MARA – From commissioning to experiments

@Tasca18
@GSI, Darmstadt
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Content

What we had before MARA?

Why MARA was built?
How it was built?

What kind of physics will be studied in coming years?

Work ahead – what we should improve

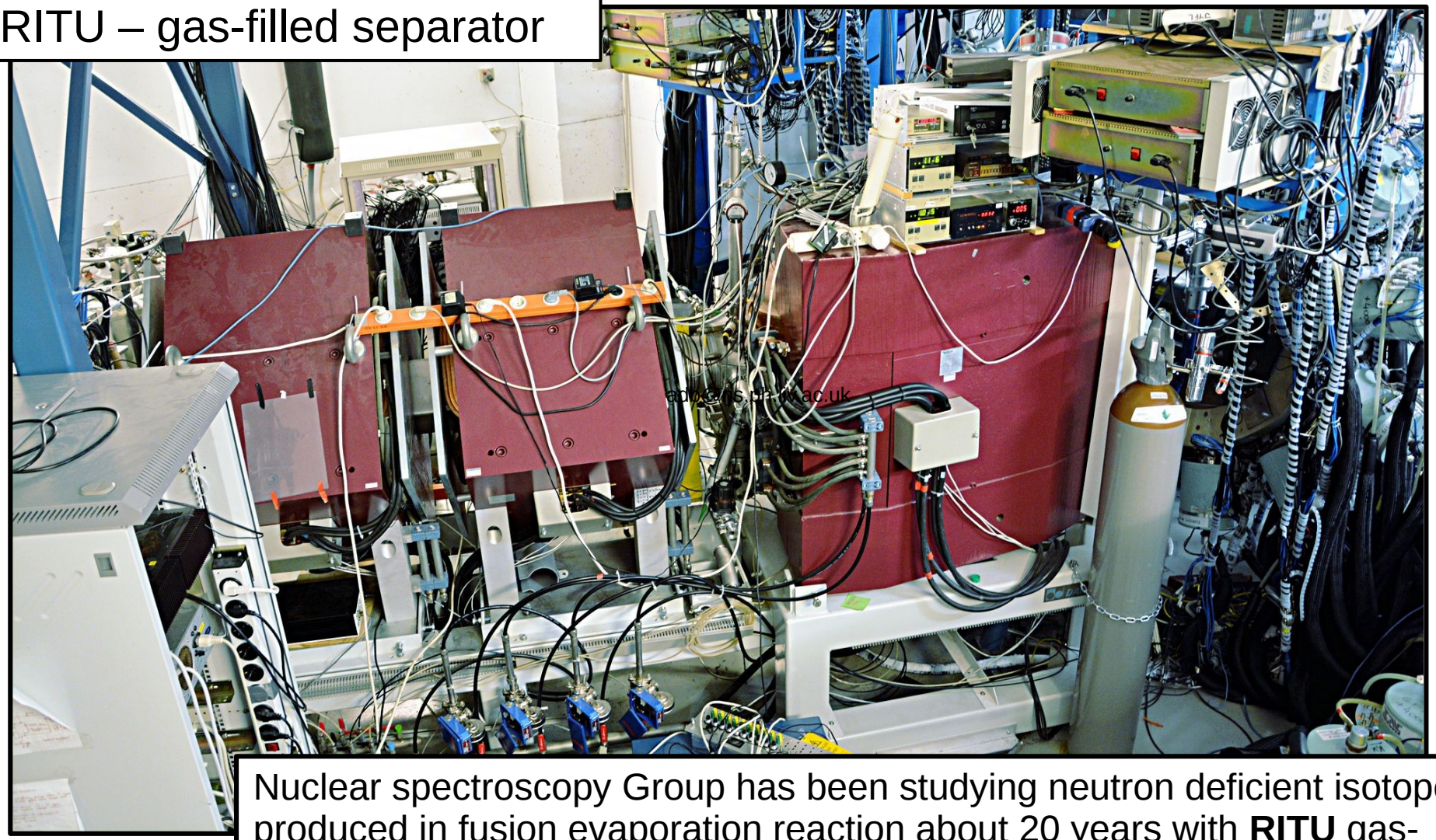
How the experiment is actually run?

The latest experiments…

The first experiments…

RITU – still excellent separator to study A>150 nuclei via fusion evaporation

RITU – gas-filled separator



Nuclear spectroscopy Group has been studying neutron deficient isotopes produced in fusion evaporation reaction about 20 years with **RITU** gas-filled recoil separator.

Why building MARA?

There were more interests in the community to study lighter mass nuclei – especially nuclei around N~Z line.

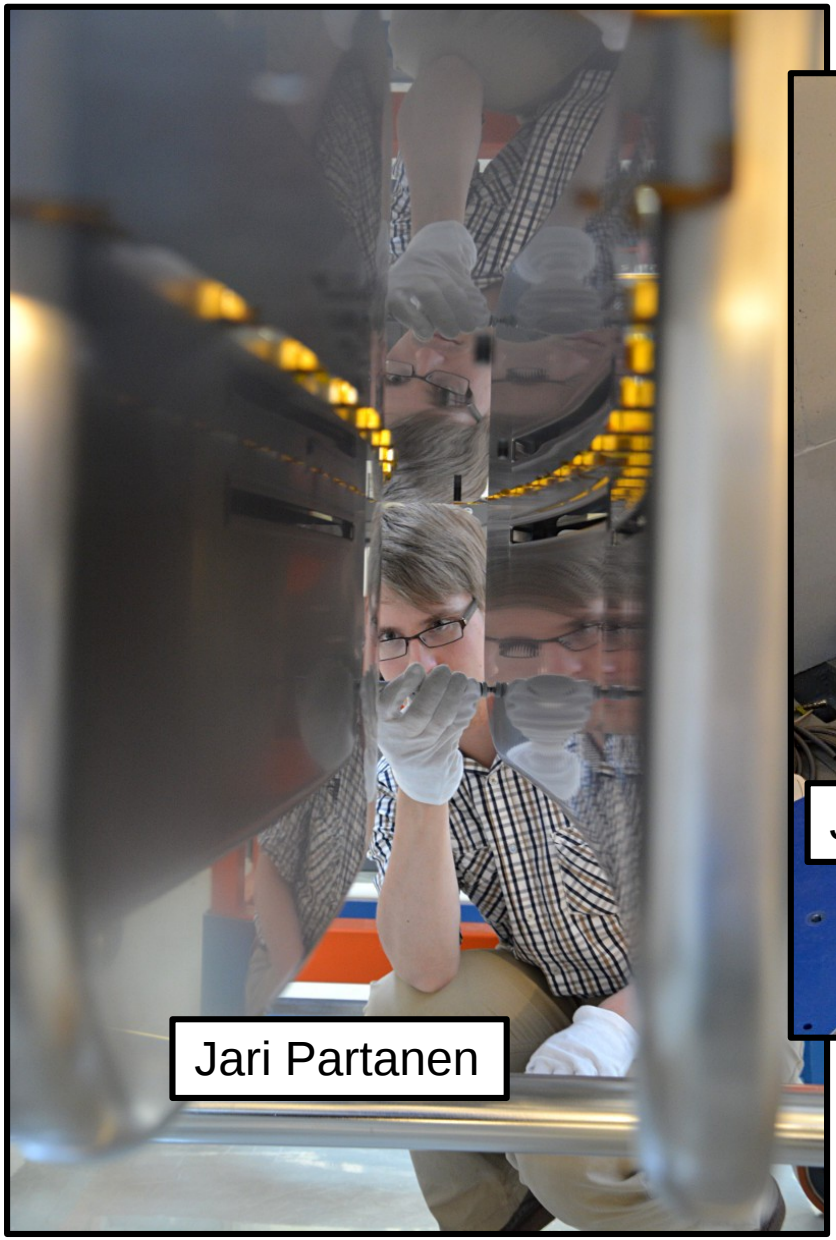
Symmetric fusion reactions (A_{beam}~A_{target}) and inverse kinematics are very often required and a gas-filled separator cannot separate well the primary beam and products.

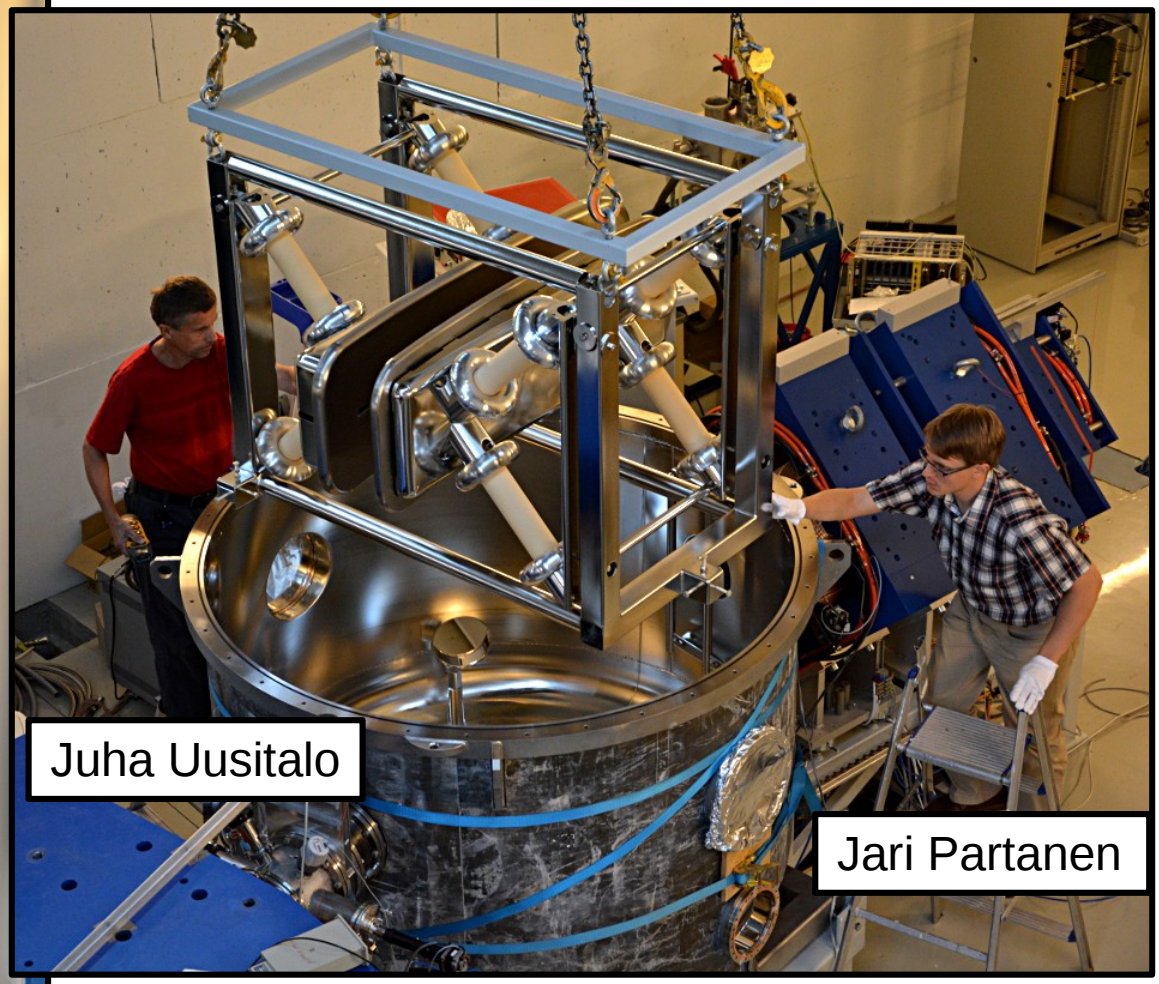
Also the total fusion recoil rate is too high at RITU focal plane.

Beta rates are too high and in order to decrease the random correlations the selectivity of a fusion evaporation channel must be enhanced.

In order to enhance weak interesting channels and confirm the origin, m/q resolution is often needed.

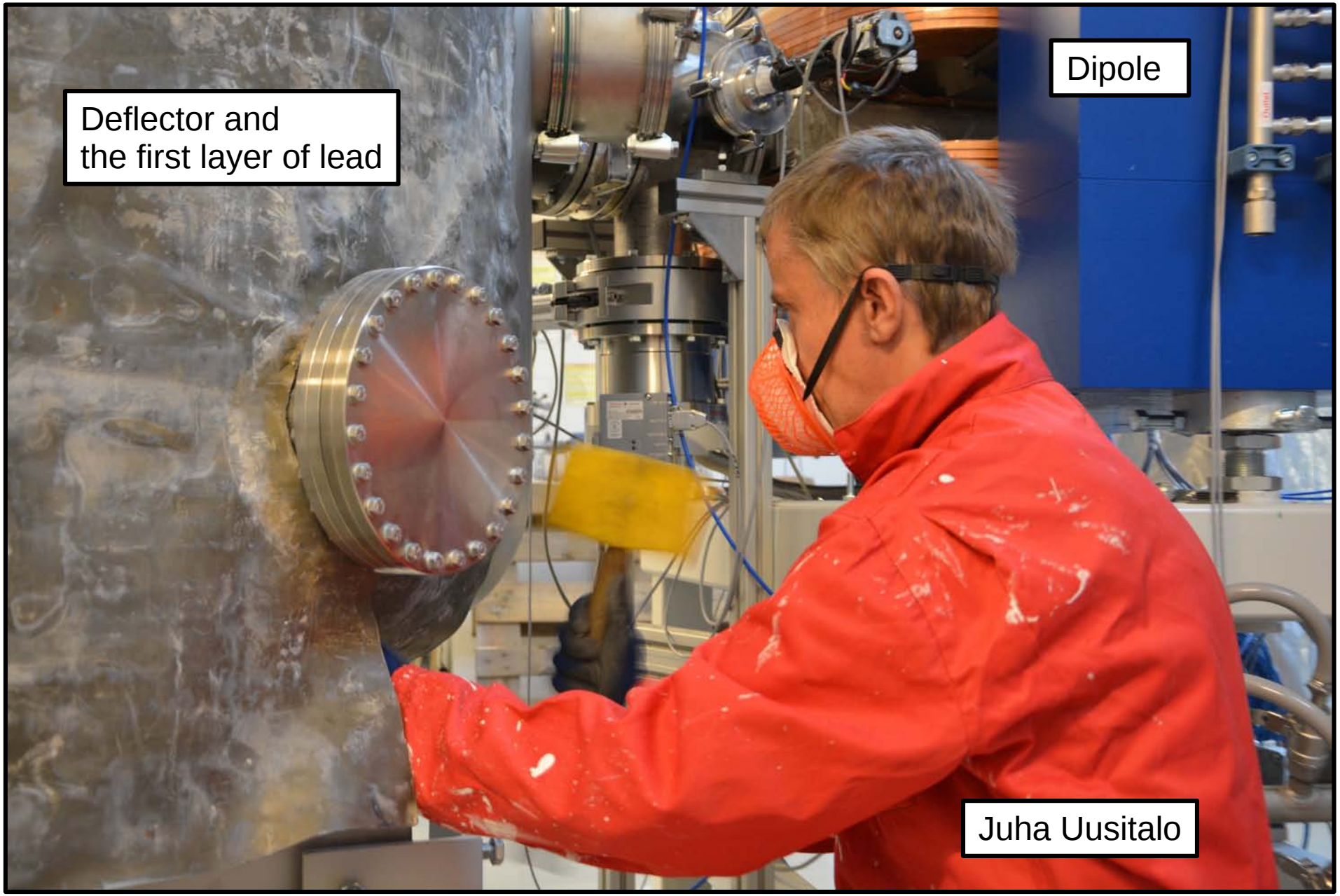
Building MARA



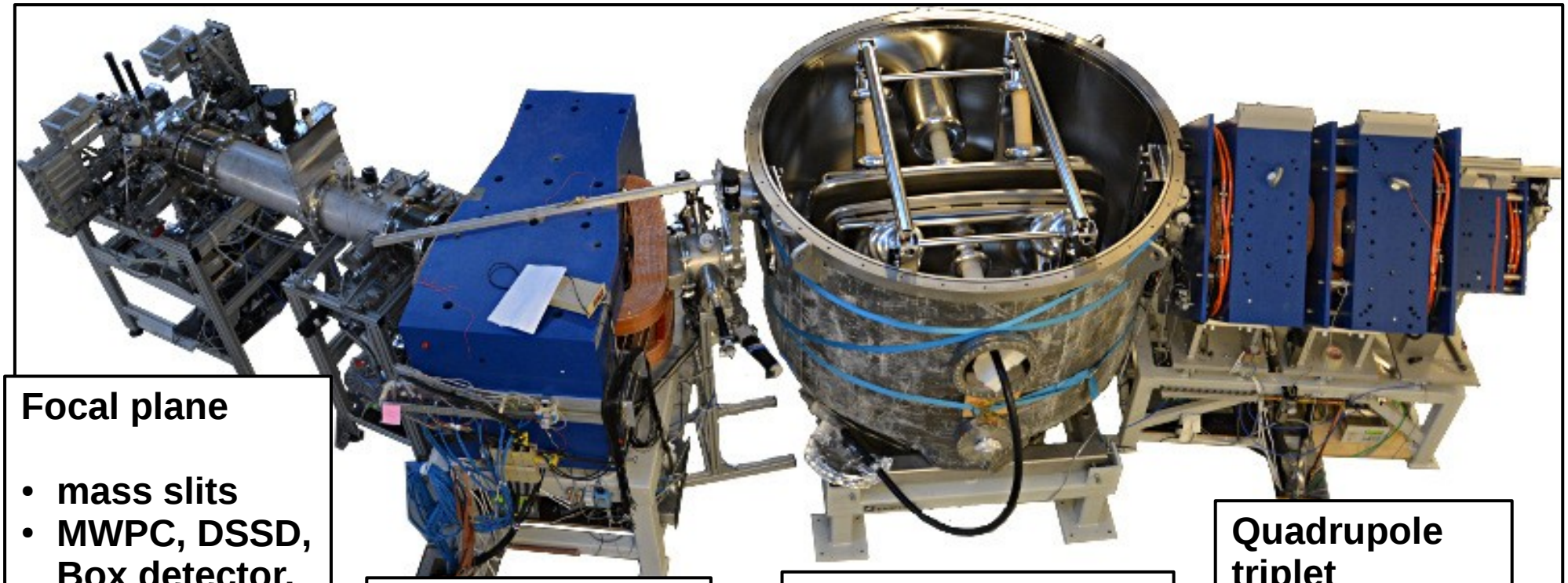


Jan Sarén always behind the camera

Building MARA



MARA – Mass Analysing Recoil Apparatus



Focal plane

- **mass slits**
- **MWPC, DSSD, Box detector, Punch through detector and Ge array**
- **In future: a dedicated beta detector**

Magnetic dipole

- **1 T, 1 m radius**
- **adjustable surface coils to change focal plane position**

Electrostatic deflector

- **beam separation**
- **+- 230 kV, 4 m radius**
- **split anode and a beam dump**

Quadrupole triplet

- **scalable first order resolving power**

Accepted proposals

M2	run	Beta-delayed proton decay of ^{77}Zr	J. Uusitalo
M3	run	Beta-delayed proton decay of ^{69}Kr	D. Jenkins
M4	run	Study of MEDs in the mass 95 mirror pair ^{95}Cd/^{95}Ag	R. Wadsworth
M5		Deformation of ^{140}Dy; daughter of the deformed ^{141}Ho Proton Emitter using Fast timing with a compact array of LaBr3 detectors at the MARA focal plane	D. Cullen
M6		Proof of principle test of lifetime measurements using charge plunger at MARA	Nara Singh
M7	run	Decay spectroscopy of extremely neutron deficient Ce, La and Ba isotopes including a search for the new isotopes ^{116,118}La and $^{117\text{-}120}$Ce	B. Cederwall J. Uusitalo
JM1		In-beam study of excited states of ^{107}Te using recoil-decay tagging with JurogamIII and MARA	B. Cederwall J. Smith
JM2		Identification of excited states in ^{78}Zr	D. Jenkins
JM3		Collectivity and shape phenomena in extremely neutron deficient La, Ce, and Pr nuclei	C. Petrache

M* = decay experiments
JM* = In-beam experiments with Jurogam III

Accepted proposals

JM4	T=0 neutron-proton correlations in ^{94}Ag	M. Bentley R. Wadsworth
JM5	Isoscalar neutron-proton pairing in N=Z nuclei ^{84}Mo and ^{88}Ru	P. Ruotsalainen C. Scholey
JM6	Excited states in the highly deformed proton emitter ^{131}Eu	D. Joss J. Uusitalo B. Cederwall
JM7	Feasibility test of a lifetime measurement in ^{74}Rb using the plunger and recoil-β tagging technique	B.S. Nara Singh
JM8	Isospin Symmetry and Shape Coexistence in Mirror Nuclei ^{71}Kr-^{71}Br	A. Boso D. Jenkins
JM9	Search for the isoscalar spin-aligned pairing scheme in self-conjugate ^{96}Cd	B. Cederwall B.S. Nara Singh

M8 run	Search for charged-particle radioactivity from ^{160}Os	R. Page
M9 will be run on October	Search for the beta-delayed proton emitters ^{133}Gd and ^{132}Eu	J. Uusitalo D. Joss

Accepted proposals

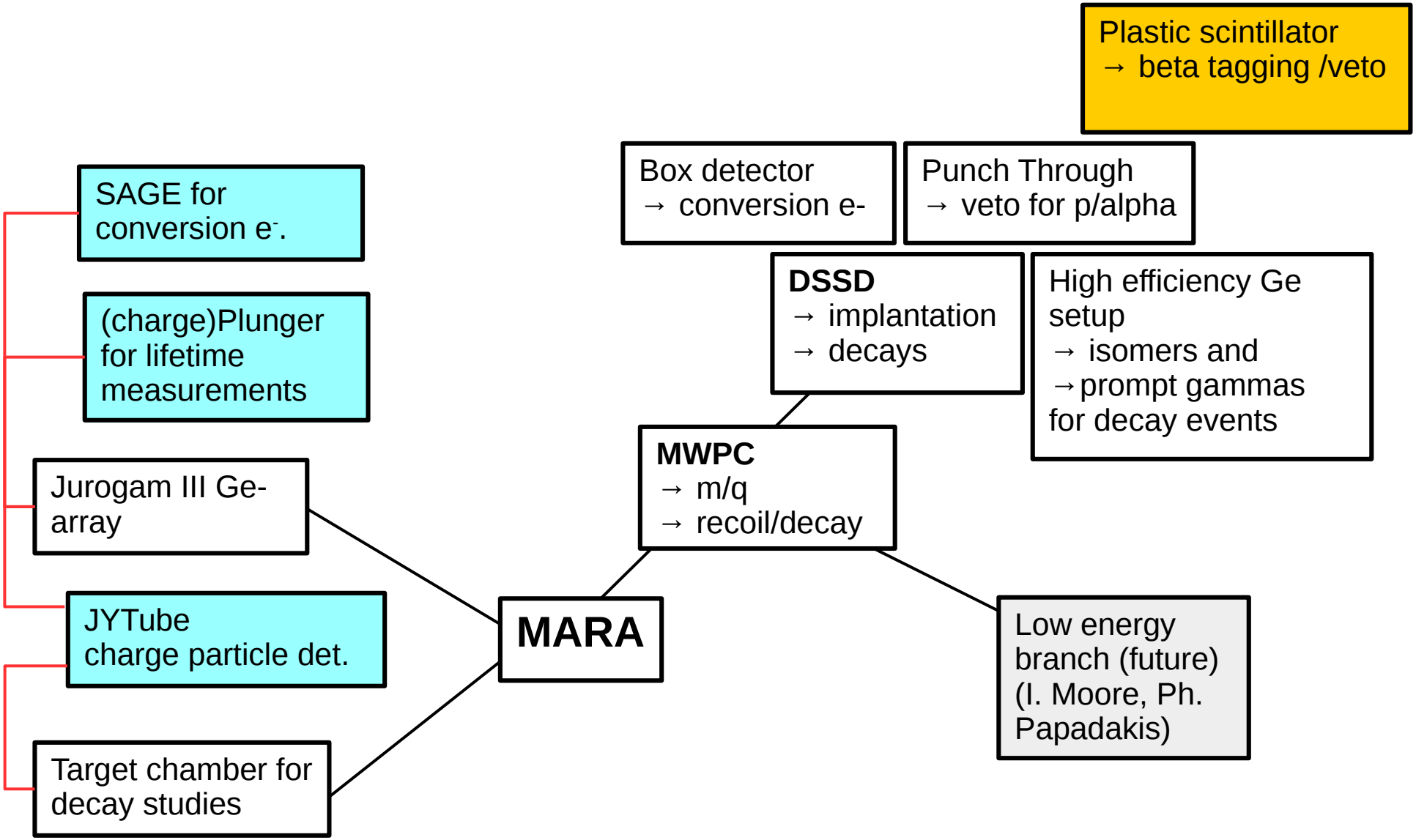
JM10	Isospin-breaking effect in the A=62 isobaric triplet: In-beam recoil-beta tagging study of ^{62}Ge and ^{62}Ga employing MARA	P. Ruotsalainen J. Uusitalo
JM11	Mirror energy differences in A=43: a tool to pin down the nature of cross-shell excitations	S. Lenzi A. Boso
JM12	Disentangling proton-neutron pairing modes in heavy N~Z nuclei	F. Recchia
JM13	Simultaneous lifetime measurements in ^{50}Fe, ^{50}Mn and ^{50}Cr isobaric analogue nuclei using DPUNS and recoil-β tagging technique to investigate isospin symmetry breaking	B.S. Nara Singh M. Giles

M12	Systematic measurement of proton-decay energies	R. Page
M13	The influence of the proton-neutron interaction and the evolution of E2 transition rates in A~150, N~82 isotones using fast-timing measurements at the focal plane of MARA	B.S. Nara Singh D. Cullen

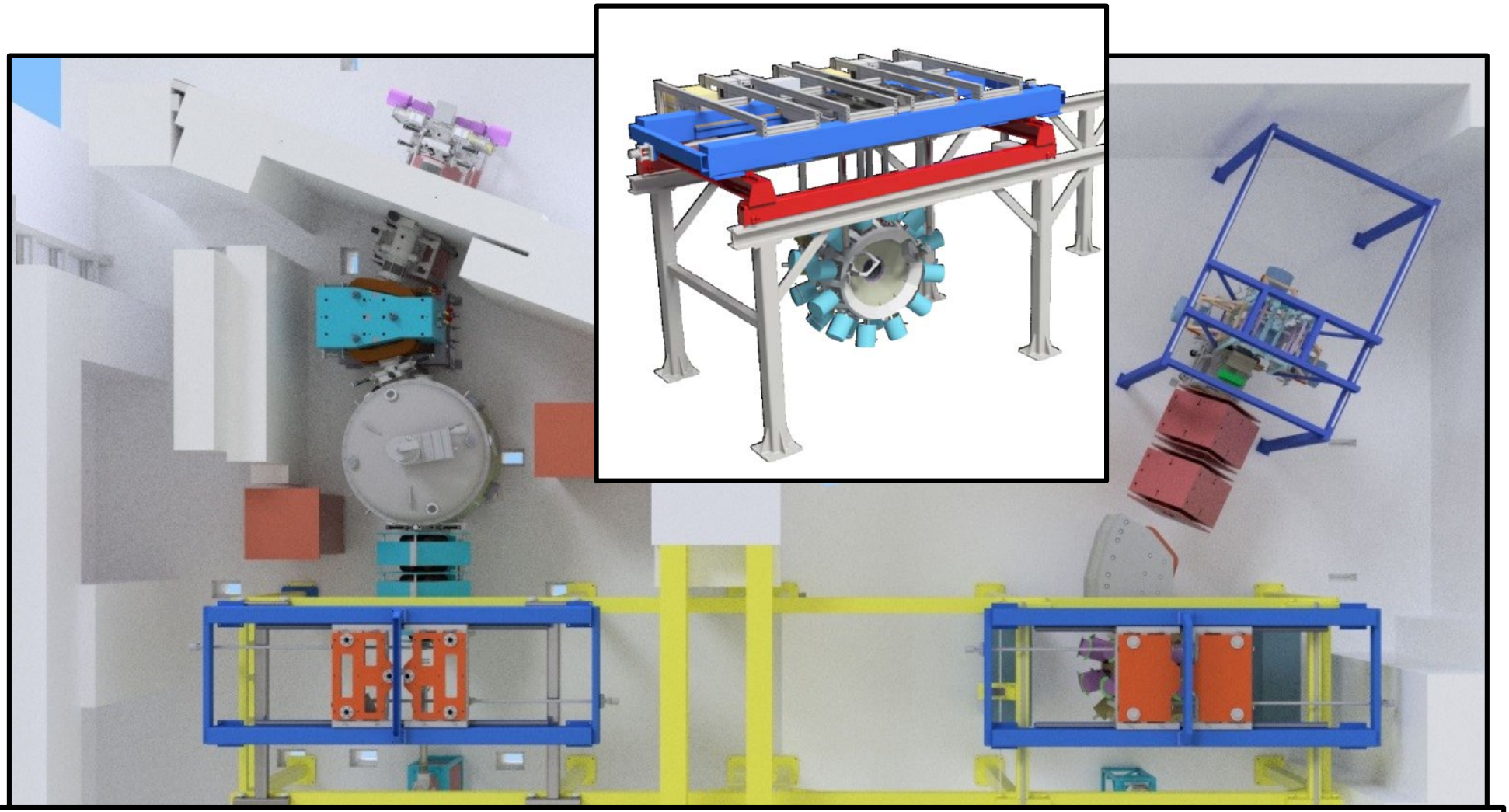
S24	In-beam spectroscopy of ^{190}Pb using the SAGE spectrometer at the MARA separator	J. Pakarinen

In total ~**230 days** of beam time approved for MARA proposals! More is coming since this does not include proposals of the last PAC call.

Running an experiment – detectors

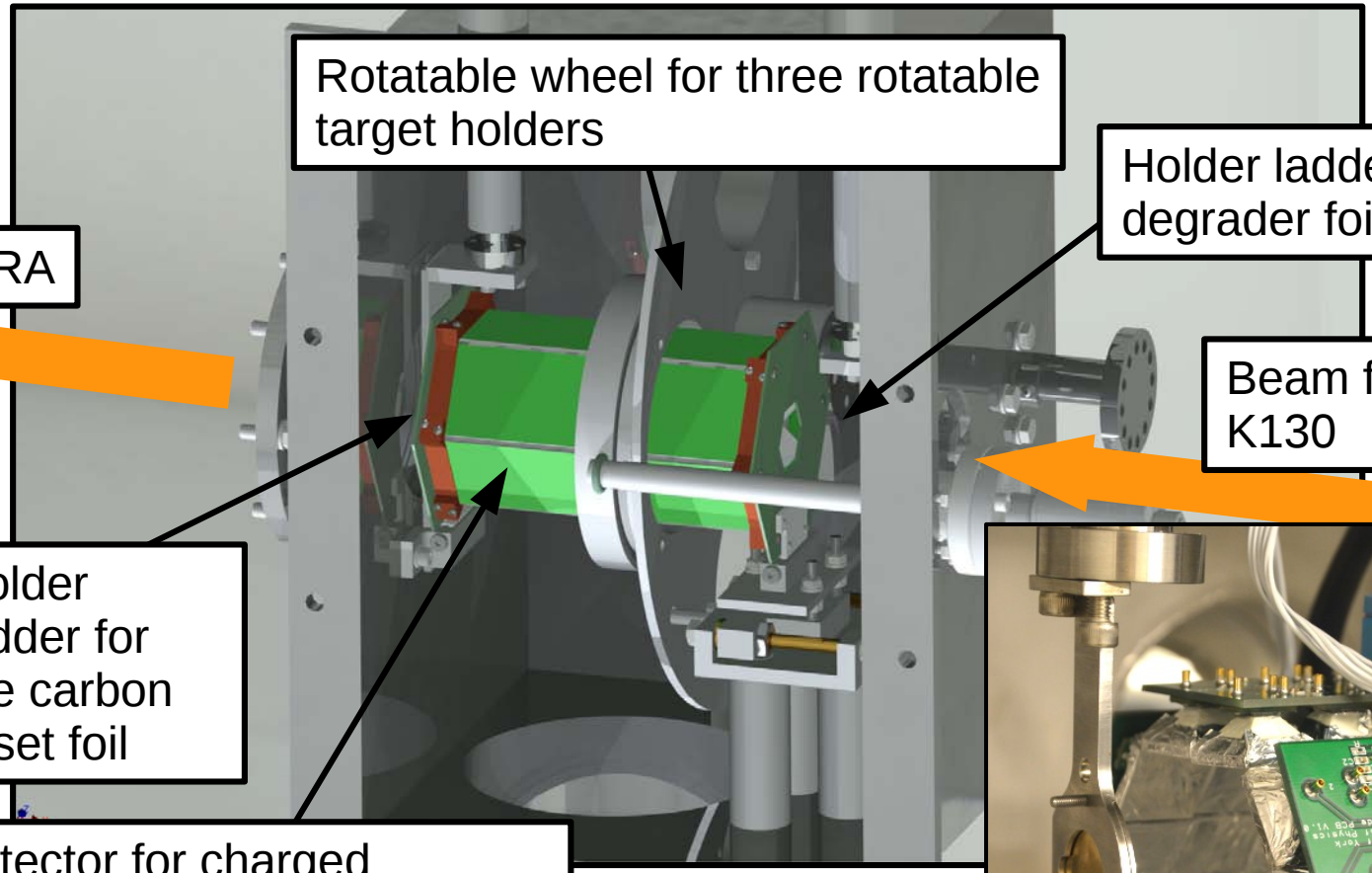


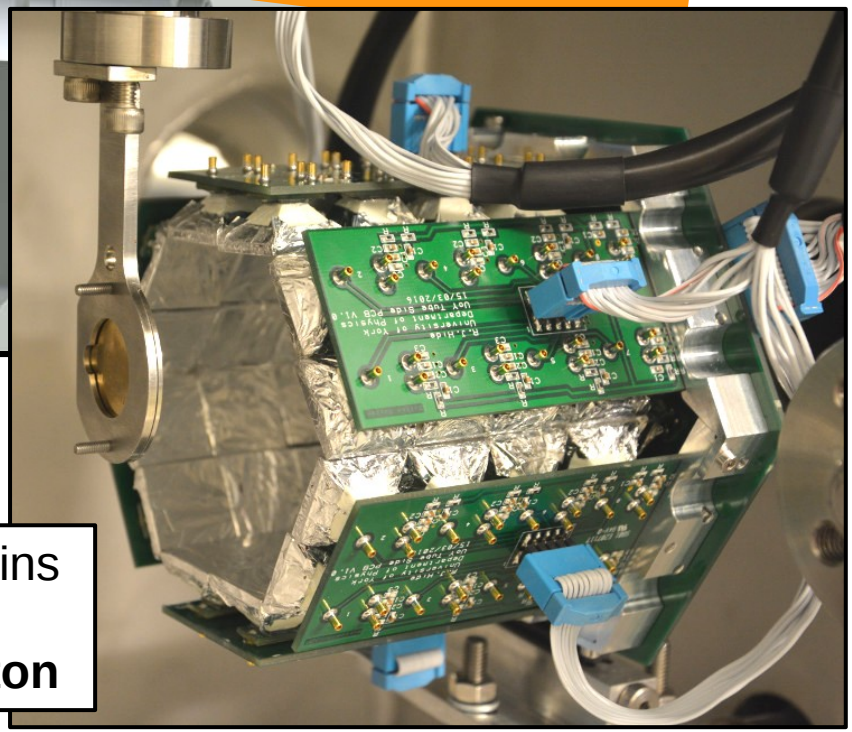
Running an experiment – detectors @ target



A crane system able to move the Jurogam III germanium array between the neighbouring RITU and MARA separators is almost ready. In-beam experiments with JUROGAM+MARA will start late this year.

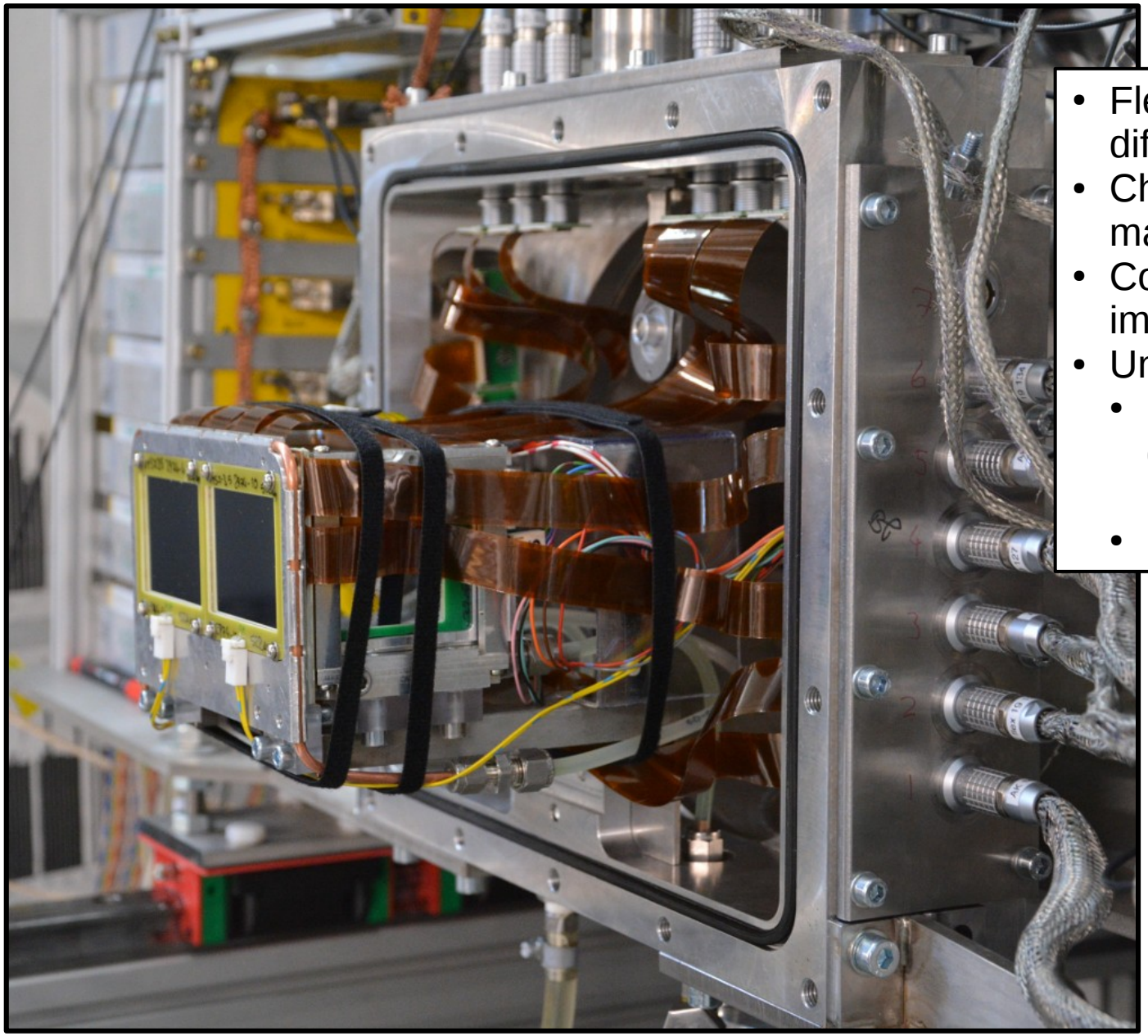
Running an experiment – detectors @ target





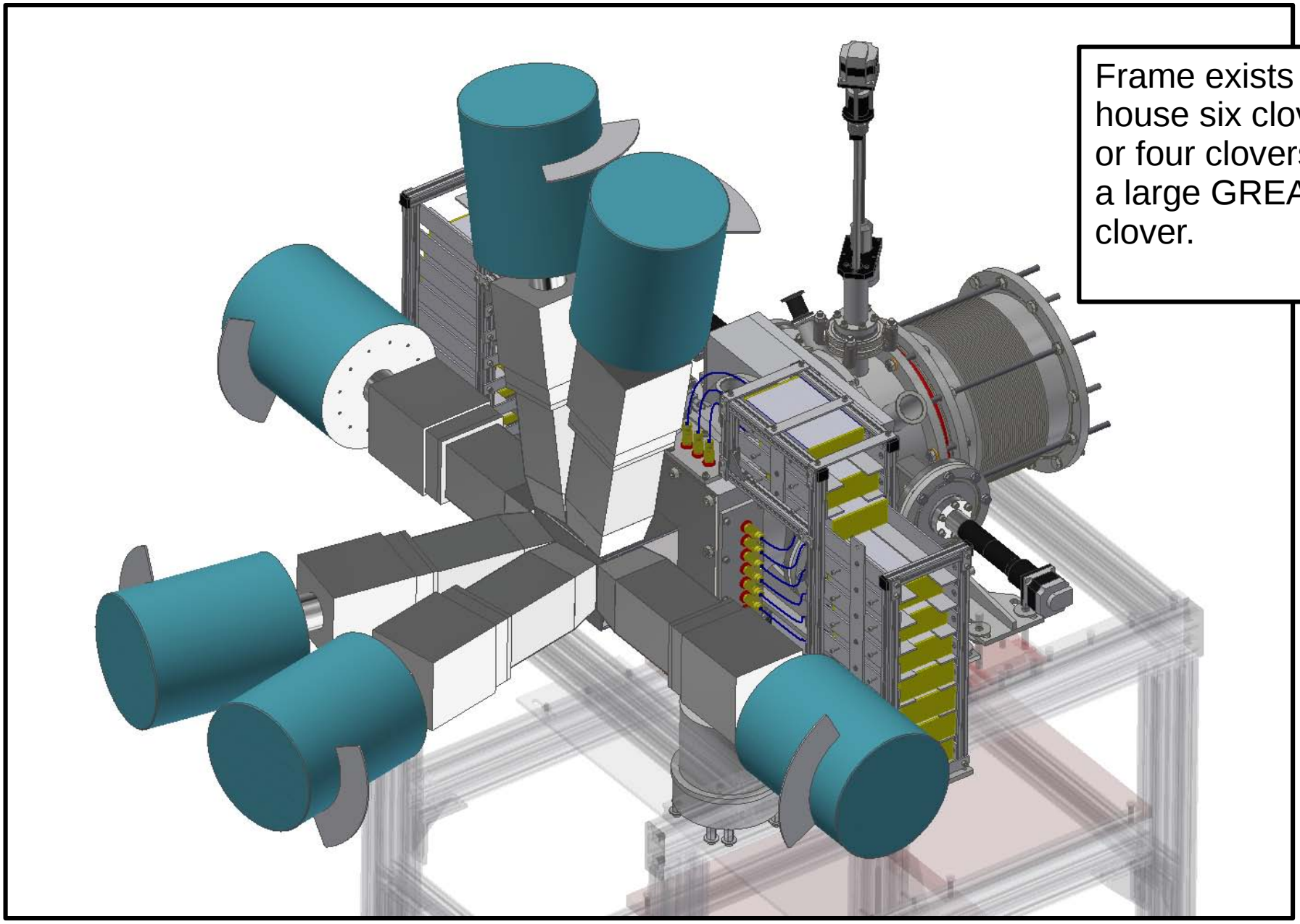
JYTube in co-operation with D. Jenkins et al., University of York
Veto efficiency ~70 % for one proton

Running an experiment – detectors @ focal plane



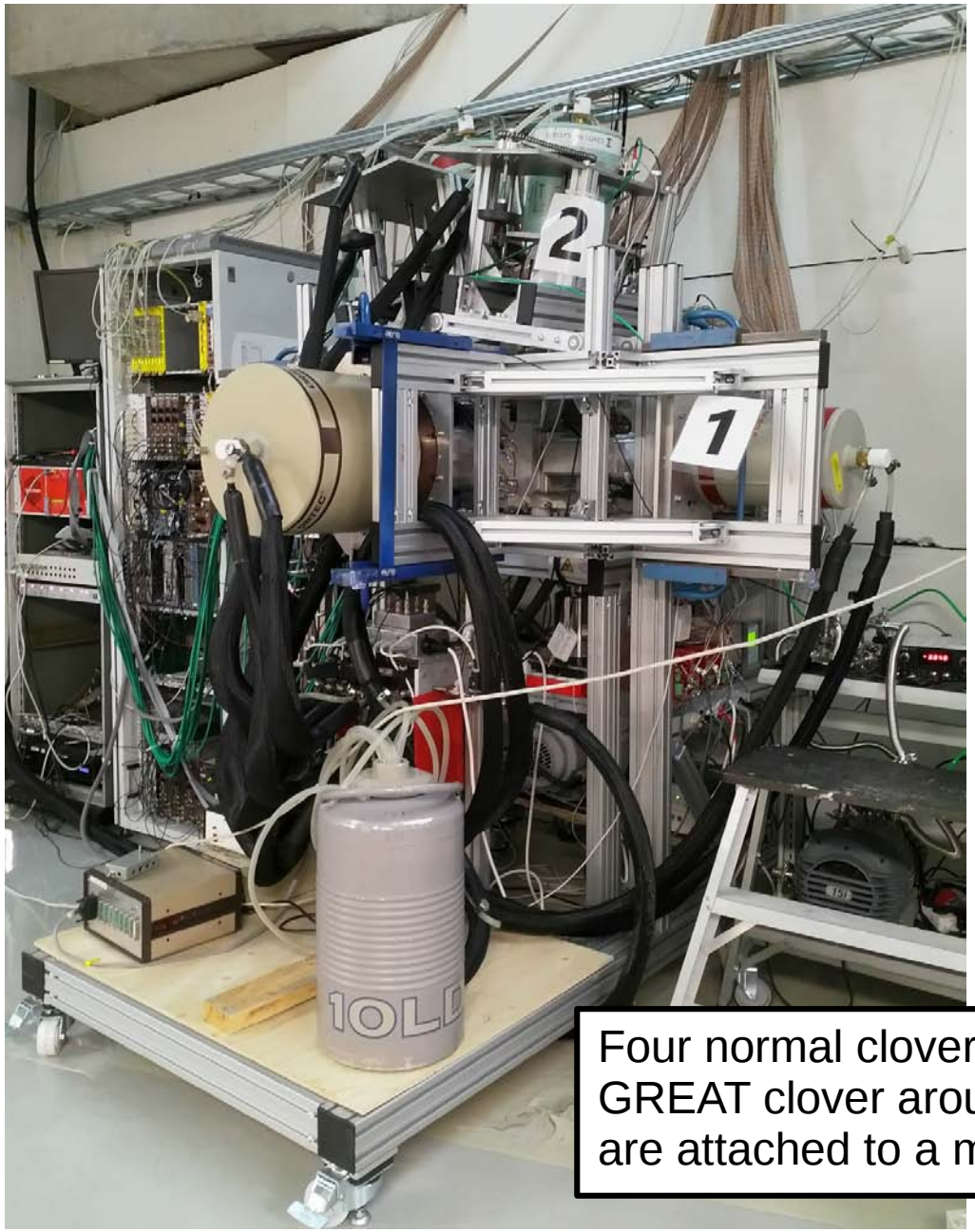
- Flexible for needs set by different experiments
- Chamber designed and manufactured at JYFL
- Compact design to improve efficiencies
- Under development:
  - low energy gamma detectors (2-3 large BEGe detectors)
  - Plastic beta detector

Running an experiment – detectors @ focal plane



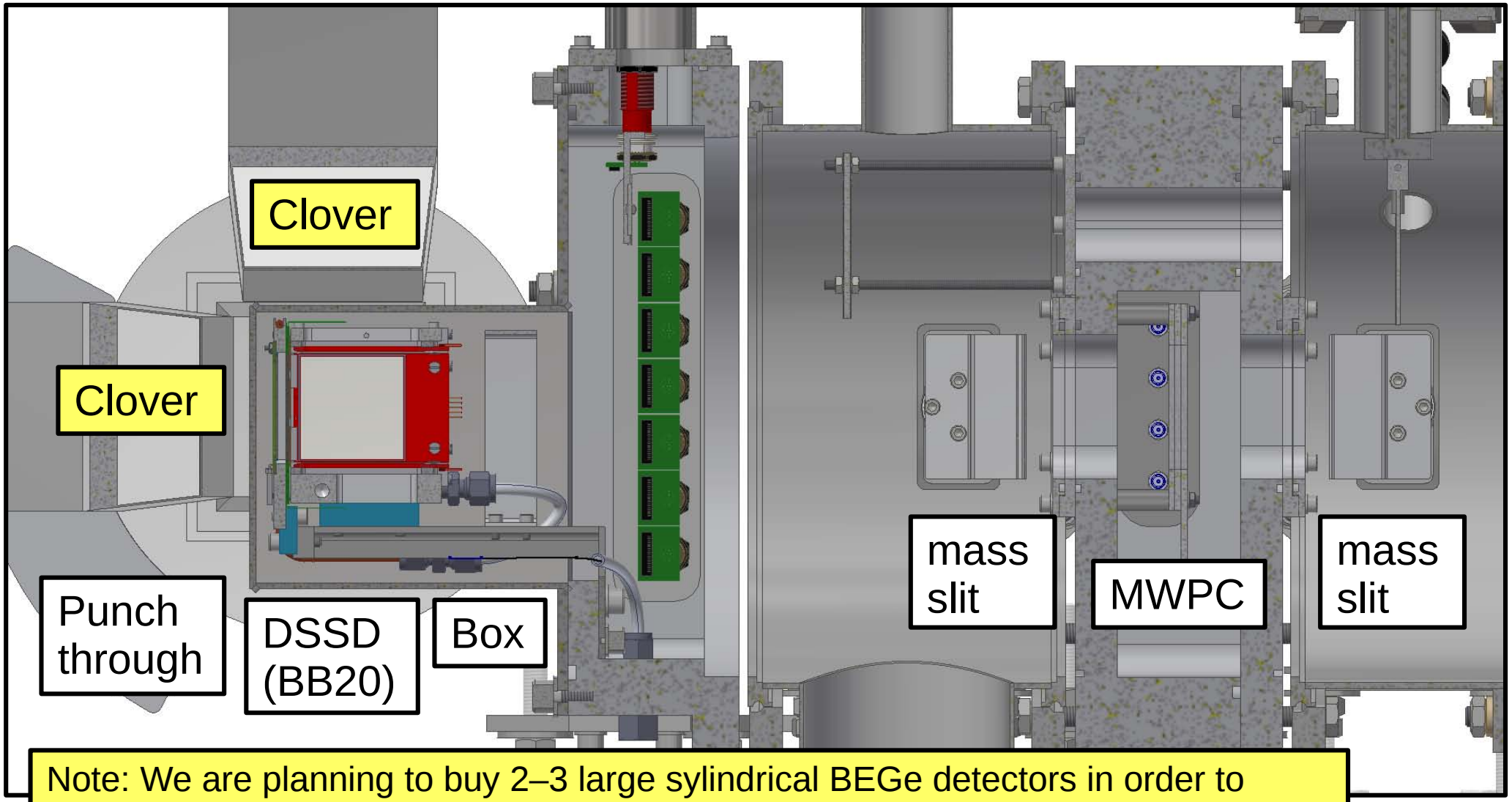
Frame exists to house six clovers or four clovers and a large GREAT clover.

Running an experiment – detectors @ focal plane



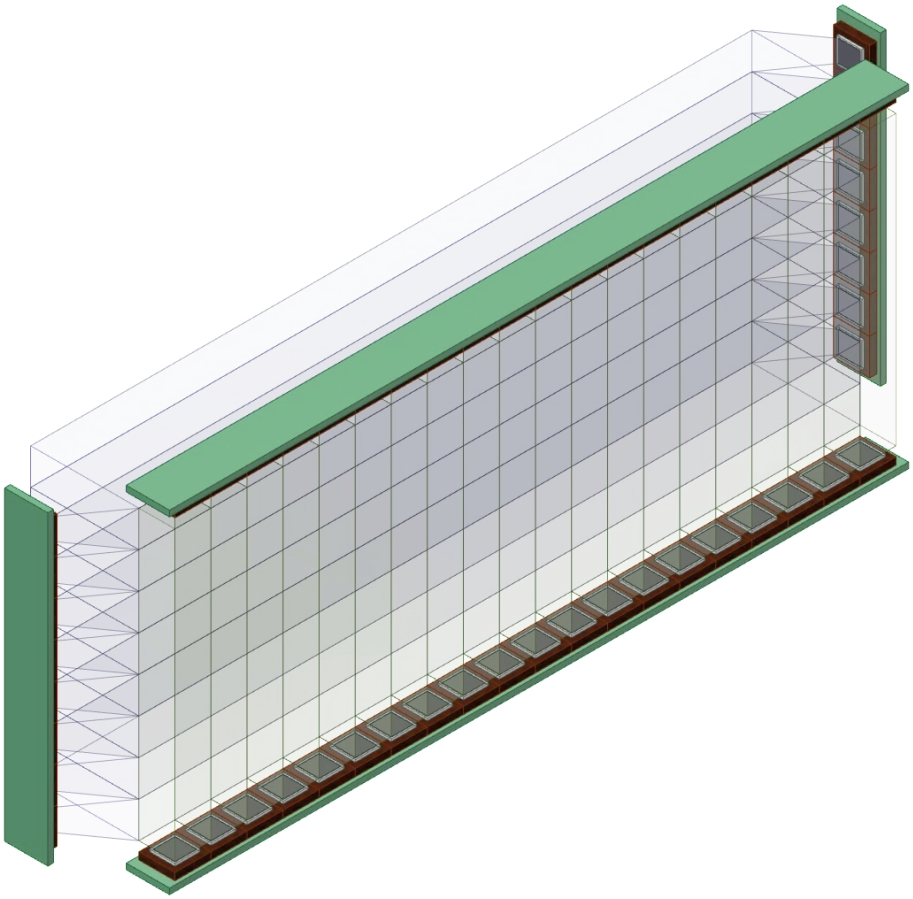
Four normal clovers and the big GREAT clover around the DSSD. All are attached to a movable frame.

Running an experiment – detectors @ focal plane



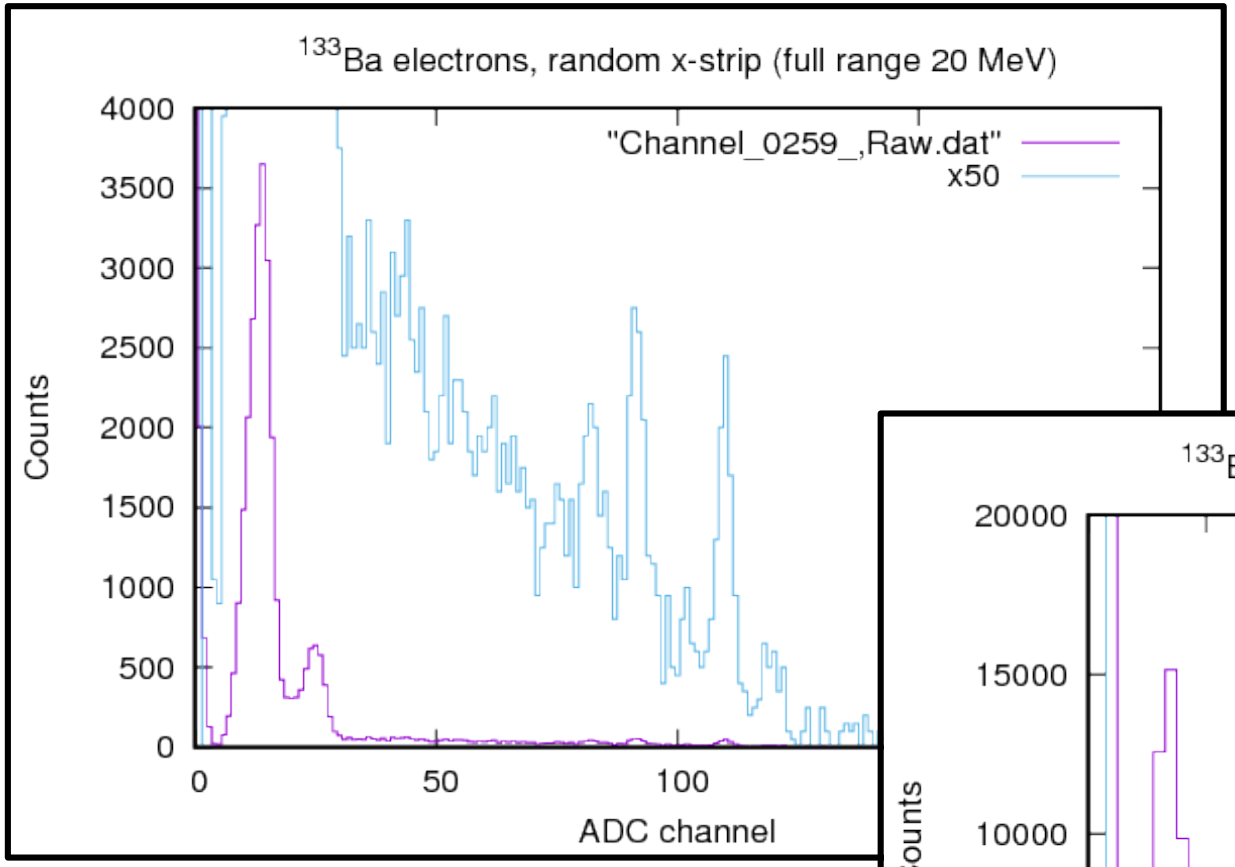
Note: We are planning to buy 2–3 large sylindrical BEGe detectors in order to enchance the low energy performance. Funding of detectors is mostly secured.

Beta detector for beta tagging experiments (under design)

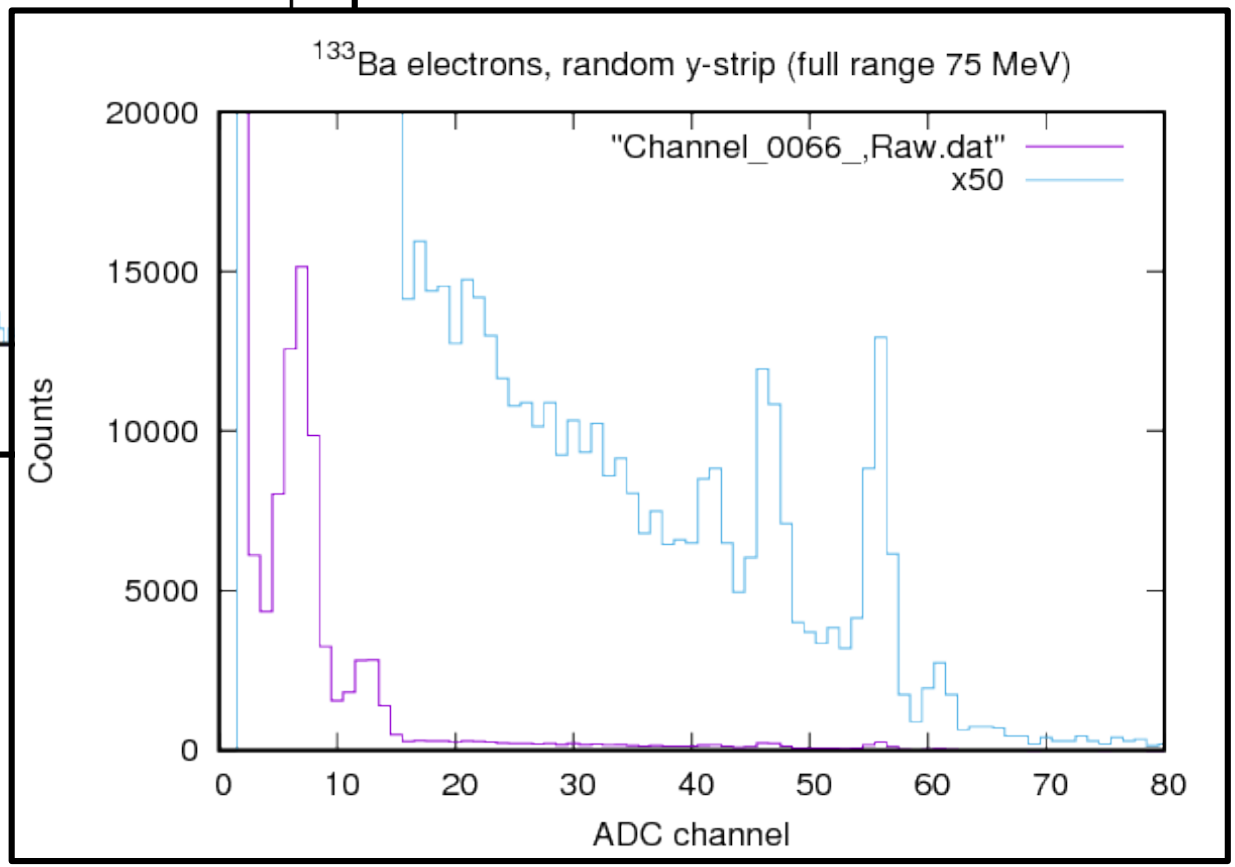


- Project started spring 2018
- Source tests in progress (master thesis project)
- Preliminary thickness about 4 cm.
- Two layers of plastic bars:
  - 1*1*H cm^3 vertical bars → x-position
  - 1*3*W cm^3 horizontal bars → y-position for high energy betas
- activated zinc sulfide phosphor (ZnS:Ag) applied to the entrance side → discrimination between punch through particles (p/alpha) and betas
- Light readout by SiPM chips
- Energy information with a gated integrator run in the digital ADCs.
- Beta tagging: selecting a high energy beta particles to enhance selectivity of a fusion recoil of interest
- Final detector should be ready to use on summer 2019.

Running an experiment – detectors @ focal plane: Micron BB20 (128x72 strips DSSD, 0.67 mm strips)



High dynamic range of the DAQ achieved: we are able to see conversion electrons even when using the full 120 MeV range.

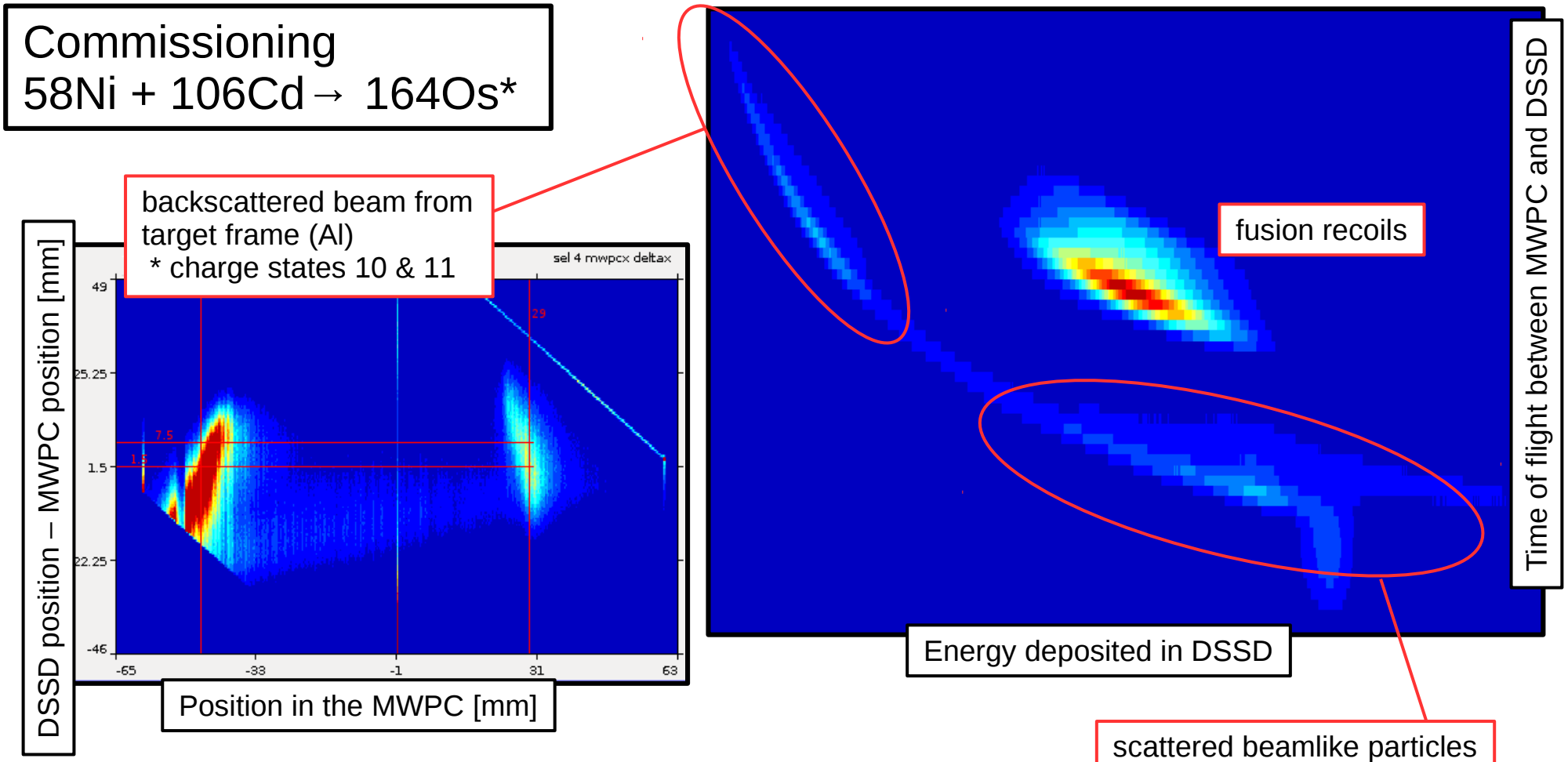


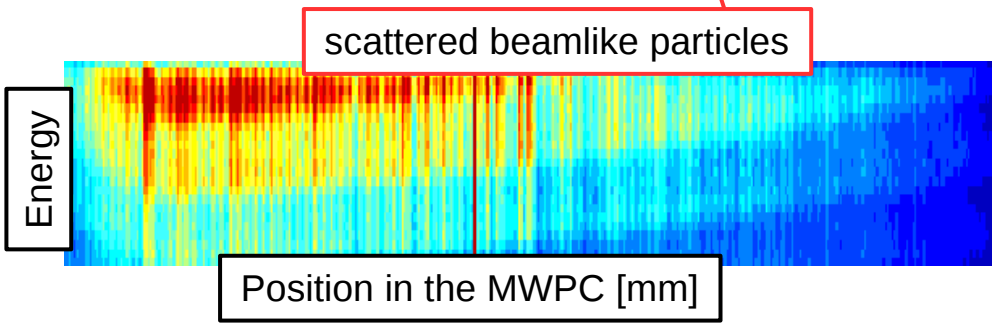
BB20 is promising:

- Threshold around 45 keV.
- Typically all strips working!
- Resolution (FWHM) around
  - ~20 keV for alphas
  - ~9 keV for electrons

Running an experiment: background (beamlike)

Commissioning
58Ni + 106Cd → 164Os*

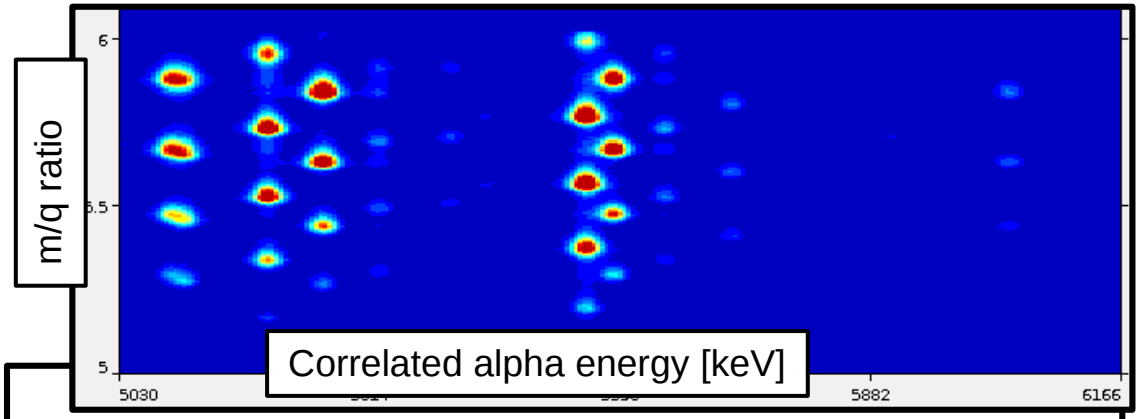


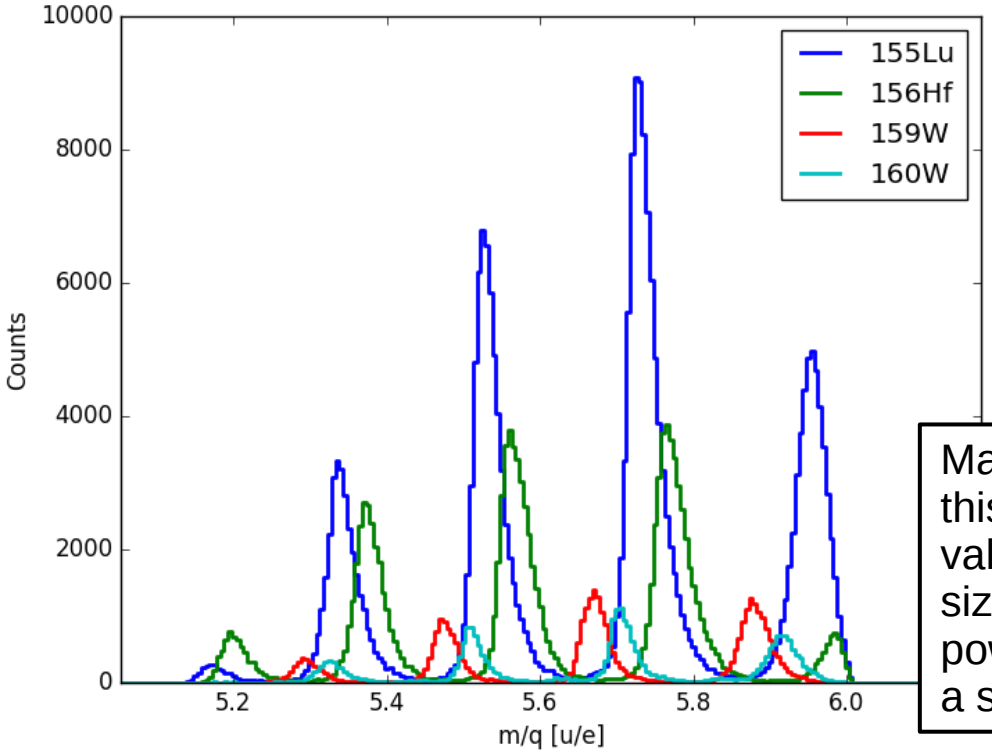


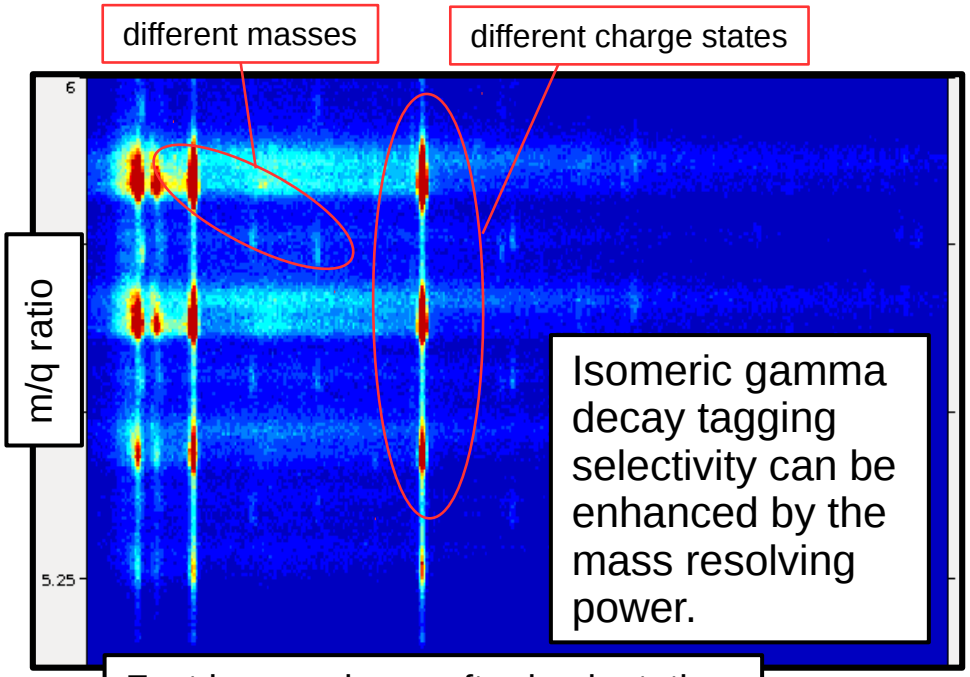
These are the main background types seen in the commissioning experiments. Rate of these have been about the same as the rate of fusion recoils. The backscattered beam m/q peaks might be slightly challenging in some experiments.

Running an experiment: m/q resolution

Commissioning 58Ni + 106Cd → 164Os*







Isomeric gamma decay tagging selectivity can be enhanced by the mass resolving power.

Fast isomer decay after implantation, Gamma ray energy

Mass resolving power of 140-150 was obtained in this reaction. By careful tuning one can reach value around 200. MRP is affected by beam spot size and aberrations. If required, mass resolving power can be increased by apertures or by using a so called high resolution mode.

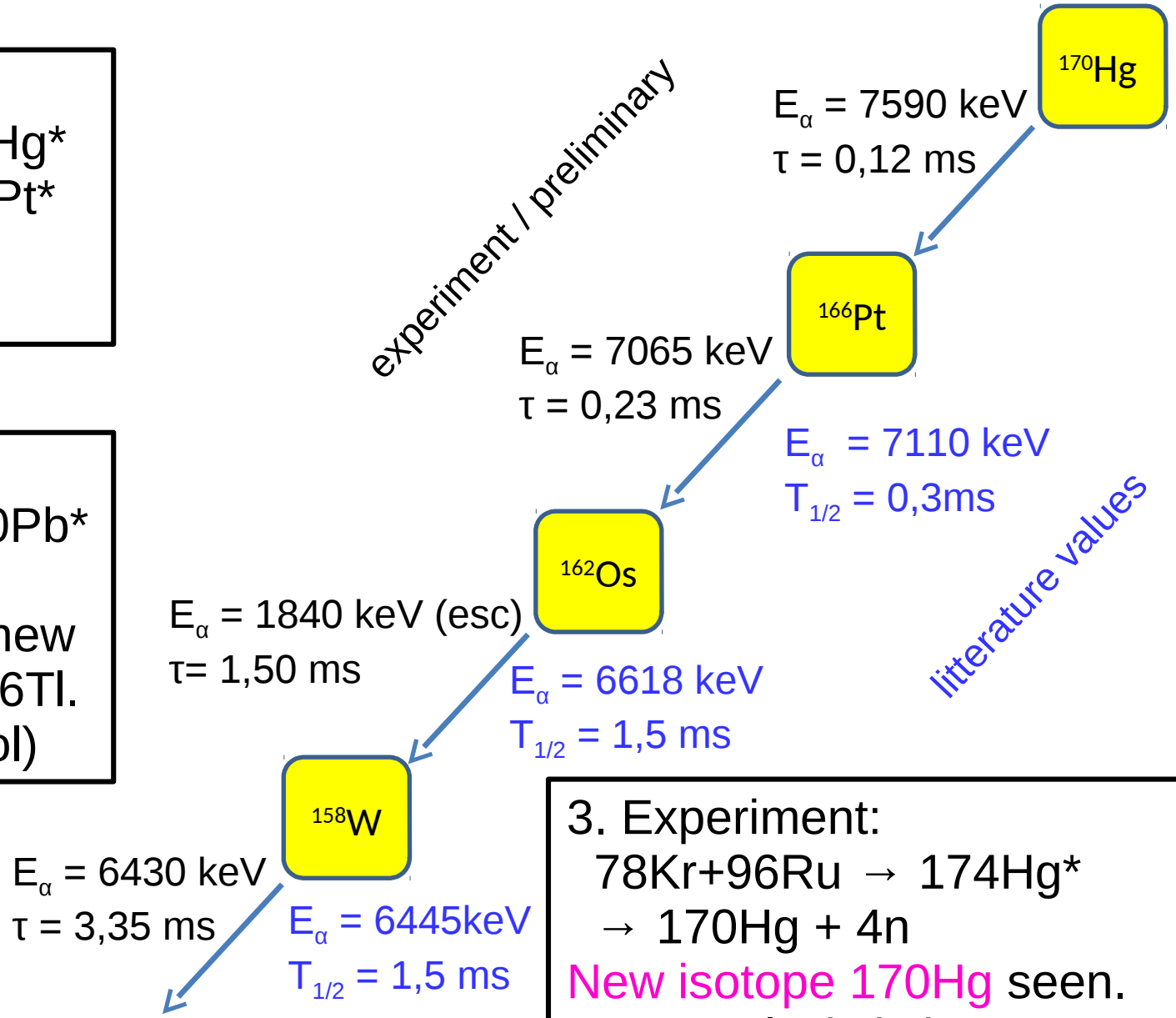
First experiments (original RITU experiments) ;-)

1. Experiment:
   78Kr+96Ru → 174Hg*
   78Kr+92Mo → 170Pt*

Two new isotopes, 169Au and 165Pt

2. Experiment:
   78Kr+102Pd → 180Pb*
   → 176Tl + p3n

We got some some new information about 176Tl. (M. Alaqeel, Liverpool)



3. Experiment:
   78Kr+96Ru → 174Hg*
   → 170Hg + 4n

New isotope 170Hg seen. Data analysis is in progress.

Difficult 3n evaporation experiment (M02-M04) ;-(

M02:
40Ca+40Ca → 80Zr* → 77Zr + 3n

Failed to see enough βp. We reached 10-50 nb level in sensitivity. 3n excitation curve is unknown. Data should be checked carefully. (J. Uusitalo)

M03:
32S+40Ca → 72Kr* → 69Kr + 3n

Failed to see enough 69Br βp. We reached 10-50 nb level in sensitivity. 3n excitation curve is unknown. (D. Jenkins)

M04:
58Ni+40Ca → 98Cd* → 95Cd + 3n

MARA was working very well. Total yield and mass distribution close to PACE4 calculations. Problems to understand low yield of 95Ag (problems in data-analysis?) A proper analysis ongoing… (U. Forsberg)

Latest experiments ;-)

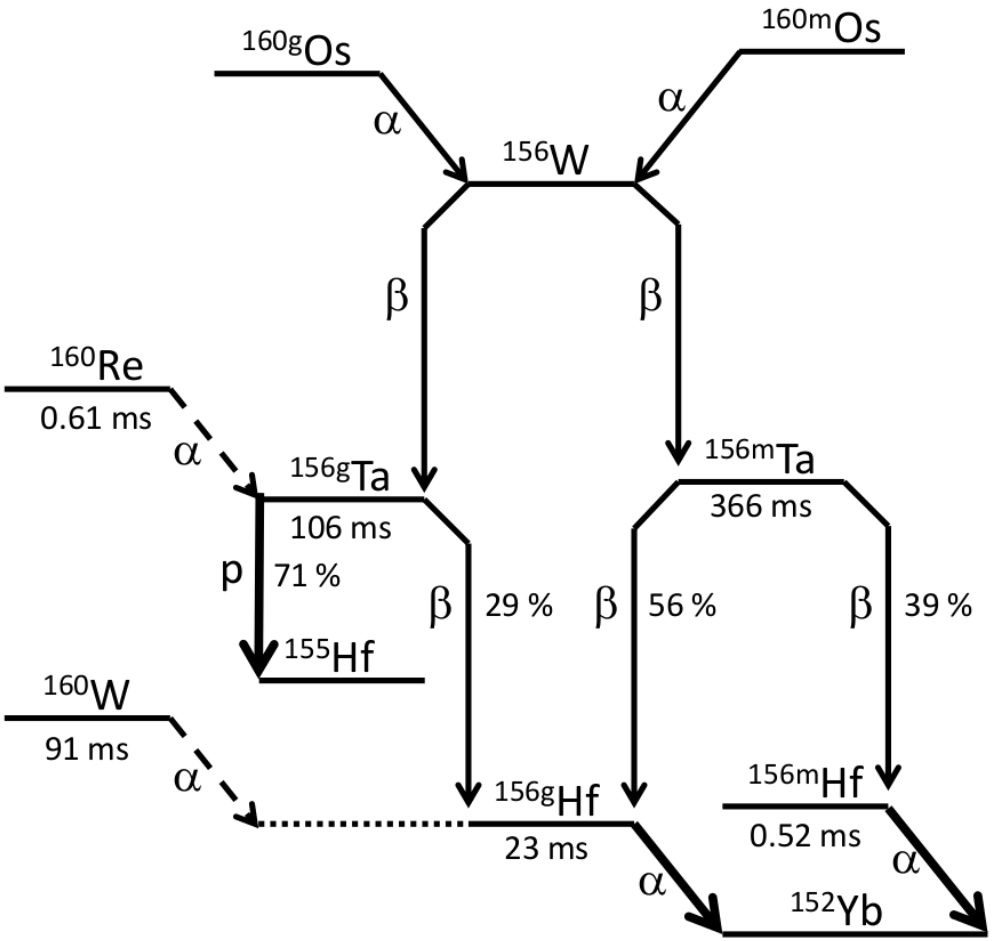
M08 (R. D. Page):
58Ni+106Cd → 164Os*
→164Os + 4n

Experiment was succesful. Two new alpha emitting isotopes 160Os and 156W were produced. Alpha decays were observed from the 160Os ground state and isomeric state.

Physics outcome:

- Isomeric state energy in 160Os
- Reduced widths for both 160Os alpha decays
- 156W lifetime

Note: alpha decays of isomers in 155Lu, 156Hf and 158W found with SHIP ;)



Analysis in progress (Andrew Briscoe, Robert Page)

Latest experiments ;-)

M07 (Bo Cederwall):
$^{64}Zn + ^{58}Ni \rightarrow ^{122}Ce^*$

Experiment was mostly succesful.

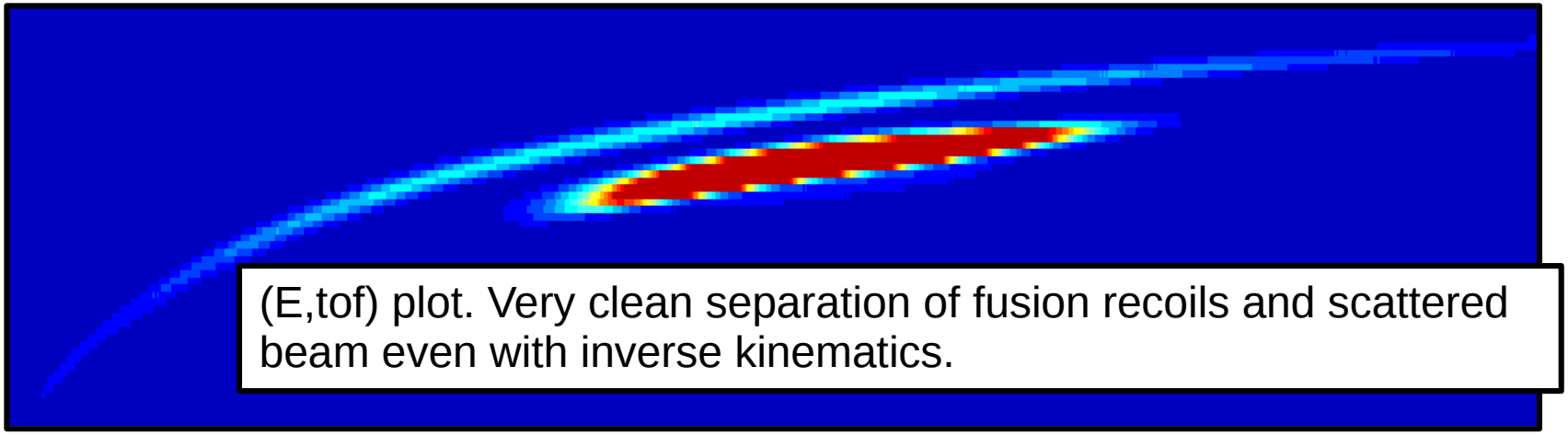
About 3-5 new isomers were found with the efficient focal plane Ge setup. Identification of the isomers were made preliminary with the JYUTube charge particle multiplicity and recoil m/q ratio giving ~Z and ~A, respectively.

New isotopes (light La and Ce) might have been produced but were not observed during the online analysis.

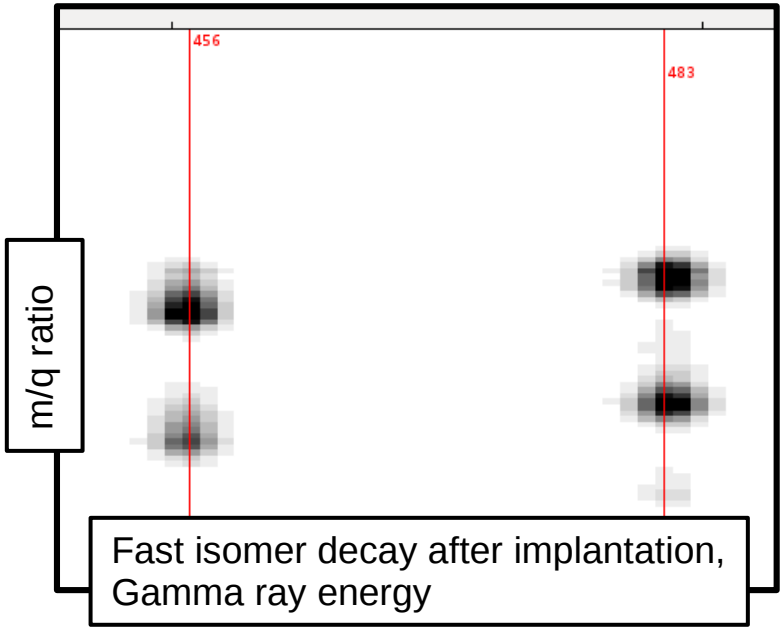
Several beam energies were used. After changing an energy, one day collecting all products with slits open (few pnA) and then allowing only 1-2 masses (up to 10 pnA). MARA was clean: about 80 % of heavy ions implanted were fusion recoils.

Latest experiments ;)

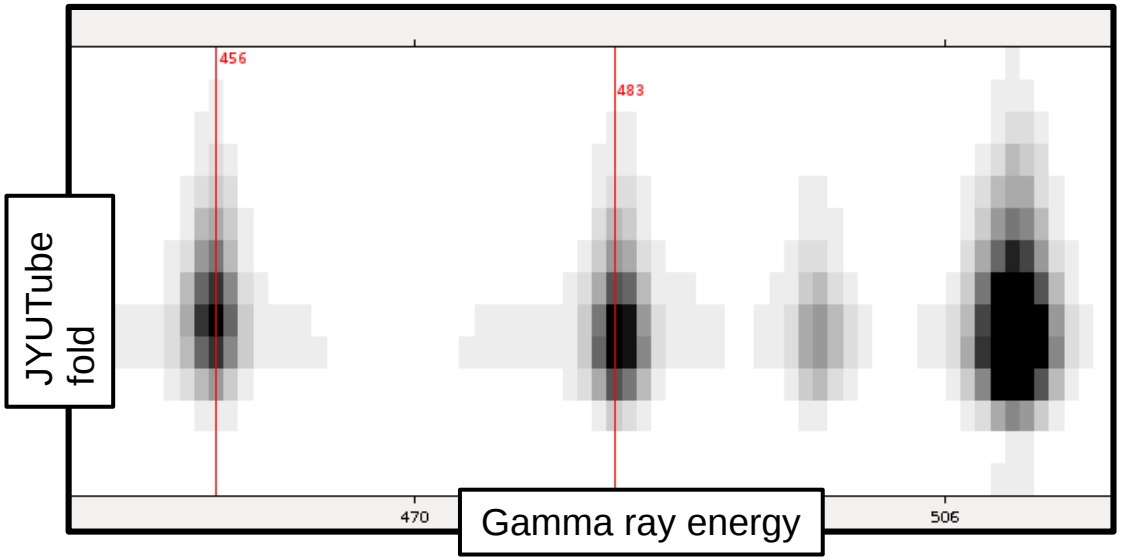
M07 (Bo Cederwall):
64Zn+58Ni → 122Ce*



(E,tof) plot. Very clean separation of fusion recoils and scattered beam even with inverse kinematics.



Fast isomer decay after implantation, Gamma ray energy



Gamma ray energy

Feelings about MARA

MARA is behaving as calculated. More precise comparison to be analysed and published.

Beam suppression is rather good and most of the experiments have had more fusion products than scattered beam particles or other background. Background is understood quite well.

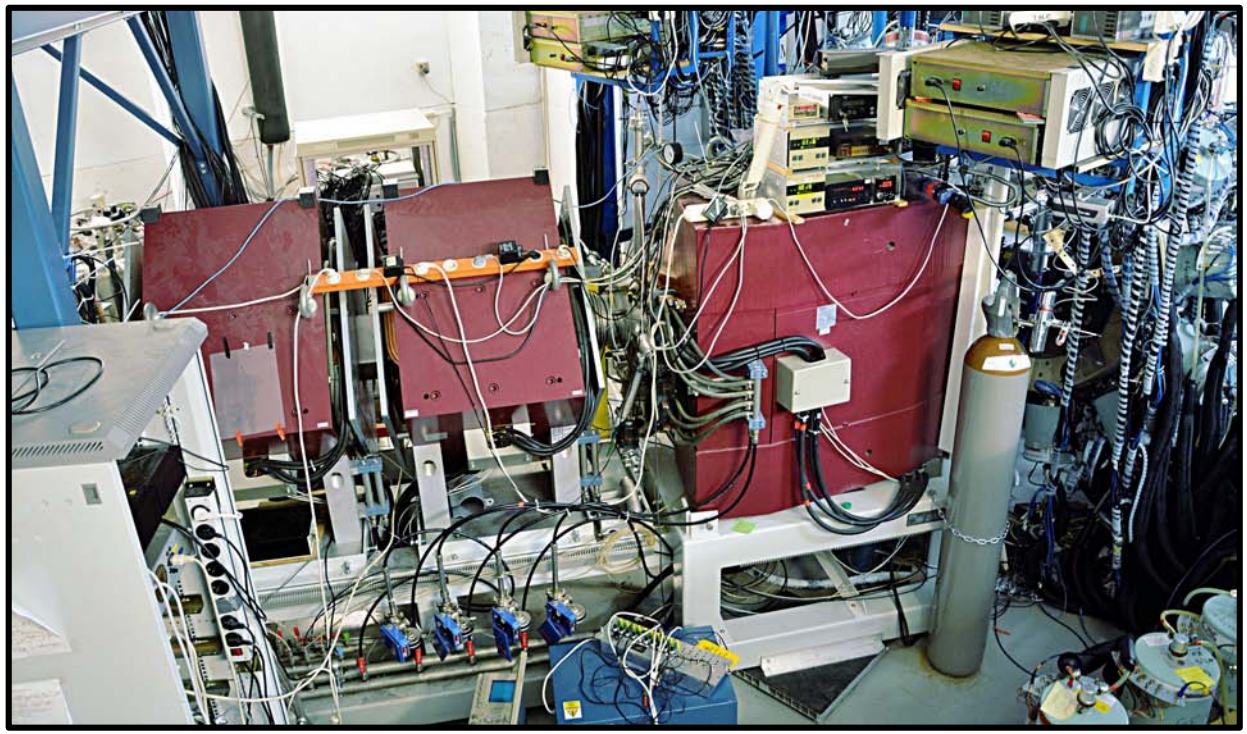
MARA has been working very well in commissioning tests and experiments. Optimal beam tuning has been learnt.

Good experiment set-up and optimization procedures have been learnt.

Mass resolution is not yet fully utilized.

MARA is a promising tool to study exotic nuclei around proton drip-line and around N~Z line. Experiments are very difficult and requires a ”perfect” detector setup.

RITU news



RITU is not forgotten. The plan is to run about 1 year MARA experiments and then use both separatators as experiments requires. In meanwhile, a new focal plane chamber and detector setup will be designed and built (will be mainly a copy of MARA fp).

Things to do

Install thicker mass slits.

Add a secondary center mass slit to improve the cutting of neighbour mass.

Modify the focal plane chamber to house BEGe detectors and optimize the chamber for low energy gammas.

Design and build a plastic beta detector for beta tagging experiments.

Improve the MWPC read out.

MAINTAIN THE SYSTEM AND RUN EXPERIMENTS

Write manuals.

Write the MARA paper ;)

Publish a reaction and transmission code for MARA.

Improve analysing software.

Improve DAQ dataflow.

Understand better the behavior of DAQ when having fast (low energy) decays.

The community

The first MARA workshop, December 2015

The community

The second MARA workshop, January 2017

Thanks

… for you and

… for all the people helping around MARA and doing numerous night shifts!