



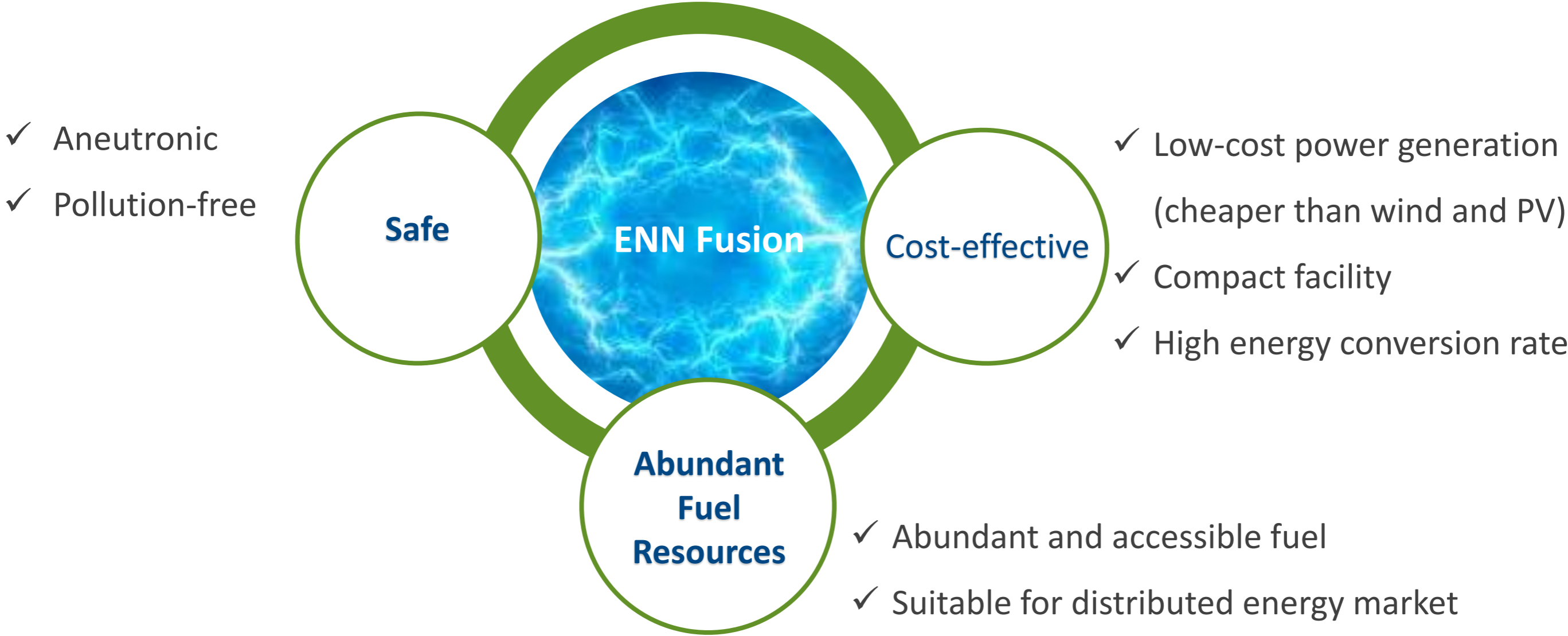
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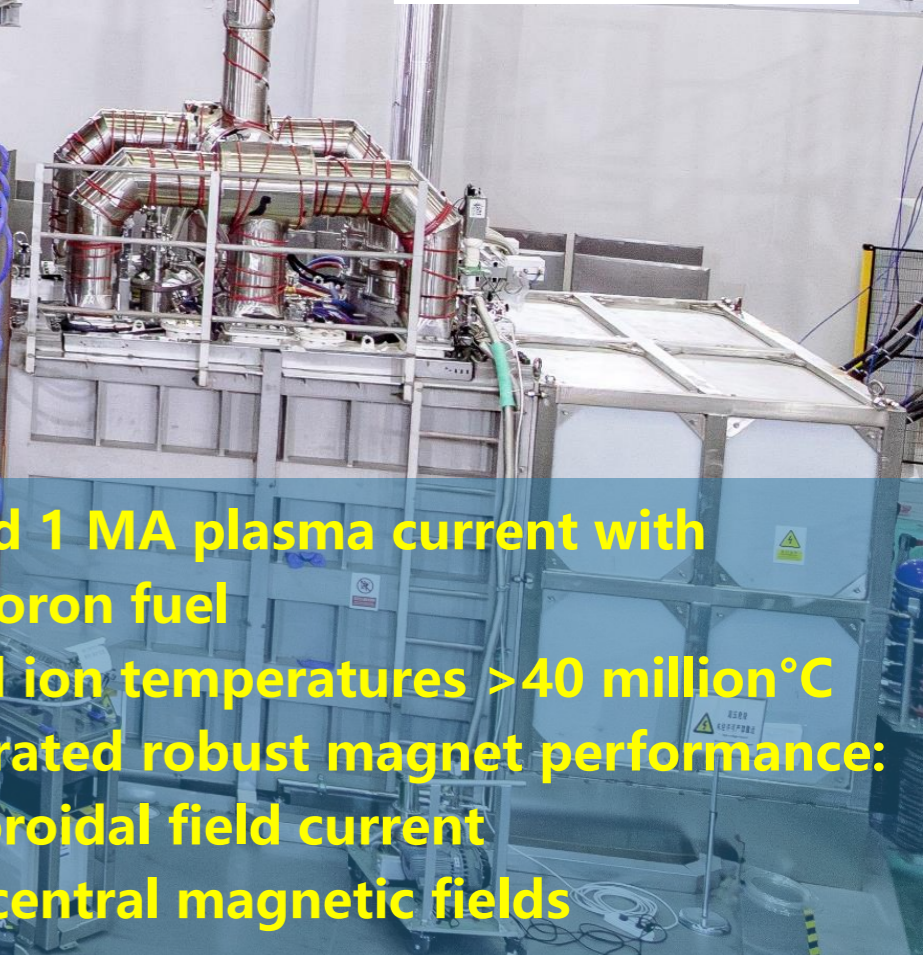
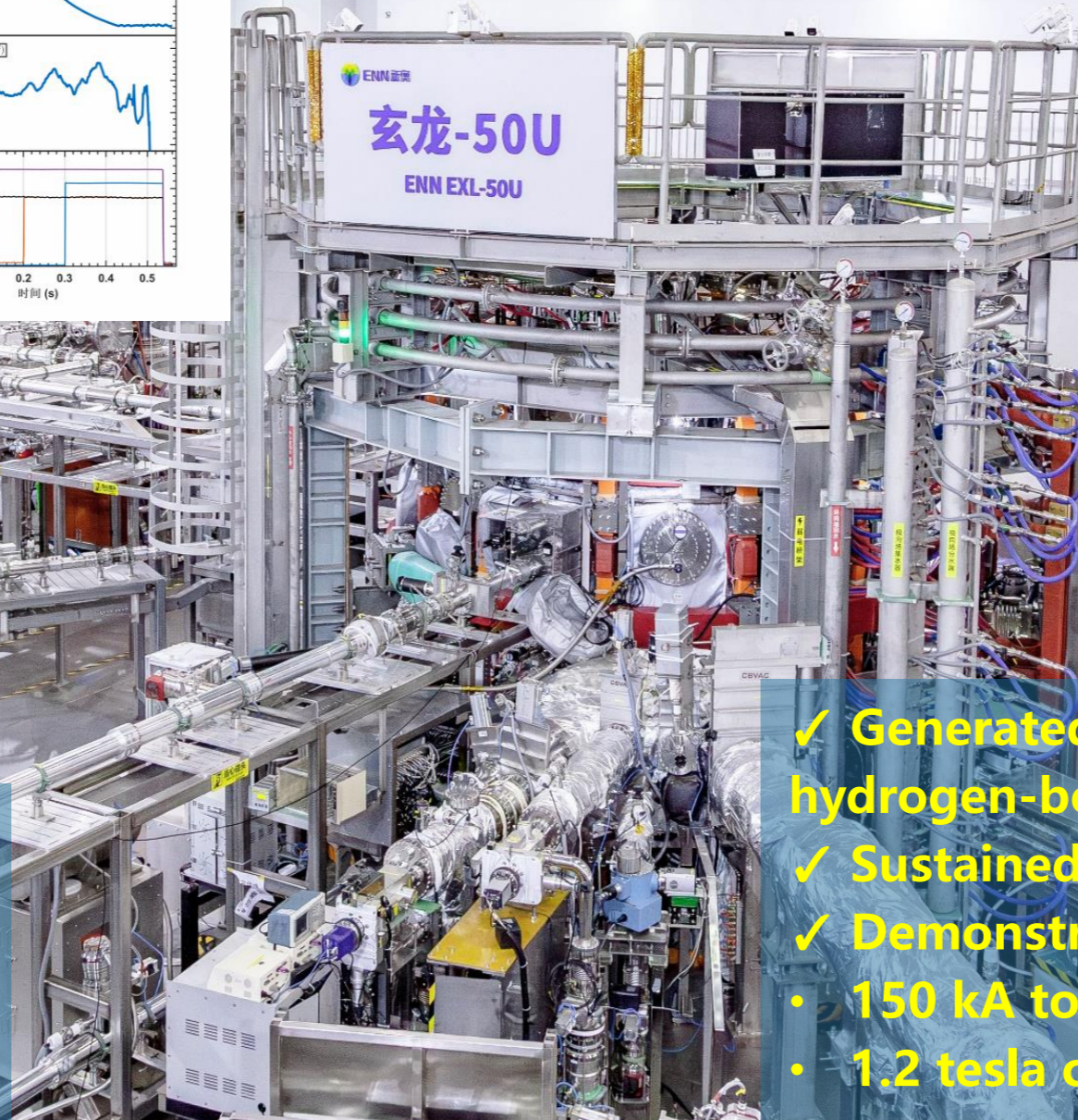
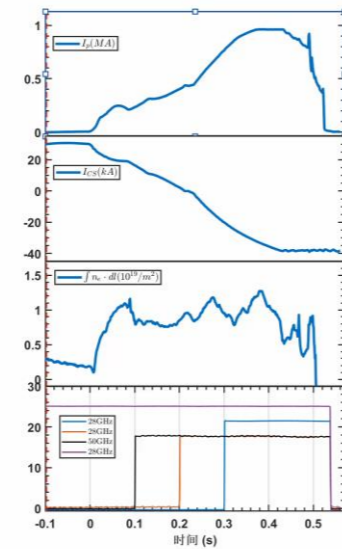
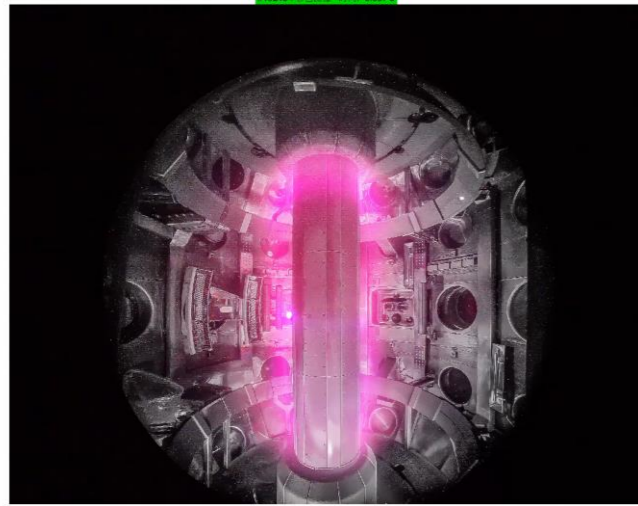
Enhancing proton-Boron Fusion Rates: The Potential of Polarized Reactants

Dr. Zhi Li
ENN Energy Research Institute
Feb 9, 2026

A Visionary Goal: Commercially Viable Fusion Power

Routine: Spherical Torus + Hydrogen Boron (advanced fuel)





✓ 18 months: From design to completed construction
✓ 3 months: From commissioning to physics experiments

- ✓ Generated 1 MA plasma current with hydrogen-boron fuel
- ✓ Sustained ion temperatures >40 million °C
- ✓ Demonstrated robust magnet performance:
 - 150 kA toroidal field current
 - 1.2 tesla central magnetic fields

EXL-50U (ENN Xuan Long-50U) Spherical Torus (ST)

Theoretical Possibility of p-¹¹B Fusion: Need for Enhanced Reaction Rates

Fusion Enhancement factor $Q = \frac{P_{fus}}{\frac{E_{th}}{\tau_E} - f_{ion}P_{fus} + P_{rad}}$

fusion power

thermal energy / energy confinement time

Fraction of fusion energy carried by charged particles

radiation power loss

Simplified ignition criterion $n_e \tau_E = \frac{3}{2} k_B Z_i (1 + Z_i) (1 + \delta_{12}) \frac{T}{\langle \sigma v \rangle Y_+}$

More precise cross-section data required.

Energy carried per reaction by charged particles.

Theoretical Possibility of p-¹¹B Fusion: Need for Enhanced Reaction Rates

Fusion Enhancement factor $Q = \frac{P_{fus}}{\frac{E_{th}}{\tau_E} - f_{ion}P_{fus} + P_{rad}}$

fusion power P_{fus}

thermal energy / energy confinement time $\frac{E_{th}}{\tau_E}$

Fraction of fusion energy carried by charged particles f_{ion}

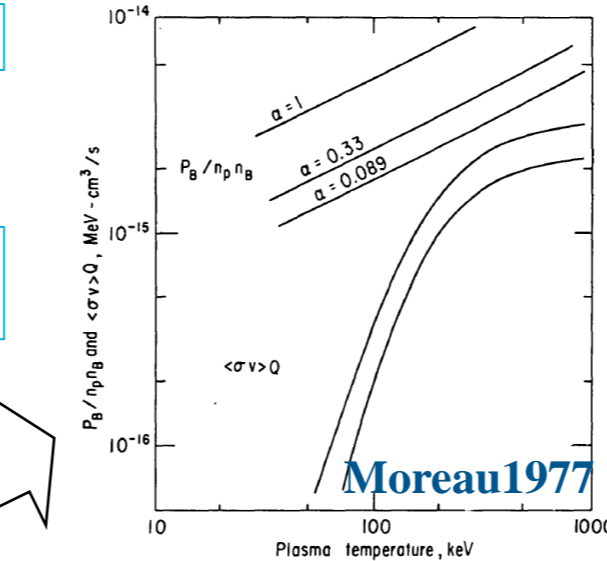
radiation power loss P_{rad}

Simplified ignition criterion $n_e \tau_E = \frac{3}{2} k_B Z_i (1 + Z_i) (1 + \delta_{12}) \frac{T}{\langle \sigma v \rangle Y_+}$

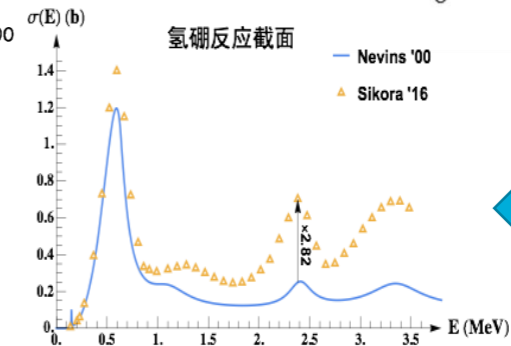
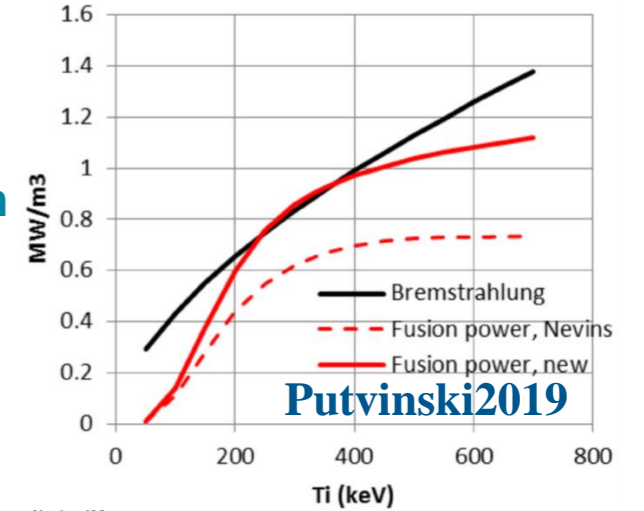
More precise cross-section data required.

Fusion reactivity $\langle \sigma v \rangle = \int \int dv_1 dv_2 \sigma(|v_1 - v_2|) |v_1 - v_2| f_1(v_1) f_2(v_2)$

Higher fusion reaction rate needed.



p-¹¹B fusion achieves ignition with new cross-section.



Remains controversial

Theoretical Possibility of p-¹¹B Fusion: Need for Enhanced Reaction Rates

Fusion Enhancement factor $Q = \frac{P_{fus}}{\frac{E_{th}}{\tau_E} - f_{ion}P_{fus} + P_{rad}}$

fusion power

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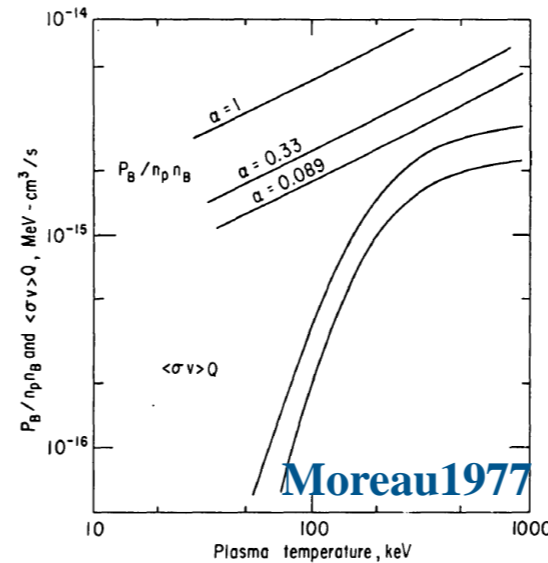
Simplified ignition criterion $n_e \tau_E = \frac{3}{2} k_B Z_i (1 + Z_i) (1 + \delta_{12}) \frac{T}{\langle \sigma v \rangle Y_+}$

More precise cross-section data required.

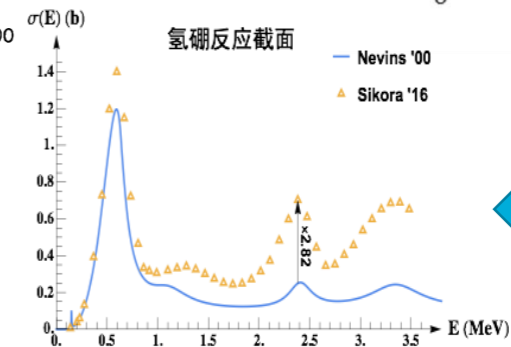
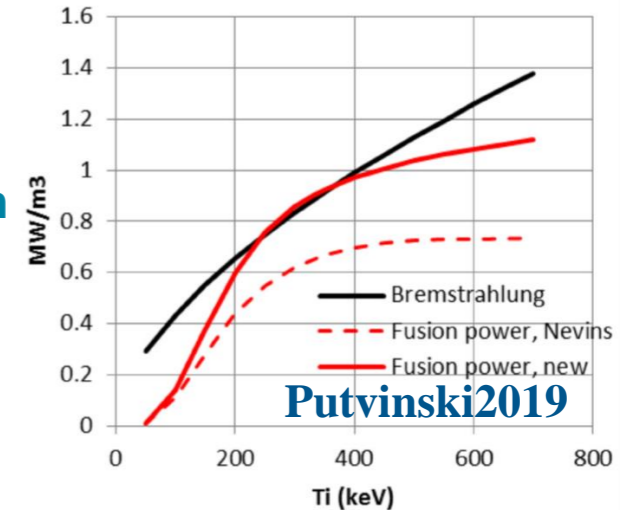
Fusion reactivity $\langle \sigma v \rangle = \int \int dv_1 dv_2 \sigma(|v_1 - v_2|) |v_1 - v_2| f_1(v_1) f_2(v_2)$

Higher fusion reaction rate needed.

Energy carried per reaction by charged particles.



p-¹¹B fusion achieves ignition with new cross-section.



Remains controversial

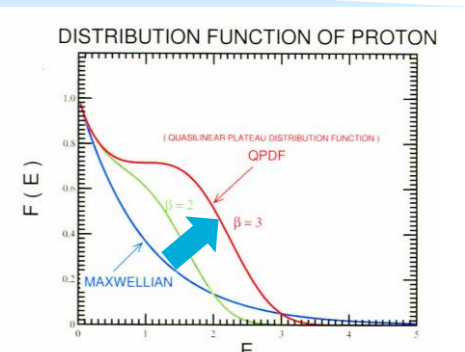
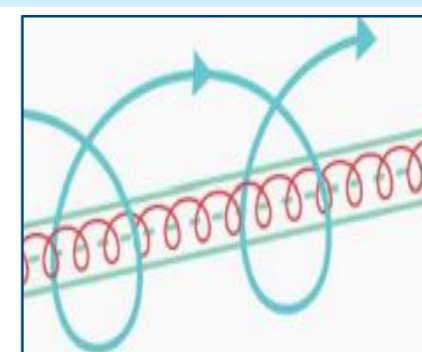
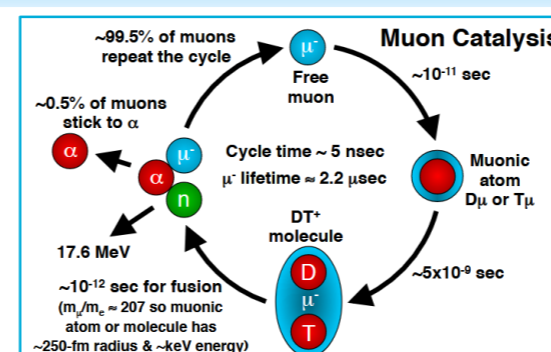
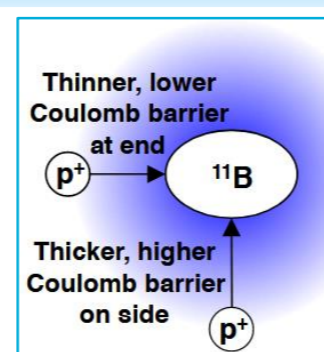
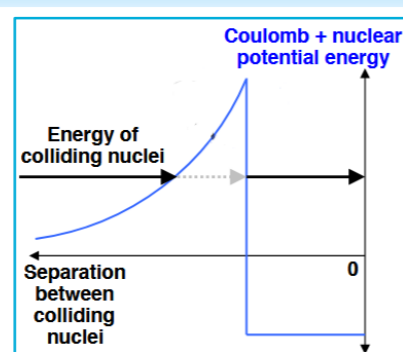
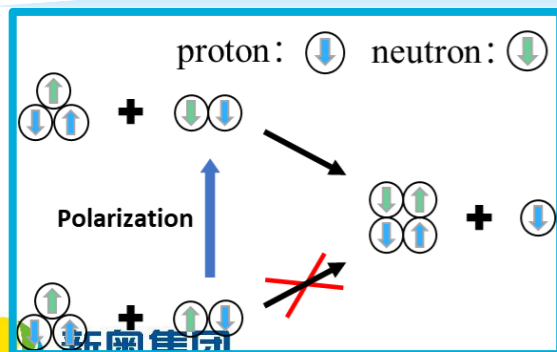
Spin-polarization

Shave Coulomb barrier Shape-polarization

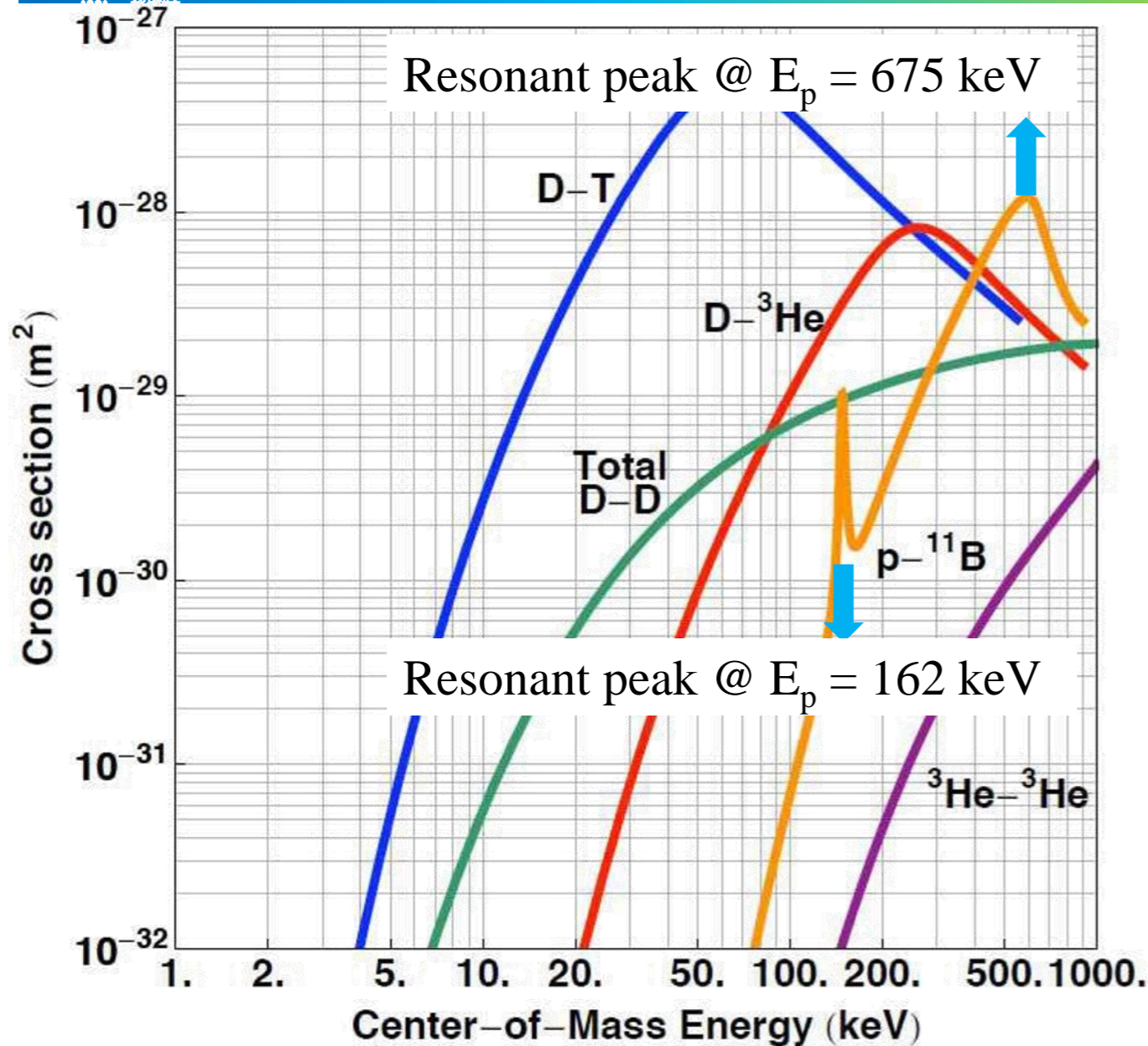
Muon Catalysis

Velocity Differential

Non-thermal



Ways to realize p-¹¹B fusion



Challenges in achieving p-¹¹B reaction within magnetic confinement fusion device:

1. Requires a higher temperature to ignite the p-¹¹B reaction
2. Low cross-section

Explorations for p-¹¹B reaction

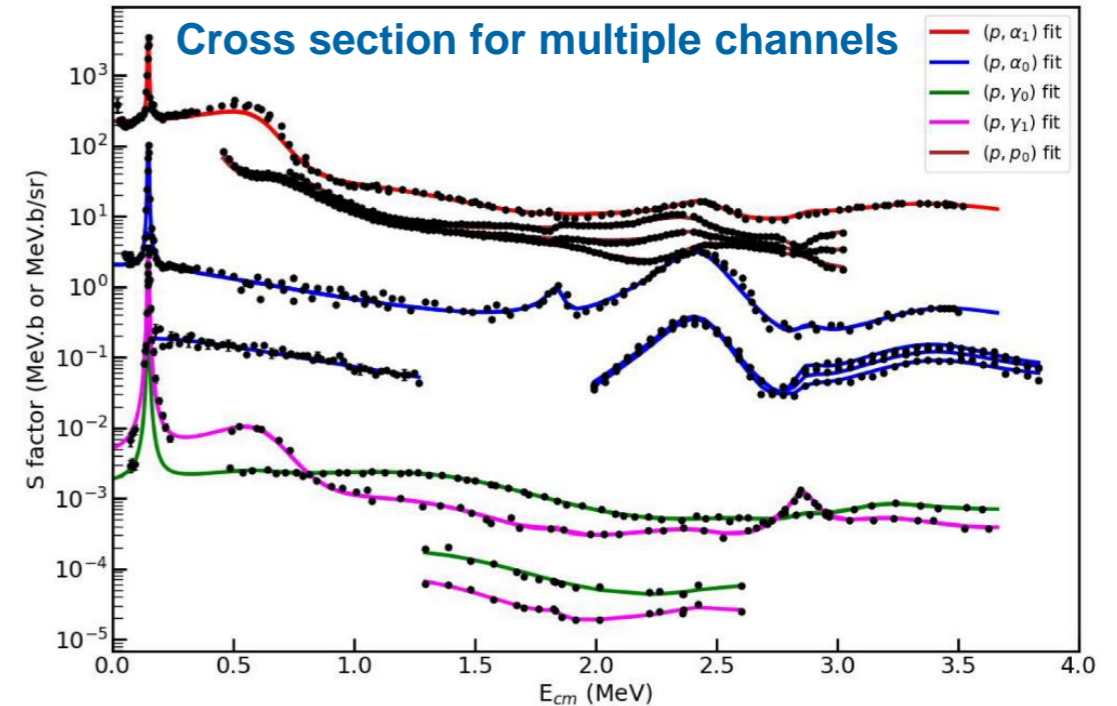
1. Realize non-Maxwellian ion distributions and raise the superthermal particle fraction
2. **Nuclear spin-polarization** ★

p-¹¹B Reaction: A Complex Process

Multi-pathway process with excited intermediates (¹²C, ⁸Be)

- ◆ $p + {}^{11}\text{B} \rightarrow p + {}^{11}\text{B}: {}^{11}\text{B}(p, p){}^{11}\text{B}$
- ◆ $p + {}^{11}\text{B} \rightarrow {}^{12}\text{C}^* \rightarrow \alpha_0 + {}^8\text{Be} \rightarrow \alpha_0 + \alpha_{01} + \alpha_{02}: {}^{11}\text{B}(p, \alpha_0)\alpha\alpha$
- ◆ $p + {}^{11}\text{B} \rightarrow {}^{12}\text{C}^* \rightarrow \alpha_1 + {}^8\text{Be}^* \rightarrow \alpha_1 + \alpha_{11} + \alpha_{12}: {}^{11}\text{B}(p, \alpha_1)\alpha\alpha$
- ◆ $p + {}^{11}\text{B} \rightarrow {}^{12}\text{C}^* \rightarrow 3\alpha: {}^{11}\text{B}(p, 2\alpha)\alpha$
- ◆ $p + {}^{11}\text{B} \rightarrow {}^{12}\text{C} + \gamma_0 (16.1 \text{ MeV}) : {}^{11}\text{B}(p, \gamma_0){}^{12}\text{C}$
- ◆ $p + {}^{11}\text{B} \rightarrow {}^{12}\text{C} + \gamma_1 (11.7 \text{ MeV}) + \gamma^* (4.439 \text{ MeV}) : {}^{11}\text{B}(p, \gamma_1){}^{12}\text{C}\gamma^*$

- Experimental measurements are unable to distinguish α particles from different channels and stages, and are interfered by scattered protons, making the data analysis highly dependent on physical models.
- The models are complex, remain controversial at present, and do not provide a complete description of the double differential cross sections.



- Through polarized scattering experiments
 - verify the predictions of polarized nuclear reaction theoretical models regarding the p-B reaction cross section enhancement
 - construct optical potentials to refine the physical model of p-B nuclear reactions.

Historical progress

Two theoretical contributions to 675 keV resonance

- Gain values match
- Angular distributions differ

ISSN 1063-7788, Physics of Atomic Nuclei, 2006, Vol. 69, No. 9, pp. 1461–1462. © Pleiades Publishing, Inc., 2006.
Original Russian Text © V.F. Dmitriev, 2006, published in Yadernaya Fizika, 2006, Vol. 69, No. 9, pp. 1496–1497.

NUCLEI
Theory

Effect of Polarization on the Cross Section for the Reaction $^{11}\text{B}(p, \alpha)^8\text{Be}^*$ and Angular Distributions of Its Products

V. F. Dmitriev*

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Received November 22, 2005

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DOI 10.1007/s10894-013-9643-8

ORIGINAL RESEARCH

Nuclear Spin-Polarized Proton and ^{11}B Fuel for Fusion Reactors: Advantages of Double Polarization in the $^{11}\text{B}(p, \alpha)^8\text{Be}^*$ Fusion Reaction

M. W. Ahmed · H. R. Weller

Published online: 14 November 2013
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Experiment for γ channel measurement:

- A_γ and CS in very low energy regime

PHYSICAL REVIEW C, VOLUME 62, 025803

The $^{11}\text{B}(\vec{p}, \gamma)^{12}\text{C}$ reaction below 100 keV

J. H. Kelley,^{1,2} R. S. Canon,^{1,3} S. J. Gaff,^{1,3} R. M. Prior,^{1,4} B. J. Rice,^{1,3} E. C. Schreiber,^{1,3} M. Spraker,^{1,4} D. R. Tilley,^{1,2}
E. A. Wulf,^{1,3} and H. R. Weller^{1,3}

¹Triangle Universities Nuclear Lab, Duke University, Durham, North Carolina 27708

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⁴Department of Physics, North Georgia College and State University, Dahlonega, Georgia 30597

(Received 5 April 2000; published 6 July 2000)

Experiment for p scattering measurement:

- A_γ and DCS at 30.3 MeV
- Optical-model parameter

2.B

Nuclear Physics A133 (1969) 255–265; © North-Holland Publishing Co., Amsterdam

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POLARIZATION IN $^{11}\text{B}(p, p)$ AND $^{11}\text{B}(p, p')$ AT 30.3 MeV

O. KARBAN †, J. LOWE, P. D. GREAVES and V. HNIZDO

Department of Physics, University of Birmingham, England

Received 20 May 1969

Spin-polarized p-¹¹B fusion (E_p=675 keV)

$$p : J^\pi = \frac{1}{2}^+ ; \quad {}^{11}\text{B} : J^\pi = \frac{3}{2}^-$$

Entrance channel:

$$\pi_p \cdot \pi_{{}^8\text{Be}} \cdot (-1)^{\ell_i} = \pi_{{}^{12}\text{C}} \rightarrow \ell_i = 0$$

$$\vec{s}_p + \vec{s}_{{}^8\text{Be}} + \vec{\ell}_i = \vec{s}_{{}^{12}\text{C}} \rightarrow \text{spin parallel } (\uparrow\uparrow)$$

Exit channel:

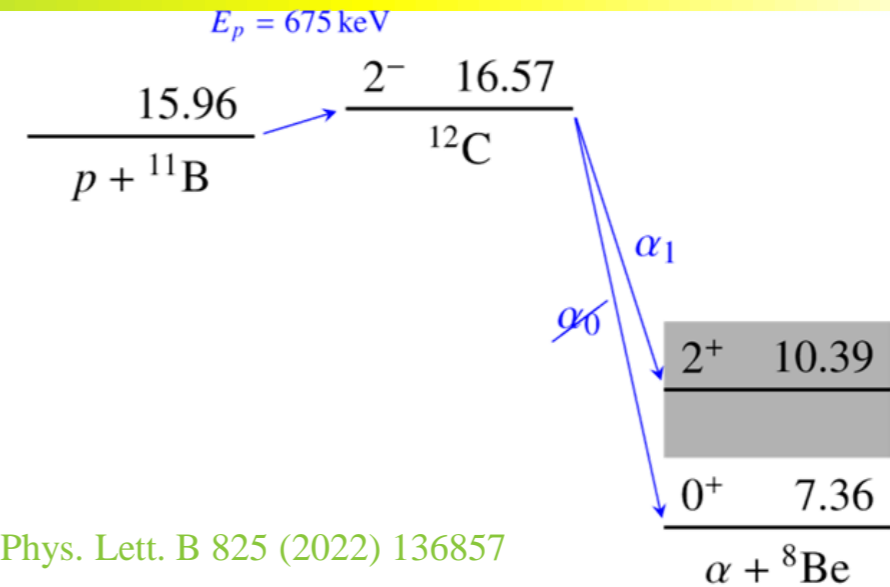
$$\alpha_0 : \ell_f = 1, 3, 5, \dots ; \quad \vec{s}_{{}^{12}\text{C}} = \vec{\ell}_f \rightarrow \times$$

$$\alpha_1 : \ell_f = 1, 3, 5, \dots ; \quad \vec{s}_{{}^{12}\text{C}} = \vec{\ell}_f + \vec{s}_{{}^8\text{Be}} \rightarrow \checkmark$$

The total cross section:

$$\sigma_0 = \sum_{\alpha} \sigma_{\alpha} = \sigma_1 + \sigma_2$$

spin antiparallel : $\frac{1}{2} \uparrow \frac{3}{2} \downarrow$ spin parallel : $\frac{1}{2} \uparrow \frac{3}{2} \uparrow$



M. Kuhlwein. Phys. Lett. B 825 (2022) 136857

$$\sigma_{\alpha} = \frac{4\pi}{(k_p^{cm})^2} \frac{(2J_{{}^{12}\text{C}} + 1)}{(2J_p + 1)(2J_{{}^{11}\text{B}} + 1)} \times \sum_{\beta} T_{(2S_{\alpha}+1)\ell_i, (2S_{\beta}+1)\ell_f}^{J_{{}^{12}\text{C}}}$$

Angular momentum-dependent Energy-Dependent

The influence of spin polarization on the reaction cross-section can be derived through the angular momentum coupling theory

Spin-polarized p-¹¹B fusion (E_p=675 keV)

Theoretical framework follows Ref. [R. M. Kulsrud. Nucl. Fusion. 26 (1986) 1443]

For the convenience, σ is expressed as

$$\sigma = \sum_{J=1,2} \sum_{m_1 m_2} P_{m_1} B_{m_2} \langle J, m = m_1 + m_2 | m_1, m_2 \rangle \sigma_J(E)$$

Spin wave function of the entrance channel

$$|s_\alpha\rangle = |\chi_p\rangle |\chi^{11B}\rangle = \sum_{m_1 m_2} a_{m_1} a_{m_2} |m_1, m_2\rangle$$

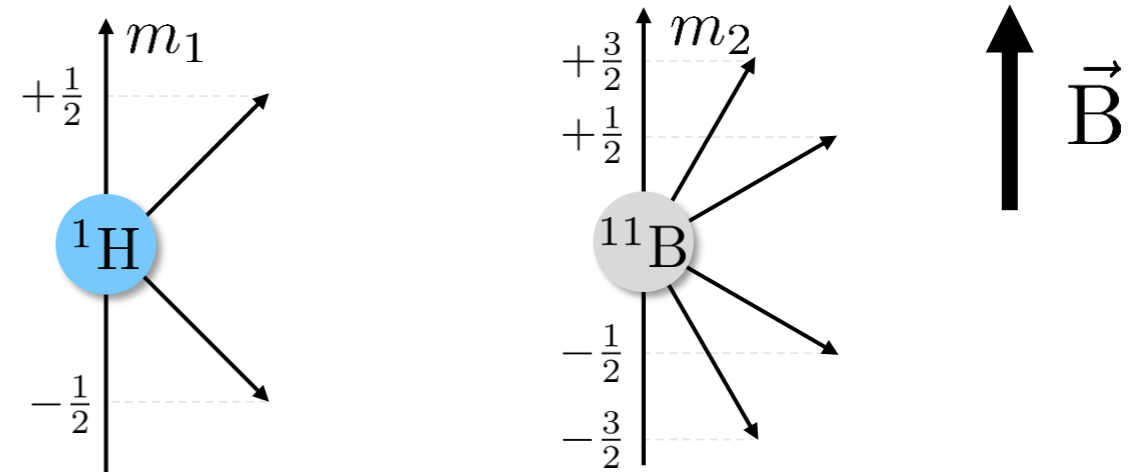
$$p : |\chi_p\rangle = \sum_{m_1} a_{m_1} |m_1\rangle ; \quad {}^{11}\text{B} : |\chi^{11B}\rangle = \sum_{m_2} a_{m_2} |m_2\rangle$$

The probabilities of magnetic substate m_1/m_2

$$P_{m_1} \equiv |a_{m_1}|^2 \quad ; \quad B_{m_2} \equiv |a_{m_2}|^2$$

The state of total angular momentum is expressed as

$$|J, m\rangle = \sum_{m_1 m_2} \left| \frac{1}{2} m_1 \frac{3}{2} m_2 \right\rangle \left\langle \frac{1}{2} m_1 \frac{3}{2} m_2 \middle| J, m \right\rangle$$



Finally, the contributions of different polarization states to the reaction cross-section can be derived.

$$\begin{aligned} \sigma = & \left[\frac{3}{4} \left(P_{-\frac{1}{2}} B_{\frac{3}{2}} + P_{\frac{1}{2}} B_{-\frac{3}{2}} \right) + \frac{1}{2} \left(B_{\frac{1}{2}} + B_{-\frac{1}{2}} \right) \right. \\ & \left. - \frac{1}{4} \left(P_{\frac{1}{2}} B_{\frac{1}{2}} + P_{-\frac{1}{2}} B_{-\frac{1}{2}} \right) \right] \sigma_1 \\ & + \left[\left(P_{\frac{1}{2}} B_{\frac{3}{2}} + P_{-\frac{1}{2}} B_{-\frac{3}{2}} \right) + \frac{1}{4} \left(P_{-\frac{1}{2}} B_{\frac{3}{2}} + P_{\frac{1}{2}} B_{-\frac{3}{2}} \right) \right. \\ & \left. + \frac{3}{4} \left(P_{\frac{1}{2}} B_{\frac{1}{2}} + P_{-\frac{1}{2}} B_{-\frac{1}{2}} \right) + \frac{1}{2} \left(P_{\frac{1}{2}} B_{-\frac{1}{2}} + P_{-\frac{1}{2}} B_{\frac{1}{2}} \right) \right] \sigma_2 \end{aligned}$$

Influence of Spin Polarization on Cross Section

❖ Polarization effects on reaction cross-section

a) Unpolarized spin $P_{m_1} = 1/2, B_{m_2} = 1/4$

$$\sigma_{unpol.} = \frac{3}{8}\sigma_1 + \frac{5}{8}\sigma_2$$

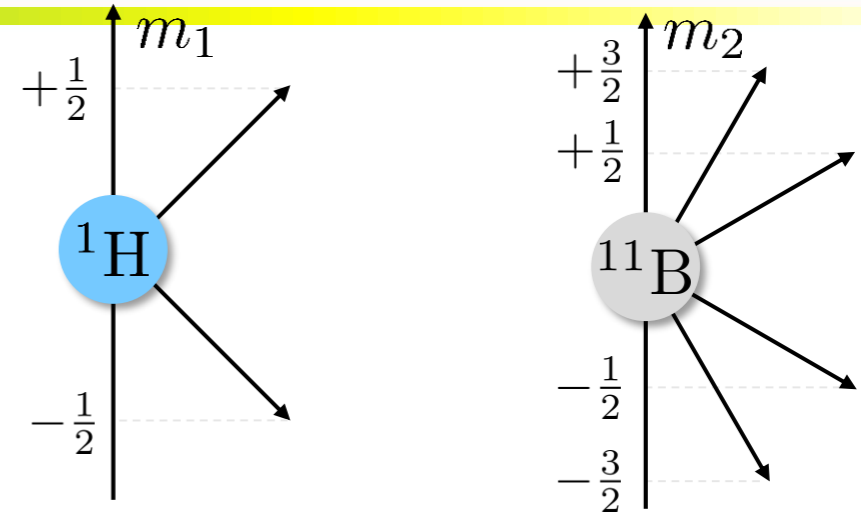
b) Spin aligned along the magnetic field

i. $P_{+\frac{1}{2}} = B_{+\frac{3}{2}} = 1$

$$\sigma_{+\frac{1}{2}, +\frac{3}{2}} = \sigma_2$$

❖ Compared with the unpolarized scenario

$$\frac{\sigma_{+\frac{1}{2}, +\frac{3}{2}}}{\sigma_{unpol.}} = \frac{\sigma_2}{\frac{5}{8}\sigma_2} = \mathbf{1.6}$$



ii. $P_{+\frac{1}{2}} = B_{+\frac{1}{2}} = 1$

$$\sigma_{+\frac{1}{2}, +\frac{1}{2}} = \frac{1}{4}\sigma_1 + \frac{3}{4}\sigma_2$$

$$\frac{\sigma_{+\frac{1}{2}, +\frac{1}{2}}}{\sigma_{unpol.}} = \frac{\frac{3}{4}\sigma_2}{\frac{5}{8}\sigma_2} = \mathbf{1.2}$$

Polarized p¹¹B reaction shows **~60% maximum enhancement** in total cross-section vs. unpolarized case

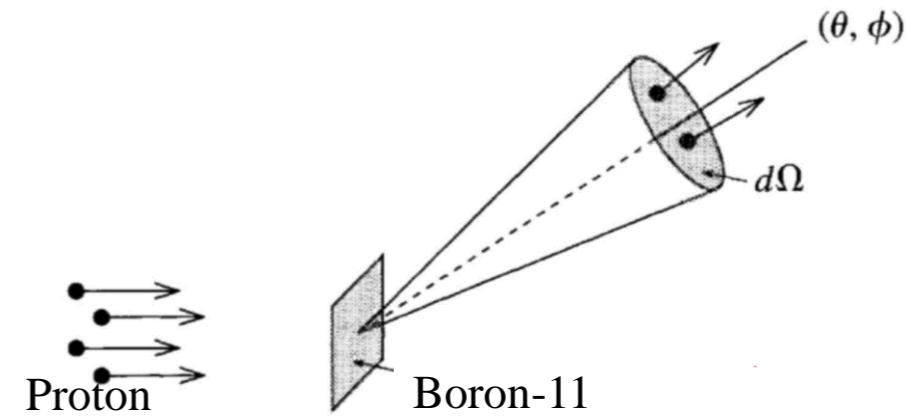
Angular distribution of spin-polarized fusion

To obtain the product angular distribution, the final-state wave function can be defined as

$$|\psi_f\rangle = \sum_m f_{2,m} |2m\rangle,$$

and the σ is expressed as

$$\sigma = \int d\Omega \sum_m f_{2,m}^2 \langle 2m|2m\rangle = \int d\Omega \sum_m f_{2,m}^2.$$



Compared with the previous expression $\sigma = \sum_{m_1 m_2} P_{m_1} B_{m_2} |\langle 2, m_1 + m_2 | m_1 m_2 \rangle|^2 \sigma_2(E)$, we have

$$\begin{aligned} |\psi_f\rangle &= \sum_{m_1, m_2} (P_{m_1} B_{m_2} \sigma_2)^{\frac{1}{2}} \langle 2, m_1 + m_2 | m_1, m_2 \rangle |2m\rangle \\ &= \sum_{m_1, m_2} \sum_{m_l, m_s} (P_{m_1} B_{m_2} \sigma_2)^{\frac{1}{2}} \langle 2, m_1 + m_2 | m_1, m_2 \rangle \langle ls, m_l m_s | 2m \rangle |ls, m_l m_s \rangle \end{aligned}$$

Angular distribution of spin-polarized fusion

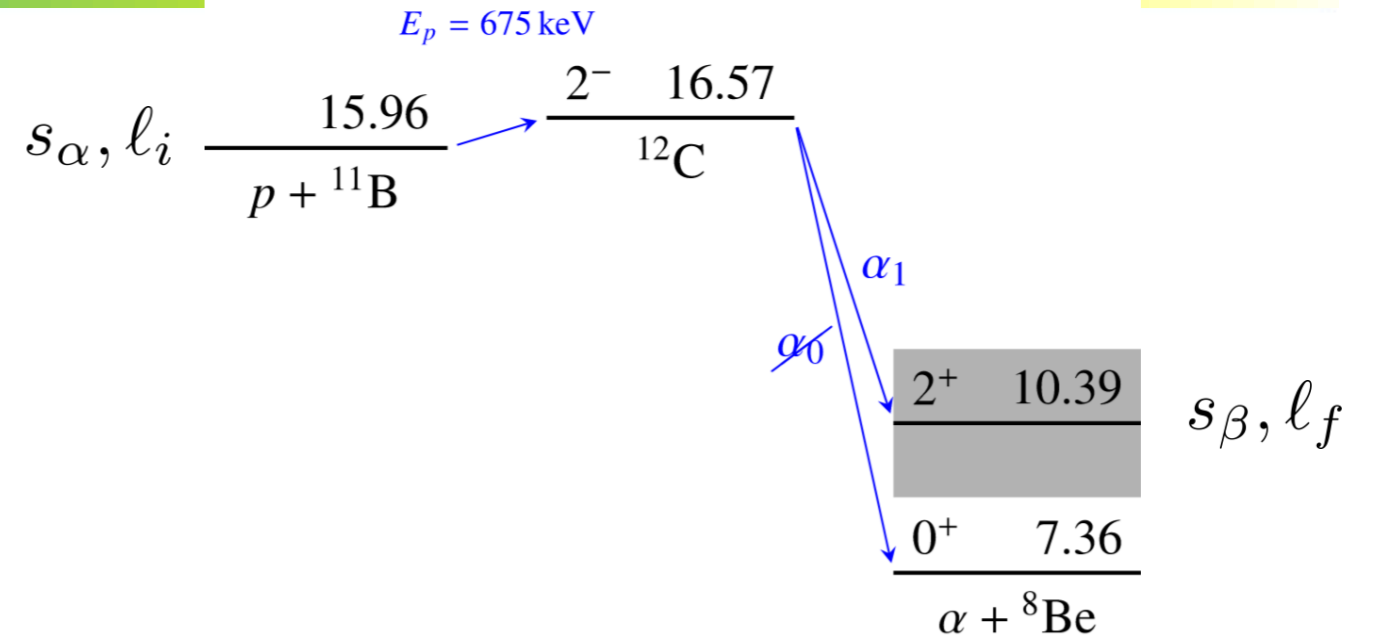
According to Ref. [M. Kuhlwein. PLB 825 (2022) 136857], the relative angular momentum of reaction products can be $\ell_f = 1, 3$.

❖ $\ell_f = 1$

$$|\psi_f\rangle_{\ell=1} = \sum_{m_1, m_2} \sum_{m_l, m_s} (\sigma_2 P_{m_1} B_{m_2})^{1/2} \langle 2, m_1 + m_2 | m_1 m_2 \rangle \langle \mathbf{12}, m_l m_s | 2 m_l + m_s \rangle | \mathbf{12}, m_l m_s \rangle$$

❖ $\ell_f = 3$

$$|\psi_f\rangle_{\ell=3} = \sum_{m_1, m_2} \sum_{m_l, m_s} (\sigma_2 P_{m_1} B_{m_2})^{1/2} \langle 2, m_1 + m_2 | m_1 m_2 \rangle \langle \mathbf{32}, m_l m_s | 2 m_l + m_s \rangle | \mathbf{32}, m_l m_s \rangle$$



Based on the final-state wave function, the angular distribution of the final state can be expressed as

$$\frac{d\sigma}{d\Omega} = \langle \psi_f | \psi_f \rangle$$

Angular distribution of spin-polarized fusion

$$P_{+\frac{1}{2}} = B_{+\frac{3}{2}} = 1$$

$$\diamond \ell_f = 1$$

$$\frac{d\sigma}{d\Omega} = \left(\frac{1}{3} |Y_{11}|^2 + \frac{2}{3} |Y_{10}|^2 \right) \sigma_2$$

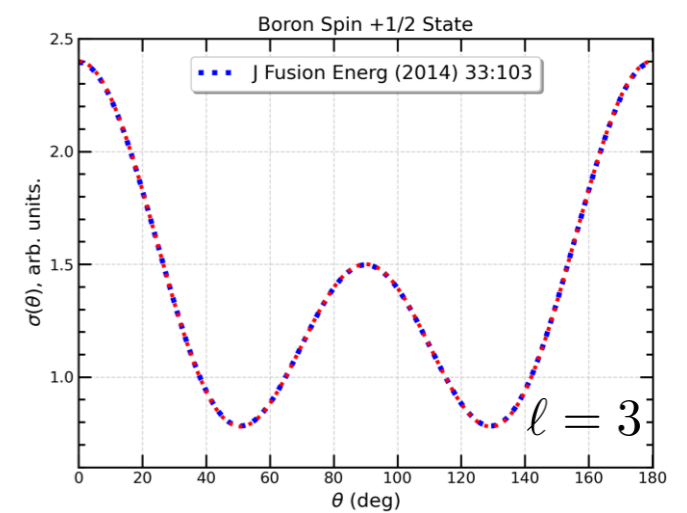
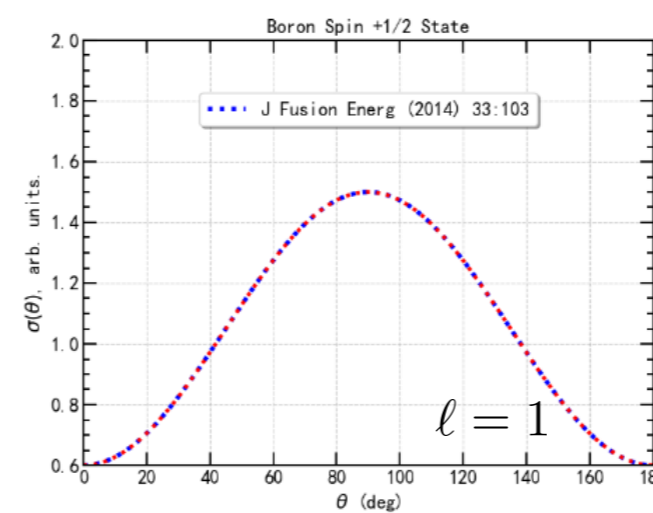
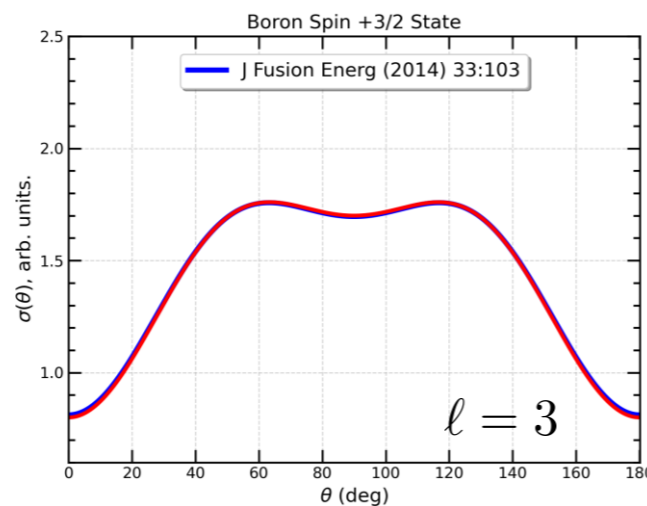
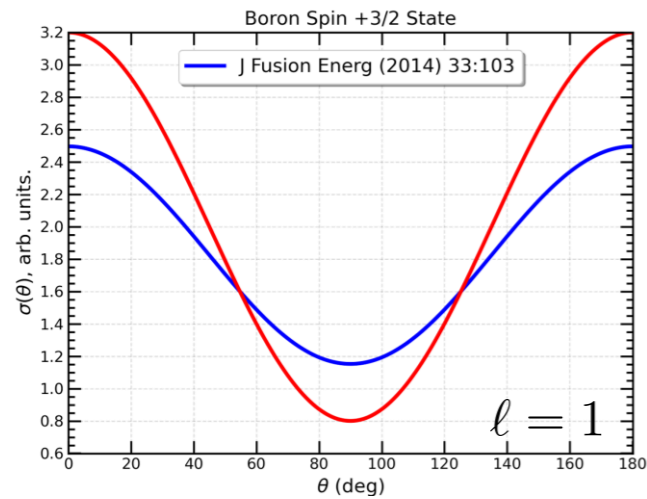
$$\diamond \ell_f = 3$$

$$\frac{d\sigma}{d\Omega} = \frac{3}{4} \left(\frac{1}{2} |Y_{11}|^2 + \frac{1}{6} |Y_{10}|^2 + \frac{1}{3} |Y_{1-1}|^2 \right) \sigma_2$$

$$P_{+\frac{1}{2}} = B_{+\frac{1}{2}} = 1$$

$$\frac{d\sigma}{d\Omega} = \left(\frac{5}{14} |Y_{33}|^2 + \frac{5}{14} |Y_{32}|^2 + \frac{3}{14} |Y_{31}|^2 + \frac{1}{14} |Y_{30}|^2 \right) \sigma_2$$

$$\frac{d\sigma}{d\Omega} = \frac{3}{4} \left(\frac{5}{14} |Y_{33}|^2 + \frac{1}{7} |Y_{31}|^2 + \frac{2}{7} |Y_{30}|^2 + \frac{3}{14} |Y_{3-1}|^2 \right) \sigma_2$$

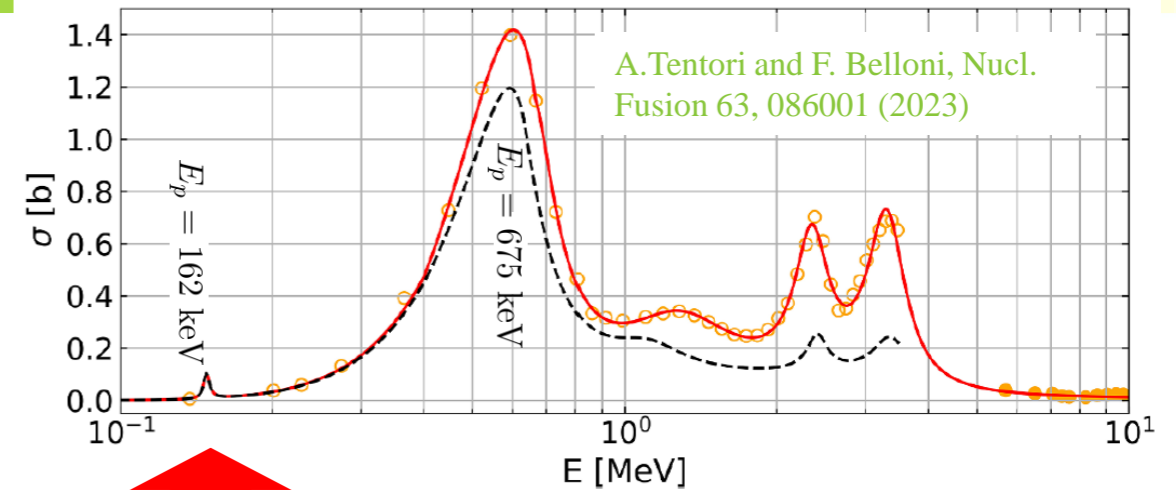
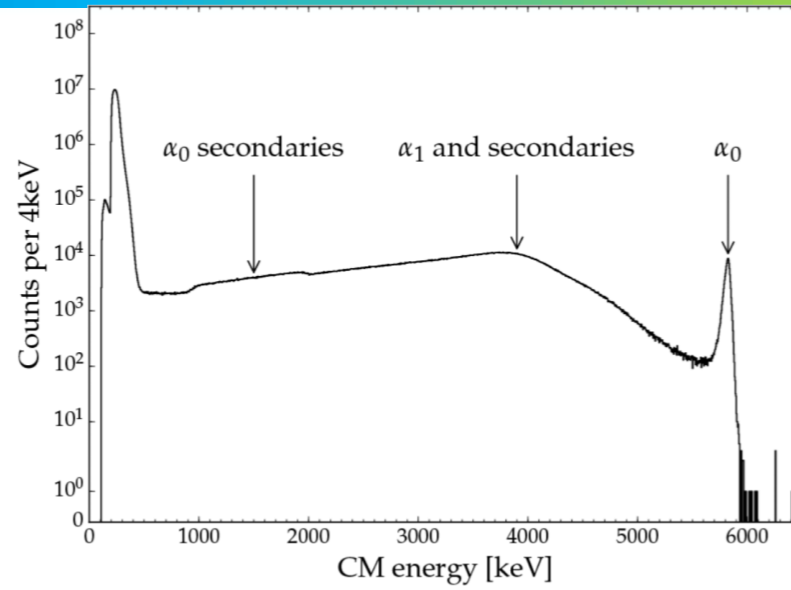


Angular distributions can be measured to verify the theoretical description.

Spin-polarized p-¹¹B fusion (E_p=162 keV)

For E_p = 675 keV, the α₁ angular distribution is difficult to identify.

Need to find a resonance state capable of decaying via the α₀ channel.



A. Tentori and F. Belloni, Nucl. Fusion 63, 086001 (2023)

$$\pi^p \cdot \pi^{^{11}\text{B}} \cdot \pi^{\ell_i} = +1 \rightarrow \ell_i = 1, 3, \dots$$

Parity conservation requires the minimum $\ell_i = 1$.

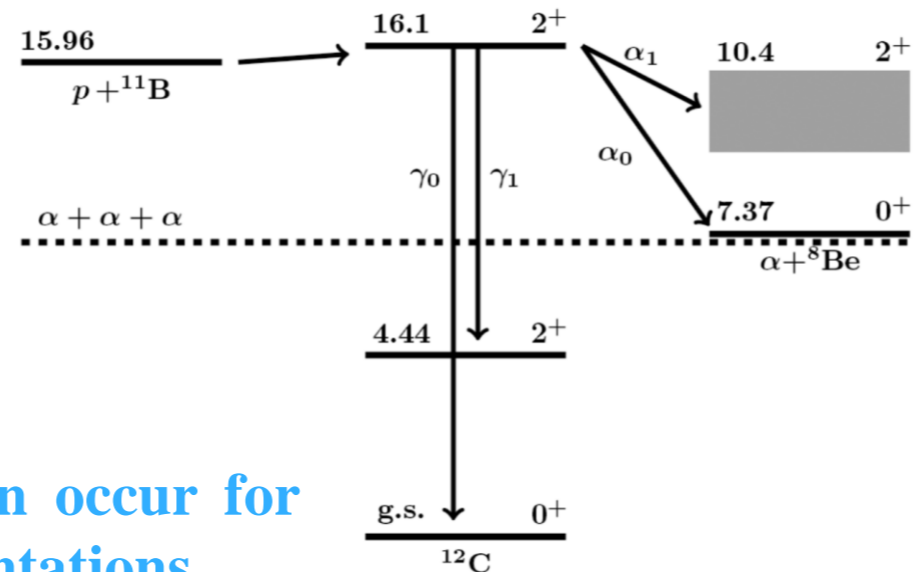
$$\text{spin antiparallel: } \frac{1}{2} \uparrow \frac{3}{2} \downarrow \quad (J_{12} = 1)$$

$$J_{12} \otimes \ell = 0, 1, 2$$

$$\text{spin parallel: } \frac{1}{2} \uparrow \frac{3}{2} \uparrow \quad (J_{12} = 2)$$

$$J_{12} \otimes \ell = 1, 2, 3$$

Reaction can occur for all spin orientations



$$s_\beta = 2 \quad \ell_f = 0, 2$$

$$s_\beta = 0 \quad \ell_f = 2$$

Spin-polarized p-¹¹B fusion (E_p=162 keV)

a) Unpolarized spin $P_{m_1} = 1/2, B_{m_2} = 1/4$

$$\sigma_{unpol.} = \frac{5}{24} (\sigma_{2\uparrow \downarrow} + \sigma_{2\uparrow \uparrow})$$

b) Spin aligned along the magnetic field

i. $P_{+\frac{1}{2}} = B_{+\frac{3}{2}} = 1$

$$\sigma_{+\frac{1}{2}, +\frac{3}{2}} = \frac{2}{3} \sigma_{2\uparrow \uparrow}$$

ii. $P_{+\frac{1}{2}} = B_{+\frac{1}{2}} = 1$

$$\sigma_{+\frac{1}{2}, +\frac{1}{2}} = \frac{1}{8} (\sigma_{2\uparrow \downarrow} + \sigma_{2\uparrow \uparrow})$$



The 162 keV resonance yields energy-distinguishable α particles, but the effect of polarization on the cross section cannot be directly derived as with the 675 keV resonance. This mainly because the $V_{so}(r)$

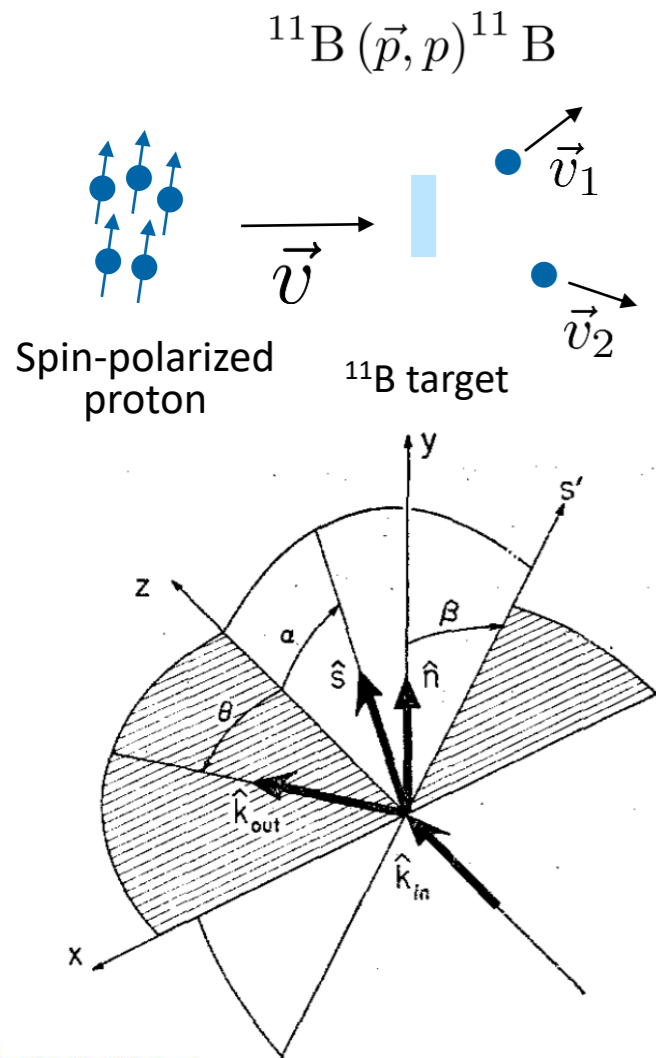
$$V(r) = V_0(r) + V_{SO}(r) \mathbf{L} \cdot \mathbf{S}$$

$$\sigma_{\alpha} = \frac{4\pi}{(k_p^{cm})^2} \frac{(2J_{12C} + 1)}{(2J_p + 1)(2J_{11B} + 1)} \times \sum_{\beta} T_{(2S_{\alpha}+1)\ell_i, (2S_{\beta}+1)\ell_f}^{J_{12C}}$$

The transition matrix elements (T) need to be determined by fitting polarized p-¹¹B reaction data.

Next Steps

To obtain the influence of nuclear spin polarization on the reaction cross section at the 162 keV resonance, experimental measurements are required to determine the spin-orbit coupling potential (V_{SO}) in the vicinity of this energy.



$$V(r) = V_0(r) + V_{SO}(r) \ell \cdot S$$

$$\frac{d\sigma}{d\Omega} = |A|^2 + |B|^2 + 2\text{Re}(AB^*) (\vec{n} \cdot \vec{s}_{in}), \quad A_y(\theta) = \frac{2\text{Re}(AB^*)}{|A|^2 + |B|^2} = \frac{\frac{d\sigma_+}{d\Omega} - \frac{d\sigma_-}{d\Omega}}{s_- \frac{d\sigma_+}{d\Omega} + s_+ \frac{d\sigma_-}{d\Omega}}$$

$$= |A|^2 + |B|^2 [1 + A_y(\theta) (\vec{n} \cdot \vec{s}_{in})]$$

Where,

$$A(\theta) = f_C(\theta) + \frac{i}{2k} \sum_l \left[(l+1) (1 - S_l^{l+\frac{1}{2}}) + l (1 - S_l^{l-\frac{1}{2}}) \right] e^{2i\sigma_l} P_l(\cos\theta)$$

$$B(\theta) = \frac{1}{2k} \sum_l \left(S_l^{l+\frac{1}{2}} - S_l^{l-\frac{1}{2}} \right) e^{2i\sigma_l} P_l^1(\cos\theta)$$

Singly polarized elastic scattering experiments + theory

⇒ Optical potential

What we want to do

Optical potential + theory

⇒ The effect of polarization at different angles

和实验数据的对比：

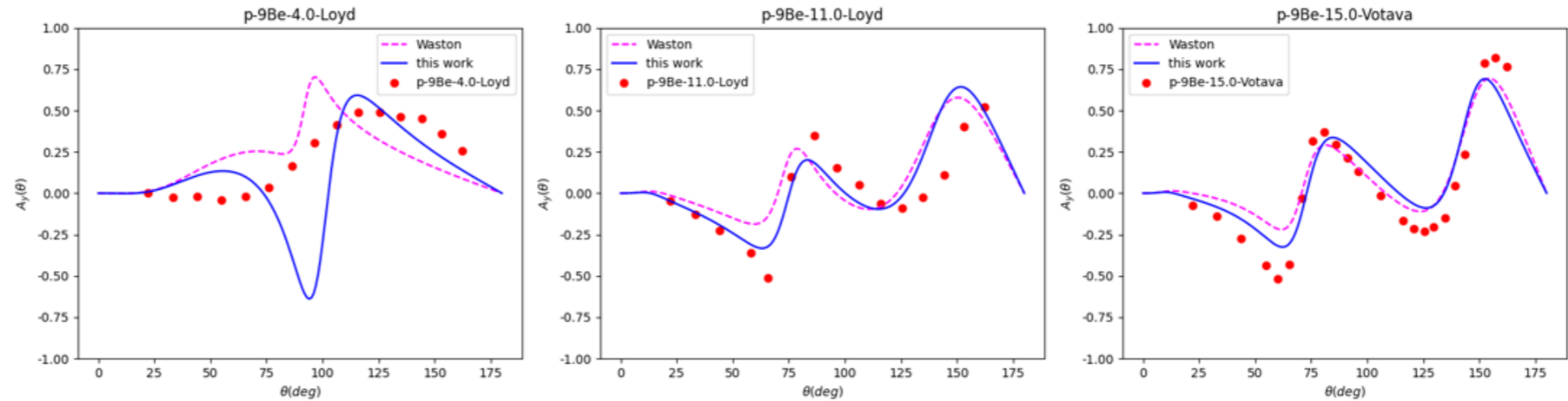
极化数据（分析本领）

蓝色实线：当前工作

紫色虚线：Watson势

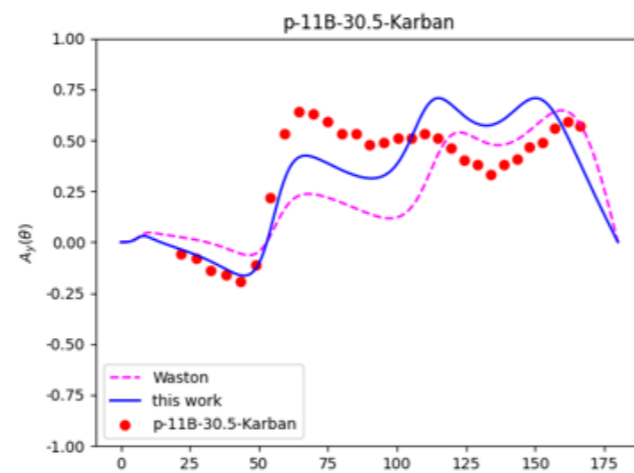
B.A. Watson, P.P. Singh, and R.E. Segel, Phys. Rev. 182, 977 (1960)

${}^9\text{Be}$ （此数据没有用于拟合参数，因此可看作是对现有结果的检验）：←



←

${}^{11}\text{B}$ ：←



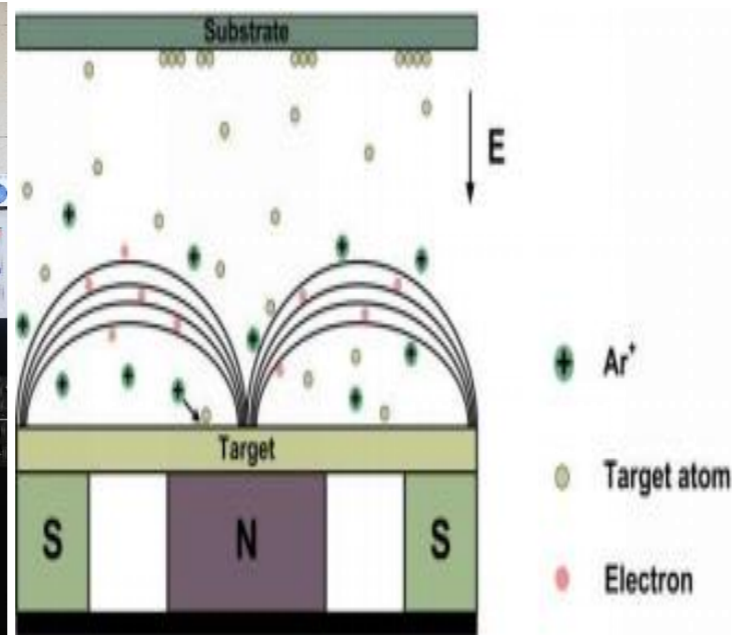
用于约束自旋轨道相互作用参数
对于计算极化截面重要

李直、杨威、高正阳
2025年10月23日 北航

By Danyang PANG, Beihang University

Experimental Boron Targets at ENN

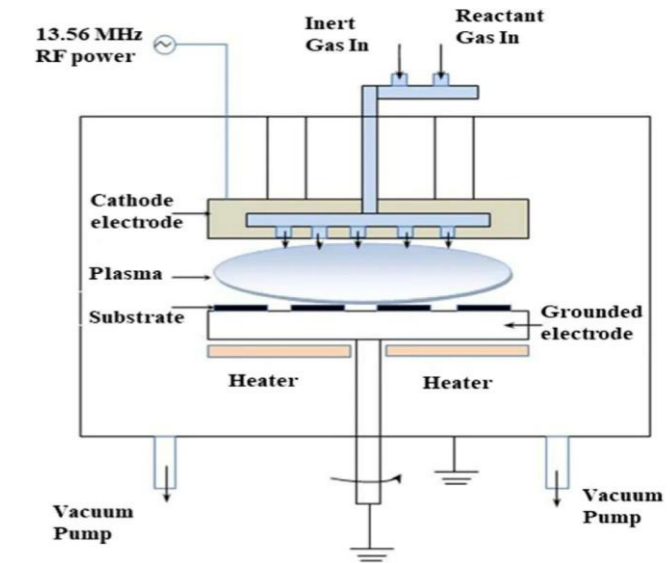
- **Boron nuclear target:** Materials containing nuclear target components (such as boron powder, borane) are deposited on a substrate to form a film through methods such as magnetron sputtering, plasma-enhanced chemical vapor deposition, (PECVD) or hot pressing, resulting in a substrate-supported boron nuclear target. Subsequently, the boron film is etched off by wet etching, retrieved, and mounted on a frame (target frame) to obtain a self-supported boron nuclear target.
- **Boron pellet:** Boron powder and a binder are used as raw materials. The boron pellet is obtained through processes such as shaping and sintering.



Magnetron sputtering



PECVD

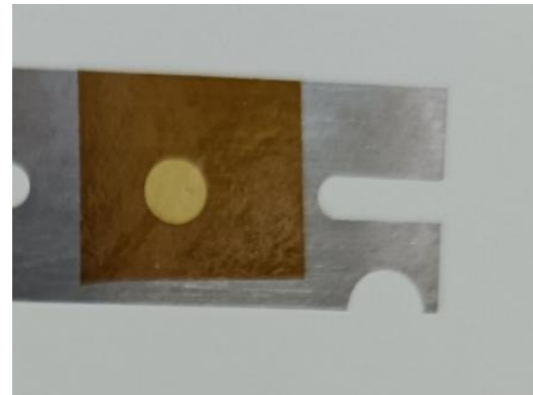


Experimental Boron Targets at ENN

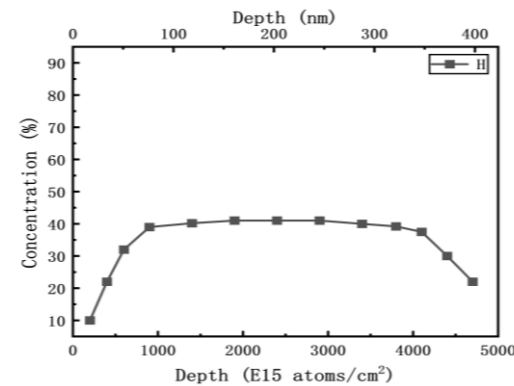
- Mastering the fabrication technology of backed and self-supported pure boron targets and hydrogen-containing boron targets, achieving the preparation of boron targets with thicknesses of 0.1-10 μ m, hydrogen content of 0-40 at%, and adjustable boron content in carbon-hydrogen-boron targets



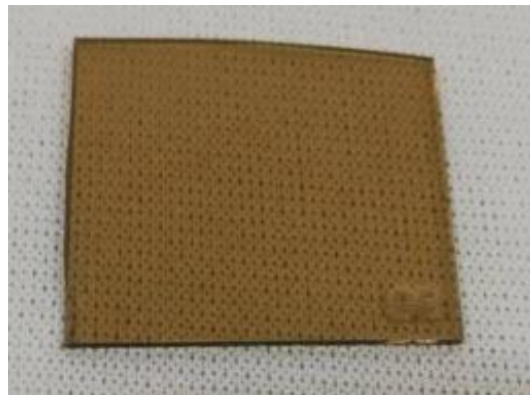
Nanometer-thick self-supporting ¹¹B target with $\phi = 10.0$ mm



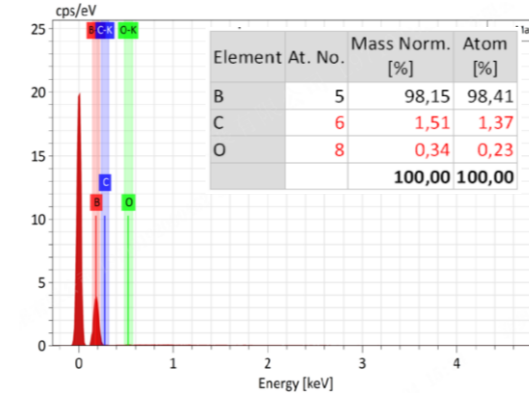
Micrometer-thick self-supporting hydrogen-containing boron target with $\Phi=5.0$ mm



Hydrogen content changes with thickness of hydrogen-containing boron target



Carbon-hydrogen-boron target

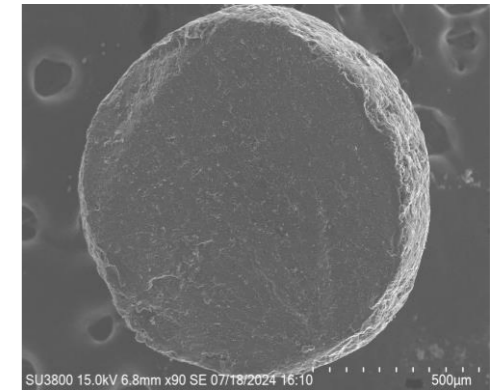


Composition test of high-purity nuclear target

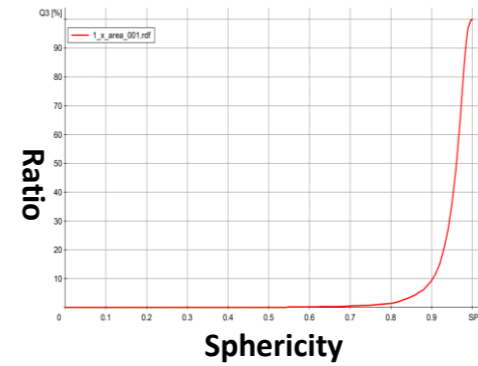
- Mastering the fabrication technology of boron pellets with a sphericity averaging about 90% and capable of being accelerated to approximately 150 m/s, along with the technology for the pellet injection.



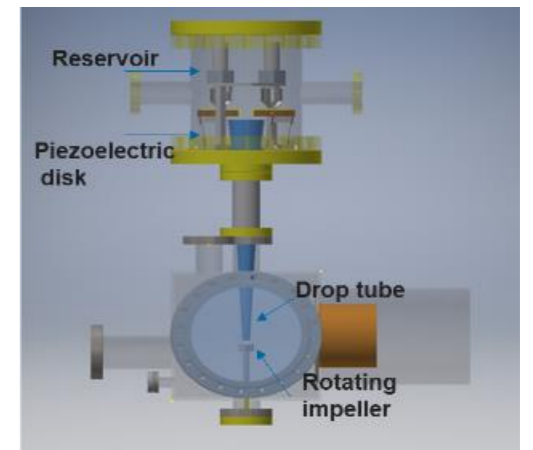
The spherical boron pellets with $\Phi=1.0$ mm



Uniform and dense cross-section of pellets

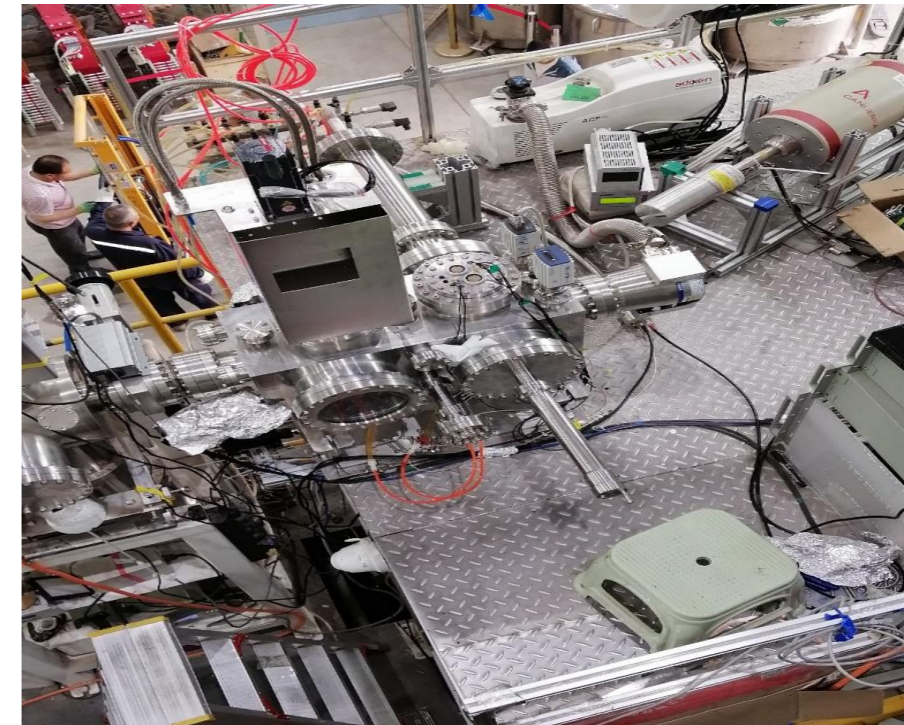
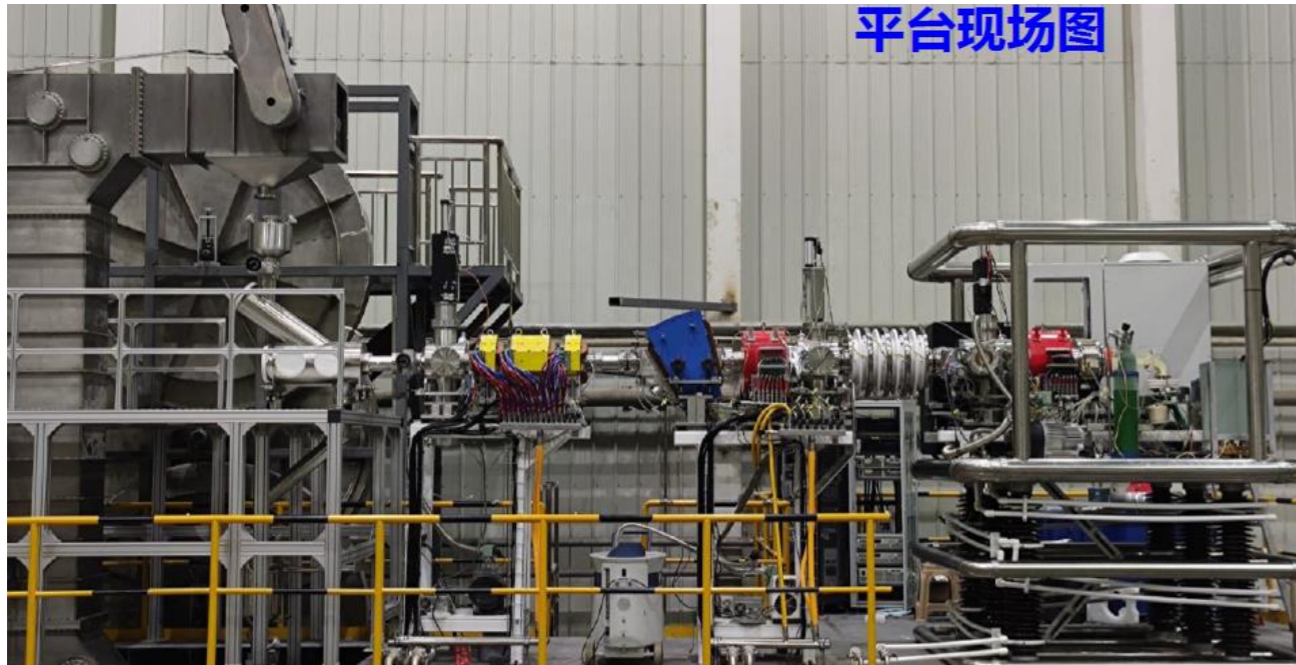


The main sphericity of pellets is above 90%



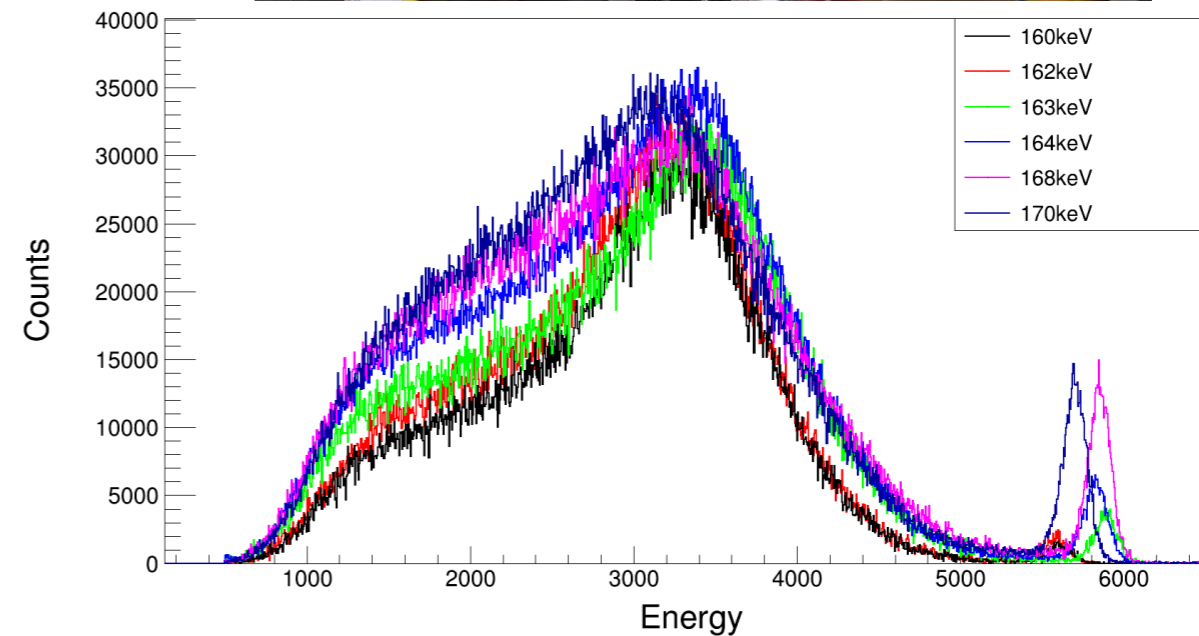
Pellet injection system

Collaborations with IMP on p-B measurement



该装置基于强流离子束热源完成颗粒流靶的热耦合测试，主要技术指标如下：

- ◆ 离子束种类：质子
- ◆ 离子束能量：< 240KeV
- ◆ 离子束流强：> 10mA
- ◆ 离子束束斑： $\phi < 20\text{mm}$
- ◆ 离子束引出模式：直流&脉冲



Summary and next step

Summary:

- ◆ Only double polarization ($P_{+1/2}, B_{+3/2}$) can achieve a 60% gain in the 675 keV resonance region
- ◆ Further derivate polarized reaction theory model for the 162 keV resonance peak and non-resonance regions
 - less demanding in experimental requirements
 - Validation through $^{11}\text{B}(\vec{p}, \alpha_0)$ channel
- ◆ ENN possess the technical expertise and can supply boron targets

Research plan and requirements:

- ◆ Propose $^{11}\text{B}(\vec{p}, p/\alpha/\gamma)^*$ measurement at low energy regime
 - Si/SiC/CZT/Semi-conductor detector: $p@100\sim 200$ keV, $\alpha@1\sim 6$ MeV
 - HPGe: $\gamma@4.44/11.7/16.1$ MeV
 - POI: Polarized rate, Ay and DCS
 - Energy range 100~200 keV, especially around 162 keV
 - Target and experiment designs depend on beam conditions (intensity/focus/pulse/purity...)

Thanks for your attention

