2nd Order Optics Minimization in LISE++

Purpose:
2nd optics minimization of existed separators

v.9.10.156
from 07/27/15

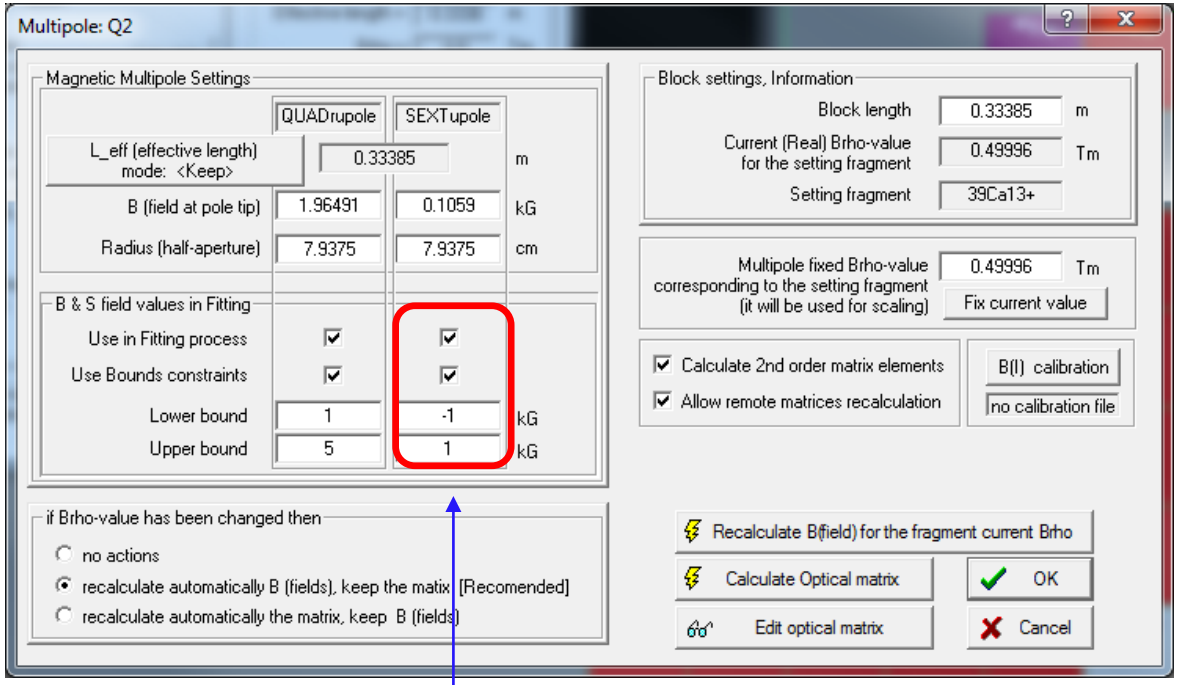
1. **Introduction: First order optics minimization in LISE++ (links)**
2. **Modification of M-multipole blocks for 2nd order optimization**
3. **Modification of the "Fitting constraints" block for 2nd order**
   - *Aberrations list*
4. **Run new minimization version**
   - *High order truncation problem*
5. **"OptBeam" : New Beam sigma vector used only in the Optics Optimization**

Acknowledgements to Drs. M.Hausmann and M.Portilio (NSCL/MSU) for fruitful discussions.

Introduction: First order optics minimization in LISE^{++}

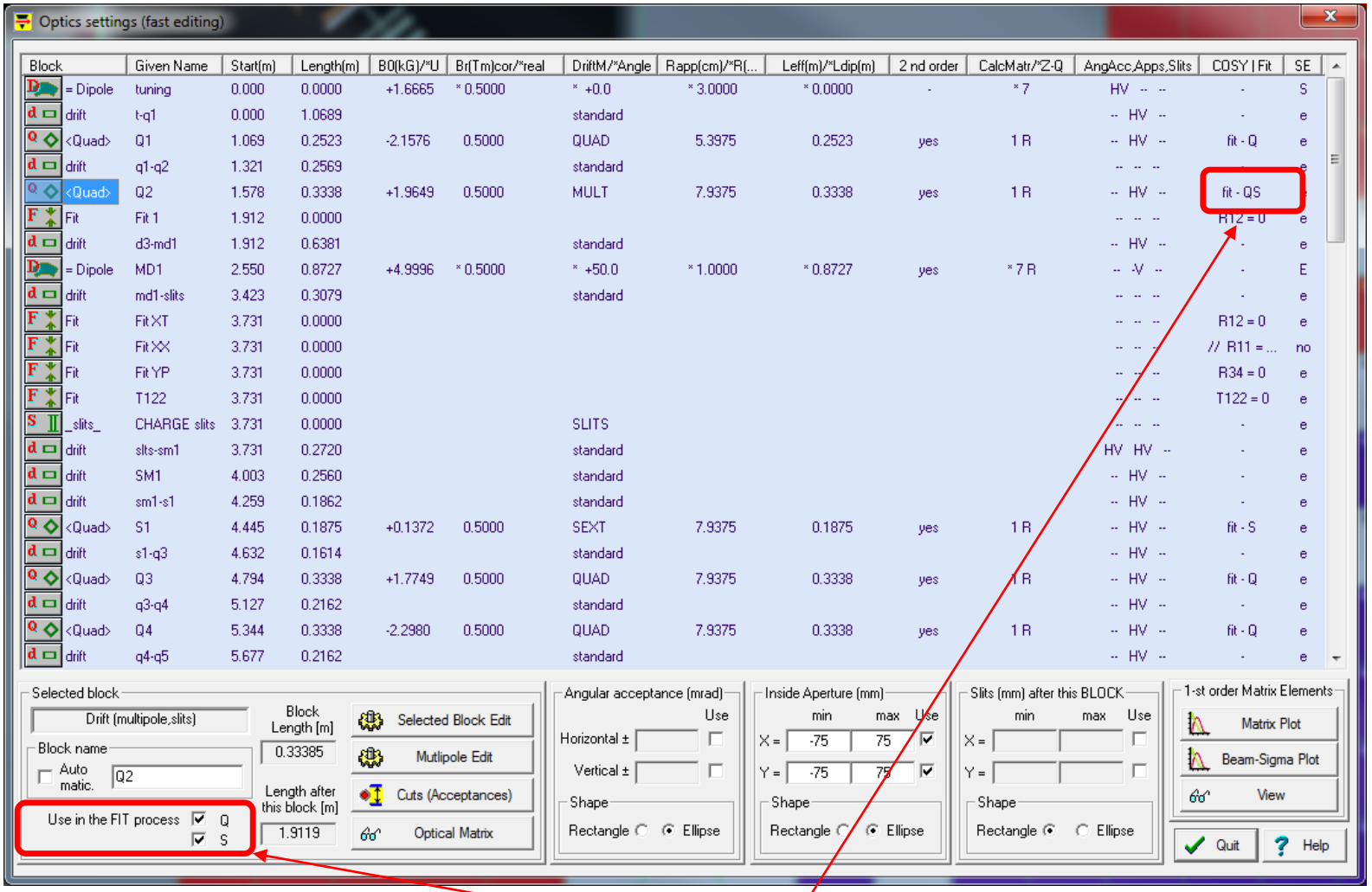
v.9.10.100	22-05-15	Optics minimization (main part)
v.9.10.119	23-06-15	Optics minimization (update)
v.9.10.142	22-07-15	Using LISE++ optics minimization for the DRAGON2000 extended configuration development

Modification of M-multipole blocks for 2nd order optimization



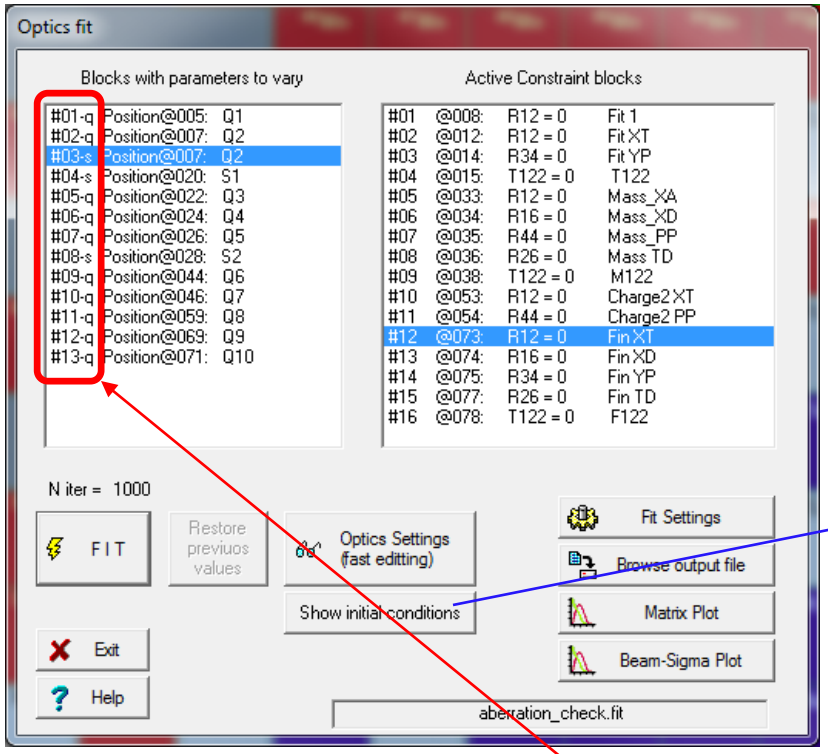
New feature: using sextupole fields in the Optimization process.
Evidently, it has an effect only in the 2nd order optimization

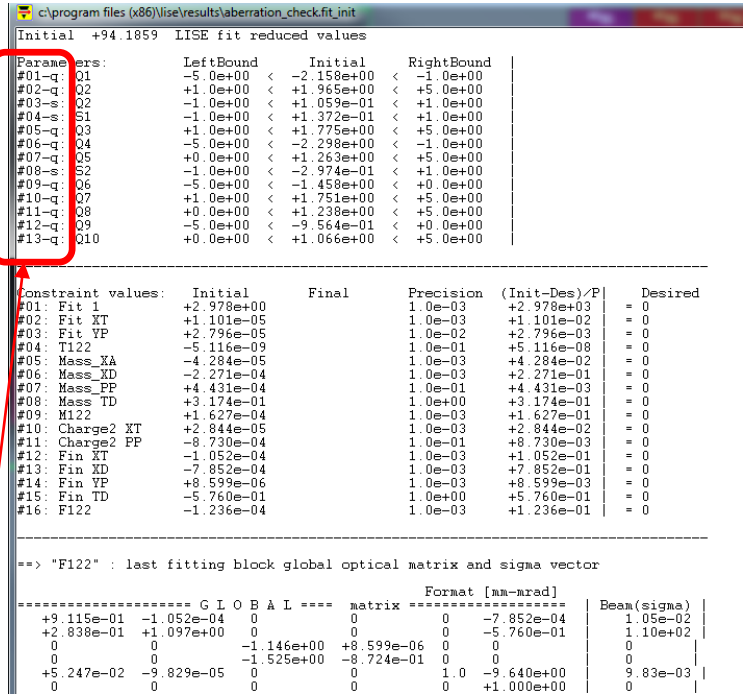
The "Optics settings" dialog and Sextupole fields for optimization



It is possible to change quickly the use of Quadrupole and/or Sextupole fields from the Optics settings dialog

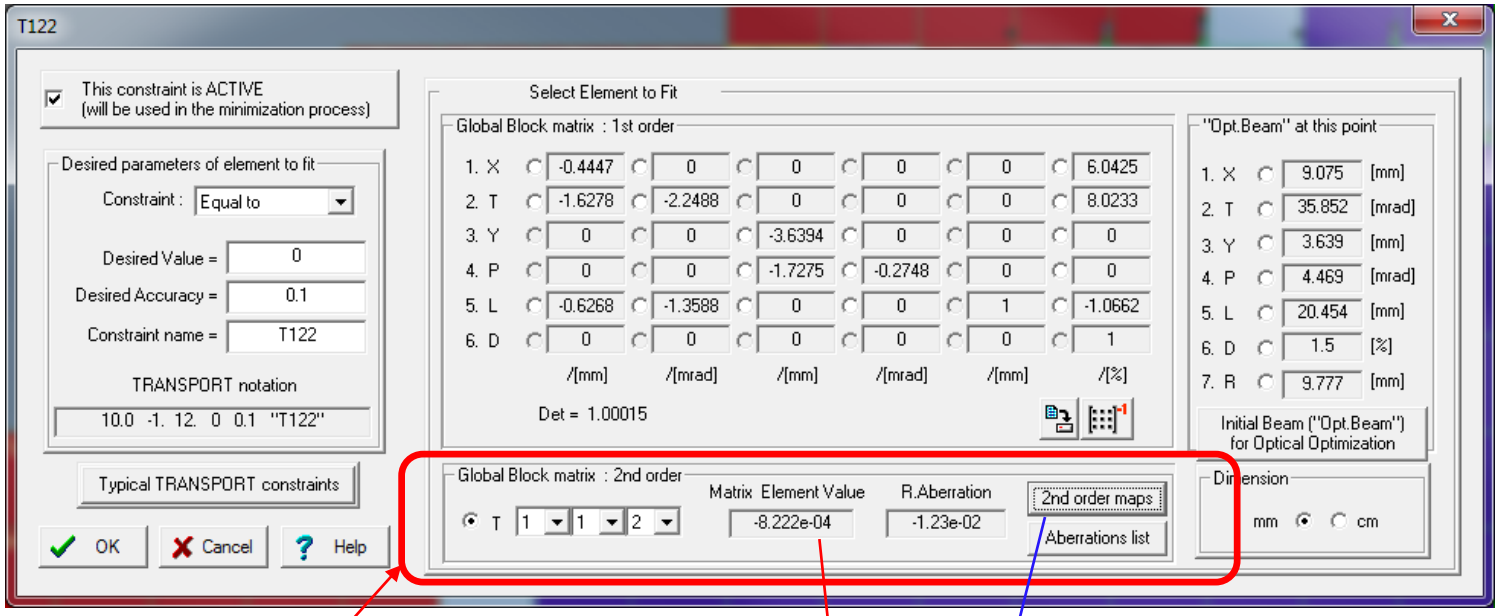
The “Optics settings” dialog and Sextupole fields for optimization



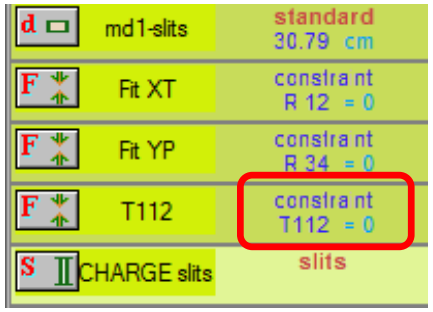


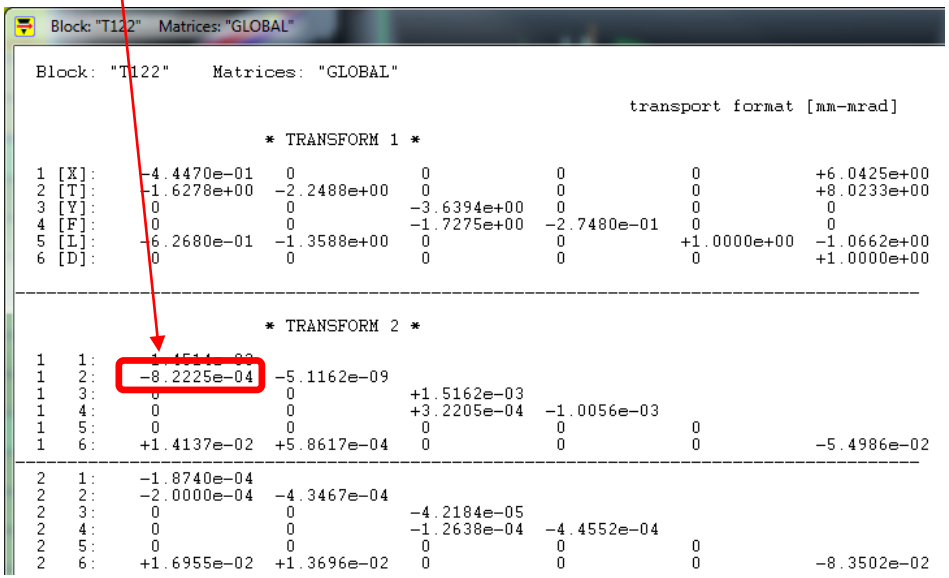
Chars “q” and “s” show what component (“q”uadrupole or “s”extupole) of multipole is used in the Optimization process

Modification of the "Fit constraint" block for 2nd order optimization

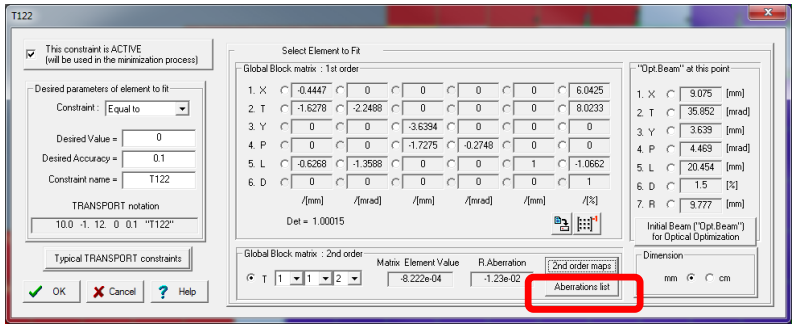


New feature: Selection of 2nd order matrix element for the "Optimization" process





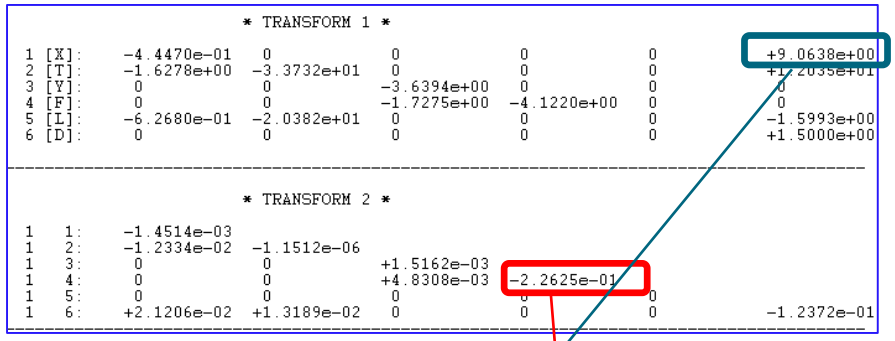
“Fit constraint” block for 2nd order optimization : Aberrations List



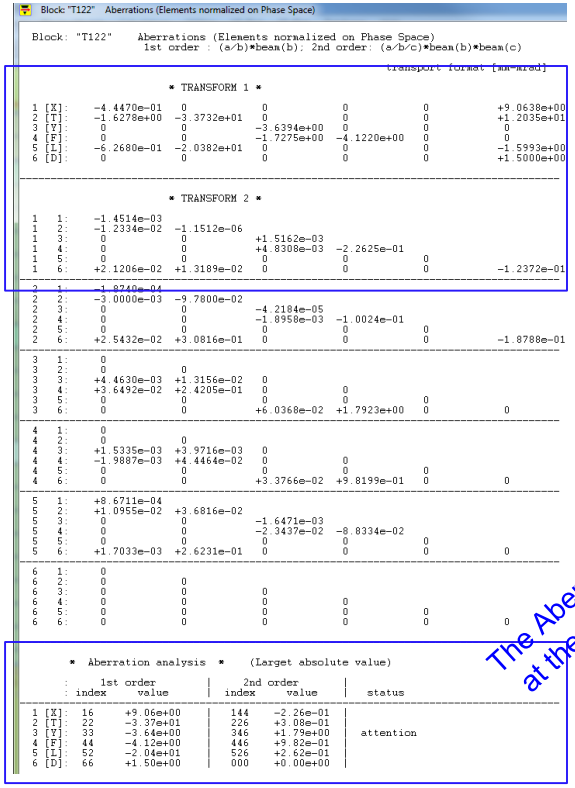
The Aberration list purpose : show a 2nd element to pay attention. Aberration value is:

1st order : $V_1 = (a|b)*s(b)$

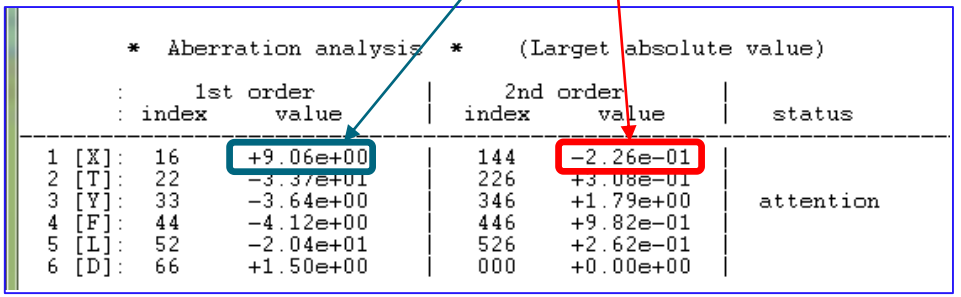
2nd order : $V_2 = (a|bc)*s(b)*s(c)$



```
                    * TRANSFORM 1 *
1 [X]:    -4.4470e-01   0            0            0            0          +9.0638e+00
2 [T]:    -1.6278e+00  -3.3732e+01   0            0            0          +1.2035e+01
3 [Y]:     0            0           -3.6394e+00   0            0          0
4 [F]:     0            0           -1.7275e+00  -4.1220e+00   0          0
5 [L]:    -6.2680e-01  -2.0382e+01   0            0            0          -1.5993e+00
6 [D]:     0            0           0            0            0          +1.5000e+00

                    * TRANSFORM 2 *
1   1:    -1.4514e-03
1   2:    -1.2334e-02  -1.1512e-06
1   3:     0            0           +1.5162e-03
1   4:     0            0           +4.8308e-03  -2.2625e-01
1   5:     0            0           0            0            0
1   6:    +2.1206e-02  +1.3189e-02   0            0            0          -1.2372e-01
```



```
Block: "T122"   Aberrations (Elements normalized on Phase Space)
Block: "T122"    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]:    -4.4470e-01   0            0            0            0          +9.0638e+00
2 [T]:    -1.6278e+00  -3.3732e+01   0            0            0          +1.2035e+01
3 [Y]:     0            0           -3.6394e+00   0            0          0
4 [F]:     0            0           -1.7275e+00  -4.1220e+00   0          0
5 [L]:    -6.2680e-01  -2.0382e+01   0            0            0          -1.5993e+00
6 [D]:     0            0           0            0            0          +1.5000e+00
                    * TRANSFORM 2 *
1   1:    -1.4514e-03
1   2:    -1.2334e-02  -1.1512e-06
1   3:     0            0           +1.5162e-03
1   4:     0            0           +4.8308e-03  -2.2625e-01
1   5:     0            0           0            0            0
1   6:    +2.1206e-02  +1.3189e-02   0            0            0          -1.2372e-01
2   1:    -1.8740e-04
2   2:    -3.0000e-03  -9.7800e-02
2   3:     0            0           -4.2184e-05
2   4:     0            0           -1.8958e-03  -1.0024e-01
2   5:     0            0           0            0            0
2   6:    +2.5432e-02  +3.0816e-01   0            0            0          -1.8788e-01
3   1:     0
3   2:     0            0
3   3:    +4.4630e-03  +1.3156e-02   0
3   4:    +3.6492e-02  +2.4205e-01   0            0
3   5:     0            0           0            0            0
3   6:     0            0           +6.0368e-02  +1.7923e+00   0          0
4   1:     0
4   2:     0            0
4   3:    +1.5335e-03  +3.9716e-03   0
4   4:    -1.9887e-03  +4.4464e-02   0            0
4   5:     0            0           0            0            0
4   6:     0            0           +3.3766e-02  +9.8199e-01   0          0
5   1:    +8.6711e-04
5   2:    +1.0955e-02  +3.6816e-02
5   3:     0            0           -1.6471e-03
5   4:     0            0           -2.3437e-02  -8.8334e-02
5   5:     0            0           0            0            0
5   6:    +1.7033e-03  +2.6231e-01   0            0            0          0
6   1:     0
6   2:     0            0
6   3:     0            0           0
6   4:     0            0           0            0
6   5:     0            0           0            0            0
6   6:     0            0           0            0            0          0
```



```
    *  Aberration analysis  *    (Larget absolute value)
      :     1st order          |     2nd order          |
      : index     value        | index     value        |   status
-----------------------------------------------------------------------
1 [X]:  16     +9.06e+00       |  144     -2.26e-01      |
2 [T]:  22     -3.37e+01       |  226     +3.08e-01      |
3 [Y]:  33     -3.64e+00       |  346     +1.79e+00      |  attention
4 [F]:  44     -4.12e+00       |  446     +9.82e-01      |
5 [L]:  52     -2.04e+01       |  526     +2.62e-01      |
6 [D]:  66     +1.50e+00       |  000     +0.00e+00      |
```

The Aberration analysis table at the bottom of the window

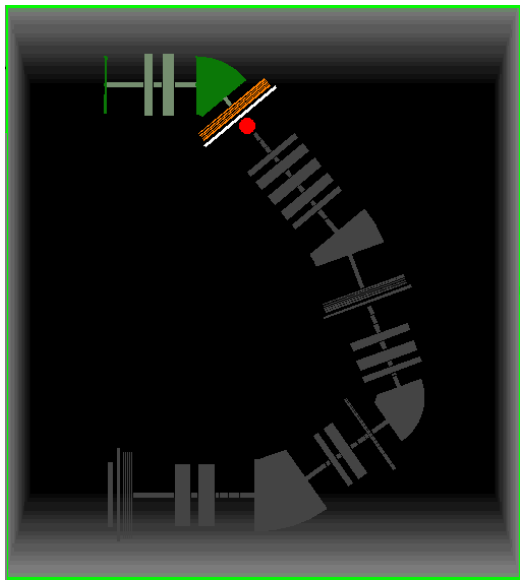
Comparison of absolute largest 1st and 2nd orders aberrations

Status messages

$V_1 < 3\,V_2$	attention
$V_1 < V_2$	Critical
$V_1 < V_2/3$	VERY critical

Run 2nd order optics minimization

The 1st part of DRAGON2000 : Target – Charge Slits



Initial settings

Q1

Magnetic Multipole Settings

	QUADrupole	SEXTupole	
L_eff (effective length) mode: <Keep>	0.2523		m
B (field at pole tip)	-2.1576	0	kG
Radius (half-aperture)	5.3975	5.3975	cm
B & S field values in Fitting			
Use in Fitting process	☑	☐	
Use Bounds constraints	☑	☐	
Lower bound	-5	-100	kG
Upper bound	-1	100	kG

Q2

Magnetic Multipole Settings

	QUADrupole	SEXTupole	
L_eff (effective length) mode: <Keep>	0.33385		m
B (field at pole tip)	1.96503	0.106	kG
Radius (half-aperture)	7.9375	7.9375	cm
B & S field values in Fitting			
Use in Fitting process	☑	☑	
Use Bounds constraints	☑	☑	
Lower bound	1	-1	kG
Upper bound	5	1	kG

Beam vector used for Optical Optimization

"Opt.Beam"

1. X	2	mm
2. T	20	mrad
3. Y	2	mm
4. P	20	mrad
5. L	0	mm
6. D	2	%

(•) mm ( ) cm

Ok

Cancel

Aberration list @ Charge Slits

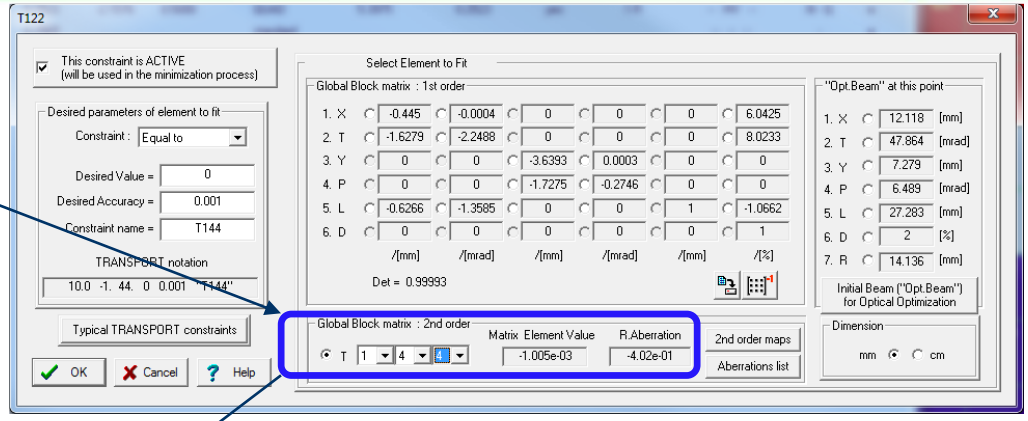
Block: "Fit YP" Aberrations (Elements normalized on Phase Space)

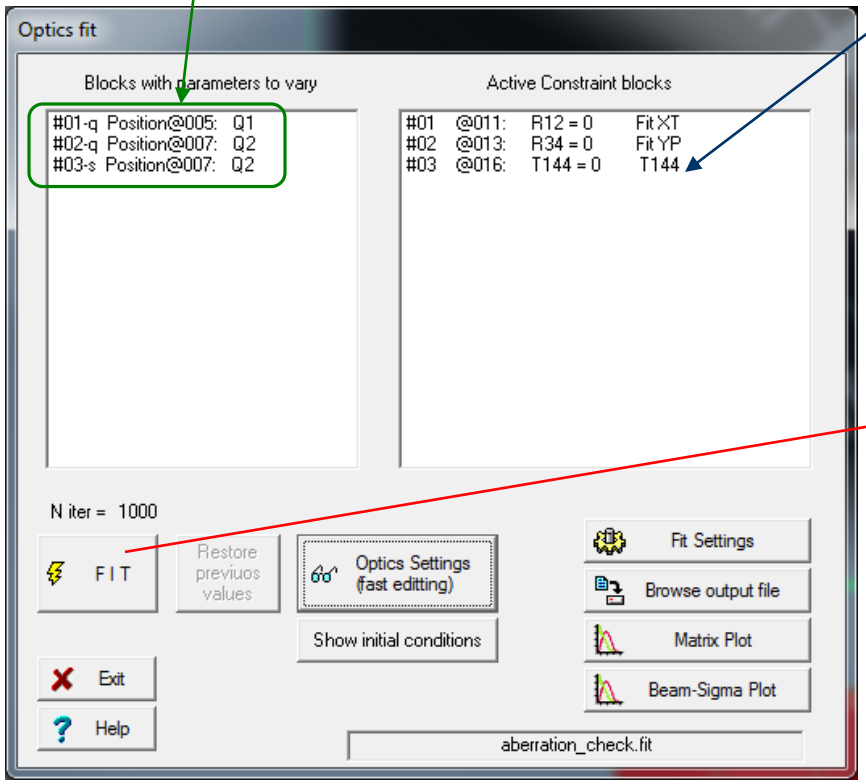
```
Block: "Fit YP"     Aberrations (Elements normalized on Phase Space)
                  1st order : (a/b)*beam(b); 2nd order: (a/b/c)*beam(b)*beam(c)

                                                                transport format [mm-mrad]

                          * TRANSFORM 1 *

1 [X]:    -8.9000e-01  -1.0000e-02   0            0            0            +1.2085e+01
2 [T]:    -3.2558e+00  -4.4978e+01   0            0            0            +1.6047e+01
3 [Y]:     0            0           -7.2784e+00  +4.0000e-03   0            0
4 [F]:     0            0           -3.4548e+00  -5.4940e+00   0            0
5 [L]:    -1.2532e+00  -2.7170e+01   0            0            0            -2.1324e+00
6 [D]:     0            0           0            0            0            +2.0000e+00

-------------------------------------------------------------------------------------------

                          * TRANSFORM 2 *

1   1:    -5.8101e-03
1   2:    -3.2928e-02  -8.9324e-05
1   3:     0            0           +6.0714e-03
1   4:     0            0           +1.2939e-02  -4.0210e-01
1   5:     0            0           0            0            0
1   6:    +5.6559e-02  +2.3549e-02   0            0            0            -2.1994e-01
-------------------------------------------------------------------------------------------
2   1:    -7.5022e-04
2   2:    -8.0057e-03  -1.7388e-01
2   3:     0            0           -1.6769e-04
2   4:     0            0           -5.0458e-03  -1.7819e-01
2   5:     0            0           0            0            0
2   6:    +6.7822e-02  +5.4786e-01   0            0            0            -3.3401e-01
-------------------------------------------------------------------------------------------
3   1:     0
3   2:     0            0
3   3:    +1.7870e-02  +3.5159e-02   0
3   4:    +9.7387e-02  +4.3065e-01   0            0
3   5:     0            0           0            0            0
3   6:     0            0           +1.6097e-01  +3.1863e+00   0            0
-------------------------------------------------------------------------------------------
4   1:     0
4   2:     0            0
4   3:    +6.1427e-03  +1.0628e-02   0
4   4:    -5.2666e-03  +7.9210e-02   0            0
4   5:     0            0           0            0            0
4   6:     0            0           +9.0040e-02  +1.7458e+00   0            0
-------------------------------------------------------------------------------------------

        *  Aberration analysis  *     (Absolute largest value)

        :     1st order          |     2nd order          |
        : index     value        | index     value        |   status
-------------------------------------------------------------------------------
1 [X]:   16      +1.21e+01       |  144     -4.02e-01      |
2 [T]:   22      -4.50e+01       |  226     +3.46e-01      |
3 [Y]:   33      -7.28e+00       |  346     +3.19e+00      |   attention
4 [F]:   44      -5.49e+00       |  446     +1.75e+00      |
5 [L]:   52      -2.72e+01       |  526     +4.66e-01      |
6 [D]:   66      +2.00e+00       |  000     +0.00e+00      |
```

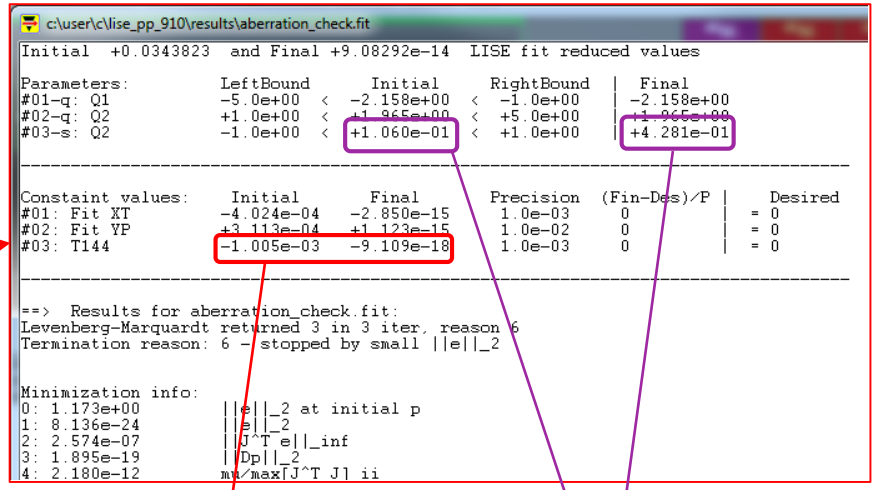
Let's try to neglect the element T144 in the optimization using Q1 & Q2 multipoles!

Run 2nd order optics minimization

Let's try to neglect the element T144 in the optimization using Q1 & Q2 multipoles!







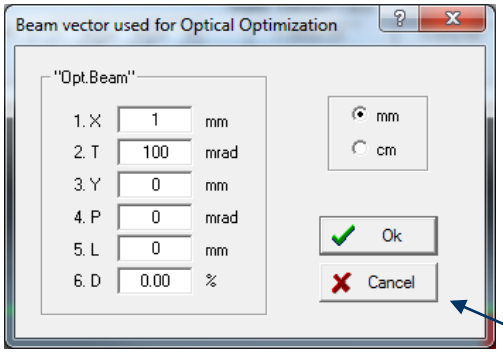
During the optimization the T144 element has been changed from 1.00e-3 to -9.1e-18

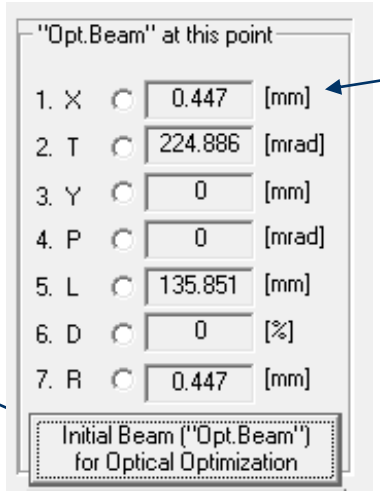
Sextupole field Q2-s has been changed from 0.106 kG to 0.428 kG

Quadrupole fields Q1-q & Q2-q have not been changed

High order truncation problem

Let's create the Beam vector for optimization with large X' component





First order X-sigma is small @ Charge Slits

Block: "T144" Aberrations (Elements r
1st order : (a/b)*bear

* TRANSFORM 1 *

1 [X]:	-4.4500e-01	-4.0000e-02	0
2 [T]:	-1.6279e+00	-2.2488e+02	0
3 [Y]:	0	0	0
4 [F]:	0	0	0
5 [L]:	-6.2660e-01	-1.3585e+02	0
6 [D]:	0	0	0

* TRANSFORM 2 *

1	1:	-1.4525e-03		
1	2:	-8.2320e-02	-2.2331e-03	
1	3:	0	0	0
1	4:	0	0	0
1	5:	0	0	0
1	6:	0	0	0
2	1:	-1.8755e-04		
2	2:	-2.0014e-02	-4.3470e+00	
2	3:	0	0	0
2	4:	0	0	0
2	5:	0	0	0
2	6:	0	0	0

Aberration list @ Charge Slits

* Aberration analysis * (Absolute largest value)

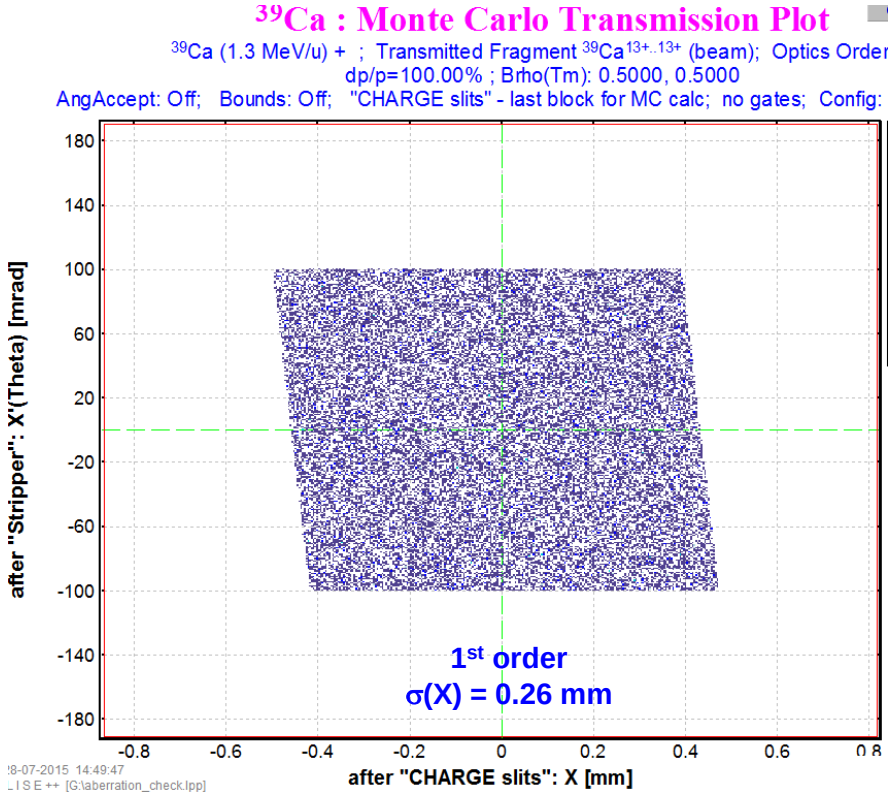
	1st order index	1st order value	2nd order index	2nd order value	status
1 [X]:	11	-4.45e-01	112	-8.23e-02	
2 [T]:	22	-2.25e+02	222	-4.35e+00	
3 [Y]:	00	+0.00e+00	000	+0.00e+00	
4 [F]:	00	+0.00e+00	000	+0.00e+00	
5 [L]:	52	-1.36e+02	522	+1.64e+00	
6 [D]:	00	+0.00e+00	000	+0.00e+00	

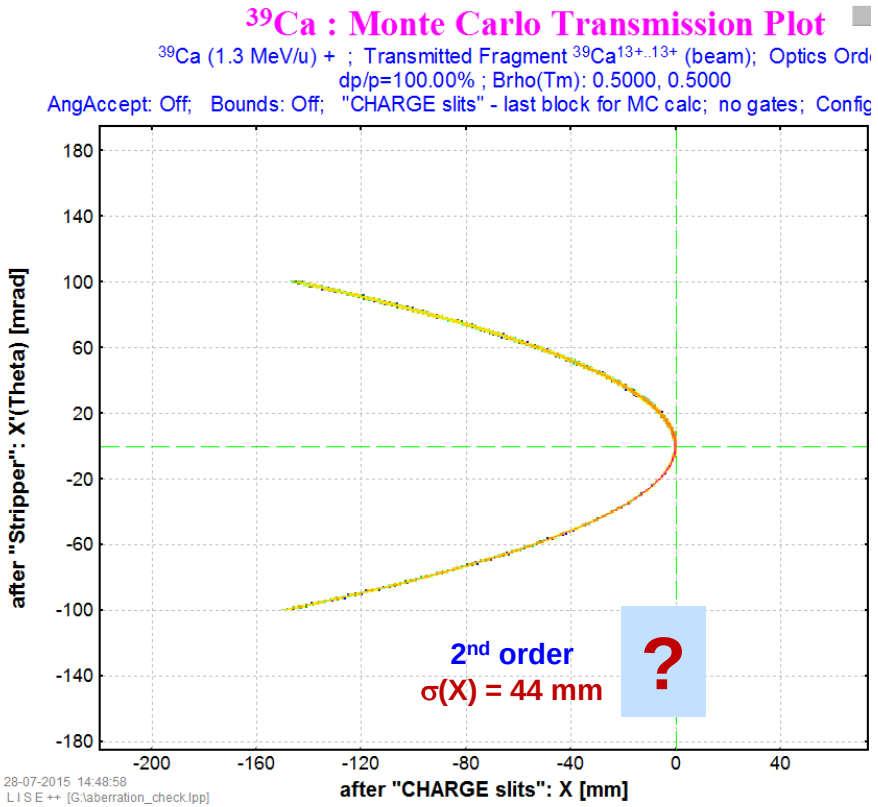
No large aberrations with using GLOBAL matrices!

High order truncation problem

But Let's run Monte Carlo calculation
the similar beam emittance

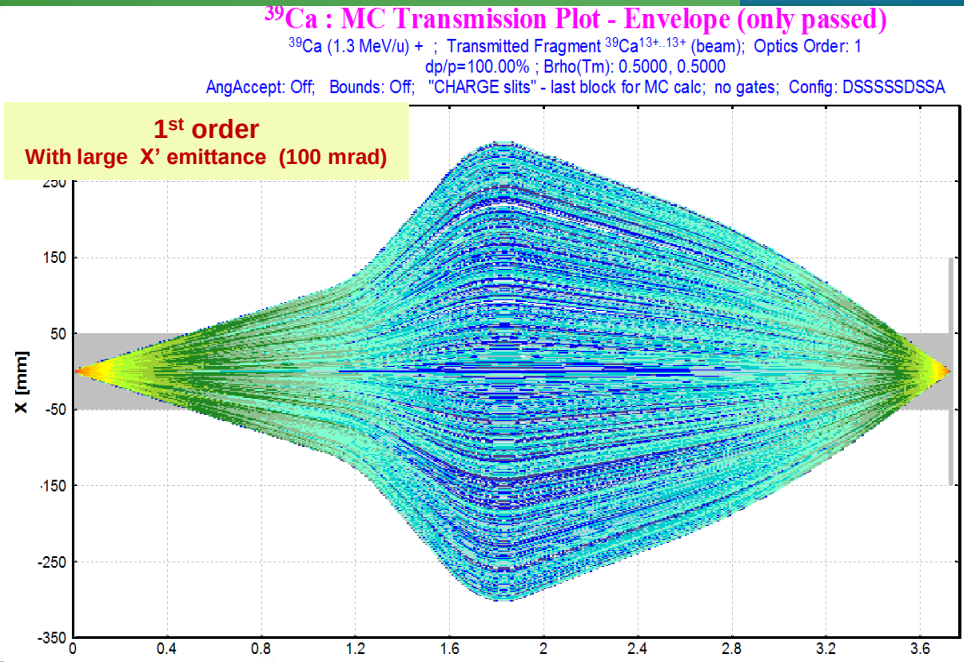
1. X	mm	1	Rectangle uniform
2. T	mrad	100	Rectangle uniform
3. Y	mm	0	Rectangle uniform
4. P	mrad	0	Rectangle uniform
5. L	mm	0	Gaussian
6. D	%	0	Rectangle uniform

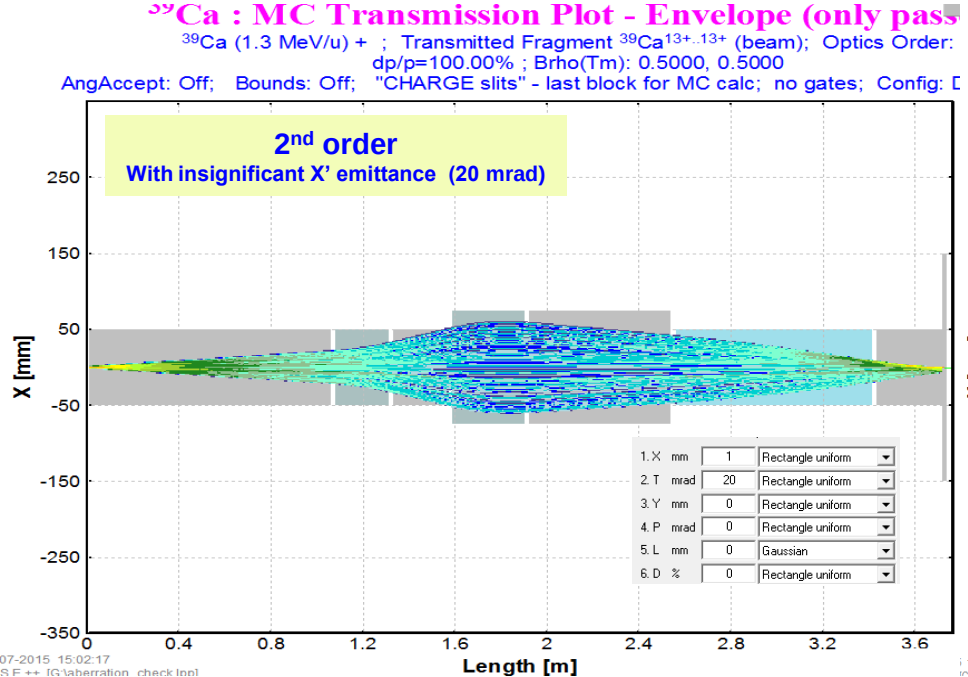


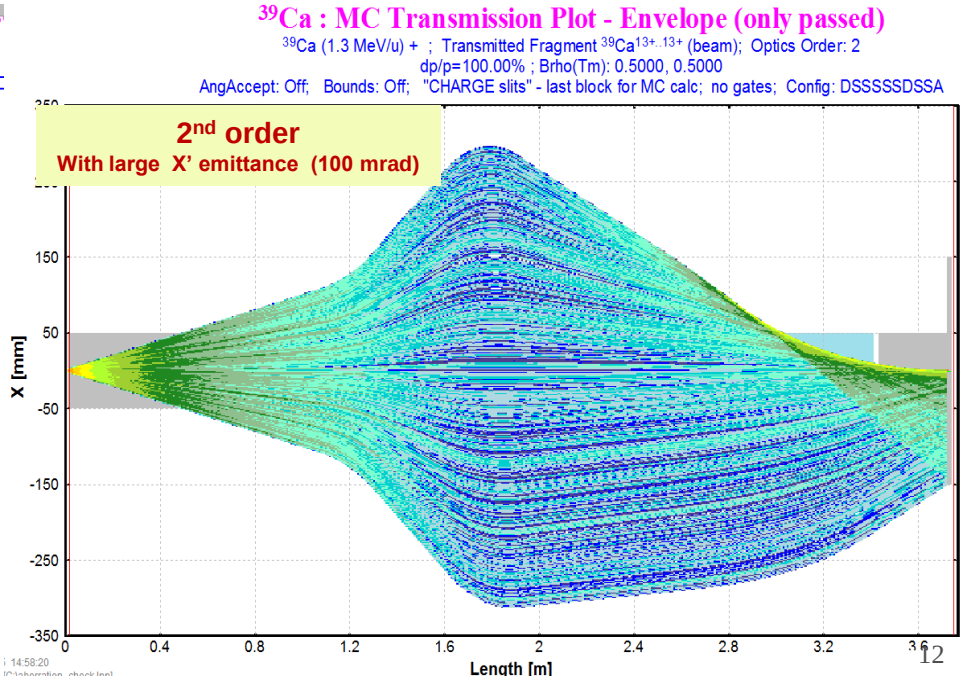


High order truncation problem

- We did not observe large values in the Aberration list calculated with the Global matrices
- Large aberrations have been observed in Monte Carlo calculations where local 2nd order matrices are used
- It is happen due to truncation of high order values with matrices multiplication
- Recommendation: not to use large Beam sigma values for optimization. 2nd order optic optimization operates with small emittances
- For large emittance the LISE++ optimization should be updated to work with Monte Carlo results.



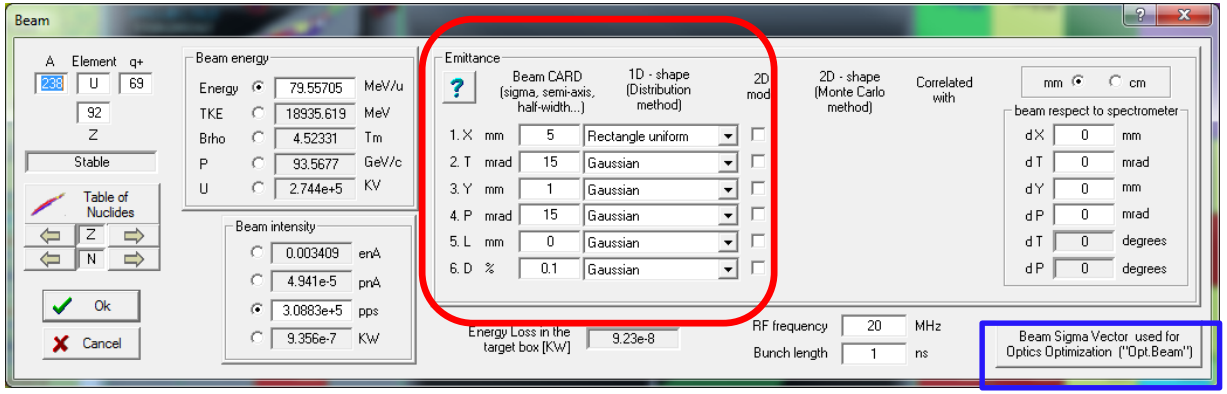




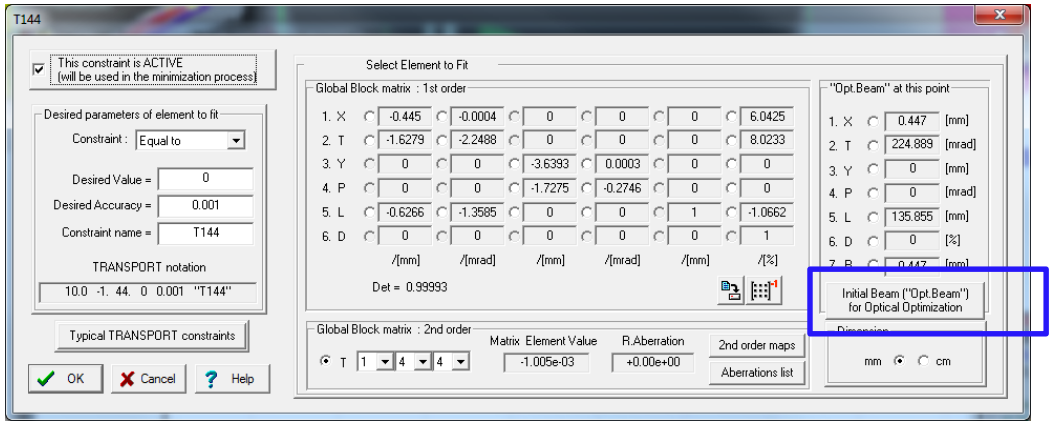
“OptBeam” : New Beam sigma vector used only in the Optics Optimization

“Main” Beam emittance is used for transmission calculations in both (“Distribution” and MC) modes, for matrices in Optical Block dialogs and so on.

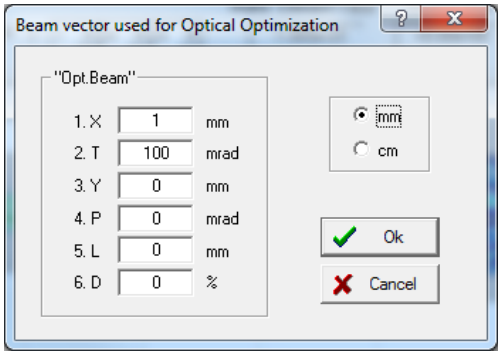
“Beam” dialog



“Fit constraint” dialog



New Beam sigma vector (“OptBeam”) used only for optics optimization in the Fit Constraint block dialog and the Optics Fit dialog.
Access to the dialog to this bema vector modification can be done through the Beam or Fit Constraint block dialogs



This new beam vector for optimization has been created to avoid additional beam emittance editing due to switching between fragment transmission calculations and the optimization mode, which done for the primary beam