The TiNA silicon detector array, development and status

Benoît Mauss

RI Physics Laboratory, Nishina Center for Accelerator-Based Science, RIKEN

SAKURA project

Study of **A**strophysical **K**ey reactions in the **U**niverse with the low-energy **RI** beam **A**pparatus

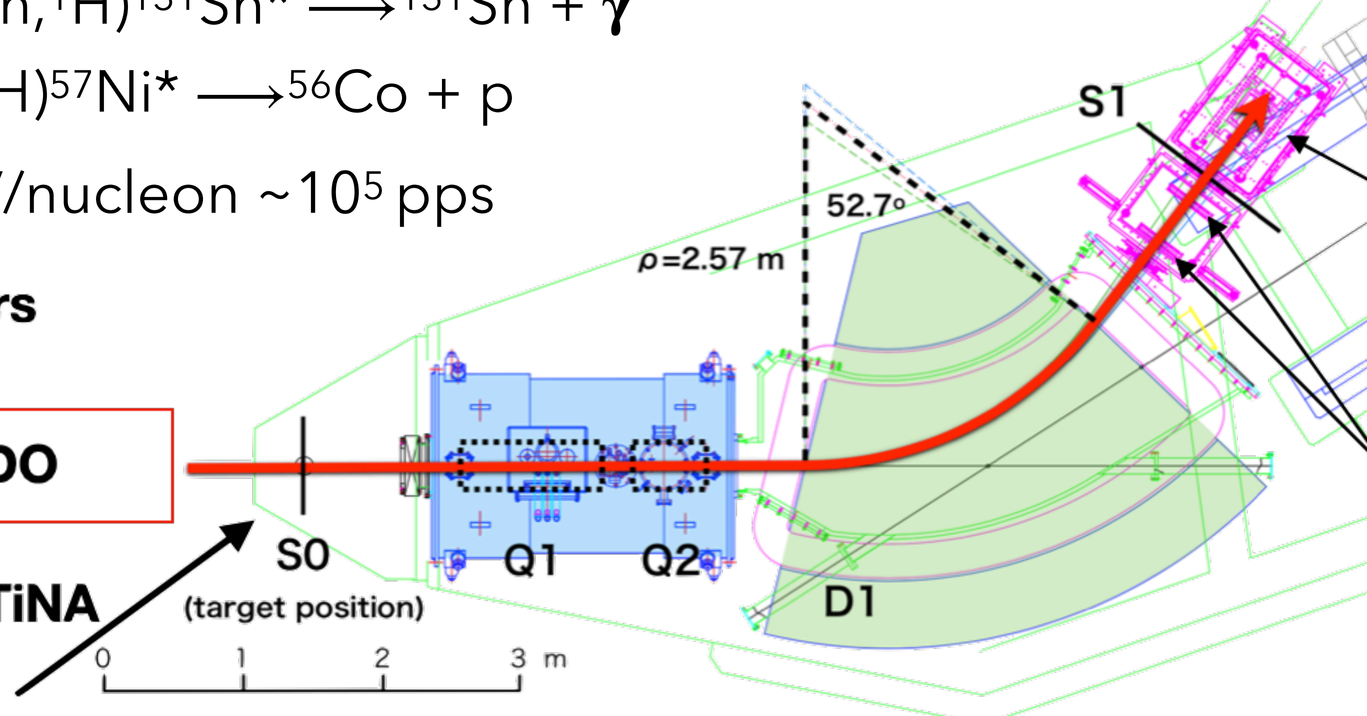
Neutron induced reaction cross sections from surrogate reactions

- $^{130}Sn(n,\gamma)^{131}Sn$ ➜ $^{2}H(^{130}Sn,^{1}H)^{131}Sn^{*} \longrightarrow {}^{131}Sn + \gamma$
- $^{56}Ni(n,p)^{56}Co$ ➜ $^{2}H(^{56}Ni,^{1}H)^{57}Ni^{*} \longrightarrow {}^{56}Co + p$

(d,p) reactions @ 15–20 MeV/nucleon ~10^{5} pps

Beam line detectors
(S. Ota's talk)

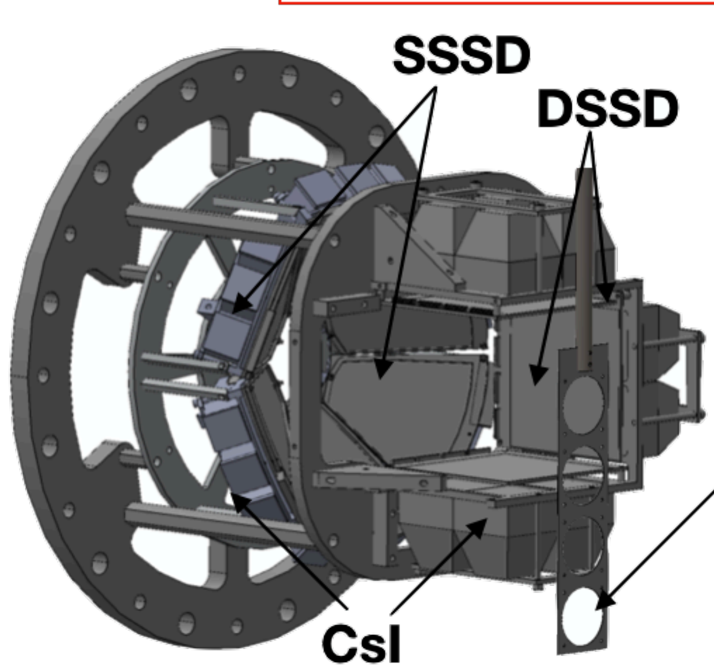
BigRIPS + OEDO



Ionization chamber
(M. Dozono's talk)

2 PPAC

TiNA



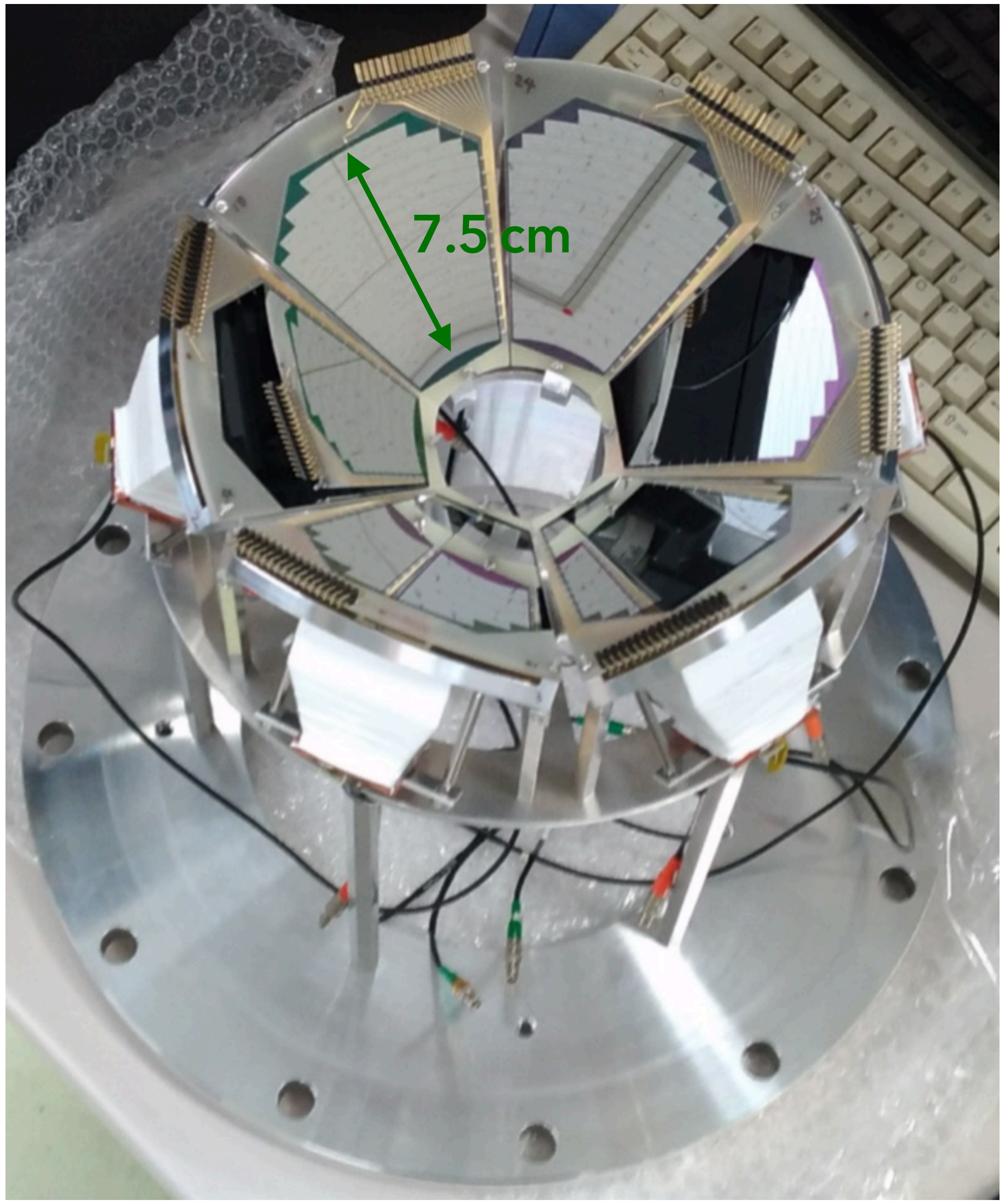
Target holder
(⌀ 5 cm max)
CD_2 target *(N. Iwasa's talk)*

SHARAQ Spectrometer
→ **Identification of the decay channel**

TiNA silicon telescope
→ **Scan the excitation energy region of astrophysical interest**

→ **Determine the excitation energy and the decay channel for each reaction event**

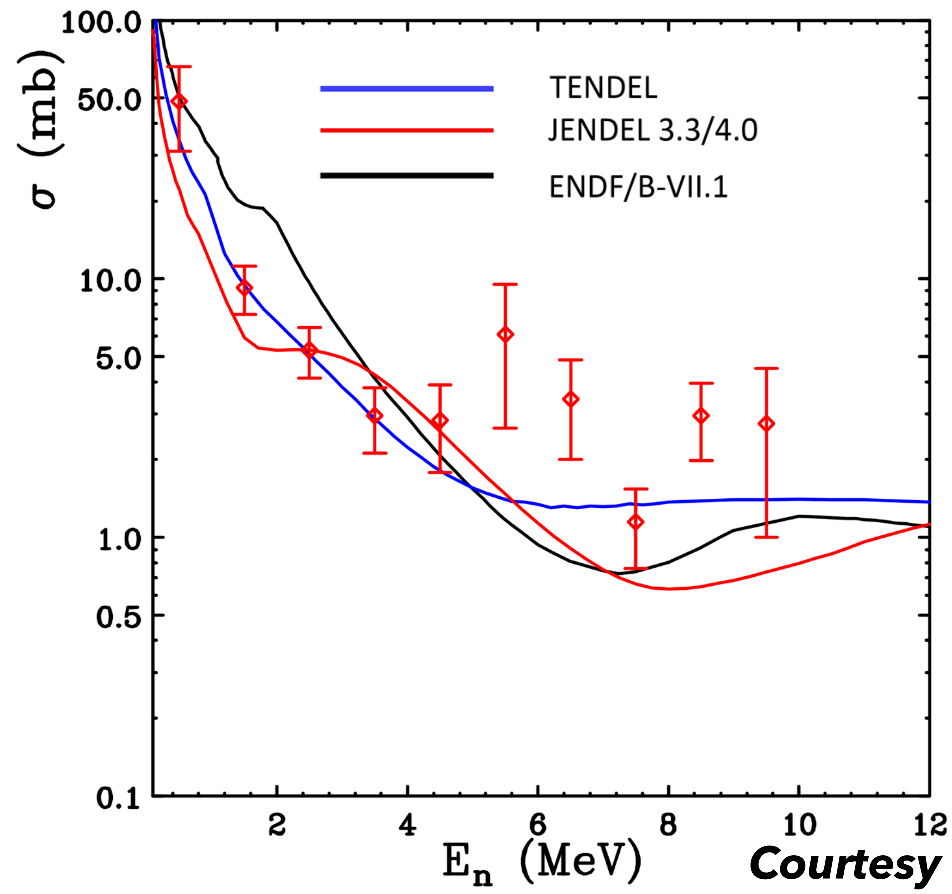
Version 1: ImPACT experiment $^{2}H(^{79}Se,^{1}H)^{80}Se^{*}$



YY1: single sided strip silicon detector
- 300 µm thick
- 16 strips
- $\sigma \approx 30$ keV

6 YY1 detectors in barrel configuration:
- Geometric efficiency (50%–80%)
- Large angle coverage (75.5° – 21.8° = 53.7°)

Investigating $^{79}Se(n,\gamma)$ cross section

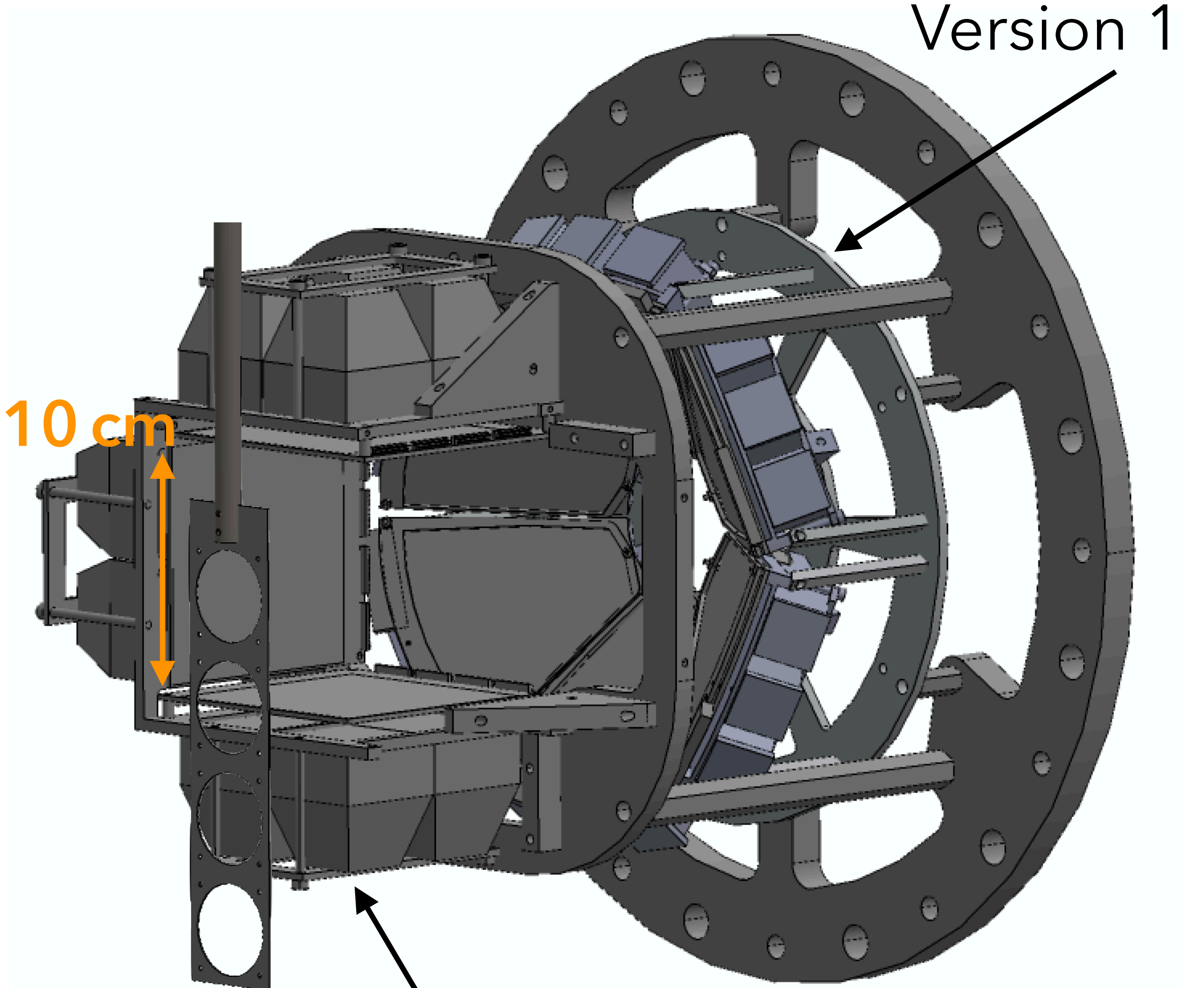


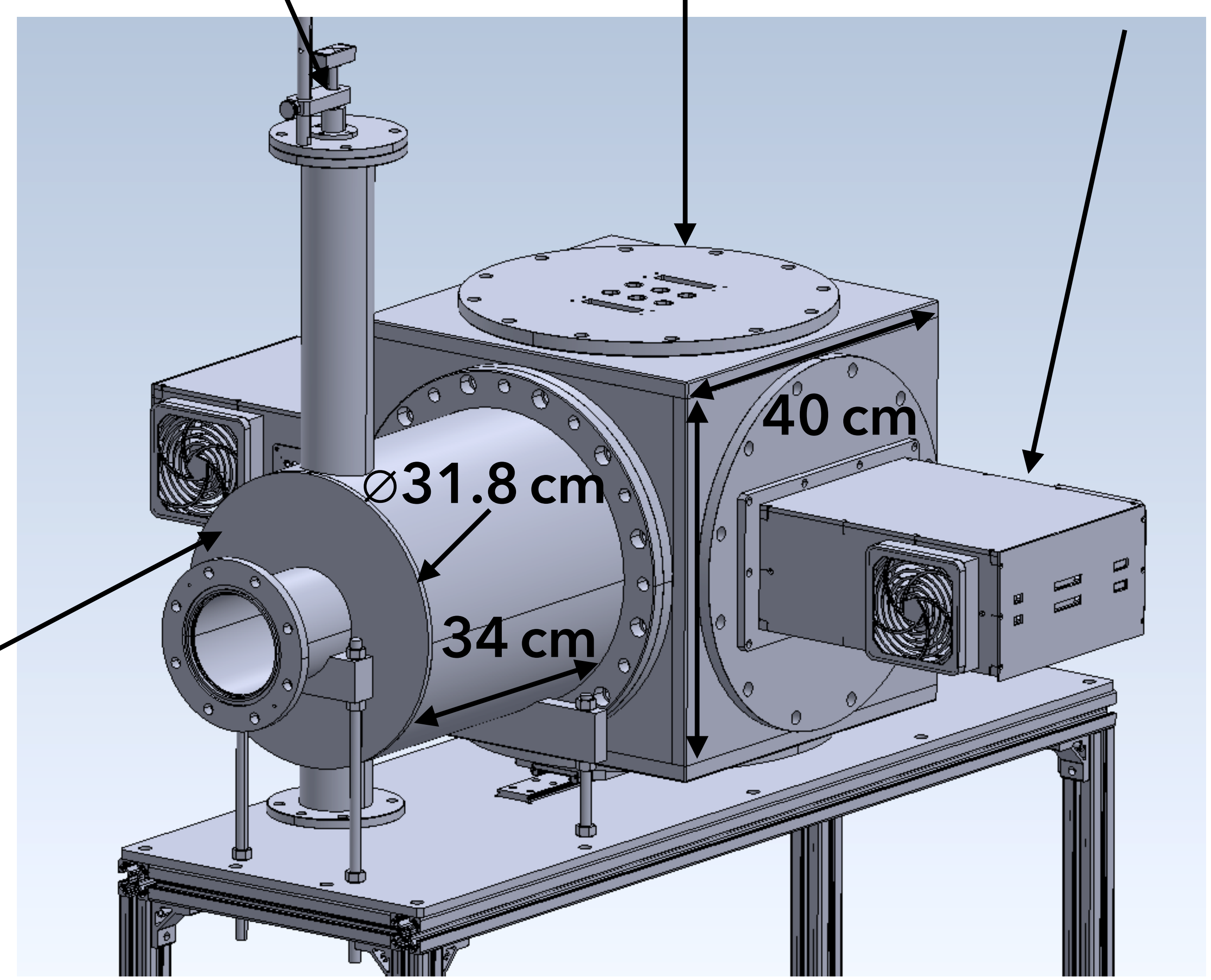
Courtesy N. Imai

Drawbacks:
- Poor angular resolution (0.7°–2.4°)
- Minimal angle covered $\boldsymbol{\theta}_{lab}$= 21.8°

→ Improvement needed

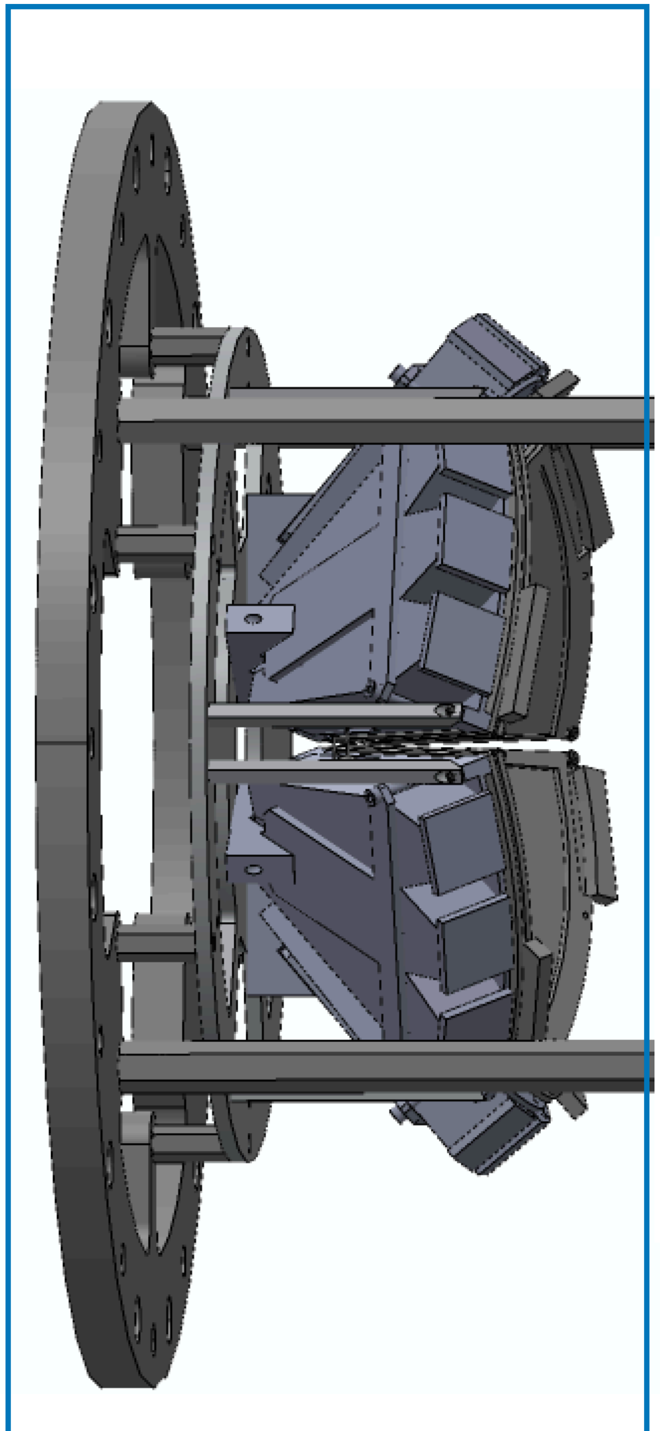
Technical drawing of TiNA version 2



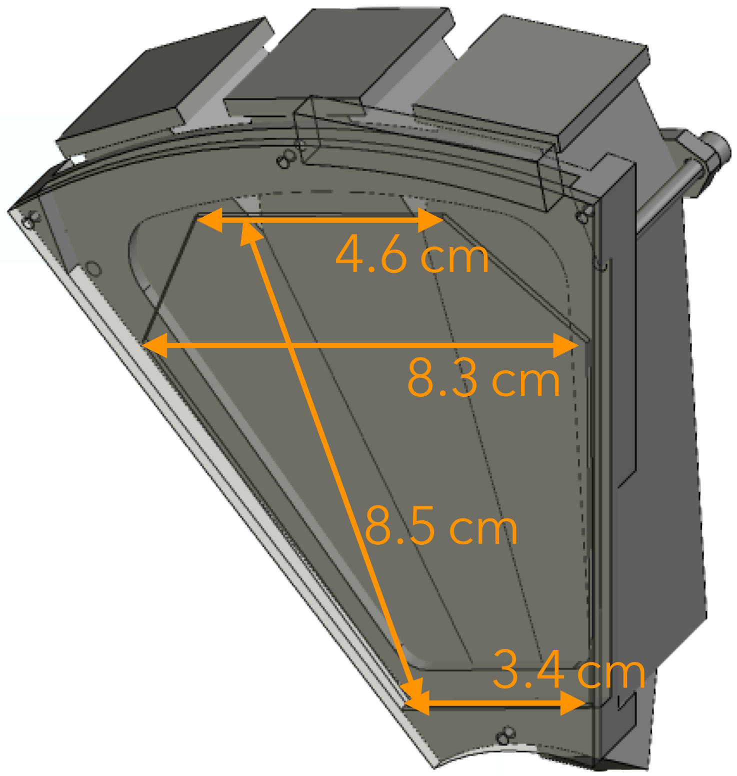


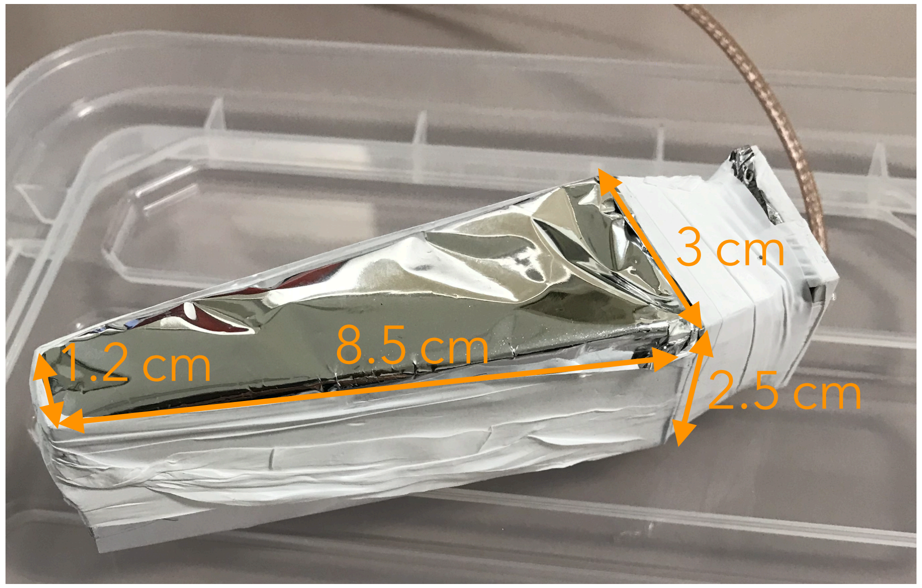
→ Partial assembly done, full assembly soon

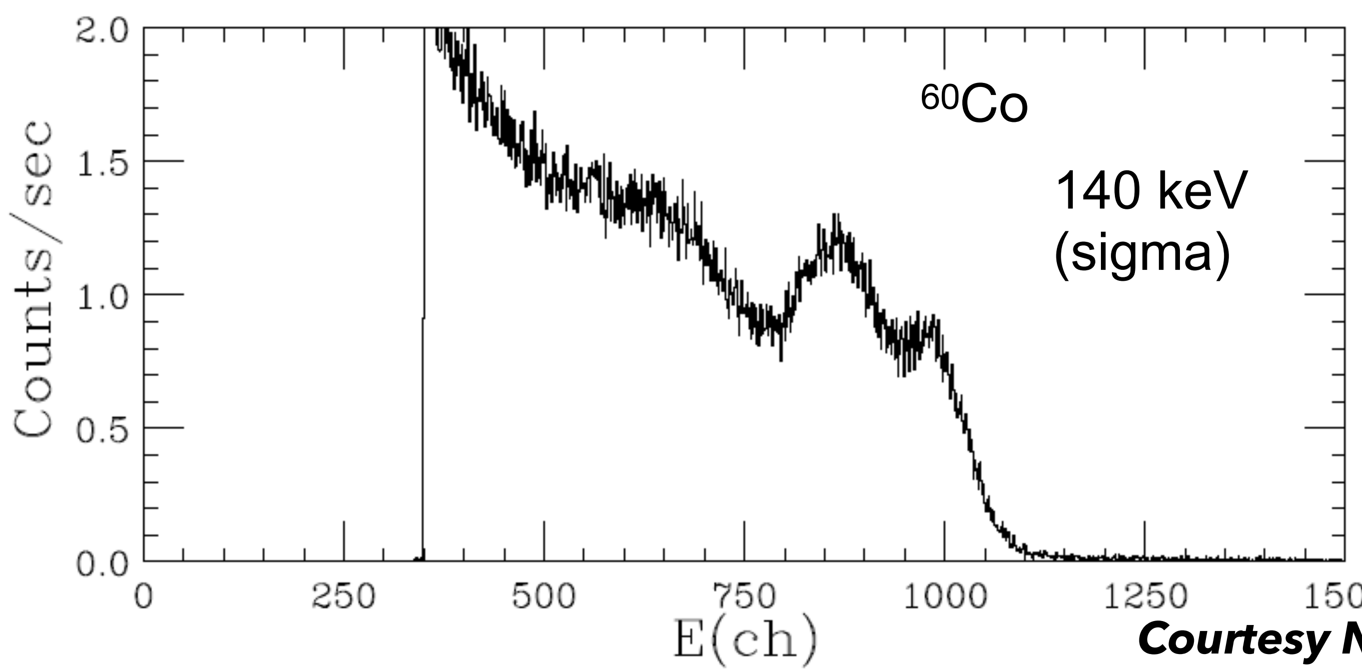
Version 2: Improvement of the YY1 telescopes



YY1 of TiNA version1







Courtesy N. Imai

→ Increased efficiency, but for SAKURA project protons will stop in YY1

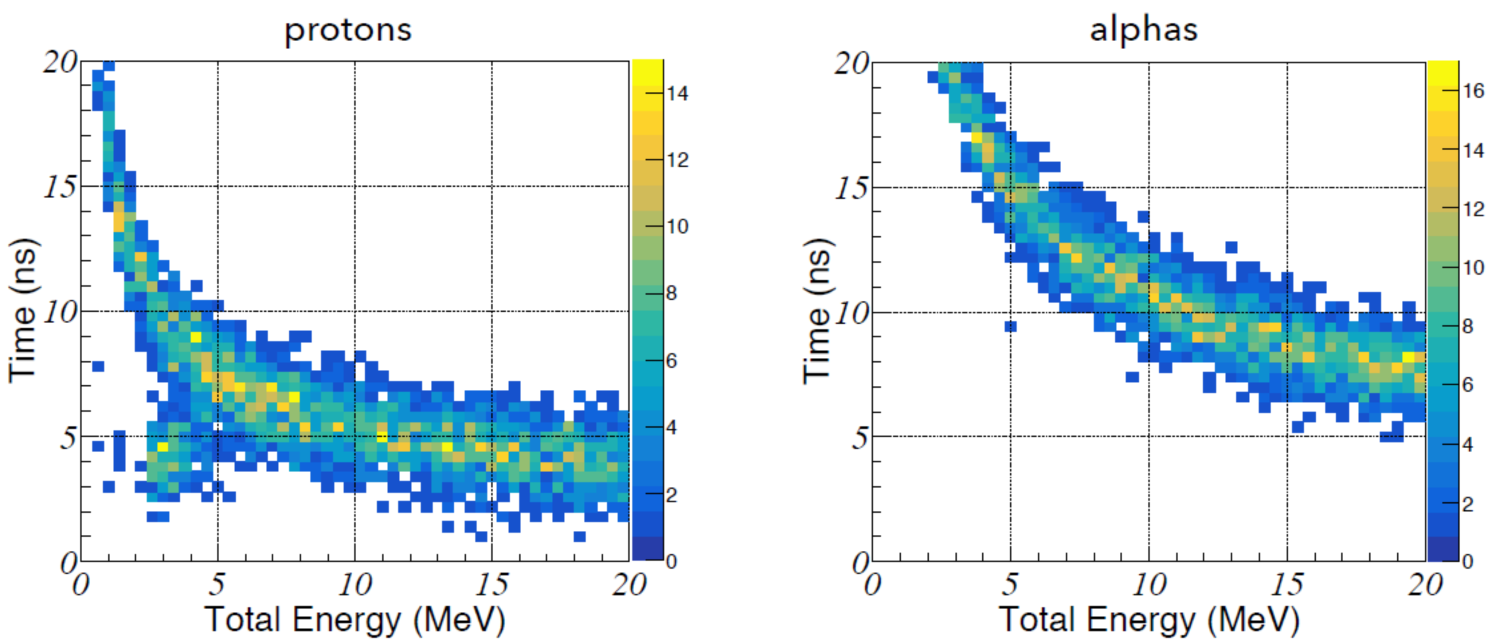
YY1 time performances and possibilities for PID

In-beam experiment with YY1 telescope showed:

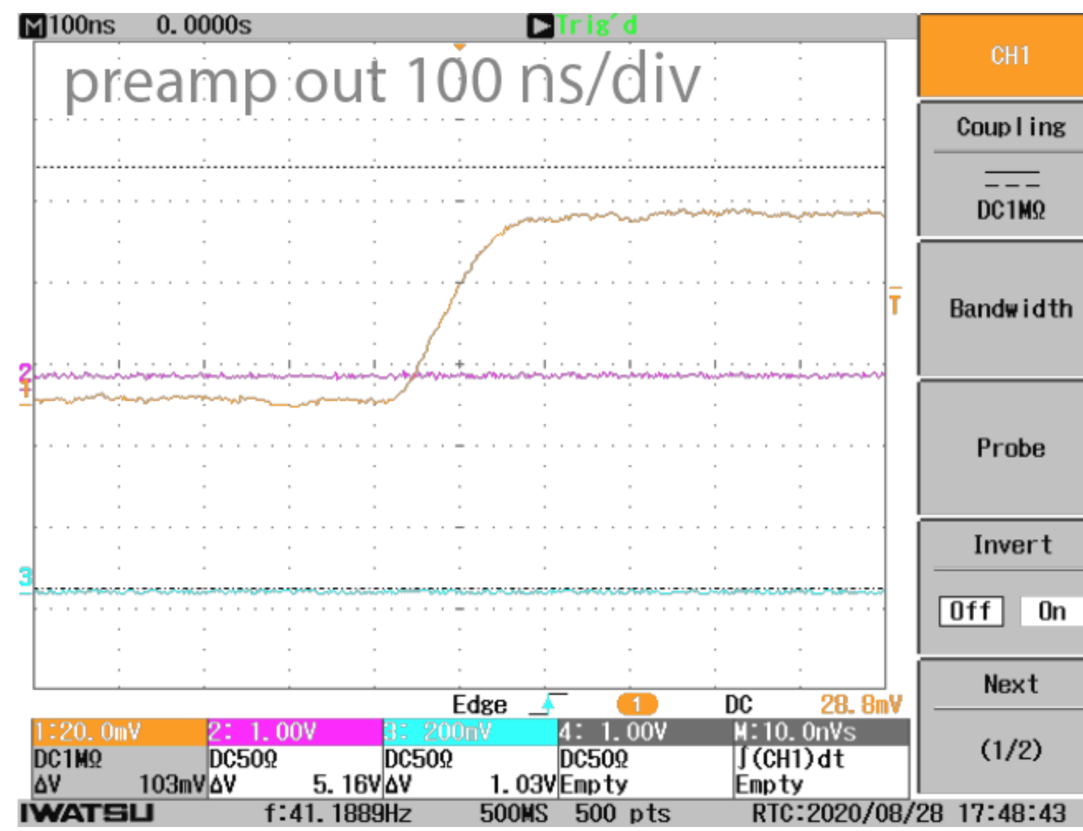
- Backside time resolution: ~3.7 ns
- MPRS16 (strips) time resolution: ~2.3 ns
  - ➡ Improvement possible and needed

New fast pre-amplifier under test

PID simulation for 1ns resolution (sigma)



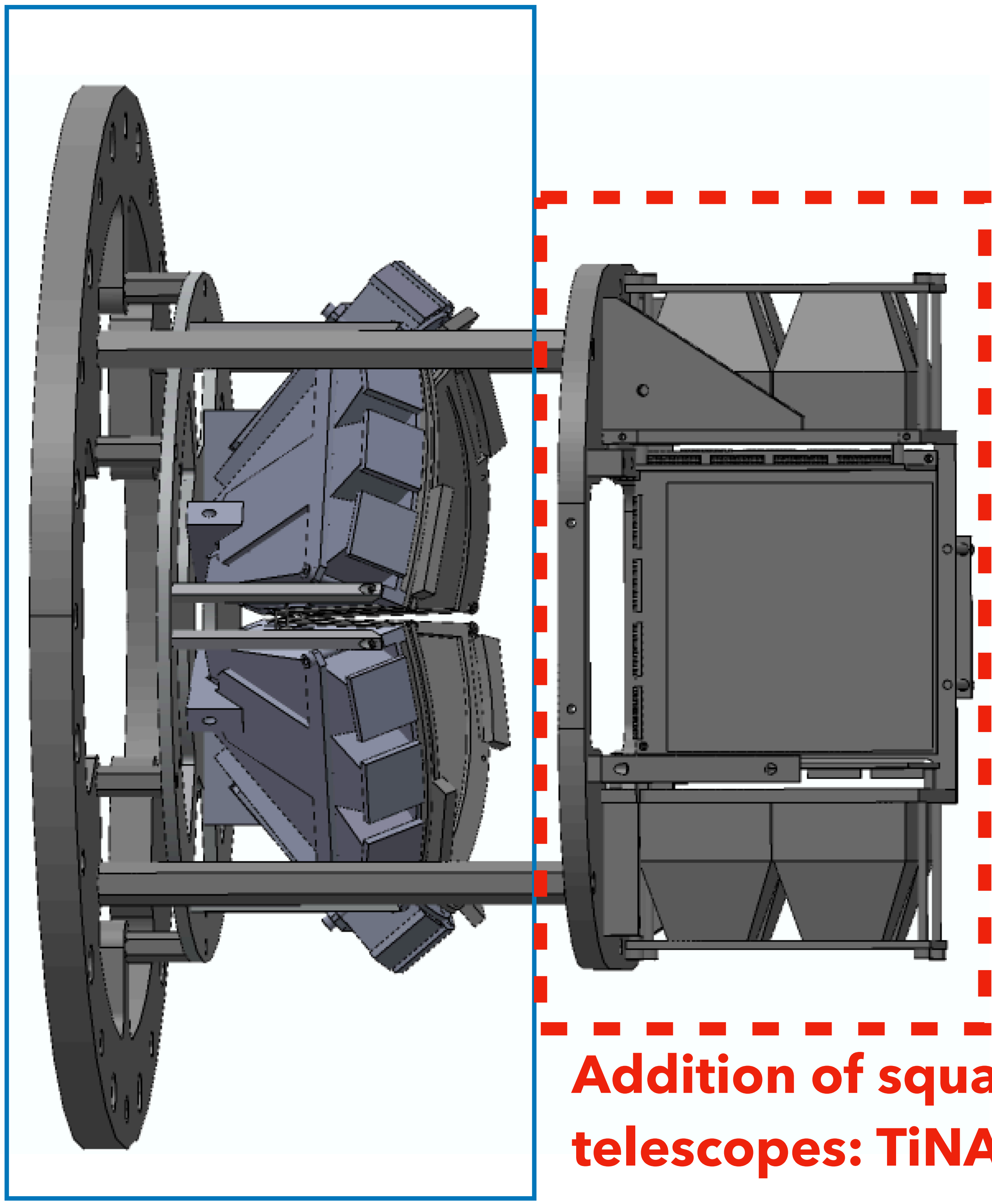
Courtesy N. Imai



Courtesy N. Kitamura

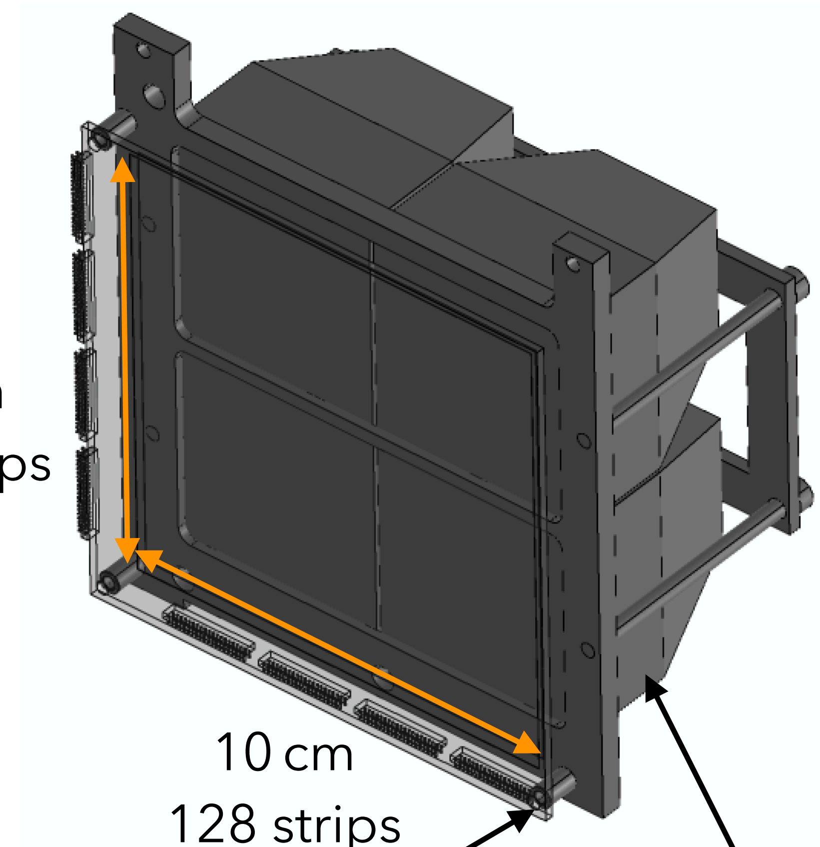
→ A new fast pre-amplifier to increase time resolution is in preparation

Version 2: Addition of square DSSD+CsI telescopes



Addition of square telescopes: TiNA version2

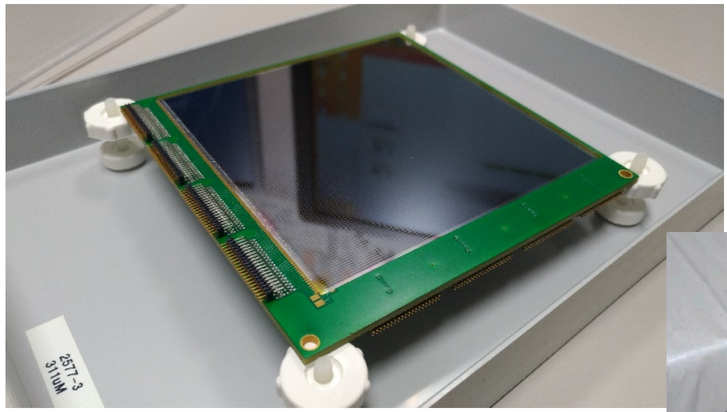
YY1 of TiNA version1



10 cm
128 strips

10 cm
128 strips

Micron type TTT2: 300μm thick



RCNP CsI: 88 MeV protons
Resolution: 120 keV (sigma)

→ Angular resolution: TTT2<0.8° and YY1<1.2°

→ Angular coverage: 10° – 80° with 70% – 90% efficiency

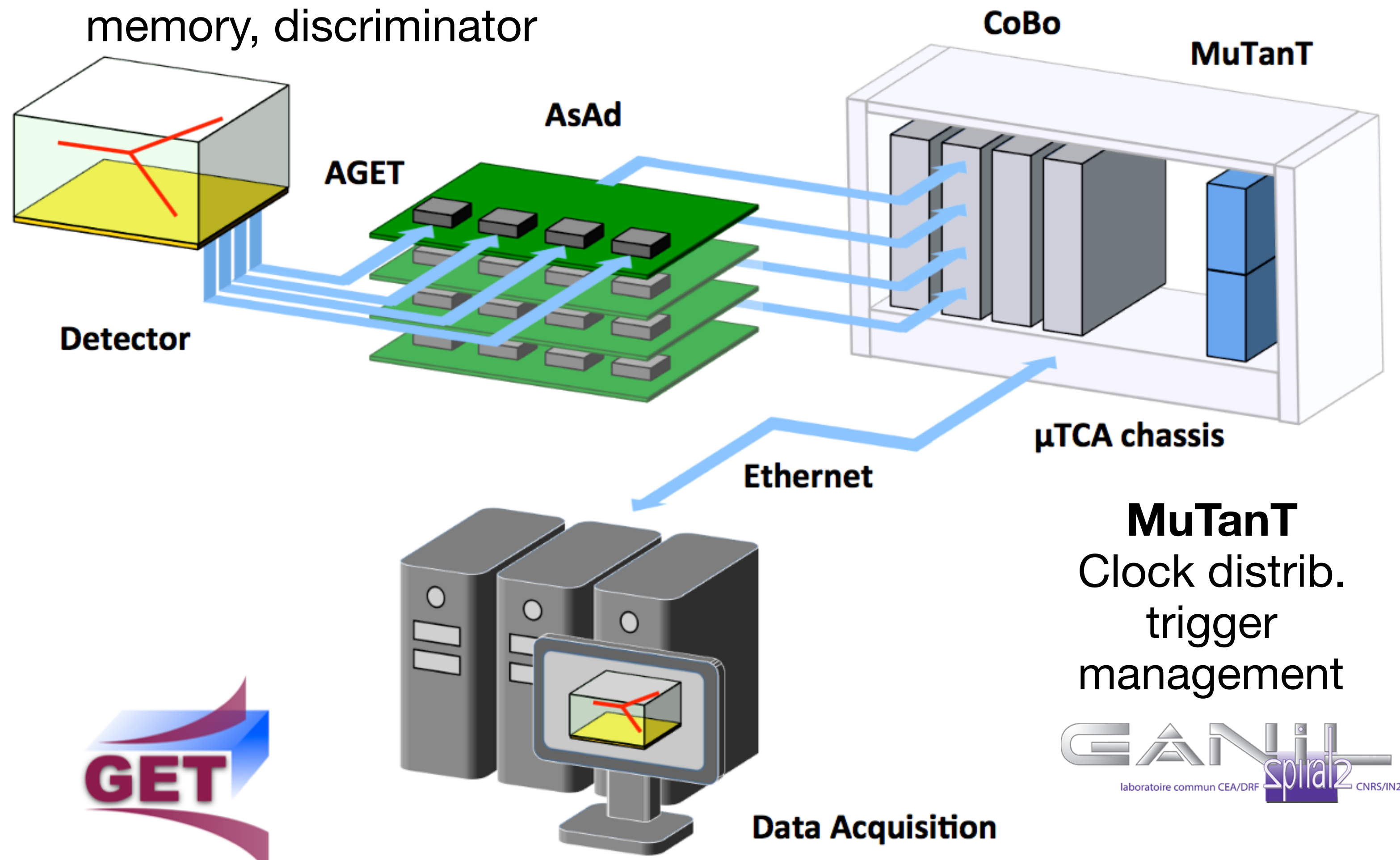
Readout of the 1024 TTT channels

GET: General Electronics for TPCs

AGET
64 channels signal processing (CSA +shaper), analog memory, discriminator

AsAd
4 chips (+config) signal & mult. coding (ADC)

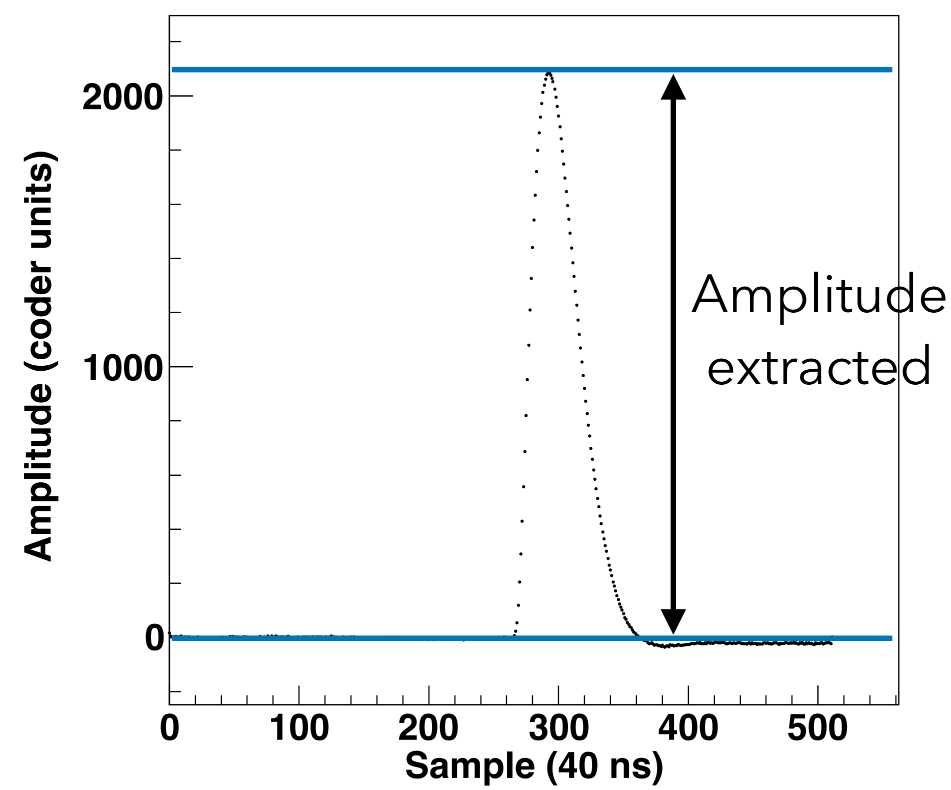
COBO
4 AsAd boards digital data management



MuTanT
Clock distrib. trigger management

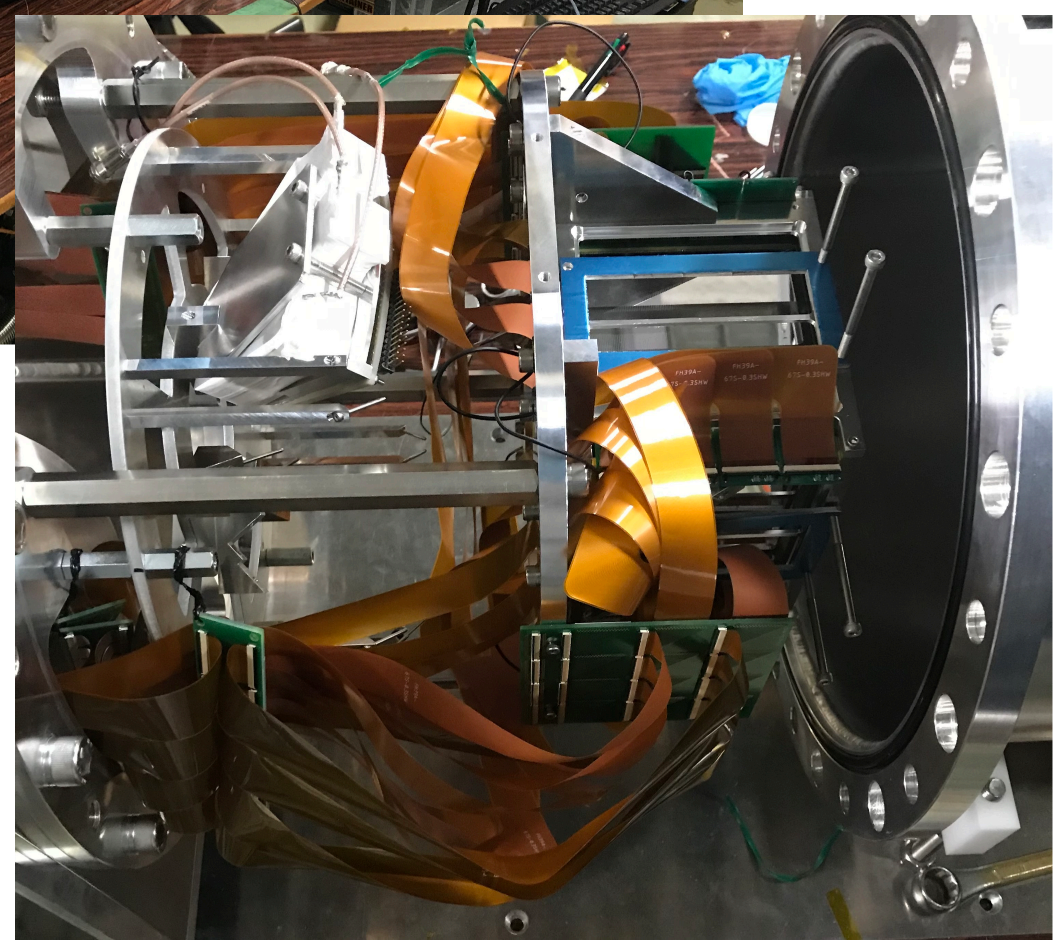
E.C. Pollacco *et al.* NIMA 887 (2018) 81–93

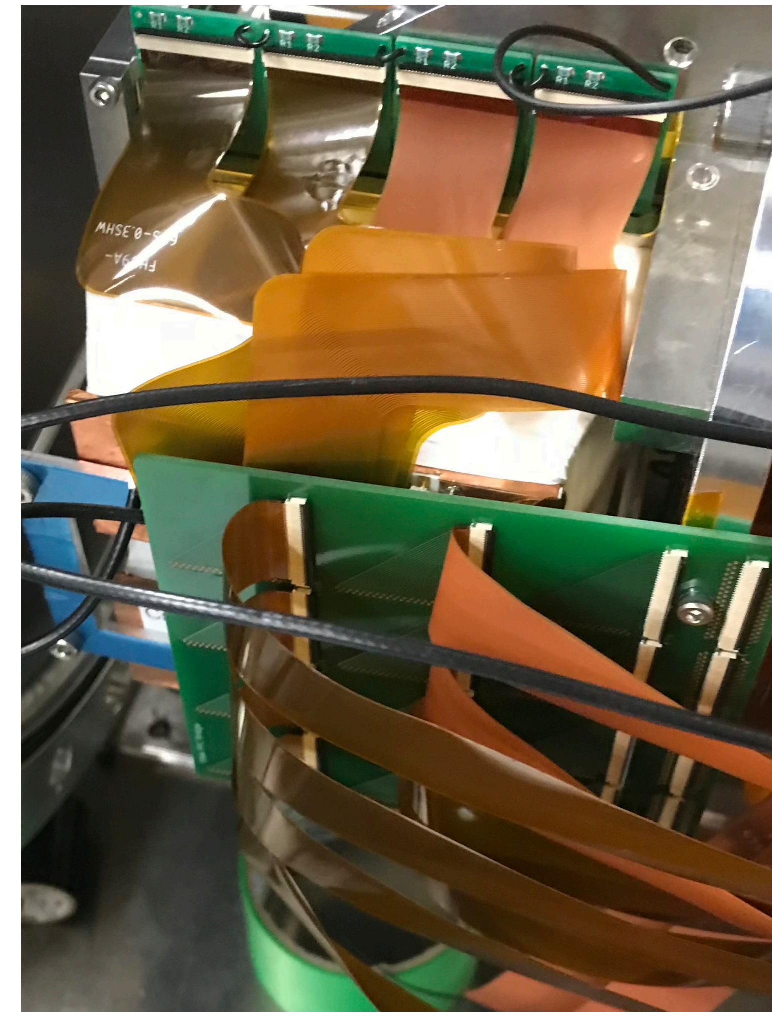
- Management of high channel density
- Digitization of the signal
- Developed and used for active targets and TPCs
- Electronic shared with CAT-M and SπRIT TPC



→ Treatment of the high channel density.

System partly assembled and tested

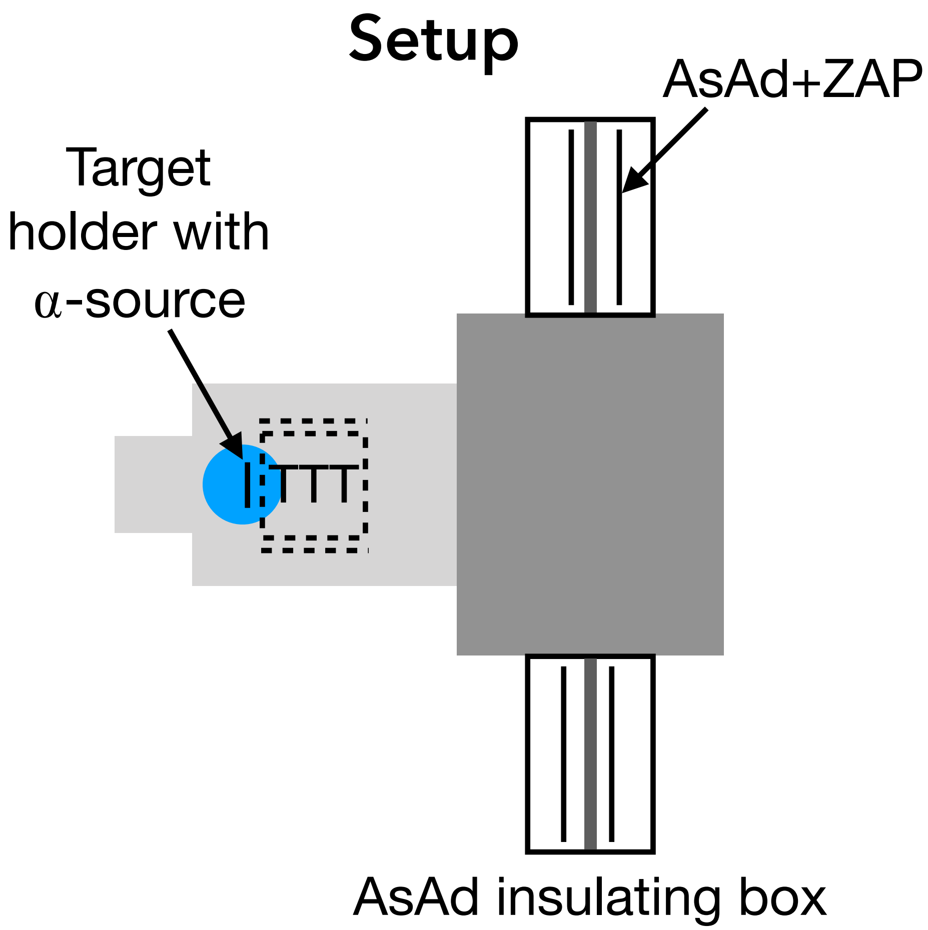


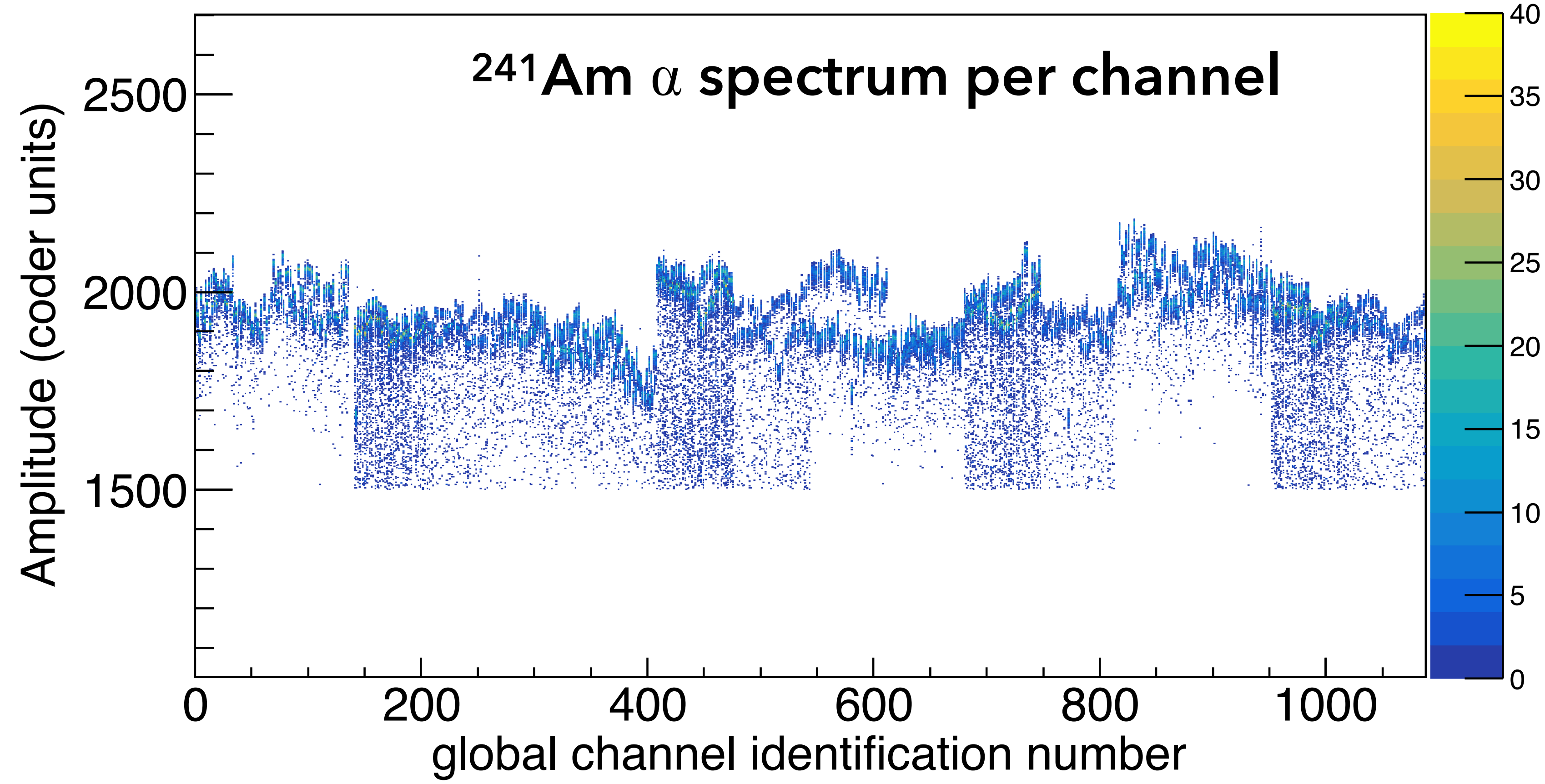


Cabling design: J.W. Hwang

→ Detector ready for full assembly. Beam test delayed

TTT performances with GET





TTT: 1024 channels

↓

16 AGET

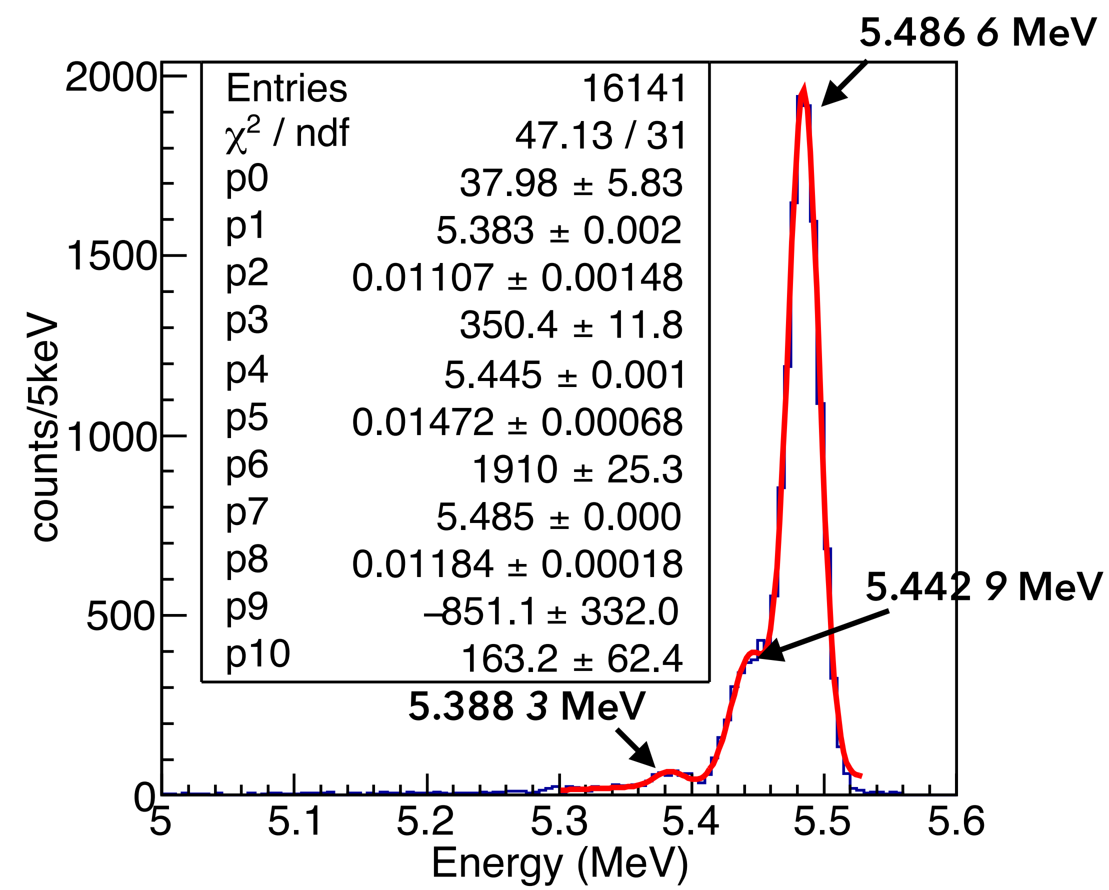
↓

4 AsAd

↓

1 CoBo

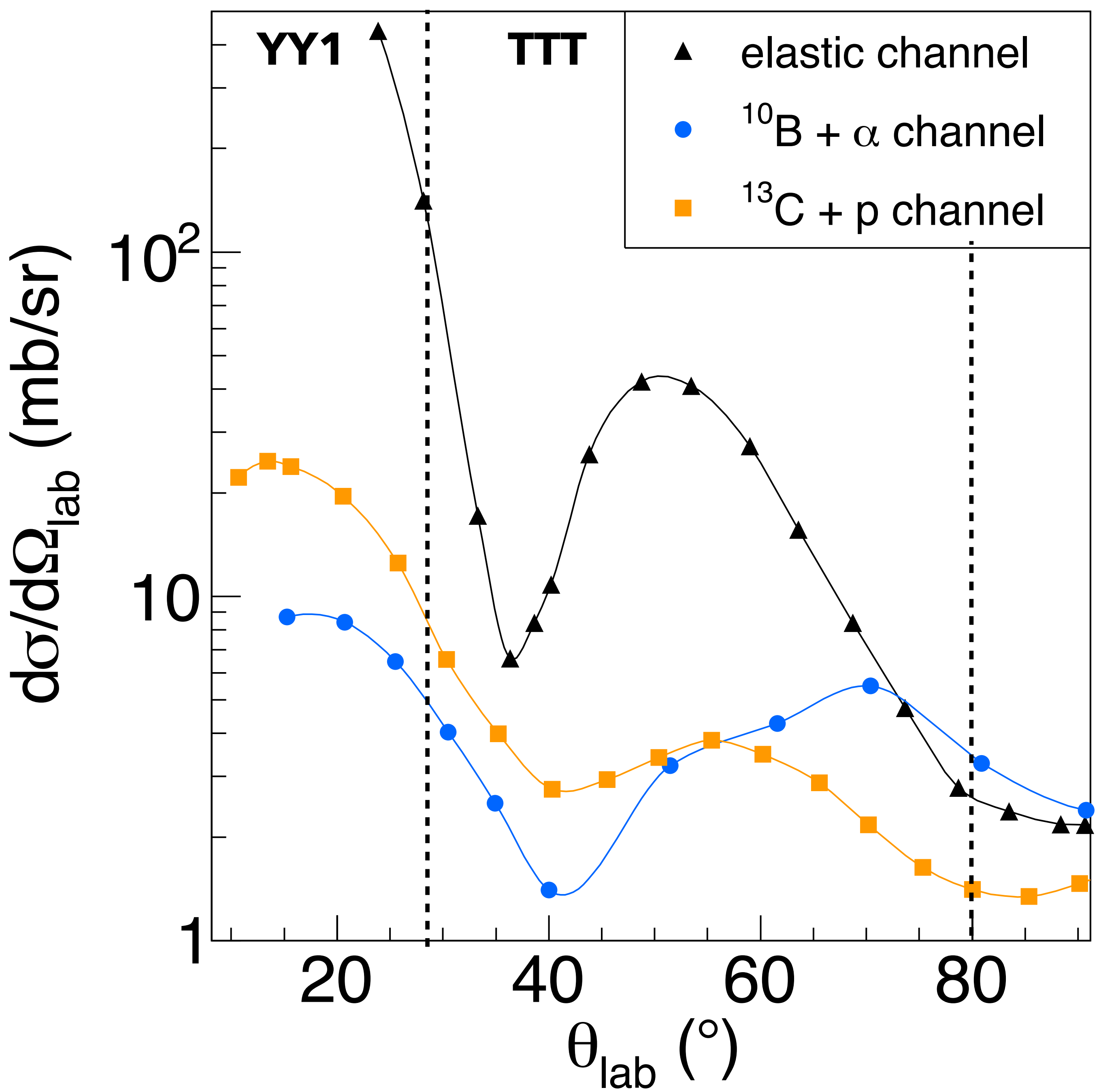
Integrated spectrum (1 TTT, front strips)



→ Main peak resolution < 20keV sigma. Tested with 140 Hz external trigger

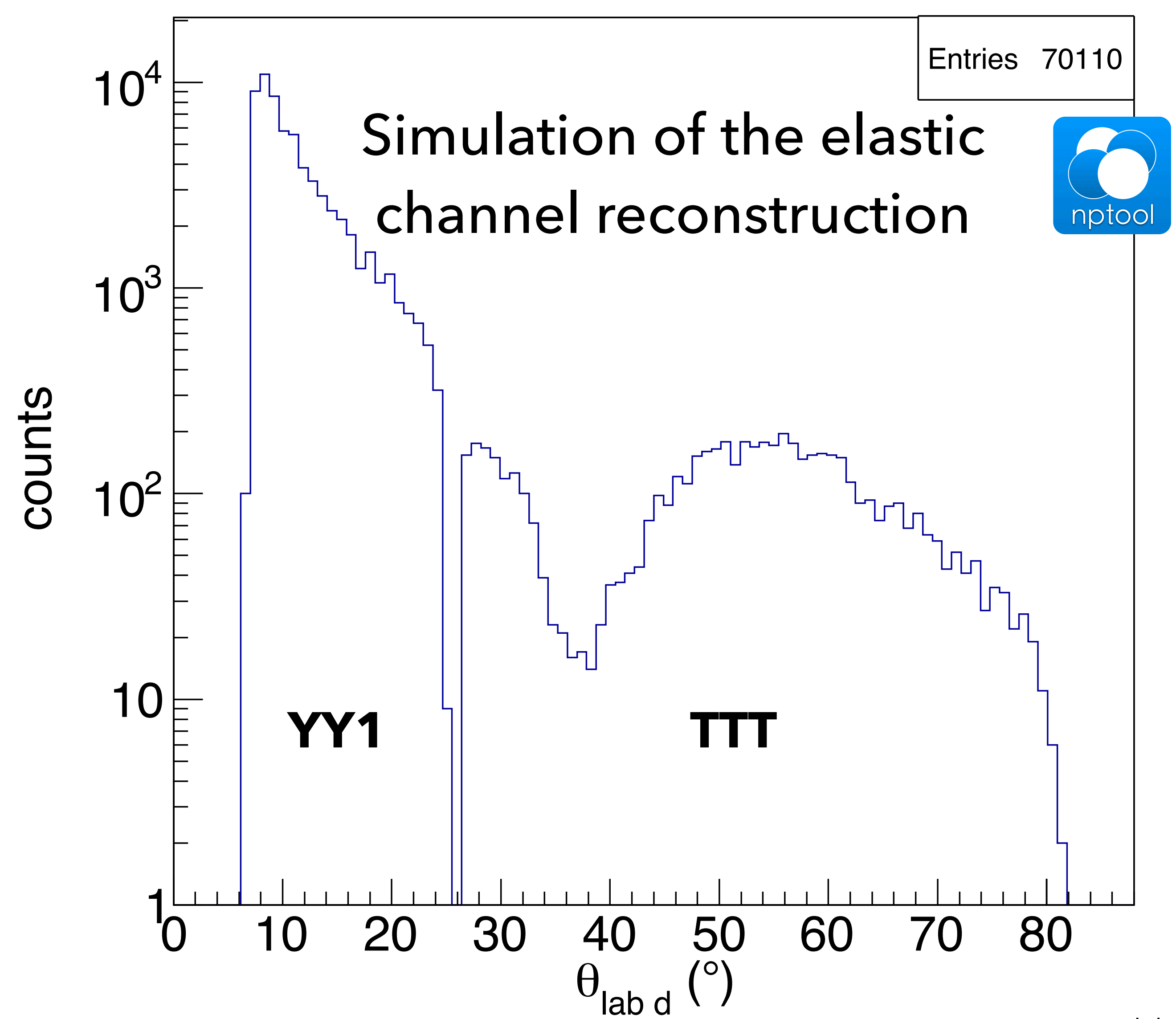
Beam test planned at the Kyushu University TANDEM

Reaction: $^{12}C(^{2}H,*)$ at 13 MeV



Performances to be tested:

- Excitation energy resolution
- Angular distribution reconstruction
- Maximum accepted trigger rate
- PID capabilities (p, d, α)



→ New schedule under discussion

Conclusion and Perspectives

Conclusion

- SAKURA project: 2 accepted experiments for neutron induced reaction studies.
- Additional nuclear structure experiment $^{2}H(^{50}Ca,^{1}H)^{51}Ca$ in the backlog.
- TiNA was developed to tackle a wide range of physics on nuclear structure and reactions, or astrophysics.
- Version 1 was successfully used to measure $^{79}Se(d,p)^{80}Se$ in the ImPACT project.
- Version 2 was developed for better resolution and wider coverage.
- The detector was partly constructed and tested with an ^{241}Am α-source.
- It is ready to be tested in-beam.

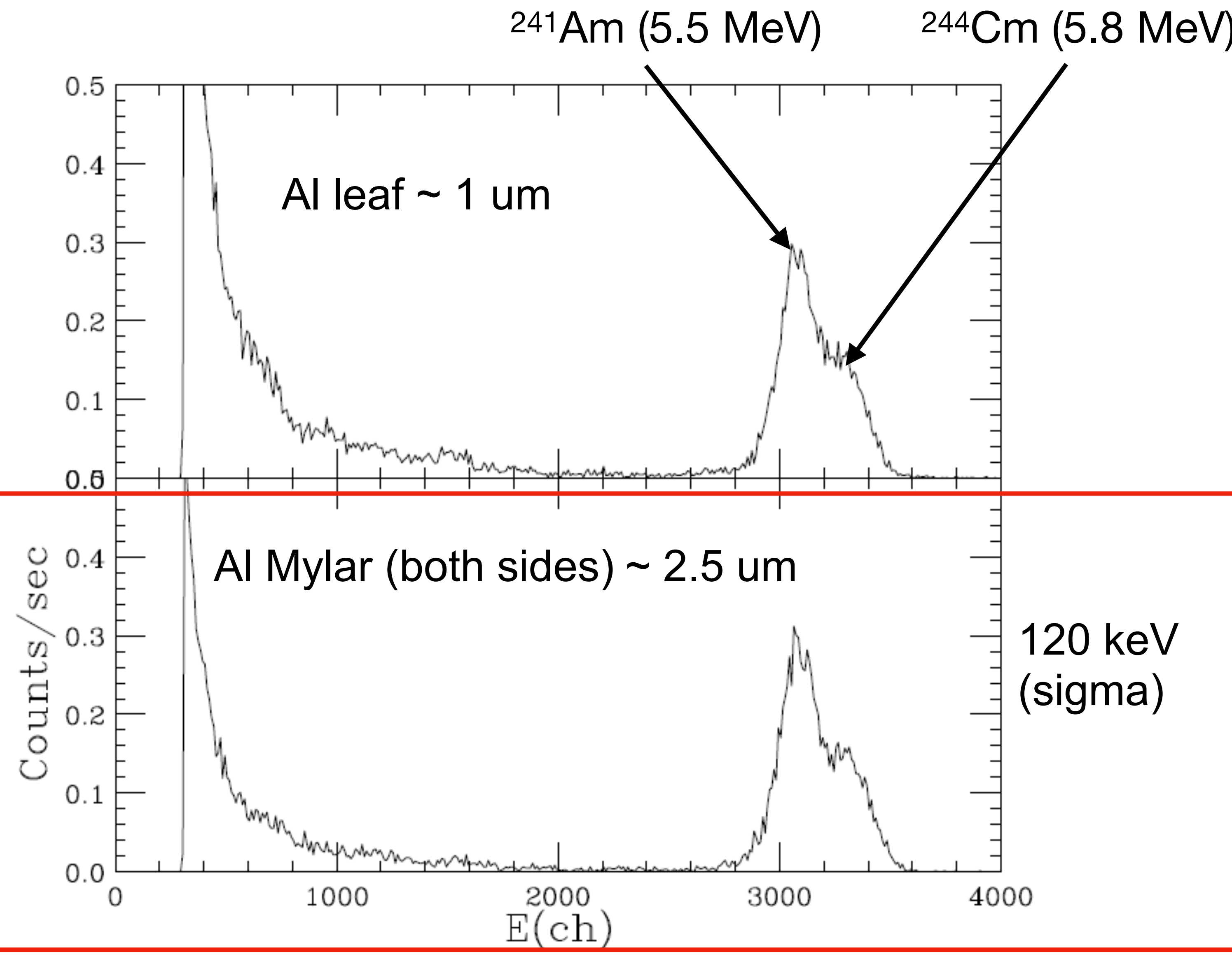
Perspectives

- Full assembly will be tested soon.
- In-beam test planned at Kyushu University TANDEM.
- Hopefully experiments will run in 2021

Thank you for your attention

RCNP CsI performances

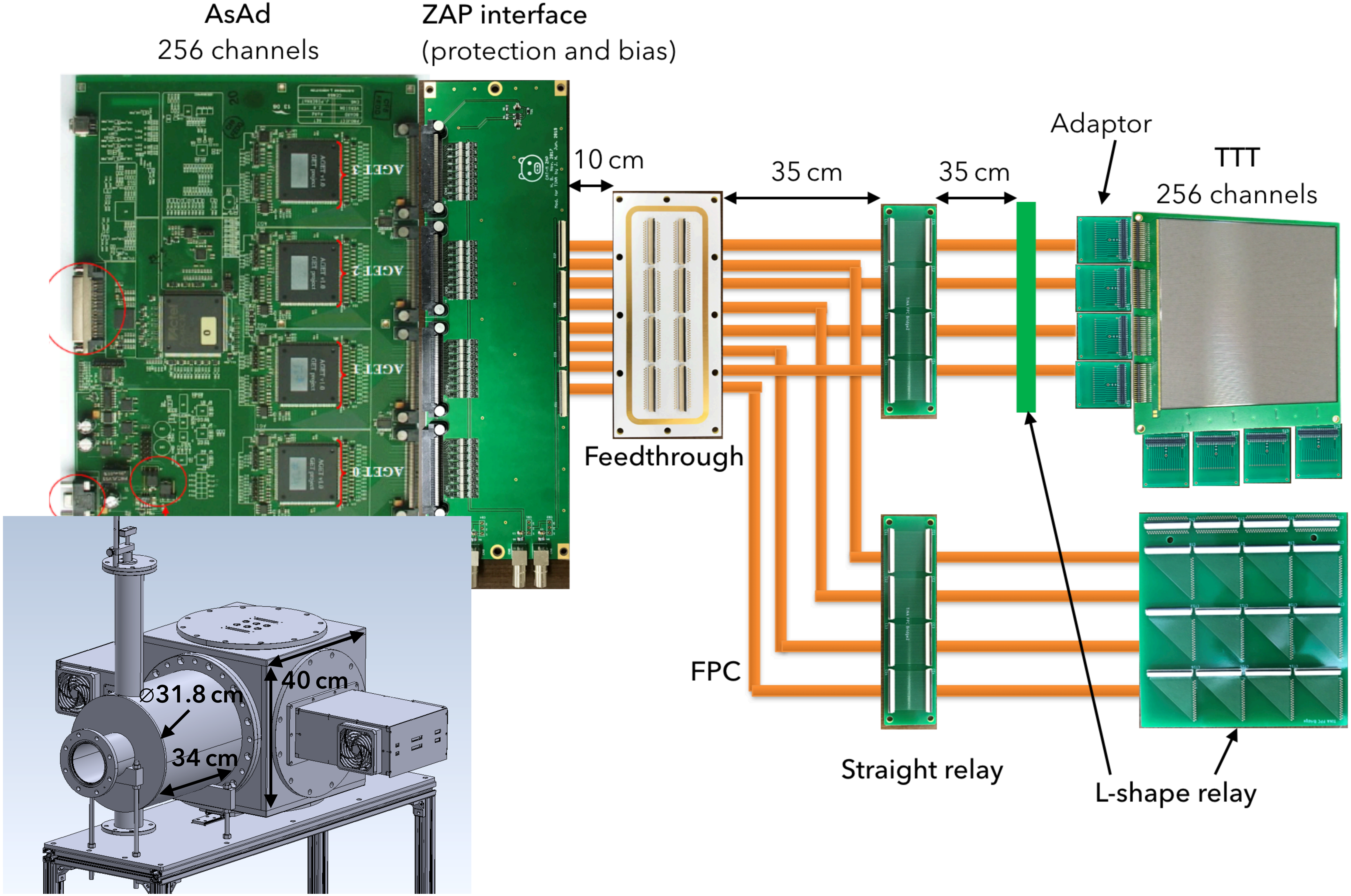
Entrance window difference



Courtesy N. Imai

Cabling and feedthrough

Cabling of the 1024 channel and feedthrough (Jongwon Hwang).



→ Link established between TTT and AsAd over long distance.

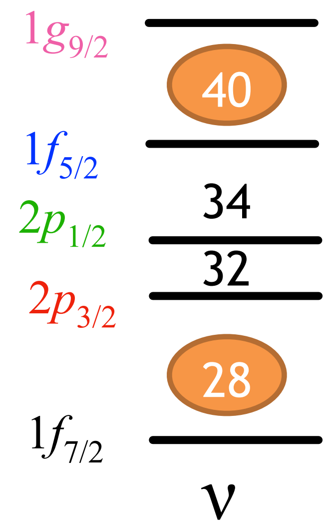
Single-particle structure in ^{51}Ca via ^{50}Ca(d,p) reaction

Experiment approved by NP-PAC 2018

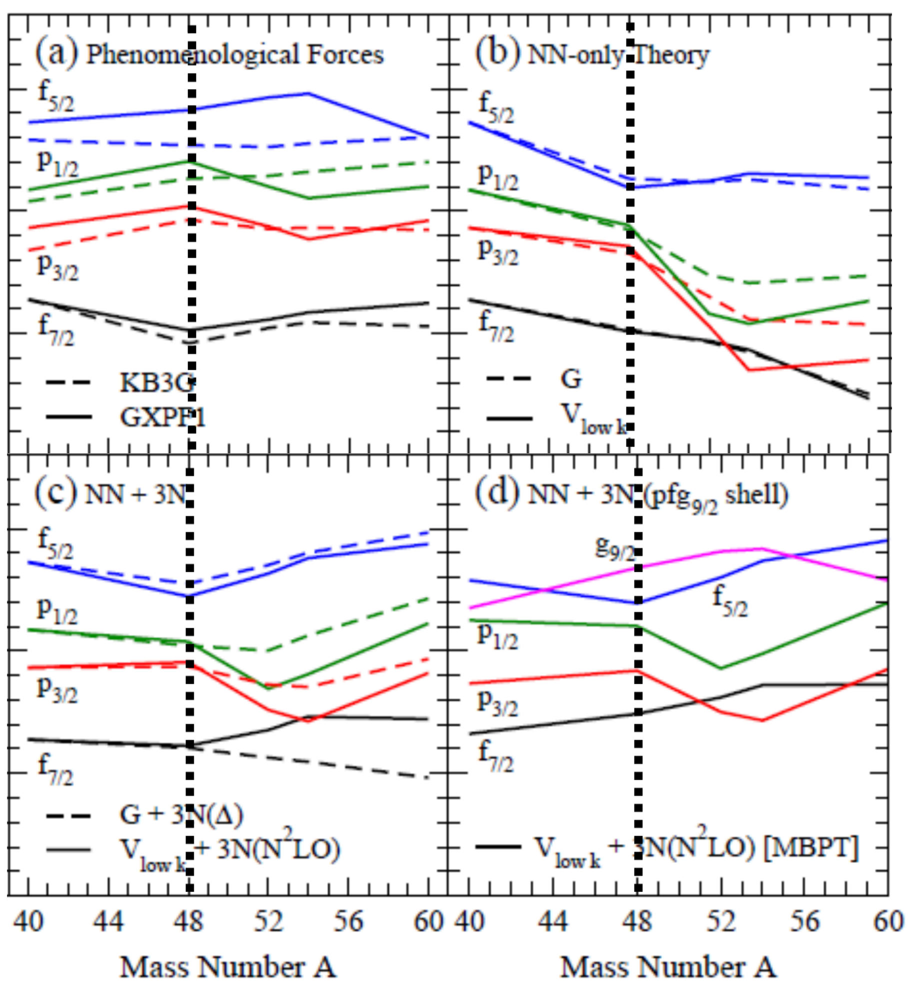
Spokesperson: K. Wimmer,
Co-spokesperson: D. Suzuki

Goal: Study of ^{51}Ca structure from ^{2}H(^{50}Ca,^{1}H)^{51}Ca

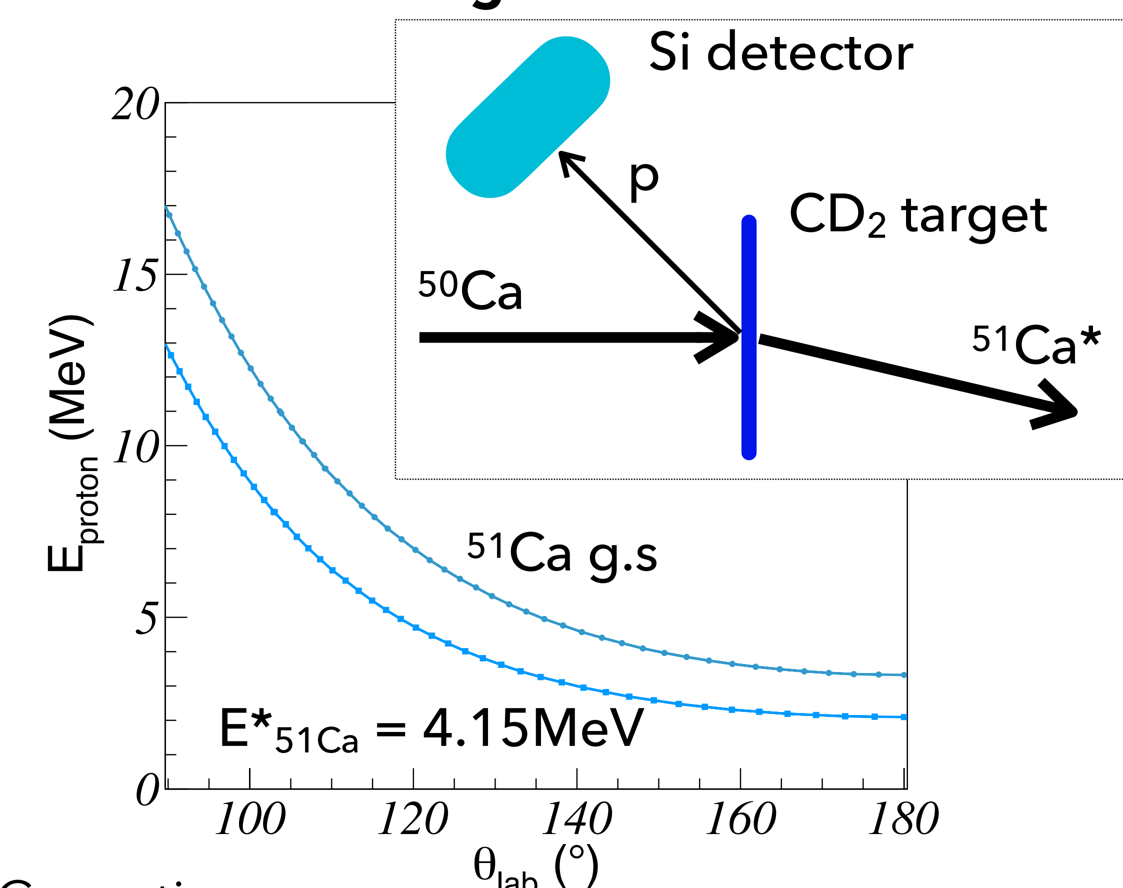
Search the single particle 2p1/2, 1f5/2 and 1g9/2 states to quantify the energy gap at N = 32, 34 and possibly at N = 40



J.D. Holt *et al.*, Jour. Phys. G 39, 085111 (2012)



Missing-mass method



+ 3 proposal with (d,p) reactions planned at upcoming NP-PAC meeting

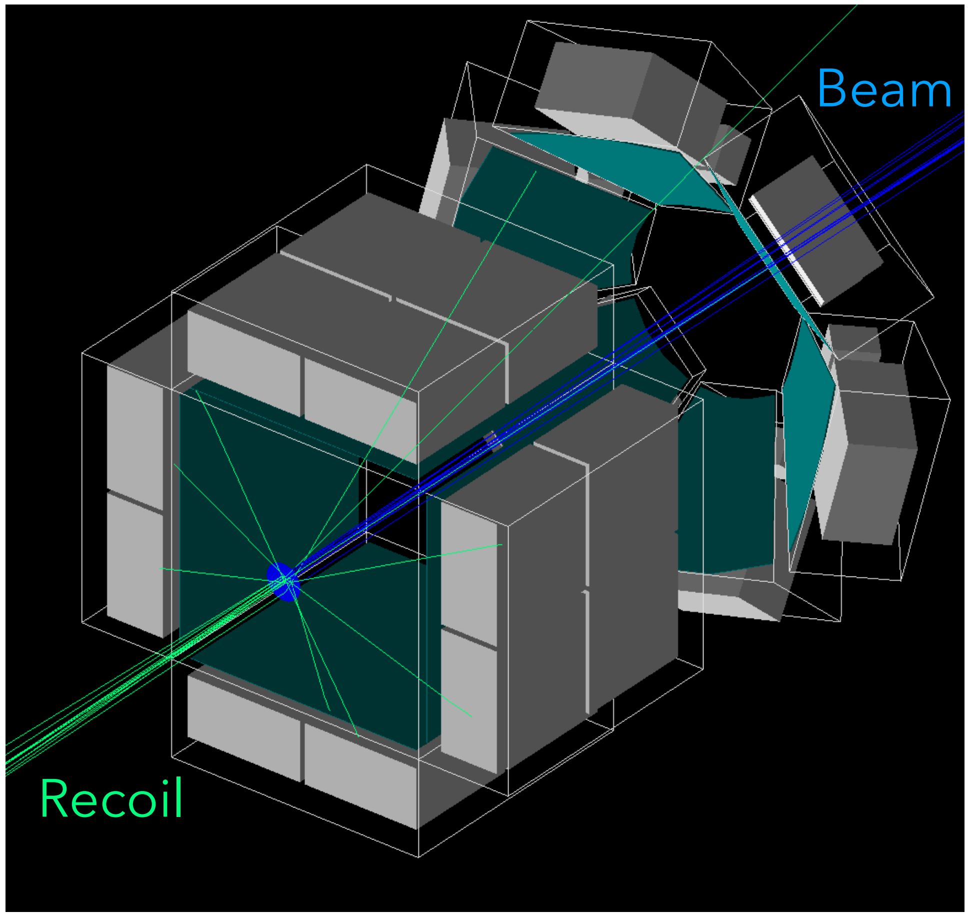
→ Silicon detectors array for missing mass spectroscopy ⇒ TiNA array

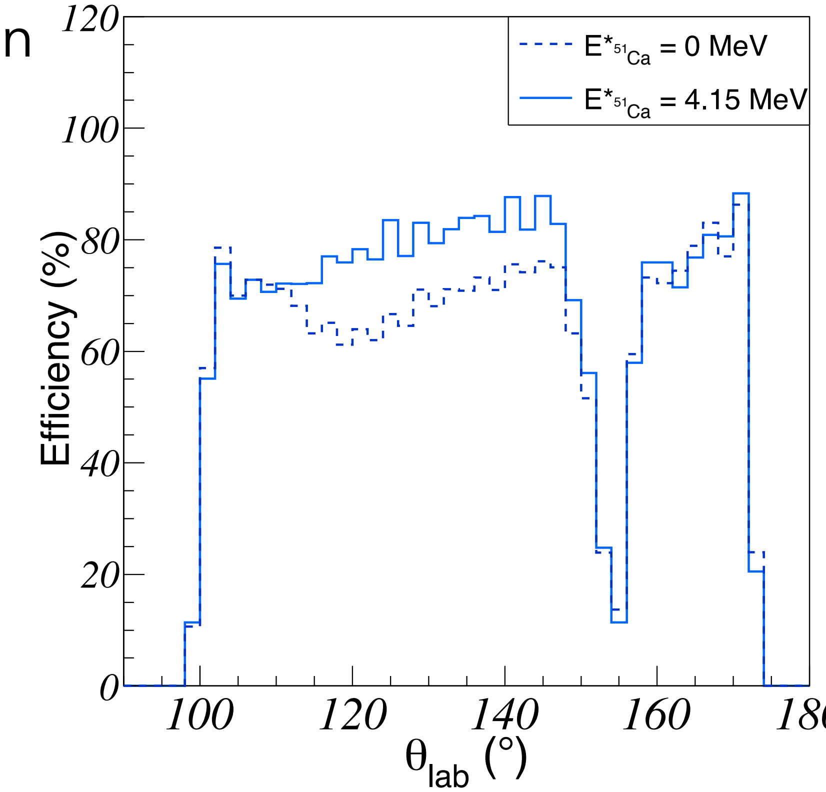
Simulations and expected angular coverage

Simulations with the *nptool* framework, based on Root and Geant4.

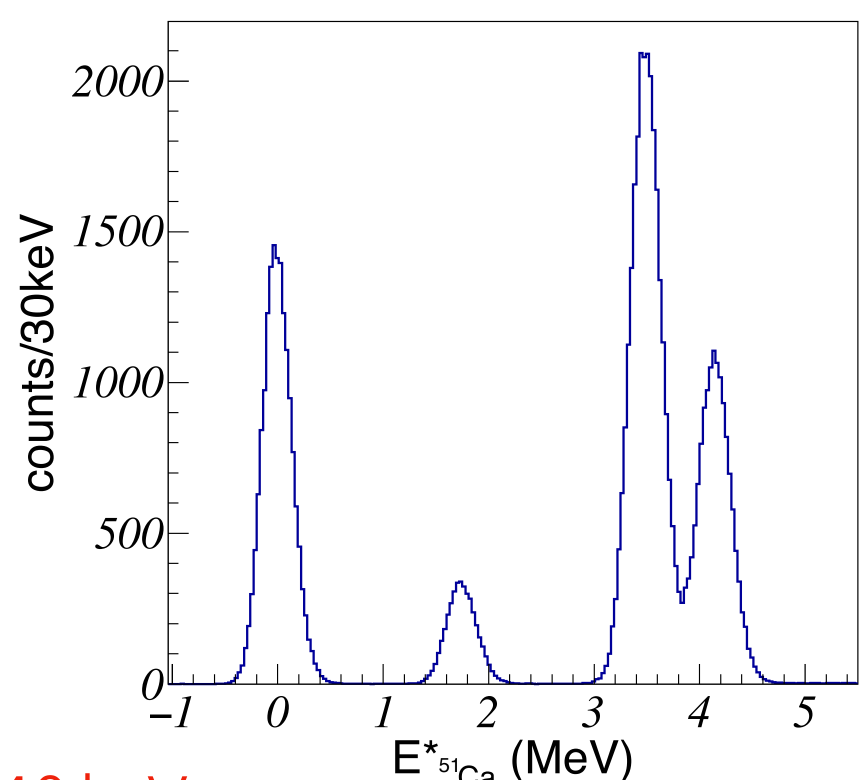
***nptool*: A. Matta *et al.*, J. Phys. G: Nucl. Part. Phys. 43 (2016) 045113**

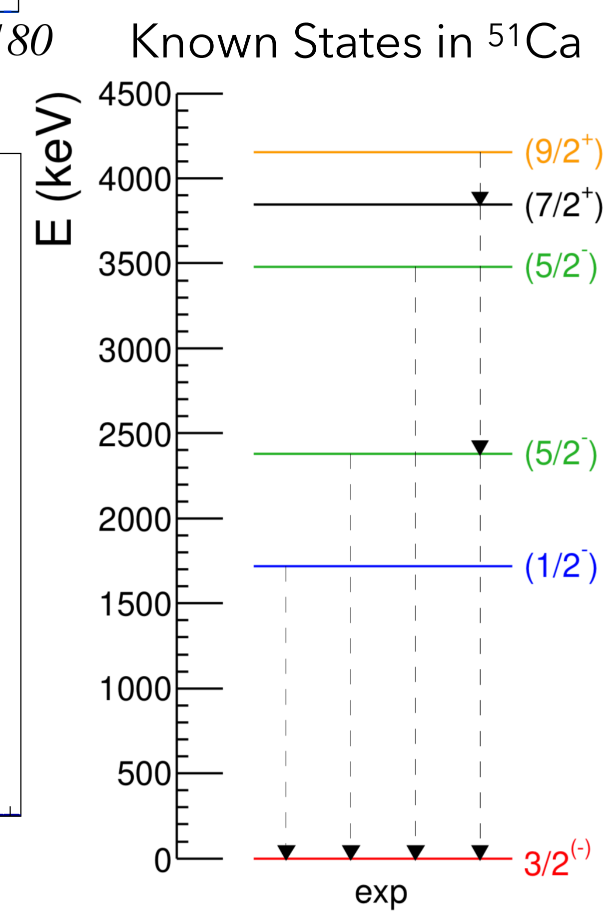
Example of $^{2}H(^{50}Ca,^{1}H)^{51}Ca$ @ 15 MeV/nucleon





Angular coverage: 100°–170°





Simulation:

- 5 μm target
- σ_{TTT} = 45 keV
- Spectroscopic factors taken from GPXF1Br calculations
- Statistics for 6 days of experiment

→ Efficiency: 60%–90%, resolution: σ = 140 keV