Neutron & Gamma Correlations using CGM in MCNP 6.2

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Outline

- Reaction Sampling in MCNP
- Cascading Gamma-ray and Multiplicity (CGM)
- CGM Modifications in MCNP 6.2
- Examples
- Results
  - Secondary spectra comparisons
  - Correlated neutrons & gammas
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$$\sigma_i \qquad \overline{\nu_f} \qquad \overline{M_n} \qquad \overline{M_\gamma}$$

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$$\overline{M}_{\gamma} = 1.4$$

$$M_{\gamma} = 1 \quad (60\%)$$

$$M_{\gamma} = 2 \quad (40\%)$$

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  - Limits correlation of secondary particles

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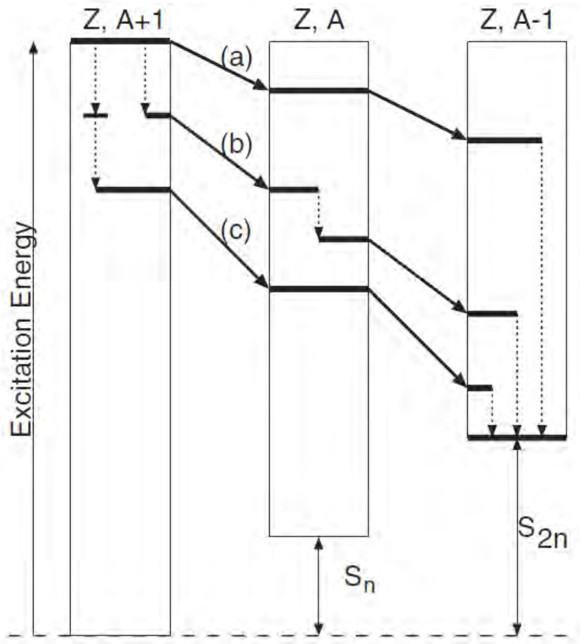

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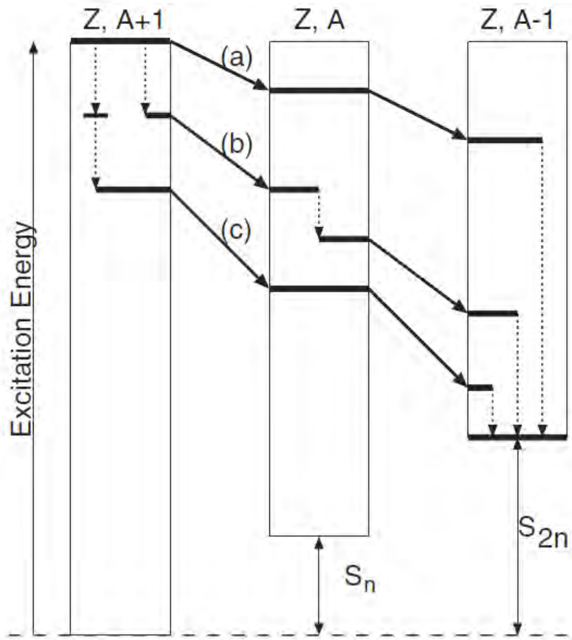

$$P(\varepsilon_n)dE_1 = \frac{T_n(E_x - S_n - E_1)\rho(Z, A-1, E_1)}{N} dE_1$$

$$P(\varepsilon_\gamma)dE_0 = \frac{T_\gamma(E_x - E_0)\rho(Z, A, E_0)}{N} dE_0$$

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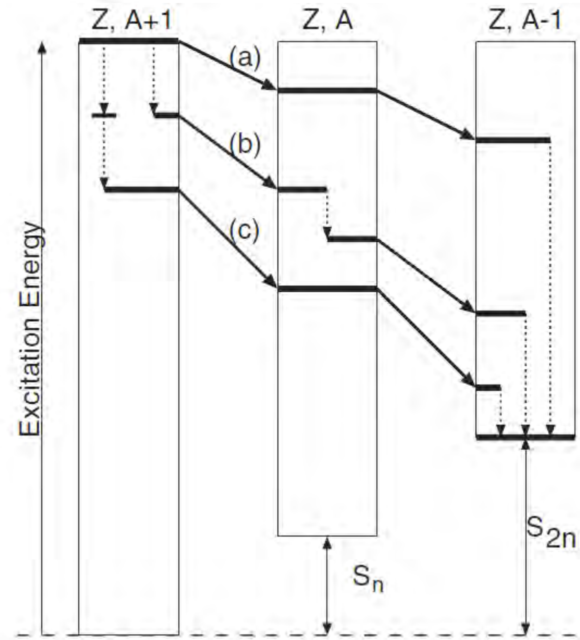

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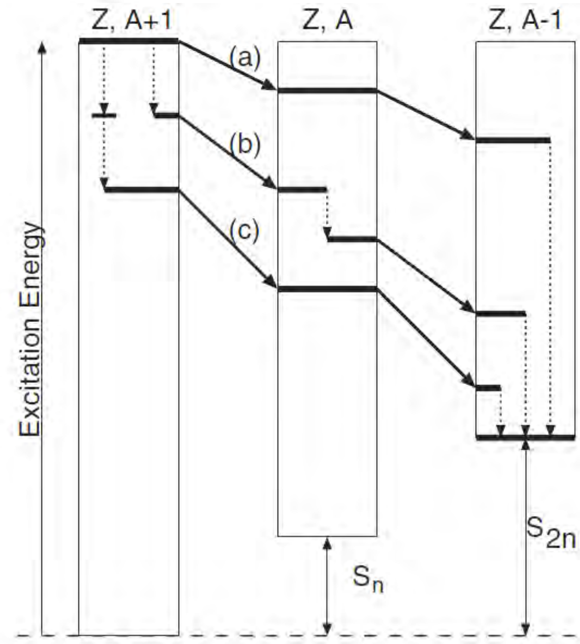
  - Provided ability to correlate secondary gammas[11]



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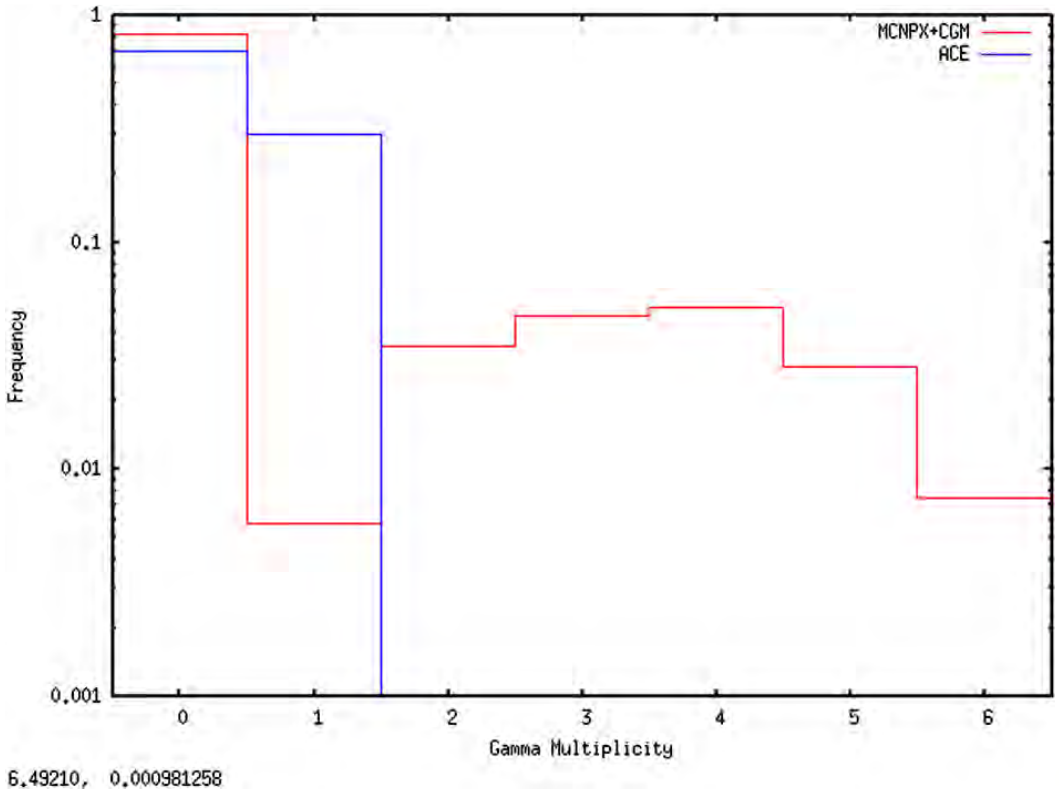
Cascading Gamma-ray and Multiplicity (CGM)

20 MeV, ^{56}Fe



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Reaction Q-value

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Neutron binding energy

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- Neutron captures forced to analog
- MCNP6 – 9th entry on PHYS:N card
- MCNPX – 8th entry on PHYS:N card

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Examples

- Thermal neutron, high Z (1 eV, ^{207}Pb)
- Fast neutron, high Z (16 MeV, ^{207}Pb)

Correlating secondary particles in MCNP

1. Activate ACE or CGM for neutron interactions

```
PHYS:n 8j 2    $ CGM
c PHYS:n 8j 1  $ ACE
```

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Correlating secondary particles in MCNP

1. Activate ACE or CGM for neutron interactions
2. Create an F1 tally for neutrons & photons

```
PHYS:n 8j 2    $ CGM
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f11:n 1
f21:p 1
```

Correlating secondary particles in MCNP

1. Activate ACE or CGM for neutron interactions
2. Create an F1 tally for neutrons & photons
3. Use the pulse-height light (PHL) tally option with an F8 tally to pair the neutron & gamma F1 tally for coincidence counting

```
PHYS:n 8j 2    $ CGM
c PHYS:n 8j 1  $ ACE
f11:n 1
f21:p 1
f8:n,p 1
ft8  PHL   1 11 1   1 21 1   0
```

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4. Bin the tally results by the # of neutrons and gammas produced

```
PHYS:n 8j 2    $ CGM
c PHYS:n 8j 1  $ ACE
f11:n 1
f21:p 1
f8:n,p 1
ft8  PHL   1 11 1   1 21 1    0
e8  0.5 1.5 2.5 3.5
fu8 0.5 1.5 2.5 3.5 4.5 5.5 6.5
      7.5 8.5 9.5 10.5 11.5 12.5
fq8 u e
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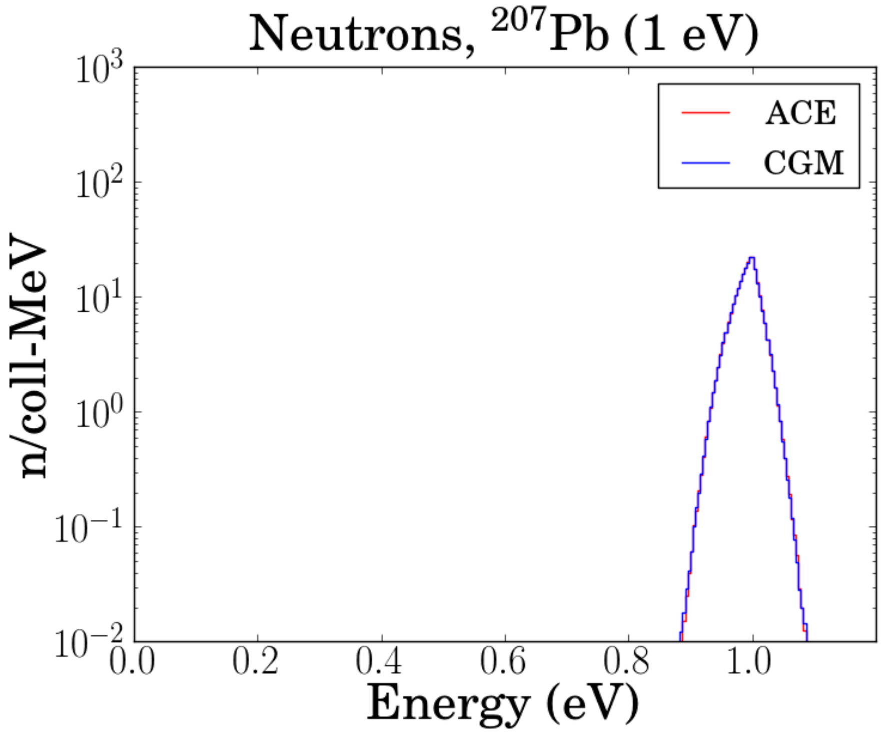
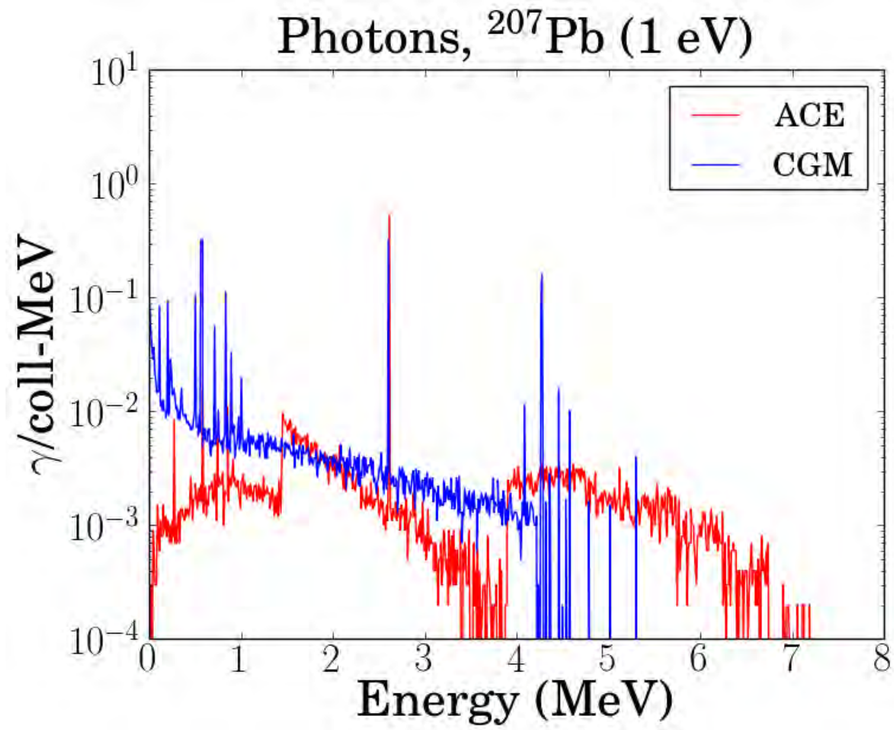

Neutrons, ^{207}Pb (1 eV)
ACE
CGM
n/coll-MeV
Energy (eV)


Photons, ^{207}Pb (1 eV)
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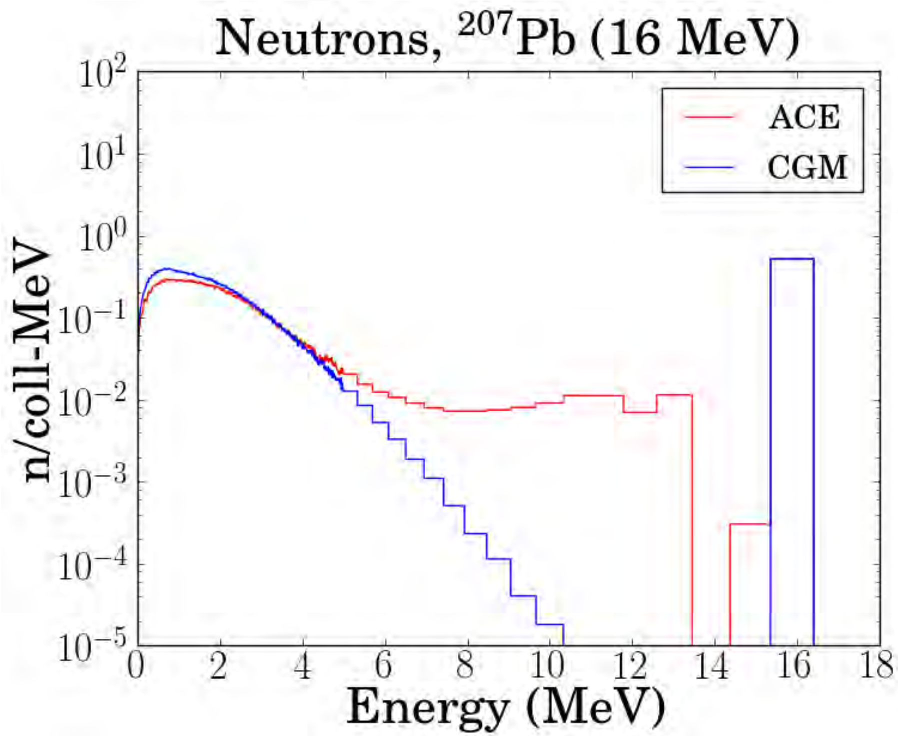
Neutrons, ^{207}Pb (16 MeV)
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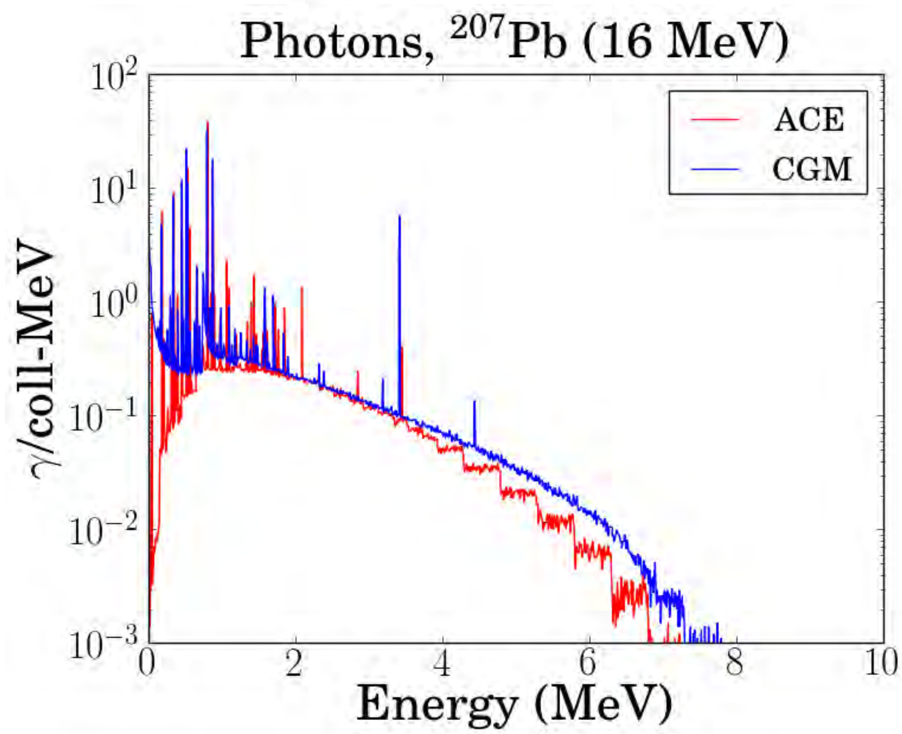
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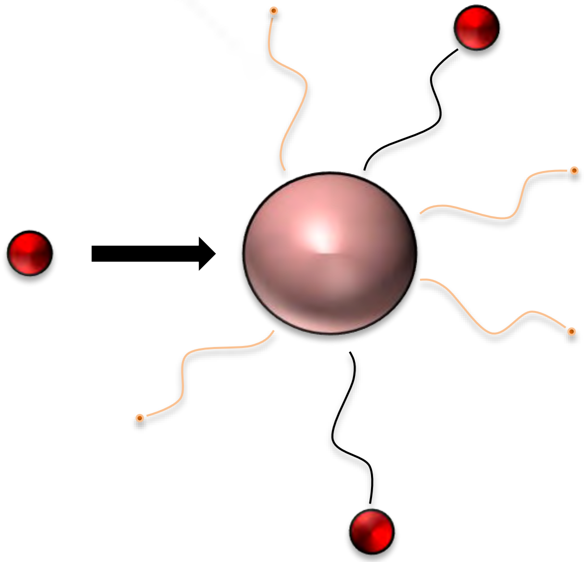

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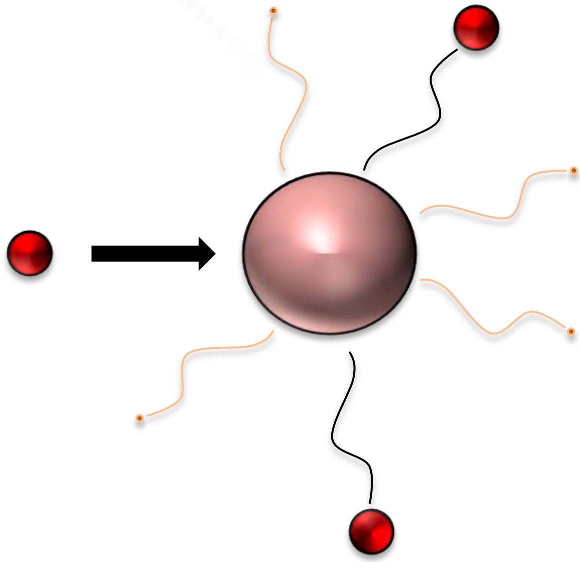
$$\left(n, M_n n' M_\gamma \gamma\right)$$



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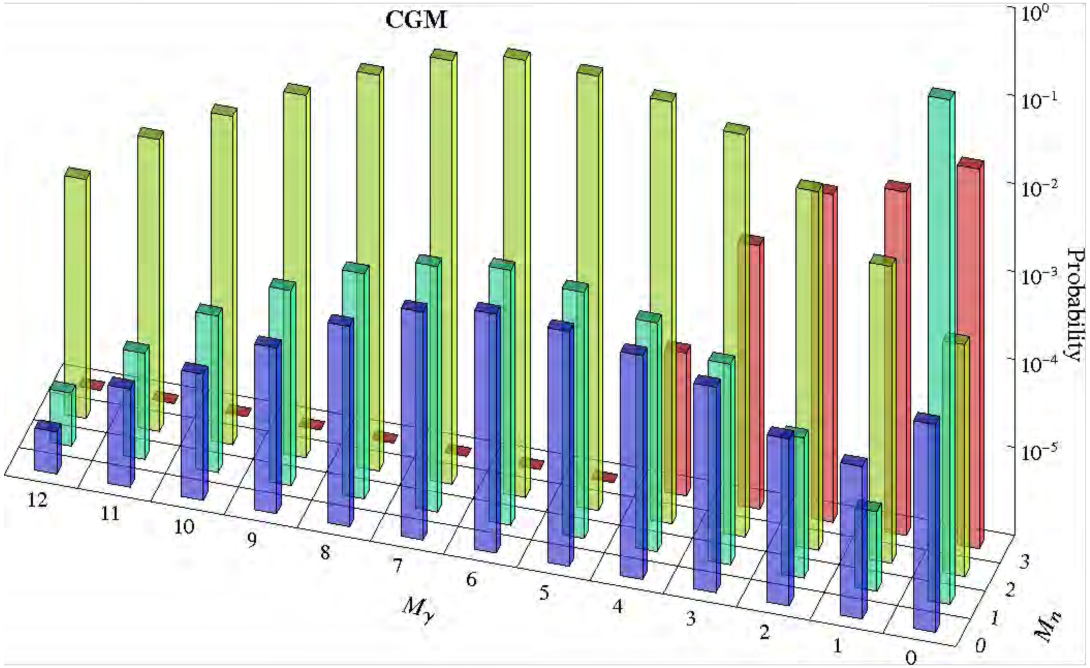

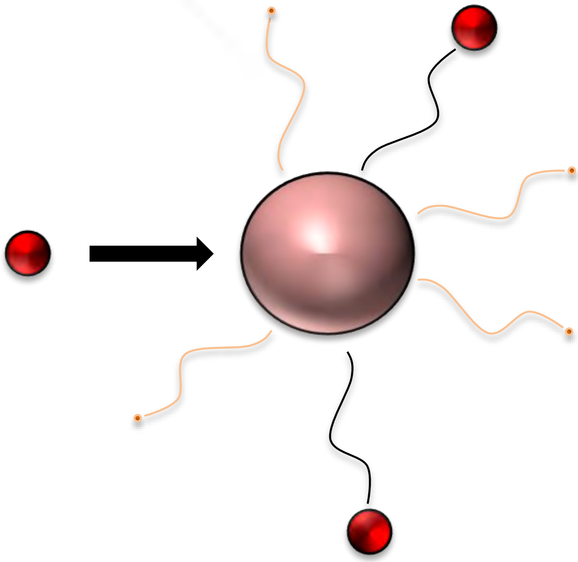

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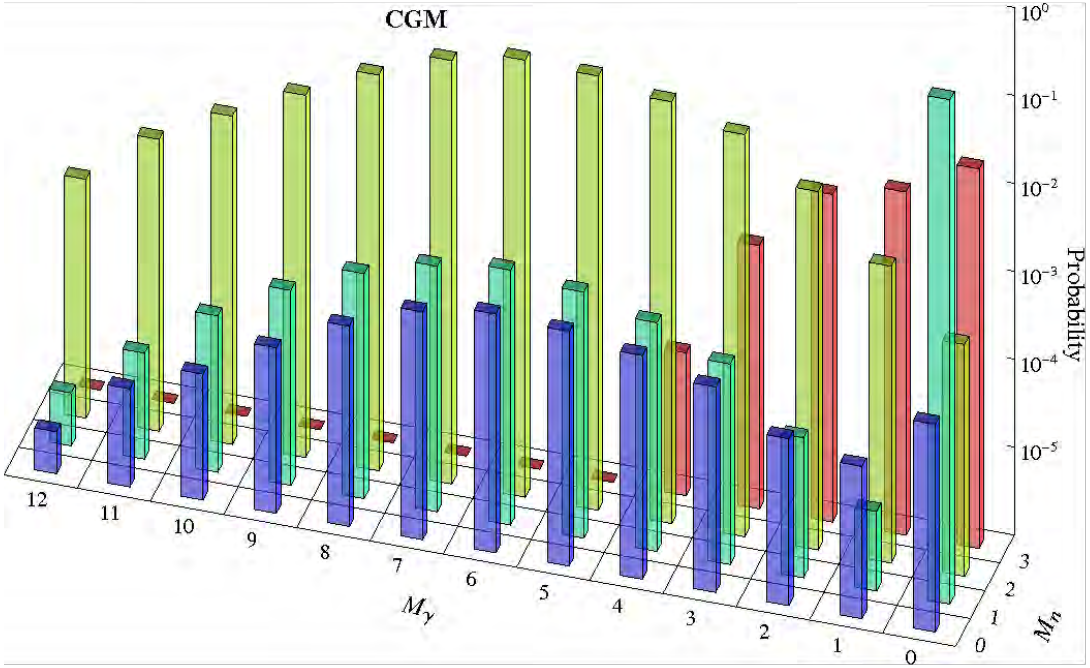
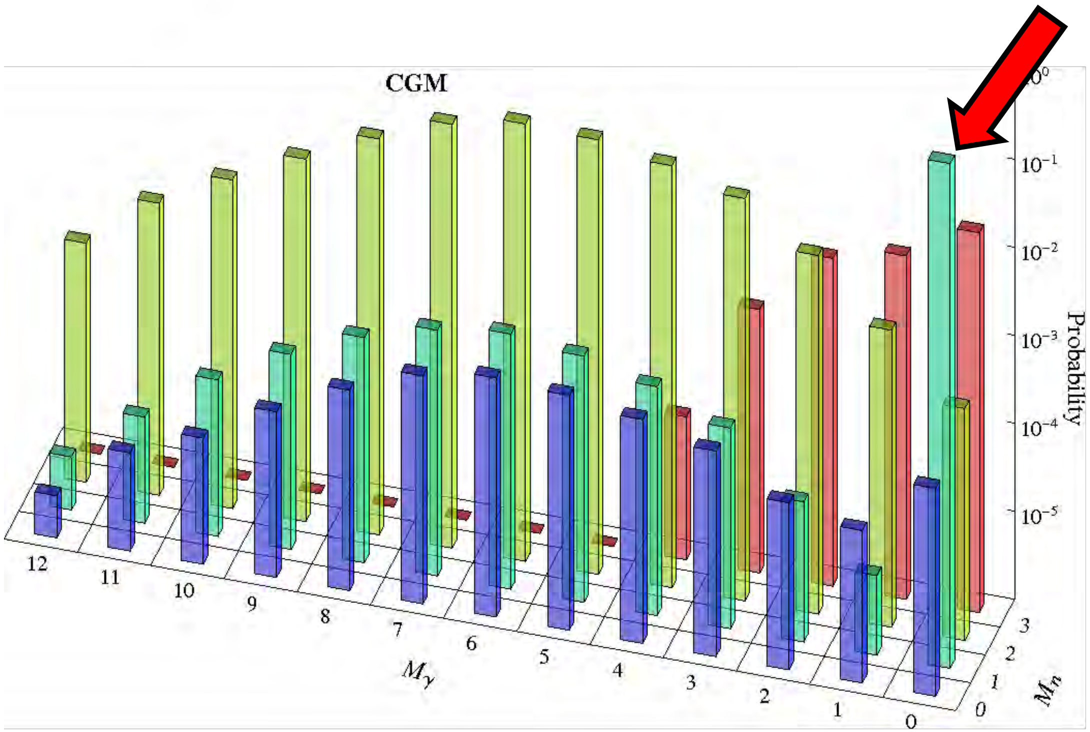


M_n	M_γ	Reaction
0	>=0	Capture (n,0n')
1	0	Elastic
1	>0	Inelastic, Threshold (n, n')
>1	>=0	Threshold (n, M_nn')

$$\left(n,\, M_n n' M_\gamma \gamma\right)$$



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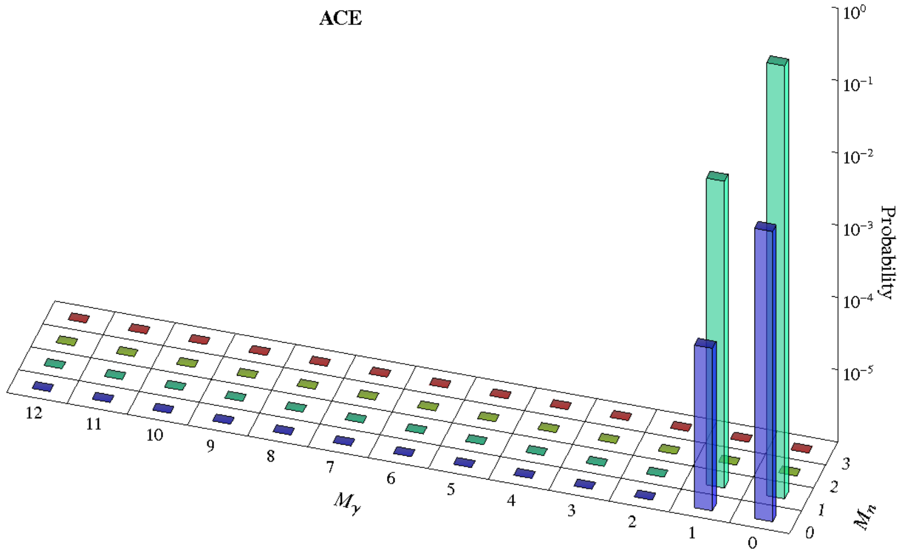
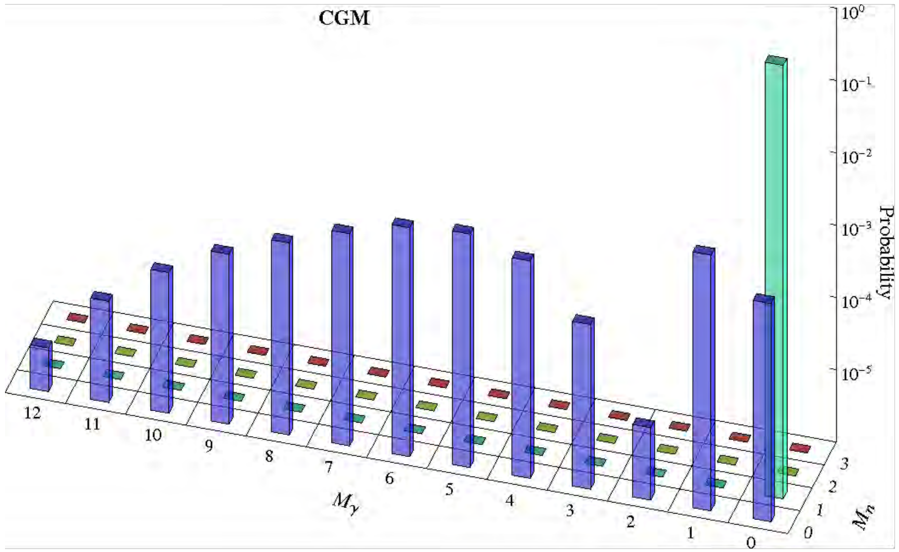
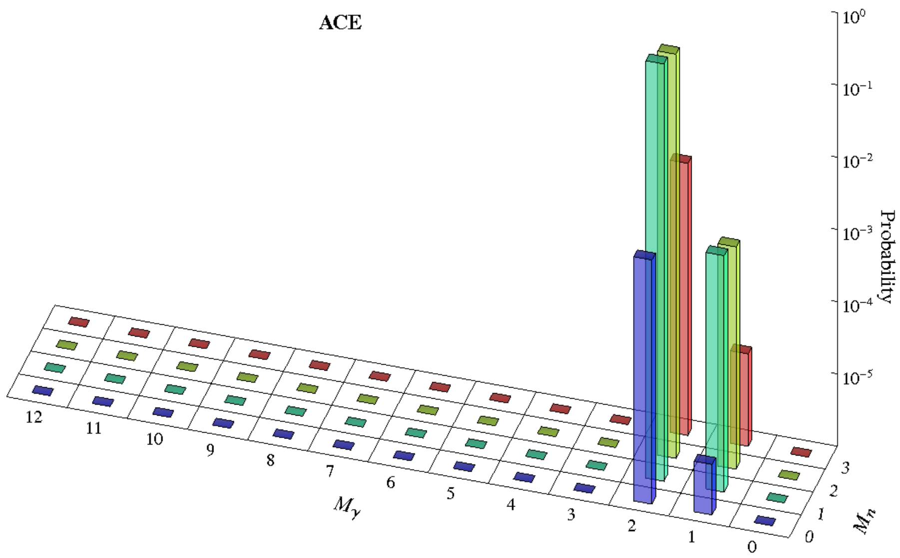
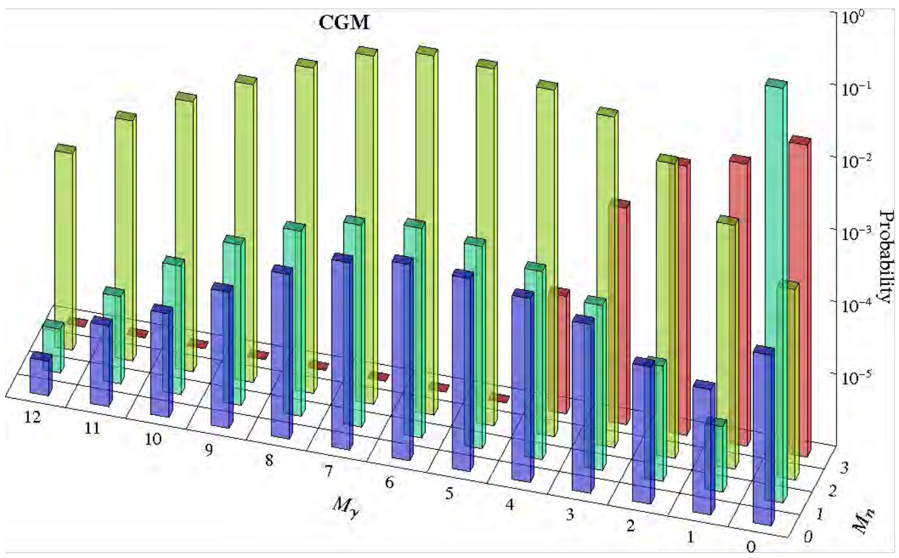
Mat.	Energy (MeV)	*rxn*	$\overline{M}_n$	$\overline{M}_\gamma$
^{207}Pb	1e-6	ACE	0.99	0.02
		CGM	0.99	0.04



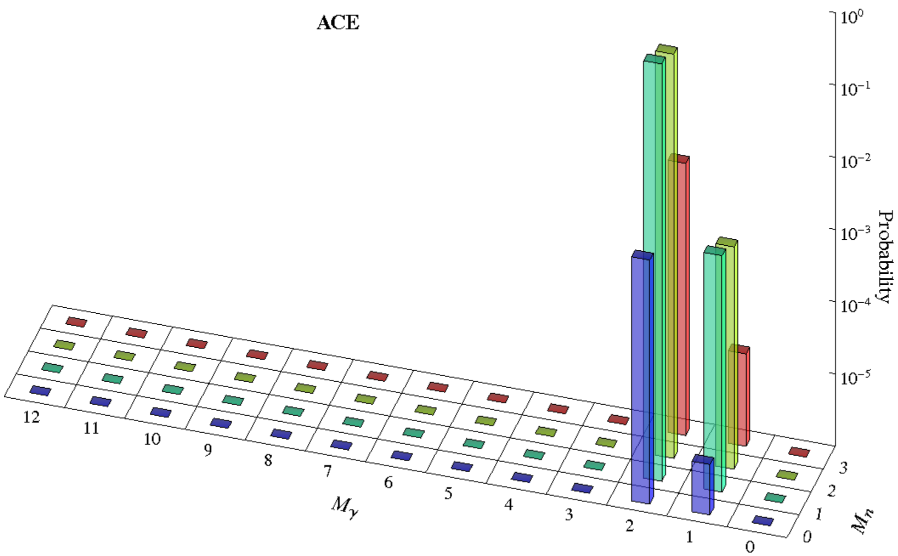


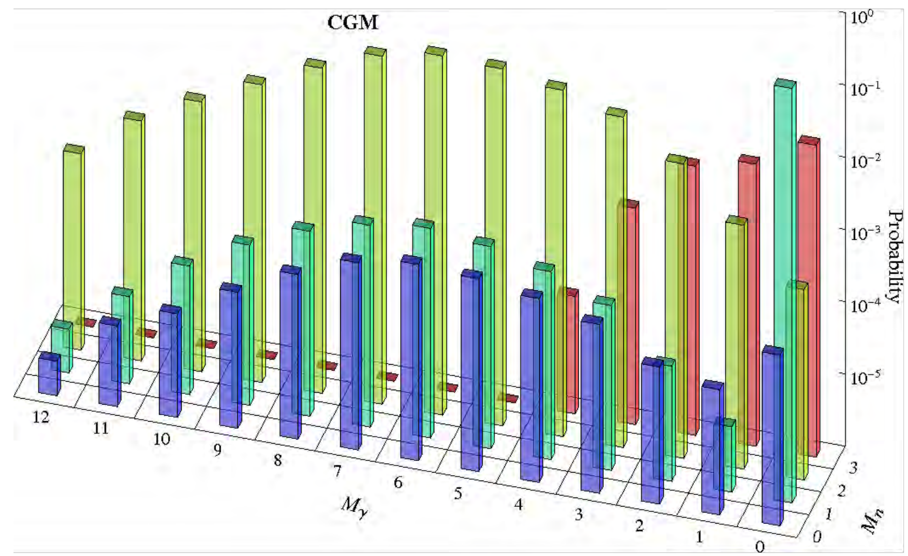
Mat.	Energy (MeV)	*rxn*	$\overline{M}_n$	$\overline{M}_\gamma$
^{207}Pb	16	ACE	1.40	2.00
		CGM	1.48	2.35





		M_n			
		0	1	2	3
$\overline{M}_\gamma$	ACE	2.00	2.00	2.00	2.00
	CGM	5.49	0.04	5.56	0.62





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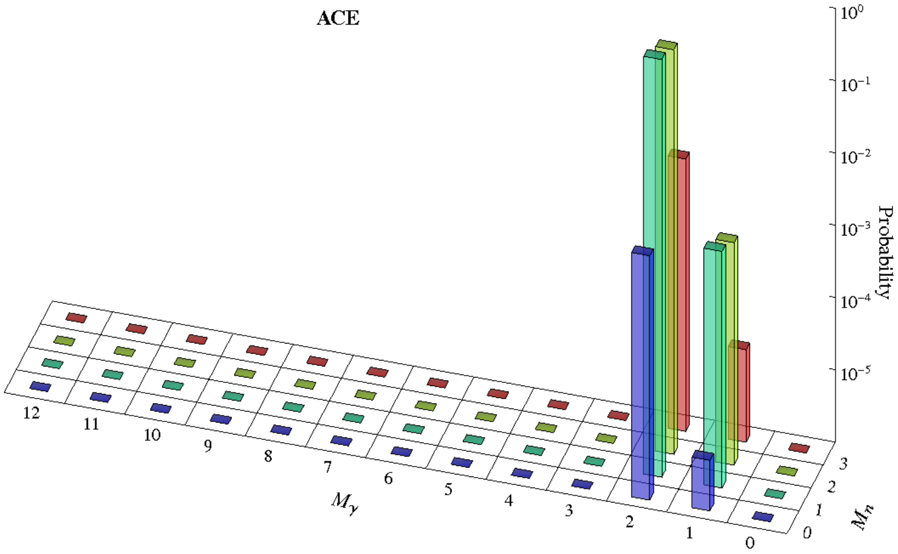
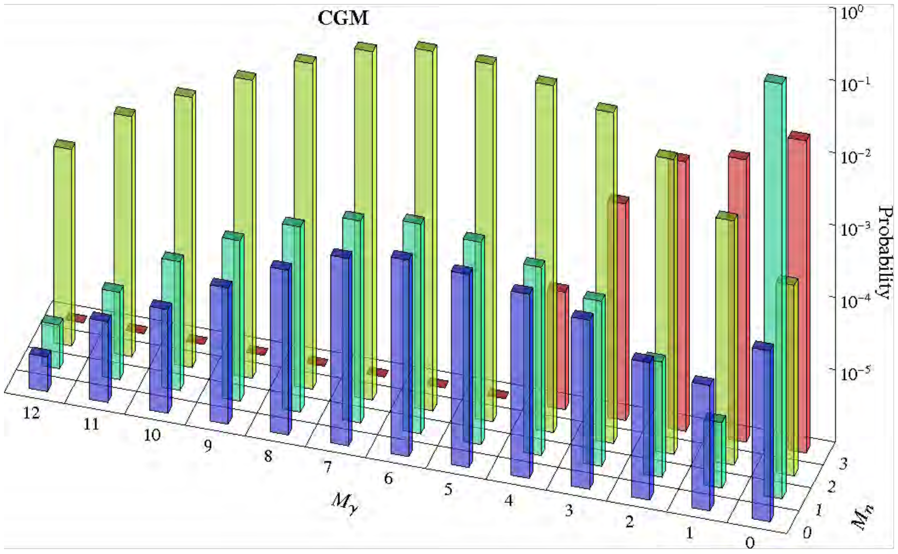
ACE samples the same M_γ distribution or all M_n!





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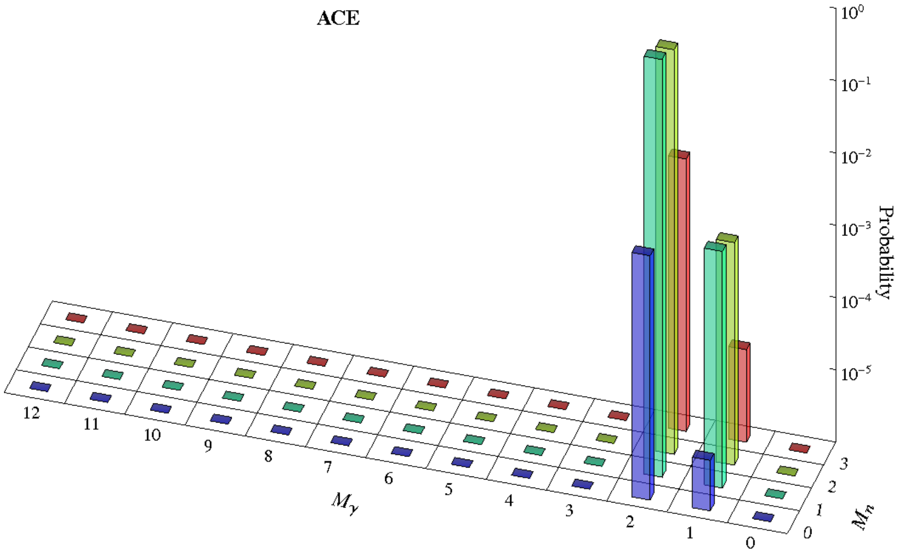
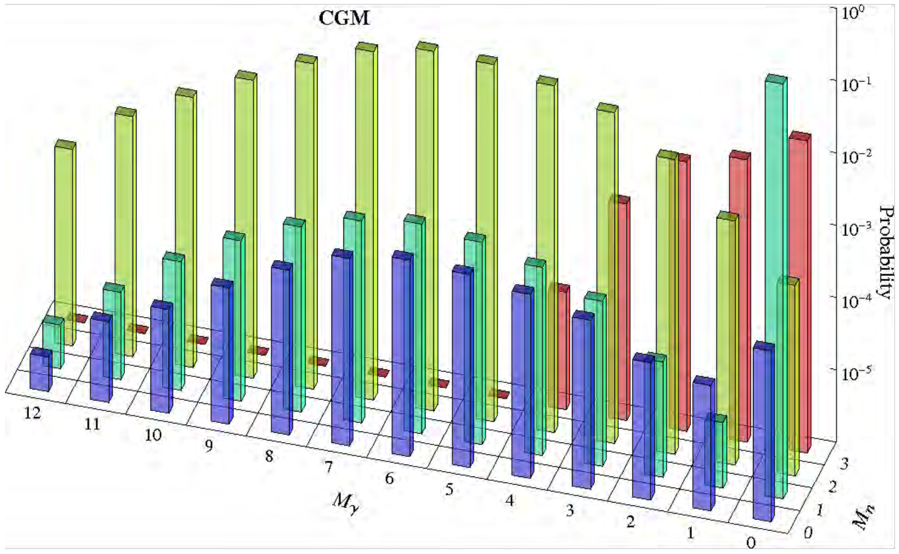
CGM has unique M_γ for each neutron multiplicity M_n!





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- Slight differences in average multiplicities between CGM/ACE

rxn	$\overline{M}_n$	$\overline{M}_\gamma$
ACE	0.75	0.88
CGM	0.75	1.03
ACE	1.22	1.18
CGM	1.47	1.33
ACE	0.99	0.02
CGM	0.99	0.04
ACE	1.40	2.00
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  - CGM suggested as theoretical model; continue utilizing ACE when average multiplicities are needed

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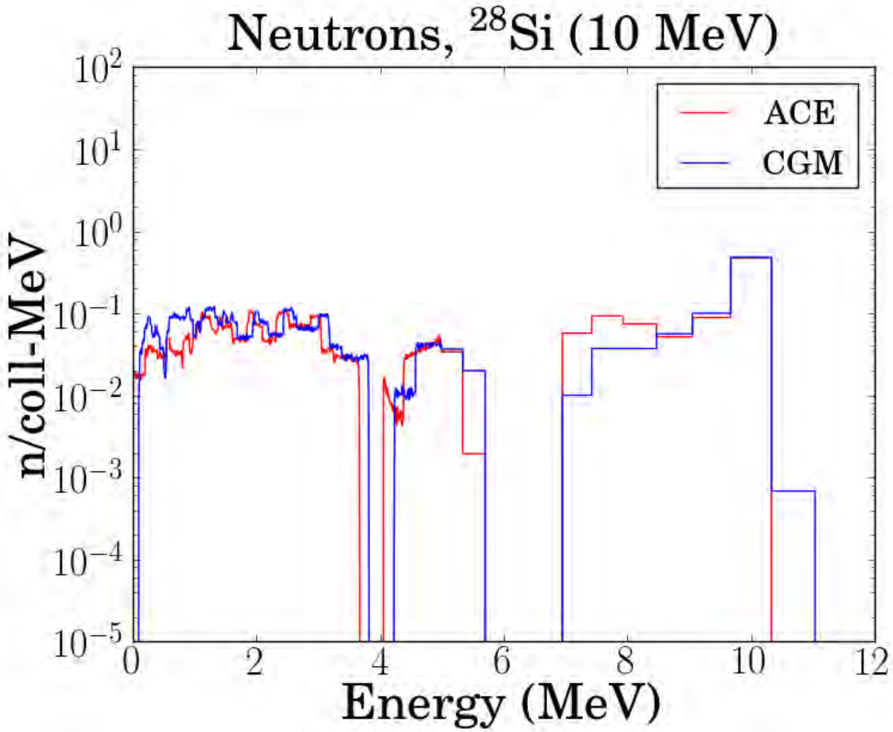
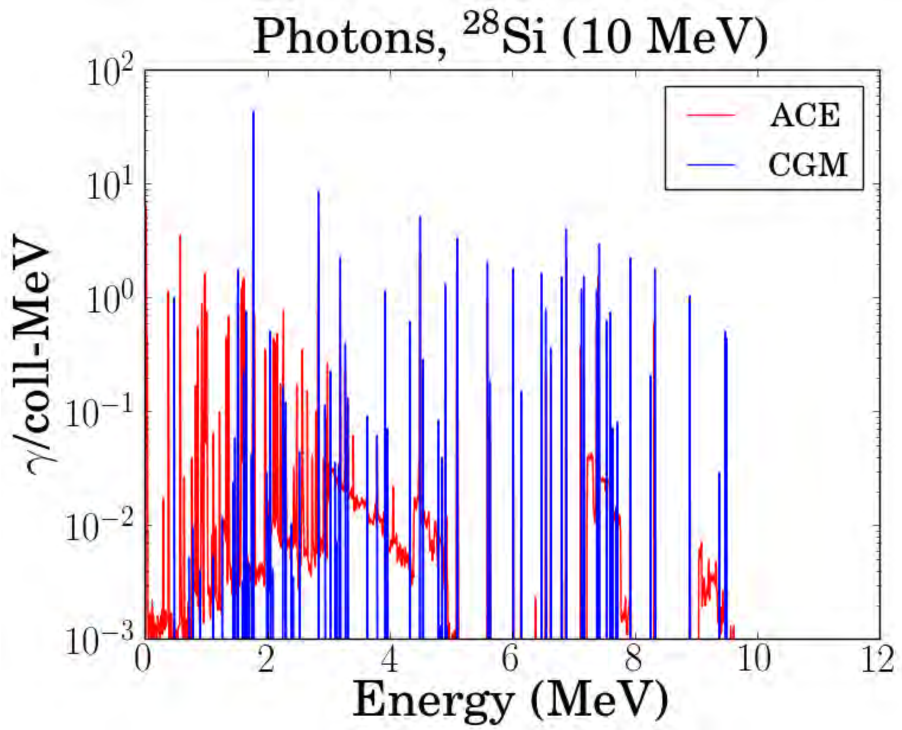
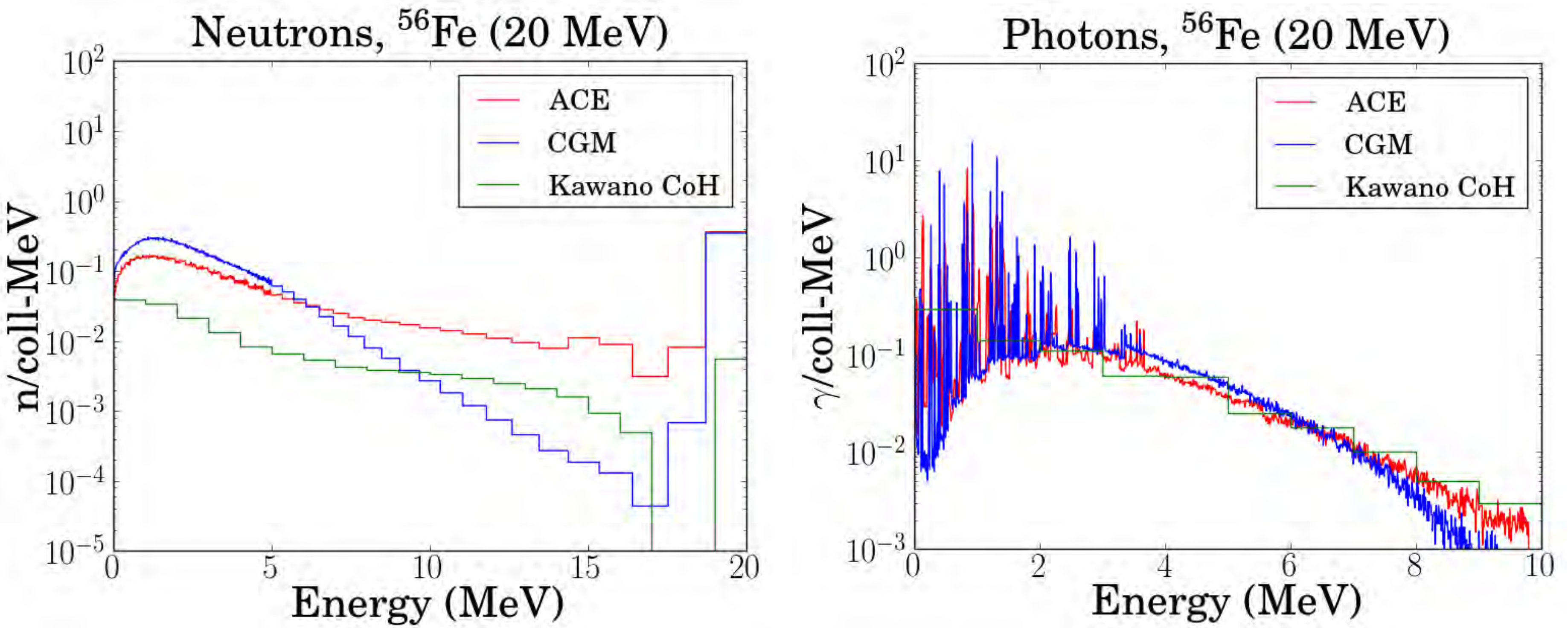
The End

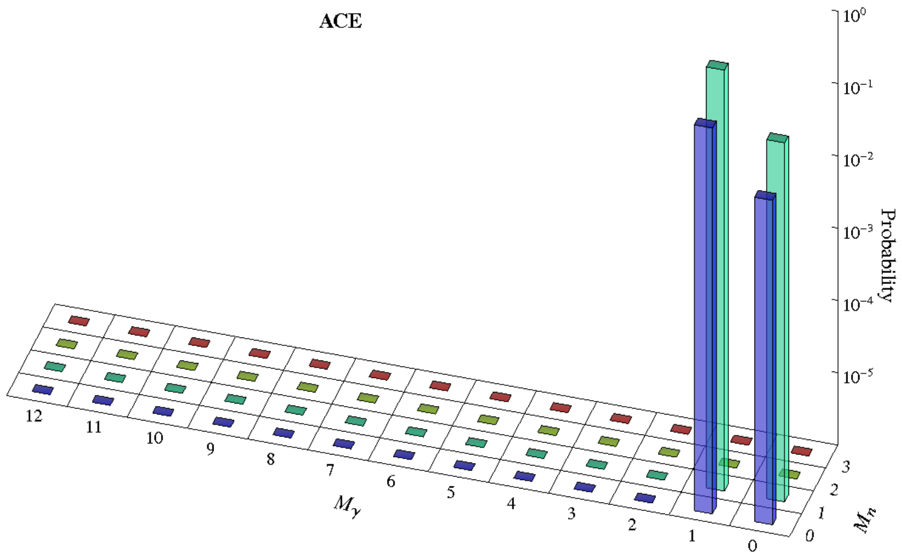
Extra Slides

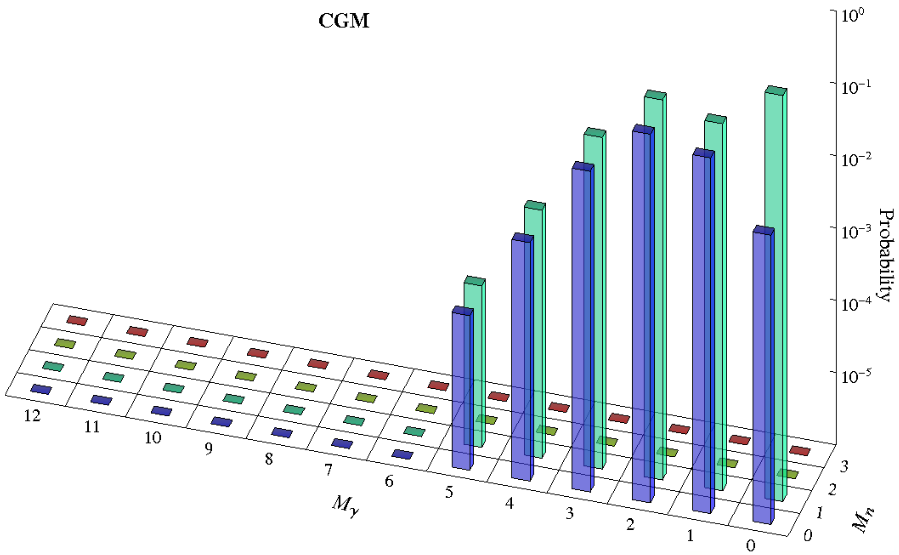

Neutrons, 28Si (10 MeV)
ACE
CGM
n/coll-MeV
Energy (MeV)


Photons, 28Si (10 MeV)
ACE
CGM
γ/coll-MeV
Energy (MeV)

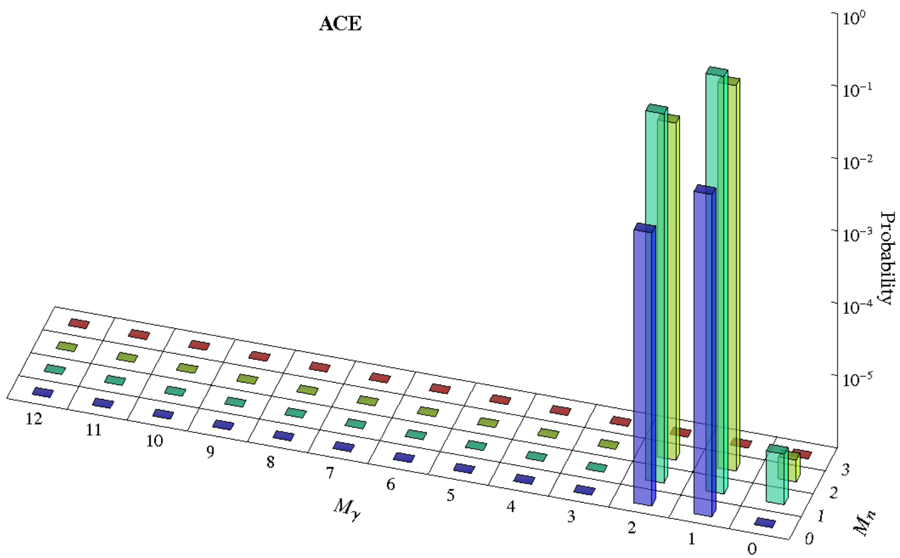

Neutrons, 56Fe (20 MeV)
n/coll-MeV
Energy (MeV)
ACE
CGM
Kawano CoH
Photons, 56Fe (20 MeV)
γ/coll-MeV
Energy (MeV)
ACE
CGM
Kawano CoH

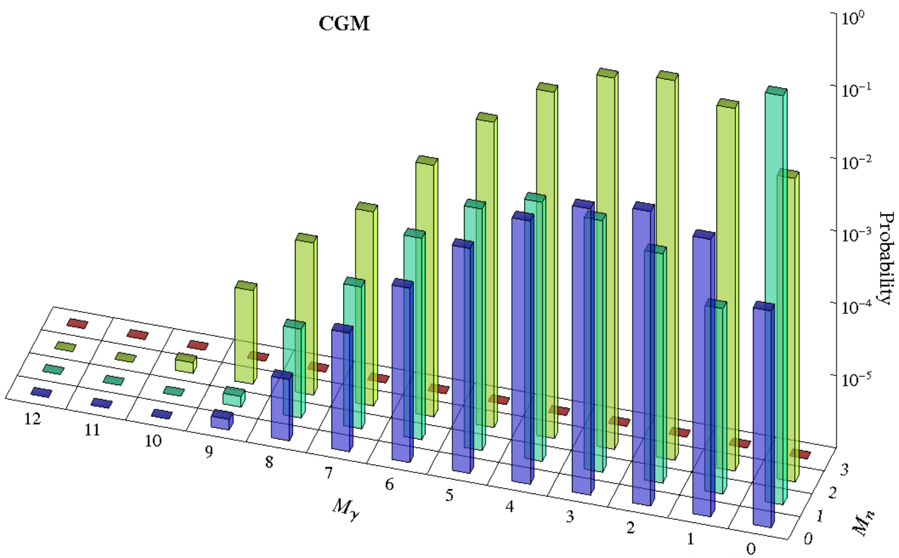
Mat.	Energy (MeV)	*rxn*	$\overline{M}_n$	$\overline{M}_\gamma$
^{28}Si	10	ACE	0.75	0.88
		CGM	0.75	1.03





Mat.	Energy (MeV)	*rxn*	$\overline{M}_n$	$\overline{M}_\gamma$
^{56}Fe	20	ACE	1.22	1.18
		CGM	1.47	1.33





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