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On-Line Separator for γ-Spectroscopic Studies

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for the GABRIELA Collaboration

Co-authors

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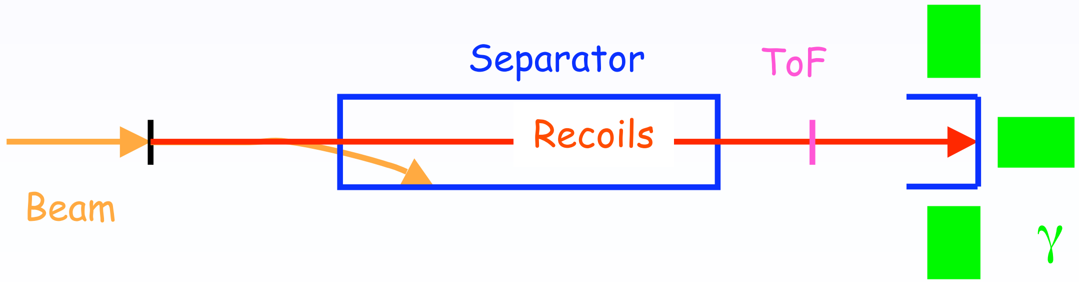
Advantages of Dubna:
availability of intense ion beams and radioactive targets!

Decay spectroscopy @ the focal plane of the recoil separator
Isomer and Decay spectroscopy
(running IN2P3-FLNR-project GABRIELA) :

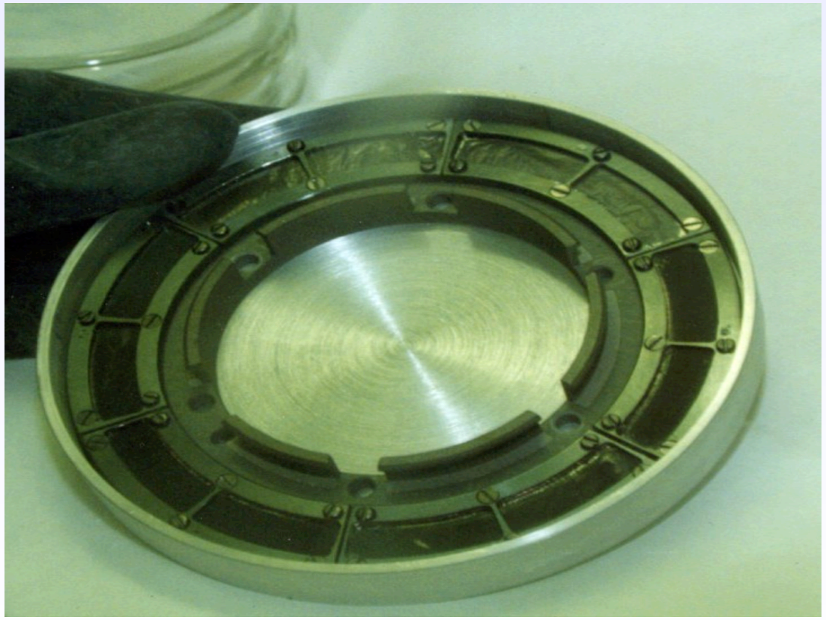
Mother		Daughter
$^{238}U\ (^{26}Mg,5n)^{259}Rf$	1.1 nb	$^{255}No_{153}$ (Z=102)
$^{242}Pu\ (^{22}Ne,5n)^{259}Rf$	5.0 nb	$^{255}No_{153}$ (Z=102)
$^{248}Cm\ (^{18}O,5n)^{261}Rf$	13 nb	$^{257}No_{155}$ (Z=102)
$^{244}Pu\ (^{22}Ne,5n)^{261}Rf$	5.0 nb	$^{257}No_{155}$ (Z=102)
$^{243}Am(^{22}Ne,4n)^{261}Db$	1.5 nb	$^{257}Lr_{154}$ (Z=103)
$^{248}Cm\ (^{22}Ne,5n)^{265}Sg$	1.3 nb	$^{261}Rf_{157}$ (Z=104)

I_{beam} ~ what the target can withstand ~ 1 – 2 pμA

Recoil energy, α, electrons



^{249}Cf - target

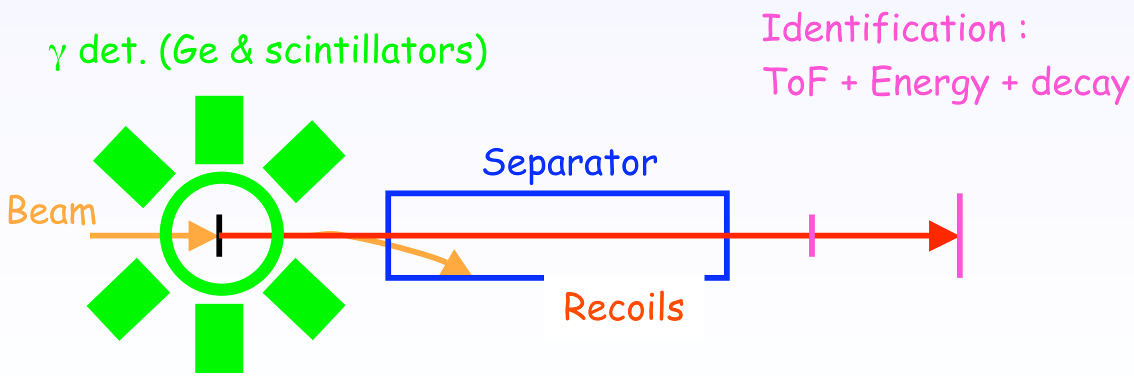


Advantages of Dubna

Prompt spectroscopy @ the target position with the RDT technique

$^{238}U(^{22}Ne,5n)^{255}No$	100 nb
$^{248}Cm(^{12}C,4n)^{256}No$	1000 nb
$^{248}Cm(^{13}C,4n)^{257}No$	1100 nb
$^{244}Pu(^{18}O,4n)^{258}No$	100 nb
$^{248}Cm(^{15}N,4n)^{259}Lr$	50 nb
$^{246}Cm(^{16}O,4n)^{258}Rf$	10 nb

I_{beam} ~ 10-20 pnA

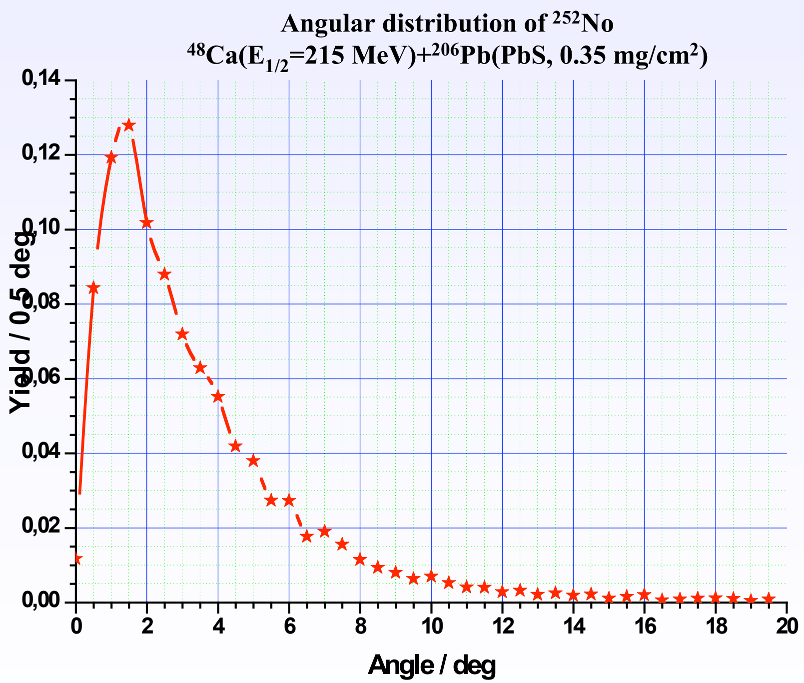


Requirements

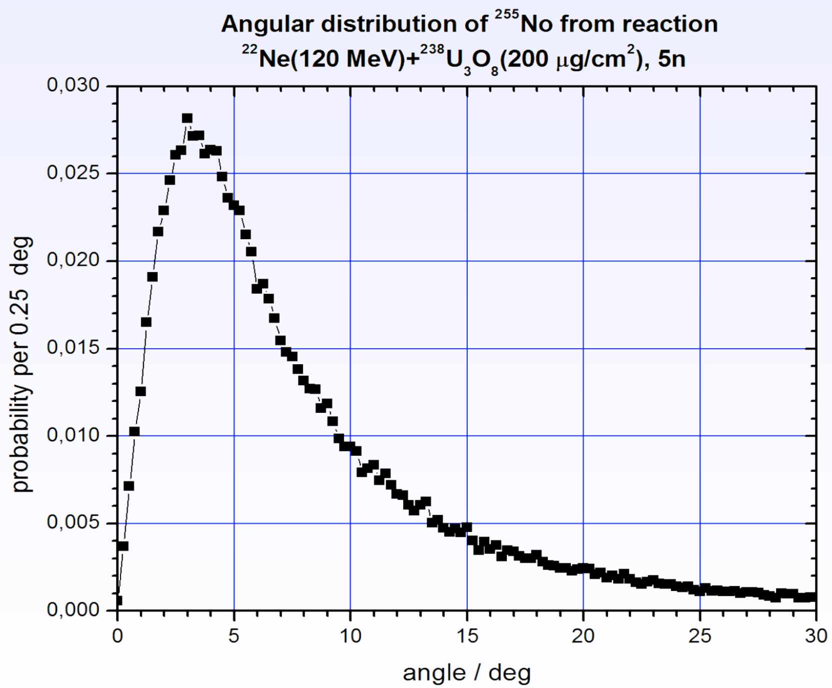
- increased yield of asymmetric reaction products:
  - ✓ larger acceptances of the separator;
  - ✓ larger transmission through the separator;
- high detection efficiency of decay products (e, α, β , γ, ff);
- tof – measurement (or "coming from outside" mark);
- shielding of target-position and focal-plane detectors from acelerator and beam dump;
- shielding of detectors from accelerator and beam dump;
- possibility of investigation of symmetric as well as asymmetric reactions;
- sufficient space for detectors at the target and focal plane positions.

Requirements for a new separator

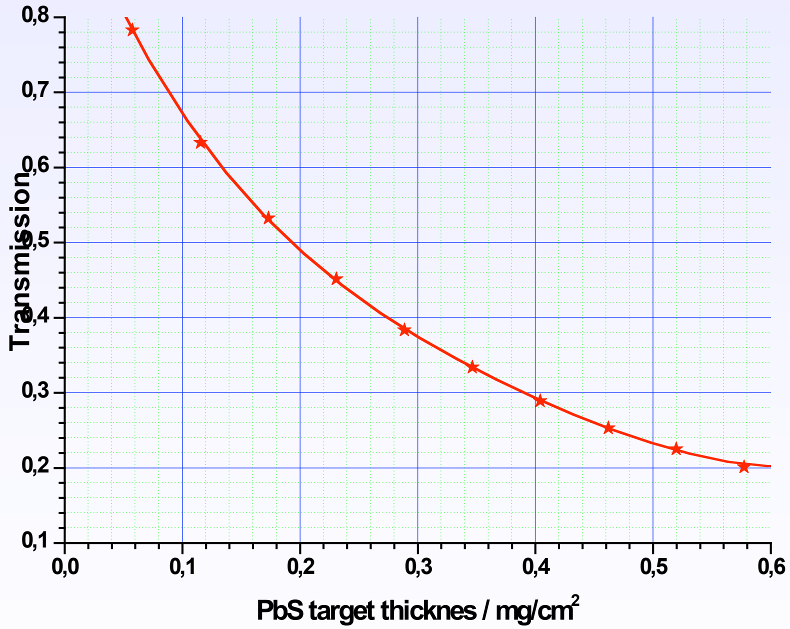
<E>~35 MeV

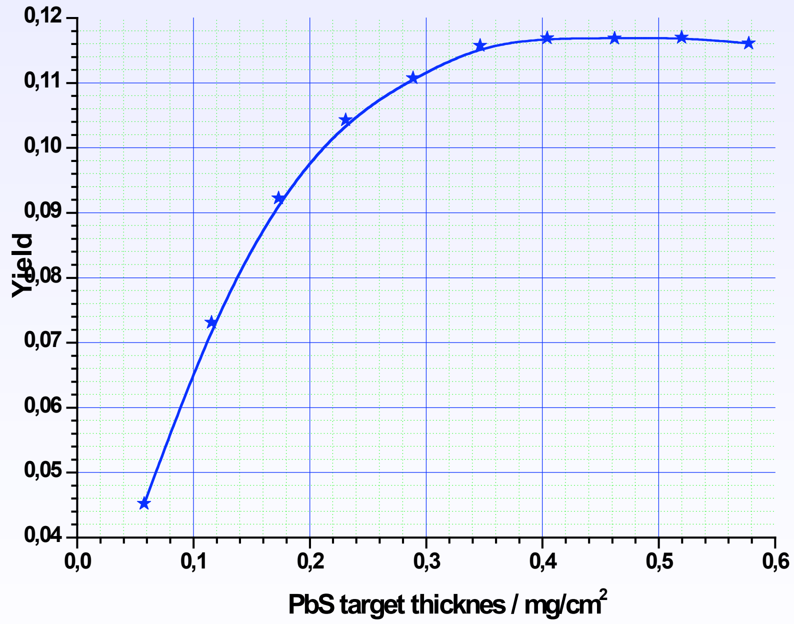


<E>~9 MeV



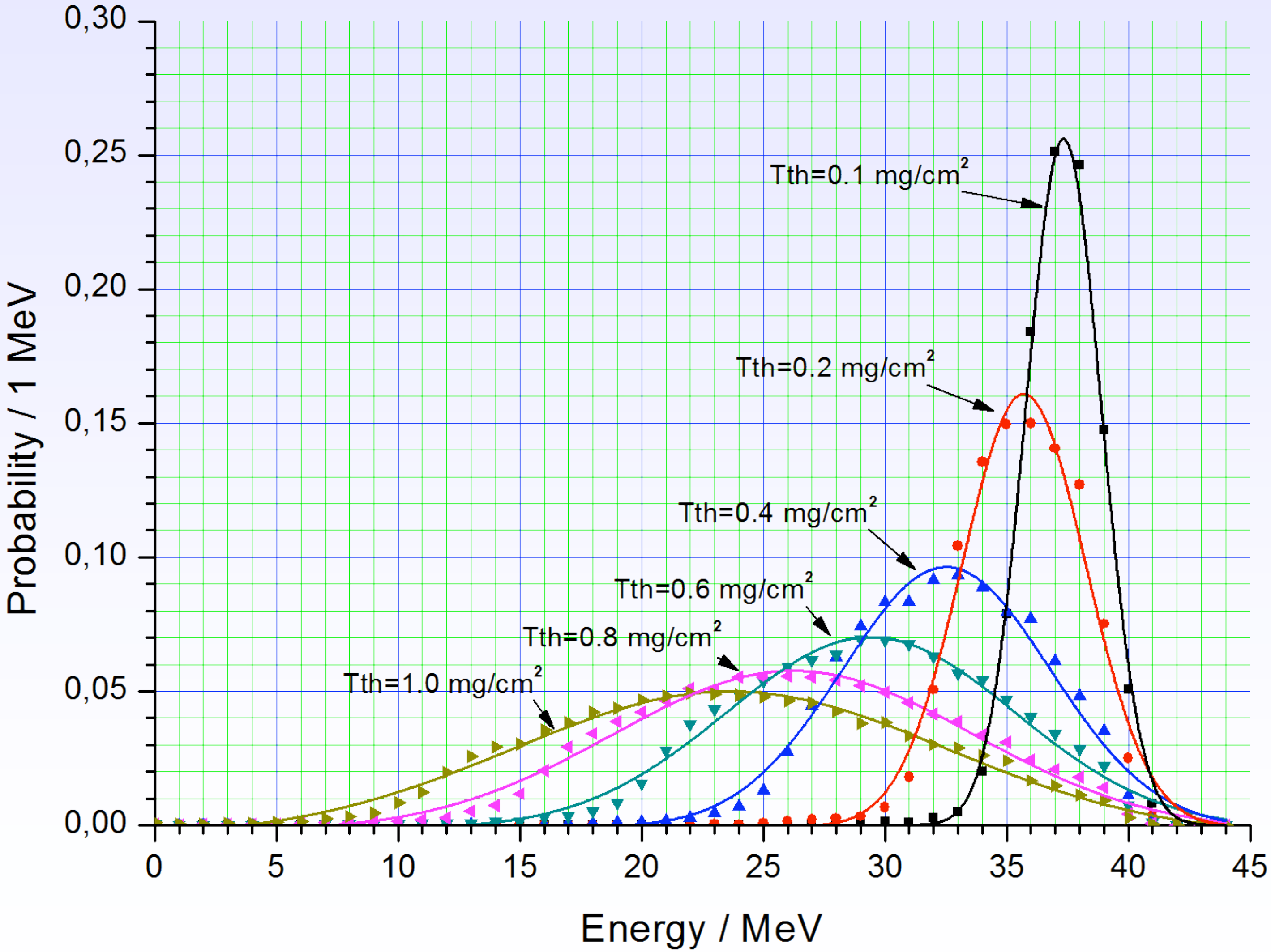
Transmission & yield of ^{252}No





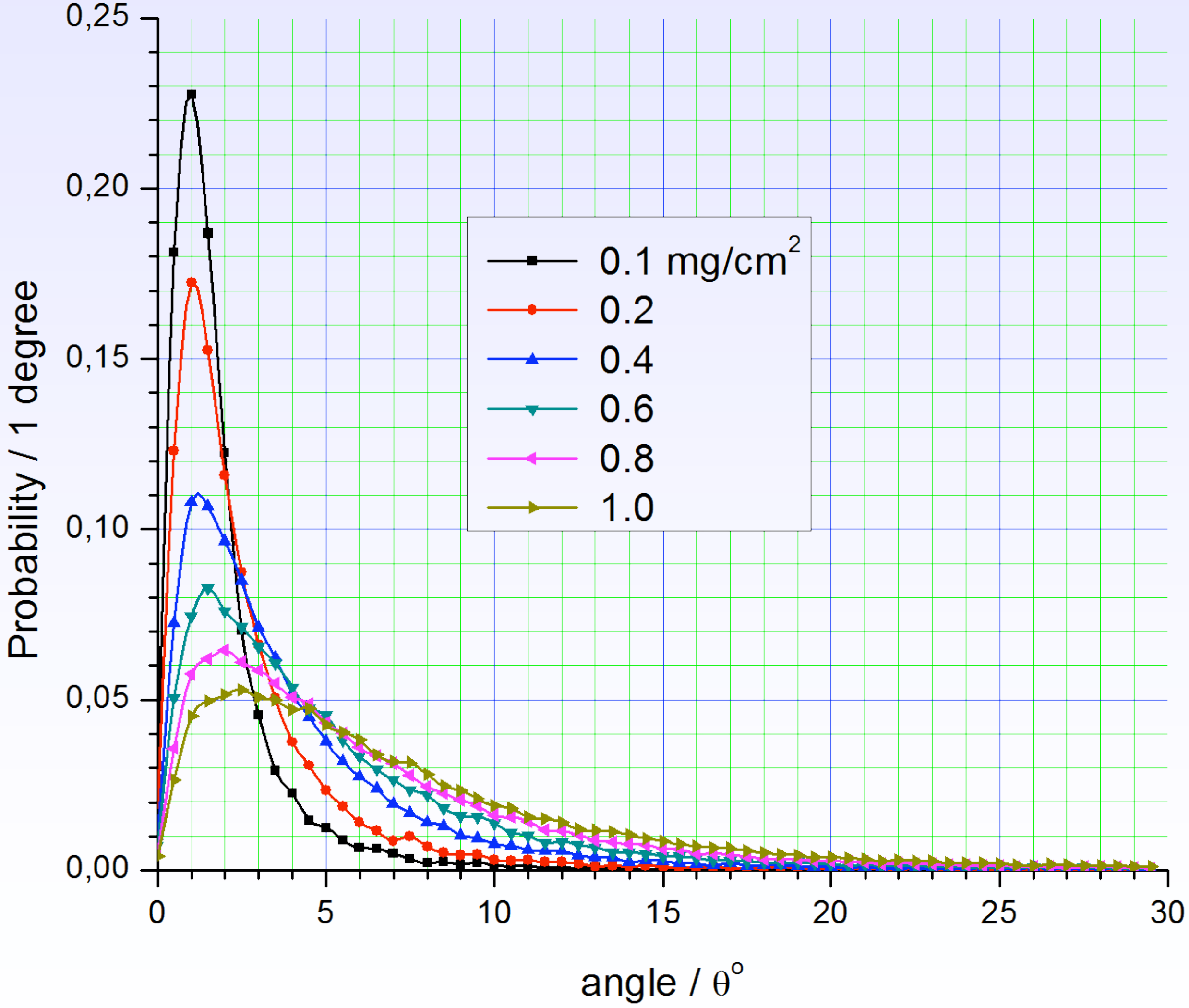
Energy distributions for different target thicknesses

$^{48}Ca + ^{238}U(UF_4) \rightarrow ^{283}112 + 3n$



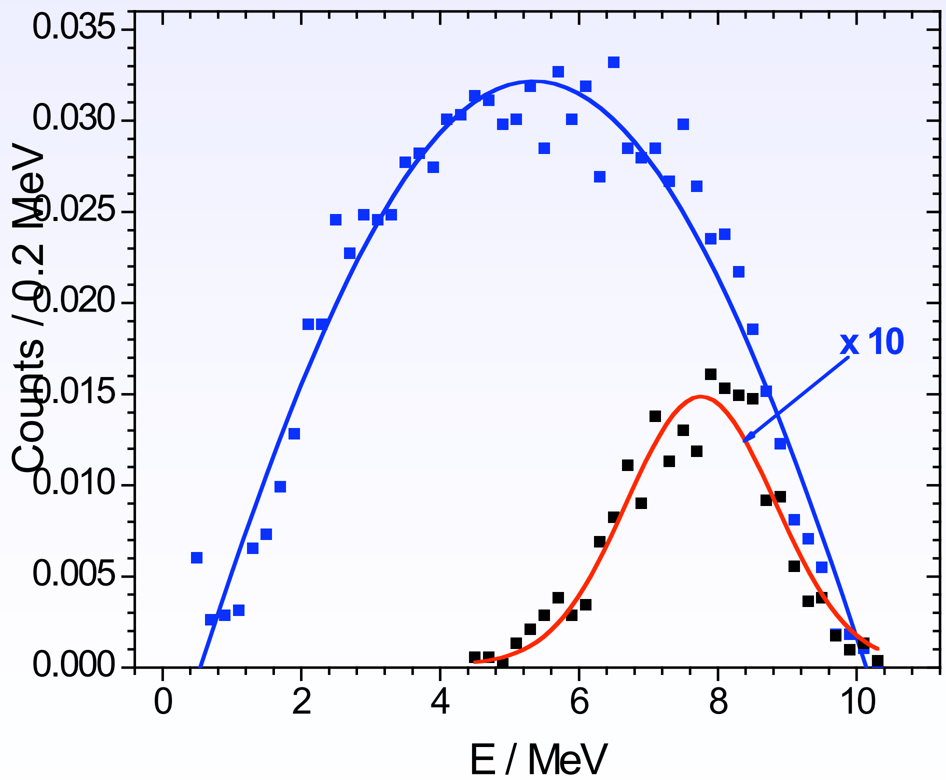
Angular distributions for different target thicknesses

$^{48}Ca + ^{238}U(UF_4) \rightarrow ^{283}112 + 3n$

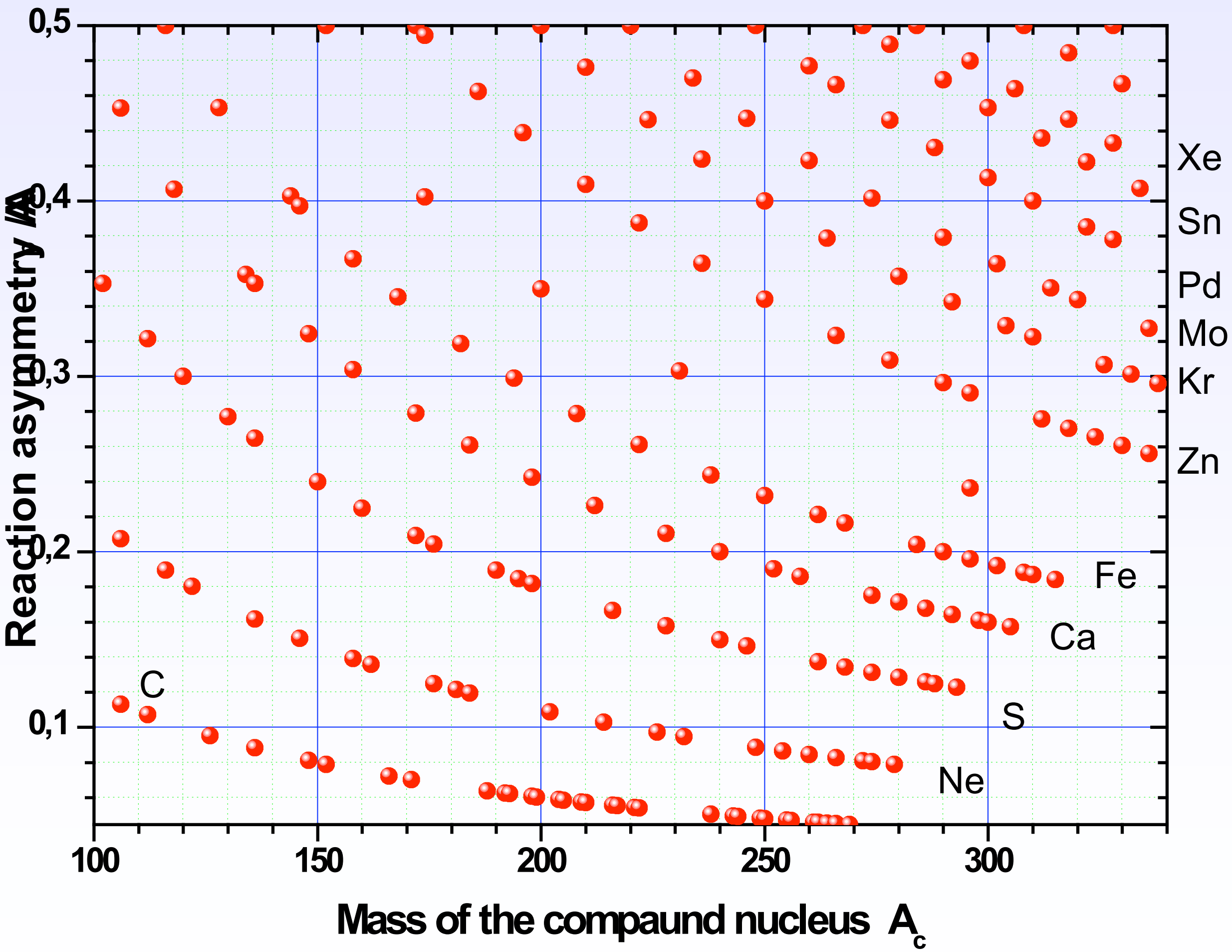


Enrgy acceptance calculations for VASSILISSA

$^{22}Ne + ^{238}U \longrightarrow ^{255}No + 5n \quad \varepsilon = 2\ \%$



Analyzed reactions



$^{22}Ne + ^{238}U \longrightarrow ^{260}No^{*}$

Nucl	E(MeV)	Bρ (vac. T·m)	Bρ (He, T·m)	Bρ (H_2. T·m)	V (cm/ns)	E/q_{vac} (MV)
^{22}Ne	112.4	0.76	0.76	0.76	3.14	11.7
^{260}No	9.5	0.74	1.82	2.45	0.26	0.99
^{238}U	34.8	0.72	1.89	2.01	0.53	1.93
^{4}He	58.5		1.1		5.3	
$^{1}H_2$	18.7			0.62	6.0	

$^{48}Ca + ^{244}Pu \longrightarrow ^{292}114^{*}$

Nucl.	E(MeV)	Bρ (vac. T·m)	Bρ (He. T·м)	Bρ (H_2. T·м)	V (cm/ns)	E/q_{vac} (MV)
^{48}Ca	236	0.88	0.94	0.94	3.1	13.0
$^{292}114$	38.8	0.79	2.0	2.18	0.51	2.0
^{244}Pu	129.7	0.83	1.65	1.49	1.0	4.2
^{4}He	67		1.2		5.7	
$^{1}H_2$	18.8			0.62	6.02	

$^{86}Kr + ^{180}Hf \longrightarrow ^{266}Hs^*$

Nucl.	E(MeV)	Bρ (vac. T·m)	Bρ (He. T·m)	Bρ (H_2. T·m)	V (cm/ns)	E/q_{vac} (MV)
^{86}Kr	400	0.96	1.12	1.12	3.0	14.3
^{266}Hs	130	0.82	1.60	1.50	0.97	3.95
^{180}Hf	350	0.92	1.23	0.92	1.94	8.96
^{4}He	68.0		1.2		5.7	
$^{1}H_2$	18.2			0.6	5.9	

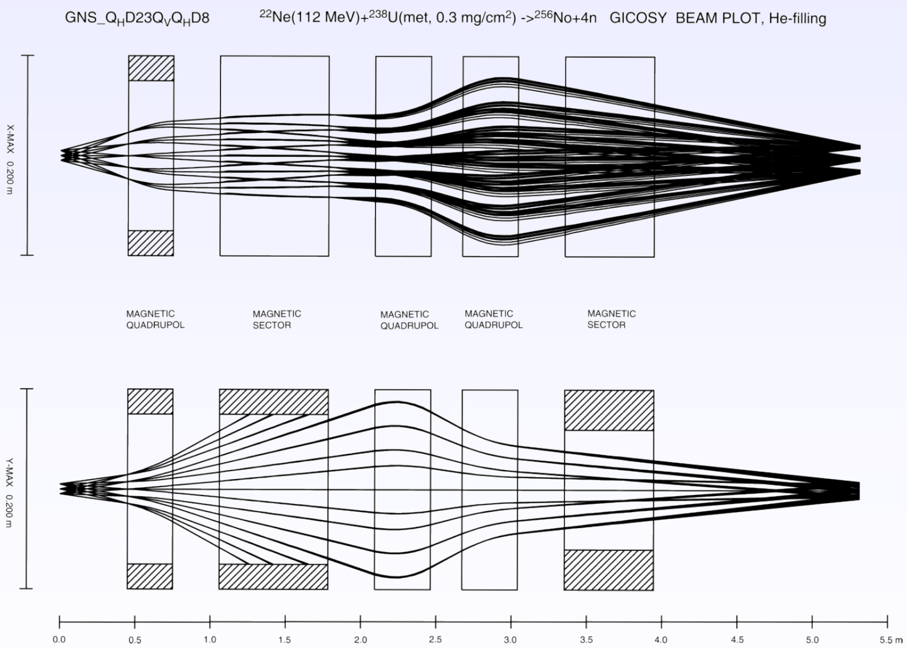
$^{156}Fe + ^{56}Fe \longrightarrow ^{112}Te^*$

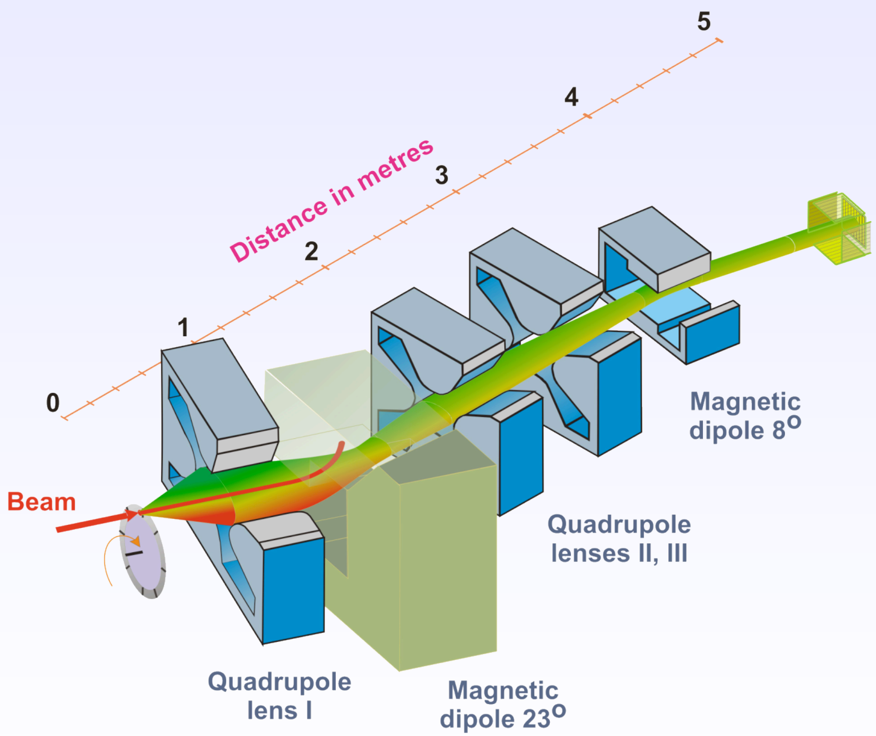
Nucl.	E(MeV)	Bρ (vac. T·m)	Bρ (He. T·m)	Bρ (H_2. T·m)	V (cm/ns)	E/q_{vac} (MV)
^{56}Fe	171	0.68	0.96	0.8	2.41	8.3
^{112}Te	85.7	0.56	1.2	0.8	1.23	3.5
^{56}Fe	171	0.68	0.96	0.8	2.41	8.3
^{4}He	42.6		0.94		4.5	
$^{1}H_2$	12.1			0.5	4.8	

$^{136}Xe + ^{136}Xe \longrightarrow ^{272}Hs^*$

Nucl.	E(MeV)	Bρ (vac. T·m)	Bρ (He. T·m)	Bρ (H_2. T·m)	V (cm/ns)	E/q_{vac} (MV)
^{136}Xe	600	1.1	1.38	1.38	3.0	15.7
^{272}Hs	300	0.95	1.39	1.21	1.46	6.85
^{136}Xe	600	1.1	1.38	1.38	3.0	15.7
^{4}He	66.6		1.2		5.7	
$^{1}H_2$	17.4			0.6	6.0	

Gas-Filled Separator



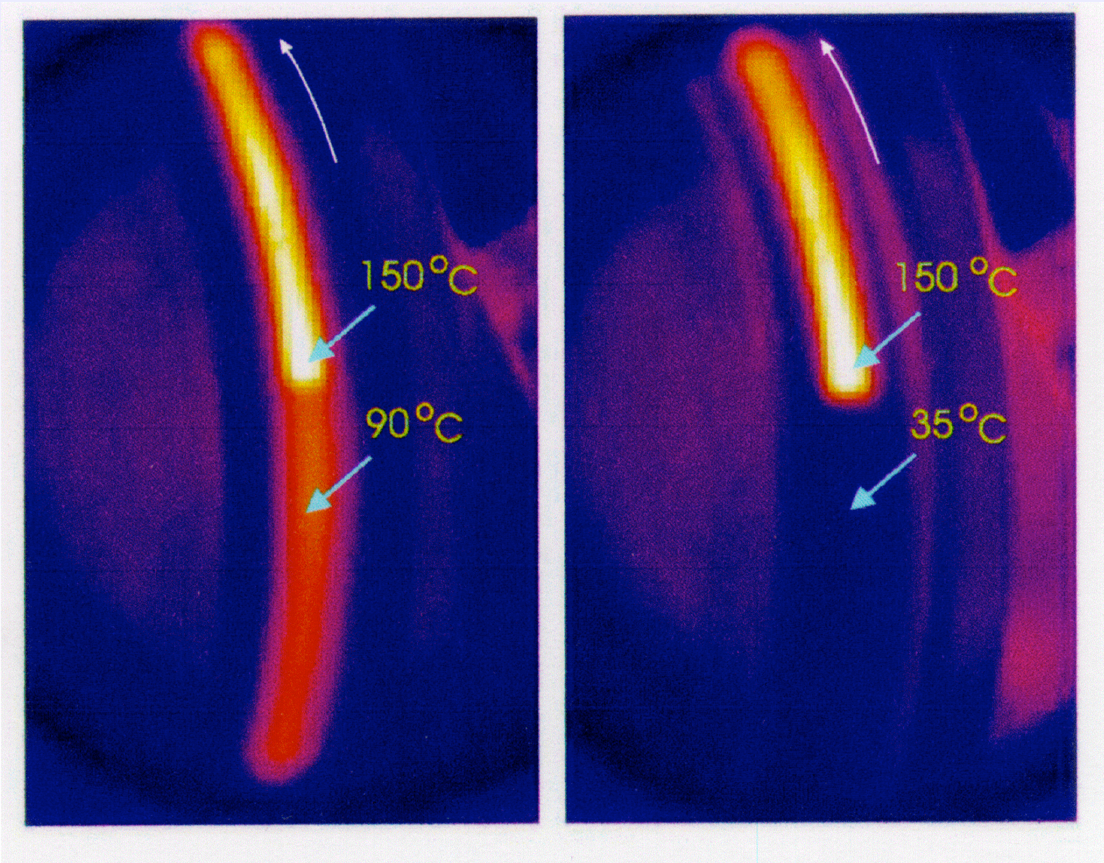


Gas-filled separator Advantages:

- presence of a gas – H_2, He;
- high energy and charge acceptances;
- additional target cooling through convection;
- low number of elements;
- no high voltage;
- low price.

Target gas cooling
(infra red snap-shots)

10^{-6} mB
P=1.3 W
T=90-150°C

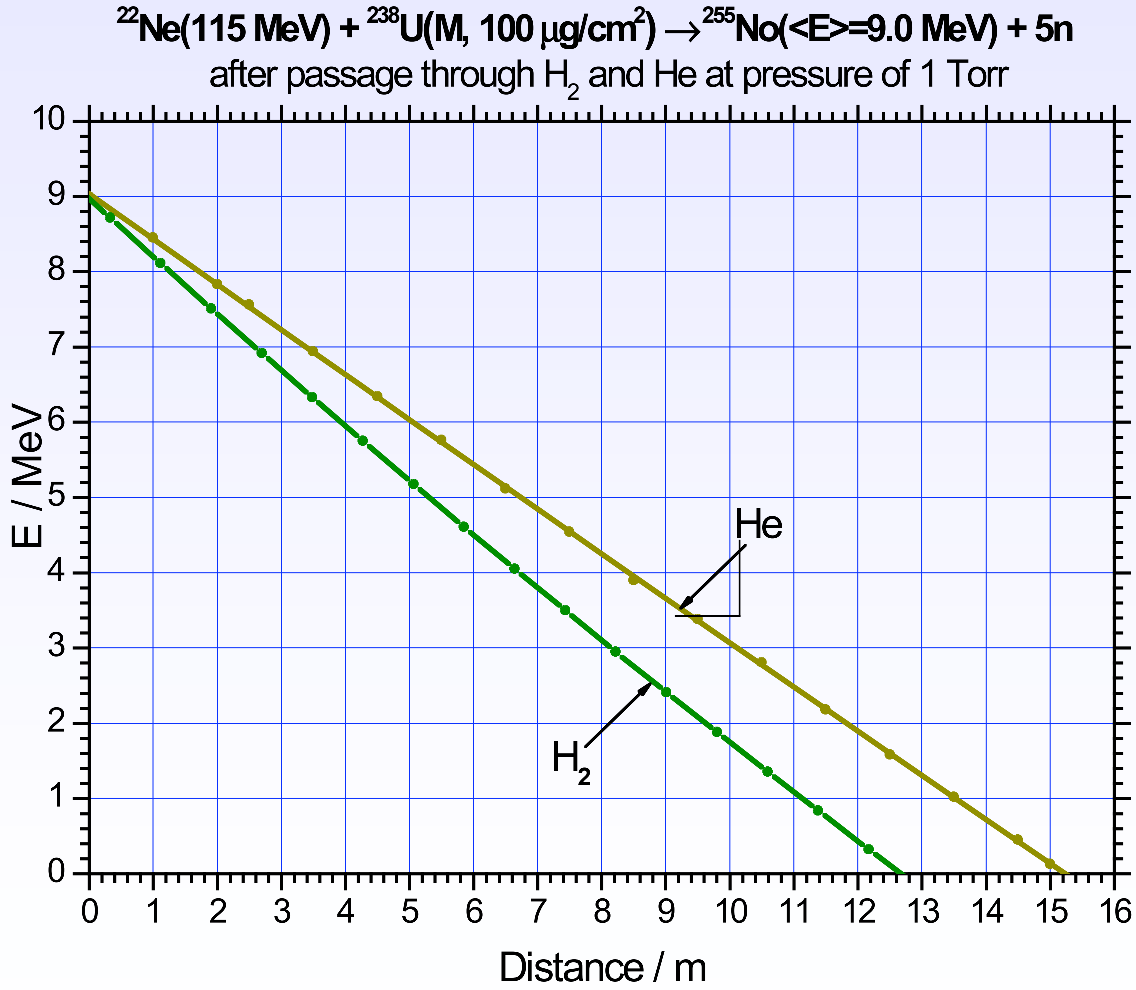


0.6 mB He
P=2.7 BW
T=35-150°C

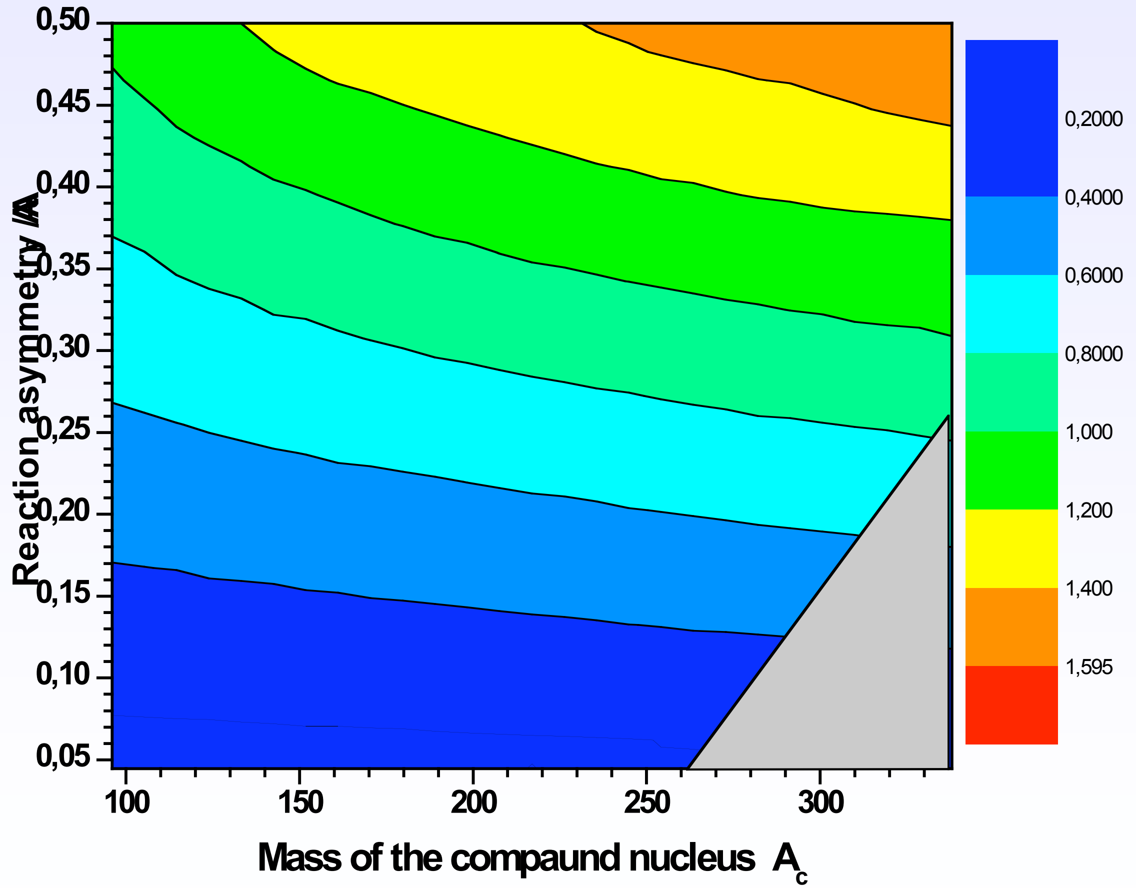
Gas-filled separator Disadvantages:

- presence of gas – H_2, He;
- not suitable for very asymmetric reactions;
- not applicable for symmetric reactions;
- very difficult (or impossible) to organize "coming from outside" mark;
- mast be short (< 5 m) → difficult to organize shielding;
- background from high energetic (15 – 20 MeV) light particles;

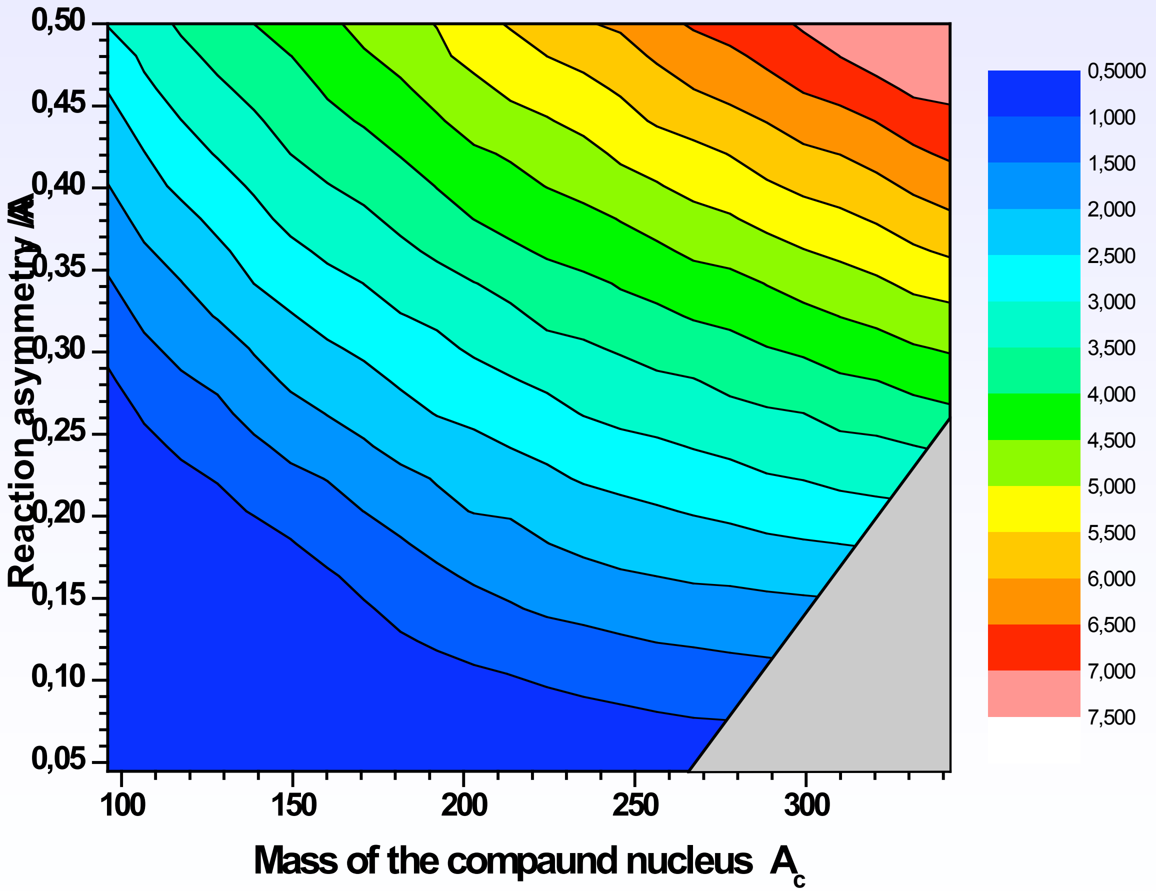
Gas filled separators for asymmetric combinations



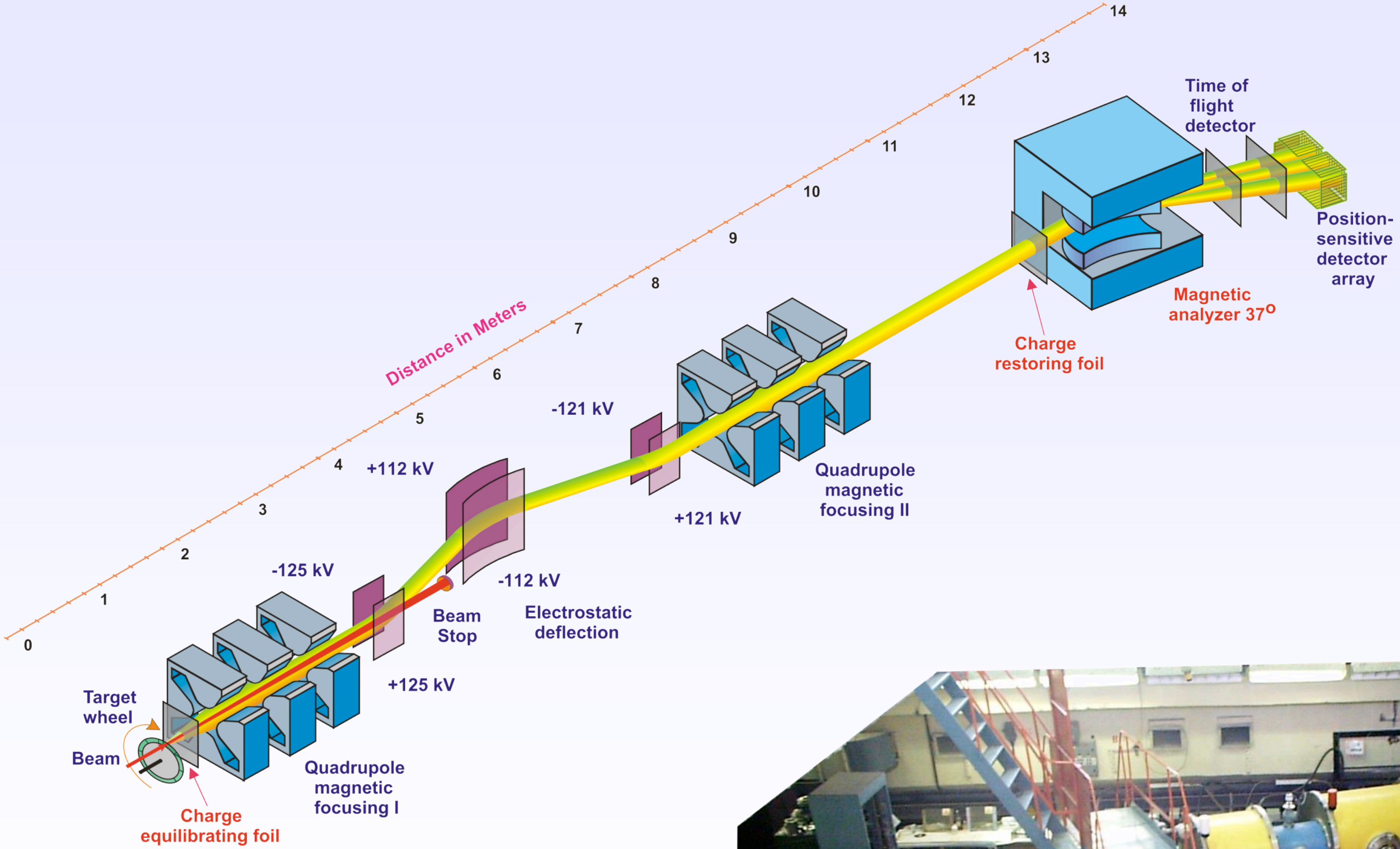
Magnetic rigidities of compound nuclei in T*m

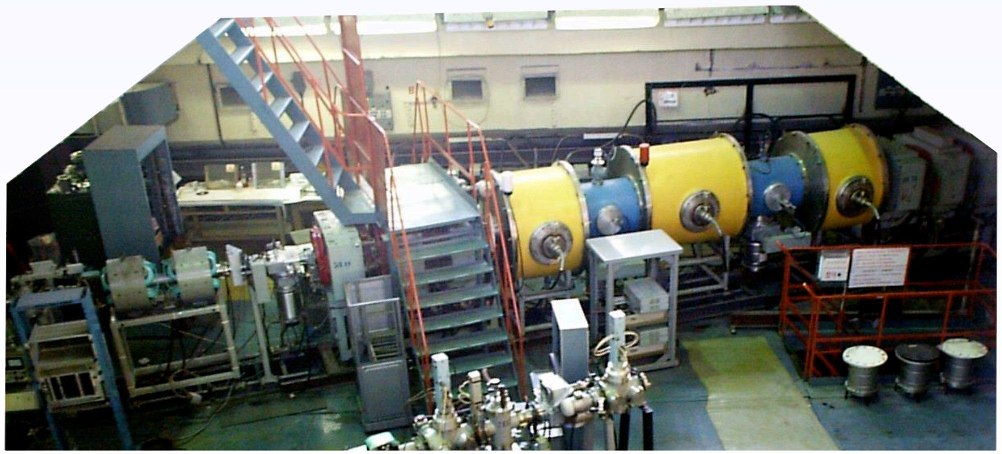


Electric rigidities of compound nuclei in MV

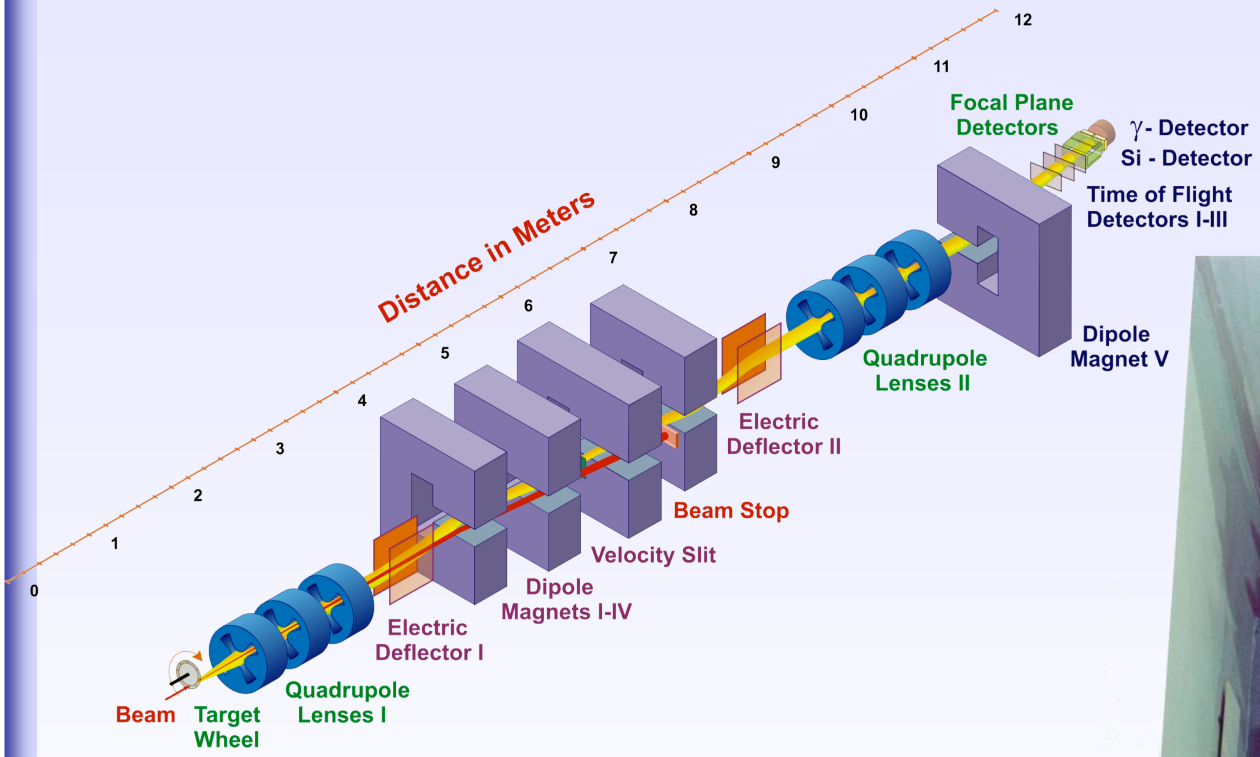


Electrostatic separator "VASSILISSA"





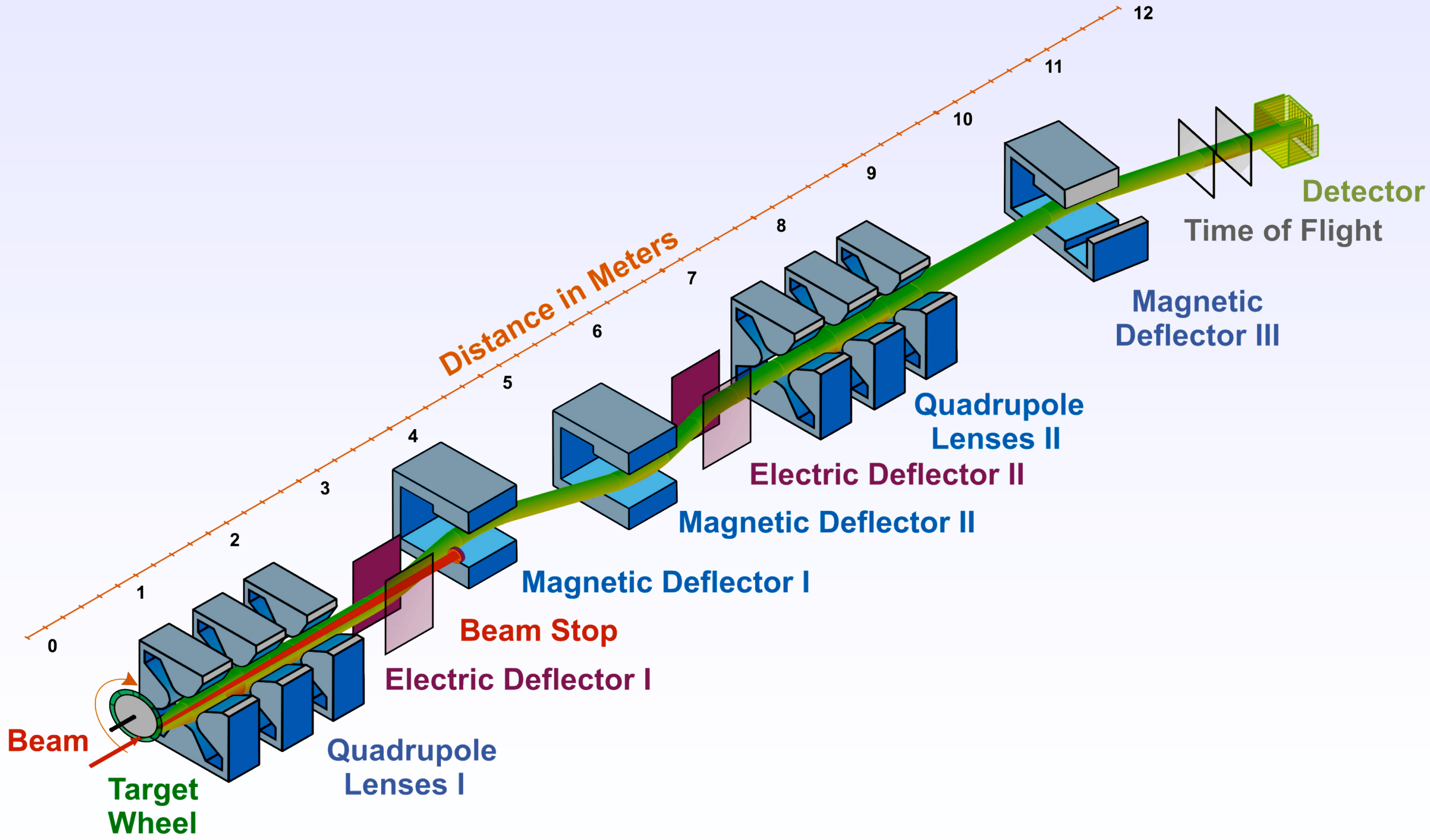
The Velocity Filter «SHIP»



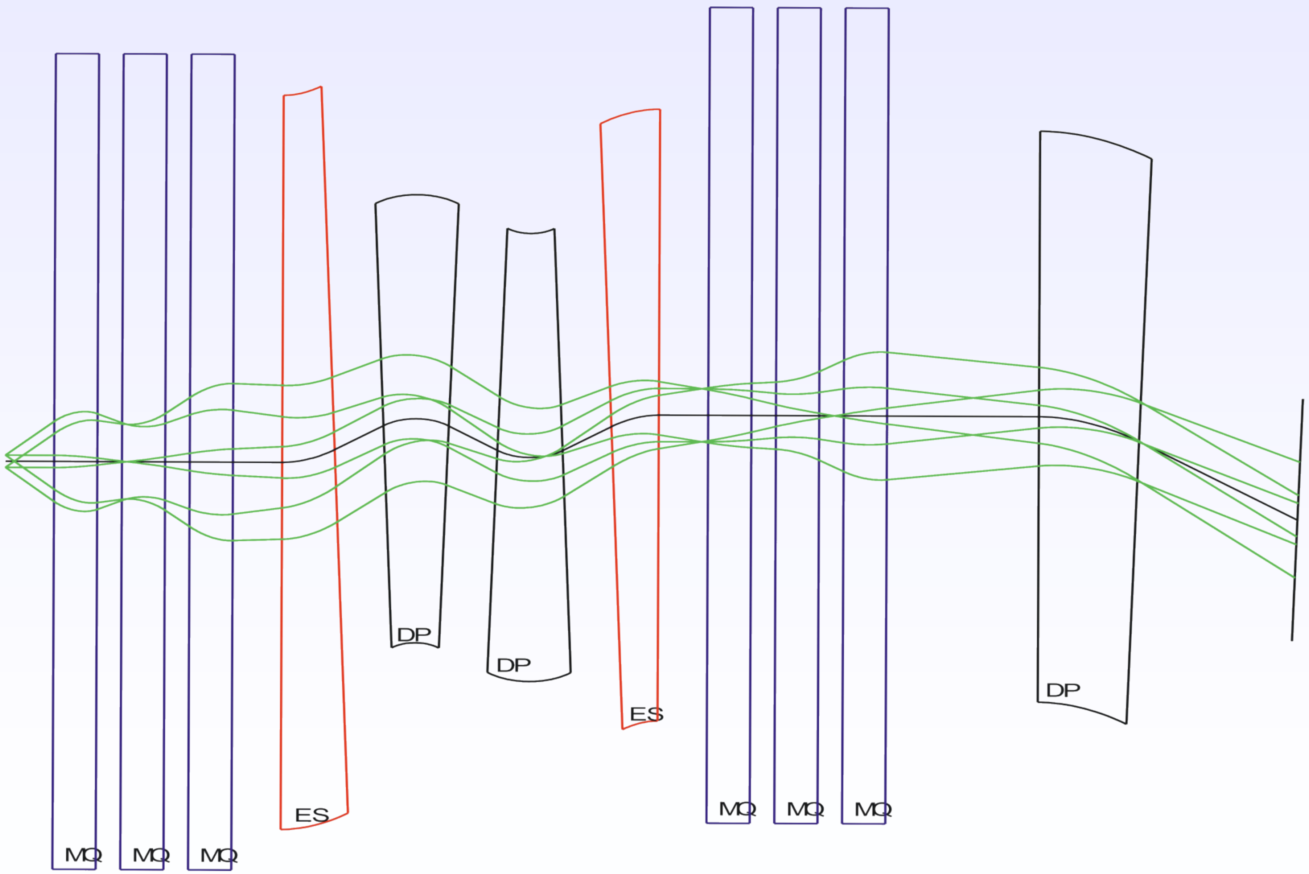
Ion optical calculations

- Only first order optics;
- COSY;
- GICOSY;
- VASFIT.

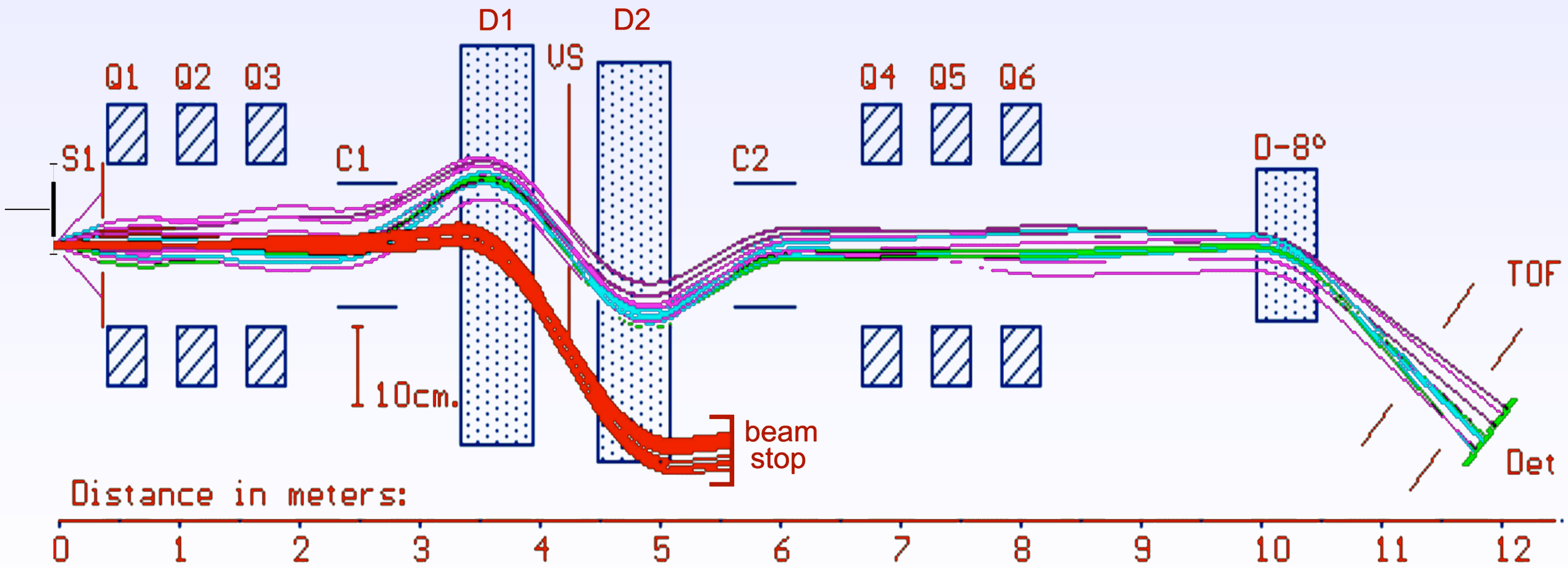
Velocity filter "ASSA" for asymmetric combinations



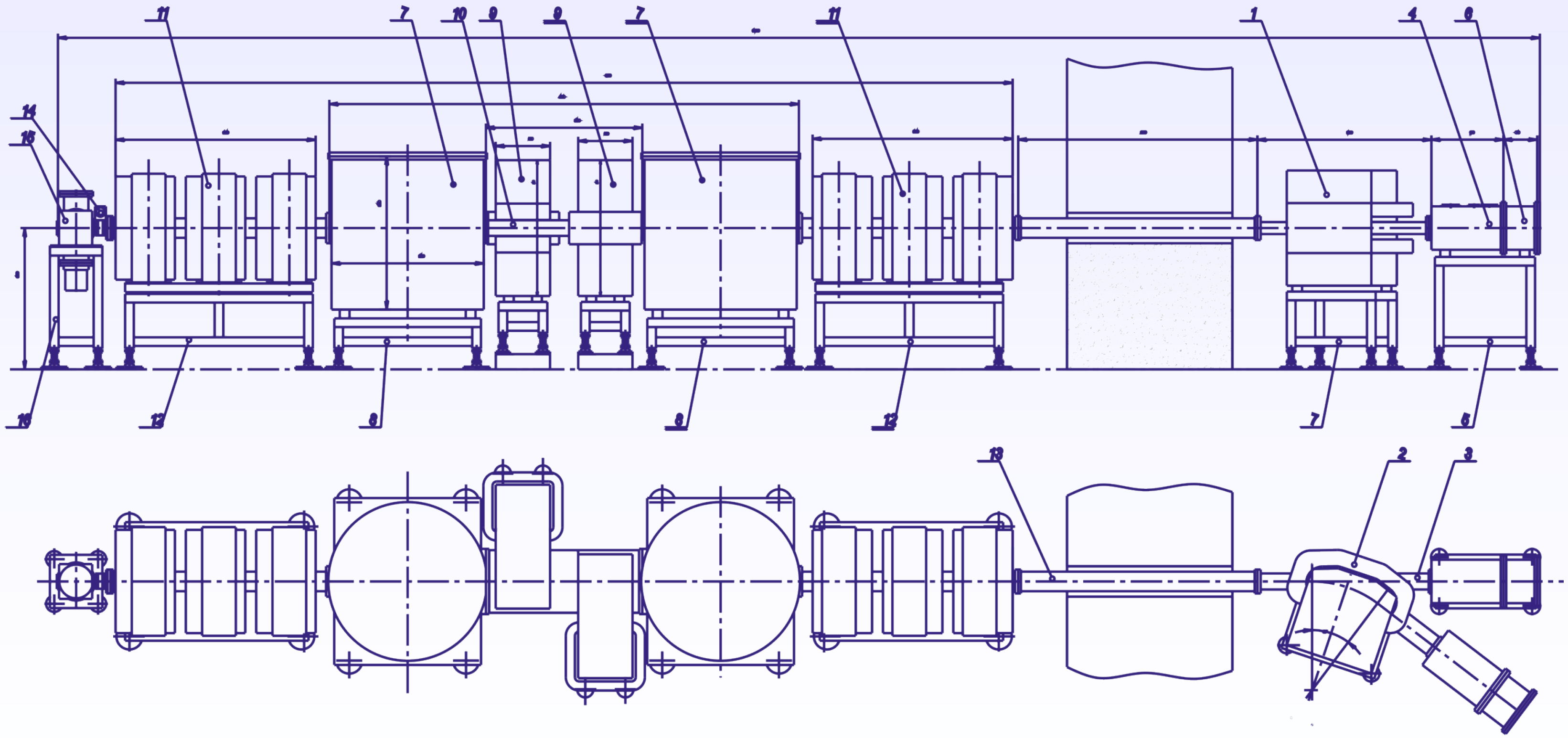
COSY - plot



ASSA
Simulation of ion trajectories



“ASSA” – technical design



Main optical elements of the new separator "ASSA"

2 Magnetic dipoles

Deflection angle	16^0
Radius of curvature	3.1 m
Maximum field	0.7 T

2 Electric dipoles

Deflection angle	8^0
Radius of curvature	3.2 m
Maximum field	40 kV/cm

6 Quadrupole lenses

Effective length	0.37 m
Bore diameter	0.2 m
Maximum field	1.3 T

1 Magnetic dipole

Deflection angle	8^0
Radius of curvature	4.25 m
Maximum field	0.5 T

Thank you for your attention!

Many thanks to the organizers!!