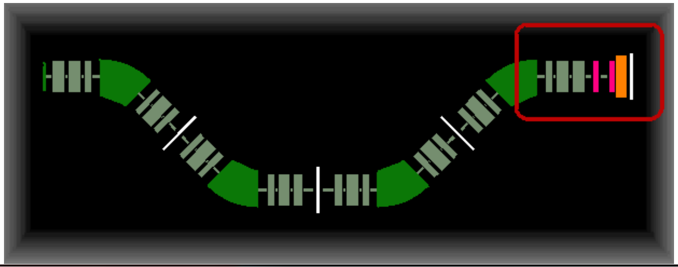
Reverse technique for A1900

v.9.10.270
from 02/03/16

1. LISE-type reverse file creation
2. Optics (1→1)
3. Optics (2→1)
4. Detector resolution for optics (1→1)
5. Contribution of straggling in wedge
6. Some remarks: charge states
7. Summary

Direct file: http://lise.nscl.msu.edu/9_10/reverse/A1900_direct.lpp
Reverse file: http://lise.nscl.msu.edu/9_10/reverse/A1900_Lreverse.lpp

Preparation of "direct" file : double focus & achromatism



Optics fit

Blocks with parameters to vary		
#01-q	Position@062:	Q098-8TA
#02-q	Position@064:	Q100-8TB
#03-q	Position@066:	Q102-8TC

Active Constraint blocks			
#01	@071:	R12 = 0	Fit Xfocus
#02	@072:	R34 = 0	Fit Yfocus
#03	@073:	R11 < 2	Fit XX
#04	@074:	R33 < 2	Fit YY
#05	@075:	R16 = 0	Fit XDisp

initial

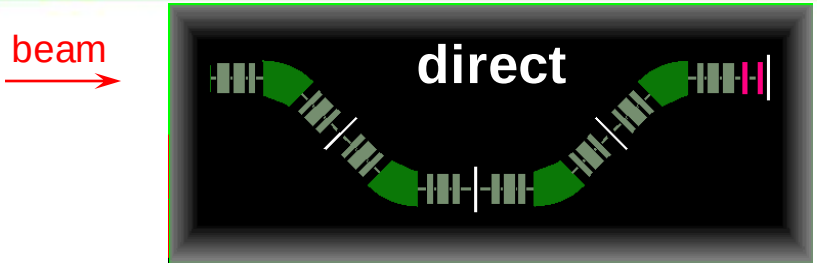
```
                                                   Format [mm-mrad]
===================== G L O B A L ====  matrix ==================== | Beam(sigma) |
  +2.794e+00  -1.111e-01  0            0            0   -1.003e-03  |    4.35e+00 |
  -1.059e+00  +4.000e-01  0            0            0   +1.173e-03  |    1.20e+01 |
   0           0          +8.870e-01  -1.107e-01   0    0           |    3.44e+00 |
   0           0          +5.809e+00  +4.025e-01   0    0           |    1.34e+01 |
  -3.983e-04  +4.452e-05  0            0            1.0 -1.088e+01  |    1.63e+01 |
   0           0          0            0            0   +1.000e+00  |    1.50e+00 |
--------------------------------------------------------------------------------------
```

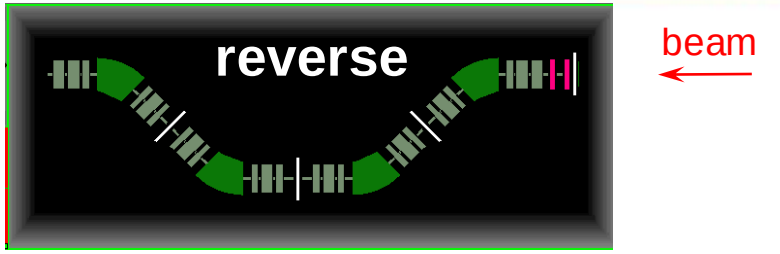
\\intranet.nscl.msu.edu\files\user\tarasov\My Documents\LISE\results\A1900 direct v3.fit

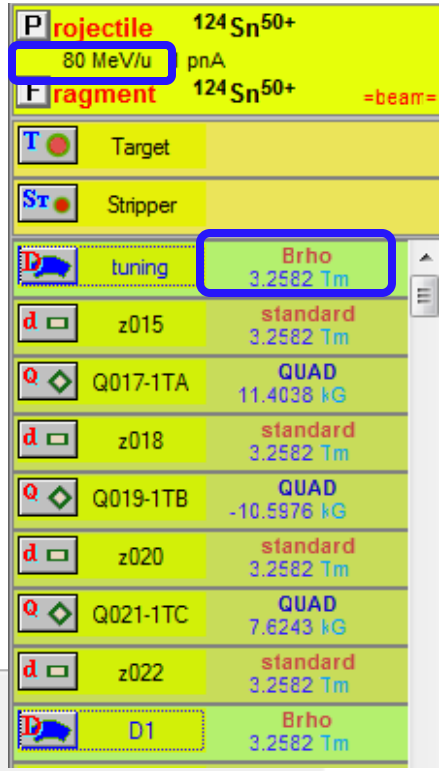
```
chi2: Initial   8.76318  and Final  0.308304  LISE fit reduced values
chi1: Initial    201.78  and Final   3.60823  LISE fit reduced values

Parameters:          LeftBound     Initial      RightBound    | Final
#01-q: Q098-8TA      -1.0e+99  <  +8.091e+00  <  +1.0e+99    | +8.305e+00
#02-q: Q100-8TB      -1.0e+99  <  -9.592e+00  <  +1.0e+99    | -1.019e+01
#03-q: Q102-8TC      -1.0e+99  <  +4.531e+00  <  +1.0e+99    | +6.018e+00
----------------------------------------------------------------------------------

Constaint values:    Initial      Final        Precision  (Fin-Des)/P  |   Desired
#01: Fit Xfocus      -1.111e-01   +6.790e-05   1.0e-03    +6.790e-02   |   = 0
#02: Fit Yfocus      -1.107e-01   -3.067e-02   1.0e-02    +3.067e+00   |   = 0
#03: Fit XX          +2.794e+00   +2.000e+00   1.0e-02    +1.422e-01   |   < 2
#04: Fit  YY         +8.870e-01   +2.002e+00   1.0e-02    +2.772e-01   |   < 2
#05: Fit XDisp       -1.003e-03   -5.418e-04   1.0e-02    +5.418e-02   |   = 0
----------------------------------------------------------------------------------

==>  Results for A1900 direct v3.fit:
Levenberg-Marquardt returned 8 in 8 iter, reason 2
Termination reason: 2 - stopped by small Dp

Minimization info:
0: 1.878e+04          ||e||_2 at initial p
1: 9.509e+00          ||e||_2
2: 1.224e+02          ||J^T e||_inf
3: 0.000e+00          ||Dp||_2
4: 2.321e-06          mu/max[J^T J]_ii
5: 8                  # iterations
6: 2                  reason for terminating
7: 806                # function evaluations
8: 8                  # Jacobian evaluations
9: 8                  # linear systems solved, i.e. # attempts for reducing error
----------------------------------------------------------------------------------

==> "Fit XDisp" : last fitting block global optical matrix and sigma vector
                                                   Format [mm-mrad]
===================== G L O B A L ====  matrix ==================== | Beam(sigma) |
  +2.000e+00  +6.790e-05  0            0            0   -5.418e-04  |    2.00e+00 |
  -1.808e+00  +4.999e-01  0            0            0   +1.598e-03  |    1.51e+01 |
   0           0          +2.002e+00  -3.067e-02   0    0           |    2.20e+00 |
   0           0          +6.055e+00  +4.068e-01   0    0           |    1.36e+01 |
  -3.983e-04  +4.452e-05  0            0            1.0 -1.088e+01  |    1.63e+01 |
   0           0          0            0            0   +1.000e+00  |    1.50e+00 |
----------------------------------------------------------------------------------

Covariance of the fit :
+2.082281e-04 -3.905964e-04 +2.048838e-04
-3.905964e-04 +1.654548e-03 -1.597016e-03
+2.048838e-04 -1.597016e-03 +1.938161e-03
----------------------------------------------------------------------------------

Options info:
0: 1.000e-03          mu
1: 1.000e-15          epsilon1   ||J^T e||_inf
2: 1.000e-25          epsilon2   ||Dp||_2
3: 1.000e-20          epsilon3   ||e||_2
4: 1.000e-06          delta      aprrox.step
```

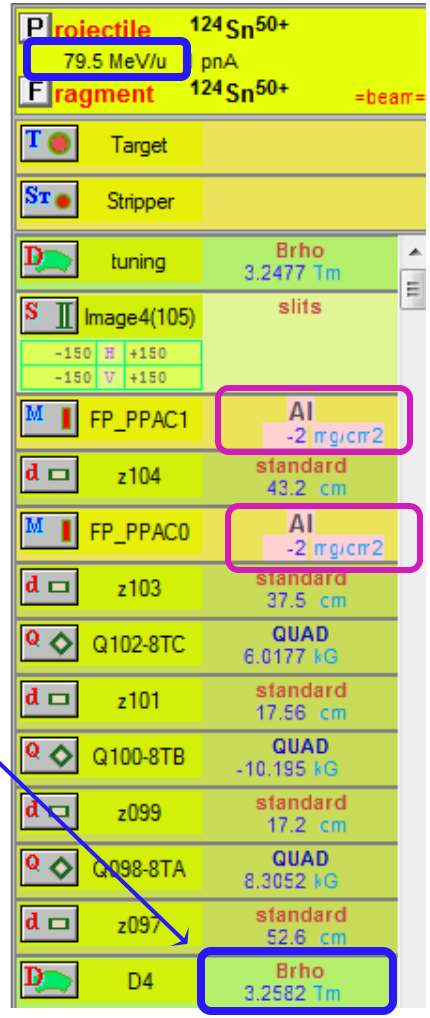
final

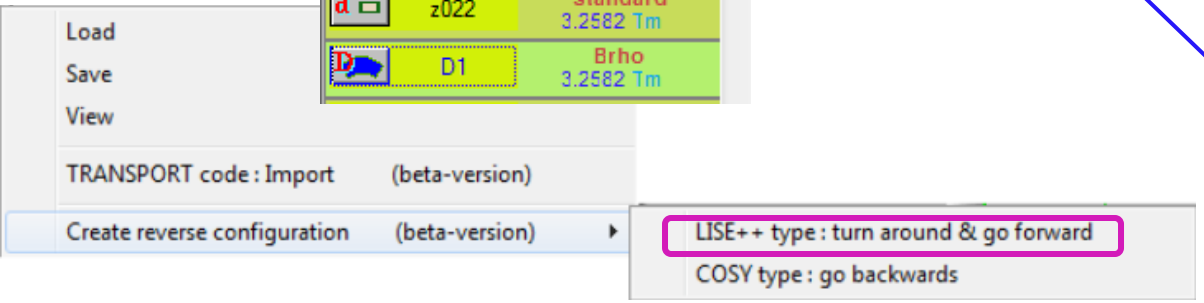
LISE-type reverse file creation



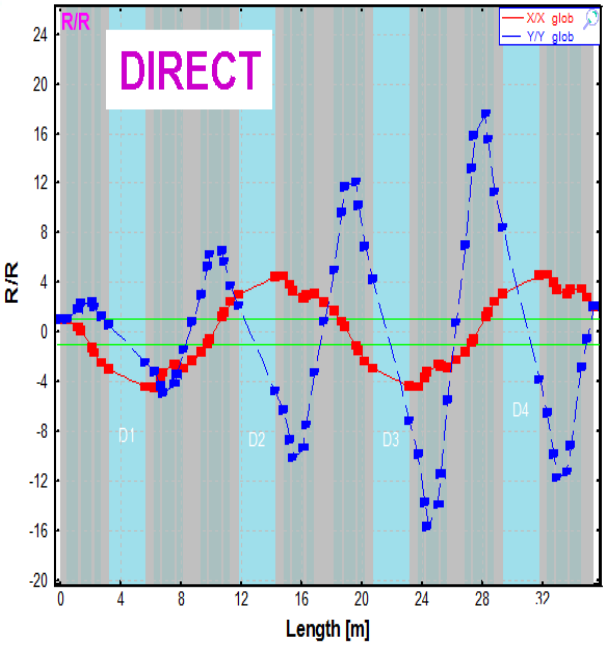


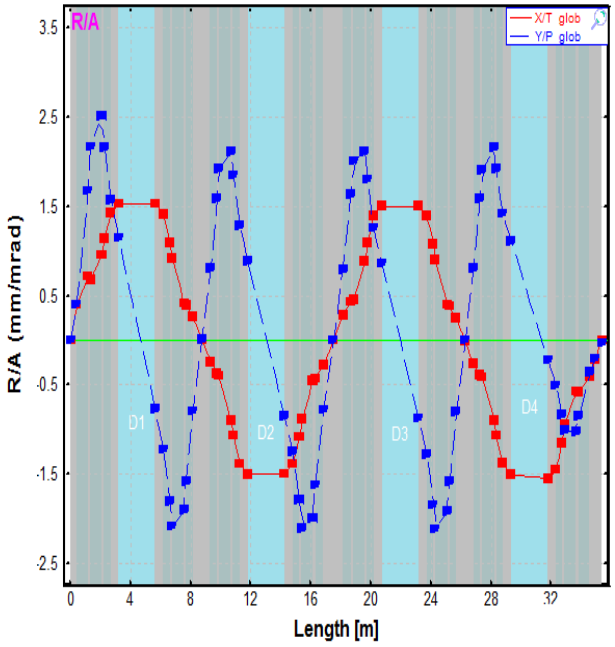


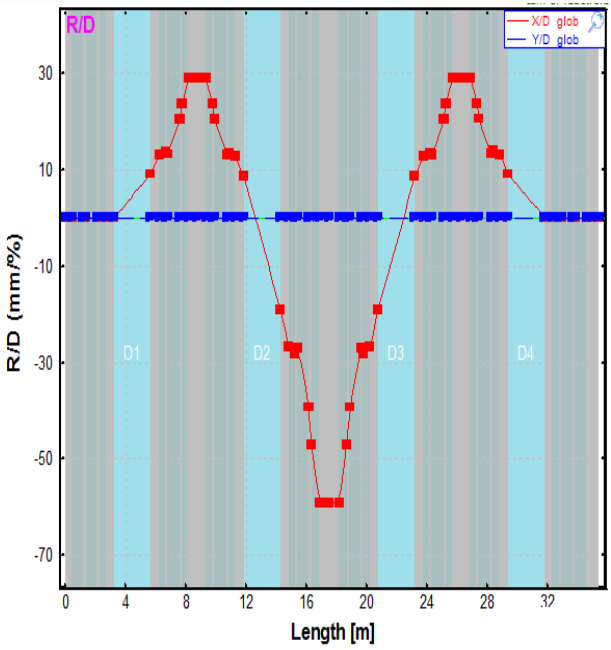


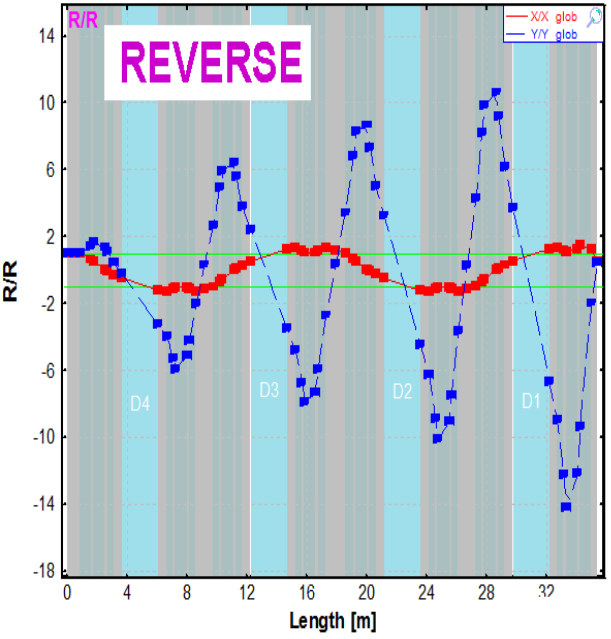


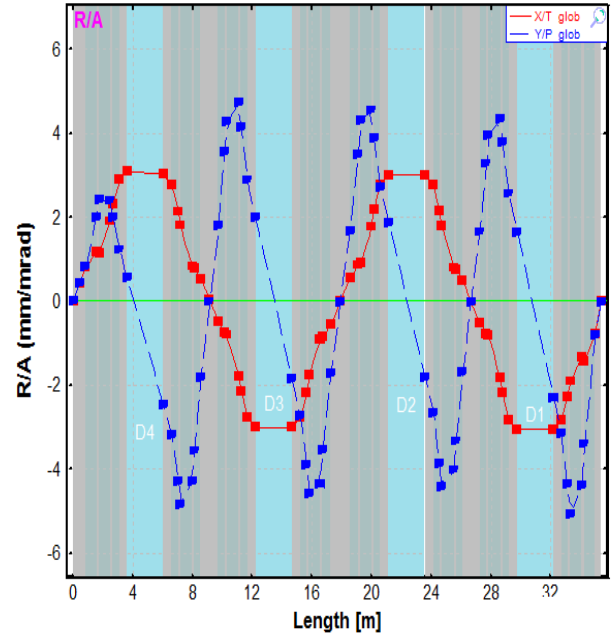
First order matrix elements: R/R, R/A, R/D

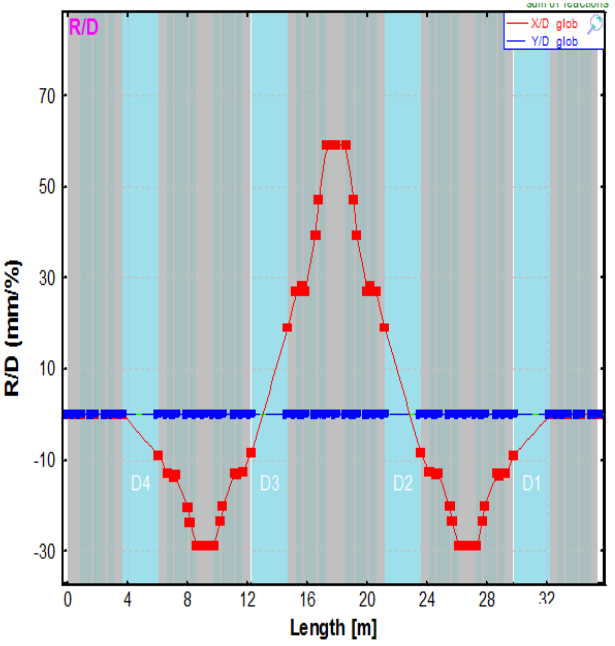




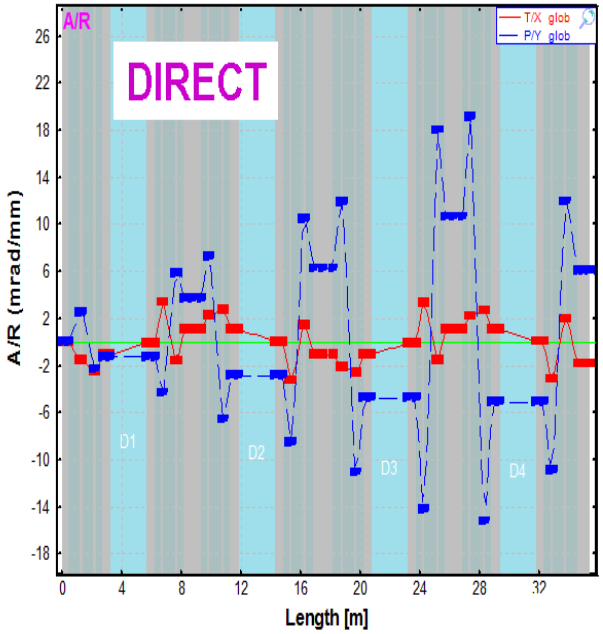


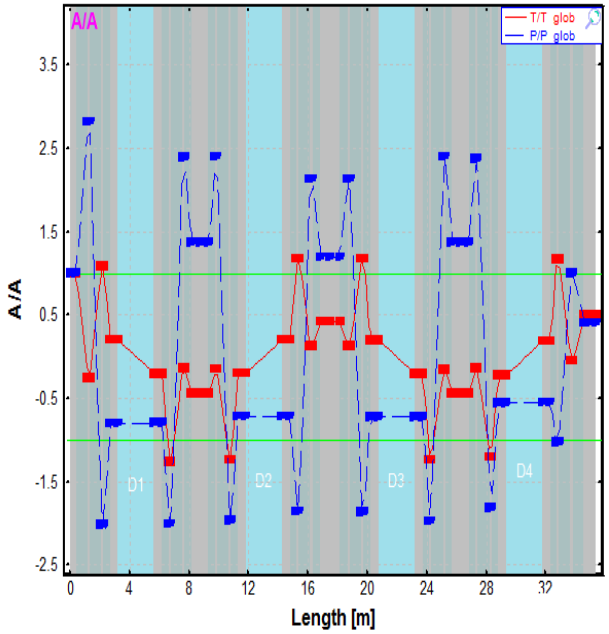


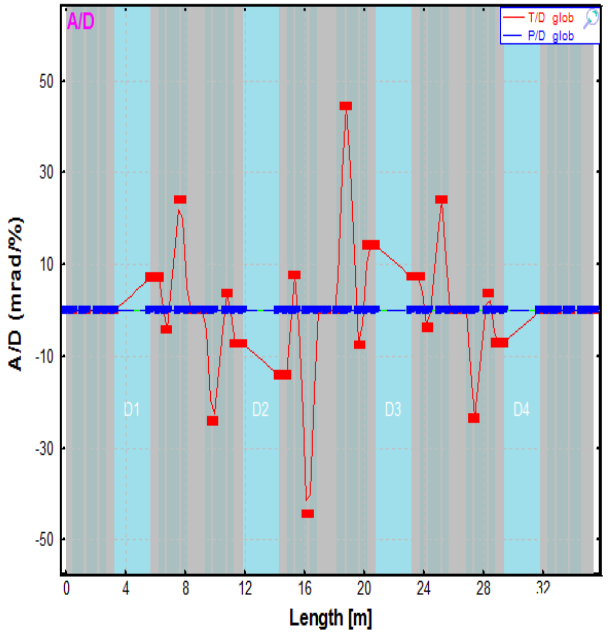


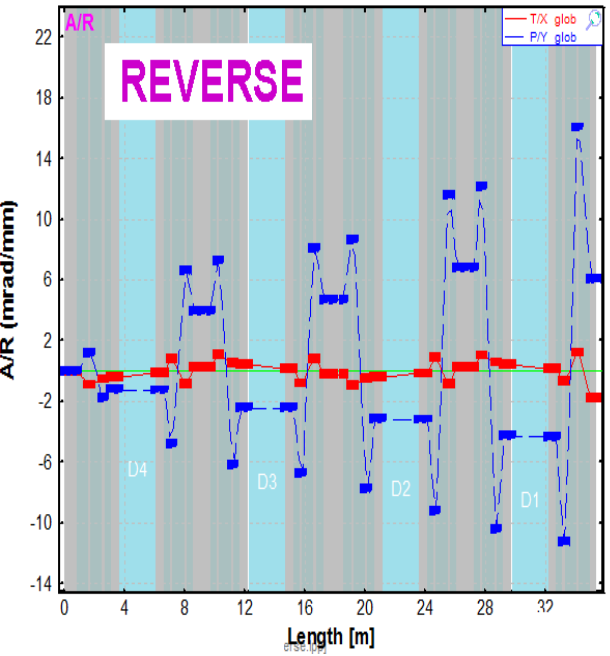


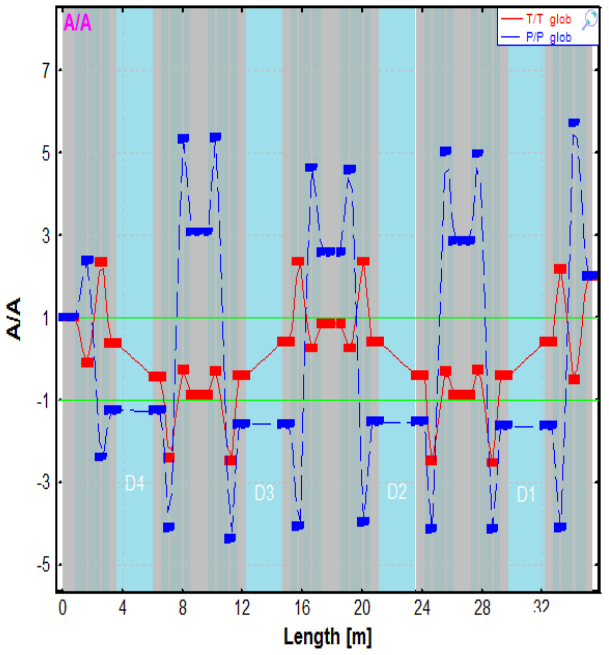
First order matrix elements: A/R, A/A, A/D

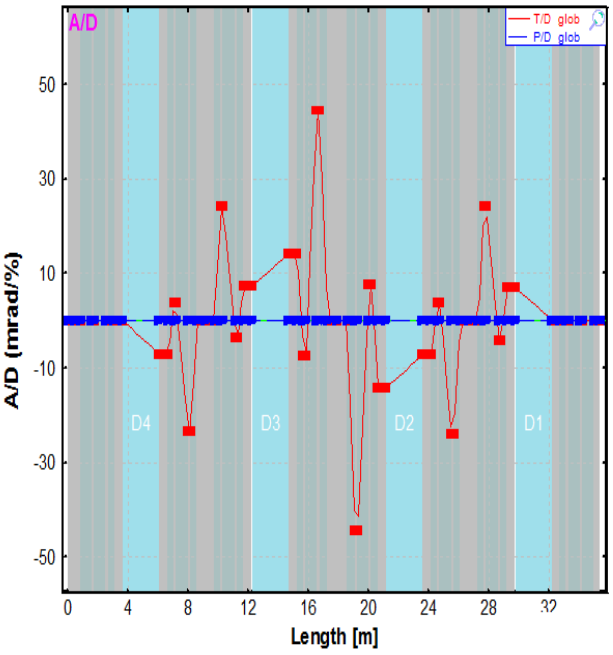












Initial emittance to generate an array of rays to benchmark

Emittance [#1]

	Beam CARD (sigma, semi-axis, half-width...)		1D - shape (Distribution method)	2D mode	2D - shape (Monte Carlo method)
1. X	mm	3	Rectangle uniform	☐	
2. T	mrad	50	Rectangle uniform	☐	
3. Y	mm	3	Rectangle uniform	☐	
4. P	mrad	40	Rectangle uniform	☐	
5. L	mm	0	Gaussian	☐	
6. D	%	2.5	Rectangle uniform	☐	

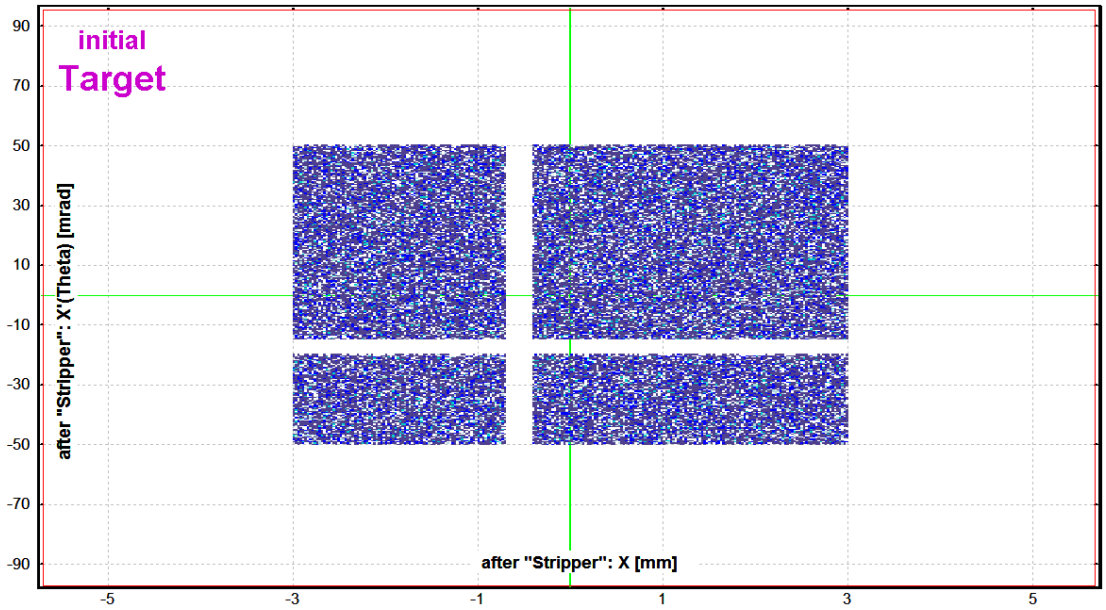
initial
Target

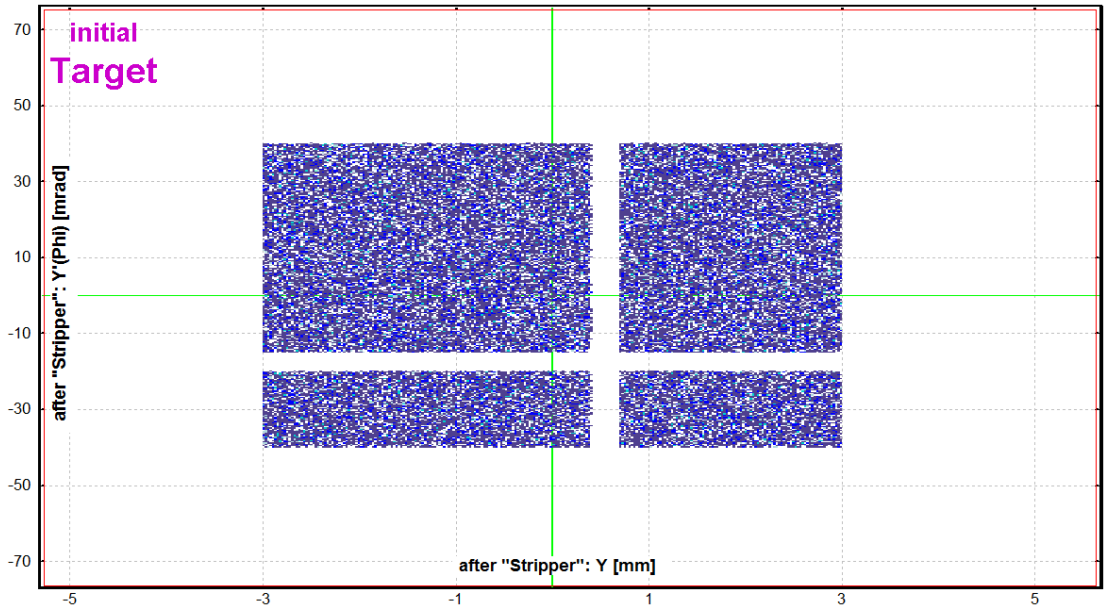
Gate 1
Settings
"NOT" [-0.7, -0.4]
< X [mm] > after Stripper

Gate 2
Settings
"NOT" [0.4, 0.7]
< Y [mm] > after Stripper

Gate 3
Settings
"NOT" [-20, -15]
< X'(Theta) [mrad] > after Stripper

Gate 4
Settings
"NOT" [-20, -15]
< Y'(Phi) [mrad] > after Stripper

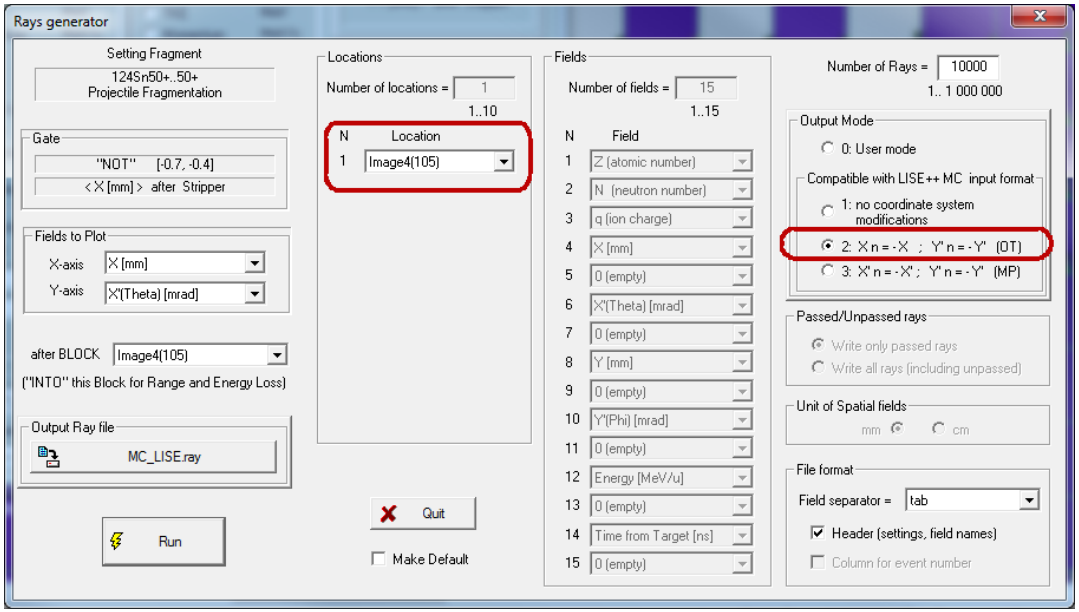




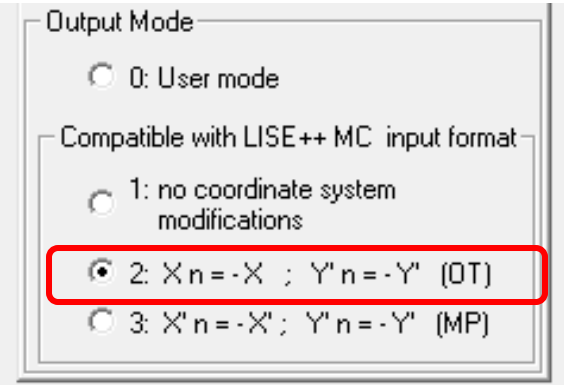
LISE-type reverse file creation

With reverse configurations it is possible to use

- experimental rays from the final point
- LSE^{++} rays generated for current reverse mode (LISE or COSY)



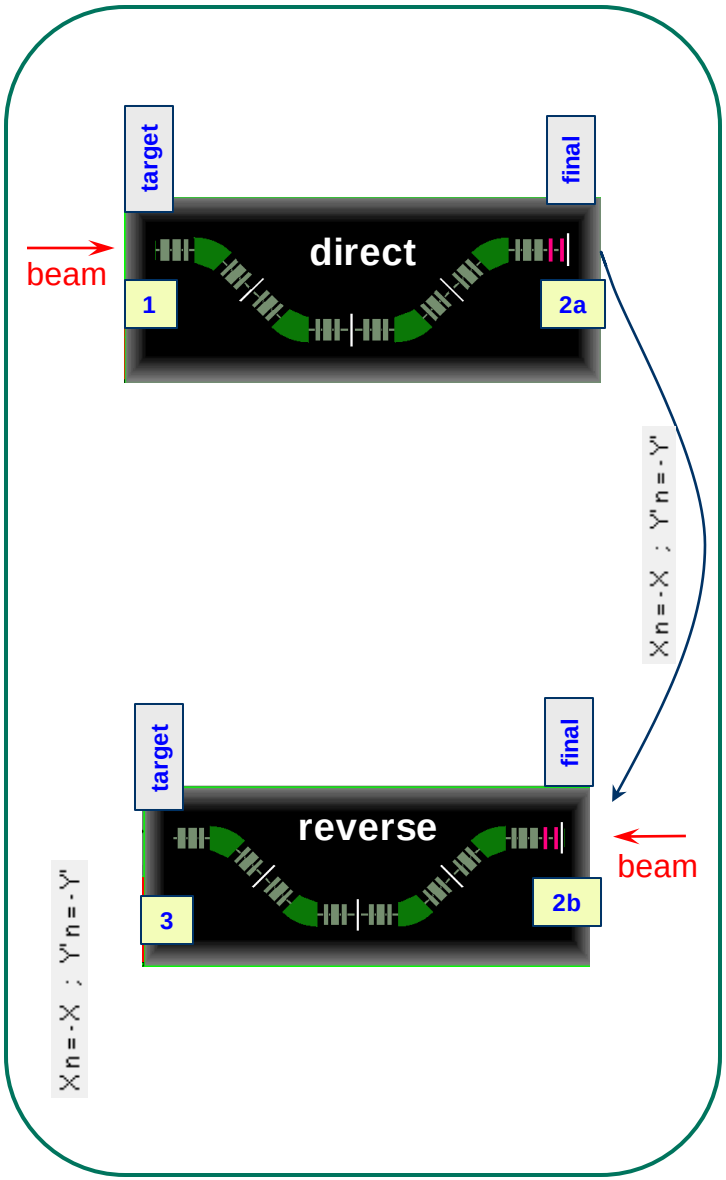
zoom

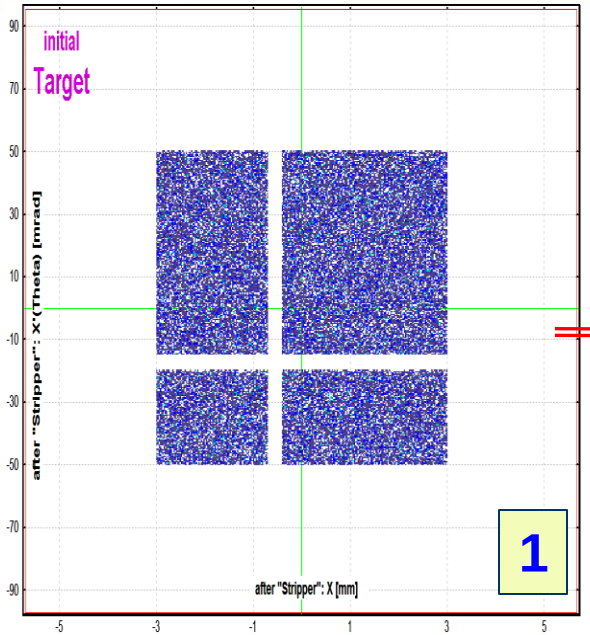


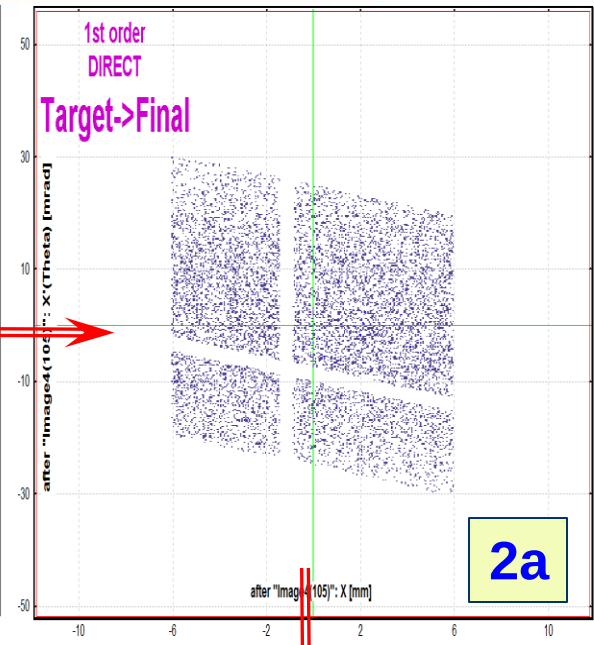
Four ray arrays have been generated at the final plane using LISE^{++} reverse mode:

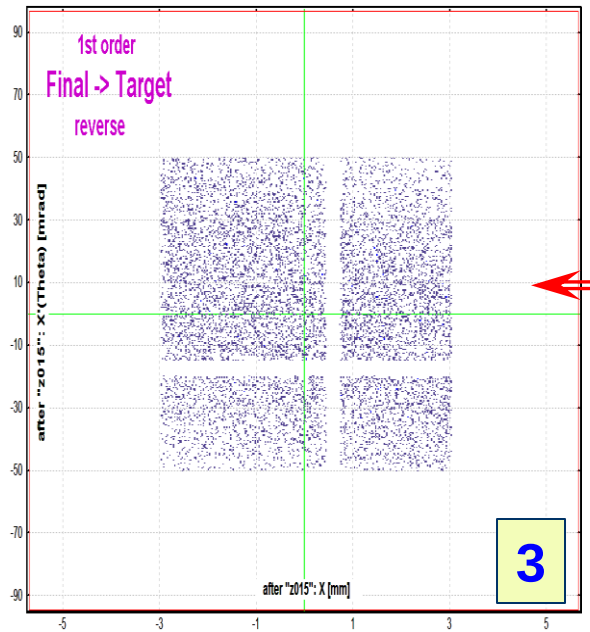
- Using 1st order optics
- Using 2nd order optics
- Using 1st order optics and thin wedge @ I2
- Using 1st order optics and thick wedge @ I2

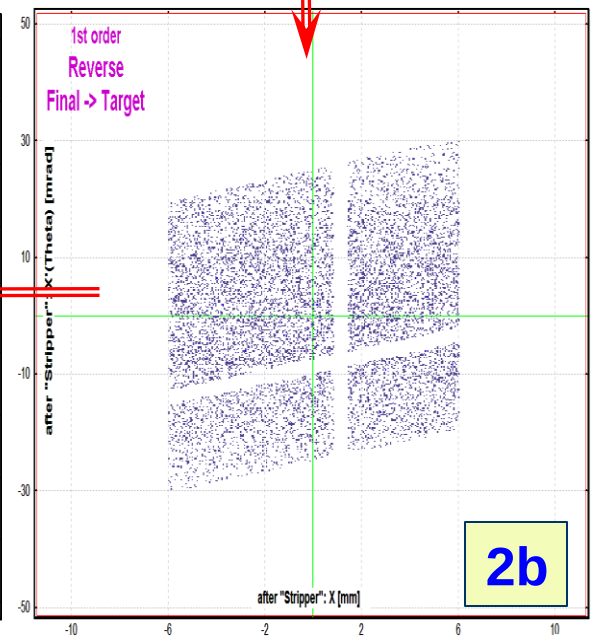
Benchmarking process of the reverse technique



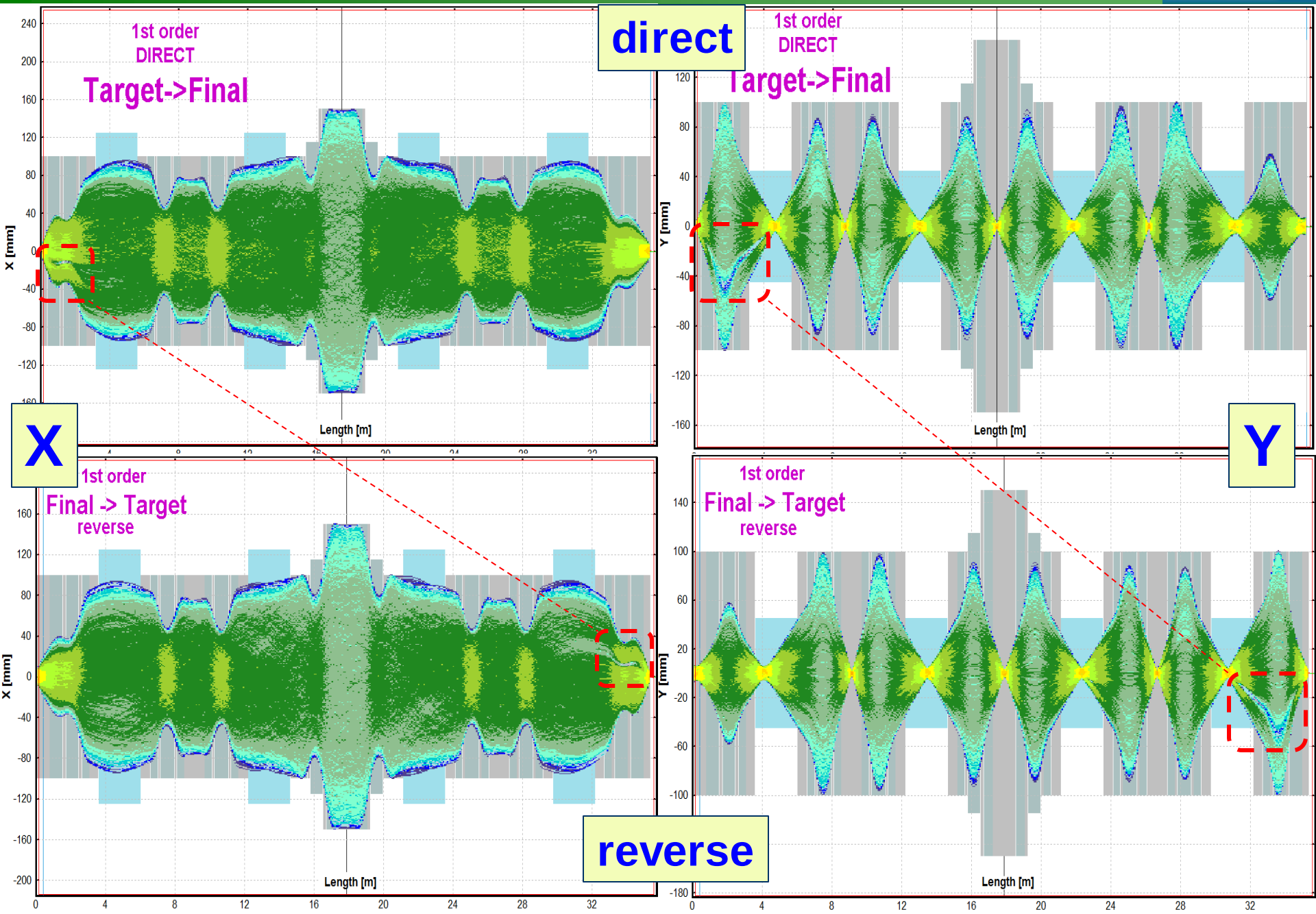




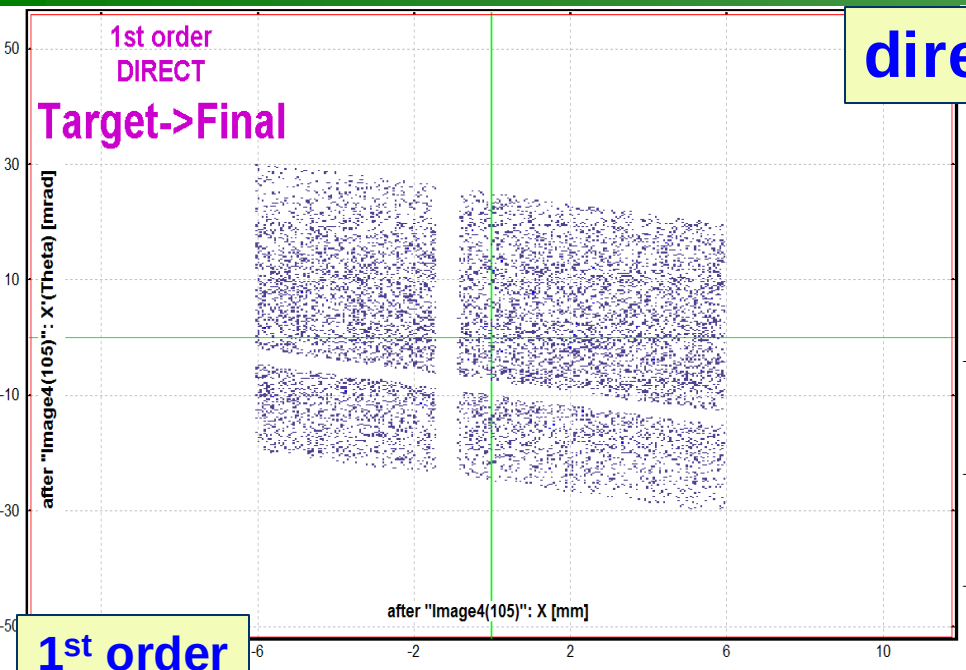




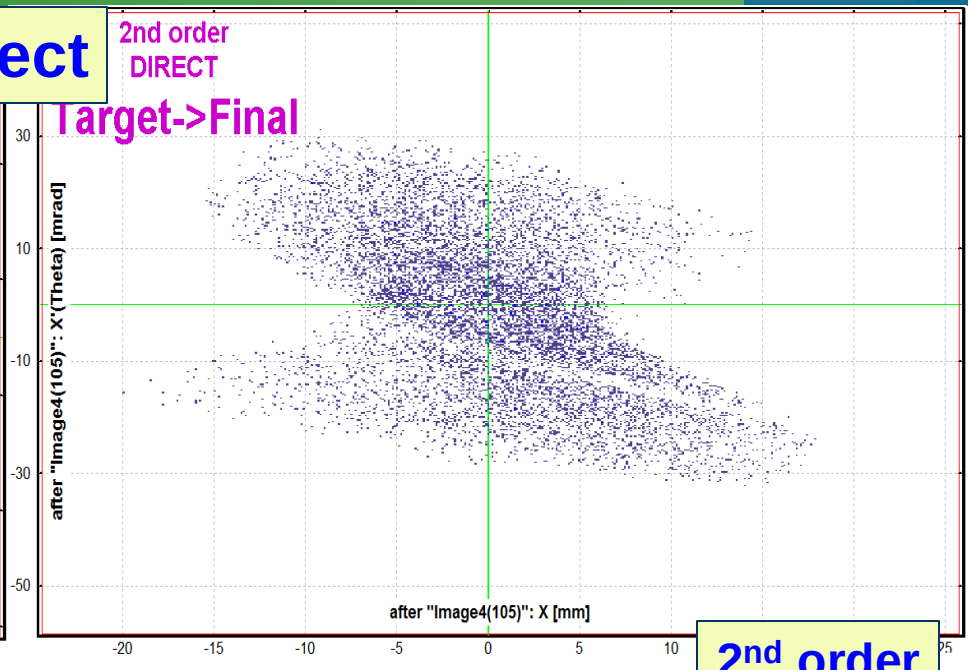
1st order optics Direct and Reverse envelopes



X vs X' reverse results

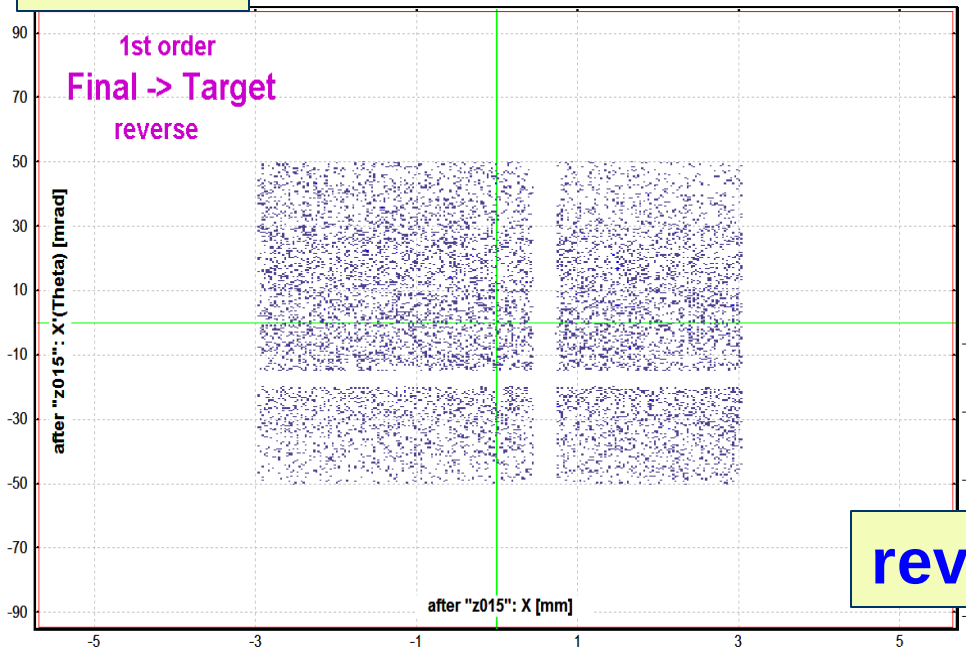


direct

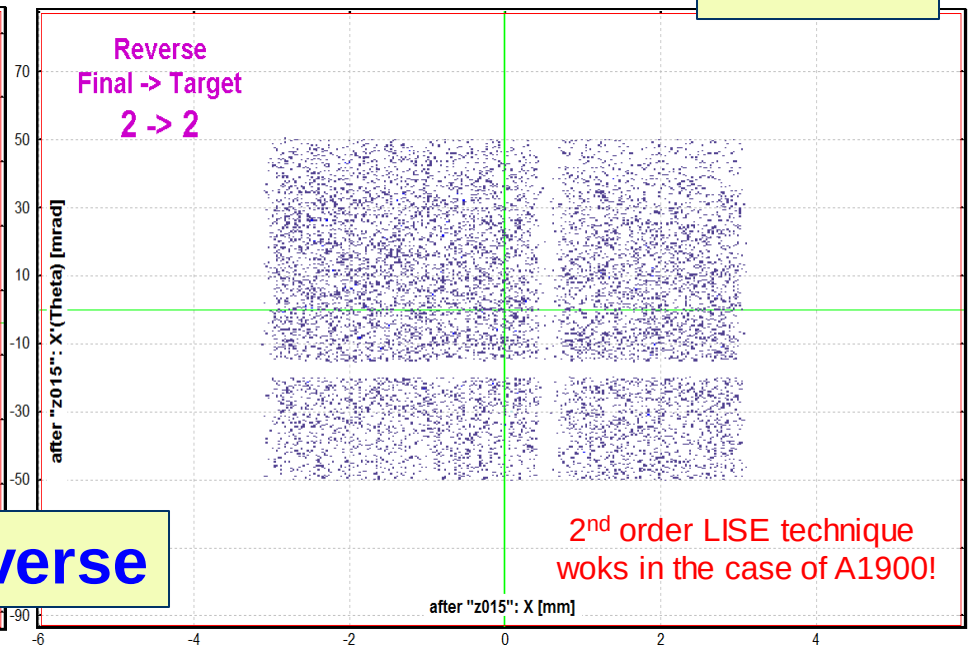


1st order

2nd order

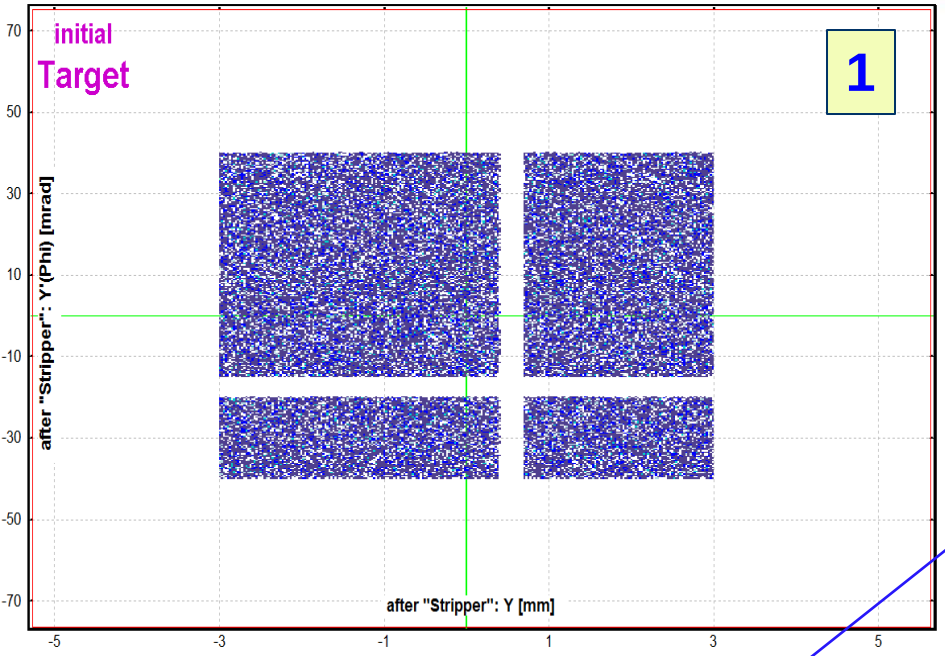


reverse



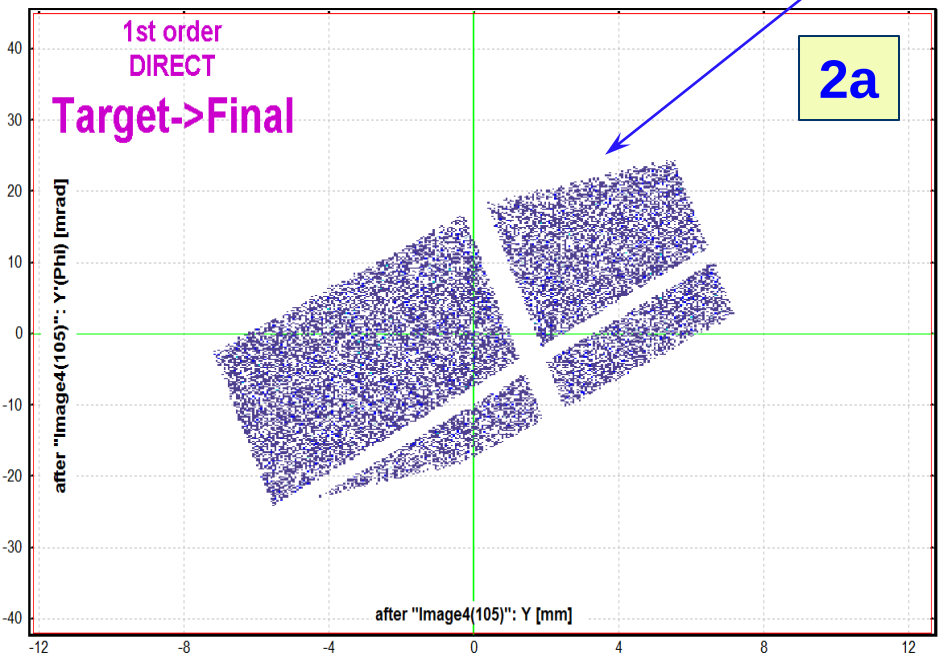
2nd order LISE technique woks in the case of A1900!

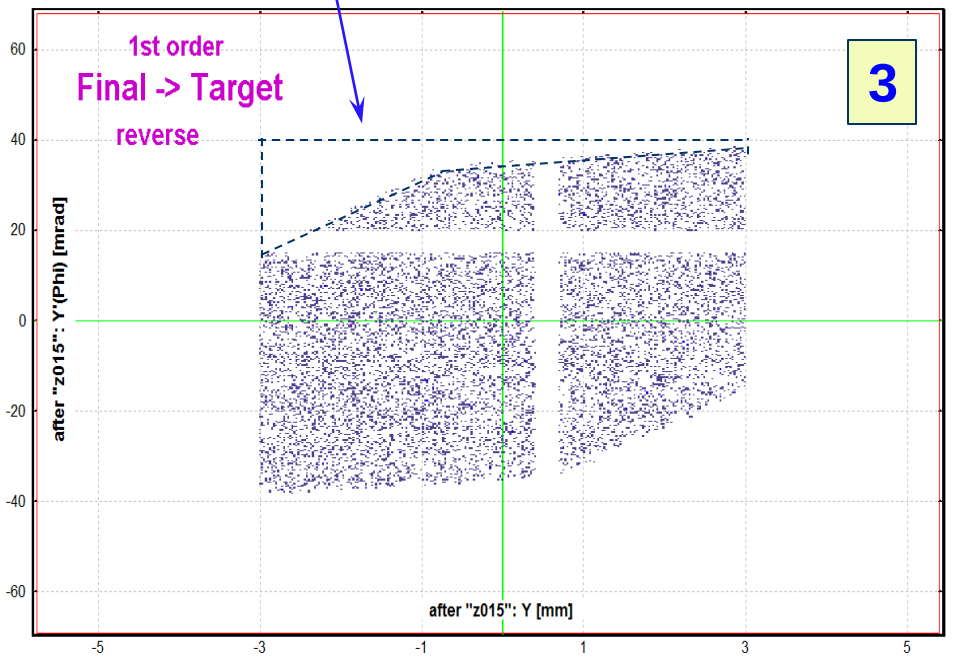
Y vs Y' direct and reverse 1st order optics plots



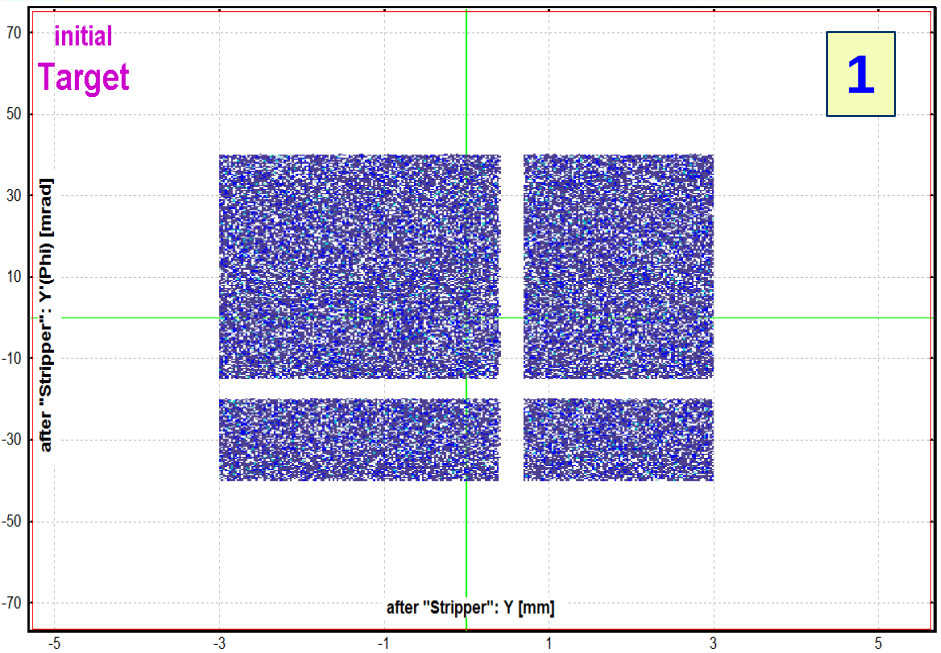
Y vs Y'
1st order

Cut by apertures
(angular acceptance)



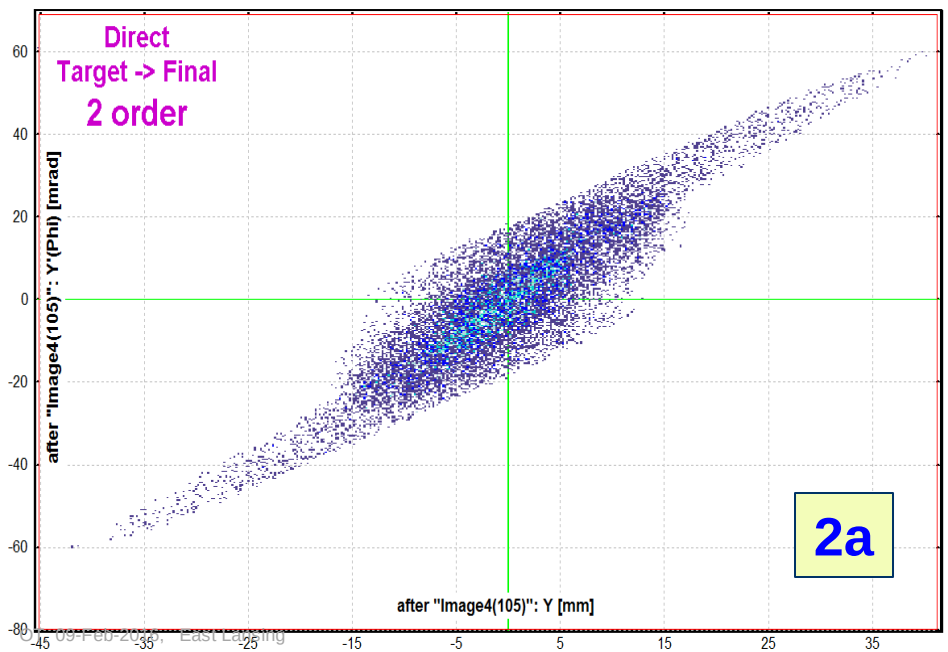


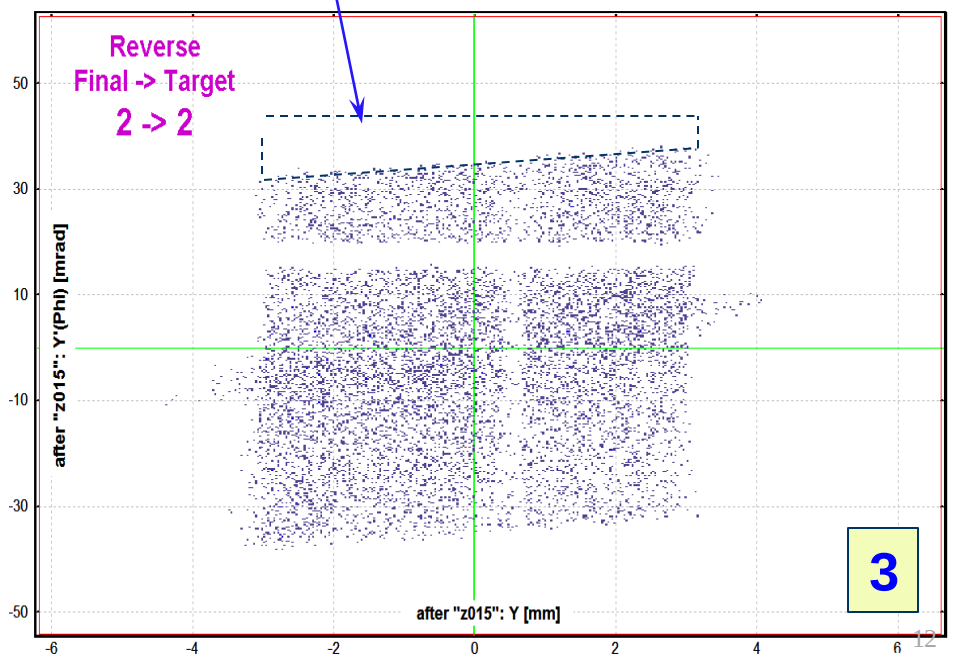
Y vs Y' direct and reverse 2nd order optics plots



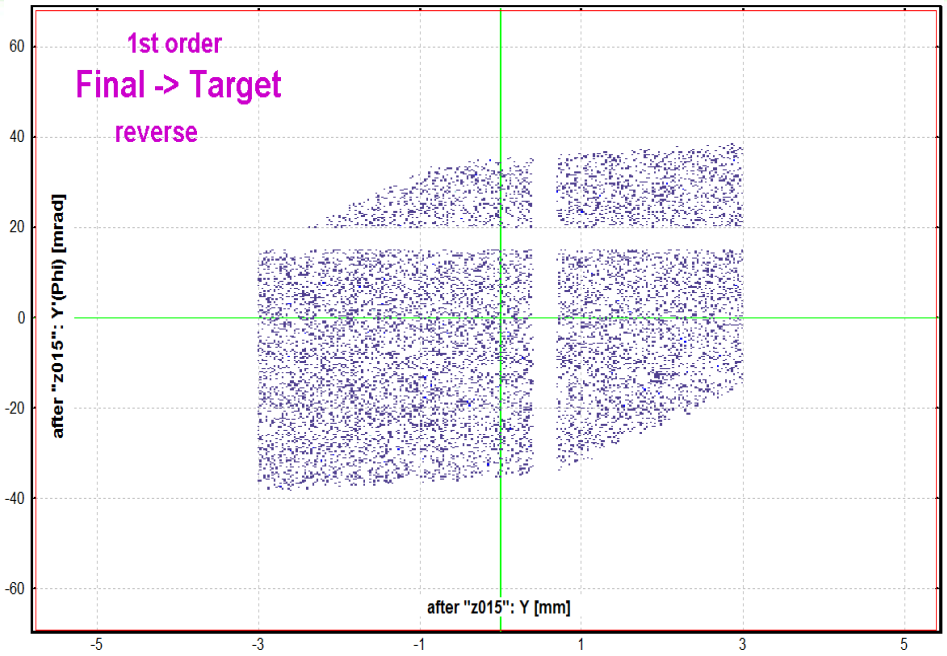
Y vs Y'
2nd order

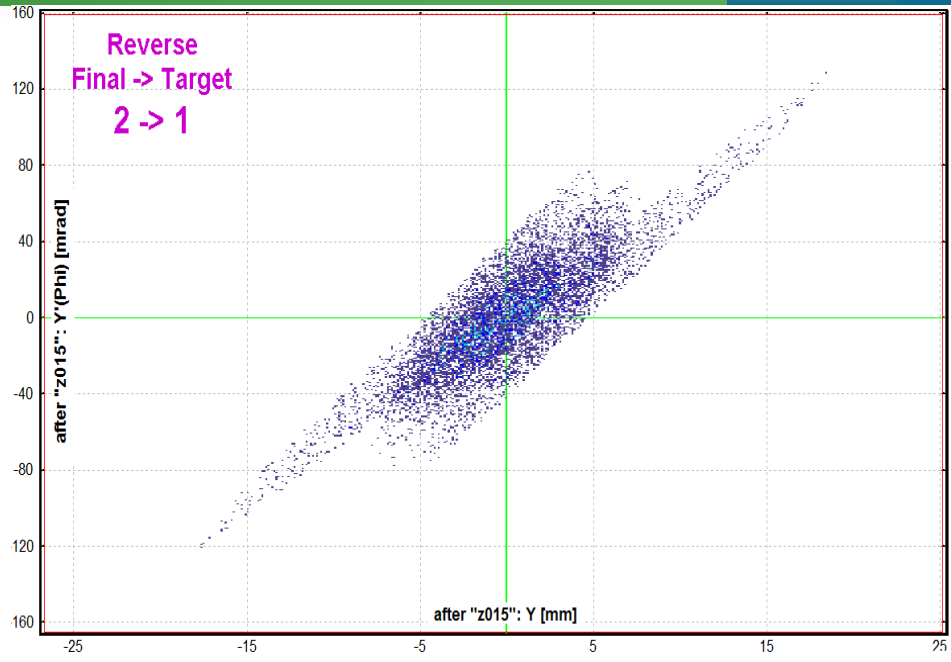
Cut by apertures
(angular acceptance)

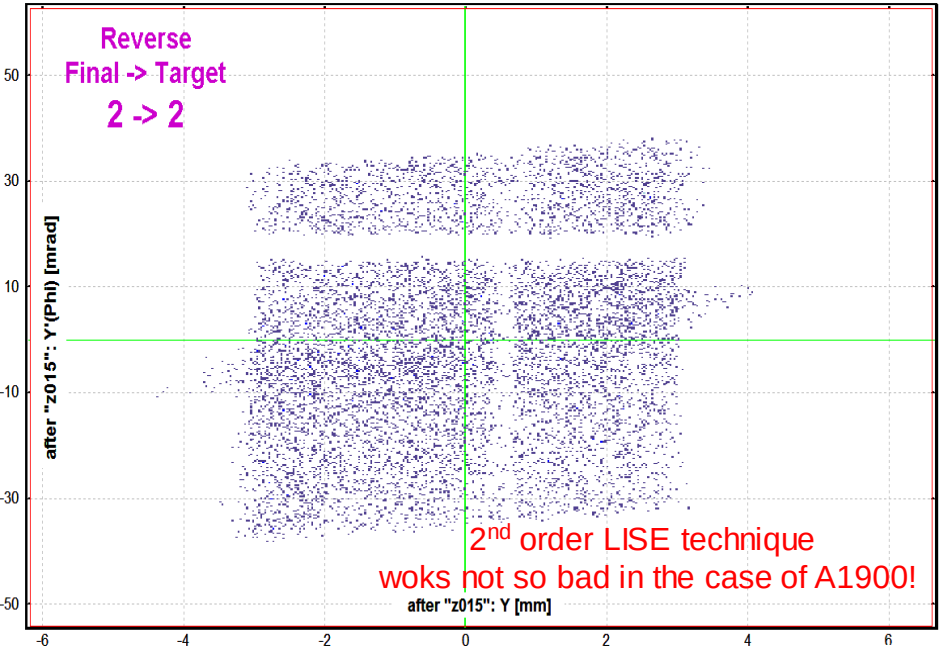


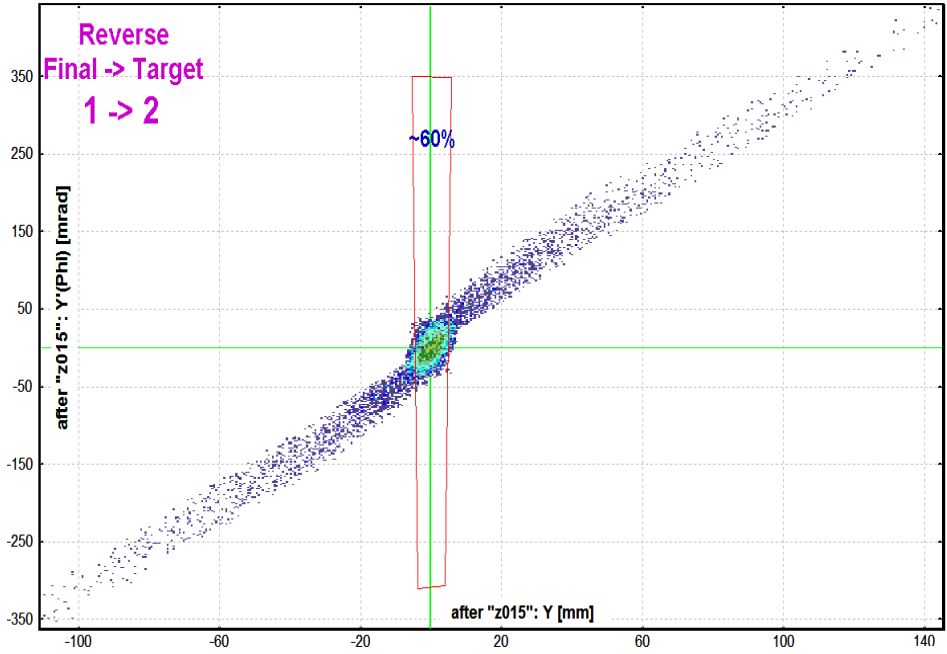


Y vs Y' reverse different optics order plots

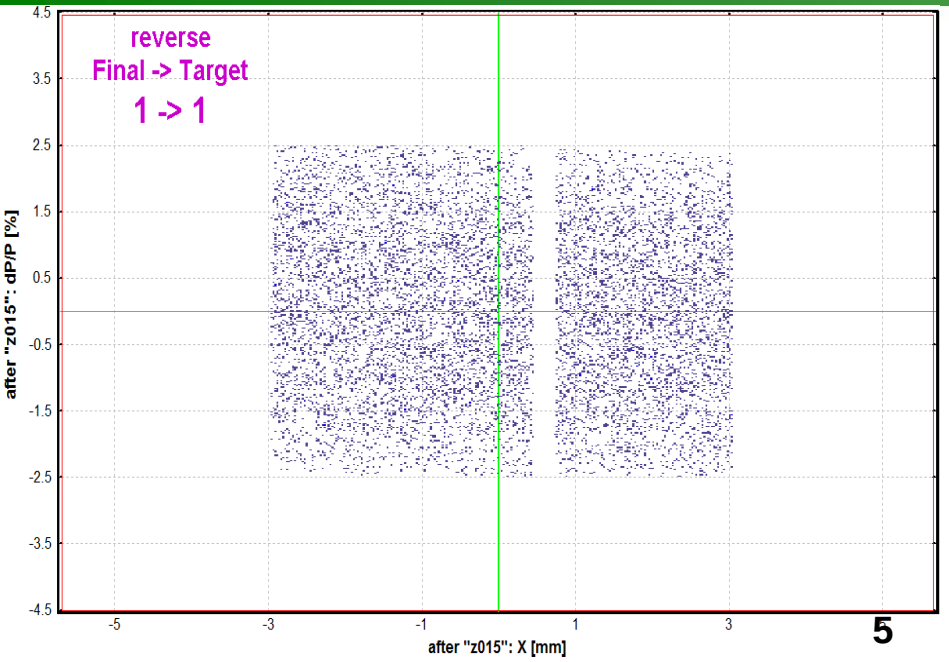








Reverse (Final → Target) : X vs. dP/P



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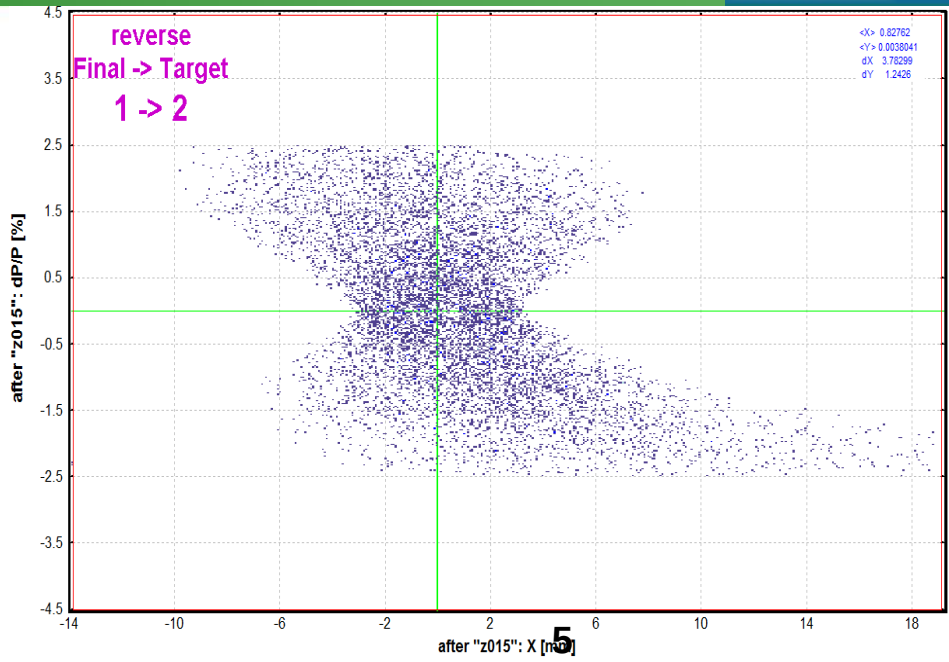
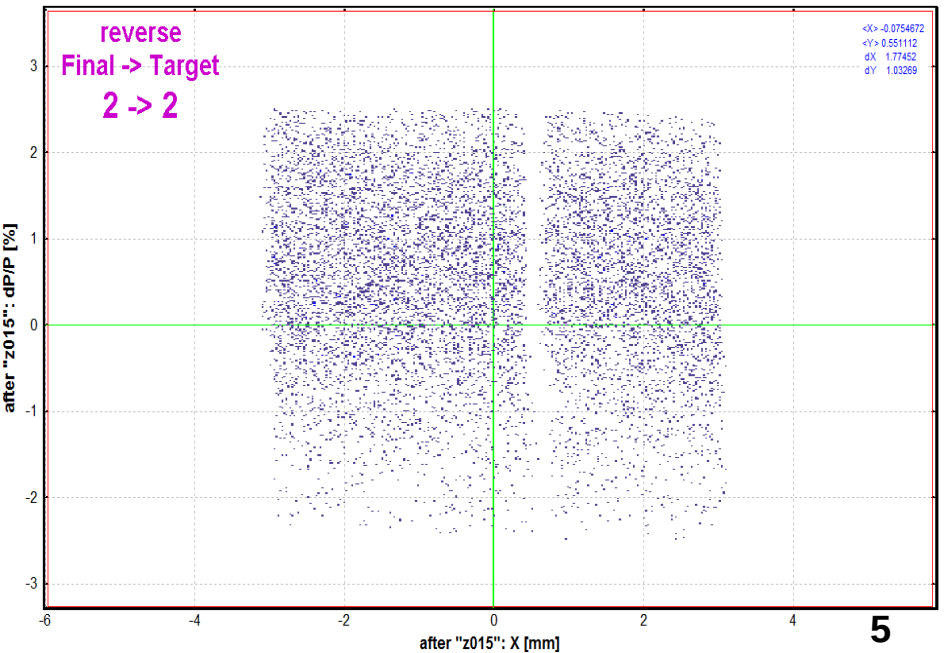


5



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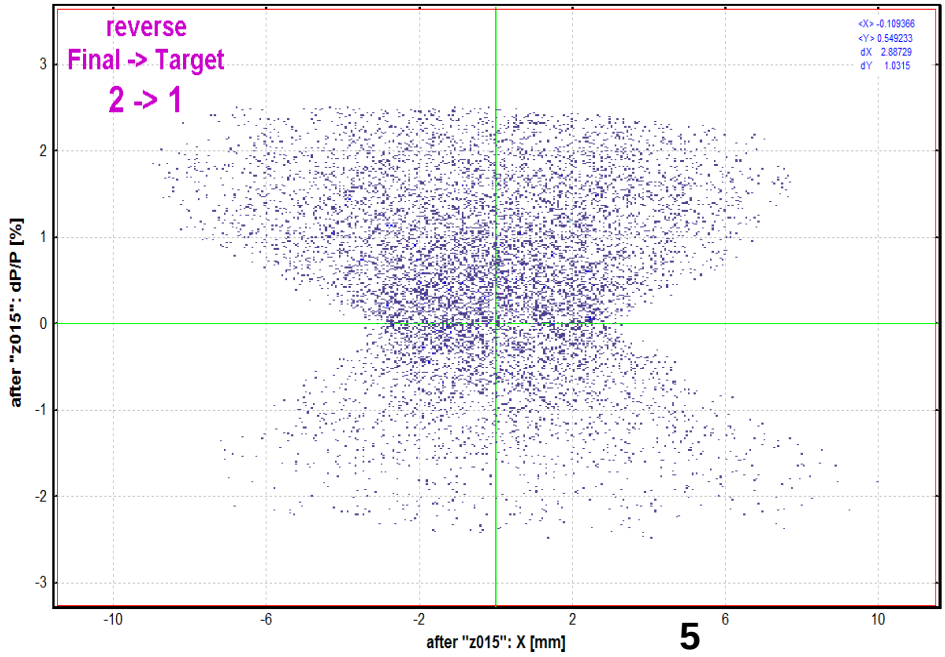
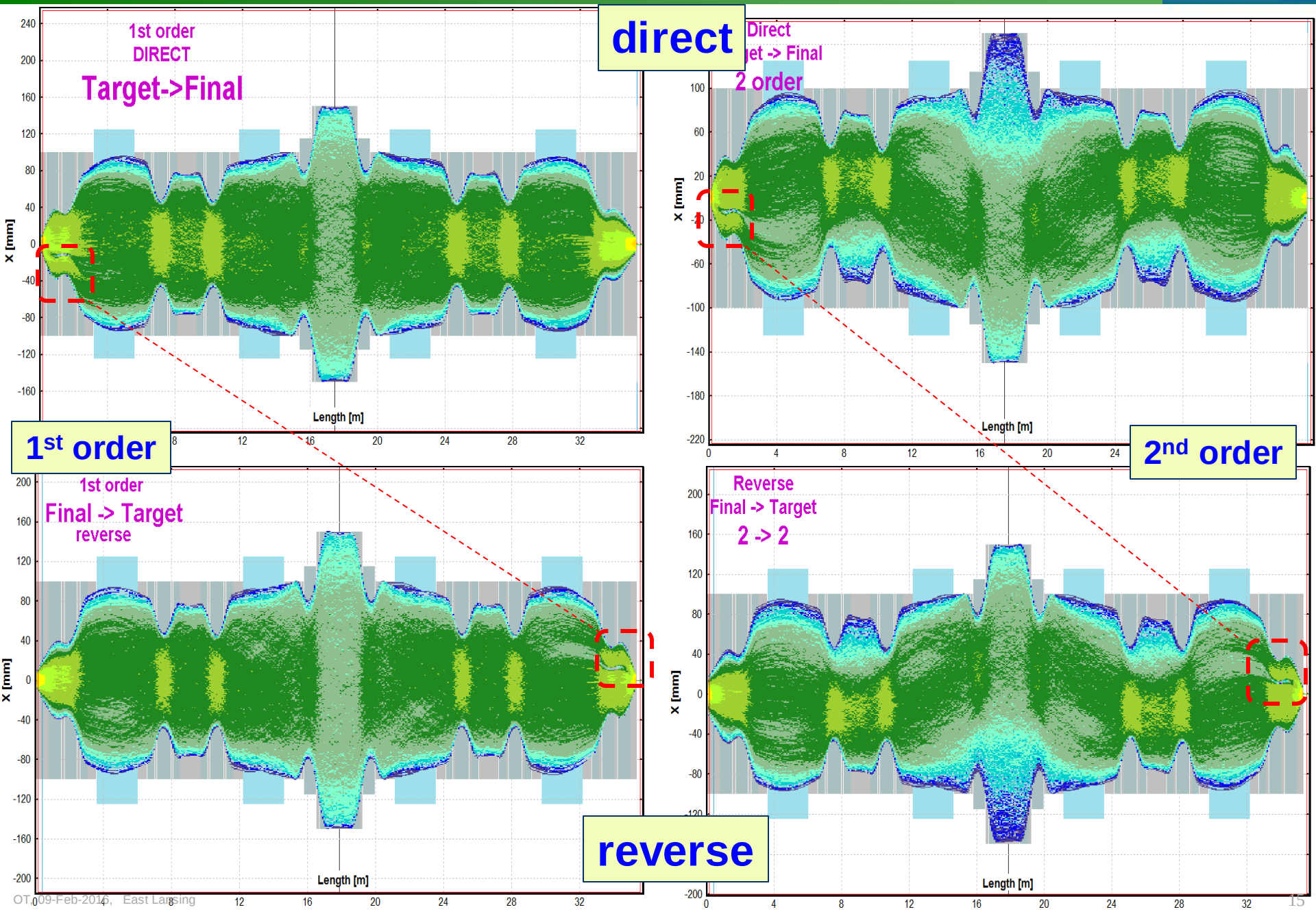
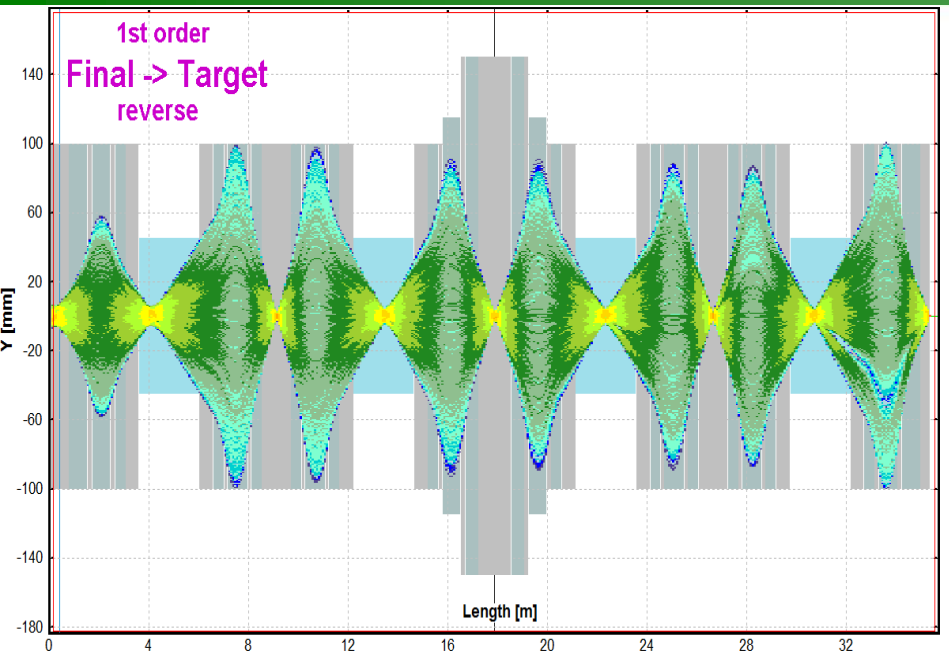


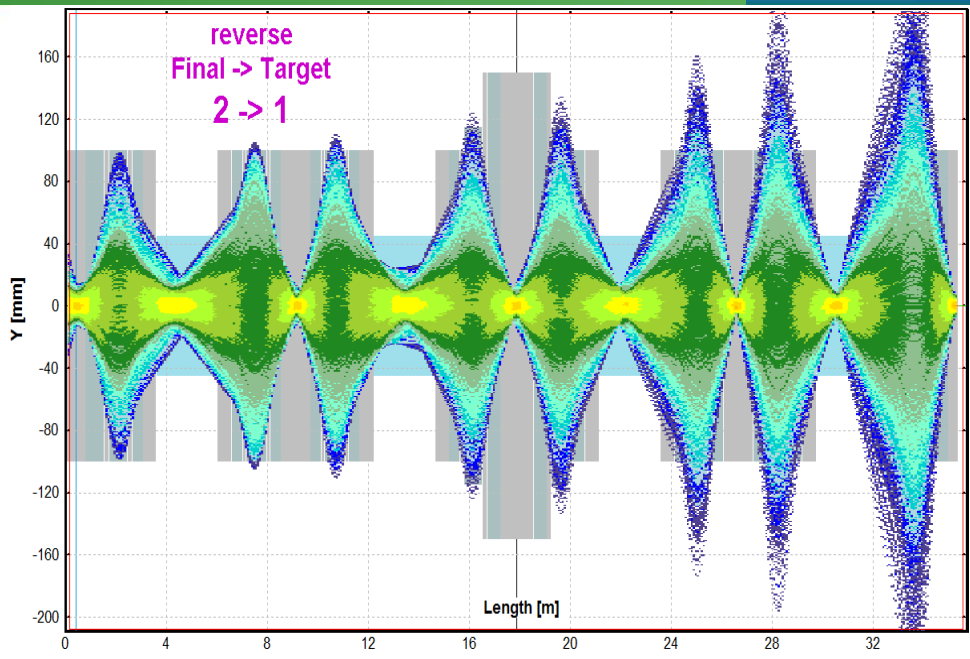
5

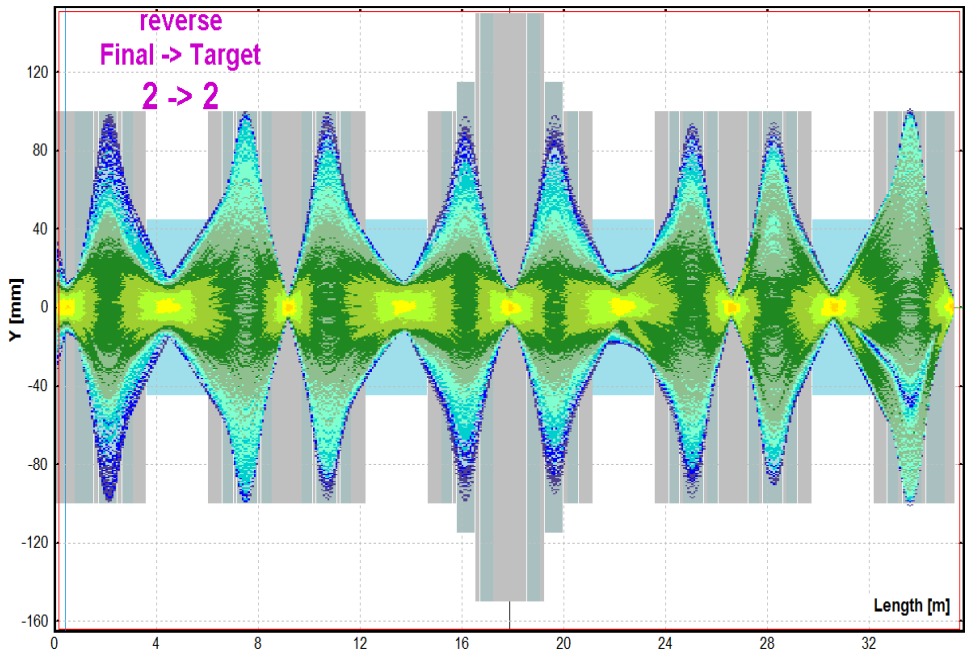
X (horizontal) direct & reverse envelopes for 1st & 2nd order optics



Y (vertical) reverse envelopes for different order optics







Using detector resolution (x,y) with 1st order optics : X vs X'

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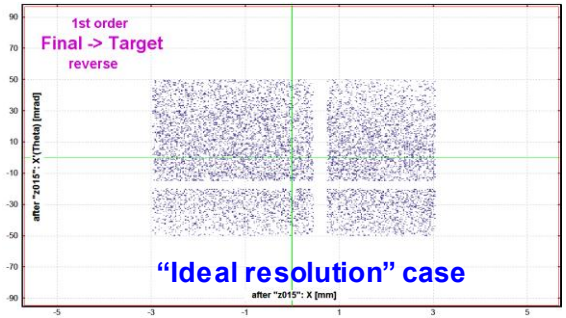
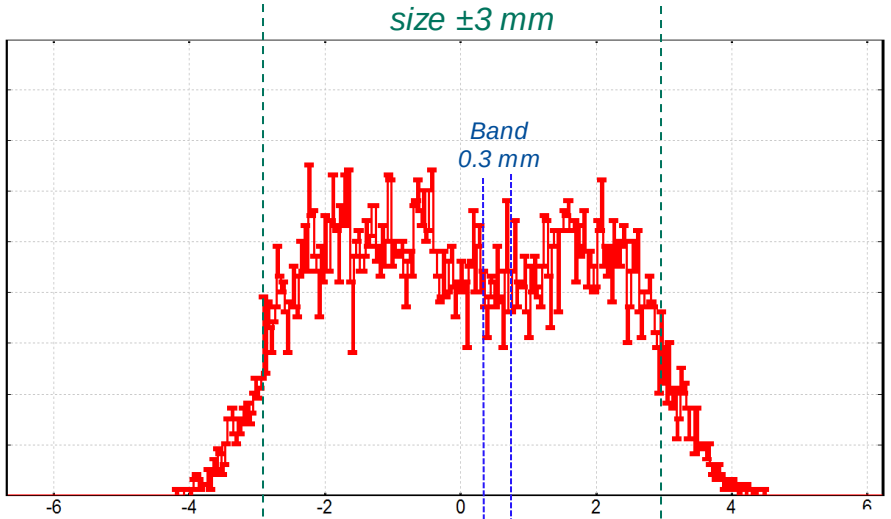
LISE++

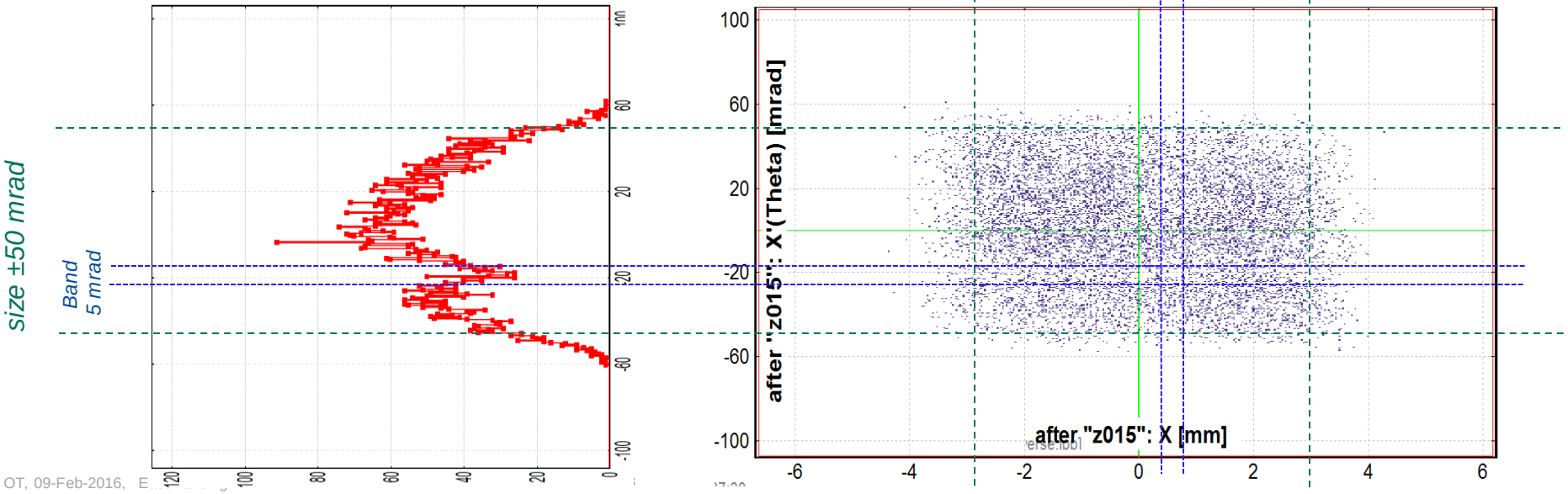
X vs X'
1st order

d(X), d(Y) = 1 mm, d(X'), d(Y') = 2 mrad, d(E) = 0 % *manually been entered in the ray file*

! 01-Z (atomi	01-N (neutro	01-q (ion chai	01-X [mm]	01-0 (empty)	01-X'(Theta) [	01-0 (empty)	01-Y [mm]	01-0 (empty)	01-Y'(Phi) [mi	01-0 (empty)	01-Energy [M	01-0 (empty)	01-Time fron
50	74	50	-0.57374	1	-20.595	2	-1.7892	1	9.0715	2	78.559	0	304.34
50	74	50	-2.3107	1	-15.824	2	1.3066	1	-17.313	2	82.128	0	298.7
50	74	50	-4.3571	1	5.0458	2	2.5585	1	9.3088	2	81.03	0	300.39





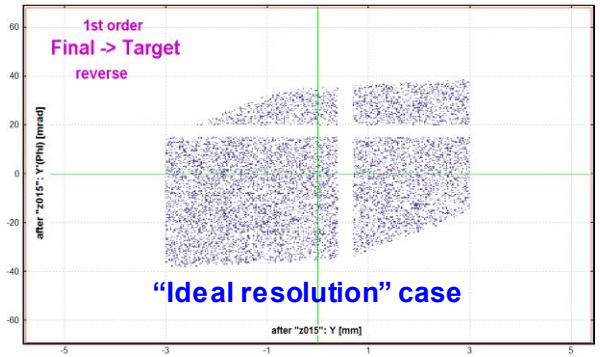


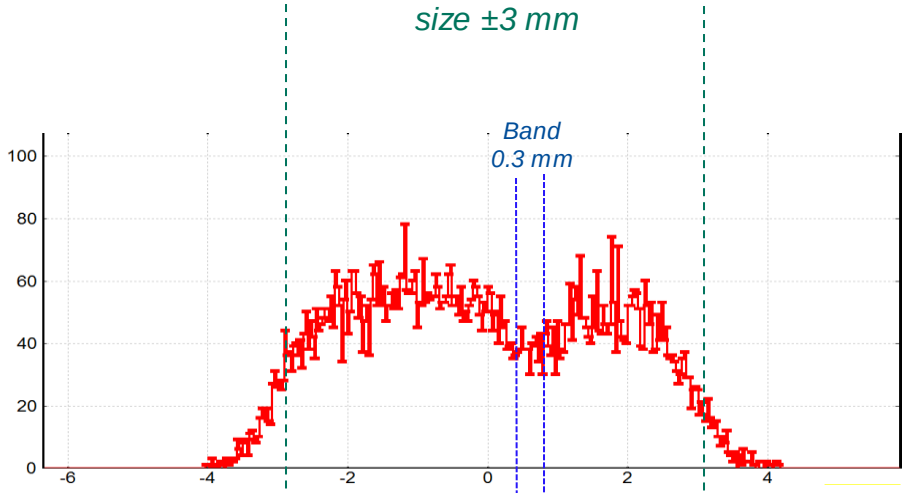
Using detector resolution (x,y) with 1st order optics : Y vs Y'

Y vs Y'
1st order

d(X), d(Y) = **1 mm**, d(X'), d(Y') = **2 mrad**, d(E) = 0 % *manually been entered in the ray file*

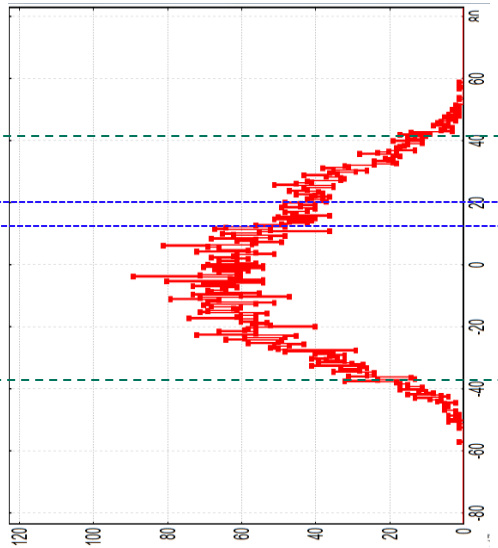
! 01-Z (atomi	01-N (neutro	01-q (ion chai	01-X [mm]	01-0 (empty)	01-X'(Theta) [	01-0 (empty)	01-Y [mm]	01-0 (empty)	01-Y'(Phi) [mi	01-0 (empty)	01-Energy [M	01-0 (empty)	01-Time fron
50	74	50	-0.57374	1	-20.595	2	-1.7892	1	9.0715	2	78.559	0	304.34
50	74	50	-2.3107	1	-15.824	2	1.3066	1	-17.313	2	82.128	0	298.7
50	74	50	-4.3571	1	5.0458	2	2.5585	1	9.3088	2	81.03	0	300.39

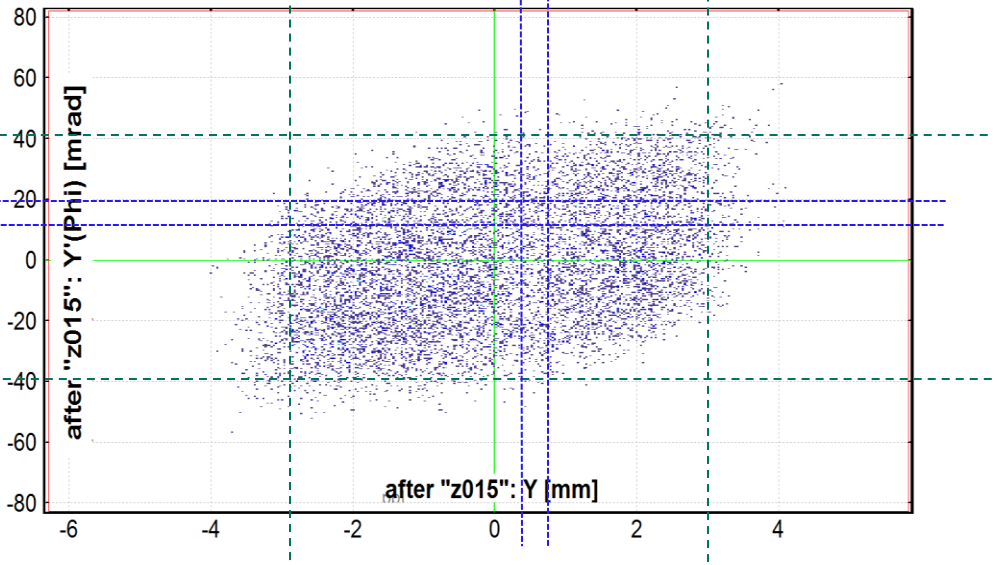




size ±40 mrad

Band
5 mrad



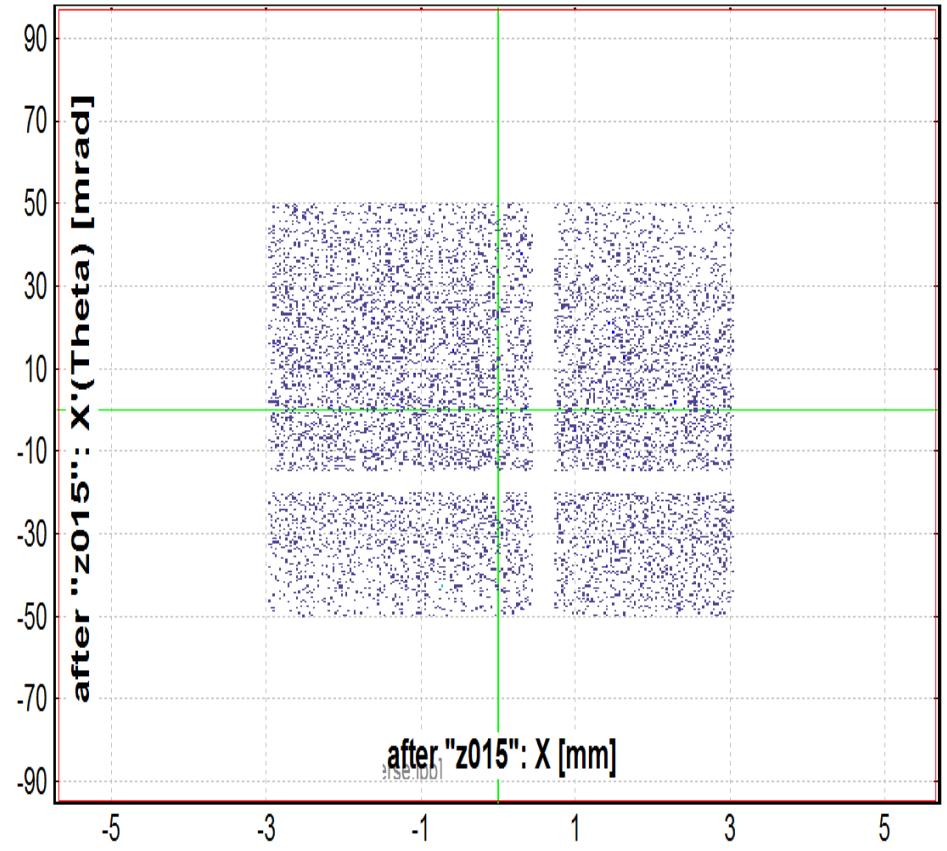


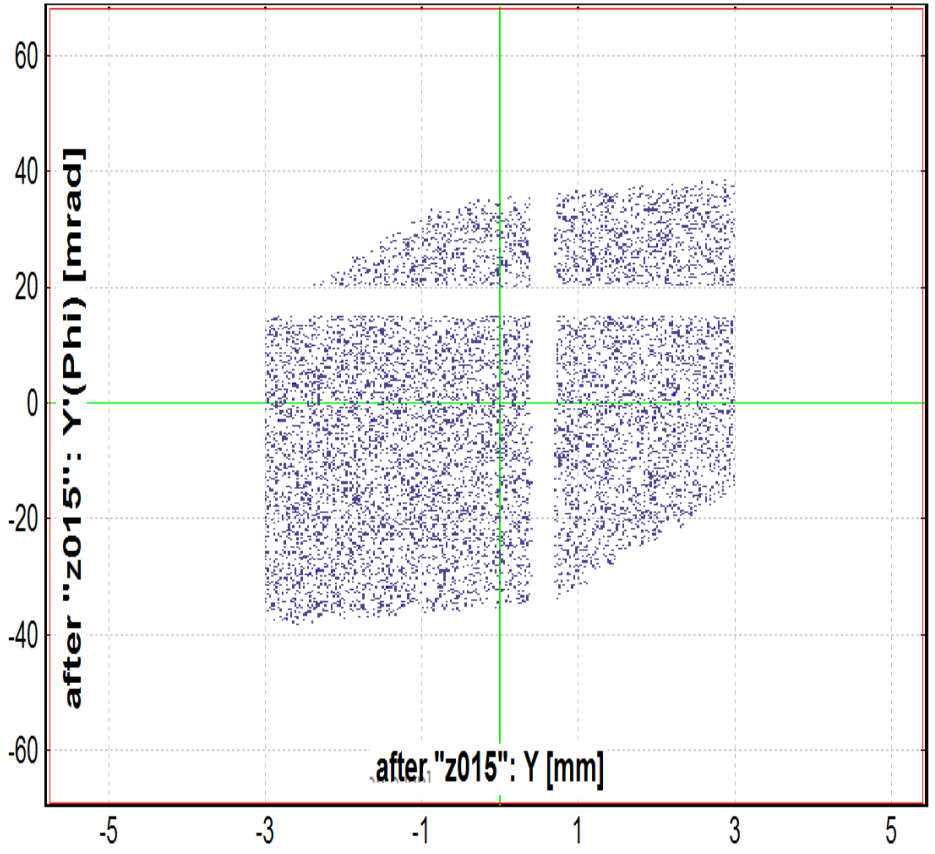
Using detector resolution (x,y) with 1st order optics : Y vs Y'

d(X), d(Y) = 0 mm, **d(X'), d(Y') =** 0 mrad, **d(E) =** **2 %** *manually been entered in the ray file*

1st order

Expected answer due to the achromatic mode

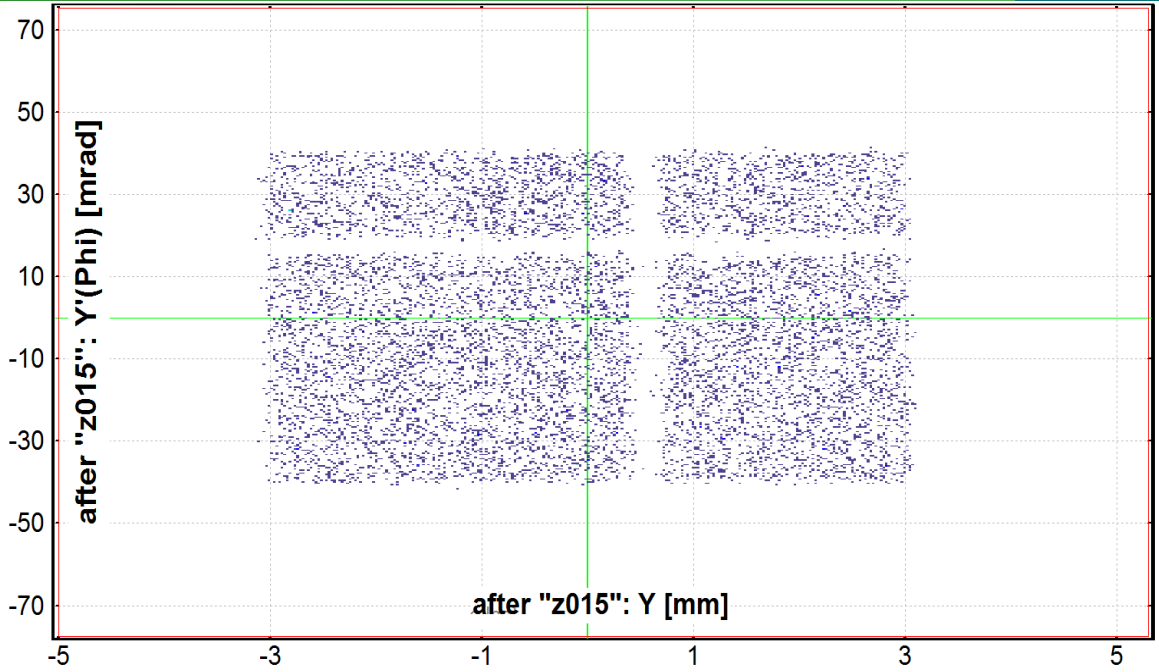




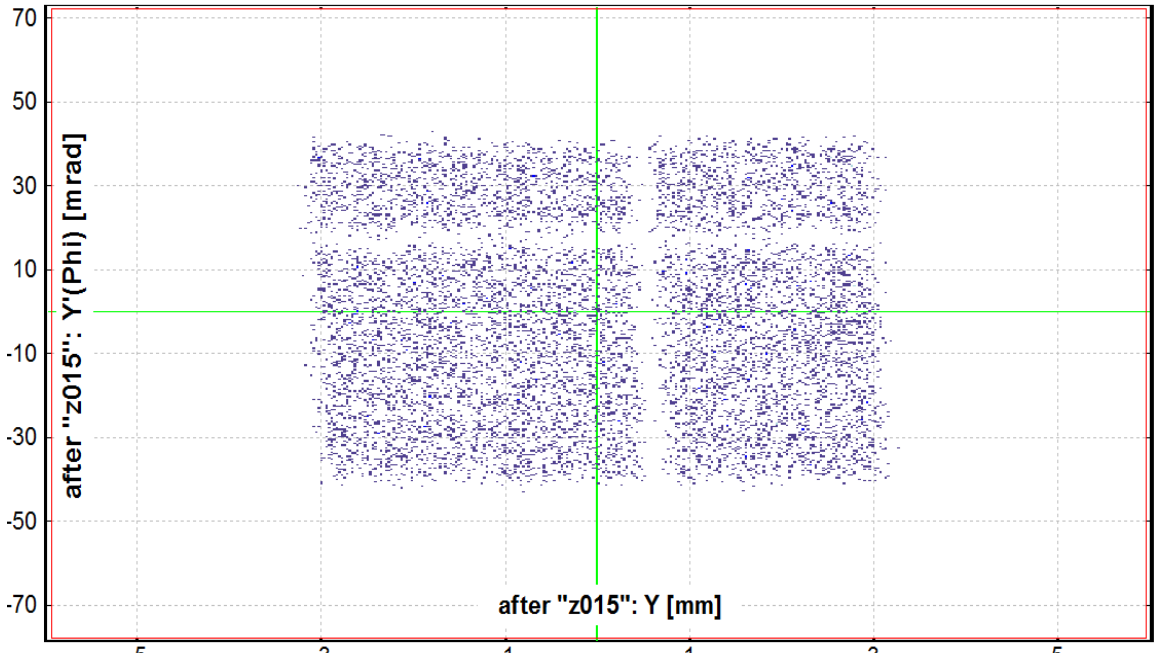
Contribution of straggling in wedge : Y vs Y'

Y vs Y'
1st order

Thin wedge:
10% of range

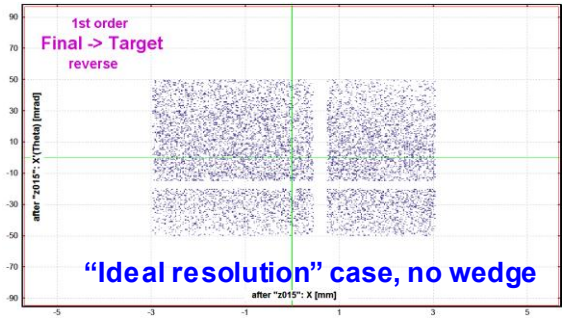


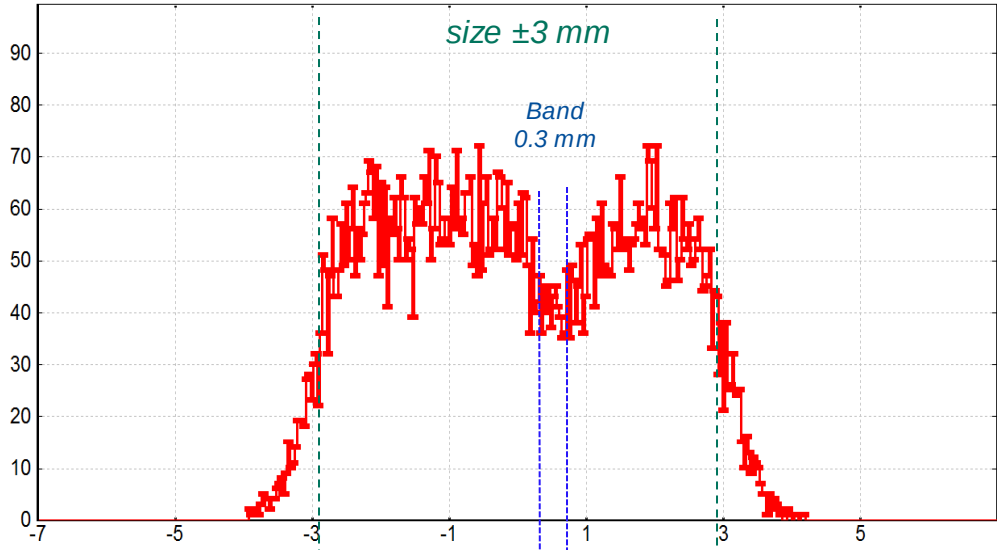
Thick wedge:
40% of range

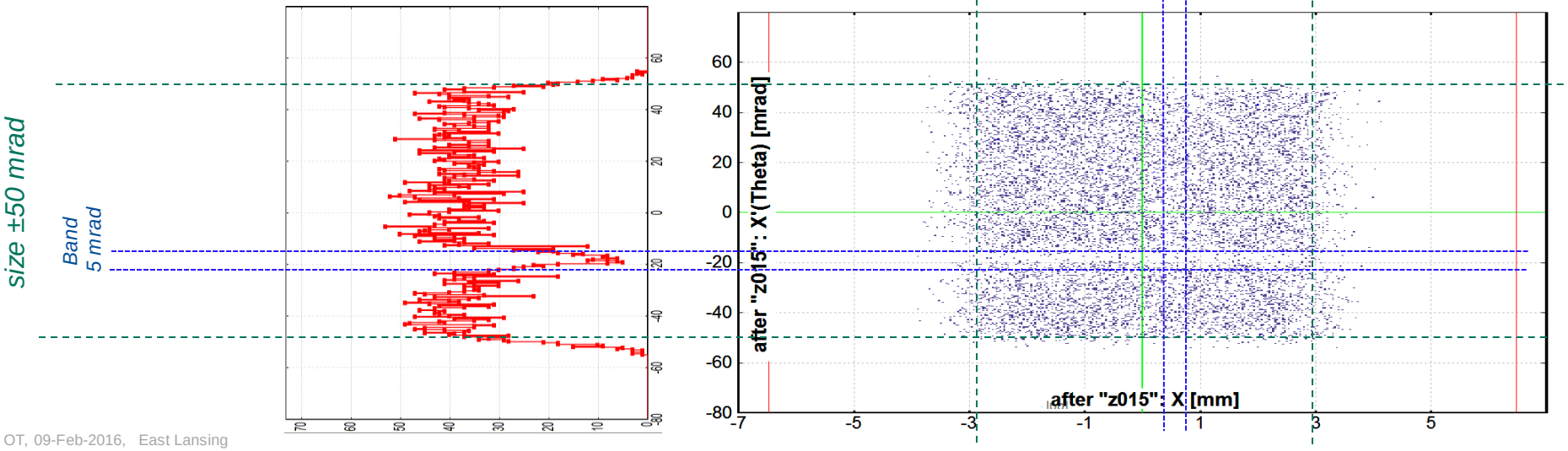


X vs X'
1st order

Thin wedge: 10% of range

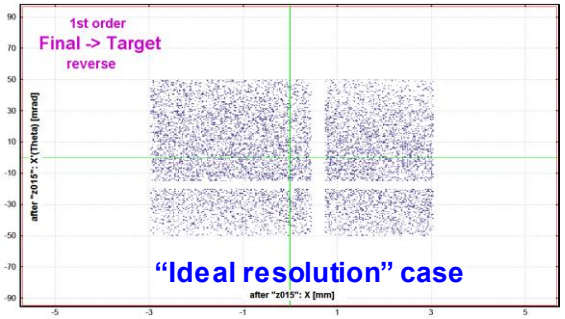


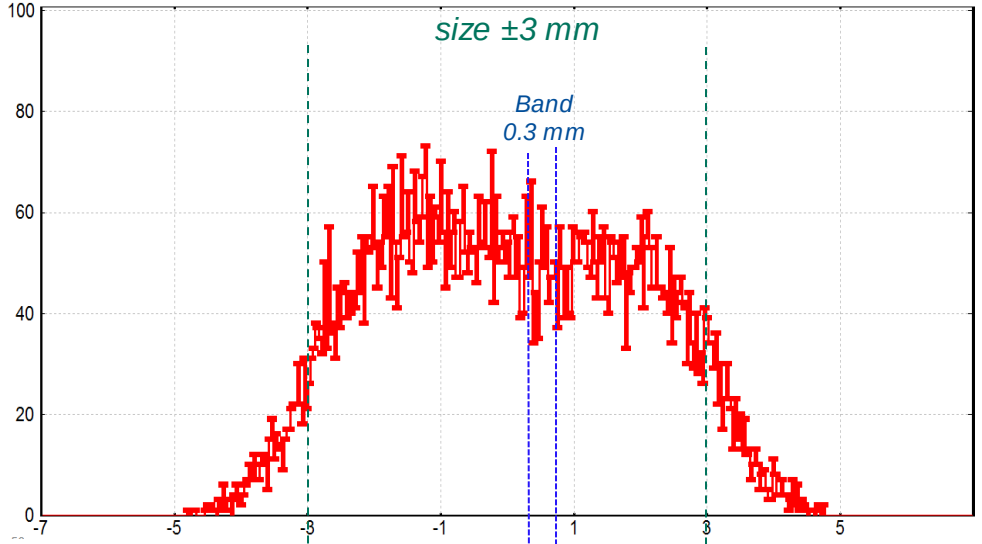




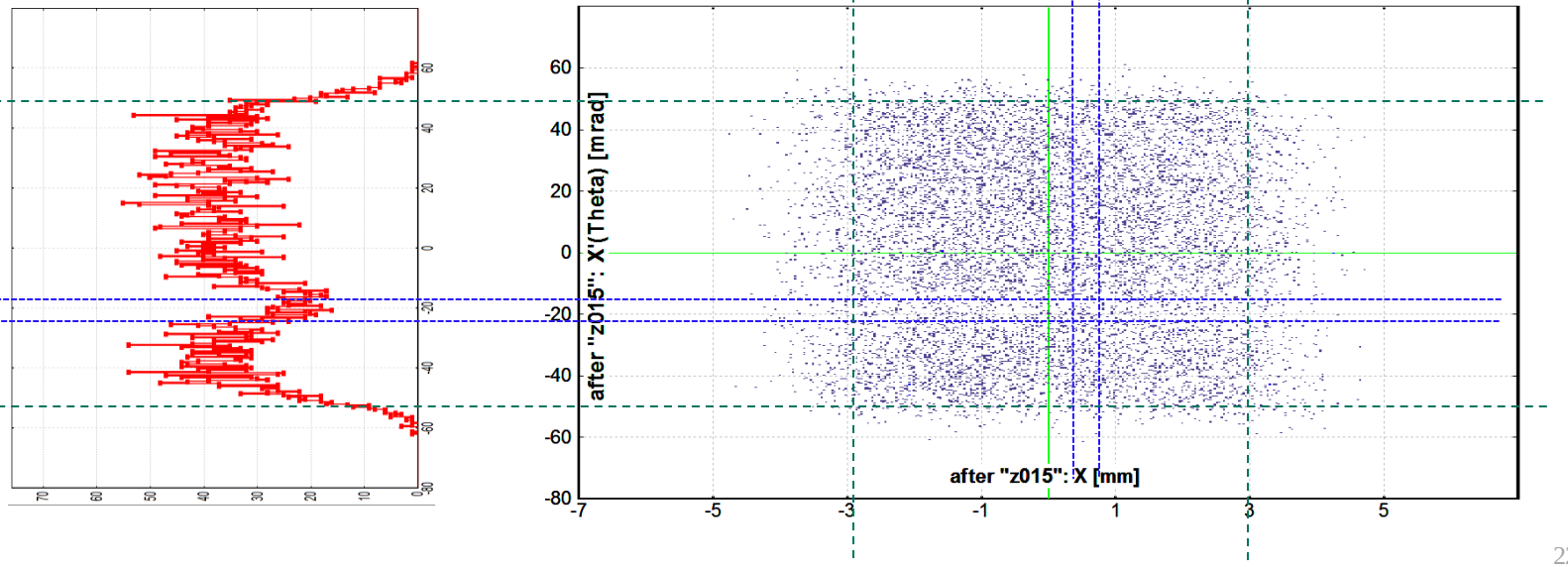
X vs X'
1st order

Thick wedge: 40% of range



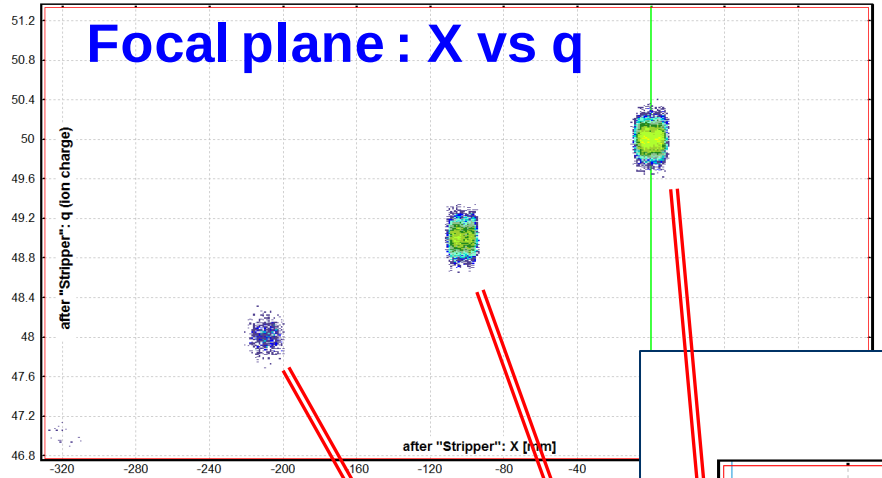


size ±50 mrad
Band
5 mrad

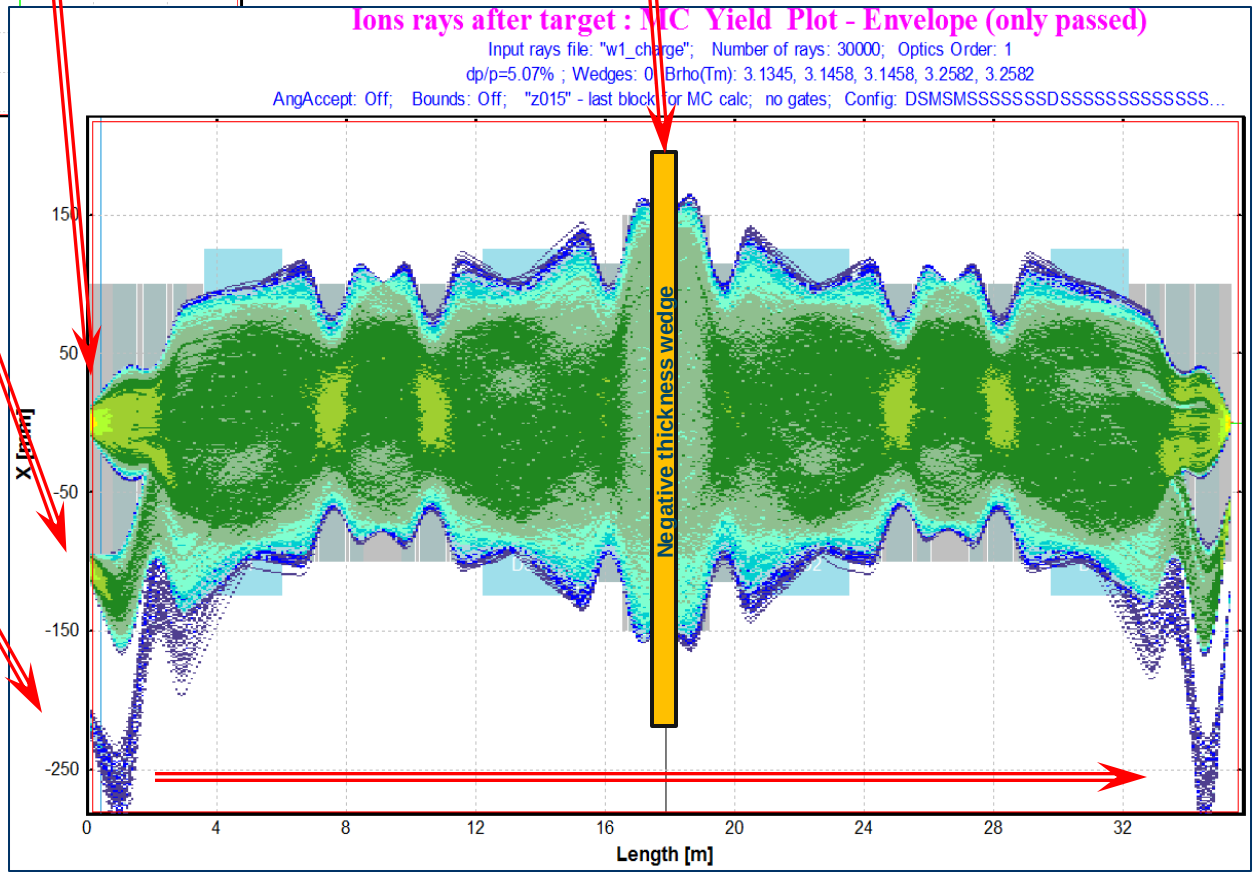


Charge states in reverse technique

Focal plane : X vs q



Negative thickness material do not change charge state distributions!!!



Summary

1. The A1900 LISE-type reverse configuration has been created, its benchmarks have been done
2. High order optics is important in the reverse A1900 case. COSY-type reverse configuration should be tested.
3. Second order LISE-type optics operates well in the reverse A1900 case
4. Energy resolution at the final focal plane detectors is not a key factor in the reverse A1900 case comparing to the S800 case
5. Use of thick wedge destroys reverse resolution quality in the horizontal spatial plane