



The experiment

Target Recoil Tracking detector for R3B at FAIR

The facility

TRT: what we are constructing in this project

Stefanos Paschalis

Nuclear Physics Community Meeting

8th January 2026

R3B at FAIR (GSI) in Germany



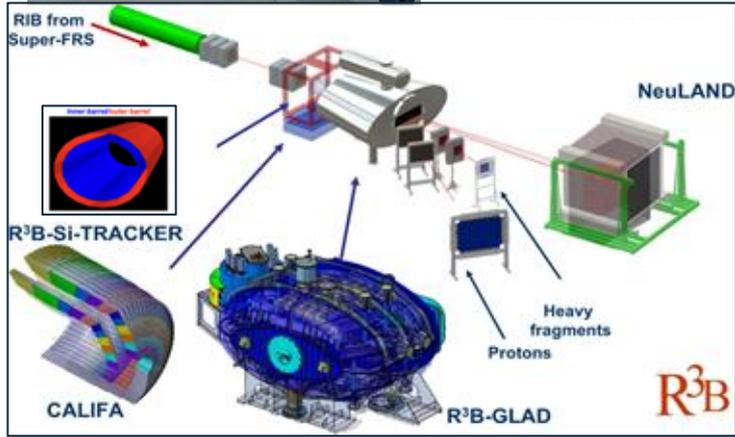
Current R3B location, Cave C

High-energy cave where R3B will be located

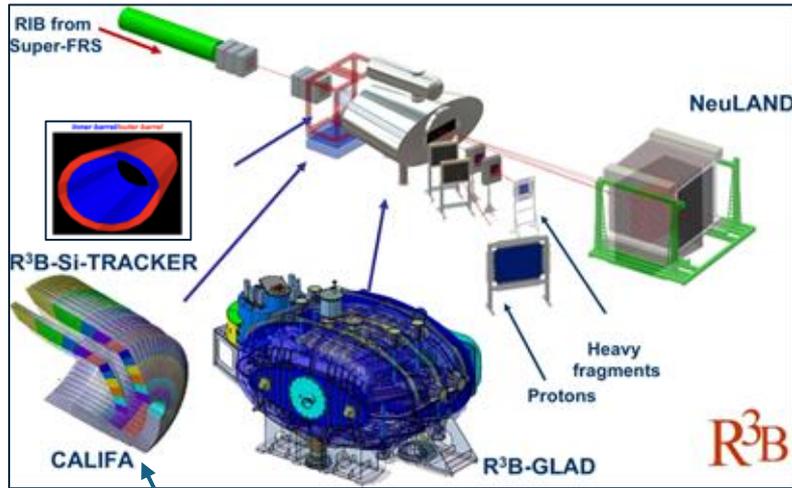
2.8 B€



Status Spring 2025
Expected completion by 2028



The R3B experimental programme

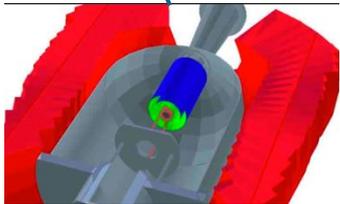


The R3B experiment serves a diverse scientific program:

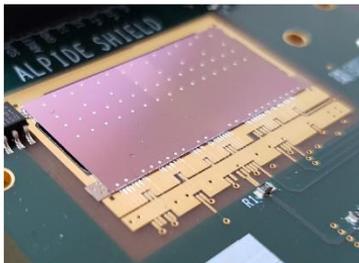
- spectroscopy of exotic nuclei at and beyond the drip lines
- equation-of-state of neutron-rich matter
- short-range correlations in exotic nuclei
- rates of astrophysically important reactions
- nuclear structure and dynamics, nuclear fission
- studies of hypernuclei

The R3B experimental setup is built around:

- a) the large acceptance, superconducting dipole magnet (GLAD),
- b) the new Large-Area Neutron Detector (NeuLAND),
- c) the gamma ray and light-charged particle spectrometer-calorimeter (CALIFA),
- d) the pixel-based **Target Recoil Tracker (TRT)** device,
- e) a suite of in-beam-tracking detectors before and after the GLAD magnet

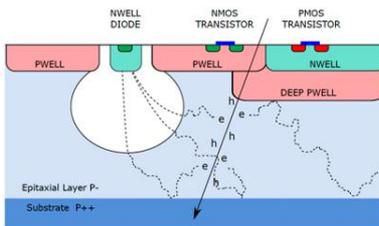


TRT device employs the ALPIDE sensor (by ALICE ITS2)



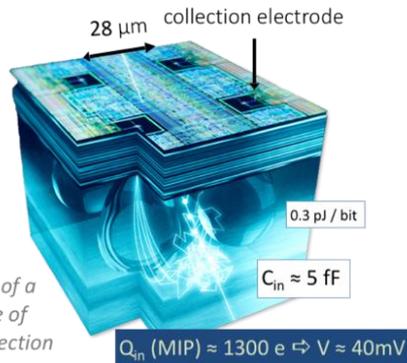
Pixel Sensor CMOS 180 nm Imaging Process (TowerJazz)

- In-pixel amplification
- In-pixel discrimination
- In-pixel (multi-) hit buffer



3 cm x 1.5 cm sensor
0.5M pixels

- 29 μm x 27 μm pixel pitch
- Continuously active front-end
- Global shutter
- Triggered or continuous readout modes



Artistic view of a SEM picture of ALPIDE cross section

G. Aglieri Rinella, NIM A845 (2017) 583

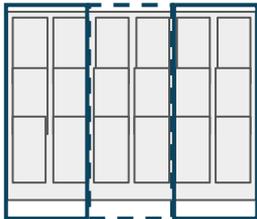
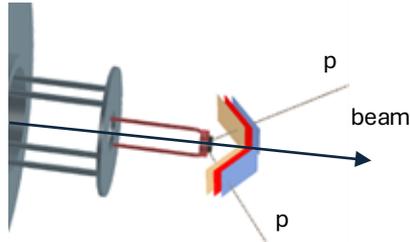
A. Di Mauro, NIM A936 (2019) 625

F.Reidt, NIM A 1032 (2022) 166632

Evolution of the TRT device

Stage 1

Two-arm configuration

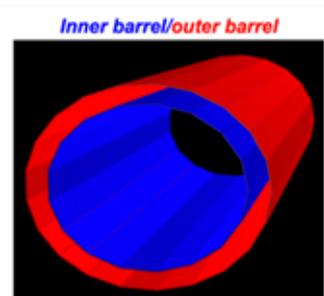


9x9 cm² 18-sensor

Overlap with **AMBER**
collaboration

Stage 2

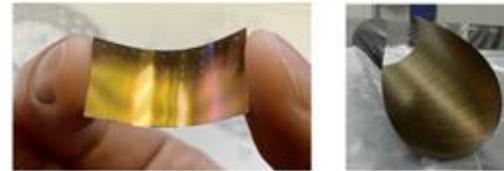
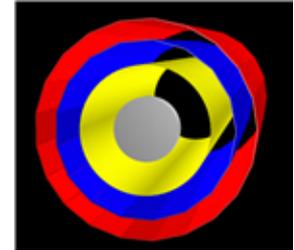
Full Barrel



9 x 3 cm = 27 cm

Far-future Stage

A layer of fully-flexible
Si wafer fitted inside
Stage 2 geometry

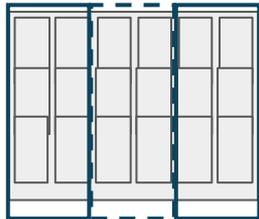
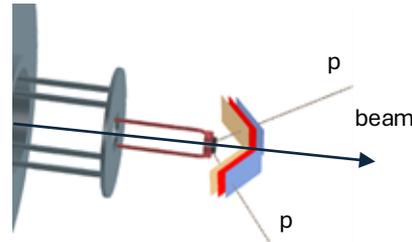


current R&D by ALICE
synergies (ALICE3 + EIC)

Evolution of the TRT device

Stage 1

Two-arm configuration

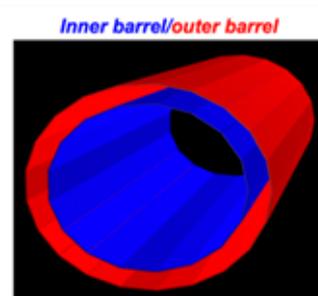


9x9 cm² 18-sensor

Overlap with **AMBER**
collaboration

Stage 2

Full Barrel

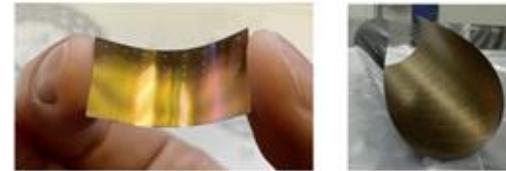
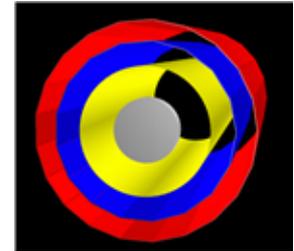


9 x 3 cm = 27 cm

R3B TRT UK project

Far-future Stage

A layer of fully-flexible
Si wafer fitted inside
Stage 2 geometry

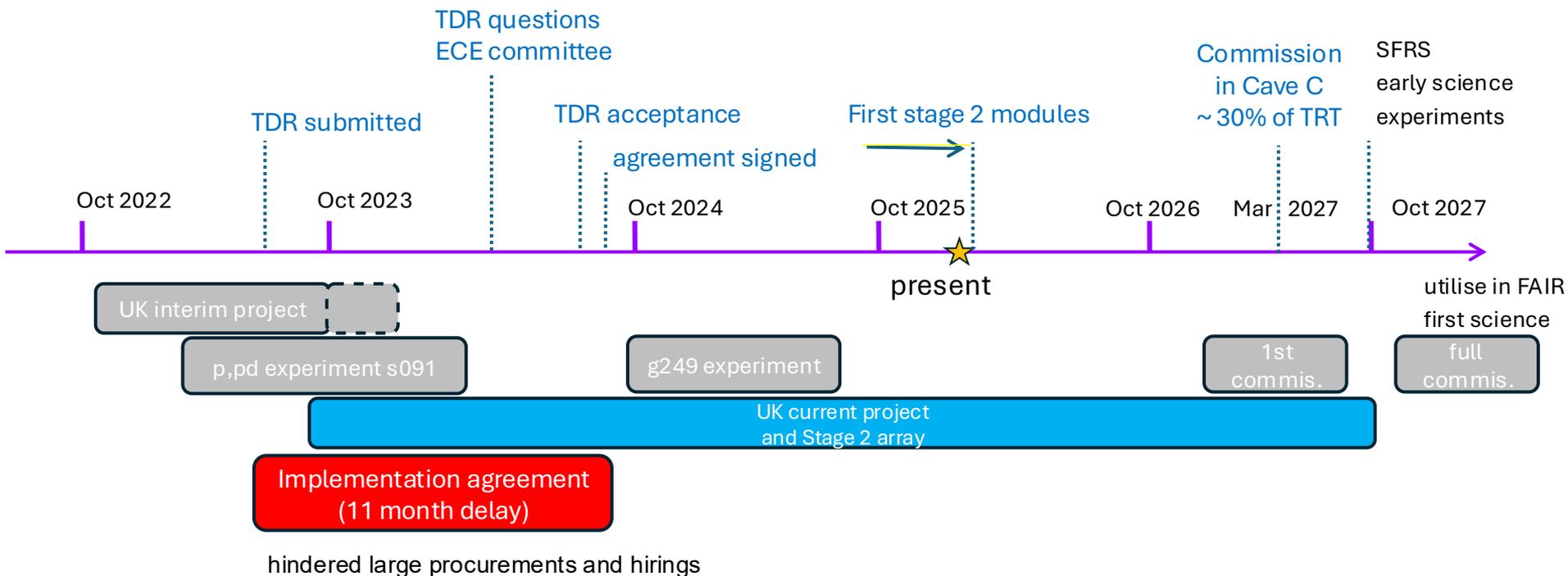


current R&D by ALICE
synergies (ALICE3 + EIC)

Deliveries of UK Stage 2 project by September 2027

- 60 HIC modules, vacuum compatible with their corresponding
 - power supplies
 - cabling and feedthroughs
 - cooling
- readout electronics hardware
- design of complete array, including thermal and stress analysis
- analysis and simulation software implementation in R3BROOT

TRT Stages and Timelines



The UK team

York

Paschalis

Petri

Hide - Chief Elect. Technician

Wilkinson - Mech. Workshop

Beatriz Amorim - PhD student

Luke Rose – PDRA started

Lukas Ponnath – PDRA - 01/26

Alejandro Giraldo – PhD - 02/26

- Project management
- Module Assembly
- Module Characterisation
- Software development
- Electronics and e-DAQ

Daresbury

Labiche

Borri

Buckland – Applied physicist

Hill - Electronic Engineer

Godfrey – Apprentice Technician

Smith - Mech. and design eng. (CC)

Sutowski - Electr. Tech 1

Unsworth - Software engineer (CC)

Helsby – FPGA engineer

- Project management
- Module Assembly
- Module Characterisation
- Software development
- Electronics and e-DAQ

Liverpool (CC):

Dave Seddon - Design engineer

RAL

Wirebonding:

Lipp - Electronic Engineer

Schneider - Technician

Booker - Technician

Metrology:

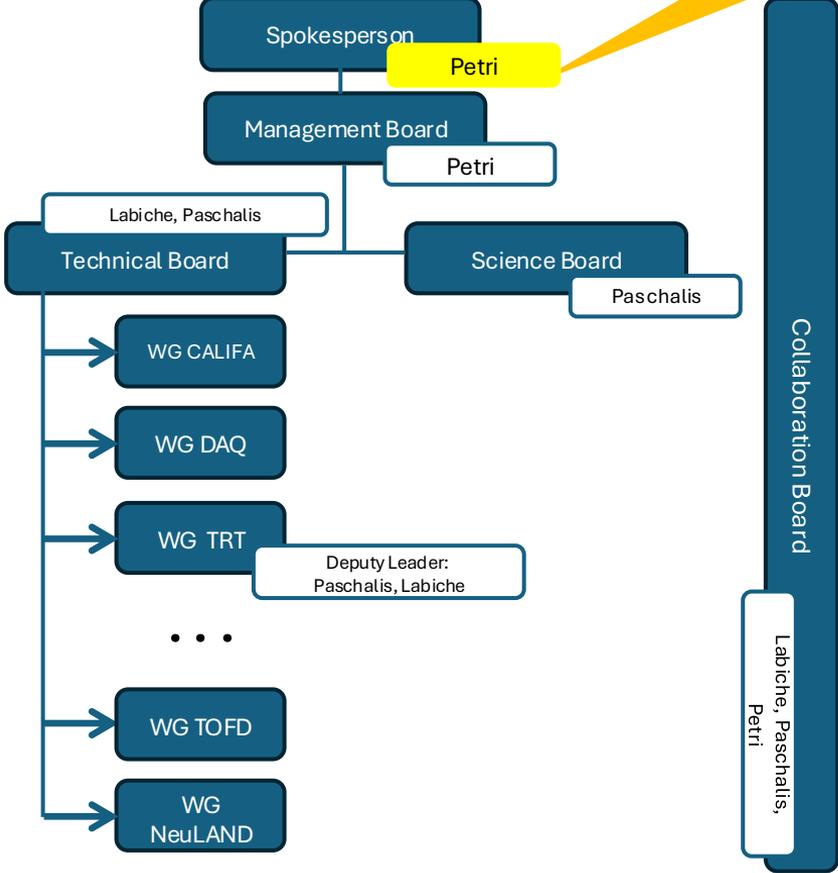
Wilsher

Allum

- Wire bonding of assembled modules + metrology (service)

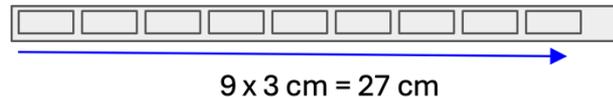
R3B Governance and UK Leadership

Marina Petri recently elected R3B spokesperson





Daresbury assembly facilities

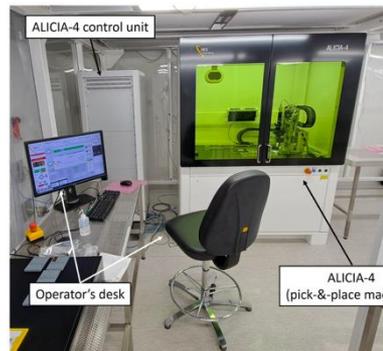
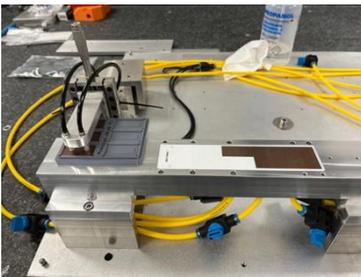
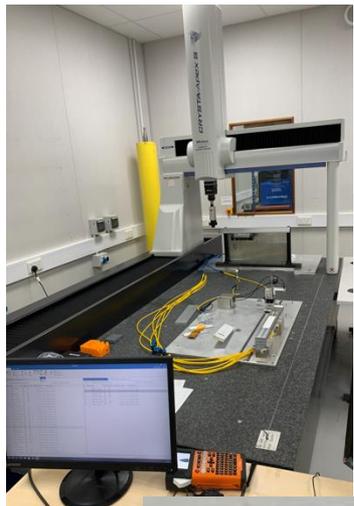


Stage 1: CMM-assisted placement

Paul Morrall

Stage 2: ALICIA, robotic placement

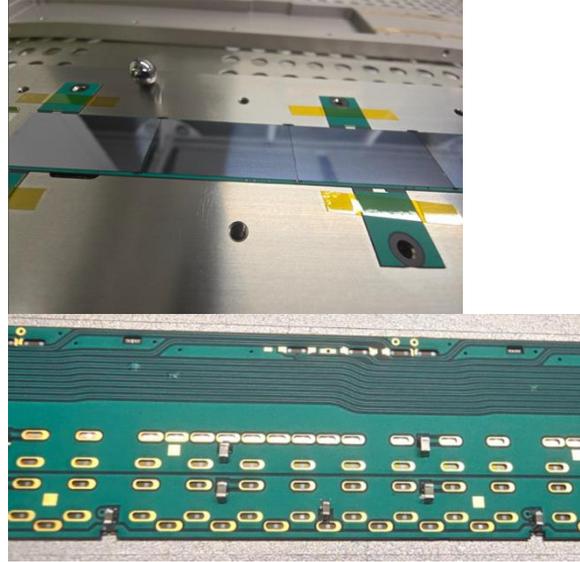
Detector Systems Group



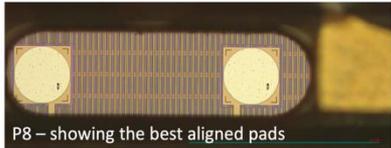
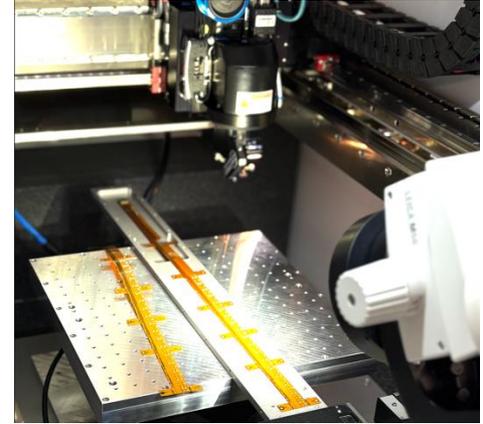
Wirebonding at GSI

Wirebonding at RAL

Module Assembly @DL



Wirebonding @RAL



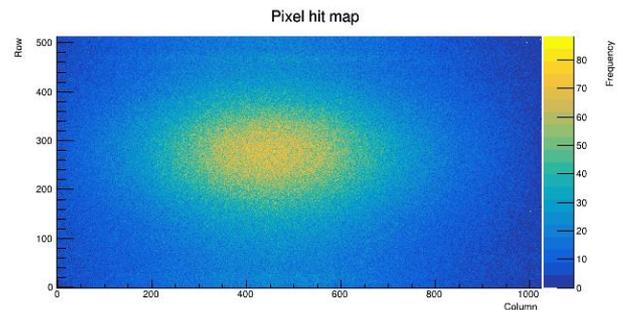
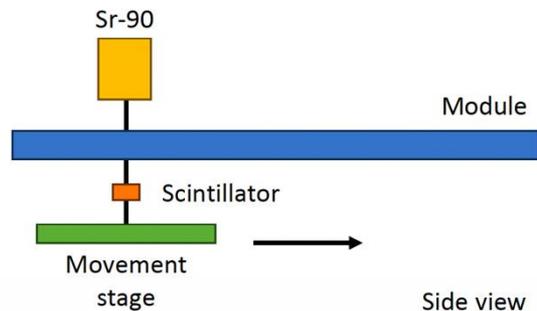
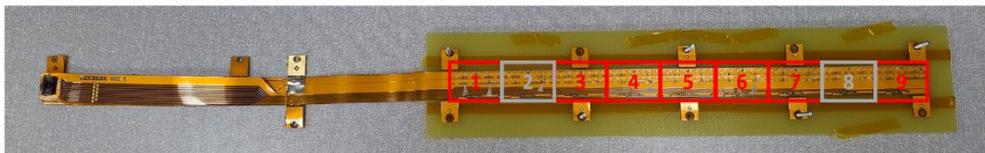
P8 – showing the best aligned pads



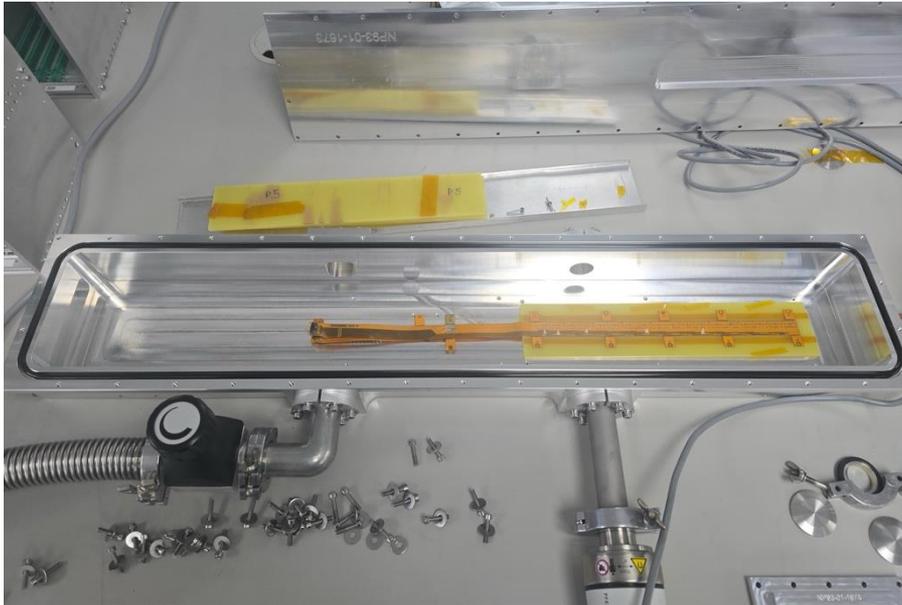
P7 – showing the best aligned pads

300um

Module characterisation with electron source



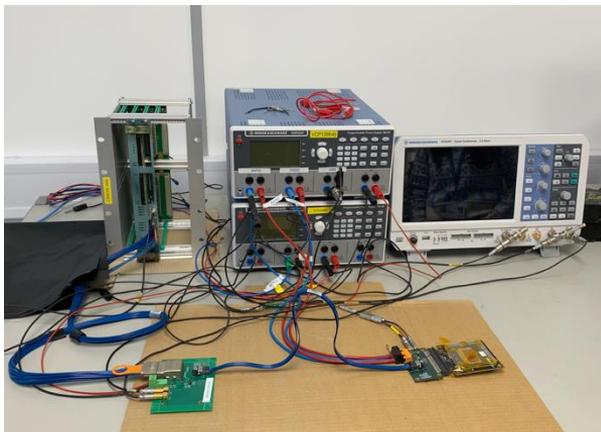
Vacuum testing



Electronics and DAQ

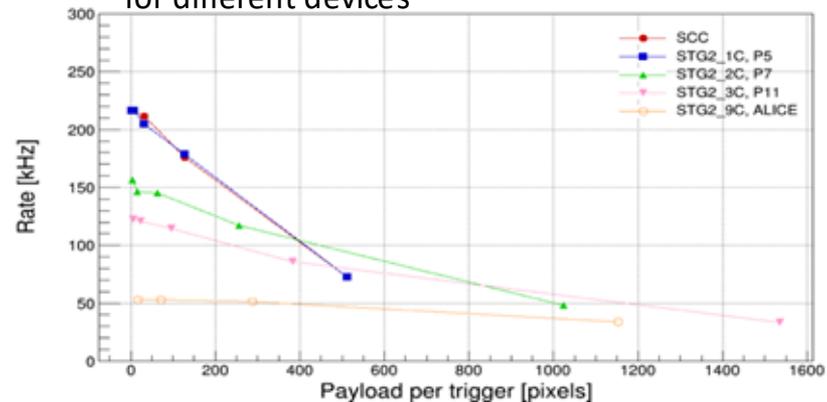
FPGA code in MOSAIC readout board has been configured to be:

- ✓ Fully compatible with R3B DAQ requirements
- ✓ Readout rate exceeding 50kHz with a 9-sensor module, meeting requirements

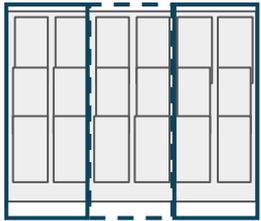


Luke Rose (York PDRA)
William Helsby (FPGA engineer)
Beatriz Amorim (York PhD student)

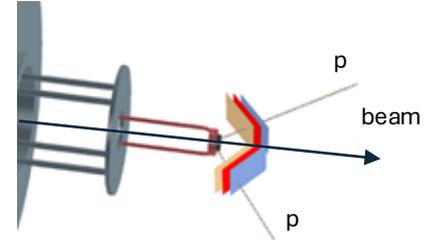
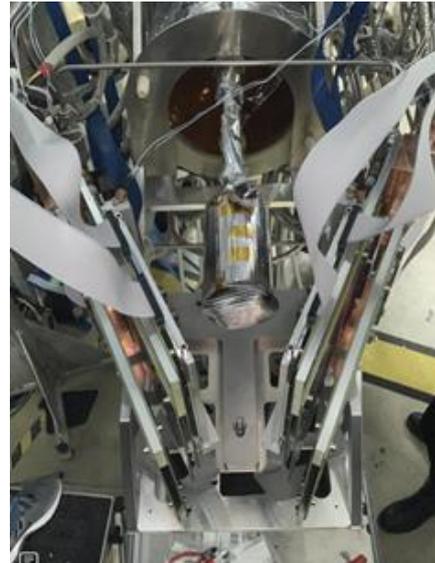
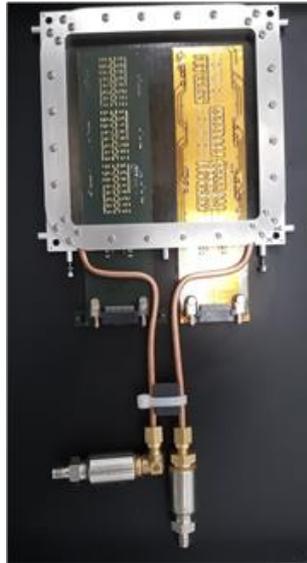
Maximum rate tests for varying constant payload
for different devices



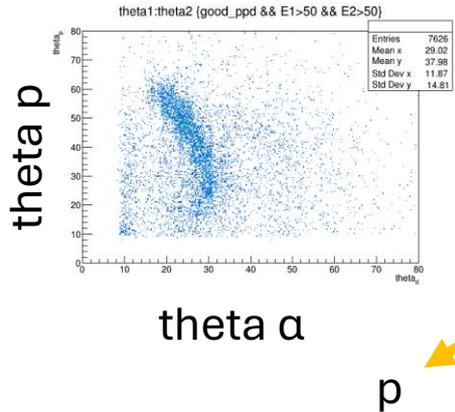
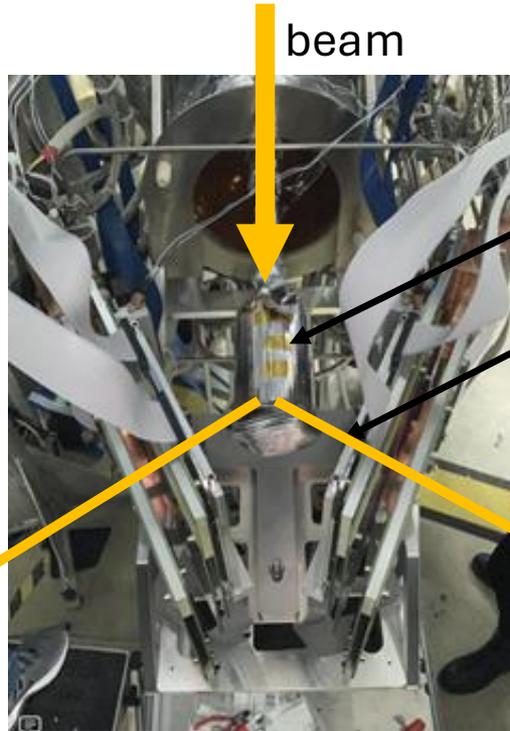
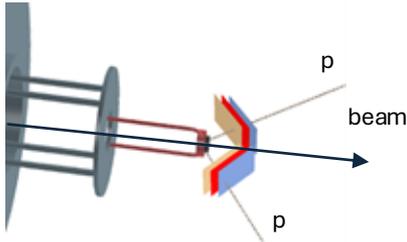
In-beam physics experiments with Stage 1 modules



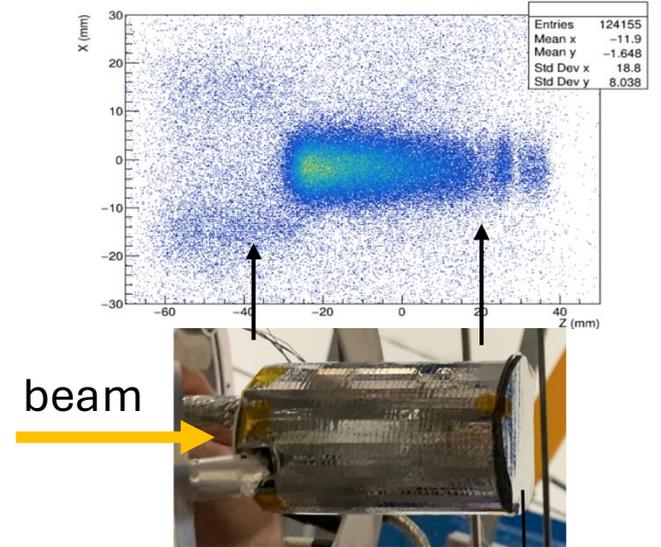
9x9 cm² 18-sensor



S091 (p,pd) experiment at R3B – Feb 2024 (Petri & Paschalis)



ALPIDE-CALIFA vertex reconstruction

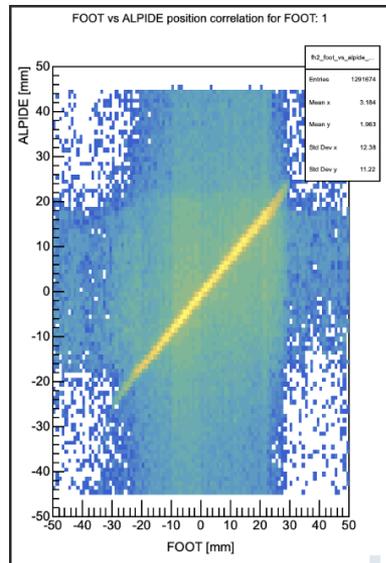
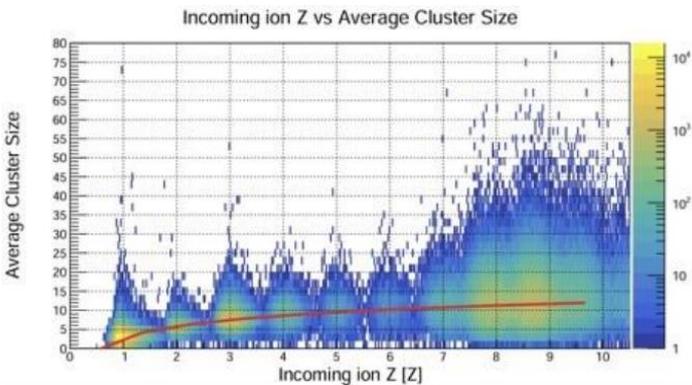


Matt Whitehead (York PhD)
Beatriz Amorim (York PhD)

Two in beam experiments with ALPIDEs at GSI in May and June 2025

In beam experiments in June 2025 employed Stage 1 **ALPIDE** modules and **MOSAIC** readout and demonstrated successfully:

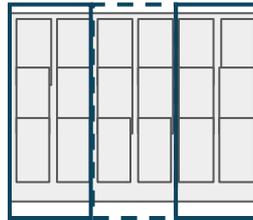
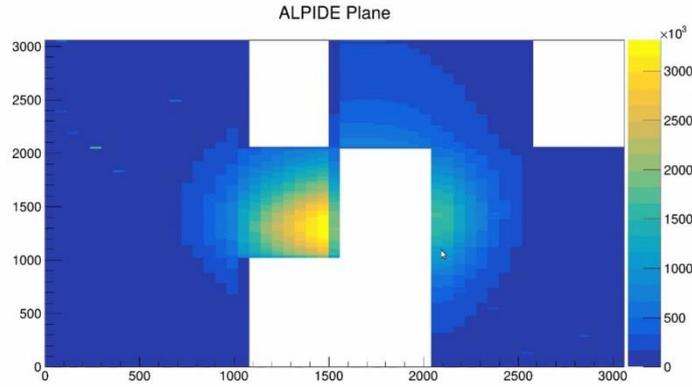
- physics correlations with other detectors using integrated in R3BDAQ



Luke Rose (PDRA)
Beatriz Amorim (York PhD student)
Matt Whitehead (York PhD student)

AMBER collab. test beam at CERN

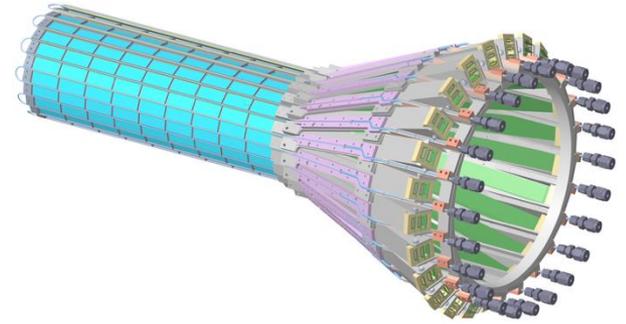
November 2025



9x9 cm² 18-sensor



Summary



- Very good overall progress on all fronts
- All required components and high-precision jigs are now available
- Assembly process is under control, wirebonding optimisation is ongoing
- Some strong knock-on effects in the timeline due delays in signing agreements
- Successful in-beam physics experiments with Stage 1 modules demonstrates already suitability of the ALPIDE sensors for our physics programme
- Strong synergies with AMBER collaboration at CERN established

Backup slides

Summary of prototypes

Prototype ID	Readiness	FPC	issue	comment
P 5	mid	Cu, Rush 1st batch		
P 6	mid	Cu, Rush 1st batch		
P 7	mid	Cu, Rush 1st batch		
P 8	mid	Cu, Rush 1st batch		
P 9	mid	Cu, Rush 1st batch		
P 10	mid	Cu, Rush 1st batch		
P 11	mid	Cu, Rush 1st batch		
P 12	mid	Cu, Rush 1st batch	new FPC gripper glue spillage	Initially aimed as high readiness
P 13	mid	Cu, Rush 1st batch	glue spillage	Initially aimed as high readiness
P 14	mid	Cu, Rush 2nd batch	FPC dimensional issue	glue spillage is again under control
P15	high	ALICE AI FPC	no issues during assembly	used gsi mask, alignment very good
P16	high	ALICE AI FPC	no issues during assembly	used gsi mask, alignment very good

FAIR-project evaluation:

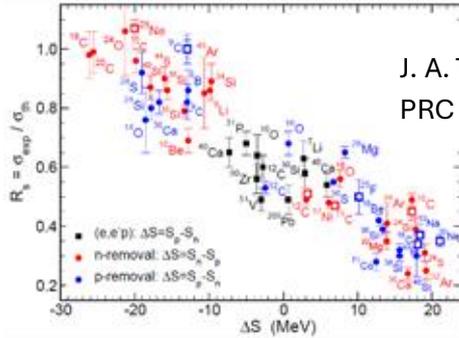
Highest priority is the High-Energy Branch (SFERS → R3B)

“The committee came unanimously to the following recommendations in order to advance FAIR to science beyond Phase-0:

- *First priority should be the completion of the S-FRS into the HEB cave for NUSTAR to carry out the Early Science program.”*

Quenching of single-particle strength

nucleon-removal reactions suggested
strong correlation with isospin



J. A. Tostevin and A. Gade
PRC 103 (2021) 054610

Contents lists available at [ScienceDirect](#)

Progress in Particle and Nuclear Physics

journal homepage: www.elsevier.com/locate/ppnp

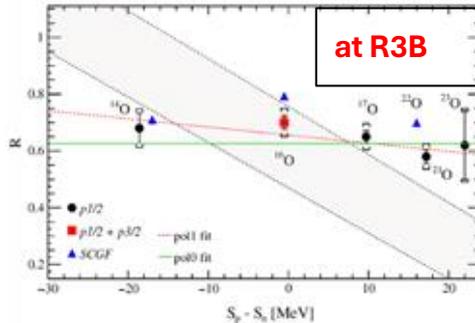
Review

Quenching of single-particle strength from direct reactions with stable and rare-isotope beams

T. Aumann^{AB}, C. Barbieri^{CD,E}, D. Bazin^{CE}, C.A. Bertulani^B, A. Bonaccorso^I, W.H. Dickhoff^J, A. Gade^{CE}, M. Gómez-Ramos^{AK}, B.P. Kay^I, A.M. Moro^{K,M}, T. Nakamura^N, A. Obertelli^{AK}, K. Ogata^{OP}, S. Paschalis^Q, T. Uesaka^T

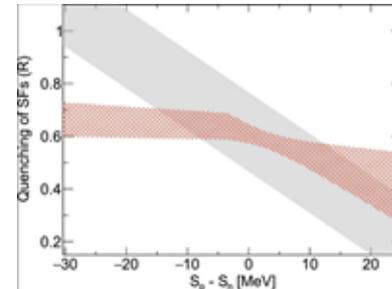
PPNP118 (2021) 103847

Quasifree (p,2p) Reactions



L. Atar, S. Paschalis et al.,
PRL 120 (2018) 052501

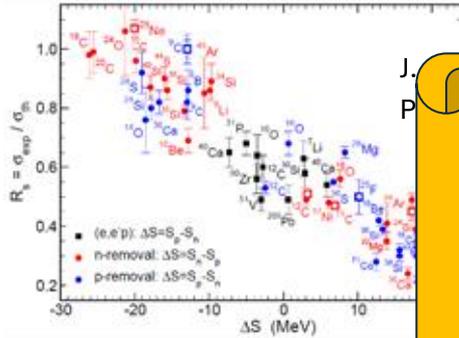
Connection with short-range correlations and (e,e'p)



S Paschalis, M Petri et al.,
PLB 800 (2020) 135110

Quenching of single-particle strength

nucleon-removal reactions suggested
strong correlation with isospin



J. P.

Complete target-recoil tracking and calorimetry is required to measure the full strength, including unbound states

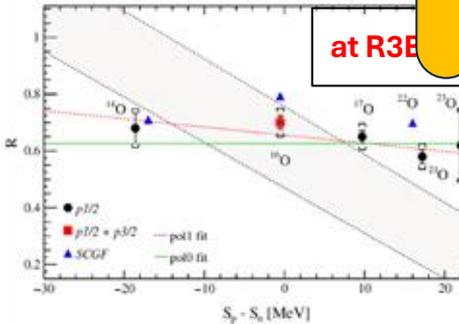


Direct reactions
A. Bonaccorso¹,
A.M. Moro^{1,2},
T. Uesaka¹

21) 103847

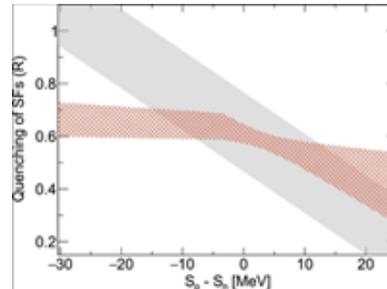
range correlations and (e,e'p)

Quasifree (p,2p) Reactions



at R3E

L. Atar, S. Paschalis et al.,
PRL 120 (2018) 052501

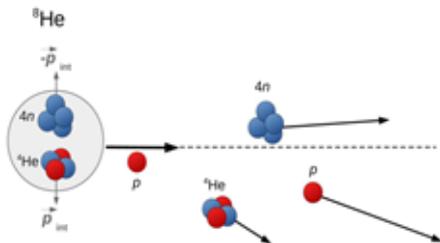


S Paschalis, M Petri et al.,
PLB 800 (2020) 135110

Quasi-free scattering reactions as a tool to access very exotic systems - the tetraneutron case

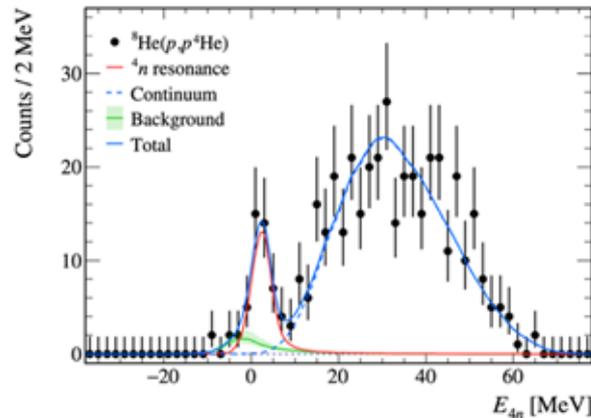
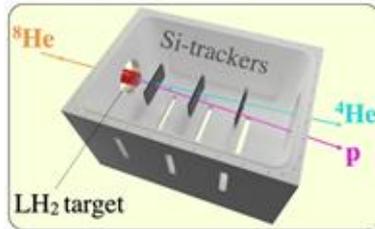


four-neutron system



A 60 year long quest

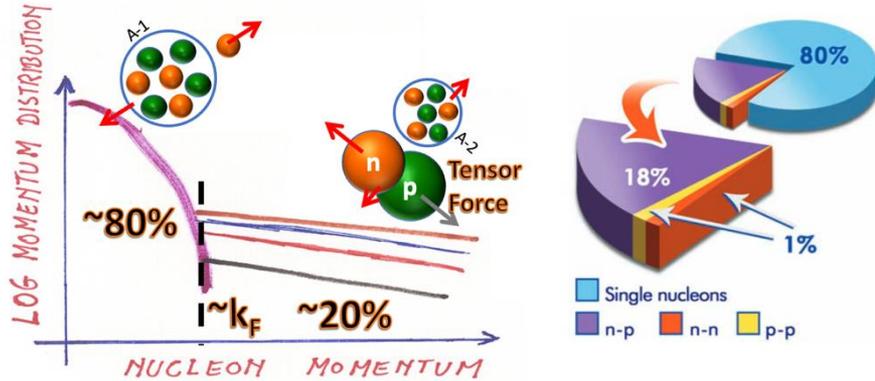
Precise
reaction-vertex reconstruction



“Observation of a correlated free four-neutron system”
Duer,..., Paschalis, *et al.* Nature **606**, 678–682 (2022)

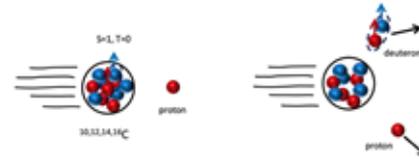
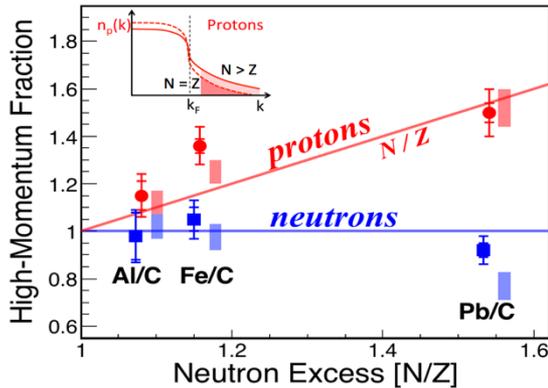
A near-threshold resonance-like structure:
 $E_r = 2.37 \pm 0.38(\text{stat.}) \pm 0.44(\text{sys.}) \text{ MeV}$
 $\Gamma = 1.75 \pm 0.22(\text{stat.}) \pm 0.30(\text{sys.}) \text{ MeV}$

Deuteron quasi-free scattering reactions: a tool to probe NN short-range correlations in atomic nuclei

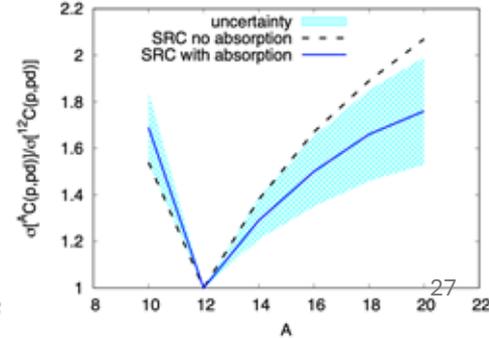
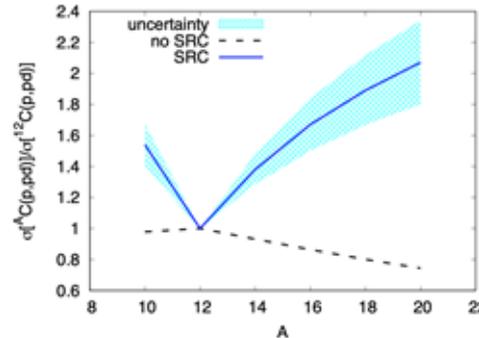


R3B Exp. G-22-00091 – Feb 2024
(Petri & Paschalis)

Manifestation of tensor part of the NN interaction which favours the $S=1, T=0$ → quasi-deuteron channel

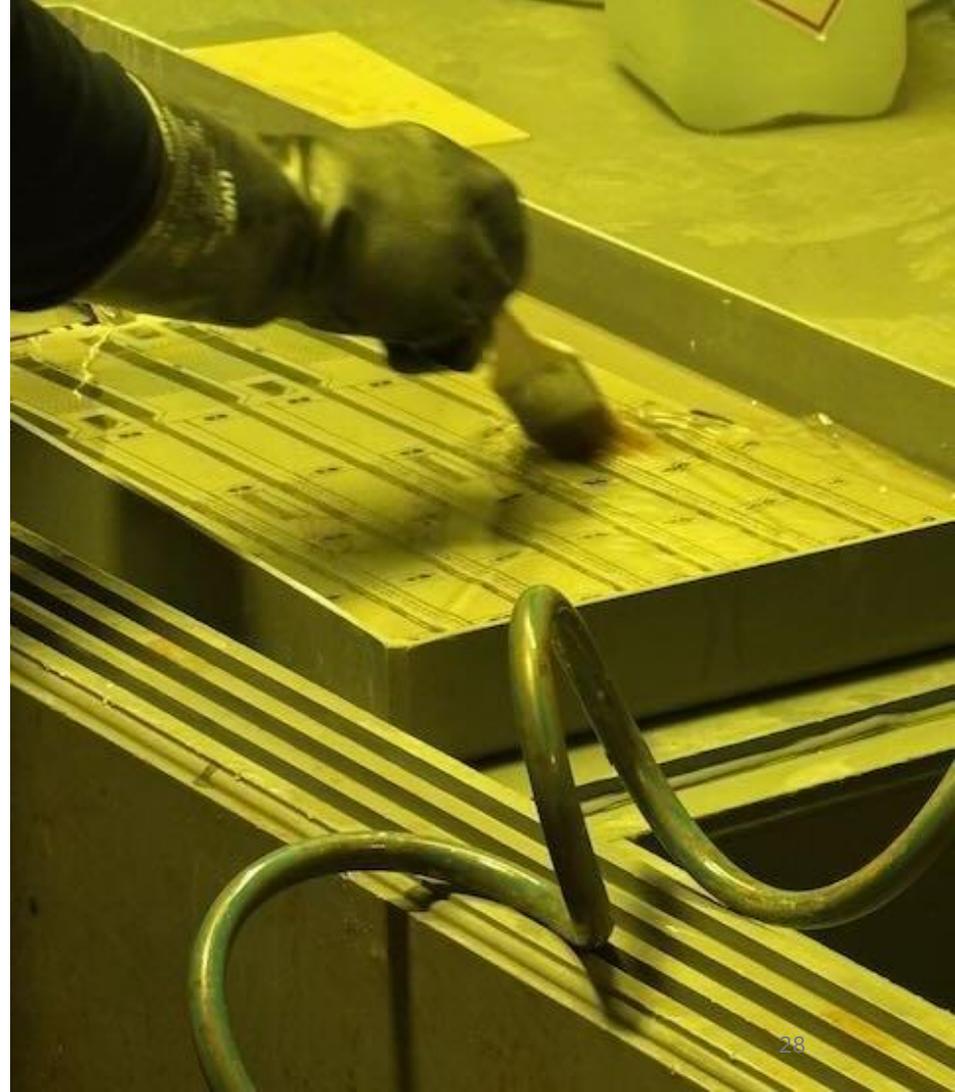
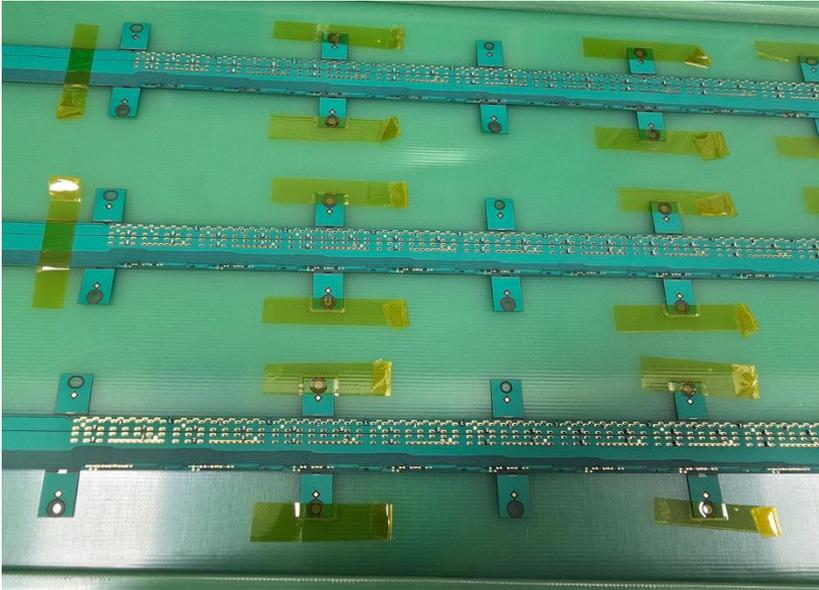


By measuring the (p, pd) cross section at **large momentum transfer**, along an isotopic chain, we are sensitive to SRC part of the wavefunction and to the suggested isospin dependence of SRC.



Al FPCs

Aluminium Flexible Printed Circuits from CERN
to minimize the material budget, just delivered!



WP1

All final jigs produced and commissioned!

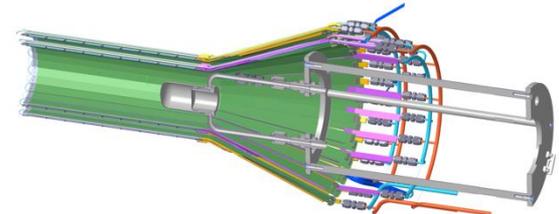
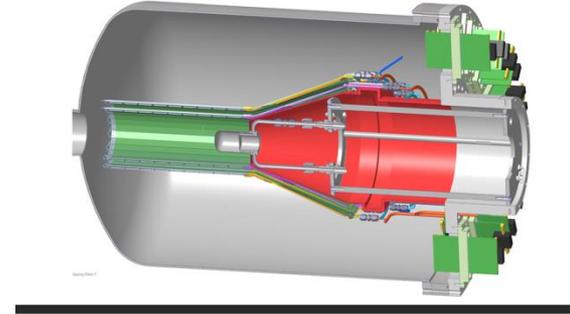
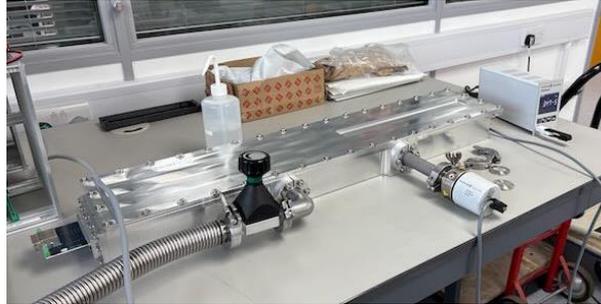
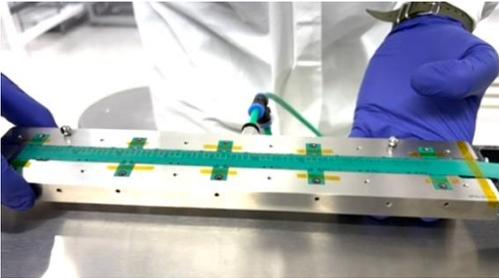
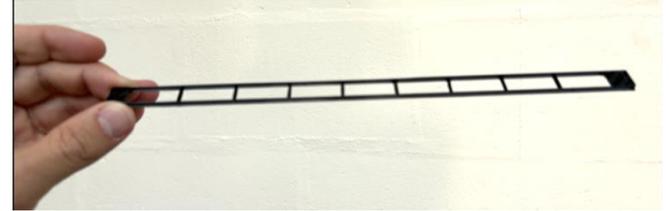
conceptual design and thermal stress analysis
Tasks 1.3 & 1.4

Precision jigs – Task 1.1a

- ✓ FPC gripper
- ✓ glue mask vacuum jig
- ✓ HIC transport plate
- ✓ Wire-bonding vacuum jig
- ✓ glue peeler
- ✓ HIC module gripper

New task: testing vacuum chamber completed!

- ✓ vacuum chamber for testing – Task 1.1b



Since the **July 2025** OsC meeting:

- Completed production of vacuum chamber
- Remaining last jig was received and metrology tested (FPC gripper)
- Produced **eleven** HIC transport plates at UoYork Machine shop (proven scalability)
- Prototype ladder, initiated discussions for production and engaged the WG (Spain/GSI)