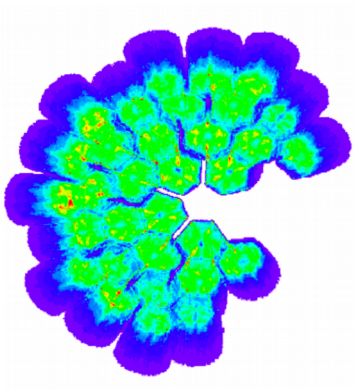


MUGAST: direct reaction with the AGATA setup @ VAMOS
- UPDATE -

Daniele Mengoni[1]

For the collaboration

[1]University of Padova, INFN Padova

GASPARD TRACE

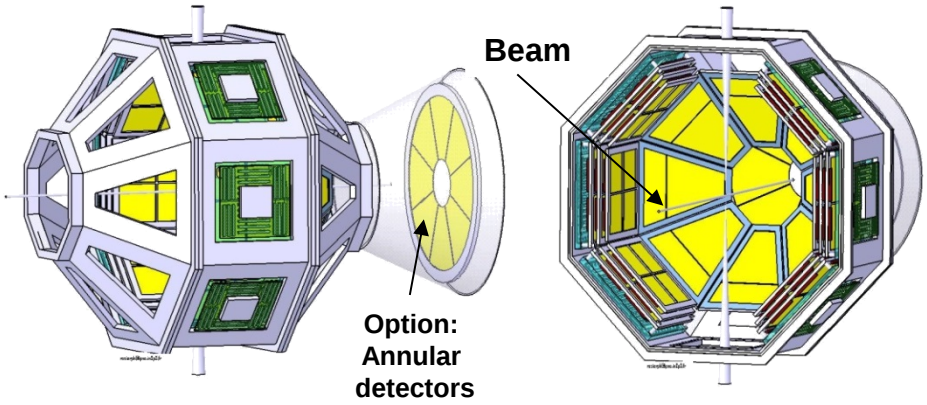
INFN

Motivations

A new Si array for structure and reaction study

GASPARD TRACE

"GASPARD-TRACE" design



4π, fully integrable in PARIS and AGATA

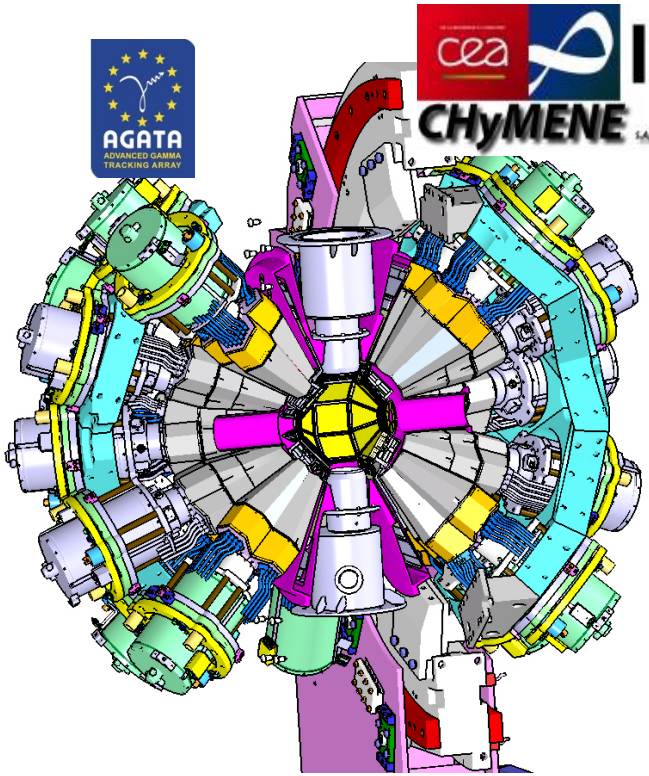
Layers of Silicon

- 500µm DSSD pitch < 1mm
- 1(or 2) x [1.5 mm DSSD pitch~3mm]

2 main shapes : square & trapezoid, large area

Electronics :

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



Motivations

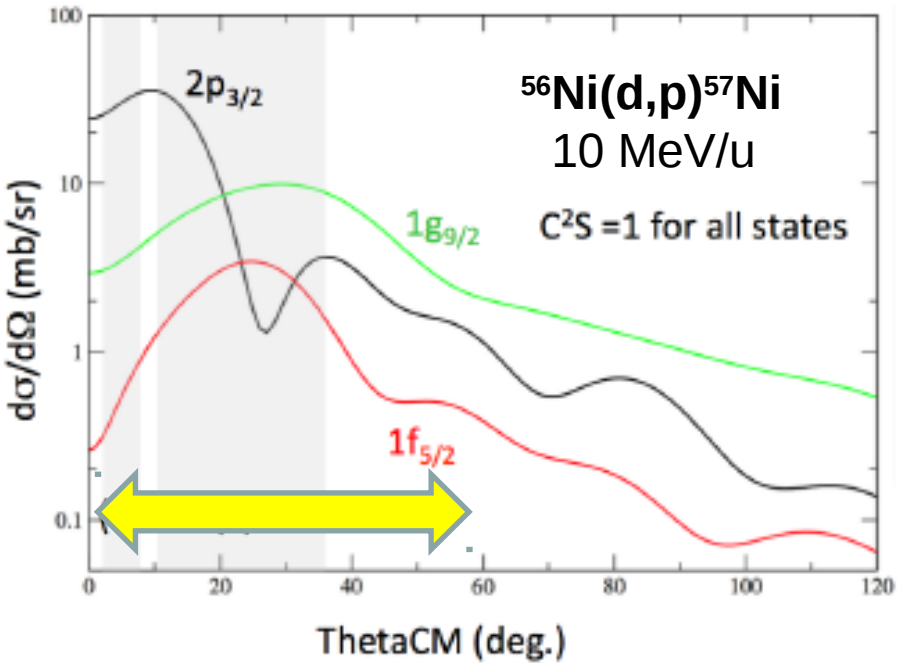
- ❑ Intermediate and heavier masses
- ❑ Higher excitation energies – Low sp strength
- ❑ Sometimes at mid-shell
- ❑ Detect/identify several channels altogether

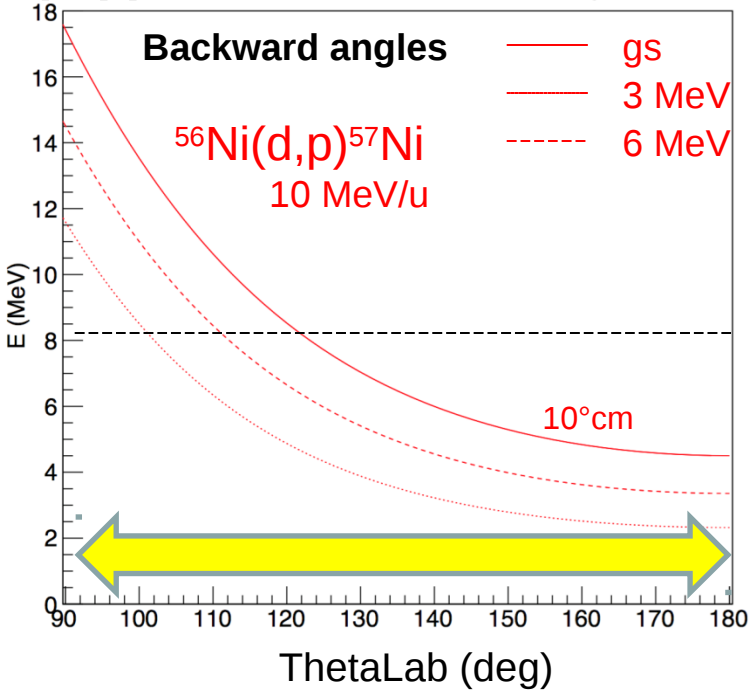
MUGAST: motivations
MUST2+GASPARD+TRACE

To perform ***high resolution reaction and spectroscopy studies*** using

- **AGATA**@ VAMOS – GANIL for some years
- The **new SPIRAL1 beam** + upgrade
- Some Si dets of future array progressively available

Focus on ***stripping reactions*** ***e.g. (d,p)*** ⇨ ***backward angles***

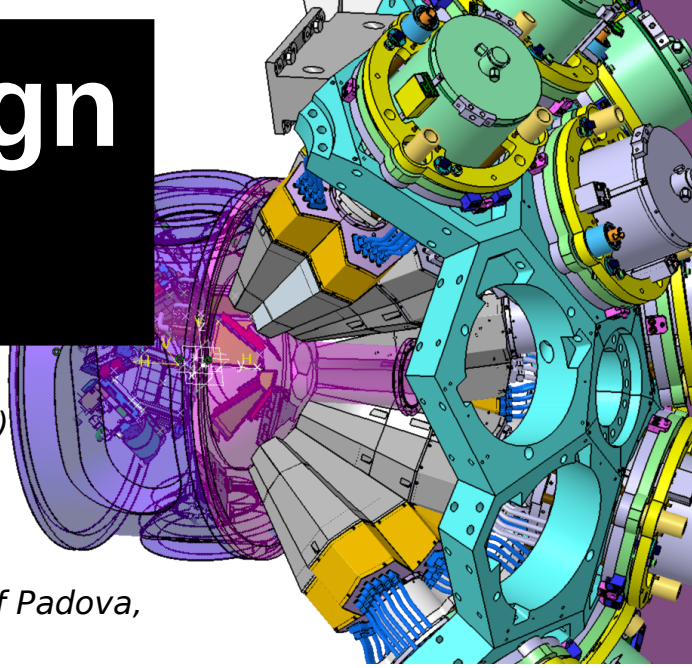




LoIs Science campaign

MUGAST+AGATA@GANIL

Spiral 1 beams



Nuclear astrophysics:

- **^{15}O(^{6}Li,d)^{19}Ne** *(C.Diget, Univ. of York, N. de Séréville, IPNO)*
- **^{25}Al(^{3}He,d)** *(N.de Séréville, F. Hammache, IPNO)*
- **^{30}P(^{3}He,d) or (d,p)** *(N.de Séréville, F.Hammache, IPNO)*
- **^{60}Fe(d,p)** *(A.Matta, W.Catford, University of Surrey)*
- **^{79}Se(d,p)^{80}Se** *(G. de Angelis, INFN-LNL, D.Mengoni, University of Padova, C.Domingo Pardo, CSIC Valencia)*

Shell evolution

- **^{56}Ni(d,p)**(d,t) *(F.Flavigny, IPNO, O.Sorlin, GANIL)*
- **^{28}Mg(d,p)** *(A.Matta, W.Carford, University of Surrey)*
- **^{74}Kr(d,p)** *(A.Matta, W.Carford, University of Surrey)*
- **^{48}Cr(d,p)^{49}Cr** *(A.Gadea, CSIC Valencia)*
- ^{30}Mg(d,d)**(d,p)** *(B.Fernandez-Dominguez, University of Santiago, W.Catford, University of Surrey)*
- **^{67}As,^{63}Ga(^{3}He,d)** *(D.Mengoni, University of Padova)*
- **^{44,46}Ar(t,p)** *(D.Mengoni, University of Padova)*
- **^{66}Ni(t,p),^{44}Ar(t,p) (^{14}C,^{12}C)(^{18}O,^{16}O)** *(L.Fortunato, J.A.Lay, University of Padova)*

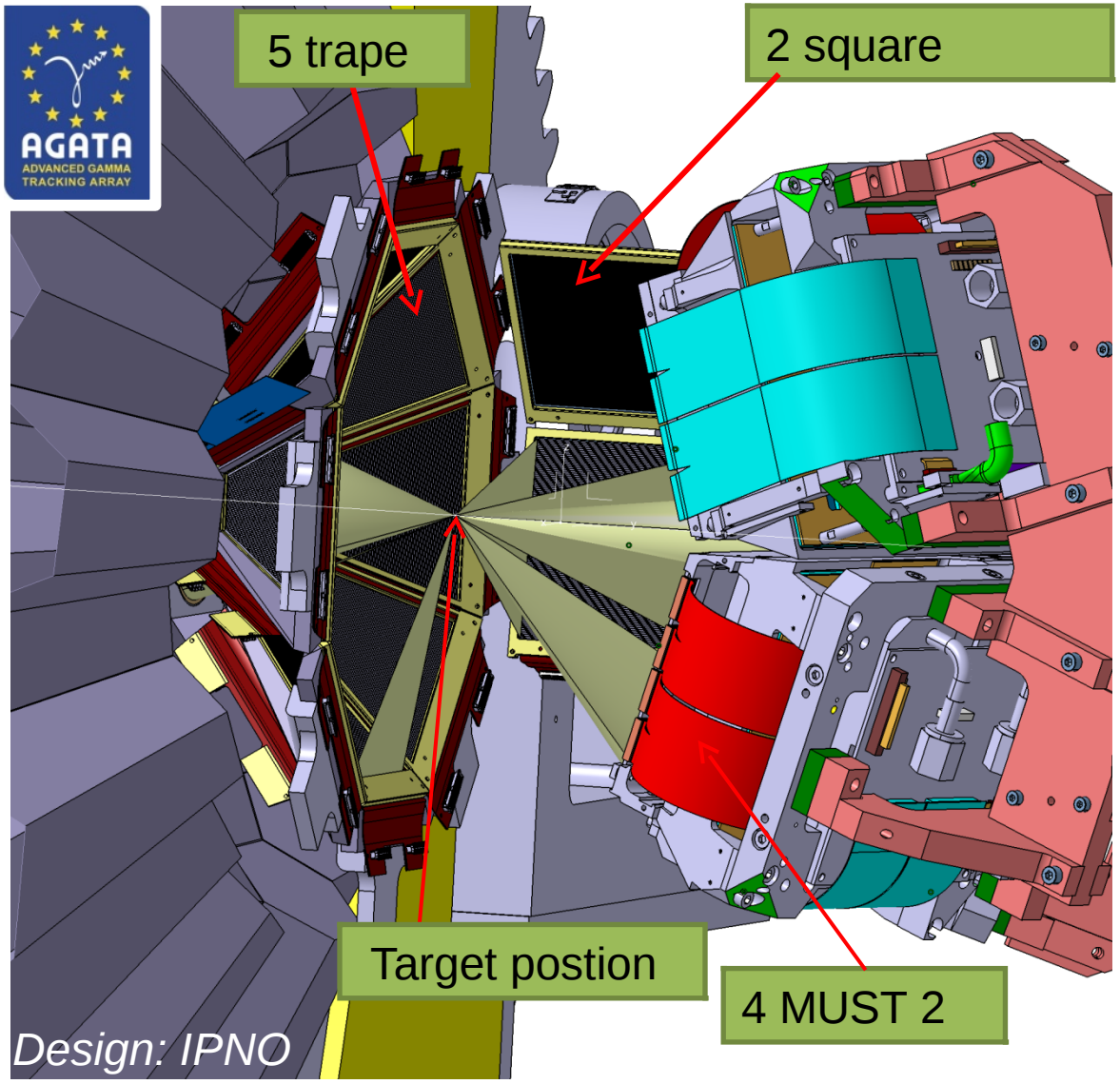
Clusters, pairing, correlations & others

- **^{56}Ni(^{3}He,p)(^{6}Li,α)** *(M.Assie, IPNO)*
- ^{45}K + ^{7}Li -> ^{46}Ca+α *(S.Leoni, University of Milano, B.Forna*
- ^{16}O + ^{A}Z *(G.Verde, INFN Catania and IPNO)*
- ^{14}O(p,p) *(I.Stefan, IPNO)*

- **8 independent LoI + Umbrella LoI**
- **Mostly stripping reactions** (backward)

Setup

MUGAST+AGATA

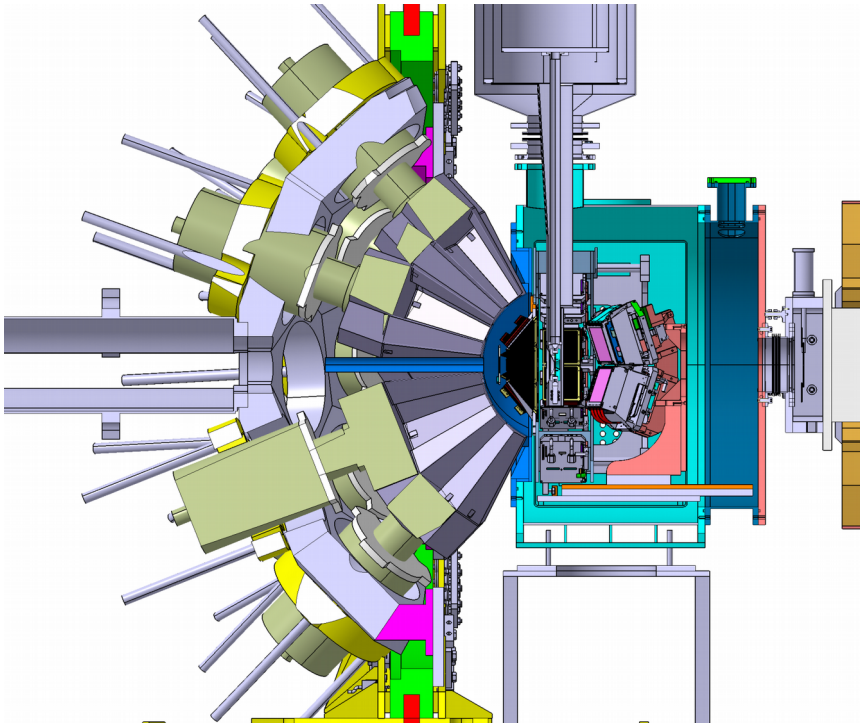


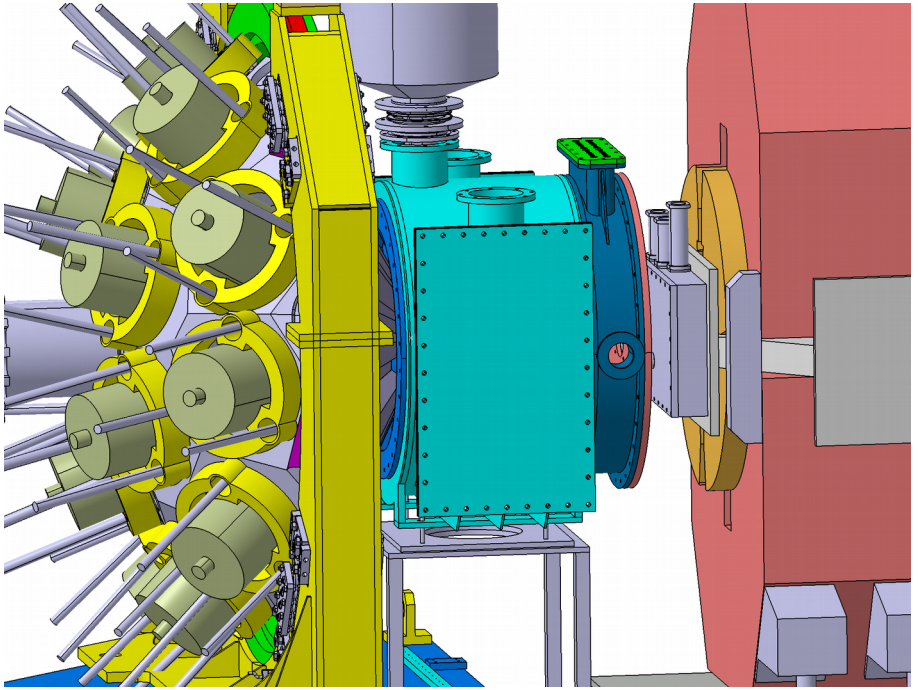
Si detectors configuration

- 5 Trapezoids + 1 Annular at bck angles
  - •Distance : **10.5 cm**
  - – Ann: 12.5cm
  - •Angles: [104.2-155.2]° + [159-169.2]°
- 2 Squares around 55.8° - 90°:
  Distance : 13.5 cm
  Angles: [60,90]°
- 4 MUST2 telescopes at fwd angles
  Angles : [10-50]°

AGATA distance: 18 cm

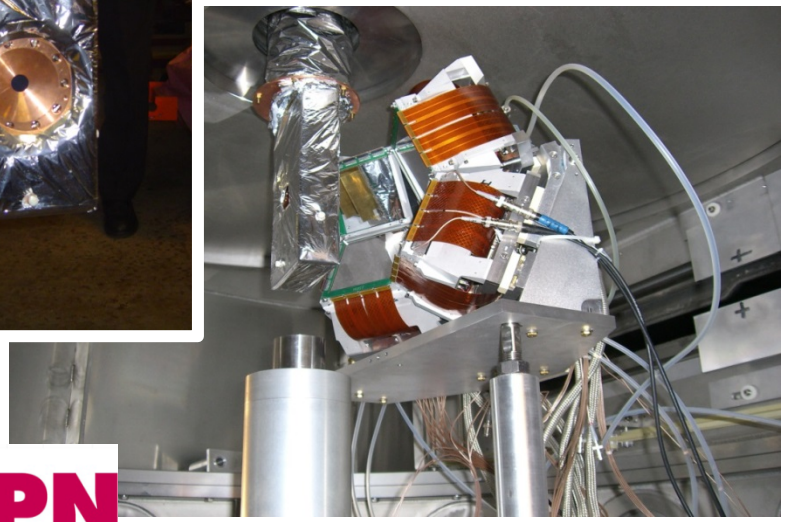
MUGAST+AGATA @VAMOS



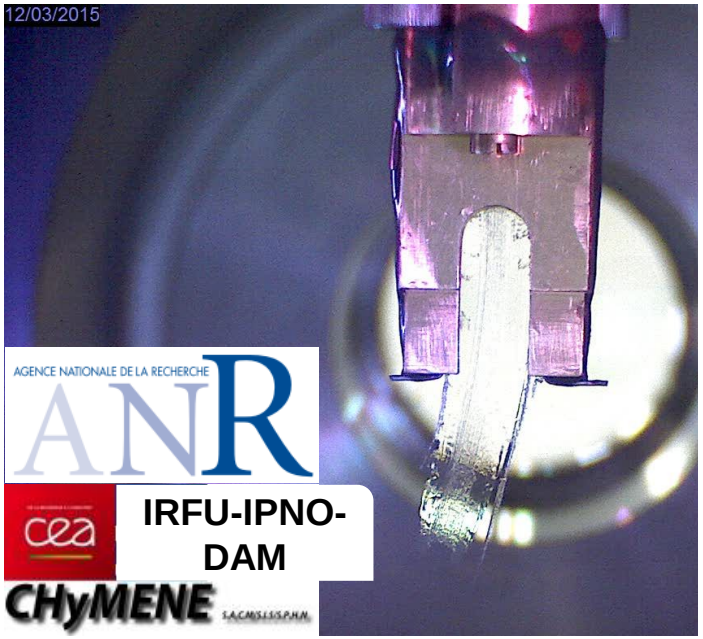


Special targets

- 4He gas target
- cooled gas cell at 5~8 K to maximize density
- Havar windows, 3.8 microns
- Used at SPEG – GANIL
- 3He version under study



- Hydrogen (h,d) target in a solid phase near triple point (~17K)
- Thickness 50 – 200 µm
- No window - C free
- Continuous flow in vacuum 2-10mm/sec
- Compatible with particle detection



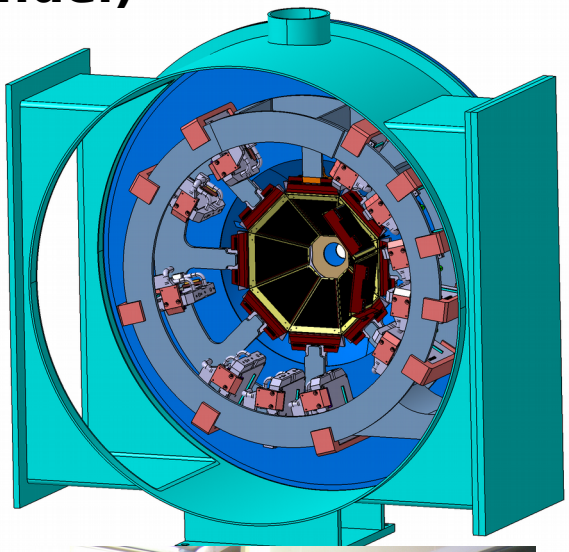
IRFU-IPNO-DAM

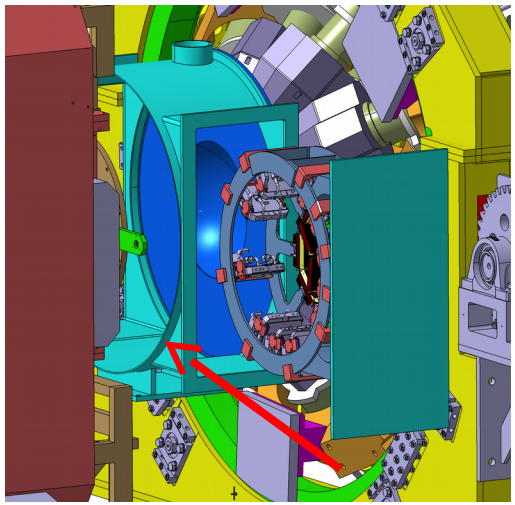
IPN INSTITUT DE PHYSIQUE NUCLÉAIRE ORSAY

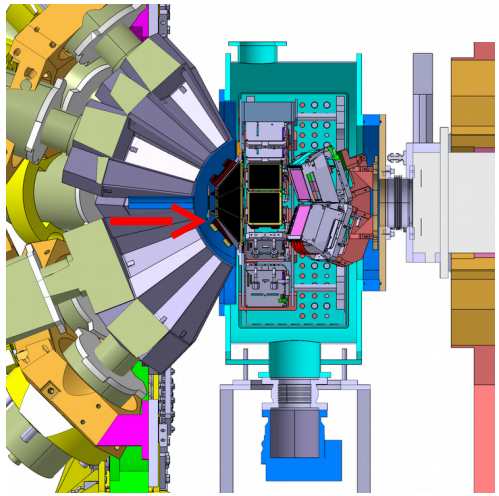
reaction chamber

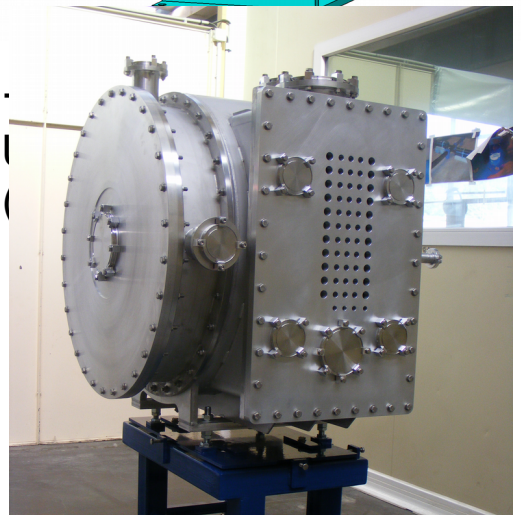
Design of the reaction chamber @IPN (E. Rindel)

- Distance AGATA-target = 18 cm
- 3 mm Al thickness towards AGATA
- No electronics behind trapezoid detector
- Capability of handling more trapezoids
- Possibility of second layer.
- Fully removable backward array
- Option for cryogenic target









Detectors

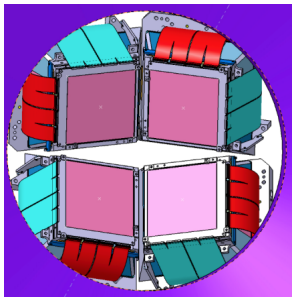
MUGAST: configuration
MUST2+GASPARD+TRACE

- **Intermediate configuration: MUGAST (MUST2-GASPARD-TRACE)**

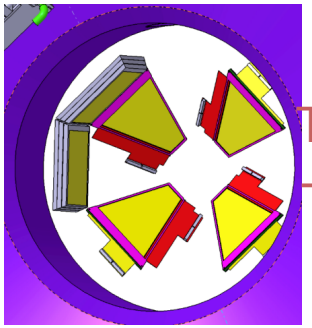
Particle detection:

- 4 GASPARD trapezoid DSSSD (backward/AGATA side)
- 1 Annular (S1-like) (backward close to 180°)
- 2 TRACE square detectors (@90°)
- 4 MUST2 Telescope (forward)

- Existing electronics (MUFEE+MUVI)



MUST2



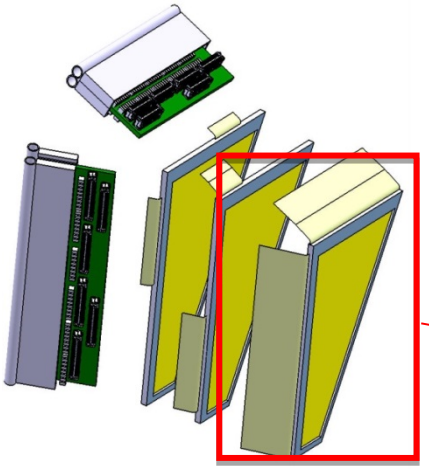
TRAPEZ. +SQUARE

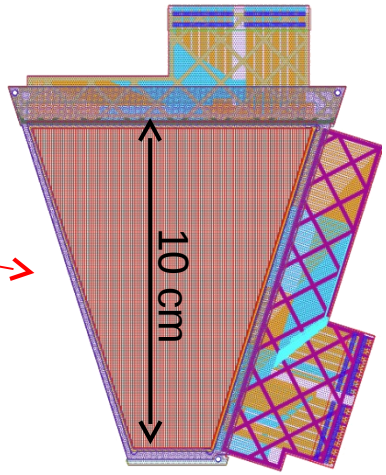
γ-detection (AGATA):

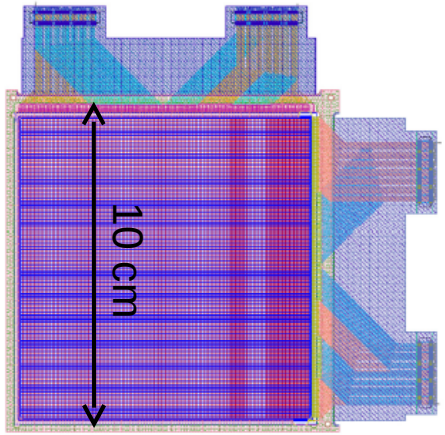
- Maximize eff: ≈ 8% @1 MeV @ 18cm *(for 11 triples)*
- Benefit from very good energy resolution (≈ few keV)

Silicon developments

- New geometries
- New packaging : thin frame, kapton at 90°
- 6”, NTD, random cut, reverse-mount
- Thin (500um) and thick (1.5mm)







Si detectors plan

1st layer (500 um, pitch~700 um)

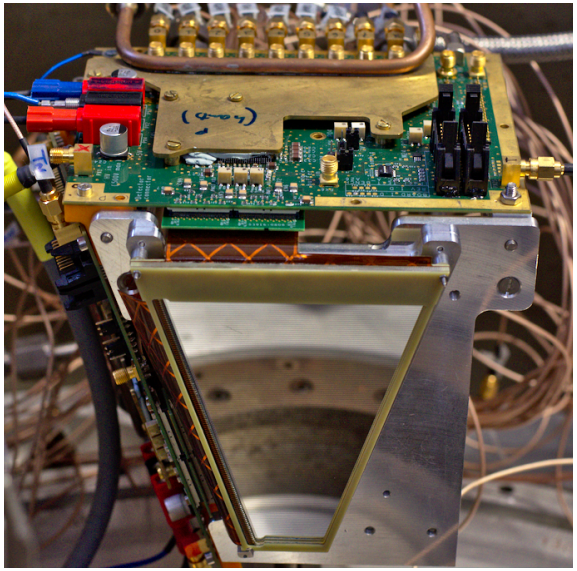
- **Trapezoid shape**
  - **2 prototypes commissioned** [IPNO]
  - **3 pre-serie ordered** [Surrey, Santiago, IPNO] (MICRON SC)
- **Square shape**
  - **2 prototypes ordered** [INFN-Padova]

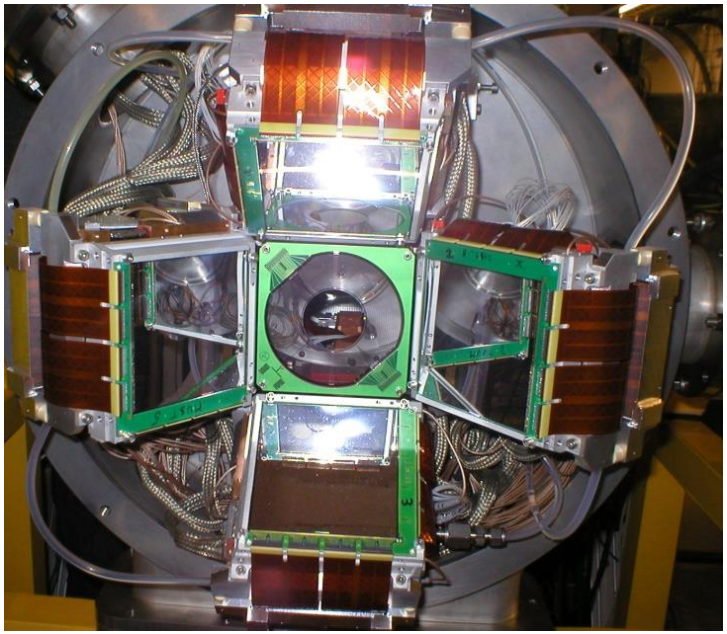
2nd layer (1.5mm, pitch~3mm)

- **2nd layer square**
  - **1 prototype ordered** [INFN-Padova] (MICRON SC)

Collaboration with BARC Mumbai foreseen

Dets. commissioning bench



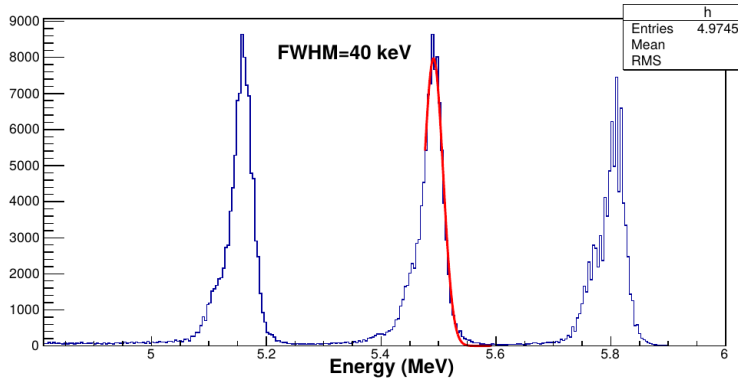


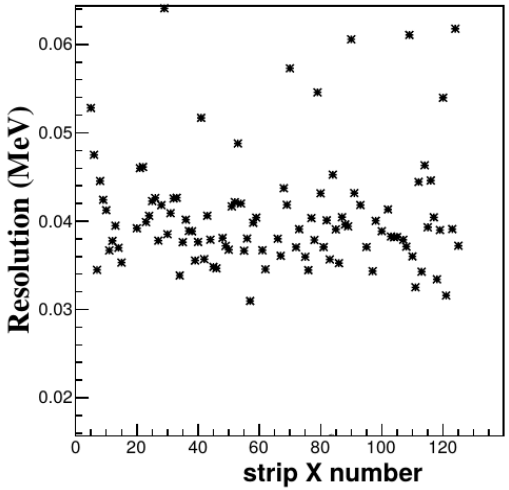
- → Digital Test bench at IPNO.: 2iPACI chips per side, 9 strips side (charge+current)
- → A modular one soon at LNL. 16X channels, Milano ASICs preamps

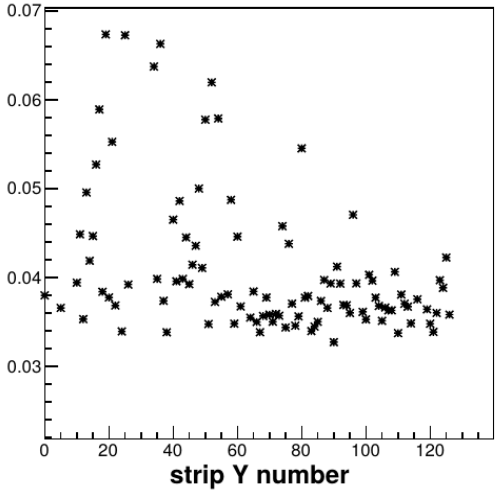
- → Realistic bench with MUST2 electronics at IPNO

Commissioning of the square/trape

- Source test



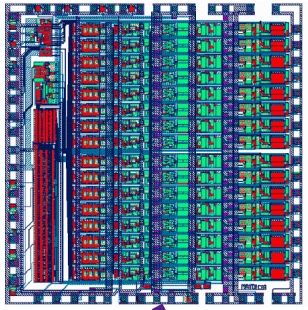




- In-beam test during the coming October 2017, IPNO Tandem

Electronics

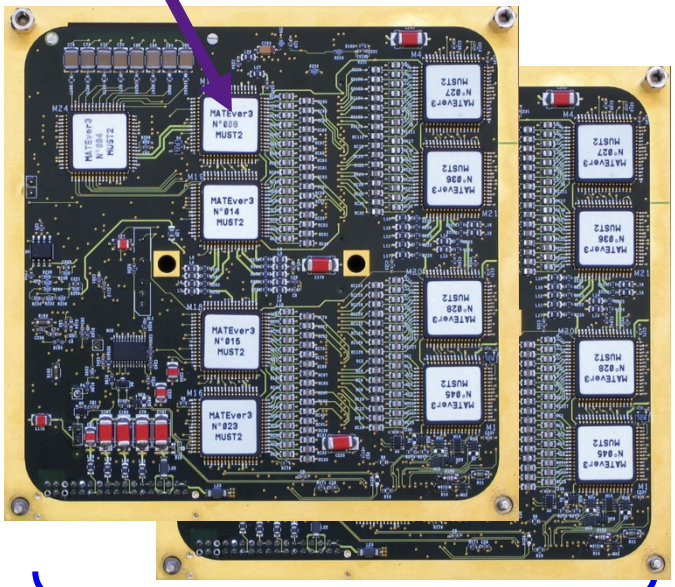
FEE/BEE : MUFEE + MUVI



- 16 channels 28 mW/ch
- Energy & Time
- Si, Si(Li) and CsI
- Multiplexer
- I2C interface

- High linear. pulser
- T sensor

MOTHER BOARDS (IPNO)



VACUUM

AIR

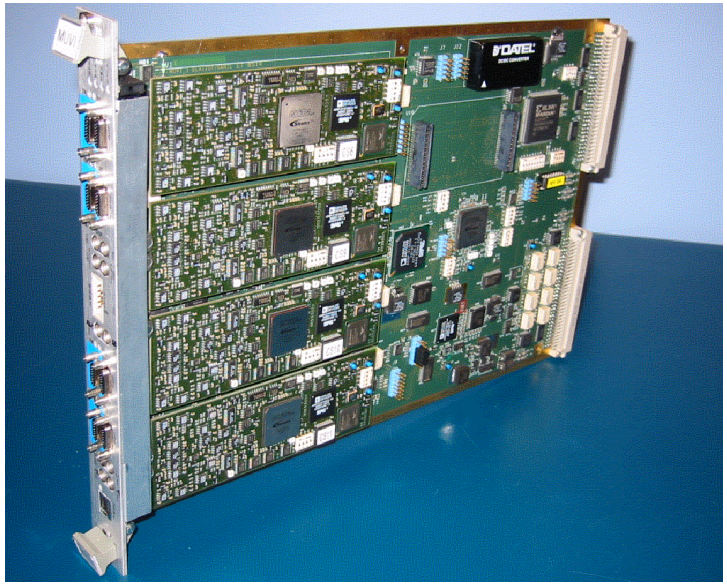
4 analog bus

Control signals

I2C bus

VXI board (GANIL)

16 ADC14 bits
2.3K parameters
2MHz
Slow Control I2C
Pedestal substraction
DNL correction



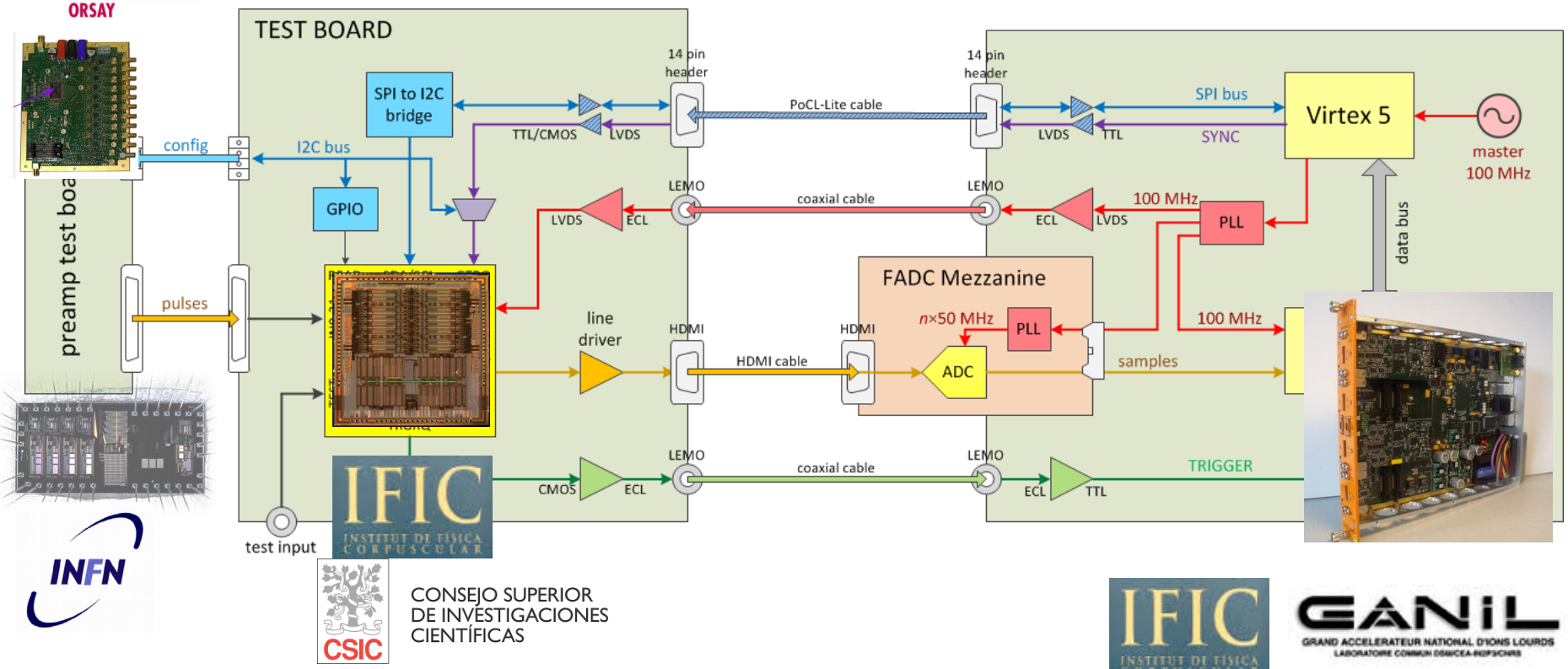
1 telescope

4 telescopes

Future elec.: Det. Board + RO unit

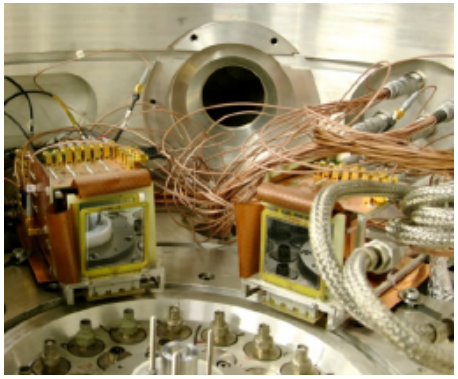
- Current and charge output (IPN)
- Charge + extended dynamics (INFN)

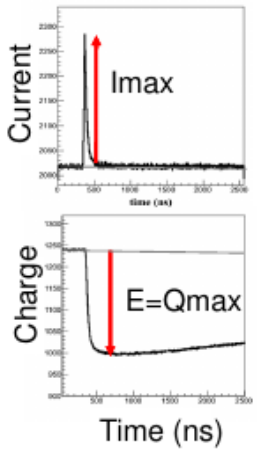
- different input polarities and signal Ranges
- 32 inputs with independent trigger
- Samples pulses @ 200 MSPS
- 224 samples from each pulse: 32 beforetrigger (30 valid) 192 after trigger
- Generates common Trigger Request signal
- No deadtime

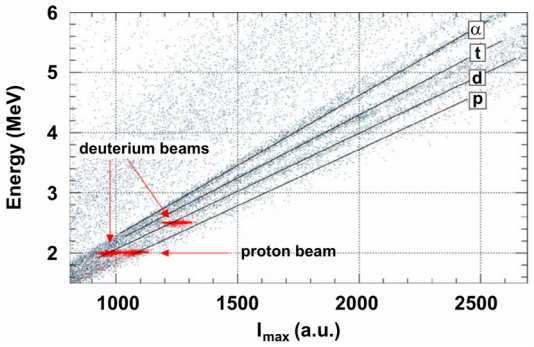


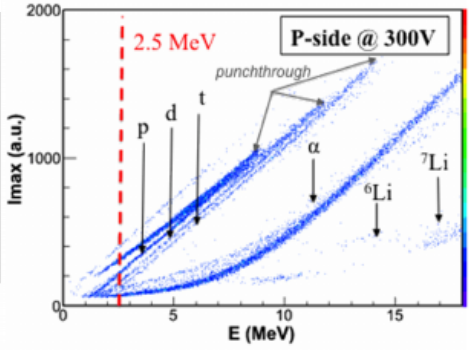
R&D on pulse shape analysis

NTD, strips

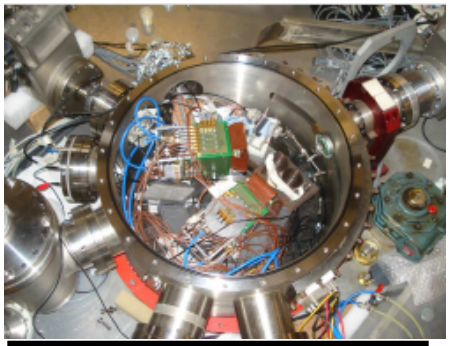


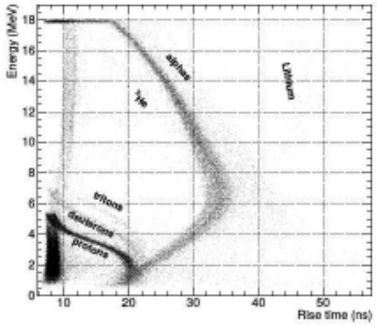




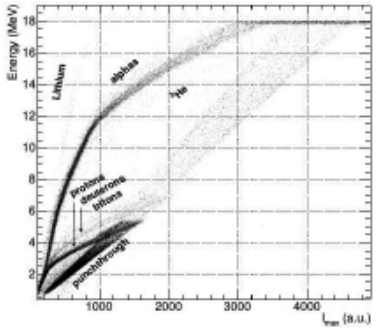


FZ pad





Gamma dets



- NTD Single pad
- Sgmented dets (DSSS&PAD)
- Gamma -ray dets

J.Duenas et al., NIMA(2012)

M.Assié et al., EPJA(2015)

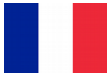
D.Mengoni et al., NIMA(2014)

Summary & Conclusions

- MUGAST array available already in 2018, technical meeting in GANIL next 9th of Nov.

- Physics programme at GANIL using AGATA @ VAMOS: proposals using the light SPIRAL1 beams will be submitted at the coming PAC

MUGAST 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)

-

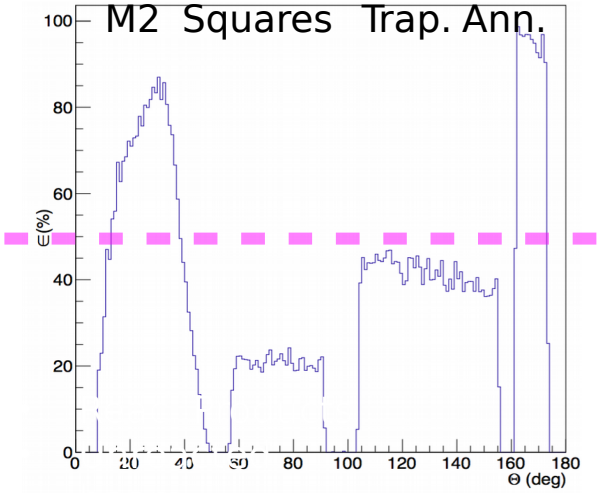
GASPARD

TRACE

>> DETECTORS		
Trapezoids proto (x2)	Commissionning	IPNO, P2IO
Trapezoids pre-serie (x3)	Ordered	Surrey/IPNO +Santiago
Squared proto (x2) + Thick proto	Ordered	INFN-Padova
Annular (x1) th = 500um	Available	IPNO, Surrey
>> ELECTRONICS		
MUST2 FEE boards x10 +1?	Available	
(MUST2 FEE new boards x7 boards+components+ASIC	Order 2016	IPNO, Saclay, LPC
MUST2 Digital boards (x4)	Available	
Kaptons prototypes	Ordered: test 09/16	IPNO
Final Kaptons (x48)	Designed	IPNO
Cables & feedthroughs	2016-2017	IPNO
>> MECHANICS		
Chamber VAMOS and supports	Final for end 2016	Surrey

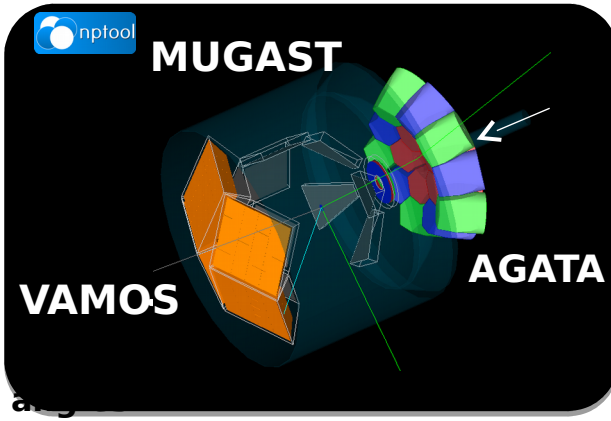
- **Reaction chamber** design ongoing **(fully funded)**
- Test bench mounted @ IPN and operational
- Kaptons:
  - design close to final:
  - Prototypes ordered for test
- ASIC for MUST2: OK
- new MUFEE : OK
- Cryogenic target possibility (under discussion)

Simulations

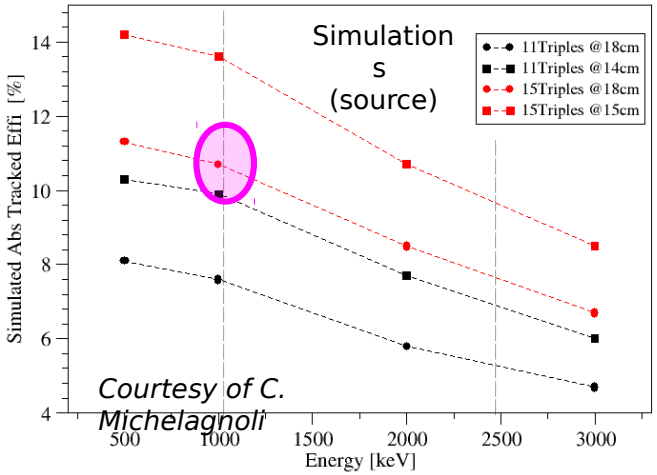


Particle detection

- **4 MUST2 Telescopes at forward a**
  - Distance : 18 cm [10-50]°
- **2TRACE squares around 90°:**
  - Distance : 13.5 cm [60,90]°
- **5 Trapezoids and one Annular:**
  - Distance : 10.5 cm – Ann: 13.4cm
  - Angles: [105-155]° + [161-174]°



A. Matta et al., J.Phys.G 43 045113 (2016)



γ detection

At 18 cm (current goal)

- ε(1.0 MeV) ~ 8%
- ε(2.5 MeV) ~ 5 %

33 det.

- ε(1.0 MeV) ~ 11 %
- ε(2.5 MeV) ~ 8 %

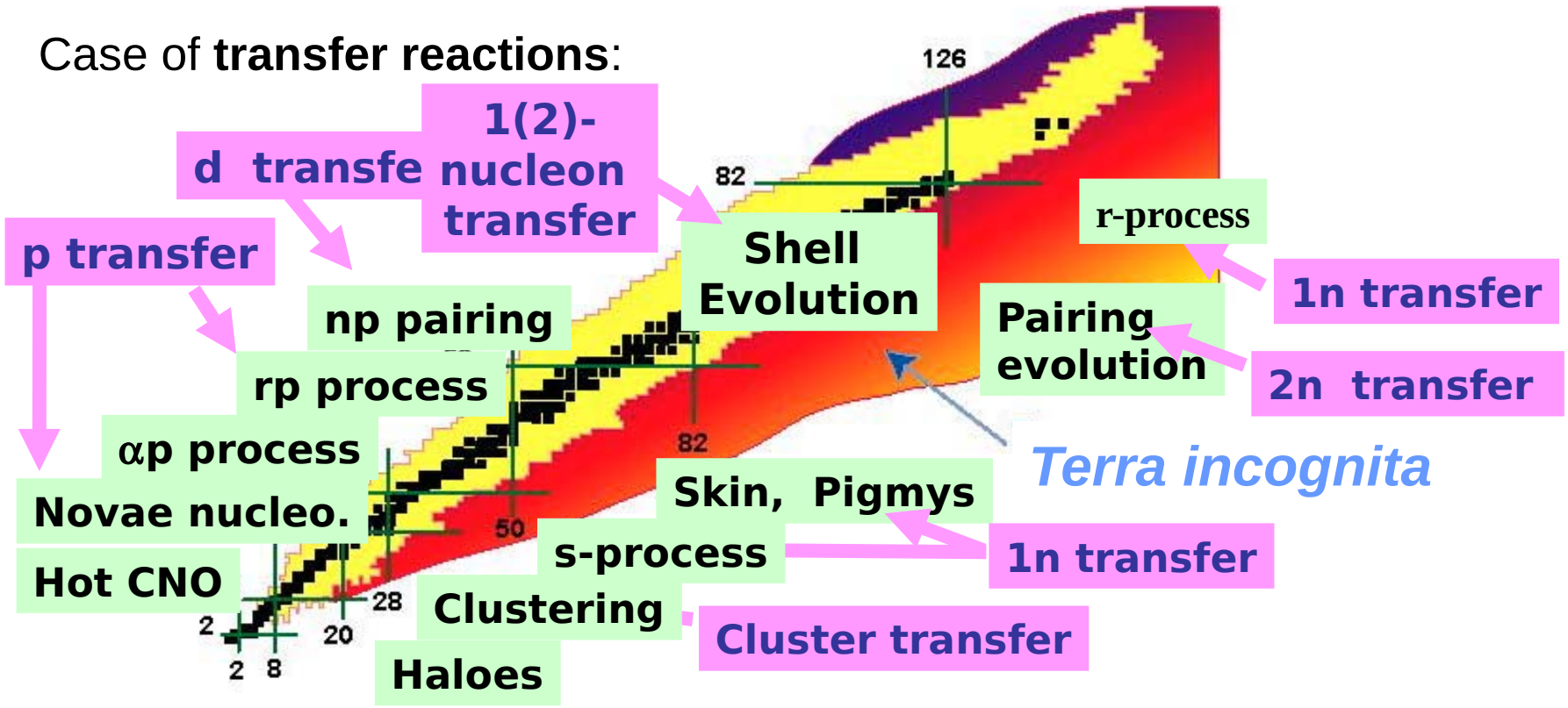
45 det.

ITEM	STATUS	who
DETECTORS		
Trapezoids proto (x2)	Commissioning	**IPNO**
Trapezoids pre-serie (x3)	Ordered	**Surrey + IPNO + Santiago**
Squared proto (x2) + Thick proto	Ordered	**INFN Padova**
Annular (x1) th = 500um	Available	**--**
MUST2 (x4)	Available	**--**
ELECTRONICS		
MUST2 FEE boards (x10)	Available	**--**
(MUST2 FEE new boards (x5) boards+components+ASICs)	To be ordered	
MUST2 Digital boards (x4)	Available	**--**
Kaptons (x48)	To be designed and ordered	
Cables & feedthroughs	To be ordered	
MECHANICS		
Chamber and supports	Under design	**Surrey**
Cooling blocks	Under design	**Surrey**

Direct Reactions

A great tool to investigate Exotic Nuclei and Nucleosynthesis

Case of **transfer reactions**:



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

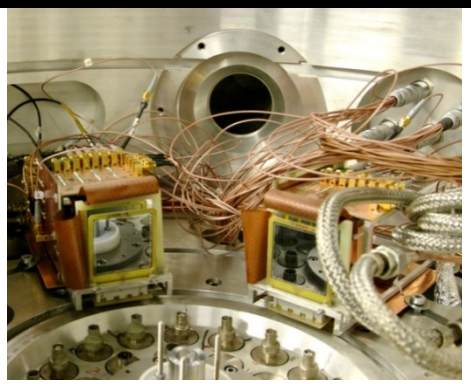
Methodology : **Radioactive Ion Beam ⟹ Light target (H,He…)**

Detect the recoil particle with high accuracy

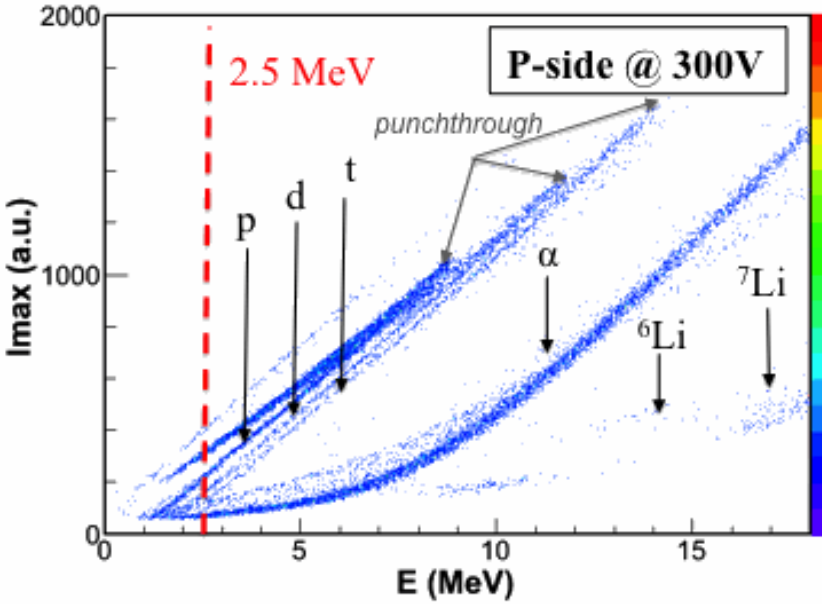
Silicon technology

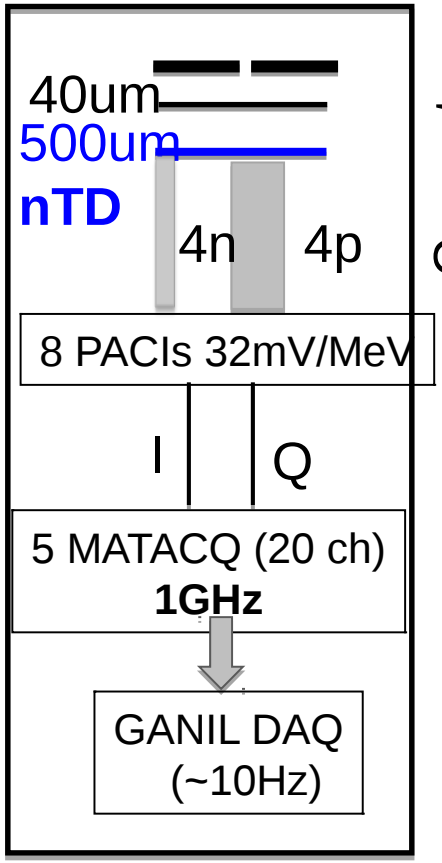
PSD for Z=1 particles

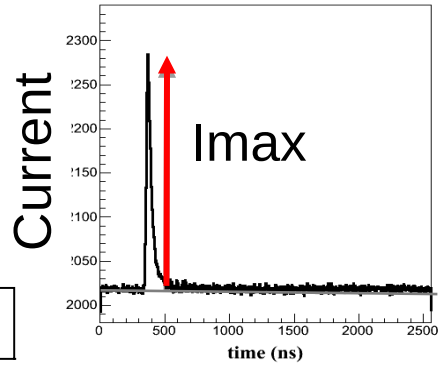
Test experiment
(IPNO tandem)
^{7}Li + ^{12}C @ 35 MeV

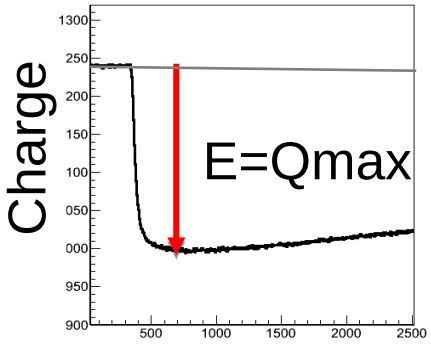


RESULTS

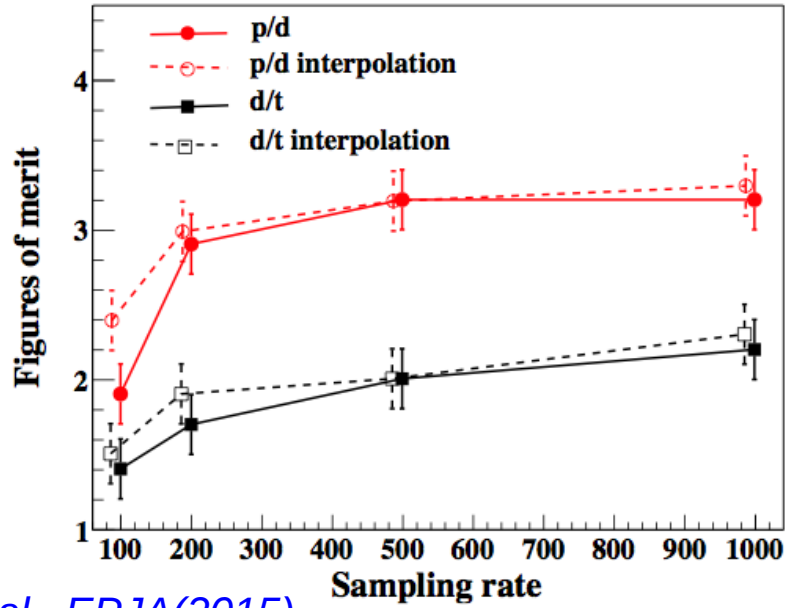






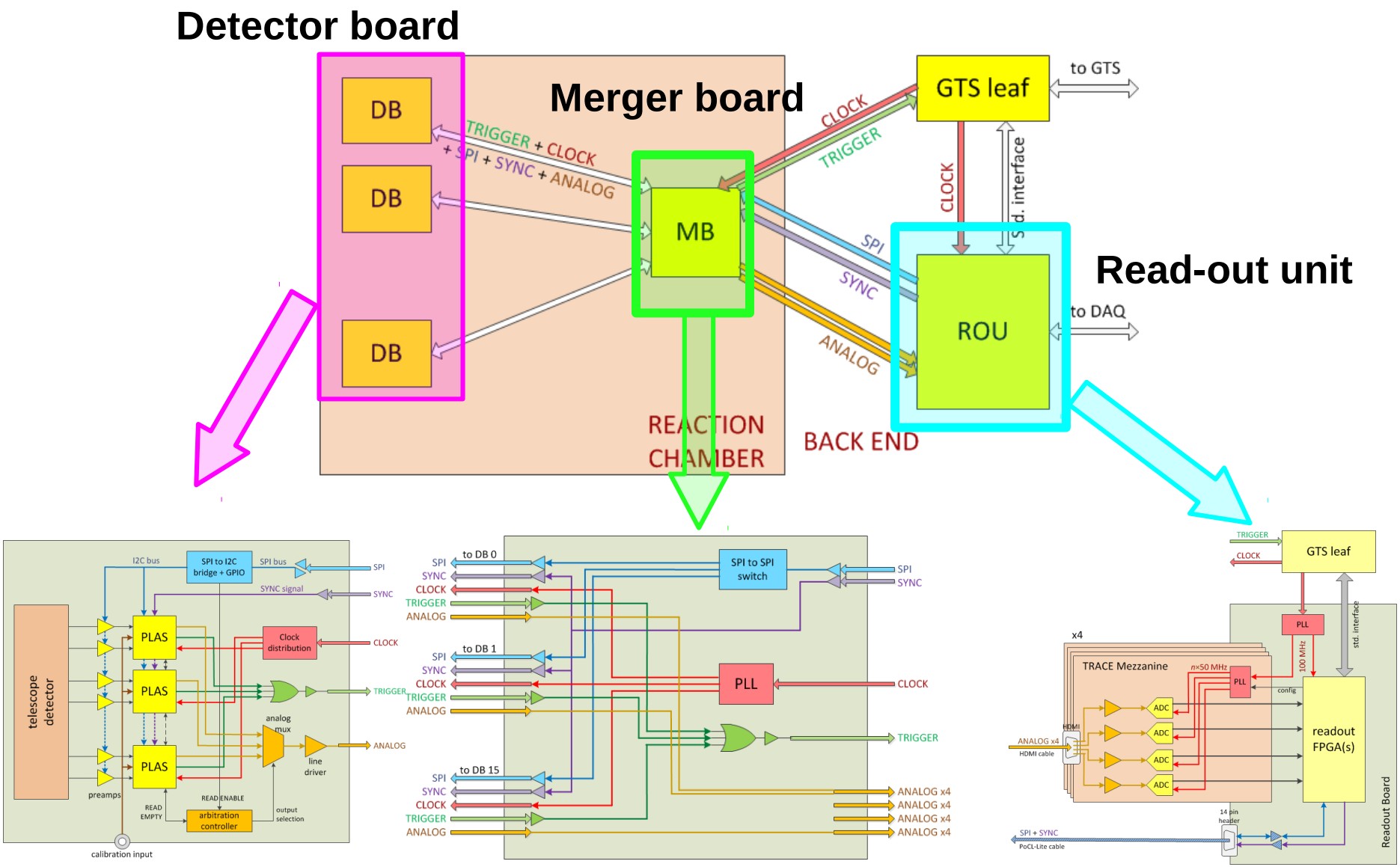


Time (ns)



M.Assié et al., EPJA(2015)

Electronics architecture



Physics with MUGAST

2 dedicated workshops organized at Orsay and Padova

- Shell structure evolution & deformation
  - Mapping of neutron orbitals around N=28 — *F.Flavigny, O.Sorlin et al.*
  - Oblate driving force in n-deficient nuclei above ^{56}Ni — *A.Goasduff, D.Mengoni, et al*.
  - Shape transition along and across N=28 — *L.Fortunato, D.Mengoni et al.*
  - Interplay of single-part and collective structures in ^{46}Ca — *S.Leoni et al.*
  - Shell evolution toward the island of inversion — *A.Matta, W.Catford, N.Orr, et al.*
  - Island of Inversion and shape coexistence in ^{30,31}Mg — *B.Fernandez-Dominguez et al.*
  - 75Kr: Shape coexistence in characterisation in light Kr — *A.Matta, W.Catford, N.Orr, et al*
- Neutron-proton pairing
  - np-pairing in fp-shell — *M. Assié et al.*
- Astrophysics
  - Breakout from hot CNO to rp process — *C.Diget et al.*
  - Explosive H-burning in Novae — *N.de Sereville, F.Hammache et al*.
  - s-process ^{79}Se(n,γ) — *G.de Angelis et al*.
  - s-process ^{60}Fe(n,γ) — *A.Matta, W.Catford, N.Orr, et al.*
- Reaction dynamics
  - Space-time characterization of emitting sources in HI collisions — *G. Verde, A.Chbihi, Q.Fable*

"Reaction and structure studies using the MUGAST+AGATA setup at VAMOS"

D.Beaumel & D. Mengoni

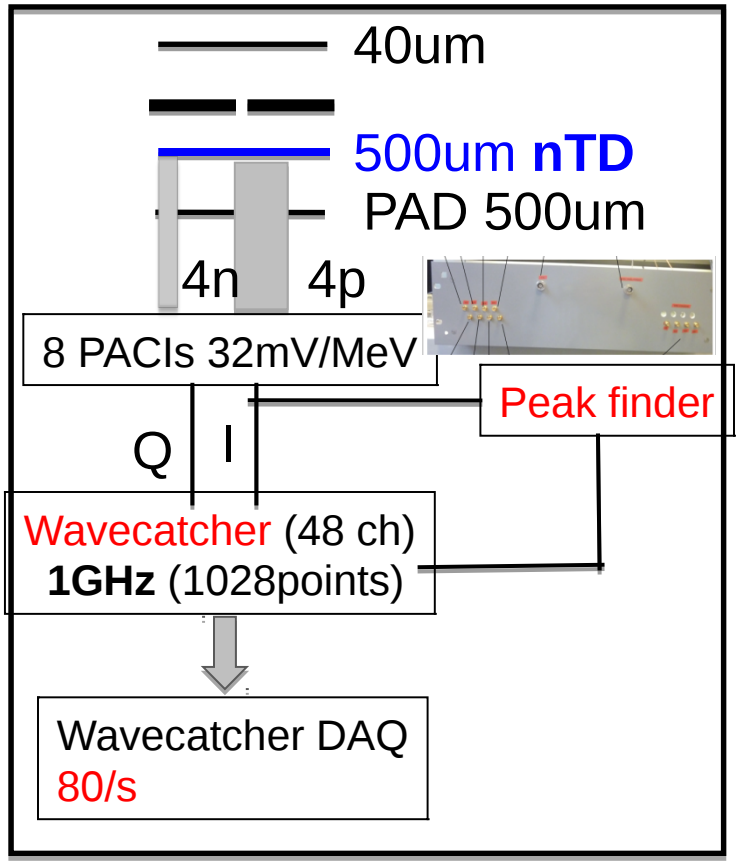
"Umbrella" LoI submitted to the coming GANIL PAC

PSD for Z=2 particles

(d,^{3}He) on mylar @ 26 MeV

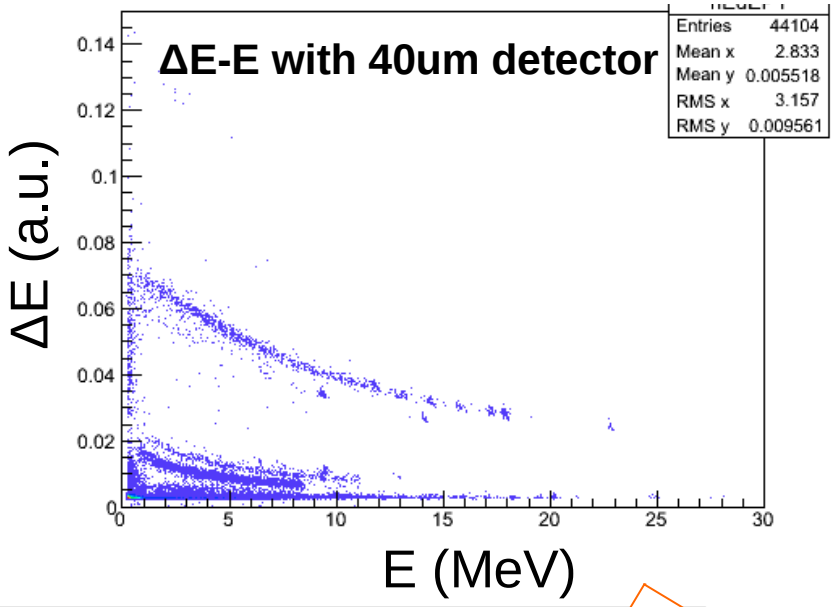
(IPNO tandem)

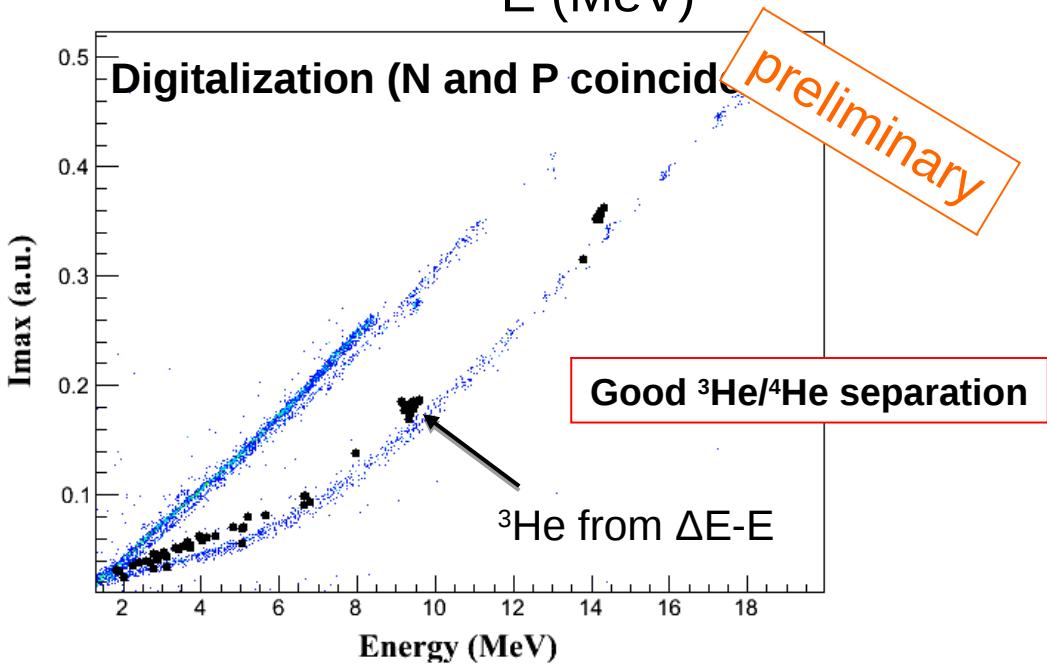
- ^{3}He/^{4}He discrimination
- test of analog peak finder on current



Under analysis

Add a ΔE detector for PID





Trapezoid detectors and test bench

Ordered to Micron semiconductors :

- **2 trapez**. prototypes nTD DSSSD ordered by IPN

(delivered end of june 2015)

- **3 more trapezoid « series » ordered**

(1 Surrey, 1 Santiago University, 1 IPN)

- **2 square** proto. nTD DSSSD **+ 1 thick sq. DSSSD**

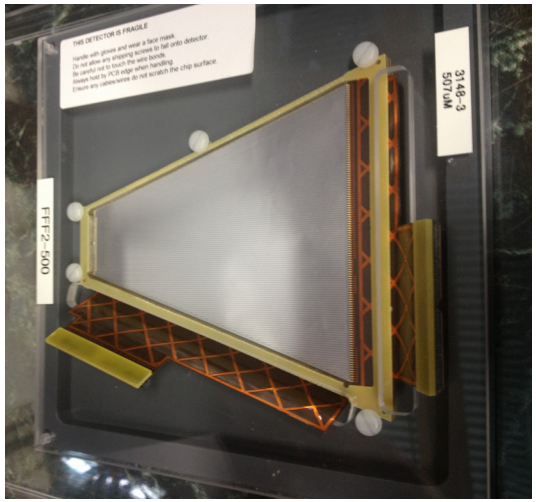
(ordered by INFN end of 2014, under fabrication)

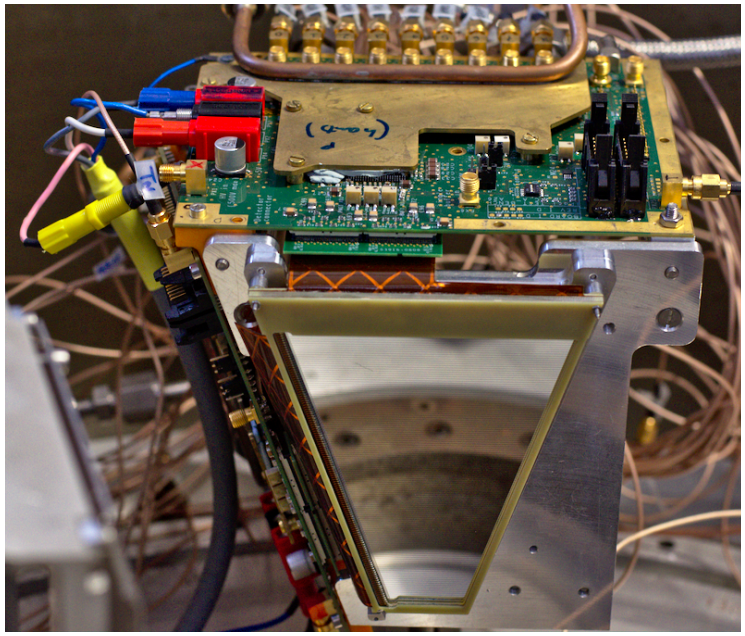
Test bench mounted @ Orsay :

- Digital test bench (GASPARD purposes)

- **Analog test bench** (256 channels) : Trapezoid + MUFEE + MUVI + GANIL acq.

Aim End of 2016 validation of prototypes

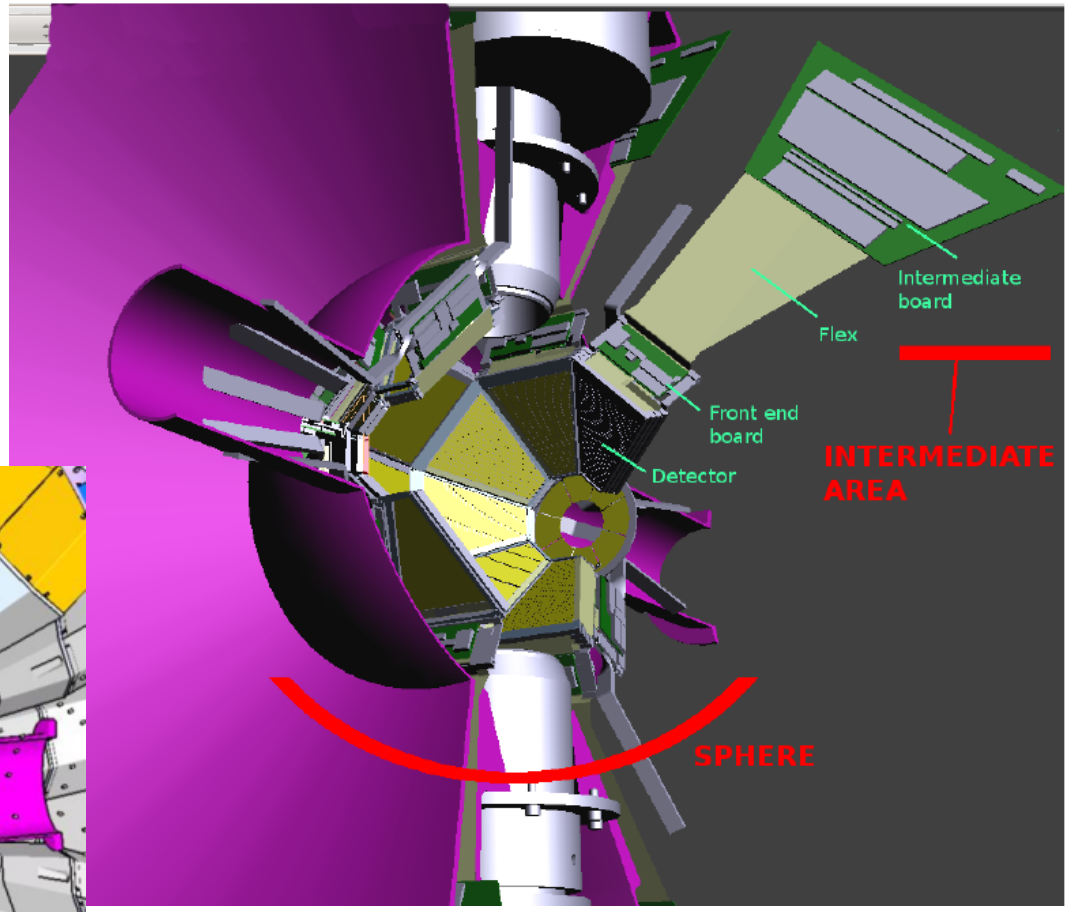


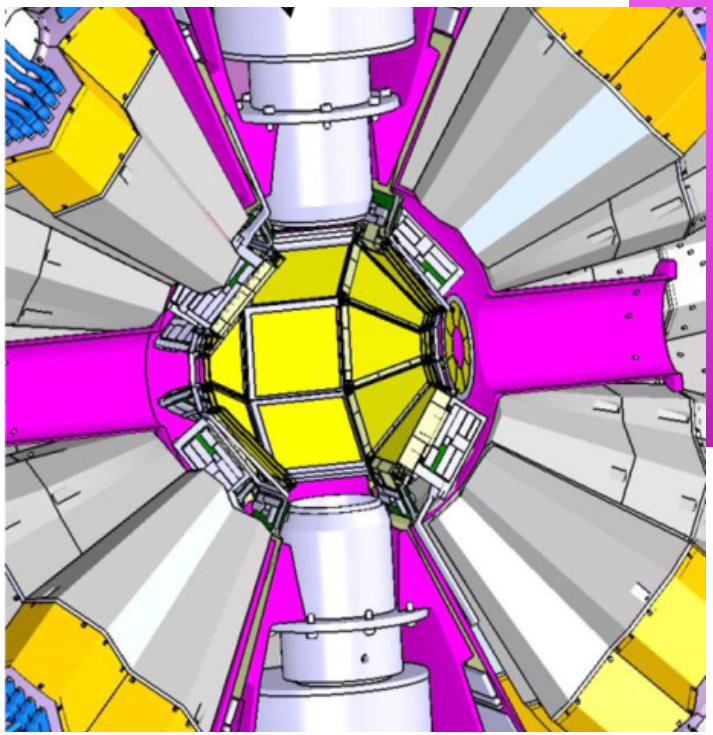


Electronics / Integration

Our challenge:

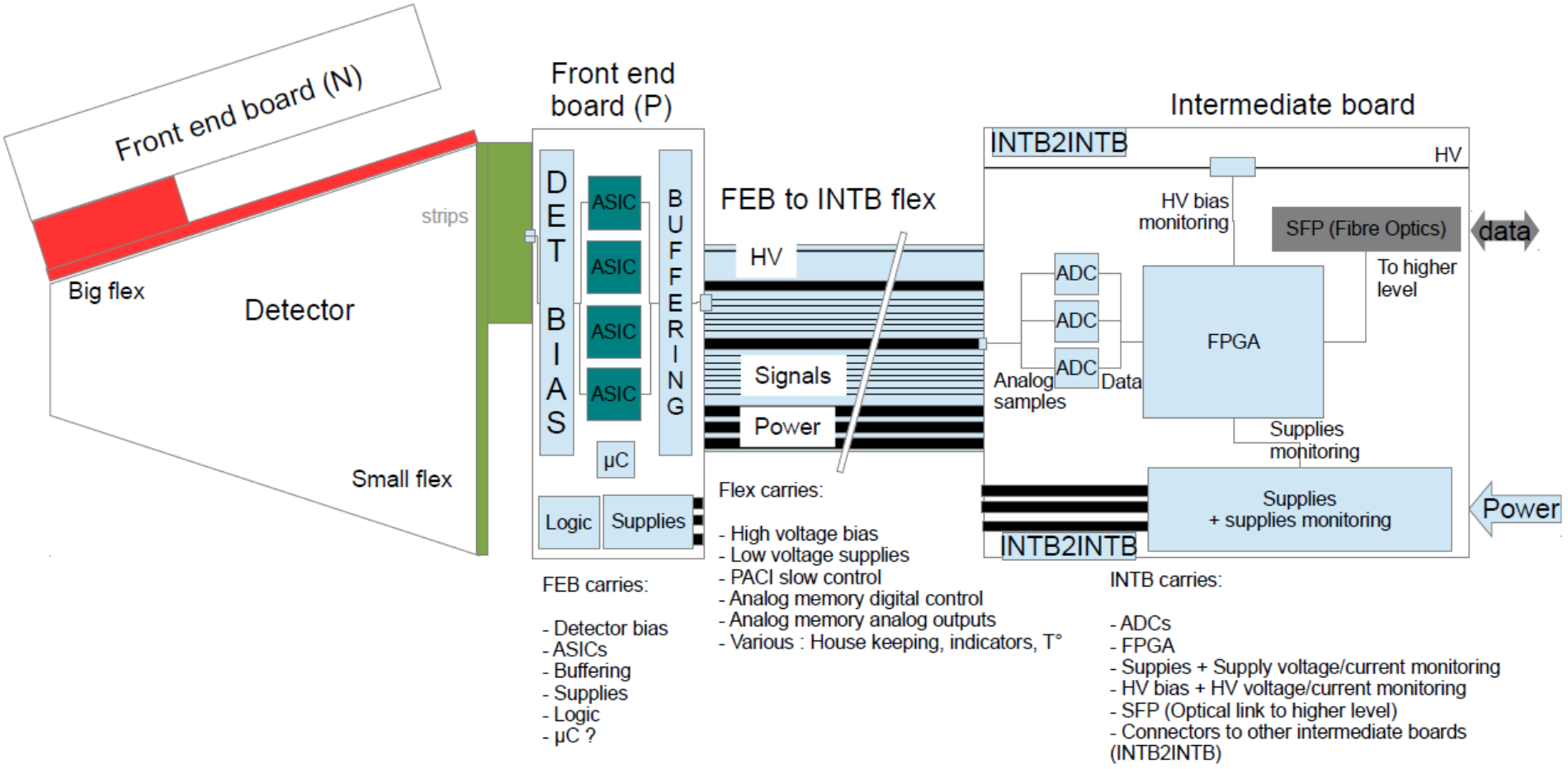
- ~ 10.000 channels
- Transparency to γ-rays





Detailed design under elaboration (IPNO)

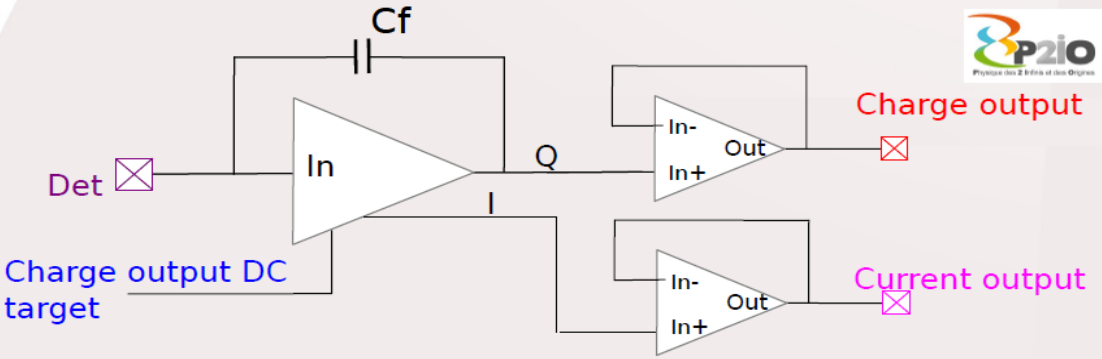
Electronics architecture



iPACI : 9 channel integrated *charge* and *current* output preamplifier

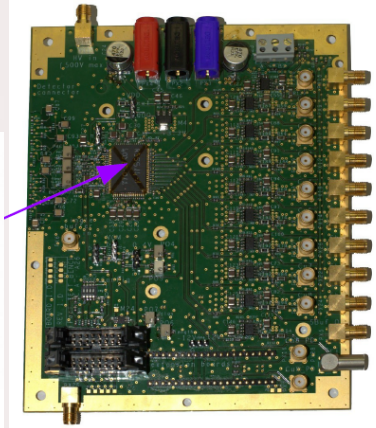
IPN INSTITUT DE PHYSIQUE NUCLÉAIRE ORSAY — SEP

1-Channel performance (simulated!)

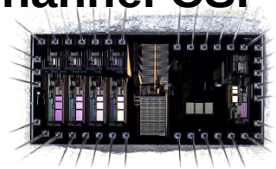


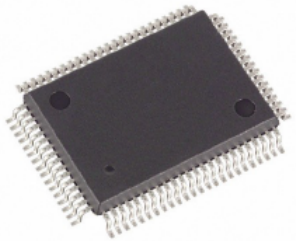
	Charge Output
Energy max (Si)	50 MeV
Charge signal swing (50MeV)	1.6V single ended
Charge gain	32mV/MeV
Equivalent noise charge (Input-refered, FWHM)	7 keV 830 e- Si
Charge resolution	12.8 bits ENOB
Charge non-linearity	< 2%
Charge output recovery time	100µs
	Current Output
Current gain	7kΩ
Current signal swing	1.5V single ended
Current signal BW	[4MHz .. 120MHz]

	System data
Technology	AMS 0.35µm BICMOS
Supply	3.3V
Detector's input capacitance	Compatible with [10pF .. 40pF] range
Compensation cap	Digitally tunneable within [0.5pF .. 2.25pF], step 0.25pF
Current consumption	12mA (40mW) / Channel
Size	220 x 100µm (PACI block) + 130 x 70µm (Buffer ch) + 130 x 70µm (Buffer cu)



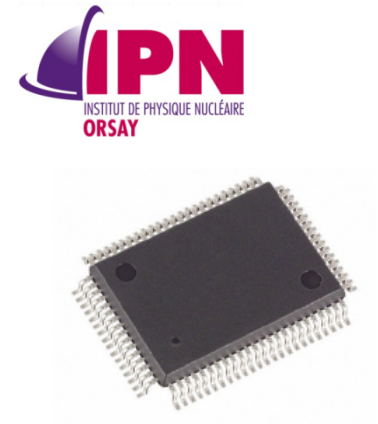
Other development: **multichannel CSP ASIC**
A.Pullia, S.Capra
INFN / Univ. Milano

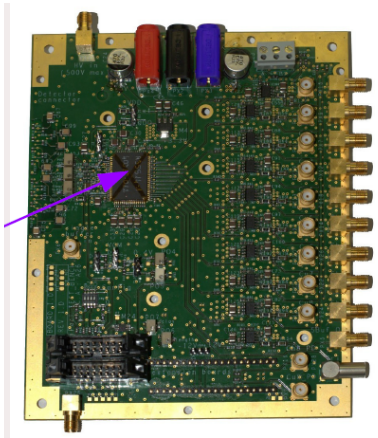




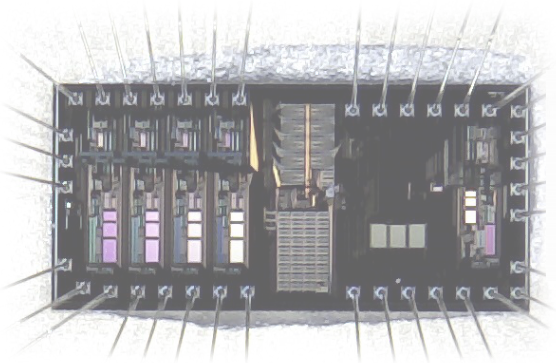
Preamplifier ASIC

- Current and charge output
- Presently 9 ch

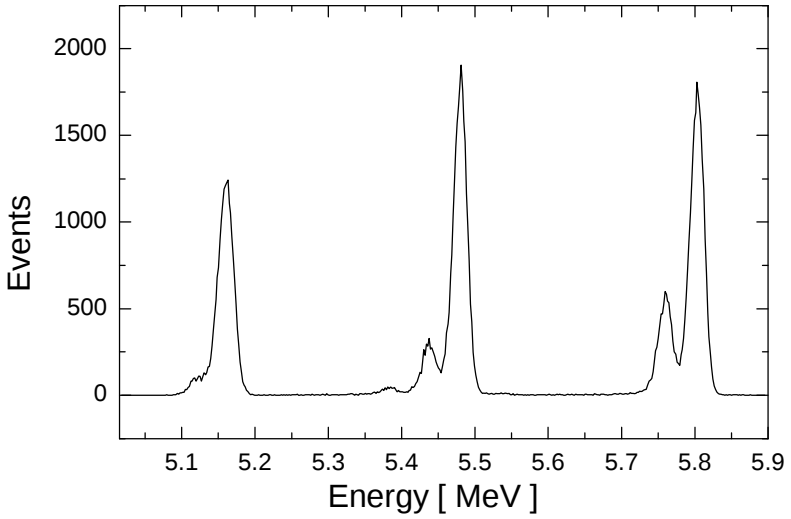




- Charge output and extend dynamics
- Presently 4 ch



Milano



ITEM	STATUS	who
DETECTORS		
Trapezoids proto (x2)	Commissioning	**IPNO**
Trapezoids pre-serie (x3)	Ordered	**Surrey + IPNO + Santiago**
Squared proto (x2) + Thick proto	Ordered	**INFN Padova**
Annular (x1) th = 500um	Available	**--**
MUST2 (x4)	Available	**--**
ELECTRONICS		
MUST2 FEE boards (x10)	Available	**--**
(MUST2 FEE new boards (x5) boards+components+ASICs)	To be ordered	
MUST2 Digital boards (x4)	Available	**--**
Kaptons (x48)	To be designed and ordered	
Cables & feedthroughs	To be ordered	
MECHANICS		
Chamber and supports	Under design	**Surrey**
Cooling blocks	Under design	**Surrey**

R&D on pulse shape analysis

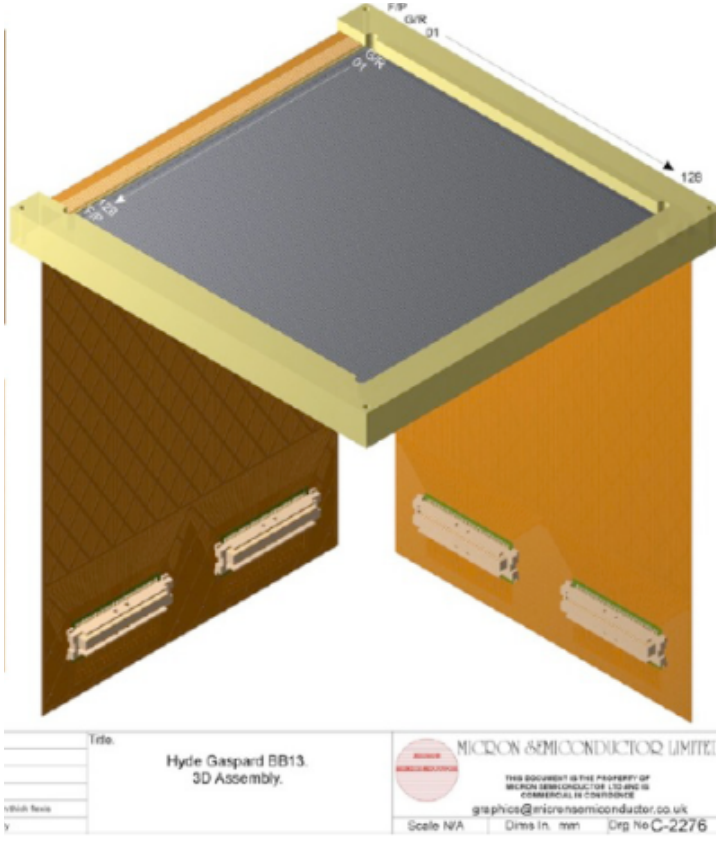
Goal: establish the method for light particles and highly segmented detectors

- **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
- ….

test experiments
at the IPNO tandem

Detector:

- 500 um nTD DSSD
  BB13 design of MSL
- 8° cut
- 128X+128Y
- pitch<500um
- special package
  90° kapton readout
  high density
  connectors



The CHyMENE H/D target system

Cible d'HYdrogène Mince pour l'Etude des Noyaux Exotiques

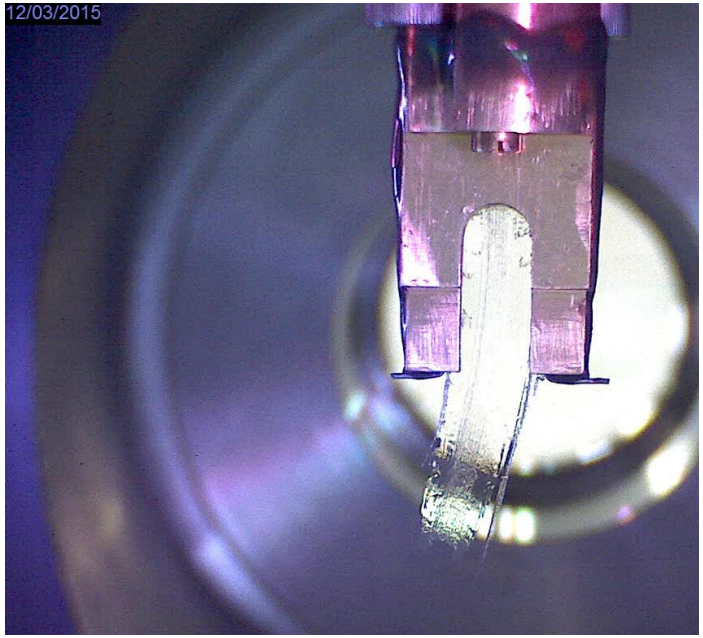
System providing continuous extrusion of ^{1}H or ^{2}H through a rectang nozzle defining the target-film thickness

- **Hydrogen target in a solid phase near triple point sH_2 ~ 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. Gi
- IPN Orsay
- CEA/DAM Bruyères

Grant from French ANR ~550k€



Tests undergoing using alpha source

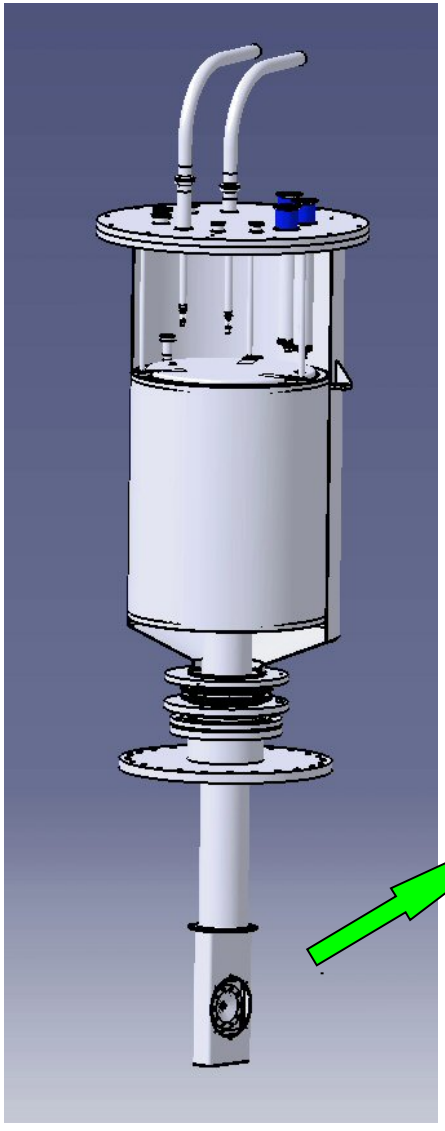
IRFU-IPNO-DAM

Cooled Helium gas target

IPNO/ Accelerator division

Designed for the use of direct reactions with ^{3,4}He probe in Inverse kinematics

Concept : cooled gas cell at 5~8 K to maximize density



Possible reactions: (α,^{3}He), (α,t), (α,^{6}He),…

Previously used
at SPEG / GANIL

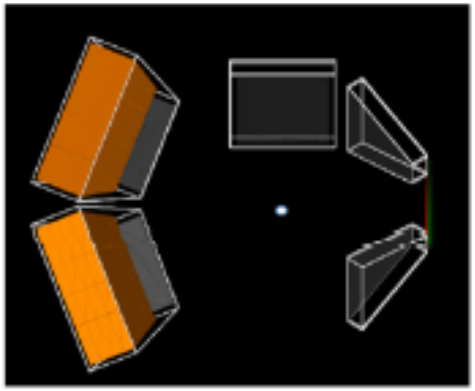
Ø 16 mm, 3mm thick
Havar windows, 3.8 microns
T = 8.5 K
P = 1 bar

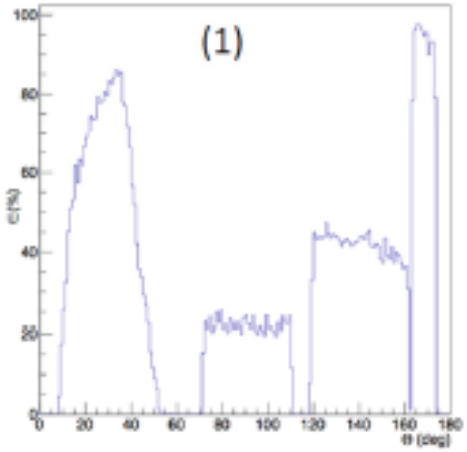
Now under study : **^{3}He version**
(^{3}He,d) proton stripping
(^{3}He,p) d transfer for np pairing

Simulations / Detection efficiency

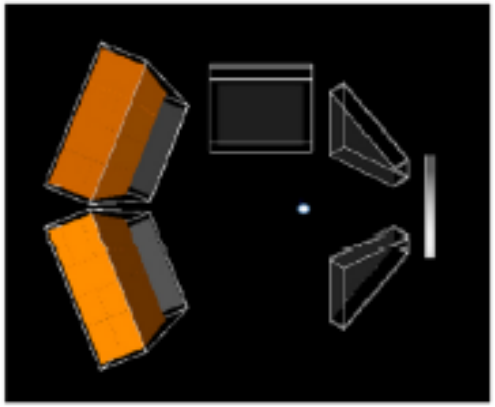
Using NPTool package

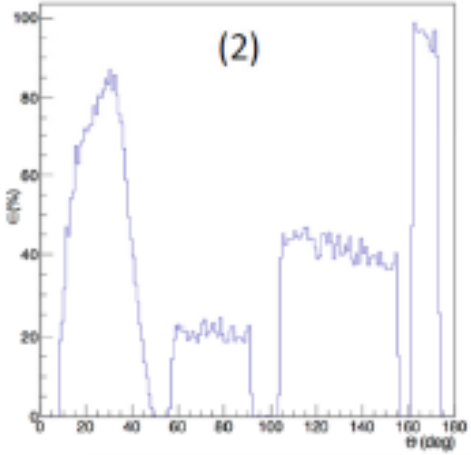
Config Initiale





Translation Trapézes +carrés vers M2 (~4cm)
+ update géométrie carrés





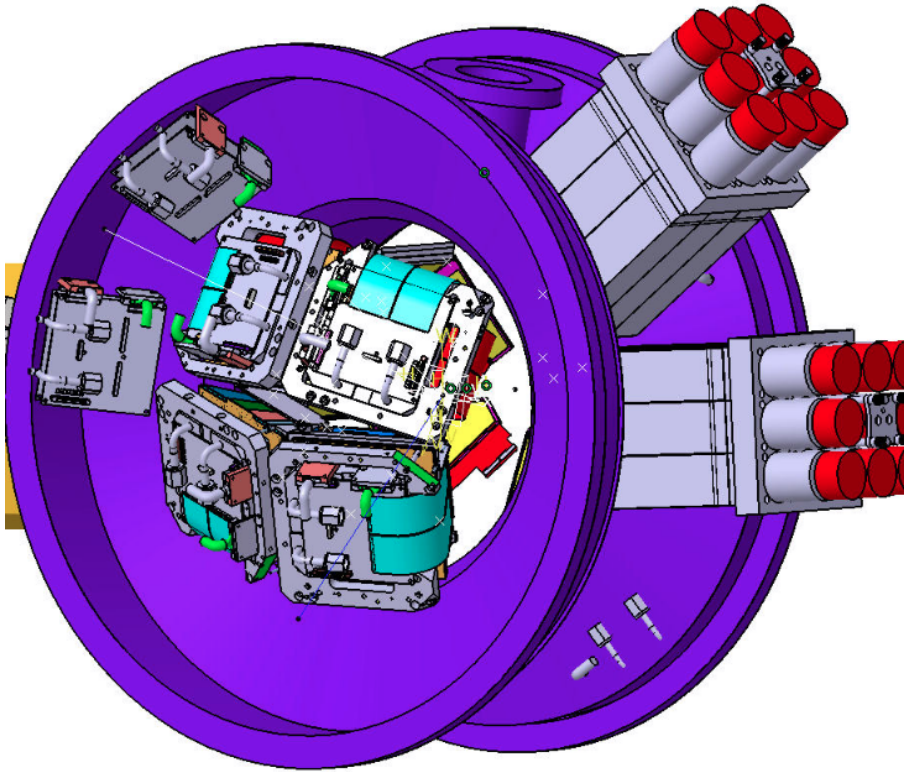
Last geometrical configuration available on demand

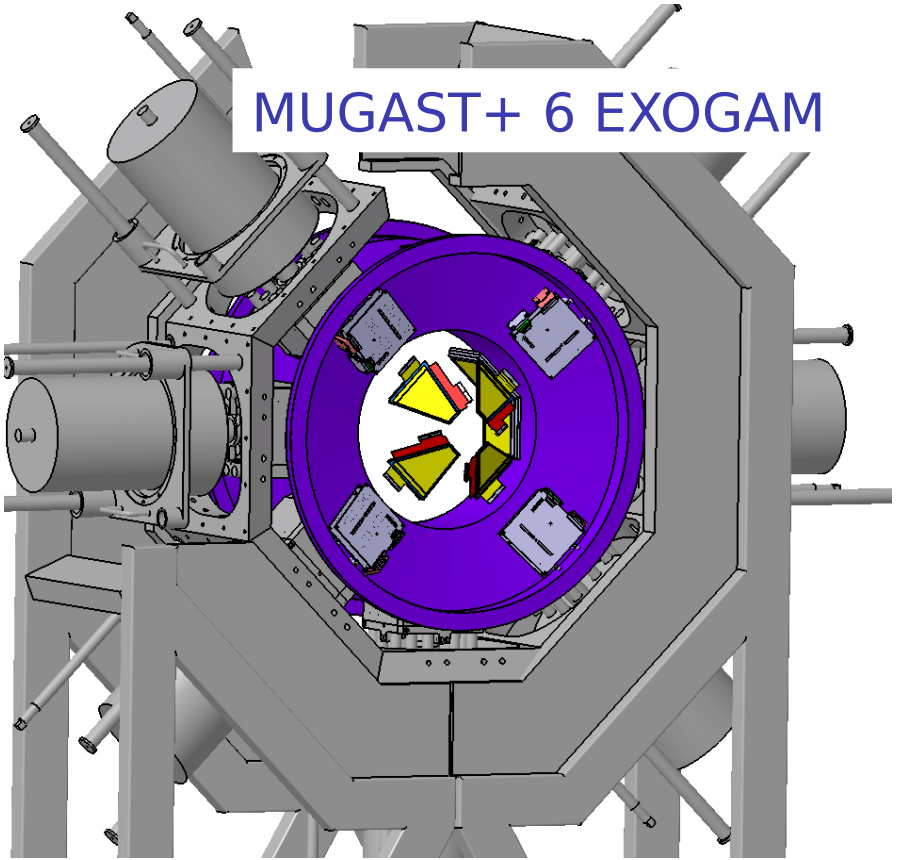
MUGAST with EXOGAM & PARIS

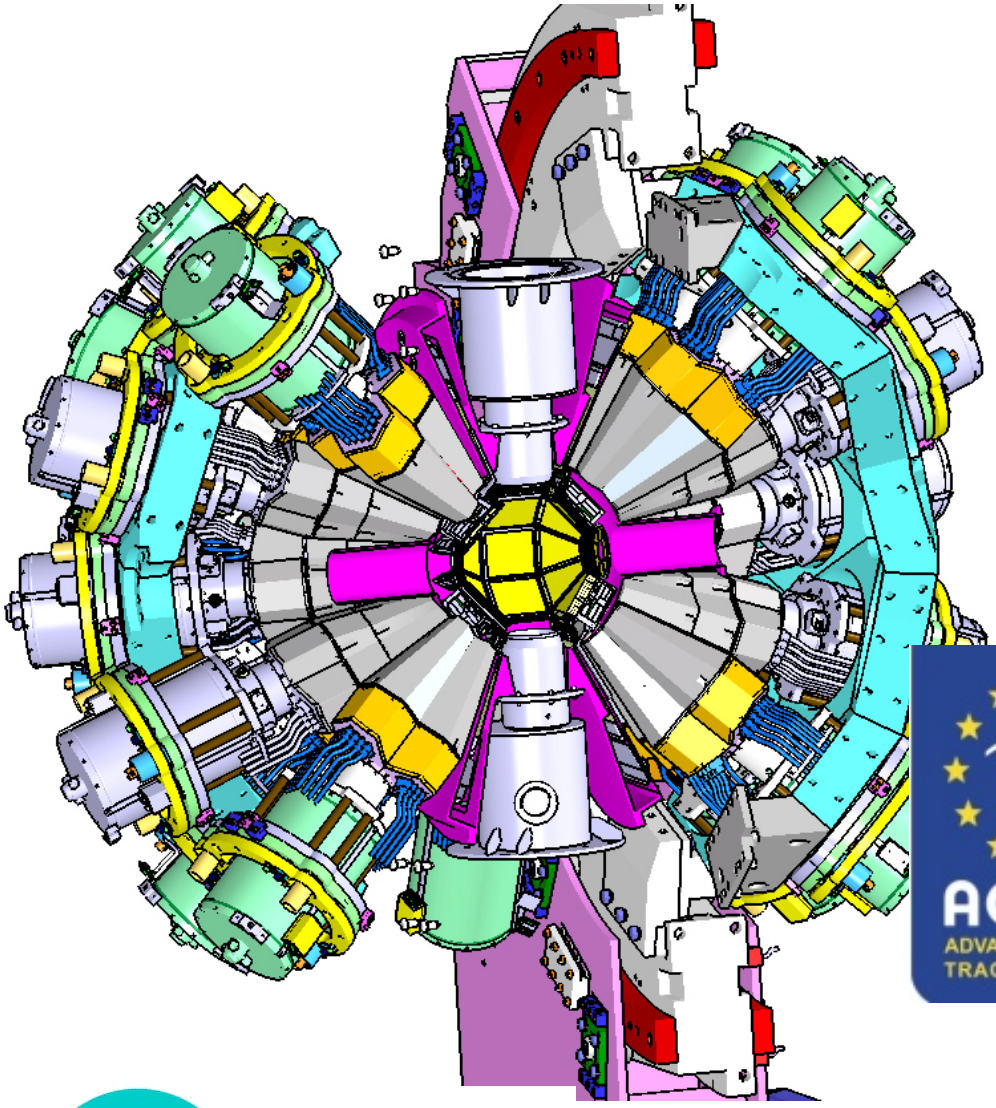
« MUGAST » configuration = MUST2 + GASPARD (trapeze) +TRACE (square)
available for AGATA campaign at GANIL **(2017)**
read by **MUST2 electronics (MUFEE+MUVI)**

Possible gamma detector's configurations :

- **6 PARIS clusters (if available)**
- **6 EXOGAM**







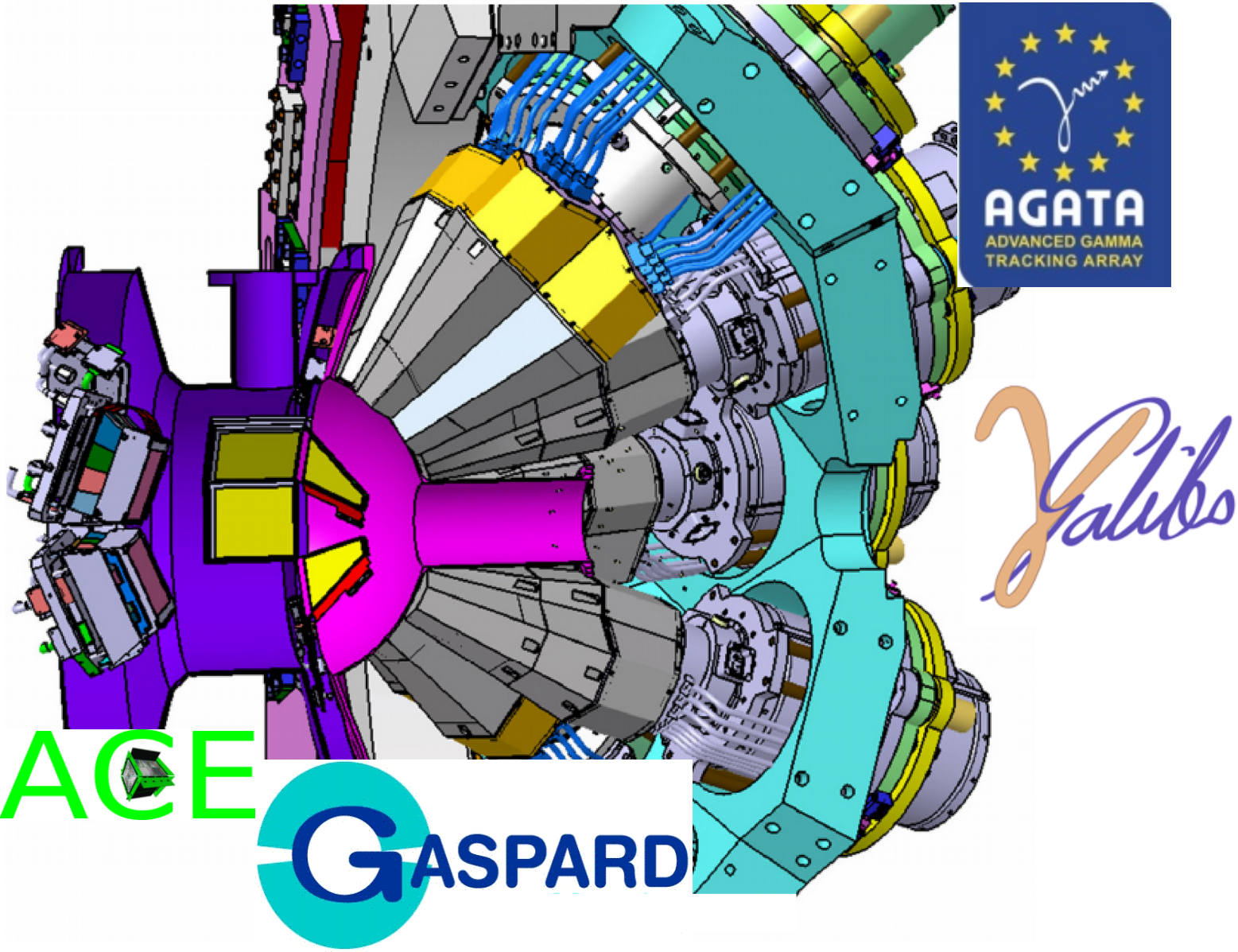
cea Irfu

CHyMENE S.A.C.M.I.S.S.P.H.N.

AGATA
ADVANCED GAMMA
TRACKING ARRAY

GASPARD

TRACE


AGATA
ADVANCED GAMMA
TRACKING ARRAY
Jalibs
TRACE
GASPARD