

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

- Introduction. Settings
- Statistics of FPinM
- Kinematics
- Methods to calculate FPinM
 - Description
 - Comparison
 - Benchmarks
 - Recommendation
- Comparison with experimental data
- FPinM & 2D-plots
- EPAX 2.15 – underproduction of light elements
- Some remarks and Next steps

Introduction. Settings

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

I2_wedge

Al Density [g/cm³] 2.702

calculate reactions in this material

Z	Element	Mass
<input checked="" type="checkbox"/>	13 Al PT	26.982
<input type="checkbox"/>	14 Si	28.086
<input type="checkbox"/>	14 Si	28.086
<input type="checkbox"/>	14 Si	28.086
<input type="checkbox"/>	14 Si	28.086

Compound dictionary

State: Solid Gas

Dimension: mg/cm² g/cm²

Thickness at 0 degree: 740.19245 mi 200 mg

Degrader profile: Wedge profile Homogeneous Curved profile

General setting of block

OK Cancel

Pink background shows that reactions will be calculated in this material

T	Target	Be 758.749 mg/cm ²
Str	Stripper	
D	D1	Brho 5.2960 Tm
S	I1_slits	slits -100 H +100
D	D2	Brho 5.2960 Tm
S	I2_slits	slits -150 H +150
W	I2_wedge	Al 300.098 mg/cm ²
M	I2_SCI	C9H10 254 micron
D	D3	Brho 5.1398 Tm
D	D4	Brho 5.1398 Tm
M	FP_PPACD	Al 2 mg/cm ²
S	FP_slits	slits -25 H +25
M		Si

Up to three secondary targets can be 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

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 transmiss. (%)	100	100	96.01
Y angular transmiss. (%)	100	100	81.3
I1_slits (%)	100	100	52.18
X space transmission (%)	100	100	52.18
Y space transmission (%)	100	100	76.66
Unreacted in mater. (%)	100	100	100
Unstopped in mater. (%)	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 transmiss. (%)	23.41	23.9	100

shows ratio of projectile intensities between secondary and primary targets

100% transmission up to secondary target

in: A1300_200SB
ion: 7.10 5 beta
5.07% total



Projectile Fragmentation

31Ne	32Ne	33Ne	34Ne	35Ne	36Ne	37Ne	38Ne	39Ne
	9.97e-3 0.351%	3.89e-2 17.217%	4.12e-3 24.419%	1.29e-4 10.759%	1.11e-6 1.35%	9.8e-10 0.018%		
30F	31F	32F	33F					
8.91e-4 0.164%	3.71e-3 1.081%	1.22e-4 5.249%	1.06e-6 0.76%					
29O								

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

Ncalc=127

Sum=1.1

No cl

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

Options Calculations Utilities 1D-Plot 2D-Plot Data

Preferences
 Production Mechanism
 Prefragment Search and Evaporation options
 Excitation energy of prefragment

Cross Sections
 Cross Section File
Options of Fragment Production in Material (wedge)
 Secondary Reactions in target
 Isotopes

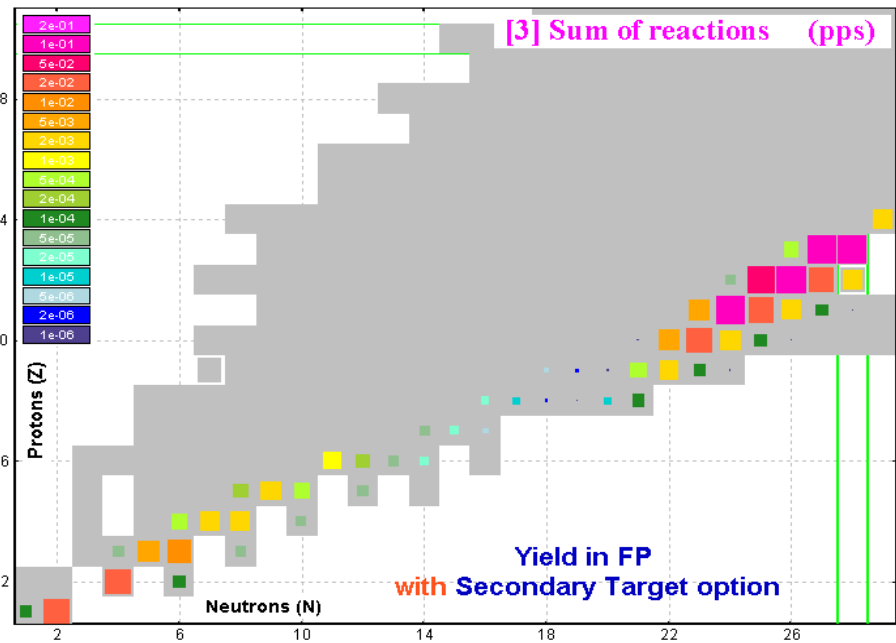
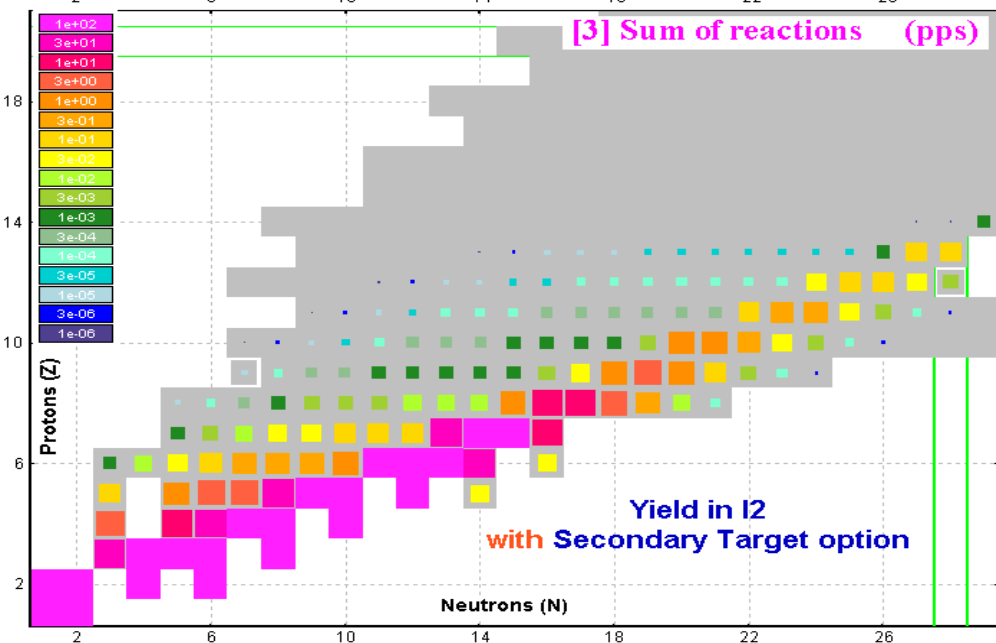
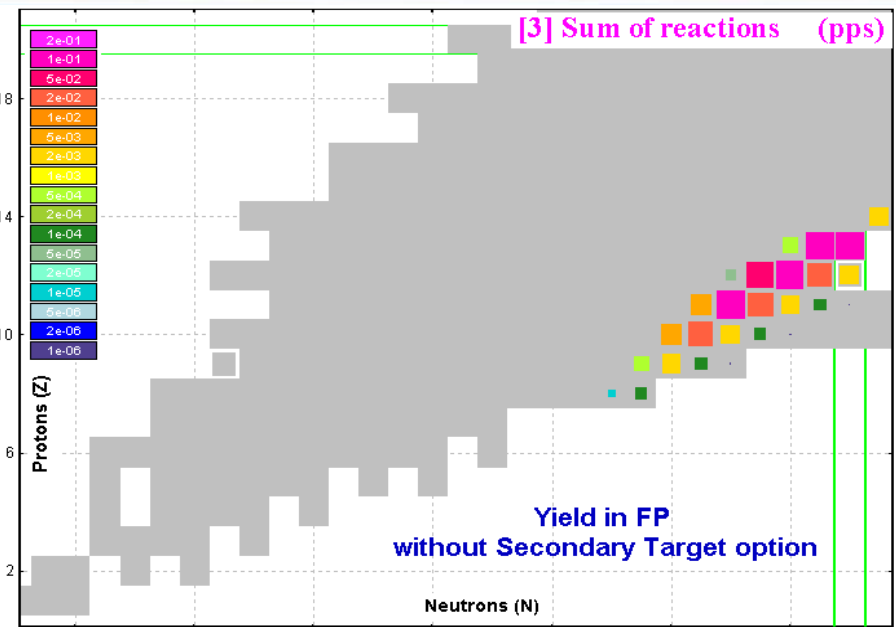
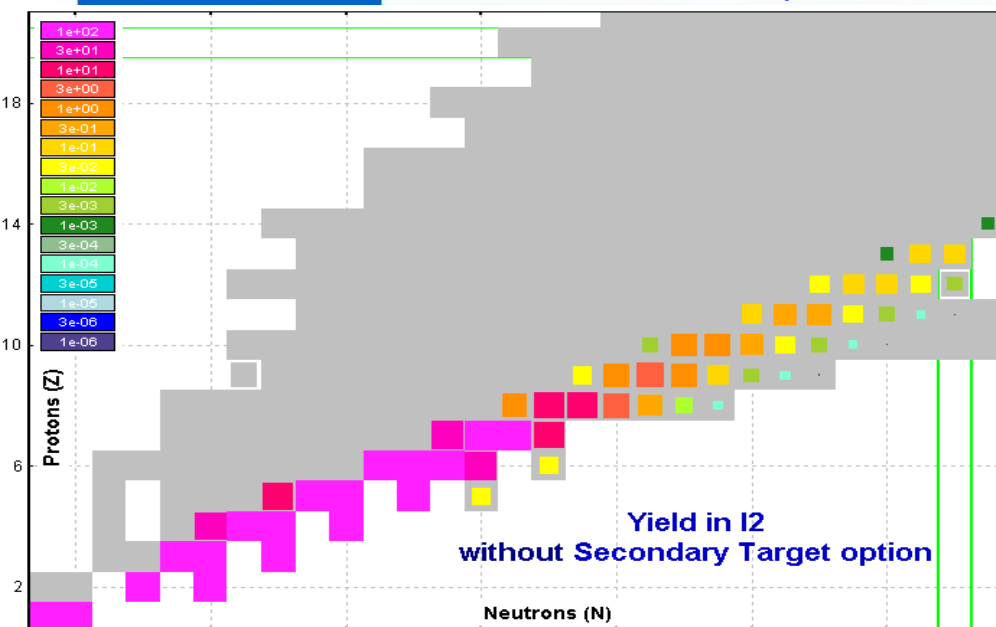
Options of Fragment Production in Material (wedge)

	ACCURATE	FAST									
Dimension of distributions used for fragment production calculations in Material or Wedge	<input checked="" type="radio"/> 16	<input type="radio"/> 8									
Use fragments produced in Material (Wedge) for fragment production in the following Material or Wedge with the "Calculate fragment production" option turned on	<input type="radio"/> Yes	<input checked="" type="radio"/> No									
Method to calculate kinematics of fragment produced in Material or Wedge	<input checked="" type="radio"/> "Distribution"	<input type="radio"/> "Gaussian"	<input type="radio"/> "Dispersion" (special case)								
Rate Threshold for the parent-daughter link	<input type="text" value="1e-8"/> pps	<input checked="" type="radio"/> set all to "Accurate" <input type="radio"/> set all to "Fast"									
<input checked="" type="checkbox"/> Show statistics of fragment production in Materials (Wedges) <input type="checkbox"/> Make default	Calculation Rectangle of fragments produced in Material * DAUGHTER region * first corner => <input type="text" value="1H"/> min <table border="1"><tr><td>Z</td><td>N</td></tr><tr><td>1</td><td>0</td></tr></table> second corner => <input type="text" value="48Ca"/> max <table border="1"><tr><td>Z</td><td>N</td></tr><tr><td>20</td><td>28</td></tr></table>			Z	N	1	0	Z	N	20	28
Z	N										
1	0										
Z	N										
20	28										
<input type="button" value="Ok"/>	<input type="button" value="Cancel"/>										

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

Ca	42Ca	43Ca	44Ca	45Ca	46Ca	47Ca	48Ca
K	41K	42K	43K	44K	45K	46K	47K
Ar	40Ar	41Ar	42Ar	43Ar	44Ar	45Ar	46Ar
Cl	39Cl	40Cl	41Cl	42Cl	43Cl	44Cl	45Cl
S	38S	39S	40S	41S	42S	43S	44S
P	37P	38P	39P	40P	41P	42P	43P
Si	36Si	37Si	38Si	39Si	40Si	41Si	42Si
Al	35Al	36Al	37Al	38Al	39Al	40Al	41Al

primary beam

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 cleared 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

Calculations Utilities 1D-Plot 2D-Plot Databases Help

Tune spectrometer for setting fragment on beam axis
 Tune spectrometer for setting fragment at middle of slit
 Goodies
 Calibrations

Transmission and rate

- Optimum Target
- Optimum Target-Wedge and Wedge-Wedge configurations
- Brho scanning
- Optimum charge state combination

Physical Calculator
 Kinematics Calculator
 Mathematical Calculator
 Evaporation Calculator
 Fusion-Residue Calculator
 Matrix Calculator

One nucleus
 Area of nuclei
 All nuclei
 Previous calculated area
 Transmission statistics
Secondary production target statistics
 Clear rate calculations
 Clear All AA,FR,FF,CF,AF, and Sec.React calculations

	40p	41p	42p	43p
--	-----	-----	-----	-----

Choose the material from the list if them more than one

Secondary Target Statistics

Secondary target: #1: I2_wedge
 #1: I2_wedge
 #2: I2_SCI

Number of parents: 66
 Number of daughters: 194
 Number of links: 5000

Total intensity of parent nuclei before the secondary target: 1.91e+06 pps
 Total intensity of daughter nuclei after the secondary target: 1.36e+03 pps

Partial analysis

Parent (outcoming)
 Daughter (incoming)

Choose fragment
 40Mg
 Number of daughters: 150

Show links

Generate the all-link table Quit

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 nb
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

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     9       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
```

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

Statistics of fragment production in materials

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

N ^o	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
49	1H	15C	9	105.17	56.22	8.05e-01	5.36e+00

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

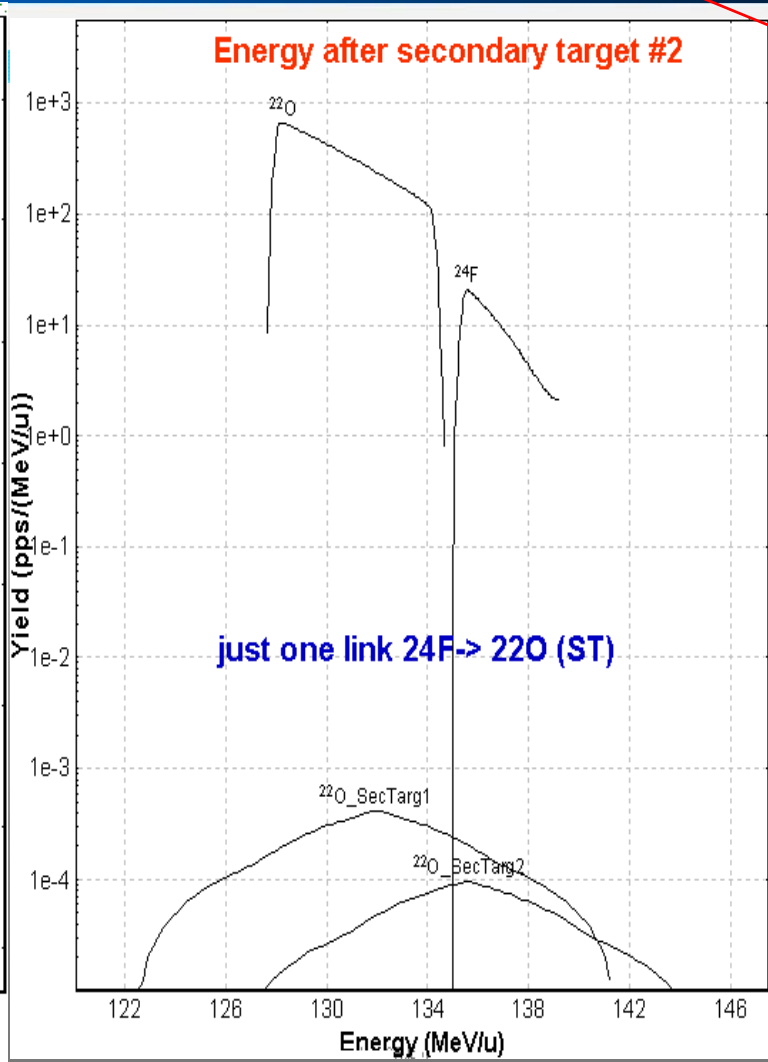
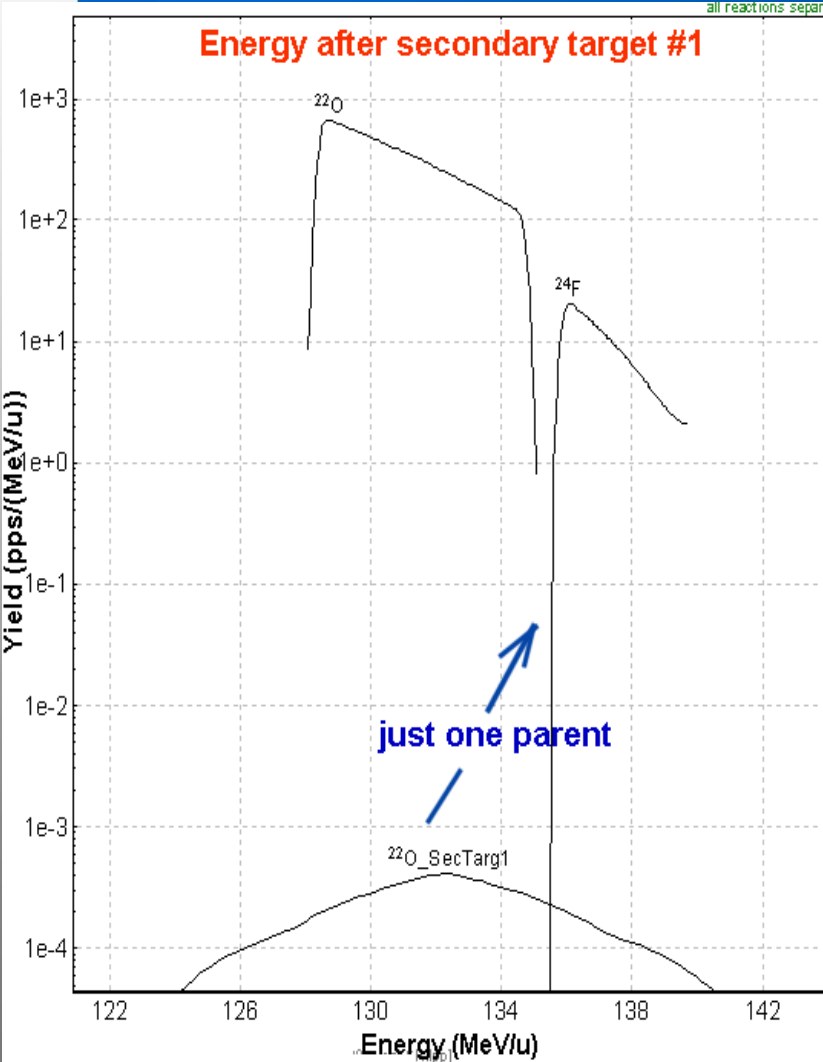
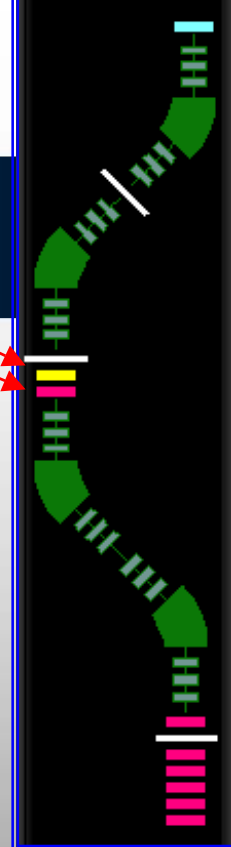
The size of this file about 1 MB.

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

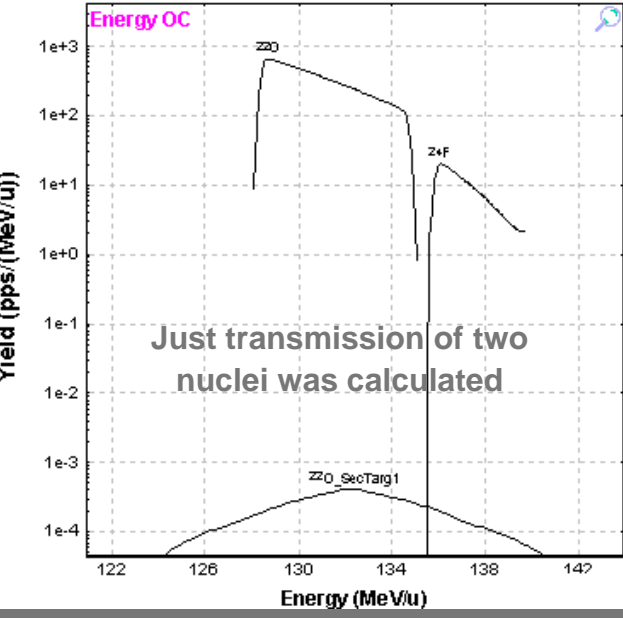
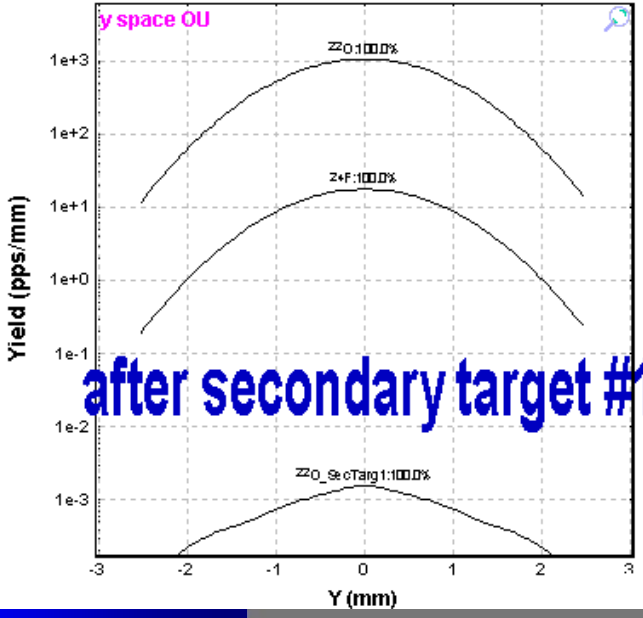
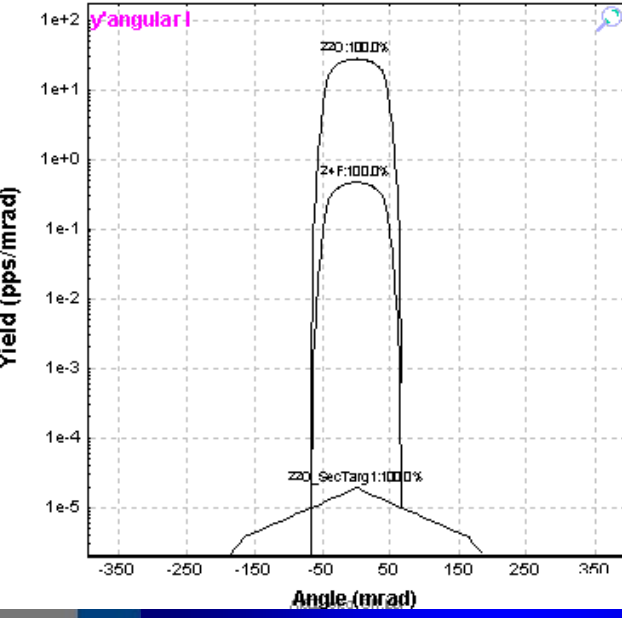
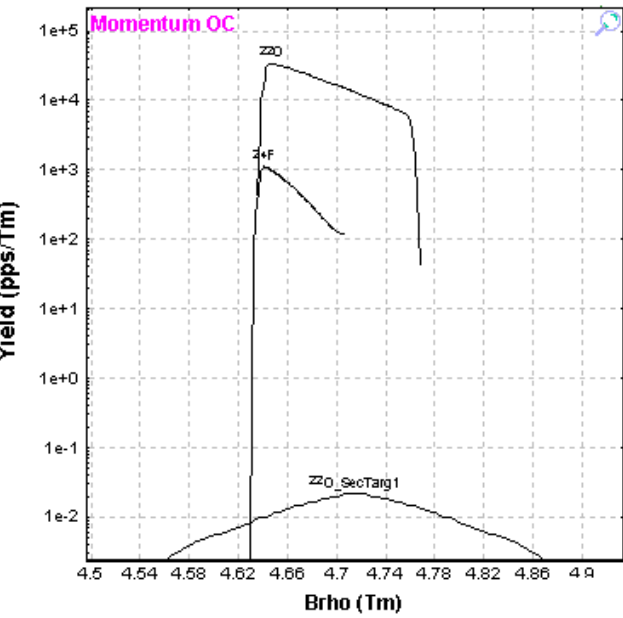
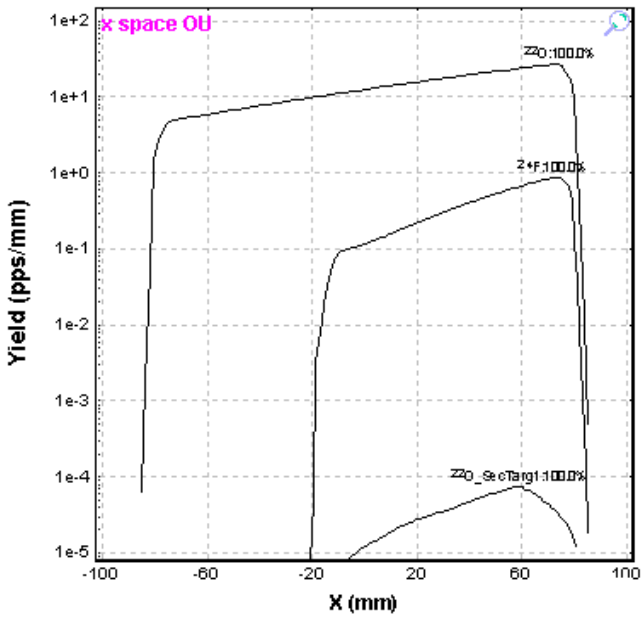
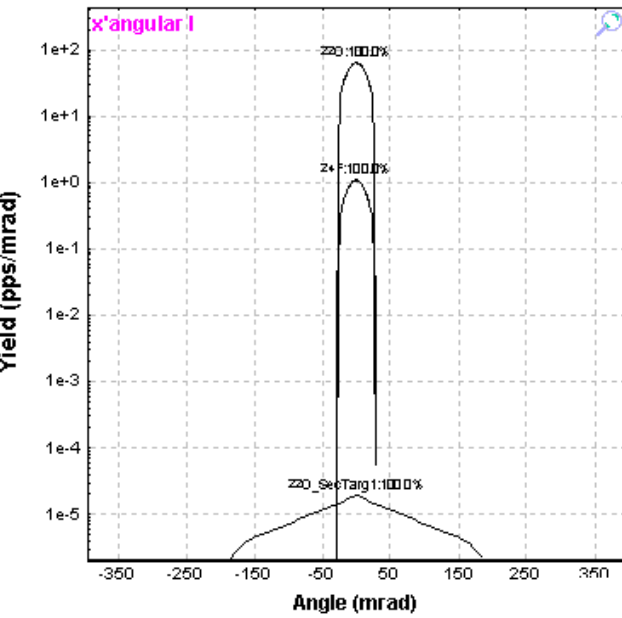
Kinematics of fragments produced in materials

Just transmission of two nuclei was calculated

reaction target #1
reaction target #2

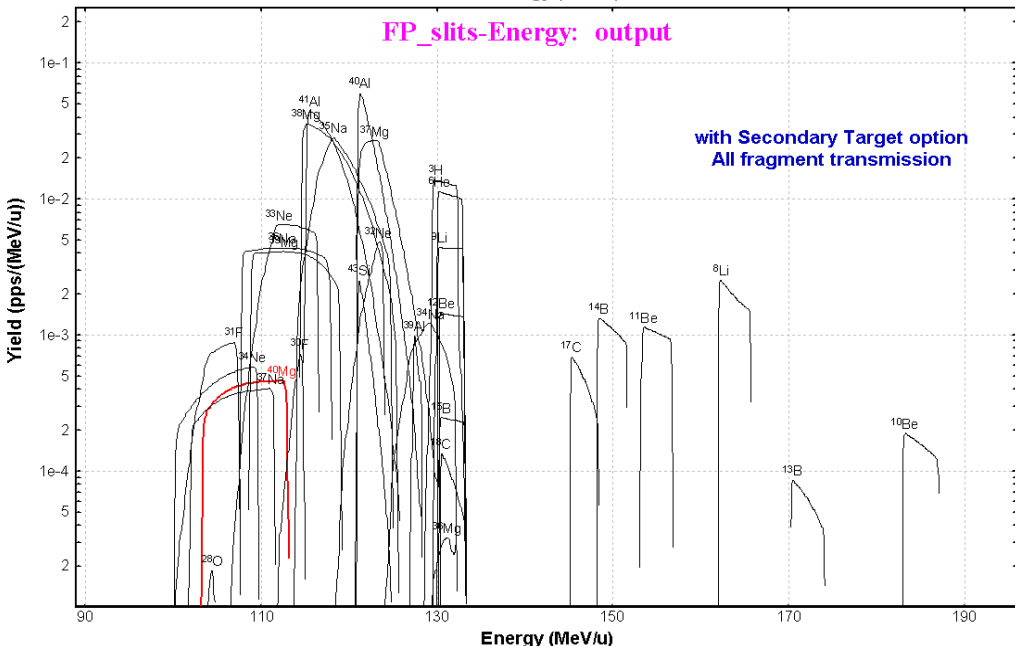
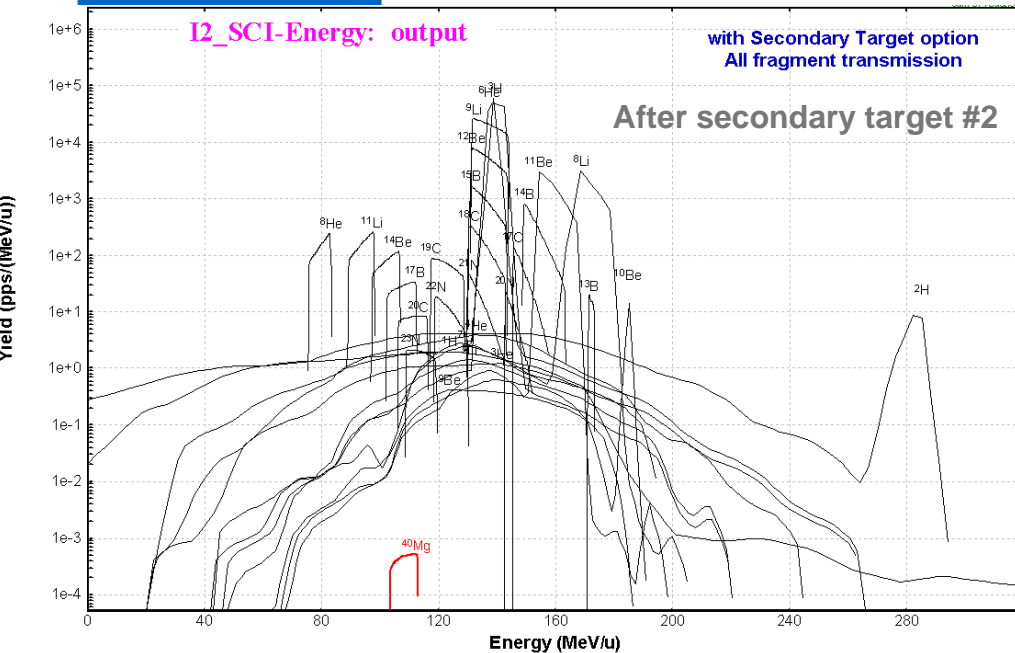


Kinematics of fragments produced in materials



after secondary target #1

Kinematics of fragments produced in materials (wedges)



Secondary Target Statistics

Secondary target: #1: I2_wedge

Number of parents: 66
Number of daughters: 194
Number of links: 5000

Total intensity of parent nuclei before the secondary target: 1.91e+06 pps
Total intensity of daughter nuclei after the secondary target: 1.36e+03 pps

Generate the all-link table Quit

Partial analysis
 Parent (outcoming)
 Daughter (incoming)
Choose fragment
40Mg
Number of daughters: 150
Show links

Secondary Target Statistics

Secondary target: #2: I2_SCI

Number of parents: 260
Number of daughters: 194
Number of links: 19327

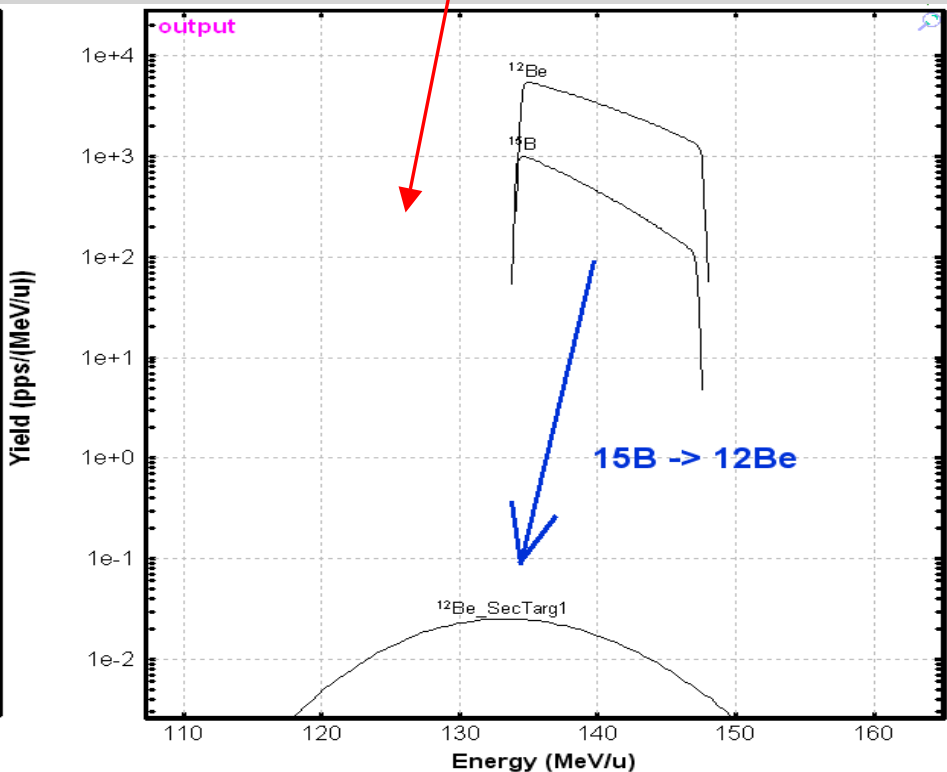
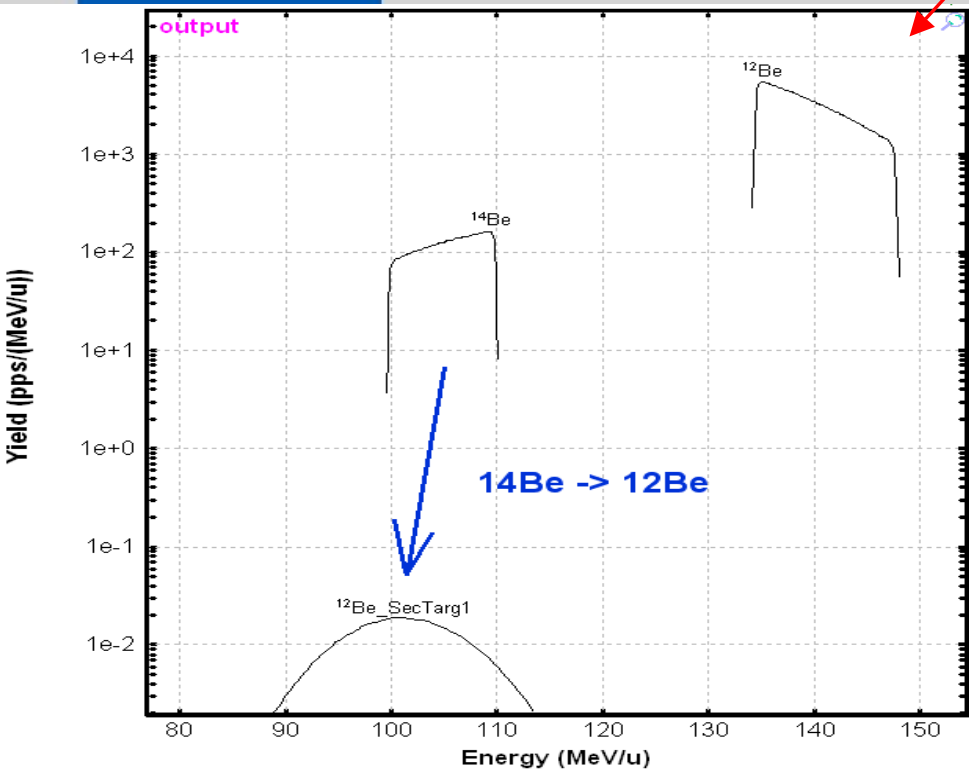
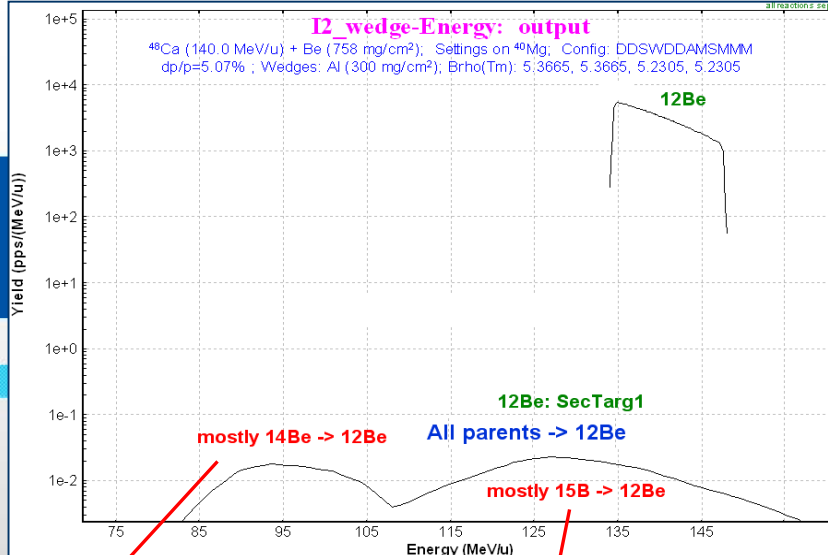
Total intensity of parent nuclei before the secondary target: 1.91e+06 pps
Total intensity of daughter nuclei after the secondary target: 2.28e+02 pps

Generate the all-link table Quit

Partial analysis
 Parent (outcoming)
 Daughter (incoming)
Choose fragment
40Mg
Number of daughters: 300
Show links

File "06506_40Mg_Al300_SR.lpp"

Parent contribution (Kinematics)



"Distribution" method - fast copy of processes in the primary target

Parent	LINK	Daughter
<i>5 distributions (dimension NP=8)</i>		
X – horizontal spatial	$X = X_{\text{parent}}$	Sum of all link X distributions
X' - horizontal angular	$X' = X'_{\text{parent}} \otimes X'_{\text{reaction}}$	Sum of all link X' distributions
Y – vertical spatial	$Y = Y_{\text{parent}}$	Sum of all link Y distributions
Y' – vertical angular	$Y' = Y'_{\text{parent}} \otimes Y'_{\text{reaction}}$	Sum of all link Y' distributions
E – energy distribution before target	$E = E_{\text{straggling}} \otimes E_{\text{rectangle}} \otimes E_{\text{goldhaber}} \otimes E_{\text{parent}}$ Rectangle → due to energy loss difference in target between projectile and fragment Egoldhaber → contribution due to reaction	Sum of all link E distributions All distribution areas are normalized on link intensities
<i>Properties</i>		
I – intensity (pps)	$I = I_{\text{parent}} * \sigma \text{ (EPAX)} * \text{Thickness(atoms)}$	I – sum of all link intensities σ – reduced cross section

No correlation between X & E

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

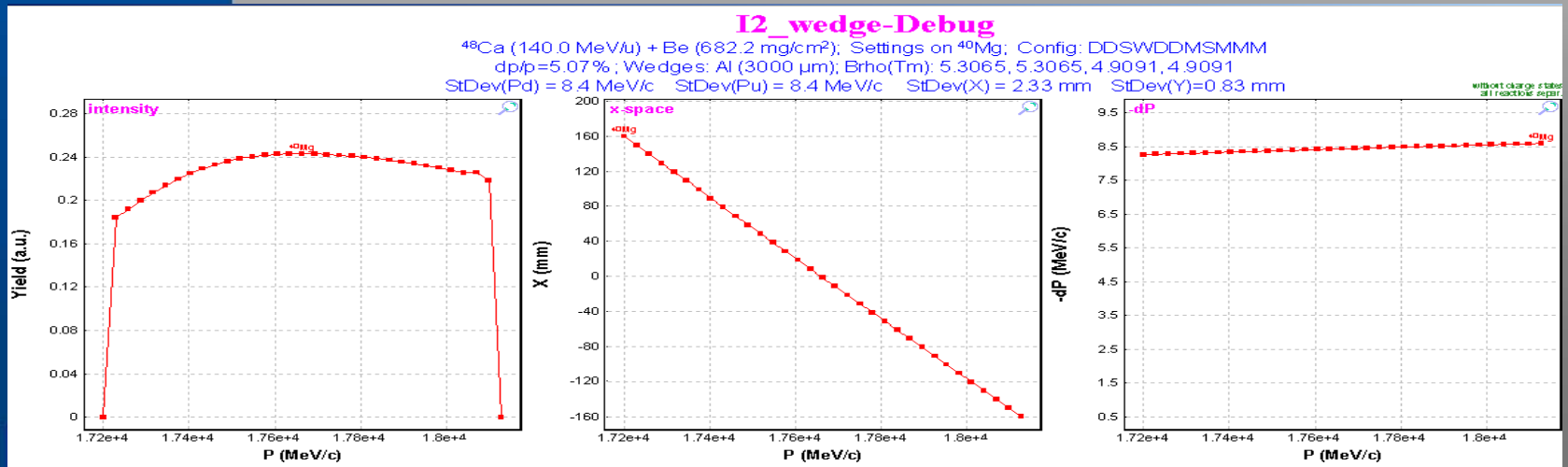
Parent	Intermediate result	Link	Daughter
X – horizontal spatial	$X = X_{\text{parent}}$	$\langle X \rangle, \sigma(X)$	Sum of Gaussians ($\langle X_i \rangle, \sigma(X_i)$)
X' - horizontal angular	$X' = X'_{\text{parent}} \otimes X'_{\text{reaction}}$	$\langle X' \rangle, \sigma(X')$	Sum of Gaussians ($\langle X'_i \rangle, \sigma(X'_i)$)
Y – vertical spatial	$Y = Y_{\text{parent}}$	$\langle Y \rangle, \sigma(Y)$	Sum of Gaussians ($\langle Y_i \rangle, \sigma(Y_i)$)
Y' – vertical angular	$Y' = Y'_{\text{parent}} \otimes Y'_{\text{reaction}}$	$Y', \sigma(Y')$	Sum of Gaussians ($\langle Y'_i \rangle, \sigma(Y'_i)$)
E – energy distribution before target	$E = E_{\text{straggling}} \otimes E_{\text{rectangle}} \otimes E_{\text{goldhaber}} \otimes E_{\text{parent}}$ Rectangle → due to energy loss difference in target between projectile and fragment Goldhaber → contribution due to reaction	$\langle E \rangle, \sigma(E)$	Sum of Gaussians ($\langle E_i \rangle, \sigma(E_i)$) 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
<p>Input parent "DistrFour" class</p> <p>Set of correlated distributions (base vs. Intesity) (base vs. X) (base vs. Y) (base vs. Y) (base vs. P),</p> <p>where the base of set can be changed for anyone from X,Y,P,E</p>	<p>Link "DistrFour" class</p> <p>DistrFour_{LINK} = Reaction ♥ DistrFour_{Parent}</p>	<p>Sum of all "DistrFour" links weighted by Intensities.</p> <p>Result : E vs. X matrix</p> <p>For the next transmission calculations the code transforms the matrix to E(X) distribution.</p>

Content of the "DistrFour" class can be visualized in Debug distribution plots



**“Dispersion” method
(version higher 7.10.15) :
main aim is creation of
the E & X correlation matrix**

Statistics of Fragment Production in Material (Wedge)

Secondary target: #1: I2_wedge

Number of parents: 65
Number of daughters: 187
Number of links: 4143

Total intensity of parent nuclei before the secondary target: 4.05e+06 pps
Total intensity of parent nuclei (with links) before the ST: 4.05e+06 pps
Total intensity of daughter nuclei after the secondary target: 2.72e+03 pps

Partial analysis:
 Parent (outcoming)
 Daughter (incoming)
 Choose fragment: 38Na
 Number of parents: 6
 Show links

E&X matrix (highlighted with a red circle)

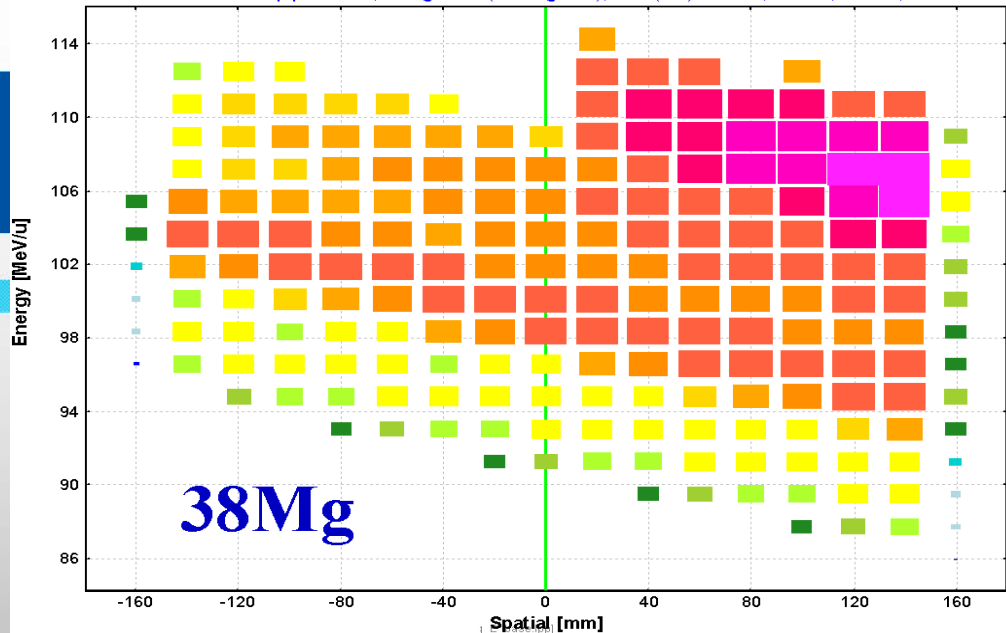
Generate the all-link table | Quit

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.

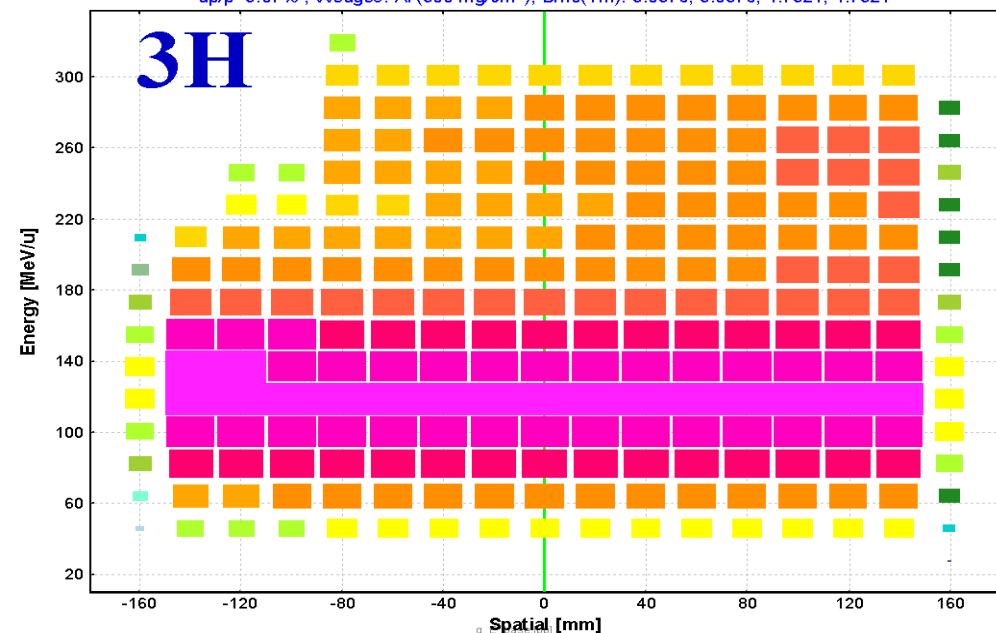
The E & X correlation matrix is applied for Monte Carlo transmission calculations

E & X matrix after Fragment Production Material
 Fragment: ³⁸Mg Intensity: 3.66e-05 Number of parents: 5 Secondary target #1: I2_wedge
⁴⁸Ca (140.0 MeV/u) + Be (1000 mg/cm²); Settings on ⁴⁰Mg; Config: DDSWDDMSMMM
 dp/p=5.07% ; Wedges: Al (500 mg/cm²); Brho(Tm): 5.0576, 5.0576, 4.7921, 4.7921



E & X matrix after Fragment Production Material

Fragment: ³H Intensity: 421 Number of parents: 58 Secondary target #1: I2_wedge
⁴⁸Ca (140.0 MeV/u) + Be (1000 mg/cm²); Settings on ⁴⁰Mg; Config: DDSWDDMSMMM
 dp/p=5.07% ; Wedges: Al (500 mg/cm²); Brho(Tm): 5.0576, 5.0576, 4.7921, 4.7921



Monte Carlo method to estimate transmission of fragments produced in material

Monte Carlo calculation of fragment transmission

A: 38, Element: na, Z: 11

Charge states: 11+ D1

Reaction mechanism: Secondary Target ~1

MC transmission options

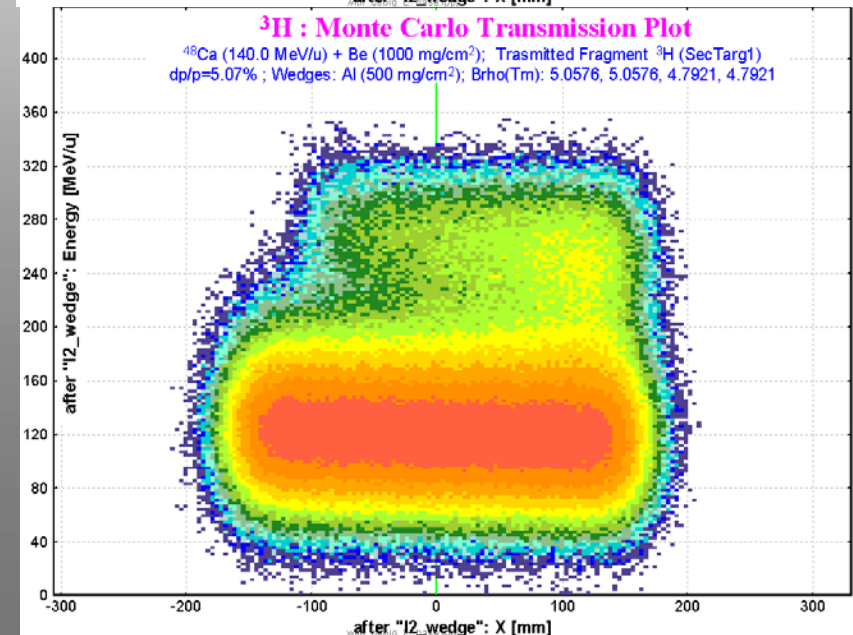
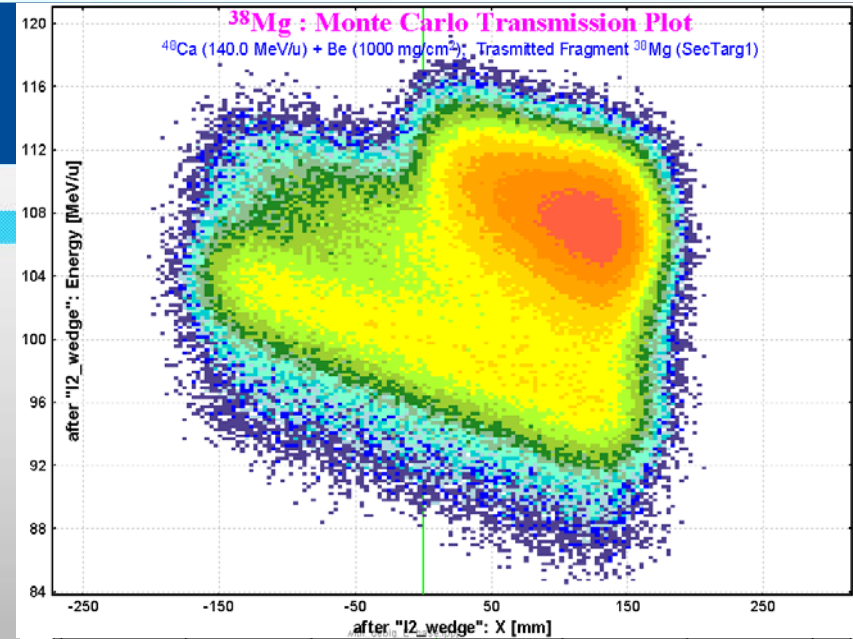
"Distribution" calculation

Monte Carlo calculation

Quit

X-coordinate After BLOCK		Y-coordinate After BLOCK	
<input checked="" type="radio"/> X	mm	<input checked="" type="radio"/> X	mm
<input 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 type="radio"/> dP/P	%
<input type="radio"/> Energy	MeV/u	<input checked="" type="radio"/> Energy	MeV/u
<input type="radio"/> TKE	MeV	<input type="radio"/> TKE	MeV
<input type="radio"/> Momentum	GeV/c	<input type="radio"/> Momentum	GeV/c
<input type="radio"/> Brho	T*m	<input type="radio"/> Brho	T*m
<input type="radio"/> Velocity	cm/ns	<input type="radio"/> Velocity	cm/ns
<input type="radio"/> Energy Loss	MeV	<input type="radio"/> Energy Loss	MeV
<input type="radio"/> Time of flight	ns	<input type="radio"/> Time of flight	ns
<input type="radio"/> Length	m	<input type="radio"/> Length	m

Stripper: I2_wedge | Start: I2_wedge | Stop: I2_wedge



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.



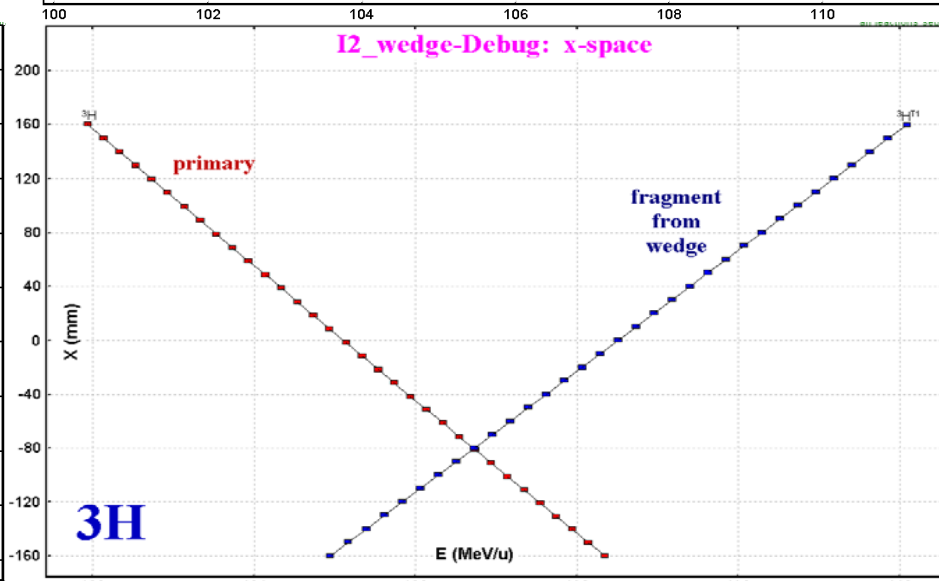
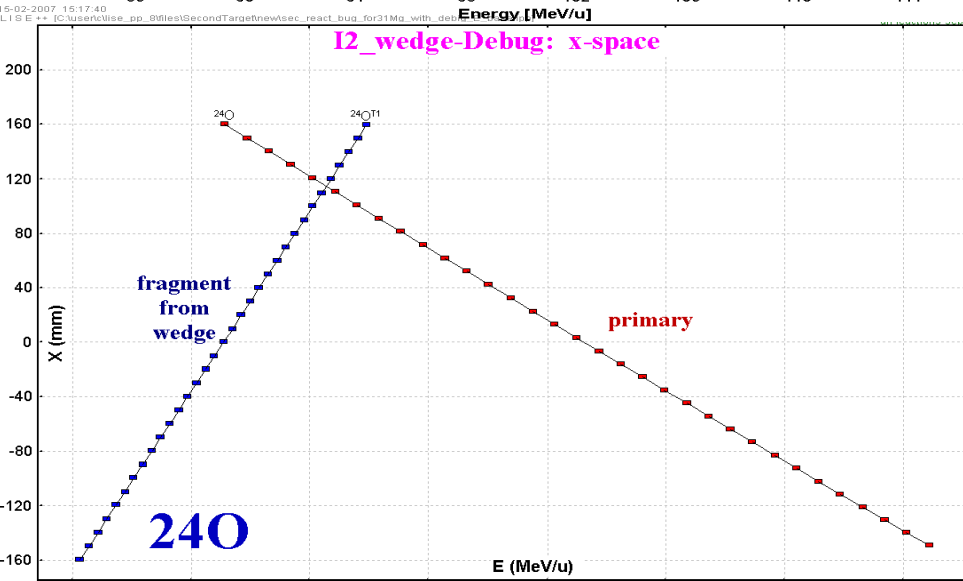
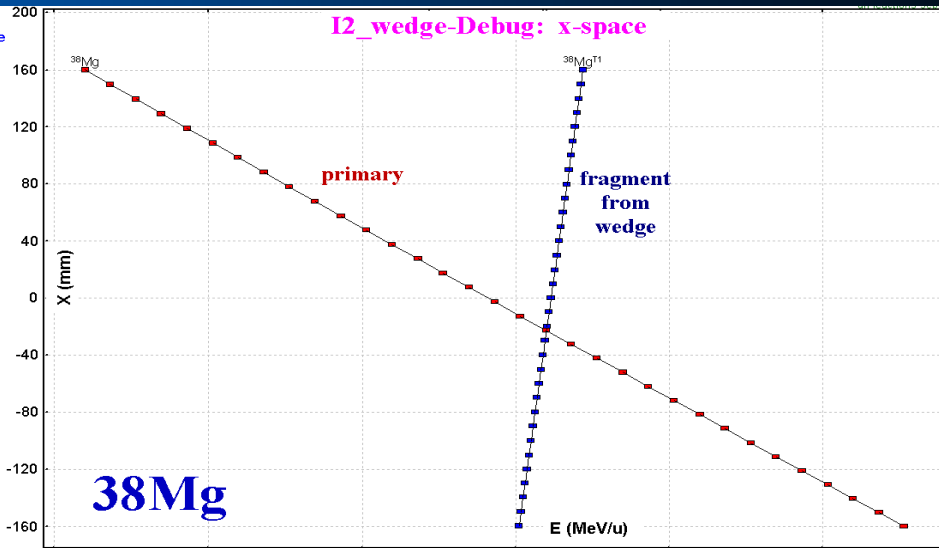
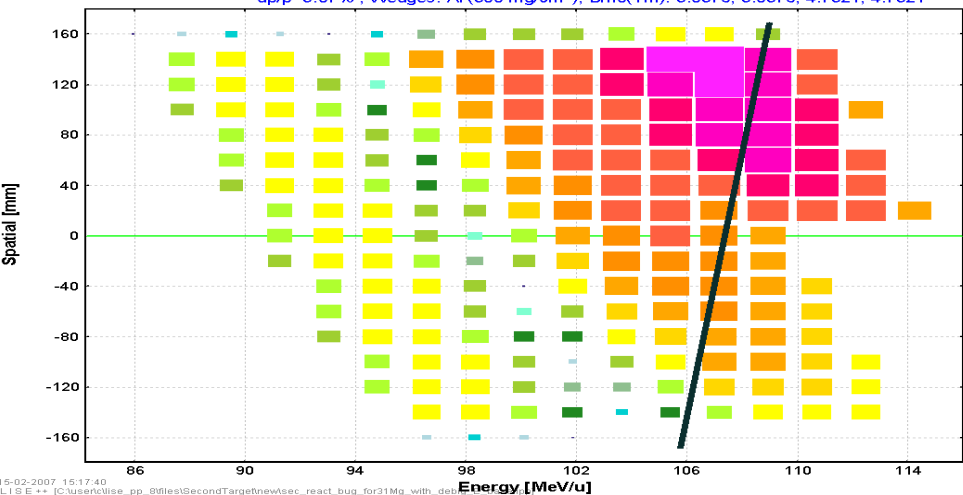
"Fragment production in Material" methods comparison: correlation E & X

No correlation after material between fragment's energy and position in "Gaussian" and "Distribution" methods.

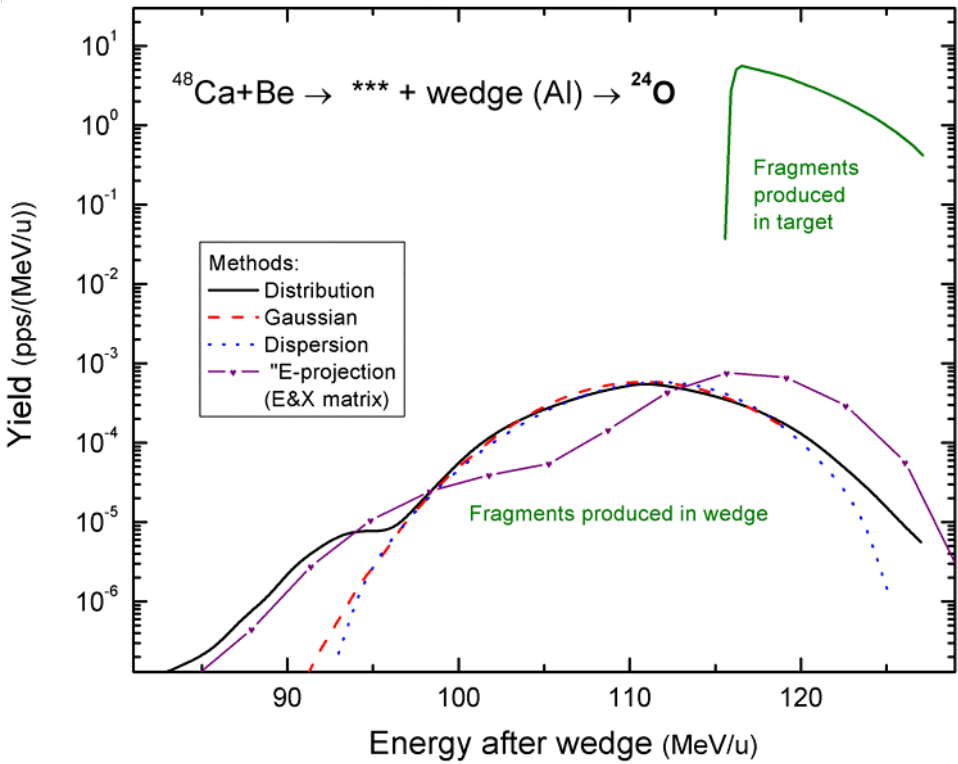
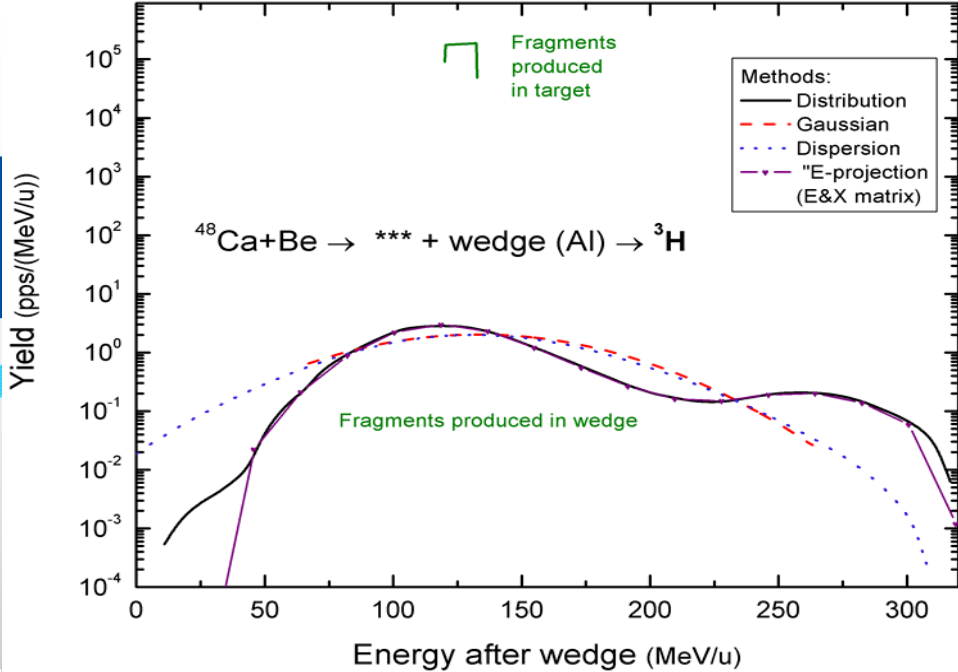
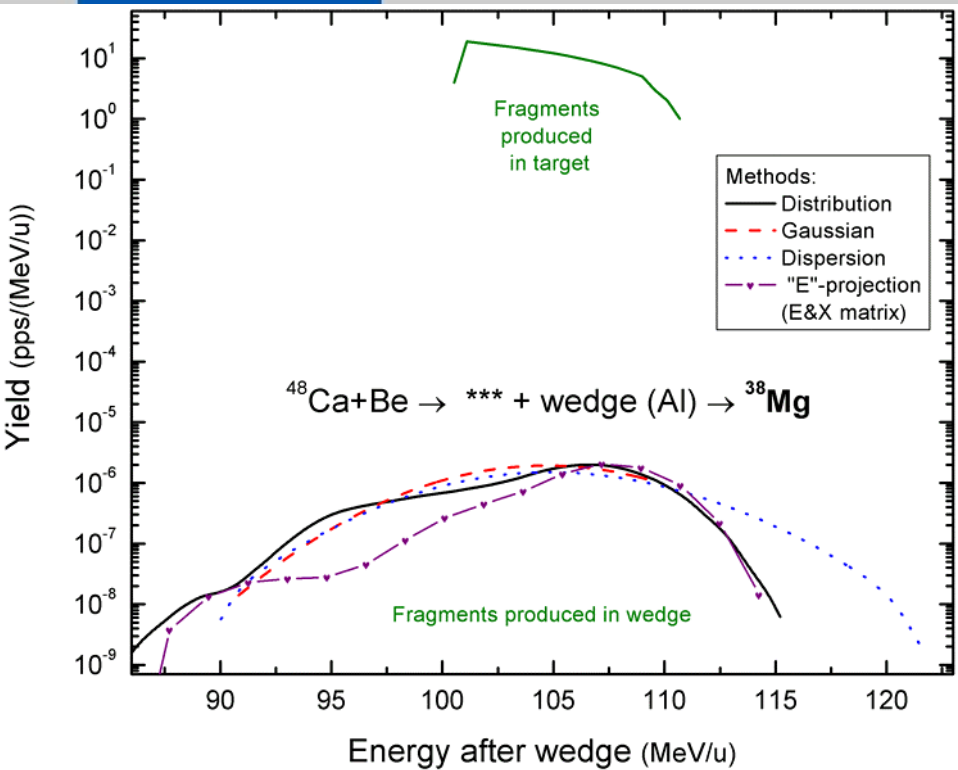
In the case of "Dispersion" method using the E & X matrix (NxN) for each X_i the code calculates $\langle E_i \rangle$. After this curve $E(X_i)$ is fitted by a line.

E & X matrix after Fragment Production Material

Fragment: ^{38}Mg Intensity: 1.44e-05 Number of parents: 4 Secondary target #1: I2_wedge
 ^{48}Ca (140.0 MeV/u) + Be (1000 mg/cm²); Settings on ^{40}Mg ; Config: DDSWADDSMMM
dp/p=5.07%; Wedges: Al (500 mg/cm²); Brho(Tm): 5.0576, 5.0576, 4.7921, 4.7921



"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%
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%
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%
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					
	gaussian		1E-10	62	289	2.3E+03	41,652	16	218	1.1E+03	30,364	139
	gaussian		1E-03	60	210	2.3E+03	21,844	14	139	1.1E+03	10,556	76
	Distribution	16	1E-03	58	239	2.5E+03	43,480	12	168	1.3E+03	32,192	192
	Distribution	8	1E-03	55	219	2.4E+03	35,196	9	148	1.2E+03	23,908	162
	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					
	gaussian		1E-05	152	570	1.5E+03	89,996	52	438	1270	78,256	52
	gaussian		1E-10	212	840	1.5E+03	209,572	112	708	1270	197,832	112
	Distribution	16	1E-10	292	992	1.9E+03	616,524	192	860	1670	604,784	192
	Distribution	8	1E-10	252	901	1.5E+03	496,824	152	769	1270	485,084	152
	Dispersion	16	1E-10				swapping					
	Dispersion	8	1E-10	1965	675	1.4E+03	swapping	1865	543	1170		1865
	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 yield 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

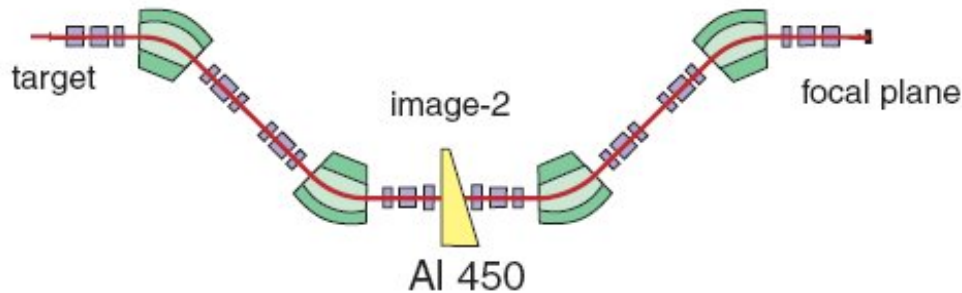
Z - atomic number of primary or ternary beams

$dZ = Z(\text{primary beam}) - Z(\text{ternary beam})$

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

Comparison with experimental data

^{58}Ni , 160 MeV/u + natNi, 811 mg/cm² → ^{46}Fe

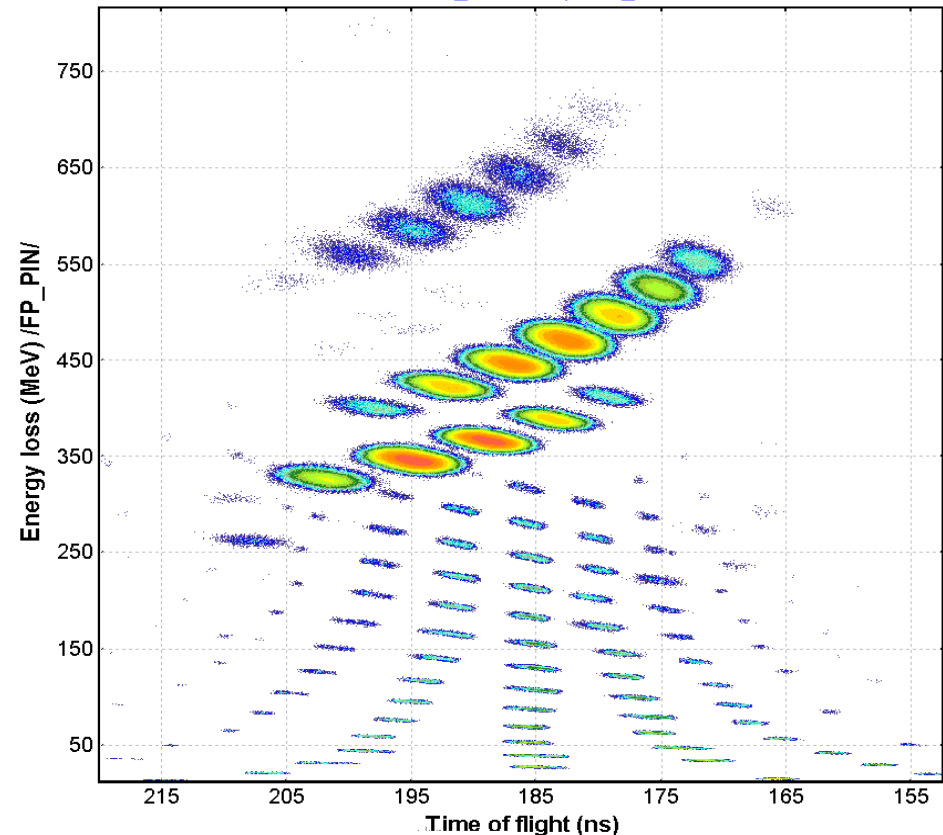
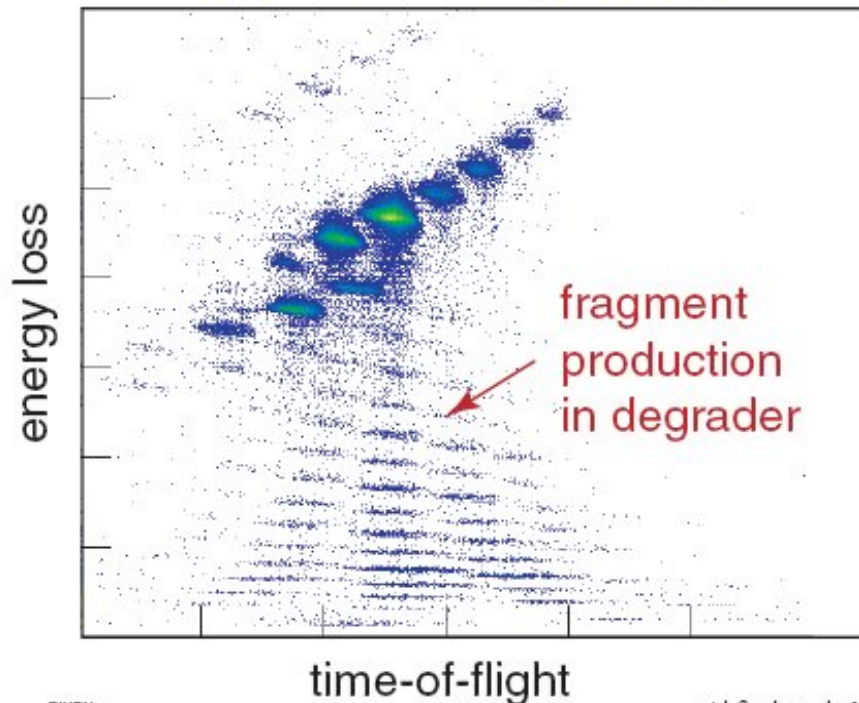


LISE++ simulations

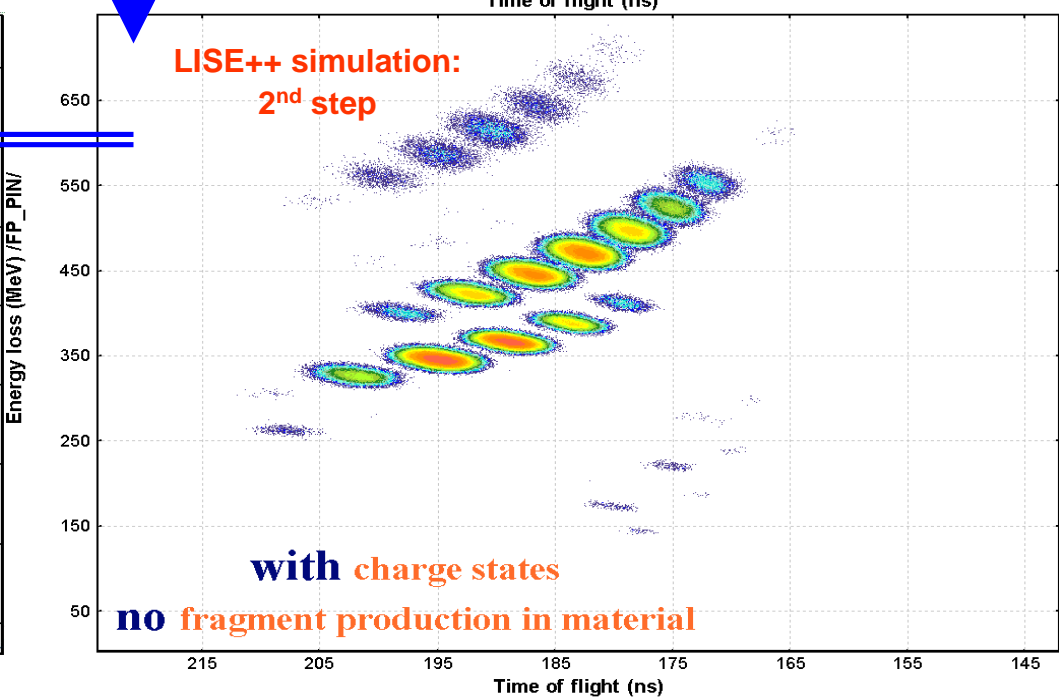
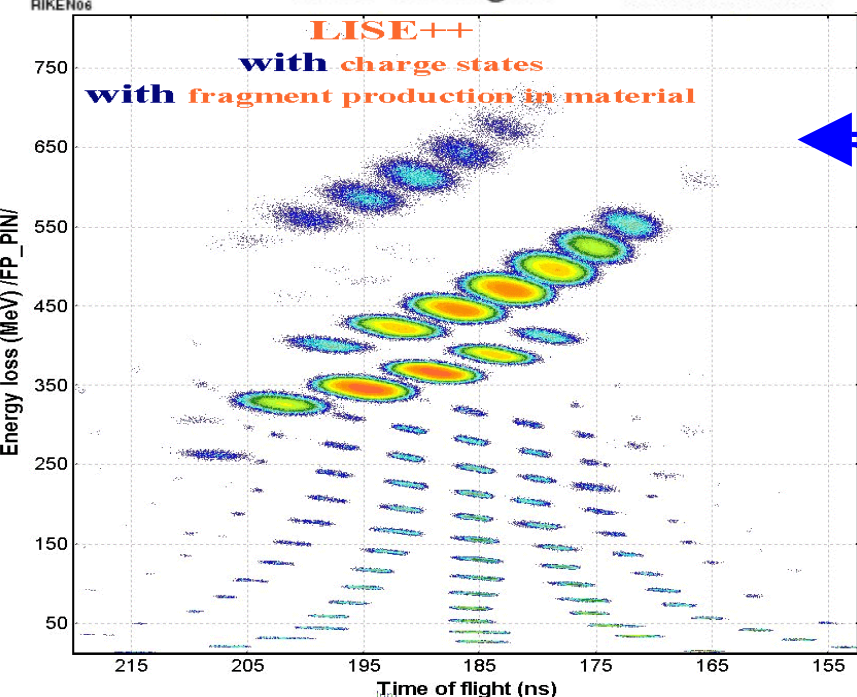
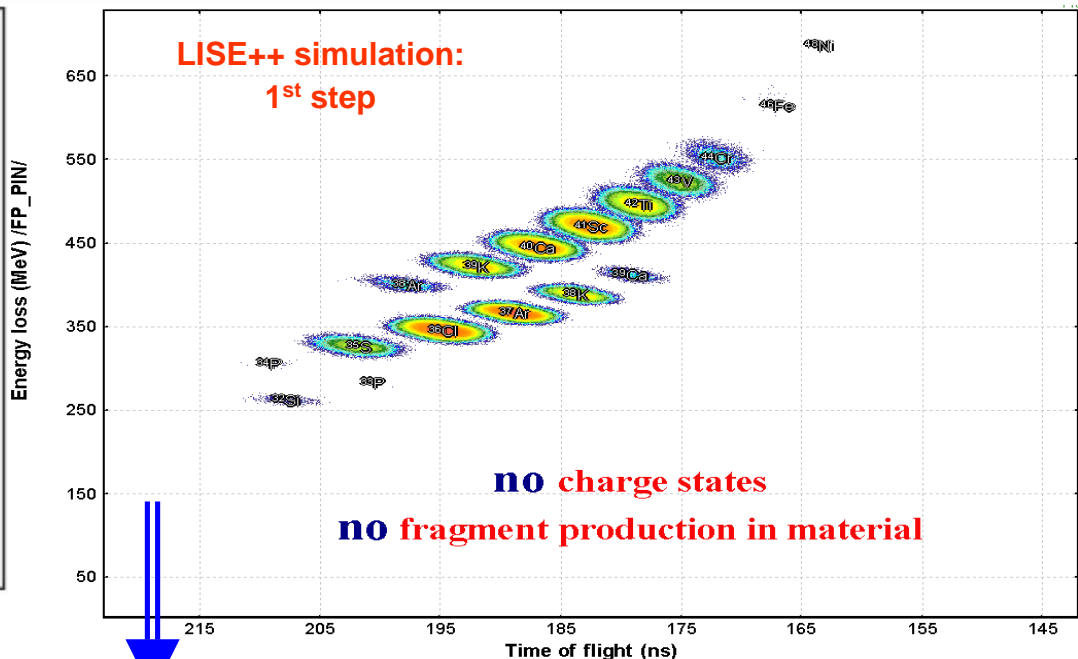
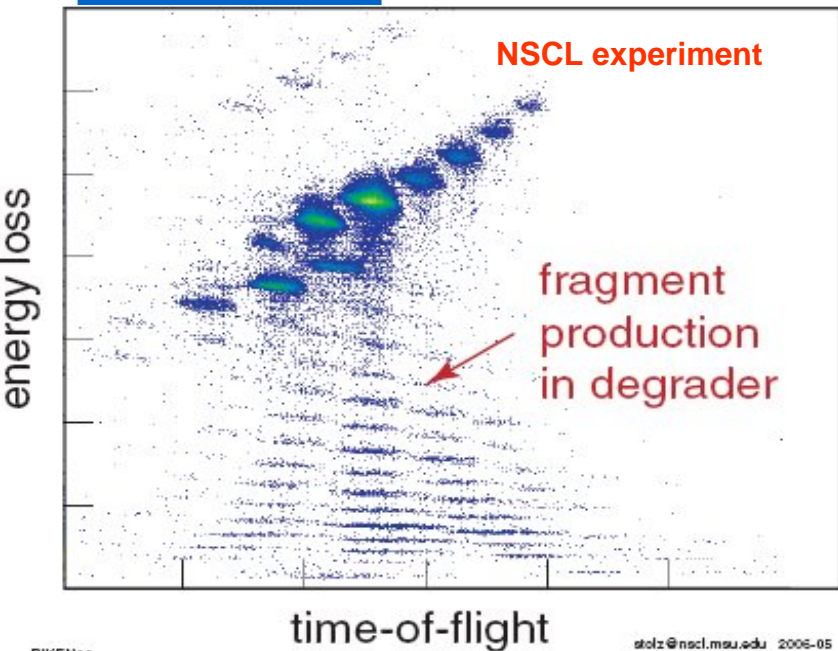
dE-TOF

^{58}Ni (160.0 MeV/u) + Ni (811 mg/cm²); Settings on ^{46}Fe 26+ 26+ 26+ 26+
 dp/p=1.66% ; Wedges: Al (450 mg/cm²); Brho(Tm): 2.7596, 2.1165
 Start: I2_SCI; Stop: FP_PIN;

degrader @ image-2 only



Comparasion with experimental data

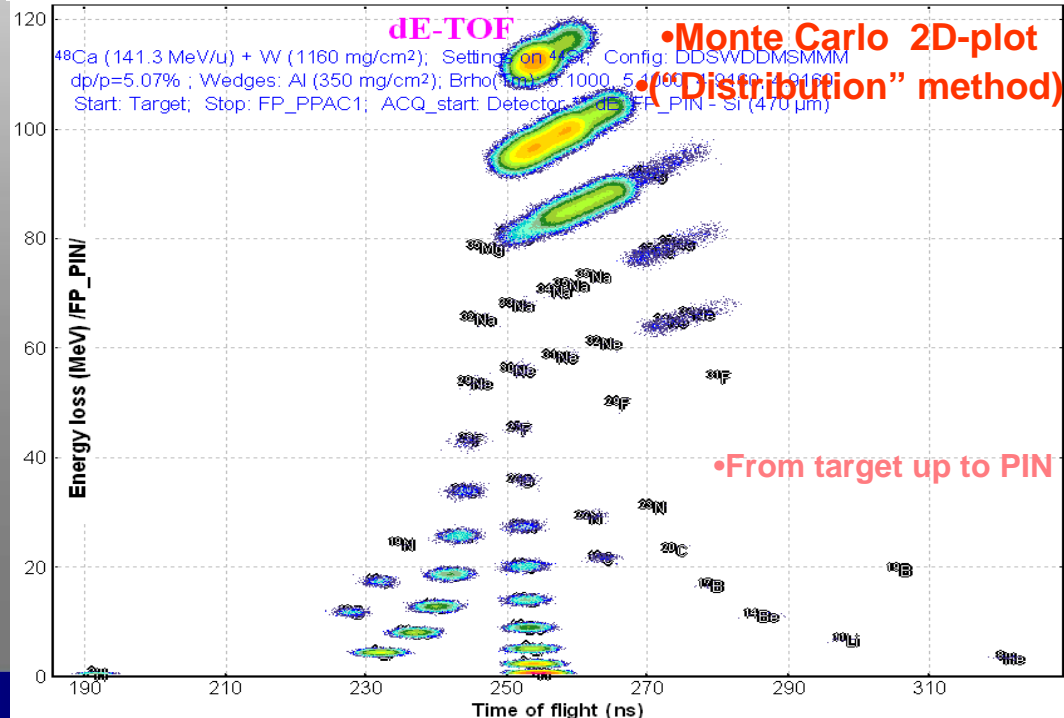
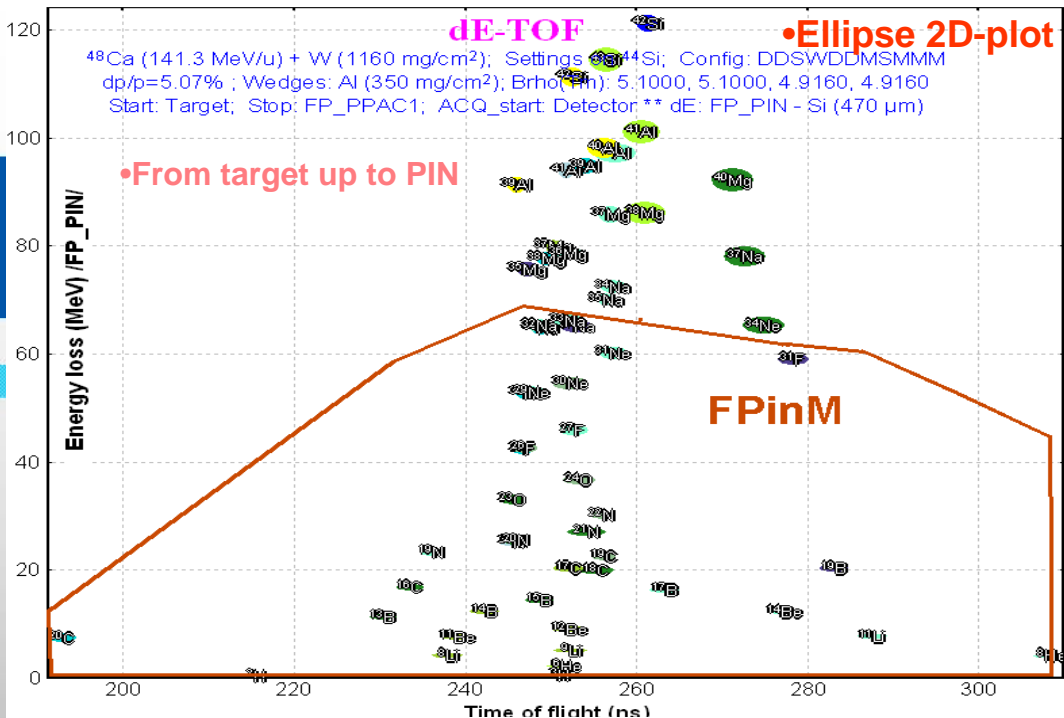
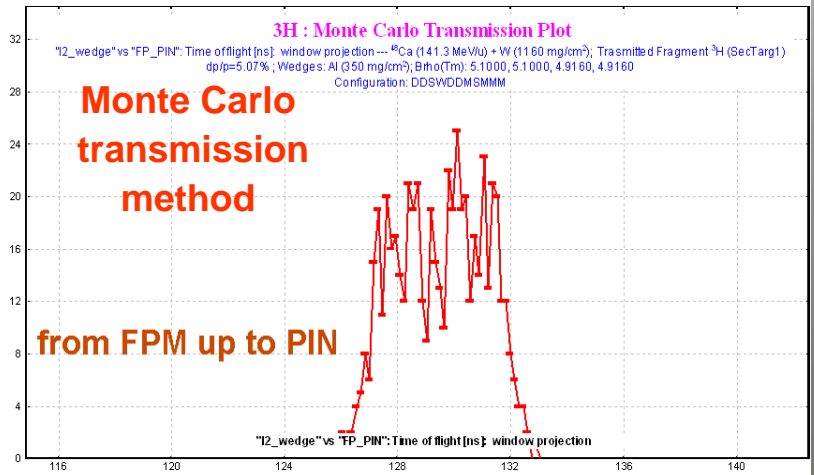
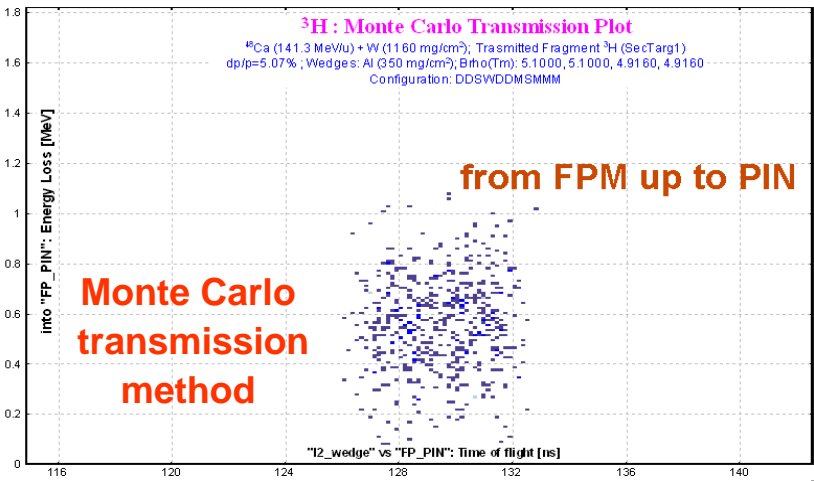




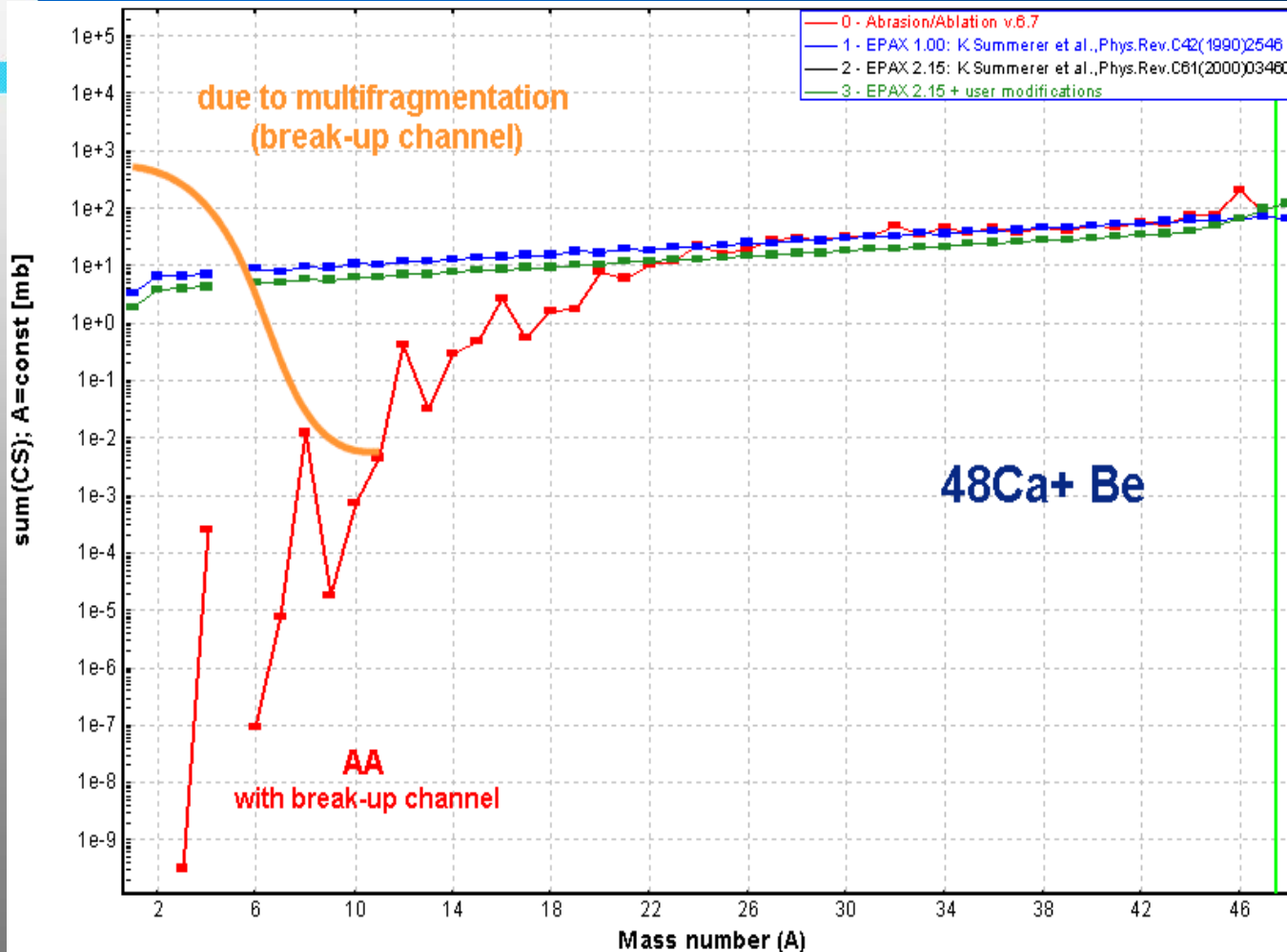
F.P. in M. & 2D-plots

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?


 $^{48}\text{Ca} + \text{Be} \rightarrow t$
 $\sigma_{\text{EPAX}} = 1.9 \text{ mb}$

From AA calculations

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

 For $^{48}\text{Ca} + \text{Be}$

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

Projectile fragmentation

Fragment velocity / Momentum distribution / **Cross section, Excitation energy and etc**

40Ar(140.0 MeV/u) + Be -> 31F

Prefragment and Evaporation options Excitation energy for Abrasion-Ablation model

Cross Sections

3 - EPAX 2.15 + user modifications

"FAST" mode for Abrasion-Ablation calculations

Use this mode only for heavy projectiles as Uranium. Evaporation distribution dimension is equal to 8.

Coefficients for modified EPAX 2.15

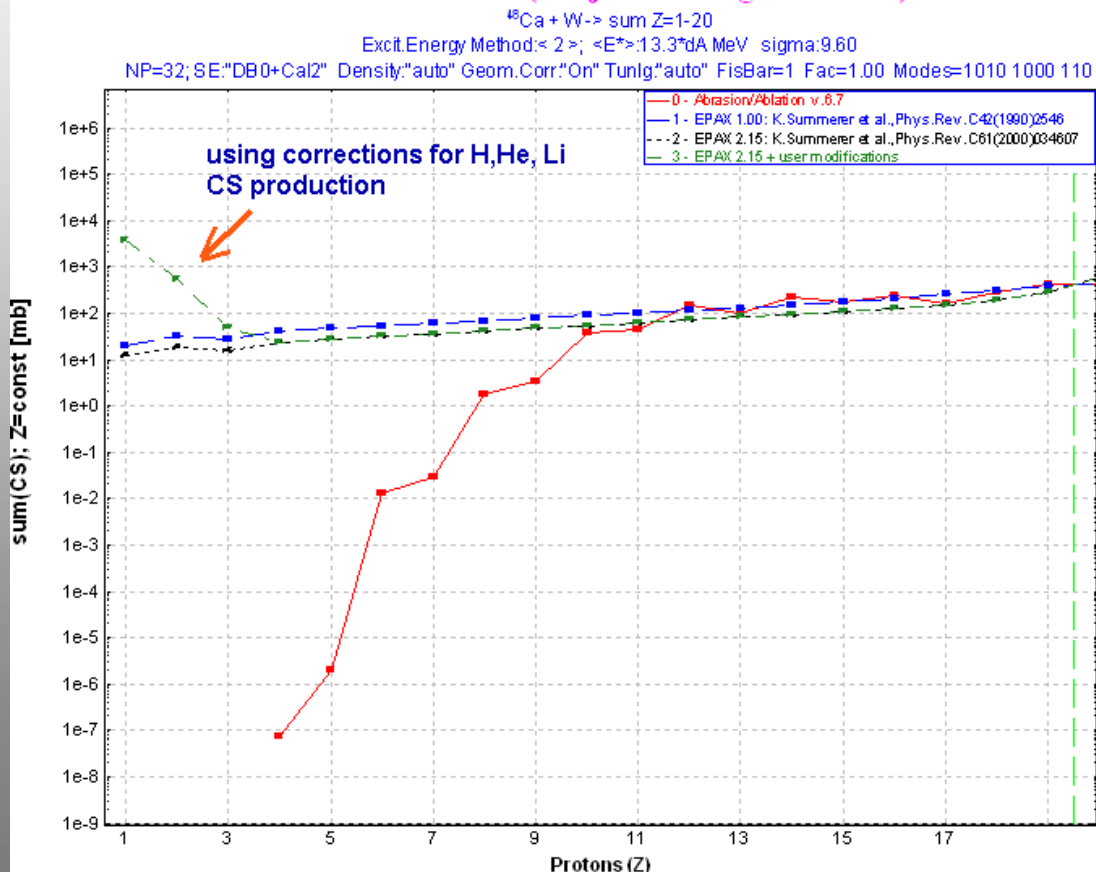
normalization		p-rich slope	
U_norm [1.0]	1	U1 [1.79]	1.788
		U2 [4.72e-3]	0.004721
U_n [1.65]	1.65	U3 [-1.3e-5]	-1.303e-5

Use corrections for H,He,Li production cross sections

Make default

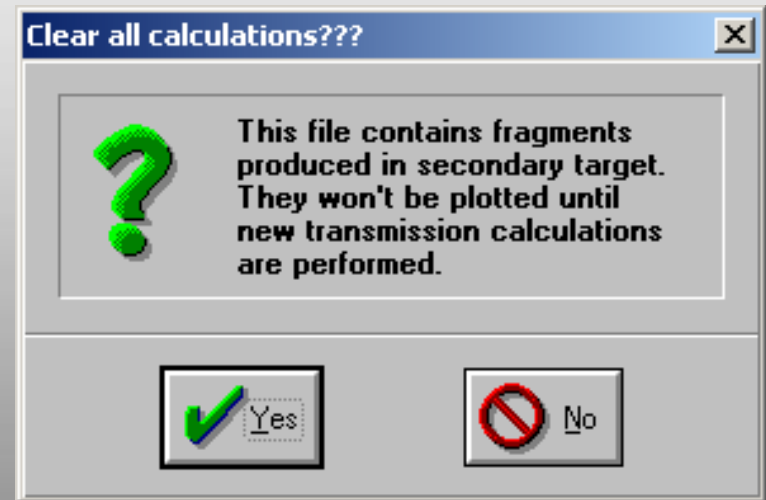
OK Cancel Help

Cross sections (Projectile Fragmentation)



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**