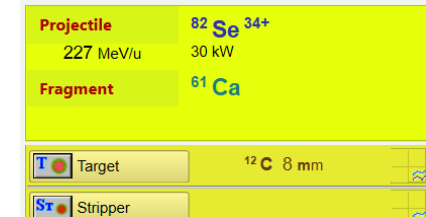


- **Goal:**  
understand why radiation benchmarks need “Light-Z yield factor = 10” vs EPAX3 + Oleg factors.
- Test: simple projectile-fragmentation case in LISE<sup>++</sup> (screenshot at right; comparison below).
- Light-particle production through the breakup-channel of highly excited fragments above the limiting temperature—assumed to undergo multifragmentation—is not included in LISE<sup>++</sup>.
- Multistep reactions in target are not included; they need dedicated study.
- The laboratory-frame kinematics of evaporated light particles must also be analyzed and compared with the current projectile-fragmentation treatment.



|     | Cross sections in mb      |                   |         |                                 |                                                 |
|-----|---------------------------|-------------------|---------|---------------------------------|-------------------------------------------------|
|     | EPAX3 +<br>Oleg's factors | EPAX3<br>original | AA      | evaporated<br>particles<br>(AA) | Ratio AA light<br>particles vs<br>EPAX3+factors |
| n   |                           |                   |         | 5.60E+03                        |                                                 |
| p   | 160                       | 0.4               | 2.3E-02 | 1.12E+03                        | 7.0                                             |
| d   | 310                       | 0.7               |         | 2.48E+02                        | 0.8                                             |
| t   | 150                       | 0.35              | 1.1E-06 | 1.35E+02                        | 0.9                                             |
| 3He | 28                        | 0.43              | 6.5E-08 | 3.70E+01                        | 1.3                                             |
| 4He | 52                        | 0.8               | 1.2E-04 | 3.79E+02                        | 7.3                                             |

**Evaporation alone gives  $\geq 7\times$  higher p and  $^4\text{He}$  yields than EPAX3 + Oleg factors.**

Factor 10 is plausible for radiation benchmarks, but remains empirical until breakup and multi-step reactions are modeled.

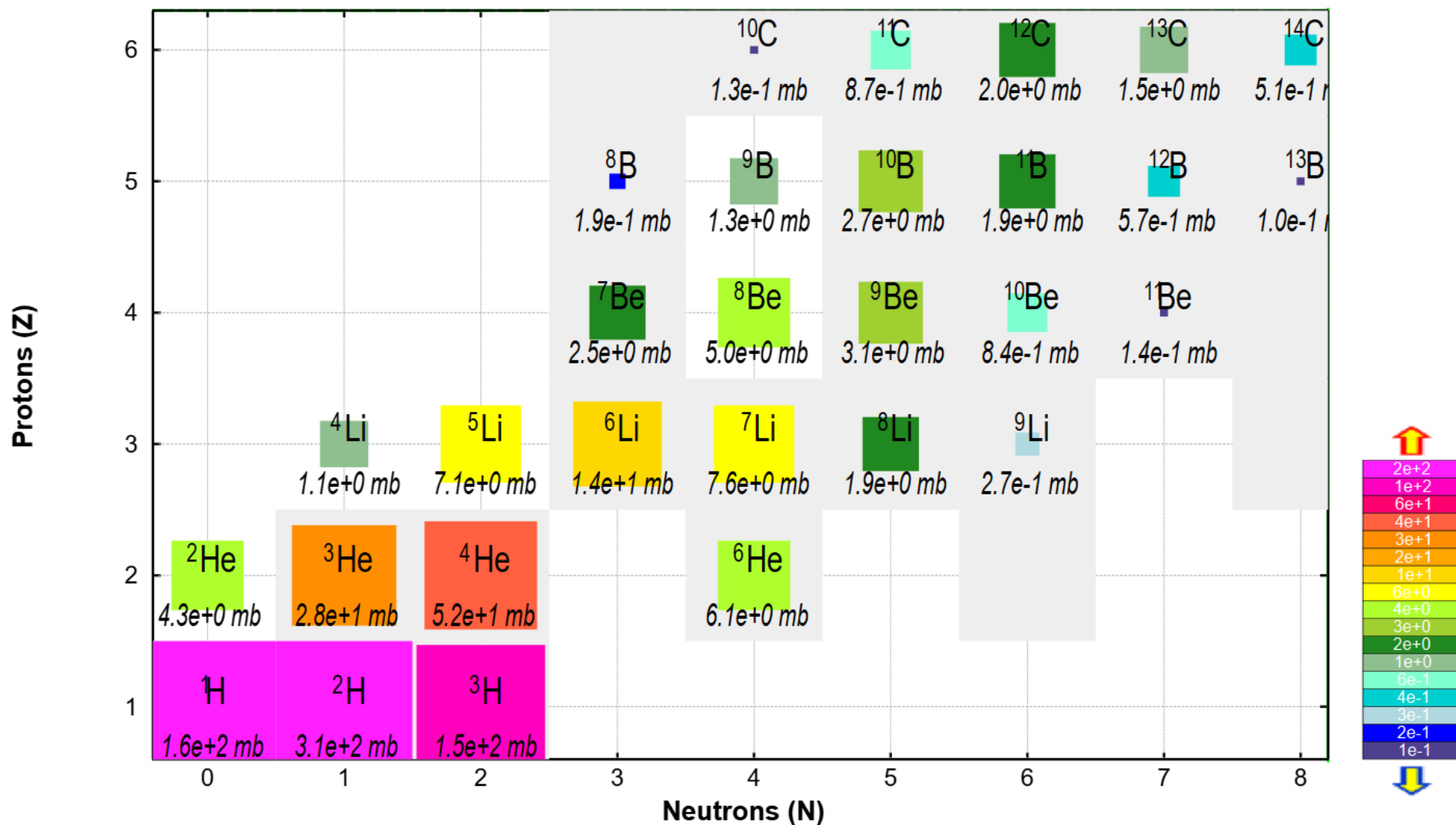
Based on the analysis presented here, which indicates that additional enhancement is required only for proton and alpha-particle yields, while the calculated yields of other light charged particles appear to be consistent with the model, an additional multiplicative **factor of 7** was applied to the **proton** and **alpha**-particle production cross sections in LISE<sup>++</sup> version 18.5.13.

This provides **consistency** between standard LISE<sup>++</sup> production-rate calculations, including power-deposition estimates, and the Prompt Radiation Calculator using a Light-Z yield *factor of 1*.

## Cross sections (Projectile Fragmentation)

$^{82}\text{Se}$  (227 MeV/u) + C  $\rightarrow$  N=0-10

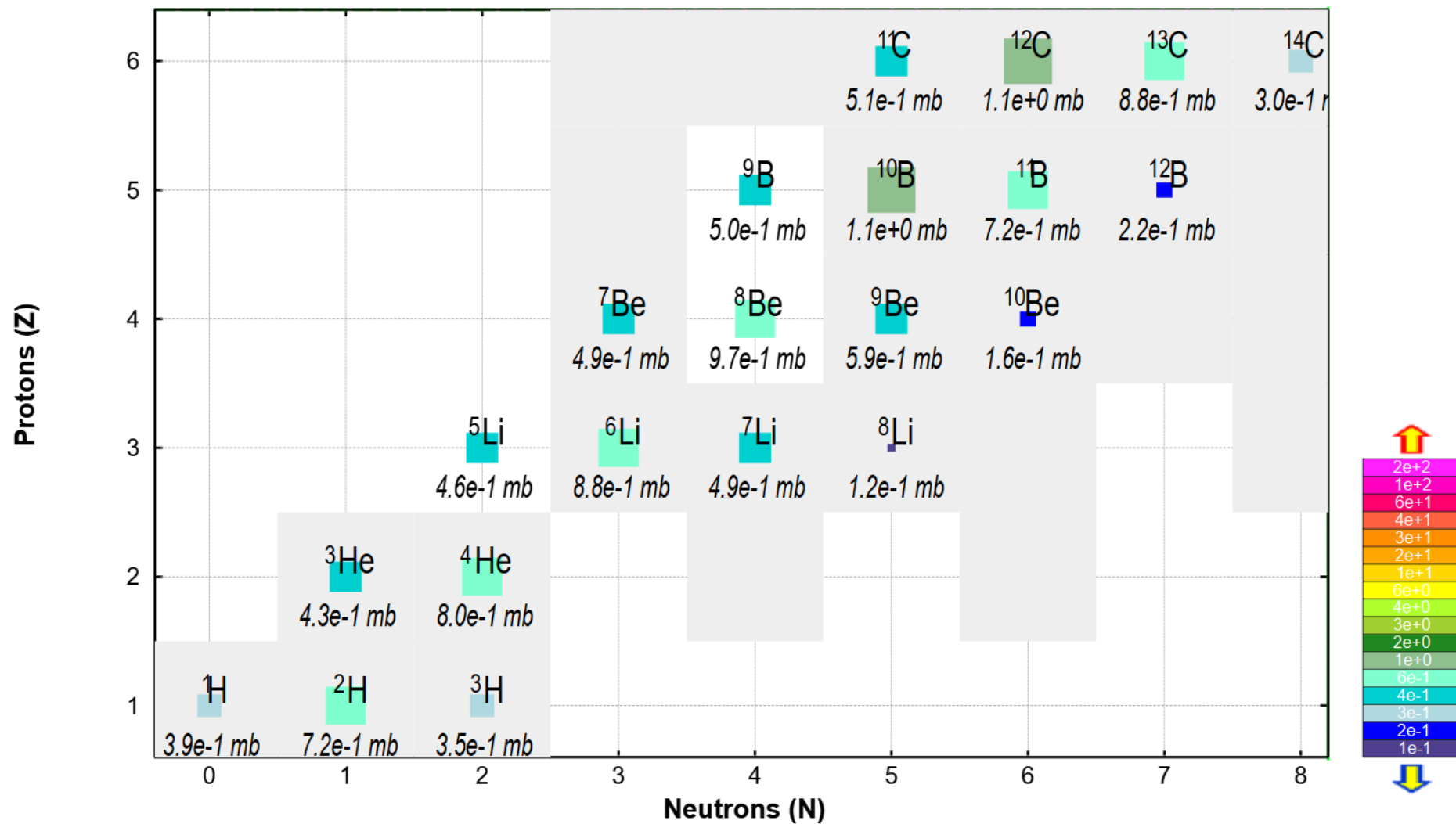
Method: 4 - EPAX 3.1a: K.Summerer,Phys.Rev.C86(2012)014601

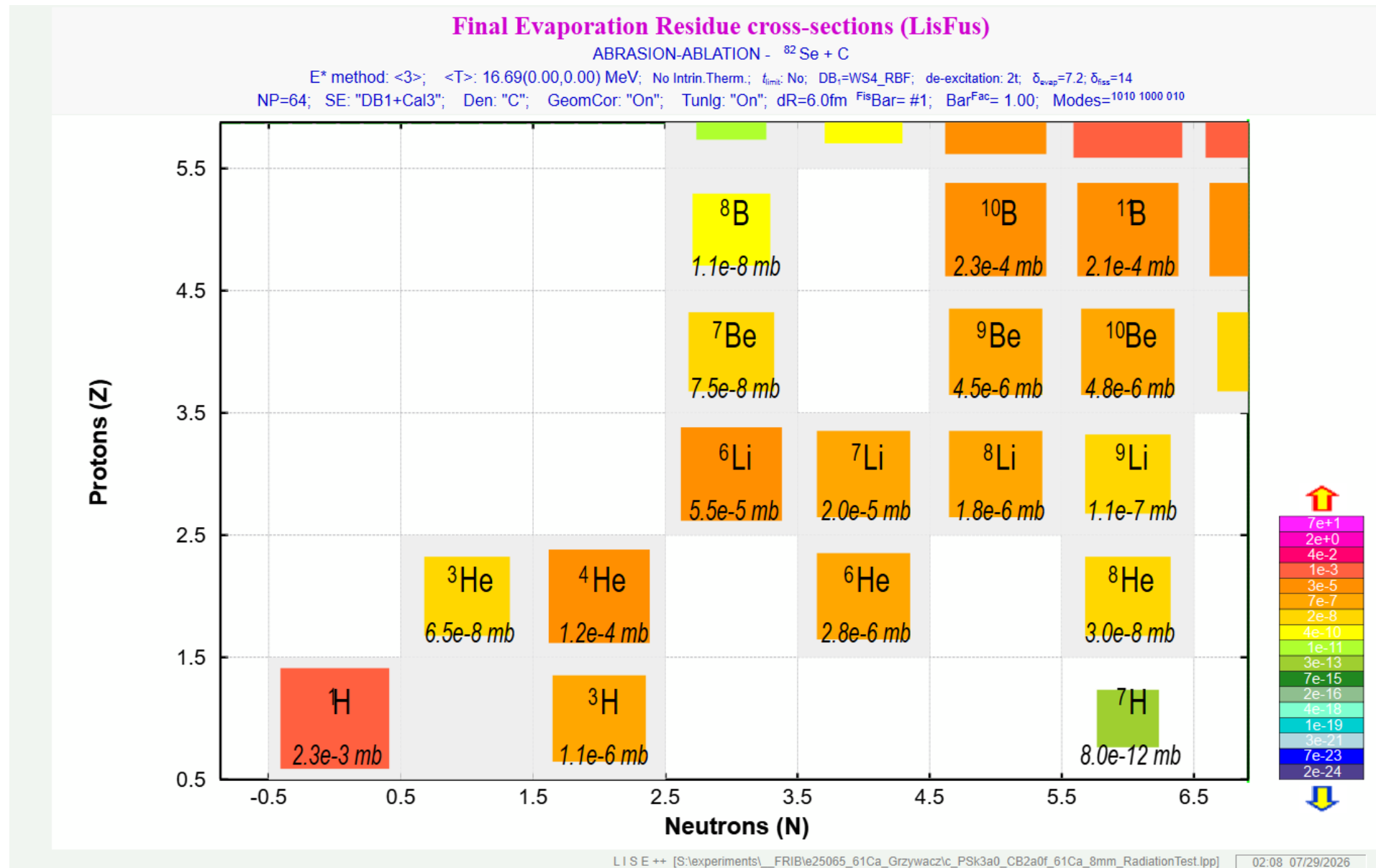


## Cross sections (Projectile Fragmentation)

$^{82}\text{Se}$  (227 MeV/u) + C  $\rightarrow$  N=0-10

Method: 4 - EPAX 3.1a: K.Summerer,Phys.Rev.C86(2012)014601





Initial excited nucleus

Initial nucleus

<sup>82</sup>Se

Initial nucleus production cross-section =  mb

make calculations down to Z =

Excitation energy window

Lower =  MeV

☒ gaussian

Upper =  MeV

☐ rectangle

Modes

☒ Fragmentation of beam (Abrasion-Ablation)
   
☐ Excited nucleus evaporation
   
☐ Load initial conditions from file

2D-plots

Final Evap.Residue CS

Decay channel analysis

Fission channel CS

Temperature

Break-up channel CS

Fission Excitation Energy

CALCULATE

Evaporation settings

A    Element    Z

60    Ca    20

$\beta^-$  decay

Table of Nuclides

←

Z=20

→

←

N=40

→

Excitation energy

Number of all calculated nuclei

1363

Final nucleus

Cross sections

Final fragment production cross-section

1.71e-13

mb

Initial production CS of Final fragment (for fragmentation or file options)

1.38e-01

mb

Cross section from EPAX 2.15

4.85e-12

mb

Separation energies, barrier

Minimum separation energy (SE)

2.61

MeV

Minimum sum of ( SE + deduced effective Coulomb barrier)

2.61

MeV

Fission barrier at L=0

45.28

MeV

Average values

< E\* > =

301.26

< T > =

6.01

< E\*<sub>fission</sub> > =

307.39

Channels

|             |          |          |          |          |          |                 |          |          |
|-------------|----------|----------|----------|----------|----------|-----------------|----------|----------|
| PARENT      | 1.60e-01 | 2.13e-02 | 2.95e-03 | 8.67e-03 | 6.85e-03 | 5.75e-04        | 2.00e-01 | 61Ca     |
| Decay modes | n        | p        | $\alpha$ | d        | t        | <sup>3</sup> He | Fission  | Break-up |
| DAUGHTER    | 3.19e-01 | 4.84e-03 | 1.31e-03 | 5.03e-03 | 8.02e-03 | 1.32e-04        | 1.35e-06 | 1.10e-09 |
|             |          |          |          |          |          |                 | 3.38e-01 | 59Ca     |
| Sum         | 5.59e+03 | 1.08e+03 | 3.79e+02 | 2.43e+02 | 1.34e+02 | 3.70e+01        | 7.68e+02 | 8.95e+02 |
|             |          |          |          |          |          |                 | 1.43e-01 | 8.18e+01 |

Output cross-section file ☐ 08234\_01206.lcs 

Browse

Show

Output file of parent daughter references ☐ 08234\_01206.lpd 

Browse

Show

Fission CS output file ☐ 08234\_01206.lfcs 

Browse

Show

Initial Prefragment Plot for final nucleus

Initial Fissile nucleus plot for final fragment