TASCA 14

GSI, Darmstadt, October 21, 2014
13th Workshop on
Recoil Separator for Superheavy Element Chemistry

SHELS - Separator for Heavy ELement Spectroscopy

A. Popeko, FLNR JINR
for
GABRIELA-collaboraton

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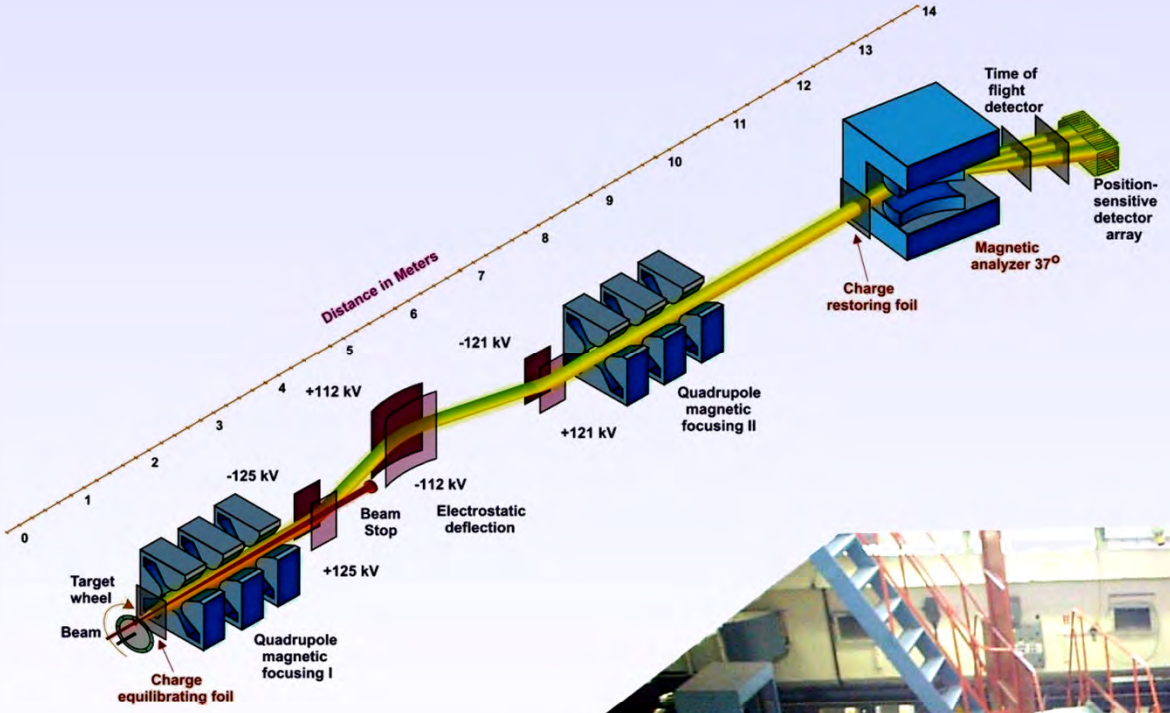
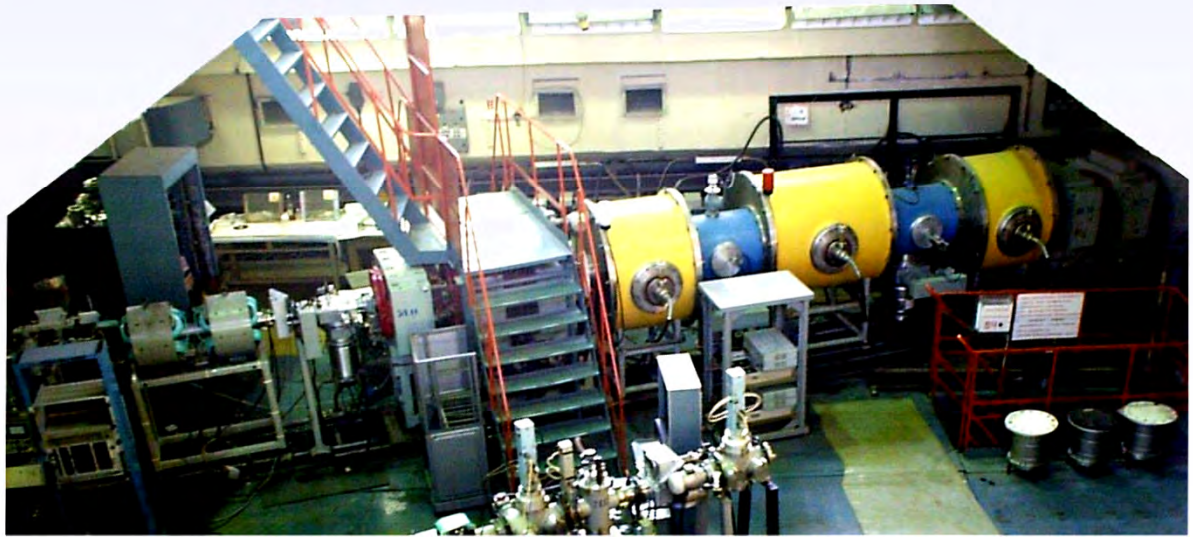
Electrostatic separator VASSILISSA
1987 – 2004 – 2012



E/q < 2 MV



GABRIELA-Collaboration

(Gamma Alpha Beta Recoil Investigations with the ELectromagnetic Analyser)

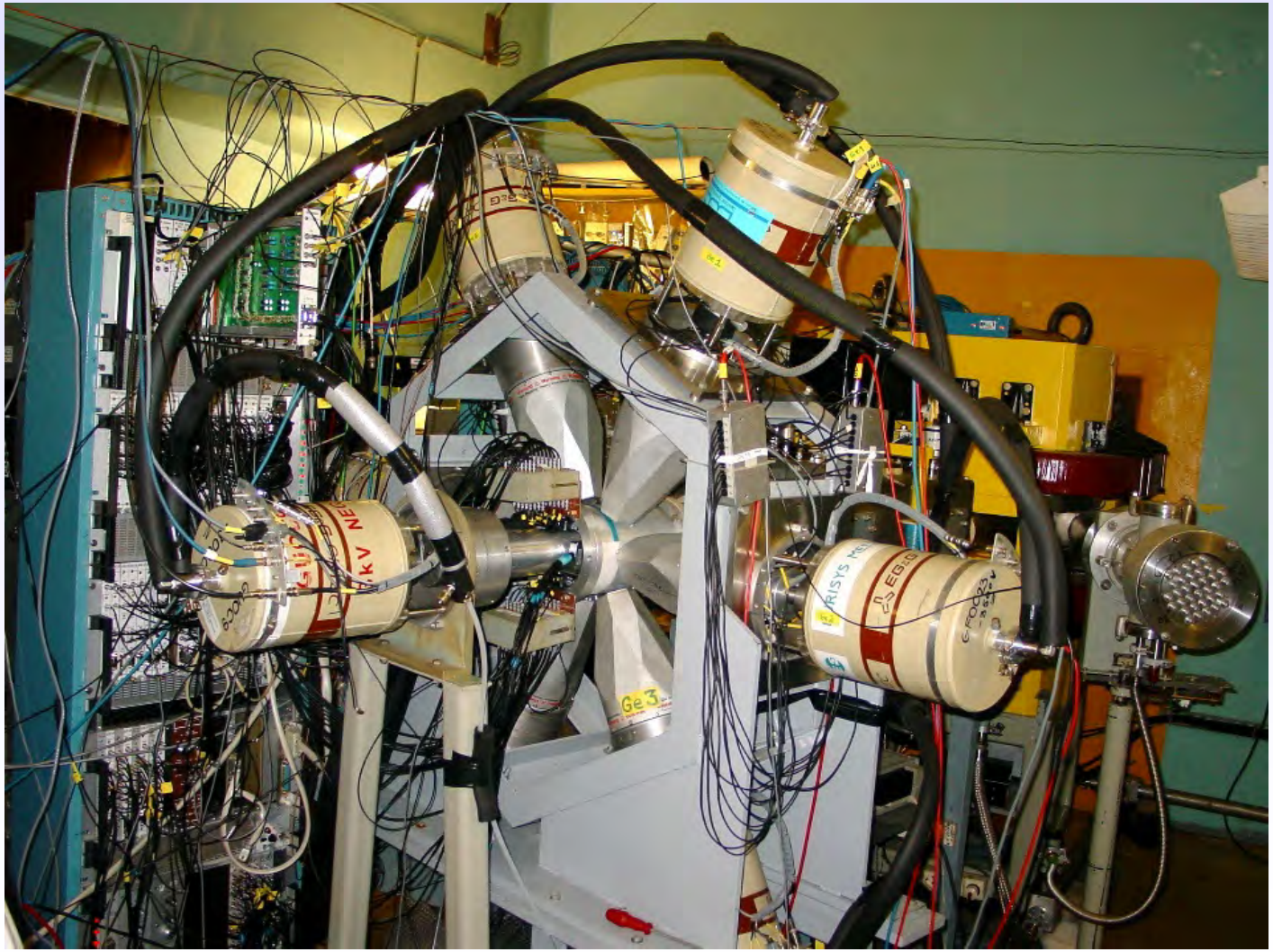
- **The joint JINR – IN2P3 (France) project entitled "Study of nuclear structure and nuclear reaction mechanism of heavy and superheavy elements: Gamma and electron spectroscopy of very heavy nuclei with Z ≈ 104" started in year 2004.**

- **The scientific aims of the collaboration were approved by the Scientific Council of IN2P3 in December 2003 and by the Scientific Council of JINR in January 2004.**

- **The collaboration, which includes groups from CSNSM Orsay and IPHC Strasbourg for IN2P3 and for JINR, a group from the FLNR Laboratory, has led 5 experimental campaigns since 2004.**

http://flerovlab.jinr.ru/flnr/vassilissa.html
http://www.csnsm.in2p3.fr/-GABRIELA-?lang=en

GABRIELA@VASSILISSA



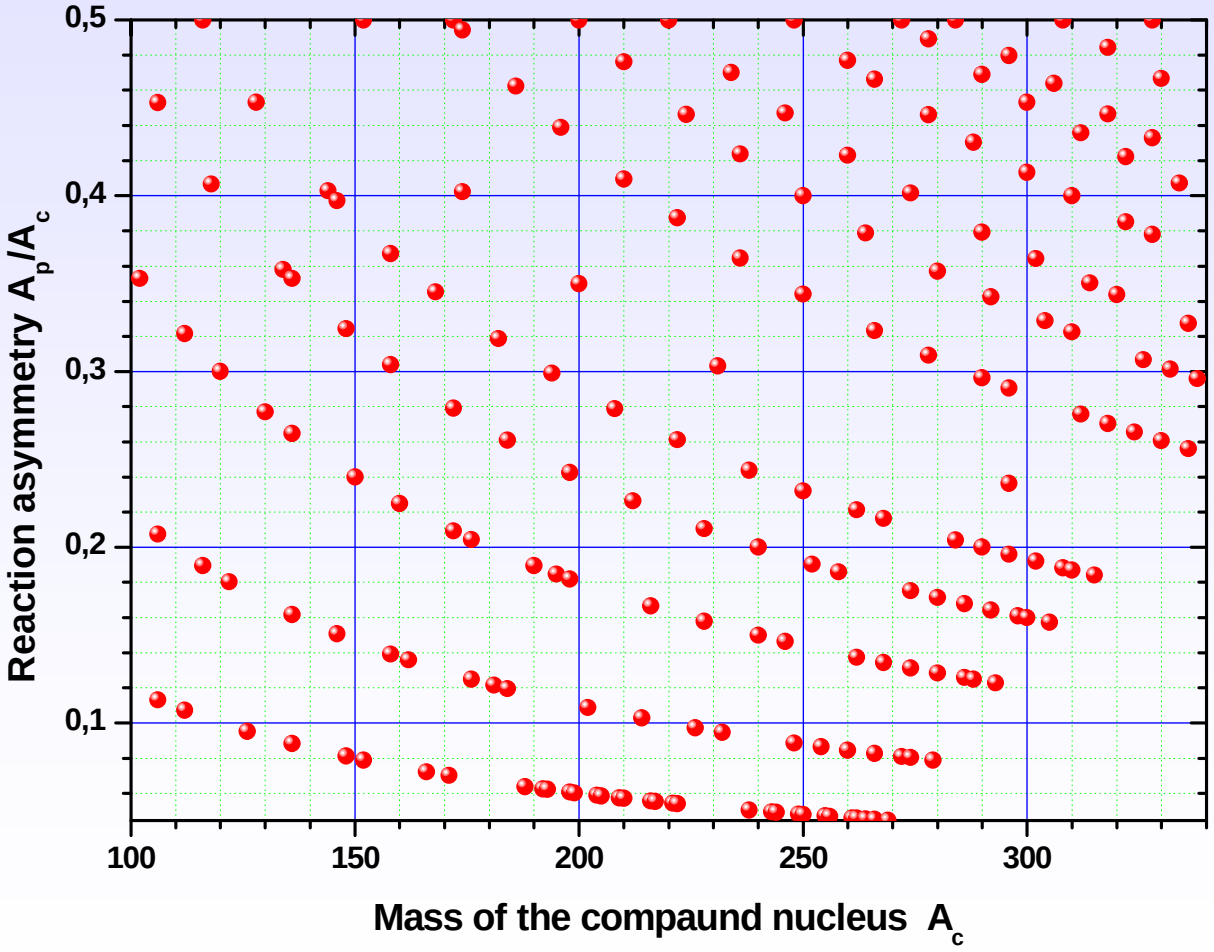
Spectroscopy of transfermium elements:

- Alpha spectroscopy - Q_α values and partial half lives, identification of new nuclides using α–α correlation method
- Spontaneous fission – TKE, prompt neutron multiplicity, partial half lives
- Beta and gamma spectroscopy – E_γ, E_β (conversion electrons), isomeric states at mother and daughter nuclei
- Correlation analysis – prompt and delayed α, β, γ correlations, assignment of isomeric states.

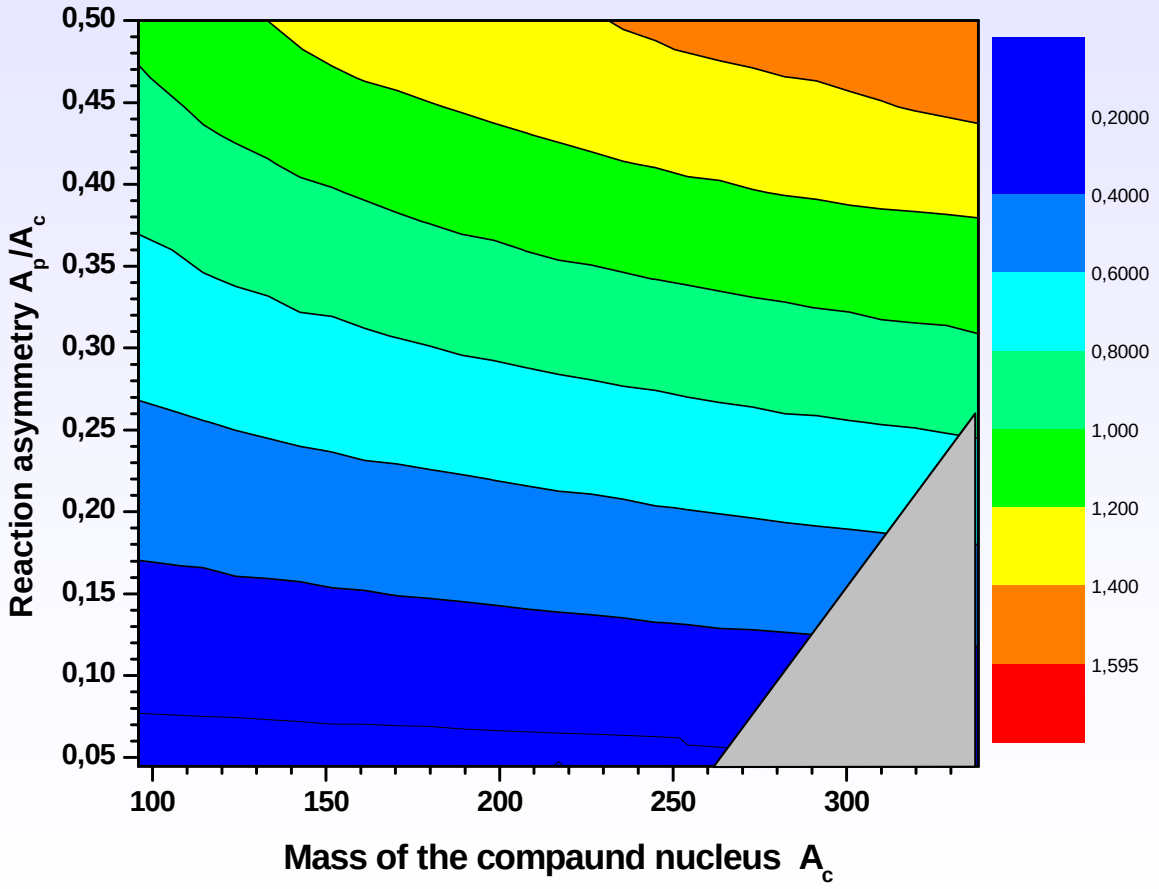
The goals of modernisation:

- **Study of heavy neutron rich isotopes, which can be produced in asymmetric combinations**
- **Study of isotopes, which can be produced in symmetric combinations**
- **Problem I: low transmission for asymmetric combinations**
- **Problem II: insufficient electric rigidity**

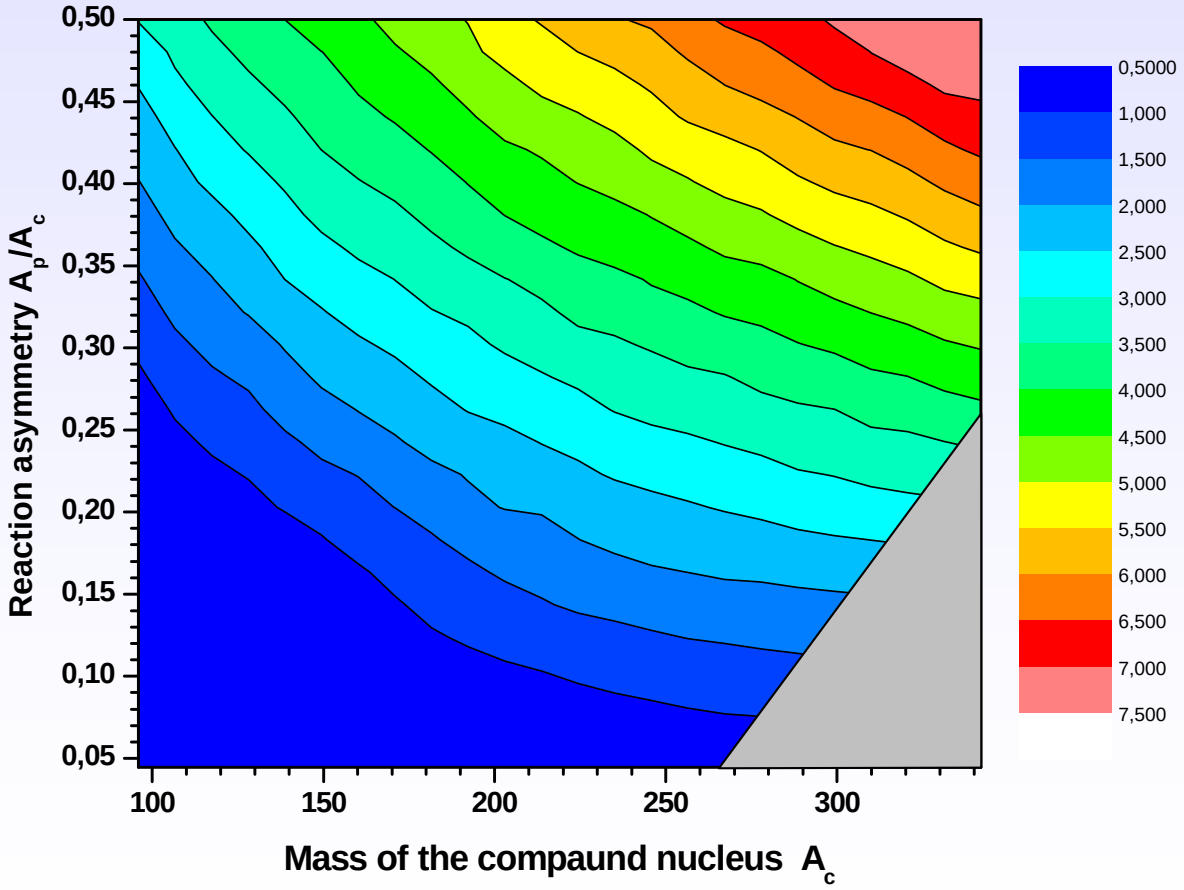
Analyzed reactions



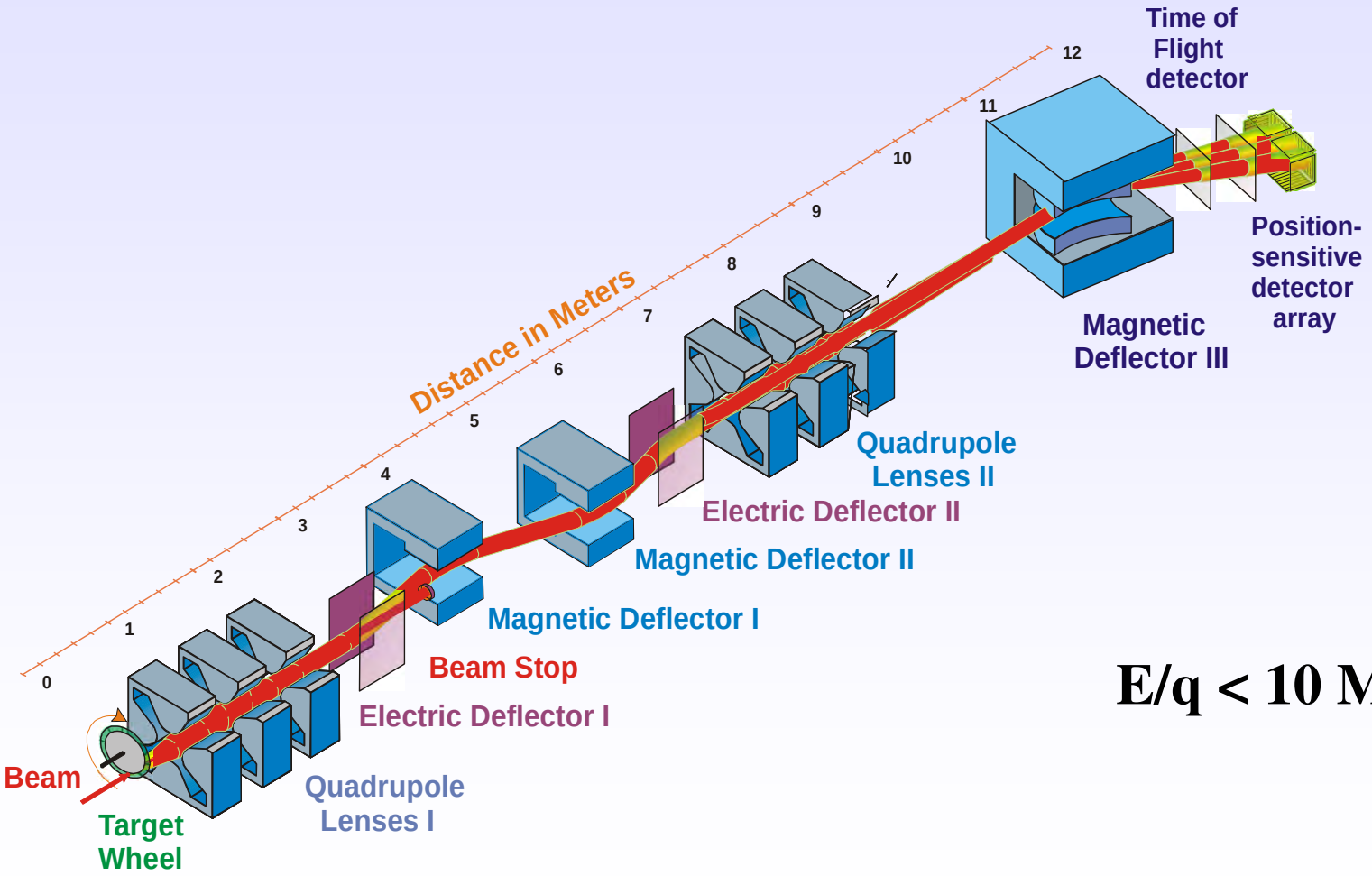
Magnetic rigidities of compound nuclei (T×m)



Electric rigidities of compound nuclei (MV)



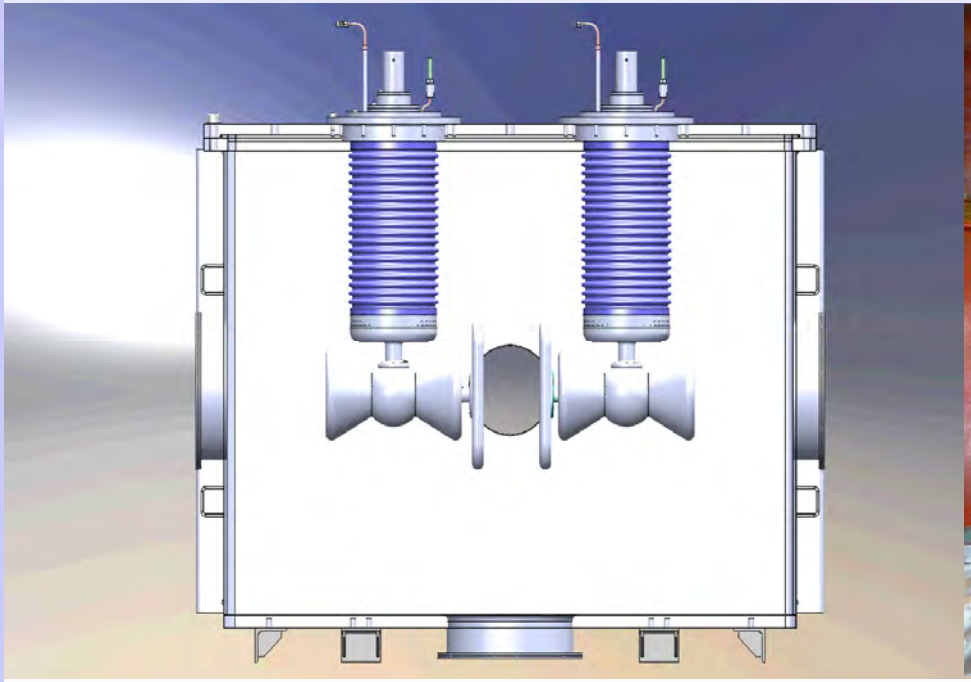
Velocity filter SHELS
(Separator for Heavy ELement Spectroscopy)



E/q < 10 MV

SHELS + GABRIELA

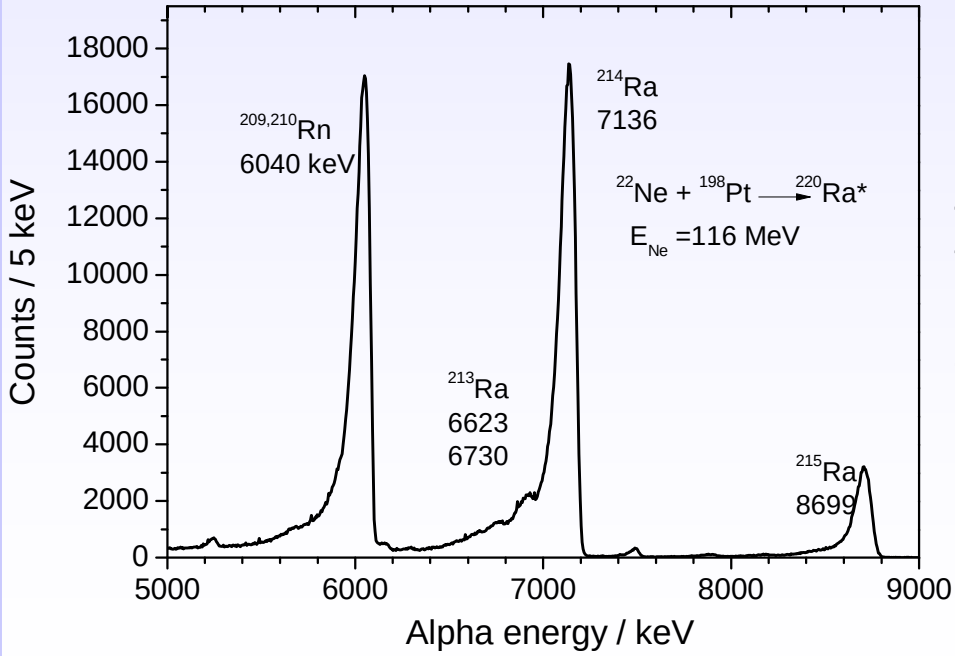
Movable plates of electrostatic deflectors

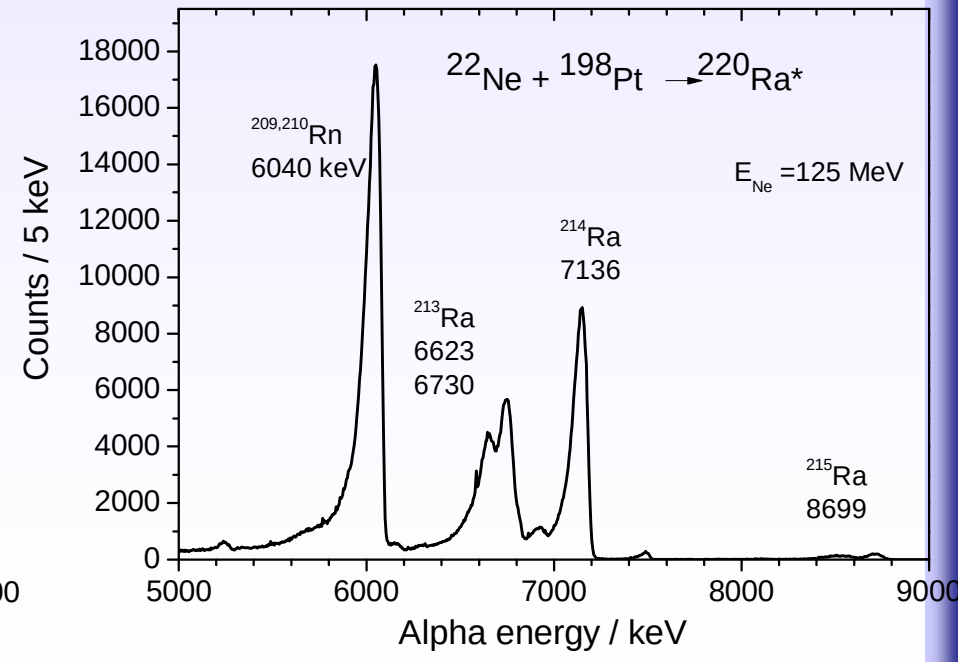


Determination of the transmission efficiency

May - July 2013

$^{22}Ne + {}^{198}Pt \rightarrow {}^{220}Ra^*$

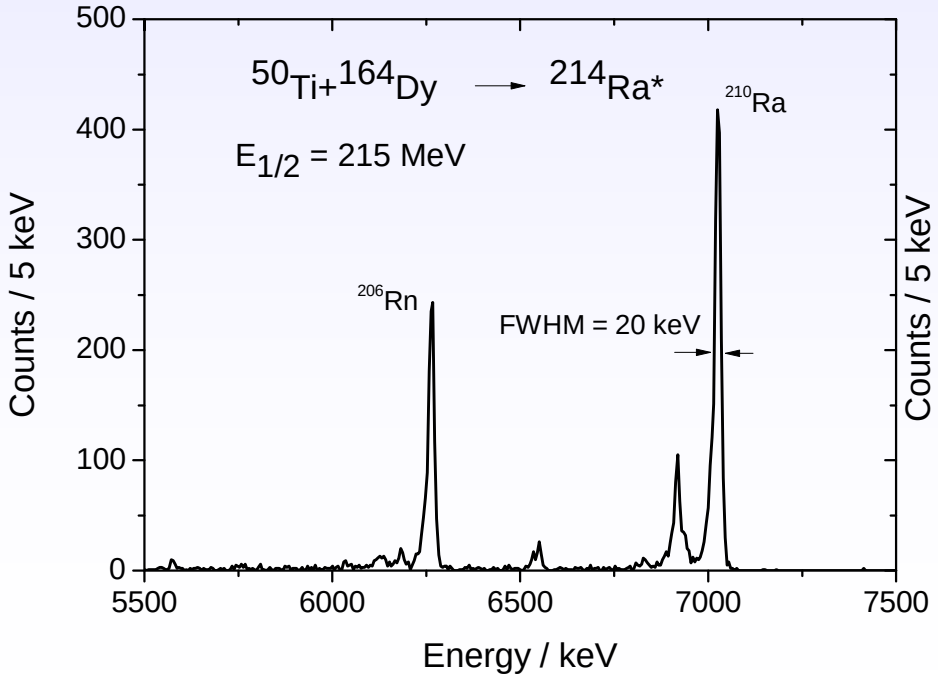


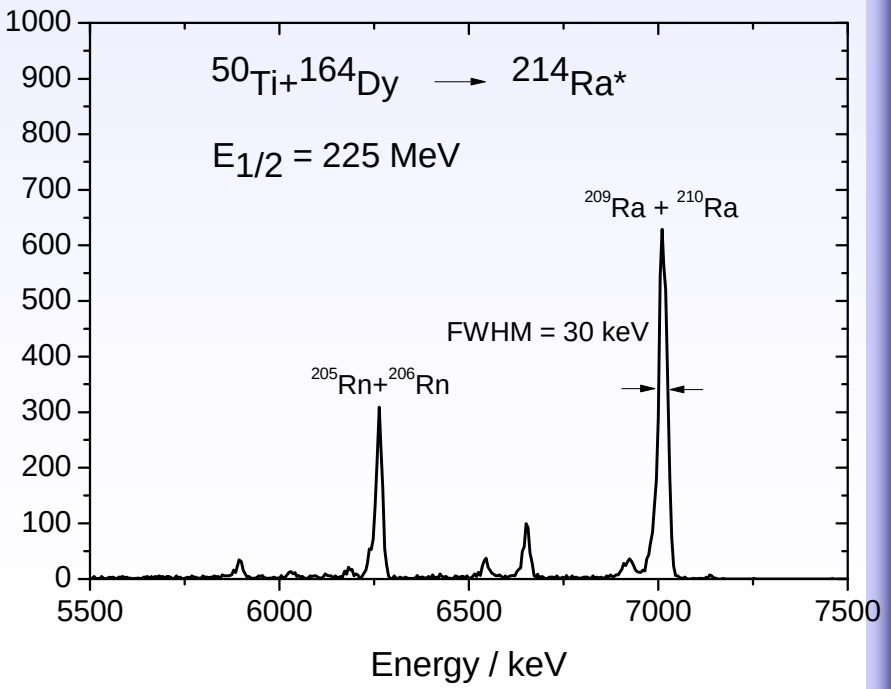


Determination of the transmission efficiency

November 2013

$^{50}Ti + {}^{164}Dy \rightarrow {}^{214}Ra^*$





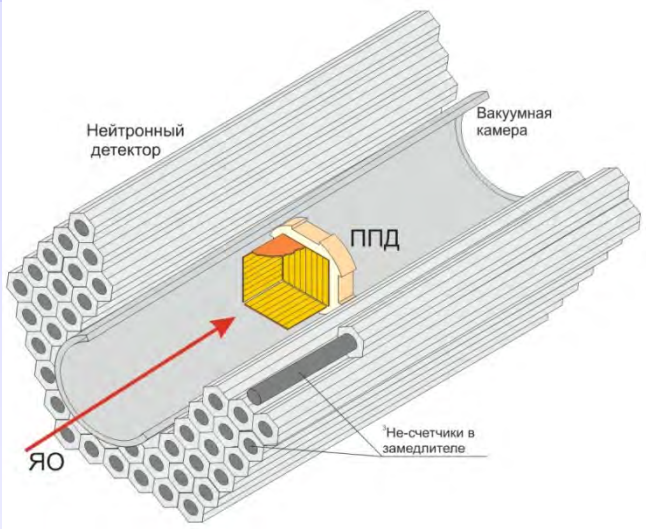
Test experiments year 2013

Reaction	$E_{beam1/2}$ MeV	Target thickness mg/cm^2	Transmission Old	New	Calc.
May - July 2013					
$^{22}Ne(^{197}Au,5n)^{214}Ac$	120	Met – 0.35	**0.03**	**0.035 - 0.05**	**0.14 Bigger detector size**
$^{22}Ne(^{198}Pt,6n)^{214}Ra$	115 -125	Met – 0.3	**0.03**	**0.035 - 0.05**	**0.14 Bigger detector size**
$^{22}Ne(^{238}U,5n)^{255}No$	**115**	**U_3O_8 – 0.35**	**0. 01**	**0.02**	**0.09 for metallic U**
November 2013					
$^{50}Ti(^{154}Sm,6n)^{198}Po$	240	Sm_2O_3 – 0.3	**0.3 (for $^{48}Ca+^{176}Yb$)**	**0.4**	**0.45**
$^{50}Ti(^{164}Dy,5n)^{209}Ra$	240	Dy_2O_3 – 0.3		**0.4**	**0.45**
$^{50}Ti(^{208}Pb,2n)^{256}Rf$	237	PbS – 0.36	**0.25 (for $^{48}Ca+^{208}Pb$)**	**0.2**	**0.4**

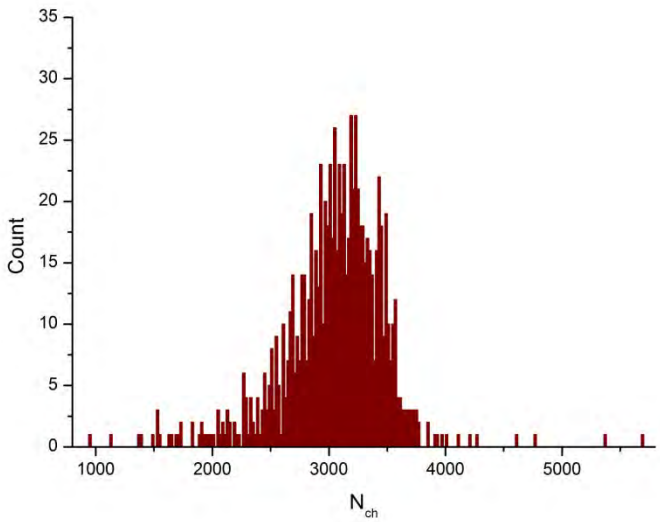
First research experiment with accelerated ^{50}Ti beam at FLNR U400 cyclotron

April 2014
^{50}Ti beam intensity – 3x10^{12} pps.
Modernized VASSILISSA separator and neutron detector at the focal plane.

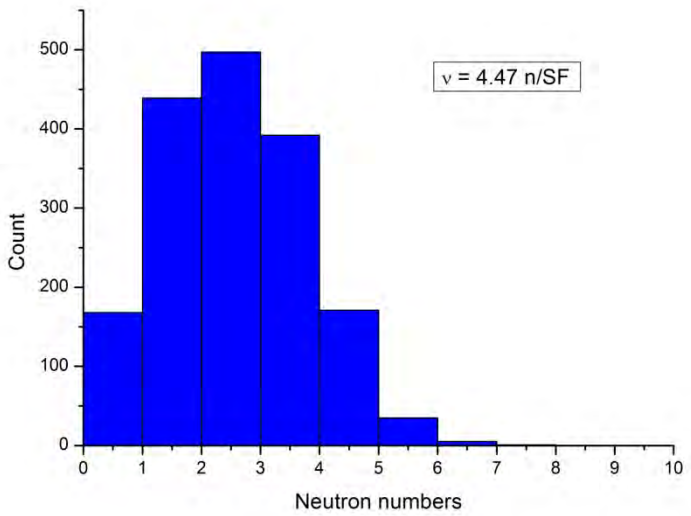
^{50}Ti + ^{208}Pb = 2n + ^{256}Rf
more than 1500 events detected.



Detector system at the focal plane of separator



TKE spectra for ^{256}Rf isotope



Neutron multiplicity measured for spontanerous fission of ^{256}Rf isotope.

Tests of γ detection at the target position

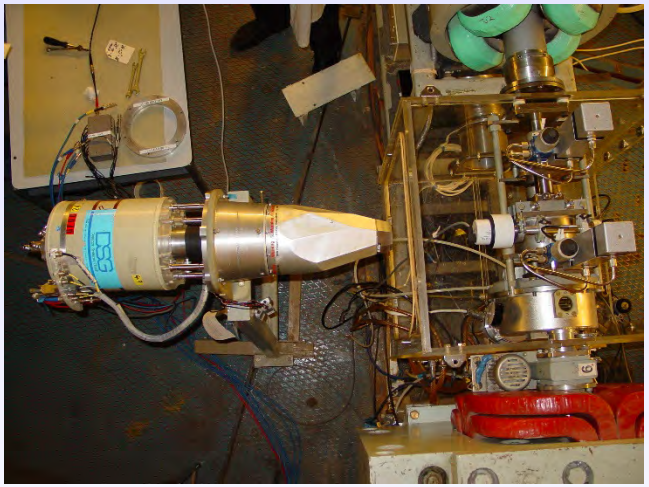
Beam intensity about 20 pnA

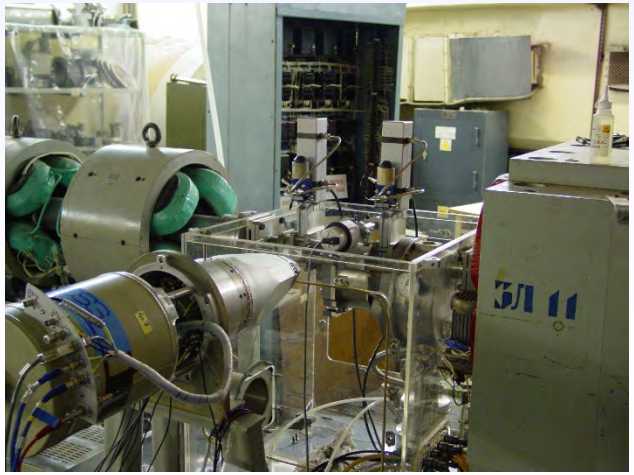
Counting rate without target 2 kHz

Counting rate with ^{208}Pb target (C backing foil) 3 kHz

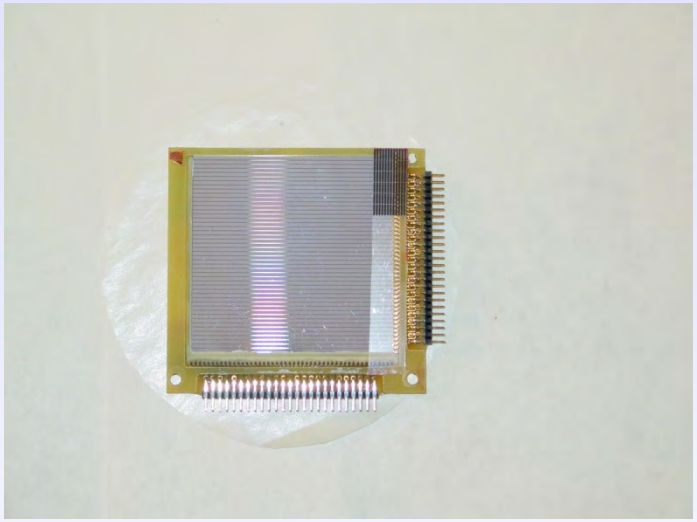
Counting rate with ^{164}Dy target (Ti backing foil) 3.5 kHz

- **Total counting rate at the focal plane at beam intensity 0.6 pμA – 700 Hz.**



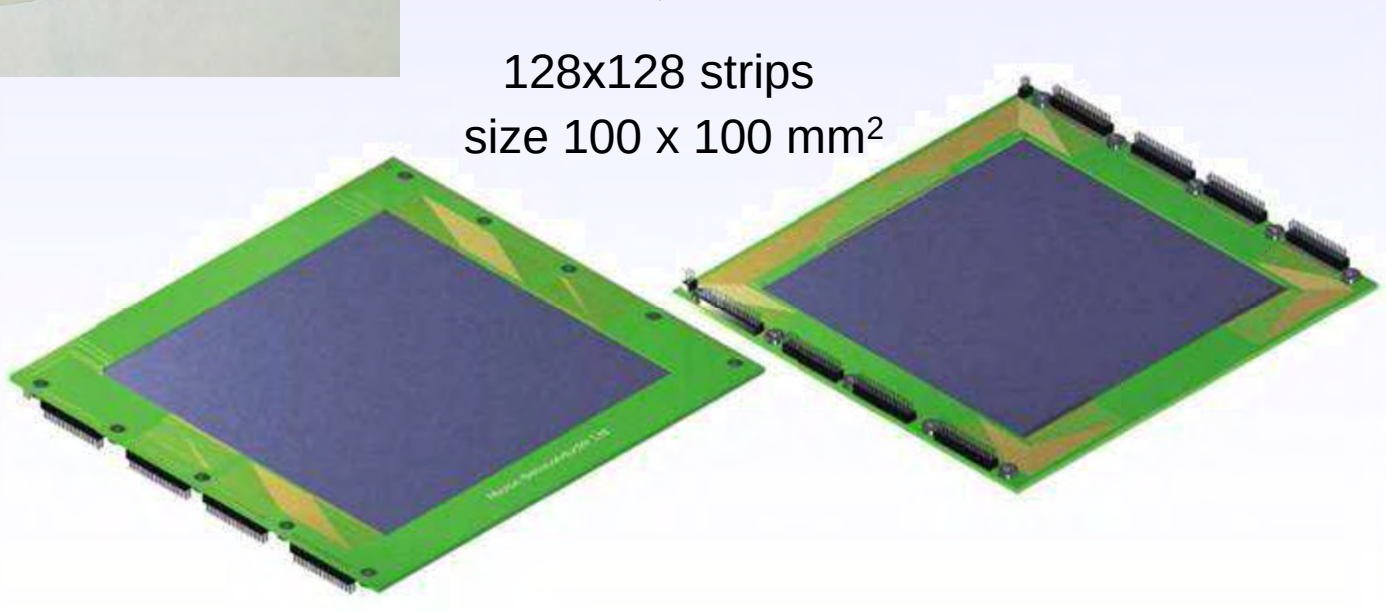


Double sided strip detectors



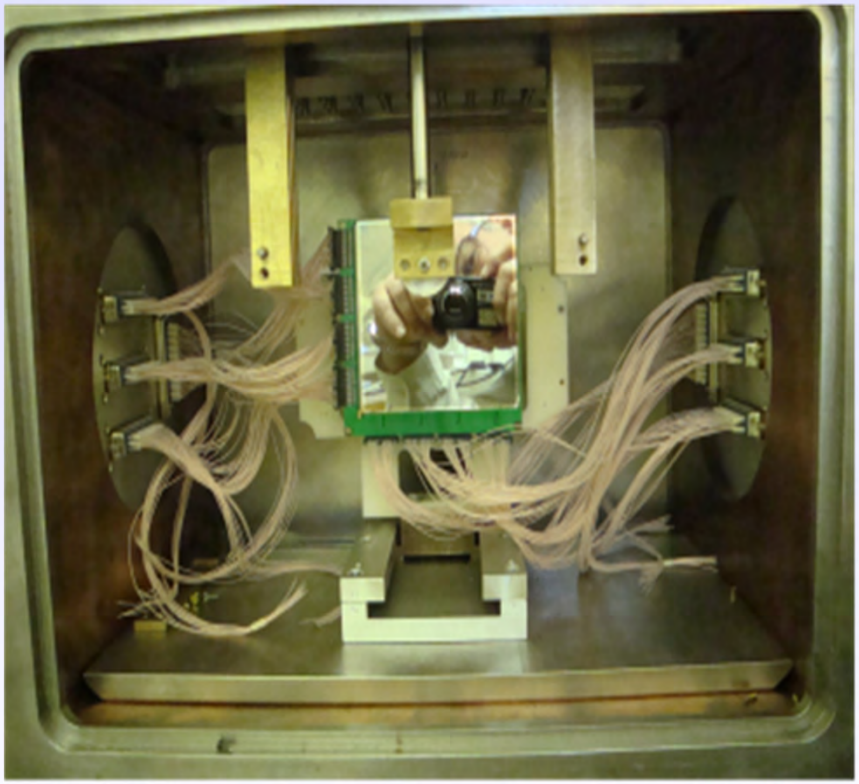
48x48 strips
size 60 x 60 mm^2

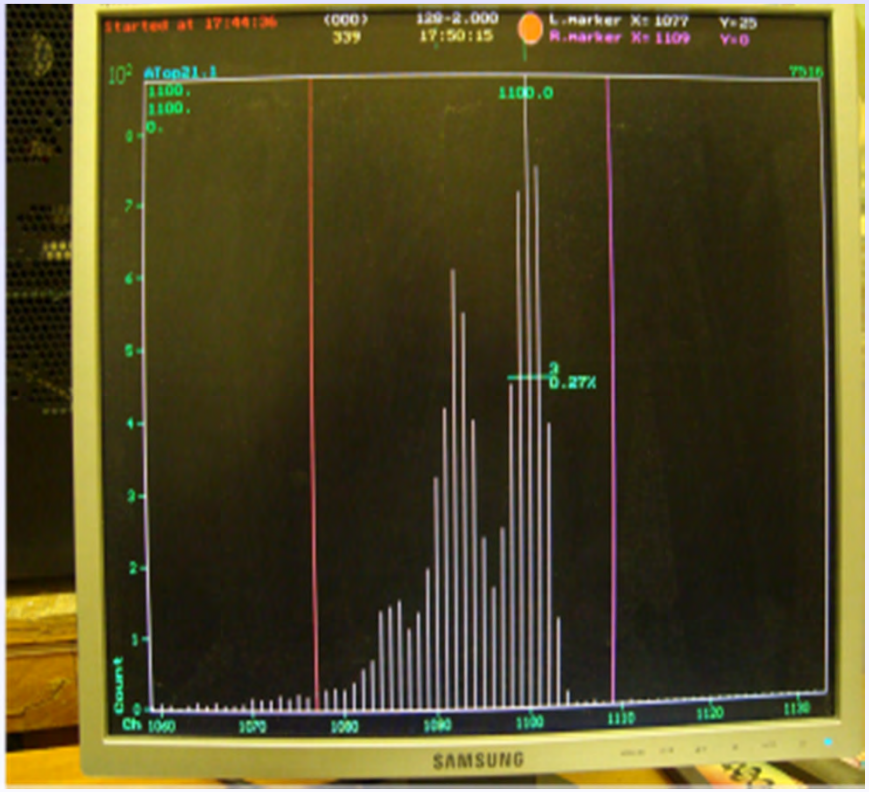
128x128 strips
size 100 x 100 mm^2



Factor of 2 in detection efficiency

Present status : Tests of new 128x128 strip DSSD





Left panel – double sided strip detector 128x128 strips, 100x100 mm^2 size.

Right panel – ^{242}Pu alpha spectrum. Energy resolution obtained is about 15 keV.

Calculated transmission efficiency of SHELS

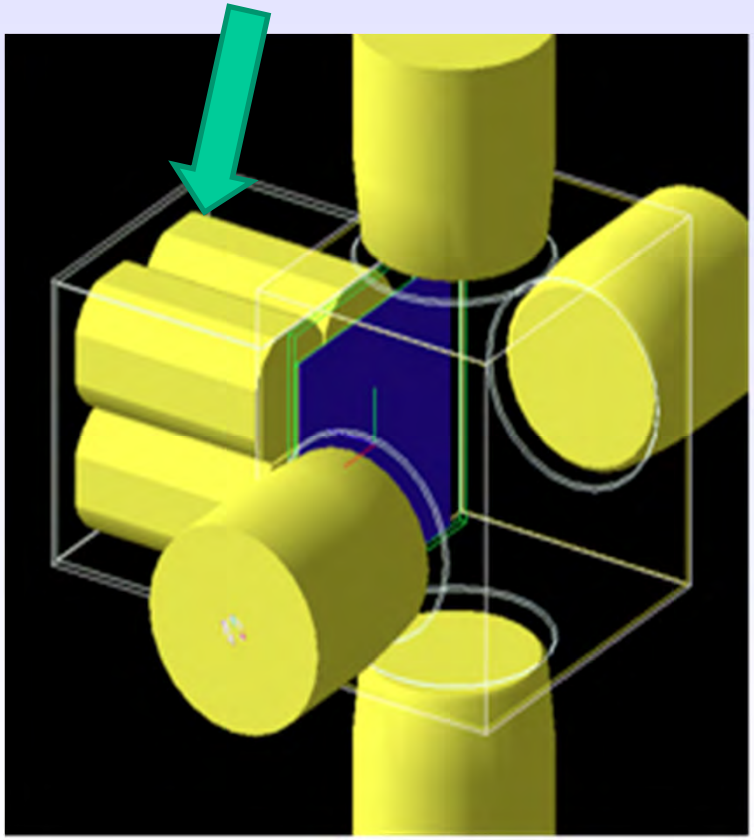
Reaction	$E_{p1/2}$ MeV	Target thickness mg/cm^2	Transmission
$^{22}Ne(^{238}U,5n)^{255}No$	115	U_3O_8 – 0.2	0.06 (now –0.02)
$^{22}Ne(^{238}U,5n)^{255}No$	115	Met – 0.2	0.09
$^{22}Ne(^{197}Au,5n)^{214}Ac$	110	Met – 0.2	0.14
$^{40}Ar(^{181}Ta,4n)^{217}Pa$	182	Met – 0.3	0.28
$^{40}Ar(^{162}Dy,7n)^{195}Po$	198	DyO_2 – 0.3	0.28
$^{242}Pu(^{22}Ne,5n)^{259}Rf$	120	PuO_2 – 0.2	0.07
$^{48}Ca(^{208}Pb,2n)^{254}No$	216	Met – 0.4	0.42

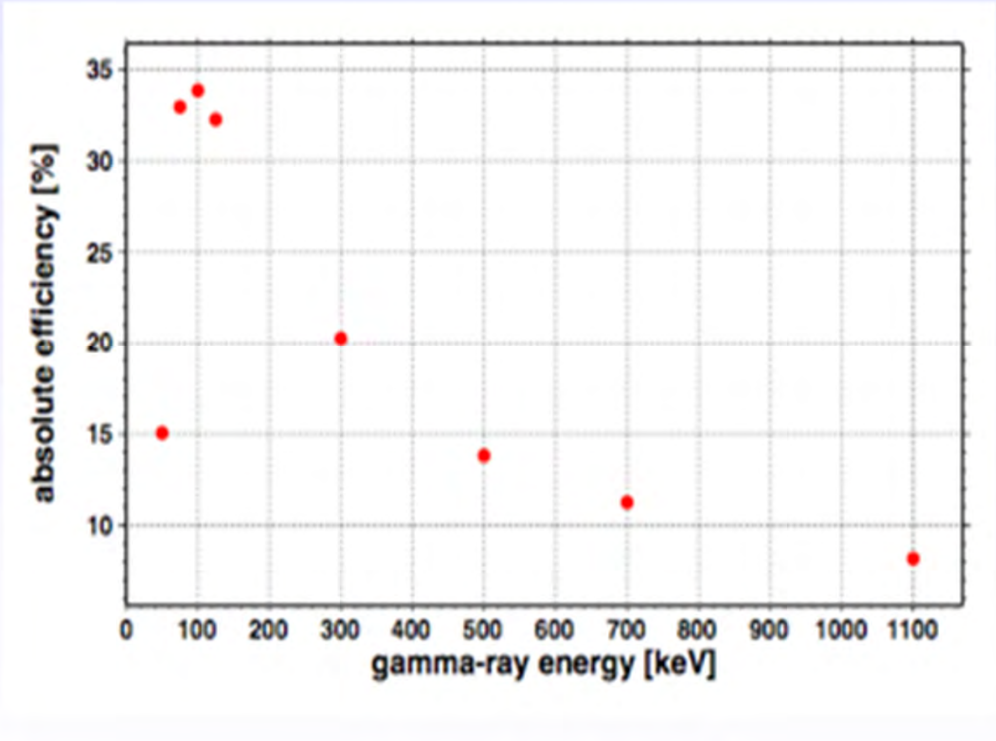
Estimated counting rates

Reaction	Cross section	Transmission %	ERs counting rate per day
$^{242}Pu(^{22}Ne,5n)^{259}Rf$	3.0 nb	7	115
$^{244}Pu(^{22}Ne,5n)^{261}Rf$	5.0 nb	7	190
$^{248}Cm(^{18}O,5n)^{261}Rf$	13 nb	4	270
$^{243}Am(^{22}Ne,5n)^{260}Db$	2.0 nb	7	70
$^{243}Am(^{22}Ne,4n)^{261}Db$	1.5 nb	7	55
$^{248}Cm(^{22}Ne,5n)^{265}Sg$	0.3 nb	6	10
$^{208}Pb(^{54}Cr,1n)^{261}Sg$	0.5 nb	50	90

GABRIELA 2015: Gamma detection efficiency estimations for new detector set up

Clover detector





Preliminary GEANT4 detector arrangement including a Clover and 4 EUROGAM phase-I. These surround the 10x10 cm^2 implantation detector (in blue) and its PCB (green). Right : A first estimate of the achievable singles efficiency as a function of photon energy f or a distributed source.

New insights into the ^{243}Am+^{48}Ca reaction

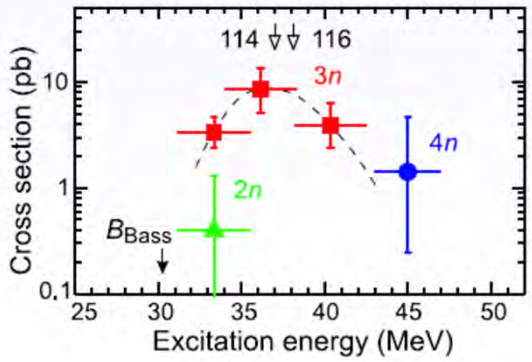
Cross section ~ 8 pb

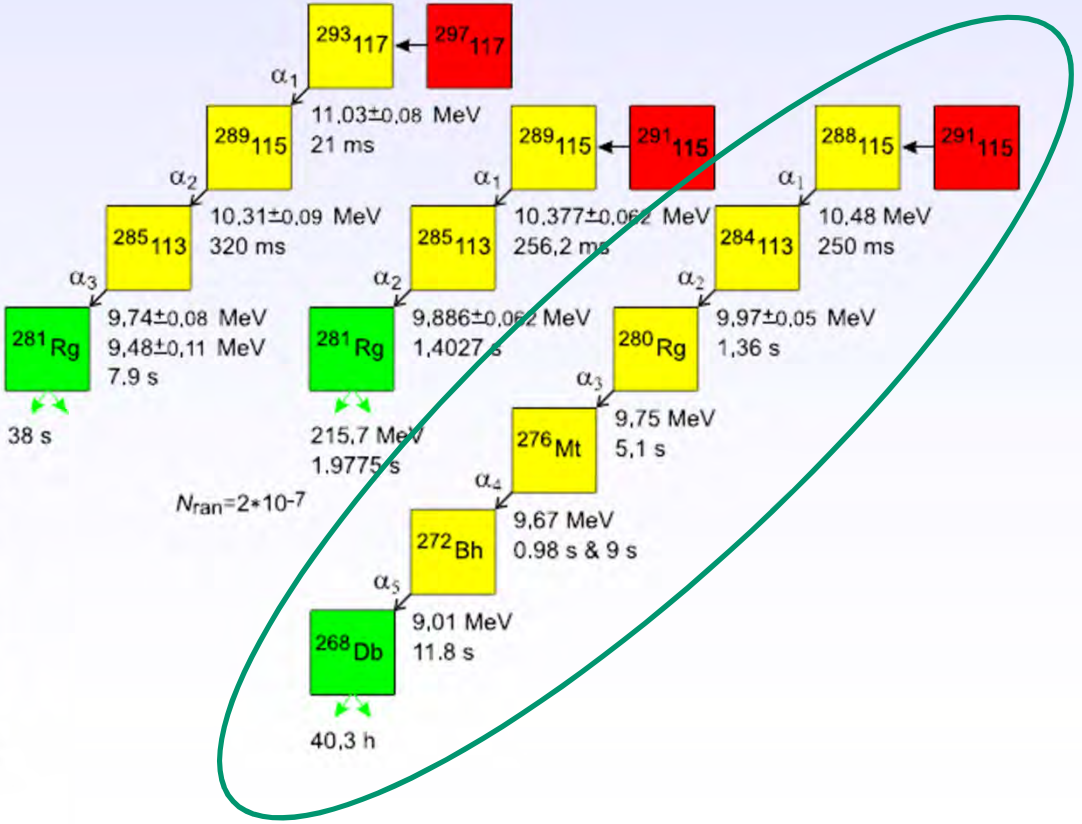
Target thickness ~ 10^{18} at/cm^2

Beam intensity ~ 5×10^{12} pps

If ε ~ 40 %

1 event per day.





Conclusion:

The separator SHELS is prepared for experiments!