Angular Straggling Contribution to Optics

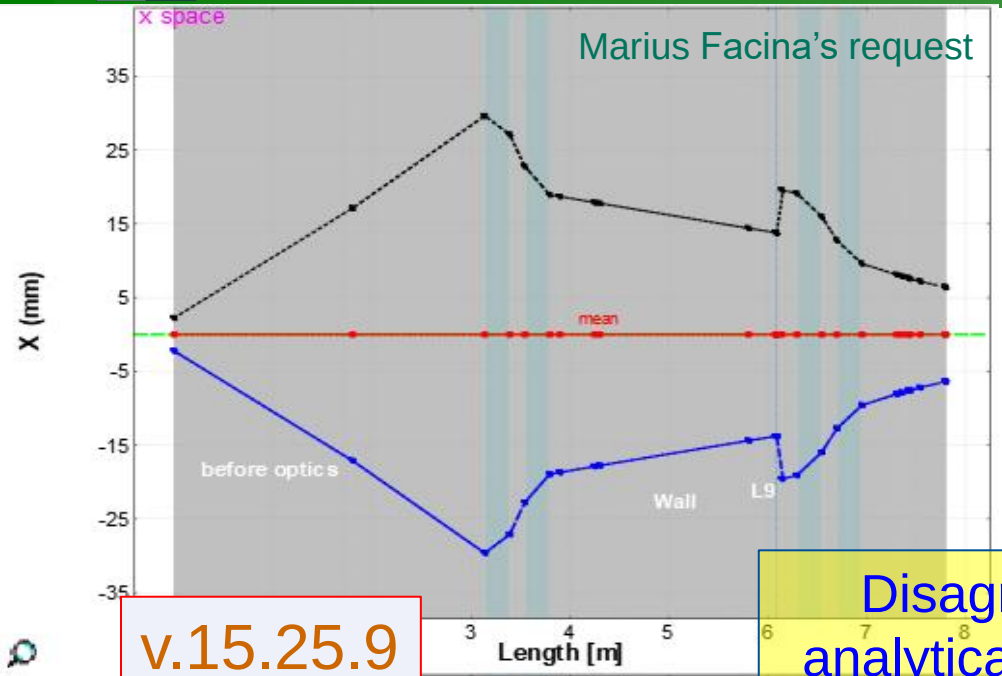
LISE++ *cute*

v.15.26.1

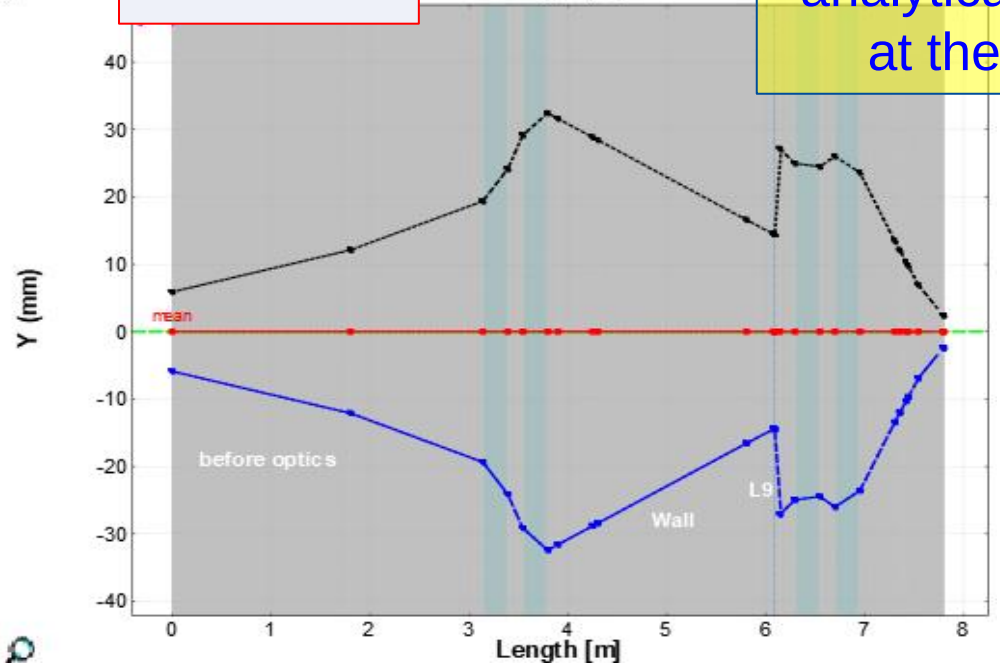
10/30/21

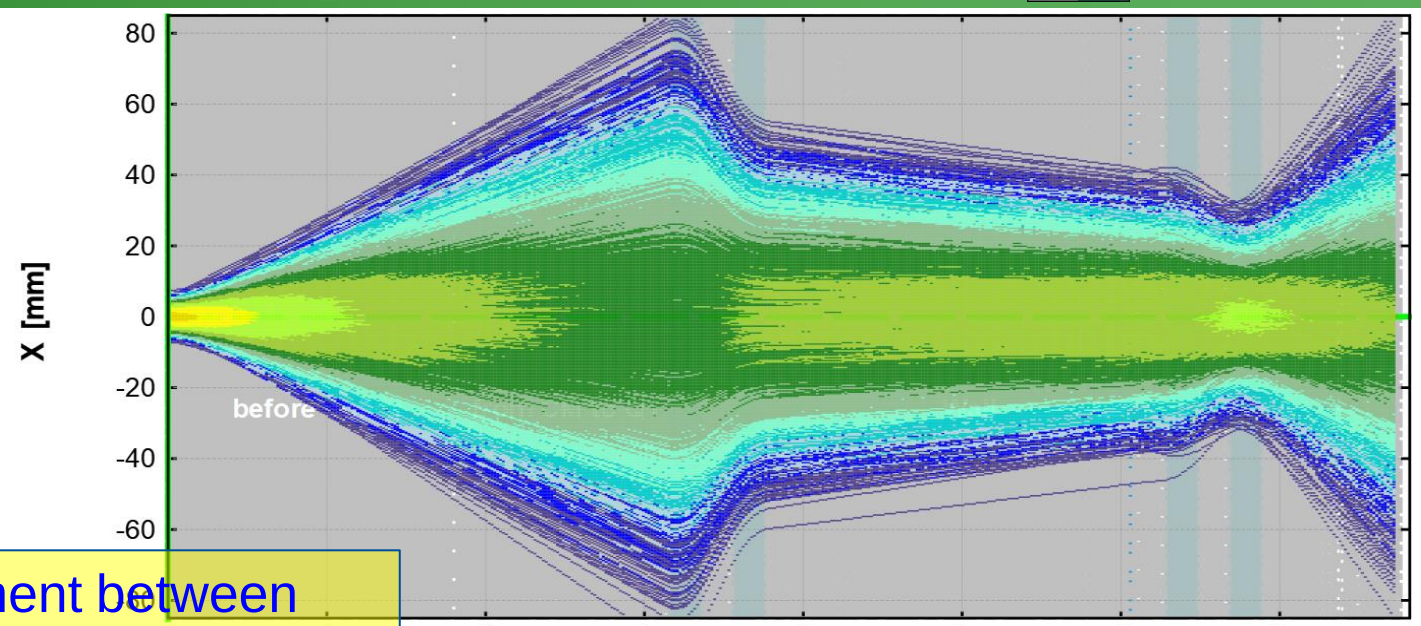
- User's request (disagreement in analytical and MC results)
- Reason of the disagreement (problem)
- Solution of the problem
- v.15.26.1 results
- Angular envelopes comparison
- Matrix envelope and Angular straggling contribution
- Visualization of Angular straggling contribution values in matrices
- How strong is the impact of angular straggling contribution at higher energy?

Reason of User's Request

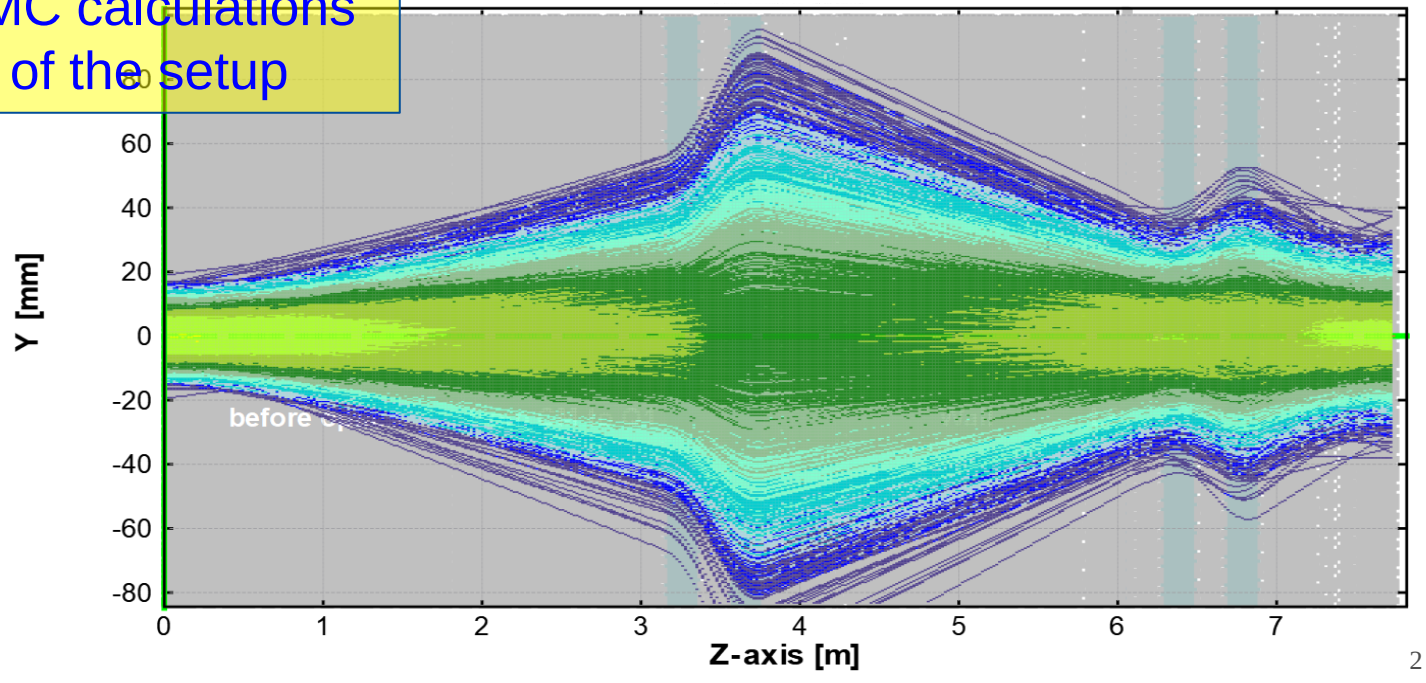


v.15.25.9





Disagreement between analytical & MC calculations at the end of the setup



Reason of the disagreement (problem)

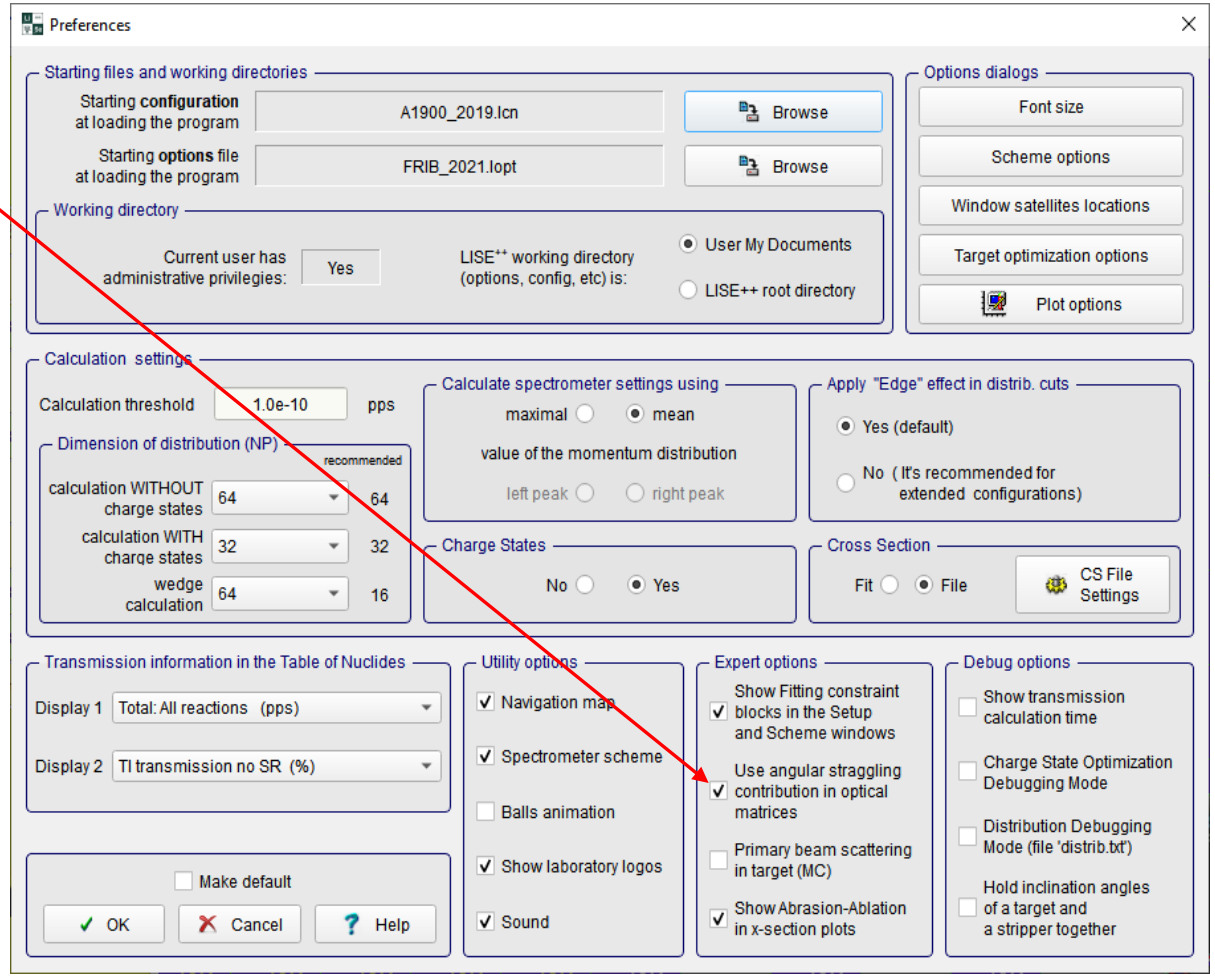
- The code did not use properly the angular straggling contribution in ion optics in the case of transmission analytical solution

- LISE was taken into account the angular straggling contribution as product ($T_n = T_c \cdot F$) of the current beam angle emittance (T_c) and the factor F,
  where $F = \text{Width}((T_c \cdot M) \otimes S) / \text{Width}(T_c \cdot M)$,
  where M is the global Angular magnification from target to this block, S is normal distribution, which sigma corresponds to the plane angular straggling value

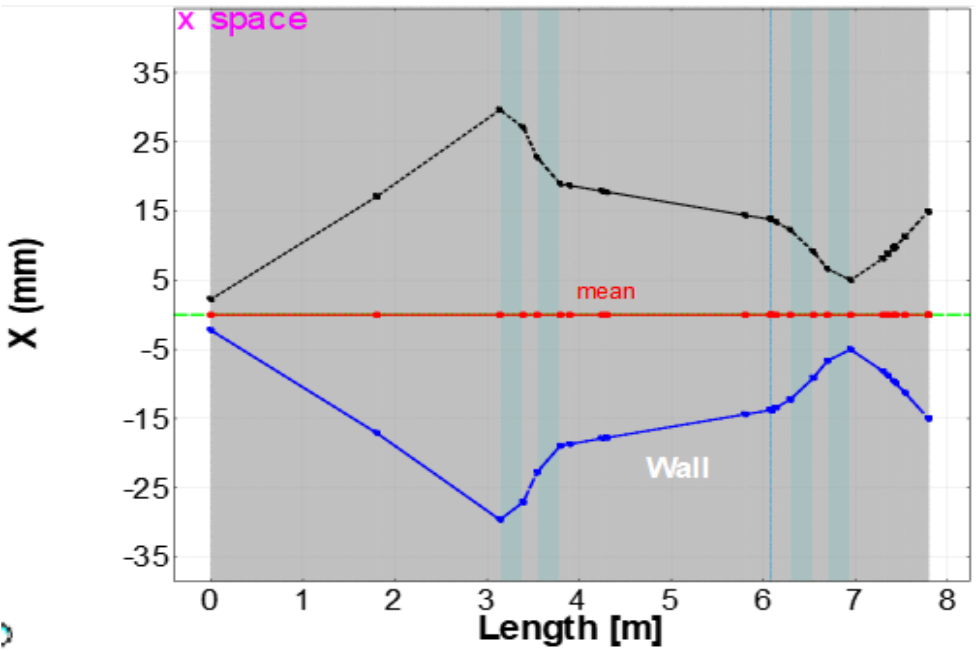
- This disagreement could be observed due to simultaneous coincidence of several factors:
  - Light Z beam
  - Low energy beam
  - No target
  - Narrow initial angular emittance
  - Heavy Z material in line
  - Material location in non-focal plane

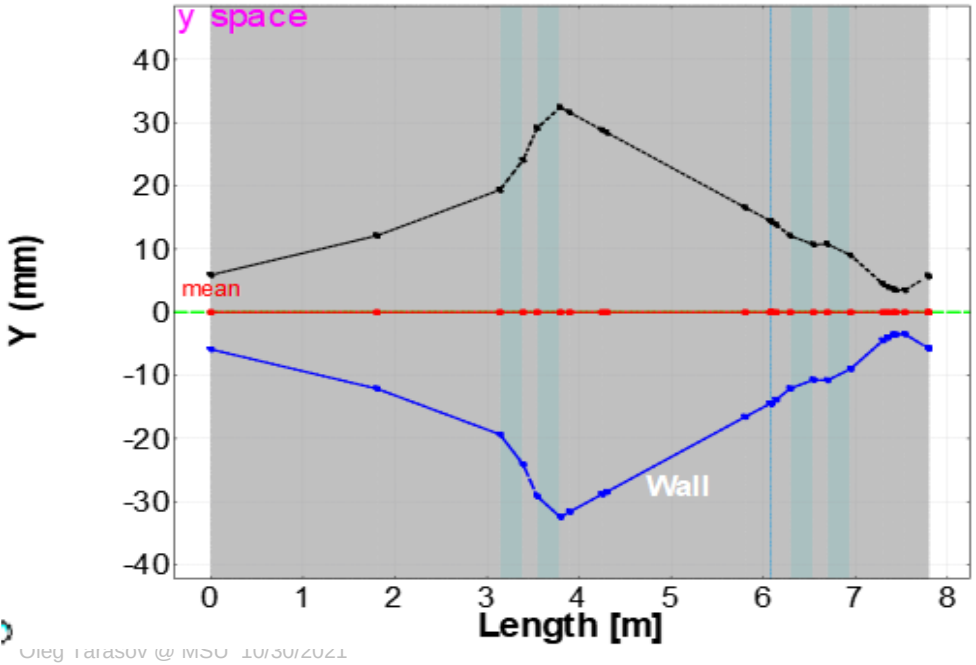
Solution of the problem

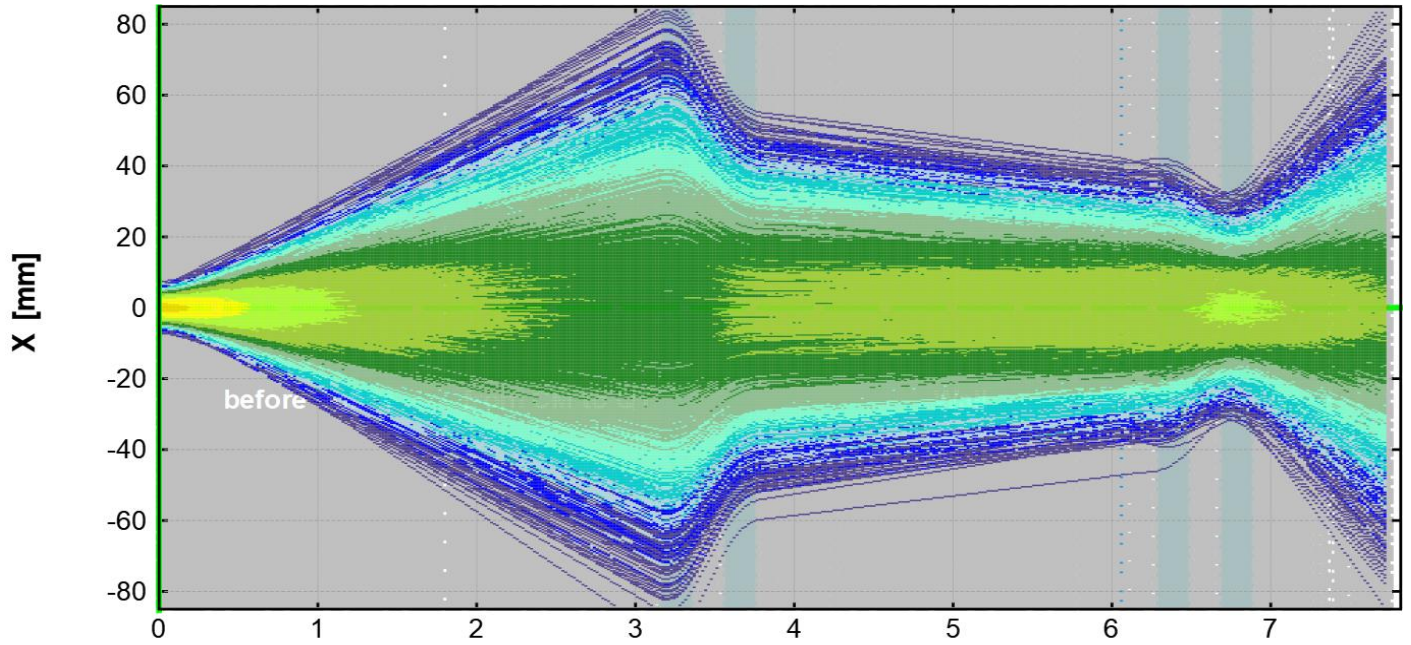
- The Compound block (material, wedge) has got the optical matrix feature in the new version
- If the corresponding option has been set in the Preference dialog, LISE calculates the factor F as ratio
  F = Width(A ⊗ S) / Width(A),
  where A is the current angular distribution in front of this material, and S is normal distribution, which sigma corresponds to the plane angular straggling value
- Then it is assumed F is angular magnification in the corresponding plane and being set to the local optical matrix (θ/θ, φ/φ)
- LISE recalculates global optical matrices starting this block
- All material matrices are set again be unitary after completion of ion transmission calculation
- The Last calculated material matrix angular magnification values are kept at material block area to retrieve in order to plot the matrix envelope or to show matrices in a window

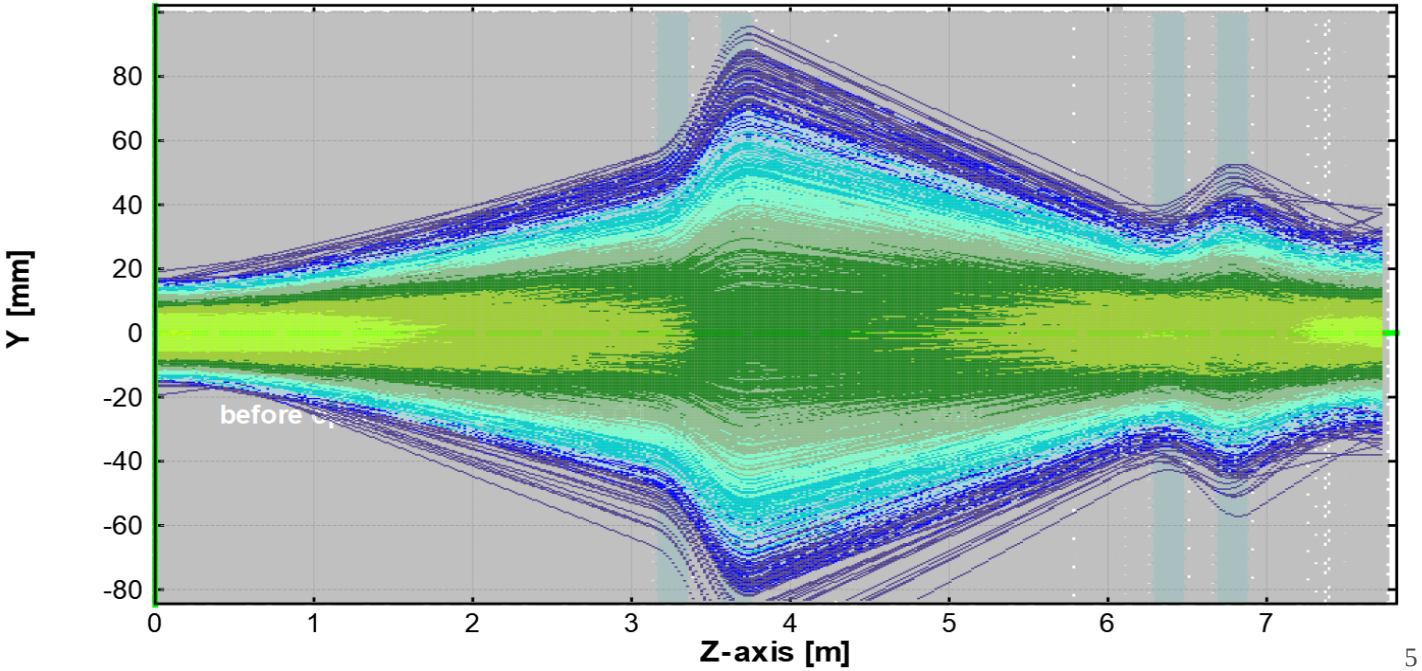


v.15.26.1 results

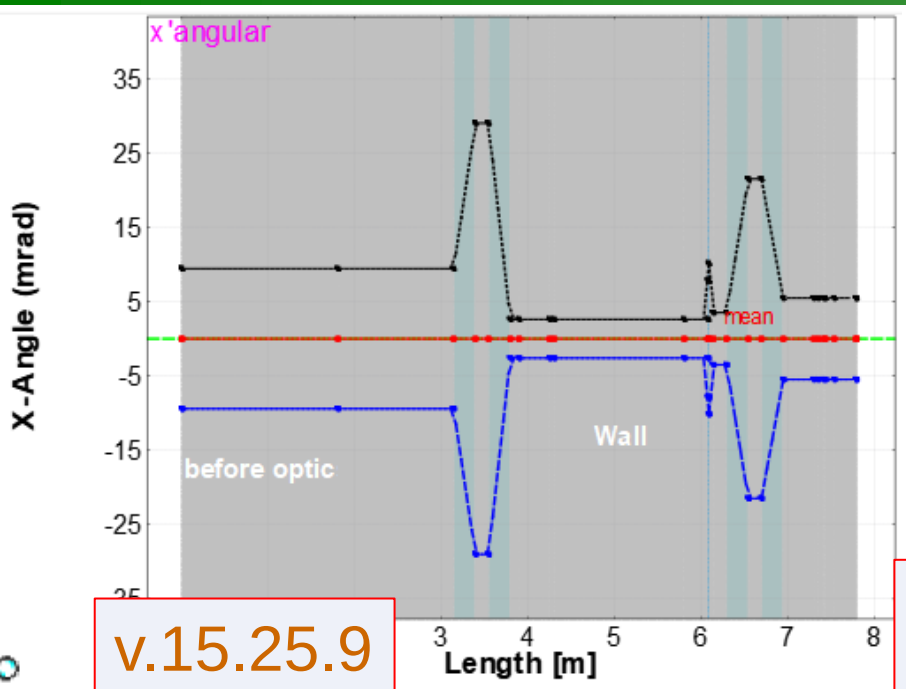




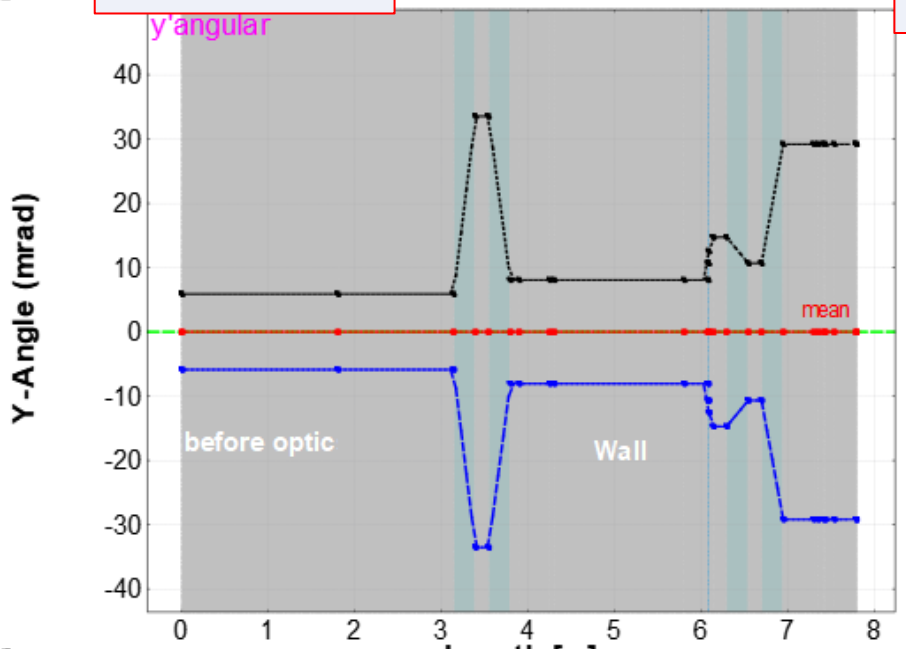


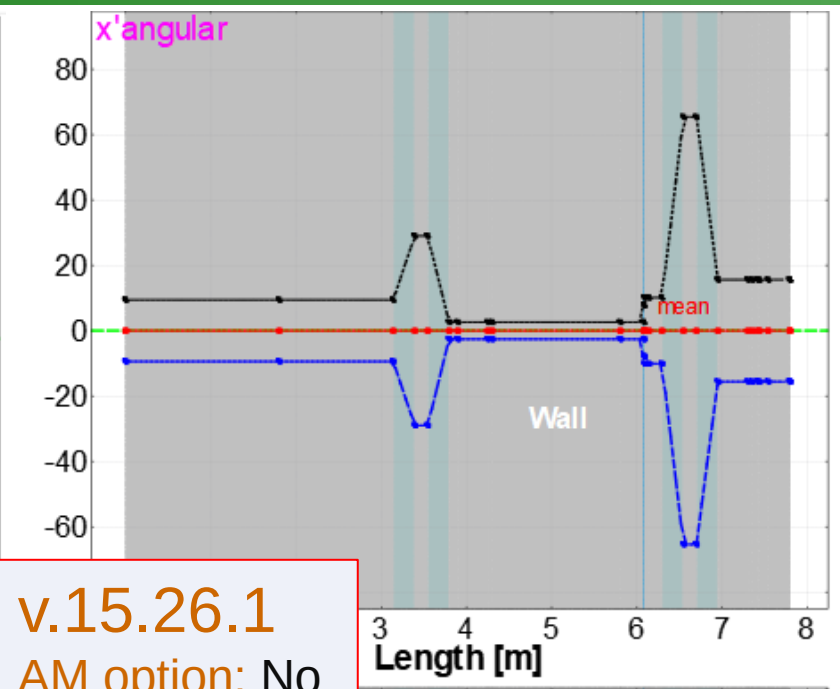


Angular envelopes comparison

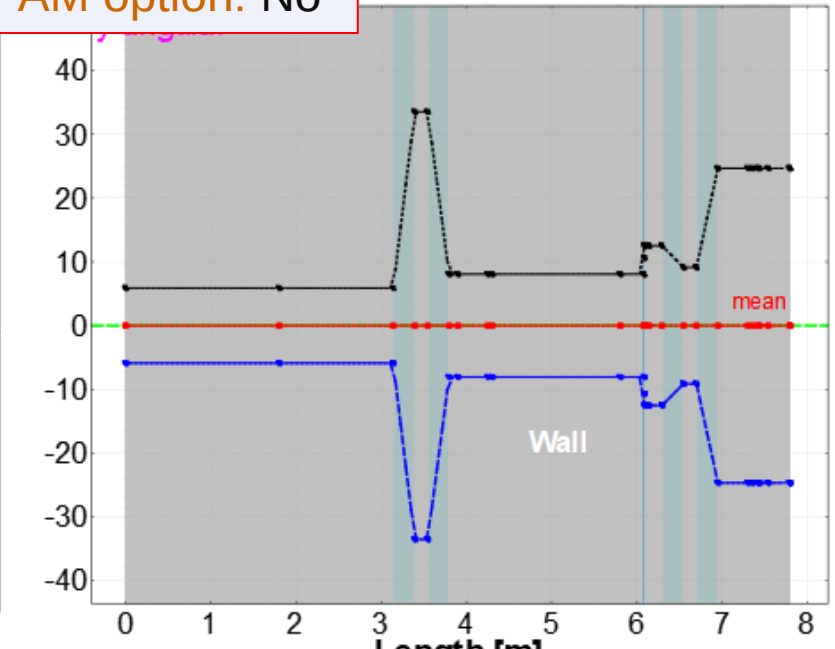


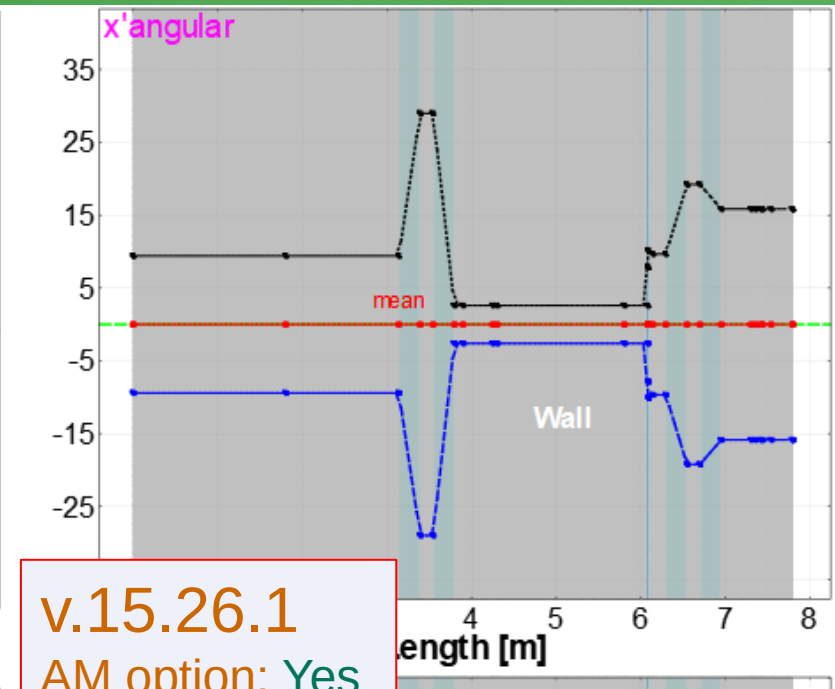
v.15.25.9



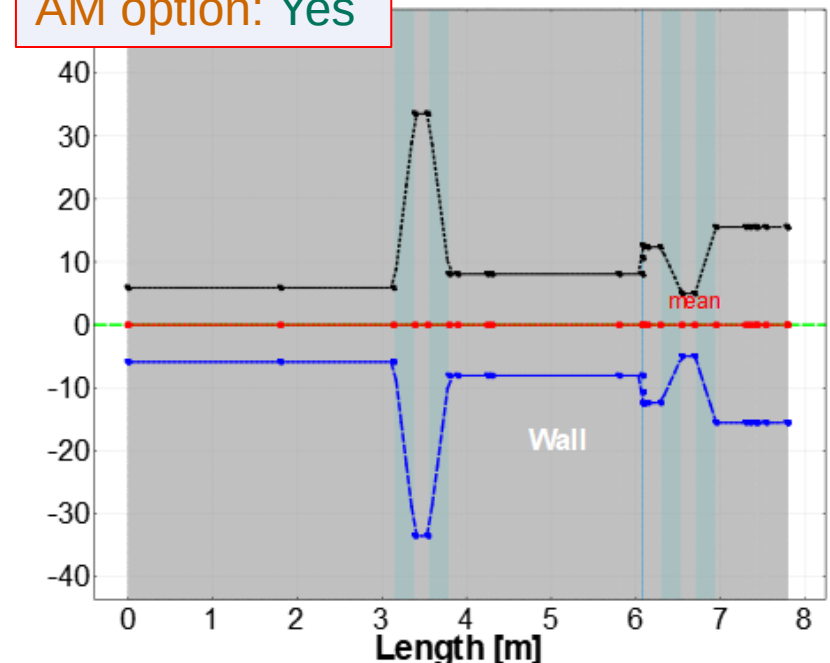


v.15.26.1
AM option: No

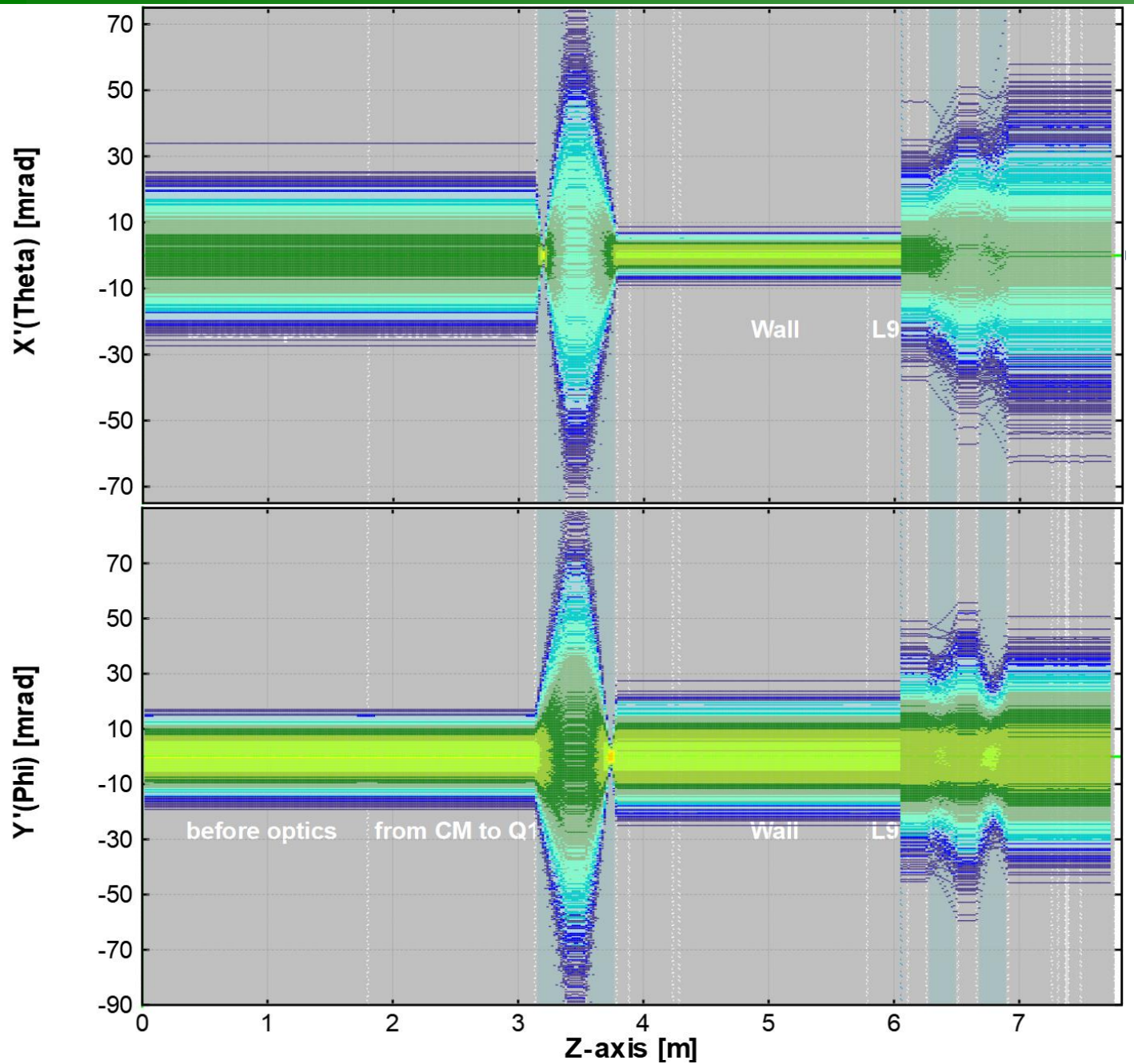


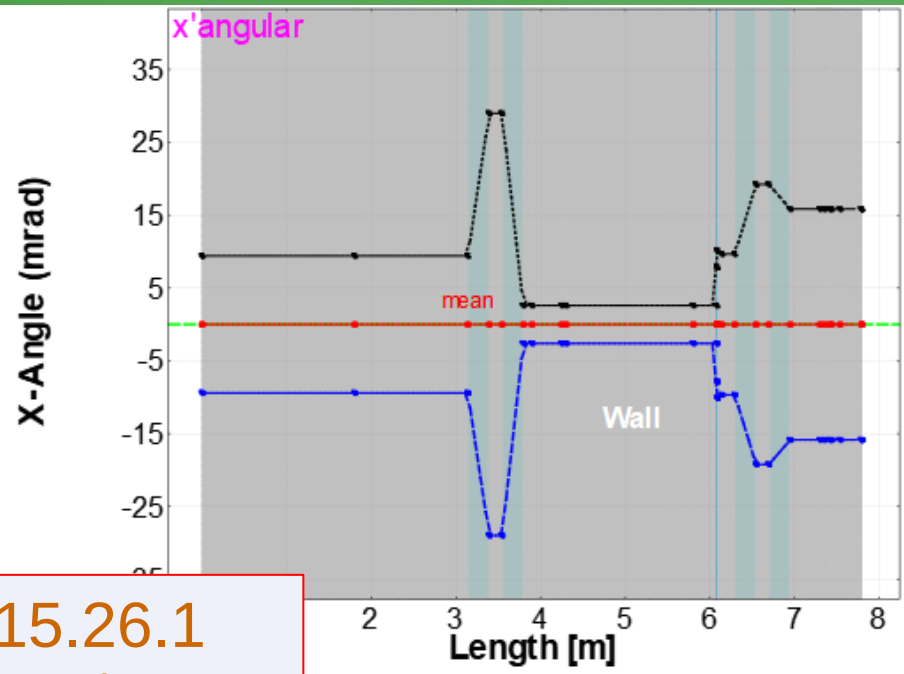


v.15.26.1
AM option: Yes

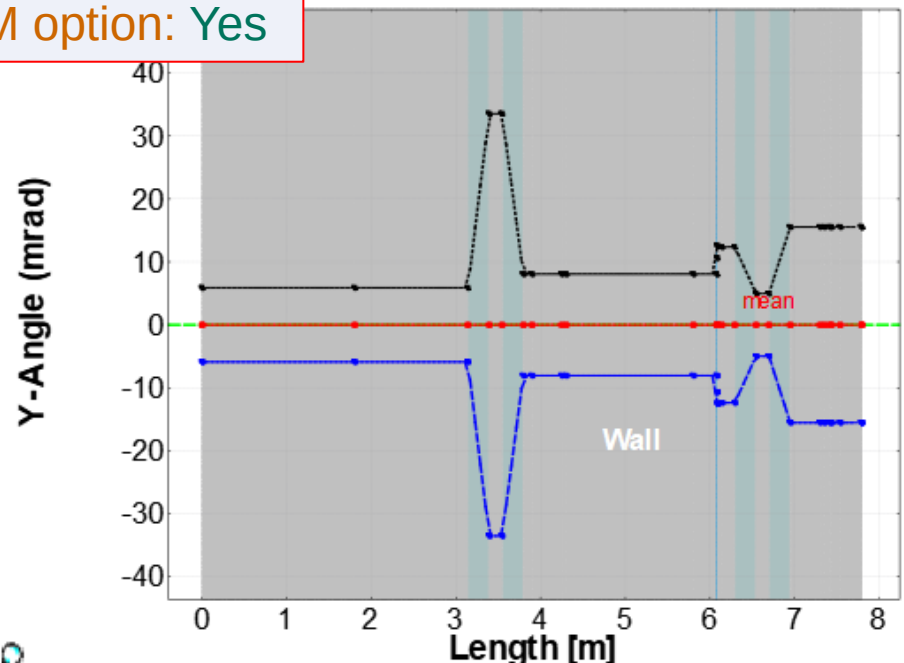


Angular envelopes comparison

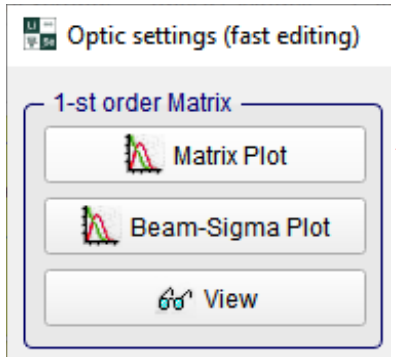


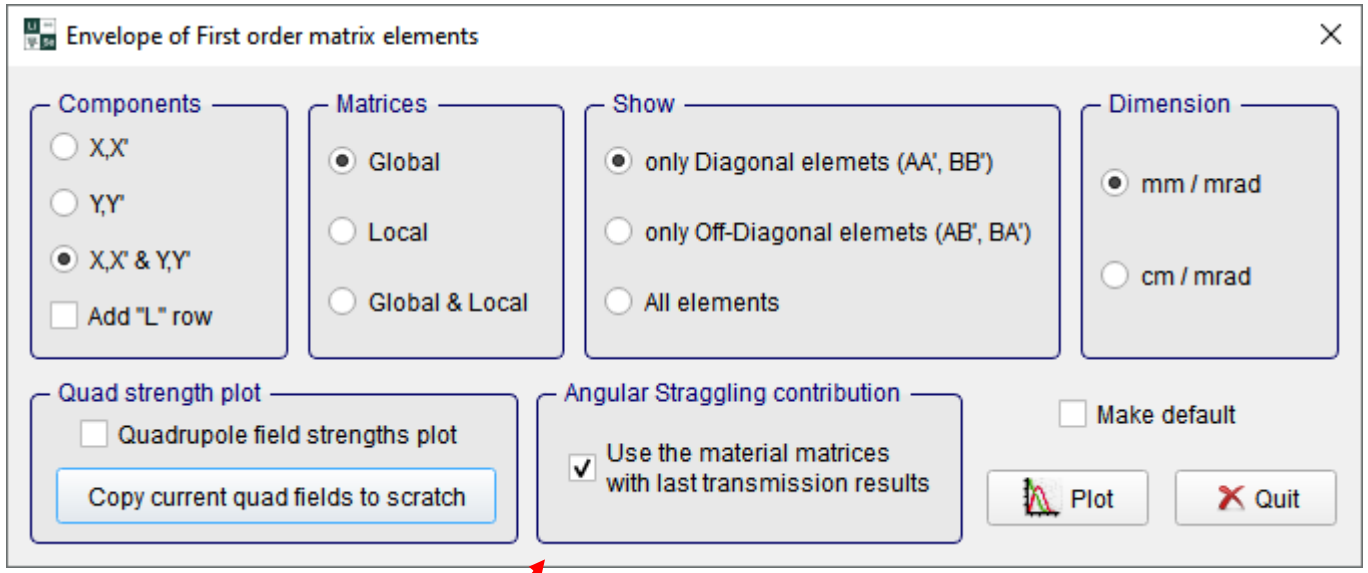


v.15.26.1
AM option: Yes

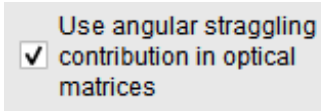


Matrix envelope and Angular straggling contribution





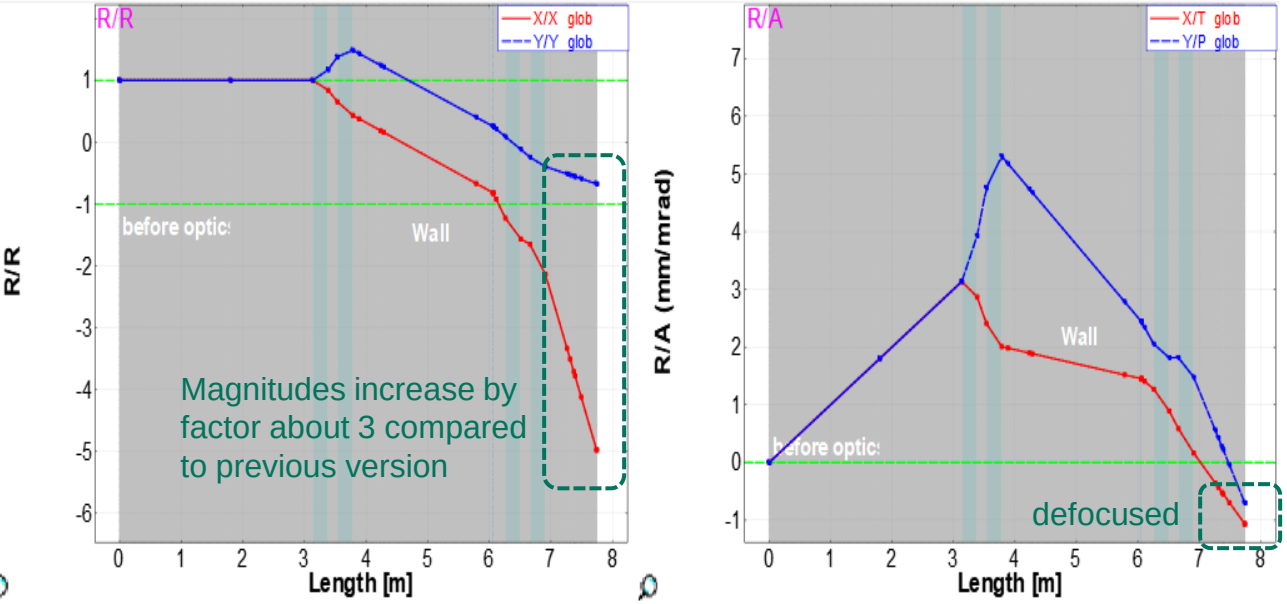
The Angular Straggling contribution frame is visible

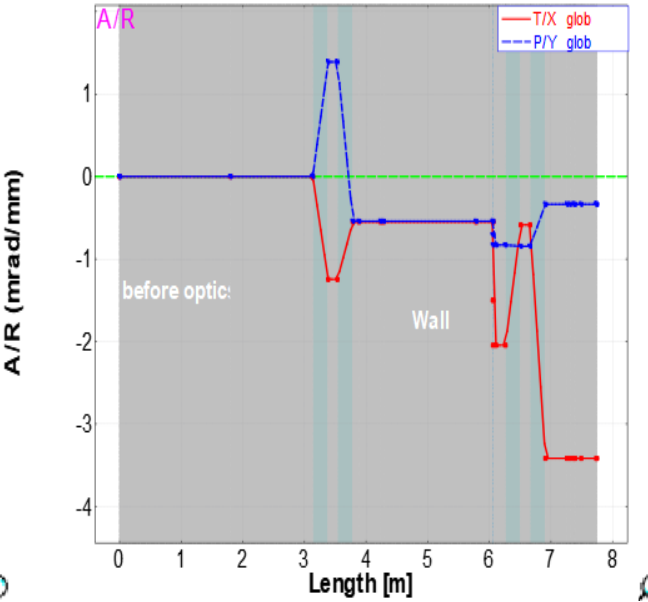
if  set in the Preference dialog

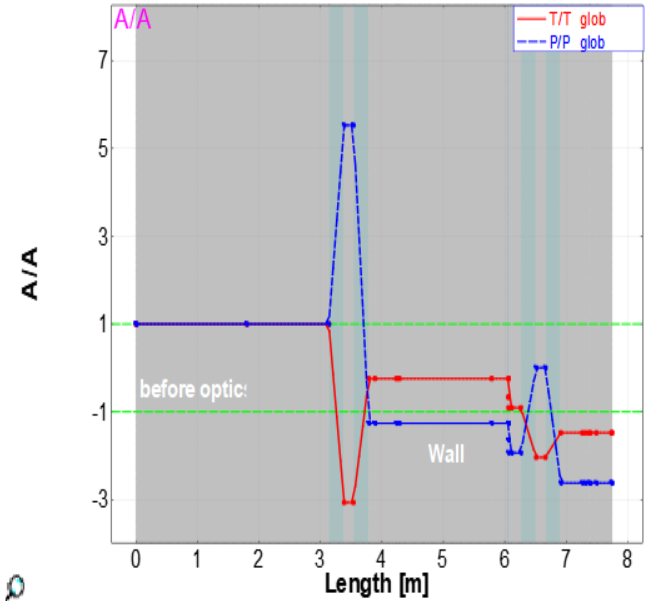
Matrix envelope and Angular straggling contribution

YES

With angular straggling contribution in matrices

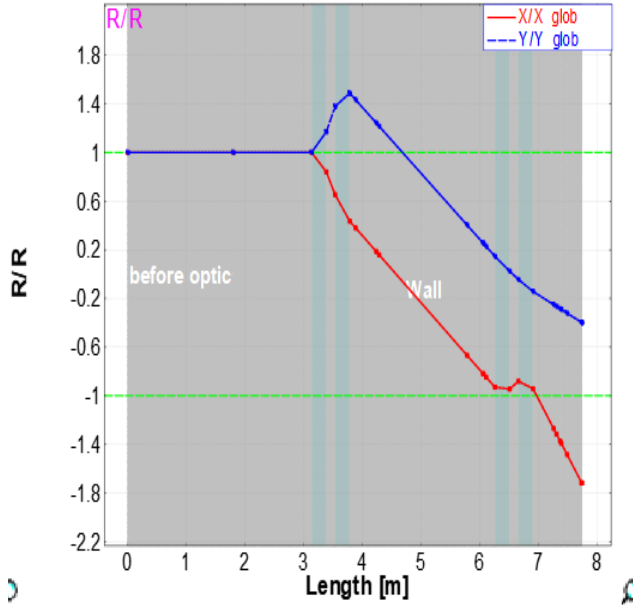


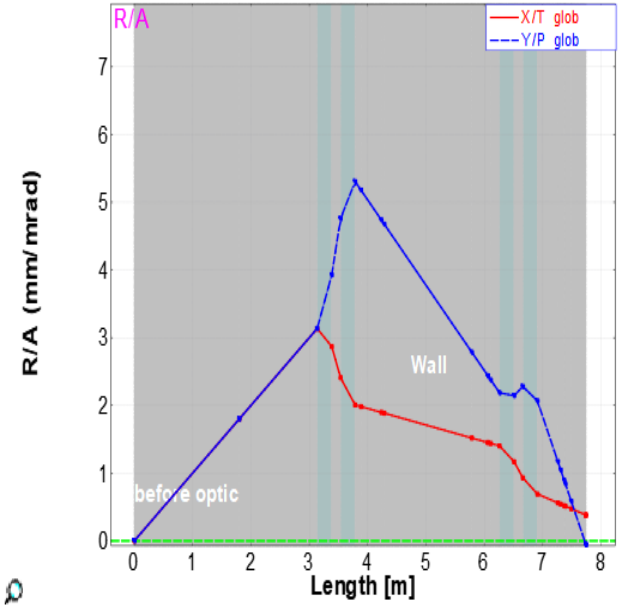


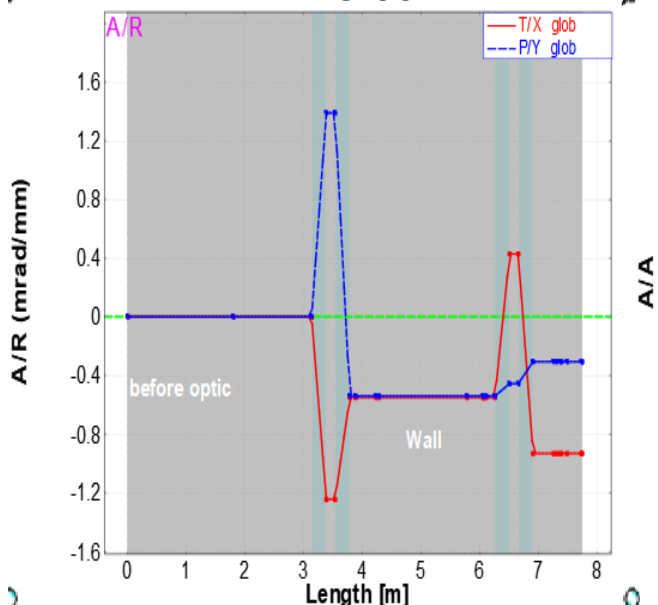


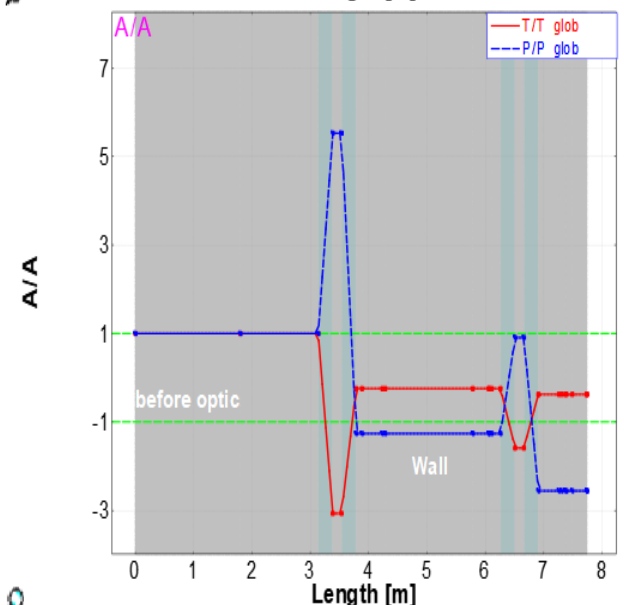
NO

Without angular straggling contribution in matrices

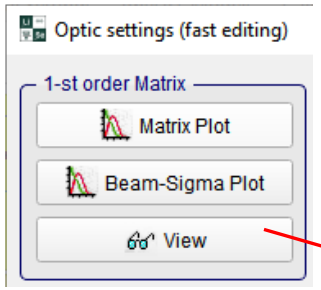




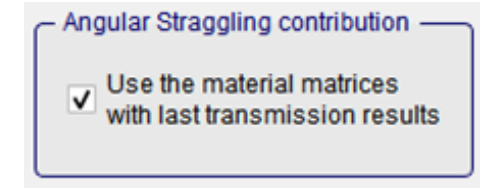




Visualization of Angular straggling contribution values in matrices



Should be set in the “Matrix plot” dialog



YES

With angular straggling contribution in matrices

```
11.  Block "L9": Drift,  Start: 5.785 m,  Length : 0.275 m
        #standard
  +1.000e+00  +2.750e-02   0           0          0    0        |  -8.191e-01  +1.452e-01   0           0          0    0        |  +1.172e+00
   0          +1.000e+00   0           0          0    0        |  -5.510e+00  -2.443e-01   0           0          0    0        |  +2.217e+00
   0           0          +1.000e+00  +2.750e-02  0    0        |   0           0          +2.545e-01  +2.439e-01  0    0        |  +1.226e+00
   0           0           0          +1.000e+00  0    0        |   0           0          -5.416e+00  -1.260e+00  0    0        |  +6.859e+00
   0           0           0           0          1.0  0        |   0           0           0           0          1.0  0        |   0
-------------------------------------------------------------------------------------------------------------------------------------------
12.  Block "fake slit": Drift,  Start: 6.060 m,  Length : 0.000 m  --- SLITS ---
-------------------------------------------------------------------------------------------------------------------------------------------
13.  Block "Havar 10 um": Material,  Start: 6.060 m,  Length : 0.000 m
       :  Co42Cr20Ni13Fe19W (10 micron)
  +1.000e+00   0           0           0          0    0        |  -8.191e-01  +1.452e-01   0           0          0    0        |  +1.172e+00
   0          +2.721e+00   0           0          0    0        |  -1.499e+01  -6.647e-01   0           0          0    0        |  +6.032e+00
   0           0          +1.000e+00   0          0    0        |   0           0          +2.545e-01  +2.439e-01  0    0        |  +1.226e+00
   0           0           0          +1.301e+00  0    0        |   0           0          -7.046e+00  -1.640e+00  0    0        |  +8.924e+00
   0           0           0           0          1.0  0        |   0           0           0           0          1.0  0        |   0
-------------------------------------------------------------------------------------------------------------------------------------------
14.  Block "Helium 1 atm": Material,  Start: 6.060 m,  Length : 0.000 m
       :  He (10 mm)
  +1.000e+00   0           0           0          0    0        |  -8.191e-01  +1.452e-01   0           0          0    0        |  +1.172e+00
   0          +1.000e+00   0           0          0    0        |  -1.499e+01  -6.647e-01   0           0          0    0        |  +6.032e+00
   0           0          +1.000e+00   0          0    0        |   0           0          +2.545e-01  +2.439e-01  0    0        |  +1.226e+00
   0           0           0          +1.000e+00  0    0        |   0           0          -7.046e+00  -1.640e+00  0    0        |  +8.924e+00
   0           0           0           0          1.0  0        |   0           0           0           0          1.0  0        |   0
-------------------------------------------------------------------------------------------------------------------------------------------
15.  Block "Havar 10 um": Material,  Start: 6.060 m,  Length : 0.000 m
       :  Co42Cr20Ni13Fe19W (10 micron)
  +1.000e+00   0           0           0          0    0        |  -8.191e-01  +1.452e-01   0           0          0    0        |  +1.172e+00
   0          +1.364e+00   0           0          0    0        |  -2.045e+01  -9.066e-01   0           0          0    0        |  +8.229e+00
   0           0          +1.000e+00   0          0    0        |   0           0          +2.545e-01  +2.439e-01  0    0        |  +1.226e+00
   0           0           0          +1.179e+00  0    0        |   0           0          -8.309e+00  -1.934e+00  0    0        |  +1.052e+01
   0           0           0           0          1.0  0        |   0           0           0           0          1.0  0        |   0
-------------------------------------------------------------------------------------------------------------------------------------------
```

compare

compare

θ/θ product is about 4!

To optimize ion optics with taken into account the angular straggling contribution, the user should manually create a matrix after materials

How strong is the impact of angular straggling contribution at higher energy?

for example: ^{82}Se (250 MeV/u) → ^{60}Ca, Preseparator wedge is Al 3mm^{t}

```
7.  Block "PS_wdg": Wedge,  Start: 18.407 m,  Length : 0.000 m
      :  Al (3 mm)
  +1.000e+00   0           0           0           0     0        |     0           0           +1.280e+00  +7.655e-06  0    -2.430e+00  |     +1.727e-01 |
   0           +1.017e+00  0           0           0     0        |     0           0           +1.038e+00  +7.962e-01  0    +1.019e-06  |     +1.863e+00 |
   0           0           +1.000e+00  0           0     0        |     +1.139e+00  +7.948e-07  0           0           0    0           |     +2.666e-02 |
   0           0           0           +1.015e+00  0     0        |     -1.380e+01  +8.925e-01  0           0           0    0           |     +2.113e+00 |
   0           0           0           0           1.0   0        |     0           0           -2.475e-01  -1.898e-01  1.0  +9.163e-01  |     +6.316e+00 |
```

Tiny magnification is less than 2% in the case of ^{60}Ca

the magnification is only 0.5% for tritons due to the broad angular distribution after reaction.
5% magnification in the case of ^{78}Ni.