ATW Simulations and the Role of Nuclear Cross-Section Data

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Assumptions for Current ATW Design

- Cylindrical lead-bismuth-eutectic (LBE) target (18 to 25 cm in radius) with proton beam entering from top
- Hexagonal/cylindrical blanket surrounds target (radius ~100 cm)
- Blanket consists of actinide/zirconium fuel rods with stainless-steel (SS) cladding and LBE coolant (this may be changed to sodium)
- ATW fuel is plutonium and minor actinides plus 0.005% residual uranium in transuranic (TRU) fuel from light-water-reactor(LWR) spent fuel

Neutronics Issues

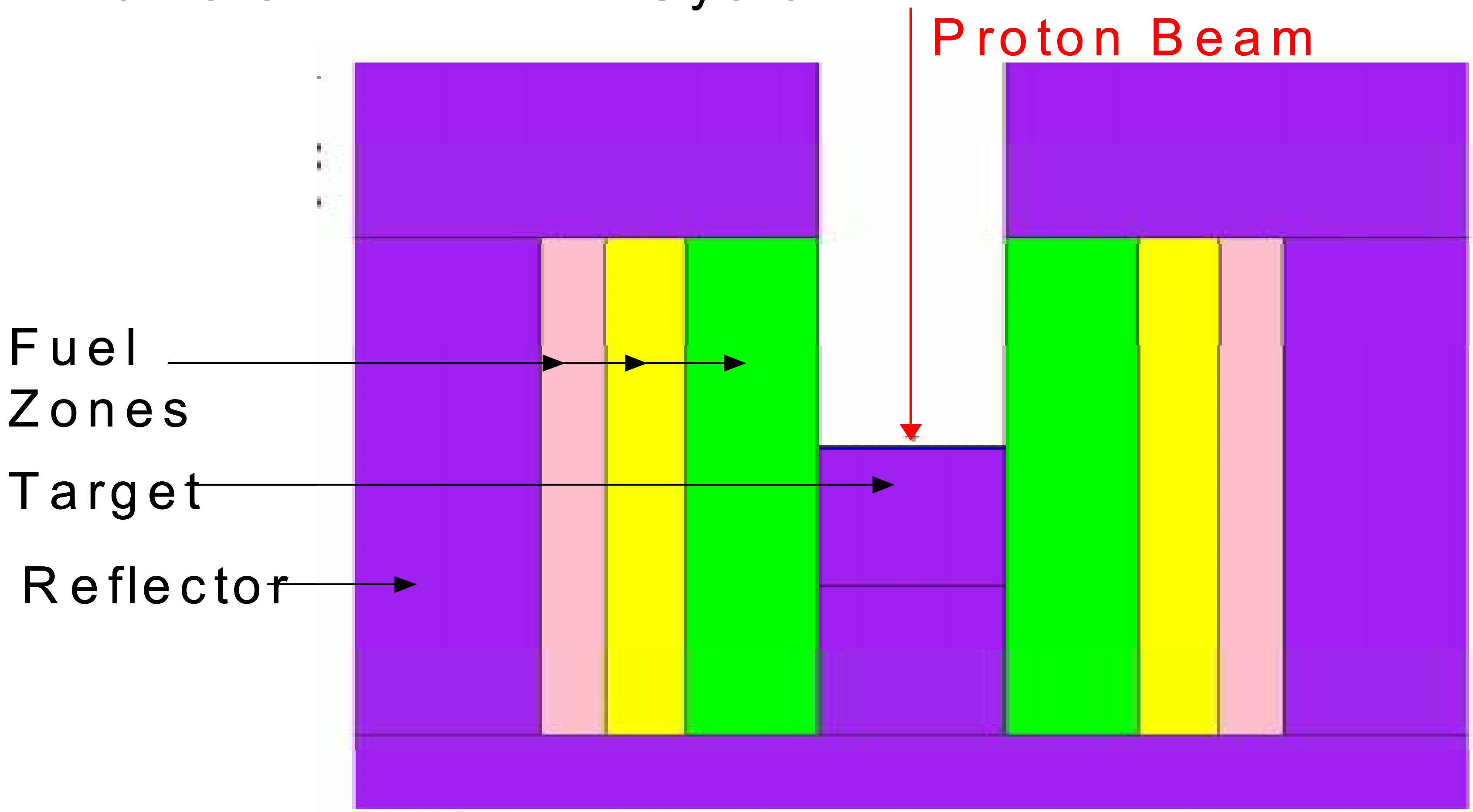
- As material is burned, so are fissile isotopes, and the effective multiplication factor (k_{eff}) drops
- To maintain chain reaction/power, (1- k_{eff}) fraction of neutrons must be produced by accelerator – higher (~0.95 to 0.97) and more stable k_{eff} preferred
- The harder (faster) the spectrum, the higher the actinide fission-to-capture ratio, which allows more effective transmutation
- Once the system is started, fission products and uranium are removed each cycle (4-6 months) and new actinides added until an equivalent amount of each actinide added is burned (steady state)

Sample Composition of ATW Fuel

Isotope	Average Core Composition
U-238	0.17
Np-237	3.36
Pu-238	5.95
Pu-239	27.29
Pu-240	35.68
Pu-241	5.46
Pu-242	10.12
Am-241	6.15
Am-242m	0.54
Am-243	1.90
Cm-242	0.43
Cm-243	0.03
Cm-244	2.15

Cross-Sectional View of LBE Target/Blanket Configuration

Profile of ATW LBE System



Cross-Section Studies

- Isotopes Examined
  - Pu-238
  - Pu-239
  - Pu-240
  - Pu-241
  - Pu-242
  - Np-237
  - Am-241
  - Cm-242
  - Cm-244
- Libraries
  - JEF-2
  - JENDL-3.2
  - BROND-2
  - CENDL-2

For each MCNP run, the library of one isotope was changed, with ENDF-VI libraries being the default

Parameters Examined

- k_{eff} and assoc. error
- Delayed Neutron Fraction (β)
- ν number of neutrons generated per fission
- Capture and Fission Cross Sections
- Fission-to-Capture Ratio
- Void Reactivity Coefficient (0 and 10% coolant)
- Temperature Reactivity Coefficient (980K – 1580K)
- Remember: Statistics DO affect results!!!

  (this contributes to large changes in void react. coeff. and positive temp. react. coeff.)

Basecase Parameters

- k_{eff} = 0.95726
- β = 0.00418 = one $ in further reactivity calculations
- ν = 3.01
- σ_c = 0.117 barns
- σ_f = 0.145 barns
- Temperature Reactivity Coeff = -$0.18
- Void Reactivity Coeff = -$75
- 10% Coolant Reactivity Coeff = -$63.5

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Pu-239

measure	JEF	JENDL	BROND	CENDL
keff	0.95037	0.957	0.95117	0.9573
error	0.00165	0.0018	0.00194	0.00199
capt. xs	0.12481	0.12461	0.12677	0.1233
fiss. xs	0.16964	0.16868	0.16862	0.16985
fiss/capt	1.35927	1.35364	1.33014	1.37757
nu	3.00617	3.00915	3.00148	3.0032

Pu-240

measure	JEF	JENDL	BROND	CENDL
keff	0.9504	0.95035	0.96168	0.95388
error	0.00185	0.00167	0.00155	0.0016
capt. xs	0.12763	0.12759	0.12729	0.12487
fiss. xs	0.16868	0.16782	0.16899	0.16824
fiss/capt	1.32159	1.31529	1.32762	1.34726
nu	3.00227	3.00506	3.02187	3.0069

Np-237

measure	JEF	JENDL	CENDL
keff	0.95593	0.95771	0.95489
error	0.00184	0.00188	0.00186
capt. xs	0.12489	0.12456	0.12392
fiss. xs	0.16898	0.16905	0.16889
fiss/capt	1.3531	1.35722	1.36298
nu	3.01574	3.0094	3.00781

Am-241

measure	JEF	JENDL	CENDL
keff	0.95626	0.95531	0.95798
error	0.00181	0.00184	0.00228
capt. xs	0.12561	0.12207	0.1244
fiss. xs	0.16881	0.16878	0.16896
fiss/capt	1.34395	1.38261	1.35825
nu	3.00767	3.0044	3.00713

Cm-242

measure	JEF	JENDL	BROND
keff	0.95699	0.95791	0.95257
error	0.00166	0.00211	0.00168
capt. xs	0.12487	0.12516	0.12406
fiss. xs	0.16948	0.1694	0.16929
fiss/capt	1.35727	1.35349	1.36454
nu	3.01205	3.01078	3.00932

Cm-244

measure	JEF	JENDL	BROND
keff	0.95494	0.95836	0.95639
error	0.00164	0.00183	0.00184
capt. xs	0.12397	0.12368	0.12352
fiss. xs	0.16894	0.169	0.16883
fiss/capt	1.36278	1.36641	1.3668
nu	3.00381	2.99994	3.02053

Pu-238

measure	JEF	JENDL	BROND
keff	0.9564	0.95914	0.95947
error	0.00169	0.00174	0.00166
capt. xs	0.12284	0.12322	0.12247
fiss. xs	0.16919	0.169	0.16877
fiss/capt	1.37732	1.37152	1.37801
nu	3.00717	3.00078	2.996

Pu-241

measure	JEF	JENDL	BROND
keff	0.95531	0.95252	0.95703
error	0.00179	0.00158	0.00186
capt. xs	0.12593	0.12493	0.12407
fiss. xs	0.16886	0.16893	0.16876
fiss/capt	1.34088	1.35216	1.36019
nu	3.00828	3.00385	3.01076

Pu-242

measure	JEF	JENDL	BROND
keff	0.95366	0.94999	1.03128
error	0.00173	0.00178	0.00202
capt. xs	0.12507	0.12443	0.11645
fiss. xs	0.16904	0.16852	0.19241
fiss/capt	1.35163	1.35435	1.65222
nu	3.00299	3.0102	2.97714

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Conclusions

- Variances are seen by using different libraries
- Cross-section libraries had largest effects on most abundant isotopes (Pu-240 is best example)
- Pu-242's BROND library showed greatest deviation in k_{eff}
- Better accuracy is needed to reduce statistical effects