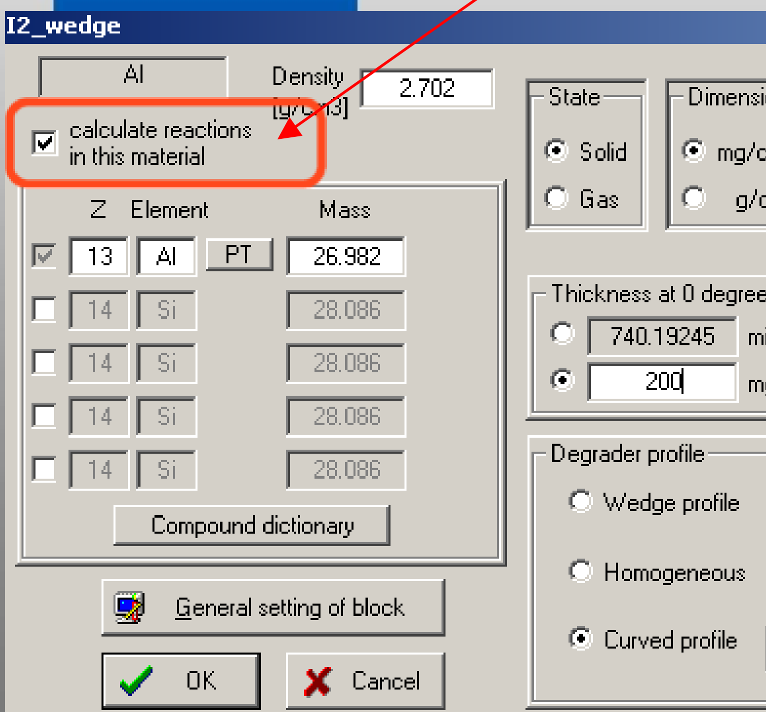
LISE++

Version 7.10 (16-APR-2007)

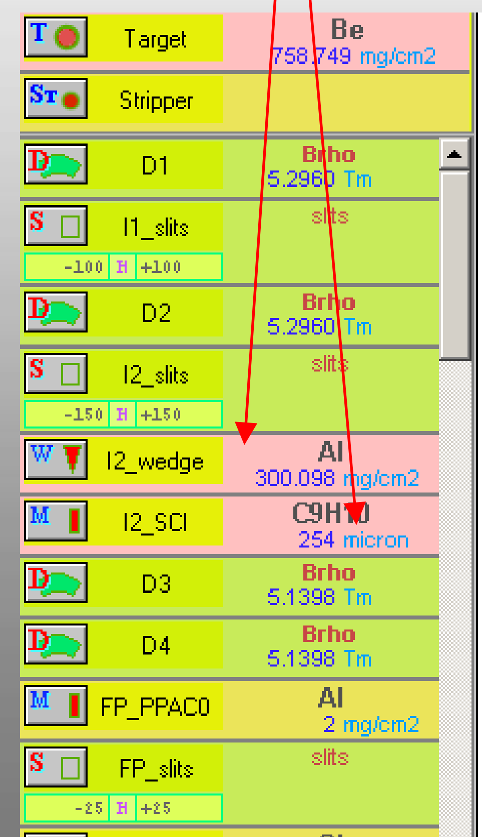
# Fragment production in Material (FPinM) or "Secondary target" in LISE++

# Introduction. Settings

Use this checkbox to make the code to consider this material as secondary target




Pink background shows that reactions will be calculated in this material




Up to three secondary targets can used in LISE++ calculations

# “Secondary reactions in wedge”

- ❖ The “Secondary reactions in wedge” task can be considered as the secondary target option of material block.
- ❖ Any material block can be used as secondary target
- ❖ Fragments produced in the secondary target for next LISE calculations assigned to “Secondary Target #” production mechanism, where “#” is the target order in the secondary reactions list.
- ❖ The “Secondary target” production mechanism can not be set as primary production mechanism in LISE
- ❖ The “Secondary target” (ST) production mechanism is based on the Projectile fragmentation reaction mechanism (angular distribution, momentum distribution, EPAX parameterization for production cross sections).
- ❖ Slits of a material block are disable if the “Fragment production in material” option is turned on.

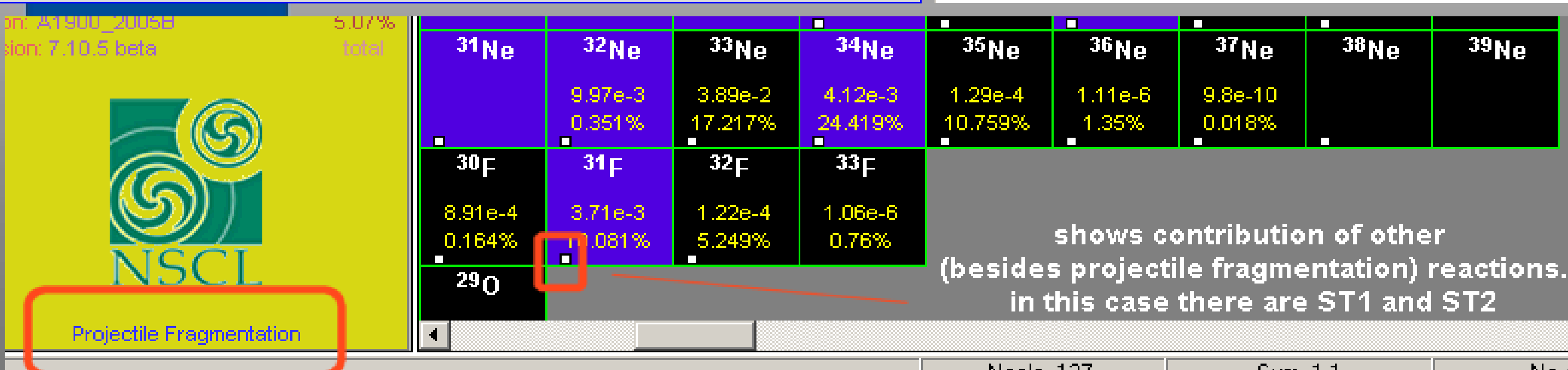
statistics 34Ne

34Ne — Beta- decay (Z=10, N=24)

| | | | | |
|---|---|---|---|---|
| Q1 (D1) | | 10 | 10 | 10 |
| Q2 (D2) | | 10 | 10 | 10 |
| Q3 (D3) | | 10 | 10 | 10 |
| Q4 (D4) | | 10 | 10 | 10 |
| **Production Rate** | **(pps)** | **2.39e-8** | **2.05e-7** | **4.12e-3** |
| Reaction | | SecTarg2 | SecTarg1 | Fragmentn |
| Sum of reactions | (pps) | 4.12e-3 | 4.12e-3 | 4.12e-3 |
| CS in the target | (mb) | 7.97e+0 | 1.24e+1 | 5.33e-10 |
| Total transmission | (%) | 1.89e-13 | 3.95e-13 | 24.419 |
| **Target** | **(%)** | **7.27e-11** | **7.27e-11** | **92.8** |
| X space transmission | (%) | 100 | 100 | 100 |
| Y space transmission | (%) | 100 | 100 | 100 |
| Unreacted in mater. | (%) | 7.27e-11 | 7.27e-11 | 92.8 |
| Unstopped in mater. | (%) | 100 | 100 | 100 |
| **D1** | **(%)** | **100** | **100** | **78.06** |
| X angular transmisn. | (%) | 100 | 100 | 96.01 |
| Y angular transmisn. | (%) | 100 | 100 | 81.3 |
| **I1_slits** | **(%)** | **100** | **100** | **52.18** |
| X space transmission | (%) | 100 | 100 | 52.18 |
| **D2** | **(%)** | **100** | **100** | **76.66** |
| X space transmission | (%) | 100 | 100 | 76.71 |
| Y space transmission | (%) | 100 | 100 | 100 |
| X angular transmisn. | (%) | 100 | 100 | 100 |
| Y angular transmisn. | (%) | 100 | 100 | 100 |
| **I2_slits** | **(%)** | **100** | **100** | **97.39** |
| X space transmission | (%) | 100 | 100 | 97.39 |
| **I2_wedge** | **(%)** | **100** | **100** | **98.65** |
| Unreacted in mater. | (%) | 100 | 100 | 98.65 |
| Unstopped in mater. | (%) | 100 | 100 | 100 |
| **I2_SCI** | **(%)** | **100** | **99.73** | **99.73** |
| Unreacted in mater. | (%) | 100 | 99.73 | 99.73 |
| Unstopped in mater. | (%) | 100 | 100 | 100 |
| **D3** | **(%)** | **2.45** | **4.79** | **99.51** |
| X space transmission | (%) | 25.32 | 47.55 | 100 |
| Y space transmission | (%) | 100 | 100 | 100 |
| X angular transmisn. | (%) | 23.41 | 23.9 | 100 |

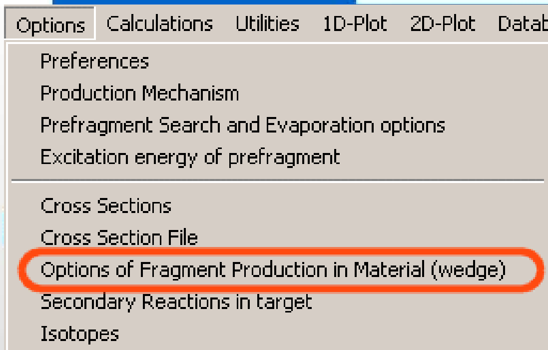
shows ratio of projectile intesities between secondary and primary targets

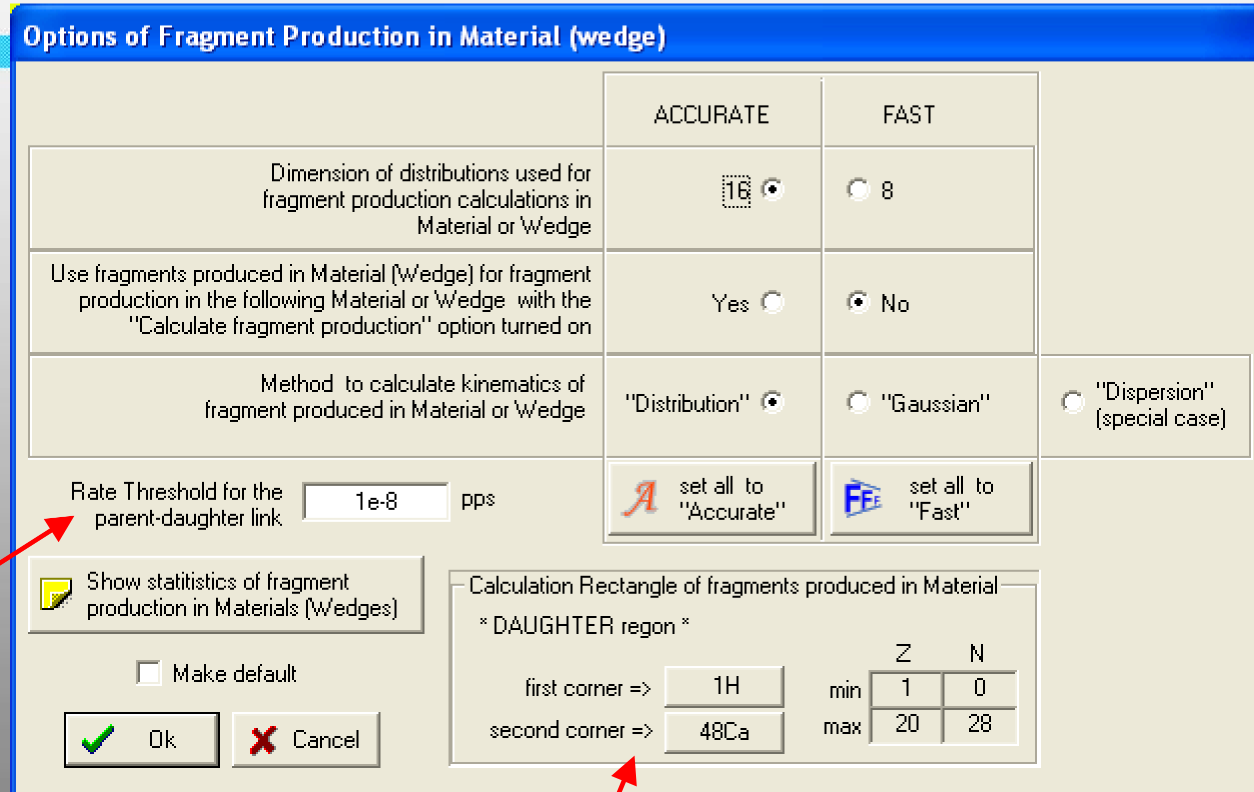
100% transmission up to secondary target




shows contribution of other (besides projectile fragmentation) reactions. in this case there are ST1 and ST2

# The "Options of Fragment Production in Material (Wedge)" dialog

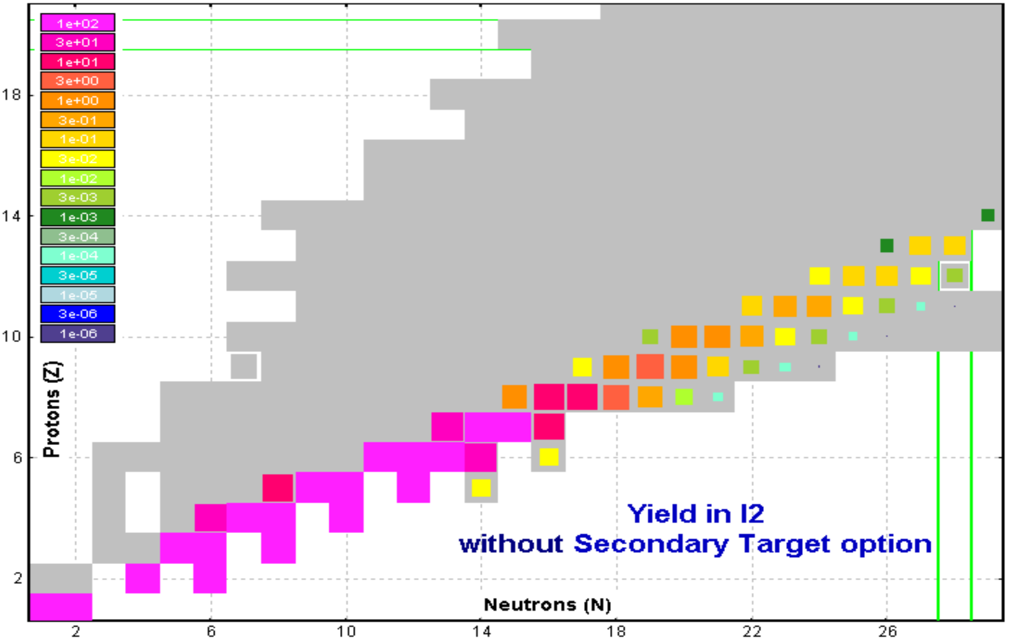


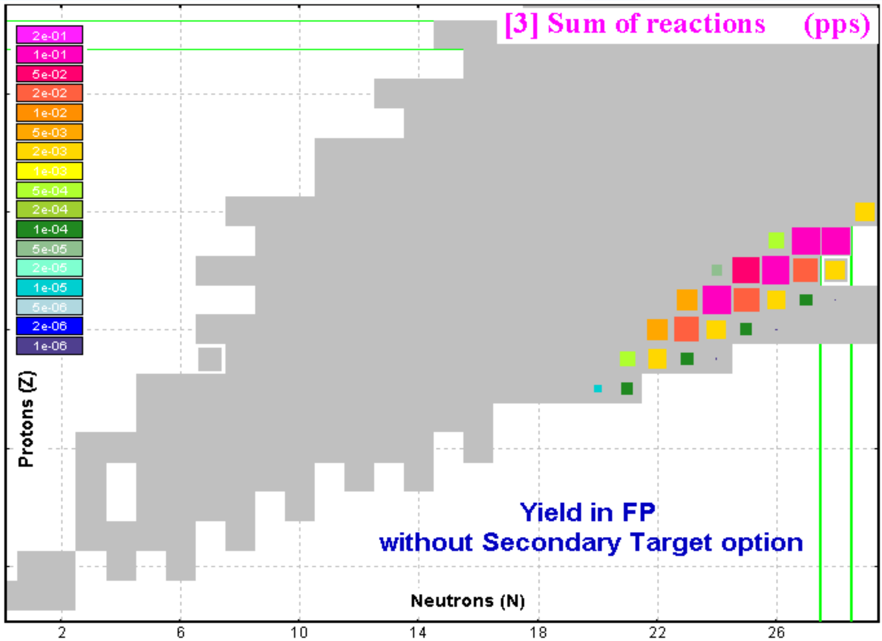



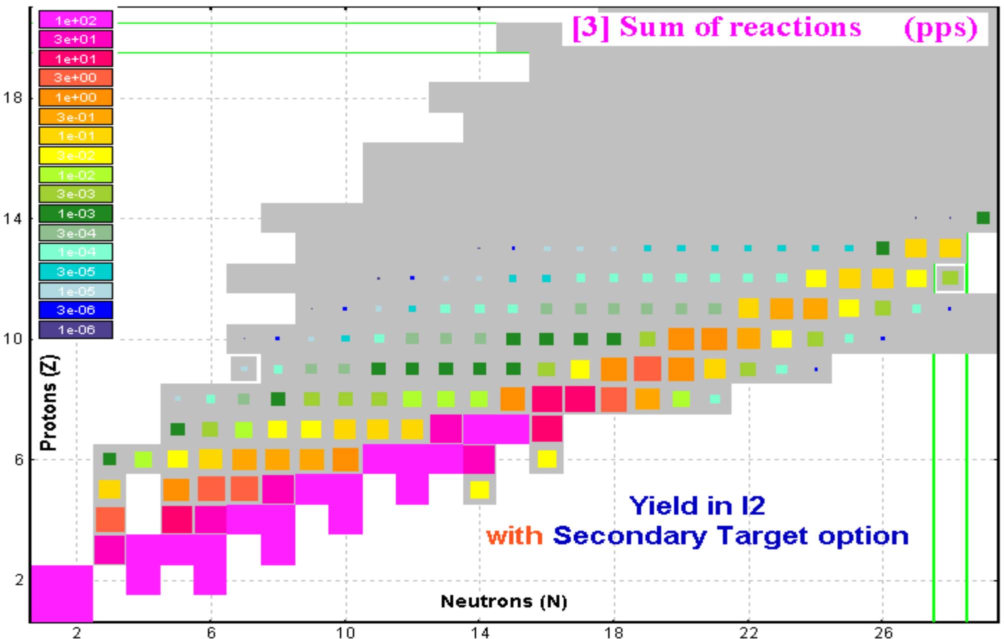

**important option to decrease a link number for heavy primary beams**

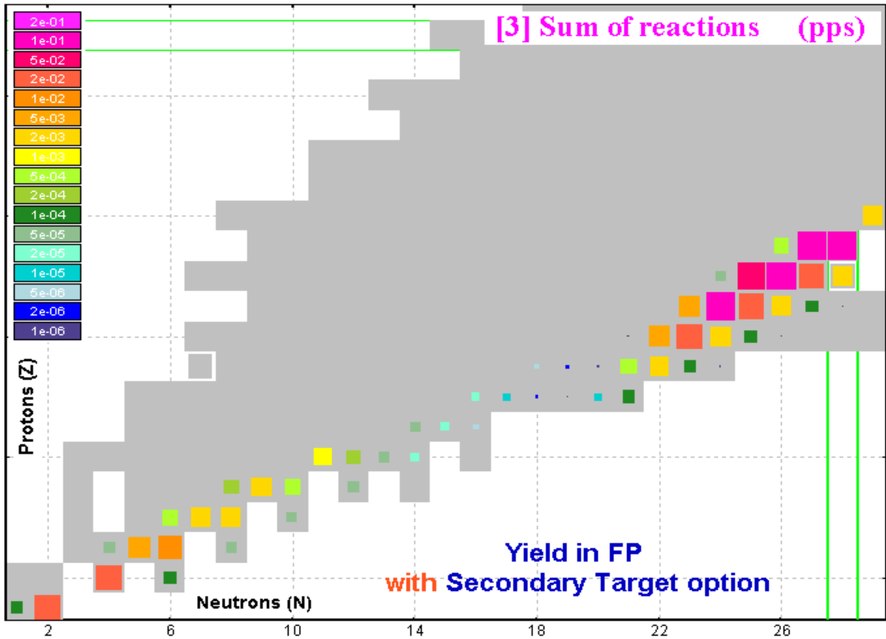
**Calculation rectangle of fragments produced in Material (version 7.10.10)**

# Yield of fragments produced in materials

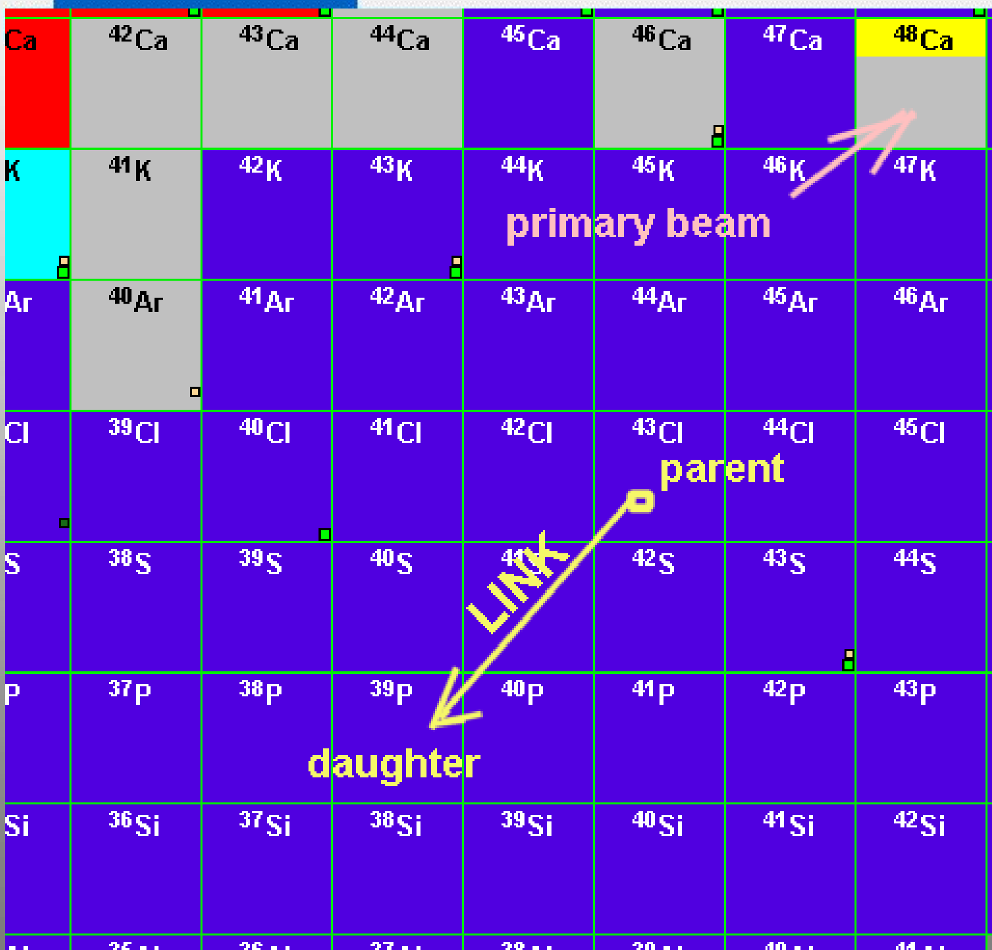


# Parent – link -Daughter




Class PARENT

Class LINK (connect parent with daughter)

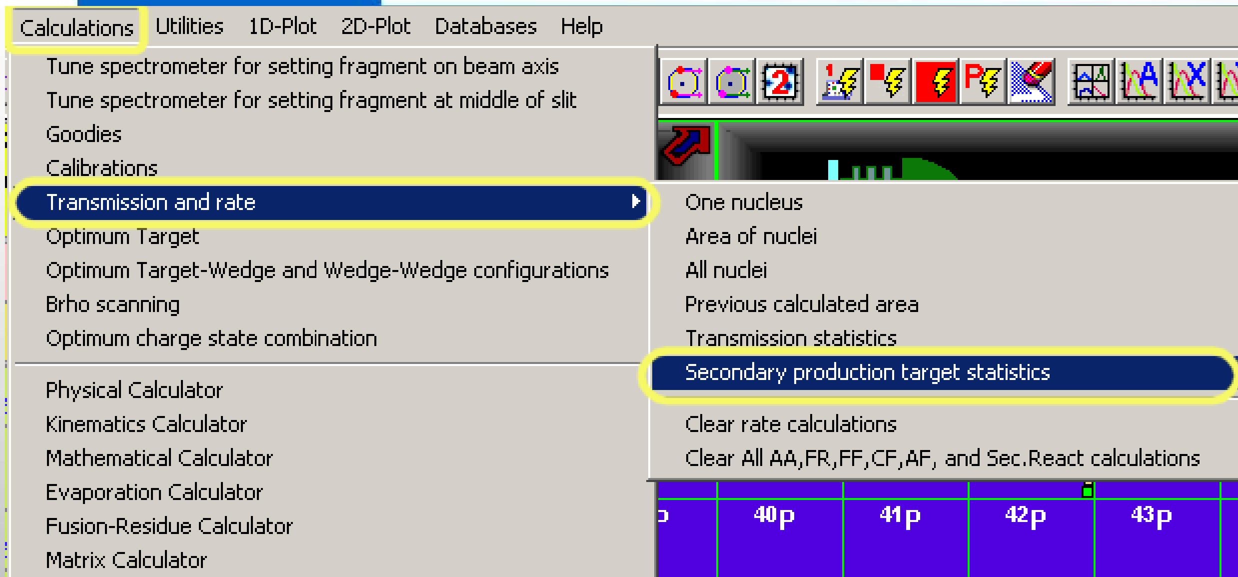
Class DAUGHTER {LIST of links}

Each secondary target has PARENT LIST and DAUGHTER LIST

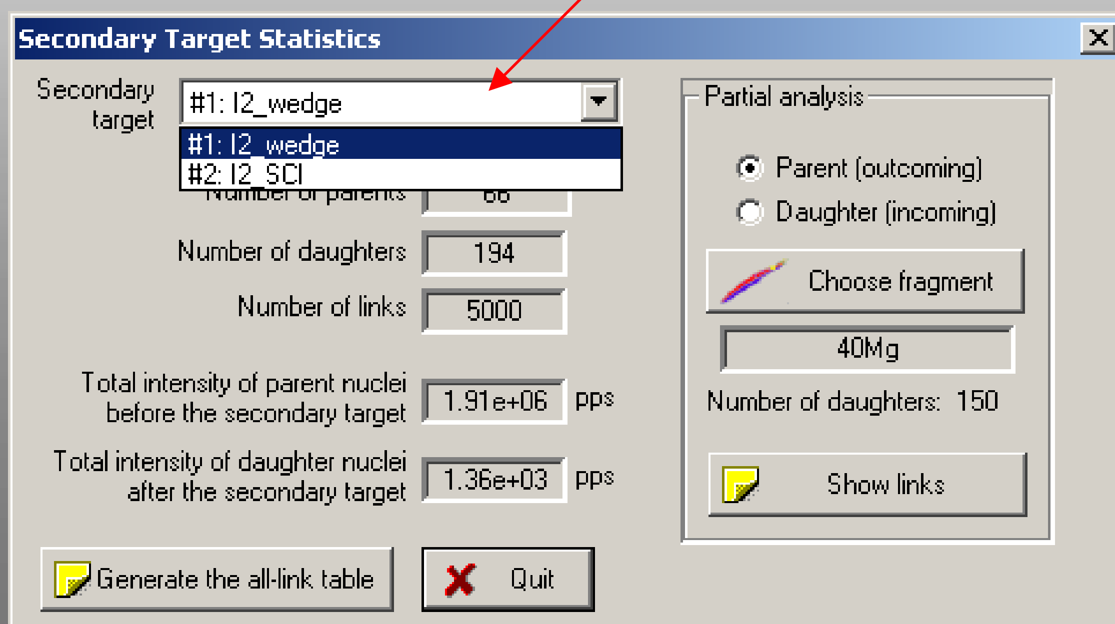
**If transmission calculations are cleared than Parent and Daughter lists (for each secondary target) will be celared too.**

The LIST template is based on the Standard Template Library.
(Not fast, but no problems with memory allocation)

# Statistics of fragment production in materials




Choose the material from the list if them more than one



LISE++

# Secondary production target statistics

**Secondary Target Statistics**

Secondary target: #2: I2_SCI

Number of parents: 260
Number of daughters: 194
Number of links: 19334
Total intensity of parent nuclei before the secondary target: 1.91e+06 pps
Total intensity of daughter nuclei after the secondary target: 2.29e+02 pps

Partial analysis
- (•) Parent (outcoming)
- ( ) Daughter (incoming)

Choose fragment: 15B
Number of daughters: 48

Show links

Generate the all-link table | Quit

**Secondary Target Statistics**

Secondary target: #2: I2_SCI

Number of parents: 260
Number of daughters: 194
Number of links: 19334
Total intensity of parent nuclei before the secondary target: 1.91e+06 pps
Total intensity of daughter nuclei after the secondary target: 2.29e+02 pps

Partial analysis
- ( ) Parent (outcoming)
- (•) Daughter (incoming)

Choose fragment: 15B
Number of parents: 191

Show links

Generate the all-link table | Quit

c:\user\c\lise_pp_8\results\parent_15B_links_target2.txt

```
Fragment: 15B 5+ 5+

Number of daughter links for all 15B charge states and reactions = 48
Number of daughter links for concrete 15B ion+reaction = 24
Reaction = Projectile Fragmentation
Charge state order  = 2

Intensity = 1.19e+04 pps
Before target: Energy = 135.37(+/-3.38) MeV/u
After target : Energy = 135.11(+/-3.38) MeV/u
```

| N` | Daugh. | CS |
|---|---|---|
| 1 | 1H | 5.39e+00 |
| 2 | 2H | 1.01e+01 |
| 3 | 3H | 6.30e+00 |
| 4 | 3He | 5.73e+00 |
| 5 | 4He | 1.12e+01 |
| 6 | 6He | 3.61e+00 |
| 7 | 8He | 2.97e-01 |
| 8 | 6Li | 1.17e+01 |
| 9 | 7Li | 1.21e+01 |
| 10 | 8Li | 6.91e+00 |
| 11 | 9Li | 3.09e+00 |
| 12 | 11Li | 4.99e-01 |
| 13 | 7Be | 4.08e+00 |
| 14 | 9Be | 1.54e+01 |
| 15 | 10Be | 1.38e+01 |
| 16 | 11Be | 9.53e+00 |
| 17 | 12Be | 6.23e+00 |
| 18 | 14Be | 4.13e+00 |
| 19 | 8B | 4.61e-01 |
| 20 | 10B | 5.84e+00 |
| 21 | 11B | 1.14e+01 |
| 22 | 12B | 1.66e+01 |
| 23 | 13B | 1.98e+01 |
| 24 | 14B | 2.66e+01 |

**result filename.**
file can be used by other Windows applicaton

c:\user\c\lise_pp_8\results\daughter_15B_links_target2.txt

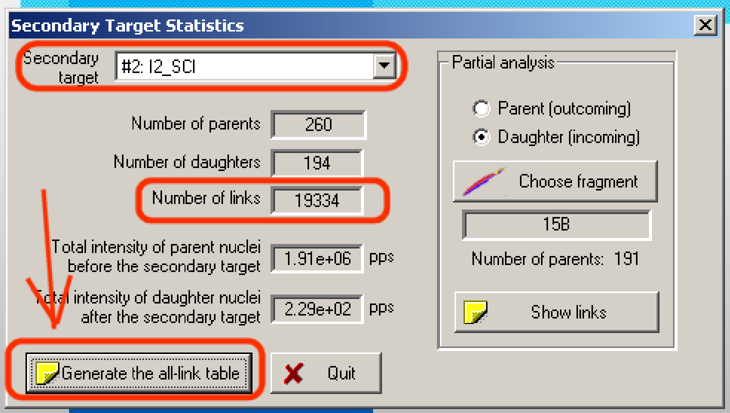
```
Fragment: 15B    (daughter)

Total Intensity     = 6.77e-02 pps
Average CS          = 8.28e+00 mb
Energy   = 119.77+/-15.63 MeV/u
X-position          = 21.28+/-62.95 mm
Y-position          = 0.00+/-0.79 mm
AX-angle  = -0.48+/-126.88 mrad
AY-angle  = 0.00+/-126.72 mrad
Number of parent links          = 191
```

**reaction 9 => it means reaction products in the secondary target ~1**

| N` | Parent | Rea-n | Energy | dEnergy | P_Intens | CS | I*CS |
|---|---|---|---|---|---|---|---|
| 1 | 17B | 9 | 126.36 | 10.12 | 1.62e-01 | 1.83e+01 | 2.97e+00 |
| 2 | 17B | 0 | 105.83 | 4.06 | 2.89e+02 | 1.83e+01 | 5.29e+03 |
| 3 | 19B | 9 | 104.71 | 5.98 | 5.33e-03 | 1.36e+01 | 7.25e-02 |
| 4 | 19B | 0 | 83.41 | 4.84 | 5.96e-02 | 1.36e+01 | 8.11e-01 |
| 5 | 16C | 9 | 123.06 | 14.89 | 9.37e-01 | 5.90e+00 | 5.53e+00 |
| 6 | 17C | 9 | 126.10 | 9.89 | 1.01e+00 | 5.74e+00 | 5.80e+00 |
| 7 | 17C | 0 | 149.81 | 4.79 | 5.12e+02 | 5.74e+00 | 2.94e+03 |
| 8 | 18C | 9 | 123.03 | 12.55 | 3.42e-01 | 6.03e+00 | 2.06e+00 |
| 9 | 18C | 0 | 134.30 | 5.40 | 2.06e+03 | 6.03e+00 | 1.24e+04 |
| 10 | 19C | 9 | 107.81 | 12.34 | 5.44e-02 | 5.93e+00 | 3.23e-01 |
| 11 | 19C | 0 | 120.10 | 5.75 | 7.97e+02 | 5.93e+00 | 4.73e+03 |
| 12 | 20C | 9 | 122.30 | 6.96 | 2.08e-02 | 5.63e+00 | 1.17e-01 |
| 13 | 20C | 0 | 107.78 | 5.95 | 8.38e+01 | 5.63e+00 | 4.71e+02 |
| 14 | 22C | 9 | 102.14 | 14.44 | 1.40e-03 | 4.81e+00 | 6.73e-03 |
| 15 | 22C | 0 | 87.45 | 6.07 | 5.80e-02 | 4.81e+00 | 2.79e-01 |
| 16 | 17N | 9 | 121.82 | 12.32 | 8.18e-02 | 5.06e-01 | 4.14e-02 |
| 17 | 18N | 9 | 134.29 | 17.44 | 9.62e-02 | 9.27e-01 | 8.92e-02 |
| 18 | 19N | 9 | 115.37 | 13.96 | 1.14e-01 | 1.33e+00 | 1.51e-01 |
| 19 | 20N | 9 | 121.90 | 6.64 | 1.22e-01 | 1.64e+00 | 2.01e-01 |
| 20 | 20N | 0 | 143.74 | 6.84 | 6.70e+01 | 1.64e+00 | 1.10e+02 |
| 21 | 21N | 9 | 114.85 | 9.70 | 5.77e-02 | 1.86e+00 | 1.07e-01 |
| 22 | 21N | 0 | 131.89 | 6.97 | 2.07e+02 | 1.86e+00 | 3.84e+02 |
| 23 | 22N | 9 | 102.09 | 14.51 | 1.03e-02 | 1.98e+00 | 2.05e-02 |
| 24 | 22N | 0 | 119.52 | 7.02 | 1.24e+02 | 1.98e+00 | 2.46e+02 |
| 25 | 23N | 9 | 123.30 | 16.10 | 2.13e-03 | 2.05e+00 | 4.37e-03 |
| 26 | 23N | 0 | 108.56 | 7.02 | 2.04e+01 | 2.05e+00 | 4.19e+01 |
| 27 | 18O | 9 | 113.91 | 12.38 | 5.07e-03 | 5.44e-02 | 2.76e-04 |

LISE++

# Statistics of fragment production in materials




c:\user\c\lise_pp_8\results\all_links_target2.txt

| N` | Daugh. | Parent | Rea-n | Energy | dEnergy | P_Intens | CS |
|---|---|---|---|---|---|---|---|
| 1 | 1H | 2H | 9 | 129.88 | 61.43 | 3.67e+02 | 4.03e+00 |
| 2 | 1H | 2H | 0 | 267.95 | 75.02 | 2.56e+02 | 4.03e+00 |
| 3 | 1H | 3H | 9 | 142.49 | 53.41 | 1.38e+02 | 4.83e+00 |
| 4 | 1H | 3H | 0 | 130.03 | 59.37 | 8.21e+05 | 4.83e+00 |
| 5 | 1H | 3He | 9 | 141.49 | 52.92 | 9.01e+01 | 5.11e+00 |
| 6 | 1H | 4He | 9 | 138.25 | 56.73 | 1.95e+02 | 5.72e+00 |
| 7 | 1H | 6He | 9 | 132.80 | 58.61 | 3.77e+01 | 6.20e+00 |
| 8 | 1H | 6He | 0 | 132.98 | 59.90 | 6.70e+05 | 6.20e+00 |
| 9 | 1H | 8He | 9 | 128.96 | 58.52 | 1.06e+01 | 6.31e+00 |
| 10 | 1H | 8He | 0 | 77.84 | 45.10 | 1.17e+03 | 6.31e+00 |
| 11 | 1H | 6Li | 9 | 132.16 | 58.36 | 6.11e+01 | 6.27e+00 |
| 12 | 1H | 7Li | 9 | 130.84 | 58.86 | 8.79e+01 | 6.33e+00 |
| 13 | 1H | 8Li | 9 | 103.17 | 55.95 | 8.18e+01 | 6.32e+00 |
| 14 | 1H | 8Li | 0 | 168.64 | 62.41 | 3.94e+04 | 6.32e+00 |
| 15 | 1H | 9Li | 9 | 125.70 | 58.47 | 8.58e+00 | 6.27e+00 |
| 16 | 1H | 9Li | 0 | 133.25 | 59.92 | 2.64e+05 | 6.27e+00 |
| 17 | 1H | 11Li | 9 | 116.63 | 55.60 | 2.95e+00 | 6.06e+00 |
| 18 | 1H | 11Li | 0 | 91.01 | 49.84 | 1.46e+03 | 6.06e+00 |
| 19 | 1H | 7Be | 9 | 130.04 | 58.52 | 4.65e+00 | 6.34e+00 |
| 20 | 1H | 9Be | 9 | 125.22 | 58.42 | 2.03e+01 | 6.27e+00 |
| 21 | 1H | 10Be | 9 | 122.90 | 58.28 | 2.49e+01 | 6.17e+00 |
| 22 | 1H | 10Be | 0 | 182.39 | 63.60 | 3.26e+01 | 6.17e+00 |
| 23 | 1H | 11Be | 9 | 115.99 | 55.33 | 2.10e+01 | 6.05e+00 |
| 24 | 1H | 11Be | 0 | 158.63 | 62.06 | 2.15e+04 | 6.05e+00 |
| 25 | 1H | 12Be | 9 | 114.14 | 56.36 | 1.49e+00 | 5.91e+00 |
| 26 | 1H | 12Be | 0 | 133.26 | 59.82 | 6.78e+04 | 5.91e+00 |
| 27 | 1H | 14Be | 9 | 107.84 | 58.73 | 6.27e-01 | 5.57e+00 |
| 28 | 1H | 14Be | 0 | 99.06 | 52.37 | 7.96e+02 | 5.57e+00 |
| 29 | 1H | 8B | 9 | 123.40 | 57.17 | 1.24e-01 | 6.33e+00 |
| 30 | 1H | 10B | 9 | 122.14 | 57.97 | 1.55e+00 | 6.15e+00 |
| 31 | 1H | 11B | 9 | 115.16 | 56.11 | 2.94e+00 | 6.02e+00 |
| 32 | 1H | 12B | 9 | 98.72 | 55.24 | 4.05e+00 | 5.88e+00 |
| 33 | 1H | 13B | 9 | 97.22 | 56.54 | 4.73e+00 | 5.73e+00 |
| 34 | 1H | 13B | 0 | 168.90 | 63.69 | 2.85e+01 | 5.73e+00 |
| 35 | 1H | 14B | 9 | 107.18 | 58.46 | 4.28e+00 | 5.56e+00 |
| 36 | 1H | 14B | 0 | 152.74 | 61.54 | 4.11e+03 | 5.56e+00 |
| 37 | 1H | 15B | 9 | 105.70 | 55.34 | 3.13e-01 | 5.39e+00 |
| 38 | 1H | 15B | 0 | 132.98 | 59.65 | 1.19e+04 | 5.39e+00 |
| 39 | 1H | 17B | 9 | 105.12 | 56.98 | 1.62e-01 | 5.02e+00 |
| 40 | 1H | 17B | 0 | 104.27 | 53.82 | 2.89e+02 | 5.02e+00 |
| 41 | 1H | 19B | 9 | 102.82 | 52.67 | 5.33e-03 | 4.64e+00 |
| 42 | 1H | 19B | 0 | 84.73 | 47.82 | 5.96e-02 | 4.64e+00 |
| 43 | 1H | 9C | 9 | 105.34 | 54.15 | 1.99e-03 | 6.26e+00 |
| 44 | 1H | 10C | 9 | 106.00 | 54.60 | 1.46e-02 | 6.15e+00 |
| 45 | 1H | 11C | 9 | 106.37 | 55.16 | 6.60e-02 | 6.01e+00 |
| 46 | 1H | 12C | 9 | 106.48 | 55.63 | 1.96e-01 | 5.84e+00 |
| 47 | 1H | 13C | 9 | 106.33 | 56.07 | 4.09e-01 | 5.68e+00 |
| 48 | 1H | 14C | 9 | 105.96 | 56.39 | 6.41e-01 | 5.52e+00 |

Print

**The size of this file about 1 MB.**

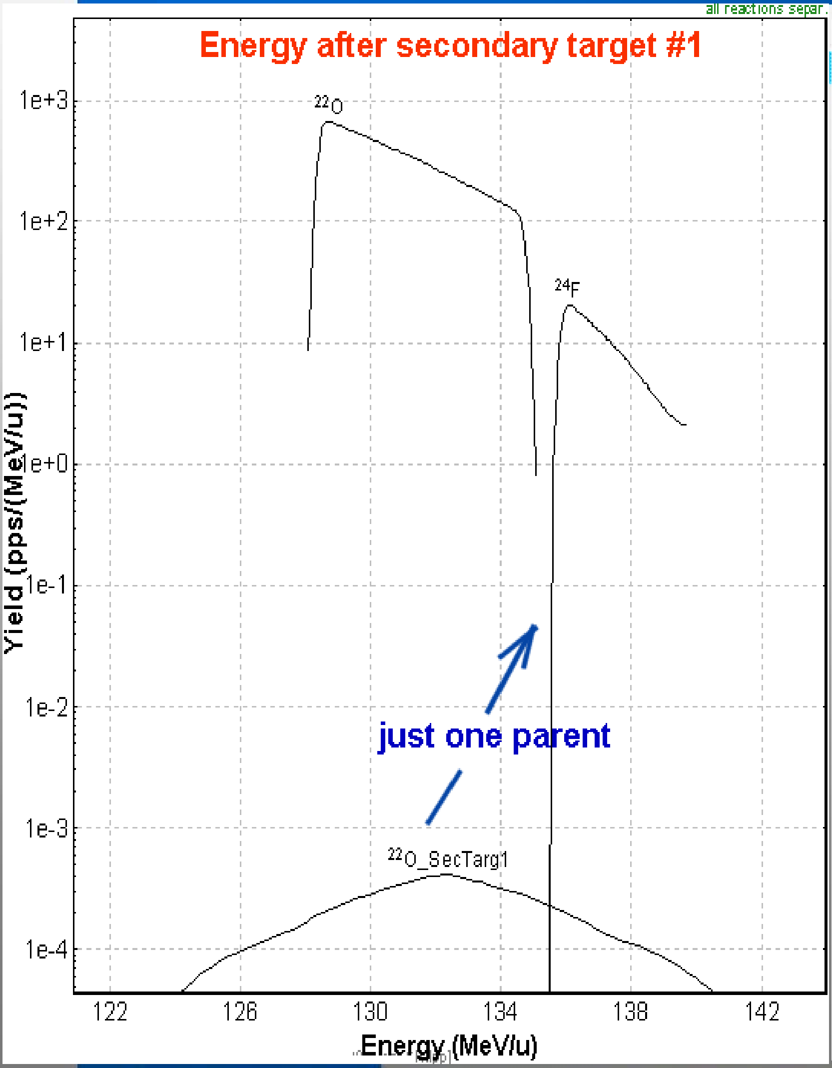
**All statistics files are located in the <LISE/results> directory**

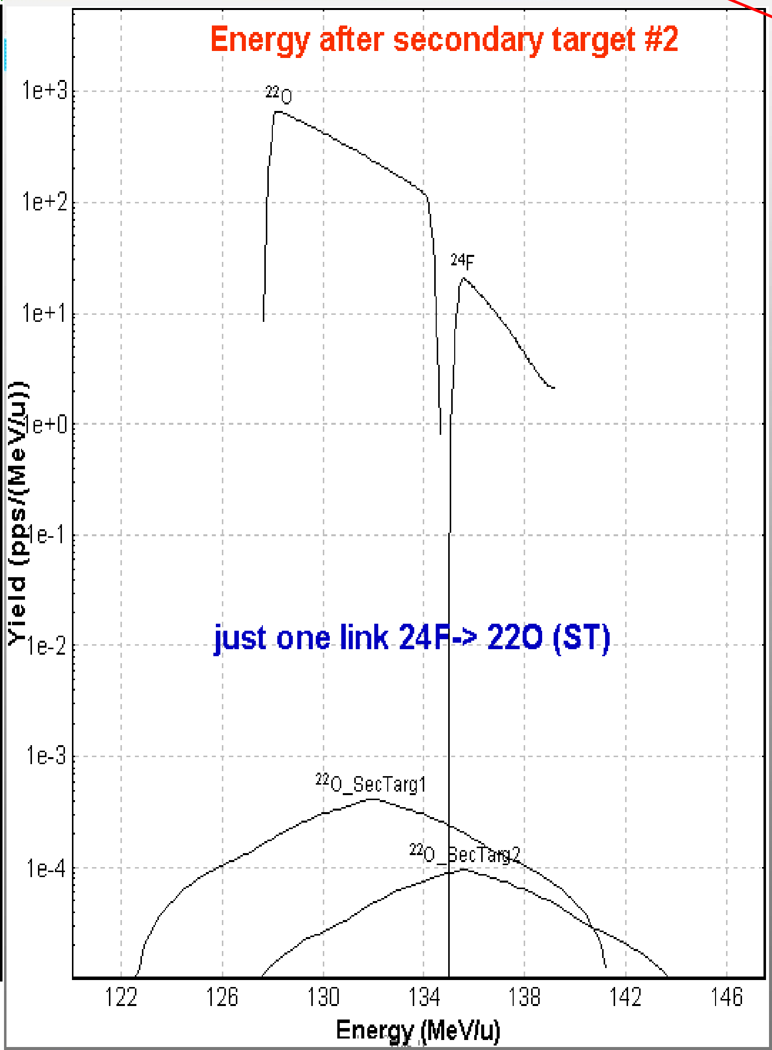
# Kinematics of fragments produced in materials

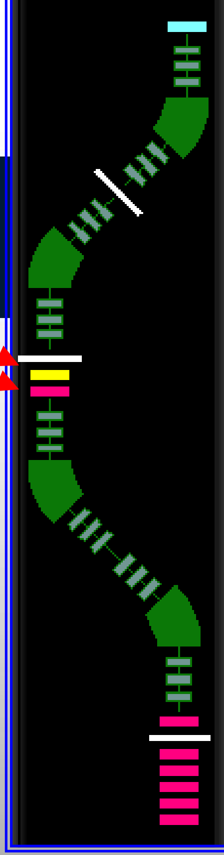
Just transmission of two nuclei was calculated

reaction target #1

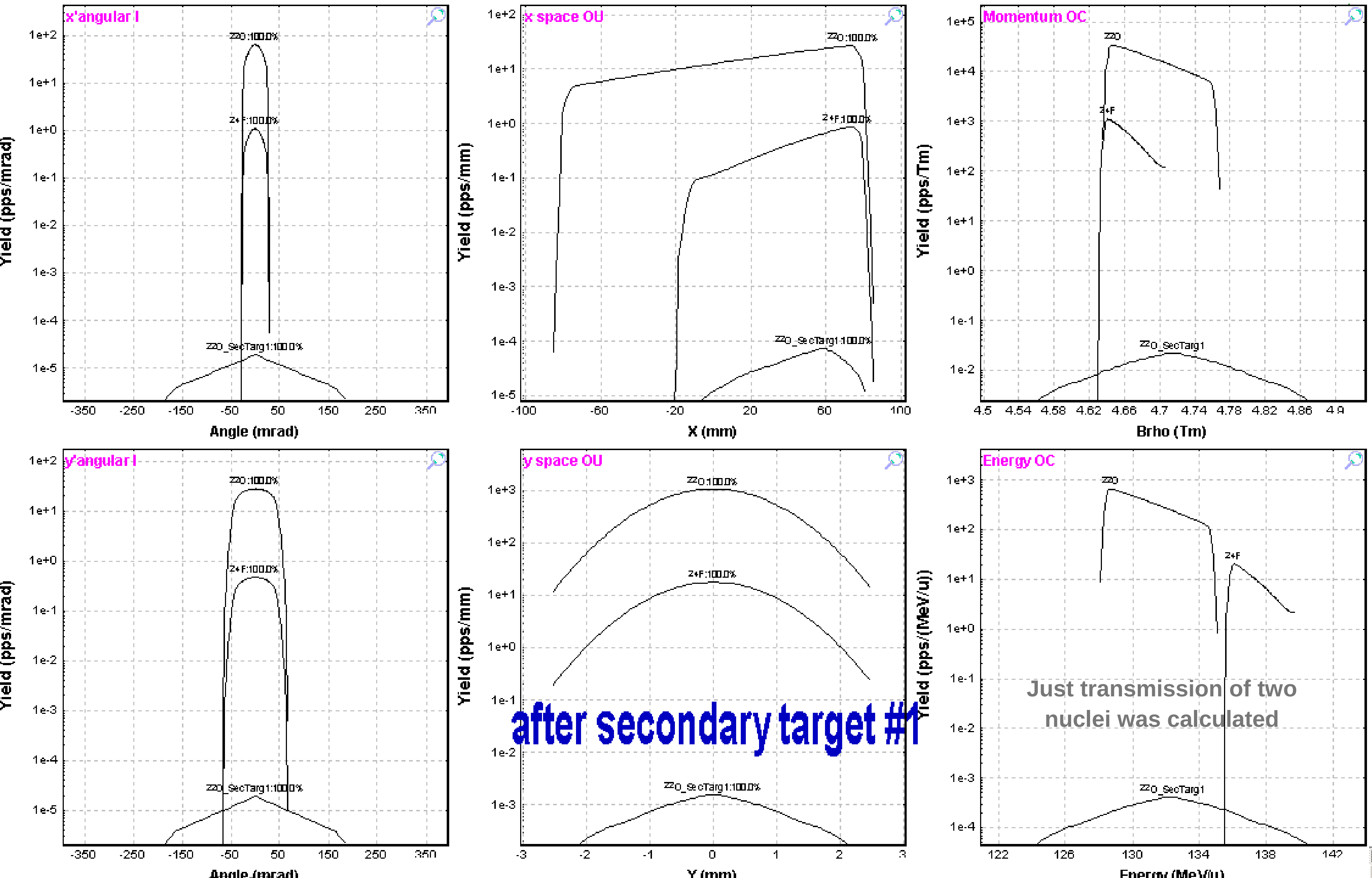
reaction target #2



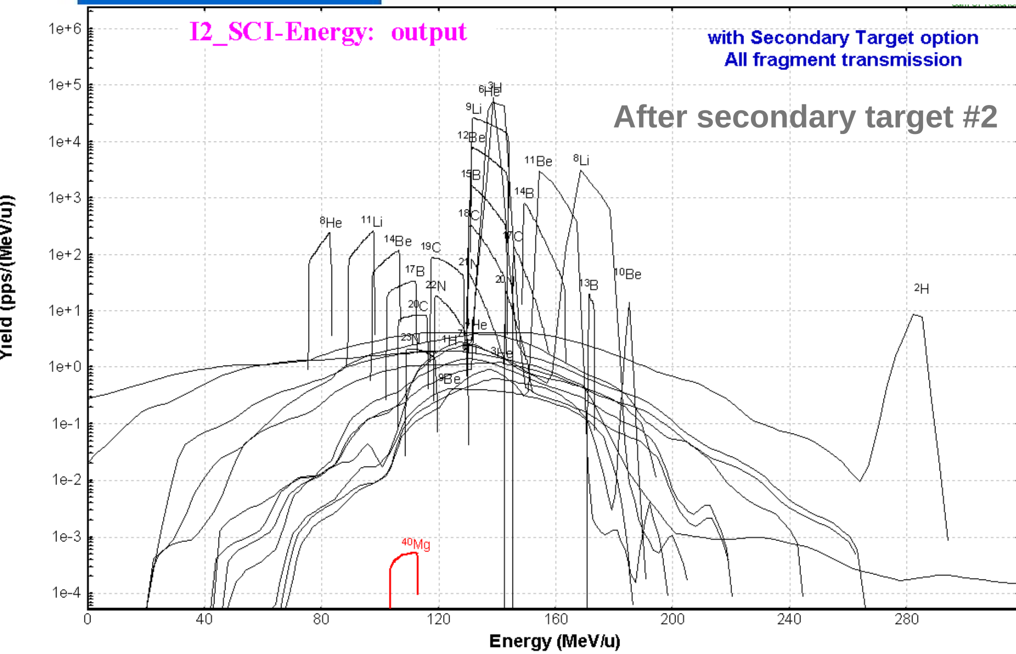



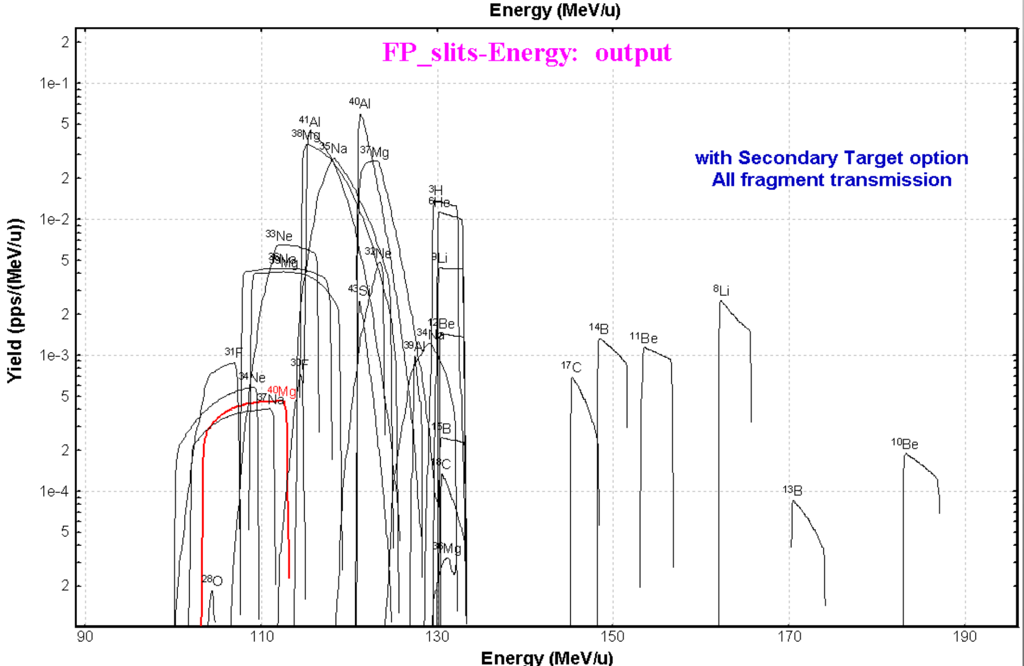
# Kinematics of fragments produced in materials

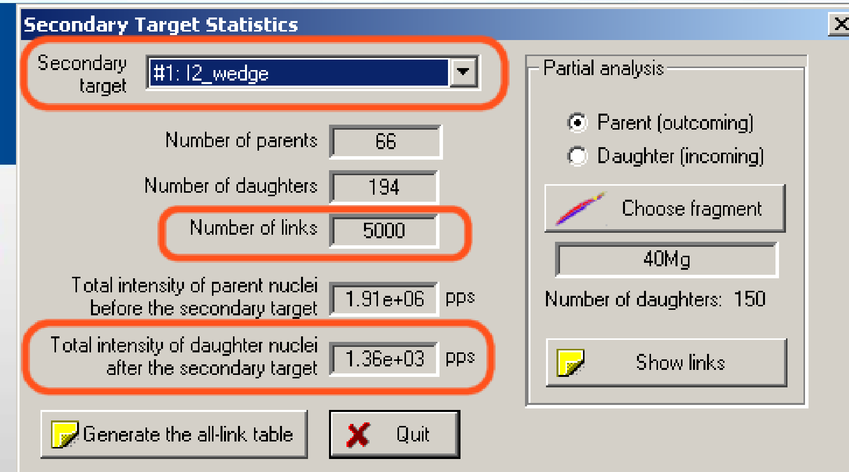


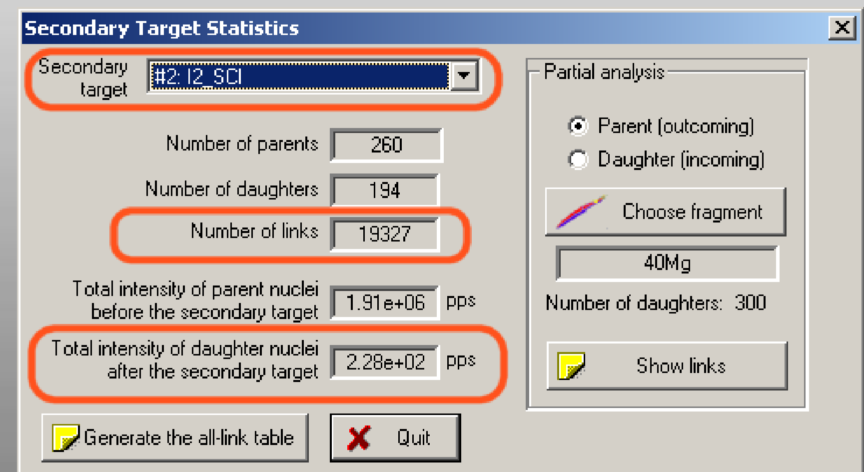
LISE++

# Kinematics of fragments produced in materials (wedges)



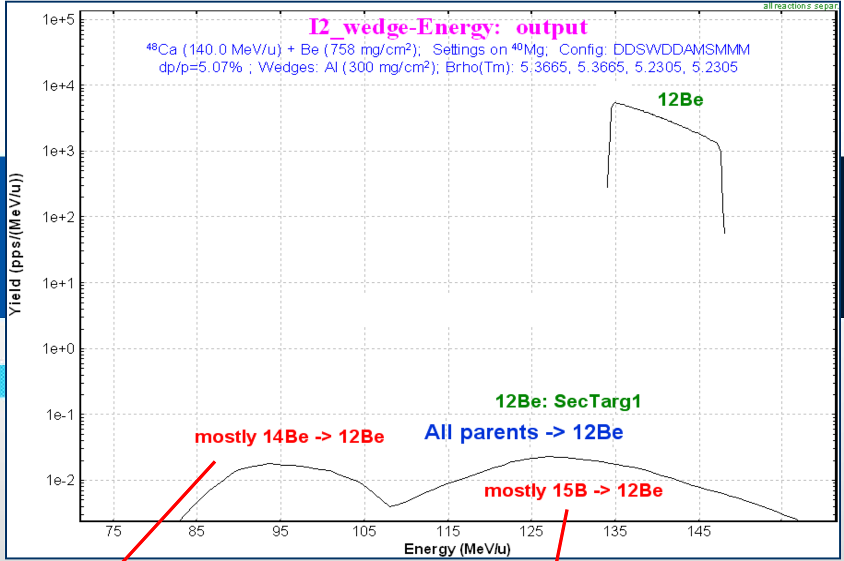



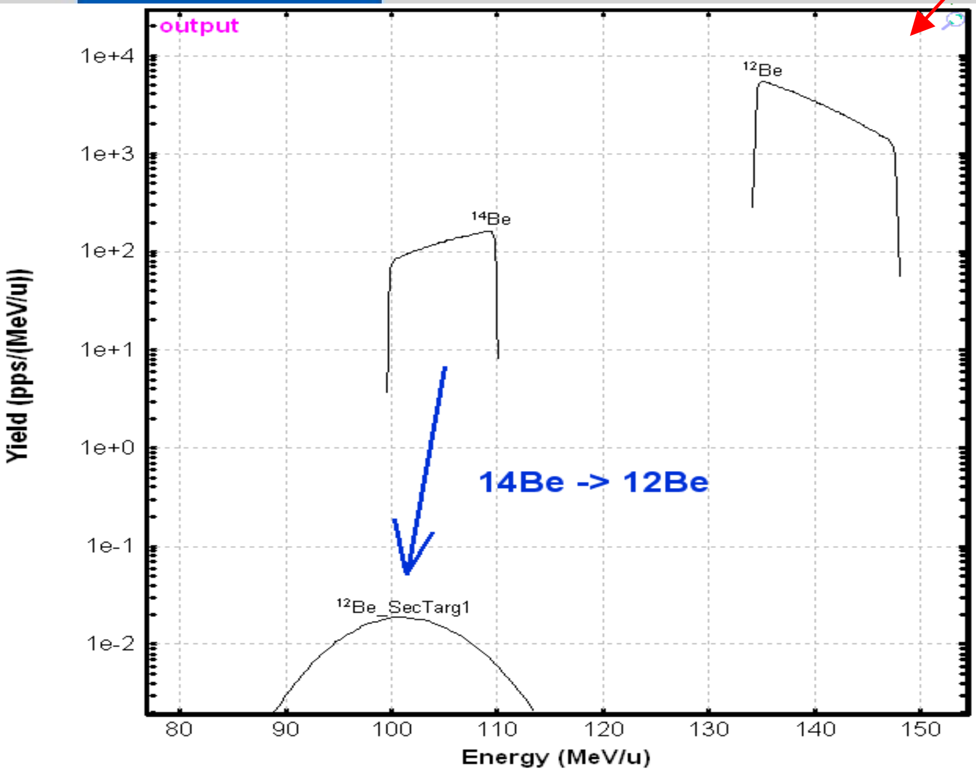



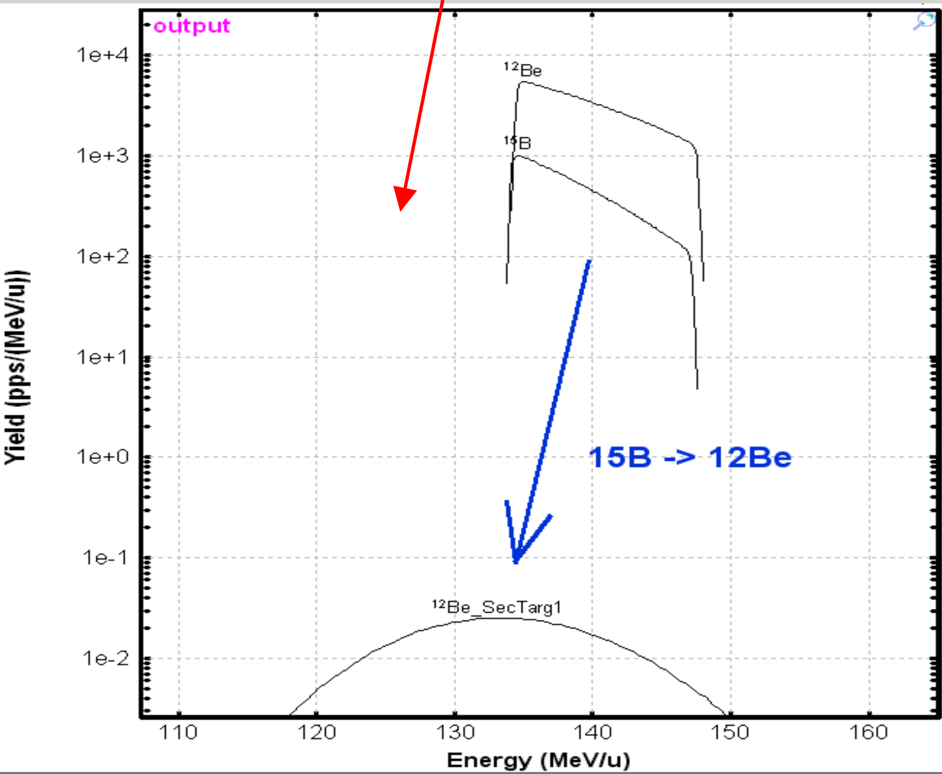




File “06506_40Mg_Al300_SR.lpp”

# Parent contribution (Kinematics)



# "Distribution" method – fast copy of processes in the primary target

| Parent | LINK | Daughter |
|---|---|---|
| *5 distributions (dimension **NP=8**)* | | |
| X – horizontal spatial | X = Xparent | Sum of all link X distributions |
| X'- horizontal angular | X' = X' parent ⊗ X' reaction | Sum of all link X' distributions |
| Y – vertical spatial | Y = Yparent | Sum of all link Y distributions |
| Y' – vertical angular | Y' = Y' parent ⊗ Y' reaction | Sum of all link Y' distributions |
| E – energy distribution before target | E = Estraggling ⊗ Erectangle ⊗ Egoldhaber ⊗ Eparent<br>Erectangle → due to energy loss difference in target between projectile and fragment<br>Egoldhaber → contribution due to reaction | Sum of all link E distributions<br>All distribution areas are normalized on link intensities |
| ***Properties*** | | |
| I – intensity (pps) | I = Iparent * σ (EPAX) * Thickness(atoms) | I – sum of all link intensities<br>σ – reduced cross section |

No correlation between X & E

# "Gaussian" method: fastest way to calculate fragment production in material

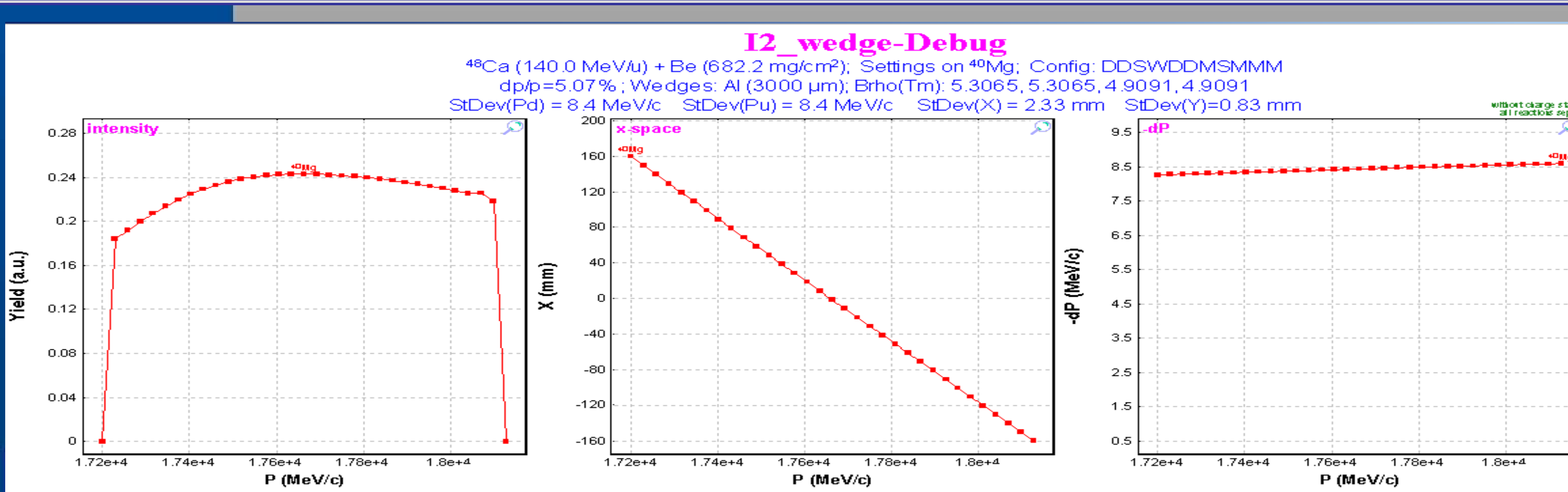
| Parent | Intermediate result | Link | Daughter |
|---|---|---|---|
| X – horizontal spatial | X = Xparent | **<X>, σ(X)** | Sum of Gaussians (<$X_i$>, σ($X_i$)) |
| X'- horizontal angular | X' = X' parent ⊗ X' reaction | **<X'>, σ(X')** | Sum of Gaussians (<$X'_i$>, σ($X'_i$)) |
| Y – vertical spatial | Y = Yparent | **<Y>, σ(Y)** | Sum of Gaussians (<$Y_i$>, σ($Y_i$)) |
| Y' – vertical angular | Y' = Y' parent ⊗ Y' reaction | **Y', σ(Y')** | Sum of Gaussians (<$Y'_i$>, σ($Y'_i$)) |
| E – energy distribution before target | E = Estraggling ⊗ Erectangle ⊗ Egoldhaber ⊗ Eparent<br><br>Erectangle → due to energy loss differenece in target between projectile and fragment<br><br>Egoldhaber → contribution due to reaction | **<E>, σ(E)** | Sum of Gaussians (<$E_i$>, σ($E_i$))<br><br>All Gaussians are normalized on link intensities |
| Intensity | (as for "Distribution" method) | **I** | |

**No correlation between X & E**

# “Dispersion” method: X & E correlation

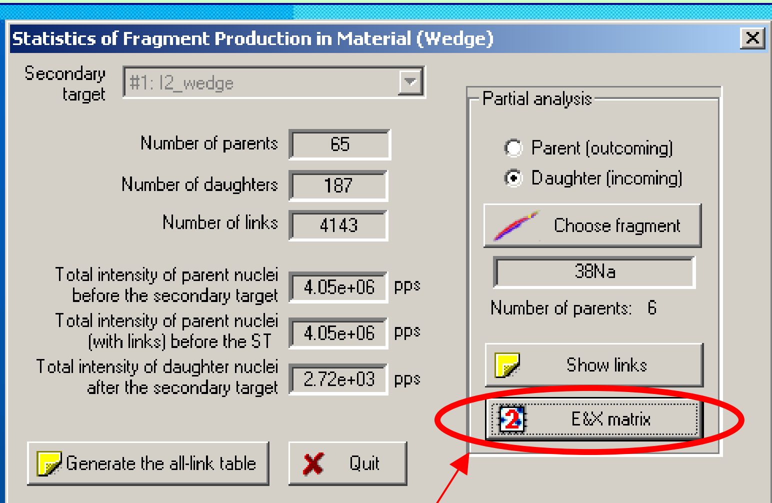
| Parent | Link | Daughter |
|---|---|---|
| Input parent<br>“DistrFour” class<br>Set of correlated distributions<br>(base vs. Intesity)<br>(base vs. X)<br>(base vs. Y)<br>(base vs. Y)<br>(base vs. P),<br><br>where the base of set can be changed for anyone from X,Y,P,E | Link “DistrFour” class<br><br>DistrFour $_{LINK}$ =<br>Reaction ♥<br>DistrFour $_{Parent}$ | Sum of all “DistrFour” links weighted by Intensities.<br><br>Result : E vs. X matrix<br><br>For the next transmission calculations the code transforms the matrix to E(X) distribution. |

**Content of the “DistrFour” class can be visualized in Debug distribution plots**



LISE++

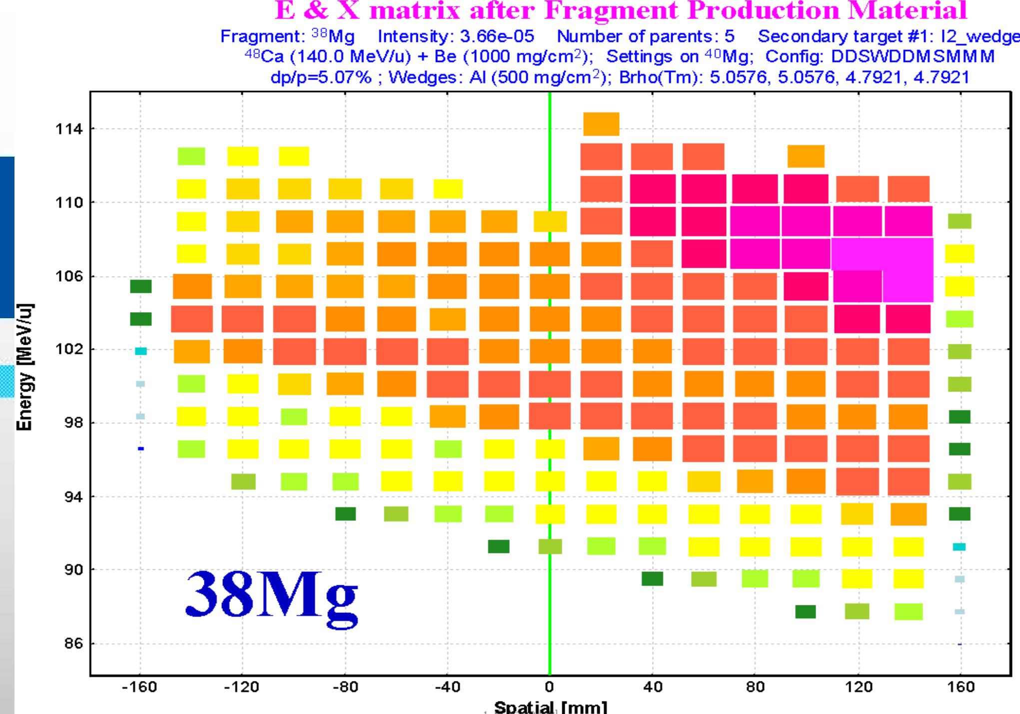
# "Dispersion" method
## (version higher 7.10.15 ) :
## main aim is creation of the E & X correlation matrix

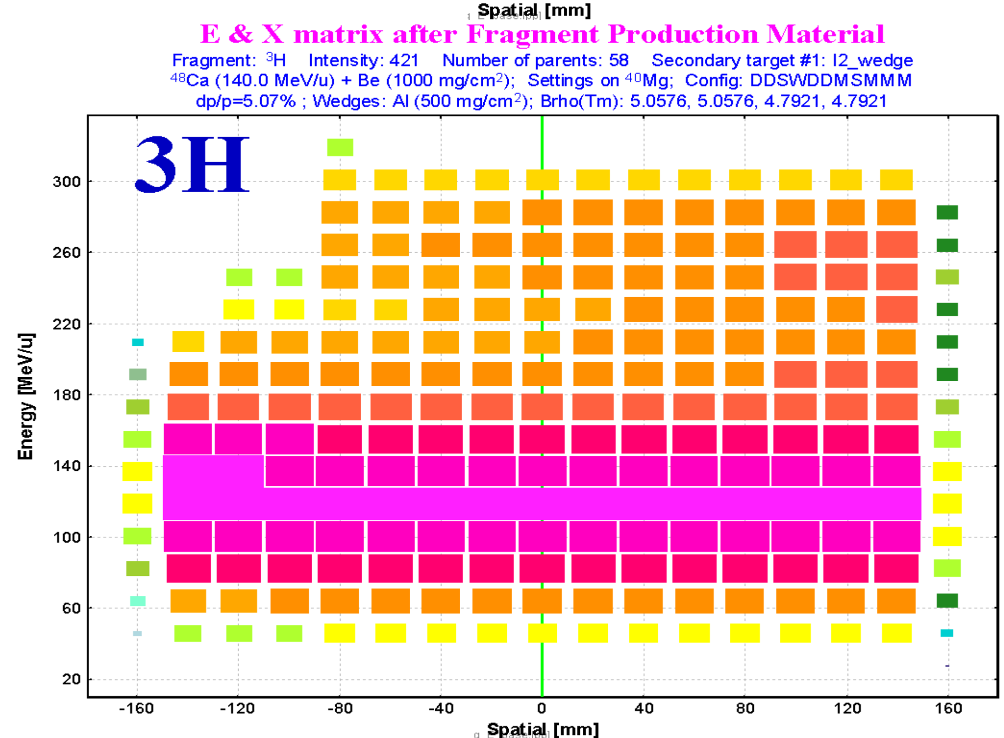



This button is enable only for "Dispersion" method when :

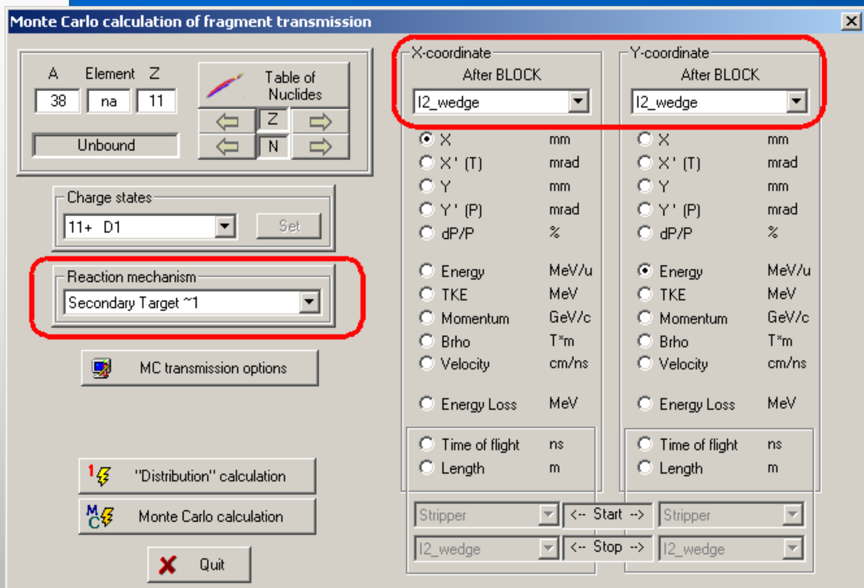
- Option "Daughter (incoming) is chosen in the "Partial analysis" groupbox
- number of parents more than zero.

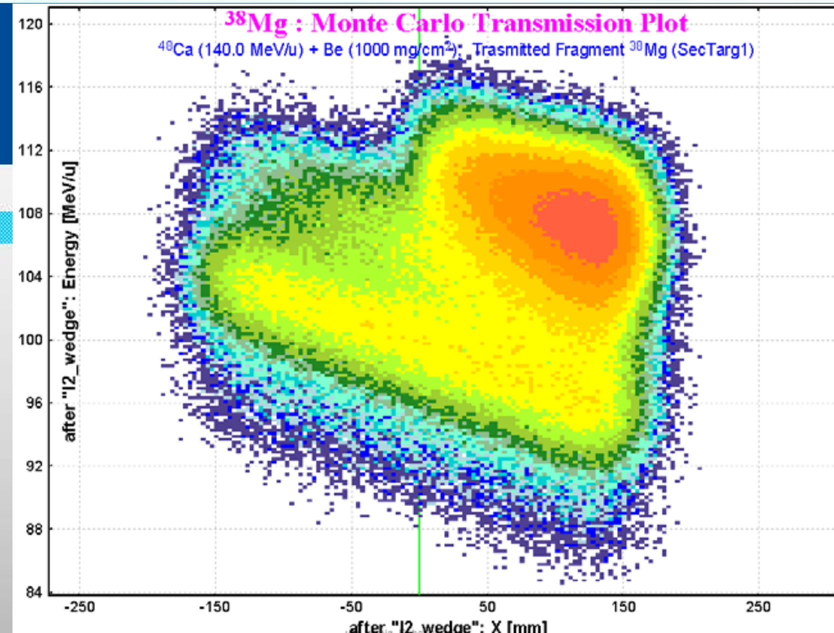
The E & X correlation matrix is applied for Monte Carlo transmission calculations

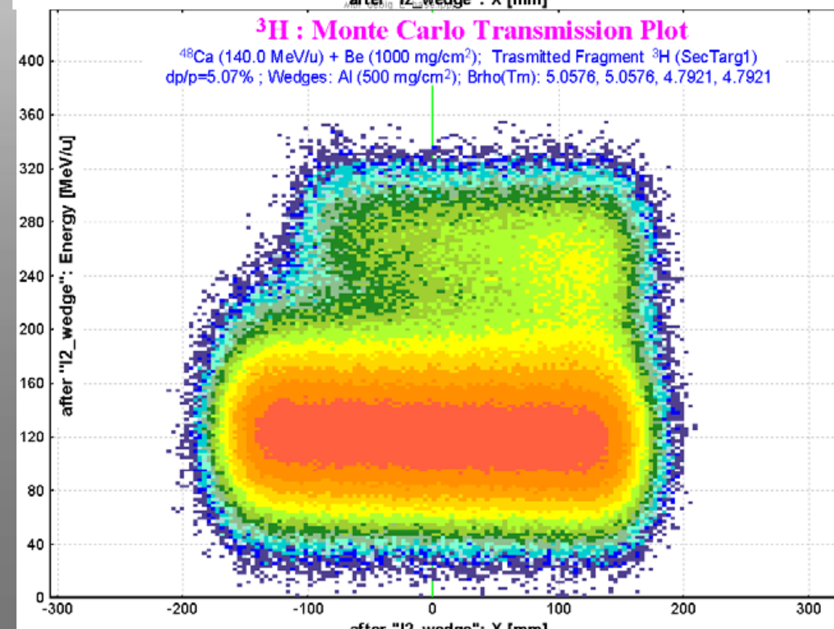


# Monte Carlo method to estimate transmission of fragments produced in material




**Using the E & X correlation matrix produced by analytical "Dispersion" method the code calculates transmission of fragments produced in material.**

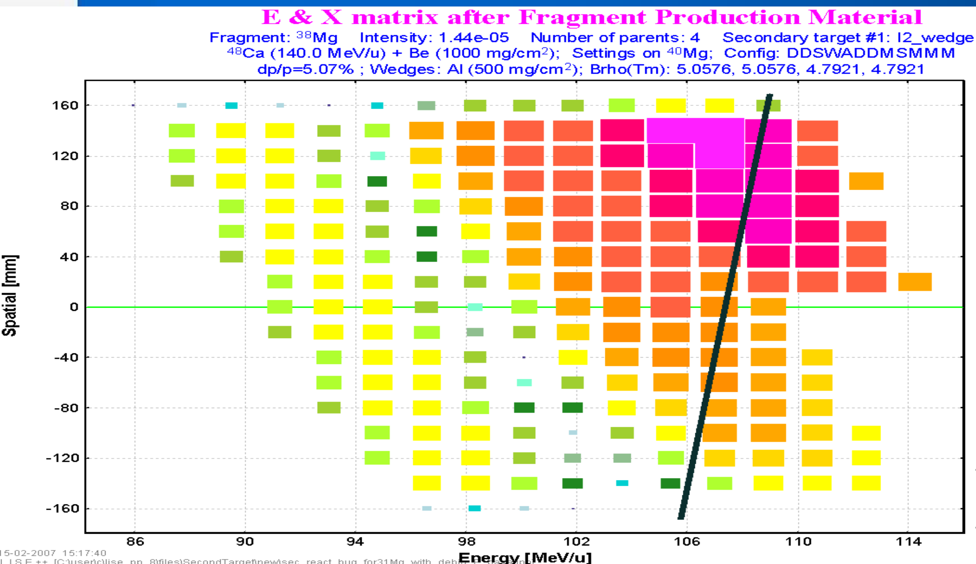
**Transmission can be calculated only for blocks beginning from this material .**

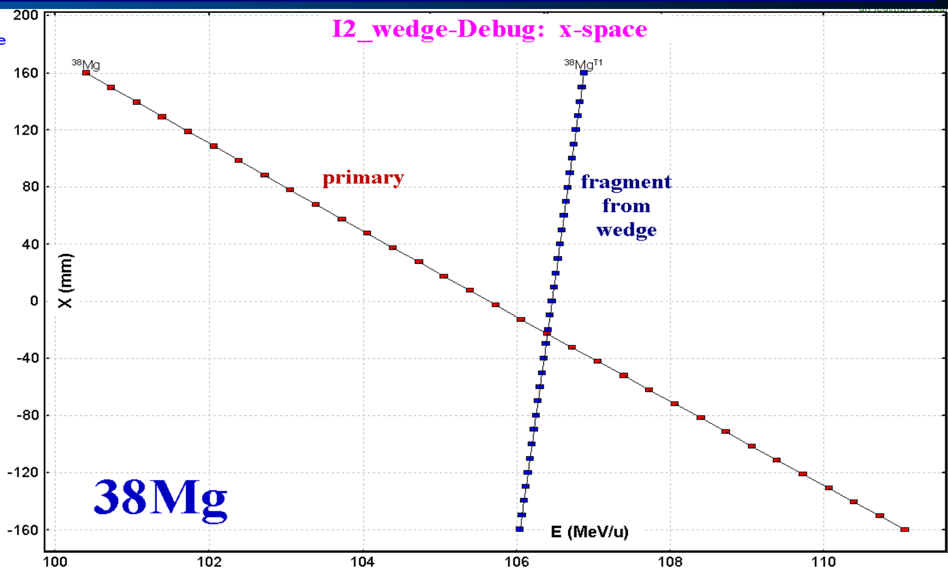
**Compare these E-X plots after materials with plots on the previous slide.**

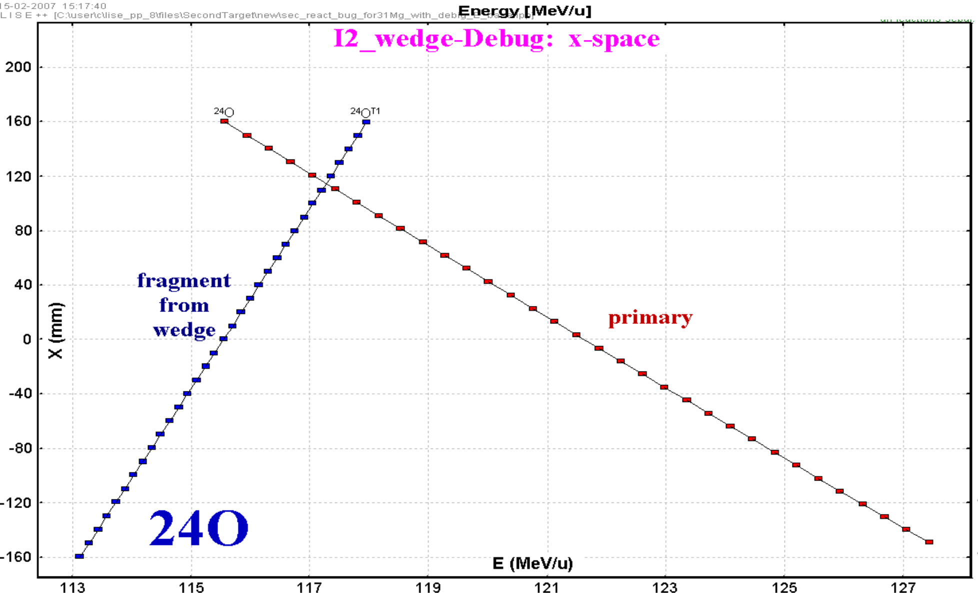
# “Fragment production in Material” methods comparison: correlation E & X

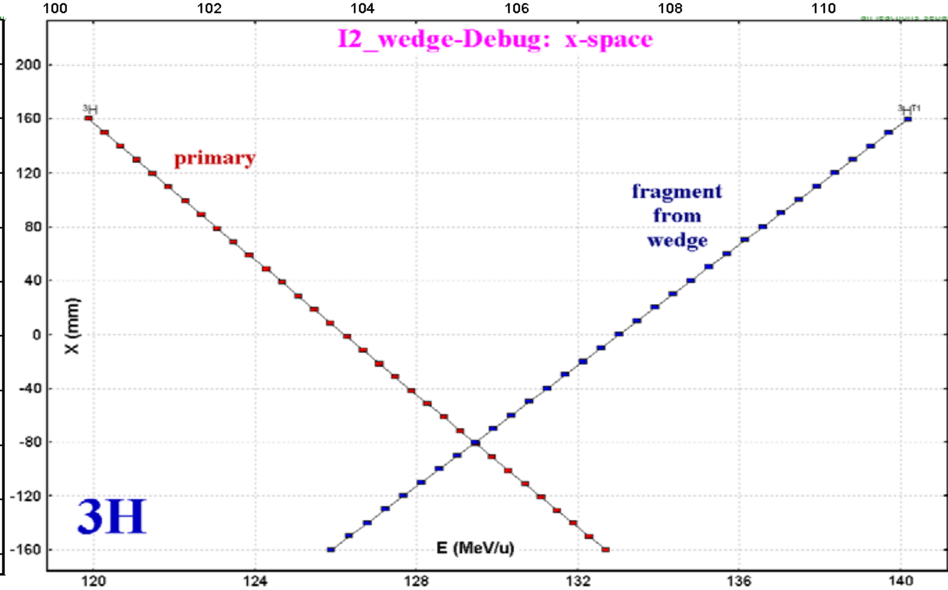
No correlation after material between fragment’s energy and position in “Gaussian” and “Distribution” methods.

In the case of “Dispersion“ method using the E & X matrix (NxN) for each $X_i$ the code calculates <Ei>. After this curve $E(X_i)$ is fitted by a line.



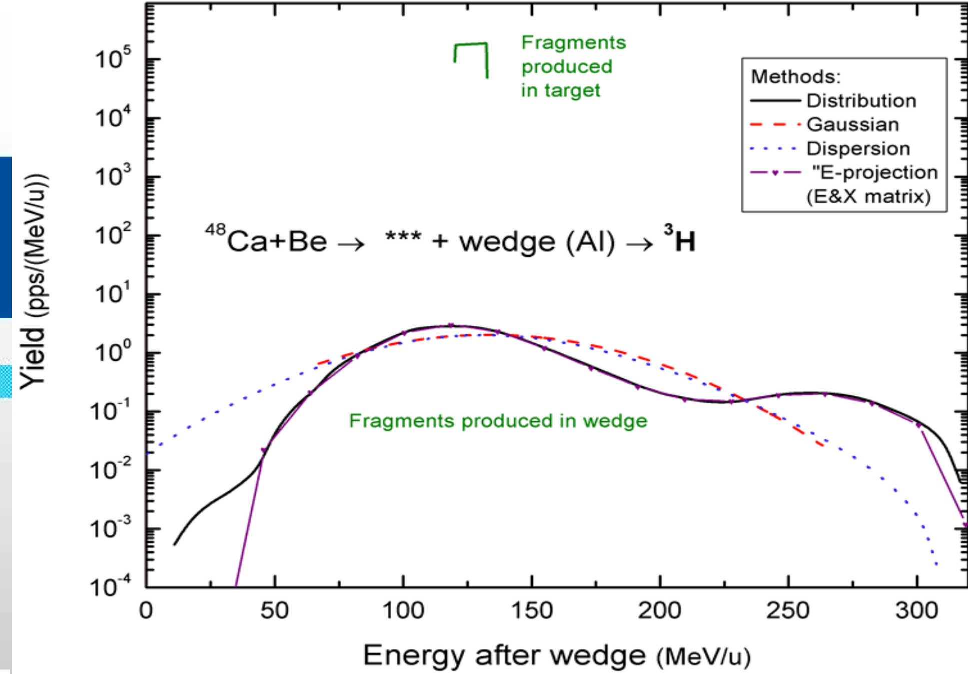



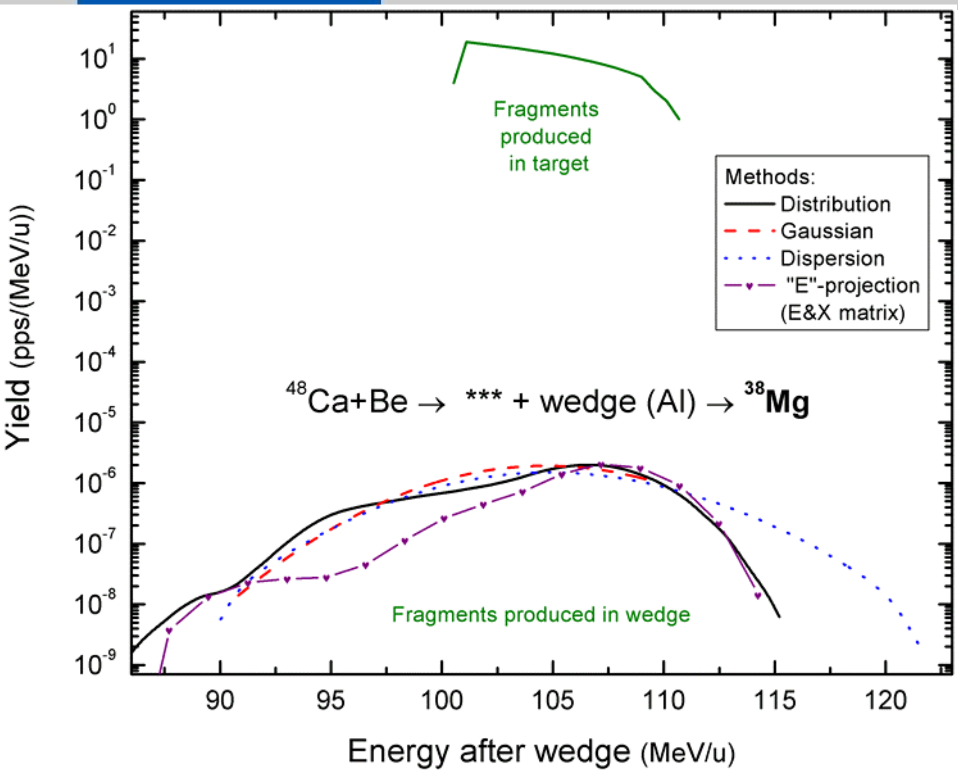



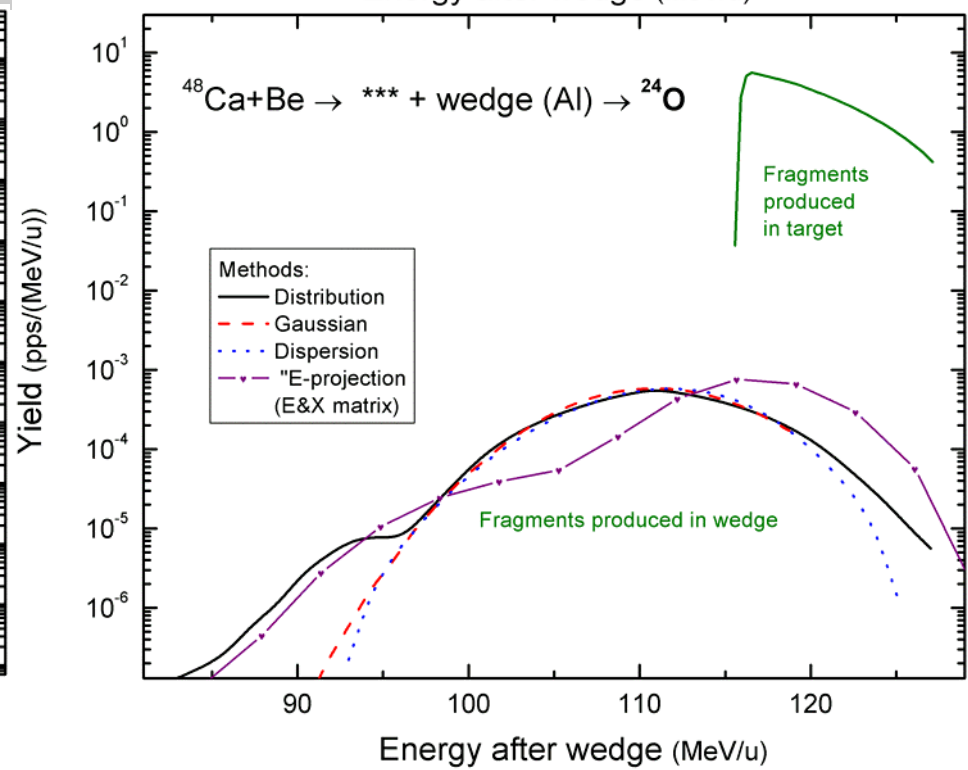



LISE++

# "Fragment production in Material" methods comparison: energy after material



# "Fragment production in Material" methods comparison: transmission

| | block transmission | dispersion(N=16) | distribution(N=16) | distribution(N=8) | gaussian | MC |
|---|---|---|---|---|---|---|
| 38Mg | dipole D3 | 5.6% | 10.3% | 9.8% | 12.1% | **4.4%** |
| | dipole D4 | 51.8% | 60.5% | 59.9% | 69.0% | **57.4%** |
| | FP slits | 25.0% | 27.6% | 28.7% | 30.9% | **24.4%** |
| | **Result** | **0.723%** | **1.719%** | **1.677%** | **2.586%** | **0.622%** |

| | block transmission | dispersion(N=16) | distribution(N=16) | distribution(N=8) | gaussian | MC |
|---|---|---|---|---|---|---|
| 24O | dipole D3 | 3.4% | 5.9% | 5.6% | 6.4% | **4.1%** |
| | dipole D4 | 48.9% | 58.7% | 58.0% | 61.8% | **60.3%** |
| | FP slits | 25.9% | 29.9% | 29.3% | 33.1% | **30.3%** |
| | **Result** | **0.428%** | **1.031%** | **0.946%** | **1.308%** | **0.746%** |

| | block transmission | dispersion(N=16) | distribution(N=16) | distribution(N=8) | gaussian | MC |
|---|---|---|---|---|---|---|
| 3H | dipole D3 | 0.28% | 0.45% | 0.31% | 0.40% | **0.49%** |
| | dipole D4 | 5.6% | 48.3% | 48.0% | 47.5% | **43.9%** |
| | FP slits | 20.4% | 25.2% | 24.9% | 25.0% | **28.8%** |
| | **Result** | **0.003%** | **0.054%** | **0.037%** | **0.048%** | **0.062%** |

| | block transmission | dispersion(N=16) | distribution(N=16) | distribution(N=8) | gaussian | MC |
|---|---|---|---|---|---|---|
| 2H | dipole D3 | | 0.012% | 0.012% | 0.005% | **0.023%** |
| | dipole D4 | | 47.4% | 46.6% | 41.6% | **39.6%** |
| | FP slits | | 24.8% | 24.4% | 22.3% | **27.3%** |
| | **Result** | **0%** | **0.0014%** | **0.0014%** | **0.0005%** | **0.0025%** |

# “Fragment production in Material” methods comparison: calculation time and use of memory

| Case | methods | dimension | Threshold for P-D link | time, sec | Ncalc | Sum, pp | Memory, KB | d_time, sec | d_Ncalc | d_Sum, pps | d_memory, KB | d_memory / dNcalc |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | no FPinM | | | 46 | 71 | 1.2E+03 | 11,288 | | | | | |
| A | gaussian | | 1E-10 | 62 | 289 | 2.3E+03 | 41,652 | 16 | 218 | 1.1E+03 | 30,364 | 139 |
| A | gaussian | | 1E-03 | 60 | 210 | 2.3E+03 | 21,844 | 14 | 139 | 1.1E+03 | 10,556 | 76 |
| A | Distribution | 16 | 1E-03 | 58 | 239 | 2.5E+03 | 43,480 | 12 | 168 | 1.3E+03 | 32,192 | 192 |
| A | Distribution | 8 | 1E-03 | 55 | 219 | 2.4E+03 | 35,196 | 9 | 148 | 1.2E+03 | 23,908 | 162 |
| A | Dispersion | 16 | 1E-03 | 72 | 187 | 2.2E+03 | 97,196 | 26 | 116 | 1.0E+03 | 85,908 | 741 |
| B | no FPinM | | | 100 | 132 | 2.3E+02 | 11,740 | | | | | |
| B | gaussian | | 1E-05 | 152 | 570 | 1.5E+03 | 89,996 | 52 | 438 | 1270 | 78,256 | 52 |
| B | gaussian | | 1E-10 | 212 | 840 | 1.5E+03 | 209,572 | 112 | 708 | 1270 | 197,832 | 112 |
| B | Distribution | 16 | 1E-10 | 292 | 992 | 1.9E+03 | 616,524 | 192 | 860 | 1670 | 604,784 | 192 |
| B | Distribution | 8 | 1E-10 | 252 | 901 | 1.5E+03 | 496,824 | 152 | 769 | 1270 | 485,084 | 152 |
| B | Dispersion | 16 | 1E-10 | | | | swapping | | | | | |
| B | Dispersion | 8 | 1E-10 | 1965 | 675 | 1.4E+03 | swapping | 1865 | 543 | 1170 | | 1865 |
| B | Dispersion | 8 | 1E-05 | 217 | 593 | 1.4E+03 | 507,124 | 117 | 461 | 1170 | 495,384 | 117 |

FPinM = Fragment Production in Material
FPM = Fragment Production Material

case A => 86Kr->78Ni (one FPM)
case B => 124Sn->78Ni (two FPMs )

background for recommended method

d_time(**) = time(**) - time(no FPinM)

# "Fragment production in Material" methods: RECOMMENDATIONS

| Task | Conditions | Recommended method |
|---|---|---|
| **Calculate total yiled of fragments produced in material** | Primary beam Z < 30, one FPM | Distribution 16 |
| | Primary beam Z < 50, one FPM | Distribution 8 |
| | Primary beam Z < 50, two FPM | Distribution 8 or Gaussian |
| | Primary beam Z > 50 | Gaussian |
| **Calculate intensity of ternary beam *** | Primary beam Z (<50) , Ternary beam dZ(<10) | Dispersion 16 |
| | Primary beam Z (>50), Ternary beam dZ(<10) | Distribution 8 or Gaussian |
| | Primary beam Z (>50) ~ Ternary beam dZ (>10) | Gaussian |

FPinM = Fragment Production in Material

FPM = Fragment Production Material

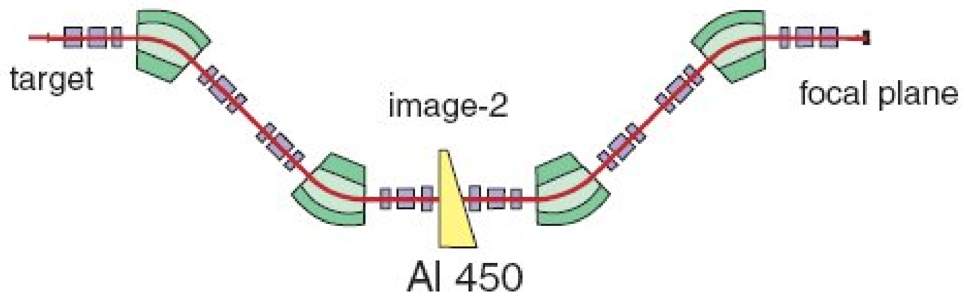
Z - atomic number of primary or ternary beams

dZ = Z(primary beam) - Z(ternary beam)

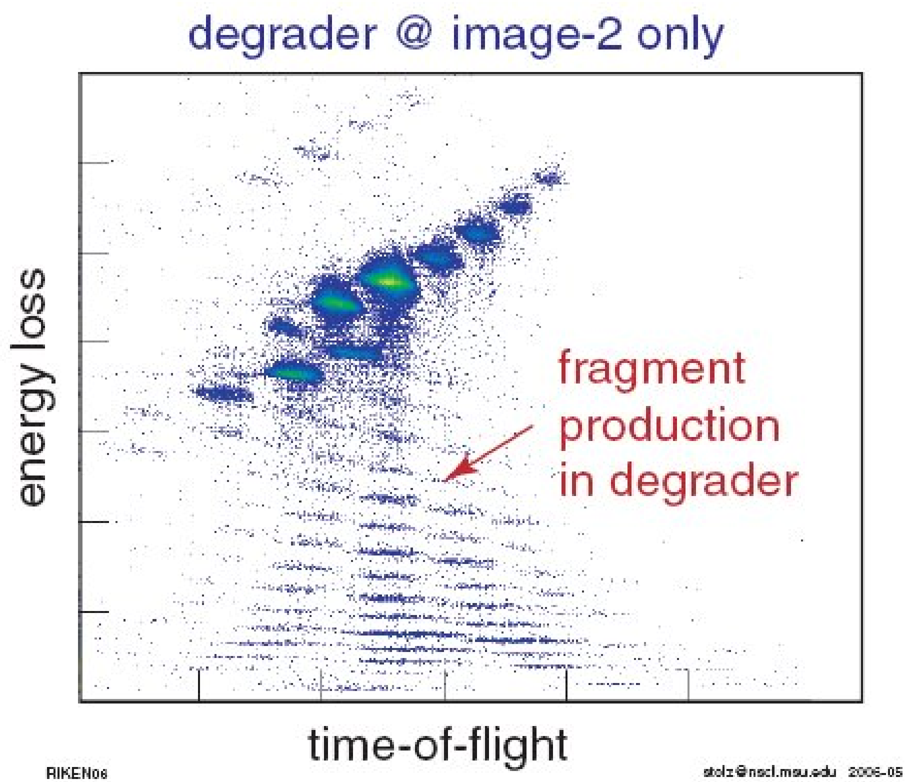
* - Use the "Calculation rectangle of FPinM" possibilty to make calculations faster

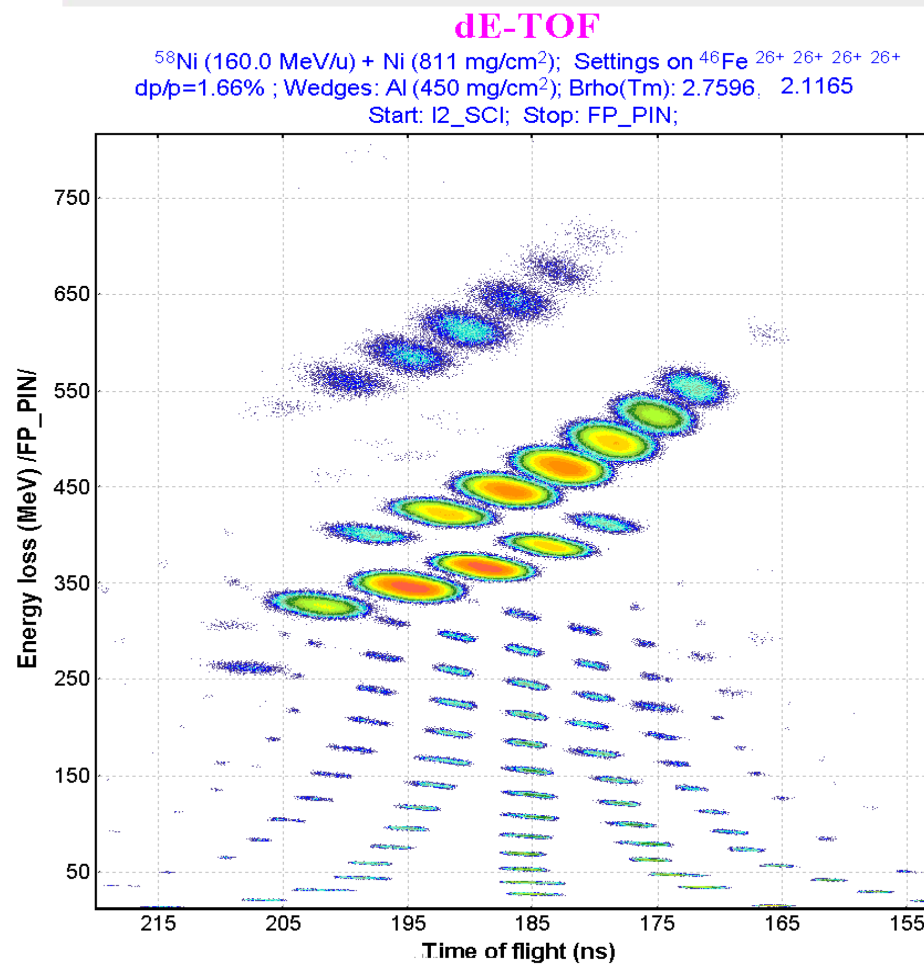
# Comparasion with experimental data

$^{58}$Ni, 160 MeV/u + $^{nat}$Ni, 811 mg/cm$^2$ → $^{46}$Fe




LISE++ simulations

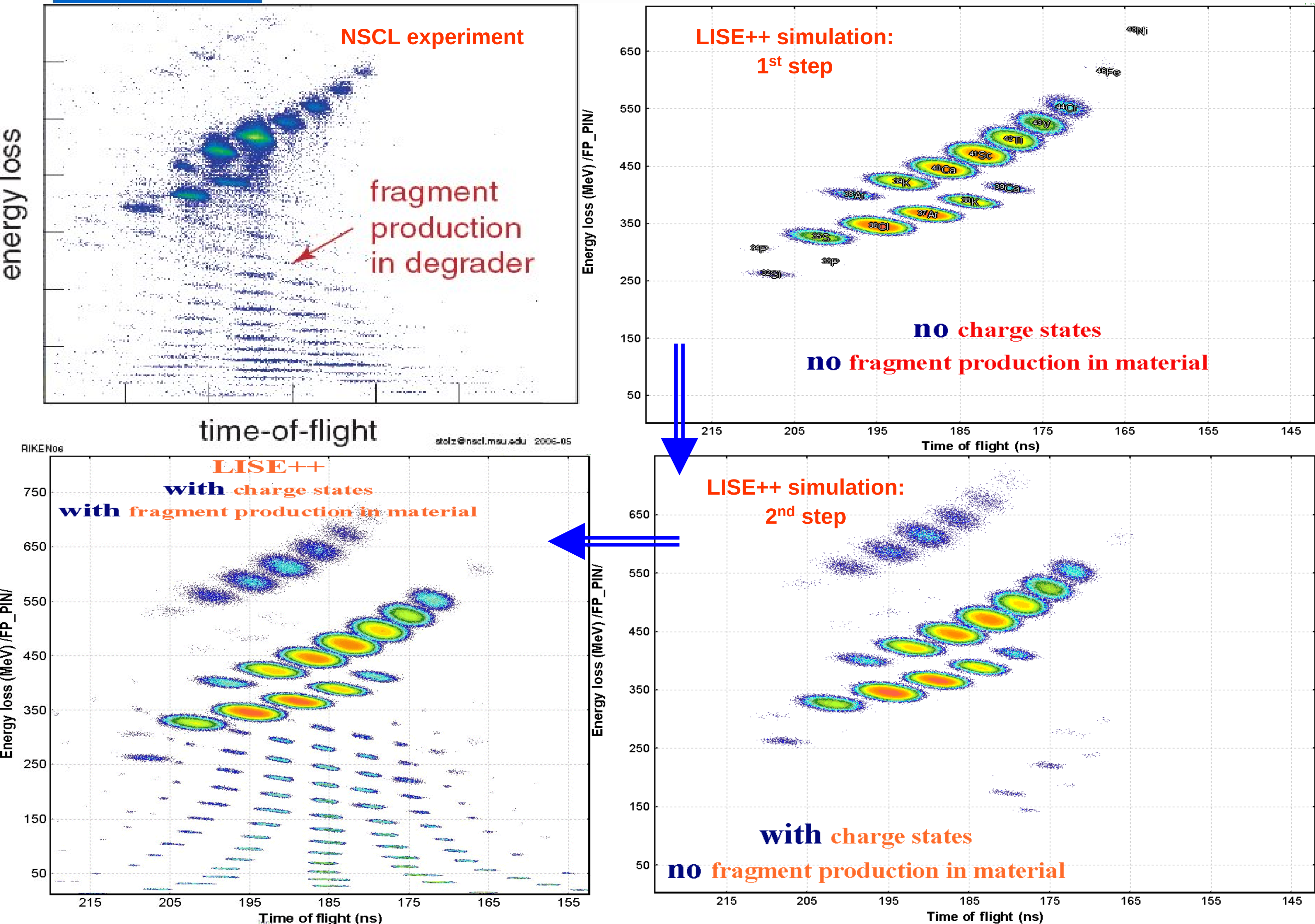





See the next slide for details

# Comparasion with experimental data

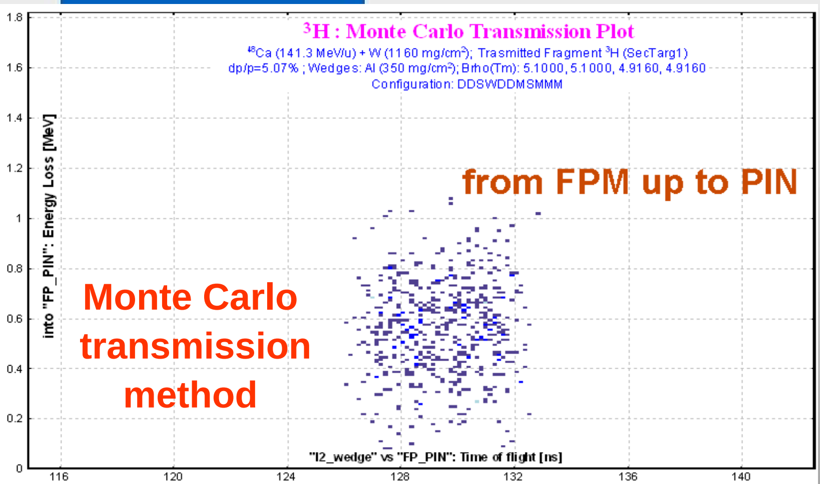


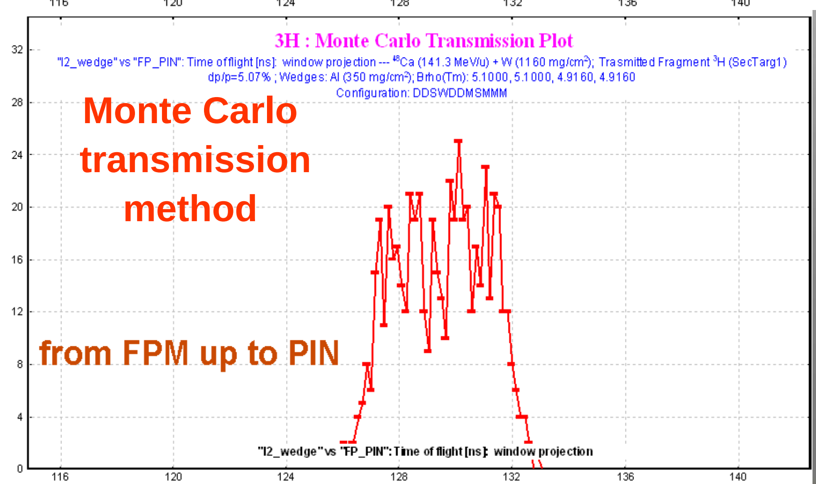
LISE++

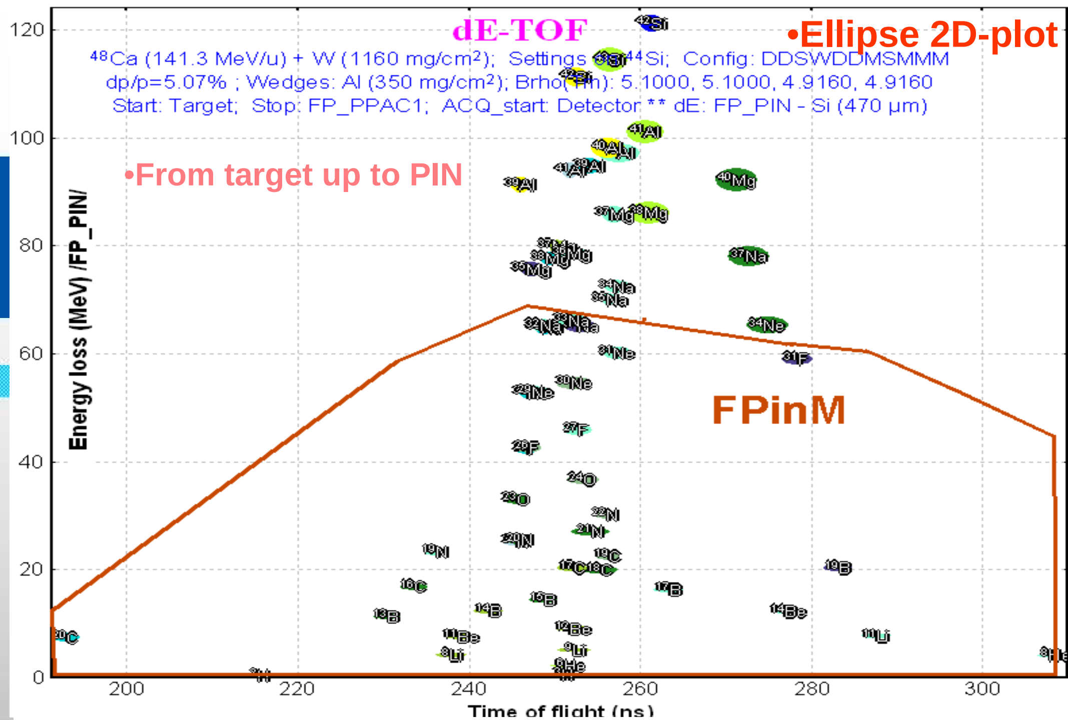
# F.P.in M.& 2D-plots

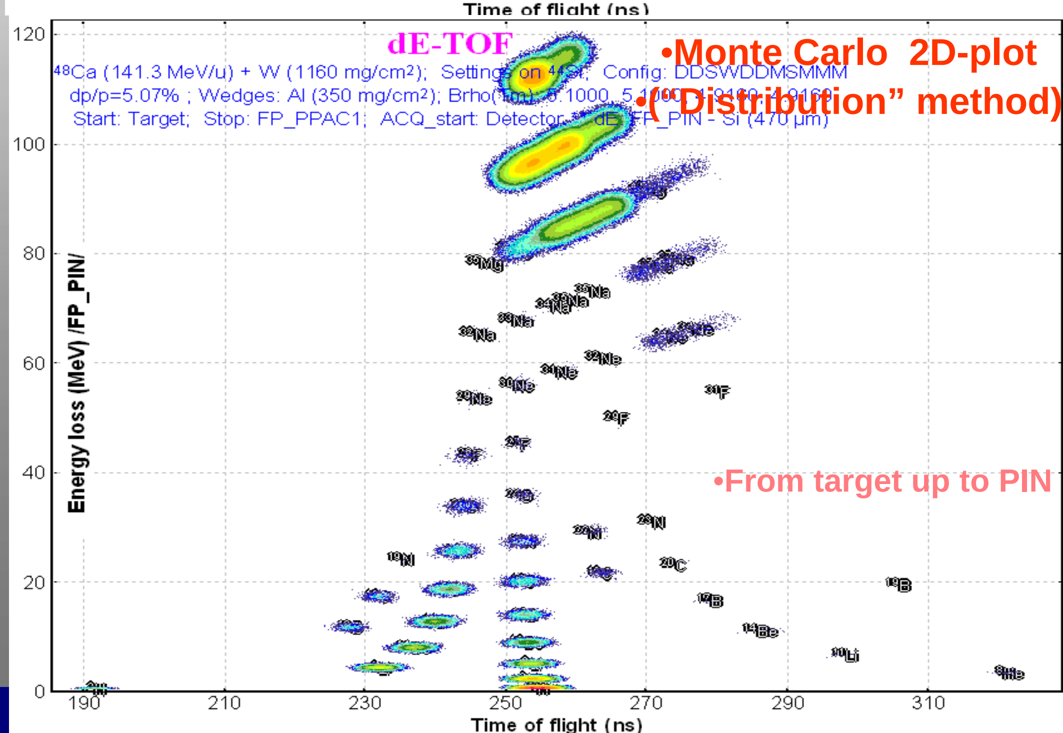
**Ellipse 2D-plot : from target up to the FPM characteristics of the more probable parent fragment are taken.**

**Monte Carlo 2D-plots: it can not be plotted correctly due to limitations of LISE MC plot method: LISE reconstructs a trajectory in that case from last block.**

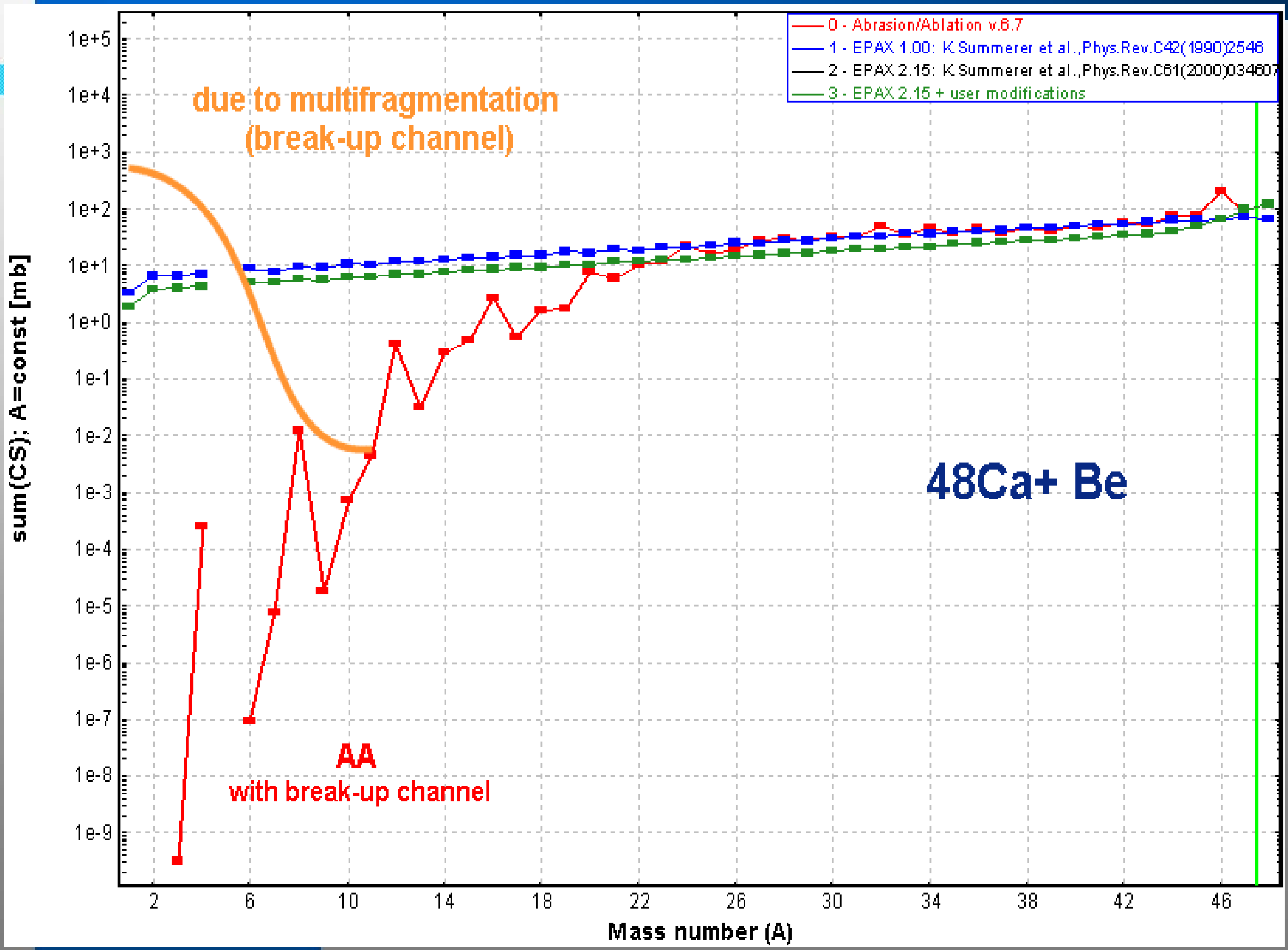


# F.P. in M. : underproduction of light elements EPAX should be modify?




$^{48}Ca$ + Be –> t

$\sigma_{EPAX}$ = 1.9 mb

**From AA calculations**

There are two additional channels to produce tritons: break-up and fragment de-excitation by emitting light particles

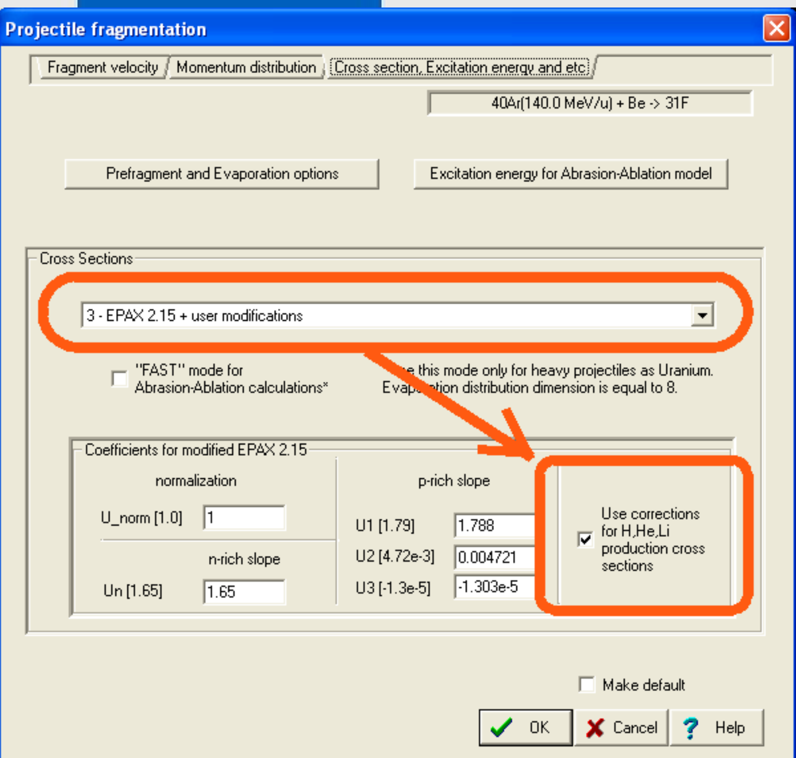
**For $^{48}$Ca+Be**

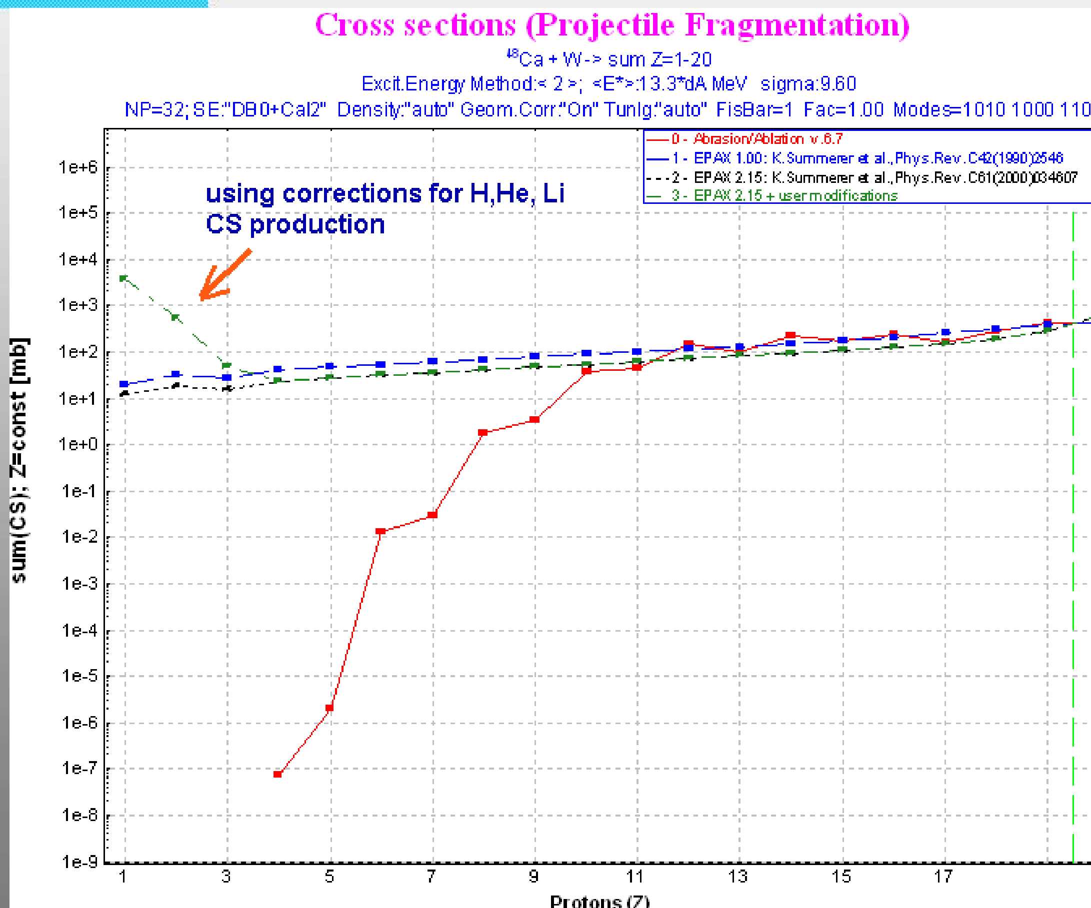
**Break-up: 60 mb**

**Emitted particles (mb)**

| | |
|---|---|
| n: | 3 800 |
| p: | 382 |
| d: | 77 |
| t: | 50 |
| α: | 132 |

# EPAX 2.15 - underproduction of light elements. CS option ~ 3: Use corrections in LISE for H,He,Li production cross sections

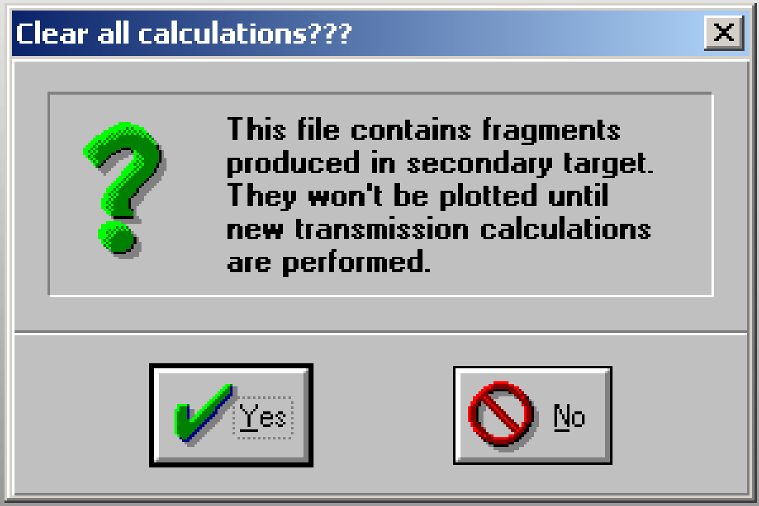


# Some remarks to Fragment production in materials

❖ Transmission results of fragments produced in secondary targets can be saved in the file. The code does not keep all information (LISTs of parent and daughters) in the file. It means when you open this file you are not able to plot results. You can just see transmission statistics.

❖ If you are opening a file which contains information about transmission results of fragments produced in materials, then the code warns you and proposes to clear all calculations (see figure). If you want to plot the data then you need to recalculate.



## Next Steps

- **Optimization for speed: ----- DONE**
  - *Develop "Gaussian" mode to calculate fragment production in secondary target (fast)*
  - *Option to limit a number of parents for one daughter (keep just more intense)*
- **Correct transmission calculations for a reaction target located in the dispersive focal plane ----- DONE**
- **Develop "Ellipse" mode**

  **in the case of fragment production in materials for 2D-plot ----- DONE**
- **Develop "Monte Carlo" mode**

  **in the case of fragment production in materials for 2D-plot ----- DONE**
- **Improve EPAX modification to increase light particle production due to contributions from multifragmentation (break-up channel of AA) and deexcitation of heavy fragments**