

# Development of new Silicon array for high resolution reaction studies



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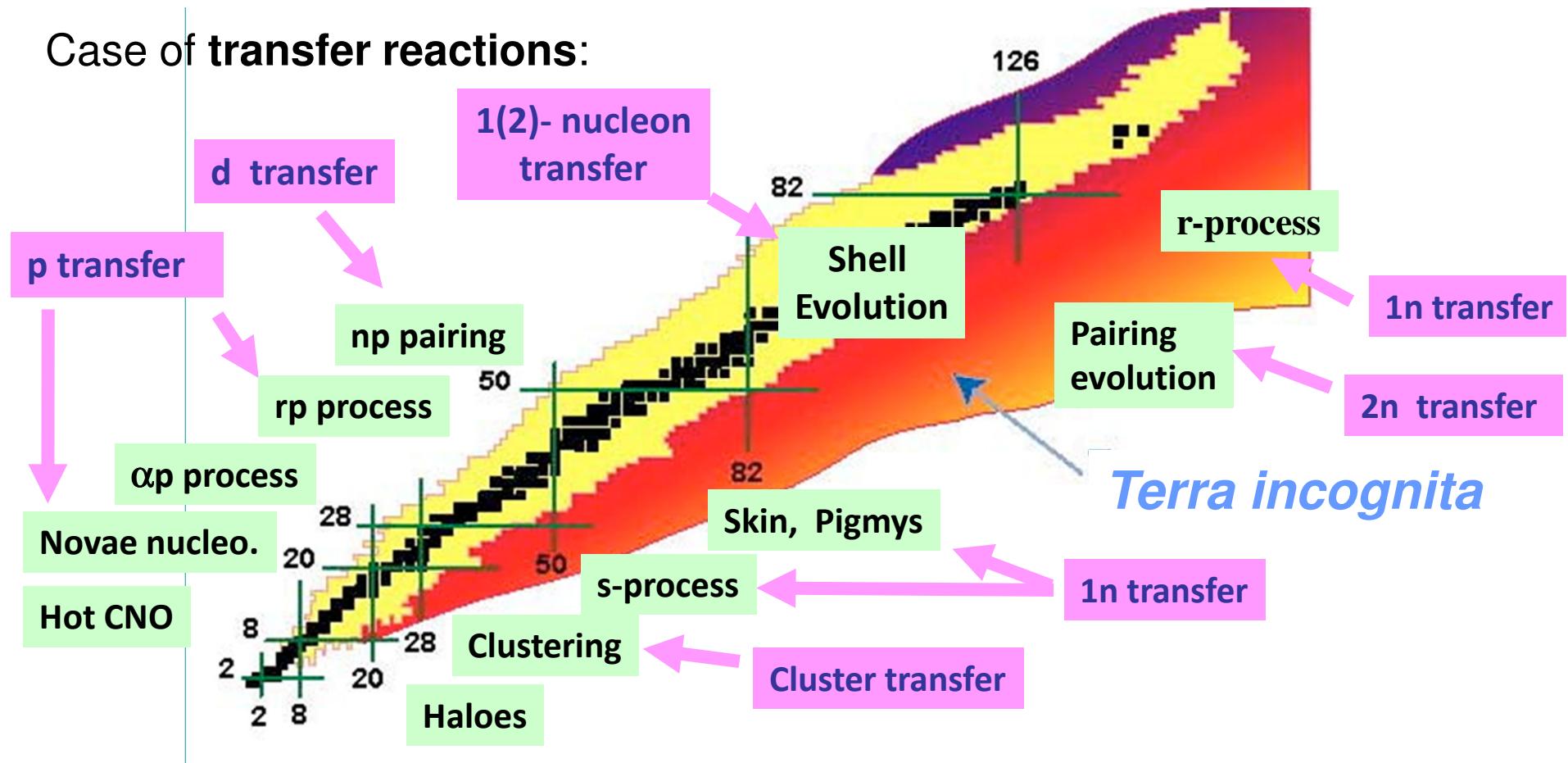


D.Beaumel,  
IPN Orsay

# Direct reactions

A great tool to investigate Exotic Nuclei and Nucleosynthesis

Case of transfer reactions:



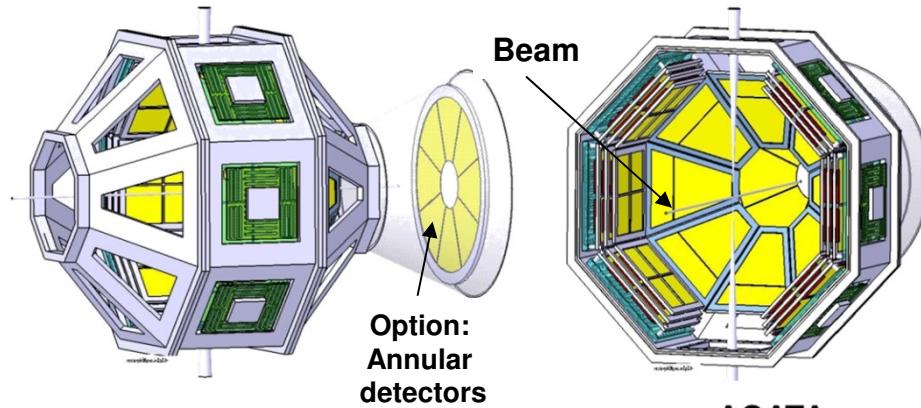
Good energy regime : few MeV/u → few tenths of MeV/u

Methodology : Radioactive Ion Beam  $\longrightarrow$  Light target (H,He...)  
 Detect the recoil particle with high accuracy  
**Silicon technology**

# *A new Si array for reaction studies*

**4 $\pi$ , fully integrable in PARIS and AGATA**

## “GASPARD-TRACE” design



## Layers of Silicon

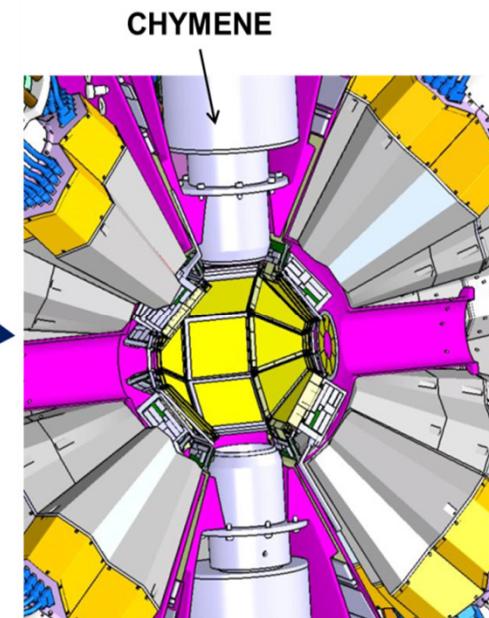
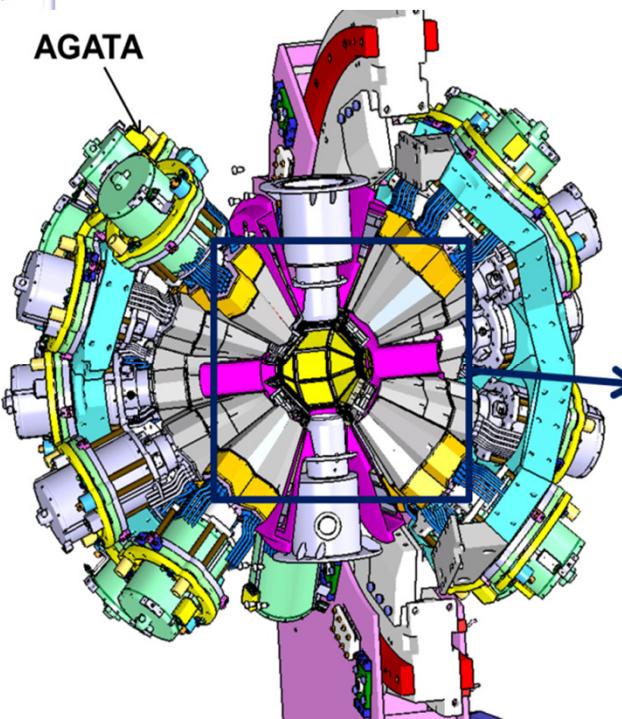
- 500 $\mu\text{m}$  DSSD pitch < 1mm
  - 1(or 2) x [1.5 mm DSSD pitch~3mm]
- 2 main shapes : square & trapezoid, large area**

## Electronics :

- ~ 10000 channels (Digital)
- high transparency to  $\gamma$ -rays
- Big integration challenge

## Other features:

- State of the art for PID  
Pulse Shape Discrimination
- Special targets ( $H, D, ^3, ^4\text{He}$ )
- Portable device



## Collaboration

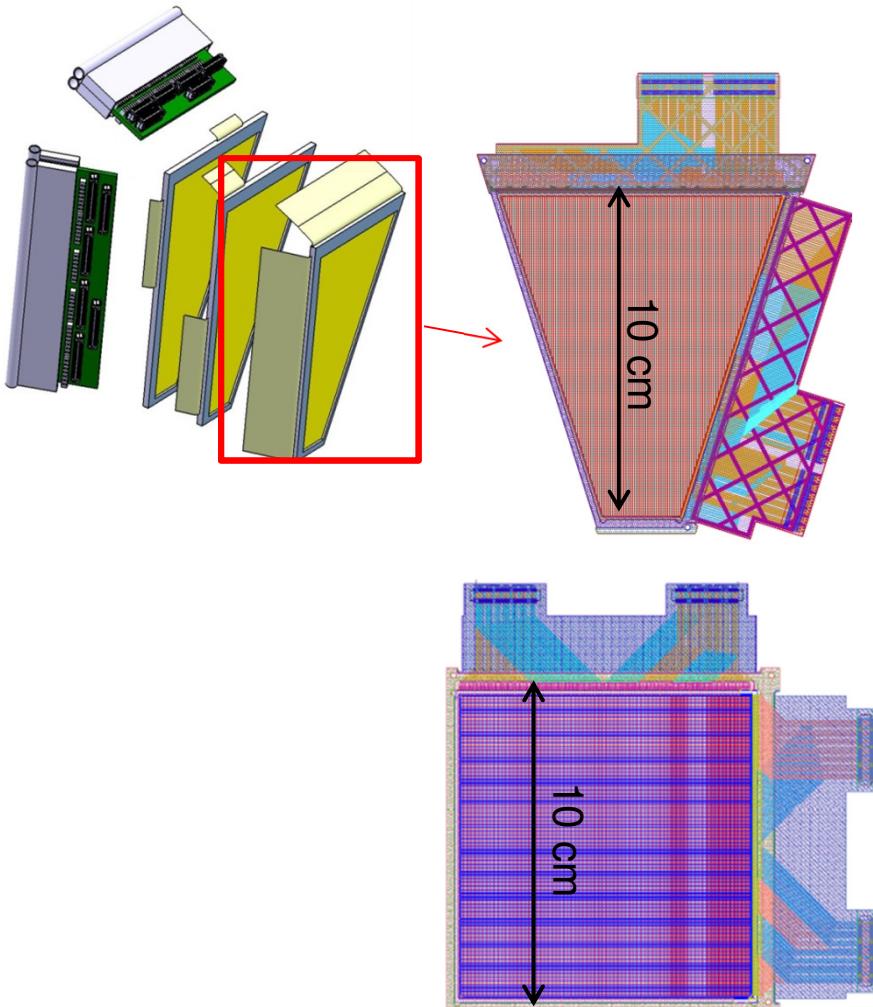
- IPN Orsay , CEA Saclay, GANIL, LPC Caen (France)
- INFN Univ. of Padova, INFN-LNL Legnaro , INFN Univ. of Milano (Italy).
- Univ. of Huelva, Univ. of Santiago de Compostella, Univ. of Valencia (Spain)
- Univ. of Surrey, STFC Daresbury (UK)
- BARC, Mumbai (India).



*Collaboration agreement under elaboration*

# *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

1<sup>st</sup> 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]

2<sup>nd</sup> layer (1.5mm, pitch~3mm)

**2<sup>nd</sup> layer square**

1 prototype ordered [INFN-Padova]  
(MICRON SC)

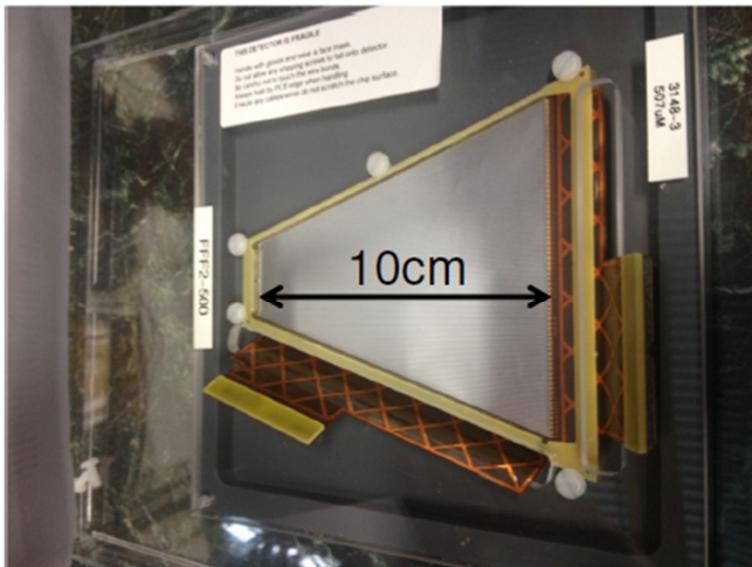
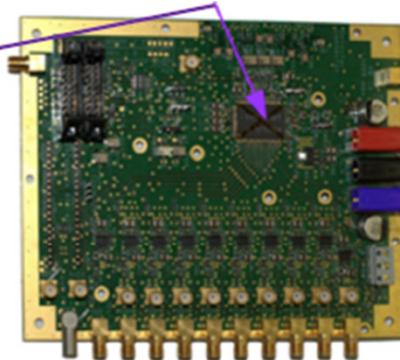
Collaboration with BARC Mumbai foreseen

# *Commissioning of trapezoid DSSD's*

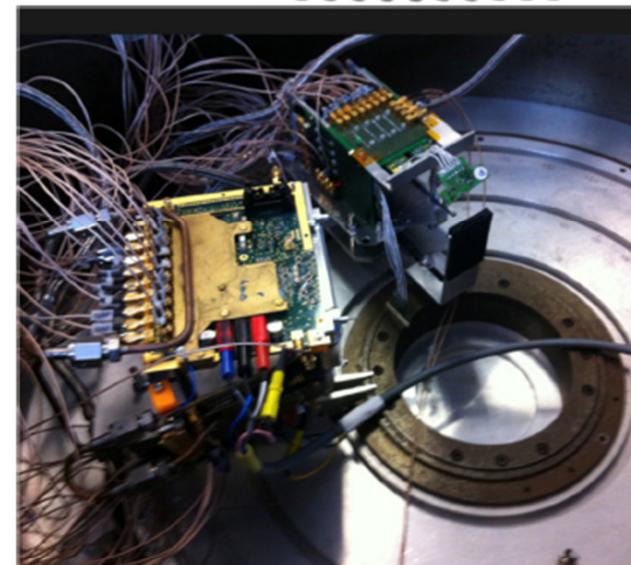
## **Test bench at IPNO**

### **>> 2 numerical test bench : PACI & iPACI**

- PACI : 4X+4Y voies
- iPACI : 9X+9Y voies (short and long strips)



Kaptons will be modified



### **>> Analogic test bench (MUST2 electronics & GANIL DAQ) now being implemented**

#### **256 channels**

- test of new detectors (prototypes)
- test of new MUFEE boards for MUGAST

# R&D on Pulse Shape Discrimination with DSSD

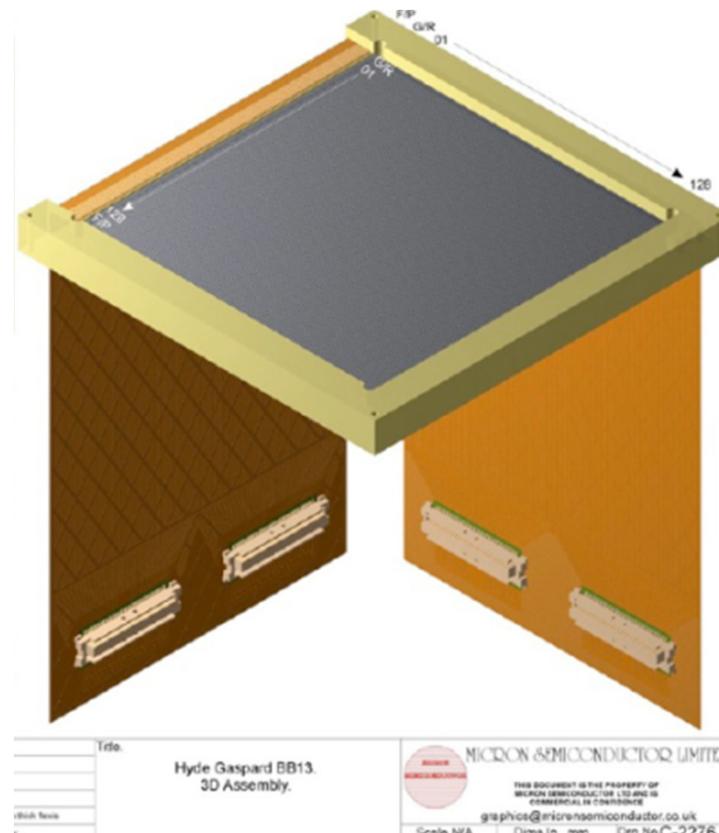
**Goal: establish the method for light particles and highly segmented detectors**

- 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

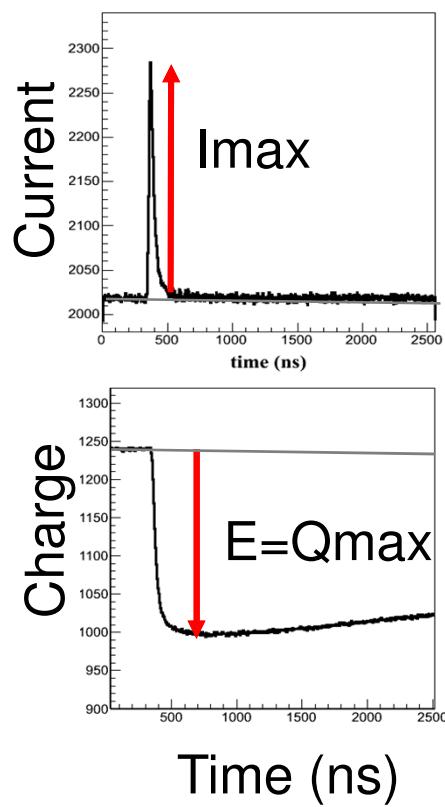
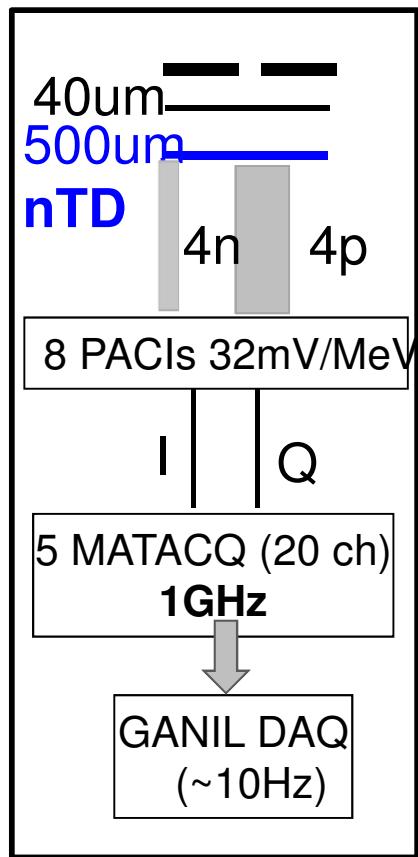
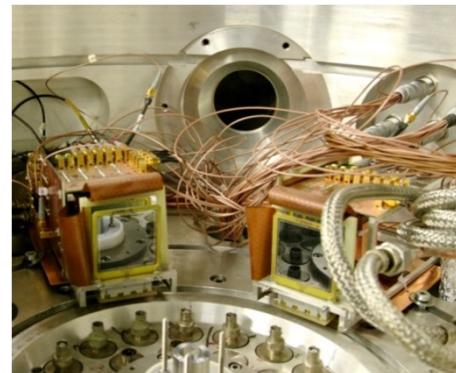
Detector:

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

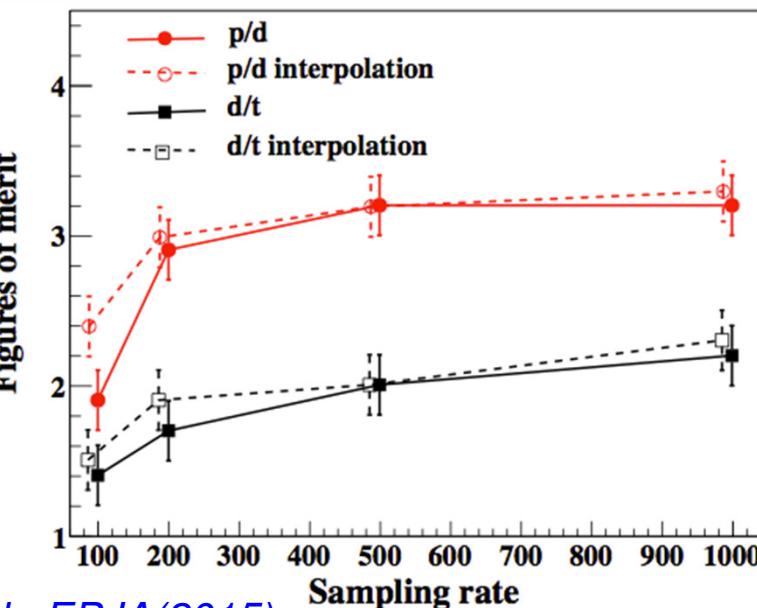
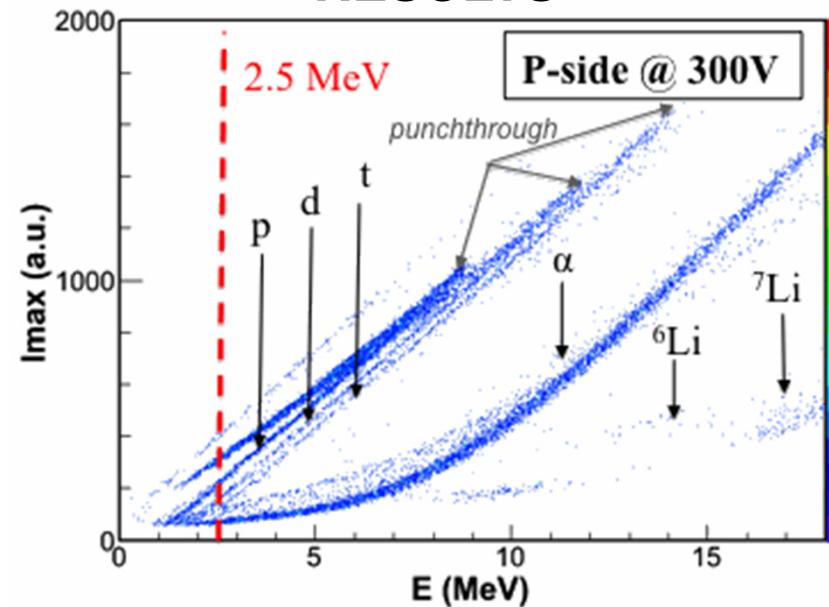


# PSD for Z=1 particles

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



## RESULTS

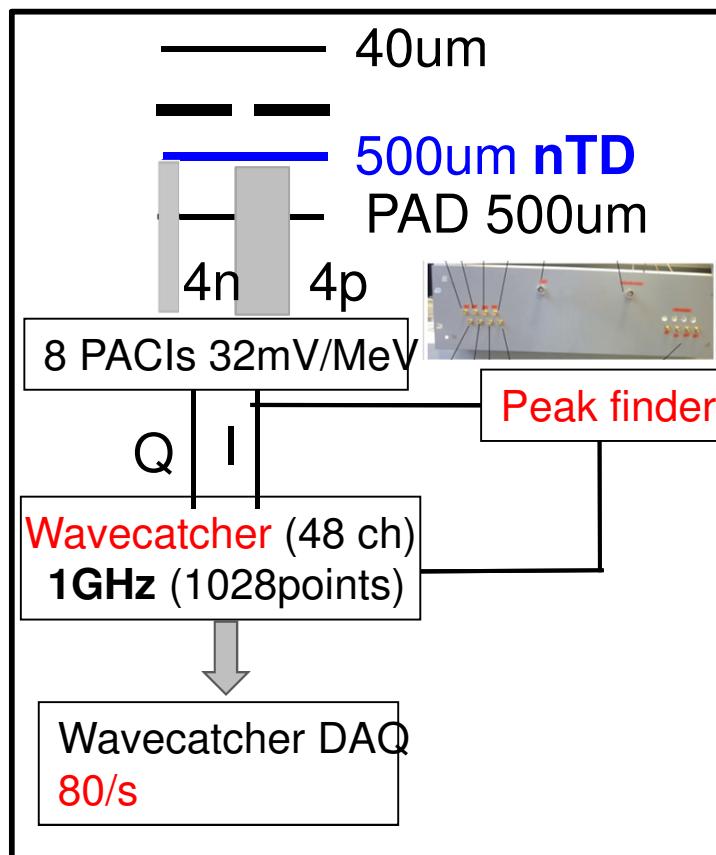


# PSD for Z=2 particles

**Reaction :**  
**(d,<sup>3</sup>He) on mylar**  
**@ 26 MeV**

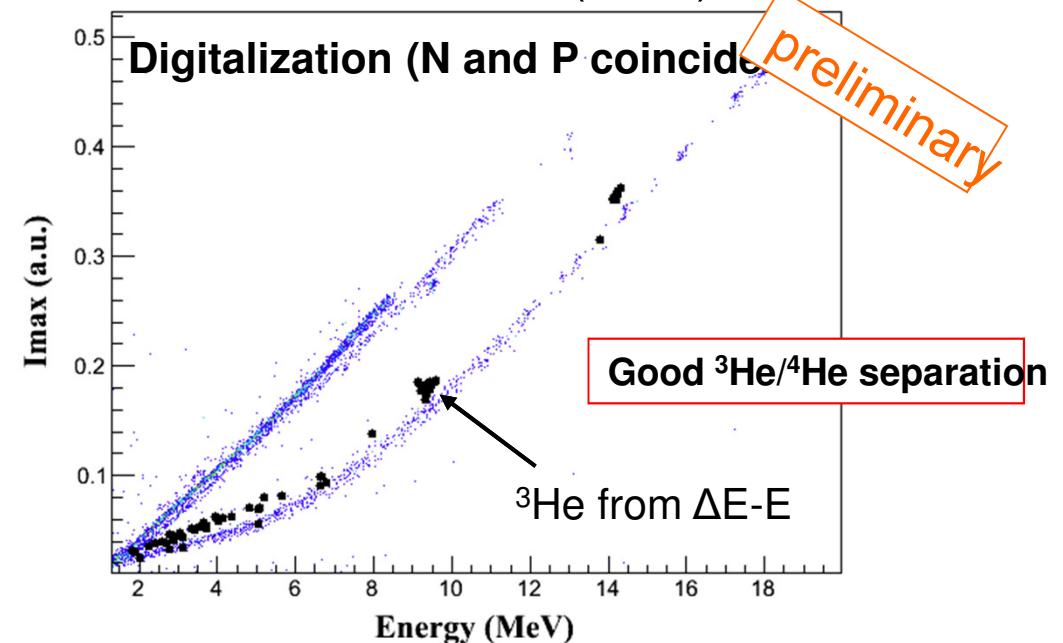
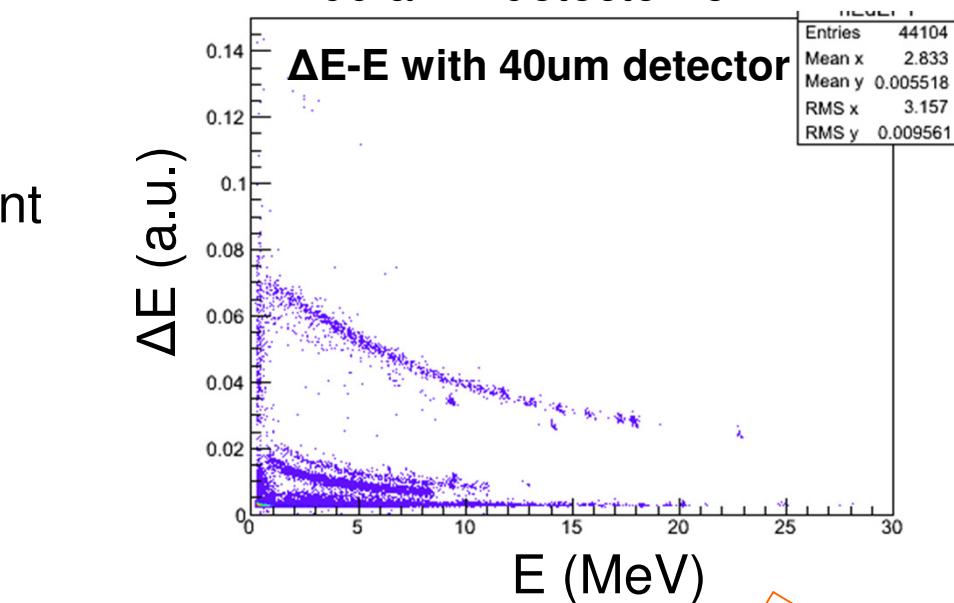
(IPNO tandem)

- <sup>3</sup>He/<sup>4</sup>He discrimination
- test of analog peak finder on current

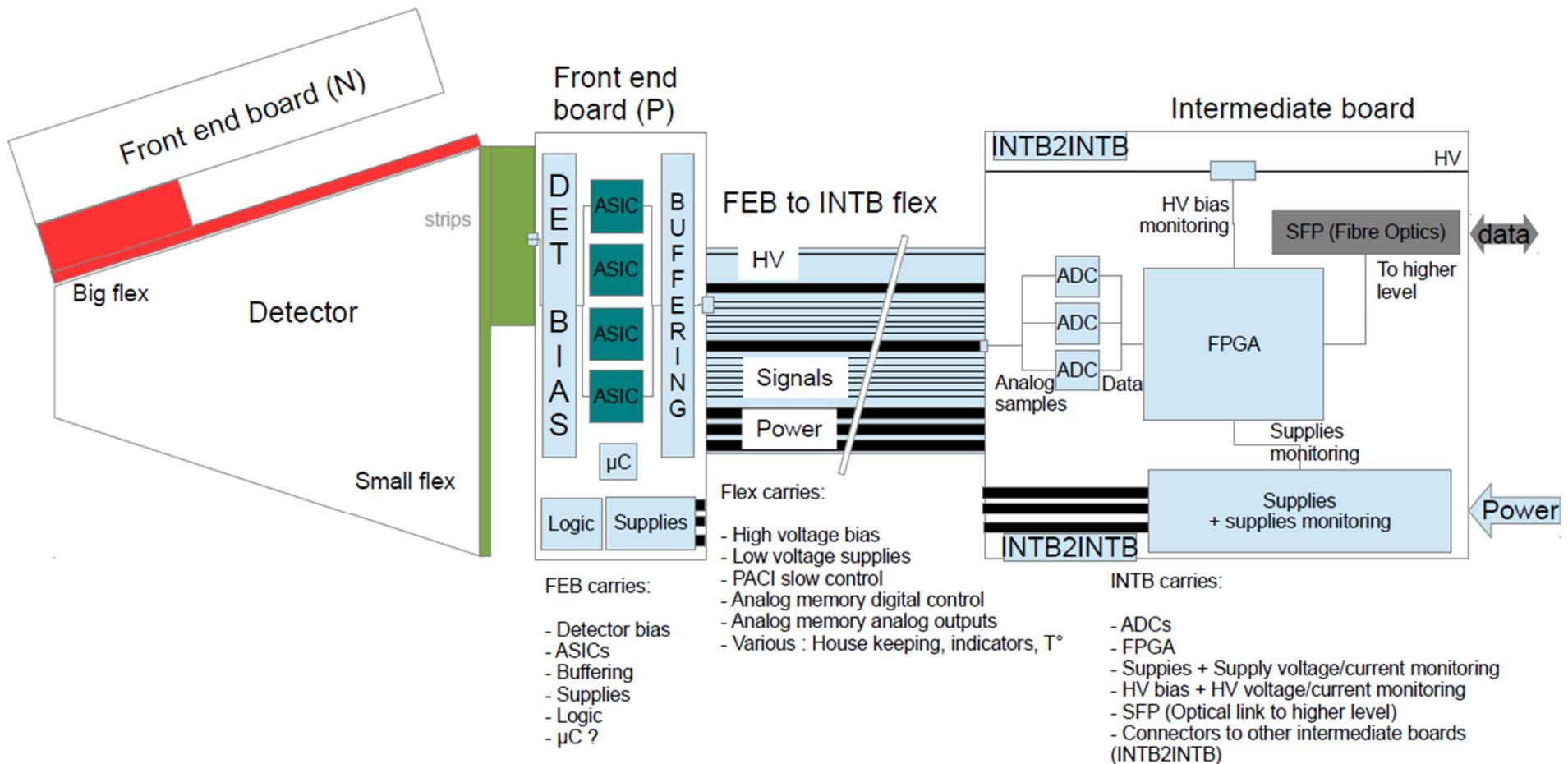


*Under analysis*

Add a  $\Delta E$  detector for PID



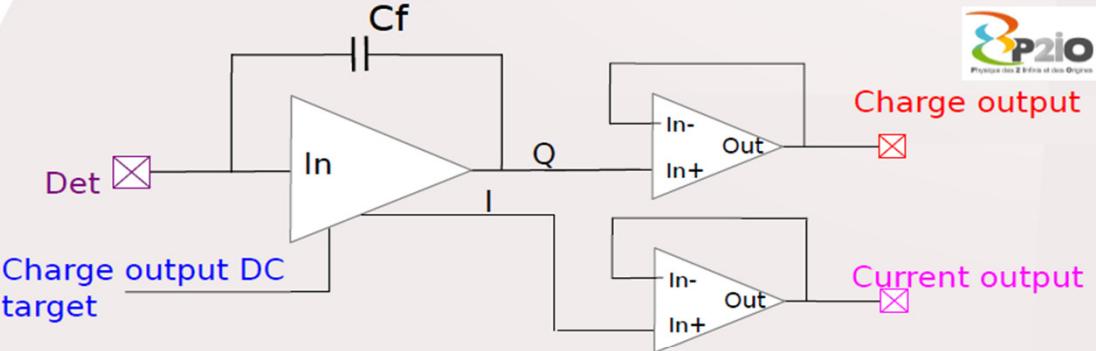
# Electronics architecture (preliminary)



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



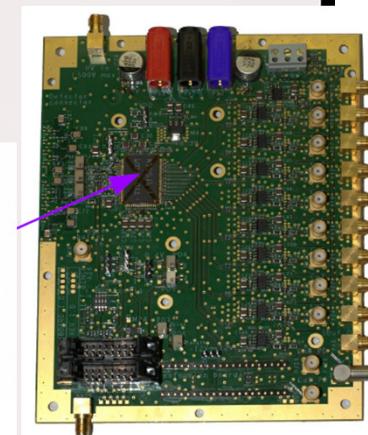
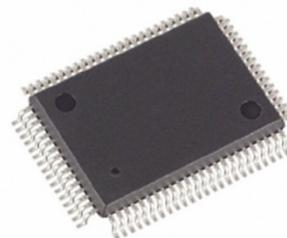
**1-Channel performance (simulated!)**



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)

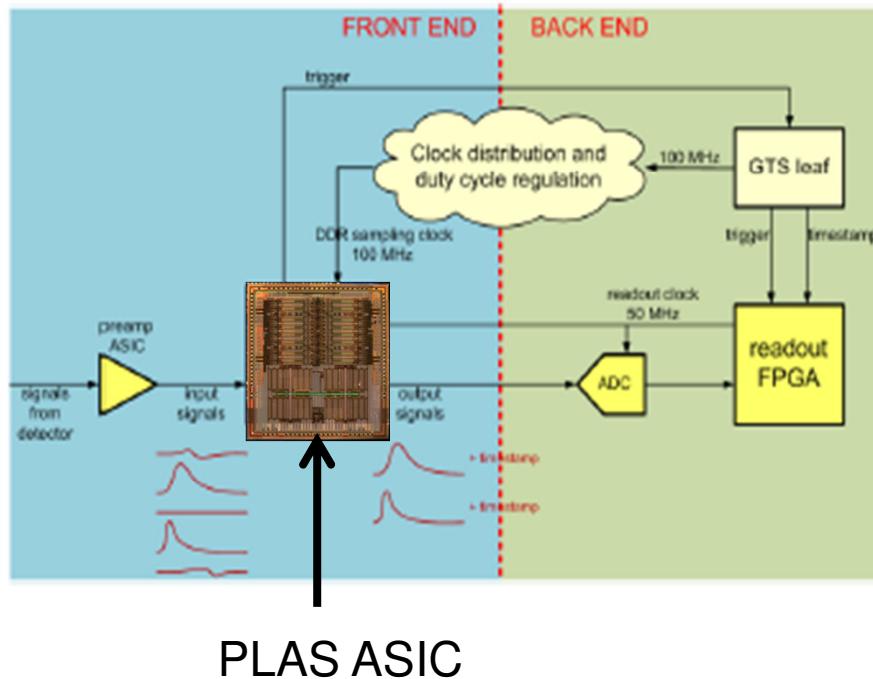
Other development: **multichannel CSP ASIC**  
 A.Pullia, S.Capra  
 INFN / Univ. Milano



# The PLAS Analog Memory ASIC

R.J.Aliaga et al., NIMA 800 (2015)

## ASIC specifications



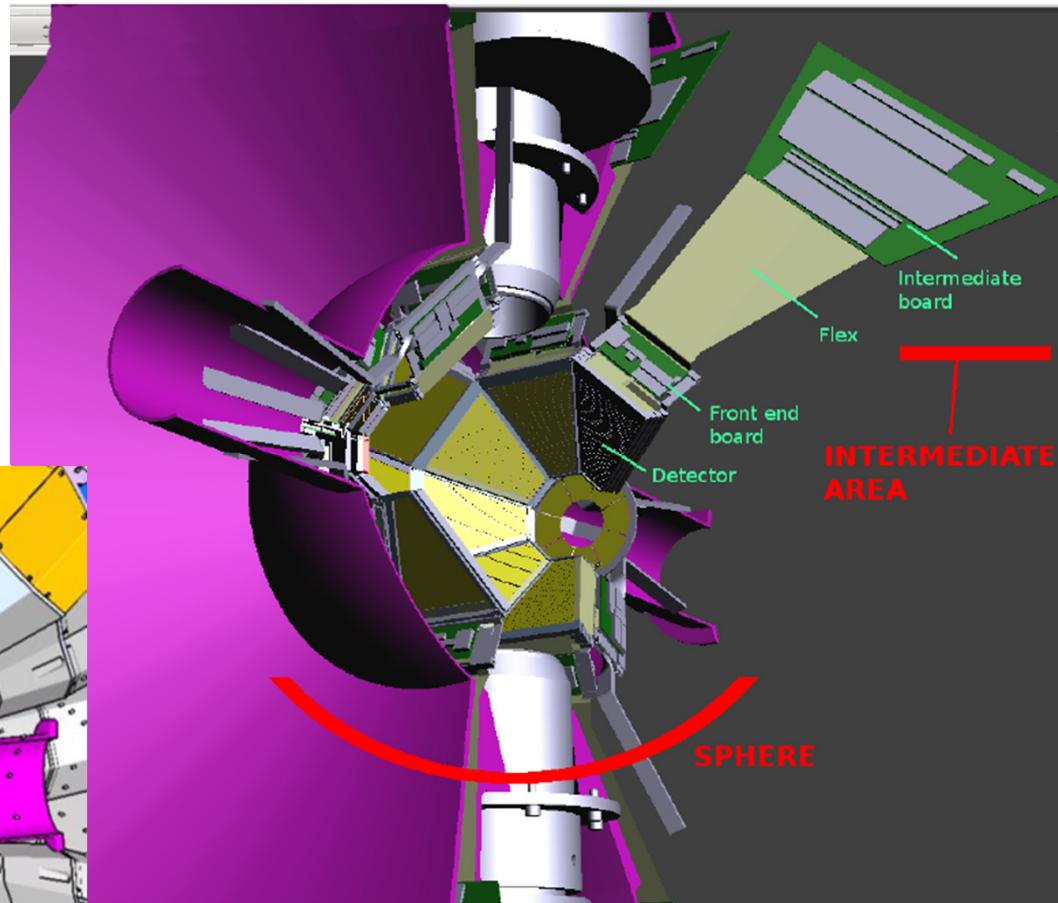
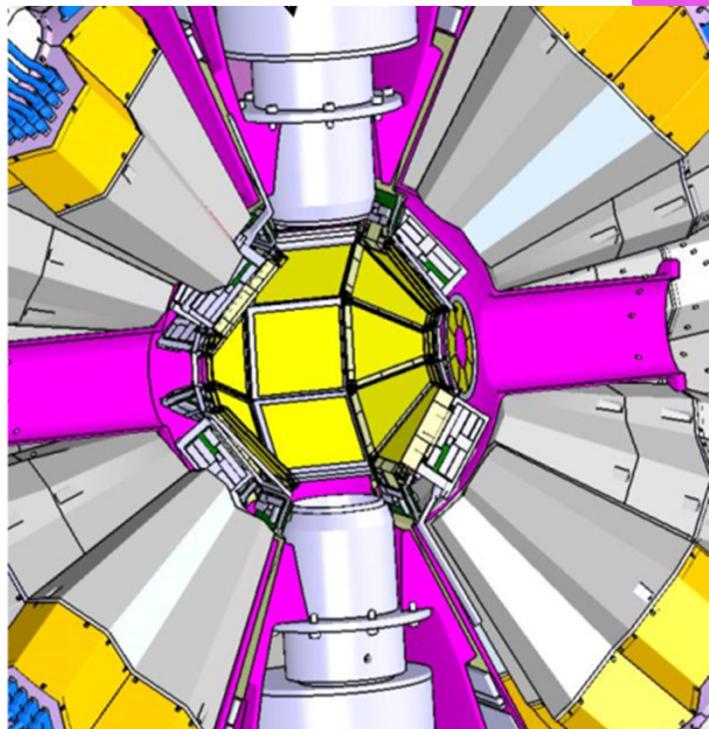
- Pulse capture:
  - 64 inputs with independent trigger (122 needed per detector → 2x ASIC)
  - Sample pulses @ 200 MHz (100 MHz DDR clock)
  - 32+192 samples from each pulse
  - Generate Trigger Request signal
  - No deadtime (limited by readout rate)
- Pulse readout:
  - Single output (analog)
  - Analog readout @ 50 MHz
  - External ADC
  - Low noise (11.5 ENOB spec)
- Other specs:
  - Pulse timestamping, synchronizable (between ASICs and with GTS)
  - Max 10 mW/channel
  - 0.18 μm CMOS technology, 1.8 V power supply

First version of the ASIC just received. To be commissioned

## *Electronics / Integration*

### Our challenge:

- ~ 10.000 channels
- Transparency to  $\gamma$ -rays



Detailed design under elaboration (IPNO)

# The CHyMENE H/D target system

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

*System providing continuous extrusion of  $^1\text{H}$  or  $^2\text{H}$  through a rectangular extruder nozzle defining the target-film thickness*

- **Hydrogen target in a solid phase near triple point**  
 $\text{sH}_2 \sim 17 \text{ K}$
- **Thickness 50 – 200  $\mu\text{m}$**
- **No window - C free**
- **Continuous flow in vacuum**  
2-10mm/sec
- **Compatible with particle detection**

CHyMENE collaboration :

- CEA/IRFU Saclay  
*project coordinator: A. Gillibert*
- IPN Orsay
- CEA/DAM Bruyères

Grant from French ANR ~550k€

# Cooled Helium gas target

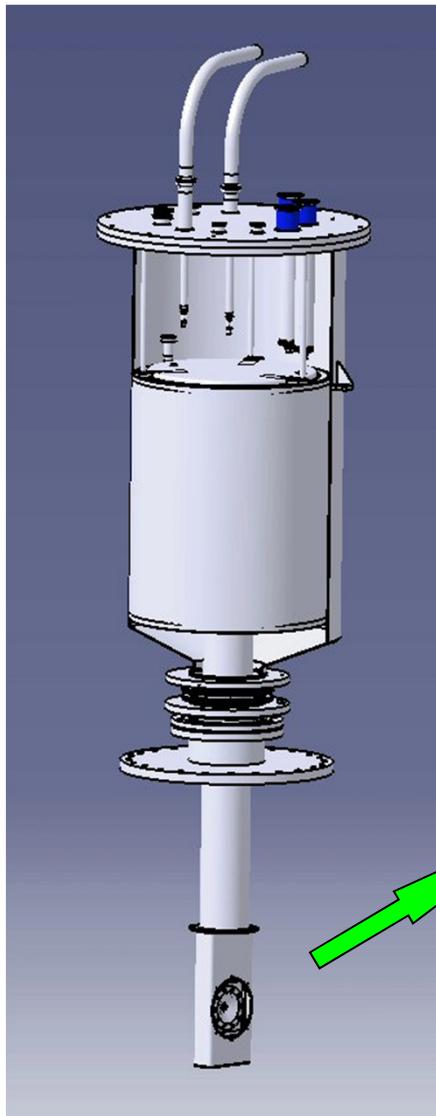
IPNO/ Accelerator division

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

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

Possible reactions:  $(\alpha, {}^3\text{He})$ ,  $(\alpha, t)$ ,  $(\alpha, {}^6\text{He})$ , ...

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 :  ${}^3\text{He}$  version

$({}^3\text{He}, d)$  proton stripping

$({}^3\text{He}, p)$  d transfer for np pairing

# MUGAST

(MUST2 - GASPARD – TRACE)

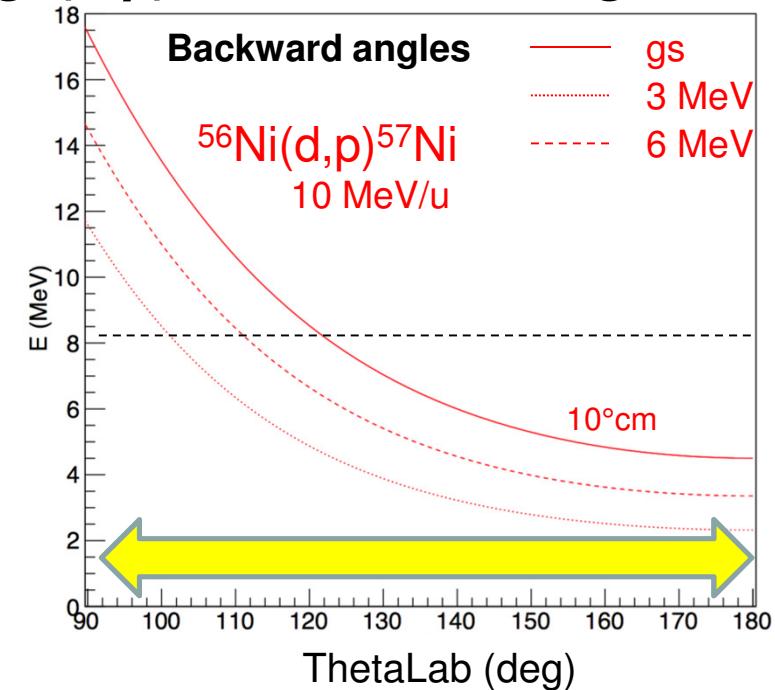
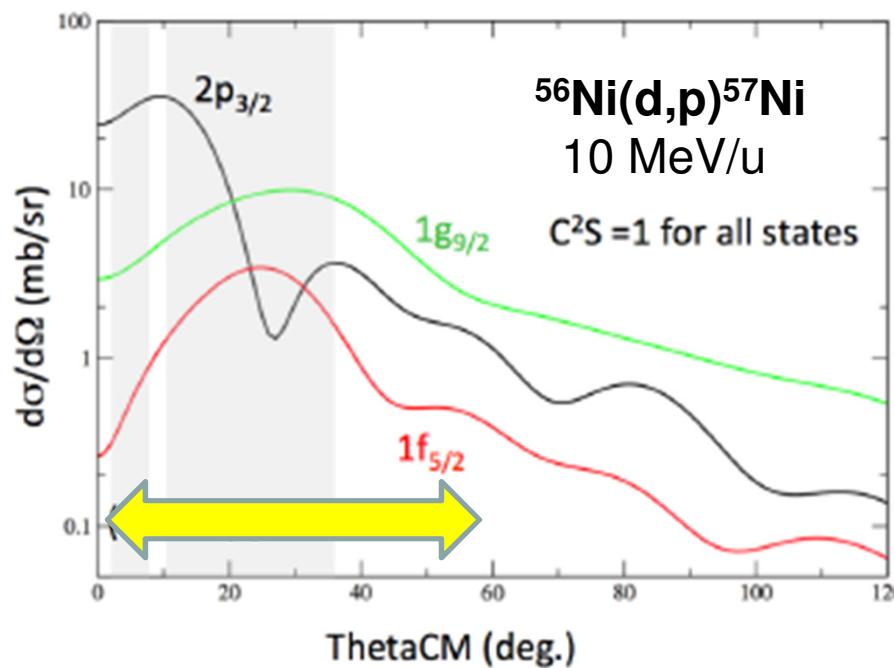
*Implementing an intermediate configuration*

- GASPARD-TRACE new detectors (+ few MUST2 telescopes)
- MUST2 electronics with new connectics  
(*timeline : 2018*)

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

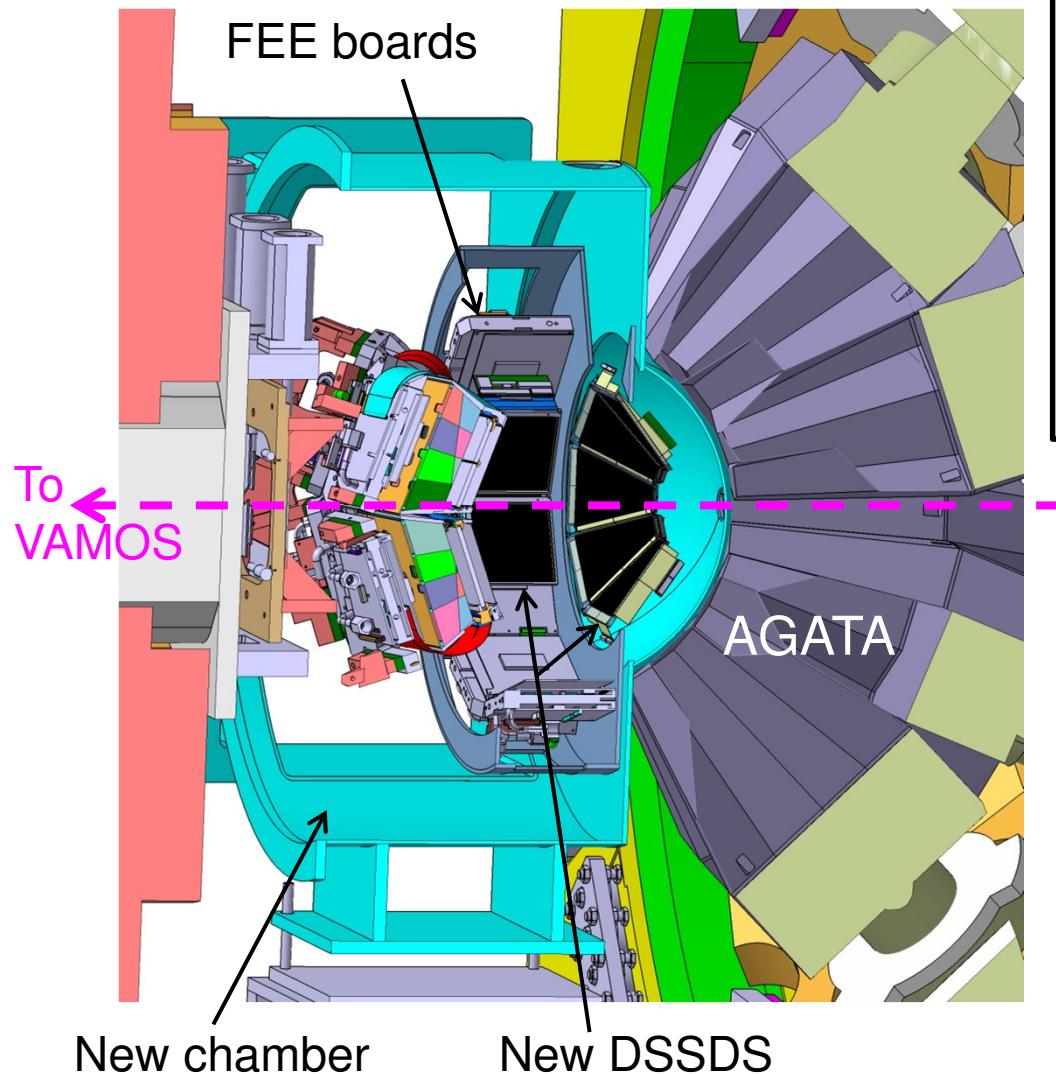
- AGATA**@ VAMOS
- The new SPIRAL1 beam

Focus on ***stripping reactions e.g. (d,p)  $\Rightarrow$  backward angles***



# MUGAST + AGATA at VAMOS/GANIL

Design: IPNO



## Si detectors configuration

- 5 Trapezoids + 1 Annular at bck angles
  - Distance : **10.5 cm** – Ann: 13.4cm
  - Angles: [105-155] $^{\circ}$  + [161-174] $^{\circ}$
- 2 Squares around 90 $^{\circ}$ :  
Distance : 13.5 cm  
Angles: [60,90] $^{\circ}$
- 4 MUST2 telescopes at fwd angles  
Angles : [10-50] $^{\circ}$

**AGATA at backward angles:**  
**Distance to target  $\simeq 18\text{cm}$**   
Eff(1 MeV)  $\sim 10\%$

**Electronics:** MUST2   
FEE boards + MUFI VXI cards

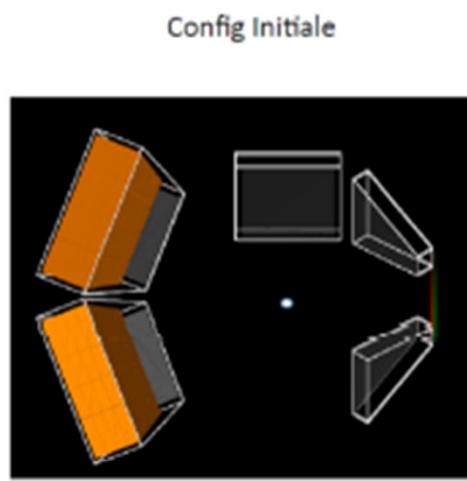


Inclusion of PARIS clusters will be studied

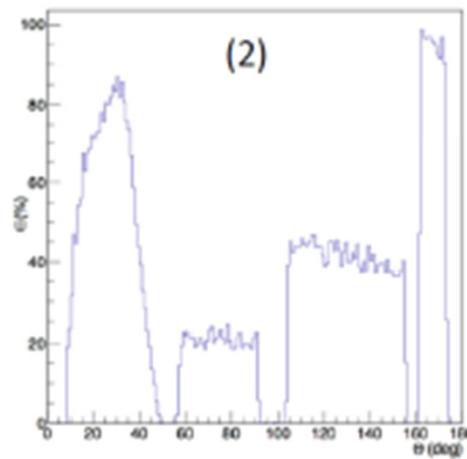
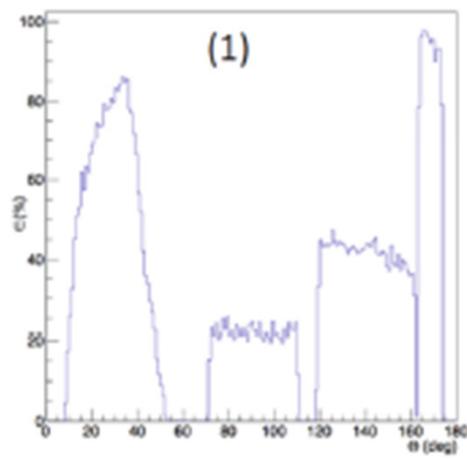
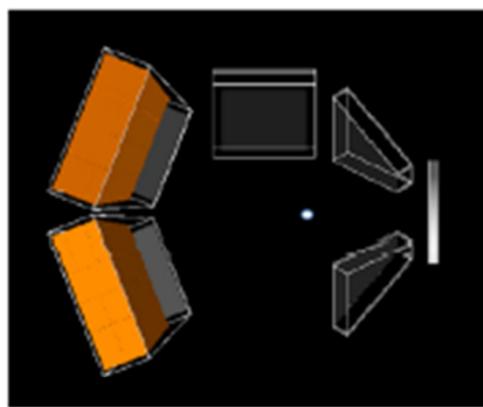
ITEM	STATUS	who
<b>DETECTORS</b>		
Trapezoids proto (x2)	Commissioning	<b>IPNO</b>
Trapezoids pre-serie (x3)	Ordered	<b>Surrey + IPNO + Santiago</b>
Squared proto (x2) + Thick proto	Ordered	<b>INFN Padova</b>
Annular (x1) th = 500um	Available	--
MUST2 (x4)	Available	--
<b>ELECTRONICS</b>		
MUST2 FEE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

## *Simulations / Detection efficiency*

Using NPTool package



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



Last geometrical configuration available on demand

# Physics with MUGAST

2 dedicated workshops organized at Orsay and Padova

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

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

*D.Beaumel & D. Mengoni*

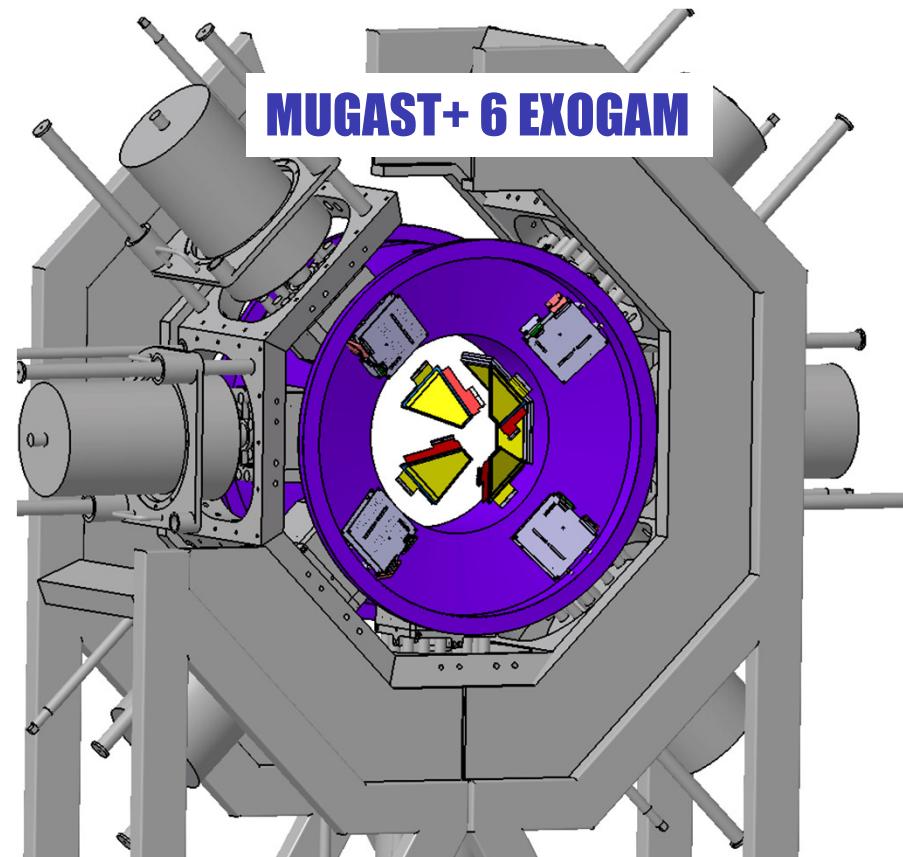
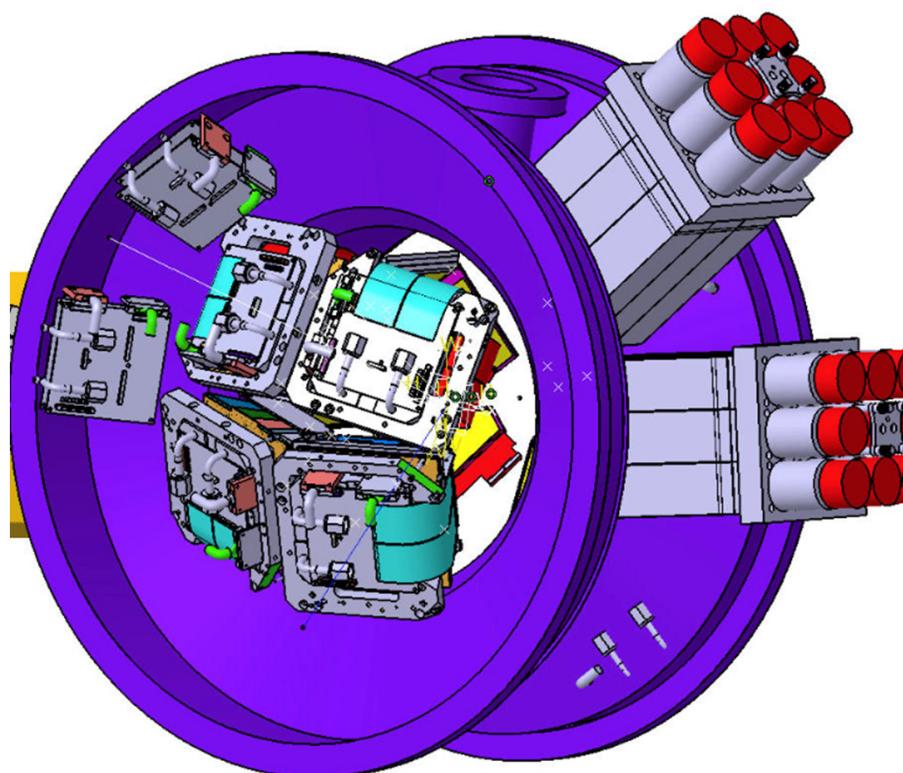
“Umbrella” *Lol submitted to the coming GANIL PAC*

# 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



*Thank you*

