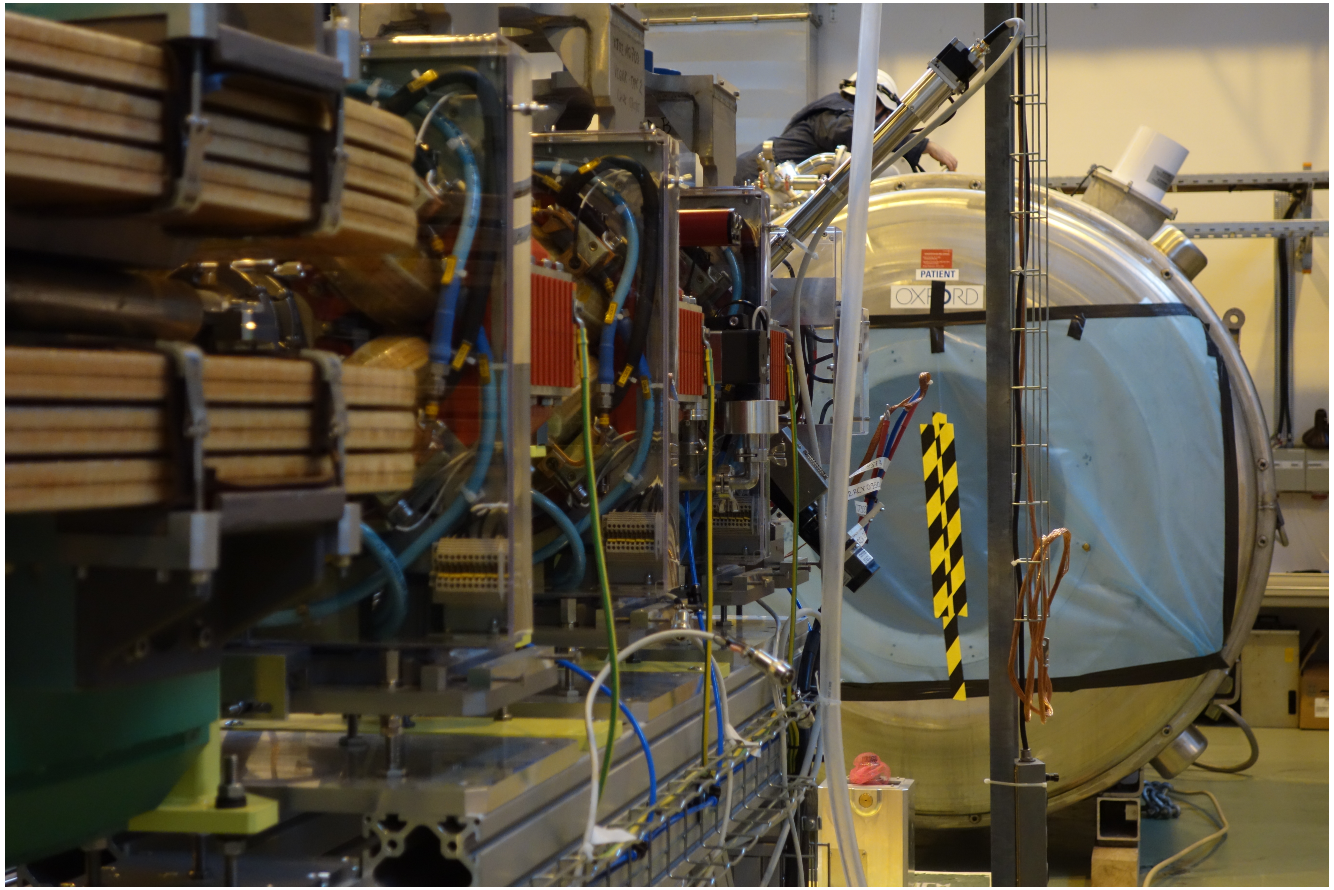


The ISOL Solenoidal Spectrometer (ISS) at HIE-ISOLDE

Sean J Freeman The University of Manchester

On behalf of the ISS Collaboration

The Plan

- A brief history of the project.
- Choices and design considerations – variety of influences (science/technical, politics, funding mechanisms).
- Recent developments and current status (mainly magnet, silicon later).
- Future plans.

Historical timeline for this project

Late 2000's: UK thinking about future projects including those based at ISOL facilities – a HELIOS-type spectrometer suggested as a possibility.

2010-2012: York University project acquires a 3T magnet - but stray field proves unworkable at ISOLDE.

2010: Idea to move Heidelberg Test Storage Ring (TSR) to ISOLDE born at NuPECC meeting, with UK involvement.

2011: Both TSR and a Solenoid ideas presented as separate project options to UK community. Formally merged as internal/external spectrometers with TSR.

2012: Submission of "Statement of Intent" triggers lengthy STFC Project Peer Review Process (STFC = UK funding agency).

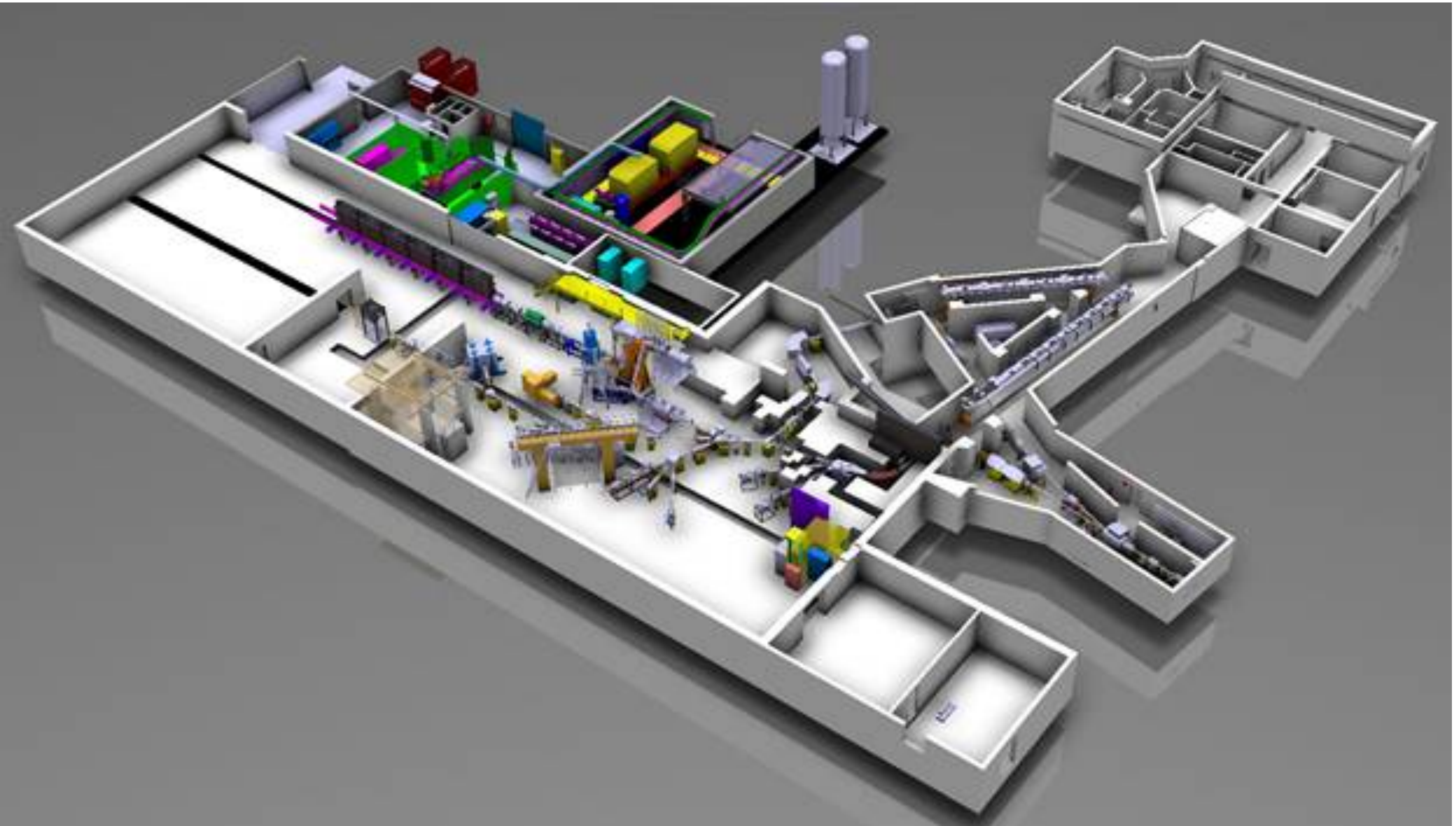
2014: CERN agrees to provide new HIE-ISOLDE beam line to use the external spectrometer before the TSR is moved. STFC approves project packages on the on-axis silicon – but no magnet!

2015: Silicon project starts. STFC approve funds (with Liverpool University) for a magnet.

2016: TSR@CERN postponed….for foreseeable future?

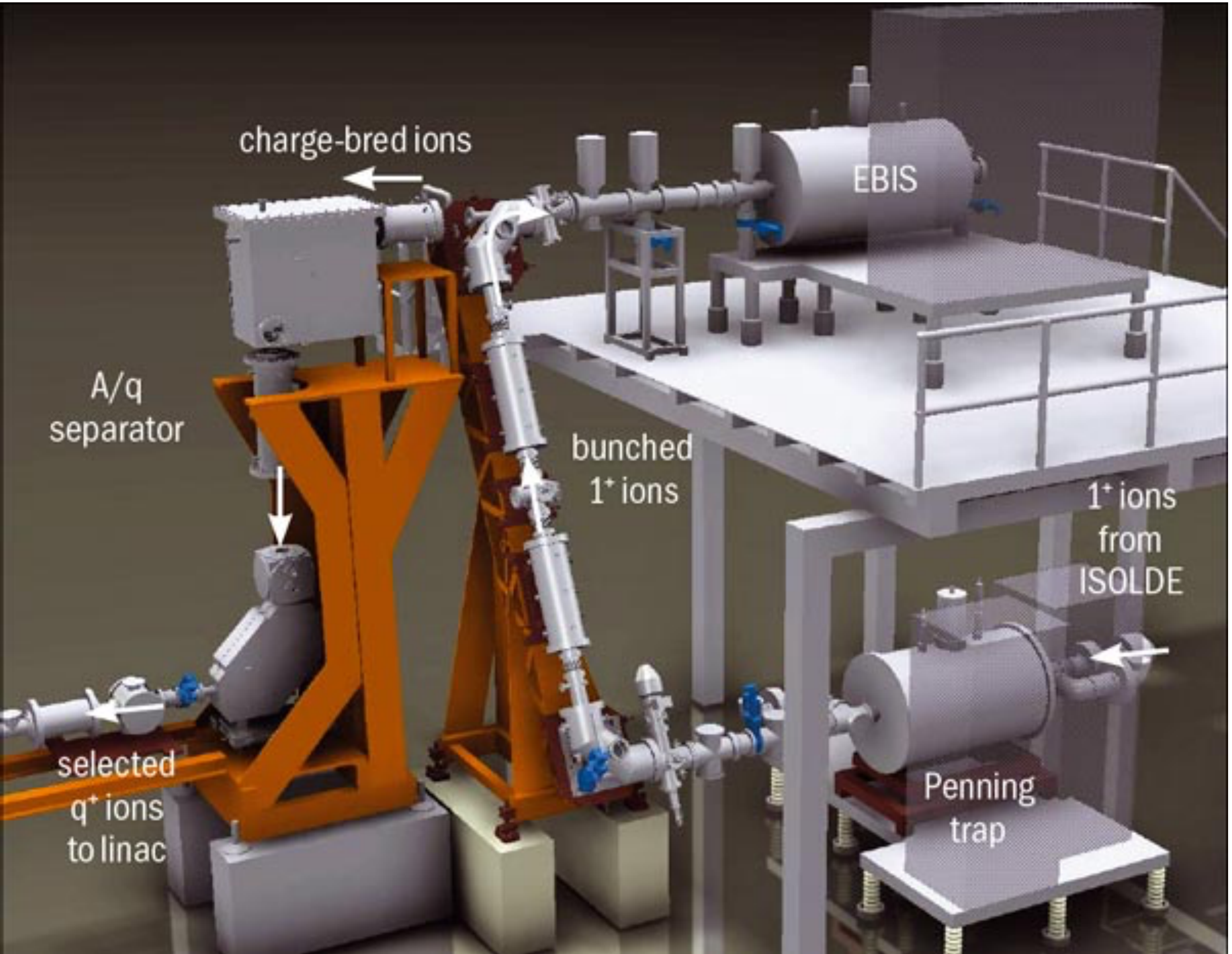
ISOLDE Radioactive Beam Facility at CERN

On-line isotope mass separator located at the Proton-Synchrotron Booster (PSB)



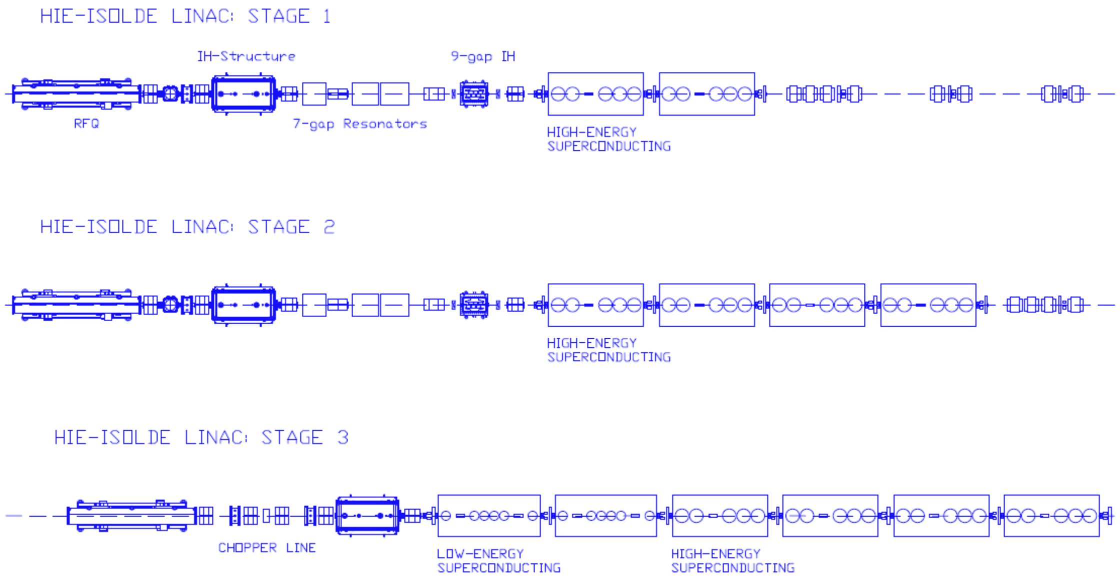
- Operating at CERN since 1967.
- Rebuilt twice with major upgrades 1974 and 1992.
- Significant expertise in physics and chemistry of ISOL production methods.
- PHYSICS OPPORTUNITY: Exceptional range of beam species >700 isotopes.
- Mass separators provide low-energy ion beams.
- POLITICS: Exploiting the UK CERN subscription.

REX-ISOLDE



- Operated at CERN 2001-2014.
- Singly-charged ions from ISOLDE mass separator.
- Accumulated, bunched and cooled in Penning trap.
- Charge bred ($m/q<4.5$) in an electron beam ion source.
- Injected into a normal conducting linac (RFQ, IH, three seven-gap spiral resonators, nine-gap IH) final energies 1.2 to 3 MeV/u − primarily Coulex.

HIE-ISOLDE – higher intensity and energy



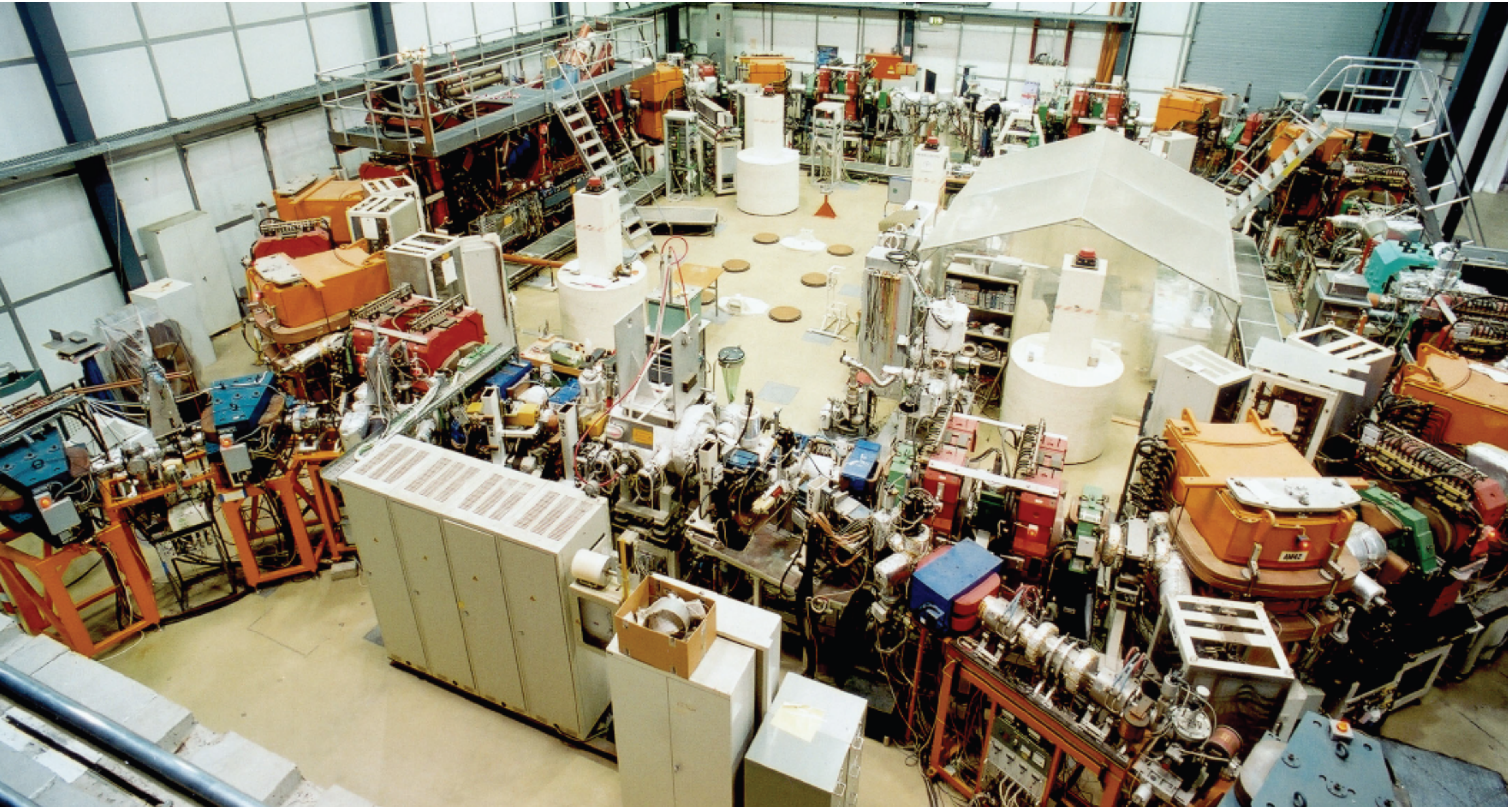
- Upgrade to a superconducting machine.
- Stage 1: two cryomodules 5.5 MeV/u for A/q=4.5 operating since mid-2016 for physics.
- Stage 2: third module in Jan 17 and four cryomodules 10 MeV/u for A/q=4.5 early 2018.

  Opportunities for direct reaction studies across the nuclear chart.

Test Storage Ring

Proposal to install a heavy-ion storage ring at HIE-ISOLDE.
In-principle opportunities:

- in-ring measurements that benefit from excellent quality cooled and recirculating light ions.
- external measurements that benefit from excellent quality cooled and extracted beams.



POLITICS: Put on hold indefinitely in 2016.

Technical Design Report

EPJ 207, 1 (2012)

Initial Project Proposal Aims

Contributions to the Q-value energy resolution for the reaction $d(^{132}Sn,p)^{133}Sn$ at 10 MeV.A

System with ***ultimate*** resolution taking advantage of the excellent beam quality of TSR.

Proposal Design Specification:

Q value resolution approaching 20keV in situations where beam straggling low.

3T magnet.

Hexagonal on-axis silicon array: 25mm from axis four wafers each 125mm long.

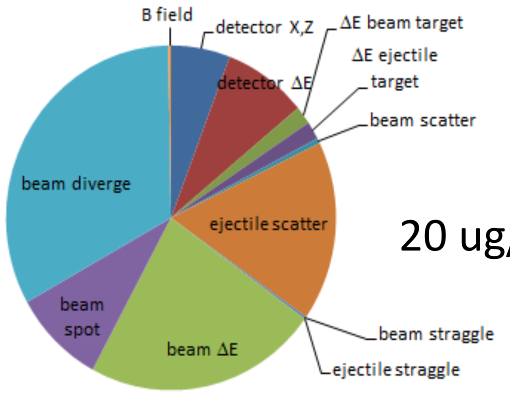
1mm thick (stops 12 MeV protons).

Double-sided strips with pitches:

0.5 mm along axis

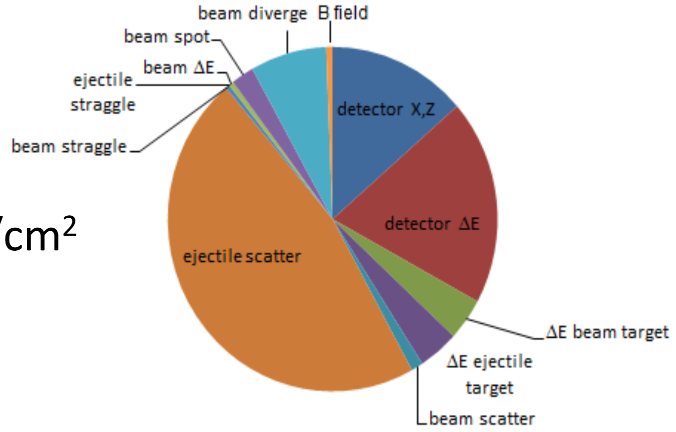
1mm orthogonal

HIE ISOLDE: 39 keV

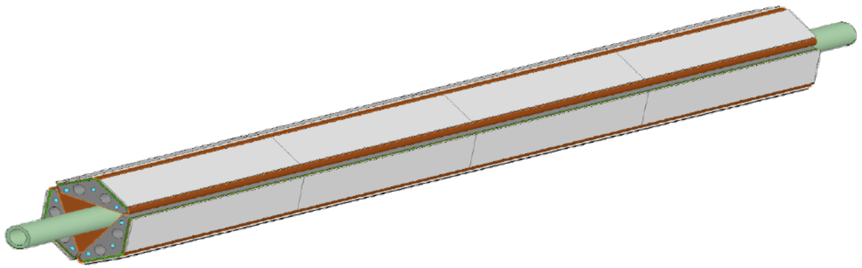


20 ug/cm²

TSR EXTRACTED: 26 keV



20 ug/cm² SIMULATION	^{30}Mg(d,p) 10MeV/u	^{132}Sn(d,p) 10MeV/u	^{146}Gd(d,p) 10MeV/u	^{206}Hg(d,p) 10MeV/u	^{225}Ra(d,d') 4MeV/u
HIE-ISOLDE 0.1mm mrad ΔE/E= 0.5%	44	45	44	47	32
TSR 0.01mm mrad ΔE/E= 0.025%	22	22	25	23	25

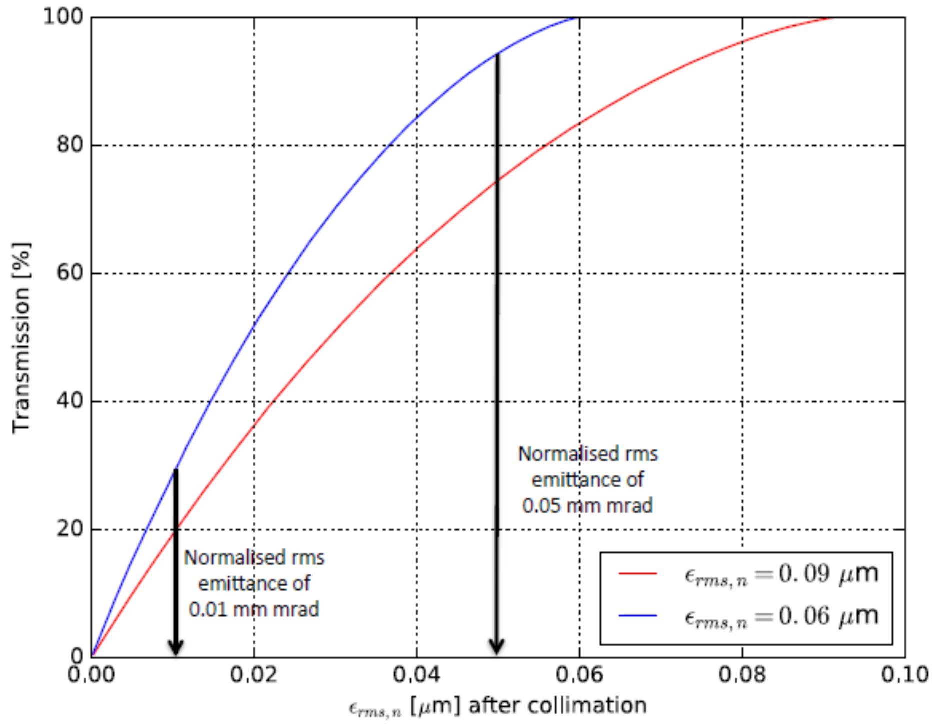


Beam intensity cost: REX at lower than optimal rep rate needed 50%, ring injection 80%, extraction 80%, longer setup 70%

Total transmission efficiency around 20% compared to HIE direct beam.

Mitigation for Lack of TSR

Matthew Fraser (CERN)



A: XTO2 – CERN already committed new beamline which becomes permanent residence.

B: Improvements in HIE beam transverse emittance could be achieved by collimation – possible to do this with two successive collimators in diagnostic boxes (separated by 90 degrees in phase advance) with intensity cost.

HIE transverse emittance estimated (normalised, 1σ) ~0.1mm mrad
Collimation to ~0.02mm mrad with efficiency of 25% - similar to TSR loss

Preliminary emittance measurements currently being analysed, more in November.

C: Improvements in beam energy spread could be achieved by switching off some cavities to debunch beam and one cavity to rotate the phase – reductions possible FWHM energy spread ΔE/E from 0.5% to 0.1% - needs detailed beam optics calculations. Will lower maximum energy.

SIMULATIONS	^{30}Mg(d,p) 10MeV/u	^{132}Sn(d,p) 10MeV/u	^{146}Gd(d,p) 10MeV/u	^{206}Hg(d,p) 10MeV/u	^{225}Ra(d,d') 4MeV/u
HIE 0.1 mm mrad ΔE/E= 0.5%	44	45	44	47	32
TSR 0.01mm mrad ΔE/E= 0.025%	22	22	25	23	25
HIE 0.02mm mrad ΔE/E=0.5%	42	42	39	42	28
HIE 0.1 mm mrad ΔE/E=0.1%	29	28	32	31	28
HIE 0.02 mm mrad ΔE/E= 0.1%	24	25	26	25	25

More work needed, TSR performance in reach?

How to Get a Magnet – Talk to your friends!

Birger Back and Peter Winter (ANL) found locations of several OR66 4T MRI systems − Brisbane warm for two years.

Feb 2016: Centre for Advanced Imaging, The University of Queensland Brisbane Australia

18th Feb – 1st March 2016

Brisbane to Singapore : Calicanto Bridge

5th March – 7th April

Singapore − Rotterdam: MSC Sarah

19th April

CERN Building 190

Cost: roughly £130k with £8k shipping c.f. order of £1M for bespoke design.

Remove Gradient Coils, Bore Cleaning and Vacuum Tests

After around five months of safety review…

SEPT 2016

Bore: 8.6×10^{-7} mb

Cryostat: 5.7×10^{-5} mb

Cold Head Refurb and Cryogenic Cooling

Moved to Building 180 to connect to helium recovery line.

Leybold refurbished cold head.

24th Jan 17: Cooled with LN2 (10k litres).
Issue with syphons: two sorts “top up” and full length “fill”.

Flushed out.

6th Feb: Fill with LHe
7.5k litres got to 24.2%
Topped up to 65%.
[100%=3300 litres −safe to move if <60%]
Left to “soak” for 5 days.

Significant help from the CERN cryogenics group and “loan” of helium!

JAN-FEB 2017

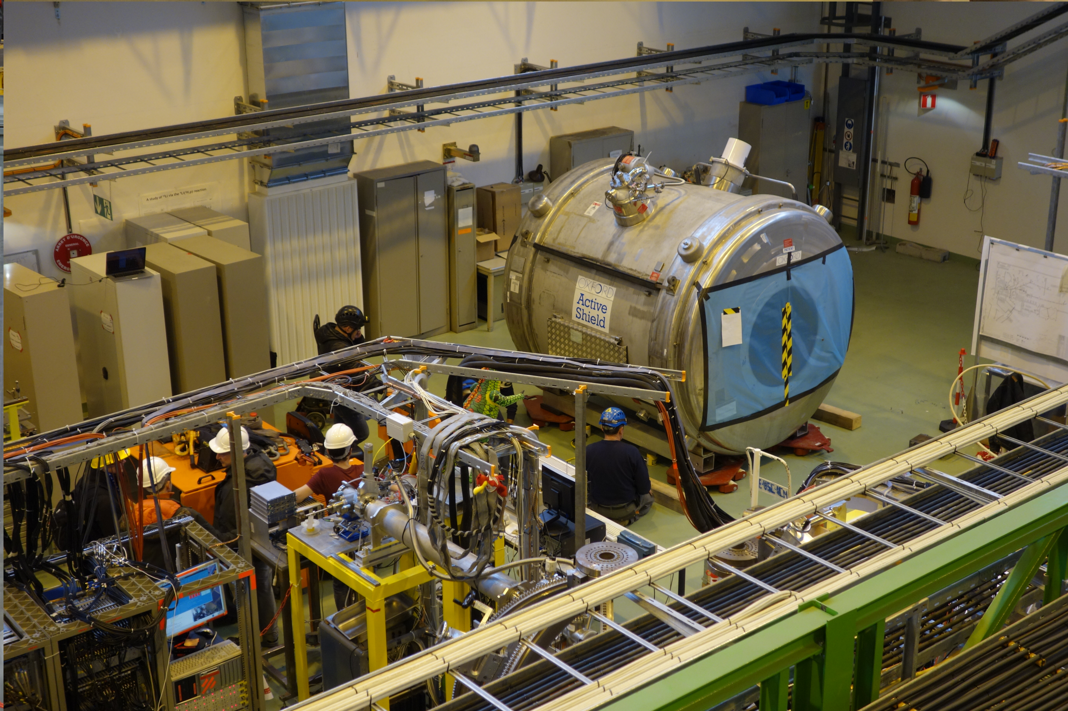
Field Test and Move to ISOLDE Hall

20^{th} Feb: Turned on but tripped after a few seconds - trivial limit issue.

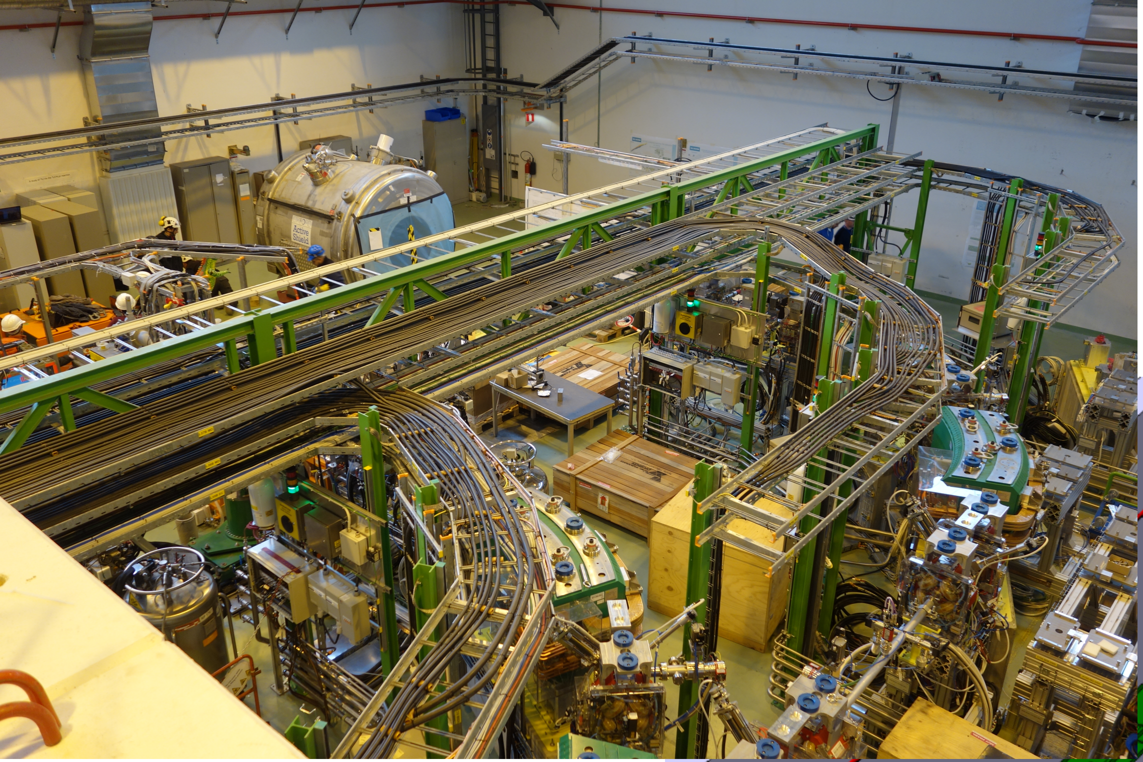
21^{st} Feb: 50A and 0.456T in around 30 minutes, paused for 1 hour, 2.75 T two hours later.
No interesting pictures!

2^{nd} March: Moved into the ISOLDE Hall, just in time!

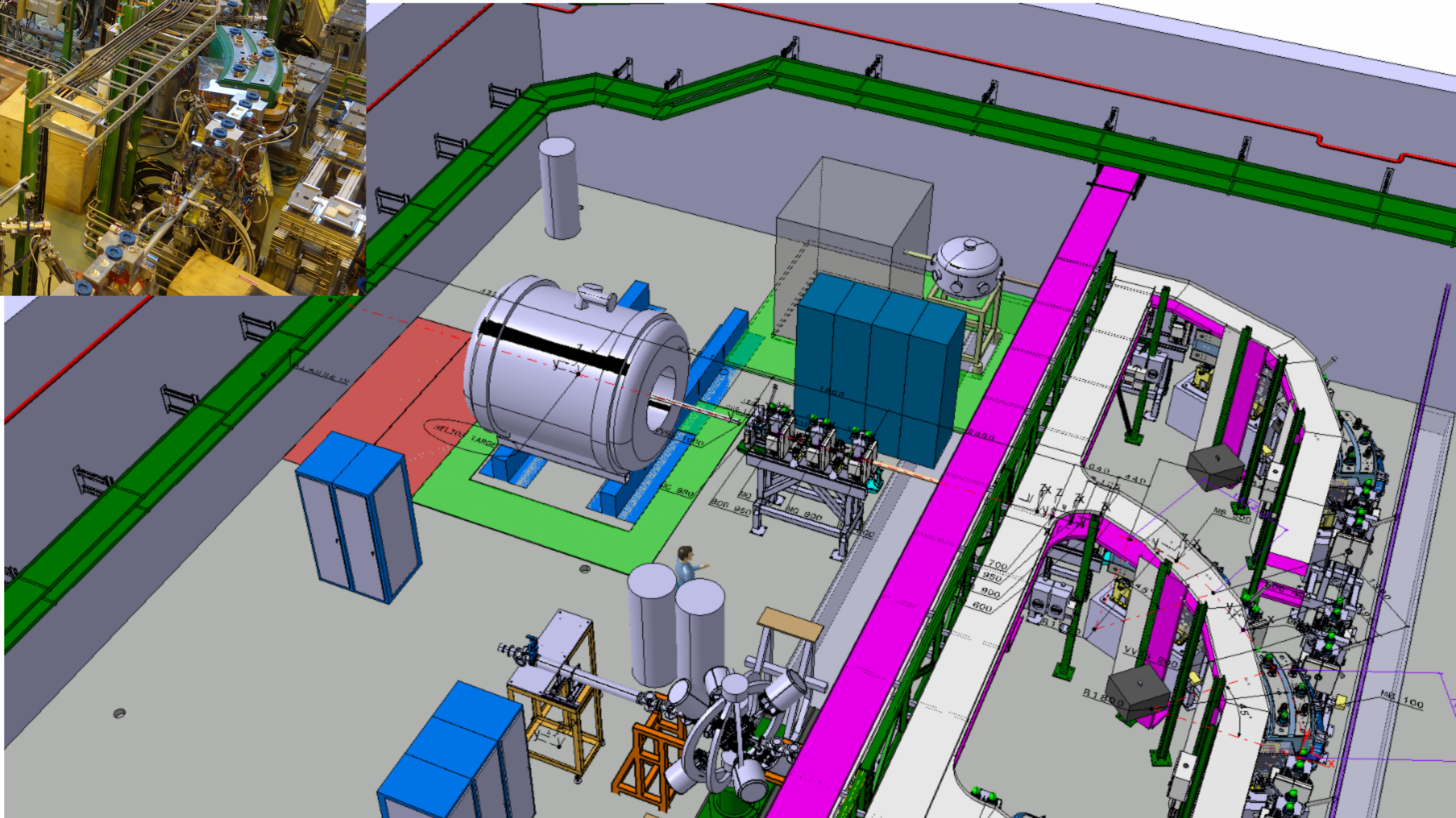
3^{rd} March: 49.8% full after ten days without the cold head.



FEB-MAR 2017



Location in ISOLDE Hall



Magnet support platform will be ready in May 17.

Design of magnetic shielding front and back in progress.

Early Implementation Initiative

Magnet infrastructure should be complete by end 2017, but timescale for completion of new silicon array is end 2019.

Planning to take opportunity to exploit the magnet in 2018 before CERN Long Shutdown 2019- early 2021 through collaboration with Argonne. Hope to deploy Argonne silicon array in the ISS magnet.

Awaiting imminent outcome of STFC NP Consolidated Grant Round to confirm some manpower and resource requests before doing detailed planning.

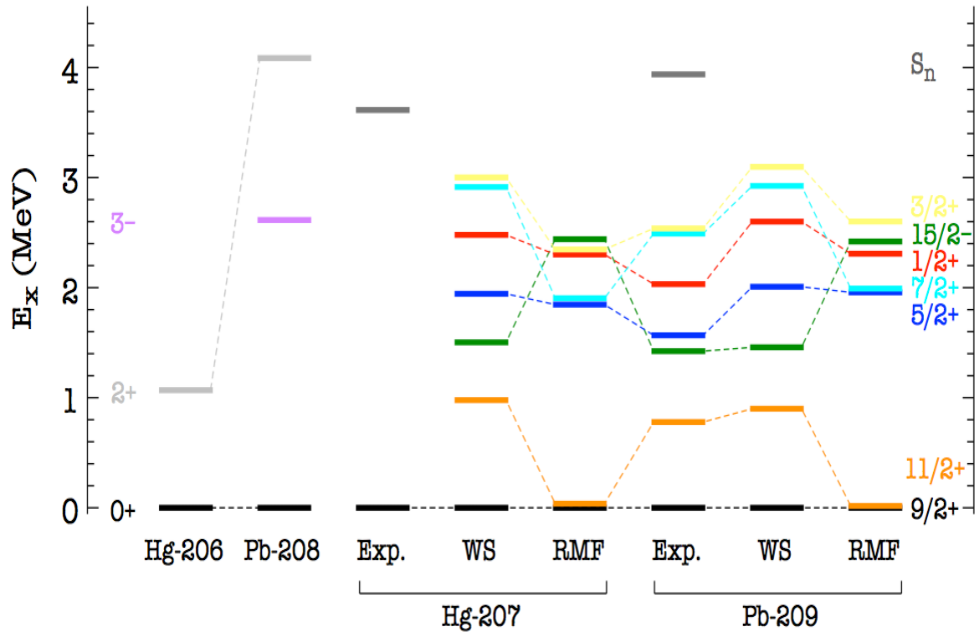
As includes request for high-rate gas recoil detector (PPAC + ion chamber).

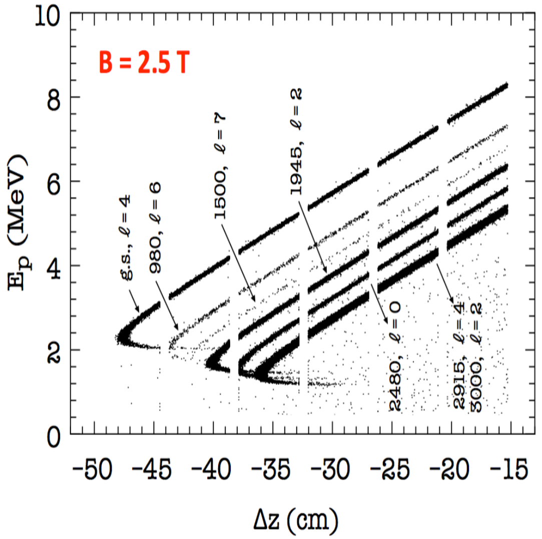
Experiment IS-631 “The (d,p) reaction on ^{206}Hg” Spokespersons: B.P. Kay and C.R. Hoffman (Argonne).

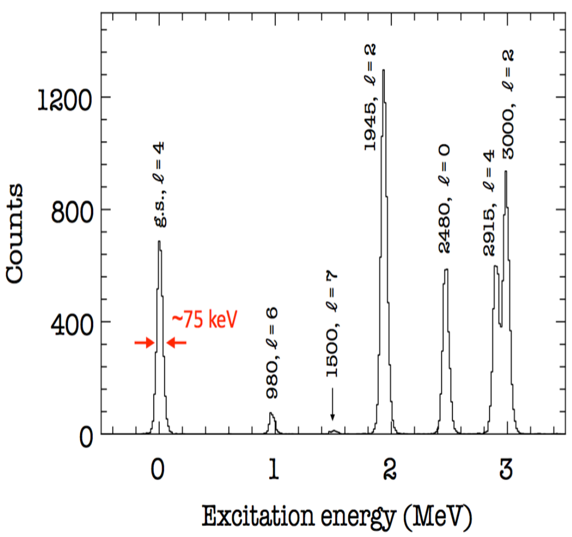
N=127 below Pb – very little nuclear structure information, terra incognita

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

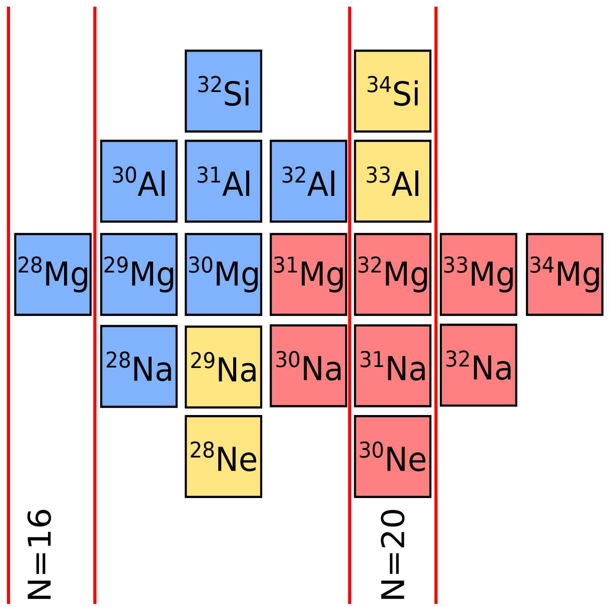
Investigation of the role of s states in halo formation.



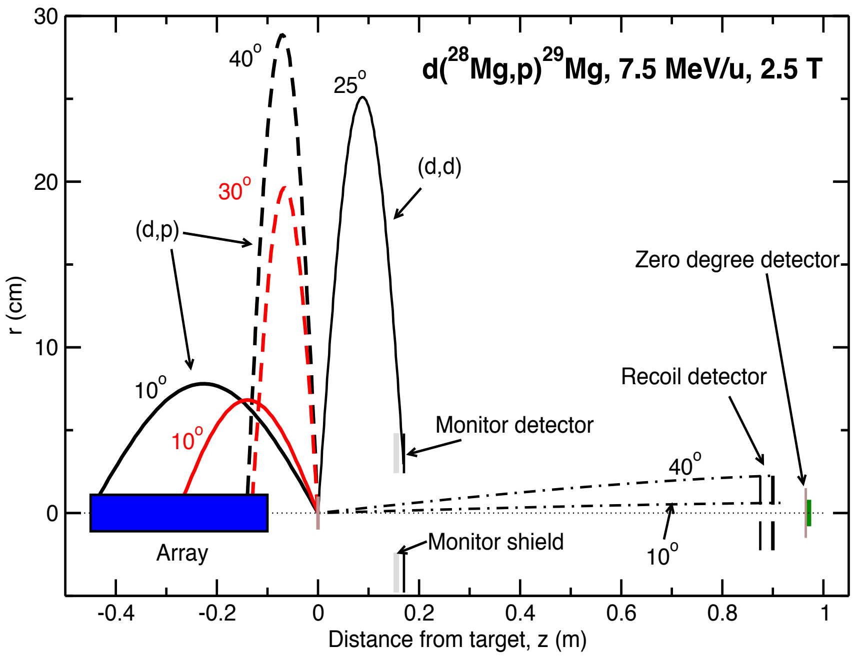


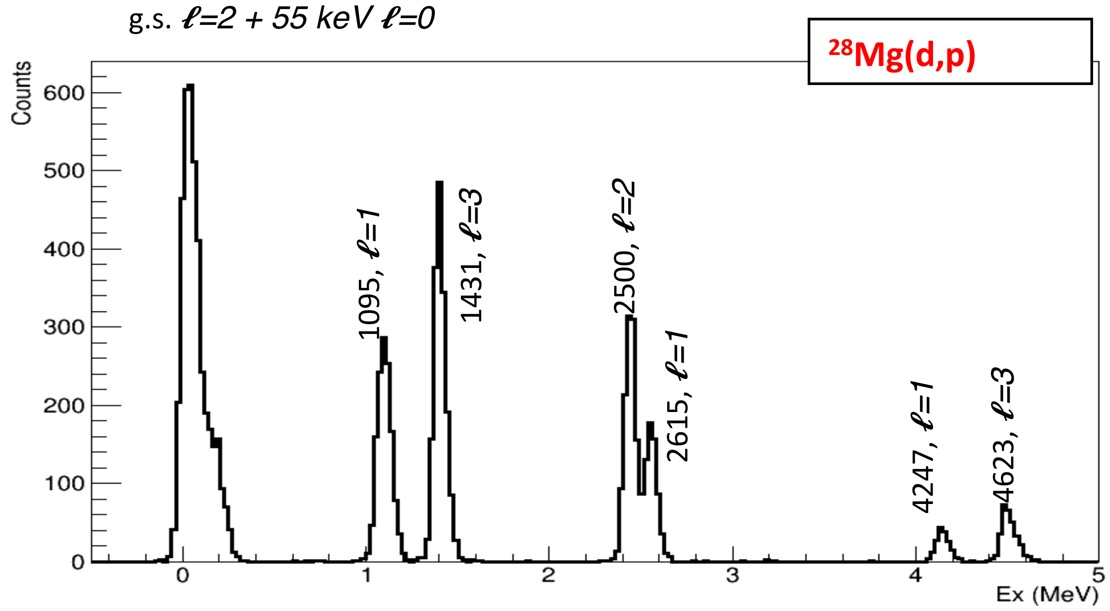


Experiment IS-621 "Single-particle behaviour towards the island of inversion: $^{28,30}Mg(d,p)$ in inverse kinematics" Spokespersons: D.K. Sharp and S.J. Freeman



Study transition of single-particle states near island of inversion.
$^{28}Mg(d,p)$ - approved, $^{30}Mg(d,p)$ – based on commissioning.
Investigate spin-orbit splitting of p-orbital and evolution of fp orbitals.
Evolution of shell structure along N=16.





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University of Tokyo, Japan
Louisiana State University, USA
CNRS, Université de Caen, France
Legnaro National Laboratory, Italy
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