SHELS: ^{48}Ca(221 MeV) + BiO_2(0.404 mg/cm^2) → $^{255}Lr^{19+}$

LISE^{++} Version 9.10.256
from 01/06/2016

Use the latest version!

- Important updates and modifications recently done

- Reaction mechanism settings
- Beam & Target settings
- Separator settings *(geometry, angular acceptance, charge states)*

- Optics Optimization
- Matrix & Beam sigma envelopes

- Monte Carlo transmission simulation
- Residue transmission analysis

- Primary beam scattering
- Primary beam charge state transmission

Important modifications and update recently done

LISE^{++} code :

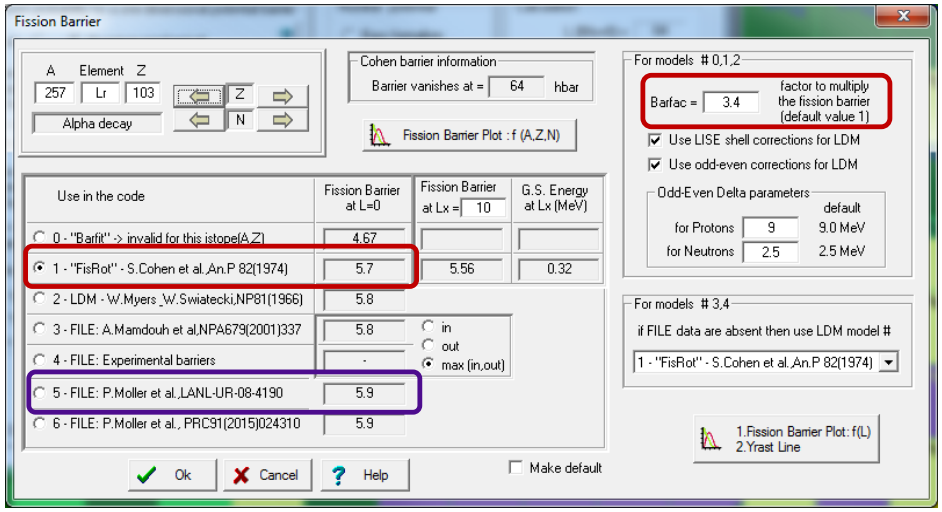
- Correction in angular straggling subroutines for low energy use
- Implementation of the Multi-layers method in MC mode for qualitative estimation of angular straggling and Coulomb scattering
- Modification and correction in the Optics optimizer utility
- Utility “Angular Straggling & Rutherford scattering probabilities”
- Possibility to simulate primary beam scattering

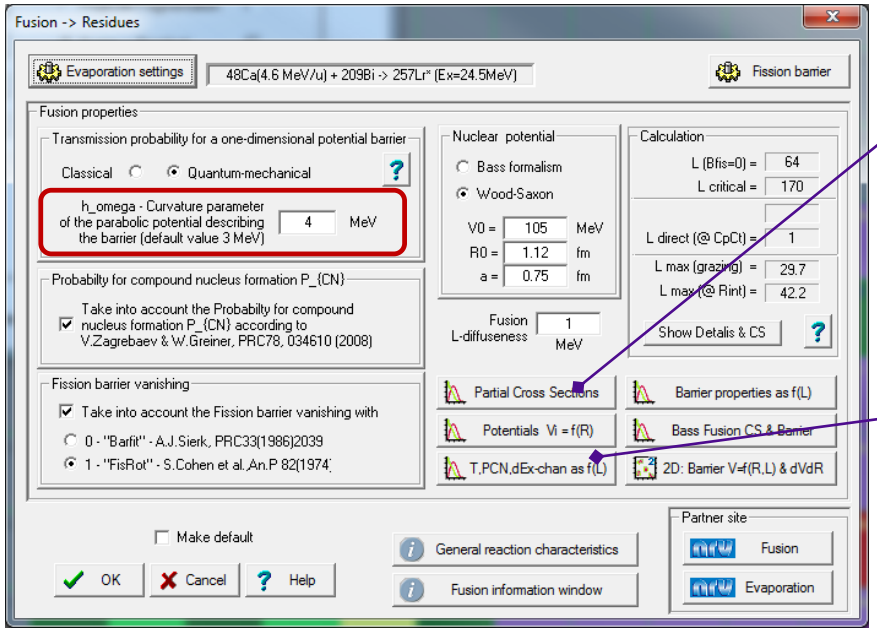
SHELS configuration file :

- Using stripping foil after a target
- Modification of initial emittance (shapes and values)
- Using fixed effective lengths
- Modification of configuration geometry based on the Word file from Autumn 2015 (length, slits and so on)
- Setting reaction mechanism parameters to obtain 300nb 2n-residue cross section

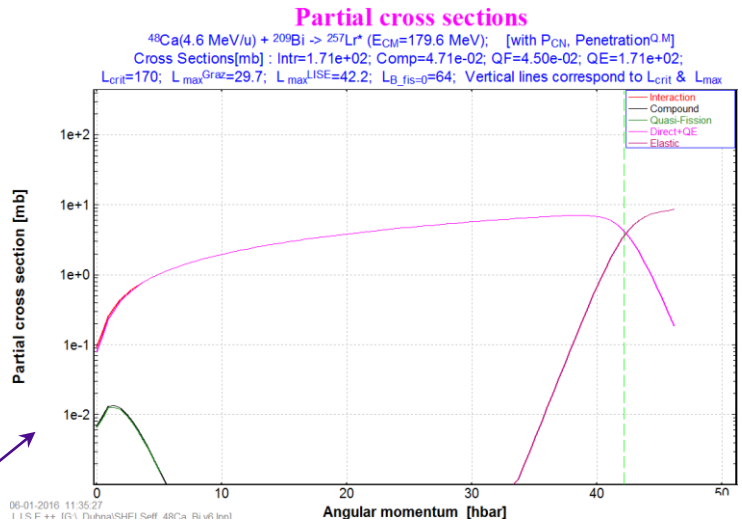
Reaction mechanism settings

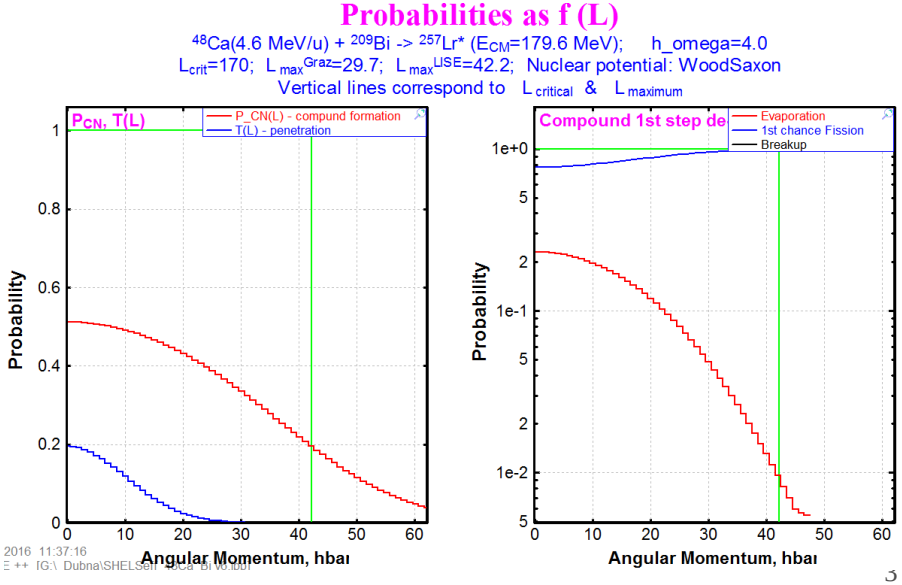
^{48}Ca(221 MeV) + Bi



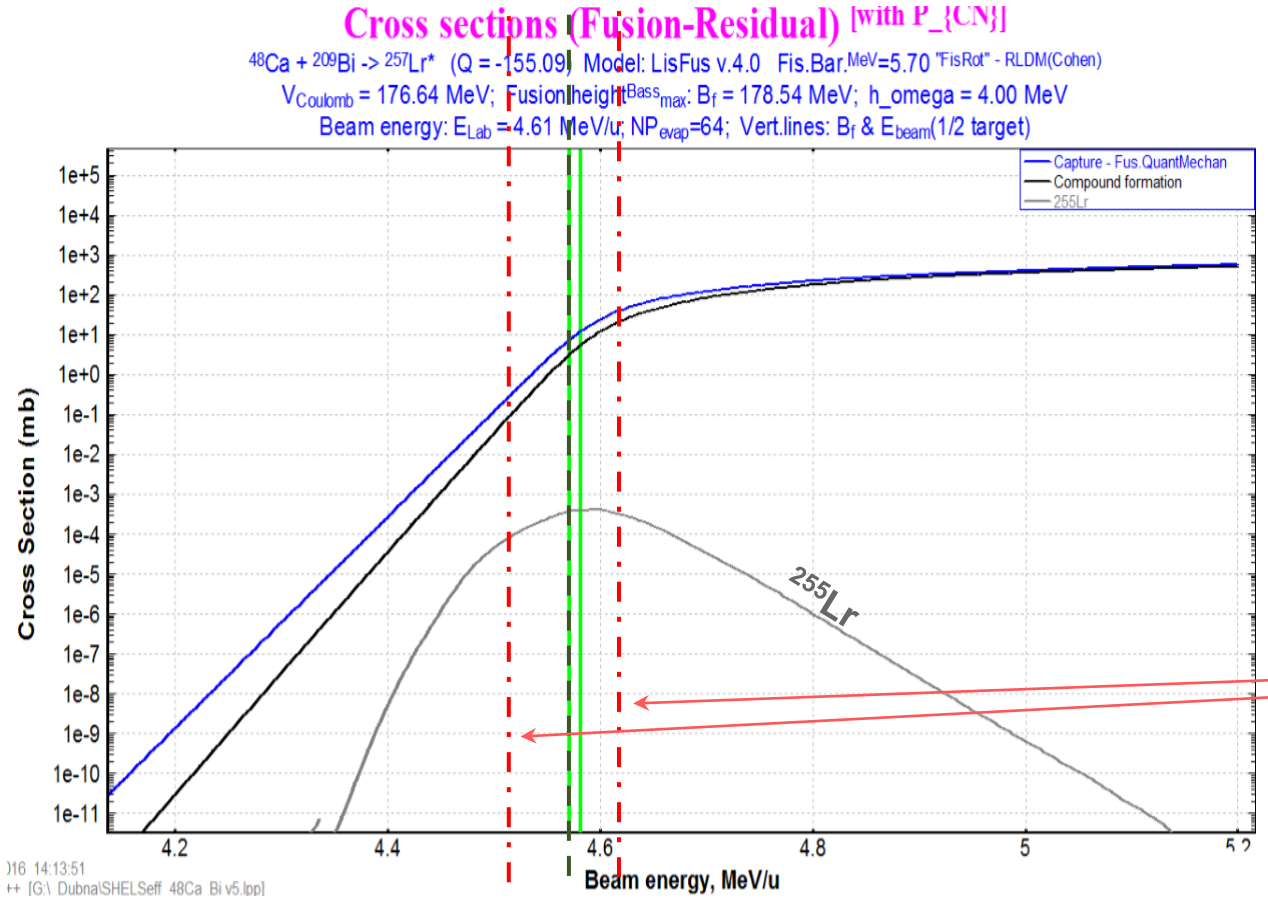


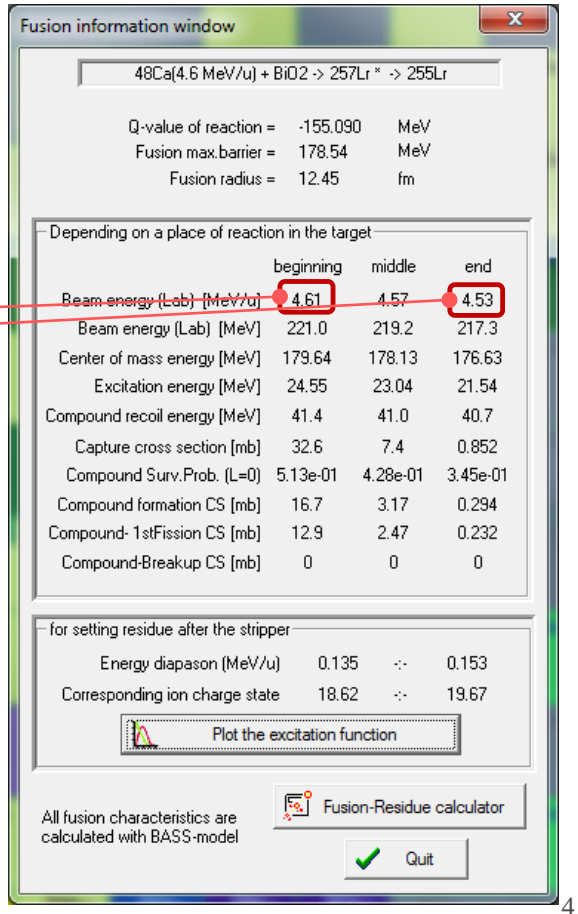
The "Barfit" model was used with BarFac=3.4,
That gives the fission barrier for ^{257}Er equal to 5.7 MeV @ L=0,
Then P.Moller's data give a little bit more (5.9 MeV)





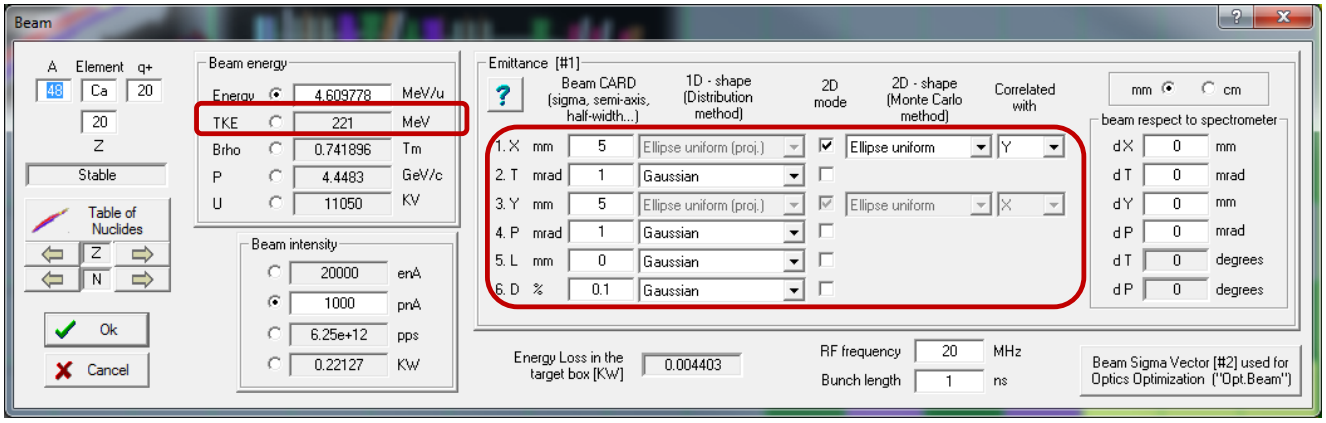
Reaction mechanism : excitation function





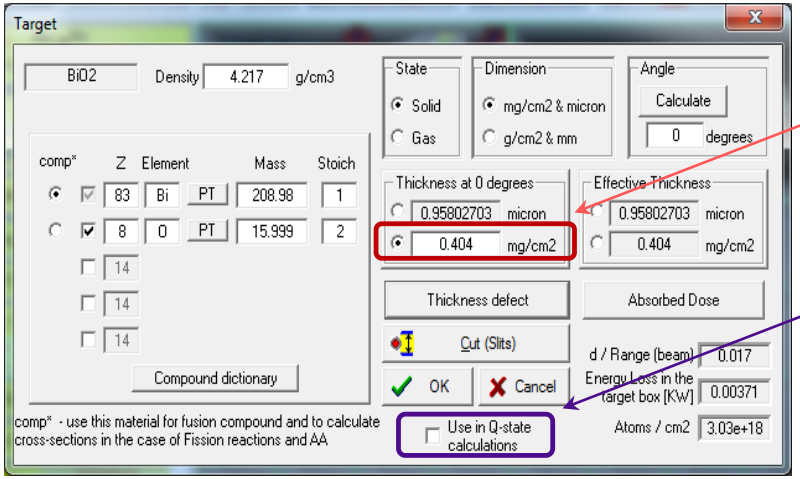
Beam, Target, and Stripper Settings

Beam

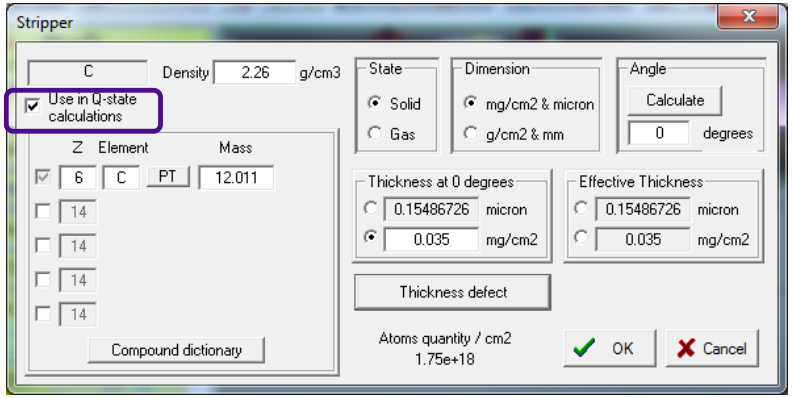


Target

209	Bi	0.35	mg/cm2
		1.01E+18	atoms
16	O	2.69E-02	mg/cm2
		1.01E+18	atoms
BiO2		4.04E-01	mg/cm2



Stripper



Charge State Settings

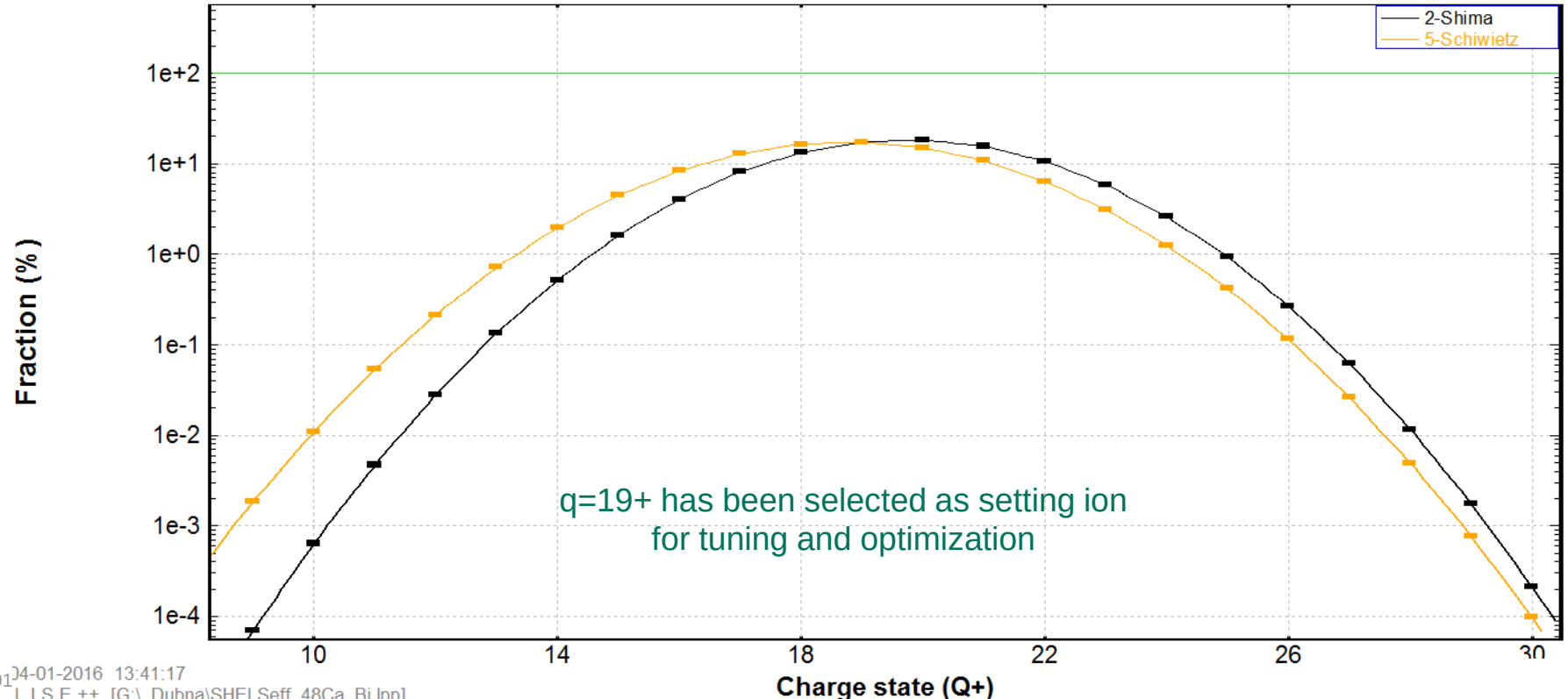
Statistics

255Lr equil.charge distr-n after Stripper (C): Fragment energy = 0.1 MeV/u
48Ca (4.61 MeV/u) + BiO2 (0.4 mg/cm2)
Calculations for 255Lr 19+ 19+ 19+ 19+ 19+ 19+ ; Material C
Charge Distribution Method is 5
Plot 1

N	distribution	x-mean	x-max	y-max	deviation	FWHM	area	SumOfCounts	LeftPsigma	RightPsigma
01	0-Winger	+4.6582e+01	+4.7000e+01	1.962e+01	2.015e+00	4.777e+00	1.0000e+02	1.000e+02	2.309e+00	1.749e+00
02	1-Leon	+1.5138e+01	+1.5000e+01	2.858e+01	1.406e+00	3.315e+00	1.0000e+02	1.000e+02	1.338e+00	1.478e+00
03	2-Shima	+1.9748e+01	+2.0000e+01	1.843e+01	2.160e+00	5.115e+00	1.0000e+02	1.000e+02	2.350e+00	1.994e+00
04	3-GLOBAL+W	+4.6582e+01	+4.7000e+01	1.962e+01	2.015e+00	4.777e+00	1.0000e+02	1.000e+02	2.309e+00	1.749e+00
05	4-GLOBAL+L	+1.5138e+01	+1.5000e+01	2.858e+01	1.406e+00	3.315e+00	1.0000e+02	1.000e+02	1.338e+00	1.478e+00
06	5-Schiwietz	+1.8769e+01	+1.9000e+01	1.738e+01	2.293e+00	5.418e+00	1.0000e+02	1.000e+02	2.465e+00	2.136e+00

255Lr equil.charge distr-n after Stripper (C)

^{48}Ca (4.61 MeV/u) + BiO2 (0.4 mg/cm^2)
Calculations for ^{255}Lr 19+ 19+ 19+ 19+ 19+ 19+ ; Material C
Charge Distribution Method is 5



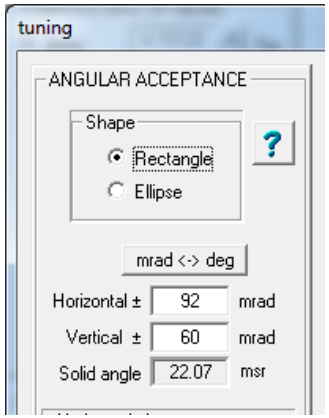
q=19+ has been selected as setting ion
for tuning and optimization

Separator settings (geometry, angular acceptance)

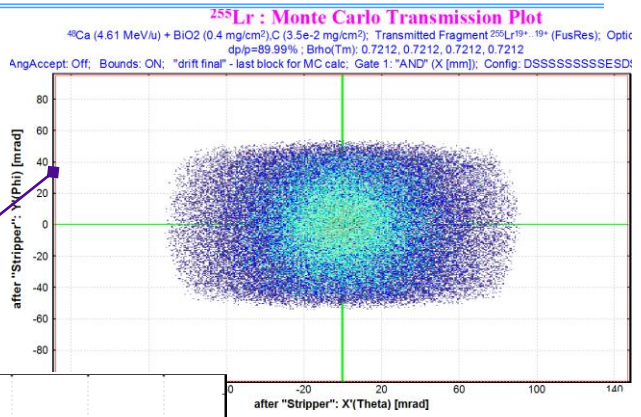
Quadrupole_5	**310мм** длина ярма	Вн.диаметр трубы в Q=**188**мм	**380мм** эффект.длина линзы	**7849**
Расстояние Q5-Q6	**270мм** Ярмо-ярмо	Внутр. диаметр трубы- **188**мм	**200мм** Эфф.границы Q5-Q6	**8049**
Quadrupole_6	**310мм** длина ярма	Вн.диаметр трубы в Q=**188**мм	**380**мм эффект.длина линзы	**8429**
Расстояние Q6-D8	**2115мм** ЯрмоQ6-ярмоD8	Внутр. диаметр трубы- **188**мм	**2036мм= (2115-35-44)** Эфф.гран.**Q6** - эфф.гран **D8**	**10456**
Dipole D8	**500мм** длина ярма D8	**Δ** = 588мм-500мм=88мм **Δ/2 = 44мм** Диаметр отв. во фланцах камеры магнита D8 -**148**мм Угол поворота **7.3°**	**588мм** эффект.длина D8	**11053**
D8-detector	**1558мм** ярмоD8- детектор	*Расстояние до детектора может варьироваться в зависимости от установленных детекторов*	**1514мм= (1558-44)** эфф.гран. **D8** - детектор	**12567**
	Длина по железу ***12541 мм***			*Длина по траектории* ***12567 мм***

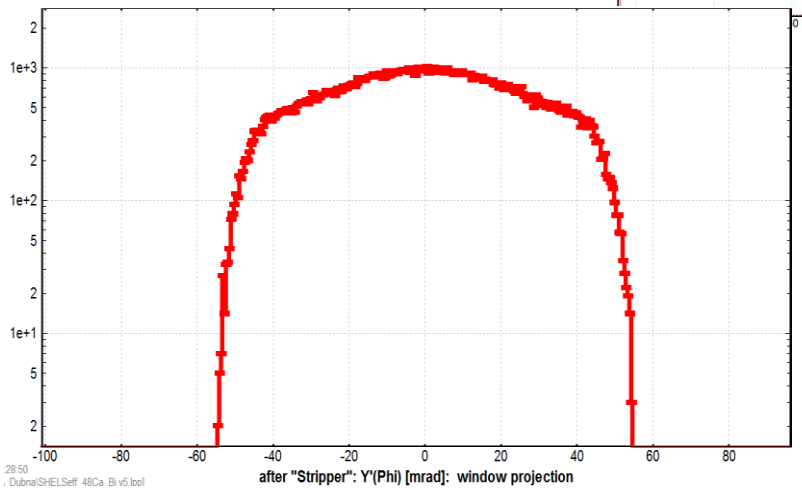
- Effective quad lengths have been fixed
- The geometry after D8 has been corrected

The Angular acceptance (used in the Distribution mode) vertical component has been modified based on MC transmission results after the optics optimization (will be discussed later).
New parameters give significantly better agreement between MC and analytical results

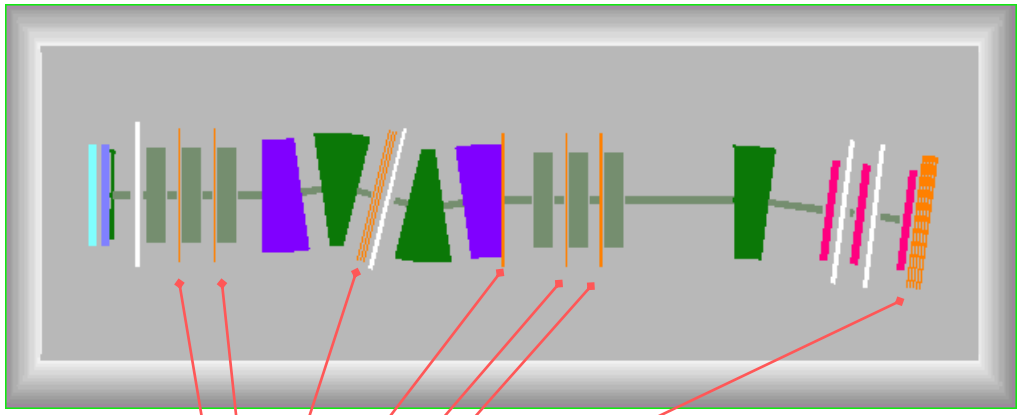


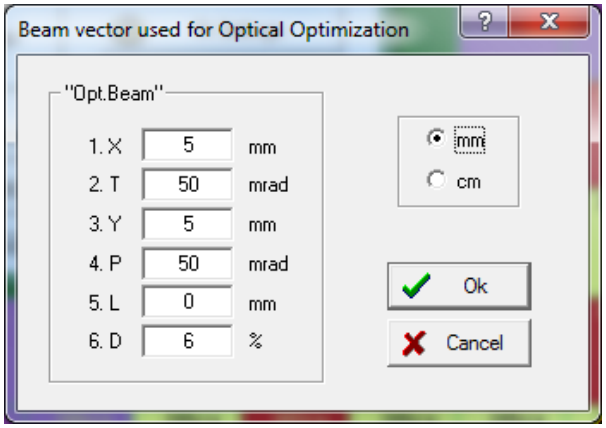
Previous values were 93 & 46





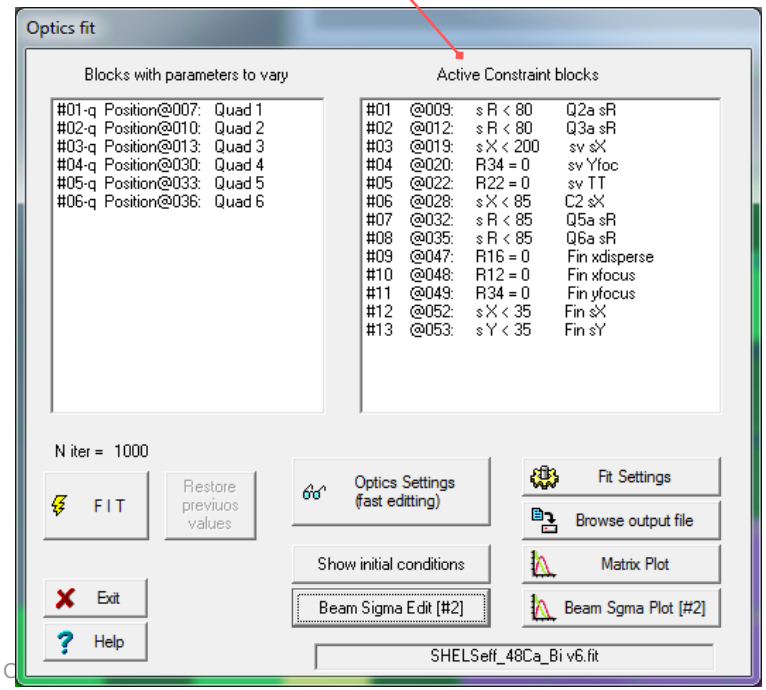
Optics optimization : main priority is high transmission





The beam emittance used for optimization was significantly increased

constraints

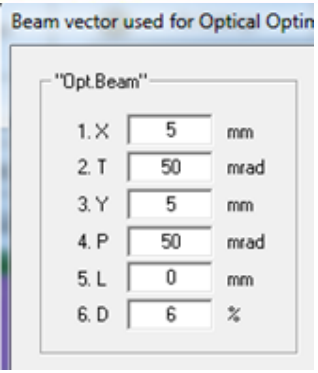


RESULTS

c:\program files (x86)\lise\results\SHELSeff_48Ca_Bi v6.fit_init

```
chi2: Initial     3.78756  LISE fit reduced values
chi1: Initial     9.94536  LISE fit reduced values

Parameters:          LeftBound       Initial      RightBound   |
#01-q: Quad 1       -1.0e+99  <  +4.515e+00  <  +1.0e+99     |
#02-q: Quad 2       -1.0e+99  <  -4.443e+00  <  +1.0e+99     |
#03-q: Quad 3       -1.0e+99  <  +1.912e+00  <  +1.0e+99     |
#04-q: Quad 4       -3.0e+00  <  +7.515e-01  <  +3.0e+00     |
#05-q: Quad 5       -1.0e+01  <  -2.510e+00  <  +0.0e+00     |
#06-q: Quad 6       +0.0e+00  <  +1.407e+00  <  +1.0e+01     |

Constraint values:    Initial        Y-value       Precision   (Init-Des)/?|     Desired
#01: Q2a sR          +8.048e+01     +8.048e+01      1.0e+00    +4.823e-01    |  < 80
#02: Q3a sR          +8.356e+01     +8.356e+01      1.0e+00    +3.558e+00    |  < 80
#03: sv sX           +6.099e+01     +2.000e+02      1.0e+00     0            |  < 200
#04: sv Yfoc         +1.390e-01     +1.390e-01      1.0e-01    +1.390e+00    |  = 0
#05: sv TT           -1.699e-02     -1.699e-02      1.0e-02    +1.699e+00    |  = 0
#06: C2 sX           +6.552e+01     +8.500e+01      1.0e+00     0            |  < 85
#07: Q5a sR          +8.484e+01     +8.500e+01      1.0e+00    +8.519e-04    |  < 85
#08: Q6a sR          +8.406e+01     +8.500e+01      1.0e+00    +3.912e-04    |  < 85
#09: Fin xdisperse   +6.931e-01     +6.931e-01      5.0e-01    +1.386e+00    |  = 0
#10: Fin xfocus      +3.089e-01     +3.089e-01      5.0e-01    +6.178e-01    |  = 0
#11: Fin yfocus      +2.116e-01     +2.116e-01      1.0e+00    +2.116e-01    |  = 0
#12: Fin sX          +3.506e+01     +3.506e+01      1.0e-01    +5.989e-01    |  < 35
#13: Fin sY          +3.027e+01     +3.500e+01      1.0e-01    +8.817e-05    |  < 35

==> "Fin sY" : last fitting block global optical matrix and sigma vector

                                                  Format [mm-mrad]
=================== G L O B A L ====  matrix ==================  | Beam(sigma) |
   -6.239e+00  +3.089e-01   0            0          0    +6.931e-01  |    3.51e+01 |
   +4.359e-01  -1.819e-01   0            0          0    +1.981e+00  |    1.51e+01 |
    0           0          +5.672e+00  +2.116e-01   0     0          |    3.03e+01 |
    0           0          +1.928e+00  +2.482e-01   0     0          |    1.57e+01 |
   +1.267e+00  -7.382e-02   0            0          1.0   +1.636e+00  |    1.23e+01 |
    0           0           0            0          0     +1.000e+00  |    6.00e+00 |
```

Optics optimization

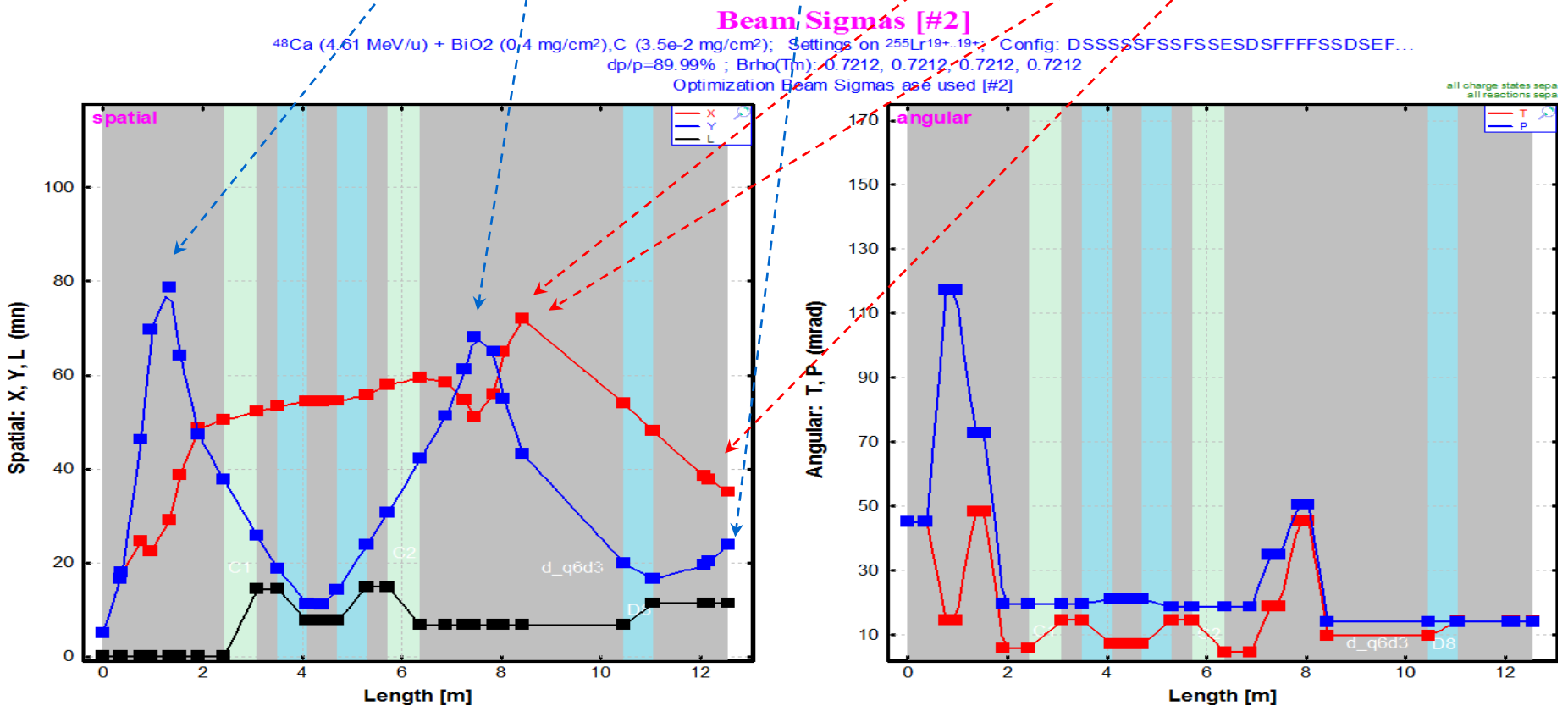


Due to large Y-spatial emittance

Due to large Y-angular emittance

Due to large X-angular emittance

Due to large X-spatial emittance



Optics optimization : Beam spatial sigma plots

"Opt.Beam"

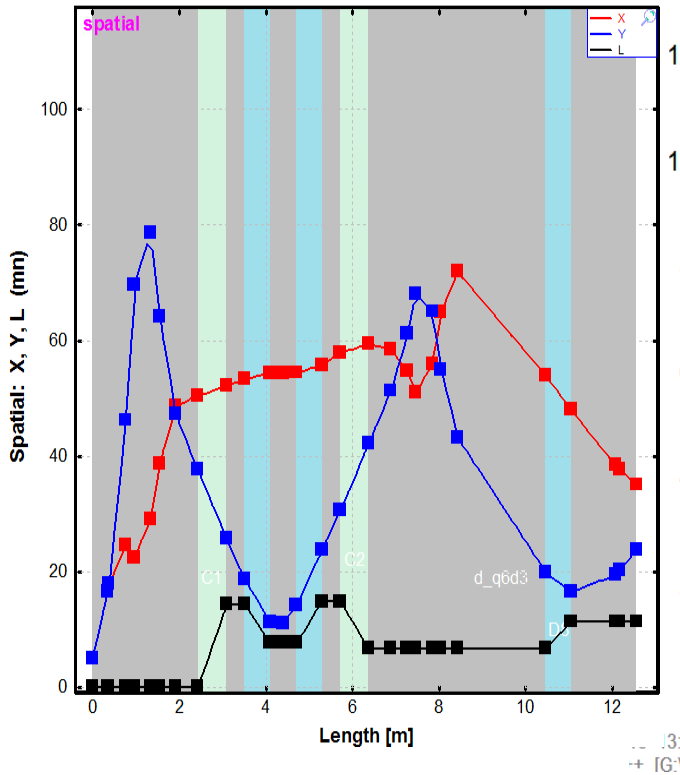
1. X	5	mm
2. T	50	mrad
3. Y	5	mm
4. P	50	mrad
5. L	0	mm
6. D	6	%

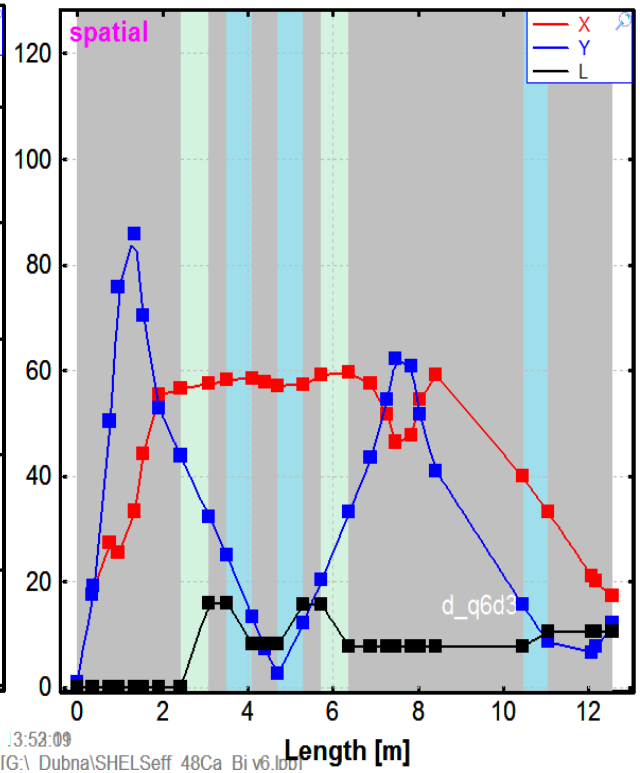
"Opt.Beam"

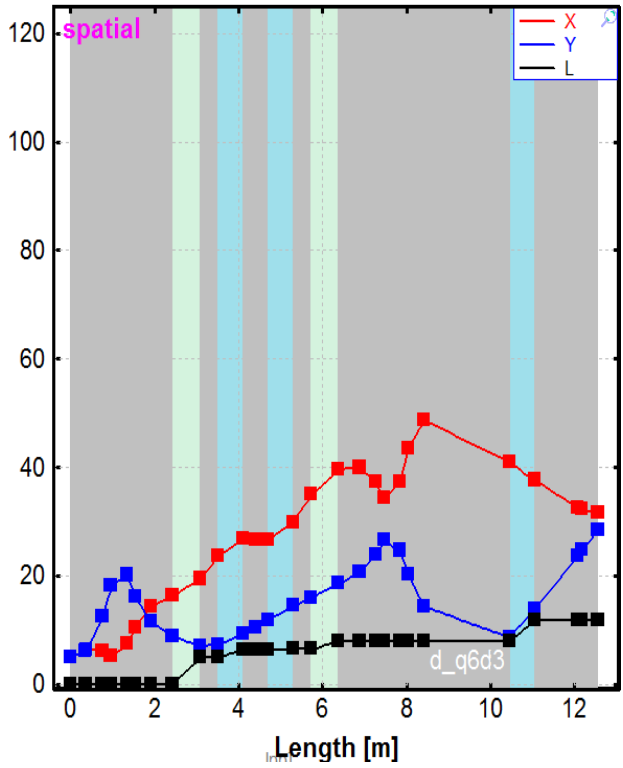
1. X	1	mm
2. T	50	mrad
3. Y	1	mm
4. P	50	mrad
5. L	0	mm
6. D	6	%

"Opt.Beam"

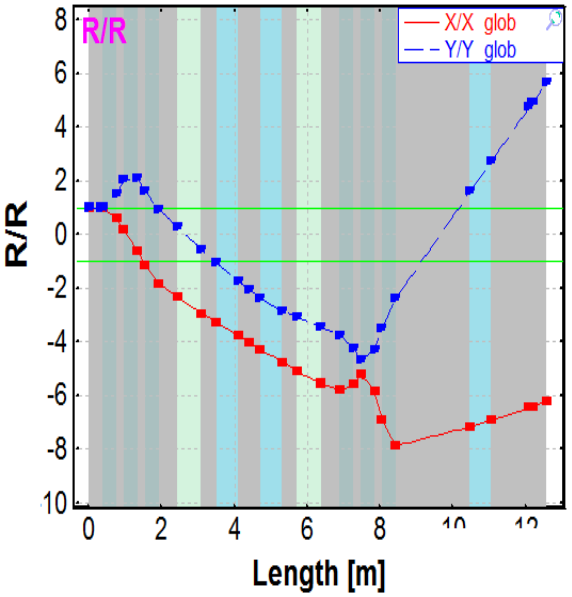
1. X	5	mm
2. T	10	mrad
3. Y	5	mm
4. P	10	mrad
5. L	0	mm
6. D	6	%

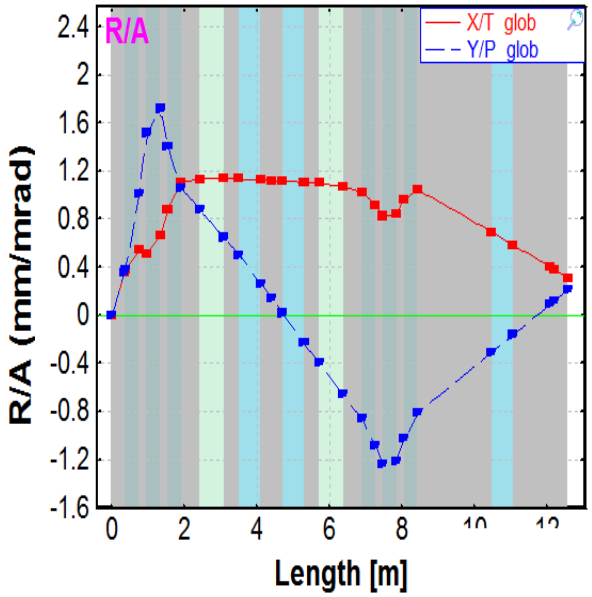


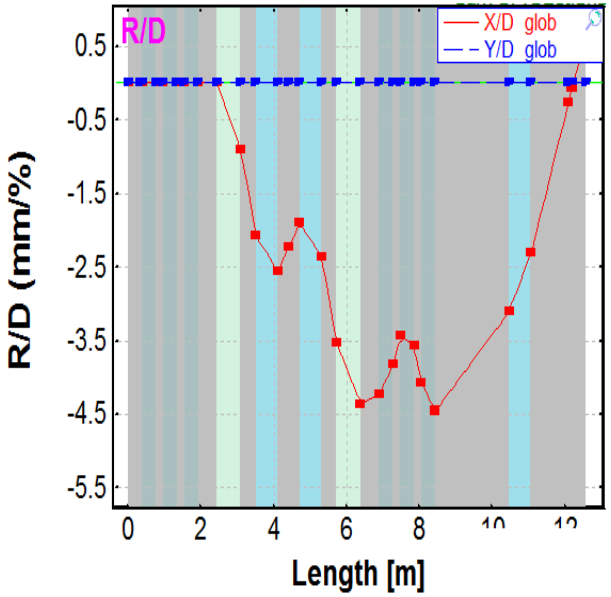


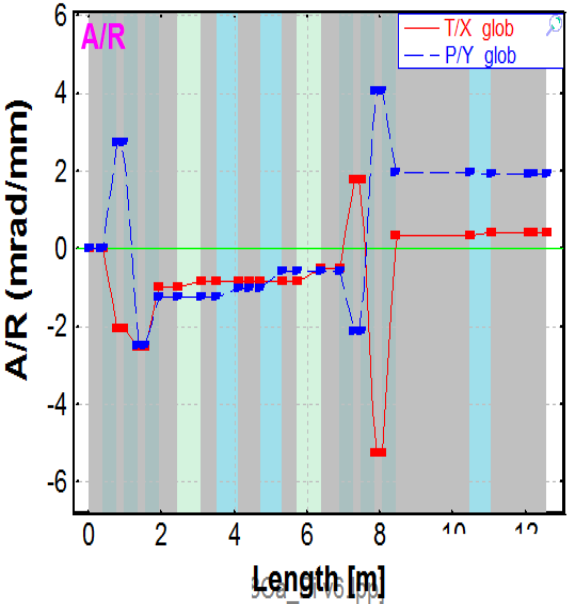


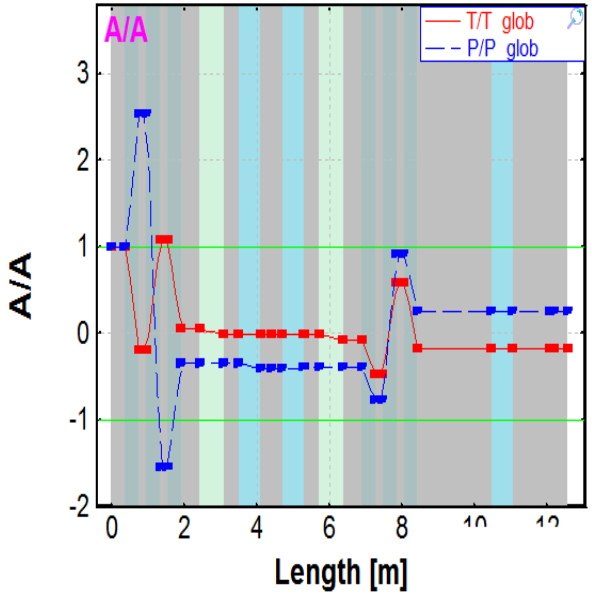
Matrix elements after the optimization

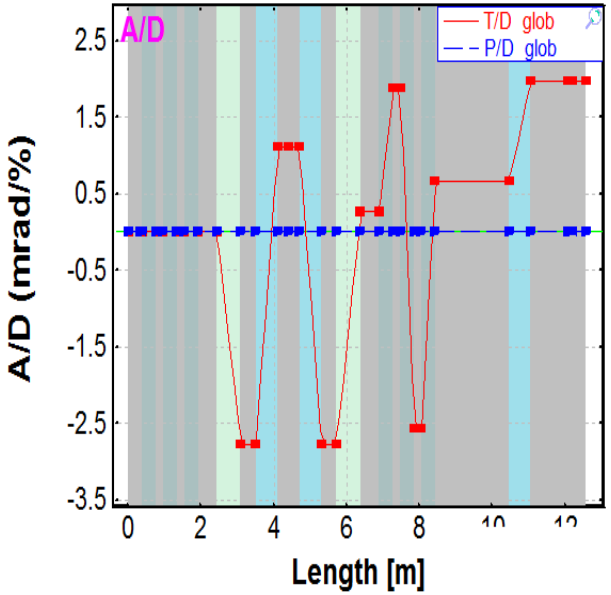








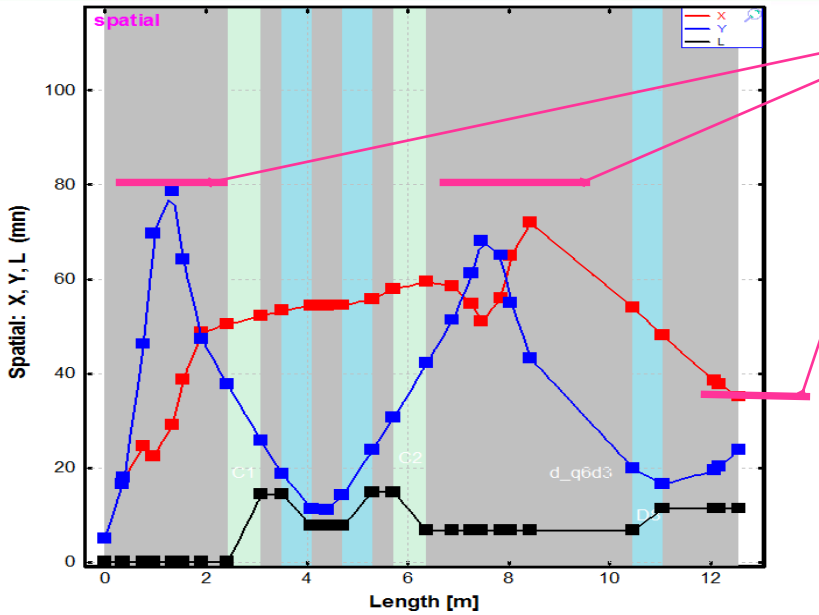


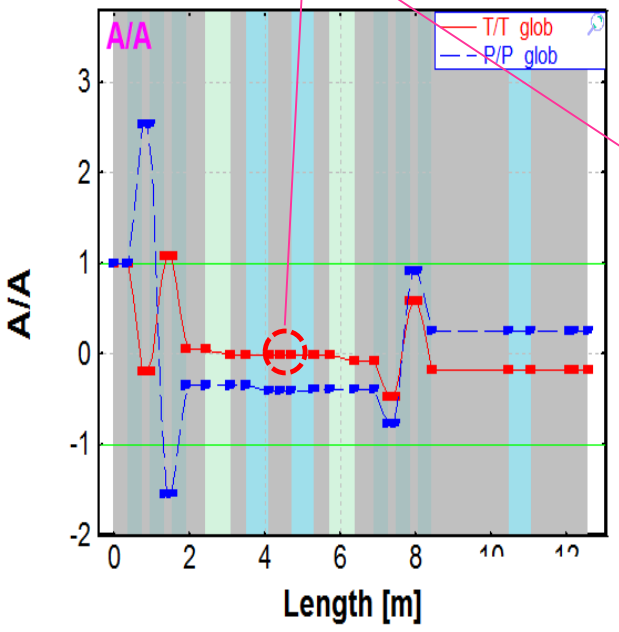


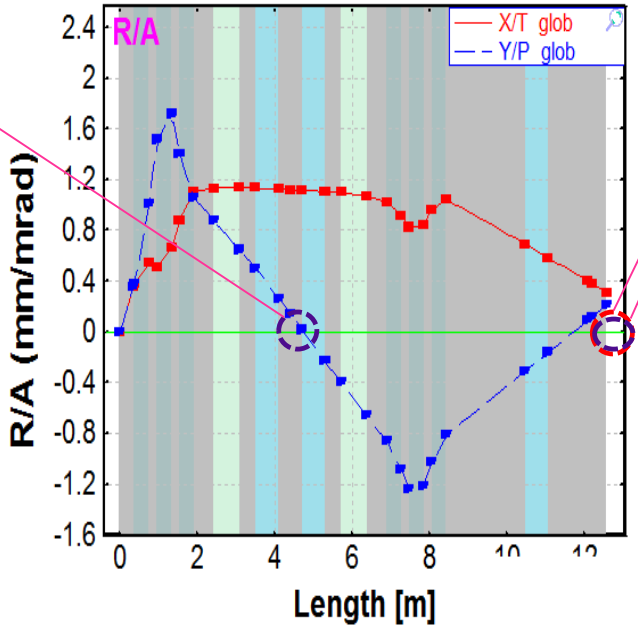
Optics optimization : constraints

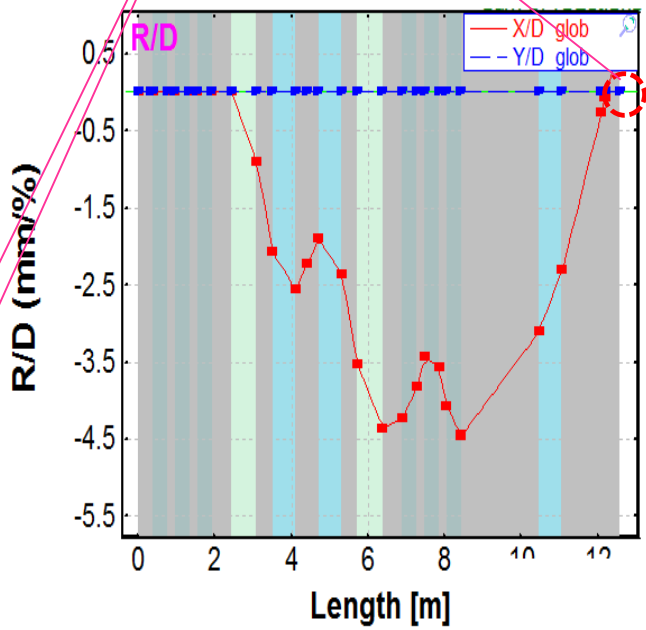
"Opt.Beam"

1. X	5	mm
2. T	50	mrad
3. Y	5	mm
4. P	50	mrad
5. L	0	mm
6. D	6	%



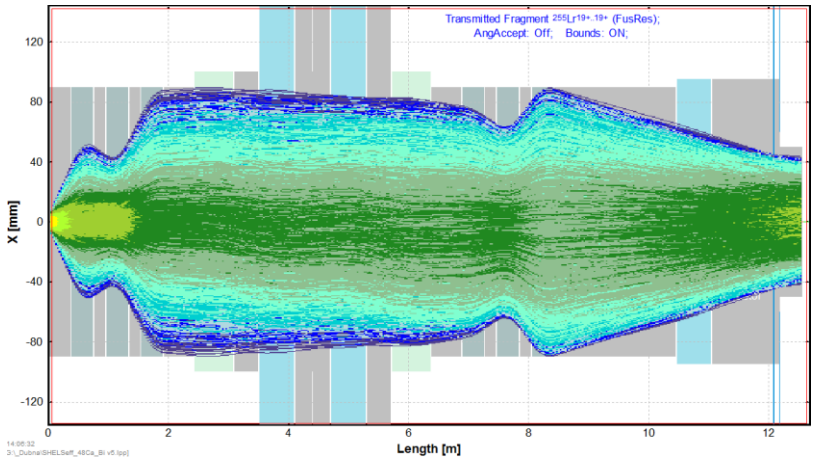


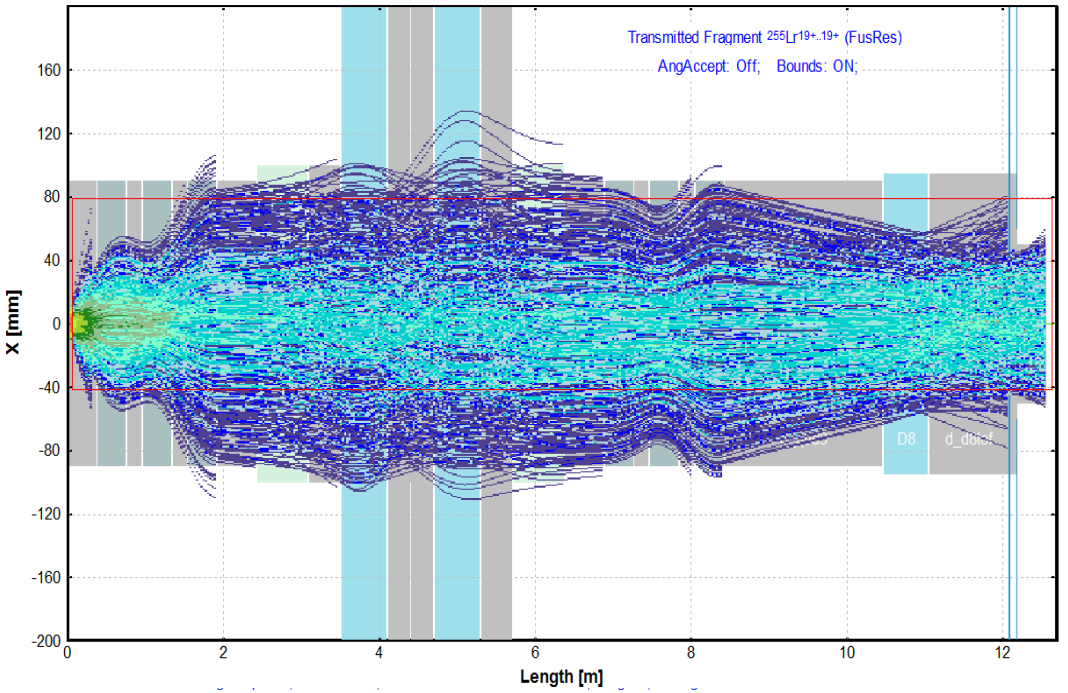




Monte Carlo Transmission

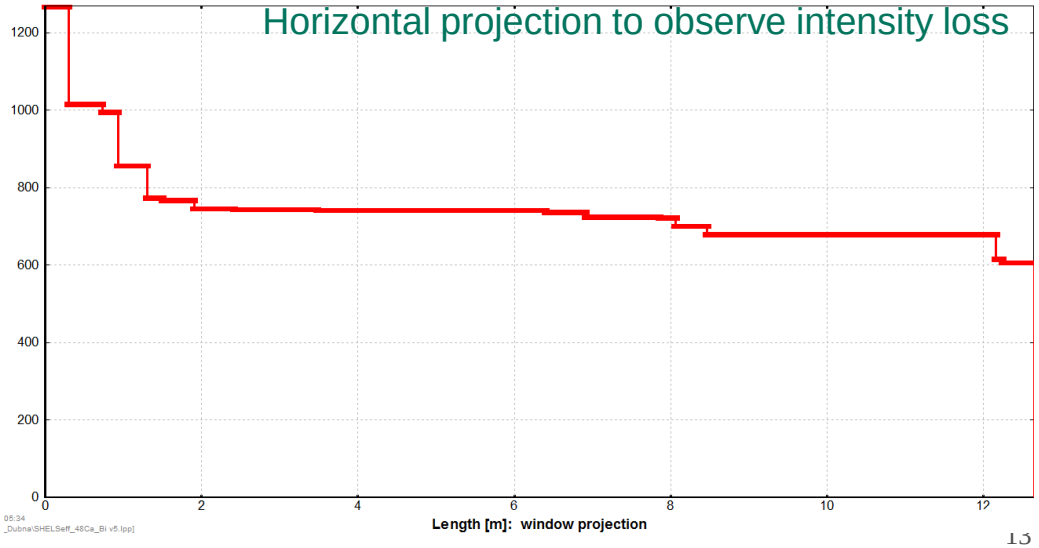
$^{255}Lr^{19+}$ transmission: 58.3%





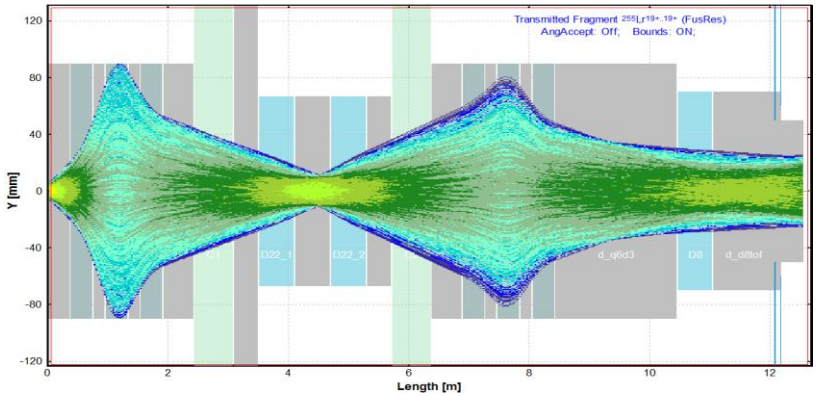
X

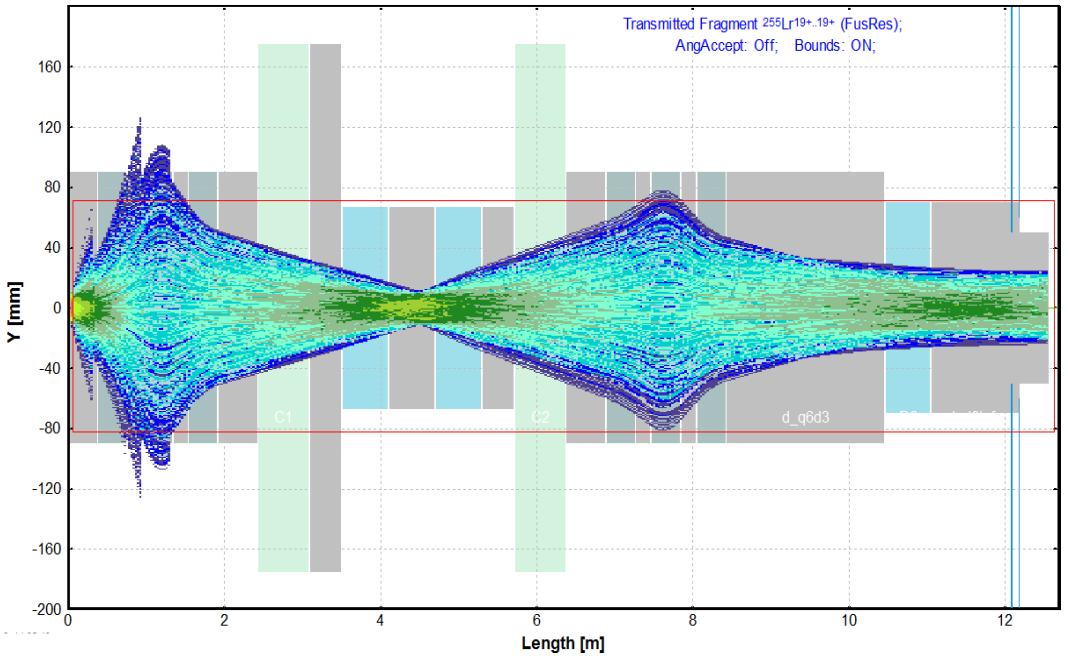
Horizontal projection to observe intensity loss



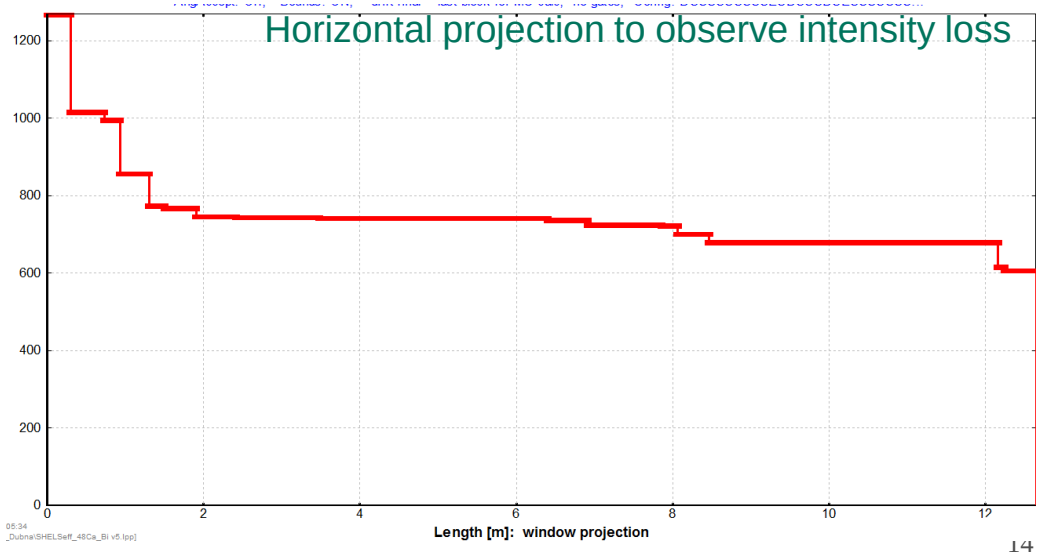
Monte Carlo Transmission

$^{255}Lr^{19+}$ transmission: 58.3%



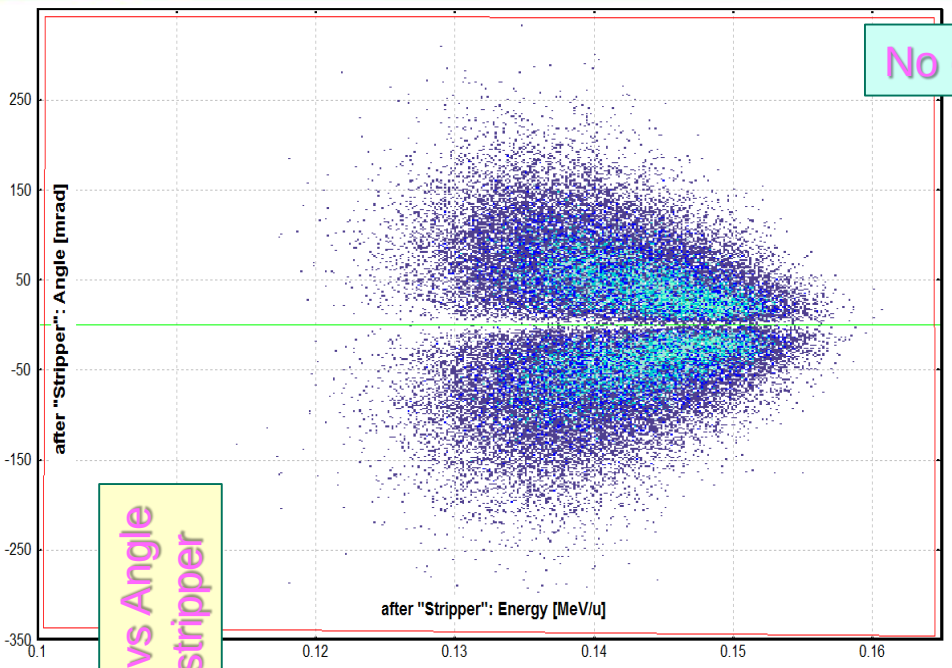


Y

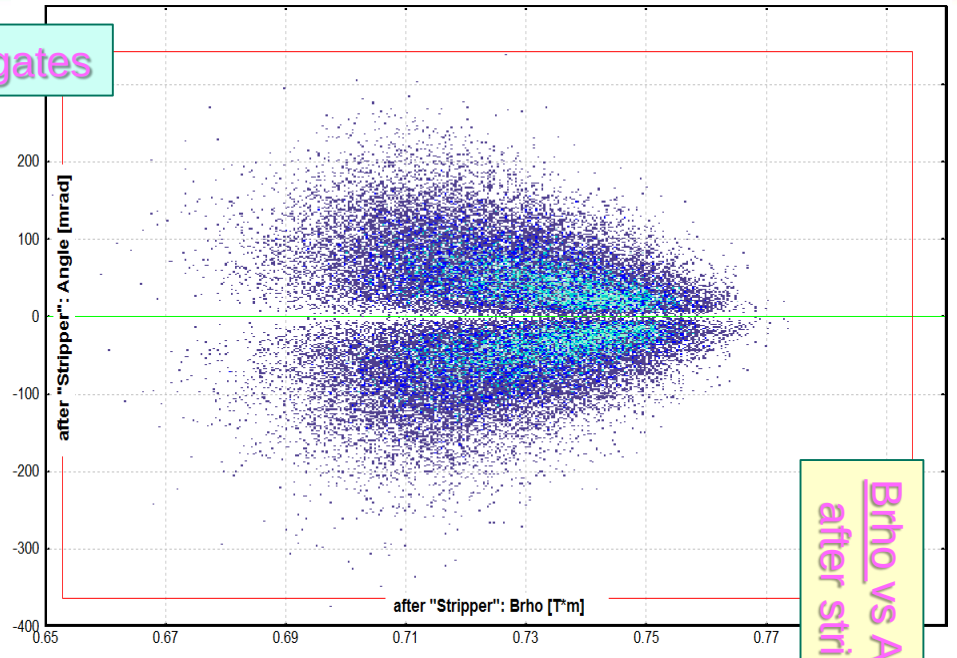


Monte Carlo Transmission Results for $^{255}Lr^{19+}$

No gates

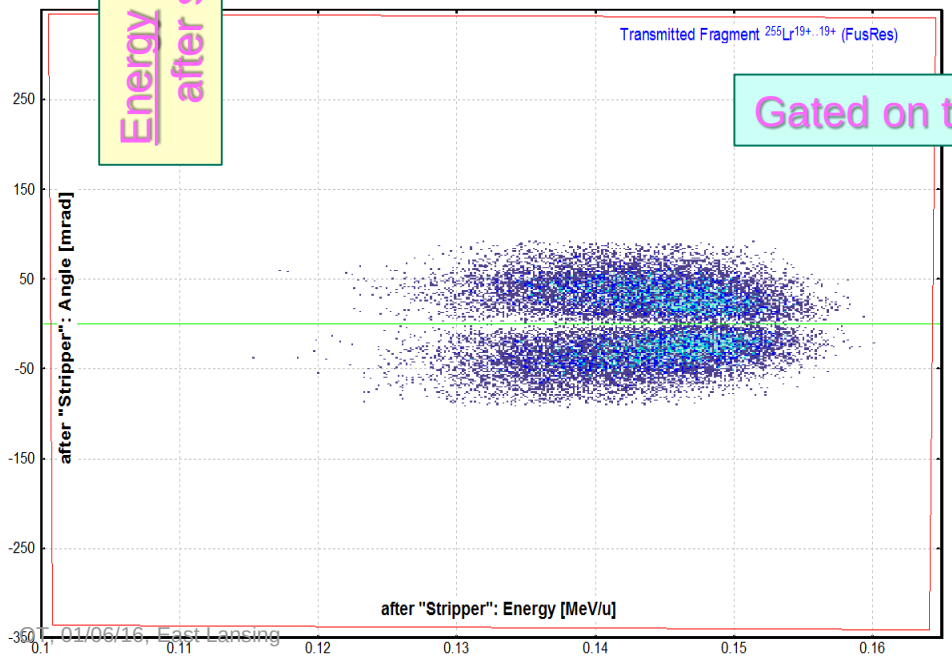


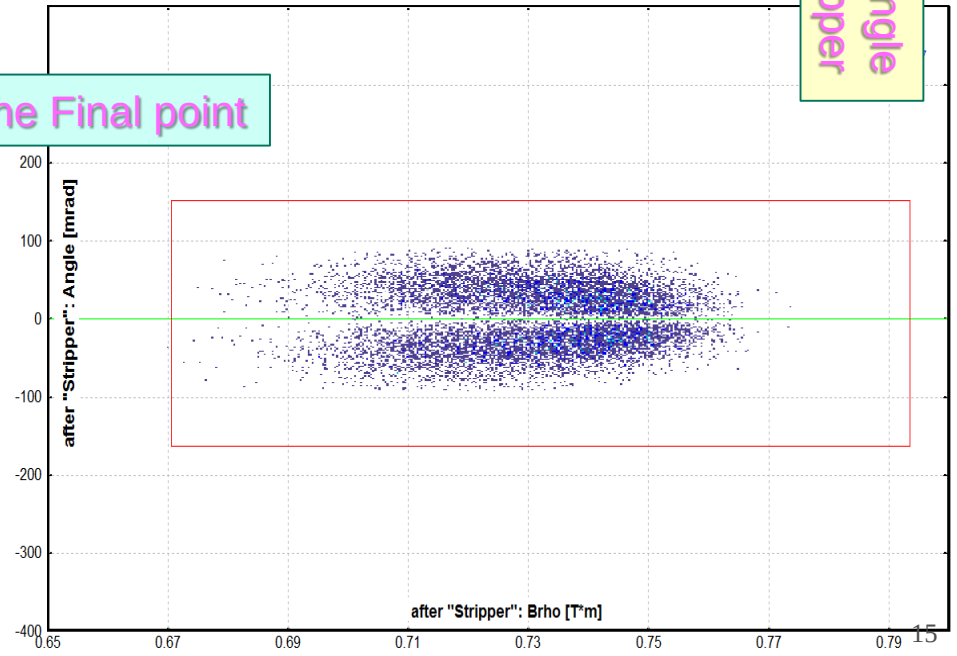
Energy vs Angle after stripper



Brho vs Angle after stripper

Gated on the Final point

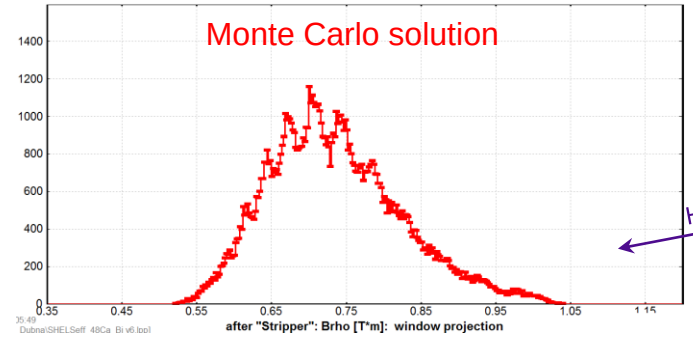


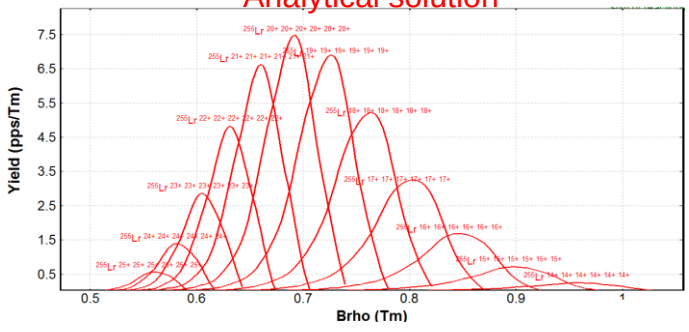


Monte Carlo Transmission Results for $^{255}Lr^{ALL+}$

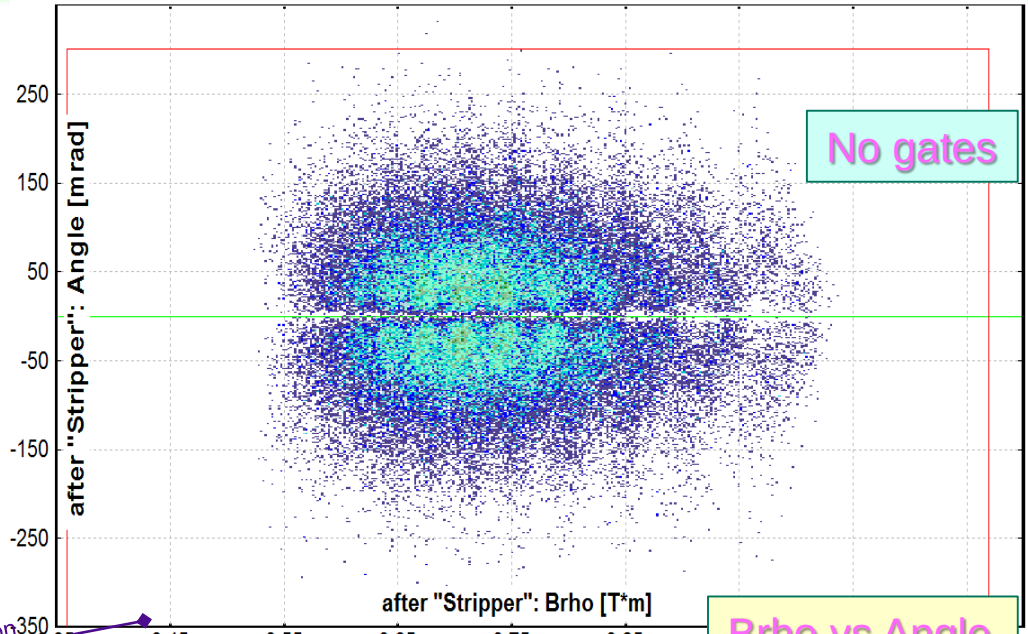
^{255}Lr $^{All+}$ transmission

Monte Carlo: *51.4%*
Analytical : *44.7%*

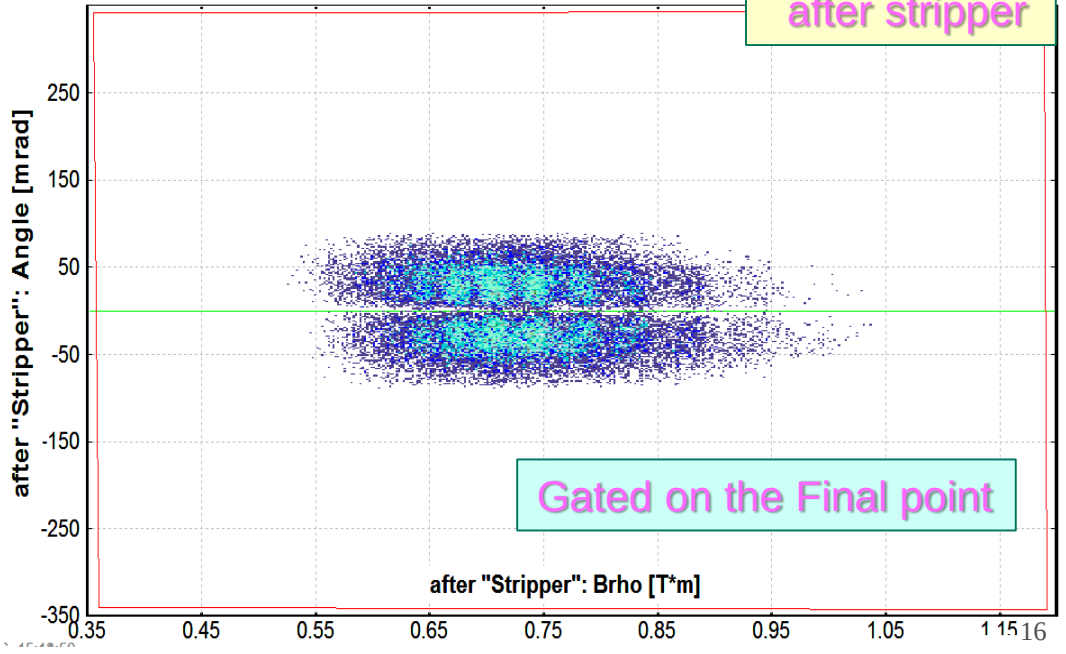




Horizontal projection



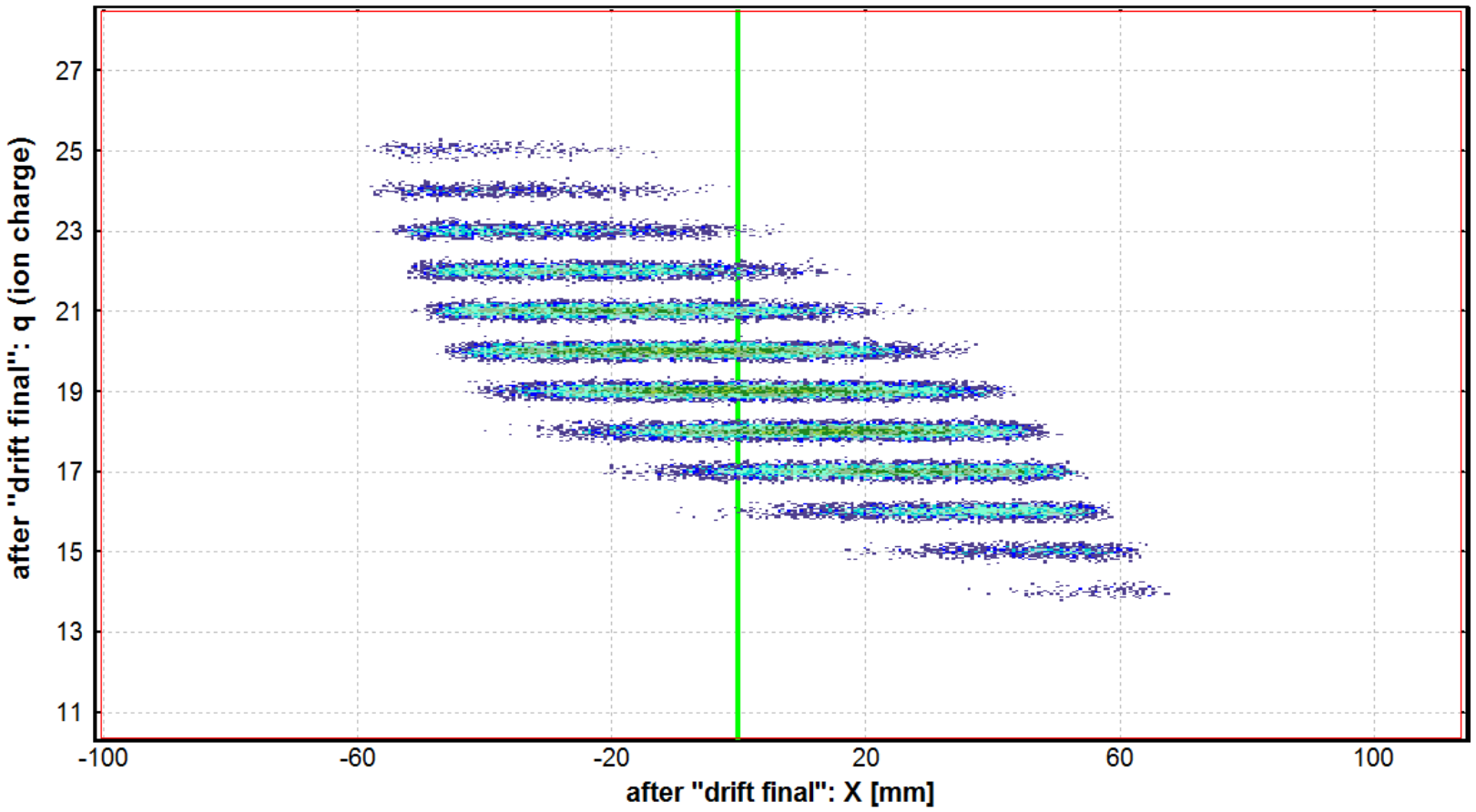
Brho vs Angle after stripper



Monte Carlo Transmission Results for $^{255}Lr^{ALL+}$

Isotope Group : Monte Carlo Yield Plot

^{48}Ca (4.61 MeV/u) + BiO2 (0.4 mg/cm^2),C (3.5e-2 mg/cm^2); Transmitted Fragment $^{255}Lr^{19+..19+}$ (FusRes); Optic
dp/p=89.99% ; Brho(Tm): 0.7212, 0.7212, 0.7212, 0.7212
AngAccept: Off; Bounds: ON; "drift final" - last block for MC calc; no gates; Config: DSSSSSSSSSESDSSSDS



X vs ion charge @ Final point

Transmission : Analytical

$^{255}Lr^{All+}$ transmission *Analytical : 44.7%*

$^{255}Lr^{19+}$ transmission *Analytical : 53.1%*

9.098 / 17.15 * 100%

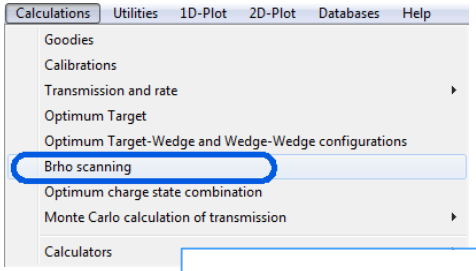
statistics: 255Lr

255Lr Alpha and Beta+ decay (Z=103, N=152) Lawrencium

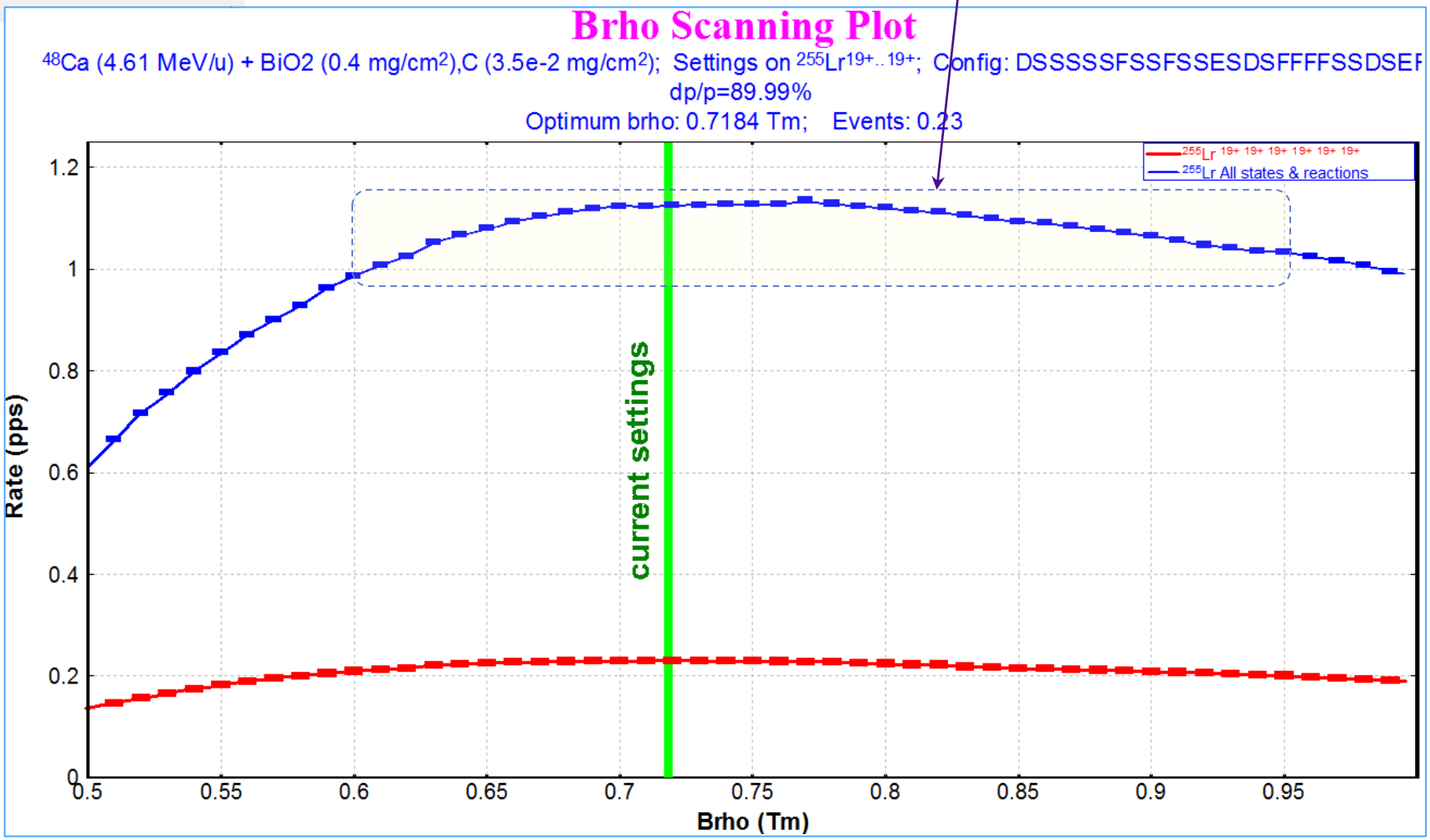
All reactions total isotope rate 1.19e+0 pps
and Overall isotope transmission 44.653 %

Q1(tuning)		25	24	23	22	21	20	19	18	17	16	15	14
Q2(C1)		25	24	23	22	21	20	19	18	17	16	15	14
Q3(D22_1)		25	24	23	22	21	20	19	18	17	16	15	14
Q4(D22_2)		25	24	23	22	21	20	19	18	17	16	15	14
Q5(C2)		25	24	23	22	21	20	19	18	17	16	15	14
Q6(D8)		25	24	23	22	21	20	19	18	17	16	15	14
Reaction		FusRes	FusRes	FusRes	FusRes	FusRes	FusRes	FusRes	FusRes	FusRes	FusRes	FusRes	FusRes
Ion Production Rate	(pps)	6.1e-3	1.99e-2	4.92e-2	1.01e-1	1.67e-1	2.34e-1	2.43e-1	1.96e-1	1.1e-1	4.77e-2	1.44e-2	2.71e-3
Total ion transmission	(%)	0.229	0.745	1.847	3.776	6.264	8.783	9.098	7.339	4.14	1.789	0.541	0.102
Total: this reaction	(pps)	1.19e+0	1.19e+0	1.19e+0	1.19e+0	1.19e+0	1.19e+0	1.19e+0	1.19e+0	1.19e+0	1.19e+0	1.19e+0	1.19e+0
X-Section in target	(mb)	1.41e-4	1.41e-4	1.41e-4	1.41e-4	1.41e-4	1.41e-4	1.41e-4	1.41e-4	1.41e-4	1.41e-4	1.41e-4	1.41e-4
Target	(%)	100	100	99.86	100	100	100	100	100	100	99.86	99.86	100
Unreacted in material	(%)	100	100	100	100	100	100	100	100	100	100	100	100
Unstopped in material	(%)	100	100	99.86	100	100	100	100	100	100	99.86	99.86	100
Stripper	(%)	0.874	2.31	5.05	9.12	13.58	16.77	17.15	14.47	10.09	5.82	2.76	1.09
Unreacted in material	(%)	100	100	100	100	100	100	100	100	100	100	100	100
Q (Charge) ratio	(%)	0.874	2.31	5.05	9.12	13.62	16.81	17.15	14.47	10.09	5.82	2.77	1.09
Unstopped in material	(%)	100	99.77	100	100	99.77	99.77	100	100	100	100	99.77	100
tuning	(%)	61.4	61.4	61.4	61.4	61.4	61.4	61.4	61.4	61.4	61.4	61.4	61.4
X angular transmission	(%)	88.45	88.45	88.45	88.45	88.45	88.45	88.45	88.45	88.45	88.45	88.45	88.45
Y angular transmission	(%)	69.42	69.42	69.42	69.42	69.42	69.42	69.42	69.42	69.42	69.42	69.42	69.42
DTS1	(%)	100	100	100	100	100	100	100	100	100	100	100	100
slits 1	(%)	99.75	99.75	99.75	99.75	99.75	99.75	99.75	99.75	99.75	99.75	99.75	99.75
X space transmission	(%)	99.75	99.75	99.75	99.75	99.75	99.75	99.75	99.75	99.75	99.75	99.75	99.75
Y space transmission	(%)	100	100	100	100	100	100	100	100	100	100	100	100
DS1Q1	(%)	100	100	100	100	100	100	100	100	100	100	100	100
Quad 1	(%)	100	100	100	100	100	100	100	100	100	100	100	100
d_q12	(%)	100	100	100	100	100	100	100	100	100	100	100	100
Quad 2	(%)	100	100	100	100	100	100	100	100	100	100	100	100
d_q23	(%)	100	100	100	100	100	100	100	100	100	100	100	100
Quad 3	(%)	100	100	100	100	100	100	100	100	100	100	100	100
d_q3c1	(%)	100	100	100	100	100	100	100	100	100	100	100	100
C1	(%)	100	100	100	100	100	100	100	100	100	100	100	100
d_c1d1	(%)	100	100	100	100	100	100	100	100	100	100	100	100
D22_1	(%)	100	100	100	100	100	100	100	100	100	100	100	100
d_d1sv	(%)	100	100	100	100	100	100	100	100	100	100	100	100
slits SV	(%)	97.08	97.04	96.96	96.8	96.54	96.49	96.68	96.41	96.07	95.48	94.84	93.57
X space transmission	(%)	97.08	97.04	96.96	96.8	96.54	96.49	96.68	96.41	96.07	95.48	94.84	93.57

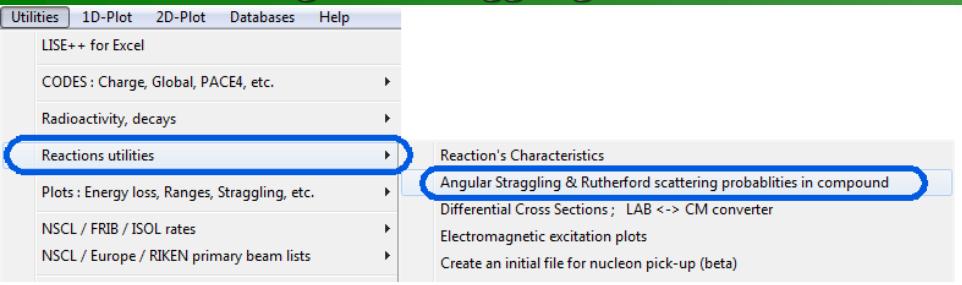
Brho scanning



The small Brho shift does not affect on ^{255}Lr yield due to very large momentum acceptance of the separator and broad momentum distribution of residues



New utility :
Angular Straggling & Rutherford scattering probabilities in compound



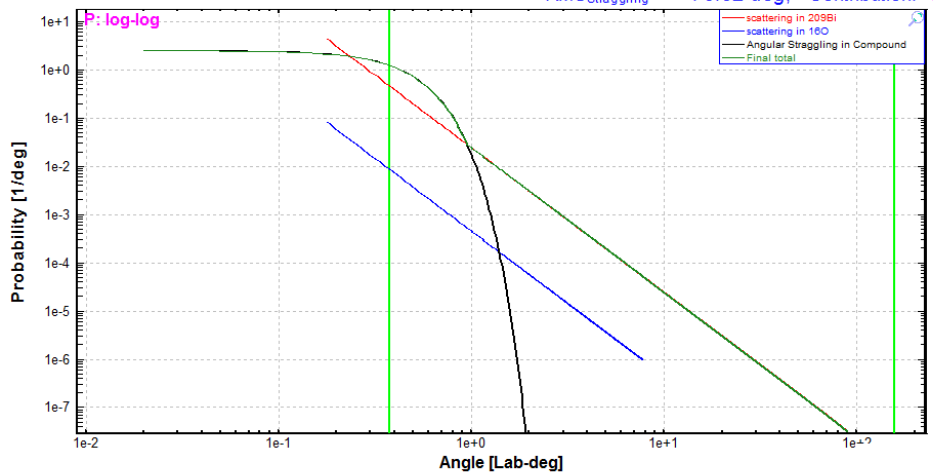
These P=f(angle) and E=f(angle) functions will be used in the Monte Carlo mode for the primary beam transmission calculations

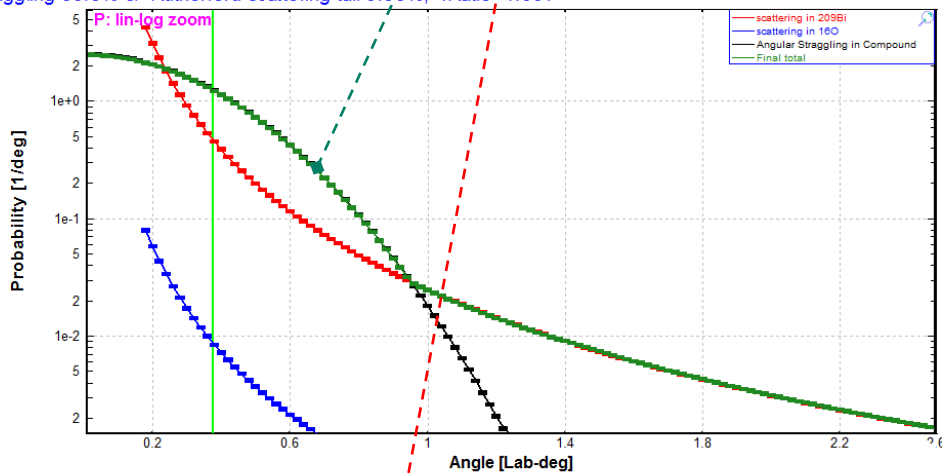
Angular Straggling & Rutherford scattering probabilities in compound

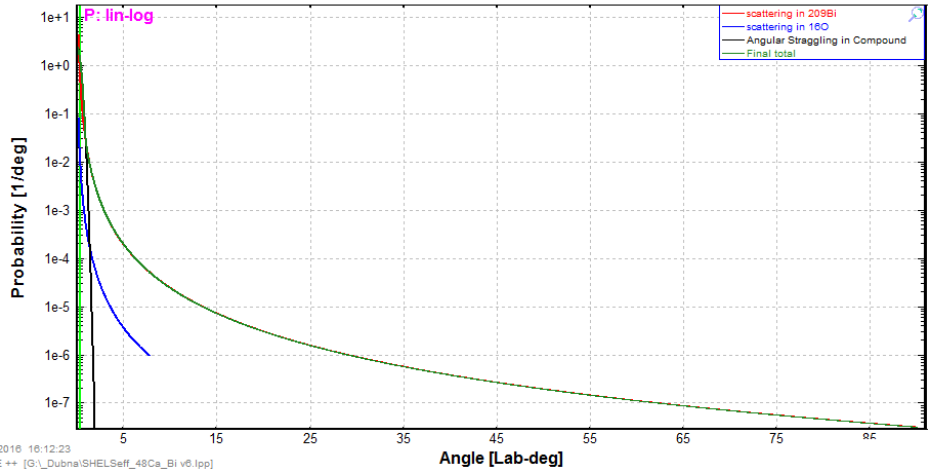
^{48}Ca (4.61 MeV/u) + BiO2 (0.4 mg/cm^2)

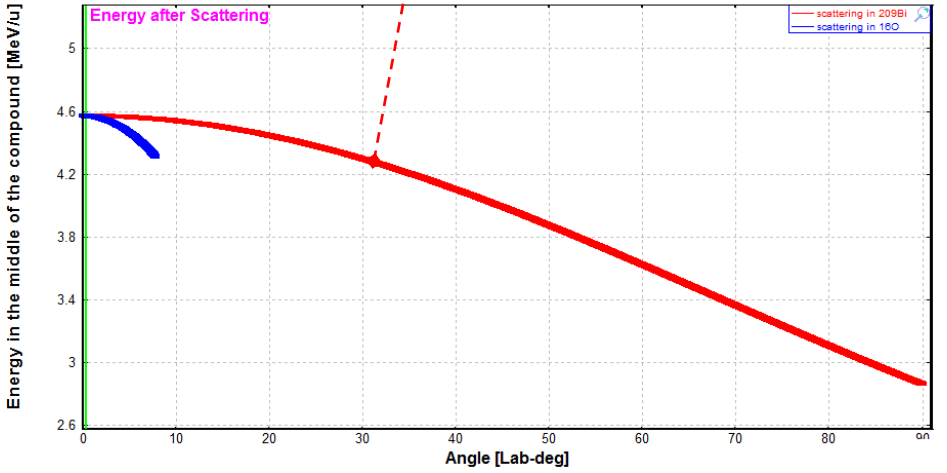
Grazing & maximum kinematic angles (in degrees) @ middle of material: [0] ^{209}Bi : 156.9 & 180.00; [1] ^{16}O : 7.8 & 19.48;

$RMS_{Straggling}^{space}$: 0.32 deg; Contribution: Straggling 99.3% & Rutherford scattering tail 0.69%; IRatio=1.007

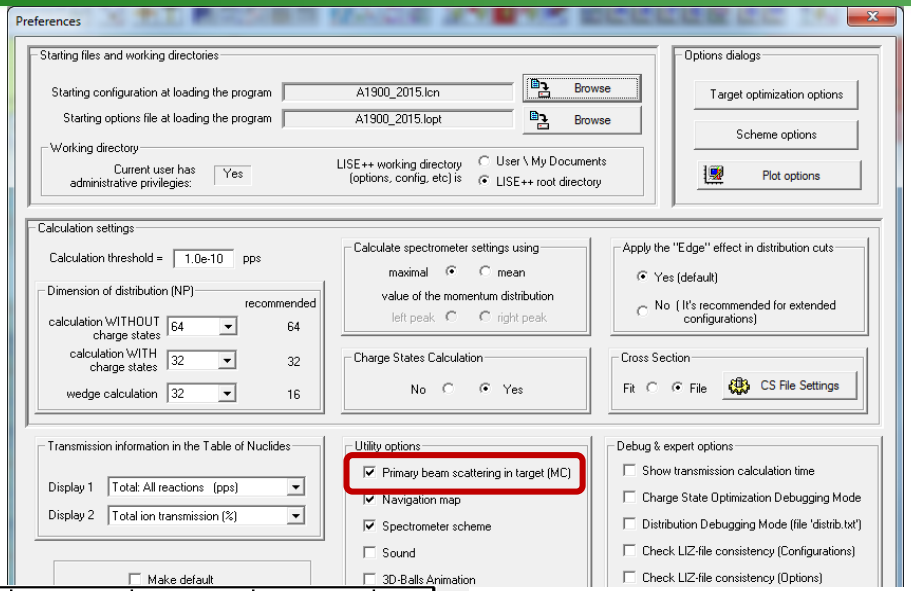


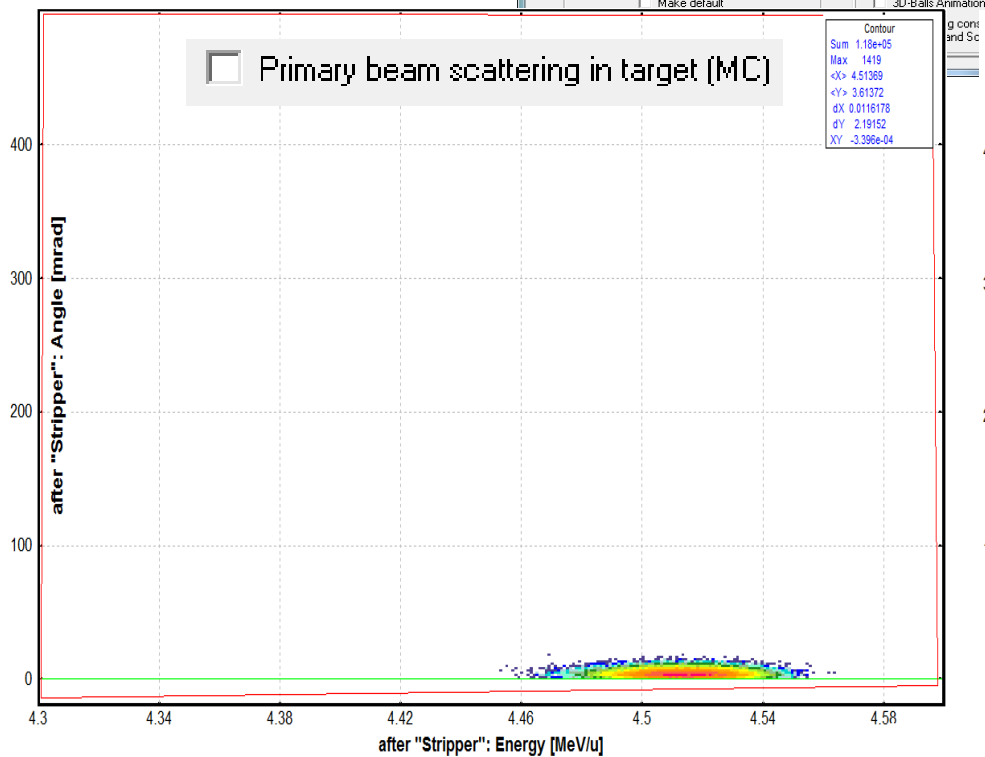


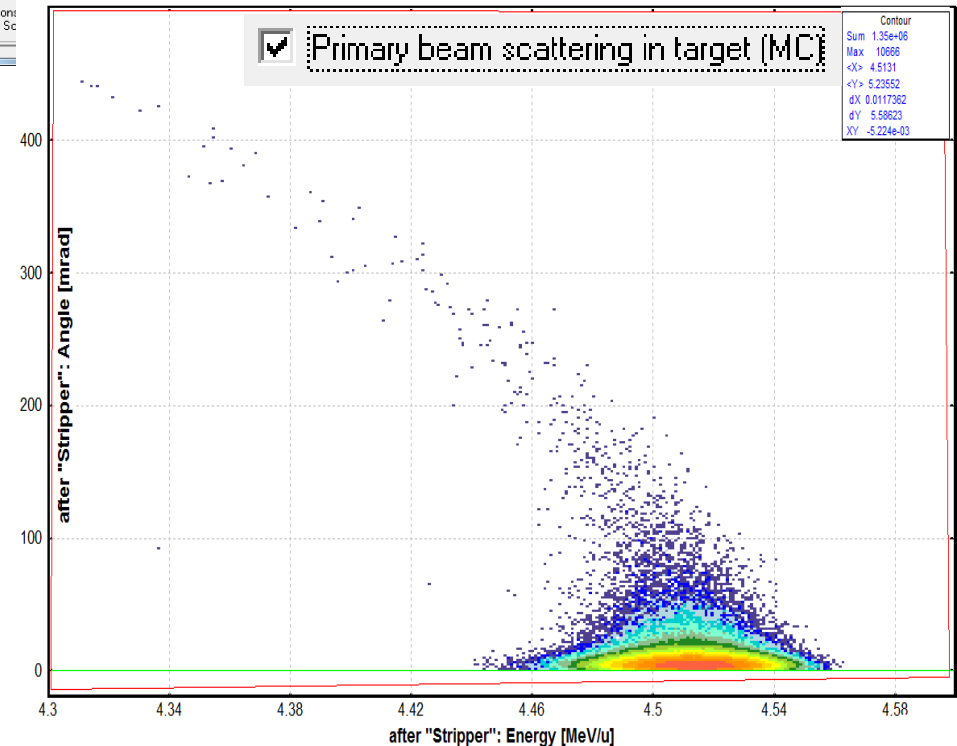




Primary beam scattering

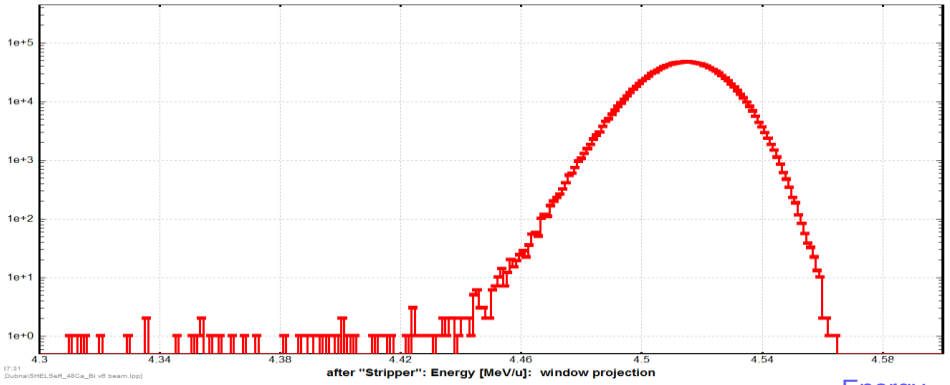






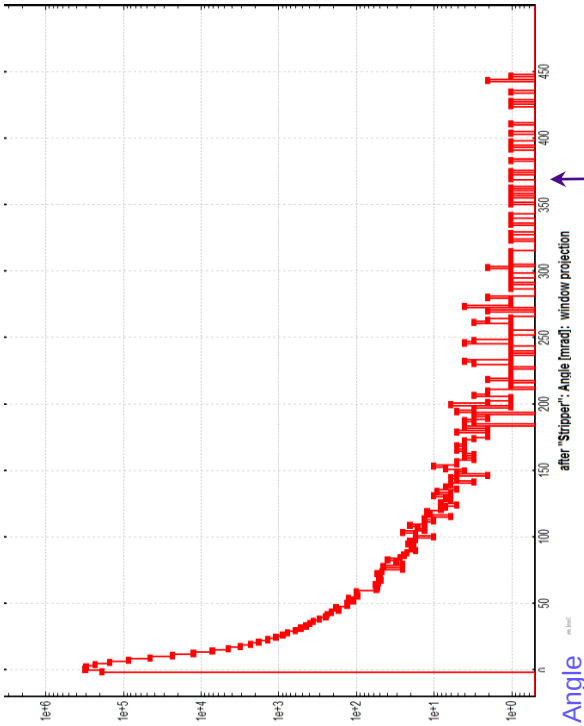
Primary beam scattering

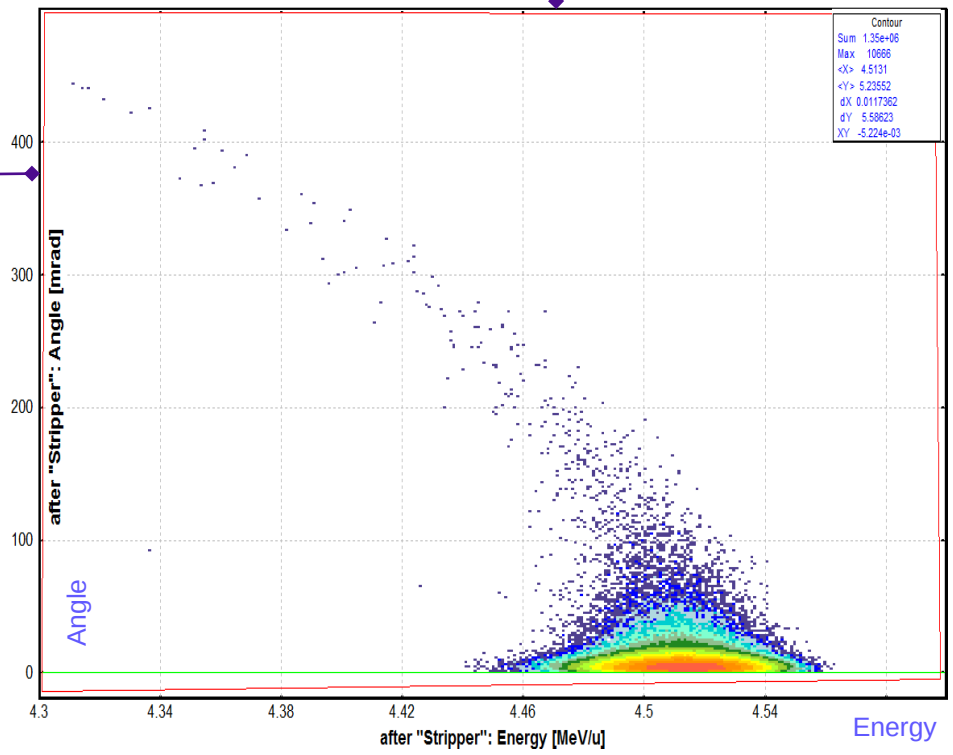
Primary beam scattering in target (MC)



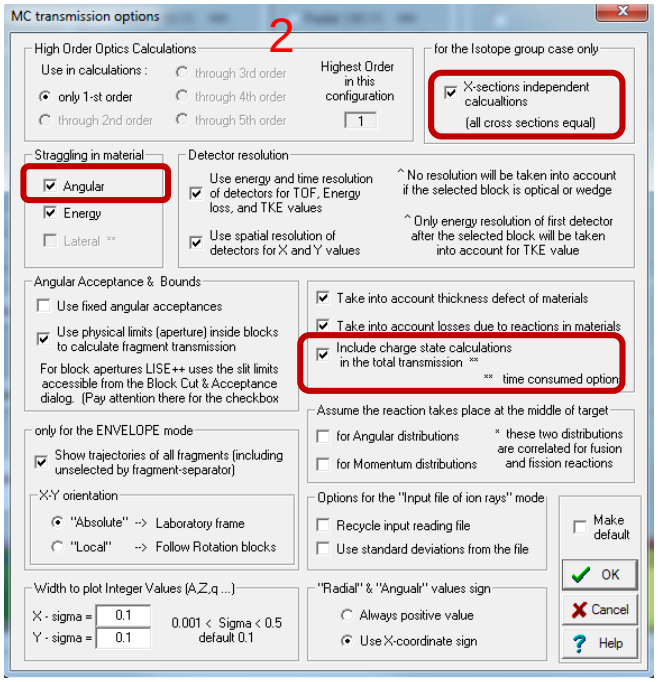
Horizontal projection

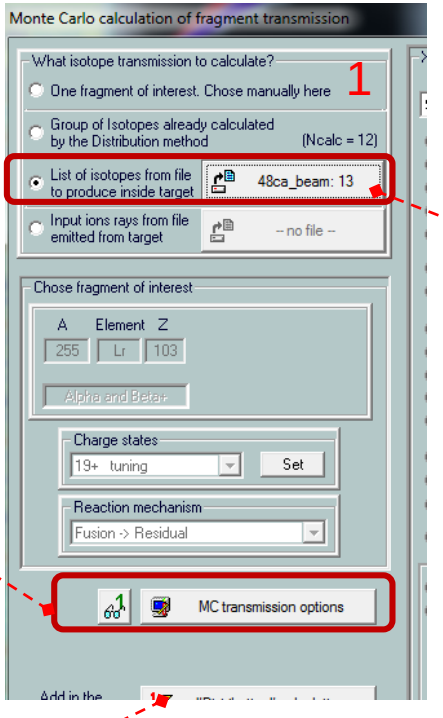
Vertical projection

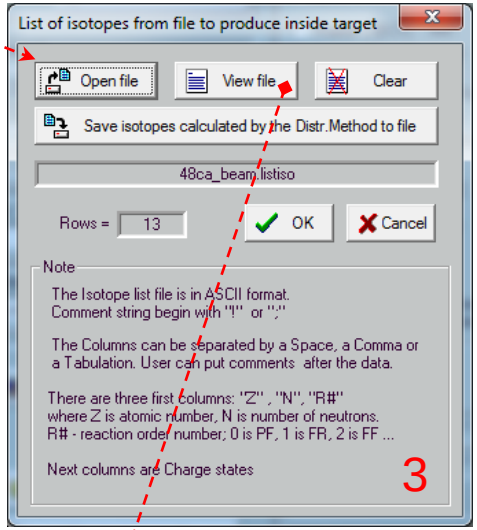


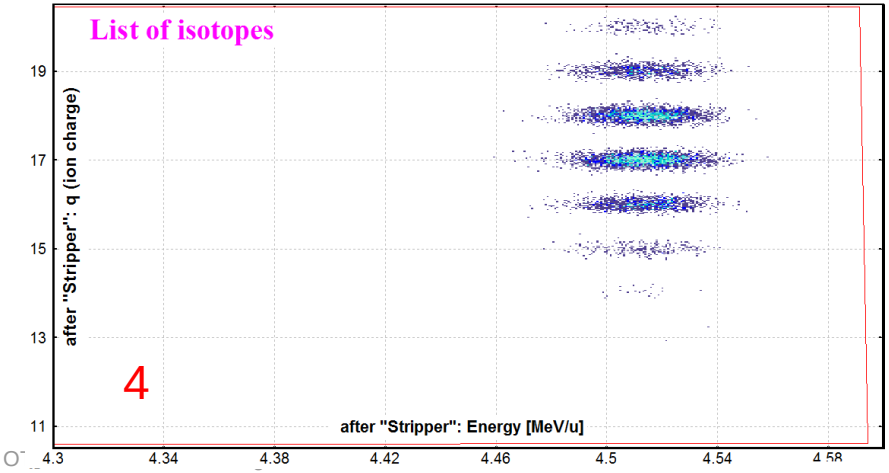


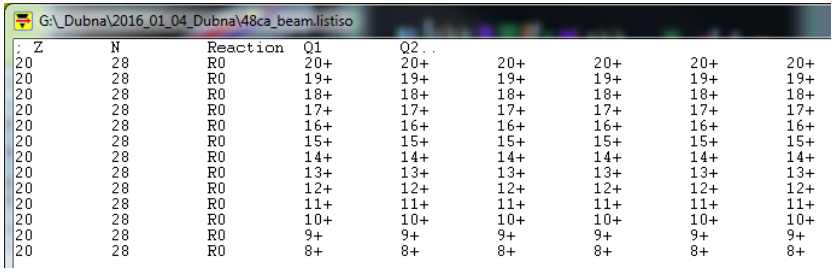
Primary beam charge states transmission settings







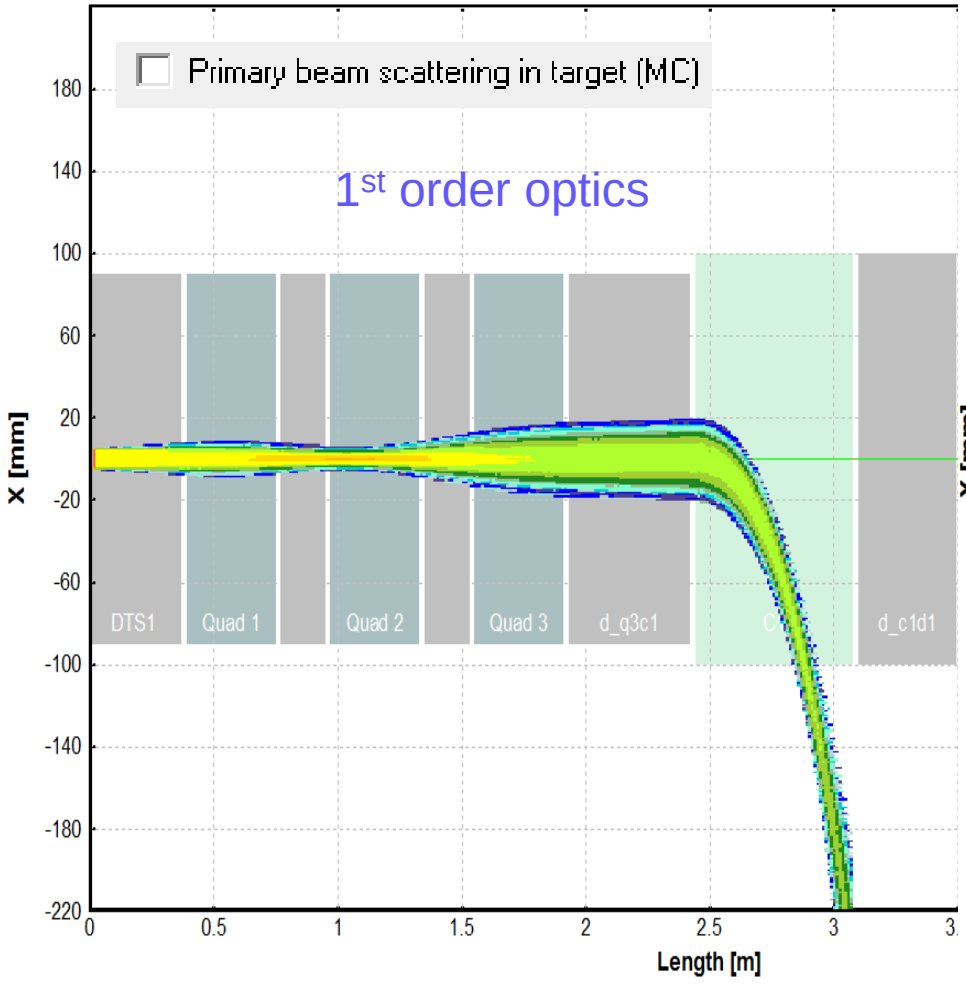


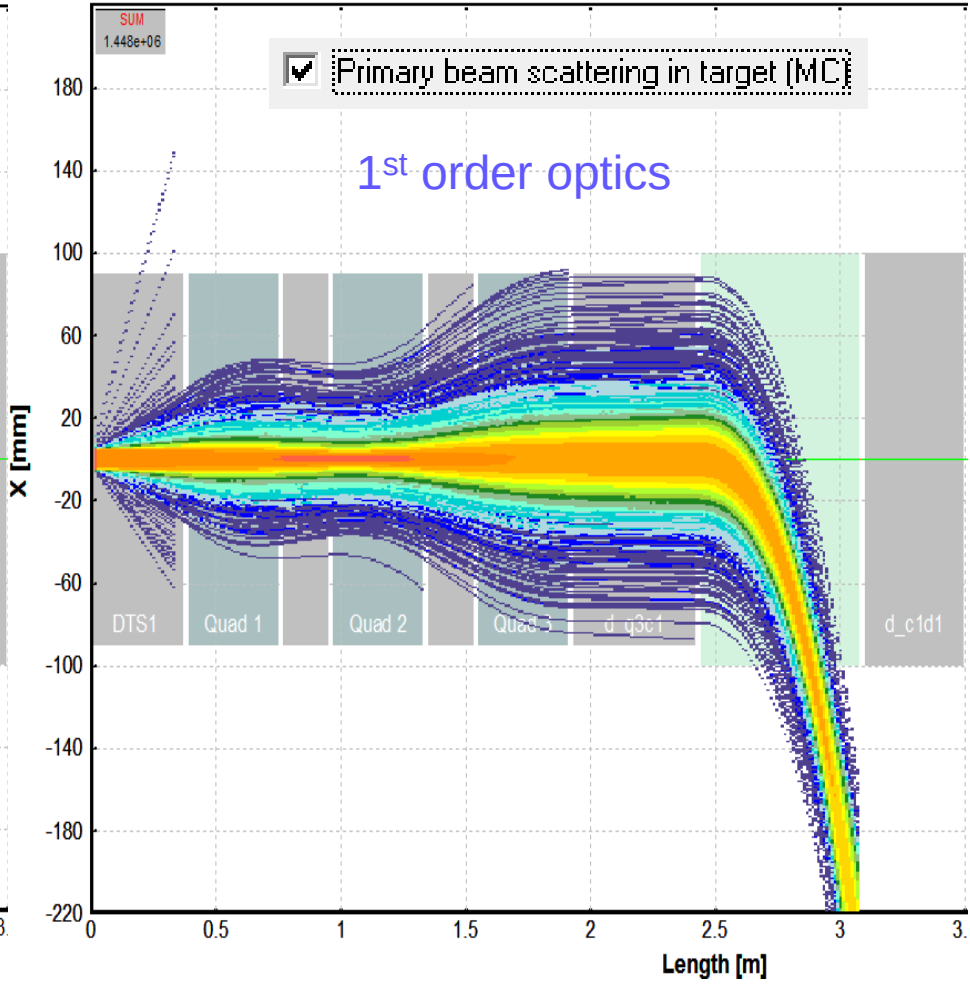

G:_Dubna\2016_01_04_Dubna\48ca_beam.listiso

; Z	N	Reaction	Q1	Q2..				
20	28	R0	20+	20+	20+	20+	20+	20+
20	28	R0	19+	19+	19+	19+	19+	19+
20	28	R0	18+	18+	18+	18+	18+	18+
20	28	R0	17+	17+	17+	17+	17+	17+
20	28	R0	16+	16+	16+	16+	16+	16+
20	28	R0	15+	15+	15+	15+	15+	15+
20	28	R0	14+	14+	14+	14+	14+	14+
20	28	R0	13+	13+	13+	13+	13+	13+
20	28	R0	12+	12+	12+	12+	12+	12+
20	28	R0	11+	11+	11+	11+	11+	11+
20	28	R0	10+	10+	10+	10+	10+	10+
20	28	R0	9+	9+	9+	9+	9+	9+
20	28	R0	8+	8+	8+	8+	8+	8+

Primary beam charge states transmission

2nd order optics has to be used
for primary beam charge states transmission !!!!!!
It will be done soon (Electrical dipole).





Primary beam charge states transmission

2nd order optics has to be used
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