Simulations of D.I. collisions with AGATA and PRISMA

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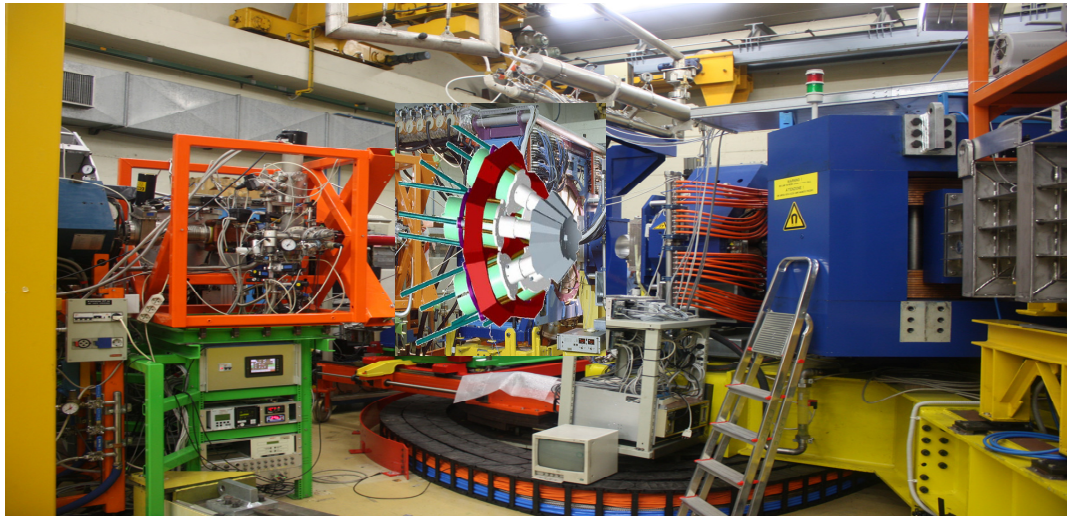
on behalf of the
UK simulation working group

Experiments of interests

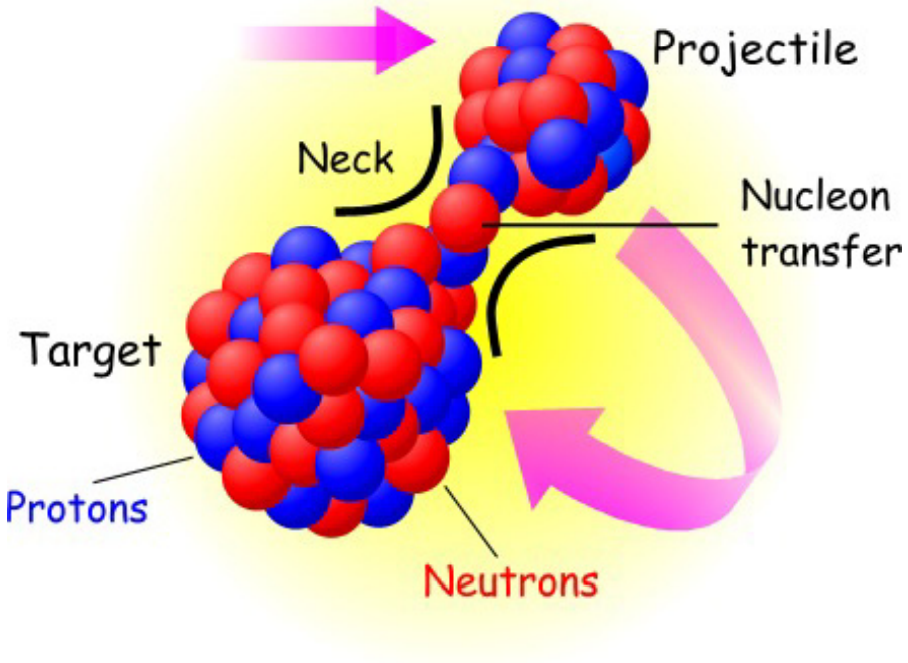
- The commissioning experiment:
  - ^{58}Ni(235MeV) + ^{96}Zr
- UK experiment proposals:
  - ^{136}Xe(750MeV) + ^{176}Yb $\rightarrow$ ^{132}Xe + ^{180}Yb (4n transfer)
  - ^{86}Kr(441 MeV) + ^{208}Pb $\rightarrow$ ^{88}Sr + ^{206}Hg (2p transfer)
  - ^{136}Xe(808 MeV)+ ^{192}Os $\rightarrow$ ^{138}Ba + ^{190}W (2p transfer)
  - ^{36}S + ^{208}Pb : ^{38}S (lifetime experiment)

All using
AGATA Demo. + PRISMA
(+ DANTE)



Deep Inelastic Collision

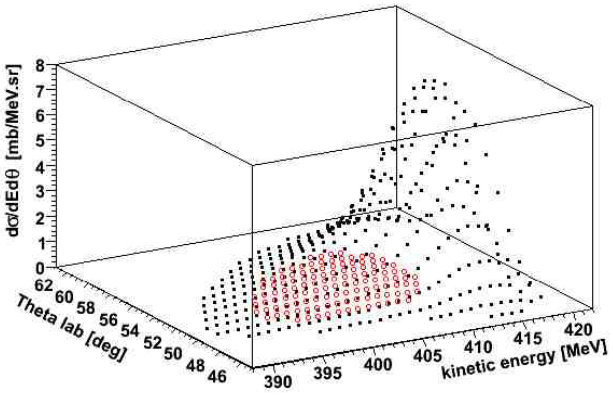
- Binary reaction with kinetic energy damping and mass exchange.



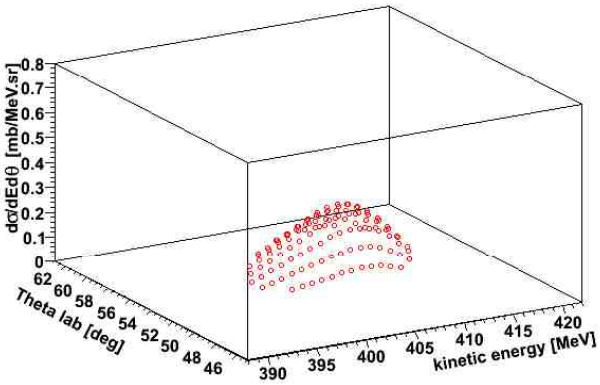
Event generator

- The projectile-like fragments

  – Use of the GRAZING code for the all the reactions.
    - $d^2\sigma/(dE \cdot d\Omega)$ (=Wilczynski plots)



$^{136}Xe + {}^{176}Yb$:
$\rightarrow {}^{136}Xe^* + {}^{176}Yb^*$
$\rightarrow {}^{132}Xe^* + {}^{180}Yb^*$



  – Use the Monte-Carlo code provided by the Milano collaborators (courtesy of S. Leoni and D. Montanari)

    - Converts the GRAZING output file in a file format appropriate to the PRISMA simulation codes.

Input file for PRISMA

Ex: 86Kr+208Pb

- FORMAT 0 4
- #
- #
- REACTION 36 86 82 208 441
- #
- $ Z A E Direction Origin
- -101 36 88 304. 0.469406 0.020517 0.882744 0 0 0
- $
- -101 37 87 305. 0.422565 0.0185853 0.906142 0 0 0
- $
- -101 36 87 308. 0.453979 0.008886 0.890968 0 0 0
- $
- -101 36 87 307. 0.469344 0.0286104 0.882552 0 0 0
- $
- …

= File of events reflecting the total and double differential cross-sections

Event generator

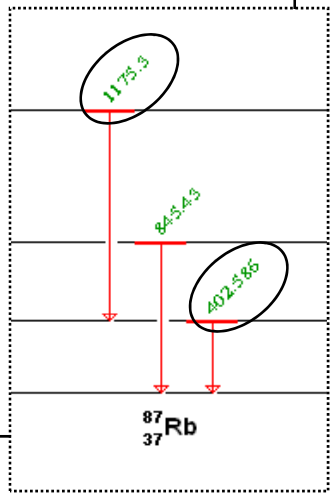
- The target-like partner
  - From kinematics formula
- The gammas:
  - RadWare database provides the ags file with the established level schemes and gamma-rays for each fragments.
    - Yrast band selected
  - Expected γ-rays (provided by spokespersons) can be added.
    - Create a new ags file.
  - GammaWare reads the ags file to randomly simulate the gamma decay cascades

Gamma files

Ex: $^{86}Kr(441MeV) + ^{208}Pb \rightarrow ^{87}Rb^* + ^{207}Tl^*$

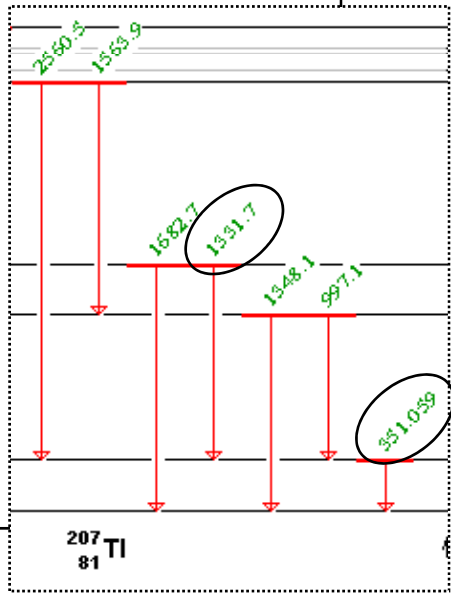
Proj.-like fragment ^{87}Rb:

```
FORMAT 4 4
#
# GAMMAS GENERATED FROM
# 87Rb_Yrast.ags LEVEL SCHEME
#
REACTION 1 1 6 12 0.0
#
EMITTED 1 1
#
$
 -101
 1 1175.3 0. 8.0
 1 402.6 0. 8.0
 $
 -101
 1 1175.3 0. 8.0
 1 402.6 0. 8.0
 $
```



Target-like partner ^{207}Tl:

```
FORMAT 4 4
#
# GAMMAS GENERATED FROM
#207Tl_Yrast.ags LEVEL SCHEME
#
REACTION 1 1 6 12 0.0
#
EMITTED 1 1
#
$
 -101
 1 1331.7 0. 8.0
 1 351.1 0. 8.0
 $
 -101
 1 1947.5 0. 8.0
 $
```



AGATA input file

Ex: 86Kr+208Pb

```
FORMAT 0 4
#
#
REACTION 36 88 82 208 441
#
EMITTED 1 1
#
#
$
-101 36 88 304 0.469406 0.020517 0.882744 0 0 0
 1 1251.1 0. 8.0
-101 82 206 366.085 -0.952021 -0.0121891 -0.305792 0 0 0
 1 296.2 0. 8.0
$
-101 37 87 305 0.422565 0.0185853 0.906142 0 0 0
 1 1175.3 0. 8.0
 1 402.6 0. 8.0
-101 81 207 348.951 -0.945577 -0.0112631 -0.325203 0 0 0
 1 1331.7 0. 8.0
 1 351.1 0. 8.0
$
-101 36 87 308 0.453979 0.008886 0.890968 0 0 0
 1 1476.0 0. 8.0
-101 82 207 361.048 -0.949644 -0.00531942 -0.313285 0 0 0
 1 1770.2 0. 8.0
 1 569.7 0. 8.0
$
-101 36 87 307 0.469344 0.0286104 0.882552 0 0 0
 1 1476.0 0. 8.0
-101 82 207 365.84 -0.952084 -0.0169902 -0.305363 0 0 0
 1 897.8 0. 8.0
```

Beginning of an event

Projectile-like frag. (Z, A, E,direction, origin)

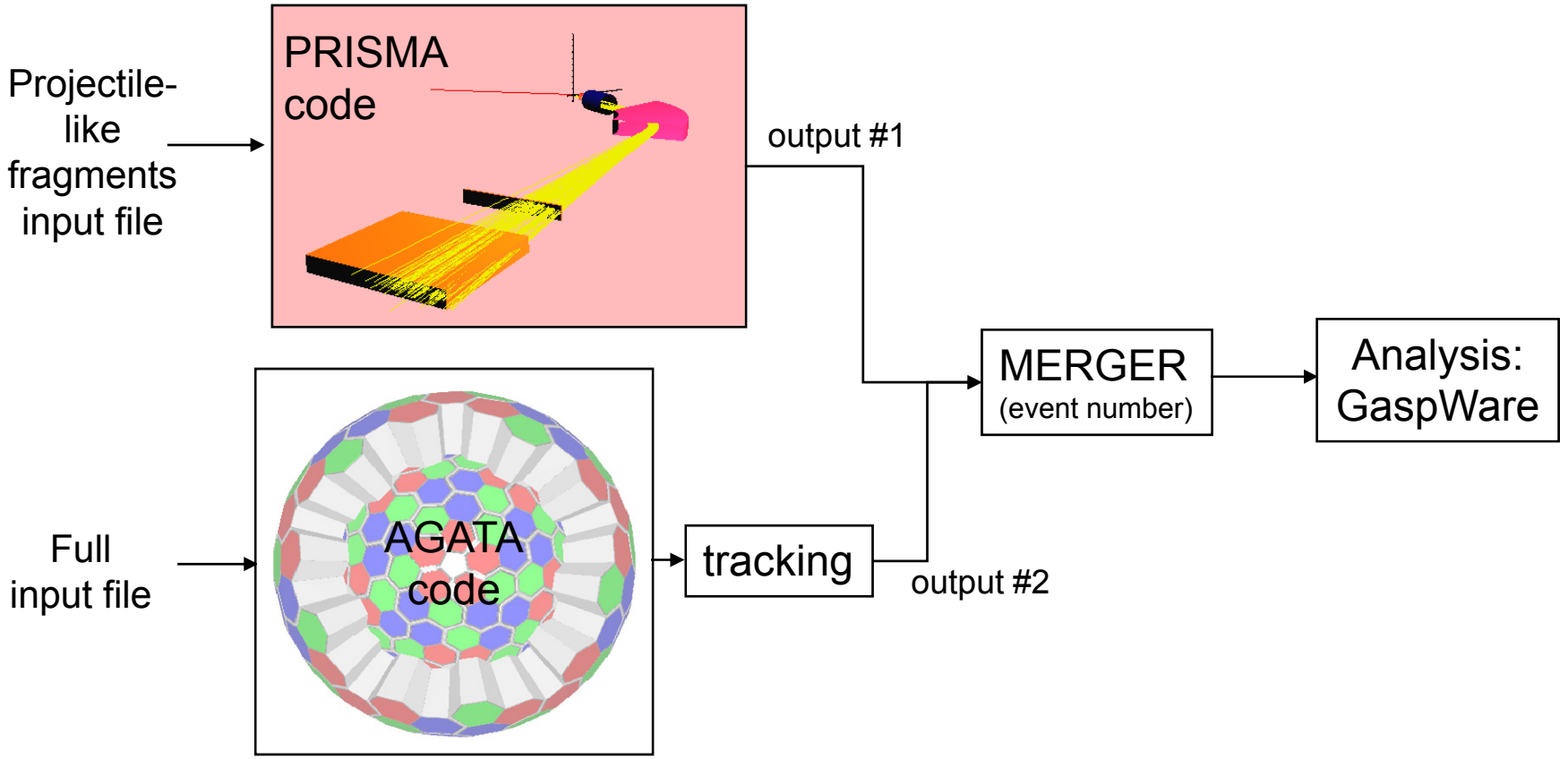
& its gammas

Target-like partner (Z, A, E,direction, origin)

& its gammas

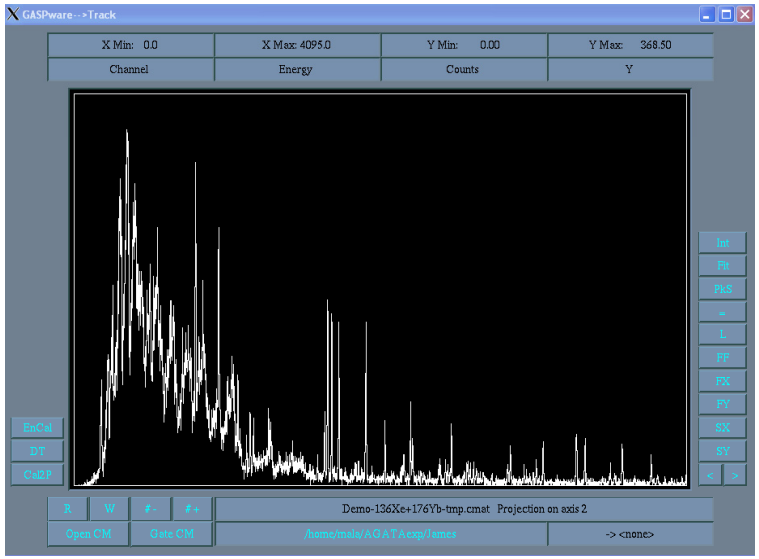
Beginning of a new event

Simulation output



Some preliminary results

Doppler corrected single γ-ray spectra in coincidence with PRISMA:



$^{136}Xe+^{176}Yb \rightarrow$

$^{132}Xe^{*}+^{180}Yb^{*}$

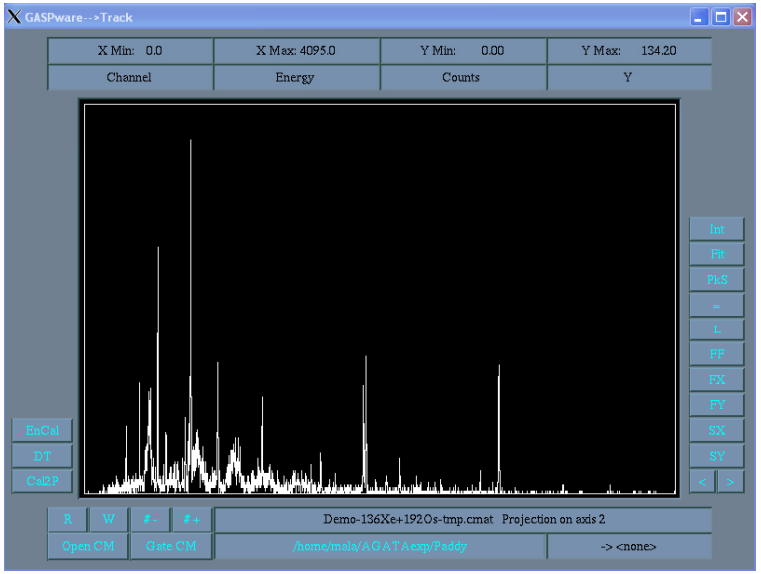
$^{134}Xe^{*}+^{178}Yb^{*}$

$^{135}Xe^{*}+^{177}Yb^{*}$

$^{136}Xe^{*}+^{176}Yb^{*}$

$^{137}Xe^{*}+^{175}Yb^{*}$

$^{138}Xe^{*}+^{174}Yb^{*}$



$^{136}Xe+^{192}Os \rightarrow$

$^{136}Xe^{*}+\ ^{192}Yb^{*}$ /100

$^{136}Ba^{*}+\ ^{190}W^{*}$

$^{138}Ba^{*}+\ ^{192}W^{*}$

Summary

- Simulations of DIC is being performed
  - for proposed experiments
  - and commissioning experiments
- An event generator is being developed using existing tools
  - Grazing code
  - Milano MC program
  - GammaWare
- A work in progress…

Thanks you

AGATA output

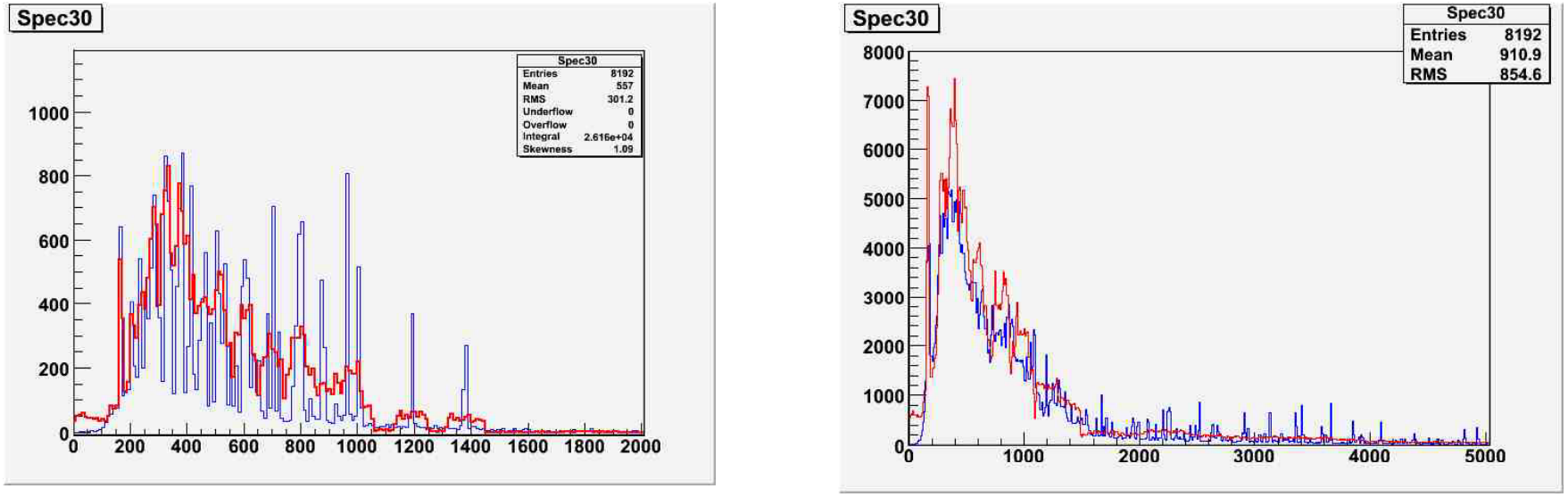


Figure 1: Results of the AGATA simulations: Left, gamma-rays from 176-178Yb nuclides (target-like fragments) without (red) and with (blue) Doppler correction. Right, same as left hand figure, but with the addition of gamma-rays from the 134-136Xe partners (projectile-like fragment) included.

Experiments of interests

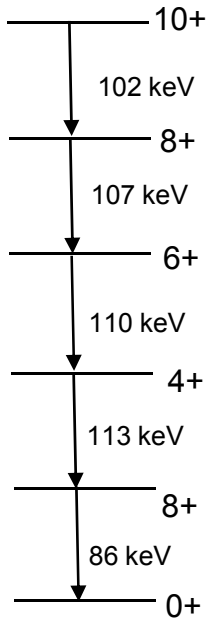
- Expected new gamma-rays for ^{180}Yb

  ^{136}Xe(750MeV) + ^{176}Yb
  ^{180}Yb (4n transfer)

  – from the VMI model based on trends of J0 and J1 parameters.
  – J0 and J1 used are 35 and 25.

^{180}Yb

Spin (hbar)	Energy level (MeV)
0	0
2	0.086
4	0.199
6	0.309
8	0.416
10	0.518



Experiments of interests

- Expected new gamma-rays for ^{206}Hg

^{86}Kr (441 MeV) + ^{208}Pb : ^{206}Hg (2p transfer)

^{206}Hg

Spin (hbar)	Energy level (MeV)
2+ (decay to g.s.)	1.068
5- (decay to 2+)	2.101
7- (decay to 5-)	2.466
4+ (decay to 2+)	2.498
6+ (decay to 4+)	3.590
8+ (decay to 7-)	3.623
10+ (decay to 8+)	3.723

Not yet observed

Example :

- $^{136}Xe + ^{176}Yb$ @ 750 MeV
- GRAZING calculations give the cross section:

N = 102	104	106	108	110	
	178	179	180	181	182	183	184	W
176	177	178	179	180	181	182	183	Ta
174	175 **0.64**	176 **1.8**	177 **2.0**	178 **3.8**	179 **1.7**	180 **0.84**	181 **0.26**	182	Hf
173 **1.1**	174 **3.2**	175 **10**	176 **17**	177 **36**	178 **16**	179 **7.6**	180 **1.3**	181 **0.61**	Lu
172 **1.0**	173 **9.6**	174 **50**	175 **156**	176 **83**	177 **189**	178 **44**	179 **6.0**	180 **1.7**	Yb
171 **1.4**	172 **2.7**	173 **6.5**	174 **13**	175 **29**	176 **12**	177 **5.2**	178 **1.4**	179 **0.62**	Tm
170 **0.21**	171 **0.43**	172 **0.99**	173 **1.0**	174 **1.7**	175 **0.97**	176 **0.56**	177	178	Er
169	170	171	172	173	174	175	176	177	Ho
168	169	170	171	172	173	174	175		Dy

Cross-sections in (mb)

beam: ^{136}Xe

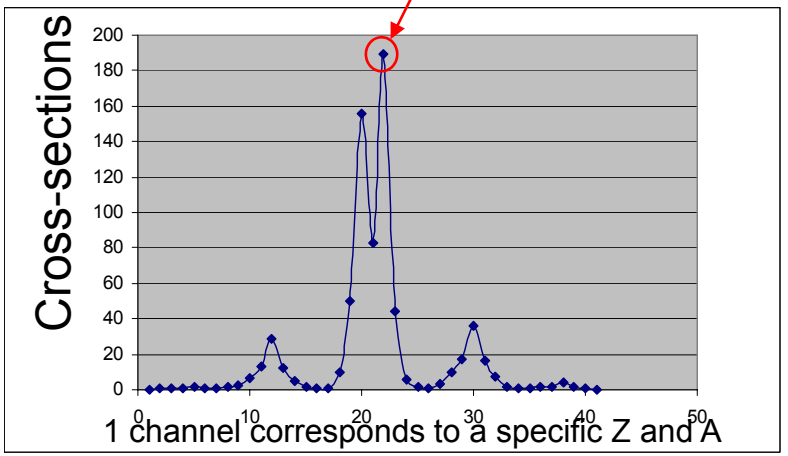
Monte-Carlo process

N =	102		104		106		108		110	
			178	179	180	181	182	183	184	W
		176	177	178	179	180	181	182	183	Ta
174	175 0.64	176 1.8	177 2.0	178 3.8	179 1.7	180 0.84	181 0.26	182		Hf
173 1.1	174 3.2	175 10	176 17	177 36	178 16	179 7.6	180 1.3	181 0.61		Lu
172 1.0	173 9.6	174 50	175 156	176 83	177 189	178 44	179 6.0	180 1.7		Yb
171 1.4	172 2.7	173 6.5	174 13	175 29	176 12	177 5.2	178 1.4	179 0.62		Tm
170 0.21	171 0.43	172 0.99	173 1.0	174 1.7	175 0.97	176 0.56	177	178		Er
169	170	171	172	173	174	175	176	177		Ho
168	169	170	171	172	173	174	175			Dy

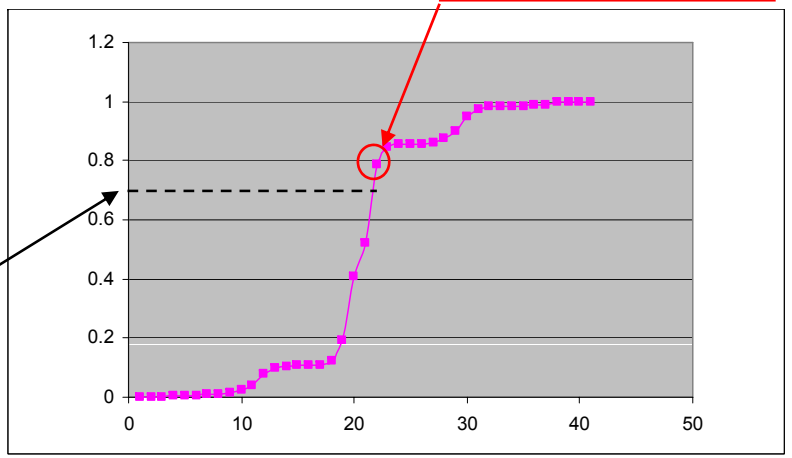
Cross-sections in (mb)

beam: ^{136}Xe

Z=70 ; N=106



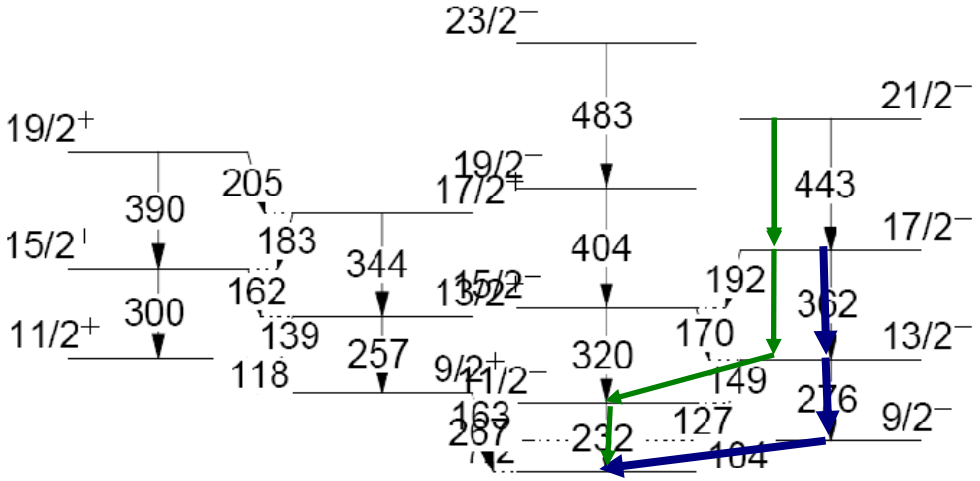
Z=70 ; N=106



Any random number between 0 and 1 is associated to a specific Z and A

Input B_i(gammas)

- FORMAT 4 4
- #
- # GAMMAS GENERATED FROM THE 175Yb_XUNDL-1.ags LEVEL SCHEME
- #
- EMITTED 1 1
- #
- $
- -101
- 1 362.0 0. 8.0
- 1 276.0 0. 8.0
- 1 104.5 0. 8.0
- $
- -101
- 1 362.0 0. 8.0
- 1 276.0 0. 8.0
- 1 104.5 0. 8.0
- $
- -101
- 1 443.0 0. 8.0
- 1 362.0 0. 8.0
- 1 148.7 0. 8.0
- 1 231.7 0. 8.0



Merged input ($A+B_i$)

```
FORMAT 0 4
#
#
REACTION 54 136 70 176 750
#
EMITTED 1 1
#
$                                   <-- Beginning of events
-101 70 175 187.5 0 0 1 0 0 0       <-- Fragments (Z, A, E,direction, origin)
 1 362.0 0. 8.0
 1 276.0 0. 8.0                     <-- Gammas
 1 104.5 0. 8.0
$
-101 70 175 187.5 0 0 1 0 0 0
 1 362.0 0. 8.0
 1 276.0 0. 8.0
 1 104.5 0. 8.0
$
-101 70 176 187.5 0 0 1 0 0 0
 1 173.5 0. 8.0
 1 153.3 0. 8.0
 1 244.1 0. 8.0
$
-101 70 177 187.5 0 0 1 0 0 0
 1 229.9 0. 8.0
 1 396.7 0. 8.0
 1 165.6 0. 8.0
```

Merged input ($A+B_i$)

```
FORMAT 0 4
#
#
REACTION 54 136 70 176 750
#
EMITTED 1 1
#
$
-101 70 175 187.5 0 0 1 0 0 0
 1 362.0 0. 8.0
 1 276.0 0. 8.0
 1 104.5 0. 8.0
$
-101 70 175 187.5 0 0 1 0 0 0
 1 362.0 0. 8.0
 1 276.0 0. 8.0
 1 104.5 0. 8.0
$
-101 70 176 187.5 0 0 1 0 0 0
 1 173.5 0. 8.0
 1 153.3 0. 8.0
 1 244.1 0. 8.0
$
-101 70 177 187.5 0 0 1 0 0 0
 1 229.9 0. 8.0
 1 396.7 0. 8.0
 1 165.6 0. 8.0
```

Beginning of events

Fragments (Z, A, E, direction , origin)

Gammas

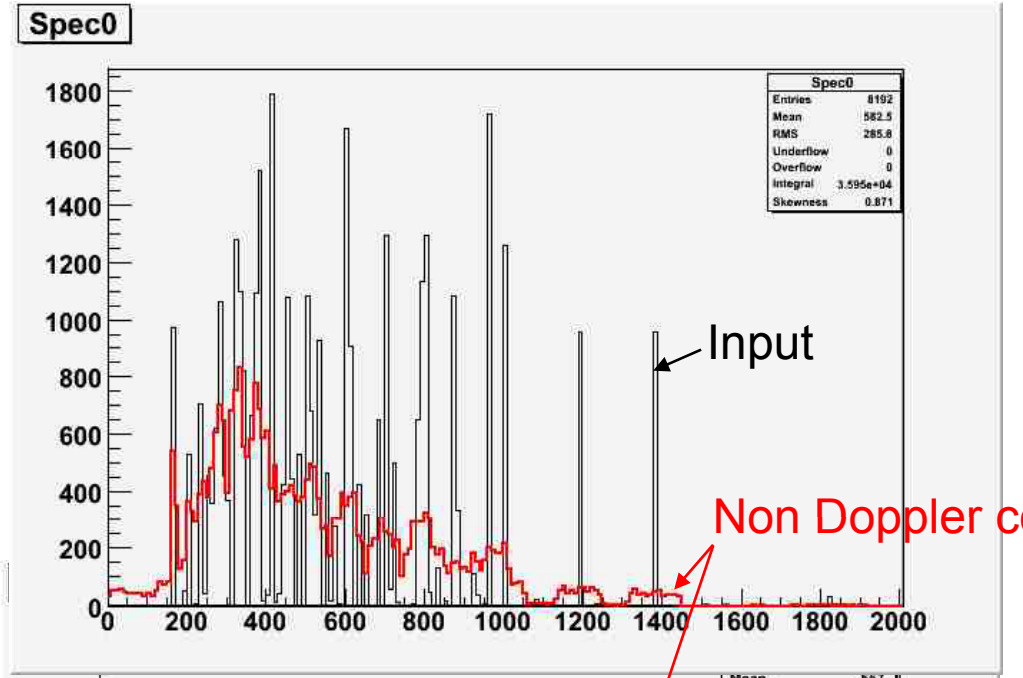
Arbitrary energy and velocity vector until the crash problem while running the Grazing code is solved

The problem with the GRAZING code has since been solved

AGATA Simulations (+ mgt)

γ from:

$^{175\text{-}178}$Yb



Still need to learn about

- GRAZING code
  - The Wilczynski plot seems to be given for projectile-like fragment only (?)
    - Solution: need to do kinematics calculations to get the angle and kinetic energy of the **target-like partner**

      Note:This is now done but need to be checked
- GaspWare
  - To analyse the simulations output.
    - E.g: apply gates on PRISMA and look coincidence in AGATA ?
  - Alternatively, write a ROOT analysis code.