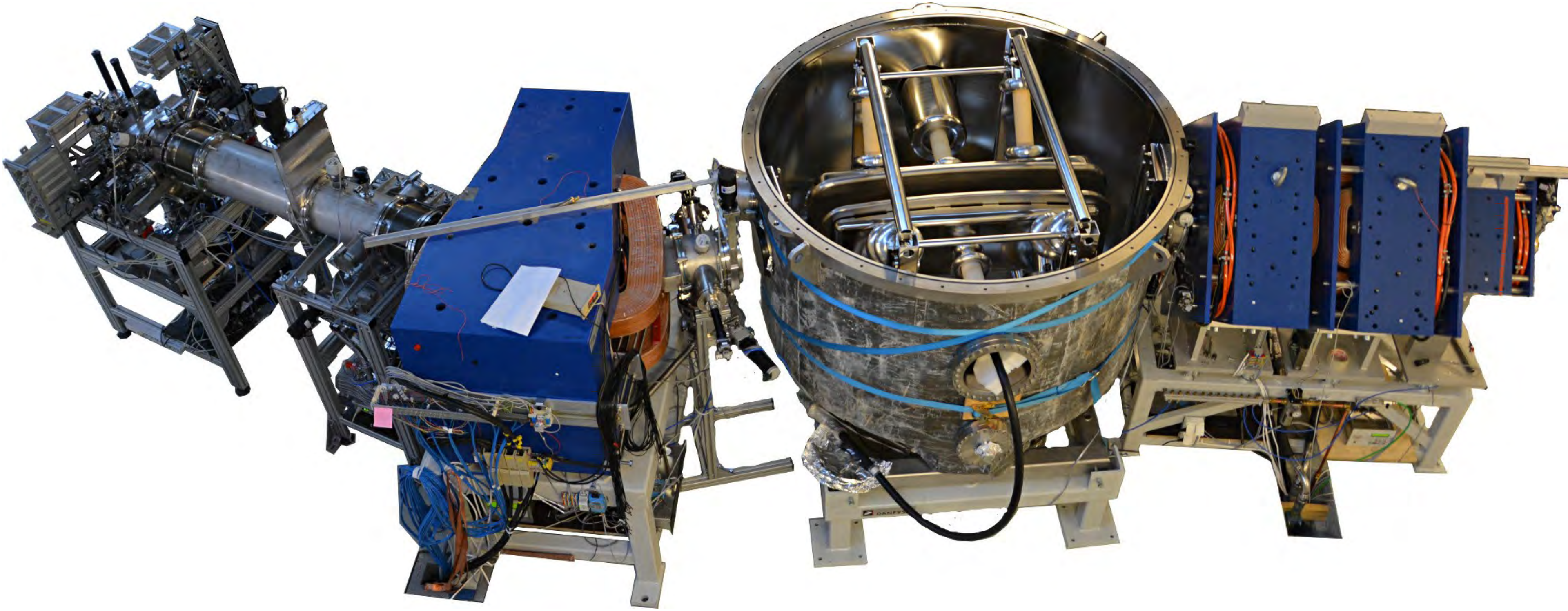
MARA, Mass Analyzing Recoil Apparatus

Jari Partanen, Jan Saren, Juha Tuunanen, Juha Uusitalo



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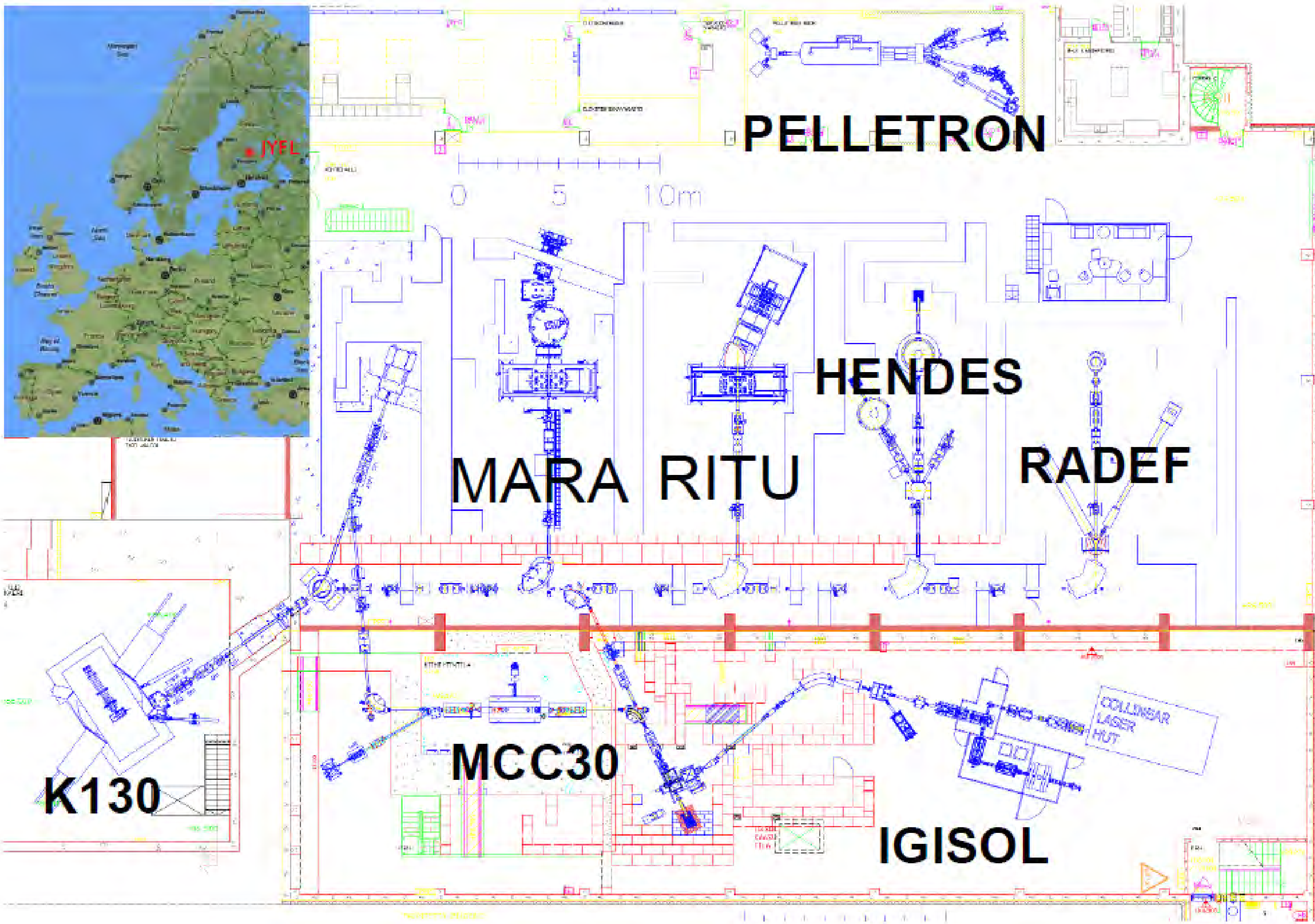
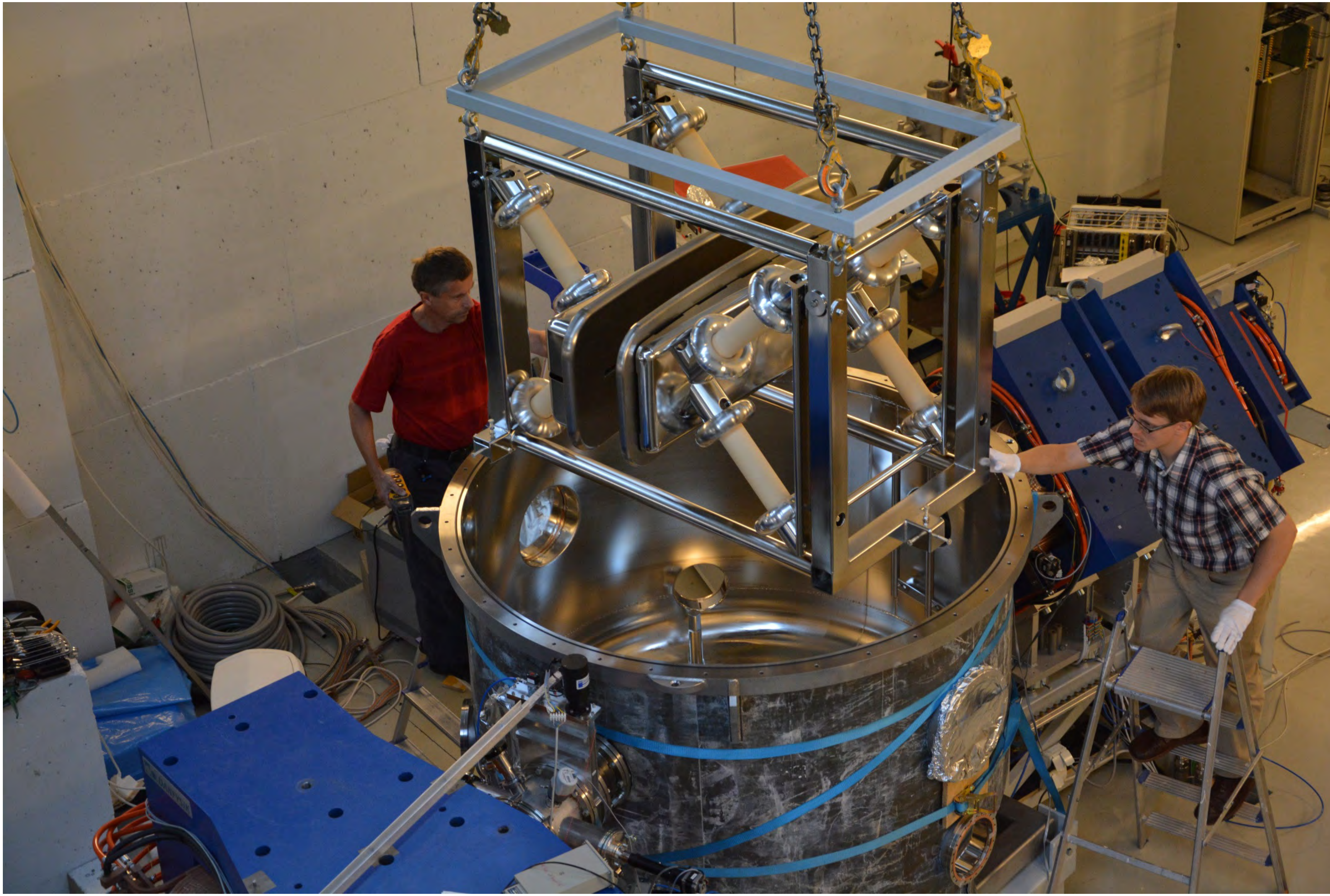

JYFL
PELLETRON
0 5 10m
MARA
RITU
HENDES
RADEF
K130
MCC30
IGISOL
COLLINEAR LASER HUT



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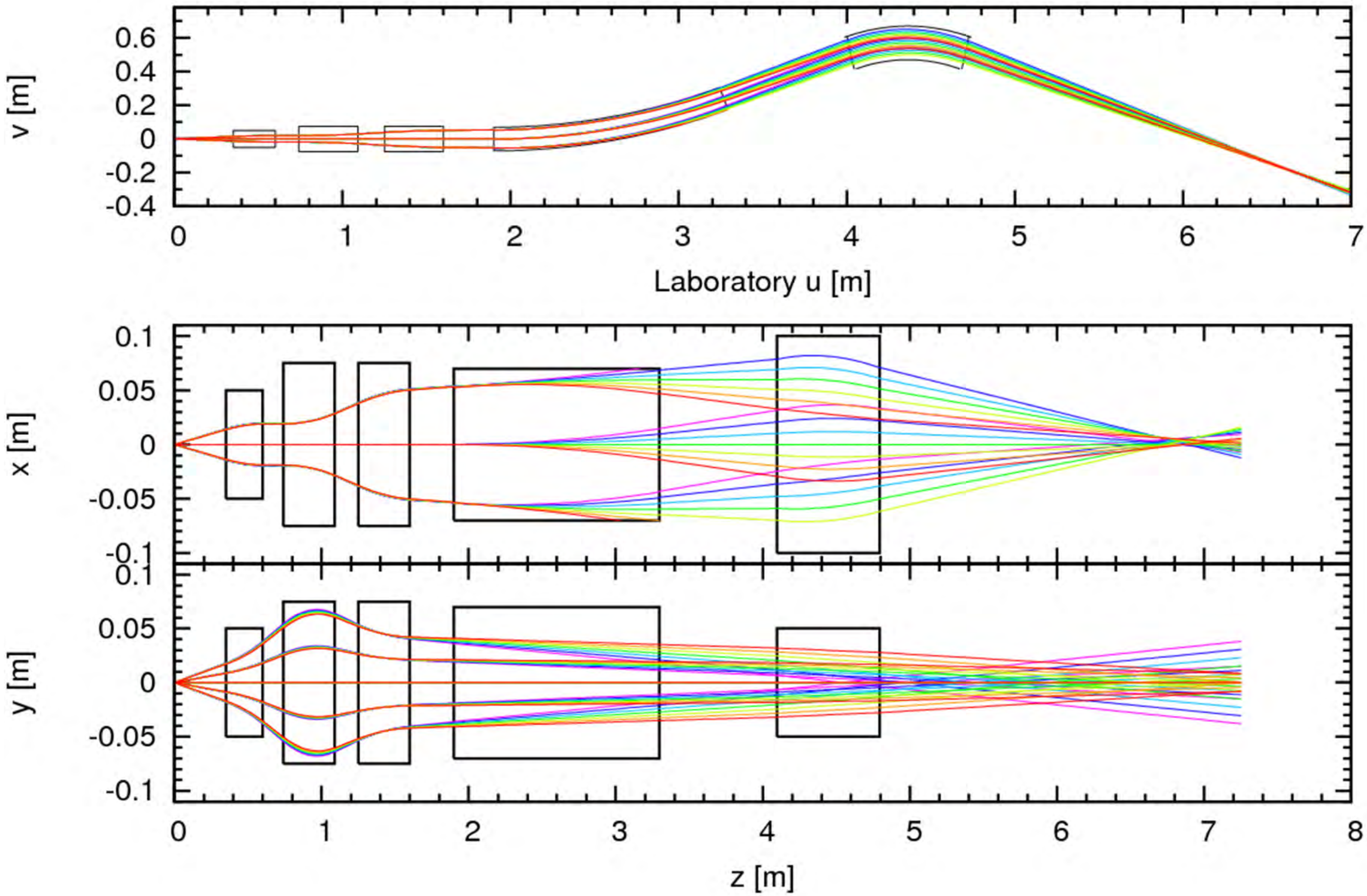
MARA



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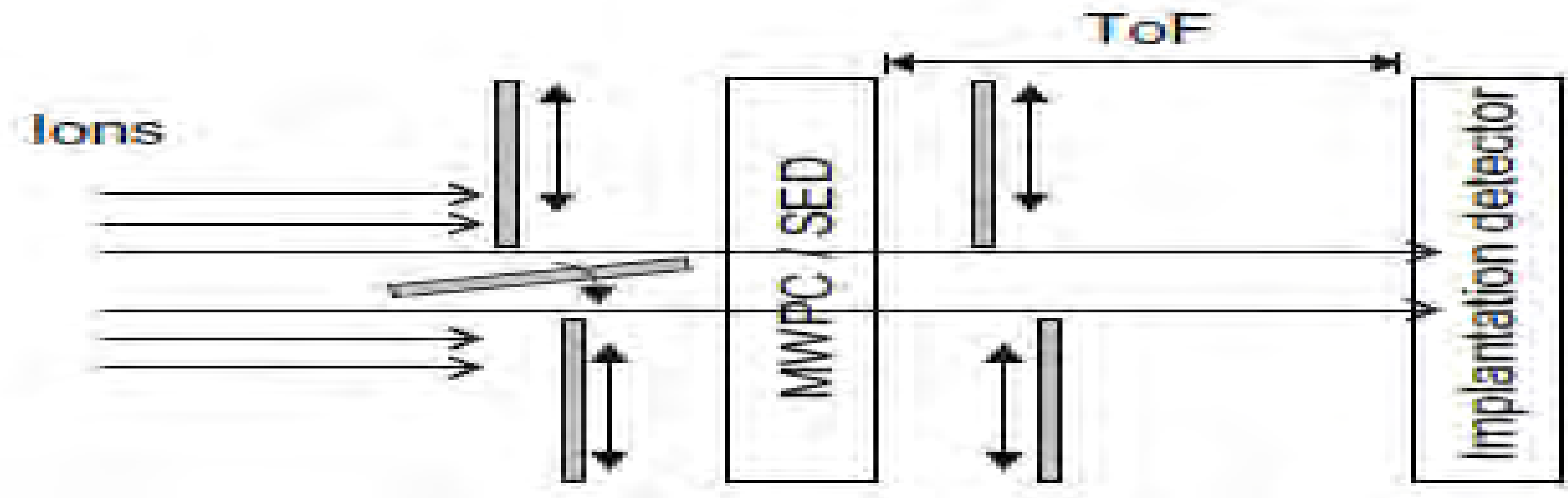
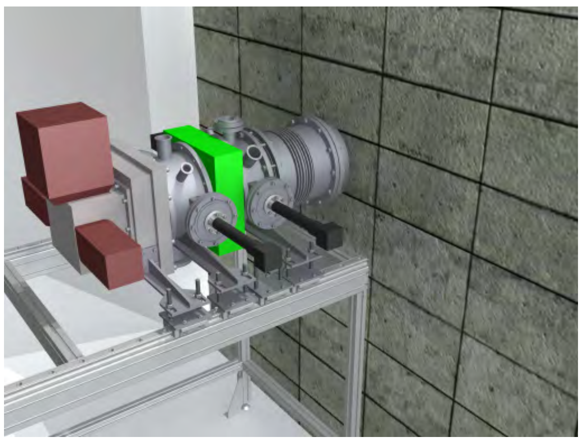
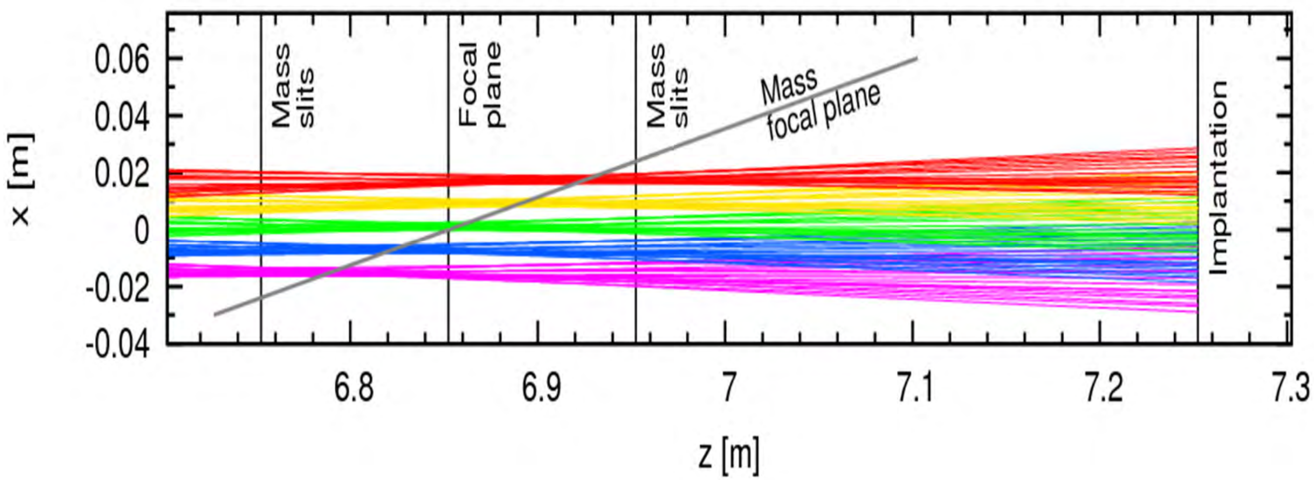
Main properties of the new JYFL MARA separator compared to FMA @ ANL

	FMA	MARA
- Configuration	QQEDMDEDQQ	QQQEDMD
- Horizontal magnification	-1.93	-1.55
- Vertical magnification	0.98	-4.48
- M/Q dispersion	10.0 mm/% (variable)	8.1 mm/%
- First order resolving power, 2 mm beam spot	259	259
- Solid angle acceptance central m/q and energy	8 msr	10 msr
- Energy acceptance for central mass and angle	+20 % - 15 %	+20 % - 15 %
- M/Q acceptance	± 4 %	± 7 %







MWPC 60 mm x 160 mm, DSSD 48 mm x 128 mm

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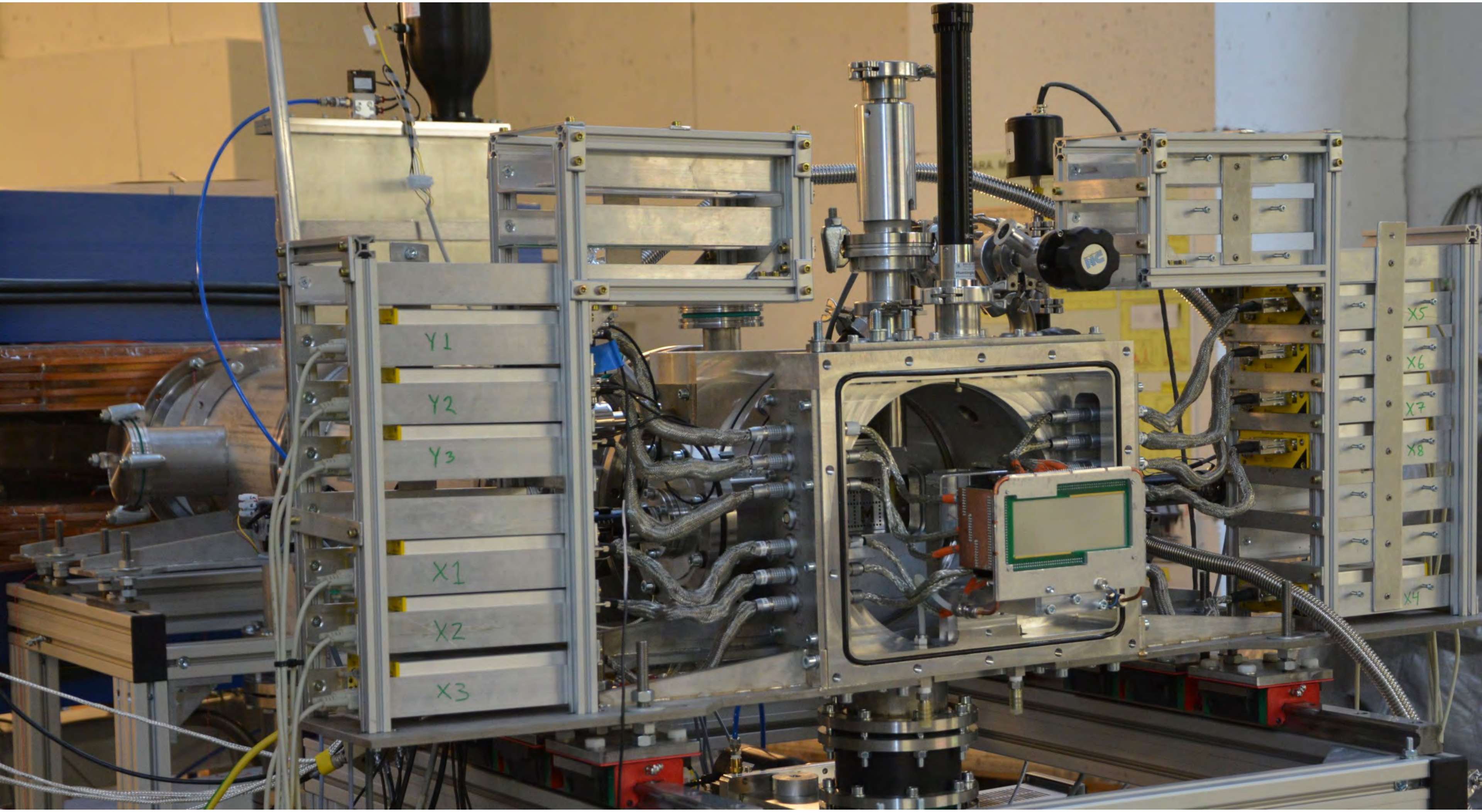

MWPC 60 mm x 160 mm, DSSD 48 mm x 128 mm, 1 mm x 1mm
in the near future: 0.67 mm x 0.67 mm, 72 chn x 192chn
Si-box and Si punch through detectors

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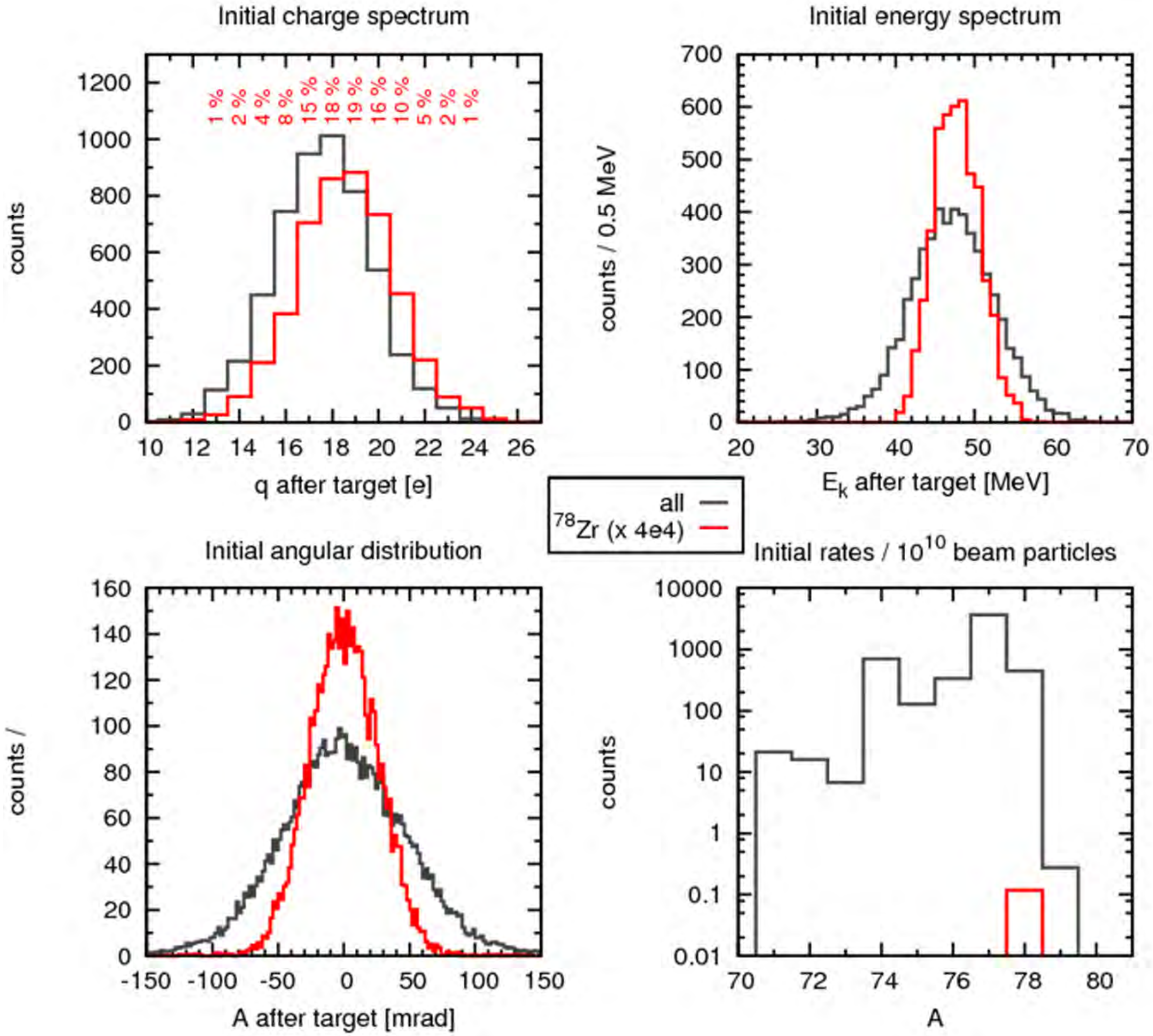
$^{40}Ca + ^{40}Ca \rightarrow ^{80}Zr^{*} \rightarrow ^{78}Zr + 2n$

E_{lab} = 110 MeV (MOT)

Target 400 µg/cm^2



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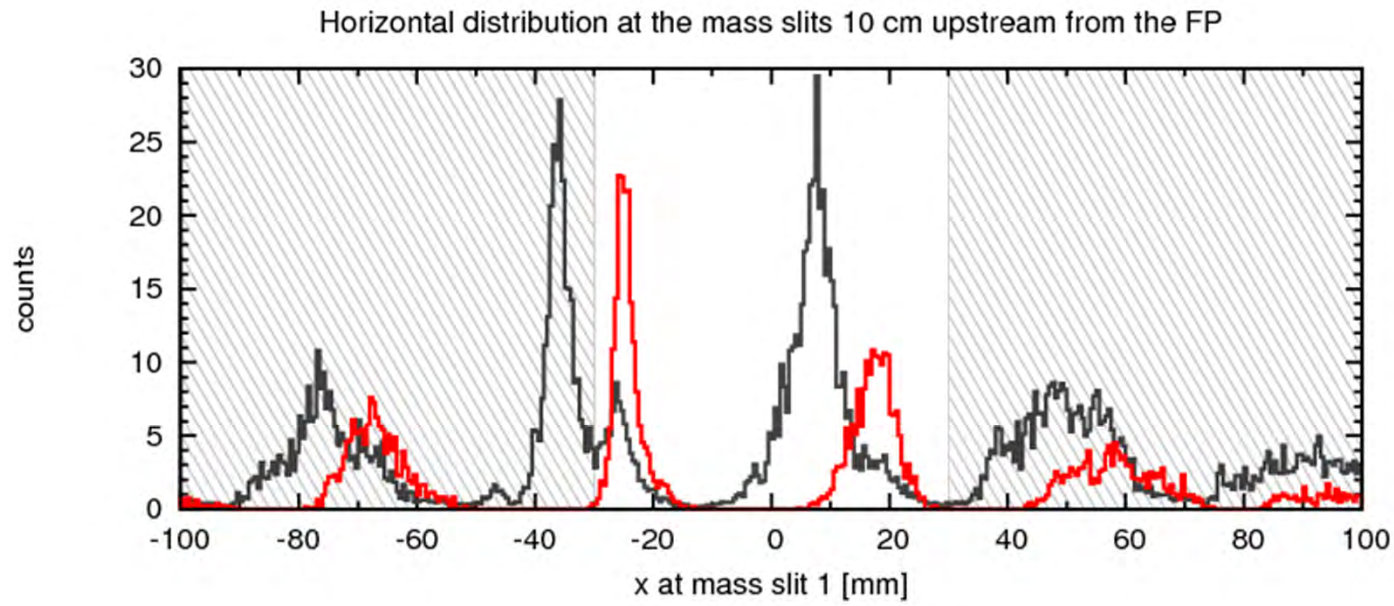
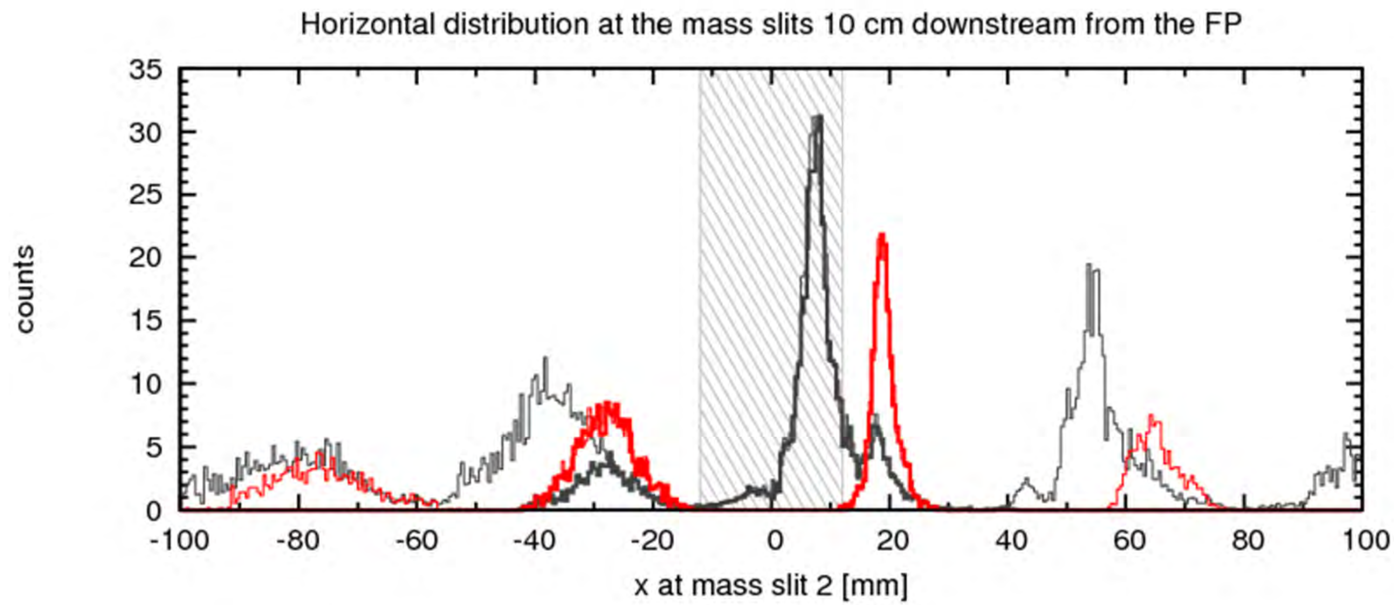
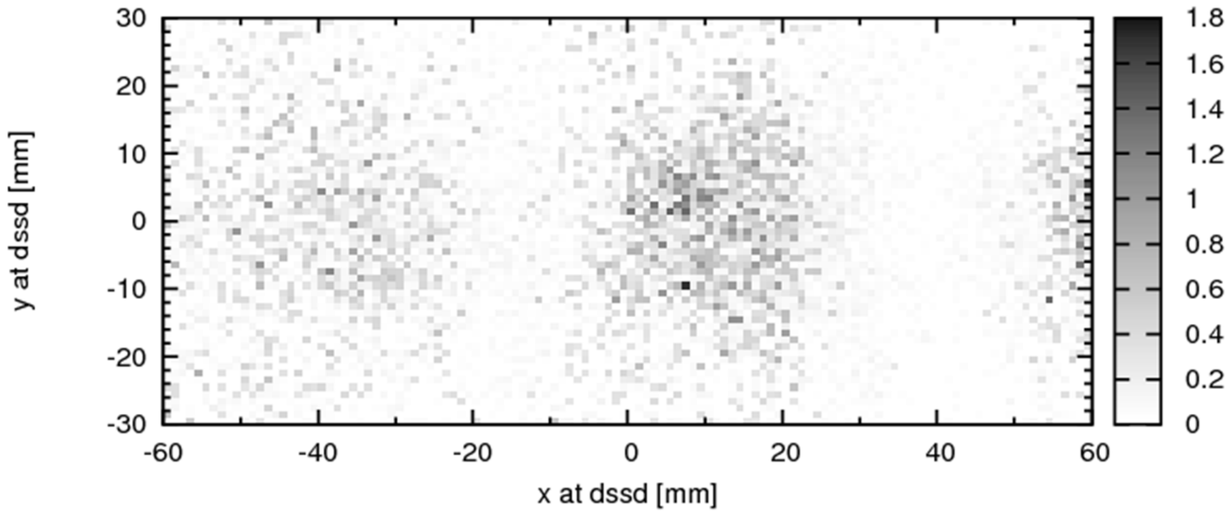


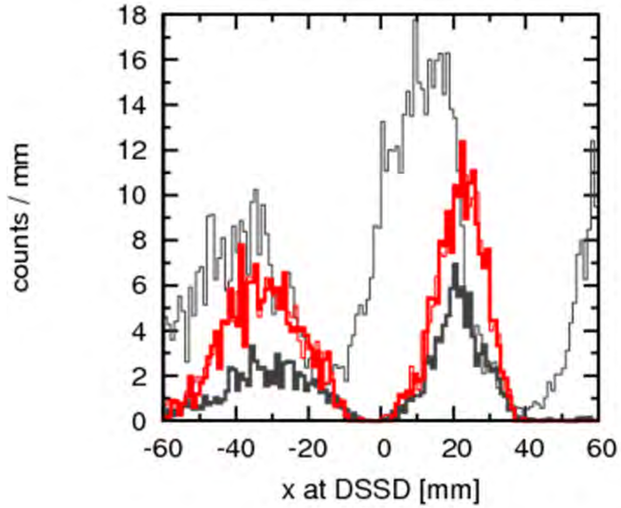
Horizontal distribution at the mass slits 10 cm upstream from the FP
counts
x at mass slit 1 [mm]

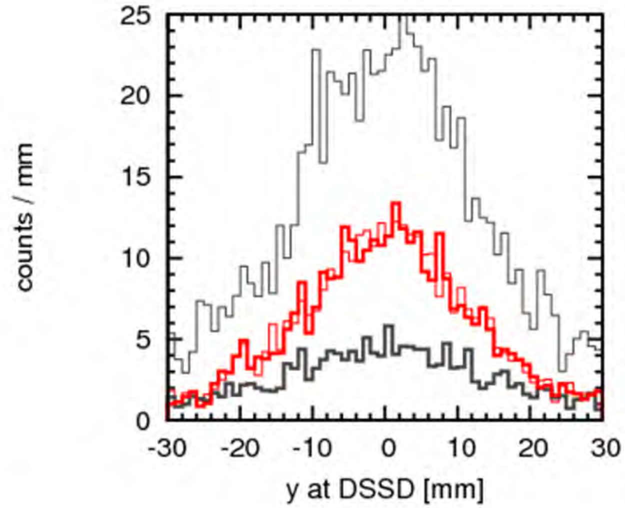


Horizontal distribution at the mass slits 10 cm downstream from the FP
counts
x at mass slit 2 [mm]

Image size 40 cm behind the MARA focal plane





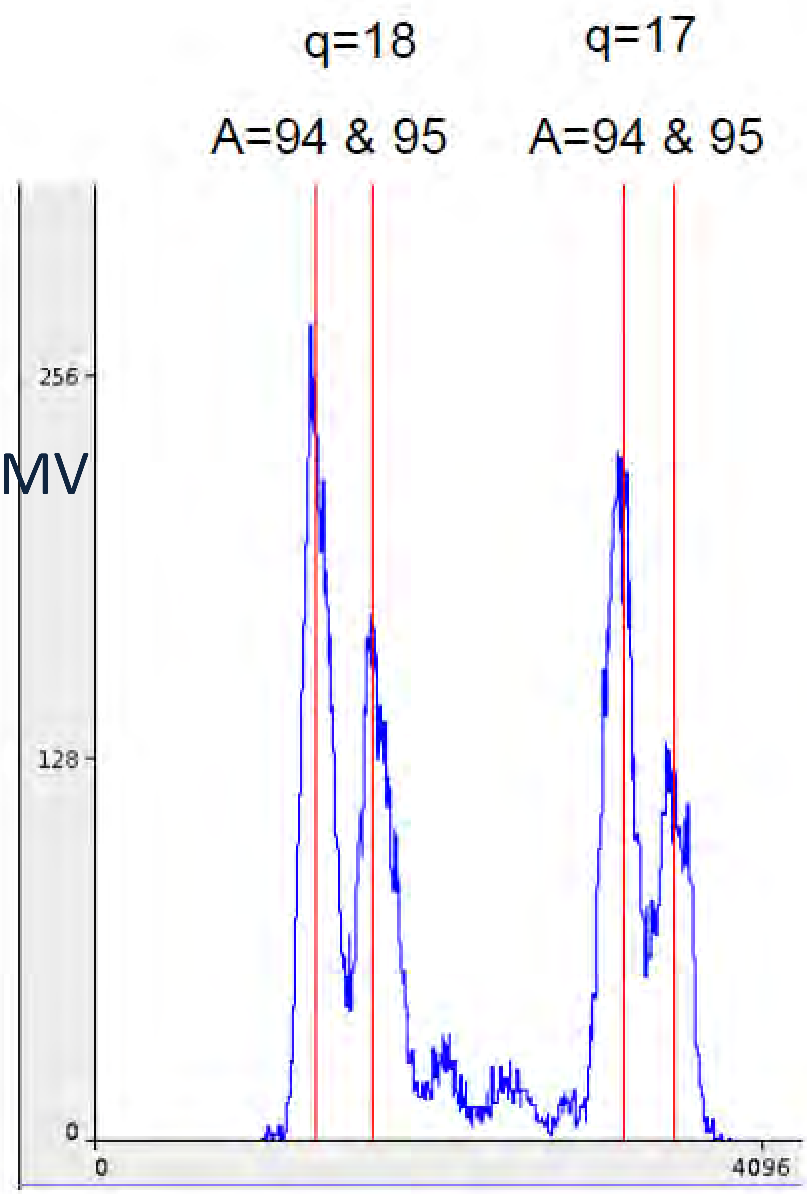


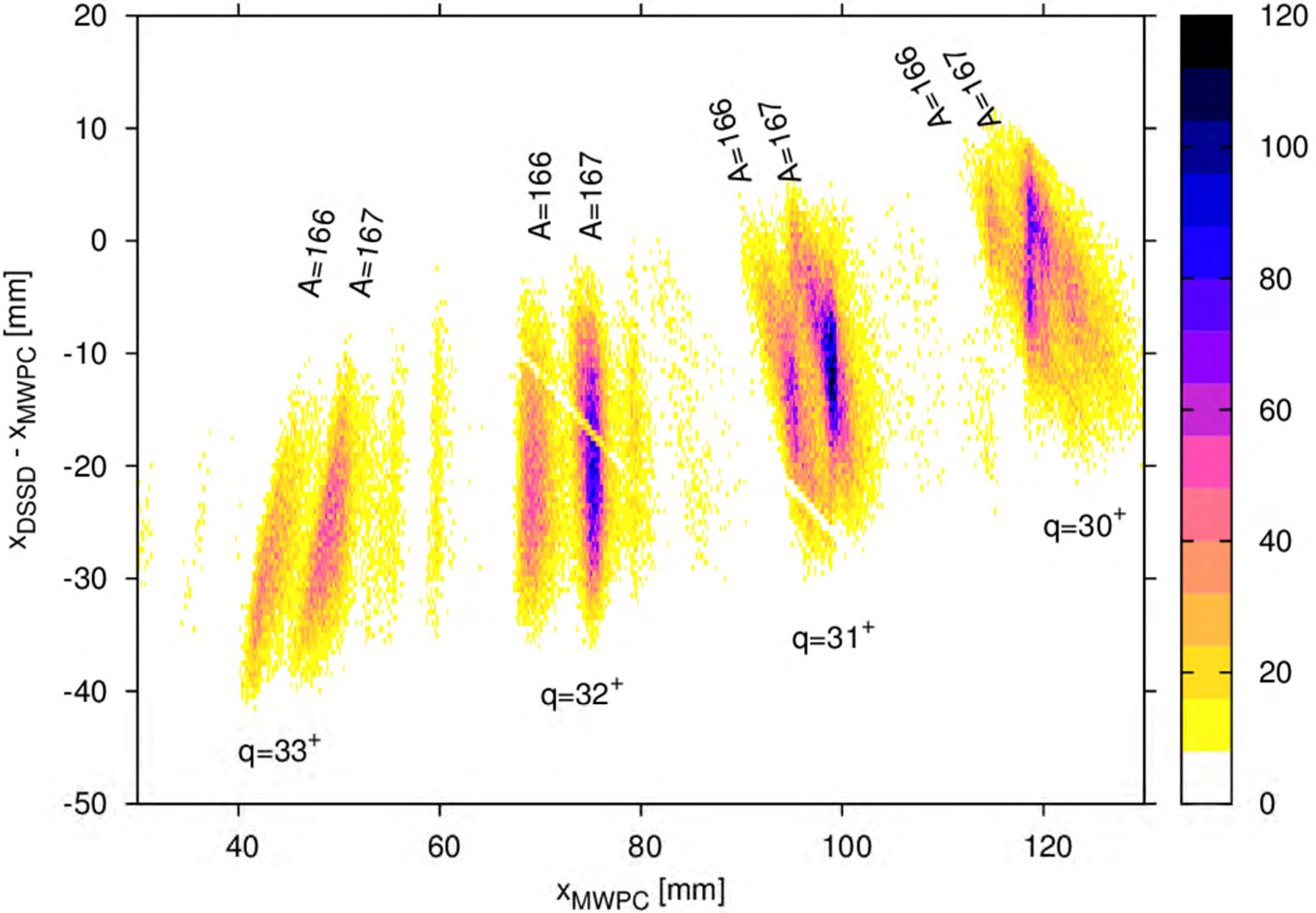
Alpha source tests:

^{239}Pu,^{241}Am, ^{244}Cm
^{148}Gd
^{226}Ra (^{214}Po)
Electric rigidities 3.18 MV -7.69 MV

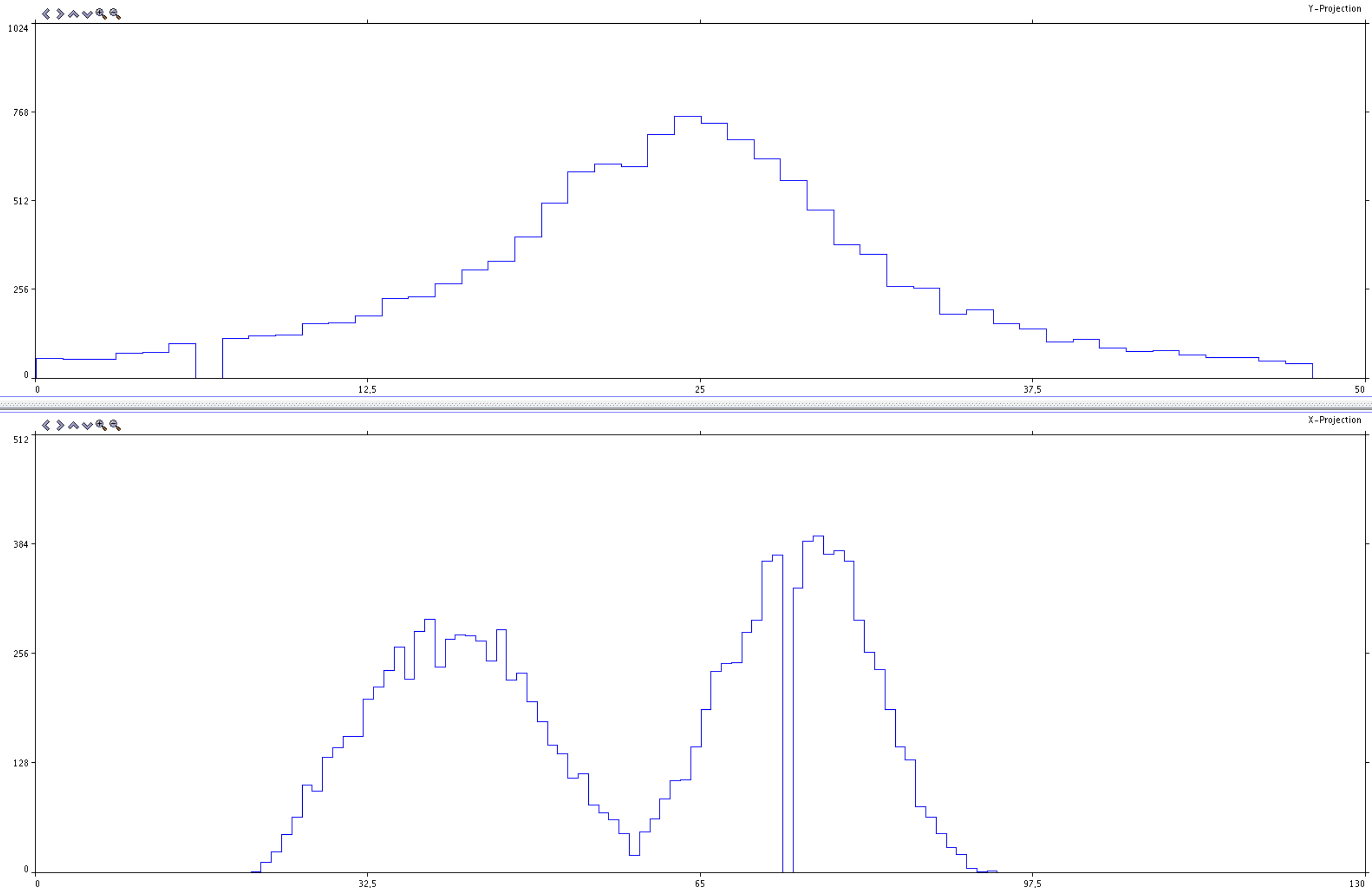
First beams with MARA:

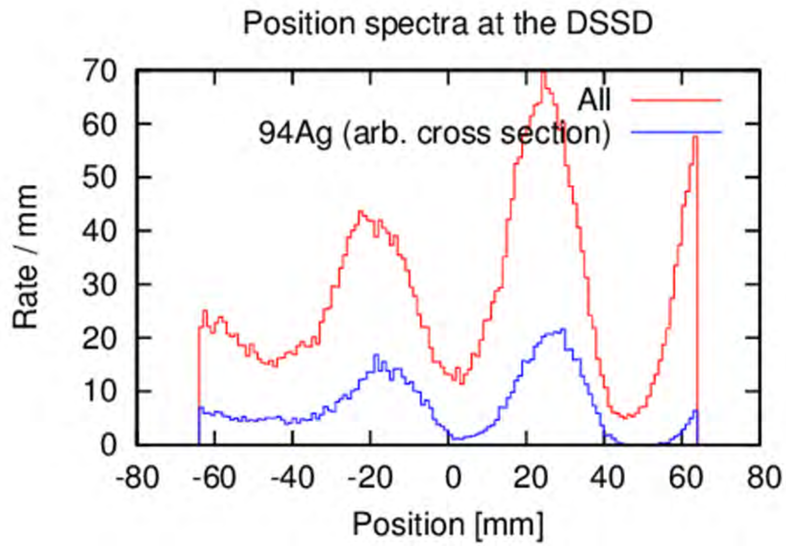
$^{40}Ar + ^{45}Sc \rightarrow ^{85}Y^*$
$^{40}Ar + ^{58}Ni \rightarrow ^{98}Pd^*$
$^{78}Kr + ^{92}Mo \rightarrow ^{170}Pt^*$

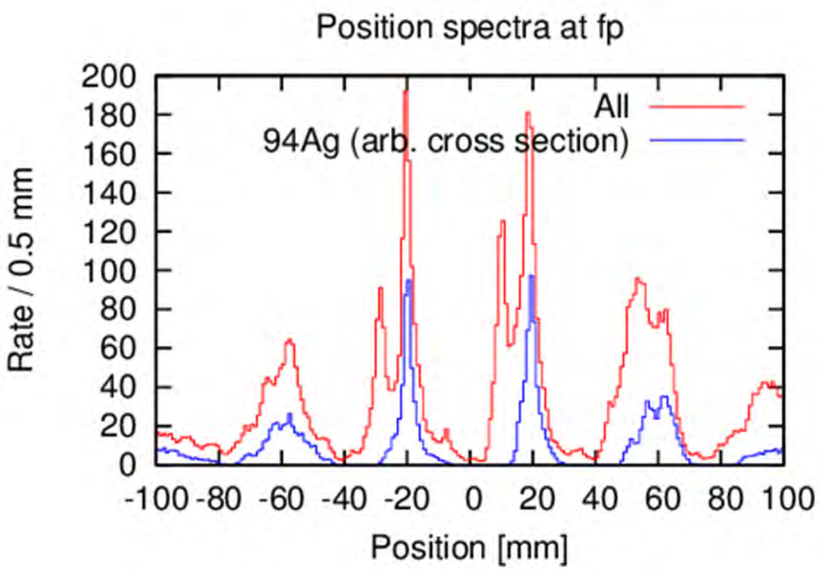


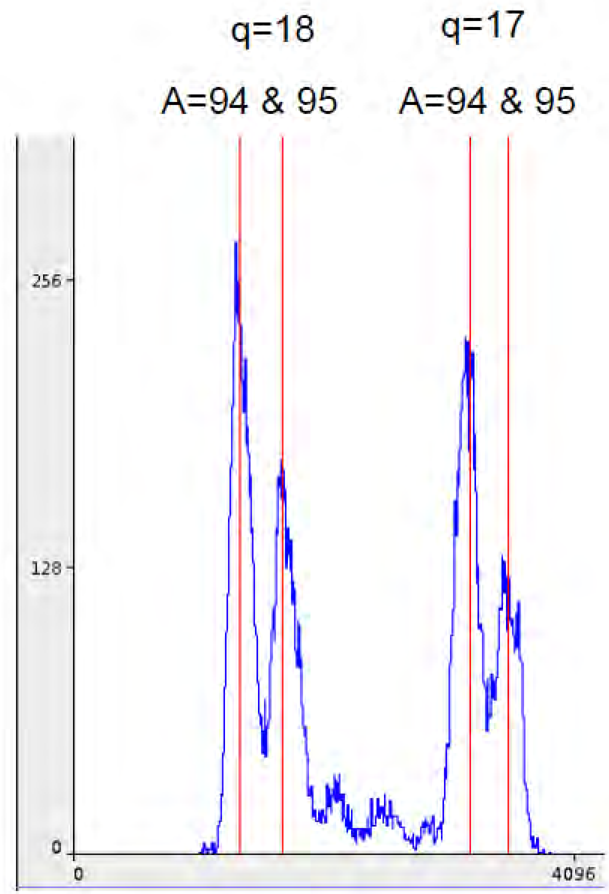


20
10
0
-10
-20
-30
-40
-50
40
60
80
100
120
x_DSSD - x_MWPC [mm]
x_MWPC [mm]
A=166
A=167
A=166
A=167
A=166
A=167
A=166
A=167
q=33+
q=32+
q=31+
q=30+
120
100
80
60
40
20
0


Y-Projection
1024
768
512
256
0
0
12,5
25
37,5
50
X-Projection
512
384
256
128
0
0
32,5
65
97,5
130


Position spectra at the DSSD
All
94Ag (arb. cross section)
Rate / mm
70
60
50
40
30
20
10
0
-80
-60
-40
-20
0
20
40
60
80
Position [mm]


Position spectra at fp
All
94Ag (arb. cross section)
Rate / 0.5 mm
200
180
160
140
120
100
80
60
40
20
0
-100
-80
-60
-40
-20
0
20
40
60
80
100
Position [mm]


q=18
A=94 & 95
q=17
A=94 & 95
256
128
0
0
4096

Proposed cases for the commissioning campaign

- $^{36}Ar + ^{45}Sc \rightarrow ^{81}Y^*$, mass 80 region, symmetric

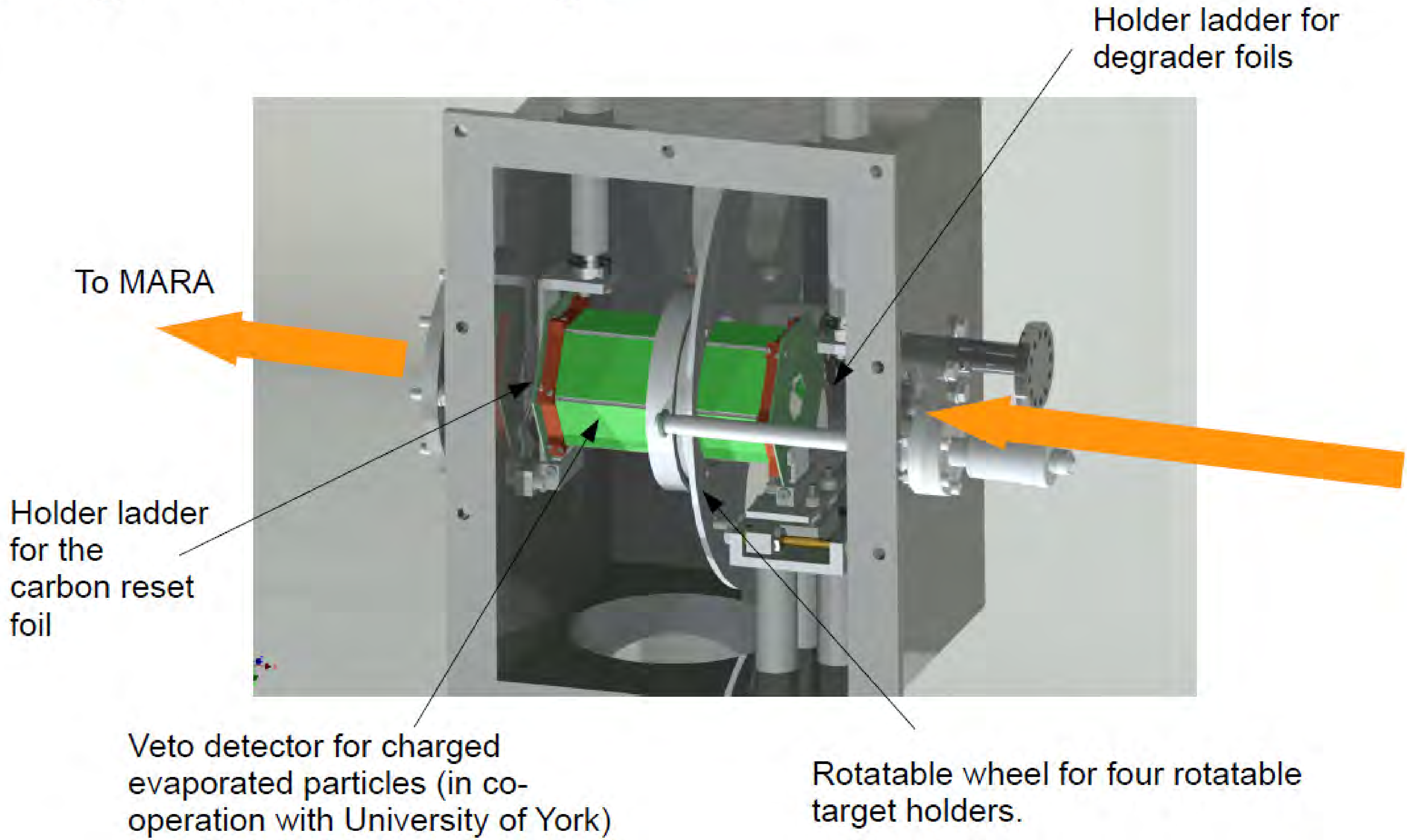
- $^{78}Kr + ^{58}Ni \rightarrow ^{136}Gd^*$, test of inverse kinematics

- $^{58}Ni + ^{106}Cd \rightarrow ^{164}Os^*$, vetotube test
    - alpha emitters, proton emitters

- $^{78}Kr + ^{92}Mo \rightarrow ^{170}Pt^*$, heavy, symmetric
    - alpha emitters, proton emitters
    - testing RDT
    - comparison to FMA

- $^{40}Ar + ^{150}Sm \rightarrow ^{190}Hg^*$, heavy, asymmetric
    - comparison to RITU

A target chamber under design:

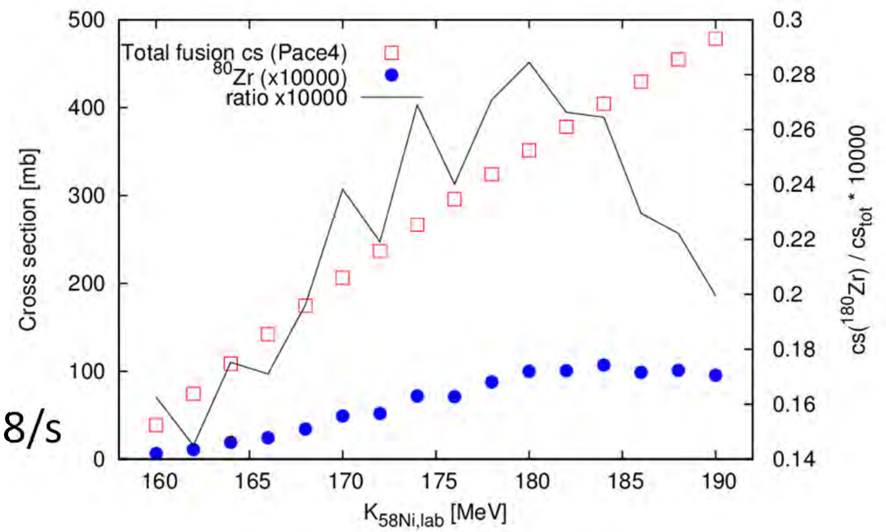


PRL 59 (1987) C. J. Lister et al.,

$^{58}Ni + ^{24}Mg \rightarrow ^{82}Zr^{*} \rightarrow ^{80}Zr + 2n$
E_{lab} = 180 MeV (MOT)
Target 500 μg/cm^2

$^{42}Ca + ^{40}Ca \rightarrow ^{82}Zr^{*} \rightarrow ^{80}Zr + 2n$
E_{lab} = 120 MeV (MOT)
Target 500 μg/cm^2

^{80}Zr 10 μb
^{80}Y 2 mb
^{80}Sr 44 mb
A = 79 250 mb
A = 77 αp ^{77}Rb, αn ^{77}Sr smaller fraction



With 10 pnA beam, ^{80}Zr yield at the target 8/s

yields at the focal plane

	Four charge states collected (~68 %)	Two charge states (mass slits, ~ 37 %)
^{80}Zr	5 Hz	3 Hz
^{80}Y	1000 Hz	600 Hz
^{80}Sr	22 kHz	12 kHz
A=79	120 kHz	10 kHz
Rest	25 kHz	10 kHz

Total	~ 170 kHz	~ 33 kHz

Possible physics program

- Complementary to RITU physics

- In-beam and delayed spectroscopic studies at and beyond the proton drip line at $30 < Z < 70$ (< 82)
  - Delayed spectroscpy,
  - β delayed proton emitters,
  - proton emitters, alpha emitters

- Gas-cell and LEB (MARA as a pre-separator)
  - laser ionization
  - MRTOF, mass measurements
  - MRTOF assisted delayed spectroscopy

- Heavier elements, No region
  - charge plunger
  - recoil shadowed electron spectroscopy

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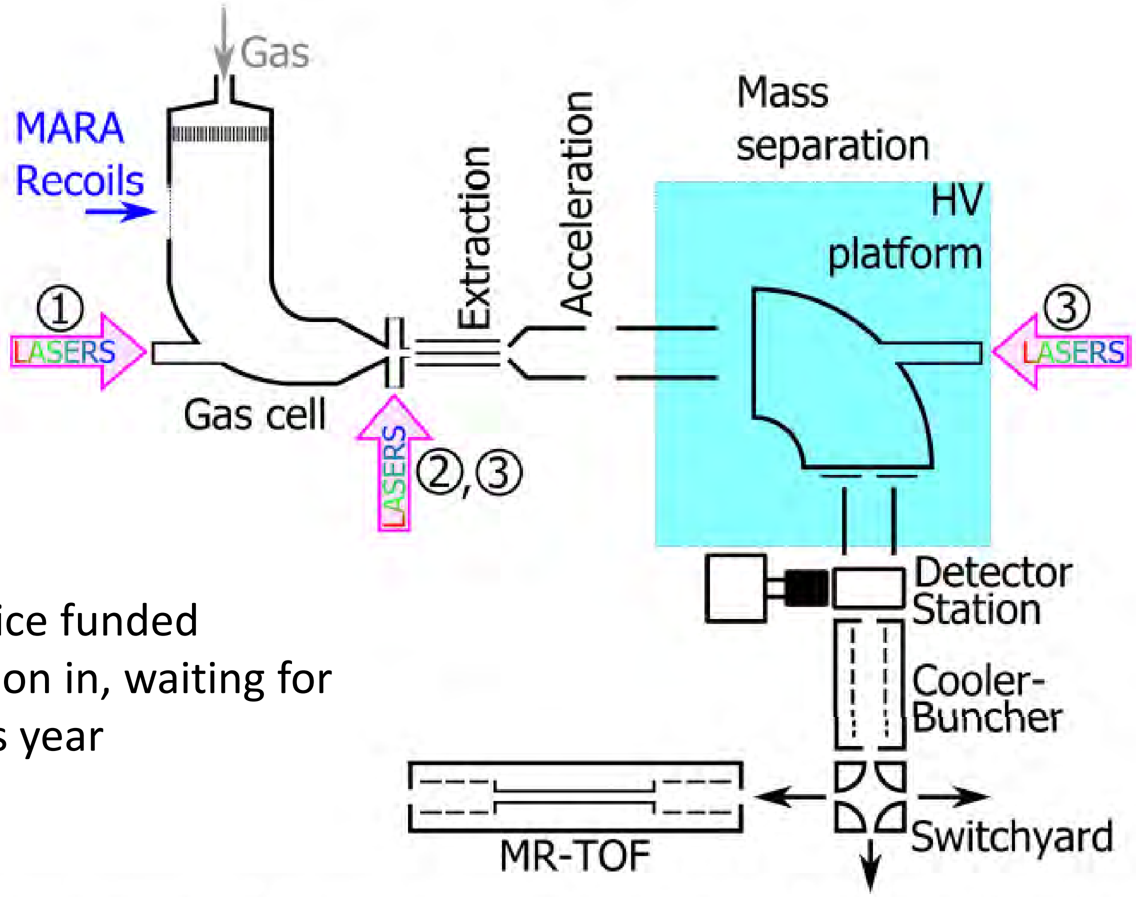
Iain Moore, Philippos Papadakis
University of Leuven group



MR-TOF device funded
FIRI application in, waiting for decisioin this year

Figure 2: A schematic overview of the low-energy radioactive ion beam facility to be constructed after the focal plane of the vacuum-mode recoil spectrometer MARA. Laser ionization is performed either in the gas cell (1), before the exit nozzle in a transverse geometry (2) or in the gas jet (3).

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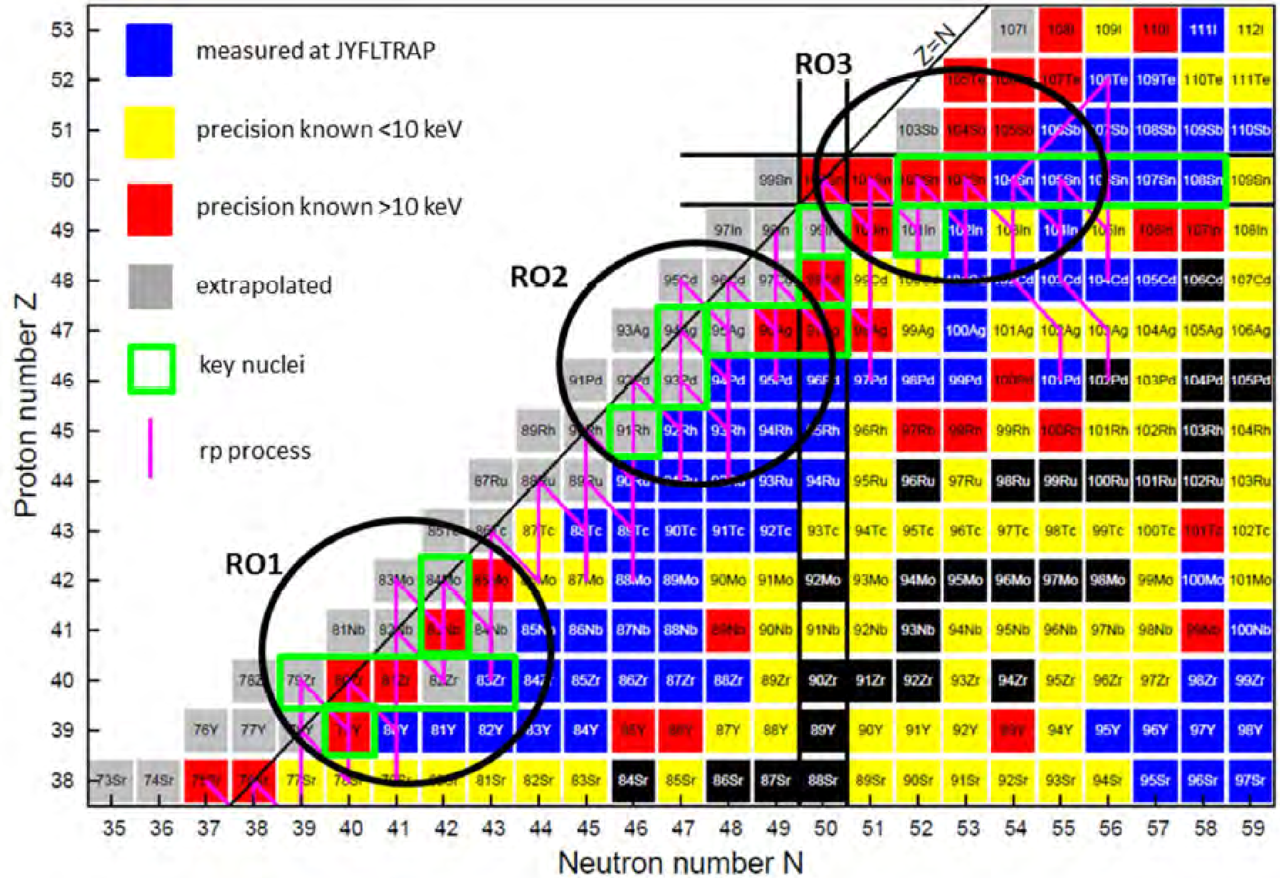

RO1: Mass and laser spectroscopy of nuclei in the region of the *N*~*Z* nucleus ^{80}Zr

- Mass measurements of $^{79-83}$Zr
- Mass measurements of ^{79}Y, ^{83}Nb and ^{84}Mo
- Resonance ionization spectroscopy from ^{87}Zr towards *N*=*Z* ^{80}Zr

RO2: Mass and laser spectroscopy of nuclei in the region of the *N*~*Z* nucleus ^{94}Ag

- Mass measurements of ^{91}Rh, ^{93}Pd and ^{94}Ag
- Mass measurements of ^{94}Ag (7^+) isomer and (21^+) isomer
- Resonance ionization spectroscopy of $^{94-97}$Ag and isomers

RO3: Mass and laser spectroscopy of *N*=50 nuclides in the ^{100}Sn region

- Mass measurements of ^{97}Ag, ^{98}Cd, ^{99}In, ^{101}In, ^{102}Sn
- Resonance ionization spectroscopy of $^{102-108}$Sn

Recoil shadow method

$^{208}Pb(^{48}Ca,2n)^{254}No$

$V = 0.017c = 5.1$ mm/ns

Z. Physik A 285, 159 – 169 (1978)

Zeitschrift für Physik A

In-Beam Spectroscopy of Low Energy Conversion Electrons with a Recoil Shadow Method – A New Possibility for Subnanosecond Lifetime Measurements

H. Backe, L. Richter, R. Willwater, E. Kankeleit, E. Kuphal*, and Y. Nakayama**
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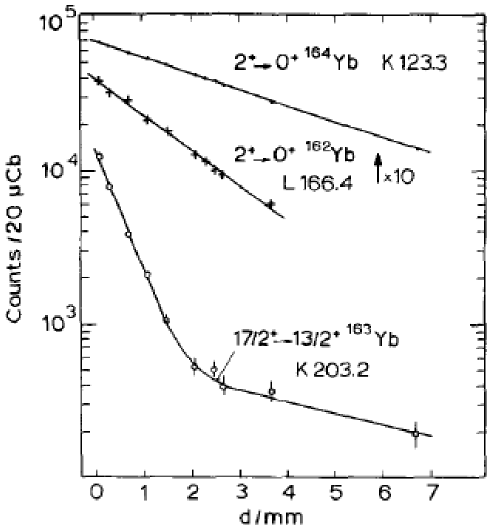
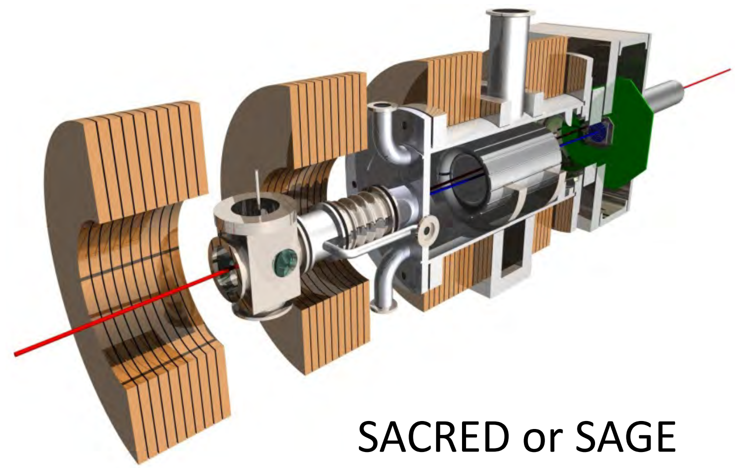


Fig. 12. Life time measurements on certain levels in ^{162,163,164}Yb with the recoil shadow method by variation of the target position d relative to the edge of the semicylindrical baffle. The results are $T_{1/2} = (971 \pm 31)$ ps and $T_{1/2} = (439 \pm 37)$ ps for the $2^+ \to 0^+$ transitions in ^{164}Yb and ^{162}Yb, respectively. For the 203.2 keV transition in ^{163}Yb the two half life components are $T^{(1)}_{1/2} = (108 \pm 7)$ ps and $T^{(2)}_{1/2} = (1.2 \pm 0.3)$ ns



SACRED or SAGE

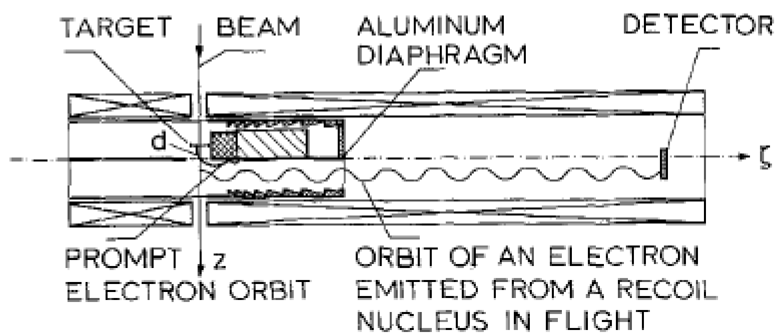


Fig. 8. The recoil shadow method. It is shown a cut through the electron transport system containing the beam and solenoid symmetry axis. The longitudinal baffle avoids detection of prompt electrons but allows very efficiently passage of delayed electrons emitted in flight

Charge plunger technique

NUCLEAR INSTRUMENTS AND METHODS 148 (1978) 369-379 ; © NORTH-HOLLAND PUBLISHING CO.

LIFETIME MEASUREMENTS OF NUCLEAR LEVELS WITH THE CHARGE PLUNGER TECHNIQUE

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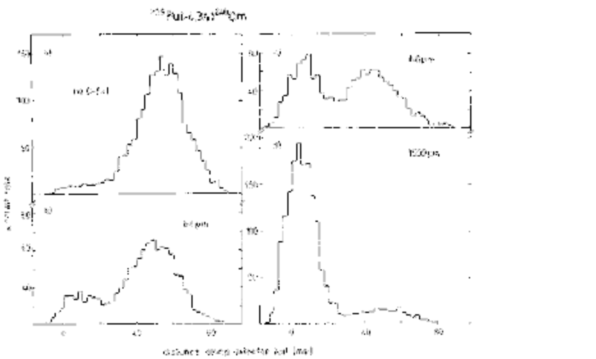
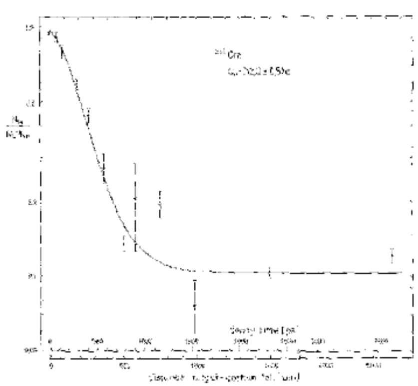
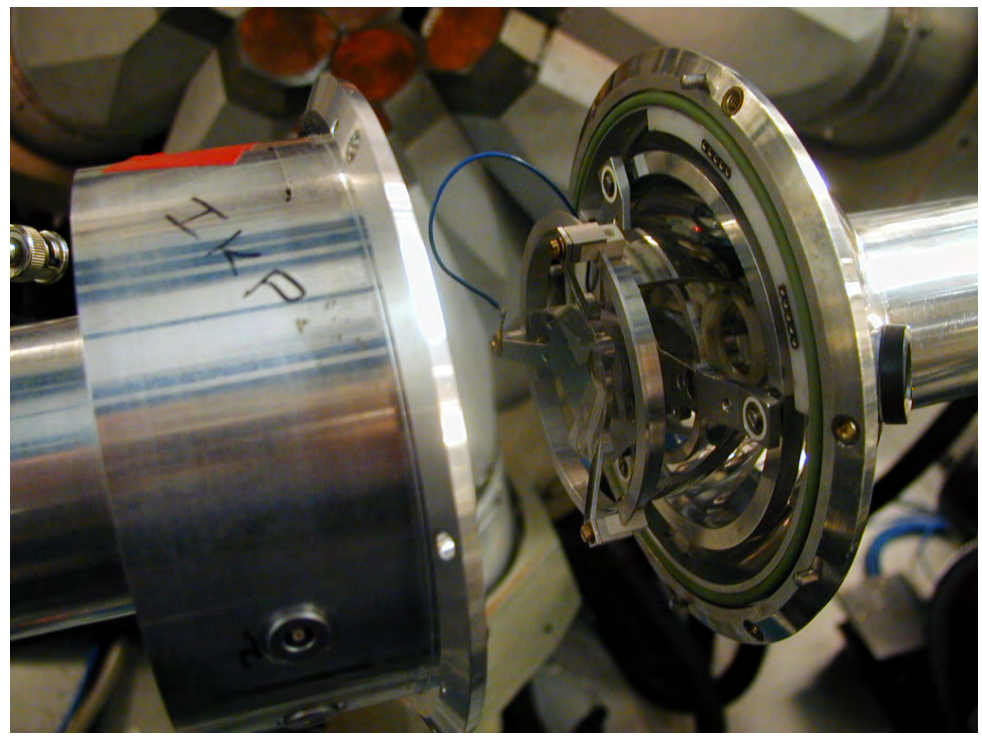
Physikalisches Institut der Universität Heidelberg and Max-Planck-Institut für Kernphysik, Heidelberg, W. Germany







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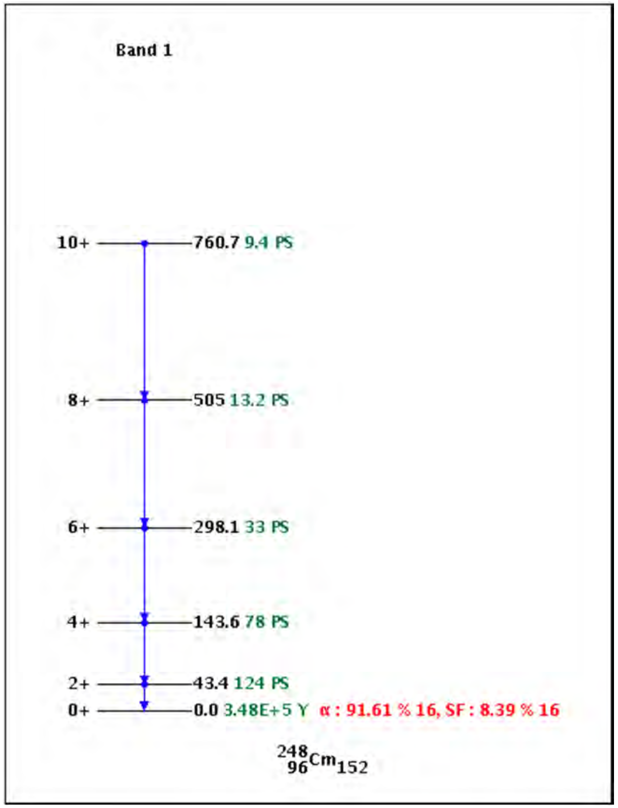
www.nndc.bnl.gov./nudat2

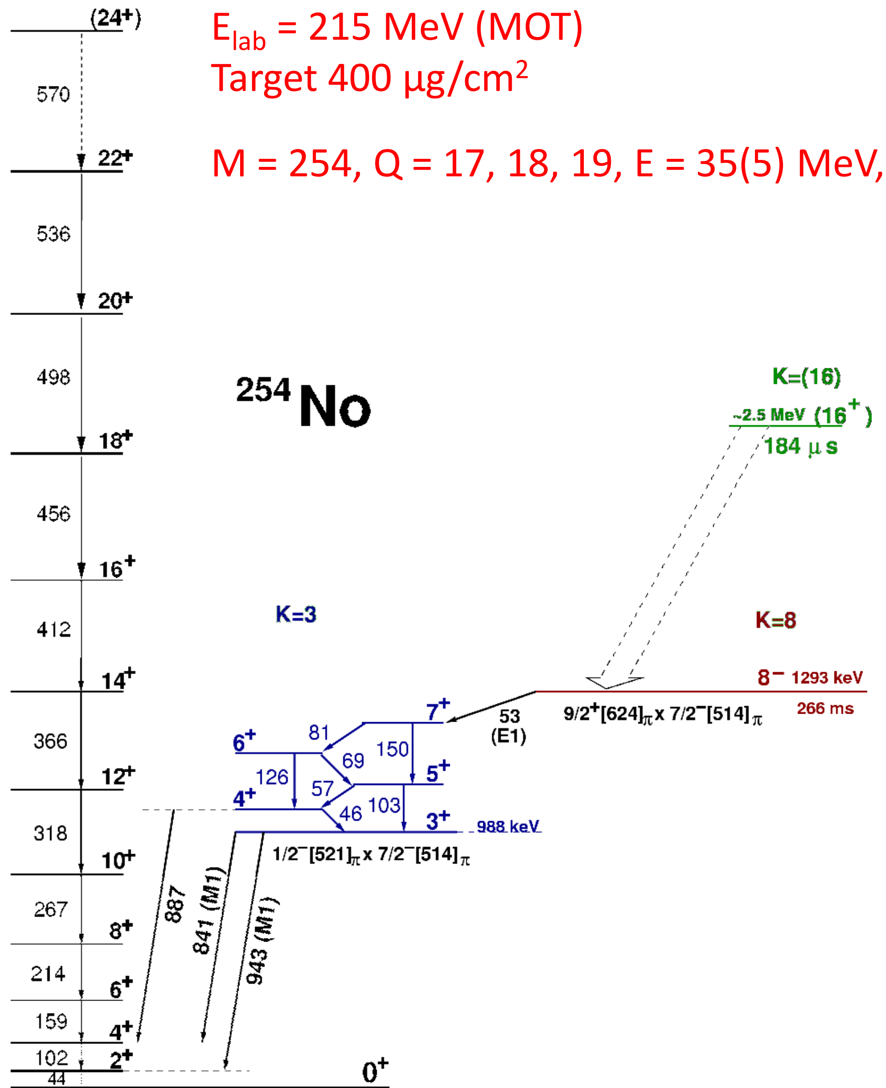
$^{48}Ca + ^{208}Pb \rightarrow ^{256}No^{*} \rightarrow ^{254}No + 2n$

E_{lab} = 215 MeV (MOT)

Target 400 μg/cm²

M = 254, Q = 17, 18, 19, E = 35(5) MeV, $\sigma_{x,y}$ = ± 50 mrad





$^{208}Pb(^{48}Ca,2n)^{254}No$

V = 0.017c = 5.1 mm/ns

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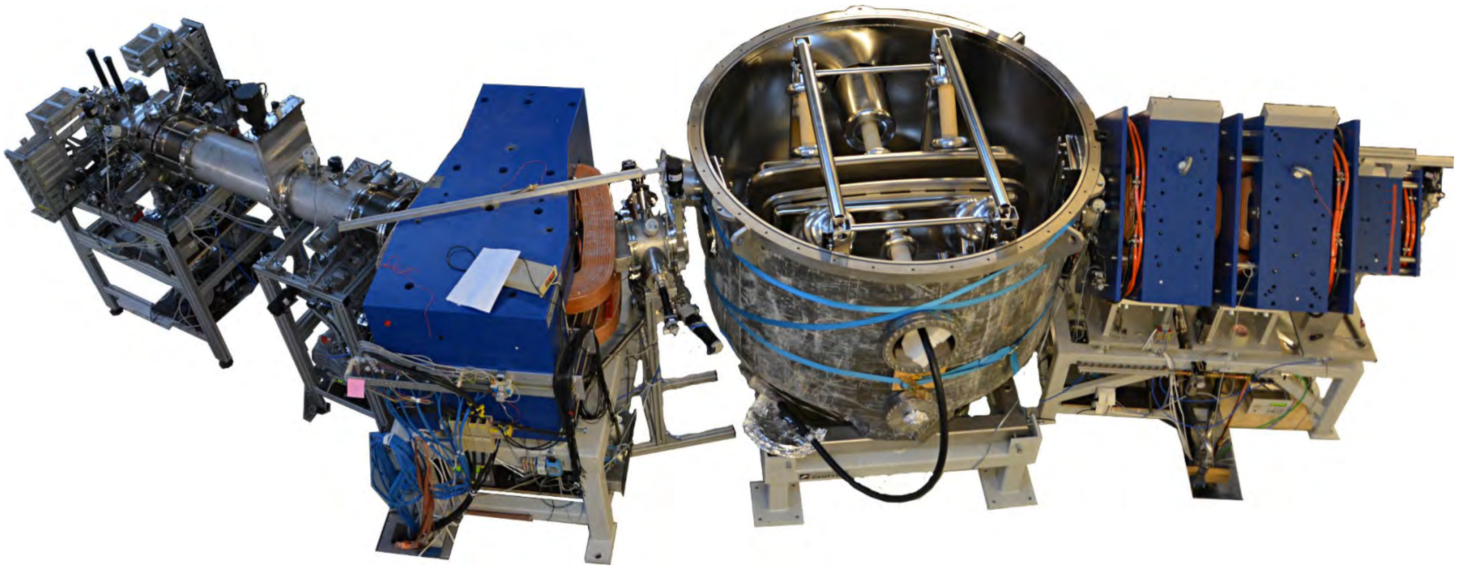
Thank you !

MARA2015: Status, Physics and Future
Workshop @ JYFLACCLAB, Jyväskylä
December 15-16, 2015



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