

# 中子俘获截面及伽马谱学 测量进展

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**中子俘获截面及伽马谱学工作小组**

第六届反角白光中子源用户研讨会，2022.8.20-22，珠海

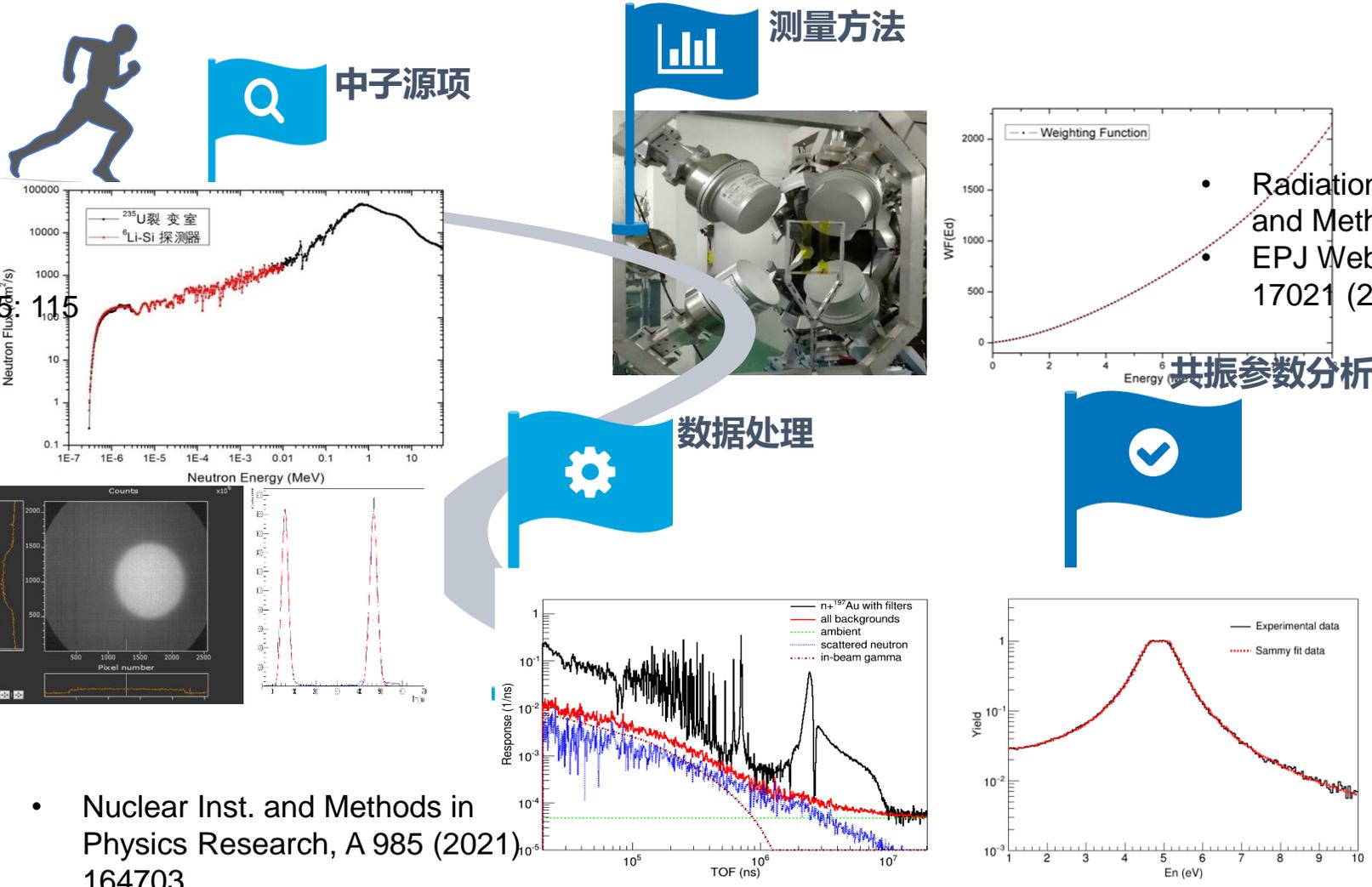
# 报告内容

- 1 C6D6进展
- 2 GTAF-II进展
- 3 伽马谱学进展

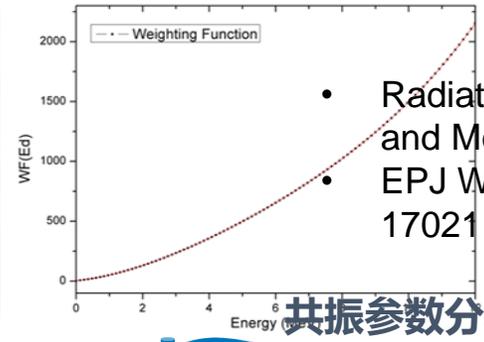
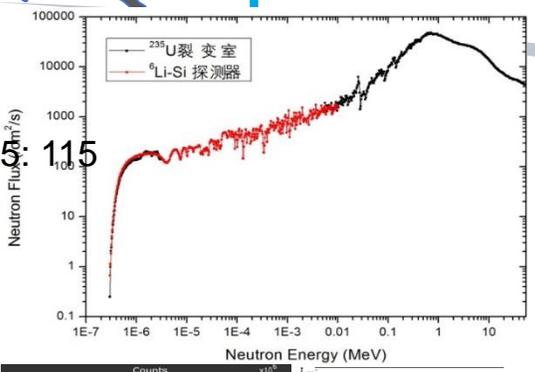
实验名称	实验负责人	束流时间	实验开展时间
GTAf-II真空管道和中子吸收体测试	栾广源	200 h	2021.10.5-2021.10.21(790 h)
1eV-100keV能谱形状和结构	任杰	55 h	2021.11.23-2021.11.26(72 h)
$^{232}\text{Th}$ 中子俘获截面测量	任杰	200 h(与后续实验共用本底测量时间)	2021.11.29开始测量, 由于疫情原因, 12月24日结束, 补充了Sn及Tm样品测量; 实际束流时间559 h
基于CSNS白光中子源的 $^{232}\text{Th}(n, \gamma)$ 截面测量	陈金根	50 h	
天然Ga中子俘获反应截面的实验测量	梅波	50 h	
Sb、Nb中子俘获反应截面高精度测量	安振东	50 h	
真空管道与中子吸收体条件下在线测量 $^{169}\text{Tm}$ 、 $^{93}\text{Nb}$ 中子俘获反应截面	张奇玮	128 h	2022.2.23-2022.2.28(113 h)
$^{117}\text{Sn}(n, g)^{118}\text{Sn}$ 反应中Gamma角分布的测量	张奇玮	150 h	2022.2.28-2022.3.9(150 h)
$^{238}\text{U}$ 、 $^{232}\text{Th}$ 中子俘获反应截面在线测量	张奇玮	150 h	2022.3.9-2022.3.17 (169 h)
GTAf补充测量	张奇玮	120 h	2022.3.17-2022.3.23(127 h)
模拟月壤CUG-1A主量与微量元素成分分析	安振东/张小平	50 h	2022.4.1-2022.4.4(70 h)
模拟月壤CUG-1A月球主要矿物成分分析	安振东	120 h	2022.4.4-2022.4.9(103 h)
钐钷中子俘获截面高精度测量研究	安振东	130 h	2022.4.9-2022.4.17(177 h)
天然Ge靶中子俘获反应截面的实验测量	梅波	130 h	2022.4.17-2022.4.24(138 h)
$^{109}\text{Ag}$ 中子俘获截面测量	王宏伟	100 h	2022.7.8-2022.7.15(119 h)
地矿样品中子活化分析	徐浩博	5 h	2022.7.10 7h

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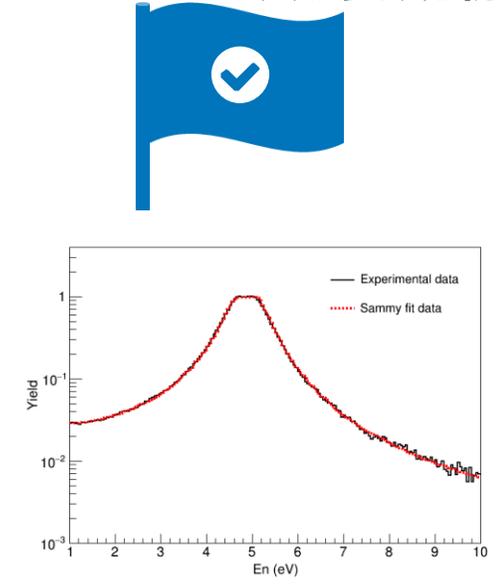
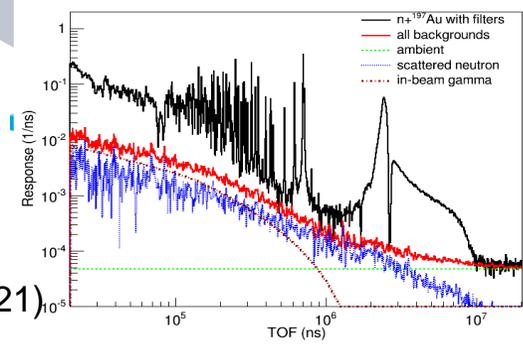
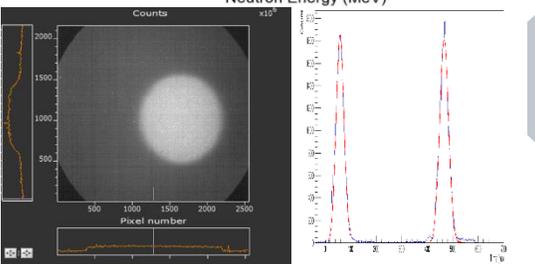
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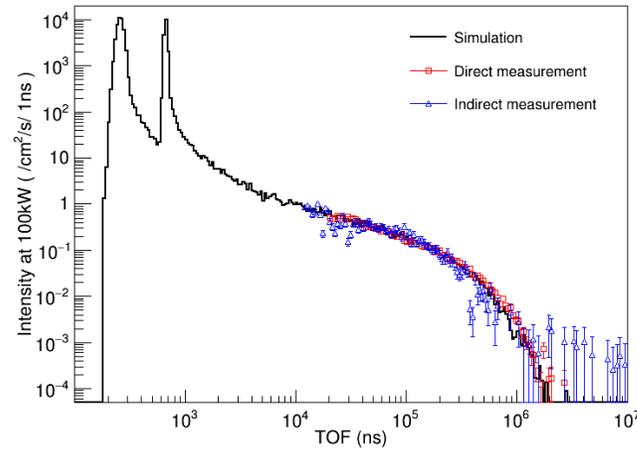
- 物理学报, Vol. 68, No.8(2019)080101
- Eur. Phys. J. A (2019) 55: 115



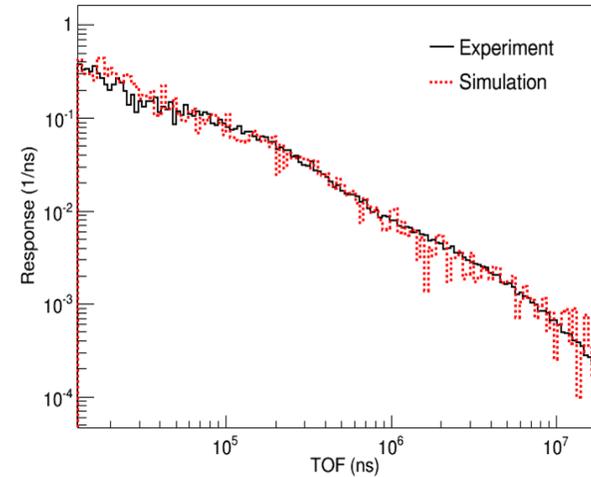
- Radiation Detection Technology and Methods (2019)3:52
- EPJ Web of Conferences 239, 17021 (2020)



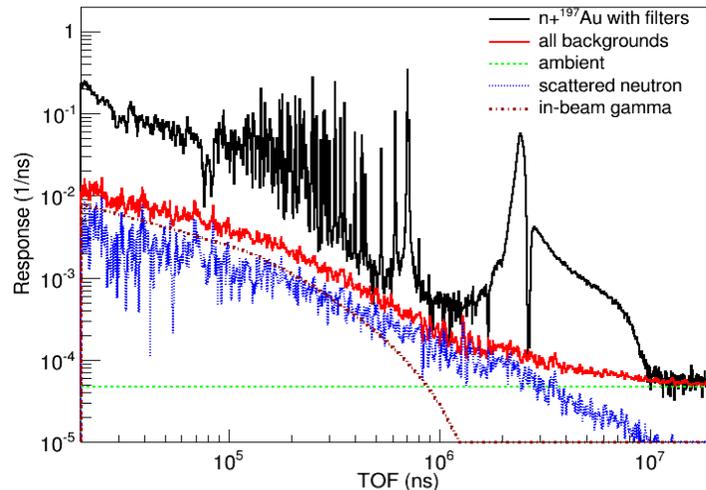
- Nuclear Inst. and Methods in Physics Research, A 985 (2021) 164703



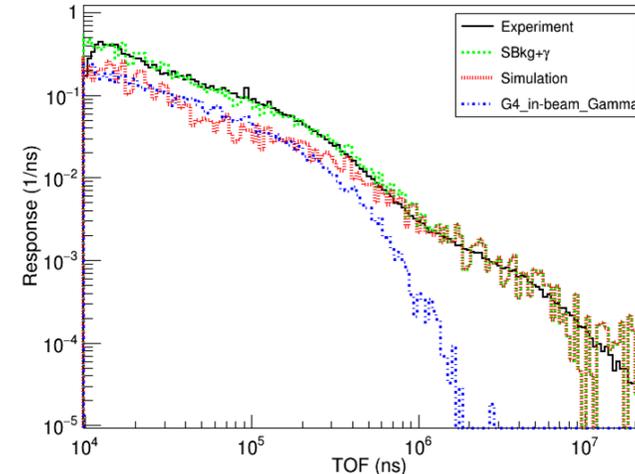
束内伽马本底的测量与模拟



碳样品散射中子本底的测量与模拟

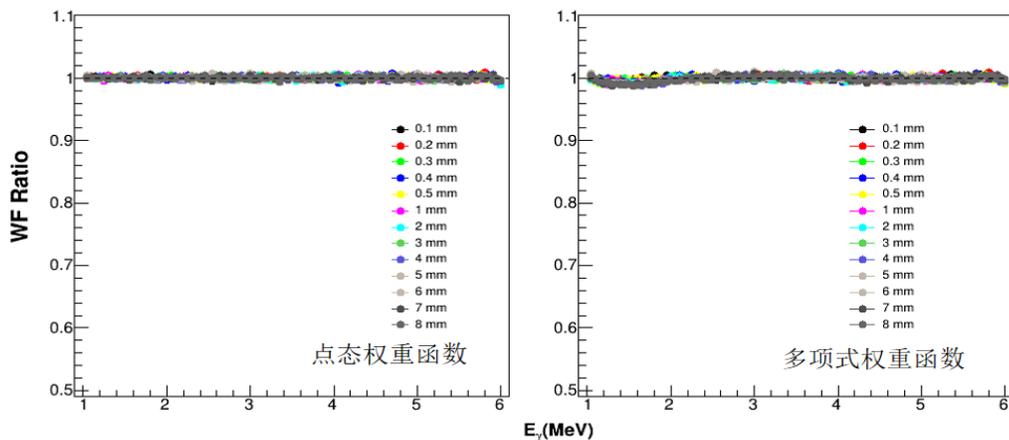


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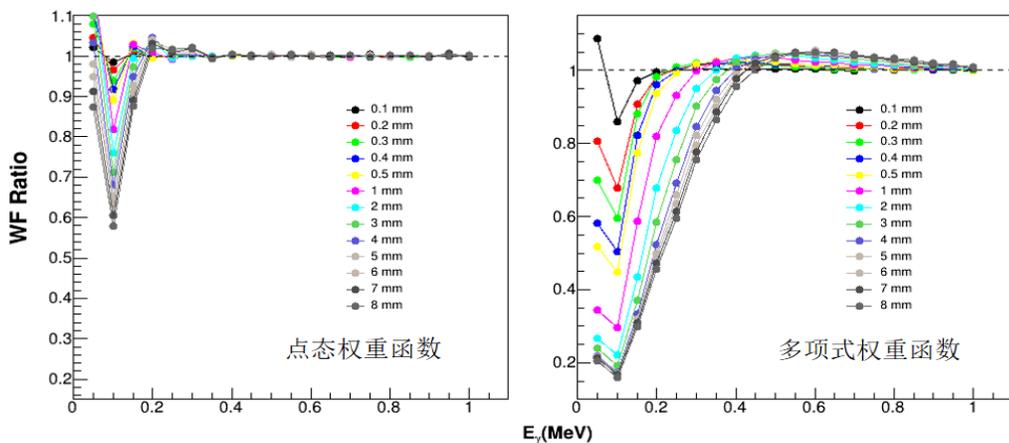
铅样品散射伽马及中子的研究

## 权重效率与能量的比值



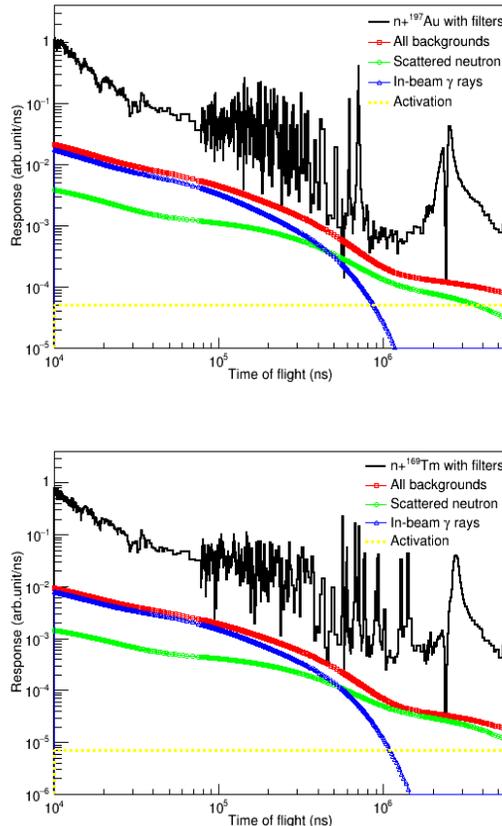
1-6 MeV

对于厚样品实验，点态权重函数有助于减小误差，尤其是低能伽马部分。

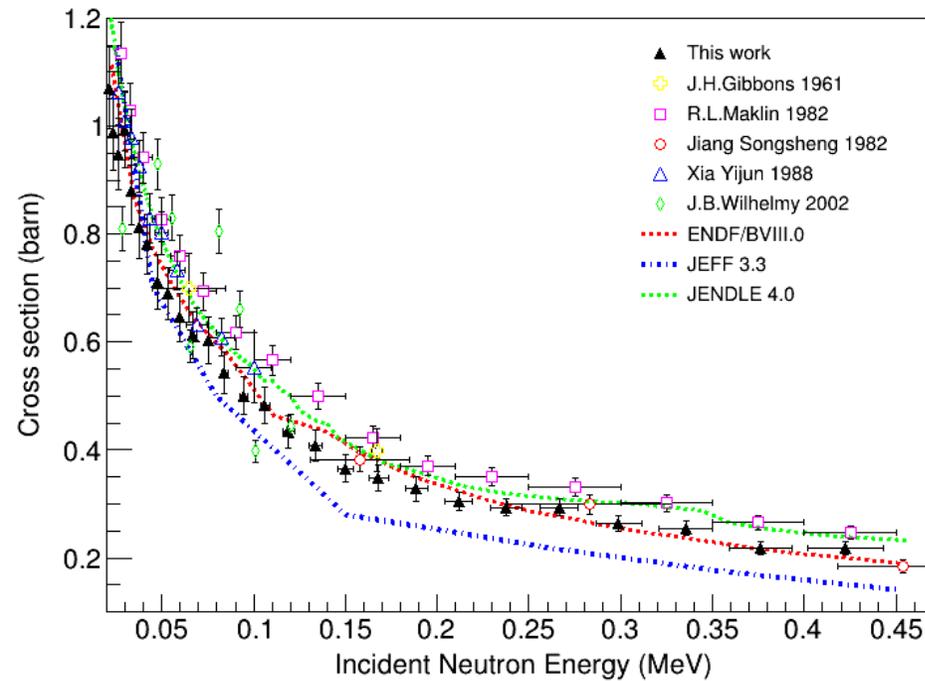


0-1 MeV

## Neutron capture cross section of $^{169}\text{Tm}$ measured at the CSNS Back-n facility in the energy region from 30 to 300 keV\*



Result is more consistent with ENDF/B-VIII.0



Chinese Physics C Vol. 46, No. 4 (2022) 044002

## Results from 1 eV to 100 eV

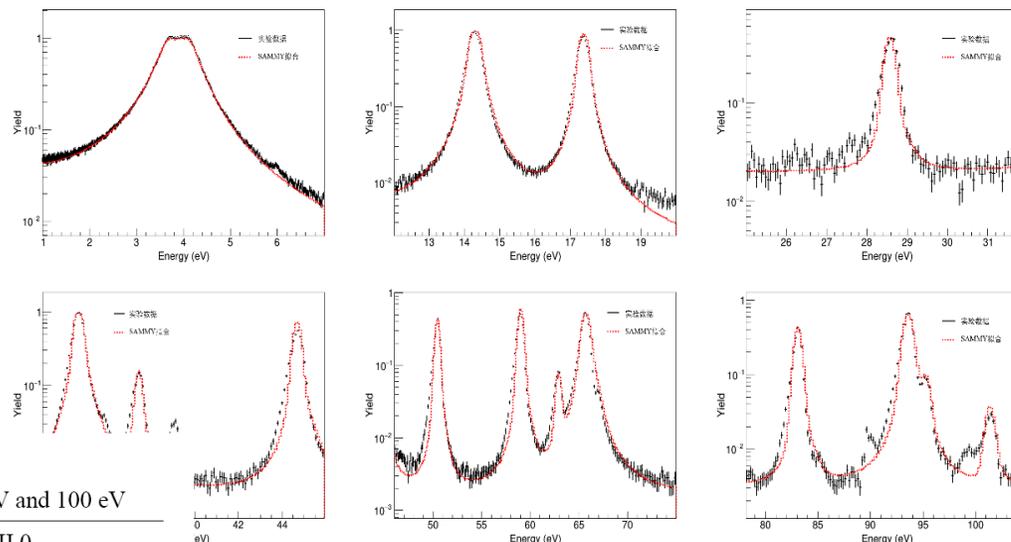
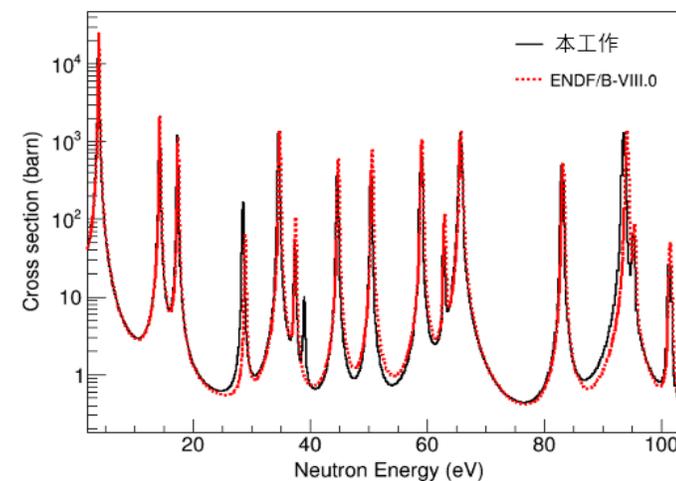


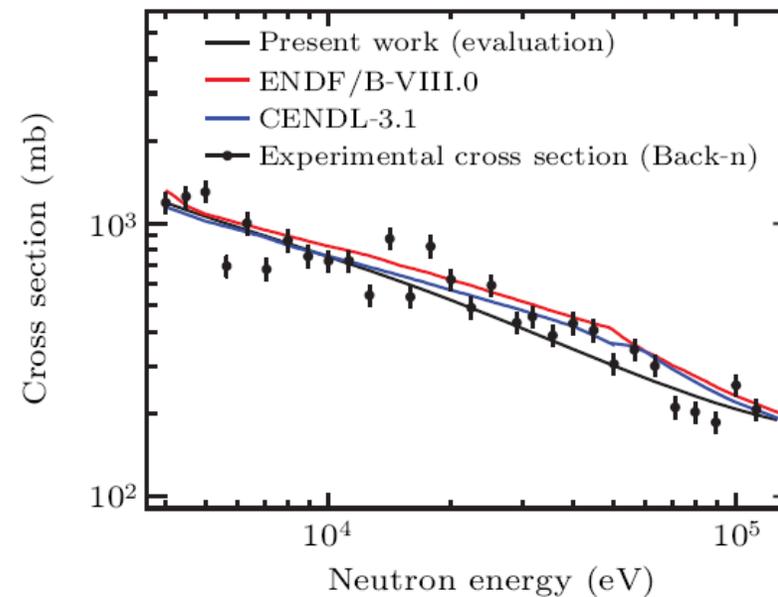
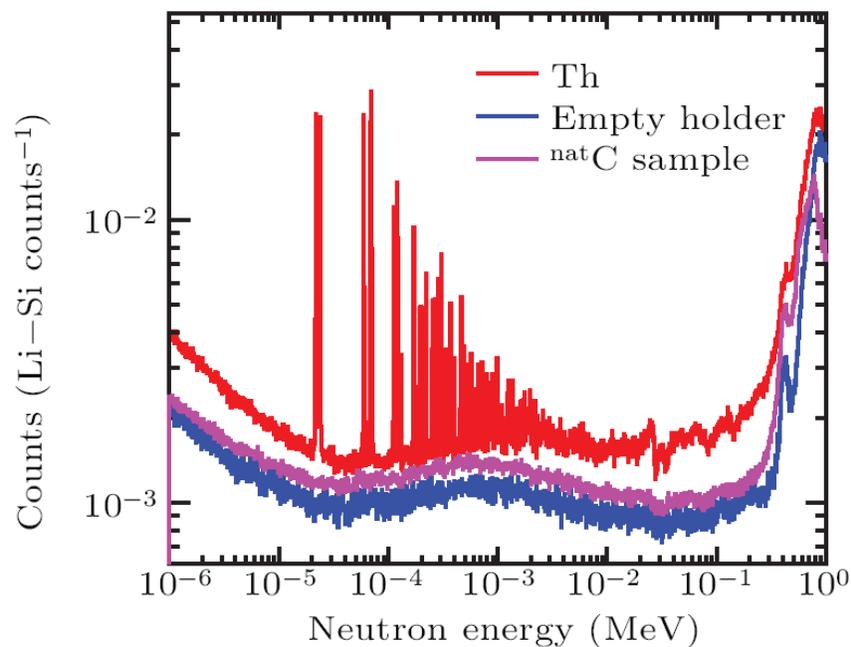
表 2 1eV-100eV 能区  $^{169}\text{Tm}$  共振参数

Table.2 The resonance parameters of  $^{169}\text{Tm}$  in the energy region between 1 eV and 100 eV

This Work					ENDF/B-VIII.0				
$E_0$ (eV)	$\Gamma_n$ (meV)	$\Gamma_\gamma$ (meV)	$l$	$J$	$E_0$ (eV)	$\Gamma_n$ (meV)	$\Gamma_\gamma$ (meV)	$l$	$J$
3.90±0.03	7.45±0.52	105.70±7.4	0	1	3.906	7.47	102.4	0	1
14.32±0.12	9.01±0.63	98.80±6.92	0	0	14.32	9.12	97.1	0	0
17.40±0.14	6.24±0.44	81.40±5.70	0	0	17.42	5.74	81.4	0	0
28.60±0.24	0.55±0.04	93.70±6.56	0	1	28.90	0.21	95.0	0	1
34.72±0.29	5.87±0.41	86.00±6.02	0	1	34.79	5.87	86.0	0	1
37.48±0.31	0.24±0.02	123.96±8.68	0	1	37.51	0.46	86.0	0	1
39.08±0.32	0.05±0.01	138.80±9.72	0	1	-	-	-	-	-
44.73±0.37	2.37±0.17	99.00±6.93	0	1	44.79	3.47	93.0	0	1



## Measurement of $^{232}\text{Th}$ (n, $\gamma$ ) cross section at the CSNS Back-n facility in the unresolved resonance region from 4 keV to 100 keV



Chin. Phys. B 31, 060101 (2022)

## New experimental measurement of $^{nat}\text{Er}(n, \gamma)$ cross sections between 1 and 100 eV

### Results:

- 1)  $^{162,164}\text{Er}$  are nuclear astrophysical p-process nuclei, which are consumed by neutron capture reaction in cosmic environment, and the cross section of neutron capture reaction is of great significance for understanding the formation of elements Er;
- 2) The  $(n, \gamma)$  cross section of  $^{nat}\text{Er}$ , using C6D6 liquid scintillator and pulse height weighting techniques to measure prompt  $\gamma$  rays, has been measured in the energy range of 1–100 eV using a back-n@CSNS.
- 3) The deduced neutron capture cross sections matches the evaluation databases ENDF/B-VIII.0, ENDF/B-VII.1, JENDL-4.0, and ROSFOND-2010, and resonance parameters extracted from the R-matrix code in the 1–100 eV region.

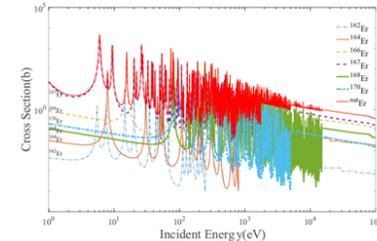
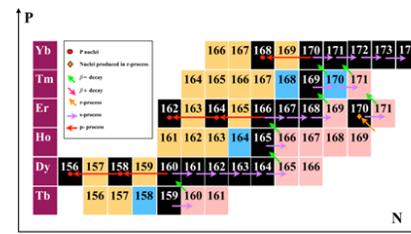
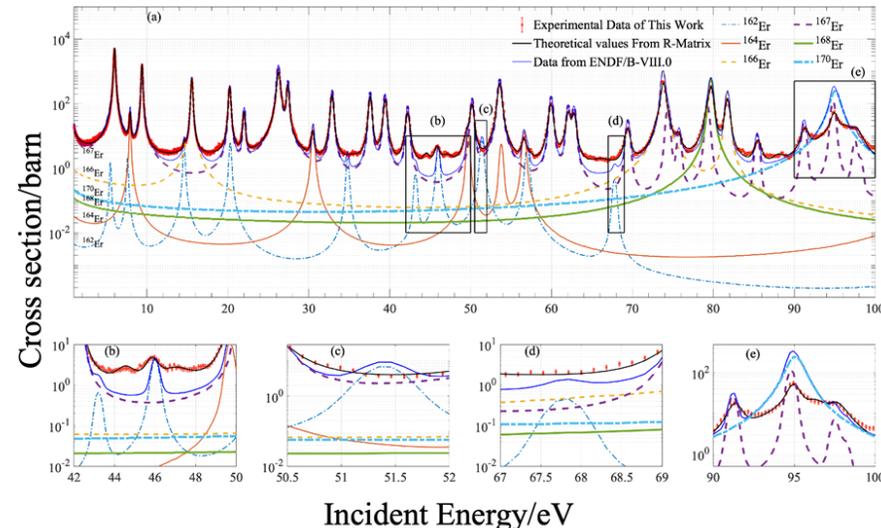


FIG. 1. The main nucleosynthesis path for  $^{nat}\text{Er}$  in massive stars.

FIG. 2. The neutron cross section  $\sigma_n$  of natural erbium calculated

[1] X.X. Li et al., Phys. Rev. C. 104.054302 (2021)  
 [2] X.R. Hu et al., Nucl. Sci. Tech.(2021)32:101  
 [3] X.X.Li et al., Nuclear Techniques, Vol. 43. No.8(2019)080501(In Chinese)

# $^{107}\text{Ag}$ Neutron Capture Cross Section

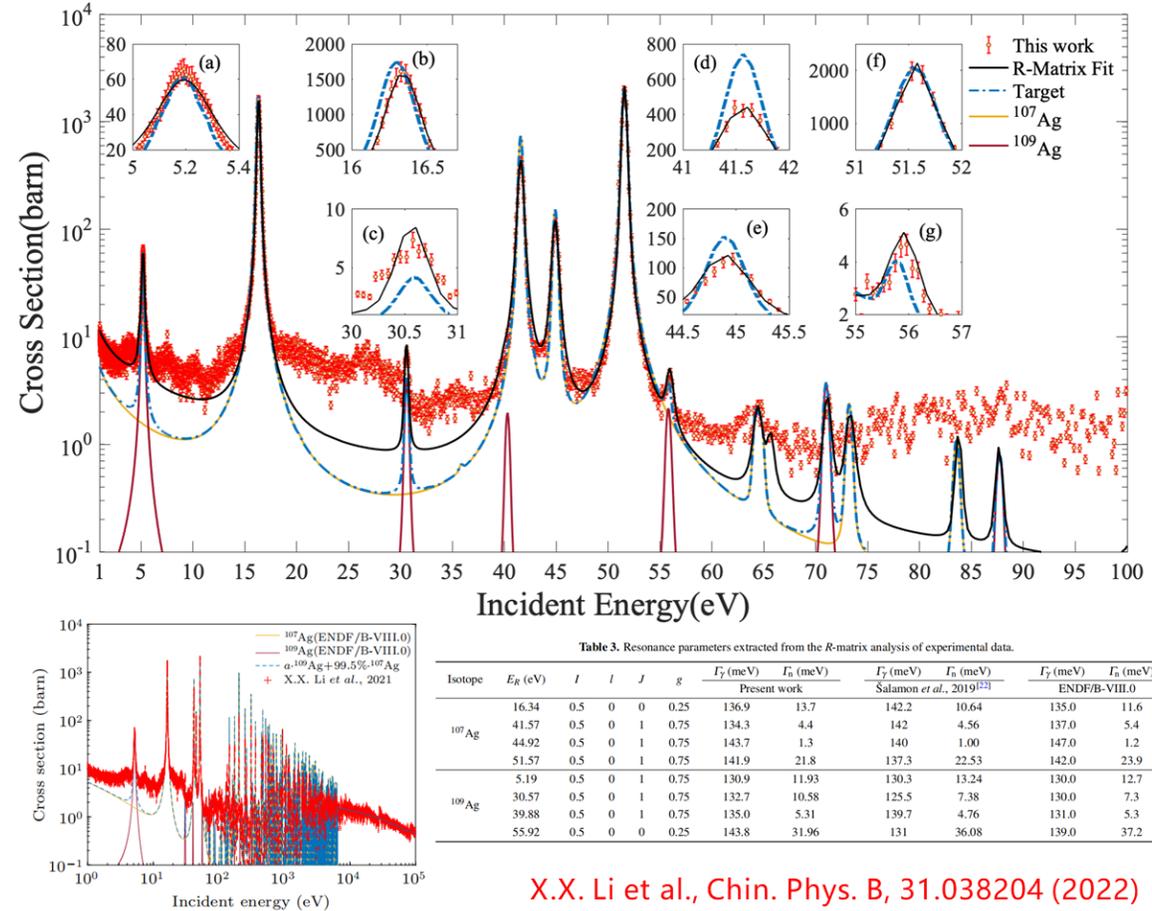
## Result:

1)  $^{107}\text{Ag}$  is an important component of the PWR Ag-In-Cd control rod, and its sub-reaction cross section is of great significance for the design and operation and maintenance of the PWR; Meanwhile,  $^{107}\text{Ag}$  is also an important weak r nucleus.

2) To accurately calculate the consumption value of the control rod, a reliable neutron reaction cross section of the  $^{107}\text{Ag}$  is required.

3) The  $(n, \gamma)$  cross section of  $^{107}\text{Ag}$  has been measured in the energy range of 1–60 eV using a back-n@CSNS.

4) The resonance parameters are extracted by an R-matrix code. All the cross section of  $^{107}\text{Ag}$  and resonance parameters are given in this paper as datasets.



X.X. Li *et al.*, *Chin. Phys. B*, 31.038204 (2022)

# $^{nat}\text{Se}$ Neutron Capture Cross Section

## Results:

1)  $^{74}\text{Se}$  is one of 35 p-nuclei, and  $^{82}\text{Se}$  is a r-only nucleus, and their (n, $\gamma$ ) cross sections are vital input parameters for nuclear astrophysics reaction network calculations.

2) The deduced neutron capture cross section was compared with ENDF/B-VIII.0, JEFF-3.2, and JENDL-4.0, and some differences were found.

3) Resonance parameters were extracted by the R-Matrix code SAMMY in the 1 eV - 1 keV region. All the cross sections of  $^{nat}\text{Se}$  and resonance parameters are given in the

datasets.

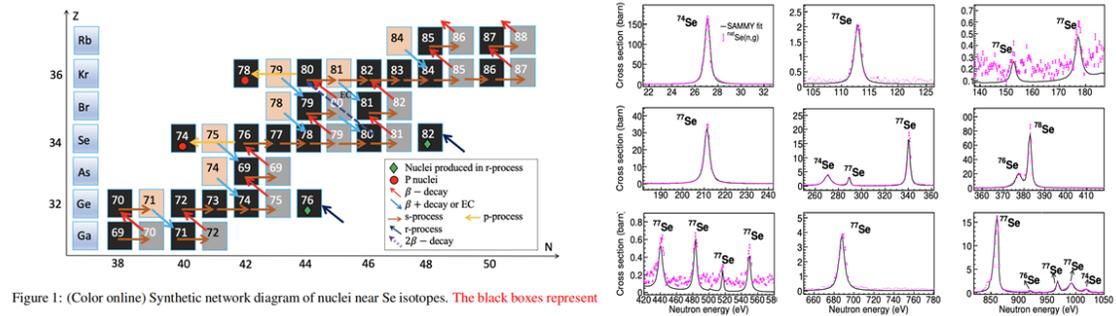
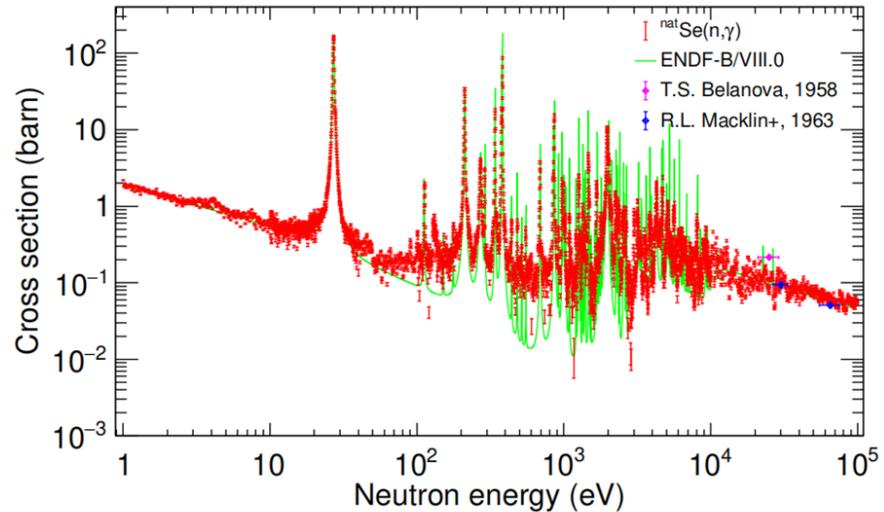
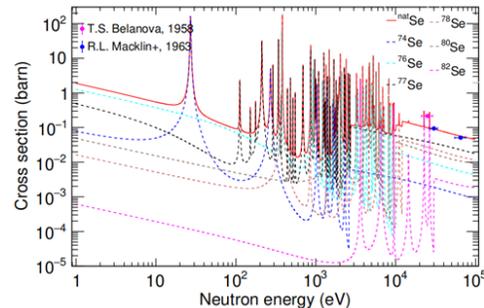
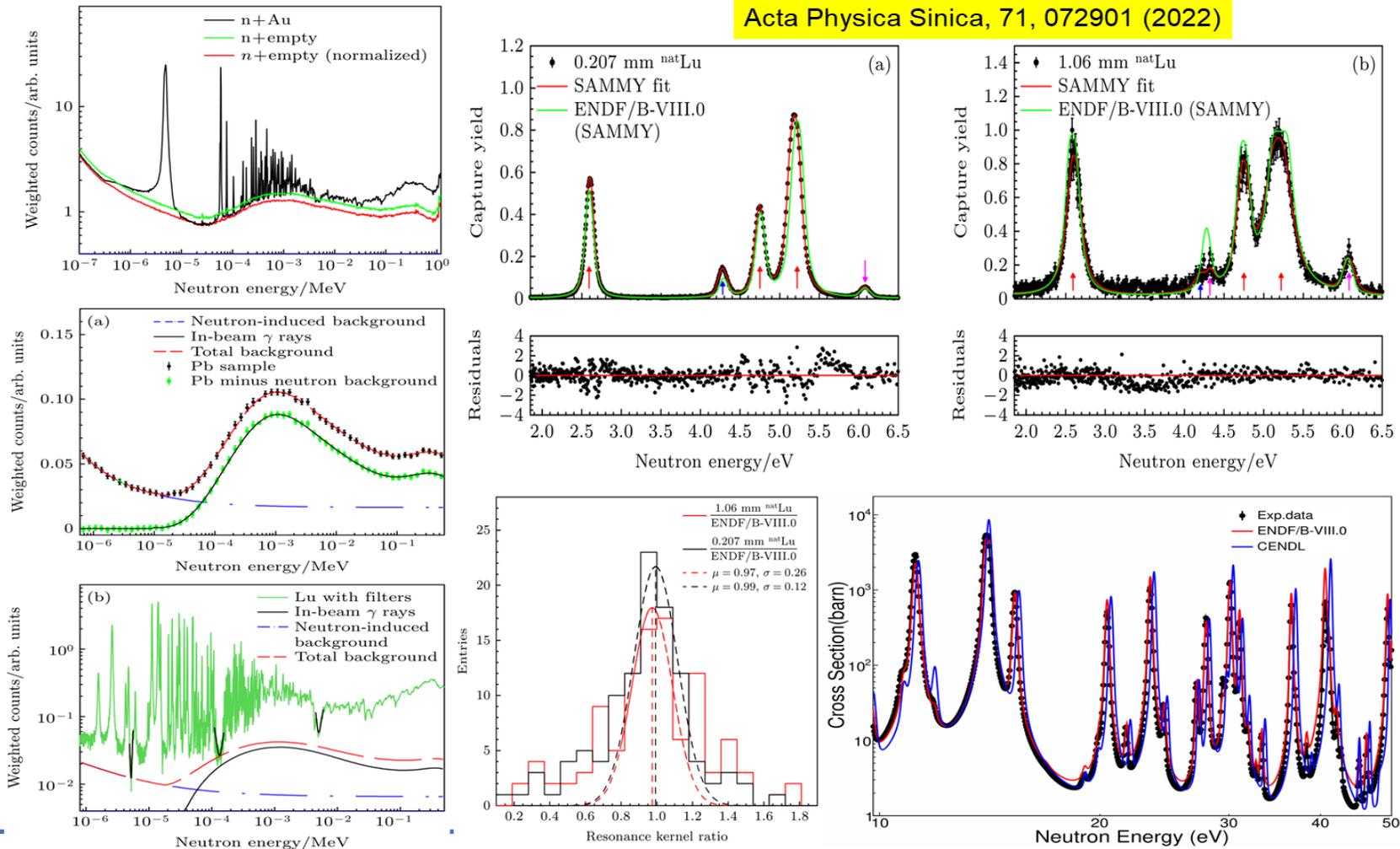


Figure 1: (Color online) Synthetic network diagram of nuclei near Se isotopes. The black boxes represent

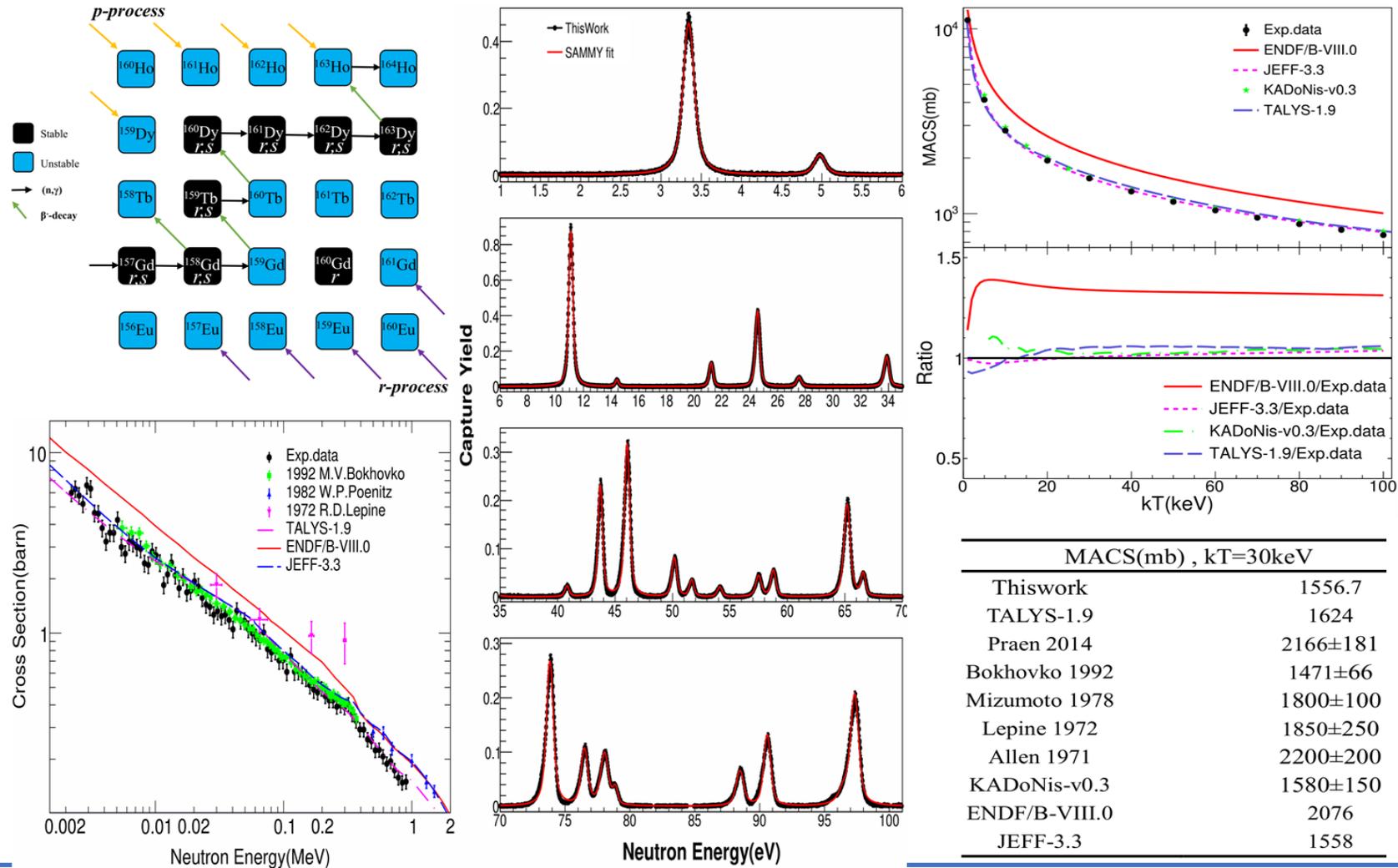
X.R. Hu et al., Accepted by Chin. Phys. B, 2022

## Neutron Capture Cross Section Measurement for $^{nat}\text{Lu}$ with different thickness at CSNS Back-n

Acta Physica Sinica, 71, 072901 (2022)



## Stellar neutron capture cross sections on $^{159}\text{Tb}$ at CSNS Back-n

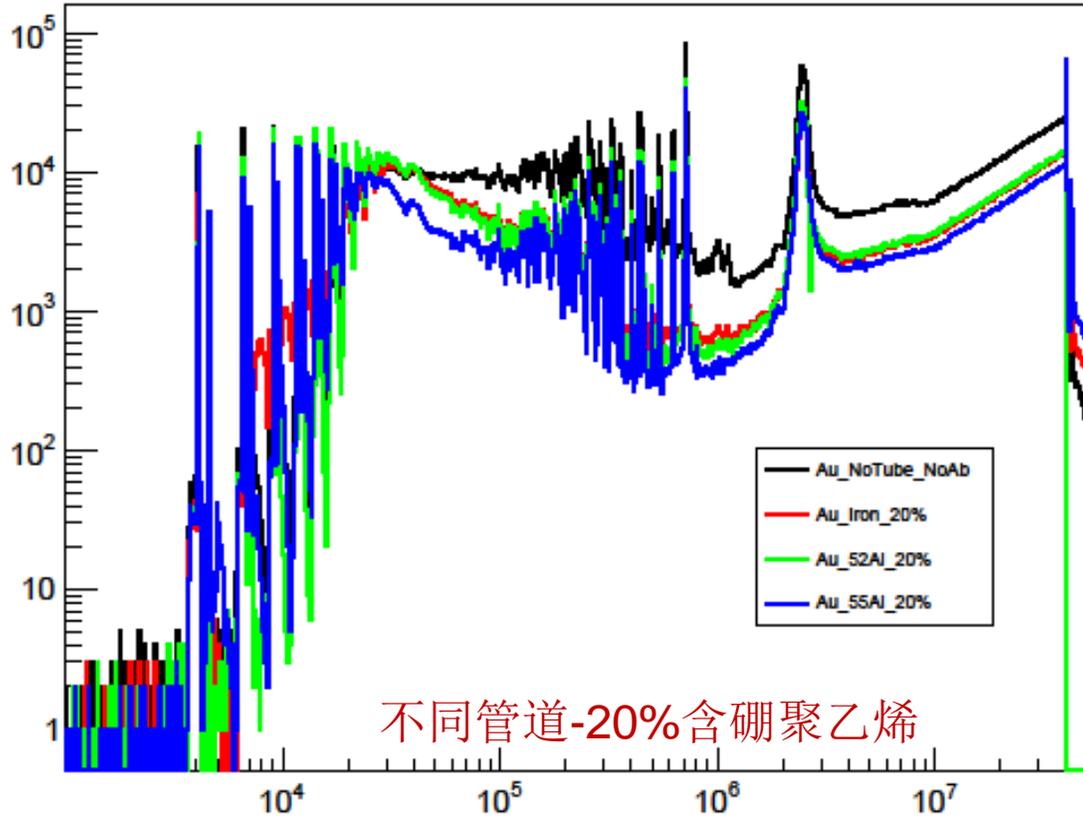


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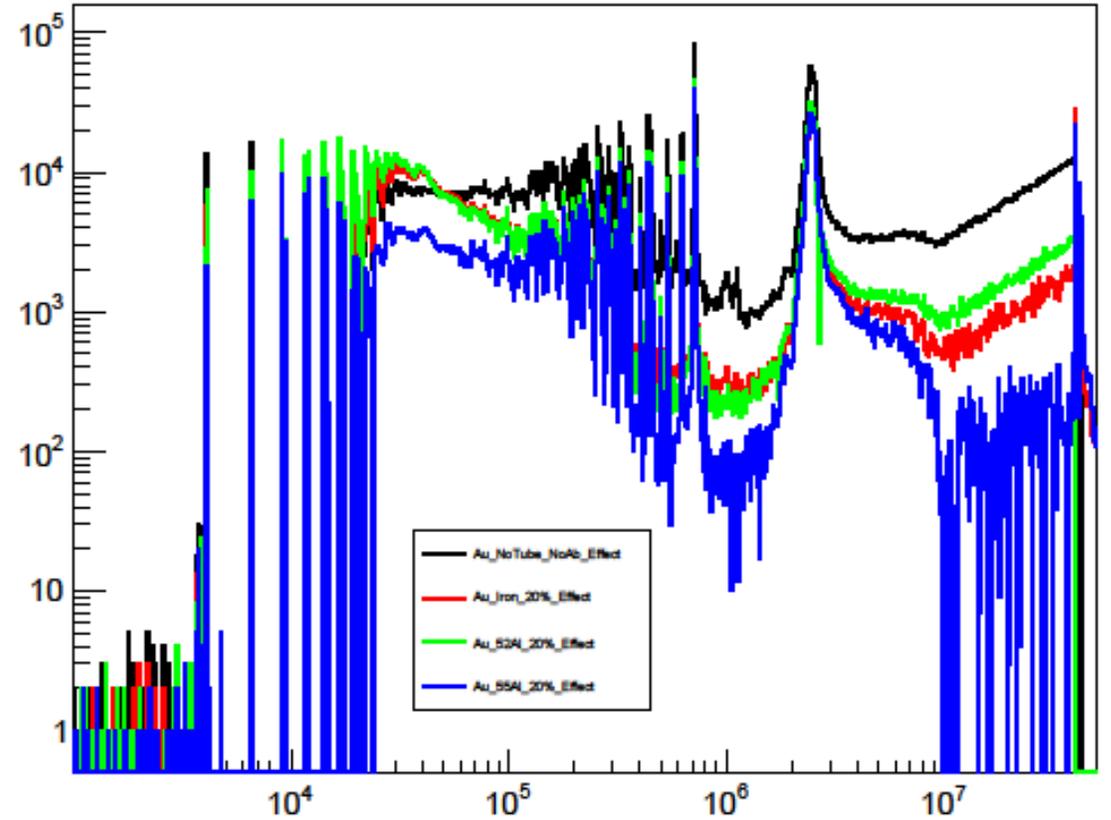
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	2月	3月	4月	5月	6月	7月	8月	9月	10月	11月	12月
2019						台架就位	探测器安装测试	内部实验：在束调试			第一次物理实验
2020					第二次物理实验			开始ET-PMT性能研究			
2021			电子学联调、信号全采集测试、第三次物理实验		XIA-DAQ测试	高纯锗联合实验		真空管道及中子吸收体对比实验 (XIA)			
2022		第四次物理实验（管道吸收体）、Sn117截面及角分布测量、U、Th截面测量					今天				铼实验
2023						PMT更新、探测器维护		第五次物理实验……			

Tspectrum1



Tspectrum1



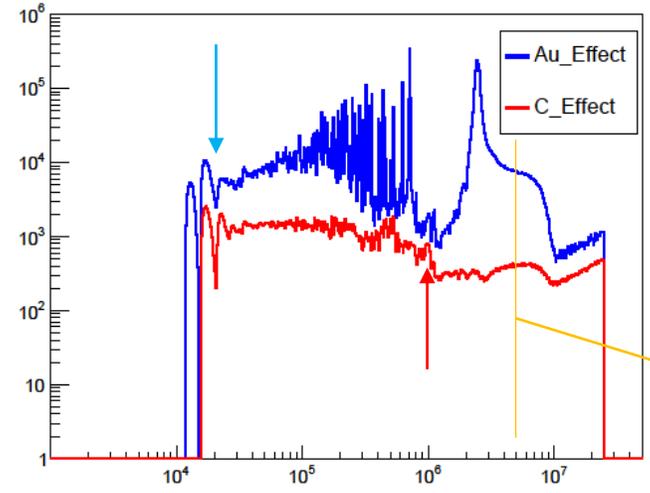
目前最佳的搭配:

真空管道: 外径55铝管  
吸收体: 20%含硼聚乙烯

效应比较

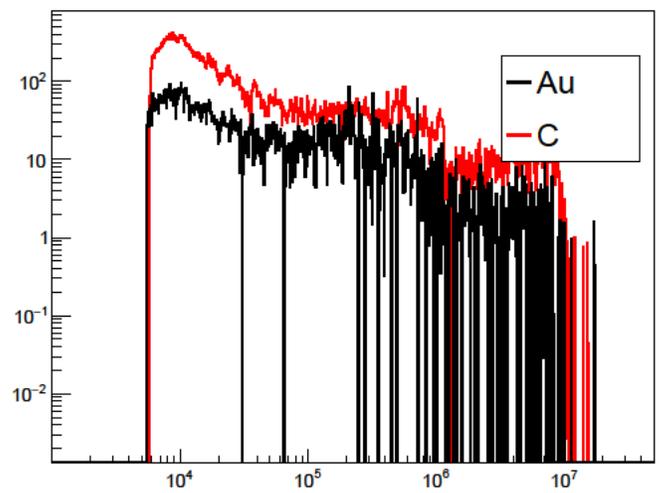
## 扣除空样品后Au、C的实验结果

Au\_TOF\_EnRange\_Mul2



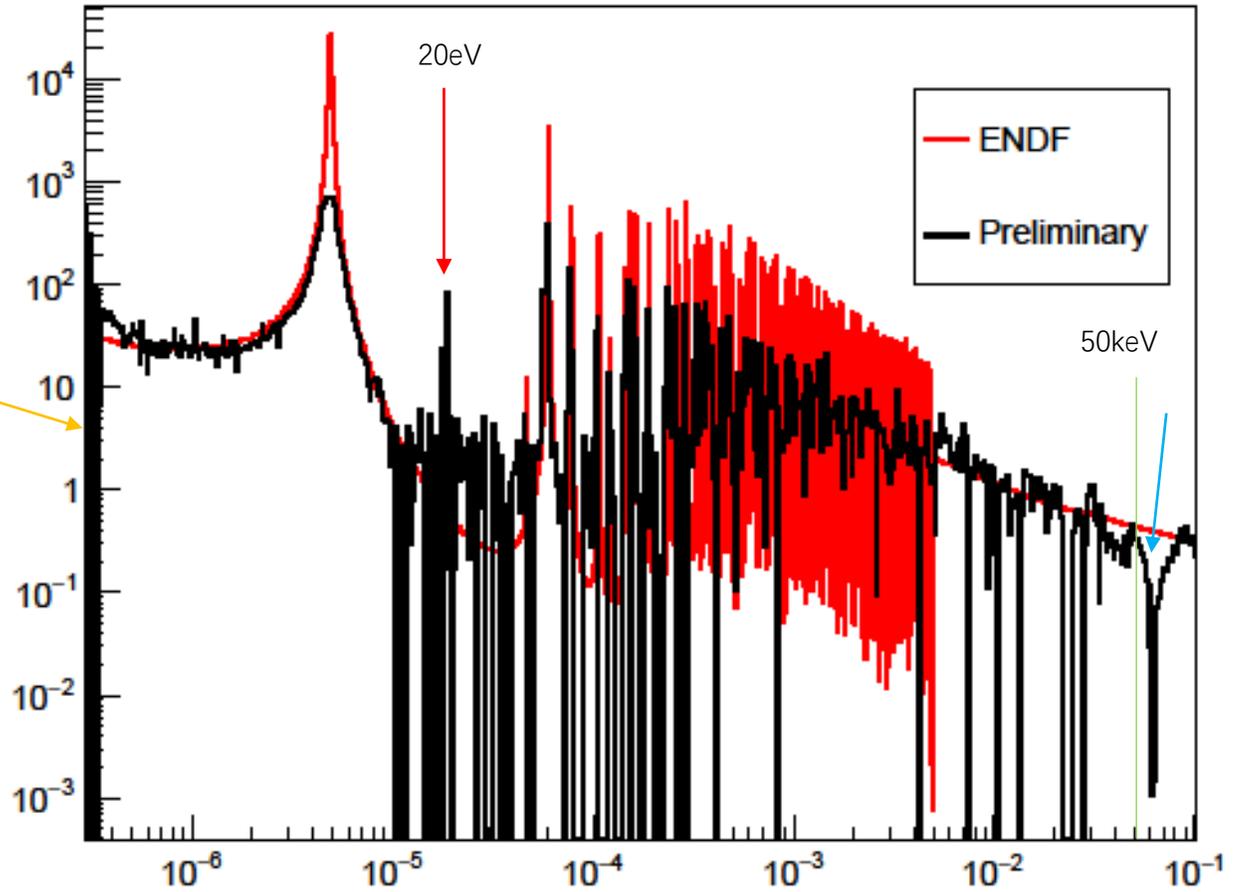
## Au扣除俘获反应后与C的模拟结果

C\_TOF\_EnRange\_Mul2



## 扣除散射中子本底后<sup>197</sup>Au (n,γ) 初步实验结果

EnergySum\_ENDF



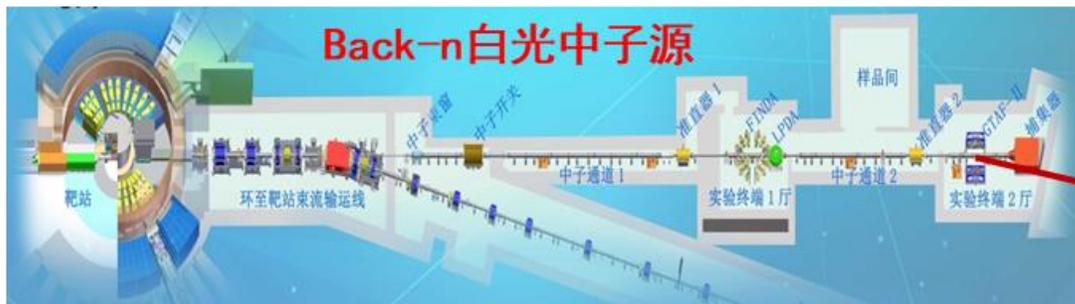
## 下一步工作重点:

- PMT的更新和探测器维护:
  - 2023年暑期停机期间完成
  - 完成后开展一批物理实验
- 裂变核中子辐射俘获截面测量
- 伽马出射角分布测量

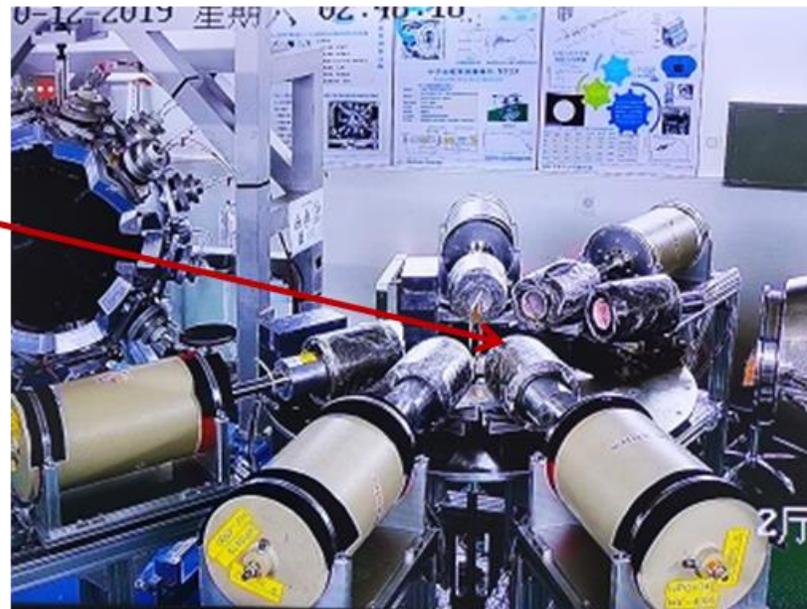
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## CSNS反角白光光源上的伽马谱学测量工作



2019年-2021年三年间已开展了核数据测量，核结构研究及核天体等方面的工作，摸索了实验条件，取得了一些实验数据，同时也面临了一些问题和困难。



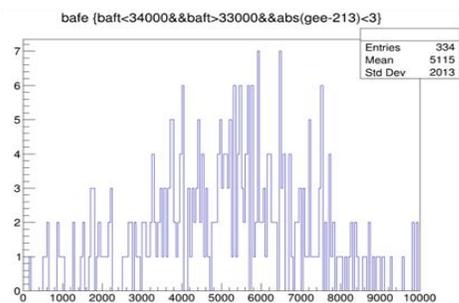
实验测量装置照片

## 同质异能素核能释放途径新技术方法研究

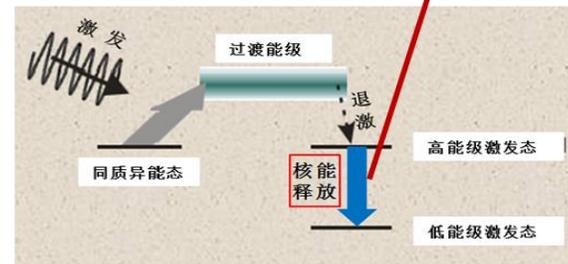
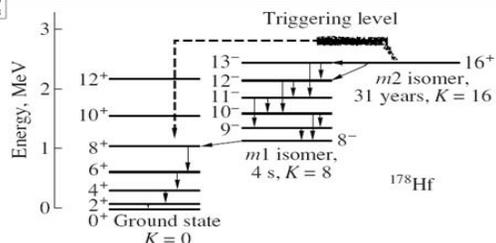
在中国散裂中子源的反角白光中子源上利用白光中子束流轰击钷靶，通过BaF2球 (GTAF) +HPGe联合实验测量探索同质异能态能量释放的新途径。通过对实验数据的分析发现了 $^{178}\text{Hf}$ 同质异能态受激能量释放的迹象，现正在进一步的分析验证中。



实验测量装置照片



实验测量得到的 $^{178}\text{Hf}$ 加和峰能谱



同质异能素核能释放途径示意图

谢谢