

The Status of Nuclear Data above 20 MeV

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*IAEA's Technical Meeting on Nuclear Data Libraries
for Advanced Systems: Fusion Devices (NuDL:FD)
31 October – 2 November 2007, Vienna*

Target Nuclides and Priorities

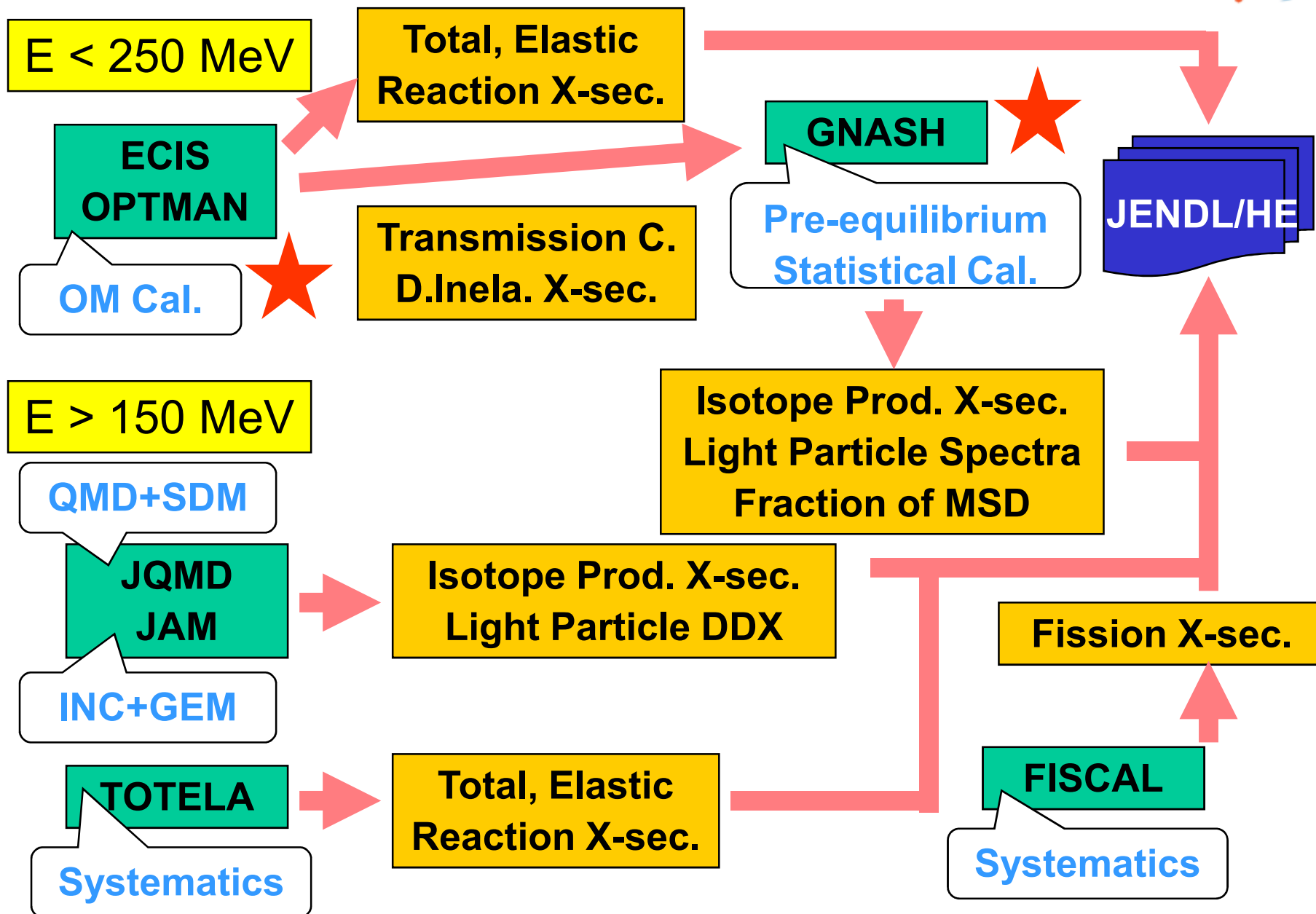
Neutron & Proton File up to 3 GeV (Total: 132 nuclides)

1 st priority (39)	<u>^1H</u> , <u>^{12}C</u> , ^{14}N , <u>^{16}O</u> , <u>^{27}Al</u> , $^{50,52,53,54}\text{Cr}$, $^{54,56,57,58}\text{Fe}$, $^{58,60,61,62,64}\text{Ni}$, <u>$^{63,65}\text{Cu}$</u> , <u>$^{180,182,183,184,186}\text{W}$</u> , $^{196,198,199,200,201,202,204}\text{Hg}$, $^{204,206,207,208}\text{Pb}$, ^{209}Bi , $^{235,238}\text{U}$
2 nd priority (43)	^9Be , $^{10,11}\text{B}$, <u>$^{24,25,26}\text{Mg}$</u> , <u>$^{28,29,30}\text{Si}$</u> , $^{39,41}\text{K}$, $^{40,42,43,44,46,48}\text{Ca}$, $^{46,47,48,49,50}\text{Ti}$, ^{51}V , ^{55}Mn , ^{59}Co , <u>$^{90,91,92,94,96}\text{Zr}$</u> , <u>$^{93}\text{Nb}$</u> , $^{92,94,95,96,97,98,100}\text{Mo}$, $^{238,239,240,241,242}\text{Pu}$
3 rd priority (40)	^2H , $^{6,7}\text{Li}$, ^{13}C , ^{19}F , ^{23}Na , $^{35,37}\text{Cl}$, $^{35,38,40}\text{Ar}$, $^{64,66,67,68,70}\text{Zn}$, $^{69,71}\text{Ga}$, $^{70,72,73,74,76}\text{Ge}$, ^{75}As , ^{89}Y , ^{181}Ta , ^{197}Au , ^{232}Th , $^{233,234,236}\text{U}$, ^{237}Np , $^{241,242,242\text{m},243}\text{Am}$, $^{243,244,245,246}\text{Cm}$
4 th priority (10)	^{15}N , ^{18}O , $^{74,76,77,78,80,82}\text{Se}$, $^{113,115}\text{In}$

Nuclides with red color (66) : Released in March 2004 as JENDL/HE-2004
Nuclides with underline are revised for JENDL/HE-2007.

Nuclides with blue color (36): Additionally Release in 2007 as JENDL/HE-2007

Evaluation Methods and Tools



OMP for Cluster Particles

- No global and wide energy range phenomenological potential parameter set previously



Simple folding potential parameter sets

Cluster Particle Emission

- Kalbach's model made significant underestimation for cluster particle emission spectra.



**Iwamoto-Harada-Sato Preequilibrium Model
(< 100 MeV)**

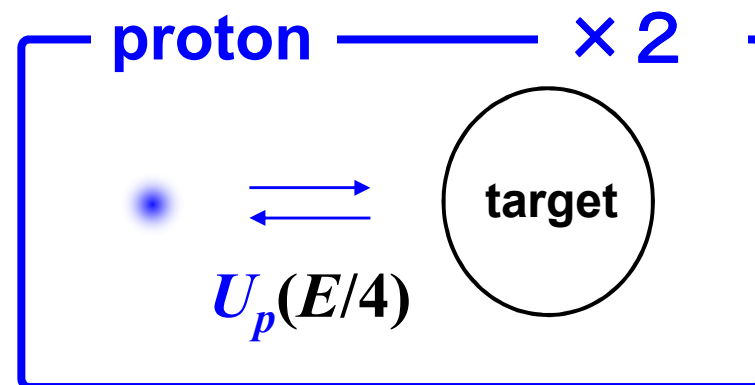
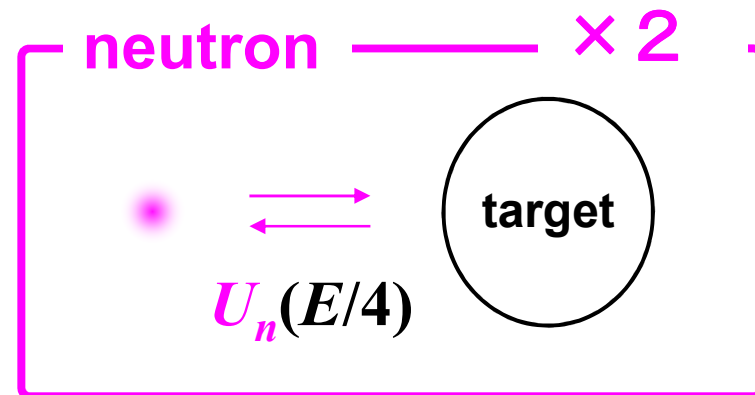
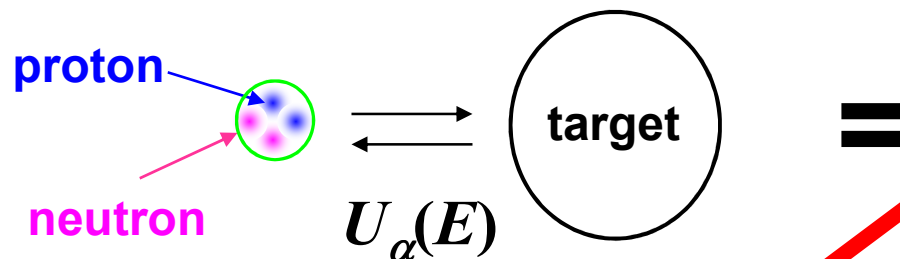
Above are applied for ^{56}Fe , Zr, Nb, W, Pb and Bi.

OMP for Cluster Particles

Based on methods proposed by Madland

Simple Folding Potential

e.g.) Alpha-Particle Potential



Potential for neutron and proton

Kunieda-Chiba-Shibata (2007)

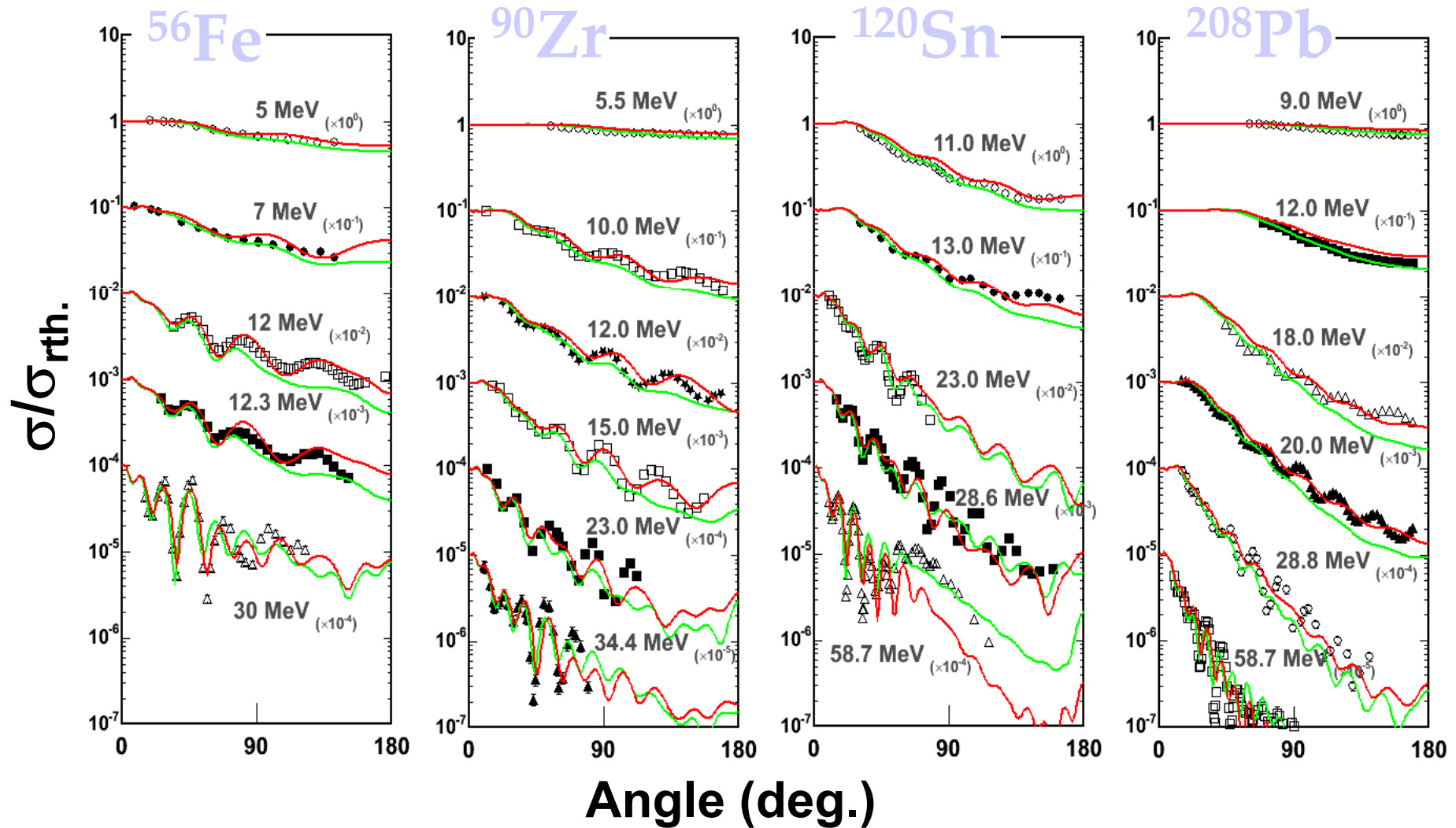
1 keV-200 MeV, $26 < A < 238$

Deuteron Elastic Scattering

○ Exp. data

— Bojowald ('88)

— Present

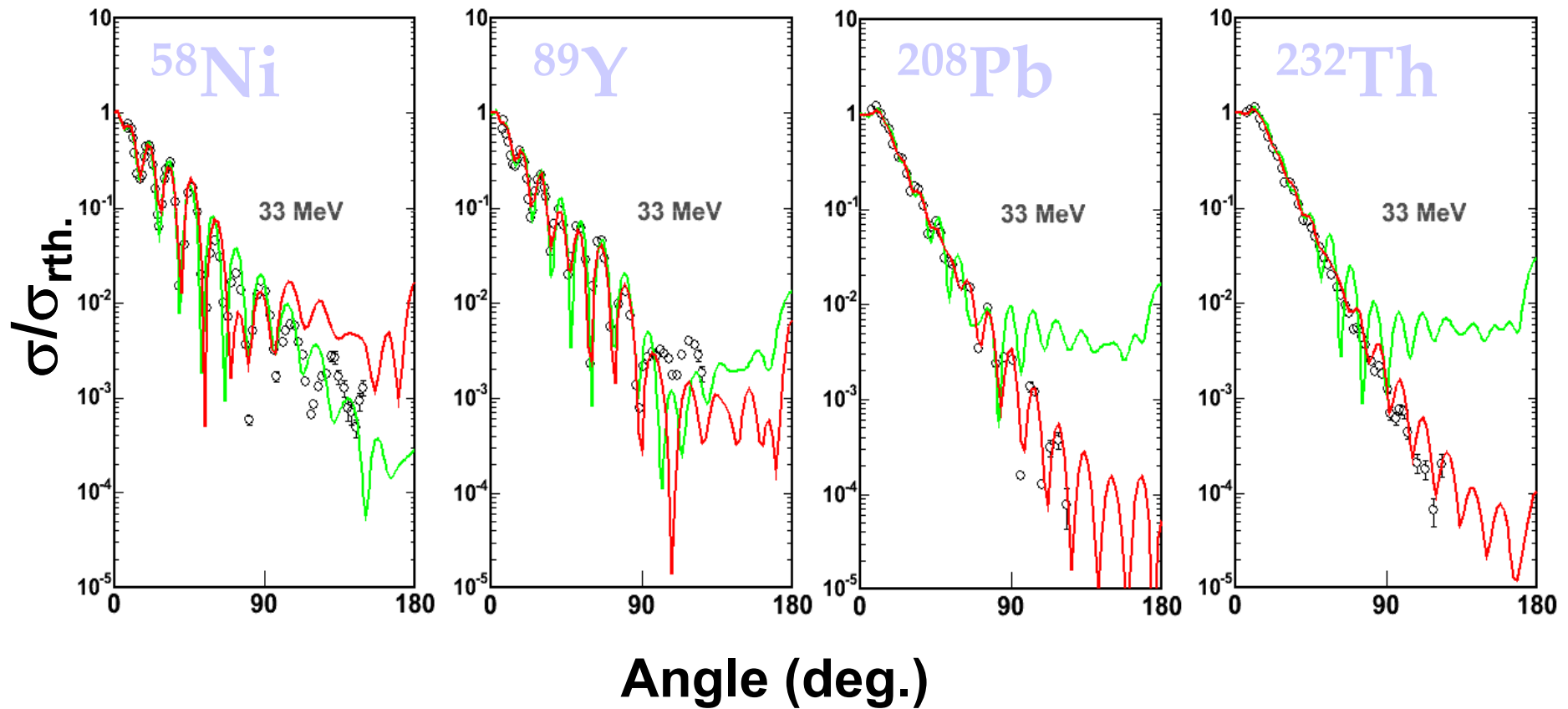


Triton Elastic Scattering

○ Exp. data

— Becchetti ('69)

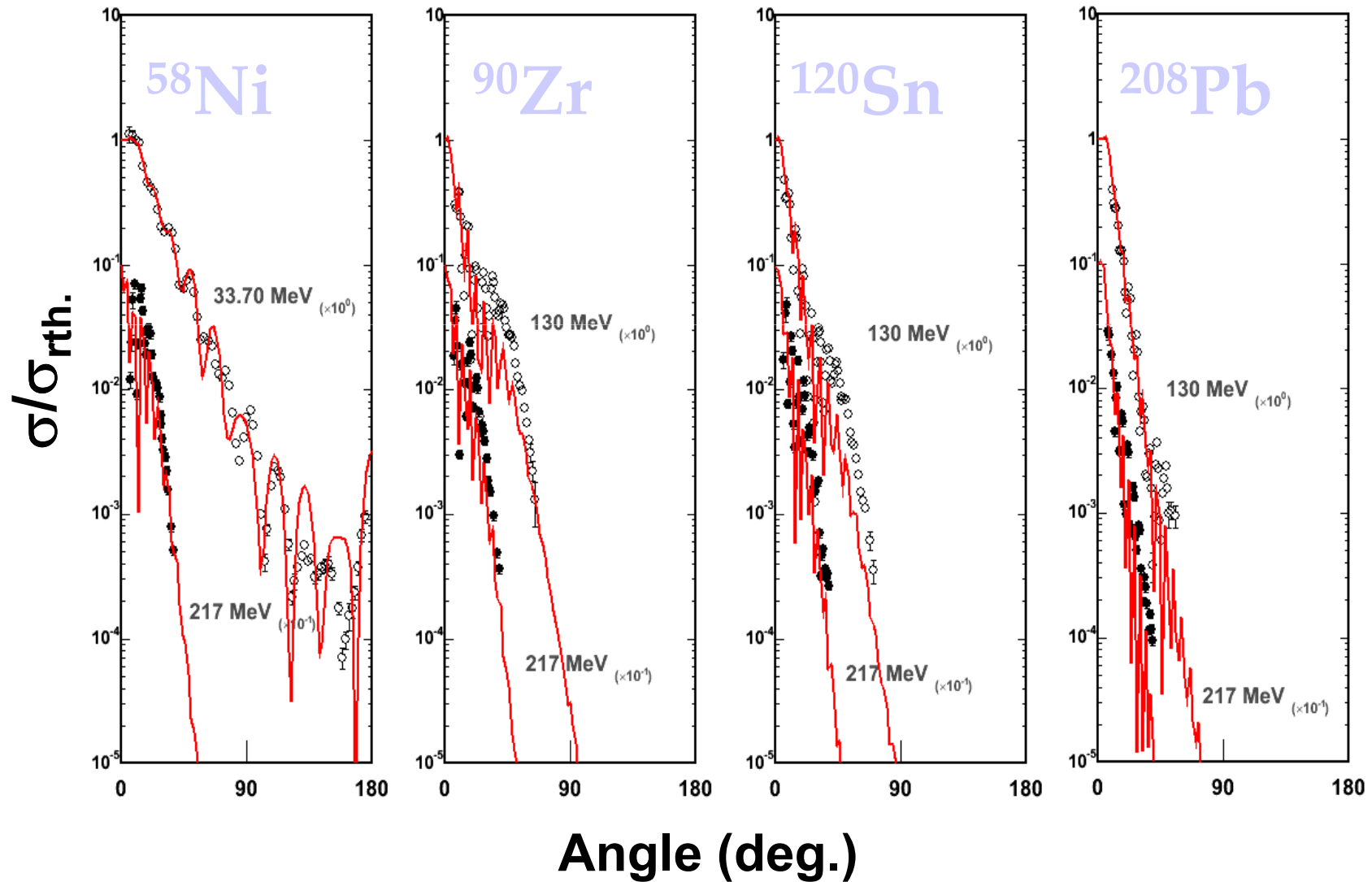
— Present



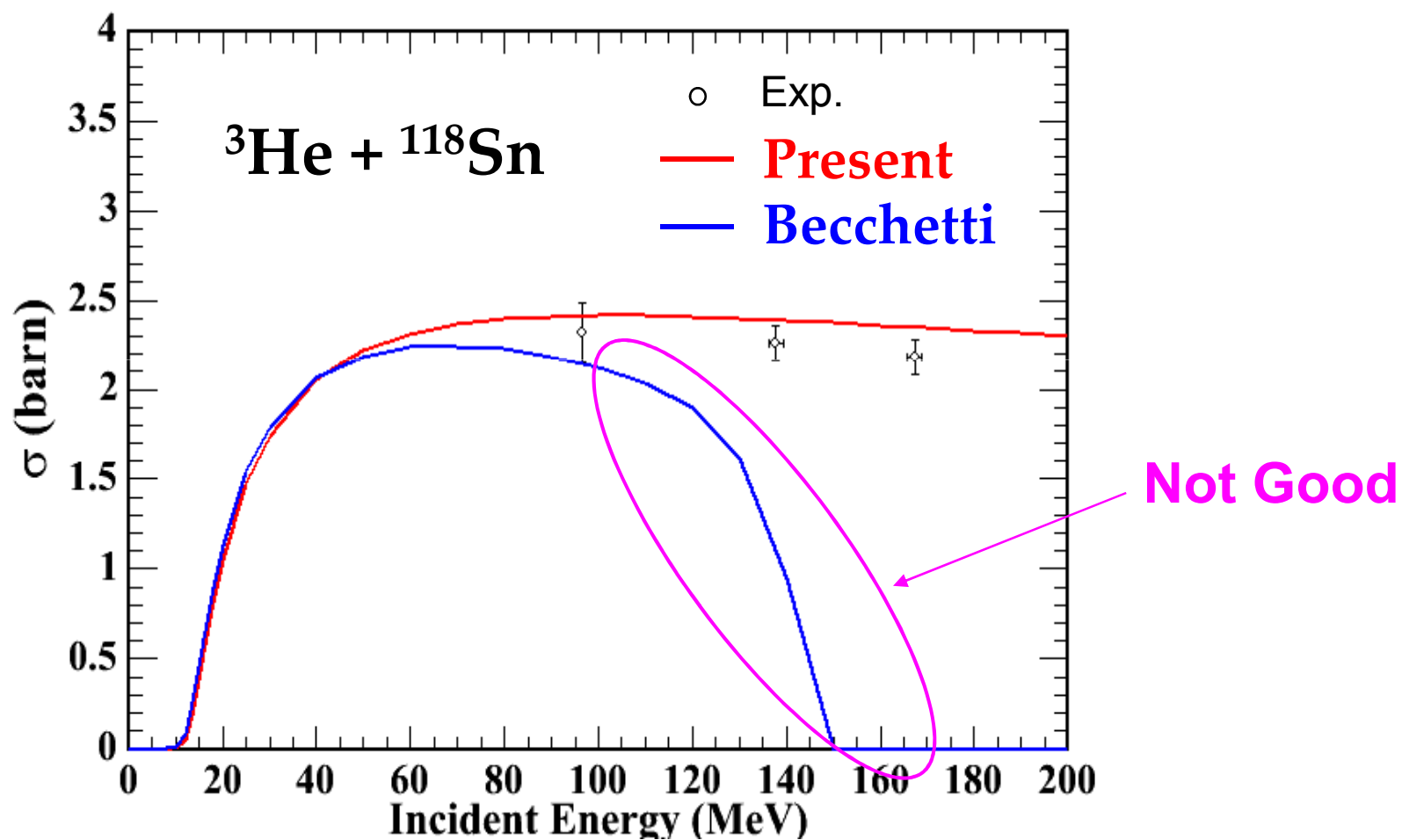
He-3 Elastic Scattering

○ Exp. data

— Present



Total Absorption Cross Section

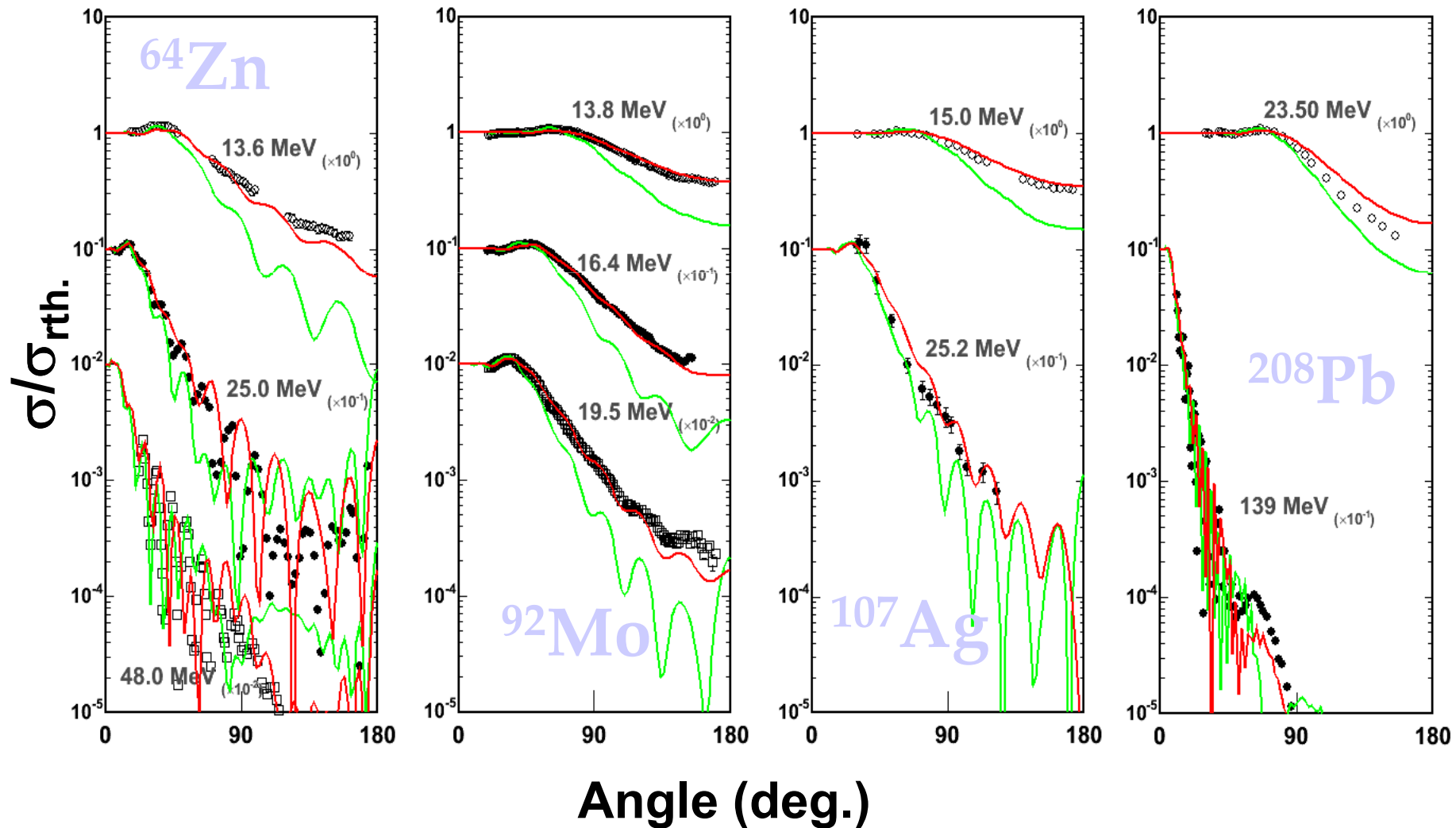


Alpha Elastic Scattering

○ Exp. data

— Avrigeanu ('94)

— Present



Preequilibrium Model for Cluster Particles

Emission Rate of Cluster Particles

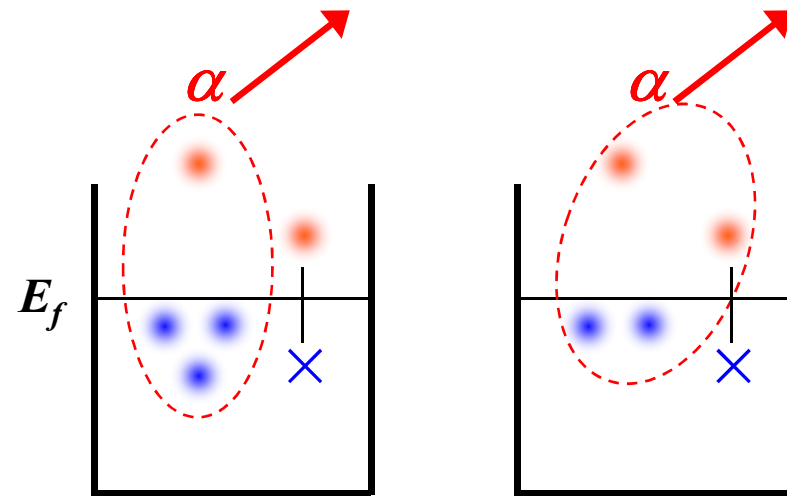
$$W_{n(l,m)}^{(x)}(\varepsilon) = \frac{2s+1}{\pi^2 \hbar^3} \mu_x \varepsilon \times \sigma_{inv.}^{(x)}(\varepsilon) \times F_{l,m}(\varepsilon) \times \frac{\omega(p-l, h, U)}{\omega(p, h, E)}$$

Inverse X-sec
(e.g. $\alpha \rightarrow$ Target)

Optical Model

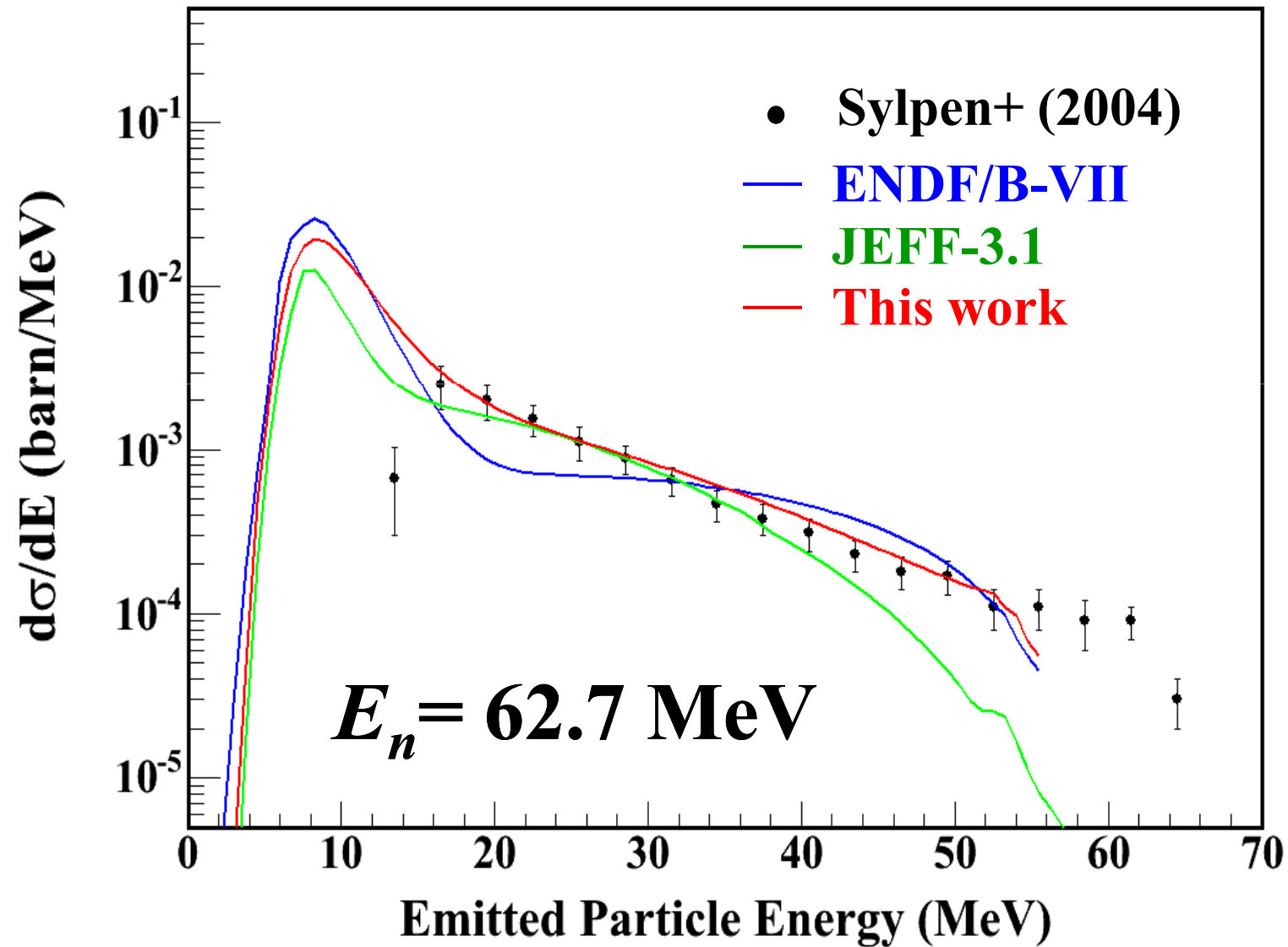
Formation Factors

Iwamoto-Harada-Sato Model

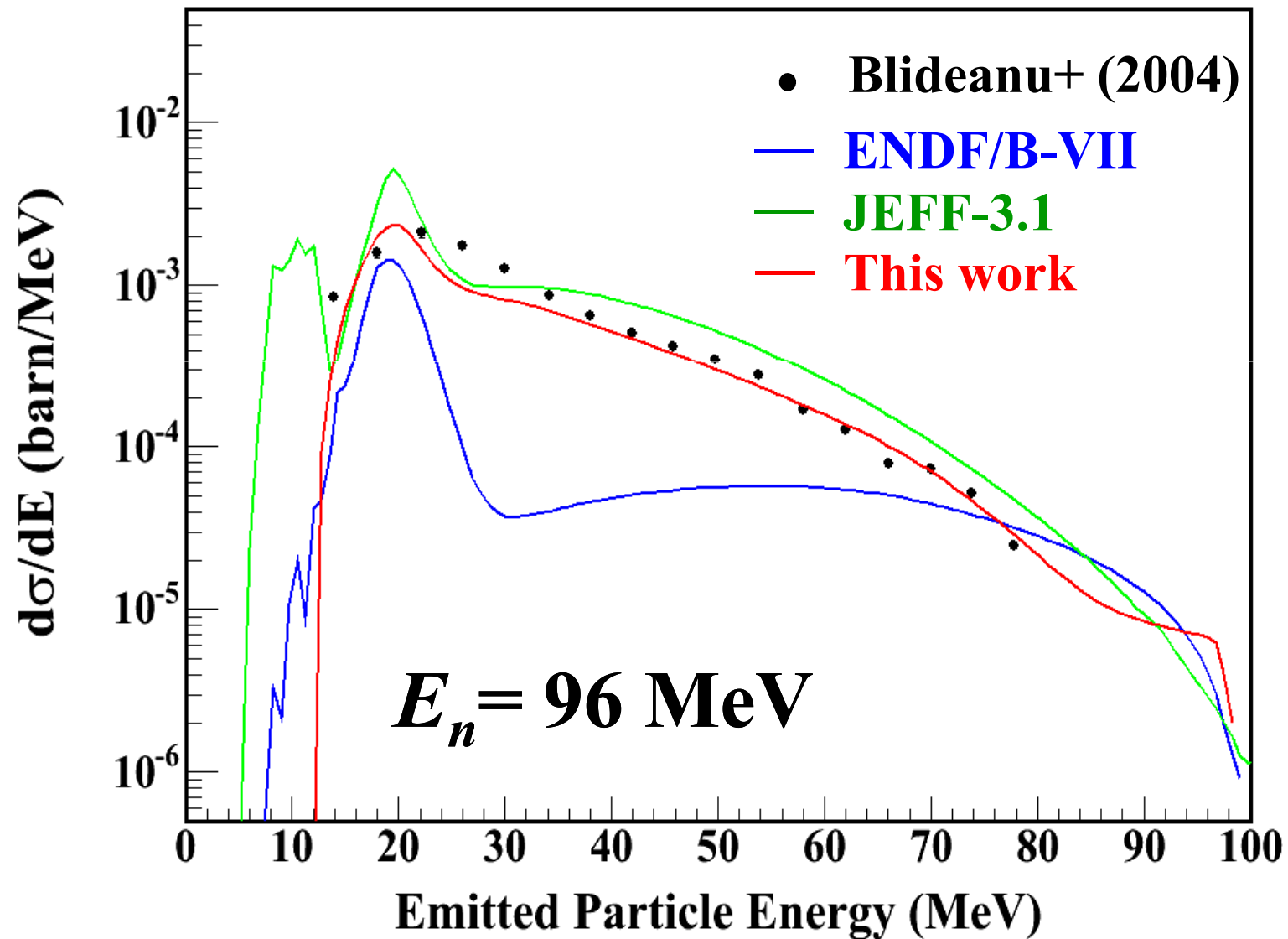


2p-1h State

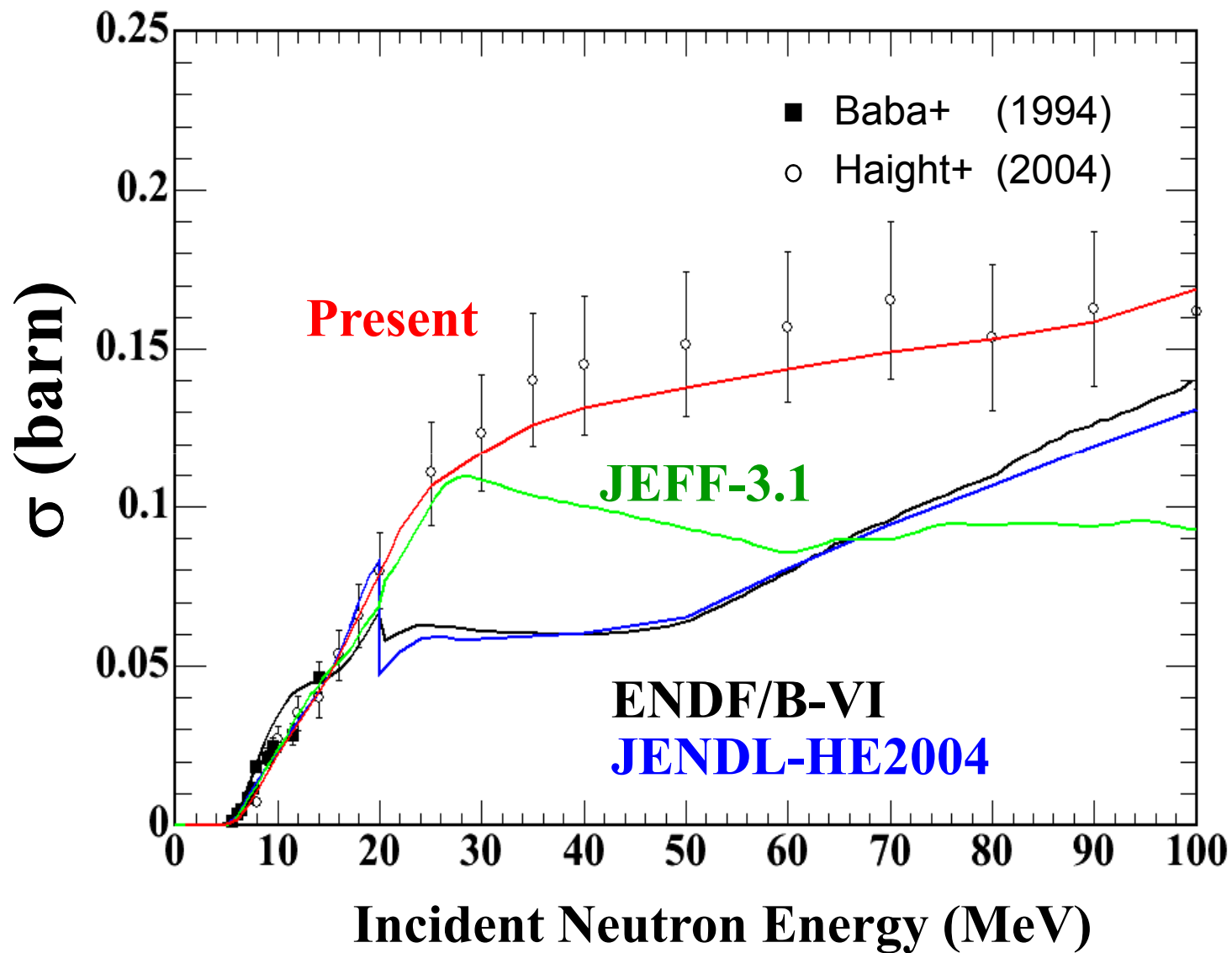
Fe(n,x α) Spectrum



Pb(n,x α) Spectrum

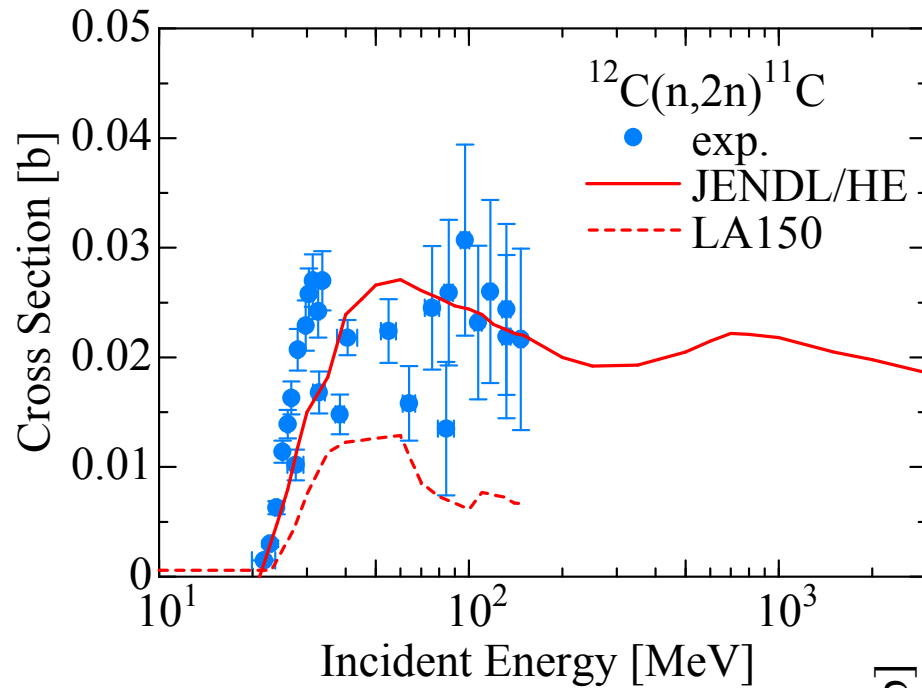


Fe(n, α) Cross Section

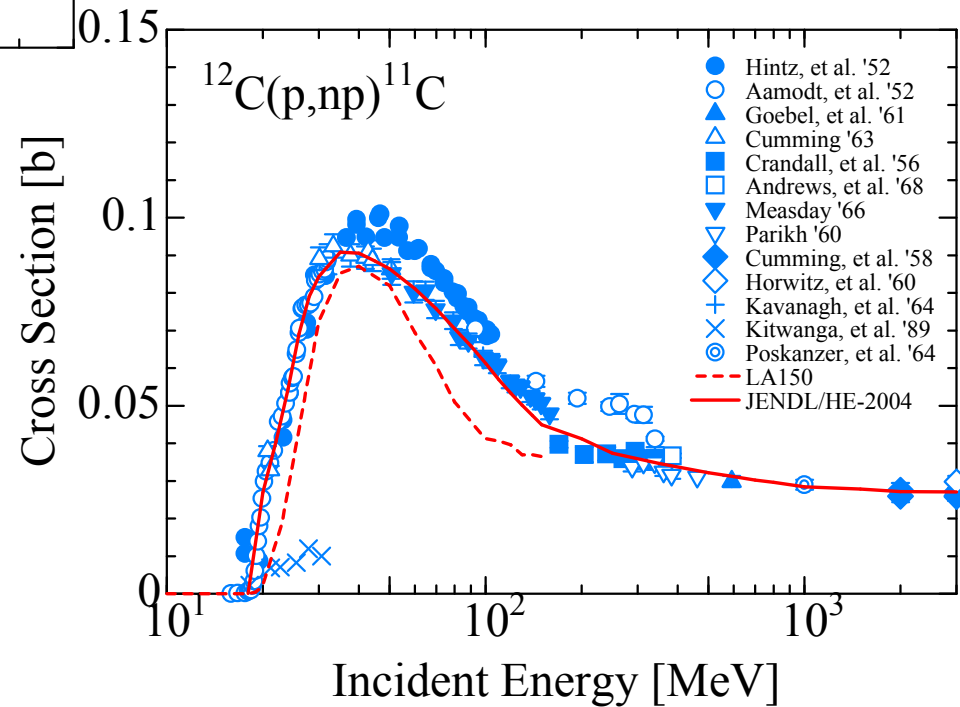


ENDF/B-VII adopts exp. data.

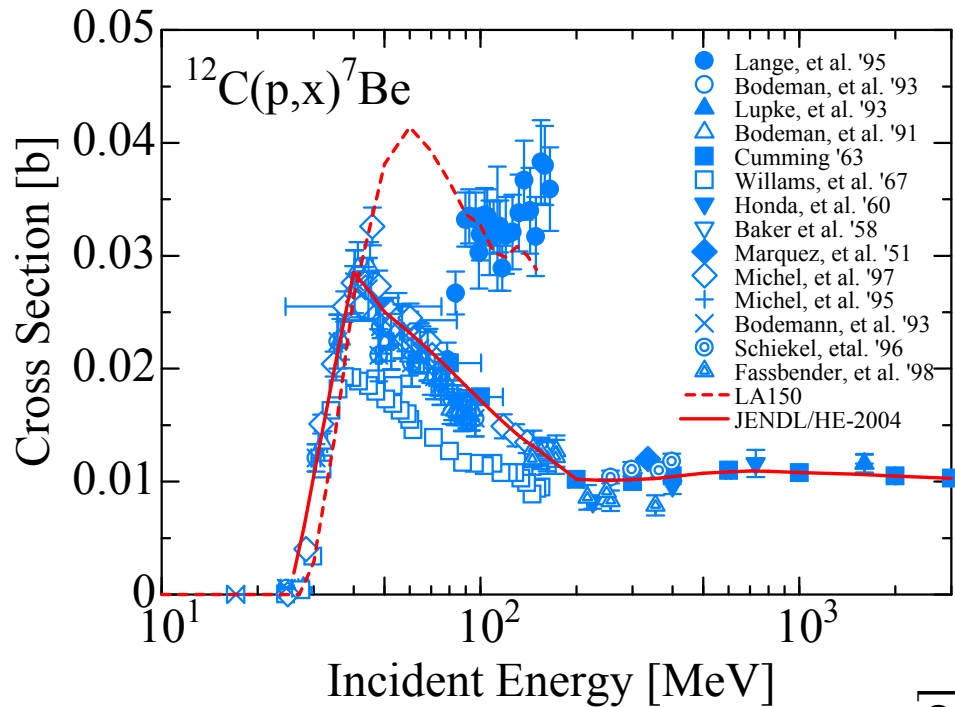
Sample of Evaluated Results



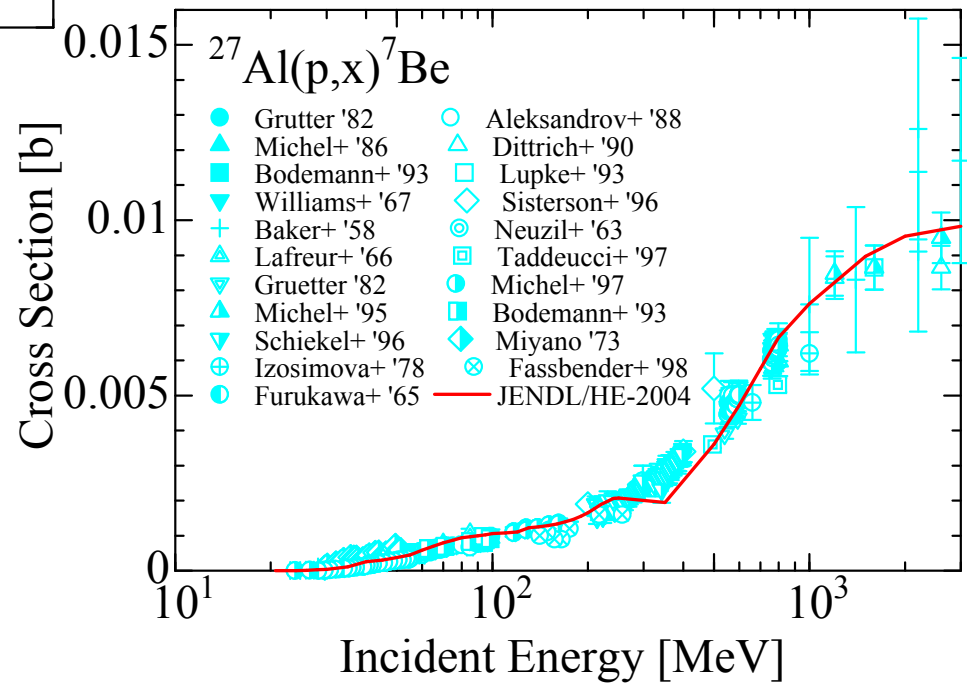
**Isotope production
cross sections : ^{12}C**



Sample of Evaluated Results

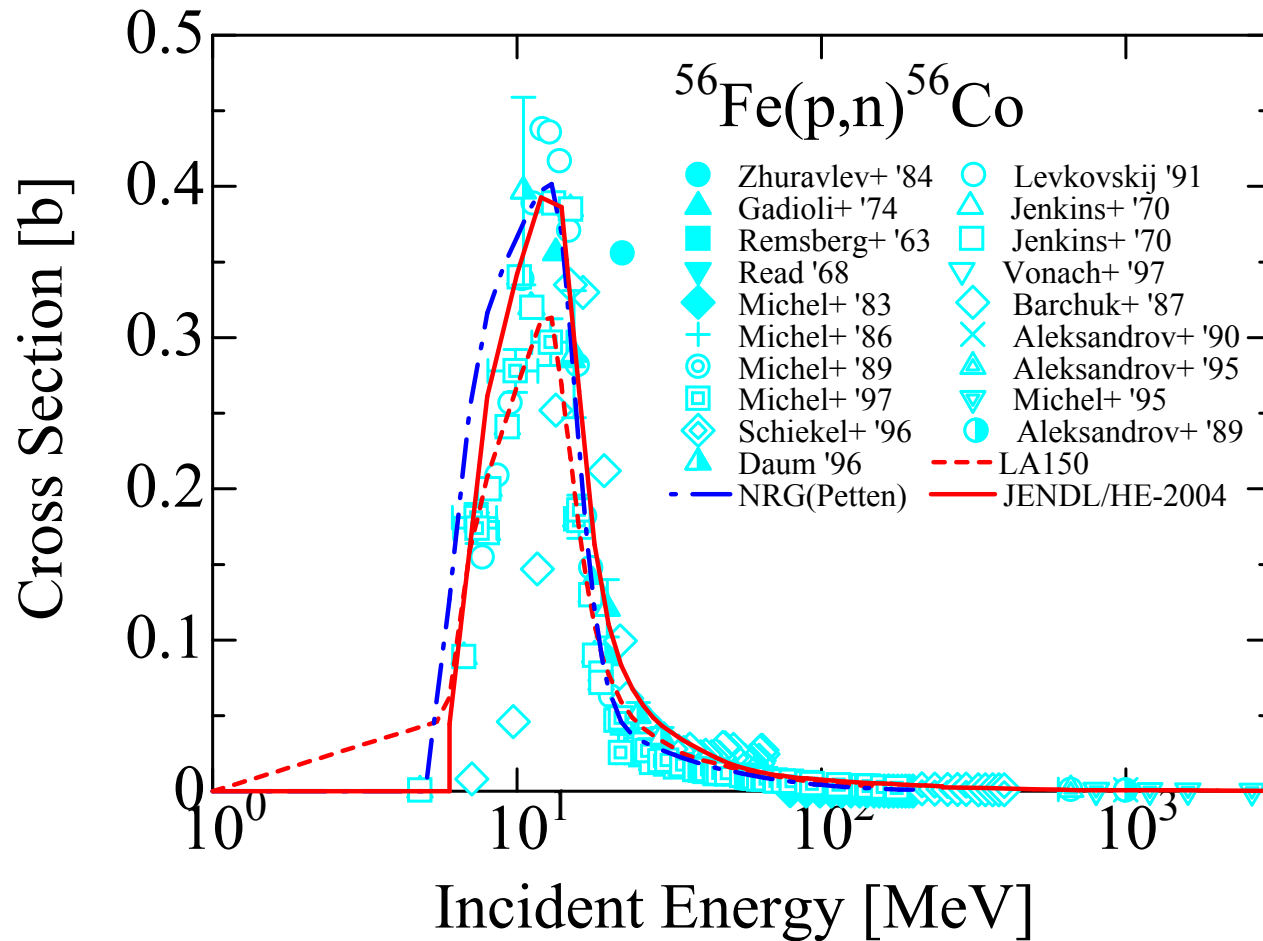


Isotope production cross sections : ^{12}C , ^{27}Al

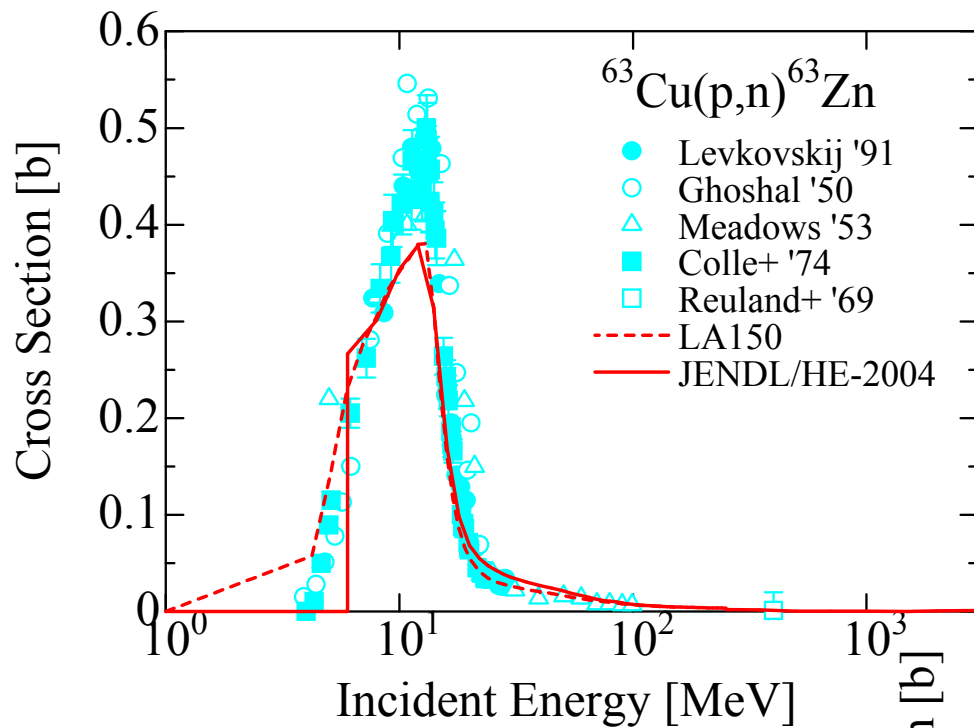


Sample of Evaluated Results

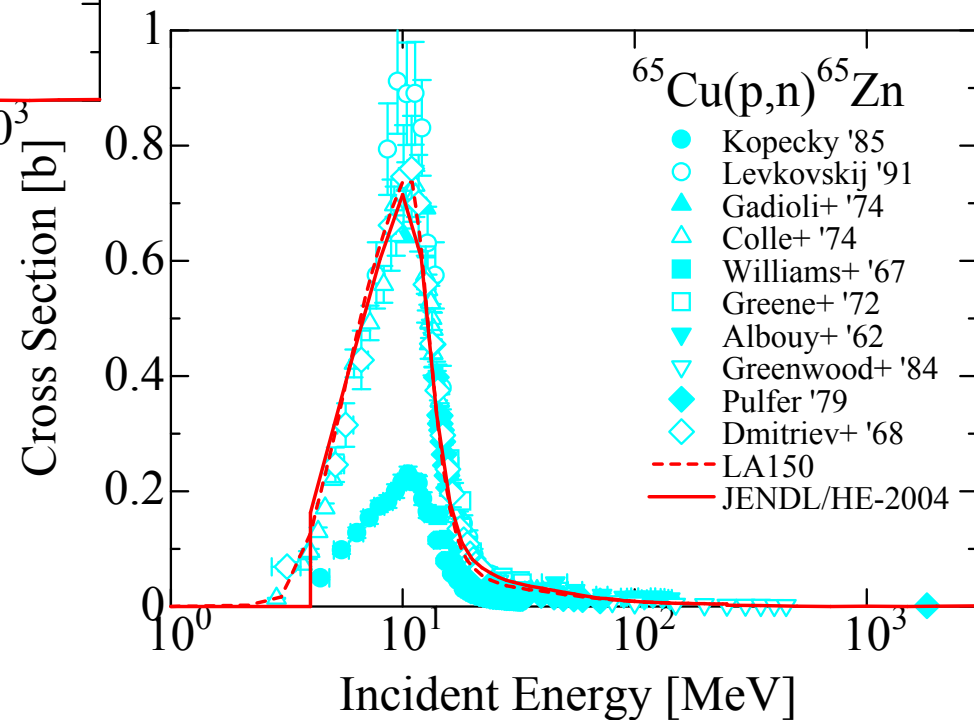
Isotope production cross sections : ^{56}Fe



Sample of Evaluated Results



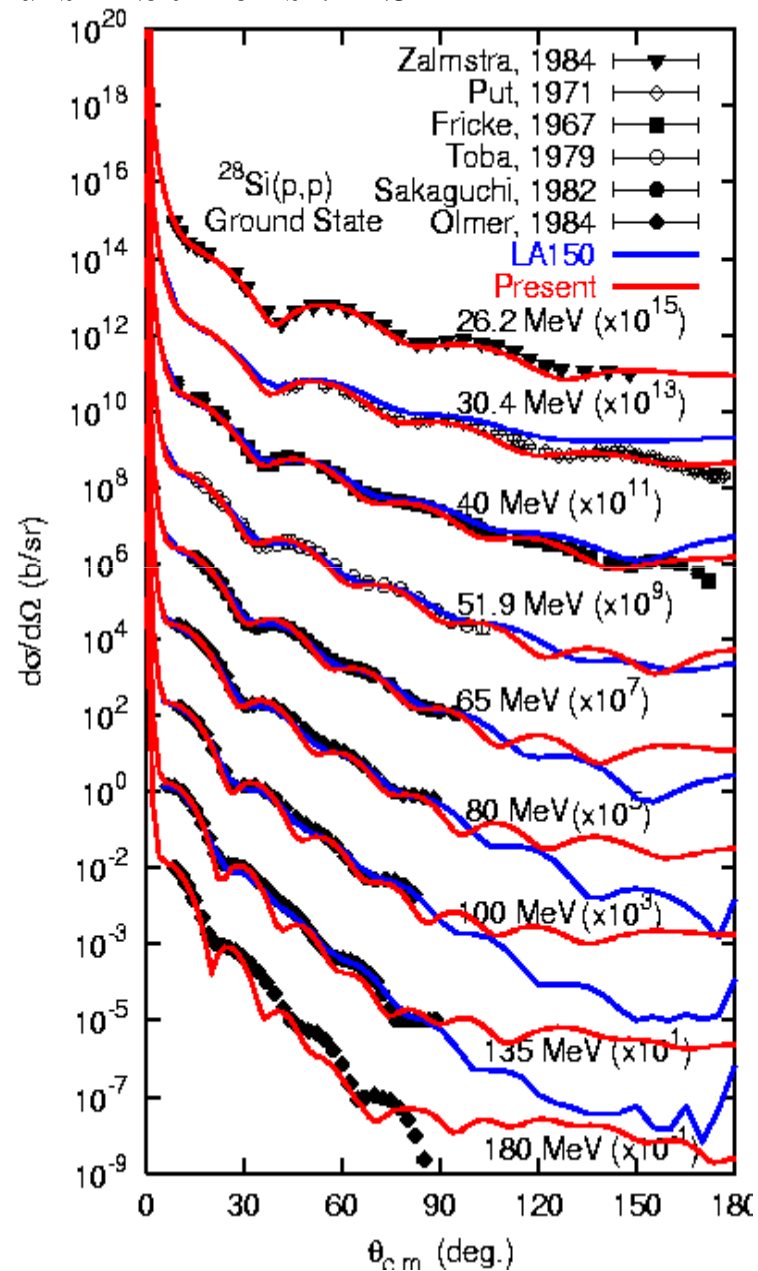
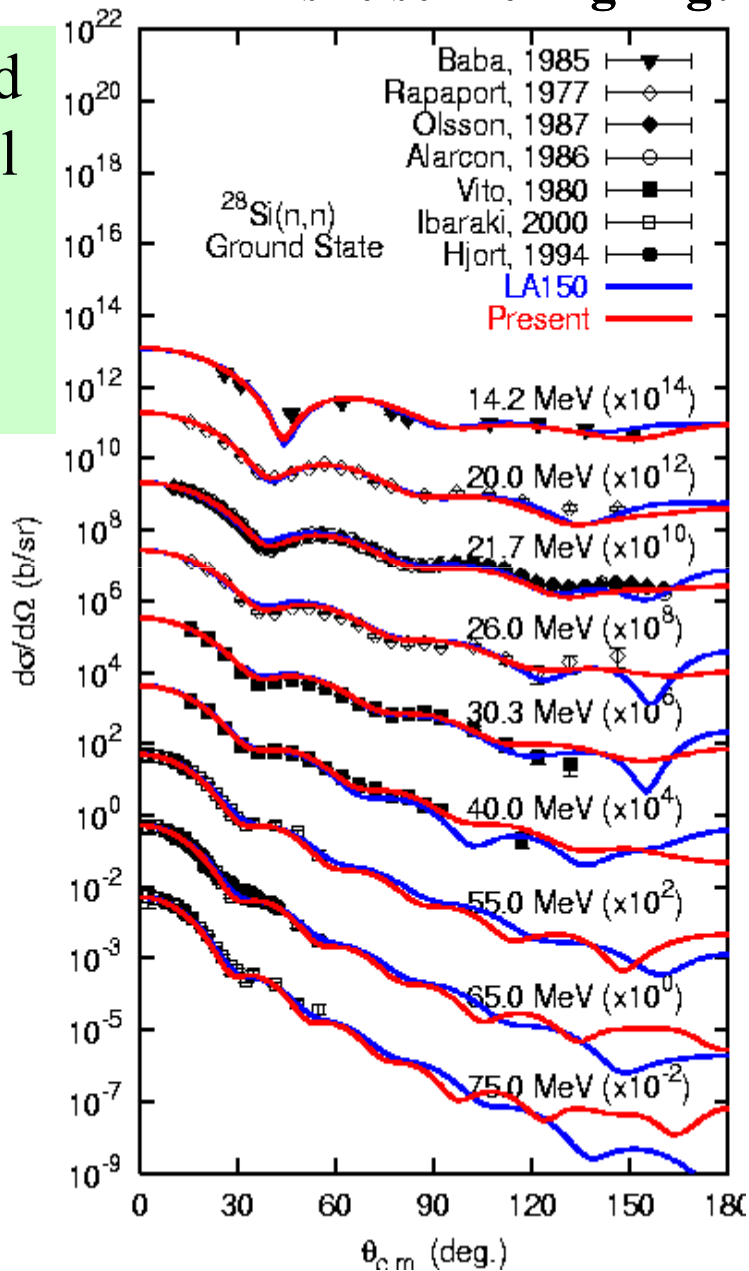
**Isotope production
cross sections : $^{63,65}\text{Cu}$**



Sample of Evaluated Results

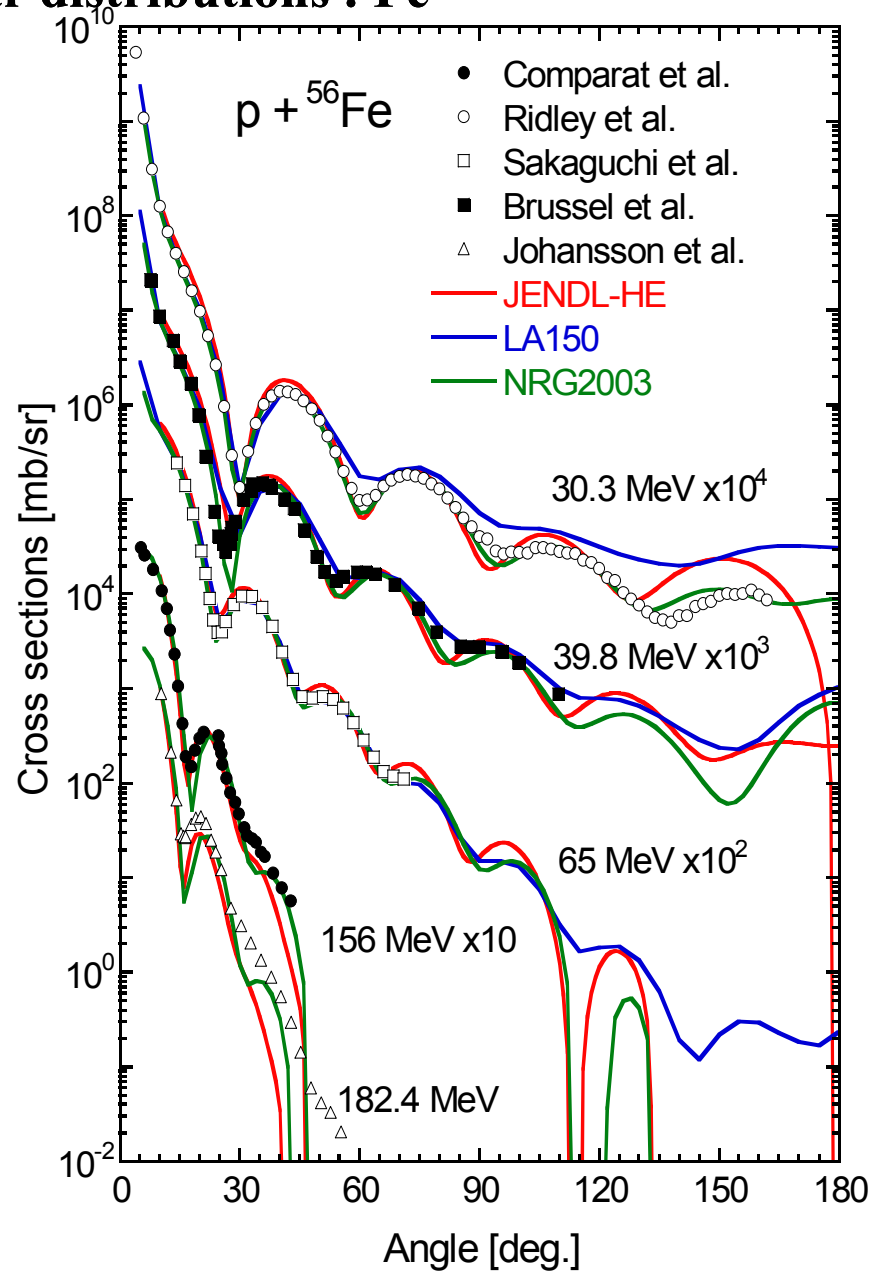
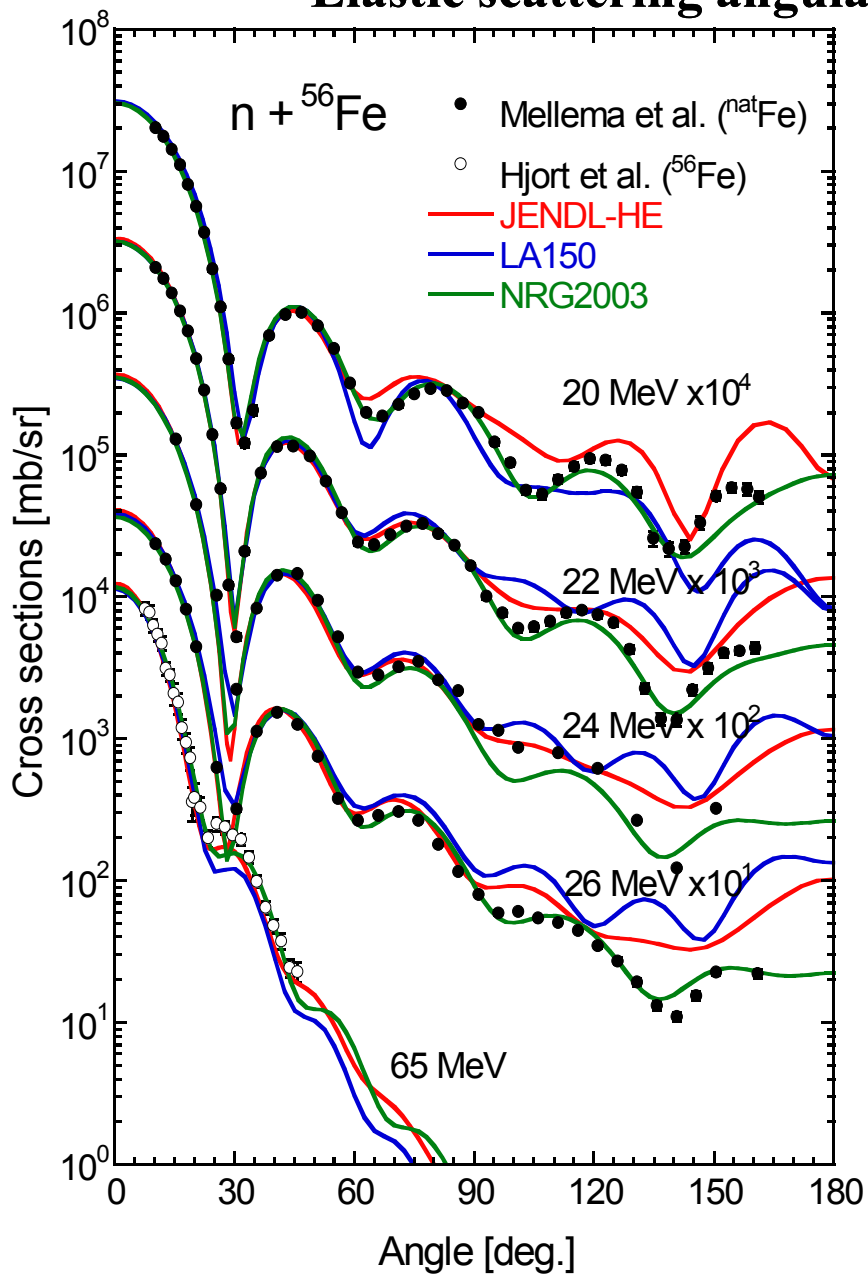
Elastic scattering angular distributions : ^{28}Si

Coupled
Channel
-Soft
Rotator
Model



Sample of Evaluated Results

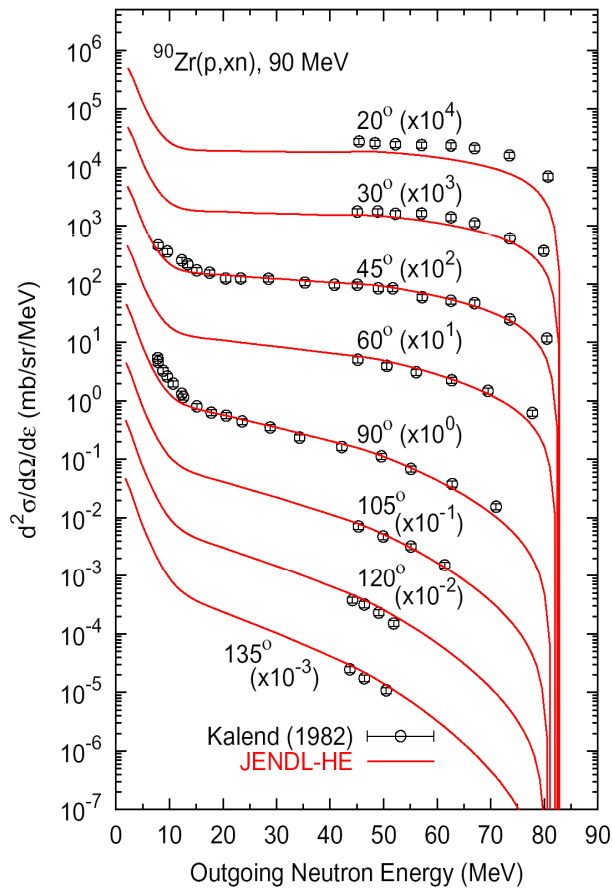
Elastic scattering angular distributions : Fe



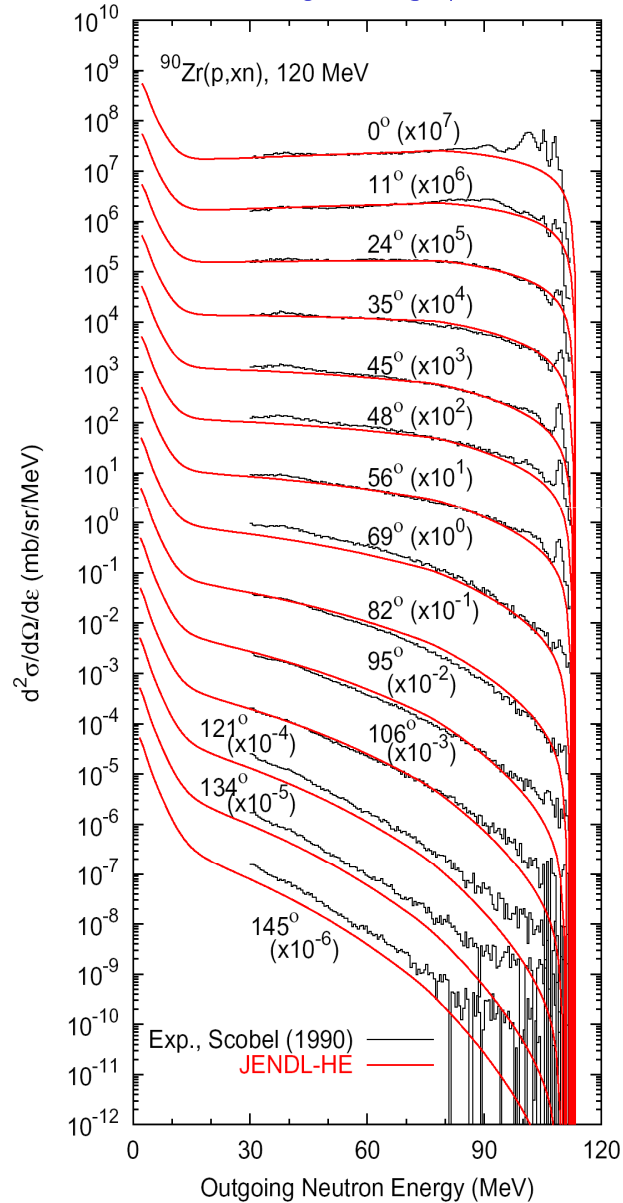
Sample of Evaluated Results

DDXs of $^{90}\text{Zr}(p,xn)$

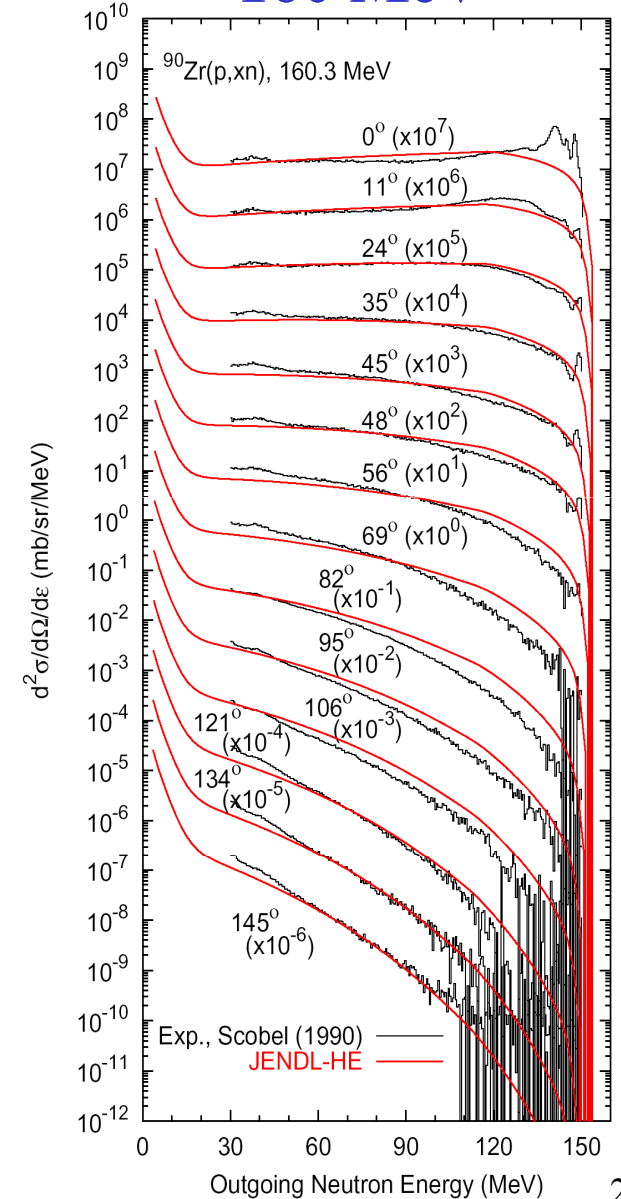
90 MeV



120 MeV



160 MeV



Benchmark Calculation (TIARA Experiment)

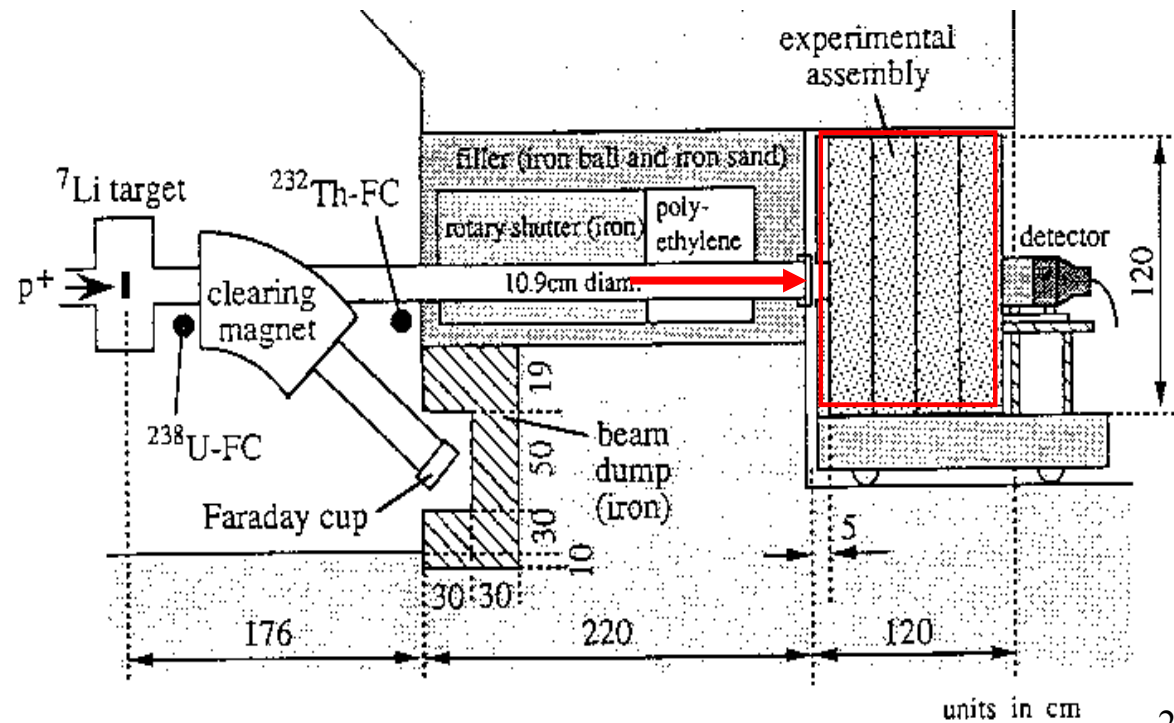
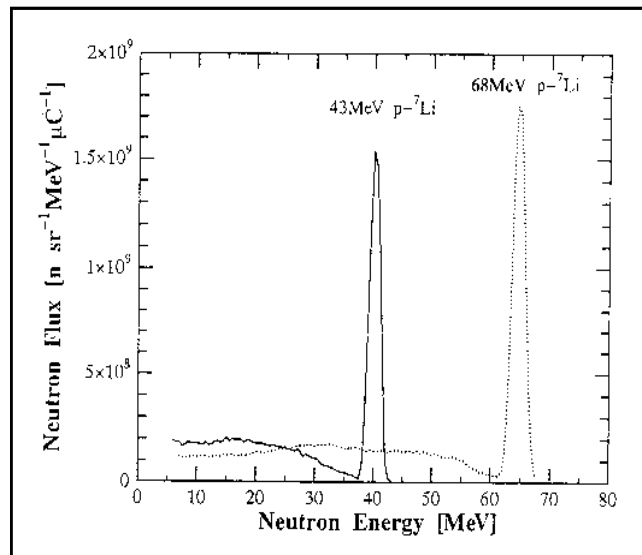
“Transmission through shields of quasi-monoenergetic neutrons generated by 43- and 68-MeV proton”

Ref.) N. Nakao et al., *Nucl. Sci. Eng.* 124, 228 (1996).

H. Nakashima et al., *Nucl. Sci. Eng.* 124, 243 (1996).

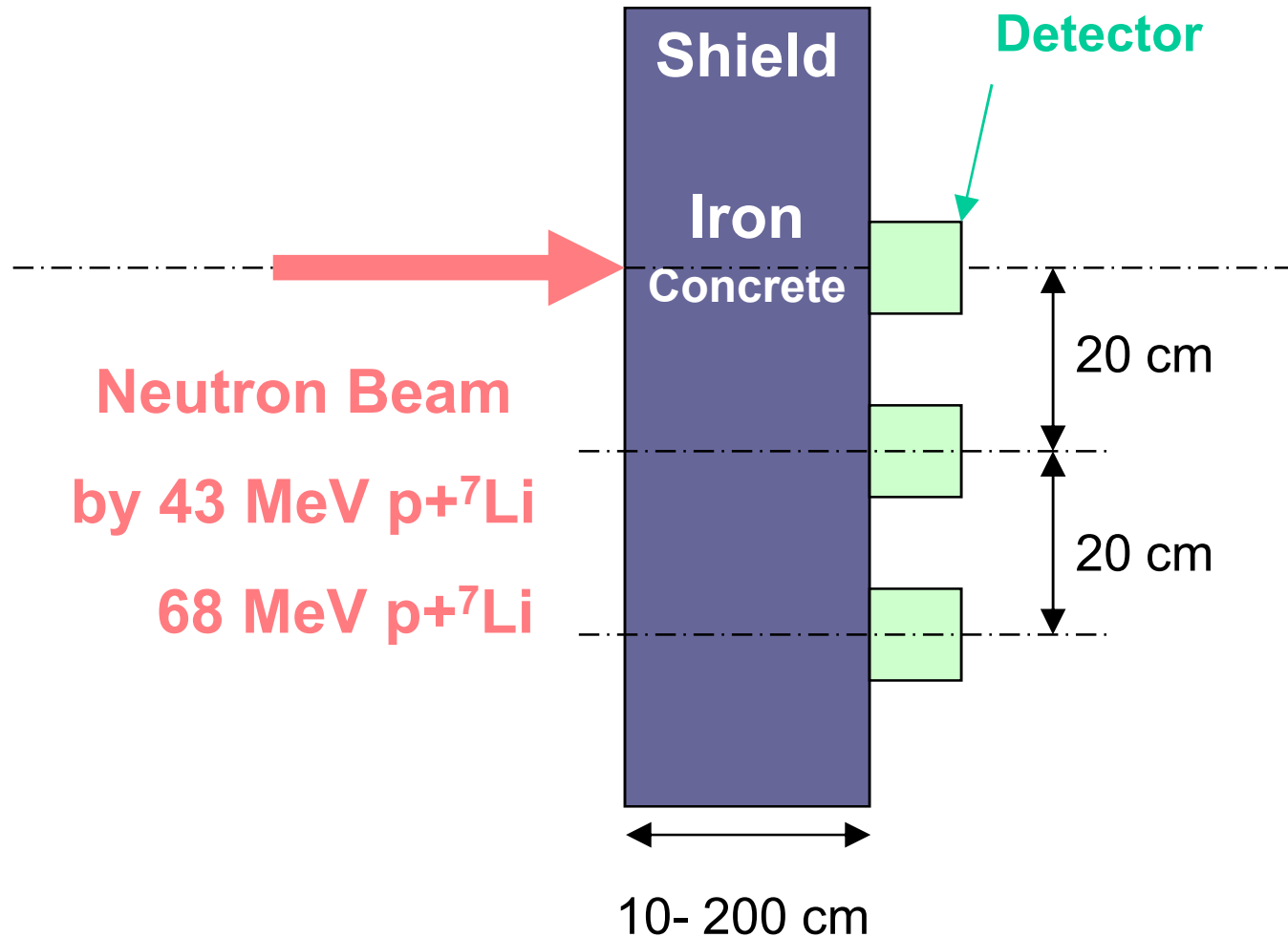
Experimental arrangement @ TIARA, JAERI

Neutron spectrum of $p+{}^7\text{Li}$



units in cm

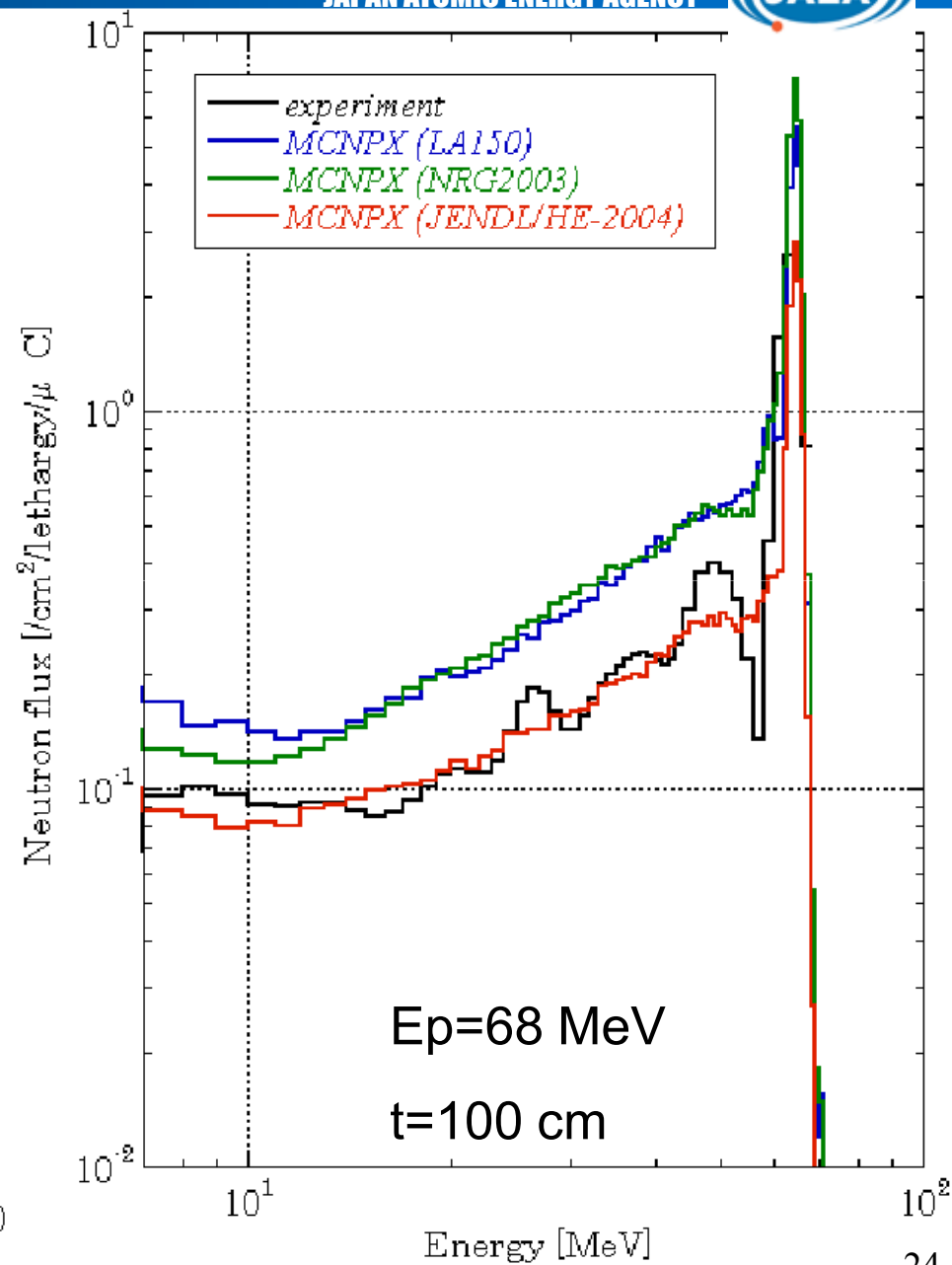
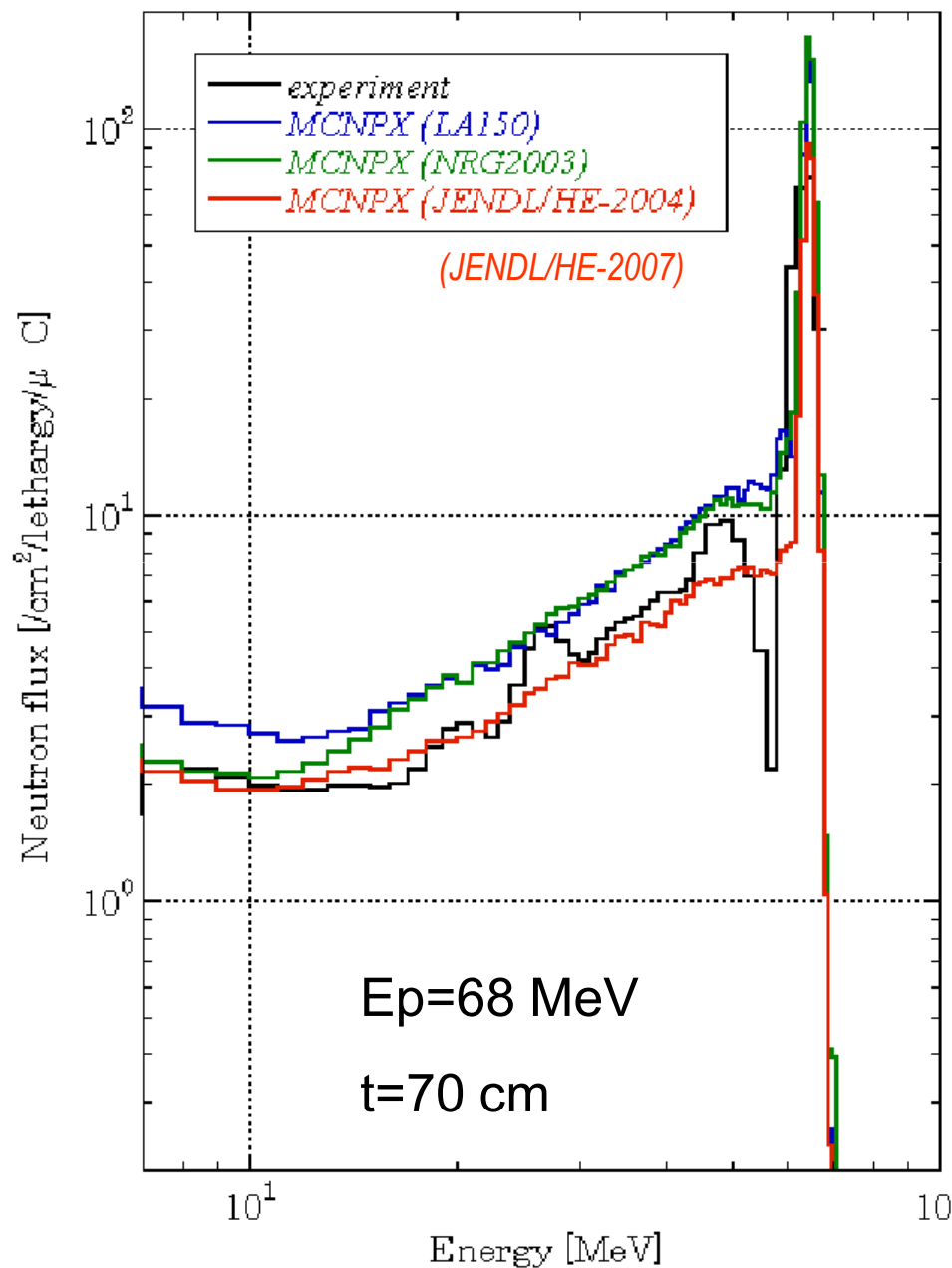
Integral Experiment at TIARA



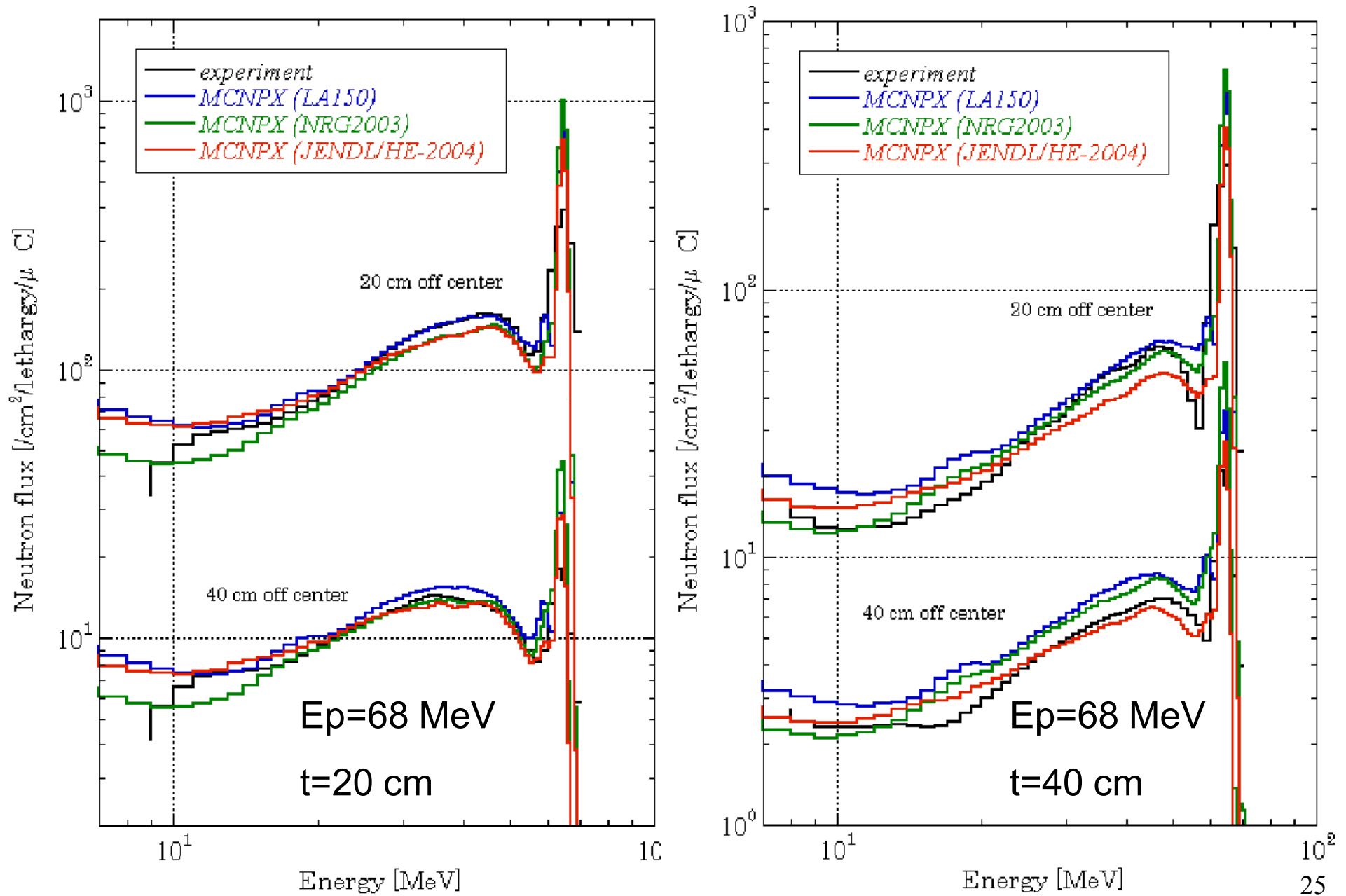
Ref.) N. Nakao et al., *Nucl. Sci. Eng.* 124, 228 (1996).

H. Nakashima et al., *Nucl. Sci. Eng.* 124, 243 (1996). 23

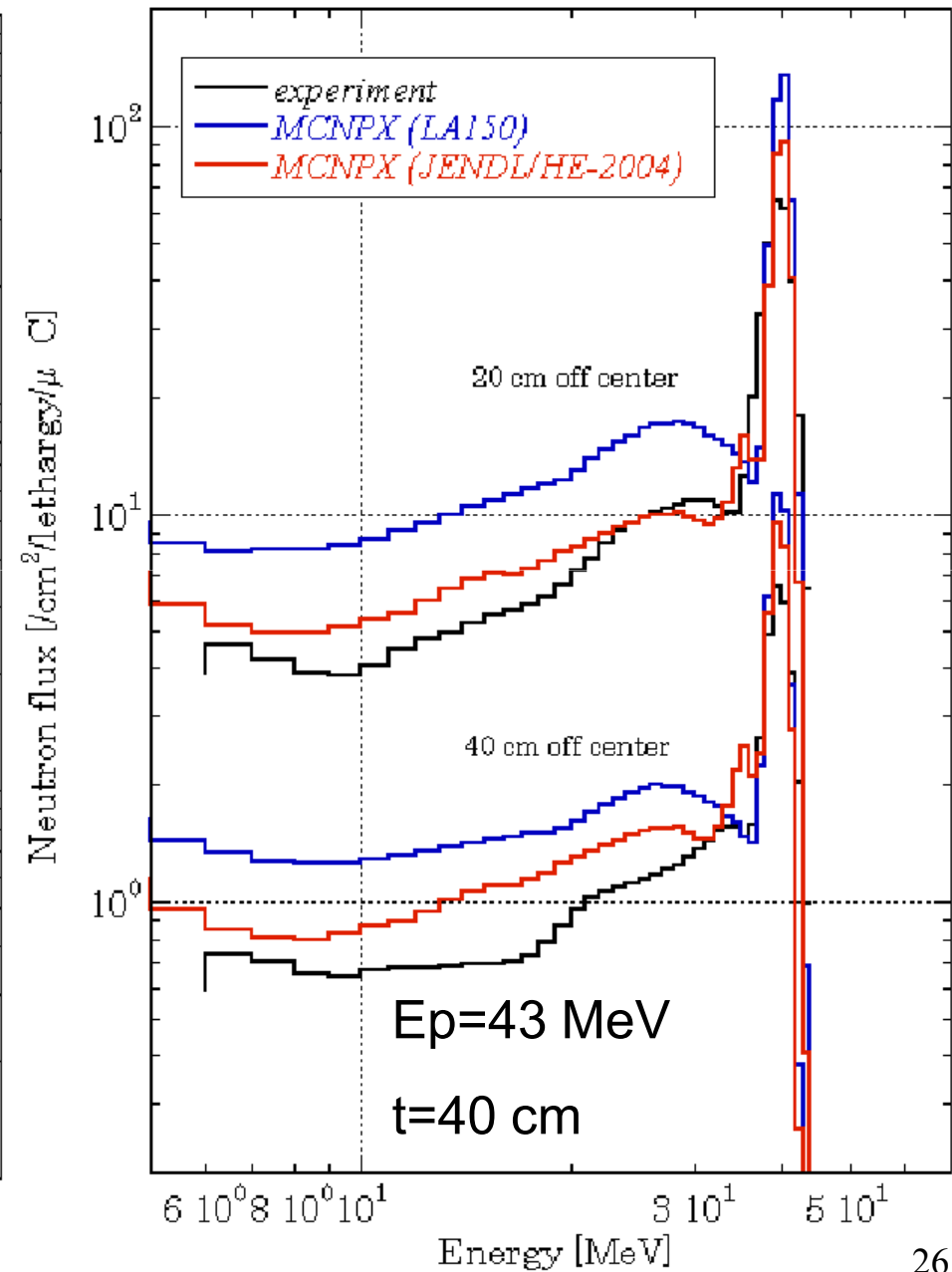
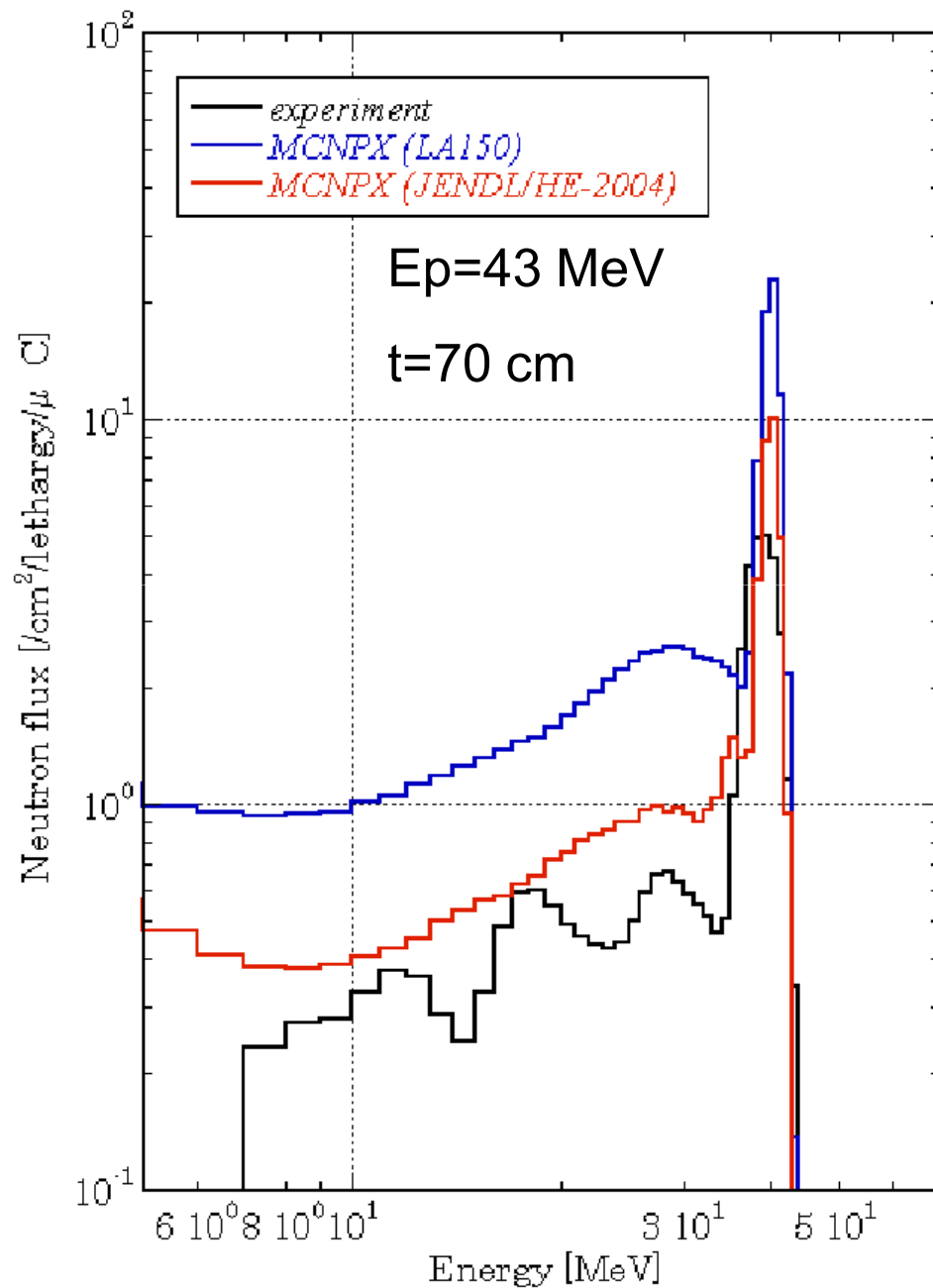
Integral Experiment at TIARA



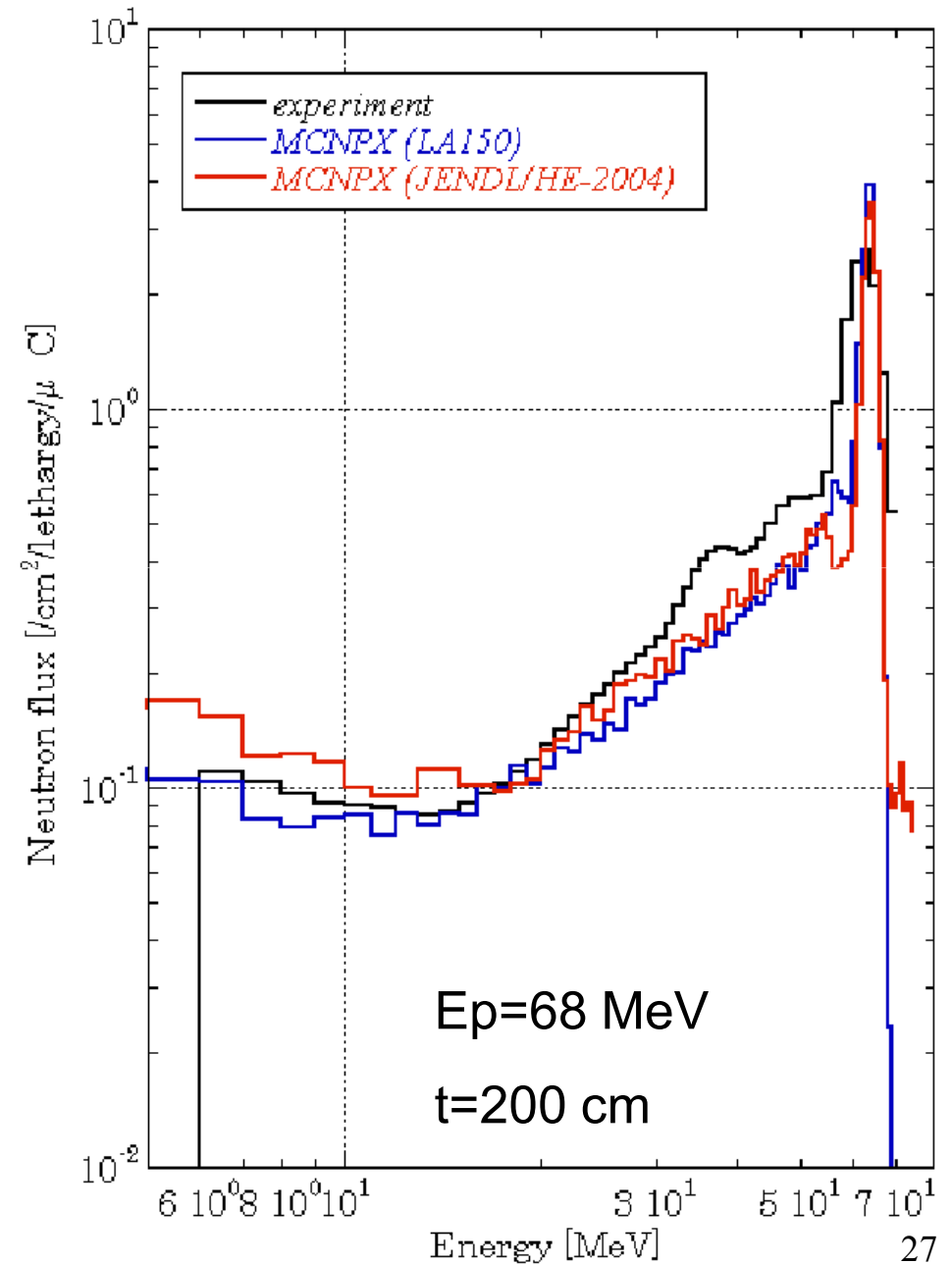
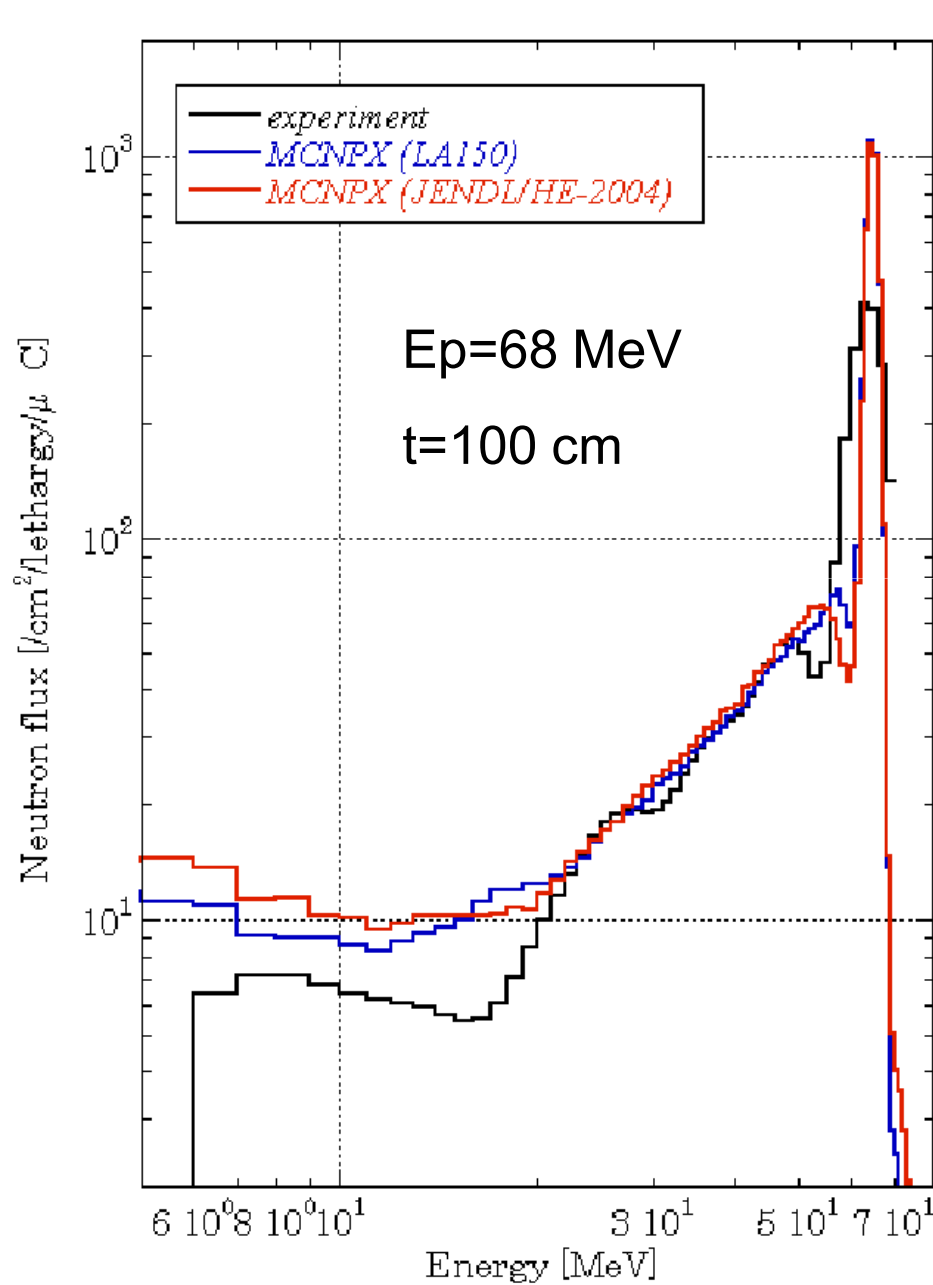
Benchmark Calculation (TIARA Experiment - Fe)



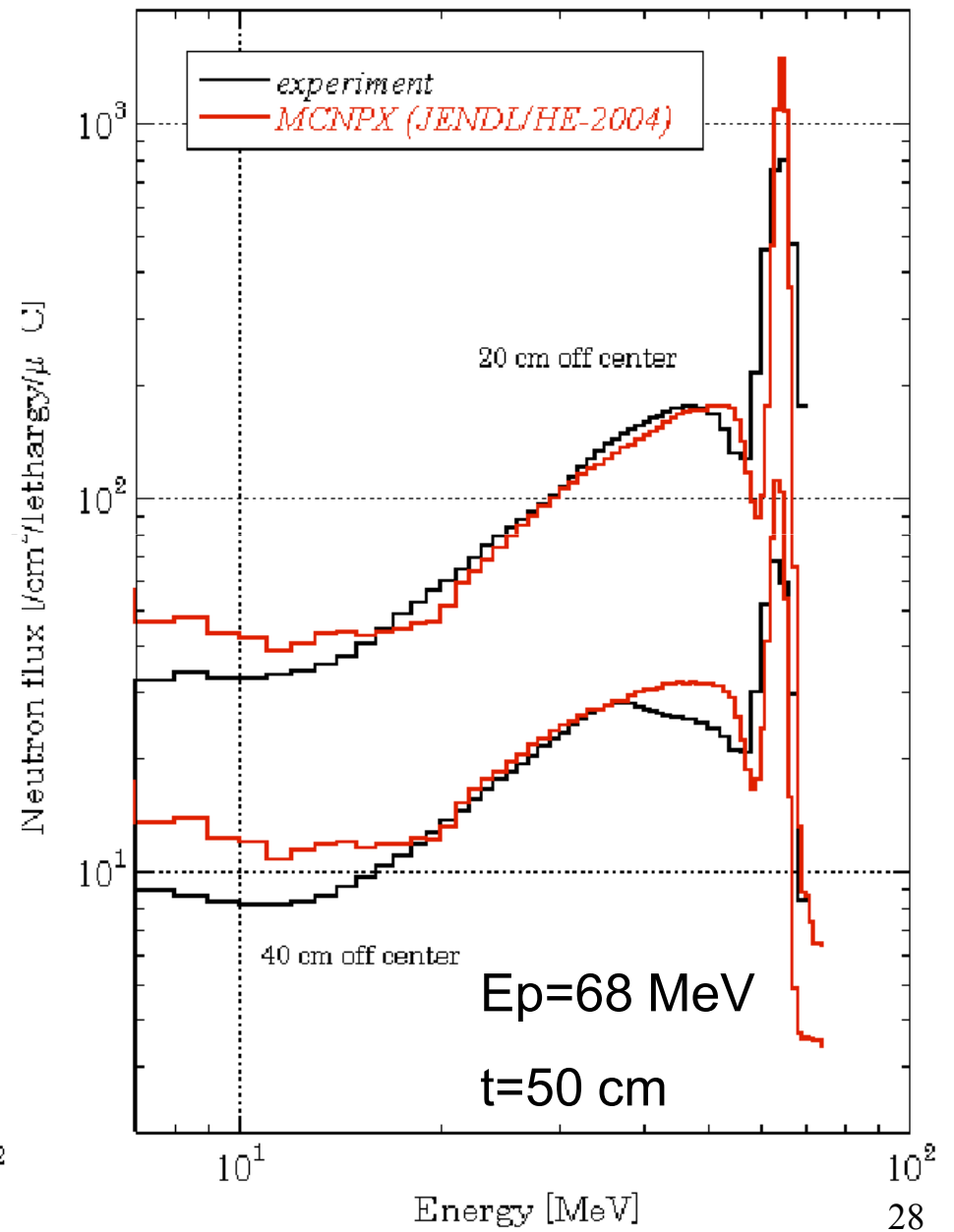
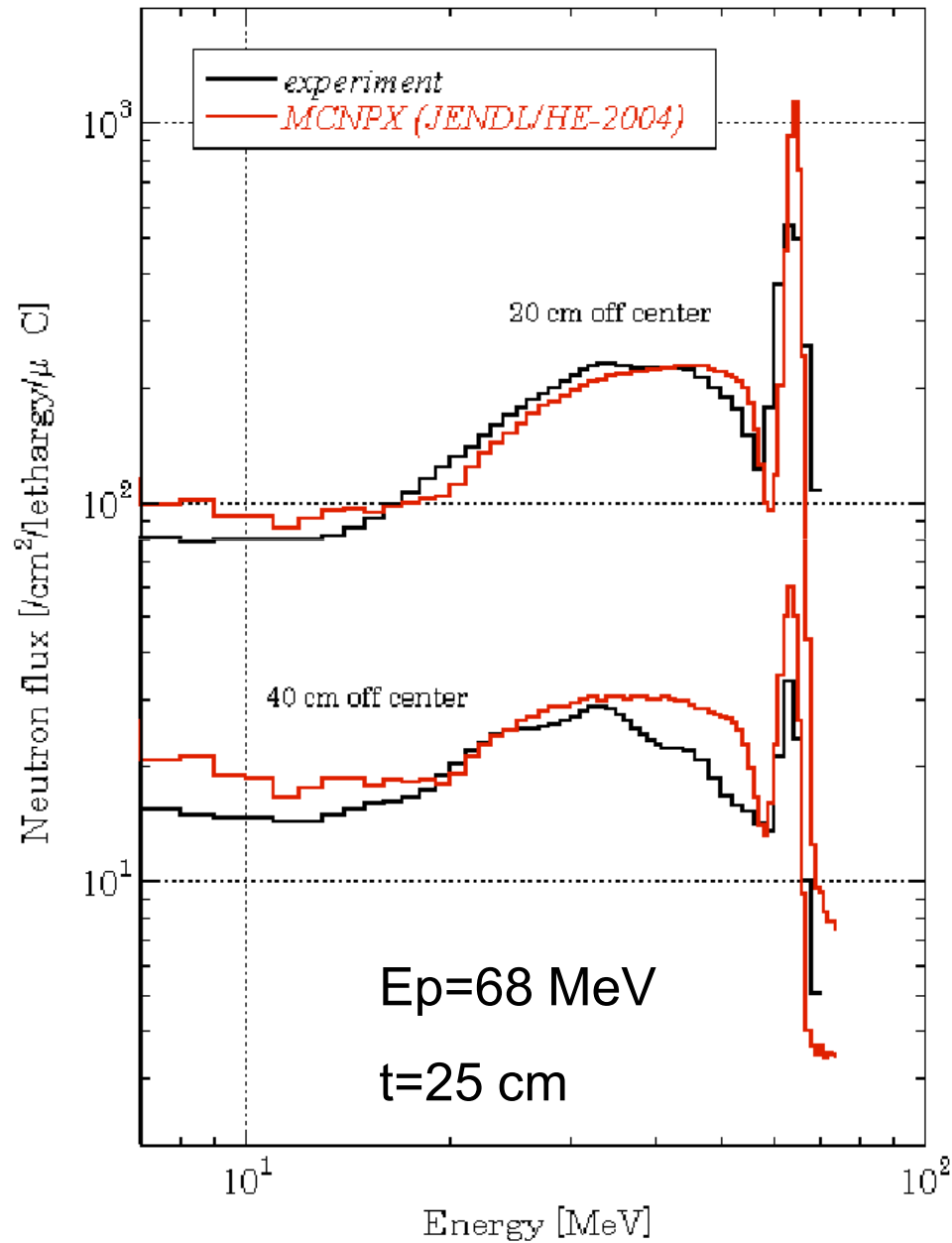
Benchmark Calculation (TIARA Experiment - Fe)



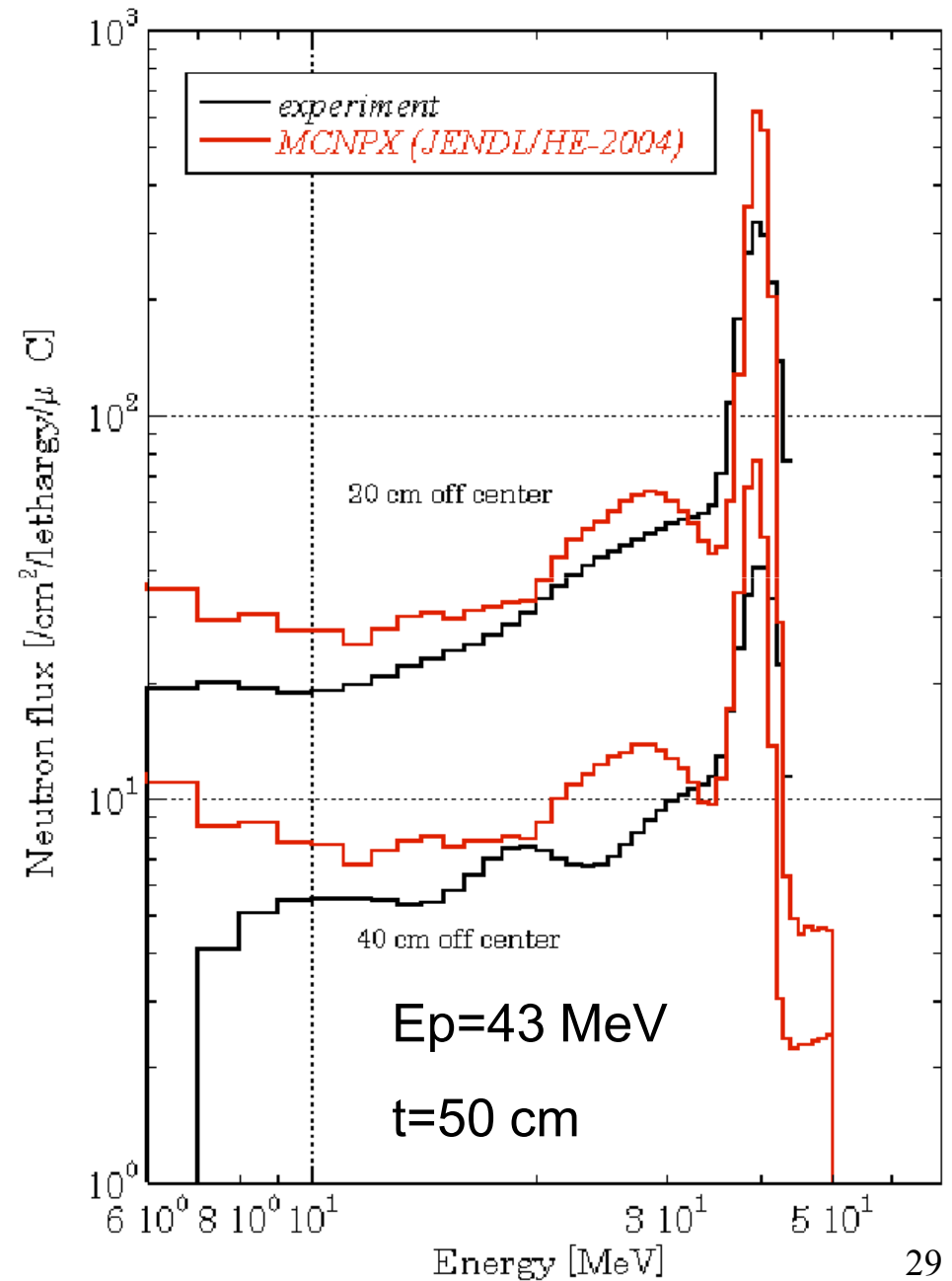
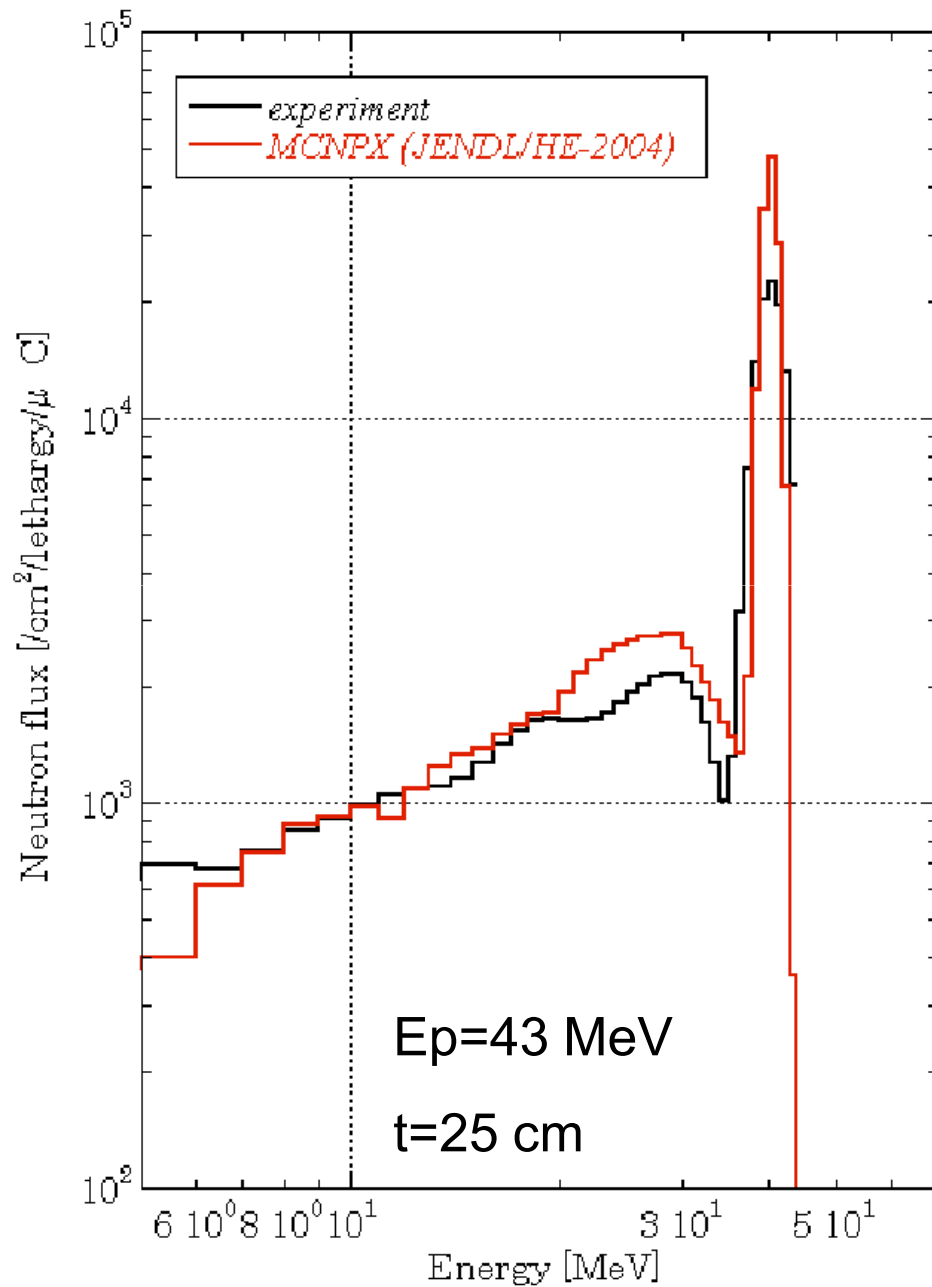
Benchmark Calculation (TIARA Experiment - Concrete)



Benchmark Calculation (TIARA Experiment - Concrete)

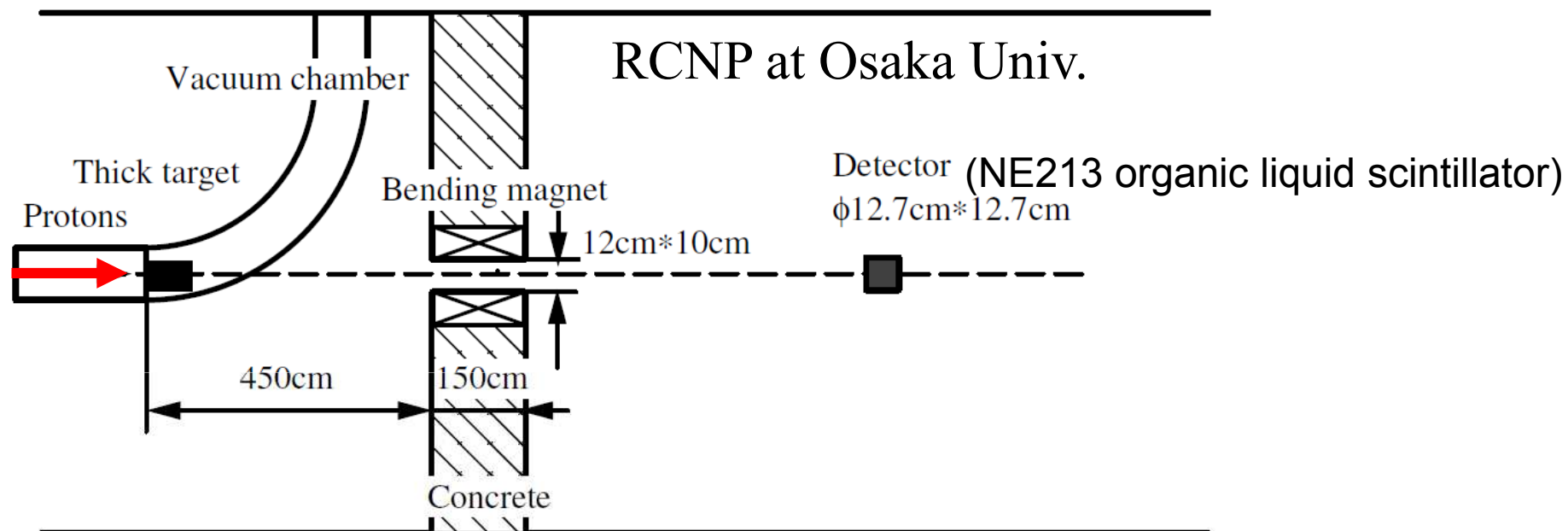


Benchmark Calculation (TIARA Experiment - Concrete)



Integral Experiment at RCNP

Experimental Set-up



Proton Energy: 250 and 350 MeV

Target: Graphite, Al, Fe, Pb

Target Thickness: full stop

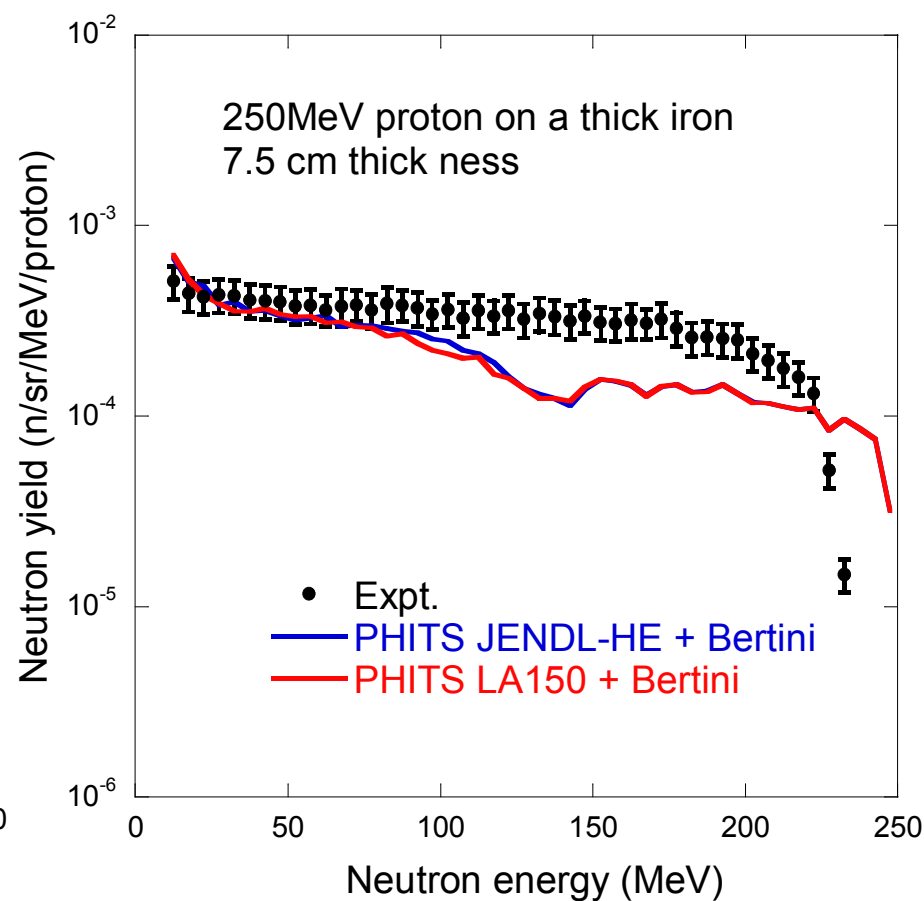
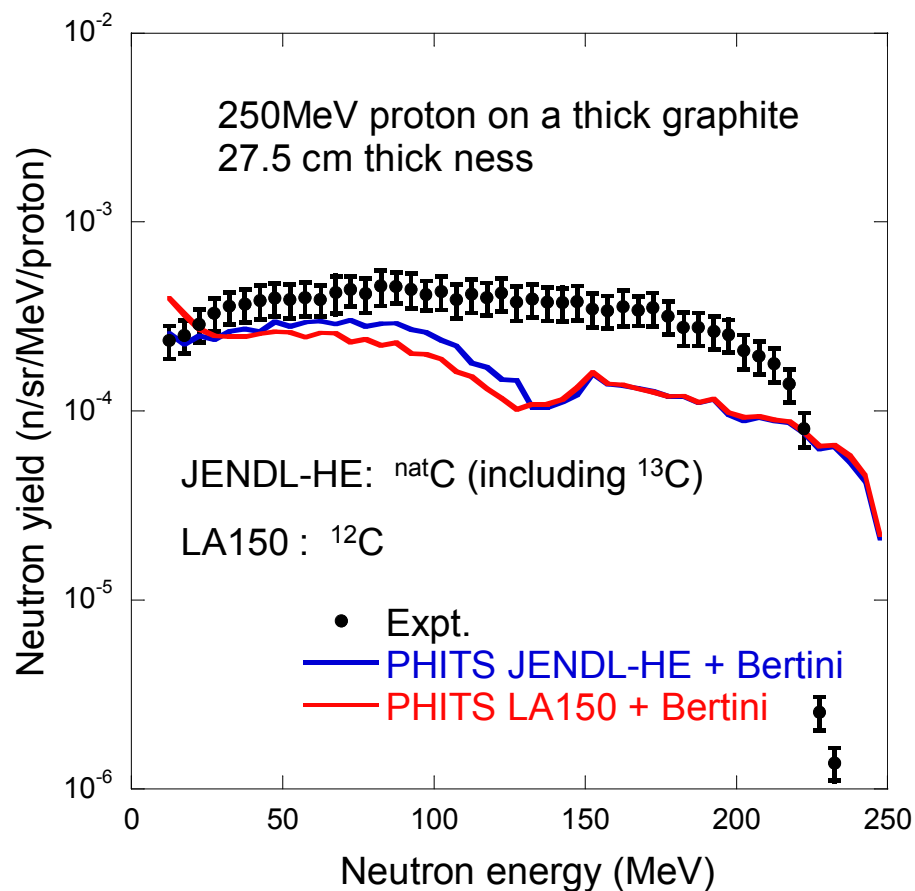
Measured Angle: 0°

Flight Distance: 11.4 m and 67.8 m (250MeV proton),
11.4 m and 95 m (350MeV proton)

Integral Experiment at RCNP

Case1: JENDL-HE vs. LA150

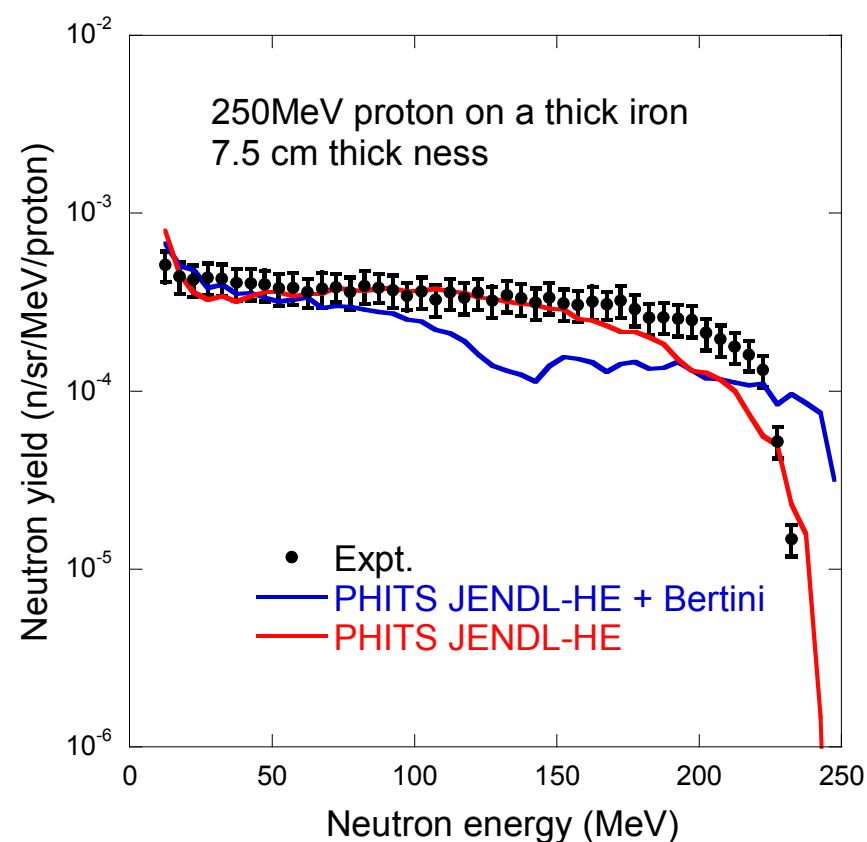
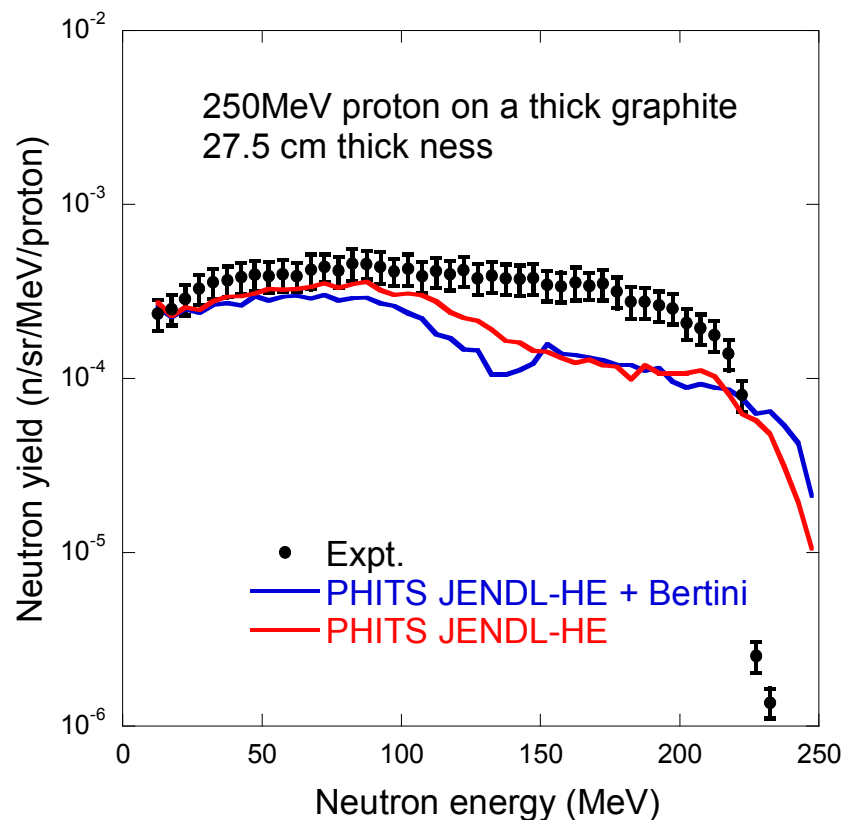
Code	INC model	Evaluated nuclear data	Proton and neutron transition energy (MeV)
PHITS	Bertini	JENDL-HE	150
PHITS	Bertini	LA150	150



Integral Experiment at RCNP

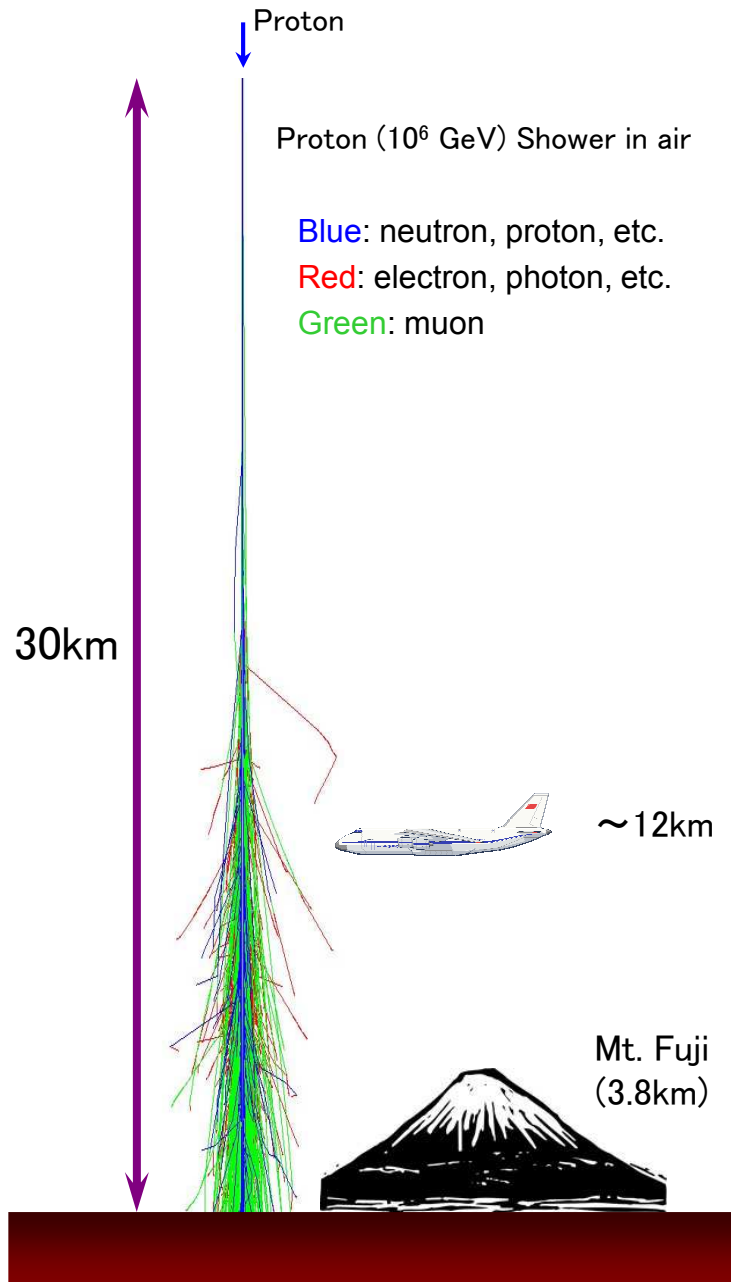
Case2: JENDL-HE with Bertini Parameterization vs. no INC

Code	INC model	Evaluated nuclear data	Proton and neutron transition energy (MeV)
PHITS	Bertini	JENDL-HE	150
PHITS	-	JENDL-HE	-

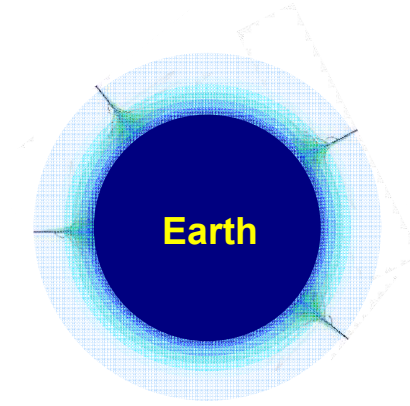


Application (Neutron Spectra Due to Cosmic-ray)

JAPAN ATOMIC ENERGY AGENCY



Database for Cosmic-ray Environment



Atmosphere Model

JENDL/HE

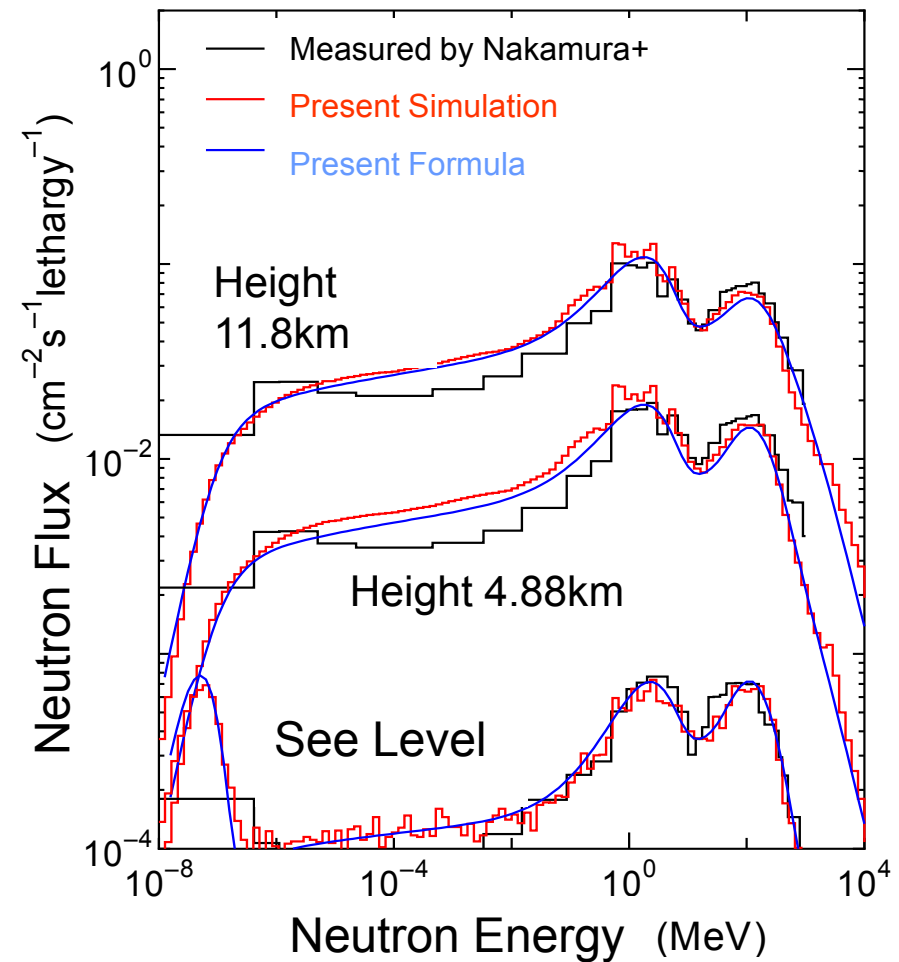
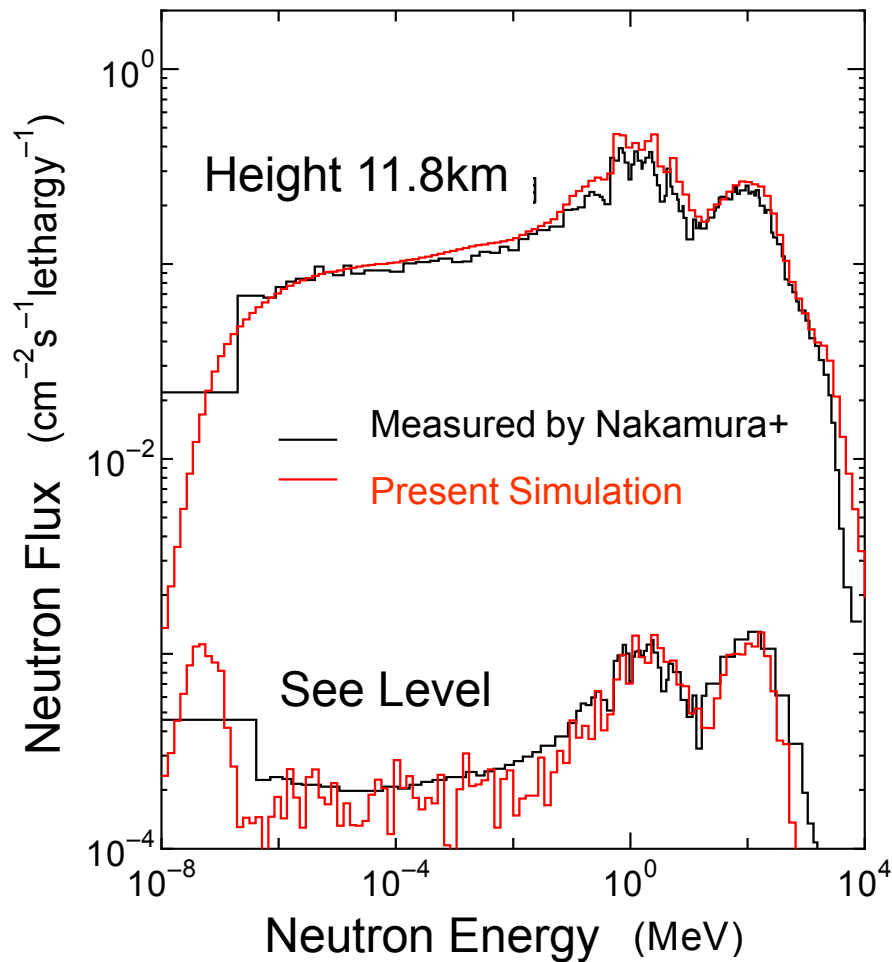


Application (Neutron Spectra Due to Cosmic-ray)

JAPAN ATOMIC ENERGY AGENCY



Calculated Results



Reviewed were status of method and tools of the evaluation for **JENDL High Energy File (JENDL/HE-2007)**. Especially, improvements of **cluster-particle emission spectra and production cross sections**.

Results of some analyses using JENDL/HE were also introduced as those of benchmark calculations. **The calculations using JENDL/HE show good performance.**

The first version of JENDL/HE (**JENDL/HE-2004**) has been released in March, 2004 with neutron and proton nuclear data of 66 nuclides up to 3 GeV. Soon, the second version of JENDL/HE (**JENDL/HE-2007**) will be released with those of totally **over 100 nuclides including actinide ones**.