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# **ENDF-6 format proposal related to JENDL PKA/KERMA File**

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- Purpose

to supply fundamental data for the estimation of the  
**radiation damage in solid materials**

- Incident Particle: neutron ( $< 50$  MeV)

- Elements Included in the File: 29 elements, 78 isotopes  
H, Li, Be, B, C, N, O, Na, Mg, Al, Si, Cl, K, Ca, Ti, V,  
Cr, Mn, Fe, Co, Ni, Cu, Ge, Zr, Nb, Mo, W, Pb, Bi

## Producing Method of PKA Spectrum

General: **ESPERANT** Code

Processed from Neutron Data in the JENDL High Energy File up to 50 MeV by Using **Effective Single Particle Emission Approximation (ESPEA)**

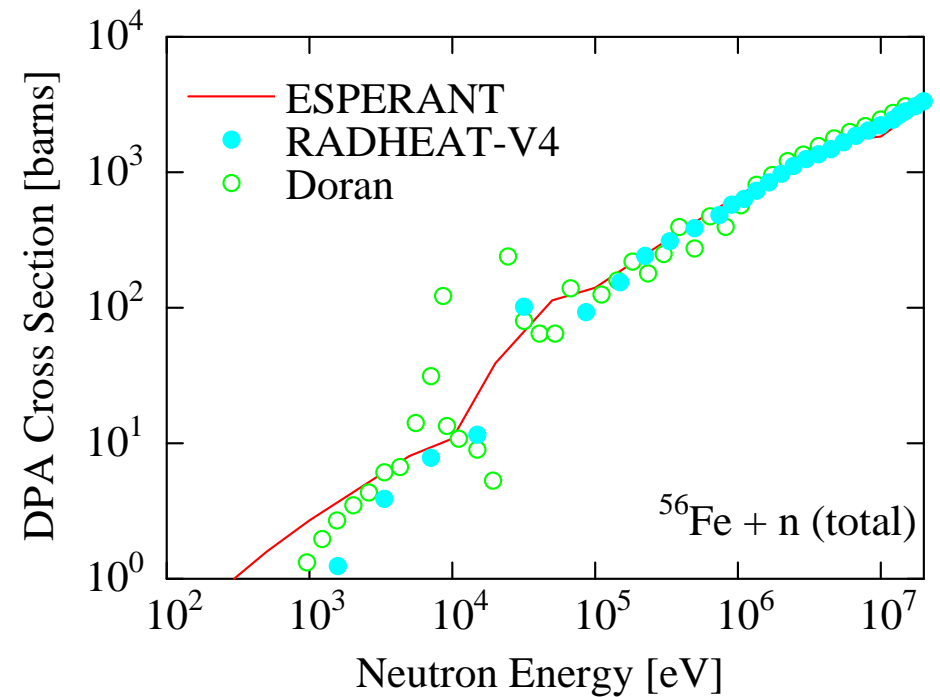
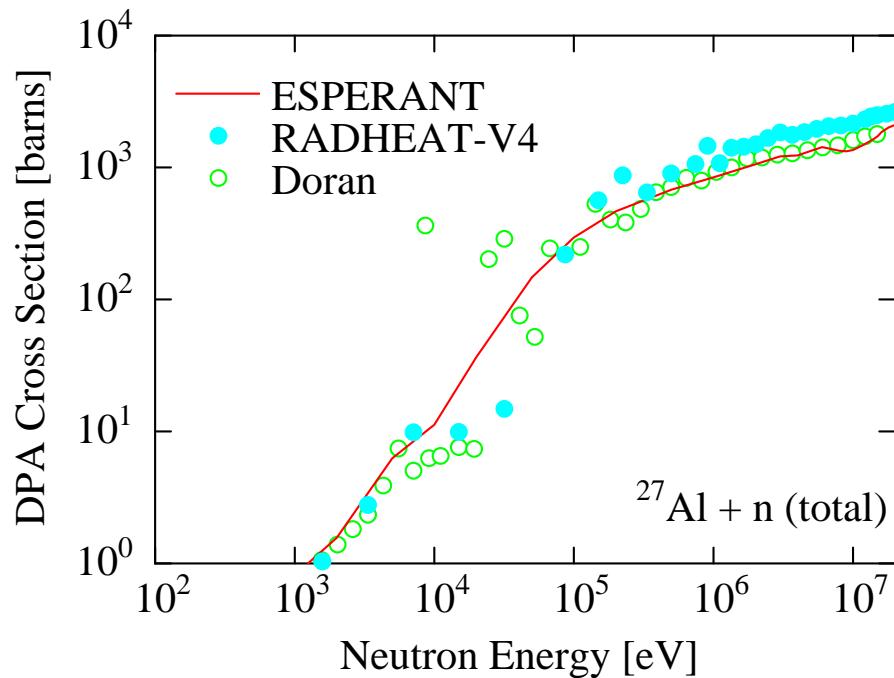
for Light Mass Nuclides

Nuclear Data and PKA Spectra are evaluated simultaneously by **SINFUL/DDX** Code.

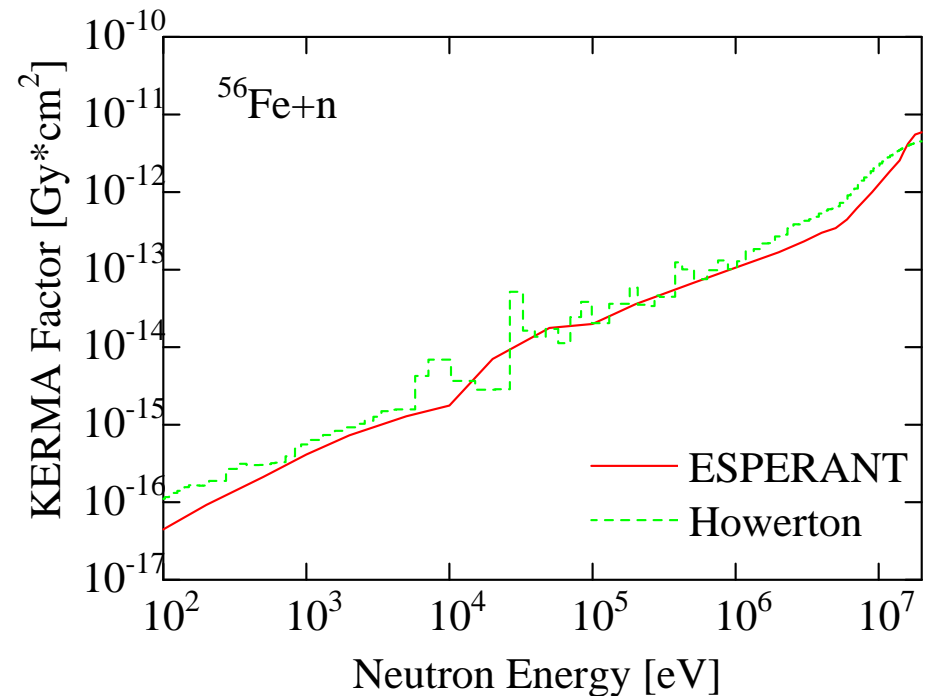
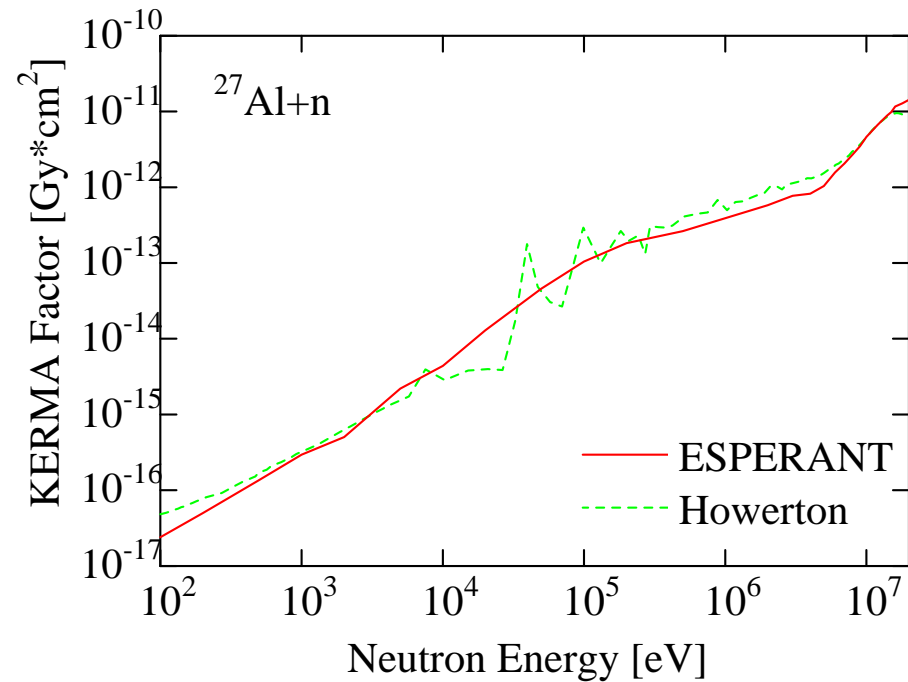
## Compilation of threshold energy for displacement: $\epsilon_d$

Atomic Number	Symbol	$\epsilon_d$ [eV]	Atomic Number	Symbol	$\epsilon_d$ [eV]
4	Be	31	27	Co	40
6	C	31	28	Ni	40
12	Mg	25	29	Cu	40
13	Al	27	40	Zr	40
14	Si	25	41	Nb	40
20	Ca	40	42	Mo	60
22	Ti	40	47	Ag	60
23	V	40	74	W	90
24	Cr	40	79	Au	30
25	Mn	40	82	Pb	25
26	Fe	40		others	25

## DPA Cross Sections of $^{27}\text{Al}$ and $^{56}\text{Fe}$



## KERMA Factors of $^{27}\text{Al}$ and $^{56}\text{Fe}$

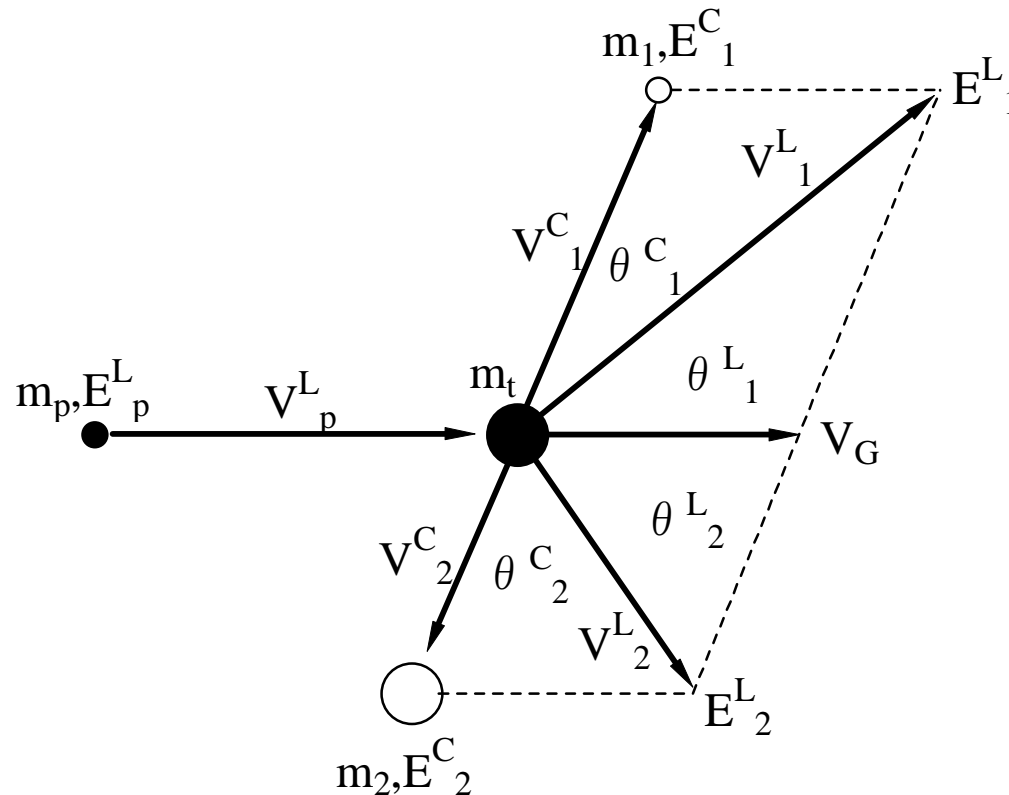


## Target Quantities and Proposal for MF Numbers

MF	quantities
3	cross sections and KERMA factor
4	angular distributions for discrete levels
6	double-differential light particles and PKA cross sections
63	DPA cross sections
66	damage energy spectra







- C, L : CMS and LAB  
 p, t, 1, 2 : incident particle, target nucleus, outgoing particle and residual nucleus  
 **$E, V, m, \theta$**  : energy, velocity, mass and emitted angle ( $\mu = \cos \theta$ )  
 **$DDX_{1C}(E_{pL}, E_{1C}, \mu_{1C})$** : **DDX of emitted particle in CMS (given)**  
 **$DDX_{2C}(E_{pL}, E_{2C}, \mu_{2C})$** : PKA spectrum in CMS

## Normalization Factor for ESPEA

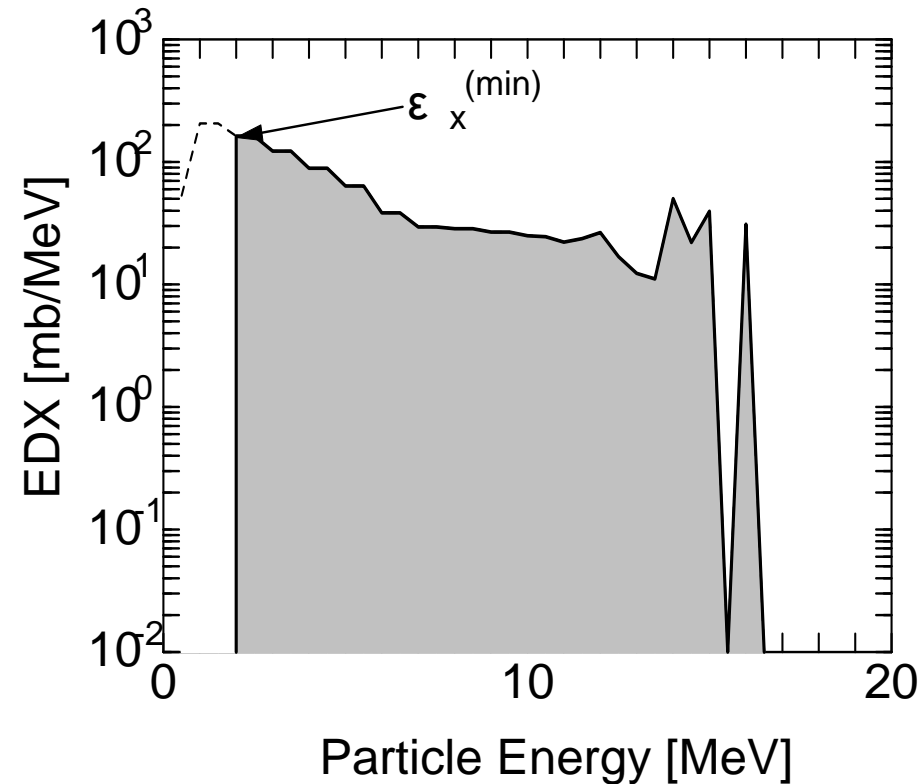
$$R = \frac{\sigma_R}{\sum_x \int_{\varepsilon_x^{(\min)}} d\varepsilon_x \int d\mu_x \sigma_x(E_p^L, \varepsilon_x, \mu_x)}$$

- $\sigma_R$ : total reaction cross section
- $\sigma_x$ : each particle emission channel
- $\varepsilon_x^{(\min)}$ : lower limit of energy for spectrum considered.

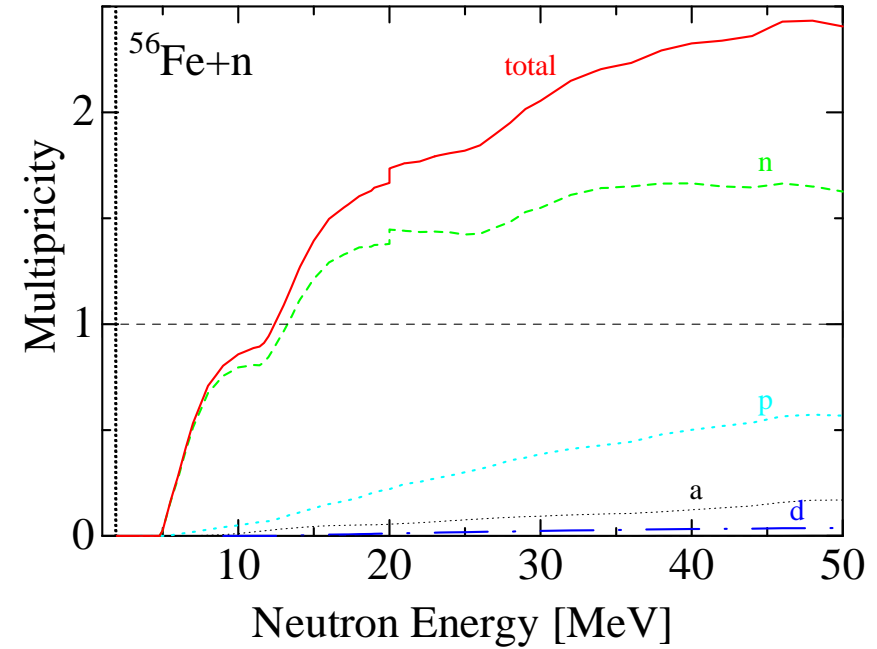
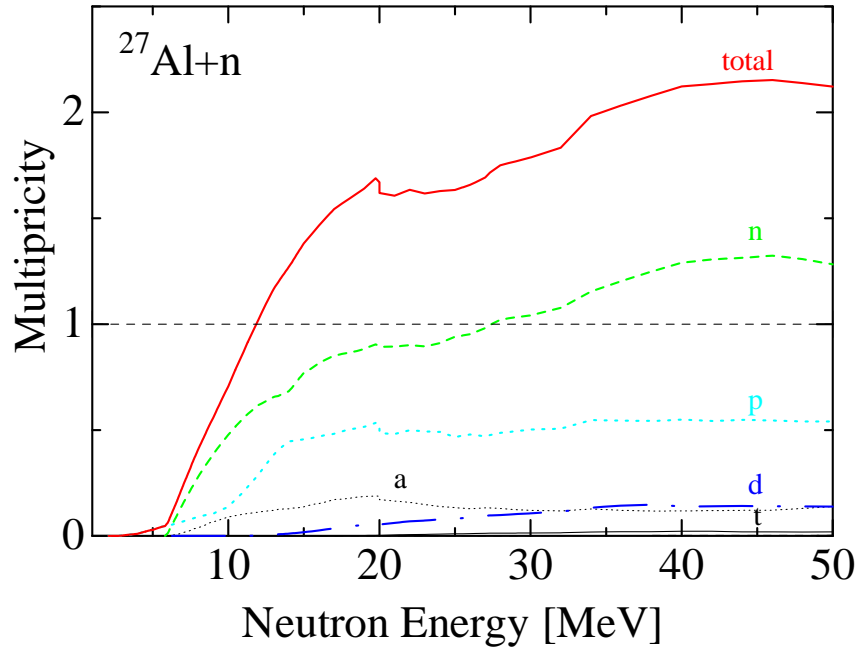
$$\int_{\varepsilon_x^{(\min)}} \varepsilon_x f_x(\varepsilon_x) d\varepsilon_x = \left[ \frac{m_t}{m_p + m_t} E_p^L + Q_x \right] \left/ \left[ 1 + \left( \frac{m_{1x}}{m_{2x}} \right)^2 \right] \right.$$

$$\int_0^\infty f_x(\varepsilon_x) d\varepsilon_x = 1$$

- $Q_x$ : Q-value of reaction  $x$
- $f_x$ : normalized **DDX1C** of reaction  $x$



## Particle Multiplicity



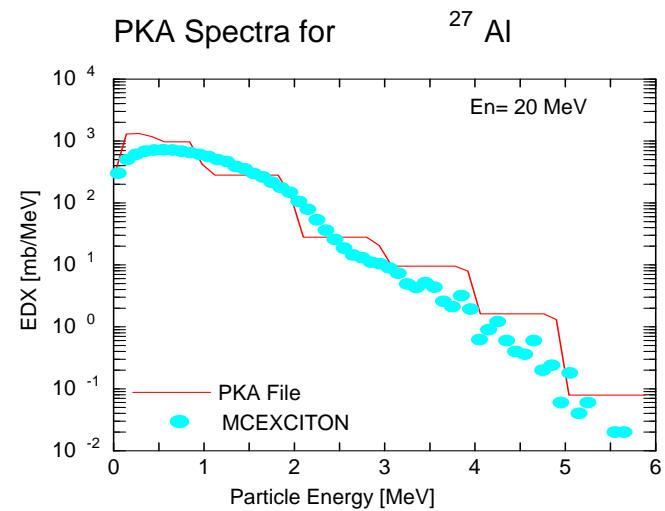
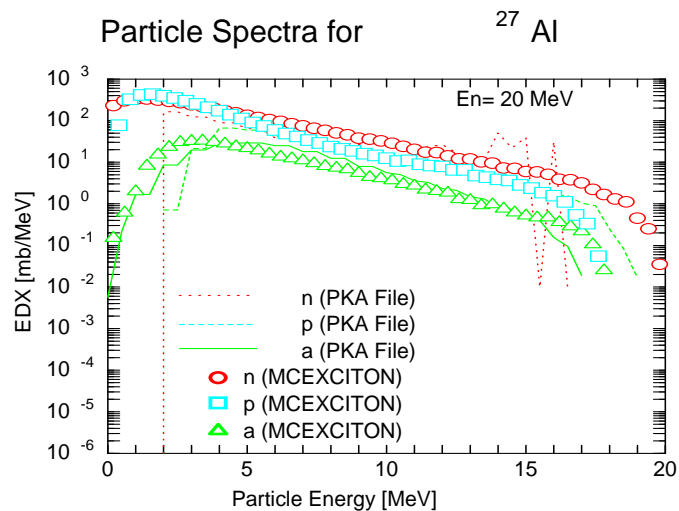
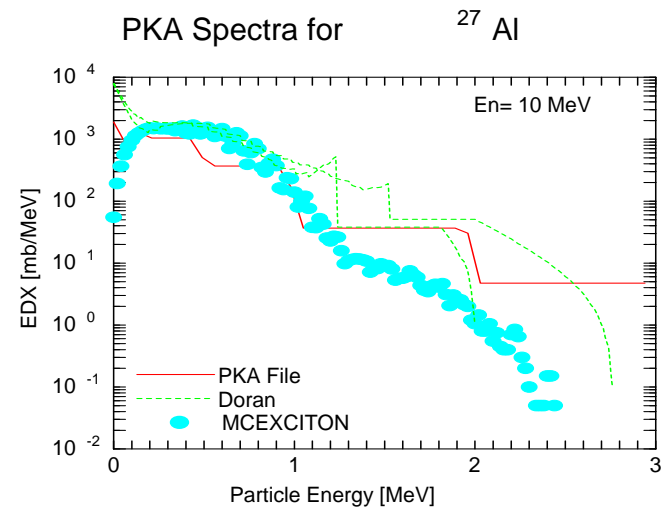
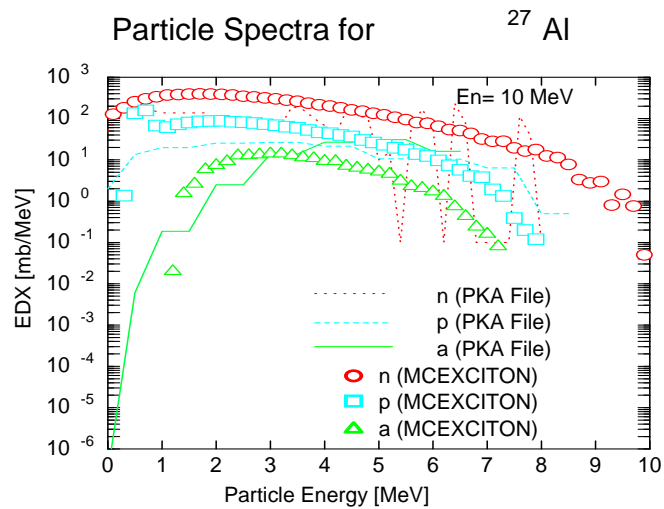
## - Purpose

to supply the PKA data to the FENDL-2 project as a trial task of ESPERANT, processing from the JENDL Fusion File below 20 MeV

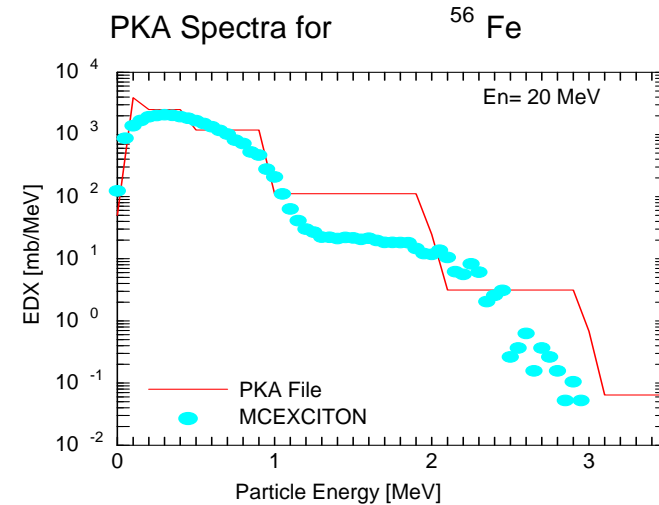
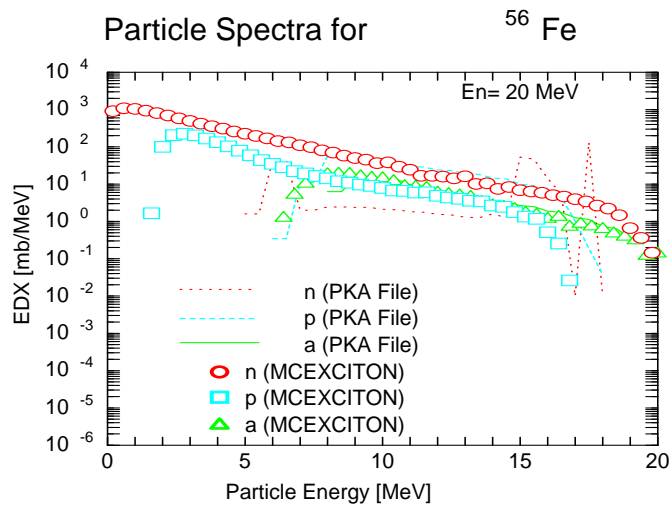
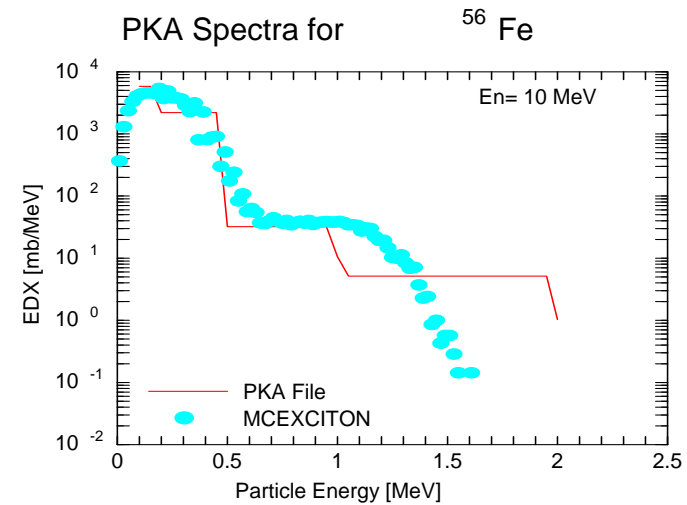
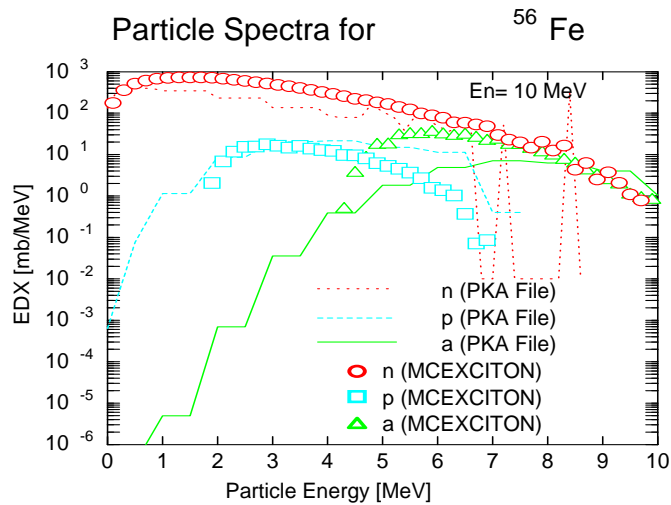
## - Included Nuclides (69 isotopes)

$^{19}\text{F}$ ,  $^{27}\text{Al}$ ,  $^{28-30}\text{Si}$ ,  $^{40,42-44,46,48}\text{Ca}$ ,  $^{46-48,50}\text{Ti}$ ,  $^{51}\text{V}$ ,  $^{50,52-54}\text{Cr}$ ,  $^{55}\text{Mn}$ ,  
 $^{54,56-58}\text{Fe}$ ,  $^{59}\text{Co}$ ,  $^{58,60-62,64}\text{Ni}$ ,  $^{63,65}\text{Cu}$ ,  $^{75}\text{As}$ ,  $^{90-92,94,96}\text{Zr}$ ,  $^{93}\text{Nb}$ ,  
 $^{92,94-98,100}\text{Mo}$ ,  $^{121,123}\text{Sb}$ ,  $^{112,114-120,122,124}\text{Sn}$ ,  $^{182-184,186}\text{W}$ ,  
 $^{204,206-208}\text{Pb}$ ,  $^{209}\text{Bi}$

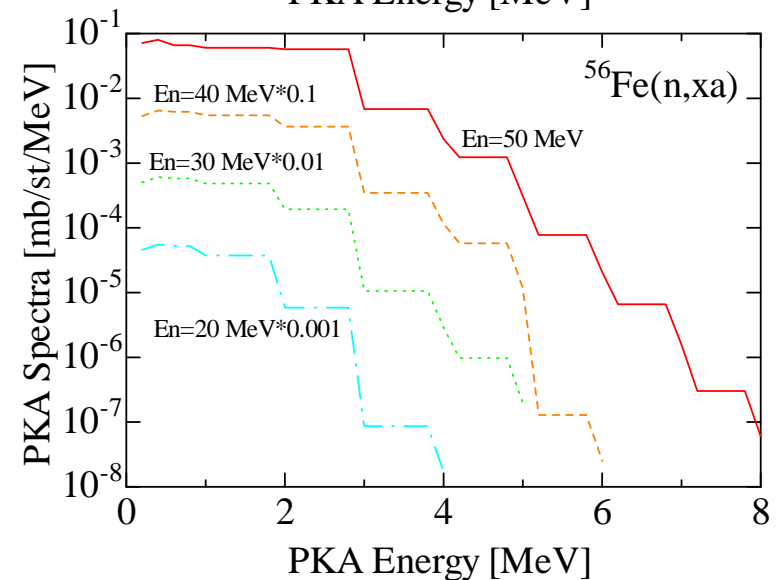
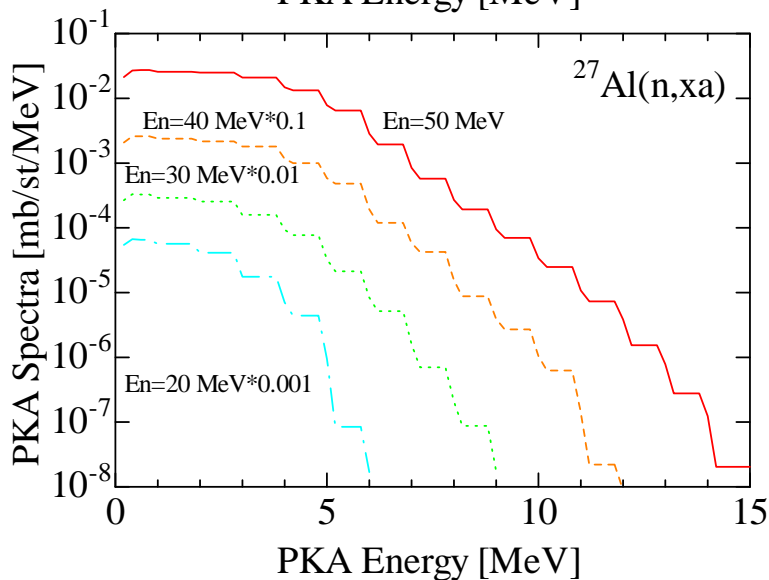
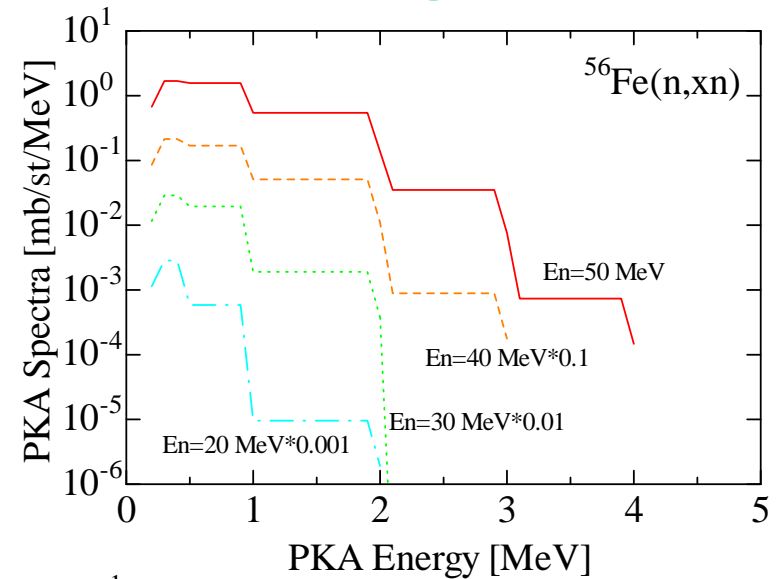
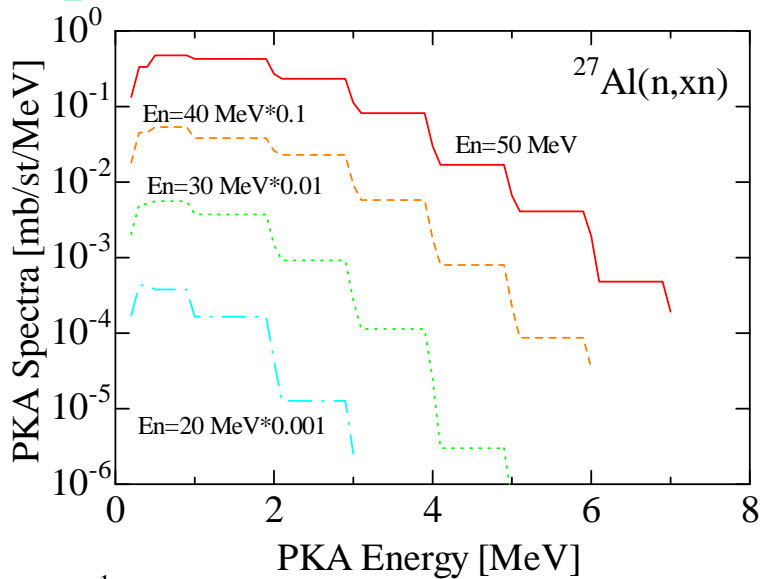
## Particle and PKA Spectra of $^{27}\text{Al}$ at 10 and 20 MeV



## Particle and PKA Spectra of $^{56}\text{Fe}$ at 10 and 20 MeV



## PKA Spectra of $^{27}\text{Al}$ and $^{56}\text{Fe}$ at Other Incident Energies



## KERMA Factor of $^{12}\text{C}$

