IPN
INSTITUT DE PHYSIQUE NUCLÉAIRE
ORSAY

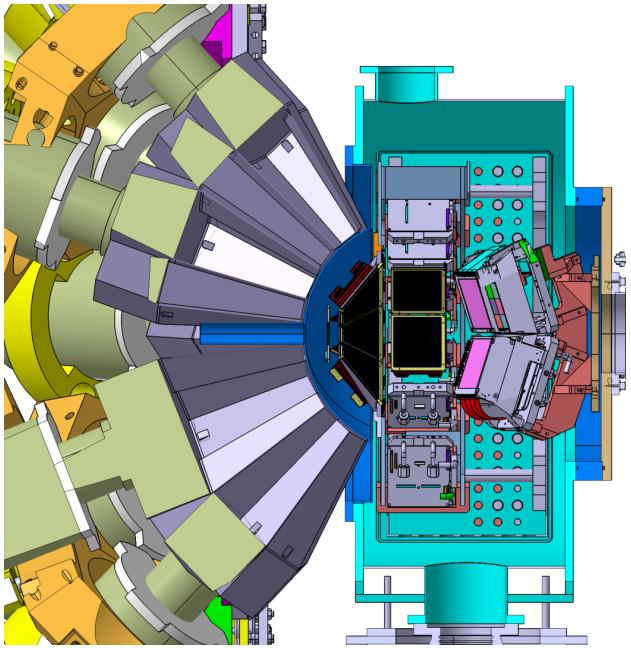
EURISOL

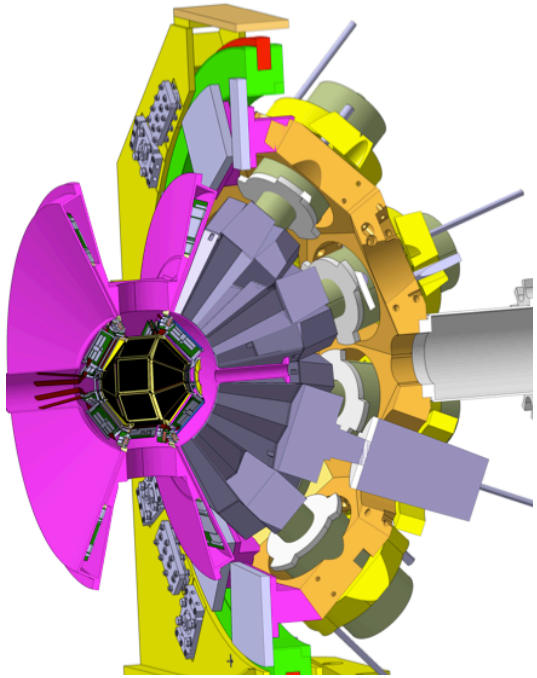
NuSPRASEN ENSAR2

Nuclear Structure Physics, Reactions, Astrophysics and Superheavy Elements Network

Silicon-technology for charged particle detection : new developments and perspectives

M. Assié, IPN Orsay

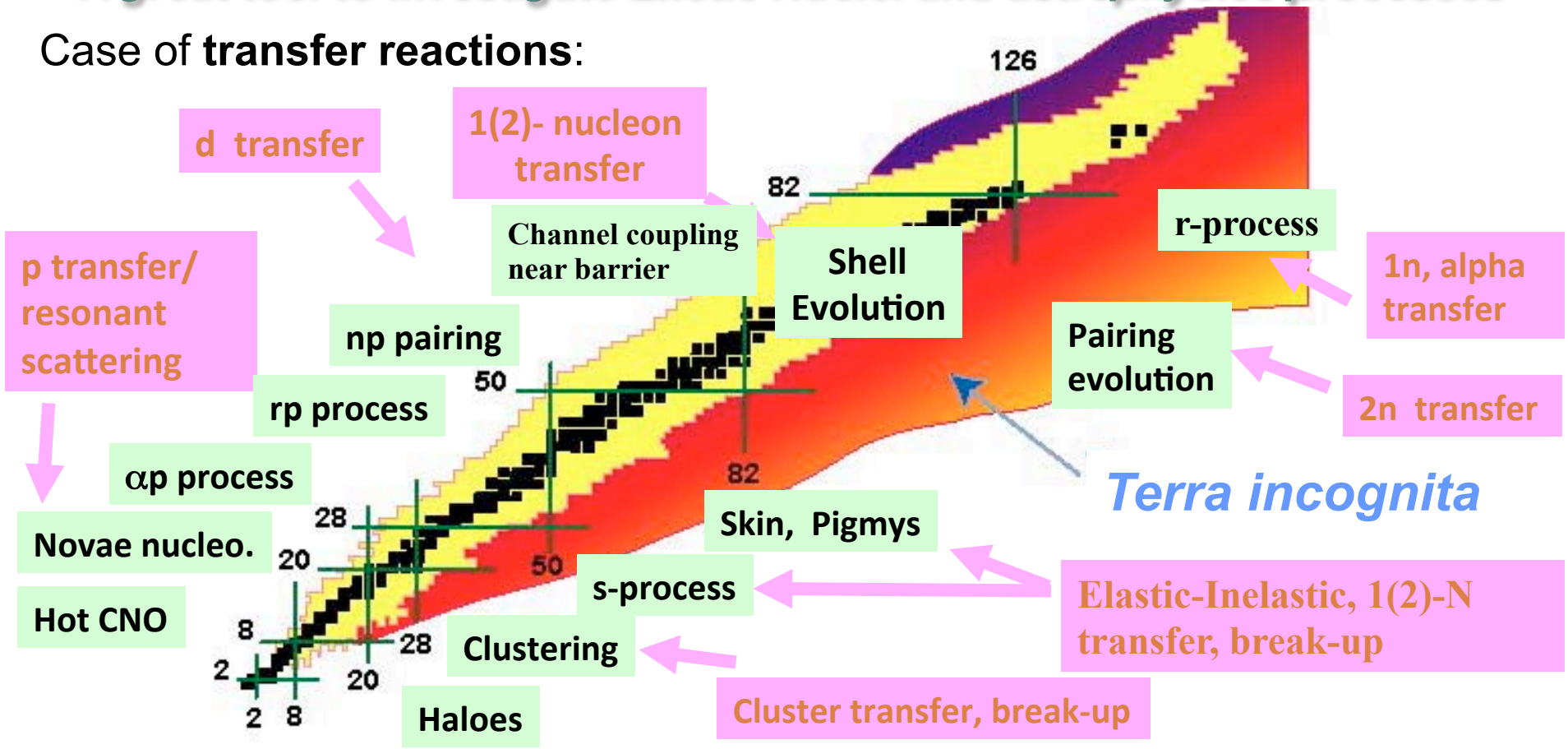




Direct reactions

A great tool to investigate Exotic Nuclei and astrophysics processes

Case of **transfer reactions**:



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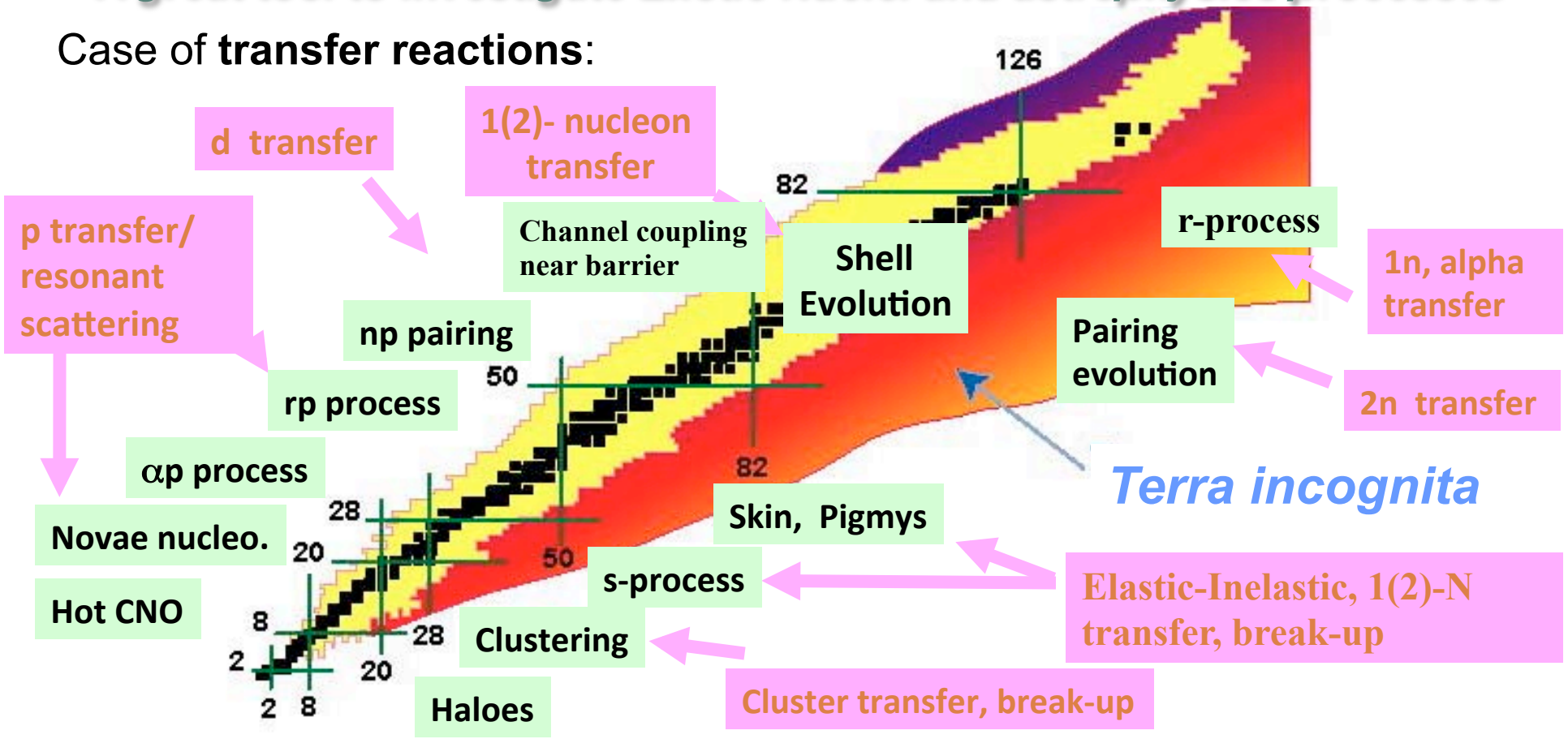

Good energy regime : few MeV/u → few tenths of MeV/u

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

Detect the recoil particle with high accuracy

Silicon technology

Direct reactions

A great tool to investigate Exotic Nuclei and astrophysics processes

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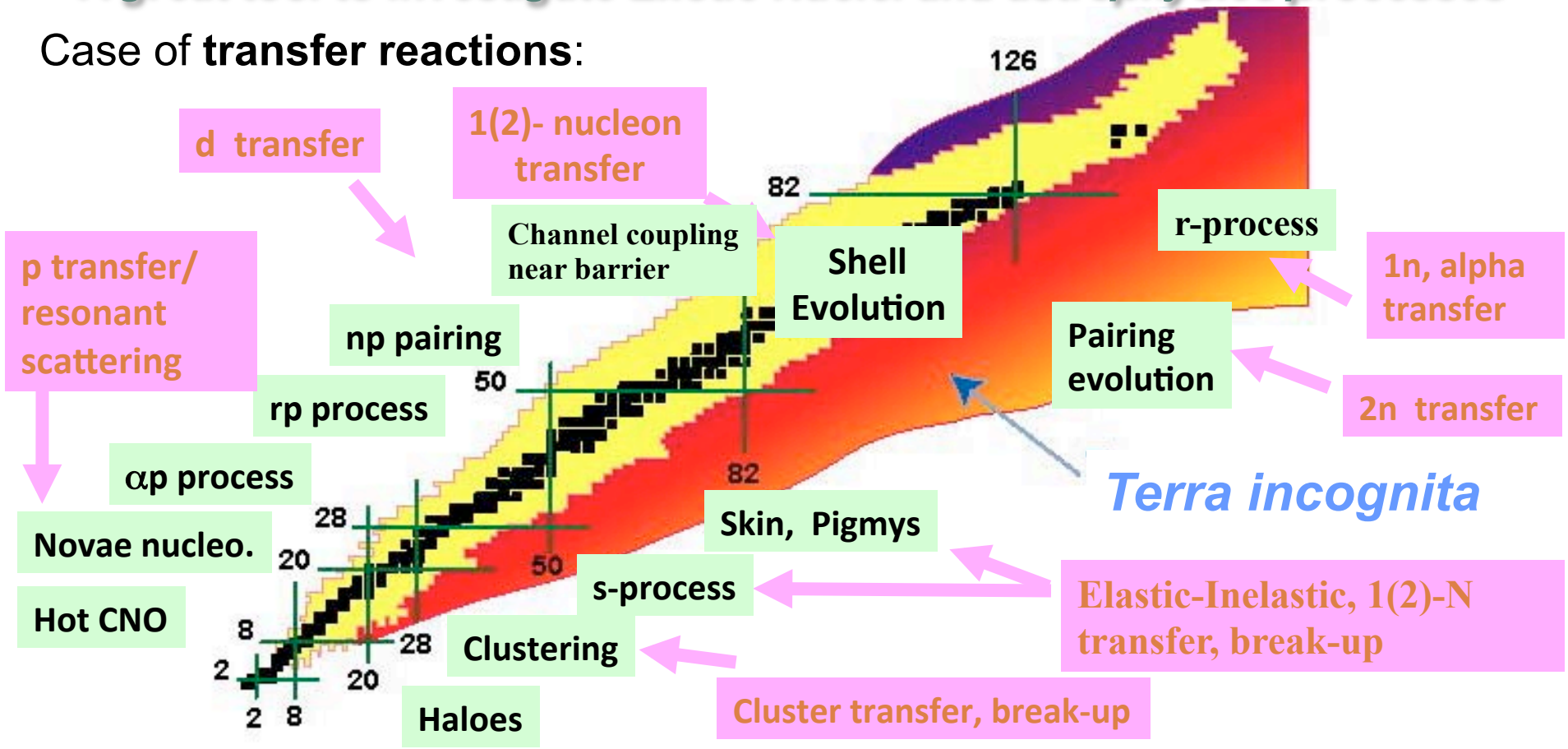

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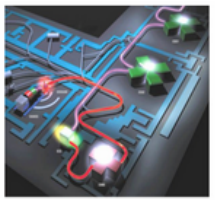

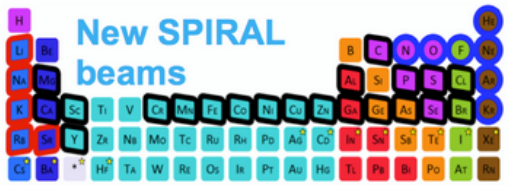

ISOLDE

SPES exotic beams for science

FAIR

Silicon-based detectors : two strategies

Difficulties with current detectors (T-REX, MUST2, Tiara…):

- particle identification at low energy (like t/^{3}He, ^{6}Li/^{6}He) based on ToF
- excitation energy resolution (dominated by target effects)
- coupling with gamma arrays

Silicon-based detectors : two strategies

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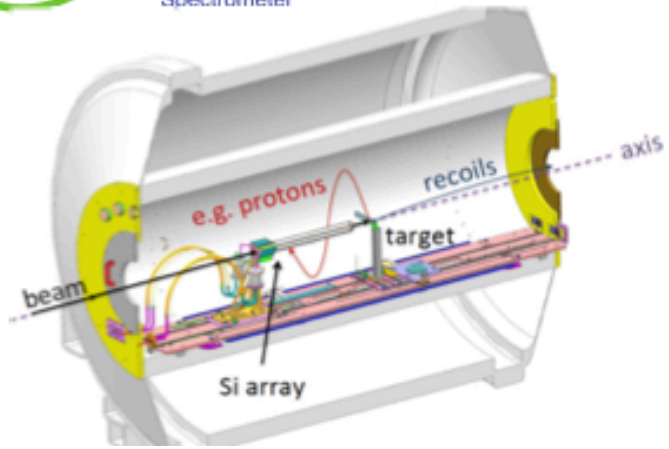
ISOLDE Solenoidal Spectrometer

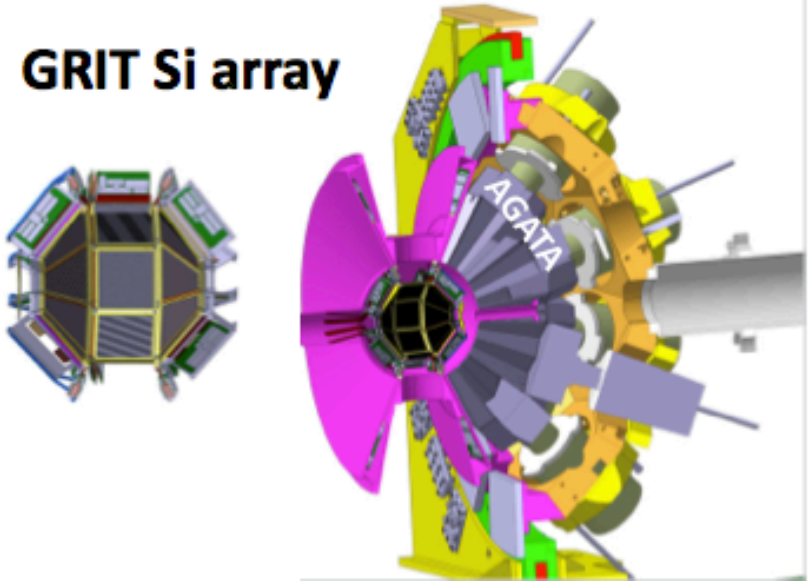


- avoid kinematics compression

to improve energy resolution

- Coupling with gamma : difficult
- solid/gas targets

GRIT Si array



- Identification by PSA technique
- high granularity -->nb channels
- coupled state-of-the-art gamma array

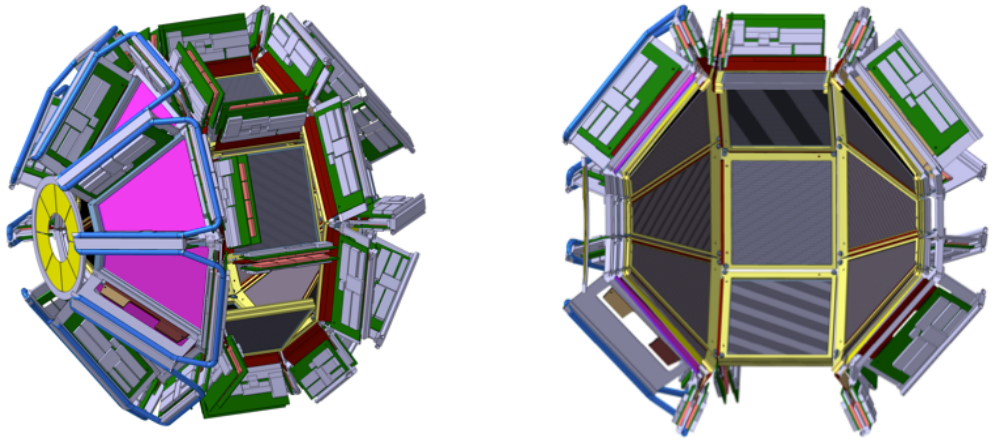
- any type of target (cryogenic,…)
- nTD type DSSSD

GRIT : Granularity Resolution Identification Transparency

4π Si array fully integrable in PARIS/AGATA/EXOGAM2/Miniball

Collaboration : INFN Padova - IPN Orsay – Surrey – LPC Caen –BARC Mumbai

Direct reactions measurement and particle-γ coincidence



. **Energy resolution (gamma) and good efficiency**

. Good **granularity** (pitch <1mm)

. radius = 23cm (defined by gamma array)

. **PSD** to identify low energy particles (1st layer)

. **Integrated electronics** (iPACI, PLAS) designed by IPN & INFN

. Integration of **special targets** **(cryogenic ,Chymène…)**

. **Versatile & transportable detector**

Layers of Silicon

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

2 main shapes : square & trapezoid, large area

Physics cases

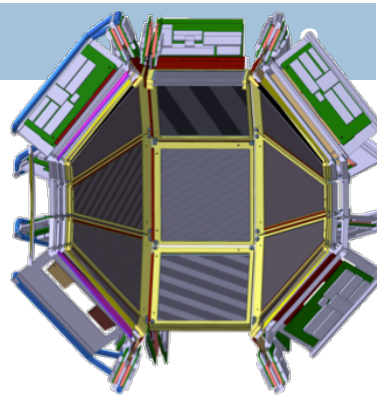
13 LoI for Spiral2

. Shell evolution
. Pairing
. Clusters
. Near Barrier reactions
. Astrophysics

+ **1 LoI ISOLDE**

www.grit.in2p3.fr

Silicon detectors for GRIT



New geometries - New packaging (thin frames, kaptons 90 deg.)
New technology : nTD, 4 deg. cut, reverse mounted
Thin and thick DSSD 6 inch

Trapezoidal DSSSD

Received from Micron Semiconductors:
- **2nd prototype** (re-designed) IPN
- **4 pre-series** IPN –Surrey-Santiago

received feb. 2017 and validated (alpha source).

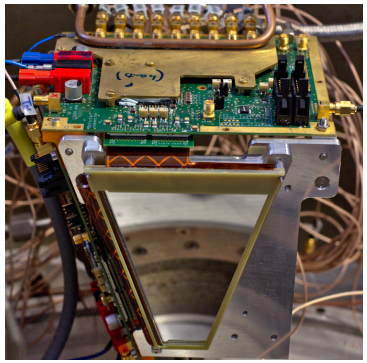
Squared DSSSD

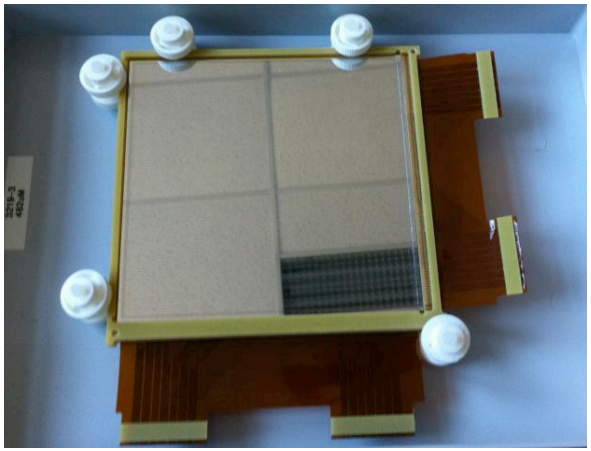
Received from Micron Semiconductors:
- **2 prototypes** 500um INFN
- **1 prototype 1.5mm** INFN

received feb. 2017
validated with alpha source

Test bench @ IPNO :
- analog (MUFEE) : 128X+128Y

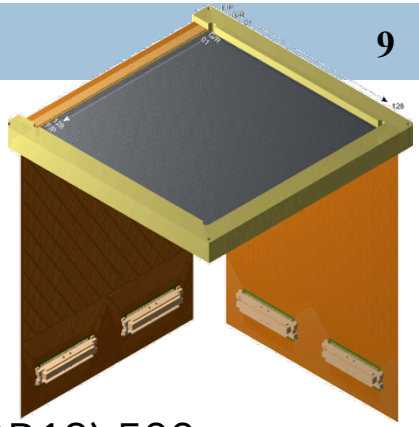
- numerical (iPACI): 9X+9Y



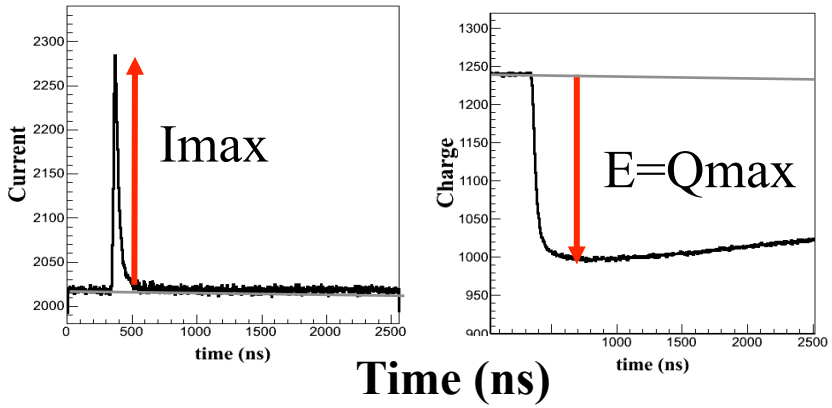


In-beam test @ ALTO end 2017
PSD for the trapezoid detectors

Pulse Shape Analysis for Z=1 particles : Current amplitude

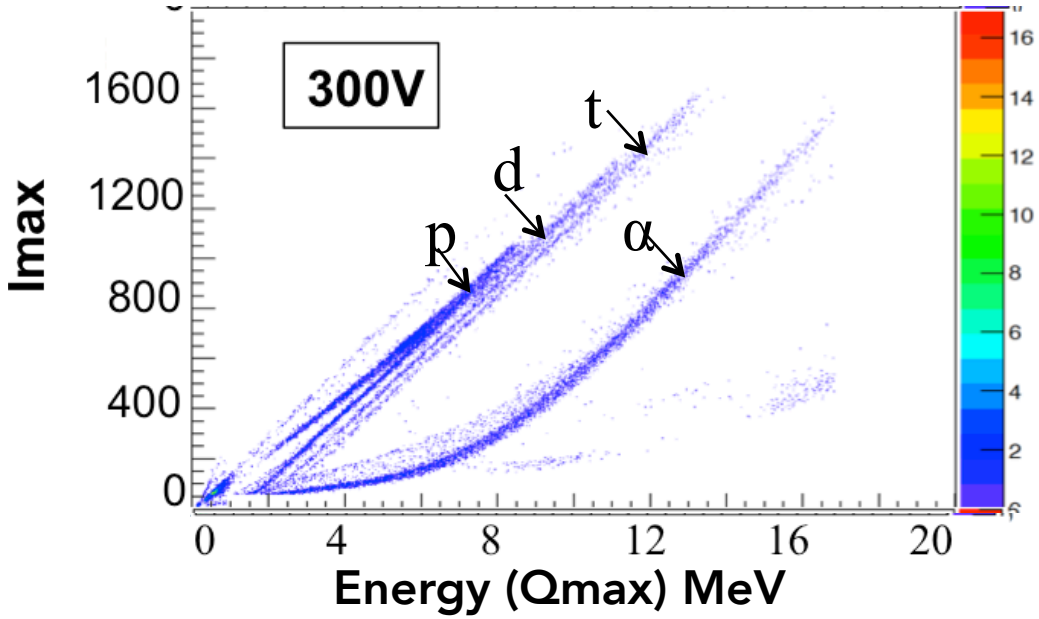


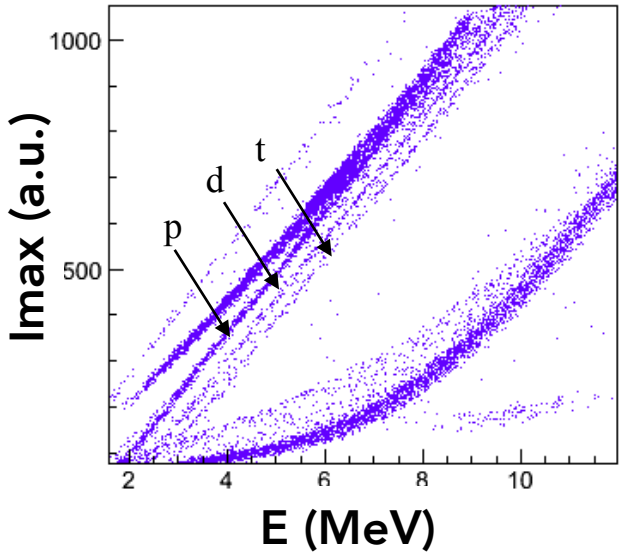
➡ Measurement of $^{7}Li+^{12}C$ at ALTO



Experimental set-up :

- Square nTD DSSSD (BB13) 500um, pitch=475um
- PACI (discrete) preamplifier (I&Q)
- MATACQ digitizers (1GHz, 2048 samples)

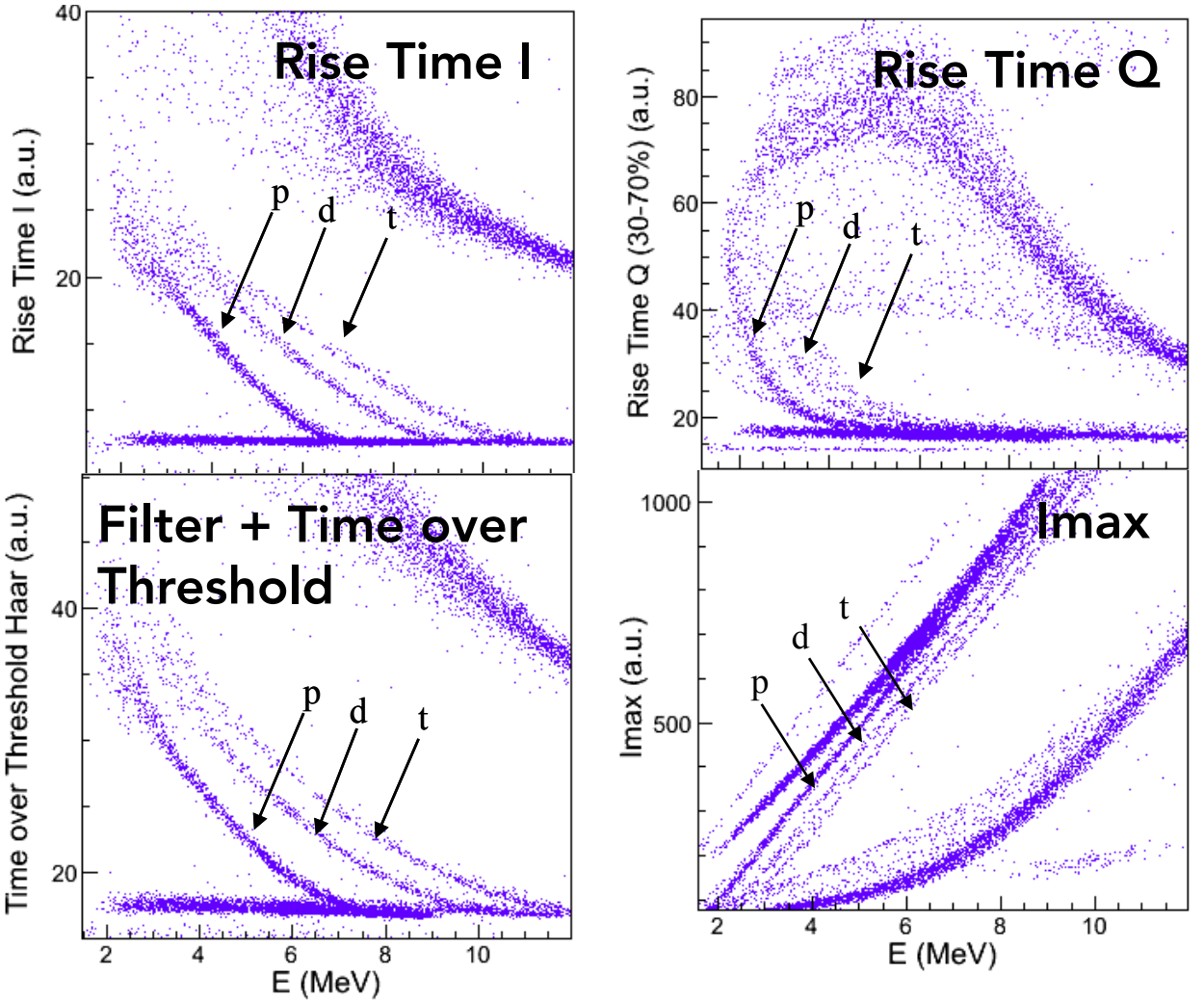




M. A., B. Lecrom et al EPJA (2015)

Pulse Shape Analysis for Z=1 particles : Other observables

FoM	p/d	d/t
Imax	3.2(2)	2.2(2)
ToT Haar	3.5(2)	2.2(2)
RT Q	1.5(2)	0.9(2)
RT I	3.0(2)	1.9(1)



M. A., B. Lecrom et al EPJA (2015) / B. Genolini et al, NIMA 2014

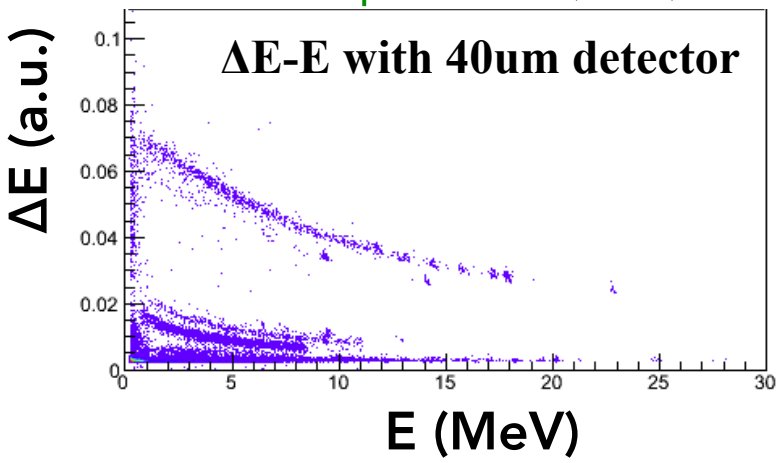
➡ Best observable without filter : amplitude of current signal

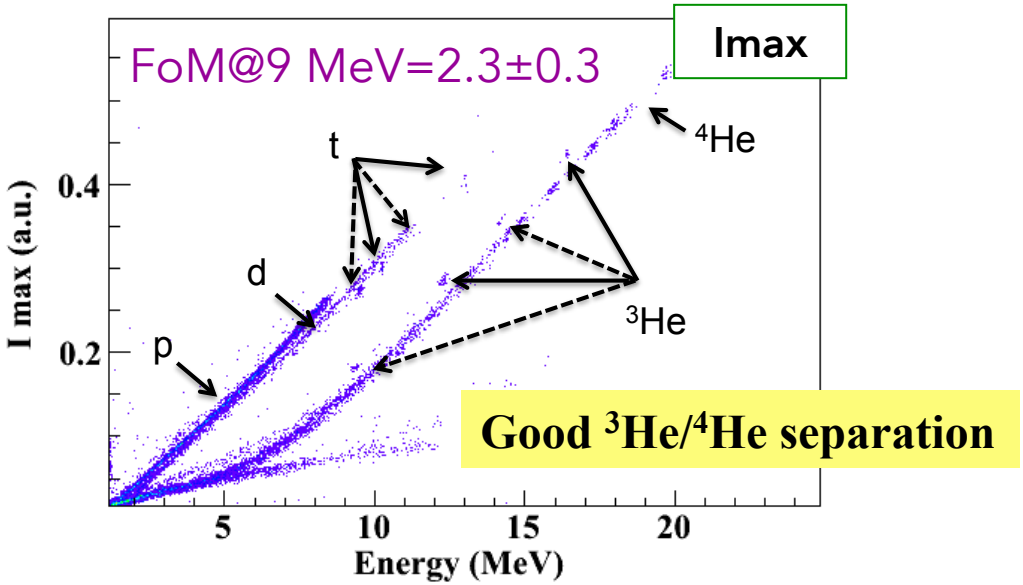
➡ Need for I,Q,T for each channel

PSA for Z=2 particles : Several observables

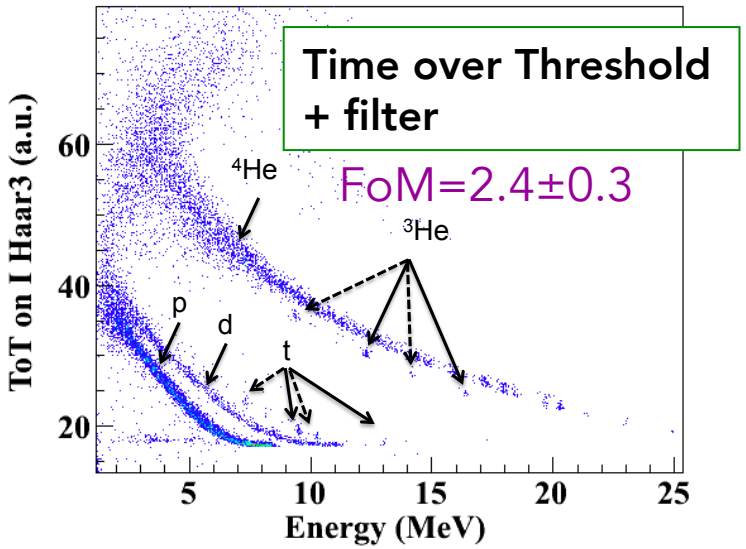
➡ Experiment @ ALTO to study Z=2 particles : **(d,^{3}He) on mylar**

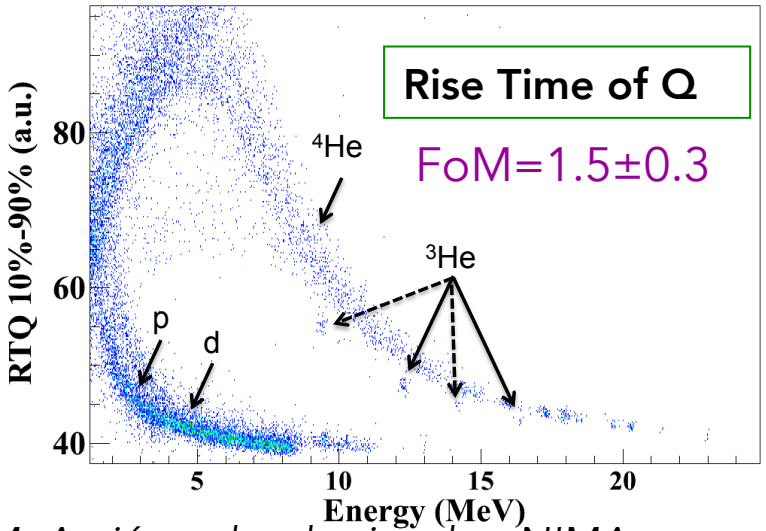
➡ ΔE-E technique vs PSA (Imax)





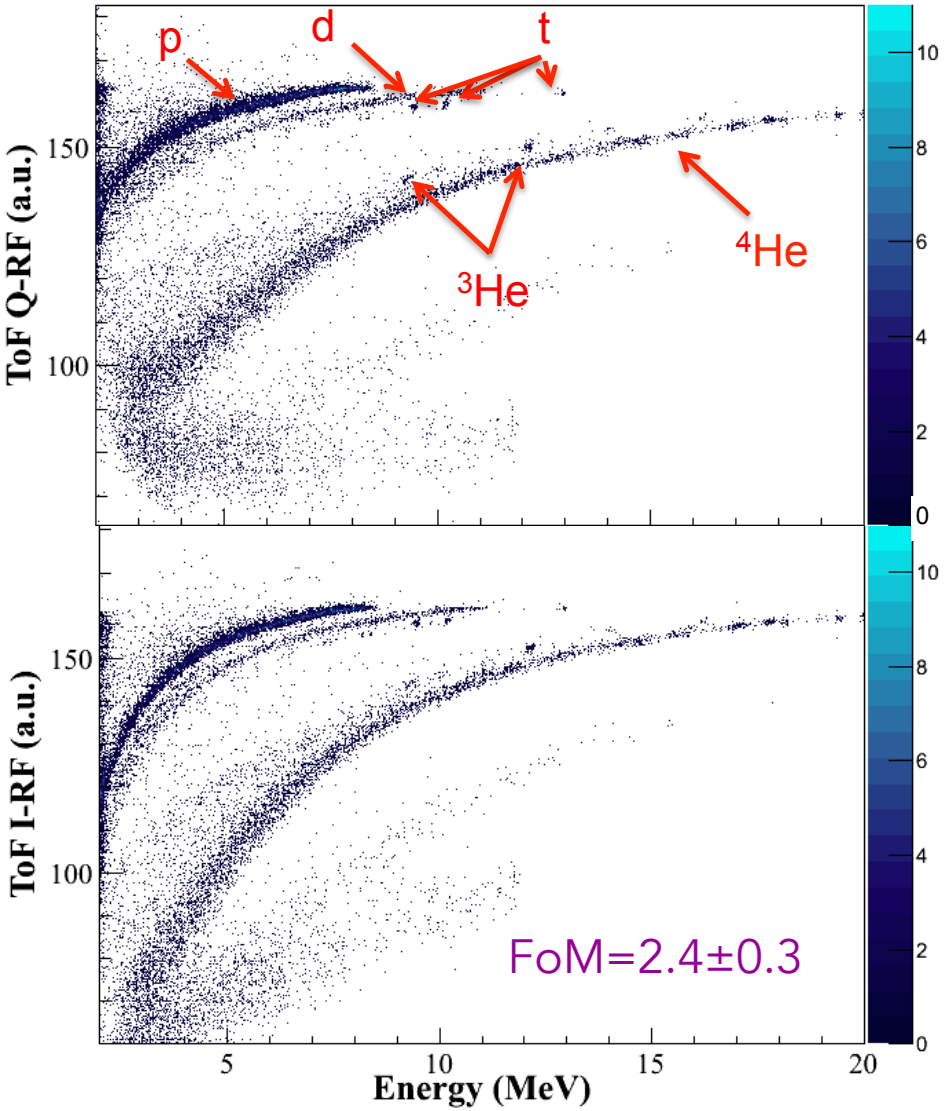
➡ Other observables

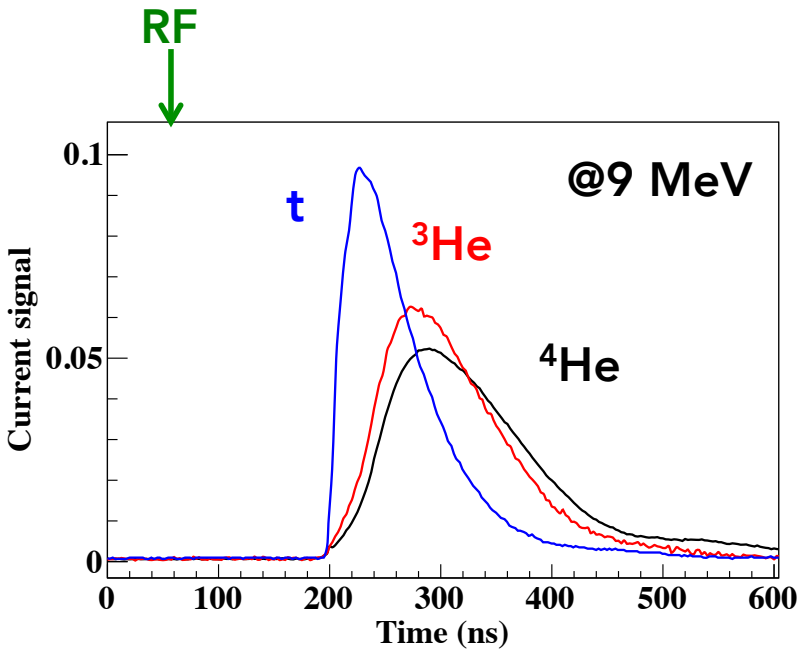




M. Assié et al, submitted to NIMA

PSA for Z=2 particles : digital Time of flight



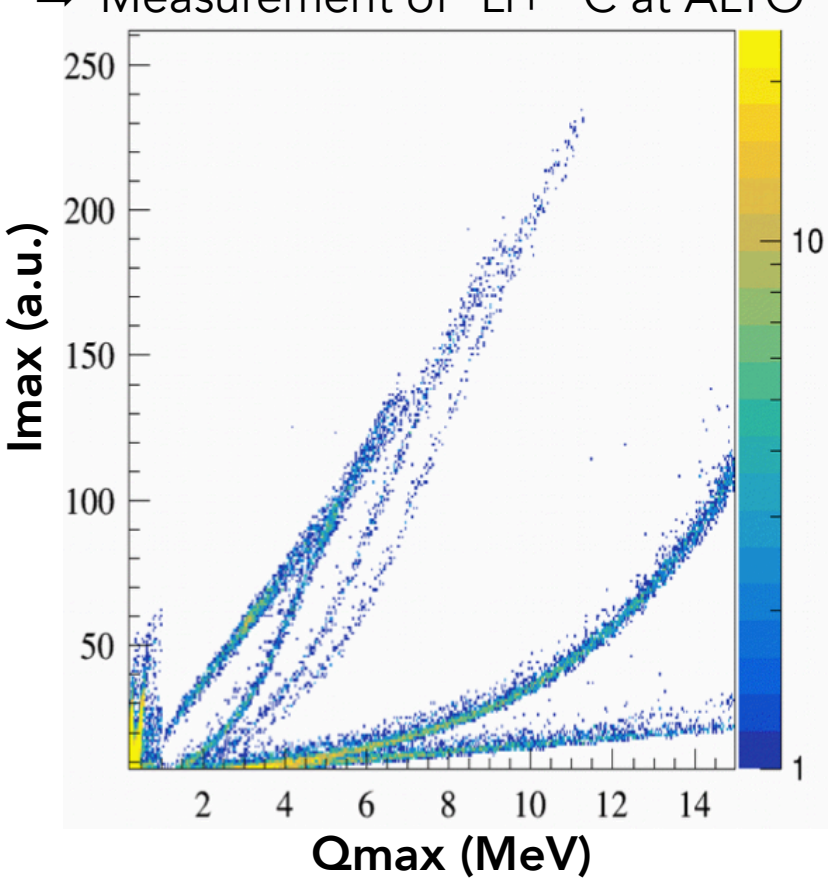


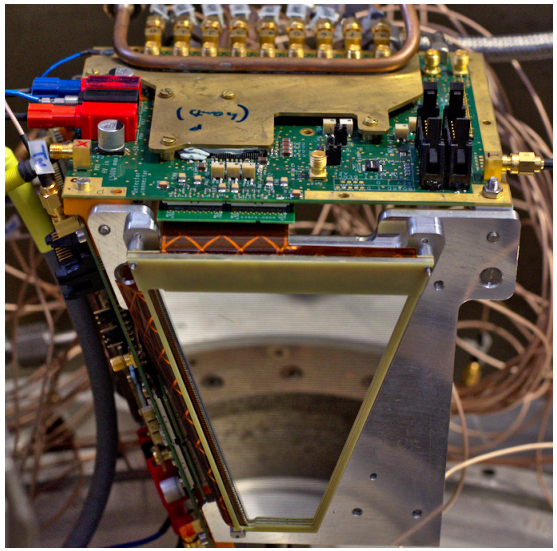
Very good separation of t, ^{3}He, ^{4}He by digital ToF technique

M. Assié et al, submitted to NIMA

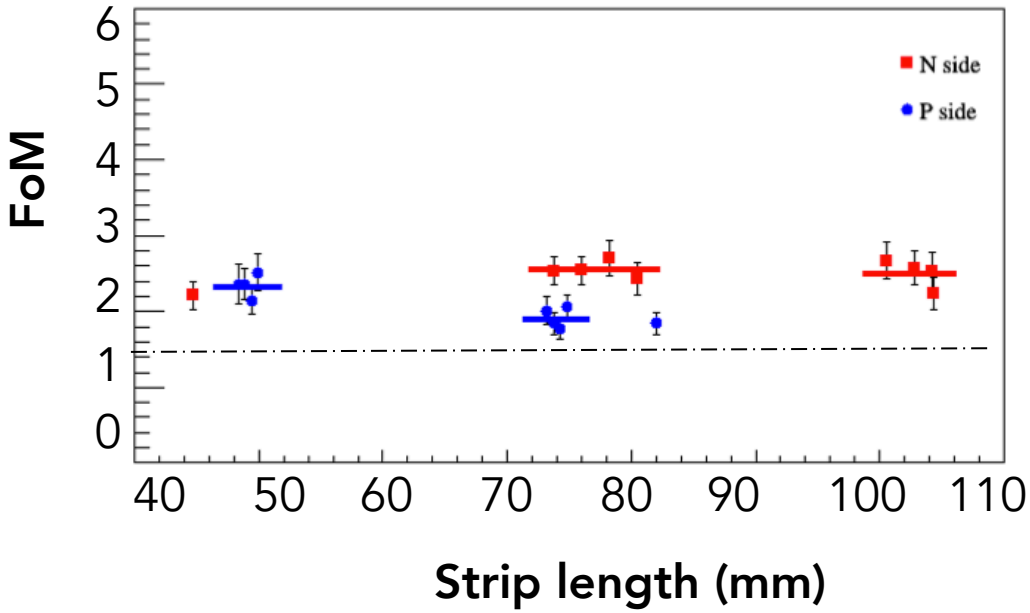
PSA with trapezoid detectors from GRIT

➡ Measurement of $^{7}Li+^{12}C$ at ALTO





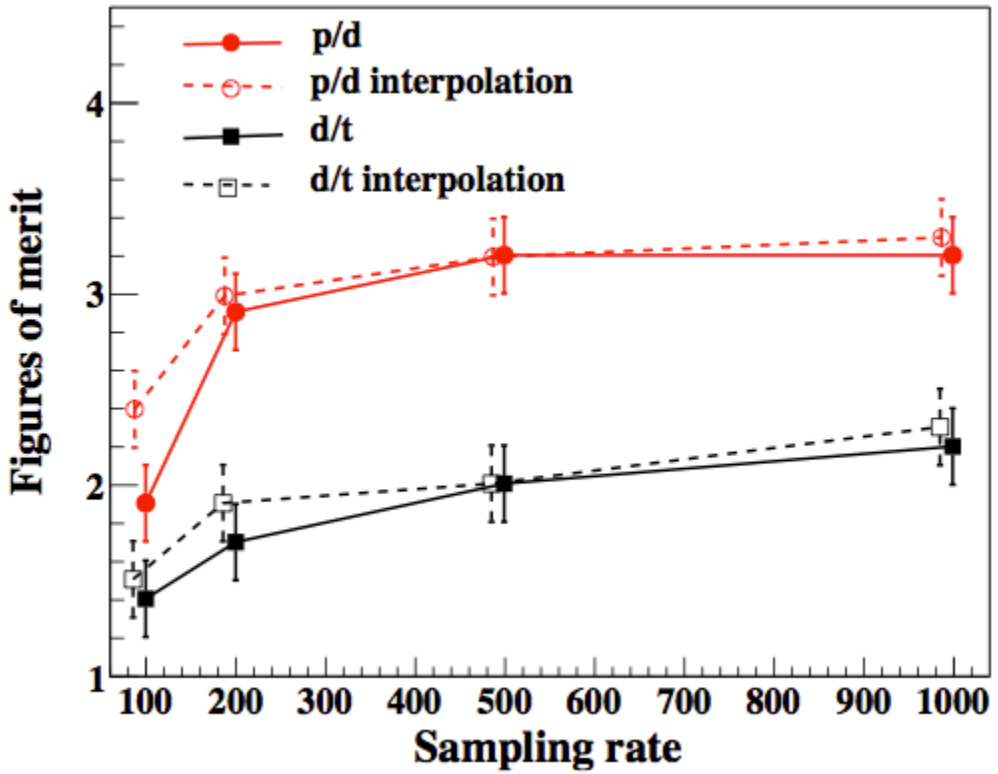
For p/d @ 3.5 MeV



➡ The length of the strip does not affect PSD of light particles

Electronics specifications : Sampling rate

- Effect of bias : best compromise is 300V (depletion)
- Other observables and Filters (Haar wavelets) : Imax or Haar+ ToT
- Effect of sampling frequency : loss of discrimination below 250MHz



For Z=1, p, d, t :

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

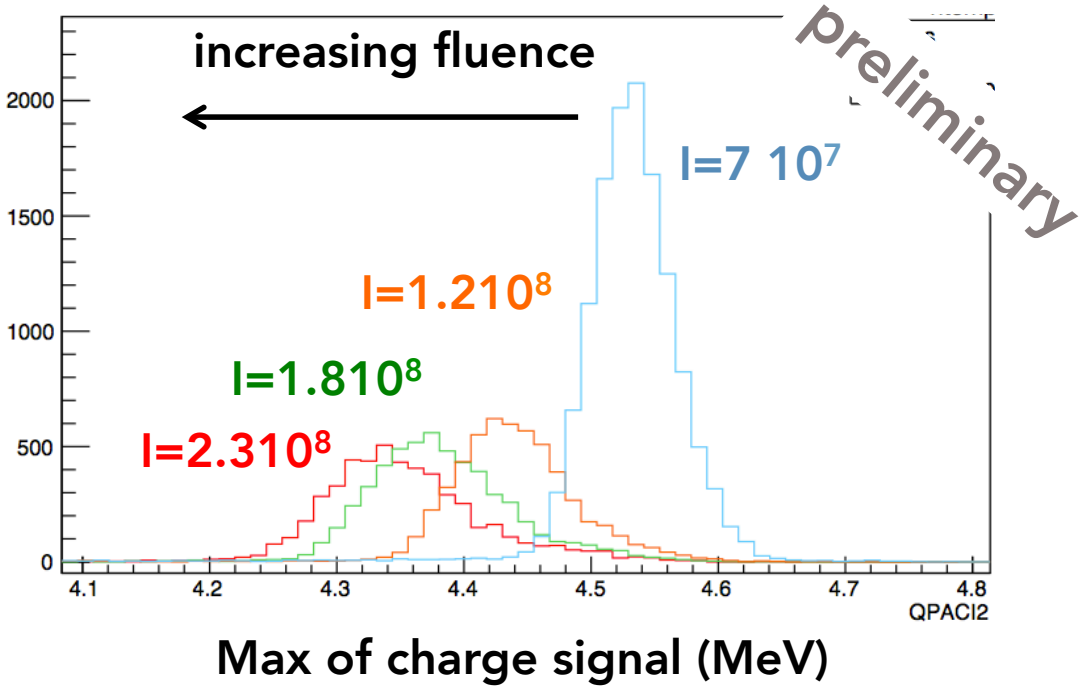
➡ **Analog electronics ? Peak finder ?**

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

M. A., B. Lecrom et al EPJA (2015) / B. Genolini et al, NIMA 2014

Radiation damage with light particles

➡ Experiment @ ALTO to study radiation damage with light particles



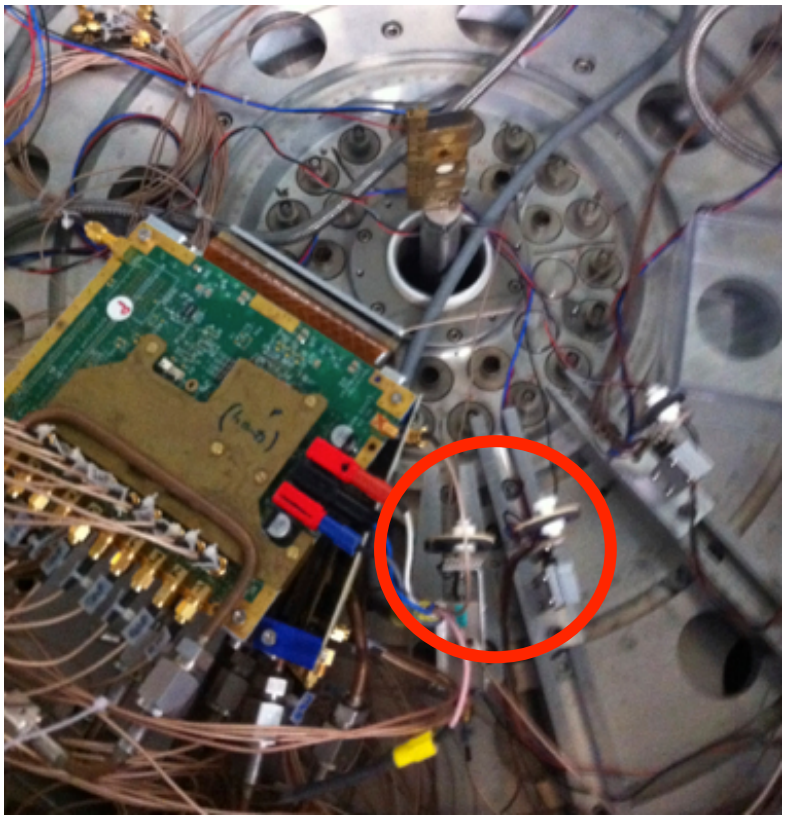
Max of charge signal (MeV)

Maximum of charge signal decreases and resolution worsen

Set-up :

- 4 MeV proton beam+ Au
- 1cm^2 nTD pad Silicon detector

same wafer as trapez.



GRIT electronics

Preamplifiers

iPACI (IPNO): integrated version of PACI

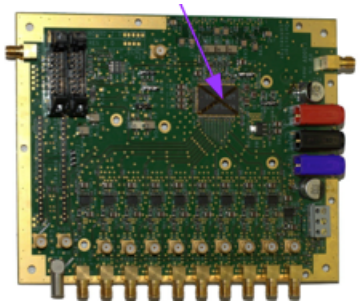
- version 1 : june 2015

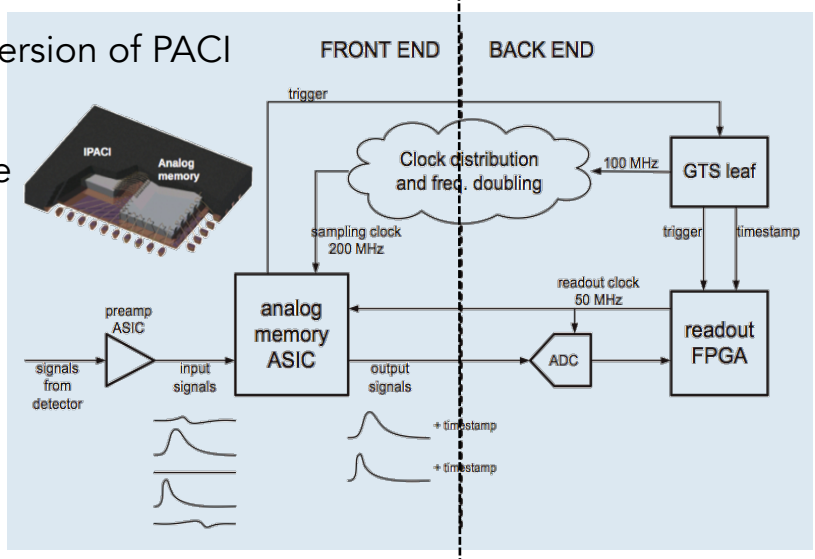
fully tested with prototype

E Range : 50 MeV

Current : +/- 1.5 V

Noise : 7 keV (FWHM)





- version 2 (fast & slow shaper, TAC) automn 2018

ToT Milano (INFN)

- version 1 : 2015, fully tested, never tested with high energy particles.

Sampling

PLAS (R. Aliaga, Valencia)

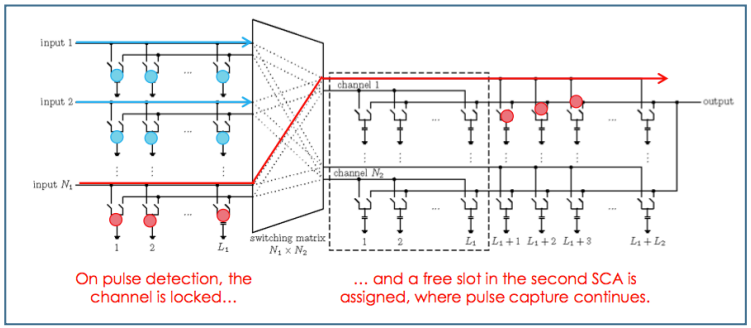
ASIC analog memory based on switched capacitors

- version 1 received sept. 2016

- version 2: submitted may 2018

FASTER v3 (D. Etasse, LPC Caen)

--> adaptation for our needs



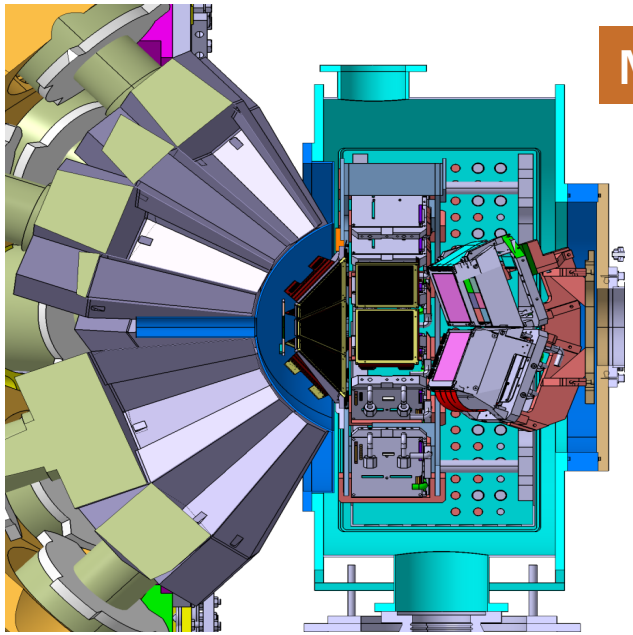
R. Aliaga, NIMA 800 (2015) 34

Tests 2019 : coupling iPACI or ToT +PLAS+ FASTER

Timelines & facilities for GRIT

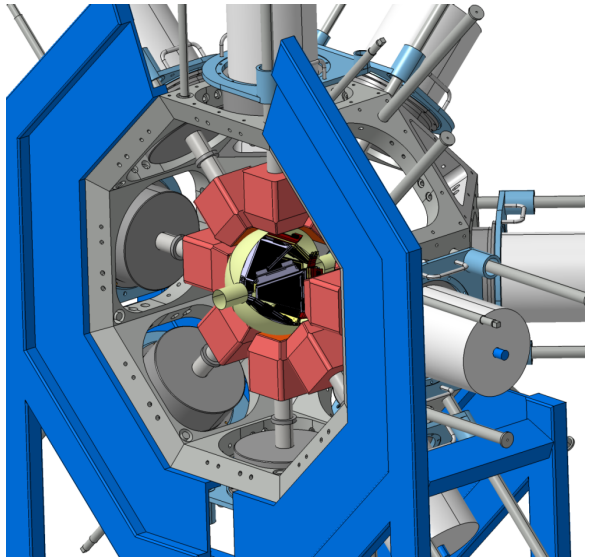
2019 2020-2021 2021-2022

MUGAST-AGATA-VAMOS@ GANIL



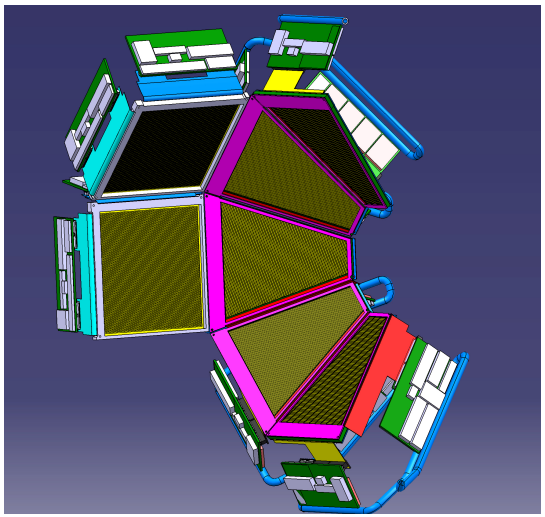
New Spiral1 beam
VAMOS-AGATA ε ~13%
12 DSSD, single-layer
specific targets
PId : ToF

MUGAST-EXOGAM@GANIL



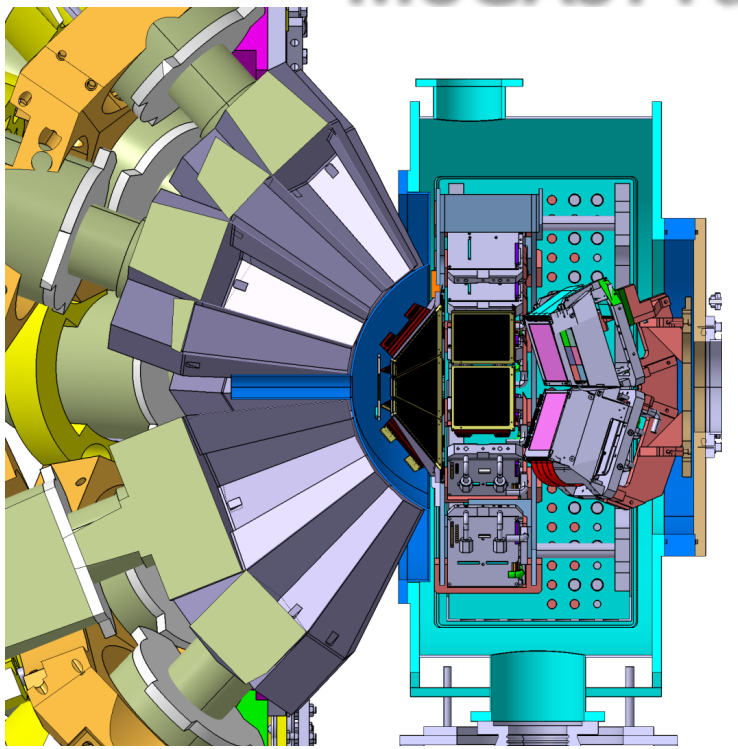
4-5 telescopes (2 layers)
spherical config.
Close config.(85 mm)

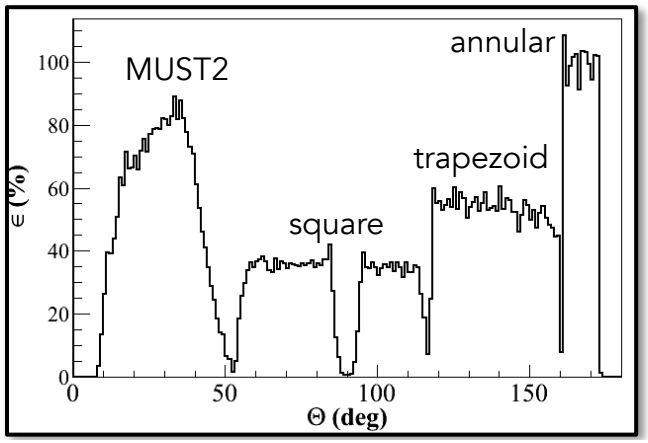
GRIT demonstrator@ISOLDE



LoI GRIT @ ISOLDE
7 detectors
PId : PSA (GRIT electronics)

MUGAST : a first step towards GRIT





Campaign beginning of 2019

- **New Spiral 1 beams** (low energy)

- **AGATA**
  . very high energy resolution
  . good efficiency : 13% at1.3MeV in 2019 @ 18cm
  (depending on number of clusters)

- **MUGAST**
  . one-layer of Silicon backward & 90 deg.
  → well-suited for stripping measurements
  . specific target (cryogenic)

- **VAMOS** : large acceptance spectrometer at 0 degree

Physics cases :

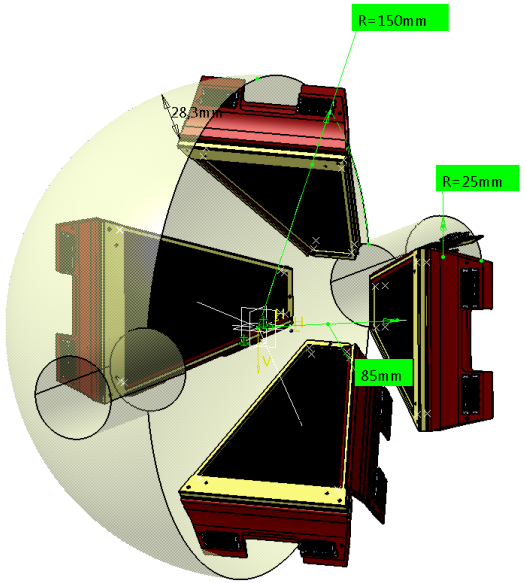
Accepted : Nuclear astrophysics : $^{15}O(^{6}Li,d)$
Unbound states : $^{14}O(p,p^{(\prime)})$ resonant elastic scatt.

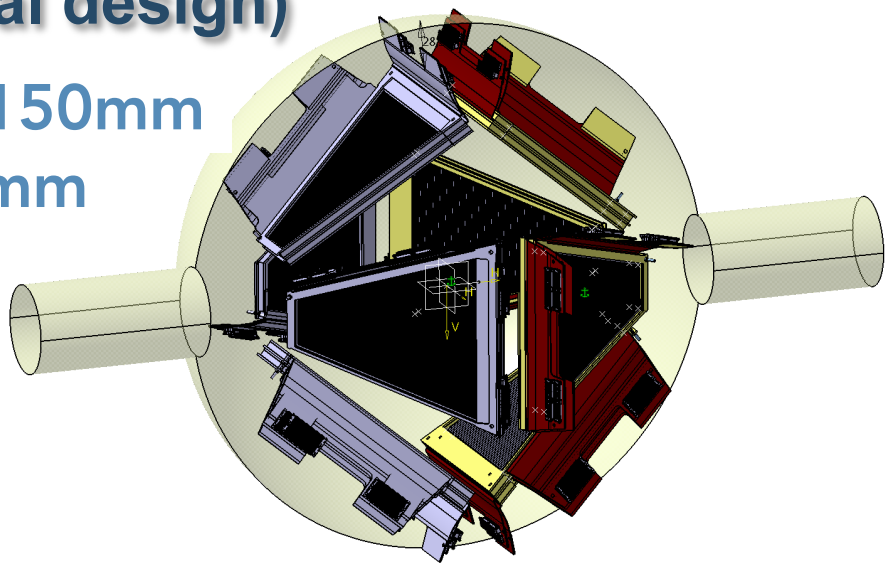
Submitted : Shell evolution, island of inversion, shape coexistence, pairing ….

GRIT Demonstrator with EXOGAM
(Conceptual design)

Chamber radius: 150mm

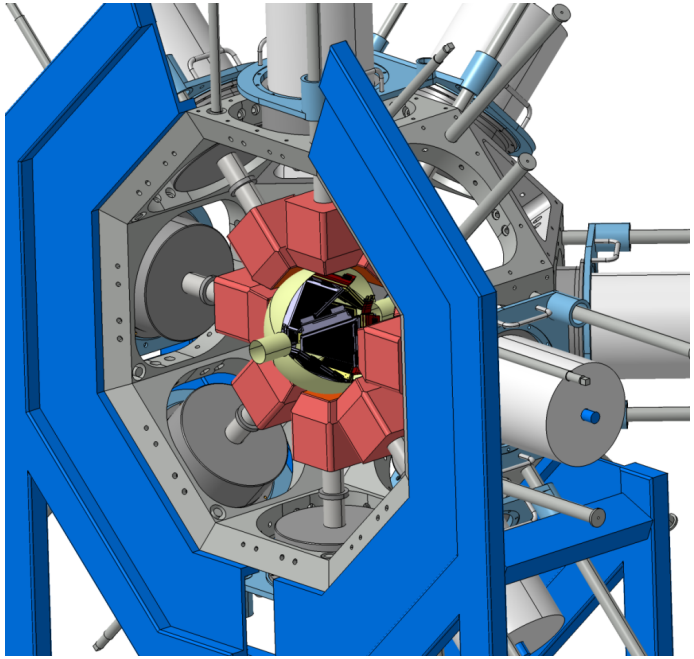
D_{target} = 85mm





- Conceptual design based on the use of 2x4 Trapezoids (2 layers : 0.5+1.5mm)
- FEE to be deported upstream and downstream the chamber

Design: E.Rindel, IPNO & LPC Caen



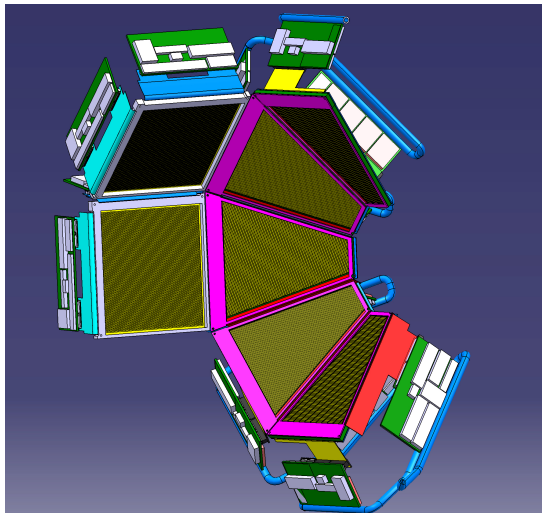
GRIT Demonstrator with Miniball @ ISOLDE

- **LoI for GRIT @ ISOLDE** (W. Catford)

Complementary reactions to be measured :

- LoI to measure ^{44}Ti(^{6}Li,d) and (^{6}Li, alpha) to study pairing and quartetting in nuclei

- Beams of interest Cr, Ge, Zn… complementary to Spiral1 new beams



+ Miniball

- **Particle Identification :**

Beam time structure --> no ToF can be used

only PSA technique ! --> new GRIT electronics

Conclusions / Summary

- **GRIT : development phase**

  - detectors prototypes + pre-series OK
  - design of numerical electronics : iPACI + PLAS + FASTER
  - mechanics to be adapted as function of electronics consumption

  --> First experiment with demonstrator foreseen end 2021 at ISOLDE

- **MUGAST : running soon !**

  - detectors prototypes + pre-series of GRIT
  - MUST2 electronics

  - AGATA-MUGAST-VAMOS campaign in april 2019

  - possibility to run with EXOGAM on LISE
  - moveable detector (experience with MUST2)