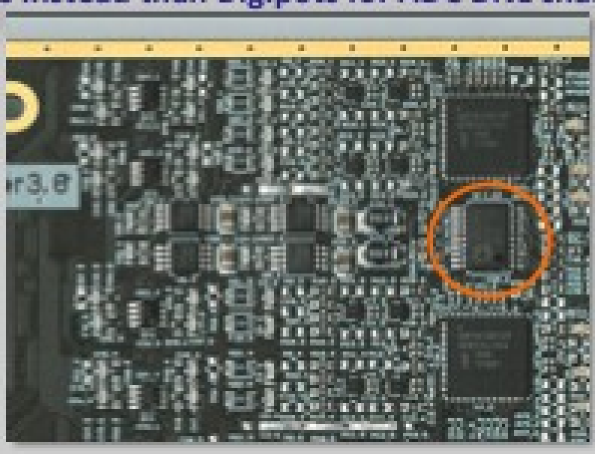


"Old" opamp: **AD8030**
e_n = 16.5 nV / Hz$^{1/2}$

"New" opamp: **LTC6247**
e_n = 4.6 nV / Hz$^{1/2}$

New opamps feature lower noise and larger bandwidth

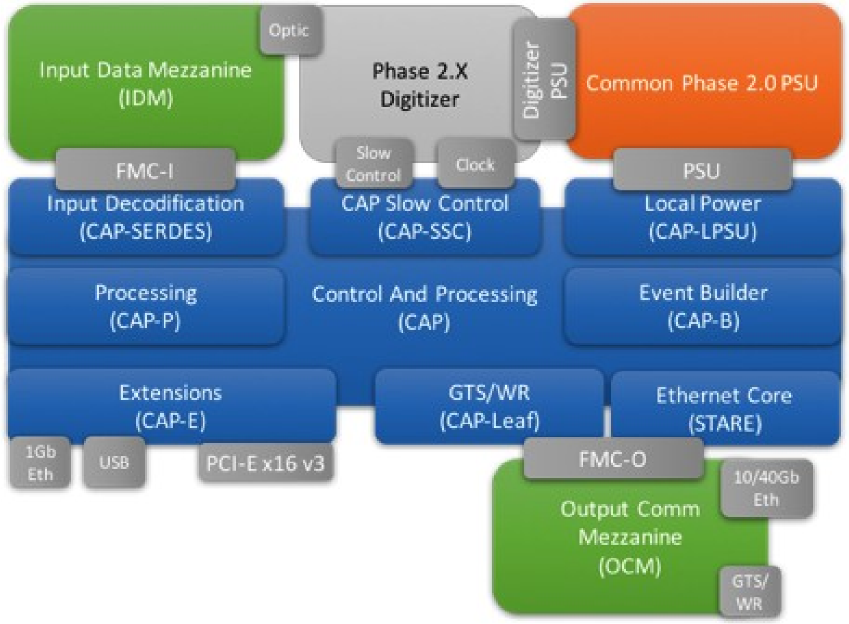
DACs instead than Digipots for ADC DNL characterization and sliding-scale correction optimization



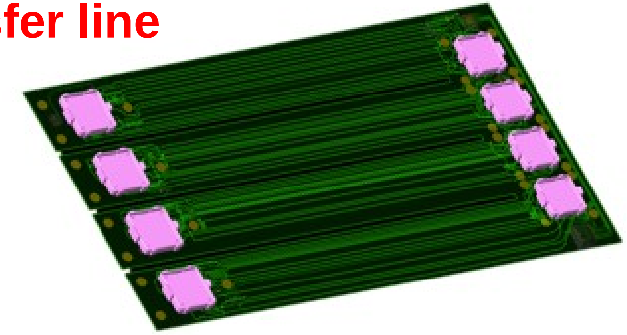
Use of DACs is envisaged in place of Digipots for high-resolution DC offset adjustment over the full ADC range.
The DC offset may then be dynamically changed in order to implement the sliding scale correction as a cure to ADC DNL.

INFN-Milano, CSNSM-Orsay, IPHC-Strasbourg, STFC-Daresbury, IFIC & ETSE-Valencia

Pre-Processing

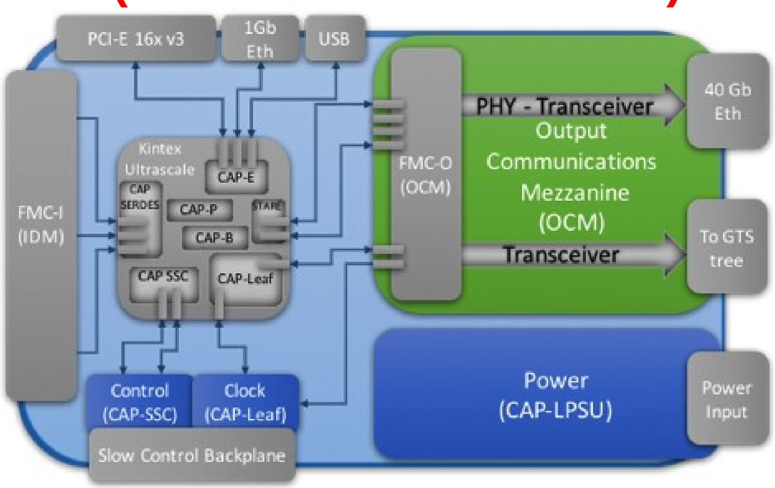


Data transfer line



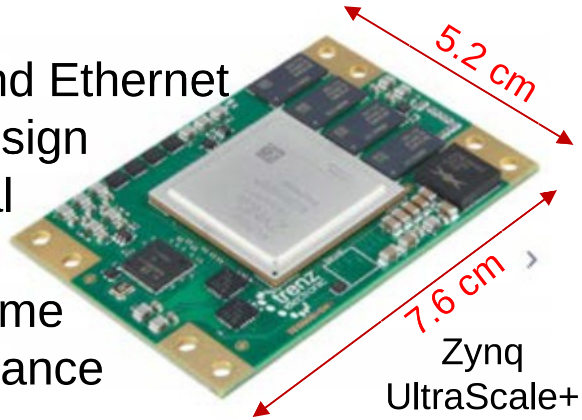
IDM Input Data Motherboard. Concentrator Board.

FPGA Processing and Control Board (Includes GTS Hardware)



Data Processing and Ethernet Transfer boards Design on SoM commercial Mezzanines.

- Reduces Design time
- Increases Maintenance capability



Zynq UltraScale+ XCZU15EG

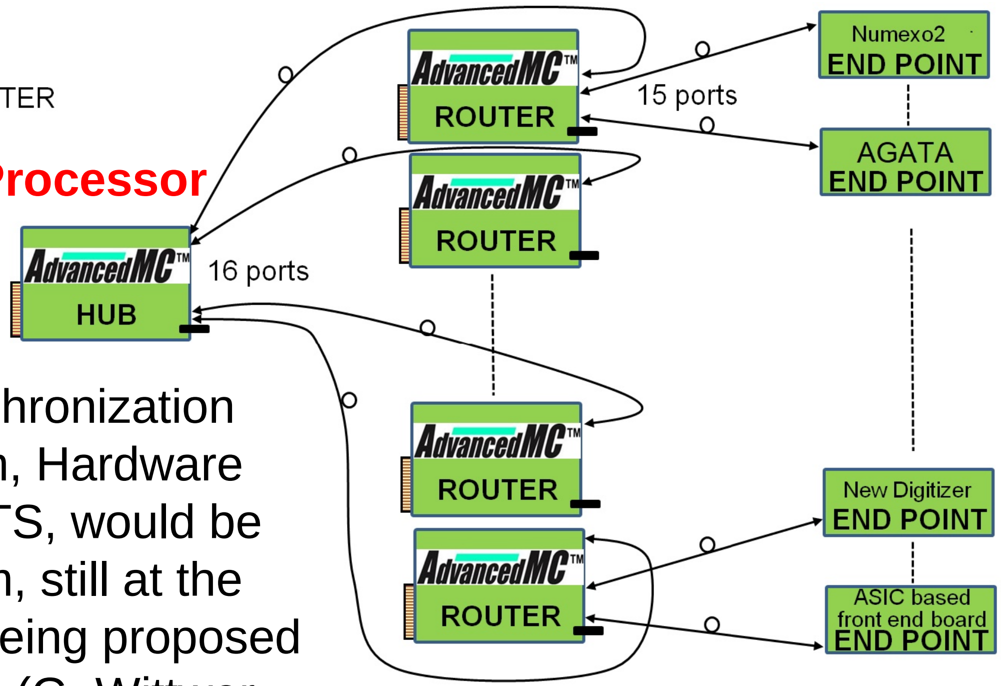
IFIC & ETSE-Valencia, CSNSM-Orsay, INFN-Milano, IPHC-Strasbourg, STFC-Daresbury,

GTS → SMART

UPGRADE OR NEW SYNCHRONIZATION/TRIGGER SYSTEM

- HUB
- ROUTER

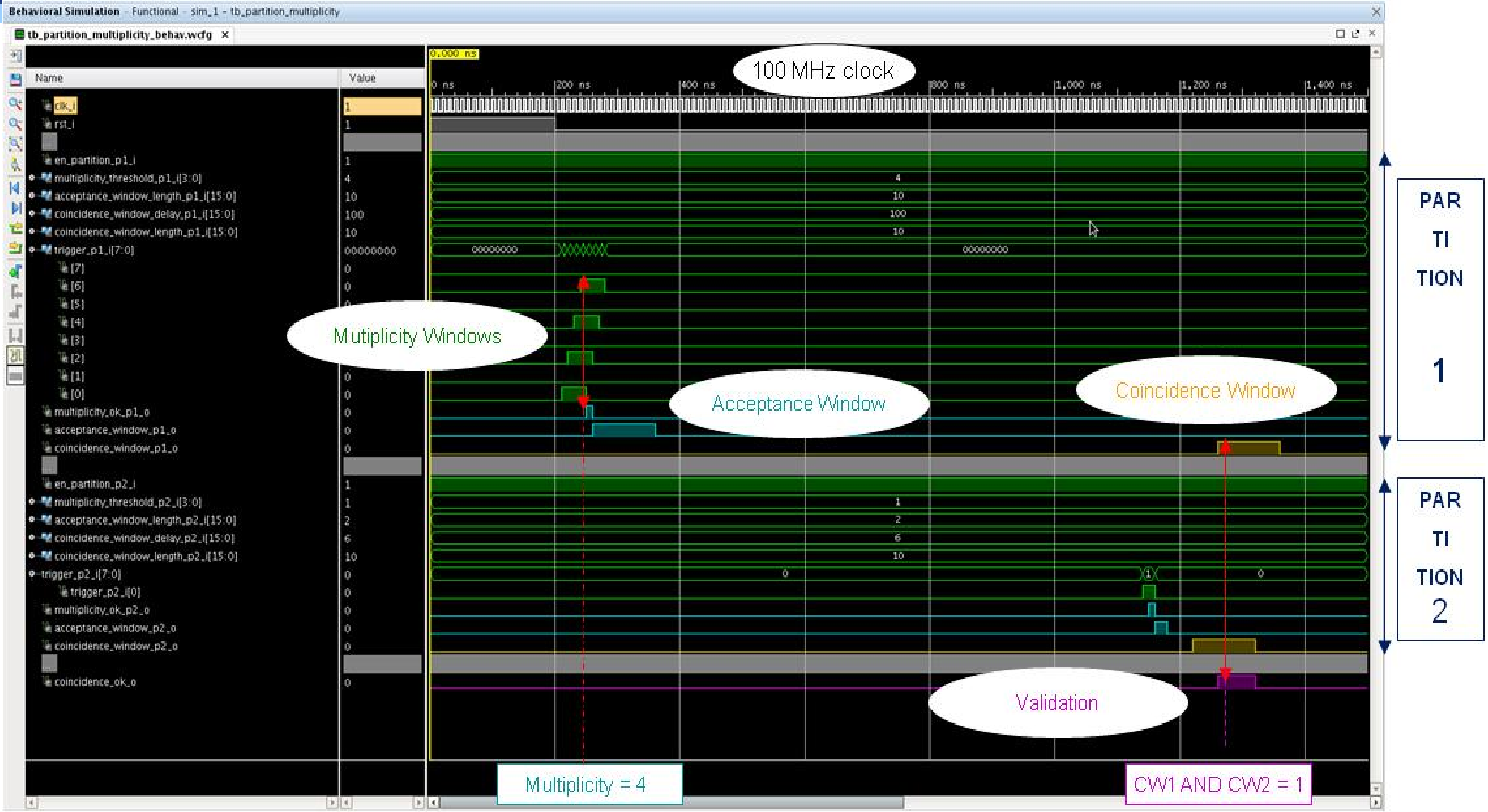
HUB+Trigger Processor



One possible Synchronization and Trigger system, Hardware compatible with GTS, would be the SMART system, still at the conceptual level, being proposed by the GANIL GAP (G. Wittwer et al.).

Expected to start in 2021 with the present GTS system but we would need to migrate towards a new system (SMART) system during the early years of the Phase 2.
Note that the pre-processing embedded GTS hardware is compatible with the SMART hardware. In SMART the HUB hosts the Trigger Processor.

NUMEXO2 / GANIL GTS Trigger Processor



Looking forward to have a Hardware and a Software Trigger Levels

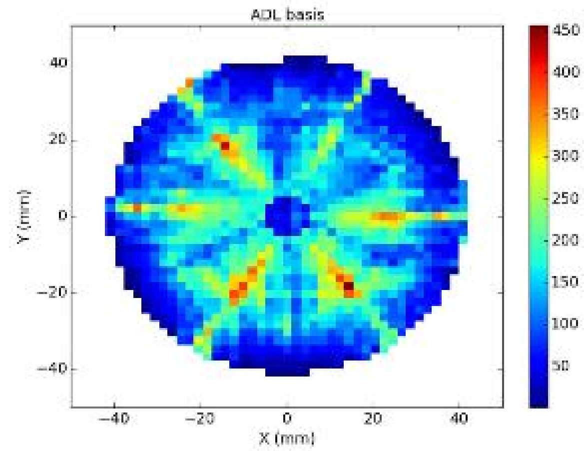
Courtesy of M.Tripon and the GANIL collaborators

GANIL-Caen, IPHC-Strasbourg, CSNSM

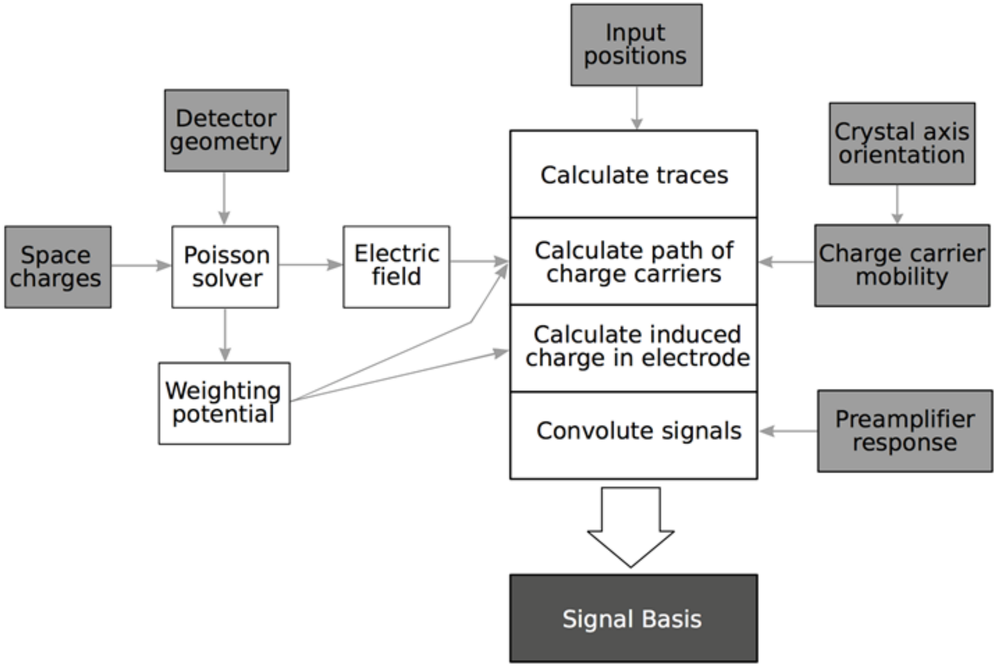
PSA & Characterization

Investigation of the dominant factors limiting the performance of the calculated basis. In collaboration with our GRETA colleagues!

- An evaluation of the impact of the temperature dependence of the mobility parameters
- The impact of a realistic charge cloud size
- Crystal dead layer related effects – the dead layer around the core electrode.
- Neutron damage limitations – how the degree of neutron damage influences the efficacy of the signal basis in addition to the energy resolution correction already implemented.
- The impact of the electronics signal chain (preamplifier,grounding/configuration)



"Clustering" of interactions with present PSA.



Uni.Liverpool, STFC-Daresbury, IPHC-Strabourg, CSNSM, GSI, Uni,Salamanca

PSA & Characterization Upgrades

The PSA:

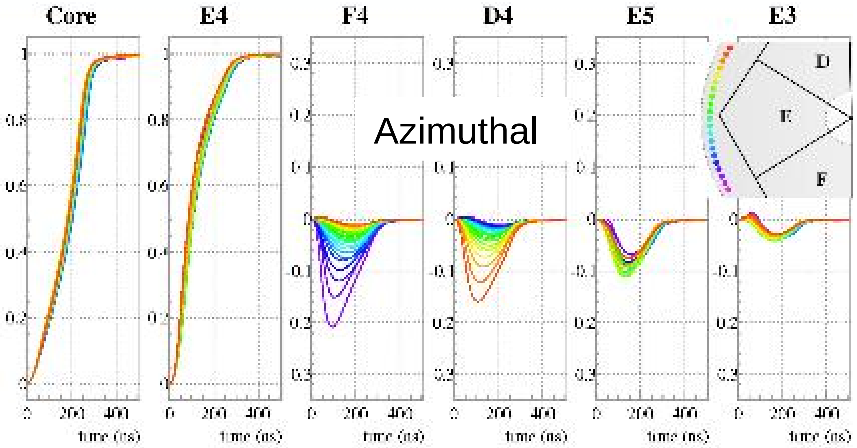
- on-going algorithm upgraded to include handling of multiple interactions in a segment.
- The performance of this algorithm will be evaluated for phase 2.
- Export of PSA position uncertainties from the PSA algorithm to the γ-ray tracking algorithm will be implemented → performance improvements in Tracking.
- An exploration into the use of other (non AGS) PSA algorithms for future implementation. Machine Learning Algorithms.

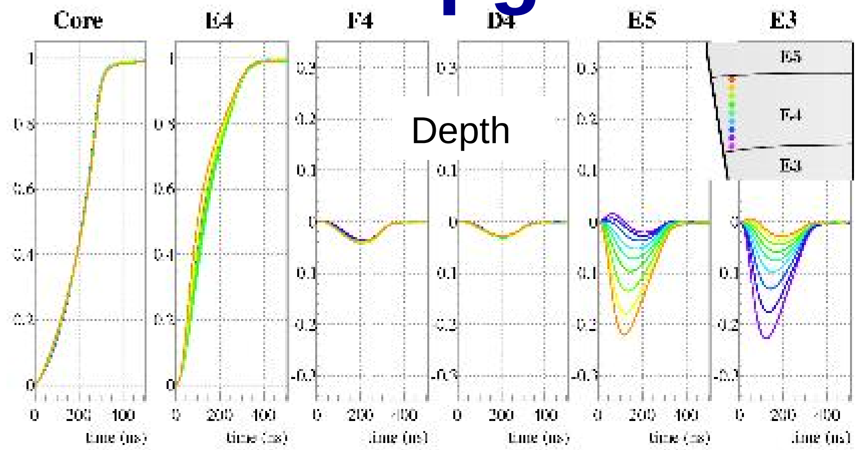
Implications on Data Flow and PSA Infrastructures

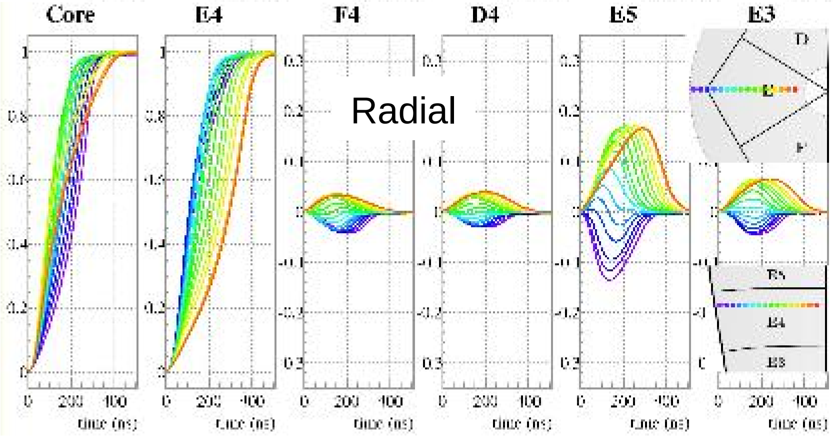
- The computation performance of the algorithm(s) needs to be optimised to run on highly parallel, multi-core nodes.
- The existing algorithm is limiting the count rate capability of AGATA phase 1.
- In AGATA phase 2, the algorithm(s) will be optimised to adapt to the new platforms and to allow flexibility in basis format, PSA outputs, and pre-processing options.
- To take advantage of the performance gains provided by massively multi-core processors these routines will need to be vectorized and multi-threaded.

Uni.Liverpool, STFC-Daresbury, IPHC-Strabourg, CSNSM, GSI, Uni,Salamanca

PSA & Characterization Upgrades







Induced current by the moving charge in the sensing contact: Ramo's Theorem. **E. Gatti, et al. NIM 193 (82) 651**

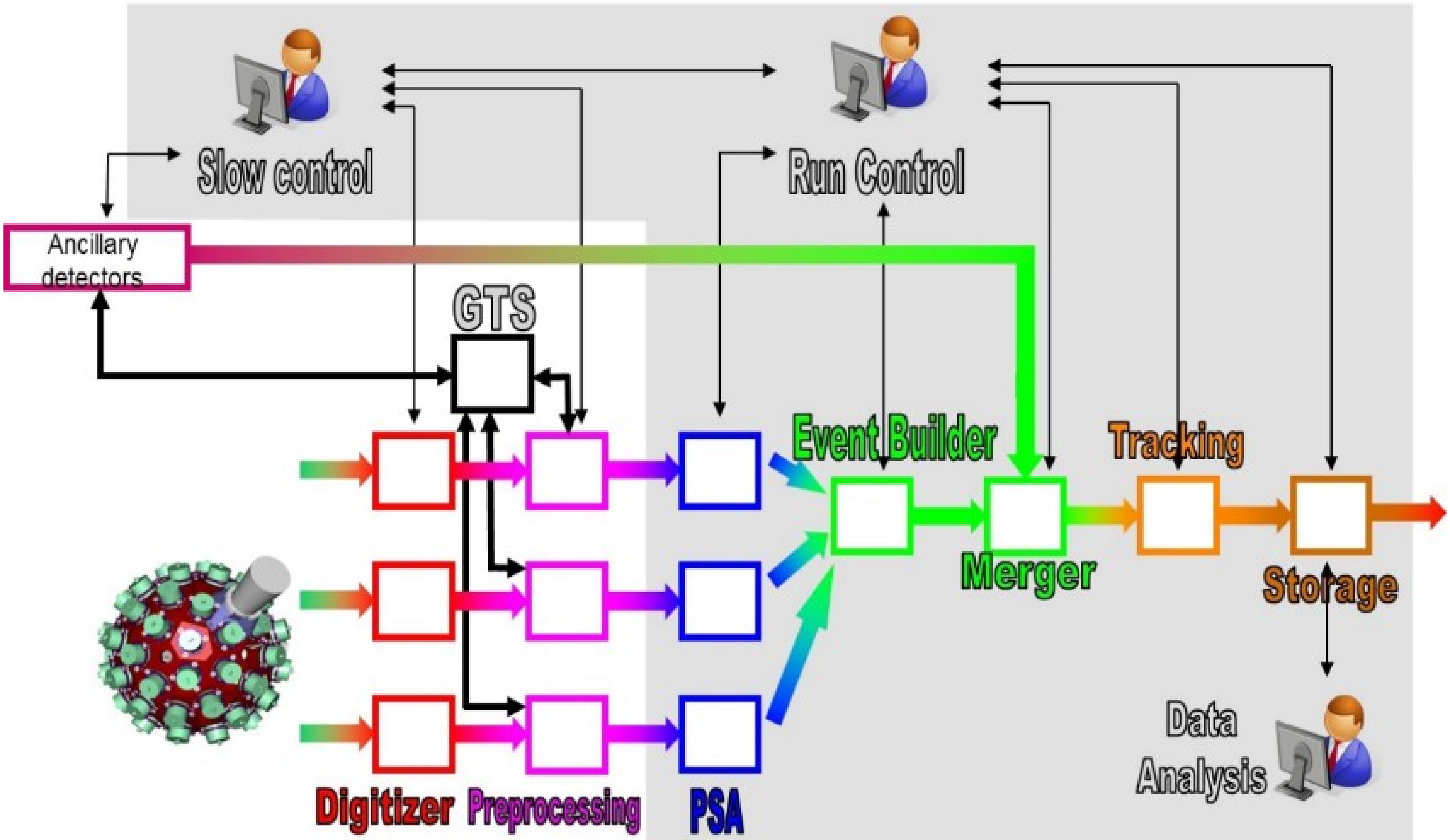
Figures courtesy of M.Ginsz, et al., IPHC Strasbourg

Fundamental tool for understanding the PSA are the Scanning Tables performing the Detector Characterization

- 5 scanning tables, and associated material (criostats, electronics, etc), existing in the collaboration Uni.Liverpool, IPHC, CSNSM, GSI, Uni.Salamanca.
- Recent Upgrade of the Uni.Liverpool and IPHC setups
- Campaign to validate the Pulse Shape Comparison Scan (PSCS) against conventional coincidence data and to obtain Pulses from n-damaged detectors.

Uni.Liverpool, STFC-Daresbury, IPHC-Strabourg, CSNSM, GSI, Uni,Salamanca

AGATA Data Flow, Control and Storage



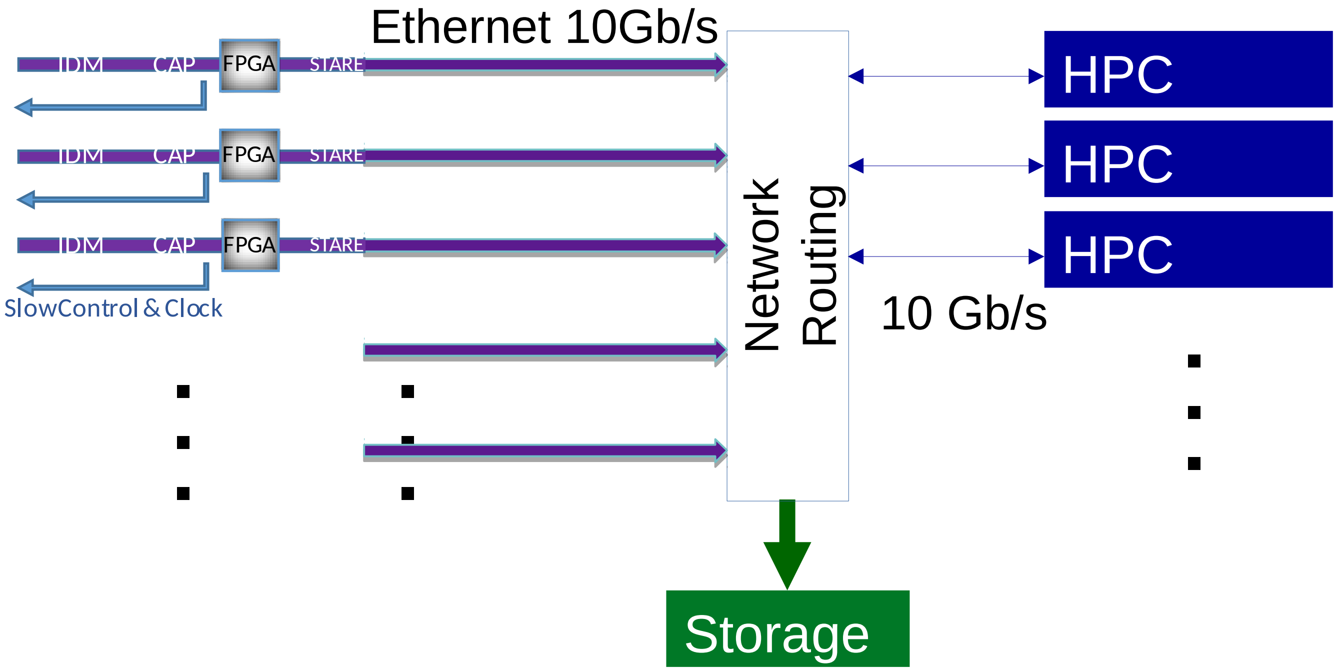
Producers (hand-out data), intermediaries (filters, mergers, …) and consumers (data storage into files, histograms, …).

No changes foreseen in the concept but in the infrastructure

CSNSM-Orsay, GANIL, INP-Lyon, IPN-Orsay

AGATA Data Flow NARVAL→ DCOD towards 4π

Present AGATA electronics is based on boards with point to point optical fiber connections. Future Electronics based on Ethernet standard



CPU can be distributed over High Performance Computer farms (HPC) :

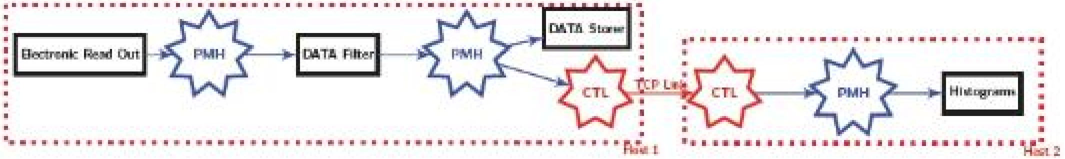
Not necessary 1 node/crystal with the load balancing and new technologies

Specially important if AGATA PSA is upgraded to more complex algorithms

DCOD (NARVAL+ Posix Memory Handler (PMH) + Common Transport Layer (CTL)):

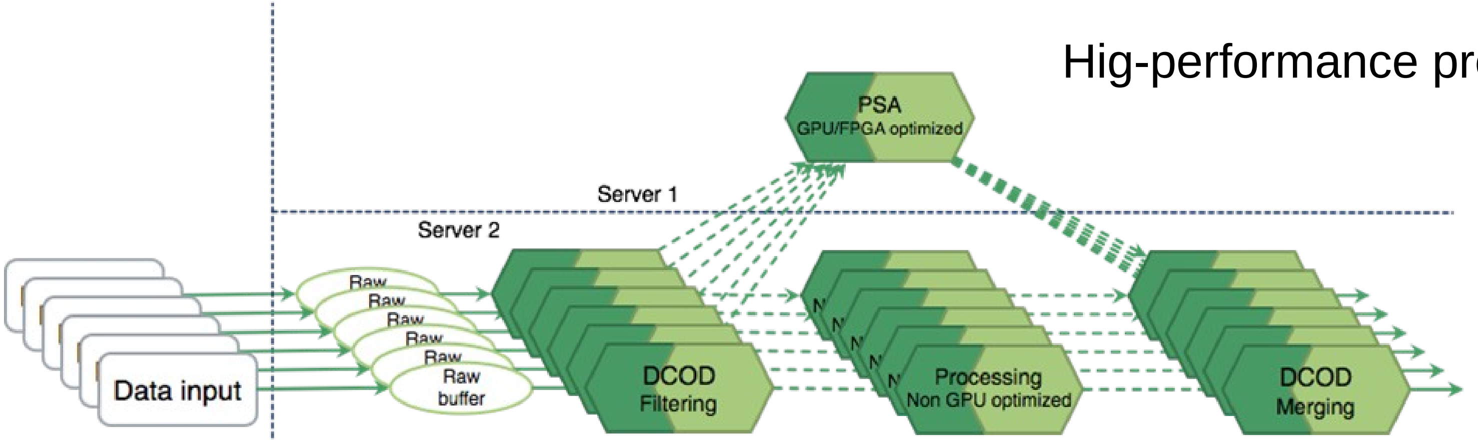
Easy to upgrade from 1π to 4π

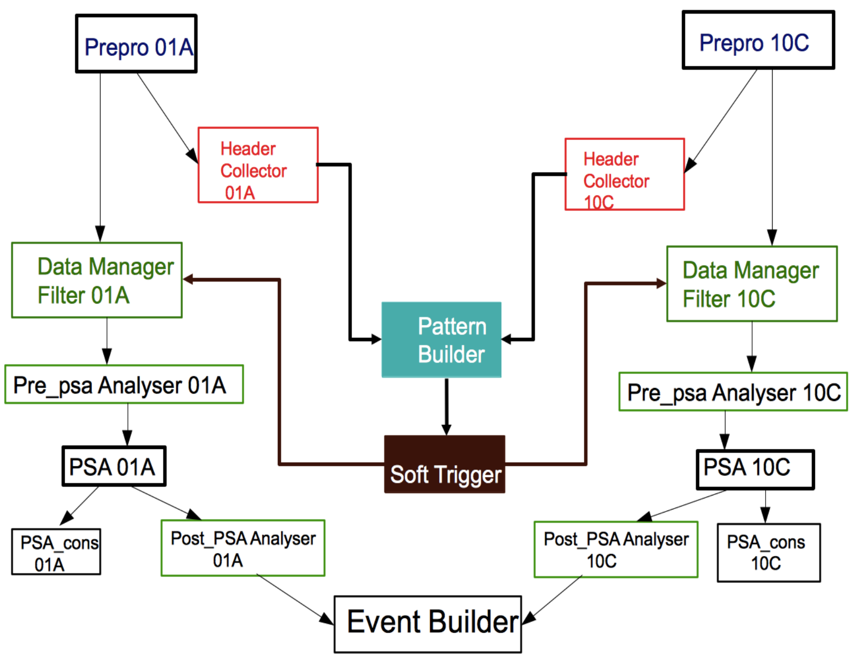
X.Grave, E Legay et al.
CSNSM-Orsay, GANIL, INP-Lyon, IPN-Orsay



AGATA Data Flow

Hig-performance processing



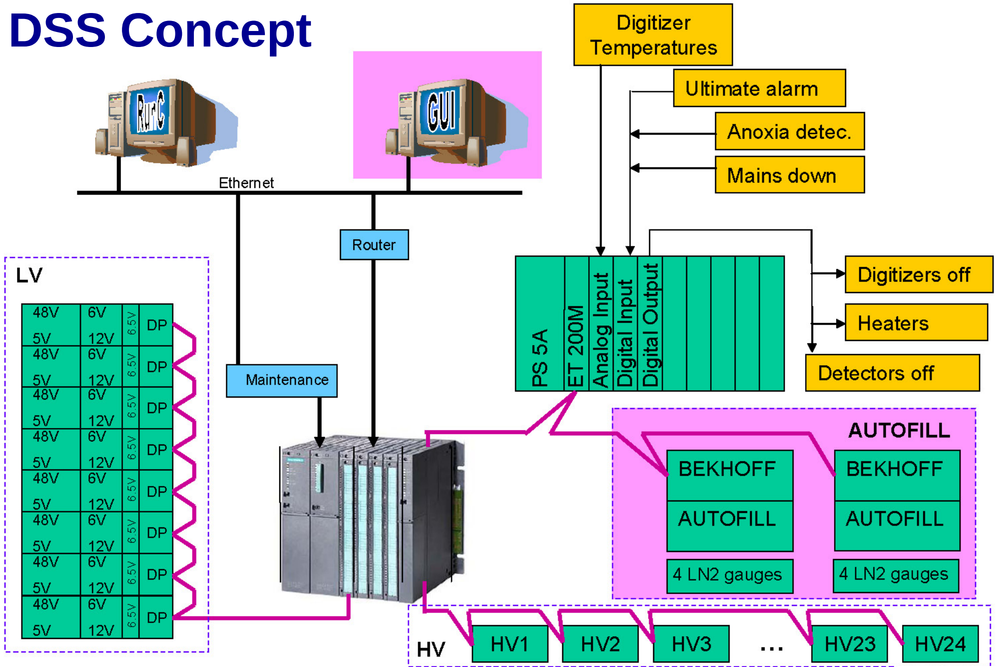


Possibility to combine the hardware trigger with a second high level Software Trigger

CSNSM-Orsay, GANIL, INP-Lyon, IPN-Orsay

Detector Support System

DSS Concept

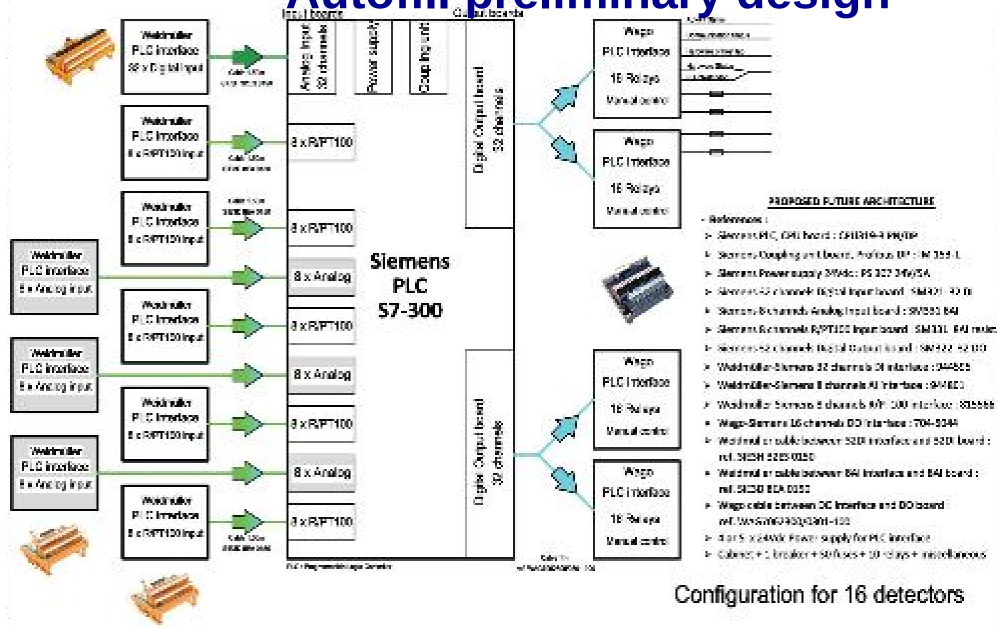


- Detector Infrastructure W.G. with the future Host Laboratories experts and experts of the AGATA Subsystems (Detector, Electronics…) having Initial discussion on how to design the future LVPS, HV, Autofill and in general the DSS.
- Not expected large changes for cabling and detector patch boxes

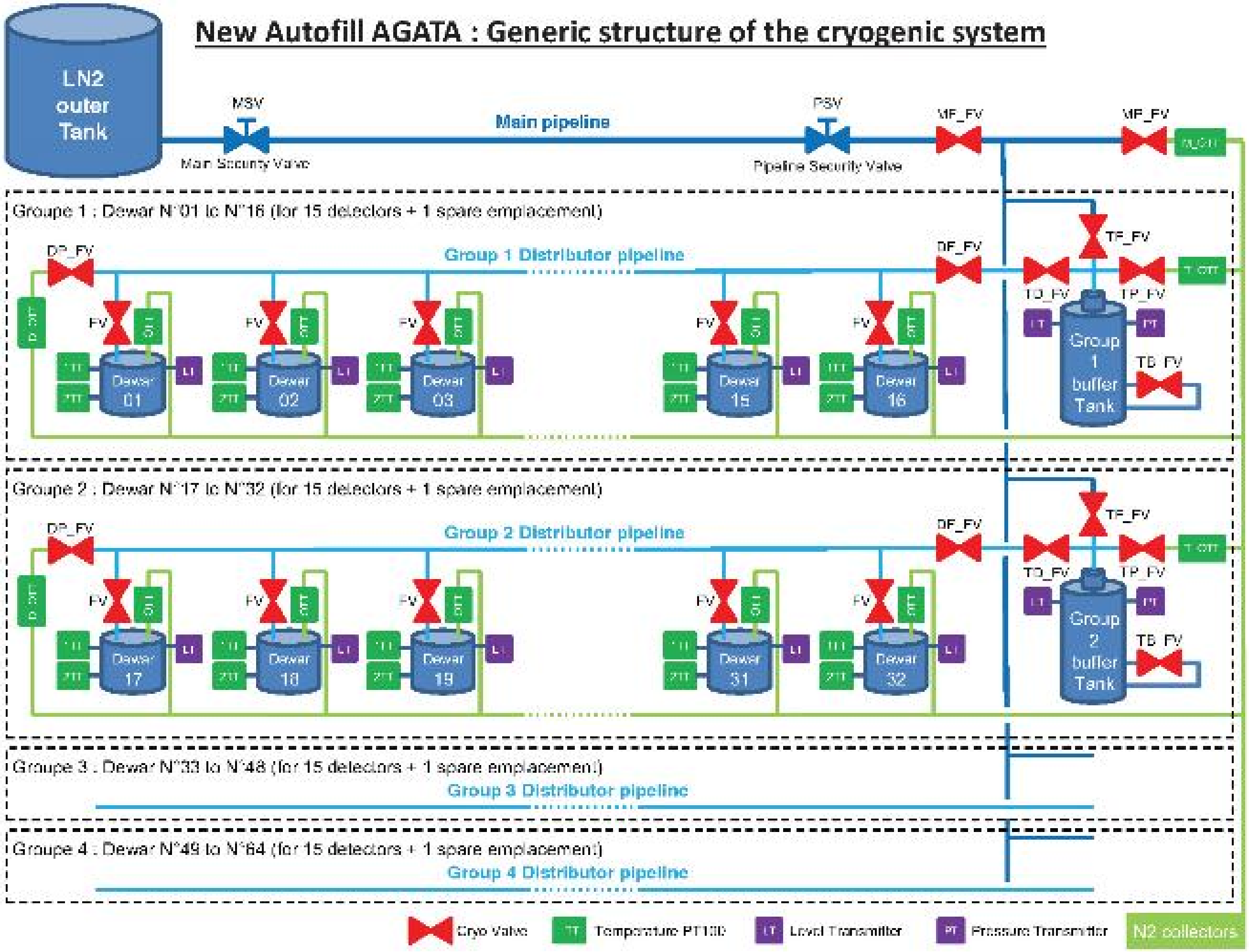
New components with reduced power requirements like DIGIOPT12 Digitizers (1/3 of the early Digitizers). LVPS 48V units should be redesign. The 6.5V modules have been already suppressed. The Pre-amplifier modules +6V/+12V and -6V/-12V will remain.

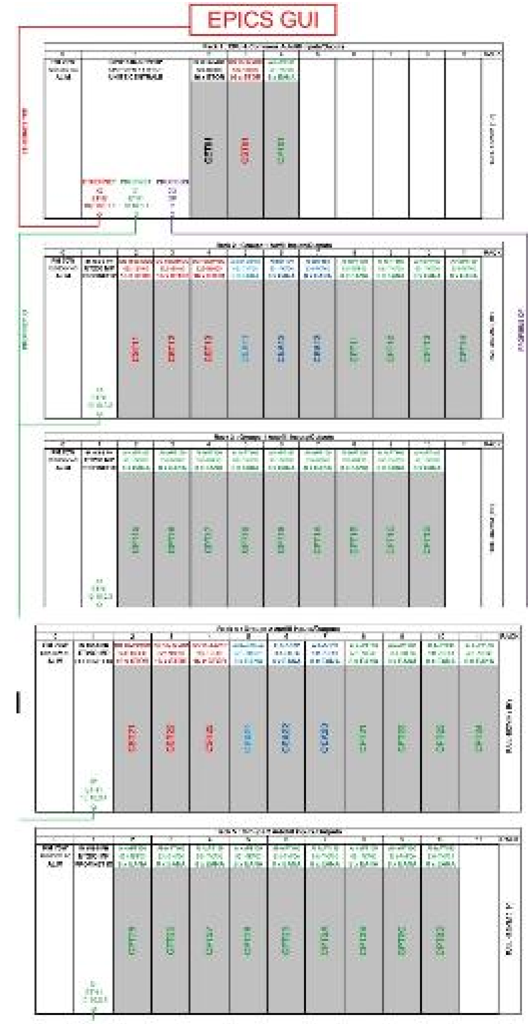
CEA Saclay, INFN-Padova, INFN-Milano, GSI, CSNSM-Orsay STFC-Daresbury, IPHC-Strasbourg, GANIL, INFN-LNL, JYFL-Jyvaskyla,

Autofill preliminary design



Detector Infrastructure: DSS Subsystems

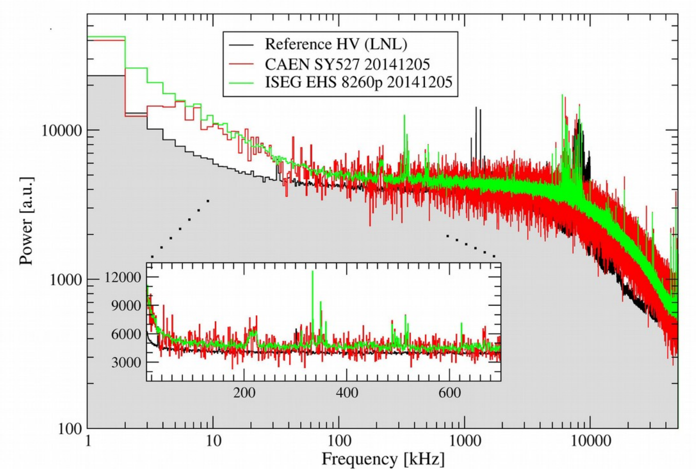




- Autofill upgrade. Extendable to manage 60 ATCs. Produced by IRFU, France.
- The upgrade of the new Autofill is based on a new PLC.
- The new GUI will be based on EPICS system, developer IRFU, France.

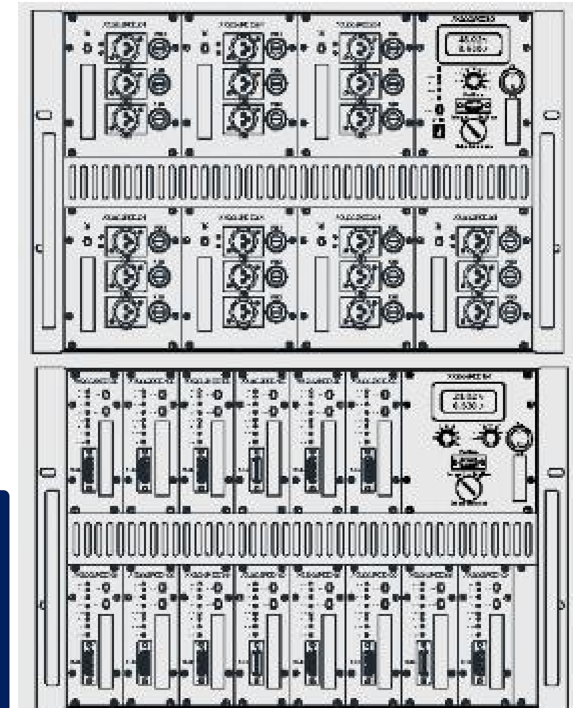
IRFU/CEA Saclay, INFN-Padova, INFN-Milano, GSI, CSNSM-Orsay
STFC-Daresbury, IPHC-Strasbourg, GANIL, INFN-LNL, JYFL-Jyvaskyla,

Detector Infrastructure: DSS Subsystems



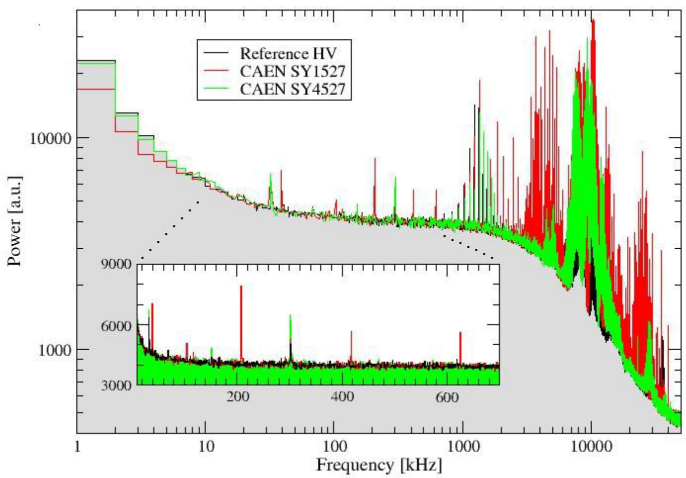
LVPS

1 ATC (2007 LVPS)



7 ATC (Phase 2 LVPS)
Developed by
IRFU/CEA Saclay

HV



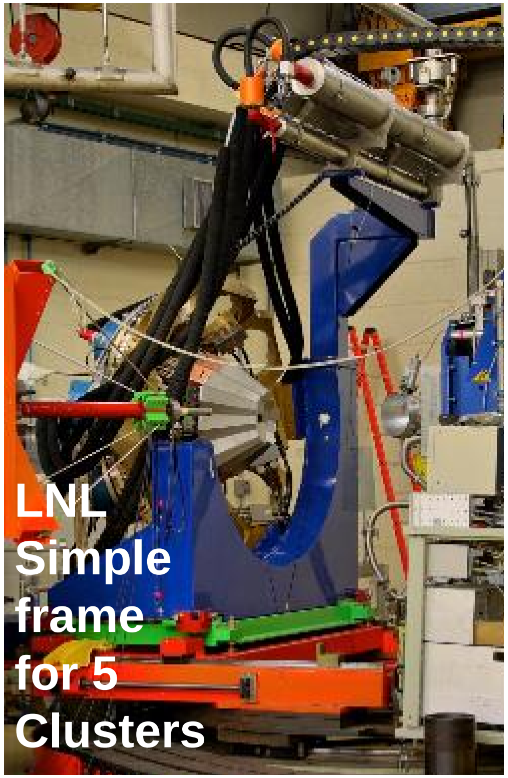
CAEN
SY4527 mainframe +
A1560H boards
ISEG
crate + EHS8260P boards

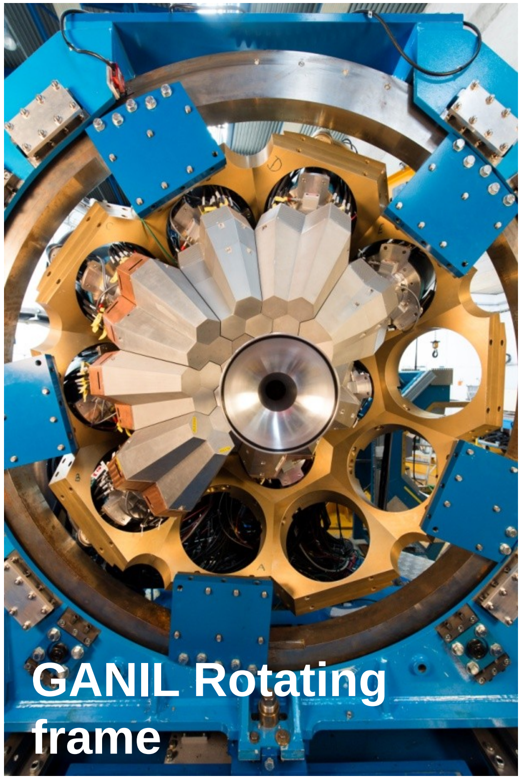
- similar performances
- excellent solutions for HPGe detectors

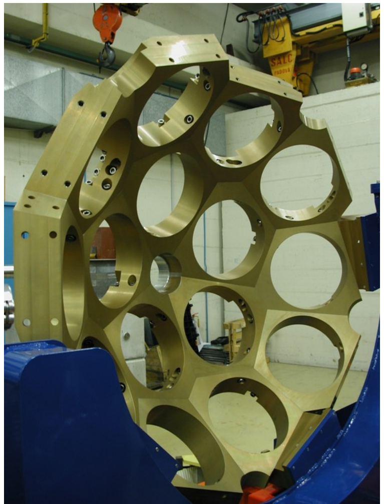
IRFU/CEA Saclay, INFN-Padova, INFN-Milano, GSI, CSNSM-Orsay
STFC-Daresbury, IPHC-Strasbourg, GANIL, INFN-LNL, JYFL-Jyvaskyla,

STFC-Daresbury

Mechanical Infrastructures





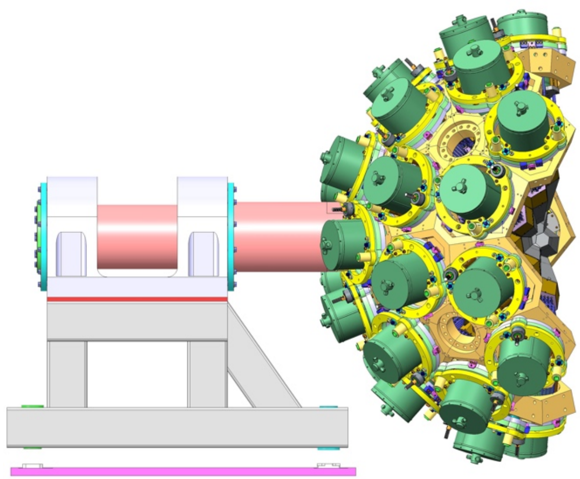


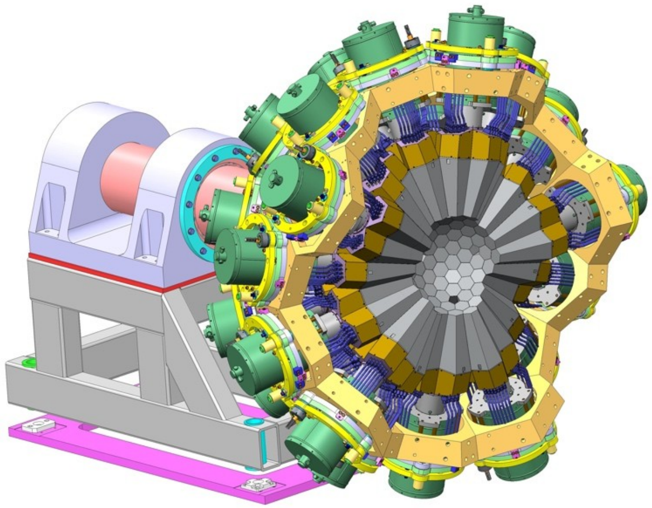
The AGATA Honeycomb is the core of the detector support mechanics. Each Host Lab has produced a Frame fulfilling the local requirements: beam-line height, space availability, array displacement.

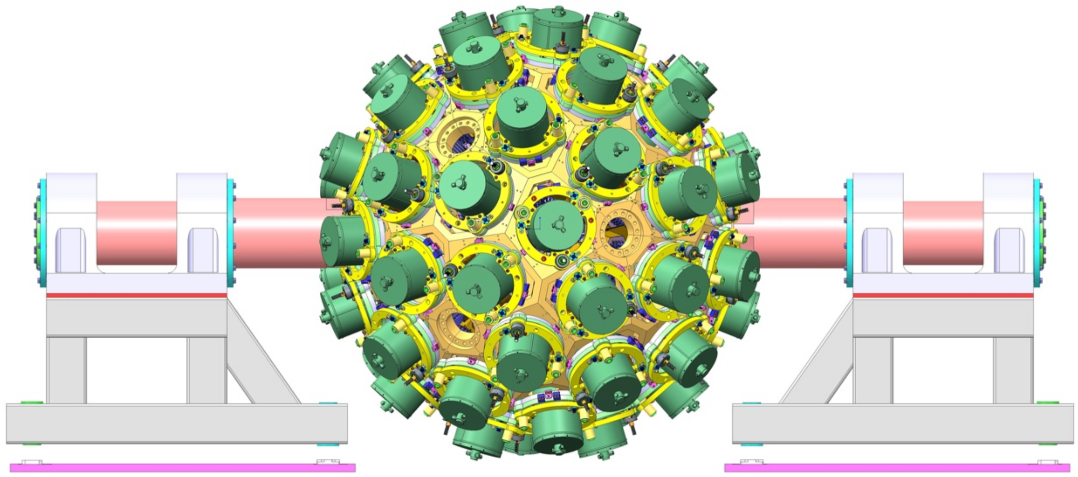
Now working on compatible mechanics

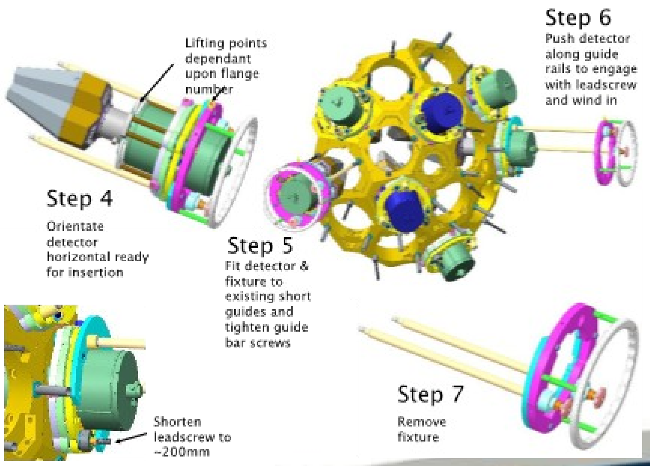
STFC-Daresbury, GANIL, INFN-LNL INFN-Milano, INFN-Padova

Mechanical Infrastructures









STFC-Daresbury, GANIL, INFN-Milano, INFN-Padova

AGATA Simulations

The development of the code will continue by coupling AGATA with ROOT. The following two options will be considered and at least one will be implemented:

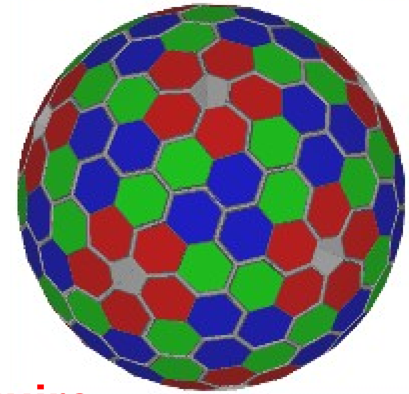
- Migrate the AGATA code, including all its event generator/ancillary detector into an existing simulation and data analysis framework such as ENSARROOT, NPTOOL, STOGS.
- Develop the AGATA code from a pure geant4 simulation code to a GEANT4+ROOT.
- External algorithms based on ROOT to simulate time-stamped AGATA data already developed to produce AGATA Data Format ADF files.
- Additional work will be carried out to integrate this algorithm into the AGATA code. (Similar capabilities exist also within the STOGS framework and could be re-used for AGATA).

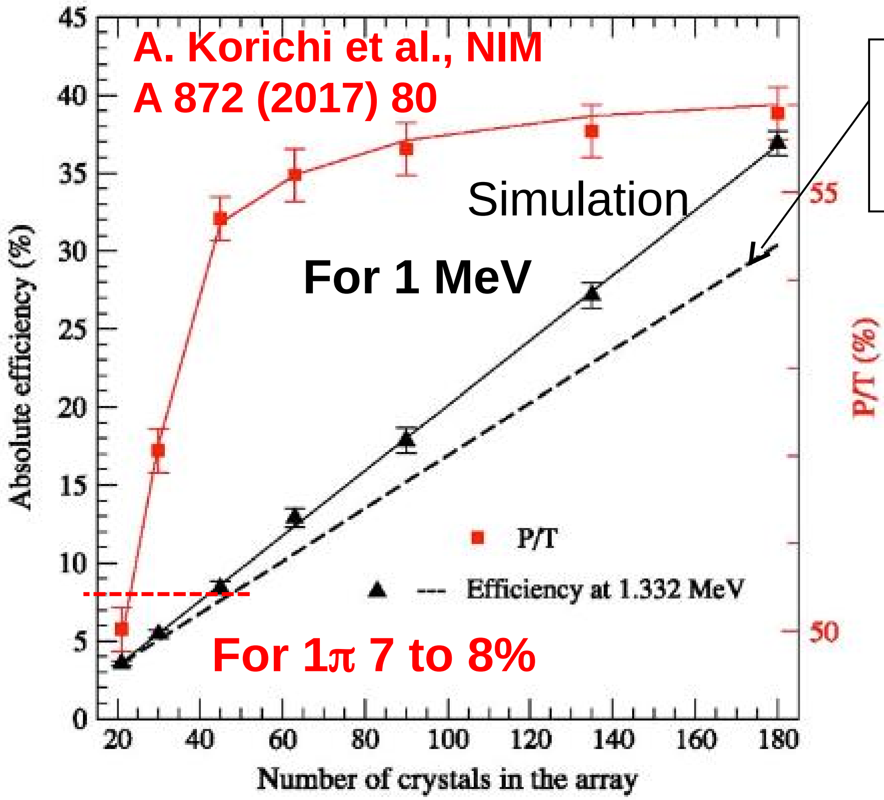
Additional work is also foreseen to develop and complete some event generators for realistic simulations. This includes generators for polarisation measurements and generators with simplified and realistic background estimate.

STFC-Daresbury, GANIL, INFN-Padova…

AGATA 4π Performance simulations

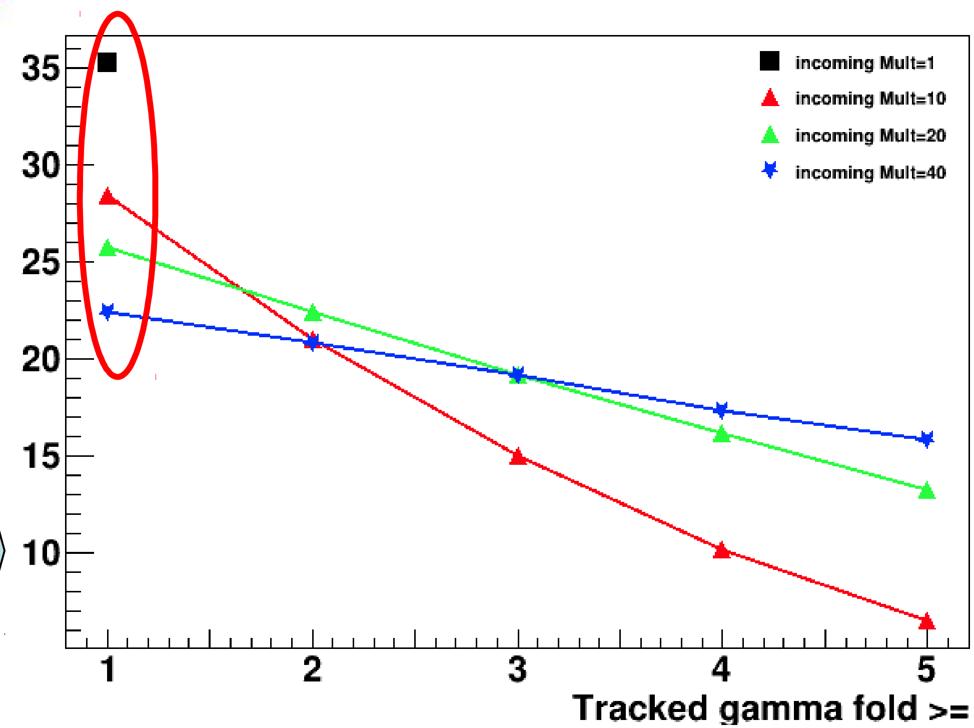
Efficiency and P/T Monte Carlo simulations for the 180 Capsules set-up with Tracking





Linear Scaling from known efficiencies

These expectations require the PSA improvements regarding multiple interactions in one segment.



Efficiency depends as well on the γ-ray multiplicity
Recent Upgraded Simulations by M.Labiche (STFC)

CSNSM-Orsay, STFC-Daresbury

AGATA Data Analysis

- Existing a guide to help the users analyzing the AGATA data produced at the local level processing. A new data analysis software "CUBIX" developed in the ROOT environment is now available in the GammaWare package.

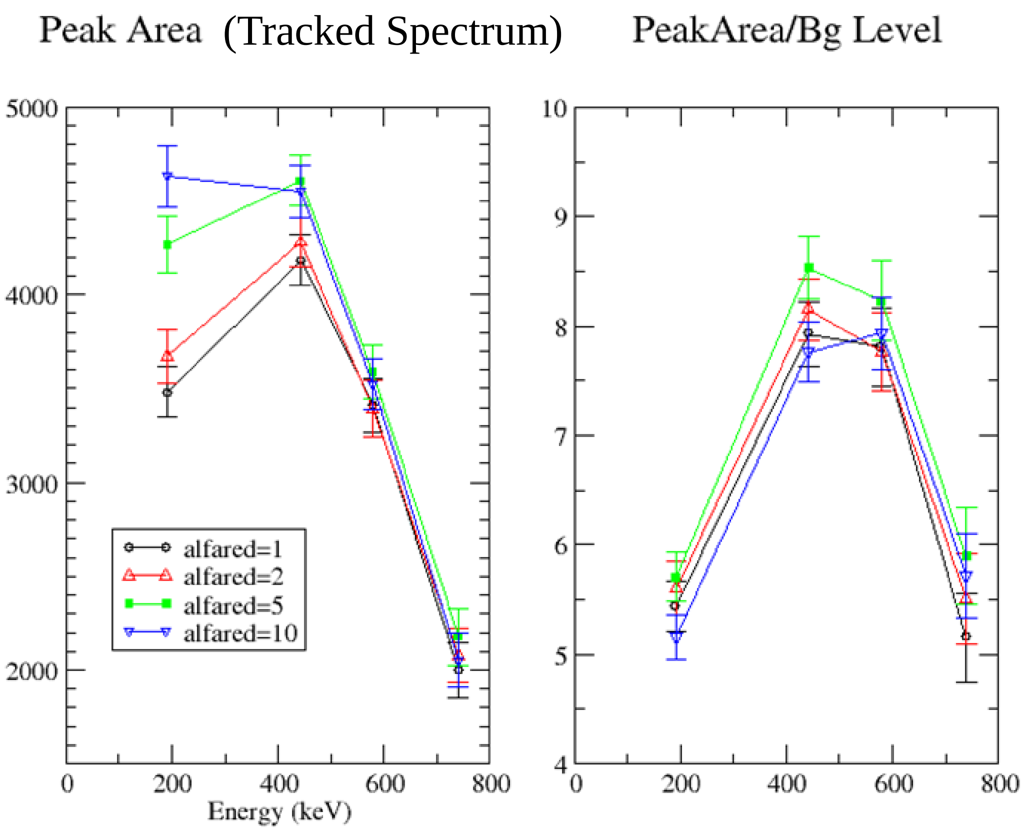
- Expected to continue in Phase2 with possible improvements, for example by implementing a faster/automatic way to perform parts of the data treatment.

- J.Dudouet and D.Ralet worked on the AGATASpy package, needed after the upgrade to DCOD. Now considered tested and marked as working, fully operational from producer to PSA.

- Periodic Workshops on Data Analysis are being organized:
  Last organized by J. Dudouet and F.Crespi took place in Orsay on January 21st to 24th, next will be late 2019 or early 2020.

Tracking Improvements

Improvement of OFT on-going: there is a new procedure to validate single interaction points: it is no longer a threshold (minprobsing) but single interactions are accepted/rejected on the basis of ranges in Ge (like in GRETA).



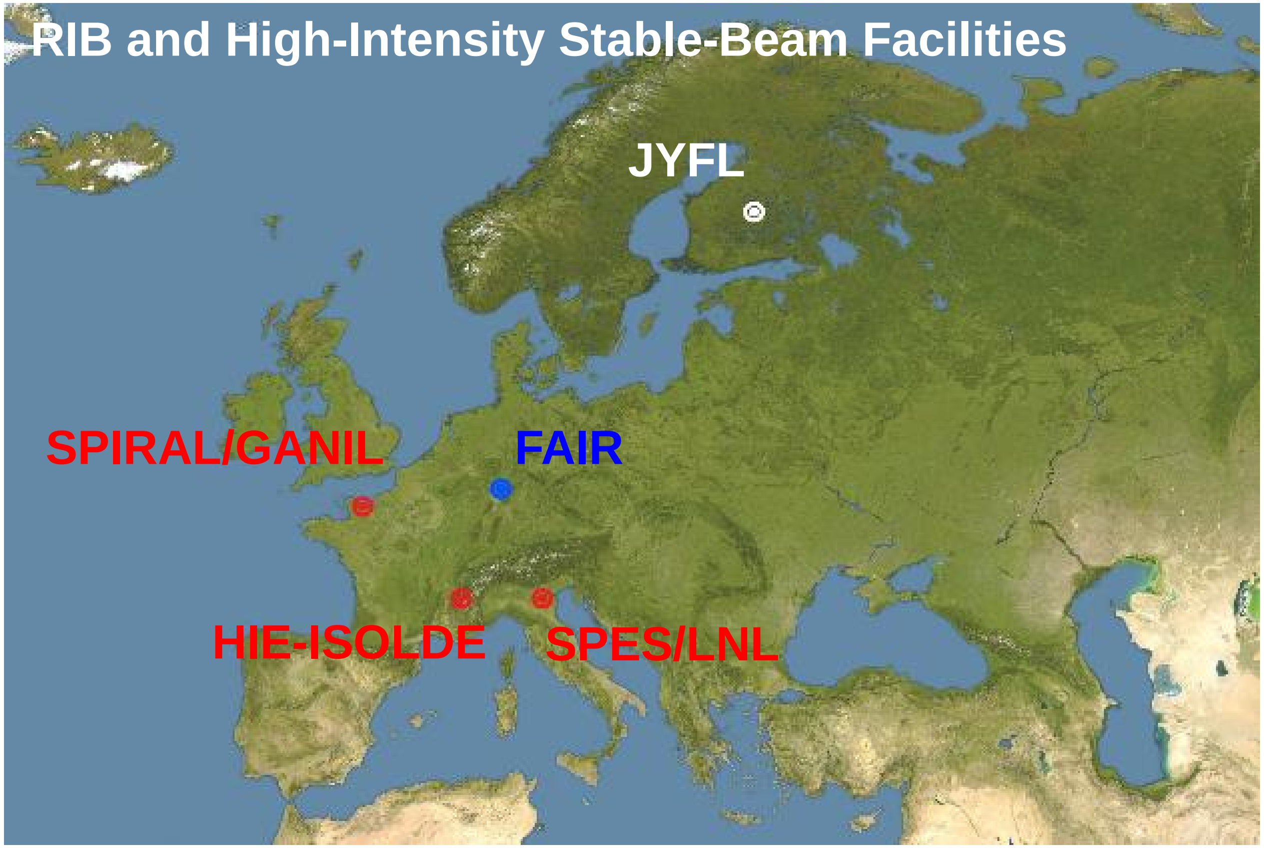
- Studying the reduction of the maximal clusterisation angle. This should reduce the background for high multiplicity events and it is being tested at Orsay with 158Er data.
- Next development oriented to use the PSA determined position error to perform the weighting of the Tracking algorithm.

A. Lopez-Martens CSNSM-Orsay,

AGATA Commissioning and Performance

- Measurements with either radioactive sources or well-known in-beam reactions. Also to validate MC-simulation codes and tools,
- Calibrated radioactive source runs to carried out prior to a new campaign
- Consistency of the results should be compared with both simulations and previous measurements.
- Monitoring of performance in the long term is important and it will be crucial to quantify the radiation damage to each of the crystals.
- During the period 2021-2030 the angular coverage of AGATA will increase
  - To extract useful physical quantities from angular distributions correlations and linear polarization measurements
  - To perform measurements depending on the perturbation of the angular distribution/correlation, e.g. g-factor measurements
  - Thus understanding of the performance of AGATA is of paramount importance.
- Commissioning will allow to check the performance figures in-beam and when coupled to complementary instrumentation

AGATA 4π and the Host Laboratories



- **High-Intensity Stable Beam Facilities:** CN, MNT, etc…
  Direct and Inverse kinematics β <~ 10%
- **ISOL Facilities:** Reaccelerated RIBs: Safe Coulex, Direct Reactions, etc…
  Direct and Inverse kinematics β ~ 10%
- **In-Flight Facilities:** In-flight RIBs: Relativistic Coulex, Knock-out, Fragmentation, etc…
  Inverse kinematics β ~ 50%

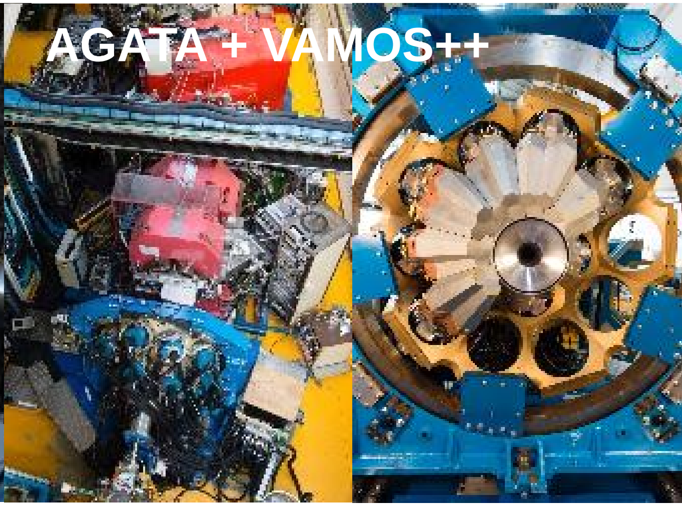
AGATA Early Implementations

With the AGATA early sub-arrays the scientific activity has been done at the three hosting Laboratories

- **INFN – LNL, Italy:** hosted the AGATA, the Demonstrator, in 2010 and 2011. AGATA will be installed again in 2021 with a programme with Stable Beams at PRISMA and other complementary detectors. From 2023 with ISOL SPES beams

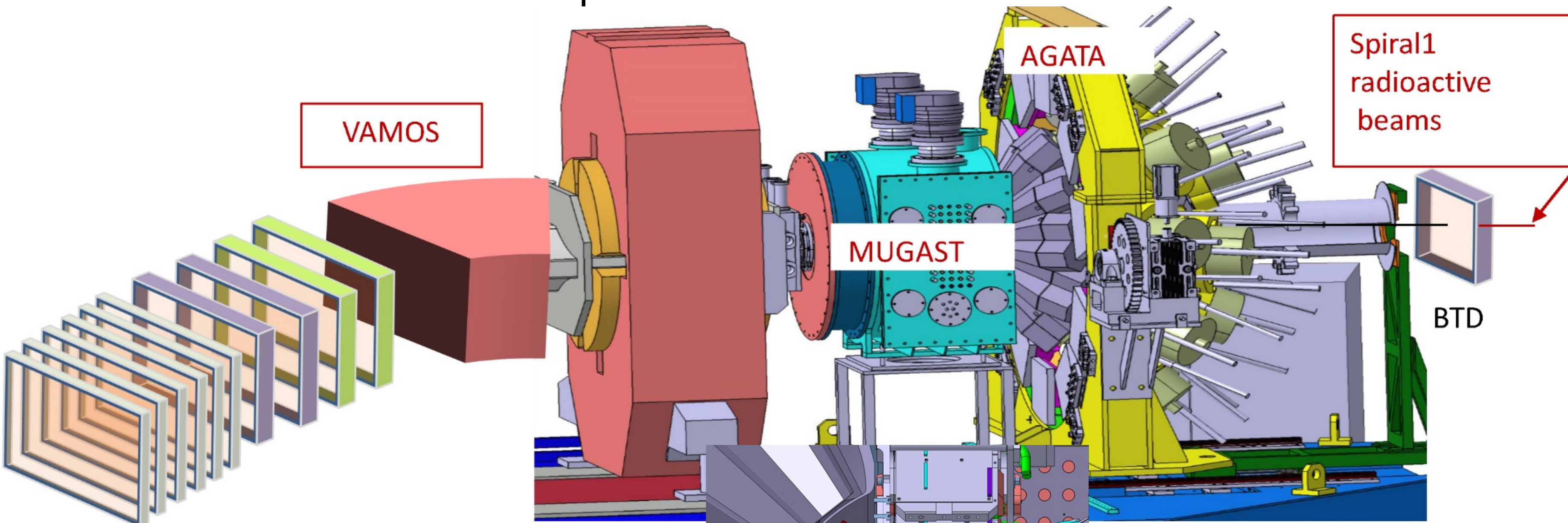
- **GSI, Germany :** hosted AGATA from 2012 to 2014 coupled with FRS and the PRESPEC detectors (tracker, LYCCA etc…). Next campaign expected in 2025

- **GANIL / SPIRAL1, France :** are hosting AGATA presently. Experimental activity coupled to VAMOS++, PARIS, NEDA+DIAMANT, MUGAST, etc…

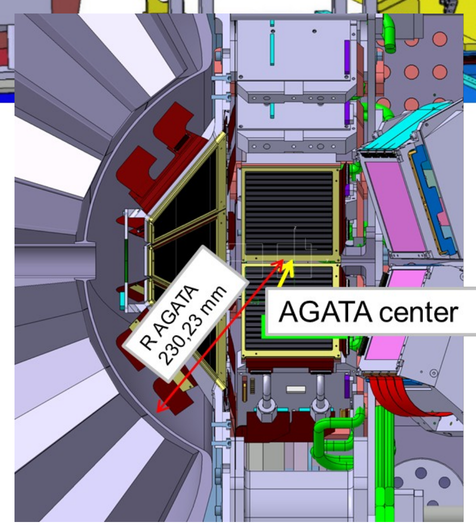


AGATA at GANIL 2020 and 2021

In 2019 and 2020 the AGATA campaign at GANIL will be devoted to experiments with ISOL beams of SPIRAL 1 in the AGATA + MUGAST+VAMOS setup.



VAMOS++ used for the reaction product identification



MUGAST: highly segmented Si detector array for direct reactions with RIBs.

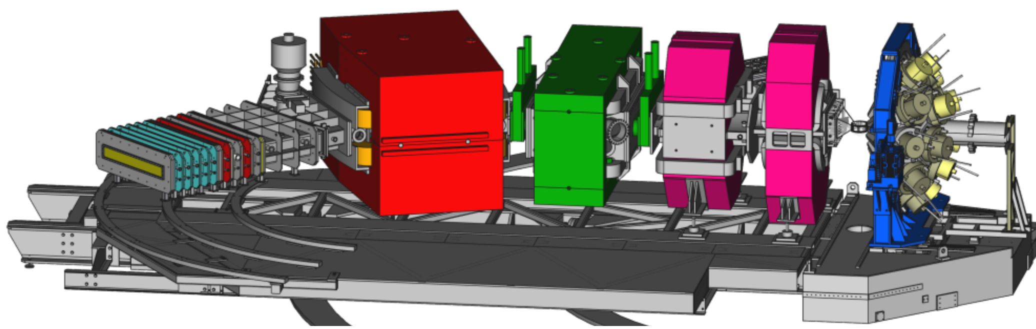
MUST2 + GRIT Detectors

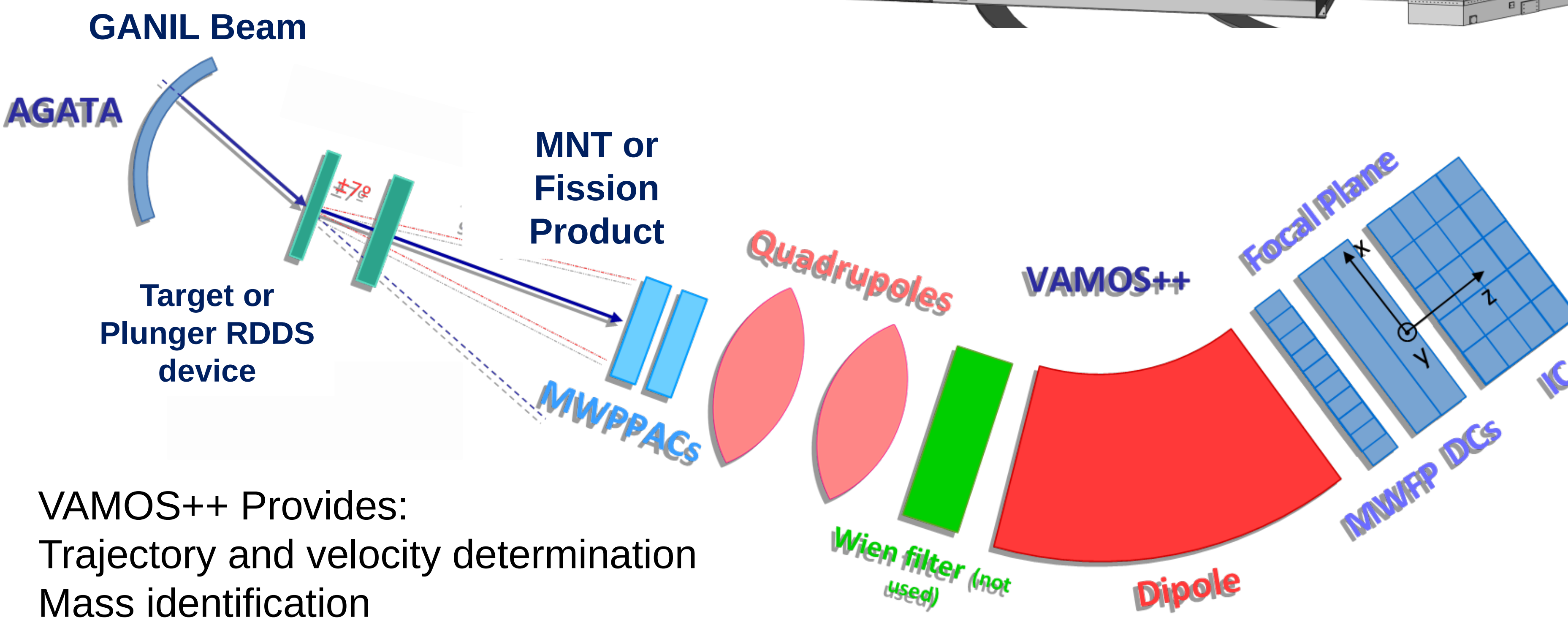
Courtesy of E.Clement

Experimental Setup

for AGATA + VAMOS++

Multi Nucleon Transfer, Deep Inelastic and Reaction Induced Fission





VAMOS++ Provides:

Trajectory and velocity determination

Mass identification

- Nucleus trajectory reconstruction
- Velocity measurement
- Total energy measurement

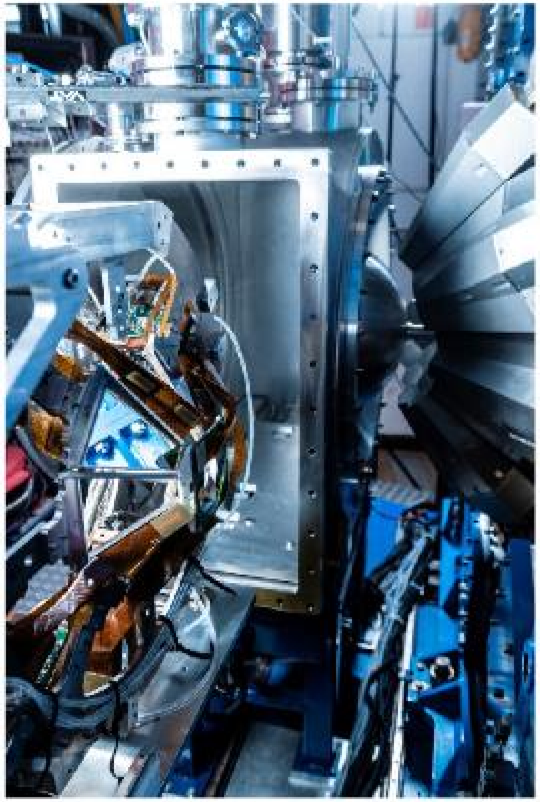
Z identification

- Energy measurement (E-E method)

Trigger MWPPAC & MWFP & GAMMA

With AGATA up to 1π

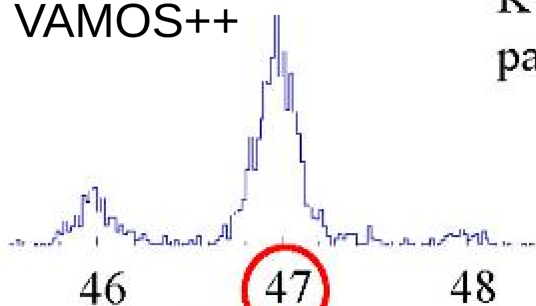
AGATA at GANIL 2019
AGATA+MUGAST+ VAMOS



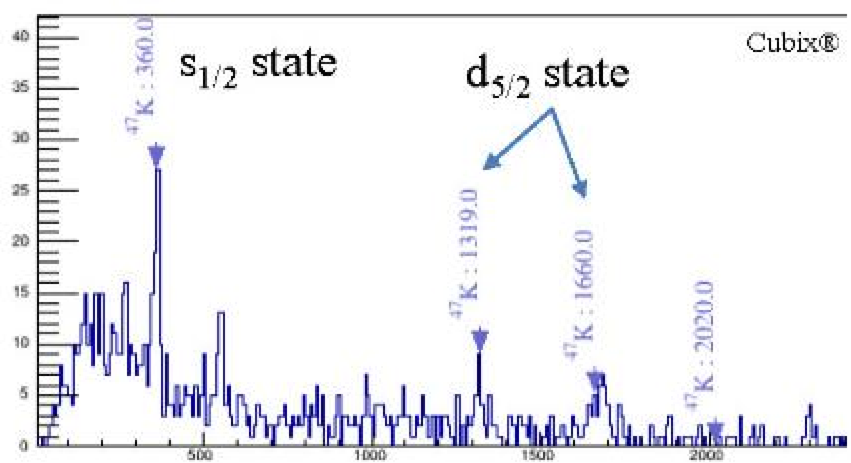
SHELL MODEL

Is there a problem with protons in N=28 nucleus ^{46}Ar ?

^{46}Ar(^{3}He,d)^{47}K to probe proton WF and study vacancies in $s_{1/2}$ and $d_{3/2}$ shells.
^{3}He cryogenic target !



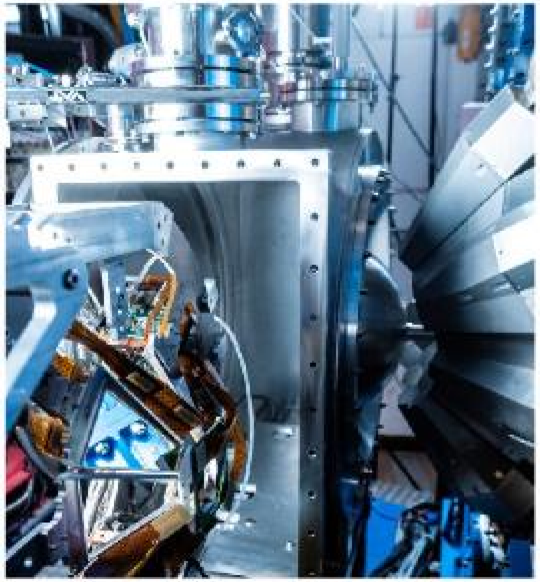
K masses isotopes in coincidence with particle at backward angle



A. Gottardo INFN, M. Assié IPN

Courtesy of E.Clement

AGATA at GANIL 2019
AGATA+MUGAST+ VAMOS



NUCLEAR ASTROPHYSICS

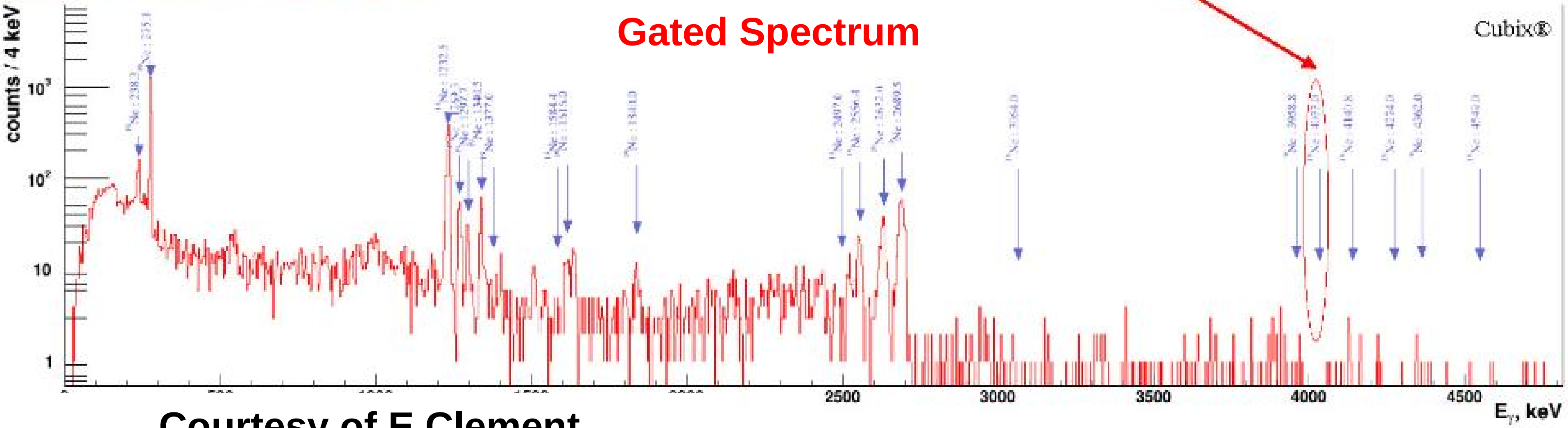
Determining the α+^{15}O radiative capture rate

^{15}O(^{7}Li,t)^{19}Ne indirect measure
Important reaction for breakout from Hot-CNO cycle to rp-process in Type I X-ray bursts

C. Diget (York), N De Séréville (IPN)

→ Expected transition not seen
It is a result, ie that the $C_s\alpha$ is small

VAMOS++ ^{19}Ne + MUGAST ^{3}H Gated Spectrum



Courtesy of E.Clement

Summary

- The AGATA collaboration is aiming now to complete the Phase 1 in 2020 and the 4π array during the coming Phase 2
- Several Subsystems, sometimes design and build for the AGATA Demonstrator (2005-2007) require upgrade
- Redesign considering long-term maintenance and replacement using commercial parts when possible and increasing the standardization (e.g. replacing the point-to-point data transfer by Ethernet)
- Aiming as well to have Improvements on mobility, compatibility, data transfer and processing to approach the best Tracking Array performance figures.

Thanks' to all the AGATA Collaborators

Thank You For Your Attention!

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Una manera de hacer Europa

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