Nuclear Physics at ISAC-II: The French Connection FR

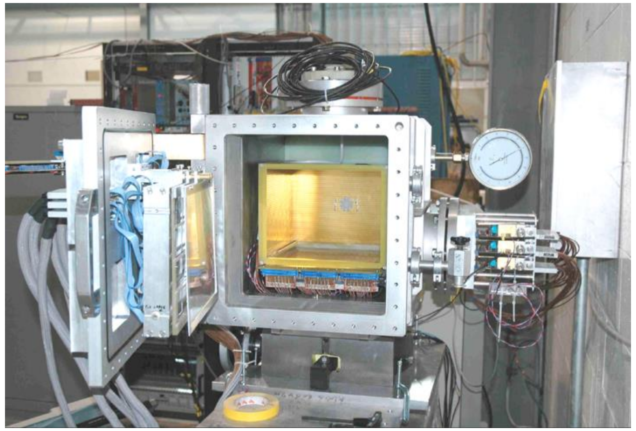
IRL-CRNS workshop

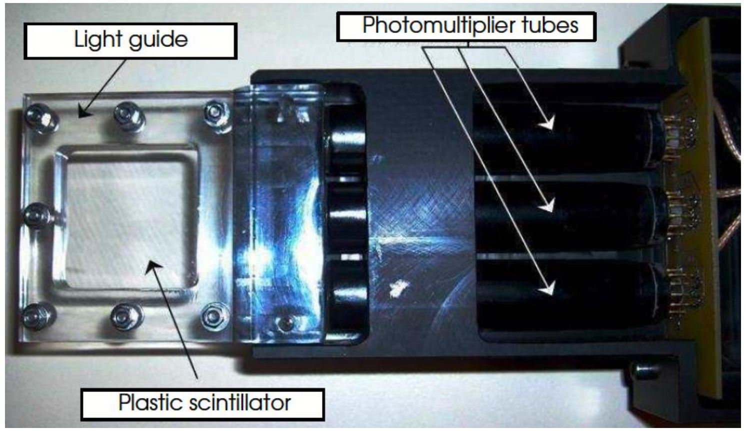
2025-09-20

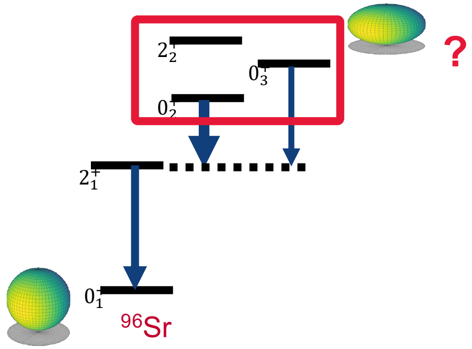
G. Hackman, TRIUMF

French Connections to the ISAC-II Program

- First ISAC-II Experiment was with MAYA
- Recent Campaign with ACTAR
- Trifoil for SHARC experiments
- ^{96}Sr etc. Coulomb excitation with TIGRESS







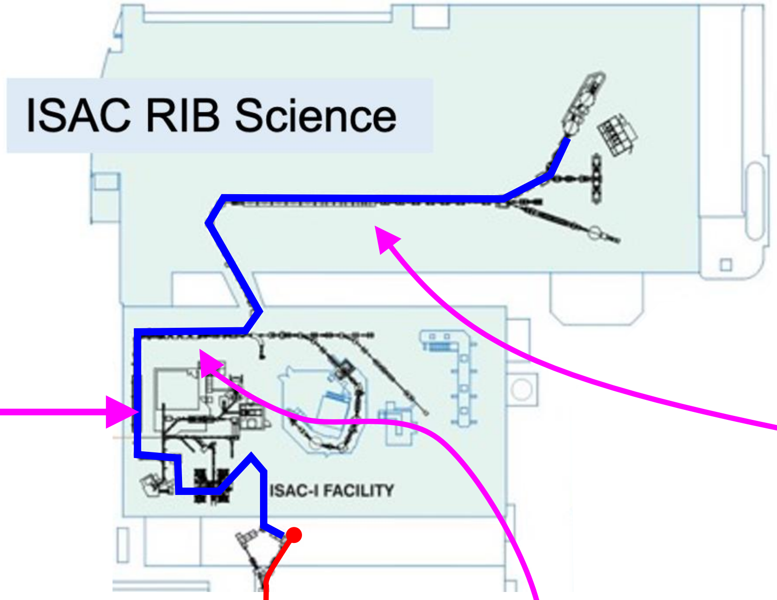
(very) Quick review of ISAC-II at TRIUMF

ISAC-II on the TRIUMF site

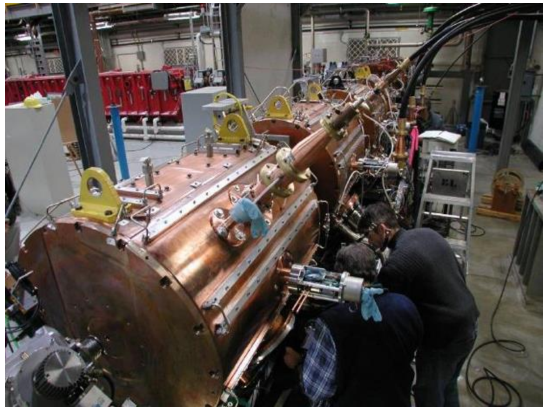
ISAC-II on the TRIUMF site

ISAC-II accelerator chain

- Step 1: Radio-Frequency Quadrupole
- 1.8% speed of light (fixed, =0.15*A* MeV)



- Step 2: Room Temperature Drift Tube Linear Accelerator
- < 5.7% speed of light (1.5*A* MeV)
- Optimized for Gamow peak for proton, alpha capture on A<30 ions

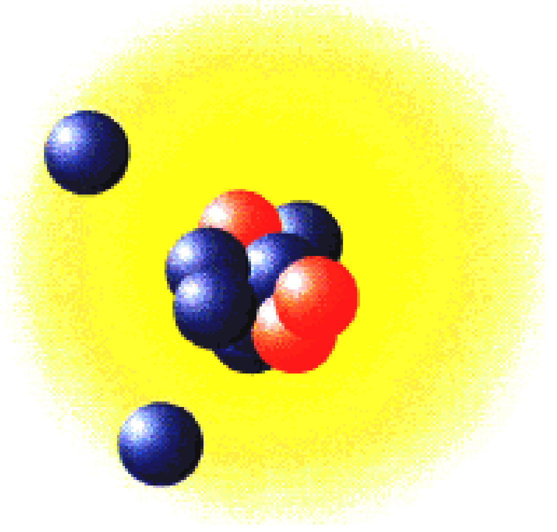


- Step 3: Superconducting Linear Accelerator
- 18% speed of light (maximum)
- (15*A* MeV for low masses, decreases for higher masses)
- Maximum ever:
- 1100 MeV ^{208}Pb

MAYA 2007

H Savajols, GANIL; T. Roger, U. Caen FR

^{11}Li beams at ISAC ~ 2007



- ^{11}Li: Halo Nucleus
- 2 weakly bound neutrons, ^{9}Li core
- Hot topic

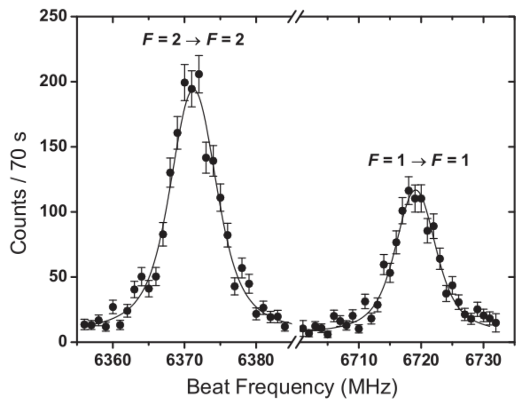


FIG. 1. Resonances in the $2s \rightarrow 3s$ transition of ^{11}Li as a function of the beat frequency between the Ti:sapphire laser and the reference diode laser. Error bars are simple counting statistics on the number of observed ion counts.

Sánchez et al, PRL 96, 033002 (2006)

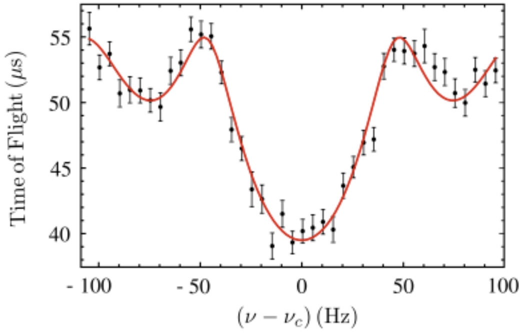
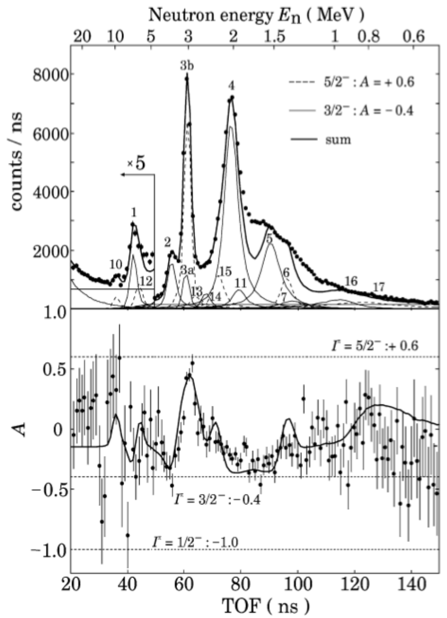


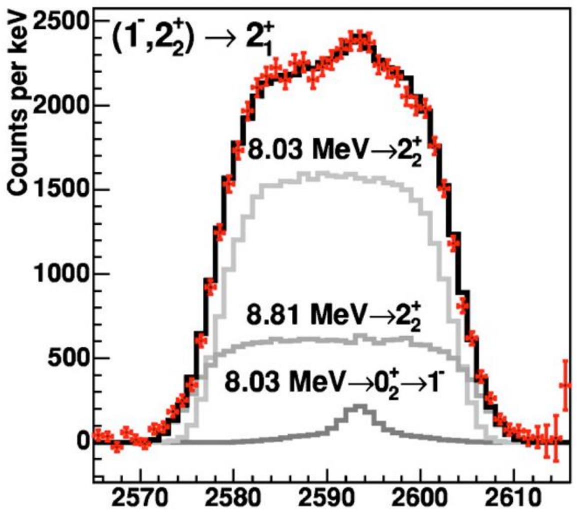
FIG. 2 (color online). A typical ^{11}Li resonance collected over 30 min, containing approximately 1000 ions. Here $\nu_c = 5\,147\,555$ Hz. The solid line is a fit of the theoretical curve [18] to the data.

Smith et al., PRL 101, 202501 (2008)

- ISAC was producing most intense ^{11}Li beams anywhere
- Charge radius, Mass
- ^{11}Li decay
  - Beta-delayed neutron branches
  - ^{10}Be excited state lifetimes



Hirayama et al., PLB 611, 239 (2005)



Sarazin et al., PRC 70, 031302(R) 2004
(French post-doc)

^{11}Li beam for first experiment at ISAC-II

- H. Savajols FR & I. Tanihata – TRIUMF sabbatical visitors
- T. Roger – U. de Caen FR
- Saw opportunity to use reactions to probe remaining questions
- ISAC-II: just coming online, high enough energy for reactions
- New device built at GANIL ready to use



MAYA Active Target TPC

- GANIL FR
- Time projection chamber: ionization tracks recorded by $(\Delta E, x, y, t_{drift})$
- convert t_{drift} to z
- Active target: ionization gas IS the target

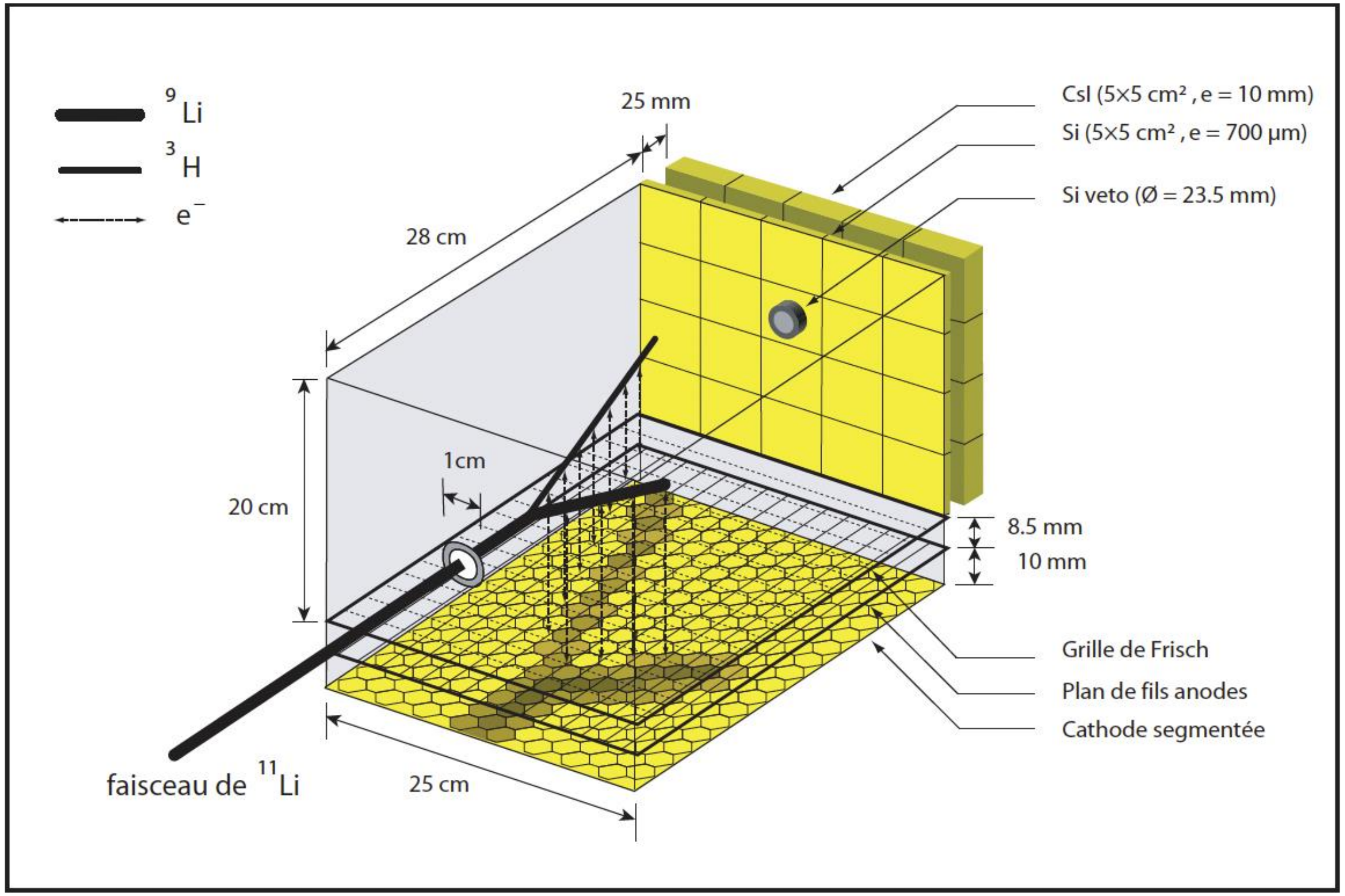
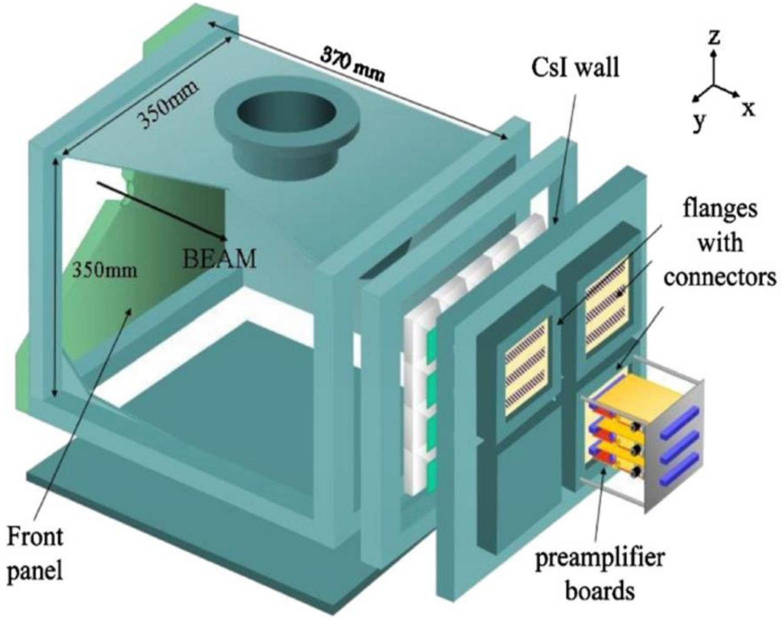
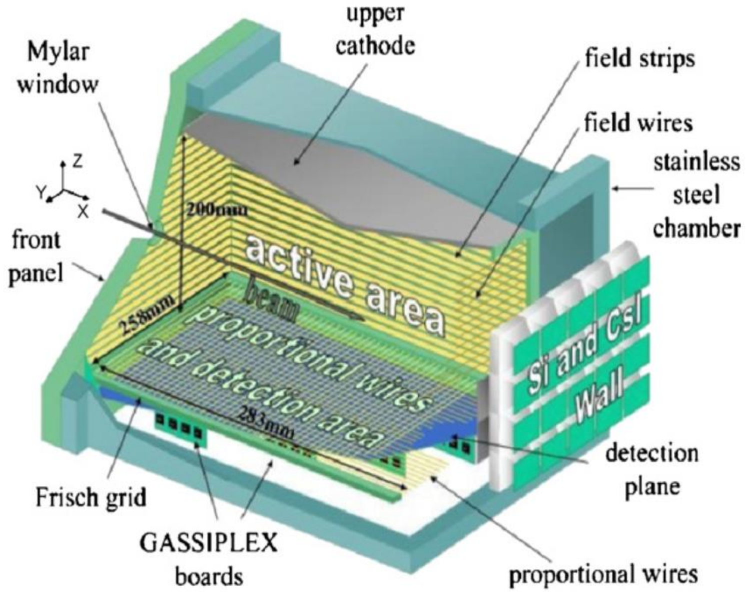
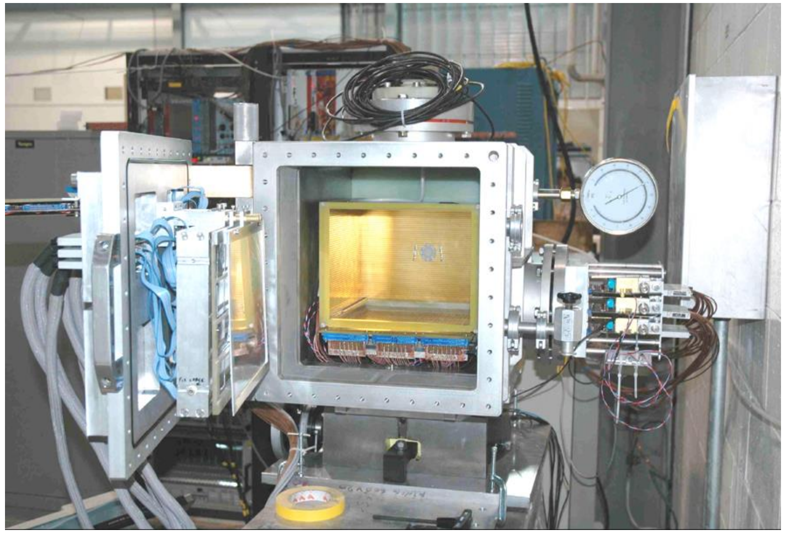


FIG. 2.2 – *La cible active MAYA. On représente ici l'exemple d'une réaction de transfert de deux neutrons du* ^{11}Li.

MAYA in more detail







MAYA in more detail

- MAYA X-Y readout plane: honeycomb
- 1024 pixels

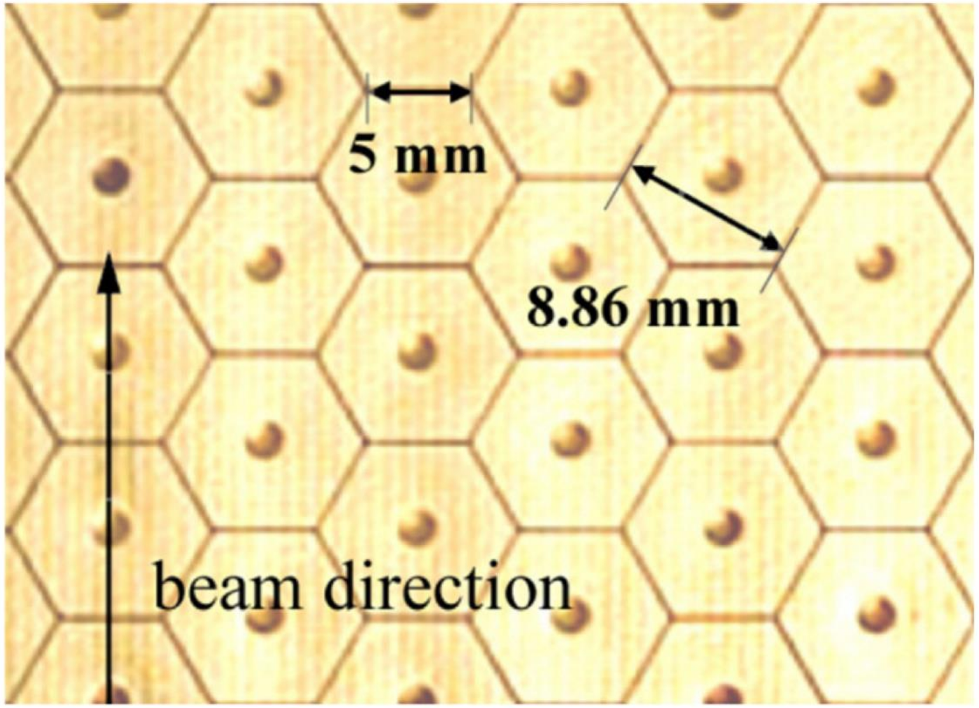
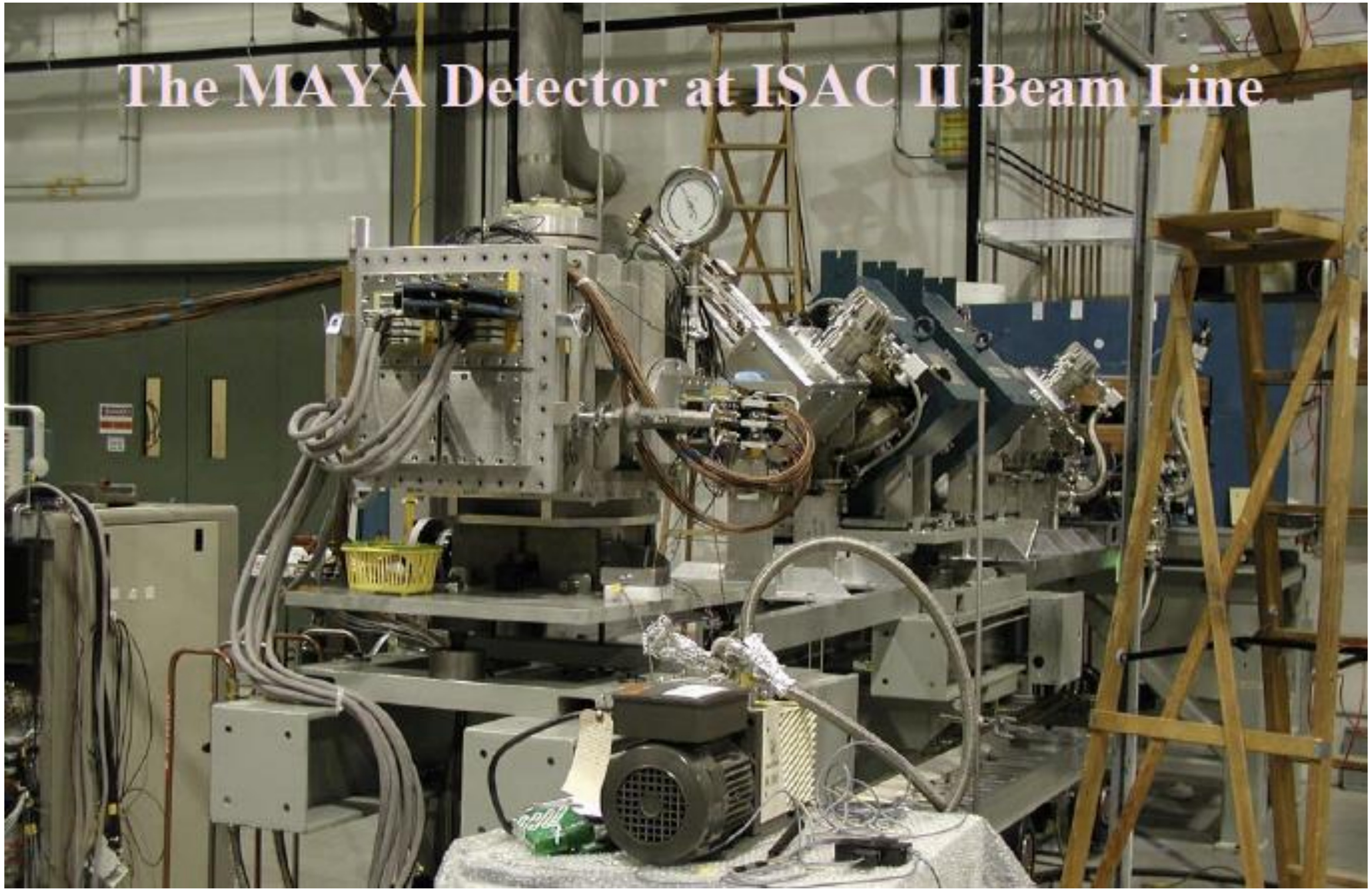


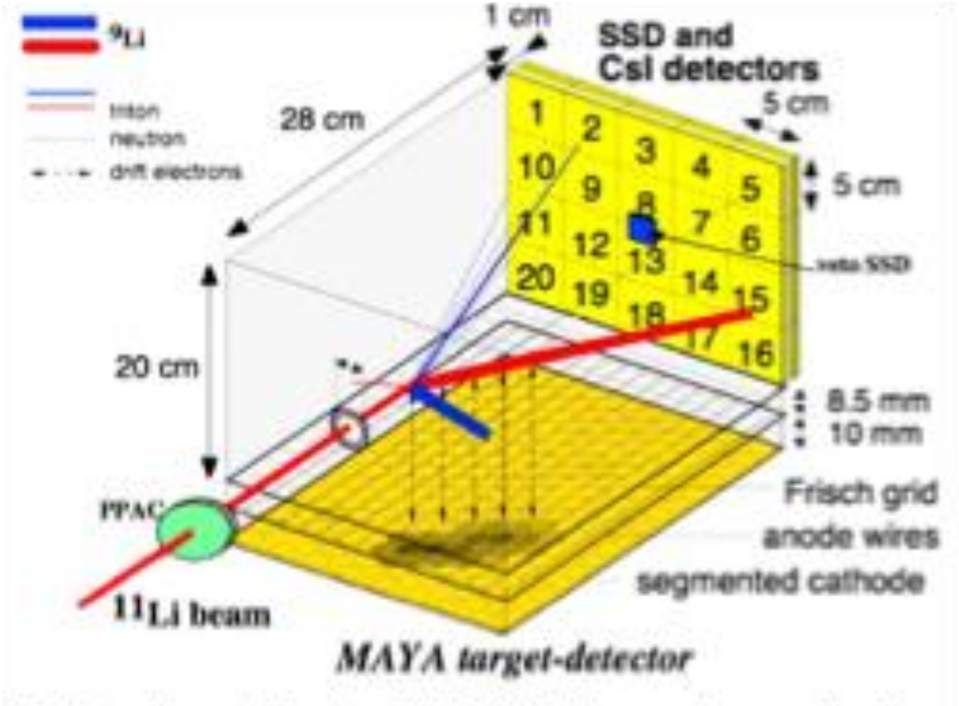
Fig. 2. Upper view of hexagonal cathode pads. The arrow shows the direction of incoming beam particles.

MAYA experiments in 2007



MAYA experiments in 2007

- $^{11}Li(p,t)^{9}Li$ inverse kinematics
- 37 MeV, 2500 per second ^{11}Li
- iC_4H_{10} gas, ~0.09 and ~0.14 atm
- Hydrogen atoms were the proton target



- Tight correlations in halo neutrons
- I. Tanihata, ... H. Savajols, T. Roger et al., PRL 100, 192502 (2008)

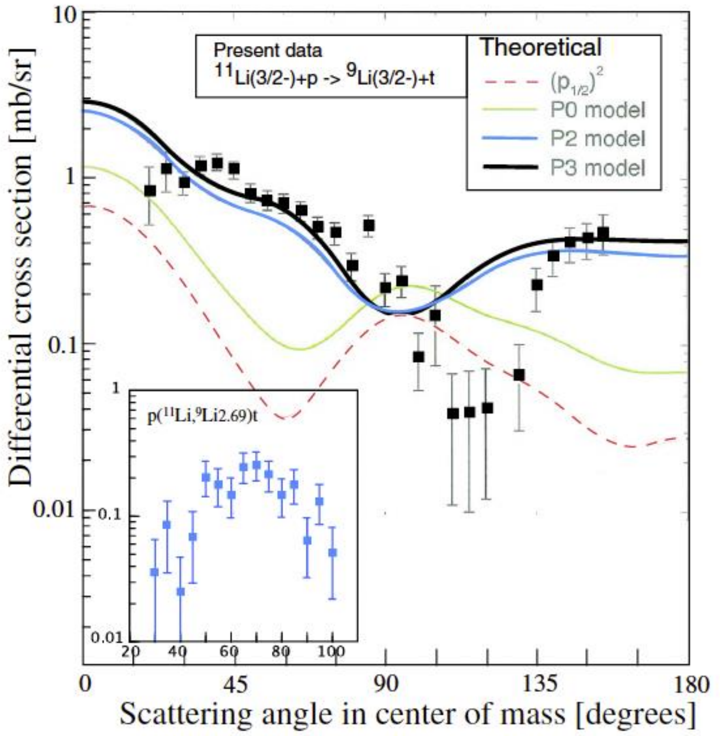
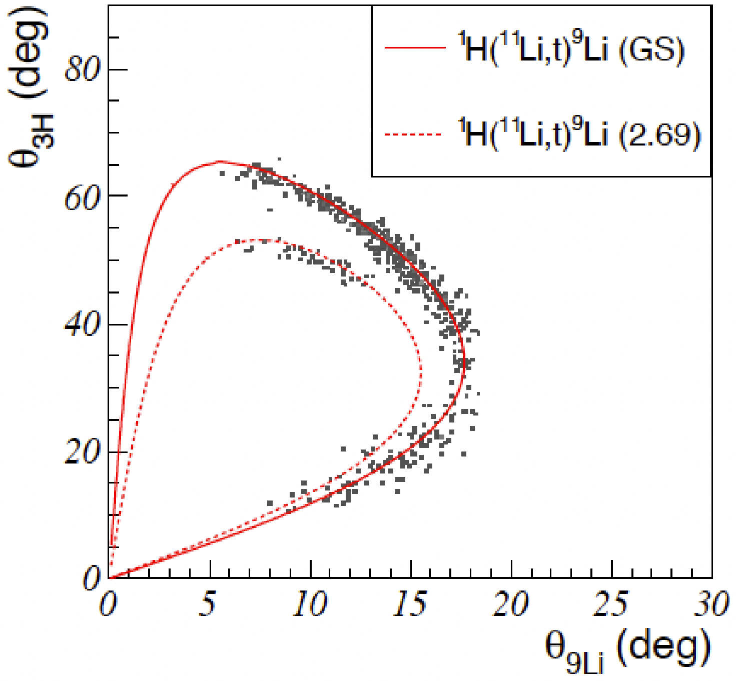


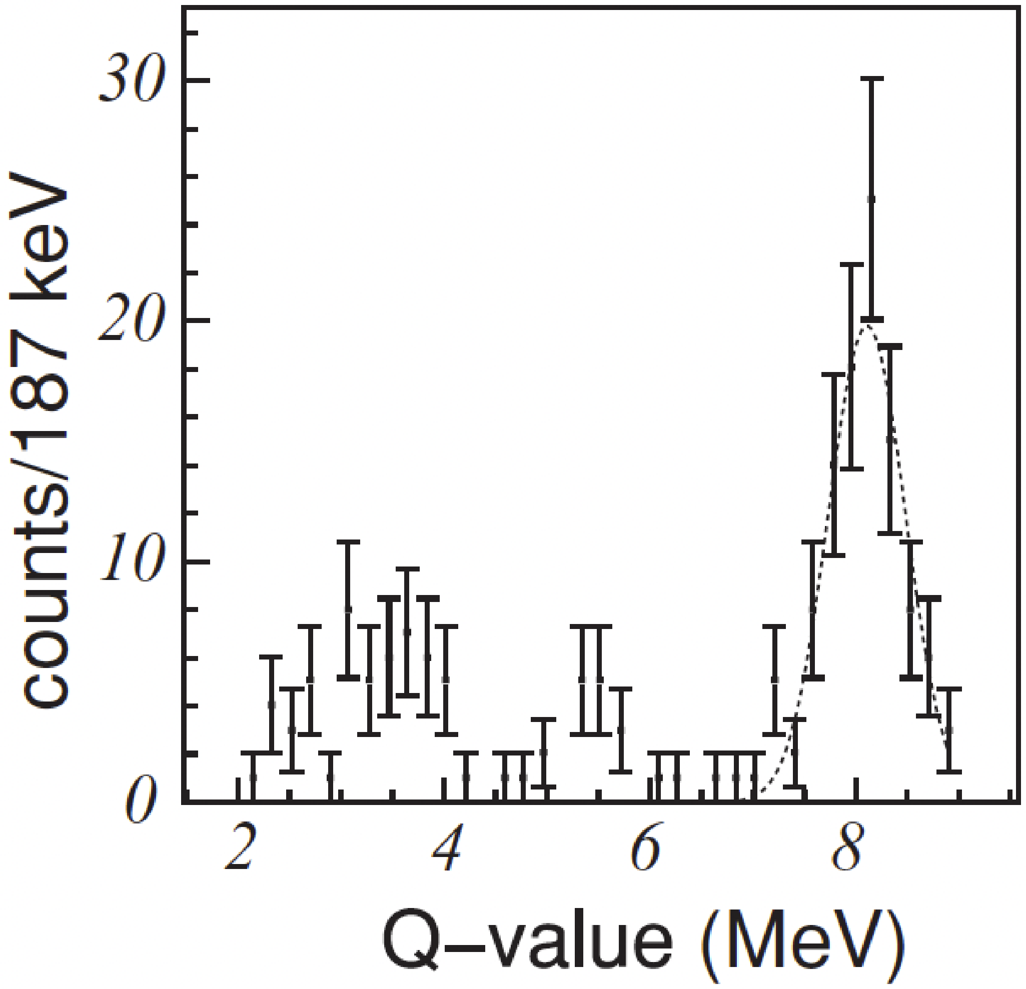
FIG. 3 (color online). Differential cross sections of the (*p*, *t*) reaction to the ground state of ^{9}Li and to the first excited state (insert). Theoretical predictions using four different wave functions were shown by curves. See the text for the difference of the wave functions.

MAYA experiments in 2007

- $^{1}H(^{11}Li, 9Li)^{3}H$
- 54 & 40 MeV, 2500 per second ^{11}Li
- iC_4H_{10} gas, 0.1 to 0.35 atm



- T. Roger, H. Savajols, I. Tanihata et al., PRC 79, 031603(R) (2009)



ACTAR 2025

T. Roger & J. Pancin, GANIL FR

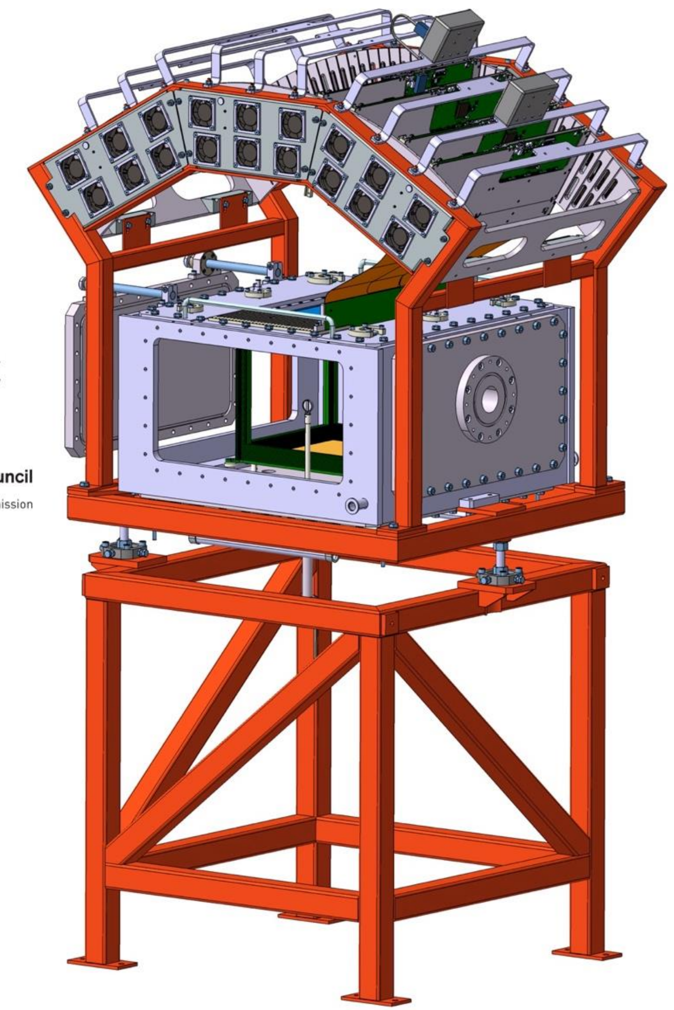
ACTAR Funding and Development History

- Slide adapted from G. Grinyer

- Active TARget
- 1.3M€ grant from European Research Council (ERC)
  - 5-year project (2014 to 2019)
  - Design and construct detector (16k channels)
  - Begin "day 1" physics program
- GANIL: Lead institution (G. Grinyer) FR

European Research Council
Established by the European Commission

- Milestones:
  - 2014: Built a small prototype (2k)
  - 2015: First in-beam test
  - 2016: Mechanical design (16k)
  - 2017: Construction begins (February)
  - 2017: Commissioning run (November)
  - 2018: First physics experiment!
- Project ended on January 31, 2019

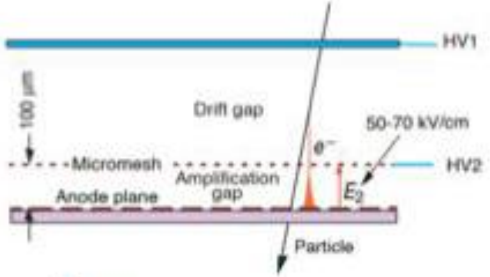


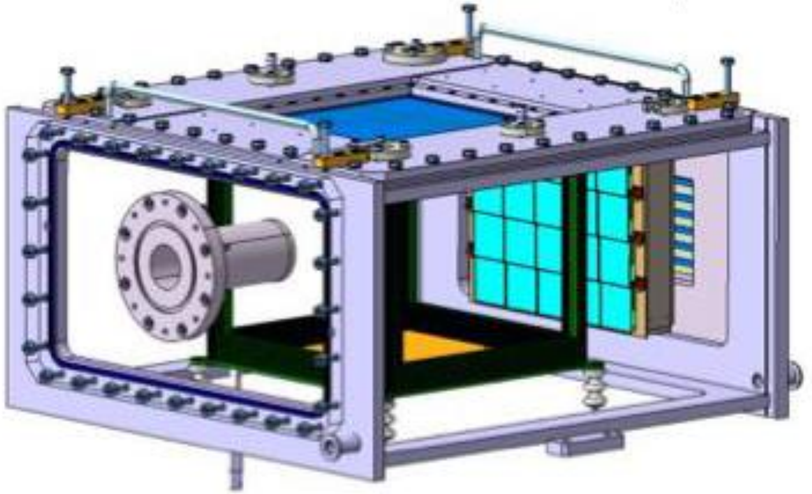
Final Design: P.Gangnant (2017)

ACTAR Active Target TPC

- Slide adapted from B. Fernández-Domínguez

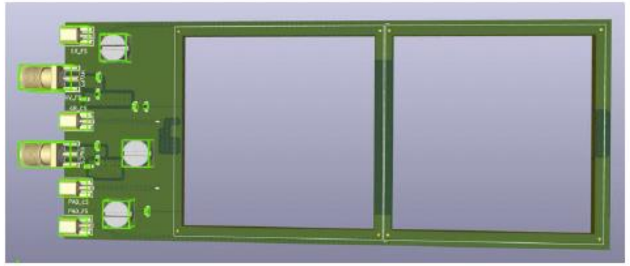
- **Cubic geometry** field cage: 25.6 cm length
- **Highly segmented pad plane :** 16384 channels: 2x2 mm2.
- **Micromegas technology** (≈128 µm gap).
- **Ancillary detectors**
- **GET electronics**

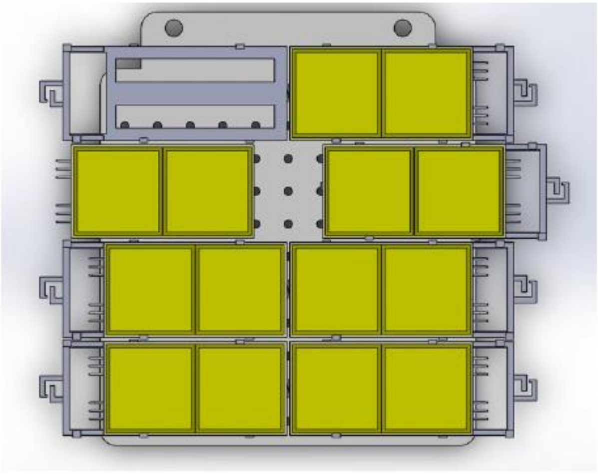




Information:

- Energy (from range or charge)
- Angle, Vertex
- Particle identification





1,5 mm

The people and institutions that made ACTAR 2025 happen

FR
GANIL

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C. Nicole

FR
LPC Caen

F. Delaunay
H. Al Falou

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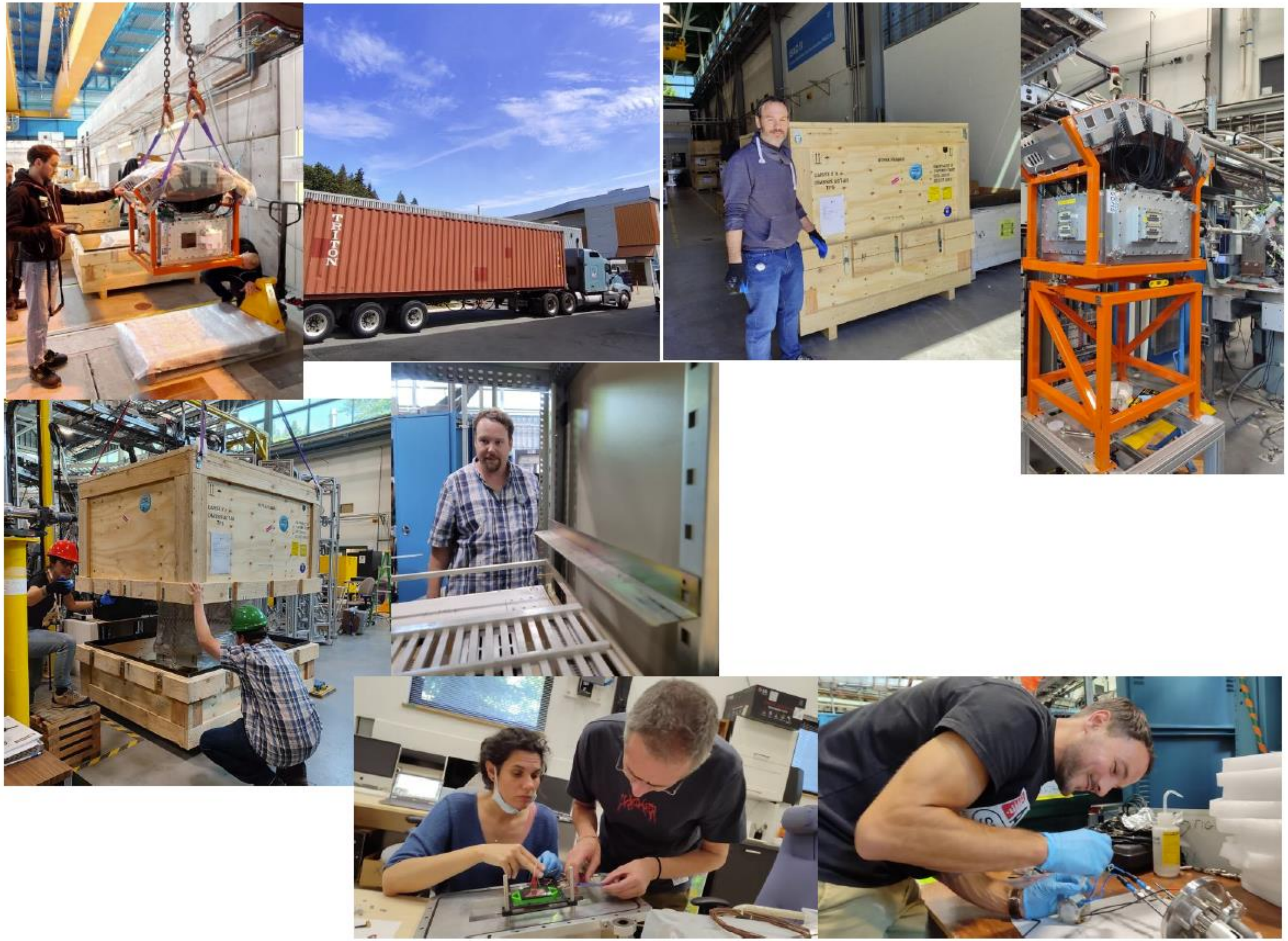
Rede CIGUS – Centros de investigación do Sistema Universitario de Galicia
Cofinanciado por la Unión Europea
Fondos Europeos

Moving to TRIUMF, 2025

- Slide adapted from B. Fernández-Domínguez

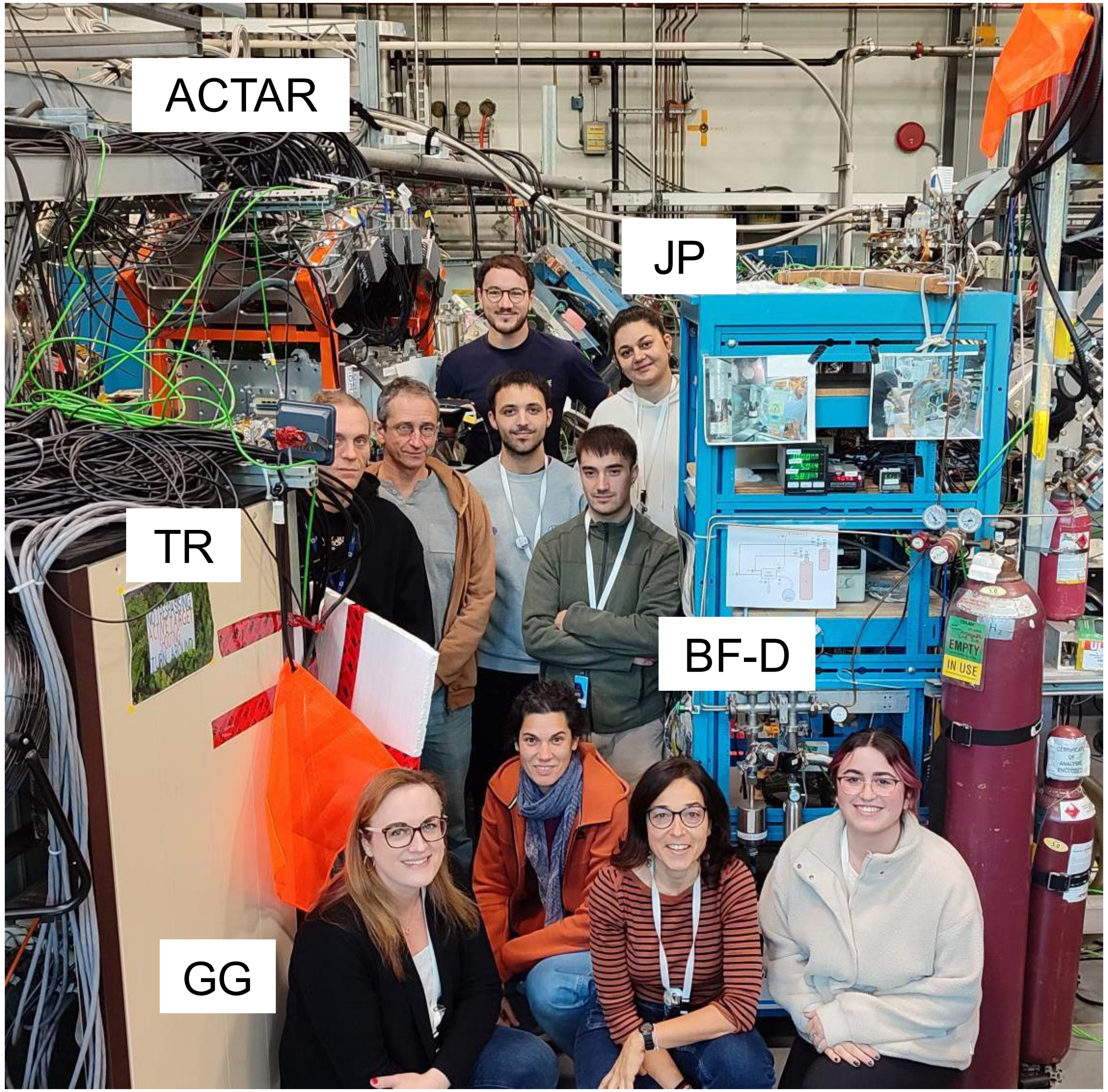


ACTAR 2025

- 18 years later, Thomas returns with ACTAR

ACTAR 2025

- Slide adapted from B. Fernández-Domínguez



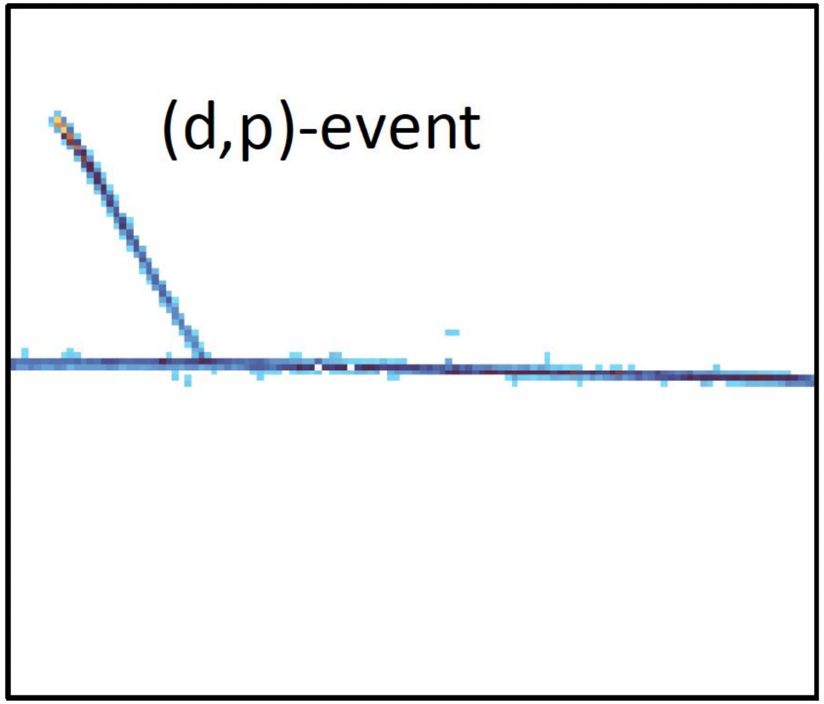
Principals:

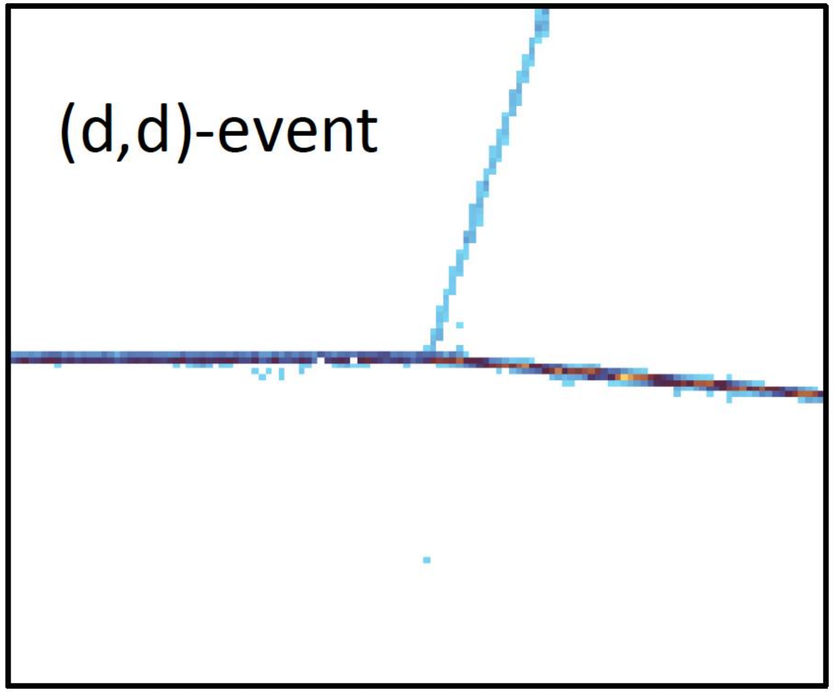
- T. Roger and J. Pancin, GANIL FR
- B. Fernández-Domínguez, U. de Santiago de Compostella
  - U. Caen Ph.D., CEA-GANIL Post-Doc FR
- G. Grinyer, U. Regina
  - ex GANIL FR

Preliminary ACTAR 2025 result: Resonances in ^{12}Li

- ^{11}Li beam (again)
- 82.5 MeV
- 0.9 atm 95% $^{2}H_2$, 5% CF_4
- Deuterium is the target
- $^{11}Li(d,p)^{12}Li$ inverse kinematics
- Then $^{12}Li \rightarrow$ $^{9}Li+3n$

I. Blanco Calviño (Ph.D. analysis)

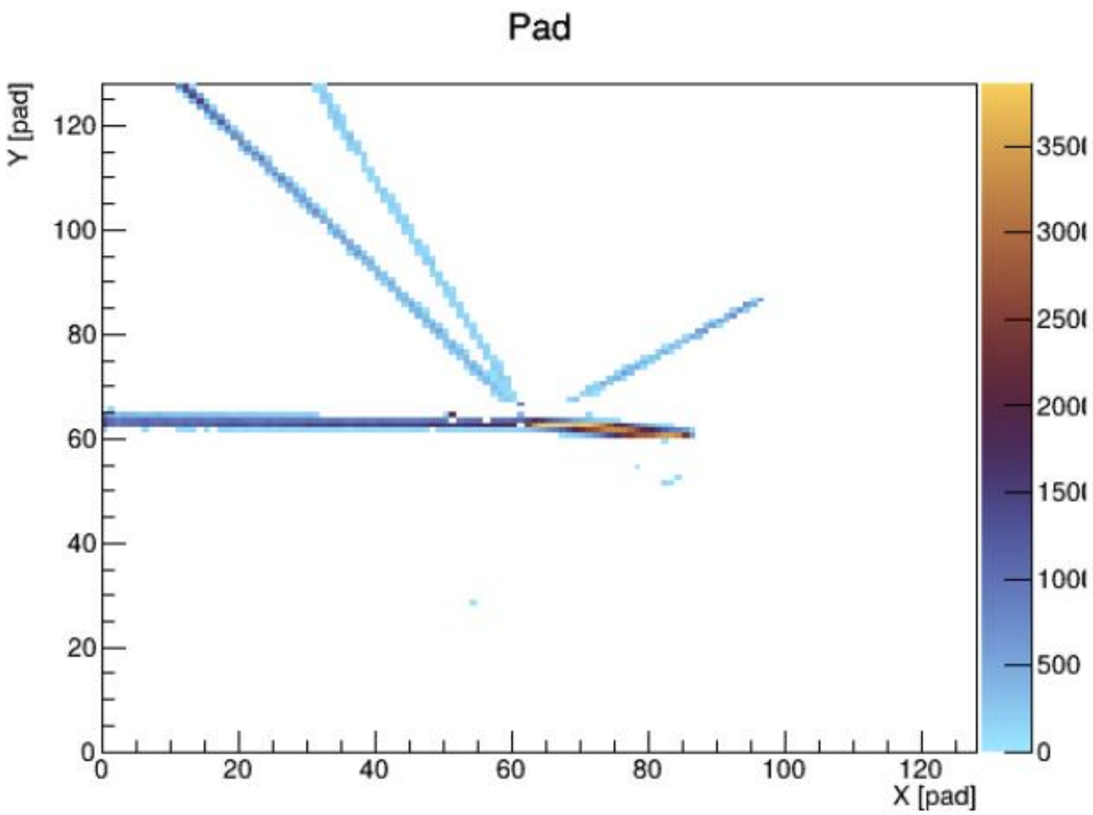


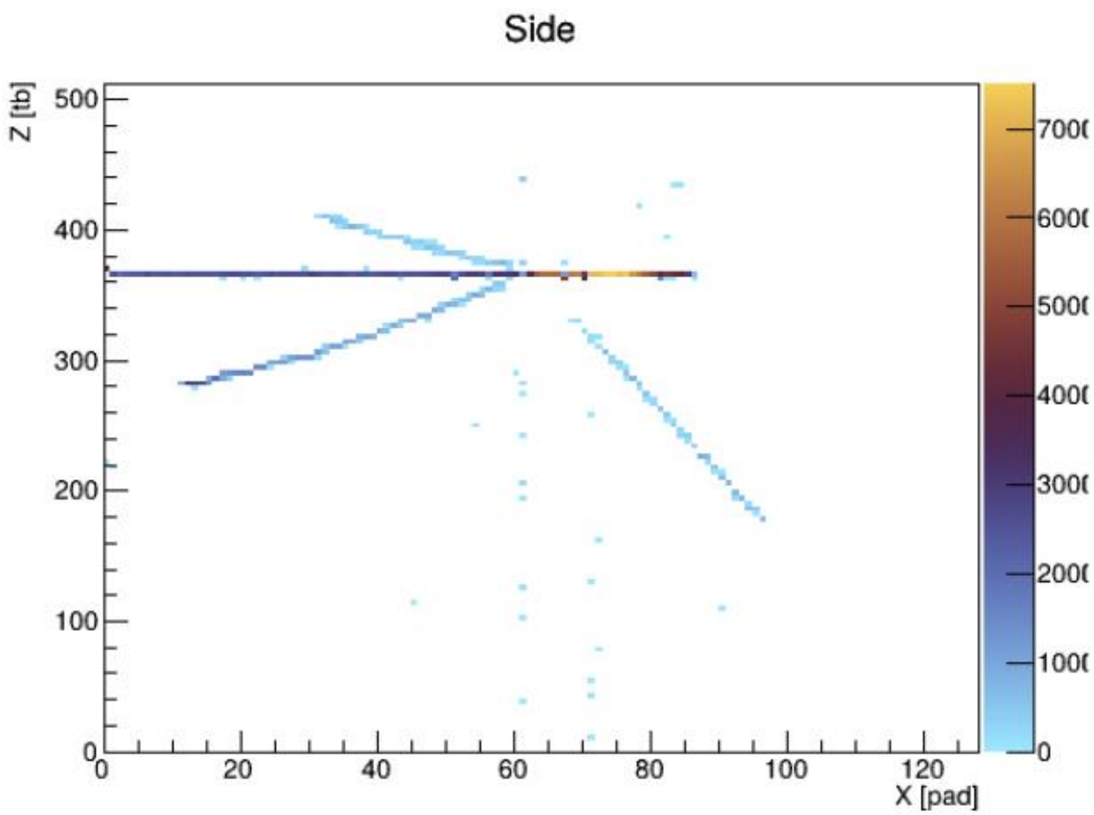


- Slide adapted from B. Ferndández-Domínguez

Preliminary ACTAR 2025 results: Exotic decay of ^{21}Al

- ^{20}Mg beam, 110 MeV
- ^{20}Mg+p -> ^{21}Al -> exotic decays
- Candidate for 3p breakup of ^{21}Al





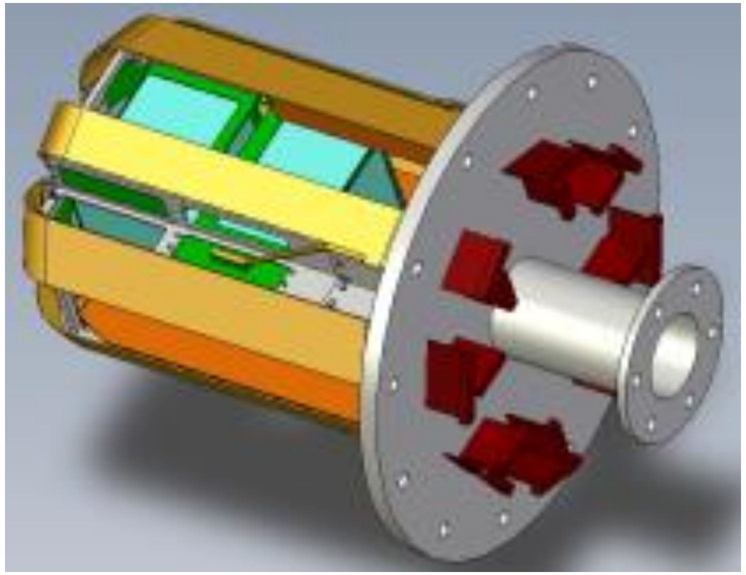
- Slide adapted from B. Fernández-Domínguez

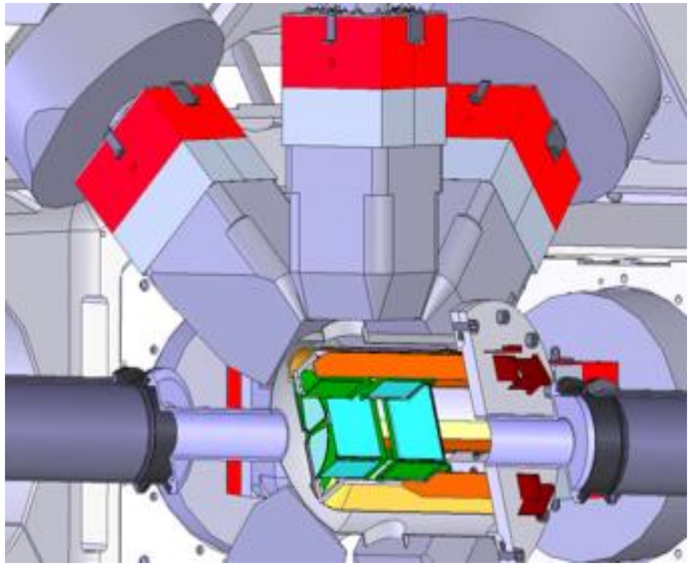
Trifoil with SHARC, 2009 and on

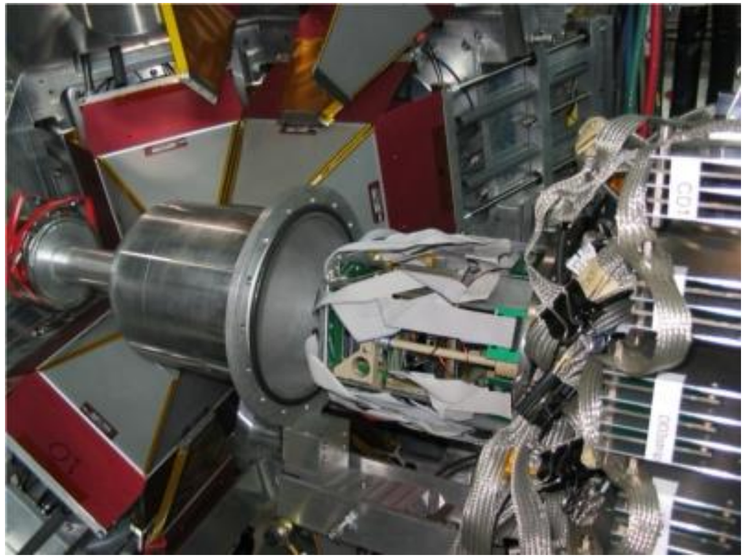
N. Orr, LPC-Caen FR

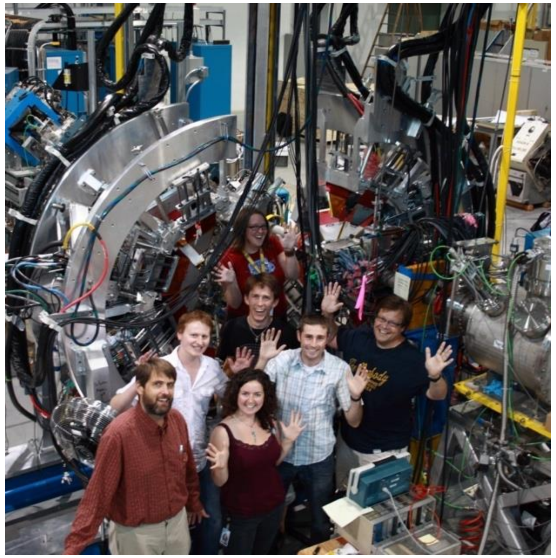
SHARC

- SHARC: Highly segmented Si array & scattering chamber
- Fits inside TIGRESS gamma array
- C. Diget, U. York, lead this project









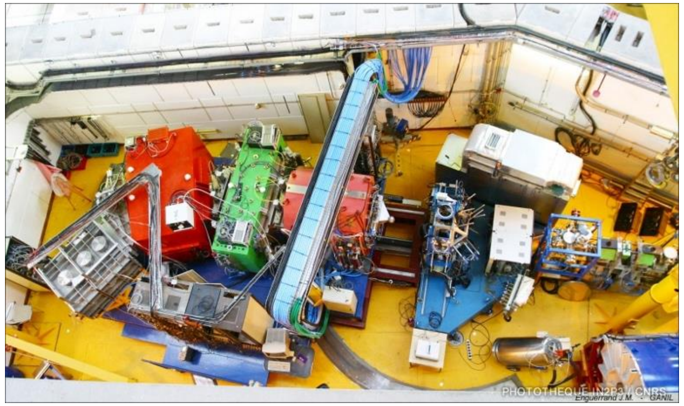
Why do we need a zero degree detector?

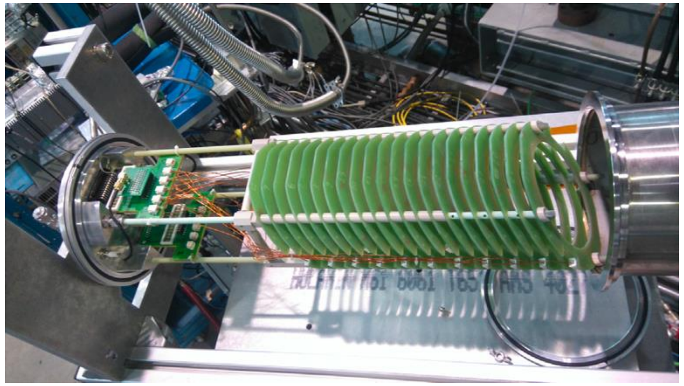
- Typical experiment: structure of exotic neutron-rich ^{A+1}Z
- Direct transfer reactions
- Inverse kinematics $^{A}Z(d,p)^{A+1}Z$, 5-10A MeV
- Beam ^{A}Z radioactive too.
- Deuterium target: deuterated polyehtylene CD_2

- BUT: ^{A}Z+C -> fusion -> evaporation of protons etc.
- Background interferes with direct reaction signal

Solution: downstream counter

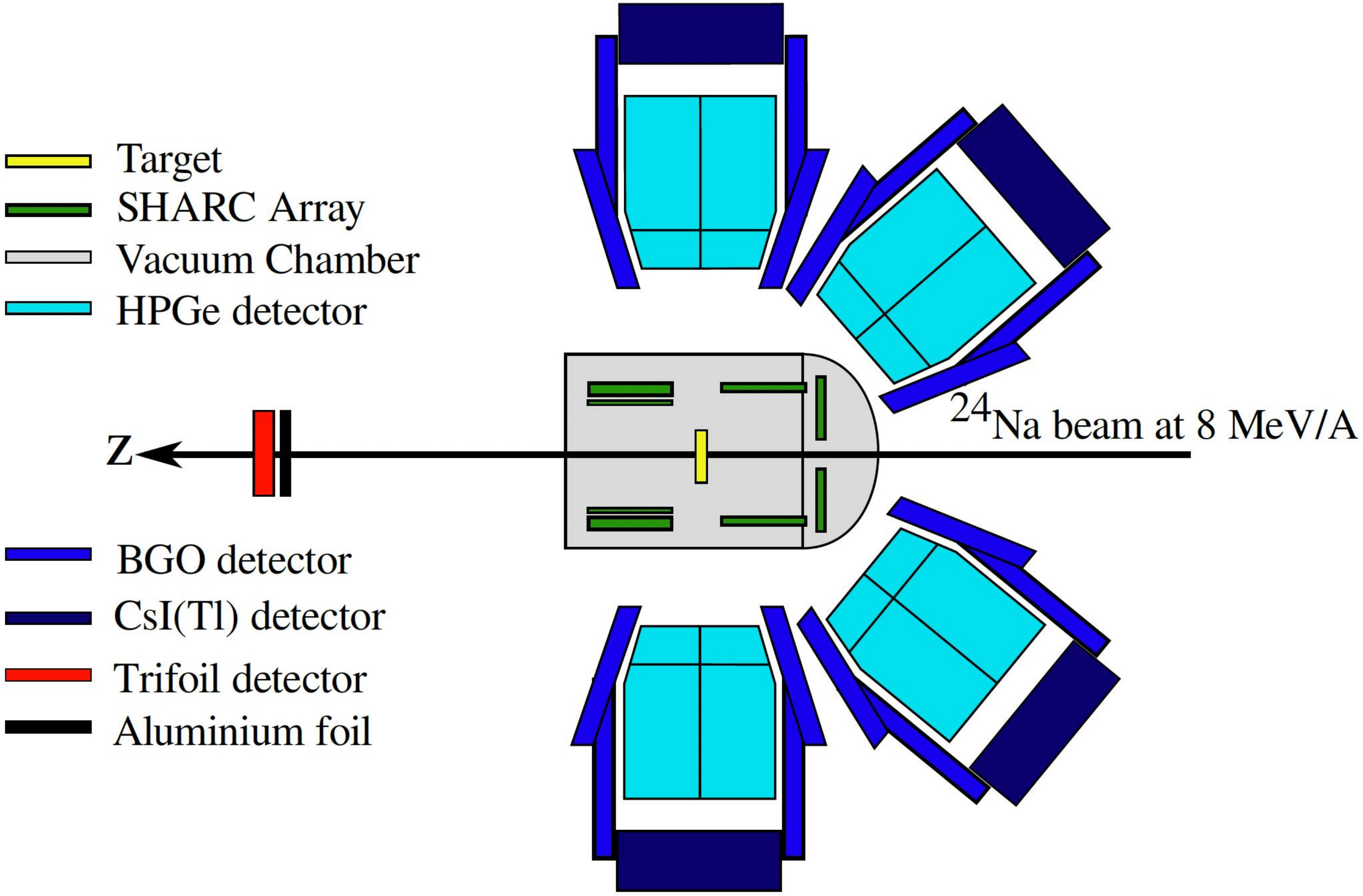
- Near 0 degrees
- Some way of discriminating good events from bad
    - (d,p); recoiling ^{A+1}Z nearly same energy, same Z as ^{A}Z beam
    - Fusion-evaporation: residual much slower, 2-6 units higher Z
- (Electro) Magnetic separator with position and Z sensitive detectors would be perfect
- Downstream gas counter alone could discriminate Z & E





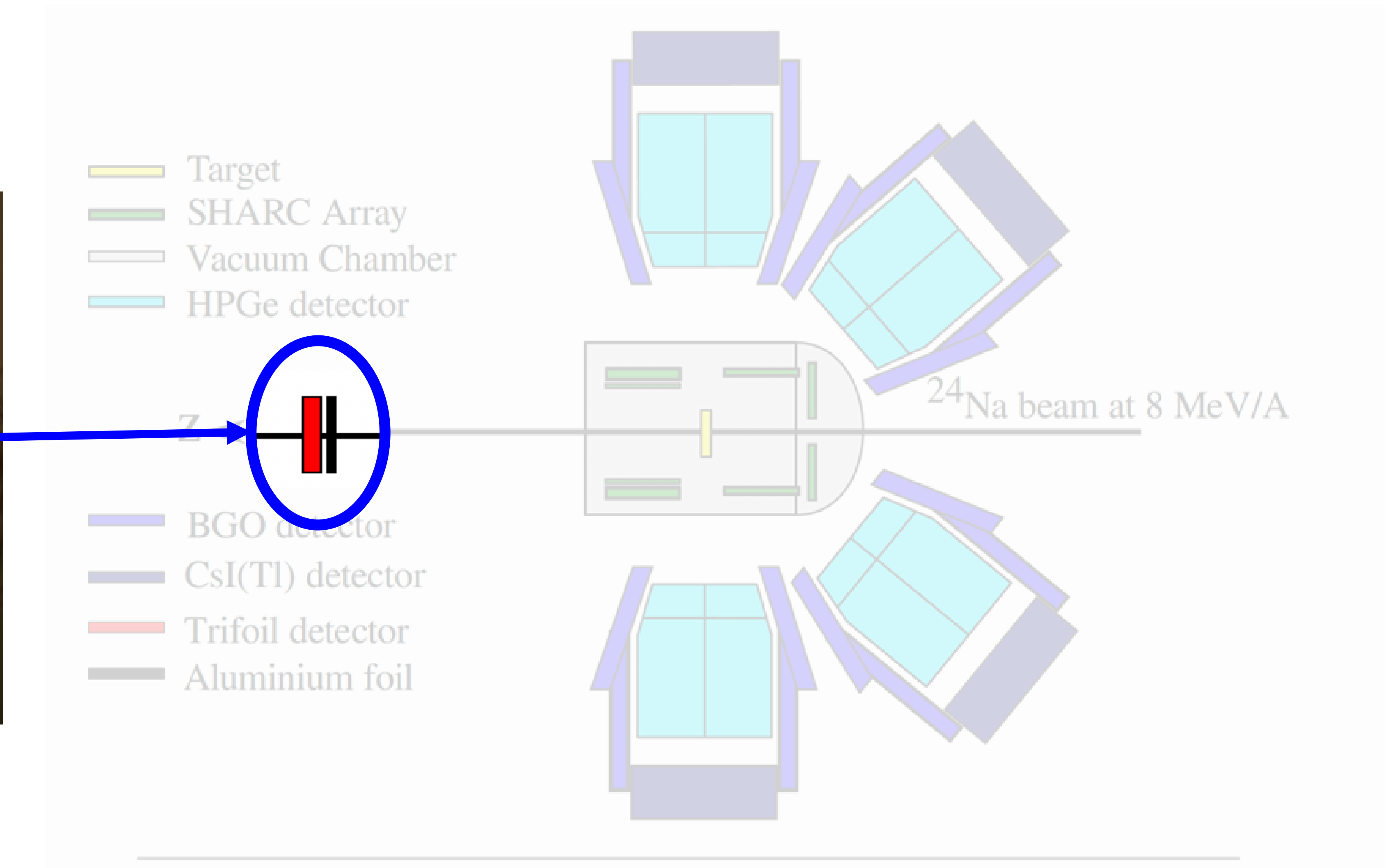
Solution: downstream counter

- Even simpler: scintillator with degrader foil
- stop high-Z, low-E fusion evaporation residue
- ... but let ^{A+1}Z go through



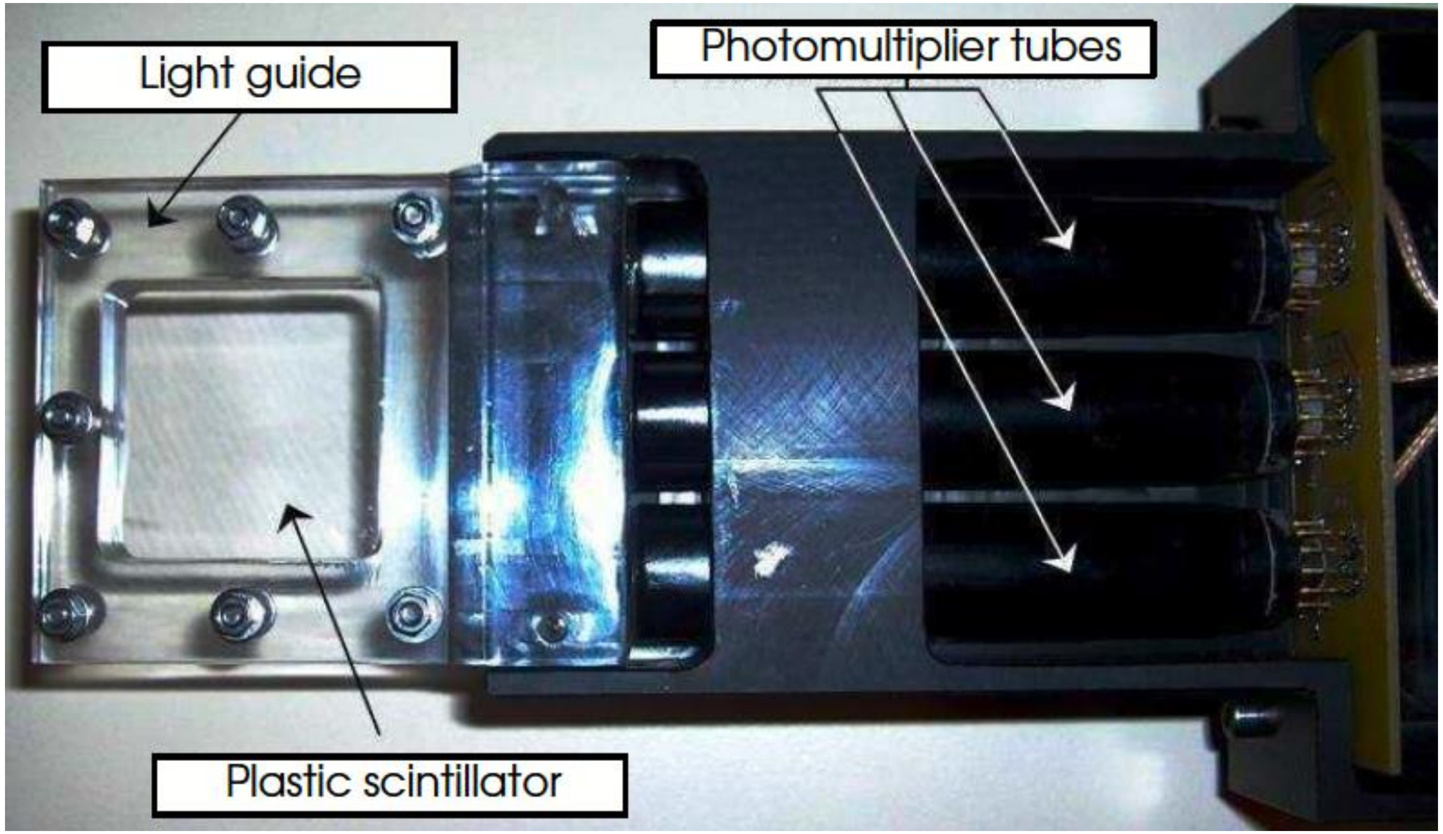
Trifoil: A simple, elegant solution

- This is where Nigel FR comes in



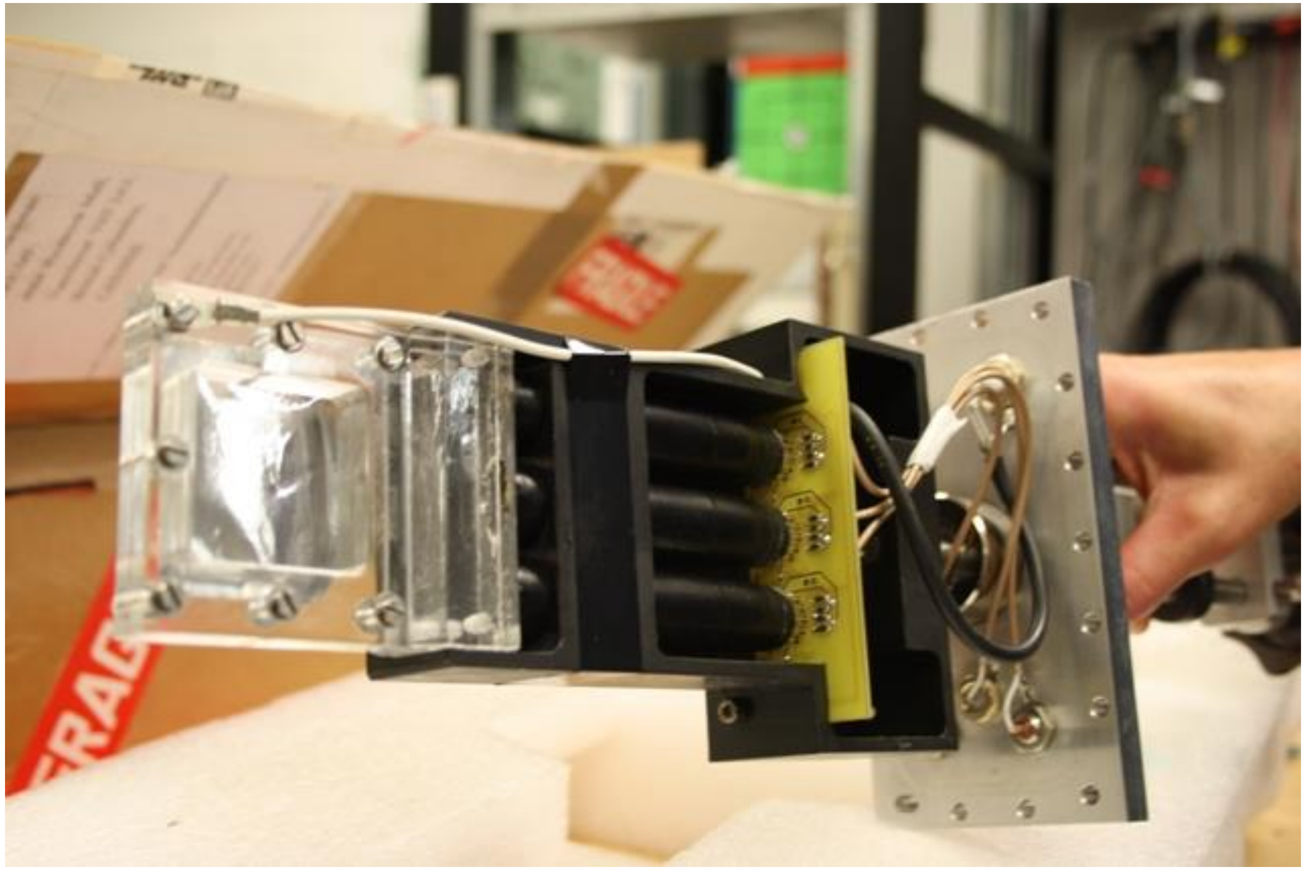
Trifoil: a simple, elegant solution

- 10 um plastic scintillator
- Framed by light guide
- Read out by three PMTs
- All built by N. Orr at LPC Caen



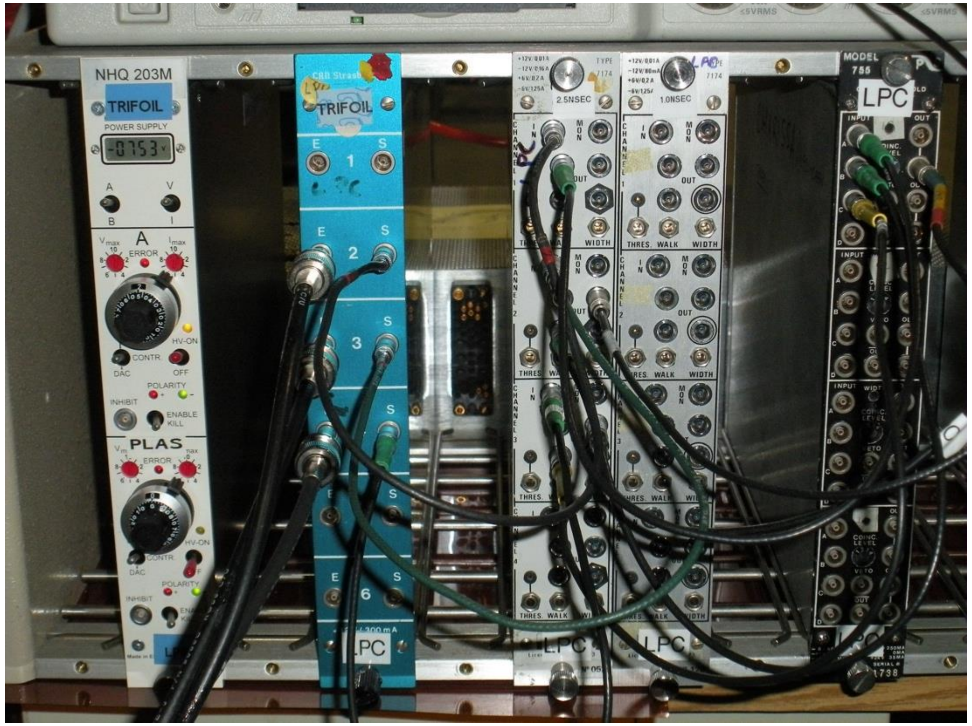
Trifoil: a simple, elegant solution

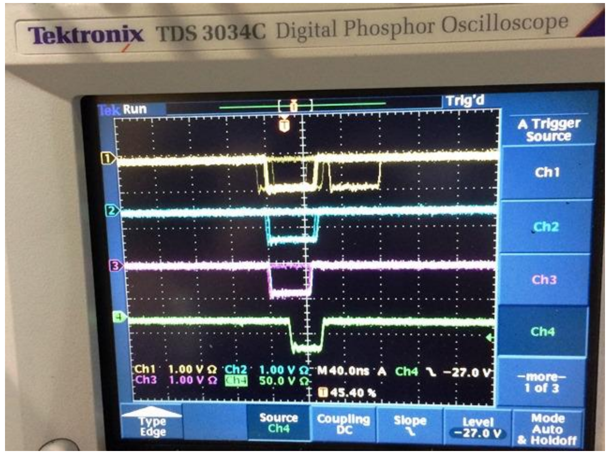
- Now shown with 30 um Al foil mounted
- More sophisticated versions: rotatable foil upstream

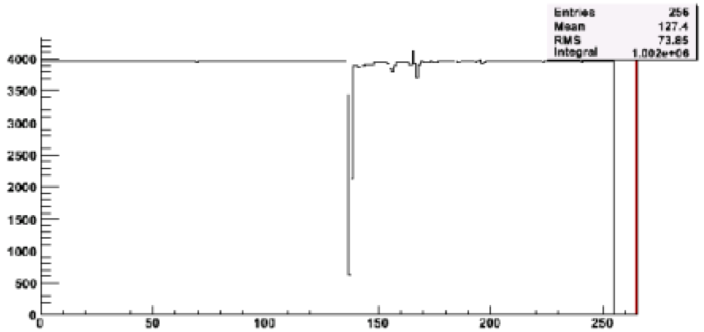


Trifoil: a simple, elegant solution

- NIM electronics
- 2 PMTs above threshold -> Trifoil trigger
- Logic signal waveform digitized & recorded

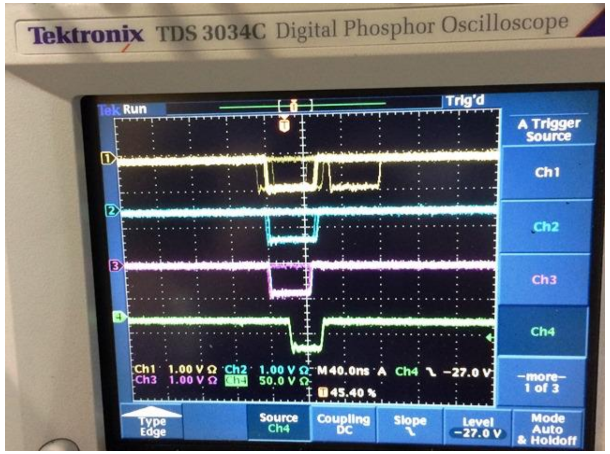


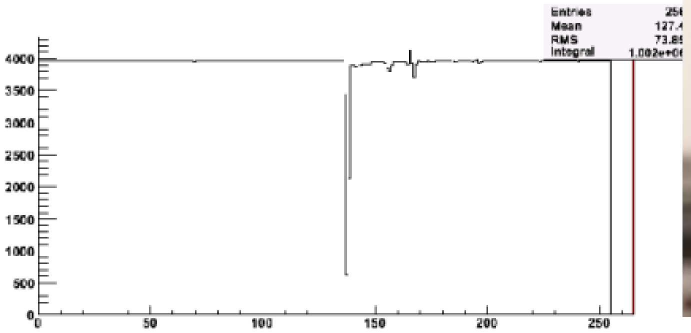


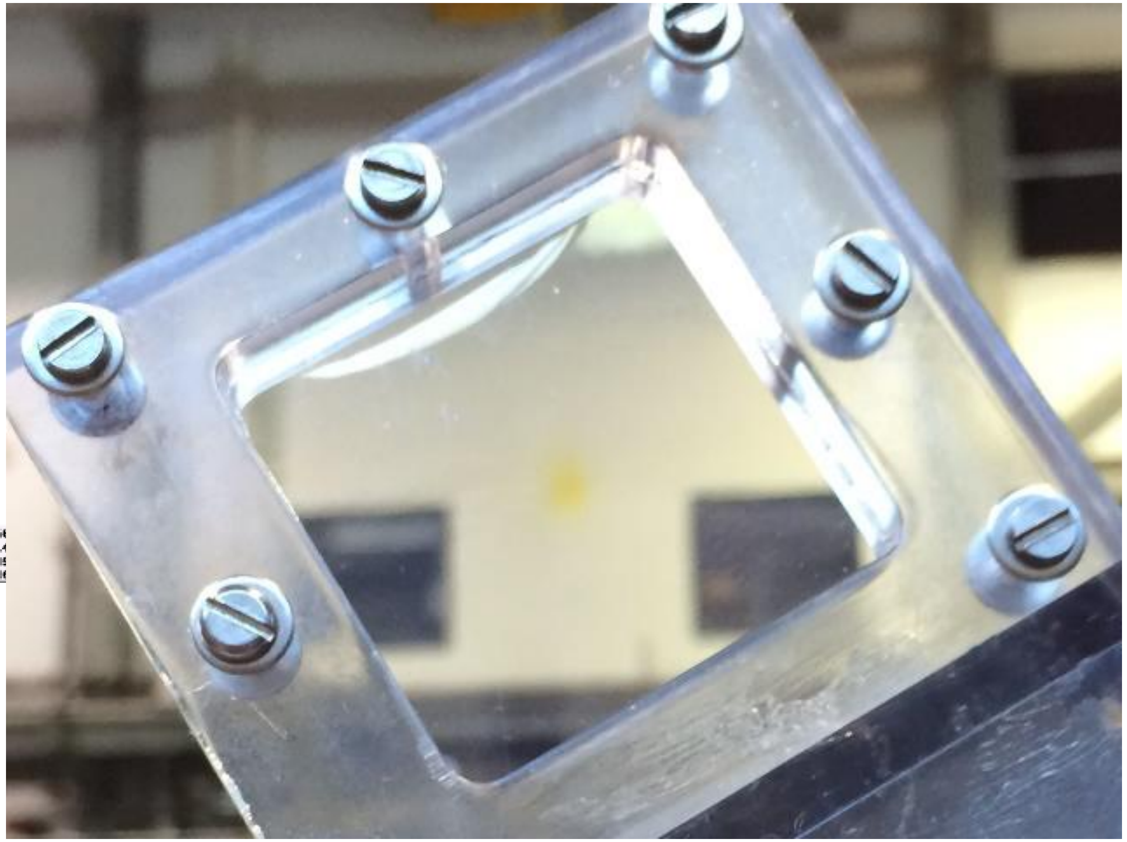


Trifoil: a simple, elegant, HIGH RATE!! solution

- DEADTIME FREE!!
- Basically an oscilloscope triggered by SHARC hit

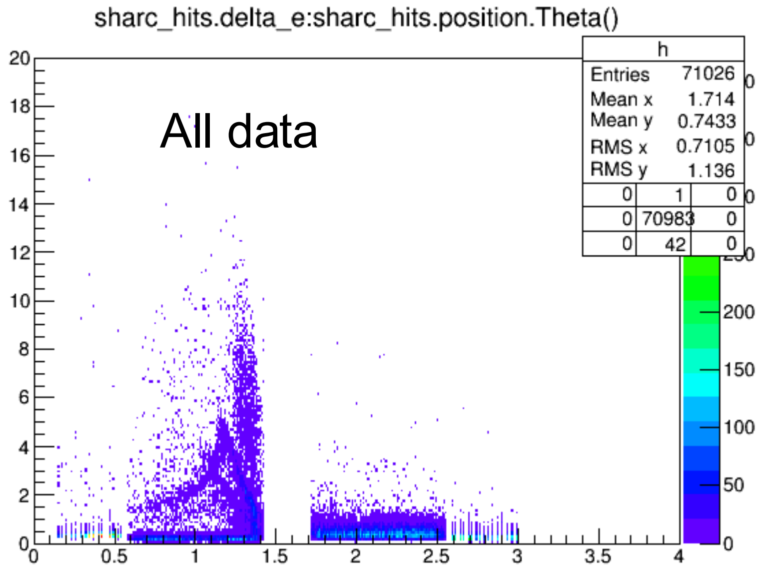


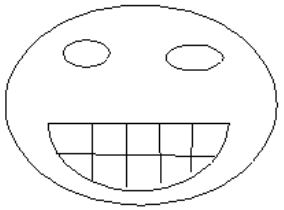




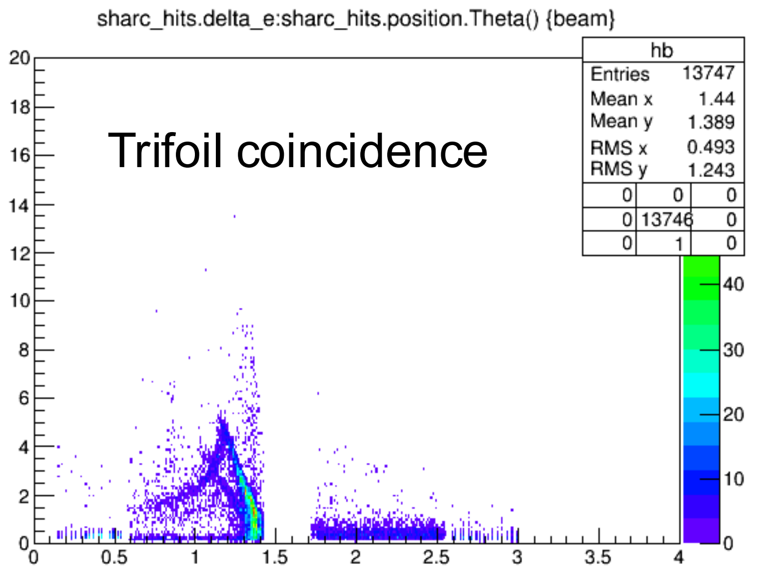
- 10^7 pps!!!!
- (Radiation damage – faint yellowish spot)

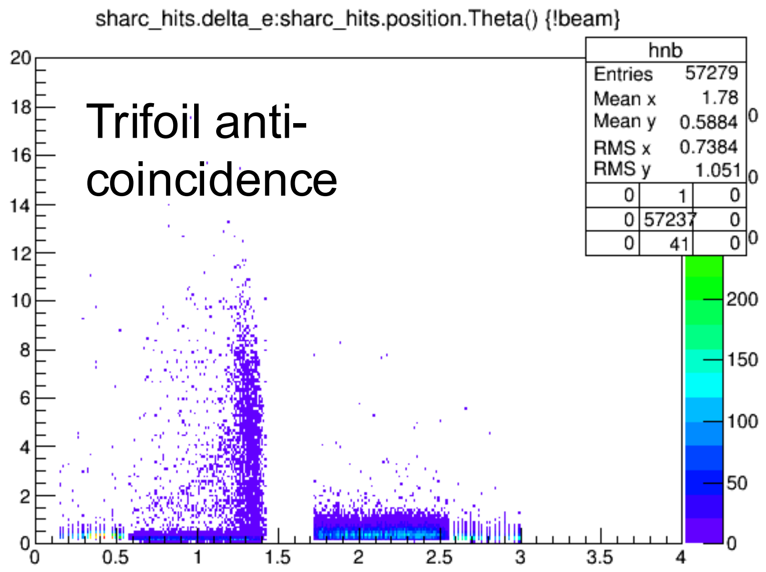
Trifoil: Does it suppress background? YES.





- From a 2013 e-log entry by Kathrin Wimmer
- Even with ^{94}Sr(d,p)!





Trifoil: Used for most SHARC beamtimes & publications*

- G.L. Wilson et al., PLB 759 417 (2016) ^{26}Na(d,p)
- S. Cruz et al., PLB 786, 94 (2018); PRC 100, 054321 (2019); PRC 102, 024335 (2020) ^{94,95,96}Sr(d,x)
- A. Matta FR et al., PRC 99, 044320 (2019) ^{28}Mg(d,p)
  - 100 ^{28}Si for each ^{28}Mg
- G. Lotay et al., PLB 833, 137361 (2022) ^{23}Ne(d,p)
- B. Greaves et al., submitted to PRC (2026) ^{21}Ne(d,p)
- A. Knapton et al., Ph.D. thesis, draft in the works ^{24}Na(d,p)

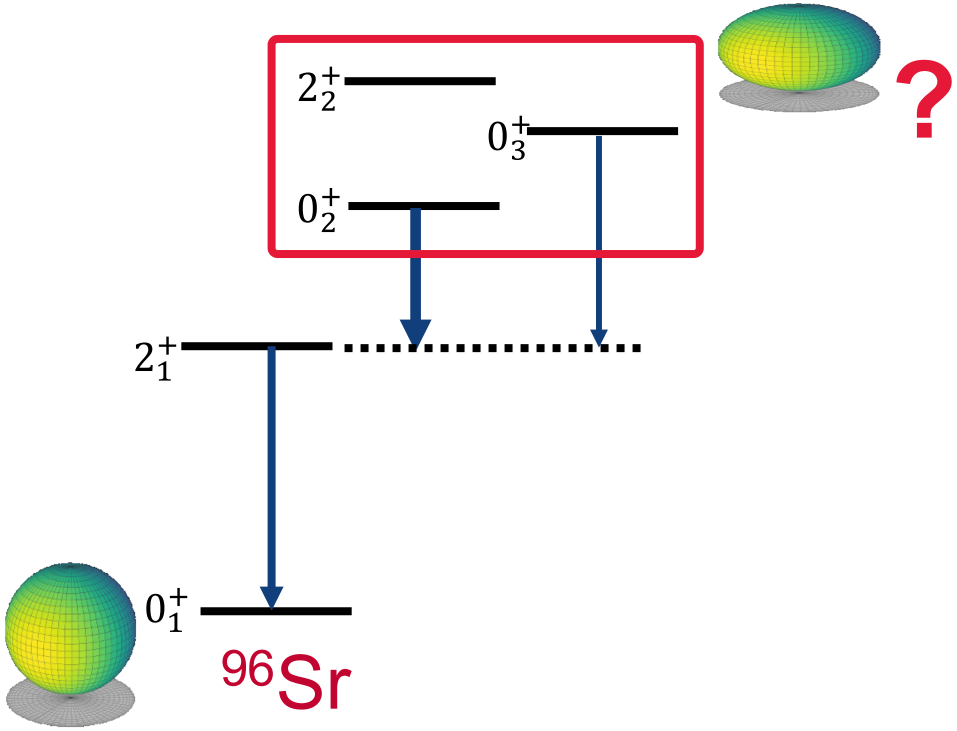
* Expect to use TRIFIC in future: D. Yates et al., JINST 21 P03028 (2026)

^{96}Sr Coulex

M. Zielinska, CEA Saclay FR

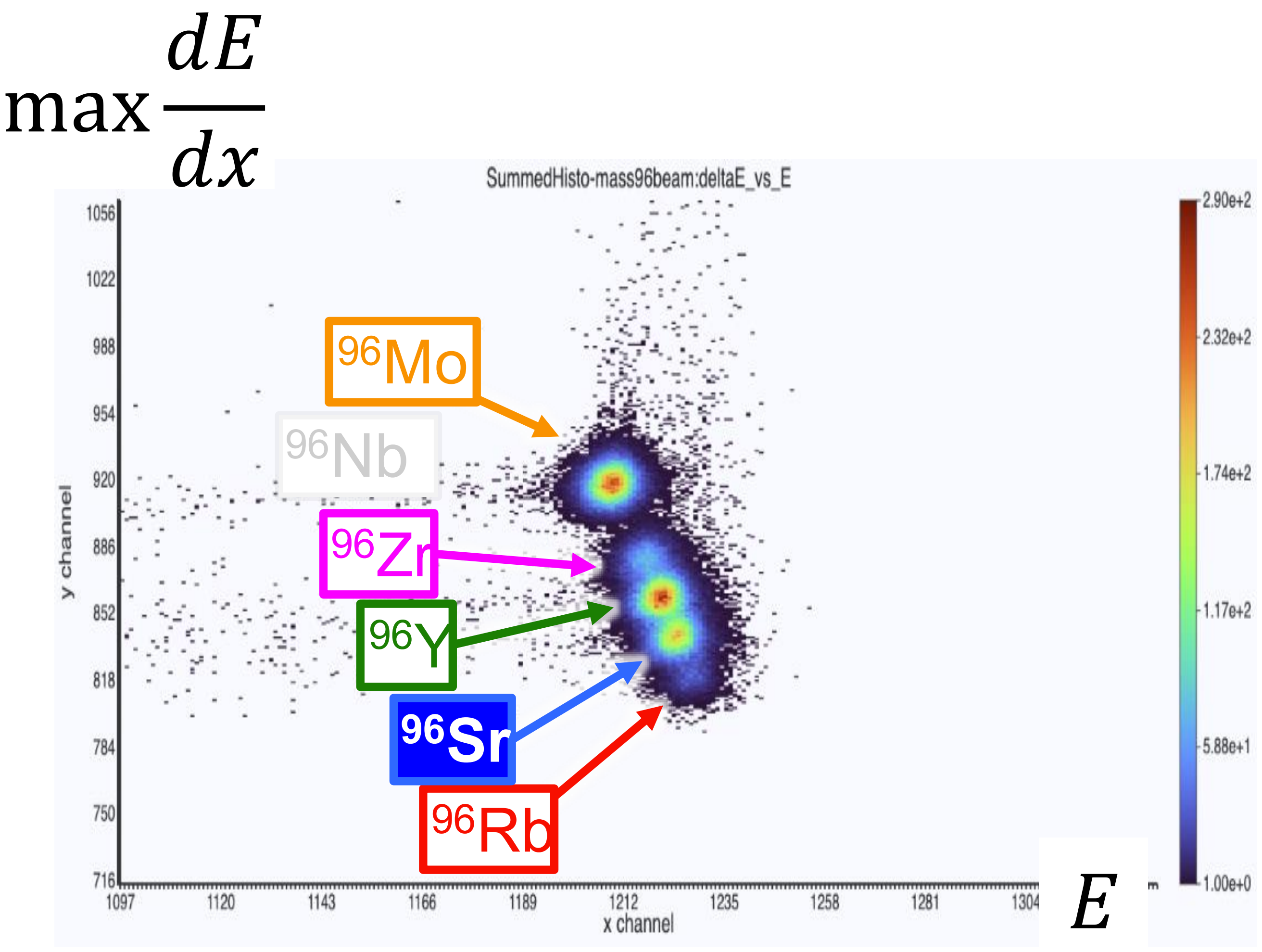
^{96}Sr Coulex and Shapes, revisited

- M. Zielinska (CEA Saclay FR): key world expert in analyzing Coulex experiments
- Co-spokesperson of ^{96}Sr Coulex experiment with TIGRESS
- With G. Colombi, P. Garrett, D. Kalaydjieva*
  - * U. Paris-Saclay FR Ph.D.
- TIGRESS gamma spectroscopy, Bambino recoil detection
- Goal: resolve open questions on deformation in this nucleus



^{96}Sr Coulex and Shapes, revisited

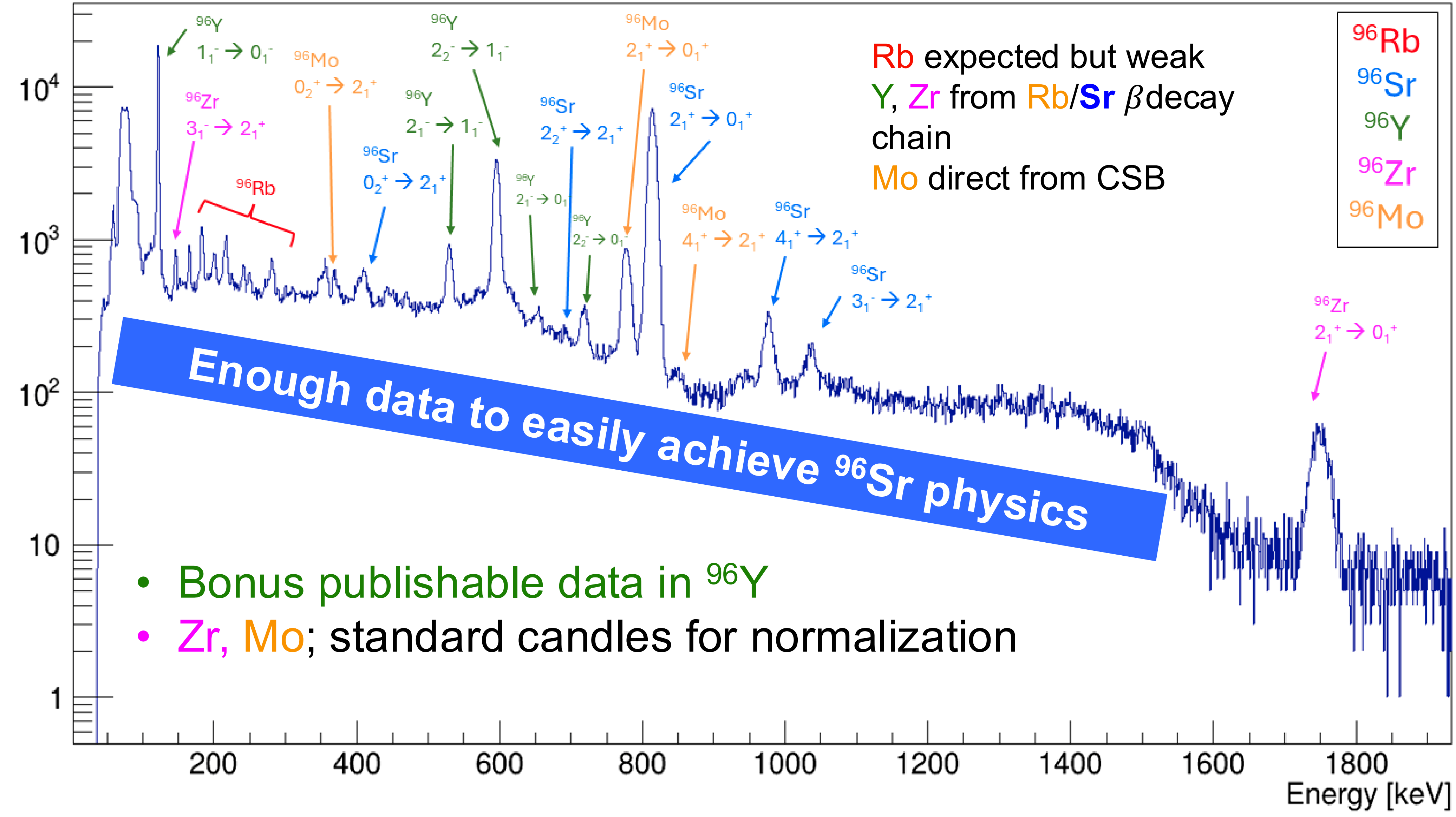
- ^{96}Sr 10 times more intense than planned for
- Beam highly “contaminated” with A=96
  - Note: RIB attenuated, CSB background at full intensity here
- But opportunities lie therein



31257	2026-01-22-15:55		S2403	Giacomo Colombi	Info	General	Spectrum Full stat 208Pb target

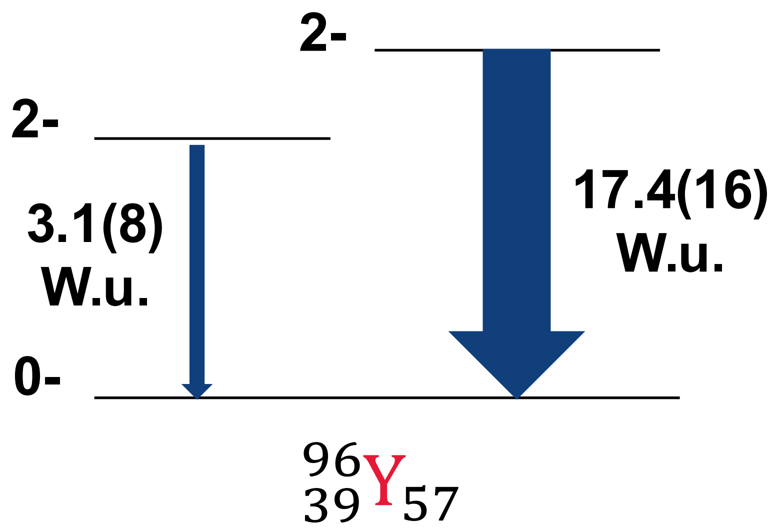
I attach the total spectrum with ~69 hours of data with the 208Pb target (pos4).
The main peaks are identified.

Attachment 1: S2403_Final_Spectrum.png

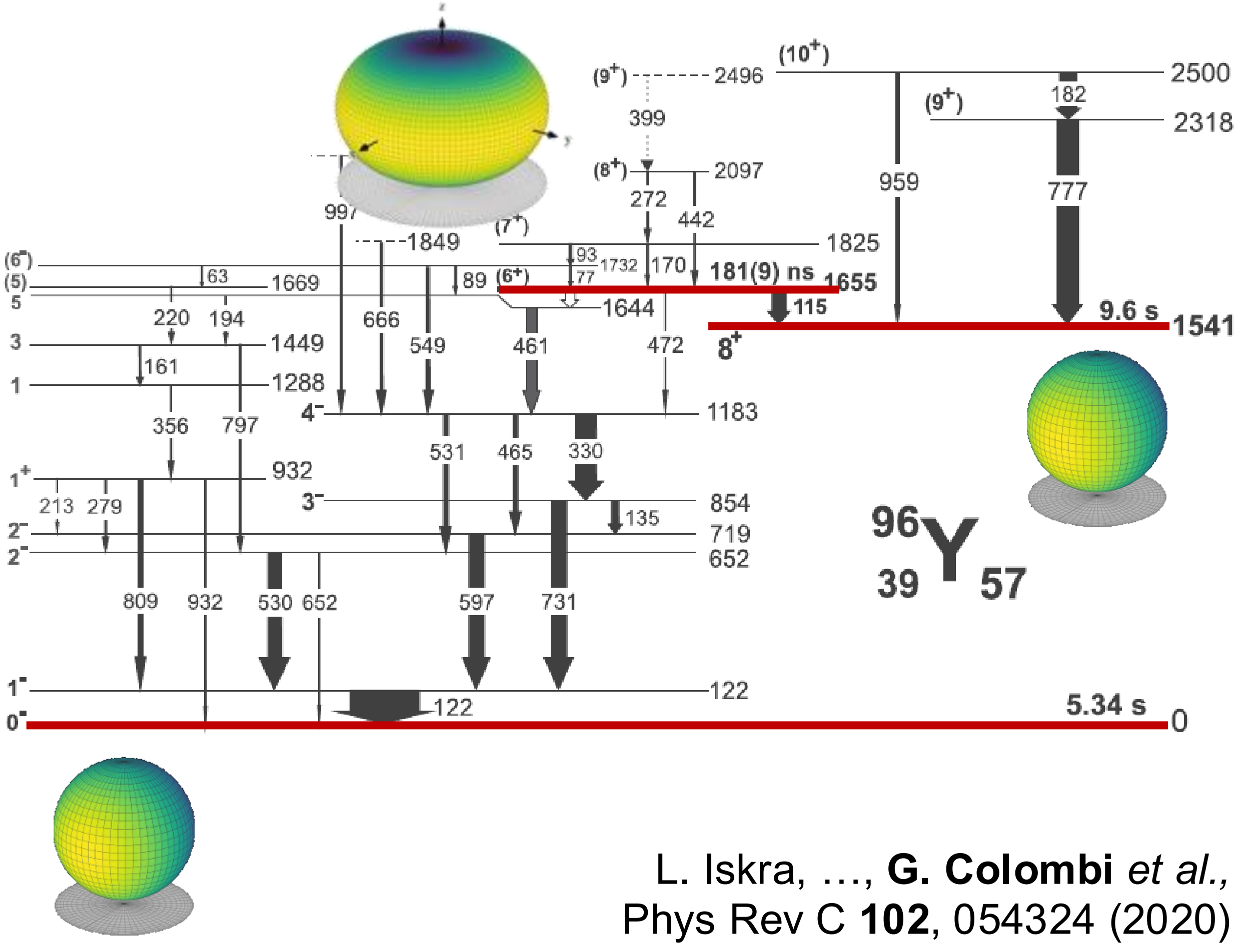


^{96}~~Zr~~ Y Coulex and Shapes, revisited

- Preliminary identification in ^{96}Y of single-particle and core-coupled states (1p proton + 1h neutron)



- Complementary to isomeric study done at FIPPS FR (ILL Grenoble) with the active fission target



L. Iskra, …, **G. Colombi** *et al.*,
Phys Rev C **102**, 054324 (2020)

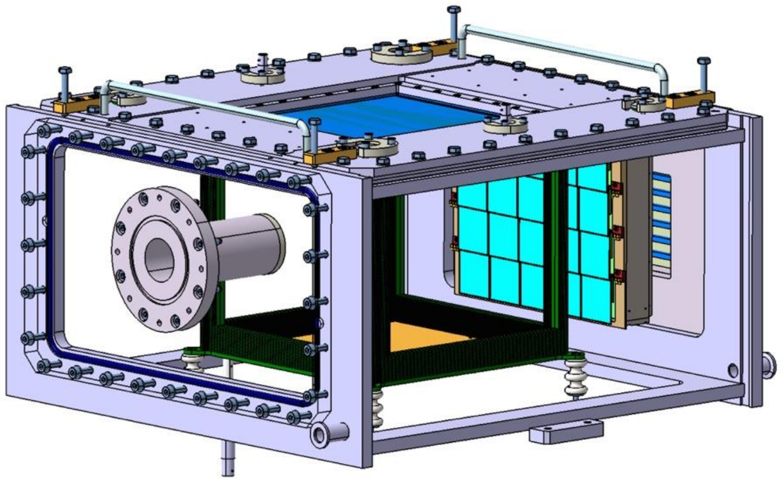
Exotic Nuclei Active Target (EXACT TPC)

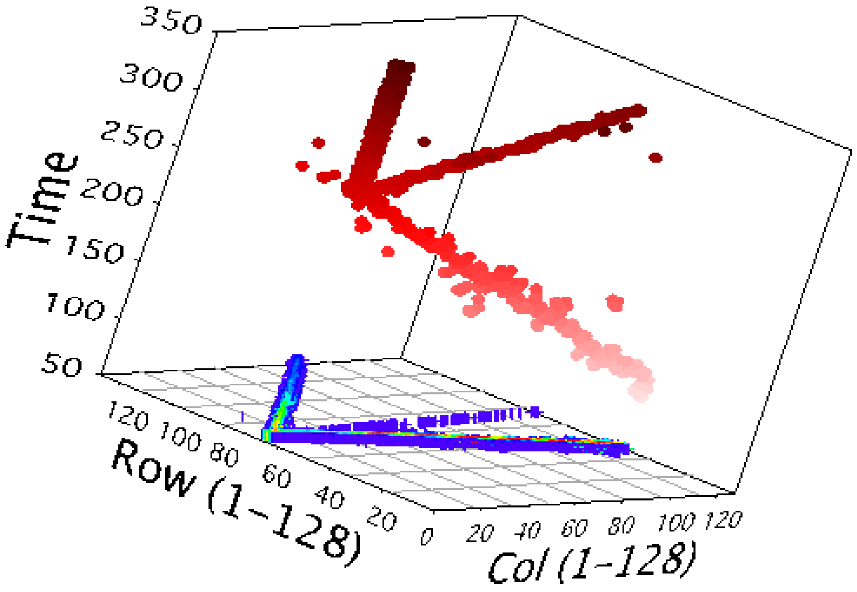
- An Active Target for TRIUMF!
  - Powerful addition to ISAC

- Broad scientific program
  - Exotic nuclear decay
  - Resonant elastic scattering
  - Capture and transfer reactions
  - Reactions on ^3He, ^4He targets

- Collaboration
  - P.I. Ritu Kanungo
  - TRIUMF, SFU, Guelph, Regina
  - McMaster, GANIL FR, Michigan State

- TRIUMF Letter of Intent
  - Endorsed (priority 1) June 2021!





TRIUMF

TRIUMF and NPAT are located on the traditional, ancestral, and unceded territory of the xʷməθkʷəy̓əm (Musqueam) people, who for millennia have passed on their culture, history, and traditions from one generation to the next on this site.

Much thanks to Beatriz, Gwen, Magda & Giacomo for sharing presentation materials and ingtriguing prelimnary results ...

... And to my colleagues from France FR for past, current and future TRIUMF collaboration

C’est tout pour aujourd’hui