

Recoil separator “SECAR” configurations in the LISE⁺⁺ package

by Oleg Tarasov

According to the LISE⁺⁺ site

LISE⁺⁺ : calculation of the transmission and yields of fragments produced and collected in a separator. This code allows to simulate an experiment, beginning from the parameters of the reaction mechanism and finishing with the registration of products selected by a separator.

- predict the separator settings necessary to obtain a specific RIB;
- predict the intensity and purity of the chosen RIB;
- simulate identification plots for on-line comparison;
- provide a highly user-friendly graphical environment;
- allow configuration for different fragment separators.

The LISE⁺⁺ code may be applied at medium-energy and high-energy facilities (fragment- and recoil-separators with electrostatic and/or magnetic selections).

2015: Go to the low energy domain!

- SHE -- Update of Fusion reaction mechanism , “SHELLS”
- S3 (GANIL), MSP144 (Dubna), PRISMA (LNL)
- Region of light nuclei – “DRAGON”,... and now “SECAR”

<http://lise.nslc.msu.edu/changes.html>

The screenshot shows the LISE++ website interface. On the left is a navigation menu with items like Home, Introduction, Documentation, Last Changes (highlighted), LISE utilities in Qt, Perspectives, Download, MOTER, PACE 4, Spectrometers, Related topics, Personal pages, Registration, and Email. The main content area is titled 'EXOTIC BEAM PRODUCTION WITH FRAGMENT SEPARATORS' and features a 'Last Changes' table. The table has two columns: 'Version' and 'Description'. A row is visible with the version '9.10.169' and date '20-08-15'. To the right of the table is a diagram of the 'Recoil separator SECAR', which is a semi-circular arrangement of various beamline components including magnets and detectors.

Version	Description
9.10.169 20-08-15	Recoil separator "SECAR"

[SECAR.pdf \(49 pages\)](#)

Version 9.10.169
from 08/20/2015

[Link: Separator “SECAR”](#)

SECAR extended configurations

- SECAR documentation
- SECAR phase1
- LISE++ modifications for SECAR
- SECAR files location
- SECAR phase 1 with COSY maps
- Optimization with LISE++

SECAR phase1: Angular Acceptance

SECAR phase1: Momentum Acceptance

SECAR phase1: Charge states selection

Experiment $^{15}\text{O}(\alpha,\gamma)^{19}\text{Ne}$

- Fusion
- Selection

Segmented configuration

Open questions

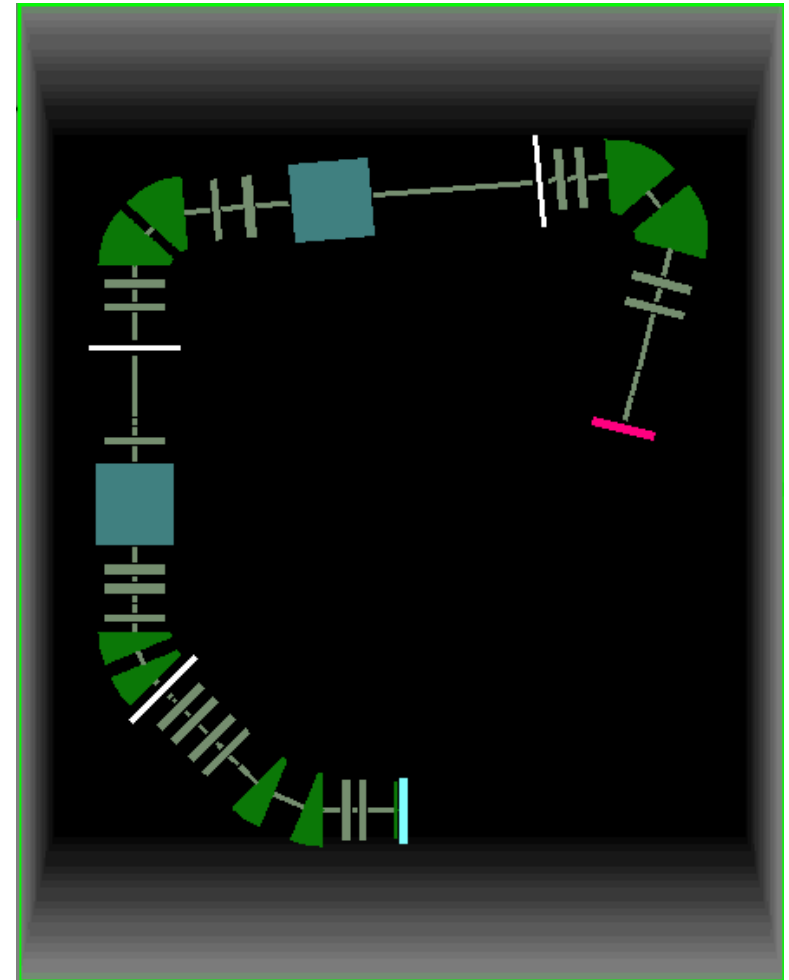
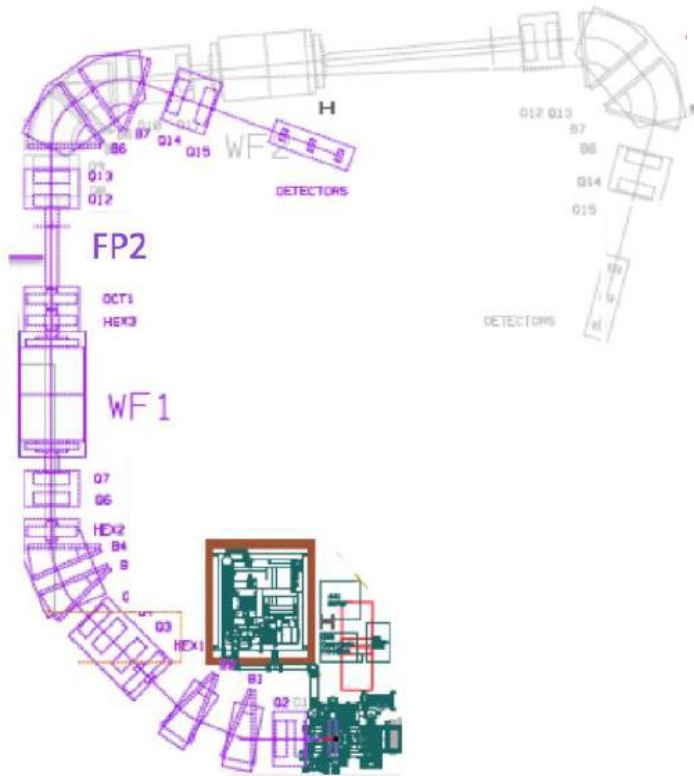
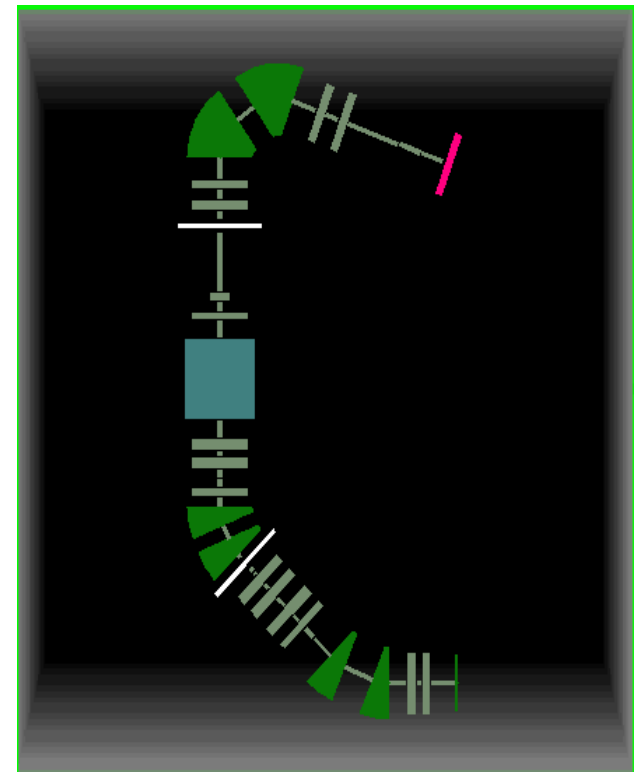


Table 3.13. SECAR Optimized Setup for a 1 VF system

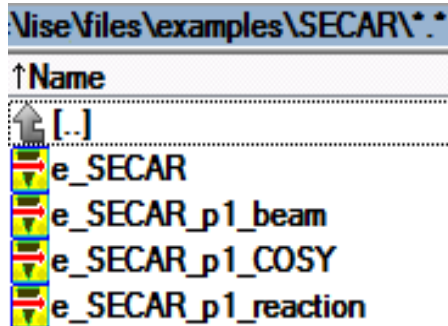
Quadrupole	Radius (m)	Pole tip field (T)	Gradient T/m
Q1	0.05	-0.36534	-7.3068000
Q2	0.068	0.21788	3.2041176
Q3	0.11	0.242644	2.2058545
Q4	0.08	-0.24501	-3.0626250
Q5	0.06	0.11128	1.8546667
Q6	0.14	0.181721	1.2980071
Q7	0.13	-0.0301475	-0.2319038
Q8			
Q9			
Q10			
Q11			
Q12	0.07	-0.22000	-3.1428571
Q13	0.05	0.20160	4.0320000
Q14	0.05	0.13147	2.6294000
Q15	0.05	-0.1450	-2.9000000
HEX(Q1)	0.05	-0.0006	
HEX1	0.11	0.008620	
HEX2	0.12	0.01449	
HEX3	0.11	-0.0435	
OCT1	0.07	0.006225	



@ LISE++

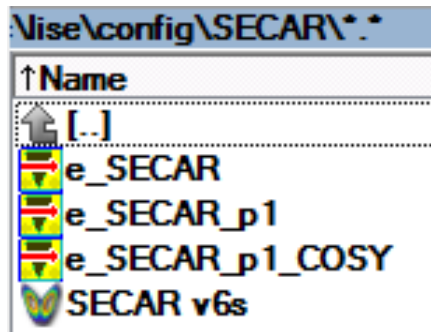


LISE⁺⁺ files



- *SECAR extended for primary beam (not optimized yet)*
- *SECAR phase1 extended for primary beam*
- *SECAR phase1 extended with COSY 5th order maps*
- *SECAR phase1 extended : $^{15}\text{O}(\alpha, \gamma)^{19}\text{Ne}$*

LISE⁺⁺ configurations



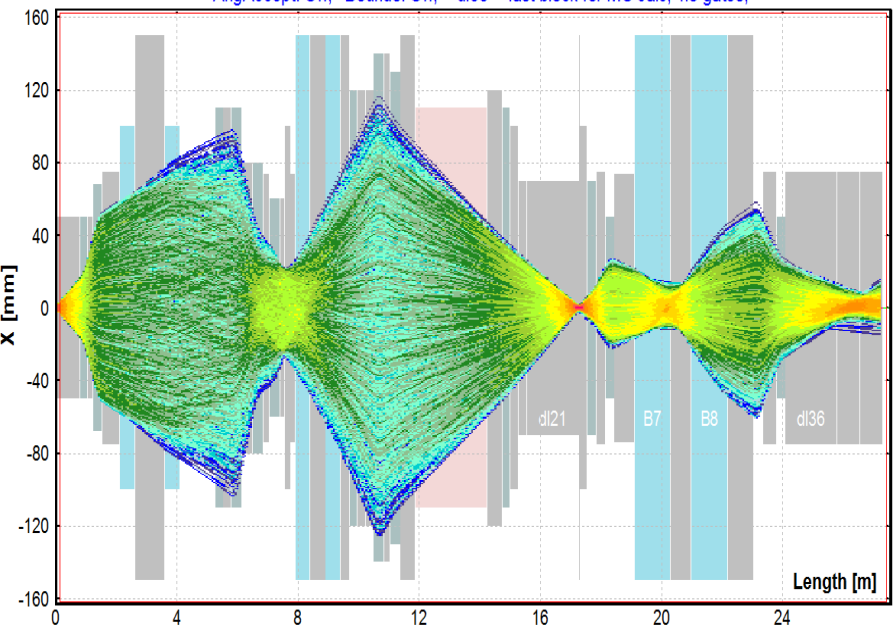
- *SECAR extended configurations*
- *COSY file to generate SECAR maps for LISE⁺⁺*

SECAR segmented configurations will be done soon

⁶⁶Se : MC Transmission Plot - Envelope

AngAccept: Off; Bounds: Off; "dl38" - last block for MC calc; no gates;

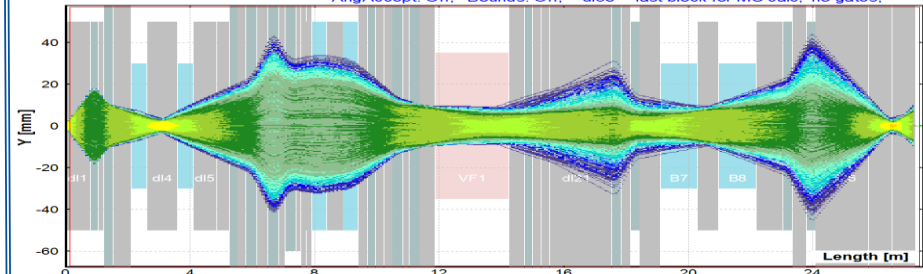
5th order



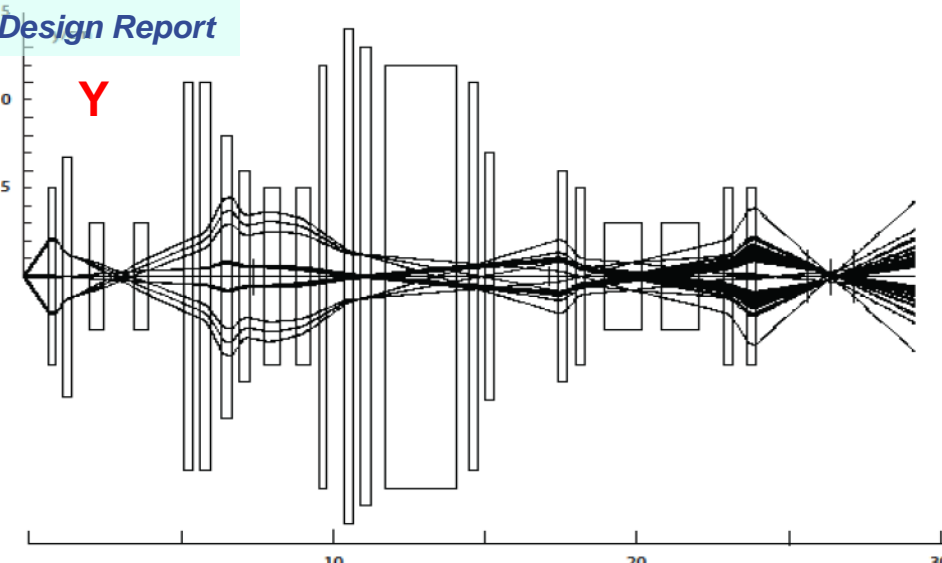
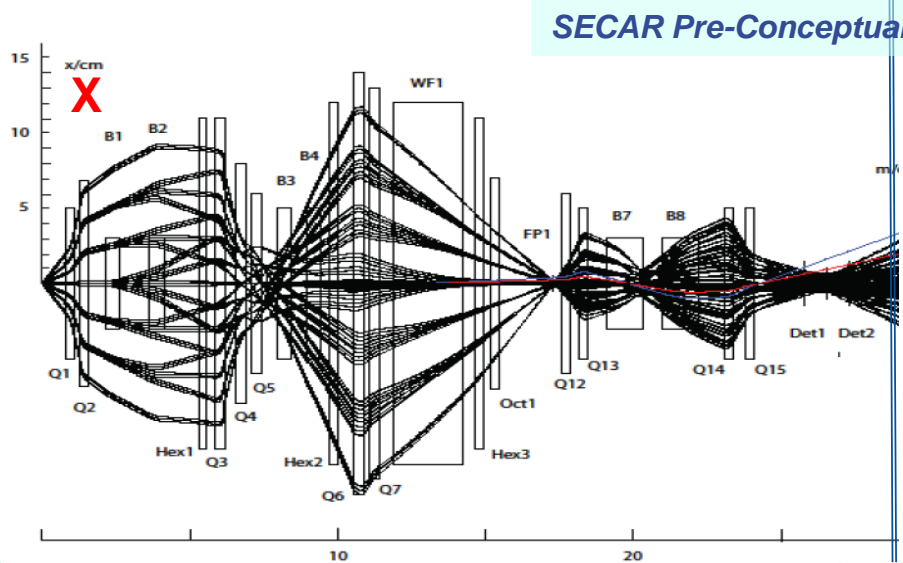
⁶⁶Se : MC Transmission Plot - Envelope

AngAccept: Off; Bounds: Off; "dl38" - last block for MC calc; no gates;

5th order



SECAR Pre-Conceptual Design Report

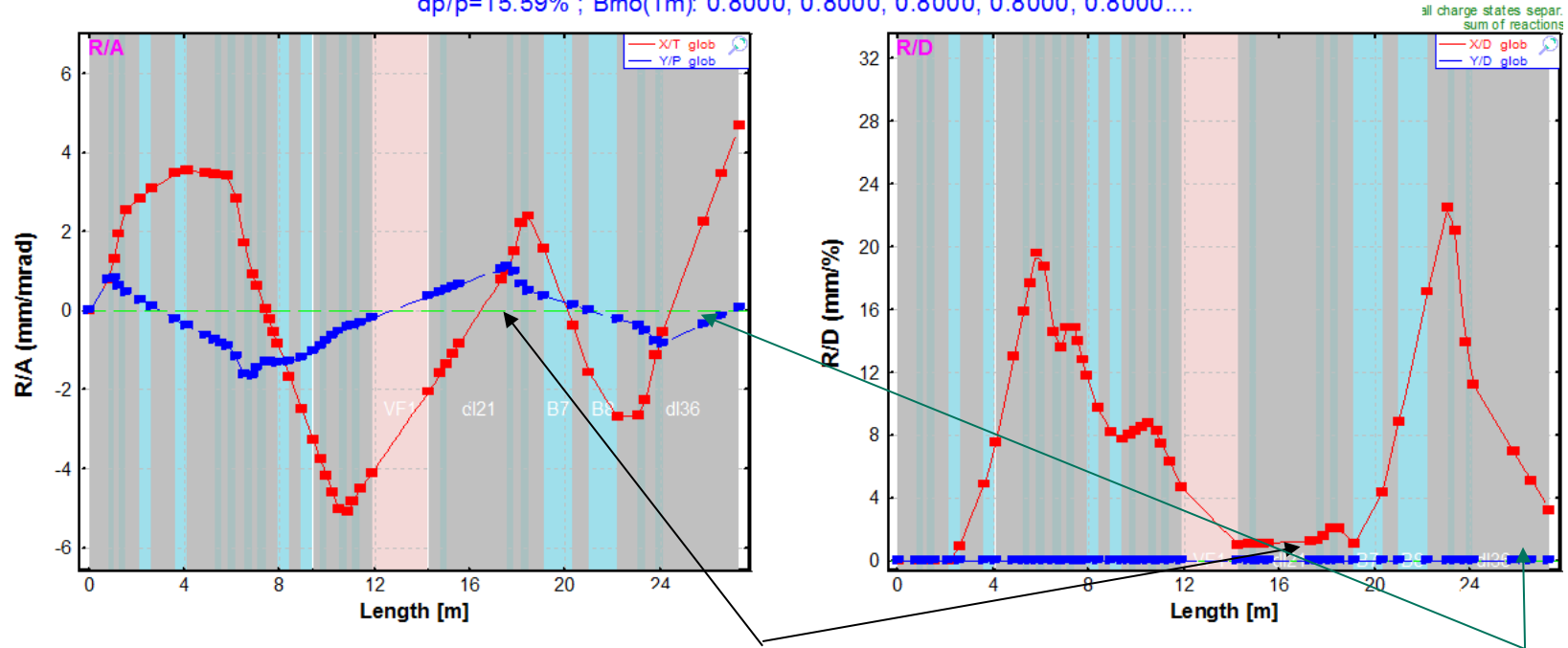


File: e_SECAR_phase1.lpp

Using fields from the SECAR Pre-Conceptual Design Report

First order matrix elements

⁶⁶Se (3.1 MeV/u) + Be (1e-3 mg/cm²); Settings on ⁶⁶Se^{21+,21+}; Config: DSSFSSFSFDSDFFSSSFSSSFSSF...
 dp/p=15.59% ; Brho(Tm): 0.8000, 0.8000, 0.8000, 0.8000, 0.8000....



FP2 – no double focus, small dispersion

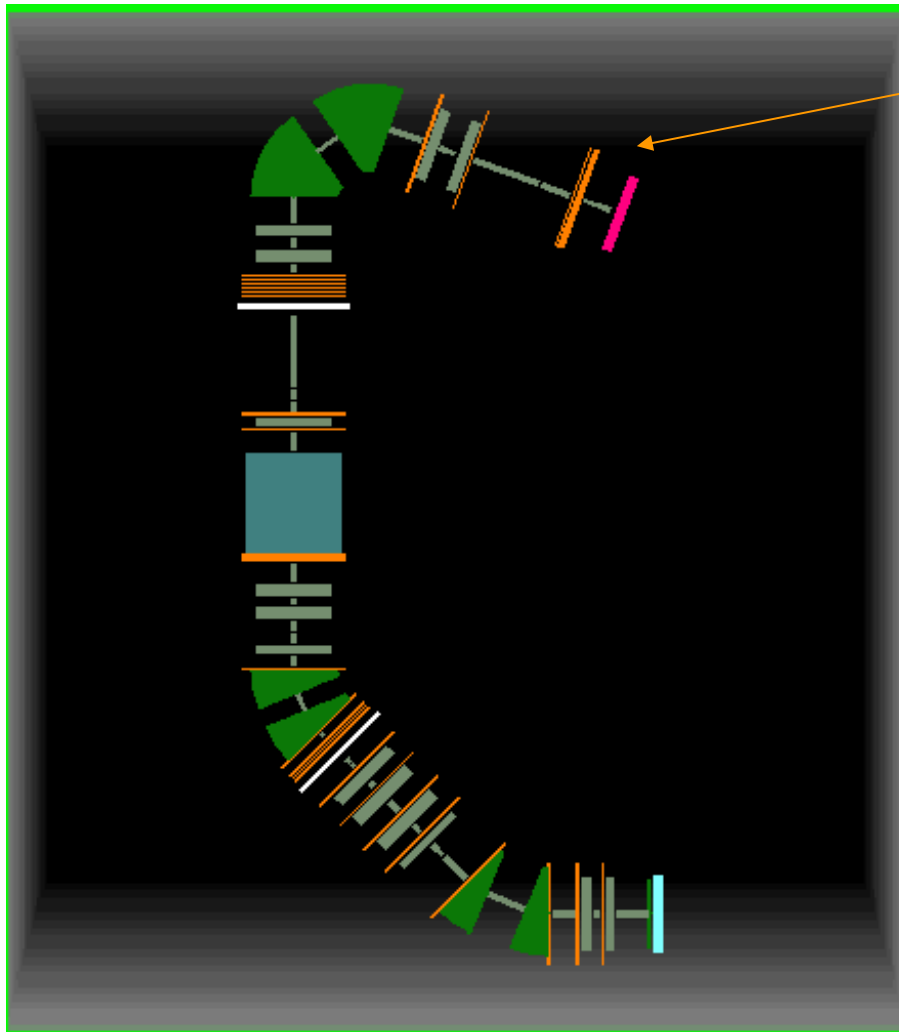
Global matrix

1.71399	0.7896	0	0	0	1.27182	[mm]
0.75758	0.93241	0	0	0	0.08012	[mrad]
0	0	15.94788	1.06042	0	0	[mm]
0	0	2.52905	0.23087	0	0	[mrad]
-0.4117	-0.9308	0	0	1	-9.86959	[mm]
0	0	0	0	0	1	[%]
/[mm]	/[mrad]	/[mm]	/[mrad]	/[mm]	/[%]	

DL37 – no X-focus, small dispersion

Global matrix

7.39269	3.46894	0	0	0	5.11233	[mm]
3.19314	1.6336	0	0	0	-2.49489	[mrad]
0	0	-1.96752	-0.13856	0	0	[mm]
0	0	11.19827	0.28033	0	0	[mrad]
2.98263	0.65761	0	0	1	-24.18632	[mm]
0	0	0	0	0	1	[%]
/[mm]	/[mrad]	/[mm]	/[mrad]	/[mm]	/[%]	



28 constraints,
11 variable fields

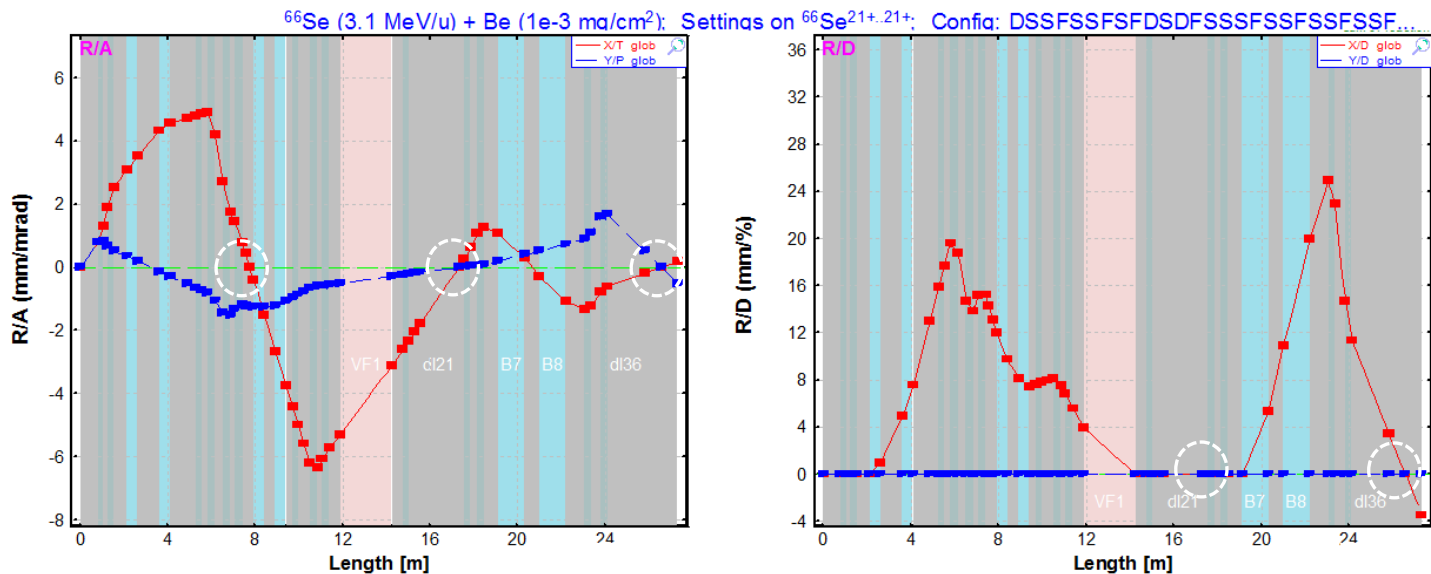
Optics fit

Blocks with parameters to vary	Active Constraint blocks
#01-q Position@005: Q1	#12 @036: sY < 50 B3_sY
#02-q Position@008: Q2	#13 @040: sY < 50 B4_sY
#03-q Position@021: Q3	#14 @049: sX < 110 VF1_sX
#04-q Position@024: Q4	#15 @050: sY < 35 VF1_sY
#05-q Position@027: Q5	#16 @053: sY < 80 Hex3_sY
#06-q Position@045: Q6	#17 @055: sX < 80 Hex3_sX
#07-q Position@047: Q7	#18 @060: R16 = 0 FP2_XD
#08-q Position@067: Q12	#19 @061: R26 = 0 FP2_TD
#09-q Position@069: Q13	#20 @062: R12 = 0 FP2_XT
#10-q Position@076: Q14	#21 @063: R33 < 12 FP2_YYp
#11-q Position@078: Q15	#22 @064: R33 > -11 FP2_YYm
	#23 @065: R34 = 0 FP2_YP
	#24 @075: s R < 50 Q14_sR
	#25 @079: s R < 50 Q15_sR
	#26 @082: R12 = 0 FP_XT
	#27 @083: R34 = 0 FP_YP
	#28 @084: R16 = 0 FP_XD

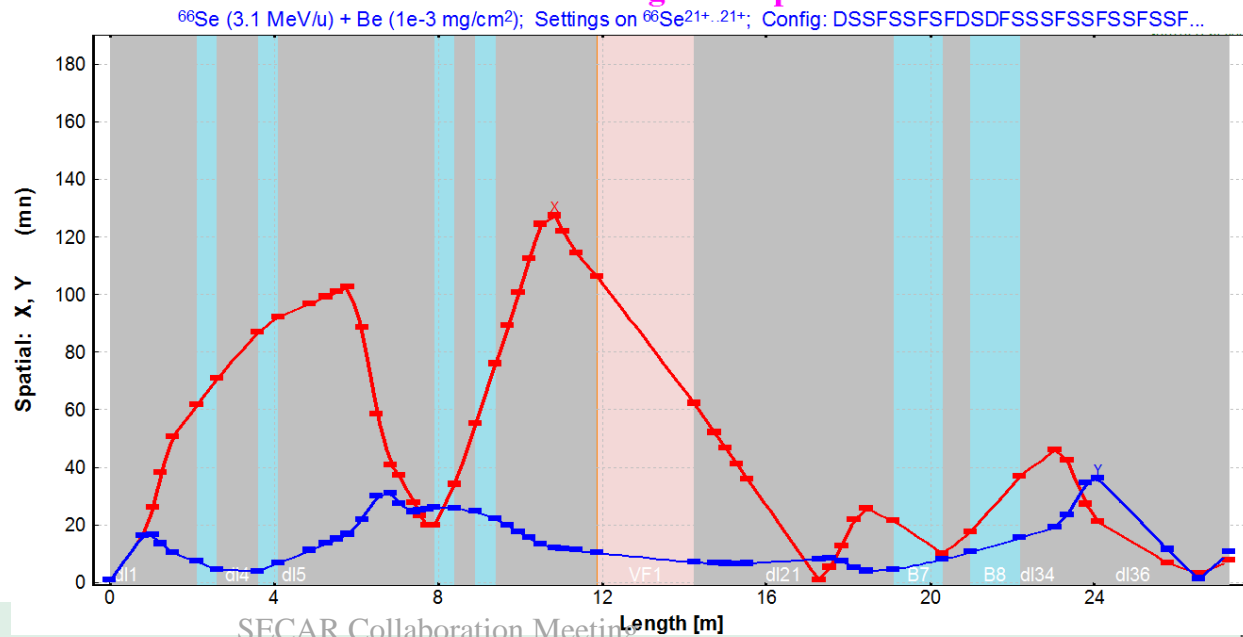
N iter = 20000

SECAR_phase1_v7_original.fit

First order matrix elements



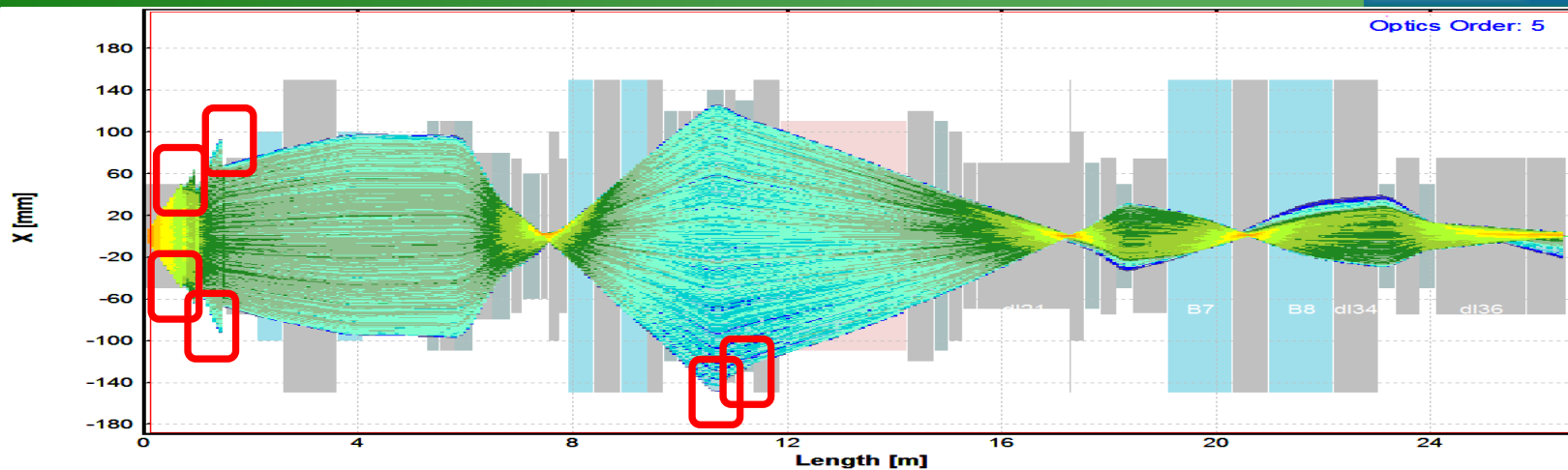
Beam Sigmas: spatial



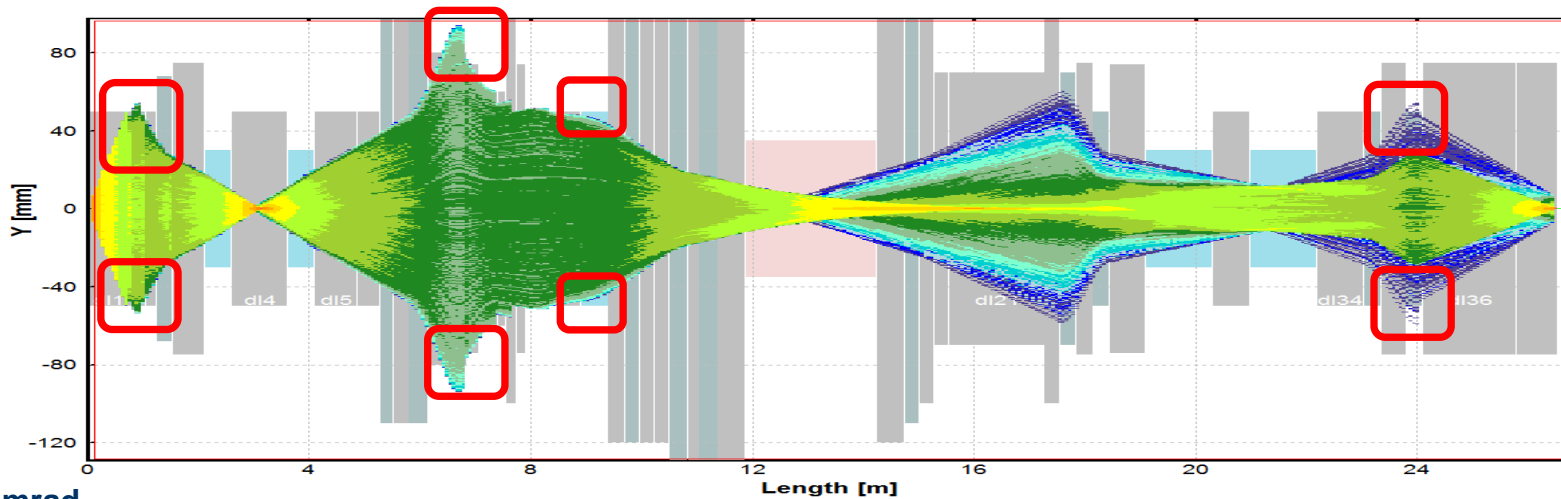
element	Initial	LISE ⁺⁺ result	delta
Q1	-3.6534	-3.4260	0.2274
Q2	2.1788	1.7540	-0.4248
Q3	2.4264	2.3870	-0.0394
Q4	-2.4501	-2.4240	0.0261
Q5	1.1128	1.1480	0.0352
Q6	1.8172	1.8350	0.0178
Q7	-0.3015	-0.2694	0.0321
Q12	-2.2000	-2.2020	-0.0020
Q13	2.0160	1.9960	-0.0200
Q14	1.3147	1.3100	-0.0047
Q15	-1.4500	-1.4450	0.0050

Angular Emittance Loss (5th order optics)

X'

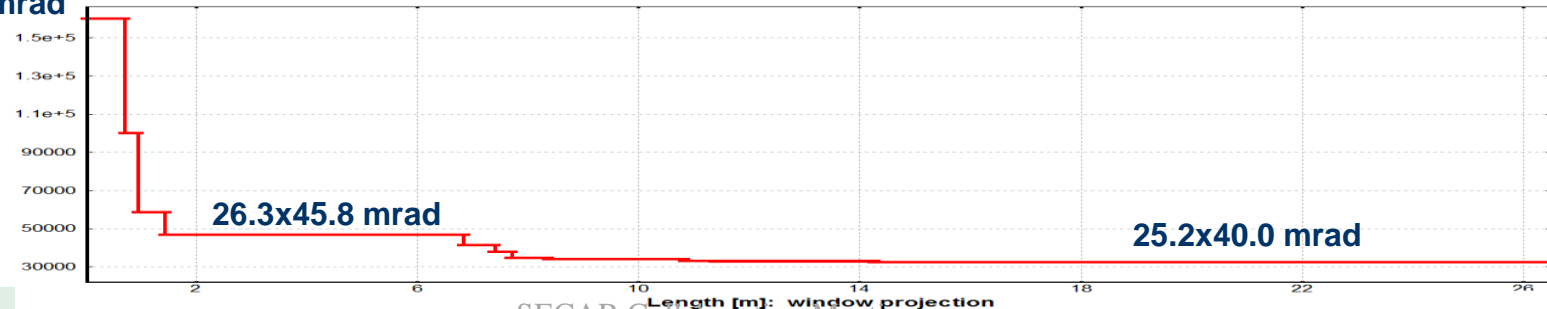


Y'



70x70 mrad

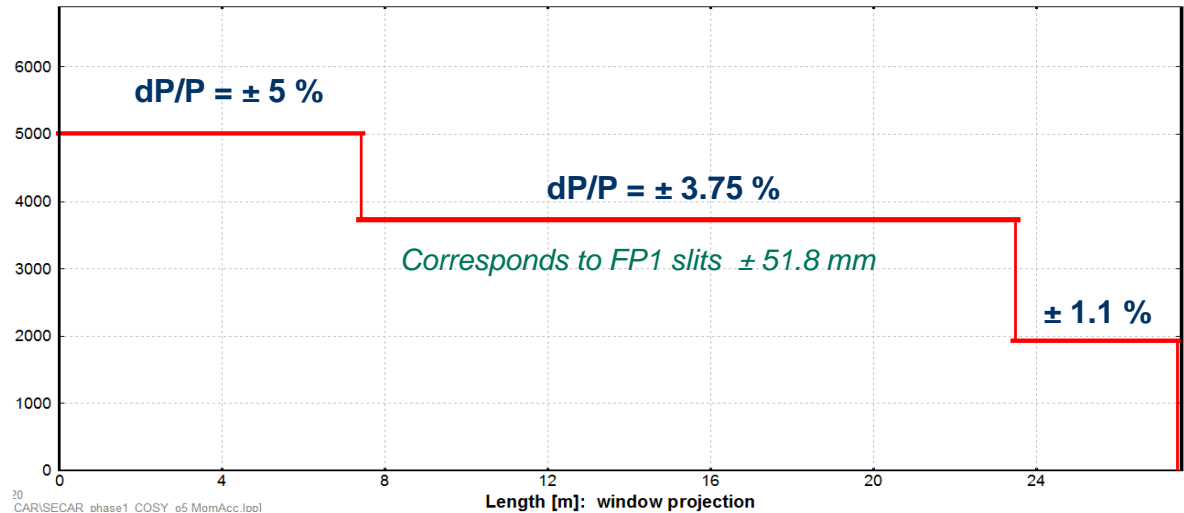
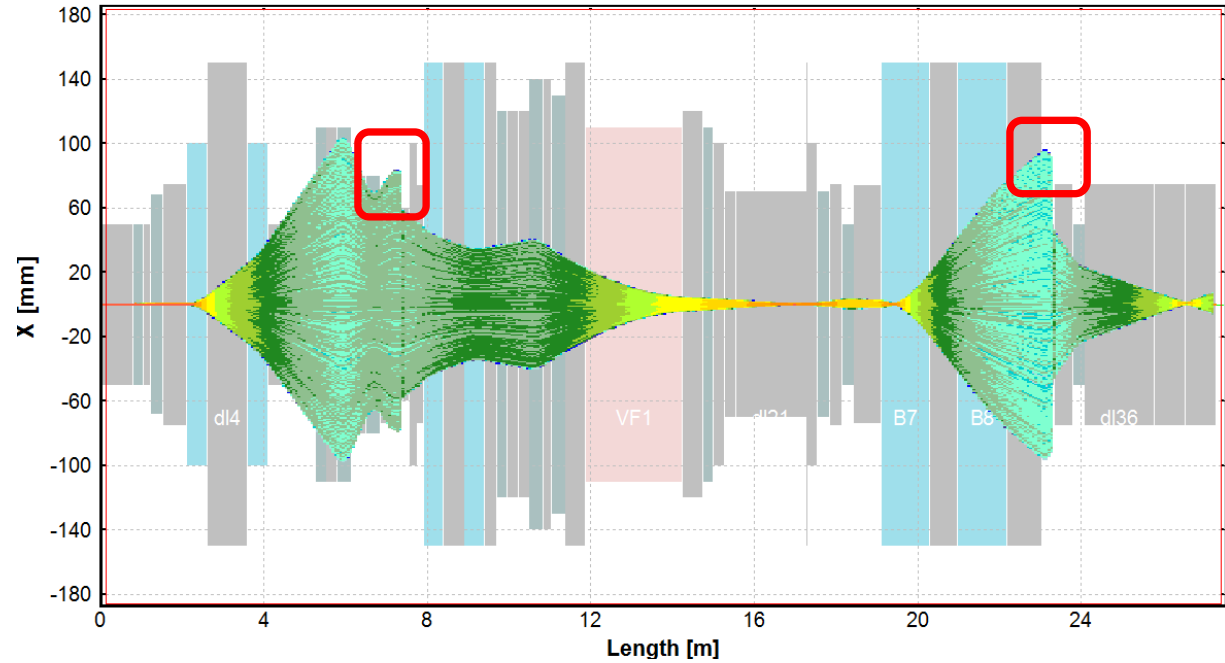
Intensity lost



1st order

Emittance		
	Beam CARD (sigma, semi-axis, half-width...)	1D - shape (Distribution method)
1. X mm	0.1	Gaussian
2. T mrad	0.1	Gaussian
3. Y mm	0.1	Gaussian
4. P mrad	0.1	Gaussian
5. L mm	0	Gaussian
6. D %	5	Rectangle uniform

AngAccept: Off; Bounds: ON; "dl38" - last block for MC calc; no gates; Optics Order: 1



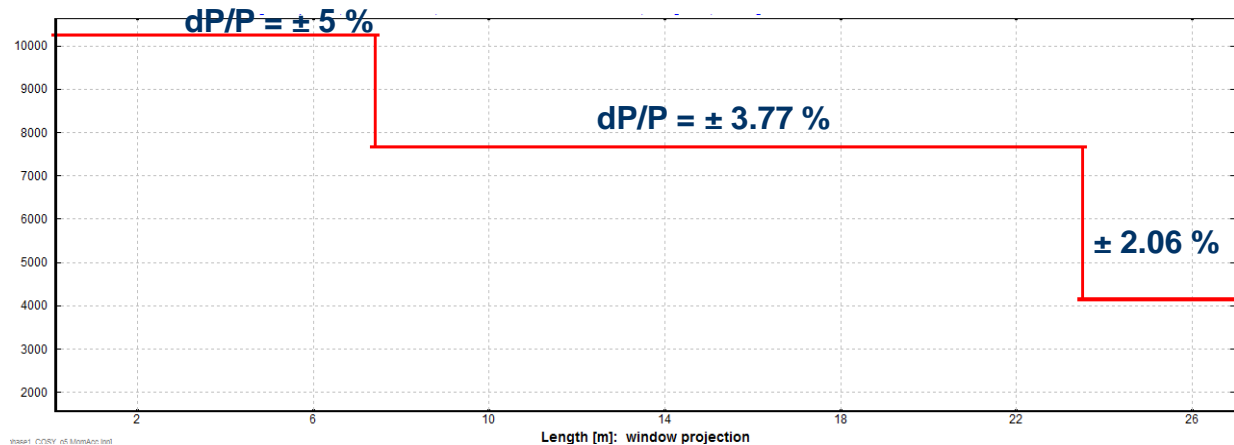
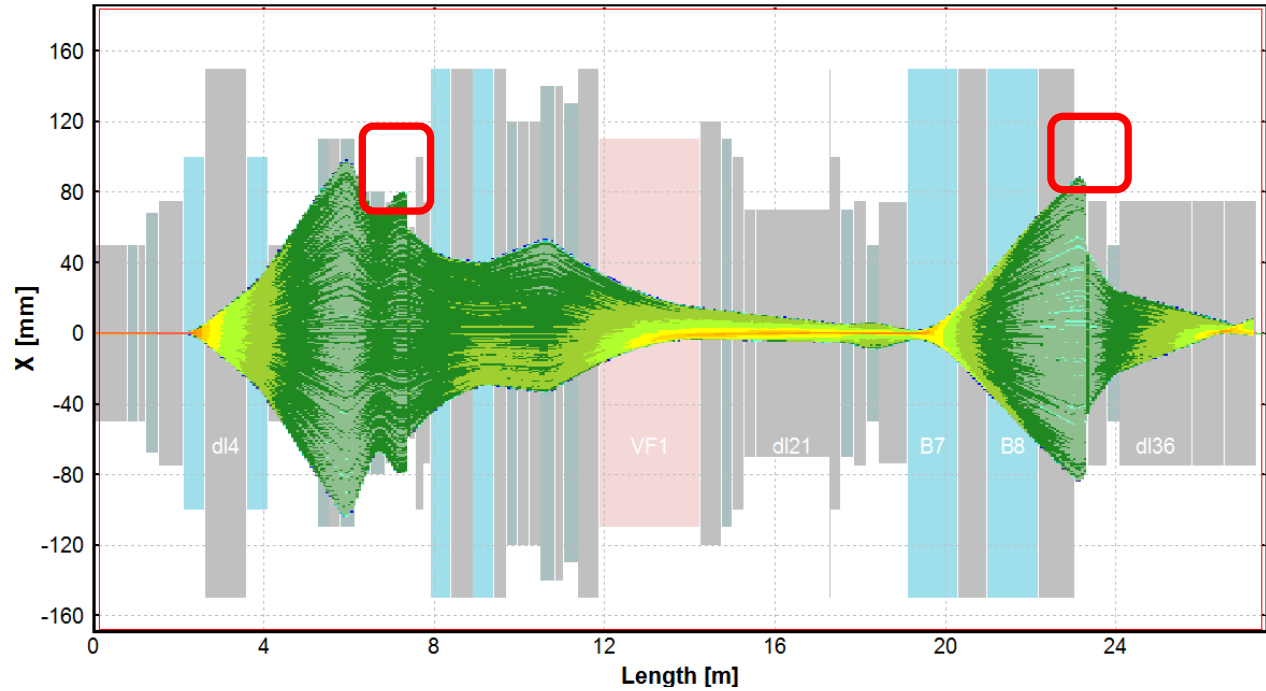
20 CARISSEAR phase1 COSY e5 MomAcc.tool

Length [m]: window projection

AngAccept: Off; Bounds: ON; "dl38" - last block for MC calc; no gates; Optics Order: 5

5th order

Emittance		
	Beam CARD (sigma, semi-axis, half-width...)	1D - shape (Distribution method)
1. X	mm 0.1	Gaussian
2. T	mrad 0.1	Gaussian
3. Y	mm 0.1	Gaussian
4. P	mrad 0.1	Gaussian
5. L	mm 0	Gaussian
6. D	% 5	Rectangle uniform

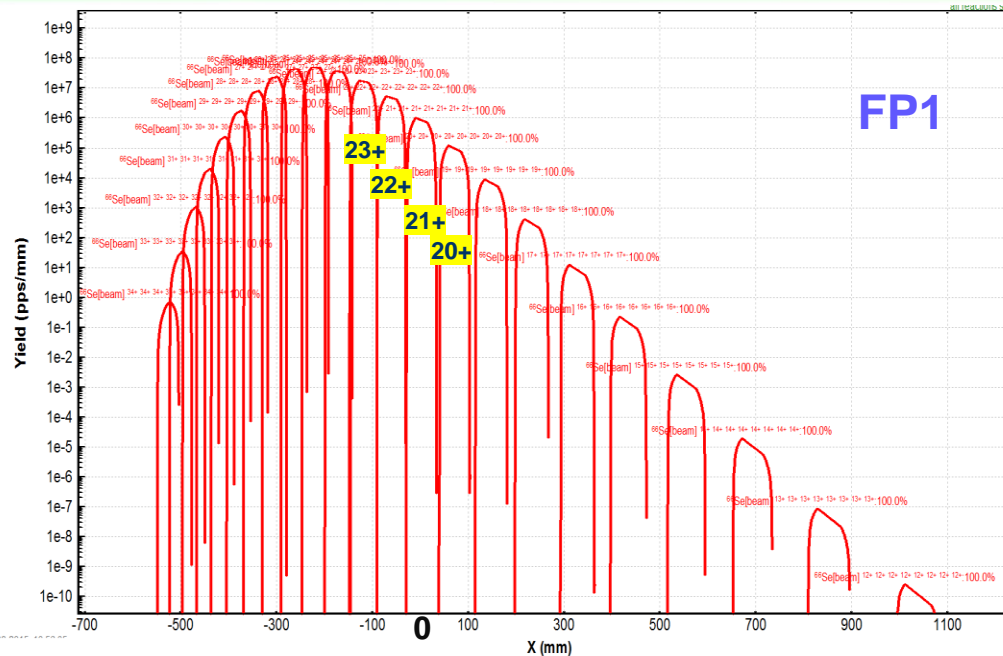


source: CERN ATLAS/ALICE

Length [m]: window projection

File: e_SECAR_p1_COSY.lpp

No slits, no apertures

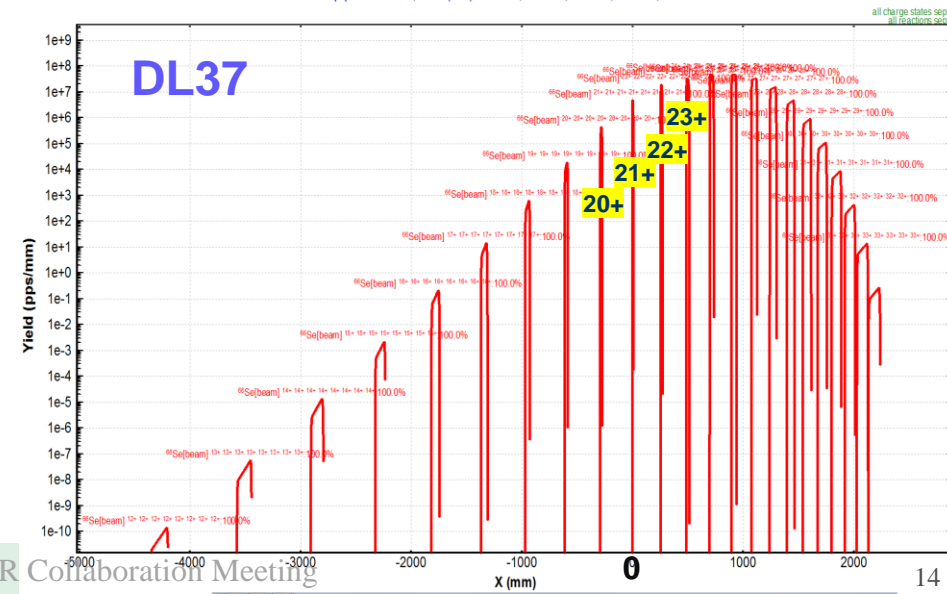
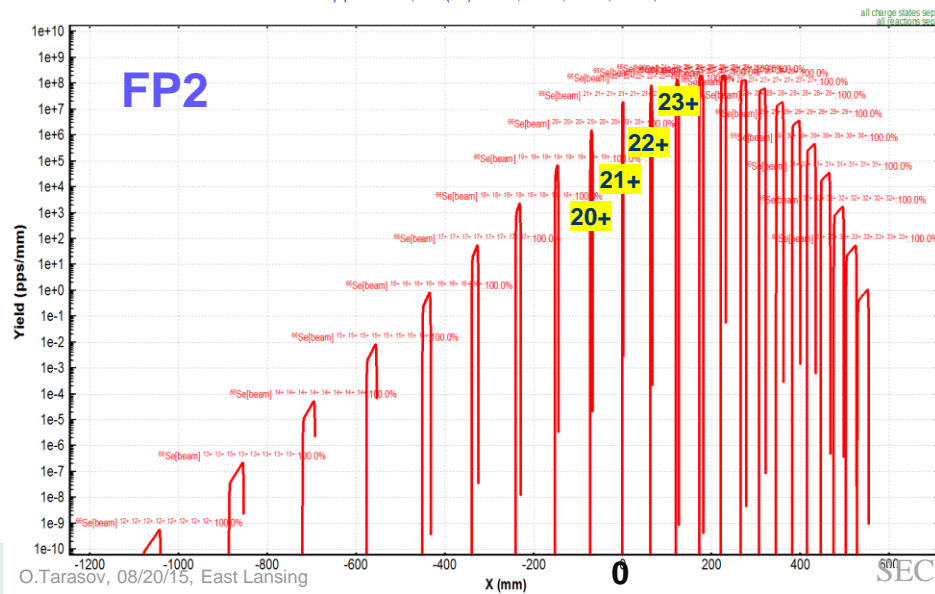


slits FP2 : Beam & SetFragment Charge States

^{66}Se (3.1 MeV/u) + Be (1e-4 mg/cm²); Settings on $^{66}\text{Se}^{21+, 21+}$; Config: DSSSSSDSDSSSSSSSSSSSSSDSDS...
dp/p=100.00%; Brho(Tm): 0.7988, 0.7988, 0.7988, 0.7988, 0.7988

dl37 : Beam & SetFragment Charge States

^{66}Se (3.1 MeV/u) + Be (1e-4 mg/cm²); Settings on $^{66}\text{Se}^{21+, 21+}$; Config: DSSSSSDSDSSSSSSSSSSSSSDSDS...
dp/p=100.00%; Brho(Tm): 0.7988, 0.7988, 0.7988, 0.7988, 0.7988...



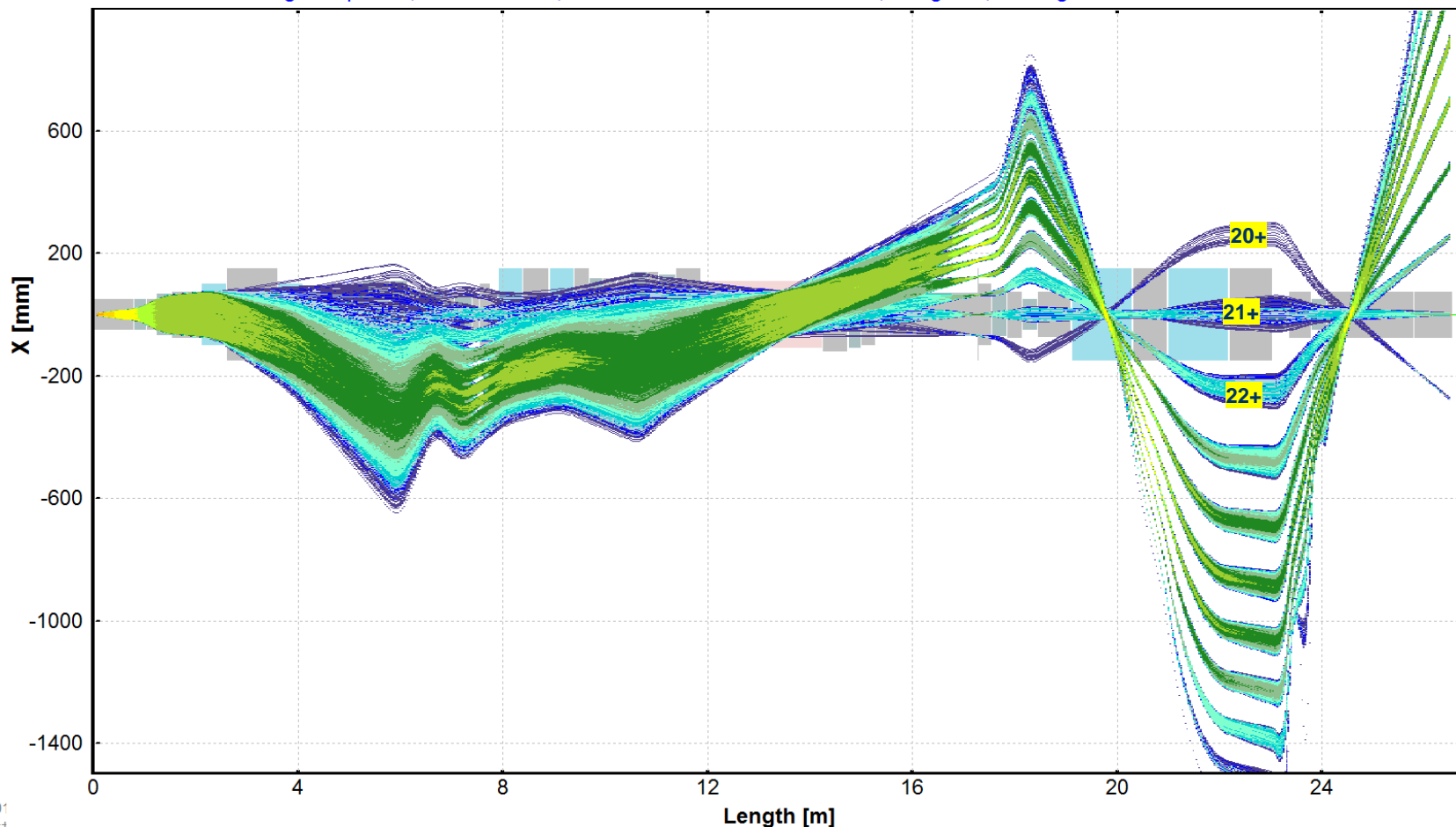
No slits, no apertures

1st order

Isotope Group : MC Yield Plot - Envelope (only passed)

⁶⁶Se (3.1 MeV/u) + Be (1e-4 mg/cm²); Transmitted Fragment ⁶⁶Se^{21+..21+} (beam); Optics Order: 1
 dp/p=100.00% ; Brho(Tm): 0.7988, 0.7988, 0.7988, 0.7988, 0.7988....

AngAccept: Off; Bounds: Off; "dl37" - last block for MC calc; no gates; Config: DSSSSSDSDSSSSSSSSSSSSSSSDSD!



01
++

Table 3.14. Transmission results for a set of crucial reactions from the target to the final focus in the single VF system.

Reaction	Energy (MeV/u)	Transmission
$^{15}\text{O}(\alpha, \gamma)^{19}\text{Ne}$	0.3	95

LISE++ settings

File: e_SECAR_phase1_reaction.lpp

Target

Gas density

He These calculations are correct just for molecular formula !!!

Parameter	Value	Dimension
Temperature (K)	293.15	K
Pressure (Torr)	10 / 760	Torr
Density	0.00219 / 0.166	mg/cm3 kg/m3 g/L

Units converter Fix Cancel

Target

He Density 2.1897e-6 g/cm3

Use in Q-state calculations Calculate density

Z	Element	Mass	Stoich
<input checked="" type="checkbox"/> 2	He	PT	4.003 / 1
<input type="checkbox"/> 14			
<input type="checkbox"/> 14			
<input type="checkbox"/> 14			
<input type="checkbox"/> 14			

Compound dictionary

State: Solid Gas Dimension: mg/cm2 & micron g/cm2 & mm Angle: 0 degrees

Thickness at 0 degrees: 100 mm 2.1897e-5 g/cm2

Effective Thickness: 100 mm 2.1897e-5 g/cm2

Thickness defect Absorbed Dose

Energy Loss in the target box [KW]: 2.91e-5

Atoms / cm2: 3.29e+18

OK Cancel

Beam

Beam

A Element q+ 15 0 5

Beam energy: Energy 0.3 MeV/u, TKE 4.5 MeV, Btho 0.2366 Tm, P 0.3547 GeV/c, U 900 KV

Beam intensity: 500 enA, 100 pA, 6.25e+11 pps, 0.00045 KW

Emittance: Beam CARD (sigma, semi-axis, half-width...), 1D - shape (Distribution method)

1. X mm	0.75	Rectangle uniform
2. T mrad	1	Rectangle uniform
3. Y mm	0.75	Rectangle uniform
4. P mrad	1	Rectangle uniform
5. L mm	0	Gaussian
6. D %	1	Rectangle uniform

Energy Loss in the target box [KW]: 2.91e-5

Ok Cancel

Production mechanism

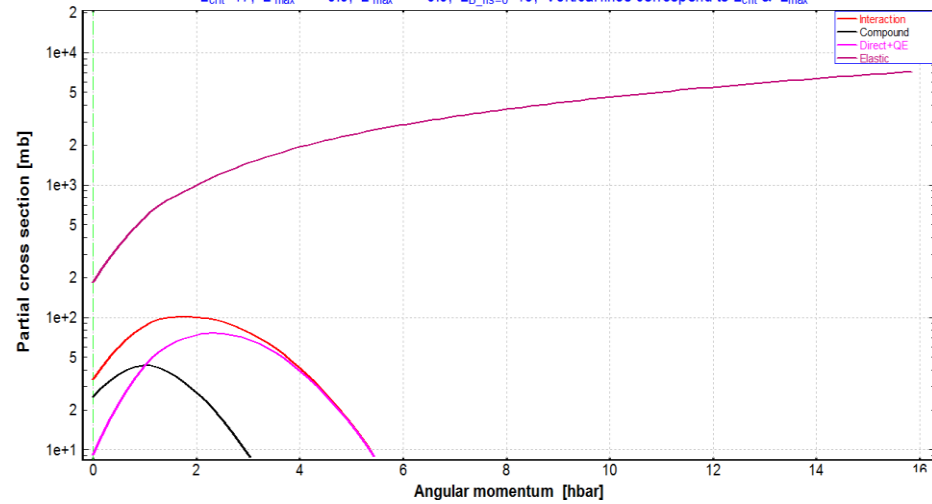
Settings Fusion -> Residual

Charge states: 5 - [< 15AMeV] G.Schiwietz, P.Grande, NIM B175-177 (2001) 125-131

Energy Losses: 1 - [H -base] J.F.Ziegler et al, Pergamon Press, NY (low energy)

Partial cross sections

$^{15}\text{O}(0.3 \text{ MeV/u}) + ^4\text{He} \rightarrow ^{19}\text{Ne}^* (E_{\text{CM}}=0.9 \text{ MeV})$; [no P_{CN} , Penetration $^{\text{Q.M}}$]
 Cross Sections[mb]: Intr=3.61e+02; Comp=1.07e+02; QE=2.54e+02;
 $L_{\text{crit}}=17$; $L_{\text{max}}^{\text{Graz}}=0.0$; $L_{\text{max}}^{\text{LISE}}=0.0$; $L_{\text{B, fis}=0}=19$; Vertical lines correspond to L_{crit} & L_{max}



Fusion information window

$^{15}\text{O}(0.3 \text{ MeV/u}) + \text{He} \rightarrow ^{19}\text{Ne}^* \rightarrow ^{19}\text{Ne}$

Q-value of reaction = 3.528 MeV
Fusion max.barrier = 2.80 MeV
 Fusion radius = 7.15 fm

Depending on a place of reaction in the target

	beginning	middle	end
Beam energy (Lab) [MeV/u]	0.30	0.29	0.28
Beam energy (Lab) [MeV]	4.5	4.3	4.2
Center of mass energy [MeV]	0.95	0.92	0.88
Excitation energy [MeV]	4.48	4.44	4.41
Compound recoil energy [MeV]	3.6	3.4	3.3

Fusion cross section [mb] 130 130 129
 Fusion- 1st Fission CS [mb] 0 0 0
 Fusion-Breakup CS [mb] 0 0 0

for setting residue after the stripper

Energy diapason (MeV/u) 0.170 ⇄ 0.174
 Corresponding ion charge state 3.31 ⇄ 3.35

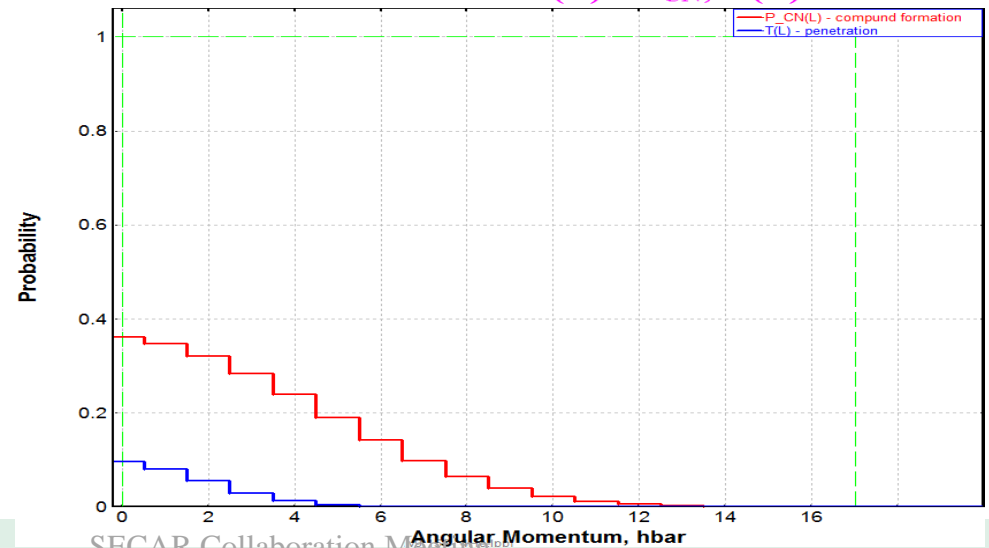
Plot the excitation function

All fusion characteristics are calculated with BASS-model

Fusion-Residue calculator

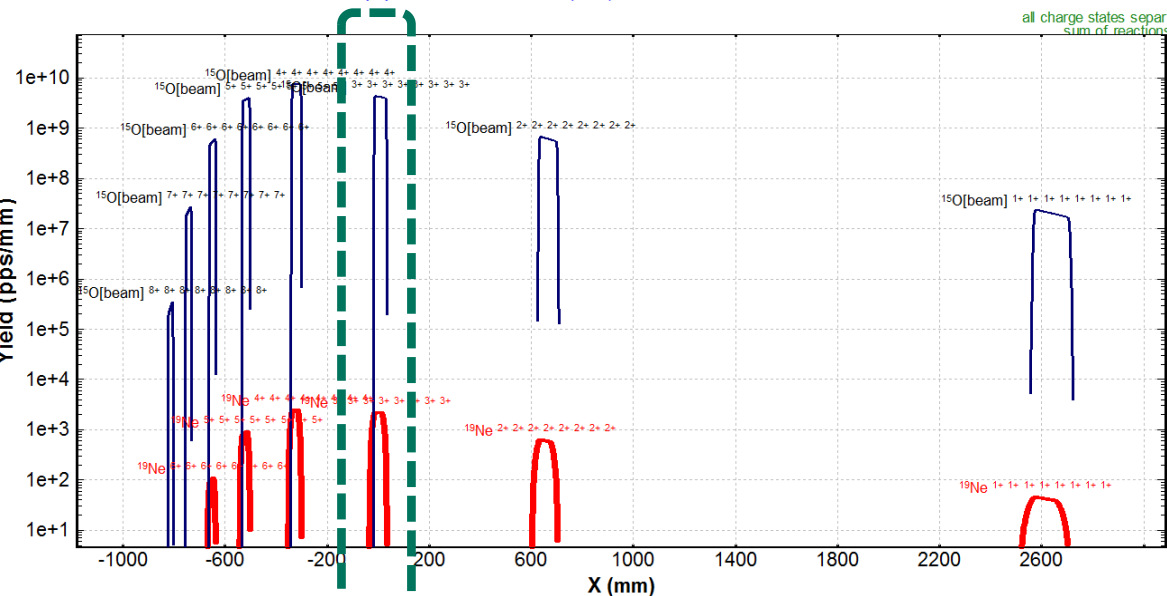
Quit

Probabilities as f(L): P_{CN} , $T(L)$



slits FP1-Xspace: output after slits

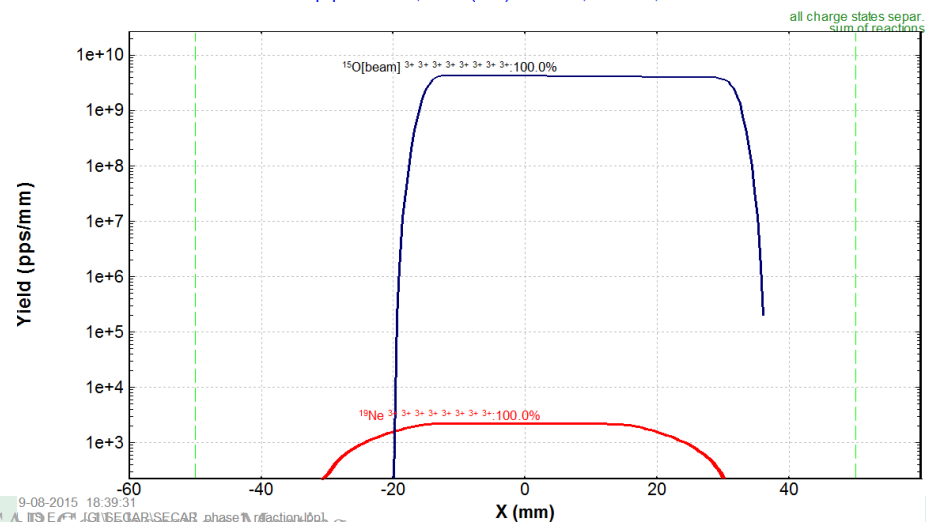
^{15}O (0.3 MeV/u) + He (100 mm); Settings on $^{19}\text{Ne}^{3+..3+}$; Config: DSSFSSSFSDSDFSSSFSSSFSSSF...
 dp/p=100.00% ; Brho(Tm): 0.3783, 0.3783, 0.3783

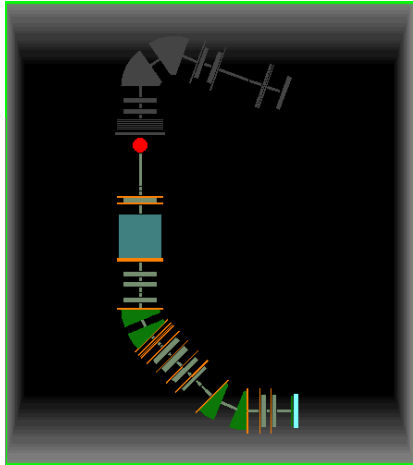


@ FP1 slits →

slits FP1-Xspace: output before slits

^{15}O (0.3 MeV/u) + He (100 mm); Settings on $^{19}\text{Ne}^{3+..3+}$; Config: DSSFSSSFSDSDFSSSFSSSFSSSF...
 dp/p=7.65% ; Brho(Tm): 0.3783, 0.3783, 0.3783

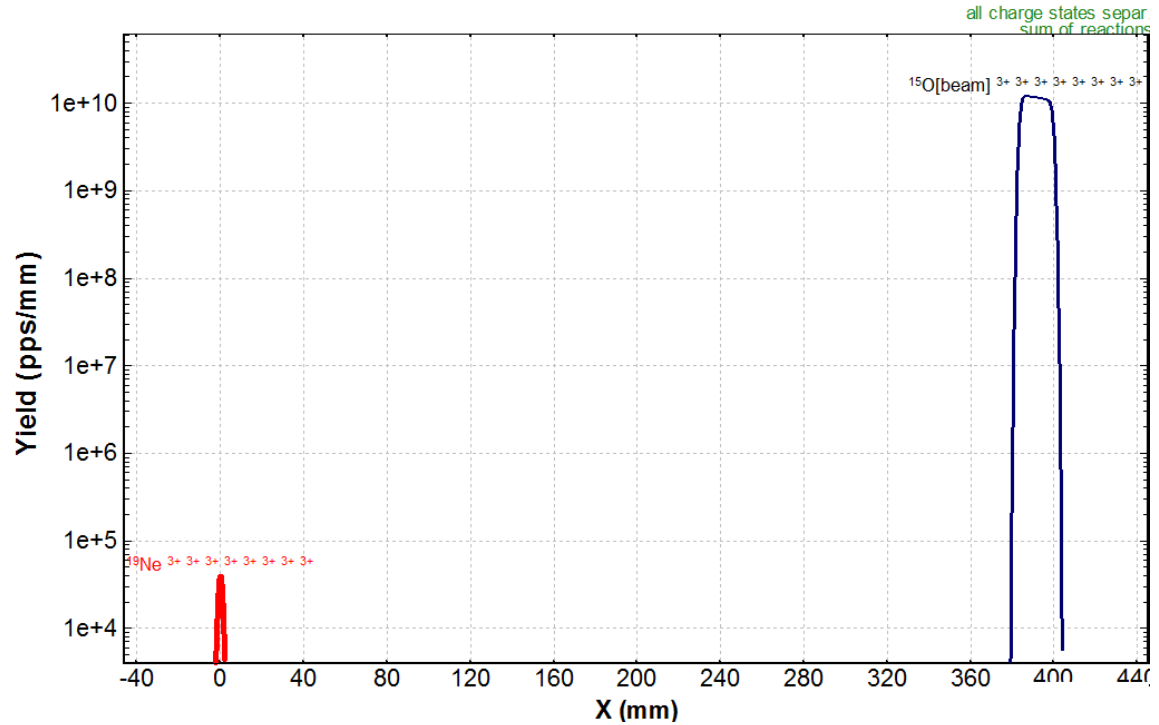




In front of the Mass Slits (FP2) with the Charge slits and Angular acceptances

dl21-Xspace: output after slits

^{15}O (0.3 MeV/u) + He (100 mm); Settings on $^{19}\text{Ne}^{3+..3+}$; Config: DSSFSSFSFDSDFFSSSFSSF;
dp/p=7.65% ; Brho(Tm): 0.3783, 0.3783, 0.3783, 0.3783, 0.3783



Pay attention for The Wien filter parameters!!!
The purpose of E(or B) choice is to compensate dispersion after dipoles!

	VF1	E	300 KV/m
		B	520.67 G
		DL	3.81 mm/%

$^{19}\text{Ne}^{3+}$ after the DL37

Only $^{19}\text{Ne}^{3+}$ passing through the separator !

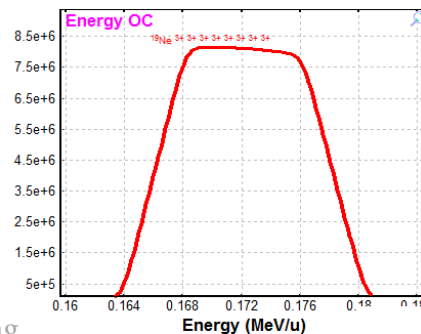
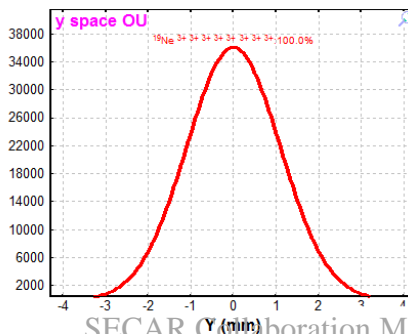
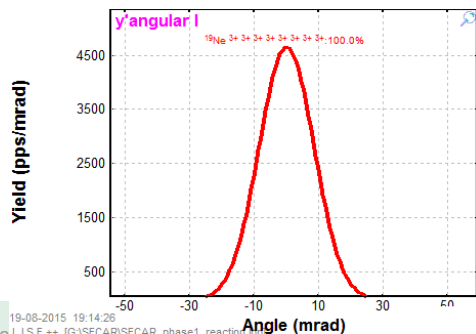
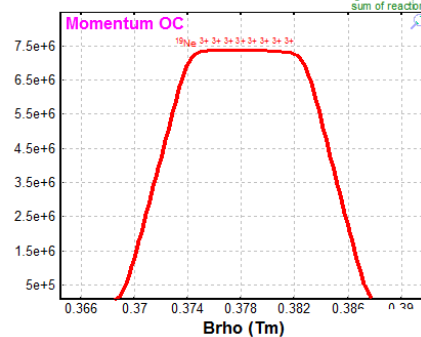
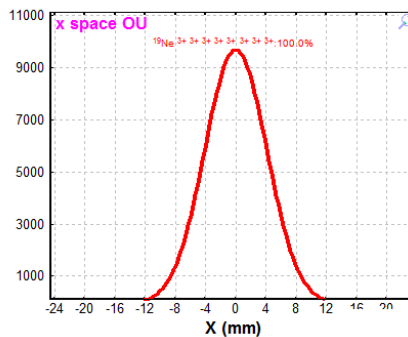
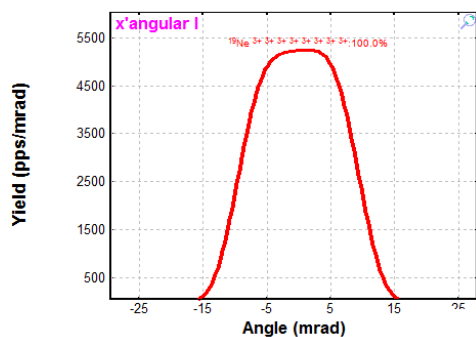
19Ne Beta+ decay (Z=10, N=9)

Q1 (tuning)		3
Reaction		FusRes
Ion Production Rate (pps)		9.9e+4
Total ion transmission (%)		37.077
Total: this reaction (pps)		9.9e+4
Total: All reactions (pps)		9.9e+4
X-Section in target (mb)		1.3e+2
Target (%)		39.09
Unreacted in material (%)		100
Q (Charge) ratio (%)		39.09
Unstopped in material (%)		100
tuning (%)		99.32
X angular transmission (%)		99.32
Y angular transmission (%)		100
d112 (%)		95.59

$^{19}\text{Ne}^{3+}$ transmission 94.8%
Main cut by the 2-nd horizontal angular acceptance

d137

^{15}O (0.3 MeV/u) + He (100 mm); Settings on $^{19}\text{Ne}^{3+..3+}$; Config: DSSFSSSFSDSFSSSFSSSFSSSFSSF...
dp/p=7.65% ; Brho(Tm): 0.3783, 0.3783, 0.3783, 0.3783, 0.3783....



Open Questions:

1. Modify the two-body kinematics mechanism for the HI & γ case
2. Primary beam scattering (large angles)
3. Create the Wien characteristics utility to compensate a dipole dispersion

Acknowledgement:

to Hendrik Schatz and Fernando Motes for documents and files providing,
to Mauricio Portillo with COSY actions

