A new high granularity Silicon Array for future reaction studies

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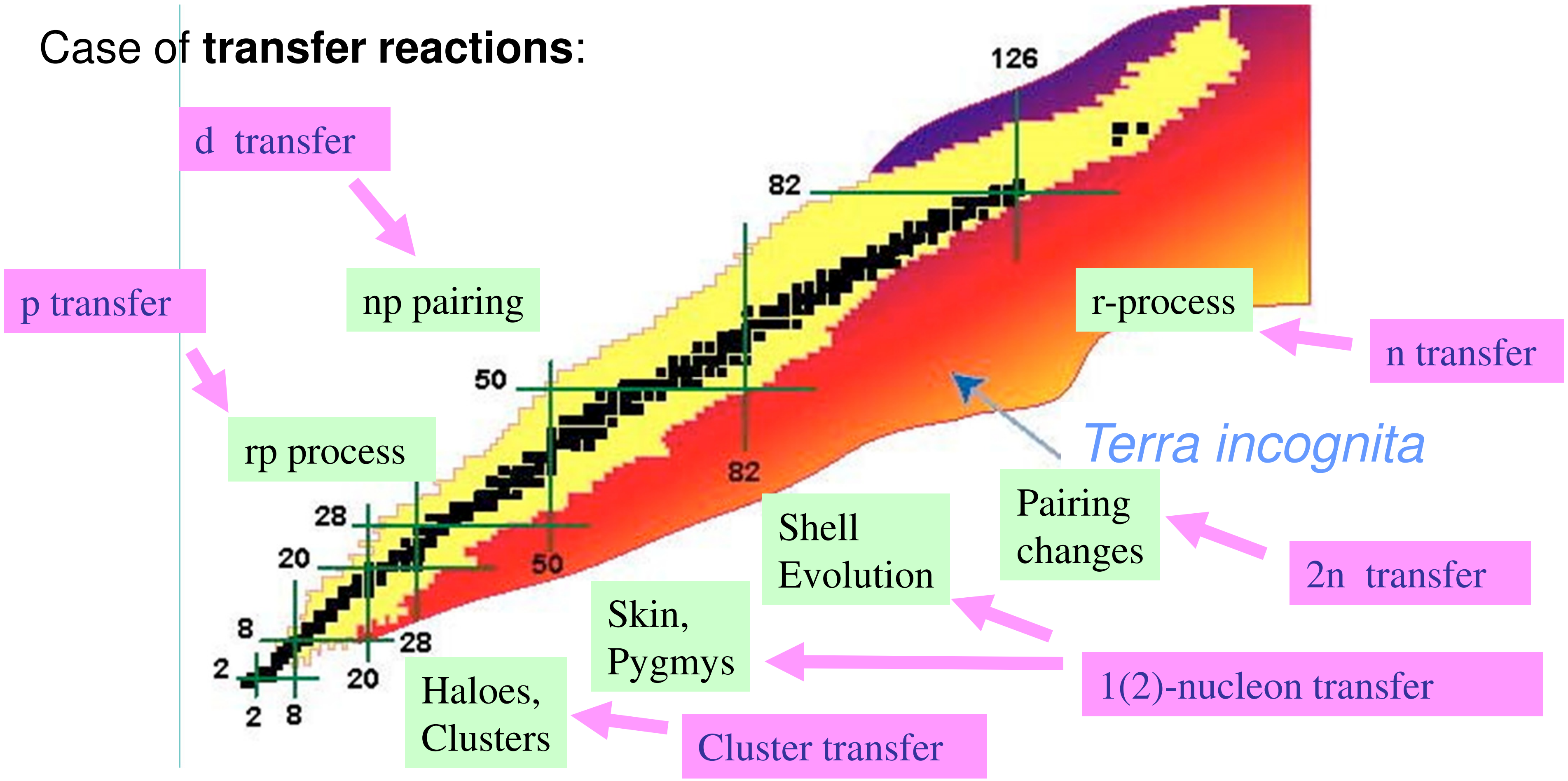
D.Beaumel,
IPN Orsay

Direct reactions

A great tool to investigate Exotic Nuclei and astrophysics processes

Case of **transfer reactions**:



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

<u>Methodology</u> : **Radioactive Ion Beam** ⟹ **Light target (H,He…)**
Detect the recoil particle with high accuracy
Silicon technology

Landscape of Si detectors for DR studies

Light Beams

Fission fragments

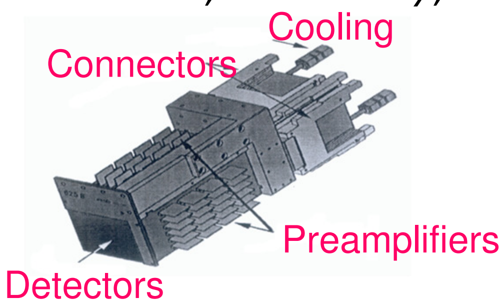
1997

2007

2017~

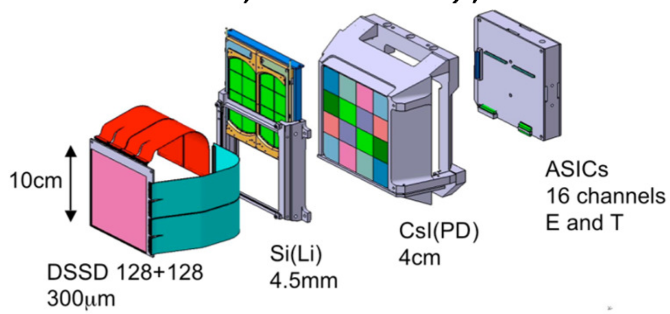
MUST

coll.: *IPN,CEA-Saclay, DAM*



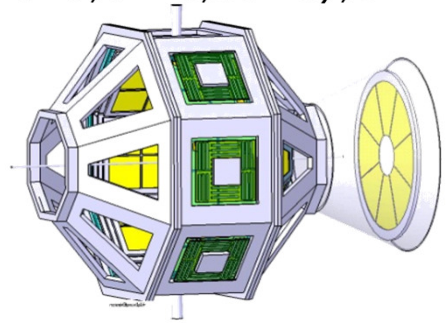
MUST2

coll.: *IPN,CEA-Saclay, GANIL*



GASPARD

coll.: *IPN, INFN, BARC*
Irfu,Huelva,STFC,Surrey,GANIL



Particle spectrocopy

E_x resolution: ~500keV

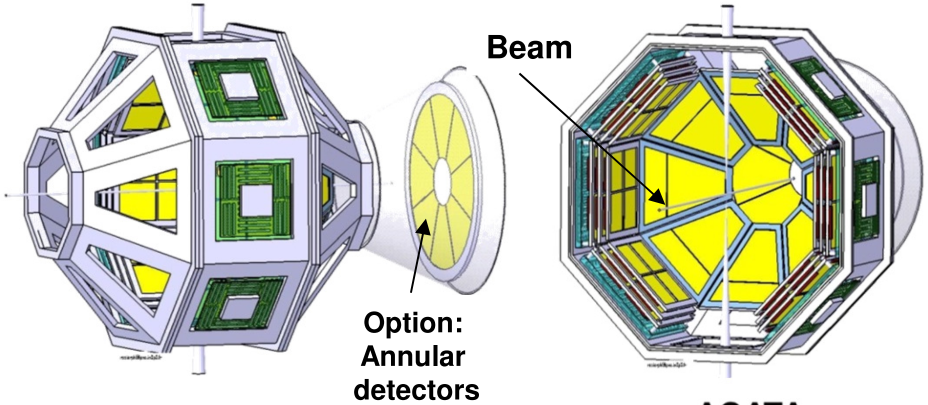
Particle-Gamma Spectroscopy

E_x resol.: ~5keV
(AGATA case)

A new Si array for reaction studies

4π, fully integrable in PARIS/AGATA/EXOGAM2

"GASPARD-TRACE" design



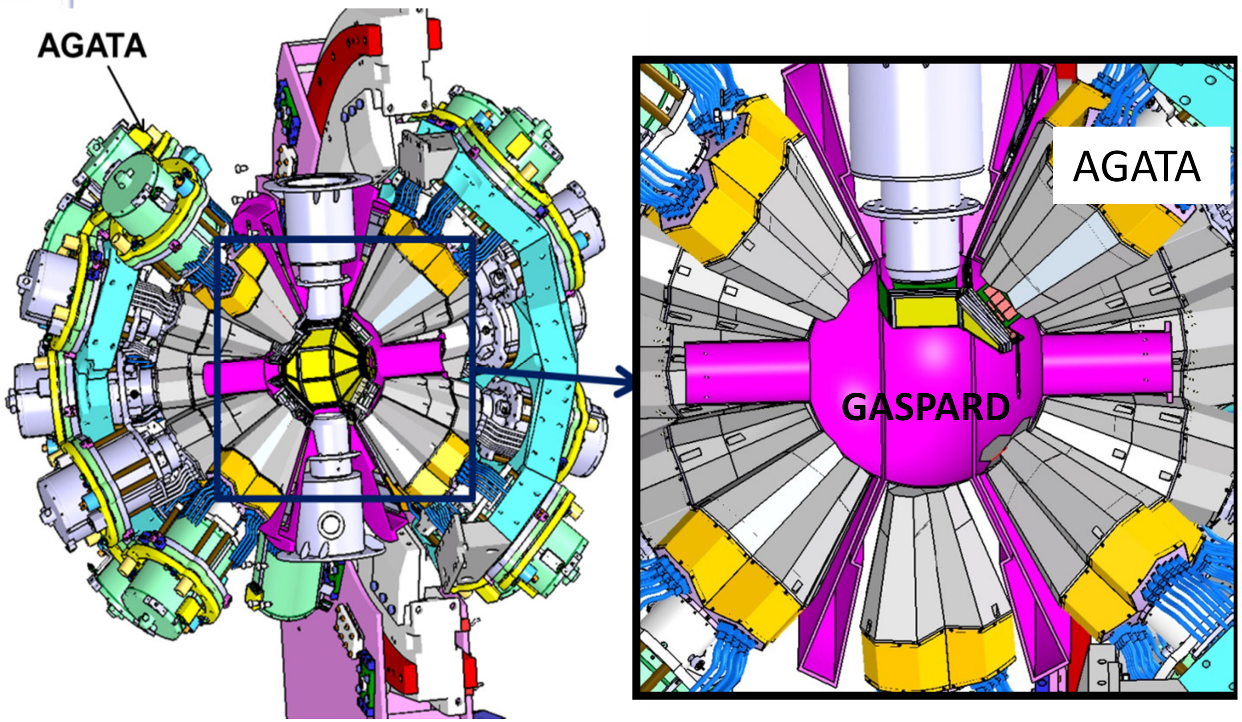
Layers of Silicon

- 300(500) μm DSSD pitch < 1mm
- 1(or 2) x [1.5 mm DSSD pitch~1mm]

2 main shapes : square & trapezoid,
large area

Electronics :

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



Other features:
- ❑ *State of the art for PID Pulse Shape Discrimination*
- ❑ *Special targets (pure H,D)*
- ❑ *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).

GASPARD TRACE

GASPARD-TRACE collaboration agreement

Under elaboration (D.Mengoni, DB)

Goal : converge towards a common portable device to be used at

2 phases scheme :

- **2015-2017 : (full) Si prototypes developments, Electronics dev. and full definition, TDR**
- **2017 ~ 2019? : Construction**

GHT Collaboration Agreement

1. Introduction

GHT (acronym for GASPARD, HYDE and TRACE, in reference to the corresponding initial projects) is an international collaboration aimed to develop a new detector for optimal study of reactions using low and intermediate energy beams at existing and forthcoming radioactive ion beam facilities. It consists in a new type of compact, highly segmented, silicon array, fully integrable within next generation gamma detectors such as AGATA and PARIS. Such new type of Silicon-based array is also meant to offer state-of-the art particle identification to improve separation of the various reaction channels and reduce the physical background. Native integration of special targets such as the pure

IPN INSTITUT DE PHYSIQUE NUCLÉAIRE ORSAY

R&D on Pulse Shape Discrimination with DSSD

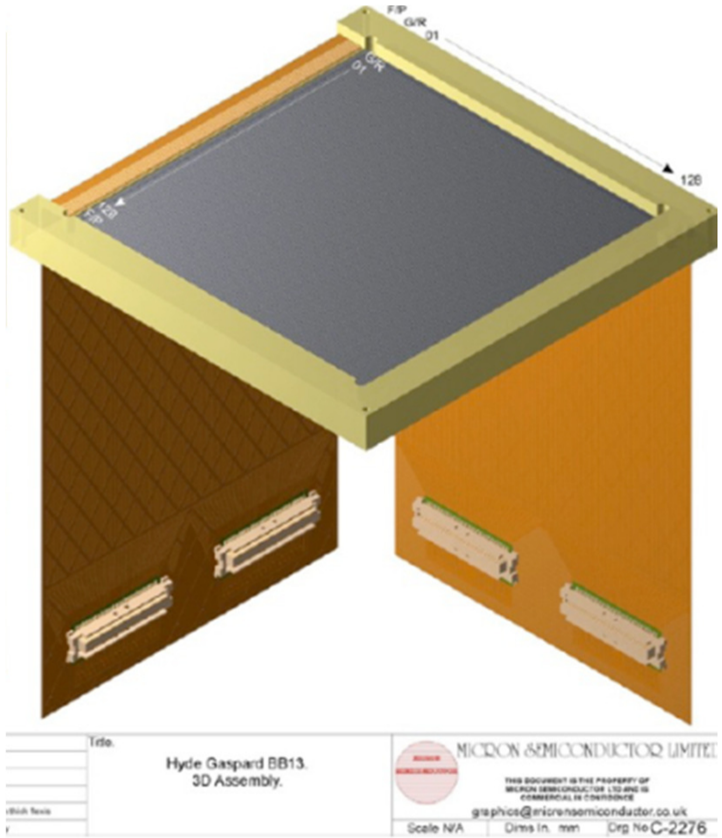
Goal: establish the method for light particles and highly segmented detectors

- **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

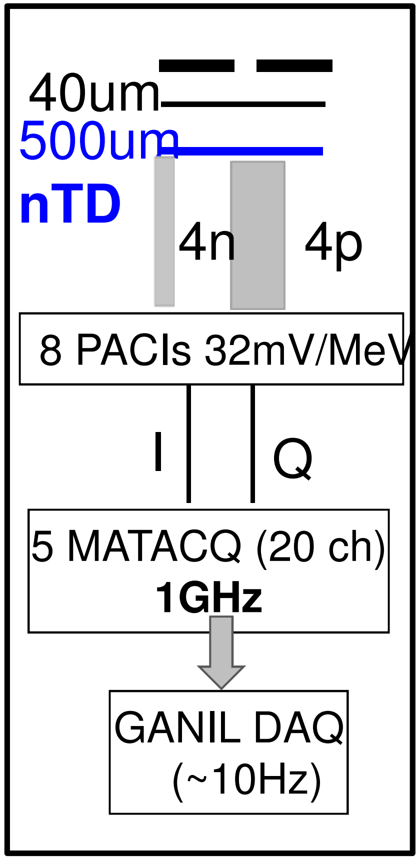
Detector:

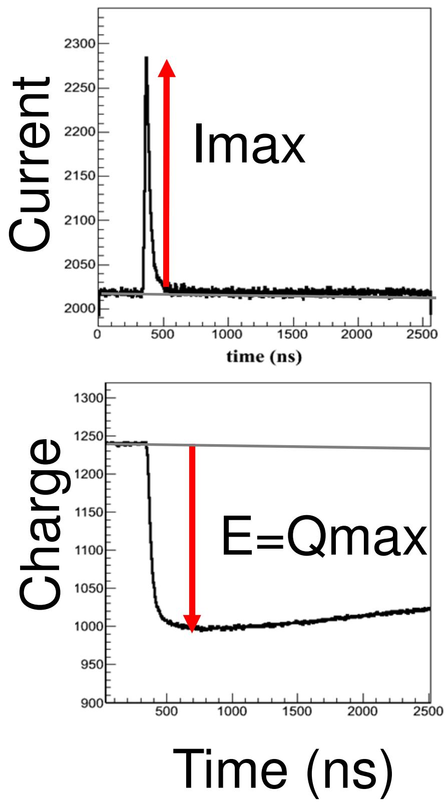
- 500 um nTD DSSD
  BB13 design of MSL
- 8° cut
- 128X+128Y
- pitch<500um
- special package
  90° kapton readout
  high density
  connectors

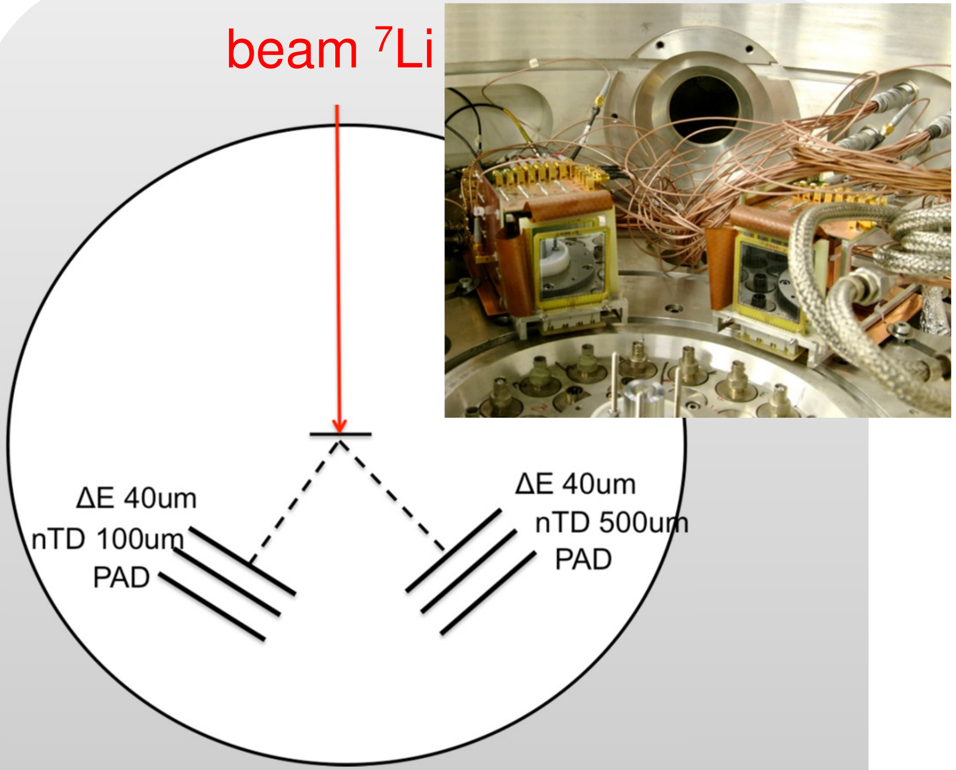


PSD for **Z=1** particles

Test experiment at IPNO tandem
Reaction:
$^{7}Li + ^{12}C$ @ 35 MeV



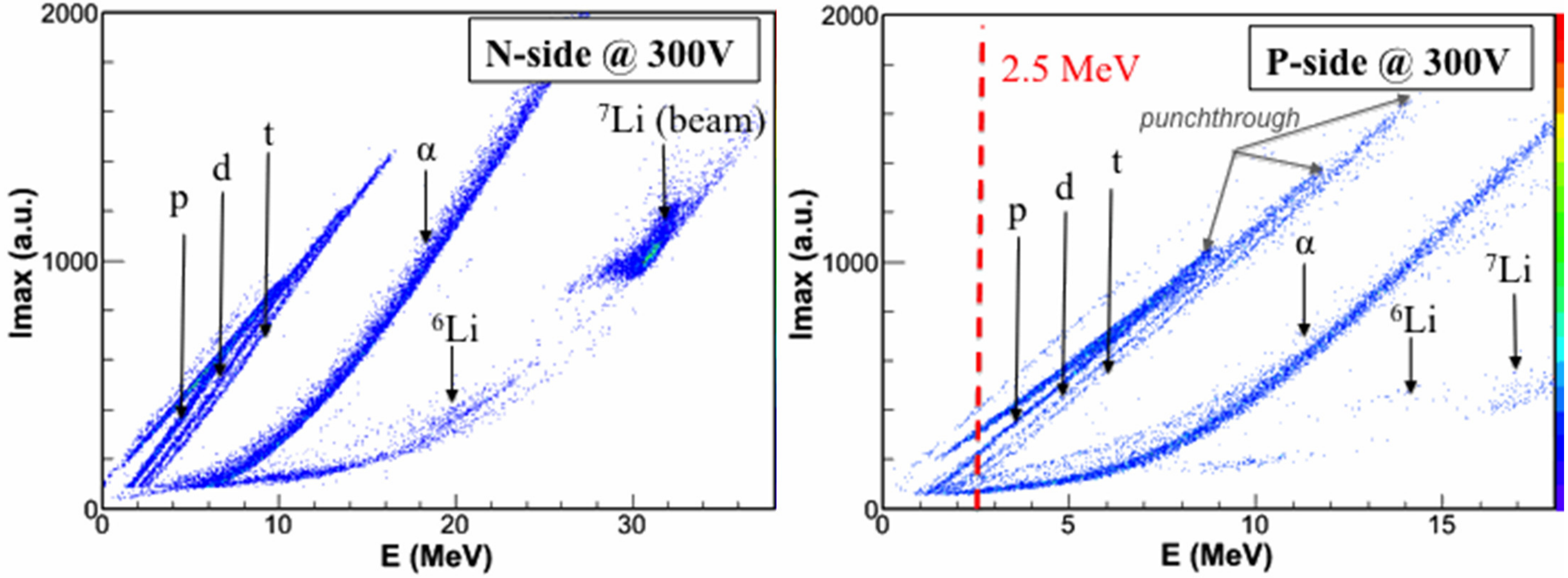




nTD 100um/500um 128X+128Y strips BB13
Preamps : PACI gain ~32 mV/MeV
Digitizers : **5 MATACQ** - **1GHz** sampling
GANIL DAQ : 20 digital channels 10Hz

PSD for light particles - **Results**

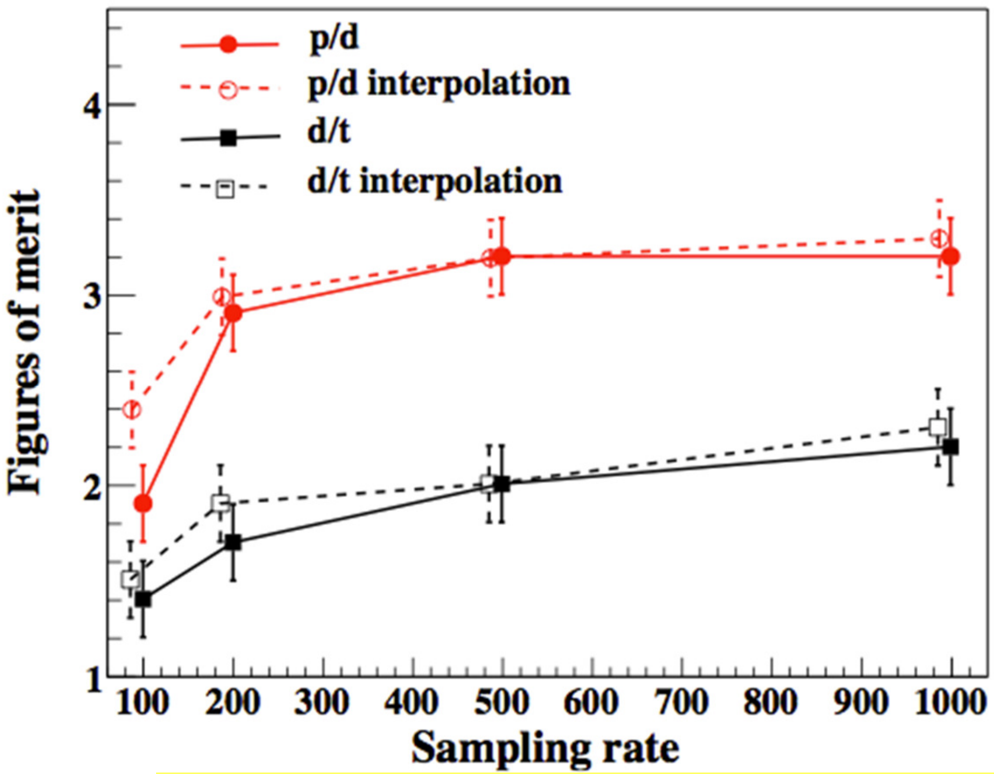
Reaction :
$^{7}Li + ^{12}C$ at 35 MeV



Discrimination achieved down to E < 2.5 MeV

M.Assié et al., EPJA(2015)

PSD - **Results for Z=1 particles**



For Z=1, p, d, t :

- Discrimination down to 2.5 MeV for 300V
- Amplitude of current signal sufficient @ 300V

➨ **Analog electronics ? Peak finder ?**

➔ ***The sampling rate should be higher than 200MHz***

- **Effect of bias :** best compromise is 300V
- **Effect of P and N-side:** lower threshold on P-side
- **Other observables and Filters (**Haar wavelets)
- **Effect of sampling frequency :** loss of discrimination below 250MHz

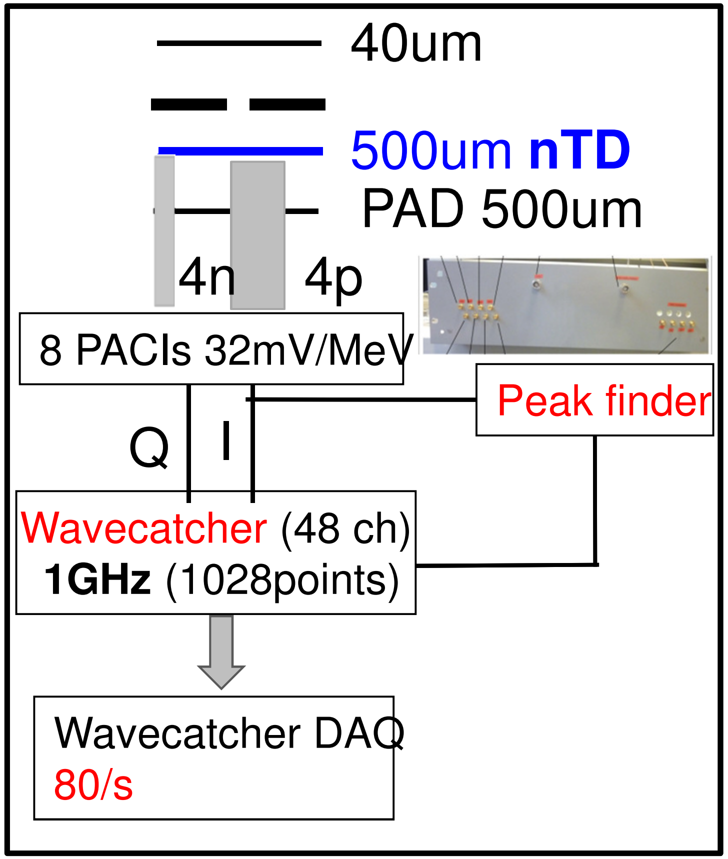
M.Assié et al., EPJA(2015)

PSD for **Z=2** particles

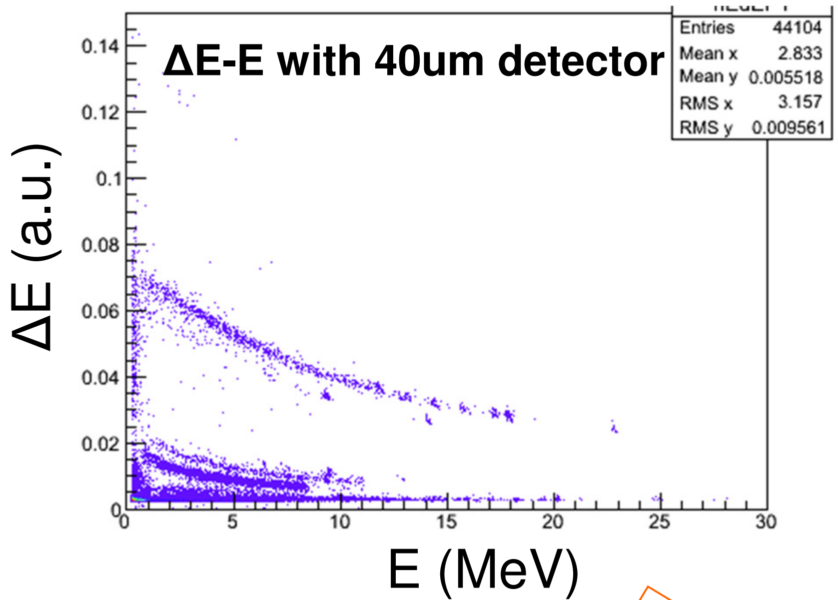
Reaction : (d,^{3}He) on mylar @ 26 MeV

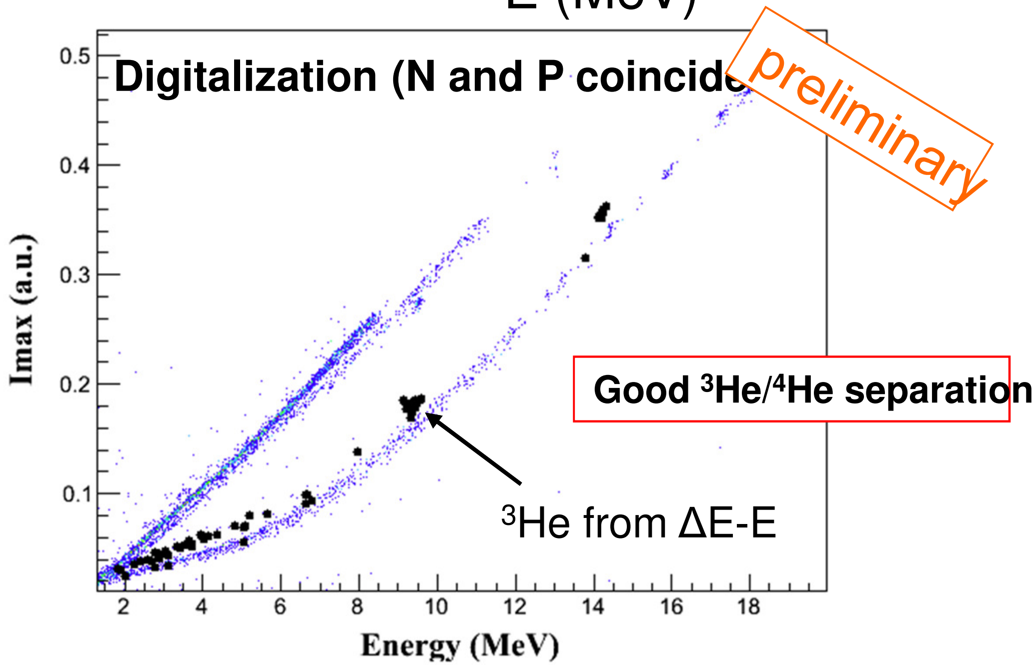
(IPNO tandem)

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



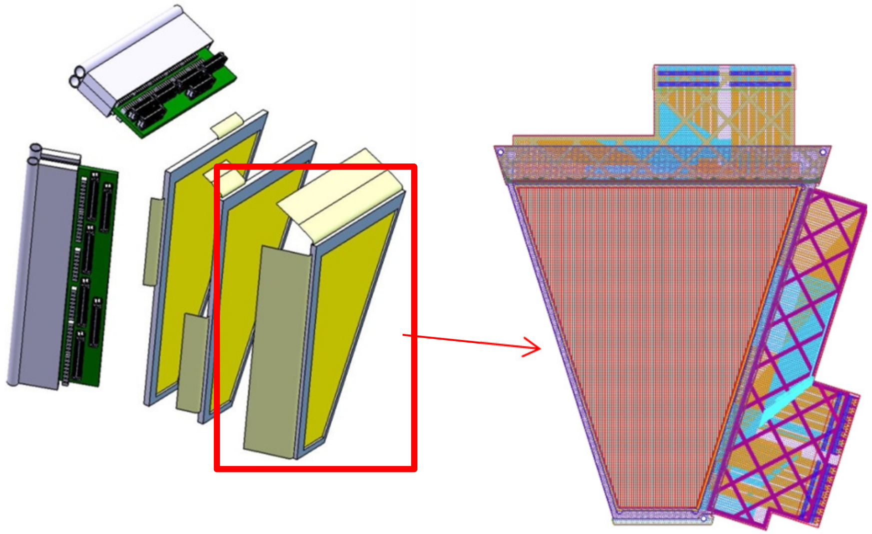
Add a ΔE detector for PID





Silicon developments

Final design (approved)



Silicon detectors plan (short term):

- .1st layer (trapez.): 2 prototypes ordered (Micron) in 2013 (IPNO)
- 1st layer(square) : 2 prototypes ordered (Micron) in 2014 (INFN-Padova)
- .2nd layer (thick square) & 2nd layer (thick trapez): BARC-IPNO

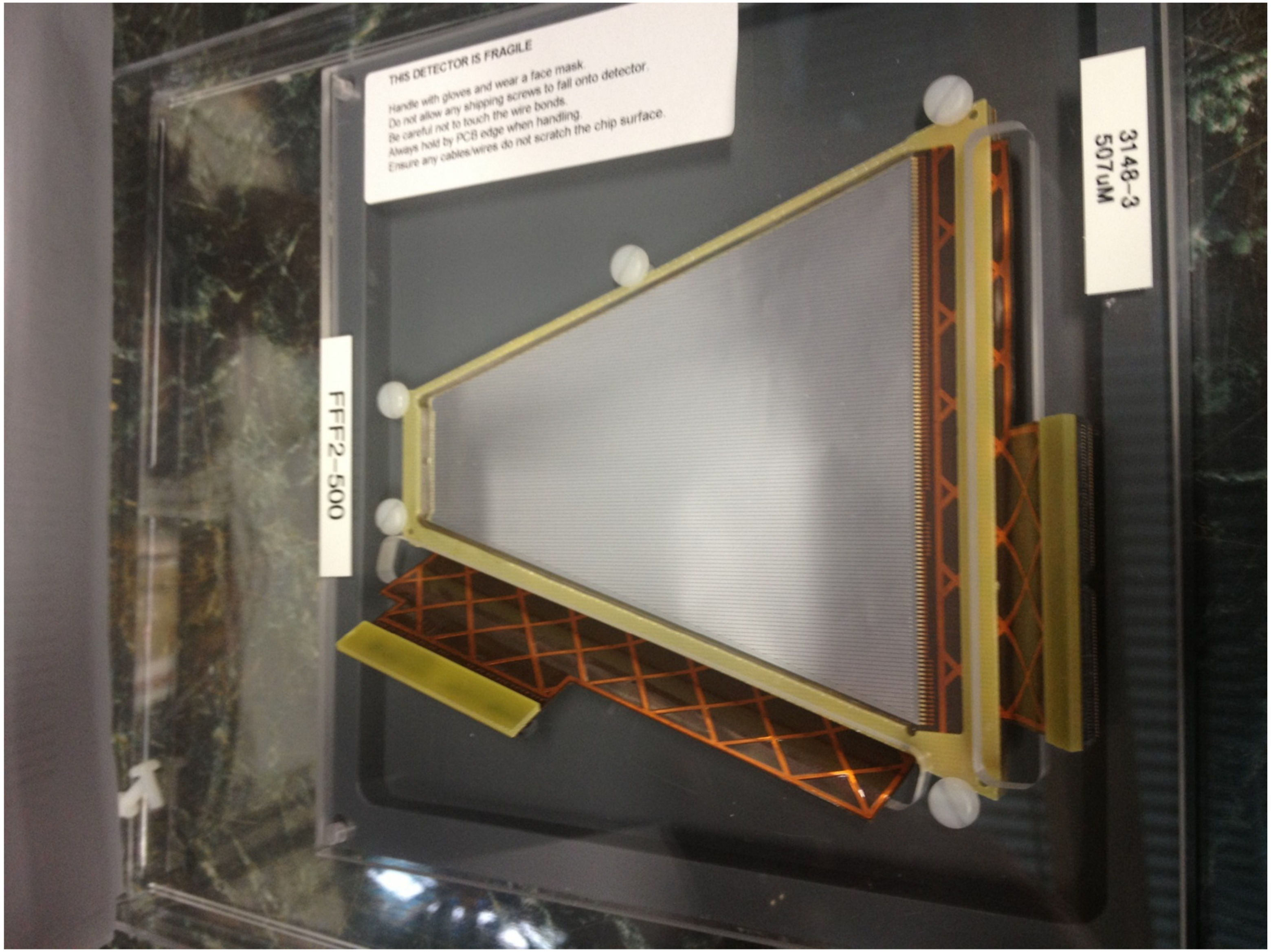
Specifications

- large area , 6'' wafers, nTD, 500um thick
- 128X+128Y (pitch~700 um)
- <100> random cut (8deg)
- Thin frame / Kapton readout at 90deg /High density connectors

<u>Test bench</u>
Test of uniformity In resistivity
Leakage current /strip, capacitance/strip, interstrip resistance

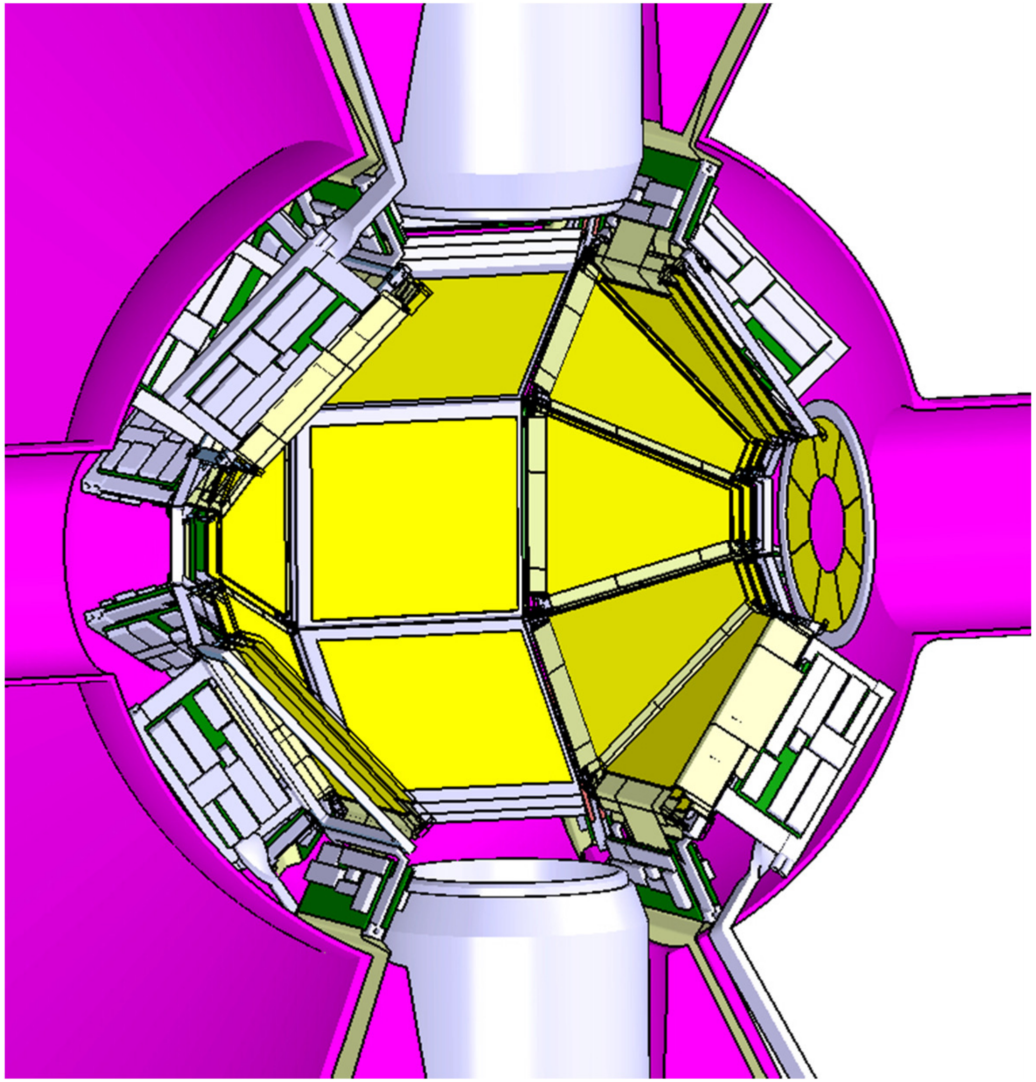
Trapezoid under commissioning

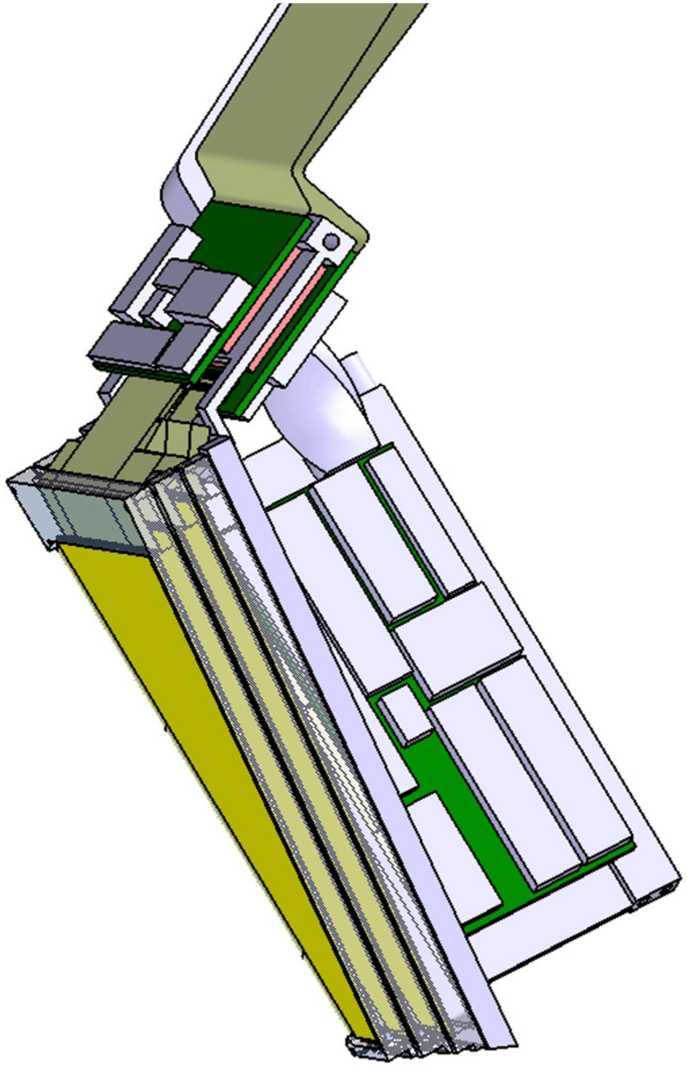
Trapezoid DSSD prototype



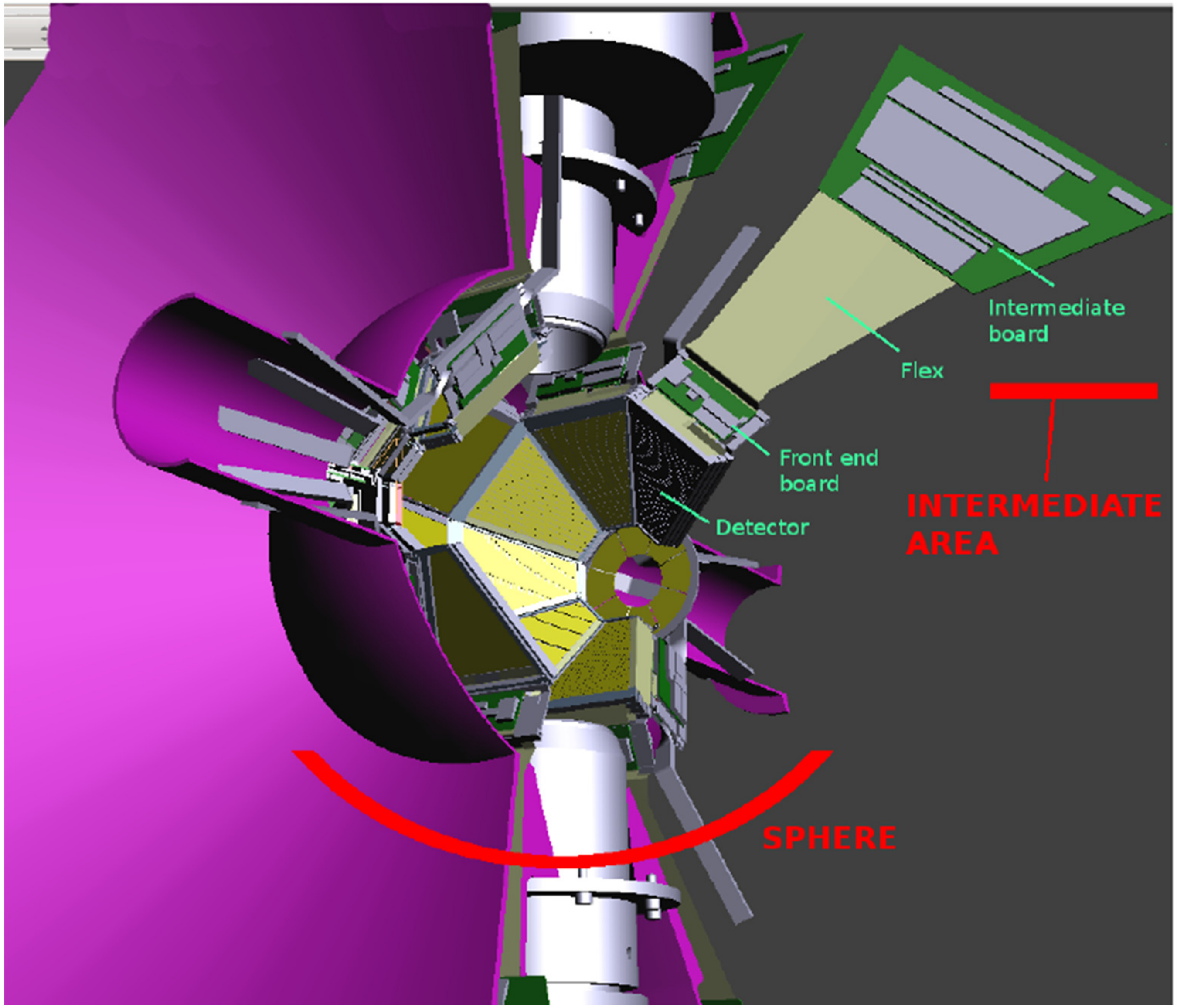
Received June 23, 2015

ELECTRONICS

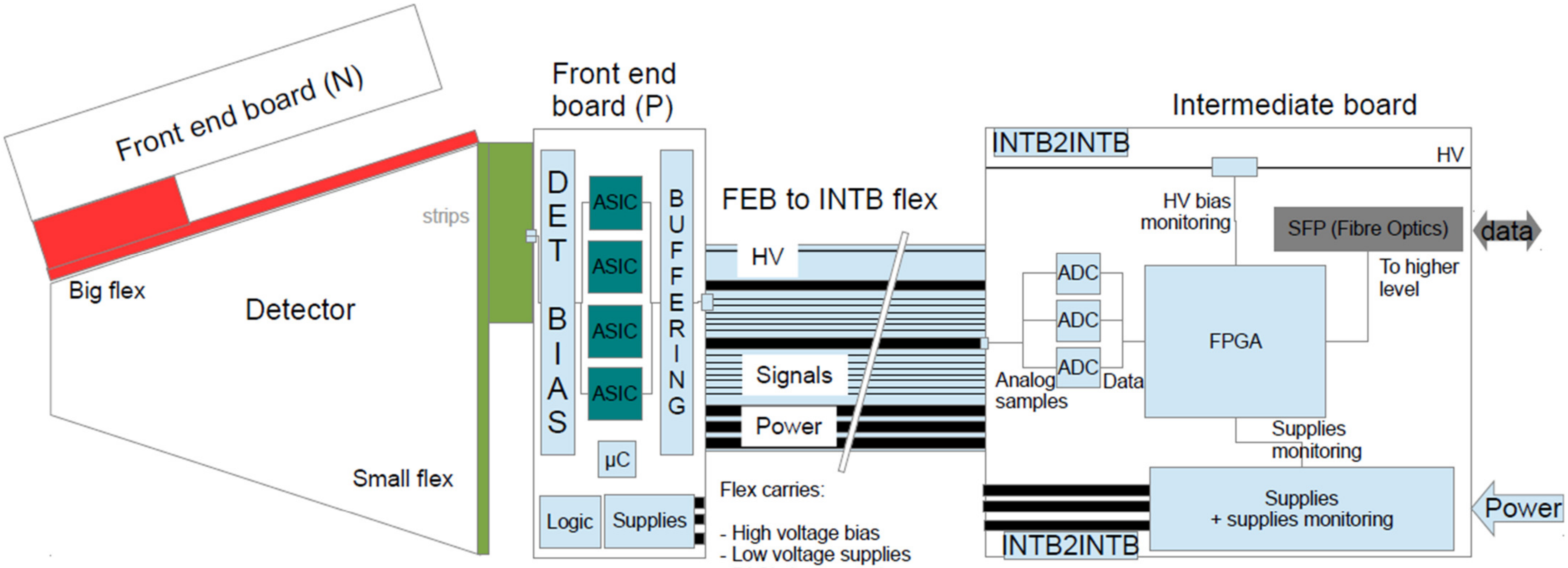




Integration of electronics



FEE architecture (preliminary)



FEB carries:

- Detector bias
- ASICs
- Buffering
- Supplies
- Logic
- μC ?

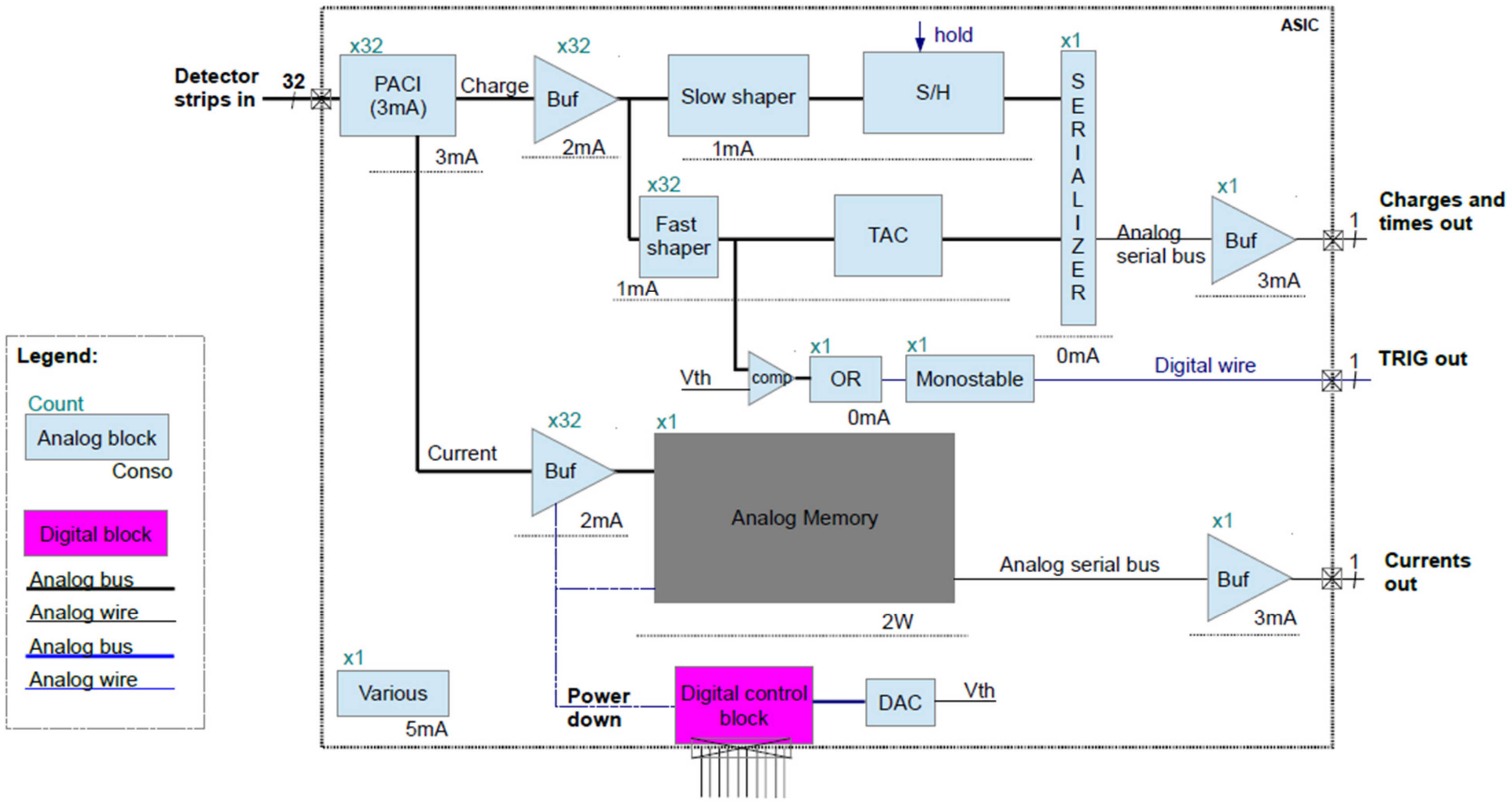
Flex carries:

- High voltage bias
- Low voltage supplies
- PACI slow control
- Analog memory digital control
- Analog memory analog outputs
- Various : House keeping, indicators, T°

INTB carries:

- ADCs
- FPGA
- Suppies + Supply voltage/current monitoring
- HV bias + HV voltage/current monitoring
- SFP (Optical link to higher level)
- Connectors to other intermediate boards (INTB2INTB)

ASIC internal architecture



Digital control:
- ASIC slow control
- Serializer sequencing
- Analog Memory control
- S/H triggering

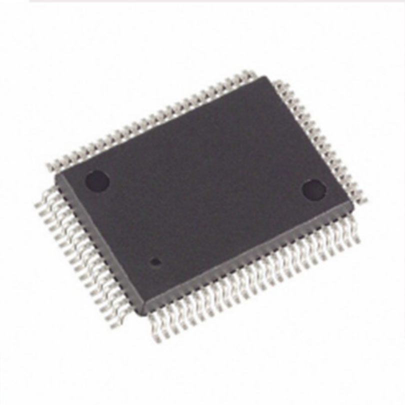
iPACI

IPACI : 9-channel integrated *Charge* and *Current* output preamplifier

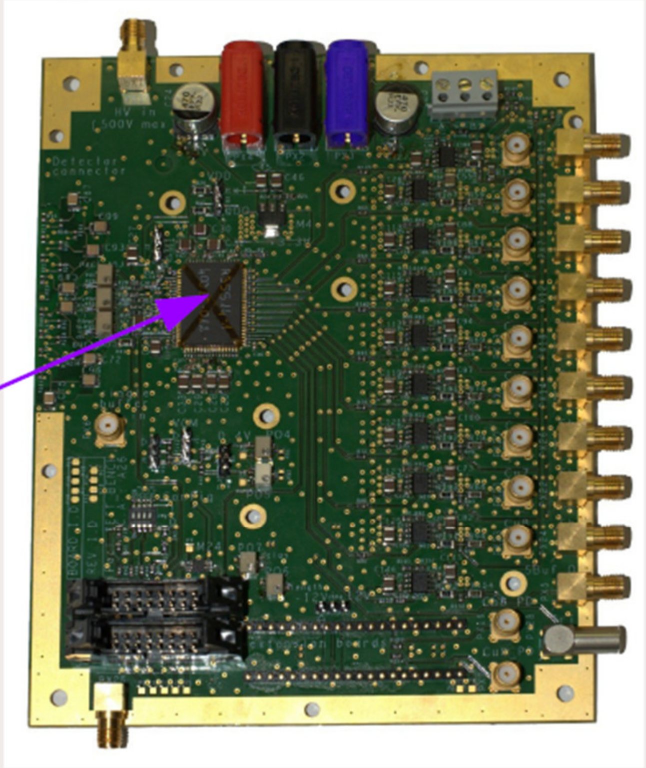
Status:
- ASIC and Testbench available, test starting soon

To do next:
- ASIC qualification via test input
- Coupling with a detector (June/15)
- Possibly ASIC redesign

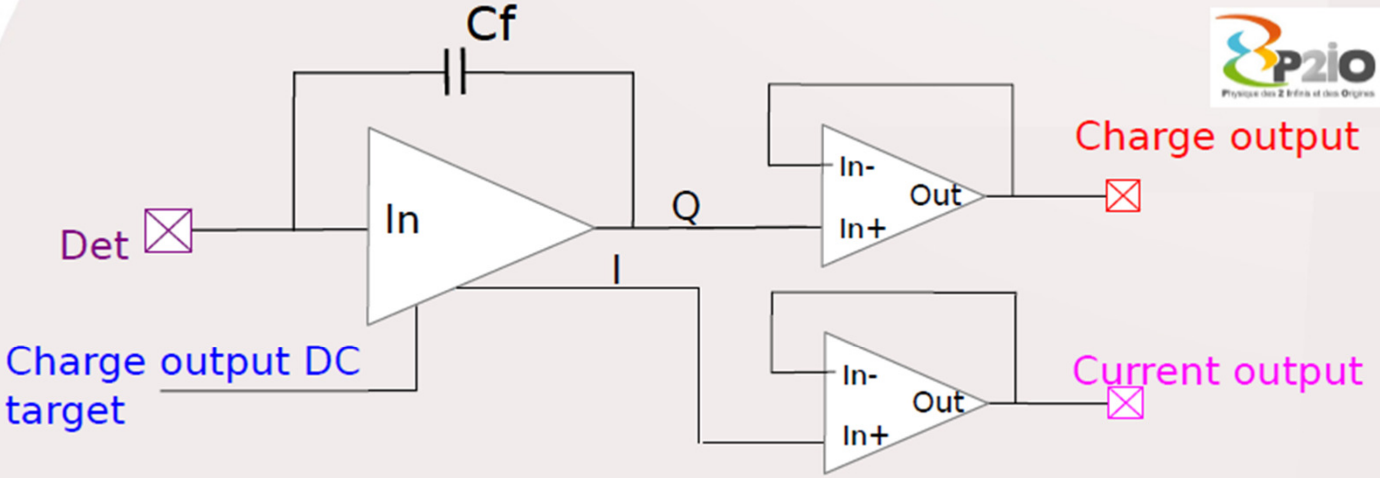
- Design slow shaper



9 **Charge** and **Current** preamps



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)

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 rectangular extruder nozzle defining the target-film thickness

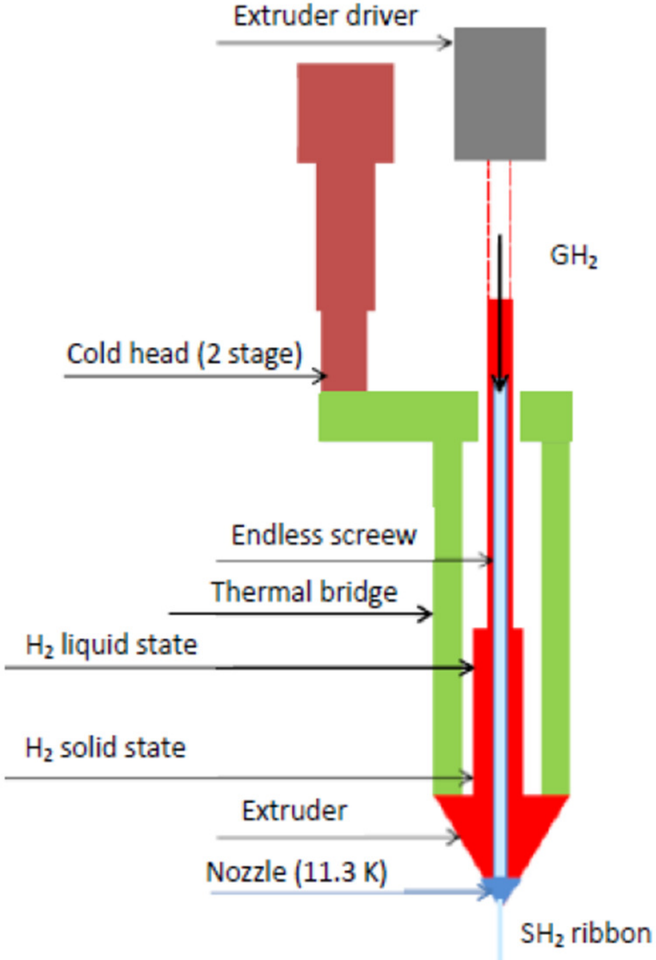
- **Hydrogen target in a solid phase near triple point**
  sH_2 ~ 17 K
- **Thickness 50 – 200 µm**
- **No window - C free**
- **Continuous flow in vacuum 2-10mm/sec**
- **Compatible with particle detection**

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

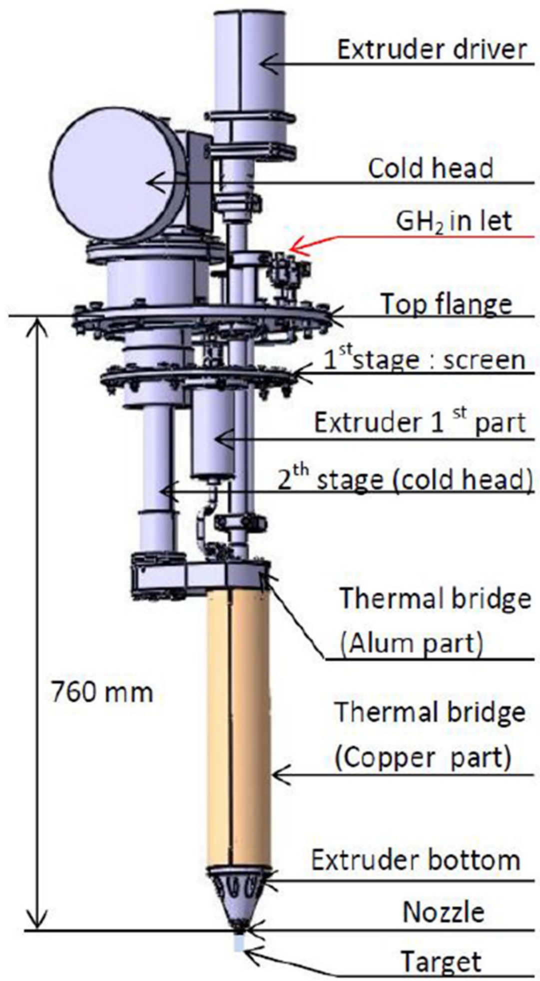
Grant from French ANR ~550k€

IRFU-IPNO-DAM

CHyMENE - Design



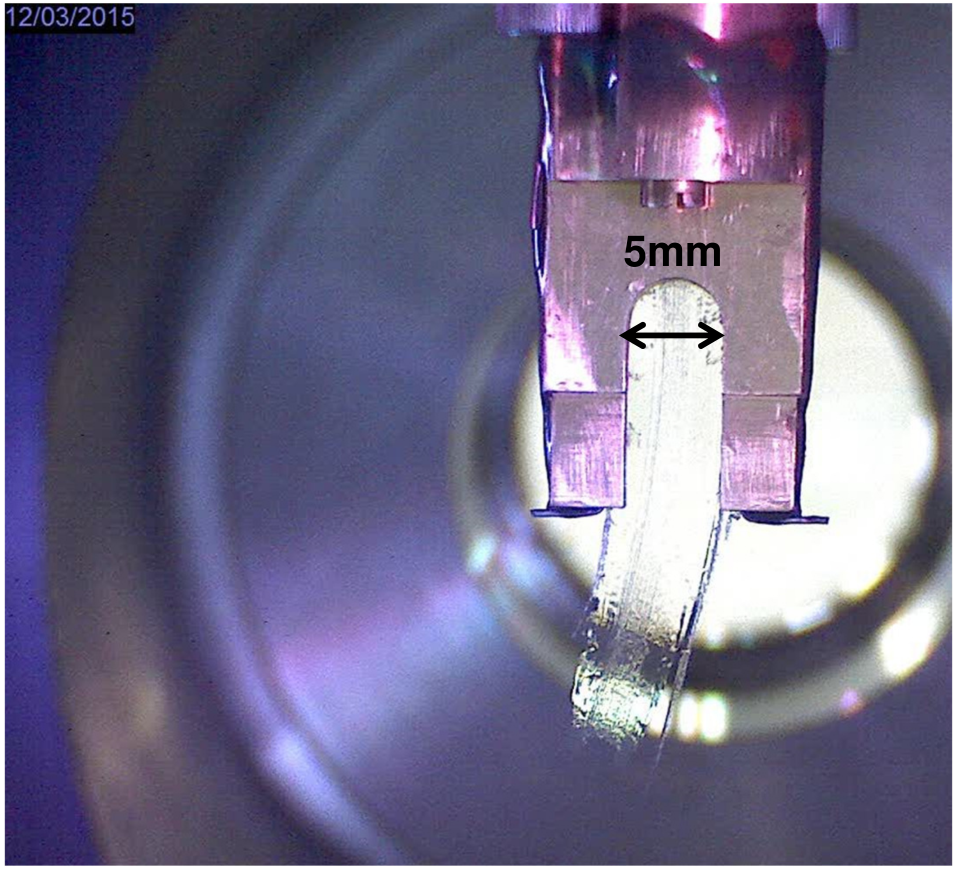
Cryogenic system in the cryostat



IRFU-IPNO-DAM

CHyMENE - Status

- Now being commissioned
  Test under beam beg. of
  2016
- Further tests of thin ribbon
  production needed
  (Nozzle material, geometry
  surface treatment, …)
- Need implement system for
  thickness measurement
  presently: α-source+SD

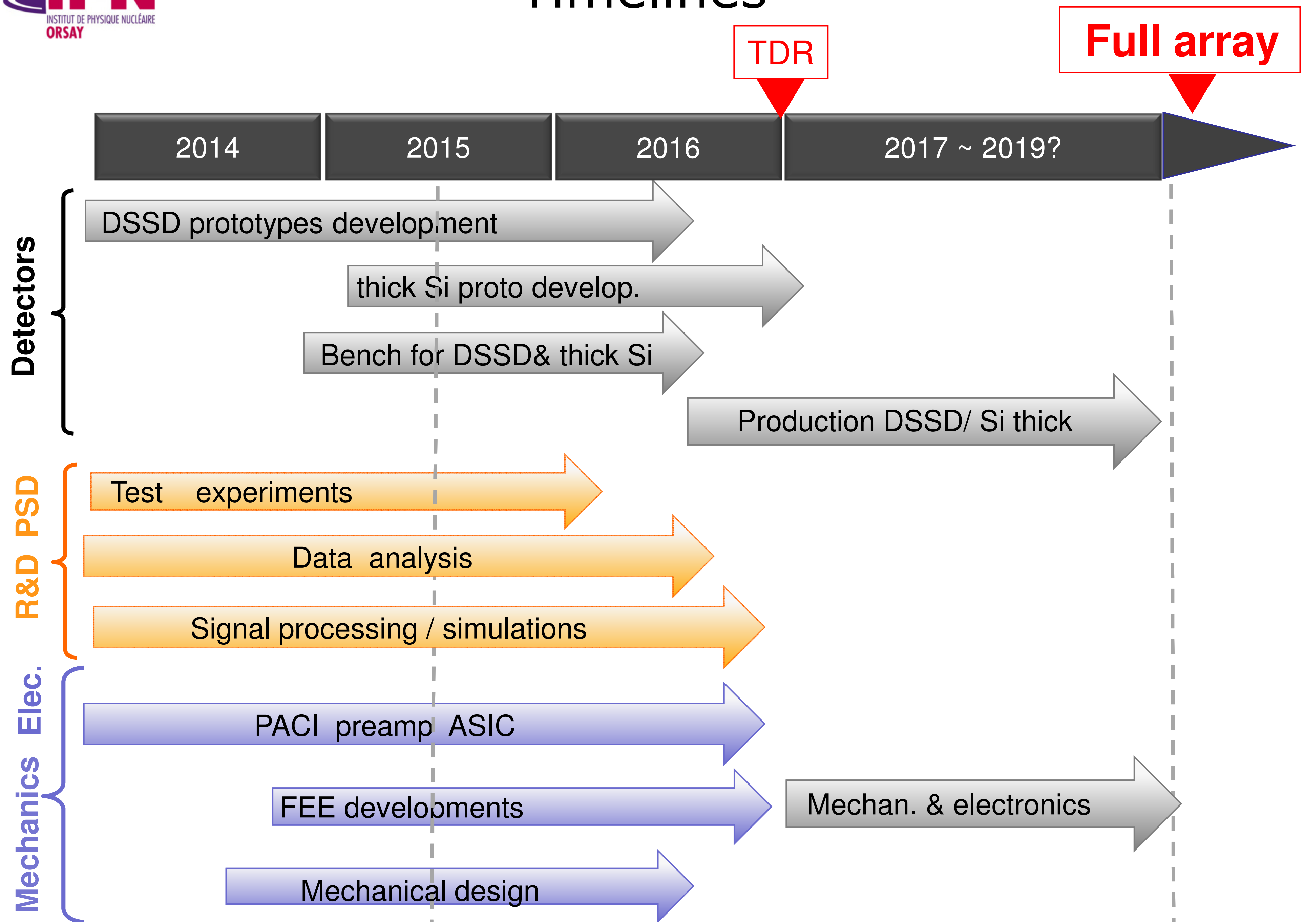


AGENCE NATIONALE DE LA RECHERCHE ANR

cea IRFU-IPNO-DAM

CHyMENE

Timelines



TDR
Full array
2014
2015
2016
2017 ~ 2019?
Detectors
DSSD prototypes development
thick Si proto develop.
Bench for DSSD& thick Si
Production DSSD/ Si thick
R&D PSD
Test experiments
Data analysis
Signal processing / simulations
Mechanics Elec.
PACI preamp ASIC
FEE developments
Mechan. & electronics
Mechanical design

MUGAST

(MUST2 - GASPARD – TRACE)

Implementing an intermediate configuration

- GASPARD-TRACE prototypes
  + few MUST2 telescopes
- One-layer philosophy (VAMOS)
- CHYMENE
- MUST2 electronics with new connectics

100 k€, 2 years (start : 2017)

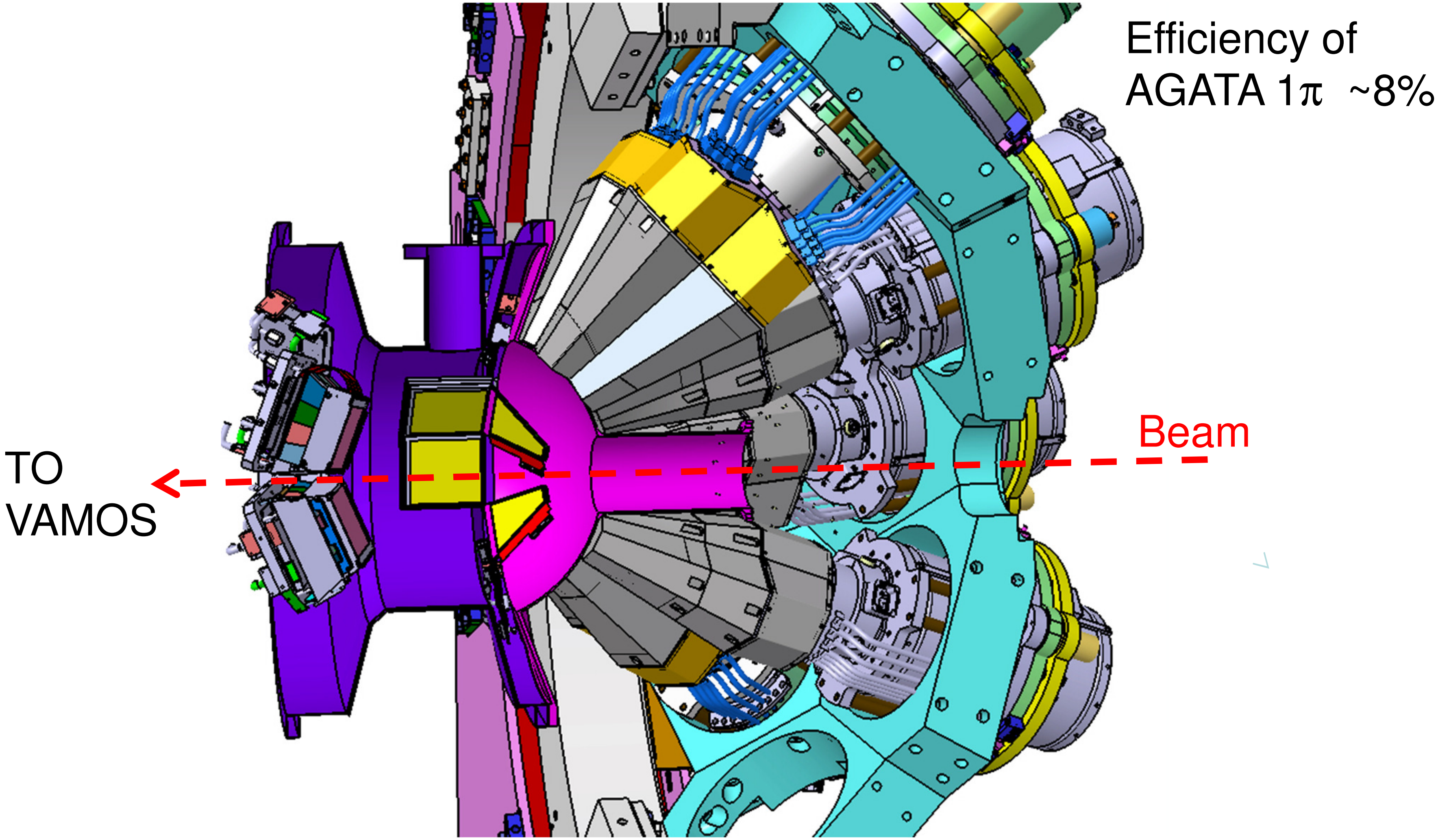
To perform **high resolution reaction studies** using

- AGATA@ VAMOS
- The new SPIRAL1 beams

In particular ***stripping reactions e.g. (d,p)***

MUGAST

(MUST2 - GASPARD – TRACE)



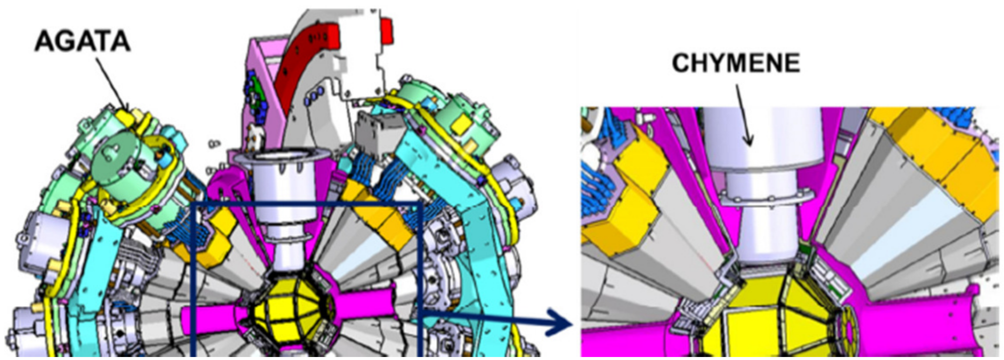
Reaction studies using the MUGAST+AGATA setup at VAMOS

Letter of Intent to the AGATA collaboration

D.Beaumel, IPN Orsay
D.Mengoni, University and INFN Padova

1. Introduction

The GASPARD and TRACE high granularity Silicon arrays have been natively designed for optimal integration in new generation gamma detectors such as AGATA with the aim of performing high-resolution reaction studies. Indeed, the coupling to AGATA allows a very large gain in excitation energy resolution, in comparison with the case where the excitation energy is deduced from the recoil charged-particle measurement. The GASPARD and TRACE collaboration are now converging to build such new-generation Si ensemble in common, with a timeline of 2019-20 for completion of the final 4π array, ready for the emerging ISOL facilities, like SPES and SPIRAL1. A view of such ultimate GASPARD-TRACE setup sitting inside AGATA is shown in Fig.1.

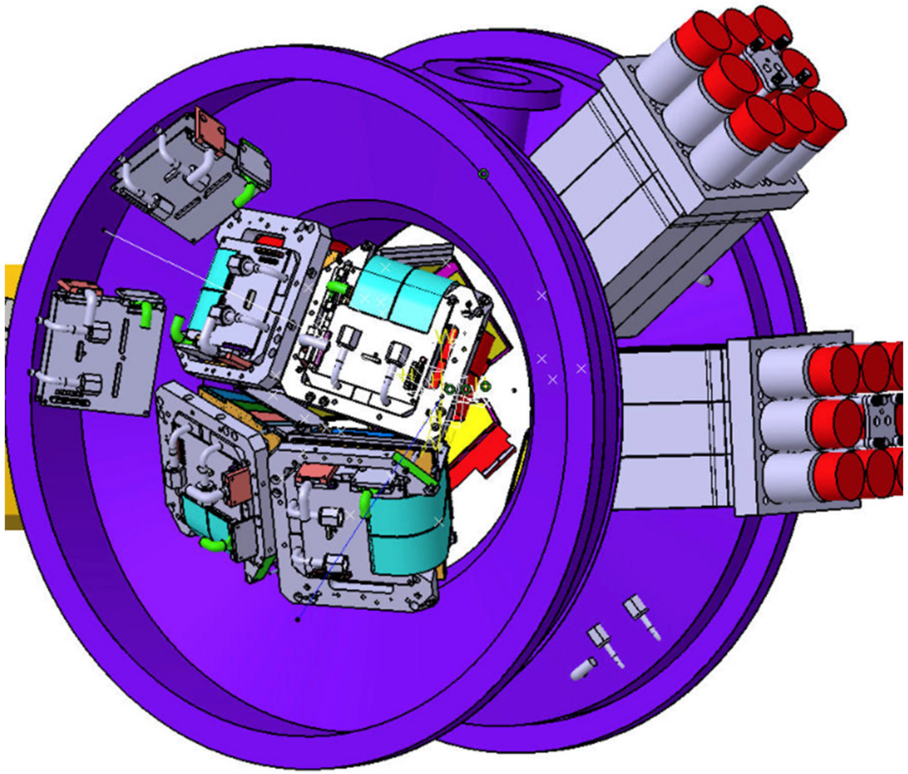


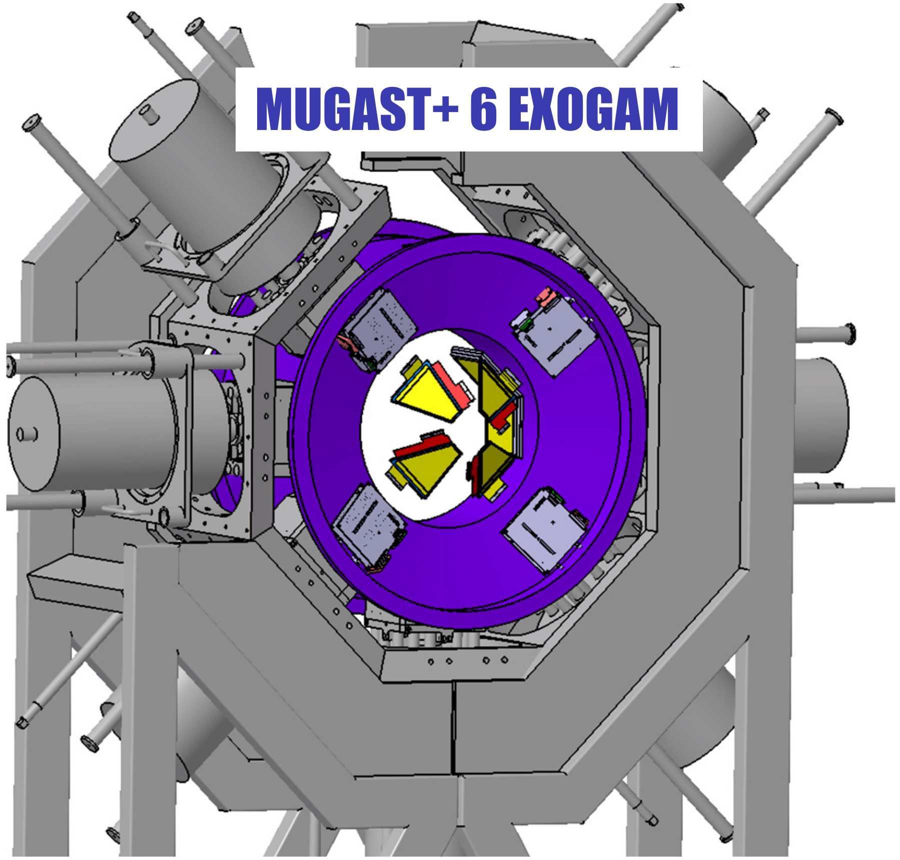
MUGAST with EXOGAM & PARIS

« 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