Measurement of the neutron spectroscopic factor in ^{10}Be

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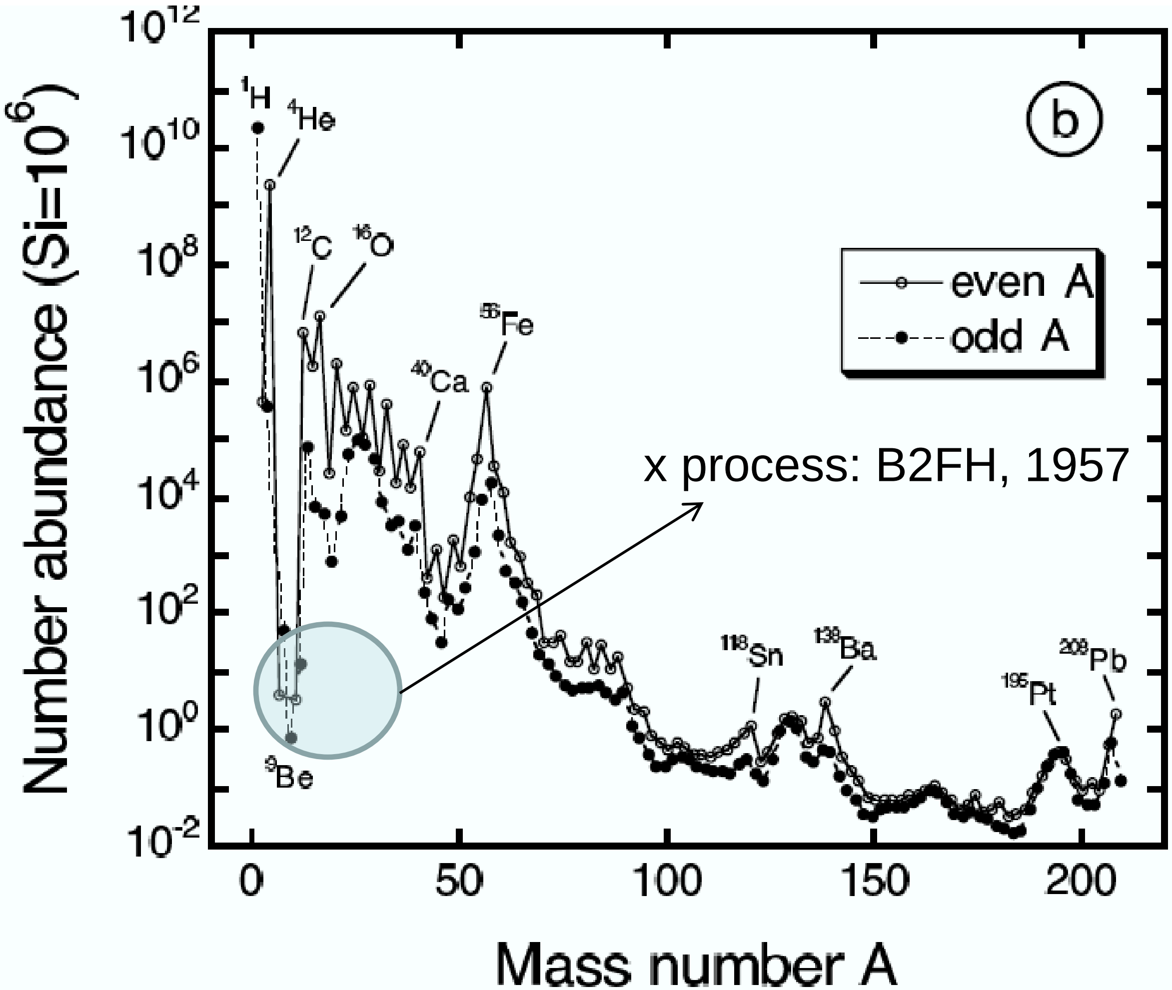
Outline

- **Why Lithium, Beryllium, Boron?**
- **How to study ^{9}Be(n, γ)^{10}Be?**
- **Experiment**
- **Summary**

Lithium, Beryllium, Boron abundances



Ref:Nuclear Physics of Stars (P7) Christian Iliadis

Destruction temperatures:

^{6}Li: 2.0 MK
^{7}Li: 2.5 MK
^{9}Be: 3.5 MK
^{10}B: 5.3 MK
^{11}B: 5.0 MK

Elisabeth Vangioni-Flam et. al, 2000

Production mechanism:

In BBN & spallation by cosmic rays (υ process):

^{6}Li, ^{7}Li, ^{9}Be, ^{10}B, ^{11}B

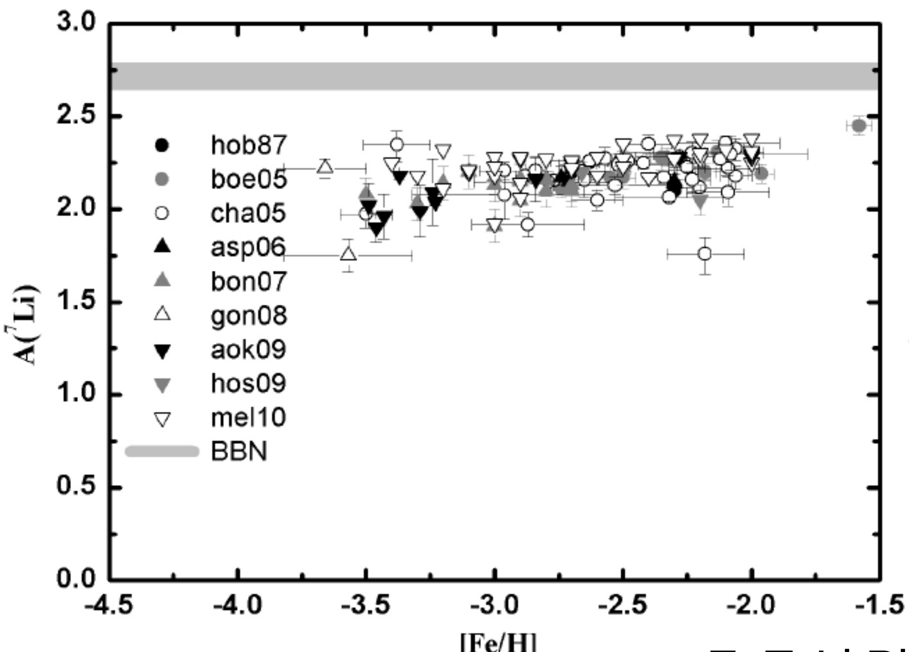
Stellar:

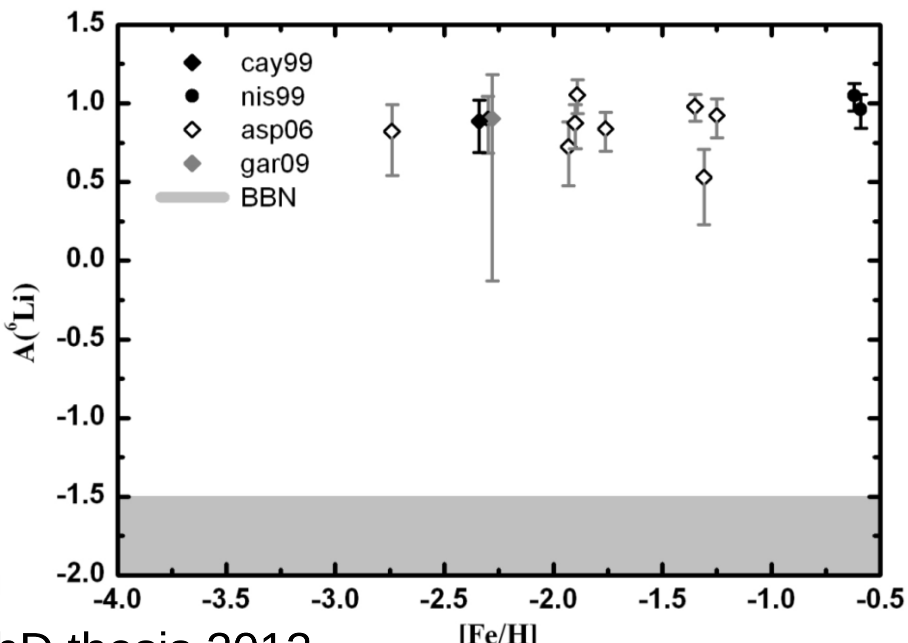
^{7}Li

Elisabeth Vangioni-Flam et. al, 2000
Pascl Hanon et. al, 1999
Projjwal Banerjee et. al, 2016

Why study Li, Be, B

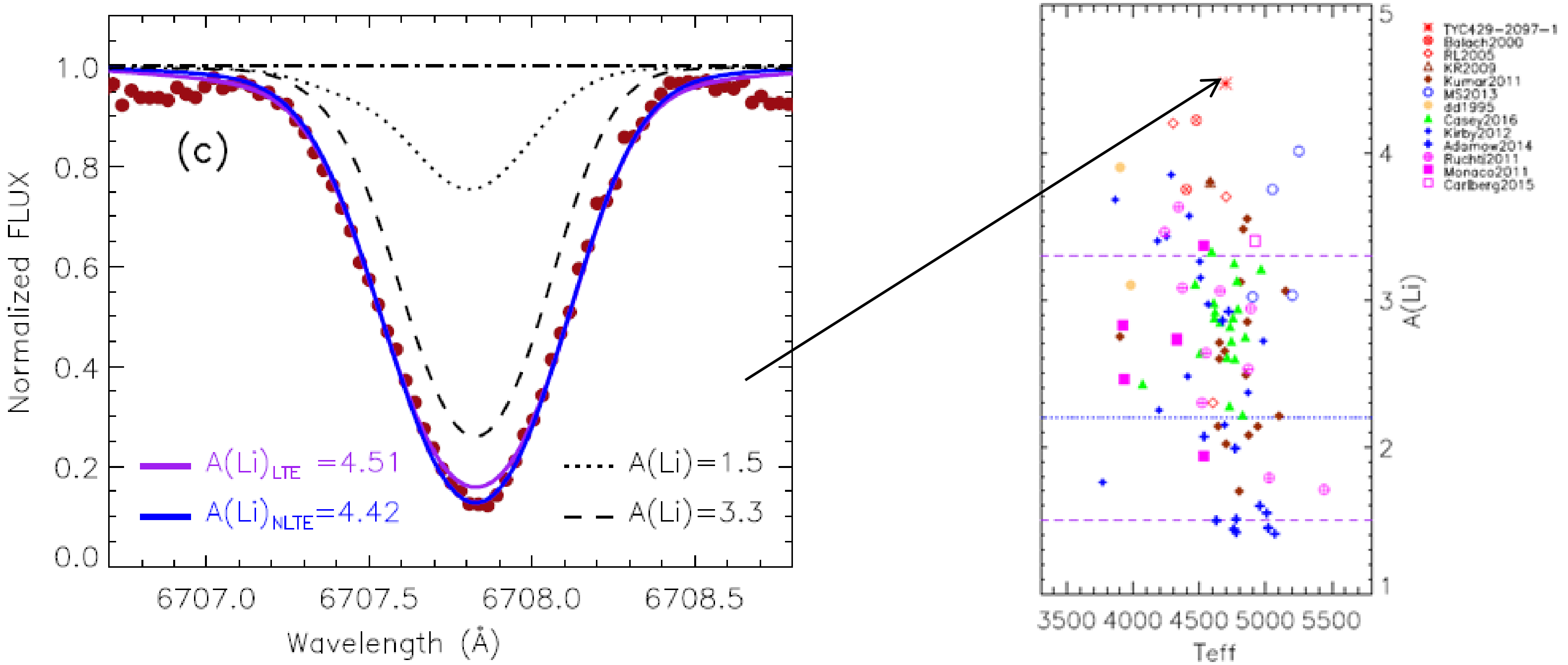
1. Lithium puzzles are not solved yet
2. How to explain the Li-rich star
3. Influence some other nuclei
4. Influence the r-process nuclei
5. ^{10}Be (τ =2.3 Myr) /^{9}Be ratio in the ESS





E. T. Li PhD thesis 2012

Li-rich star

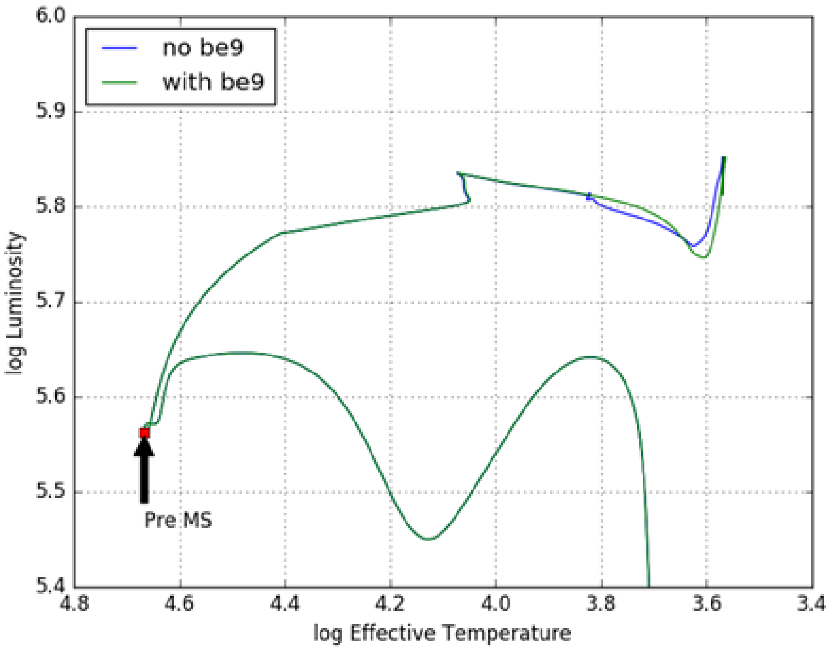


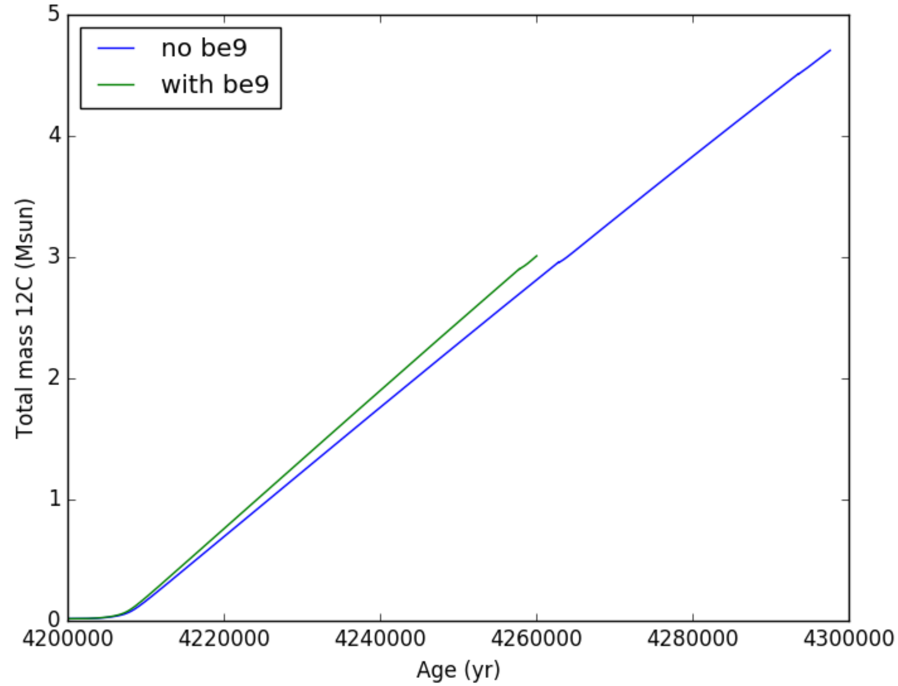
Discovery of the most Li-rich star: revealing the nature of Li enrichment

Hong-Liang Yan[1], Jian-Rong Shi*[1,2], Yu-Tao Zhou[1,2], Yong-Shou Chen[3], Er-Tao Li[4], Suyalatu Zhang[5], Shao-Lan Bi[6], Ya-Qian Wu[6], Zhi-Hong Li[3], Bing Guo[3], Wei-Ping Liu[3], Qi Gao[1,2], Jun-Bo Zhang[1], Ze-Ming Zhou[1,2], Hai-Ning Li[1], and Gang Zhao†[1,2]

submitted to Nature astronomy

Influence to other nuclei and stellar evolution



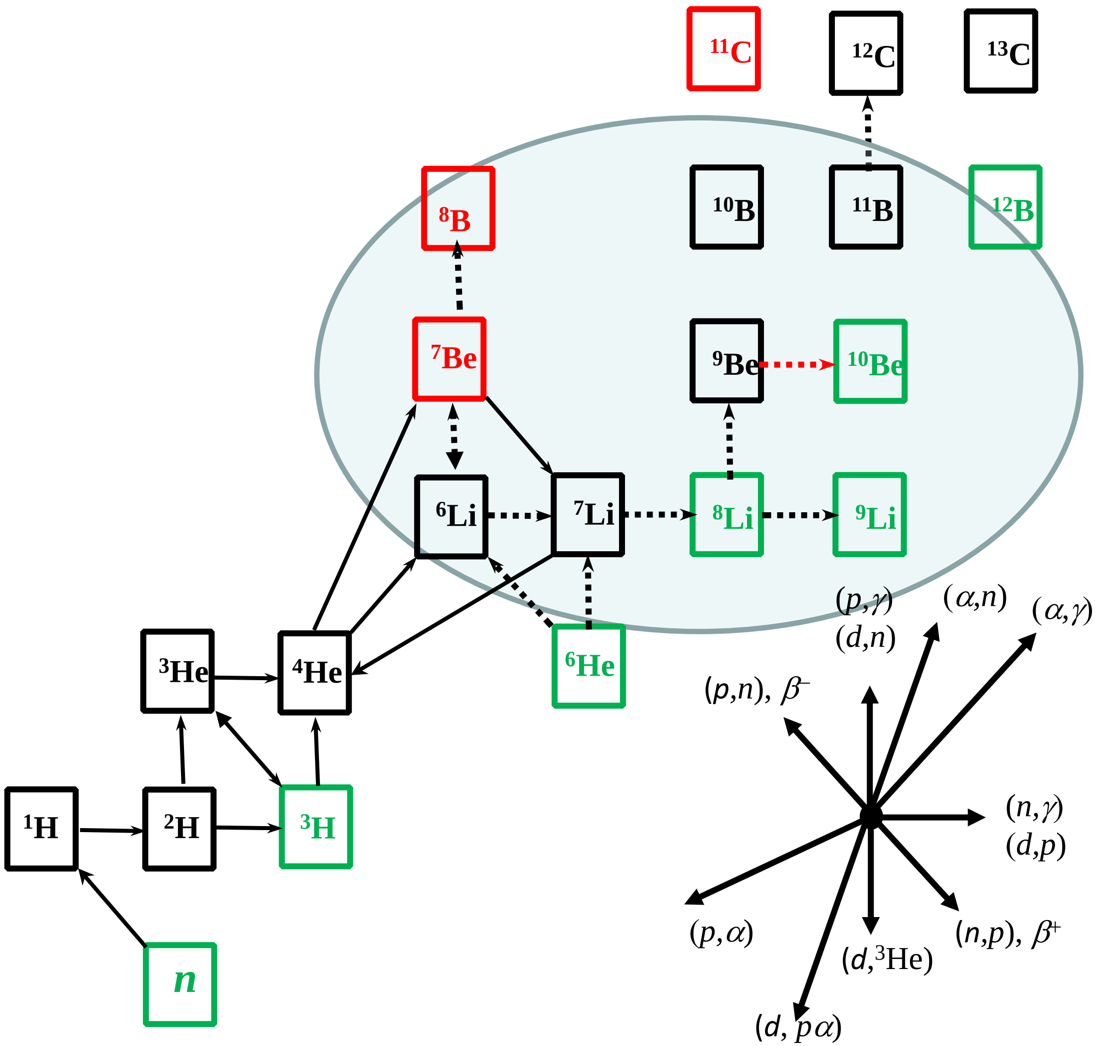


MESA calculation

50Msun, Z=0.014

MESA: http://mesa.sourceforge.net/

What we have done

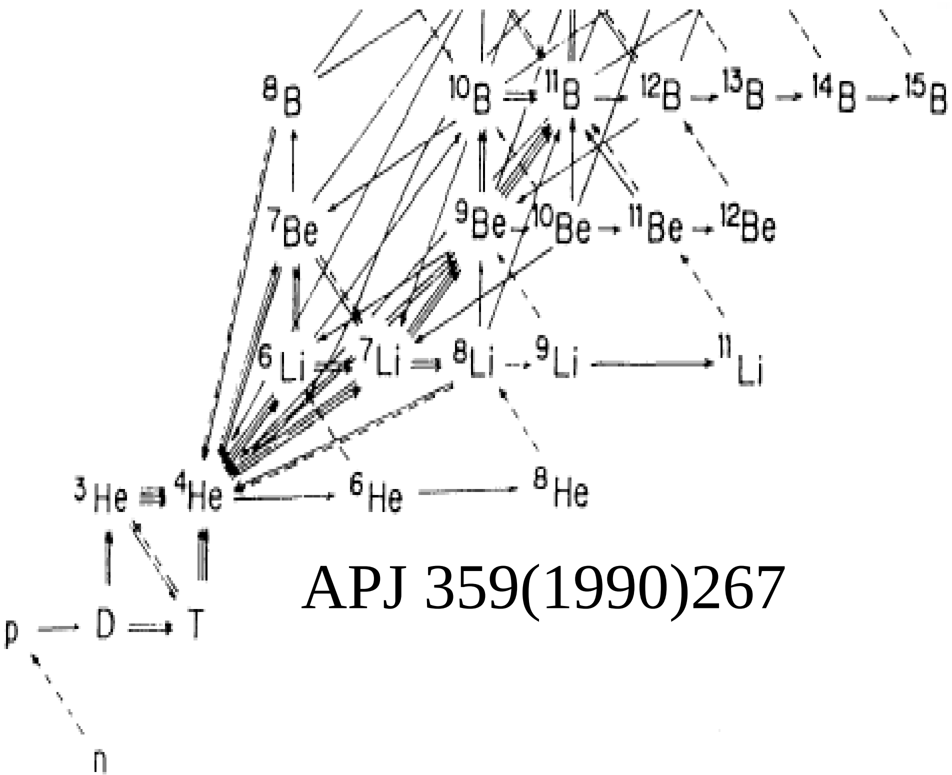


^{7}**Be(p, γ)**^{8}**B** PRL 77(1996)611
^{6}**He(p, n)**^{6}**Li** PLB 527(2002)50
^{8}**Li(n, γ)**^{9}**Li** PRC 71(2005)052801
^{6}**He(p, γ)**^{7}**Li** CPL 27(2010)052101
^{6}**He(p, γ)**^{7}**Li** EPJA 44(2010)1
^{6}**Li(n, γ)**^{7}**Li** CPL 27(2010)052101
Review: SC 54(2011)1
^{8}**Li(p, γ)**^{9}**Be** PRC 87(2013)017601
^{11}**B(p, γ)**^{12}**C** PRC 90(2014)067601
^{7}**Be(d, τ)**^{6}**Li** CPC 42(2018)044001
……

What sites do we need to consider ^{9}Be(n, γ)^{10}Be reaction

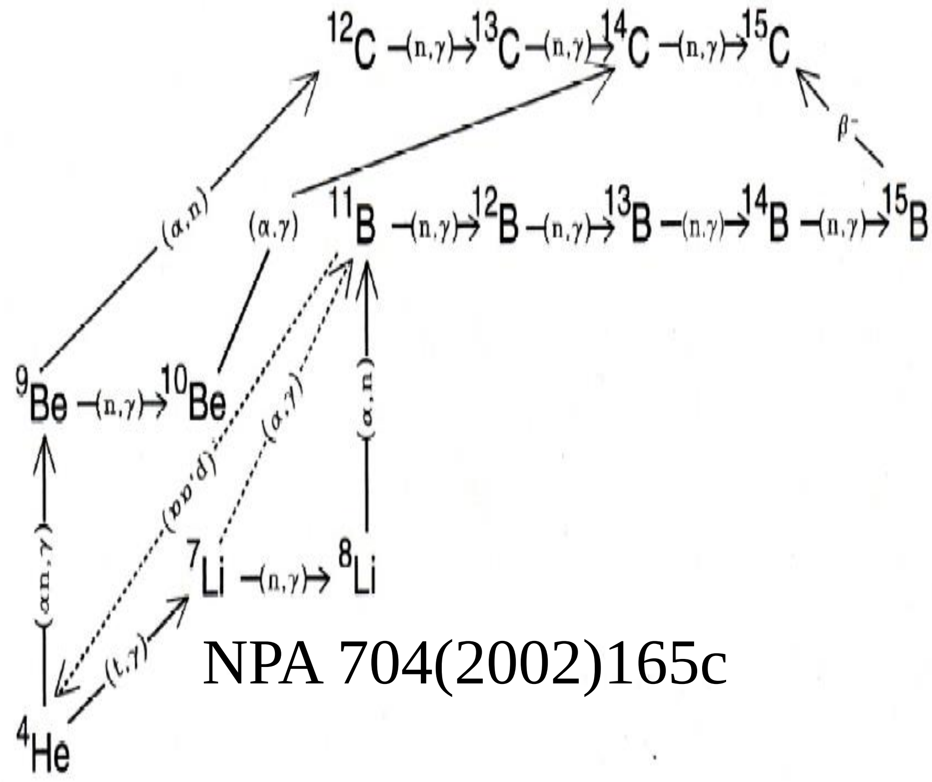
Neutron rich environments
Can produce ^{9}Be

BBN



APJ 359(1990)267

Affect r-process

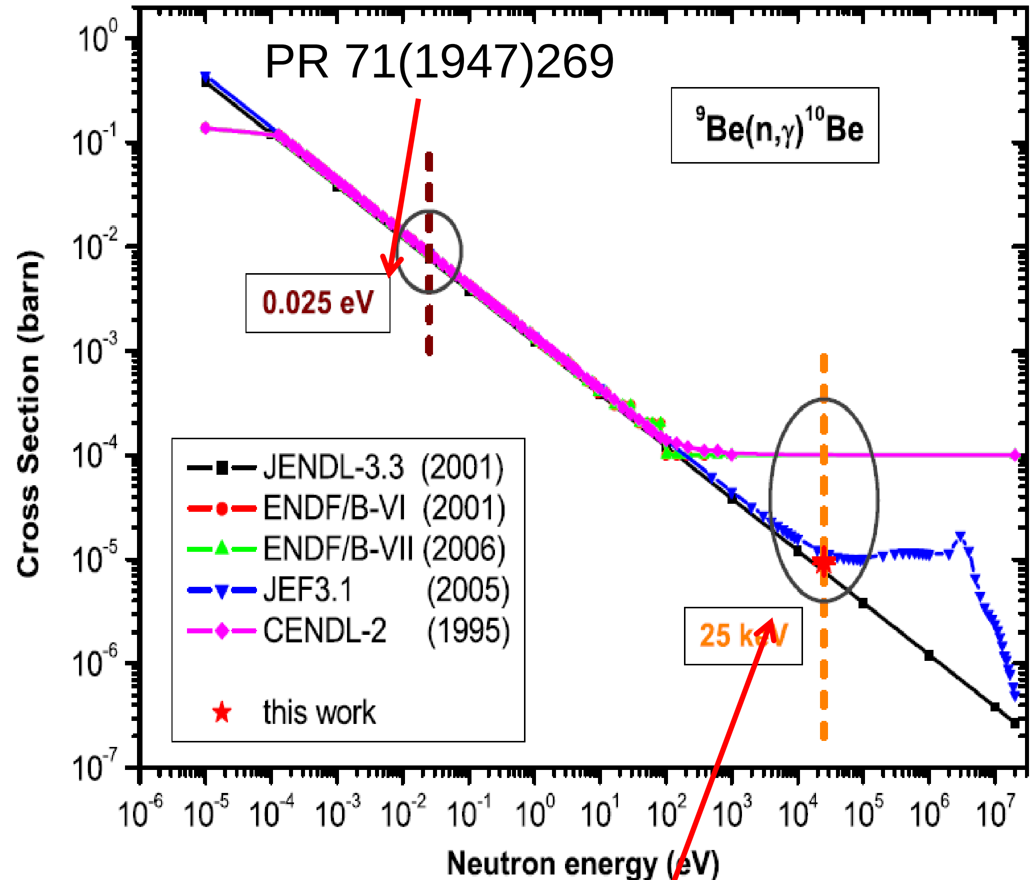


NPA 704(2002)165c

$^{9}Be(n, \gamma)^{10}Be$ experimental data

- Direct measurement:
  - Thermal neutron data：
    - PR 71(1947)269
  - AMS method:(μb)
    - JPG**35** (2008) 014018

- Indirect method:
  - Spectroscopic factor



JPG**35** (2008) 014018

Spectroscopic factor method

^{9}**Be(a, b)**^{10}**Be** angular distribution

(a, b) = (d, p)、 (^{7}Li, ^{6}Li)、 (^{11}B, ^{10}B)、 (^{10}Be, ^{9}Be) 、 (^{13}C, ^{12}C) …

DWBA calculation

$$\left(\frac{d\sigma}{d\Omega}\right)_{EXP} = S_{13C} S_{9Be} \left(\frac{d\sigma}{d\Omega}\right)_{DWBA}$$

S_{9Be}

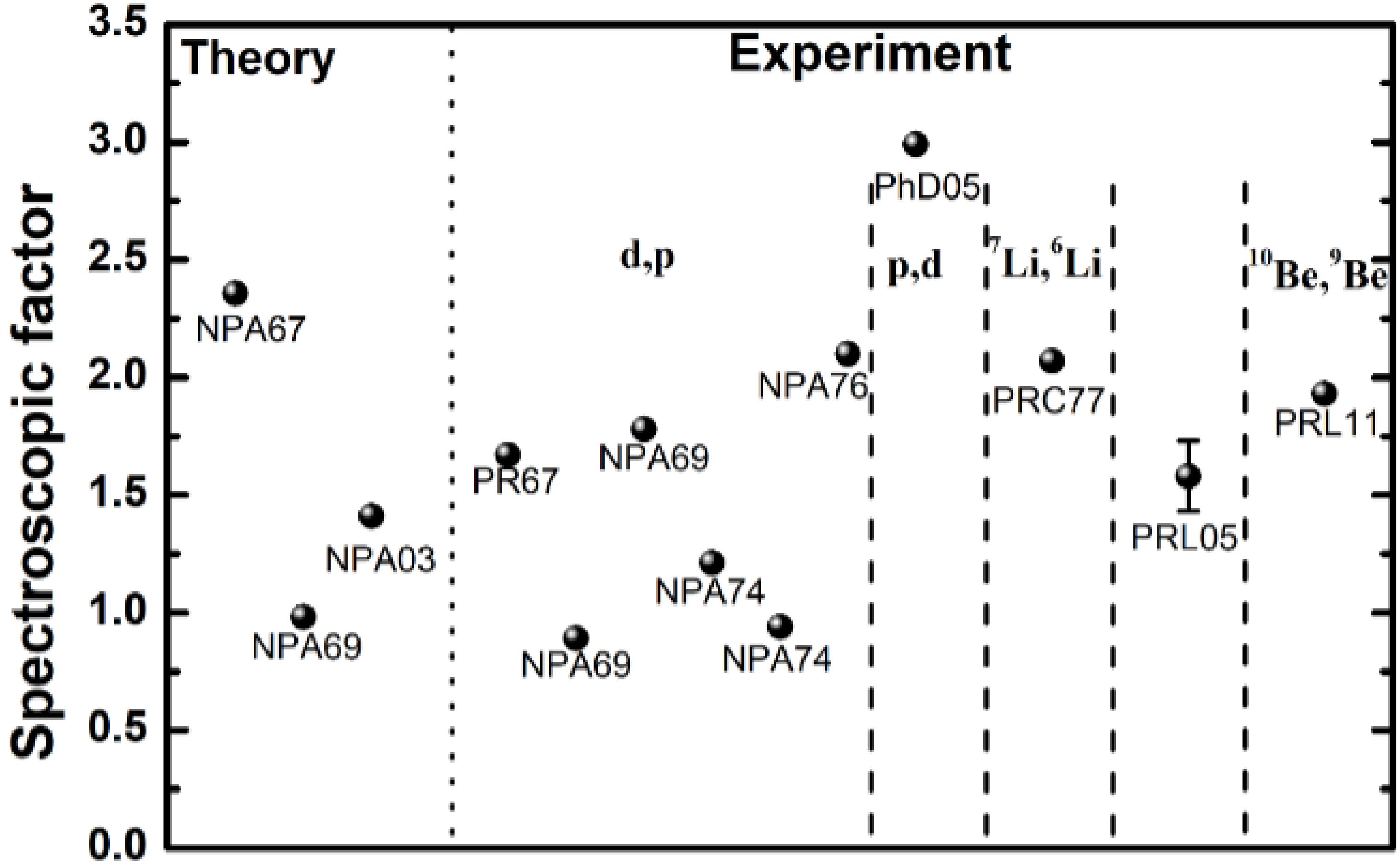
^{9}Be(n, γ)^{10}Be excitation function ,

astrophysical S factor and reaction rates

Advantages of **(^{13}C, ^{12}C) :**

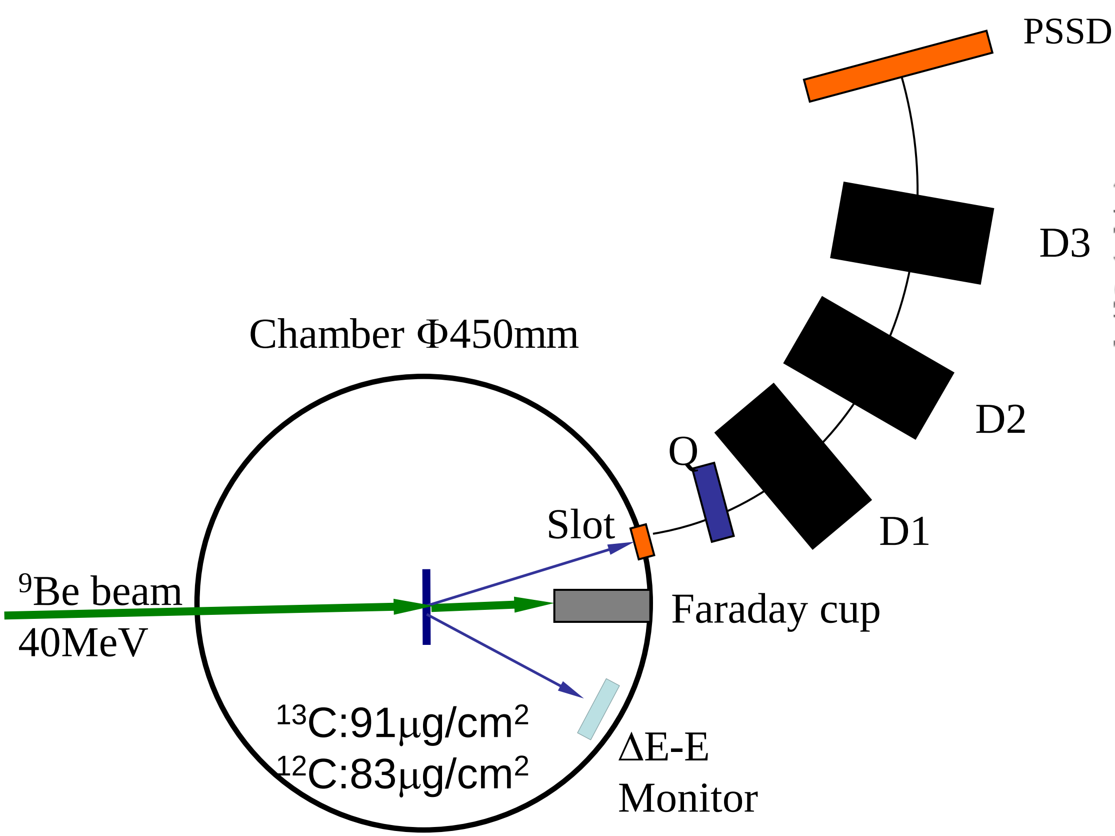
1. Small error of S_{13C}
2. Simple neutron transfer mechanism

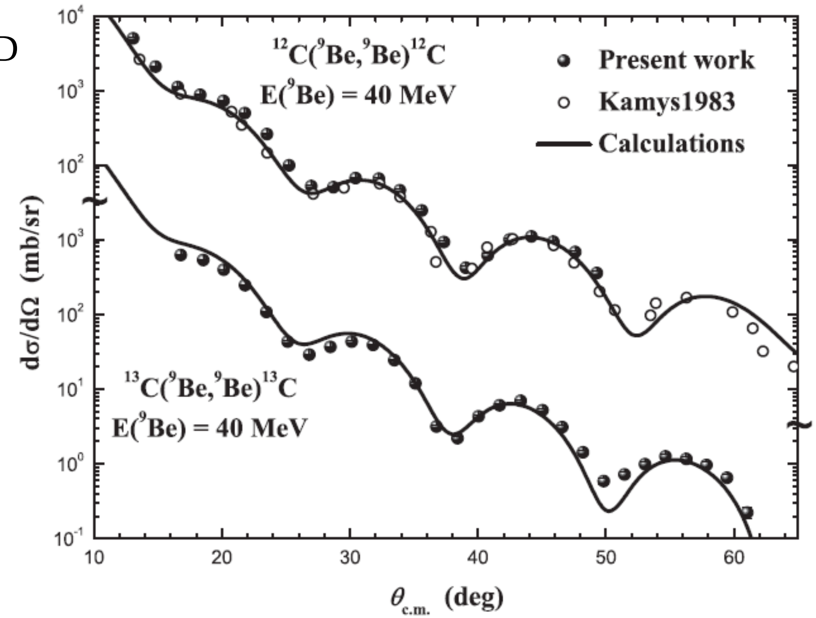
^{10}Be neutron spectroscopic factor



^{10}Be neutron spectroscopic factor

Experimental setup

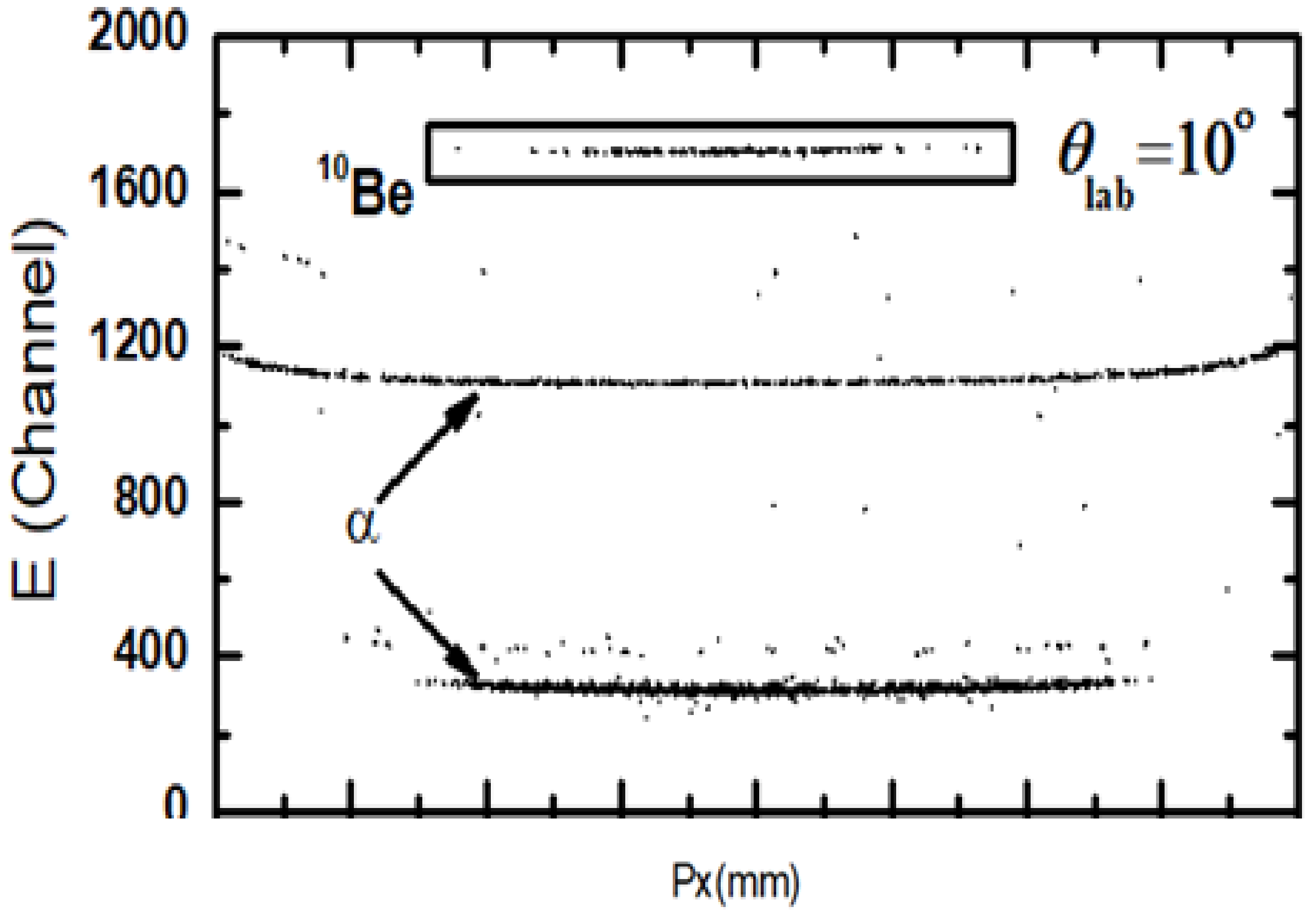




Set	En	Ex
V	127.0	33.69
r_r	0.80	0.97
a_r	0.78	0.92
W_v	13.9	6.52
r_v	1.25	1.51
a_v	0.70	0.48
r_c	1.0	1.2

Z. H. Li … et, al, PRC 87(2013)017601

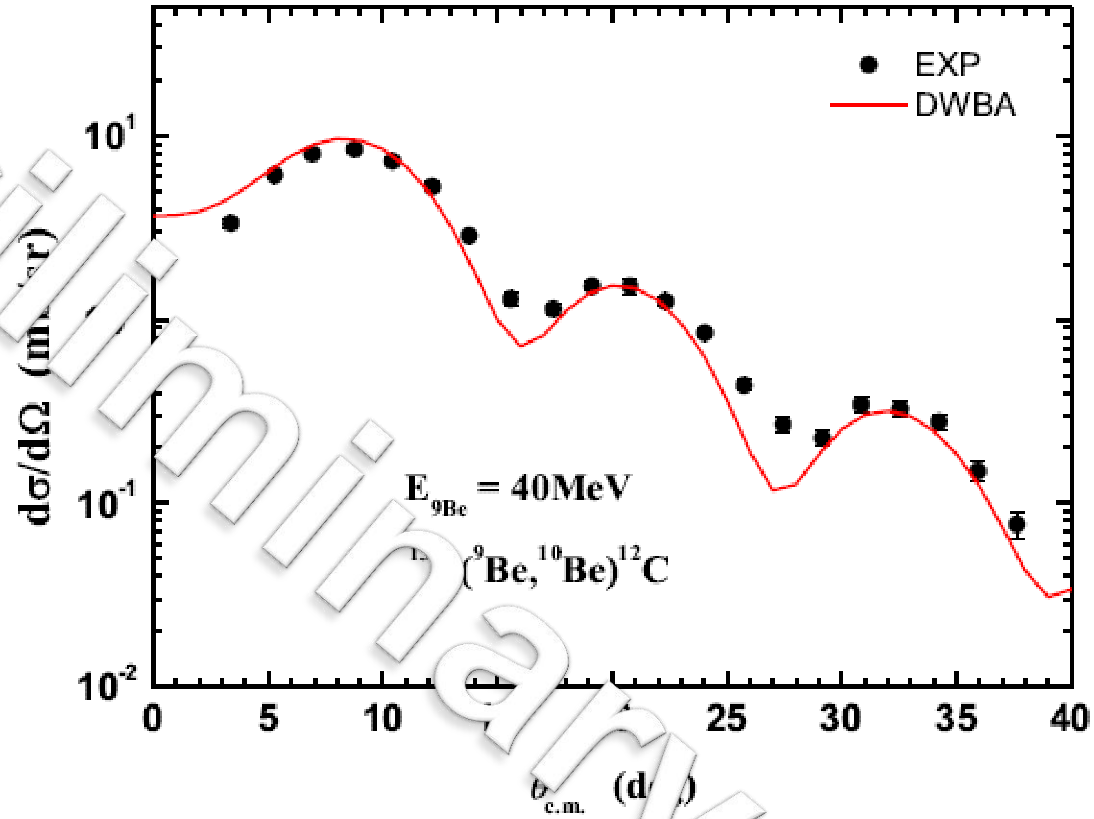
Plot of E vs Px



Two-dimensional scatter plot of kinetic energy (E) vs horizontal position (Px)

$^{13}C(^{9}Be, ^{10}Be)^{12}C$ angular distribution

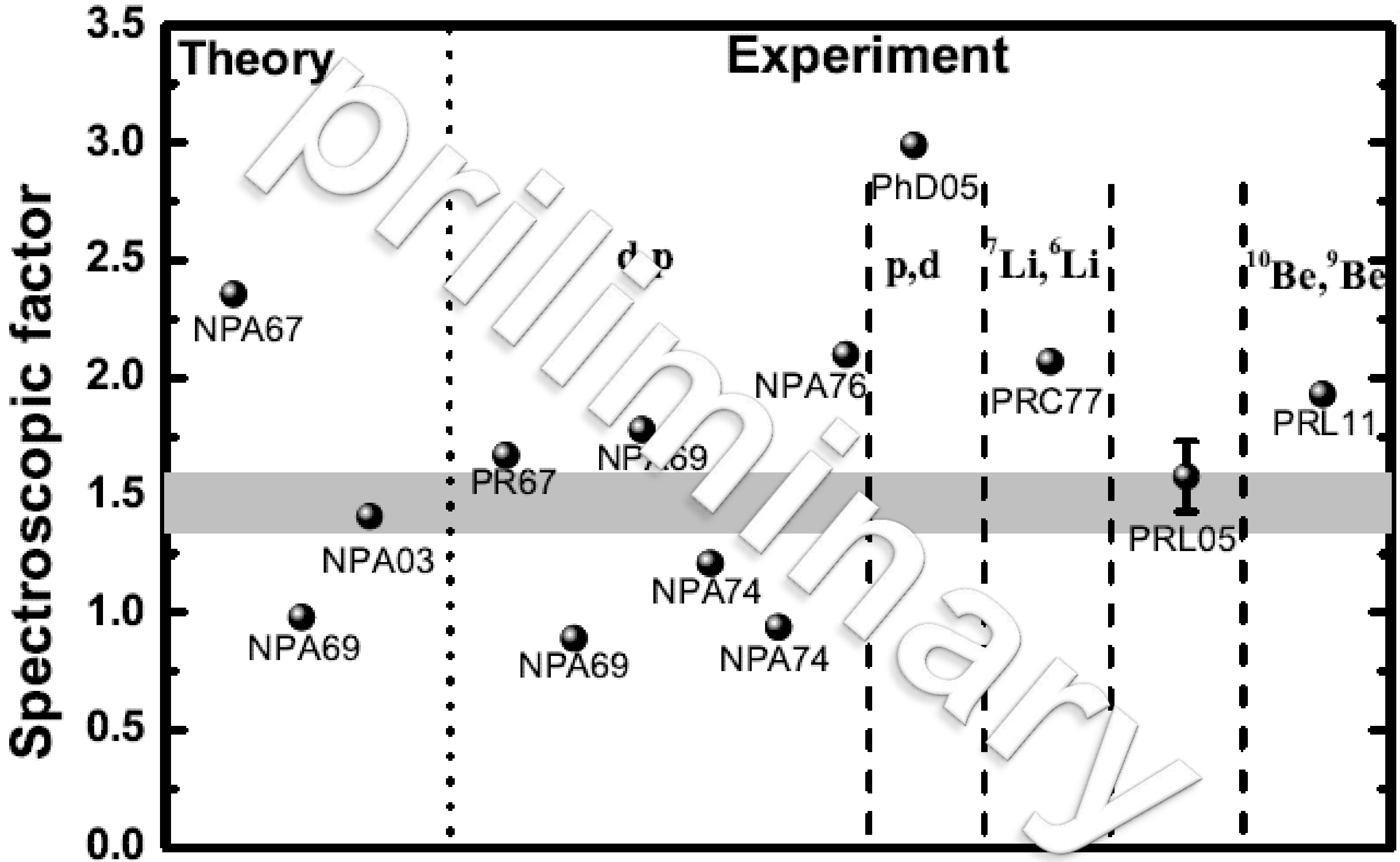
$$\left(\frac{d\sigma}{d\Omega}\right)_{EXP} = S_{13C} S_{9Be} \left(\frac{d\sigma}{d\Omega}\right)_{DWBA}$$



S_{13C}=0.81±0.04
From $^{12}C(^{13}C, ^{12}C)^{13}C$
NPA 284(1977)114

S_{10Be}=1.48±0.10

^{10}Be neutron spectroscopic factor



$S_{10Be}=1.48\pm0.10$

Summary and Future plan

- **Summary:**

a) Li, Be, B have a lot of problems, and our project,

b) Measured the angular distribution of $^{13}C(^{9}Be, ^{10}Be)^{12}C$ reaction,

c) Obtained the neutron spectroscopic factor of ^{10}Be by DWBA.

- **Future plan:**

a) Calculate the reaction rates of $^{9}Be(n, \gamma)^{10}Be$,

b) Calculate its influence in BBN and CCSN,

c) Binary stars & Neutron merger?

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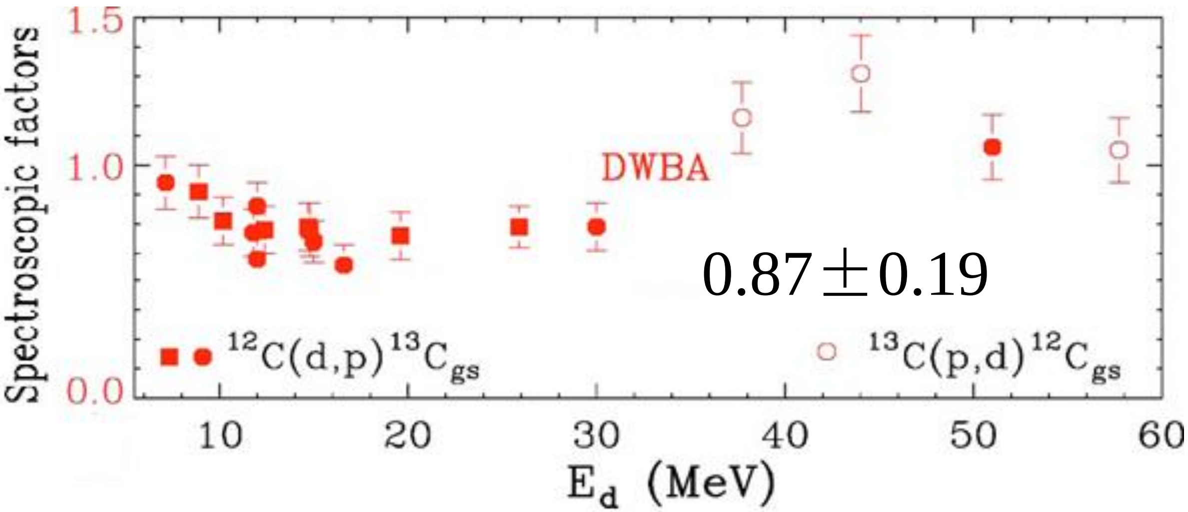
Thank you for your attention.

Why $^{13}C(^{9}Be, ^{10}Be)^{12}C$?

Advantages：

1. Small error of S_{13C}
2. Simple neutron transfer mechanism



0.87±0.19

PRC 69(2004)064313

$^{12}C(^{13}C, ^{12}C)^{13}C$

$S_{13C}=0.81\pm0.04$

NPA 284(1977)114