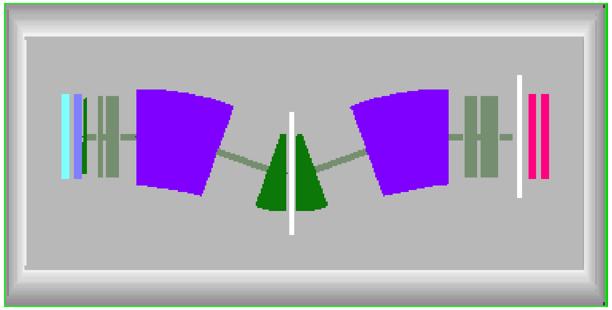
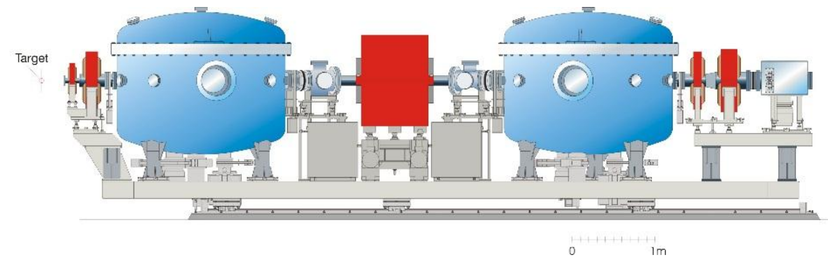
EMMA (ElectroMagnetic Mass Analyzer) @ TRIUMF

Version 9.10.207 from 11/17/2015

Link: Separator “EMMA” @ TRIUMF





- ❑ EMMA extended configuration
  - Documentation
  - EMMA files location
  - Optics
  - Optimization
- ❑ Angular Acceptance
- ❑ Momentum Acceptance
- ❑ Benchmarks
- ❑ Charge state selection
- ❑ LISE^{++} analytical and MC envelopes
- ❑ Reaction d(^{132}Sn,p)^{133}Sn
  - Decreasing Angular Acceptance for better selection

EMMA documentation sources

1.

Available online at www.sciencedirect.com
SCIENCE DIRECT®

ELSEVIER

Nuclear Instruments and Methods in Physics Research A 544 (2005) 565–576

NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH
Section A
www.elsevier.com/locate/nima

EMMA: A recoil mass spectrometer for ISAC-II at TRIUMF

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Available online 11 March 2005

2. The EMMA settings example and apertures kindly provided by Matt Williams (TRIUMF)

EMMA files location @ LISE^{++} package

LISE^{++} package / files

\LISE\files\examples\TRIUMF*.*

Name	Ext	Size	↓Date
[..]		<DIR>	11/17/2015
EMMA_beam	lpp	133,012	11/17/2015
EMMA_reaction	lpp	137,443	11/17/2015
e_DRAGON2000_reaction_2body	lpp	353,121	09/16/2015
s_DRAGON2000_reaction_2body	lpp	55,413	09/16/2015
e_DRAGON2000_39Ca_beam	lpp	355,049	07/22/2015
e_DRAGON2000_reaction	lpp	357,464	07/22/2015
s_DRAGON2000_reaction	lpp	55,647	07/22/2015

→ *EMMA for the primary beam A=100,q=20+,E=180MeV*

→ *EMMA for the reaction ^{132}Sn(6MeV/u)+CD_2(0.1 mg/cm^2) ..*

LISE^{++} package / configurations

\LISE\config\TRIUMF*.*

Name	Ext	Size	↓Date
[..]		<DIR>	11/17/2015
EMMA	lcn	112,029	11/17/2015
s_DRAGON2000	lcn	34,357	07/22/2015
e_DRAGON2000	lcn	329,085	07/22/2015

→ *EMMA configuration*

LISE^{++} site / 9_10/ EMMA

lise.nscl.msu.edu/9_10/EMMA/

Index of /9_10/EMMA

Name	Last modified	Size
Parent Directory		-
EMMA_beam_AA.lpp	2015-11-17 15:19	129K
EMMA_beam_MA.lpp	2015-11-17 15:20	129K
EMMA_beam__original.lpp	2015-11-16 12:02	124K
EMMA_reaction_AAlimit.lpp	2015-11-17 16:46	134K
EMMA_reaction_NoGold.lpp	2015-11-17 12:27	131K

The next files been used for the analysis presented in this work

→ *file to define Angular Acceptance*
→ *file to define Momentum Acceptance*
→ *file with "original" quad-values*
→ *the same as "EMMA_reaction.lpp" with small X'-acceptance*
→ *the same as "EMMA_reaction.lpp" without the gold degrader*

EMMA optics settings

Optics settings (fast editing)

Block	Given Name	Start(m)	Length(m)	B0(kG)/*U	Br(Tm)cor/*real	DriftM/*Angle	Rapp(cm)/*R(...	Leff(m)/*Ldip(m)	2 nd order	CalcMatr/*Z-Q	AngAcc,Apps,Slits	COSY | Fit	SE
= Dipole	tuning	0.000	0.0001	+3.2873	* 0.9862	* +0.0	* 3.0000	* 0.0000	-	* 19	HV -- --	-	S
drift	Drift 1	0.000	0.2470			standard					-- HV --	-	e
<Quad>	Q1	0.247	0.1398	+13.4745	0.9862	QUAD	3.5000	0.1398	yes	1 R	-- HV --	-	e
drift	drift Q12	0.387	0.0350			standard					-- HV --	-	e
<Quad>	Q2	0.422	0.2988	-8.7698	0.9862	QUAD	7.5000	0.2988	yes	1 R	-- HV --	-	e
drift	drift Q2E	0.721	0.3723			standard					-- HV --	-	e
=ElecDip	ElecDip 1	1.093	1.7453	*546.4kV	0.9862	* +20.0	* 5.0000	* 1.7453	-	* 19 R	-- HV --	-	E
drift	drift ED	2.838	1.2250			standard					-- HV --	-	e
= Dipole	DipoleA	4.063	0.3491	-9.8619	* 0.9862	* -20.0	* 1.0000	* 0.3491	yes	* 19 R	-- -- --	-	E
slits	dip slits	4.412	0.0000			SLITS					-- -- HV	-	e
= Dipole	DipoleB	4.412	0.3491	-9.8619	* 0.9862	* -20.0	* 1.0000	* 0.3491	yes	* 19 R	-- -- --	-	E
drift	drift DE	4.761	1.2225			standard					-- HV --	-	e
=ElecDip	ElecDip 2	5.984	1.7453	*546.4kV	0.9862	* +20.0	* 5.0000	* 1.7453	-	* 19 R	-- HV --	-	E
drift	drift EQ3	7.729	0.3649			standard					-- HV --	-	e
<Quad>	Q3	8.094	0.2988	-5.7122	0.9862	QUAD	7.5000	0.2988	yes	1 R	-- HV --	fit - Q	e
drift	drift Q34	8.393	0.0300			standard					-- HV --	-	e
<Quad>	Q4	8.423	0.4018	+6.8799	0.9862	QUAD	10.0000	0.4018	yes	1 R	-- HV --	fit - Q	e
drift	drift Q4FP	8.825	0.3076			standard					-- HV --	-	e
slits	FP slits	9.132	0.0000			SLITS					-- -- HV	-	e

All “E”-blocks.

Extended configuration

EMMA aperture and slit settings

Quads & Dipoles settings

! FILE: G:\EMMA\EMMA_reaction.lpp

slits | apertures

1 N or	2 Block name	3 Kind of Block	4 Start (m)	5 Length (m)	6 DriftMode Angle(°)*	7 B0(kG)	8 Br-corrsp Br-dip*	9 Rapp(cm) R(m)*	10 L_eff(m) Len(m)*	11 2nd order	12 Calc Mode	13 AngAcc mode	14 Slits shape	15 Xmin slit	16 Xmax slit	17 Ymin slit	18 Ymax slit	19 Appert shape	20 Xmin limit	21 Xmax limit	22 Ymin limit	23 Ymax limi
1.	tuning	Dipole	0.000	0.000	+0.0 *	+3.287	0.9862*	3.00*	0.00*	-		HV	rectn					ellps				
2.	Drift 1	Drift	0.000	0.247	standard							--	rectn					rectn	-31	+31	-31	+31
3.	Q1	Drift	0.247	0.140	multipole	+13.475	0.9862	3.50	0.14	yes	1	--	rectn					ellps	-31	+31	-31	+31
4.	drift Q12	Drift	0.387	0.035	standard							--	rectn					rectn	-67	+67	-67	+67
5.	Q2	Drift	0.422	0.299	multipole	-8.770	0.9862	7.50	0.30	yes	1	--	rectn					ellps	-68	+68	-68	+68
6.	drift Q2E	Drift	0.721	0.372	standard							--	rectn					ellps	-68	+68	-68	+68
7.	ElecDip 1	ElecDip	1.093	1.745	+20.0 *	546.4kV	0.9862*	5.00*	1.75*	-		--	rectn					rectn	-62	+62	-200	+200
8.	drift ED	Drift	2.838	1.225	standard							--	rectn					rectn	-102	+102	-46	+46
9.	DipoleA	Dipole	4.063	0.349	-20.0 *	+9.862	0.9862*	1.00*	0.35*	yes		--	rectn					rectn				
10.	dip slits	Drift	4.412	0.000	SLITS							--	rectn	-200	+200	-50	+50	rectn				
11.	DipoleB	Dipole	4.412	0.349	-20.0 *	+9.862	0.9862*	1.00*	0.35*	yes		--	rectn					rectn				
12.	drift DE	Drift	4.761	1.222	standard							--	rectn					rectn	-102	+102	-46	+46
13.	ElecDip 2	ElecDip	5.984	1.745	+20.0 *	546.4kV	0.9862*	5.00*	1.75*	-		--	rectn					rectn	-62	+62	-200	+200
14.	drift EQ3	Drift	7.729	0.365	standard							--	rectn					ellps	-68	+68	-68	+68
15.	Q3	Drift	8.094	0.299	multipole	-5.712	0.9862	7.50	0.30	yes	1	--	rectn					ellps	-68	+68	-68	+68
16.	drift Q34	Drift	8.393	0.030	standard							--	rectn					ellps	-75	+75	-75	+75
17.	Q4	Drift	8.423	0.402	multipole	+6.880	0.9862	10.00	0.40	yes	1	--	rectn					ellps	-92	+92	-92	+92
18.	drift Q4FP	Drift	8.825	0.308	standard							--	rectn					ellps	-75	+75	-75	+75
19.	FP slits	Drift	9.132	0.000	SLITS							--	rectn	-50	+50	-75	+75	rectn				

! symbol "*" after values denotes, that these values belongs to Dipole settings, where column names are found in the second row of titles, and also marked by "*"
! Column 08: "Br-corrsp" - quadrupole(sextupole) field is scaled to this Brho-value; "Br-dip*" - dipole magnetic rigidity [T*m]
! Column 09: "Rapp(cm)" - radius(half-aperture) of quadrupole(sextupole) in cm; "R(m)-dip*" - dipole raidus [m]
! Column 10: "L_eff(m)" - effective length of quadrupole(sextupole) in m, wich is used for Optical matrix calcualtiuons; "Len(m)*" - dipole length at ther central axis [m]
! Column 12: "Calc mode" - only for quadrupole(sextupole); 0 - no actions; 1 - recalculate automatically B(field), keep matrix;
! 2 - recalculate automatically the matrix, keep B(field)
! Column 13: "AngAcc mode" - "H(V)" : horizontal(vertical) angular acceptance will be applied for this block
! Columns 15-18,20-23: slits and aperture(limit) sizes in [mm]. If slit or aperture(limit) does not have action, then its size value is absent

These aperture parameters are used to obtain angular and momentum acceptances of the separator.

This settings list can be produced in LISE++ using menu "Experimental Settings -> Optics -> Optics settings: View and Print"

EMMA optics : “original” quads

- LISE^{++} does not provide information for mass dispersion
- So, this value can not be used for optimization constraint
- Quad values have been taken from EMMA beam example
- All matrices have been calculated inside LISE^{++}

EMMA_beam__original.lpp

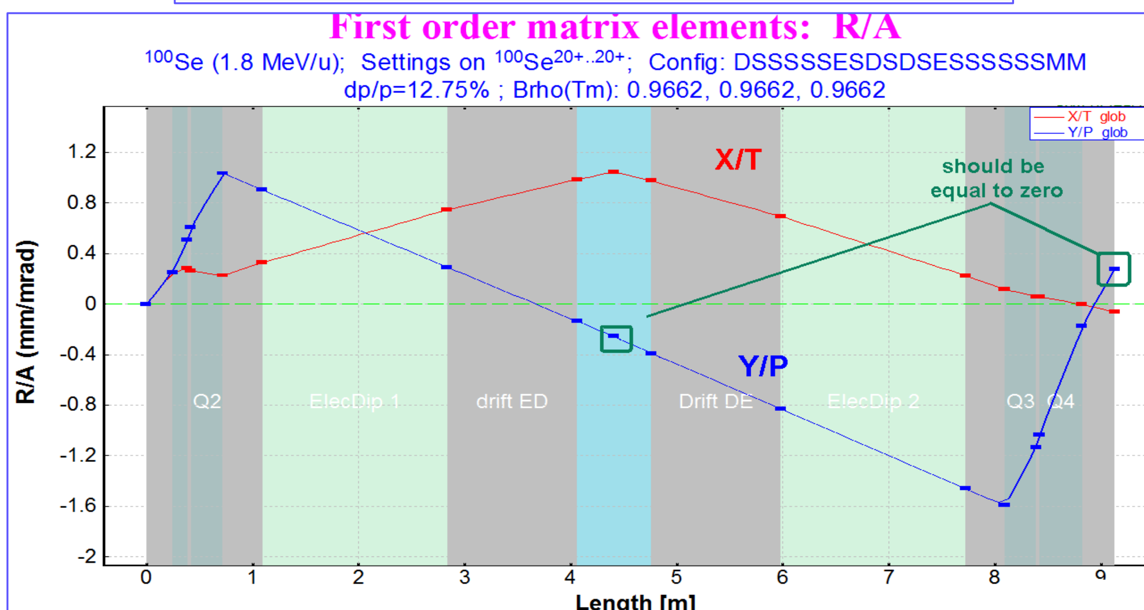
Block	Given Name	Start(m)	Length(m)	B0(kG)/*U
= Dipole	tuning	0.000	0.0001	+3.2207
drift	Drift 1	0.000	0.2470	
<Quad>	Q1	0.247	0.1398	+13.2014
drift	drift Q12	0.387	0.0350	
<Quad>	Q2	0.422	0.2988	-8.8066
drift	drift Q2E	0.721	0.3723	
=ElecDip	ElecDip 1	1.093	1.7453	*450.2kV
drift	drift ED	2.838	1.2250	
= Dipole	DipoleA	4.063	0.3491	-9.6620
slits	dip slits	4.412	0.0000	
= Dipole	DipoleB	4.412	0.3491	-9.6620
drift	Drift DE	4.761	1.2225	
=ElecDip	ElecDip 2	5.984	1.7453	*450.2kV
drift	drift EQ3	7.729	0.3649	
<Quad>	Q3	8.094	0.2988	-6.0155
drift	drift Q34	8.393	0.0300	
<Quad>	Q4	8.423	0.4018	+7.7544
drift	drift Q4FP	8.825	0.3076	
slits	FP slits	9.132	0.0000	

Global LISE^{++} matrix with these quad values

Note: No Y-focus, large Y/Y value

Global matrix

1. X	-1.39041	-0.06271	0	0	0	-0.17579	[mm]
2. T	11.83996	-0.18545	0	0	0	0.58394	[mrad]
3. Y	0	0	2.89856	0.2765	0	0	[mm]
4. P	0	0	11.85629	1.47582	0	0	[mrad]
5. L	-0.12694	6.922e-3	0	0	1	7.90368	[mm]
6. D	0	0	0	0	0	1	[%]
	/[mm]	/[mrad]	/[mm]	/[mrad]	/[mm]	/[%]	



EMMA optics : modification

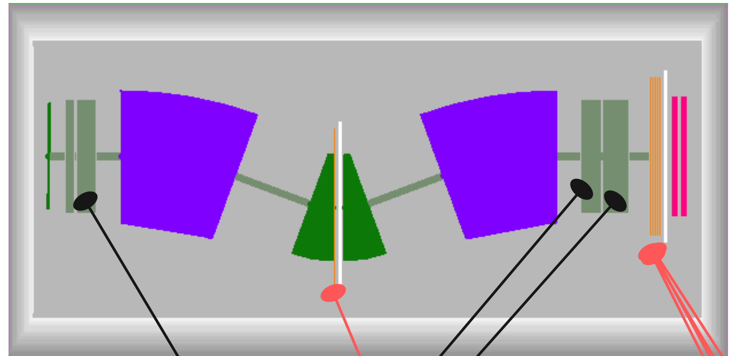
- LISE^{++} optimization was done to get Y-focus in the middle of M-dipole, X- & Y- focuses @ the end, R11 & R33 values according to the EMMA paper

EMMA_beam__original.lpp

Block	Given Name	Start(m)	Length(m)	B0(kG)/*U
= Dipole	tuning	0.000	0.0001	+3.2207
drift	Drift 1	0.000	0.2470	
<Quad>	Q1	0.247	0.1398	+13.2014
drift	drift Q12	0.387	0.0350	
<Quad>	Q2	0.422	0.2988	-8.8066
drift	drift Q2E	0.721	0.3723	
=ElecDip	ElecDip 1	1.093	1.7453	*450.2kV
drift	drift ED	2.838	1.2250	
= Dipole	DipoleA	4.063	0.3491	-9.6620
slits	dip slits	4.412	0.0000	
= Dipole	DipoleB	4.412	0.3491	-9.6620
drift	Drift DE	4.761	1.2225	
=ElecDip	ElecDip 2	5.984	1.7453	*450.2kV
drift	drift EQ3	7.729	0.3649	
<Quad>	Q3	8.094	0.2988	-6.0155
drift	drift Q34	8.393	0.0300	
<Quad>	Q4	8.423	0.4018	+7.7544
drift	drift Q4FP	8.825	0.3076	
slits	FP slits	9.132	0.0000	

EMMA_beam.lpp

Block	Given Name	Start(m)	Length(m)	B0(kG)/*U
= Dipole	tuning	0.000	0.0001	+3.2207
drift	Drift 1	0.000	0.2470	
<Quad>	Q1	0.247	0.1398	+13.2014
drift	drift Q12	0.387	0.0350	
<Quad>	Q2	0.422	0.2988	-8.5920
drift	drift Q2E	0.721	0.3723	
=ElecDip	ElecDip 1	1.093	1.7453	*450.2kV
drift	drift ED	2.838	1.2250	
= Dipole	DipoleA	4.063	0.3491	-9.6620
Fit	F_DipY	4.412	0.0000	
Fit	F_DipX	4.412	0.0000	
slits	dip slits	4.412	0.0000	
= Dipole	DipoleB	4.412	0.3491	-9.6620
drift	Drift DE	4.761	1.2225	
=ElecDip	ElecDip 2	5.984	1.7453	*450.2kV
drift	drift EQ3	7.729	0.3649	
<Quad>	Q3	8.094	0.2988	-5.5964
drift	drift Q34	8.393	0.0300	
<Quad>	Q4	8.423	0.4018	+6.7405



Optics fit

Blocks with parameters to vary

#01-q Position@007: Q2
#02-q Position@019: Q3
#03-q Position@021: Q4

Active Constraint blocks

#01	@012:	R34 = 0	F_DipY
#02	@023:	R16 = 0	F_R16
#03	@025:	R34 = 0	F_R34
#04	@026:	R12 = 0	F_R12
#05	@027:	R11 = -2.08	F_R11
#06	@028:	R33 = 1.33	F_R33

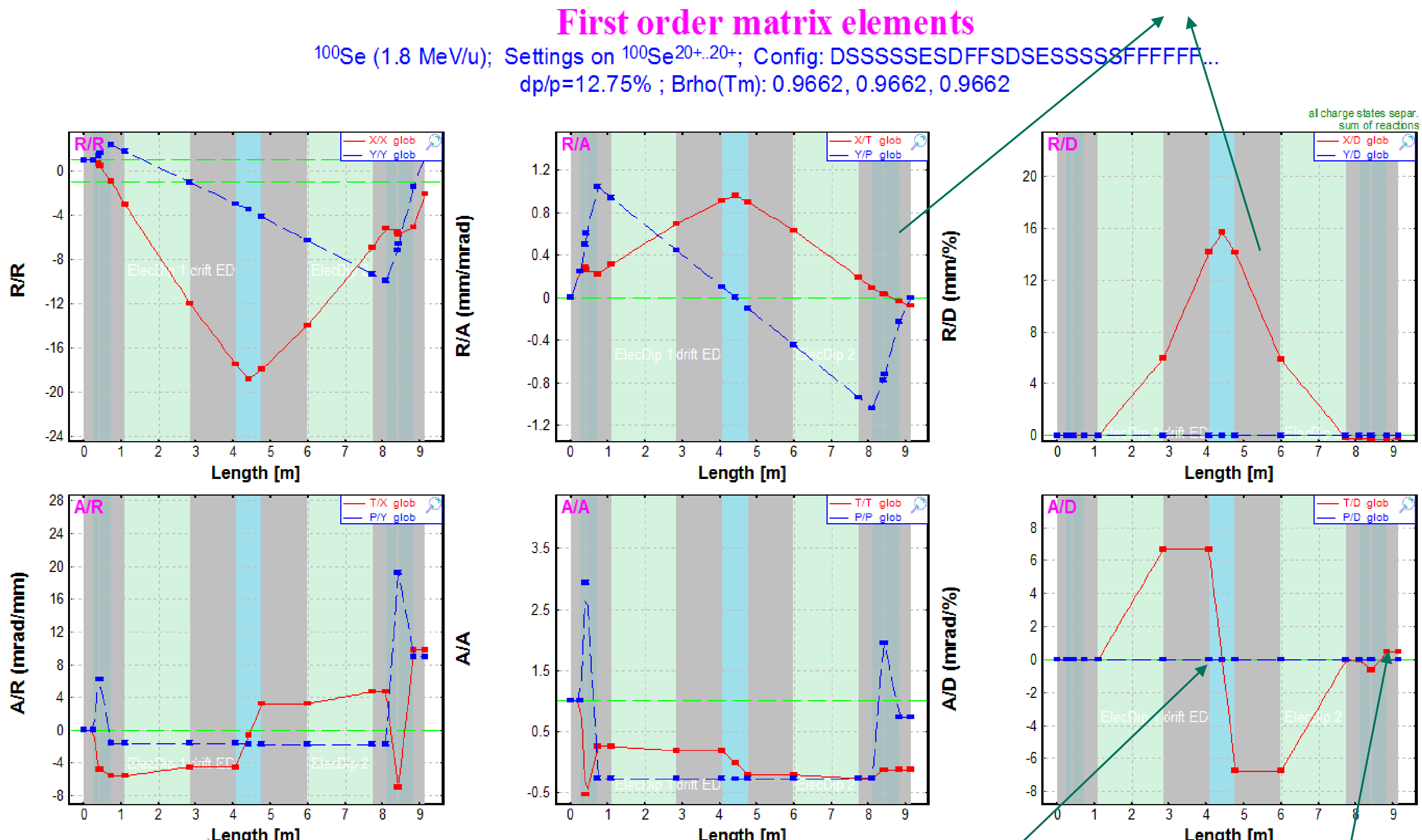
Global LISE^{++} matrix with new quad values

Global matrix

-2.07981	-0.0736	0	0	0	-0.22594	[mm]
9.77991	-0.13474	0	0	0	0.45385	[mrad]
0	0	1.35247	-1.103e-3	0	0	[mm]
0	0	8.96657	0.73193	0	0	[mrad]
-0.12657	6.385e-3	0	0	1	7.90368	[mm]
0	0	0	0	0	1	[%]
/[mm]	/[mrad]	/[mm]	/[mrad]	/[mm]	/[%]	

EMMA 1st order matrix elements

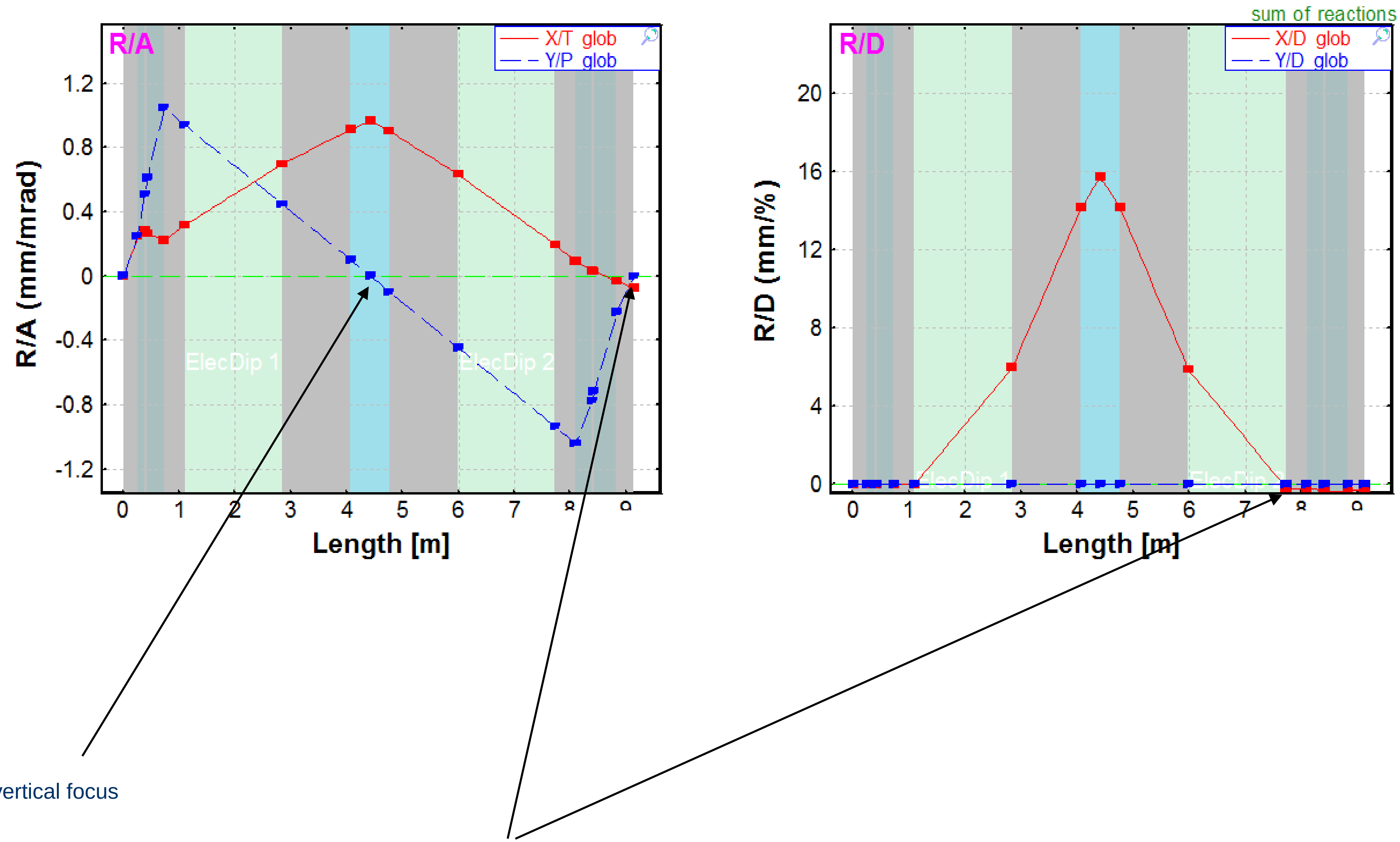
Will be zoomed on the next page



zero angular dispersion

Almost zero angular dispersion

EMMA 1st order matrix elements (zoom)



vertical focus

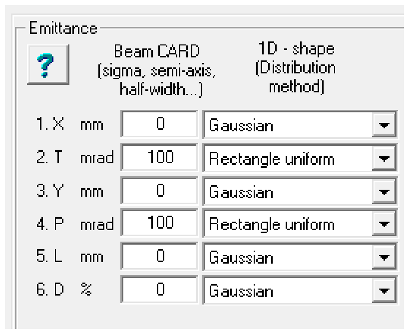
FP – double focus, double achromatic

[See details for angular acceptance with the next link http://lise.nscl.msu.edu/9_8/SE_blocks.pdf#page=5](http://lise.nscl.msu.edu/9_8/SE_blocks.pdf#page=5)

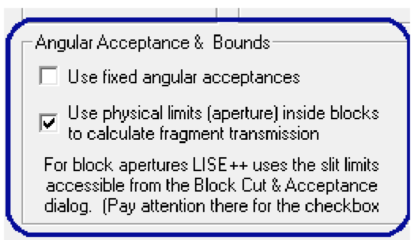
EMMA_beam_AA.lpp

Settings

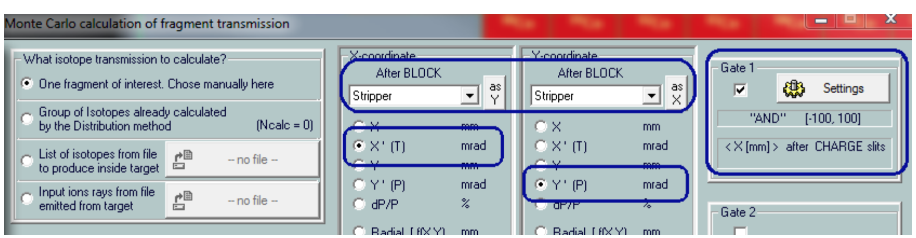
Beam dialog



Monte Carlo options

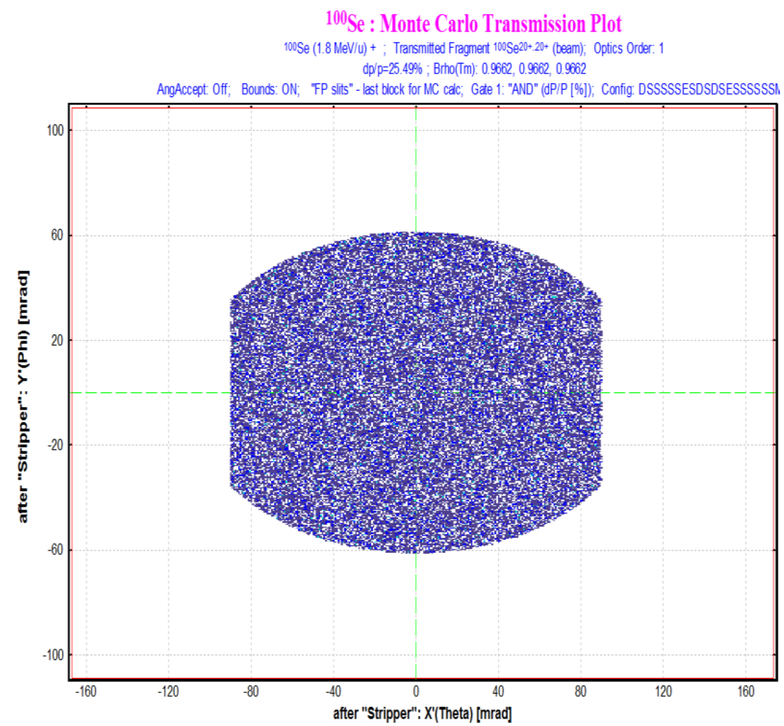


Monte Carlo Transmission settings

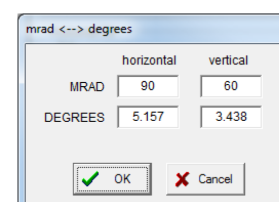


Coming to the FP

Initial emittance gated on the final focal plane

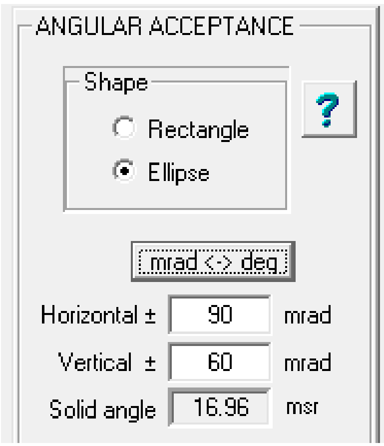


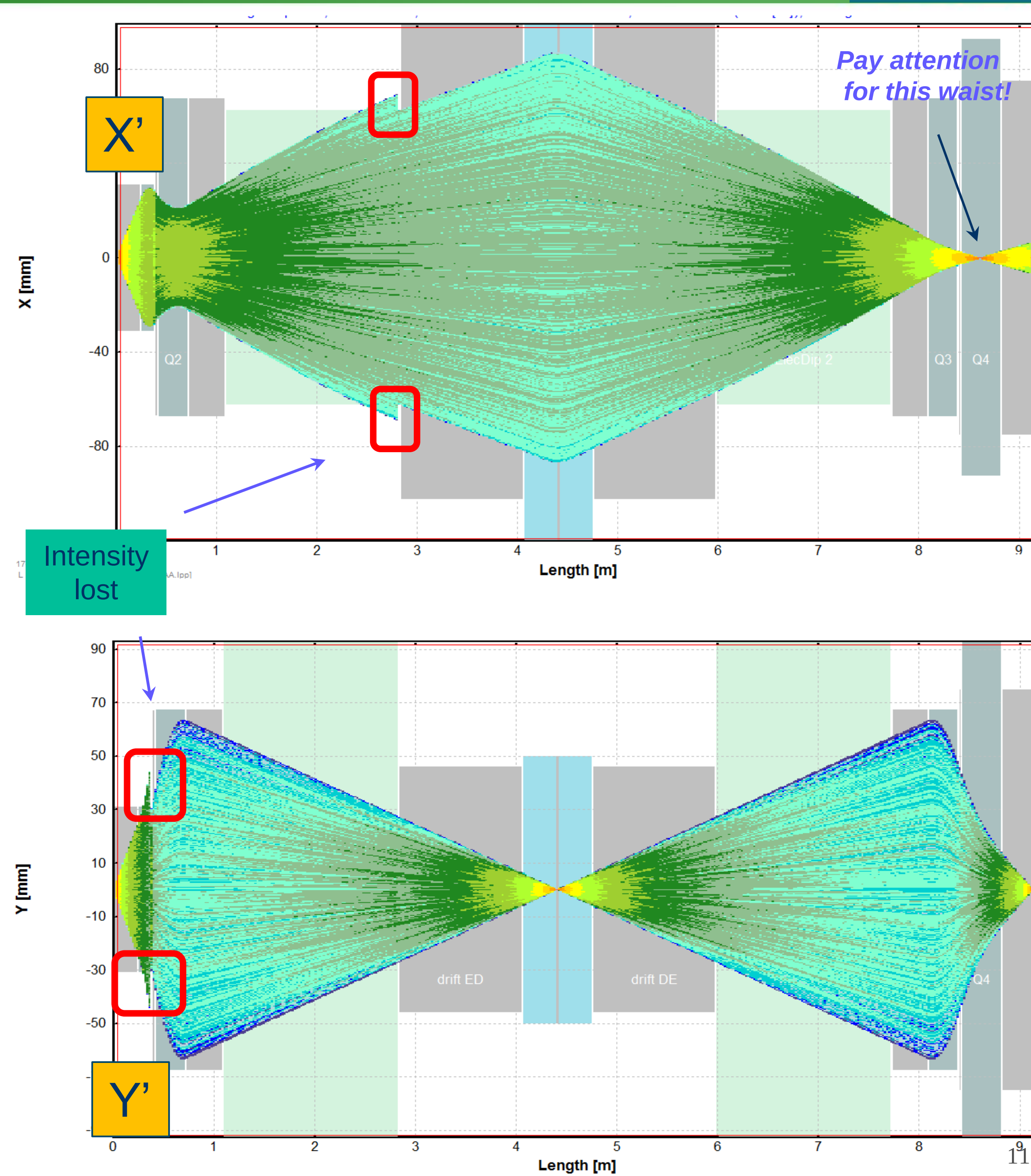
Angular acceptance is equal to ±90 x ± 60 mrad, that corresponds to 17 msr (ellipse)



Angular Acceptance : Results

EMMA_beam_AA.lpp





"Distribution" method
With set Angular Acceptances

Emittance

		Beam CARD (sigma, semi-axis, half-width...)	1D - shape (Distribution method)
1. X	mm	0	Rectangle uniform
2. T	mrad	60	Gaussian
3. Y	mm	0	Rectangle uniform
4. P	mrad	60	Gaussian
5. L	mm	0	Gaussian
6. D	%	0	Gaussian

100Se Unknown (Z=34, N=66)

Q1 (tuning)		20
Q2 (ElecDip 1)		20
Q3 (DipoleA)		20
Q4 (DipoleB)		20
Q5 (ElecDip 2)		20
Reaction		BEAM
Ion Production Rate	(pps)	1.63e+10
Total ion transmission	(%)	52.022
Total: this reaction	(pps)	1.63e+10
Total: All reactions	(pps)	1.63e+10
X-Section in target	(mb)	beam
Target	(%)	100
Q (Charge) ratio	(%)	100
tuning	(%)	52.02
X angular transmission	(%)	82.61
Y angular transmission	(%)	62.98

"Monte Carlo " method
With set Angular Acceptances
No bounds

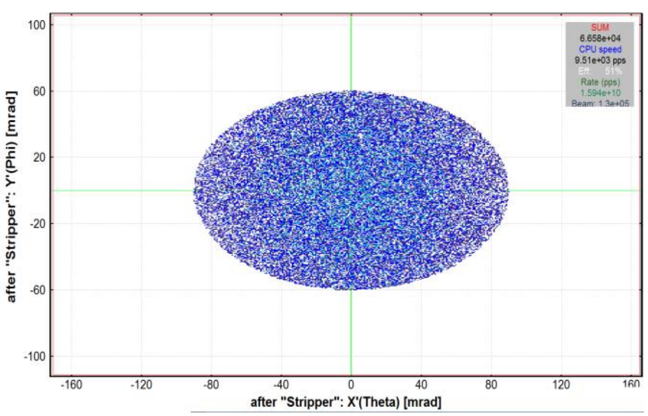
Angular Acceptance & Bounds

- [x] Use fixed angular acceptances
- [ ] Use physical limits (aperture) inside blocks to calculate fragment transmission

For block apertures LISE++ uses the slit limits accessible from the Block Cut & Acceptance dialog. (Pay attention there for the checkbox

#	Ion	N of Passed	N of Initial	Transmission	
All		66579	130560	51.00%	
0	100Se	167370	327680	51.08%	(+/-0.12%

Target	100.0%
tuning	51.00%
Angular acceptance	51.00%



"Monte Carlo " method
No Angular Acceptances
WITH bounds

Angular Acceptance & Bounds

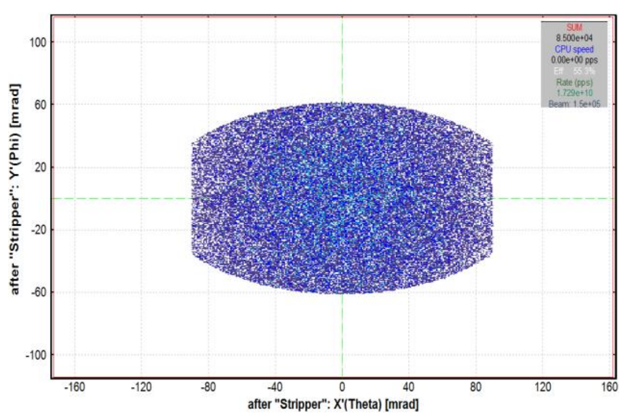
- [ ] Use fixed angular acceptances
- [x] Use physical limits (aperture) inside blocks to calculate fragment transmission

For block apertures LISE++ uses the slit limits accessible from the Block Cut & Acceptance dialog. (Pay attention there for the checkbox

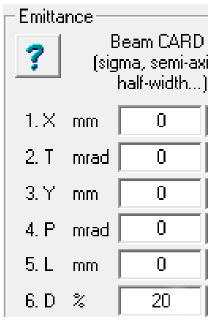
100Se : Monte Carlo Transmission Plot

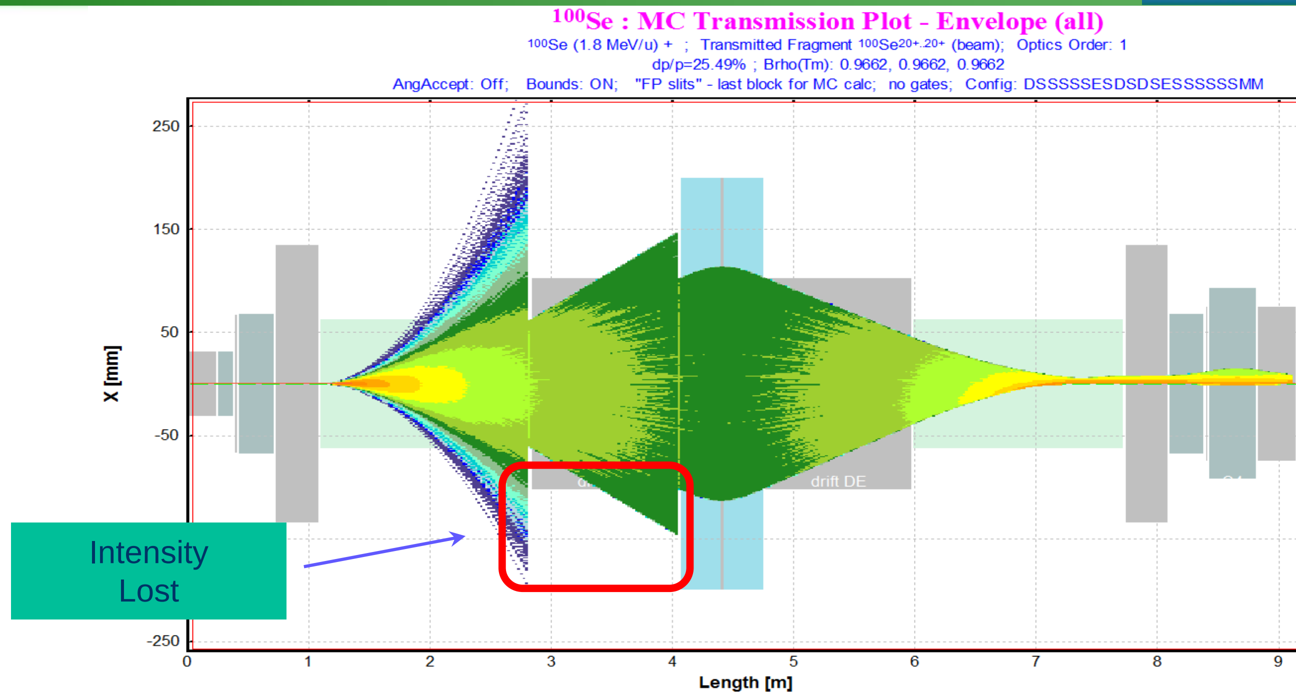
100Se (1.8 MeV/u) + ; Transmitted Fragment 100S
dp/p=25.49% ; Brho(Tm): 0.9662, 0.9662, 0.9662
AngAccept: Off; Bounds: ON; "FP slits" - last

#	Ion	N of Passed	N of Initial	Transmission	
All		85045	153693	55.33%	
0	100Se	84995	153600	55.34%	(+/-).1



Momentum Acceptance



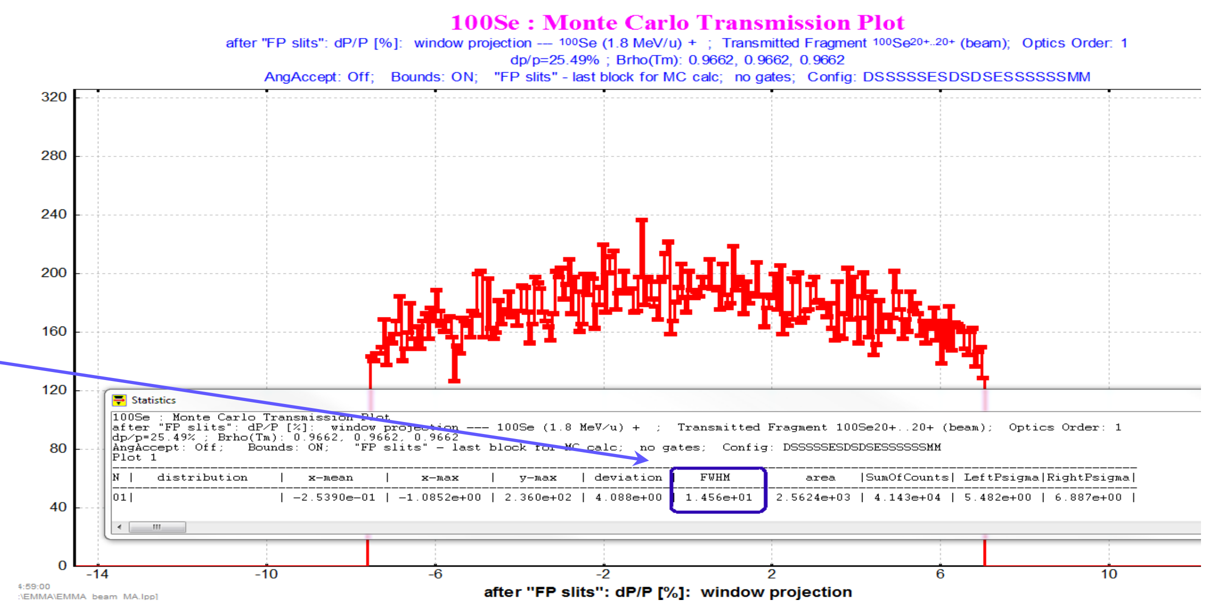


Momentum acceptance is defined by the ED1 gap

Corresponds to the Dipole X-aperture ± 115 mm

ΔP/P = ± 7.3 %
(ΔE/E = ± 14.6 %)

1st order



N	distribution	x-mean	x-max	y-max	deviation	FWHM	area	SumOfCounts	LeftPsigma	RightPsigma
01		-2.5390e-01	-1.0852e+00	2.360e+02	4.088e+00	1.456e+01	2.5624e+03	4.143e+04	5.482e+00	6.887e+00

EMMA acceptances benchmark

Emittance corresponding to the acceptances

Emittance

		Beam CARD (sigma, semi-axis, half-width...)	1D - shape (Distribution method)
1. X	mm	1	Gaussian
2. T	mrad	90	Gaussian
3. Y	mm	1	Gaussian
4. P	mrad	60	Gaussian
5. L	mm	0	Gaussian
6. D	%	7.3	Gaussian

Note: Horizontal slits has to be applied for the "Distribution" method to limit momentum acceptance which happens due to apertures.

"Distribution" method

With set Angular Acceptances and H.slits in MD +/- 130 mm

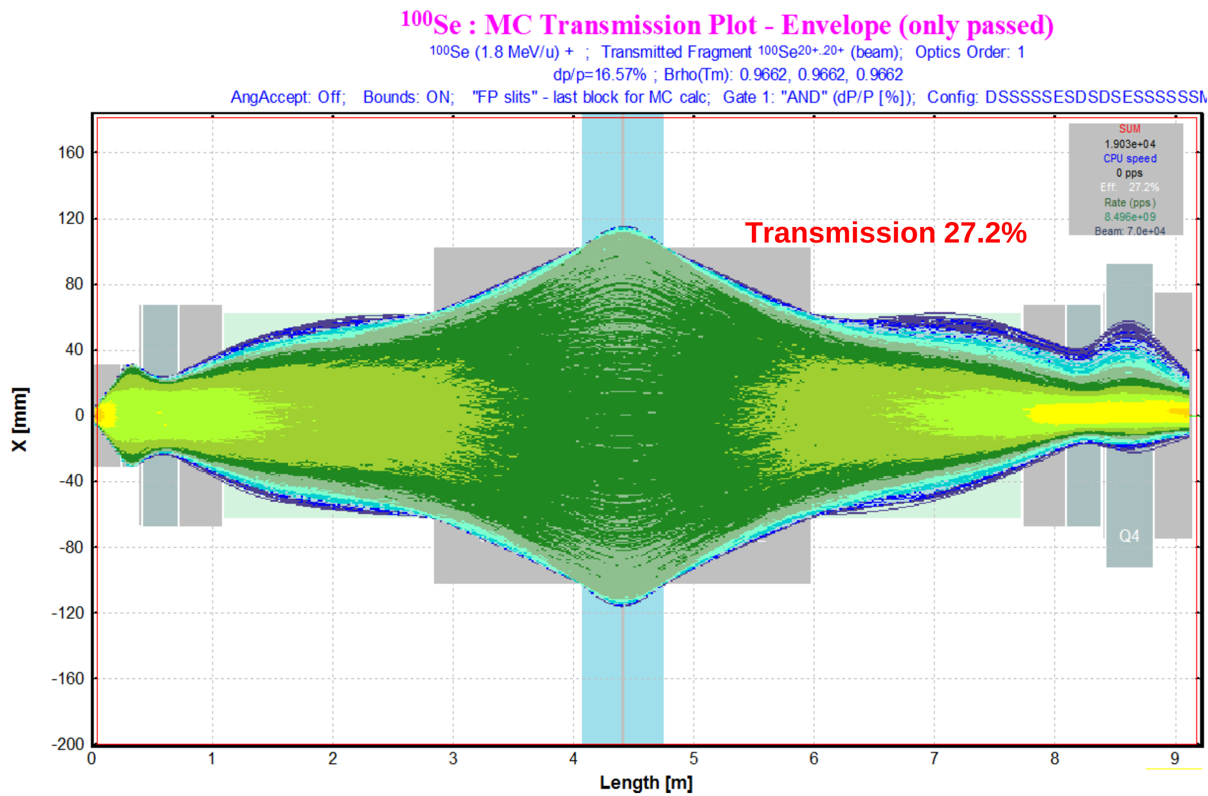
statistics: 100Se

100Se Unknown (Z=34, N=66)

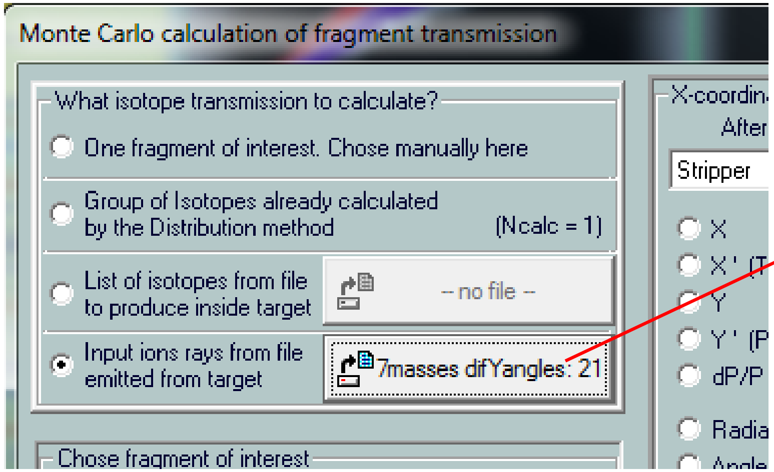
Q1 (tuning)		20
Q2 (ElecDip 1)		20
Q3 (DipoleA)		20
Q4 (DipoleB)		20
Q5 (ElecDip 2)		20
Reaction		BEAM
Ion Production Rate	(pps)	7.87e+9
Total ion transmission	(%)	25.187
Total: this reaction	(pps)	7.87e+9
Total: All reactions	(pps)	7.87e+9
X-Section in target	(mb)	beam
Target	(%)	100
Q (Charge) ratio	(%)	100
tuning	(%)	39.68
X angular transmission	(%)	63.01
Y angular transmission	(%)	62.98
Drift 1	(%)	100
Q1	(%)	100
drift Q12	(%)	100
Q2	(%)	100
drift Q2E	(%)	100
ElecDip 1		
drift ED		
DipoleA		
dip slits	(%)	63.47
X space transmission	(%)	63.47
Y space transmission	(%)	100

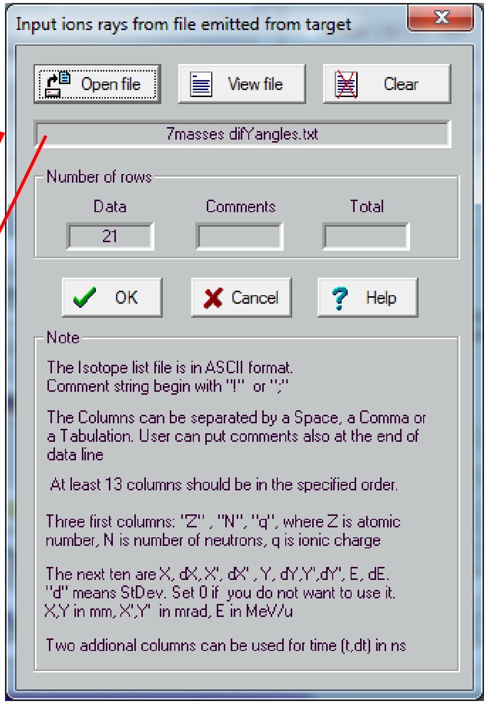
H.slits in MD +/- 130 mm

"Monte Carlo " method; No Angular Acceptances; WITH bounds



Benchmarks with input rays





In order to reproduce NIMA plots, input rays files has been created to use in the LISE^{++} MC dialog

Z	N	q	X (mm)	dX	X' (mrad)	dX'	Y (mm)	dY	Y' (mrad)	dY'	E,MeVu	dE
50	46	20	0	0	0	1	0	0	-34	0.1	1.87555	0
50	47	20	0	0	0	1	0	0	-34	0.1	1.85606	0
50	48	20	0	0	0	1	0	0	-34	0.1	1.83701	0
50	49	20	0	0	0	1	0	0	-34	0.1	1.81829	0
50	50	20	0	0	0	1	0	0	-34	0.1	1.8	0
50	51	20	0	0	0	1	0	0	-34	0.1	1.782	0
50	52	20	0	0	0	1	0	0	-34	0.1	1.76443	0
50	53	20	0	0	0	1	0	0	-34	0.1	1.74714	0
50	54	20	0	0	0	1	0	0	-34	0.1	1.73022	0
50	46	20	0	0	0	1	0	0	0	0.1	1.87555	0
50	47	20	0	0	0	1	0	0	0	0.1	1.85606	0
50	48	20	0	0	0	1	0	0	0	0.1	1.83701	0
50	49	20	0	0	0	1	0	0	0	0.1	1.81829	0
50	50	20	0	0	0	1	0	0	0	0.1	1.8	0
50	51	20	0	0	0	1	0	0	0	0.1	1.782	0
50	52	20	0	0	0	1	0	0	0	0.1	1.76443	0
50	53	20	0	0	0	1	0	0	0	0.1	1.74714	0
50	54	20	0	0	0	1	0	0	0	0.1	1.73022	0
50	46	20	0	0	0	1	0	0	34	0.1	1.87555	0
50	47	20	0	0	0	1	0	0	34	0.1	1.85606	0
50	48	20	0	0	0	1	0	0	34	0.1	1.83701	0
50	49	20	0	0	0	1	0	0	34	0.1	1.81829	0
50	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0	34	0.1	1.8	0
50	51	20	0	0	0	1	0	0	34	0.1	1.782	0
50	52	20	[illegible]	0	0	1	[illegible]	[illegible]	[illegible]	0.1	[illegible]	0
50	53	20	0	0	0	1	0	0	34	0.1	1.74714	0
50	54	20	0	0	0	1	0	0	34	0.1	1.73022	0

9 different masses @ $E\rho$=18 MV with Y-angles of -2,0,+2 degrees (as @ NIMA Fig.2)

MC options

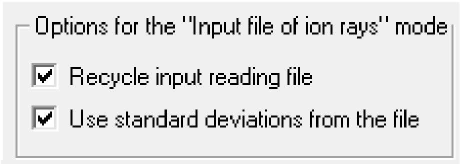


Fig.2 : Benchmarks for Y-angle & Mass

NIM A544 (2005) 565

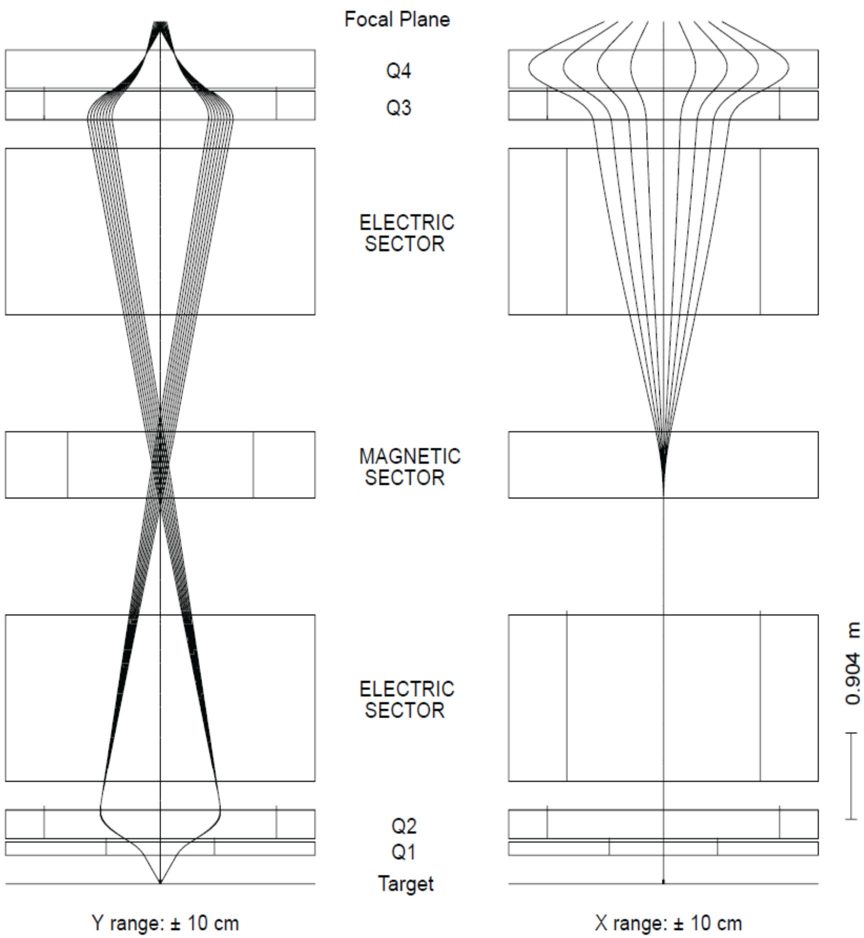
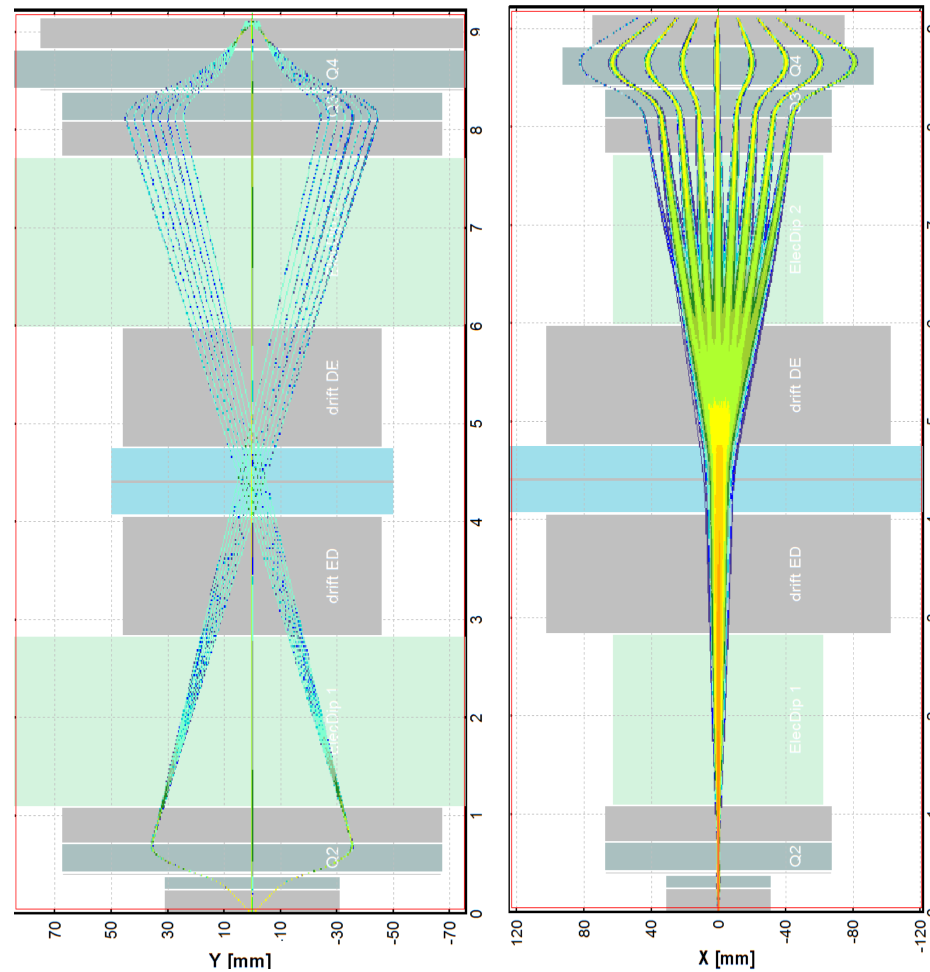


Fig. 2. Calculated mass focus of EMMA, showing rays corresponding to 9 adjacent masses emitted from the target with vertical angles of −2°, 0°, and 2°. At the focal plane, the 9 masses are seen to be dispersed horizontally and focussed vertically. Angular focussing in the horizontal direction is shown in Fig. 4.

LISE++



2nd order

1st order

Fig.3 : Benchmarks for Y-angle & Energy

NIM A544 (2005) 565

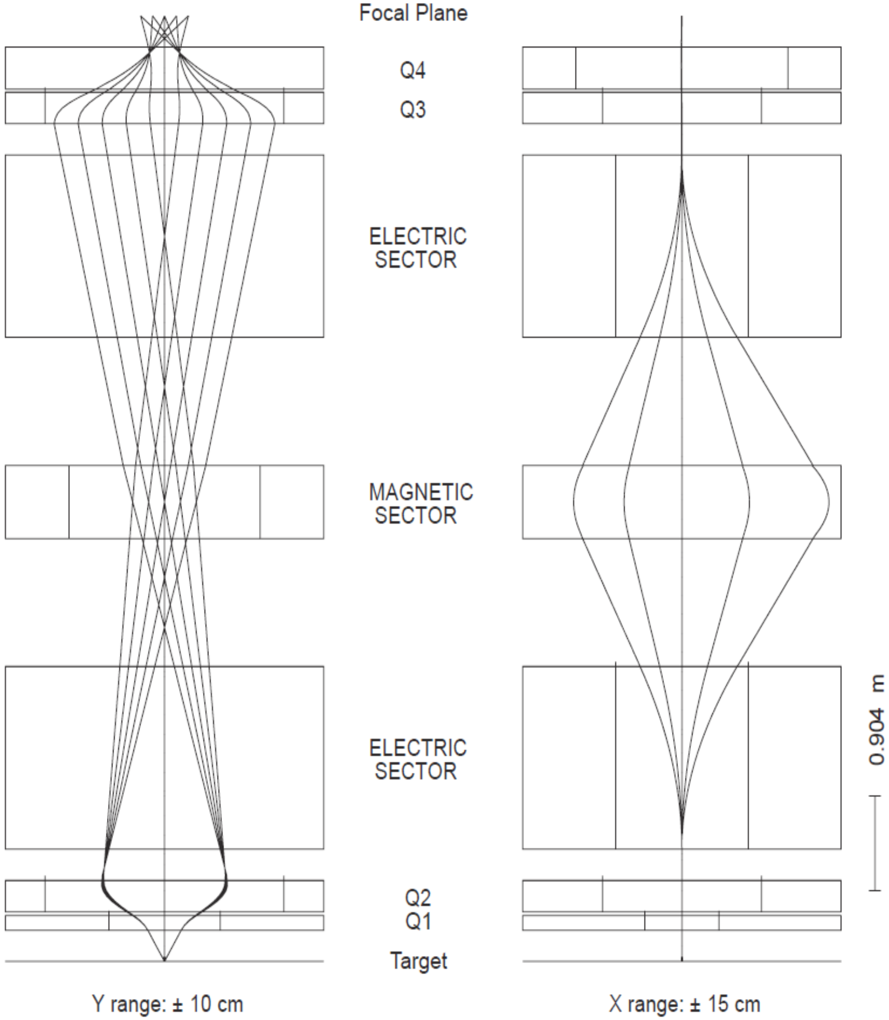
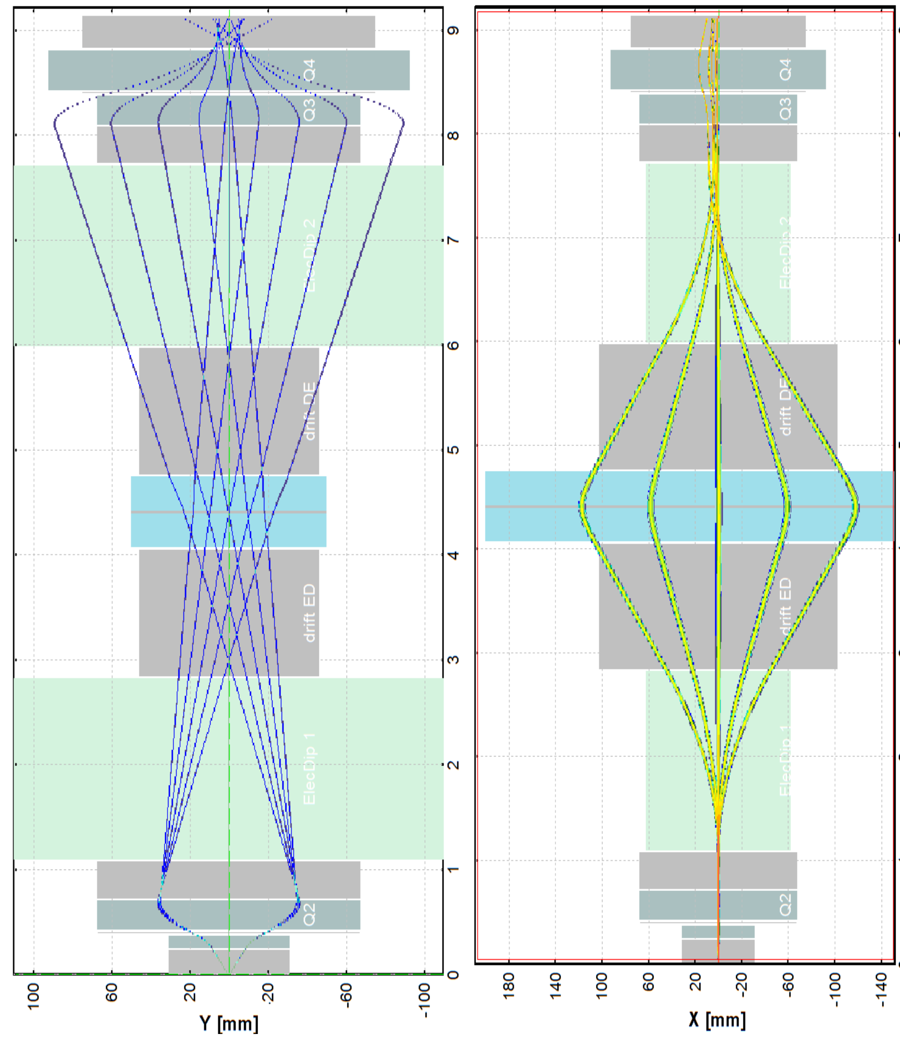


Fig. 3. Calculated energy focus of EMMA, showing rays corresponding to a single mass emitted from the target with vertical angles of −2°, 0°, and 2°, and with energies deviating from the central value by 0, ±7.5%, and ±15%. Chromatic aberrations in the vertical direction are evident in the vertical extent of the final focus.

LISE++

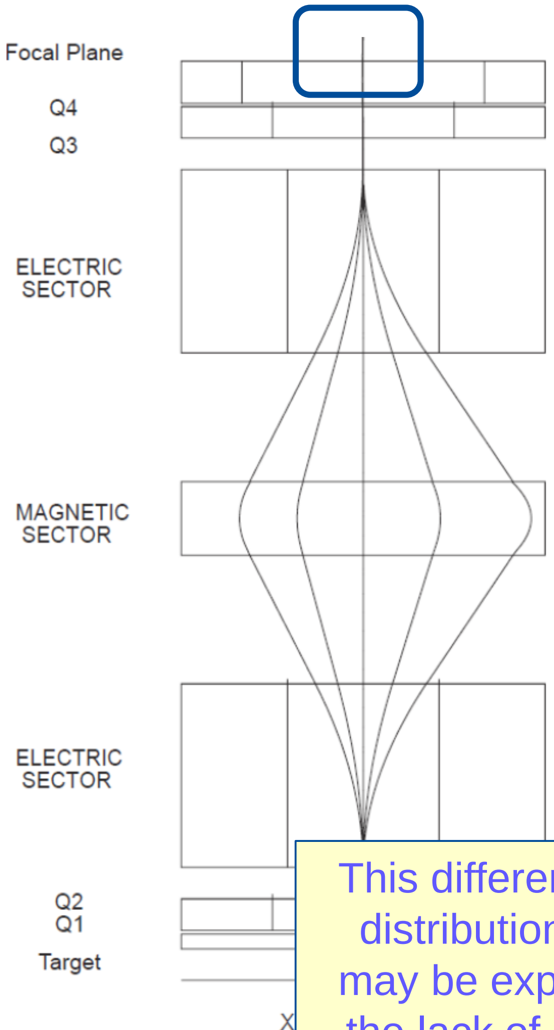


2nd order

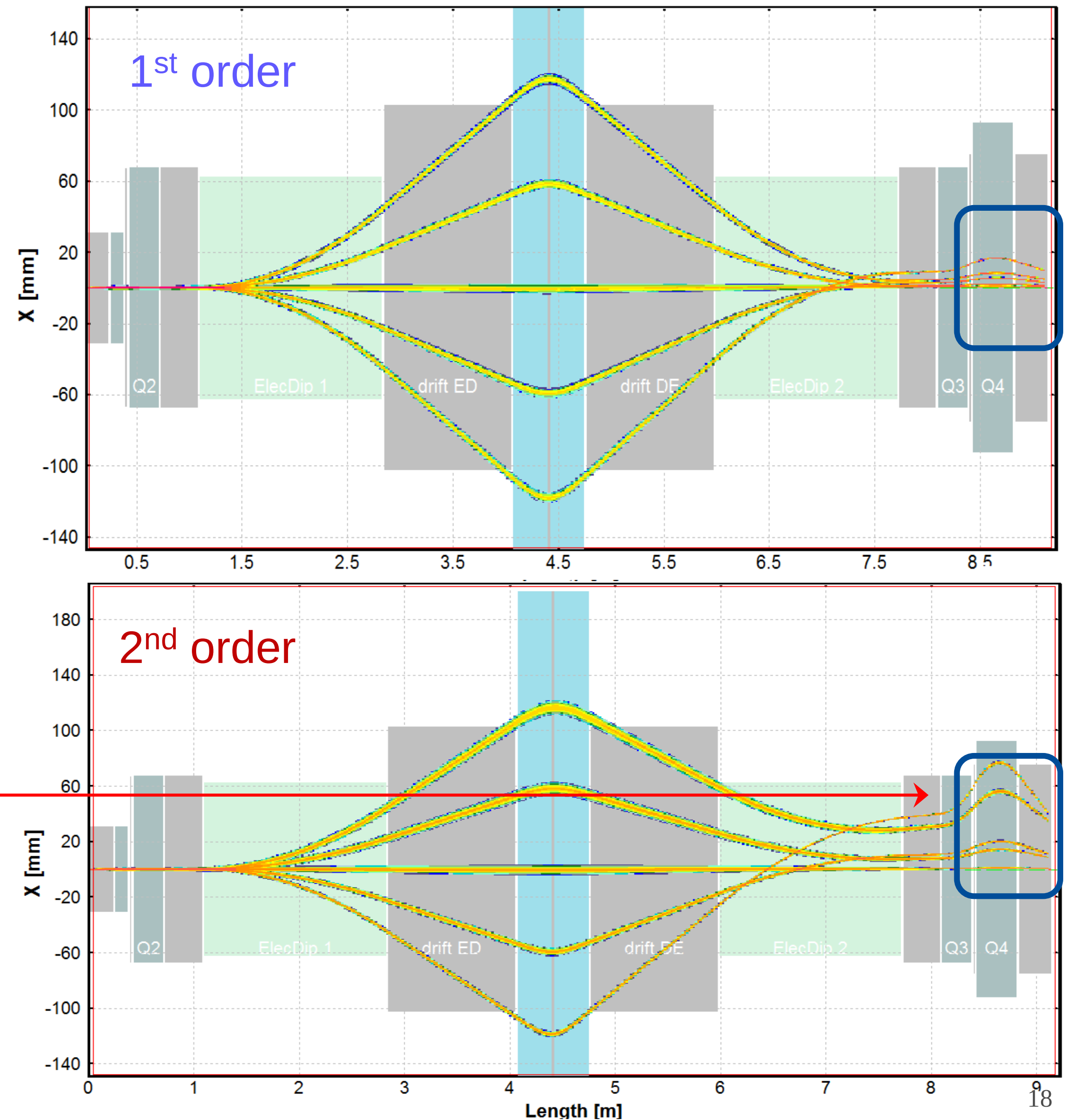
1st order

Fig.3 : Benchmarks for Y-angle & Energy (continue)

NIM A544 (2005) 565



LISE^{++}

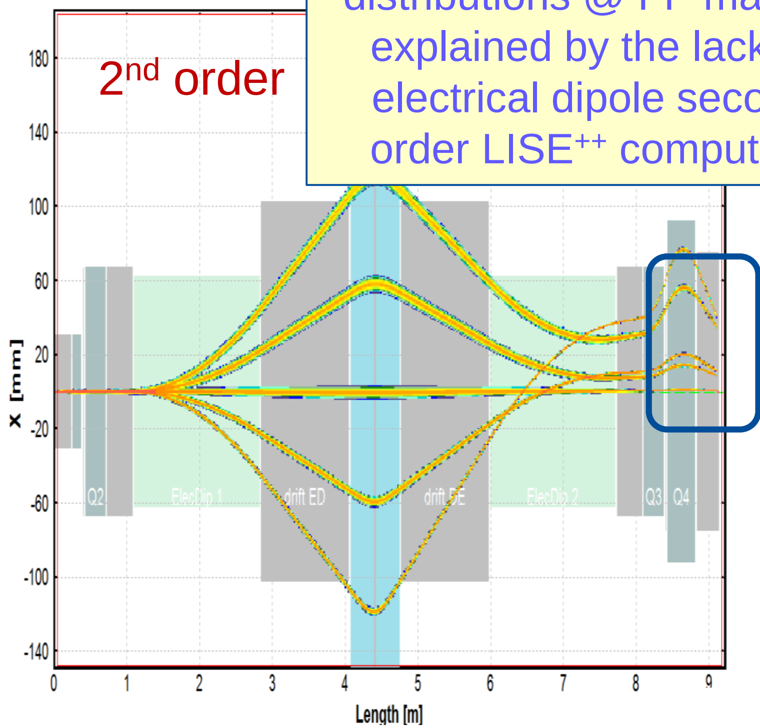


This difference in X-distributions @ FP may be explained by the lack of electrical dipole second order LISE^{++} computing (see next slide)

Benchmarks for Y-angle & Energy (continue 2)

LISE++

This difference in X-distributions @ FP may be explained by the lack of electrical dipole second order LISE++ computing



COSY map of the 1st FMA ED

```
Block: "ElecDip 1"     Matrices: "LOCAL"
                                                     transport format [mm-mrad]

                        * TRANSFORM 1 *

 1 [X]:   +8.8066e-01  +1.3403e+00   0            0            0            +4.7736e+00
 2 [T]:   -1.6746e-01  +8.8066e-01   0            0            0            +6.6983e+00
 3 [Y]:    0            0           +1.0000e+00  +1.3963e+00   0             0
 4 [F]:    0            0            0           +1.0000e+00   0             0
 5 [L]:   -6.6983e-01  -4.7740e-01   0            0           +1.0000e+00  -1.1195e+00
 6 [D]:    0            0            0            0            0            +1.0000e+00

---------------------------------------------------------------------------------------

                        * TRANSFORM 2 *

 1   1:   -7.0421e-05
 1   2:   +5.7684e-04  +2.0555e-04
 1   3:    0            0            0
 1   4:    0            0            0           -2.3879e-04
 1   5:    0            0            0            0            0
 1   6:   +5.6337e-03  +3.7316e-03   0            0            0            -6.4959e-02
---------------------------------------------------------------------------------------
 2   1:   -1.9250e-05
 2   2:   -2.7437e-05  -3.4838e-04
 2   3:    0            0            0
 2   4:    0            0            0           -3.3507e-04
 2   5:    0            0            0            0            0
 2   6:   +4.8891e-03  +1.0975e-03   0            0            0            -9.7813e-02
---------------------------------------------------------------------------------------
 3   1:    0
 3   2:    0            0
 3   3:    0            0            0
 3   4:   +6.7013e-04  +4.7758e-04   0            0
 3   5:    0            0            0            0            0
 3   6:    0            0            0           +1.1200e-03   0             0
---------------------------------------------------------------------------------------
 4   1:    0
 4   2:    0            0
 4   3:    0            0            0
 4   4:    0            0            0            0
 4   5:    0            0            0            0            0
 4   6:    0            0            0            0            0             0
---------------------------------------------------------------------------------------
 5   1:   -1.5074e-04
 5   2:   -3.3419e-04  -8.0337e-04
 5   3:    0            0            0
 5   4:    0            0            0           -6.4213e-04
 5   5:    0            0            0            0            0
 5   6:   +5.3665e-03  -9.4913e-04   0            0            0            +1.5452e-02
---------------------------------------------------------------------------------------
```

After the drift 1.2 m

For $\Delta d = +7.5\%$

$\Delta x = \Delta x_{1d} + \Delta x_{2dd} + (\Delta t_{1d} + \Delta t_{2dd}) * L =$ + 85.1 mm

For $\Delta d = -7.5\%$

$\Delta x = \Delta x_{1d} + \Delta x_{2dd} + (\Delta t_{1d} + \Delta t_{2dd}) * L =$ - 105.7 mm

!!! Electric dipole x/d^2 & t/d^2 values are very important for the analyzer and should calculated by LSE++ in future

$\Delta x_{1d} = (t/d) * \Delta d = 4.77\text{mm}/\% * 7.5\% = 35$ mm

$\Delta x_{2dd} = (x/d/d) * \Delta d * \Delta d =$
-6.5e-2 mm/%/% * 7.5% * 7.5% = -3.7 mm

$\Delta t_{1d} = (t/d) * \Delta d = 6.7\text{mrad}/\% * 7.5\% = 50.3$ mrad

$\Delta t_{2dd} = (t/d/d) * \Delta d * \Delta d =$
-9.8e-2 mrad/%/% * 7.5% * 7.5% = -5.5 mrad

Fig.4 : Benchmarks for X- & Y-angles

NIM A544 (2005) 565

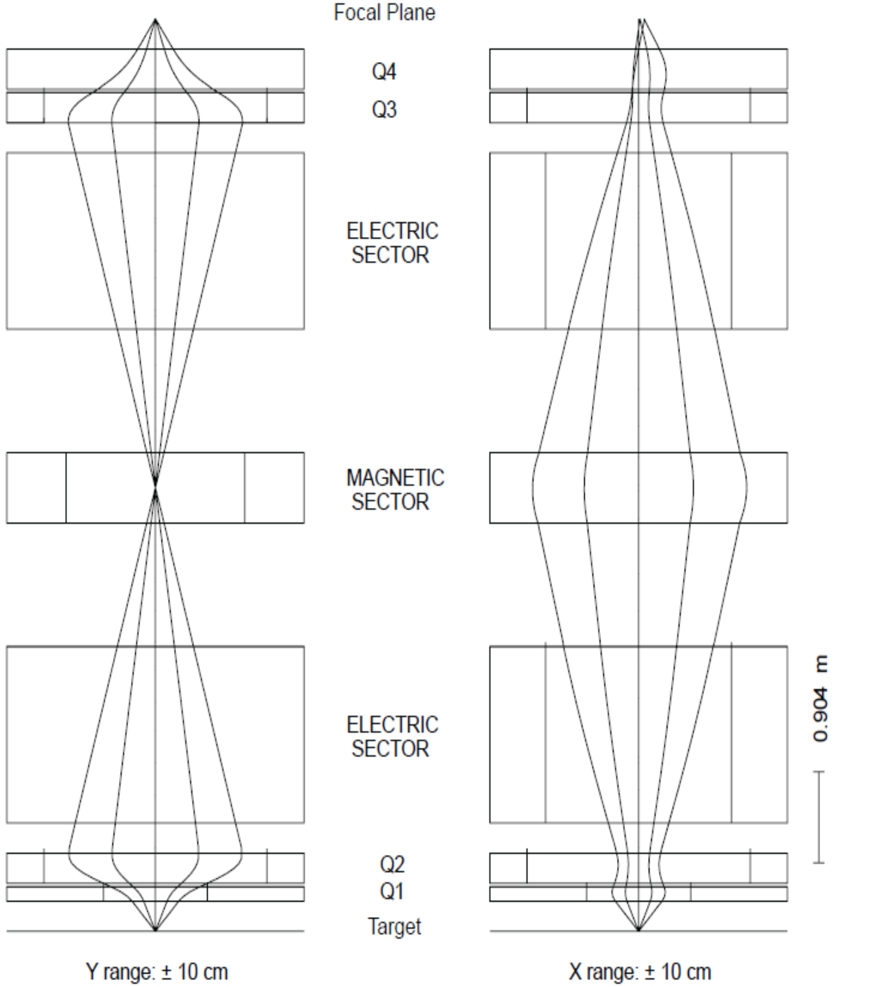
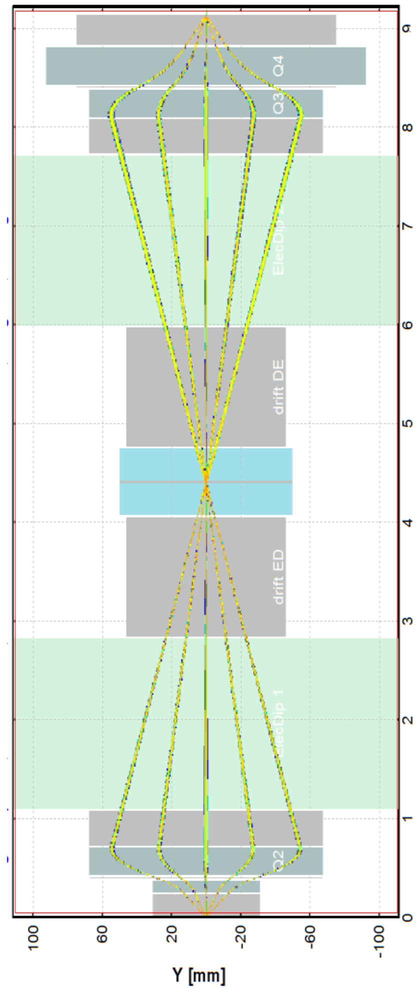
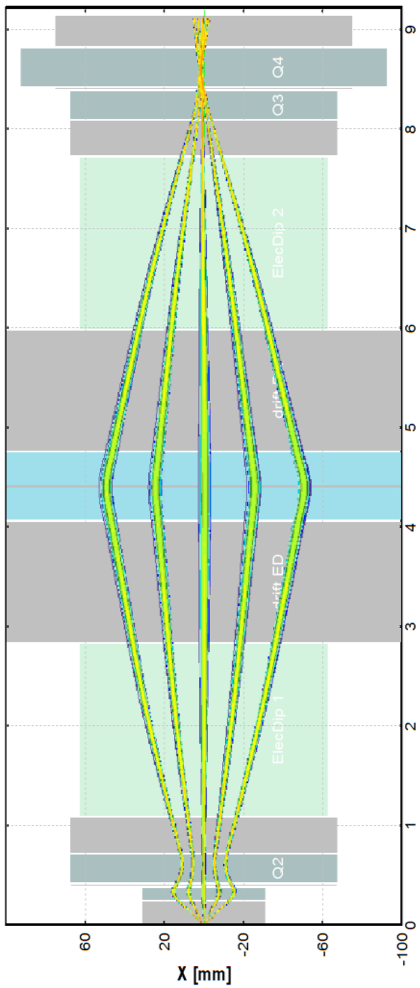


Fig. 4. Calculated spatial focus of EMMA, showing rays corresponding to a single mass emitted from the target with angles of 0, ±1.5°, and ±3° in the vertical and horizontal directions. The dominant geometric aberration in the dispersive direction, proportional to the square of the horizontal angle, is evident in the horizontal extent of the final focus.

LISE++



2^{nd} order



2^{nd} order

Fig.5 : Benchmarks for Masses with large emittance (1)

NIM A544 (2005) 565

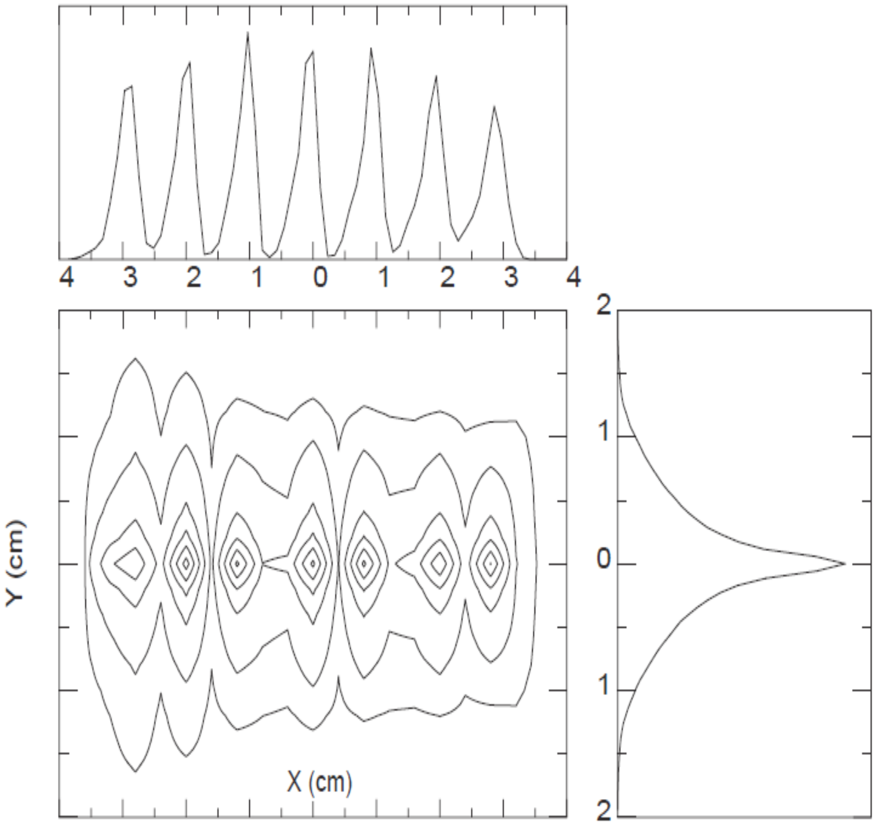


Fig. 5. Calculated M/q spectrum of EMMA centred about mass 100, showing 7 adjacent masses from 97 to 103 emitted from the target with uniform angular spreads of ±3° in the horizontal and vertical directions, and a uniform energy distribution of ±10%.

LISE++ 1st order

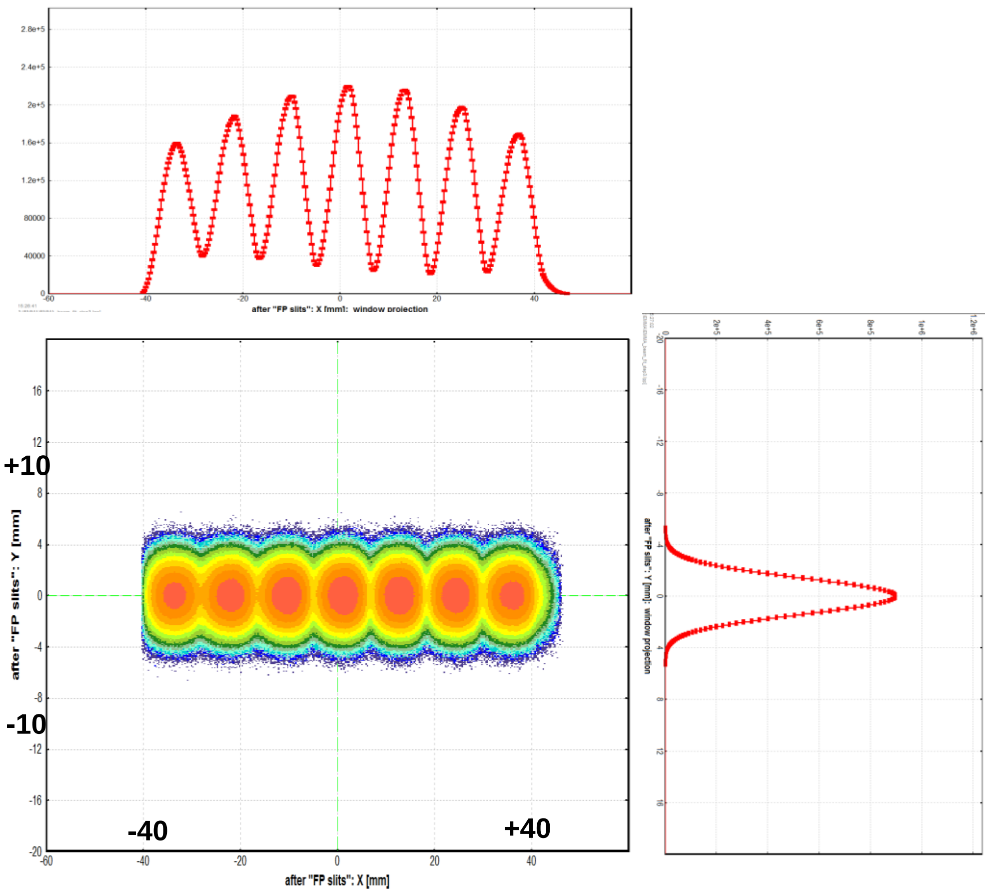


Fig.5 : Benchmarks for Masses with large emittance (2)

2nd order

NIM A544 (2005) 565

LISE++

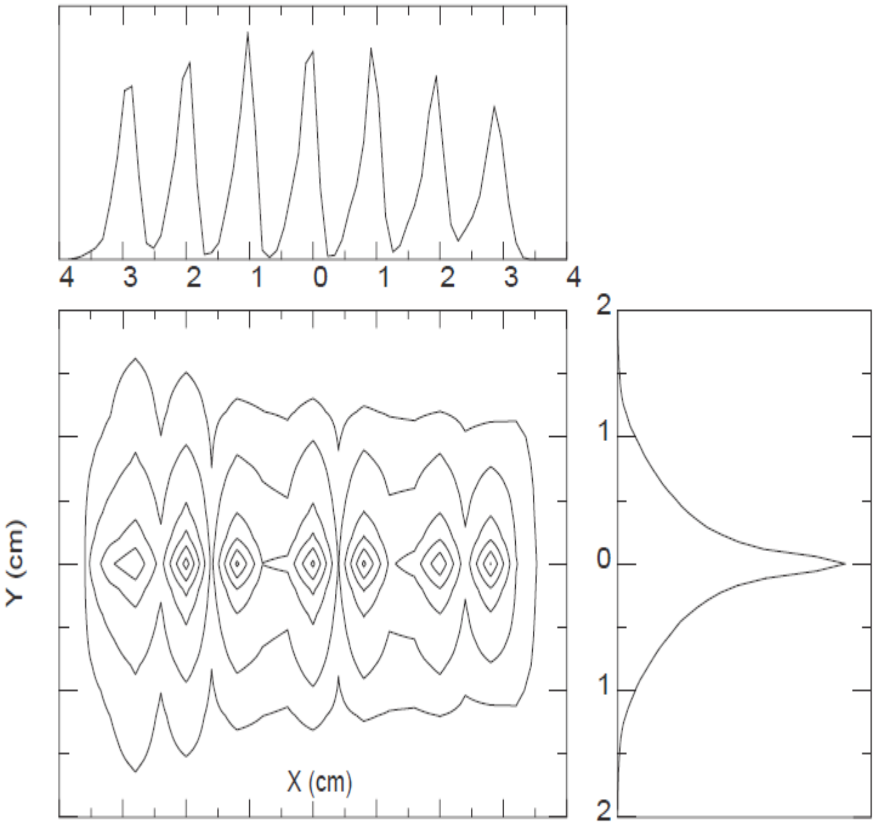
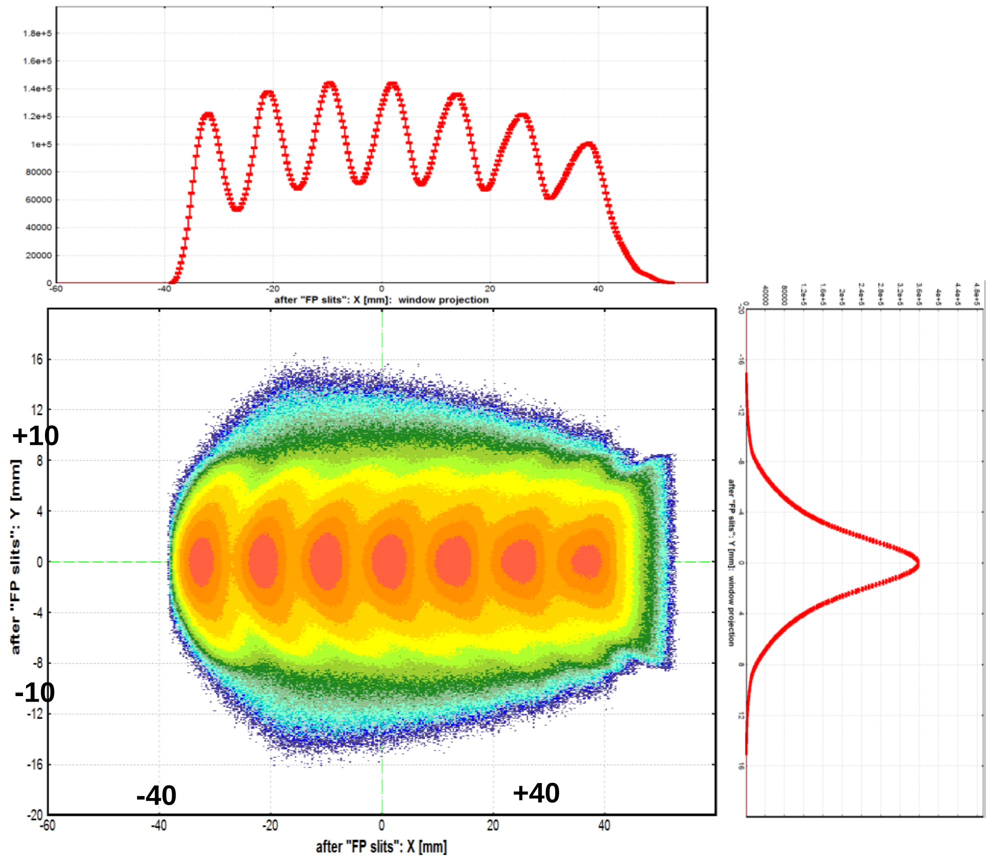
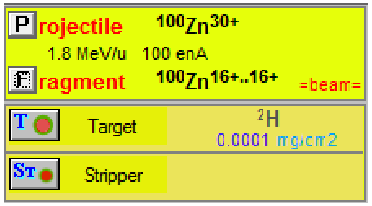


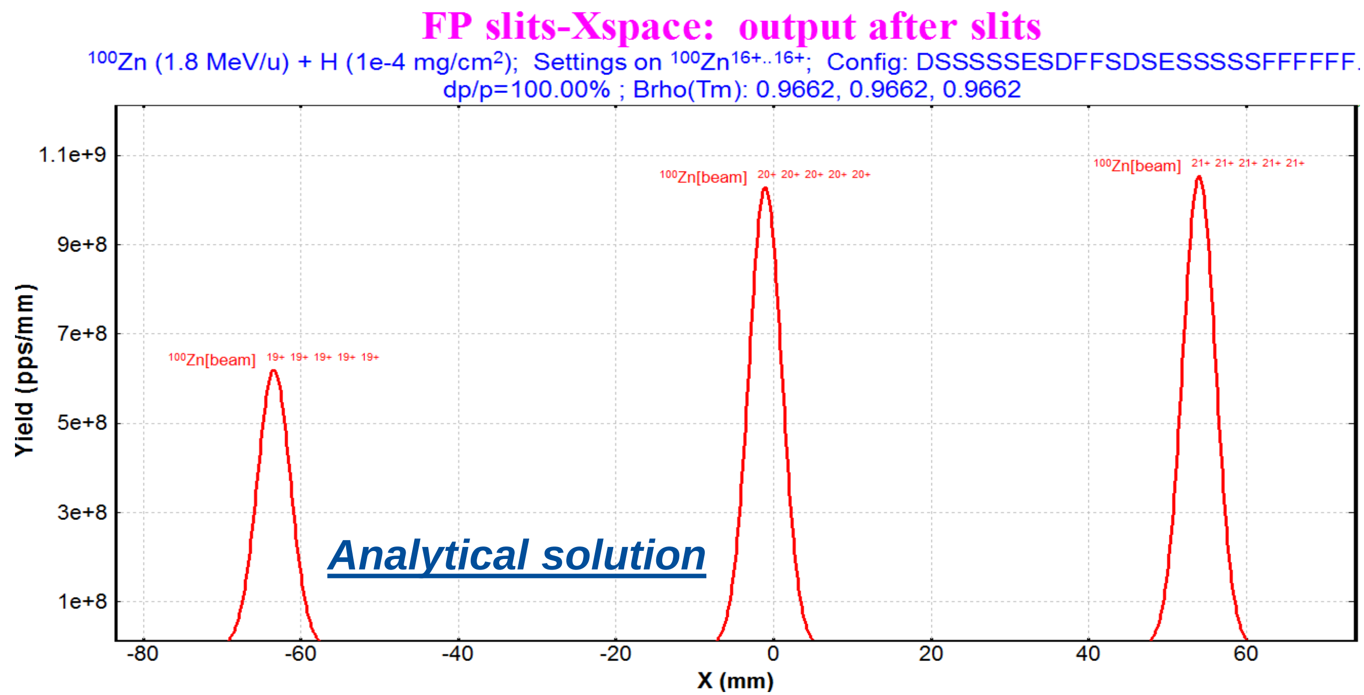
Fig. 5. Calculated M/q spectrum of EMMA centred about mass 100, showing 7 adjacent masses from 97 to 103 emitted from the target with uniform angular spreads of $\pm 3^{\circ}$ in the horizontal and vertical directions, and a uniform energy distribution of $\pm 10\%$.

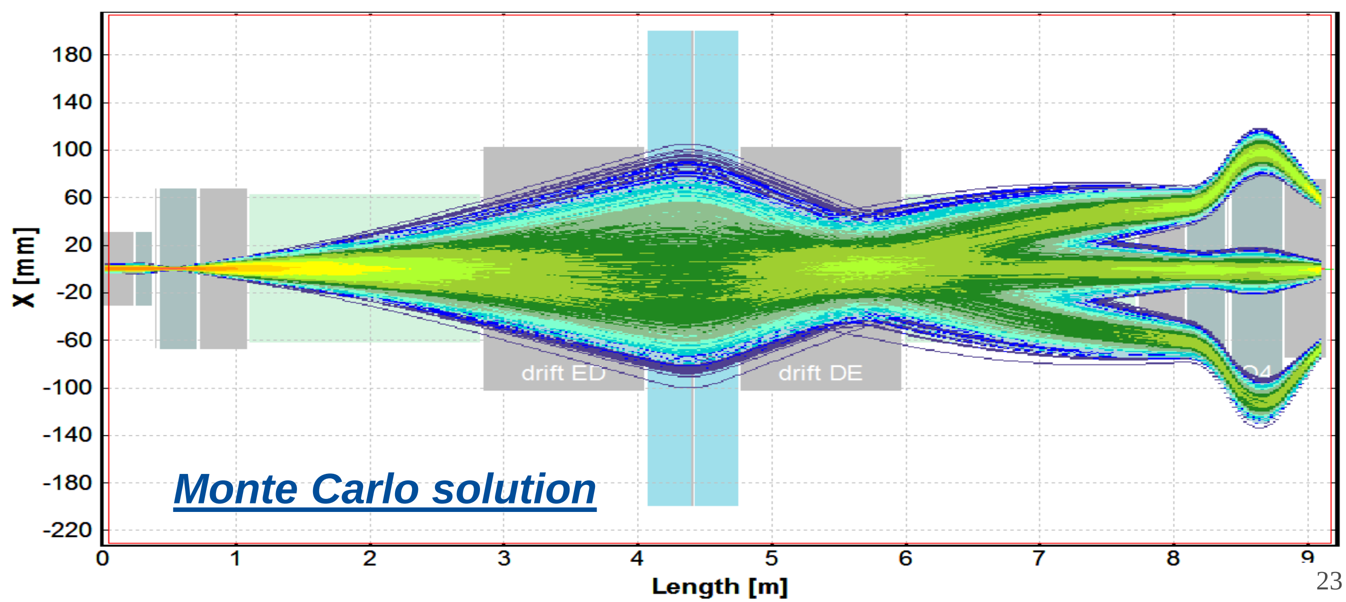


Charge state selection



Very thin target for charge state simulation with “virtual” A=100 beam



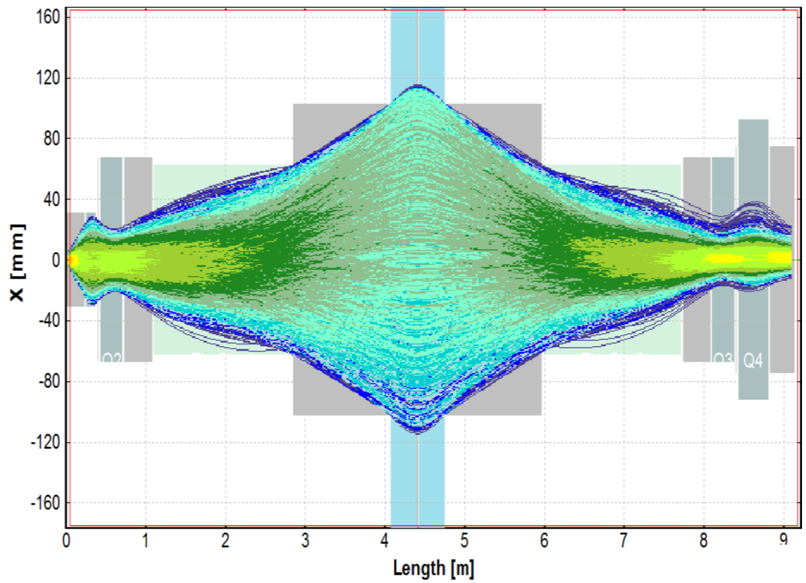


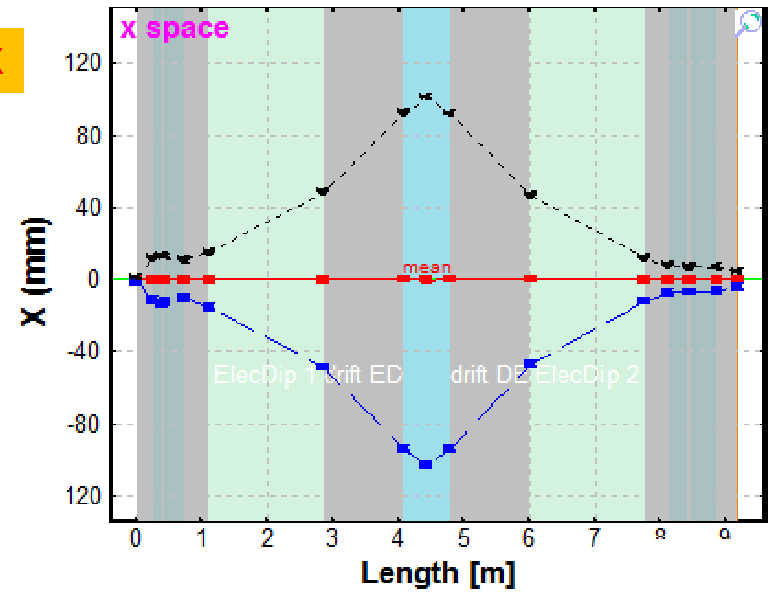
Envelopes : LISE++ MC & analytical solutions → X & Y

LISE++ MC

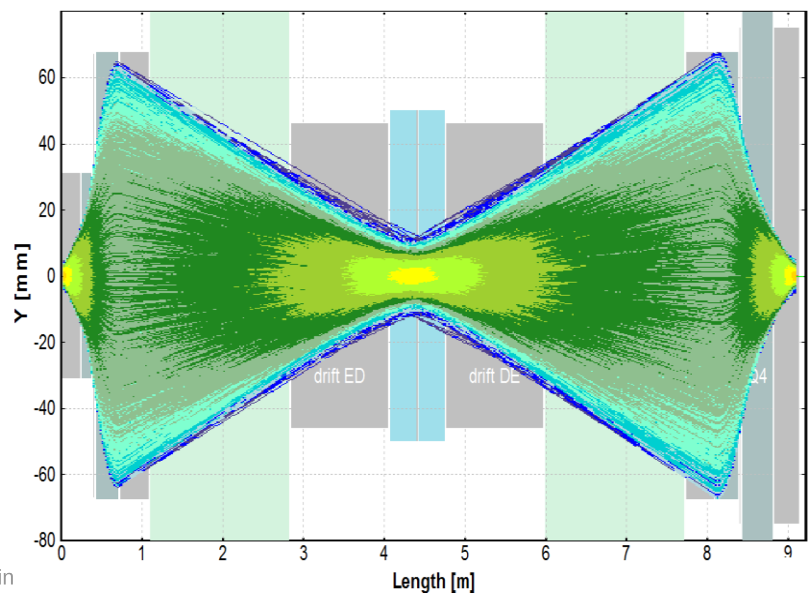
LISE++ analytical

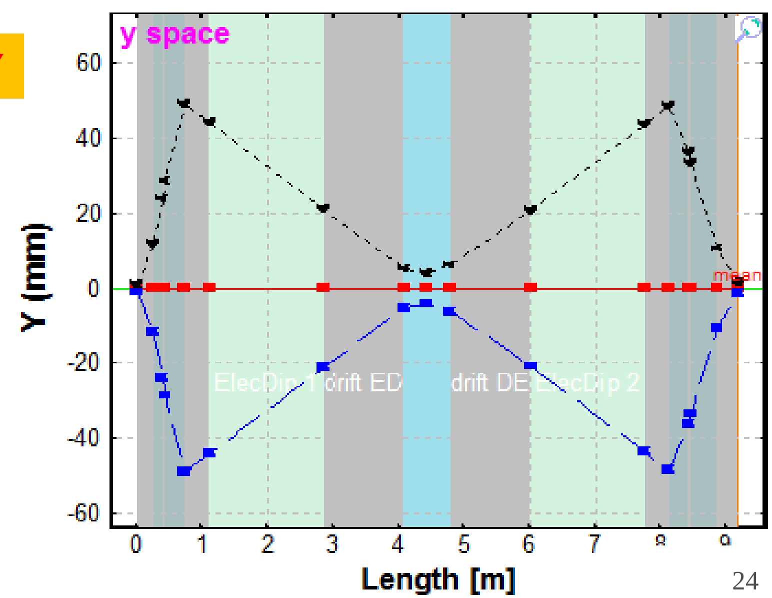
X





Y



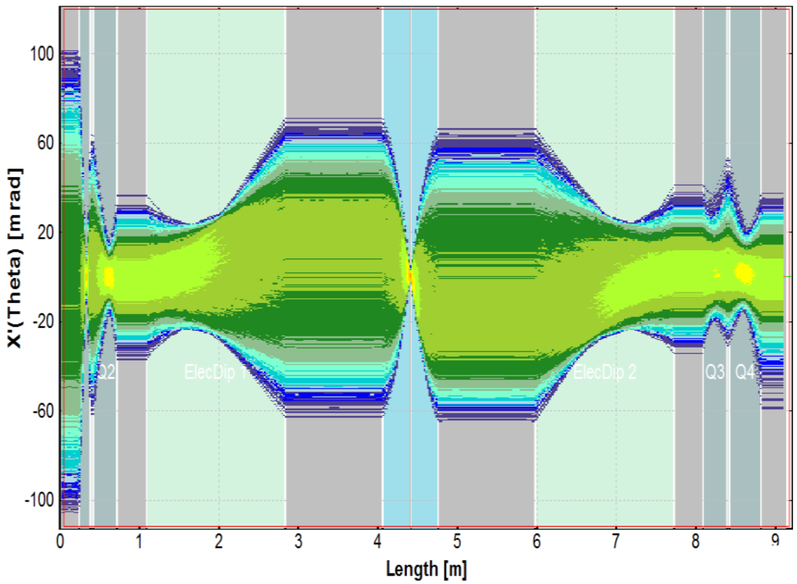


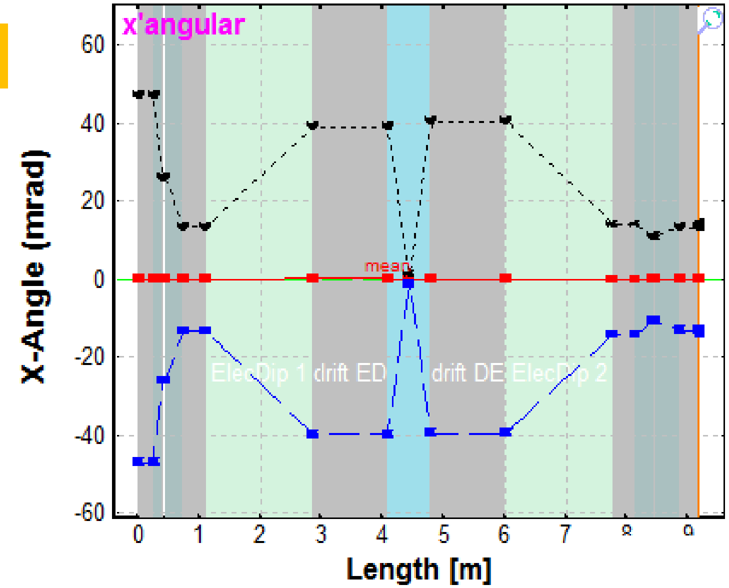
Envelopes : LISE++ MC & analytical solutions → X' & Y'

LISE++ MC

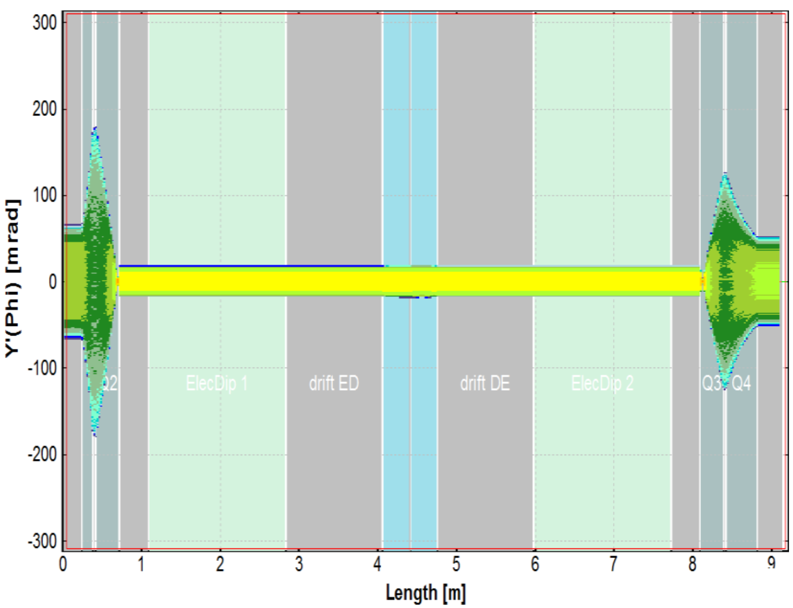
LISE++ analytical

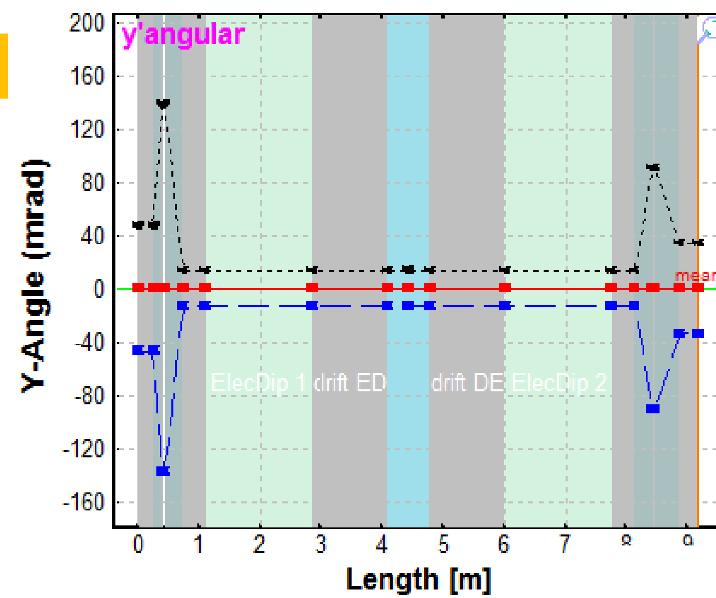
X'





Y'

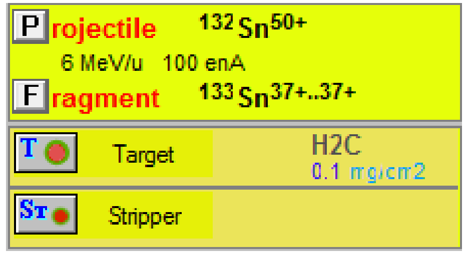




Reaction d(^{132}Sn,p)^{133}Sn

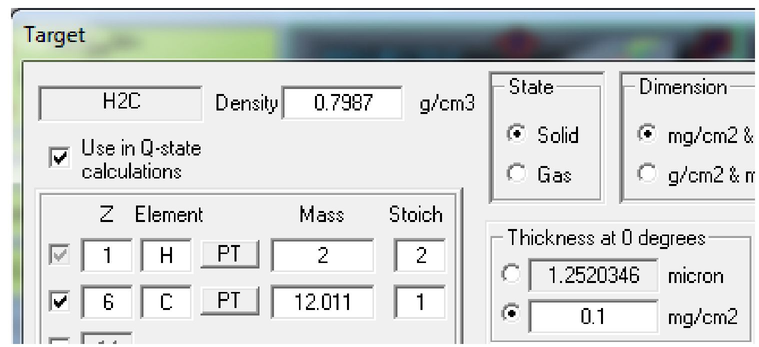
EMMA_reaction_NoGold.lpp

Without gold degrader

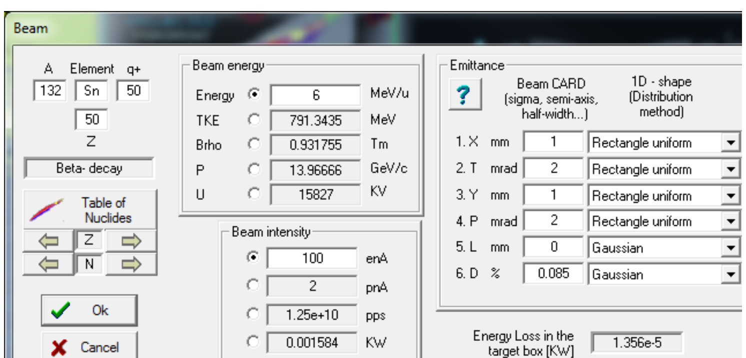


LISE^{++} settings

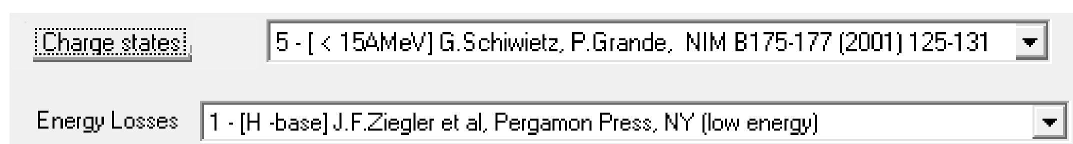
Target



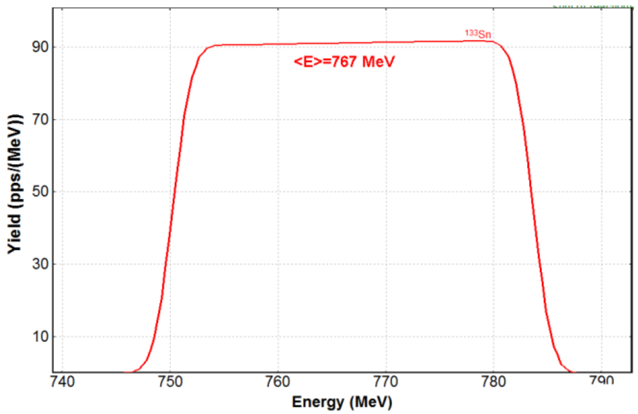
Beam



Production mechanism

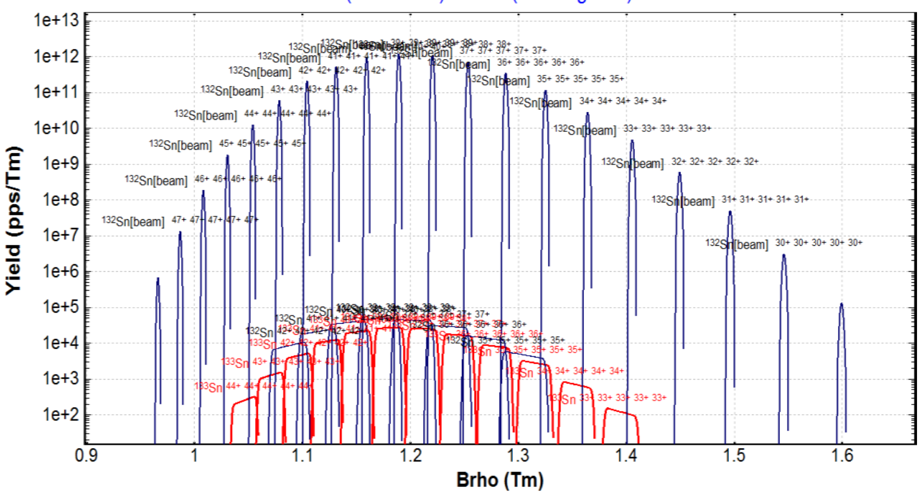


Reaction d(^{132}Sn,p)^{133}Sn : fragment distributions



Q = 41^{+} and energy 782 MeV are indicated in NIMA paper

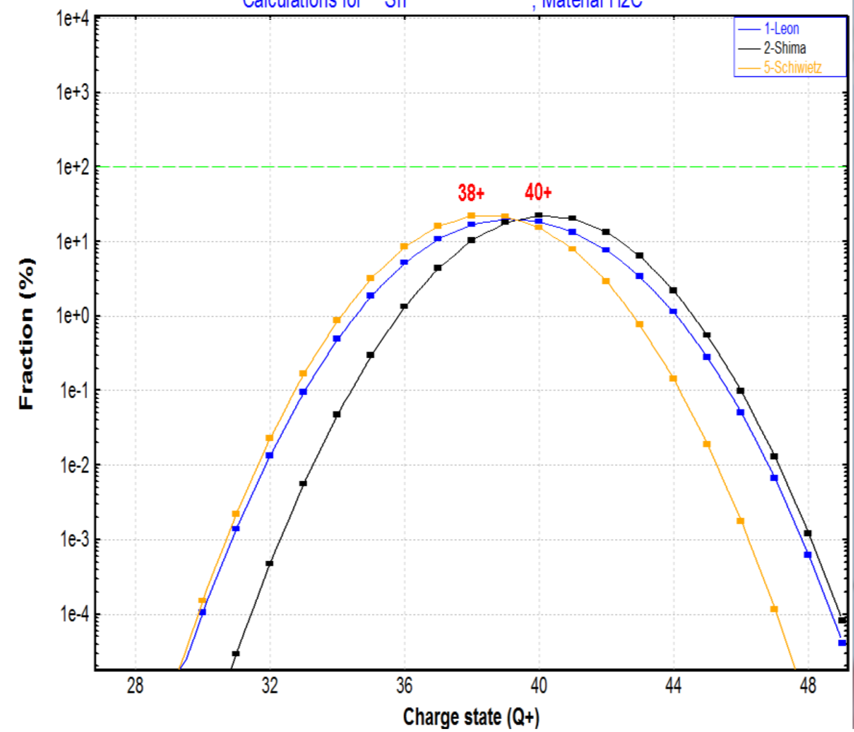
^{132}Sn (6.0 MeV/u) + H2C (1e-1 mg/cm^2)



133Sn after Target (H2C): Fragment energy = 5.8

^{132}Sn (6.0 MeV/u) + H2C (1e-1 mg/cm^2)

Calculations for ^{133}Sn $^{37+\ 37+\ 37+\ 37+\ 37+}$; Material H2C



Please, Compare with Fig.6 NIMA paper →

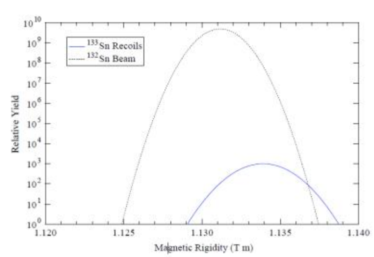
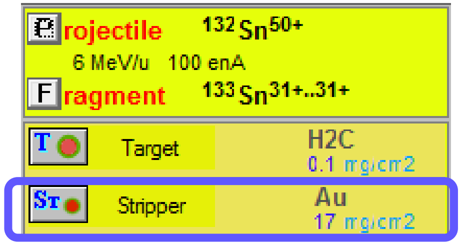


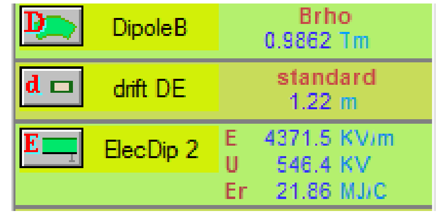
Fig. 6. Magnetic rigidities of beam and recoils from d(^{132}Sn,p)^{133}Sn at 6 MeV/nucleon, calculated for a 100 μg cm^{-2} (CD$_2$)$_n$ target and a realistic ISAC-II beam energy spread of ±0.17% (1σ). This figure dramatically illustrates why a magnetic spectrometer cannot be used to separate beam and recoils in this reaction.

Reaction d(^{132}Sn,p)^{133}Sn (with gold degrader)



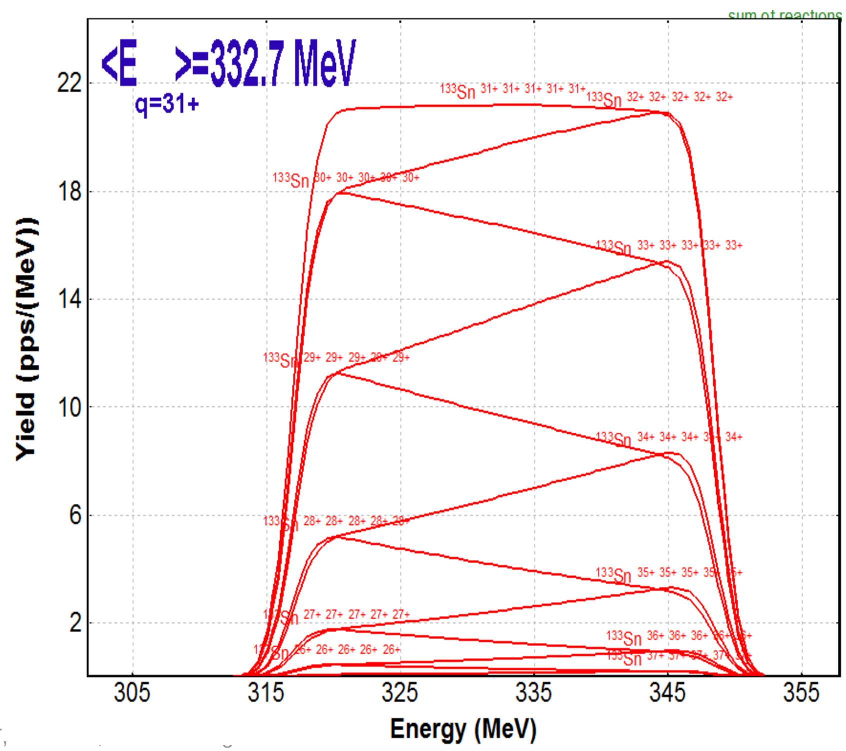
EMMA_reaction.lpp

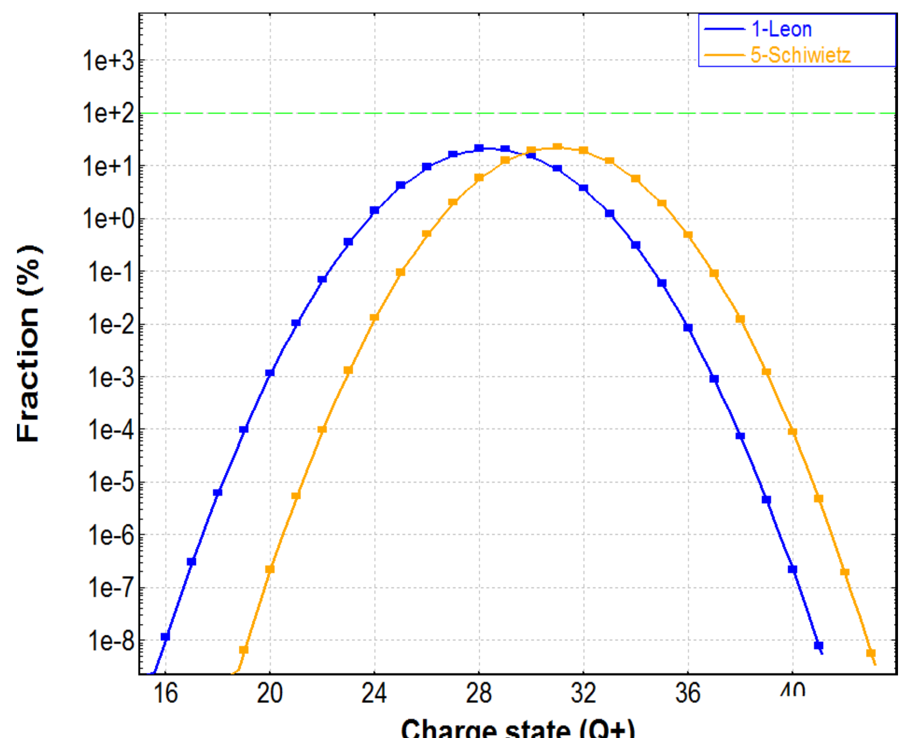
With degrader



Q = 37^{+} (?????) and energy 463 (??) MeV are indicated in NIMA paper

^{133}Sn distributions after the gold degrader





Reaction d(^{132}Sn,p)^{133}Sn (with gold degrader)

MICHIGAN STATE UNIVERSITY LISE++

"Distribution" method
(analytical solution)

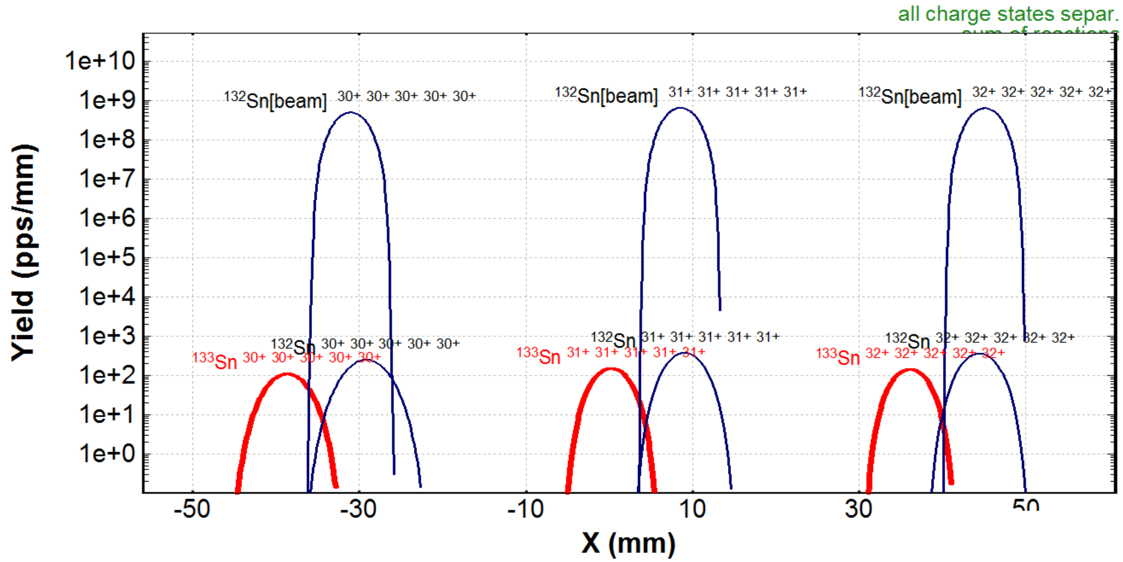
statistics: 133Sn

133Sn Beta- decay (Z=50, N=83) Tin

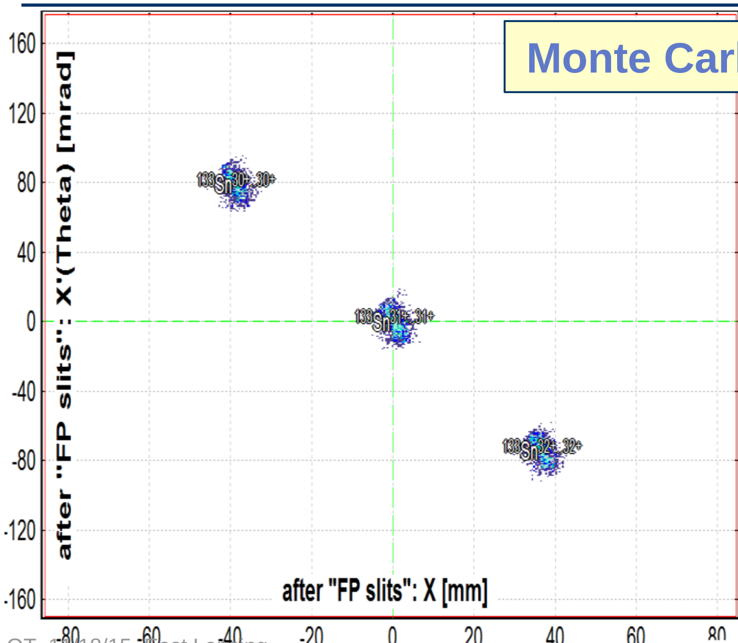
All reactions total isotope rate 1.81e+3 pps
and Overall isotope transmission 59.472 %

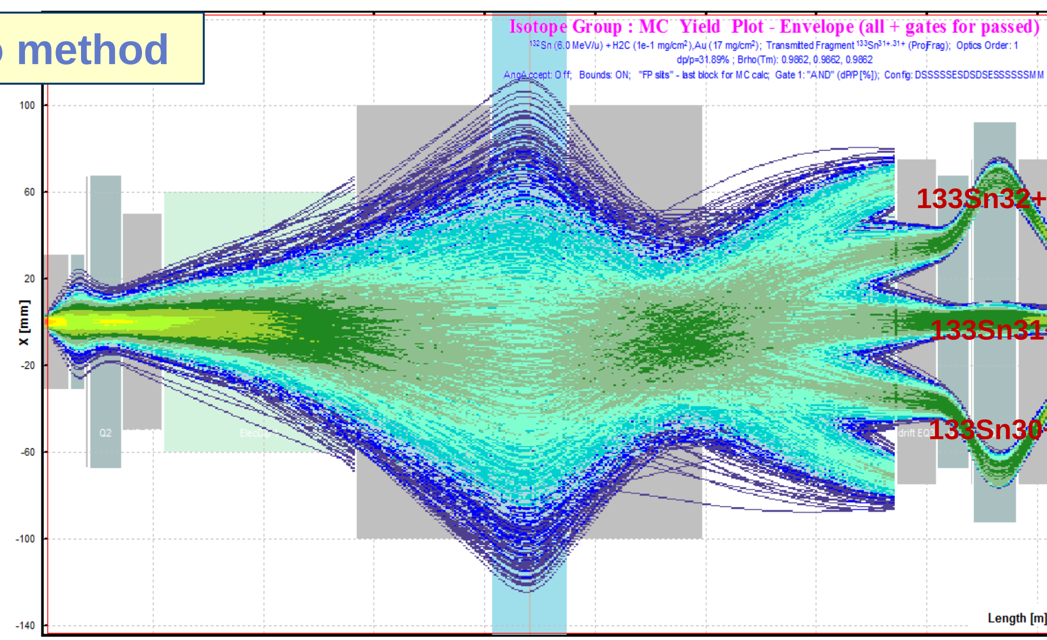
		32	31	30
Q1 (tuning)		32	31	30
Q2 (ElecDip 1)		32	31	30
Q3 (DipoleA)		32	31	30
Q4 (DipoleB)		32	31	30
Q5 (ElecDip 2)		32	31	30
Reaction		TwoBody	TwoBody	TwoBody
Ion Production Rate	(pps)	6.19e+2	6.65e+2	5.26e+2
Total ion transmission	(%)	20.336	21.853	17.282
Total: this reaction	(pps)	1.81e+3	1.81e+3	1.81e+3
X-Section in target	(mb)	2.16e+1	2.16e+1	2.16e+1
Target	(%)	100	100	100
Unreacted in material	(%)	100	100	100
Unstopped in material	(%)	100	100	100
Stripper	(%)	20.34	21.85	17.28
Unreacted in material	(%)	100	100	100
Q (Charge) ratio	(%)	20.34	21.85	17.28
Unstopped in material	(%)	100	100	100

FP slits-Xspace: output after slits



Monte Carlo method





Reaction $d(^{132}Sn,p)^{133}Sn$ (with gold degrader)

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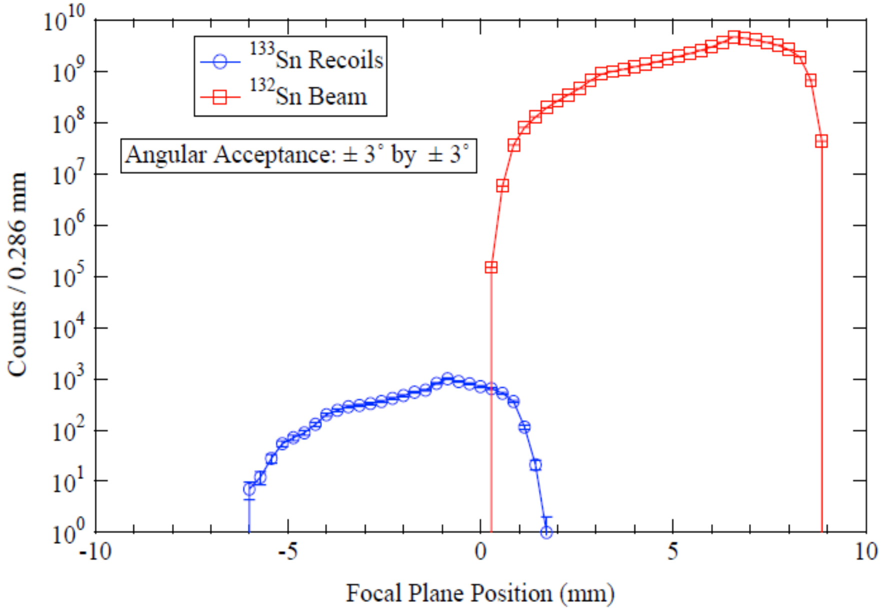
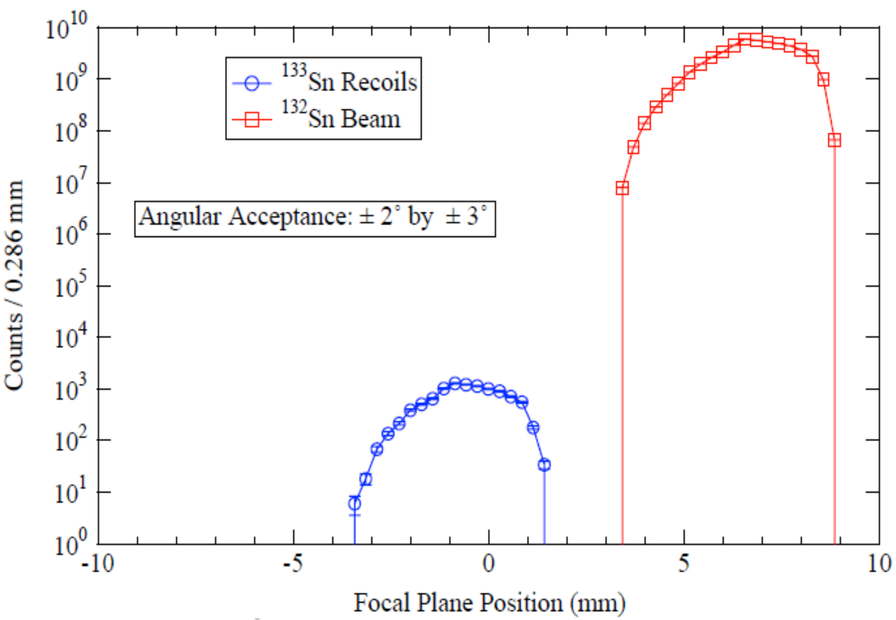
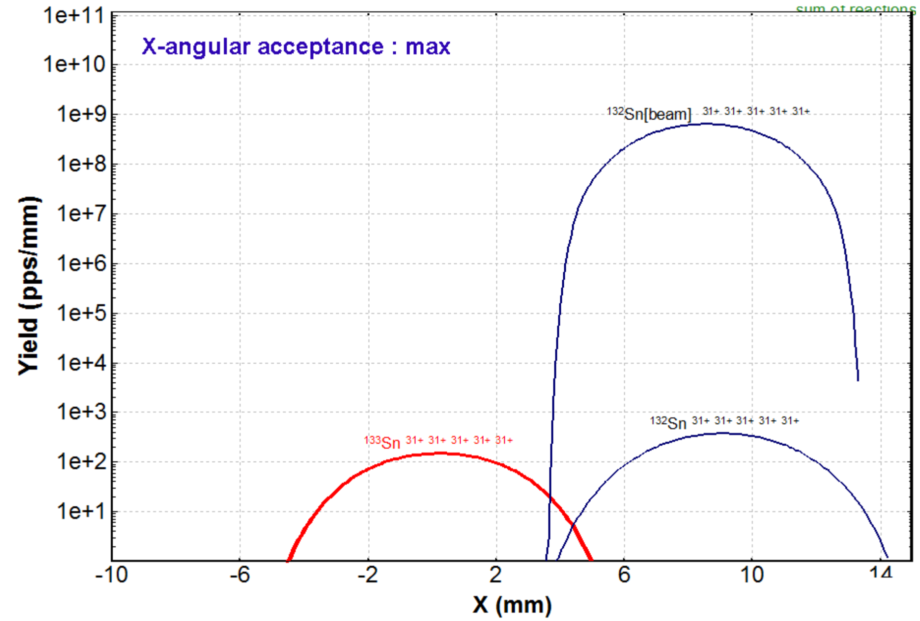
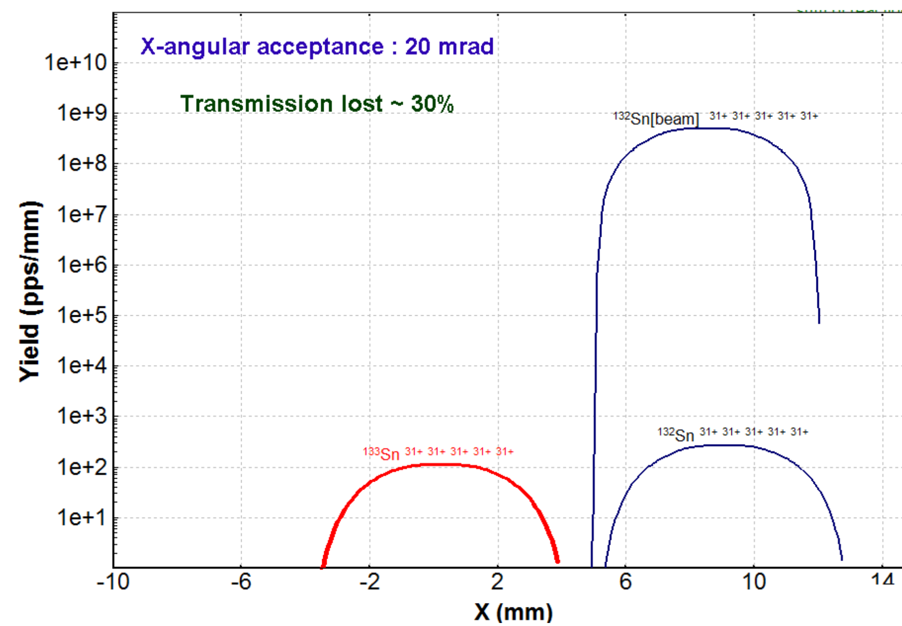


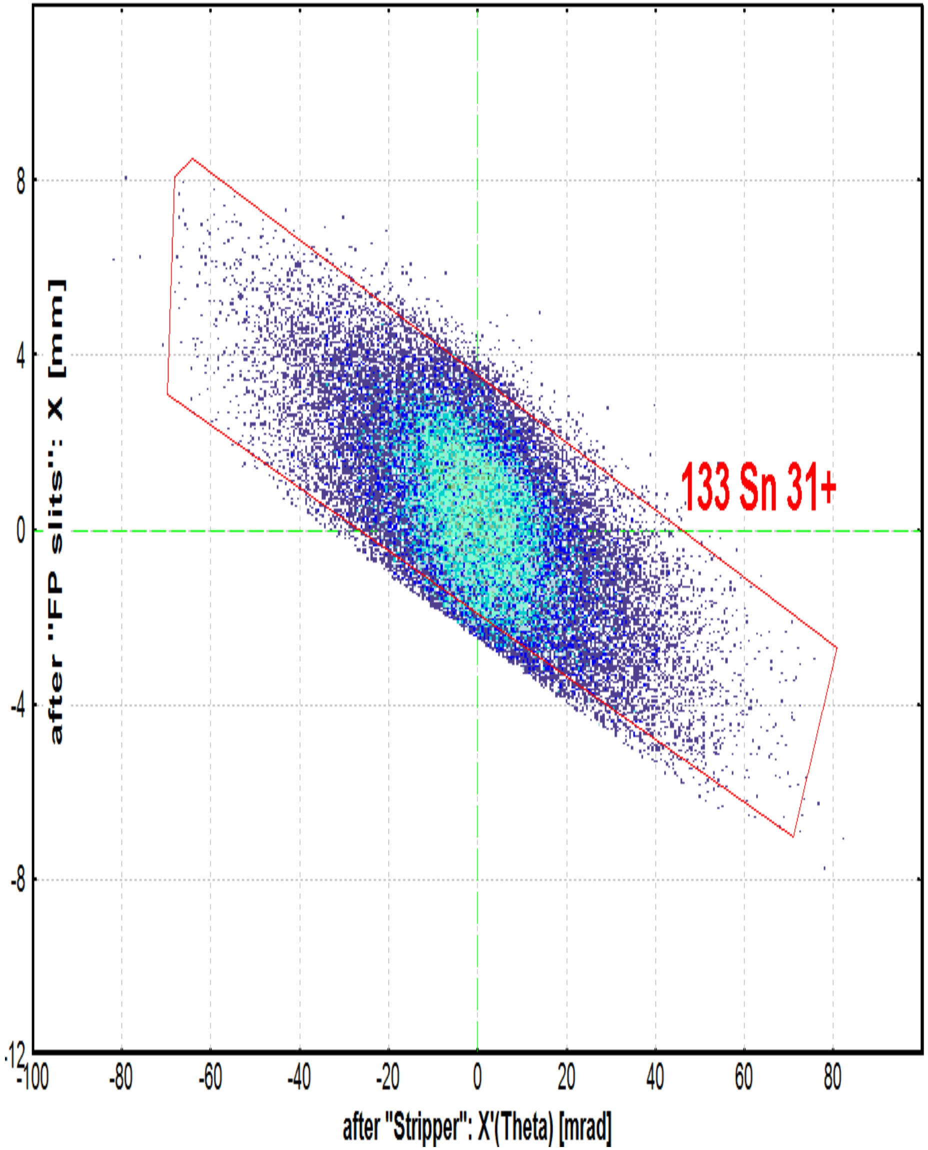


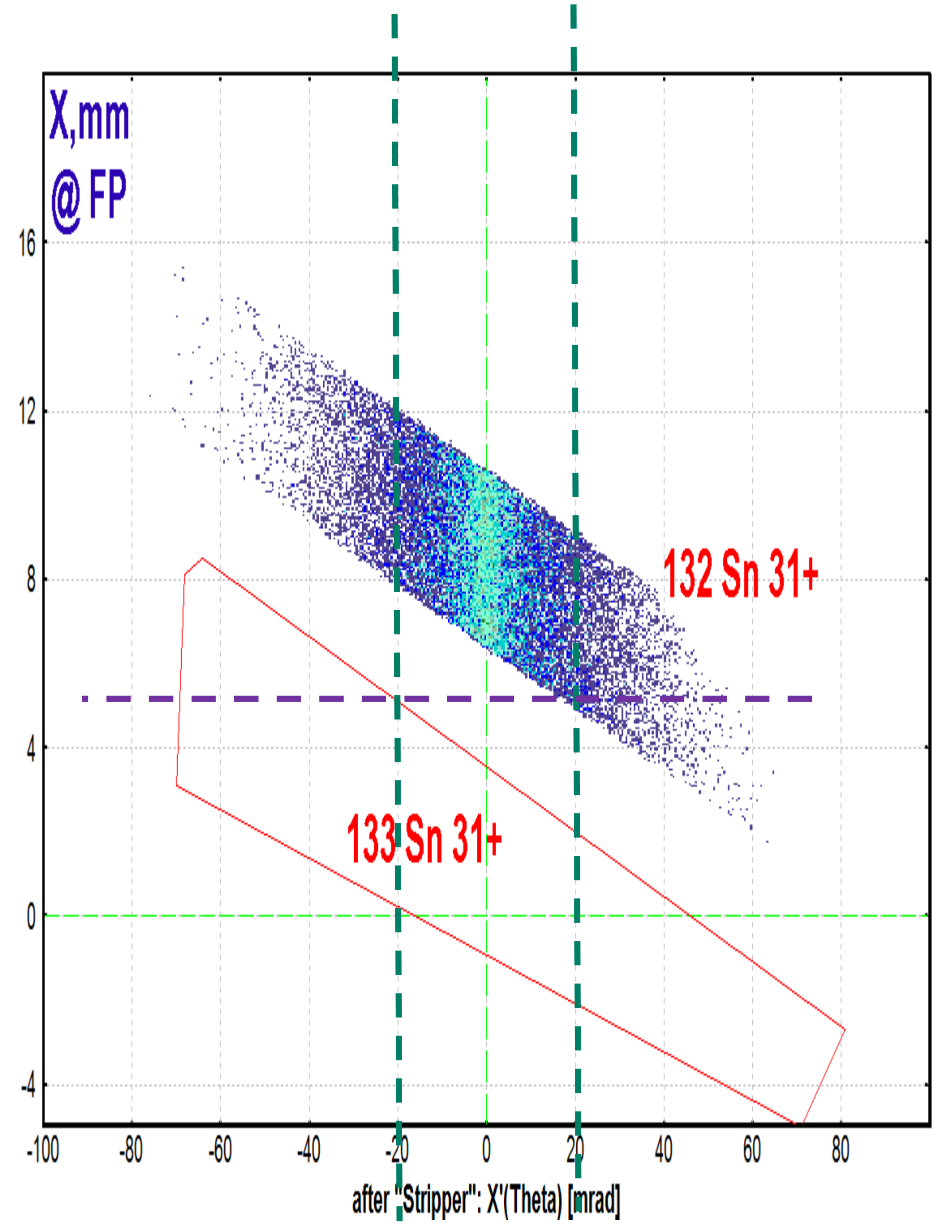
LISE^{++}





Using Angular Acceptance to FP X-resolution





Outlook

Open Questions:

1. Mass & charge dispersion values calculation
2. Using Mass & charge dispersion values for optimization
3. Electrical dipole second order matrix calculation! (new)