Status of the commissioning of SIRIUS and possible upgrades

- IJClab : V. Alaphilipe, L. Gibelin, K. Hauschild, N. Karkour, X. Lafay, D. Linget, A. Lopez-Martens, F. Leblanc & 10 interns from MIT UL ESME universities.
- GANIL : R. Chakma, J. Piot, D. Ackermann, M. Blaizot, A. Boujrad, L. Càceres, E. Clément, S. Coudert, J. Goupil, S. Herlant, G. Lebertre, F. Lutton, C. Maugeais, J. Pancin, F. Saillant, H. Savajols, G. Wittwer
- IPHC : P. Brionnet, O. Dorvaux, H. Faure, B. Gall, Th. Goeltzenlichter, C. Mathieu
- IRFU : M. Authier, Th. Chaminade, A. Drouart, J. Kallunkathariyil, H. LeProvost, Z. Favier, B. Sulignano, Ch. Theisen

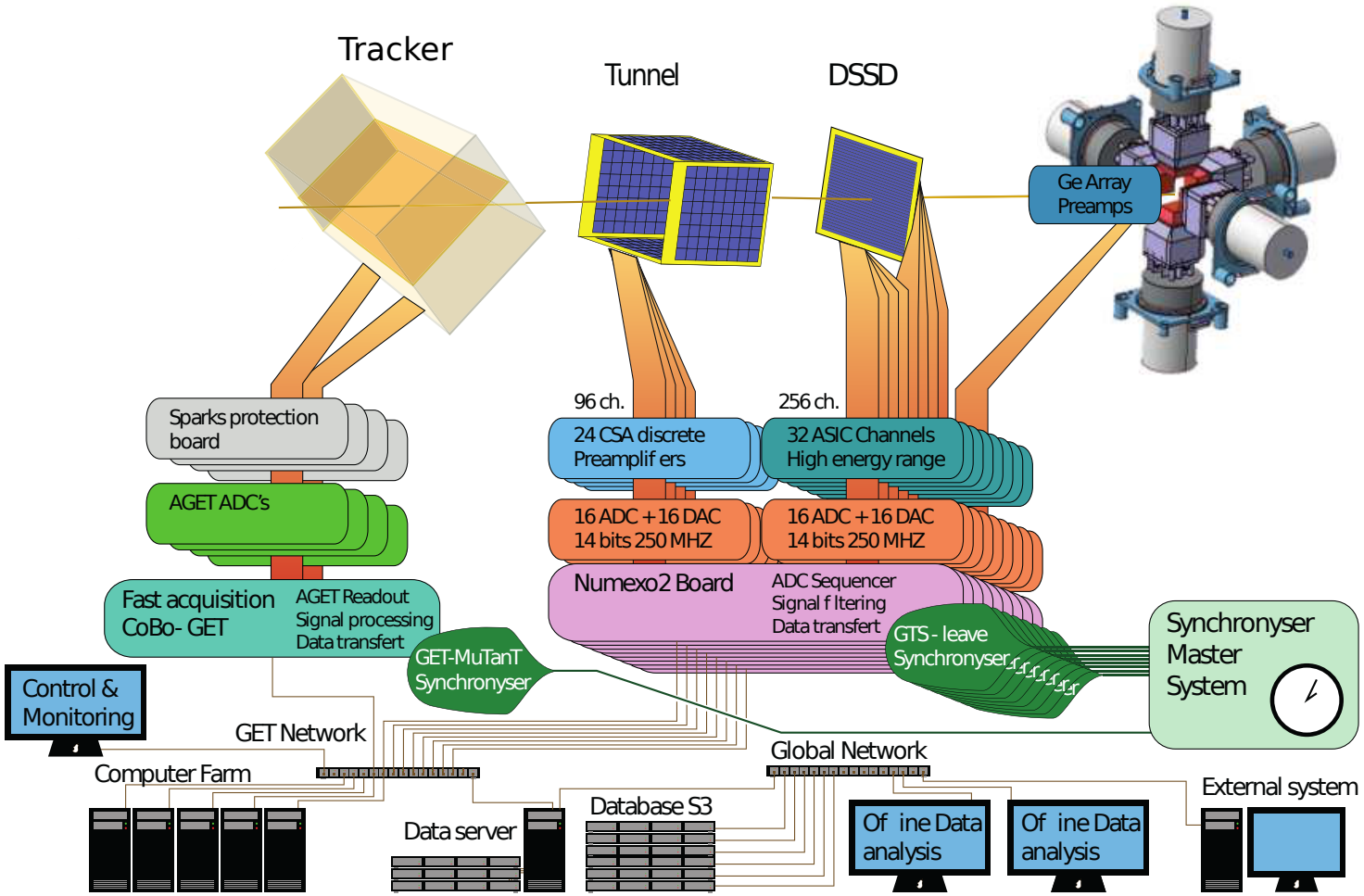
Spectroscopy and Identification of Rare Isotopes Using S^3

S3 has been funded by the French Research Ministry, National Research Agency (ANR), through the EQUIPEX (EQUIPment of EXcellence) reference ANR-10EQPX- 46, the FEDER (Fonds Européen de Développement Economique et Régional), the CPER (Contrat Plan Etat Région), and supported by the U.S. Department of Energy, Office of Nuclear Physics, under contract No. DE-AC02-06CH11357 and by the E.C.FP7-INFRASTRUCTURES 2007, SPIRAL2 Preparatory Phase, Grant agreement No.: 212692.

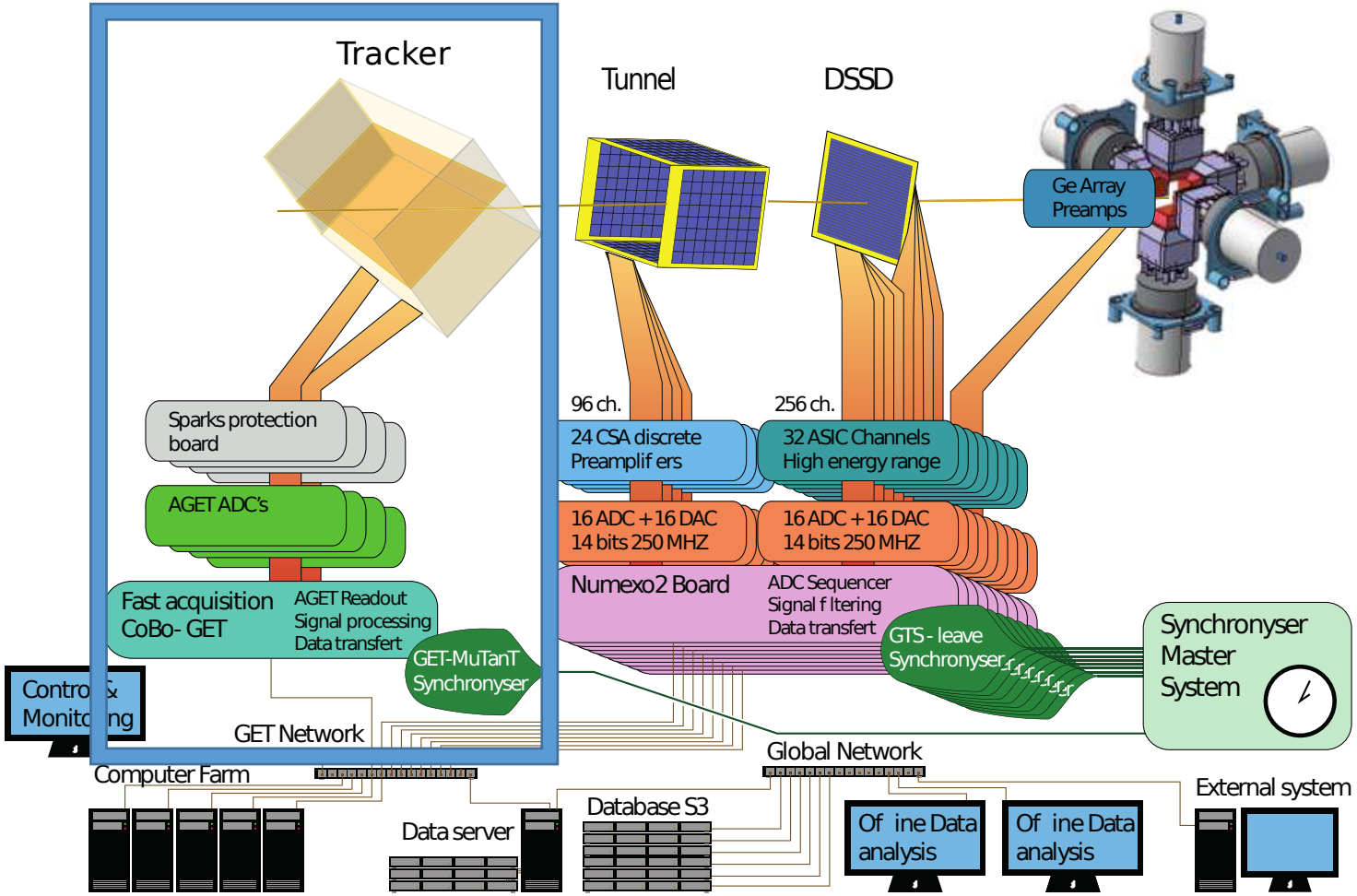
SIRIUS has been funded by the CPIER (Contrat Plan Etat Inter Régional)

Rikel Chakma's contact is funded by the Région Normadie & FEDER through the SoSIRIUS RIN tremplin Grant

SIRIUS system schematic



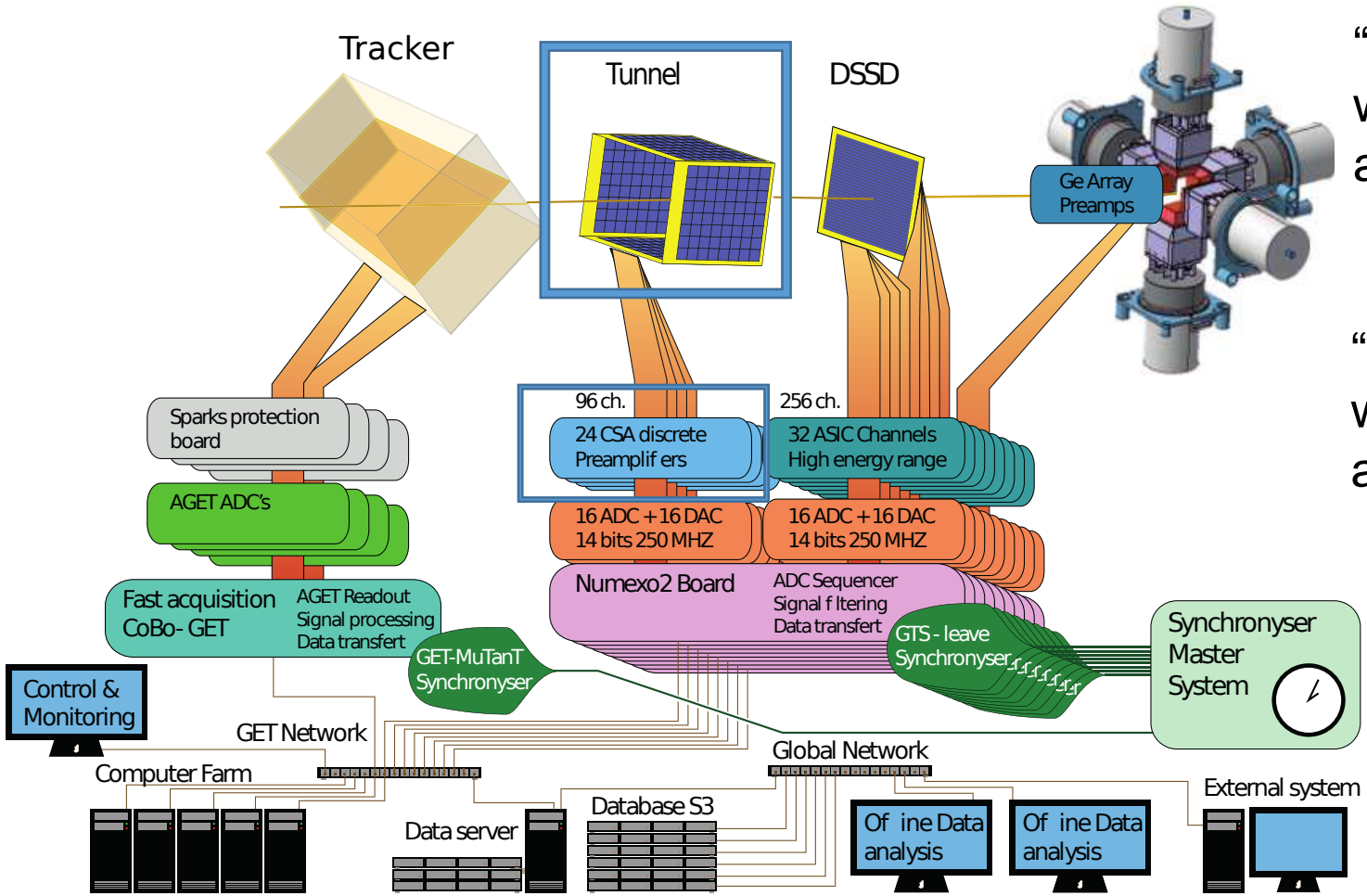
SIRIUS system schematic



"Tracker" was developed and being tested at GANIL with electronics from the GET Collaboration

(eg NIM A840 (2016) 15
NIM A887 (2018) 81)

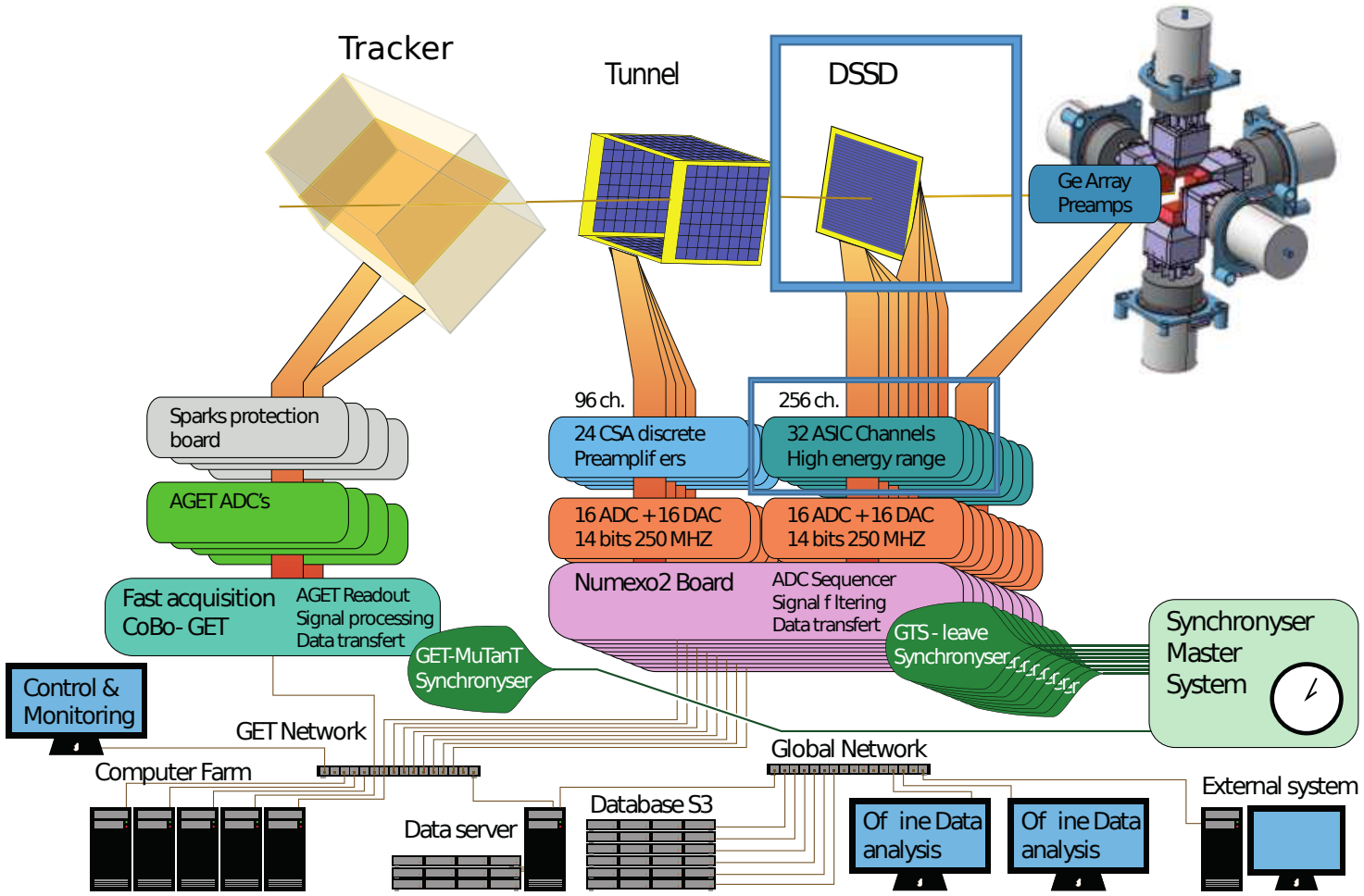
Overview…



"Tunnel" silicon detectors were developed and tested at the IPHC

"Tunnel" front-end electronics were developed and tested at the IJCLab

Overview…

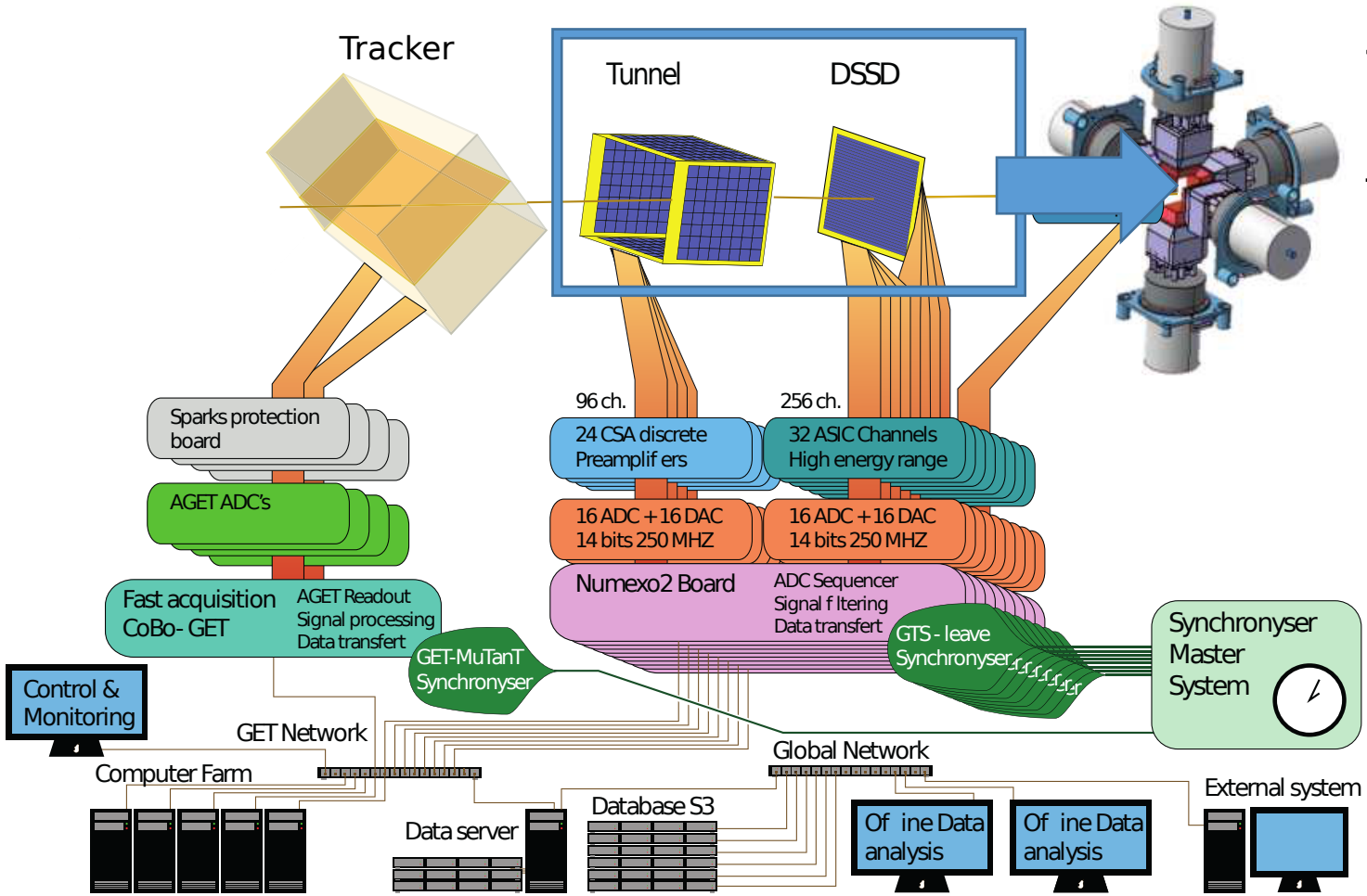


The Silicon detector is an upgrade of MUSETT [IRFU]

NIM A 747 (2014) 69

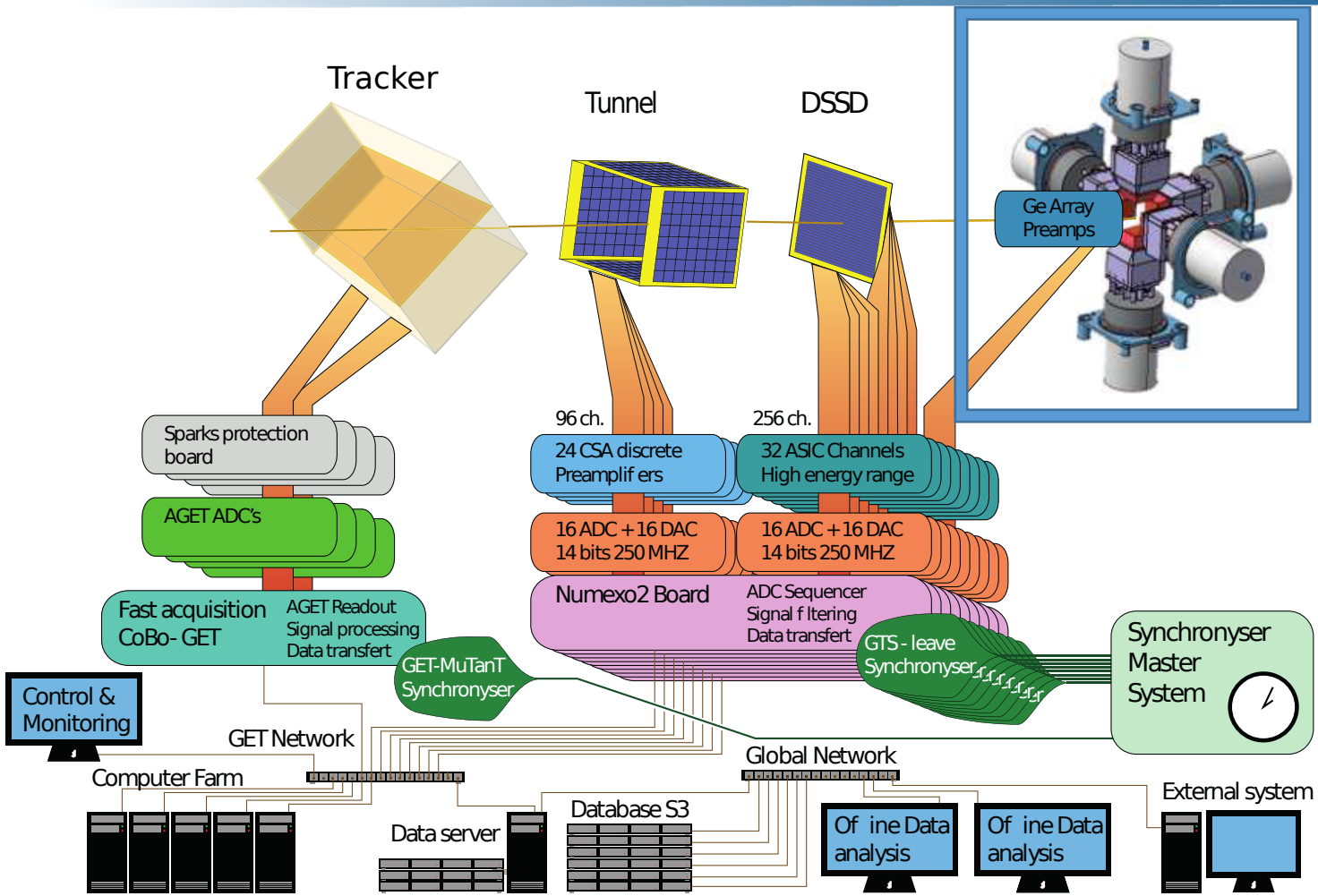
DSSD front-end electronics were developed and tested at IRFU/CEA Saclay.

Overview…



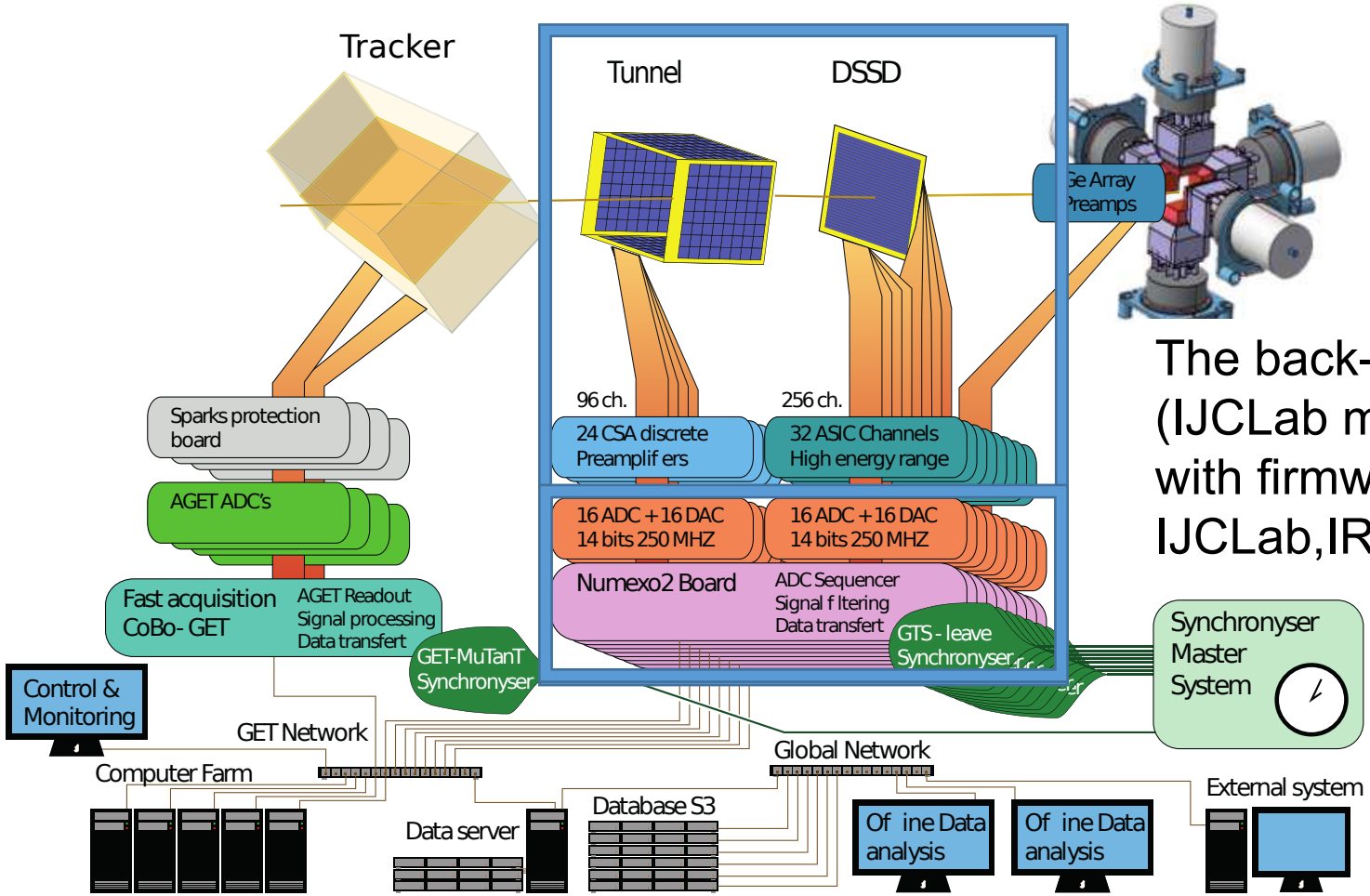
The vacuum chamber housing the silicon is from the IPHC as is the mechanical structure to hold the Si

Overview…



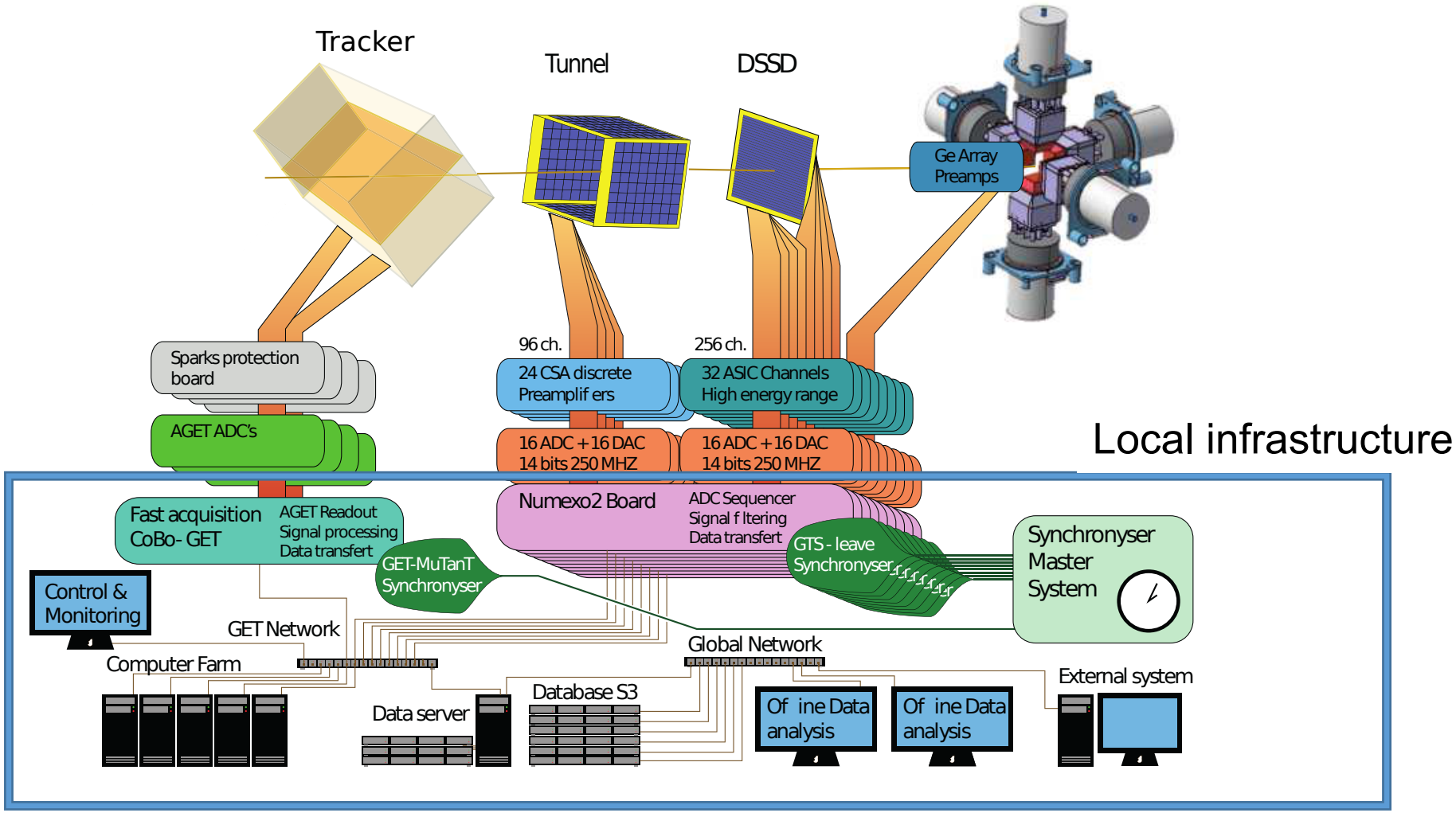
The Ge array is 5 EXOGAM clovers

Overview…

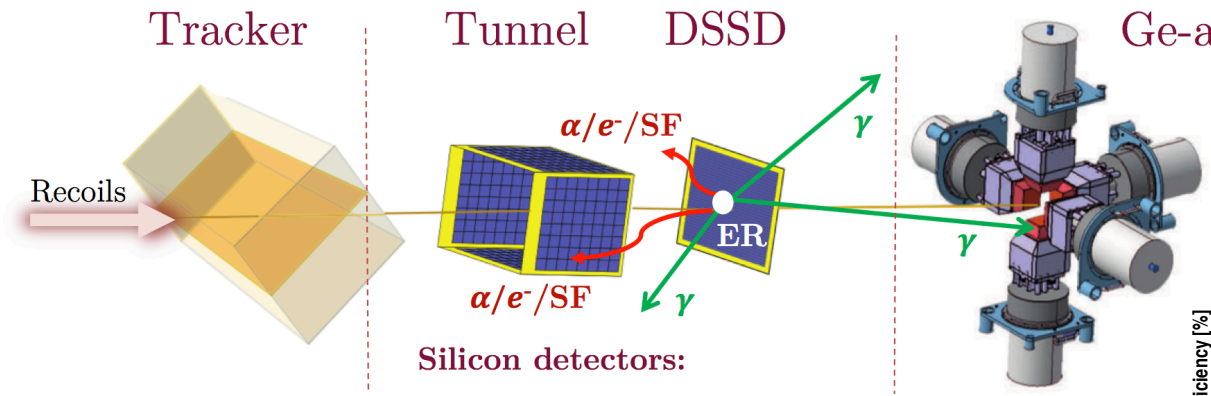


The back-end electronics for the Si uses (IJCLab modified) NUMEXO2 boards with firmware developments from IJCLab,IRFU and GANIL

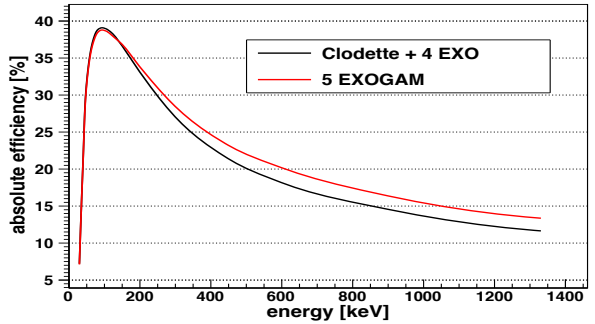
Overview…


Tracker
Tunnel
DSSD
Ge Array Preamps
Sparks protection board
AGET ADC's
96 ch.
24 CSA discrete Preamplif ers
256 ch.
32 ASIC Channels High energy range
16 ADC +16 DAC 14 bits 250 MHZ
16 ADC +16 DAC 14 bits 250 MHZ
Numexo2 Board
ADC Sequencer
Signal f ltering
Data transfert
Fast acquisition CoBo- GET
AGET Readout
Signal processing
Data transfert
GET-MuTanT Synchronyser
GTS - leave Synchronyser
Synchronyser Master System
Local infrastructure
Control & Monitoring
GET Network
Global Network
Computer Farm
Database S3
Data server
Of ine Data analysis
Of ine Data analysis
External system

SIRIUS at the focal plane of S3



- X- and γ-ray spectroscopy
- Isomer tagging
- α – γ/X



SED (Tracker)

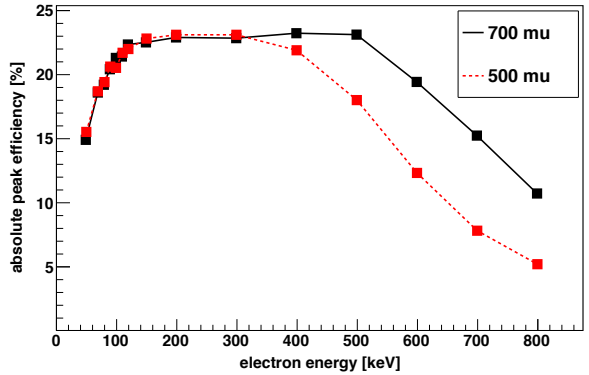
- provides Time-of-Flight start
- position information → A/ΔA ~ 300
- marker to distinguish implanted recoils from decays

DSSD

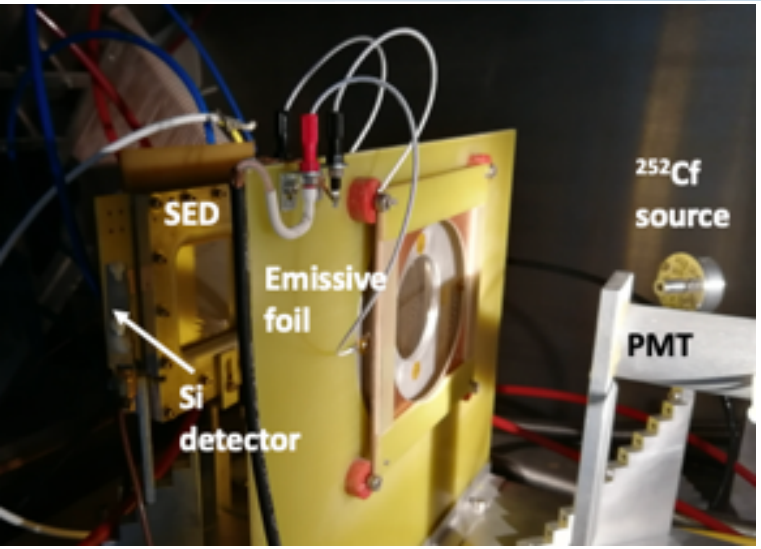
- Time-of-Flight stop → (E_{DSSD} vs TOF)
  - recoils / transfer / scattered beam
- Position/time correlations
  - decay chain construction
  - isomer tagging

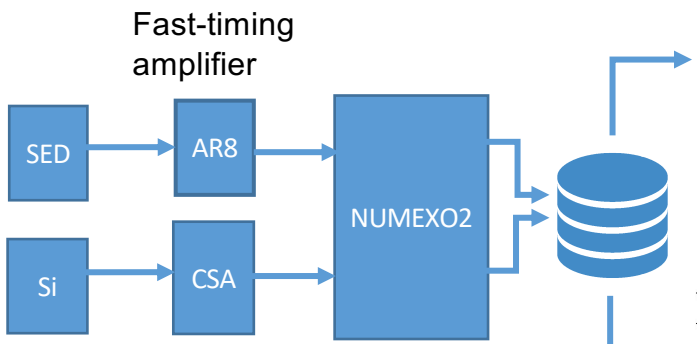
Tunnel

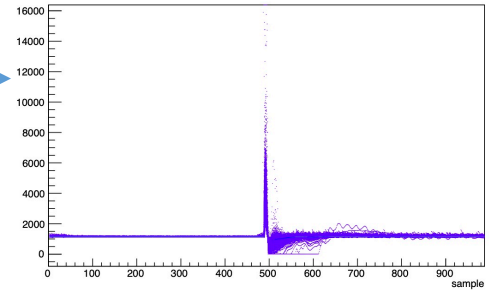
- discrete internal conversion spectroscopy (multipolarities)
- Isomer tagging
- α – ICE



(mini) SED – DSSD Time-of-Flight Proof of Principle [2021]

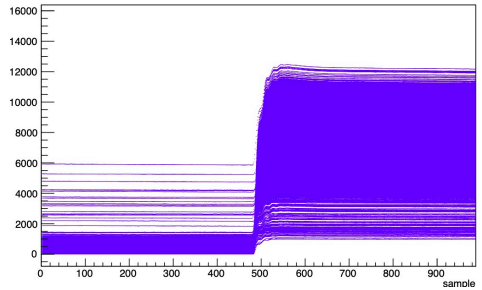




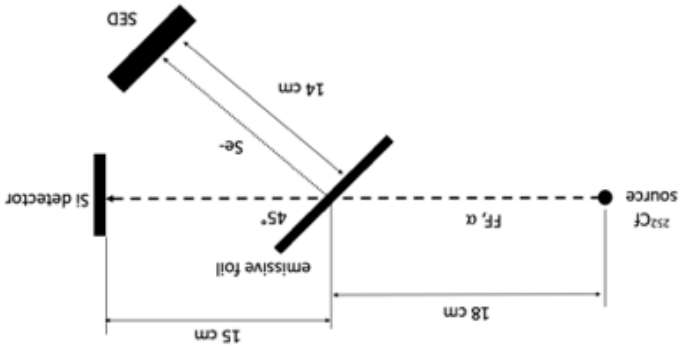


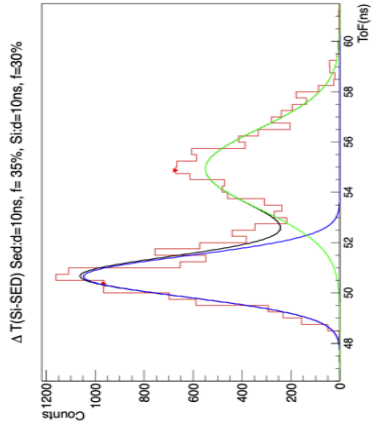
Offline DSP

Digital CFD

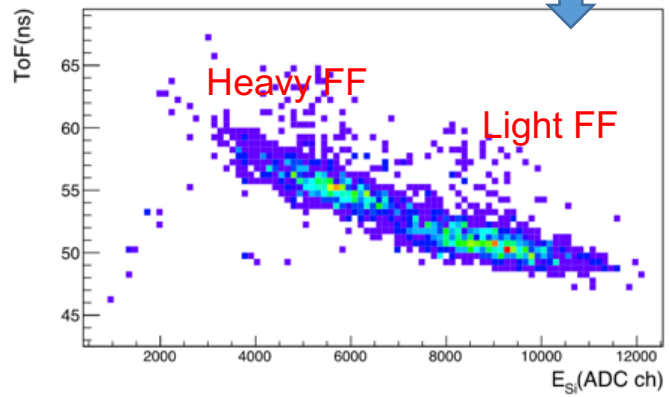


Digital CFD & energy

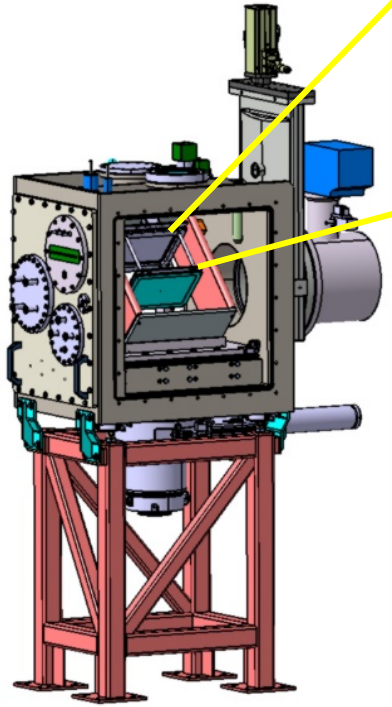


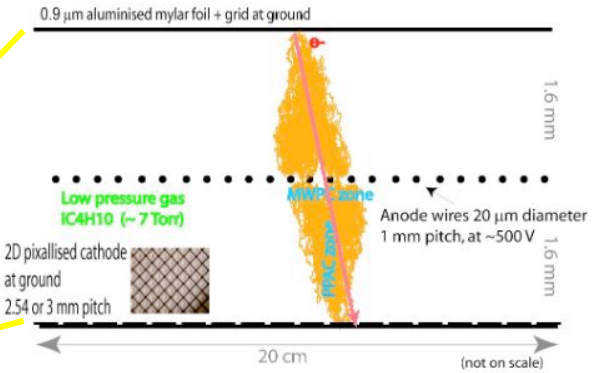


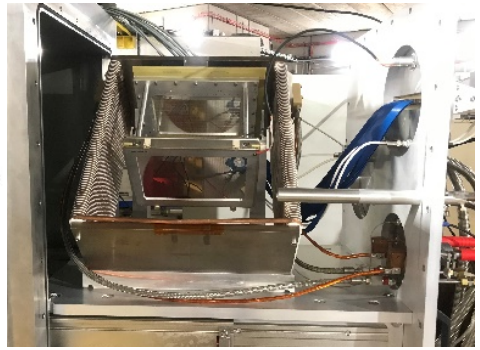
$\sigma_{lightFF}$ = 325 ps

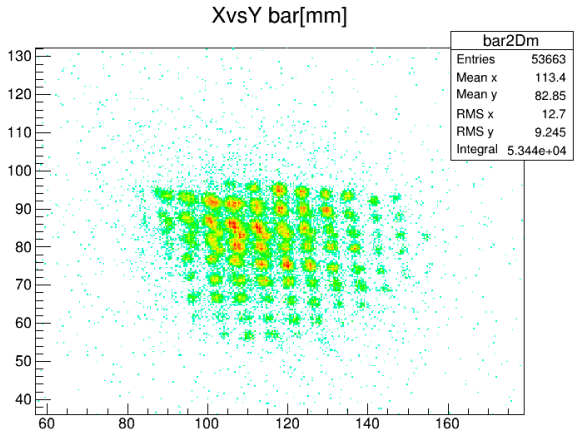


In beam tests of the tracker system with ^{238}U @ 6MeV/n [March 2022]







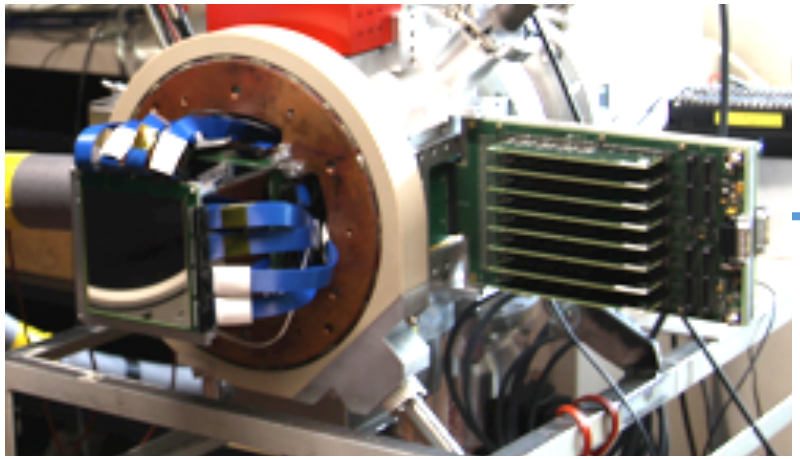


pepperpot image from beam test

- Goals:
  - measure timing and spatial resolution and acquisition performance versus counting rate and gas type (iC_4H_{10} and CF_4)

- analysis on-going, but so far:
  - Best obtained spatial resolutions below 0.5mm(σ): $A/\Delta A \sim 300$ [2D pixelated cathode → AGET]
  - Best obtained time resolutions below 100 ps(σ) [annode wires + FastAmp → NUMEXO]

Status of the (128x128) DSSD: delivered and installed



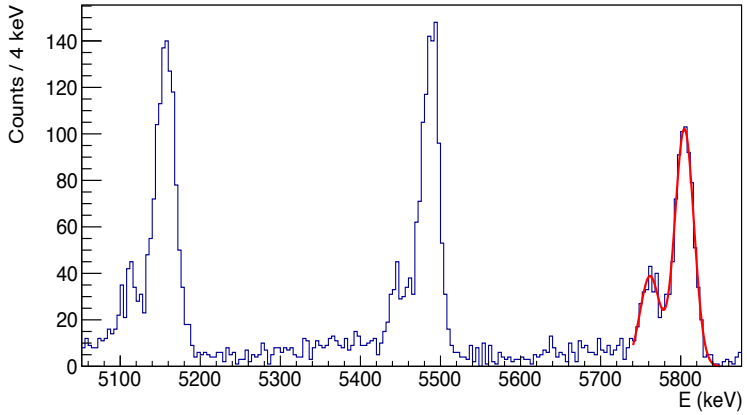
improved MUSETTdetector

[8+8] NUMEXO2
200 MHz digitization

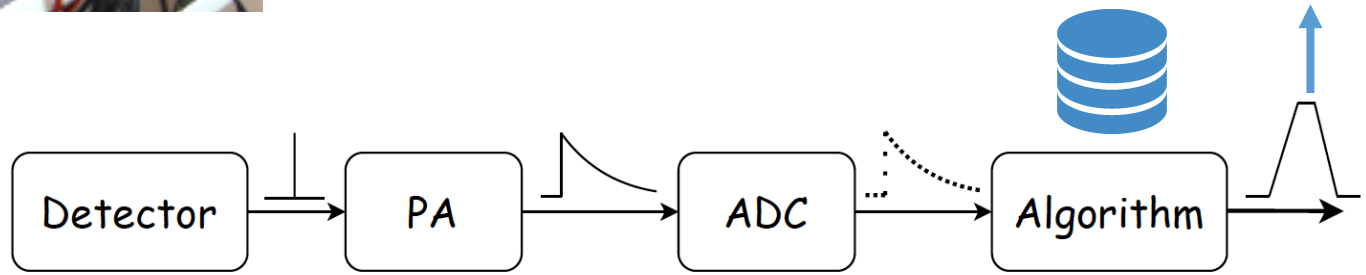
HDMI cables

Traces saved to disc

FWHM(1 strip) = 20.9(5) keV

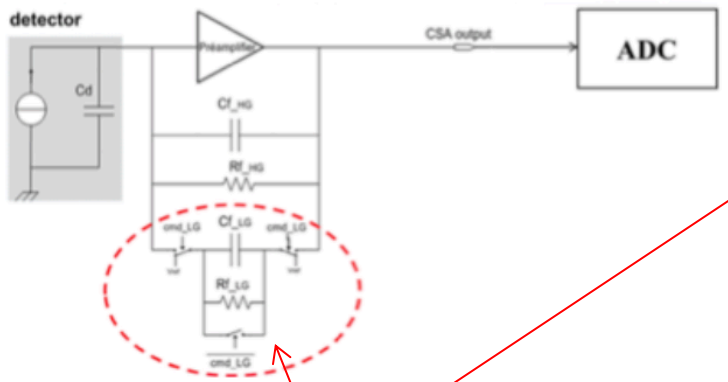


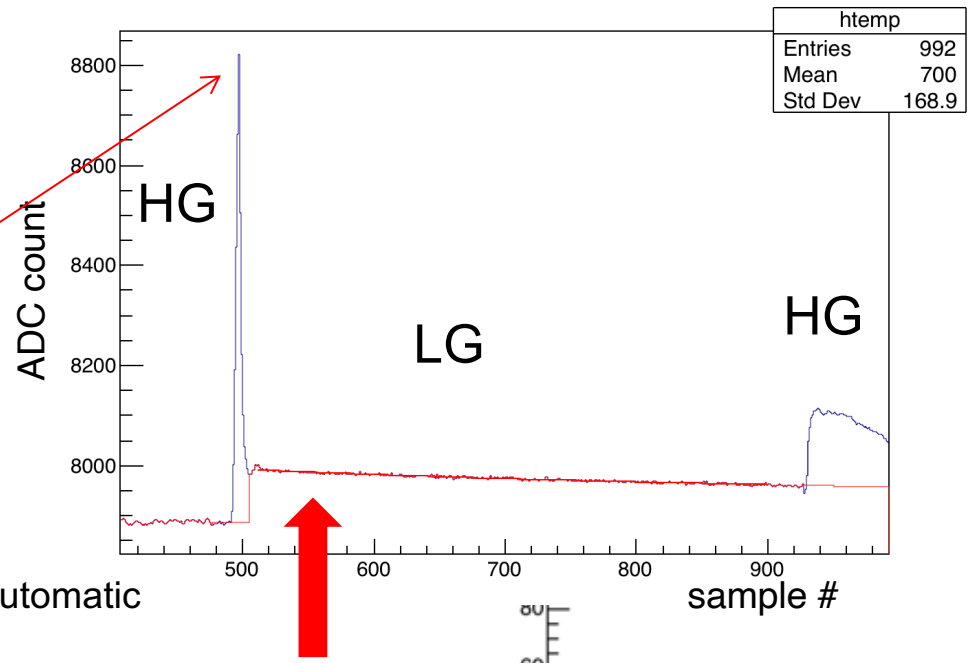
Junction Side	
Entrance window	~50 nm
Strip Width	730 um
Strip Separation	30 um
Reduced oxide width	14 % → 5 %



- Energy
- Time
- remove pile-up
- detection of short lived isomers

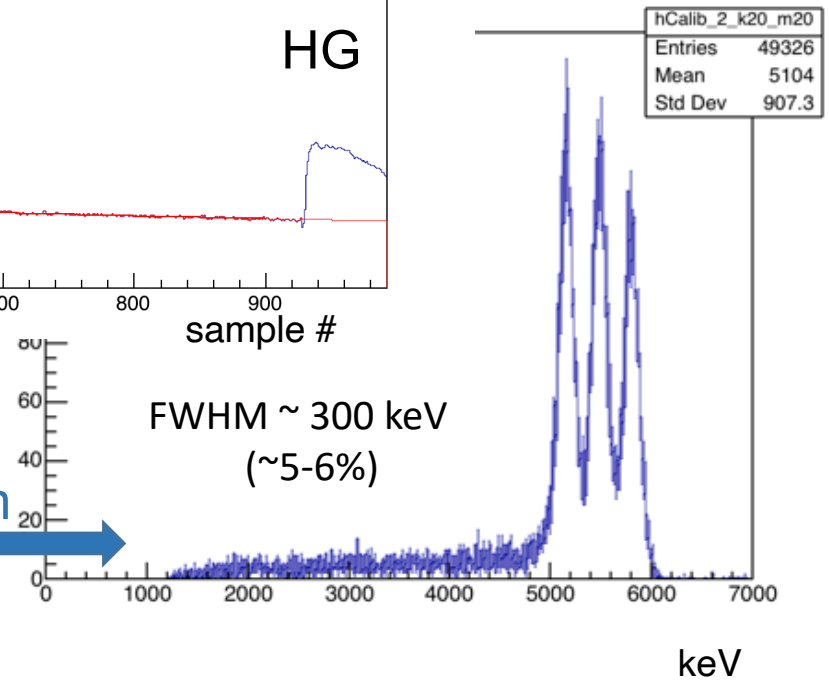
Inovative extension of range





When the PA output exceeds a given threshold an automatic switch in gain occurs (HG → LG) with a reset to HG later

DSP Energy Algorithm



typically:

- ❖ High gain < 40 MeV (FWHM 20 keV) (recoils, α, Σ)
- ❖ Low gain 40 MeV - 500 MeV (@5%) (SF and beam)

Status of the TUNNEL: the “strippypad”

Strip-like readout of pixels : new development for SIRIUS at the IPHC
allows pixelation with readout connectors away from DSSD

MSPX080-1 Detector design

CHIP Dimensions

Active area : 97160x97160 µm²
Thickness ~ 670 µm

PIXEL Size

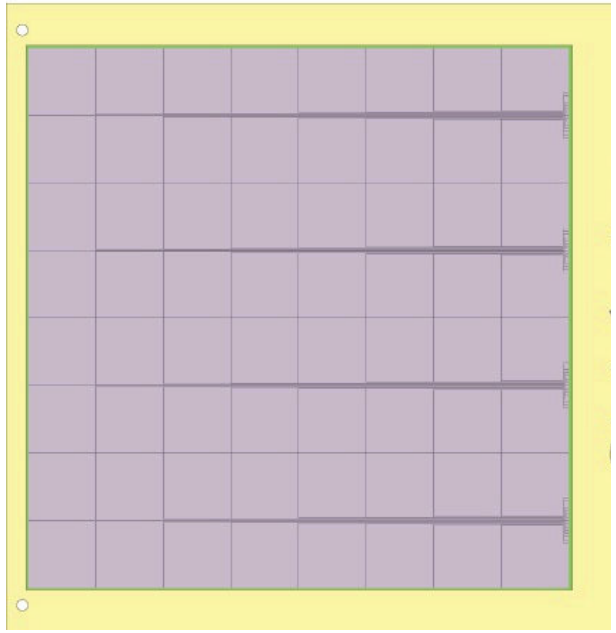
from 11260x12040 µm² to 12040x12040 µm²

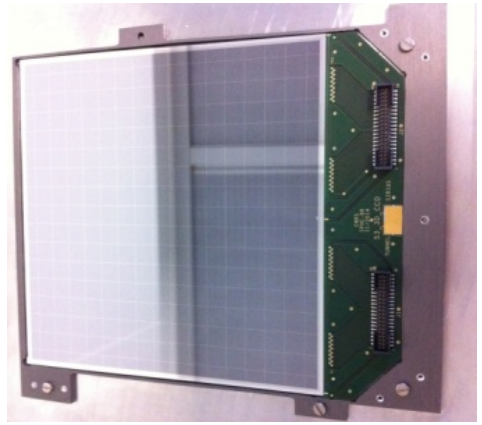
PIXEL separation

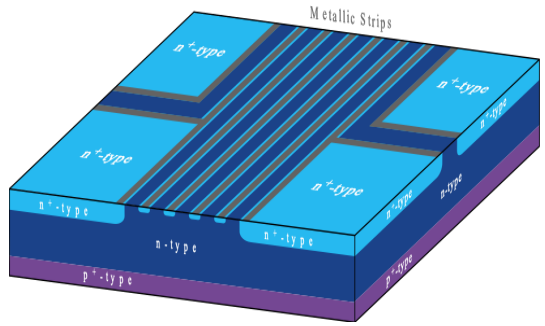
x-direction 120 - 1680 µm
y-direction 120 µm

Ohmic side Tracking

width 30 µm
separation 80 µm



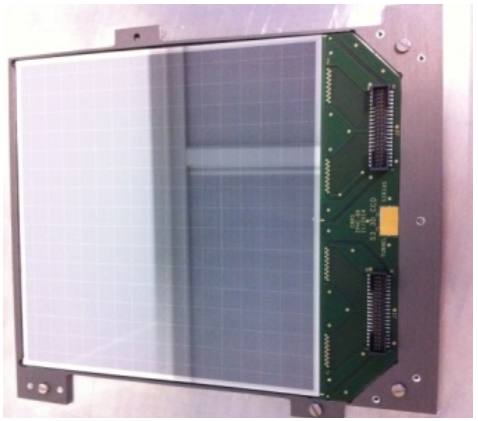


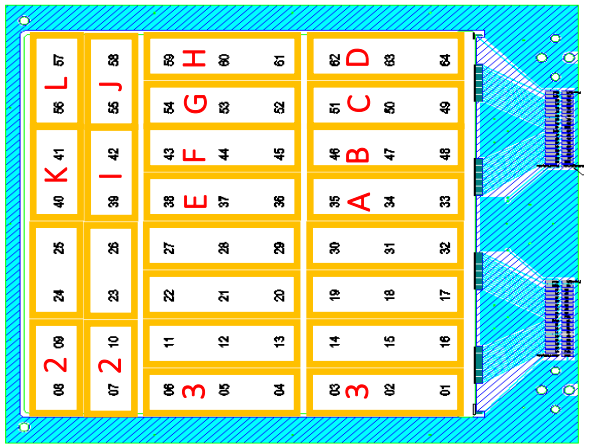


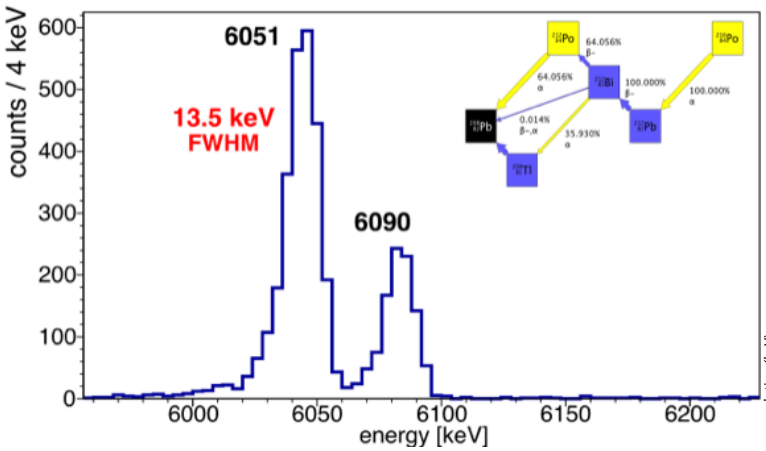
Nuclear Inst. and Methods in Physics Research, A 1015 (2021) 165770

TUNNEL detector and preamp validation tests @ the IPHC [2015]

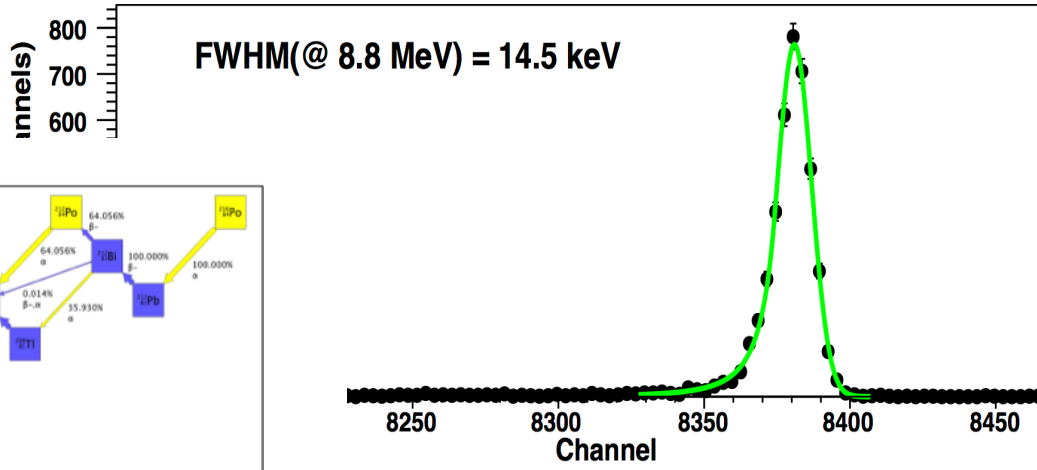
Collimated source on single pixel + IJCLab preamp + TNT-D [detector cooled to -15C]

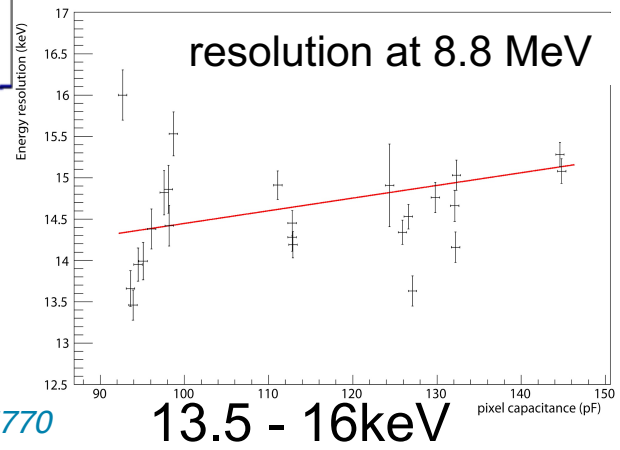






CREMAT + TNT-D [grouped PIXELS]
[detector cooled to -15C]

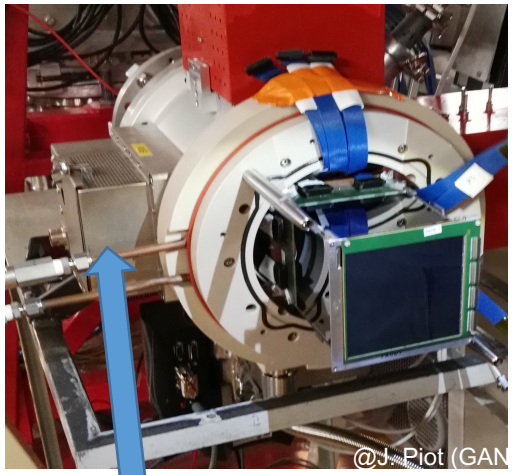




13.5 - 16keV

Nuclear Inst. and Methods in Physics Research, A 1015 (2021) 165770

TUNNEL and front-end electronics delivered mounted in SIRIUS



<u>March 2022</u>: installation tests (same detector as 2015 @ IPHC)

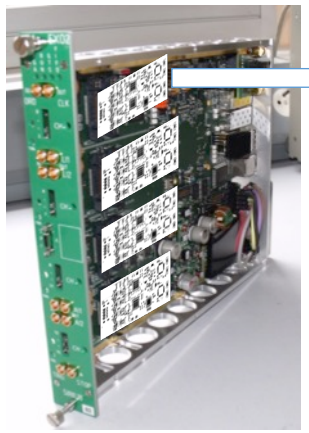
Quick integration test using available VAMOS firmware

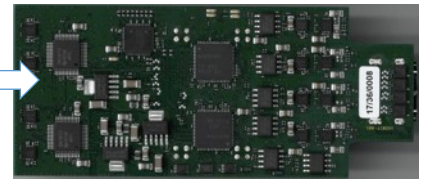
→ online energy determination

FWHM = 20 keV @ 5.8 MeV…

(parameters not optimised need to redo)

94 FADC-DAC cards have been delivered (DSSD + TUNNEL + 6)

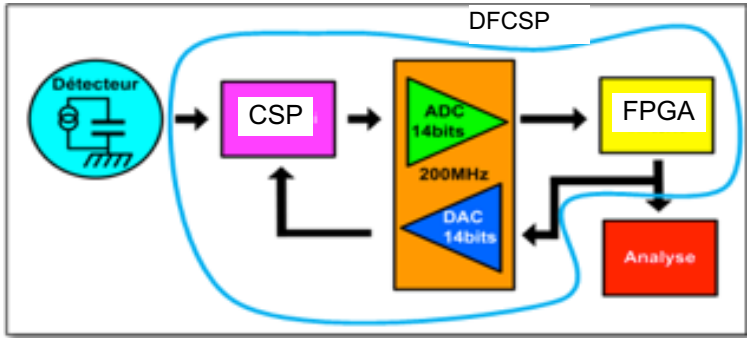


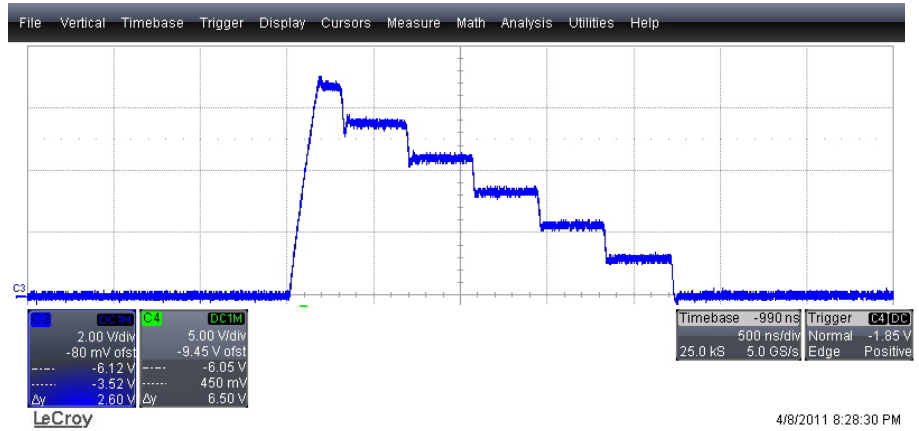


Digital feedback for the TUNNEL – another inovative to extend the energy range

0 - 30 MeV (standard signal → standard treatment)

Principle of FEE Digital Feedback CSP is to inject charge to desaturate the preamplifier by injecting charge via a DAC which is controlled by the FPGA.





The Digital Feedback Firmware R&D is designed and tested in EXOGAM V6 version.
The Proof of Principle is validated but the RAM consumption inside the FPGA mean only 14 channels fit
(trying to squeeze in the last two…)

Latest SIRIUS FPGA firmware tests [10+11/10/2022]

All 256 strips of the DSSD instrumented into 16x NUMEXO2 digitisers

several alpha sources → 1 kHz / channel

perfectly stable with no DAQ data errors

dead-time due to signal readout evaluated at 1 μs

[5 μs data stored but 6 μs to read out]

(alpha signal triggered a generator)

Decimation on the FPGA tested (5 ns → 10 ns sampling ie 5 μs → 10 μs)

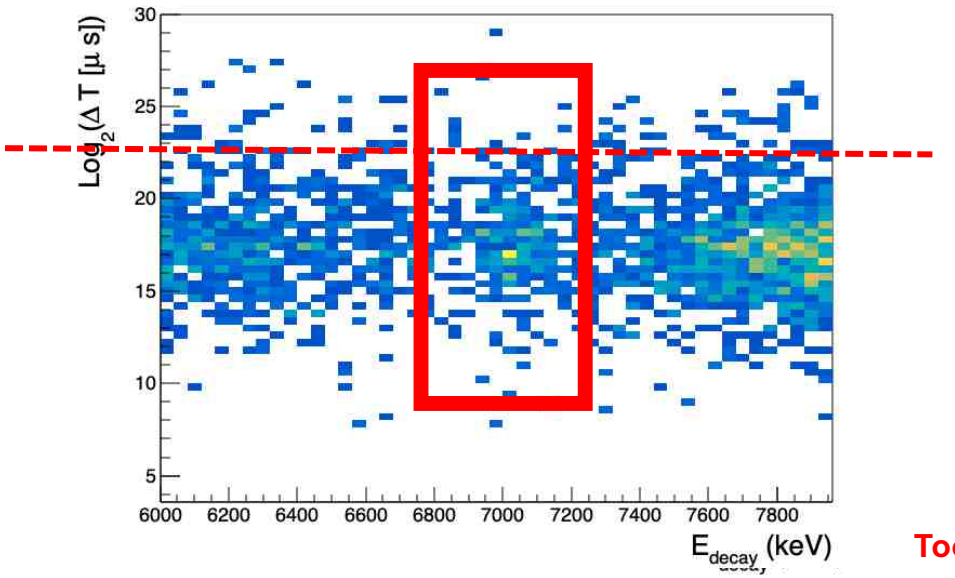
might be required for longer integration time on the MWD for the TUNNEL

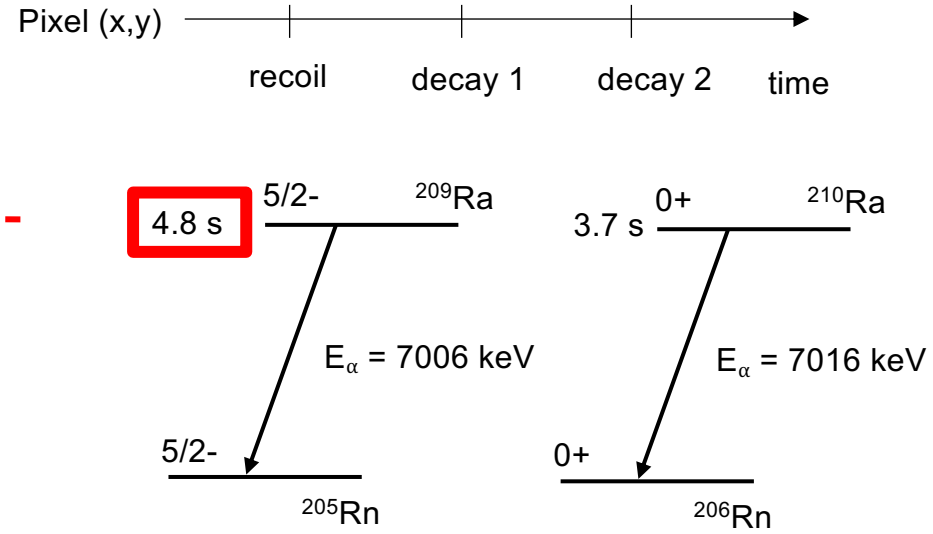
(analysis ongoing)

Online commissioning tests at LISE2000 ?…. (2019 & 04/2021)

Objective: Determine if LISE2000 is suitable for commissioning SIRIUS
^{174}Yb(^{40}Ar, 4-5n)$^{210-209}$Ra : [σ = 1.4 mbarn, T_x ~ 0.5%, I_B ~ 30 pnA] → ~1x10^5 implants / 3UT
"simple" test with just a MWPC + DSSD to examine rejection of scattered beam

Analysis: standard position and temporal correlations (DSSD) → Recoil – alpha decay plots





Too much background

Rejection ~1e7
10 pnA → 6000 pps in the Si

Near future plans

→ time to put in “series” SIRIUS detectors (tunnel and DSSD)

check the performance (3α & ^{133}Ba)

resolutions and thresholds

→ add a Ge

Alpha – Gamma/X-ray coincidences (eg ^{241}Am)

→ Firmware integration Q1 2023 (merge the parallel developments)

→ commissioning of SIRIUS on FULIS ?

shake out the bugs to ensure complete operability when installed on S3

only way to validate Tracker – DSSD time-of-flight

only way to test VETO detector (as a VETO)

collaboration needs the opportunity to train on the setup

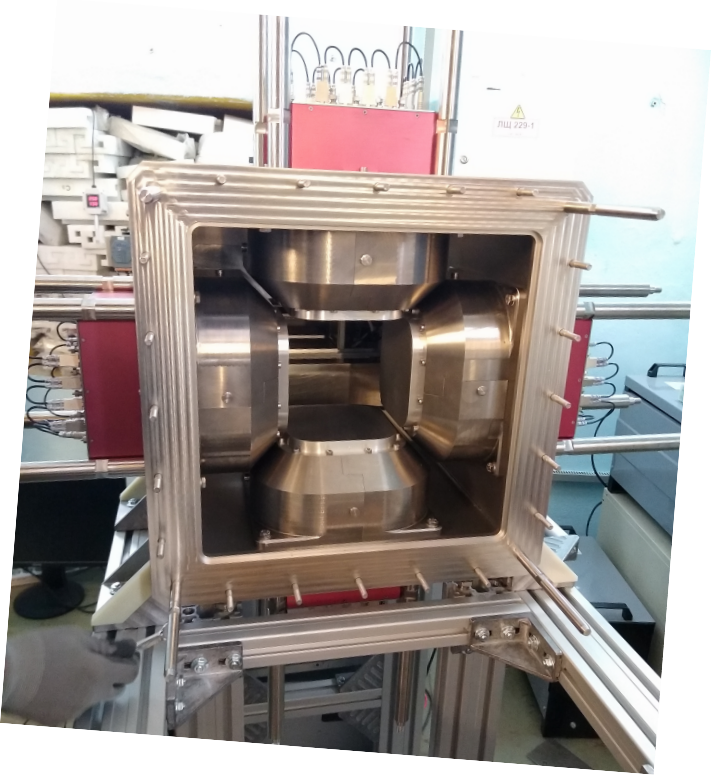
provide S3 with a functioning system for it’s commissioning

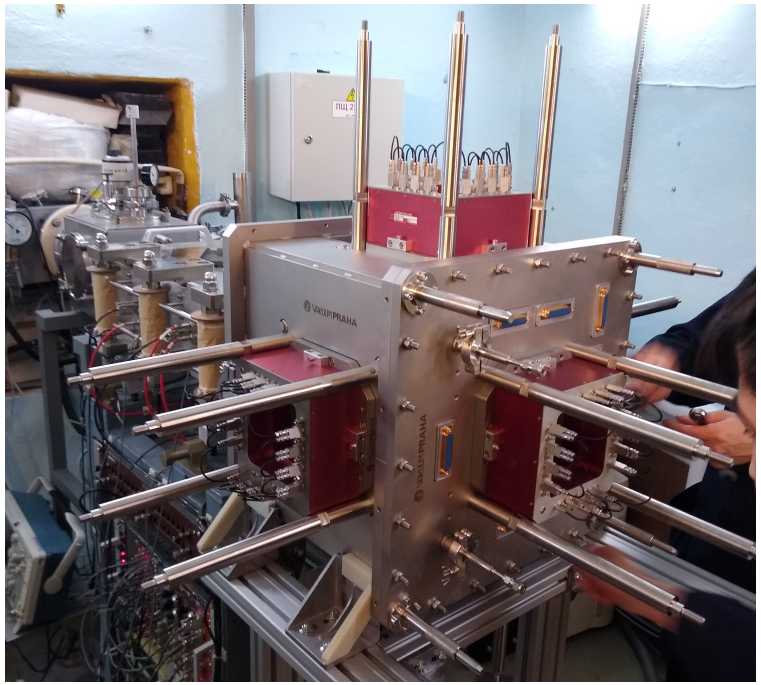
Possible upgrades

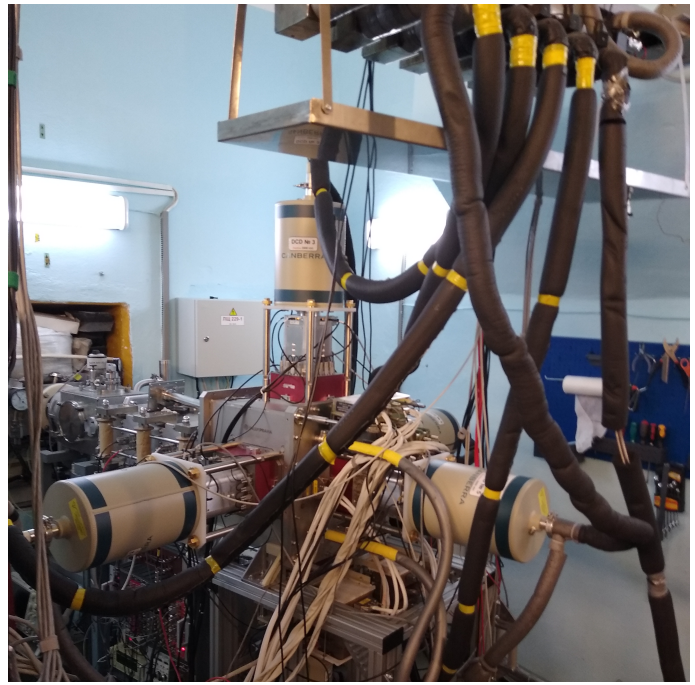
Looking at parallel developments at other sites:

"Lundium" array – basically sticking your (unshielded) clovers in the chamber

5 Clover GABRIELA upgrade: array with active (outside) and passive shielding inside



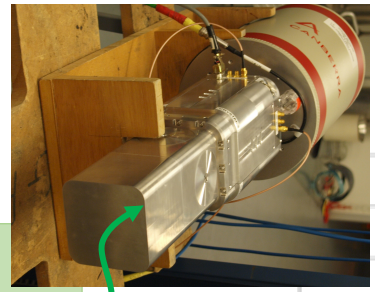


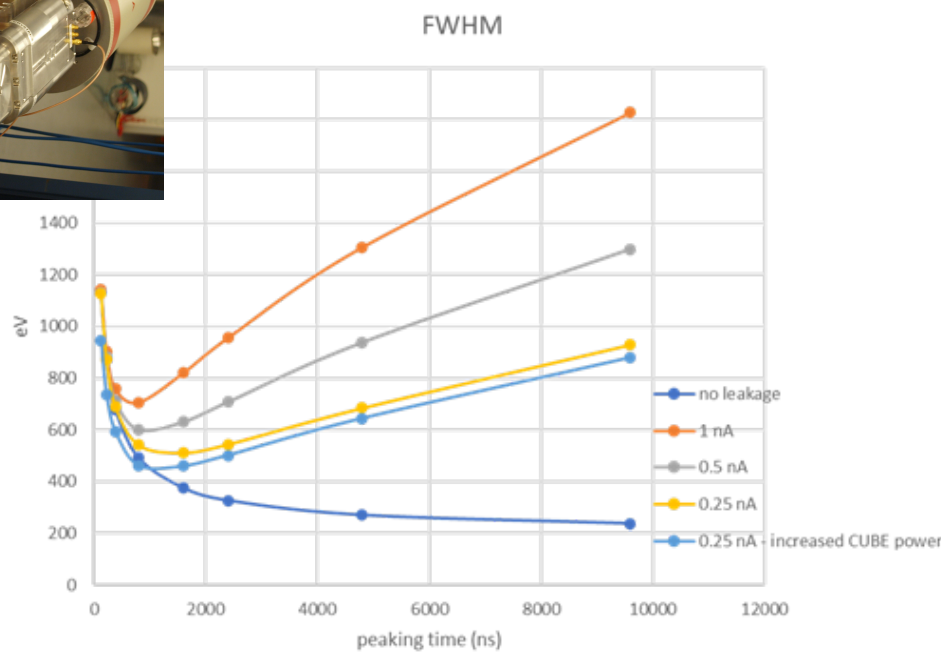


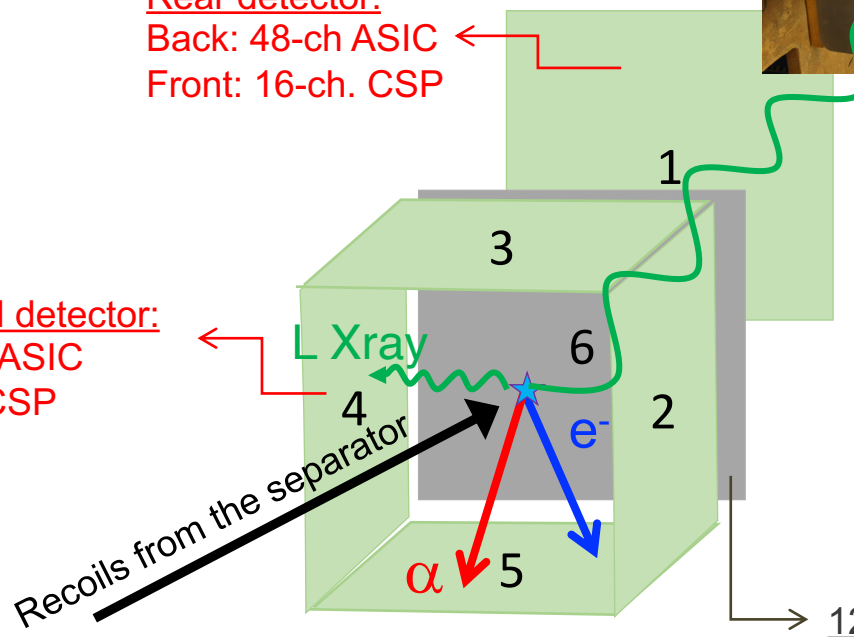
Possible upgrades

"SHEXI" upgrade studied for GABRIELA

replace the tunnel and VETO with thicker Si with strips of <10 pF + ASICs

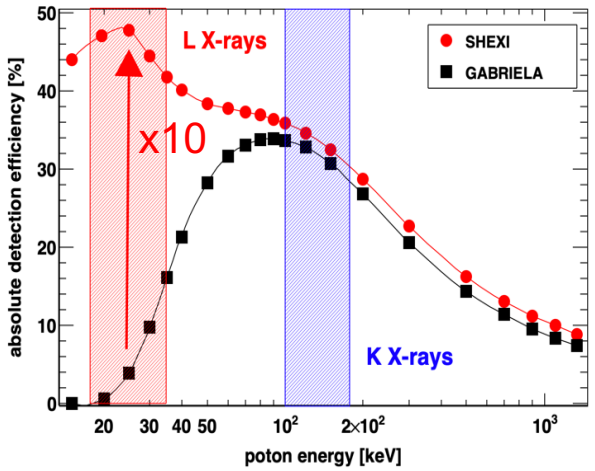


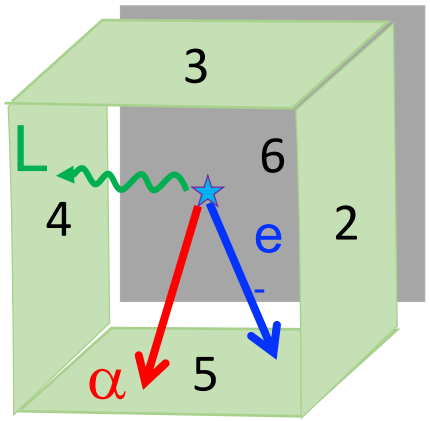


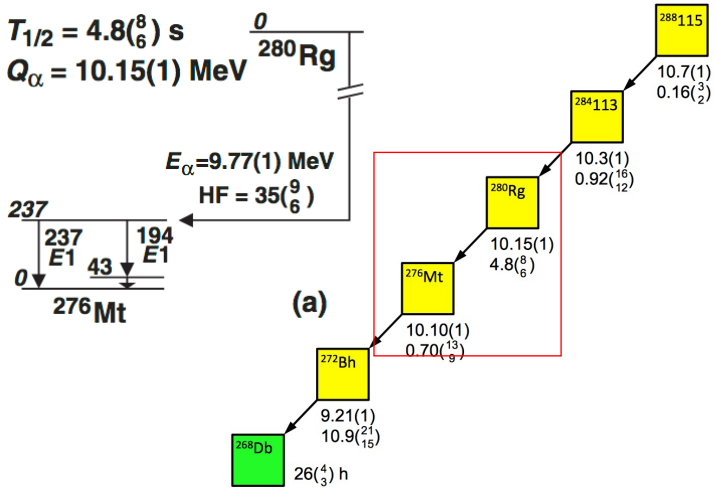


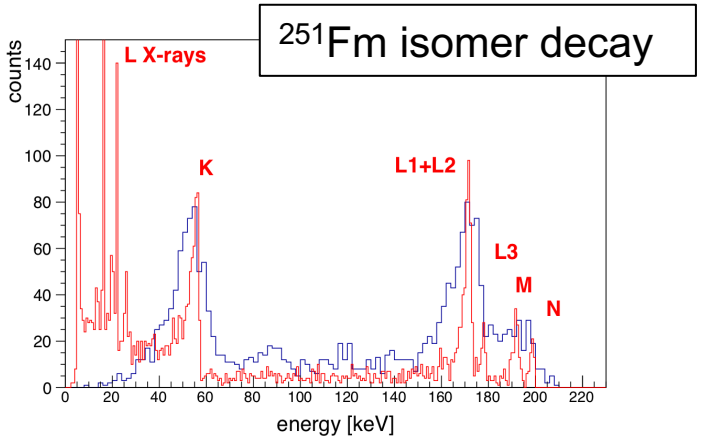
Gain ?

The SHEXI advantage: keeps L-Xray and γ-ray detection separate → reduce summing effects

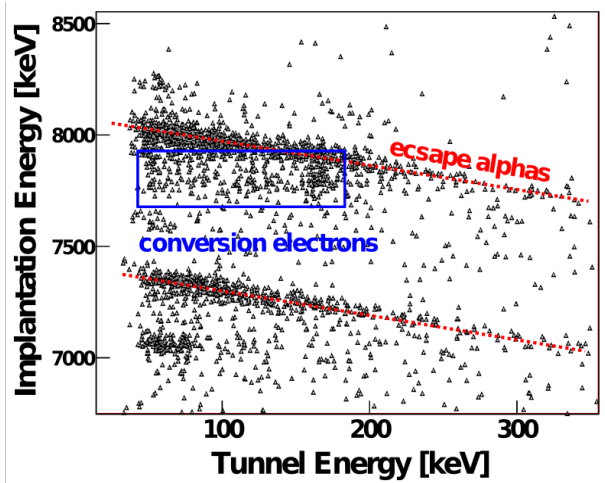


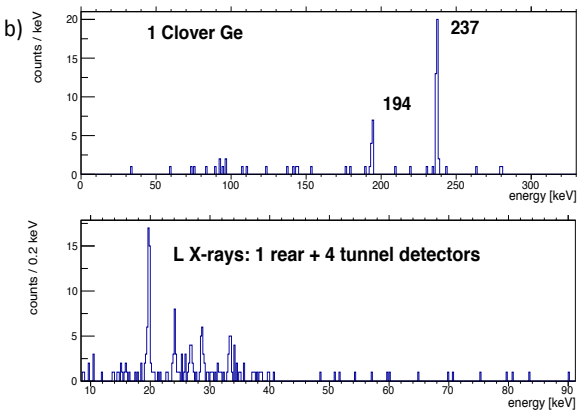






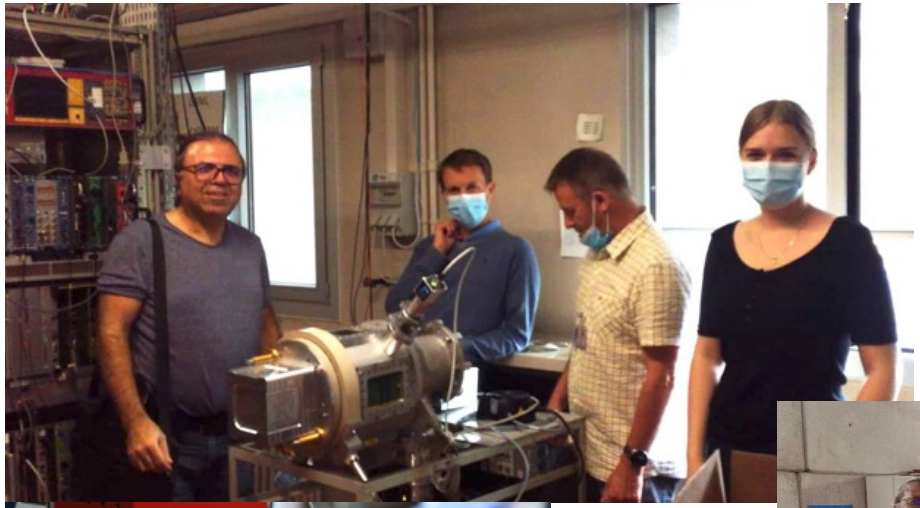
K. Rezynkina et al., Phys. Rev. C 94 (2018) 054332

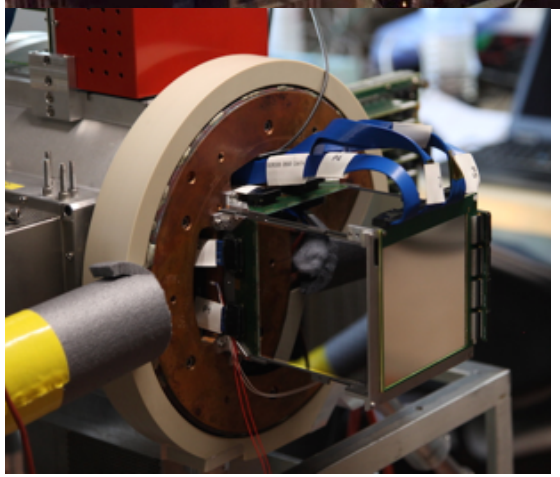




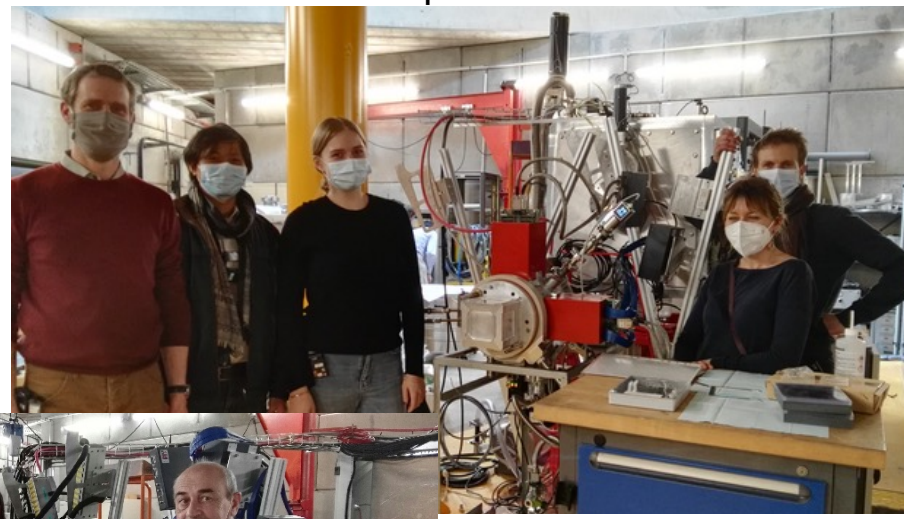
Photos to end….

IRFU 2020 During COVID 19





GANIL April 2021



GANIL October 2021