Improving RR Security

Rethinking Self-Protection

Building on *C. Hansell, F. Dalnoki-Veress, Examining Self-Protection Requirements: Methods to Improve Security of HEU materials, presented at the International Symposium on Nuclear Security, Vienna, 30 March - 3 April 2009*

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Outline

- HEU proliferation concern
- Concept of Self-Protection
- Evaluating Self-Protection
- Analysis of typical MTR
- Recommendation of removal of fuel after 5 months

HEU Proliferation Concern

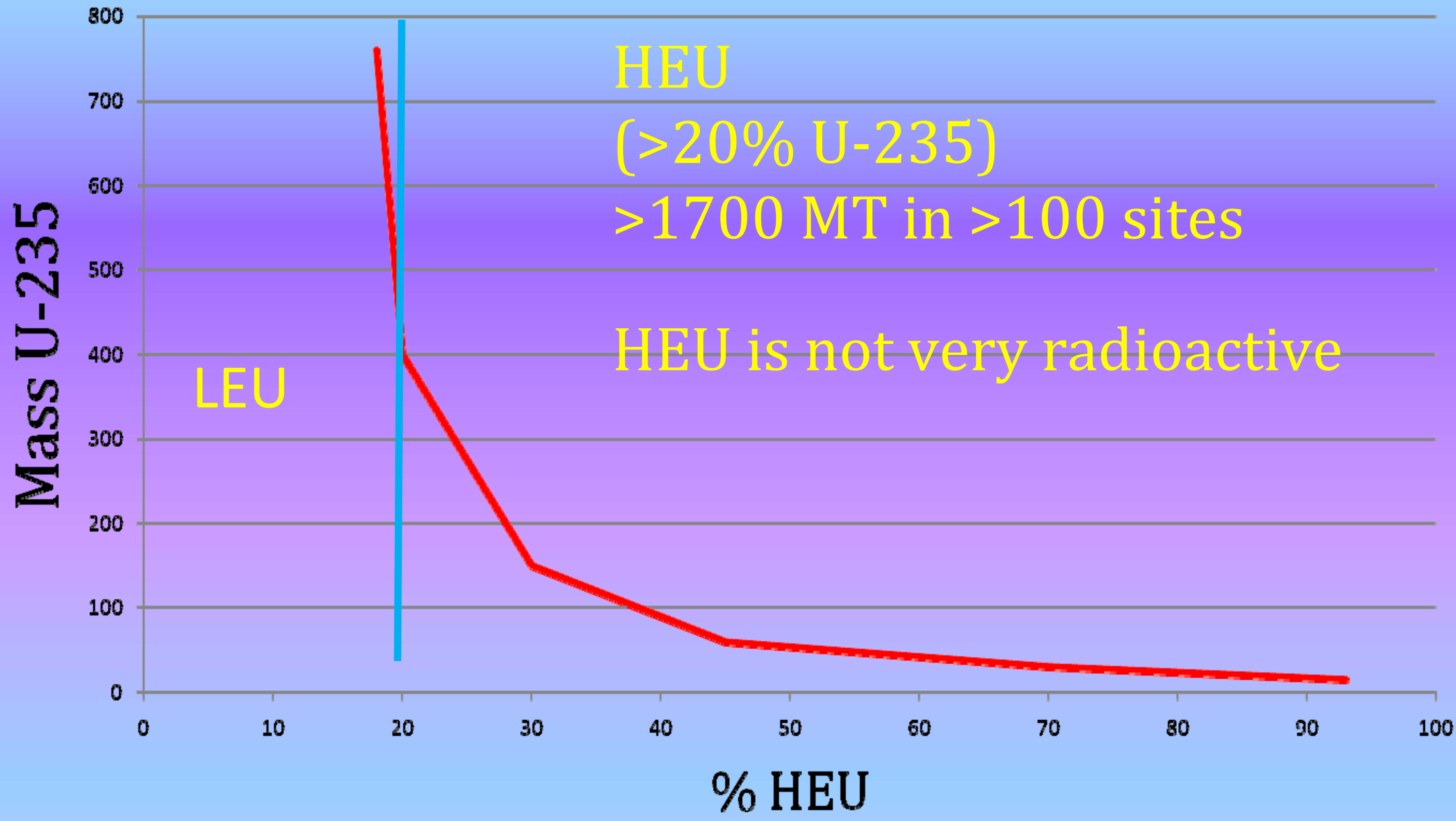


Figure adapted from A. Glaser and F. v. Hippel, Arms Control Today, Jan/Feb 2006

Notion of Self-Protection (SP)

IAEA Recommendations for the physical protection of SNM (INFCIRC/225/Rev.4) → Graded System

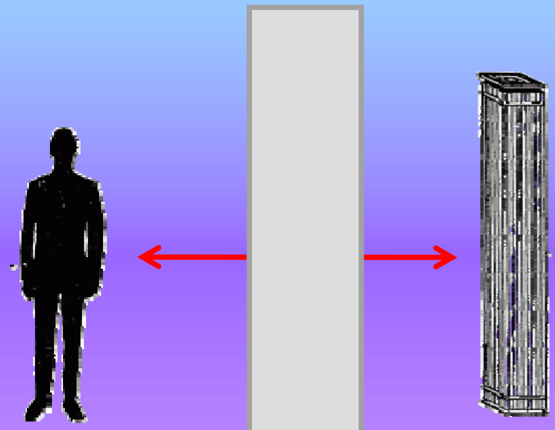
Enrichment (E)	CAT 1	CAT 2	CAT 3
E>20% →	M>5kg	1 kg<M<5 kg	15 g <M<1 kg
10%<E<20% →		M>10 kg	1 kg < M < 10 kg
E<10% →			M>10 kg
Irradiated but >1 Gy/hr	Cat Befor Irr +1	Cat Before Irr +	

Decreasing Level of Security →

Nuclear exceeding 1 Gy/hr (100 rads/hr) at 1 m unshielded enjoy a lower category (1975 regulation)

IAEA "Self-protection" : Irradiated fuel/targets protected from theft by psychological deterrent (high dose deters theft)

To Summarize: A Different Perspective



SAFETY

Dose from fuel/targets as low as possible

ALARA

Shielding to prevent exposure

SECURITY/ NONPROLIFERATION

Dose from fuel/targets as high as possible

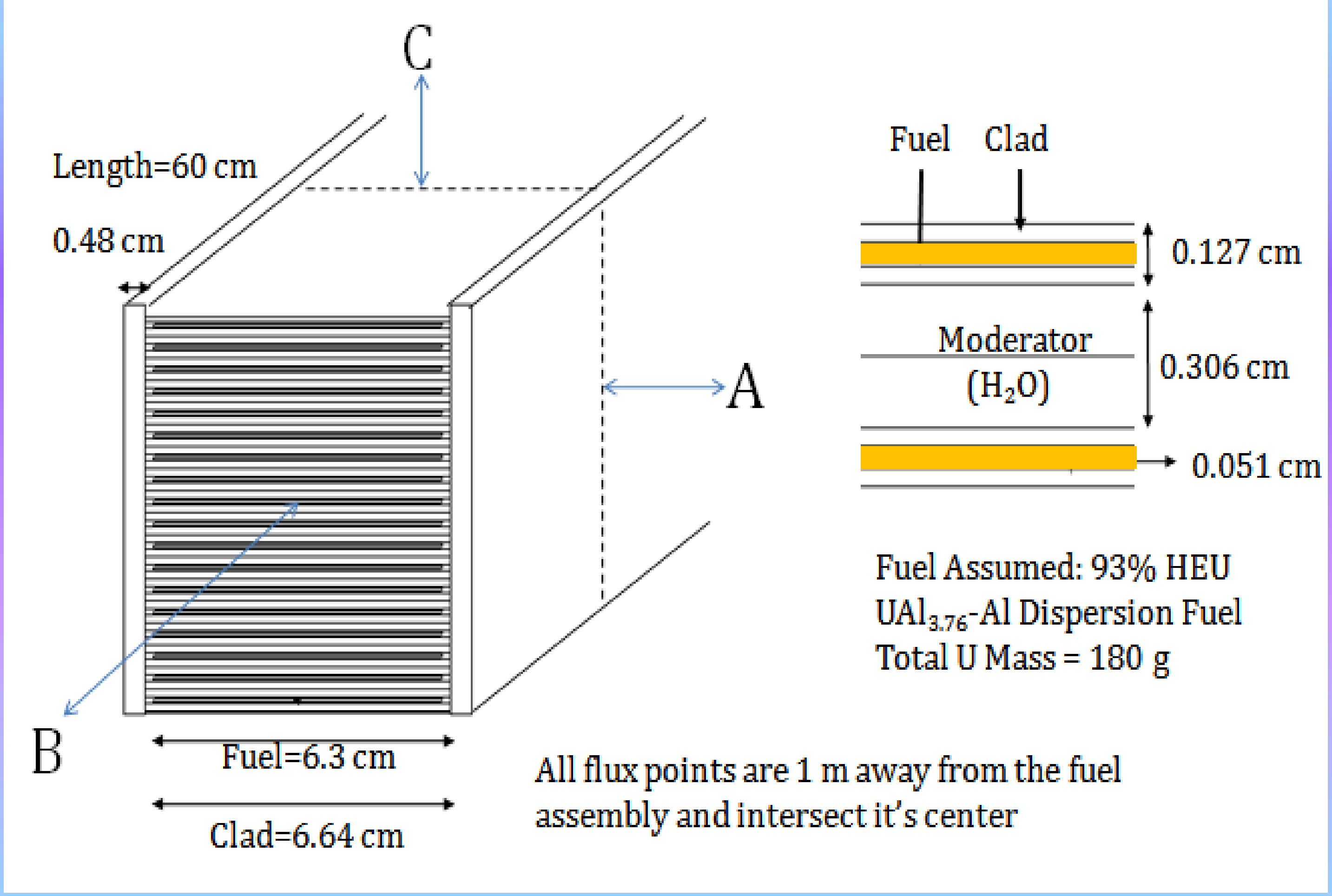
Self-Protecting

Barrier to prevent access

Evaluating SP

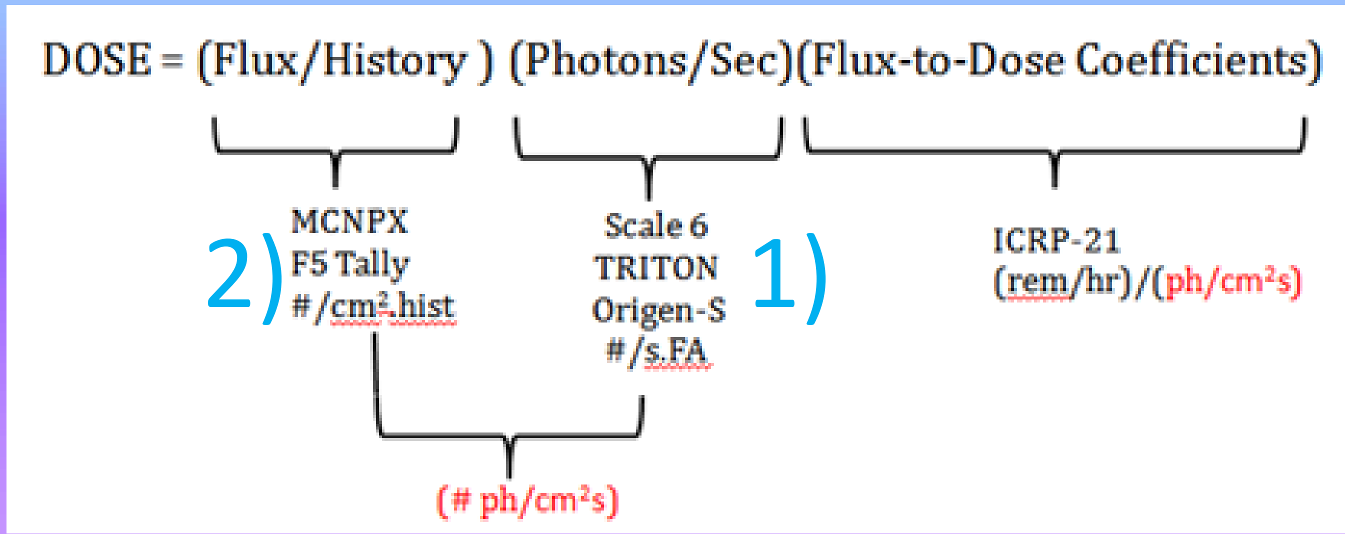
- Many authors have criticized the 1 Gy/hr criterion (Lyman, E., Von Hippel,F., Arms Control Today, April 2008)
- Coates *et al* (ORNL,2005) defined SP as "incapacitance" and found that SP dose is 2 orders of magnitude higher
- Koeling and Barts (LANL,1982) found that spent nuclear fuel could be easily stolen in time < time for "incapacitance"
- Pond and Matos (96): Thorough evaluation of SP of different reactor types for 1 Gy/hr (IAEA regulation)
- Similar calculations for **10 Gy/hr** and 19-plate MTR fuel (Typical MTR : Tecdoc-643)
- Iso-dose curves as a function of T_{irr} and T_{decay} to determine when fuel must be removed

19-Plate MTR Dose Calculation



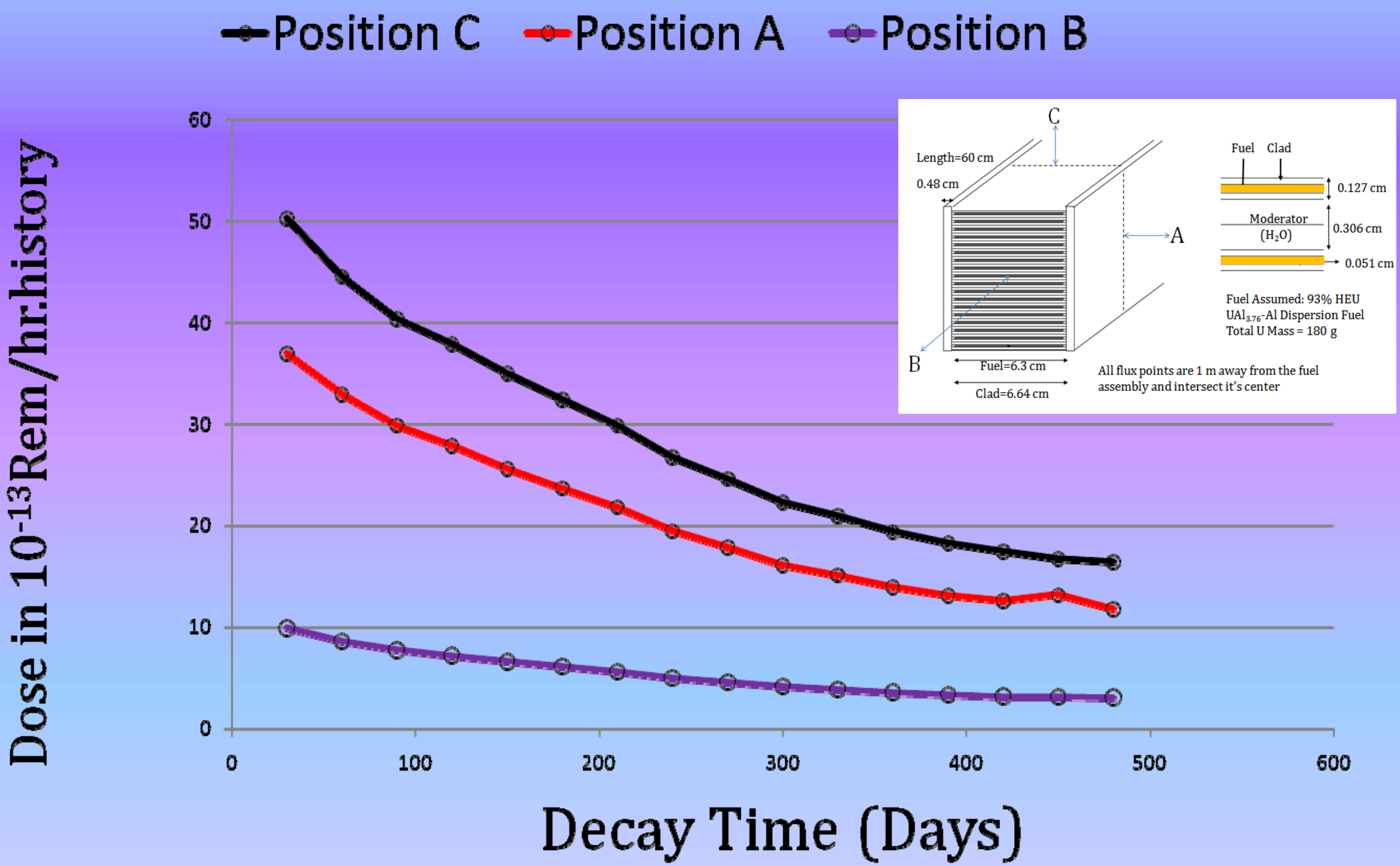
- Dose evaluated at 3 different points

19-Plate MTR Dose Calculation



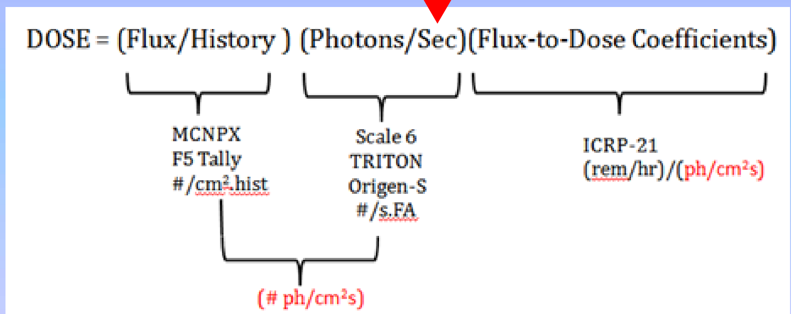
- Scale6/Triton model for 19 plate MTR
- Origen-S calculation for # of photons/FA.bin
- MCNPX F5 (Point source tally)
- ICRP-21 dose conversion coefficients

Dose/History as a Function of T_{decay}



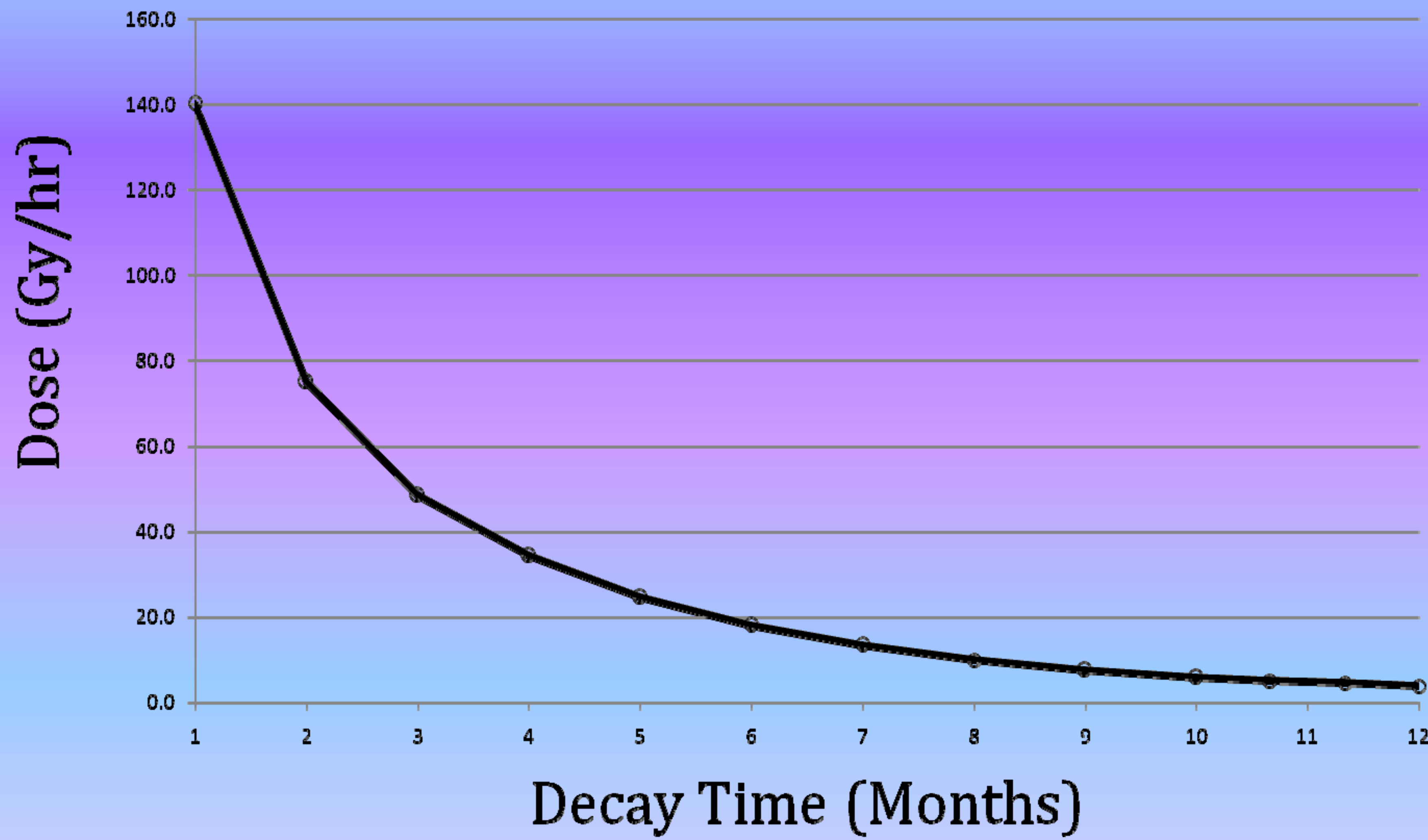
Matrix of Doses Gy/hr.g$_{U-235}$

Decay Time (Days)	MTR 19 Plate Fuel Assembly Irradiation (Days)- Note the dose is in Gy/hr.g U-235												
	0	**30**	**60**	**90**	**120**	**150**	**180**	**210**	**240**	**270**	**300**	**330**	**360**
	30	4.638	3.426	2.779	2.353	2.051	1.814	1.626	1.475	1.351	1.245	1.158	1.082
	60	1.996	1.636	1.405	1.232	1.099	0.988	0.896	0.821	0.757	0.703	0.656	0.616
	90	1.176	1.007	0.886	0.789	0.711	0.645	0.590	0.544	0.504	0.470	0.441	0.416
	120	0.799	0.696	0.619	0.556	0.505	0.460	0.423	0.392	0.366	0.343	0.323	0.306
	150	0.555	0.488	0.438	0.396	0.362	0.332	0.307	0.286	0.268	0.252	0.239	0.227
	180	0.396	0.351	0.317	0.289	0.265	0.245	0.228	0.214	0.201	0.191	0.181	0.173
	210	0.286	0.255	0.232	0.213	0.197	0.183	0.172	0.162	0.153	0.146	0.139	0.134
	240	0.204	0.184	0.169	0.156	0.145	0.136	0.128	0.121	0.115	0.110	0.106	0.102
	270	0.152	0.138	0.128	0.119	0.112	0.105	0.100	0.095	0.091	0.087	0.084	0.081
	300	0.114	0.105	0.097	0.091	0.086	0.082	0.078	0.075	0.072	0.069	0.067	0.065
	320	0.031	0.088	0.082	0.078	0.074	0.070	0.067	0.064	0.062	0.060	0.058	0.057
	340	0.026	0.079	0.075	0.071	0.067	0.064	0.062	0.059	0.057	0.056	0.054	0.053
	360	0.020	0.067	0.063	0.060	0.057	0.055	0.053	0.051	0.049	0.048	0.047	0.046

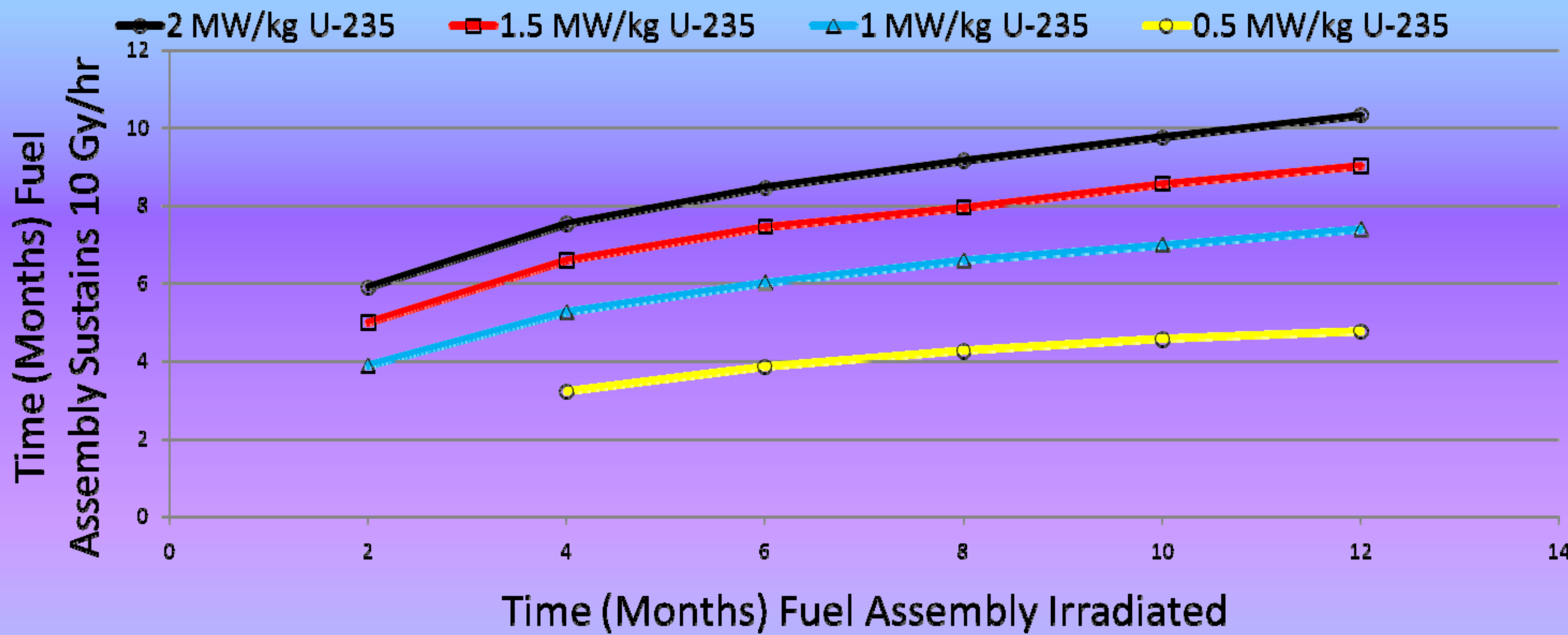


Assume: 1.266 g U-235/MWd
Calculate Dose for any power density, Tirr and Tdecay

Dose Rate as a Function of Time for 19-Plate Reactor Irradiated 150 days at 2MW/kg U-235



10 Gy/hr Iso-Dose Curves
Different Power Densities



Typical flat-plate fuel assemblies (Tirr>4 Months & power density > 1 MW/kg U-235) 10 Gy/hr is sustained for < 5 months

→ Suggestion remove fuel after 5 months

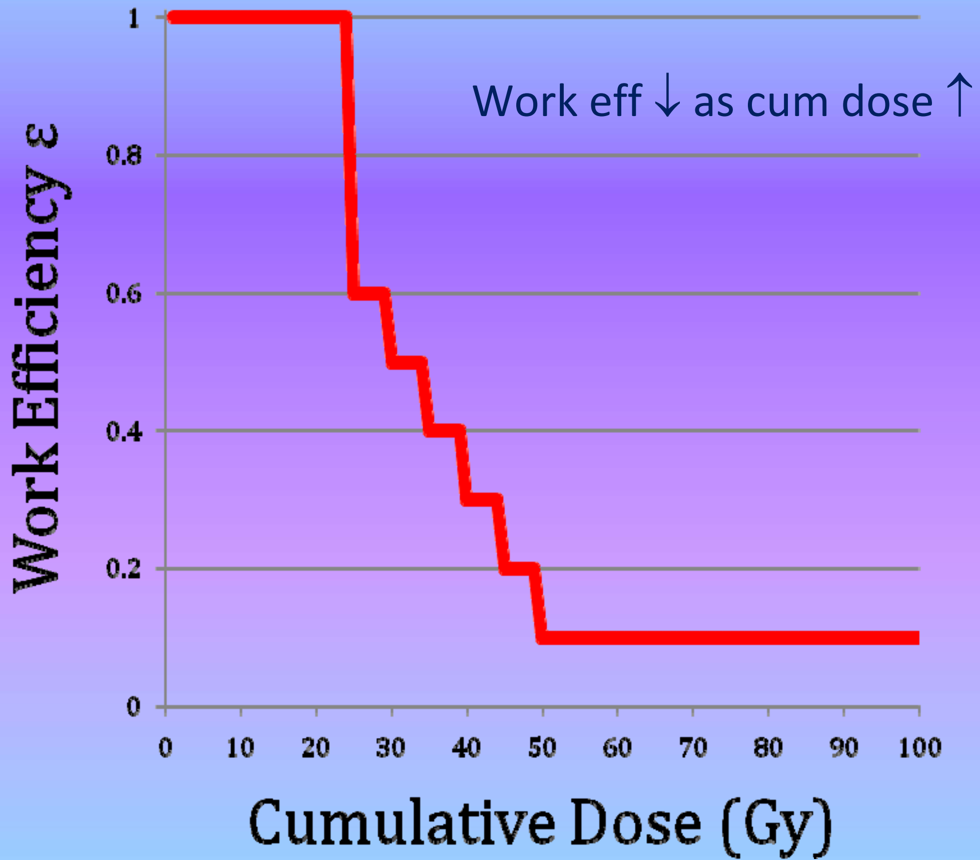
Conclusions

- IAEA notion of SP is 1 Gy/hr
- Studies have shown 100 Gy/hr is more appropriate if the notion of SP is effective

  $\rightarrow$ Requires immediate removal of fuel
  (coordination of task) if HEU
- Typical fuel assembly analysis suggests that 10 Gy/hr can be sustained for < 5 months for typical power densities and irradiation times
- Suggestion is to remove irradiated fuel ~5 months after irradiation better if sooner

Quantifying Self-Protection (SP)

- Coates *et al* attempted to quantify SP based



$\varepsilon(T)\ T < S$

Where, T = time
ε(T) = Work Efficiency
S= Time to complete task

Ass: 25 Gy cumulative dose for incap.
Task requires 10 min – task complete

- SP depends on the situation considered
- Realistic scenario suggests a SP dose ~ 100 Gy/hr