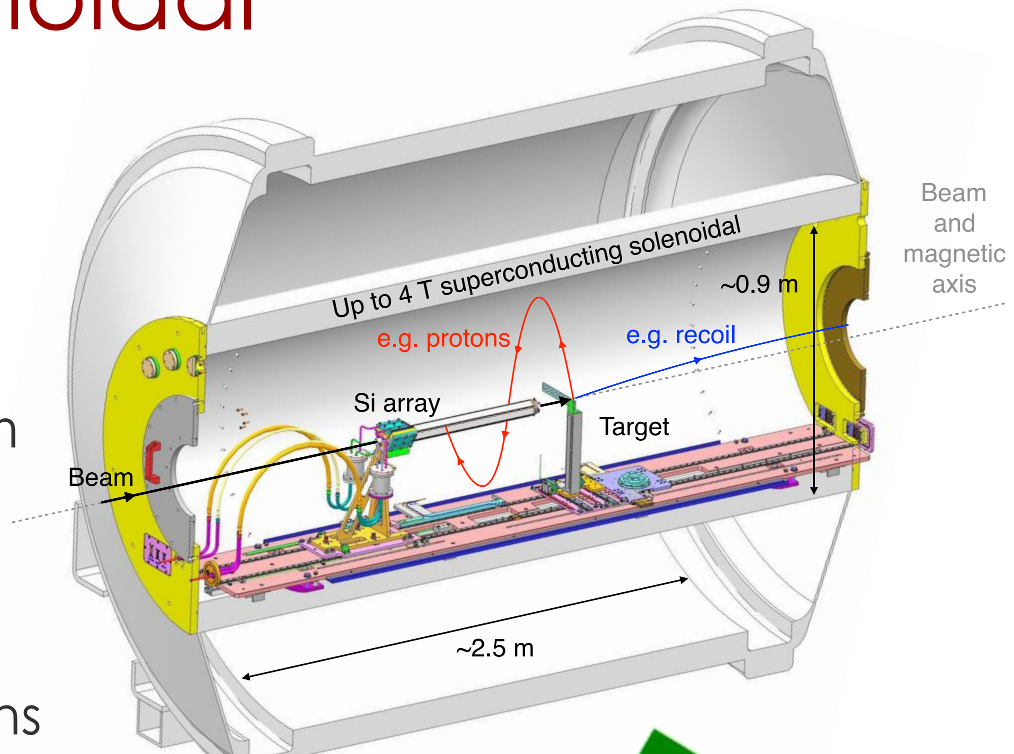
07/02/17

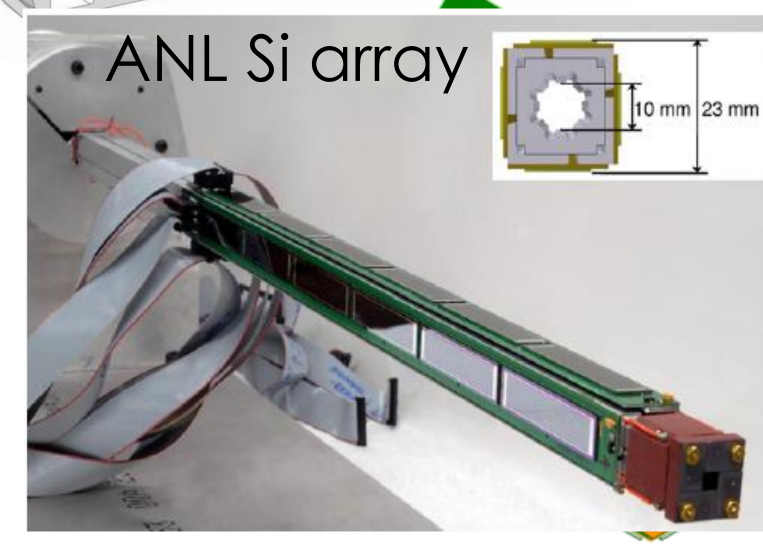
ISS – The ISOLDE Solenoidal Spectrometer

Liam Gaffney (ISOLDE-CERN)
on behalf of the ISS Collaboration

ISS – ISOLDE Solenoidal Spectrometer

- 4T superconducting solenoid.
- Obtained as MRI magnet from Brisbane.
  - Arrived @ CERN in April 2016.
- Dedicated to transfer reactions with HIE-ISOLDE.
- New Si array designed and under construction (ready after LS2).
  - First experiments with ANL array.
- SpecMAT will also use magnet.

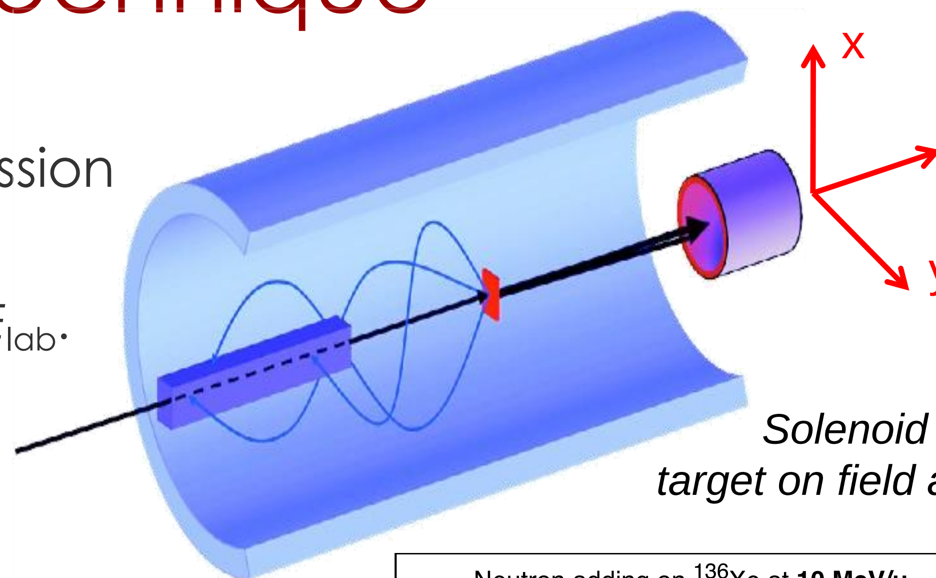




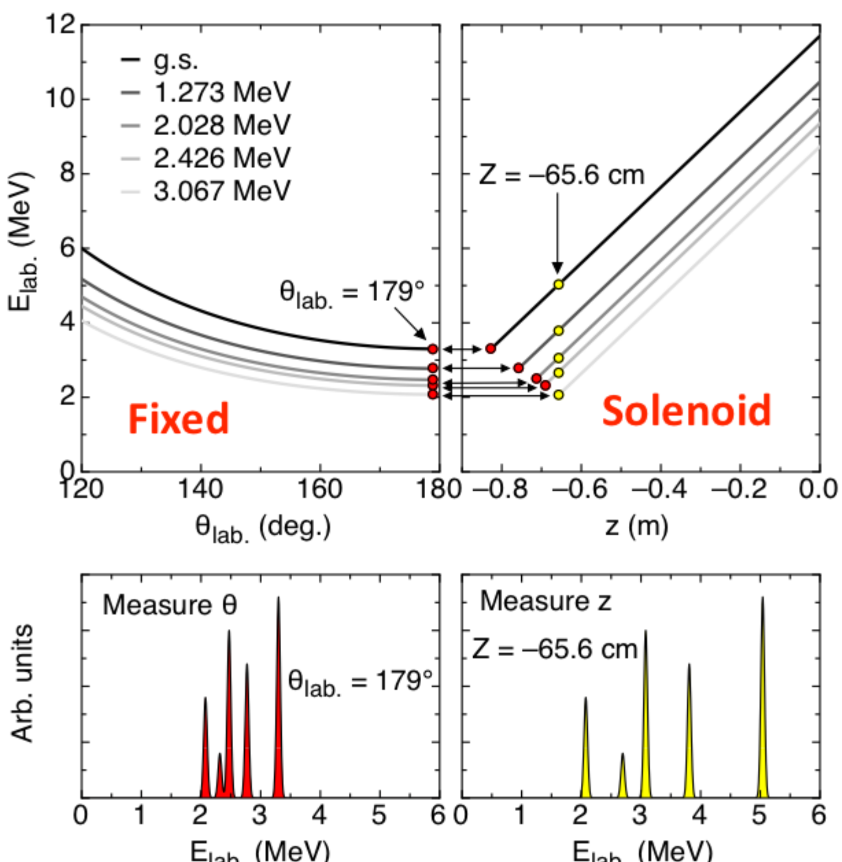
Principle of the technique

- Suffers no kinematic compression of Q-value spectrum.
  - Linear relationship of E_{com} vs. E_{lab}.

Heavy ejectile detected in recoil detector.



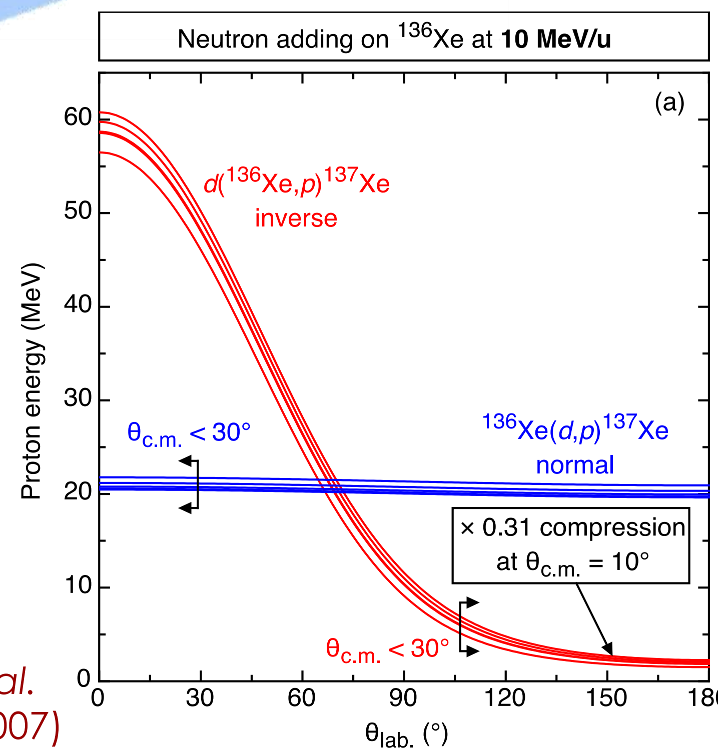
Solenoid with target on field axis.



Heavy RIBs necessitates inverse kinematics.

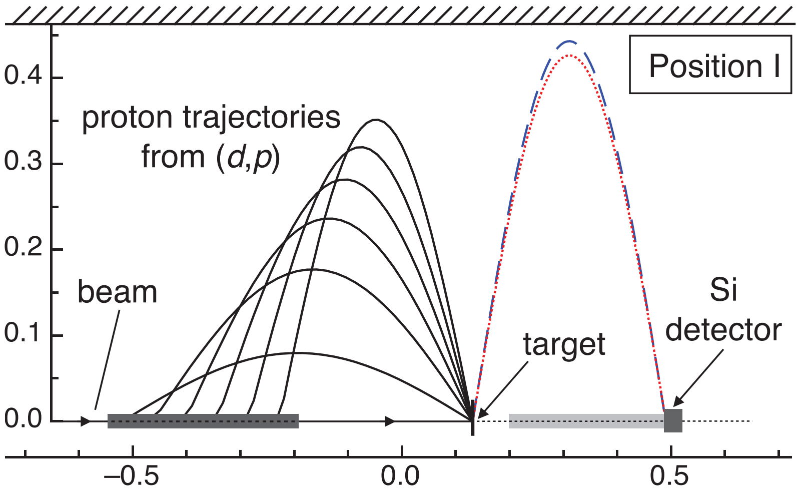
Difficult to resolve states in energy.

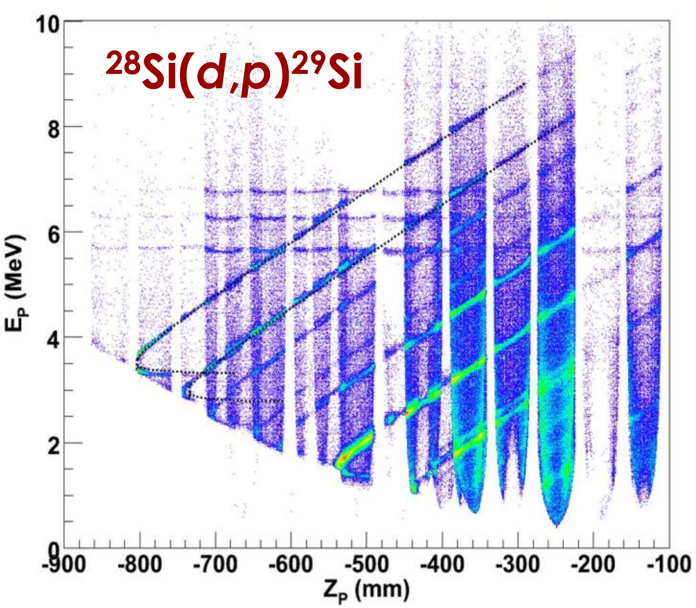
A. Wuosmaa *et al.* NIMA **580**,1290 (2007)

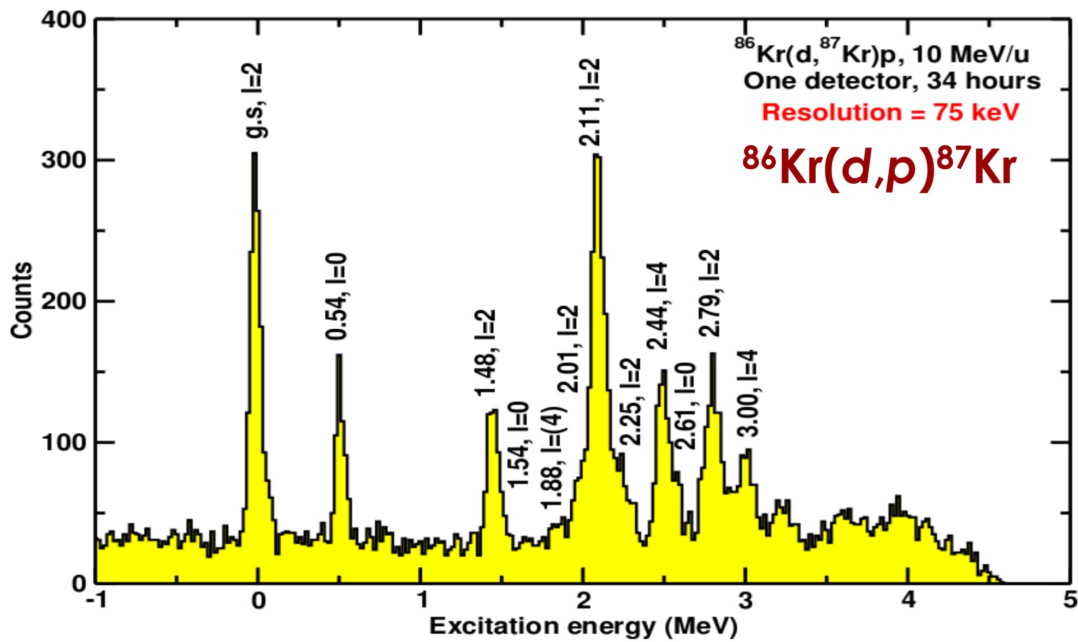


Example of HELIOS@ANL

- Demonstrated in multiple experiments with 12 < *A* < 136.
- Resolution of 75 keV achieved.
  - In-flight beams ~100 keV.
- Array to be used with ISS@ISOLDE.







J. C. Lighthall *et al.* NIMA **622** (2010) 97

D.K. Sharp *et al*, Phys.Rev.C **87** 014312 (2013)

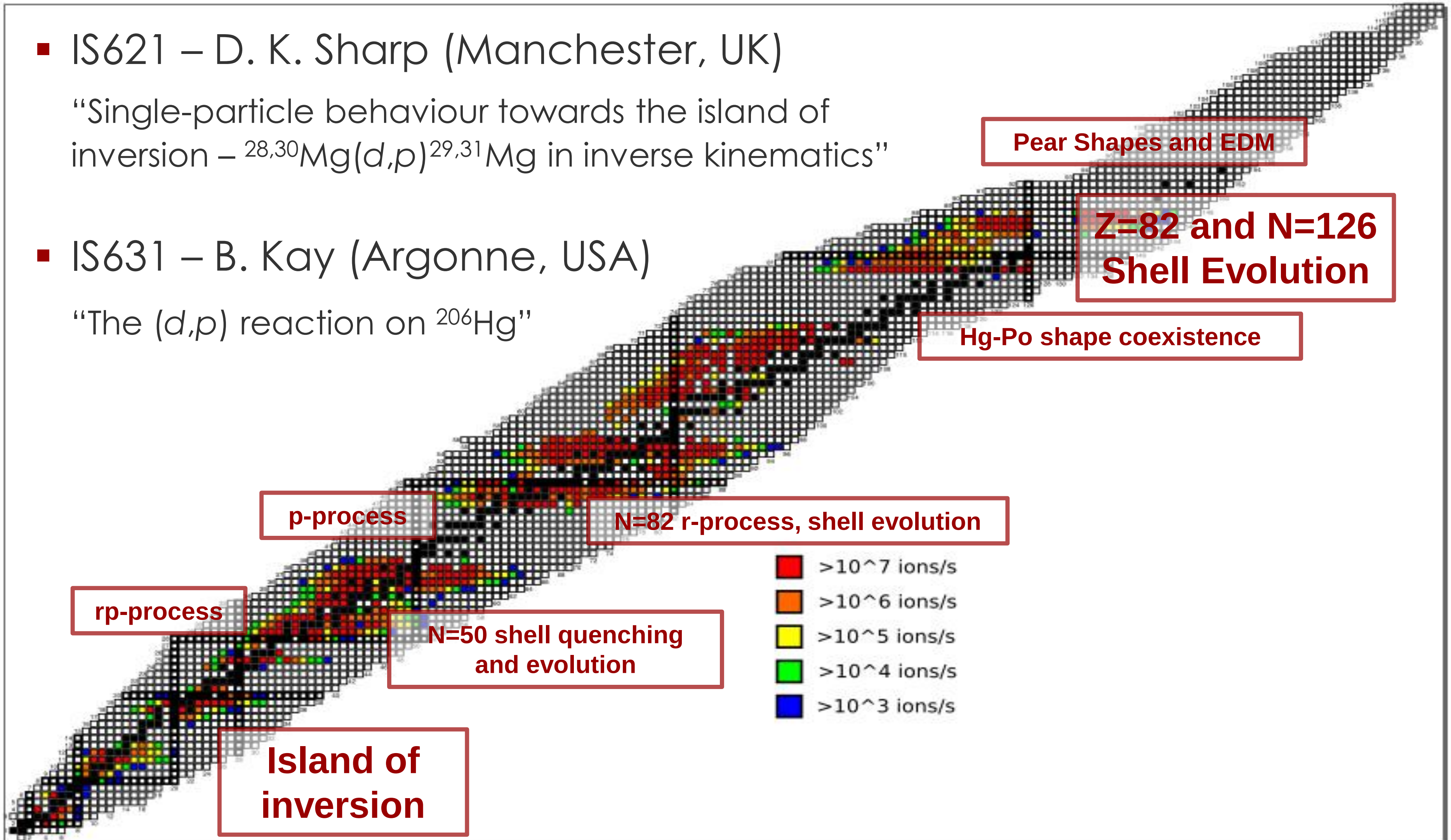
Physics with ISS @ ISOLDE

- IS621 – D. K. Sharp (Manchester, UK)

  "Single-particle behaviour towards the island of inversion – ^{28,30}Mg(*d*,*p*)^{29,31}Mg in inverse kinematics"

- IS631 – B. Kay (Argonne, USA)

  "The (*d*,*p*) reaction on ^{206}Hg"



Timeline of events

2017 →

Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb	Mar.
Delivery						Design and construction of Si array -->					
		Safety files									
						Vacuum tests					
									LN_2		
										He	
										Energize	
										Move to ISOLDE	

← 2016 →

- First experiments in 2018, before LS2.

- Delivery of stable beams at end of 2017?

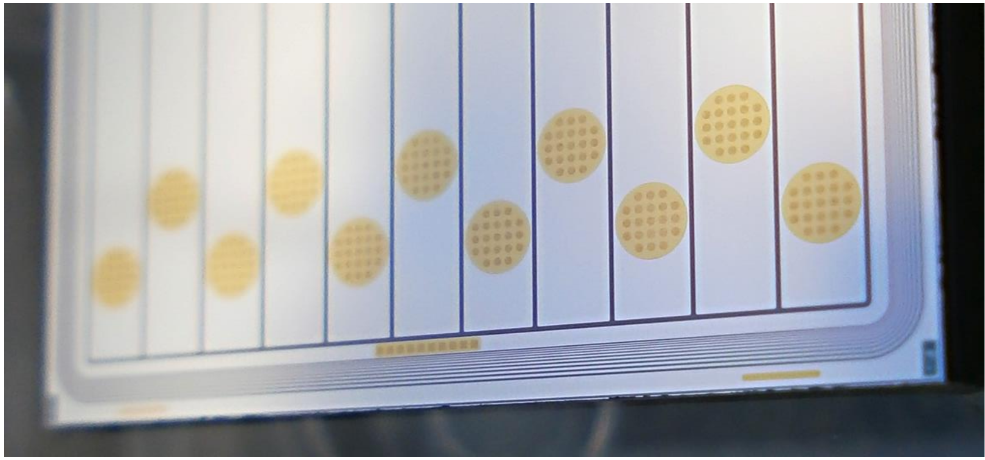
Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.
array -->				HIE-ISOLDE campaign				
	Coupling to XT02							
		Shielding -->						
		Field mapping -->						

← 2017 →

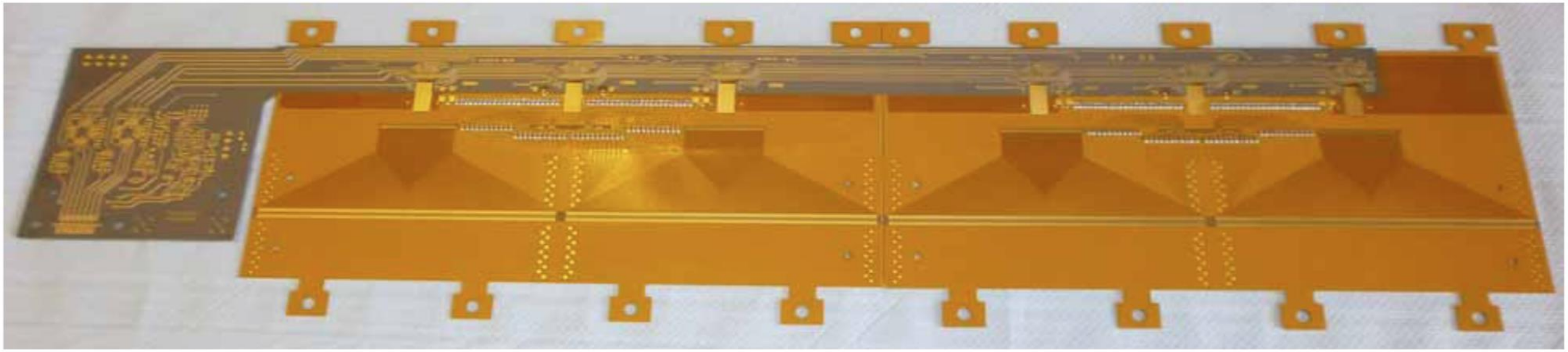
Long-term preparations

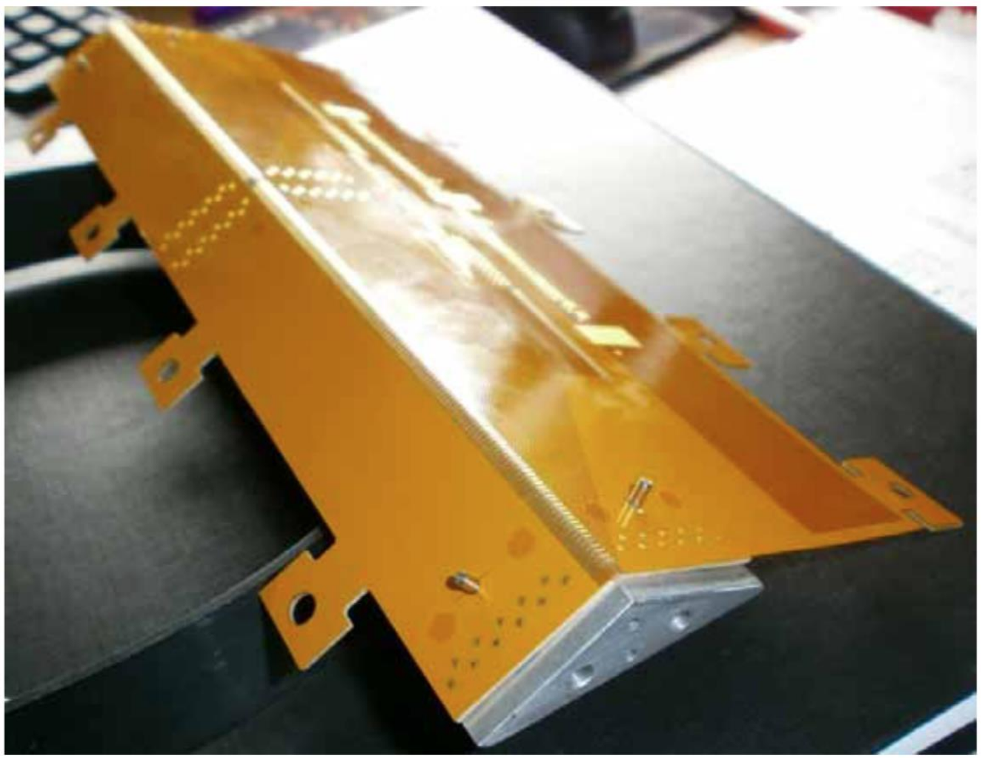
- Silicon DSSSD detectors being assembled in Liverpool clean room.
  - Ohmic (glued)
  - Junction (wire bonding)

- Active area = 11 x 2 mm

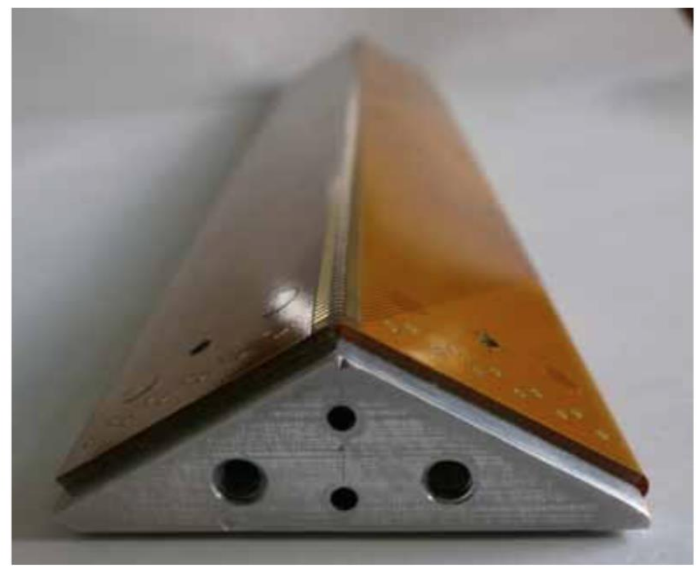


Si and PCB progress

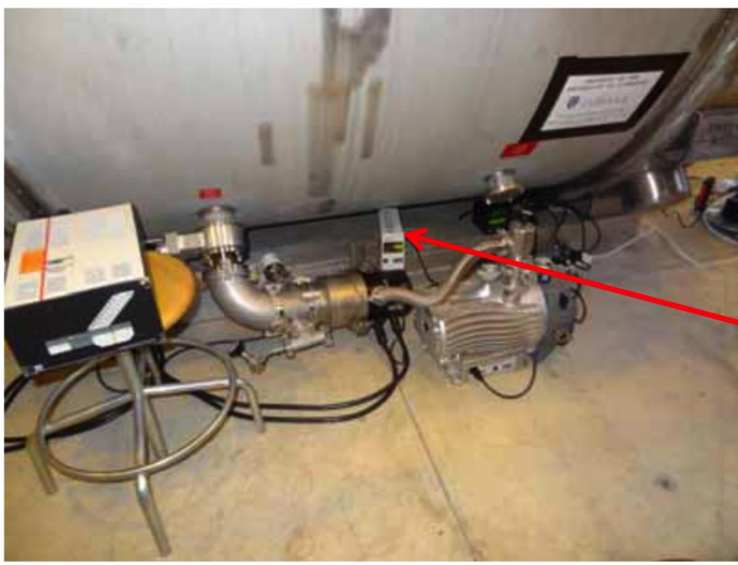




Flex PCB bend tests successful



Vacuum tests



OVC 5.69x10^{-5}mbar

Bore 8.6x10^{-7}mbar

Cooling of the magnet

- Initial problem with syphon to fill the magnet.
  - Only had "top-up" syphon
  - Full-length "fill" syphon delivered 24.01.2017

Photos courtesy of Paul Morrall (Daresbury)

Cooling of the magnet

- Endoscopic camera used to ensure syphon engaged.
- Filling started 24.01.2017 (10,000 ltrs of LN2 used in pre-cool).

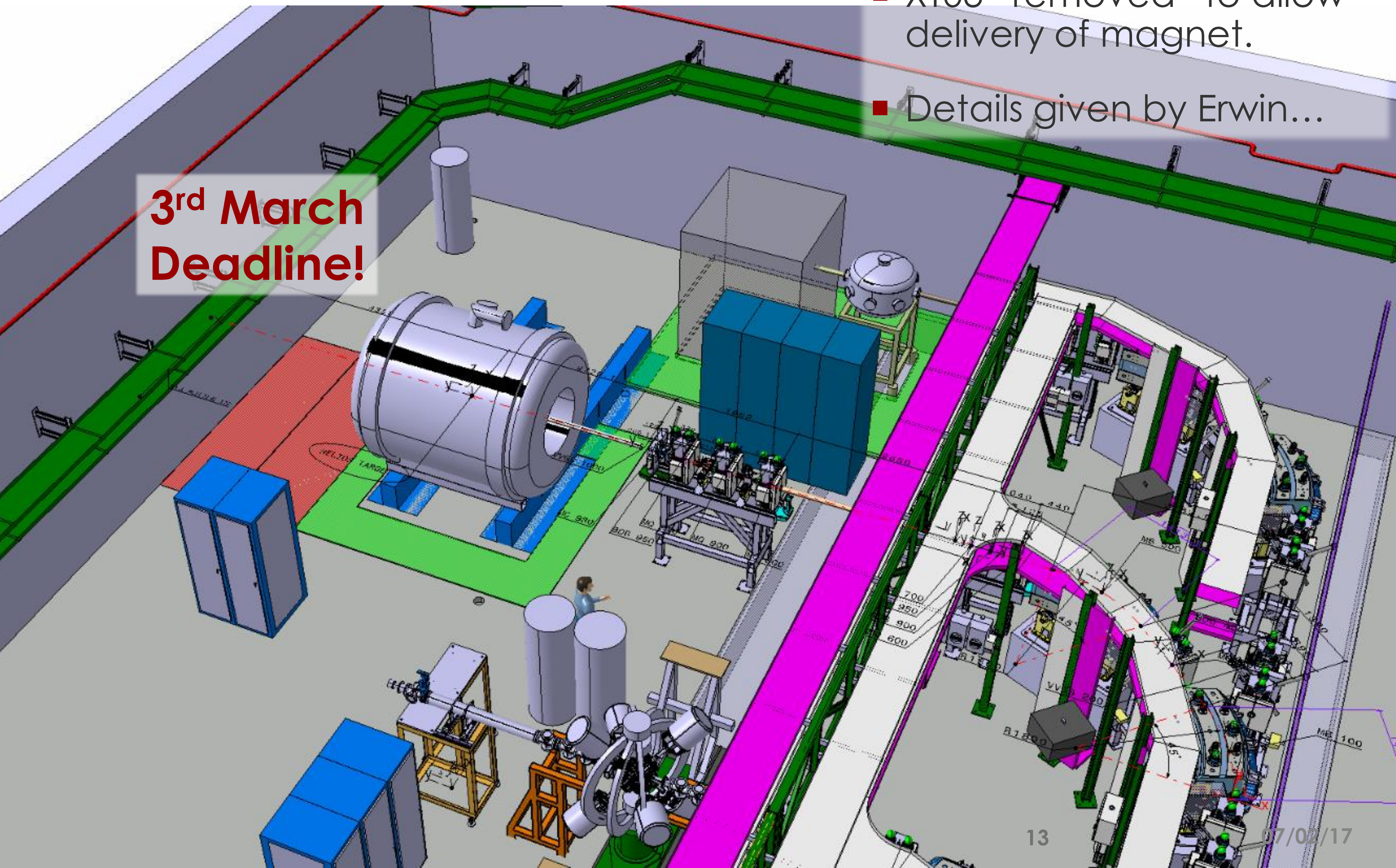
Cooling of the magnet

- Cooling with liquid He started yesterday 06.02.2017.
  - "Pump and purge" preceded fill, to empty of N_2, which would freeze on contact with cold He and block inlets/recovery.

Layout in ISOLDE hall

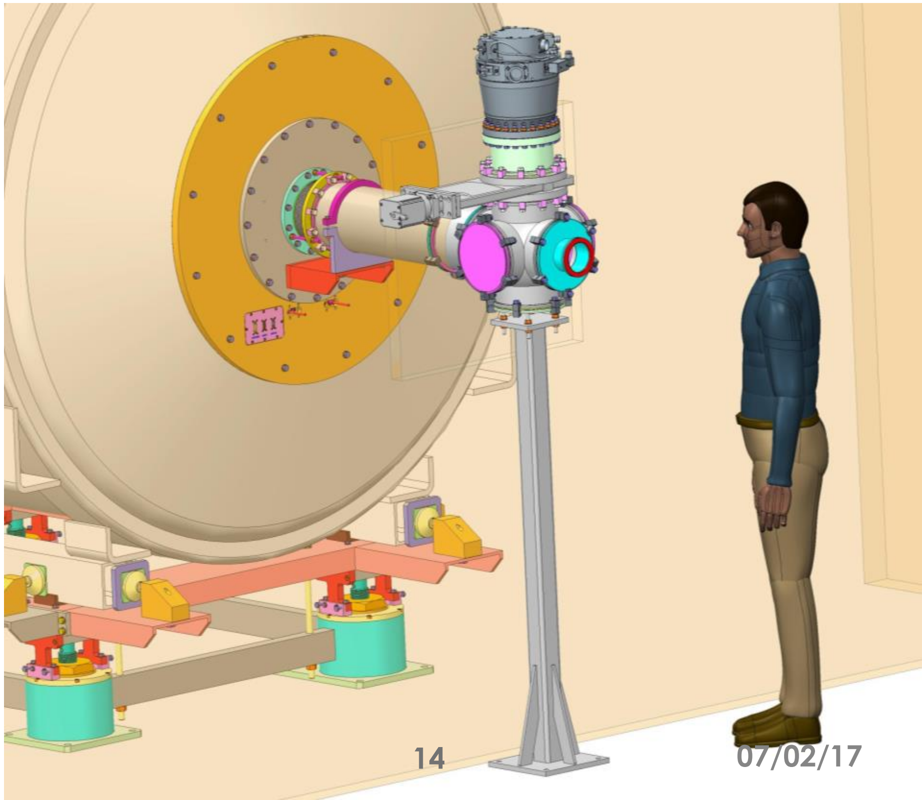
- Holes drilled for fixing of support structure.
- XT03 “removed” to allow delivery of magnet.
- Details given by Erwin…

3rd March Deadline!

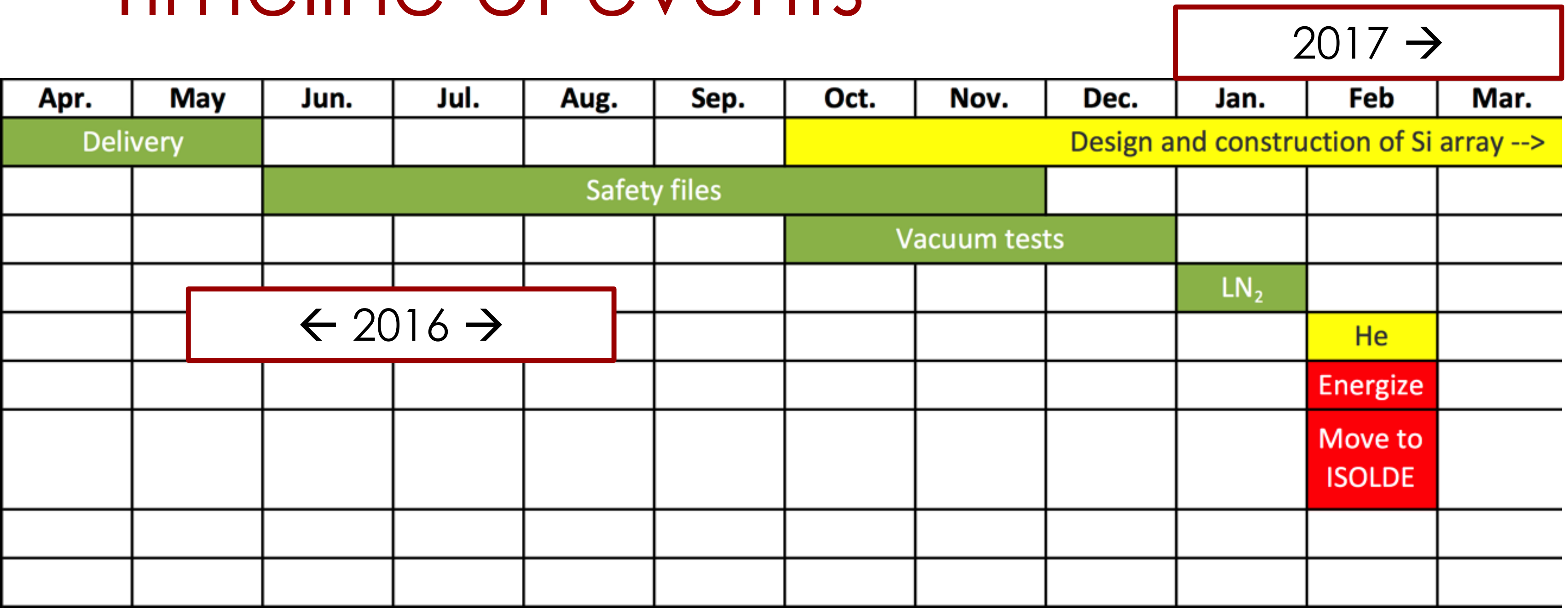


Integration with HIE-ISOLDE

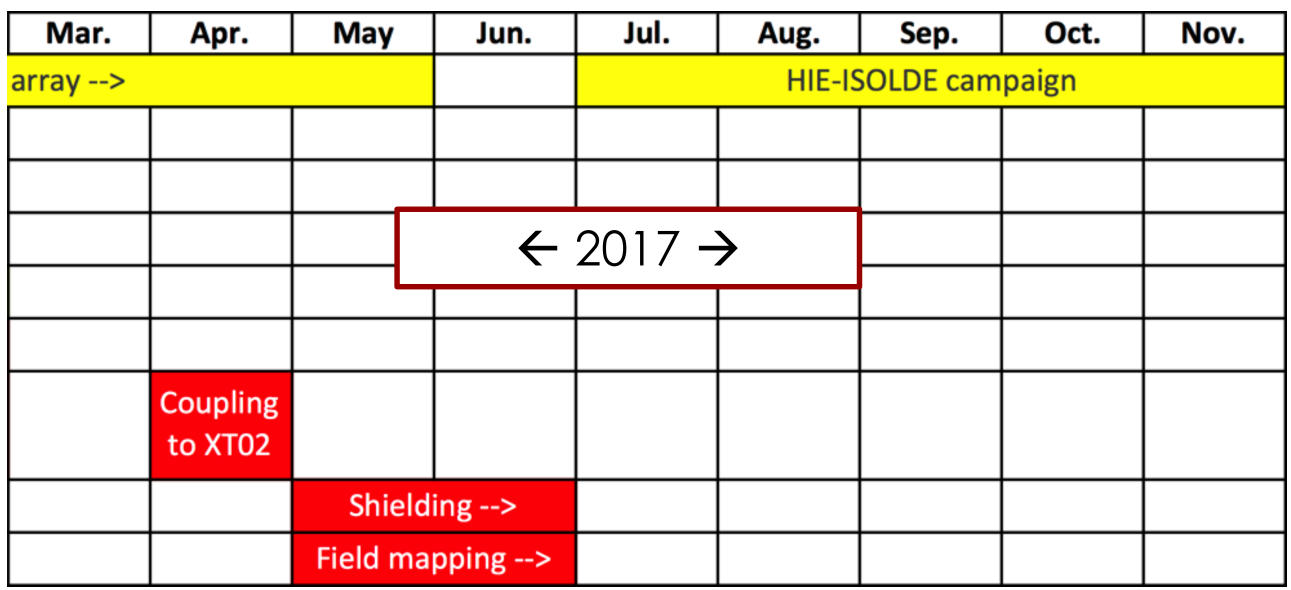
- Team from Daresbury, UK, working alongside CERN teams from HIE-ISOLDE and safety.
- Essentially complete:
  - Extra valve required, design tweaked by Alan Grant.
  - Final step to include shielding.
- Shielding calculations:
  - Performed by Matthew Fraser.
  - Design analysis underway by Jeremie Bauche.
  - Likely to be manufactured in UK.
- Support structure:
  - Under construction in Daresbury.
  - To be delivered end of April 2017.



Timeline of events



- "Hard" deadline of 3rd March to move into ISOLDE
- XT03 beam line to be rebuilt.



Collaboration

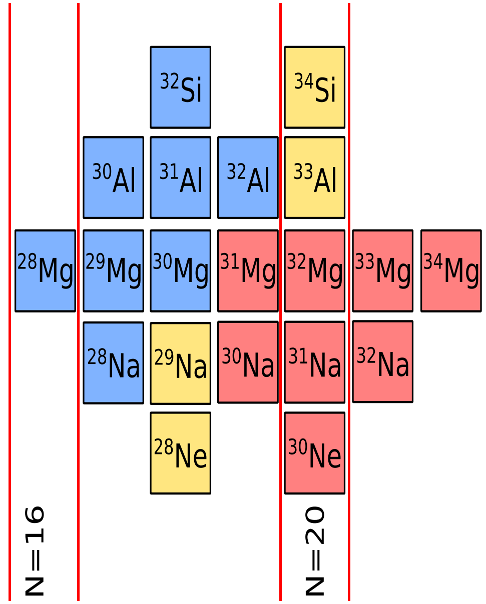
University of Liverpool, UK
The University of Manchester, UK
Argonne National Laboratory, USA
University of Surrey, UK
University of the West of Scotland, UK
STFC Daresbury, UK
TU Darmstadt, Germany
KU Leuven, Belgium
University of Tokyo, Japan
Louisiana State University, USA
CNRS, Université de Caen, France
Legnaro National Laboratory, Italy
Catania National Laboratory, Italy

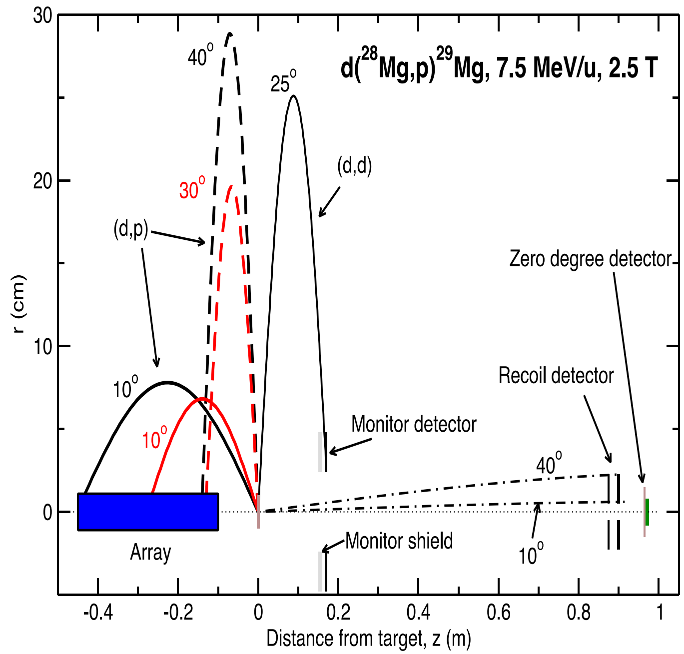
Thanks to: **David Sharp** (Manchester), **Robert Page** (Liverpool), **Ian Lazarus** (Daresbury) and **Paul Morrall** (Daresbury)

- This slide is intentionally blank

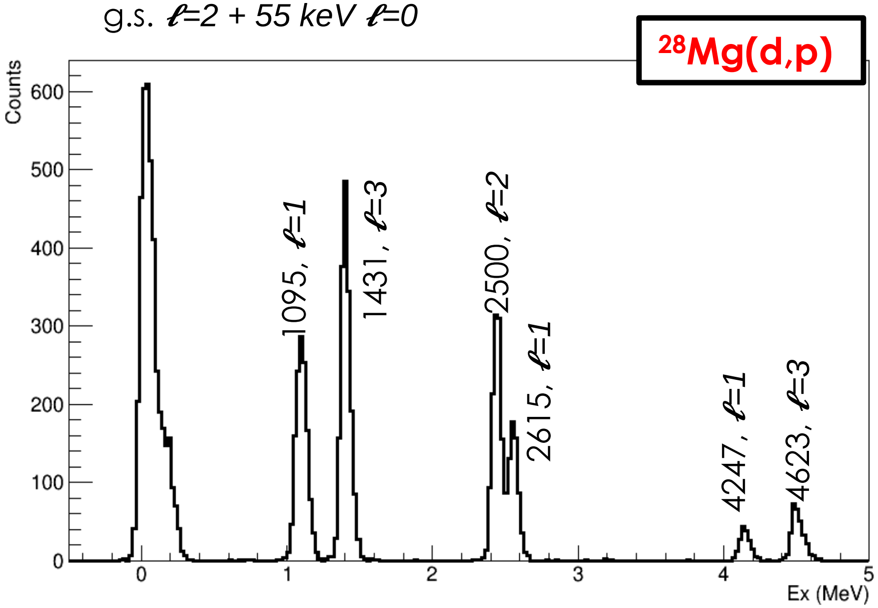
Proposed first measurements – ^{28,30}Mg,(d,p)

Study transition of single-particle states from outside to inside island of inversion
^{28}Mg(d,p) - approved, ^{30}Mg(d,p) – based on commissioning
Recoil detector used to identify reaction of interest
Identify bound and unbound states
Investigate spin-orbit splitting of p-orbital and evolution of fp orbitals





g.s. ℓ=2 + 55 keV ℓ=0



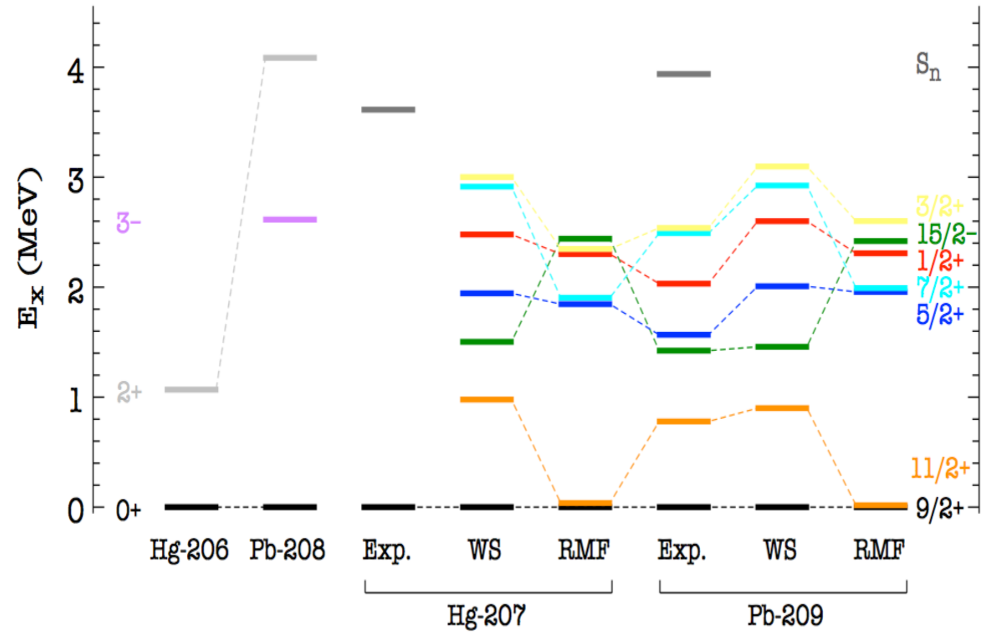
Marc Labiche simulations using NPTool

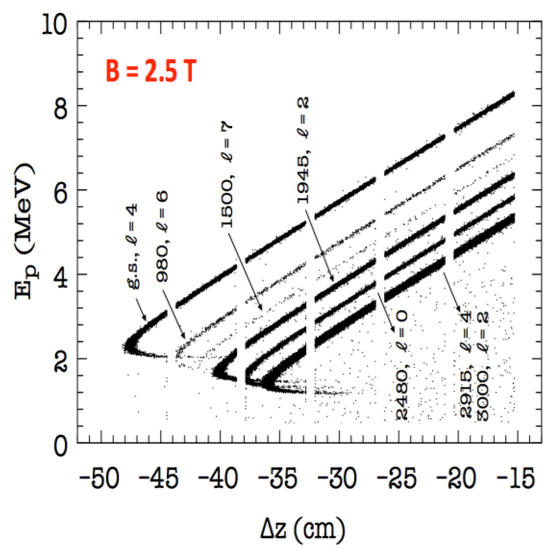
Proposed first measurements – ^{206}Hg(d,p)

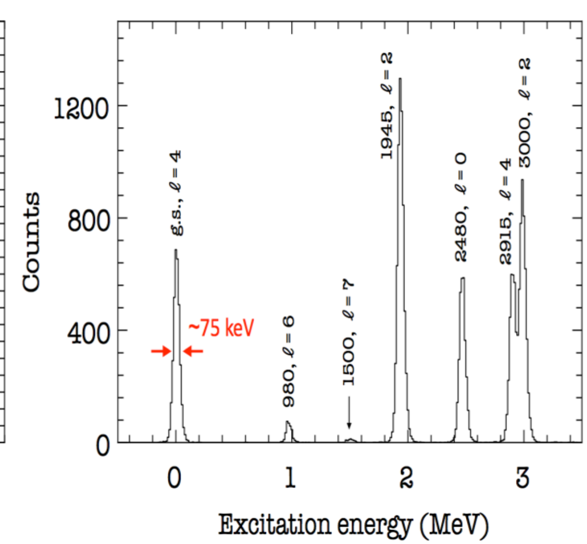
N=127 below Pb – very little nuclear structure information, terra incognita

Evolution of single-particle structure not investigated in lead region – requires heavy RIB's which HIE-ISOLDE can provide

Investigation of the role of s states in halo formation.



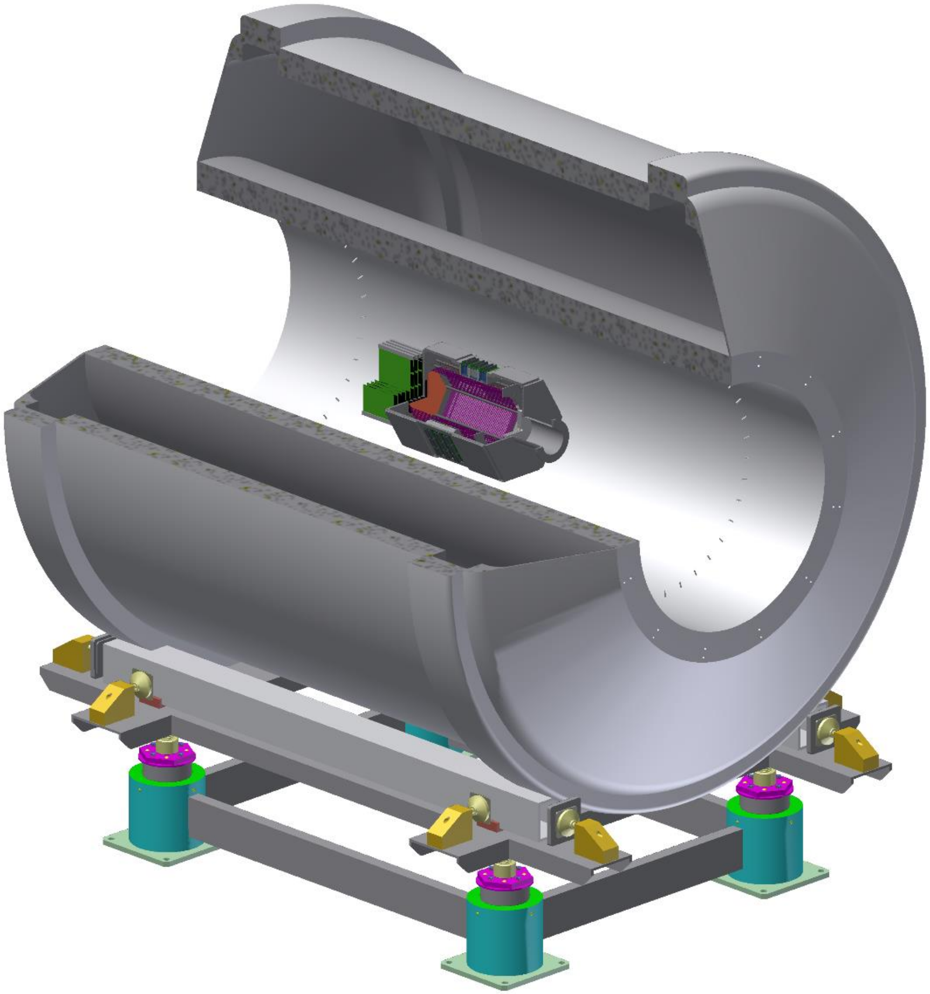




Marc Labiche simulations using NPTool

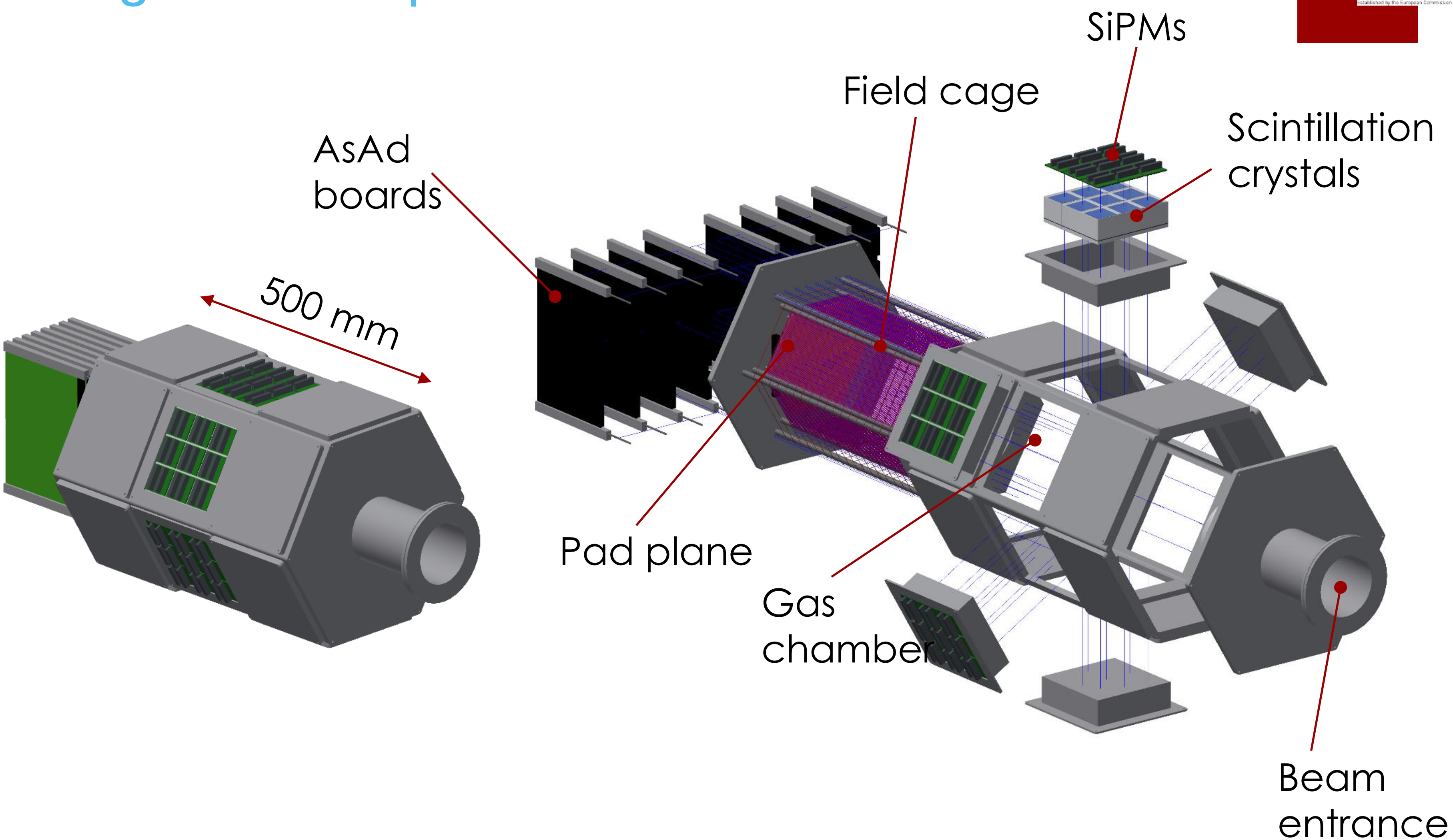
The SpecMAT detector

- TPC will be surrounded by a gamma-ray detection array.
- Detector will be placed in a high magnetic field (up to 4T).
- Charged-particle energies reconstructed from the curvature of their trajectories.
- Gamma-ray detection with scintillation array for detailed spectroscopy of populated states in transfer reactions.

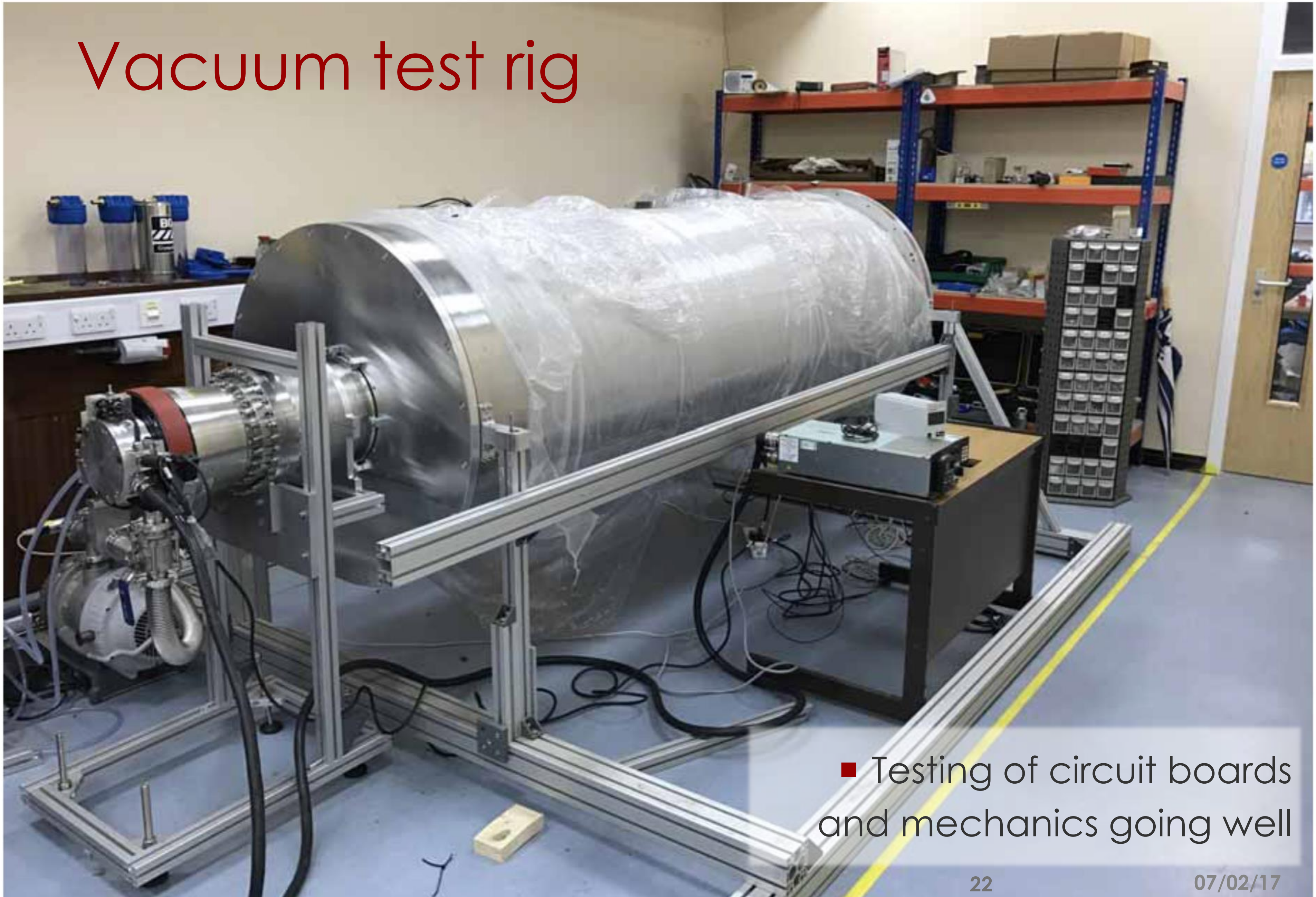


European Research Council
Established by the European Commission

Design of the SpecMAT detector



Vacuum test rig

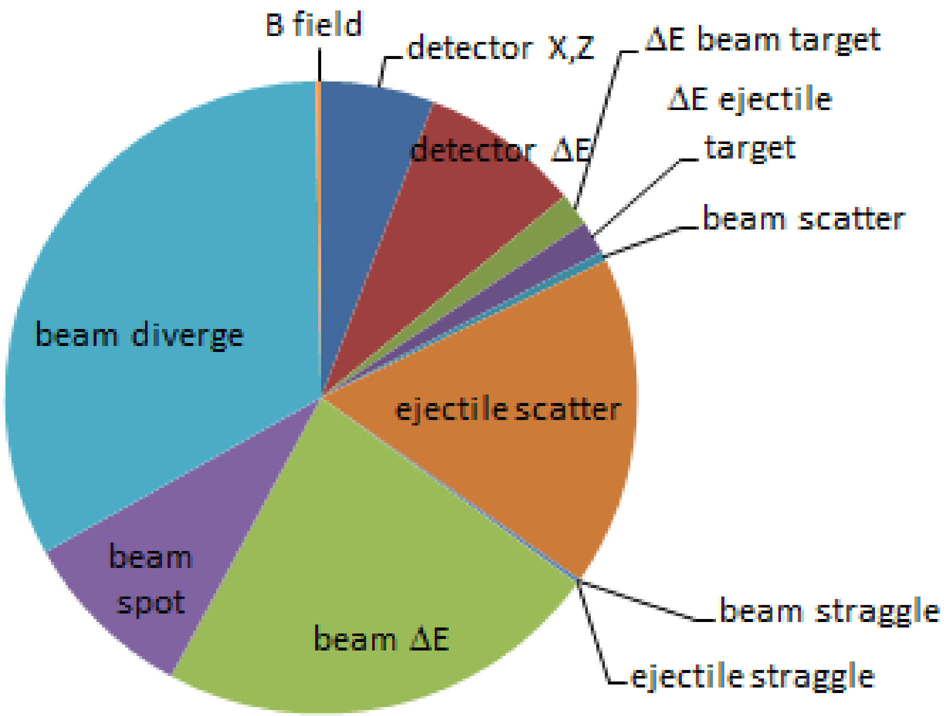


- Testing of circuit boards and mechanics going well

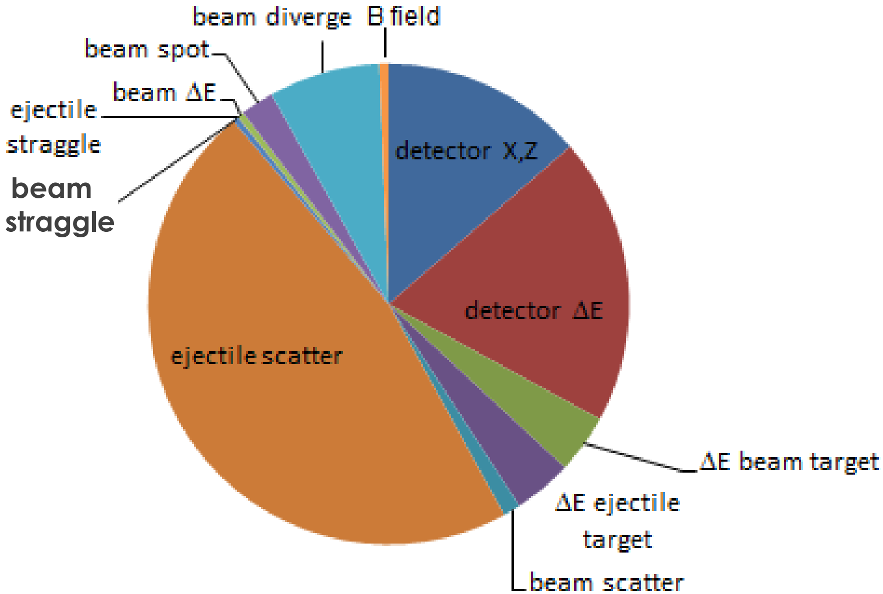
Q-value resolution

EXTERNAL SPECTROMETER: d(^{24}Ne,p)^{25}Ne @ 10 MeV/u

HIE-ISOLDE beam: **38 keV**



Cooled TSR beam: **22 keV**



Calculations by P.A. Butler

HIE-ISOLDE transverse emittance

90% transverse emittance is 0.3 mm mrad (normalised)

(M.Fraser, communicated 25 March 2014)

1 σ transverse emittance = $0.3/(1.65)^2$ = 0.110 mm mrad (normalised)

1 σ geometric emittance = $0.110/\beta\gamma$ = 0.110/0.14 for 10 MeV/u =0.78 mm mrad

= ½ divergence x ½ beam diameter

If the FWHM beam spot = 2.3 mm and the FWHM divergence = 1.8 mrad then

1 σ geometric emittance = $2.3 \times 1.8 /(2.35)^2$ = 0.75 mm mrad

If the transverse emittance (normalised, 1 σ) is reduced to 0.01 mm mrad then

FWHM beam spot = $2.3/\sqrt{10}$ = 0.73 mm; FWHM divergence = $1.8/\sqrt{10}$ = 0.57 mrad

momentum and energy spread

FWHM energy spread $\Delta E/E$ = 0.0022 (RMS) *2.35 = 0.005

(from “TSR at ISOLDE: Collimation efficiency in the HEBT” by M. Fraser, slide 6)

Possible to achieve FWHM $\Delta p/p$ = 0.0002 (1 σ) *2.35 = 0.00047

FWHM $\Delta E/E$ = 0.001

Efficiency

[illegible] on TSR beams [illegible]response from the user community: Transverse collimation in HIE-ISOLDE, making use of bunch-rotation to reduce the longitudinal momentum [illegible]

For a transverse emittance comparable to using cooling in the TSR (0.01 mm mrad), the collimation efficiency is 9% compared to that using cooling which is 22%

[illegible]

Single plane transmission efficiency will increase from 30% to 50% if emittance doubles to 0.02 mm mrad.

Overall efficiency will change from 30% x 30% = 9%, to 50% x 50% = 25%, comparable to that of the TSR

[illegible] mrad [illegible] is no longer gaussian so we cannot use FWHM in this way; should use the rms [illegible]