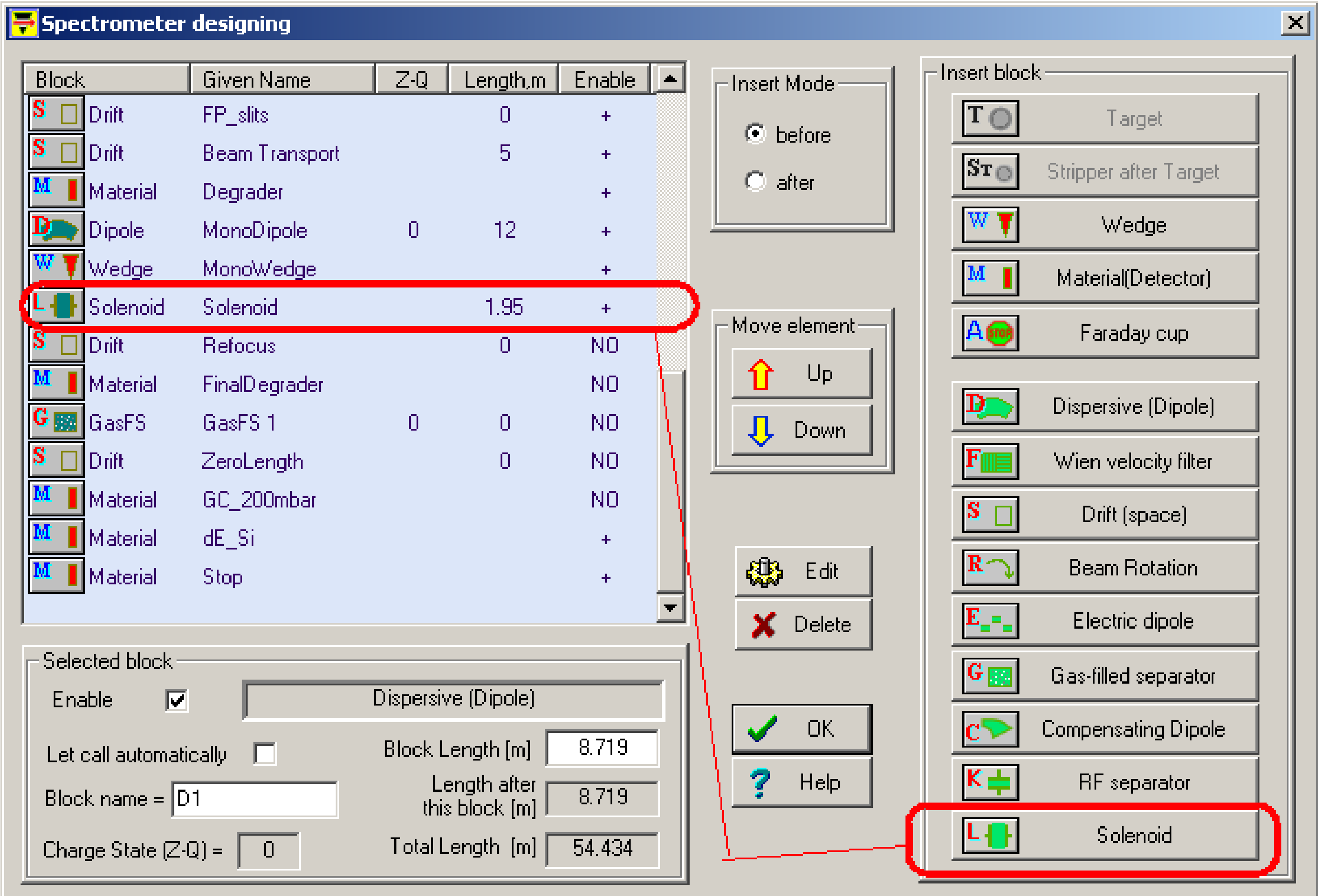
Solenoid is the new block in LISE++

version 8.3.59

Requests of
D.J.Morrissey (NSCL),
G.Chubarian & © (TAMU)

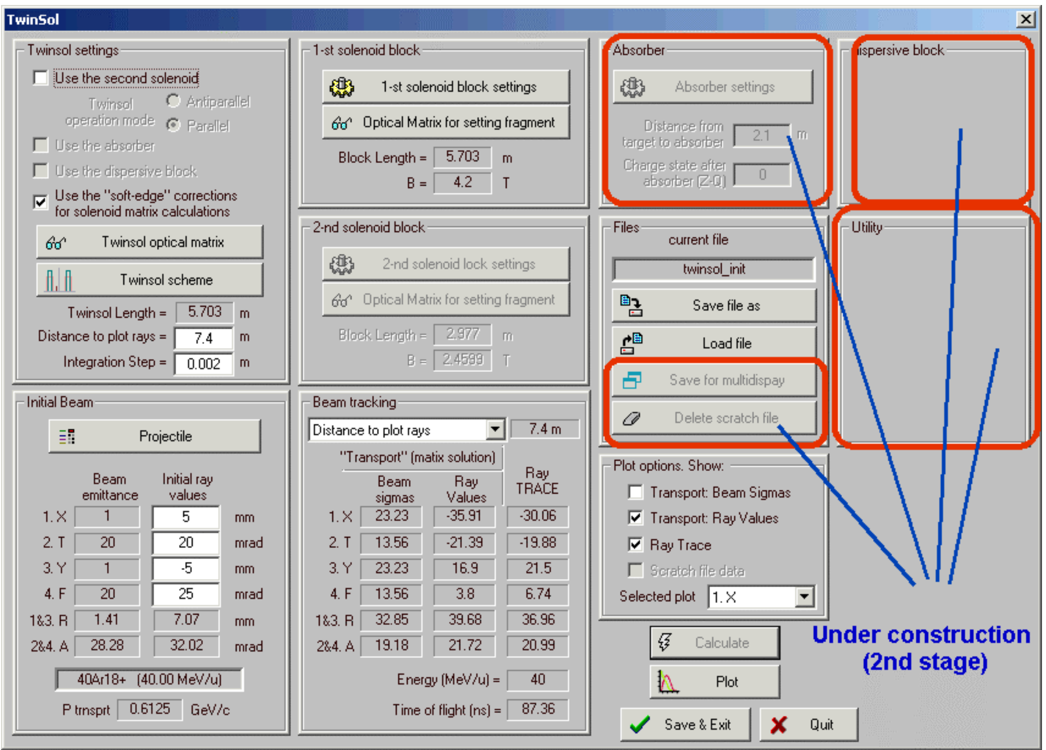


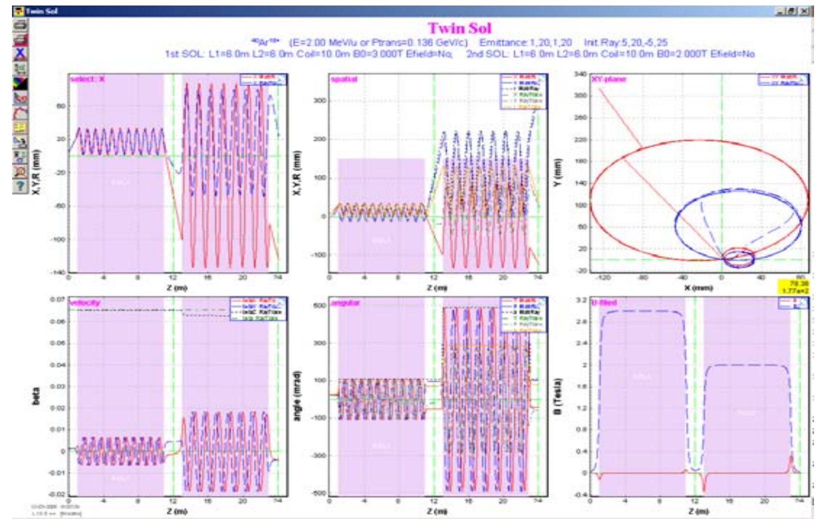
The code operates under MS Windows environment and provides a highly user-friendly interface.
It can be freely downloaded from the following internet addresses:
http://www.nscl.msu/edu/lise

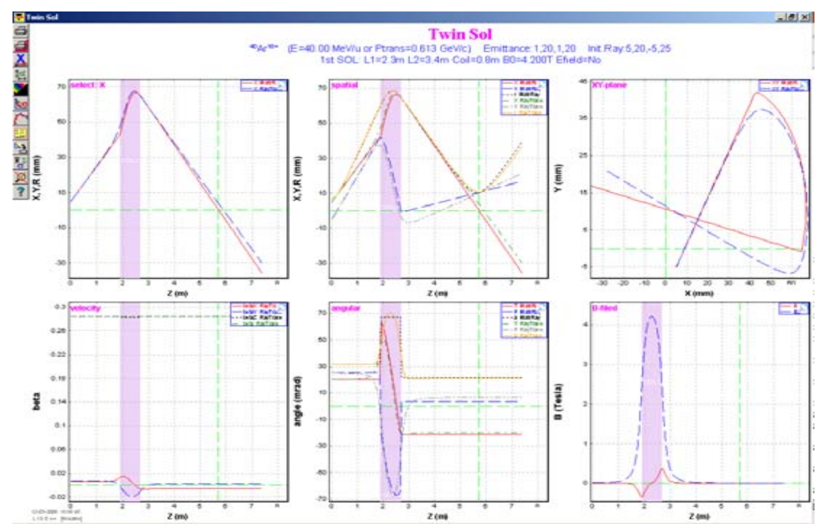
Introduction : TwinSol (Solenoid) utility

version 7.6.56 (03-MAR-2006)

http://groups.nscl.msu.edu/lise/paper/2006_june_utilities.pdf







Introduction : Update of the TwinSol utility

05/30/08 version 8.3.45

http://groups.nscl.msu.edu/lise/8_3/TwinsolUtility_v8_3_45.pdf

Function of

19. matrix: X/X

- 01. beam sigma: X
- 02. beam sigma: T (X')
- 03. beam sigma: Y
- 04. beam sigma: P (Y')
- 05. beam sigma: R (X&Y)
- 06. beam sigma: A (P&T)
- 07. beam ray: X
- 08. beam ray: T (X')
- 09. beam ray: Y
- 10. beam ray: P (Y')
- 11. beam ray: R (X&Y)
- 12. beam ray: A (P&T)
- 13. ray trace: X
- 14. ray trace: T (X')
- 15. ray trace: Y
- 16. ray trace: P (Y')
- 17. ray trace: R (X&Y)
- 18. ray trace: A (P&T)
- 19. matrix: X/X
- 20. matrix: X/T
- 21. matrix: X/Y
- 22. matrix: X/P
- 23. matrix: T/X
- 24. matrix: T/T
- 25. matrix: T/Y
- 26. matrix: T/P
- 27. matrix: Y/X
- 28. matrix: Y/T
- 29. matrix: Y/Y
- 30. matrix: Y/P
- 31. matrix: P/X
- 32. matrix: P/T
- 33. matrix: P/Y
- 34. matrix: P/P
- 35. Field: BR
- 36. Field: BZ

from

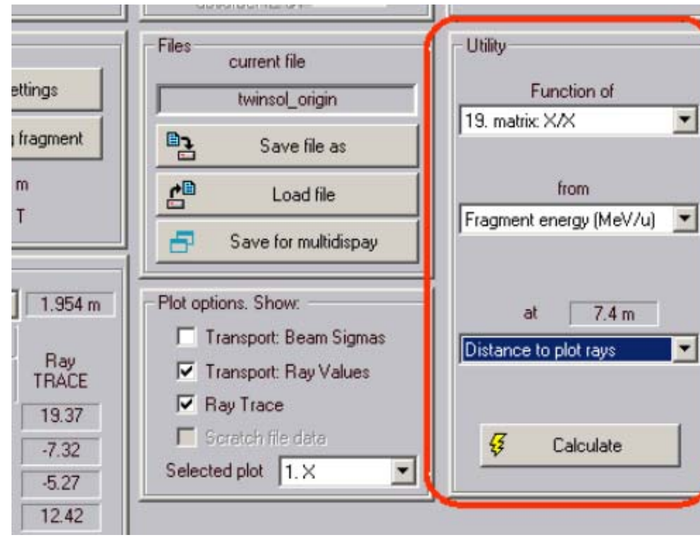
1-st solenoid: B_field Max

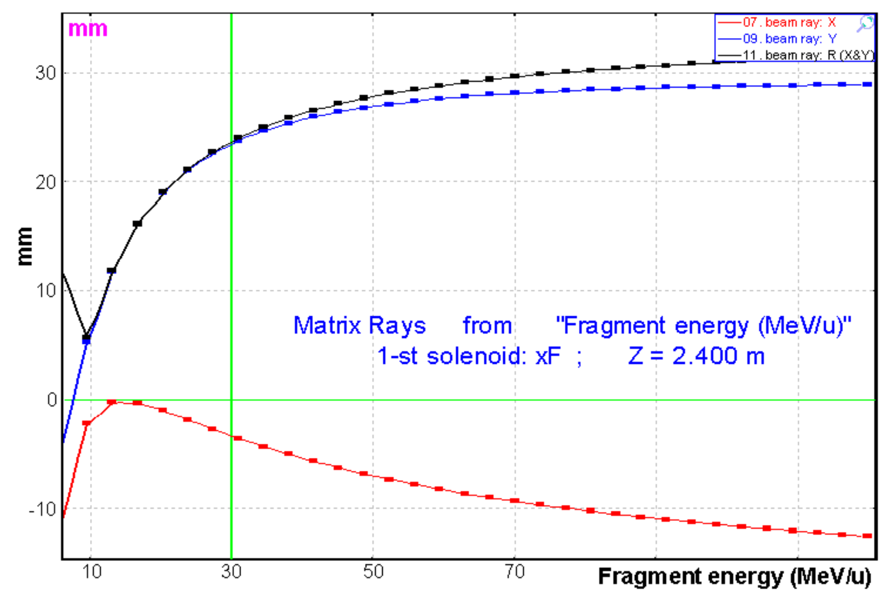
- 1-st solenoid: B_field Max
- 1-st solenoid: I (Current)
- 1-st solenoid: Coil Length
- 1-st solenoid: Effective Radius
- 1-st solenoid: 1-st half
- 1-st solenoid: 2-nd half
- 2-nd solenoid: B_field Max
- 2-nd solenoid: I (Current)
- 2-nd solenoid: Coil Length
- 2-nd solenoid: Effective Radius
- 2-nd solenoid: 1-st half
- 2-nd solenoid: 2-nd half
- 3-nd solenoid: B_field Max
- 3-nd solenoid: I (Current)
- 3-nd solenoid: Coil Length
- 3-nd solenoid: Effective Radius
- 3-nd solenoid: 1-st half
- 3-nd solenoid: 2-nd half
- Fragment energy (MeV/u)

at 1.877 m

2-nd solenoid: x0

- 1-st solenoid: x0
- 1-st solenoid: x1L
- 1-st solenoid: x1R
- 1-st solenoid: xC
- 1-st solenoid: x2L
- 1-st solenoid: x2R
- 1-st solenoid: xF
- 2-nd solenoid: x0
- 2-nd solenoid: x1L
- 2-nd solenoid: x1R
- 2-nd solenoid: xC
- 2-nd solenoid: x2L
- 2-nd solenoid: x2R
- 2-nd solenoid: xF
- 3-nd solenoid: x0
- 3-nd solenoid: x1L
- 3-nd solenoid: x1R
- 3-nd solenoid: xC
- 3-nd solenoid: x2L
- 3-nd solenoid: x2R
- 3-nd solenoid: xF
- Distance to plot rays





Memo: Solenoid optics

http://people.web.psi.ch/rohrer_u/trantext.htm#Solen

Urs C. Rohrer, PSI (SIN), CH-5232 Villigen-PSI, Switzerland

SOLENOID: Type code 19.0

Inside the solenoid, particles possessing a transverse velocity will describe an orbit which is helical in space. In order to study these movements, the beam centroid may be shifted and traced through the solenoid.

For B * L > Brho , the solenoid has to be divided into a sufficient amount of smaller elements in order to get an accurate image of the particle rays. But the R-matrix used in transport includes the fringe field effects at the entrance and exit of the solenoid.

First-order matrices for the solenoid:

1) Entrance face :

```
      1  0 0 0 0 0
      0  1 K 0 0 0
Ri =  0  0 1 0 0 0     2 * K = B / Brho
     -K  0 0 1 0 0
      0  0 0 0 1 0
      0  0 0 0 0 1
```

2) Exit face :

```
      1 0  0 0 0 0
      0 1 -K 0 0 0
Ro =  0 0  1 0 0 0
      K 0  0 1 0 0
      0 0  0 0 1 0
      0 0  0 0 0 1
```

3) Homogeneous field:

```
      1   S*C/K    0  S*S/K    0  0
      0   2*C*C-1  0  2*S*C    0  0
Rh =  0   -S*S/K   1  S*C/K    0  0
      0   -2*S*C   0  2*C*C-1  0  0
      0   0        0  0        1  0
      0   0        0  0        0  1
```

C = cos(K*L)
S = sin(K*L)

‘soft-edge’ solenoid – edge effect

Alex Bogacz, Workshop on Muon Collider Simulations, Miami Beach, FL December 15, 2004

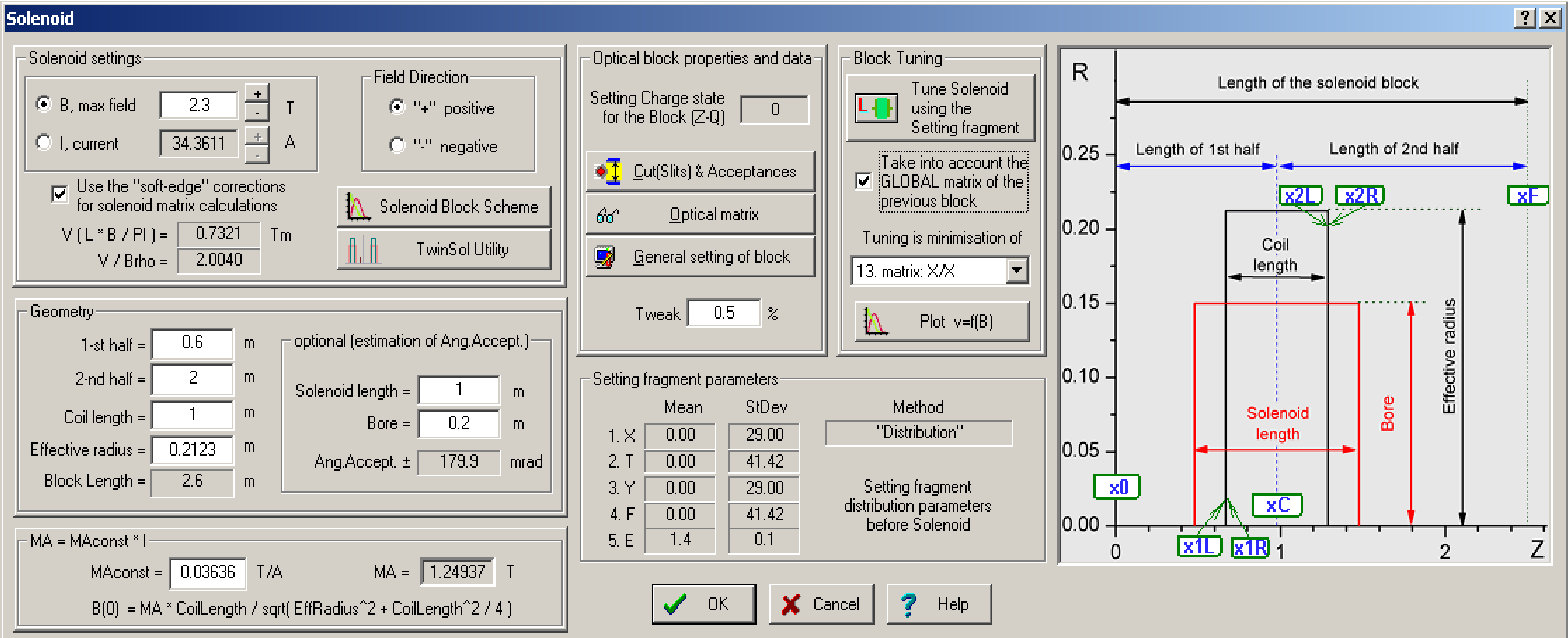
$$\mathbf{M}_{\text{soft sol}} = \mathbf{M}_{\text{edge}}\,\mathbf{M}_{\text{sol}}\,\mathbf{M}_{\text{edge}}$$

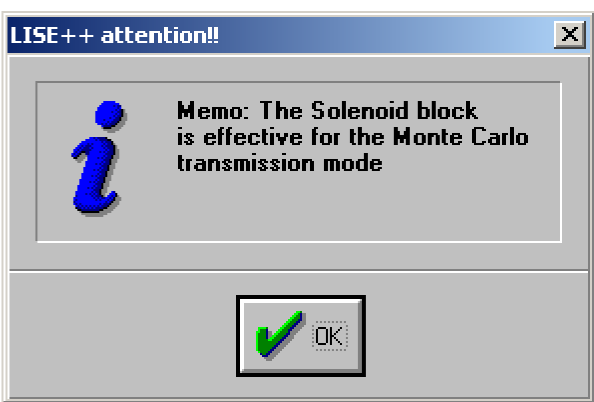
$$\mathbf{M}_{\text{edge}} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ -\Phi_{\text{edge}} & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & -\Phi_{\text{edge}} & 1 \end{bmatrix}$$

$$\Phi_{\text{edge}} = \frac{1}{2}\left(\int_{-\infty}^{\infty} B_z^2(s)\,ds - B_0^2 L\right) = -\frac{k^2 a}{8}$$

$$k = eB_0/pc$$

The Solenoid block dialog





Calculation of setting fragment parameters in front of the solenoid and solenoid tuning are done by the "Distribution" method.

Phase space distributions and transmission with the Solenoid block are recommended with the Monte Carlo transmission method.

The Settings fragment parameters

Setting fragment parameters in front of Solenoid

Beam

Emittance

Beam CARD (sigma)			beam respect to spectrometer		
1. X	1	mm	dX	0	mm
2. T	20	mrad	dT	20	mrad
3. Y	1	mm	dY	0	mm
4. P	20	mrad	dP	20	mrad
5. L	0	mm	dT	1.15	degrees
6. D	0.07	%	dP	1.15	degrees

Setting fragment parameters

	Mean	StDev
1. X	14.00	29.00
2. T	20.00	41.42
3. Y	14.00	29.00
4. F	20.00	41.42
5. E	1.4	0.1

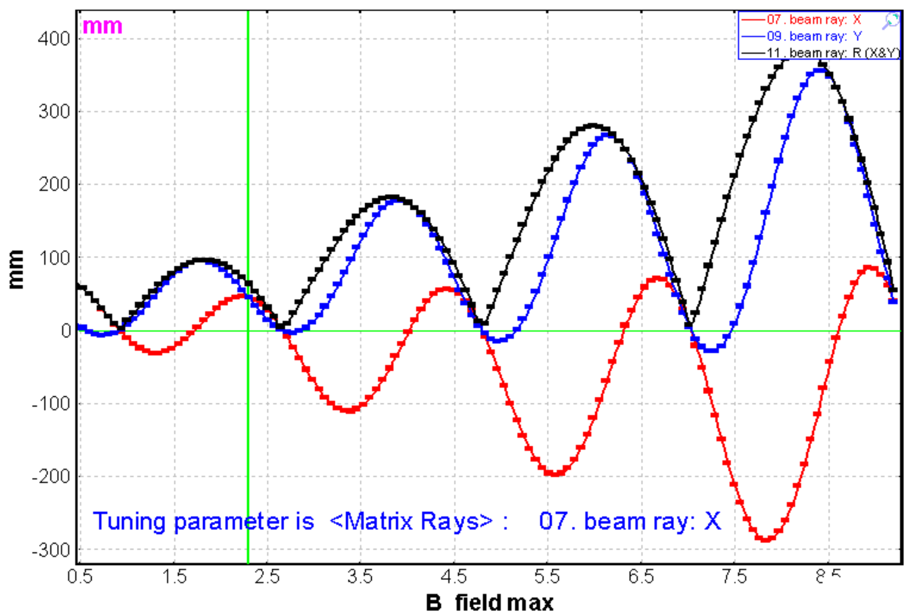
Method: "Distribution"

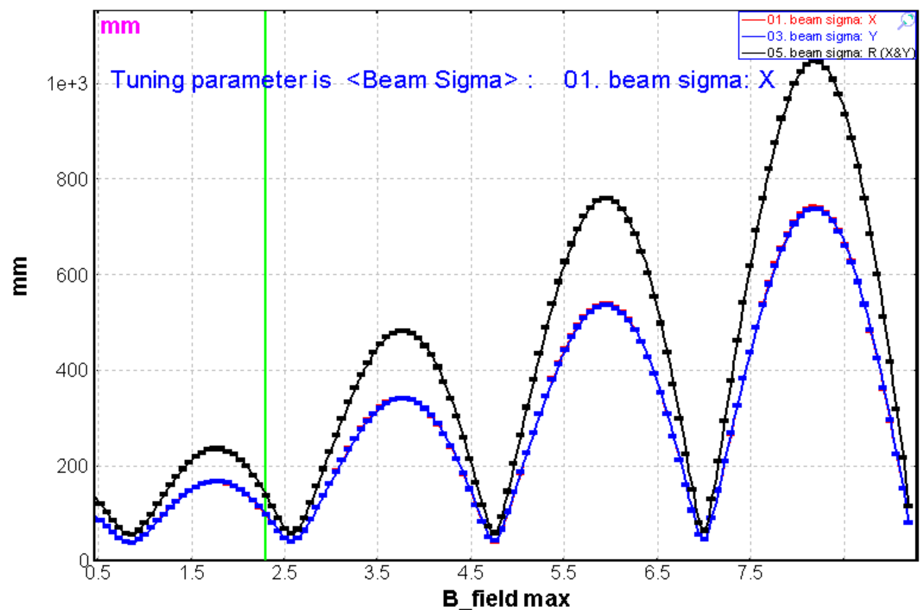
Setting fragment distribution parameters before Solenoid

- "Distribution" method is used if setting fragment transmission up to the solenoid block is more than 0%
- Otherwise "Gaussian" method (based on 5 points determining a distribution shape. Used in "Ellipse" 2D-plot, The "Goodies" dialog)

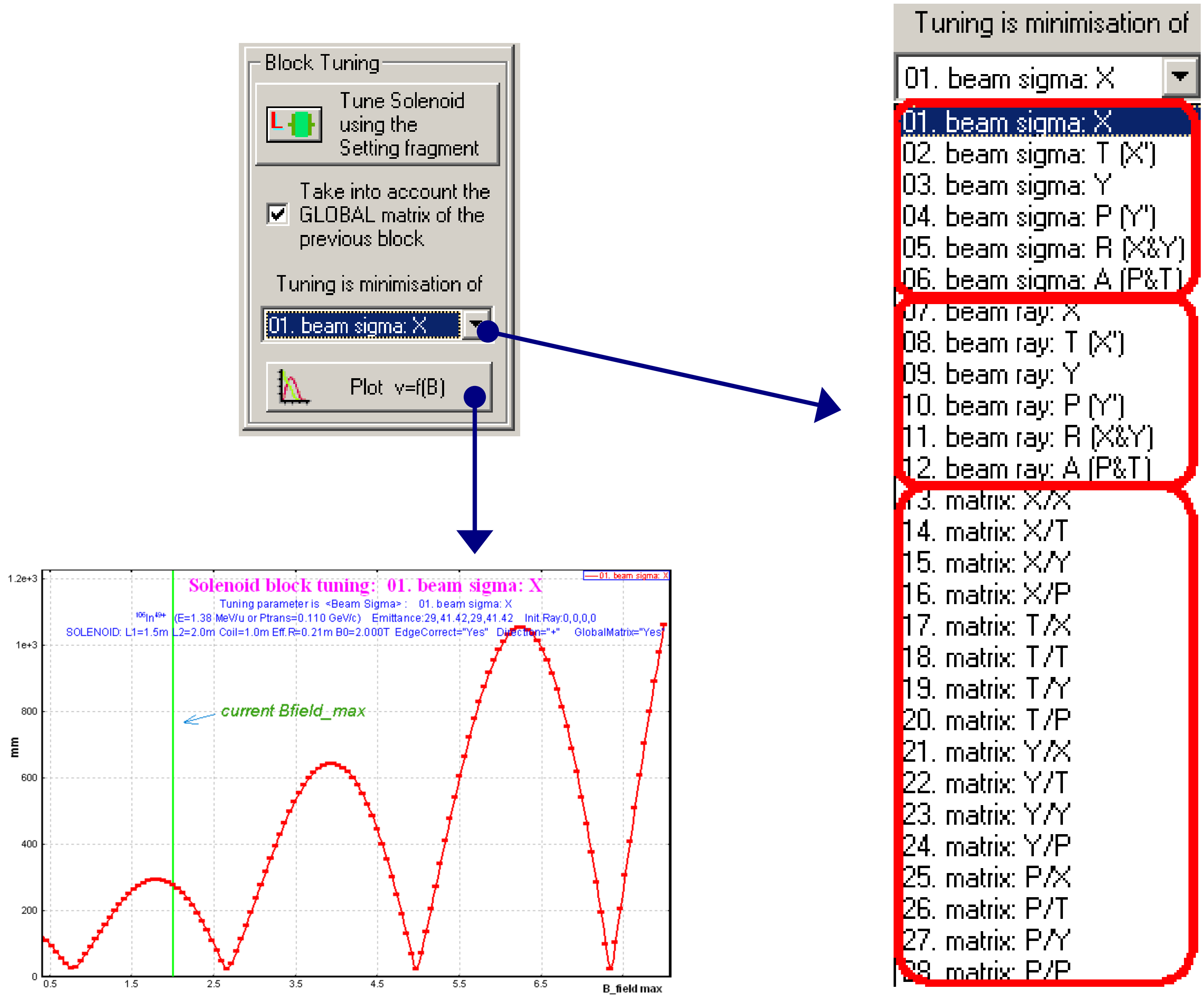
it is used for "beam ray" tuning

it is used for "beam sigma" tuning

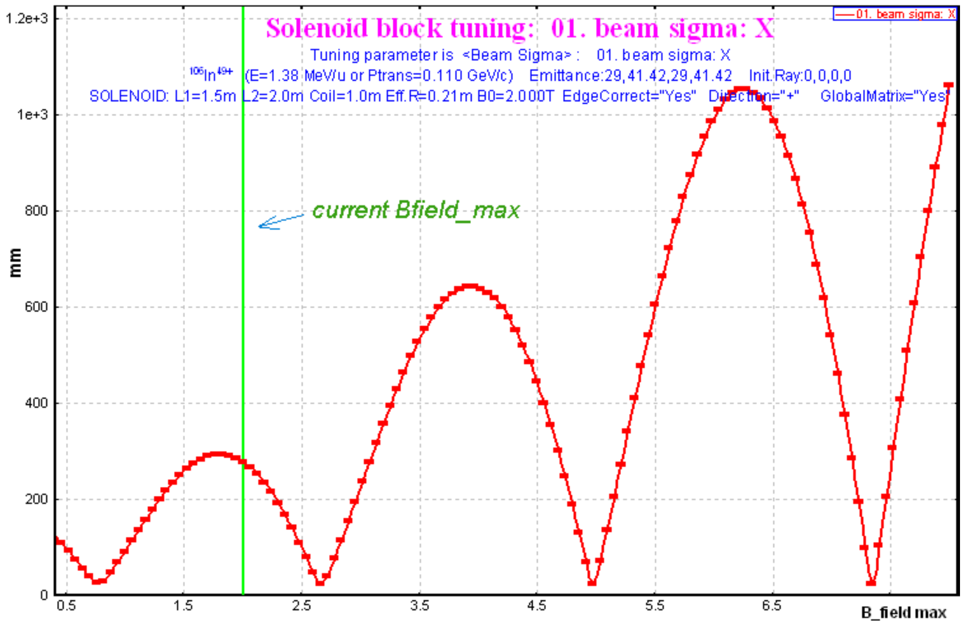


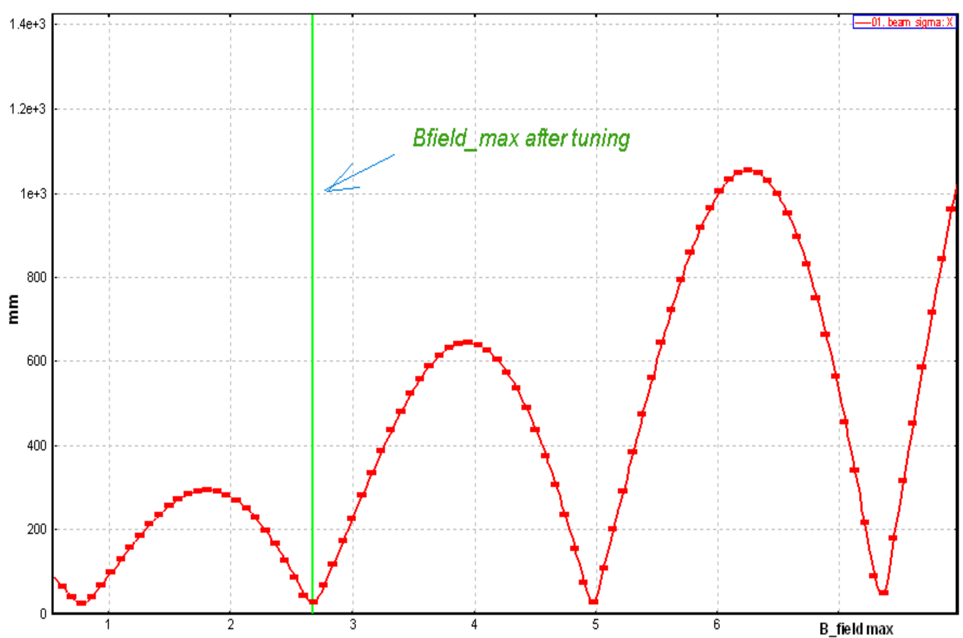


Solenoid Tuning



Solenoid Tuning : Looking for nearest minimum





B_{curr} = max (B_{curr}, 0.1)
X_{min} = B_{curr} * 0.05
X_{max} = B_{curr} * 20

coef = exp(ln(X_{max}/X_{min}) / NP_Tune_Plot)

X_i = Xmin * coef ^{i}

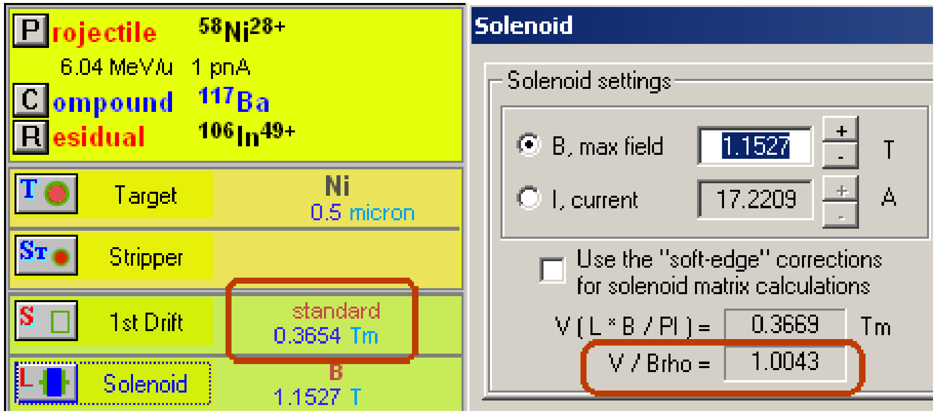
at B_{curr}
i_{start} = NP_Tune_Plot / 2

Go to both directions (left & right) from i_{start}

Search for 1-st minimum

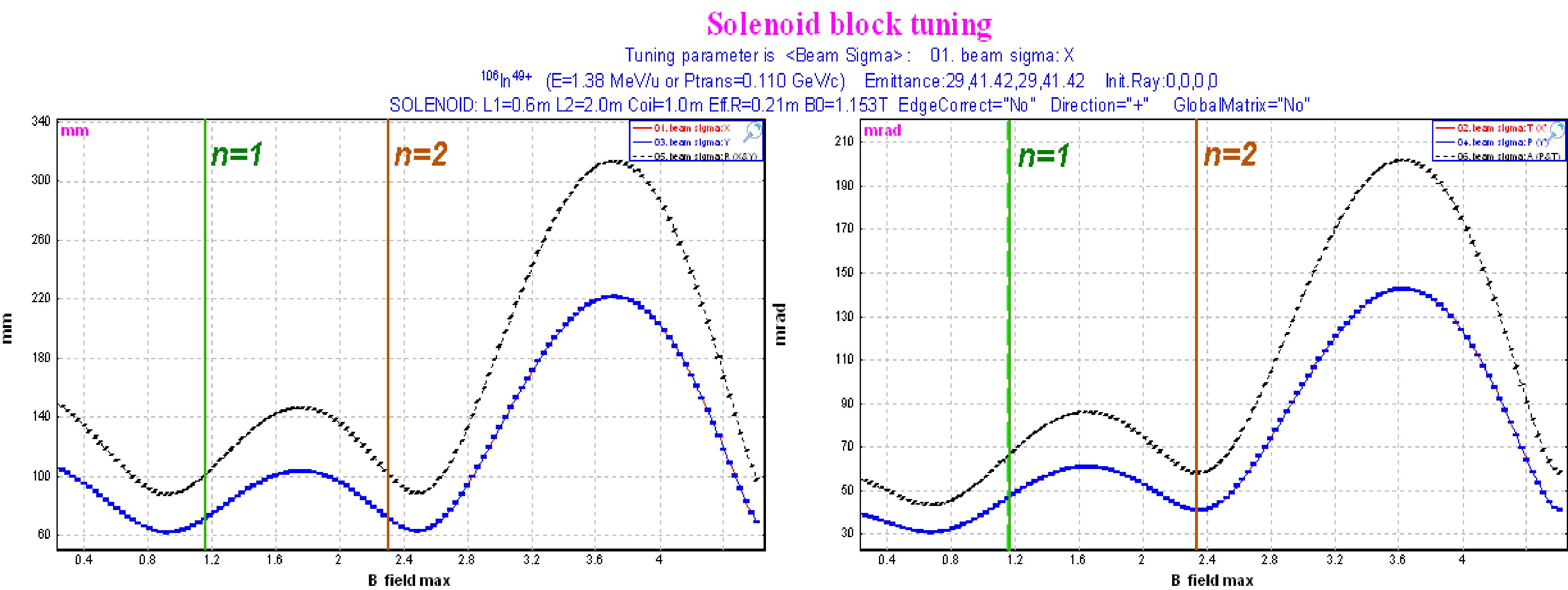
```
#define NP_Tune_Plot 512
#define NP_Tune_fit  16
```

V = Reduced Brho-value. Beam sigma



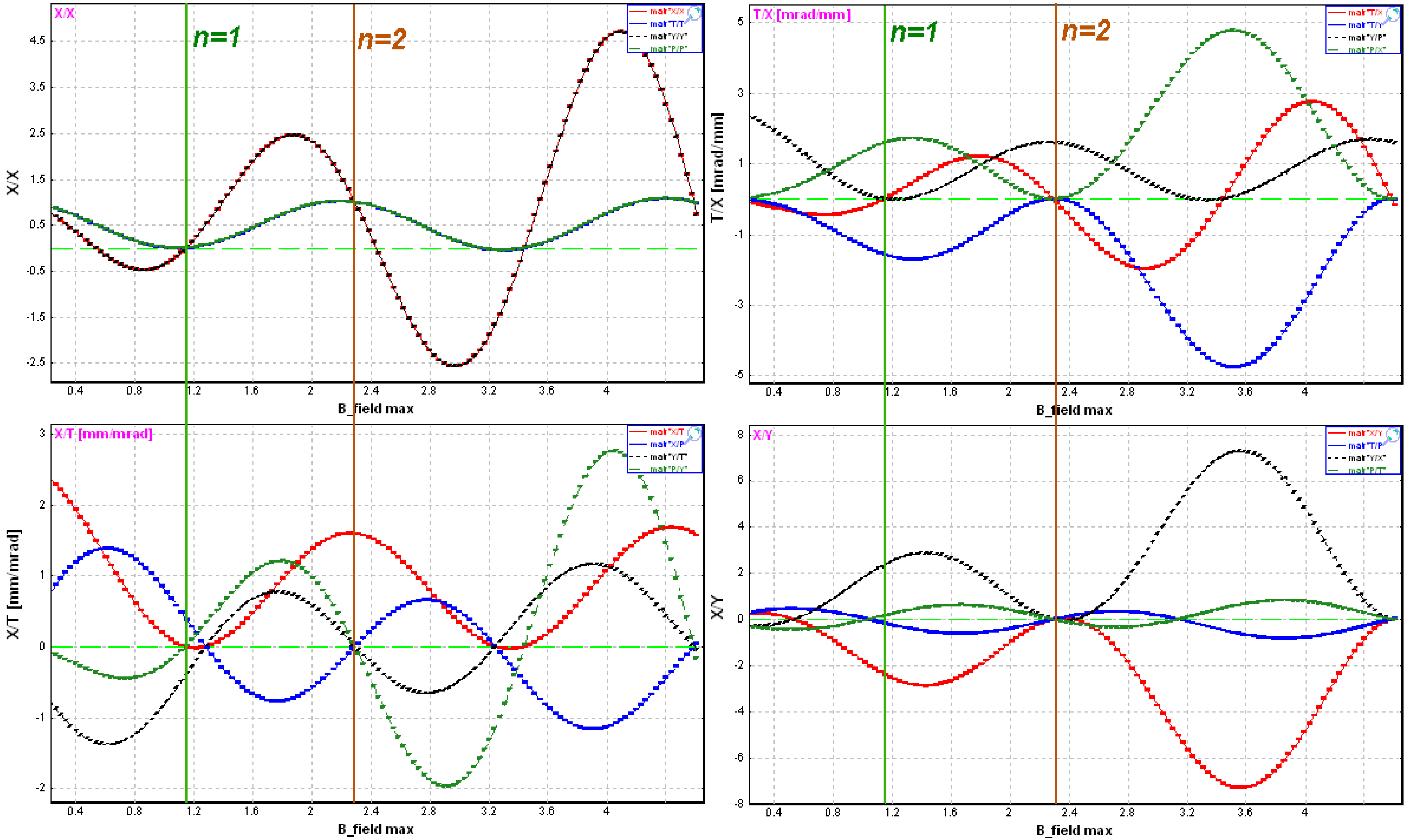
Use Local matrix
No "soft-edge" corrections

http://groups.nscl.msu.edu/lise/8_3/solenoid_test.lpp



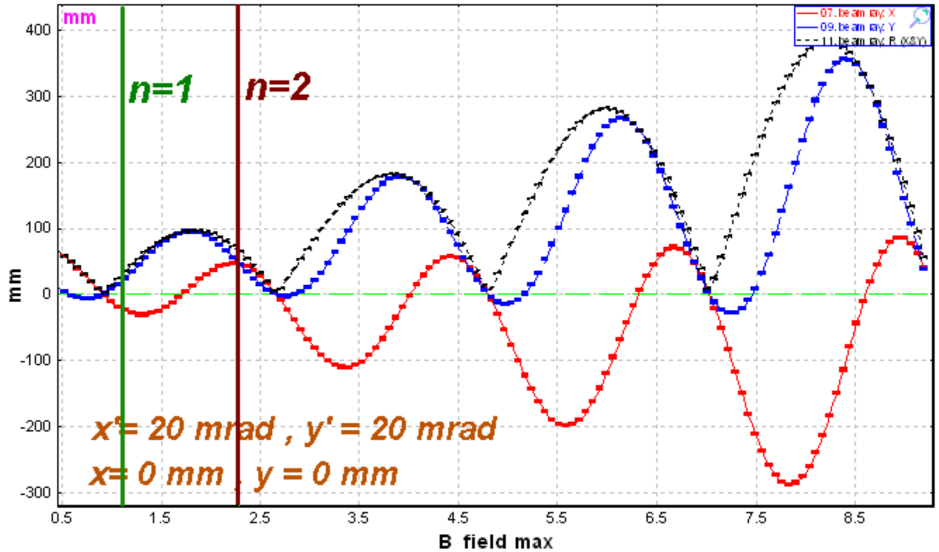
V = Reduced Brho-value. Matrix coefficient

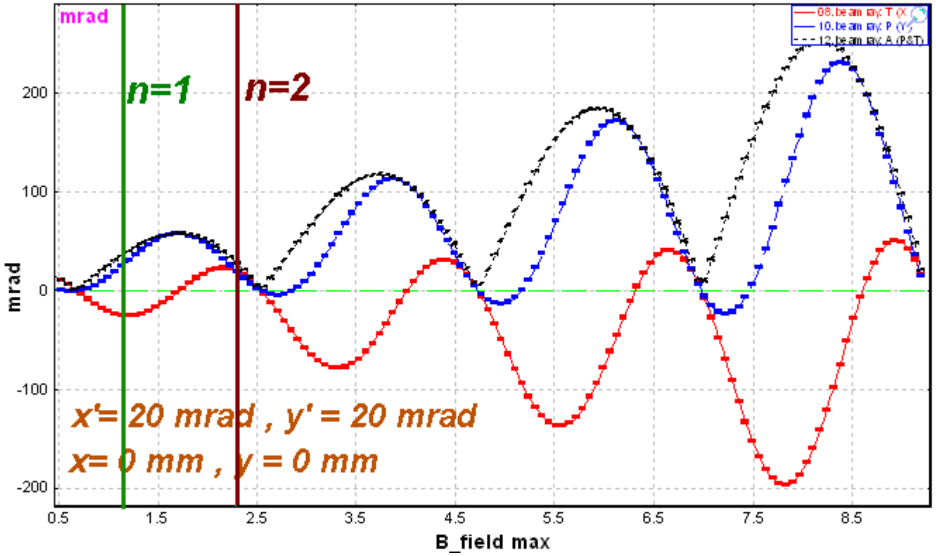
Local matrix. No “soft-edge” corrections

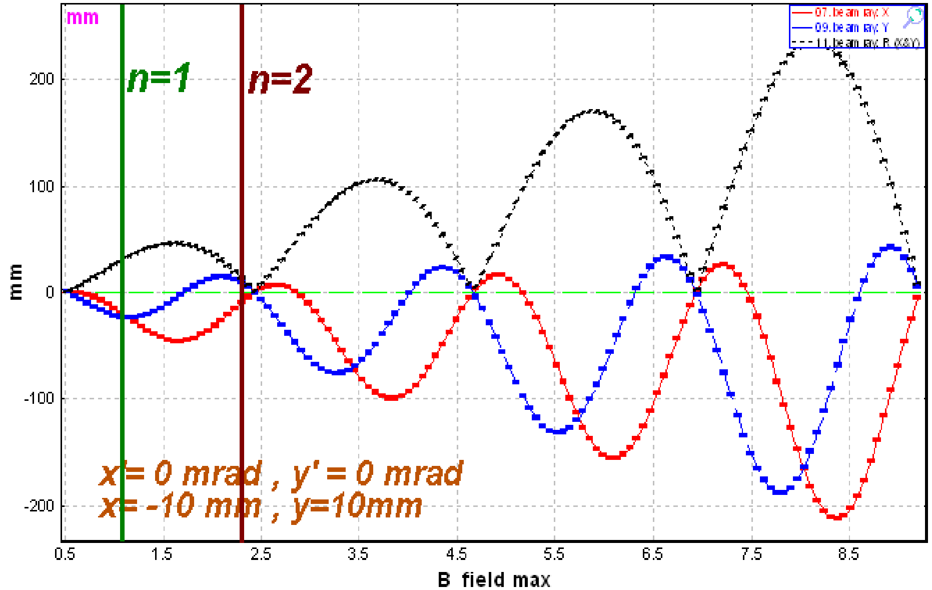


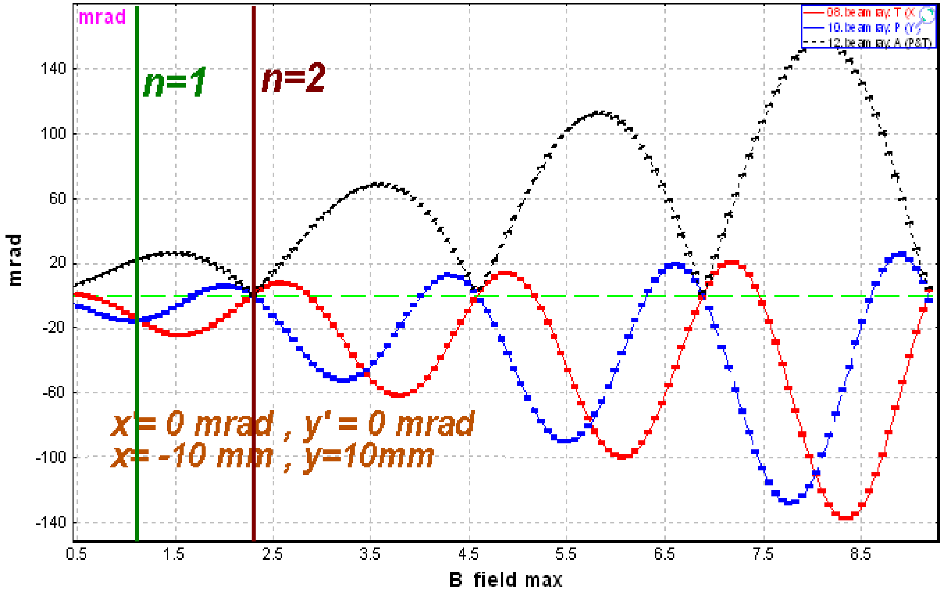
V = Reduced Brho-value. Beam Ray

No "soft-edge" corrections

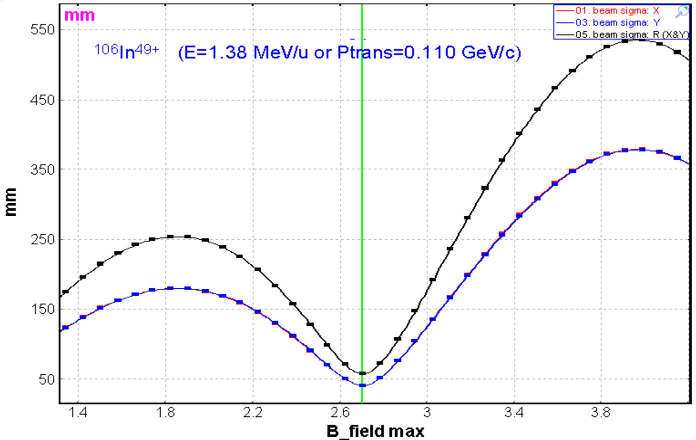








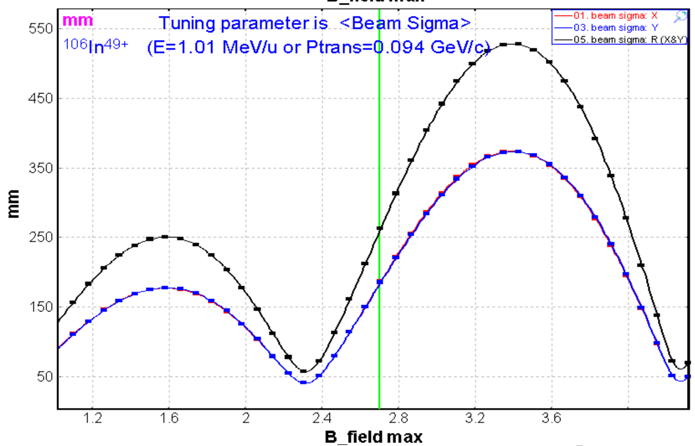
Matrices as function of Energy and A,Z



^{106}In at 1.4 MeV/u

Block matrix						
1. X	-0.9105	1.1786	-0.5655	0.7319	0	0
2. T	-1.1175	0.6539	-0.694	0.4061	0	0
3. Y	0.5655	-0.7319	-0.9105	1.1786	0	0
4. F	0.694	-0.4061	-1.1175	0.6539	0	0
5. L	0	0	0	0	1	0
6. D	0	0	0	0	0	1
	/[mm]	/[mrad]	/[mm]	/[mrad]	/[mm]	/[%]

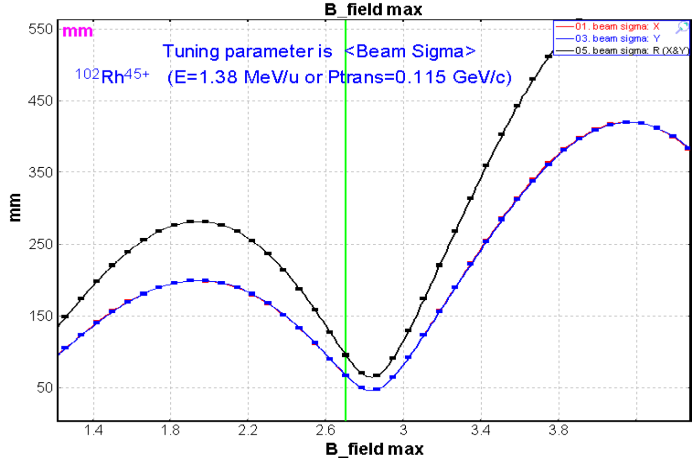
Global matrix							Beam
-0.9105	0.5413	-0.5655	0.3361	0	0	[mm]	12.654
-1.1175	-0.1283	-0.694	-0.0797	0	0	[mrad]	3.292
0.5655	-0.3361	-0.9105	0.5413	0	0	[mm]	12.927
0.694	0.0797	-1.1175	-0.1283	0	0	[mrad]	3.306
0	0	0	0	1	0	[mm]	0
0	0	0	0	0	1	[%]	0.07
/[mm]	/[mrad]	/[mm]	/[mrad]	/[mm]	/[%]		



^{106}In at 1.0 MeV/u

Block matrix						
1. X	-1.8574	0.1773	-4.4777	0.4273	0	0
2. T	-1.3632	0.0511	-3.2863	0.1231	0	0
3. Y	4.4777	-0.4273	-1.8574	0.1773	0	0
4. F	3.2863	-0.1231	-1.3632	0.0511	0	0
5. L	0	0	0	0	1	0
6. D	0	0	0	0	0	1
	/[mm]	/[mrad]	/[mm]	/[mrad]	/[mm]	/[%]

Global matrix							Beam
-1.8574	-1.1229	-4.4777	-2.7071	0	0	[mm]	59.83
-1.3632	-0.9031	-3.2863	-2.1773	0	0	[mrad]	48.098
4.4777	2.7071	-1.8574	-1.1229	0	0	[mm]	57.823
3.2863	2.1773	-1.3632	-0.9031	0	0	[mrad]	46.476
0	0	0	0	1	0	[mm]	0
0	0	0	0	0	1	[%]	0.07
/[mm]	/[mrad]	/[mm]	/[mrad]	/[mm]	/[%]		



^{102}Rh at 1.4 MeV/u

Block matrix						
1. X	-0.0842	1.4274	-0.0341	0.5788	0	0
2. T	-0.6504	0.8264	-0.2637	0.3351	0	0
3. Y	0.0341	-0.5788	-0.0842	1.4274	0	0
4. F	0.2637	-0.3351	-0.6504	0.8264	0	0
5. L	0	0	0	0	1	0
6. D	0	0	0	0	0	1
	/[mm]	/[mrad]	/[mm]	/[mrad]	/[mm]	/[%]

Global matrix							Beam
-0.0842	1.3685	-0.0341	0.5549	0	0	[mm]	29.009
-0.6504	0.3711	-0.2637	0.1505	0	0	[mrad]	7.903
0.0341	-0.5549	-0.0842	1.3685	0	0	[mm]	30.068
0.2637	-0.1505	-0.6504	0.3711	0	0	[mrad]	8.181
0	0	0	0	1	0	[mm]	0
0	0	0	0	0	1	[%]	0.07
/[mm]	/[mrad]	/[mm]	/[mrad]	/[mm]	/[%]		

Methods of Transmission calculation vs. Solenoid

Tuning

Calculation of setting fragment parameters in front of the solenoid and solenoid tuning are done by the “Distribution” method.

Transmission

Distribution method:
Local solenoid matrix , and following recalculation of Global matrices for <u>average energy</u> of each ion.
Non-zero X/T, T/X, X/Y, Y/X, X/P, P/X, T/Y, Y/T, X/P, P/X, Y/P, P/Y matrix coefficients wash out all structures.

Monte Carlo method uses only local matrices. Solenoid local matrix is recalculated <u>for EACH ray (for each fragment energy)</u>.

Phase space distributions and transmission calculations with the Solenoid block are recommended with the Monte Carlo transmission method.

Block matrix

1. X	-0.0842	1.4274	-0.0341	0.5788	0	0
2. T	-0.6504	0.8264	-0.2637	0.3351	0	0
3. Y	0.0341	-0.5788	-0.0842	1.4274	0	0
4. F	0.2637	-0.3351	-0.6504	0.8264	0	0
5. L	0	0	0	0	1	0
6. D	0	0	0	0	0	1
	/[mm]	/[mrad]	/[mm]	/[mrad]	/[mm]	/[%]

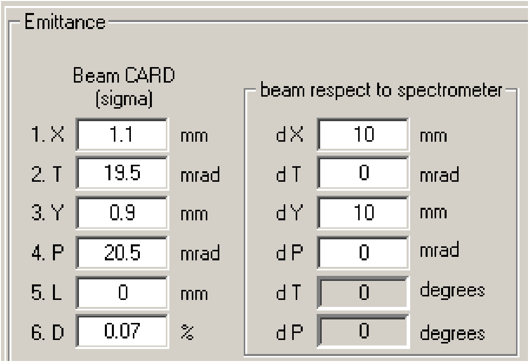
Global matrix

-0.0842	1.3685	-0.0341	0.5549	0	0	[mm]
-0.6504	0.3711	-0.2637	0.1505	0	0	[mrad]
0.0341	-0.5549	-0.0842	1.3685	0	0	[mm]
0.2637	-0.1505	-0.6504	0.3711	0	0	[mrad]
0	0	0	0	1	0	[mm]
0	0	0	0	0	1	[%]
/[mm]	/[mrad]	/[mm]	/[mrad]	/[mm]	/[%]	

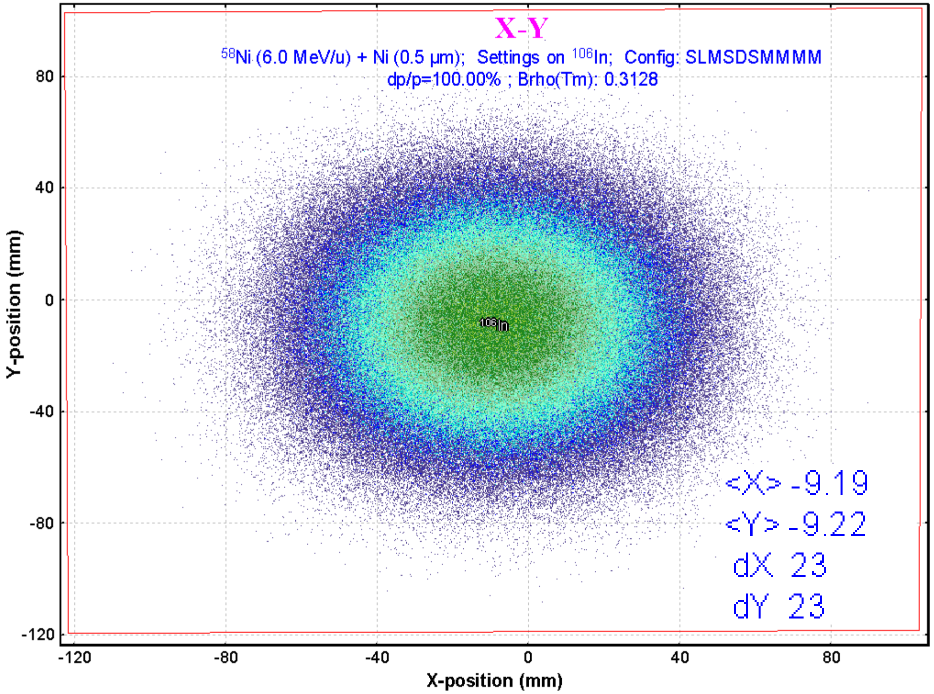
Beam

29.009
7.903
30.068
8.181
0
0.07

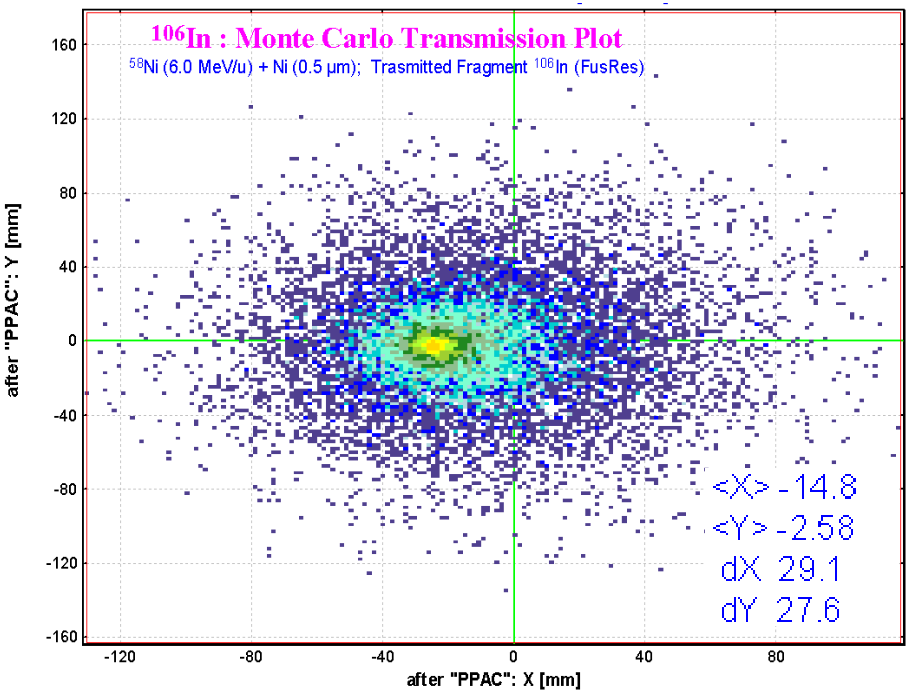
Methods of Transmission calculation: X vs Y



Distribution method



Monte Carlo method

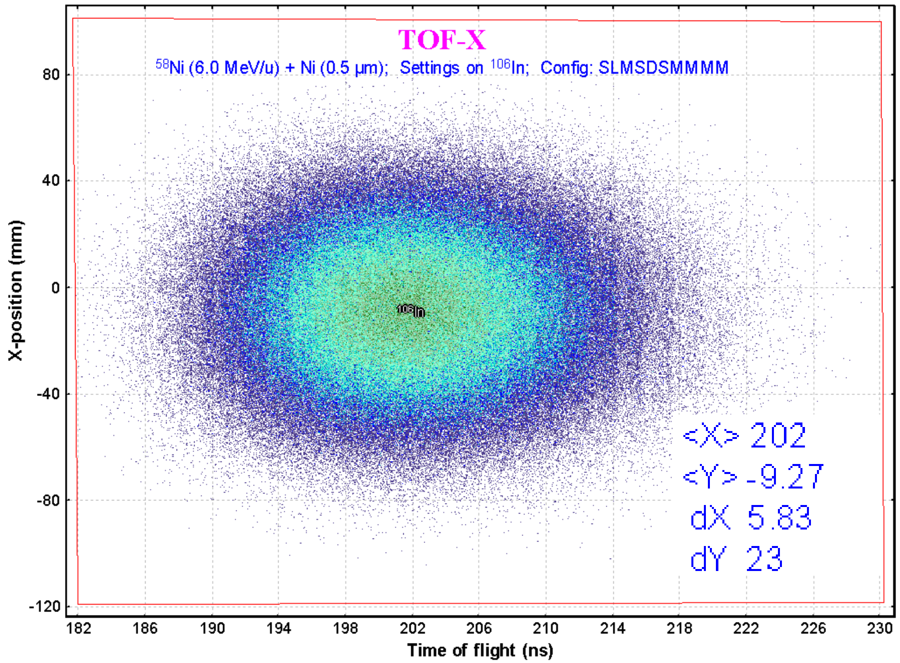


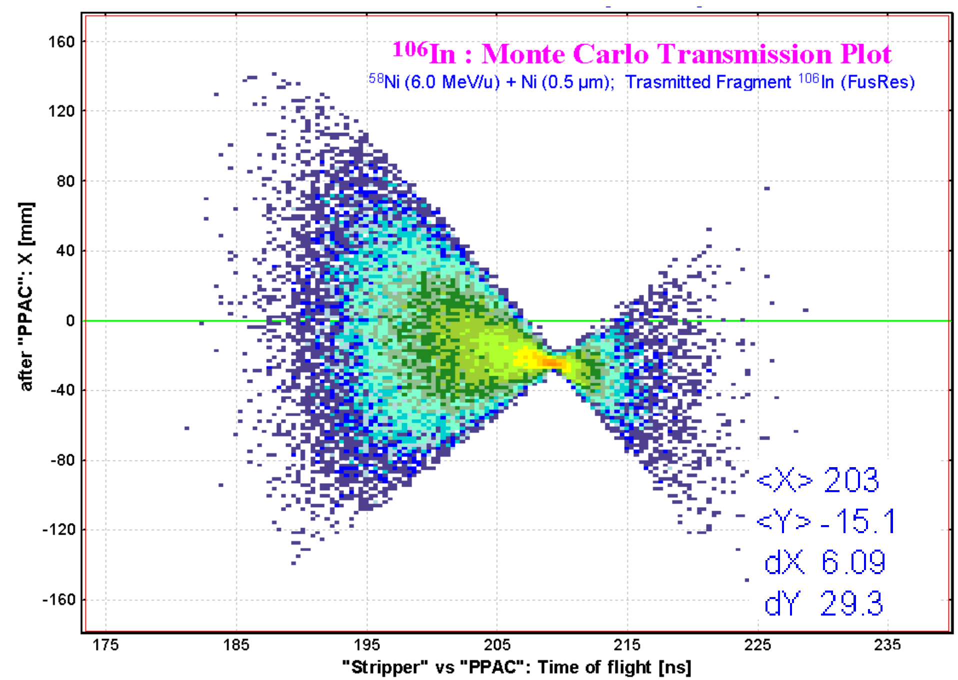
Methods of Transmission calculation: X vs TOF

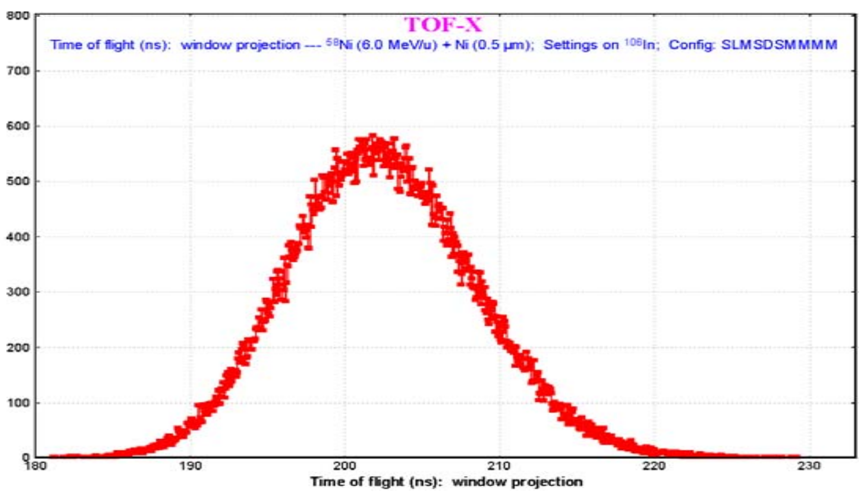
Distribution method

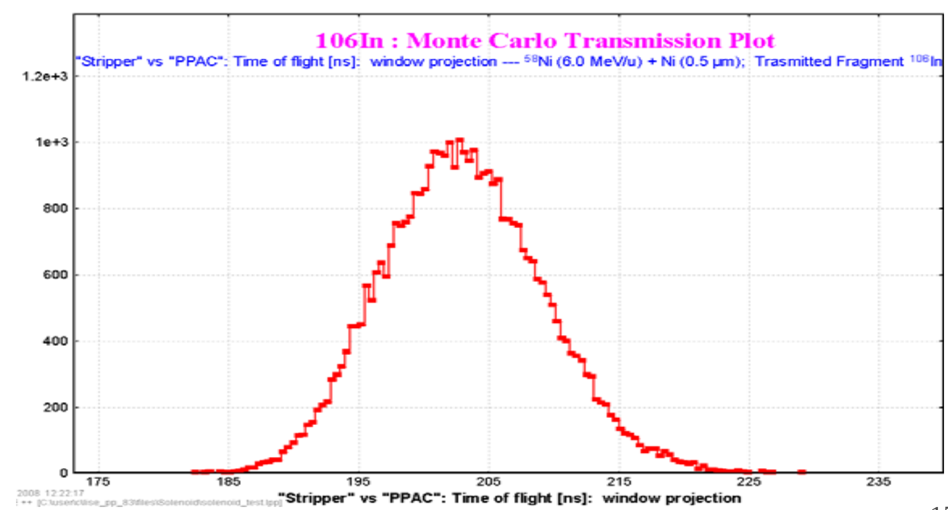
After solenoid

Monte Carlo method



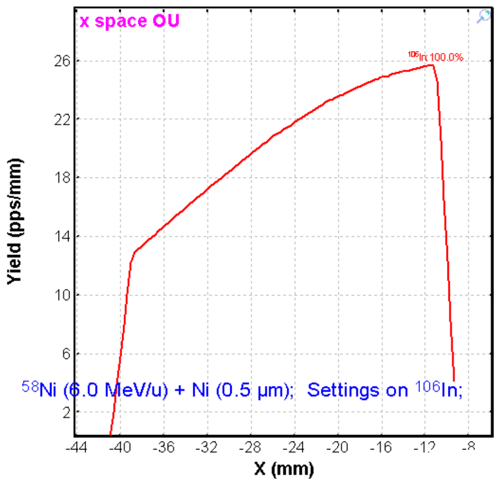


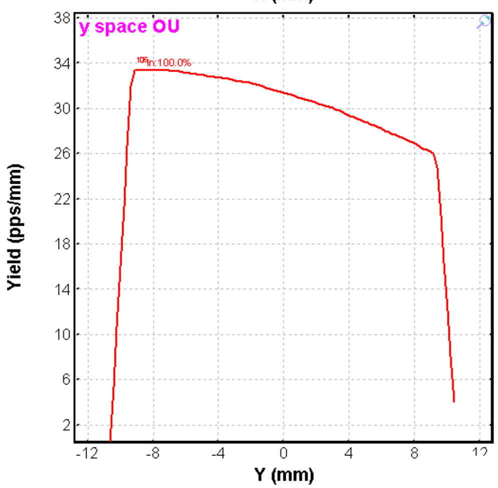


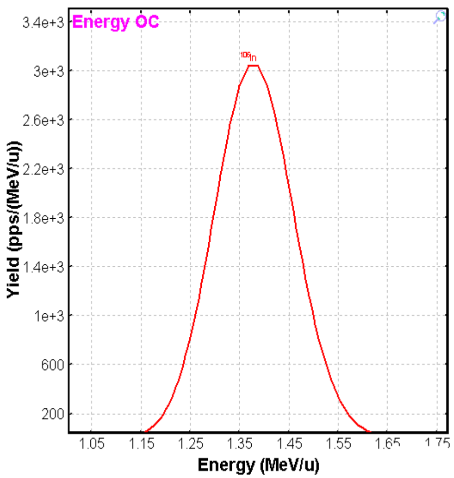


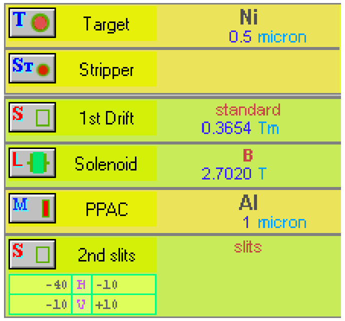
Methods of Transmission calculation: X vs TOF

Distribution method





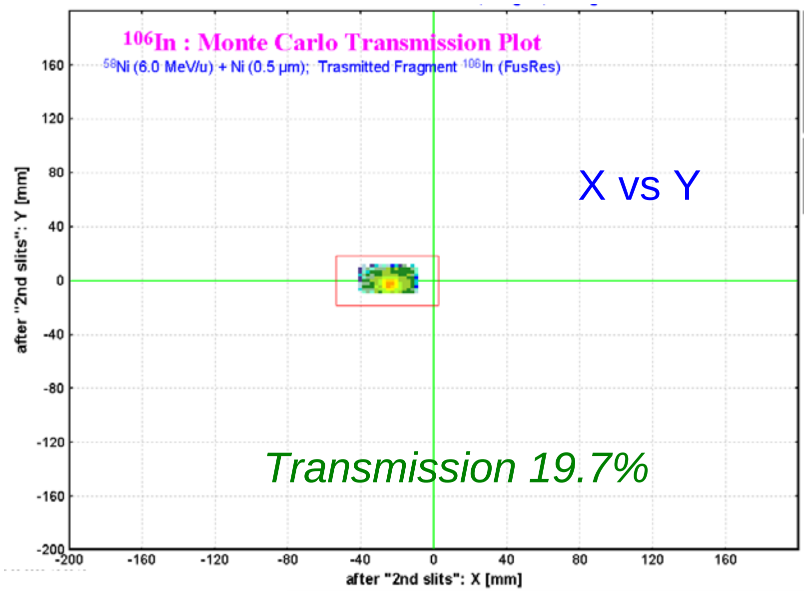


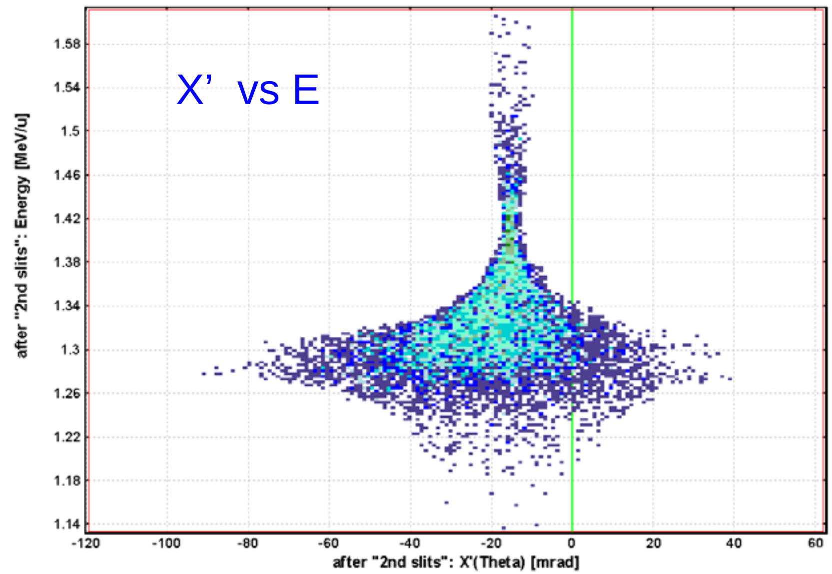


After 2nd slits

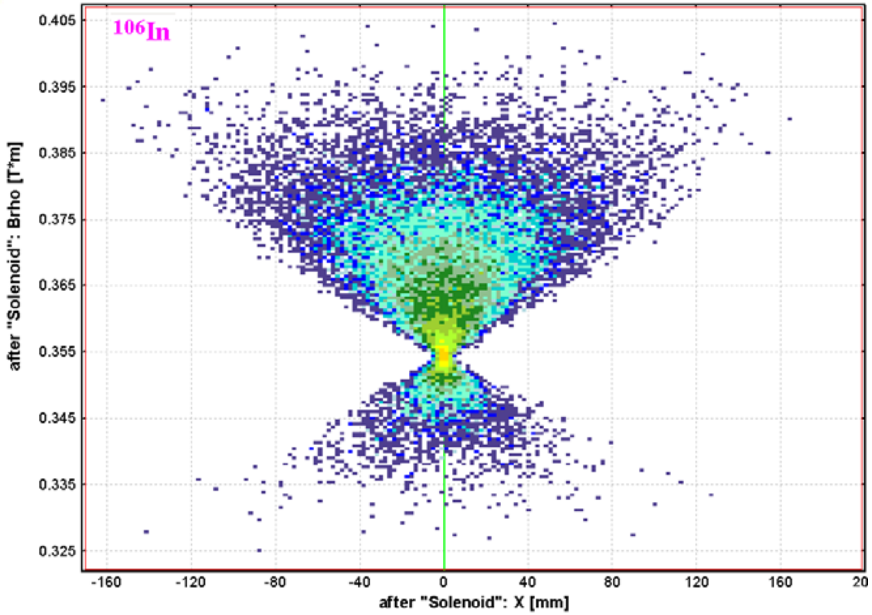
Transmission 10.5%

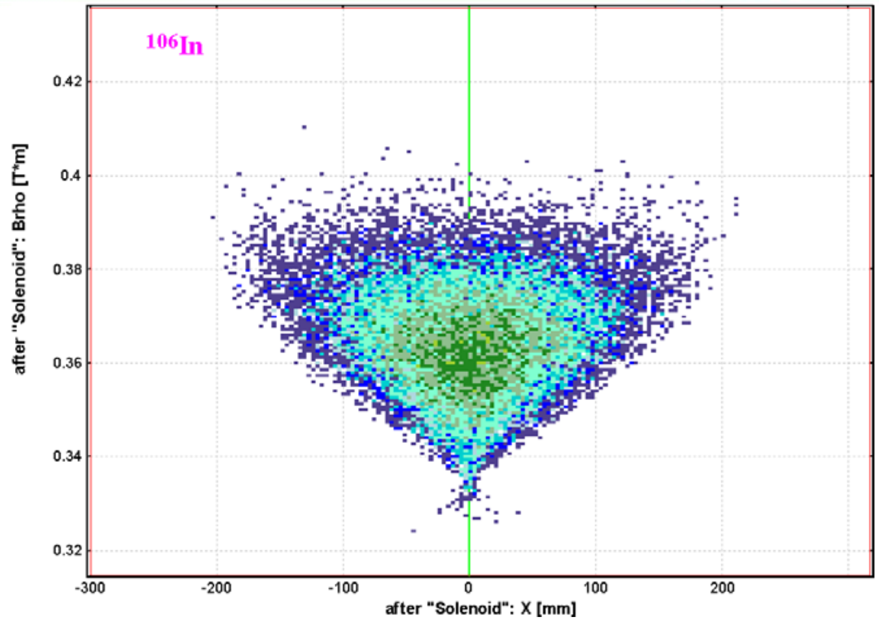
Monte Carlo method





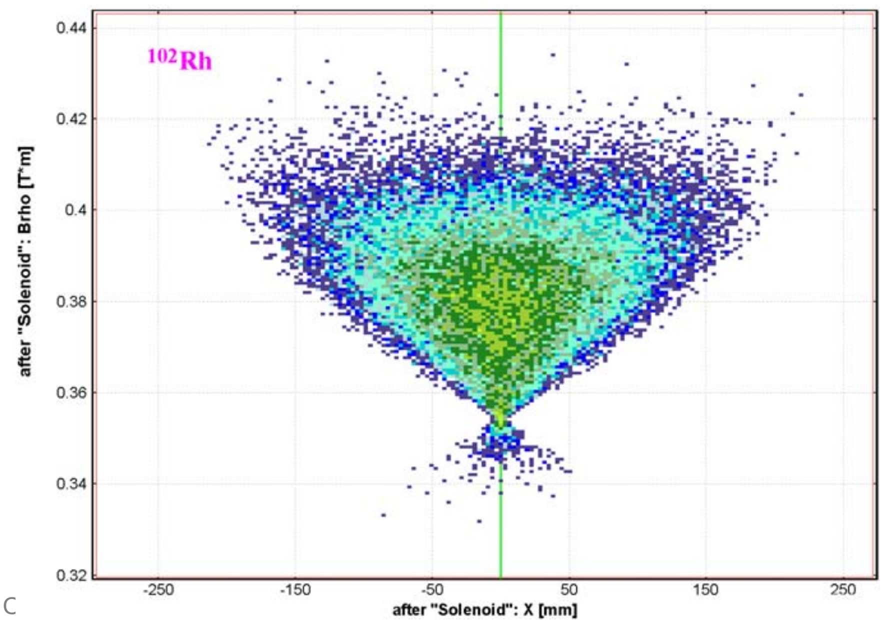
Function of Field

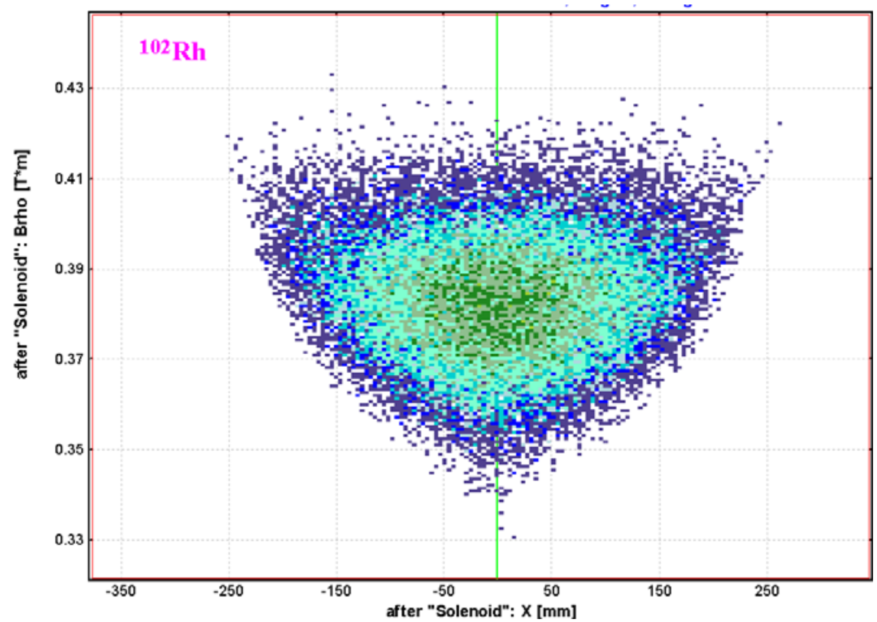




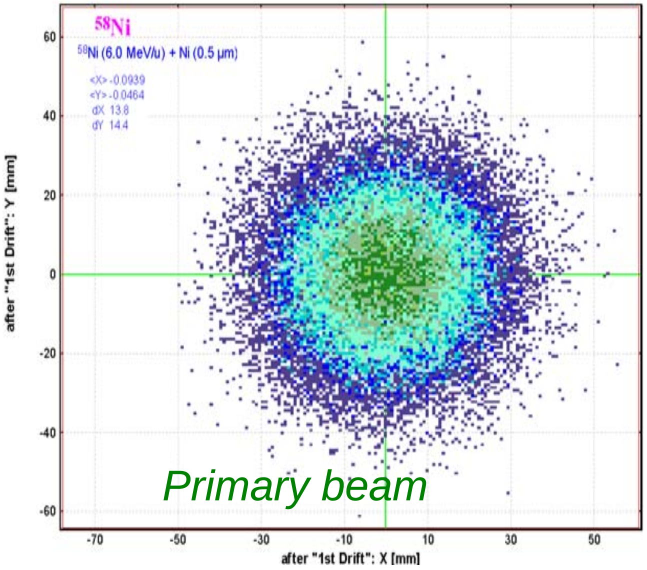
$B_{solenoid}$ = 2.7 T

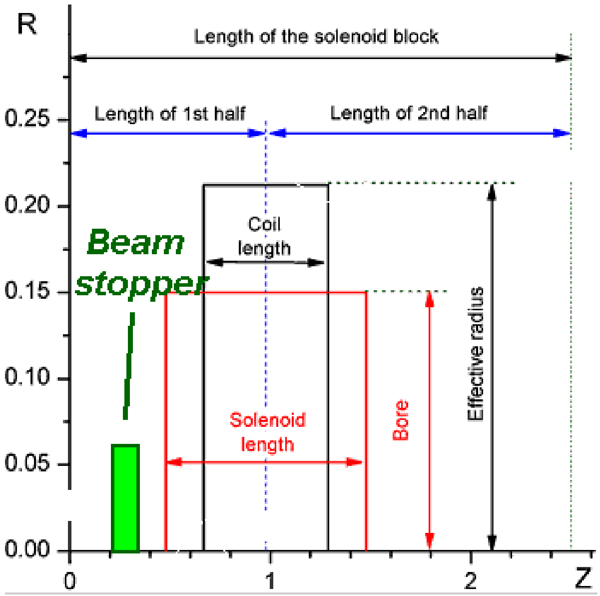
$B_{solenoid}$ = 2.55 T

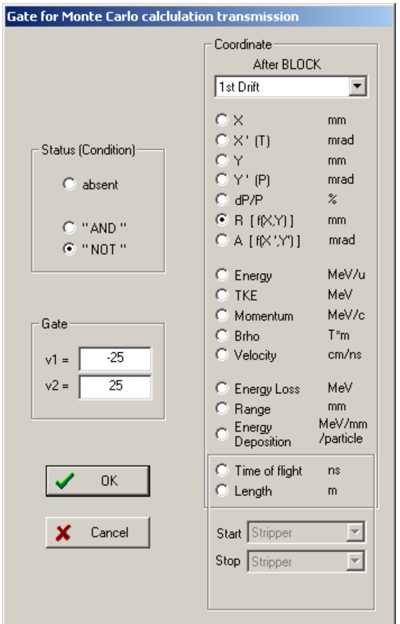


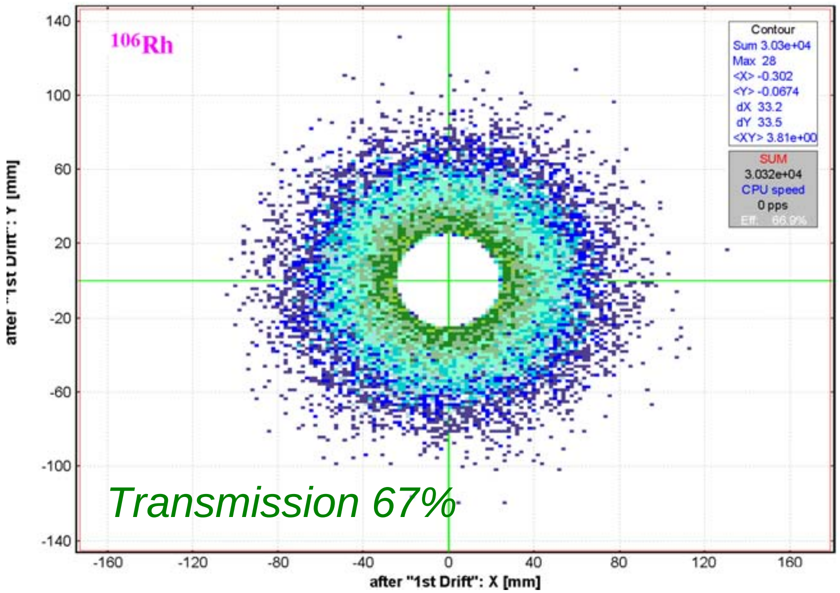


Working with Solenoid: Beam Stopper

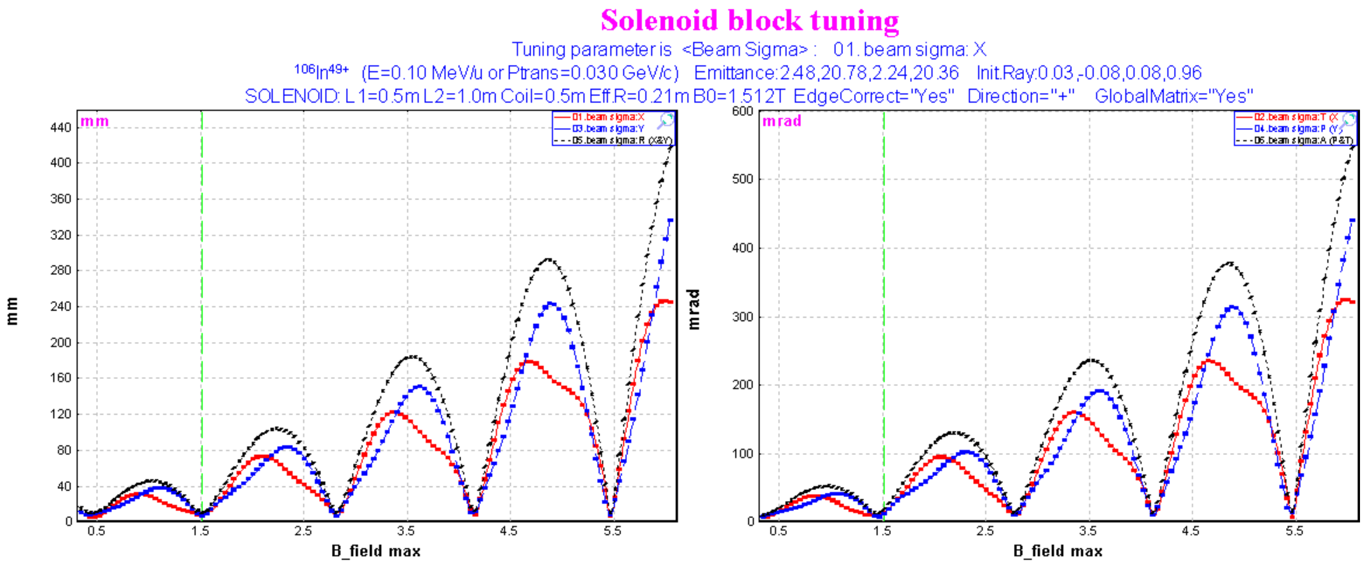


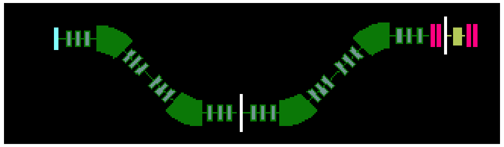






Solenoid & Fragment-Separator or Dipole



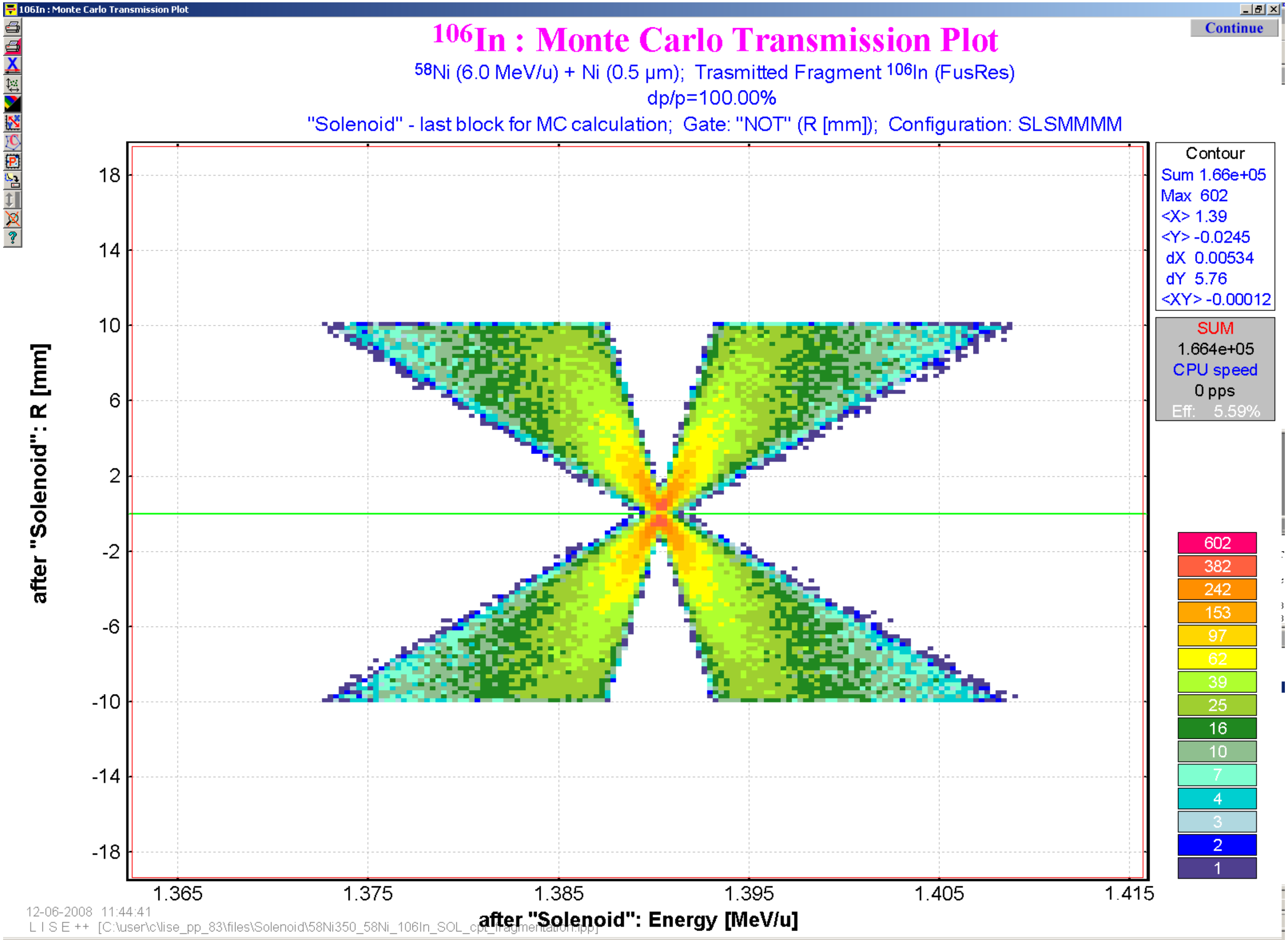


106In transmission 15%

102Rh transmission 3%

For 2% momentum acceptance

Conclusion


106In : Monte Carlo Transmission Plot
Continue
106In : Monte Carlo Transmission Plot
58Ni (6.0 MeV/u) + Ni (0.5 μm); Trasmitted Fragment 106In (FusRes)
dp/p=100.00%
"Solenoid" - last block for MC calculation; Gate: "NOT" (R [mm]); Configuration: SLSMMMM
after "Solenoid": R [mm]
18
14
10
6
2
-2
-6
-10
-14
-18
1.365
1.375
1.385
1.395
1.405
1.415
after "Solenoid": Energy [MeV/u]
Contour
Sum 1.66e+05
Max 602
<X> 1.39
<Y> -0.0245
dX 0.00534
dY 5.76
<XY> -0.00012
SUM
1.664e+05
CPU speed
0 pps
Eff: 5.59%
602
382
242
153
97
62
39
25
16
10
7
4
3
2
1
12-06-2008 11:44:41
L I S E ++ [C:\user\c\lise_pp_83\files\Solenoid\58Ni350_58Ni_106In_SOL_cpt_fragmentation.lpp]