Spectrometers and mass separation for HIE-ISOLDE

A presentation for the ISOLDE group meeting 10/9/2014

Gry M. Tveten

Post doc, Department of Physics, University of Oslo. g.m.tveten@fys.uio.no

UiO : Department of Physics
University of Oslo

In Nuclear physics mass separation usually refers to the separation of ions by electromagnetic sector fields:

The Lorentz force

$F_B = d(m\mathbf{v})/dt = (ze)\mathbf{v} \times B$

↓

Deflection according to $m\mathbf{v}/(ze)$

The Coulomb force

$\mathbf{F}_E = d(m\mathbf{v})/dt = (ze)\mathbf{E}$

↓

Deflection according to $mv^2/(ze)$

Spectrometers are devices that provide ion mass identification, but not necessarily physical separation.

A spectrometer or mass separator has been proposed for nuclear reaction studies with post accelerated beams at HIE-ISOLDE

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EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

Letter of Intent to the
ISOLDE and Neutron Time-of-Flight Experiments Committee
for experiments with HIE-ISOLDE

A Spectrometer for Nuclear Reaction Studies at HIE-ISOLDE

G. Tveten[1], J. Cederkall[2], S. Siem[1], A. Goergen[1], M. Guttormsen[1], P. Hoff[1], D. Di Julio[2], C. Fahlander[2], P. A. Butler[3], D.T. Joss[3], M. Scheck[3], A. Blazhev[4], J. Jolie[4] , N. Braun[4], P. Reiter[4], N. Warr[4], D. G. Jenkins[5], R. Wadsworth[5], S. Freeman[6], J. Iwanicki[7], P. Napiorkowski[7], M. Zielinska[7], M. Huyse[7], P. van Duppen[8], R. Raabe[8], R. Krucken[9], M. Aliotta[10], T. Davinson[10], Th. Kroll[11], J. Leske[11], N. Pietralla[11], T. Grahn[12], J. Uusitalo[12], R. Orlandi[13], J. Pakarinen[14], D. Voulot[14], F. Wenander[14]

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- Physically separating a beam of interest from contamination
- Particle spectroscopy
- Selecting channel of interest in a nuclear reaction
- Event tagging
- Cleaning up spectra

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- Time-of-flight devices

The simplest separator you can make is just a dipole magnet.

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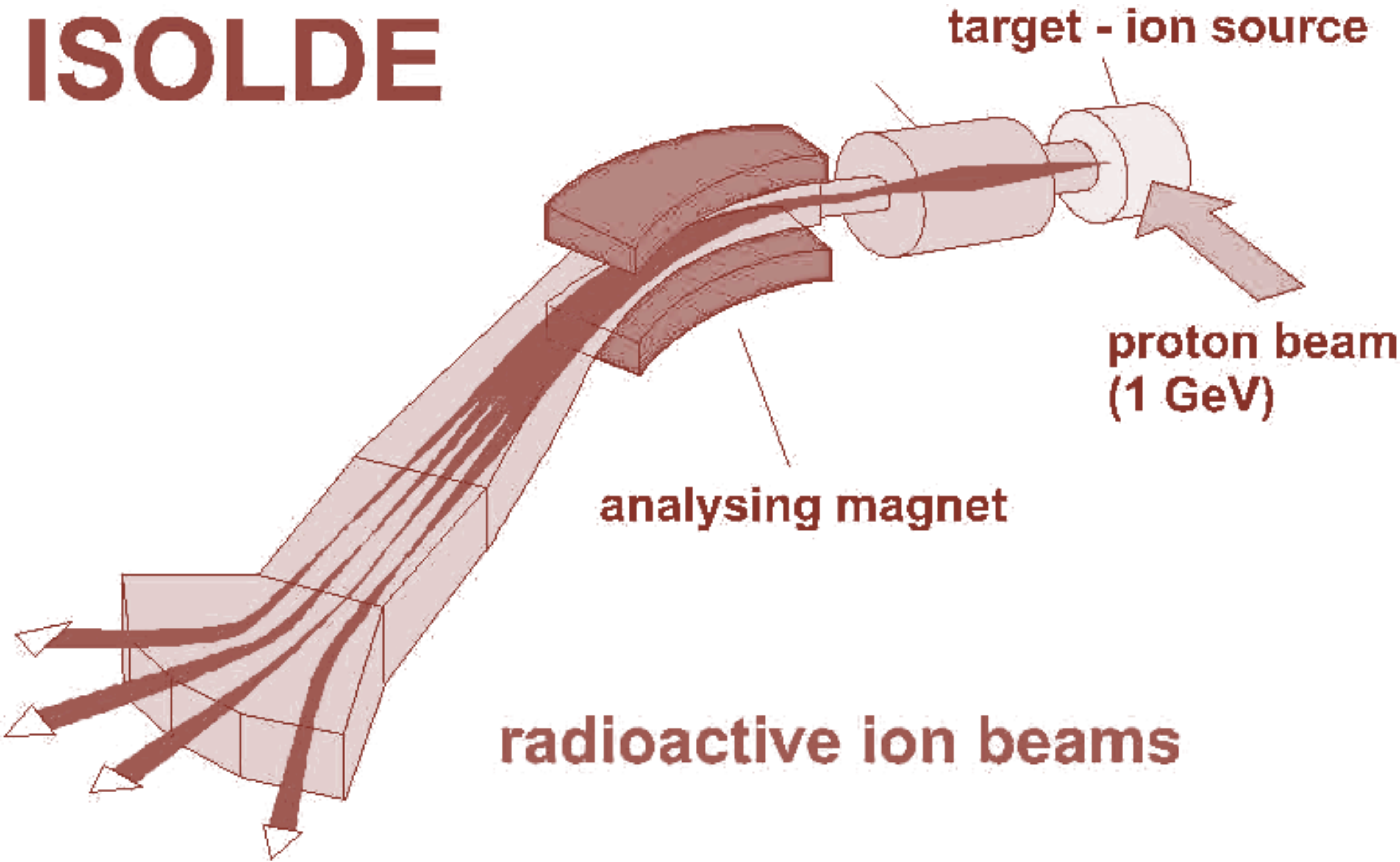
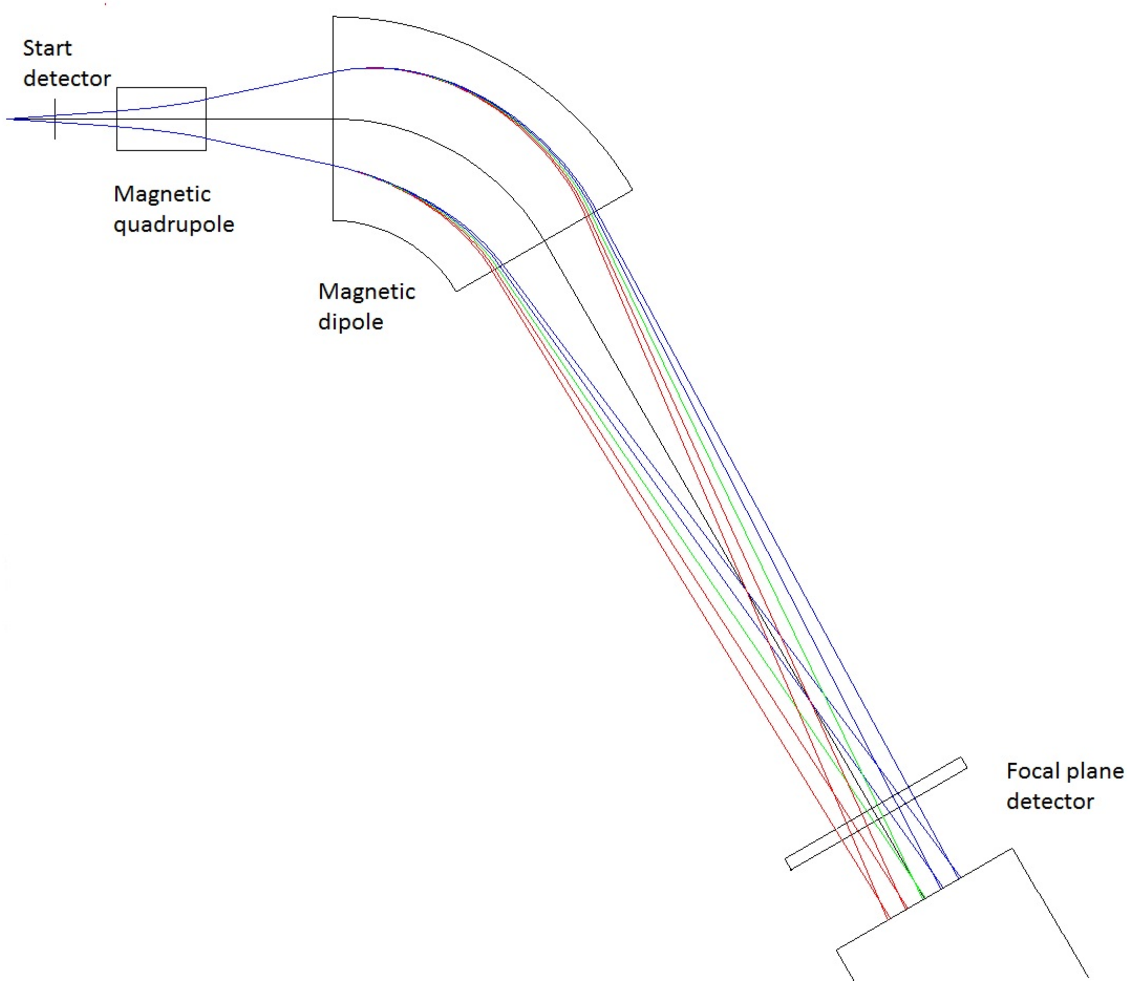
An exampe of such a device is the General Purpose Separator:



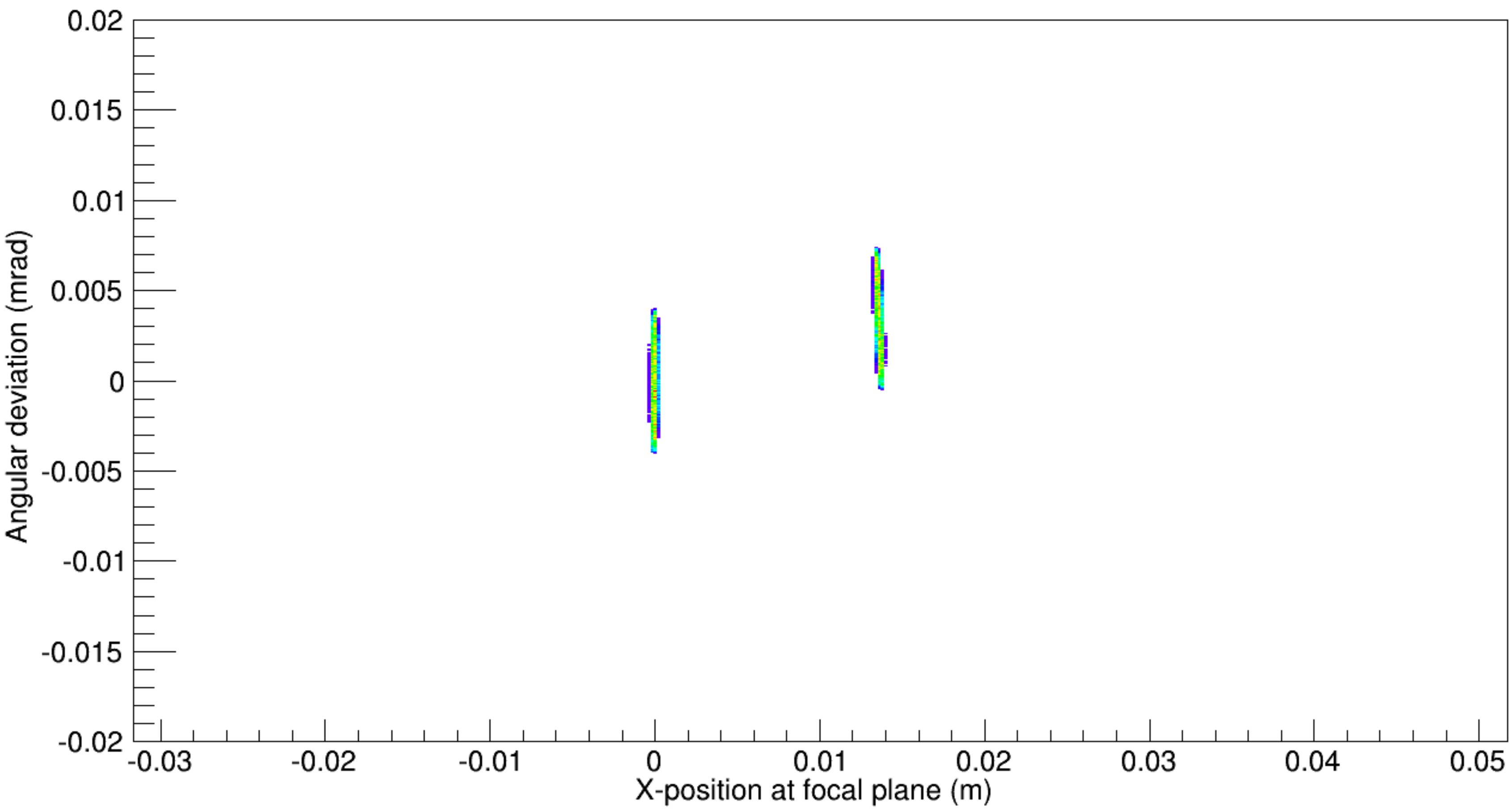
Three classes of separating devices are frequently used in nuclear physics, namely

- Mass separators providing A/q-separation at a focal plane
- Time-of-flight devices
- Ray-tracing spectrometers

The magnetic spectrometer should ideally work like this:

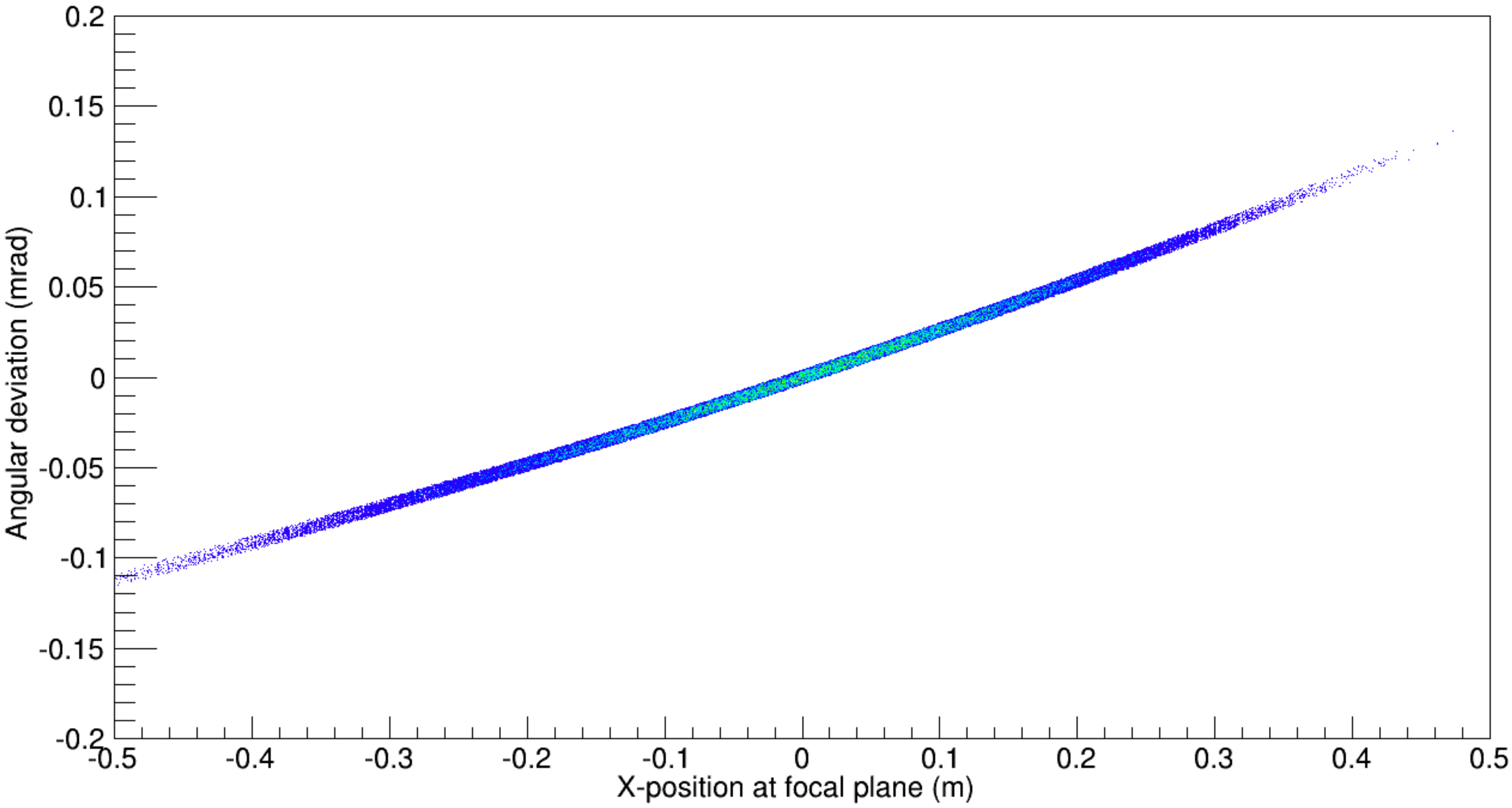


Reference mass A=130 and emittance of 1 π•mm•mrad



Result for the magnetic spectrometer without energy variation

Reference mass A=130 and emittance of 1 π•mm•mrad



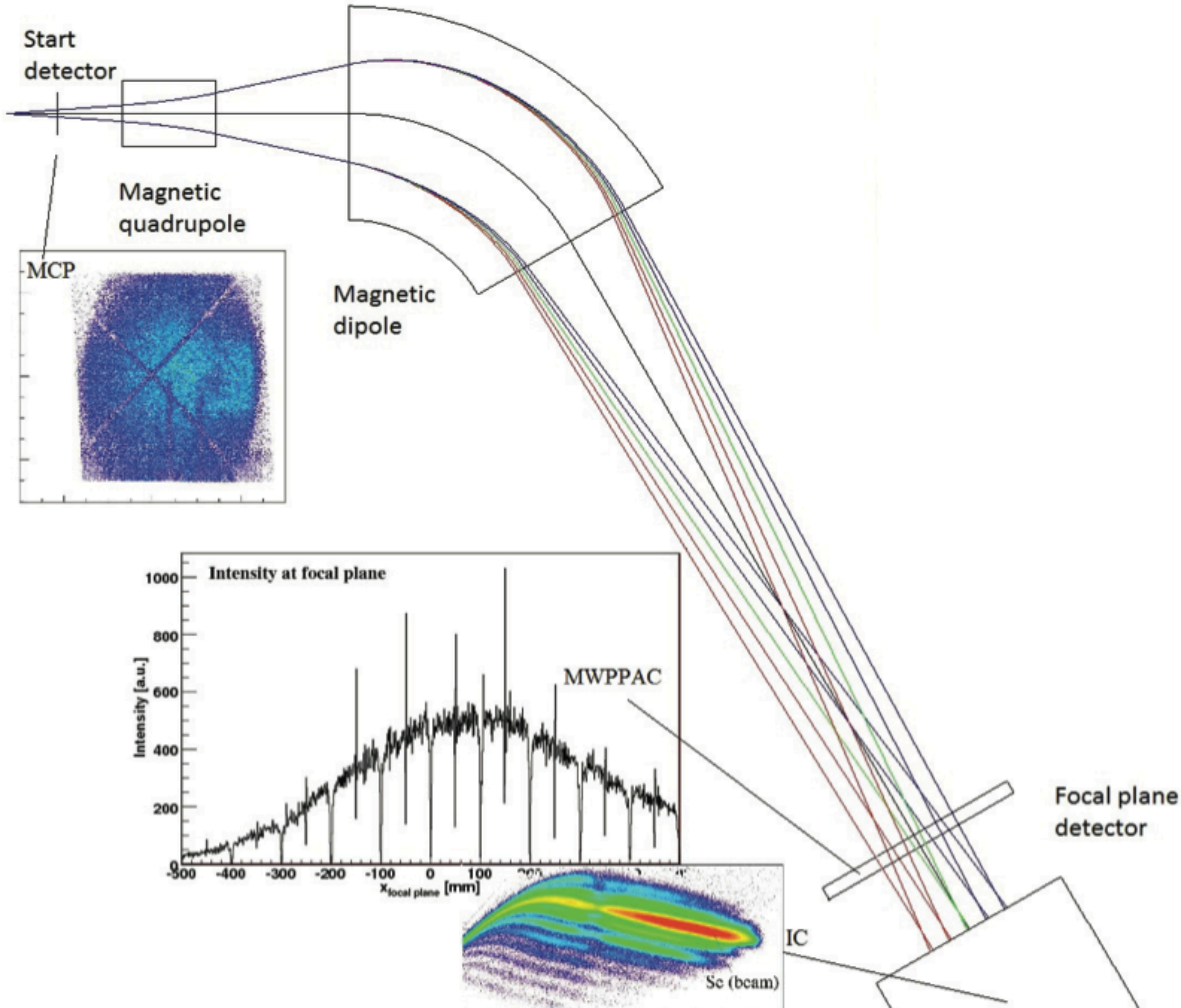
Result for the magnetic spectrometer with 15% energy variation

The solution is to trace the rays of the detected ions.

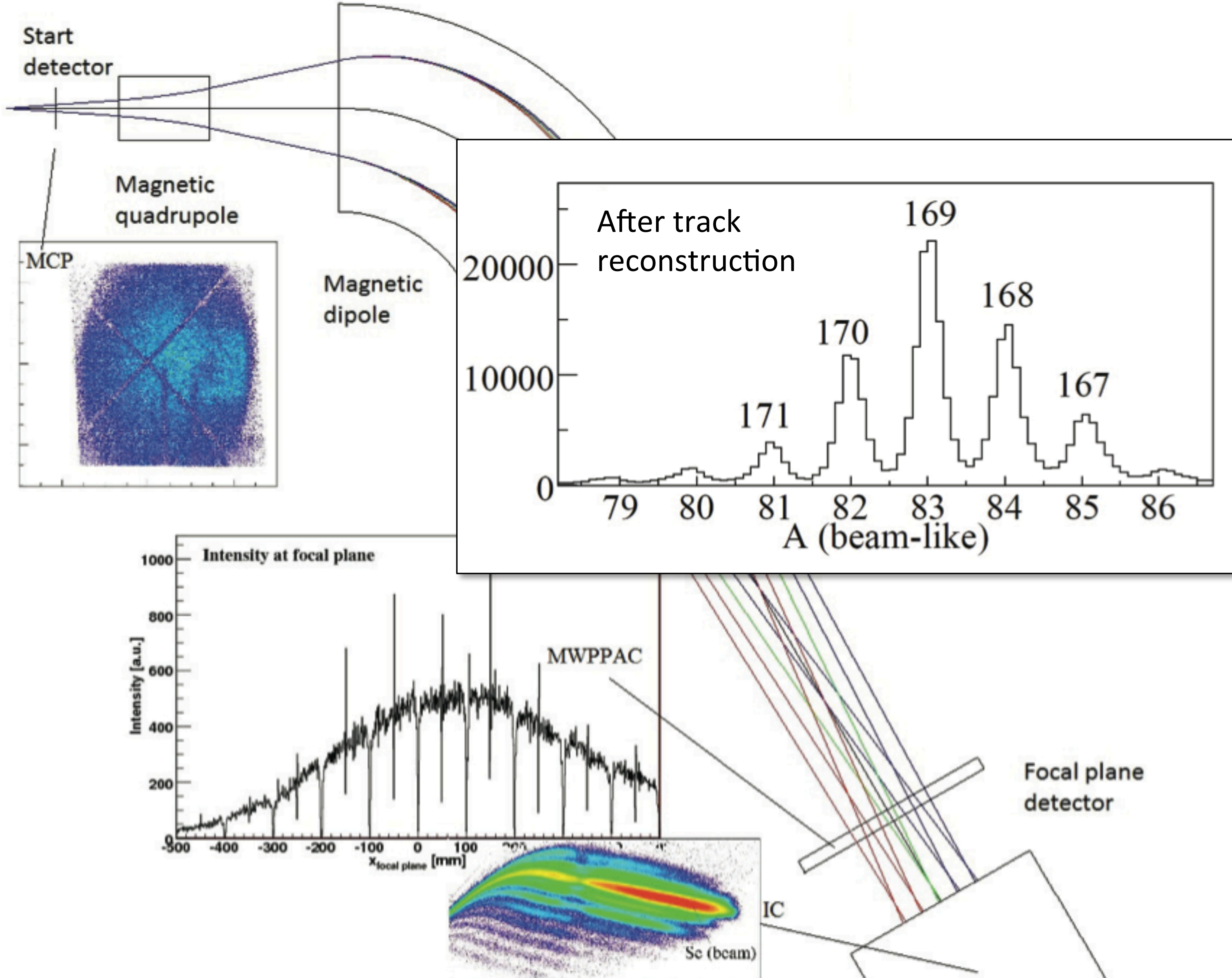
http://clara.lnl.infn.it/

The solution is to trace the rays of the detected ions. One example of such a device is the PRISMA spectrometer at LNL.

http://clara.lnl.infn.it/



Start detector
Magnetic quadrupole
Magnetic dipole
MCP
Intensity at focal plane
Intensity [a.u.]
$x_{focal\ plane}$ [mm]
MWPPAC
Focal plane detector
IC
Sc (beam)

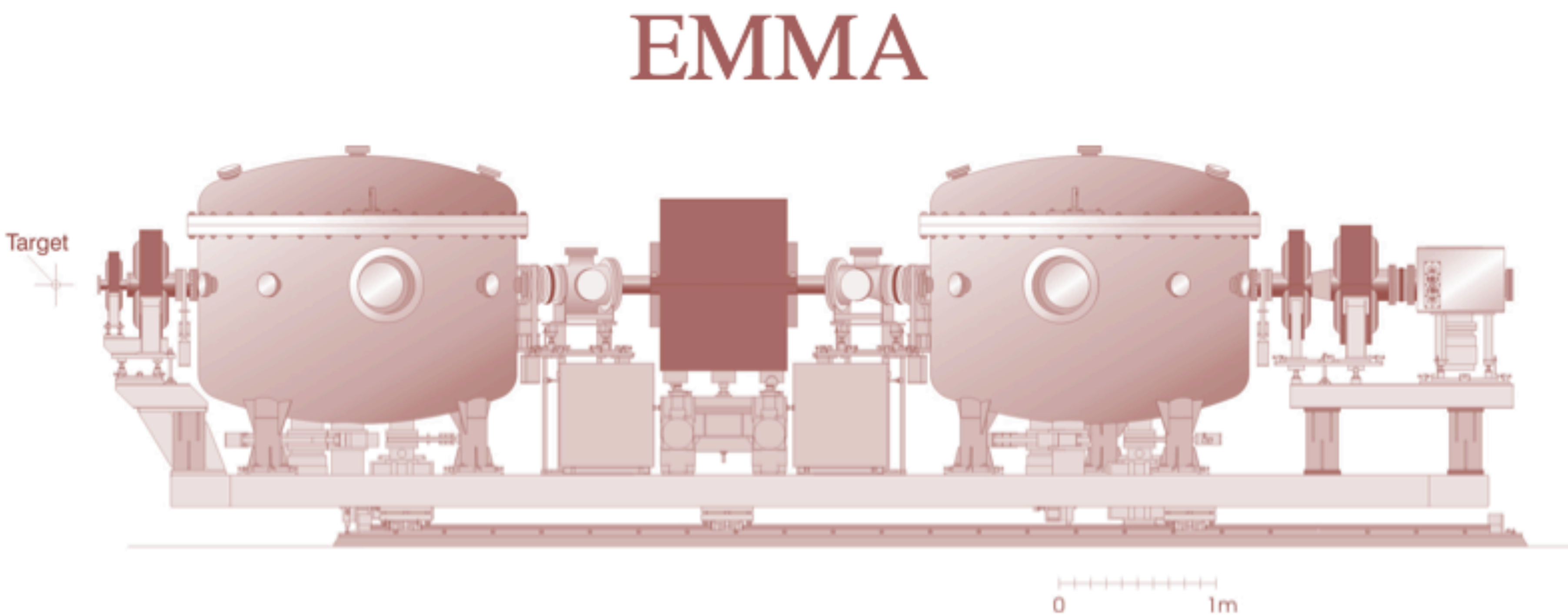


Start detector
Magnetic quadrupole
MCP
Magnetic dipole
After track reconstruction
169
170
168
171
167
20000
10000
0
79 80 81 82 83 84 85 86
A (beam-like)
Intensity at focal plane
Intensity [a.u.]
1000
800
600
400
200
0
-500 -400 -300 -200 -100 0 100
$x_{focal\ plane}$ [mm]
MWPPAC
Focal plane detector
IC
Sc (beam)

Mass separator A/q-separation at the focal plane

http://davids.triumf.ca/emma.htm

A/q-separation at the focal plane:



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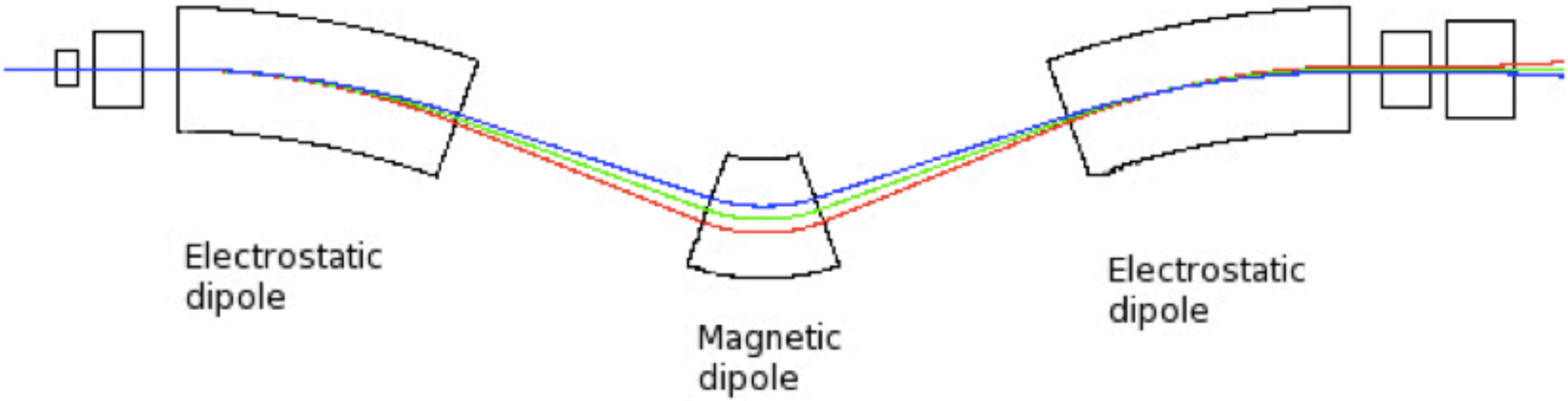
The energy and angular dispersion is cancelled leaving dispersion at the focal plane according to A/q.



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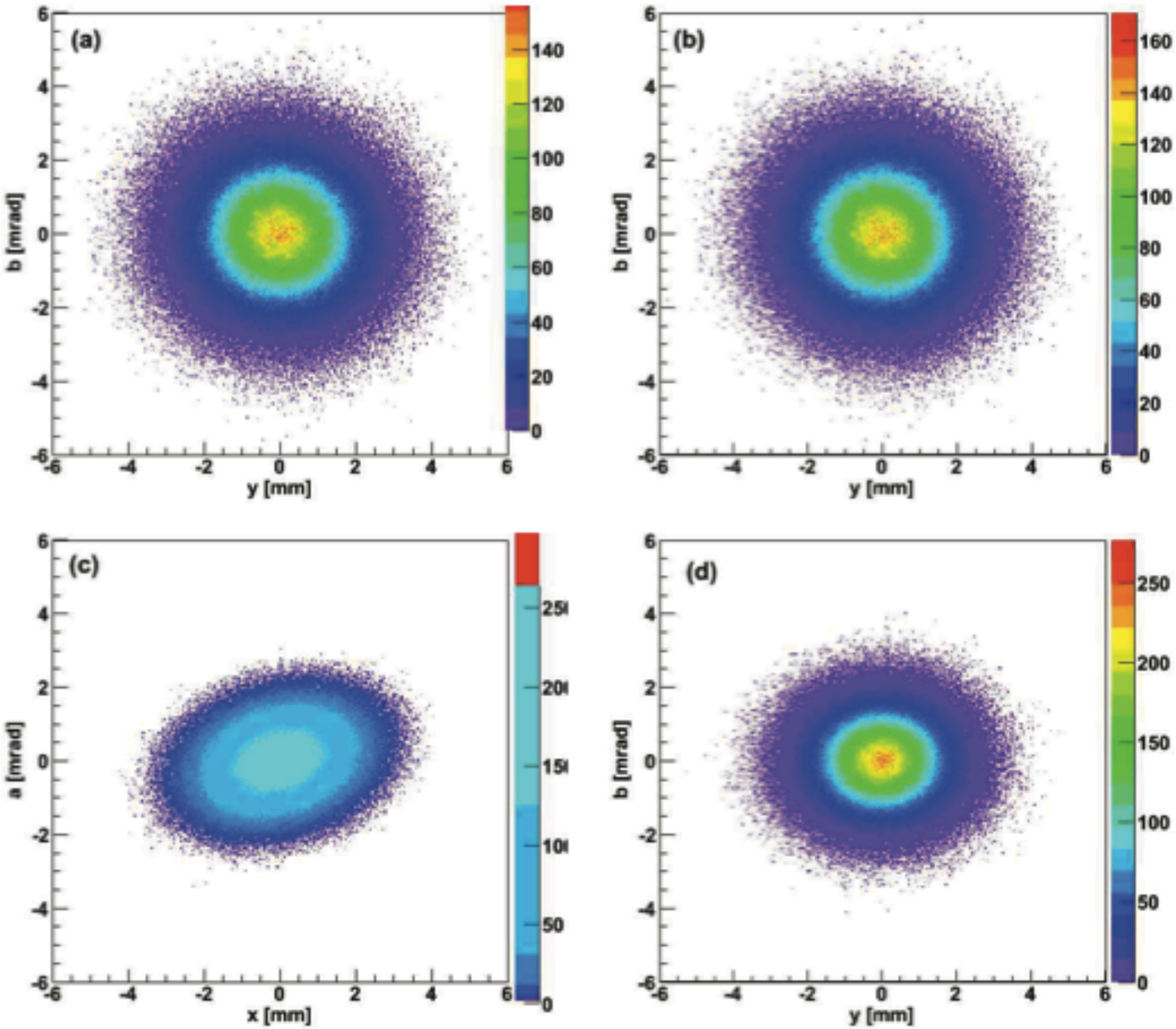
Beam parameters at HIE-ISOLDE



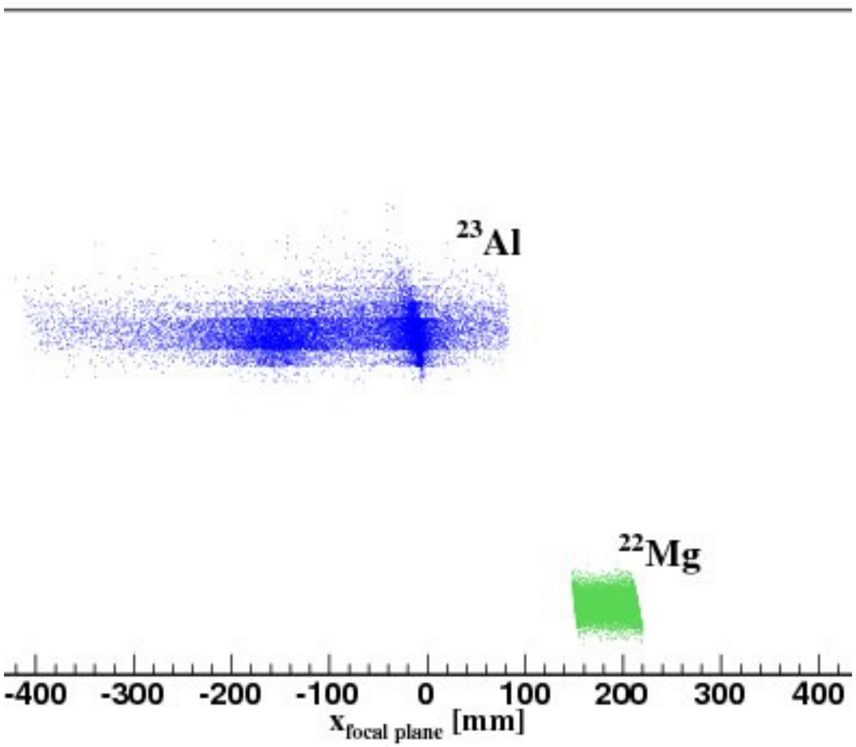
5 Mev/u

10 Mev/u

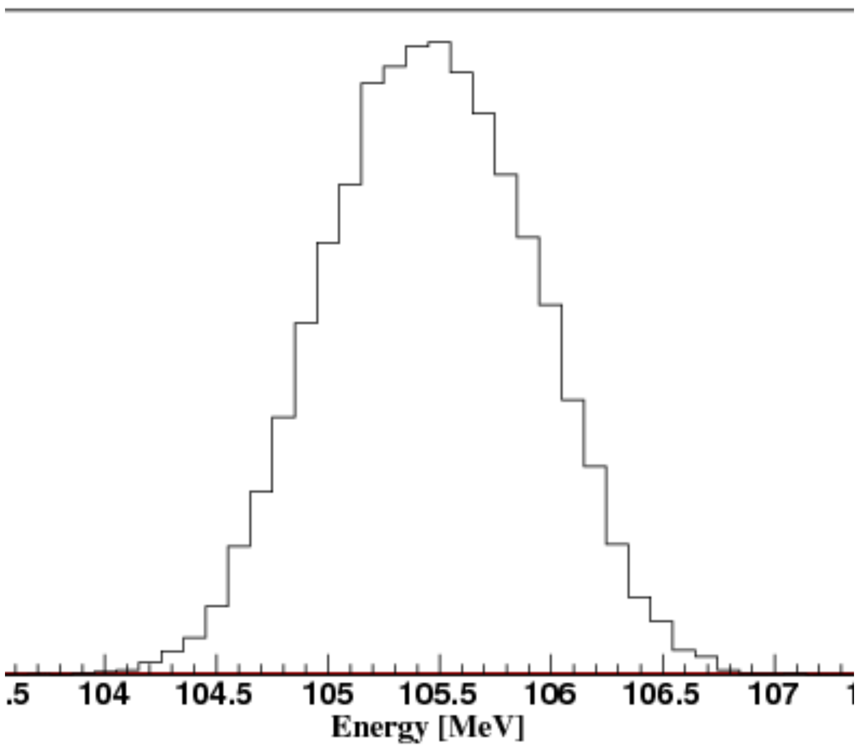
PHYSICS CASES

^{23}Al as the product of interest

Ray-Tracer

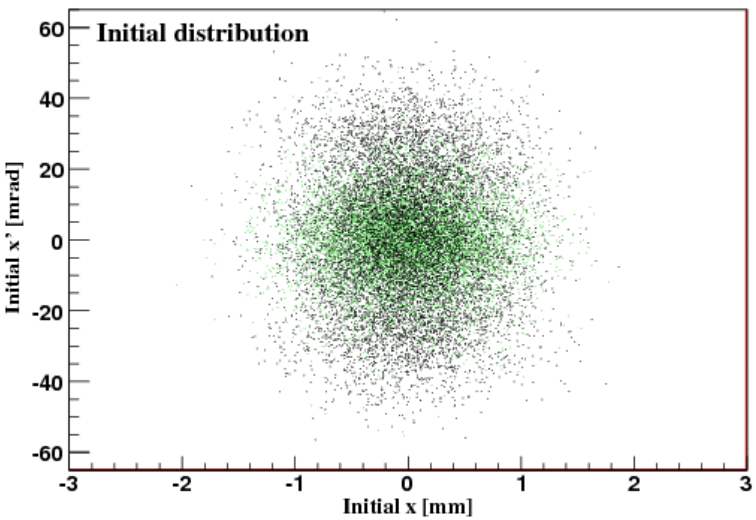


Mass separator

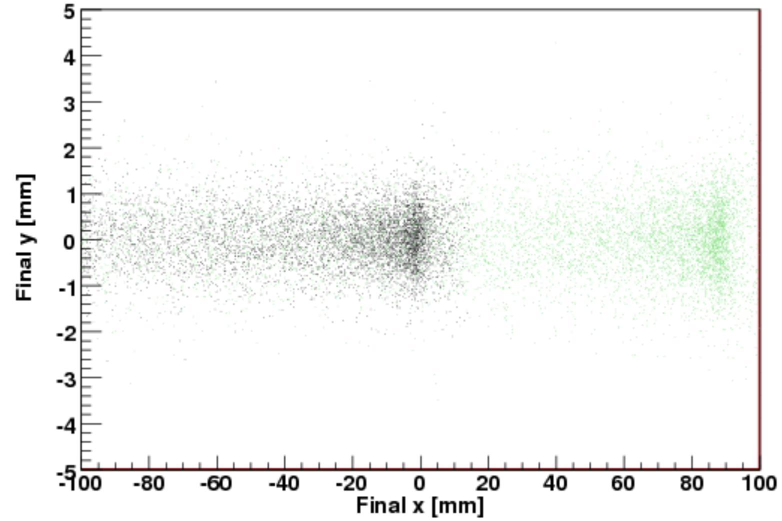


^{133}Sn as the product of interest

Ray-Tracer

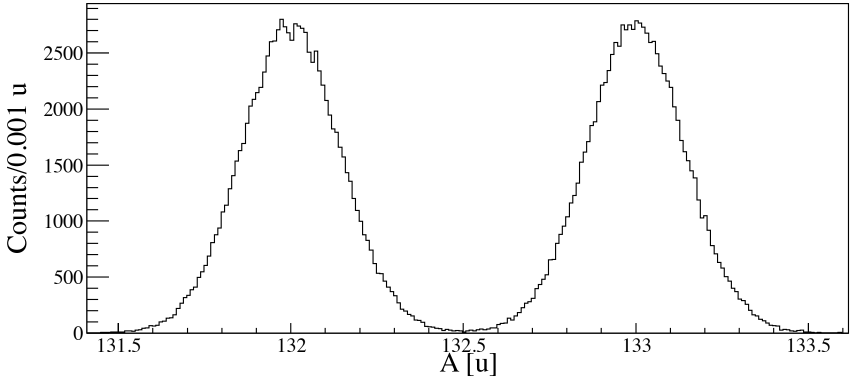


Mass separator

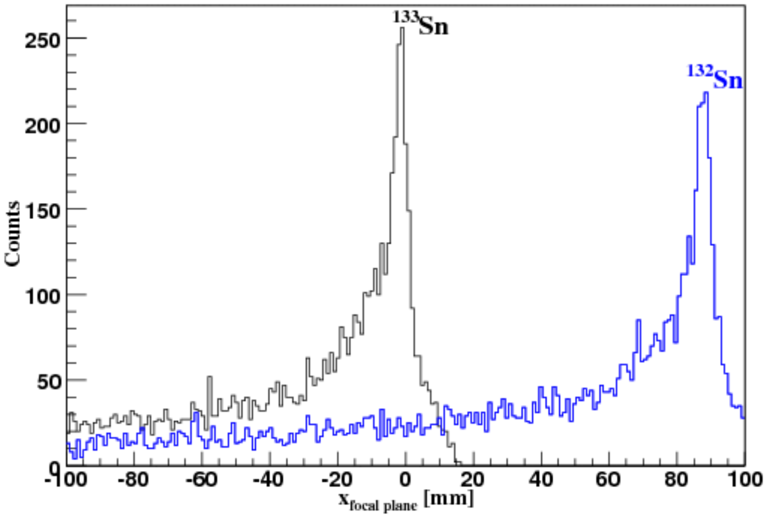


^{133}Sn as the product of interest

Ray-Tracer, after tracking



Mass separator



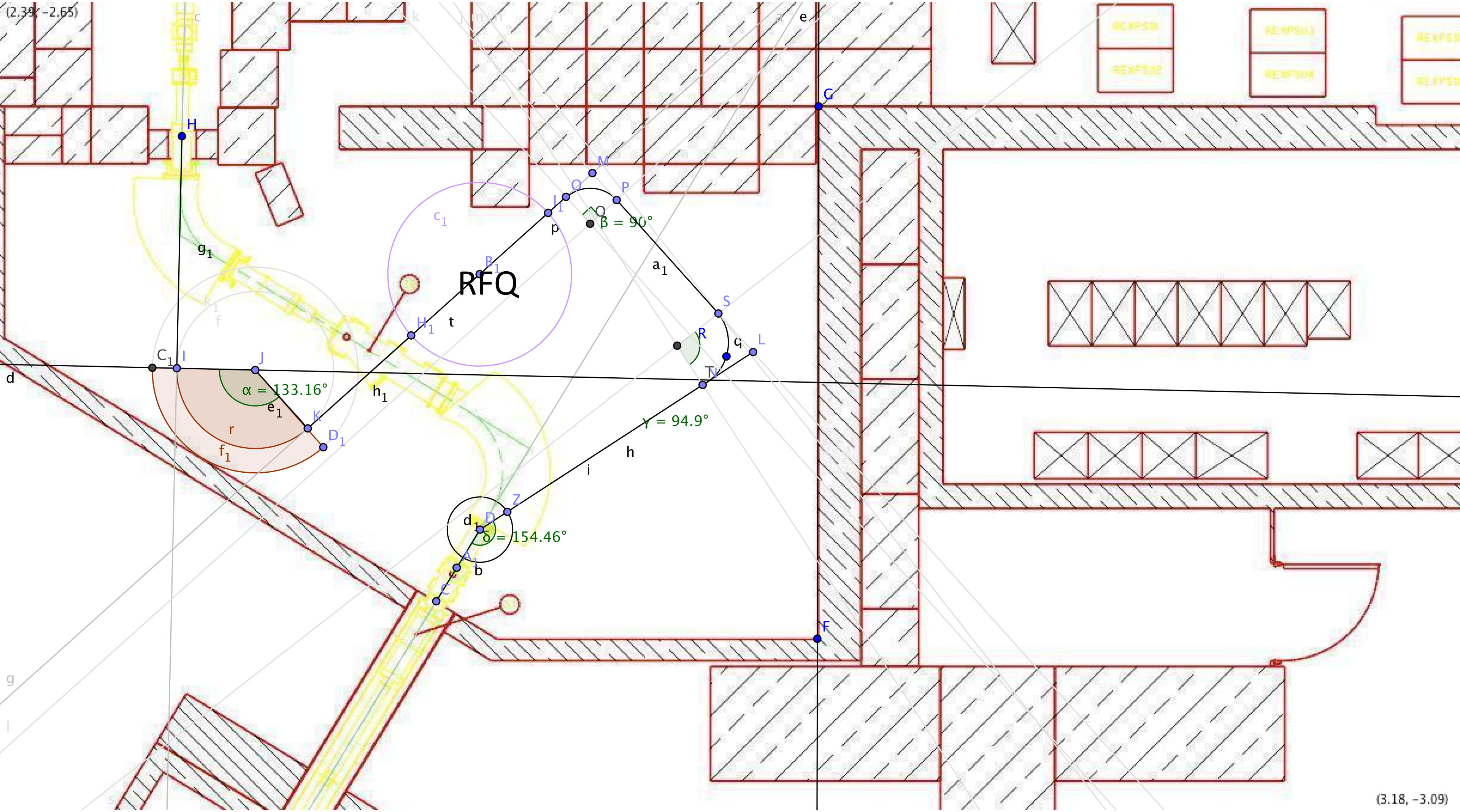
Summary

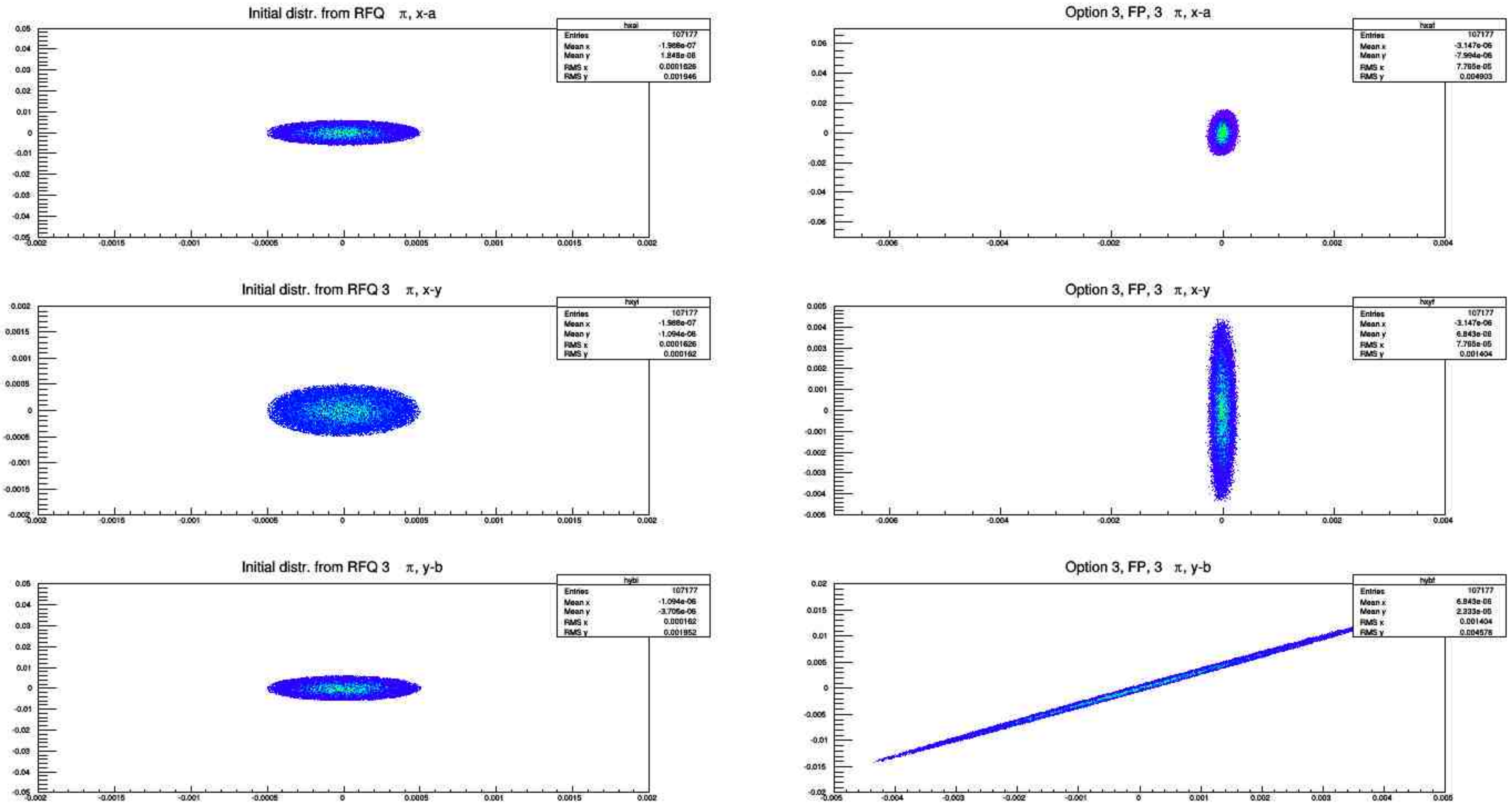
Reaction	Beam energy	Yield Alt.1	$\Delta A/A$	Yield Alt.2	$\Delta A/A$	Beam rej.
^{9}Li(d,n)^{10}Be	5.0 MeV/u	100%	236	54%	983	100%
^{22}Mg(d,n)^{23}Al	5.0 MeV/u	55%	256	54%	806	100%
^{68}Ni(d, n)^{69}Cu	5.0 MeV/u	99 %	327	22 %	330	88.1%
^{68}Ni(d, n)^{69}Cu	10 .0 MeV/u	97 %	319	22 %	331	87.7%
^{132}Sn(d,p)^{133}Sn	5.0 MeV/u	98 %	318	38 %	368	93 %
^{132}Sn(d,p)^{133}Sn	10.0 MeV/u	96 %	298	36 %	354	95 %
^{191}Pb(^{d}d,p)^{192}Pb	5.0 MeV/u	97 %	274	14.6 %	398	90 %
^{191}Pb(^{d}d,p)^{192}Pb	10.0 MeV/u	96 %	271	6.6 %	363	96 %

HRS upgrade

- The aim is better resolution than the app. 5000 today

One possible layout





Ion optical calculations by M. Augustin

Thanks for your attention!

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