The ISOBARIC separator of the SPES project

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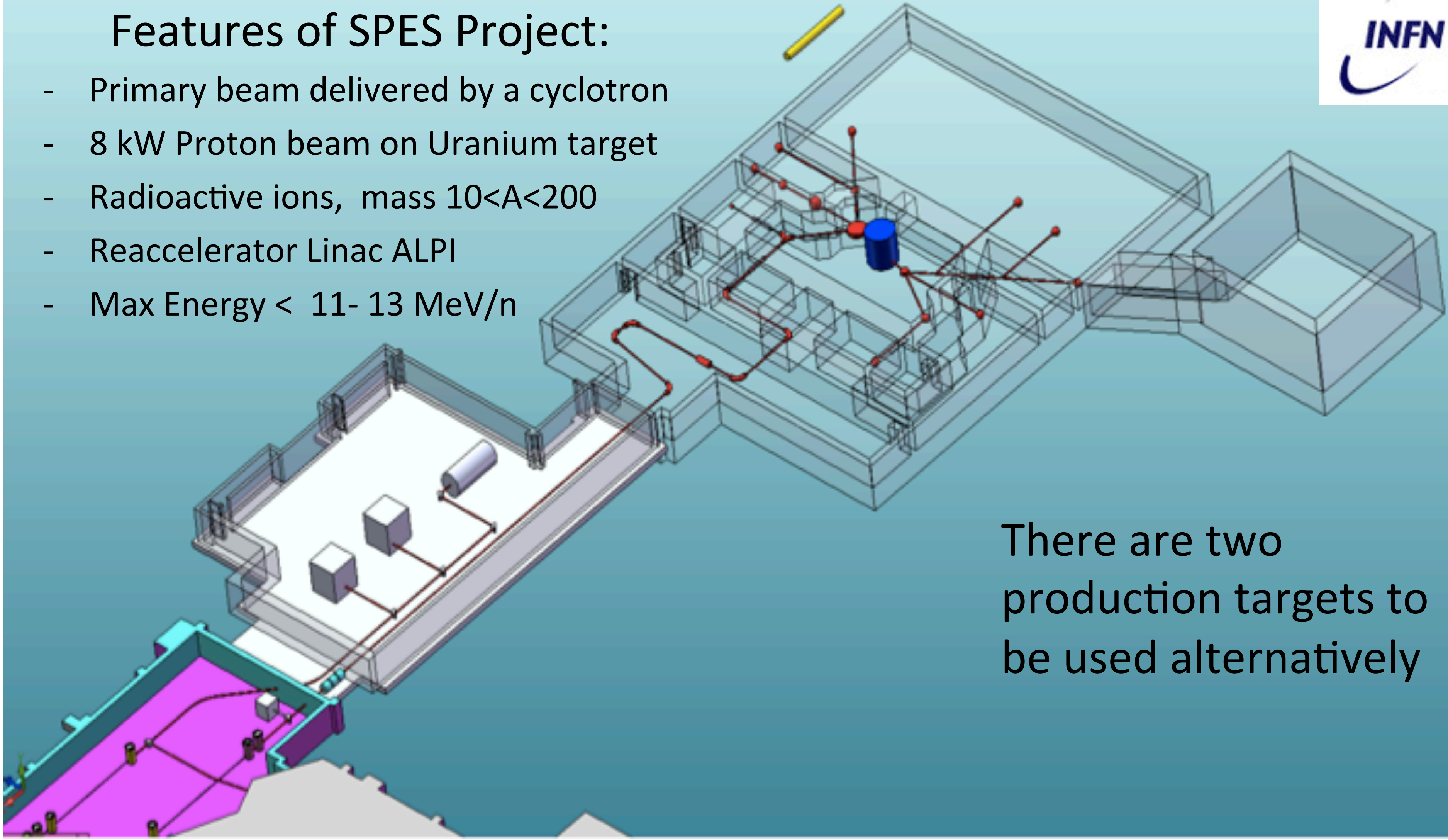
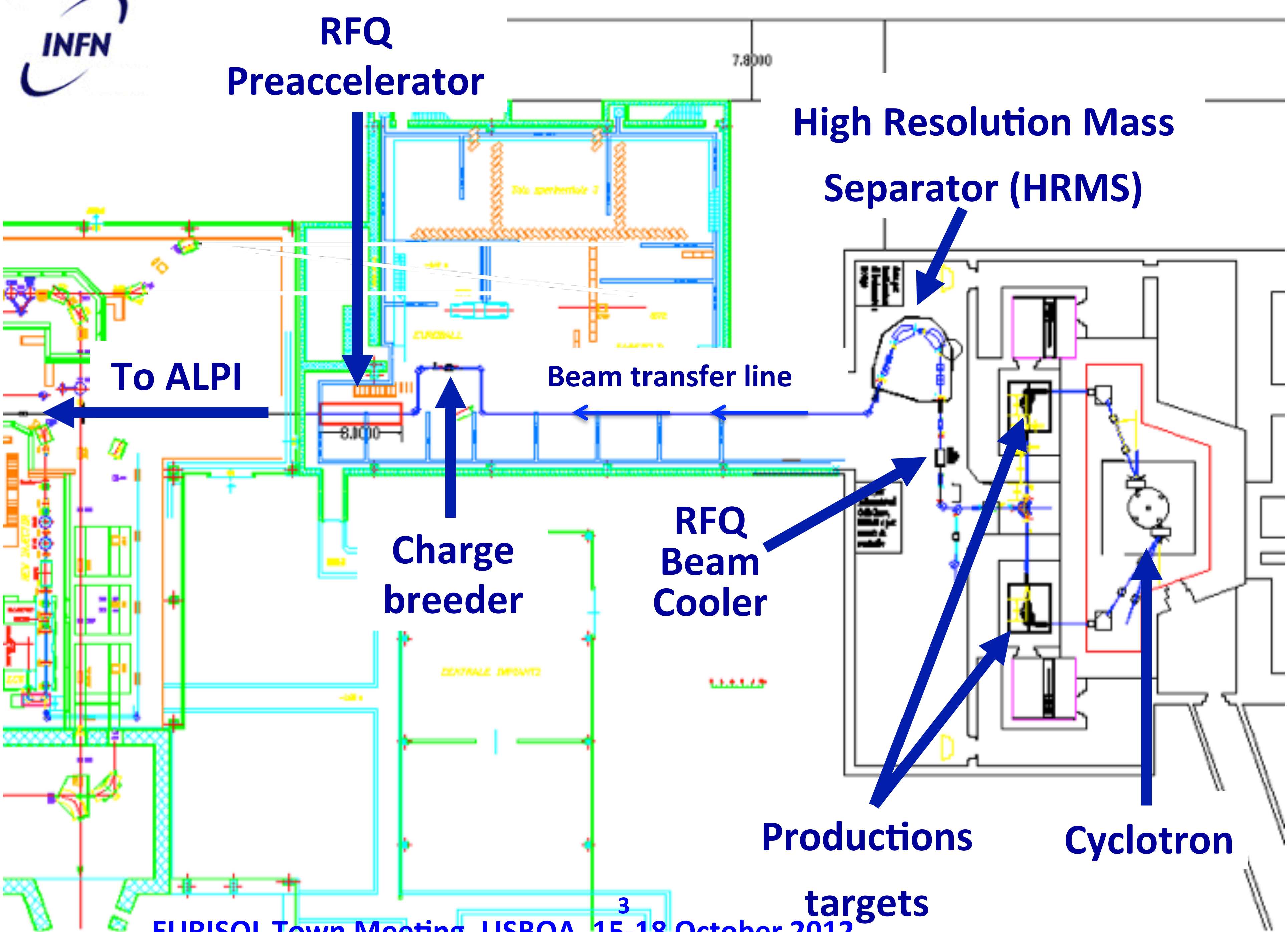
On behalf of SPES project

Features of SPES Project:

- Primary beam delivered by a cyclotron
- 8 kW Proton beam on Uranium target
- Radioactive ions, mass 10<A<200
- Reaccelerator Linac ALPI
- Max Energy < 11- 13 MeV/n

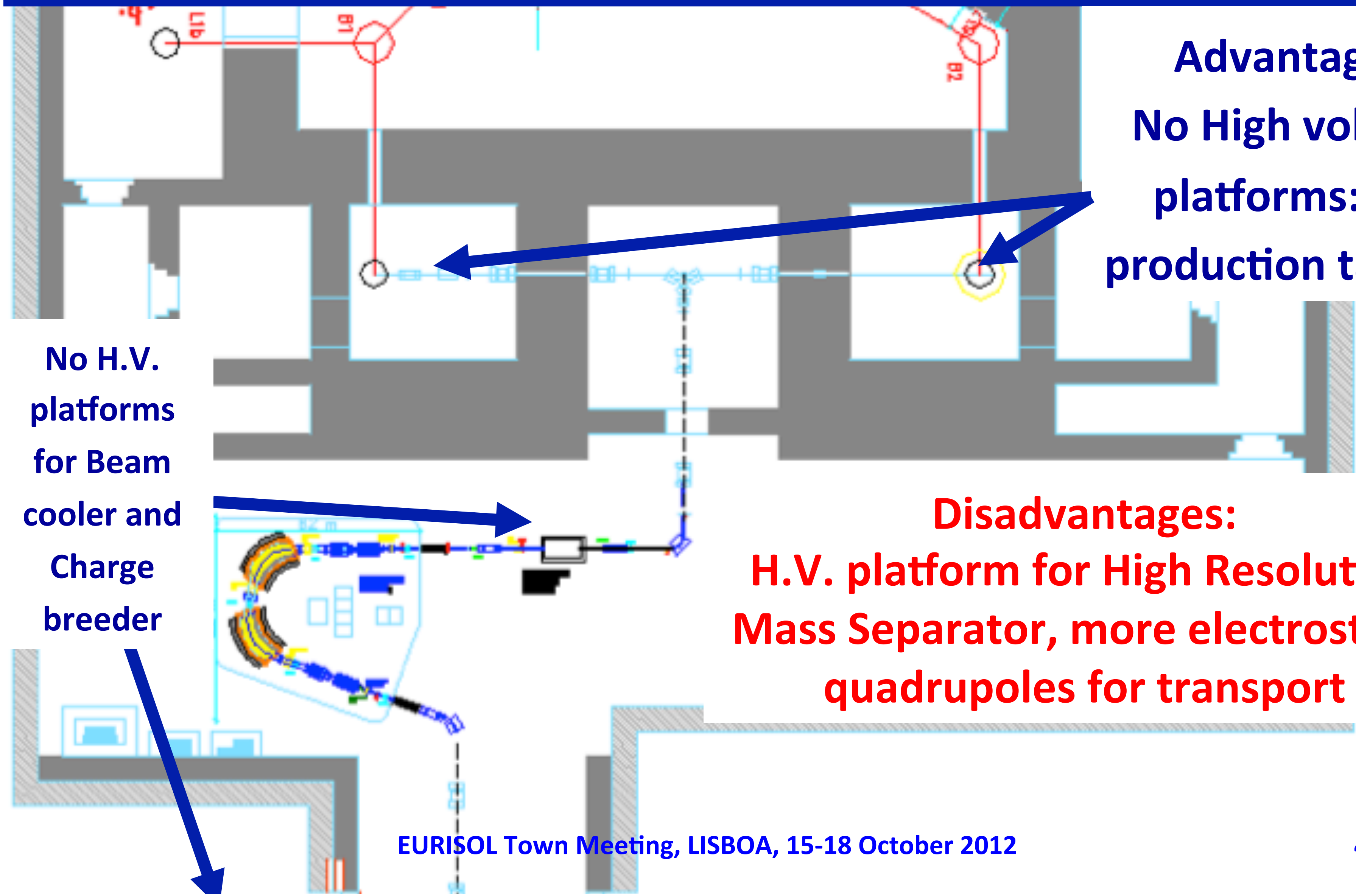


There are two production targets to be used alternatively



RFQ Preaccelerator
High Resolution Mass Separator (HRMS)
To ALPI
Beam transfer line
Charge breeder
RFQ Beam Cooler
Productions targets
Cyclotron

SPES, updated beam transport layout, transport of secondary beam with E=40-60 keV



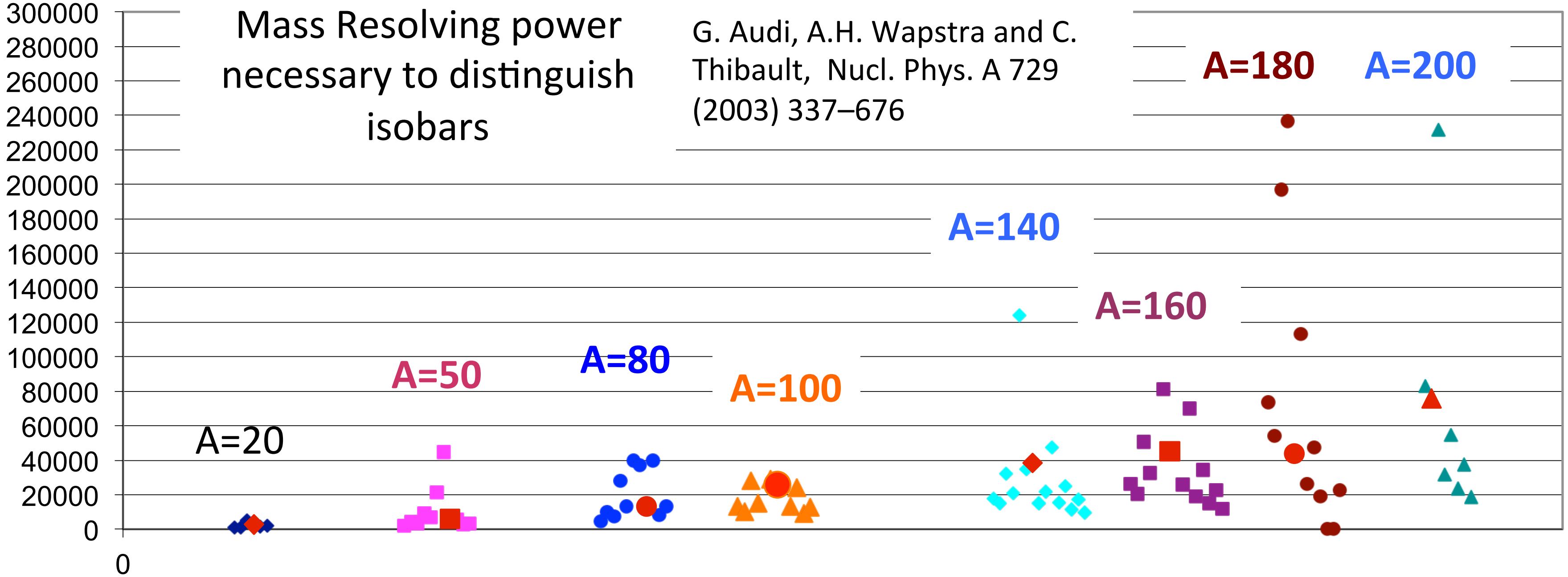
Advantages

No High voltage platforms: for production target

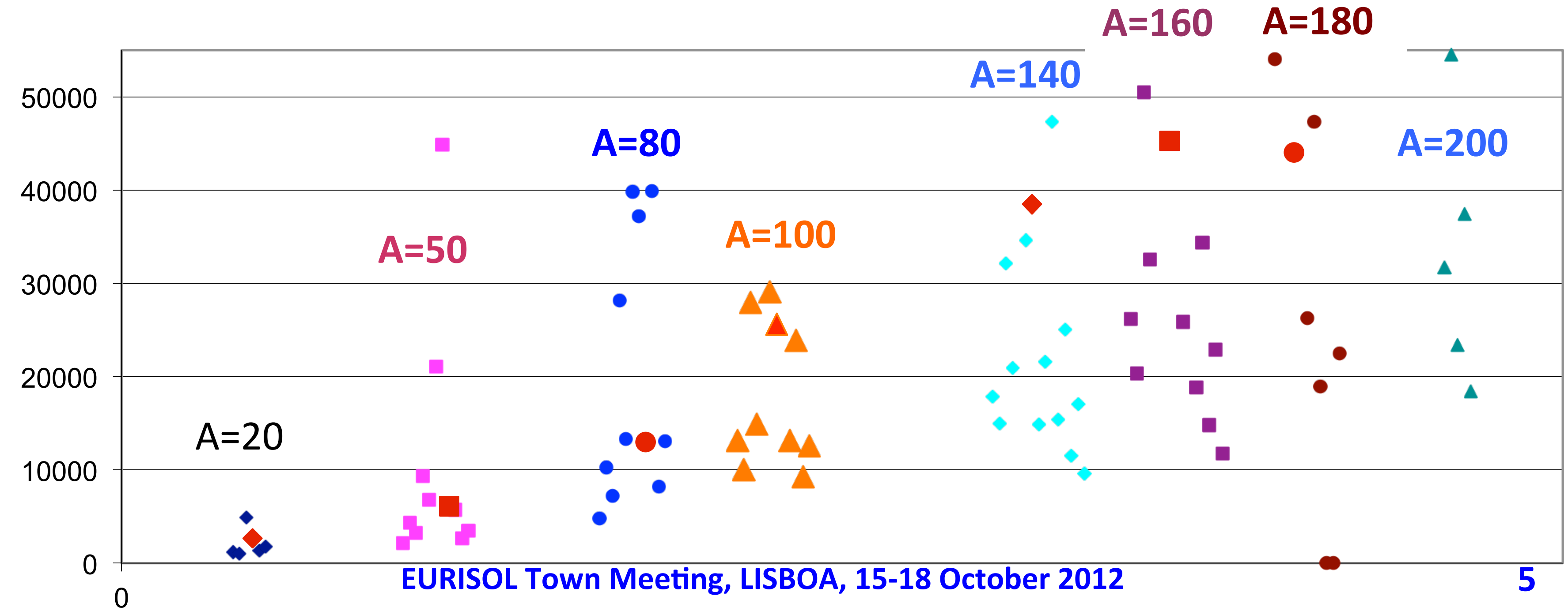
No H.V. platforms for Beam cooler and Charge breeder

Disadvantages:

H.V. platform for High Resolution Mass Separator, more electrostatic quadrupoles for transport

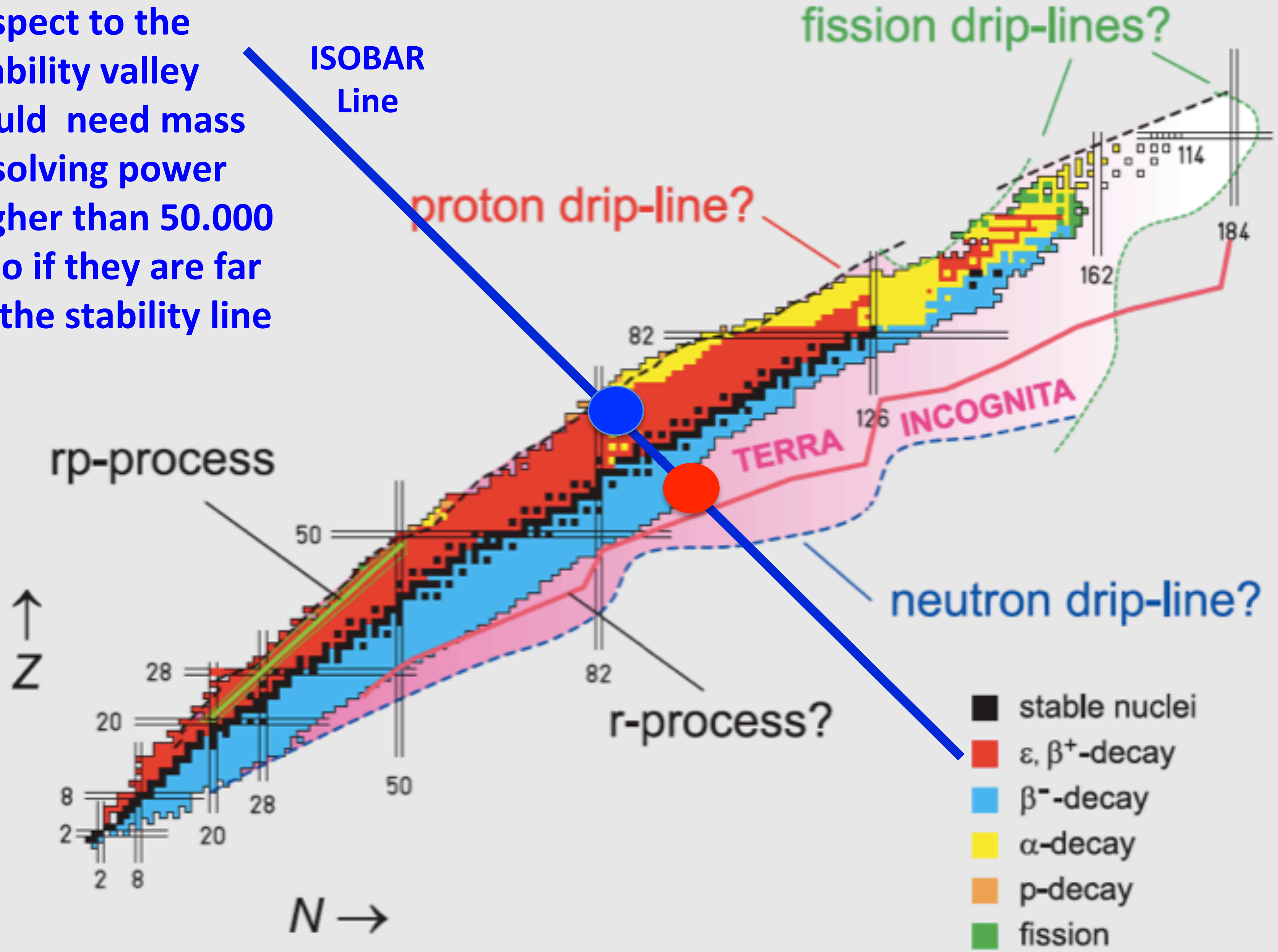


Mass Resolving power necessary to distinguish isobars
G. Audi, A.H. Wapstra and C. Thibault, Nucl. Phys. A 729 (2003) 337–676
300000
280000
260000
240000
220000
200000
180000
160000
140000
120000
100000
80000
60000
40000
20000
0
0
A=20
A=50
A=80
A=100
A=140
A=160
A=180
A=200



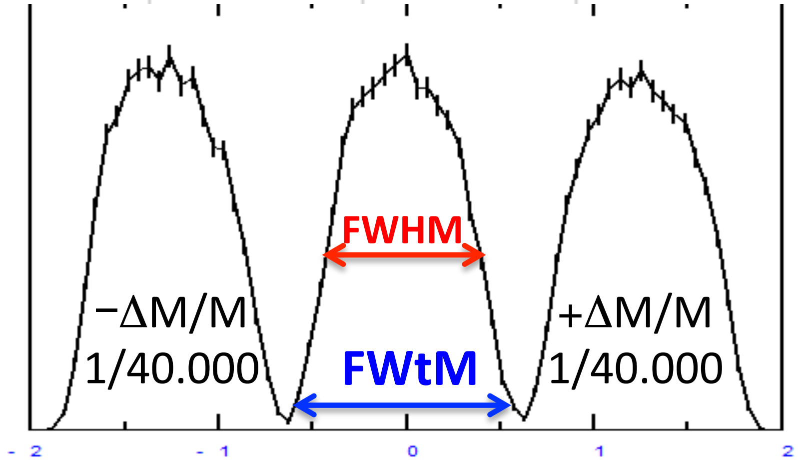
50000
40000
30000
20000
10000
0
0
A=20
A=50
A=80
A=100
A=140
A=160
A=180
A=200

Isobars symmetric respect to the stability valley could need mass resolving power higher than 50.000 also if they are far of the stability line



Isobars A=100

	Neutrons	Protons	Mass
23570	62	38	99935350
13377	61	39	99927760
60191	60	40	99917760
-52093	59	41	99914182
-154895	58	42	99907477
	57	43	99907658
Stable →	56	44	99904220
	55	45	99908122
	54	46	99908506
	53	47	99916100
	52	48	99920290
	51	49	99931110
-27083			99939040



Isobars A=140

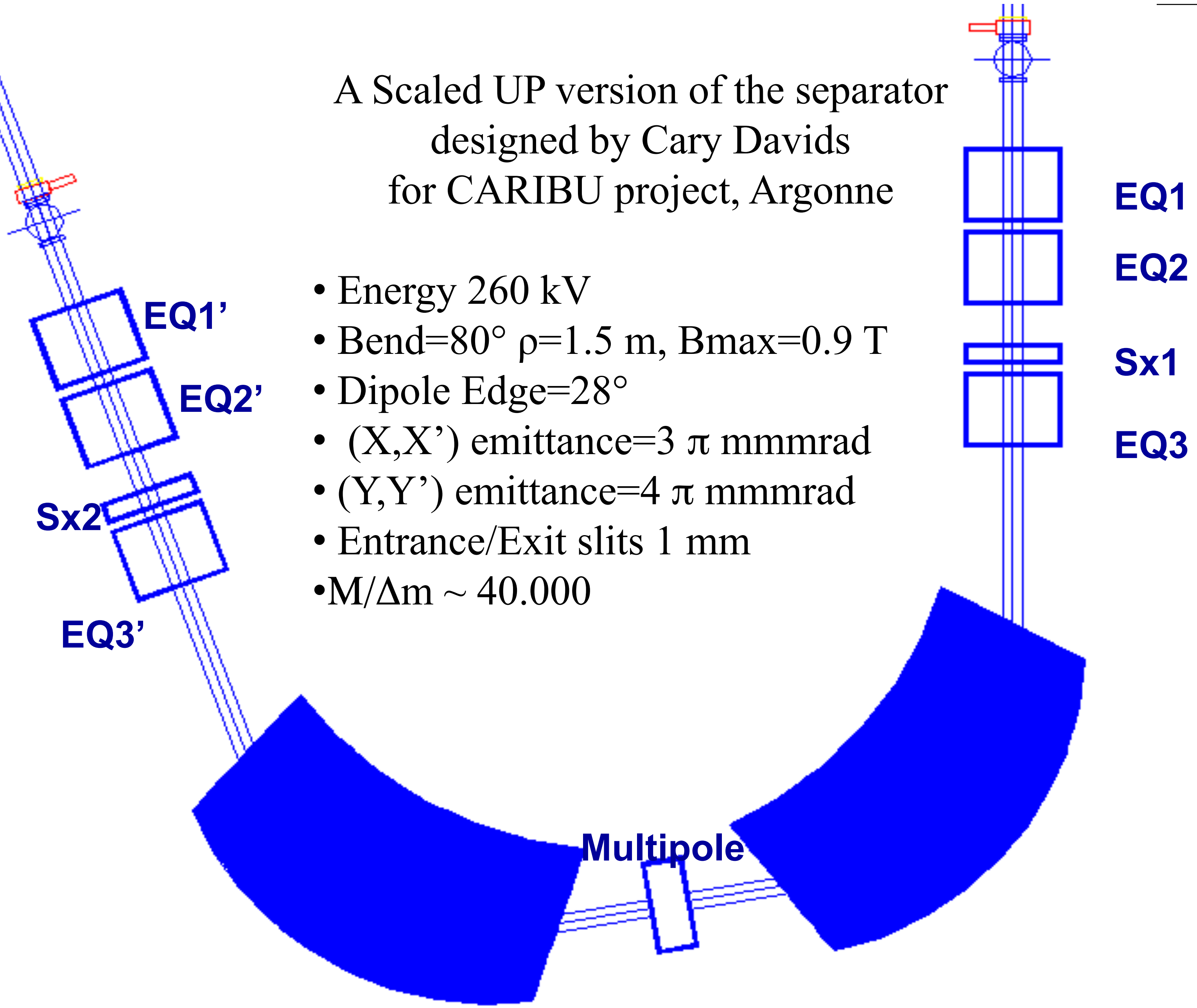
	Neutrons	Protons	Mass
13005	88	52	139938850
11656	87	53	139931000
24986	86	54	139921640
112655	85	55	139917282
91505	84	56	139910605
	83	57	139909478
Stable →	82	58	139905439
	81	59	139909076
132617	80	60	139909550
	79	61	139916040
	78	62	139918995
	77	63	139928090
27015	76	64	139933670
	75	65	139945810
	74	66	139954010
	73	67	139968540

$FWtM/R_{16}=1/40000$

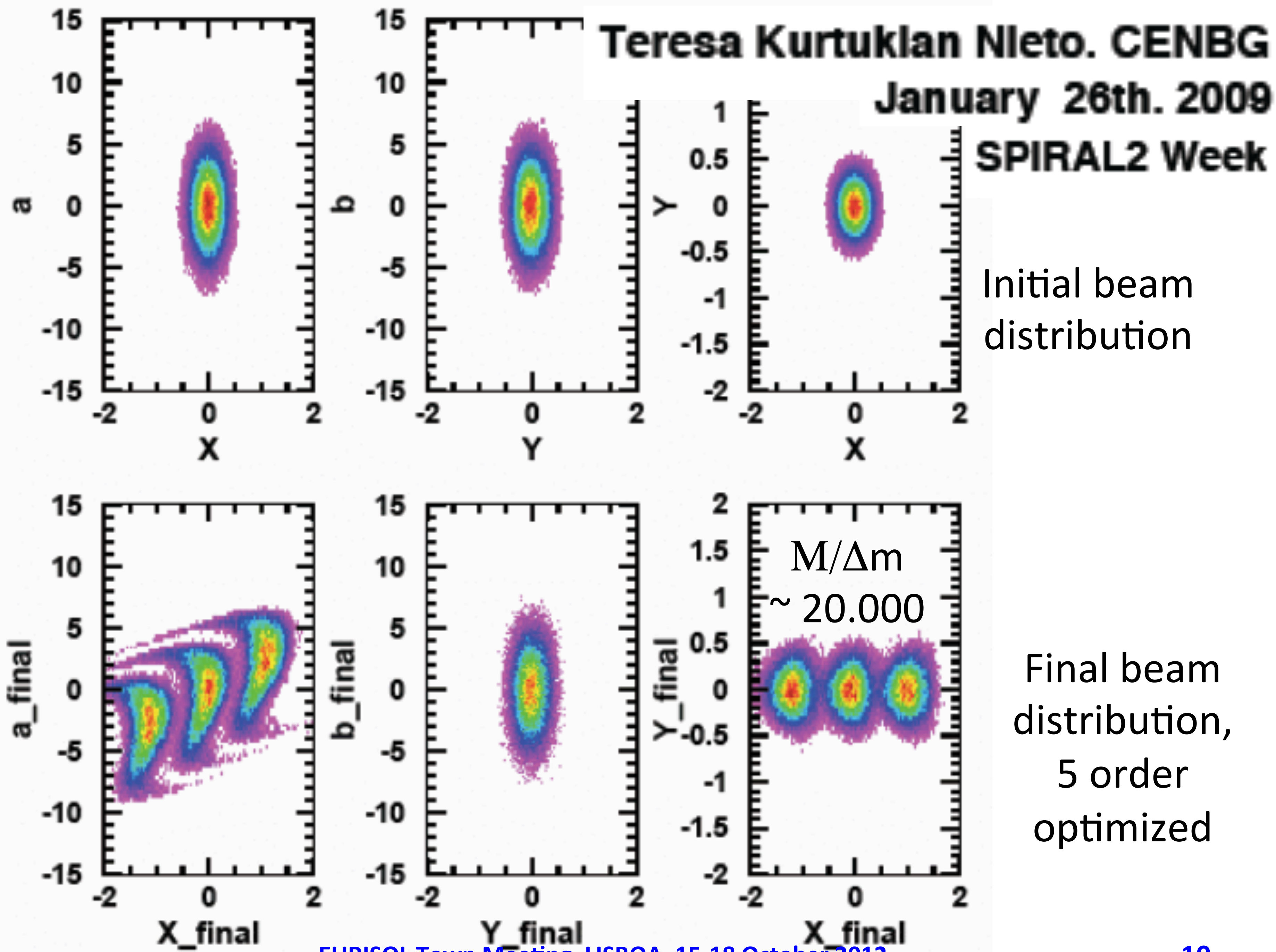
Isobars with similar intensities well separated

A Scaled UP version of the separator designed by Cary Davids for CARIBU project, Argonne

- Energy 260 kV
- Bend=80° ρ=1.5 m, Bmax=0.9 T
- Dipole Edge=28°
- (X,X') emittance=3 π mmmrad
- (Y,Y') emittance=4 π mmmrad
- Entrance/Exit slits 1 mm
- M/Δm ~ 40.000

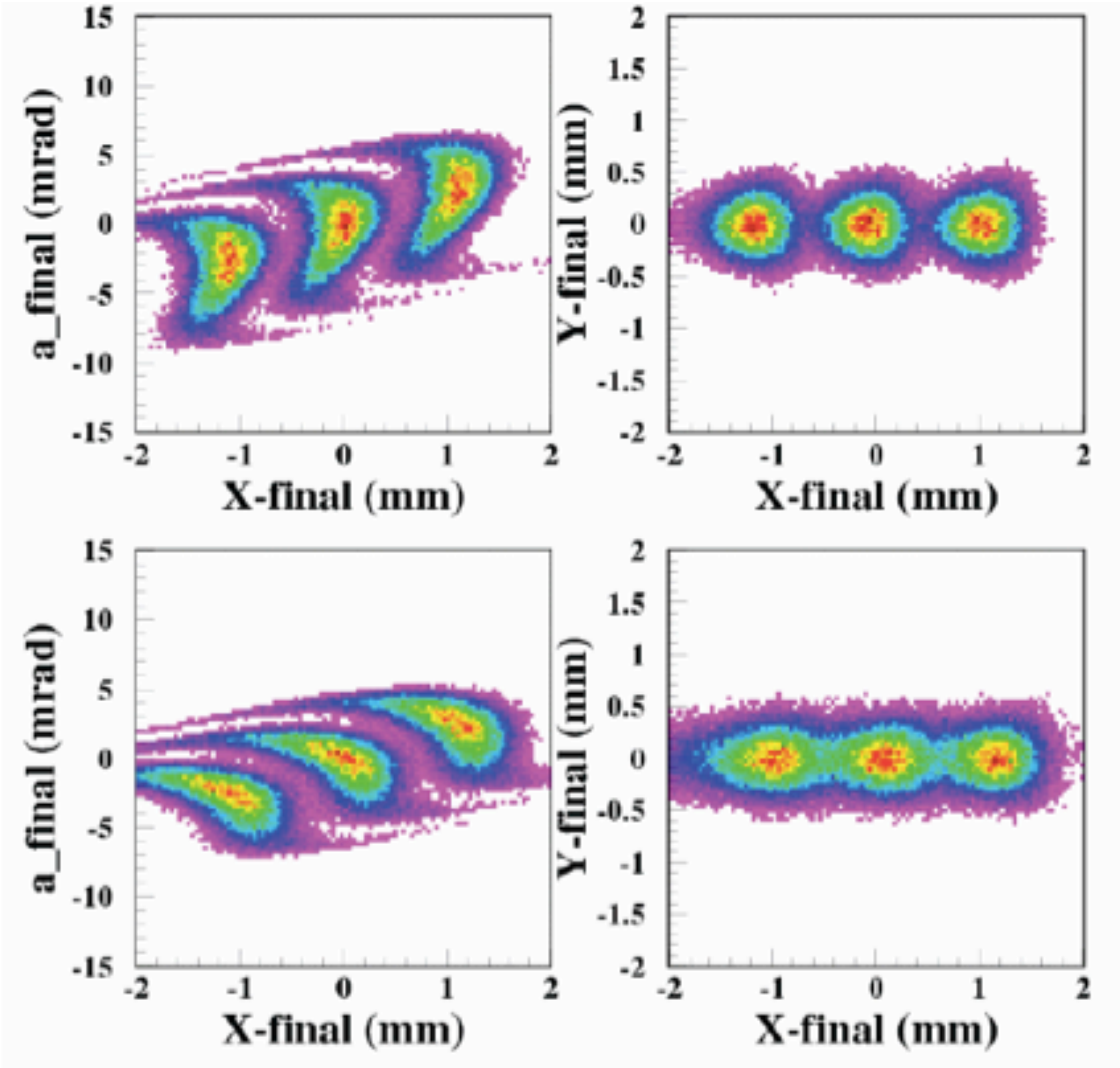


Parameters	CARIBU	SPES-LNL
Bending radius	500 mm	1500 mm
Beam Energy	50 keV	260 keV
Magnetic field A=20	2.9 kGauss	2.2 kGauss
Magnetic field A=200	9.1 kGauss	6.9 kGauss
Bending angle	60°	80°
Entrance/exit angle	23	28.4°
Pole gap	80 mm	<80 mm
Pole width	620 mm	<640 mm
Free space between dipoles	2 x 25 cm	2 x 45 cm ÷ 2 x 65 cm
Multipole Eff. Length	30 cm	**20 cm** → 40 cm
Multipole diameter	40 cm	40 → **50 cm**
Matching Quads Leff.	20 cm	40 cm
Focusing Quads Leff.	24 cm	40 cm



Initial beam distribution

Final beam distribution, 5 order optimized



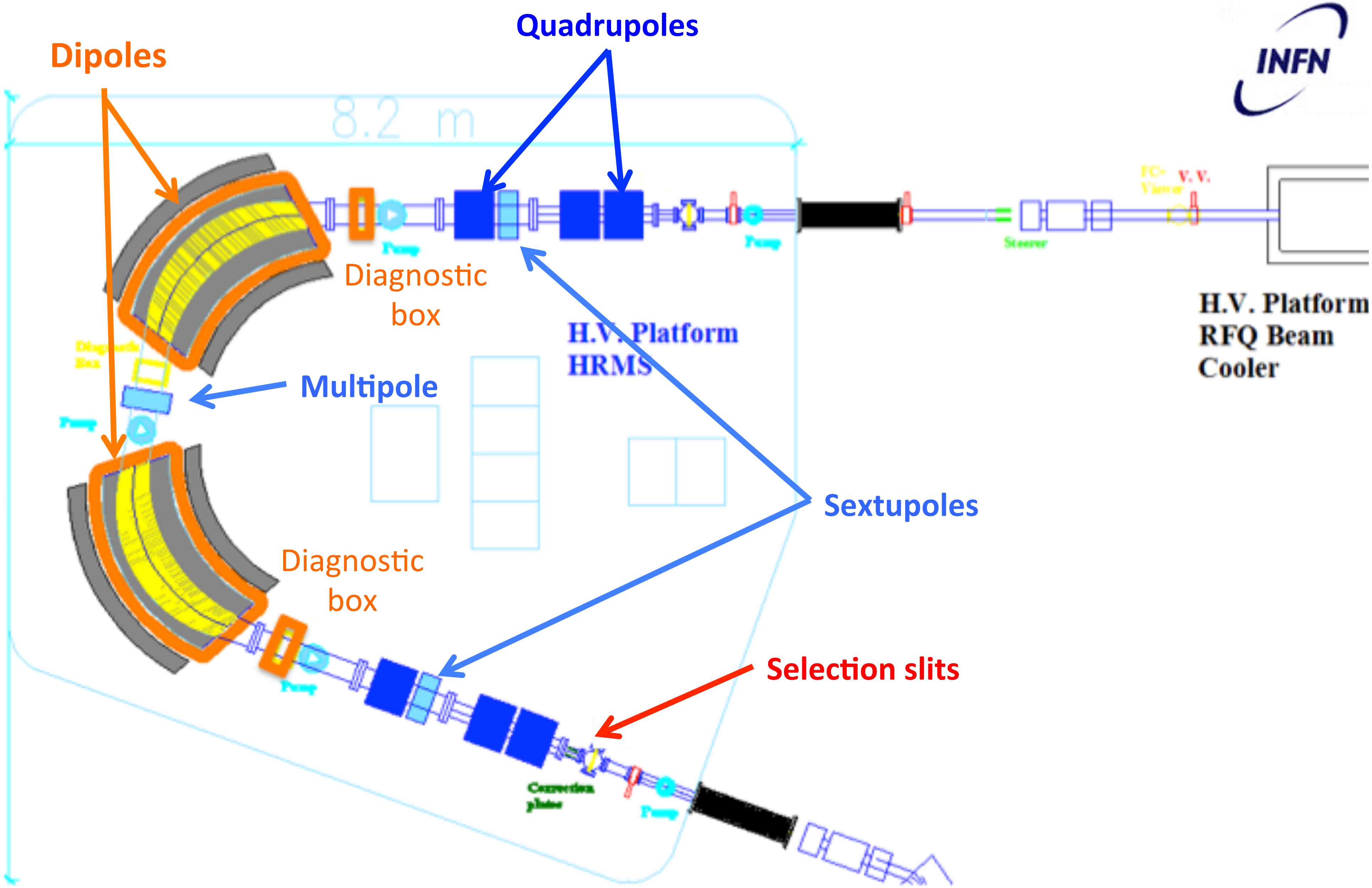
Phase spaces calculated to 5th order

50000 particles with mass deviations -1/20000, 0, +1/20000

A shift in the multipole of 0.2 mm in the x-direction induces a deformation in the x-a phase space which is responsible for the blur in the final mass separation. In this example m/Δm is reduced to ~11000

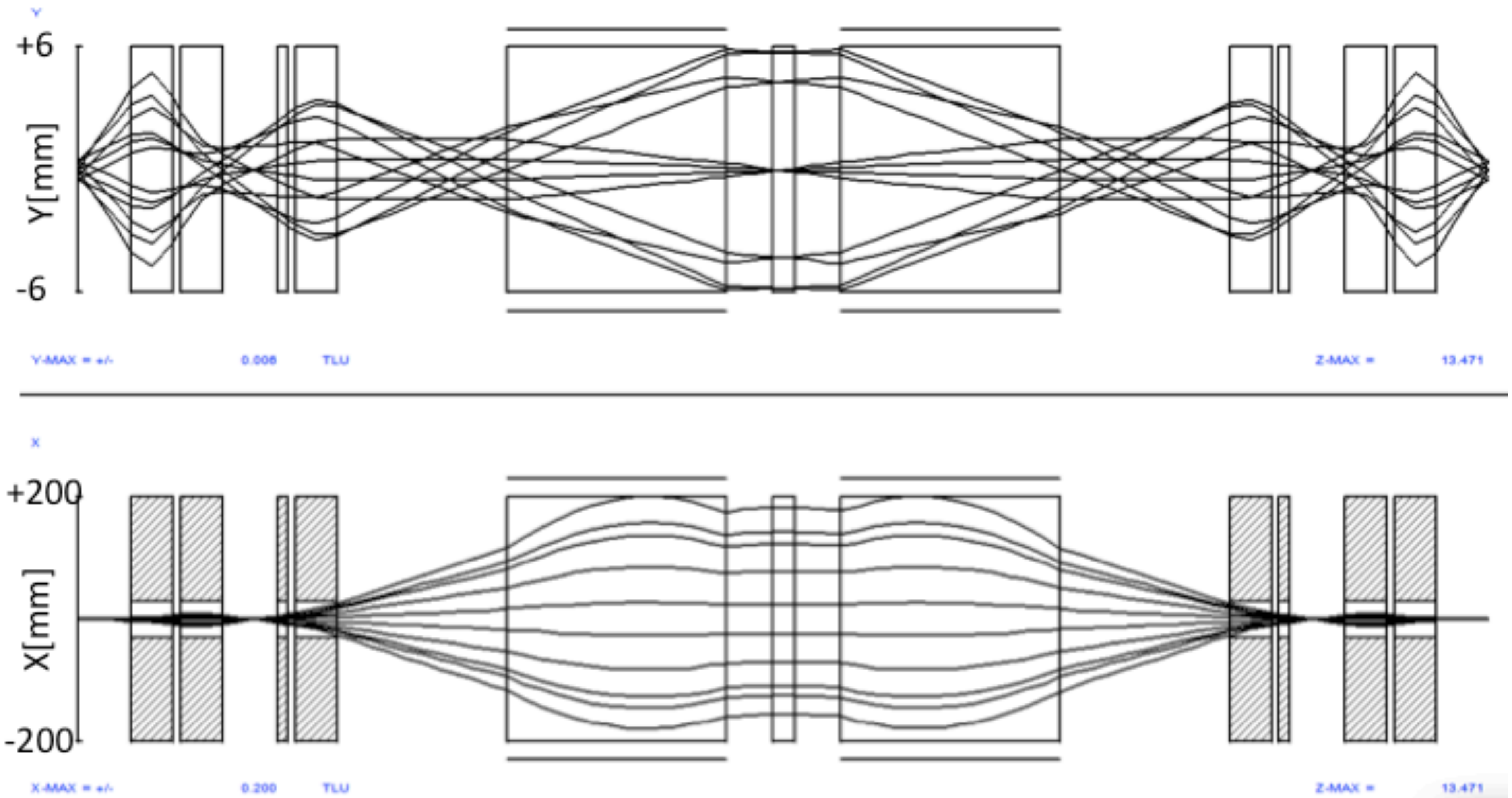
Teresa Kurtukian Nieto. CENBG   SPIRAL2 Week   January 26th. 2009   12

Coefficient of thermal dilatation for stainless steel
12 micron/(m K), for L=8 m and ΔT= 1K → ΔL= 0.096 mm

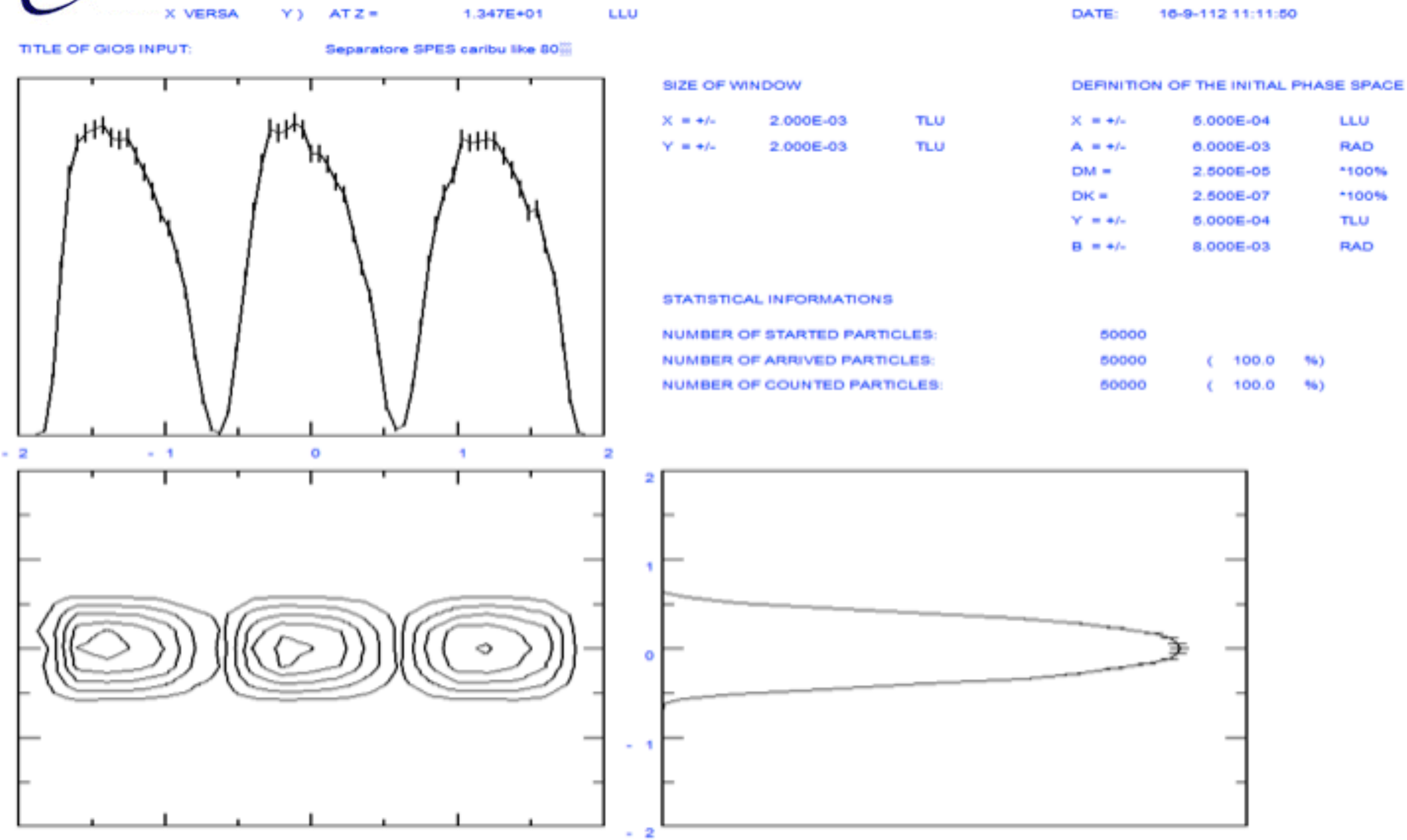


Dipoles
Quadrupoles
8.2 m
Diagnostic box
H.V. Platform HRMS
Multipole
Sextupoles
Diagnostic box
Selection slits
H.V. Platform RFQ Beam Cooler

Beam energy 260 keV,
(X,X') emittance=3 π mmmrad, (Y,Y') emittance=4 π mmmrad



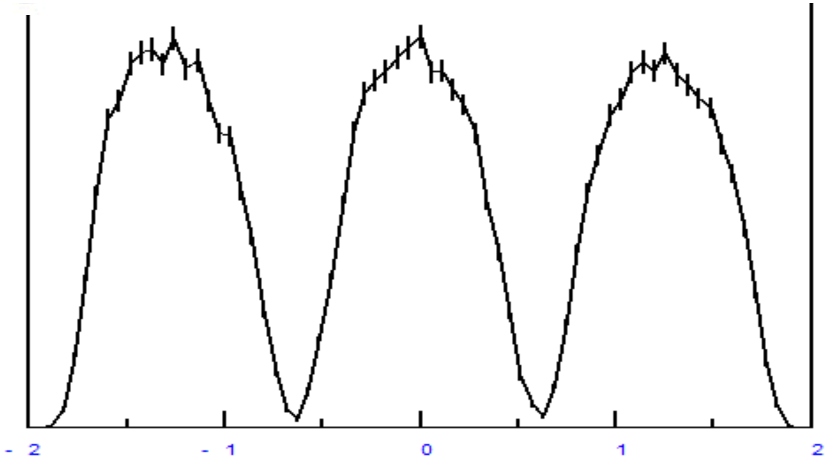
Mass $\Delta M/M = 2.5\ 10^{-5} \rightarrow 1/40000$



What do we learn about HRMS design for EURISOL ?

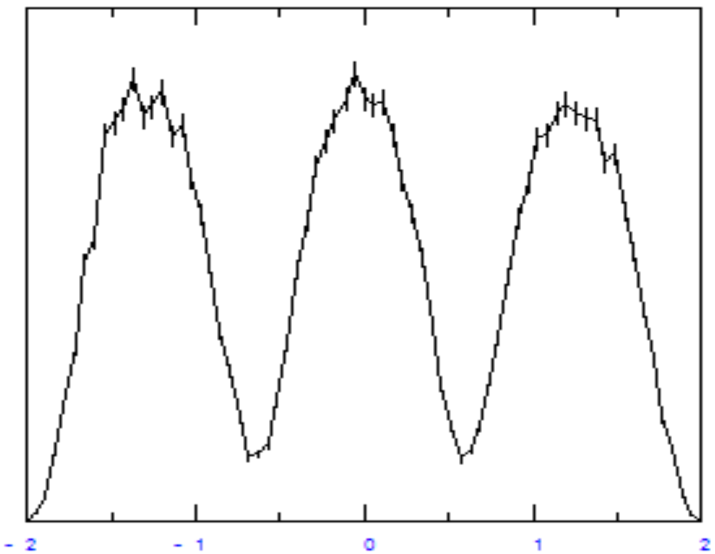
If we use the HRMS with beam of 100 keV and with energy spread ±1 eV the spectra will have this feature

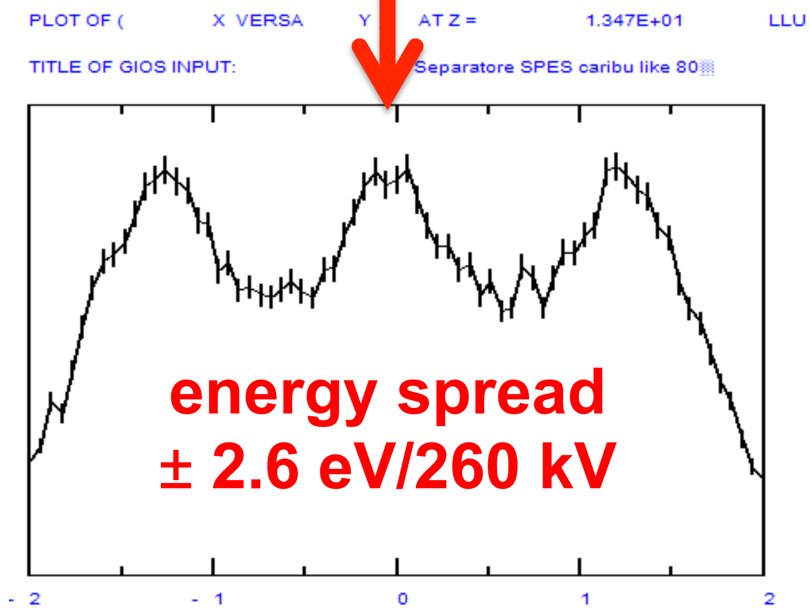
energy spread ±0.5 eV/ 260 kV

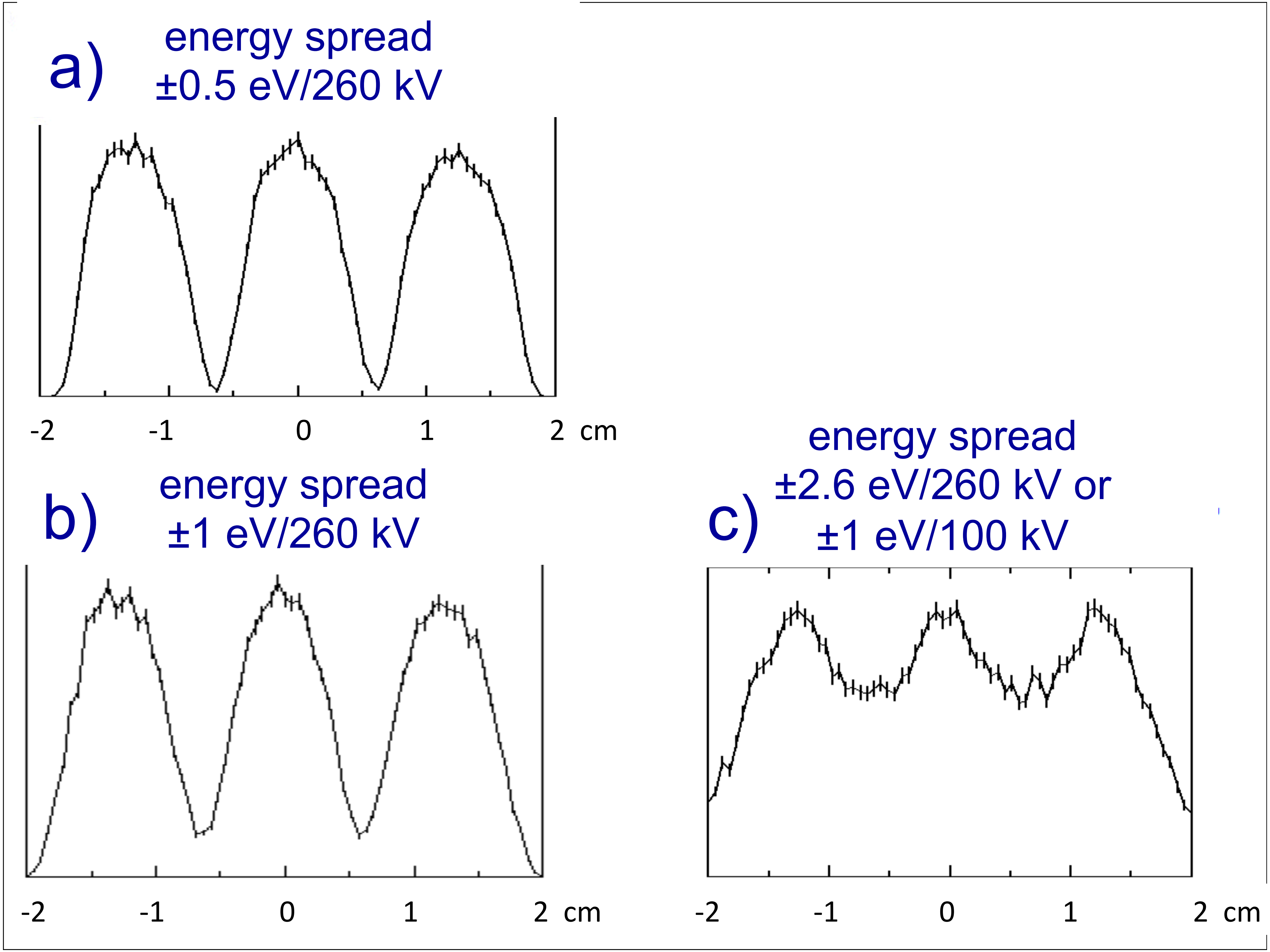


energy spread ±1 eV/260 kV

Δm/M= 1/40.000

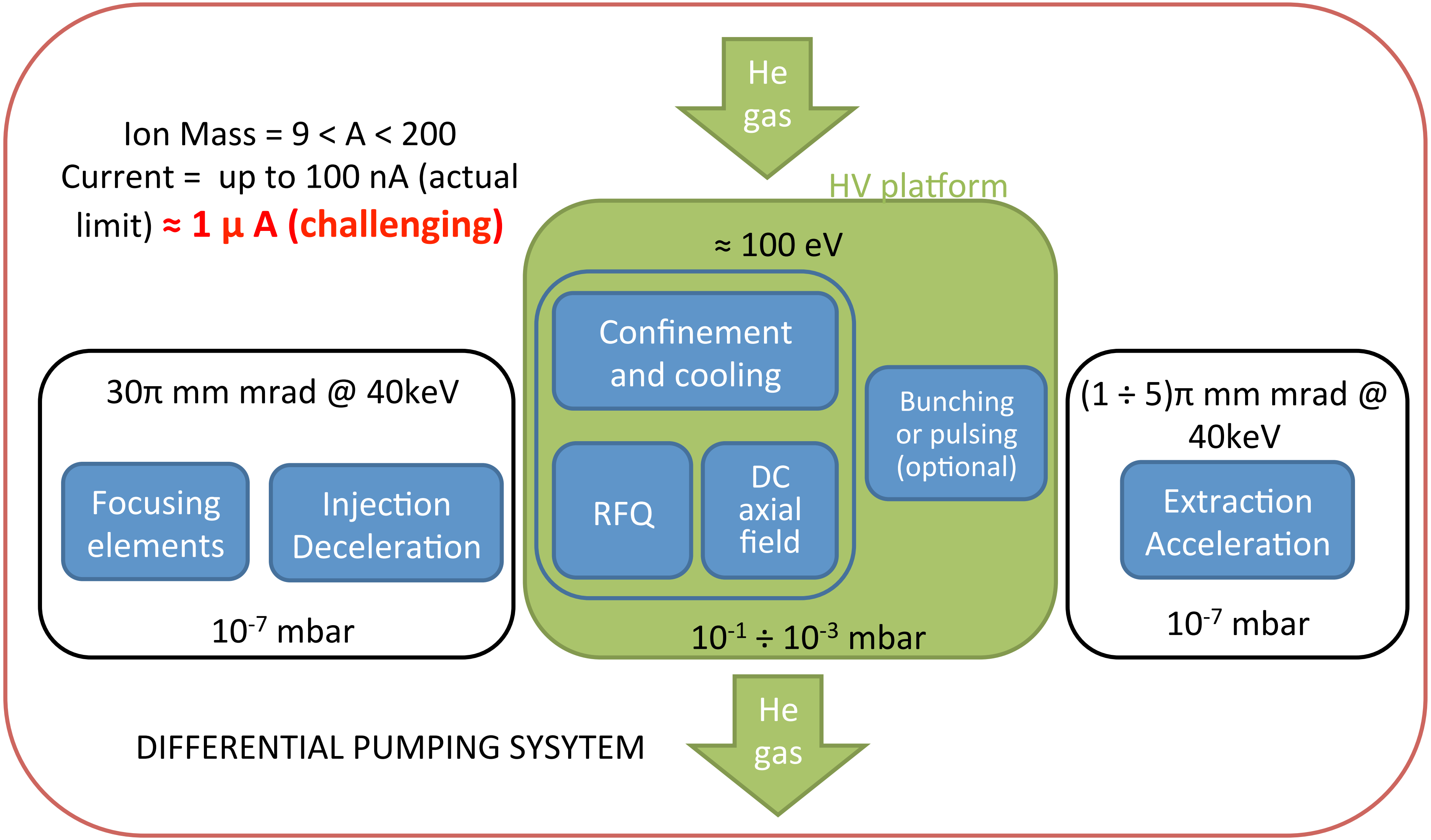






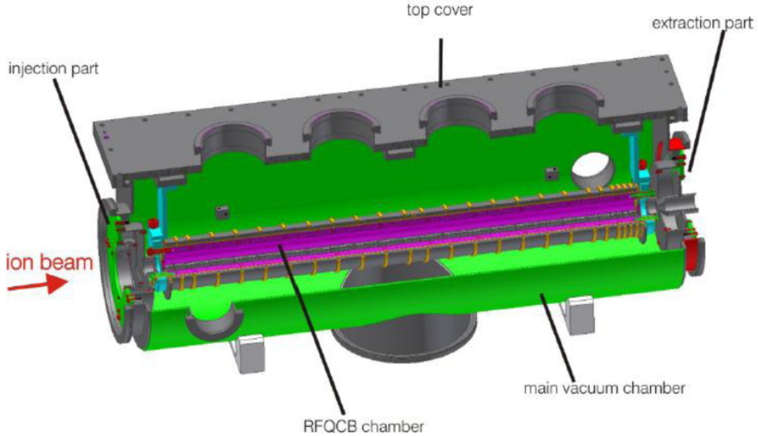
a)
energy spread
±0.5 eV/260 kV
-2
-1
0
1
2 cm
b)
energy spread
±1 eV/260 kV
-2
-1
0
1
2 cm
c)
energy spread
±2.6 eV/260 kV or
±1 eV/100 kV
-2
-1
0
1
2 cm

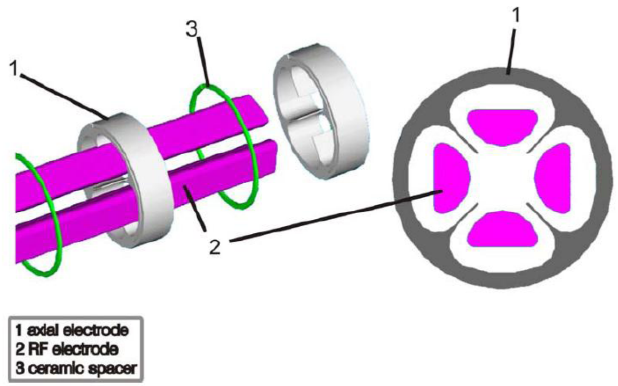
RFQ Cooler System Layout

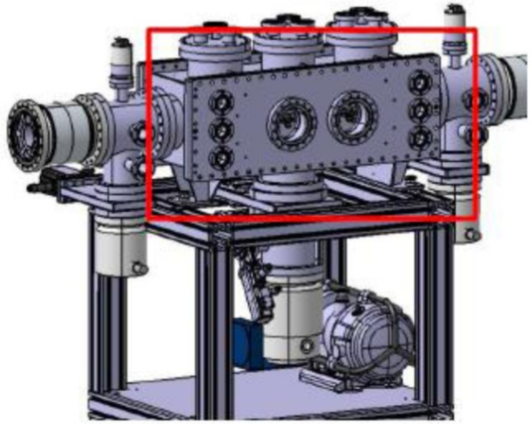


ISCOOL

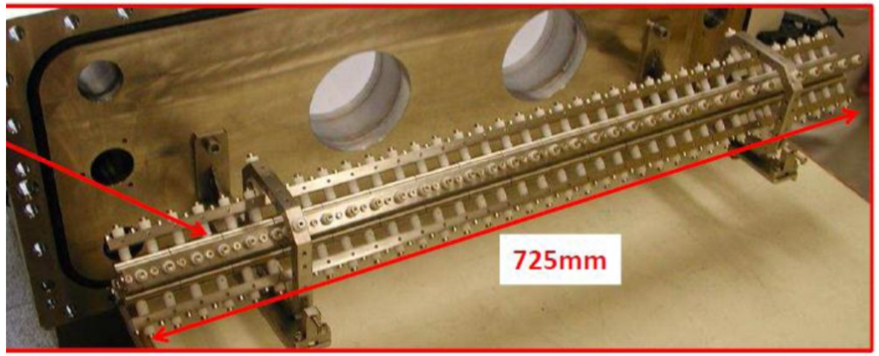
Mass range	10÷300 u
Transverse emittance	< 20 π ·mm·mrad
Intensity	< 10^{10} ions/s
Mean energy	60 keV
Energy spread	5 eV
Type of beam-timing	CW





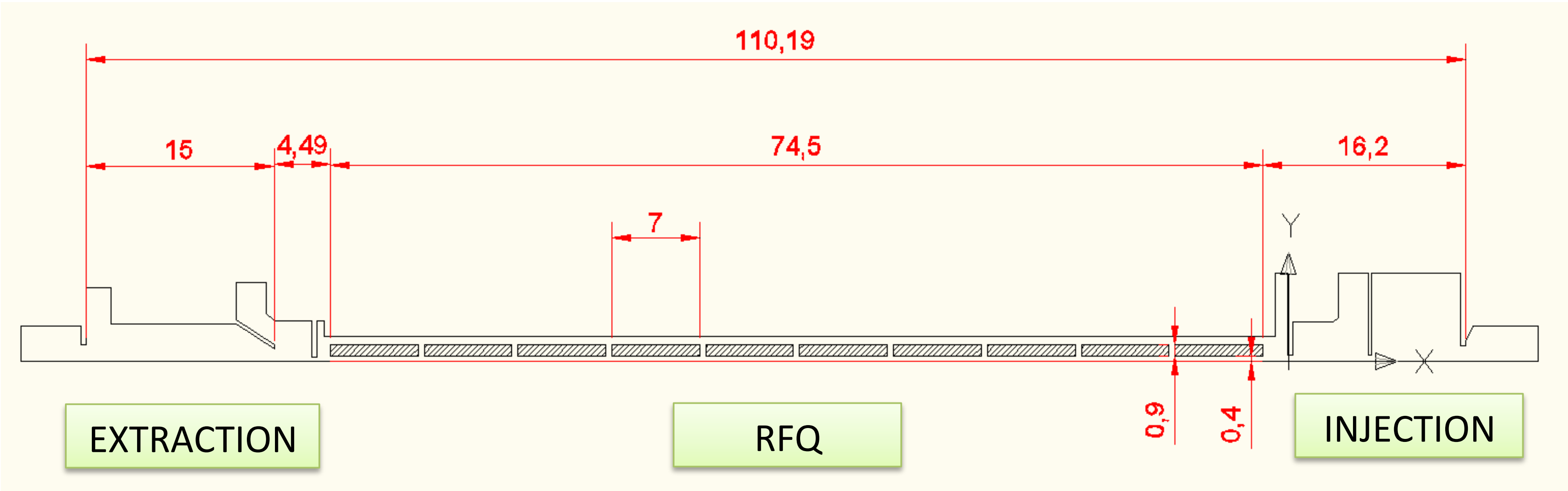


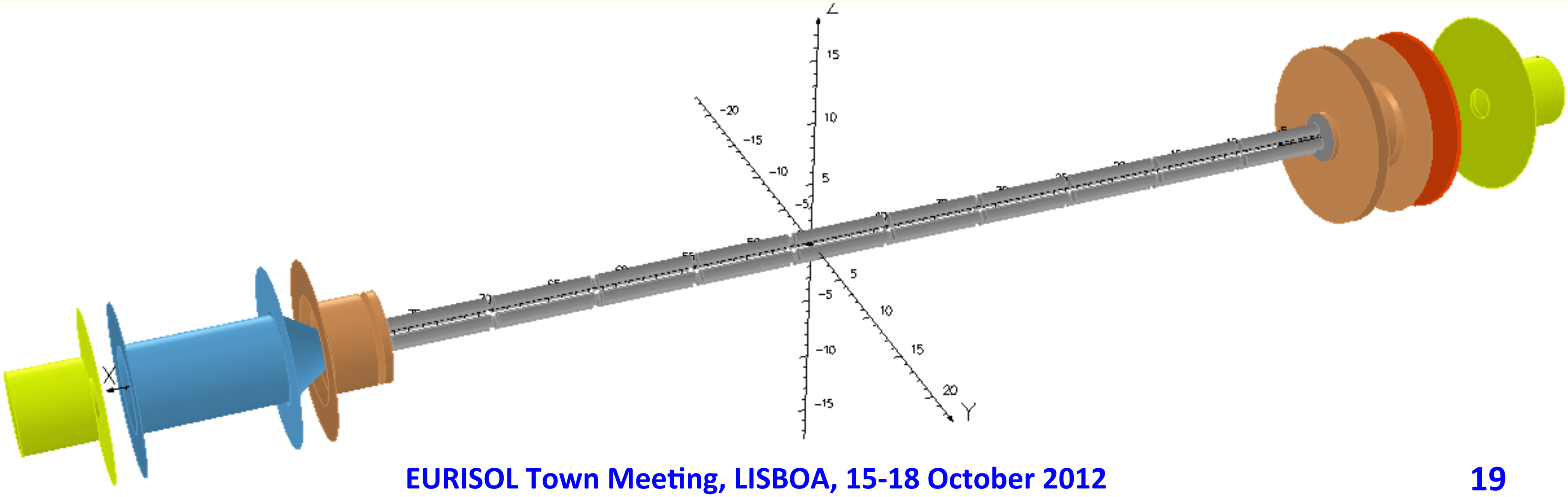
SHIRAC2



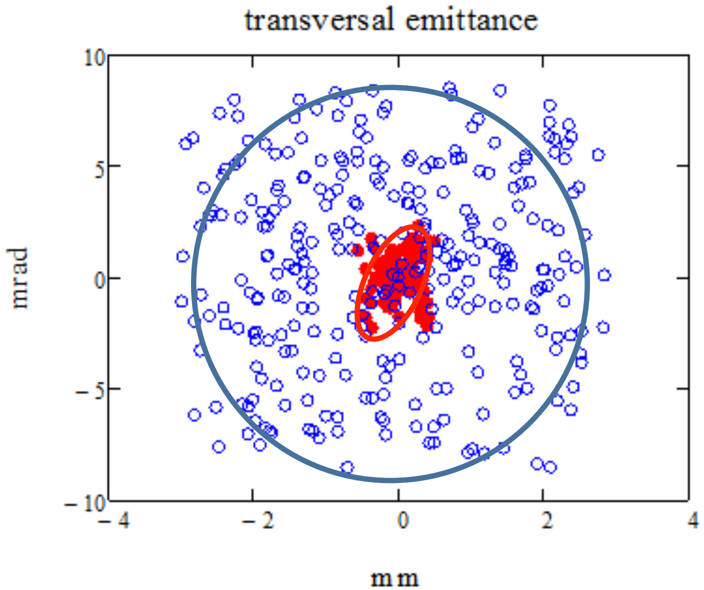
Intensité	~ µA	
Masse	6 – 240 UMA	
Acceptance	80 π.mm.mrad à 60 keV	
Transmission	> 12 UMA	20 %
	> 40 UMA	40 %
	> 90 UMA	60 %
Emittance en sortie	< 3 π.mm.mrad à 60 keV	
ΔE	≤ 1 eV	

PRELIMINARY DESIGN SPES RFQ-COOLER (OPERA code)





RFQ dynamics simulation



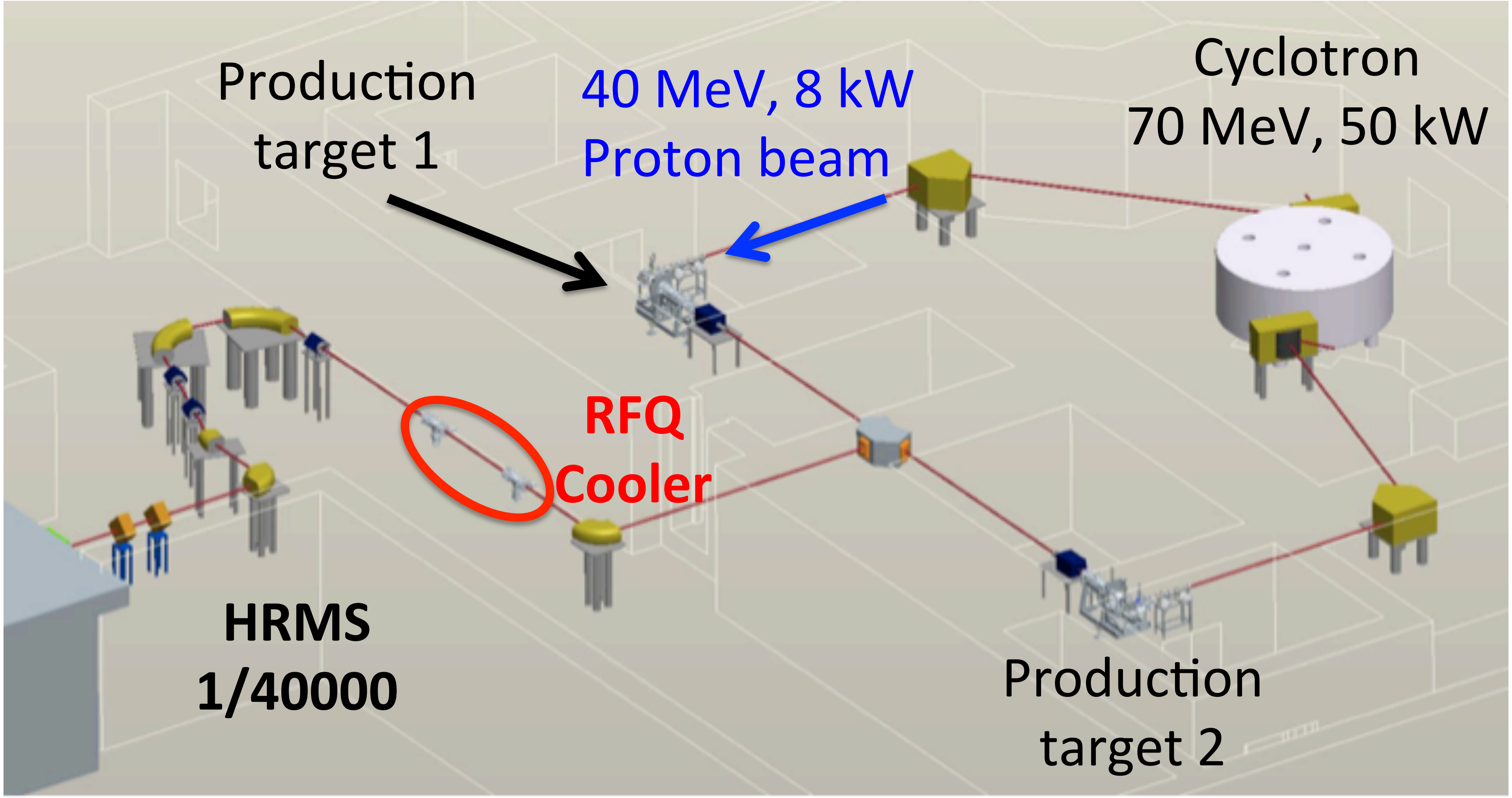
Cs+, A=133
Einj=200 eV
Vq=1500 volt
frf=5.57 MHz
V1=100 Volt
dV=10 Volt
He pressure =2.5 Pa
q=0.22 (Mathieu param.)

Emittance reduction factor of 10

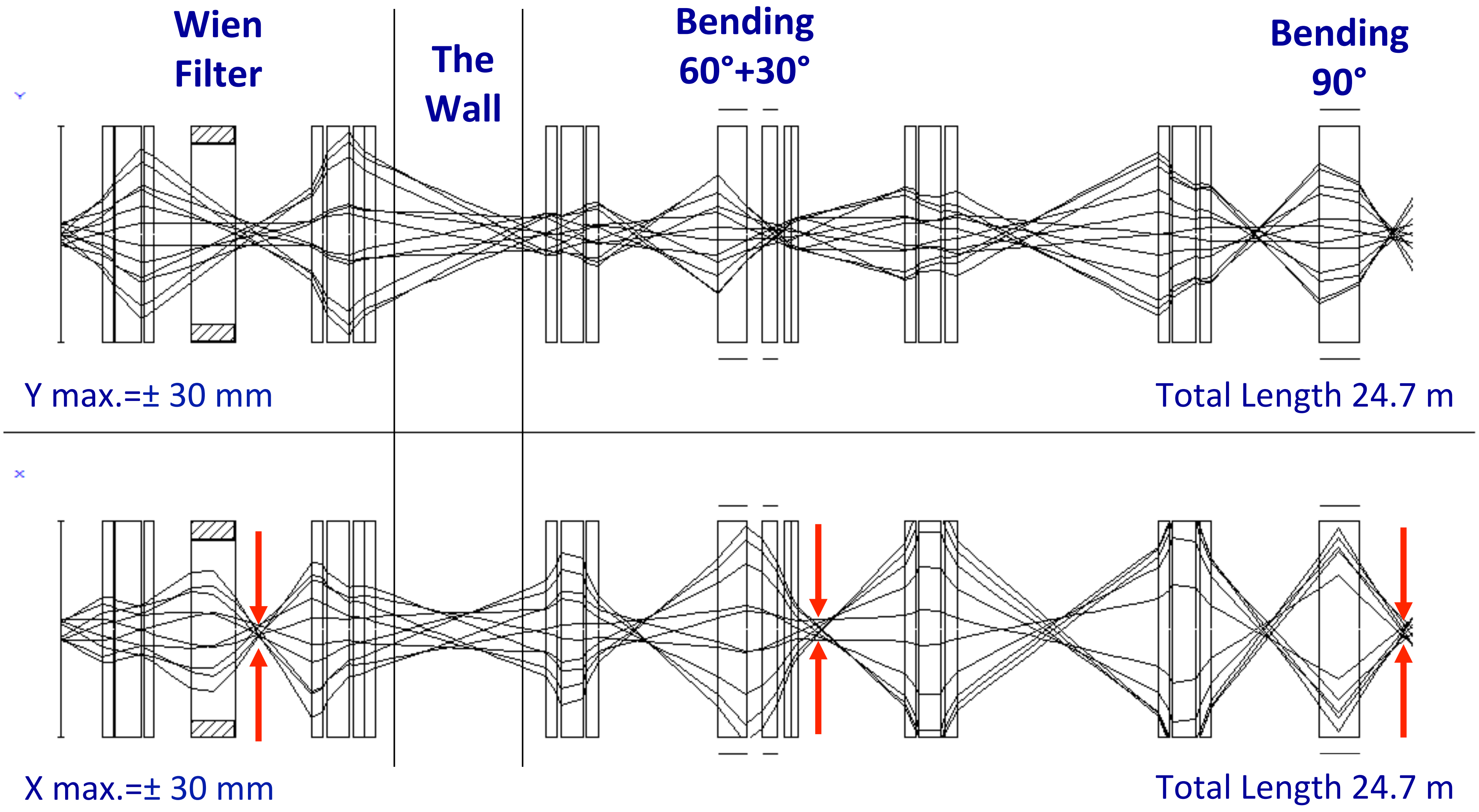
SPES RFQ Beam Cooler parameters

Mass Range	9-200 amu
Transverse Emittance Injected beam	30 π mm mrad @ 40 keV 0.024 π mm mrad norm.
Emittance Reduction factor	10 (max)
Beam Intensity	50-100 nA → x10^{11} pps
Energy spread	< 5 eV
RF Voltage range	0.5 – 2.5 kV (1 kV at q=0.25)
RF Frequency range	1 -30 MHz (3.5 – 15 MHz at q=0.25)
RFQ gap radius (ro)	4 mm
RFQ Length (total)	700 mm
Pressure Buffer Gas (He) range	0.1 – 2.5 Pa
Ion energy during the cooling	100 -200 eV

Performances of the Beam Cooler depends also by the beam intensity injected

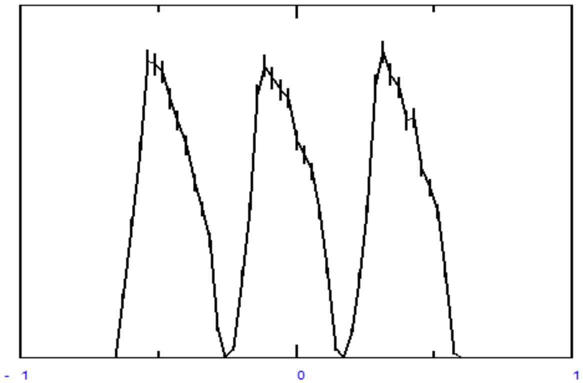


Design of the beam transport line up to the Beam Cooler Gios simulation, 3° order in x and y included, emittance=39 π mm.mrad

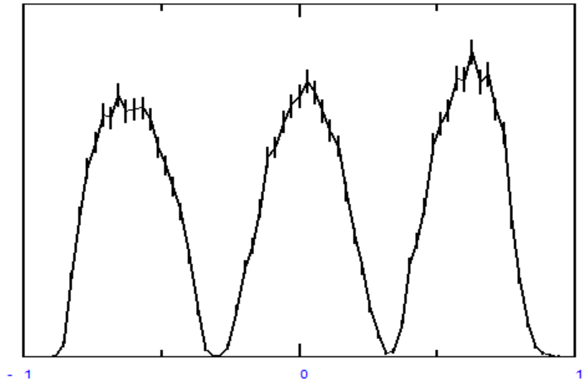


Purification of the beam injected in the Beam Cooler
Gios simulation, 3° order in x and y included, emittance=39 π mm.mrad

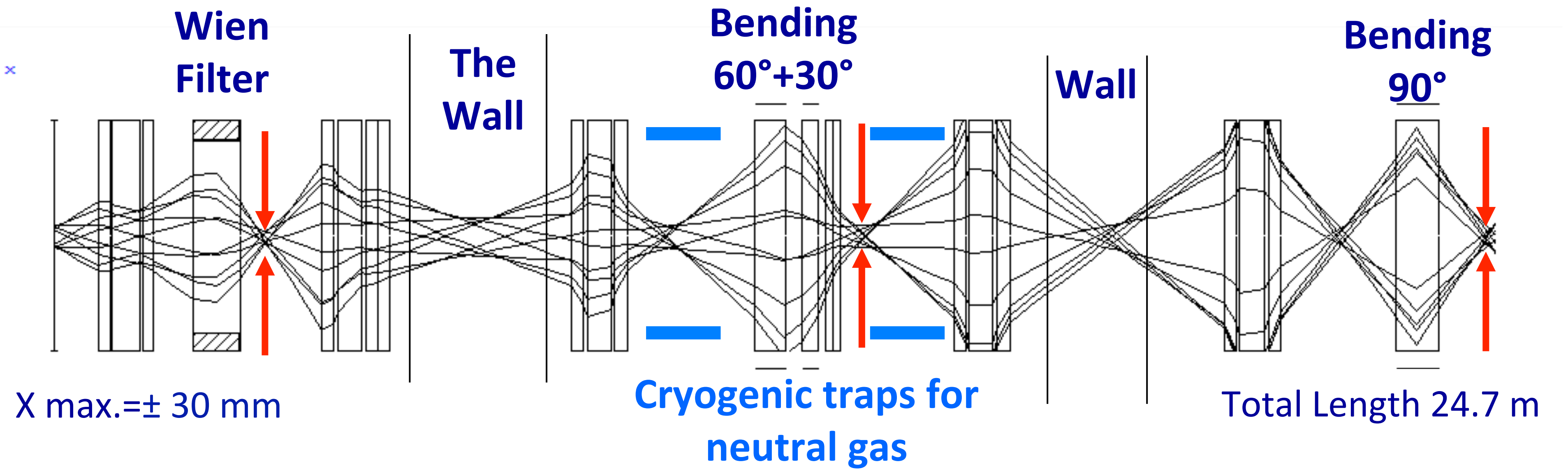
M/Δm=100

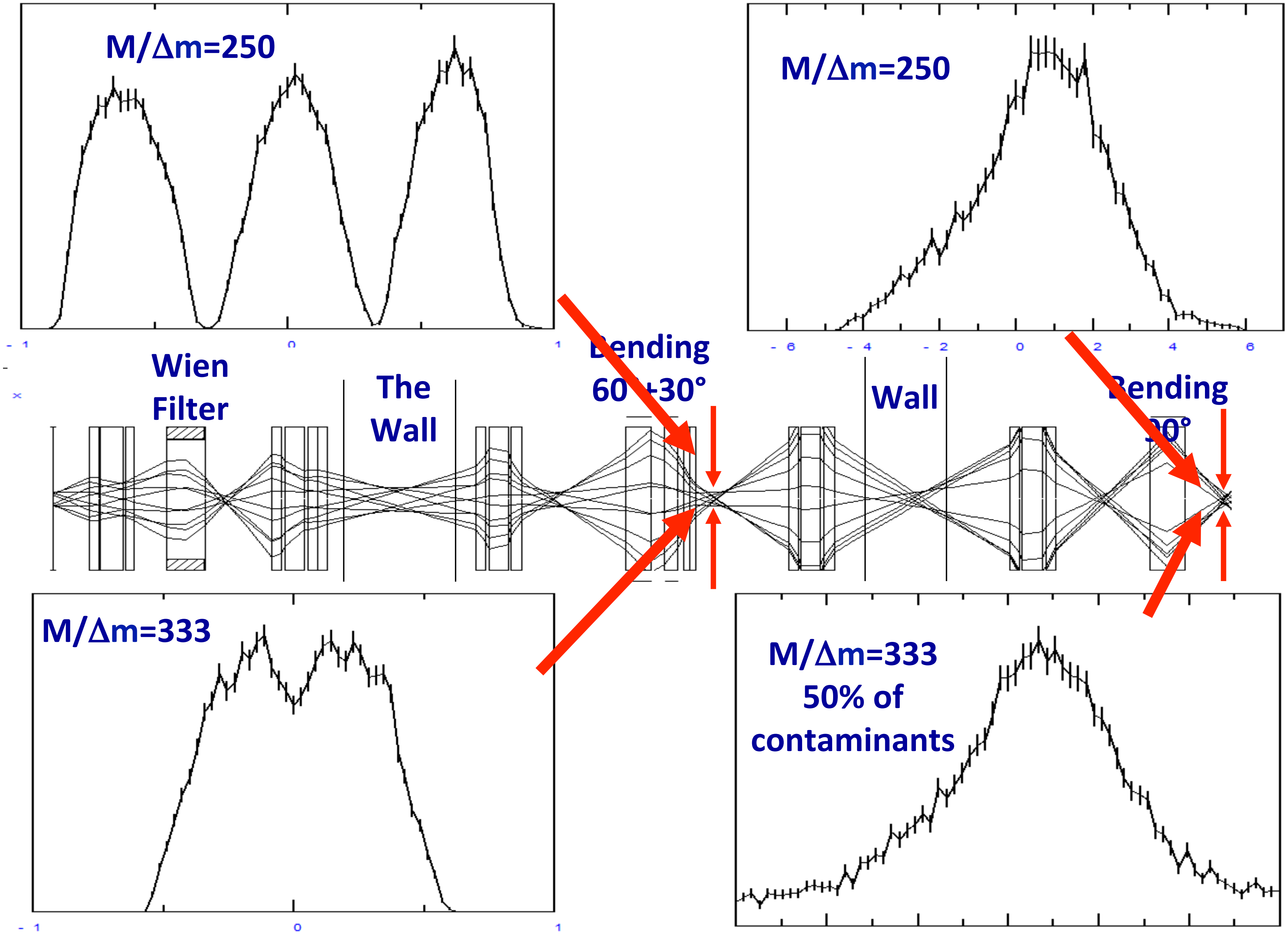


M/Δm=250



Despite the bending radii of dipoles are now 50 cm, we achieved a good mass resolution

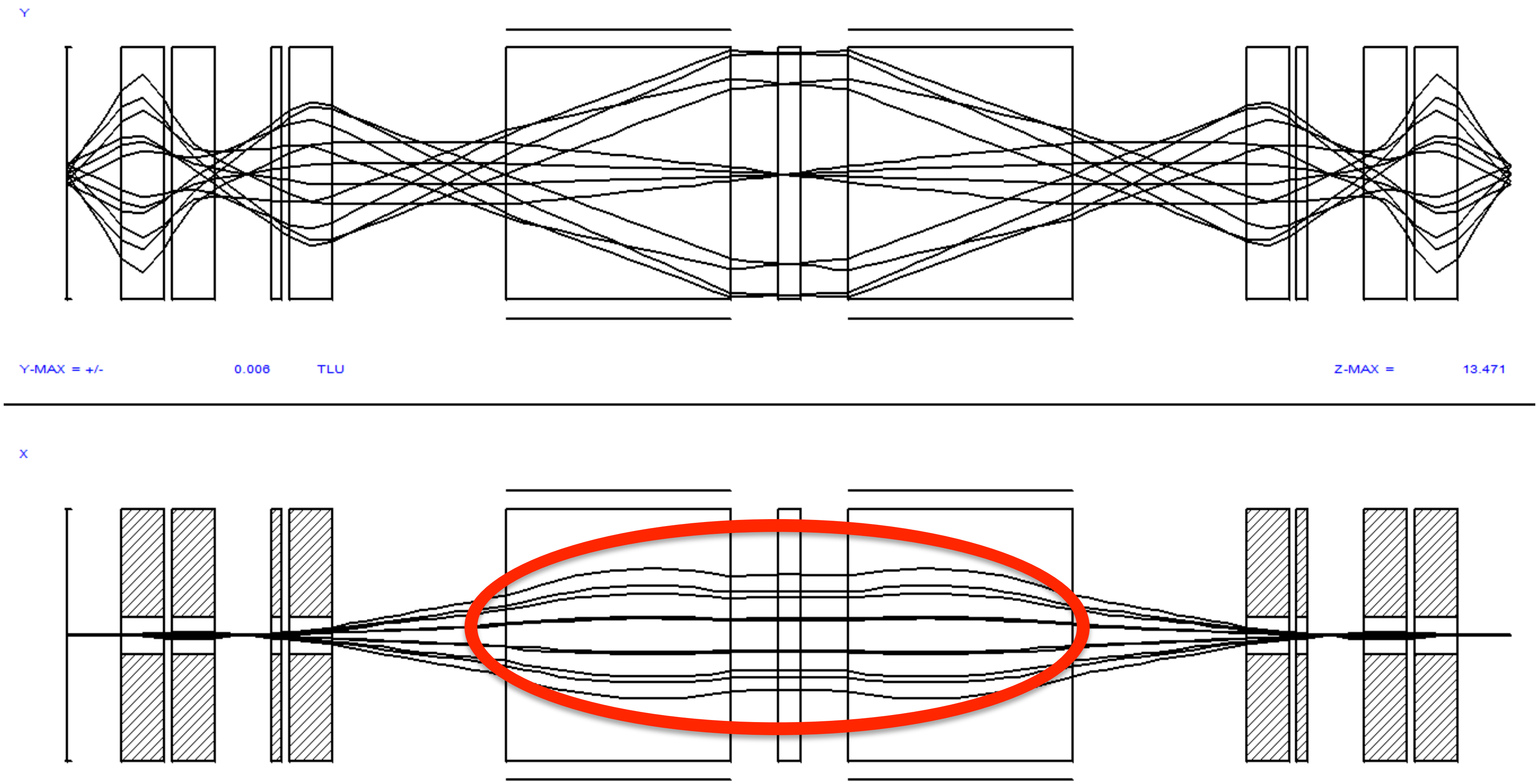




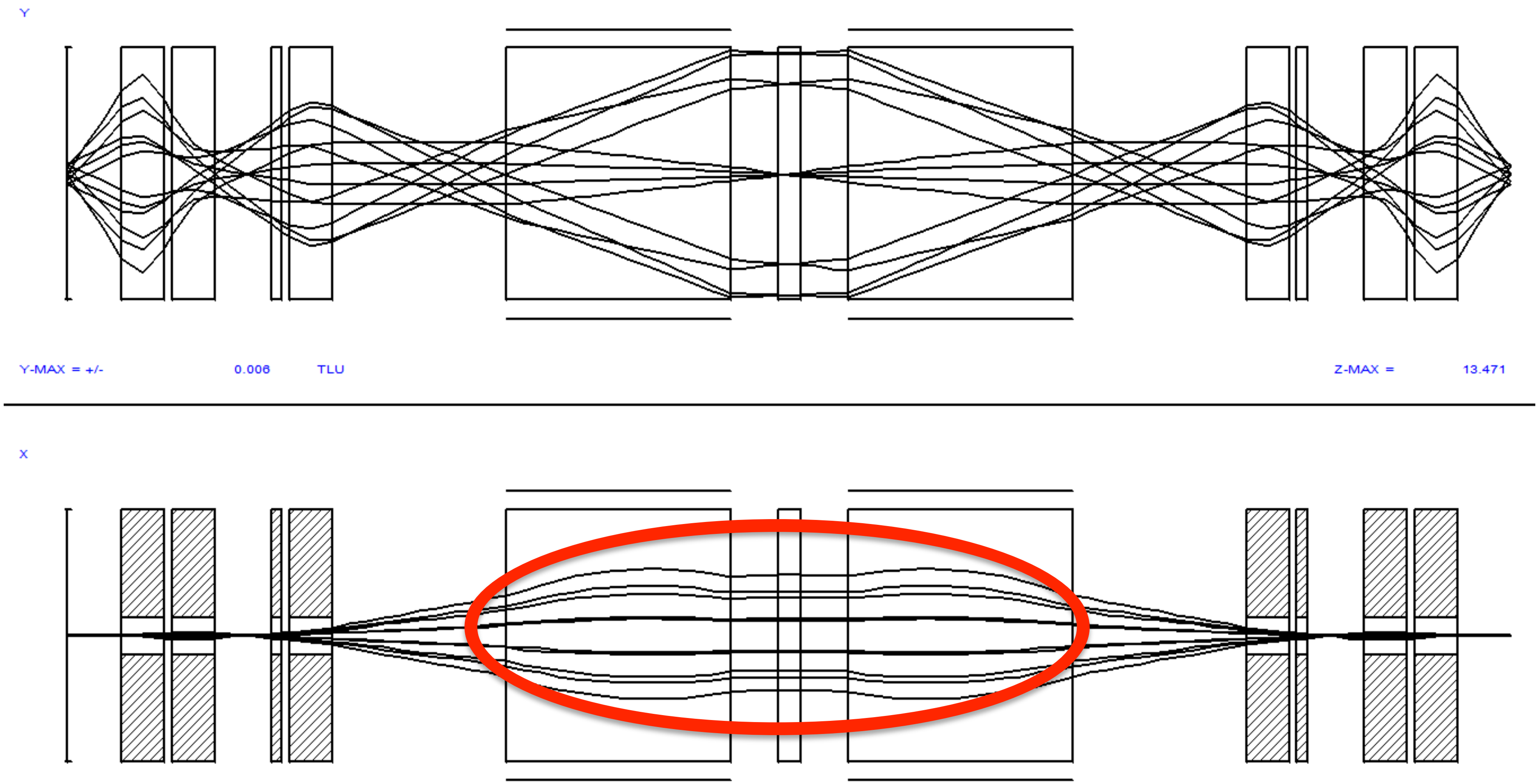
M/Δm=250
-1
0
1
M/Δm=250
-6
-4
-2
0
2
4
6
Wien Filter
The Wall
Bending
60 +30°
Wall
Bending
M/Δm=333
-1
0
1
M/Δm=333
50% of
contaminants
-6
-4
-2
0
2
4
6

Beam energy 260 keV,

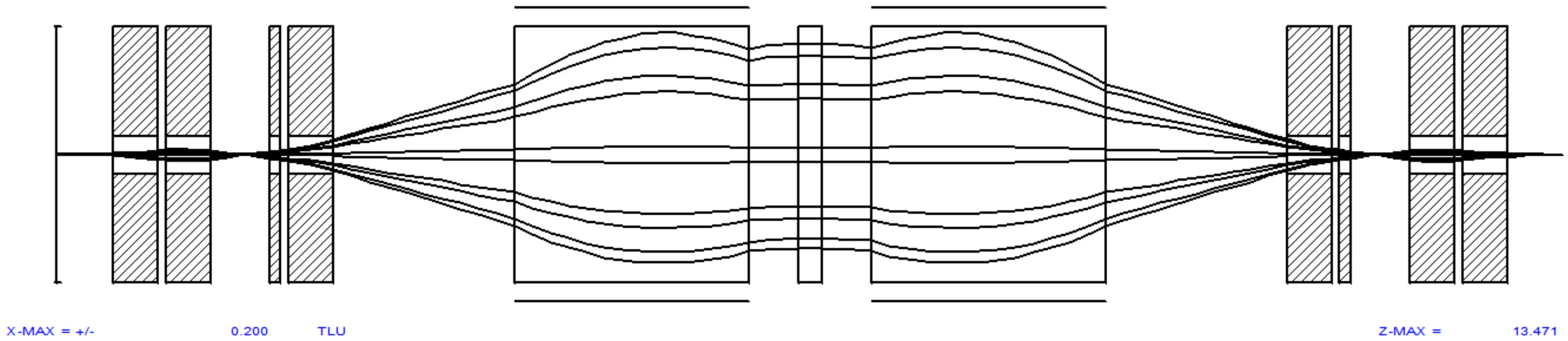
(X,X') emittance=1.5 π mm.mrad → 3.4 π mm.mrad @ 50 keV

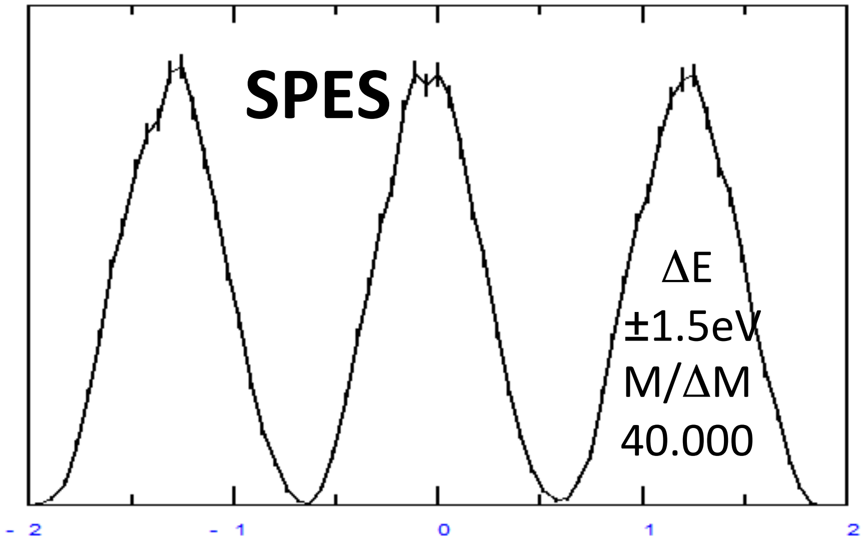


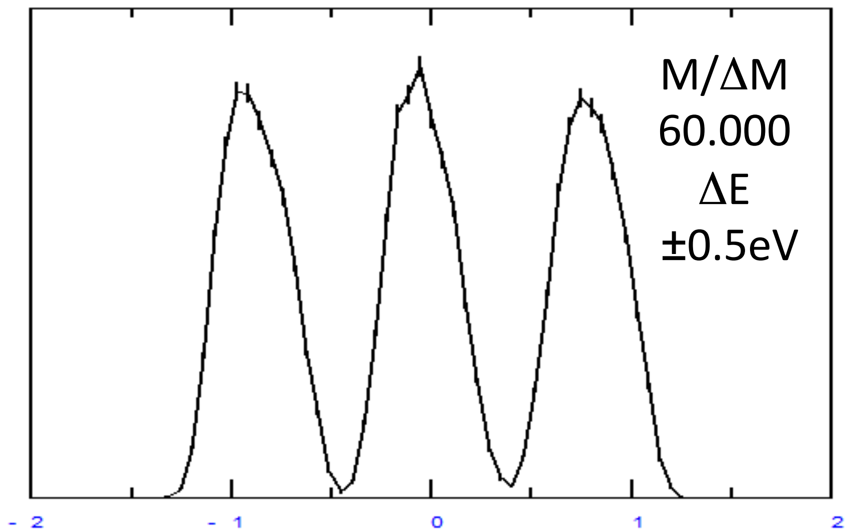
Beam energy 260 keV, beam size at entrance slit 1 mm,
(X,X') emittance=1.5 π mm.mrad → 3.4 π mm.mrad @ 50 keV



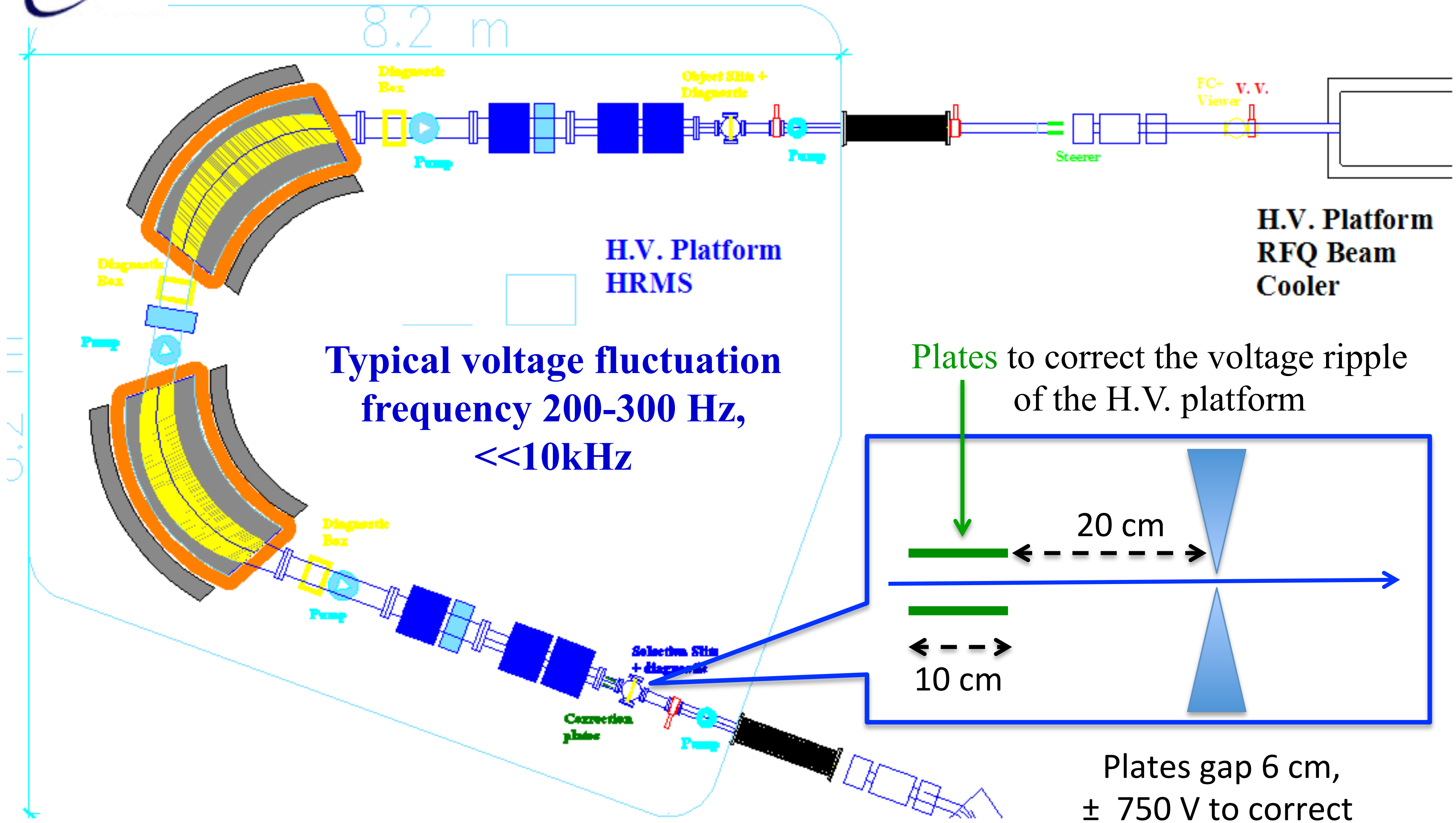
Beam energy 260 keV, Beam size at entrance slit 0.5 mm, (X,X') emittance=1.5 π mm.mrad → 3.4 π mm.mrad @ 50 keV







Active compensation of H.V. Platform fluctuation



Typical voltage fluctuation frequency 200-300 Hz, <<10kHz

Plates to correct the voltage ripple of the H.V. platform

Plates gap 6 cm,
± 750 V to correct
± 5 V platform ripple

Program of activity to complete the HRMS design:

- Complete the study using COSY infinity code, to minimize the 5th order aberrations;

- Simulation with 3D electromagnetic code of the electrostatic quadrupoles and of the magnetic dipoles and their optimization;

- Perform raytracing of particles across the simulated magnetic and electric field maps to verify the expected performances and possible countermeasures (shimming of the dipoles, surface coils …);

- Simulations of position imperfections and active/passive corrections tools;

Conclusions:

- SPES HRMS could be the first HRMS with resolving power 40.000 in operation before Eurisol;

- The performances of HRMS depends not only by its parameters but also and probably mainly by the Beam Cooler performances;

- We have to learn a lot about the problems to operate this new class of HRMS and the platform voltage could mitigate the problems;