INSTITUT DE PHYSIQUE NUCLÉAIRE
ORSAY

New detection systems for direct reaction studies in Europe

- Introduction
- The GRIT array
- ACTAR active target
- SpecMAT
- ISS Solenoid project

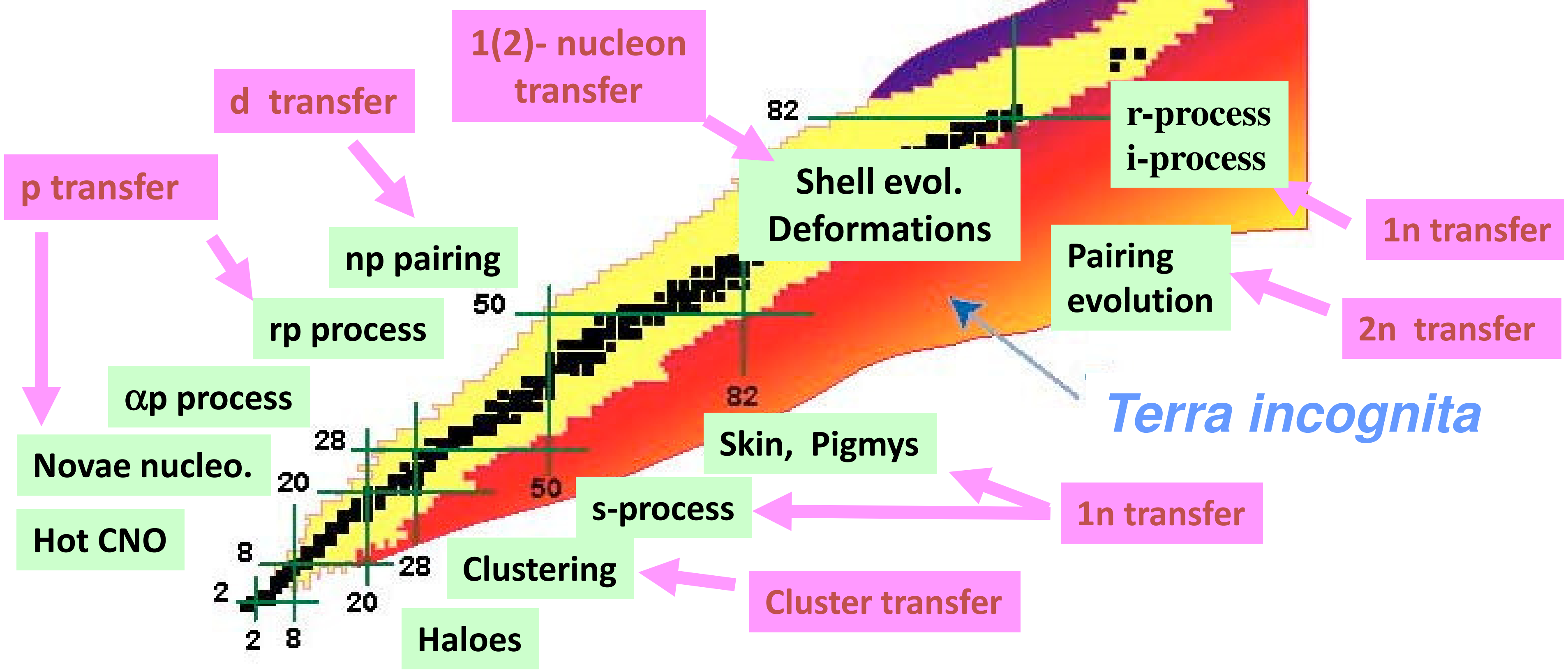
D.Beaumel,
IPN Orsay

Lisbon meeting, Nov 15-16,2017

Direct reactions

A great tool to investigate Exotic Nuclei and Astrophysical processes

Case of **transfer reactions**:



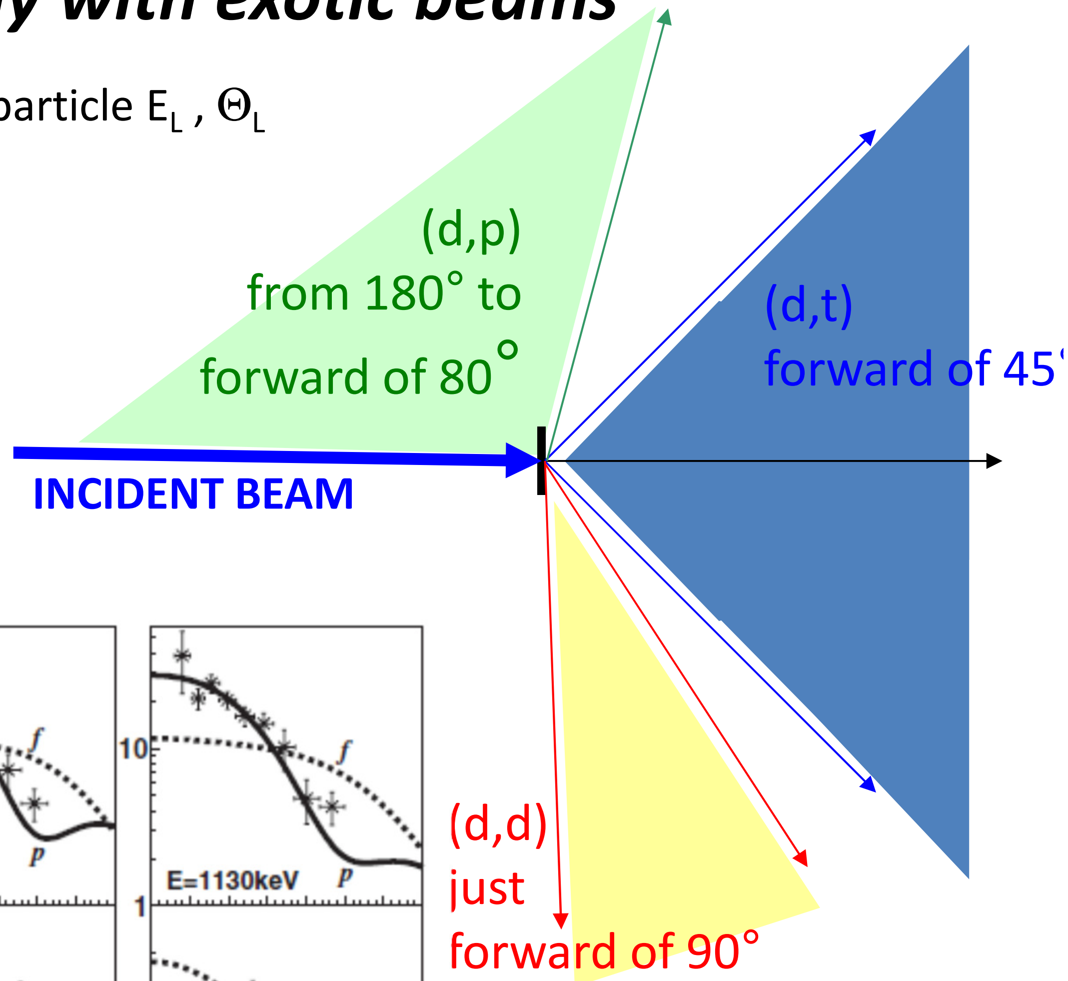
Good energy regime : 5 ~ 50 MeV/u ➡ **Core program for ISOL facilities**

Methodology with exotic beams

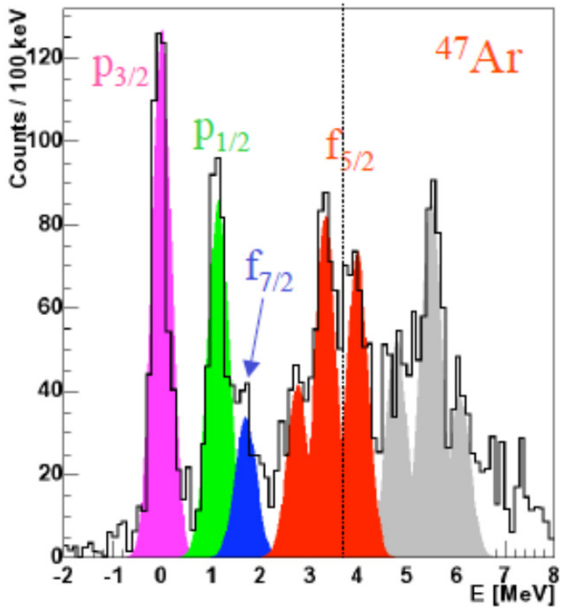
Early works : detect the light recoiling particle E_L , Θ_L

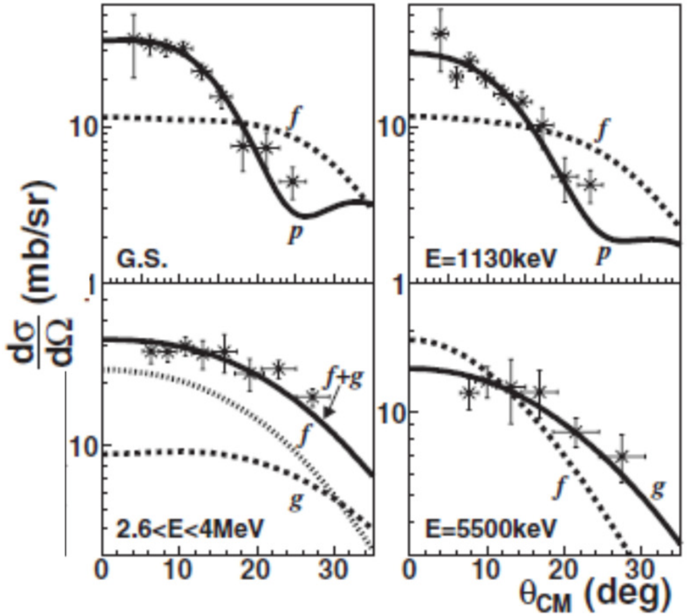
- Excitation energies
- Differential cross-sections

⇒ **Spin, parities and**
Overlaps < i|f >
(Shell Model, ab initio,..)

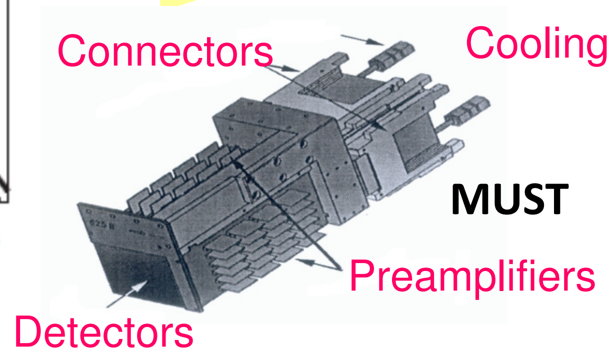


Ex: ^{46}Ar(d,p) @ GANIL/SPEG
using the **MUST** array





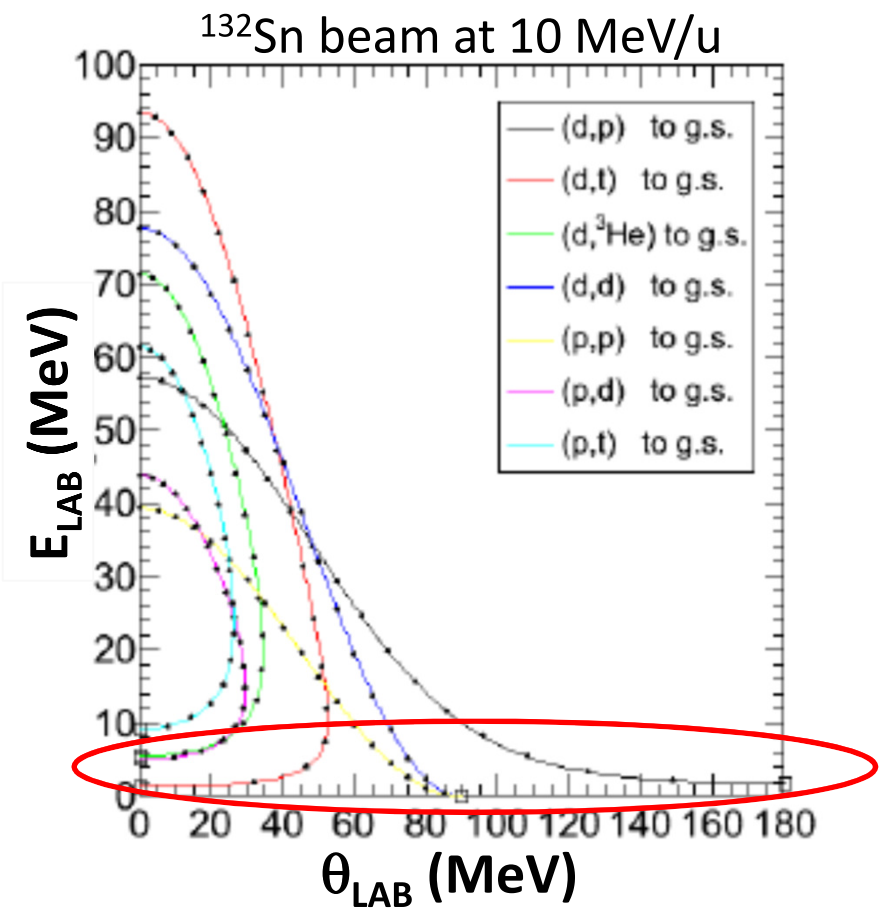
Reduction of N=28 gap
L.Gaudefroy, O.Sorlin et al., PRL (2006)



Y.Blumenfeld et al., NIM A421 (1999)

Constraints due to kinematics

Need
- ➢ **Large angular acceptance**
- ➢ **Large dynamic range**
- ➢ **Low threshold**
- ➢ **Thin target**



Kinematics weakly dependent
On mass (and on E) of the beam

➡ **General purpose system**

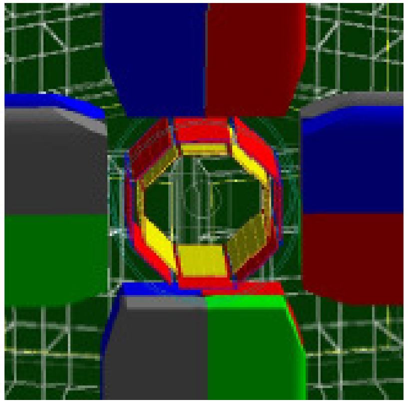
Limitations
- ➢ **Target thickness**
- ➢ **Kinematical compression**
  (d,p) with 1mg/cm2 CD2
  ΔEp ~100 keV ⇒ ΔEx ~ 400 keV

NB: Need also
- ➢ **Good PID for the recoil and the beam-like residue**

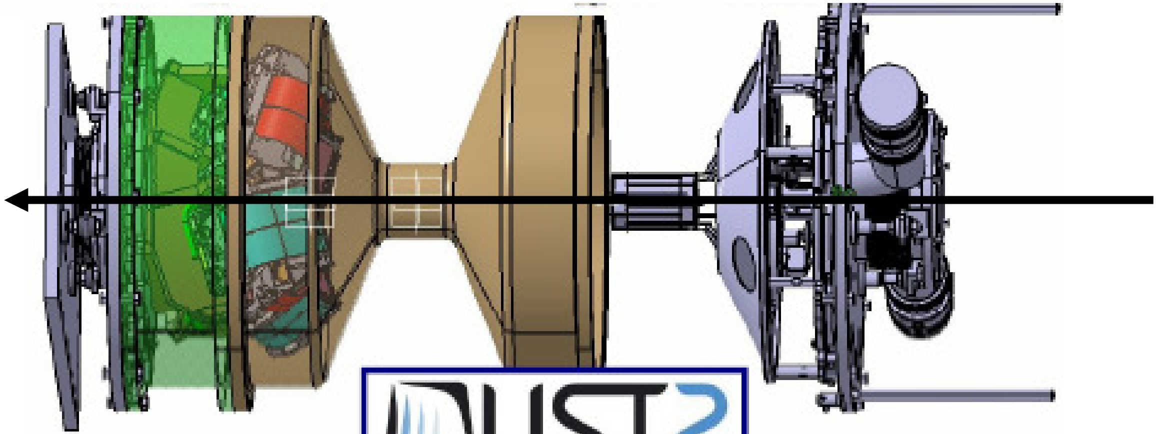
➡ **DEVELOPMENT OF NEW SYSTEMS**

Si-based systems currently operating for p-γ coincidence measurements

γ-rays $\Rightarrow E_x$



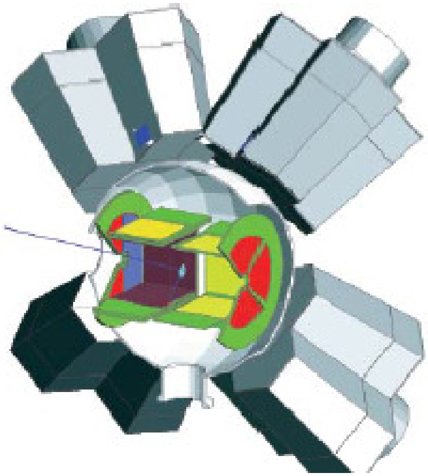
4 EXOGAM

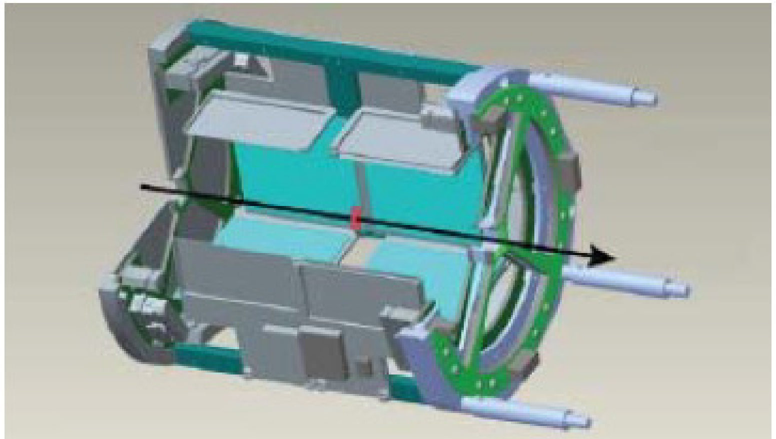


MUST2

TIARA

T-REX + MINIBALL



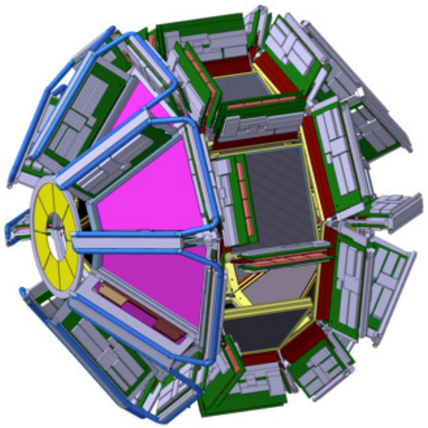


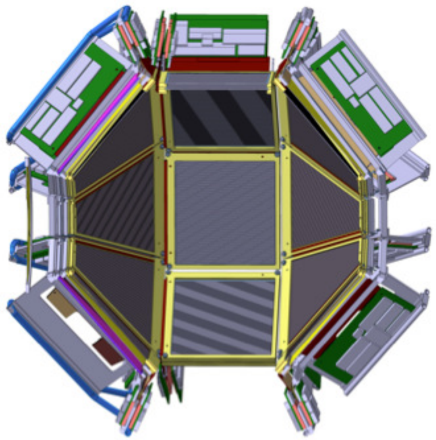
GRIT project

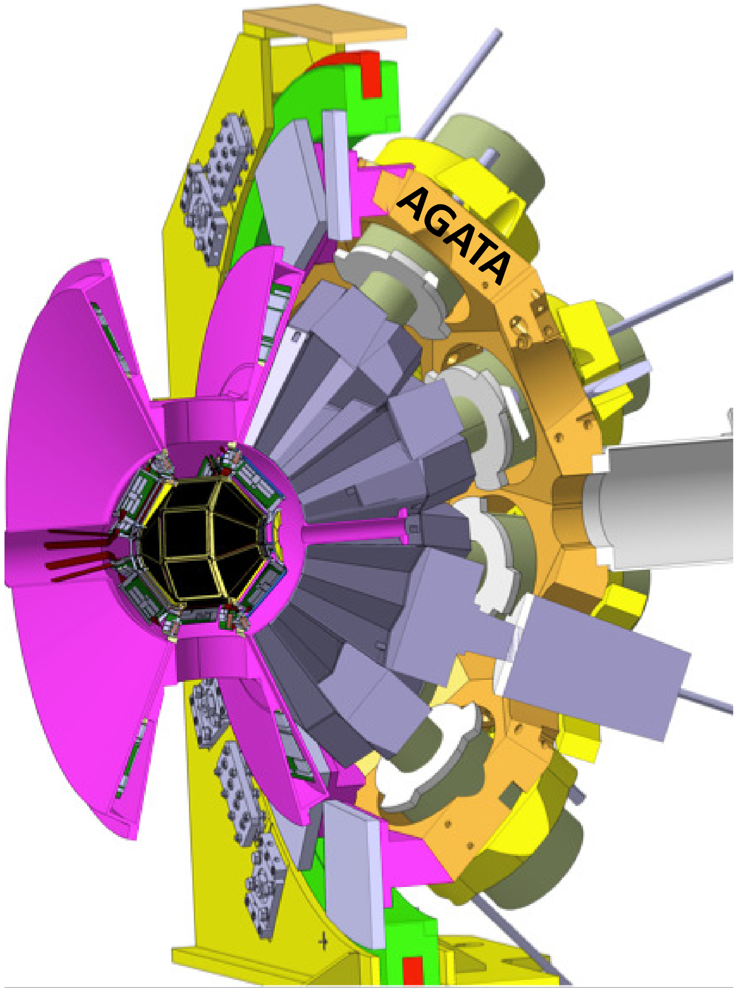
(Granularity, Resolution, identification, Transparency)

(GASPARD-TRACE collaboration)

4π Si array fully integrable in AGATA & PARIS







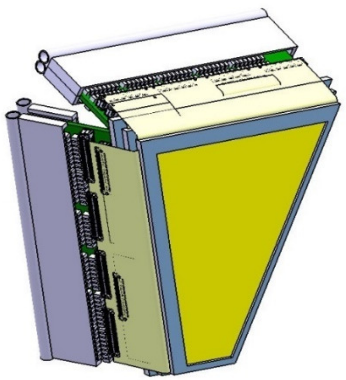
- High efficiency for particles and gamma-rays
- High granularity (strip pitch < 1 mm)
- Large dynamical range
  0.5 + 1.5 + 1.5 mm thick DSSD's (forward hemisphere)
  0.5 + 1.5 mm DSSD's (backward hemisphere)
- Special targets (Cooled ^{3,4}He cell, pure H, tritium)
- PID using Pulse Shape Analysis techniques
- New Integrated electronics

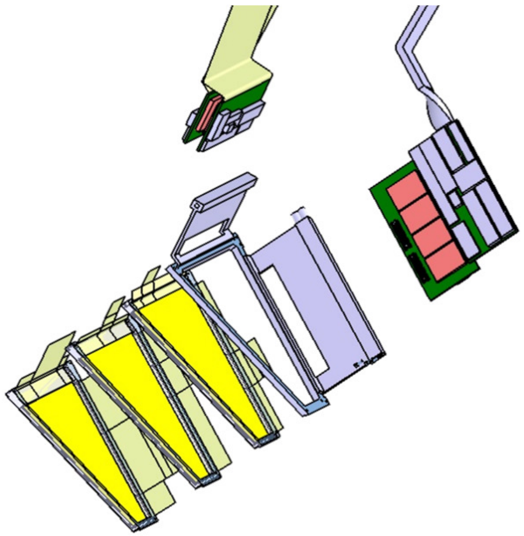
GRIT Design

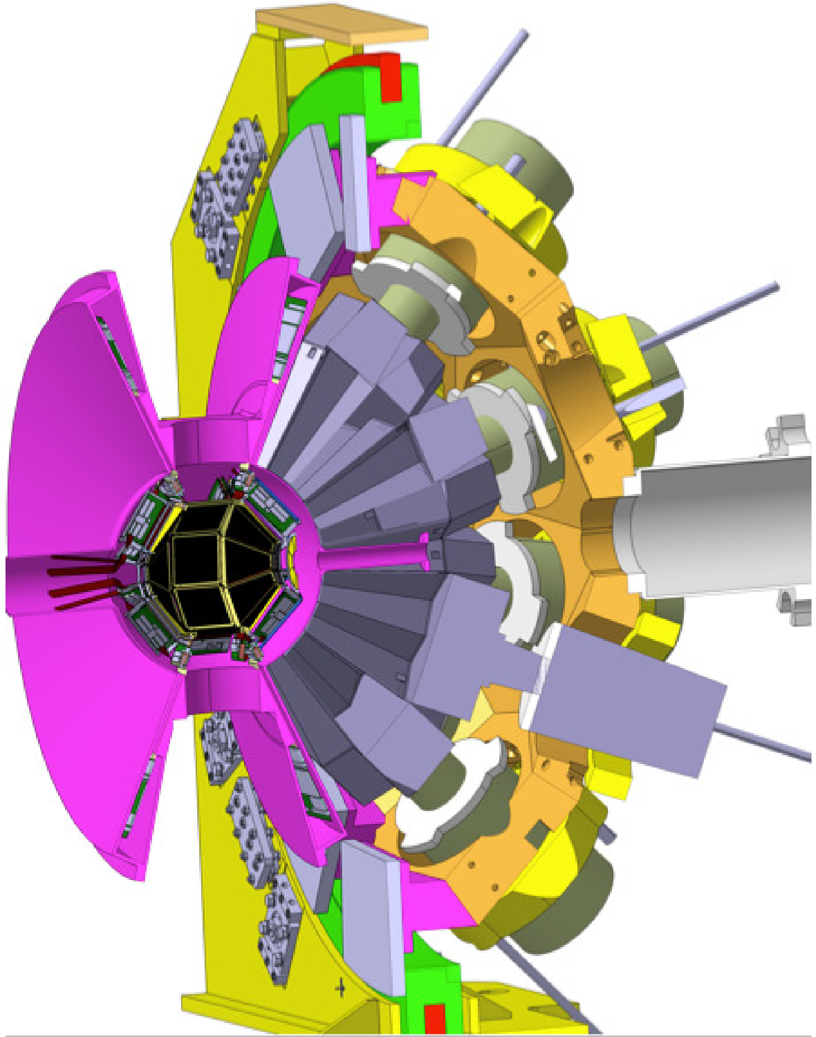
Constraints :

- AGATA radius = 23 cm (detectors + electronics)
- Integration of special targets (CHyMENE & ^{3,4}He)
- **Transparency to gamma-rays**
- FEE inside vacuum → power dissipation few kW
- ~10 000 electronics channels

> ➢ 2 detector's geometries + annular squared and trapezoids
> ➢ New telescope design
> ➢ Special chamber

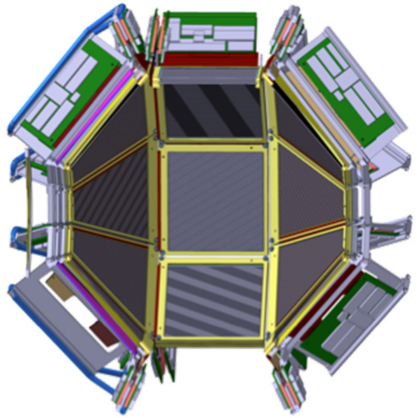




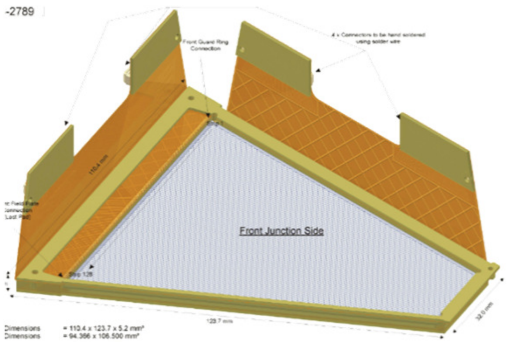


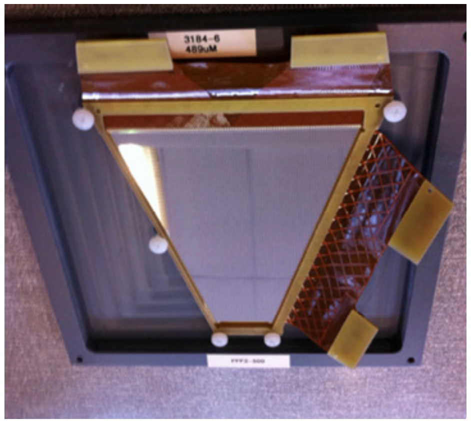
Detectors for GRIT

- Trapezoid and squared
- Special packaging: very thin frame
  Kapton readout at 90°
- NTD, random cut, reverse mount
- 6’’ wafers, 128 X + 128 Y
- Thin and thick

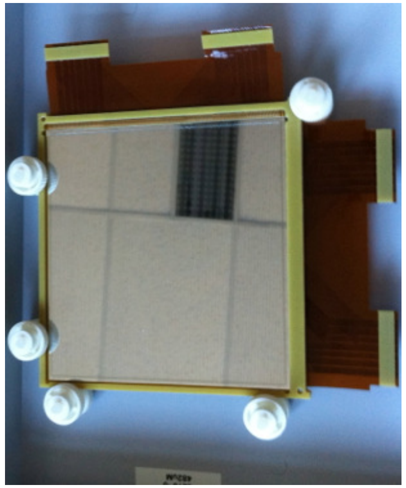


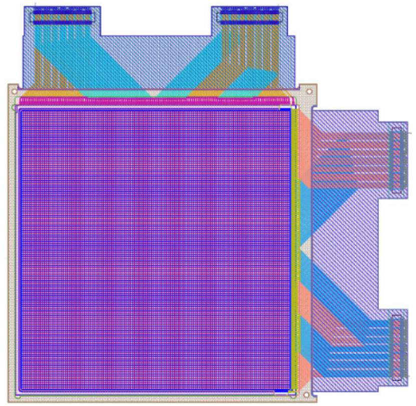
Trapezoidal DSSD





Squared DSSD





Commissioned :
- 2 prototypes 500um IPNO
- 4 pre-series (Surrey U., IPNO, Santiago)

Commissioned :
- 2 prototypes 500um INFN
- 1 prototype 1.5mm INFN

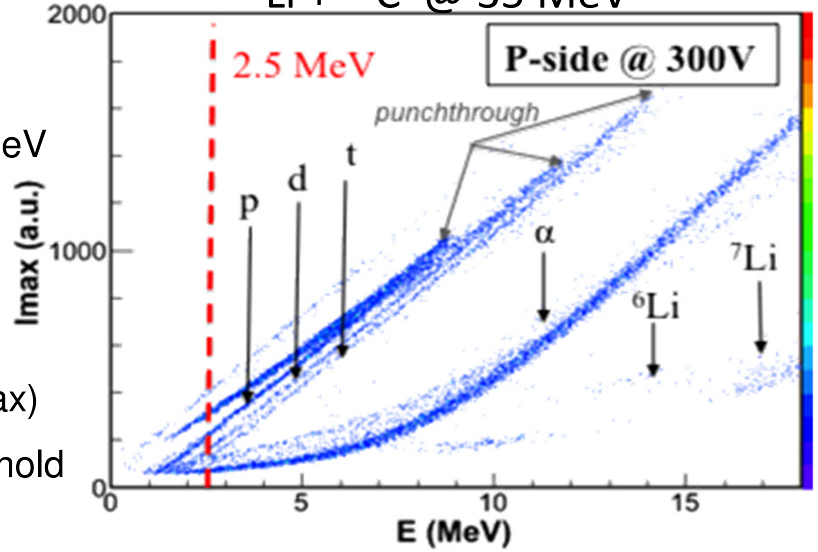
PSA studies for GRIT

R&D for highly segmented detectors

- 500 um nTD DSSD, BB13 design of MSL
- 8° cut, 128X+128Y

J. Duenas et al, NIMA 2012
J. Duenas et al, NIMA 2013
B. Genolini et al, NIMA 2013
J. Duenas et al, NIMA 2014
D. Mengoni et al, NIMA 2014
M. Assié et al, EPJA 2015

$^{7}Li + ^{12}C$ @ 35 MeV



Light particle discrimination @ Tandem-ALTO Orsay:

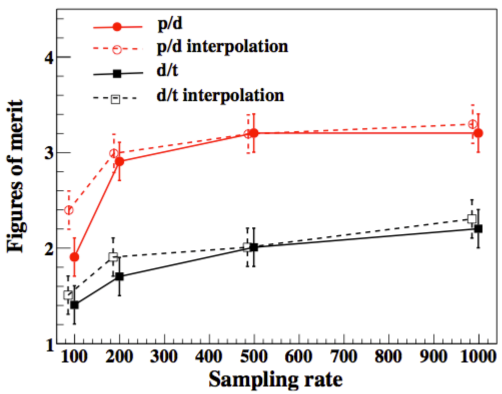
- Z=1 **: BB13**+PACI+MATACQ --> discrimination down to 2.5 MeV
  M. Assié et al., EPJA (2015)
- Z=2 : **BB13**+ PACI+WaveC → good discrimination $^{3}He/^{4}He$
  M. Assié et al., in prep.

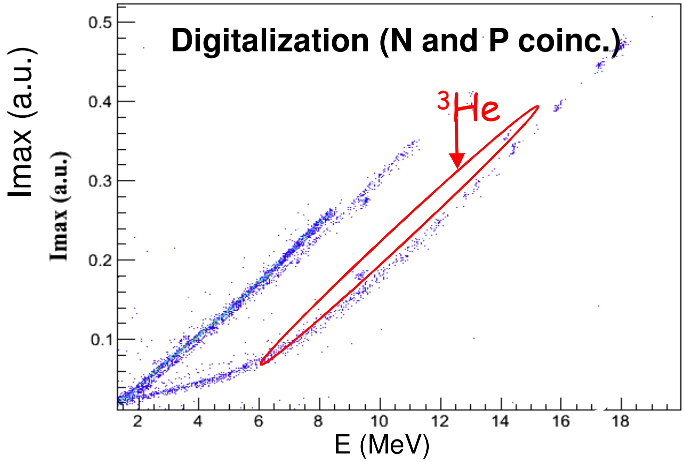
Best observable for PSD :

- At depletion -> Raw data : maximum of the current signal (Imax)
- At nominal bias ->Filtered data : Haar filter + Time over Threshold

Electronics specifications :

- ADC sampling rate : > 200MHz
- Noise study
- Time resolution needed





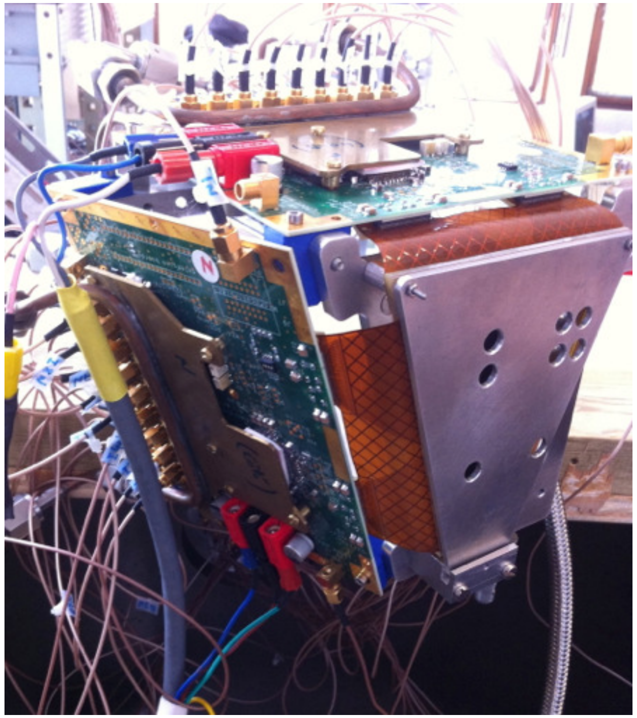
To be investigated :

- capacitance effect
- radiation damage effect

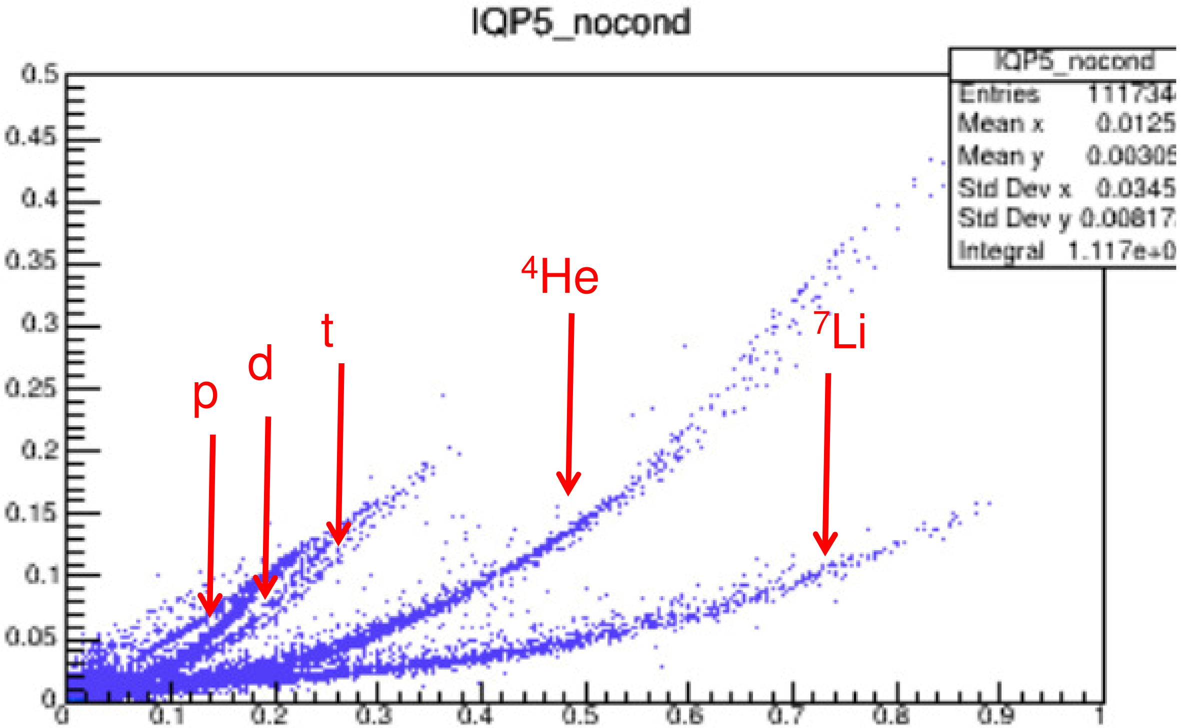
From M.Assié

Aside: Pulse shape analysis with trap. detectors

--> Test at ALTO 2 weeks ago for PSA with trapezoidal detectors



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



Online spectrum, no condition…

From: M.Assié

Electronics for GRIT

Preamplifier (IPNO)
Digitization (INFN)

iPACI : integrated (ASIC) version of PACI

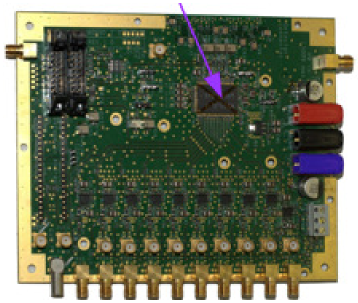
<u>version 1</u> : june 2015

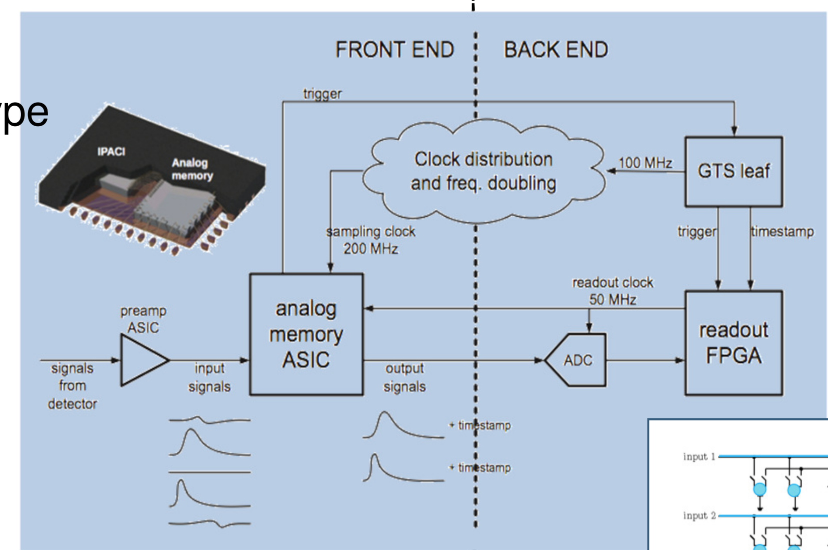
fully tested with prototype

E Range : 50 MeV

Current : +/- 1.5 V

Noise : 7 keV (FWHM)





- <u>version 2</u> (fast & slow shaper, TAC)
  end of 2017

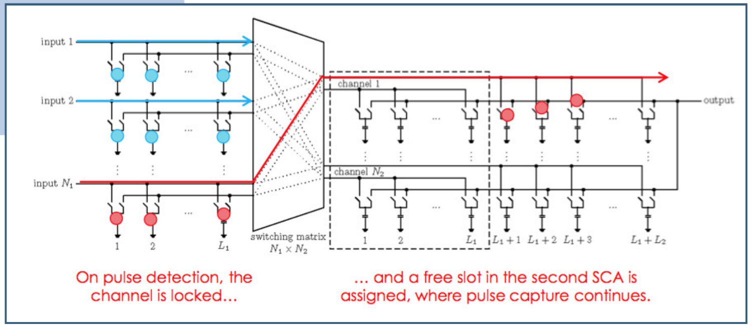
PLAS (R. Aliaga, Valencia)

ASIC analog memory

(switched capacitors)

- <u>version 1</u> received sept. 201

NUMEXO2 : adaptation for our needs in progress



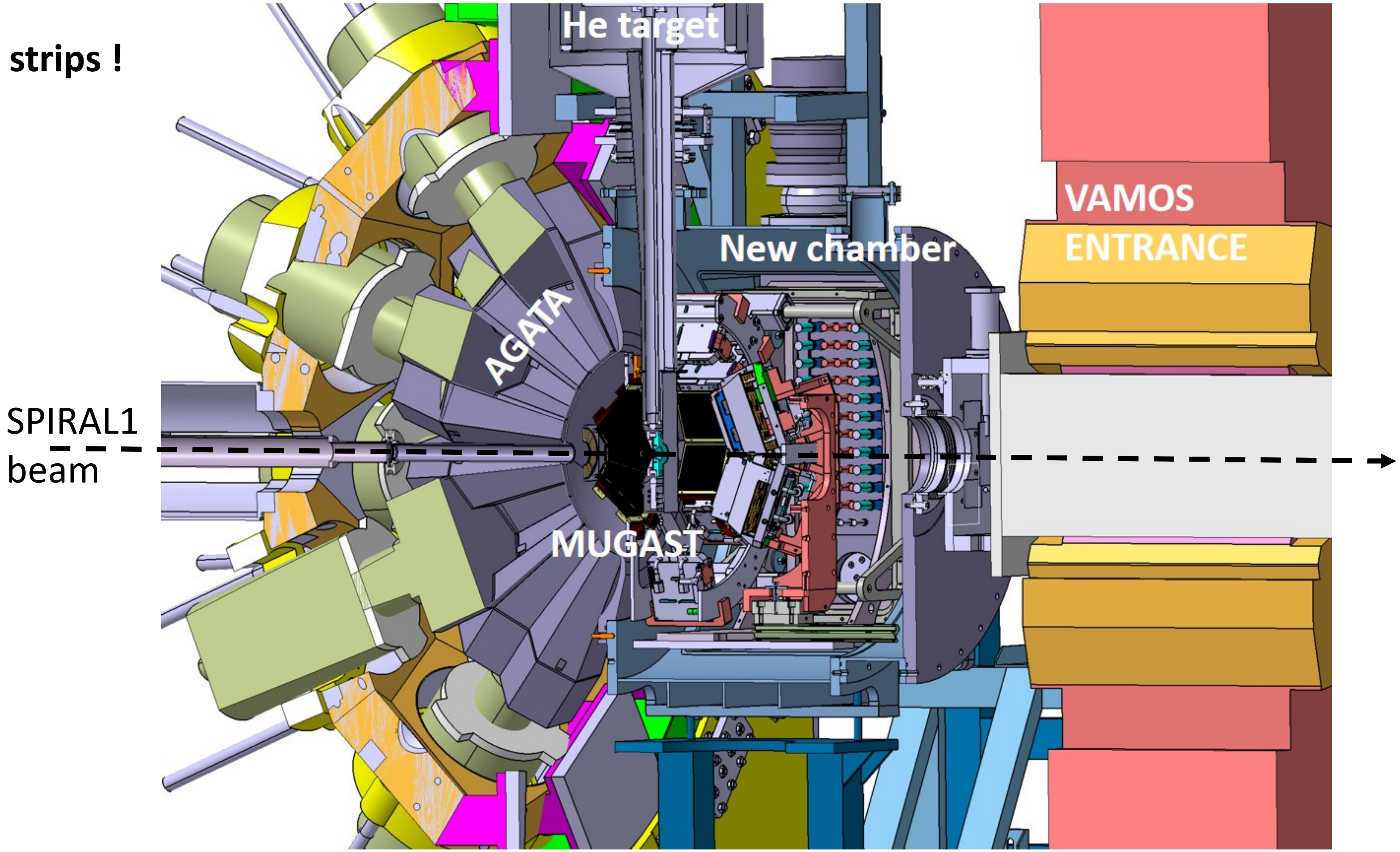
R. Aliaga, NIMA 800 (2015) :

Tests 2017 : coupling iPACI+PLAS+ NUMEXO2

MUGAST *an intermediate step towards the ultimate array*

MUGAST: New detectors of GRIT + MUST2 electronics coupled with AGATA @ VAMOS
⇒ First High resolution Direct Reactions studies at Ganil (new SPIRAL1 beams)

3000 strips !



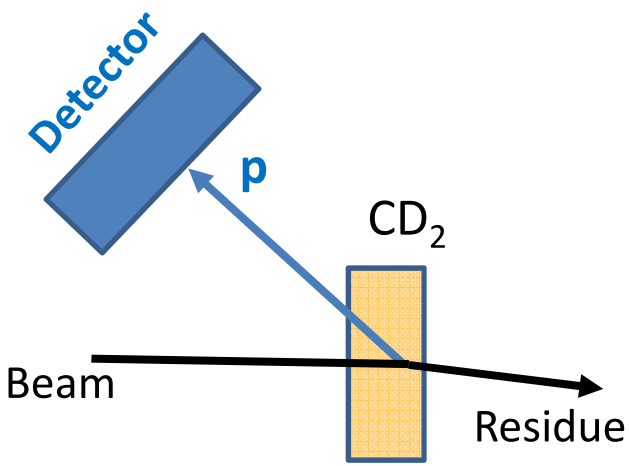
First campaign with Spiral1 beams foreseen 2019-2020

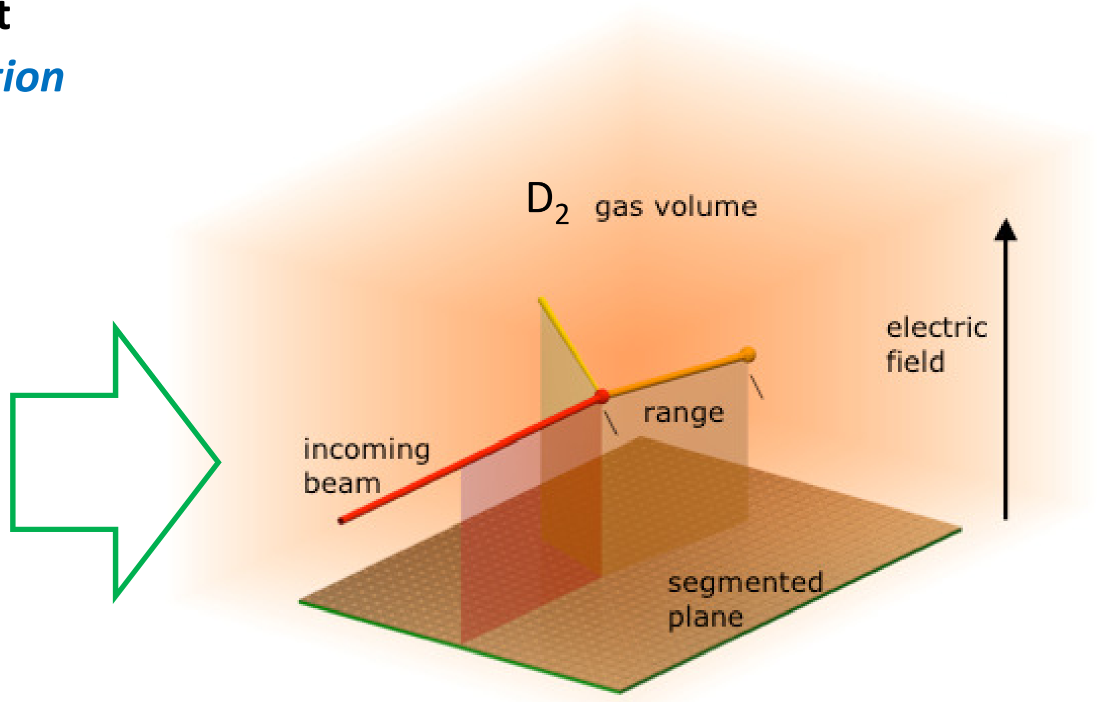
IPNO, INFN-Padova, Surrey, Santiago, GANIL

Active Target - concept

(d,p) reaction with SOLID target

Strong target effect on E_x resolution





- **Vertexing allows use of thicker target without loss of resolution**
- Pure target

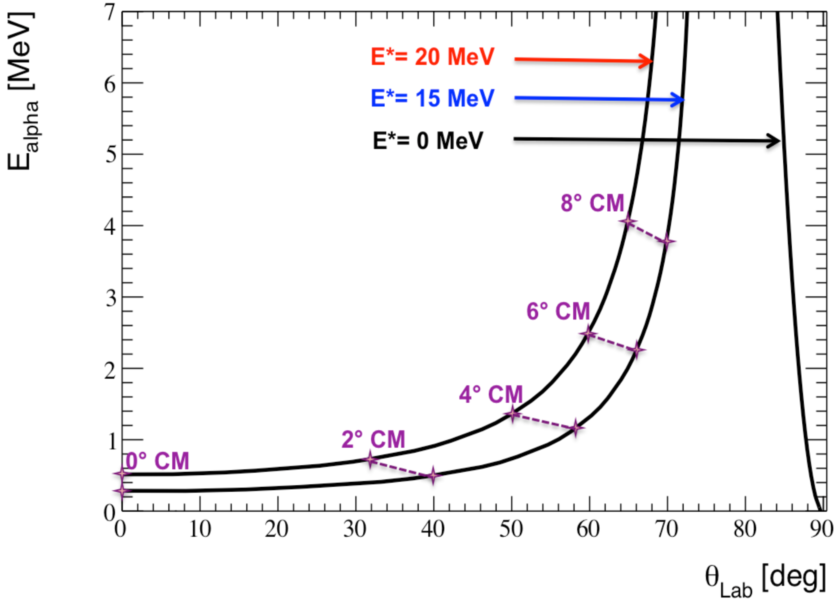
Well adapted for
- Very low intensity beams
- Study of excitation functions
- Very low energy recoils

Low-E recoil reactions

Giant resonances studies e.g. GMR

^{68}**Ni(α,α')** @ 50 *A* MeV

Q ≈ -15 MeV

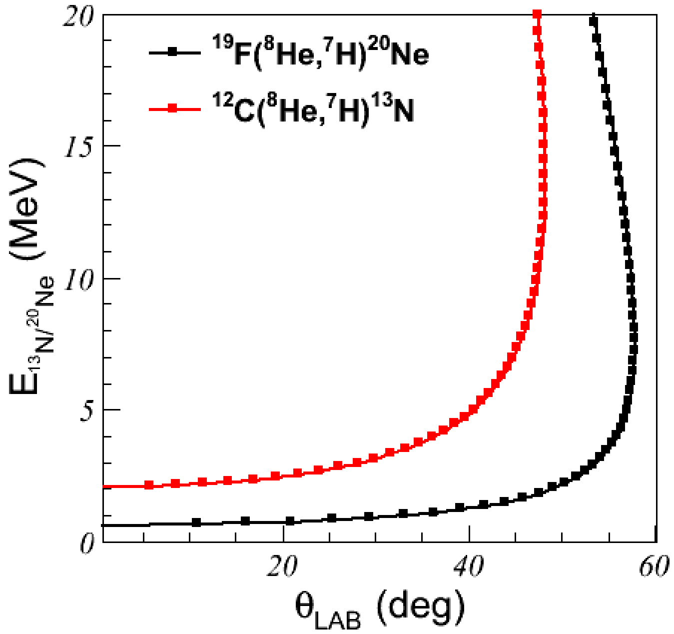


M. Vandebrouck, PhD thesis, Université Paris-Sud XI (2013)

Transfer with heavy ions

^{8}He(^{19}F, ^{20}Ne) ^{7}H @ 15*A* MeV

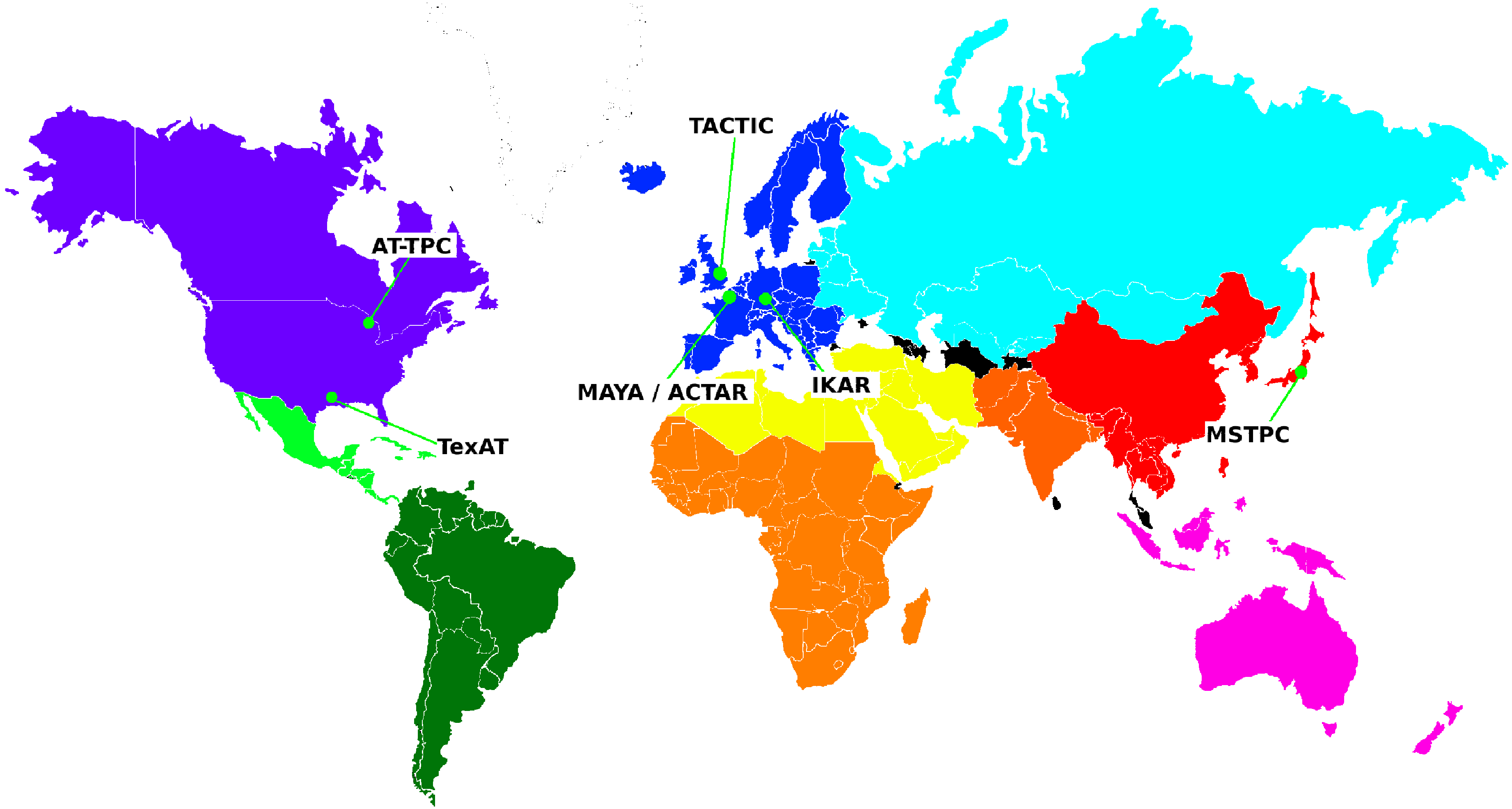
Q ≈ -13 MeV



Active Targets Worldwide

- Study of nuclei with short half-life, produced with small intensity
- Use of thick target without loss of resolution
- Detection of very low energy recoils

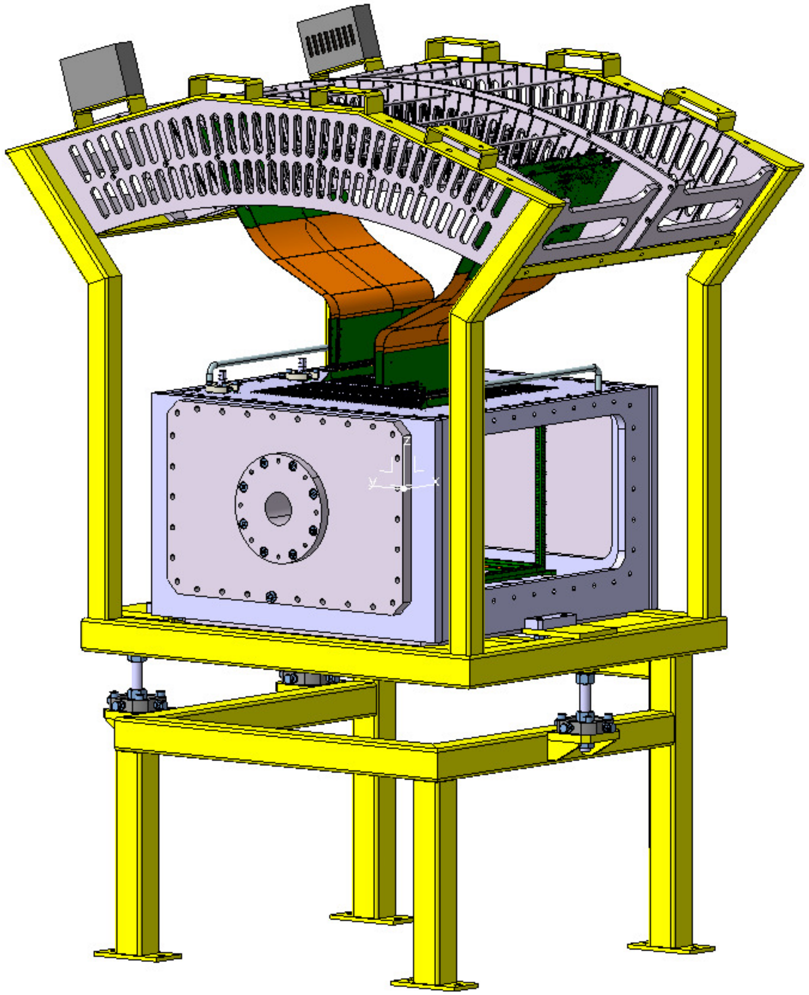
Active target: (Gaseous) detector in which the atoms of the gas are used as a target



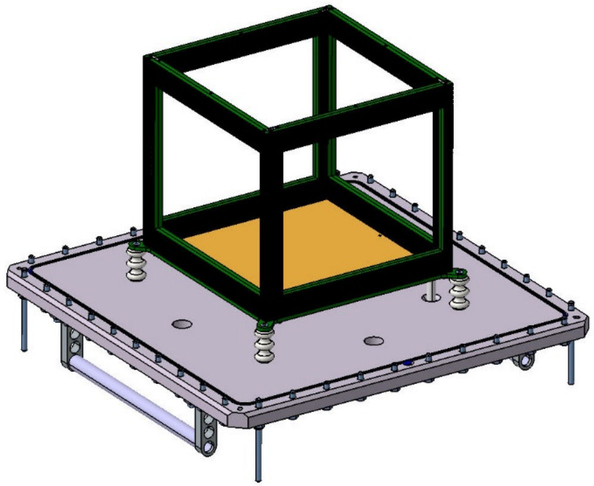
ACTAR TPC

ACTAR TPC: new generation active target – ERC Grant G.F. Grinyer

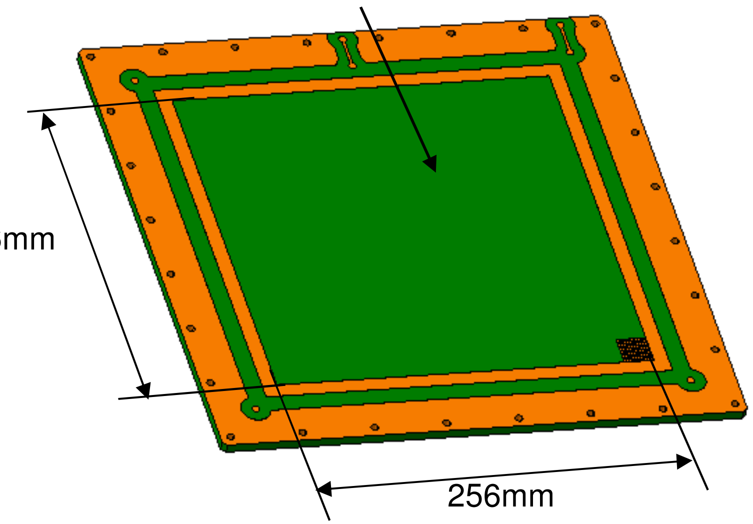
Collaboration: GANIL, KU Leuven, CENBG, CEA/Irfu, IPNO, Santiago U



European Research Council
Established by the European Commission



128x128 Pads 2x2mm area



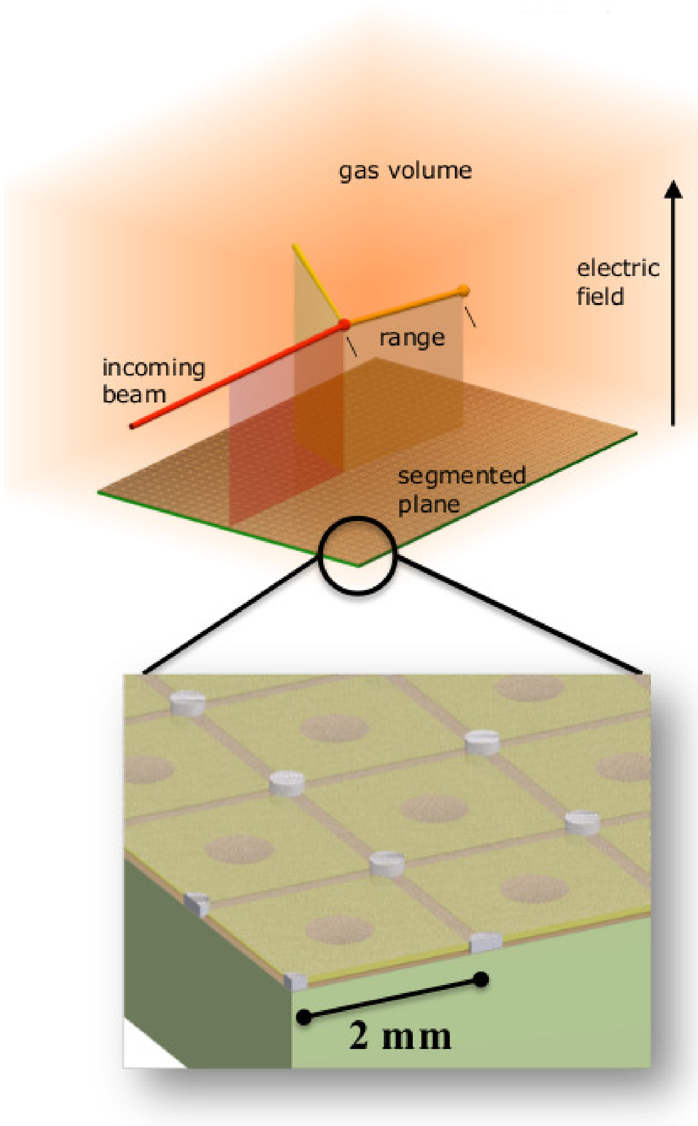
ACTAR TPC: Detector design

❑ Drift region:
→ Demonstrator: 1 mm pitch single wire field cage
→ Final chamber: double wire field cage
→ Simulations ongoing

❑ Amplification region:
→ Micromegas, 220 μm gap: OK for low pressure
→ Fast timing, robust, cost effective

❑ Segmented pad plane:
→ Very high density: 2x2 mm² (= 25 channels/cm²)
→ **Total 16348 electronics channels, digitized GET system**

❑ Auxiliary detectors:
→ Telescopes for escaping particles (Si+Si or Si+CsI)

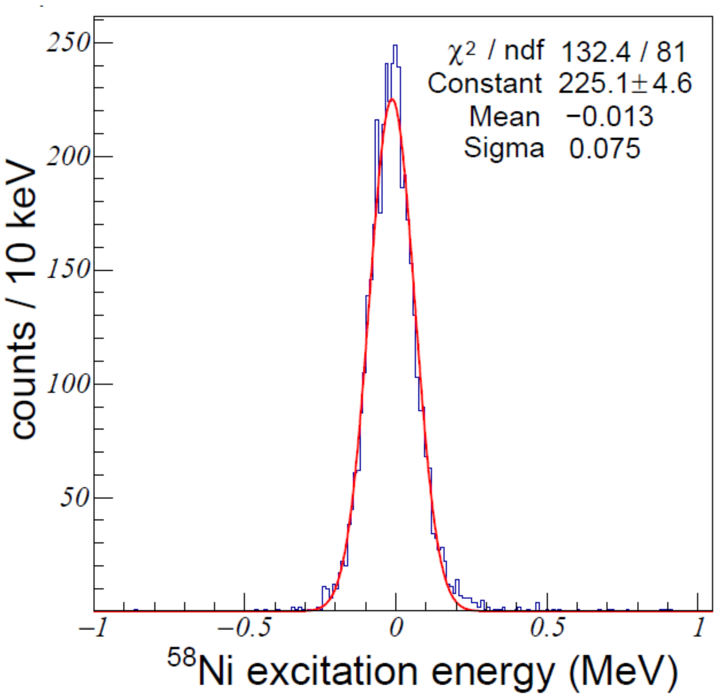


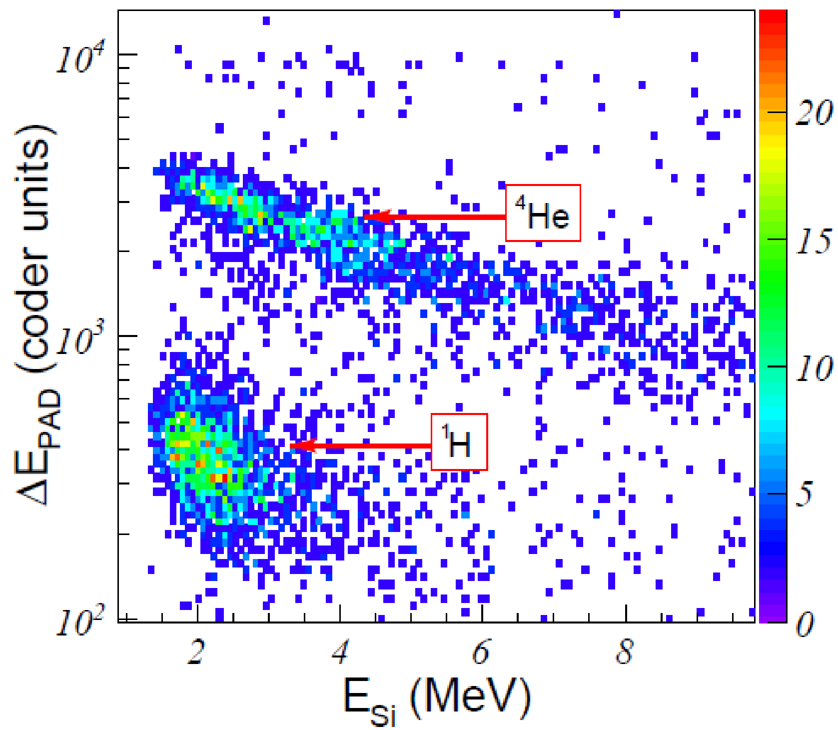
Detector performances with the 64x32 pads demonstrator:

→ **Angular resolution** tested with a laser (no straggling) :
$\Delta\Theta$ = 0.06° FWHM

→ Excitation energy resolution tested with ^{58}Ni(p,p) @ Elab = 3A MeV → ~ 0 MeV
ΔE_x = 175 keV FWHM

→ PID capabilities (room for improvement)



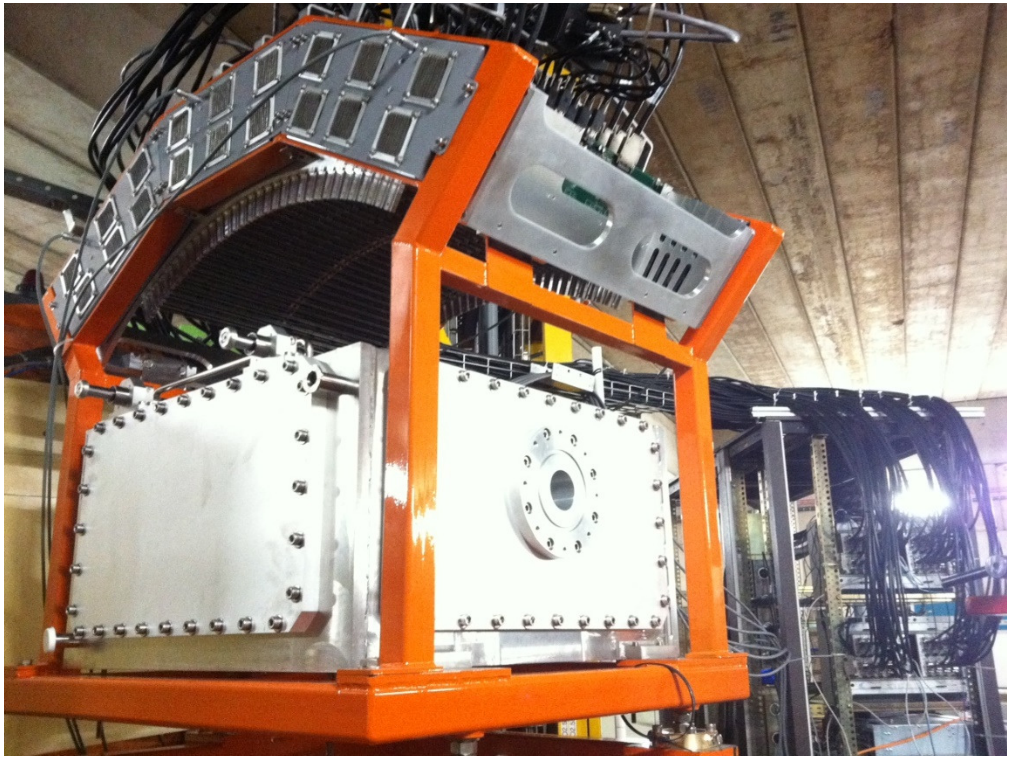


ACTAR TPC: status and outlooks

Status of the detector today:

→ Mounted on the G3 beam line of GANIL
→ All electronics plugged (~ 5% failure)
→ Field cage successfully mounted and polarized
→ First tests in alpha source ongoing
→ Commissioning exp. end of November $^{18}O(p,p)$ resonant scattering reaction

ACTAR on G3 beam line



Planned experiments (2018 - 2019)

→ **Resonant scattering with ^{17}F and ^{32}Ar on proton: SPIRAL1 beams**
→ **Proton decay studies of ^{48}Ni and ^{54}Ni: LISE fragmentation beams**

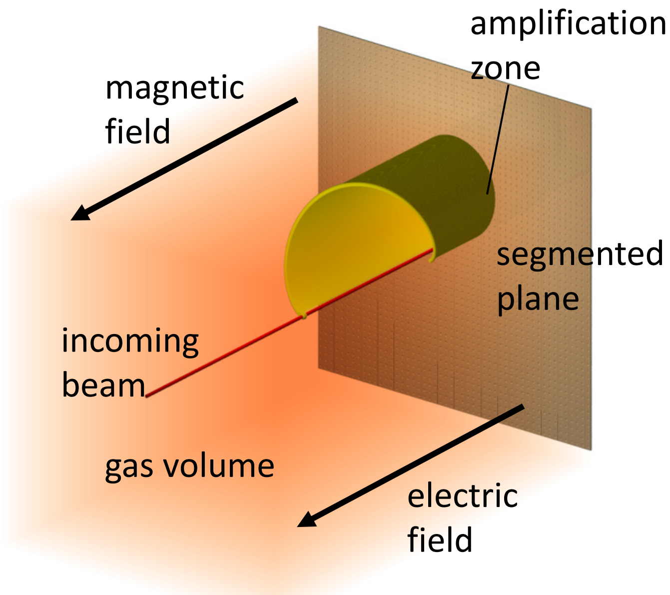
Experiments proposed at the coming GANIL PAC

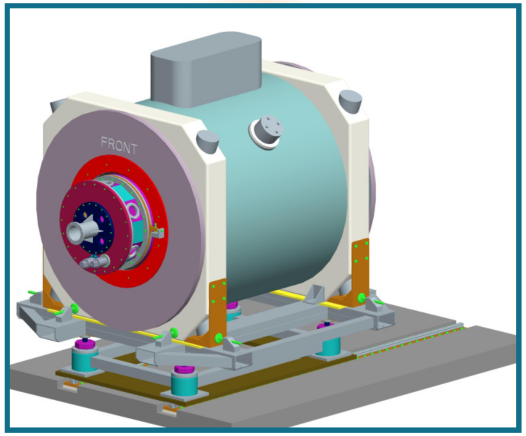

Workshop on Active Targets and Time Projection Chambers for High-intensity and Heavy-ion beams in Nuclear Physics
Second GDS Topical Meeting
16-19 January 2018. Santiago de Compostela, Spain
• Physics with Gas Detections Systems (GDS)
• Active Target and TPCs: ongoing and forthcoming projects
• Experiments with high-intensity and heavy-ion beams
• Gas properties for high-intensity and heavy-ion beams
• Ancillary detectors for high-intensity and heavy-ion beams
• Simulations and electronics for GDS
Information and registration:
https://indico.in2p3.fr/event/16443/
ENSAR2
GDS
USC
IPN
INFN
KU LEUVEN

SpecMAT
Spectroscopy of exotic nuclei
in a Magnetic Active Target

The instrument

- Active target
  Efficiency
  Tracking of particles trajectories
  → reconstruction of the vertex
  large target thickness preserving
  god resolution
- Magnetic field
  Parallel to the beam direction
  Confine charged particles
  Minimize material
- Gamma-ray detection
  Improve resolution
  Scintillation crystals for good efficiency

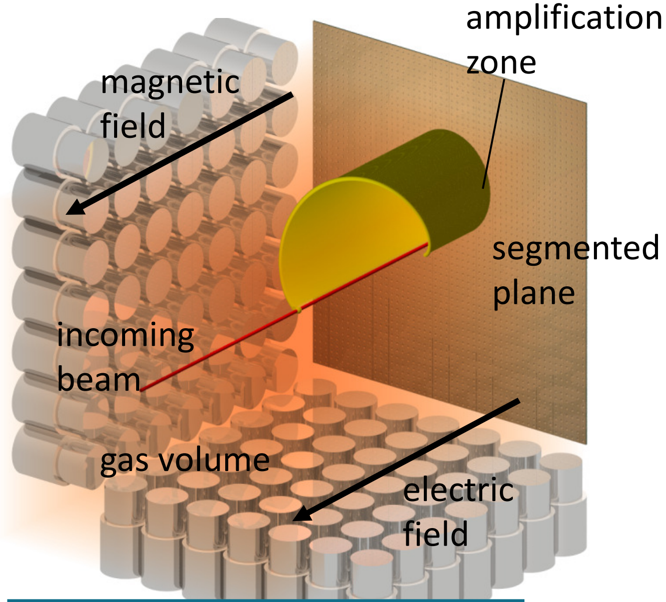


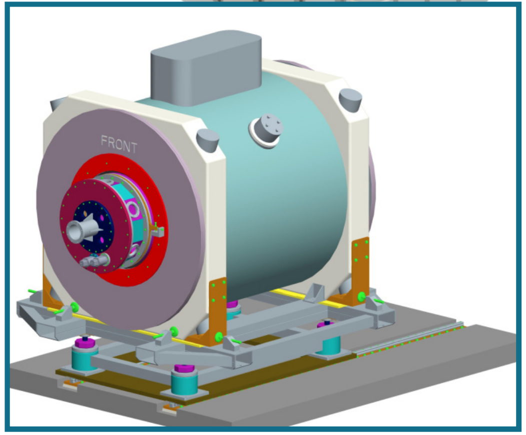


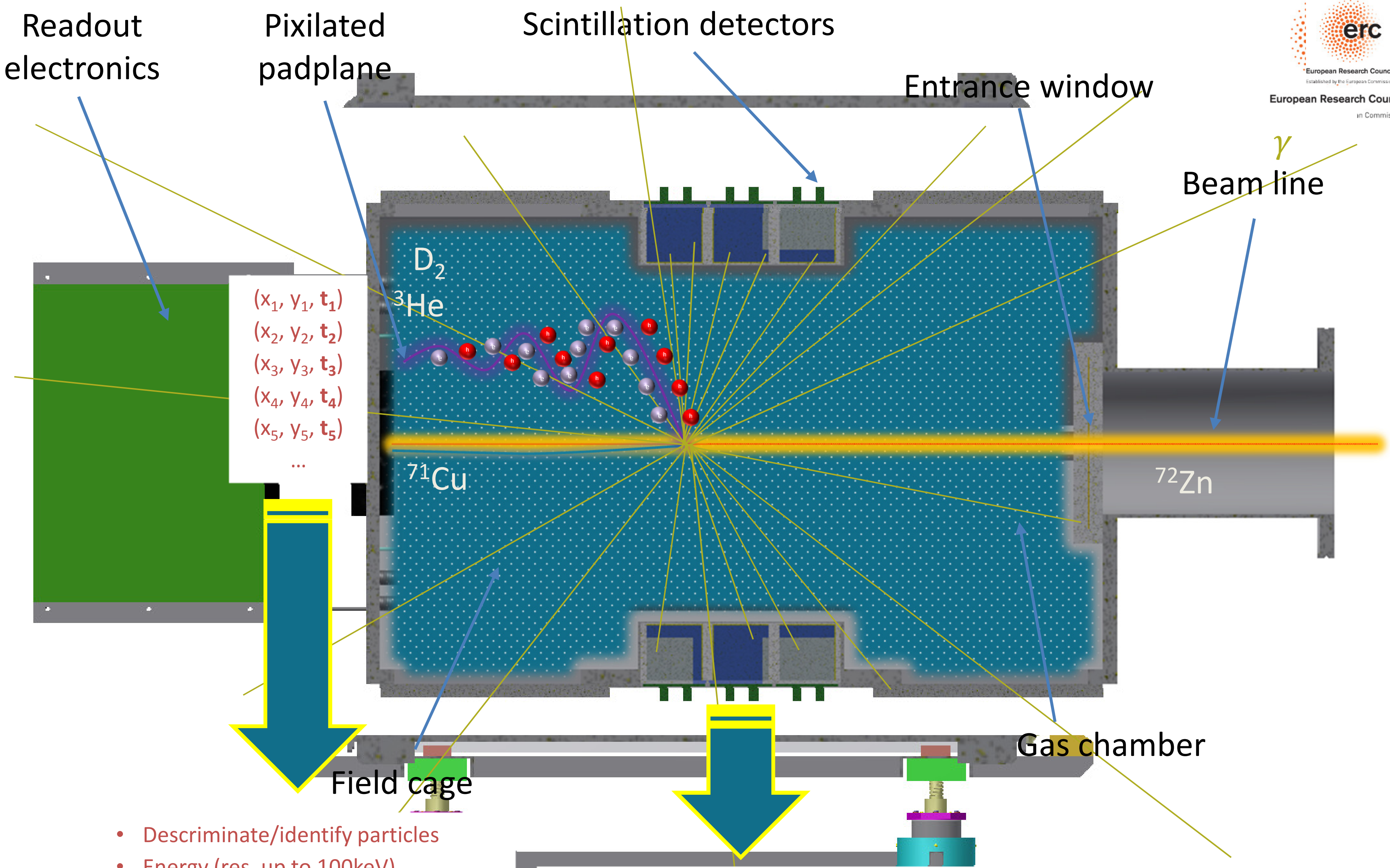
The instrument

- Active target
  Efficiency
  Tracking of particles trajectories
  → reconstruction of the vertex
  large target thickness preserving
  god resolution
- Magnetic field
  Parallel to the beam direction
  Confine charged particles
  Minimize material
- Gamma-ray detection
  Improve resolution
  Scintillation crystals for good efficiency

Challenge:
optimise efficiency and energy resolution
of gamma detection in magnetic field







- Descriminate/identify particles
- Energy (res. up to 100keV)
- Angular distribution

- Gamma spectroscopy (res. up to 26keV @ 662keV)

Technical solutions

Gamma detectors

- 2”x 2”x 2” $CeBr_3$ crystals from Hellma (Germany)
- J-series SiPM array
- Custom break-out board
- Assembly: Scionix (Holland) guaranteed resolution: **3.9%**

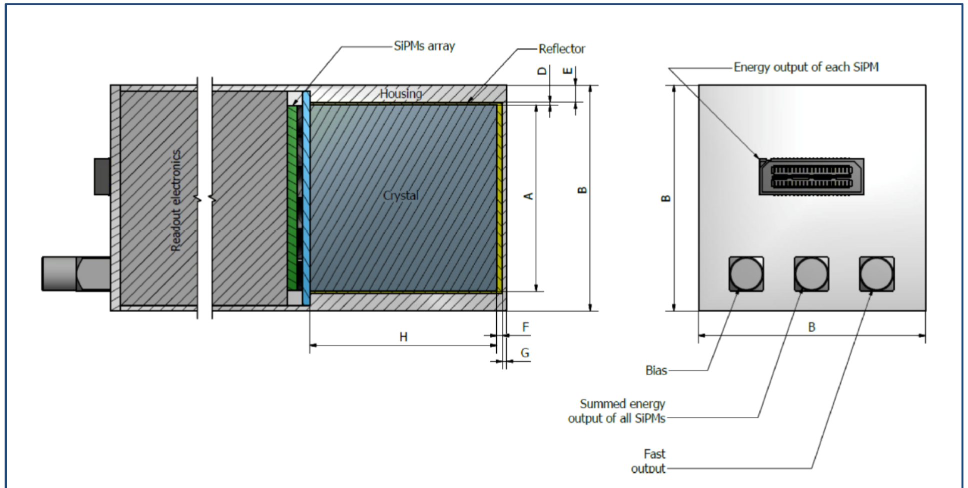
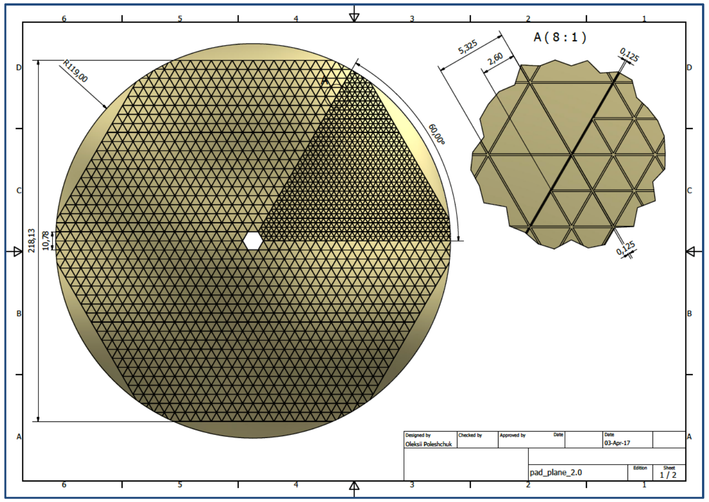


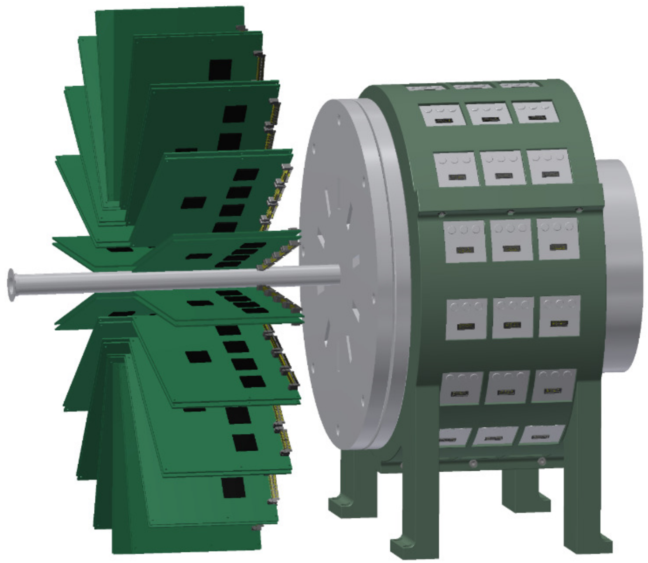
Fig. 1 Schematic drawing of the scintillation detector

GET electronics

Pad plan for commissioning



Preliminary design



SpecMAT
Plans and timelines

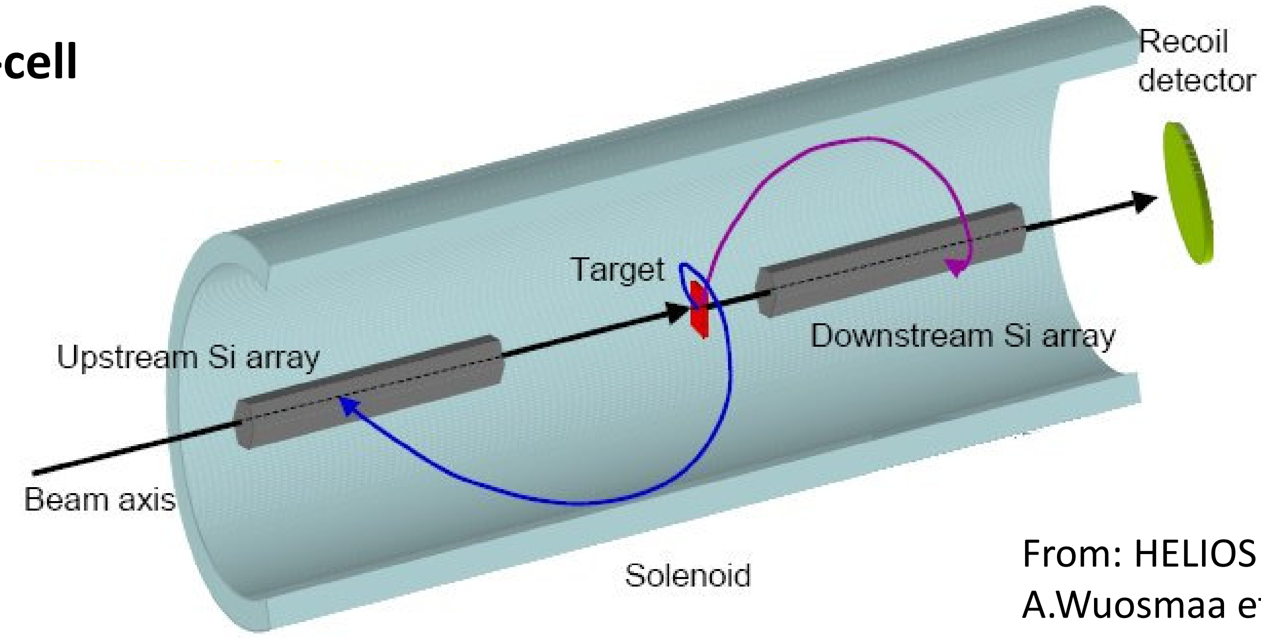
- Scintillation detectors purchased, delivery within 8 months
- Chamber design in progress (drift cage, connectics,…)
- GET electronics (2000 channels) acquired
- First version pad plane and assembly by Spring 2018
- First commissioning measurements in 2018-19

  (2 LoI’s submitted to INTC for the shutdown period)

Solenoid Spectometer systems

Solenoid spectrometer concept

- **Solid or gas-cell target**
- **B = 2~5 T**



From: HELIOS proposal
A.Wuosmaa et al.

Light particles follow helical cyclotron trajectories and return to axis after single orbit
⇒ Can cover ≅4π with 2 pencil-shape Si arrays

Particles travel a fixed period of time T_{cyc} (M,Q) indep. of E,θ

⇒ Can be used for PID

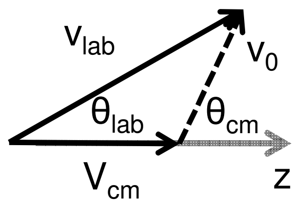
Particle	T_{cyc} (ns) for 2T	T_{cyc} (ns) for 5T
p	32.8	13.1
d, α	65.6	26.2
t	98.4	39.4
^{3}He	49.2	19.7

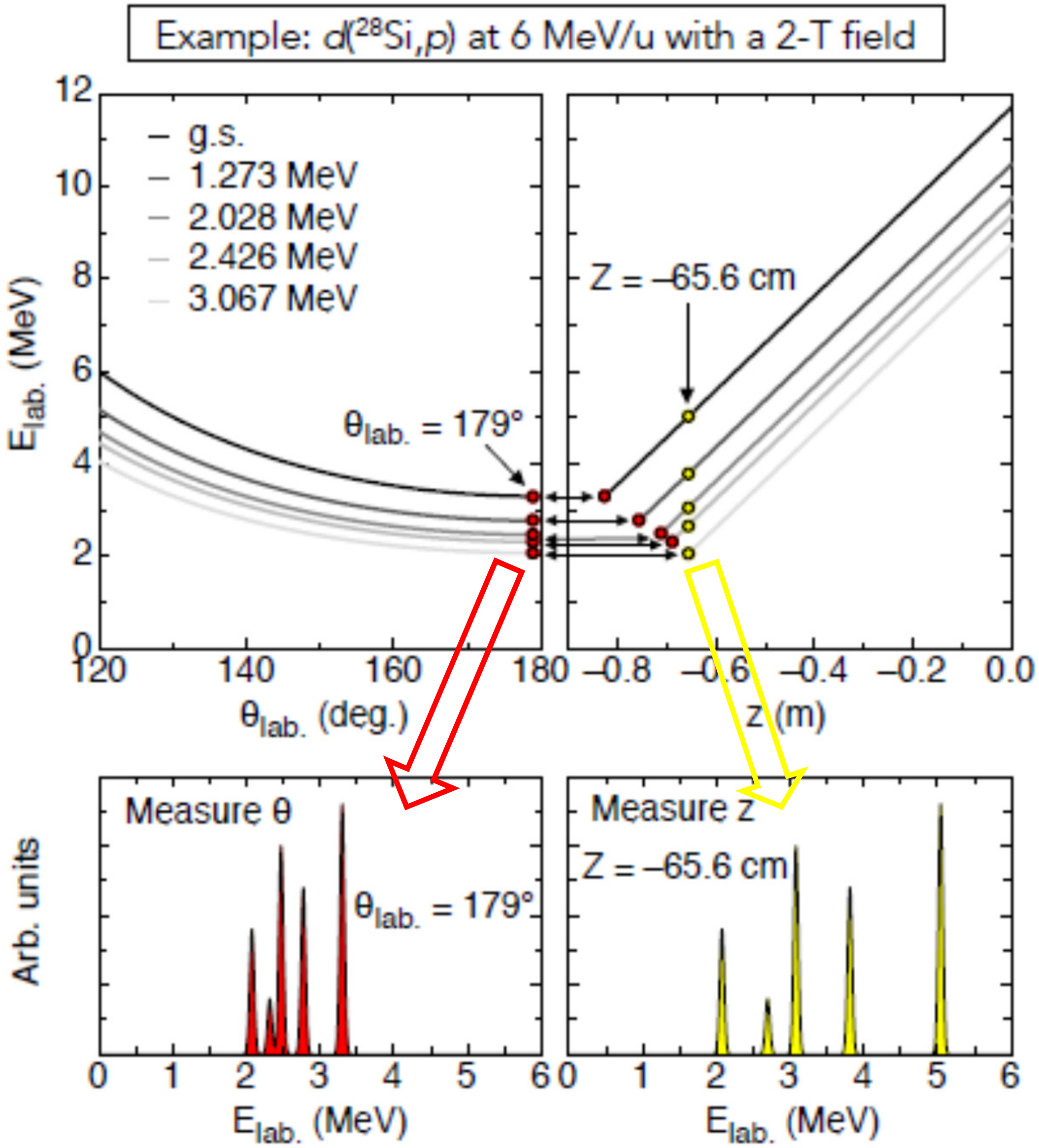
Solenoid spectrometer concept

Removes kinematic compression

$$E_{\rm cm} = E_{\rm lab} + \frac{mV_{\rm cm}^2}{2} - \frac{mzV_{\rm cm}}{T_{\rm cyc}}$$

$$\cos\theta_{\rm cm} = \frac{v_{\rm lab}^2 - V_{\rm cm}^2 - v_0^2}{2v_0V_{\rm cm}}$$



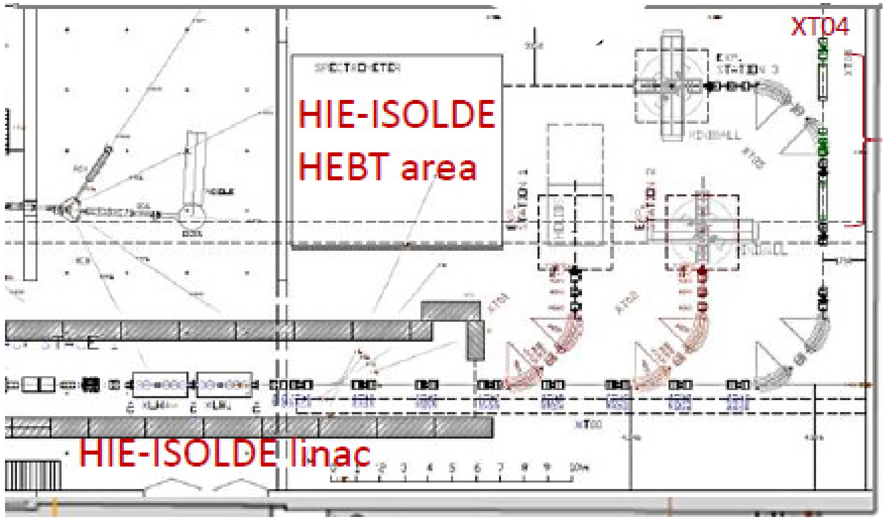


- **Improved E_{cm} resolution**

The ISOLDE Solenoidal Spectrometer project

ISOLDE Solenoidal Spectrometer

- UK STFC funded
- To be installed on XT02 beam line



UNIVERSITY OF LIVERPOOL

Science & Technology Facilities Council

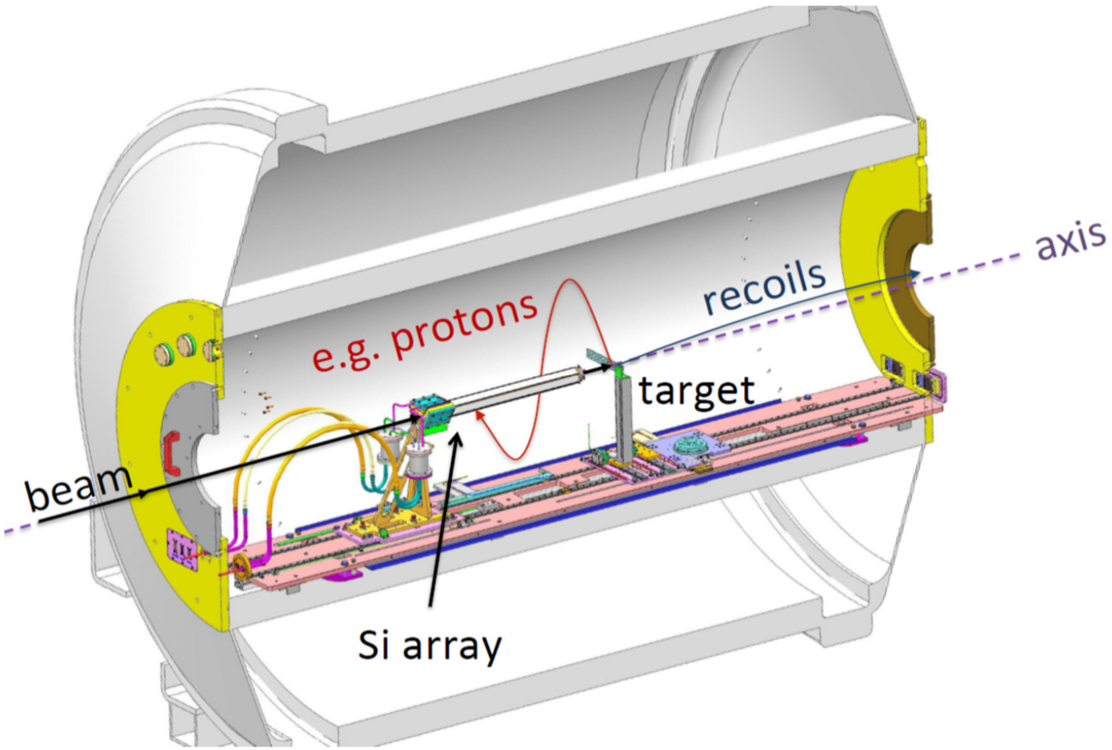
Argonne NATIONAL LABORATORY

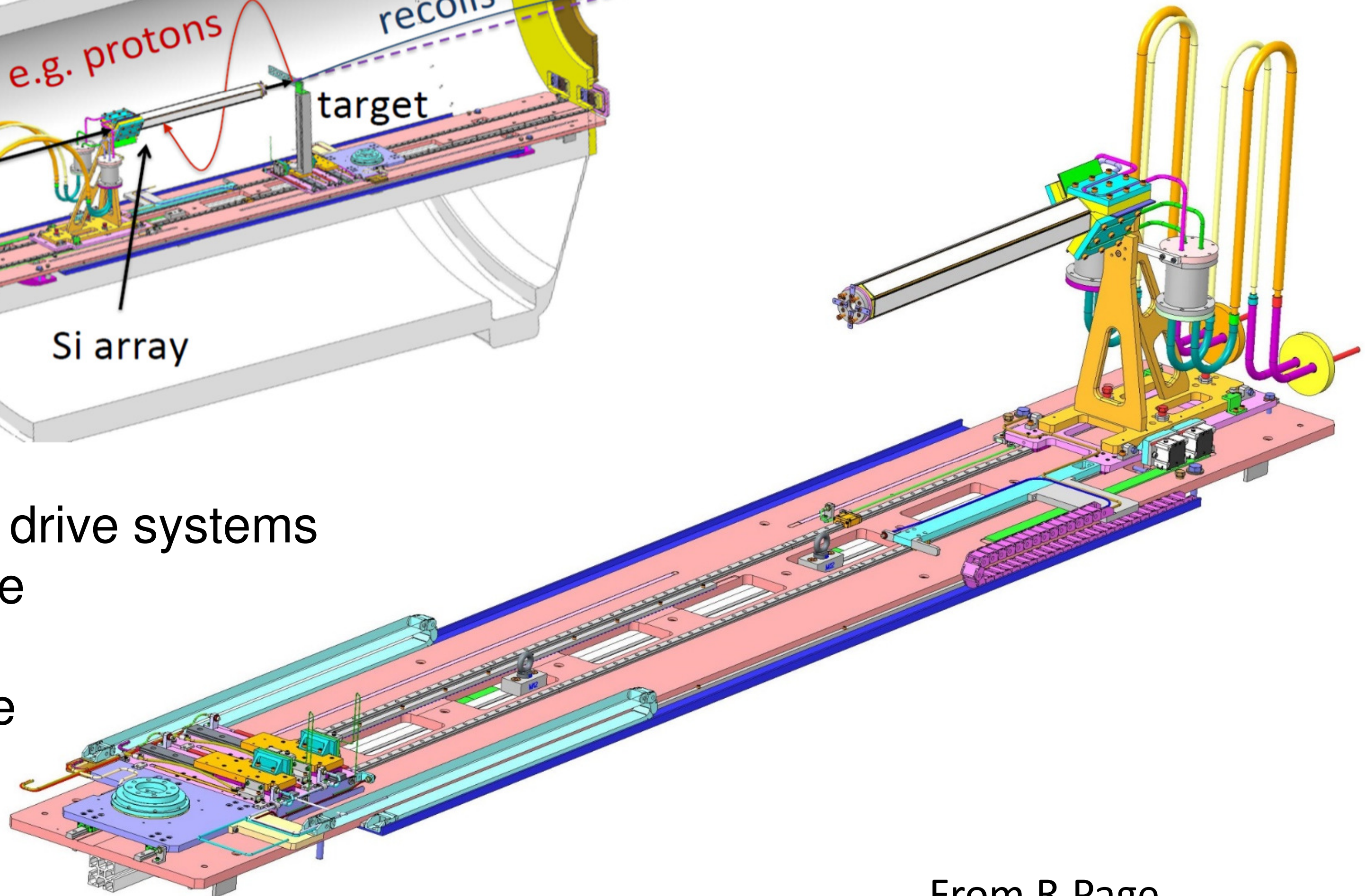
MANCHESTER 1824 The University of Manchester

UNIVERSITY OF SURREY

KU LEUVEN

ISS Mechanical Design

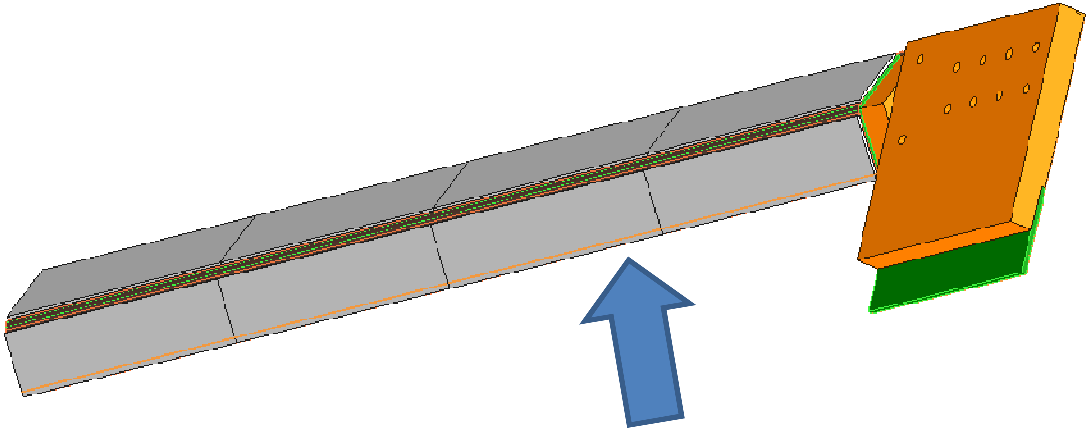




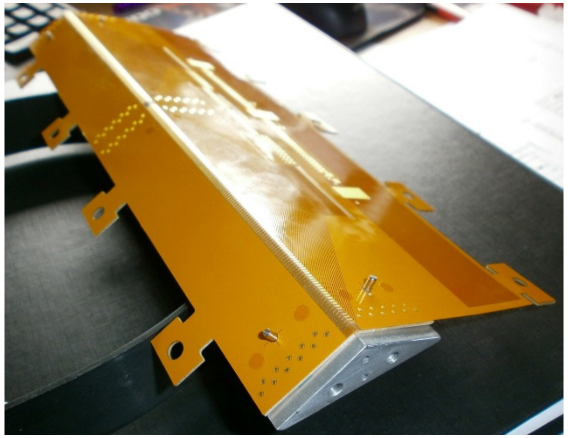
Target & detector drive systems
Hexagonal Si tube
~50 cm long
4 DSSDs per face
ASIC readout
Cooled

From R.Page

ISS Si detector module

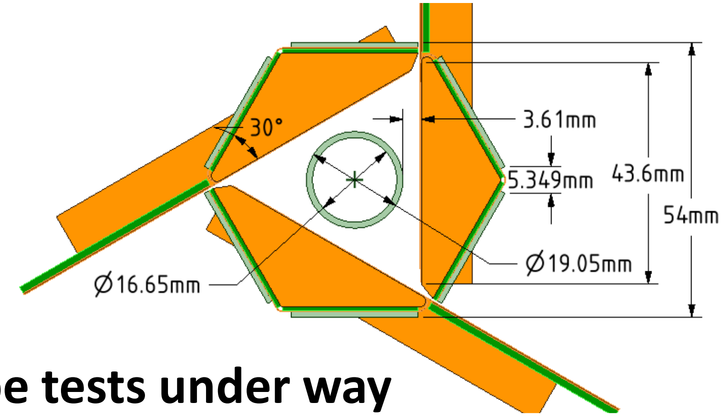


READOUT
6 R^3B ASICs
0 – 50 MeV
128 channels
100 MHz time stamp
daisy-chained



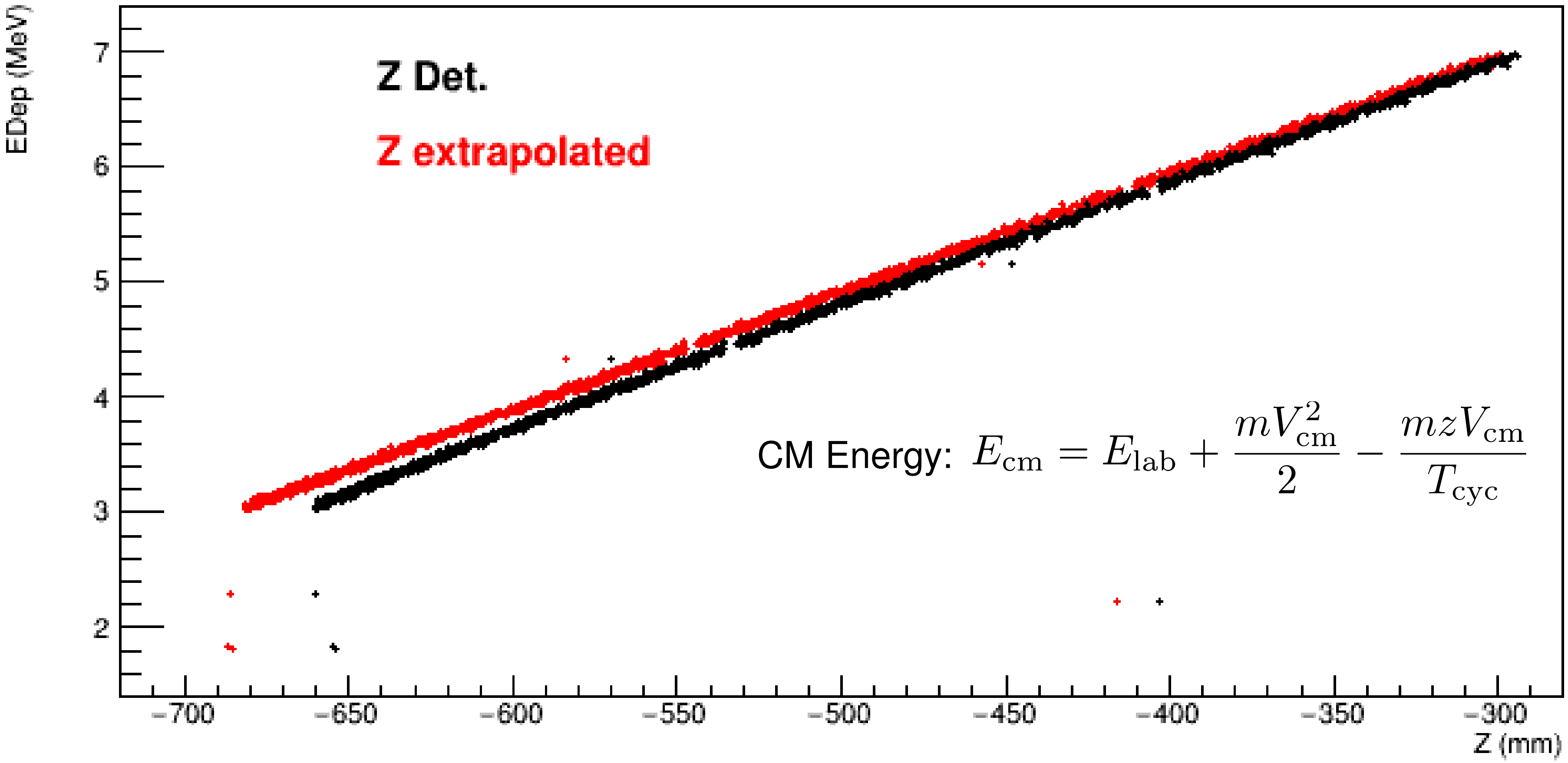
DETECTOR
DSSDs: 1 mm thick
x: 128 × 0.95 mm
y: 11 × 2 mm

➢ First DSSDs delivered



Prototype tests under way

Reconstructing the z position



Algorithm devised by P. Butler
Implemented in GEANT4 by M. Labiche

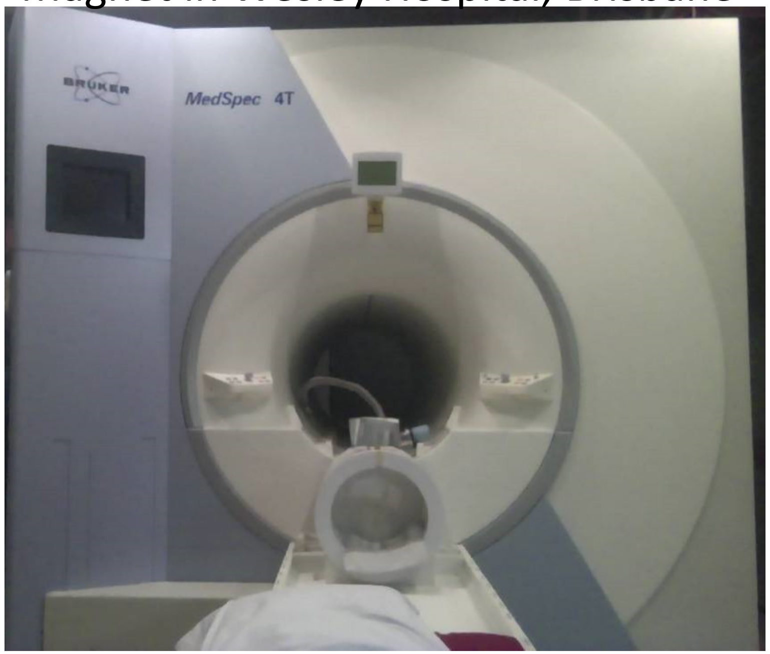
From R.Page

Magnet procurement

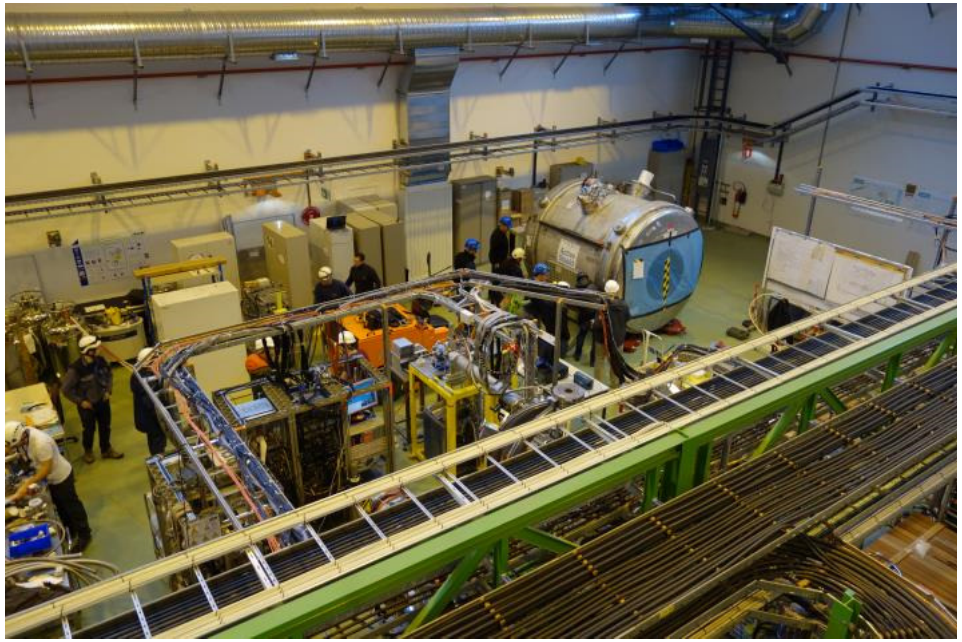
- Magnet available from Brisbane (UQ)
  - OR66 4T ex-MRI magnet
  - "Active shield" reduces stray field
  - Installed February 2003
  - Discharged then warmed ~2013

Funding request (STFC/UoL)
June 2015
Magnet ordered November 2015

Magnet in Wesley Hospital, Brisbane

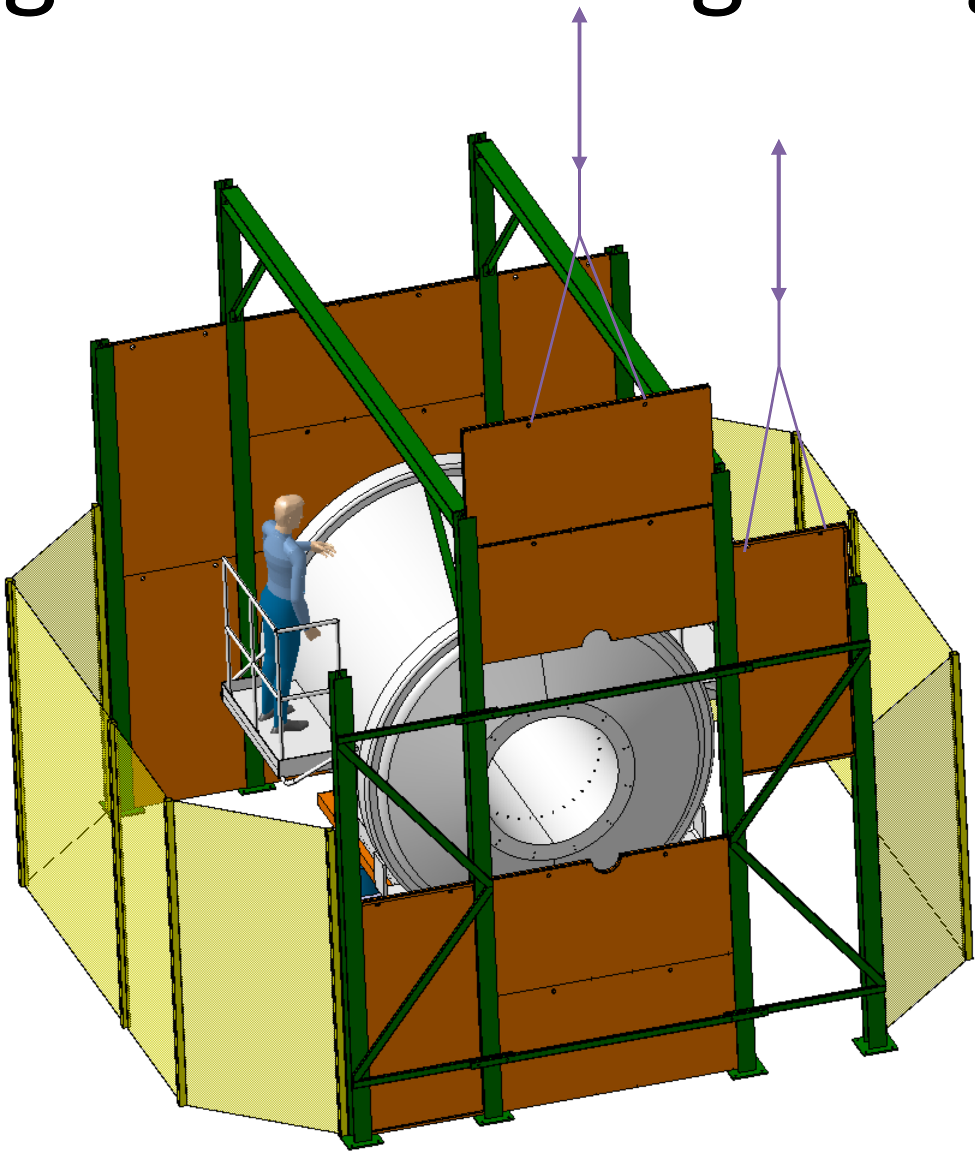


Now installed in the Isolde Hall



- **Magnet recommissioned (cleaning, vacuum test, cooling…)**
- **ISOLDE integration continuing**

Magnetic shielding design



Jérémie Bauche, Kevin Buffet & Yacine Kadi (CERN)

R.Page

Exploitation plans

early exploitation before LS2

stable & long-lived isotope running during LS2

+ commissioning of the ISS Si array

+ commissioning of gas recoil detector…

followed by ISS running after LS2

ISOLDE Solenoidal
Spectrometer

Thank you