Fundamental symmetry violation in the neutron nuclei interaction

报告人：樊瑞睿（中国科学院高能物理研究所）

报告内容来自：NOPTREX合作组，北京大学，JINR-FLNP

核物理的宇称破坏

The violation of Parity in nuclear

Theoretical Framework

We could understand the vectors characteristics under Parity and Time transformation with their classical expression.

Parity Transformation:

$$\vec{k} = m\frac{d\vec{r}}{dt} \qquad \vec{k} = m\frac{d(-\vec{r})}{dt} \qquad \boxed{\vec{k} \to -\vec{k}}$$

P-odd

$$\vec{L} = m\left(\vec{r} \times \frac{d\vec{r}}{dt}\right) \qquad \vec{L} = m\left((-\vec{r}) \times \frac{d(-\vec{r})}{dt}\right) \qquad \boxed{\vec{L} \to +\vec{L}}$$

P-even

探索宇称破坏的实验

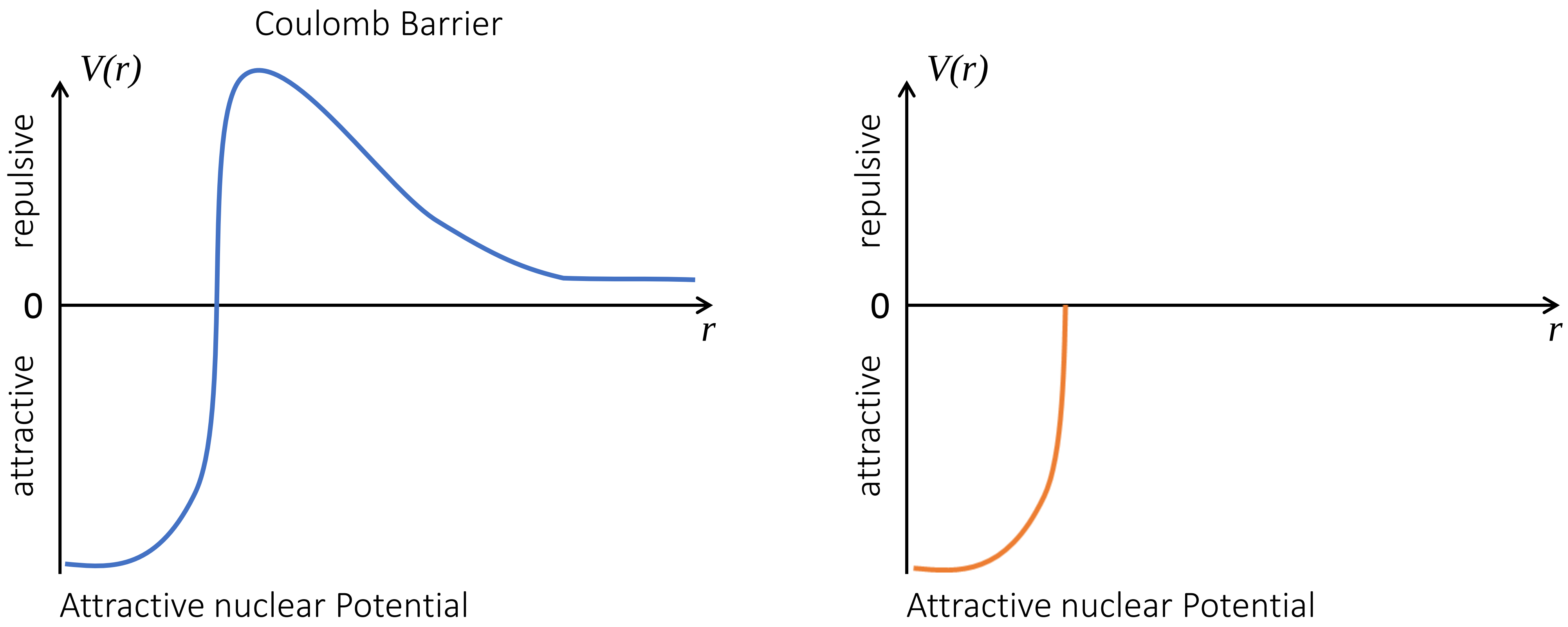
$$\vec{p} + p \to p + p$$

通过纵向极化的质子与非极化的质子靶散射测量的实验有四组，结果如下：

$$A_L(\bar{p}p; 13.6\ MeV) = (-0.93 \pm 0.20 \pm 0.05) \times 10^{-7}$$
$$A_L(\bar{p}p; 15\ MeV) = (-1.7 \pm 0.8) \times 10^{-7}$$
$$A_L(\bar{p}p; 45\ MeV) = (-1.57 \pm 0.23) \times 10^{-7}$$
$$A_L(\bar{p}p; 221\ MeV) = (+0.84 \pm 0.34) \times 10^{-7}$$

Parity violation in proton proton scattering at 13.6-MeV. Phys Lett B. (1991) 256:11–4.
Parity violation in the scattering of 15 MeV protons by hydrogen. AIP Conf Proc. (1979) 51:224–30.
Precision measurement of parity violation in proton proton scattering at 45-MeV.Phys Rev Lett. (1987) 58:1616.
Parity violation in proton proton scattering at 221-MeV. Phys Rev C. (2003) 68:034004.

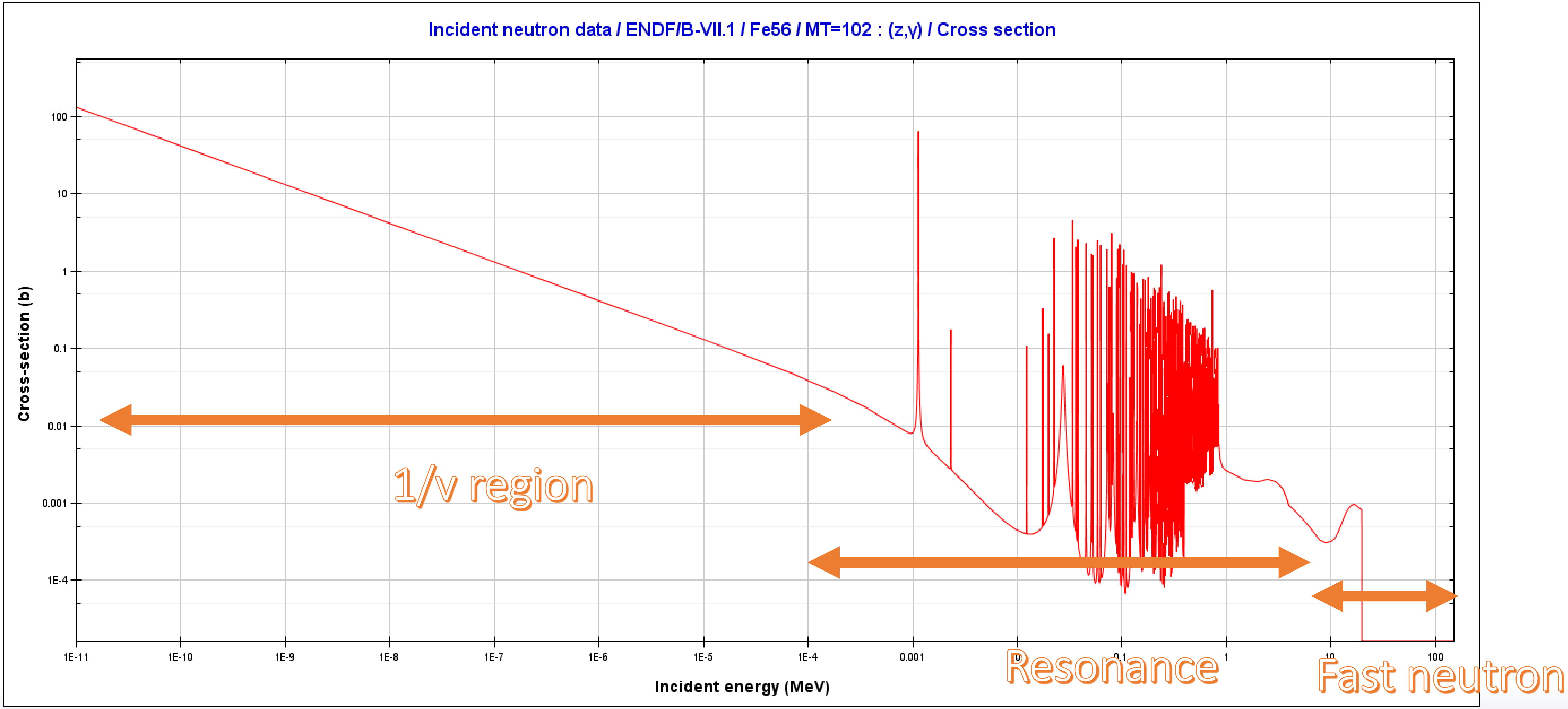
Coulomb barrier



Proton

Neutron

A typical cross section of the neutron induced reaction



Neutron induced cross section

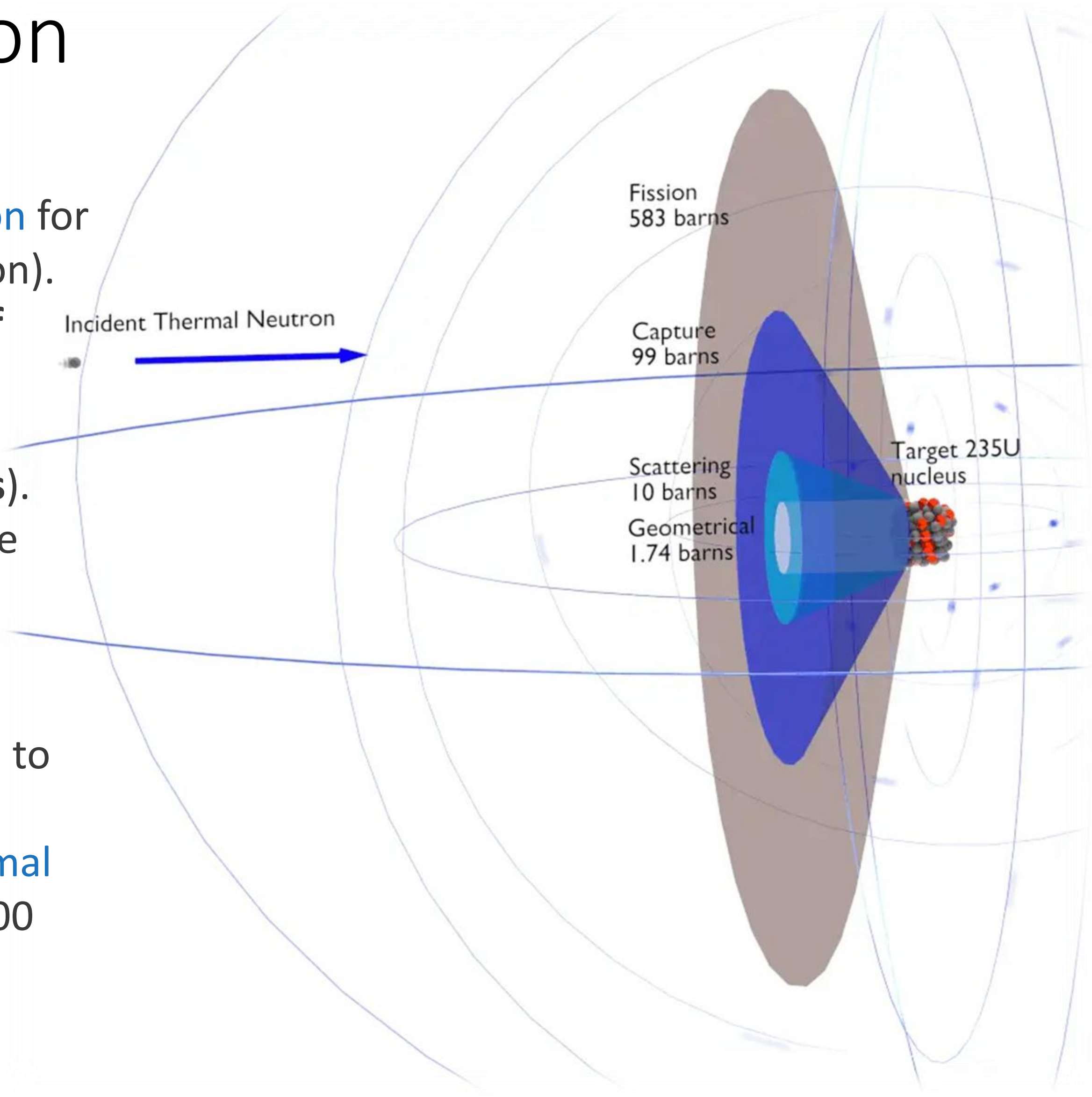
Typical Values of Microscopic Cross-sections

•**Uranium 235** is a fissile isotope and its fission cross-section for thermal neutrons is about **585 barns** (for 0.0253 eV neutron). For fast neutrons its fission cross-section is **on the order of barns**.

•**Xenon-135** is a product of U-235 fission and has a **very large neutron capture cross-section** (about **2.6 x 10^6 barns**).

•**Boron** is commonly used as a **neutron absorber** due to the high neutron cross-section of isotope ^{10}**B**. Its **(n,alpha) reaction** cross-section for thermal neutrons is about **3840 barns** (for 0.025 eV neutron).

•**Gadolinium** is commonly used as a **neutron absorber** due to very high neutron absorbtion cross-section of two isotopes ^{155}**Gd** and ^{157}**Gd**. ^{155}Gd has 61 000 barns for thermal neutrons (for 0.025 eV neutron) and ^{157}Gd has even 254 000 barns.



https://www.nuclear-power.com/neutron-cross-section/

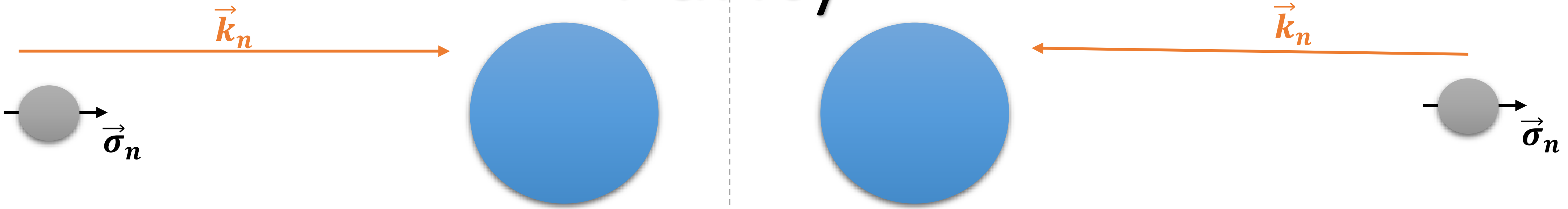
极化束流

We have a little bit of freedom when it comes to how we write $\boldsymbol{f}$, our **forward scattering amplitude**. What are some easy to control/understand experimental observables when it comes to scattering neutrons off of (polarized) nuclei?

$\vec{k}_n$: **neutron momentum**

$\vec{\sigma}_n$: **neutron spin**

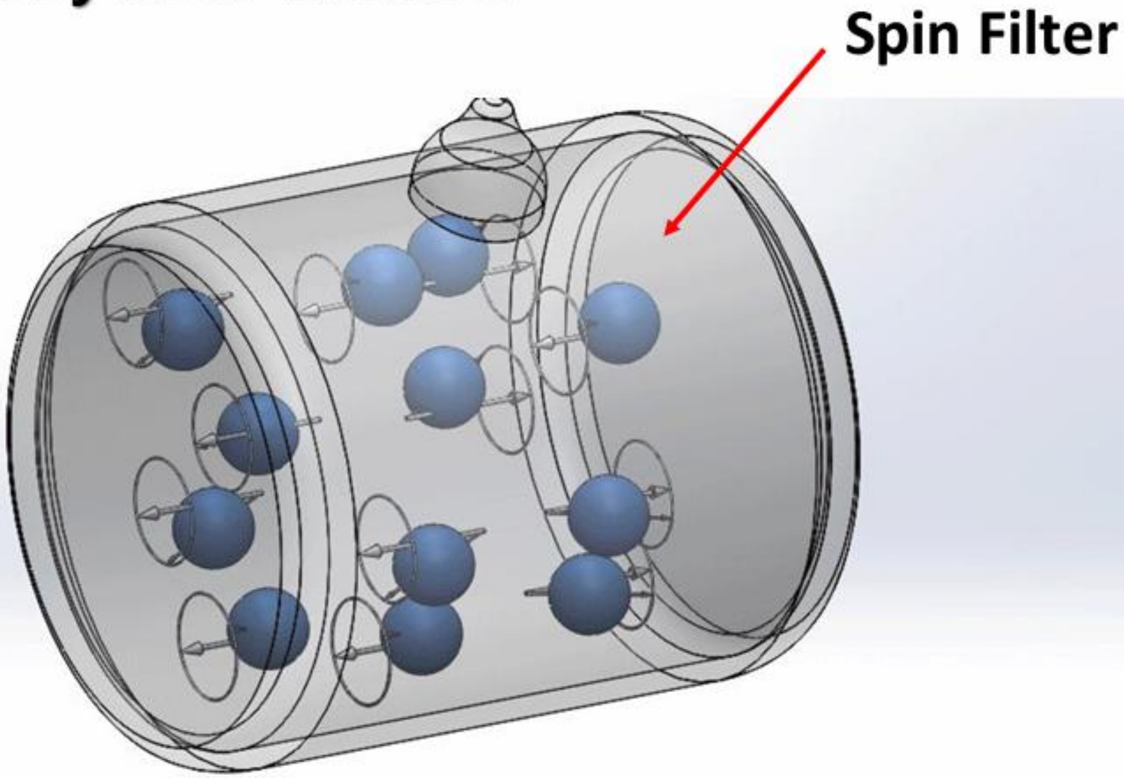
Parity



极化束流或极化的靶是在真实物理实验中构建赝标物理量的最好方式。

^{3}He中子极化装置

Polarize ^{3}He By SEOP Method



Including system:

- Air heating
- Rb/K/^{3}He filled filter
- High power pumping laser
- Magnetic field
- ….

Advantages:

- High Pressure ^{3}He
- Beamline Accessible
- Spin Reversible
- Pre-pumping
- Polarization Stable

探索宇称破坏的实验

$$\vec{n} + p \to d + \gamma$$

NPD实验使用极化中子轰击质子，
寻找被质子俘获后γ出射角度与中子
极化方向不对称性关系。最终结果：

$$\alpha_\gamma = (-3.0 \pm 1.4 \pm 0.2) \cdot 10^{-8}$$

Blyth D, Fry J, Fomin N, Alarcon R, Alonzi L, Askanazi E,et al. First observation of P-odd γ asymmetry in polarizedneutron capture on hydrogen. Phys Rev Lett. (2018) 121:242002.

NPDGamma experiment

探索宇称破坏的实验

$$\vec{n} + {}^{3}He \rightarrow p + 3H$$

实验使用极化中子轰击^{3}He，寻找出射质子与入射中子夹角不对称性关系。最终结果：

$$\alpha_z = (-1.55 \pm 0.97 \pm 0.24) \cdot 10^{-8}$$

The n3He experiment: parity violation in polarized neutron capture on 3He. arXiv preprint arXiv:2004.10889 (2020).
The Parity violating asymmetry in the 3He(n,p)3H reaction. Phys Rev C. (2010) 82:044001
First precision measurement of the parity violating asymmetry in cold neutron capture on 3He. arXiv preprint arXiv:2004.11535 (2020).

宇称破缺的放大

Parity Violation Amplification

宇称破坏的增强的两条路线

Effects of weak interactions: parity nonconservation and time-invariance violation, can be enhanced up to 10^6 times in compound nuclei. This factor is produced by (i) "simple" kinematical enhancement (ratio of the s-wave to the p-wave neutron capture amplitudes), and (ii) very large density of compound resonances (dynamical enhancement). The latter phenomenon should be generic to many complex many-body systems (rare-earth atoms, atomic clusters, quantum dots in solids, etc.), and is strongly related to the problem of quantum chaos. This review is devoted to the theoretical aspects of the problem. Statistical theory is used to calculate the r.m.s. value and the distribution of matrix elements of the weak perturbations between compound states. The behaviour of effects upon averaging over many compound resonances is studied. It is shown that the effects, though of random sign, are not suppressed by such averaging. Valence mechanism, rotational doublet states, doorway states are considered as possible sources of regular contributions to the effect. The renormalization of weak interaction by the the strong interaction and its relation to the problem of π-mesons in nuclear matter is discussed.

Flambaum, V. V., & Gribakin, G. F. (1995). Enhancement of Parity and Time-Invariance Violating Effects in Compound Nuclei. *Physics Letters B*, 354(4), 423-503.

Brief history of the experiments(1)

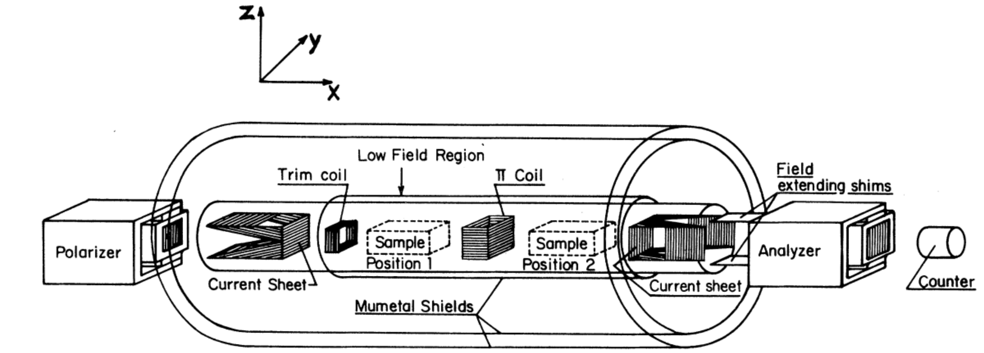


FIG. 1. Schematic view of experimental apparatus. The neutron beam polarization is along $\hat{z}$ and momentum along $\hat{x}$.

in 1980 after the ILL measurements [64] on tin with polarized cold neutrons. In ^{117}Sn PNC effects were observed: the spin rotation angle $\Phi=(3.7\pm0.3)\times10^{-5}$rad/cm and the cross section longitudinal asymmetry ***A*=(9.8±4.0)×10⁻⁶**.

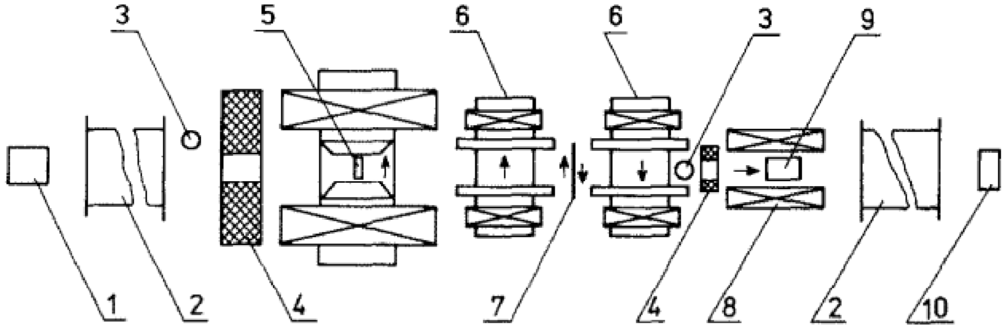


Fig. 1. Experimental arrangement: 1 – reactor, 2 – evacuated neutron guide tube, 3 – monitors, 4 – collimators, 5 – polarized proton target, 6 – electromagnets of the guide field, 7 – current sheet, 8 – solenoid, 9 – sample, 10 – neutron detector. Arrows along the neutron beam path show the direction of magnetic field.

Experiments at Dubna were performed using the IBR-30 pulsed reactor as a neutron source for time-of-flight measurements. The proton-filter transmission technique for polarizing resonance neutrons was first developed at the Joint Institute of Nuclear Research (JINR) by another team.

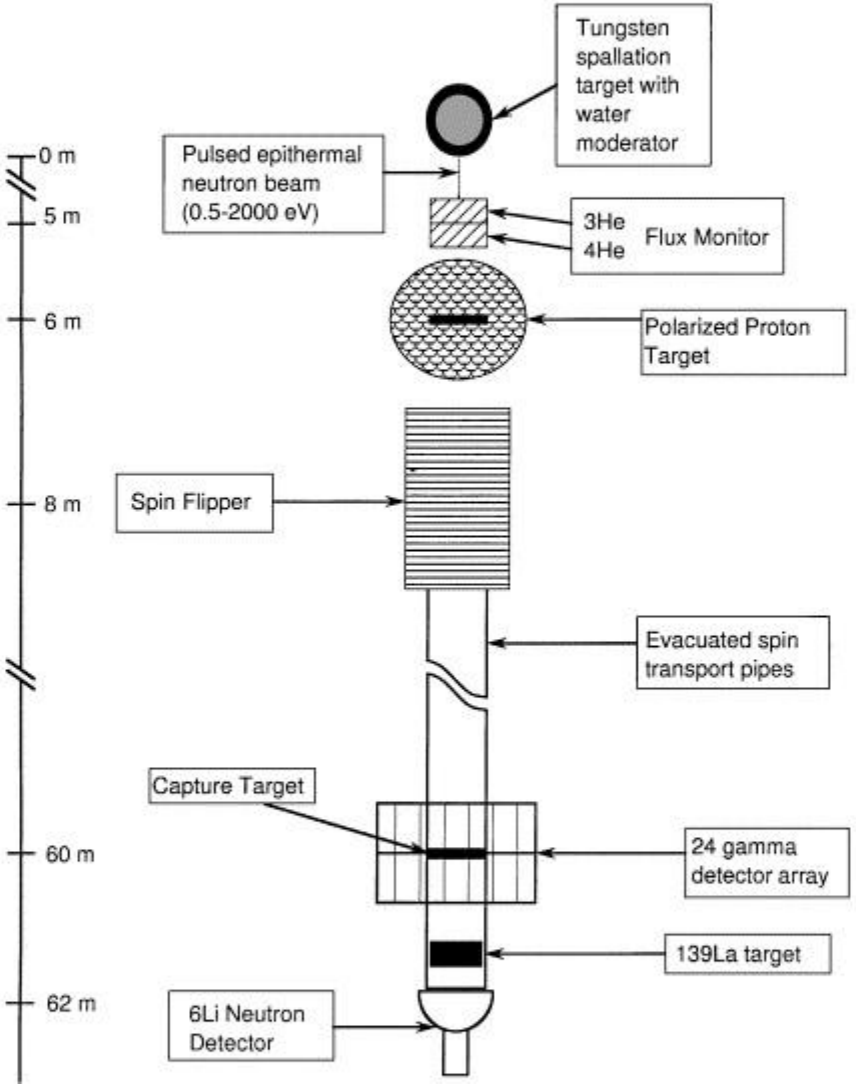
Phys. Rev. Lett., 45 (1980), p. 2088
Nucl. Phys. A, 398 (1983), p. 93
Phys. Lett., 12 (1964), p. 334

Brief history of the experiments(2)

KIAE (Kurchatov Institute of Atomic Energy), Moscow ^{117}Sn and ^{139}La

KEK (High Energy Institute), Tsukuba, ^{139}La

TRIPLE Collaboration

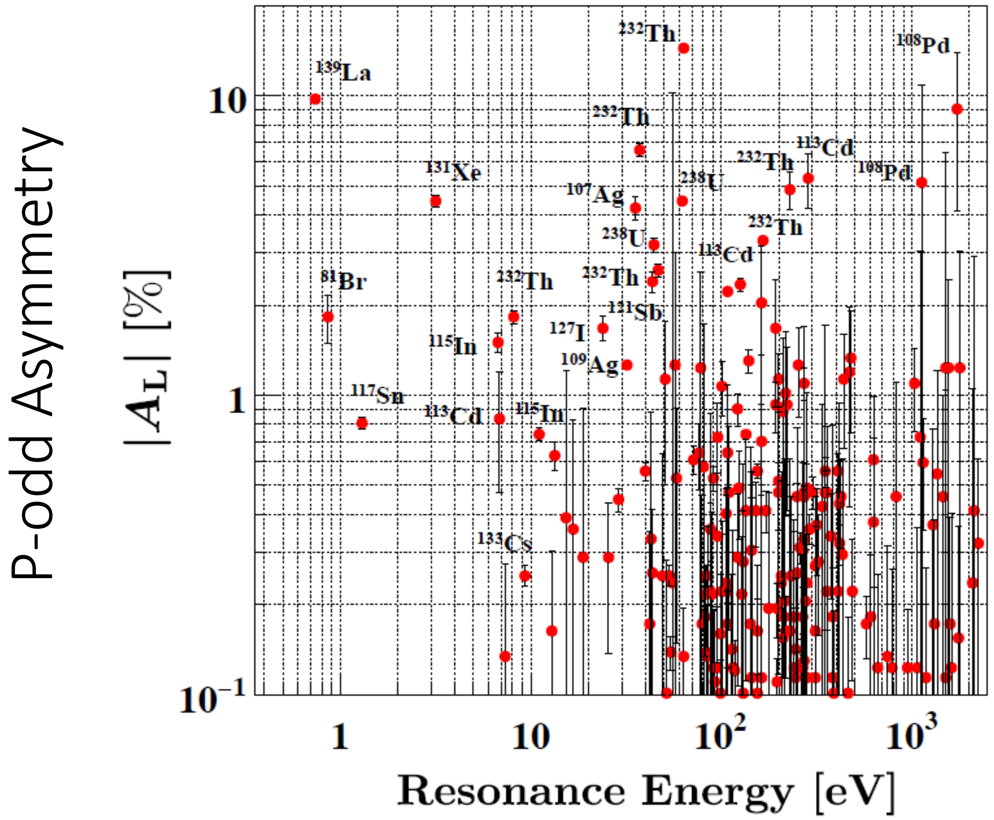


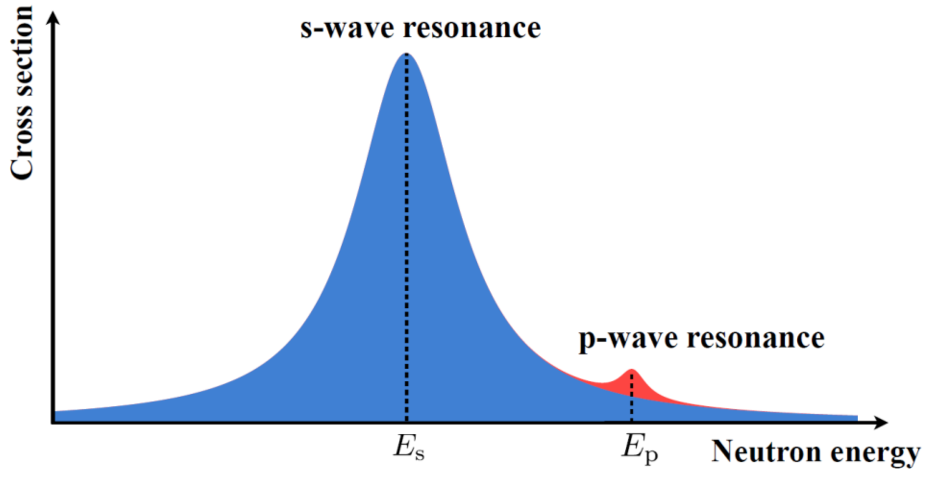
S.A. Biryukov et al., Yad. Fiz. 45 (1987) 1511 [Sov. J. Nucl. Phys. 45 (1987) 937].
Nucl. Phys. A, 504 (1989), p. 289
Physics Reports, Volume 354, Issue 3, November 2001, Pages 157-241

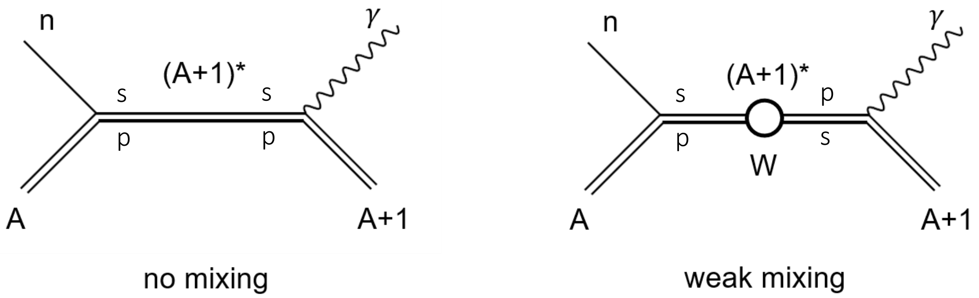
s,p-wave mixing enhances P-odd effects

Weak NN interaction amplitude: $Gm_\pi^2 \sim 10^{-7}$

Observed $\sim 10^6$ enhancement of P-odd effects!







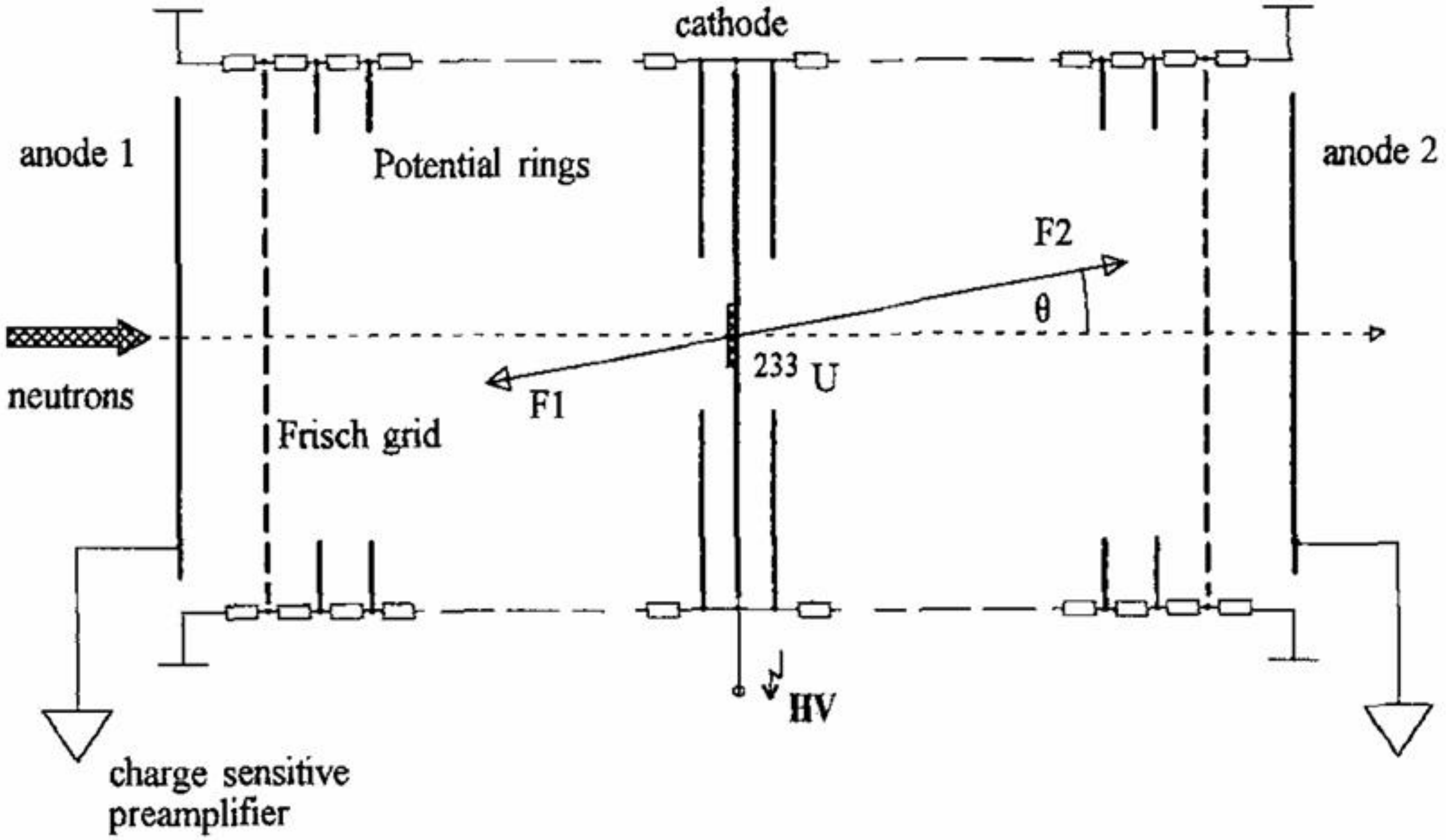
Feynman diagram of (n, γ) channel

另一个故事

$$W(\theta) = 1 + \alpha\vec{\boldsymbol{\sigma}}\cdot\vec{\boldsymbol{p}} = 1 + \alpha\cos\theta$$

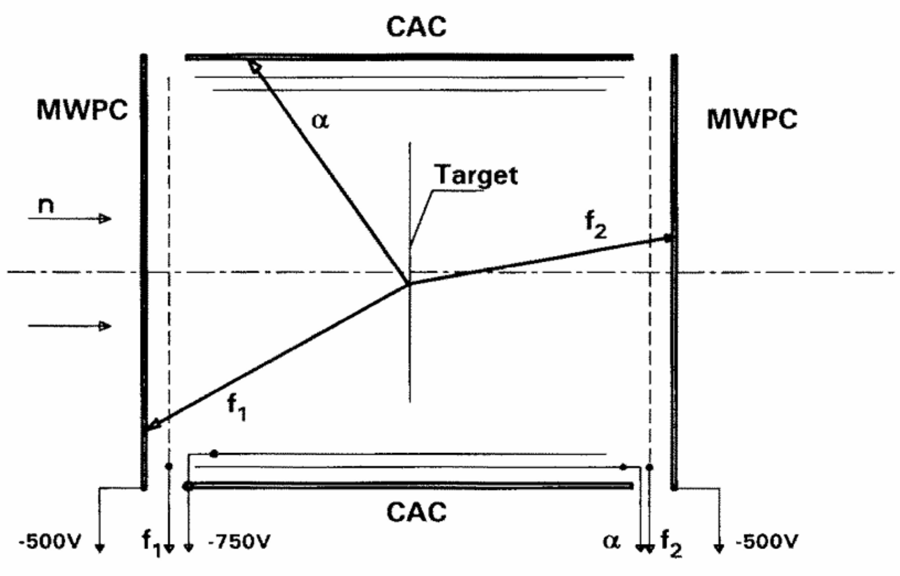
The asymmetry coefficient for the group of light fission fragments is

$$\alpha = (3.29 \pm 0.31) \times 10^{-4}$$



1. JETP Lett. 1979, 30, 470. 99.
2. JETP Lett. 1979, 30, 527. 100.
3. JETP Lett. 1980, 32, 41. 101.
4. Sov. Phys. Usp. 1980, 23, 3231.
5. Z. Physik A - Hadrons and Nuclei 351, 281–288 (1995).

三分裂变



$$\alpha_{nf}^{exp} = \frac{(\vec{N} - \overleftarrow{N})}{(\vec{N} + \overleftarrow{N})} \approx 10^{-4}$$

$$\frac{\alpha_{nf}^{ter}}{\alpha_{nf}^{bin}} = 1.12 \pm 0.08 \; in \; ^{239}Pu(n,f)$$

$$\frac{\alpha_{nf}^{ter}}{\alpha_{nf}^{bin}} = 1.05 \pm 0.1 \; in \; ^{233}U(n,f)$$

1.宇称不守恒相关性：实验测得的三元裂变与二元裂变的宇称不守恒不对称性系数比值接近1，表明两者在宇称不守恒方面没有显著差异。
2.三元裂变的发射时机：根据实验结果和理论模型，三元裂变中的轻粒子（如α粒子）在裂变过程的最后阶段才被发射，即在通过双峰裂变势垒的外鞍点之后。
3.裂变路径的一致性：实验结果表明，无论是二元还是三元裂变，裂变核在变形空间中的路径在通过第二鞍点之前是一致的。
4.理论模型的支持：实验结果与现有理论模型一致，支持了三元裂变是一个两步过程的观点，即在接近分裂点时，二元裂变后序贯发射第三个轻粒子。

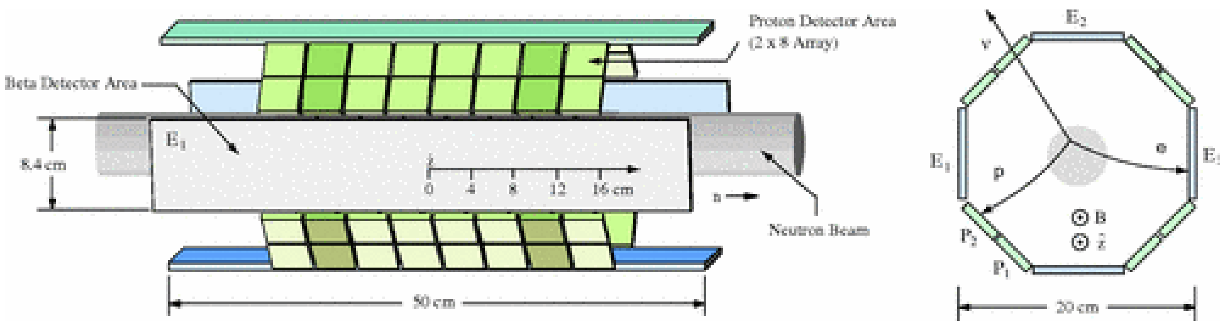
Z Physik A 321, 271–274 (1985).
Nuclear Physics A Volume 567, Issue 2, 17 January 1994, Pages 303-316

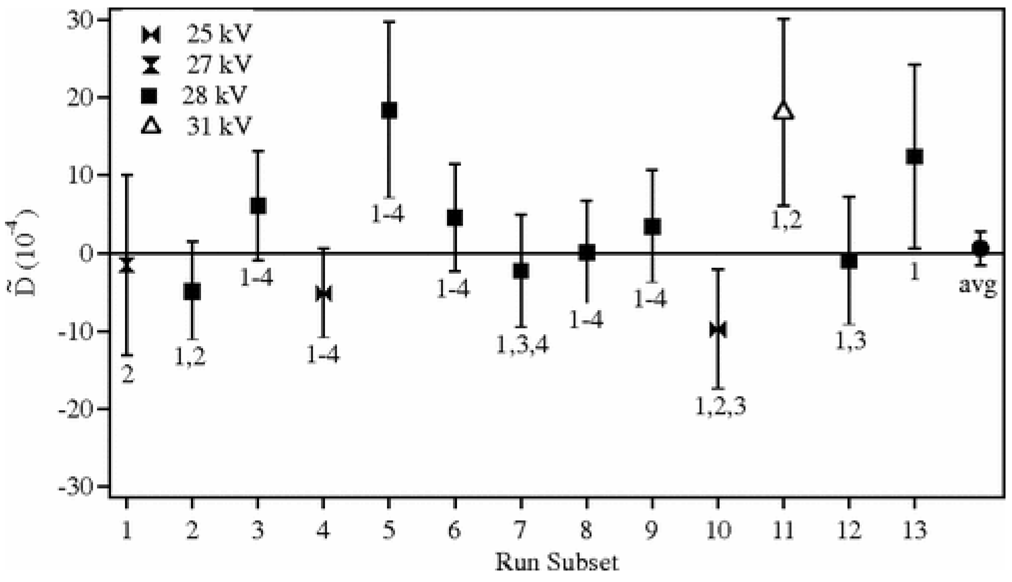
时间反演破缺
Time reversal violation

New Limit on Time-Reversal Violation in Beta Decay

极化中子衰变概率dW可以表示为

$$dW \propto 1 + \alpha \frac{\boldsymbol{p}_e \cdot \boldsymbol{p}_\nu}{E_e E_\nu} + b \frac{m_e}{E_e} + \boldsymbol{P} \cdot \left(A \frac{\boldsymbol{p}_e}{E_e} + B \frac{\boldsymbol{p}_\nu}{E_\nu} + \boldsymbol{D} \frac{\boldsymbol{p}_e \times \boldsymbol{p}_\nu}{\boldsymbol{E}_e \boldsymbol{E}_\nu}\right)$$





$$D = [-0.96 \pm 1.89(stat) \pm 1.01(sys)] \times 10^{-4}$$

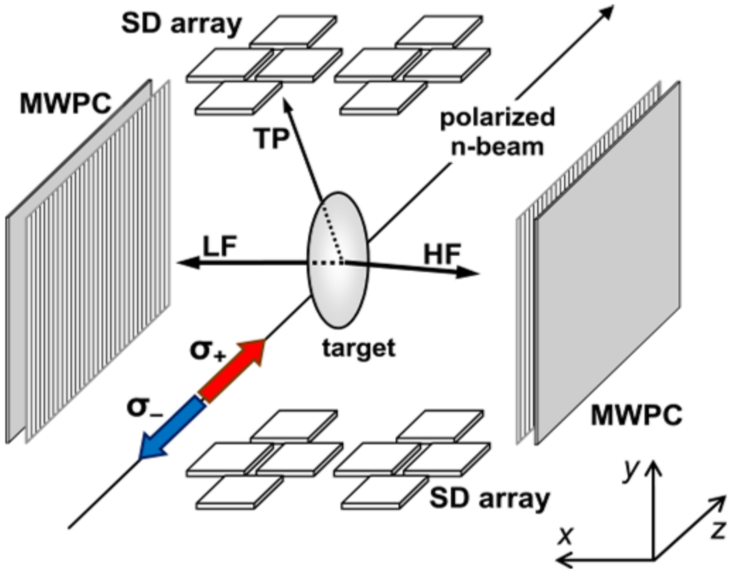
Phys. Rev. Lett. **107**, 102301

杜布纳团队的三体裂变测量尝试

实验观察到的 B 的期望值 为 **$-(2.35 \pm 0.05) \times 10^{-3}$**，这个值远大于预期

quite unlikely. Compared to the sizes of the well-established PNC effects in fission and the dynamical enhancements factors of 10^3 encountered there, for a violation of time reversal invariance to become visible at the level observed in the present experiment further enhancement factors in excess of 10^3 would be required. Such huge enhancement factors are not anticipated by theory [8].

have first of all to be extended to other nuclei with spins and polarizations after neutron capture differing from those of the ^{233}U(n,f) reaction at thermal energies analyzed here. Also the dependence of the effect on neutron energy should be of interest. Finally, in view of the surprisingly strong dependence of the triple correlation on the energy of the ternary particles it has to be asked whether this is true for all types of particles and/or whether the effect is possibly linked to only a few specific ternary particles.



$$B = \hat{\sigma} \cdot [\widehat{p_{LF}} \times \widehat{p_{TP}}]$$

AIP Conf. Proc. 447, 395–404 (1998)
AIP Conf. Proc. 529, 577–585 (2000)
Nuclear Instruments and Methods in Physics Research A 440 (2000) 618-625

中子与原子核相互作用

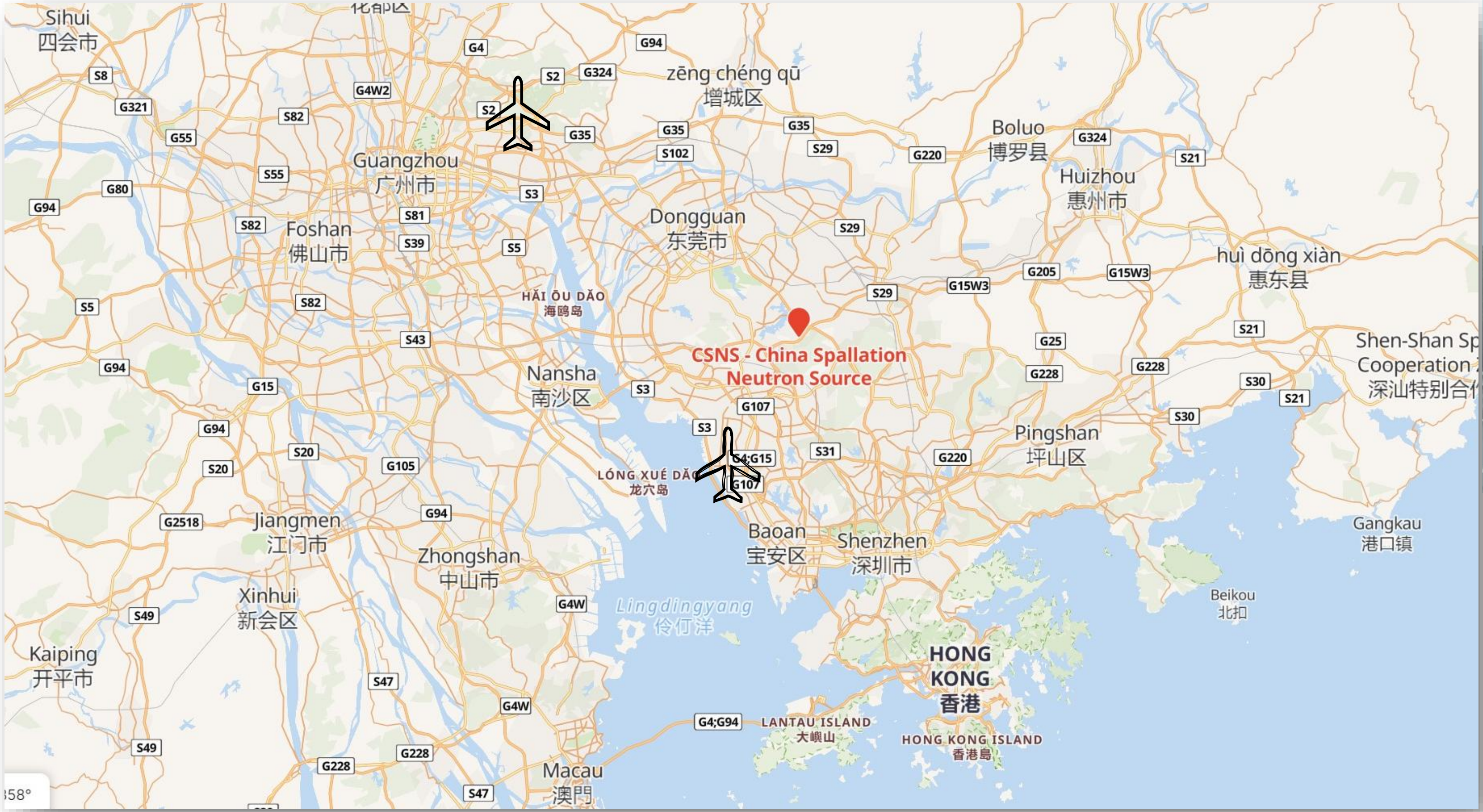
- 中子与原子核相互作用的基本对称性破缺研究
  - 宇称破缺研究
    - 中子与轻核相互作用 10^{-7}
  - 宇称破缺的放大效应 10^{-3}
    - 裂变截面中的宇称破缺
    - 共振俘获中的宇称破缺
  - 时间反演破缺
    - 放大效应中的时间反演 $10^{-?}$

中国散裂中子源

China Spallation Neutron Source

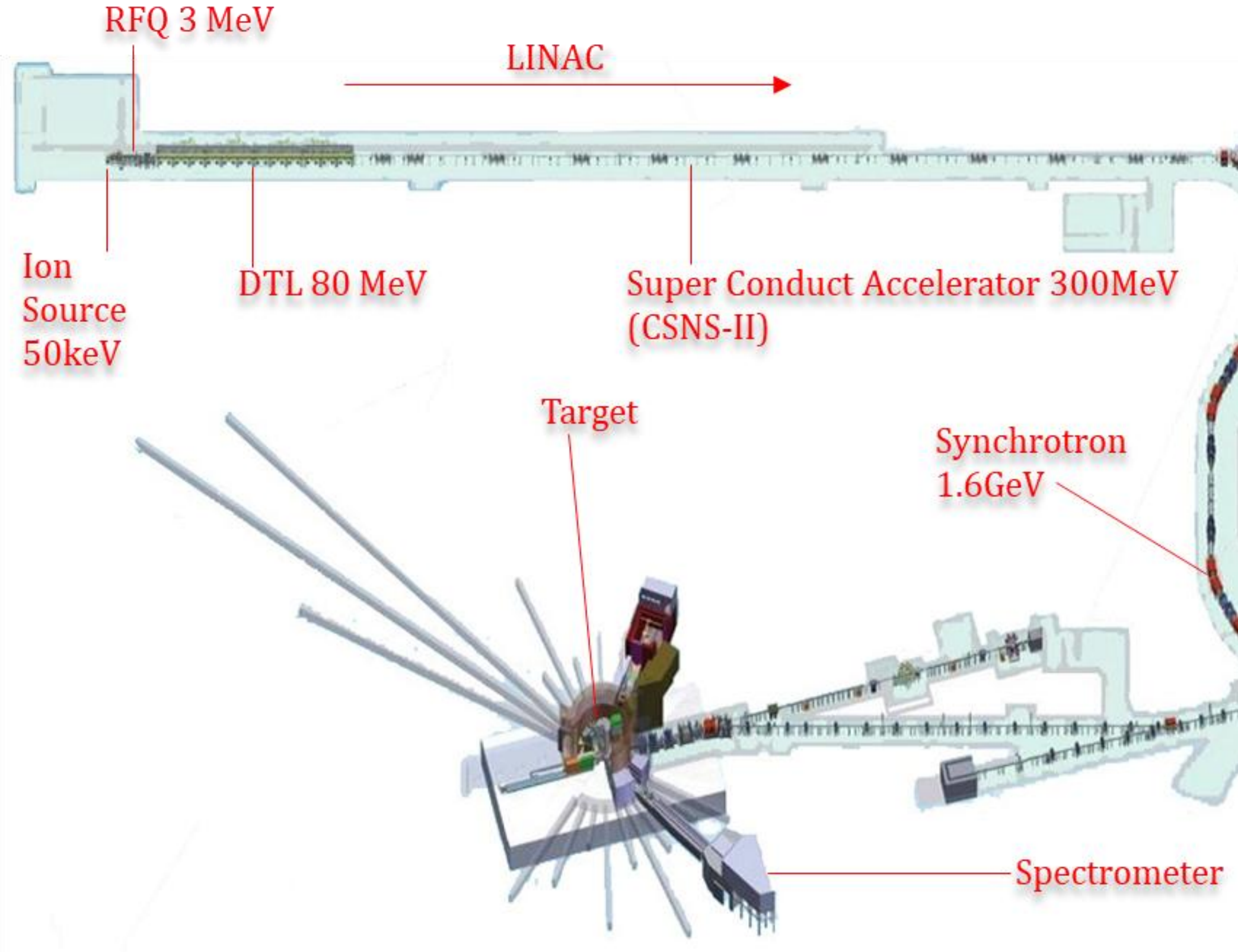
Spallation Neutron Source Centers Around the World

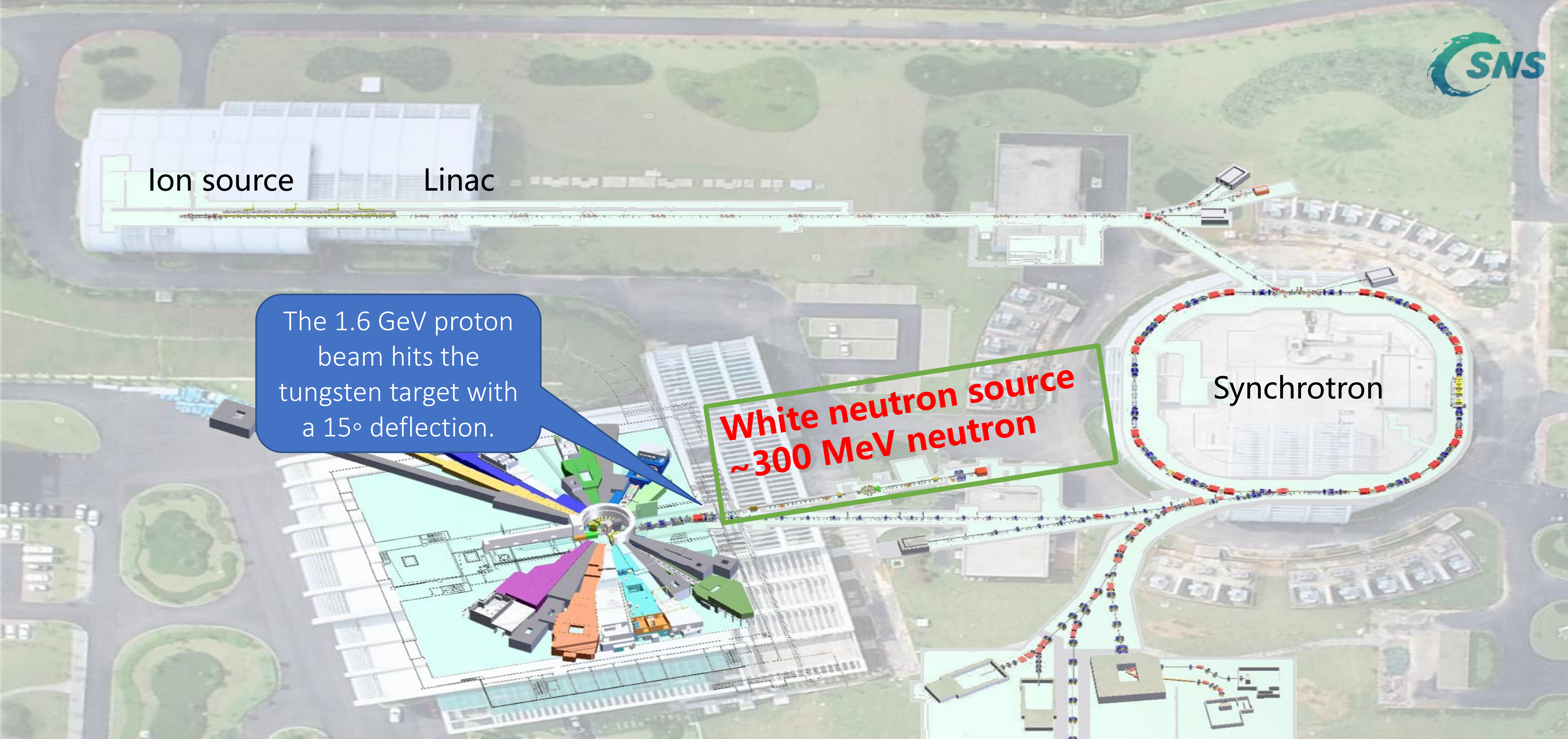
The location of the China Spallation Neutron Source



It's located next to Zhuhai, in Dongguan City, Guangdong Province, about a 40-minute drive from Shenzhen Airport.


南方先进光源（预研）
SAPS
中国散裂中子源
CSNS

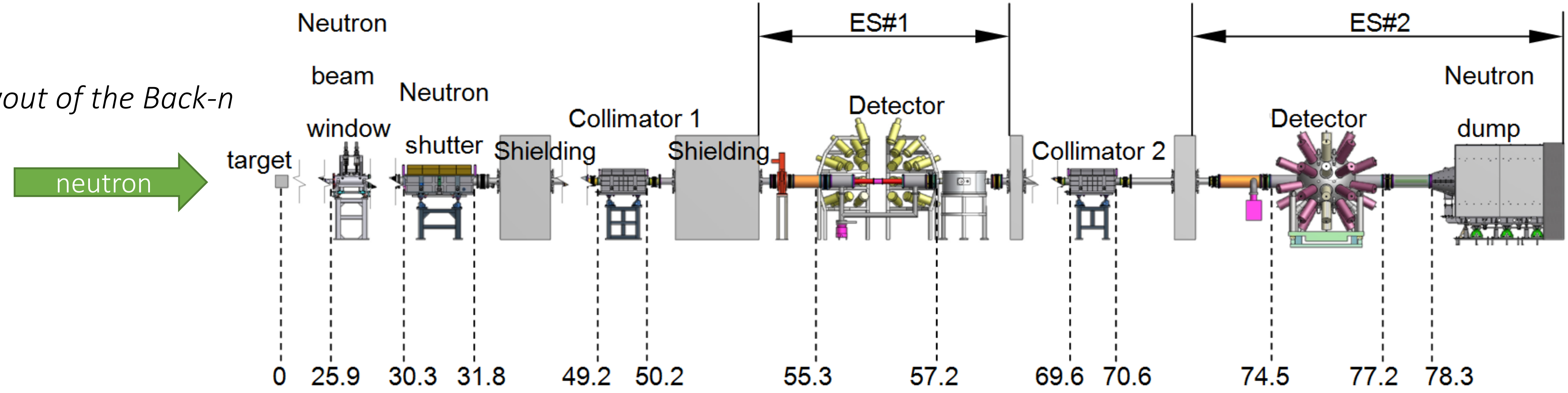

RFQ 3 MeV
LINAC
Ion Source 50keV
DTL 80 MeV
Super Conduct Accelerator 300MeV (CSNS-II)
Target
Synchrotron 1.6GeV
Spectrometer



The Back-n is a white neutron beam line that is opposite to the target station direction. It started running in 2018 for nuclear data measurements.

Back-n

Layout of the Back-n

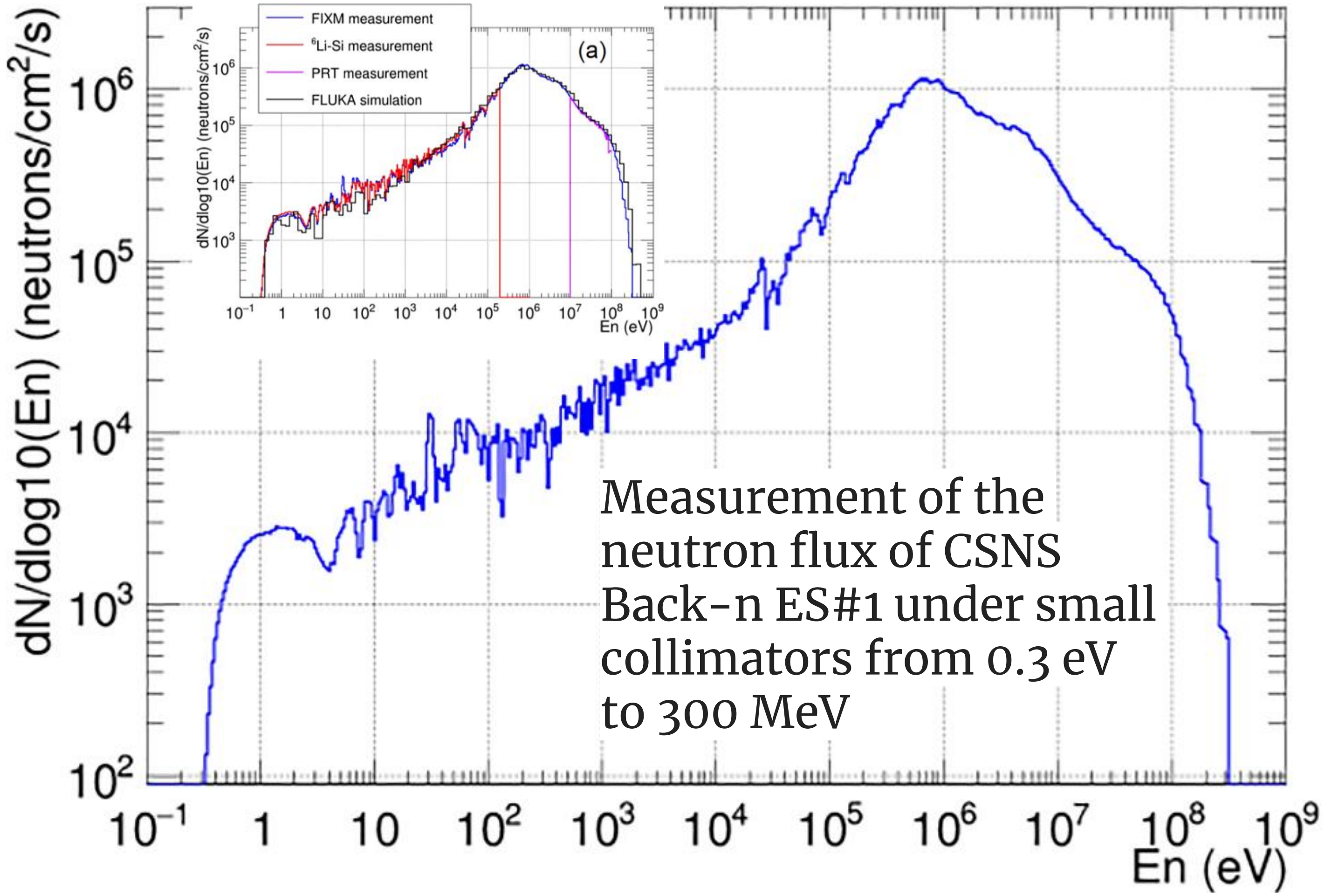


Shutter (mm)	Coll#1 (mm)	Coll#2 (mm)	ES#1 spot (mm)	ES#1 flux ($n/cm^2/s$)	ES#2 spot (mm)	ES#2 flux ($n/cm^2/s$)
Φ3	Φ15	Φ40	Φ15	1.27E5	Φ20	4.58E4
Φ12	Φ15	Φ40	Φ20	2.20E6	Φ30	7.81E5
Φ50	Φ50	Φ58	Φ50	4.33E7	Φ60	1.36E7
78×62	76×76	90×90	75×50	5.98E7	90×90	2.18E7

The back-streaming neutrons are leading to the Back-n tunnel, which has a long flight distance for the neutron time-of-flight method. Two end stations ES#1 and ES#2 are constructed for different nuclear data measurements. The ES#1 has a distance of about 55 m, and ES#2 is about 70 m from the target. Different sets of beam spots, collimator apertures and neutron fluxes at Back-n at 100 kW in proton beam power can be found in table.

1. 2017 JINST 12 P07022
2. Eur. Phys. J. A (2019) 55: 115

Back-n neutron energy spectrum measurement



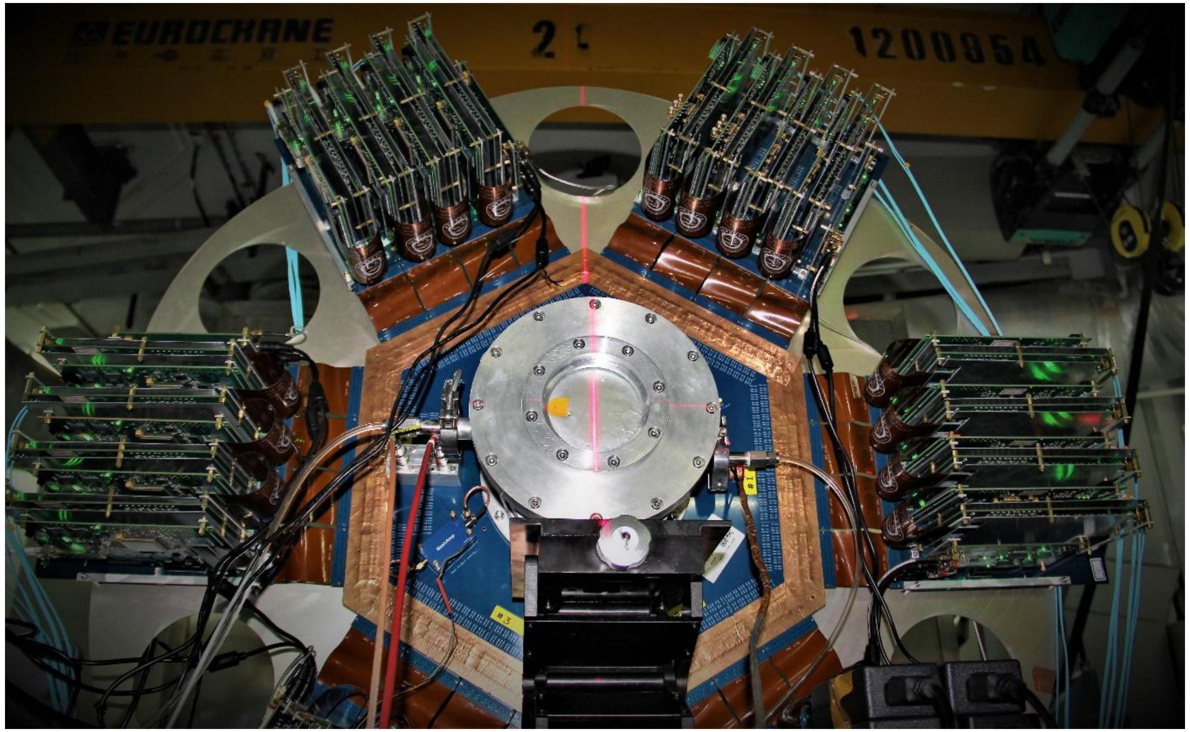
Measurement of the neutron flux of CSNS Back-n ES#1 under small collimators from 0.3 eV to 300 MeV

Energy range	flux (neutrons/cm^2/s)
0.1-1 eV	4.08×10^3
1-10 eV	1.79×10^4
10-100 eV	3.01×10^4
0.1-1 keV	5.01×10^4
1-10 keV	1.23×10^5
10-100 keV	4.30×10^5
0.1-1 MeV	2.98×10^6
1-10 MeV	2.77×10^6
10-200 MeV	6.21×10^5
Total	7.03×10^6

We used different reference cross-sections to measure the energy spectrum, including: (n, p), ^{6}Li(n, t), ^{235}U(n, f), ^{238}U(n, f)

Eur. Phys. J. A (2019) 55: 115
Chen, Y., Qiu, Y., Li, Q. *et al. Eur. Phys. J. A* **60**, 63 (2024).

Back-n的两大探测器系统（MTPC团队和原子能院）

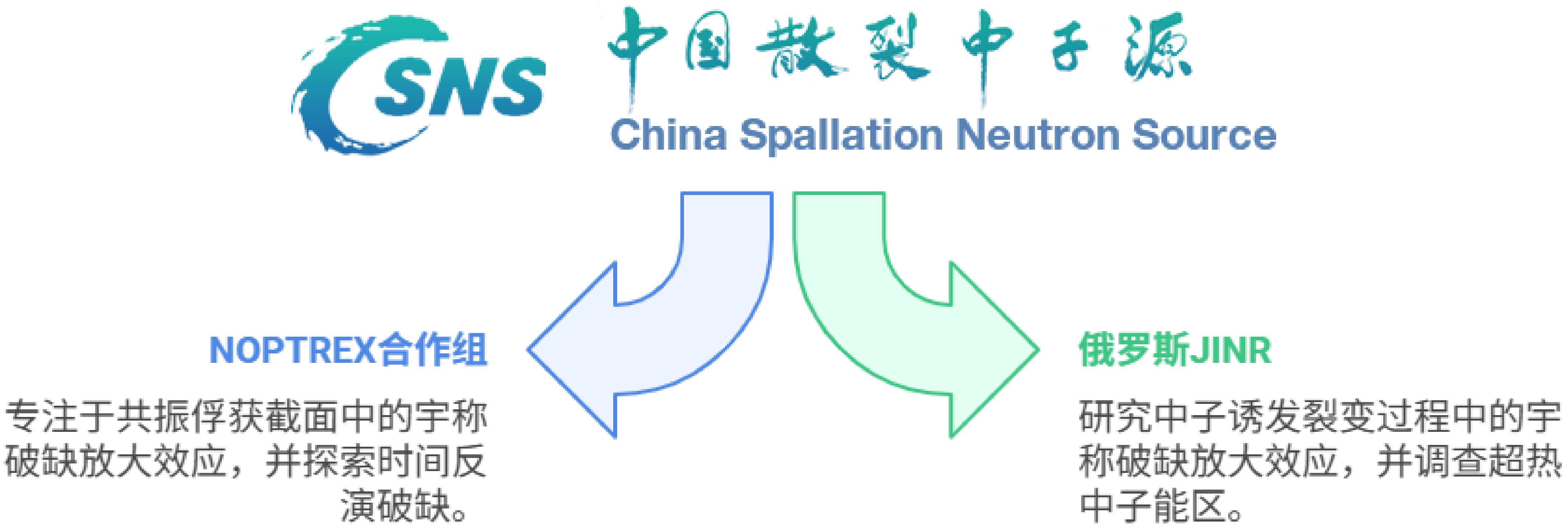


多用途时间投影室

BaF_2探测器阵列

MTPC团队由高能所、原子能院、中科大、北大、中山大学、深圳大学等单位组成

PV & CPV



Made with Napkin

NOPTREX Collaboration List October 2022

C. Auton[16], E. Babcock[29], M. Barlow[30], L. Barron-Palos[27], J. D. Bowman[18], J. Carini[16], L. E. Charon-Garcia[27], E. Y. Chekmenev[32], C. Crawford[19], J. Curole[16], K. Dickerson[16], J. Doskow[16], D. Eigelbach[20], S. Endoh[1,3], **R. Fan[15]**, J. Fry[24], H. Fujioka[7], B. M. Goodson[22], V. Gudkov[17], C. Haddock[21], K. Hagino[11], H. Harada[3], P. Hautle[28], M. Hino[11], K. Hirota[1], I. Ide[1], M. Iinuma[6], H. Ikegami[10], T. Ino[4], R. Ishiguro[13], S. Ishimoto[4], K. Ishizaki[1], T. Iwata[9], C. Jiang[18], W. Jiang[15], K. Kameda[7], G. N. Kim[14], A. Kimura[3], P. King[23], M. Kitaguchi[1], Y. Kiyanagi[1], J. Koga[2], H. Kohri[8], A. Komives[31], S. W. Lee[14], H. Lu[16], G. Luan[34], D. Lutes[16], M. Luxnat[16], T. Matsushita[1], M. McCrea[36], K. Mishima[4], Y. Miyachi[9], T. Momose[5], T. Morishima[1], Y. Niinomi[1], I. Novikov[25], T. Okudaira[1], K. Ogata[8], T. Oku[3], G. Otero[16], J. Peck[19], S. Penttila[18], A. Perez-Martin[27], B. Plaster[19], X. Ruan[34], D. Sahibnazarova[19], K. Sakai[3], S. Samiei[16],D. Schaper[20], R. Shchepin[33] ,T. Shima[8], H. M. Shimizu[1], W. M. Snow[16], D. Spayde[35], H. Tada[1], J. Tang[15], Z. Tang[20], Y. Tani[7], S. Takada[2], Y. I. Takahashi[11], D. Takahaski[12], K. Taketani[8], K. Tateishi[10], X. Tong[15], T. Uesaka[10], J. Vanderwerp[16], M. Veillette[26], G. Visser[16], N. Wada[1], Y. Wang[19], T. Yamamoto[1], Y. Yamagata[10], X. Yamanaka[1] , H. Yoshikawa[8], T. Yoshioka[2], M. Yosoi[8] , M. Zhang[15,16], Q. Zhang[34], G. Ziemyte[19]

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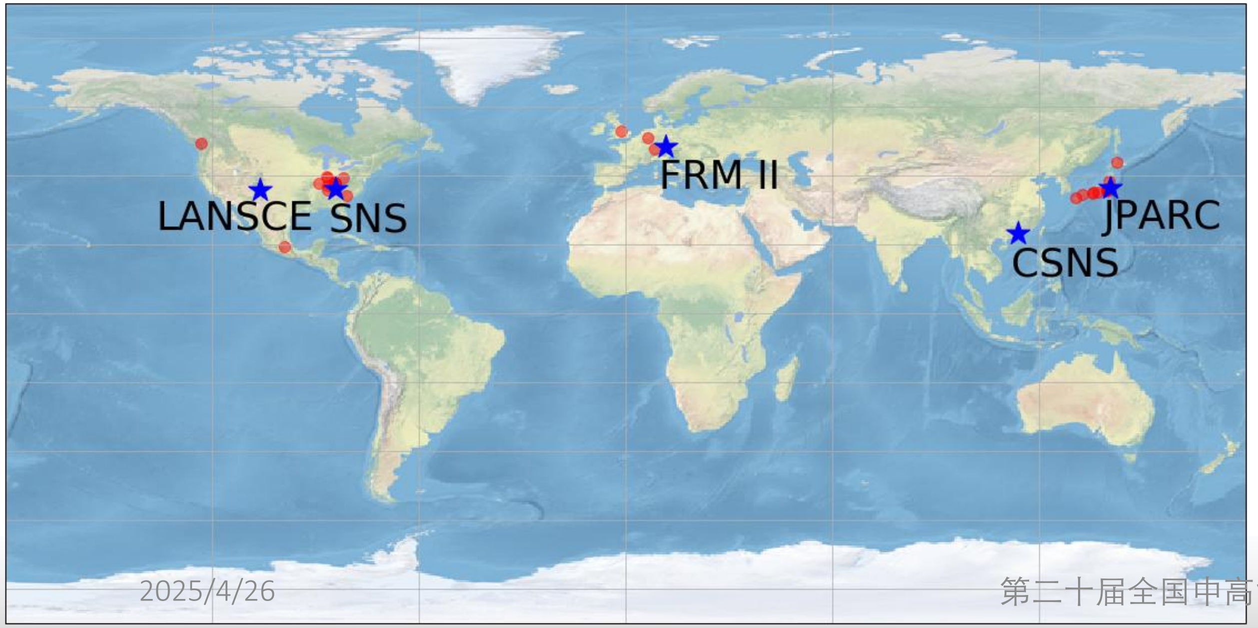
[1]Nagoya, [2]Kyushu, [3]JAEA, [4]KEK, [5]British Columbia, [6]Hiroshima, [7]Tokyo Inst. Tech., [8]Osaka, [9]Yamagata, [10]RIKEN, [11]Kyoto, [12]Ashikaga, [13]Japan Women's, [14]Kyungpook, [15]CSNS, [16]Indiana, [17]South Carolina, [18]ORNL, [19]Kentucky, [20]LANL, [21]Phase III Physics, [22]Southern Illinois, [23]Ohio, [24]Eastern Kentucky, [25]Western Kentucky, [26]Berea, [27]UNAM, [28]PSI, [29]Juelich, [30]Nottingham, [31]DePauw, [32]Wayne State, [33]SDSM&T, [34]CIAE, [35]Hendrix, [36]Manitoba



中国组成员：高能所、原子能院、理化所、山东大学、大湾区大学

NOPTREX

Neutron Optical Parity and Time-Reversal EXperiment

NOPTREX Theoretical Framework

$$\boldsymbol{f} = \boldsymbol{f}_0 + \boldsymbol{f}_1\left(\vec{\boldsymbol{\sigma}}_{\boldsymbol{n}}\cdot\vec{\boldsymbol{I}}\right) + \boldsymbol{f}_2\left(\vec{\boldsymbol{\sigma}}_{\boldsymbol{n}}\cdot\vec{\boldsymbol{k}}_{\boldsymbol{n}}\right) + \boldsymbol{f}_3\left(\vec{\boldsymbol{\sigma}}_{\boldsymbol{n}}\cdot\left[\vec{\boldsymbol{k}}_{\boldsymbol{n}}\times\vec{\boldsymbol{I}}\right]\right) + \boldsymbol{f}_4\left(\vec{\boldsymbol{\sigma}}_{\boldsymbol{n}}\cdot\left(\vec{\boldsymbol{I}}\times\vec{\boldsymbol{k}}_{\boldsymbol{n}}\right)\left(\vec{\boldsymbol{I}}\cdot\vec{\boldsymbol{k}}_{\boldsymbol{n}}\right)\right)$$

f_0=P-even, T-even Spin Independent

f_1=P-even, T-even Spin Independent (pseudomagnetic)

f_2=P-odd, T-even P-violation

f_3=P-odd, T-odd TP-violation

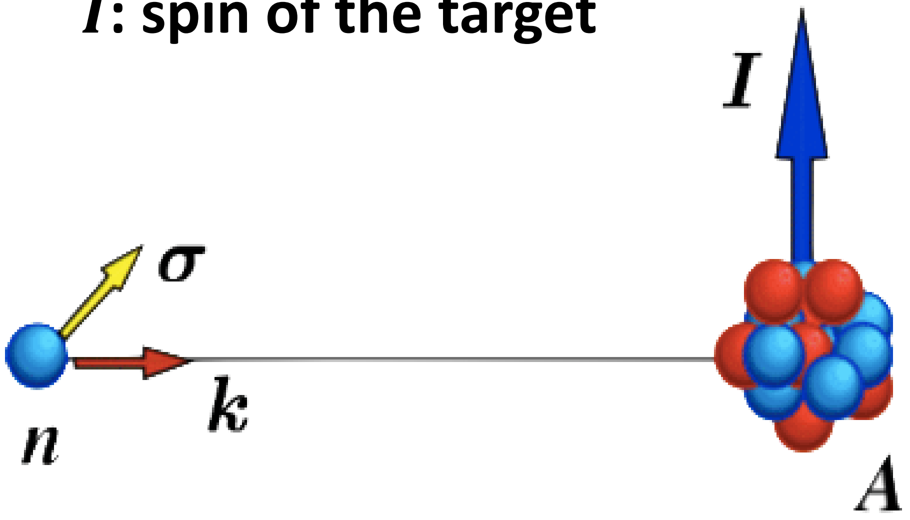
f_4=P-even, T-odd T-violation

What we are mostly interested in!

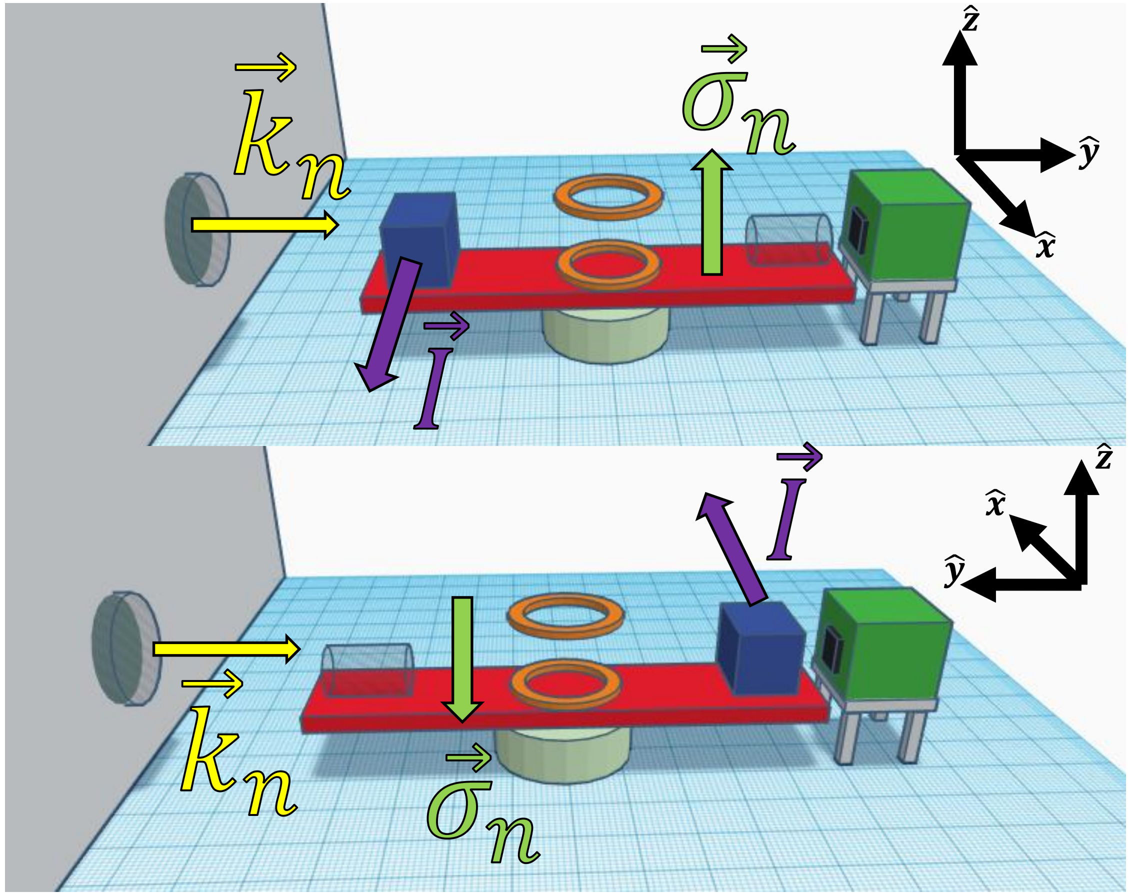
$\vec{\boldsymbol{k}}_{\boldsymbol{n}}$: neutron momentum

$\vec{\boldsymbol{\sigma}}_{\boldsymbol{n}}$: neutron spin

$\vec{\boldsymbol{I}}$: spin of the target



Basic idea of NOPTREX



$f_3\left(\vec{\sigma}_n\cdot\left[\vec{k}_n\times\vec{I}\right]\right)$

P-odd, T-odd
forward scattering
term

By isometry, the product of two reflections is equivalent to a rotation. A rotation about $\hat{z}$ is equivalent to reflections about $\hat{x}, \hat{y}$.

→ The rotation inverts $\vec{k}_n$.

→ Reversing the $\vec{B}$ field

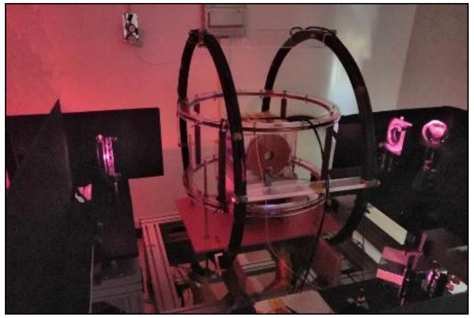
polarizing the target reverses $\vec{I}$.

→ Flip the neutron spin to reverse $\vec{\sigma}_n$.

Take a look at the direction of our observables—all reversed!

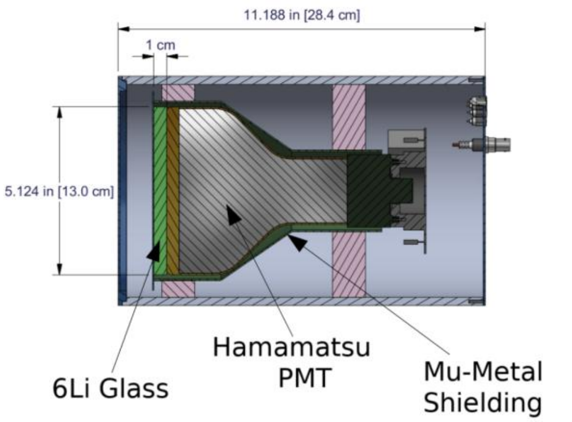
NOPTREX

- NOPTREX
  - Epithermal neutron
  - Selection of target nuclei with high t-violation amplification factor
  - Validating the S-P Mixing Model
- Development of neutron polarization technology
- Development of nuclear polarization technology
- Neutron detection



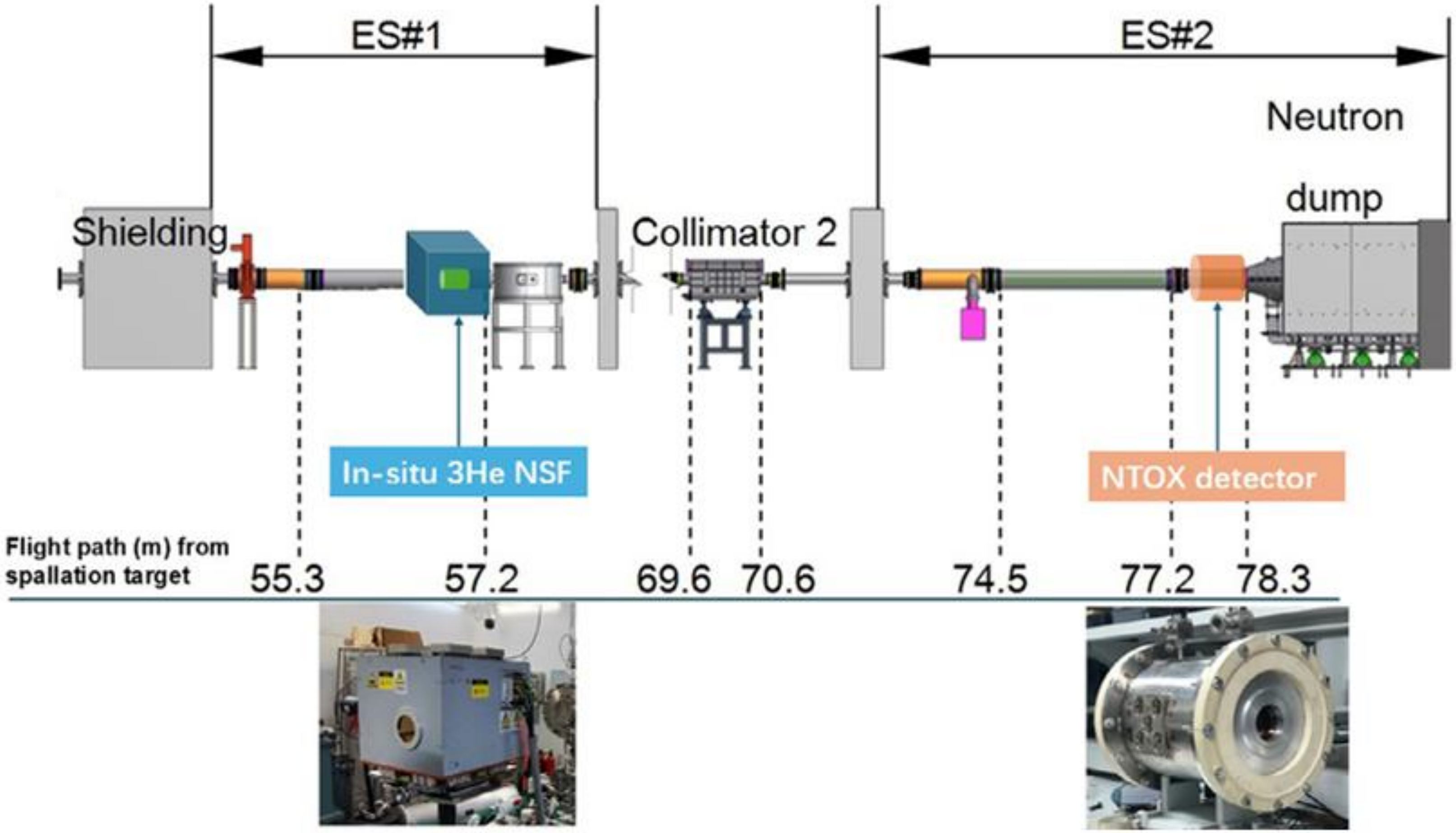
^{3}**He spin-exchange optical pumping**

dynamic nuclear polarization

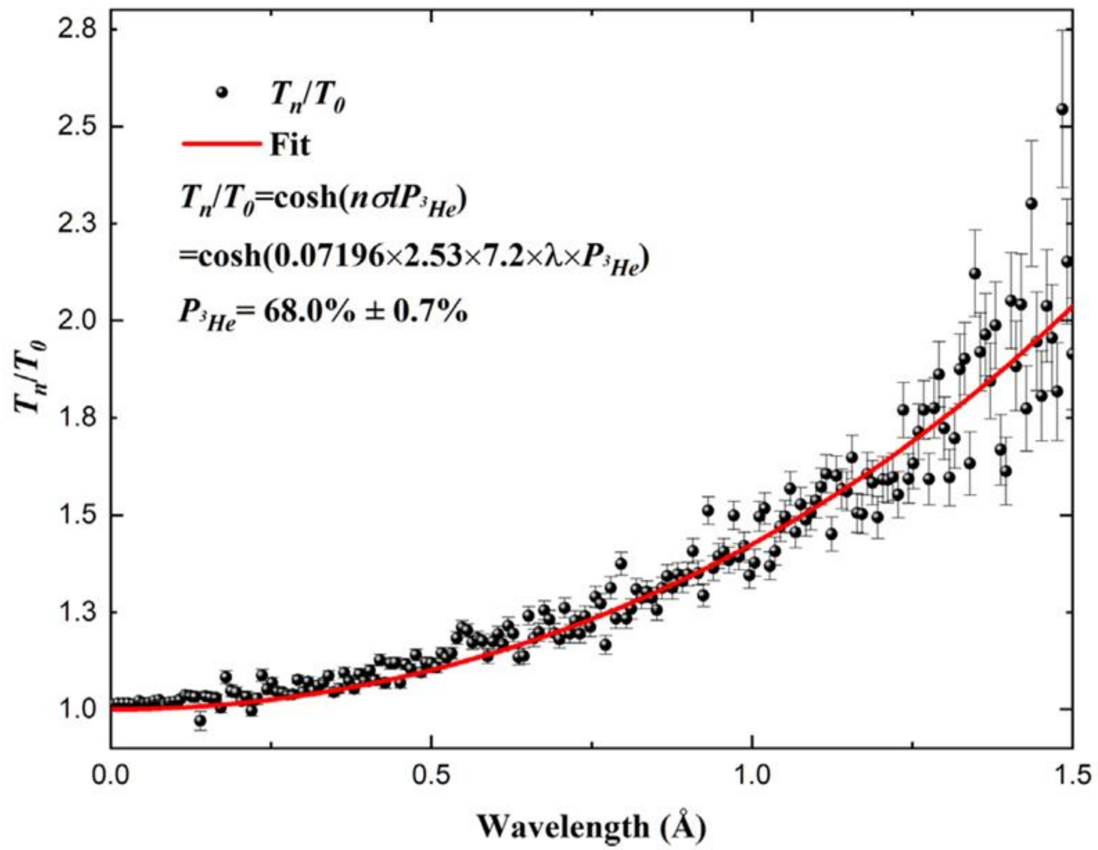


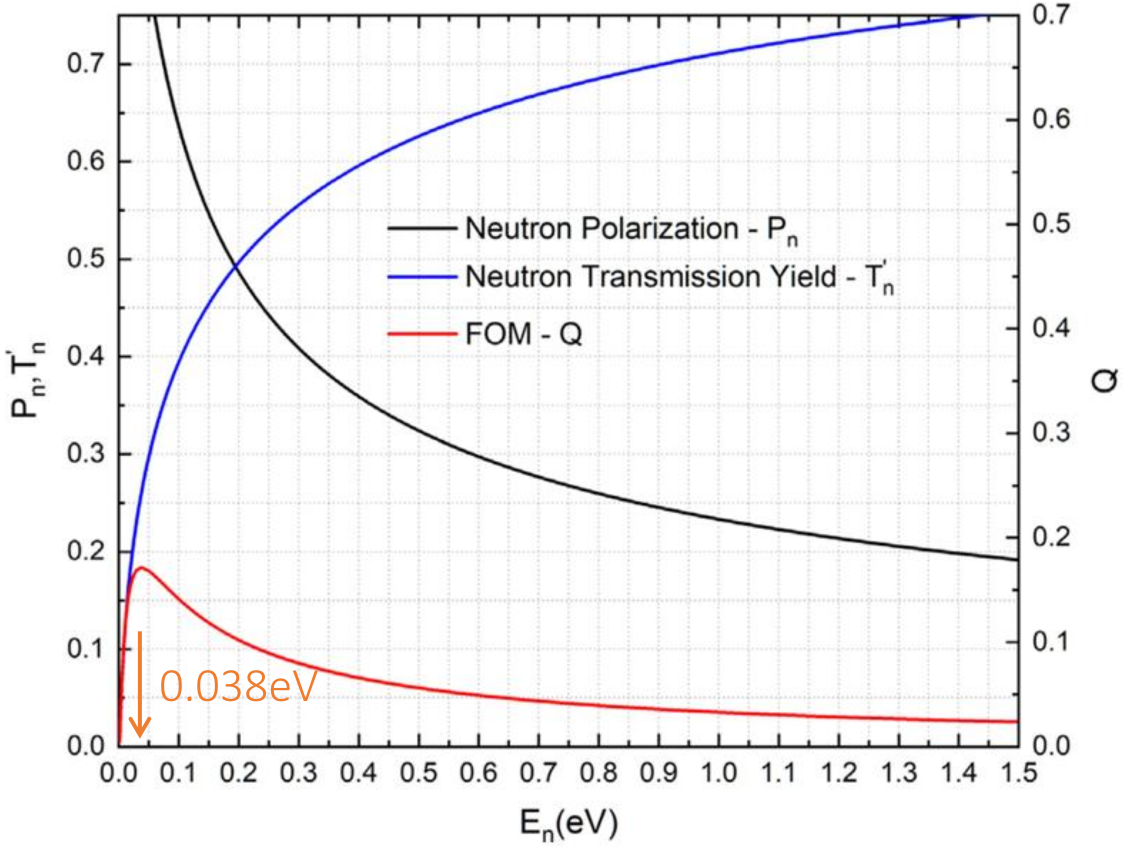
Side view of the detector design

Back-n polarized 3He transmission experiment



实验结果



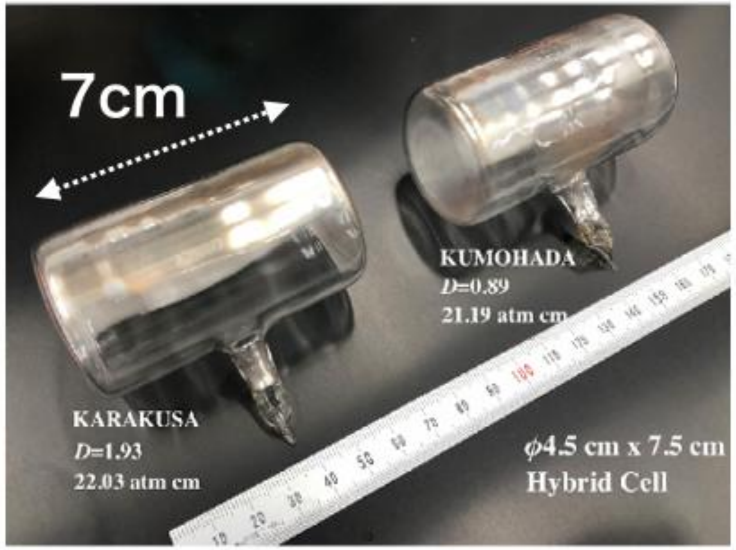


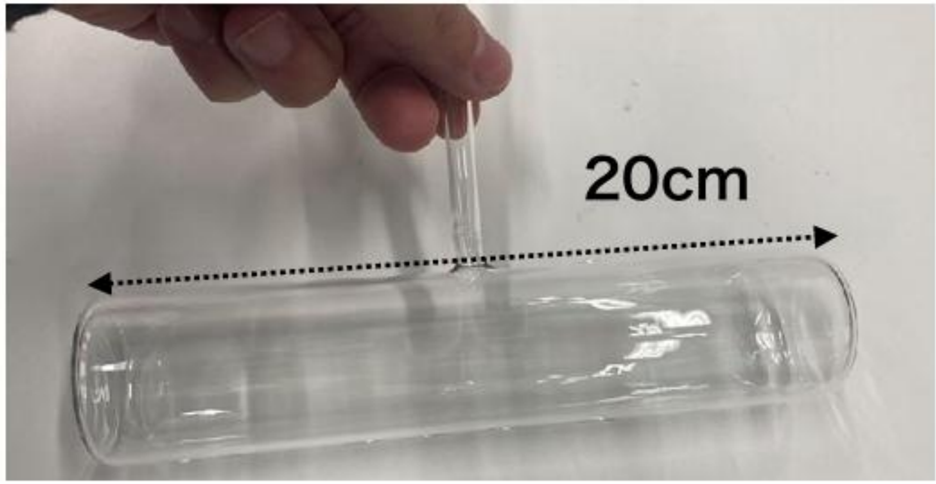
First use of a polarized 3He neutron spin filter on the Back-n White Neutron Source of CSNS, NIMA, 1072,2025,170184

高效率极化系统

^3He gas thickness > 3 atm. × 15 cm (up to 3 atm. × 20 cm)

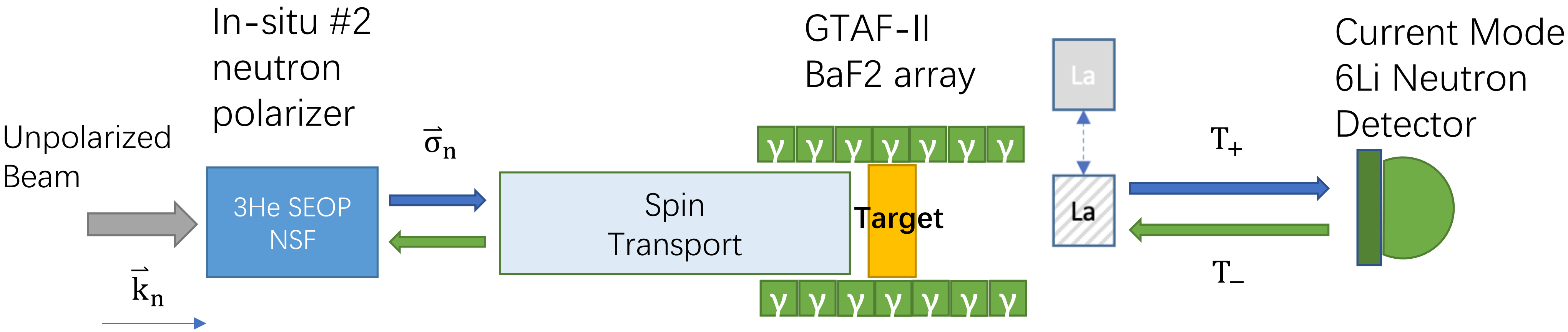
cell fiducial cross section ≥ 5 cm × 5 cm





Courtesy of: Takuya(Nagoya Uni)

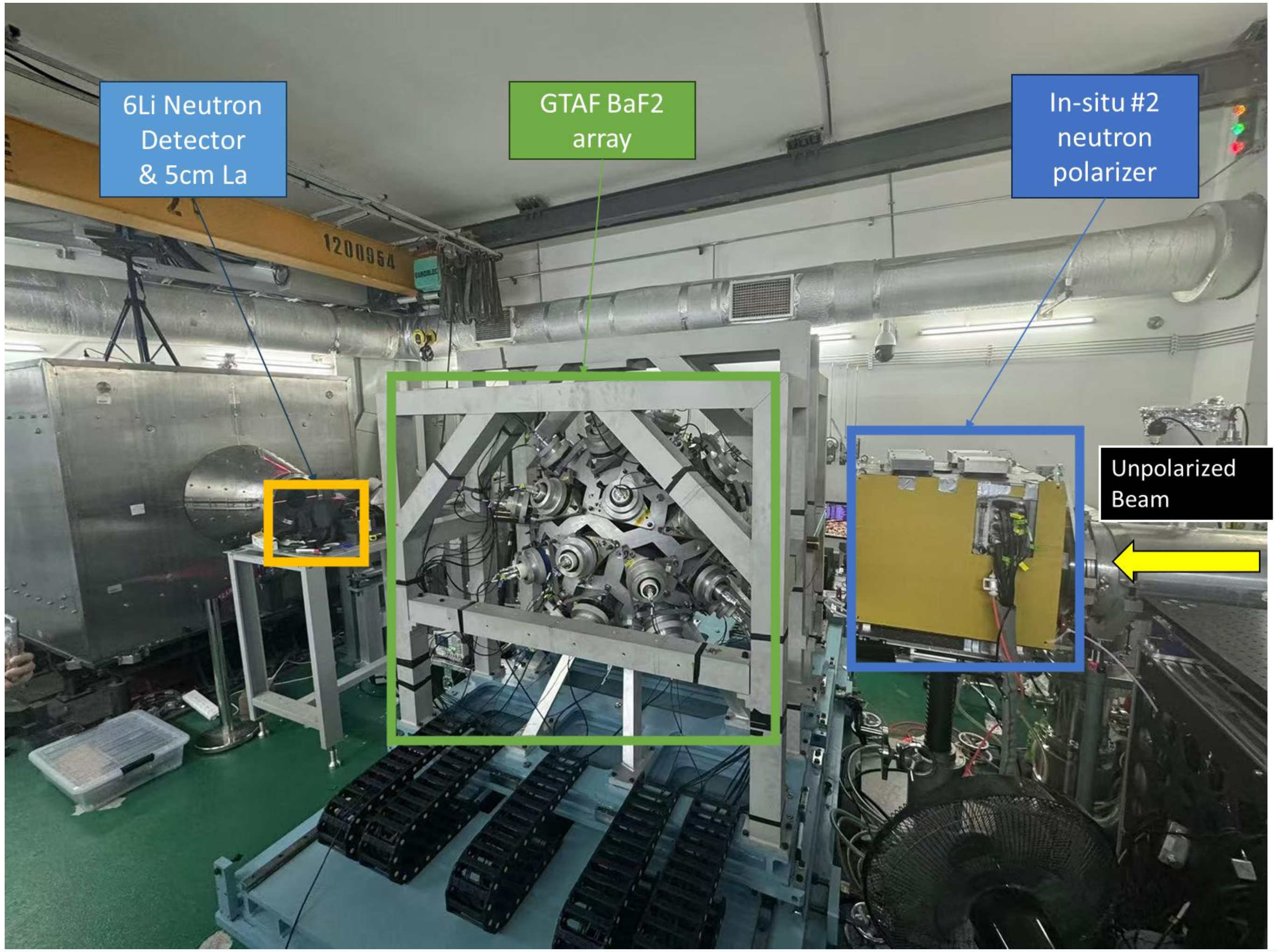
Parity Violation in p-wave resonances of unmeasured nuclei

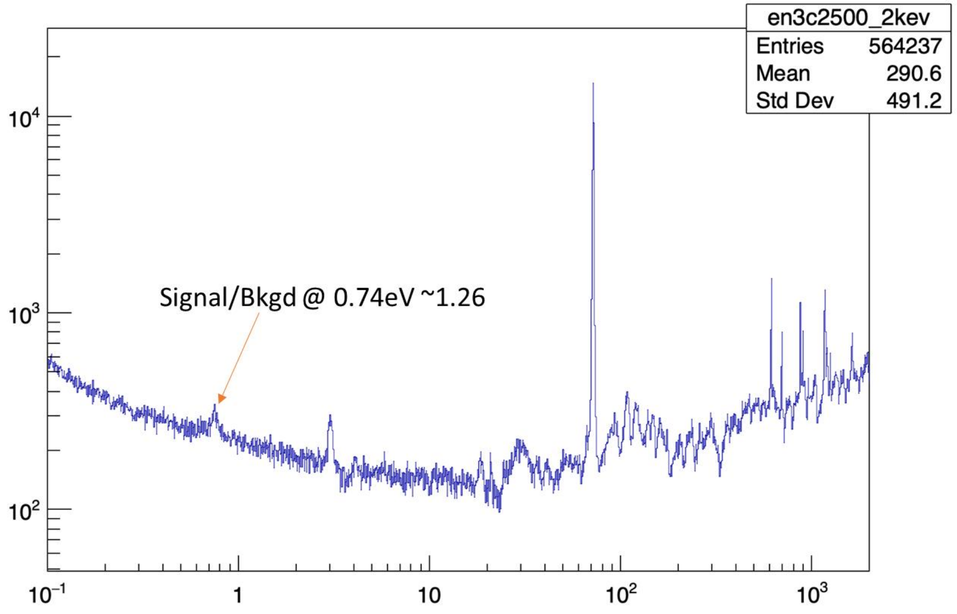


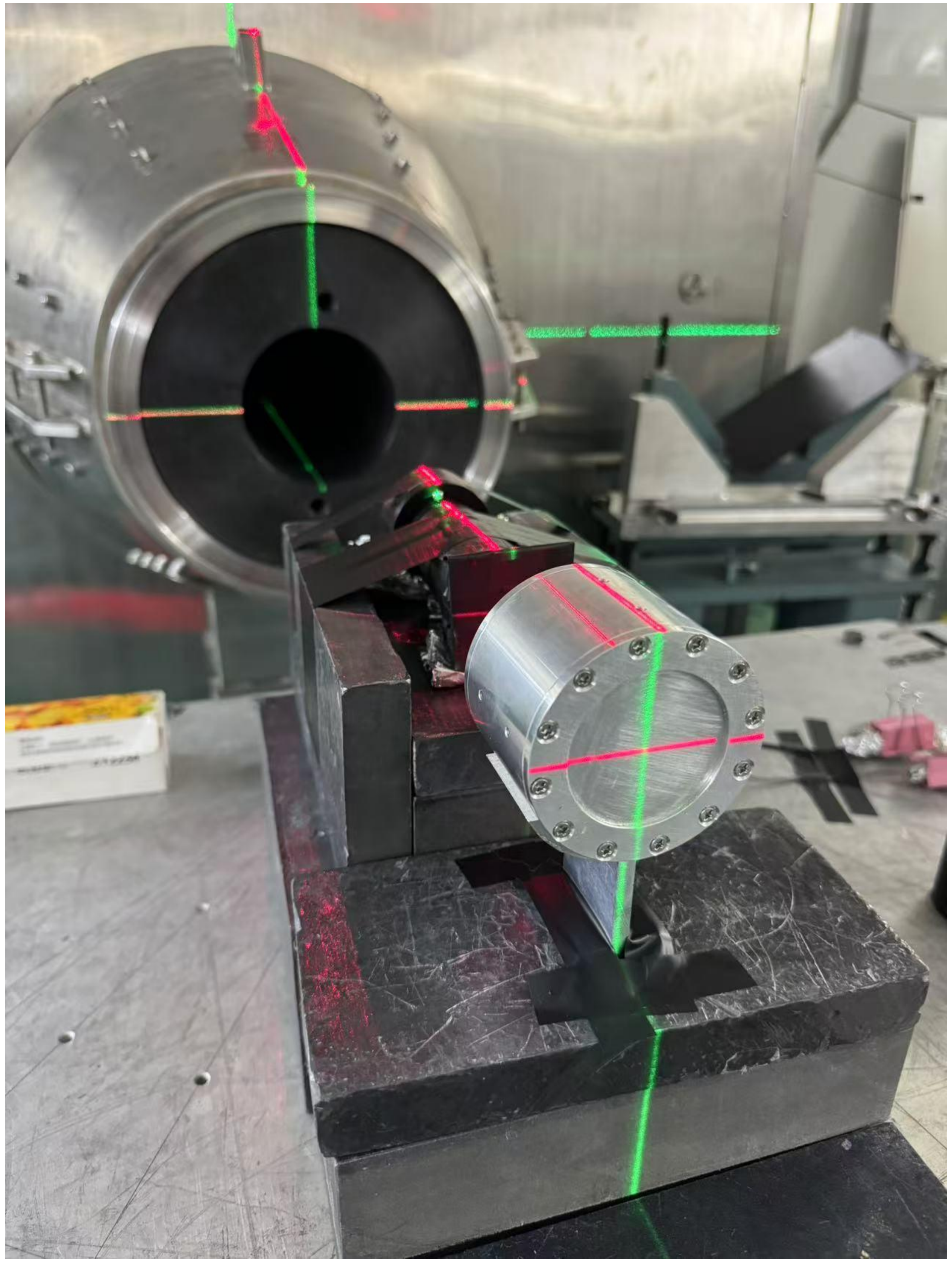
Beamtime: 240h

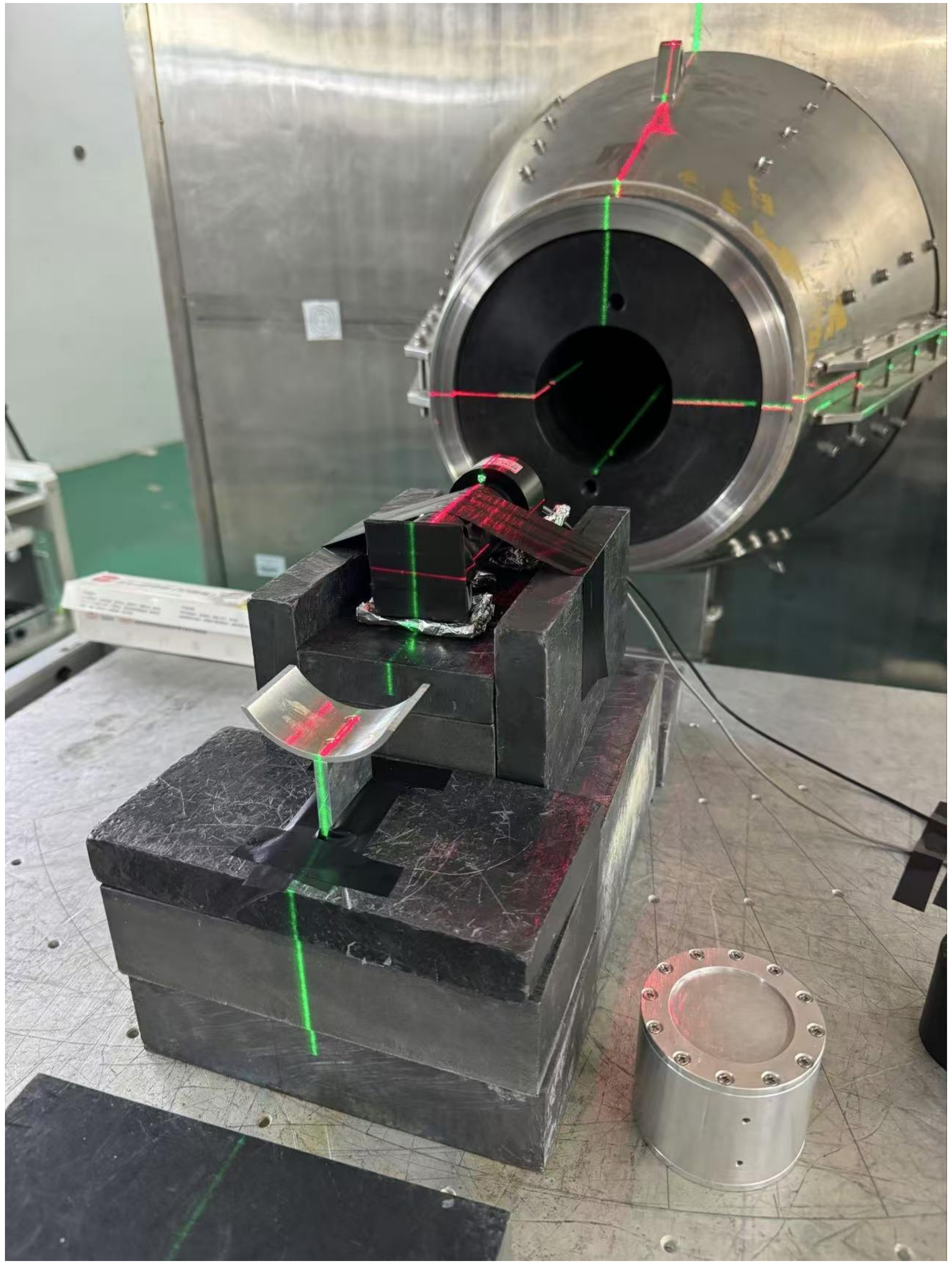
Time: Dec 31st, 2024 – Jan 11th, 2025

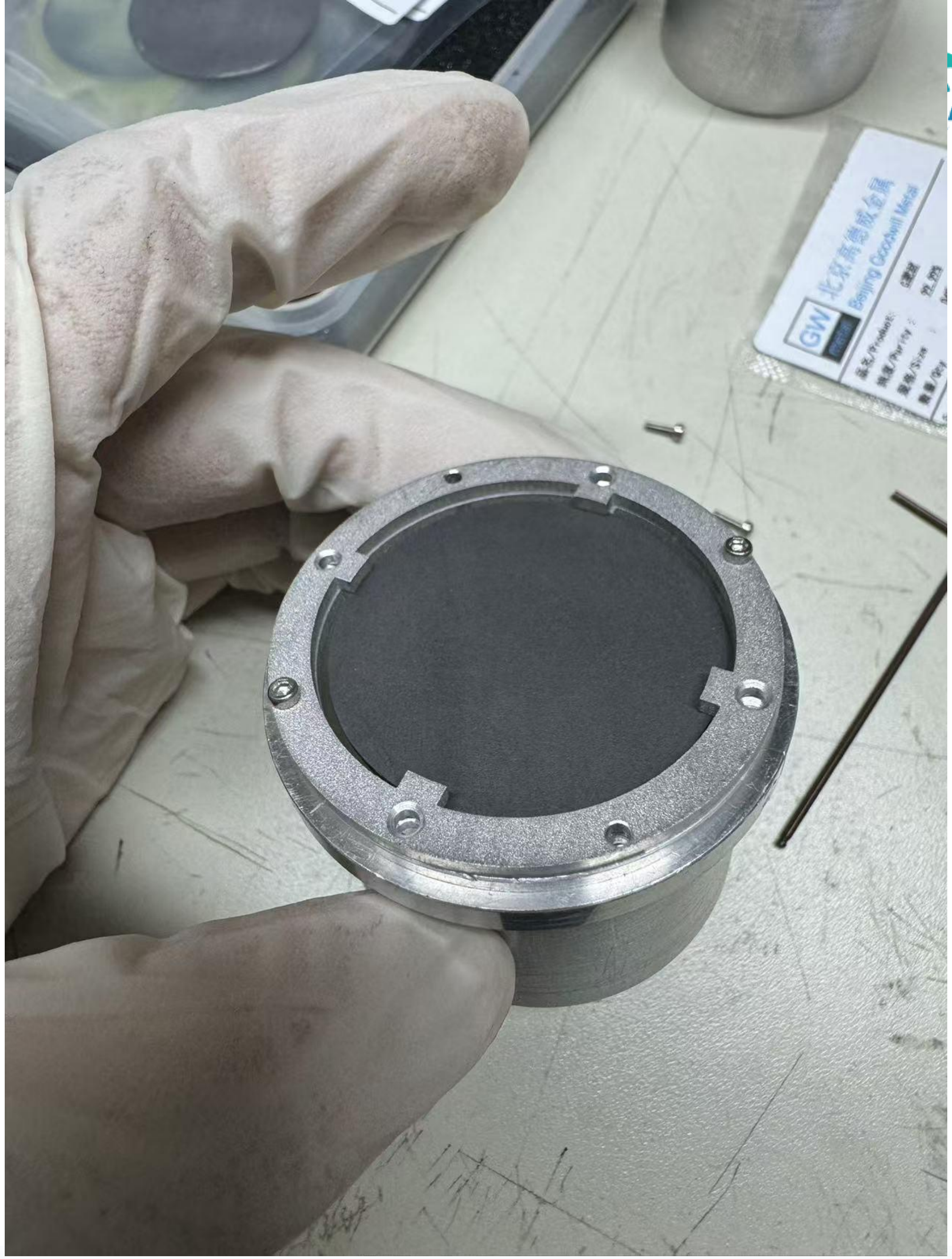
2025年1月的第一次尝试





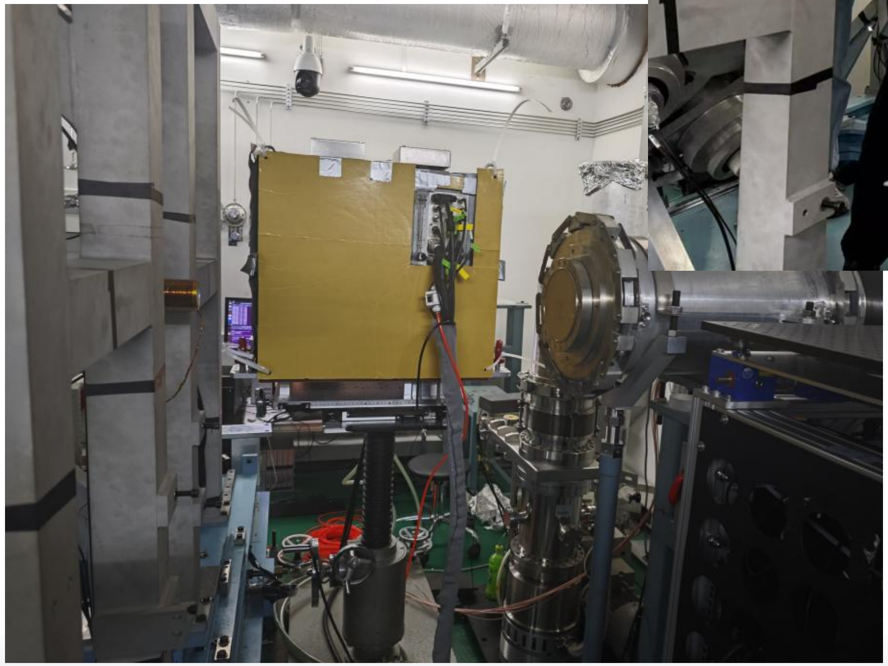




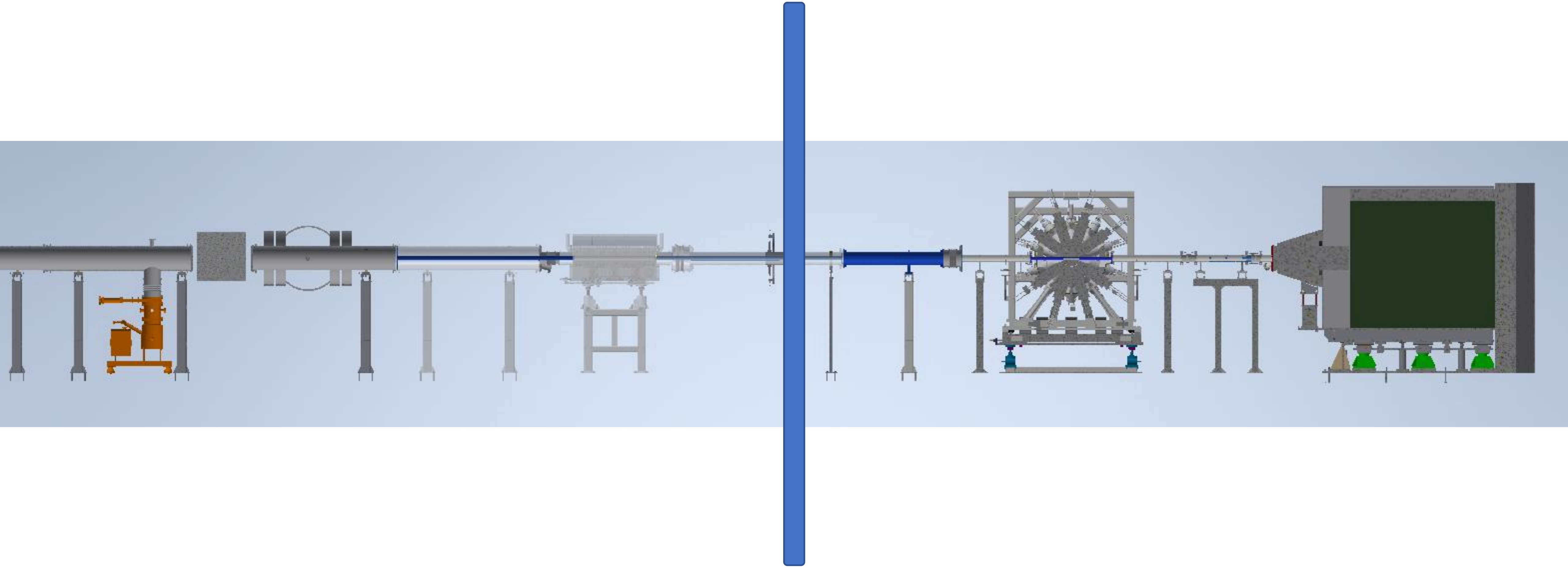


中子屏蔽的诸多问题

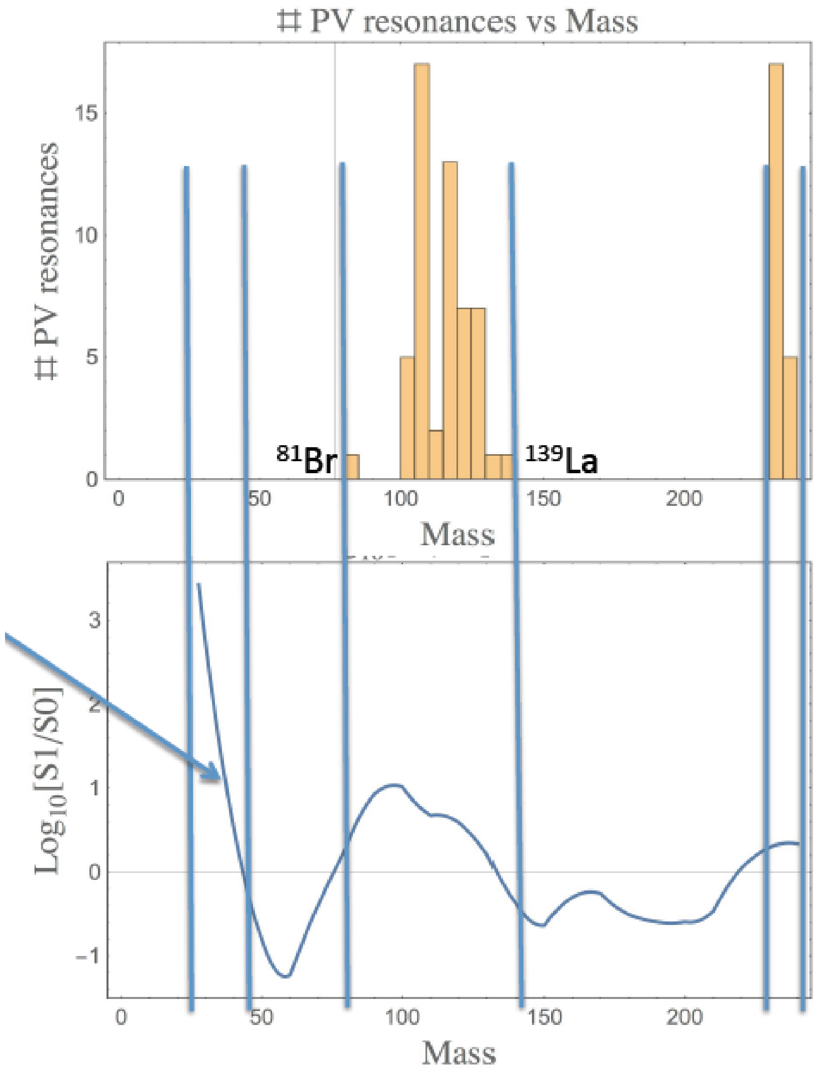
1. In-situ 3He neutron polarizer:
    1. 4 face B 3mm shielding
    2. 1 face Pb 1mm shielding
2. Copper solenoid in place
3. Sample in air
4. 6Li detector in place
5. 15mins data



极化中子装置设计



PV resonances found by TRIPLE



PV resonances occur
If S1/S0 is between
1/3 and 10. The best
TRIPLE resonances
Have S1/S0 ~ 1

NOPTREX合作组下一步计划

What about 140<A<210?

No data!

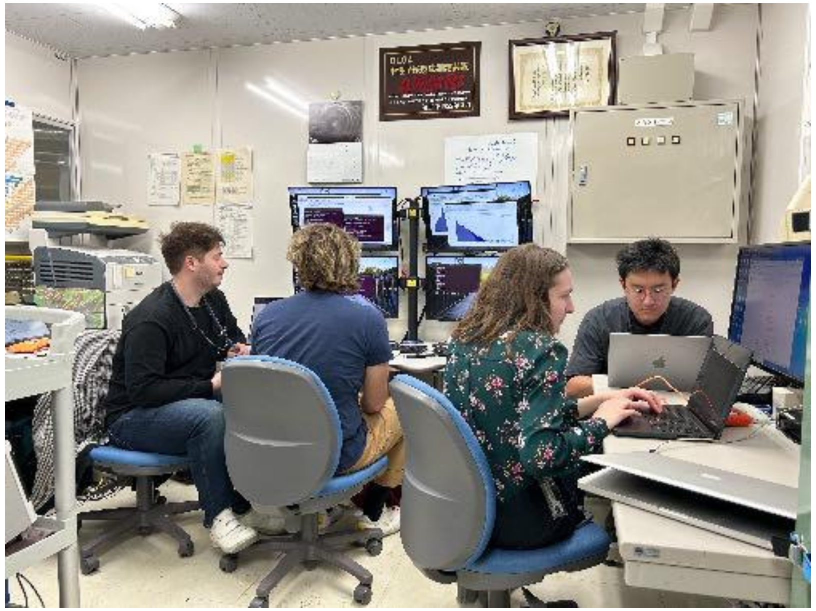
Courtesy of: W. M. Snow(Indiana Uni)

JPARC P Violation Scientific Work 2021-2025

(1) Search for P-odd asymmetries in unmeasured nuclei, for:

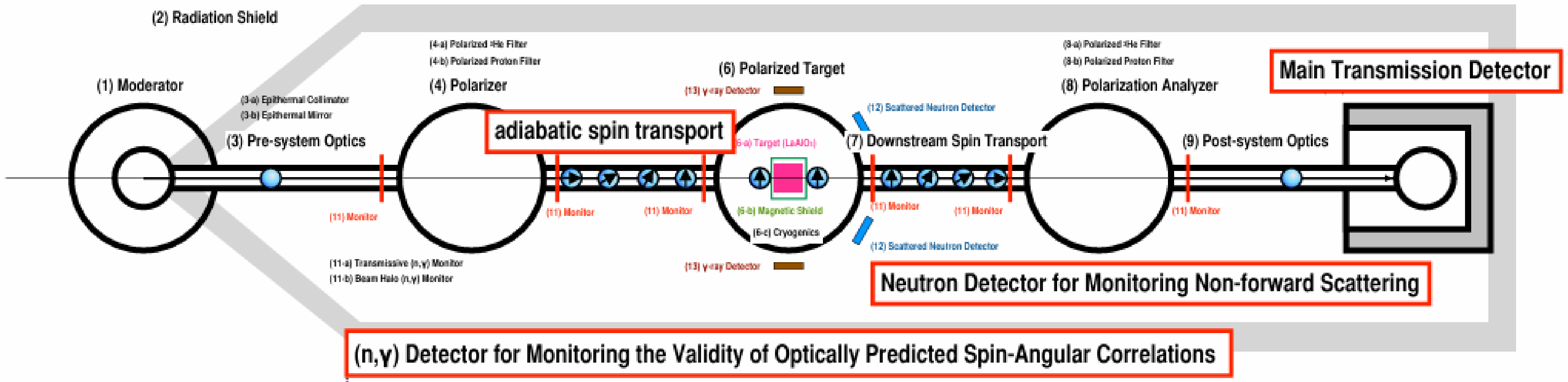
(a) New nuclei for P-odd/T-odd NOPTREX time reversal experiment
(b) Test of statistical theory of parity violation in heavy nuclei

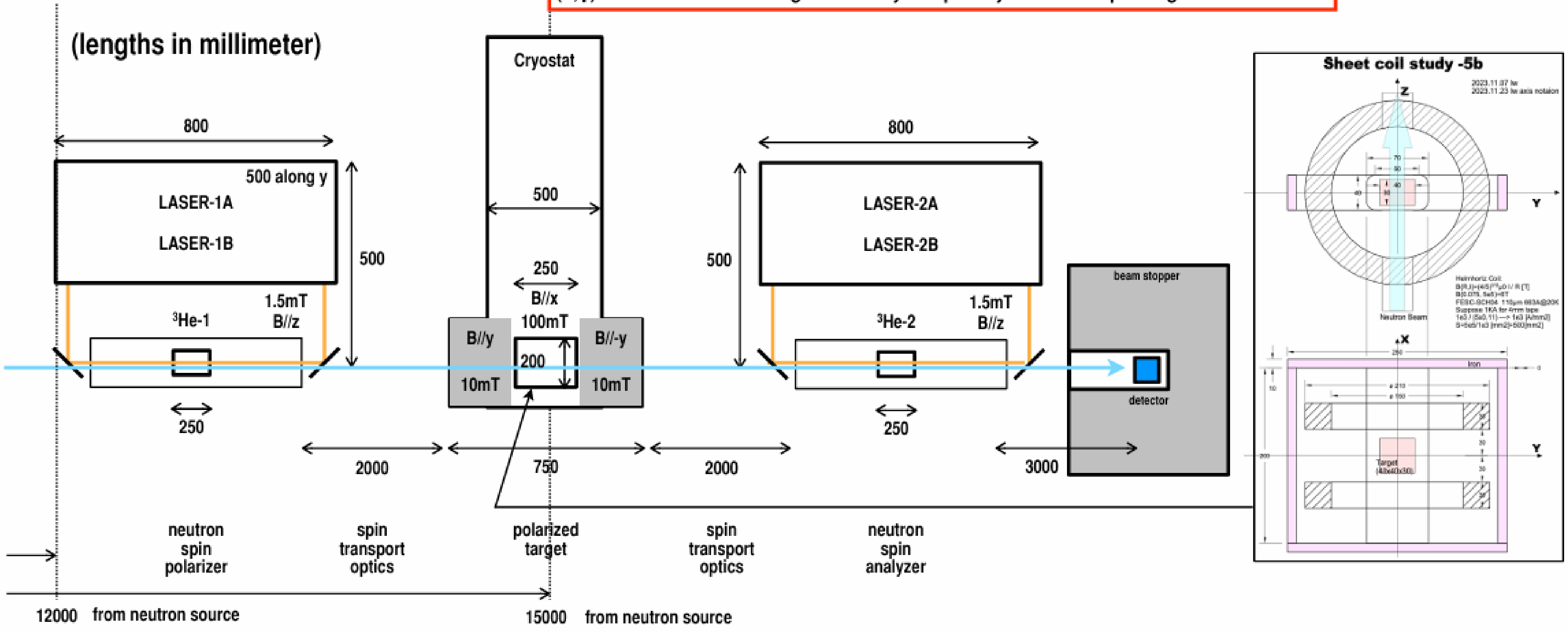
(2) Search for new p-wave resonances in unmeasured nuclei



First NOPTREX experiment with China, Japan, US groups!

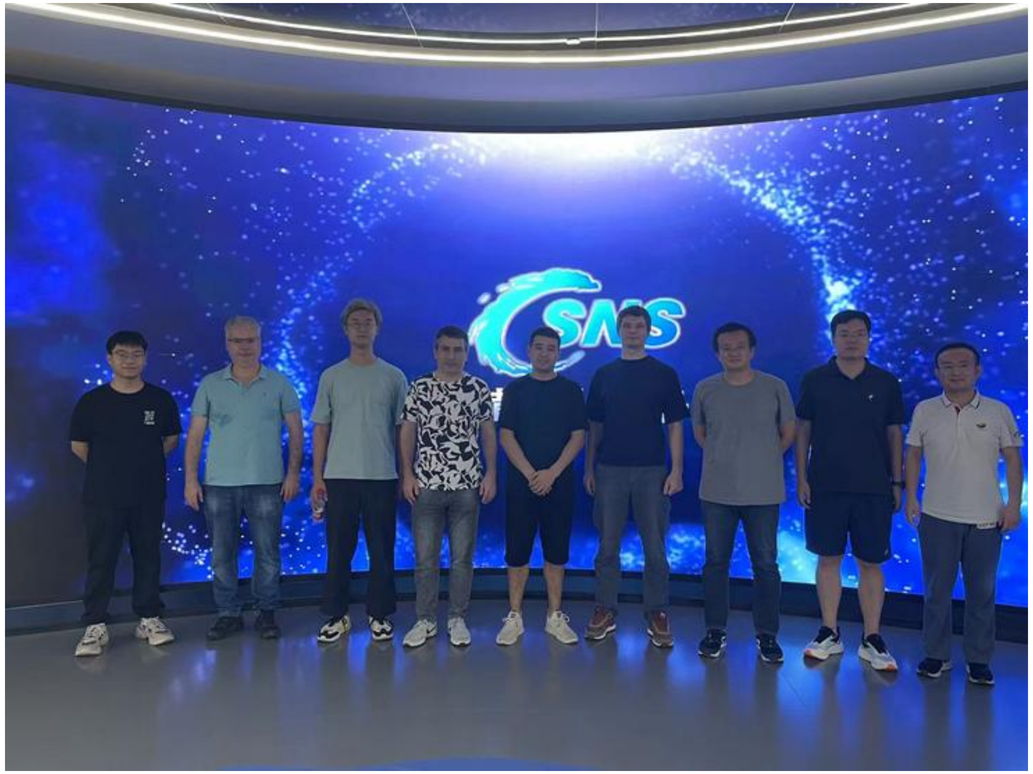
Setup (Phase-II)

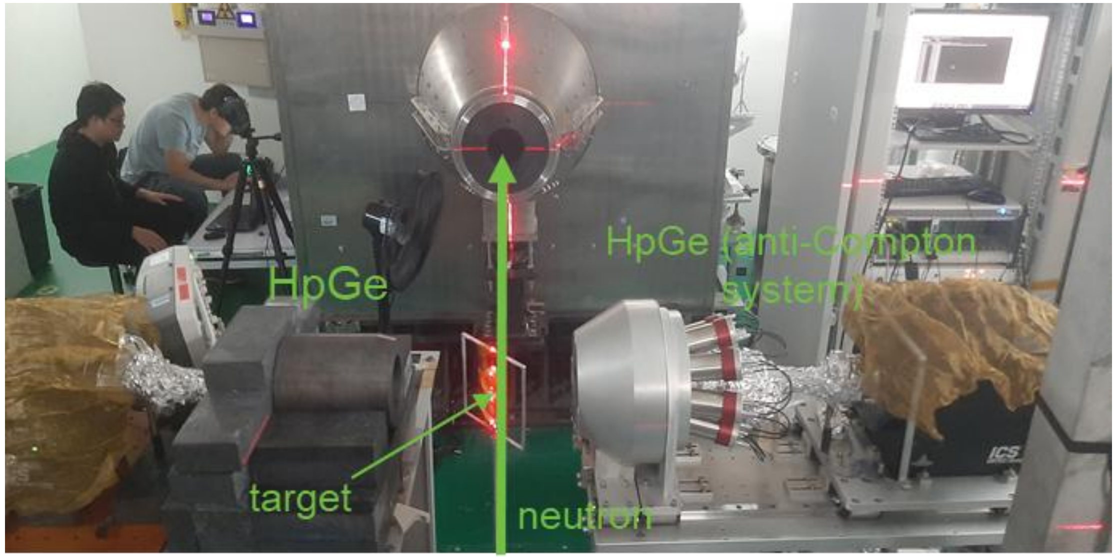


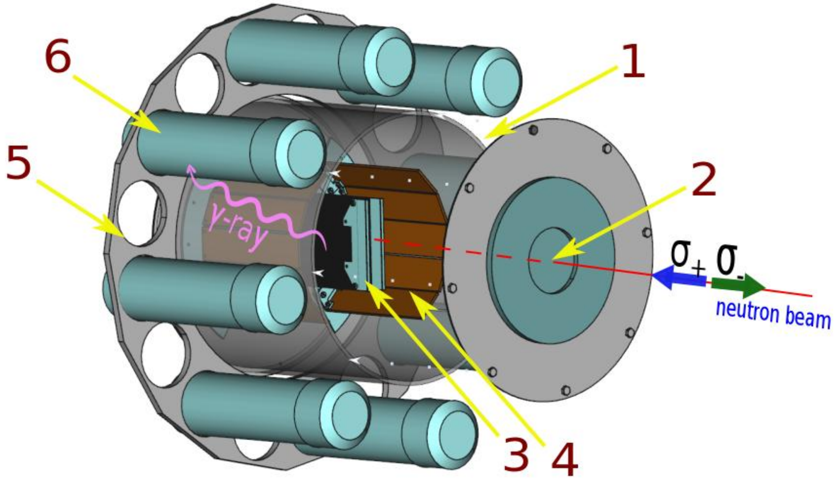


Courtesy of: Shimizu(Nagoya Uni)

JINR-FLNP团队

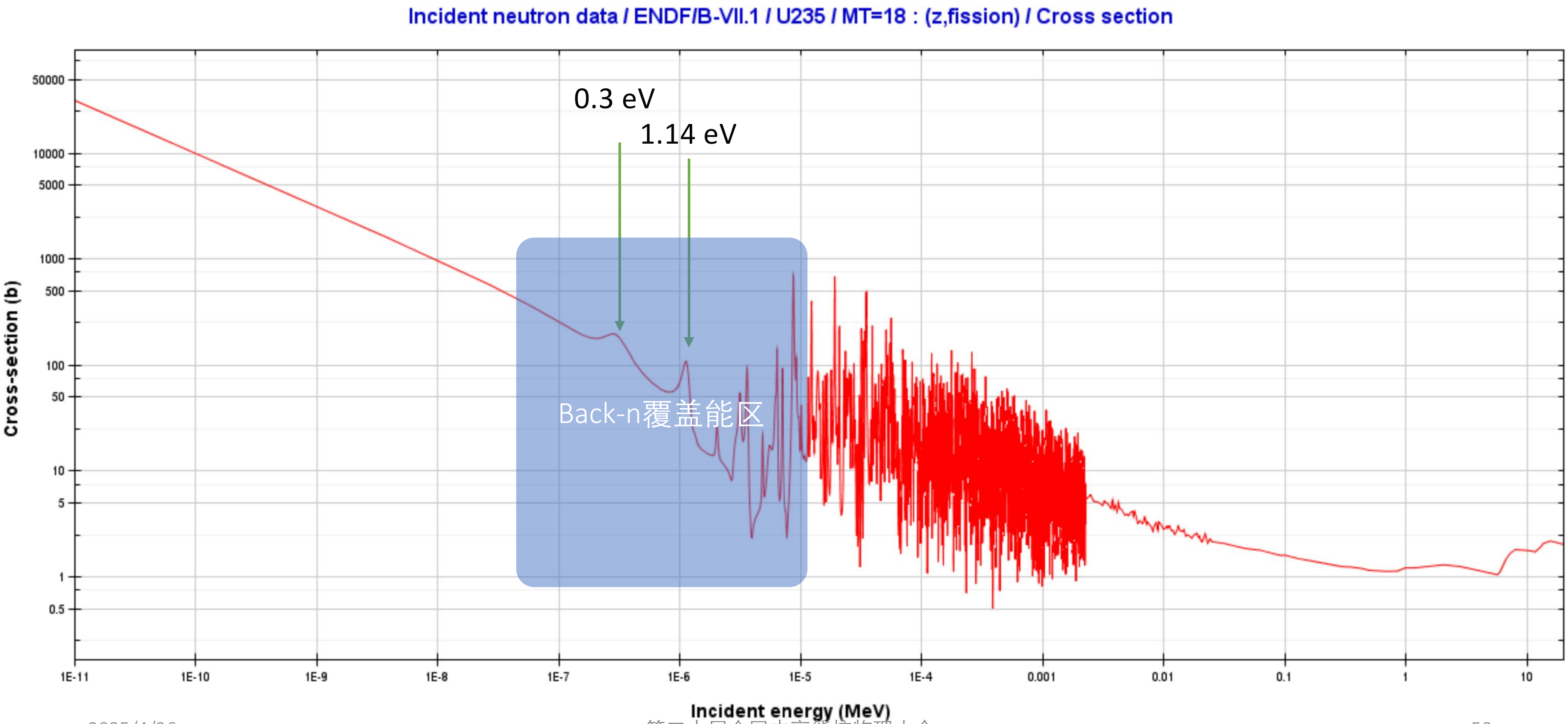






Courtesy of: Gadir(JINR FLNP)

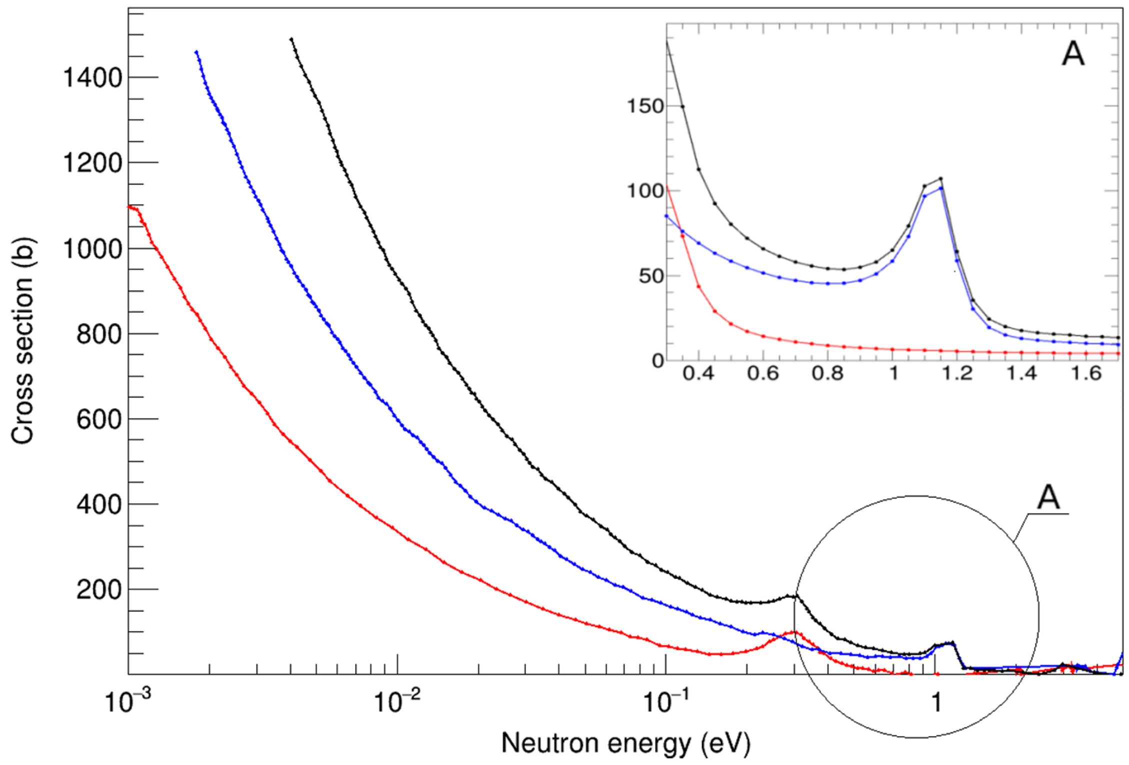
共振态的宇称破坏测量



Incident neutron data / ENDF/B-VII.1 / U235 / MT=18 : (z,fission) / Cross section
0.3 eV
1.14 eV
Back-n覆盖能区
Cross-section (b)
50000
10000
5000
1000
500
100
50
10
5
1
0.5
1E-11
1E-10
1E-9
1E-8
1E-7
1E-6
1E-5
1E-4
0.001
0.01
0.1
1
10
Incident energy (MeV)

为什么是1.14eV?

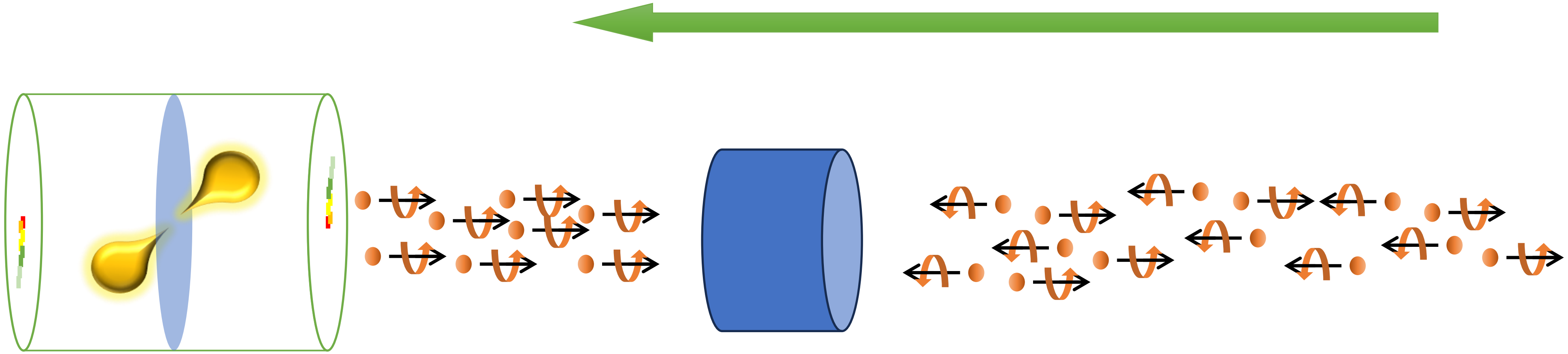
选择在1.14 eV处测量PV效应，主要是因为这个能量点是^{235}U核的一个纯共振态，主要由J = 4的自旋态贡献。这使得实验结果更加清晰，能够直接反映单一自旋态对宇称破缺效应的贡献，从而验证理论模型并深入理解裂变机制。此外，这个能量点的实验条件相对成熟，适合在现有的极化中子源上进行研究



When a ^{235}U nucleus in its ground state (spin I = 7/2) captures an s wave neutron (with an orbital angular momentum of 0), a compound ^{236}U nucleus is formed in states with spins J+ = 1 + 1/2 = 4 and J = 1 – 1/2 = 3. Spin-separated Fission cross sections for ^{236}U* depending on the energy of the incident neutron. Red line corresponds to J = 3 spin, blue line to J = 4 spin, black line to the sum of both, respectively. Calculated by SAMMY

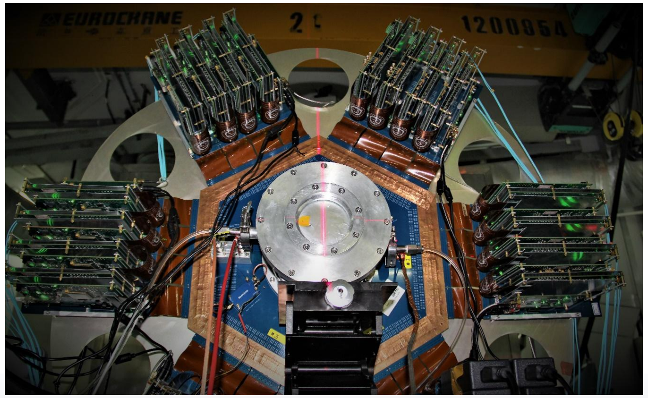
Courtesy of: Daniyar(JINR FLNP)

一个初步的实验方案



Time Project Chamber

Neutron Spin Filter



$$B = \hat{\sigma} \cdot [\widehat{p_{LF}} \times \widehat{p_{TP}}]$$

中子与原子核相互作用

- 中子与原子核相互作用的基本对称性破缺研究
  - 宇称破缺研究 — 高通量冷中子源
  - 宇称破缺的放大效应 — 超热中子能区
  - 时间反演破缺 — ？？？

ISINN31

- The ISINN conference is the International Seminar on Neutron and Nuclear Reactions organized by the FLNP of JINR and is held annually.
- In 2025, it will be hosted by CSNS from May 26 to 31.
- This conference is highly relevant to the NOPTREX experiment's theme, and I warmly welcome everyone to attend in Dongguan.

https://indico.ihep.ac.cn/event/23550/

感谢各位老师聆听！

苔花如米小，也学牡丹开