Probe element synthesis in star with JUNA in deep underground

Weiping Liu
JUNA chief scientist JUNA
CIAE/SUSTech

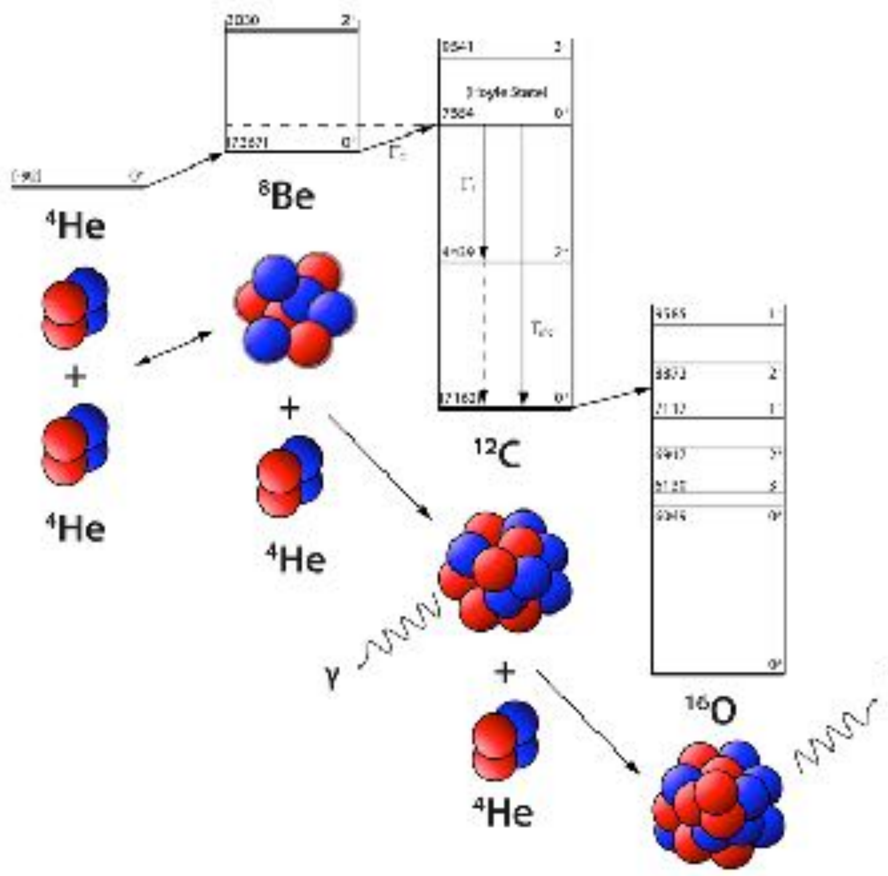
HELIUM25 - Helium burning and perspectives for underground labs
Helmholtz-Zentrum Dresden-Rossendorf, Germany
July 21 – 25, 2025

Supported by NSFC, Yalong power, THU, CAS and CNNC

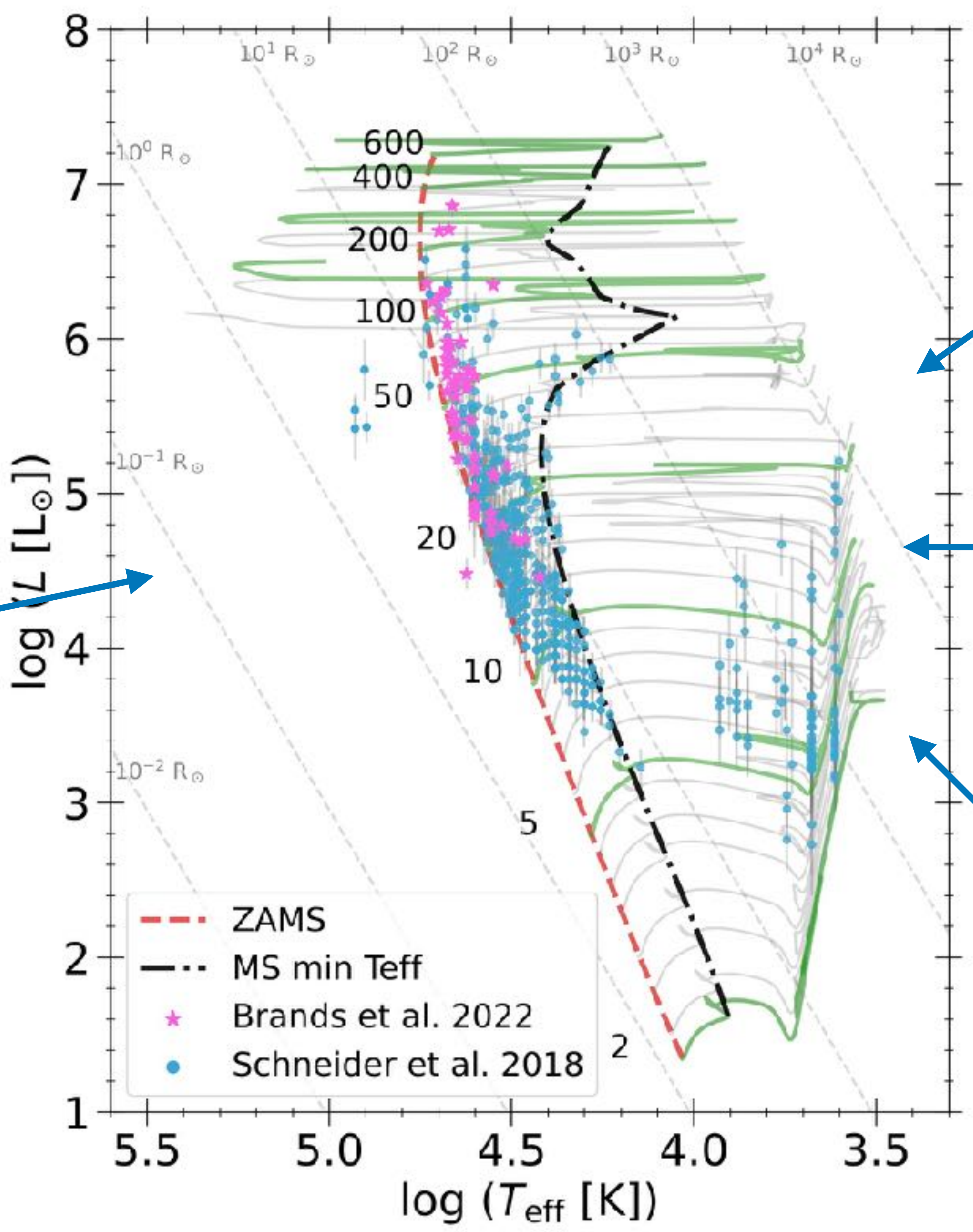
北京师范大学 BEIJING NORMAL UNIVERSITY
中国科学院近代物理研究所 Institute of Modern Physics, Chinese Academy of Sciences
中国原子能科学研究院 中核集团 CHINA INSTITUTE OF ATOMIC ENERGY
雅砻江流域水电开发有限公司 YALONG RIVER HYDROPOWER DEVELEPOMENT COMPANY, LTD.
南方科技大学 SOUTHERN UNIVERSITY OF SCIENCE AND TECHNOLOGY
上海交通大学 SHANGHAI JIAO TONG UNIVERSITY
山东大学 SHANDONG UNIVERSITY
四川大学 SICHUAN UNIVERSITY
深圳大学 SHENZHEN UNIVERSITY
中山大學 SUN YAT-SEN UNIVERSITY
清華大學

Input to simulations and important reactions

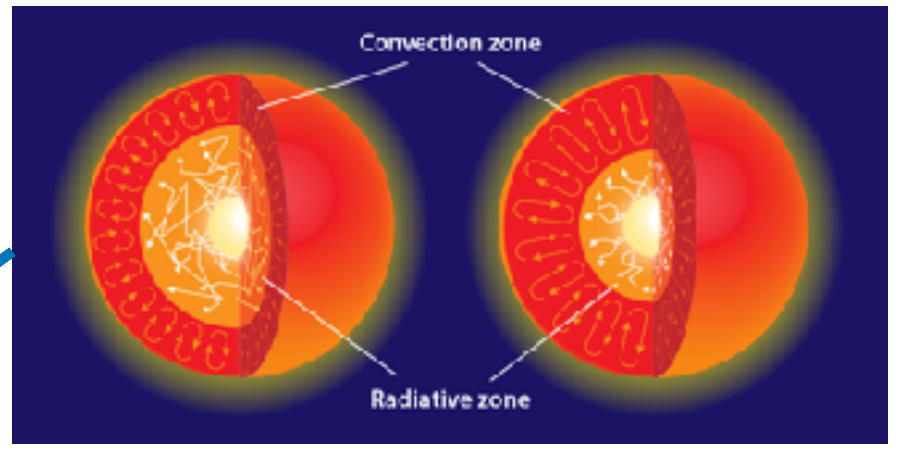
nuclear reactions



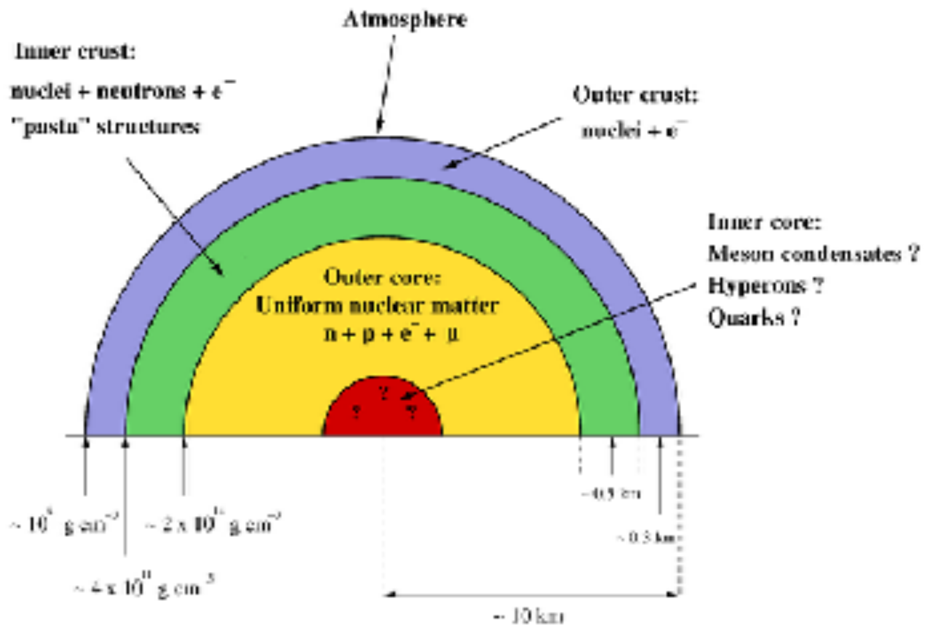
Reaction
$p(p, \beta^+ \nu)D$
$p(D, \gamma)^3He$
$^3He(^3He, \gamma)2p + ^4He$
$^4He(^3He, \gamma)^7Be$
$^7Be(e^-, \gamma)^7Li$
$^7Li(p, \gamma)^4He + ^4He$
$^7Be(p, \gamma)^8B$
$^{12}C(p, \gamma)^{13}N$
$^{13}C(p, \gamma)^{14}N$
$^{14}N(p, \gamma)^{15}O$
$^{15}N(p, \gamma)^4He + ^{12}C$
$^{15}N(p, \gamma)^{16}O$
$^{16}O(p, \gamma)^{17}F$
$^{17}O(p, \gamma)^4He + ^{14}N$
$^{17}O(p, \gamma)^{18}F$
$^{18}O(p, \gamma)^4He + ^{15}N$
$^{18}O(p, \gamma)^{19}F$
$^{19}F(p, \gamma)^4He + ^{16}O$
$^{19}F(p, \gamma)^{20}Ne$
$^4He(2\,^4He, \gamma)^{12}C$
$^{12}C(^4He, \gamma)^{16}O$
$^{14}N(^4He, \gamma)^{18}F$
$^{15}N(^4He, \gamma)^{19}F$
$^{16}O(^4He, \gamma)^{20}Ne$
$^{18}O(^4He, \gamma)^{22}Ne$
$^{20}Ne(^4He, \gamma)^{24}Mg$
$^{22}Ne(^4He, \gamma)^{26}Mg$
$^{24}Mg(^4He, \gamma)^{28}Si$
$^{13}C(^4He, n)^{16}O$
$^{17}O(^4He, n)^{20}Ne$
$^{18}O(^4He, n)^{21}Ne$
$^{21}Ne(^4He, n)^{24}Mg$
$^{22}Ne(^4He, n)^{25}Mg$
$^{25}Mg(^4He, n)^{28}Si$
$^{20}Ne(p, \gamma)^{21}Na$
$^{21}Ne(p, \gamma)^{22}Na$
$^{22}Ne(p, \gamma)^{23}Na$
$^{23}Na(p, \gamma)^4He + ^{20}Ne$
$^{23}Na(p, \gamma)^{24}Mg$
$^{24}Mg(p, \gamma)^{25}Al$
$^{25}Mg(p, \gamma)^{26}Al^g$
$^{25}Mg(p, \gamma)^{26}Al^m$
$^{26}Mg(p, \gamma)^{27}Al$
$^{26}Al^g(p, \gamma)^{27}Si$
$^{27}Al(p, \gamma)^4He + ^{24}Mg$
$^{27}Al(p, \gamma)^{28}Si$
$^{26}Al(p, \gamma)^{27}Si$
$^{26}Al(n, p)^{26}Mg$
$^{12}C(^{12}C, n)^{23}Mg$
$^{12}C(^{12}C, p)^{23}Na$
$^{12}C(^{12}C, ^4He)^{20}Ne$
$^{20}Ne(\gamma, ^4He)^{16}O$



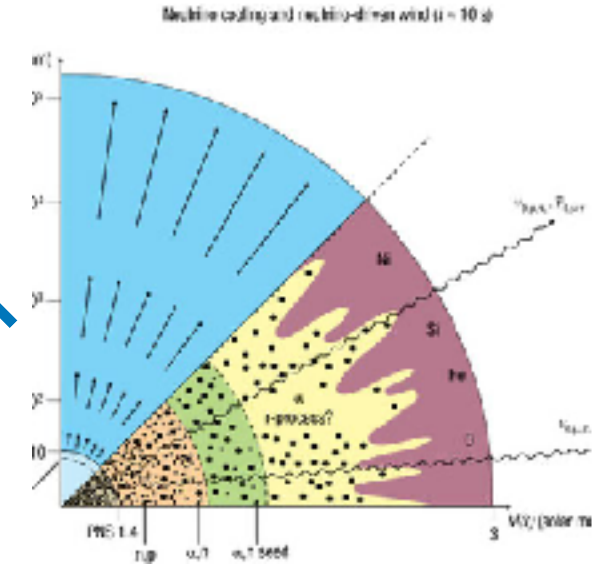
opacities



equation of state



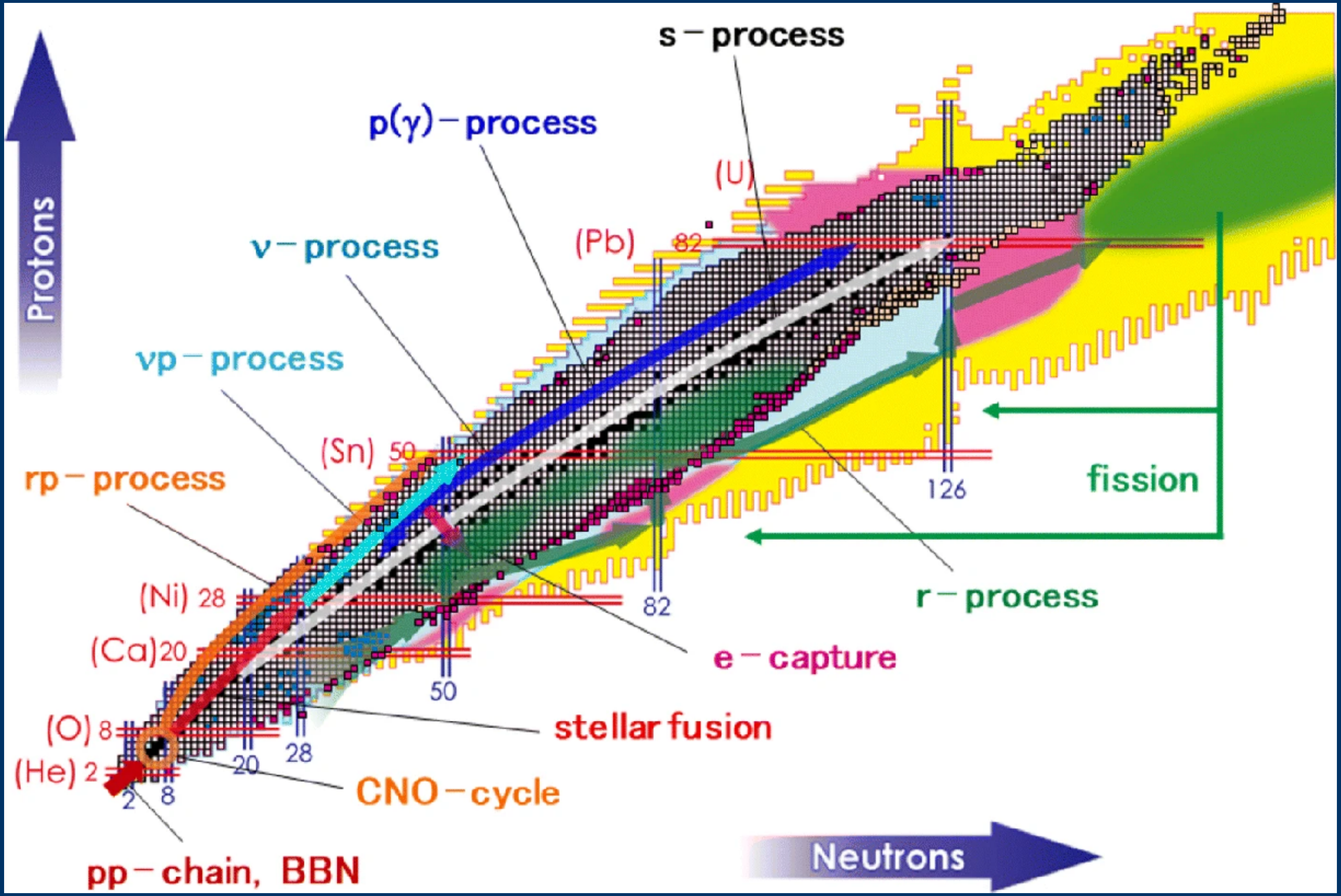
energy loss by ν_e



studied or planed in JUNA

MNRAS 476, 496–511 (2018)
arXiv:2501.12917v2 [astro-ph.SR] 23 Jan 2025

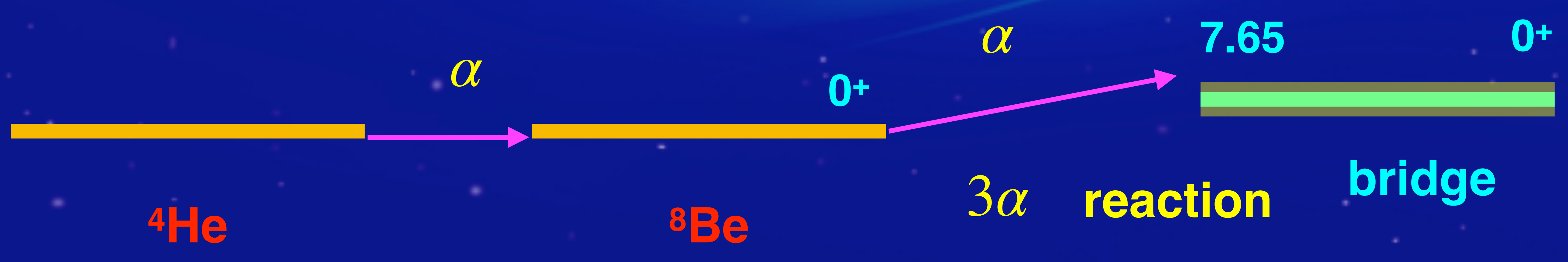
Major astrophysics process



- **Benchmark:**
  $^{7}Be(p,\gamma)^{8}B$, $^{19}F(p,\gamma)^{20}Ne$
- **Bottleneck:**
  $^{12}C(\alpha,\gamma)^{16}O$, $^{12}C+^{12}C$
- **Neutron source:**
  $^{13}C(\alpha,n)^{16}O$, $^{22}Ne(\alpha,n)^{25}Mg$
- **Many more:**
  by sensitivity

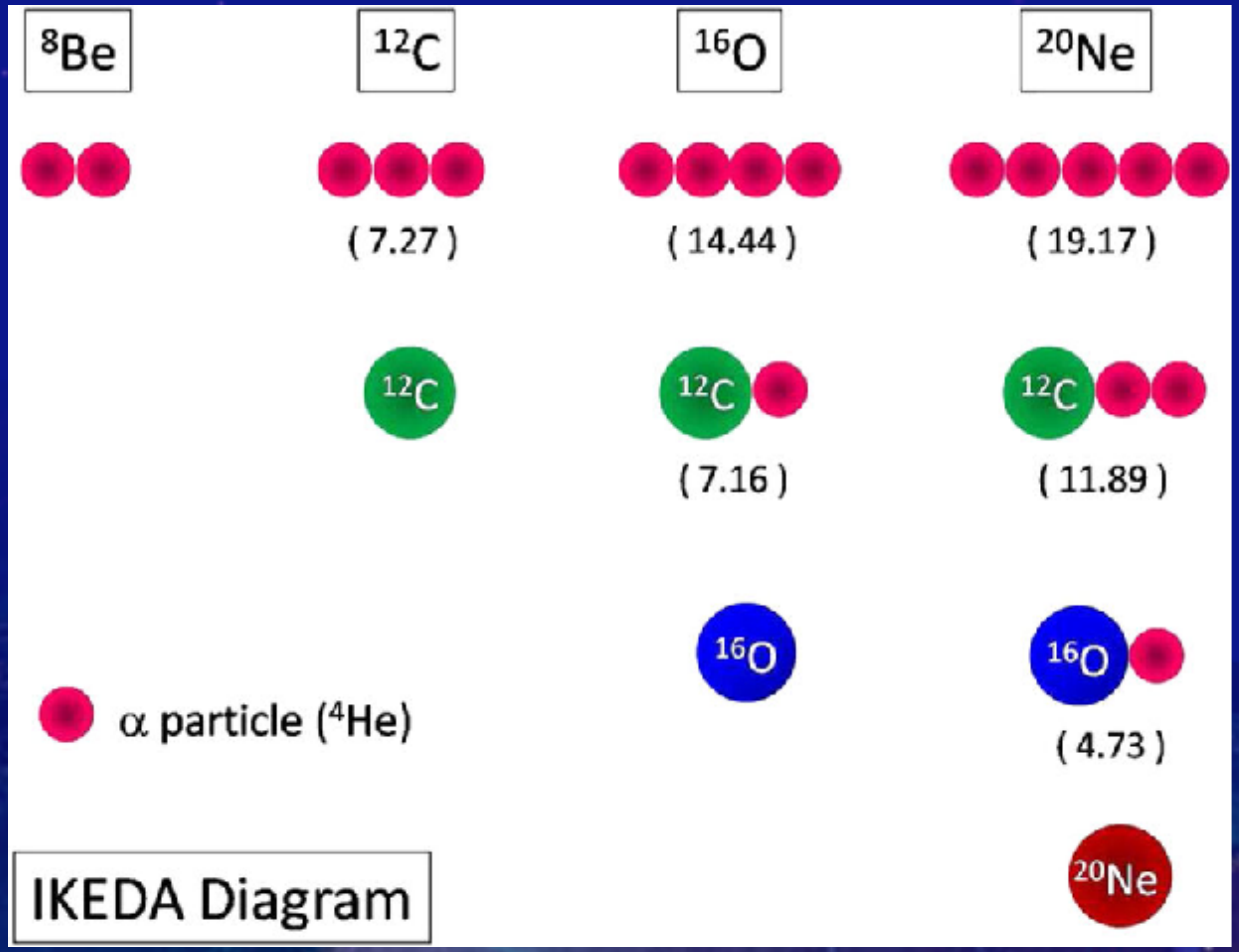
- Progress in nuclear astrophysics of east and southeast Asia…Toshitaka Kajino*, …, WPL*, …, Xiaodong Tang*,… et al., AAPPSBulletin (2021) 31:18

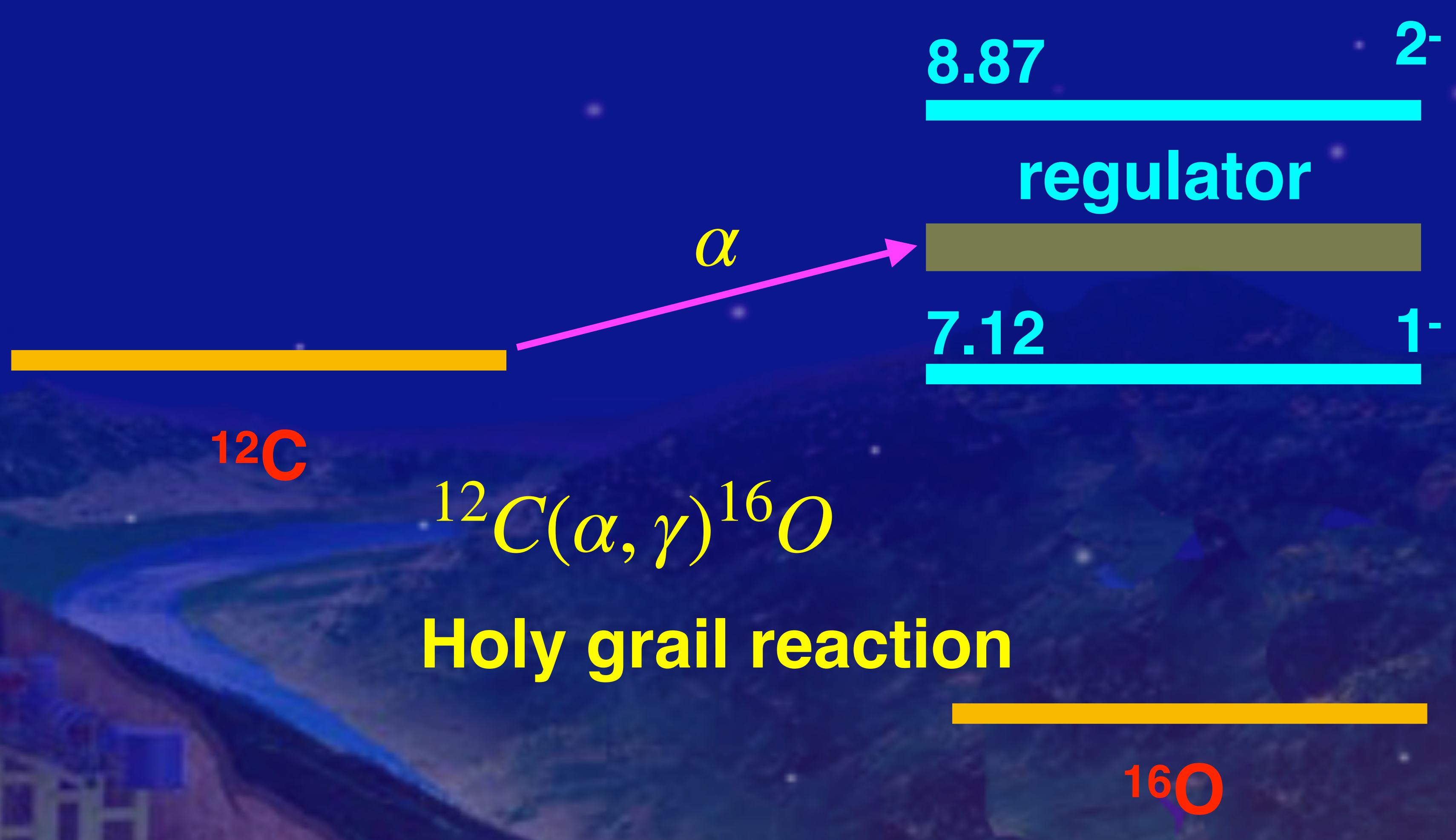
α cluster, state of nuclei, fate of star



1954, Hoyle state, large amount of Carbon

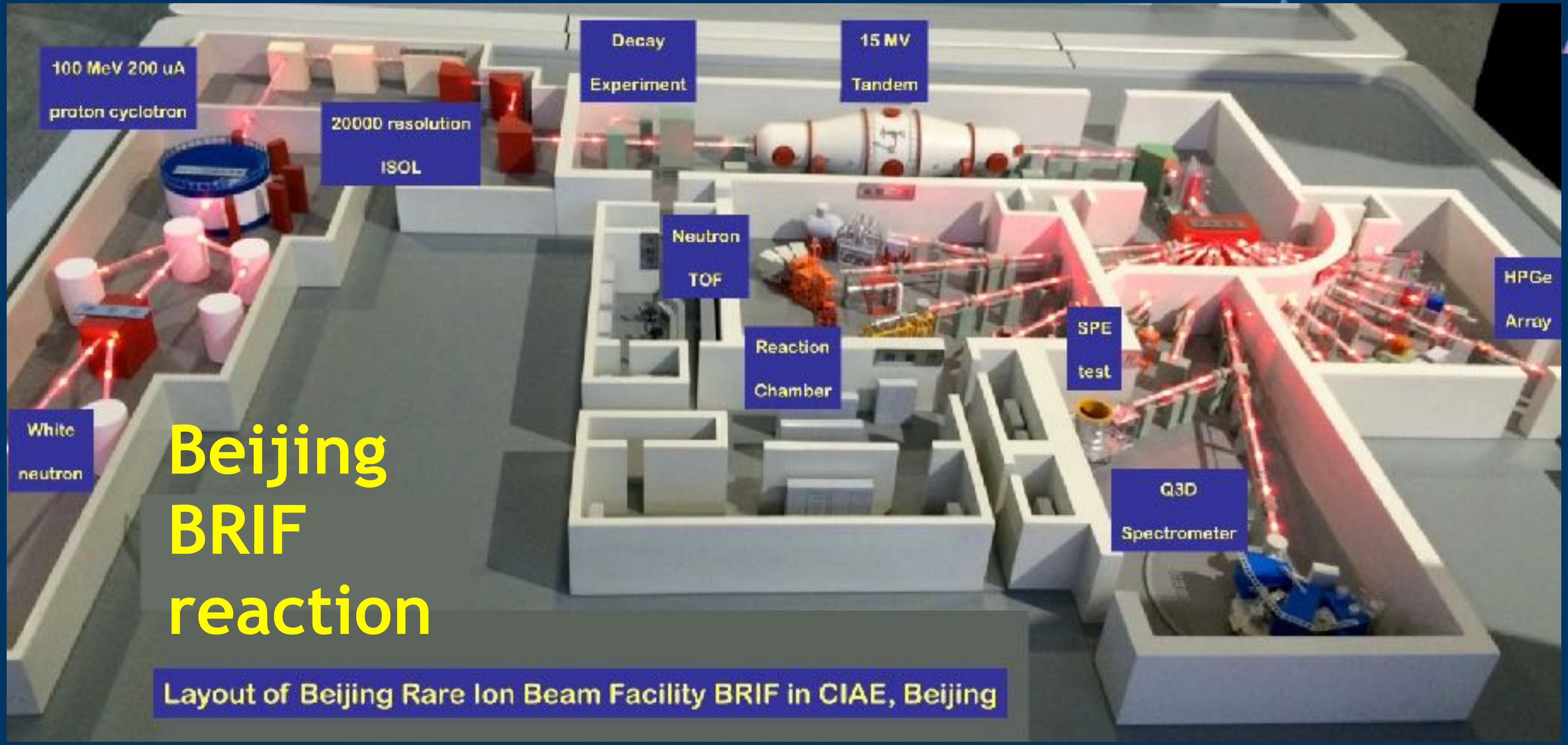
Fred Hoyle (1915-2001)
APJS 1(1954)121

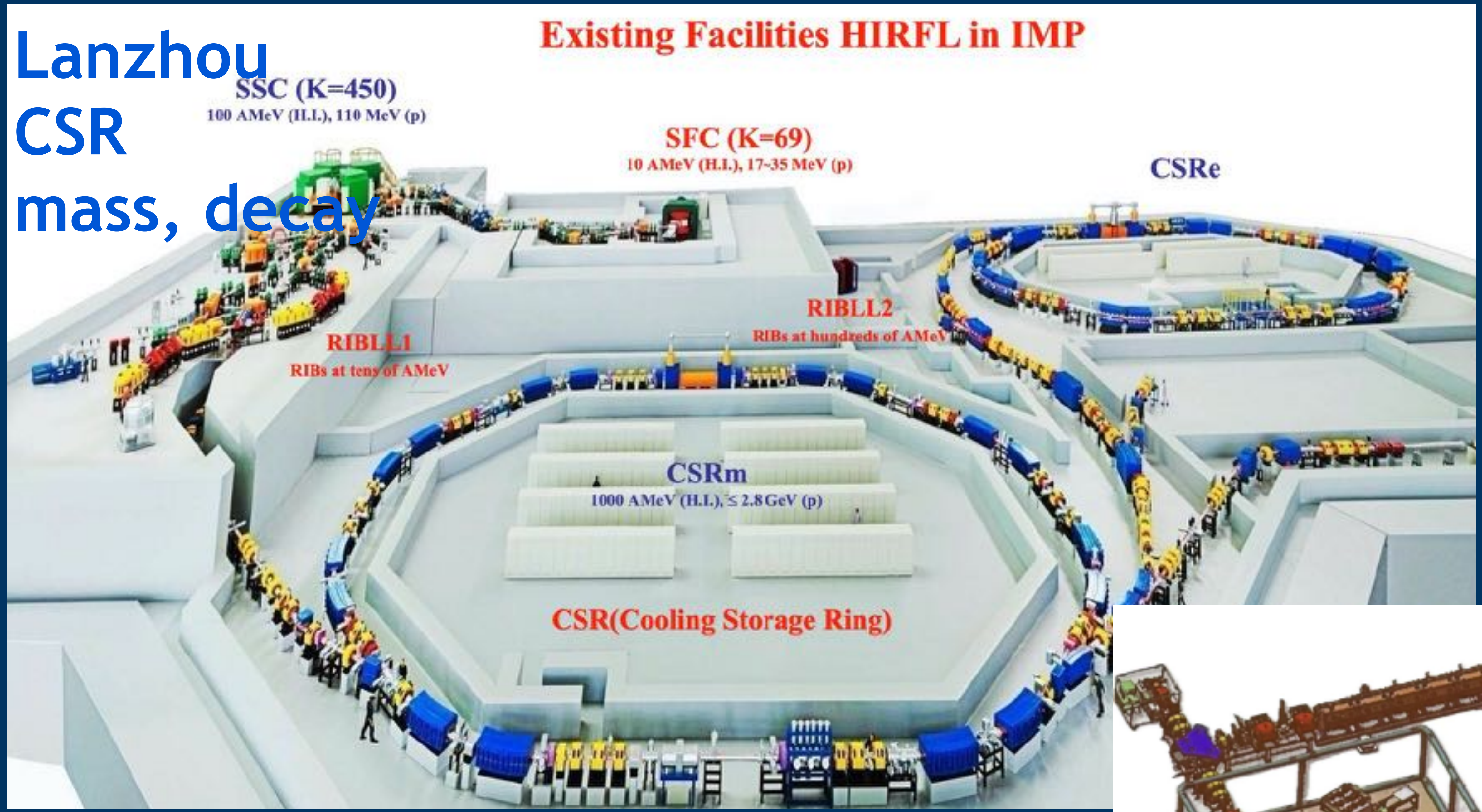


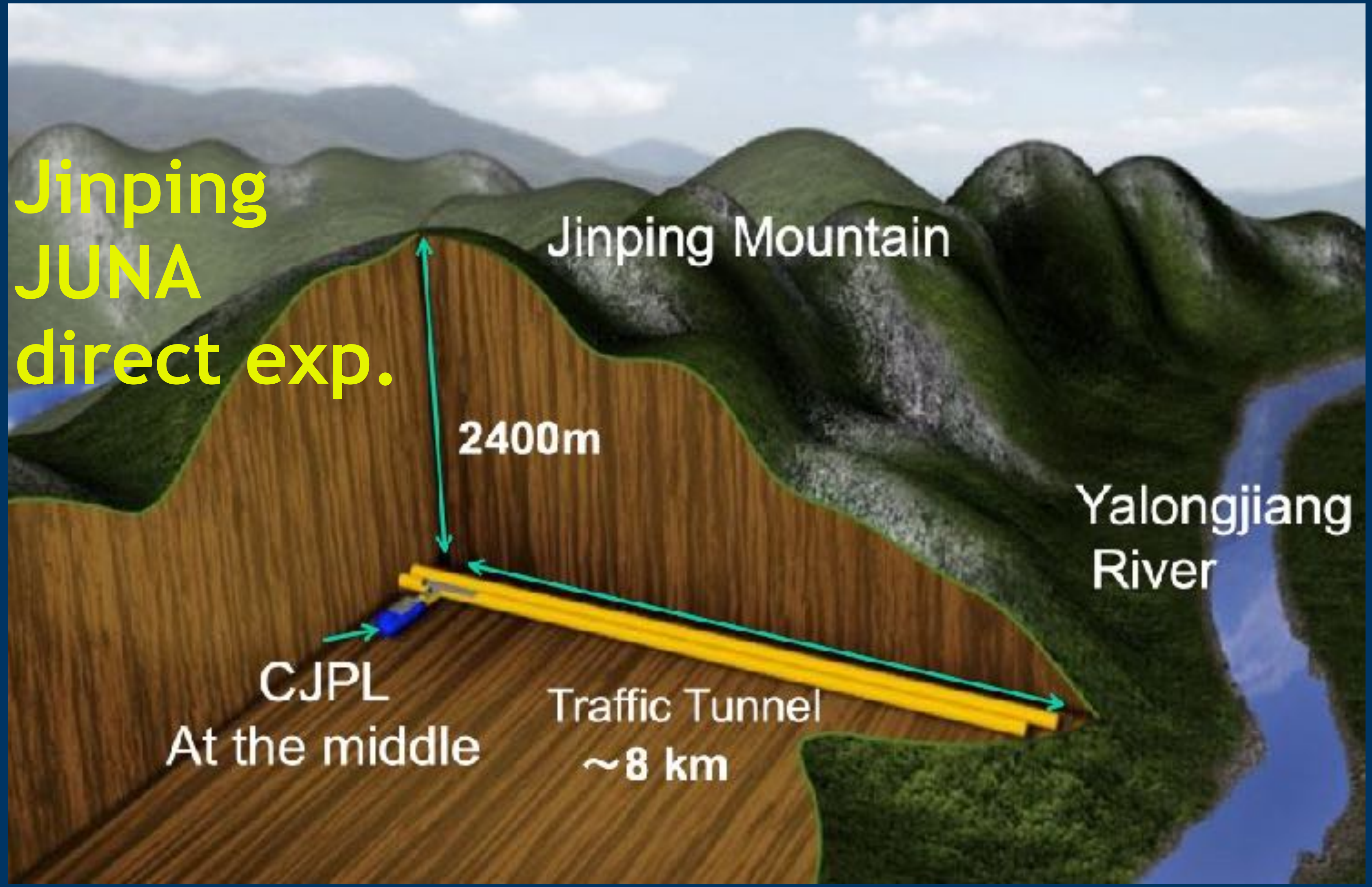


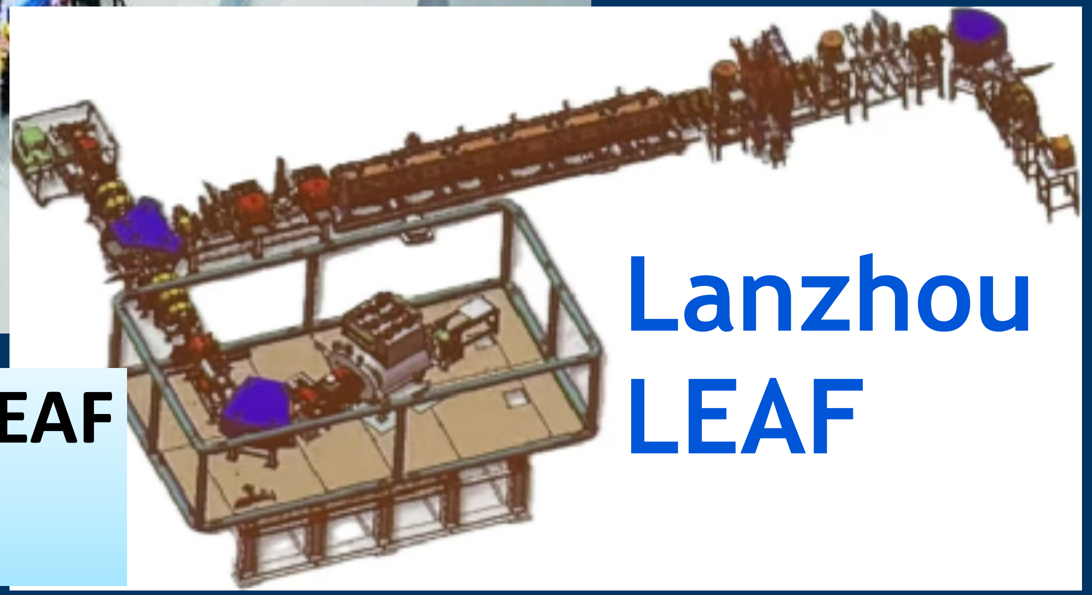
Adequate amount: for sun burn long, for human live

Major facilities in China





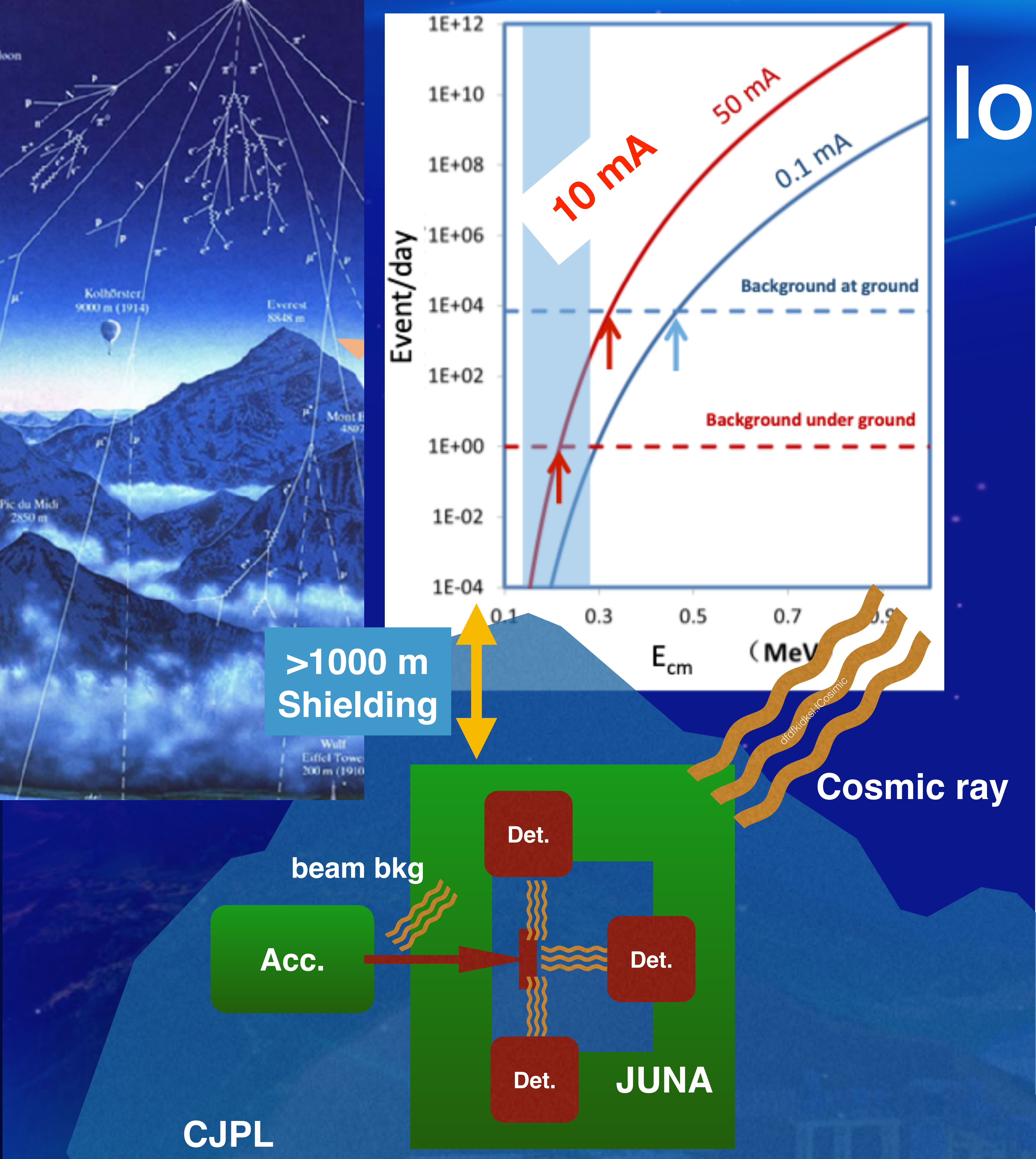


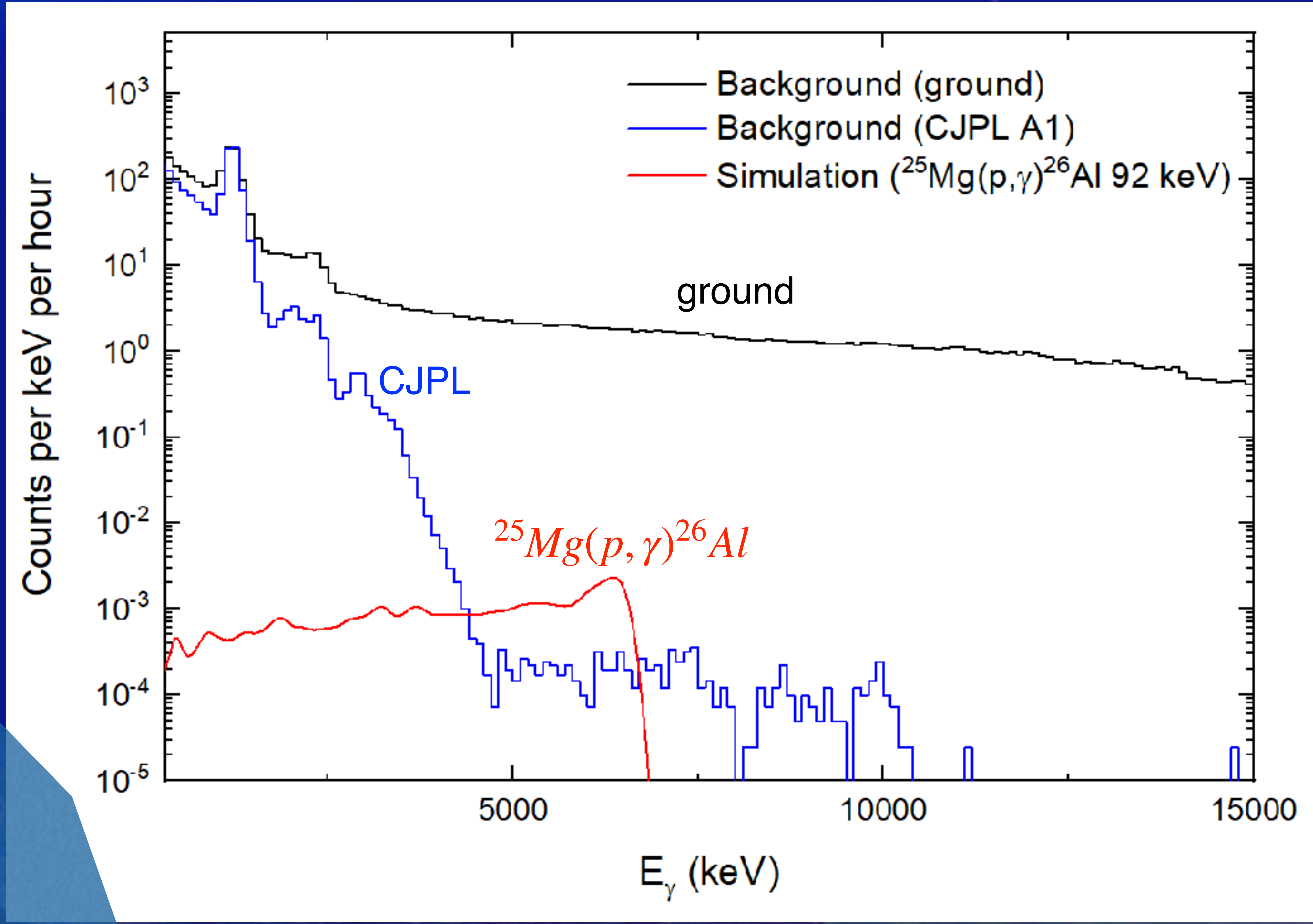


In this NIC, LEAF
C+C, Li

W. P. Liu, 2025, Dresden

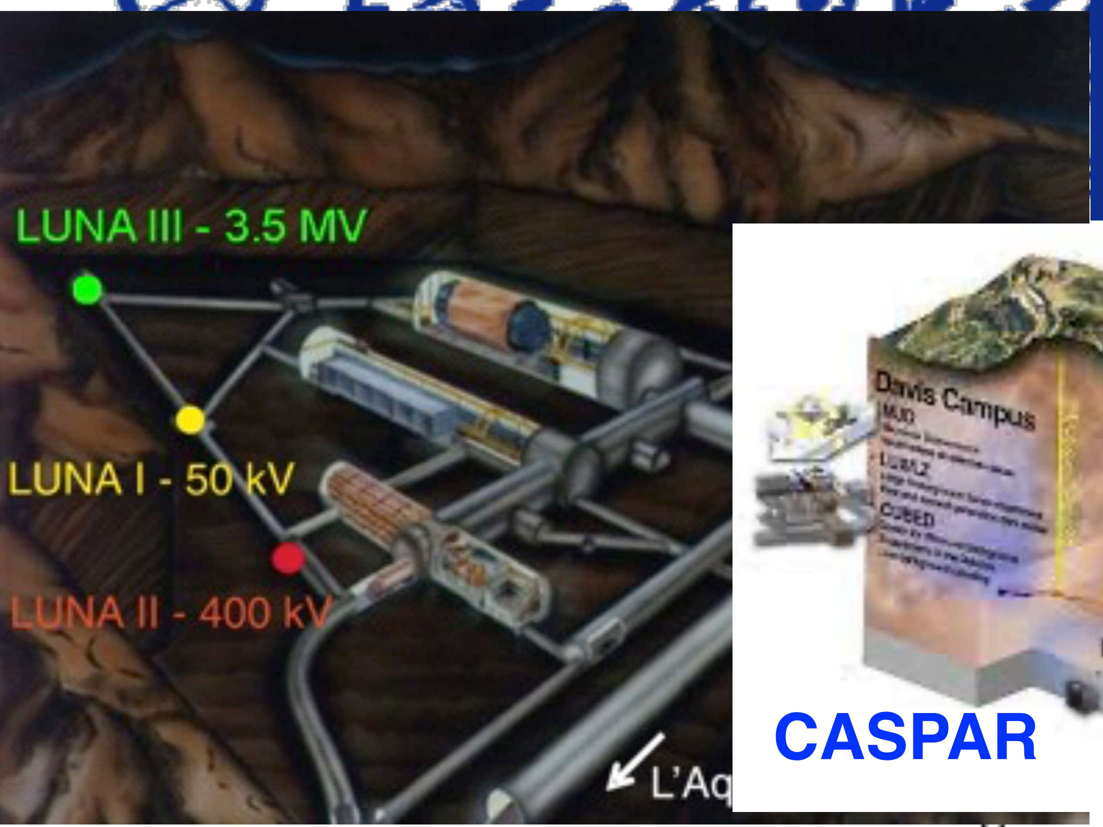
low bkg+high intensity

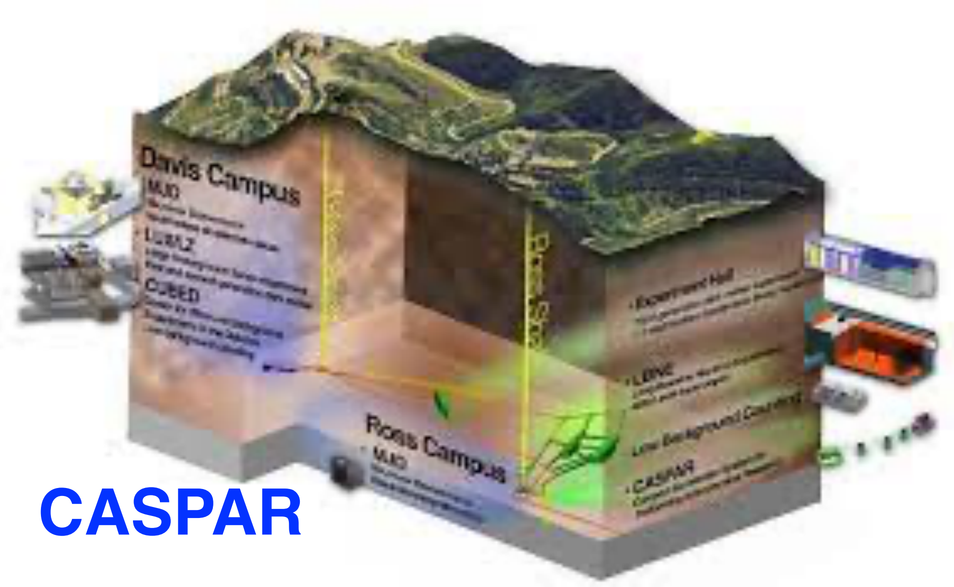




WPL et al., Sci. China 59(2016)2

LUNA, CASPAR and Felsenkeller





CASPAR

F. Cavanna et al., PRL 115(2015)252501, $^{22}Ne(p,\gamma)^{23}Na$.

F. Ciani et al. PRL 127(2021)152701, $^{13}C(\alpha,n)^{16}O$

V. Mossa et al., Nature 587(2020)210 , $D(p,\gamma)^{3}He$

A. C. Dombos et al., PRL 128(2022)162701, $^{18}O(\alpha,\gamma)^{22}Ne$

LUNA

$^3He(^3He,2p)^4He$
PRL82(1999)5205

$^2H(^3He,p)^4He$
PLB482(2000)43

$^2H(p,\gamma)^3He$
NPA 706(2002)203

$^3He(\alpha,\gamma)^7Be$
PRL 97(2006)122502

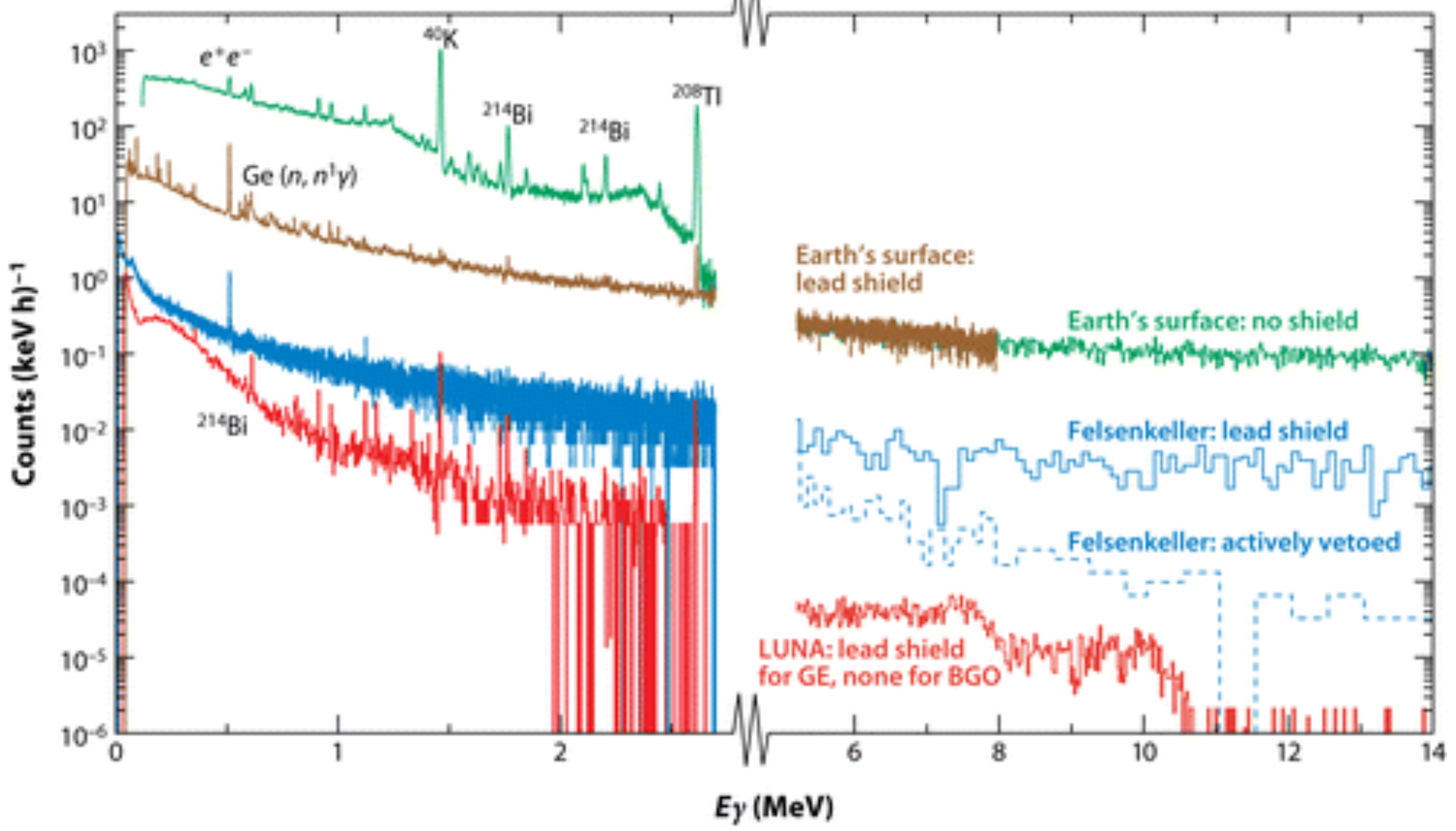
$^{14}N(p,\gamma)^{15}O$
PLB 591(2004)61

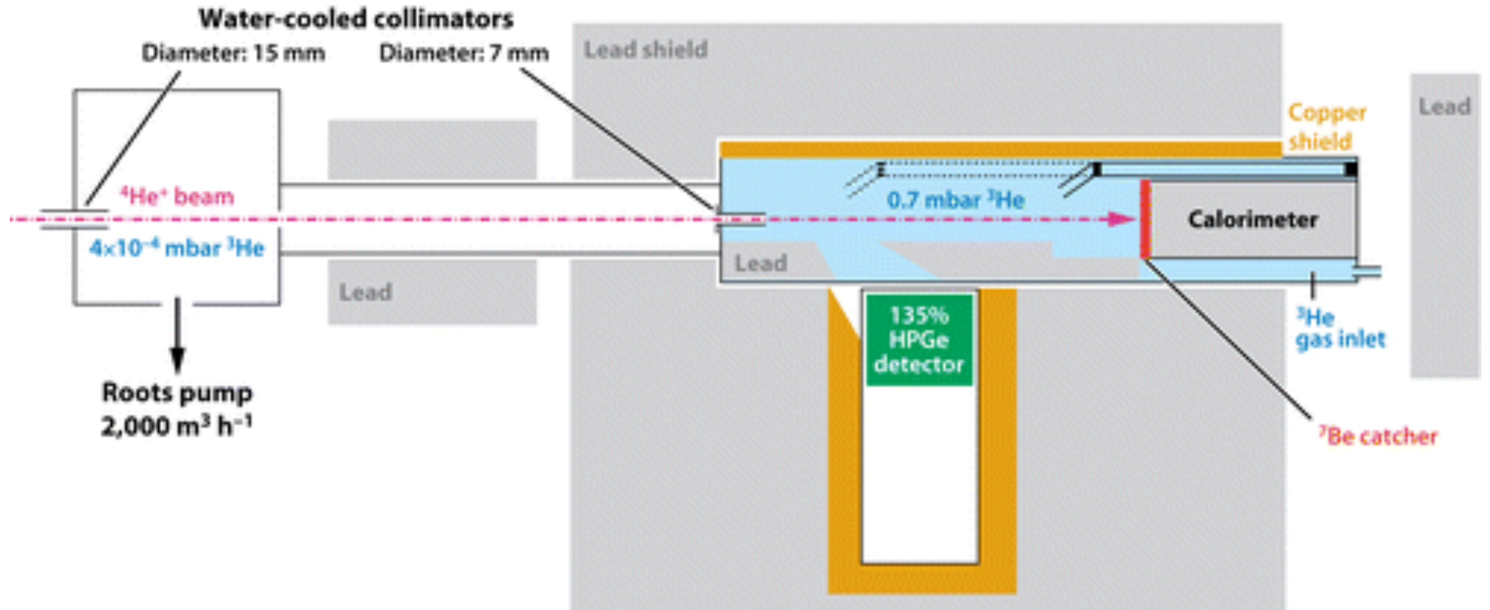
$^{15}N(p,\gamma)^{16}O$
PRC82, 055804(2010)

$^{17}O(p,\gamma)^{18}F$
PRL 109, 202601(2012)

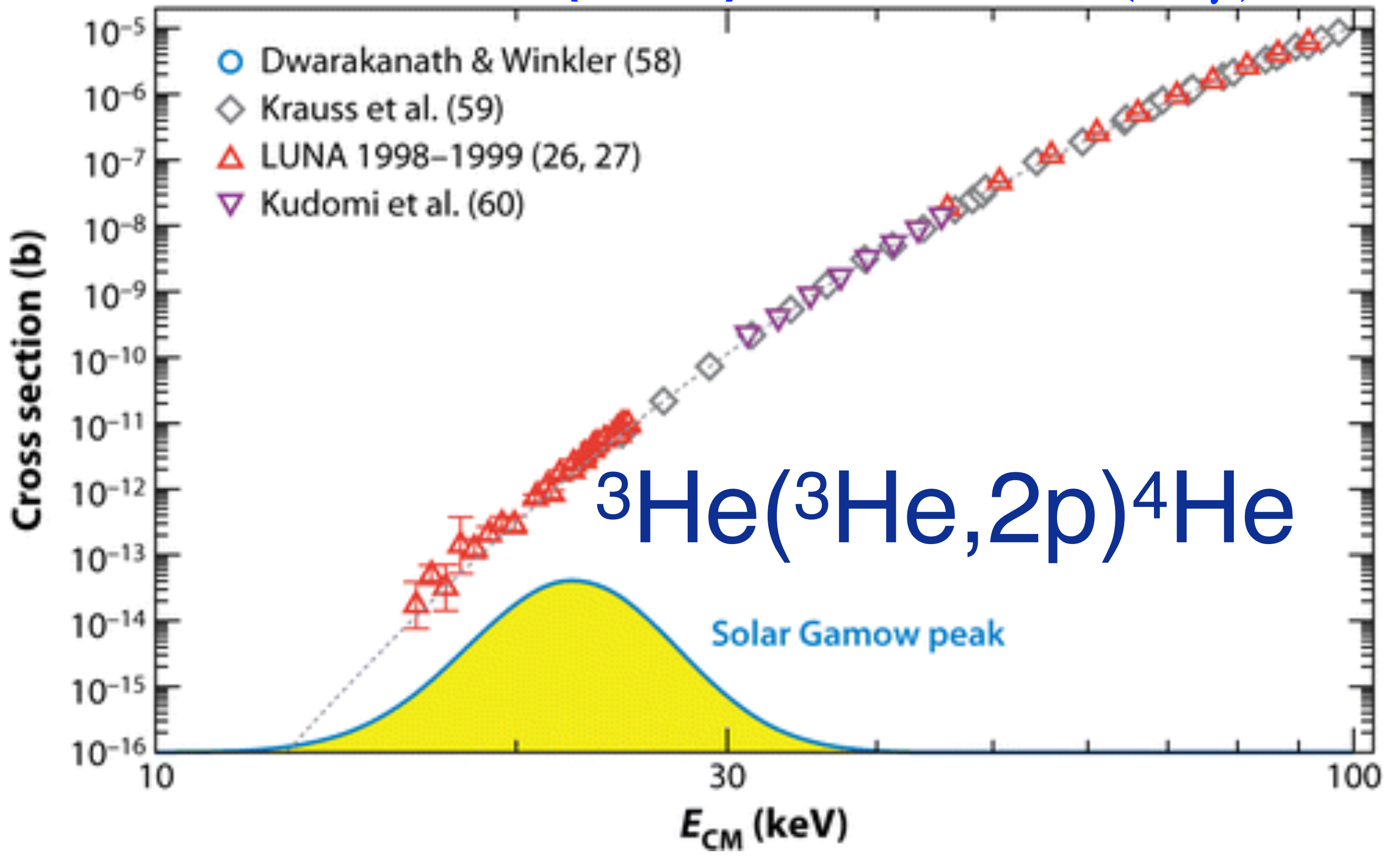
$^{25}Mg(p,\gamma)^{26}Al$
PLB 707(2012) 60

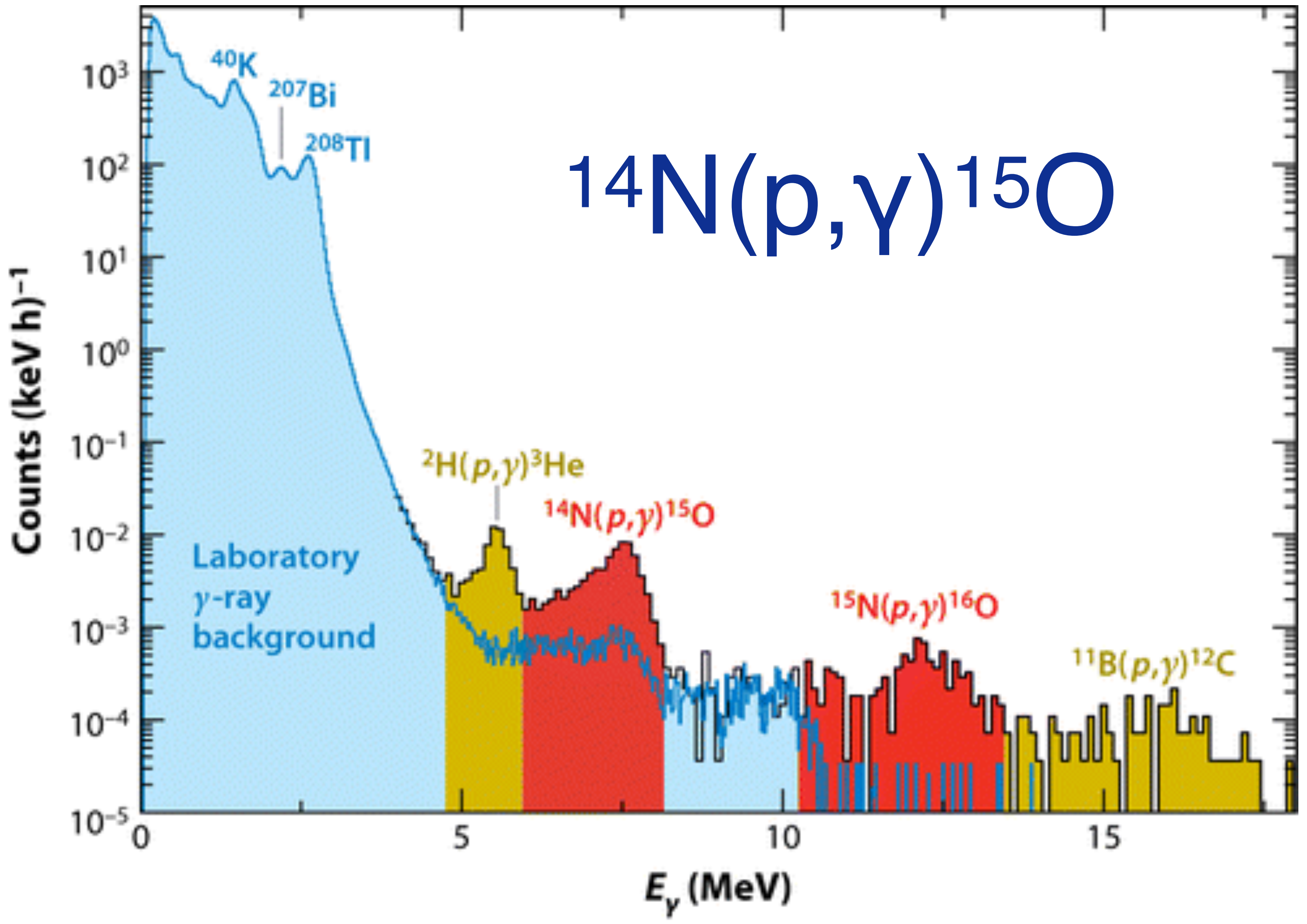
R. M. Gesuè et al., PRL 133(2024)052701, $^{17}O(p,\gamma)^{18}F$





Broggini C, et al. 2010. Annu. Rev. Nucl. Part. Sci. 60:53–73

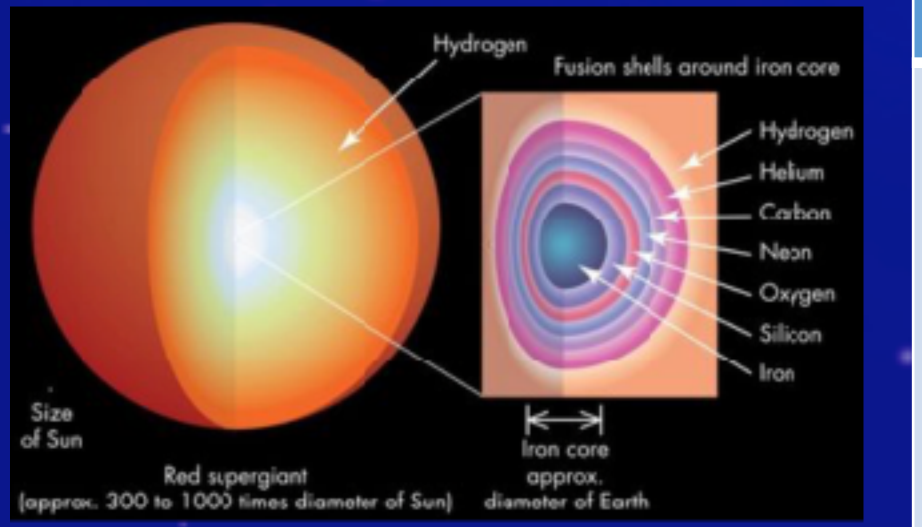


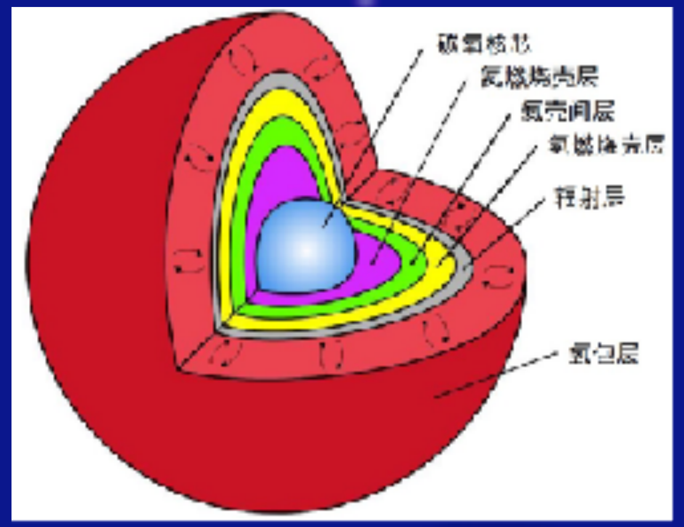


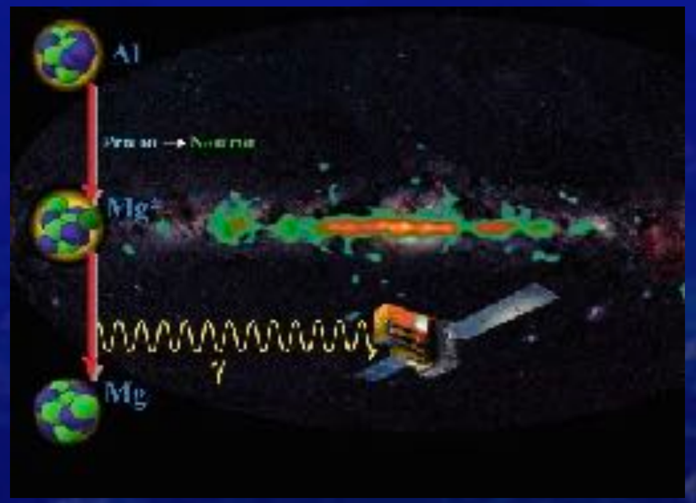
Felsenkeller
$^3He(\alpha,\gamma)^7Be$
$^2H(p,\gamma)^3He$
$^{12}C(p,\gamma)^{13}N$
$^{12}C(\alpha,\gamma)^{16}O$

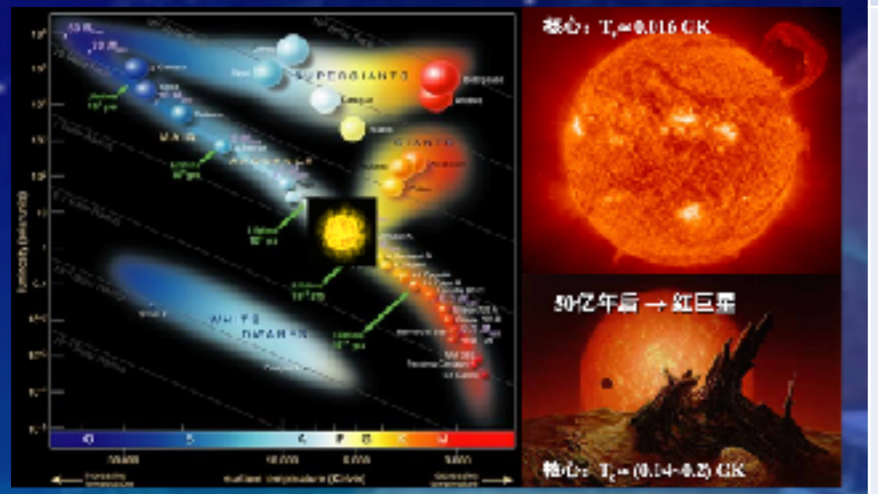
In this NIC, LUNA $^{14}N(p,\gamma)^{15}O$, Gyruky $^{16}O(p,\gamma)^{17}F$, Robb LUNA MV, Junker and posters

Uncertainty remained for key reactions

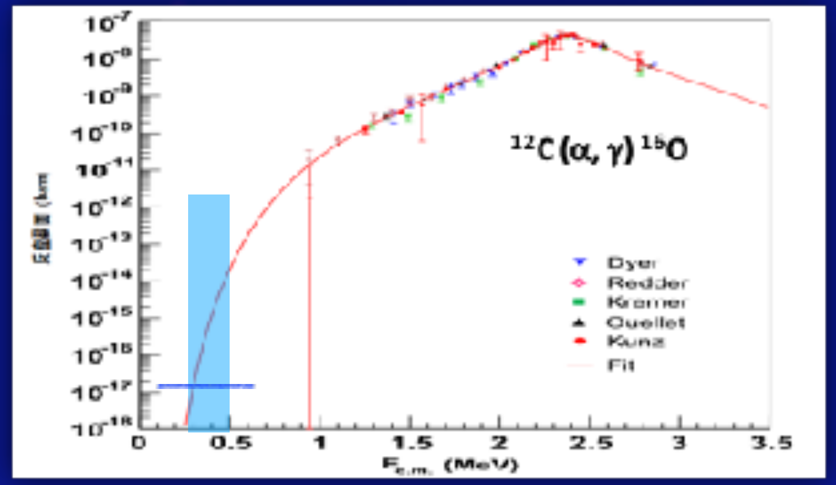




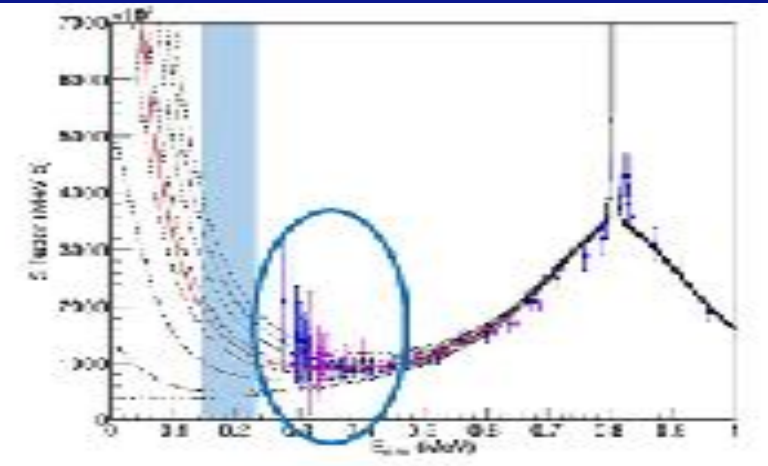




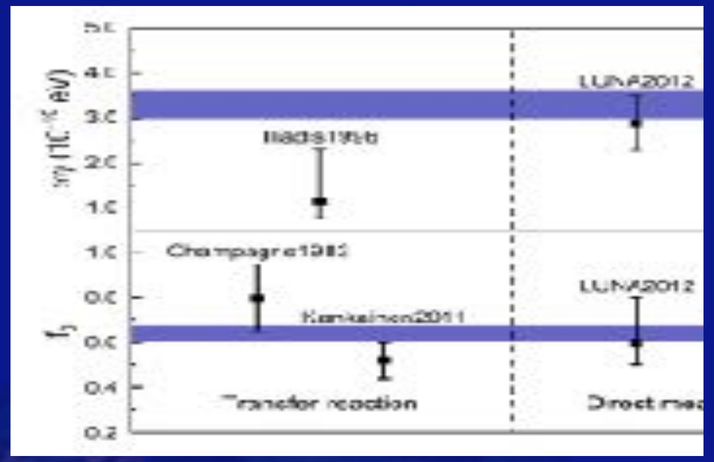
Physics	Reaction	Current	Desired
Massive star	$^{12}C(\alpha,\gamma)^{16}O$	60% 890 keV	20% 220-380 keV
s-process neutron source	$^{13}C(\alpha,n)^{16}O$	60% 230 keV	10% 140-230 keV
Galaxy ^{26}Al source	$^{25}Mg(p,\gamma)^{26}Al$	20% 92 keV	5% 50-300 keV
F aboundace	$^{19}F(p,\alpha)^{16}O$	80 % 189 keV	5 % 50-250 keV



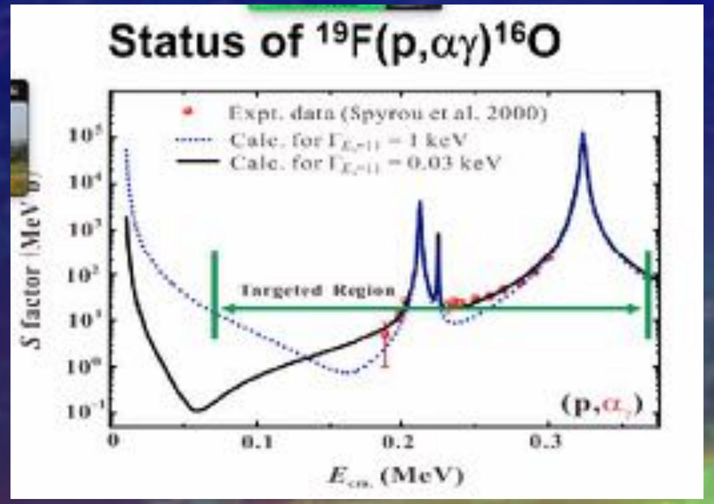
R. J. deBoer et al., RMP vol. 89, 2017



Y. P. Shen, B. Guo, WPL, PPNP 119(2021)103857



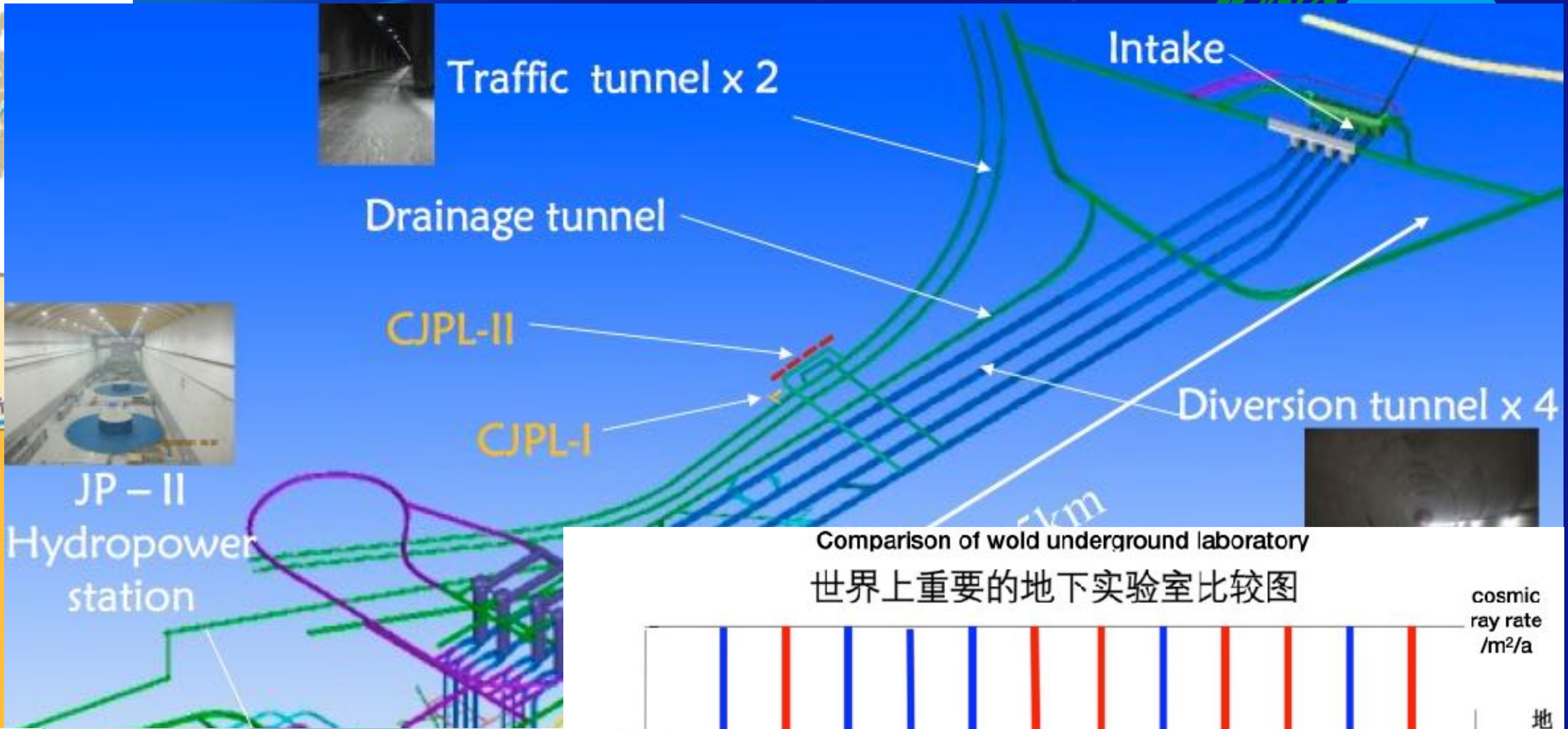
G.F. Ciani et al. PRL 127(2021)152701

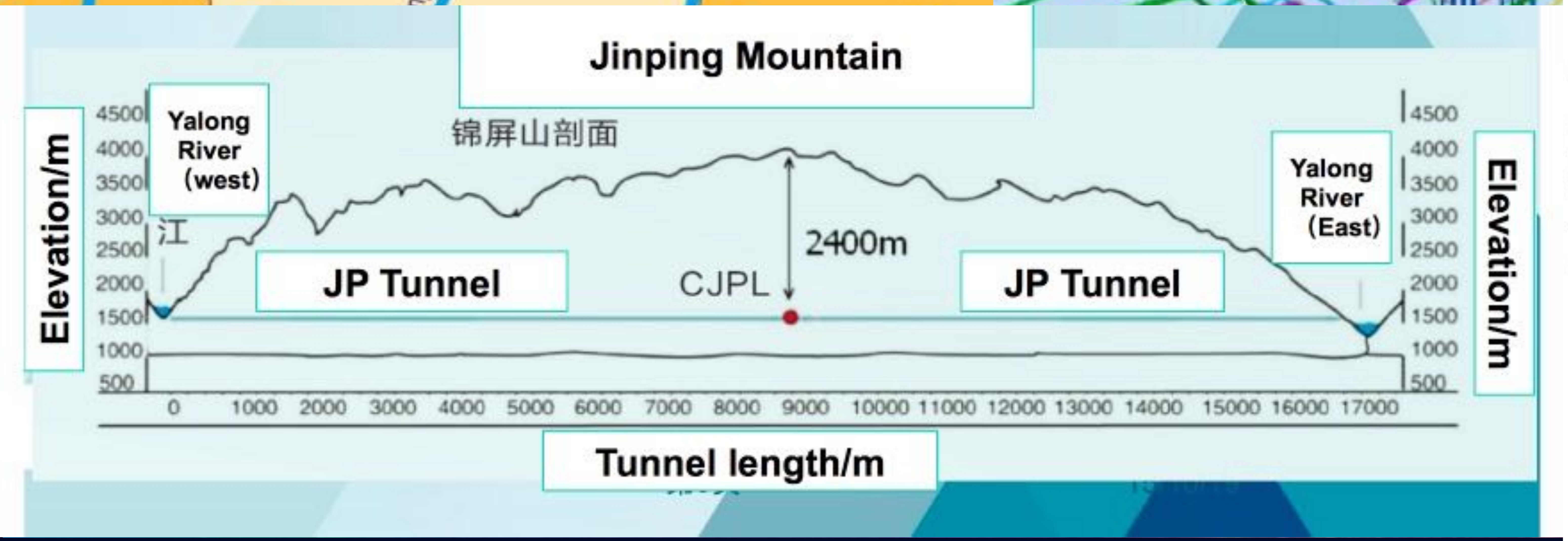


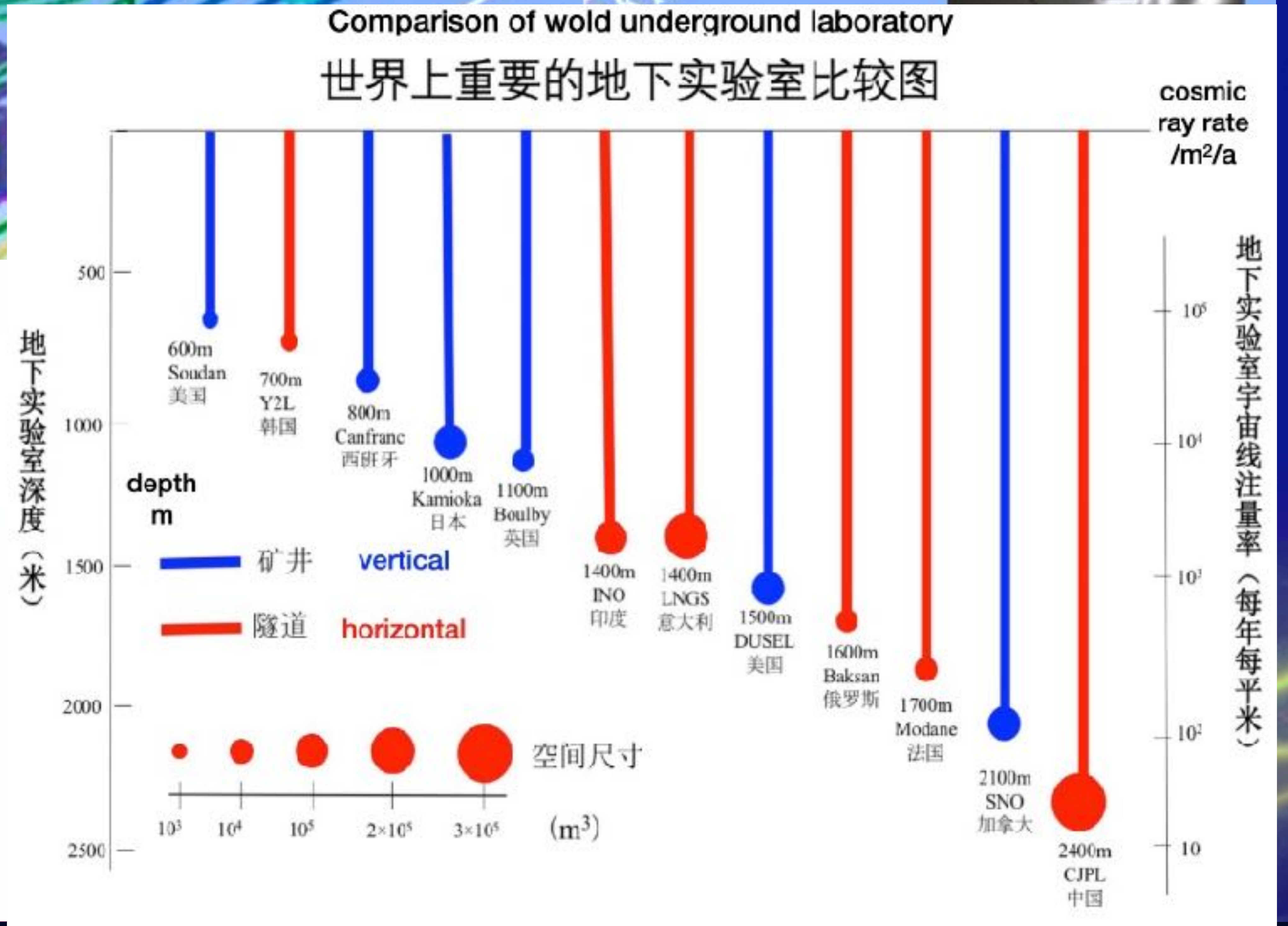
J. J. He et al., Sci. China Phys 59（2016）652001

WPL et al., Sci. China 59(2016)2

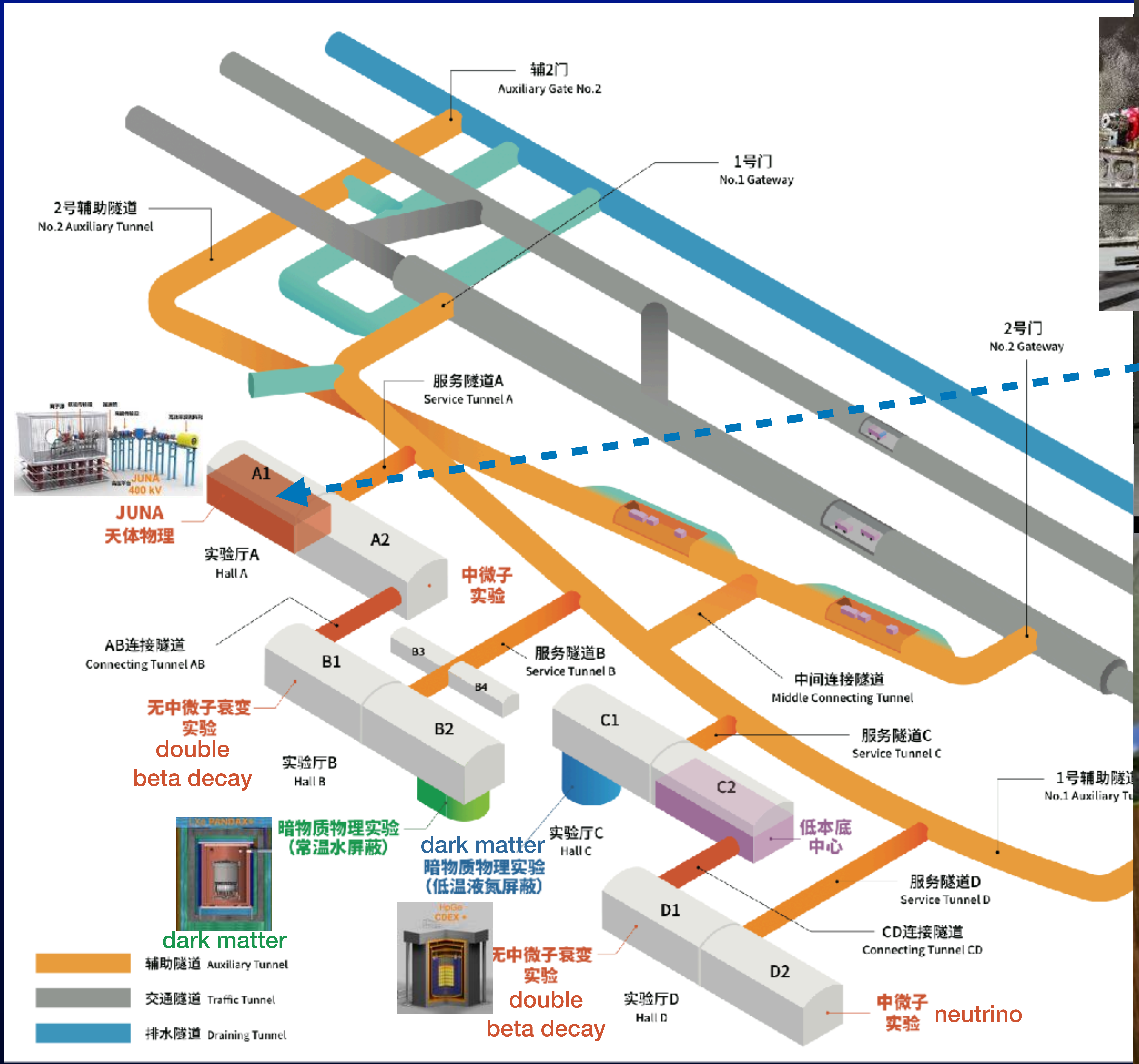
China Jinping: CJPL



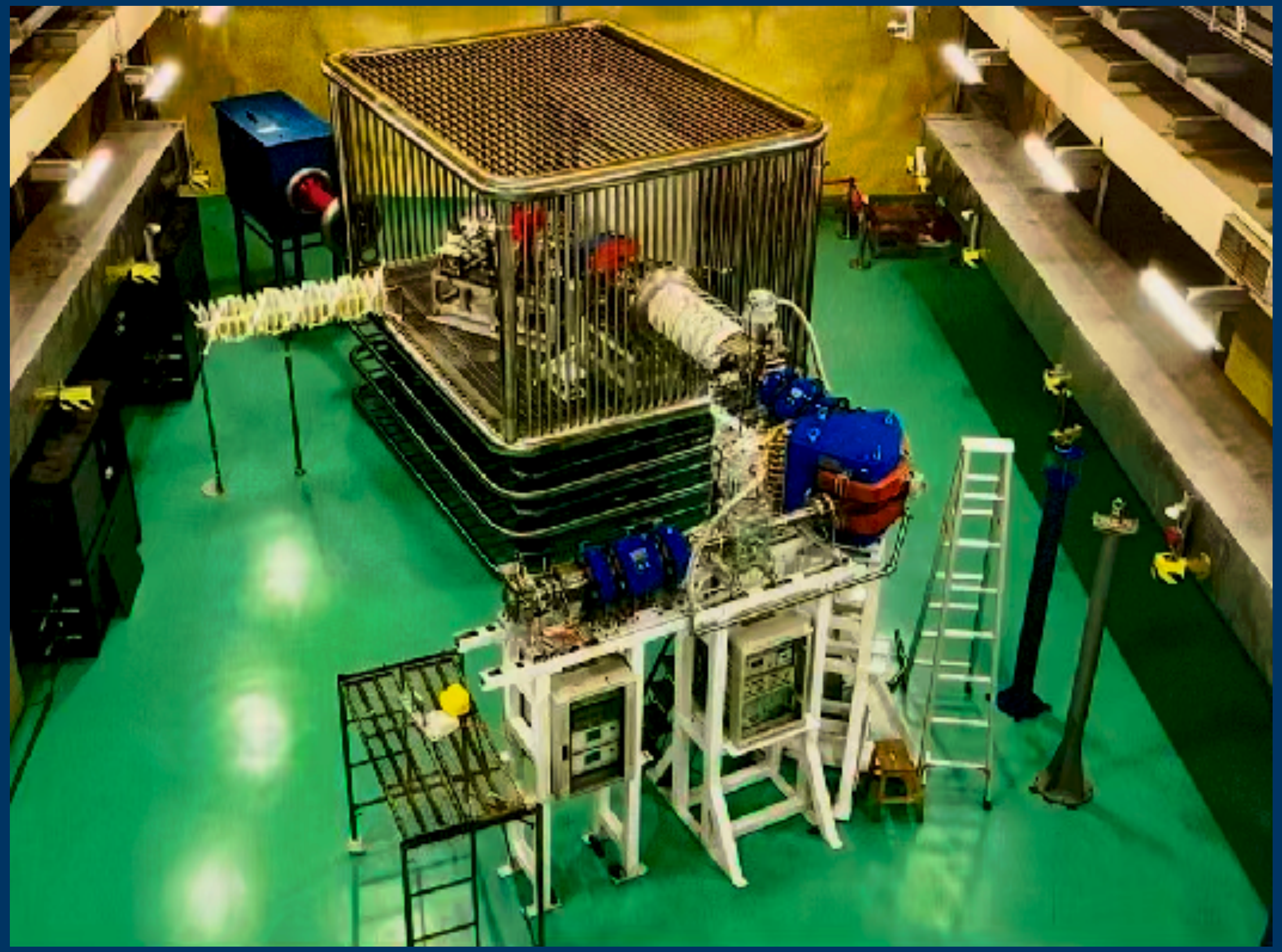




Most silent location: CJPL



JUNA dream team



Group leader

Weiping Liu
$^{12}C(\alpha,\gamma)^{16}O$
Yangping Shen, CIAE
Jun Su, BNU
PI

Acc. installation
Arjun Li

A1 construction
Hongwei Yang

Site support
Xiaopan Cheng

Acc. operation
Long Zhang

Bing Guo
$^{22}Ne(\alpha,n)^{25}Mg$
CIAE

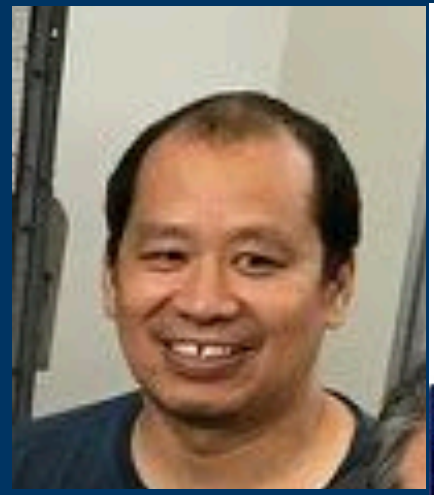
Shuo Wang
$^{14}N(p,\gamma)^{15}O$
SDU

Xiaodong Tang
$^{13}C(\alpha,n)^{16}O$
Ion source IMP

Zhihong Li
$^{25}Mg(p,\gamma)^{26}Al$
CIAE
Jun Su, BNU

Jianjun He
$^{19}F(p,\alpha)^{16}O$
BNU

Gang Lian
Lab. exp. sup.
CIAE



Bao Quncui, CIAE
Liangting Sun, IMP
Ion source and acc.

Supported by the National Natural Science Foundation of China, Grant No. 11490560, 2015

WPL et al., Sci. China 59(2016)2

JUNA Milestone

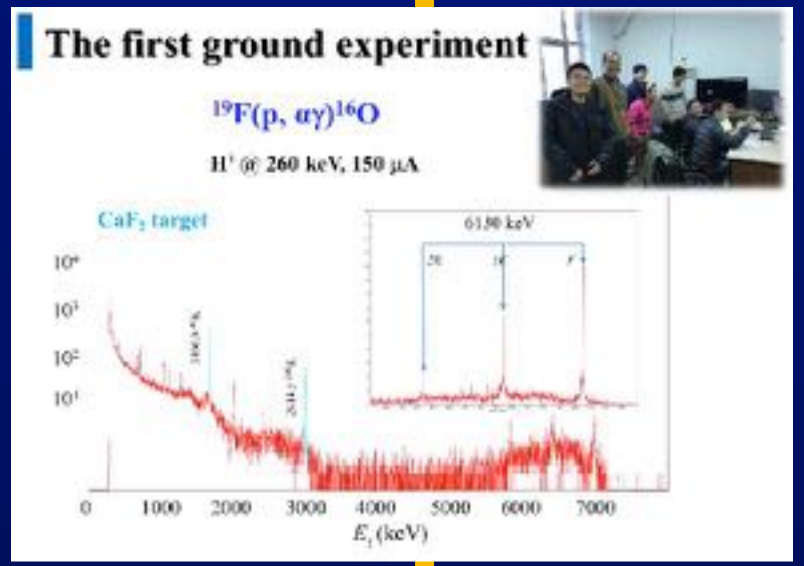
Aug. 2013
Kickoff meeting

Jan. 2015
Project inauguration

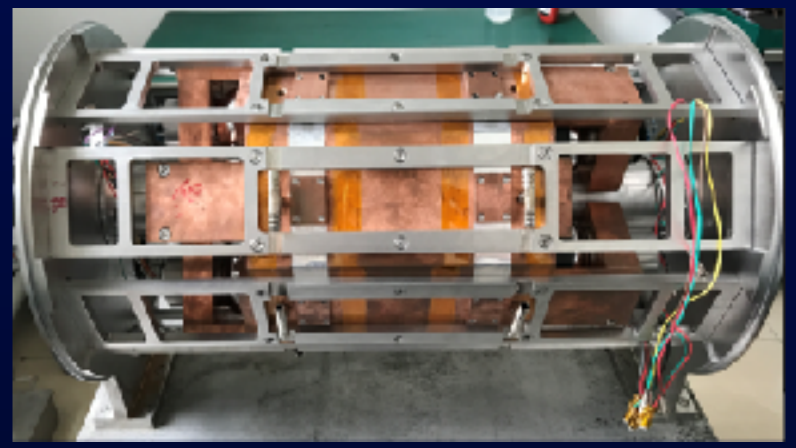
Mar. 2016
On site start

May 2017
Beam on ground

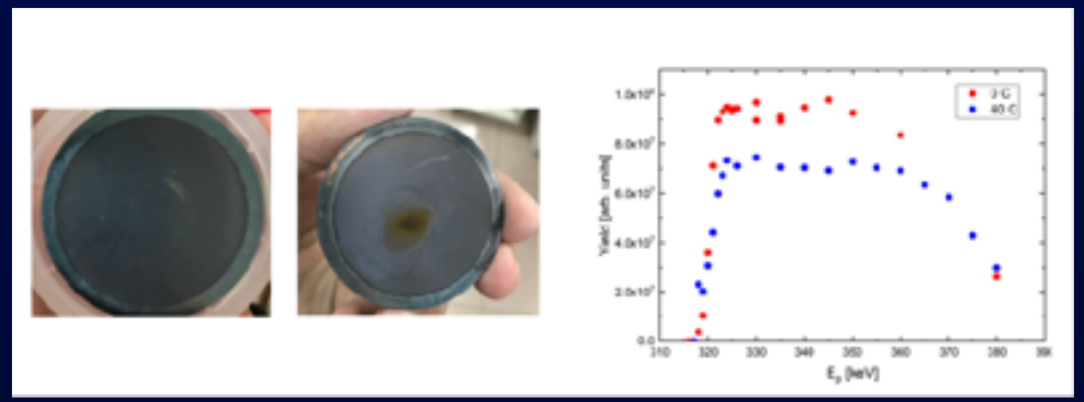
Dec. 2017
3 mA on ground



Dec. 2018
Der. Ready
Beam 10 mA



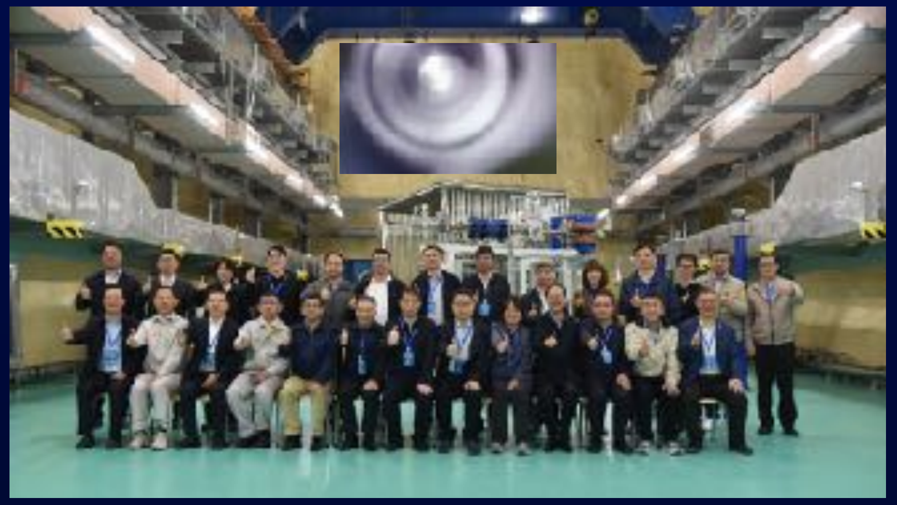
April 2019
Target ready
Acc. Ready



Dec. 2020
Beam underground

April 2021
^{25}Mg, ^{19}F, ^{13}C and ^{13}C run 1

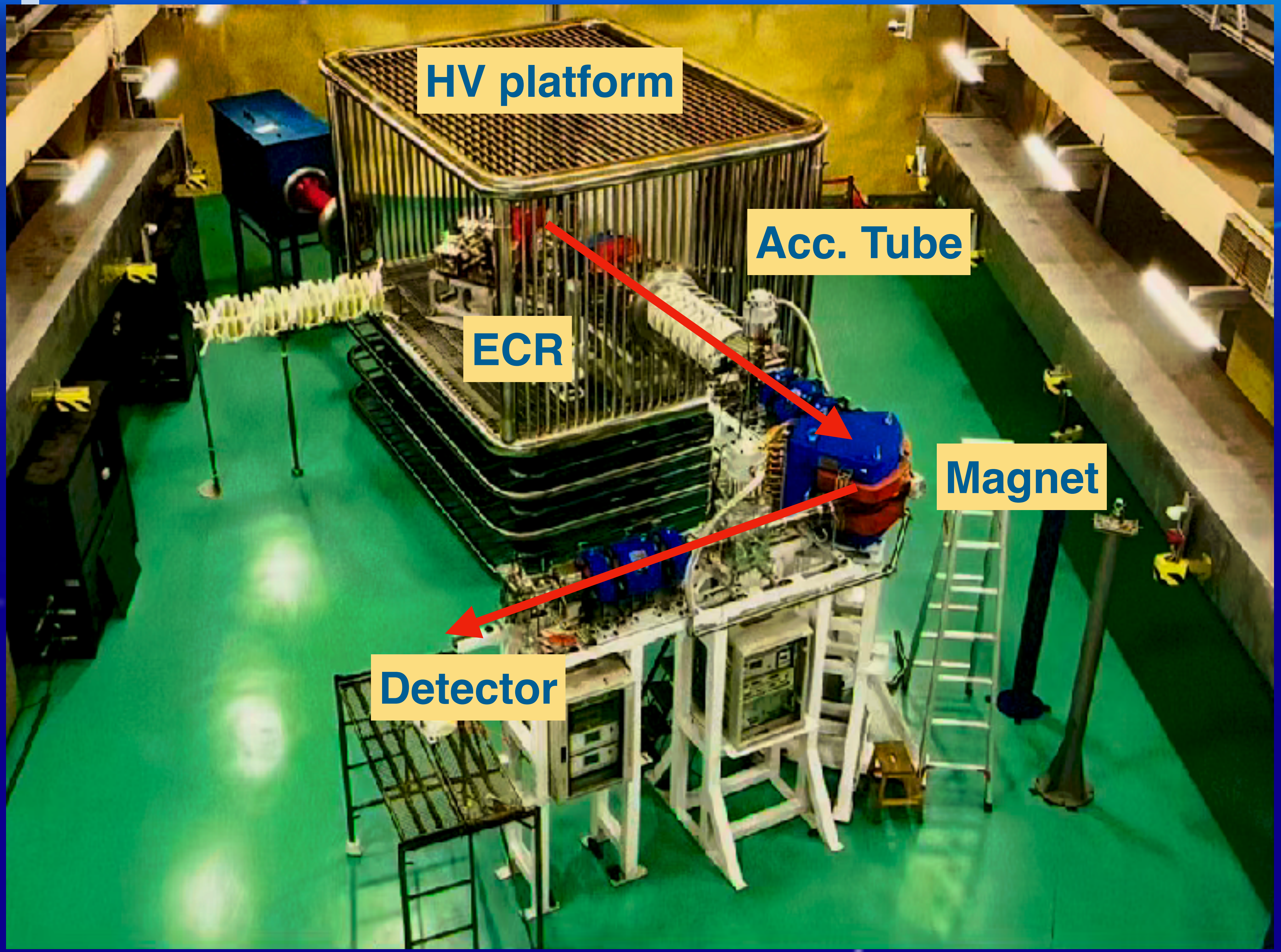
May 2025
Upgrading got 2 mA He^{1+} ready for run2

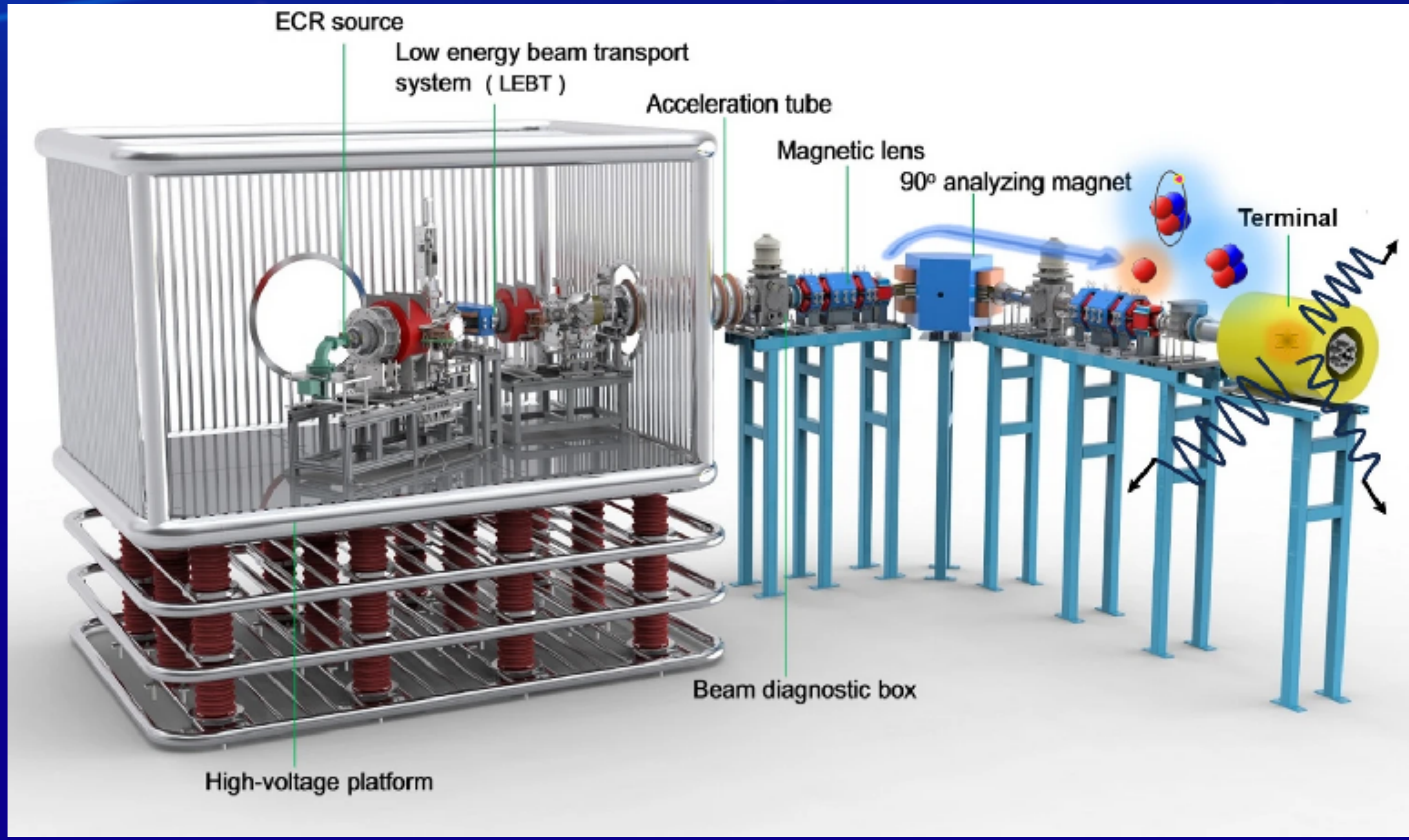


WPL et al., Sci. China 59(2016)2

JUNA accelerator

锦屏深地核天体物理实验
Jinping Underground Nuclear Astrophysics Experiment

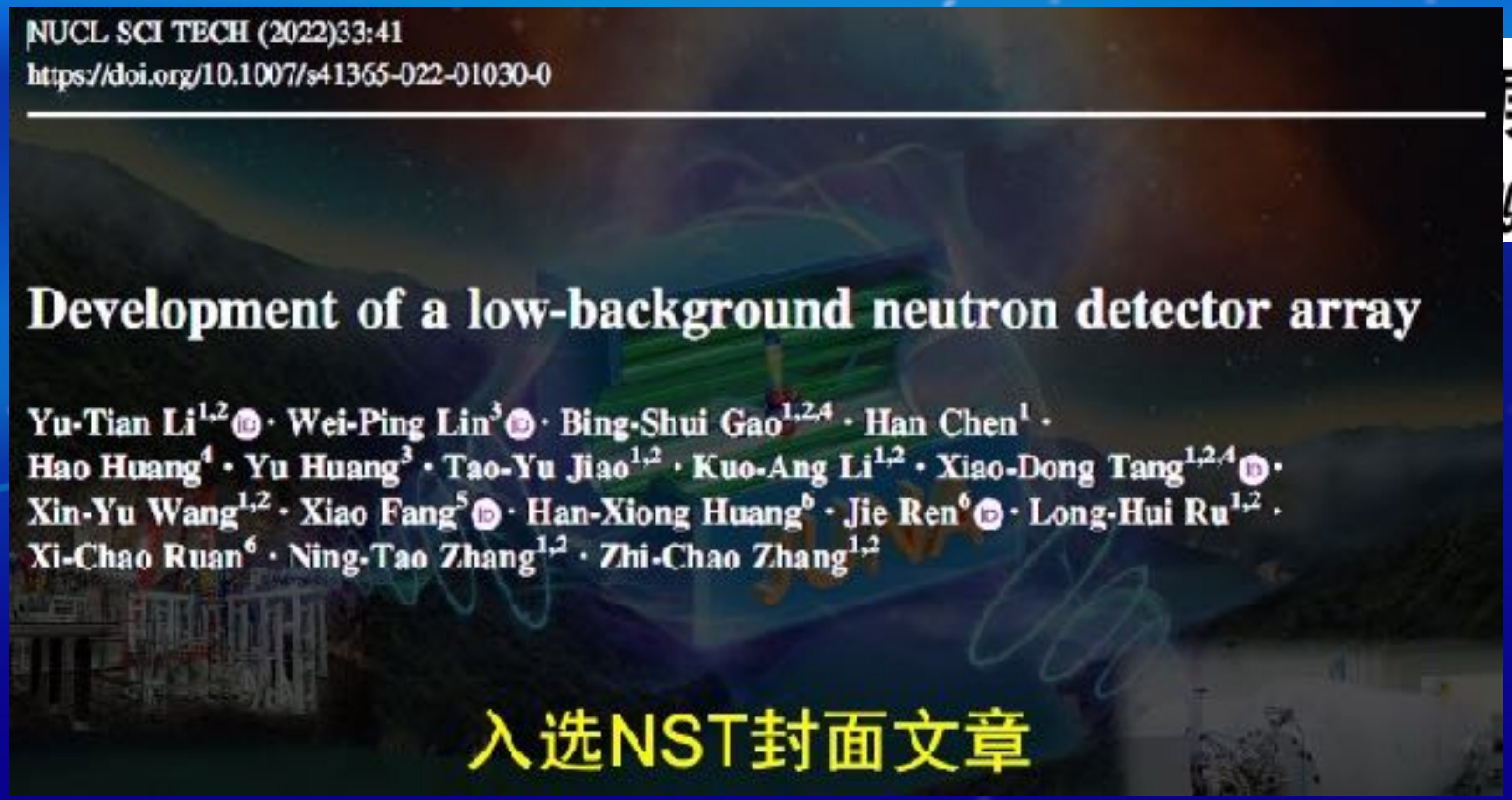




	lab depth m	cosmic μ bkg （cm^{-2} s^{-1}）	beam energy （keV）			beam intensity （emA）			energy stability
			H+	He+	He2+	H+	He+	He2+	
LUNA	1400	2×10^{-8}	50-400	50-400	3.5 MV	0.3~1	0.3~0.8	---	0.05%
CASPAR	1500	4×10^{-9}	100-1000	100-1000	1 MV	0.1	0.1	---	0.05%
JUNA	2400	**2×10^{-10}**	50-400	50-400	**100-800**	**2-10**	**2-10**	**1-2**	**0.04%**
Felsenkeller	45	$\sim10^{-7}$			5 MV		30 uA		

WPL et al., Sci. China 59(2016)2

Detector tech.

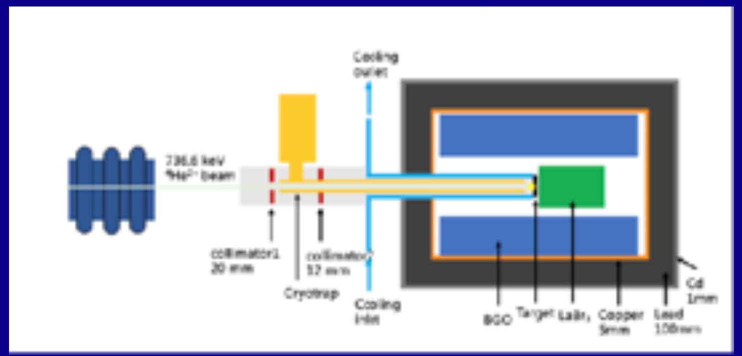

NUCL SCI TECH (2022)33:41
https://doi.org/10.1007/s41365-022-01030-0

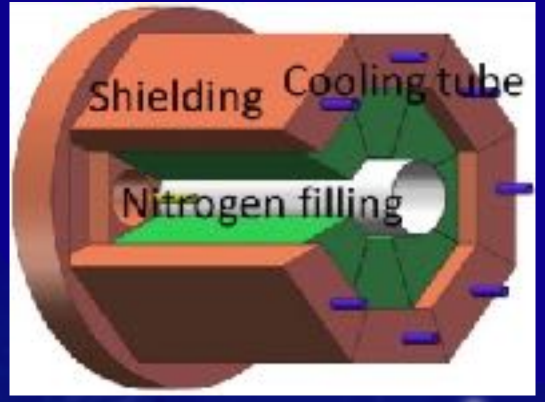
Development of a low-background neutron detector array

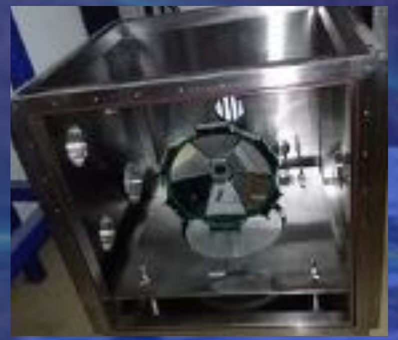
Yu-Tian Li[1,2] · Wei-Ping Lin[3] · Bing-Shui Gao[1,2,4] · Han Chen[1] · Hao Huang[4] · Yu Huang[3] · Tao-Yu Jiao[1,2] · Kuo-Ang Li[1,2] · Xiao-Dong Tang[1,2,4] · Xin-Yu Wang[1,2] · Xiao Fang[5] · Han-Xiong Huang[6] · Jie Ren[6] · Long-Hui Ru[1,2] · Xi-Chao Ruan[6] · Ning-Tao Zhang[1,2] · Zhi-Chao Zhang[1,2]

入选NST封面文章

屏深地核天体物理实验
g Underground Nuclear Astrophysics Experiment







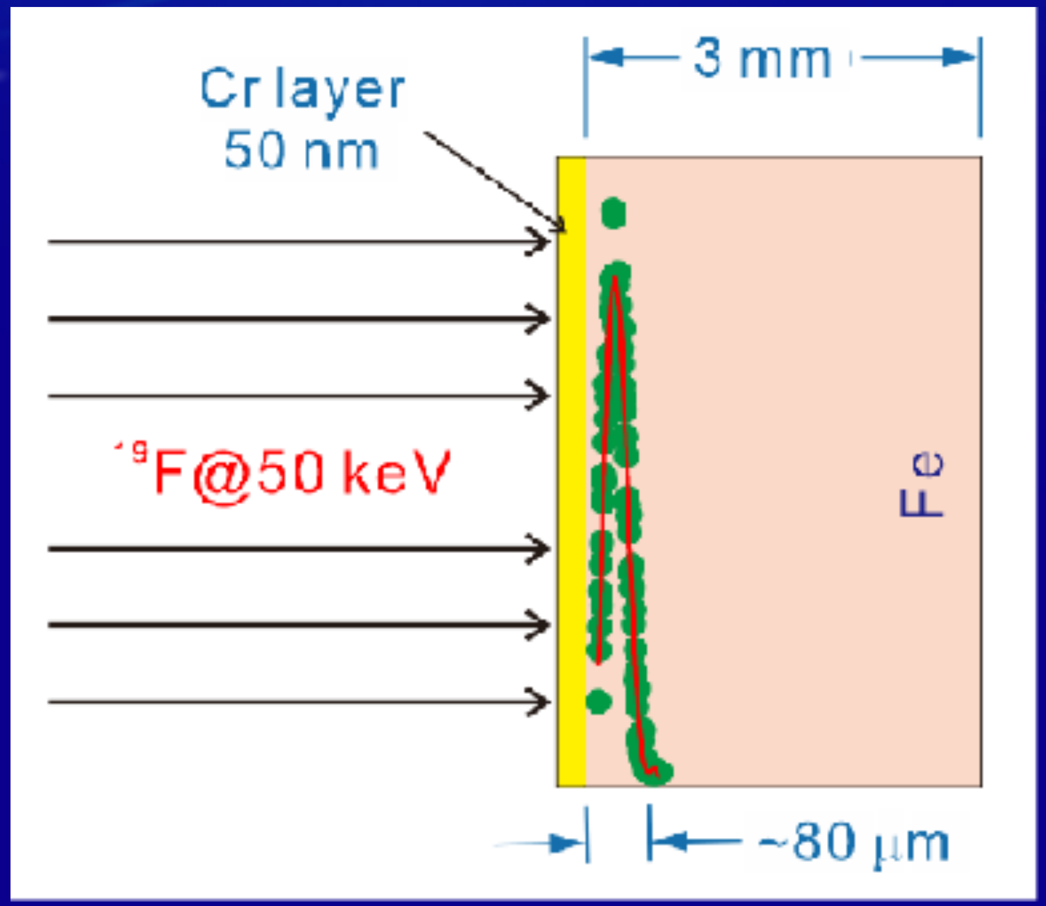
reaction	technology	publication	world best	JUNA
^{12}C	BGO+LaBr		down to 891 keV	down to 552 keV
^{25}Mg	BGO array X8	Atomic ST 52(2018)140	resolution17 %	11 %
^{13}C	^{3}He array X24	NST33(2022) 41, cover story	Exptripolation	Self consisitent
^{19}F	Charged particle array		170 keV	down to 100 keV

High radiation resistant target

3-10 X better than previous targets

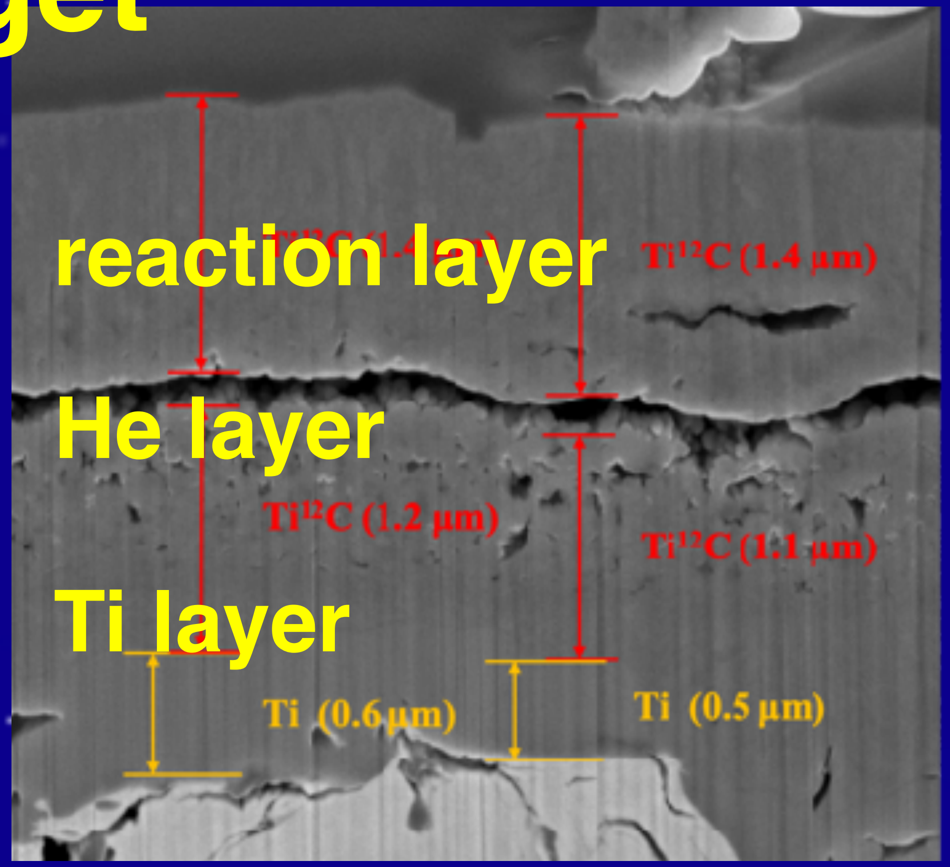
^{19}F Implantation

- High-purity iron substrate
- Magnetron chrome plating
- 100 C



^{12}C Deposit target

- FCVA
- ^{12}C 99.99%
- 400 C

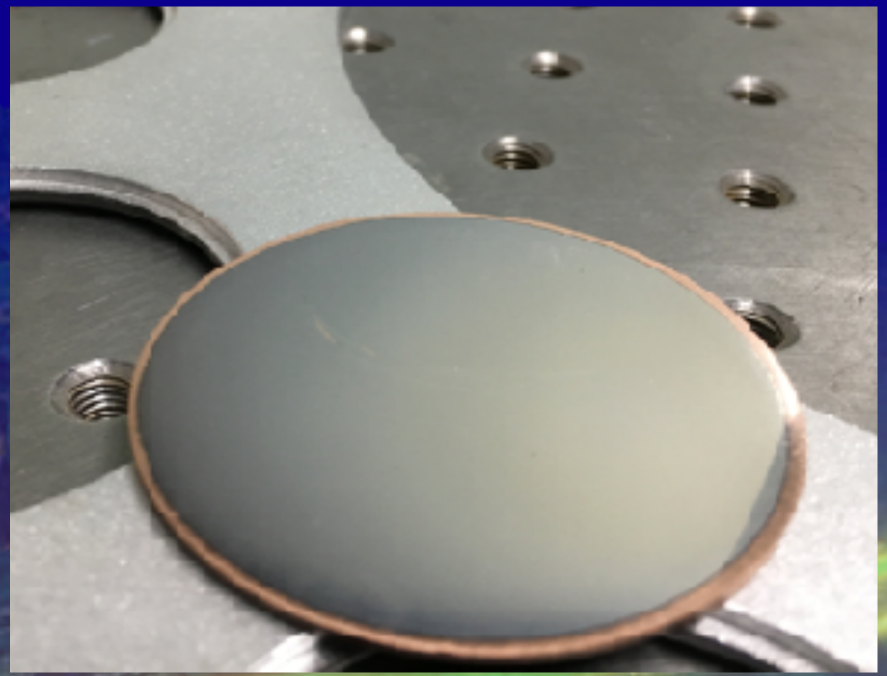


^{13}C Thick target

- High-temperature and high-pressure sintering
- 0.5kW/cm^2
- 400 C

^{25}Mg Hybrid layers

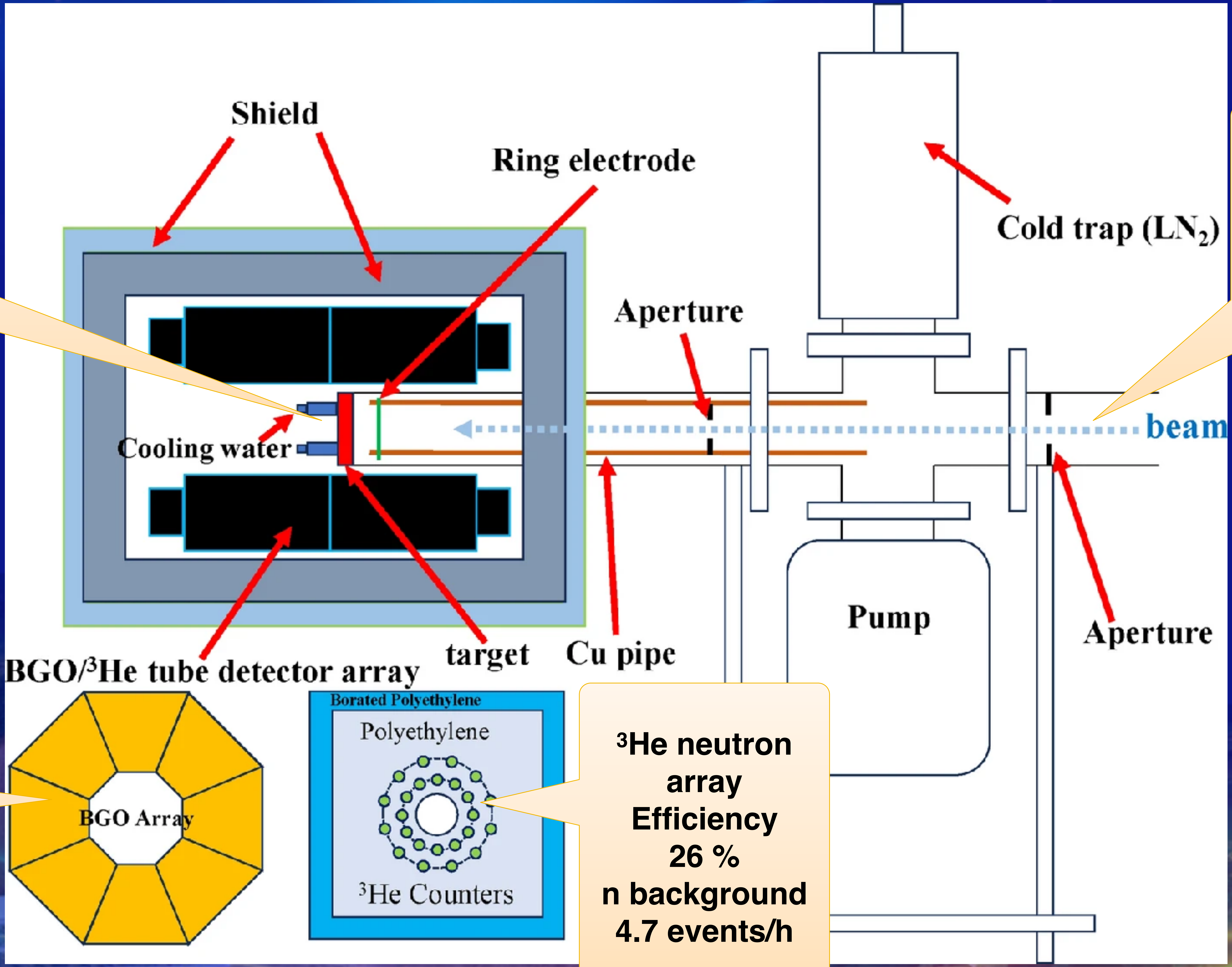
- Cr+Mg+Cr
- rotating coating
- 300 C



JUNA detector setup

Target
thick target
2 mm
thin target
50 g/cm²

BGO gamma array
Resolution
6-10 %
Efficiency
60 %
background
10^{-4} /keVh
@ 6–8 MeV

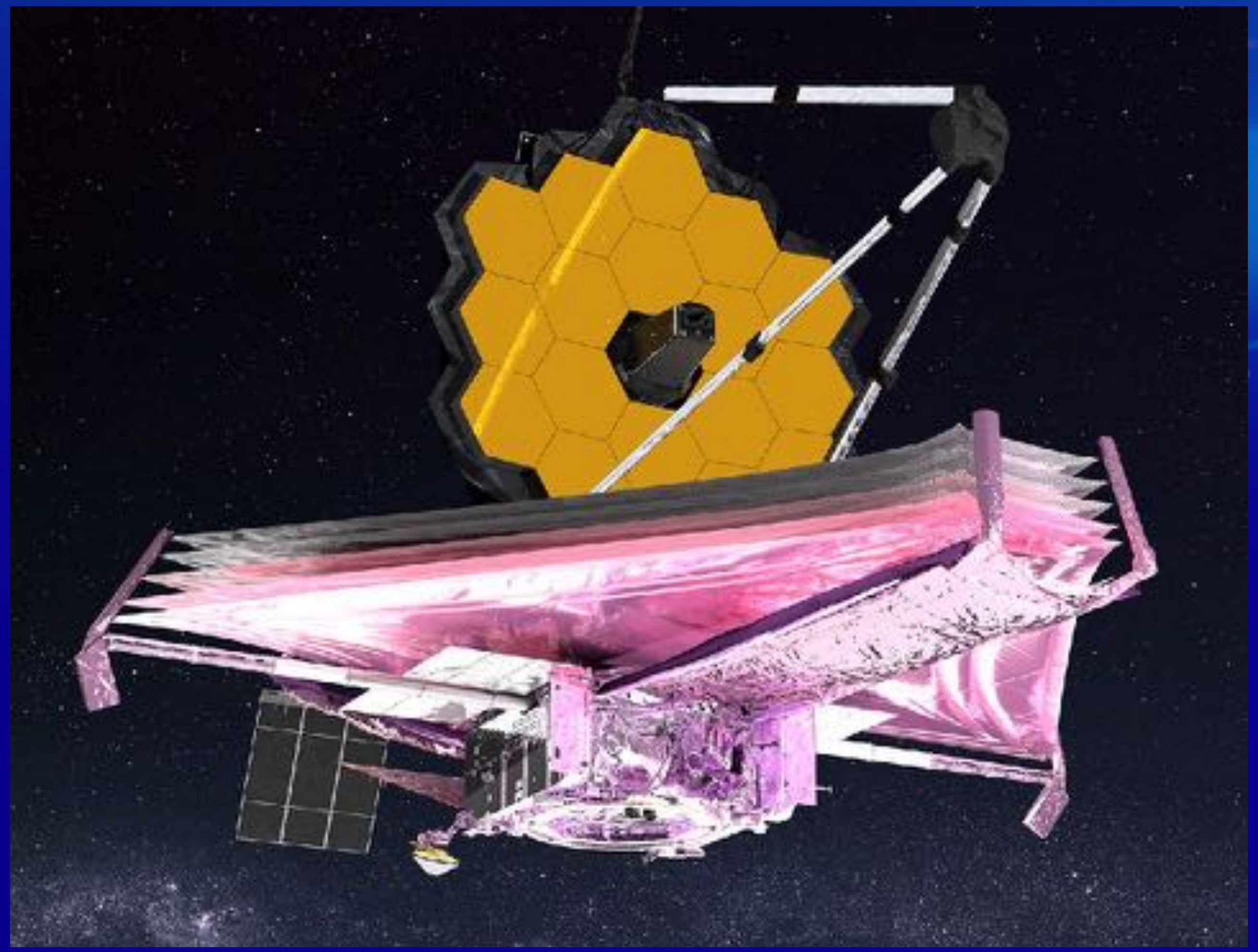


Beam
proton
alpha
1-2 emA

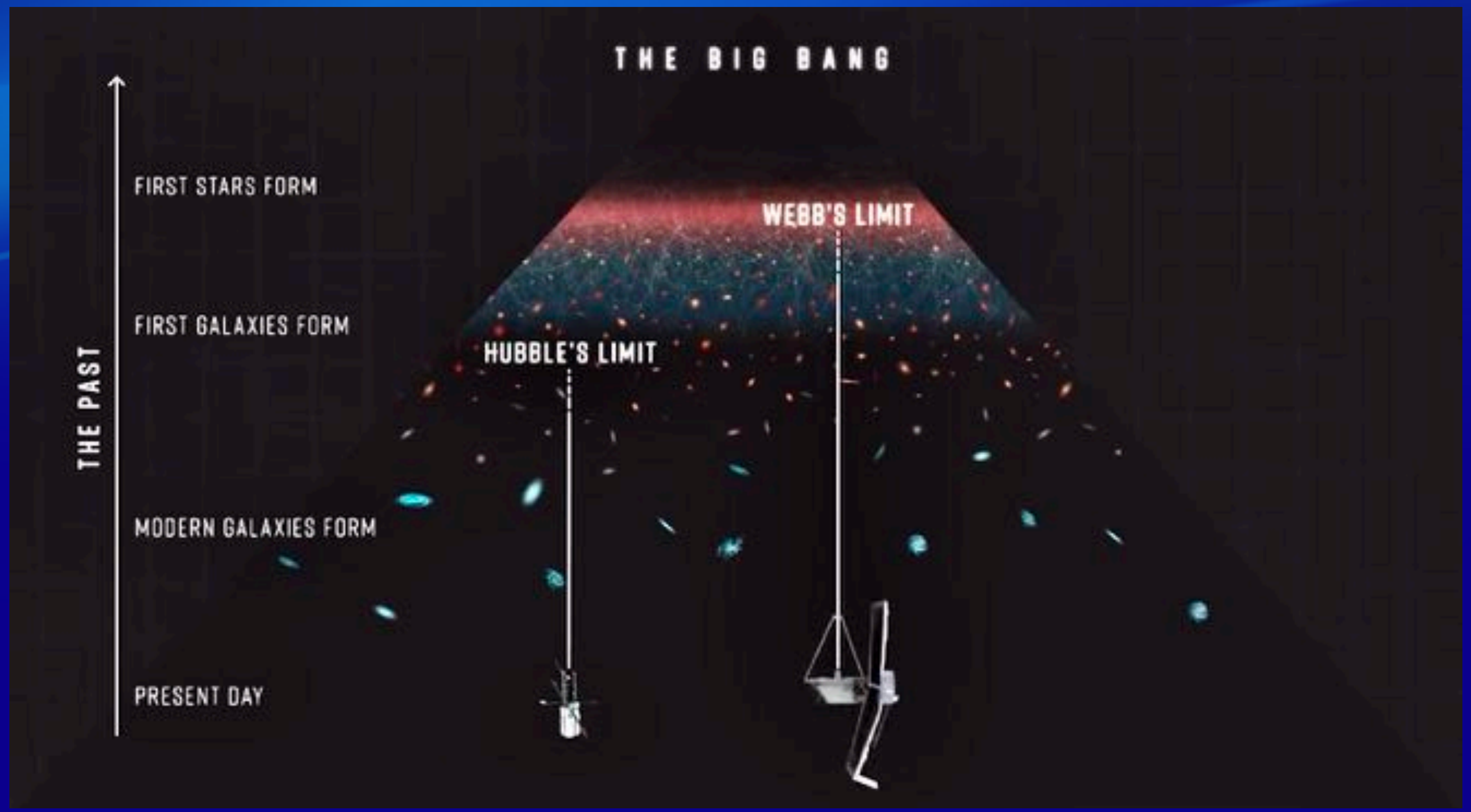
^{3}He neutron array
Efficiency
26 %
n background
4.7 events/h

^{19}F(p,γ)^{20}Ne： HCNO break，explain Ca in oldest star?

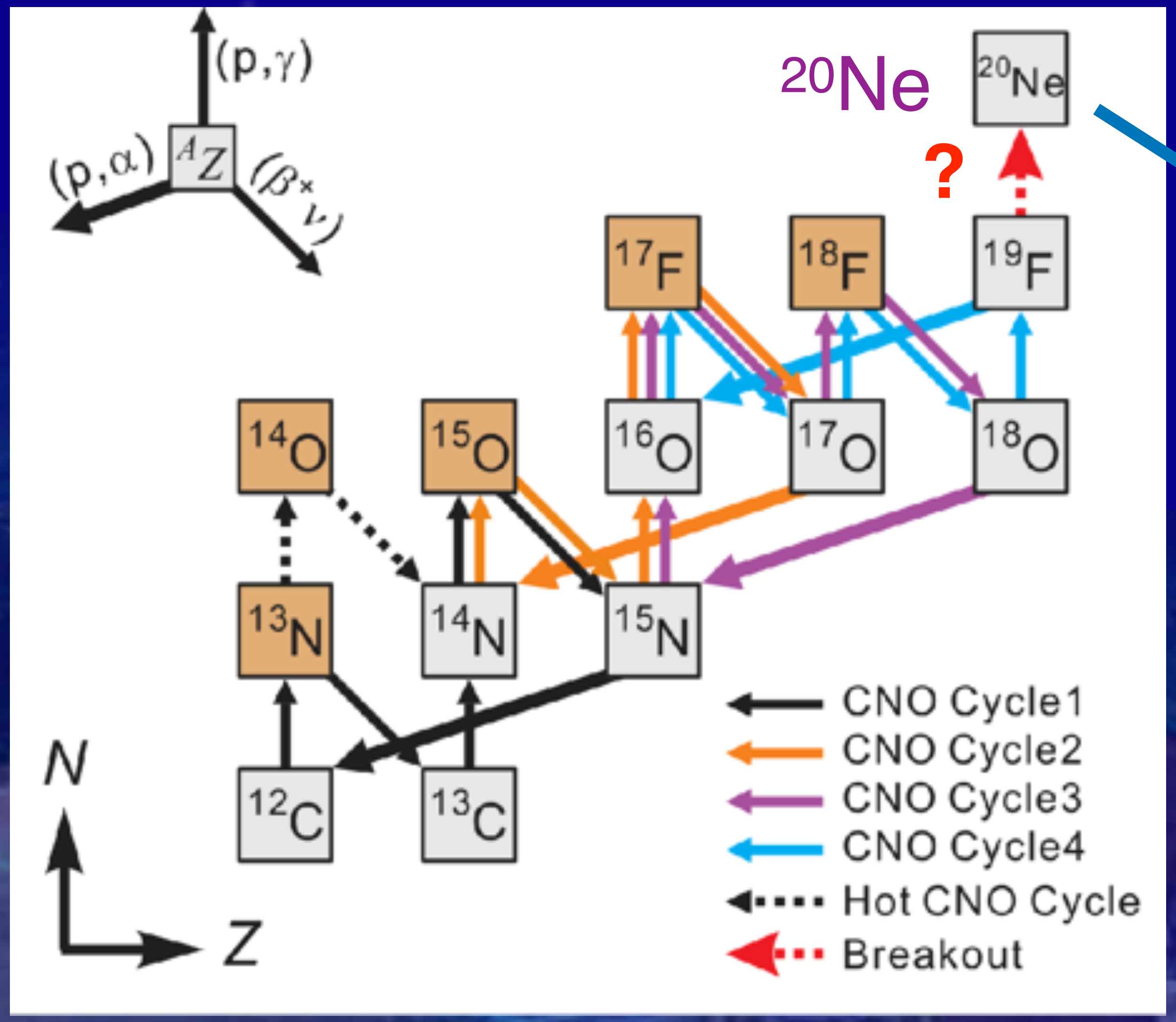
锦屏深地核天体物理实验
Jinping Underground Nuclear Astrophysics Experiment

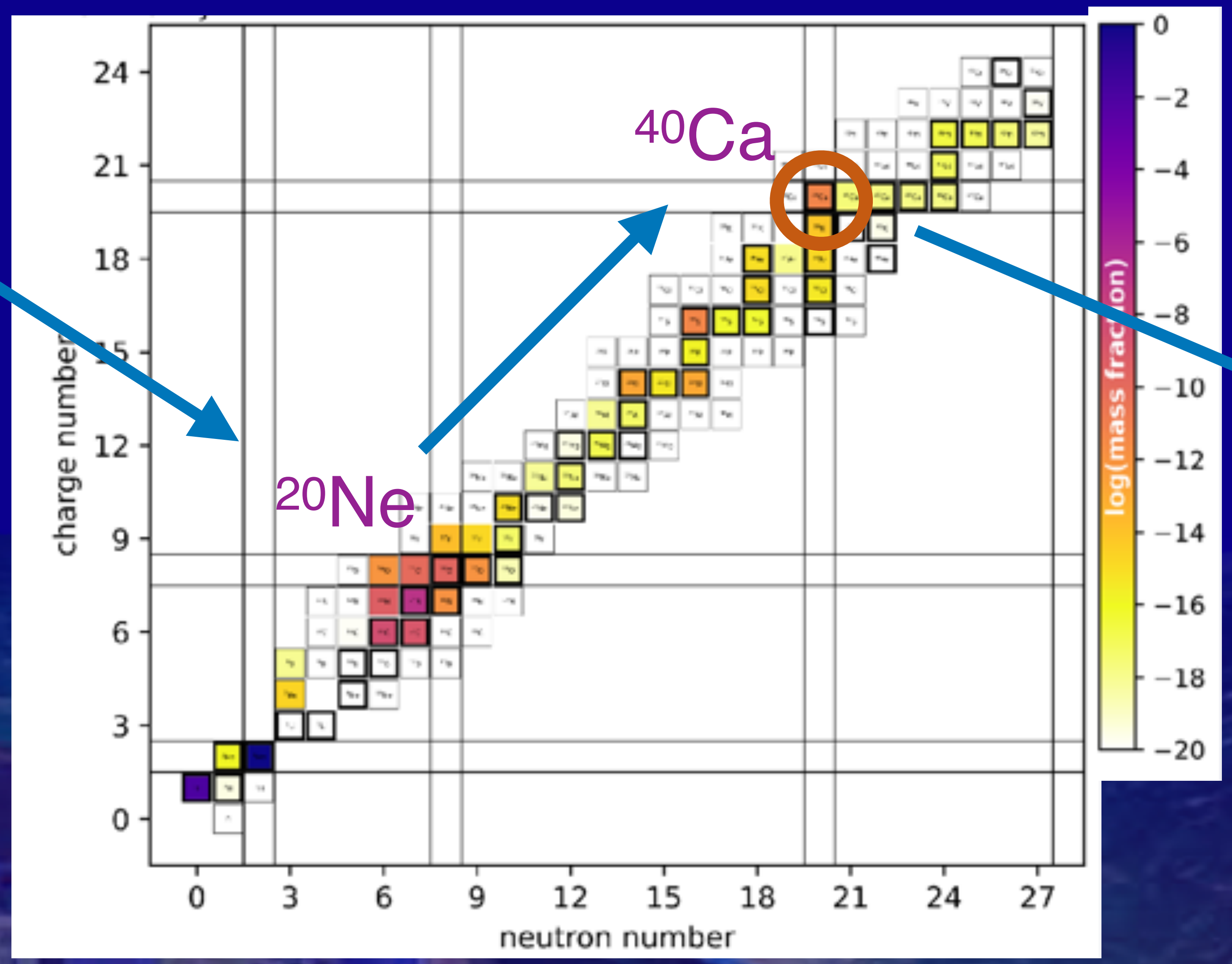


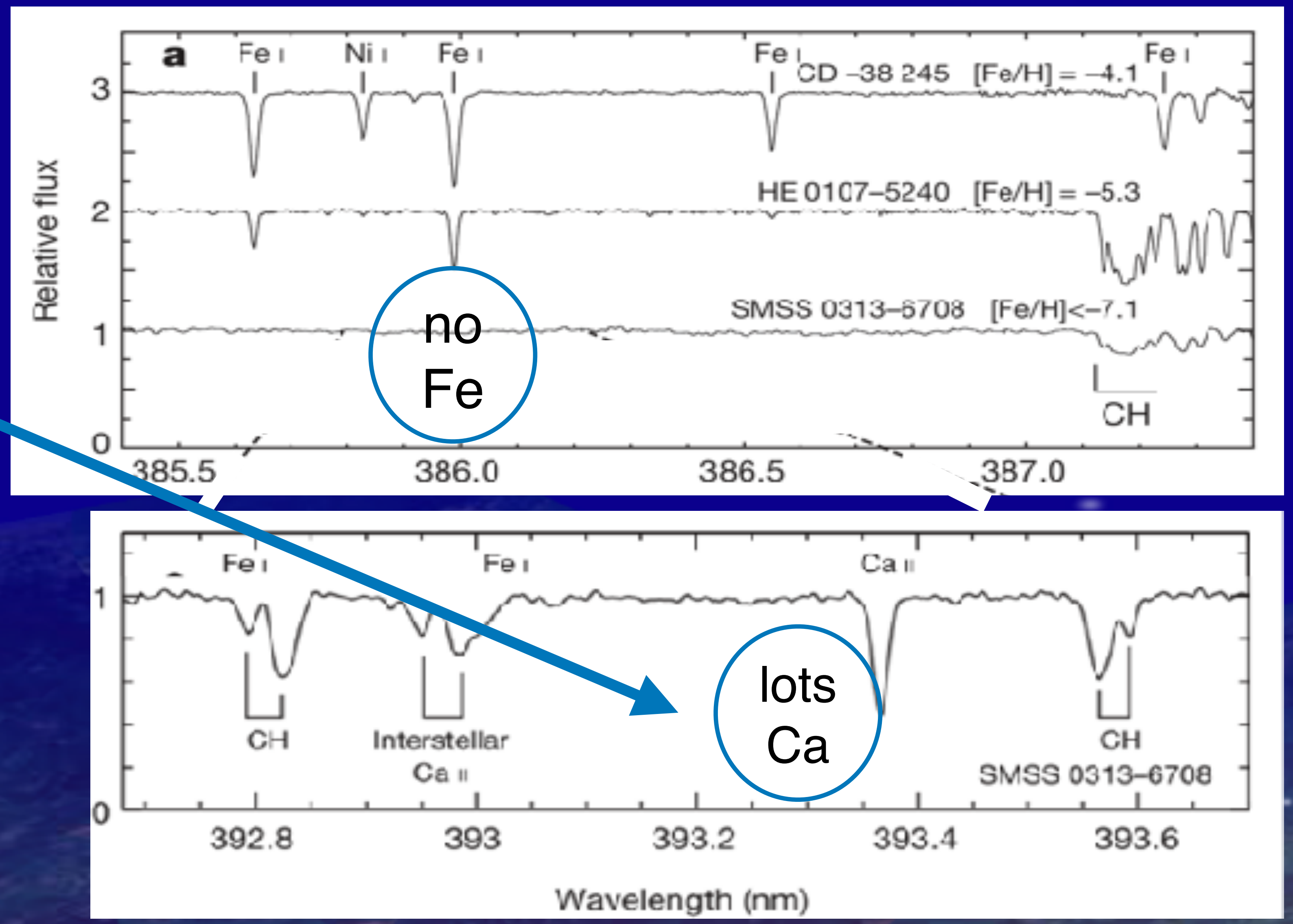
JWST



S.C. Keller et al., Nature 506 (2014) 463







Solution: ^{19}F(p,g)^{20}Ne rate one order large?

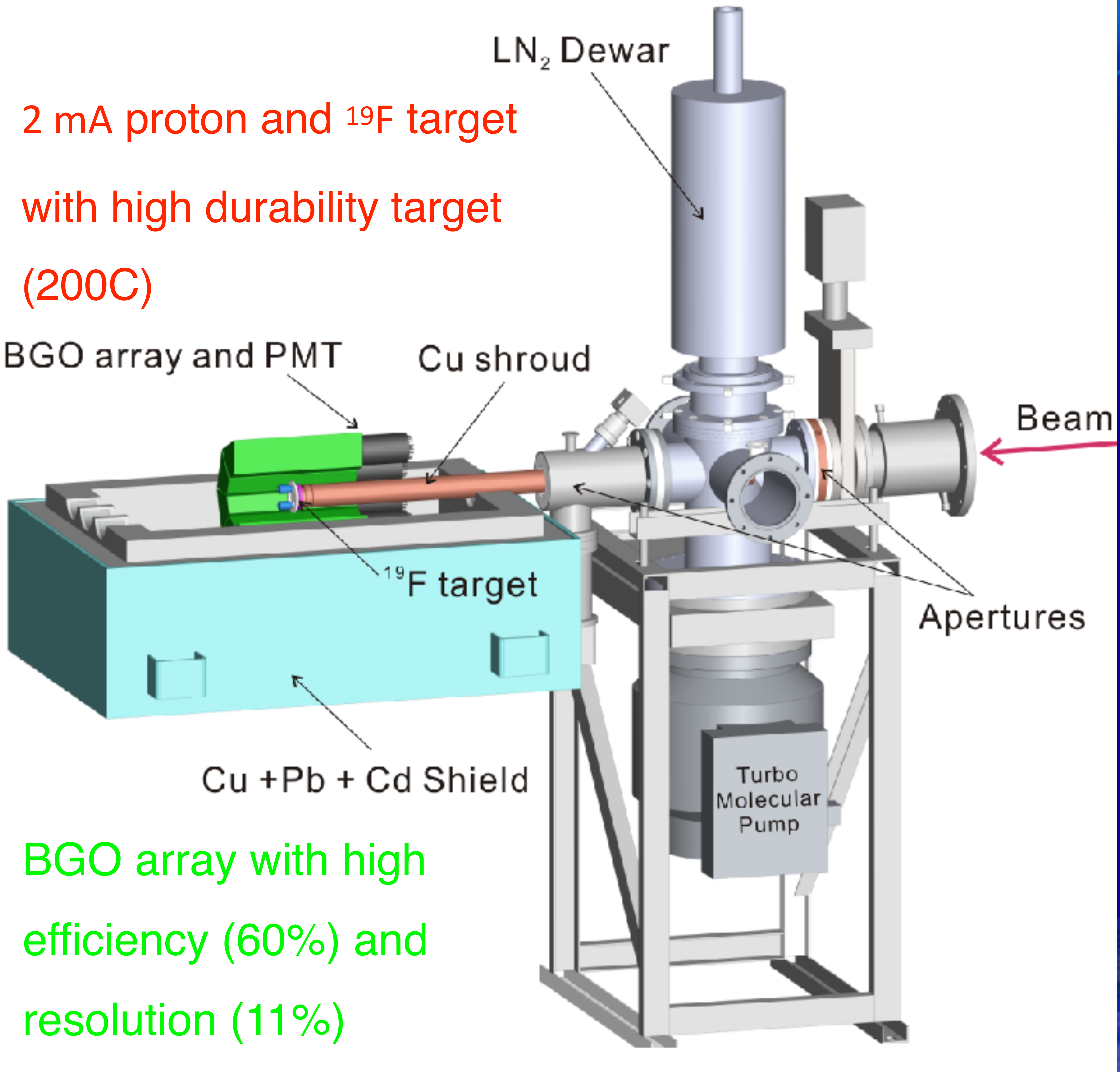
SMSS 0313-6708：lots of Ca, but no Fe?

Experiment setup

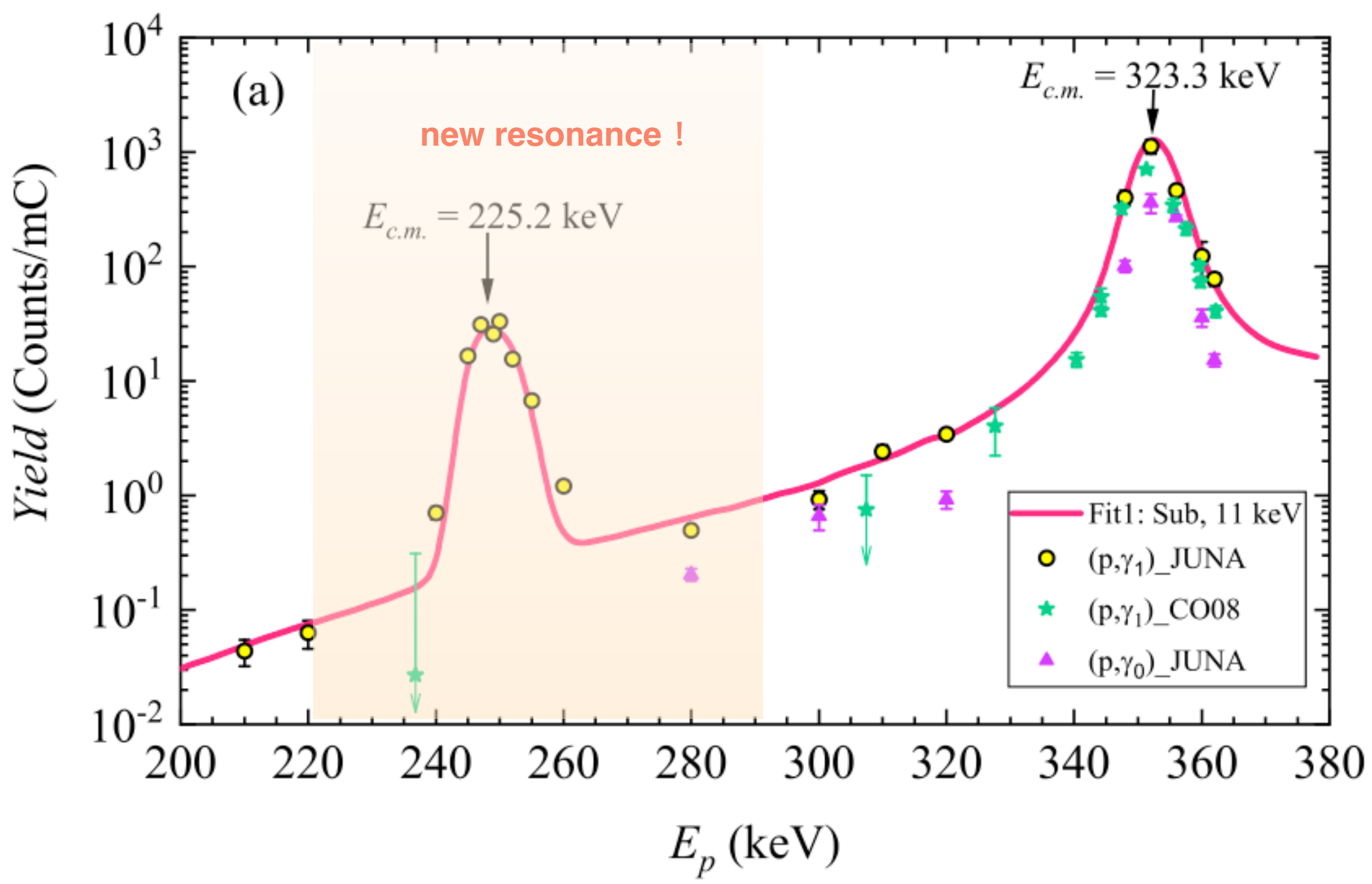
PI: J. J. He, BNU
with L. Y. Zhang, BNU

锦屏深地核天体物理实验
Jinping Underground Nuclear Astrophysics Experiment

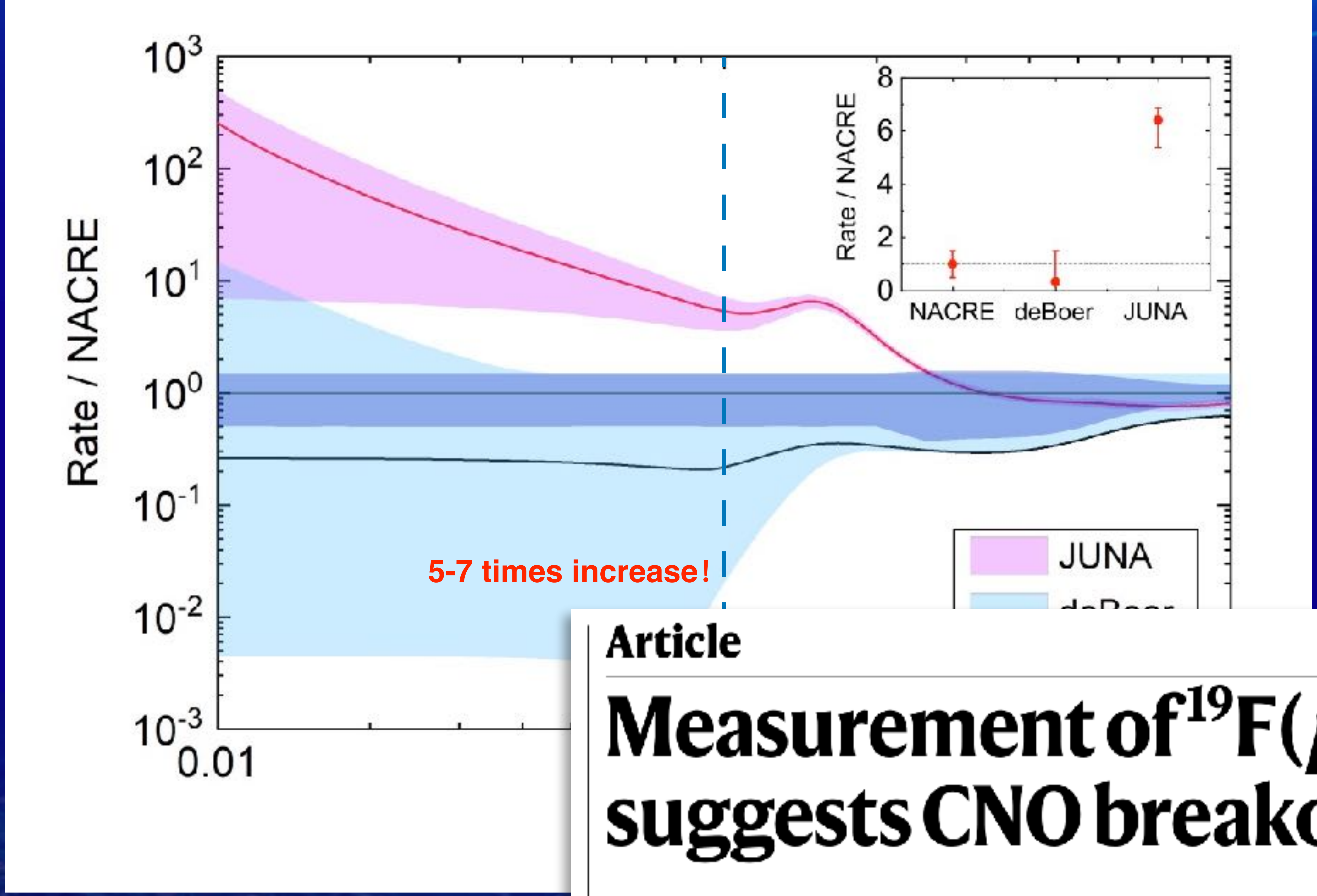
2 mA proton and ^{19}F target with high durability target (200C)

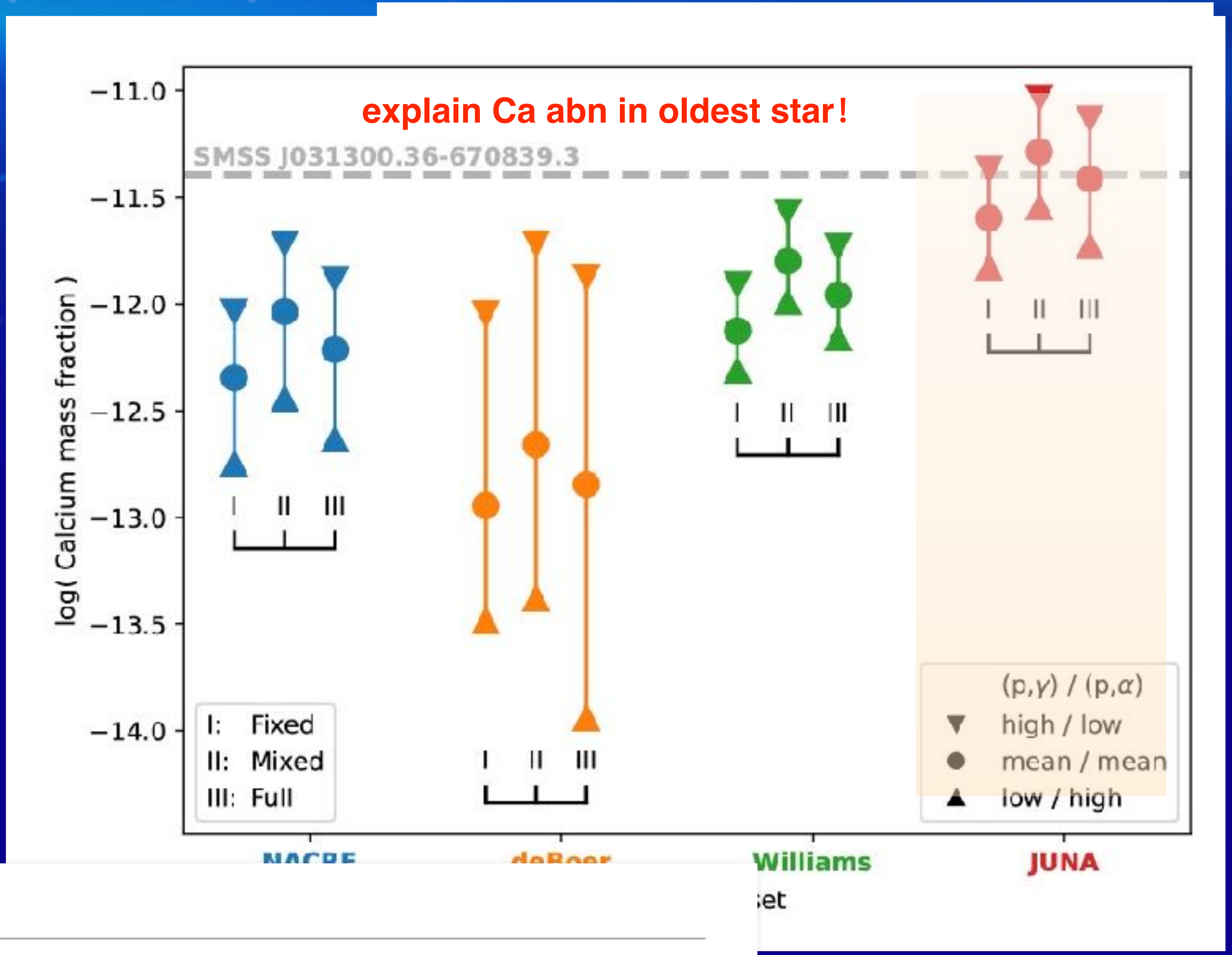


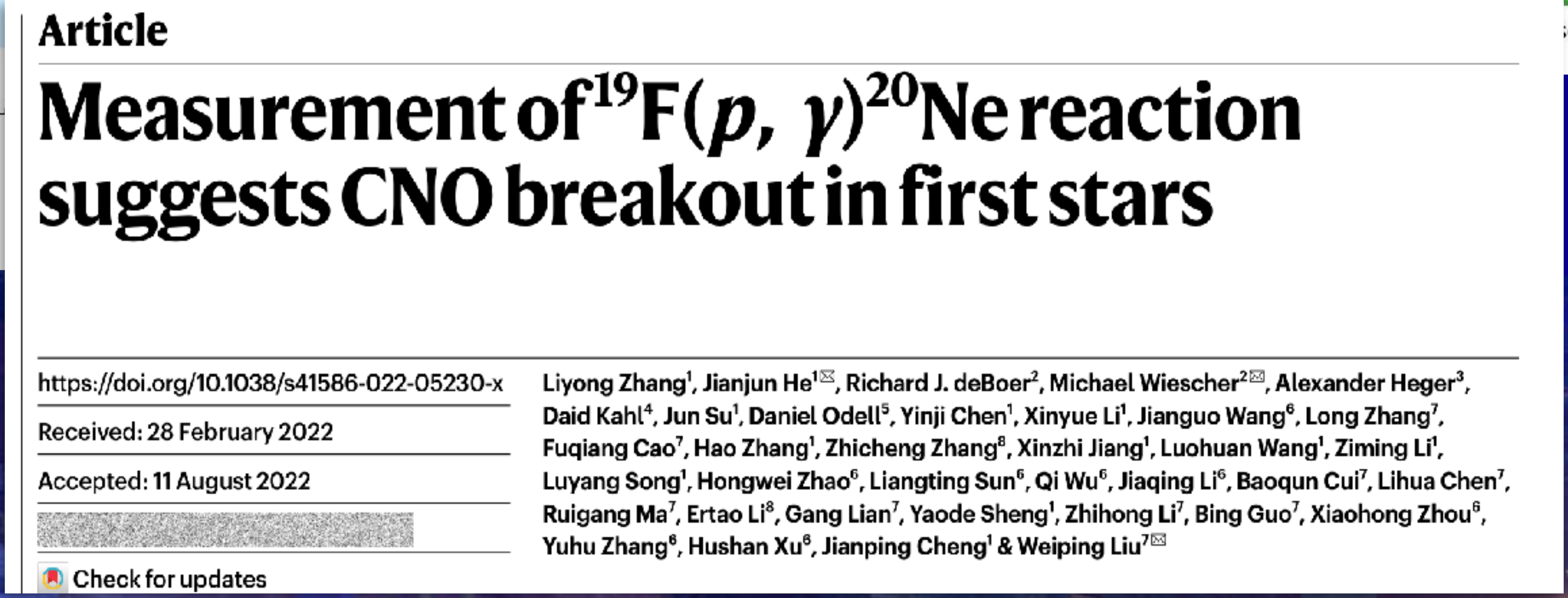
BGO array with high efficiency (60%) and resolution (11%)



$^{19}F(p,\gamma)^{20}Ne$ implications







Article

Measurement of $^{19}F(p,\gamma)^{20}Ne$ reaction suggests CNO breakout in first stars

https://doi.org/10.1038/s41586-022-05230-x

Received: 28 February 2022

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Check for updates

Liyong Zhang[1], Jianjun He[1]✉, Richard J. deBoer[2], Michael Wiescher[2]✉, Alexander Heger[3], Daid Kahl[4], Jun Su[1], Daniel Odell[5], Yinji Chen[1], Xinyue Li[1], Jianguo Wang[6], Long Zhang[7], Fuqiang Cao[7], Hao Zhang[1], Zhicheng Zhang[8], Xinzhi Jiang[1], Luohuan Wang[1], Ziming Li[1], Luyang Song[1], Hongwei Zhao[6], Liangting Sun[6], Qi Wu[6], Jiaqing Li[6], Baoqun Cui[7], Lihua Chen[7], Ruigang Ma[7], Ertao Li[8], Gang Lian[7], Yaode Sheng[1], Zhihong Li[7], Bing Guo[7], Xiaohong Zhou[6], Yuhu Zhang[6], Hushan Xu[6], Jianping Cheng[1] & Weiping Liu[7]✉

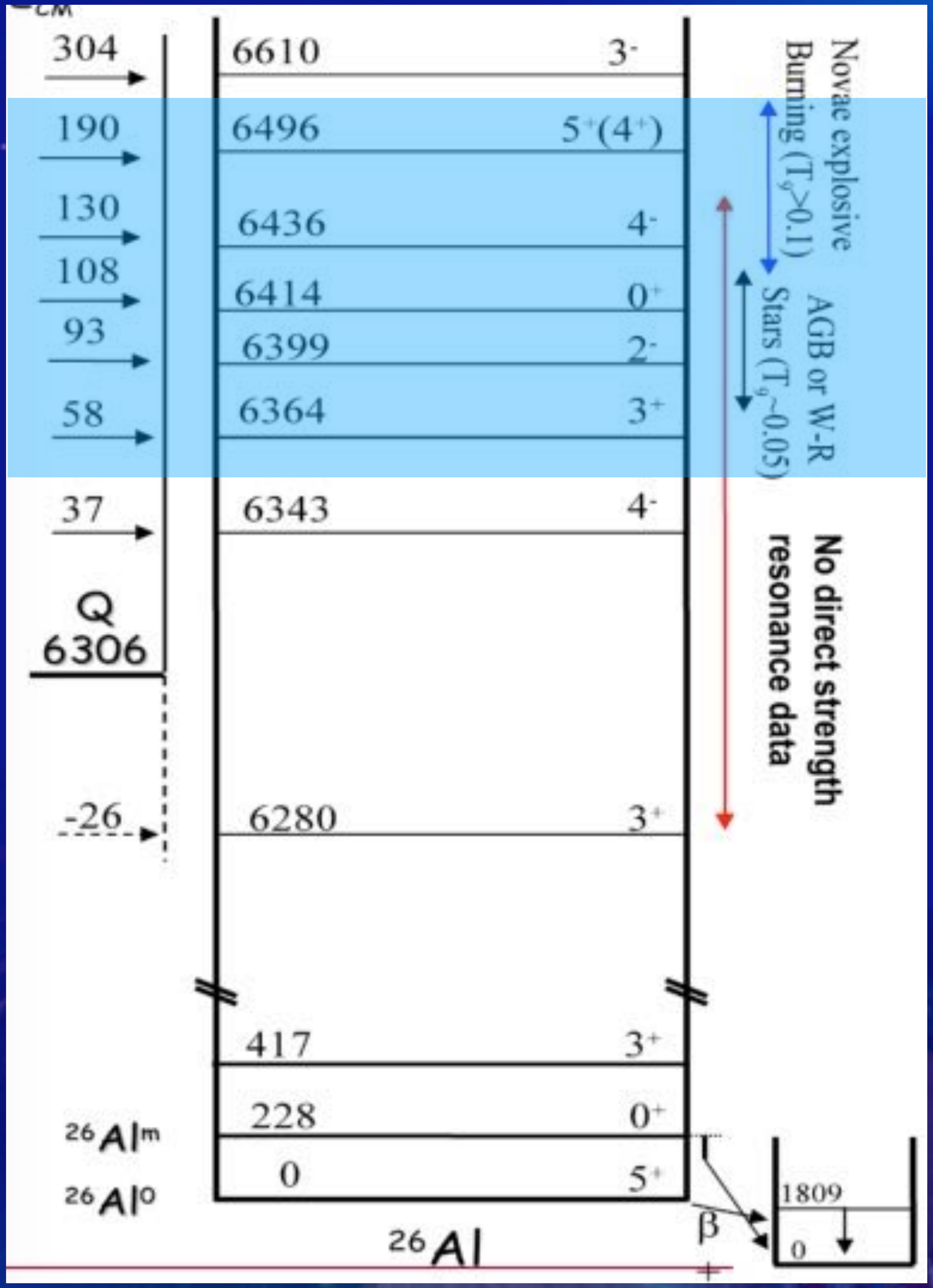
L. Y. Zhang, J. J. He*, …, WPL*, Nature 610(2022)656, Selected as news and views

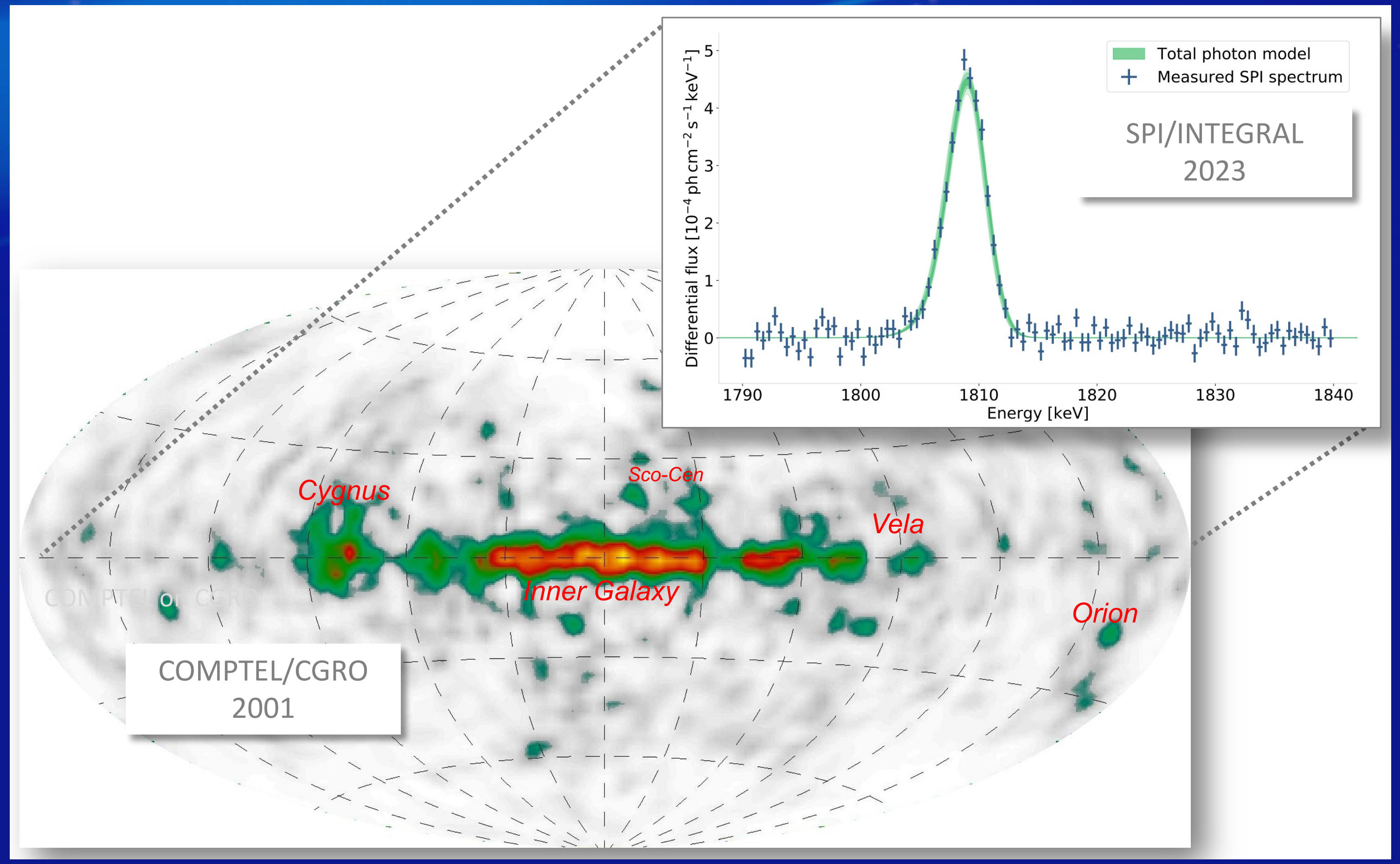
^{25}Mg(p,γ)^{26}Al： gamma astronomy

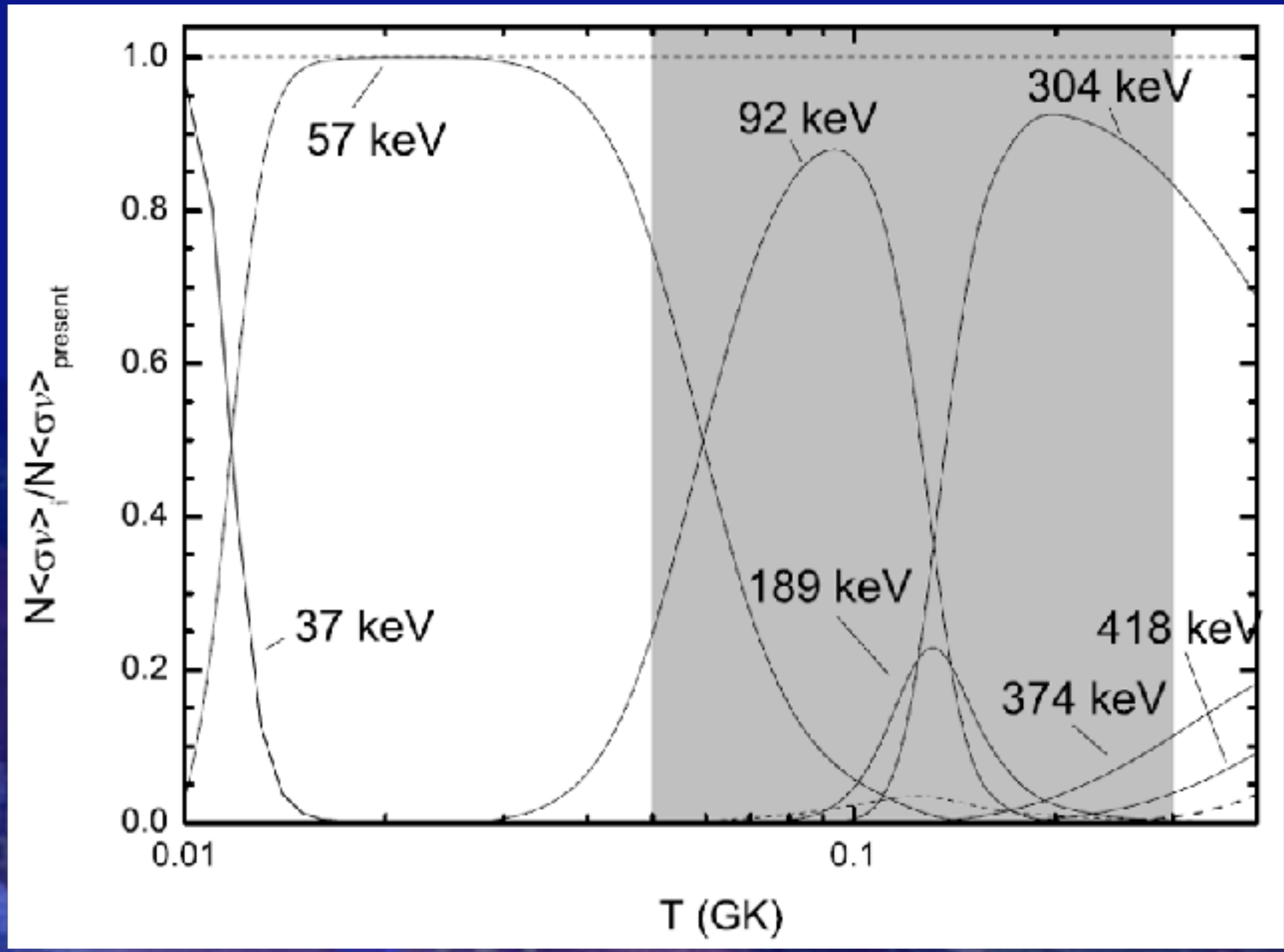
Exp.: Jan. 1-15, 2021

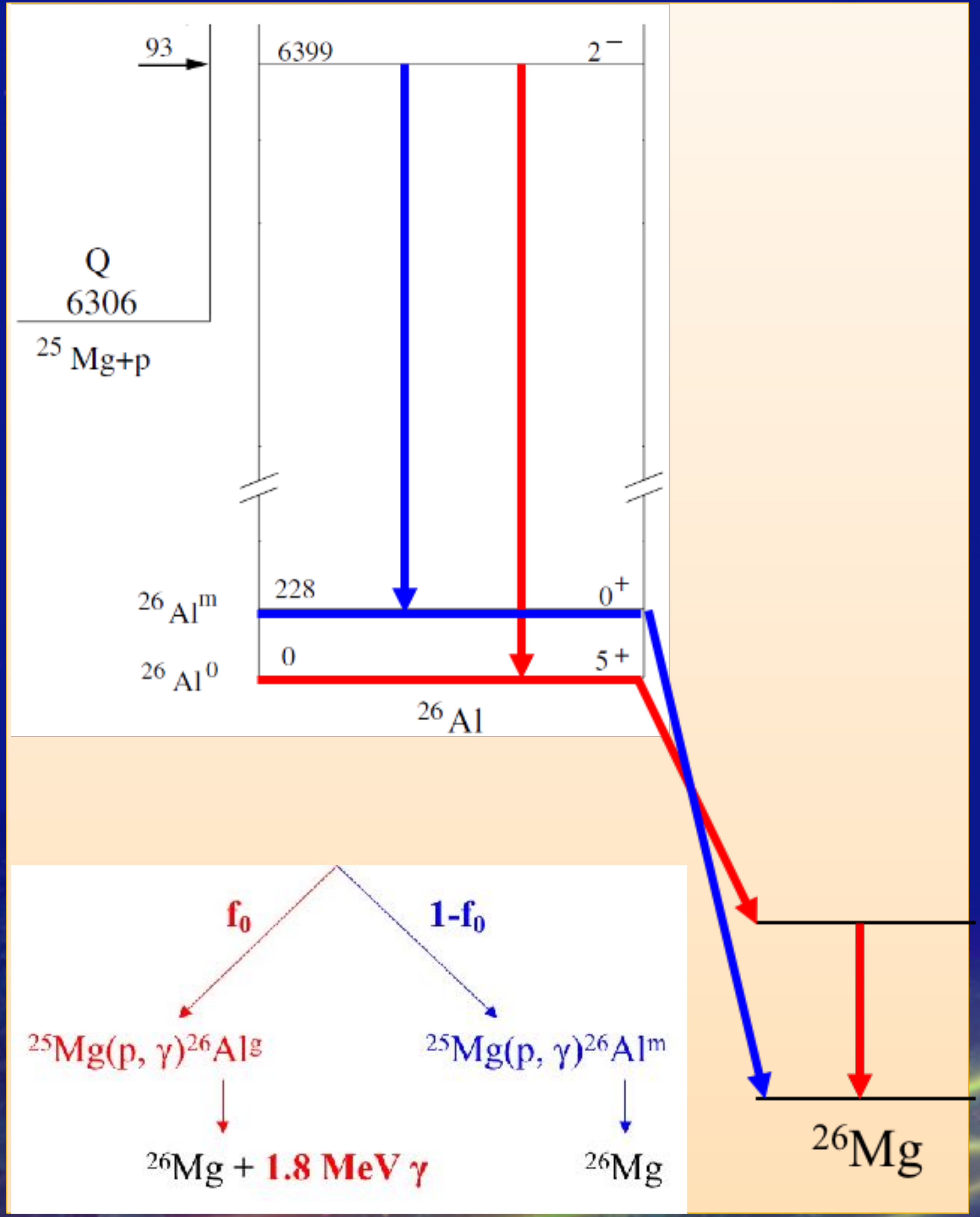
PI: Z. H. Li, CIAE

J. Su, CIAE/BNU



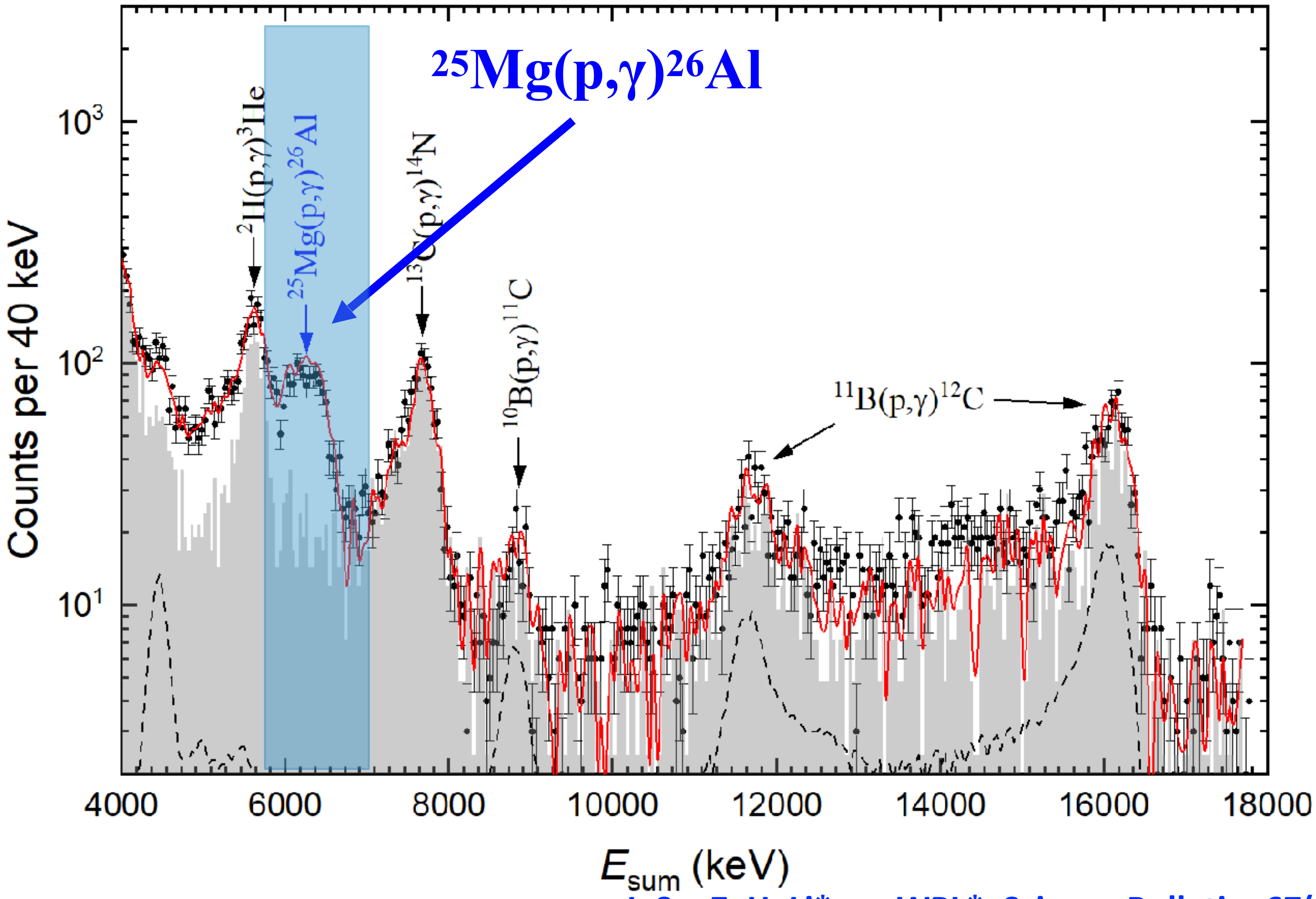






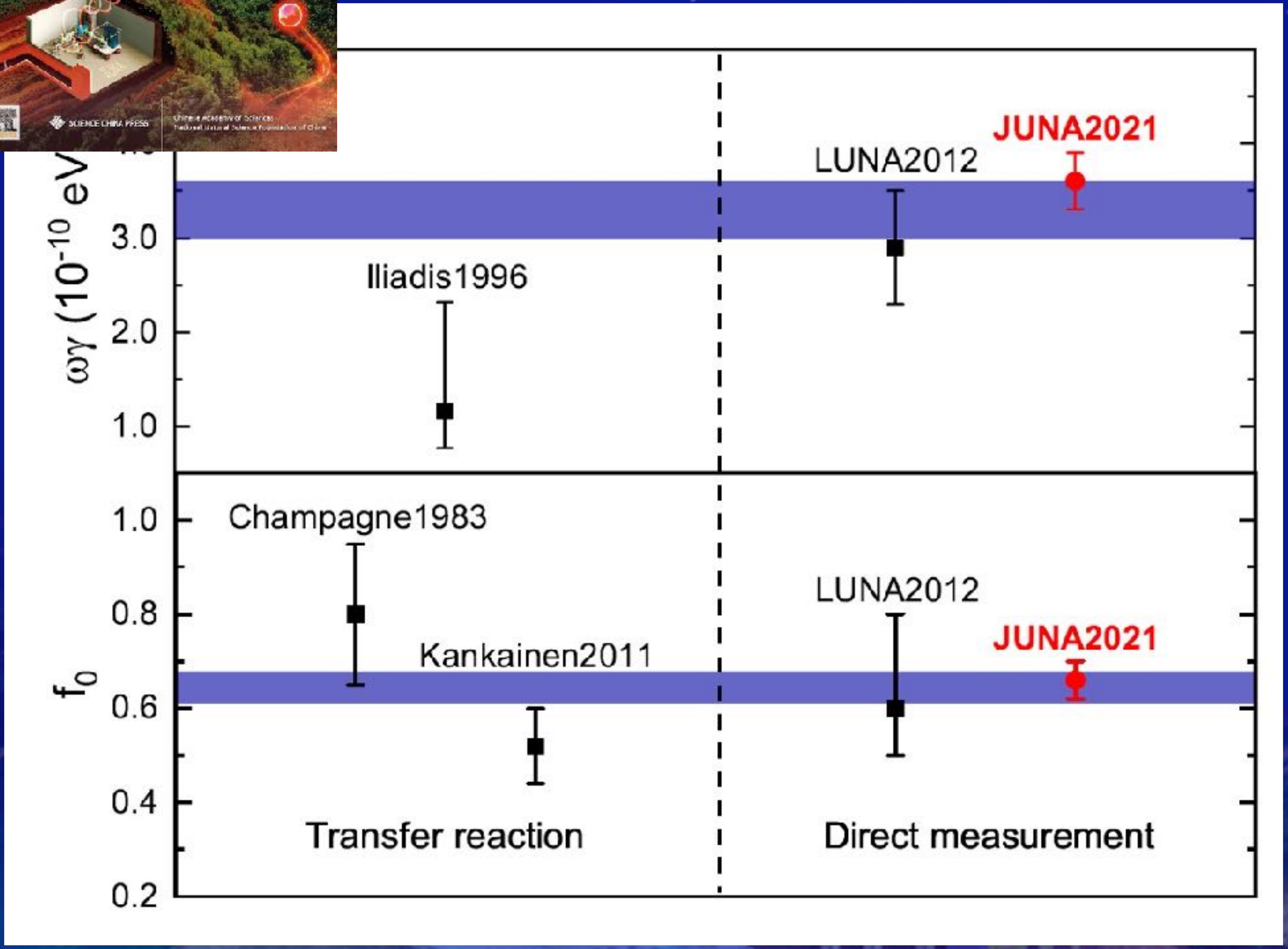
Z. H. Li et al., Sci. China Phys 58. 082002(2015), J. Su et al., Science Bulletin, 67(2022)2 （cover paper）

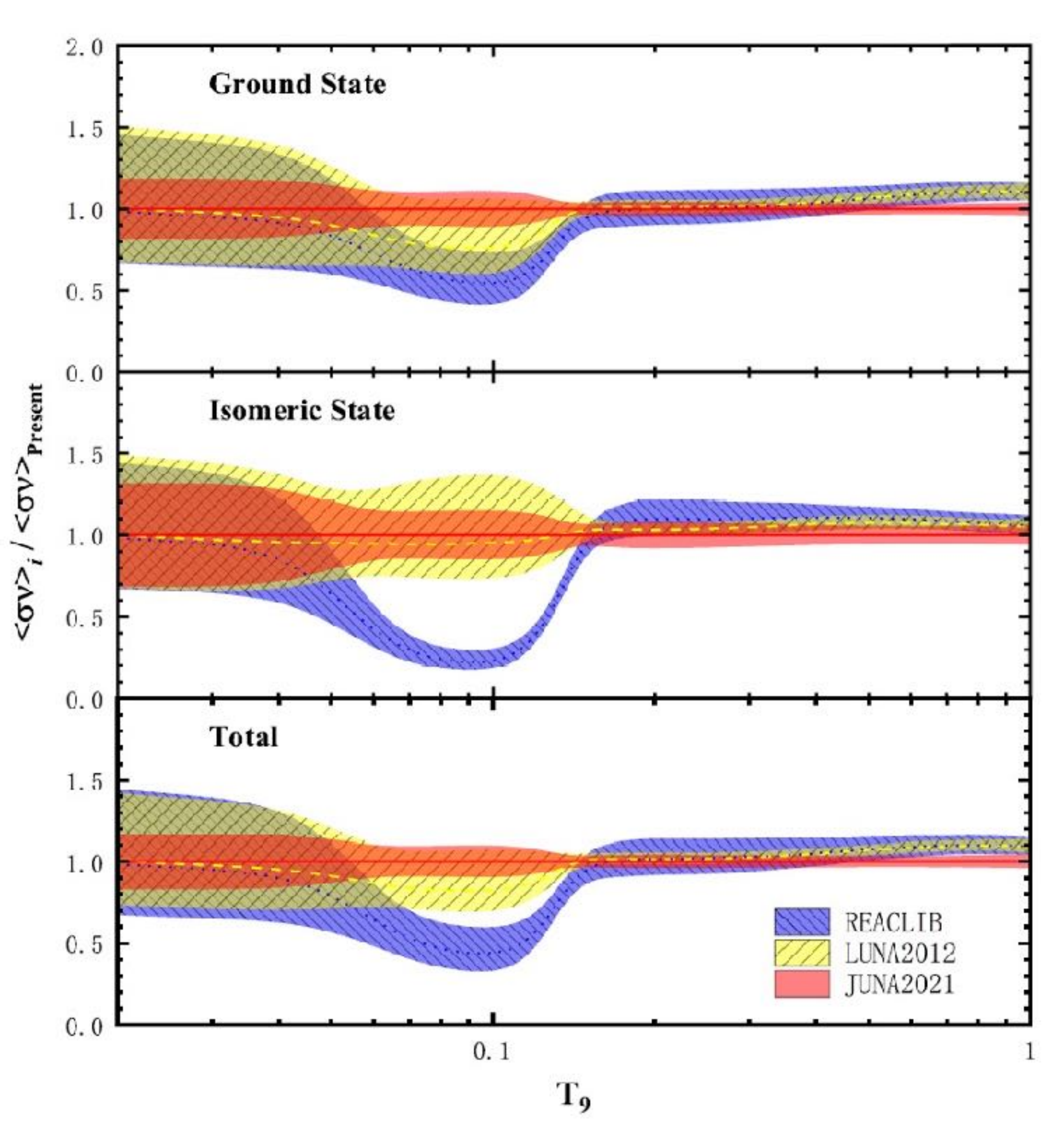
JUNA results



J. Su, Z. H. Li*,...., WPL*, Science Bulletin, 67(2022)2, cover paper

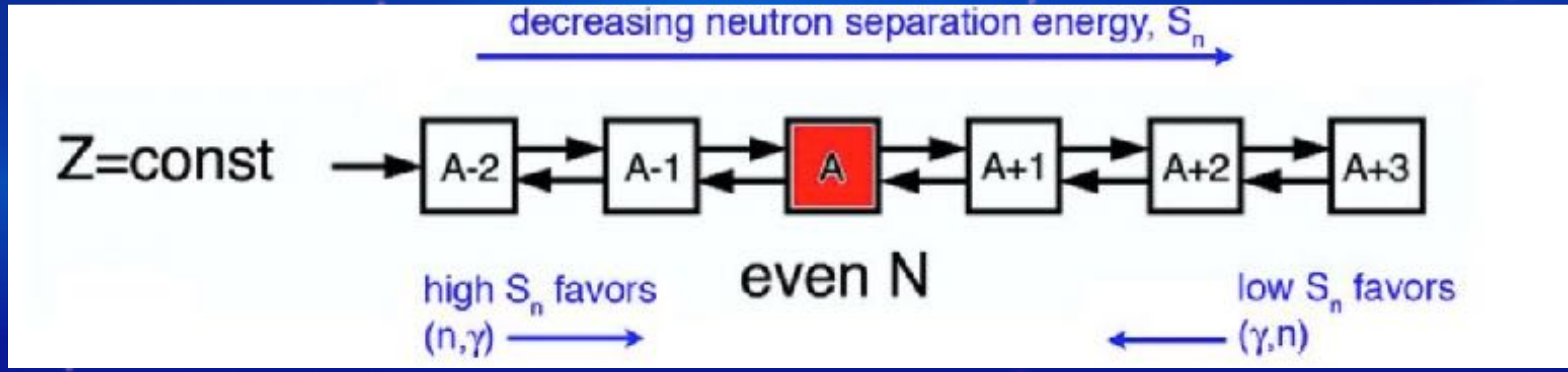
JUNA result of $^{25}Mg(p,\gamma)^{26}Al$

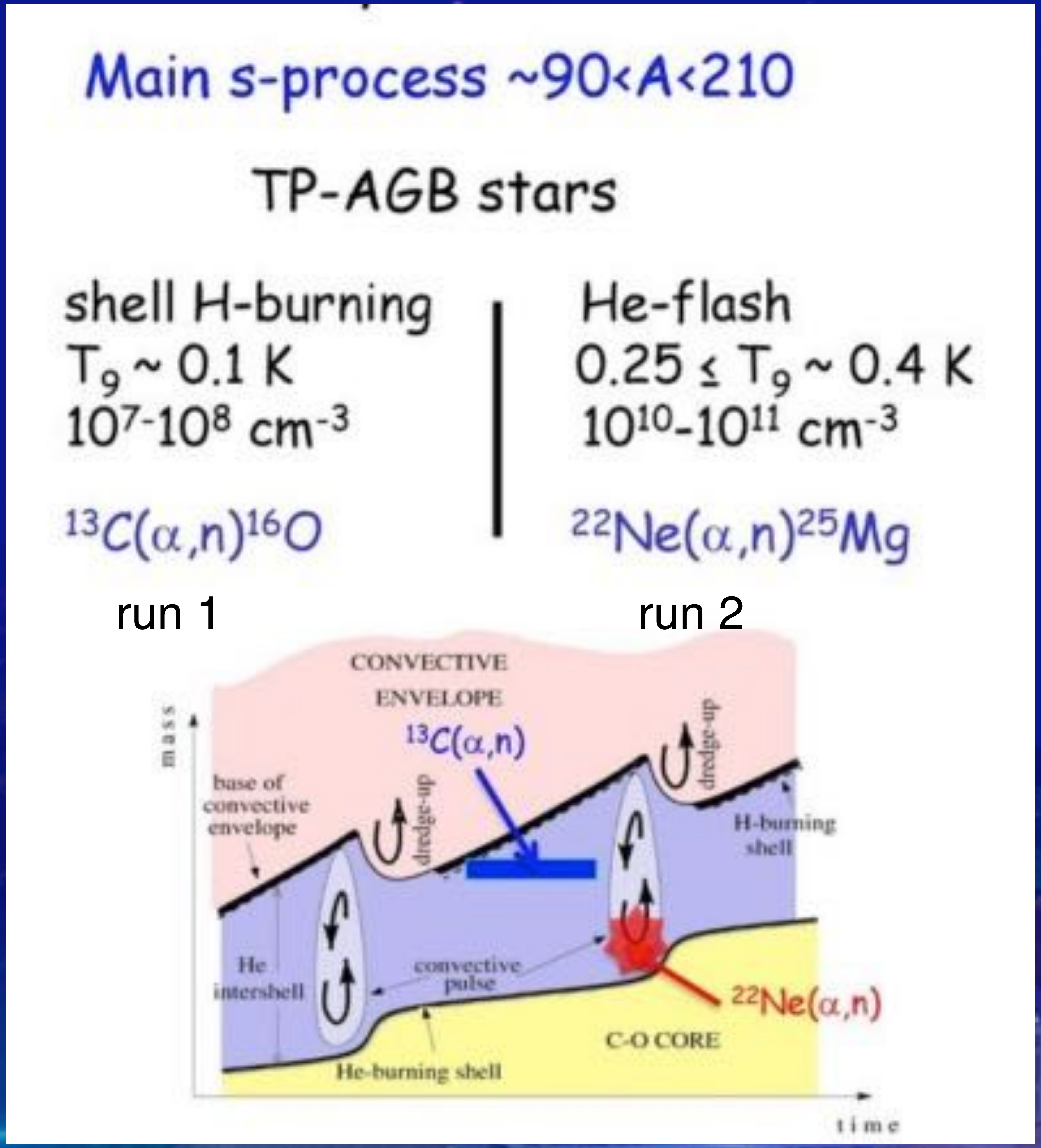


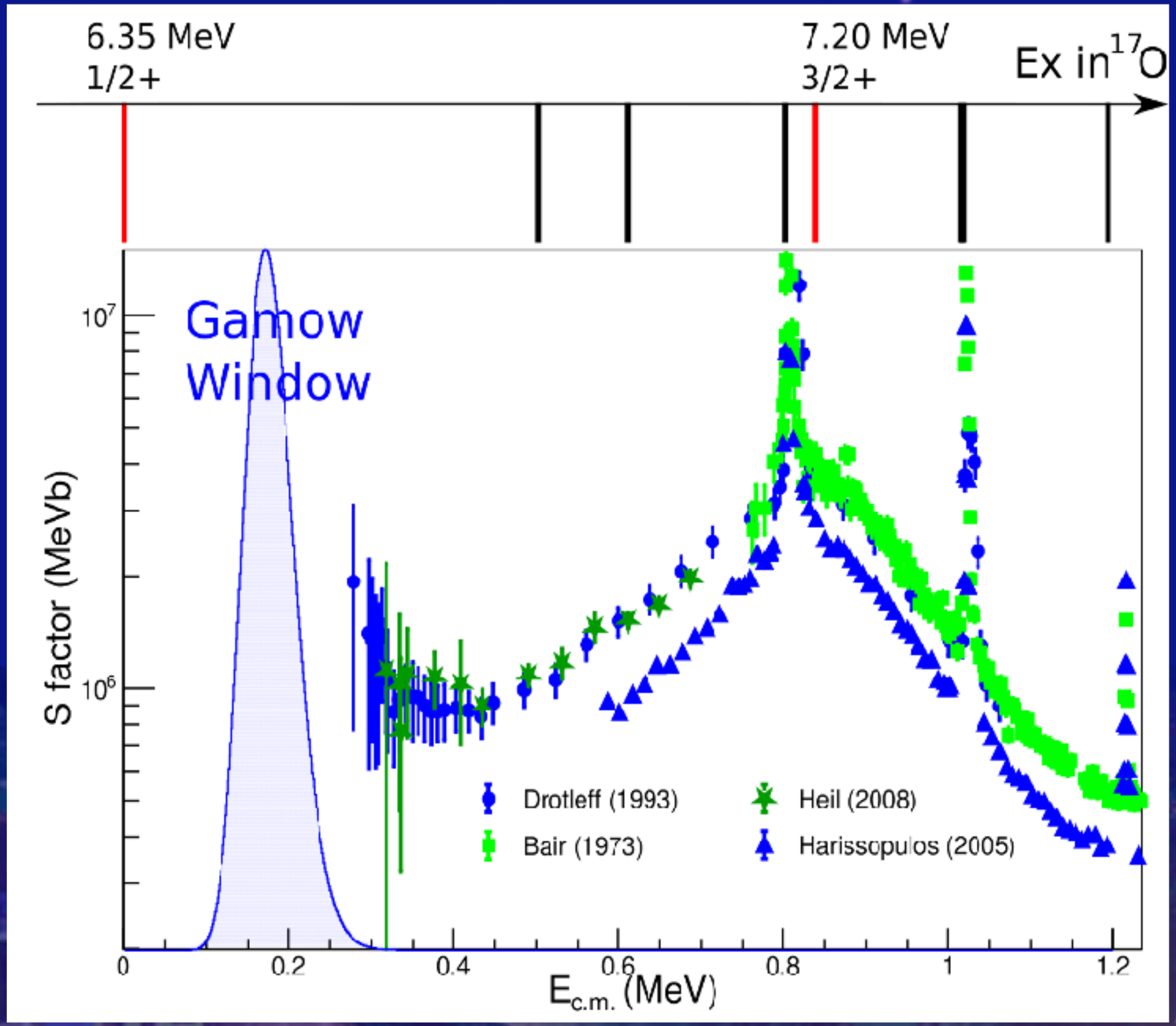


J. Su, Z. H. Li*,…., WPL*, Science Bulletin, 67(2022)2,cover paper

$^{13}C(\alpha,n)^{16}O$ neutron source reaction for heavy elements







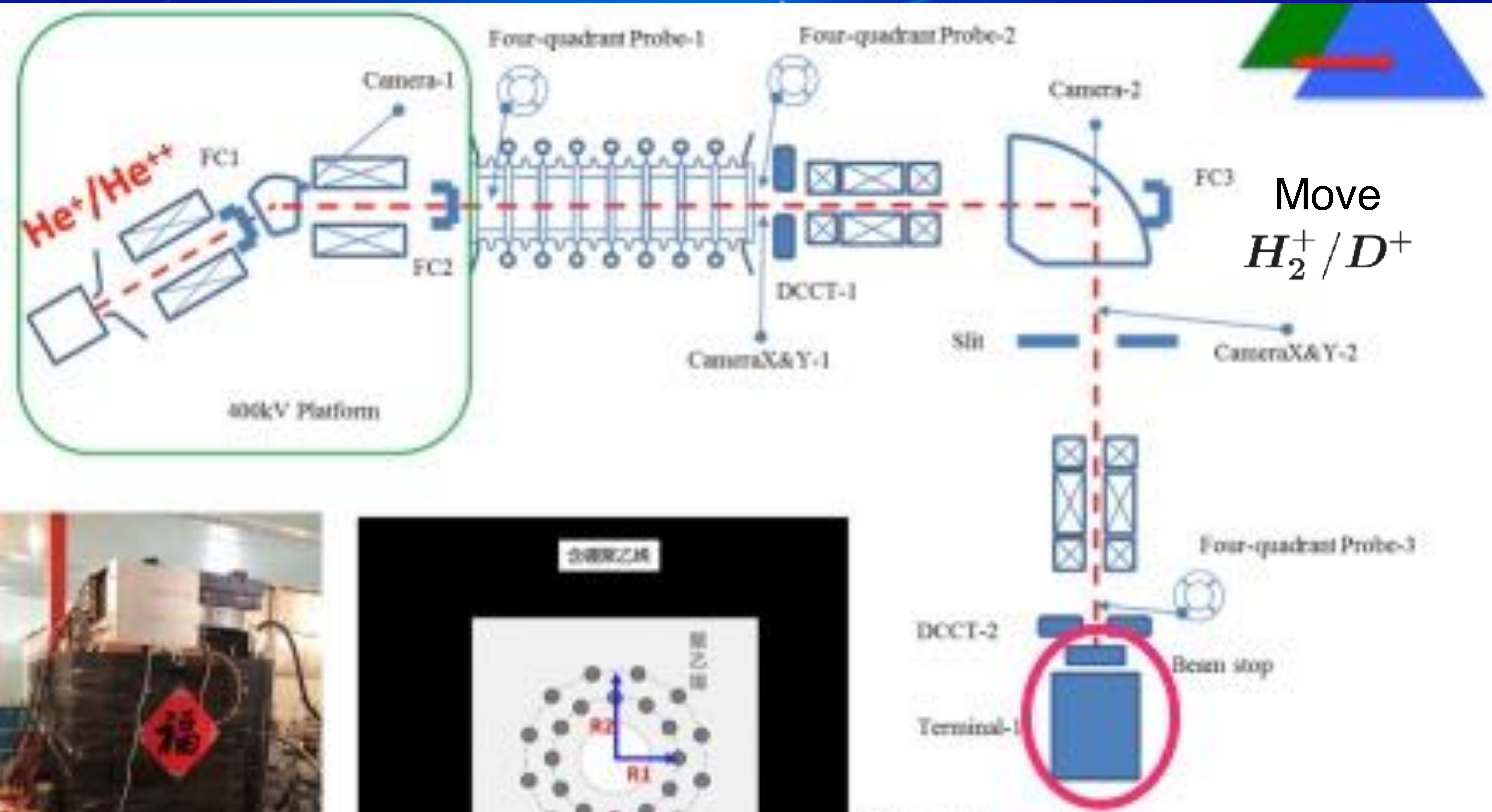
PI: X. D. Tang, IMP

B. Gao, IMP

Exp.: Jan. 27-Feb. 16, 2021

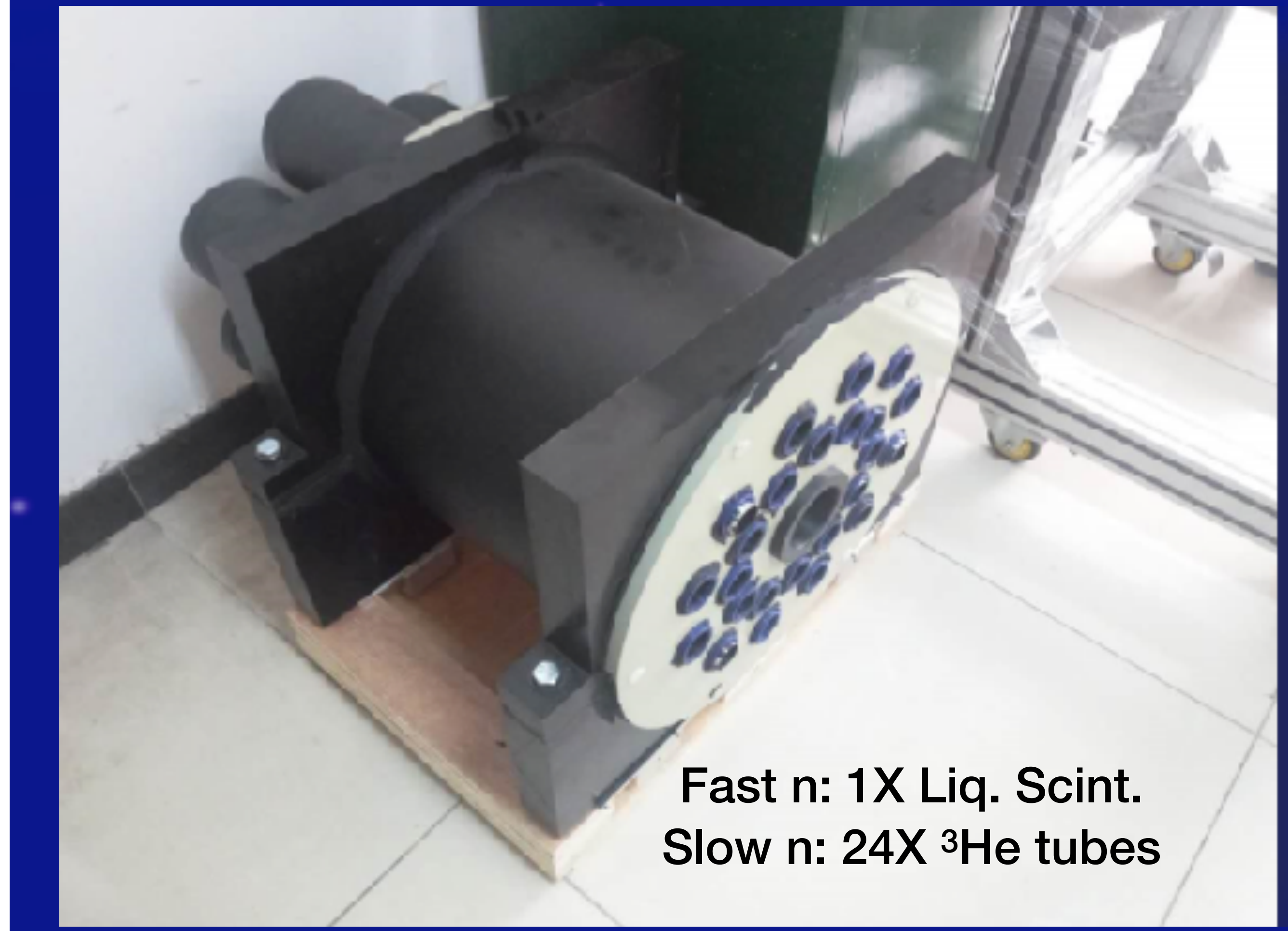
B. Gao, …, Y. D. Tang*,…, WPL*, $^{13}C(\alpha,n)^{16}O$, PRL 129(2022)132701

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



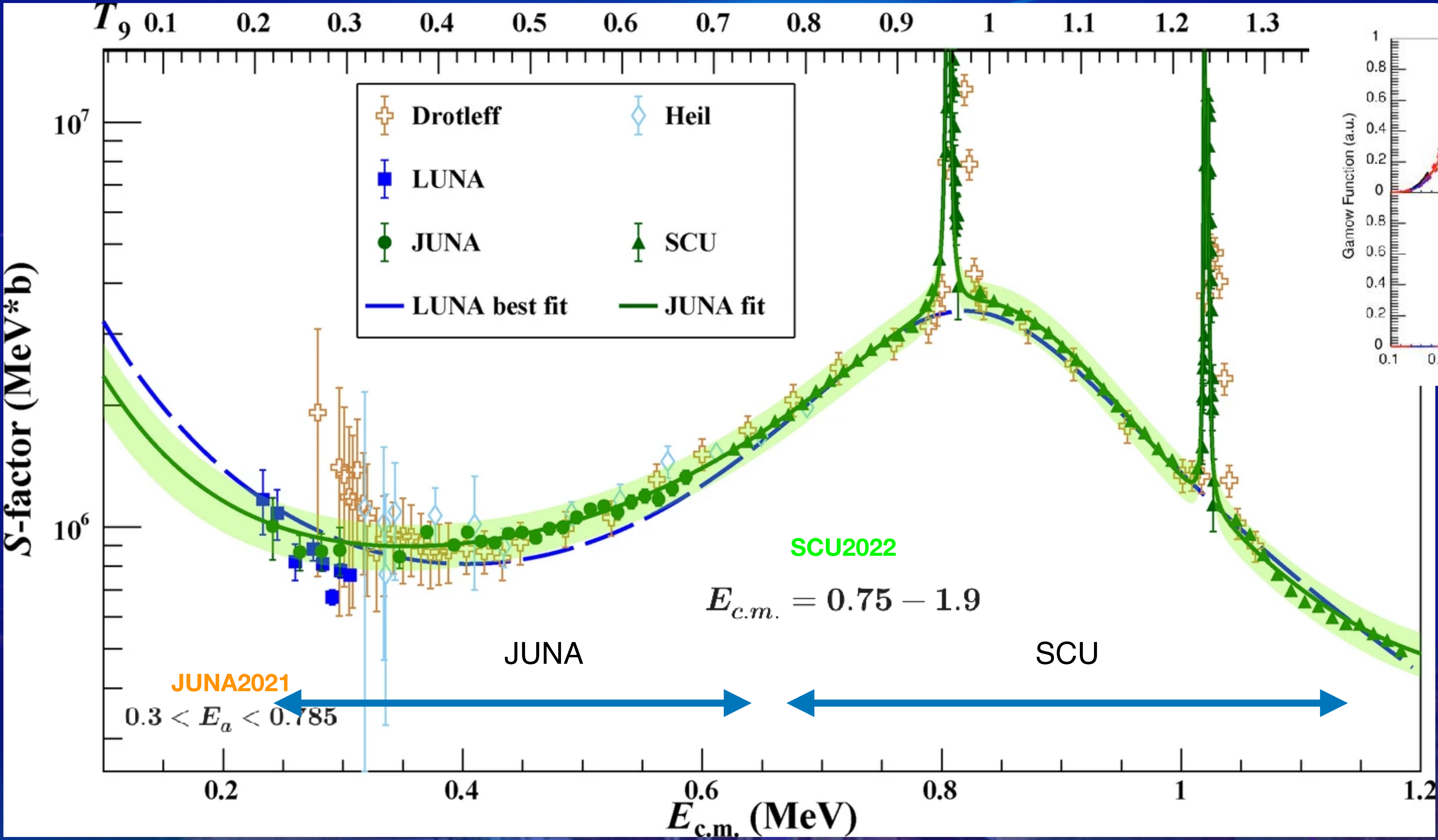
Move H_2^+/D^+

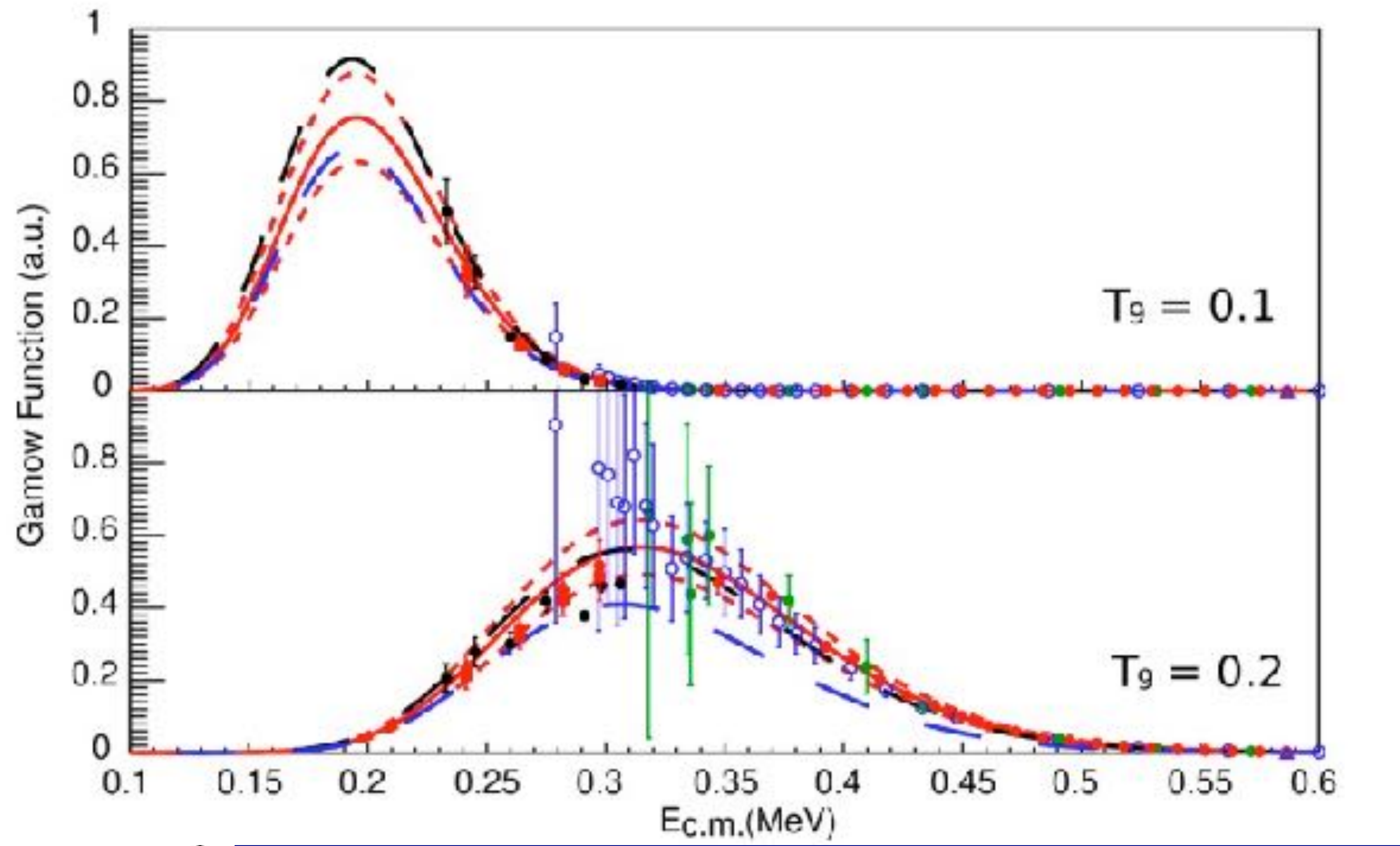
He++: 1pmA
He+: 1pmA,
^{13}C thick target (2mm) x 3



B. Gao, …, Y. D. Tang*,…, WPL*, $^{13}C(\alpha,n)^{16}O$, PRL 129(2022)132701

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





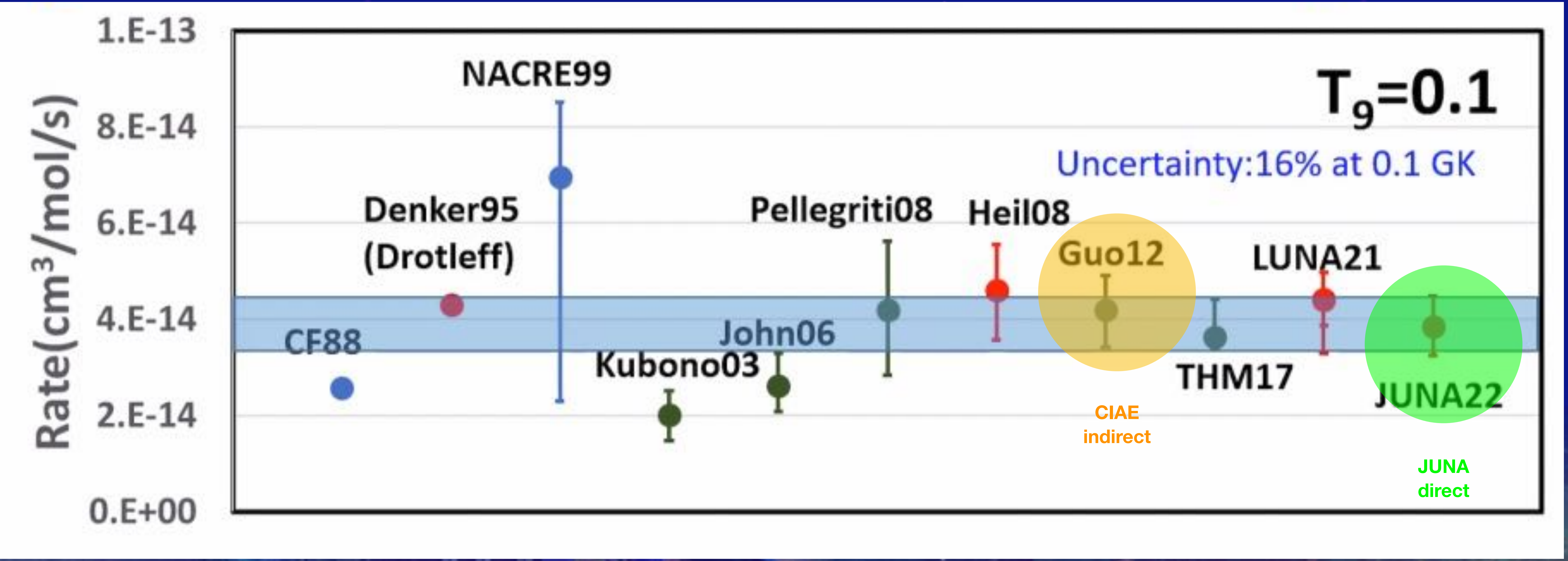
- mA thick target, differential method to pin down thickness
- magnetic removal of He^{2+}, cover 0.4 MeV to 0.8 MeV (JUNA), cover i-process; to 1.2 MeV tandem, calibration of eff. , cross check other date
- n background 5/hour, 2.5 MeV eff. 25%, good S/N

B. Gao, …, Y. D. Tang*,…, WPL*, $^{13}C(\alpha,n)^{16}O$, PRL 129(2022)132701

Resolve conflict in30 years research

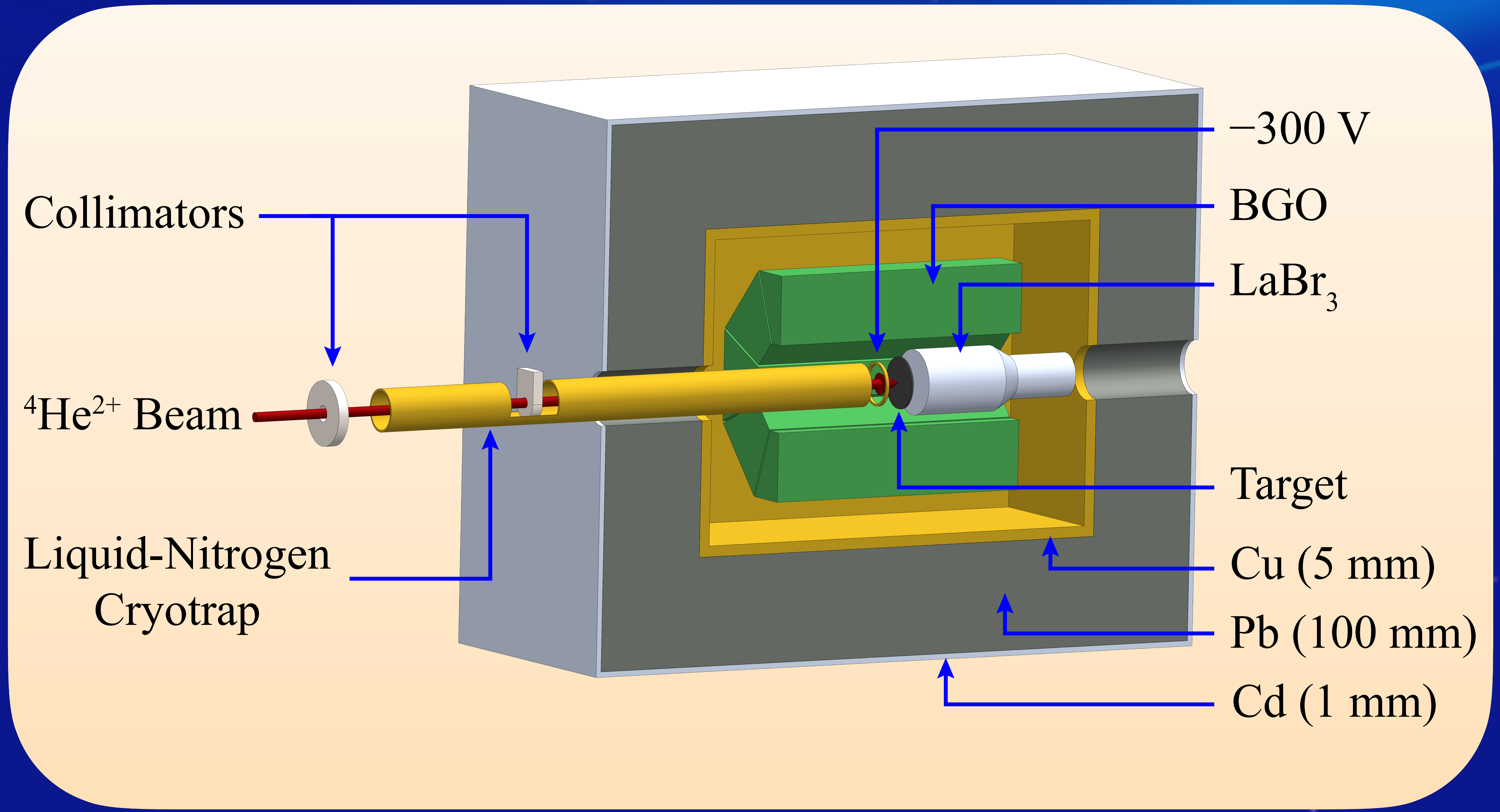
Annu. Rev. Nucl. Part. Sci. 2023. 73:315–40

Recent studies of the low-energy range of the $^{13}C(\alpha,n)^{16}O$ reaction rate at the deep underground accelerator facilities of LUNA in Italy (83) and JUNA in China (84) have removed most of the uncertainties in the extrapolation of the previous higher-energy data [the NACRE II compilation (85)]. The low-energy data match well the prediction of a recent R-matrix analysis (86)

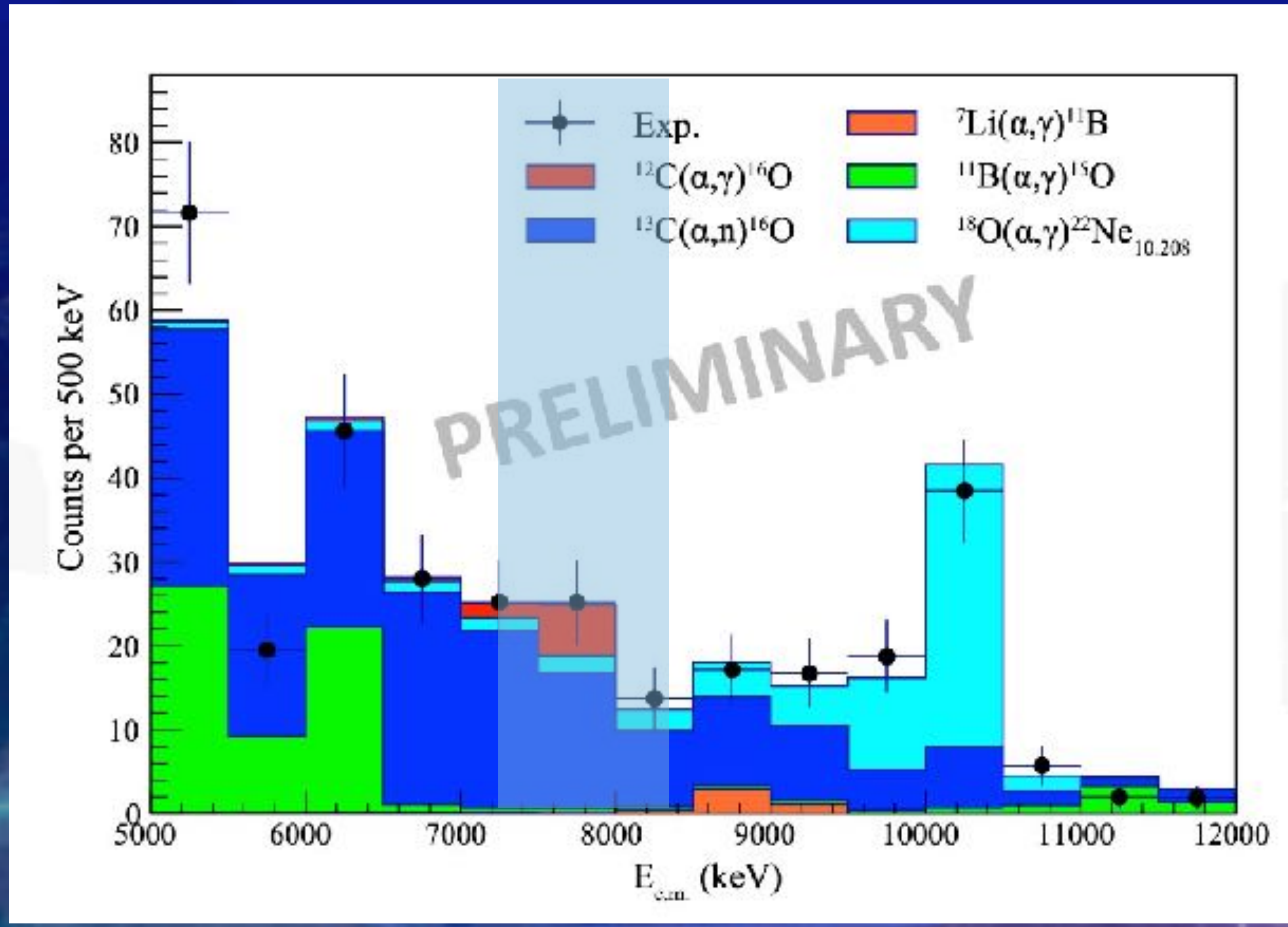


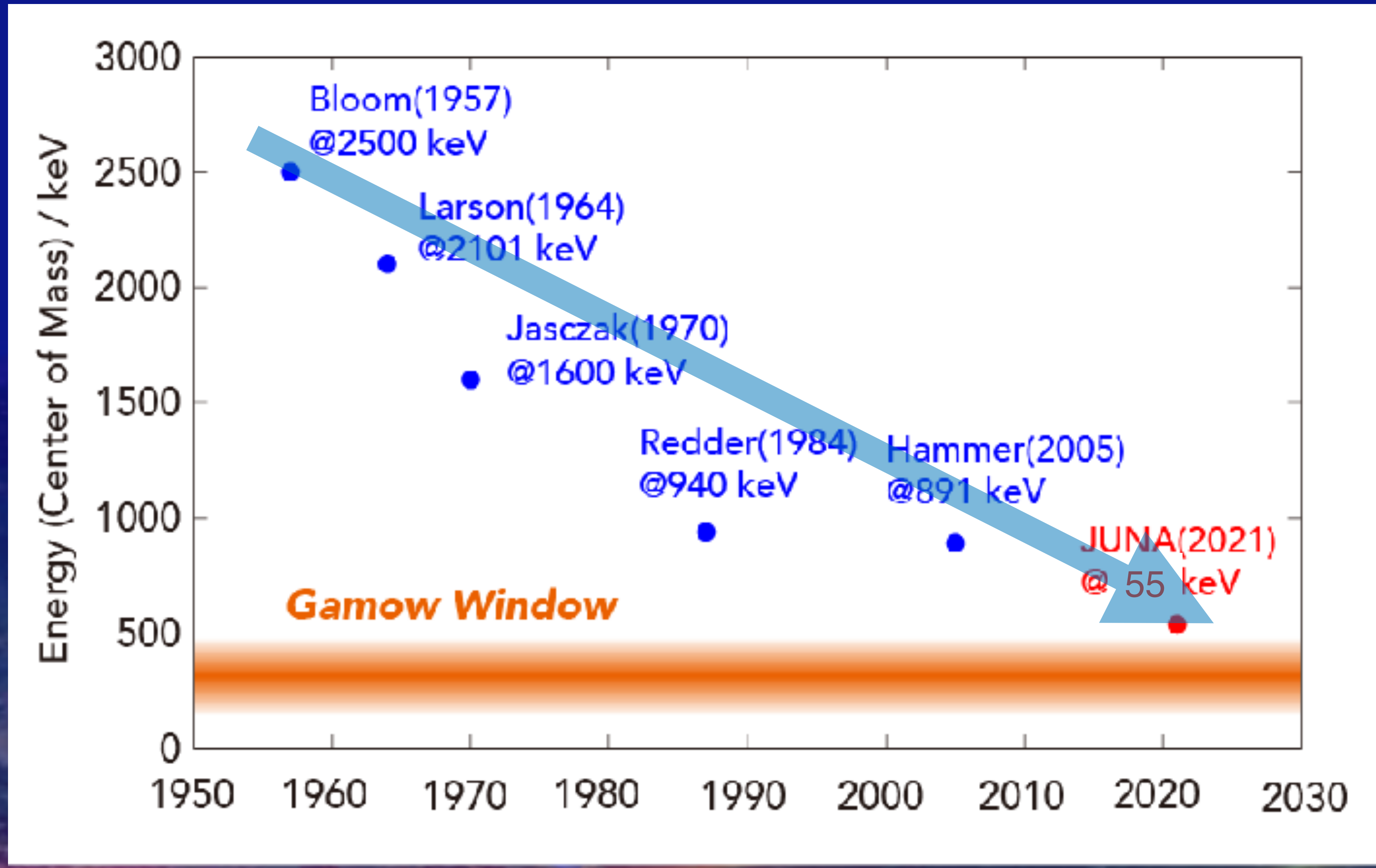
B. Gao, …, Y. D. Tang*,…, WPL*, $^{13}C(\alpha,n)^{16}O$, PRL 129(2022)132701
B. Guo*, Z. H. Li,…, WPL*, Astrophys. J. 756(2012)193.

Status for $^{12}C(\alpha,\gamma)^{16}O$, see Y. P. Shen talk

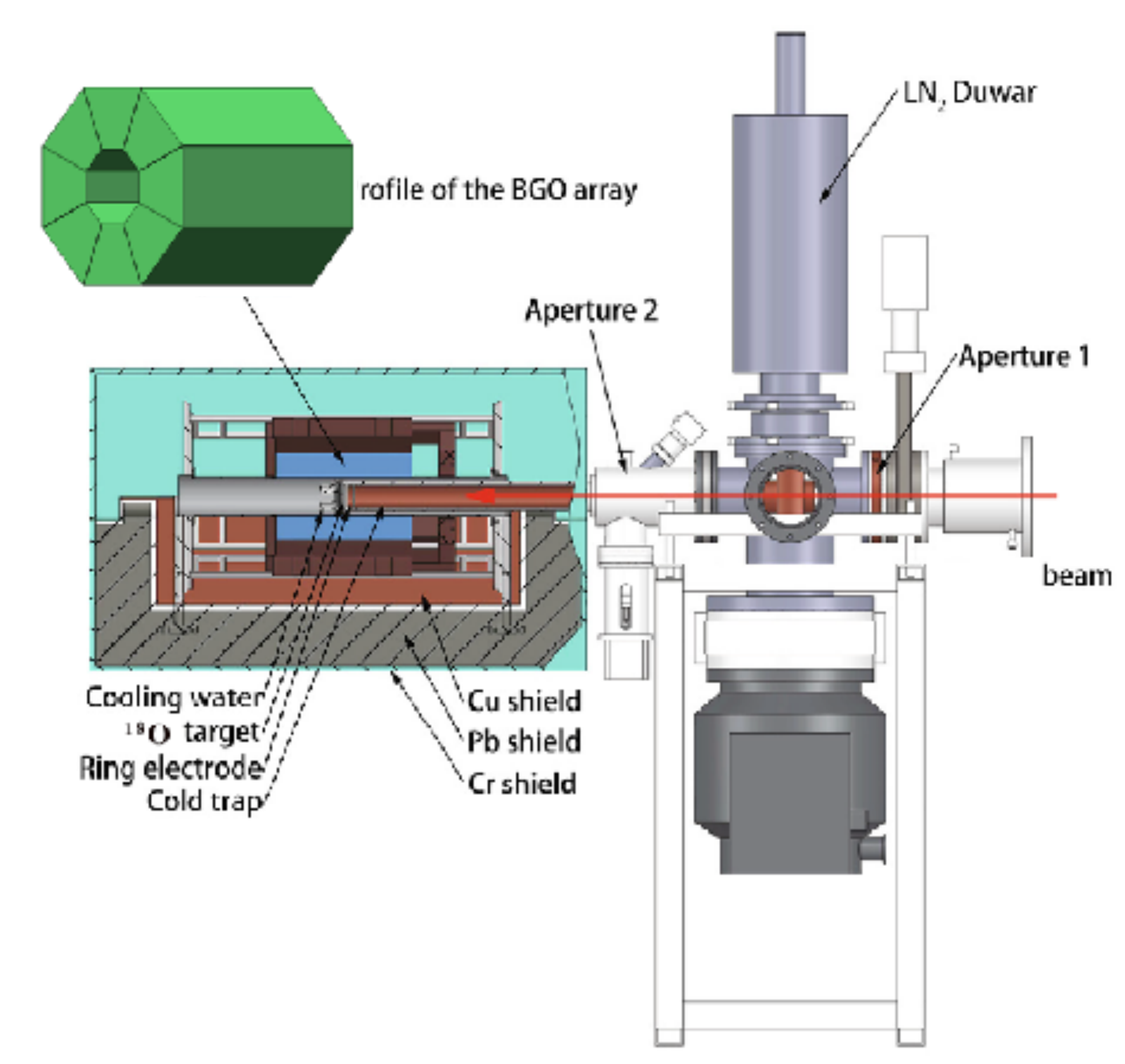


- >1000 C @552, 582 and 612 keV He^{2+}, with FCVA CTi targets
- BGO+$LaBr_3$ veto
- Sensitivity of 10^{-12} b @$E_{c.m.}$ = 552 keV, with 1 σ confidence
- Confidence aiming at 3 σ, by run 2 with high efficiency +60%, and diamond target in 2025-2026

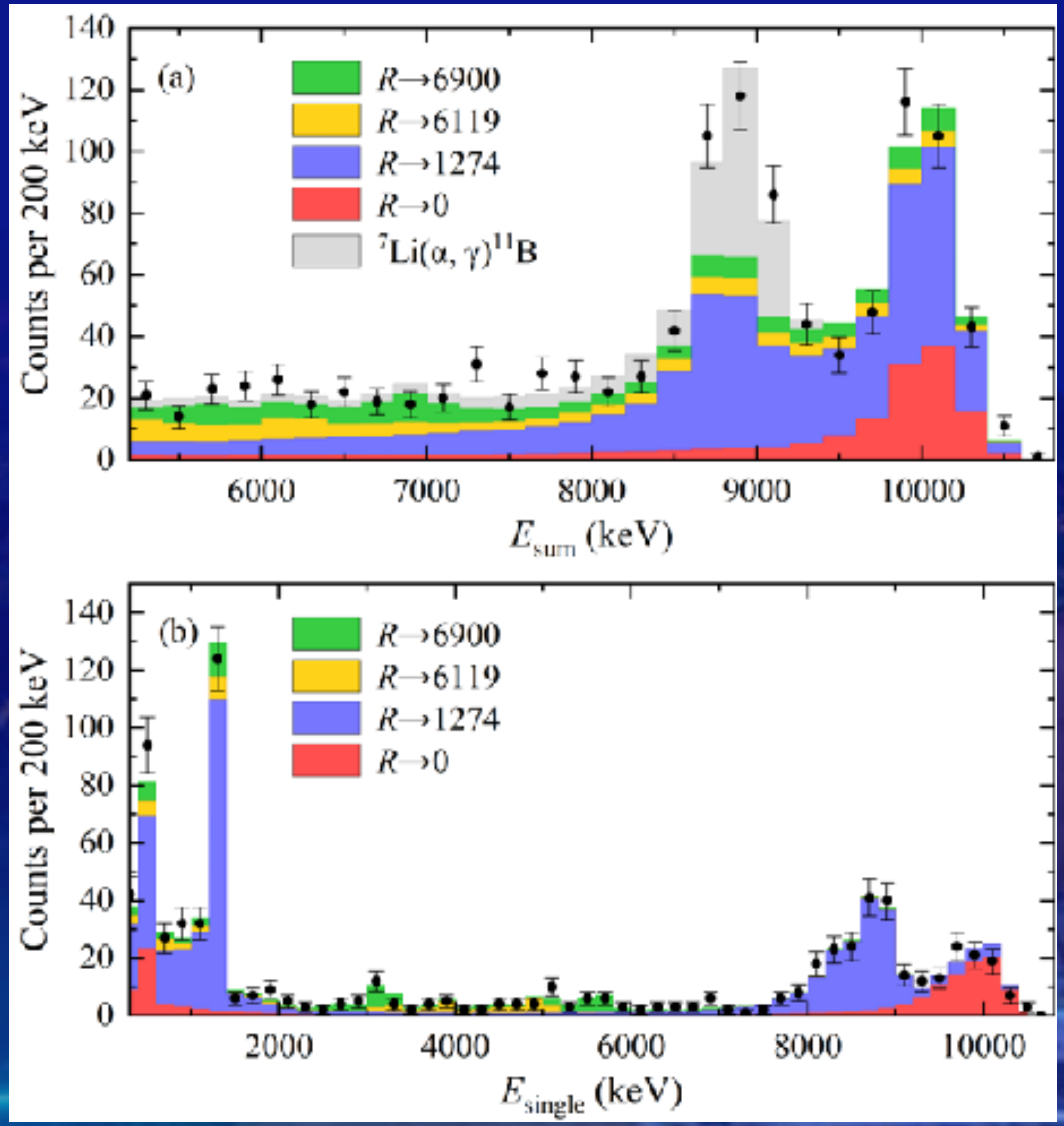


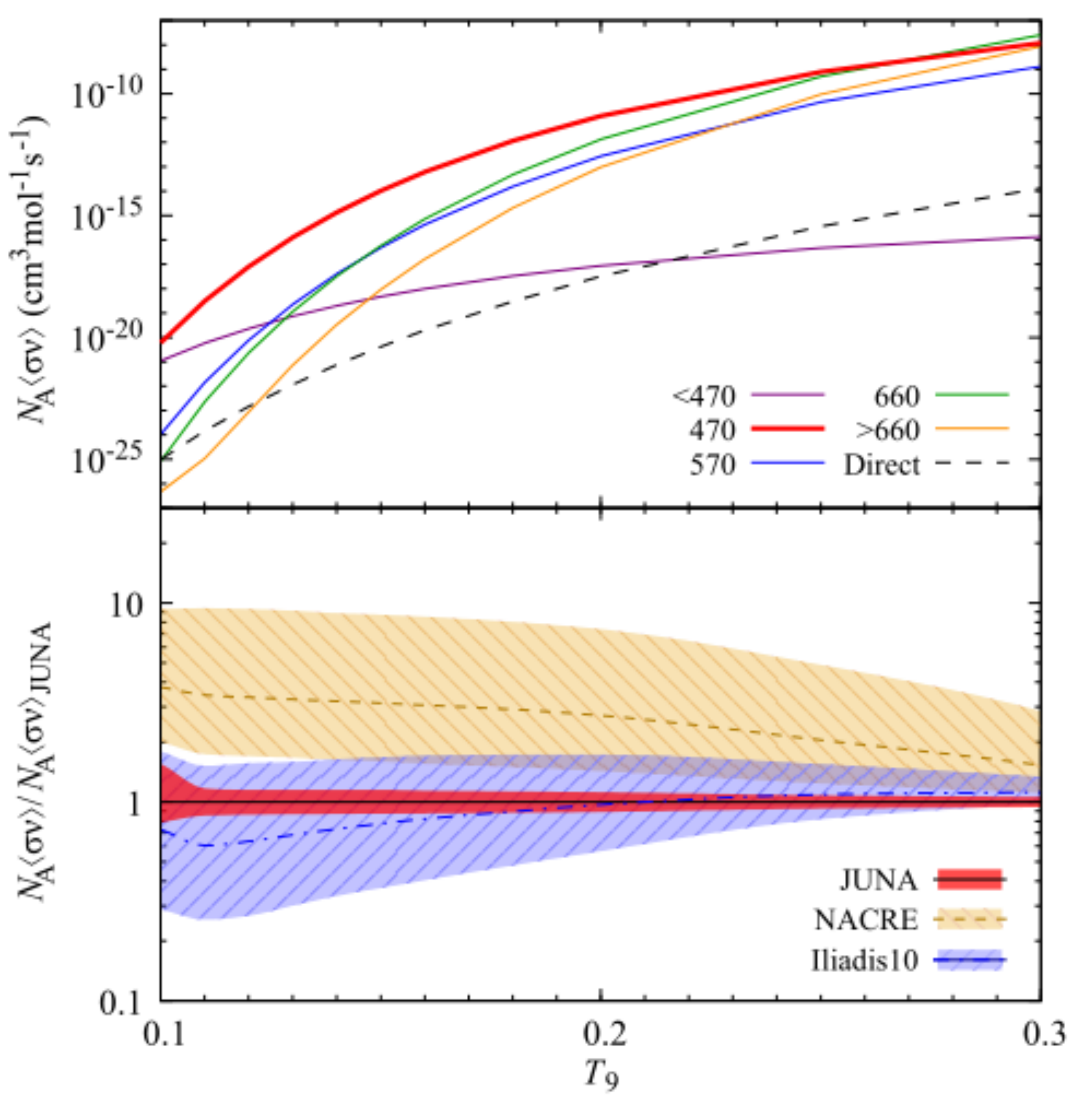


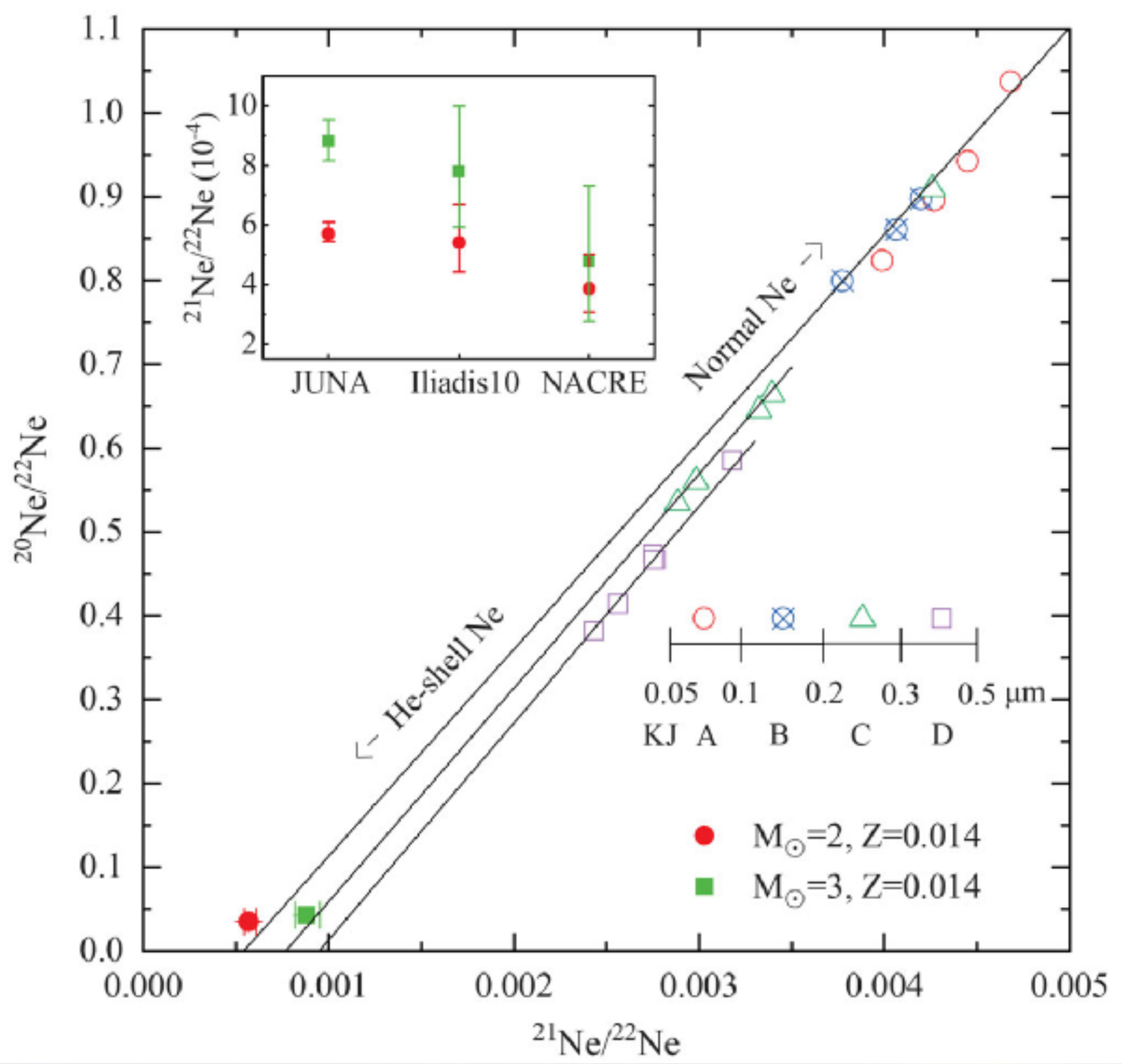
$^{18}O(\alpha,\gamma)^{22}Ne$ reaction and SiC grains



- $^{21}Ne/^{22}Ne$ in SiC grains, aintershell of AGB star
- $^{4}He^{2+}$ beam with 0.5 mA at 470-800 keV, $Ti^{18}O$ target and BGO array
- Improved E_R and $\omega\gamma$, precise reaction rates
- SiC from the He shell, and ^{22}Ne is significantly enhanced







L. H. Wang et al., Phys. Rev. Lett. 130, 092701 (2023)

JUNA results from Run-1

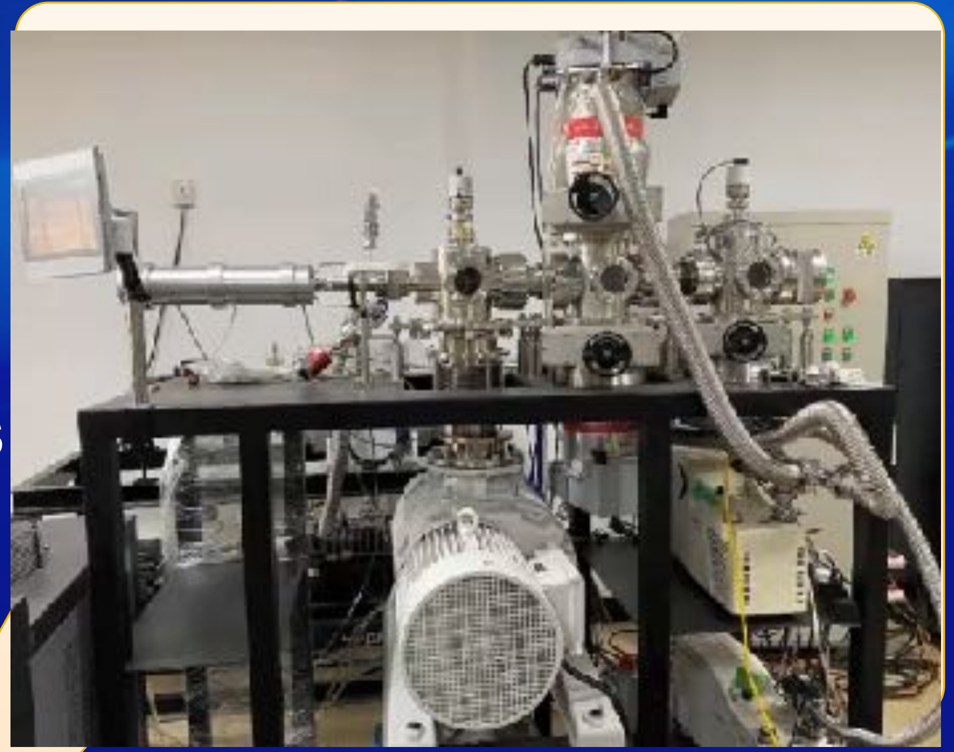
Reaction	Quantities	Best data before	JUNA data	Publication
Holy grail $^{12}C(\alpha,\gamma)^{16}O$	Lowest energy/keV	891	**552**	**Feasibility by run 1**
	Cross section/b	10^{-11}	**10^{-12}**	
Neutron source $^{13}C(\alpha,n)^{16}O$	Energy range/keV	230-300	**240-1900**	**PRL 129(2022)132701**
	s-process	50%	**20%**	
^{26}Al abundance $^{25}Mg(p,\gamma)^{26}Al$	Uncertainty	21%	**8%**	**Science Bulletin 67(2022)2 Cover paper**
F abundance $^{19}F(p,\alpha\gamma)^{16}O$	Lowest energy/keV	189	**72**	**PRL 127(2021)152702 Editor suggestion**
	Uncertainty	80%	**5%**	
Ne isotope ratio $^{18}O(\alpha,\gamma)^{22}Ne$	Uncertainty	472±18 keV	**474.1±1.1 keV**	**PRL 130(2023)092701**
CNO breakout $^{19}F(p,\gamma)^{20}Ne$	Lowest energy/keV	300	**200**	**Nature 610(2022)656 News and views**

Ready for JUNA Run-2

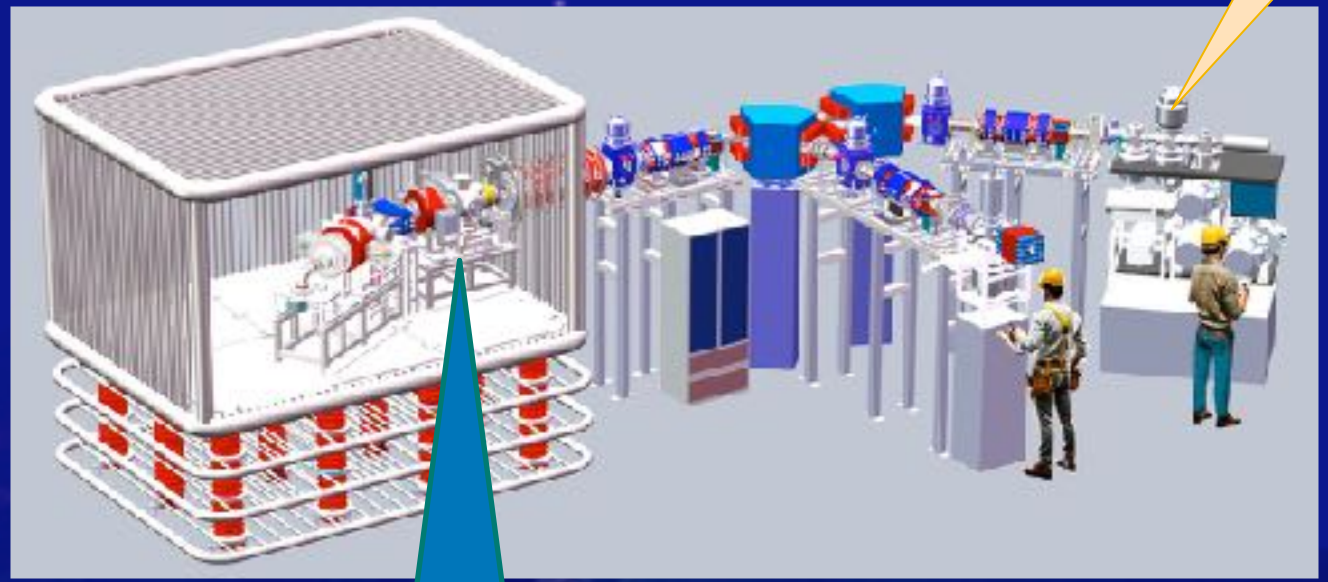
- CJPL IAC highly recommend JUNA and gave green lights for next 5 years and support JUNA using A1 space

- High density radiation hard target and gas target, higher efficiency neutron and gamma detectors

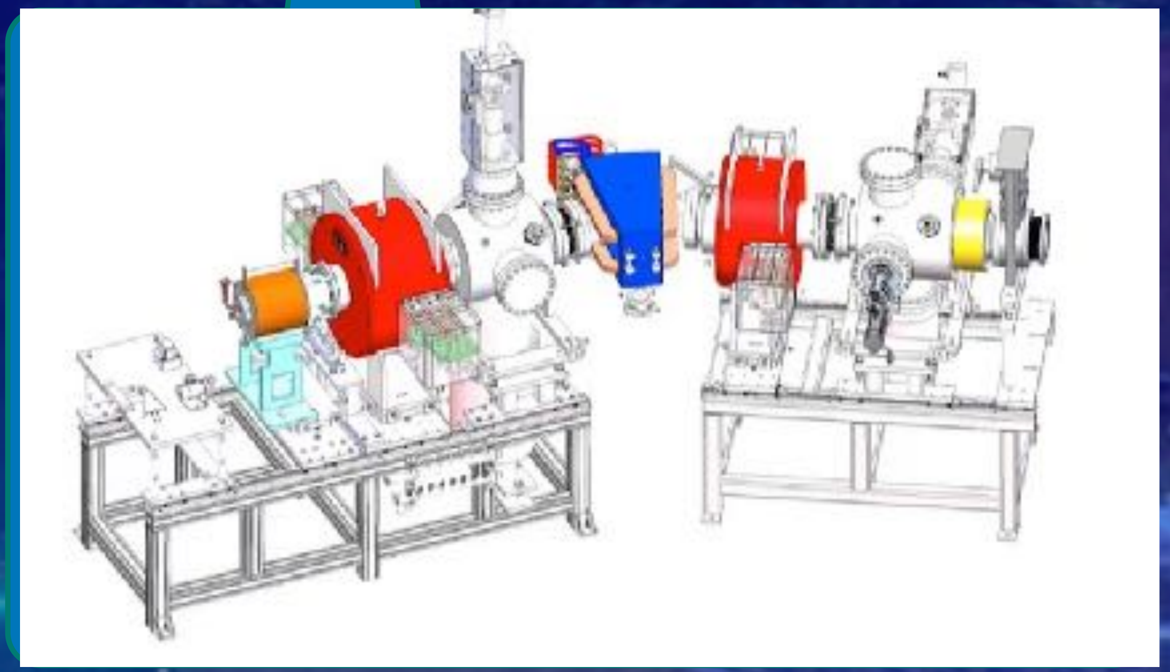
- Run 2 proposal evaluated and approved from July 2025 to February 2026



Gas jet target



New beam line for JUNA Run-2



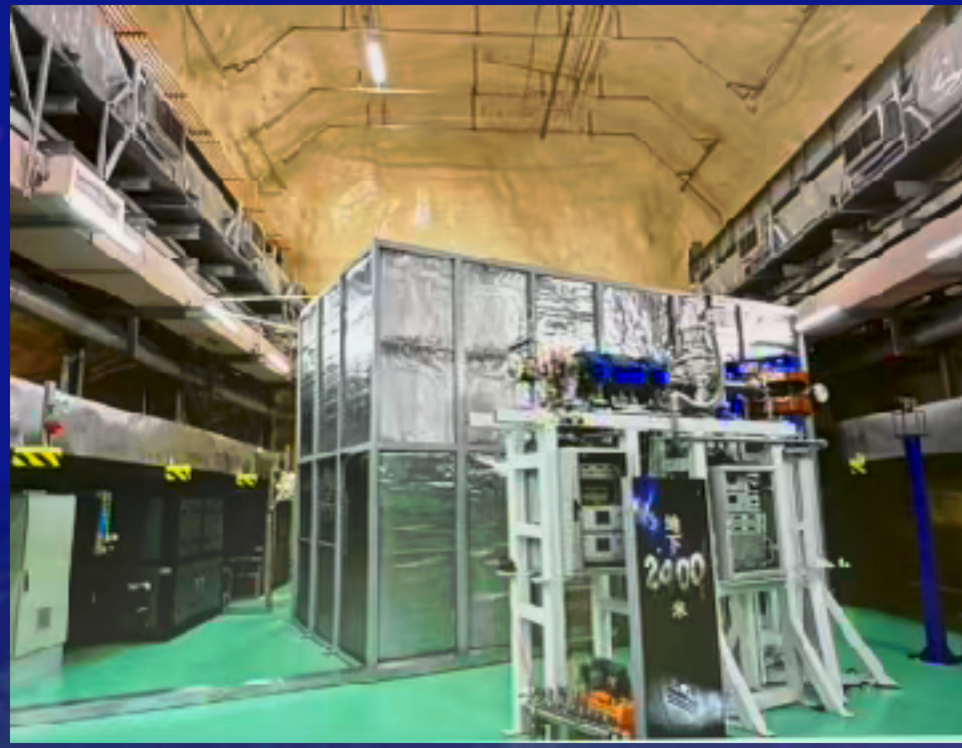
Improved ion source

Run-2 kickoff meeting April 24, 2024

Run-2 plan approved May 15, 2025

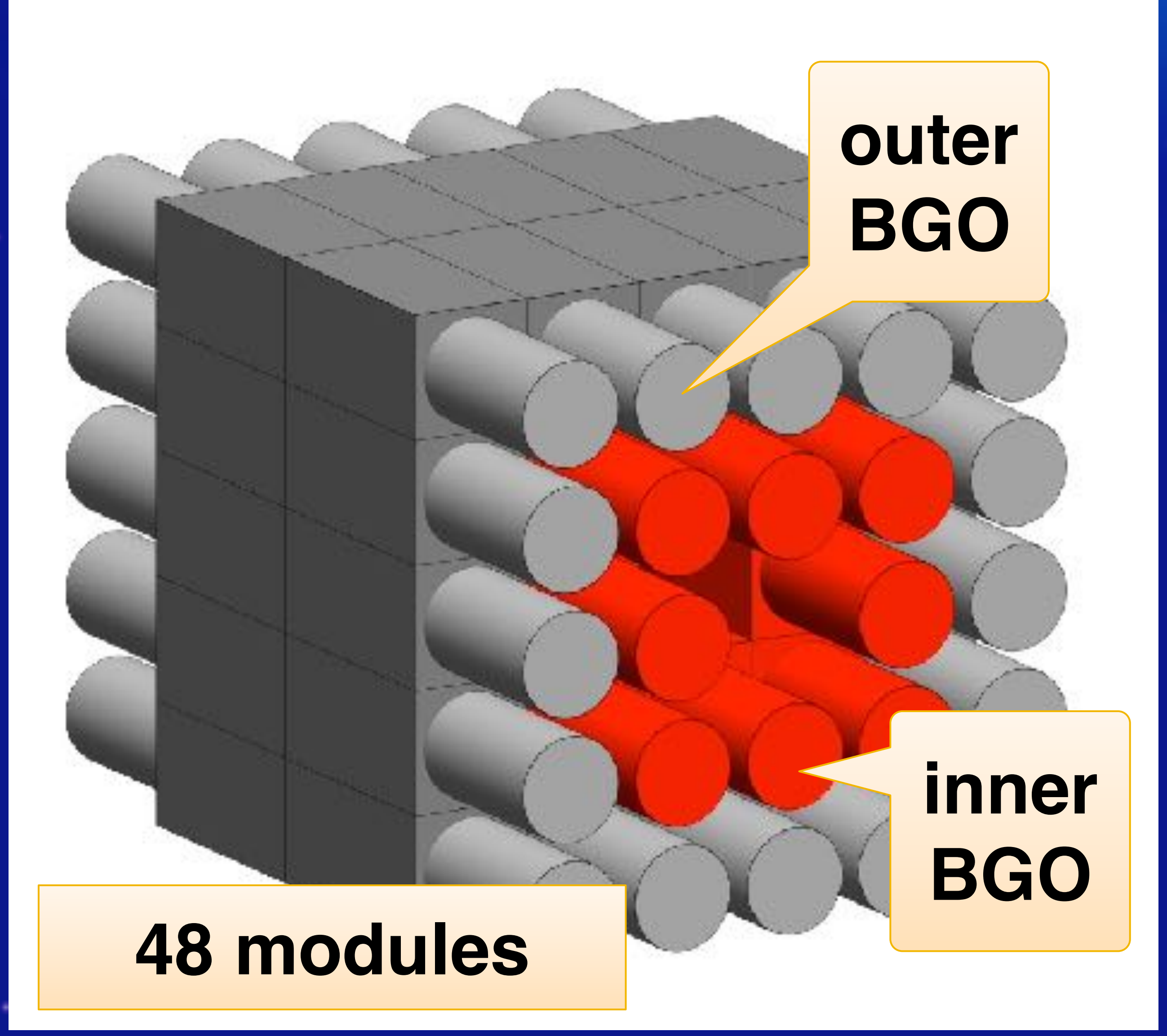
Sept., 2024, OMEG, CJPL-II A1 ready

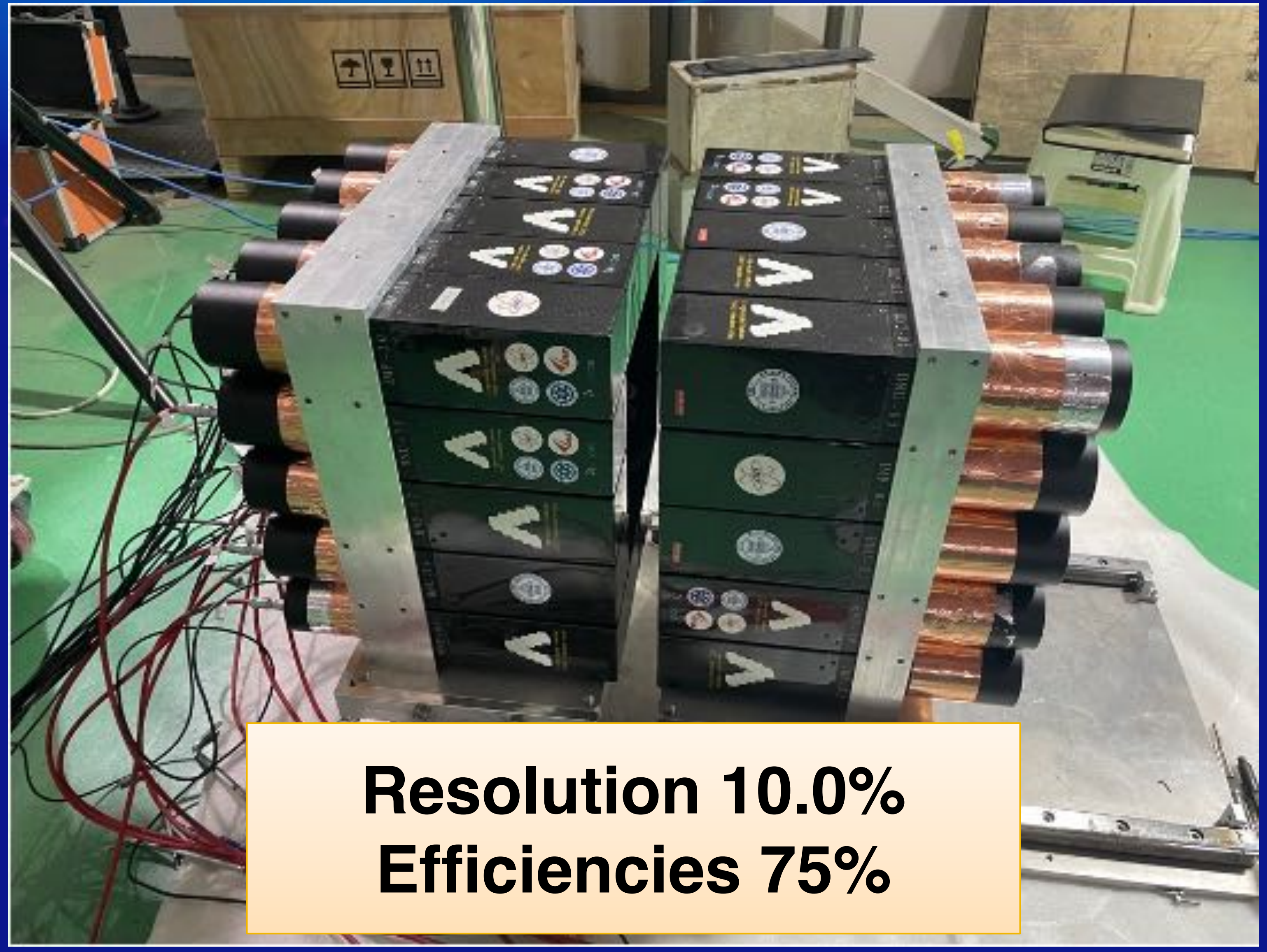
October, 2024 Accelerator in A1



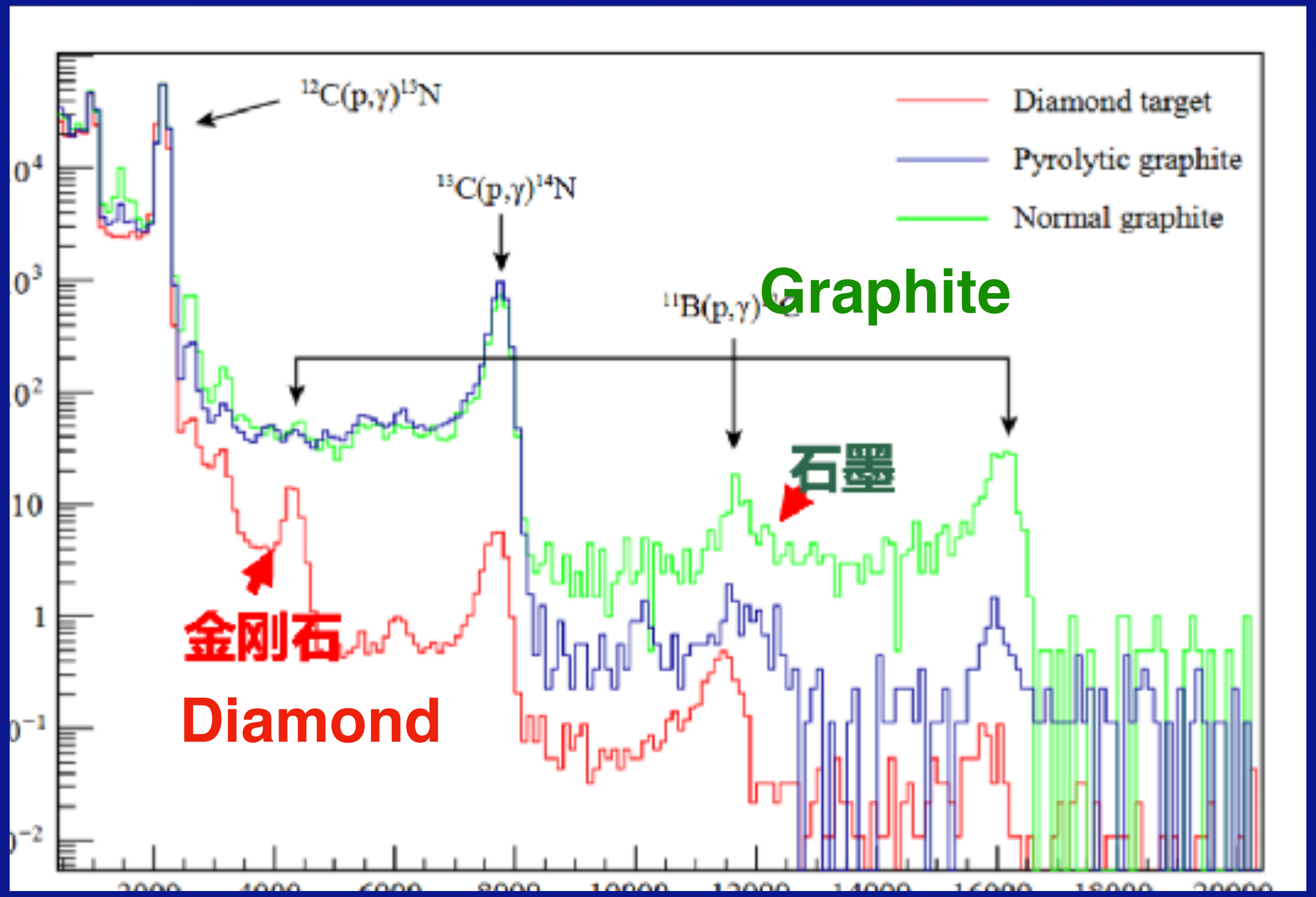
May, 2025 Accelerator ready for beam

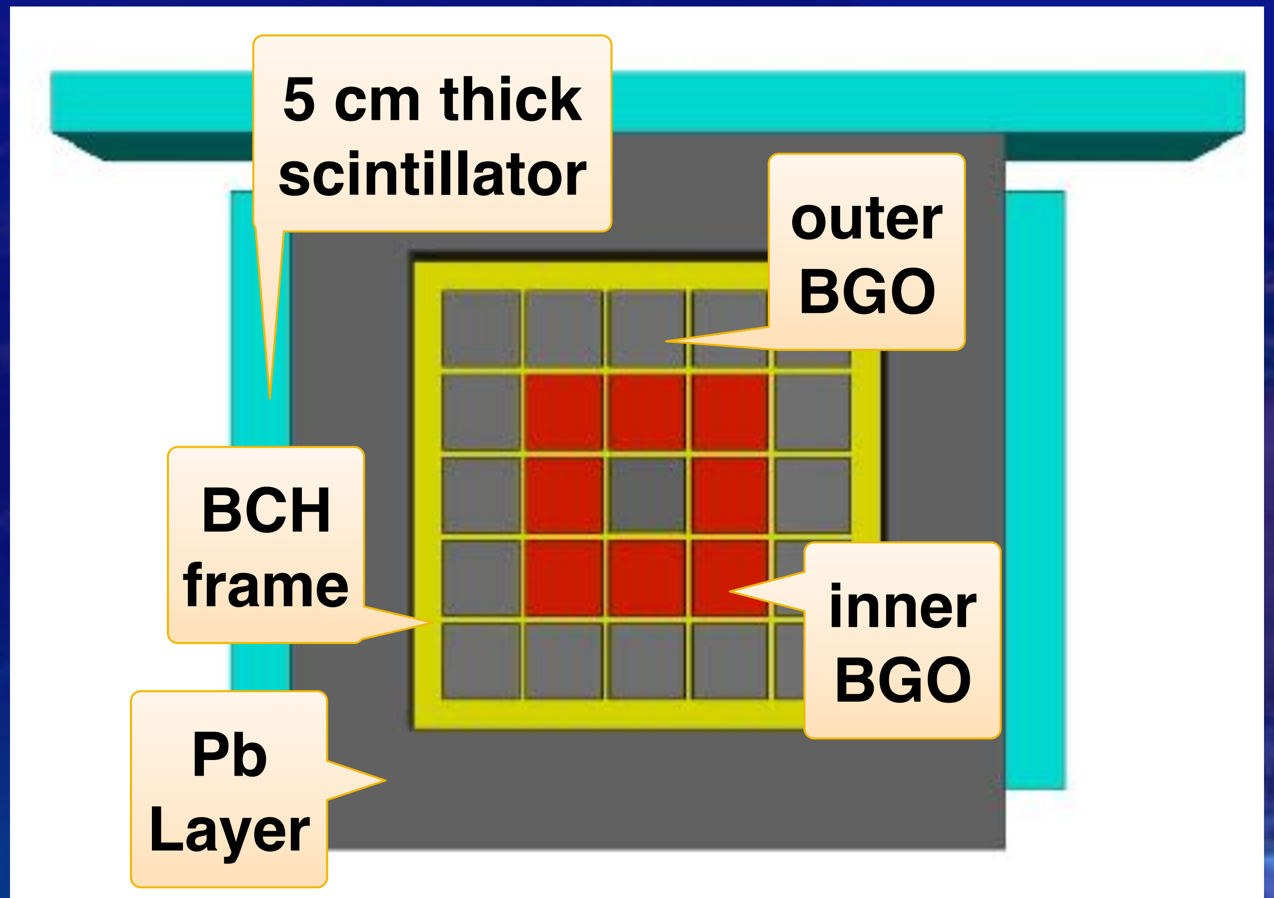
LAMDA-II array and diamond target test

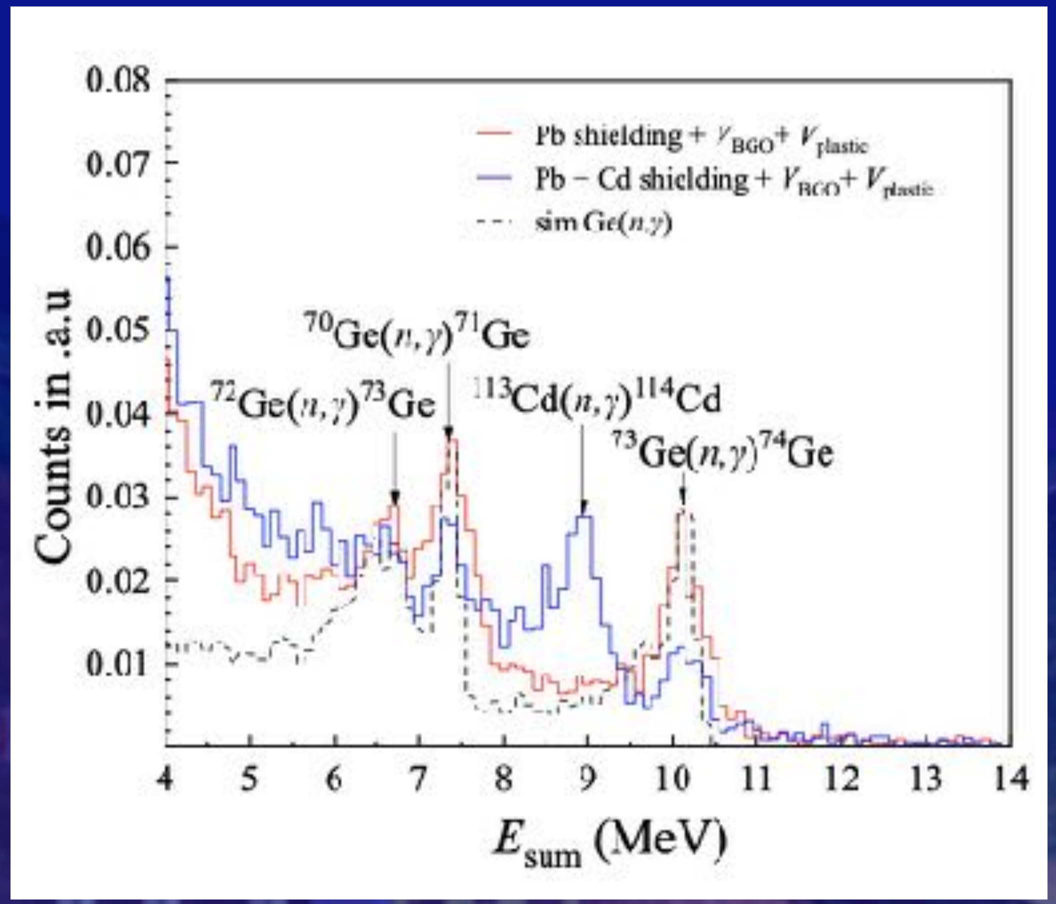


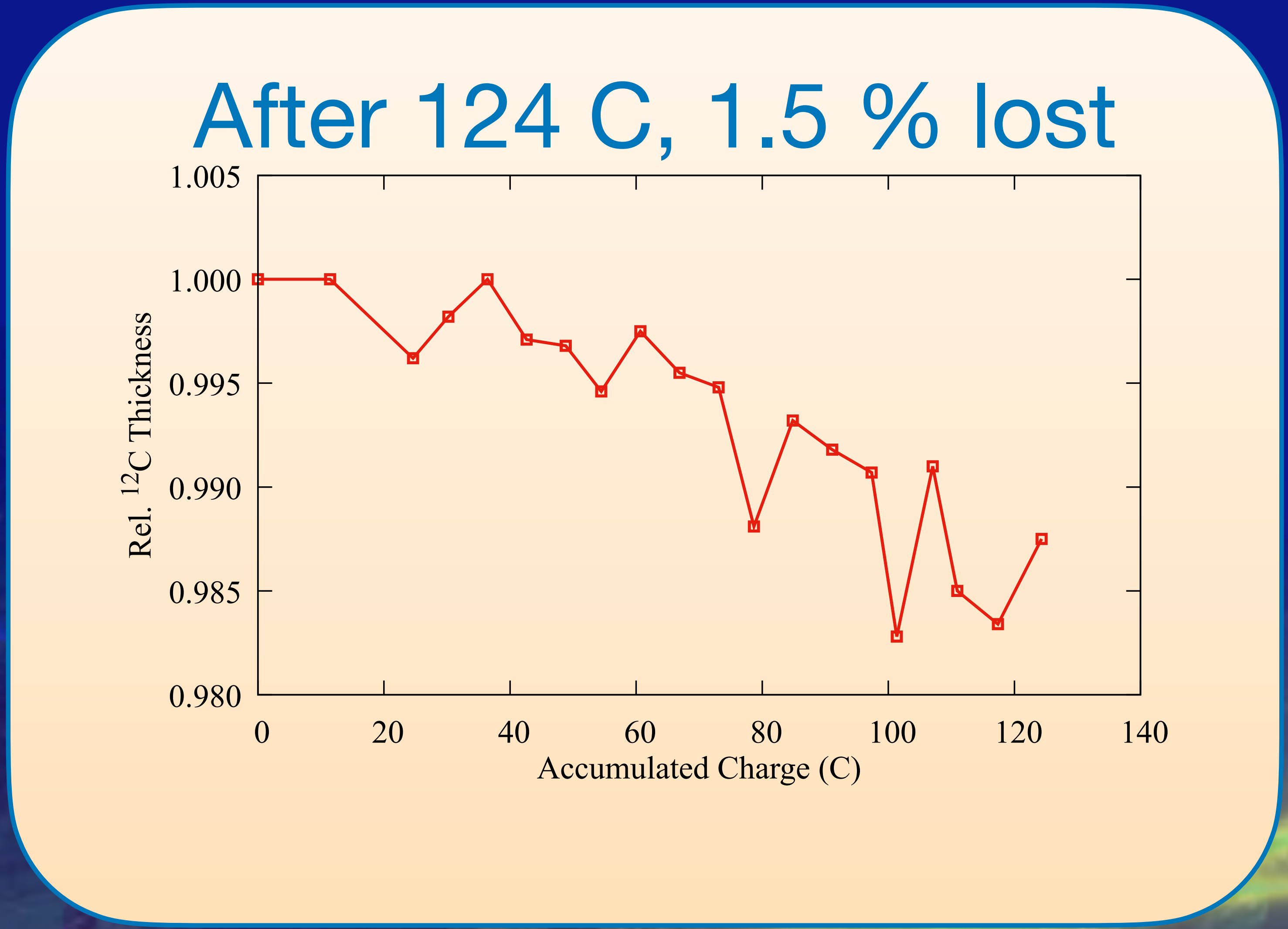


BKG: 2-10 X than Graphite







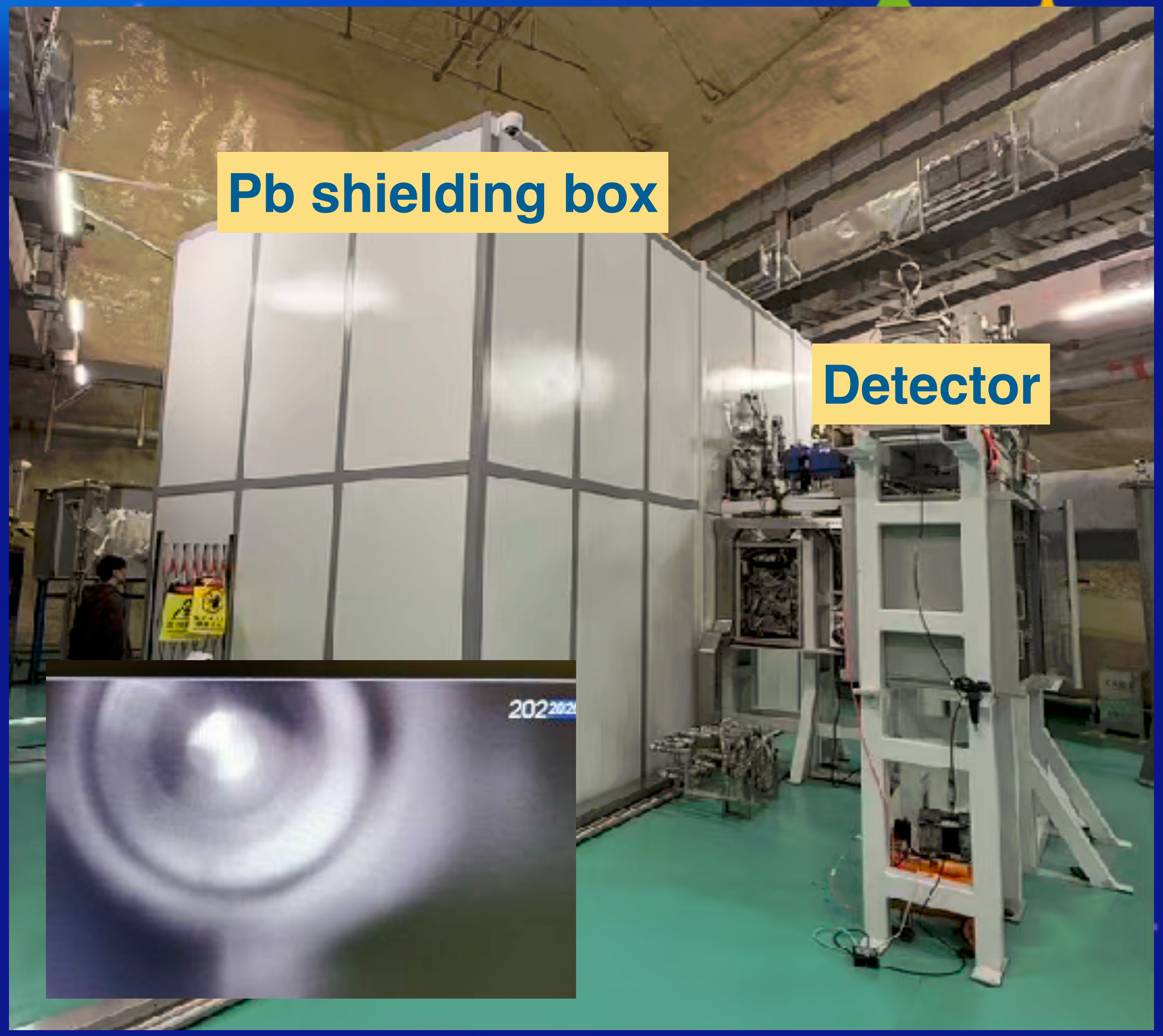


NST 0887 (2024)

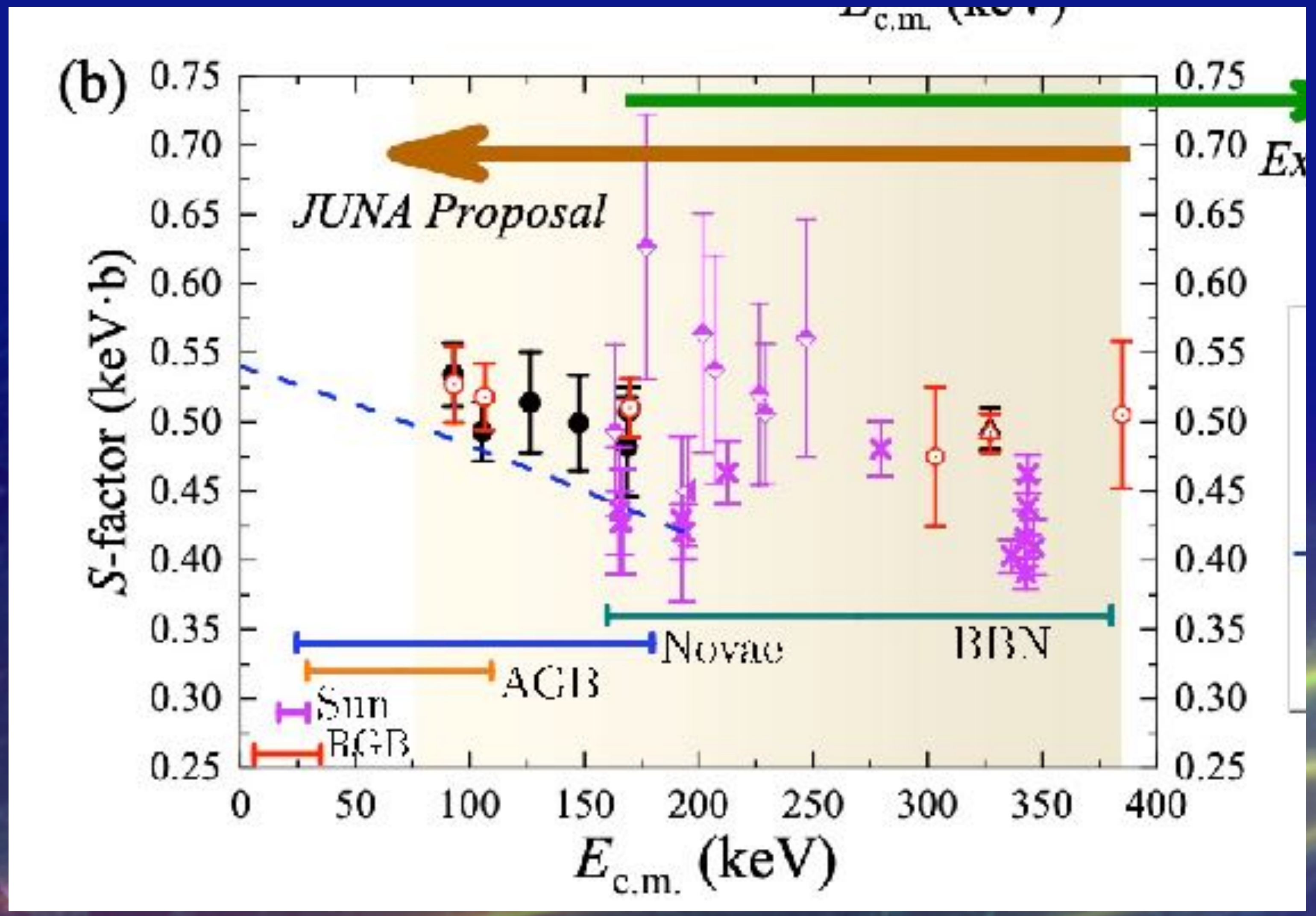
NIMB 565, 16542 (2025)

JUNA Run-2 Exp.: 2025-2027

- **From Run-1 to lower energy**
  - $^{12}C(\alpha,\gamma)^{16}O$, **confidence from 1$\sigma$ to 3σ**
  - $^{13}C(\alpha,n)^{16}O$, **full coverage of s-process**
  - $^{19}F(p,\gamma)^{20}Ne$, **cover 80-150 keV with high precision**
  - $^{14}N(p,\gamma)^{15}O$, **Solar neutrino**
- **Using gas target**
  - $^{22}Ne(\alpha,n)^{25}Mg$, **weak s-process n source**
  - $^{3}He(\alpha,\gamma)^{7}Be$, **solar metallicity, Li abundance, 80-380 keV**

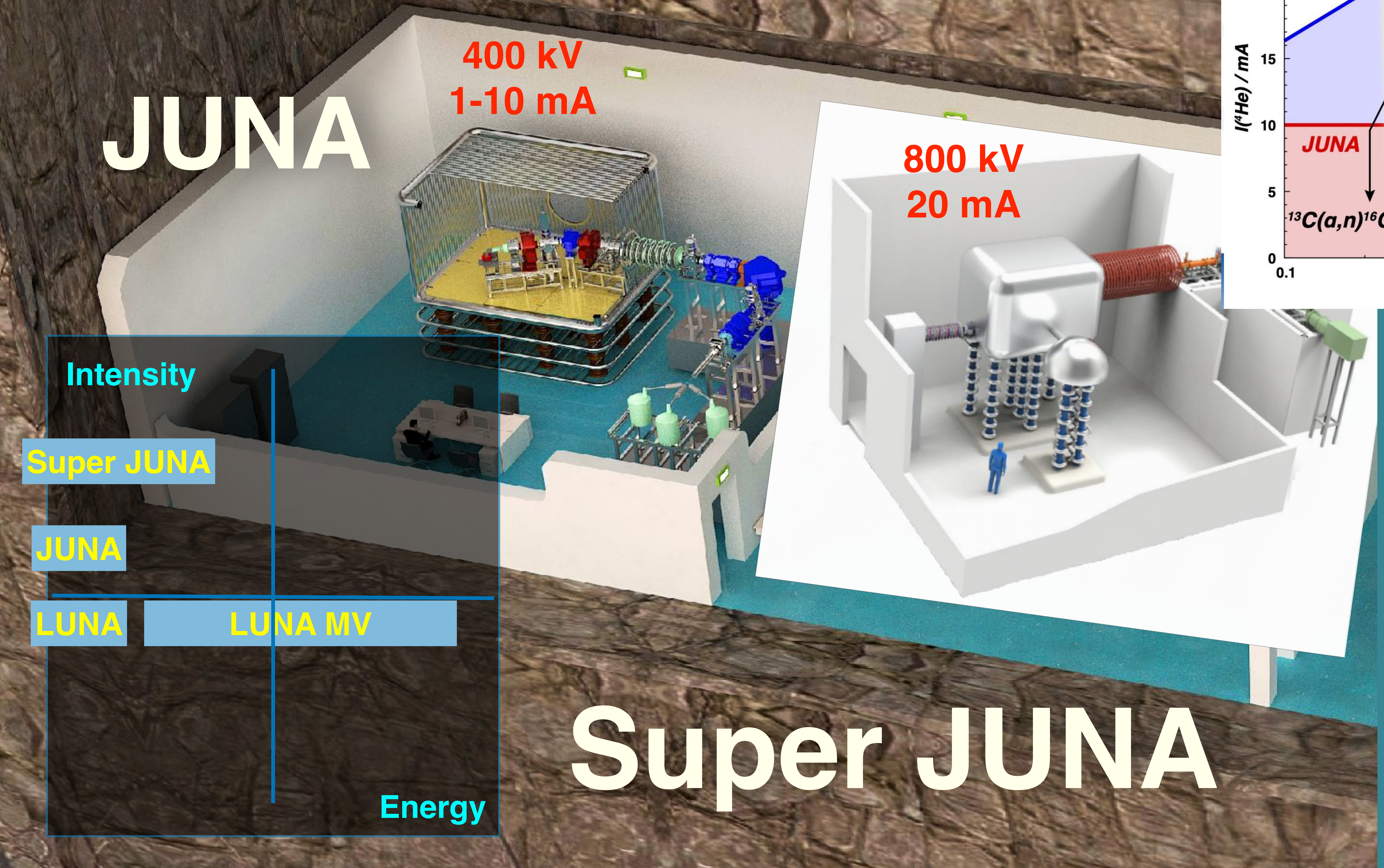


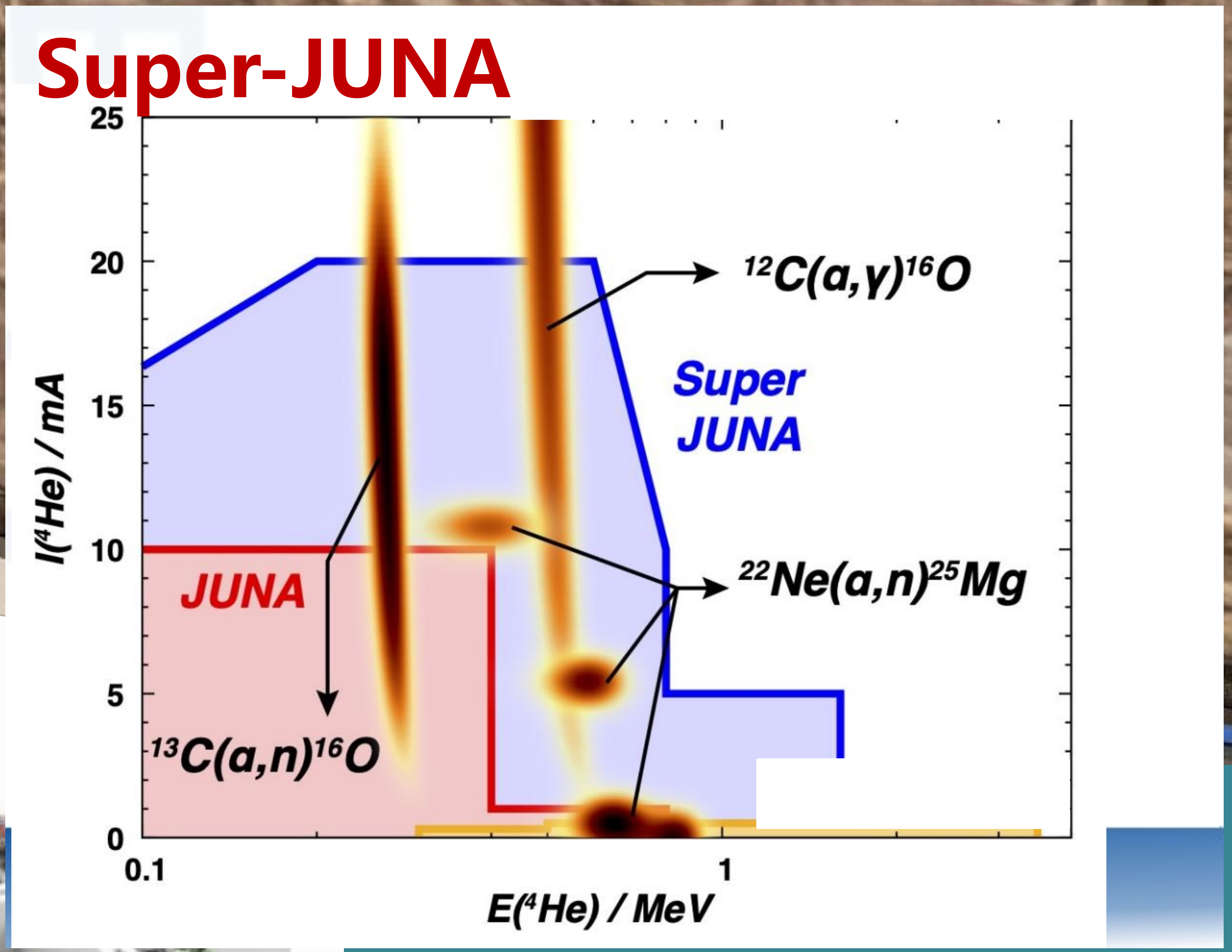
Run-2 is coming! May 22, 2025, 2 mA 230 keV He^{1+} beam!



锦屏深地核天体物理实验

Jinping Underground Nuclear Astrophysics Experiment





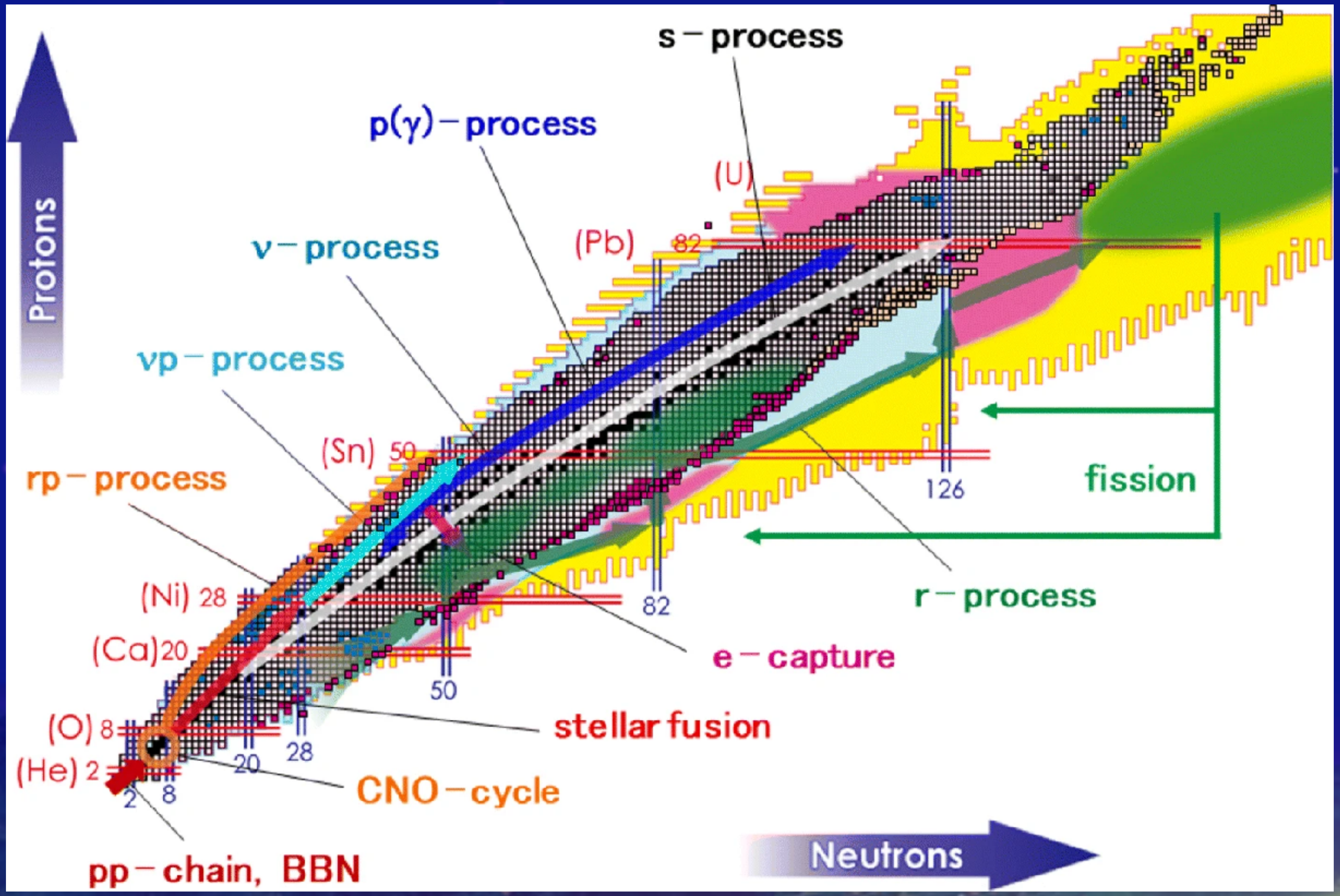
- Double beam time
- More close to Gamow window
- Connect to higher energy range

Future study of nuclear astrophysics

- **Underground, LUNA, CASPAR, JUNA,…**
- **Explosive process, RIBLL, RIBF, FRIB, TRIUMF, BRIF,…**
- **Mass, ESR, CSR, RI-Ring,…**
- **Decay, RIBF, RIBLL, BRIF, ISOLDE,…**
- **Neutron capture, CERN n-tof, CSNS, ….**
- **Novel approach, SLEGES, ELI-NP, Laser facilities,…**
- **Theory, simulation, …**
- **Space based, gamma observatory,…**

Future: FRIB, RAON, FAIR, HIAF, ELI-NP, BISOL, Super JUNA…, will open up new opportunities!

Progress in nuclear astrophysics of east and southeast Asia…Toshitaka Kajino*, …, WPL*, …, Xiaodong Tang*,… et al., AAPPSBulletin (2021) 31:18



Take home message from JUNA

- **Nuclear astrophysics is a frontier in nuclear physics and rapid developing in China, thank to to the progress of BRIF and HIRFL, and JUNA from 2020, for reaction, mass and decay**

- **JUNA started online reactions from Jan. 2021 by Run 1, with mA p and He beams with 400 kV open platform with keV precision, BGO and ^{3}He array, 100 C duration target**

- **With JUNA Run 1, $^{25}Mg(p,\gamma)^{26}Al$ reached high precision, $^{12}C(\alpha,\gamma)^{16}O$ showed feasibility, 225 keV resonance in $^{19}F(p,\gamma)^{20}Ne$ explained Ca abundance of oldest star, and discrepancies of neutron source $^{13}C(\alpha,n)^{16}O$ resolved**

- **JUNA reinstalled in new A1 hall CJPL Spet. 2024 with He beam May 2025, Run-2 will start by July 2025, with experimental plan approved, eg., $^{12}C(\alpha,\gamma)^{16}O$**

- **From 2026, we will open proposals by Run 3 for international users with support from NSFC, please join us in CJPL, and also lots of job opportunities in Chinese universities !**

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Ref. J. Chen SUSTech