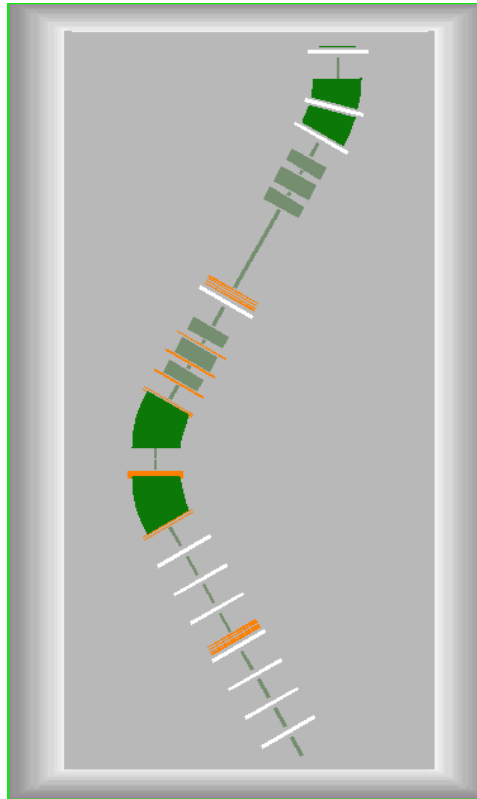


LISE++ v.9.10.280

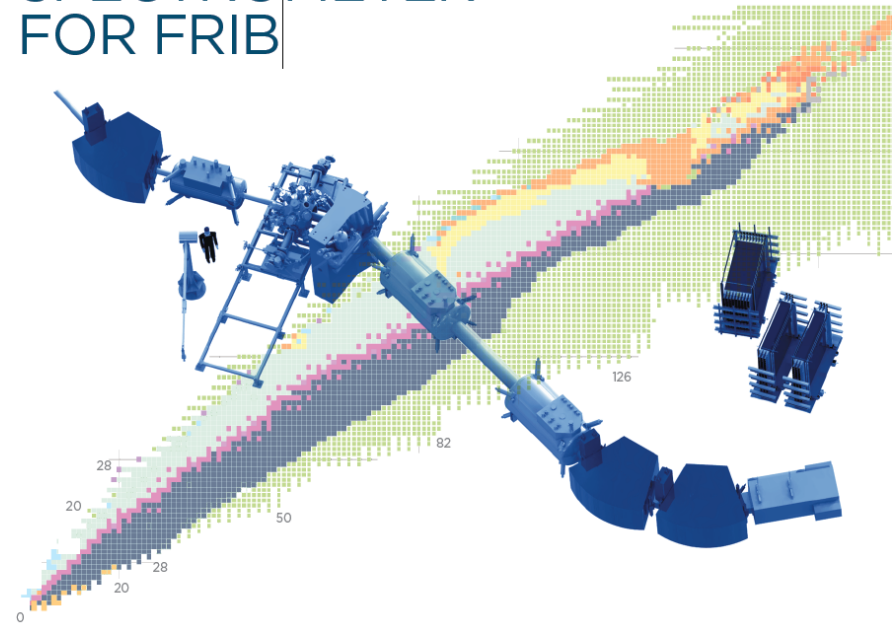


HRS Preconcept #25 from May 2014

[http://lise.nsci.msu.edu/9\\_10/HRS/HRS\\_v3.lpp](http://lise.nsci.msu.edu/9_10/HRS/HRS_v3.lpp)

# HRS

A HIGH RIGIDITY  
SPECTROMETER  
FOR FRIB



<http://hrs.lbl.gov/>

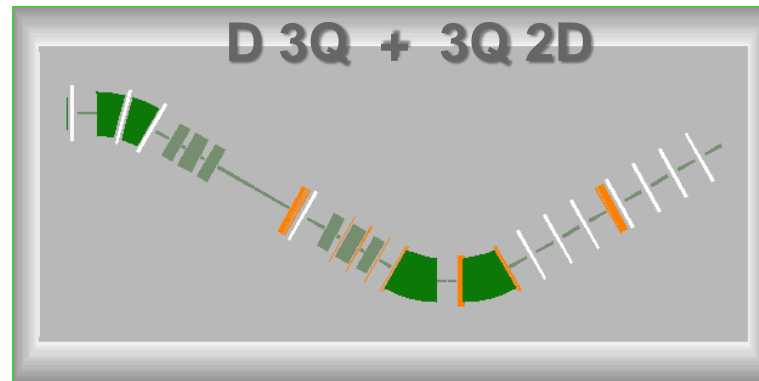
<http://hrs.lbl.gov/design> :

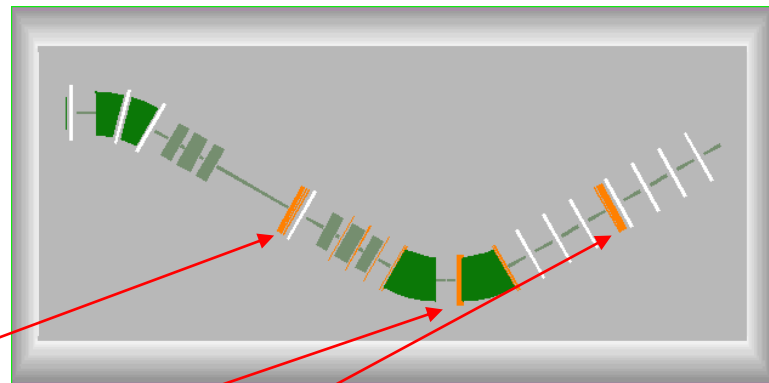
As input to the first HRS workshop, pre-conceptual, first-order ion-optical design studies were performed to provide a basis for discussion of the technical needs and boundary conditions, as well as scientific opportunities. Please refer to this [document](#) as a first guide for the properties of the HRS.

[http://lise.nsl.msui.edu/9\\_10/HRS/HRS\\_v3.lpp](http://lise.nsl.msui.edu/9_10/HRS/HRS_v3.lpp)

The HRS configuration in the LISE++ code has been created based on the “HRS Preconcept May 2014 #25” TRANSPORT file kindly presented by Th.Baumann.

Discussions with Th.Baumann are very appreciated.





**Optics fit**

| Blocks with parameters to vary |                   | Active Constraint blocks |                       |
|--------------------------------|-------------------|--------------------------|-----------------------|
| #01-q                          | Position@011: 2QA | #01                      | @017: R12 = 0 FocX    |
| #02-q                          | Position@013: 2QB | #02                      | @018: R34 = 0 FocY    |
| #03-q                          | Position@015: 2QC | #03                      | @019: sX < 300 F2_sX  |
| #04-q                          | Position@023: 3QA | #04                      | @020: sY < 400 F2_sY  |
| #05-q                          | Position@026: 3QB | #05                      | @025: sY < 250 3QBY   |
| #06-q                          | Position@029: 3QC | #06                      | @027: sX < 150 3QBX   |
|                                |                   | #07                      | @030: sX < 200 3QCX   |
|                                |                   | #08                      | @032: sX < 300 D2X1   |
|                                |                   | #09                      | @033: sY < 100 D2Y1   |
|                                |                   | #10                      | @037: R22 = 0 F_D2A   |
|                                |                   | #11                      | @039: sY < 50 F_D2Y   |
|                                |                   | #12                      | @040: R44 = 0 F_D2B   |
|                                |                   | #13                      | @042: sX < 300 F_D2X2 |
|                                |                   | #14                      | @043: sY < 100 F_D2Y2 |
|                                |                   | #15                      | @051: R12 = 0 F_FocX  |
|                                |                   | #16                      | @052: R44 = 0 F_BB    |
|                                |                   | #17                      | @053: R11 < 1 F_uX    |

N iter = 100

**FIT** Restore previous values

Optics Settings (fast editing) Fit Settings

Browse output file

Show initial conditions Matrix Plot

Beam Sigma Edit [#2] Beam Sigma Plot [#2]

HRS\_v3.fit

```

c:\program files (x86)\lise\results\HRS_v3.fit_init
Chi2: Initial 0.494243 LISE fit reduced values
chi1: Initial 2.95852 LISE fit reduced values

Parameters:      LeftBound  Initial  RightBound
#01-q: 2QA       +0.0e+00 < +1.900e+01 < +3.0e+01
#02-q: 2QB       -3.0e+01 < -2.883e+01 < +0.0e+00
#03-q: 2QC       +0.0e+00 < +2.427e+01 < +3.0e+01
#04-q: 3QA       +0.0e+00 < +2.005e+01 < +2.5e+01
#05-q: 3QB       -3.0e+01 < -2.905e+01 < +0.0e+00
#06-q: 3QC       +0.0e+00 < +1.712e+01 < +3.0e+01

-----
Constraint values:  Initial      Y-value      Precision  (Init-Des)/P      Desired
#01: FocX           +2.987e-08    +2.987e-08    1.0e-04    +2.987e-04        = 0
#02: FocY           +5.885e-06    +5.885e-06    1.0e-03    +5.885e-03        = 0
#03: F2_sX          +3.972e+01    +3.000e+02    1.0e-02    0                  < 300
#04: F2_sY          +1.209e+00    +4.000e+02    1.0e-01    0                  < 400
#05: 3QBY           +7.932e+01    +2.500e+02    1.0e-01    0                  < 250
#06: 3QBX           +1.226e+02    +1.500e+02    1.0e-02    0                  < 150
#07: 3QCX           +2.000e+02    +2.000e+02    1.0e-01    +1.164e-02        < 300
#08: D2X1           +2.152e+02    +3.000e+02    1.0e-01    0                  < 300
#09: D2Y1           +6.002e+01    +1.000e+02    1.0e-01    0                  < 100
#10: F_D2A          +3.122e-01    +3.122e-01    1.0e+01    +3.122e-02        < 50
#11: F_D2Y          +4.868e+01    +5.000e+01    1.0e+01    +2.671e-01        = 0
#12: F_D2B          +8.955e-02    +8.955e-02    1.0e-01    +8.955e-01        = 0
#13: F_D2X2        +2.519e+02    +3.000e+02    1.0e+00    0                  < 300
#14: F_D2Y2        +4.215e+01    +1.000e+02    1.0e-01    0                  < 100
#15: F_FocX        -2.254e-06    -2.254e-06    1.0e-03    +2.254e-03        = 0
#16: F_BB          +7.649e-02    +7.649e-02    1.0e-01    +7.649e-01        = 0
#17: F_uX          +1.097e+00    +1.098e+00    1.0e-01    +9.785e-01        < 1
#18: F_dX          +1.097e+00    -1.000e+00    1.0e-01    +1.228e-03        > -1

-----
==> "F_dX" : last fitting block global optical matrix and sigma vector

-----
Format [mm-mrad]
-----
          G L O B A L      matrix -----
+1.097e+00  -2.254e-06  0  0  0  -6.655e+01  3.33e+02
+2.886e-01  +9.117e-01  0  0  0  -6.367e+00  4.84e+01
0  0  +5.728e+00  -7.456e-01  0  0  3.04e+01
0  0  +7.536e-01  +7.649e-02  0  0  3.15e+00
-1.222e+00  -6.067e+00  0  0  1.0  -2.829e+01  2.81e+02
0  0  0  0  0  +1.000e+00  5.00e+00
  
```

Beam vector used for Optical Optimization

"Opt.Beam"

|      |    |      |
|------|----|------|
| 1. X | 1  | mm   |
| 2. T | 40 | mrad |
| 3. Y | 1  | mm   |
| 4. P | 40 | mrad |
| 5. L | 0  | mm   |
| 6. D | 0  | %    |

mm  
 cm

Beam vector used for Optical Optimization

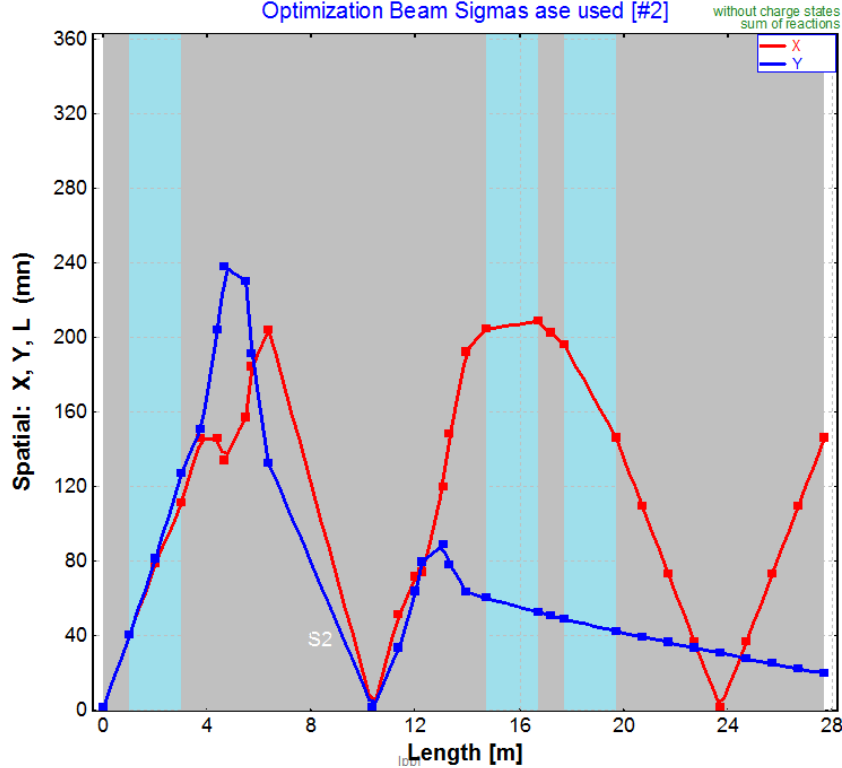
"Opt.Beam"

|      |    |      |
|------|----|------|
| 1. X | 1  | mm   |
| 2. T | 40 | mrad |
| 3. Y | 1  | mm   |
| 4. P | 40 | mrad |
| 5. L | 0  | mm   |
| 6. D | 5  | %    |

mm  
 cm

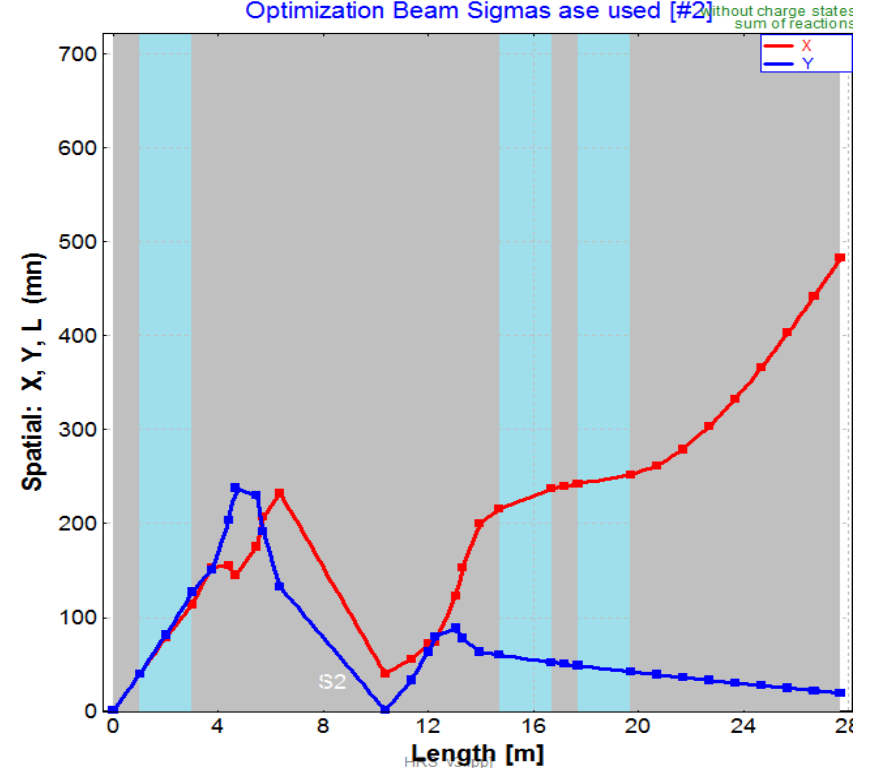
## Beam Sigmas [#2]: spatial

<sup>1</sup>H (1624.93 MeV/u); Settings on <sup>1</sup>H; Config: DSSDSDSSSSSSSSFFFSSSSSF;  
 dp/p=100.00% ; Brho(Tm): 7.9989, 7.9989, 7.9989, 7.9989, 7.9989  
 Optimization Beam Sigmas ase used [#2]



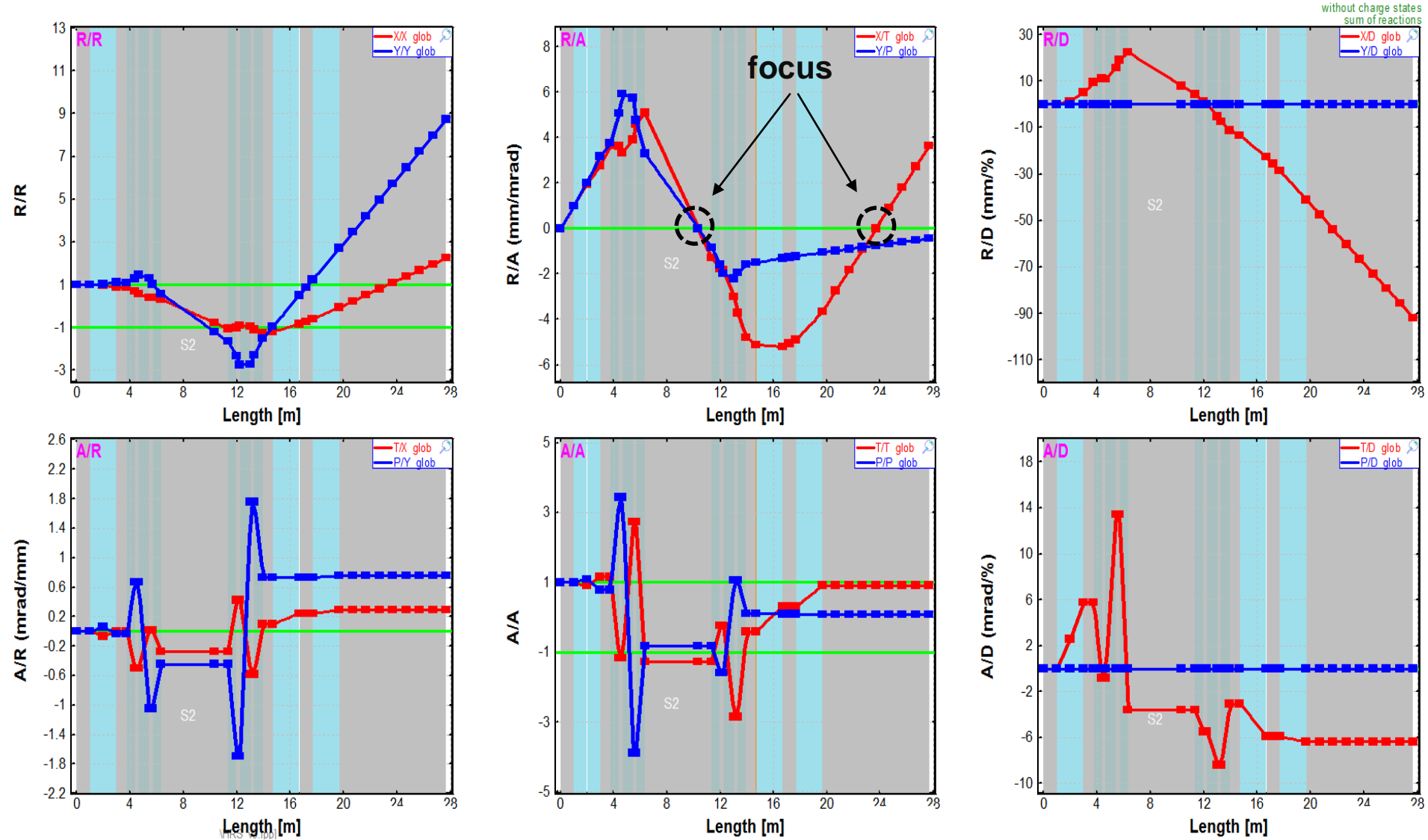
## Beam Sigmas [#2]: spatial

(1624.93 MeV/u); Settings on <sup>1</sup>H; Config: DSSDSDSSSSSSSSFFFSS  
 dp/p=100.00% ; Brho(Tm): 7.9989, 7.9989, 7.9989, 7.9989, 7.998  
 Optimization Beam Sigmas ase used [#2]



## First order matrix elements

<sup>1</sup>H (1624.93 MeV/u); Settings on <sup>1</sup>H; Config: DSSDSDSSSSSSSSFFSSSSFSFS...  
 dp/p=100.00% ; Brho(Tm): 7.9989, 7.9989, 7.9989, 7.9989, 7.9989



## Initial emittance

Emittance [#1]

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

|      |      |    |                   |
|------|------|----|-------------------|
| 1. X | mm   | 0  | Gaussian          |
| 2. T | mrاد | 60 | Rectangle uniform |
| 3. Y | mm   | 0  | Gaussian          |
| 4. P | mrاد | 40 | Rectangle uniform |
| 5. L | mm   | 0  | Gaussian          |
| 6. D | %    | 0  | Gaussian          |

Angular Acceptance & Bounds

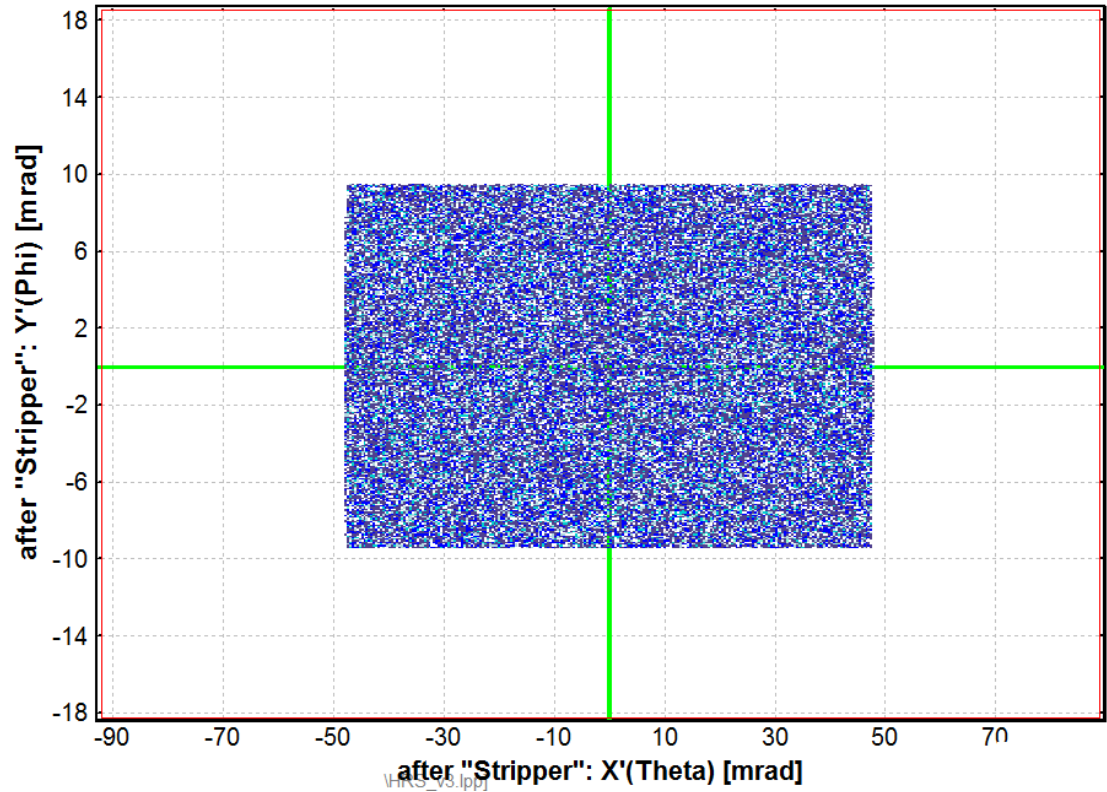
Use fixed angular acceptances

Use physical limits (aperture) inside blocks to calculate fragment transmission

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

only for the ENVELOPE mode

Show trajectories of all fragments (including unselected by fragment-separator)



X-coordinate After BLOCK

Stripper as Y

X mm

X' (T) mrad

Y mm

Y' (P) mrad

Y-coordinate After BLOCK

Stripper as X

X mm

X' (T) mrad

Y mm

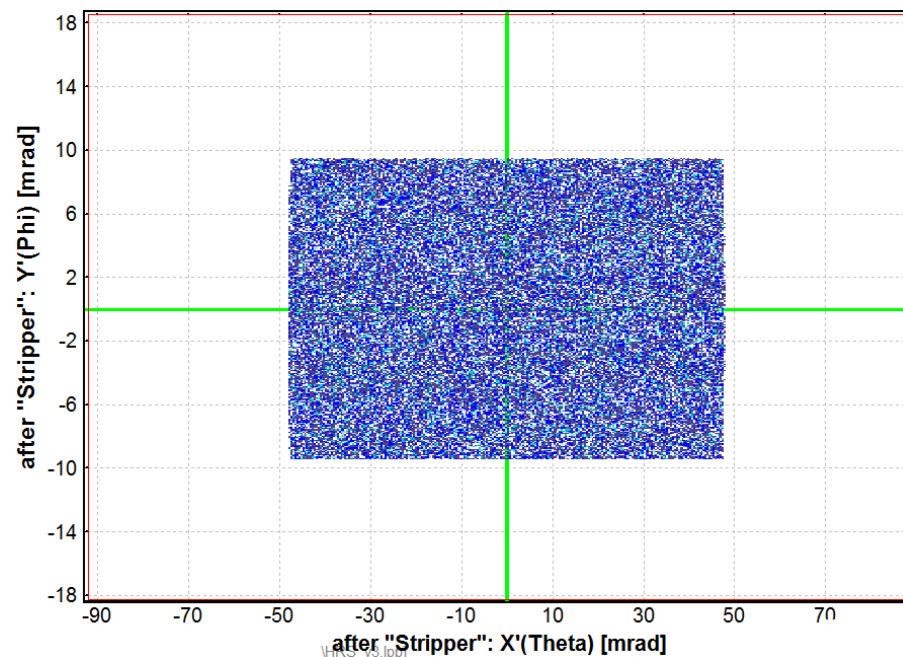
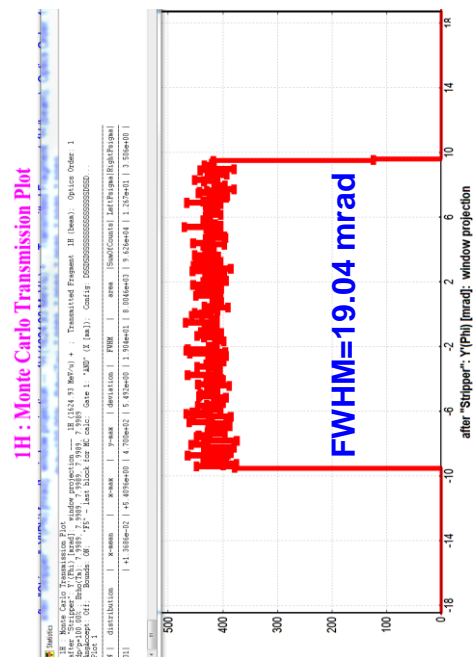
Y' (P) mrad

Gate 1

Settings

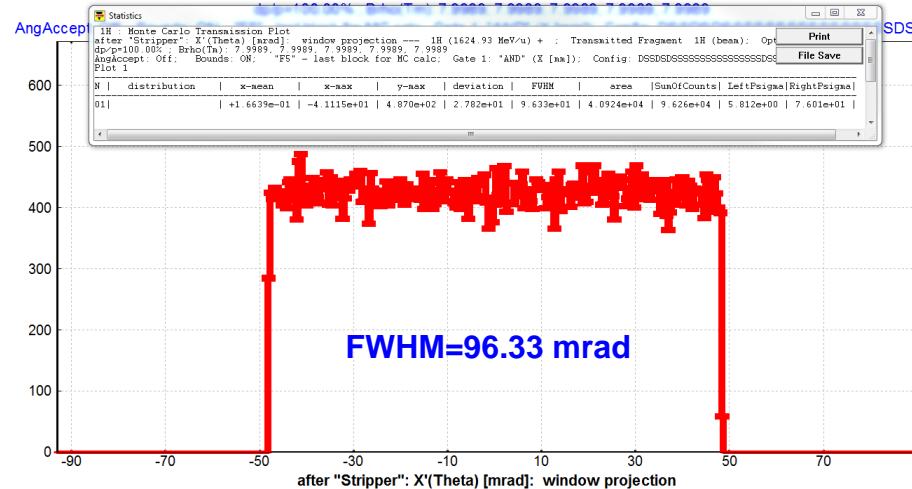
"AND" [-100, 100]

< X [mm] > after F5



**1H : Monte Carlo Transmission Plot**

after "Stripper": X'(Theta) [mrad]: window projection --- 1H (1624.93 MeV/u) + : Transmitted Fragment 1H (beam); Optics Order:



**Angular acceptance:**

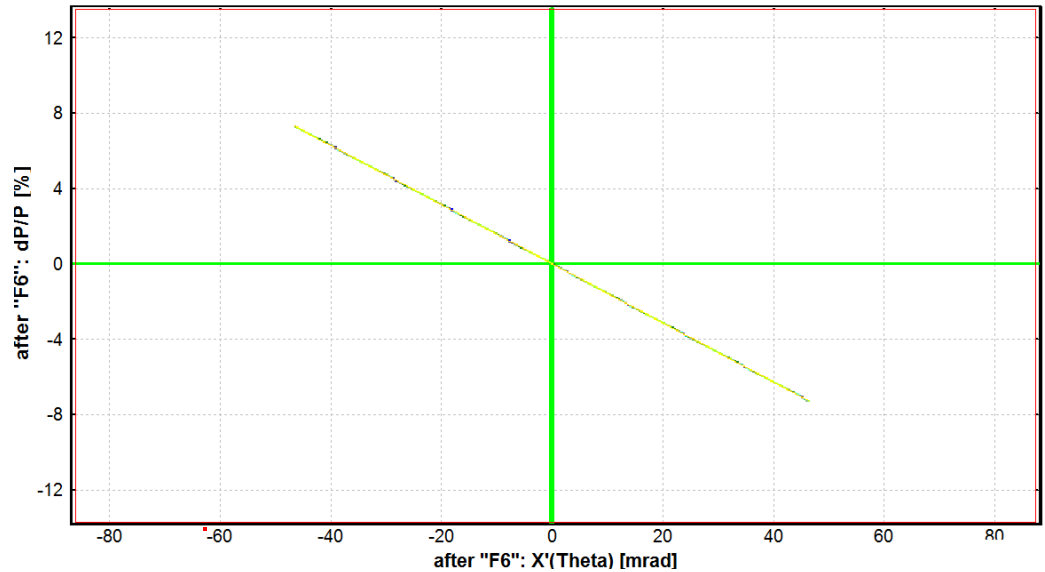
- Horizontal =  $\pm 48.2$  mrad (rectangle)
- Vertical =  $\pm 9.5$  mrad (rectangle)



## Initial emittance

Emittance [#1]

|           | Beam CARD<br>(sigma, semi-axis,<br>half-width...) | 1D - shape<br>(Distribution<br>method) | 2D<br>mode               |
|-----------|---|--|--------------------------|
| 1. X mm   | 0   | Gaussian                               | <input type="checkbox"/> |
| 2. T mrad | 0   | Rectangle uniform                      | <input type="checkbox"/> |
| 3. Y mm   | 0   | Gaussian                               | <input type="checkbox"/> |
| 4. P mrad | 0   | Rectangle uniform                      | <input type="checkbox"/> |
| 5. L mm   | 0   | Gaussian                               | <input type="checkbox"/> |
| 6. D %    | 10  | Rectangle uniform                      | <input type="checkbox"/> |



*In the current concept it is limited by apertures of the last quadrupoles*

### Angular Acceptance & Bounds

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

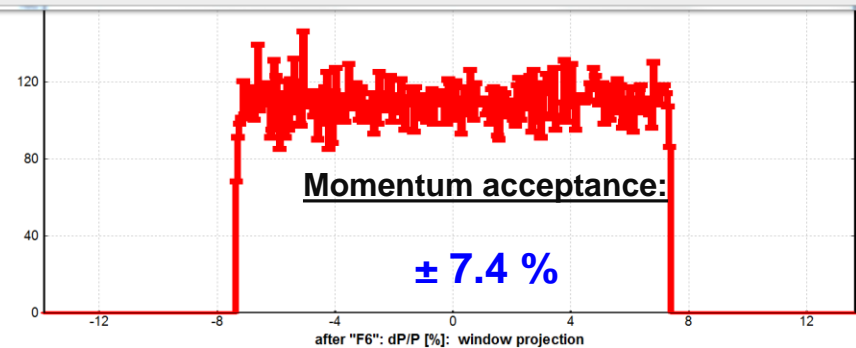
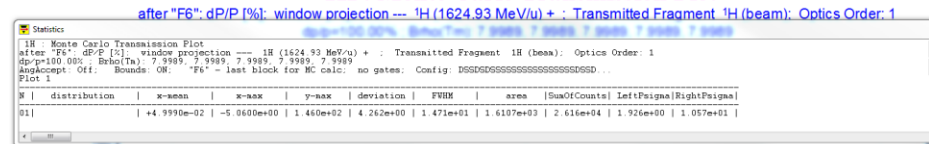
For block apertures LISE++ uses the slit limits accessible from the Block Cut & Acceptance dialog. (Pay attention there for the checkbox

### only for the ENVELOPE mode

- Show trajectories of all fragments (including unselected by fragment-separator)

| X-coordinate                            |      | Y-coordinate                          |      |
|---|------|---------------------------------------|------|
| After BLOCK                             |      | After BLOCK                           |      |
| F6                                      | as Y | F6                                    | as X |
| <input type="radio"/> X                 | mm   | <input type="radio"/> X               | mm   |
| <input checked="" type="radio"/> X' (T) | mrad | <input type="radio"/> X' (T)          | mrad |
| <input type="radio"/> Y                 | mm   | <input type="radio"/> Y               | mm   |
| <input type="radio"/> Y' (P)            | mrad | <input type="radio"/> Y' (P)          | mrad |
| <input type="radio"/> dP/P              | %    | <input checked="" type="radio"/> dP/P | %    |

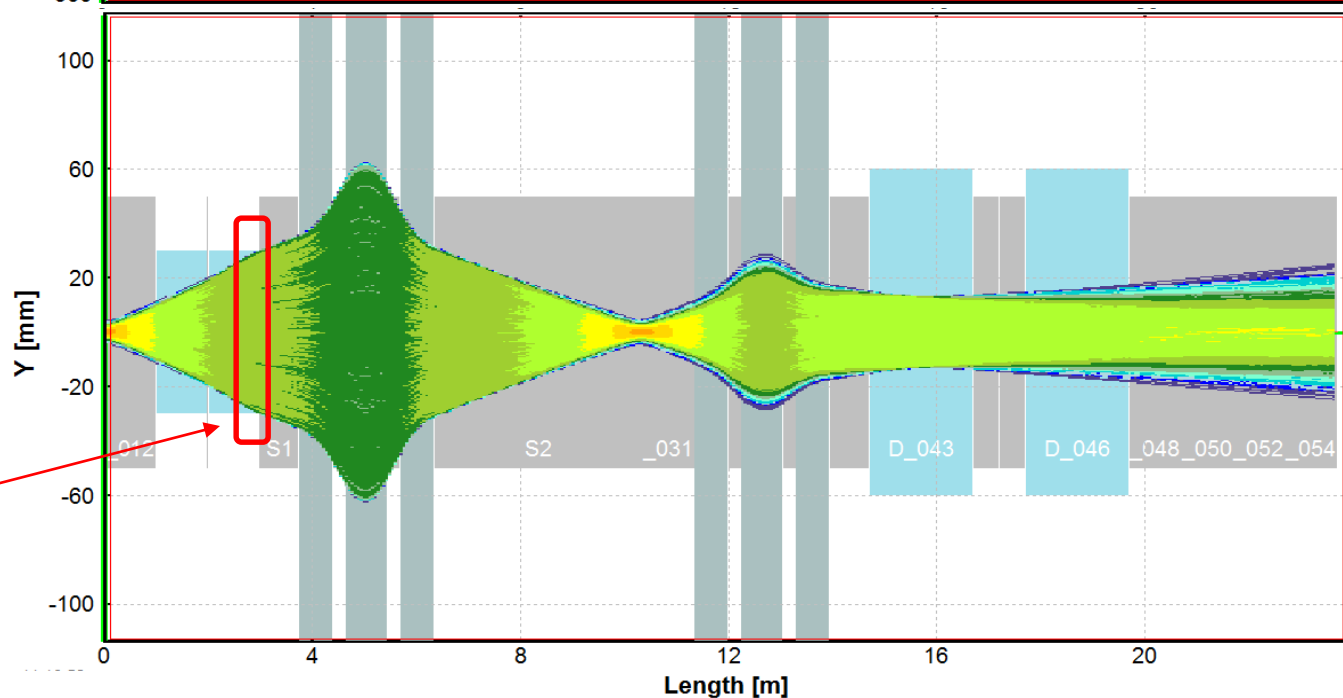
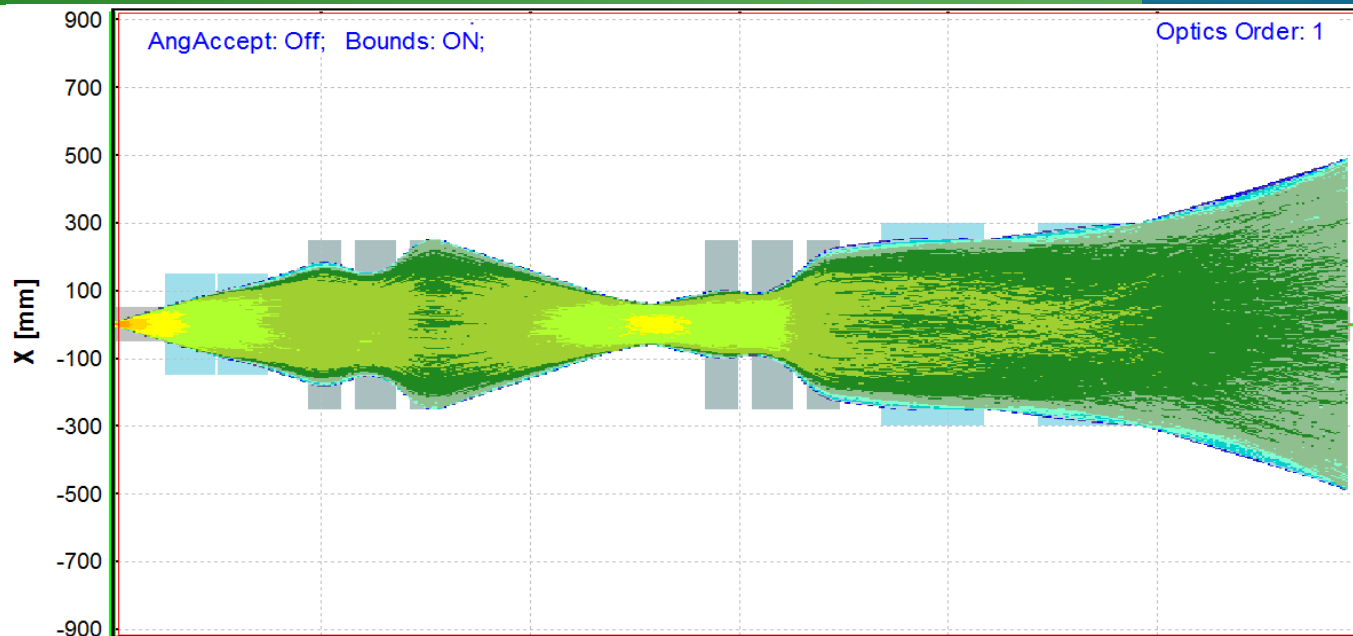
### 1H : Monte Carlo Transmission Plot





## Initial emittance

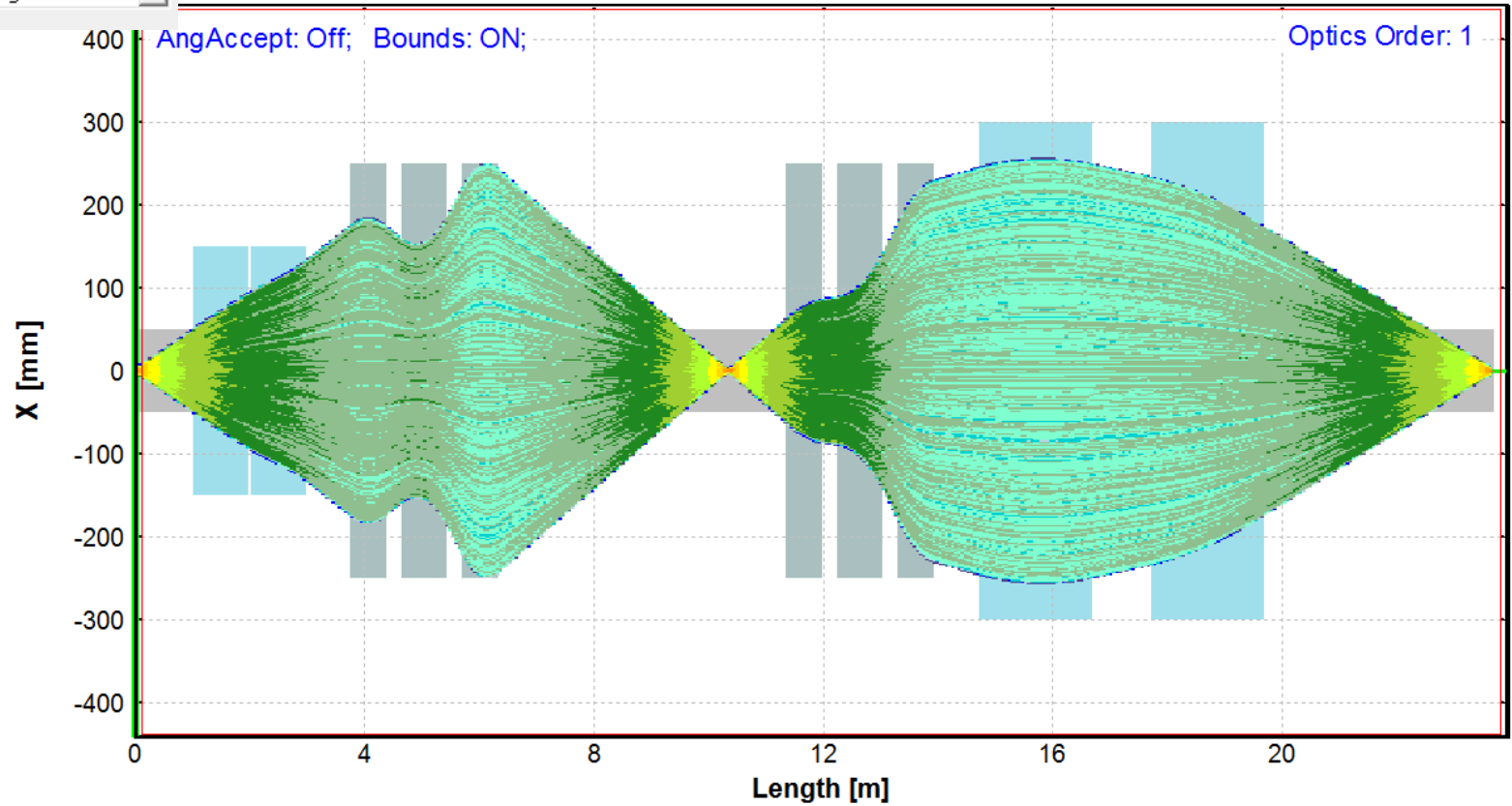
| Emittance [#1] |   |  |
|----------------|---|--|
|                | Beam CARD<br>(sigma, semi-axis,<br>half-width...) | 1D - shape<br>(Distribution<br>method) |
| 1. X mm        | 1   | Gaussian                               |
| 2. T mrad      | 48.2  | Rectangle uniform                      |
| 3. Y mm        | 1   | Gaussian                               |
| 4. P mrad      | 9.5   | Rectangle uniform                      |
| 5. L mm        | 0   | Gaussian                               |
| 6. D %         | 7.4   | Rectangle uniform                      |



Limitation of vertical acceptance

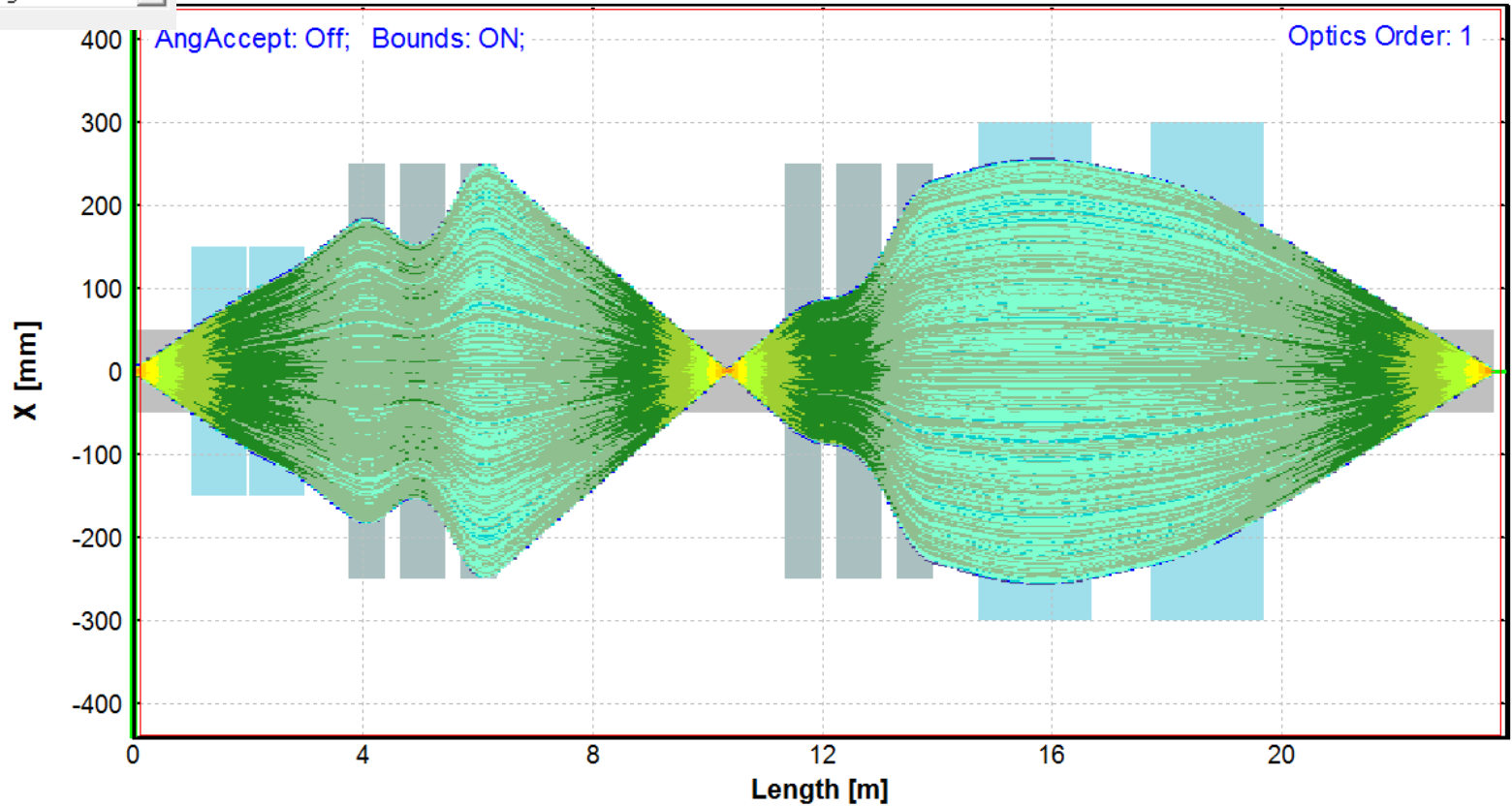
## Initial emittance

| Emittance [#1] |   |  |
|----------------|---|--|
|                | Beam CARD<br>(sigma, semi-axis,<br>half-width...) | 1D - shape<br>(Distribution<br>method) |
| 1. X mm        | 1   | Gaussian                               |
| 2. T mrad      | 48.2  | Rectangle uniform                      |
| 3. Y mm        | 1   | Gaussian                               |
| 4. P mrad      | 9.5   | Rectangle uniform                      |
| 5. L mm        | 0   | Gaussian                               |
| 6. D %         | 0   | Rectangle uniform                      |



## Initial emittance

| Emittance [#1] |   |  |
|----------------|---|--|
|                | Beam CARD<br>(sigma, semi-axis,<br>half-width...) | 1D - shape<br>(Distribution<br>method) |
| 1. X mm        | 1   | Gaussian                               |
| 2. T mrad      | 48.2  | Rectangle uniform                      |
| 3. Y mm        | 1   | Gaussian                               |
| 4. P mrad      | 9.5   | Rectangle uniform                      |
| 5. L mm        | 0   | Gaussian                               |
| 6. D %         | 0   | Rectangle uniform                      |



**Fitting constraint @ F6**

This constraint is ACTIVE (will be used in the minimization process)

Desired parameters of element to fit  
 Constraint: Lower limit is  
 Desired Value = -1  
 Desired Accuracy = 0.1  
 Constraint name = F\_dX  
 TRANSPORT notation  
 10.1 -1. 1. -1 0.1 "F\_dX"

Global Block matrix : 1st order

|      |         |          |        |         |   |          |
|------|---------|----------|--------|---------|---|----------|
| 1. X | 1.0968  | -2.25e-6 | 0      | 0       | 0 | -66.5491 |
| 2. T | 0.2886  | 0.9117   | 0      | 0       | 0 | -6.3669  |
| 3. Y | 0       | 0        | 5.7283 | -0.7456 | 0 | 0        |
| 4. P | 0       | 0        | 0.7536 | 0.0765  | 0 | 0        |
| 5. L | -1.2221 | -6.0673  | 0      | 0       | 1 | -28.2936 |
| 6. D | 0       | 0        | 0      | 0       | 0 | 1        |

Global Block matrix : 2nd order

|                      |            |           |
|----------------------|------------|-----------|
| Matrix Element Value | +8.113e-05 | +8.11e-05 |
| R.Aberration         |            |           |
| 2nd order maps       |            |           |

Aberrations: list

Beam sigma vector used for aberrations

Beam vector used for Optical Optimization

"Opt.Beam"

|      |    |      |
|------|----|------|
| 1. X | 1  | mm   |
| 2. T | 40 | mrاد |
| 3. Y | 1  | mm   |
| 4. P | 40 | mrاد |
| 5. L | 0  | mm   |
| 6. D | 5  | %    |

mm  
cm

Ok  
Cancel

Block: "F\_dX" Aberrations (Elements normalized on Phase Space)

Block: "F\_dX" Aberrations (Elements normalized on Phase Space)  
 1st order : (a/b)\*beam(b); 2nd order : (a/b/c)\*beam(b)\*beam(c)  
 transport format [mm-mrad]

\* TRANSFORM 1 \*

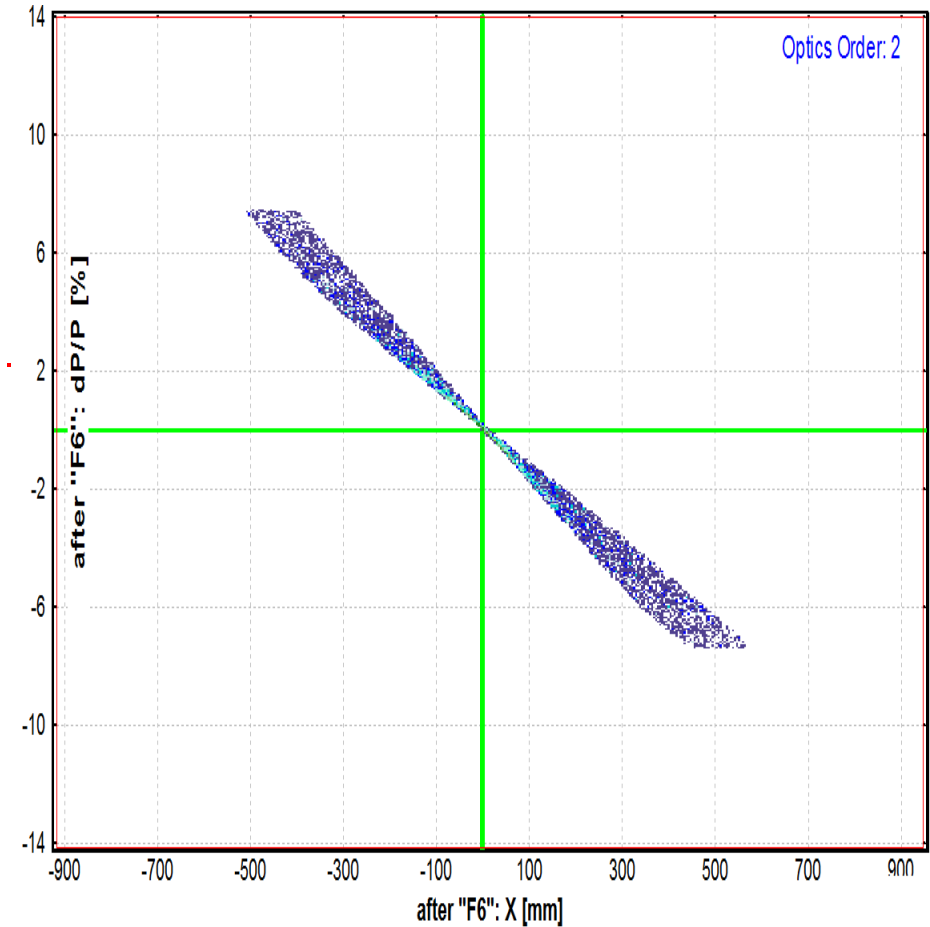
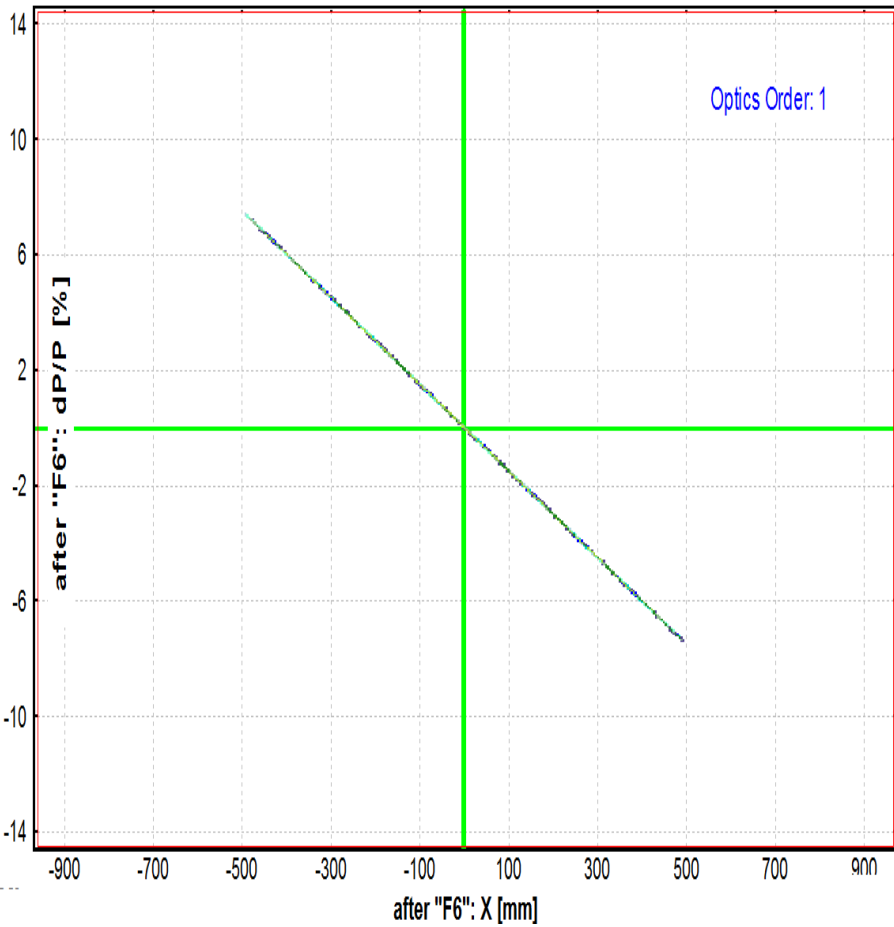
|        |             |             |             |             |             |
|--------|-------------|-------------|-------------|-------------|-------------|
| 1 [X]: | +1.0968e+00 | -9.0000e-05 | 0           | 0           | -3.3275e+02 |
| 2 [T]: | +2.8860e-01 | +3.6468e+01 | 0           | 0           | -3.1835e+01 |
| 3 [Y]: | 0           | 0           | +5.7283e+00 | -2.9824e+01 | 0           |
| 4 [F]: | 0           | 0           | +7.5360e-01 | +3.0600e+00 | 0           |
| 5 [L]: | -1.2221e+00 | -2.4269e+02 | 0           | 0           | -1.4147e+02 |
| 6 [D]: | 0           | 0           | 0           | 0           | +5.0000e+00 |

\* TRANSFORM 2 \*

|      |             |             |             |             |             |
|------|-------------|-------------|-------------|-------------|-------------|
| 1 1: | +8.1128e-05 | 0           | 0           | 0           | 0           |
| 1 2: | +6.7662e-03 | +5.5691e+00 | 0           | 0           | 0           |
| 1 3: | 0           | 0           | -2.4687e-04 | 0           | 0           |
| 1 4: | 0           | 0           | -3.5419e-02 | +3.0735e+00 | 0           |
| 1 5: | 0           | 0           | 0           | 0           | 0           |
| 1 6: | +3.3002e-02 | +1.2150e+00 | 0           | 0           | +1.6707e+01 |
| 2 1: | +3.5658e-06 | 0           | 0           | 0           | 0           |
| 2 2: | +9.1623e-03 | +8.9118e-01 | 0           | 0           | 0           |
| 2 3: | 0           | 0           | -4.7798e-05 | 0           | 0           |
| 2 4: | 0           | 0           | -3.0191e-03 | +3.8031e-01 | 0           |
| 2 5: | 0           | 0           | 0           | 0           | 0           |
| 2 6: | -1.8941e-03 | -9.8444e-01 | 0           | 0           | +1.6078e+00 |
| 3 1: | 0           | 0           | 0           | 0           | 0           |
| 3 2: | 0           | 0           | 0           | 0           | 0           |
| 3 3: | -9.6944e-04 | -2.8725e-01 | 0           | 0           | 0           |
| 3 4: | -2.3619e-02 | -1.0214e+01 | 0           | 0           | 0           |
| 3 5: | 0           | 0           | 0           | 0           | 0           |
| 3 6: | 0           | 0           | -4.0531e-02 | -7.3020e+00 | 0           |
| 4 1: | 0           | 0           | 0           | 0           | 0           |
| 4 2: | 0           | 0           | 0           | 0           | 0           |
| 4 3: | -1.4465e-04 | -3.2199e-02 | 0           | 0           | 0           |
| 4 4: | +8.4874e-04 | -5.2316e-01 | 0           | 0           | 0           |
| 4 5: | 0           | 0           | 0           | 0           | 0           |
| 4 6: | 0           | 0           | -7.8027e-03 | -6.1984e-01 | 0           |
| 5 1: | +4.8844e-06 | 0           | 0           | 0           | 0           |
| 5 2: | -2.5269e-02 | +1.0208e+00 | 0           | 0           | 0           |
| 5 3: | 0           | 0           | +1.0680e-04 | 0           | 0           |
| 5 4: | 0           | 0           | +9.6359e-04 | +2.1641e+00 | 0           |
| 5 5: | 0           | 0           | 0           | 0           | 0           |
| 5 6: | +3.8043e-02 | +5.6963e+00 | 0           | 0           | +6.6427e+00 |

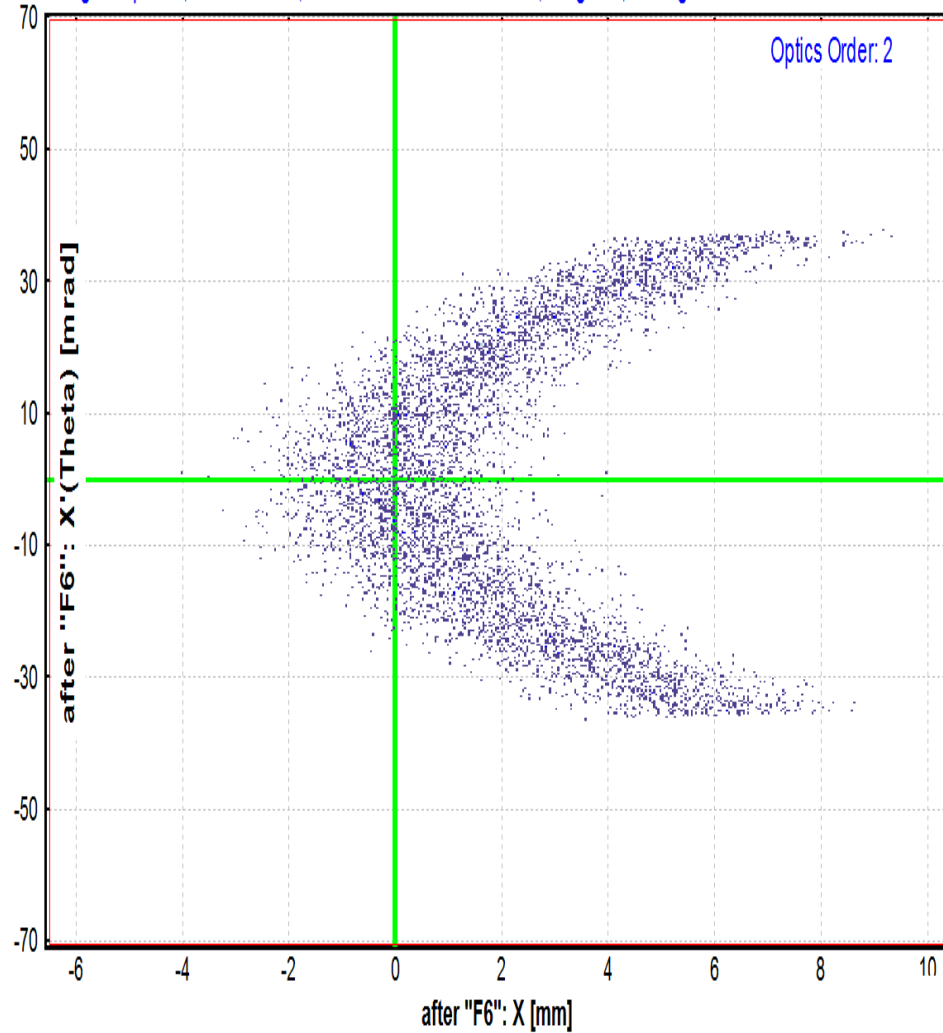
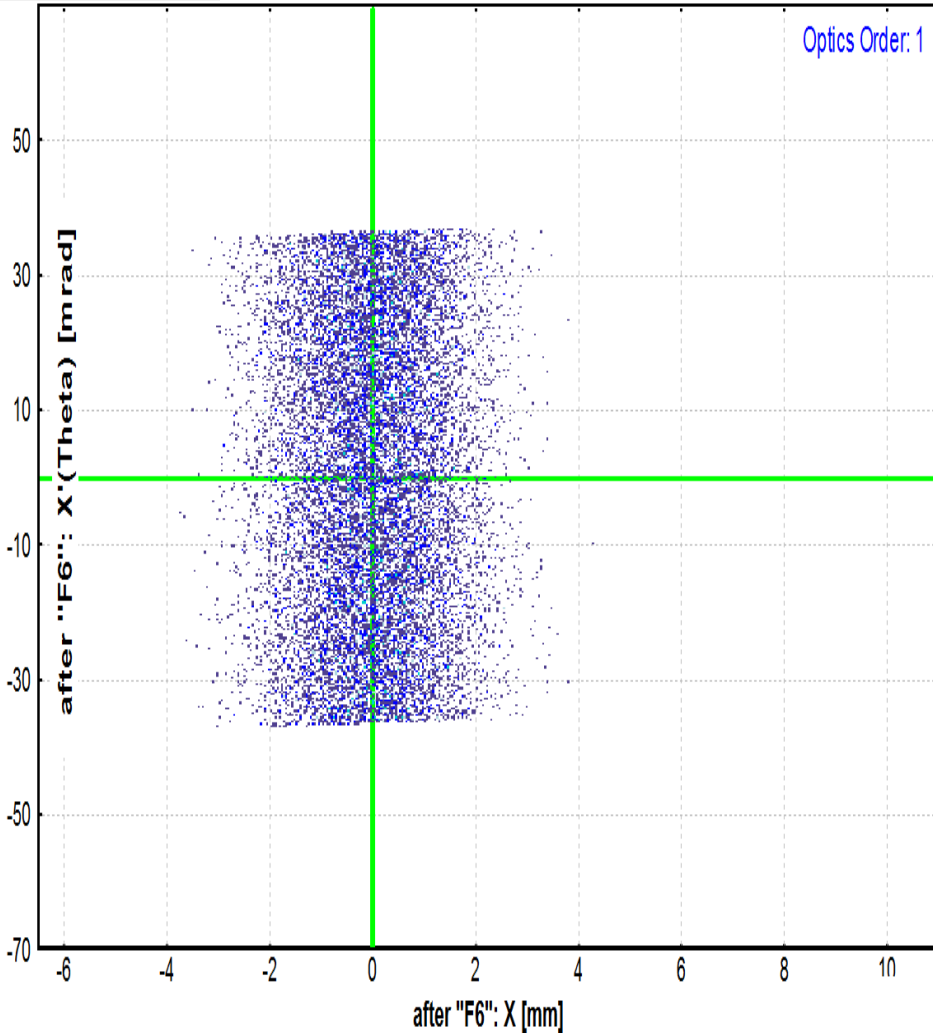
x/θ<sup>2</sup>  
x/δ<sup>2</sup>  
y/θφ

$x/\delta^2$



|      |      |    |
|------|------|----|
| 1. X | mm   | 1  |
| 2. T | mrاد | 40 |
| 3. Y | mm   | 1  |
| 4. P | mrاد | 40 |
| 5. L | mm   | 0  |
| 6. D | %    | 0  |

$x/\theta^2$



|      |      |    |
|------|------|----|
| 1. X | mm   | 1  |
| 2. T | mrاد | 40 |
| 3. Y | mm   | 1  |
| 4. P | mrاد | 40 |
| 5. L | mm   | 0  |
| 6. D | %    | 0  |

$y/\theta\phi$

