

核天体物理创新群体报告

柳卫平
2012年12月14日
北京香山饭店

无线网
名称：**E9830-b519**
密码：**00994265**

项目基本情况

- 题目：元素核合成中的关键科学问题研究
- 起止时间：2011年1月-2013年12月
- 项目号：11021504
- 项目组成员
- 原子能院：柳卫平，李志宏，王友宝，陈永寿，郭冰，连钢，白希祥
- 国家天文台：施建荣
- 兰州近物所：何建军
- 美国圣母大学：唐晓东

本次会议报告的安排

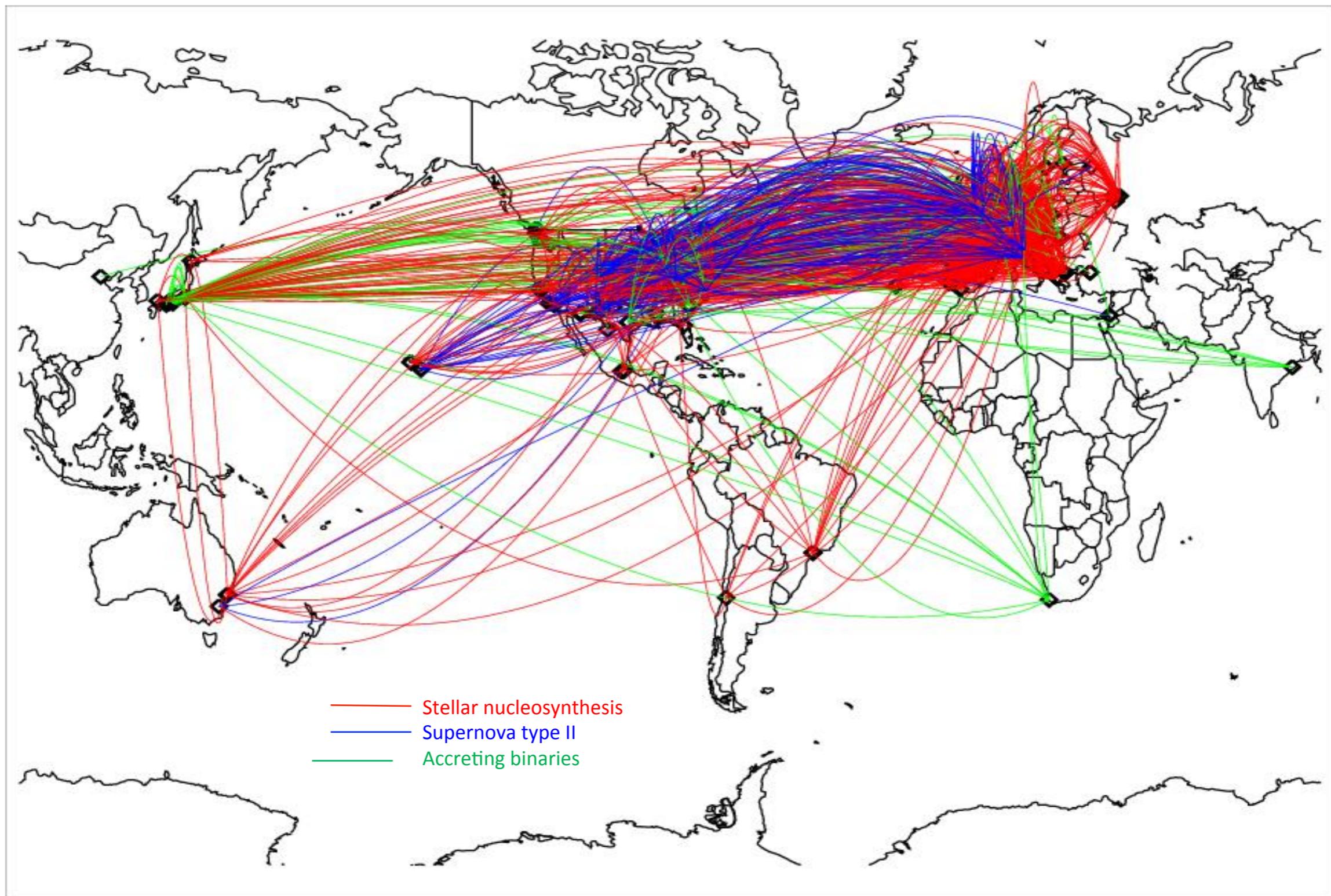
- 柳卫平，群体启动以来成果总结和进一步发展思考
- 李志宏，原初锂丰度研究进展
- 王友宝， **$^{22}\text{Na}+\text{a/p}$** 共振散射的实验研究
- 陈永寿，**Fifty years of the s-process**
- 施建荣，恒星中的重元素丰度分布
- 连 钢，超导螺线管谱仪
- 白希祥，恒星氦燃烧关键反应 $^{3}\text{a}-^{12}\text{C}$ 和 $^{16}\text{O}(\text{a},\text{g})^{12}\text{C}$ 的研究动态
- 唐晓东，中国核天体物理研究的憧憬和展望
- 胡 钧，近物所核天体物理研究进展
- 舒能川，核反应网络方程计算程序的界面开发和反应率的灵敏度计算
- 高早春，基于投影壳模型的谱因子理论进展
- 顾建中，**Tensor force effect on the structure of light nuclei**
- 郭 冰，氟丰度与第一代恒星演化研究进展
- 庞丹阳，**Towards a systematic nucleus-nucleus potential with a single-folding model**
- 第二天：对群体下步发展的讨论

报告内容提要

- 核天体物理的发展趋势
- 群体的研究计划回顾
- 群体的组织思路
- 群体研究进展
- 思考的问题

核天体物理的发展趋势

JINA网络



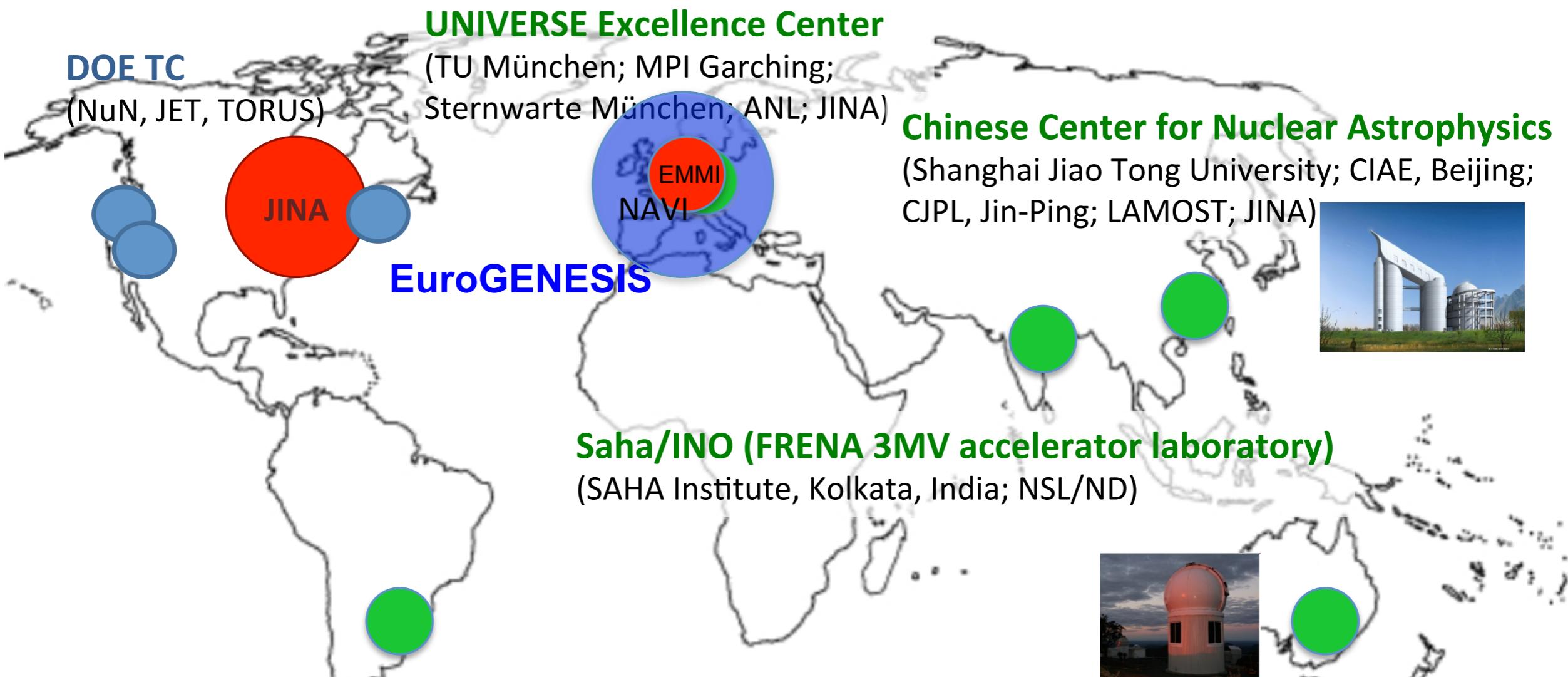
来自 Michael Wiescher

JINA concept with worldwide impact



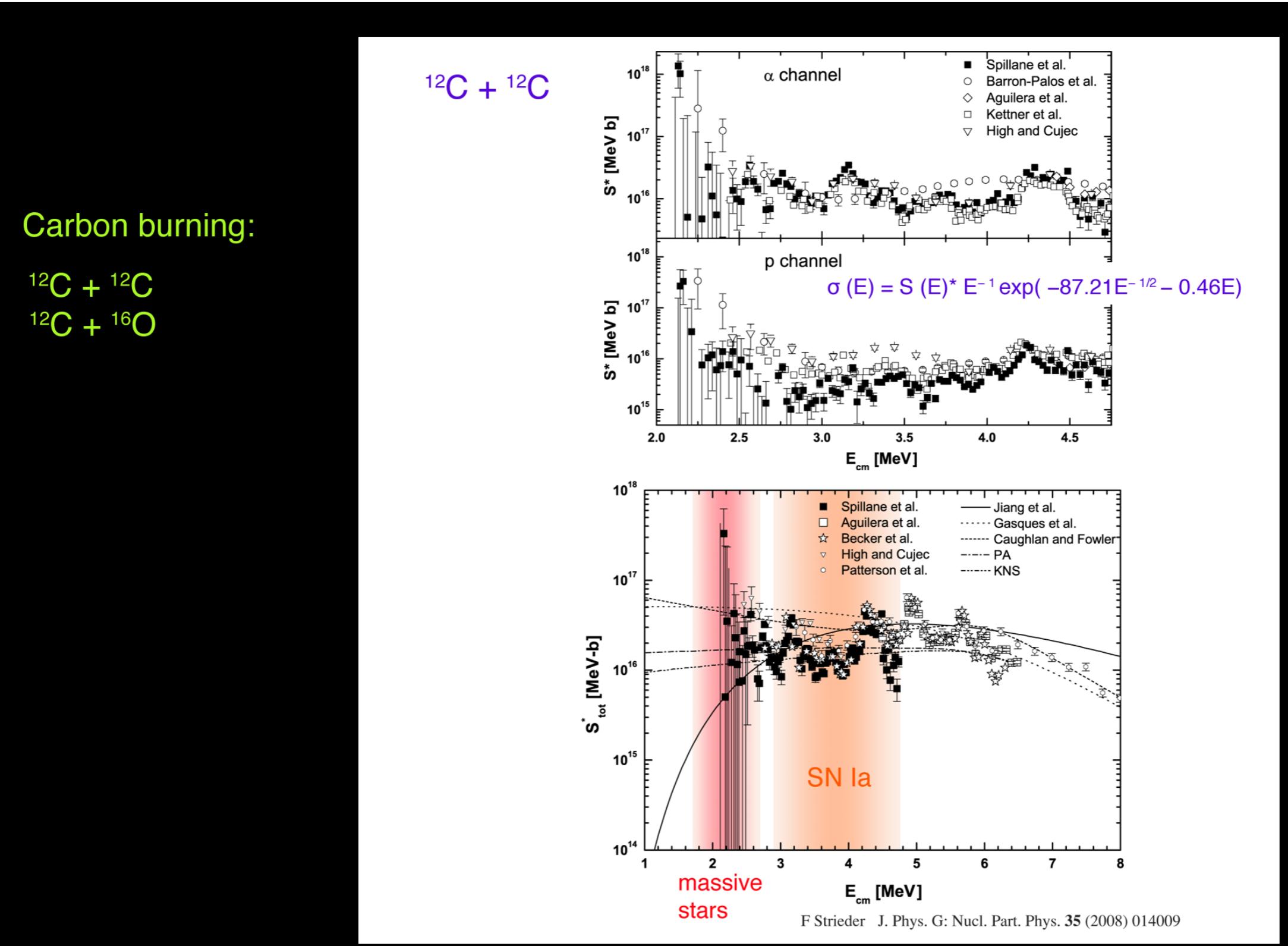
EMMI Helmholtz Alliance ; JINA founding member

(GSI, German; U. Tokyo, Japan; U. Paris, France; LBNL; JINA)



来自 Michael Wiescher

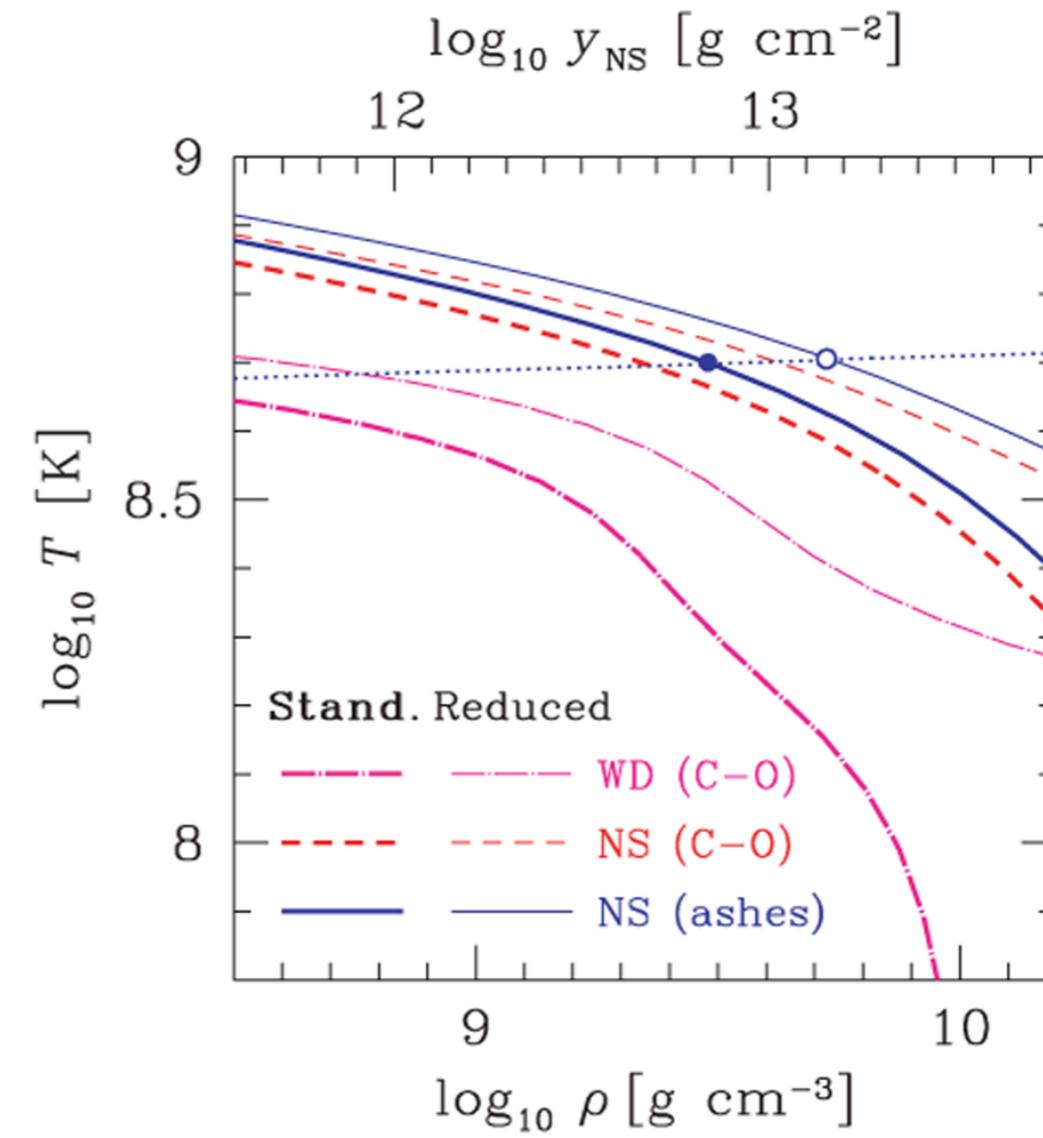
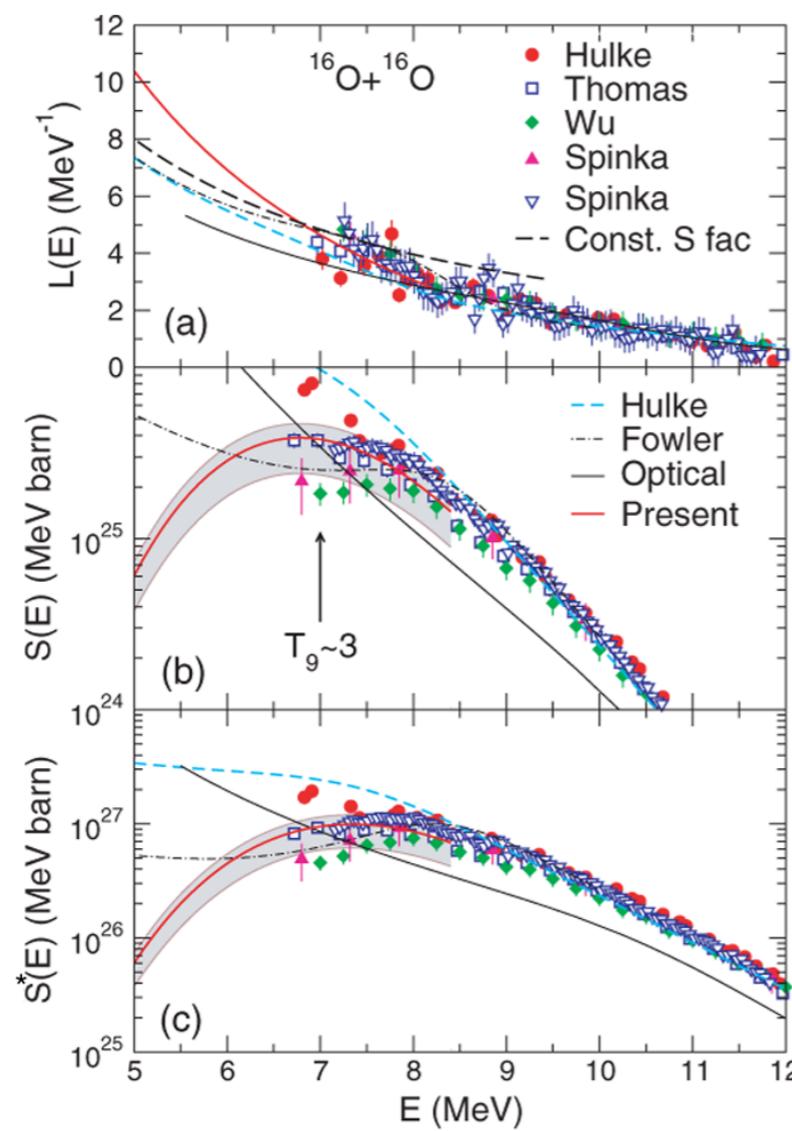
关键的核数据



来自 Champagne

外推的不确定性

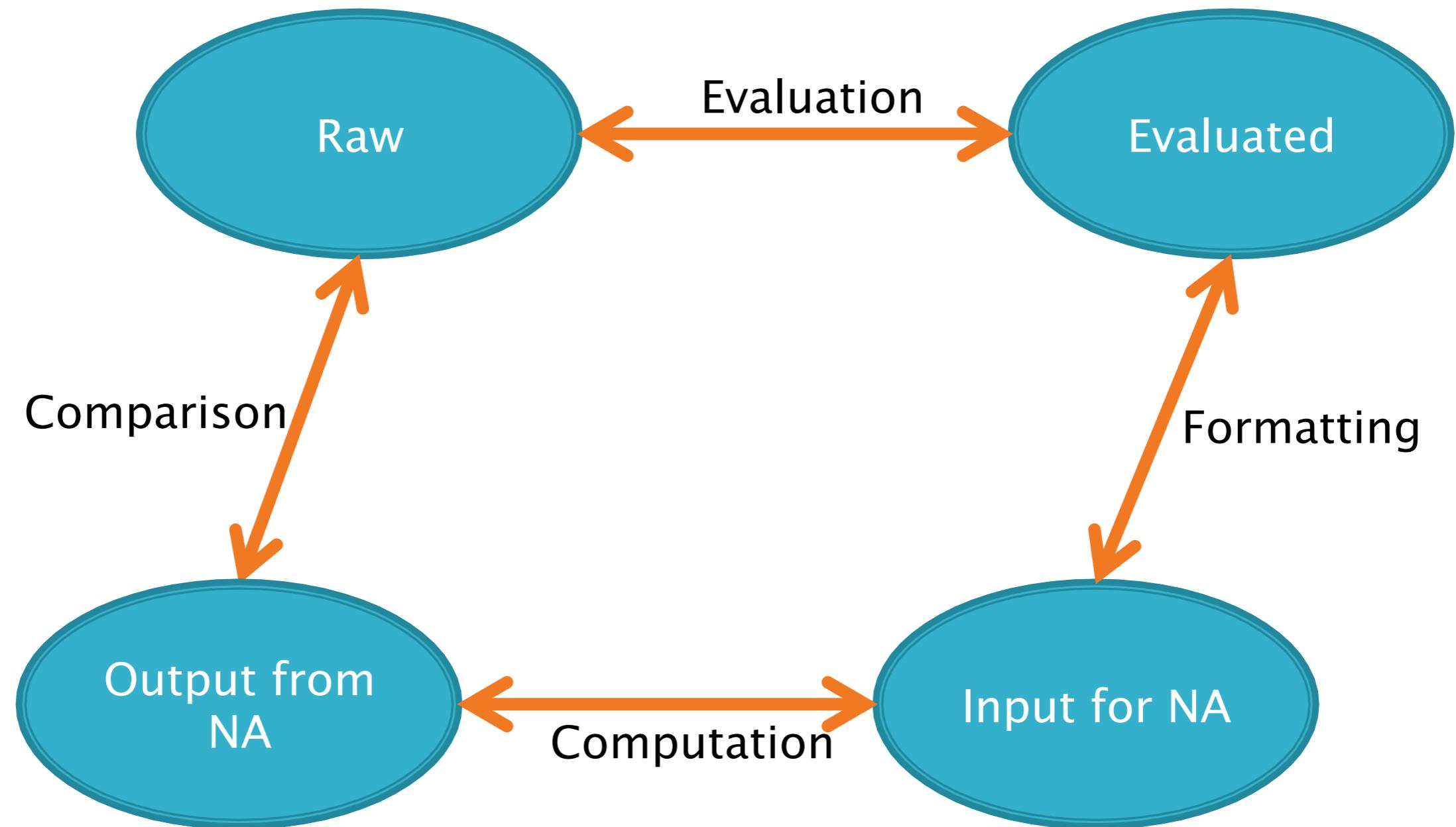
from C.L. Jiang, Phys. Rev. C75, 015803 (2007)



L.R. Gasques et al., Phys. Rev. C 76, 035802 (2007)

来自 Champagne

数据的重要性



来自 **Richard H. Cyburt**

理论、间接和直接测量

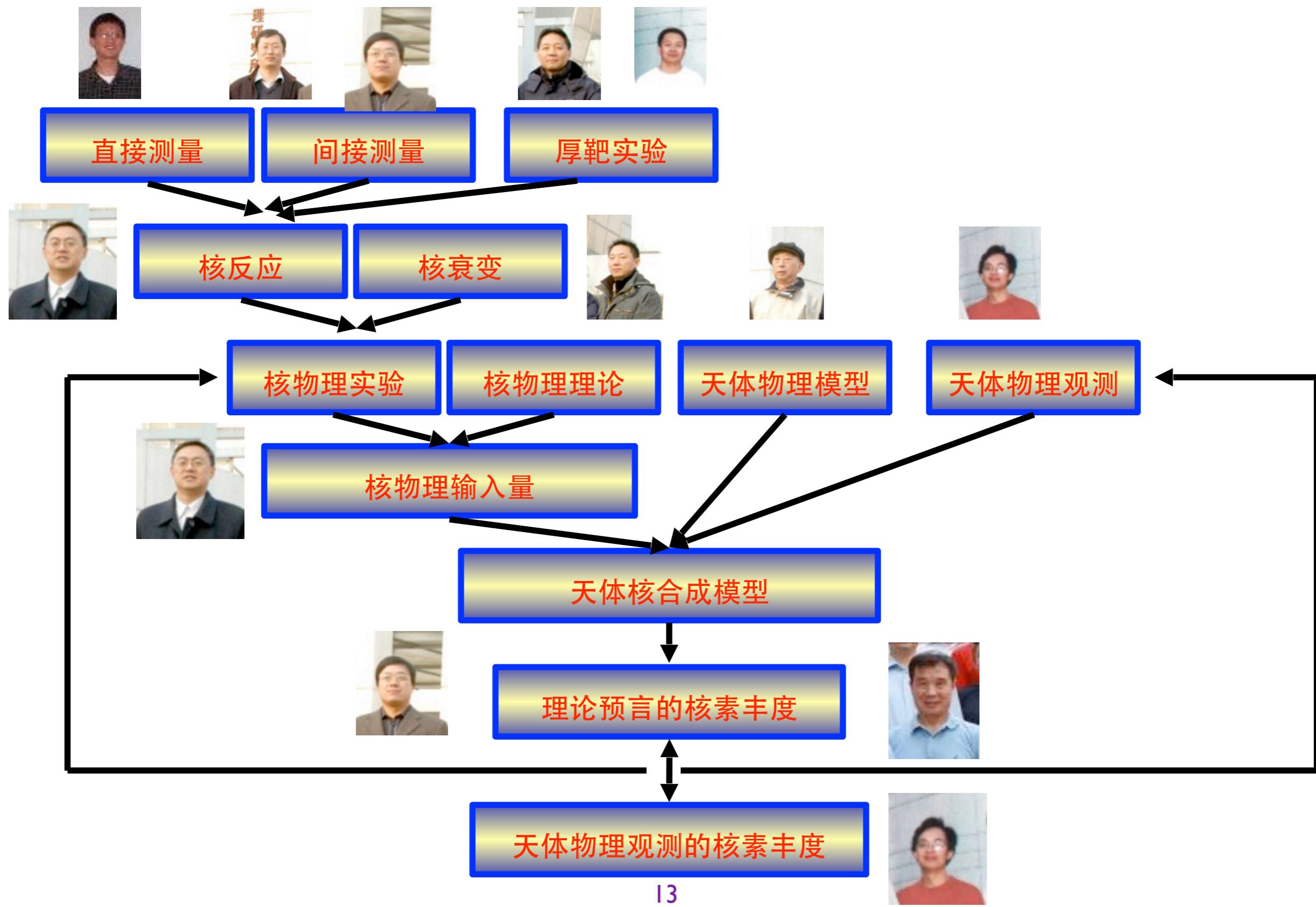
- Individual nuclear reaction rates matter for explosive H/He burning
- • We need theory to identify the most important rates → Nuclear theory
- → Astrophysical models
- → Sensitivity studies
- → But be skeptical – recognize the assumptions
- • Indirect studies are crucial
- → E_r and J^π are most important properties
- → We should learn as much as we can through indirect studies → What is impact of simultaneous loss of Yale and HRIBF?
- → Can others (TUNL/ND) fill need? Beam energy is an issue
- • We should directly measure the most important cross sections → Direct measurements are possible with modest beam intensities
- → 10^6 for (α, p)
- → 10^8 for (p, γ) → Few successes thus far
- • We need a variety of radioactive ion beams
- → FRIB is the only opportunity to make transformational change
- • SECAR needed for measurements of capture reactions at FRIB/ReA3

来自J. C. Blackmon

群体针对的

- 恒星平稳演化阶段最重要的热核反应在天体物理能区的直接测量，国际合作，美国合作实验
- 高能区带电粒子反应截面向天体物理能区的合理外推，国际合作
- 若干关键的平稳核燃烧阶段和爆发性rp及r过程核反应截面的间接测量，国内为主，原子能院实验完成
- rp和r过程涉及核素衰变性质、质量、反应和共振态性质的测量，兰州起步，实验完成
- 核天体物理反应和衰变性质的理论研究、数据库和网络方程的建立，国内为主
- 通过关键数据输入网络计算，结合元素丰度的观测研究天体核合成的场所，结合国台

学科交叉和群体研究分工



研究工作的展开思路

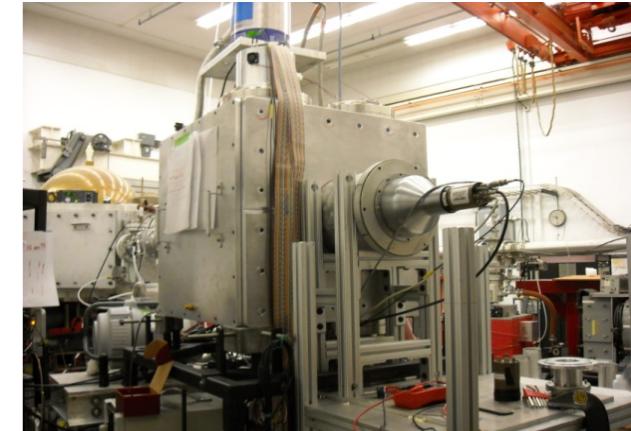
- 开展直接测量，检验和澄清间接测量的分歧
- 在**TRIUMF**实验室开展 (p,γ) 反应直接测量，澄清理论和实验分歧， ^{33}S 数据处理完成；将融合反应截面的测量向下扩展，检验**Hindrance**低能外推模型，在**UND**开展
- 通过间接测量确定关键核天体物理反应数据
- 利用渐近归一化常数和核谱因子方法，在原子能院和日本理化所开展恒星平稳燃烧轻核区 (p,γ) 和 (n,γ) 反应间接测量， $^{13}C(a,n)^{16}O$
- 开展不稳定核束的共振弹性散射研究，得出核天体物理感兴趣的激发态共振参数， ^{22}Na
- 开展核素的衰变性质测量
- 在兰州近物所开展快速质子俘获rp过程核素衰变测量，得出系统性的衰变半衰期和**GT**强度分布数据，对壳模型理论计算进行刻度， ^{53}Ni 等
- 实验与理论相结合，将反应和衰变数据带入网络计算，与天文观测数据相比较，研究元素核合成的天体场所
- 将以上得到的反应和衰变数据输入核天体物理数据库，利用网络方程对元素丰度进行预言，研究元素核合成的天体场所，rp过程的计算

I、恒星平稳演化阶段最重要的热核反应在天体物

- $^{11}\text{C}(\text{p},\gamma)^{12}\text{N}$, CIAE-TRIUMF-, 高温pp链中重要反应，间接测量的S-因子不确定度很大，无共振数据；本实验将直接测量 2^+ 共振态，任国际合作实验发言人，11月28日视频会报告，预计明年开展实验
- $^{33}\text{S}(\text{p},\gamma)^{34}\text{Cl}$, Yale-TRIUMF-CIAE, 解释观测新星中 ^{33}S 过丰现象，反应率只有高能量数据，不确定度对丰度影响很大（两个量级），本实验直接测量100-400keV范围，实验数据处理完毕，文章准备中
- 计划使用美国圣母大学新建的低能强流离子加速器，将融合反应截面的测量向下扩展，开展 $^{12}\text{C}+^{12}\text{C}$ 、 $^{12}\text{C}+^{16}\text{O}$ 和 $^{16}\text{O}+^{16}\text{O}$ 反应的直接测量，检验最新提出的Hindrance低能外推模型，我组李云居派出6个月，参加唐晓东组实验
- 围绕锂丰度问题，利用国际合作，在已有实验基础上，开展系统研究，李志宏在NIC和中日核物理会上报告

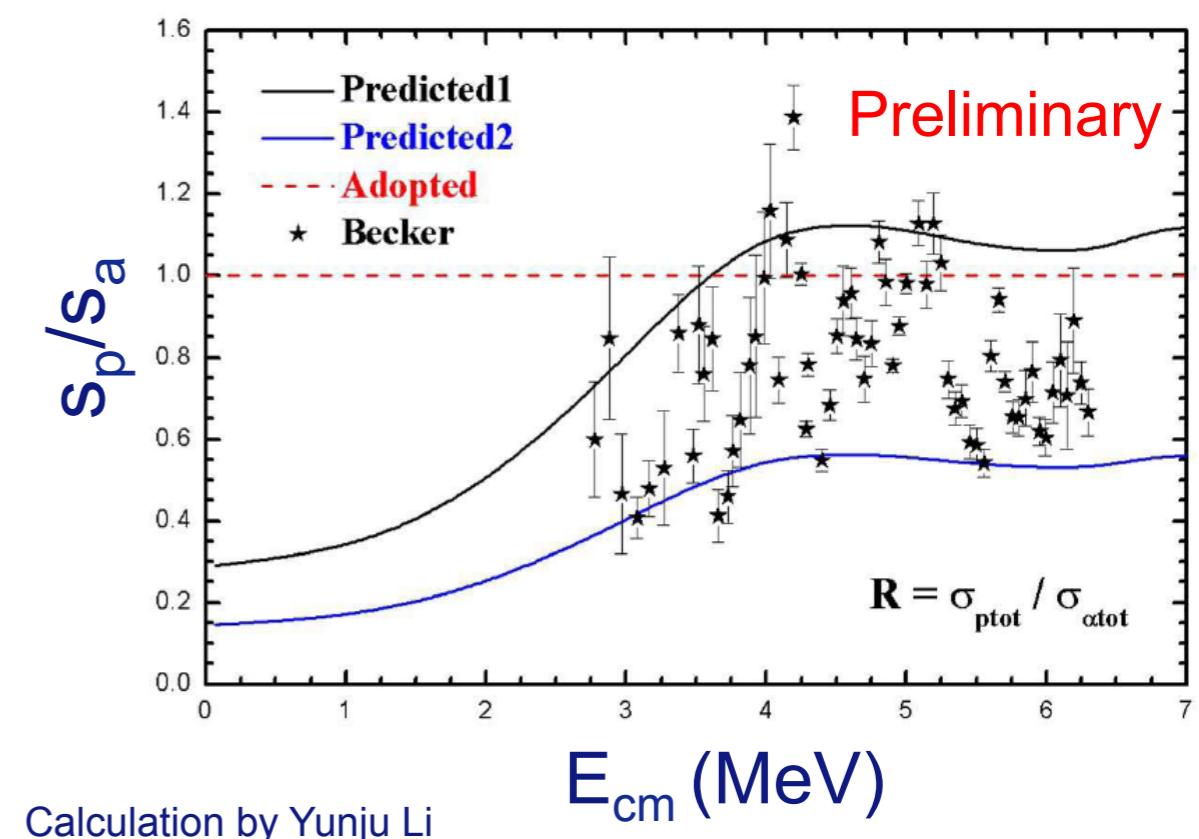
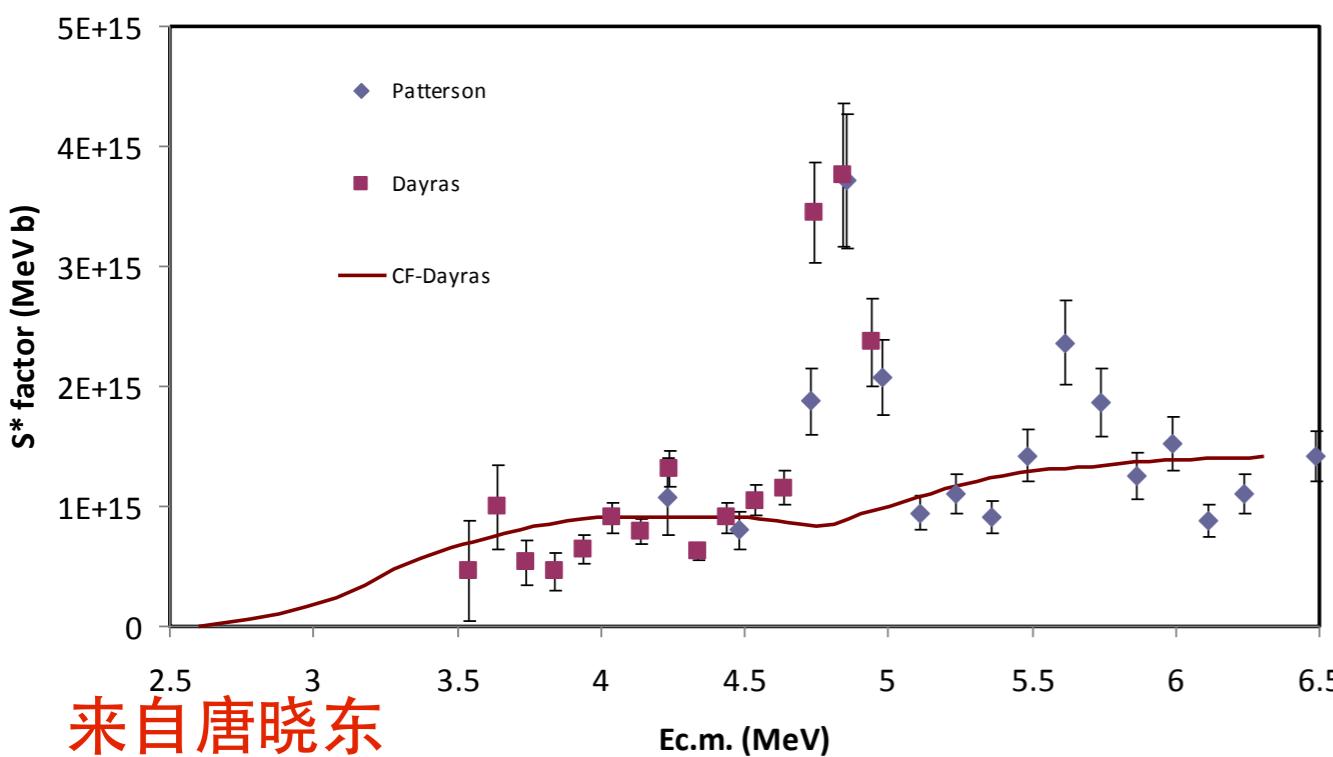
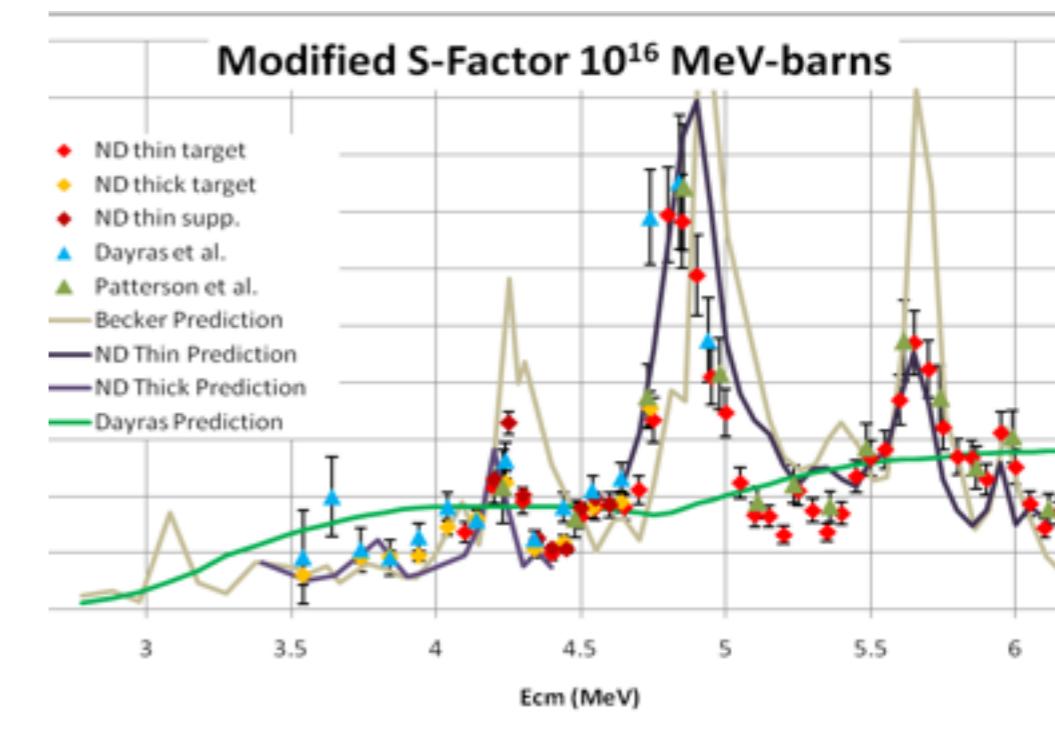
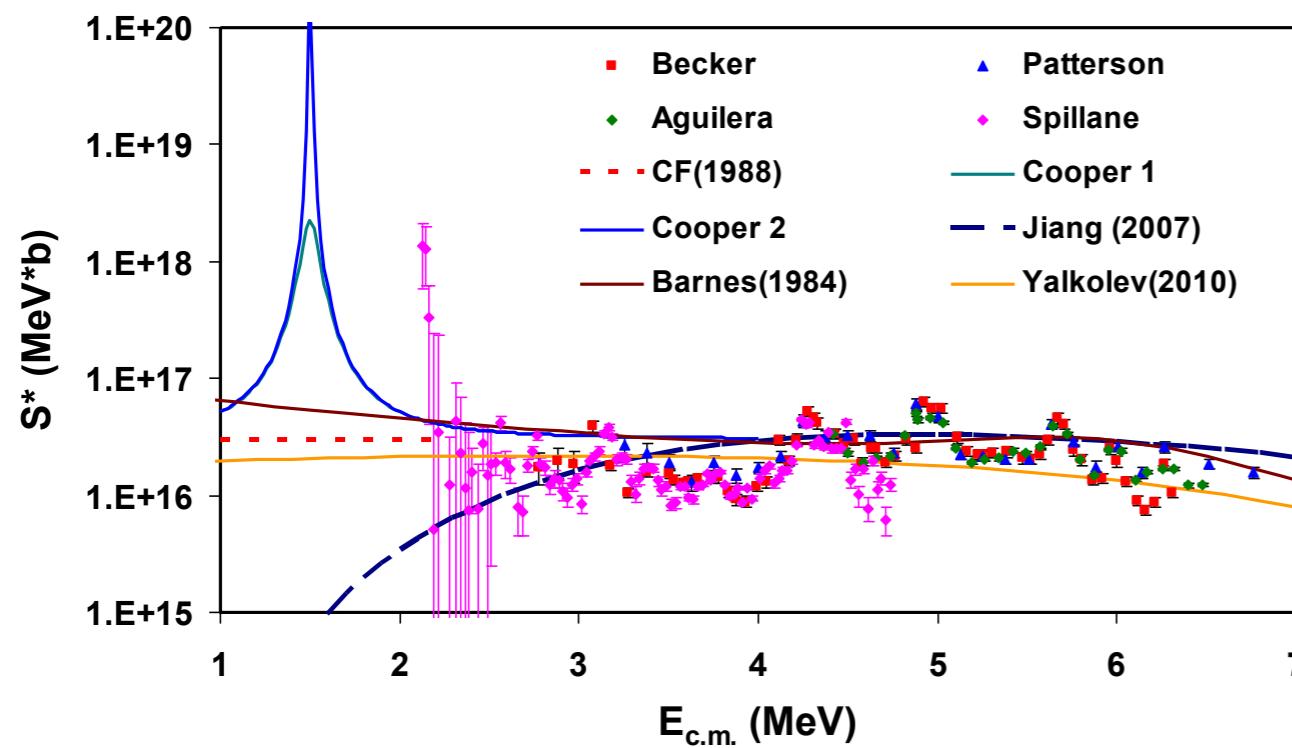
在UND的研究计划

- 利用带电粒子探测器阵列，将重离子熔合反应能量推向平稳核燃烧的窗口
- 实验分两阶段进行
- 建立带电粒子探测器阵列并在美国圣母大学串列上检测，同时开展聚变系统的系统研究
- 利用新建**5 MV**强流加速器将测量能量推向更低。该加速器在**2011**年底建成，同时从理论上发展可靠的低能外推模型

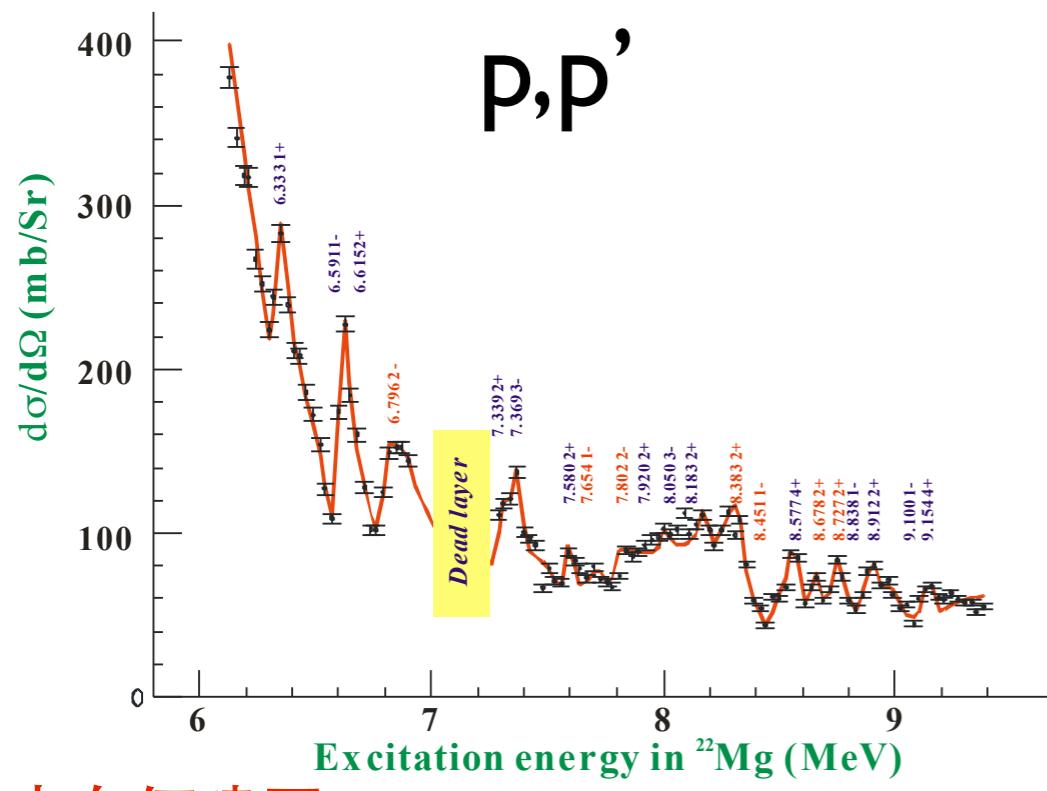
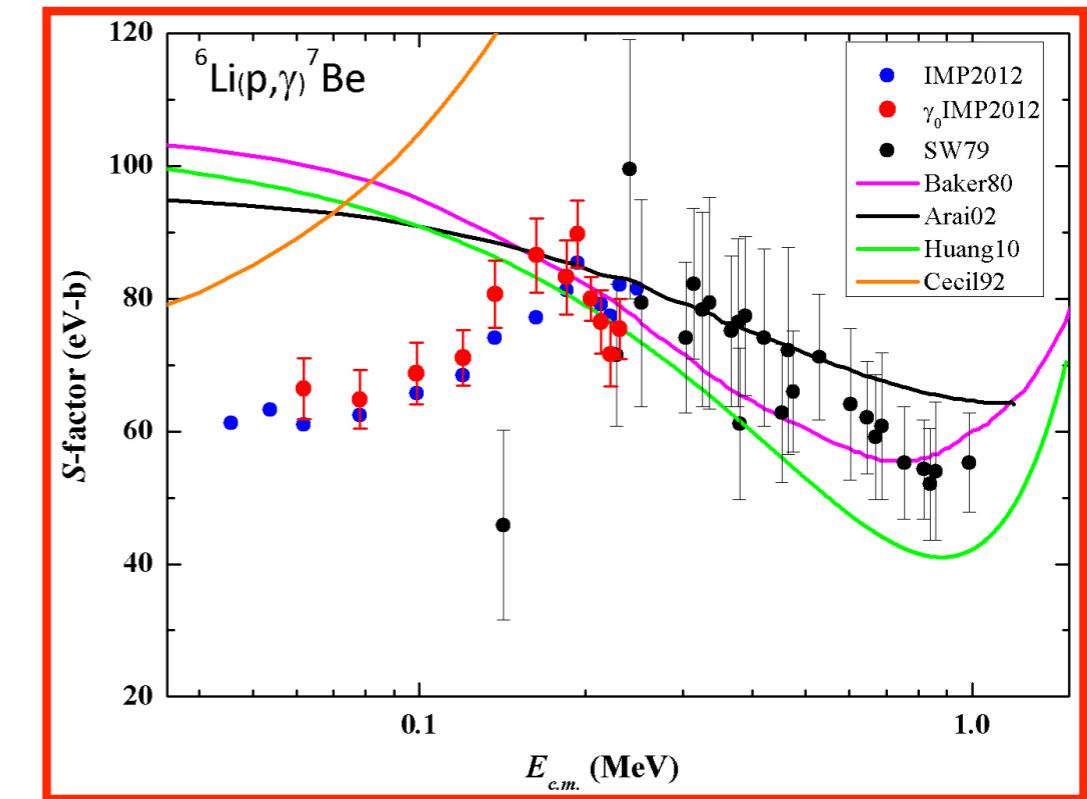


来自唐晓东

阶段研究成果

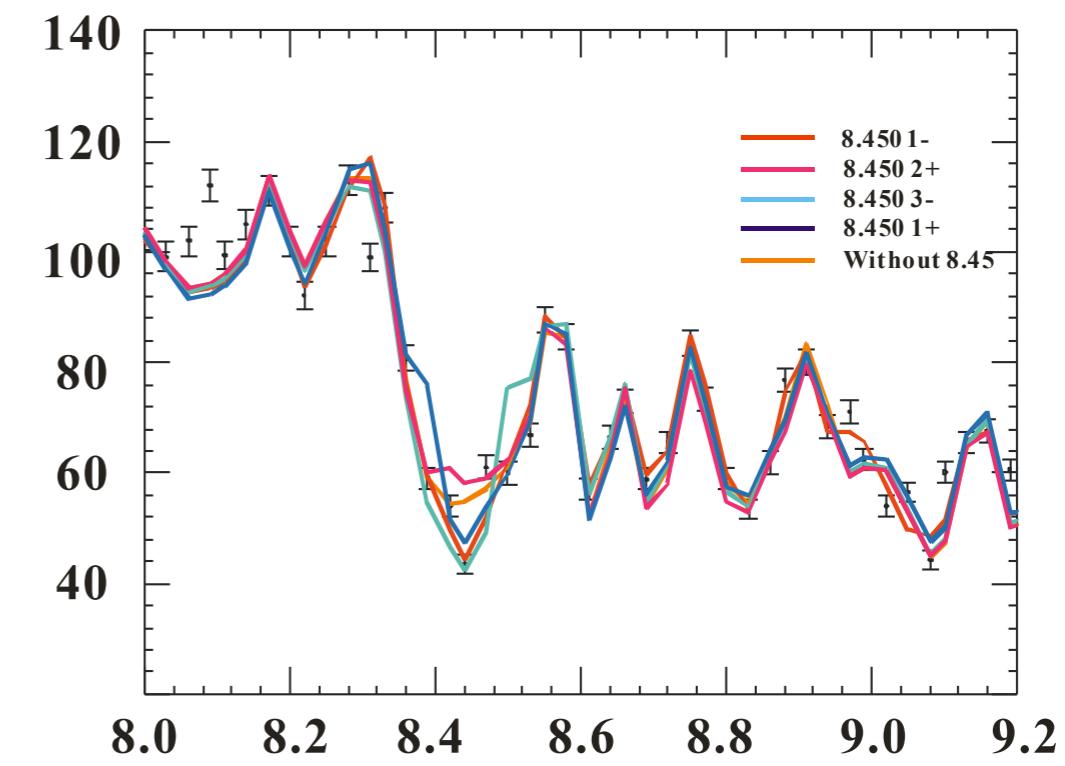


近物所的进展

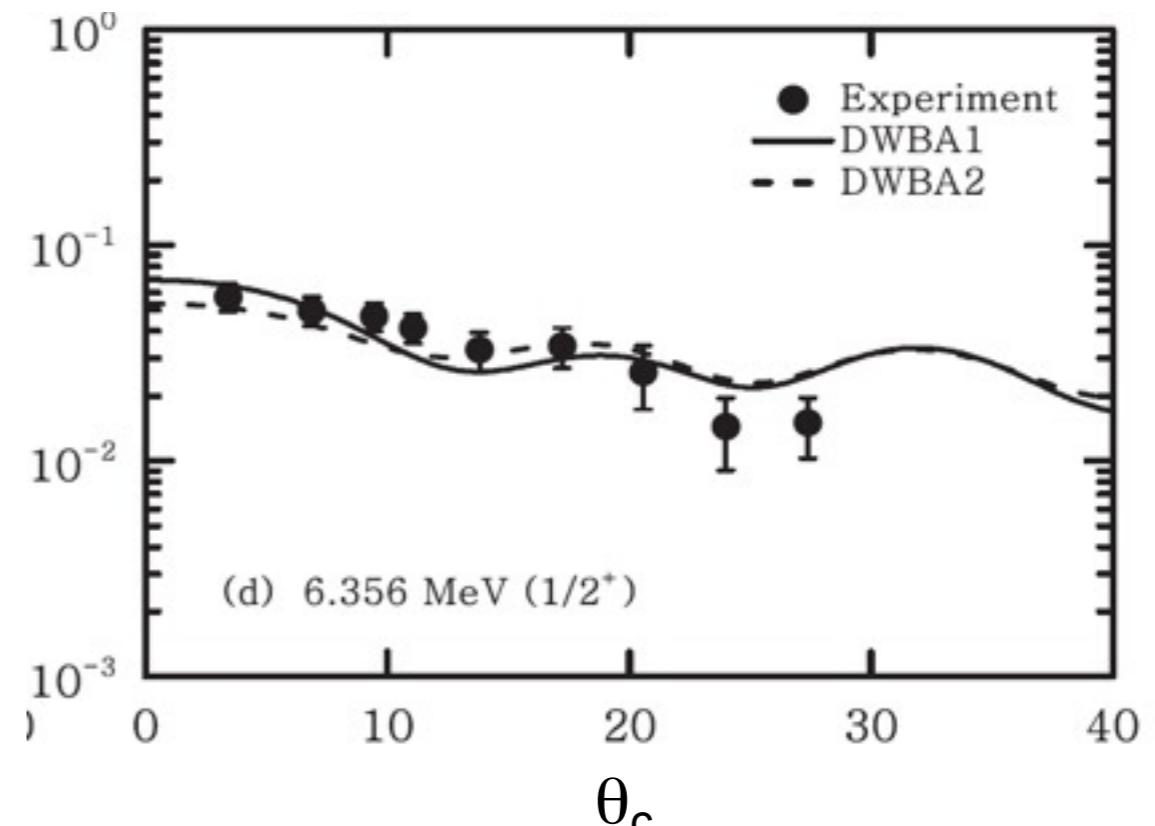
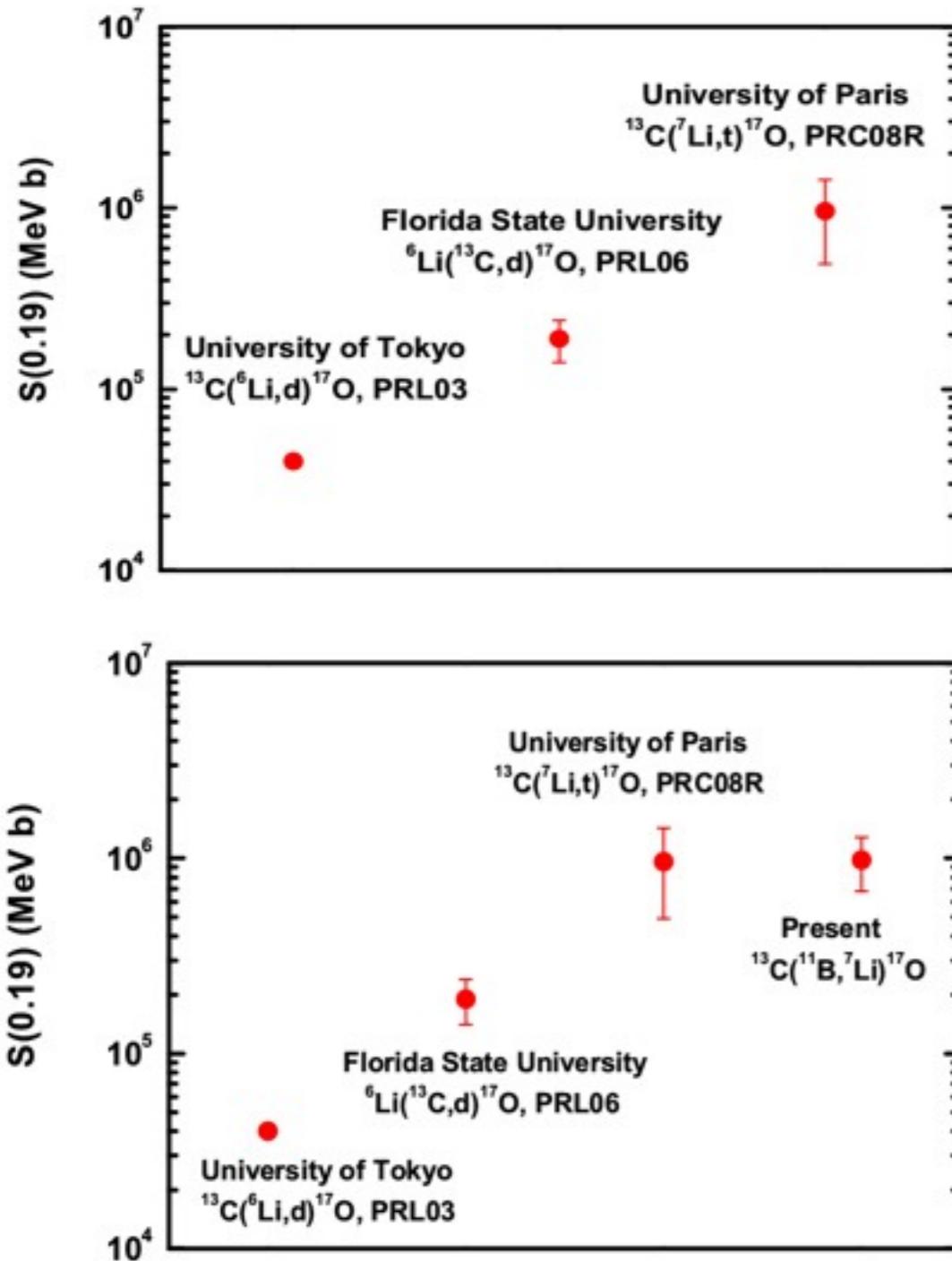


来自何建军

18



$^{13}\text{C}(\alpha, n)^{16}\text{O}$



THE ASTROPHYSICAL JOURNAL, 756:19 (10pp), 2012 September 10
© 2012. The American Astronomical Society. All rights reserved. Printed in the USA.

doi:10.1088/0004-637X/756/2/19

NEW DETERMINATION OF THE $^{13}\text{C}(\alpha, n)^{16}\text{O}$ REACTION RATE AND ITS INFLUENCE ON THE s -PROCESS NUCLEOSYNTHESIS IN AGB STARS

B. Gao (郭冰)¹, Z. H. Lu (李志宏)², M. LUGARO³, J. BUNIAN², D. Y. PANG (庞丹阳)^{3,4}, Y. J. LI (李云洁)¹, J. SU (苏俊)¹, S. Q. YAN (颜胜权)¹, X. X. BU (白希祥)⁵, Y. S. CHEN (陈永寿)¹, Q. W. FAN (樊启文)¹, S. J. JIN (金孙均)¹, A. I. KARAKAS⁴, E. T. LU (李二涛)¹, Z. C. LI (李志常)¹, G. LIAN (连钢)¹, J. C. LU (刘建成)¹, X. LIU (刘鑫)¹, J. R. SHI (施建荣)¹, N. C. SHU (舒能川)¹, B. X. WANG (王宝祥)¹, Y. B. WANG (王友宝)¹, S. ZENG (曾波)¹, AND W. P. LIU (柳卫平)¹

¹ China Institute of Atomic Energy, P.O. Box 2751, Beijing 102413, China; wylu@ciac.ac.cn, probin@ciac.ac.cn

² Monash Centre for Astrophysics, Monash University, Clayton 3800, Victoria, Australia

³ School of Physics and State Key Laboratory of Nuclear Physics and Technology, Peking University, Beijing 100871, China

⁴ Research School of Astronomy & Astrophysics, Mount Stromlo Observatory, Weston Creek ACT 2611, Australia

⁵ National Astronomical Observatories, Chinese Academy of Science, Beijing 100012, China

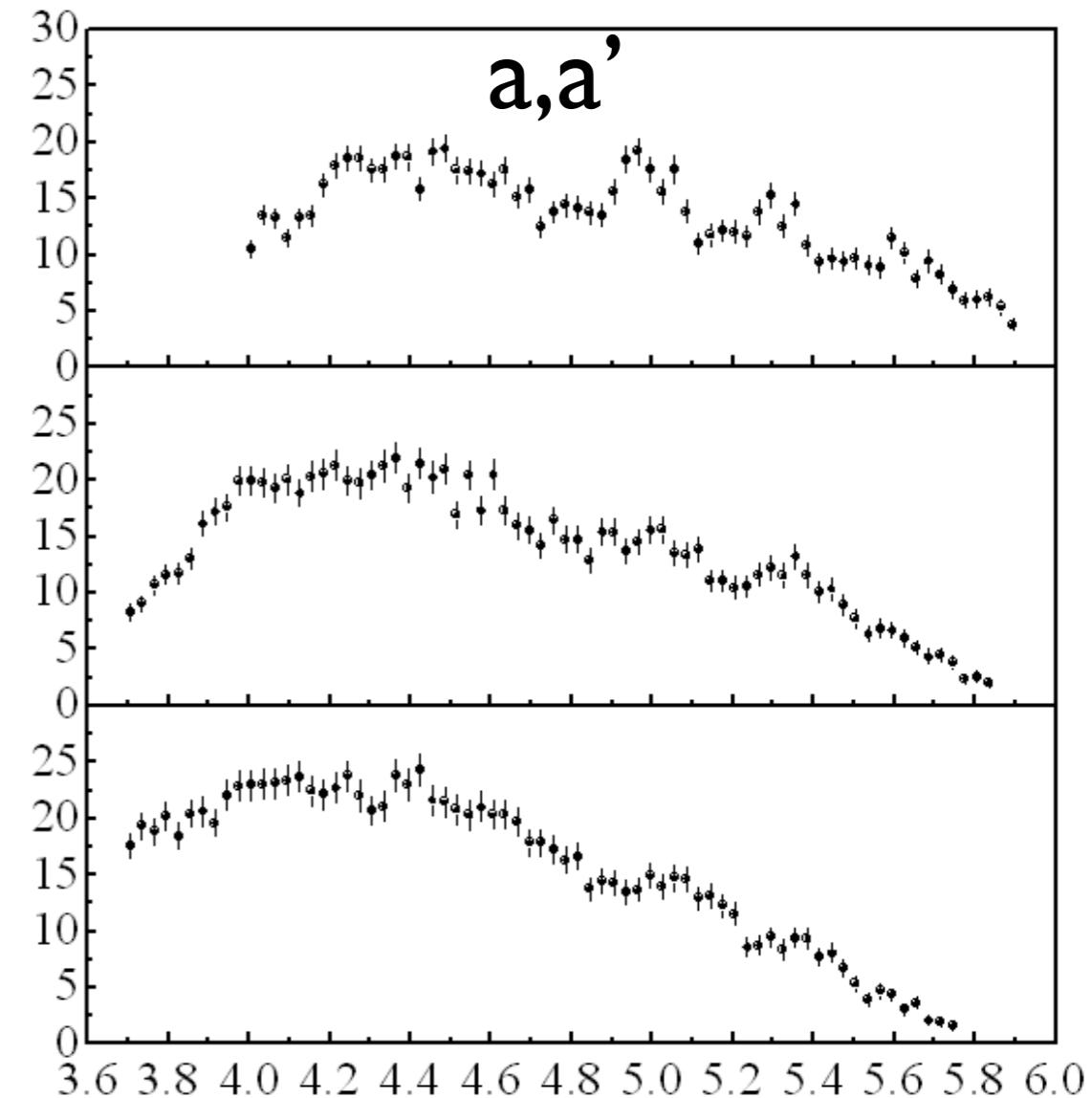
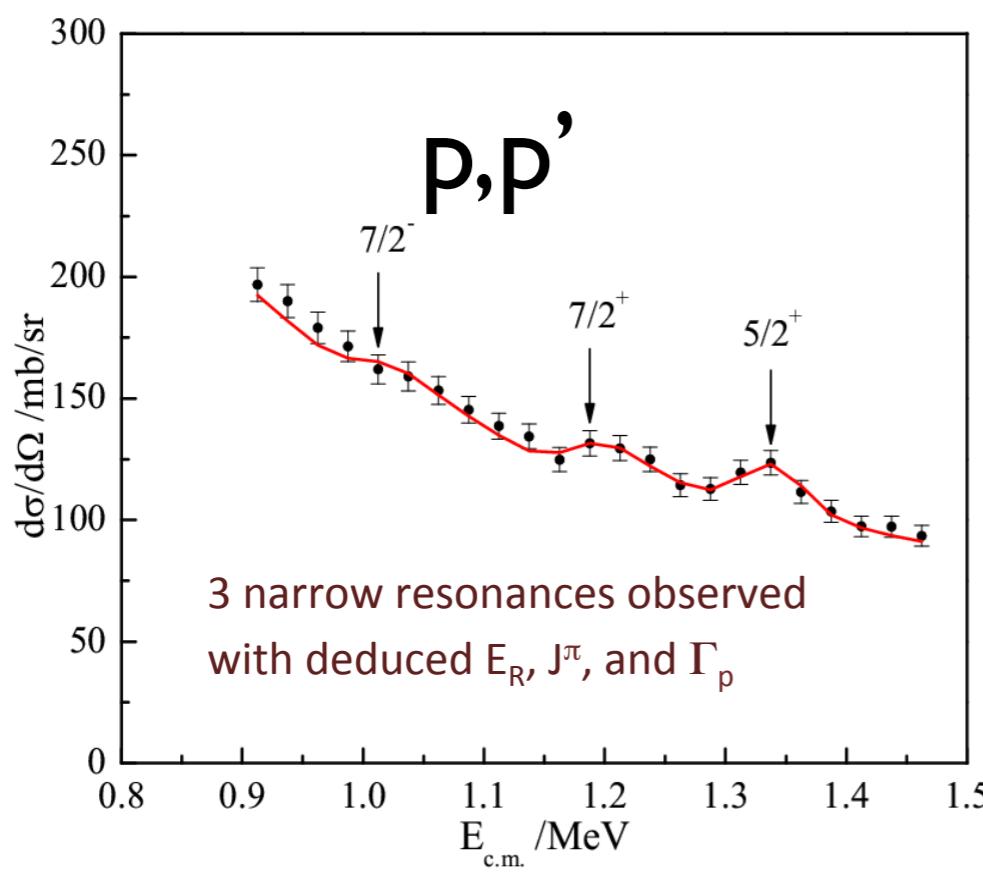
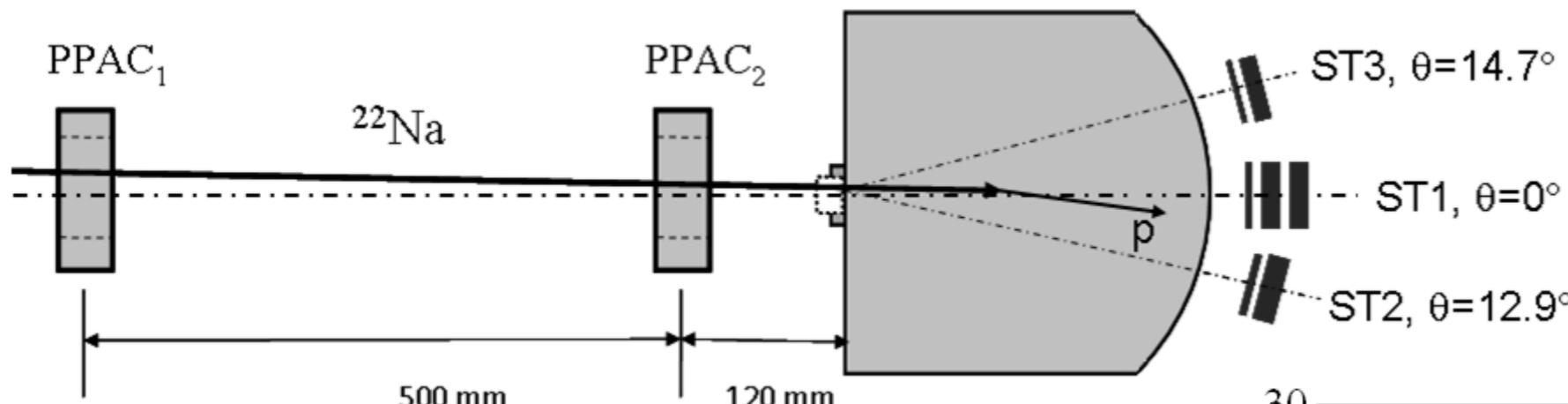
Received 2012 February 15; accepted 2012 July 18; published 2012 August 27

ABSTRACT

We present a new measurement of the α -spectroscopic factor (S_0) and the asymptotic normalization coefficient for the 6.356 MeV $1/2^+$ subthreshold state of ^{17}O through the $^{13}\text{C}(^{11}\text{B}, ^{7}\text{Li})^{17}\text{O}$ transfer reaction and we determine the α -width of this state. This is believed to have a strong effect on the rate of the $^{13}\text{C}(\alpha, n)^{16}\text{O}$ reaction, the main neutron source for slow neutron captures (the s -process) in asymptotic giant branch (AGB) stars. Based on the new width we derive the astrophysical S -factor and the stellar rate of the $^{13}\text{C}(\alpha, n)^{16}\text{O}$ reaction. At a temperature of 100 MK, our rate is roughly two times larger than that by Caughlan & Fowler and two times smaller than that recommended by the NACRE compilation. We use the new rate and different rates available in the literature as input in simulations of AGB stars to study their influence on the abundances of selected s -process elements and isotopic ratios. There are no changes in the final results using the different rates for the $^{13}\text{C}(\alpha, n)^{16}\text{O}$ reaction when

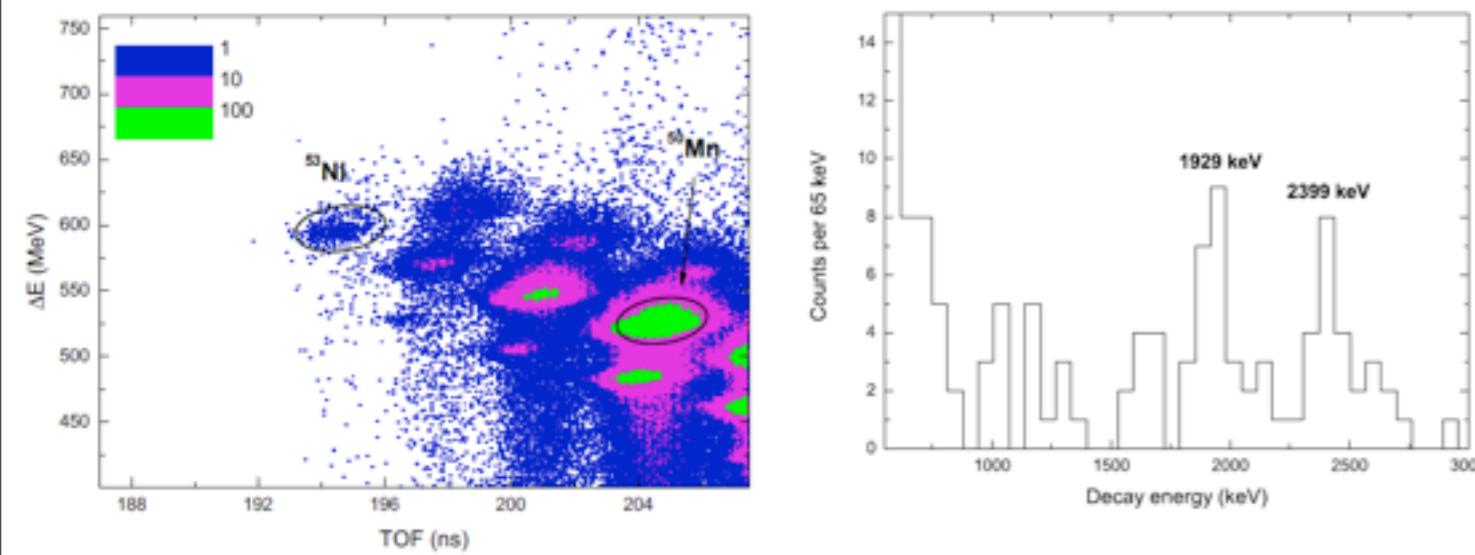
来自郭冰

22Na+p,a实验进展

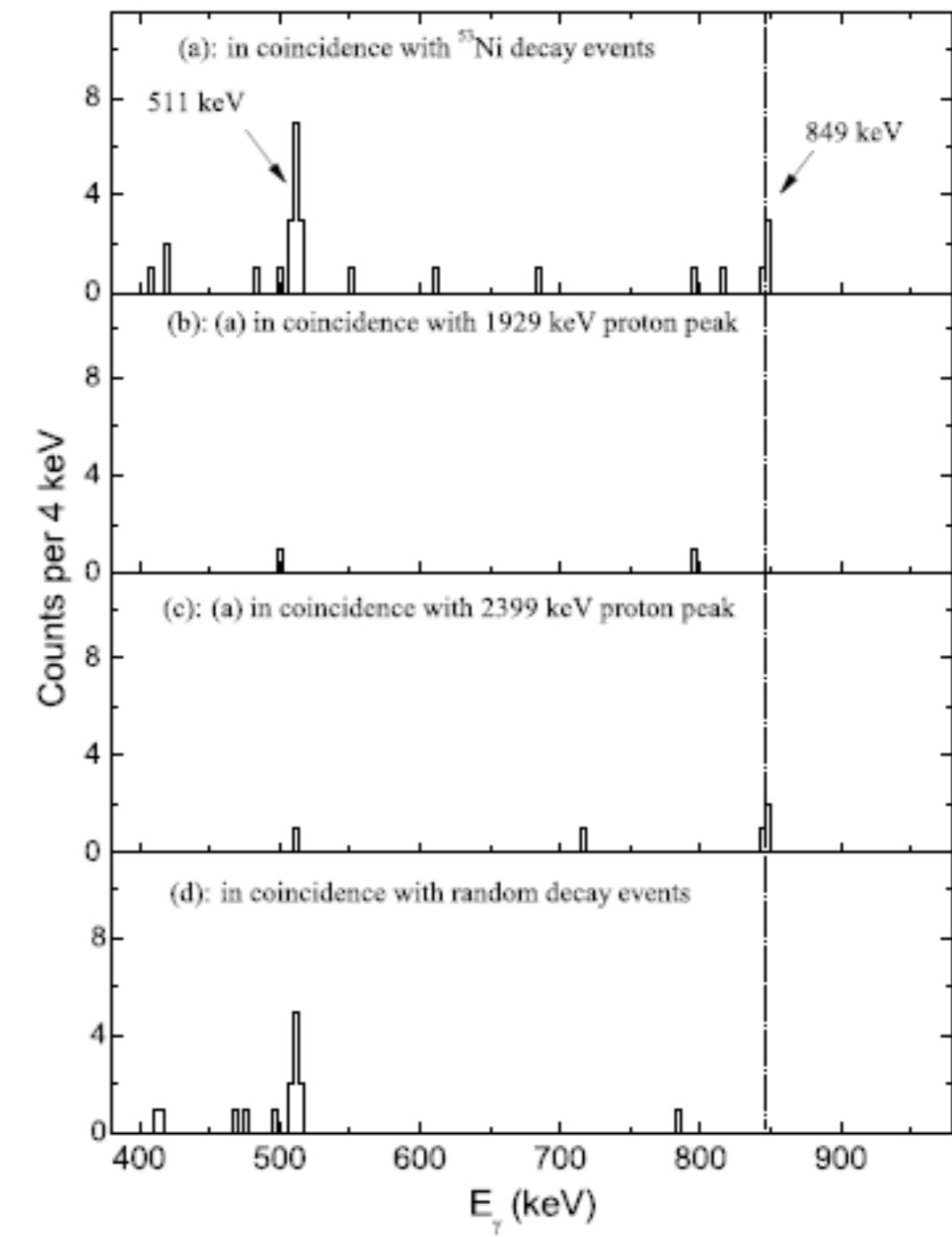


来自王友宝

53Ni工作 - I

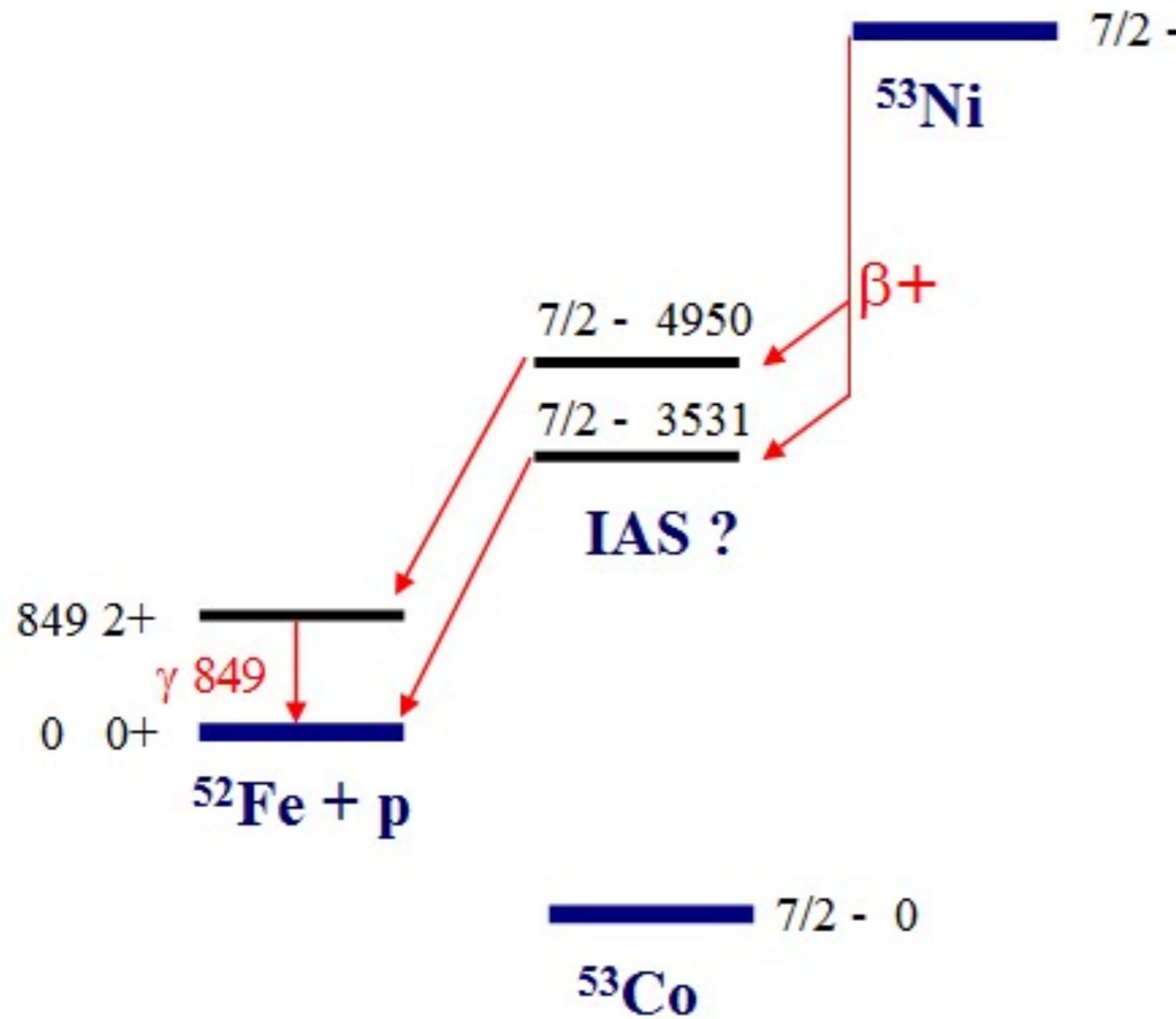


Nucleus	Half life(ms)		
	Present work	Previous work	Recommended data
⁵³ Ni	56±8	55.2±0.7 [4]	55.2±0.7
⁵⁴ Ni	113±9	103±9 [10]	108±6
⁵² Co	103±7	115±23 [11]	104±7
⁵³ Co	230±17	240±9 [10]	238±8
⁵¹ Fe	301±4	305±5 [12]	303±3
⁵⁰ Mn	288±7	283.29±0.08 [13]	283.29±0.08

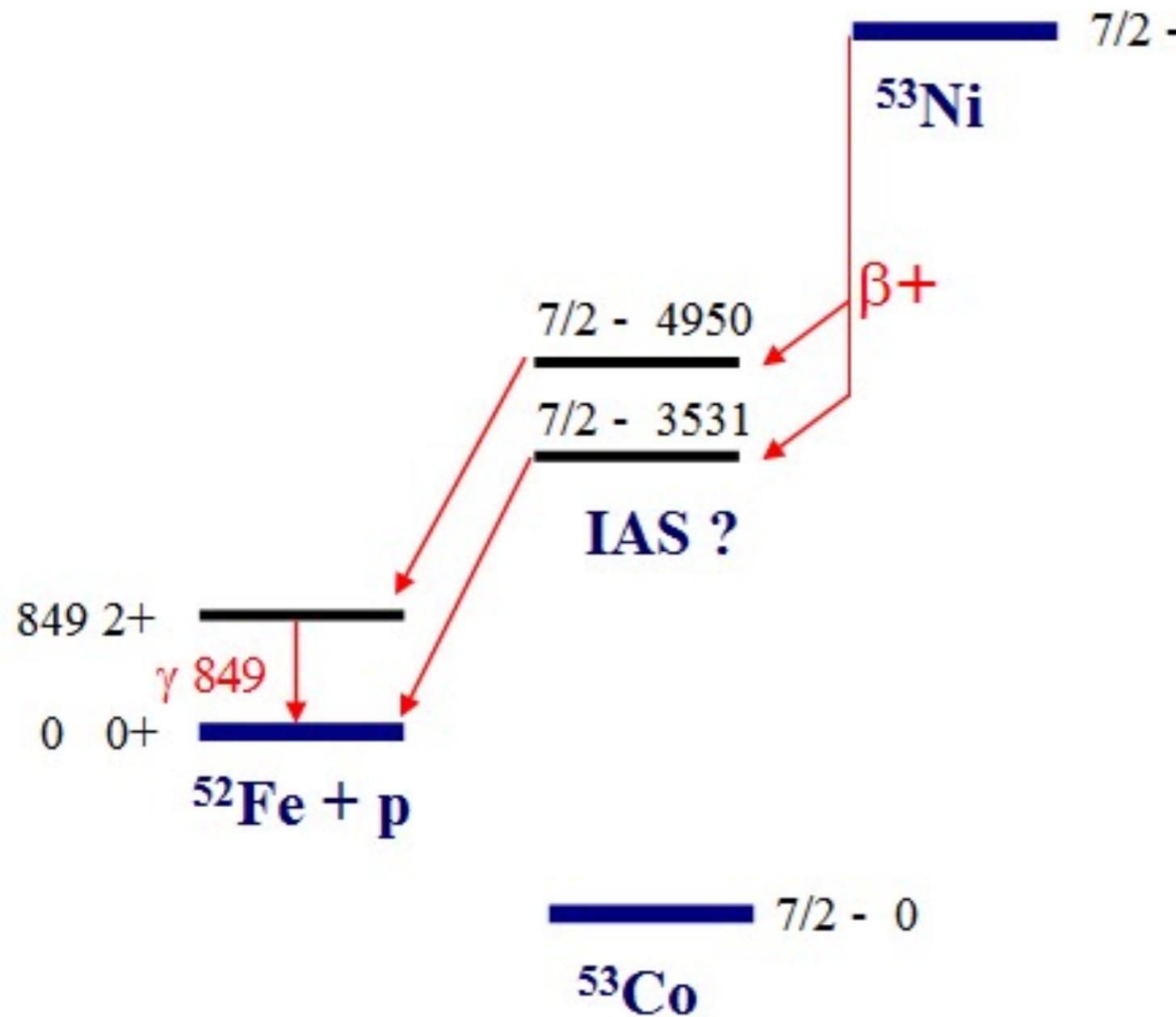


来自苏俊

53Ni工作-2



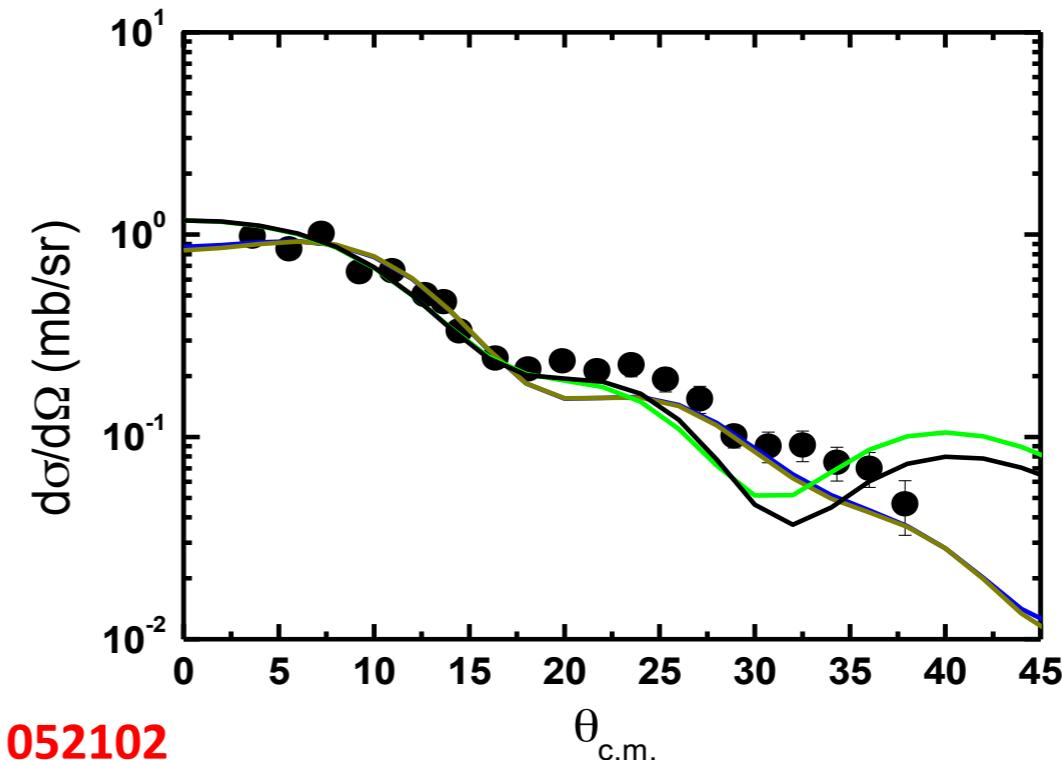
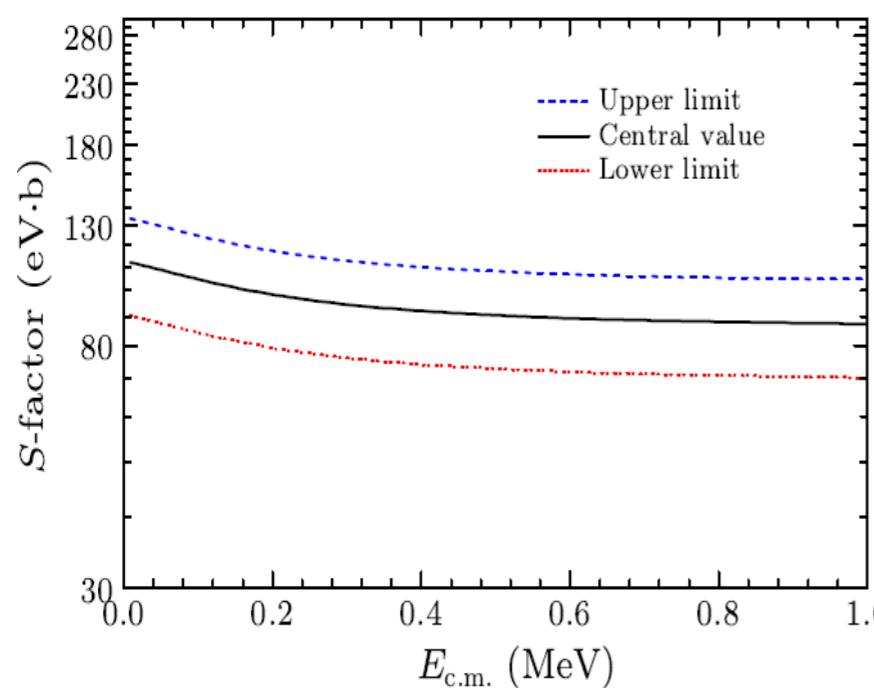
53Ni工作-2



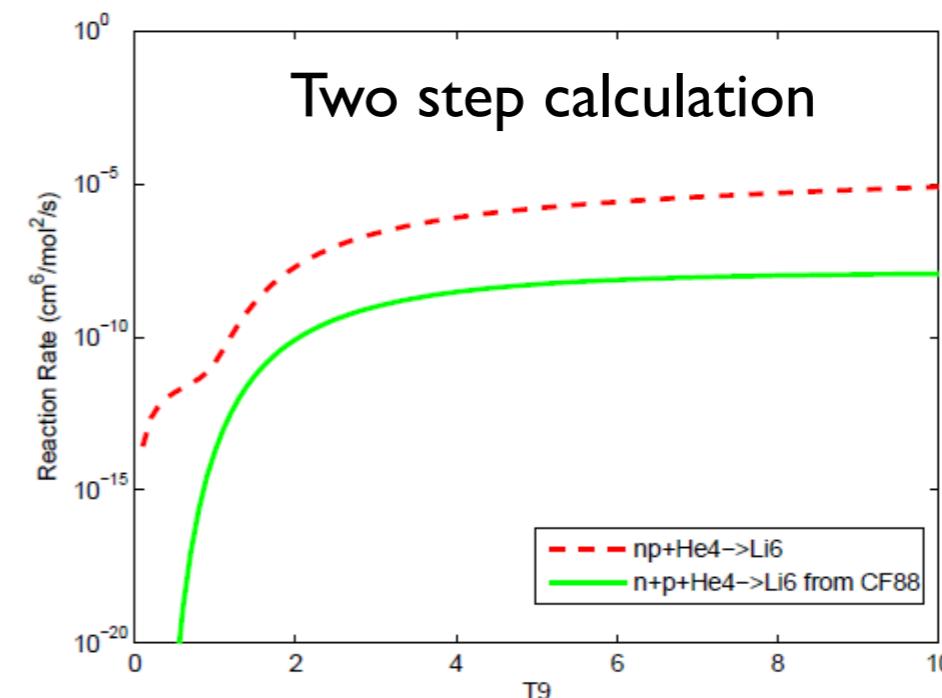
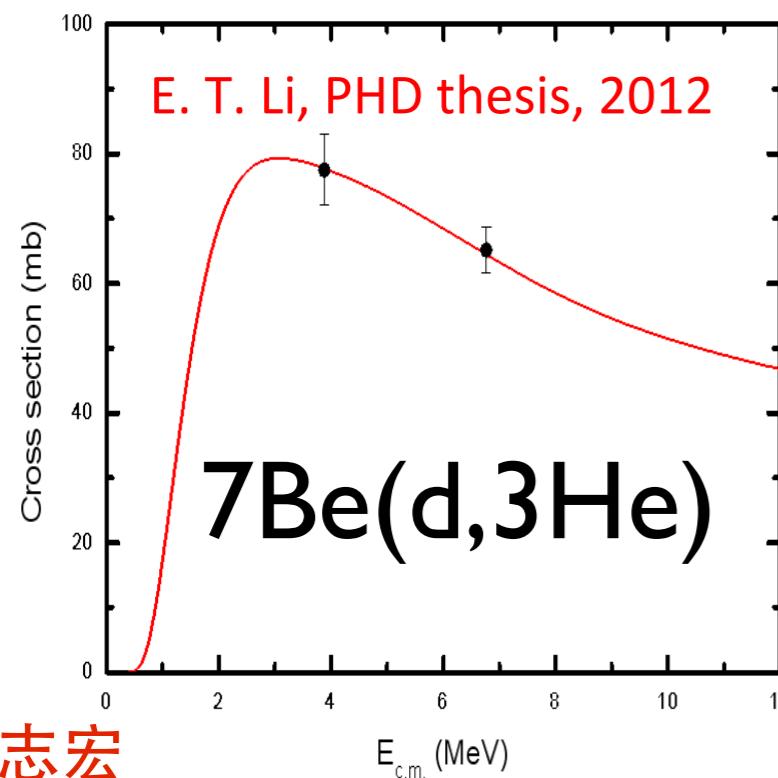
- 如果峰4未与849伽马符合，且认为是IAS峰，则IAS的能量降低849 keV
- 如果峰6与伽马符合，且认为是IAS峰，则IAS能量抬高470 keV
- 两种可能性均较大偏离IMME系统学、镜像核对称性和角动量匹配
- 已投PRC
- 需要更高统计证实，兰州实验计划中

锂丰度相关反应最新测量

由 ${}^6\text{He}(\text{d},\text{n}){}^7\text{Li}$ 反应的角分布导出了 ${}^6\text{He}(\text{p},\gamma){}^7\text{Li}$ 反应的天体物理S因子



E. T. Li et al., CHIN. PHYS. LETT. Vol. 28, No. 5 (2011) 052102



来自李志宏

群体的国内外合作



需要思考的问题

- 群体集成效应的体现
- 还有那些条件可以利用的， 国内， 国外
- 我们的带动作用， 学术， 人才， 队伍
- 新的增长点在哪里
- 如何更好与天体物理交叉
- 如何与其他群体竞争， 我们有希望到第三期吗

