The GASPARD Project

GAmma **SP**ectroscopy and **PA**rticle **D**etection

D.Beaumel, IPN Orsay

- ✓ The GASPARD concept
- ✓ Current work on particle-gamma experiments
- ✓ LoI for SPIRAL2 phase 2
- ✓ Status & timelines of the project

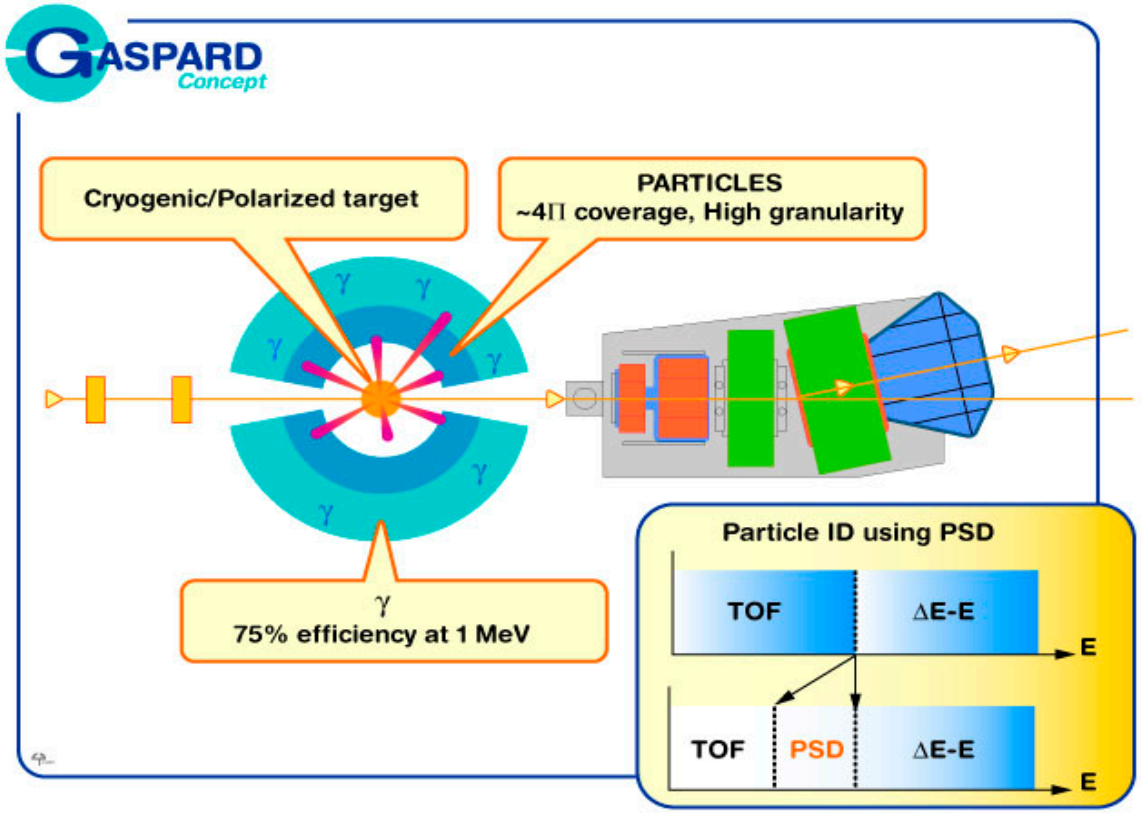
GASPARD CONCEPT

GAmma SPectroscopy and PArticle Detection

A new arrray for optimal study of reactions with SPIRAL2 beams

Optimized for PA –GA coincidences

- ***E* resolution gain>10 w/r particles only***
- ***High efficiency for γ w/r MUST2/TIARA/EXOGAM***
- ***Gamma spectroscopy of populated states***
- ***channel selection***
- ***…***



GASPARD : A 4π particle array fully integrable in major gamma arrays (PARIS, AGATA, EXOGAM2)

Other features of GASPARD

- ***Excellent PID for light particles***
  PSA technique for particle ID
- ***Integration of special targets***
  - ***Pure and windowless H or D***
  - ***Cooled ^{4}He or ^{3}He gas***
  - ***Triton targets for e.g. (t,p)***
    0^{+}_{2} states, pairing, etc…
  - ***Any solid target***
    e.g. ^{6}Li, ^{7}Li for p, α, … transfer
  - ***Polarized targets (require high intensities)***

- ***Capability to handle high intensity beams***
- ***Large dynamical range***
- ***Easy coupling with spectrometers***

Particle - γ detection for direct reactions studies

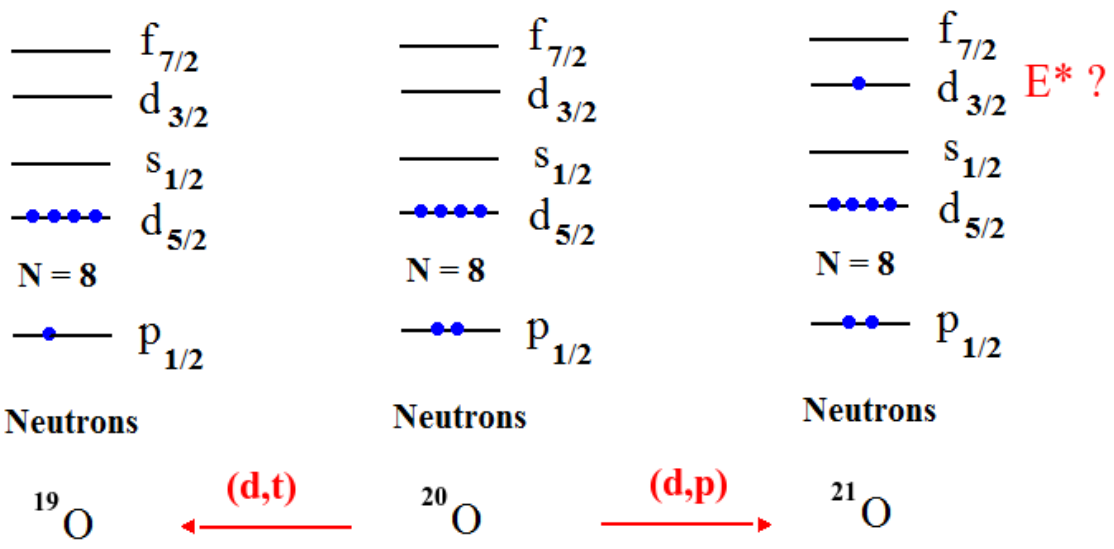
Some recent examples

Shell evolution in neutron-rich sd-shell nuclei using 1n transfer reaction on ^{20}O and ^{26}Ne

- **Motivation:**
  Measure accurately the development of the N=14,16 magic number across Neon and Oxygen isotopes

- **Method: 1-neutron transfer reactions**
  - ✓ **Directly probe the single-particle structure**
  - ✓ **Measure s.p. energies, shell gaps, spec. factors**
  - ✓ **Here: simultaneaous measurement of pickup and stripping reactions**

Case of ^{20}O :



These two experiments are the result of a France-UK collaboration :

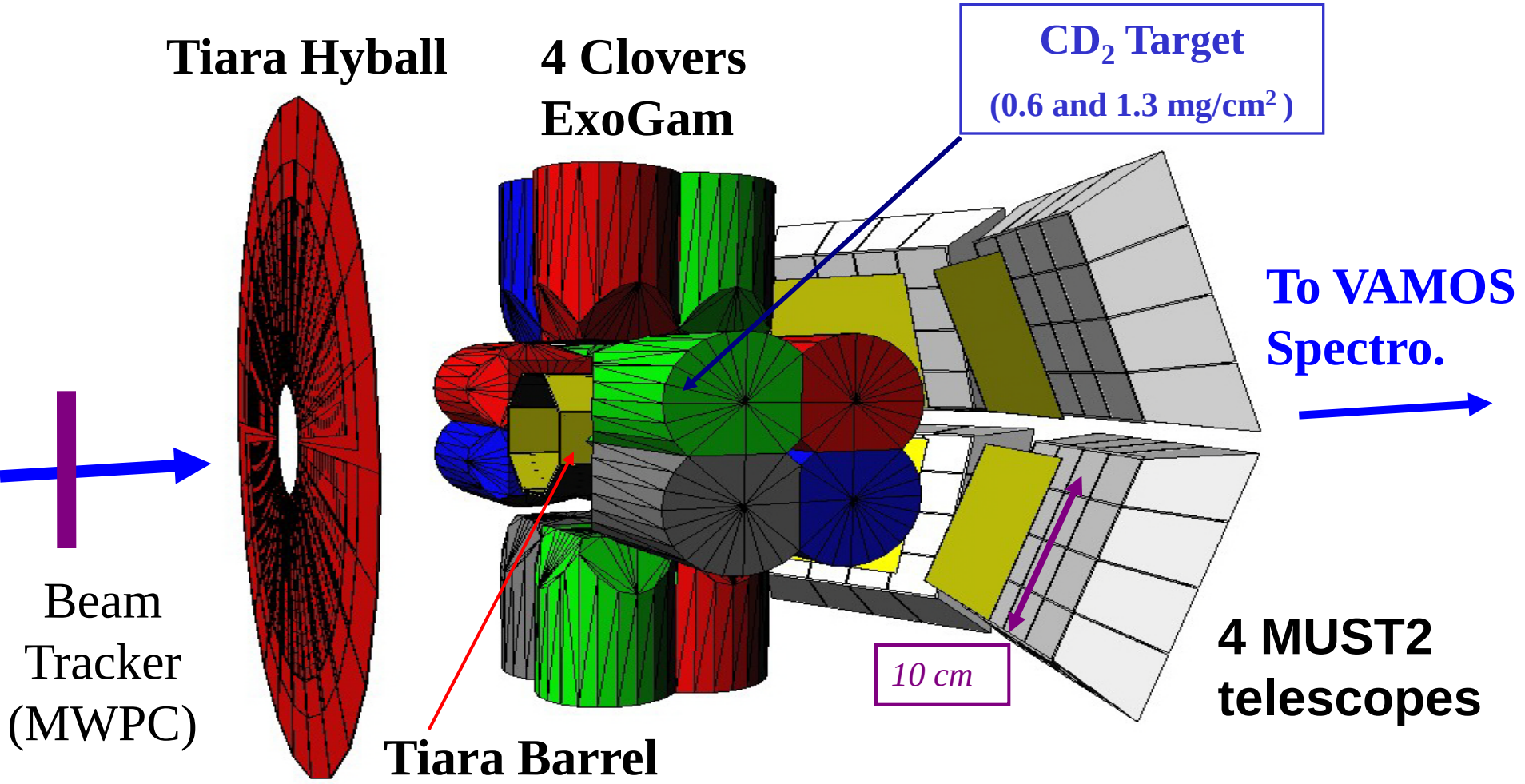
N. L. Achouri[2], H. Al Falou[2], N. I. Ashwood[3], D. Beaumel[1], Y. Blumenfeld[1], S. M. Brown[4], W. N. Catford[4], R. Chapman[7], M. Chartier[5], N. Curtis[3], F. Delaunay[2], B. Fernandez-Dominguez[5], C. Force[6], G. de France[6], S. Franchoo[1], J. Guillot[1], D. Gupta[10], P.Haigh[3], F. Hammache[1], M. Labiche[8], V. Lapoux[9], R. C. Lemmon[8], F. Maréchal[1], B. Martin[9], X. Mougeot[9], B. Mouginot[1], L. Nalpas[9], A. Navin[6], N. A. Orr[2], N. Patterson[4], B. Pietras[5], E.C. Pollacco[9], A. le Prince[2], A. Ramus[1], M. Rejmund[6], J. A. Scarpaci[1], N. de Séréville[1], I. Stefan1], O. Sorlin[6], J. S. Thomas[4], G. L. Wilson[4].

(1) Institut de Physique Nucléaire, Université Paris-Sud-11-CNRS/IN2P3 (France)
(2) LPC, Caen (France)
(3) U. Birmingham (UK)
(4) U. Surrey (UK)
(5) U. Liverpool (UK)
(6) GANIL Caen (France)
(7) U. West of Scotland (UK)
(8) STFC Daresbury Laboratory (UK)
(9) CEA Saclay (France)
(10) VECC Kolkata (India)

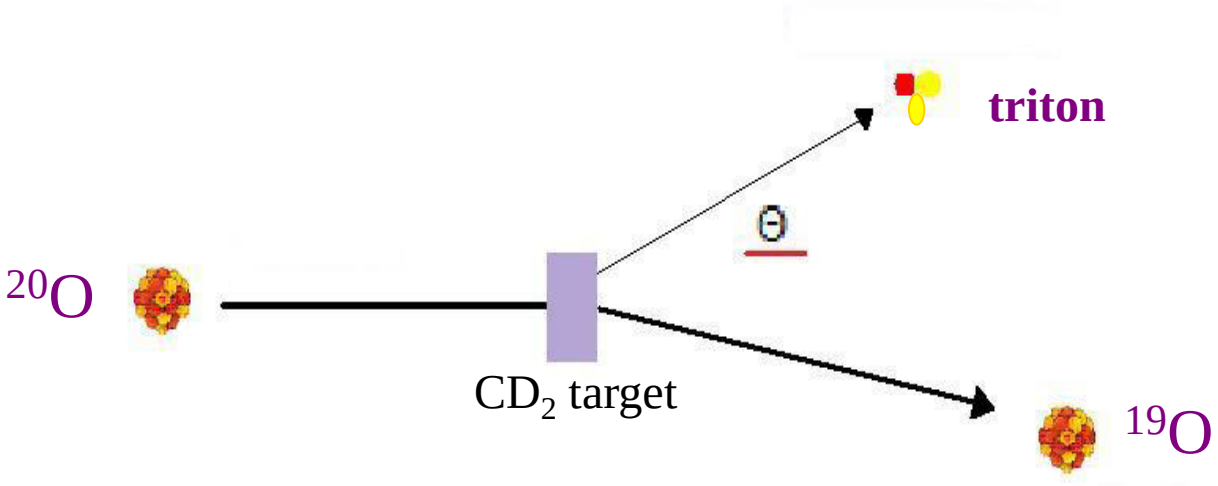
Preliminary results from:
A. Ramus (PhD student at IPNO)
J. Thomas (Postdoc at Univ of Surrey)

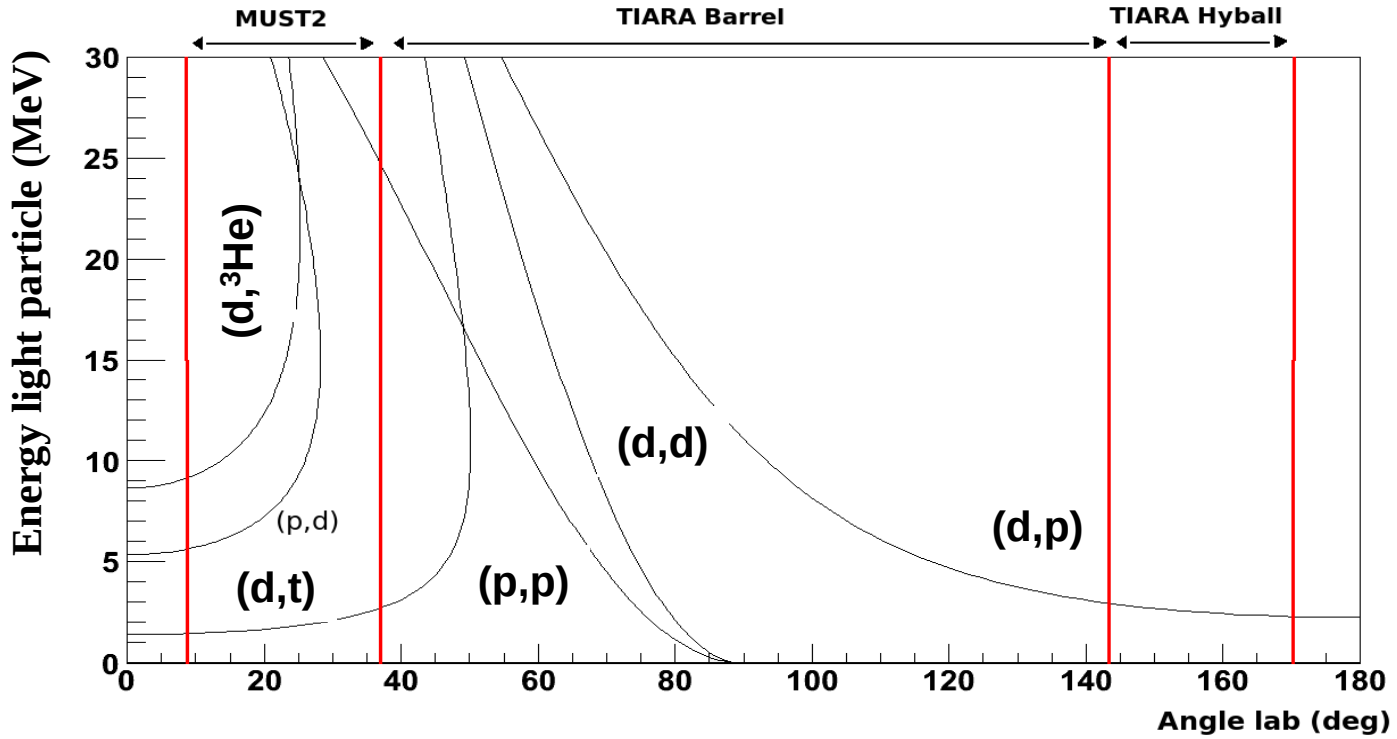
Experimental approach

A combined setup

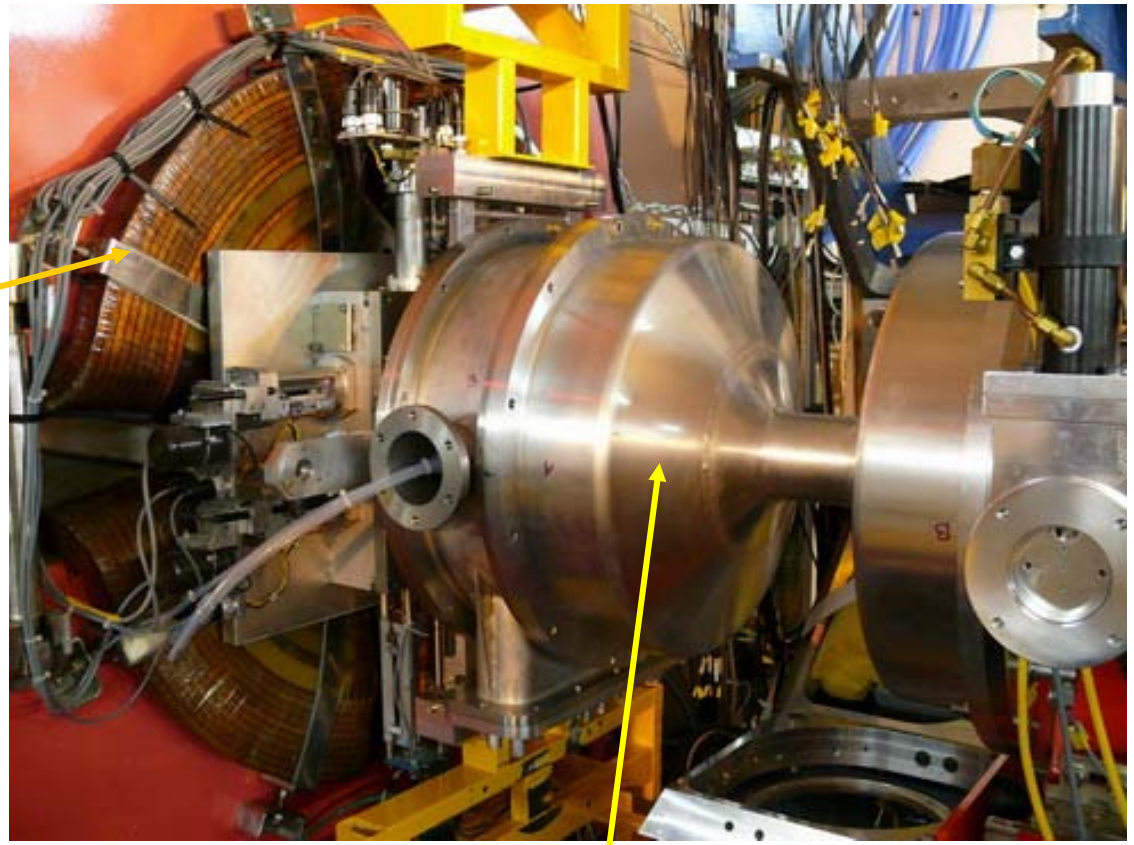


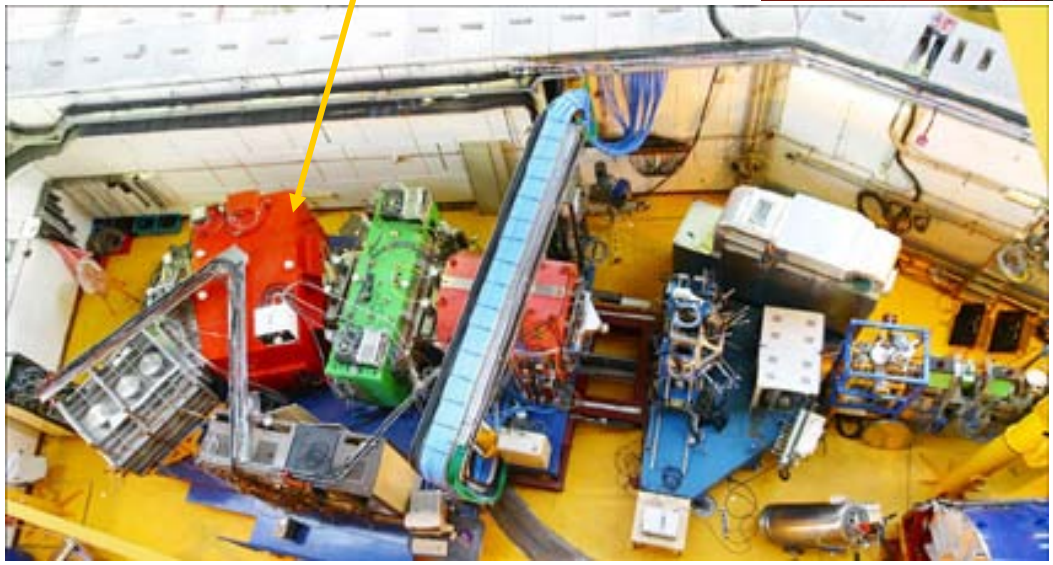
Study of (d,t) (d,p) reactions with the missing mass method:





VAMOS

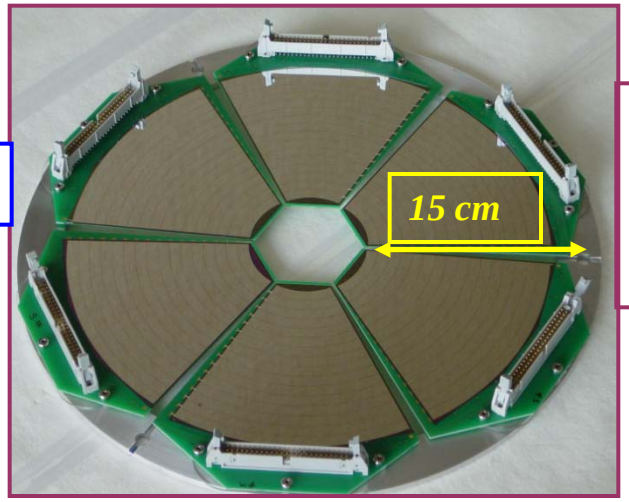




MUST2 & TIARA inside

Recoil particle detectors

TIARA Hyball

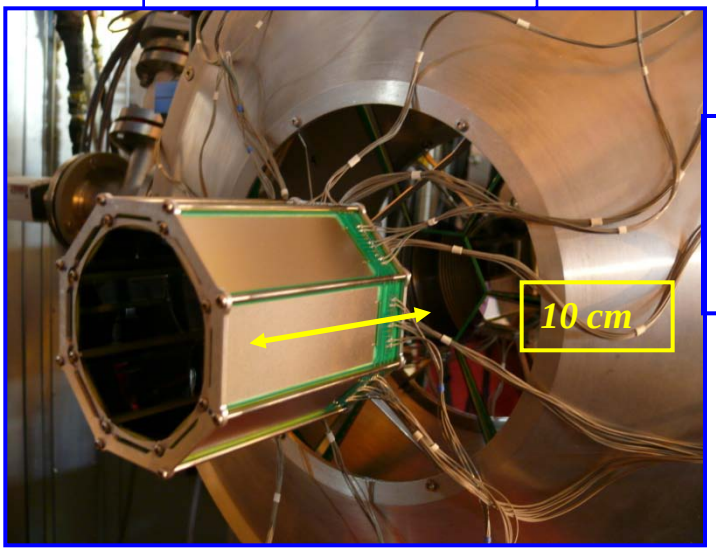


- **Annular Detector divided in 6 sectors:**

  => Each sector: 16 strips to measure Θ

  8 wedges to measure Φ

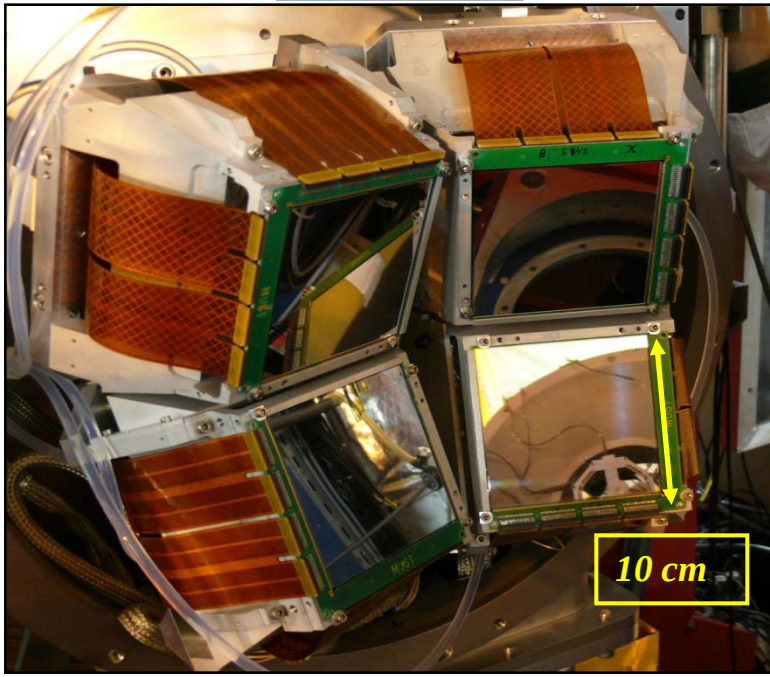
TIARA Barrel



2 layers

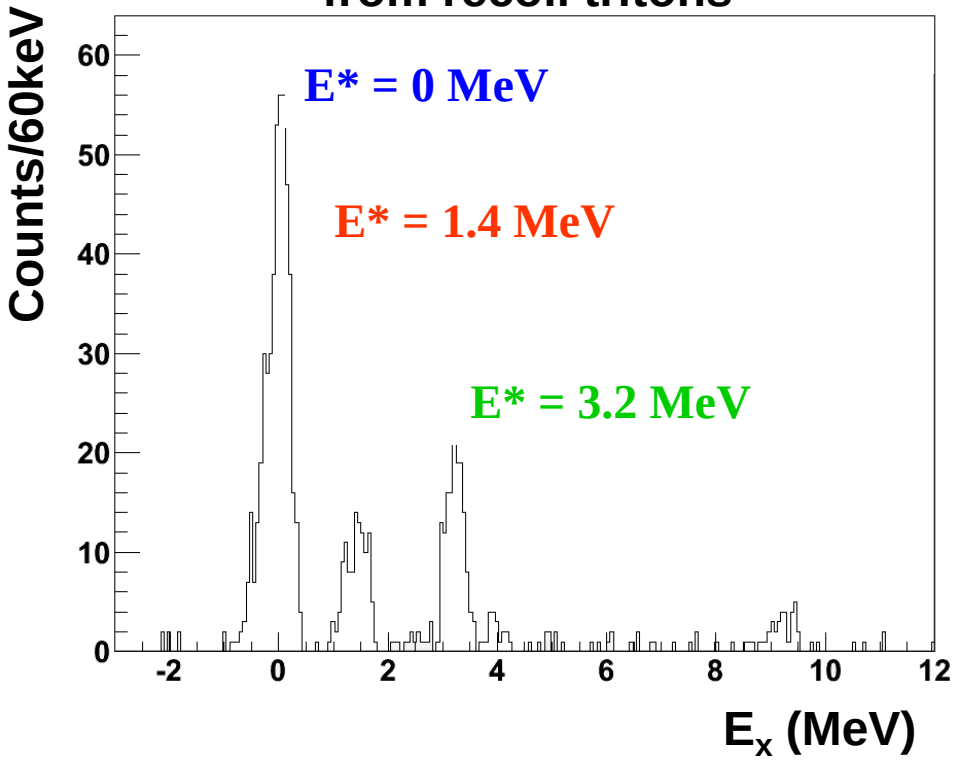
-Measure Θ
(Resistive Strips)

MUST 2

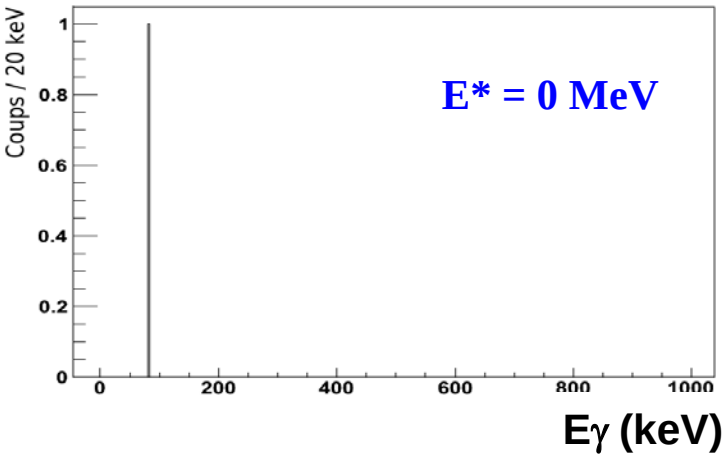


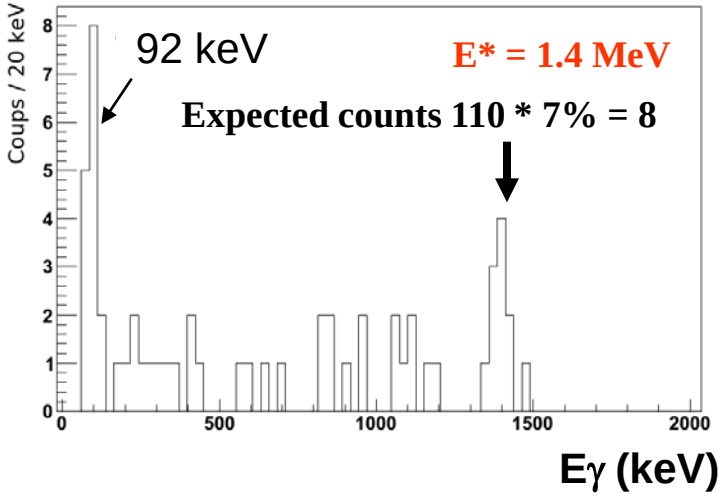
$^{20}O(d,t)^{19}O$
γ-particles coincidences

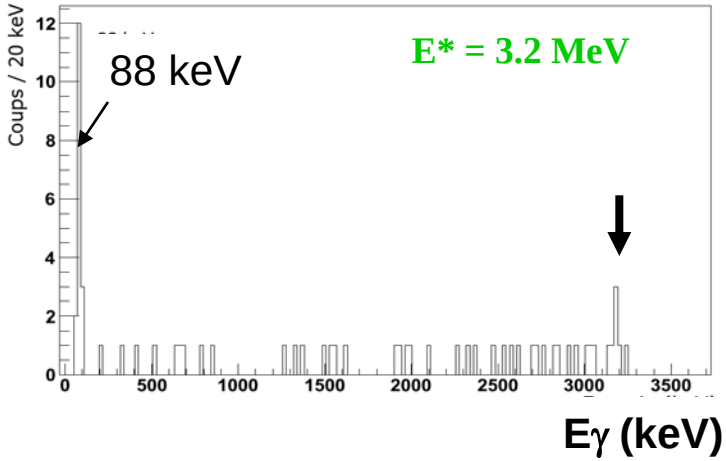
Ex (MeV) : excitation energy in ^{19}O from recoil tritons



Filtered by triton + ^{19}O in VAMOS





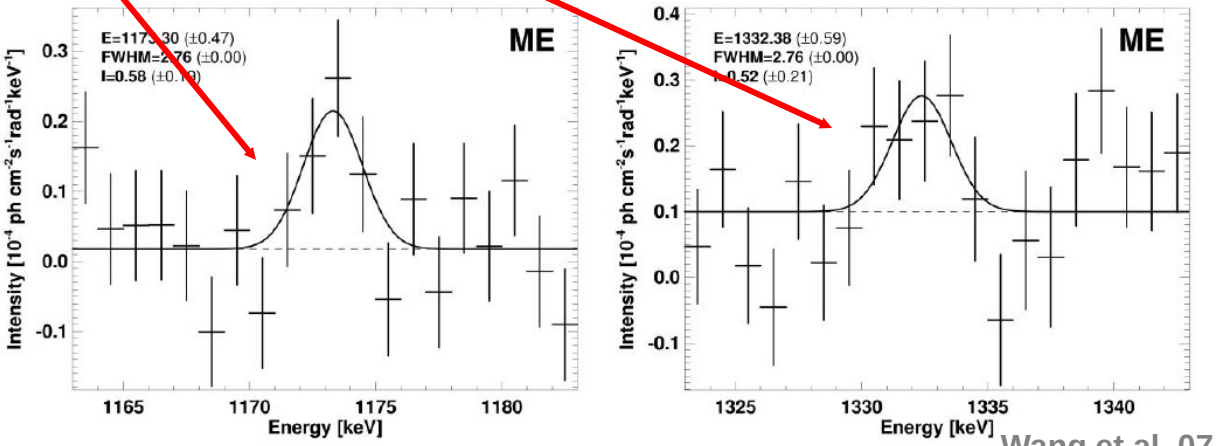


E530 experiment: Study of $^{60}Fe(d,p)^{61}Fe$

RHESSI & **INTEGRAL** missions

↓

γ-rays @ 1.173 & 1.332 MeV from decay of **^{60}Fe** ($T_{1/2}$=1.5 10^6 yr)



Wang et al. 07

Production of **^{60}Fe** in core-collapse supernovae type II depend strongly on the uncertain $^{59}Fe(n,\gamma)^{60}Fe$ & $^{60}Fe(n,\gamma)^{61}Fe$ reactions

Courtesy from F.Hammache

E530 Participants

S. Giron, F. Hammache, N. de Séréville, D. Beaumel, S. Franchoo, J. Guillot, F. Maréchal,
A. Matta, Y. Matea, L. Perrot, J. A. Scarpaci, I. Stefan
(IPN-Orsay)

G. De France, O. Sorlin, J. Burgunder, L. Caceres, E. Clement, G. De France, B. Fernandez, S. Grevy, R. Raabe, O. Sorlin, C. Stoedel, J.C. Thomas (GANIL-Caen)

F. Flavigny, A. Gillibert, V. Lapoux, L. Nalpas, A. Obertelli
(SPhN Saclay)

G. Duchene, M. Moukaddam (IRES-Strasbourg)

J. Gibelin (LPC-Caen)

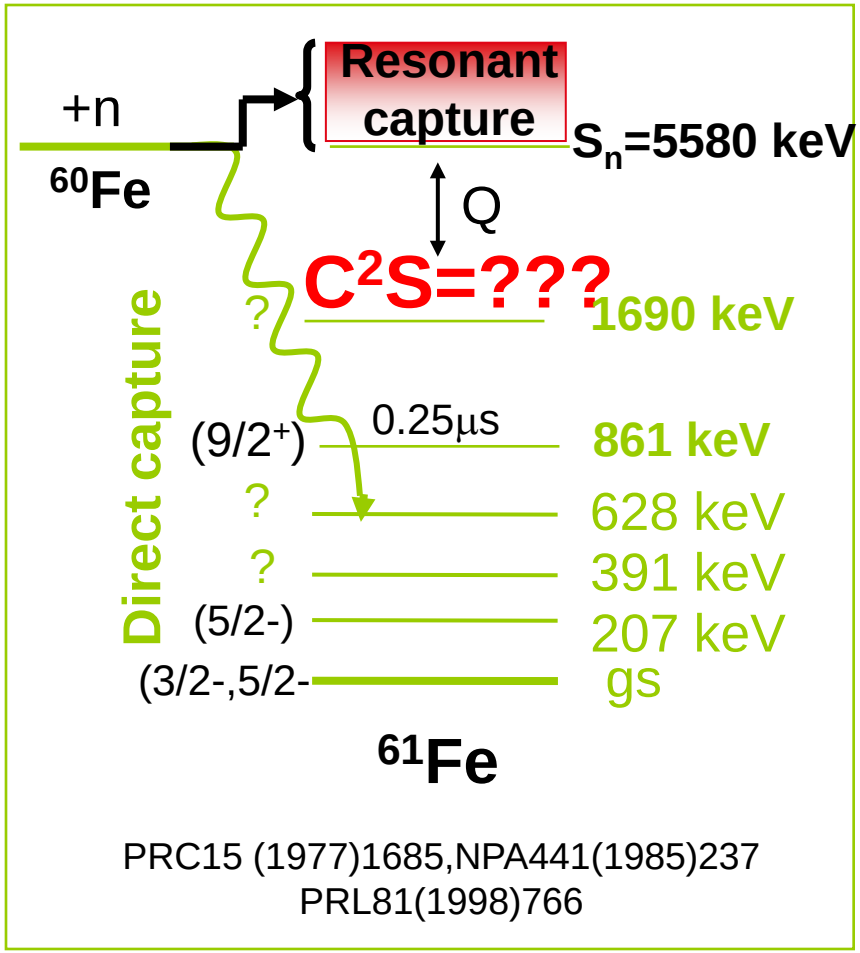
Y. Togano, M.Takechi (Riken)

M. Heil (GSI-Darmstadt)

J. Kiener (CSNSM)

BUT: lack of ^{61}Fe spectroscopic information

⇒ Big uncertainties in the **^{60}Fe** yields predictions



Direct $\sigma_{^{60}Fe(n,\gamma)^{61}Fe}$ depends on

E_x, J^π & C^2S of ^{61}Fe

⇓

(d,p) transfer reaction

⇓

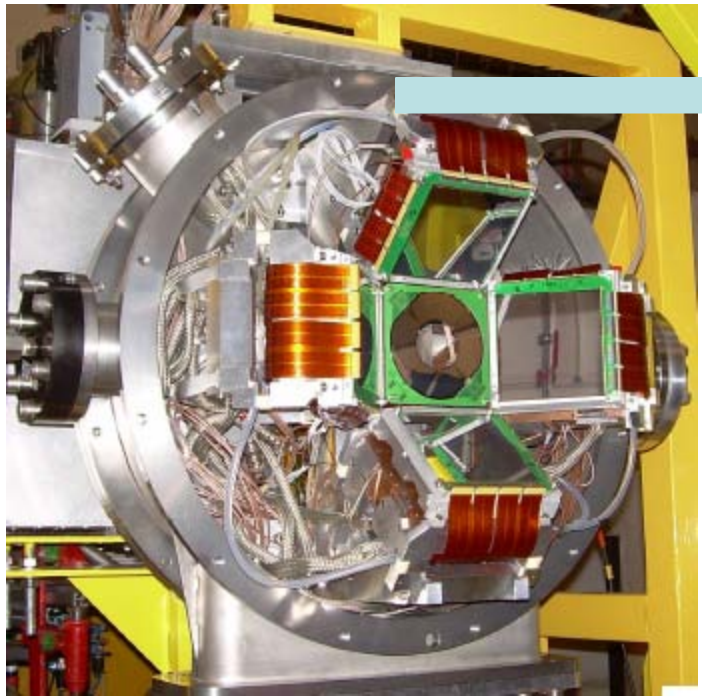
check the validity of the shell model calculations used in ^{60}Fe(n,γ)^{61}Fe cross section calculation

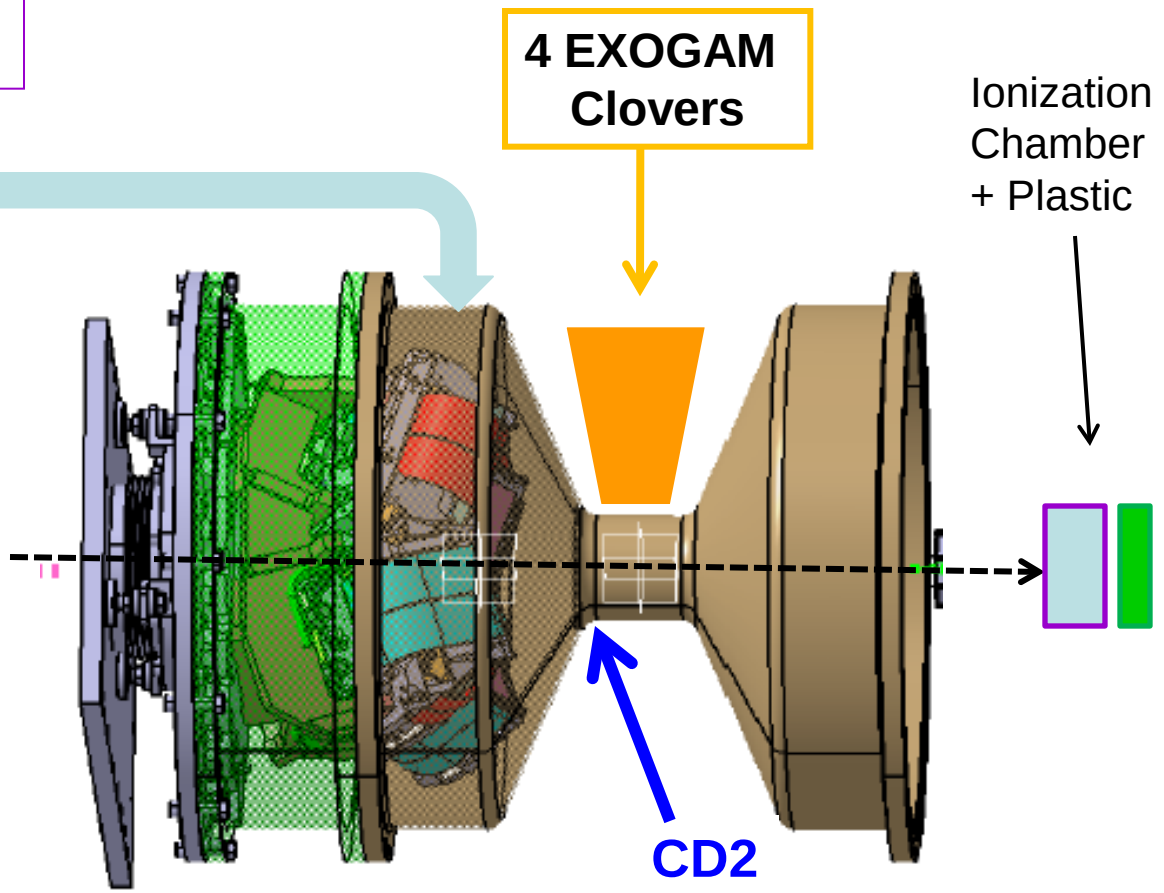
Courtesy from F.Hammache

Recent MUST2 campaign using fragmentation beams at LISE
MUST2 + annular detectors combined with EXOGAM

- Shell structure evolution near N=40, towards N=50 — ^{68}Ni(d,p)
- Density dependence of the $p_{1/2}$-$p_{3/2}$ S.O. splitting — ^{34}Si(d,p)
- Astrophysics – nucleosynthesis of ^{60}Fe — ^{60}Fe(d,p)

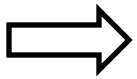
4 MUST2 telescopes + S1 annular in the backward hemisphere

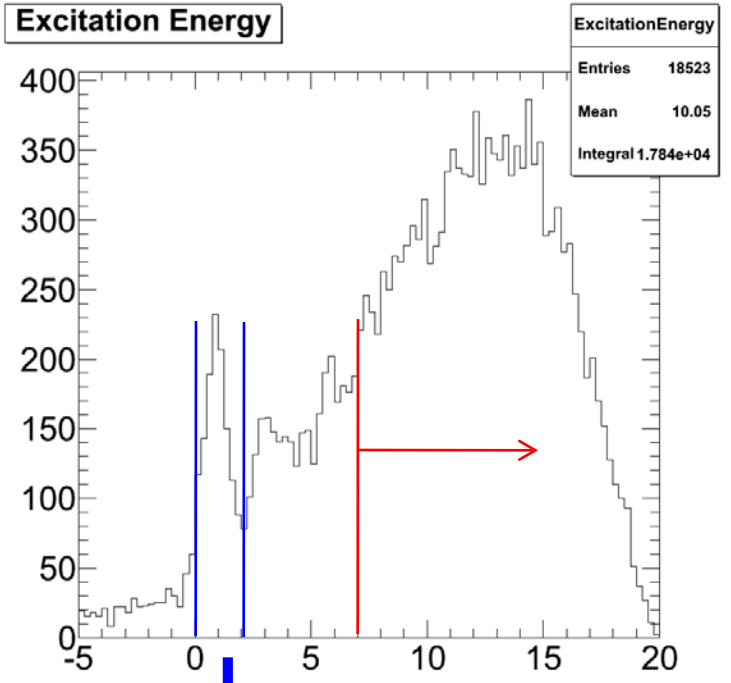




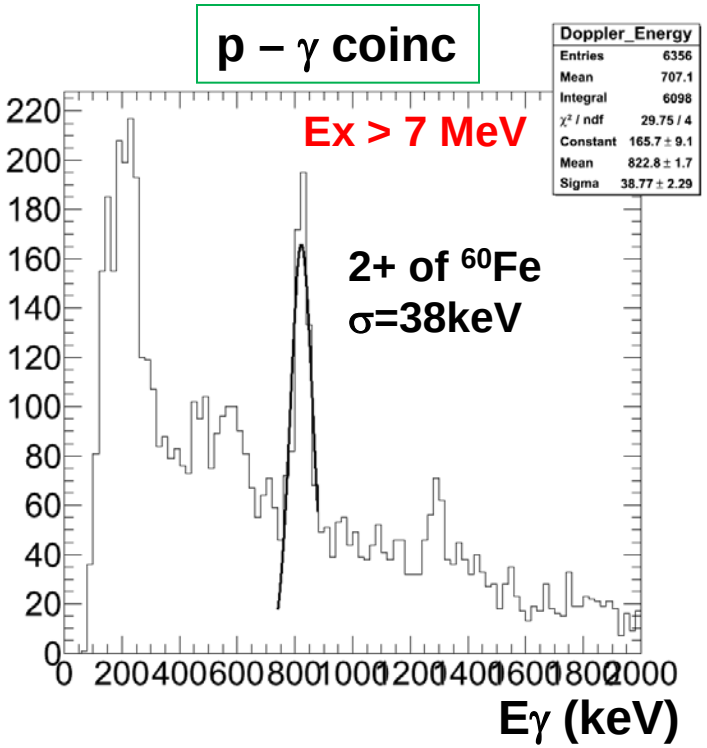
Preliminary results for ^{60}Fe(d,p)^{61}Fe

Ex (MeV) : excitation energy in ^{61}Fe from recoil protons

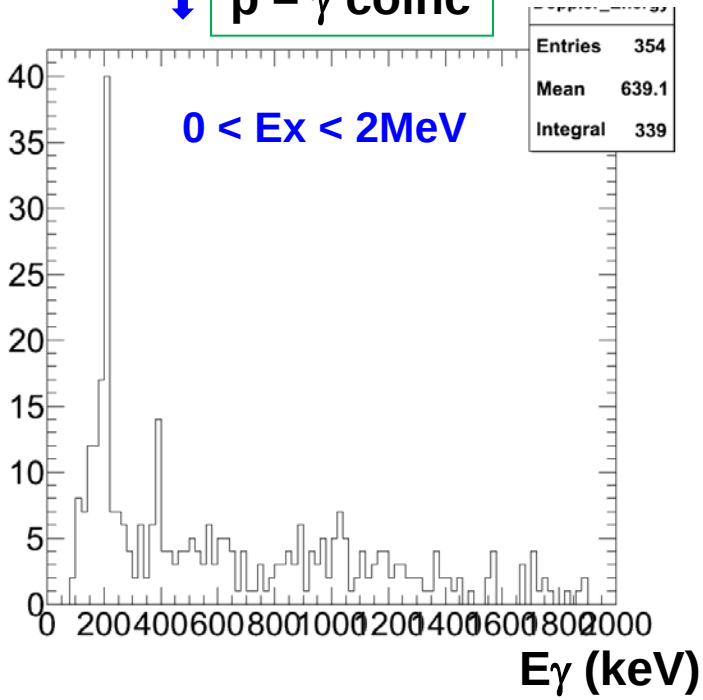




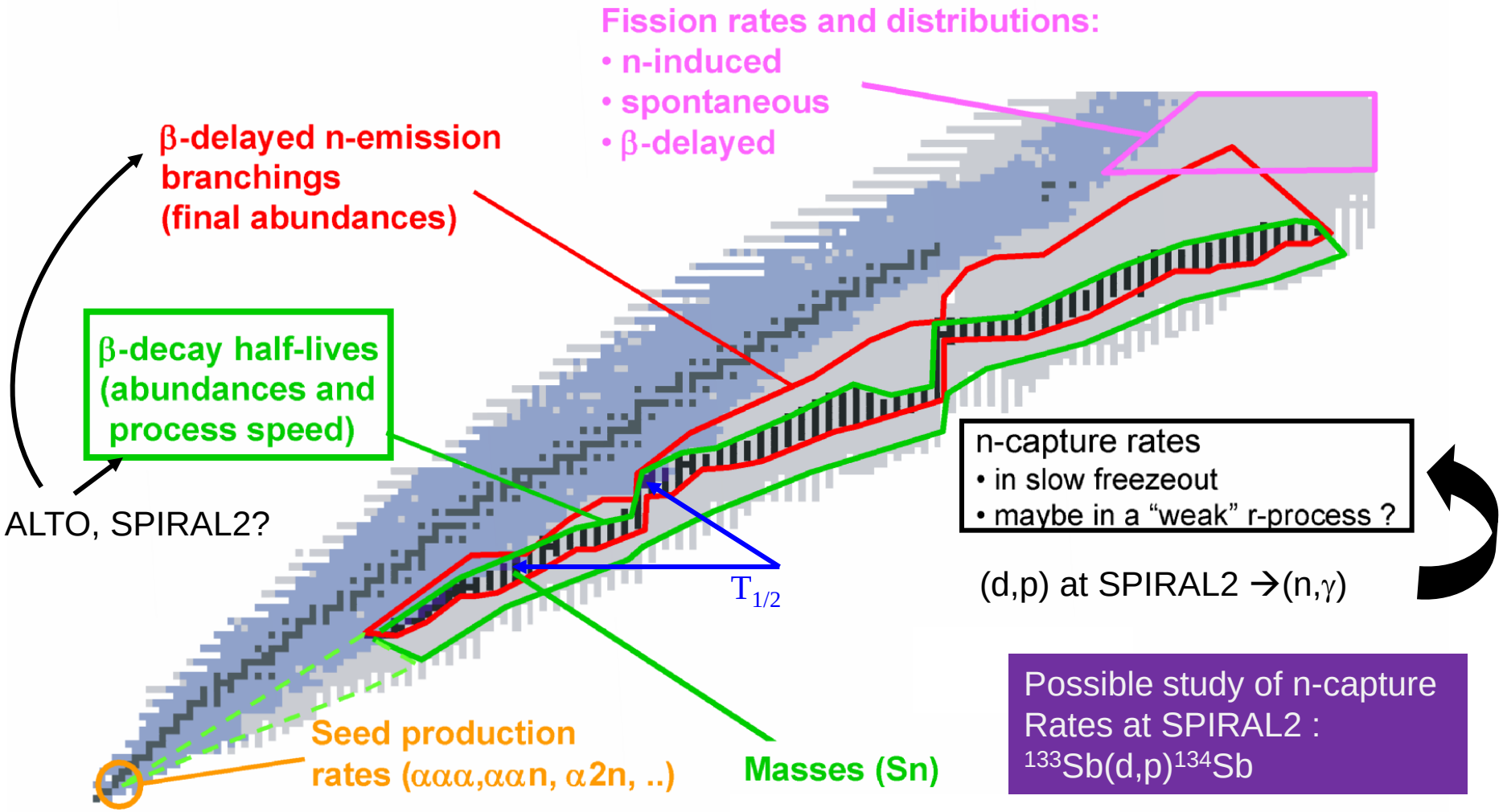
p – γ coinc



p – γ coinc



R process and nuclear physics



Possible study of n-capture Rates at SPIRAL2 : $^{133}Sb(d,p)^{134}Sb$

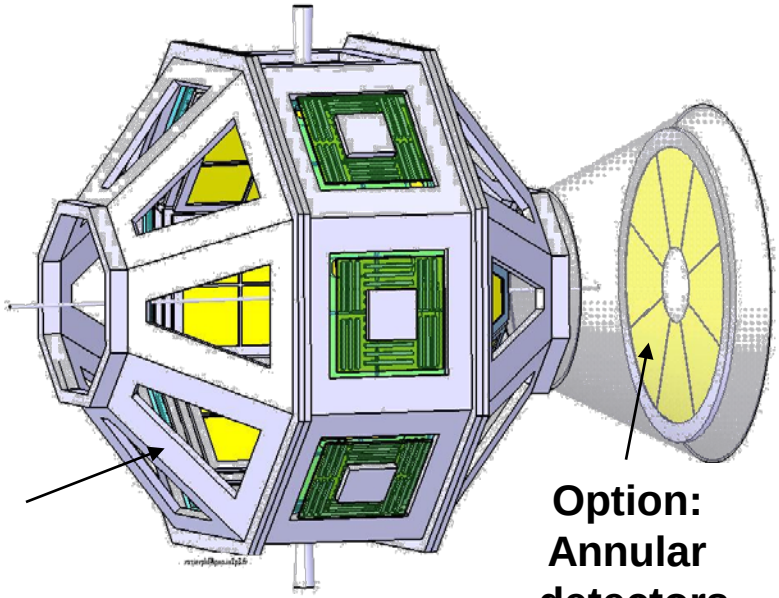
Courtesy from F.Hammache

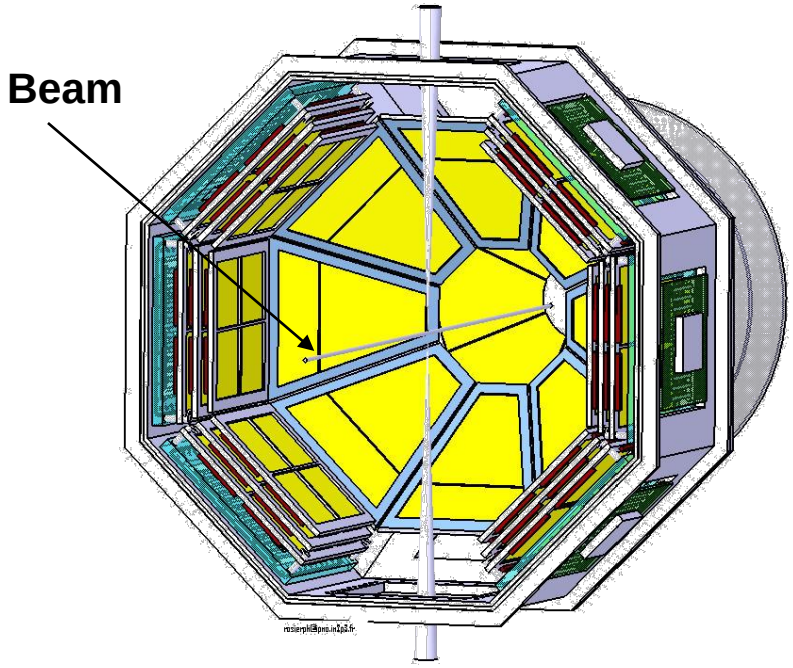
GASPARD design

GAmma SPectroscopy and PArticle Detection

"GASPHYDE" design - **fit inside AGATA**

Basis: DSSD's, 4" technology





Layers of Silicon :

- 300(500) μm DSSD pitch < 1mm
- 1x [1.5 mm DSSD pitch~3mm] (BWD)
- 2x [1.5 mm DSSD pitch~3mm] (FWD)

➢Integration of special targets(cryogenic,…)

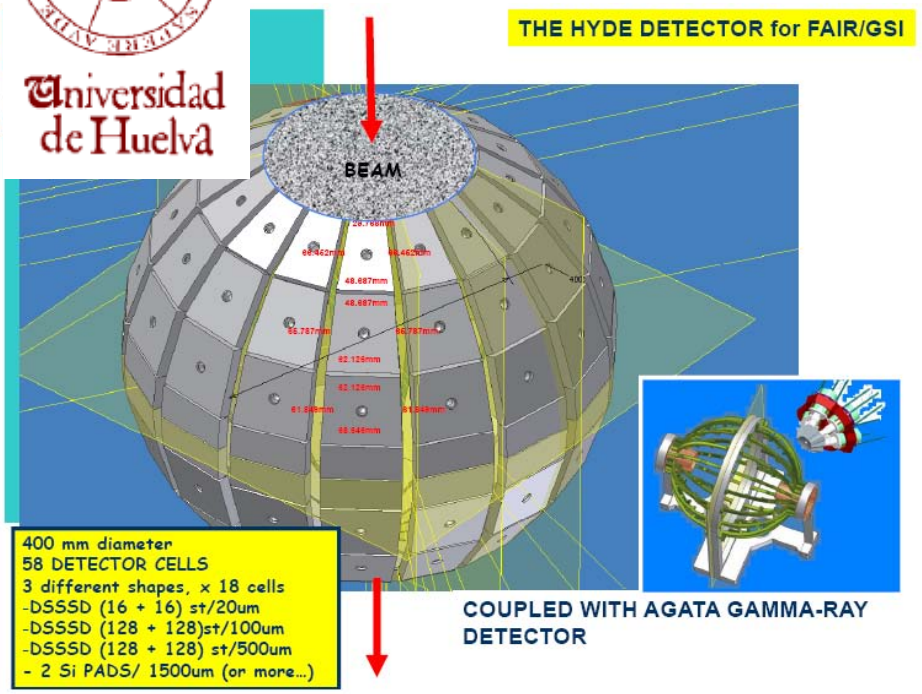
ELECTRONICS:
~ 15000 channels (Digital)
• Integration and effects on γ-ray under study
Preamps to be in vacuum

GASPARD Partners

- ***University of Huelva HYDE project***
- ***STFC Daresbury***
- ***University of Surrey***
- ***BARC/TIFR***

Universidad de Huelva

HYDE



Collaborations with other projects:

FAZIA (Silicon/PSA)
ACTAR (Physics, FEE/DAQ)
TRACE (FEE) under discussions
EXL (Silicon/PSA) under discussions

Simulations for GASPARD

Marc Labiche, STFC Daresbury
Nicolas de Séréville, IPN Orsay
Angel Sanchez Benitez, University of Huelva

Main framework: GEANT4

- Monte-Carlo simulation code written in C++

Starting point: NPTool

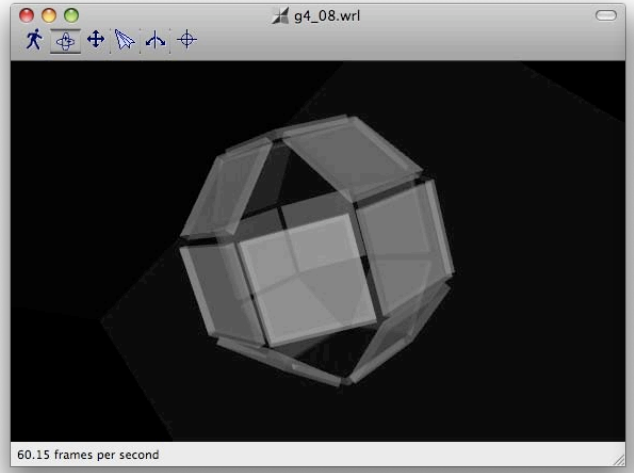
- Initially developped at IPNO for simulating the MUST2 array (Adrien Matta)
- First version: only charged particles detectors included
  Now includes gamma detectors from the PARIS array

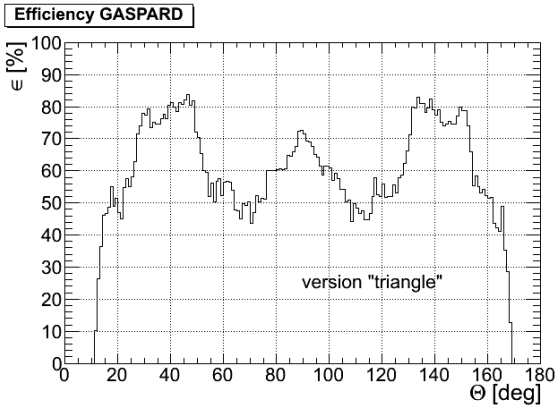
Two components:

- NPSimulation
  detector geometry & event generator (cross-section, kinematics, …)
  produces event file in root format
- NPAnalysis
  Set of tools (macros, programs) analysing the output file
  Calculate efficiency detection, excitation energy, …

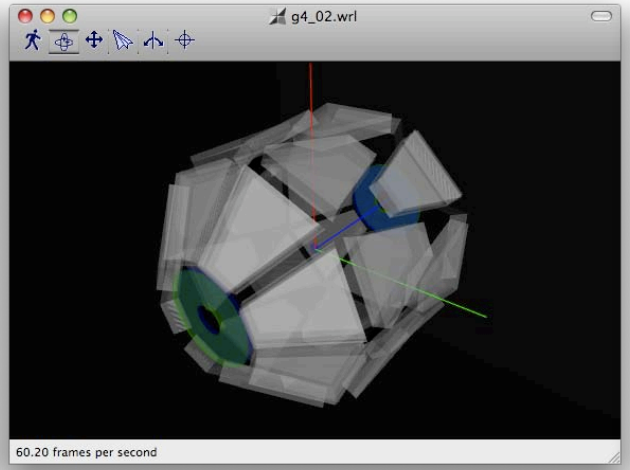
Realistic geometries

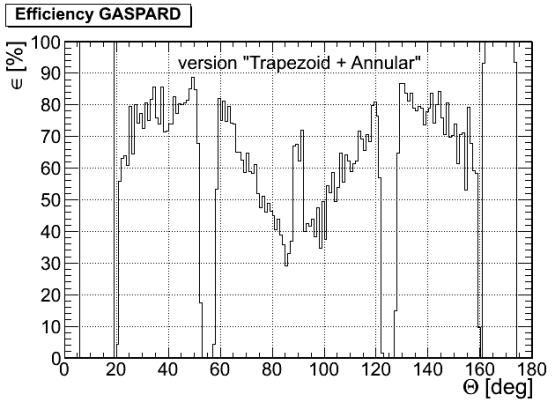
Square shape



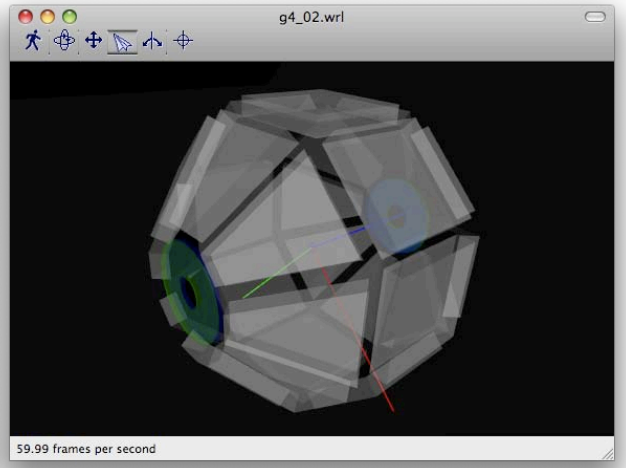


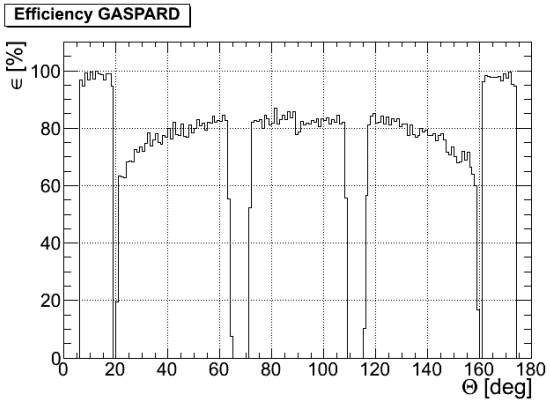
Trapezoid shape





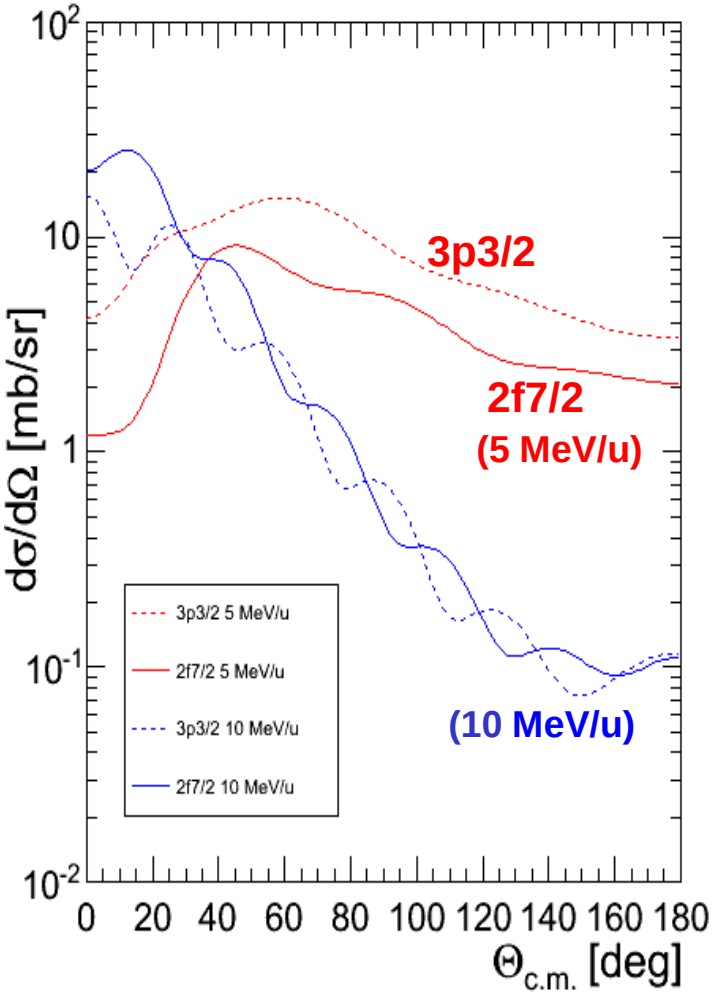
GaspHyde shape





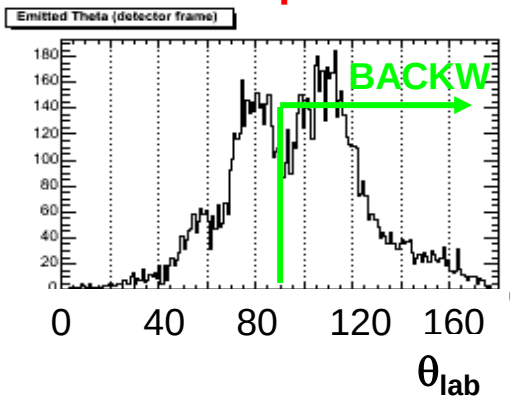
Simulations for $^{132}Sn(d,p)^{133}Sn$

CROSS-SECTIONS
FRESCO (ZR-FRC)

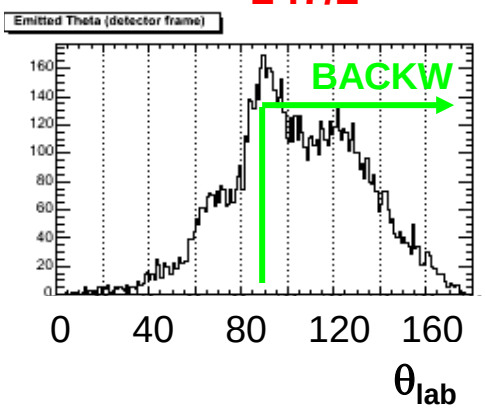


YIELDS
(10 MeV.A)

3 p3/2



2 f7/2



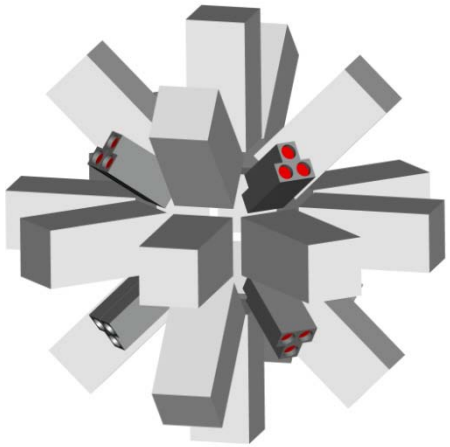
Other aspects studied:

- ***Effect on E* of***
  - ✓ ***Strip pitch***
  - ✓ ***Target thickness***
  - ✓ ***Beam tracking***
  - ✓ ***D2 vs CD2***
  - ✓ ***…***

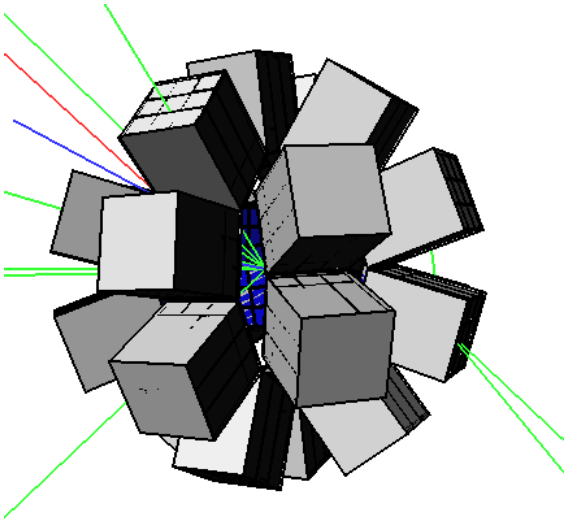
Downloadable version of the simulation package at :

http://gaspard.in2p3.fr

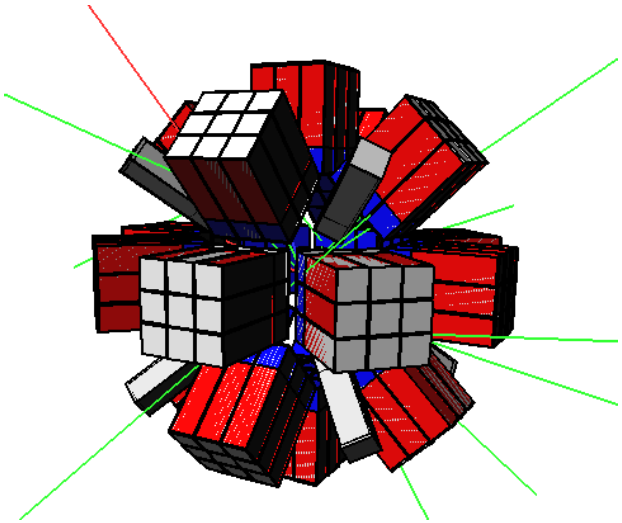
PARIS in NPTOOL
Spherical configurations



PARIS180
18 clusters + 18 phoswich
R = 235 mm
(8 clusters in main ring)



PARIS234
26 clusters
R = 235 mm
(10 clusters in main ring)



PARIS168
18 clusters + 6 phoswich
R = 208 mm
(8 clusters in main ring)

Under study :

- Efficiencies for spherical and cubic configurations
- Effect of FEE boards/connectics on low E gammas

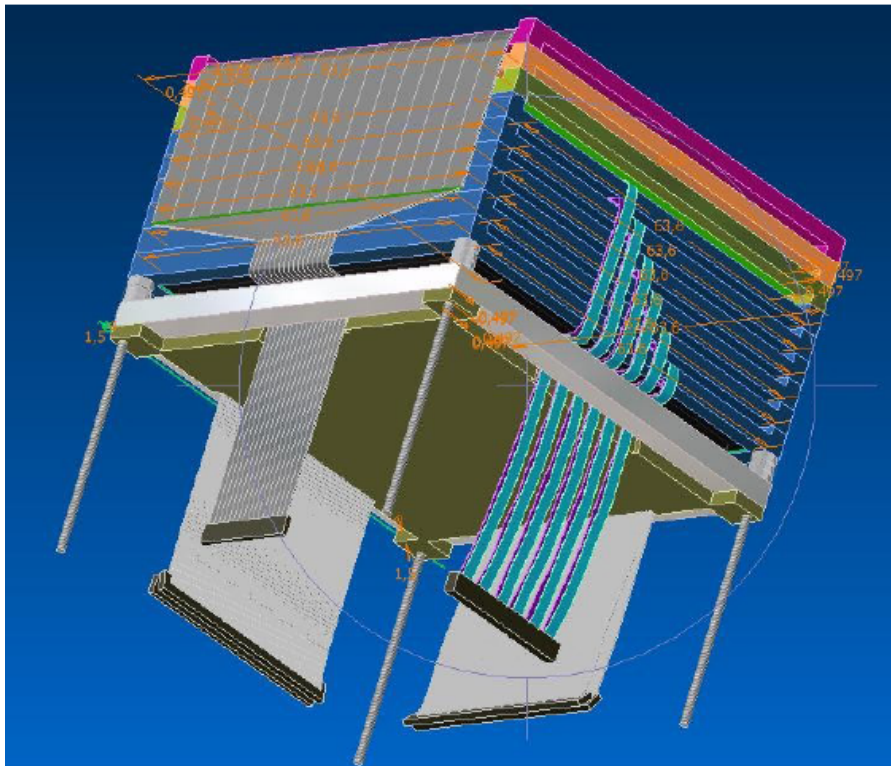
Next step:

Simulations with AGATA

Test of PSA with DSSDs under beam

Prototype telescope under constructions at Huelva using :

- ***20,100, 500 μm thick NTD + 1500 μm thick DSSDs from MICRON SC***
- ***500μm NTD DSSD CNM (Barcelona)***



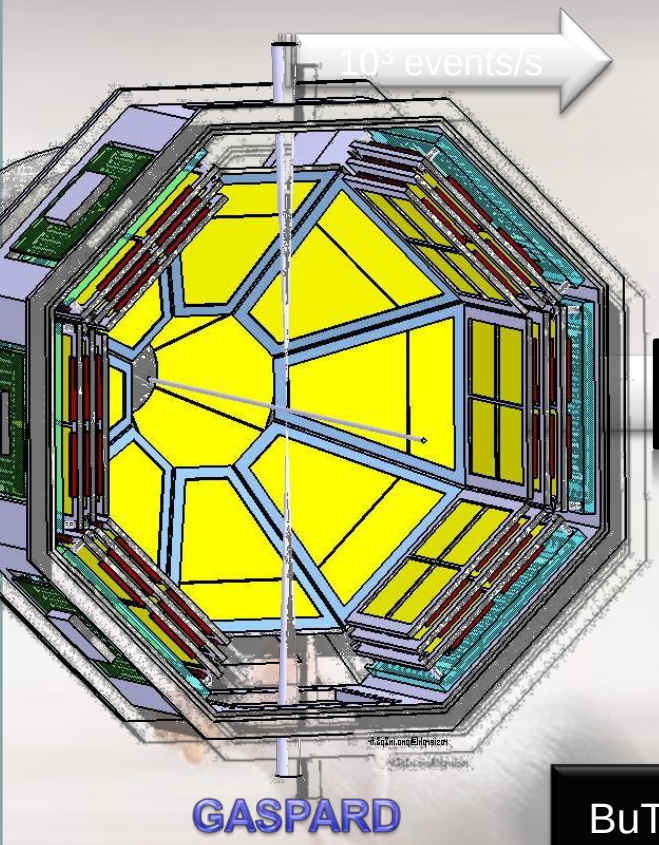
Next test experiment:
Orsay tandem, first half of 2011

- **Possible collaboration with TIFR, BARC**
  Prototype DSSD to be built by BHARAT Electronics
  Test at Mumbai
  Workplan to be discussed

भारत इलेक्ट्रॉनिक्स
BHARAT ELECTRONICS
QUALITY. TECHNOLOGY. INNOVATION

Time-Slice, Trigger & Band Width

Common Dead Time
Or
Individual AGET Dead-Time



GASPARD

10^3 events/s

5 G. Bit

1G. Bit

10 Giga Bit

AsAdA
SIC
ADC
FPGA
PULSE
R
T/V/I

CoBo
FPGA

Mutant
Trigger
FPGA

µ-TCA

BuTiS/GTS

SUPPORTED BY ANR

Emanuel Pollacco IRFU/SPhN

The CHYMENE program

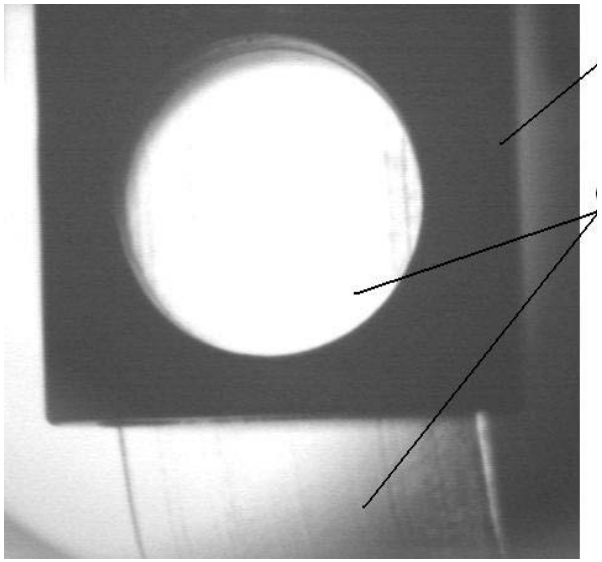
Cible d'HYdrogène Mince pour l'Etude des Noyaux Exotiques

A. Gillibert (Saclay)

Collaboration: IRFU/SPhN (Saclay), SBT (Grenoble), PELIN Lab. (St Petersburg)

A pure, windowless, thin H or D target

R&D using a prototype from PELIN (St Petersburg)



Extruder nozzle

Hydrogen ribbon (0.2x11mm)

Ribbon of thickness ≈ 100 µm now routinely produced

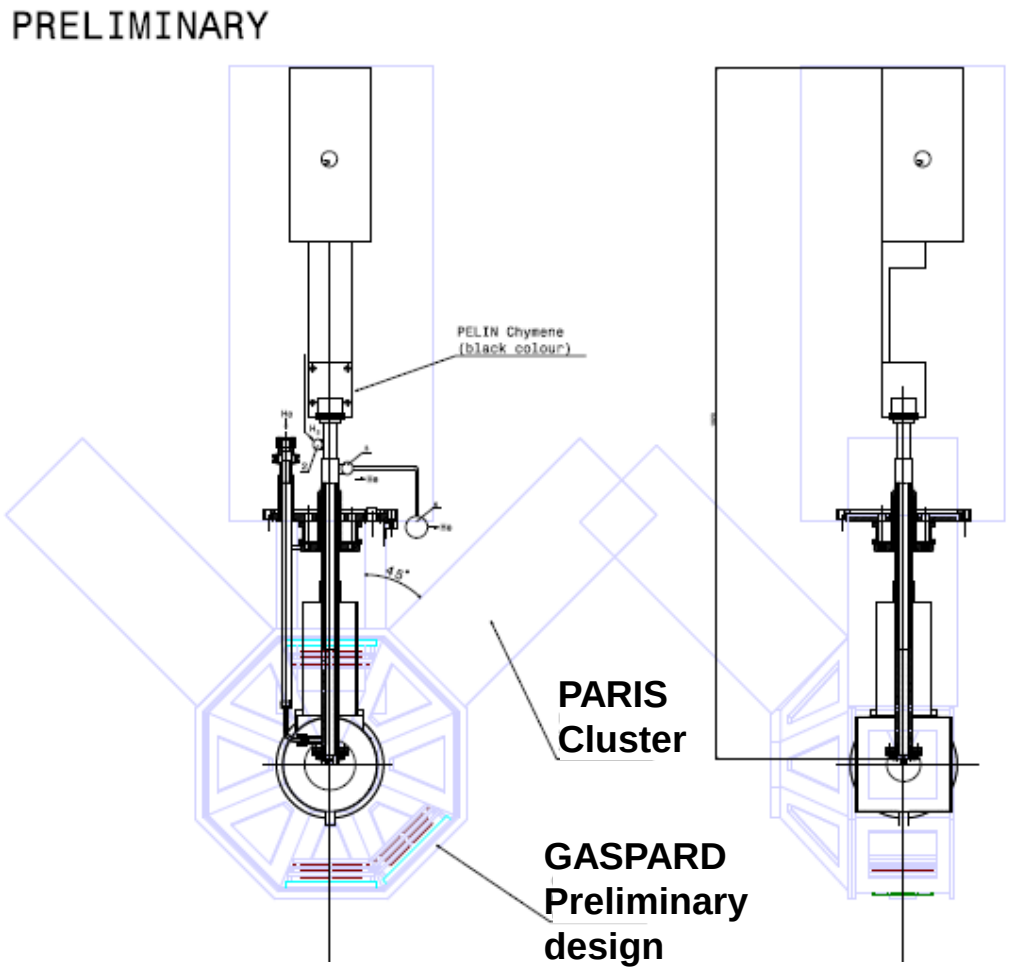
Goal: 50 µm with good homogeneity

Issues : Homogeneity, bad vacuum and Si detectors,…

Test under beam performed last spring – data currently analyzed

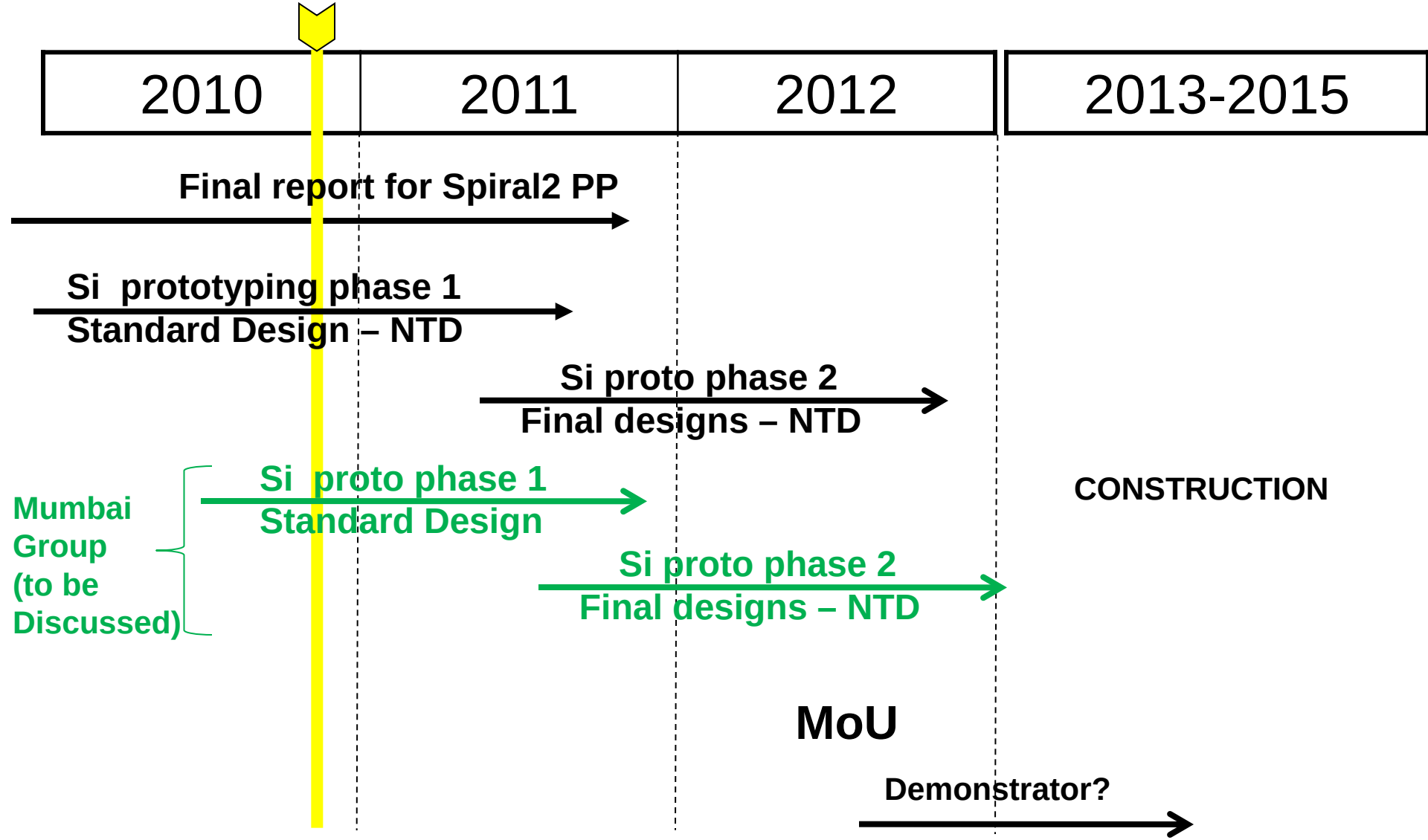
CHYMENE with GASPARD

PELIN prototype with GASPARD/PARIS :



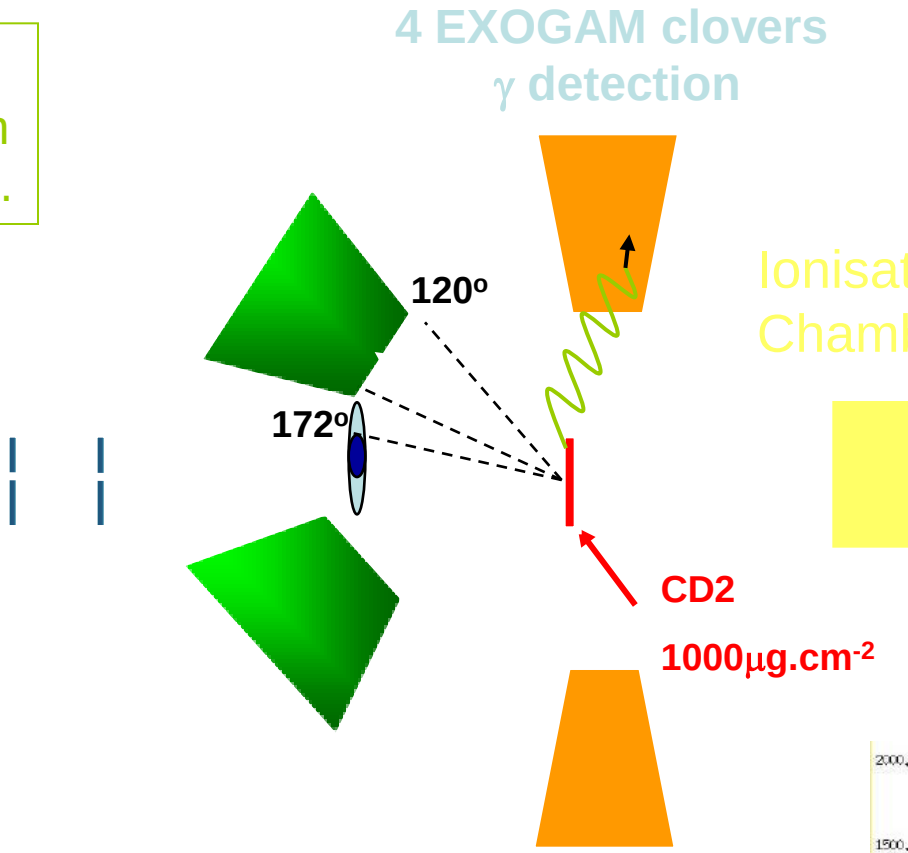
Final version of Chymene to be optimized for integration in GASPARD

GASPARD Timescales



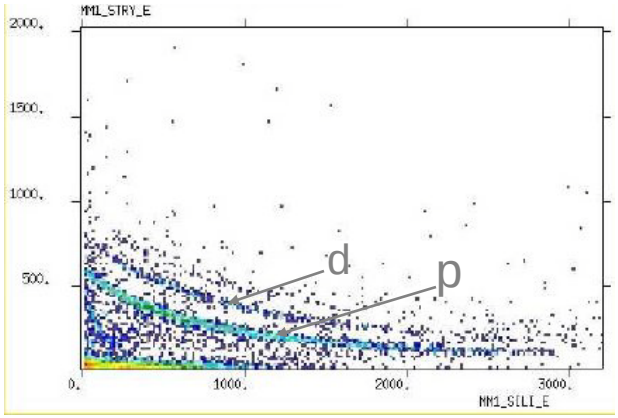
Experimental Setup for E530

CAT : - MWPC.
-Proton emission point localisation.

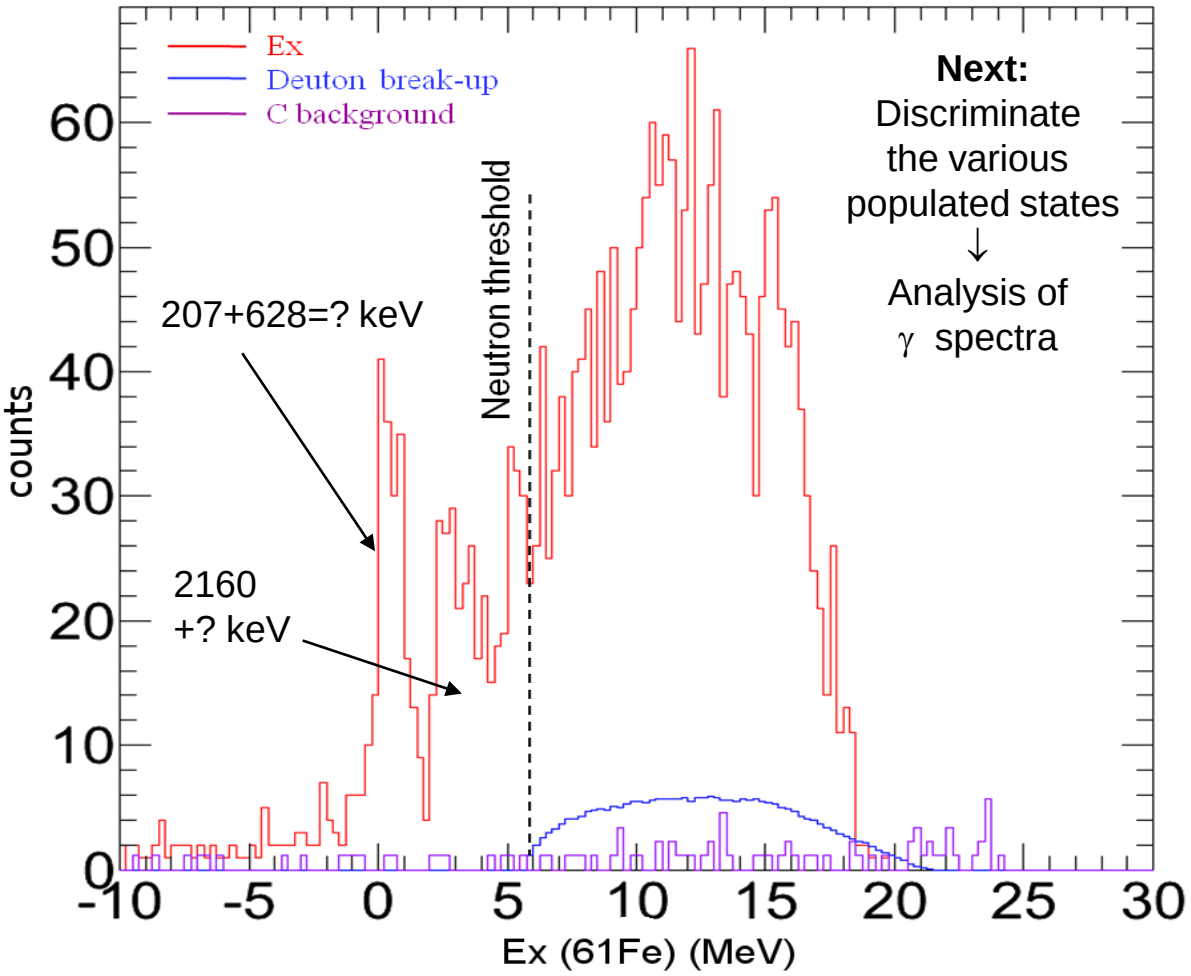


Identification detectors (ToF, dE)

MUST2 : -Si Strip (300μm) + SiLi (4.5 mm) detectors.
-Proton impact localisation.
-Proton energy measurement.
S1: Si annular detector (500 μm, 64 strips in Θ and 16 in Φ)

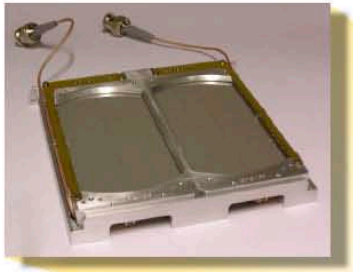


Preliminary results



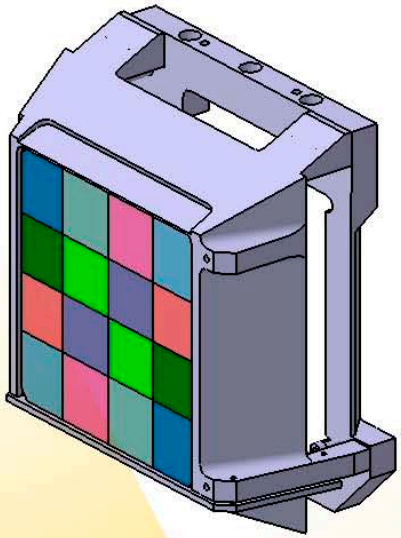
Collaboration: IPN Orsay/Saclay/GANIL

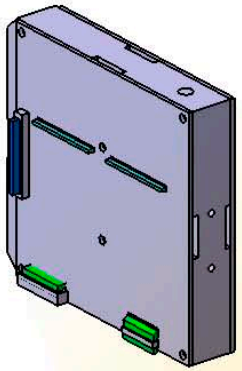
- 16 channels
- Energy & Time
- Si, Si(Li) and CsI
- Multiplexer
- I2C interface



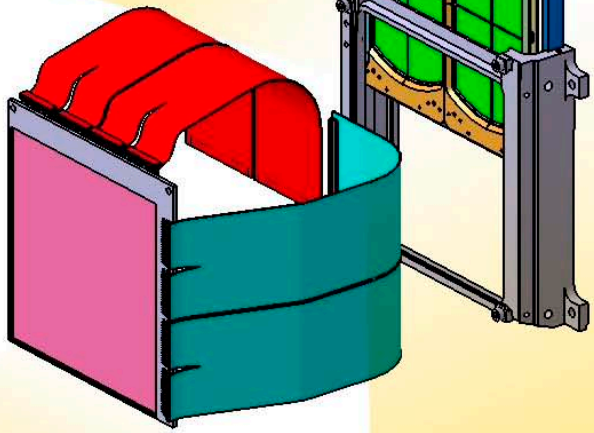
Si(Li) 5mm

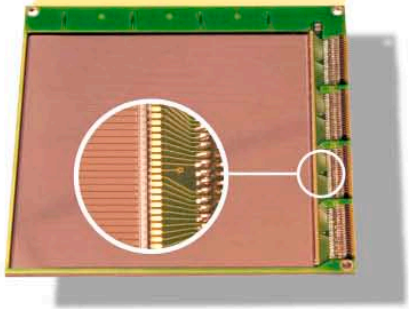
CsI 4cm

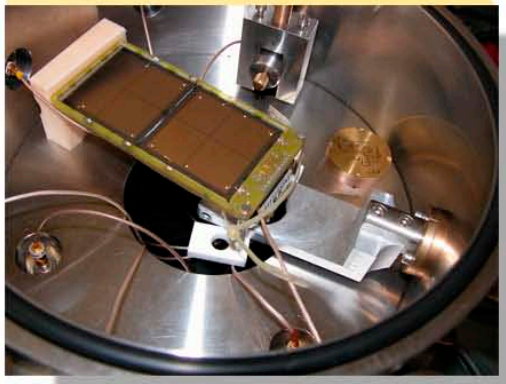


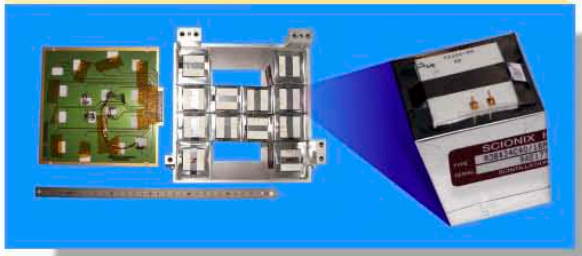


DSSD
10x10cm²
128X+128Y
300μm



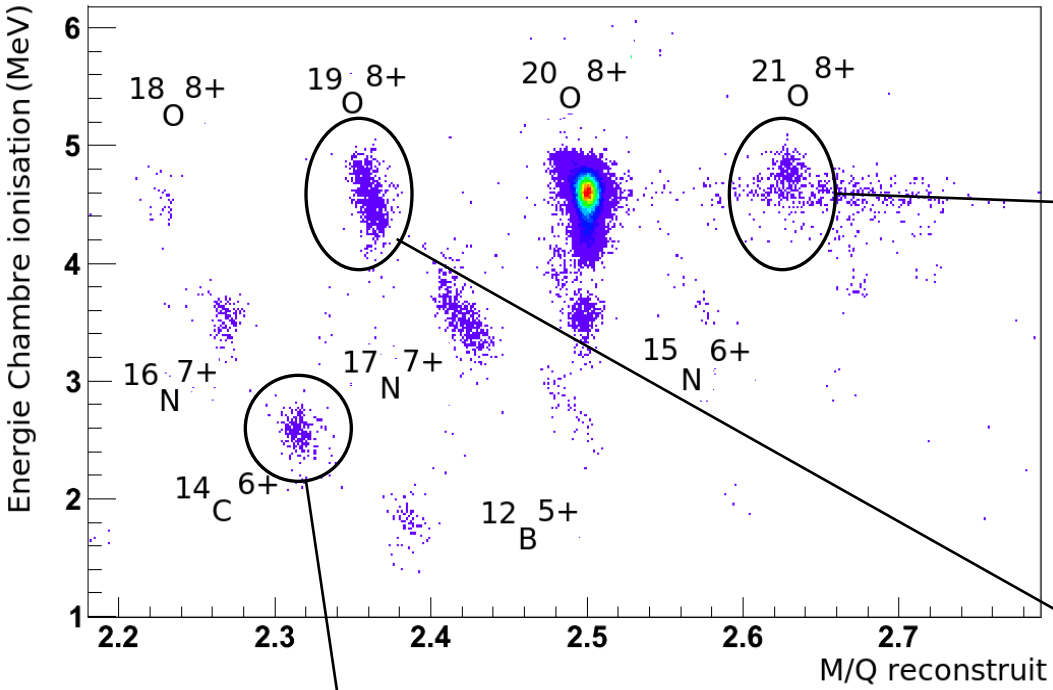




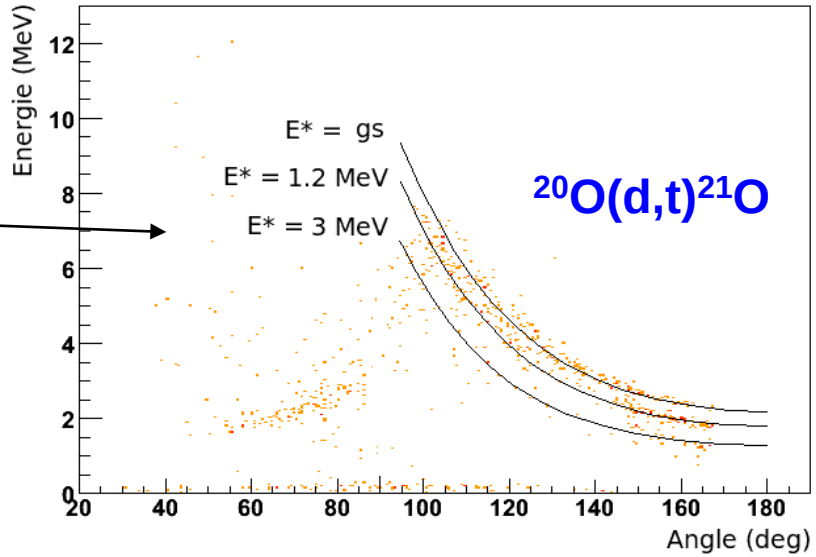


Kinematical lines

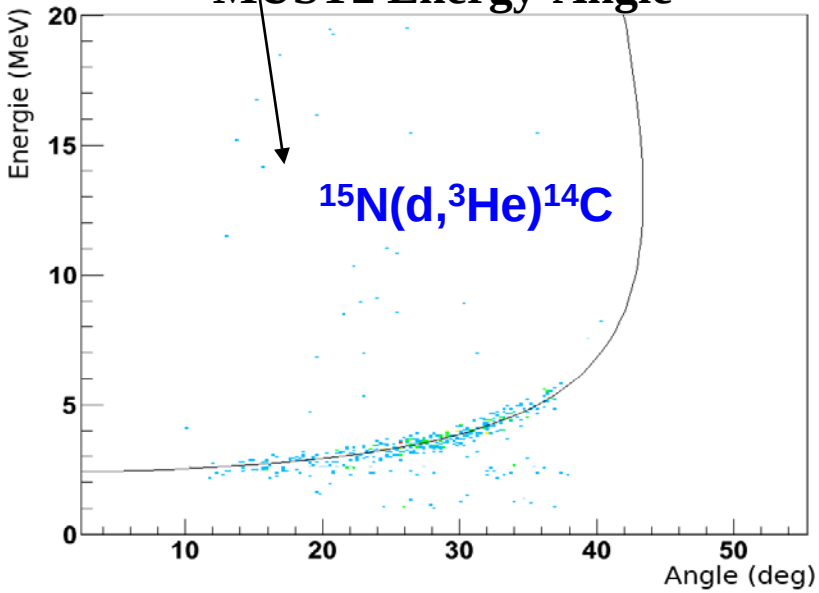
PID in VAMOS



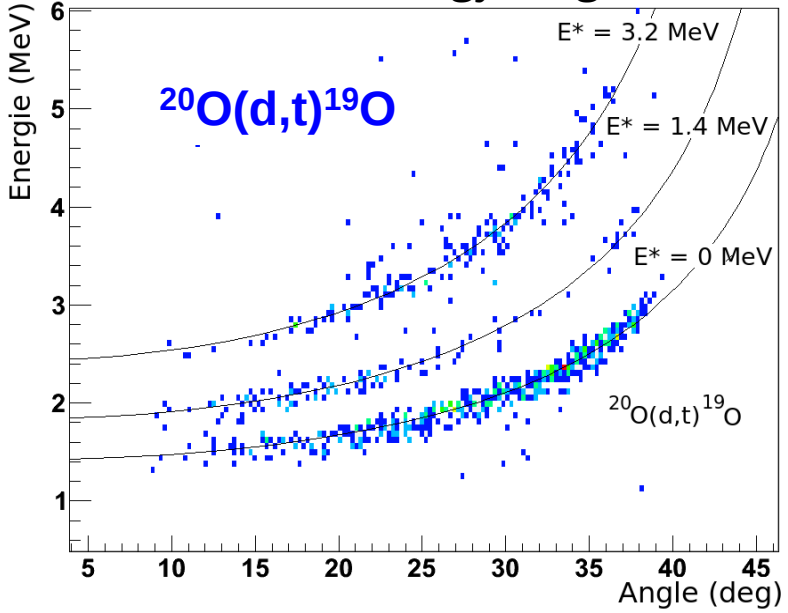
TIARA Energy-Angle



MUST2 Energy-Angle

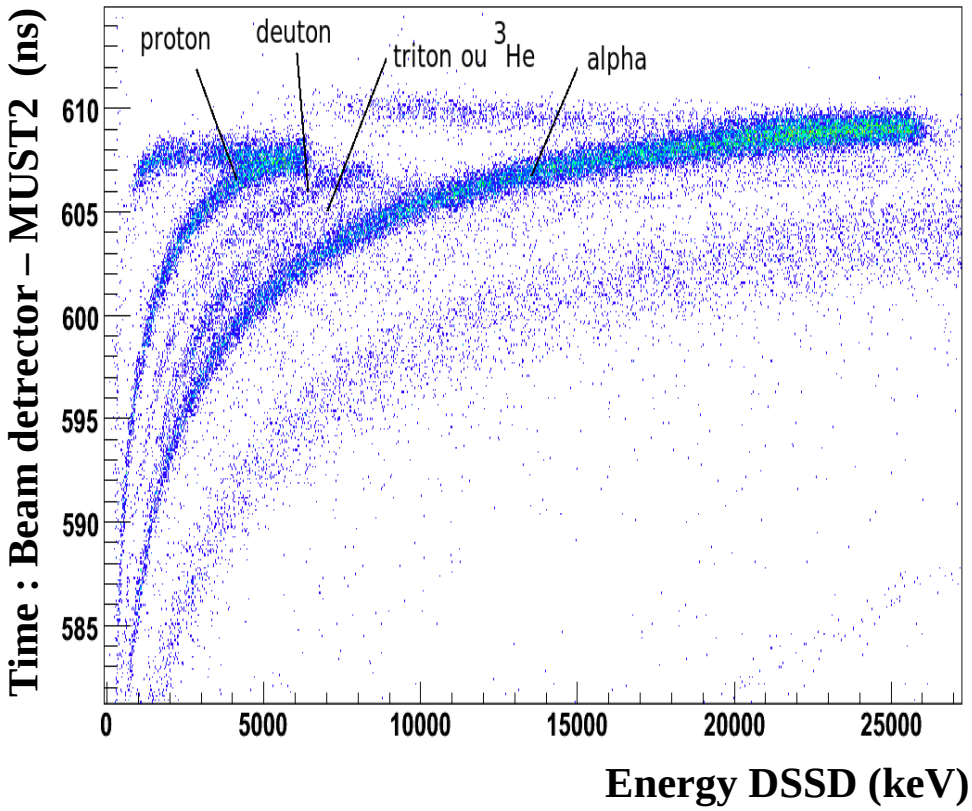


MUST2 Energy-Angle



PID of light particles with MUST2

E-TOF identification



E-ΔE identification