



北京航空航天大学
BEIHANG UNIVERSITY

RIB facilities in China

Bao-Hua SUN

bhsun@buaa.edu.cn

Beihang University, Beijing



核科学与技术研究中心
Research Center for Nuclear Science and Technology

(Low energy) Nuclear physics

第十五届全国核结构大会合影

2014.10.25 广西师范大学

national nuclear reaction conference (2013) @ Shenzhen

national nuclear structure conference (2014) @ Guilin

national nuclear physics conference (2013) @ Shanghai



2015 Nuclear reaction conference

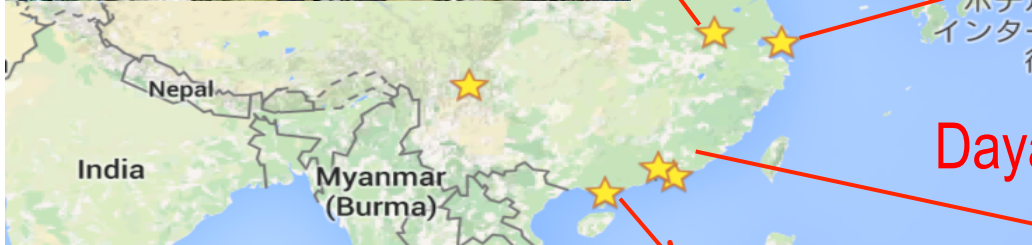
2015年全国核反应会议暨核物理973项目年会

中国 贵阳 2015年7月25日-29日



~ several tens Univ. (theo.)
~ 10 Univ. (exp.)

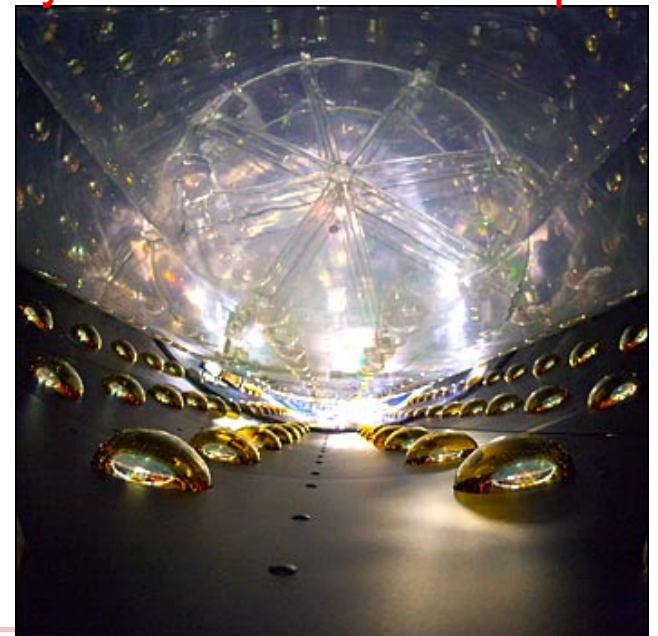
Nuclear physics related facilities: applications



Shanghai Synchrotron Radiation Facility



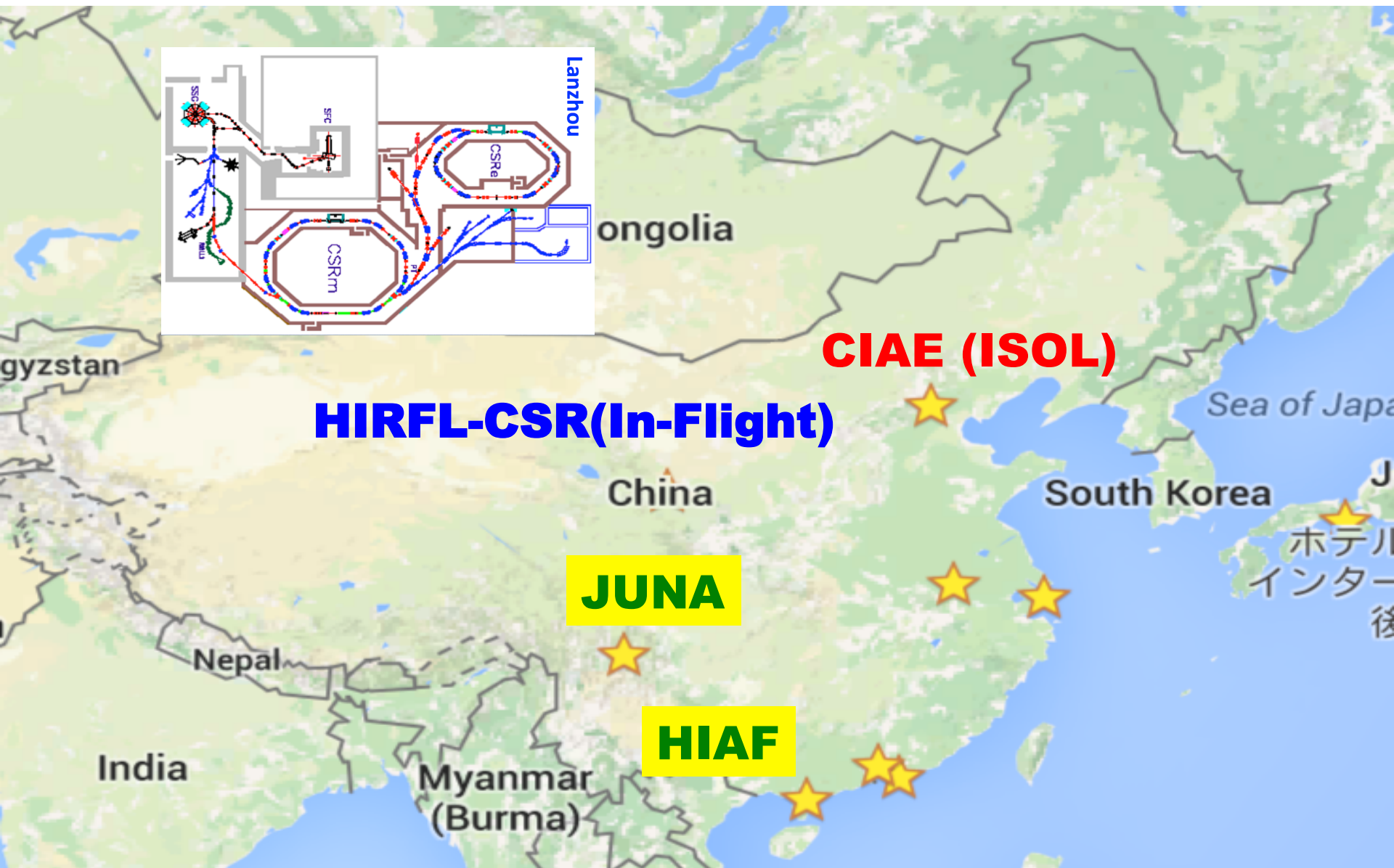
Daya Bay Reactor Neutrino Experiment



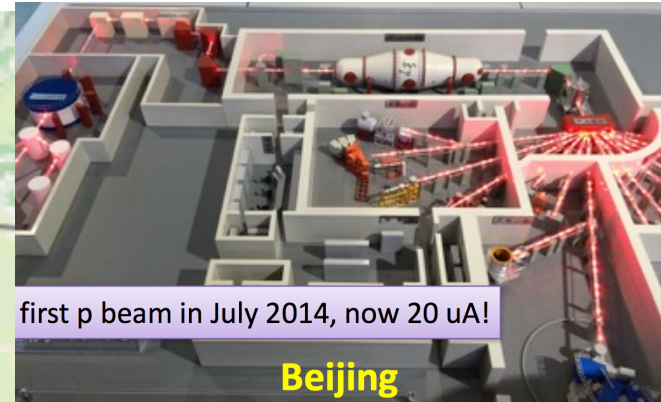
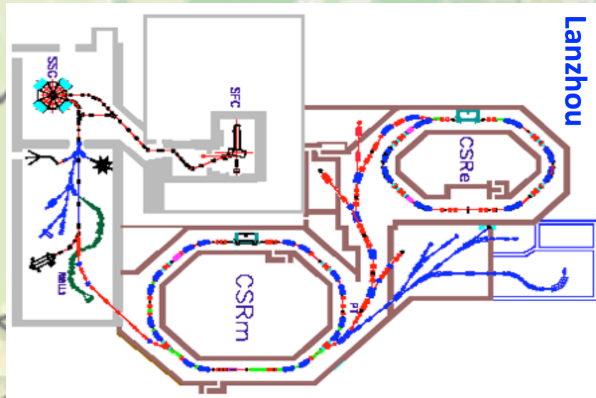
China Spallation Neutron Source (2016)



RIB facilities



RIB facilities



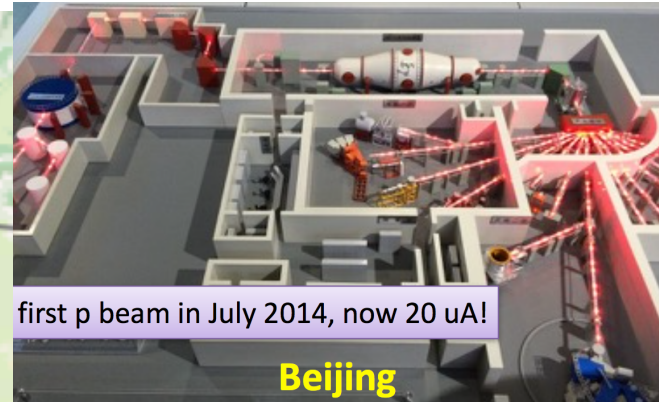
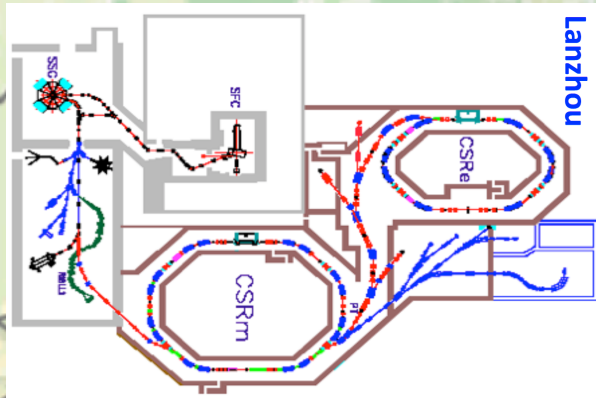
HIRFL-CSR(In-Flight)

CIAE (ISOL)

JUNA

HIAF

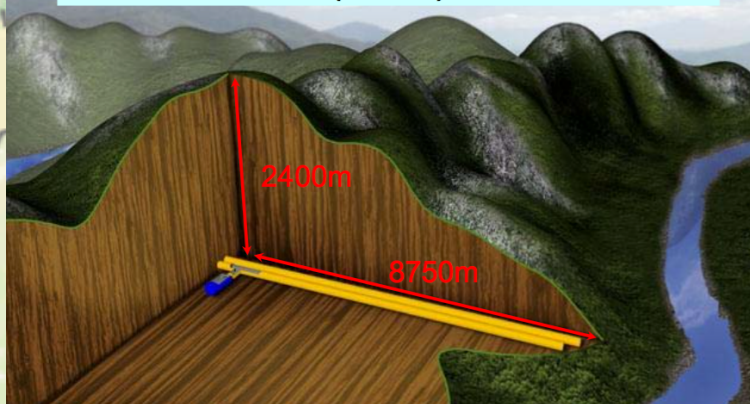
RIB facilities



HIRFL-CSR(In-Flight)

CIAE (ISOL)

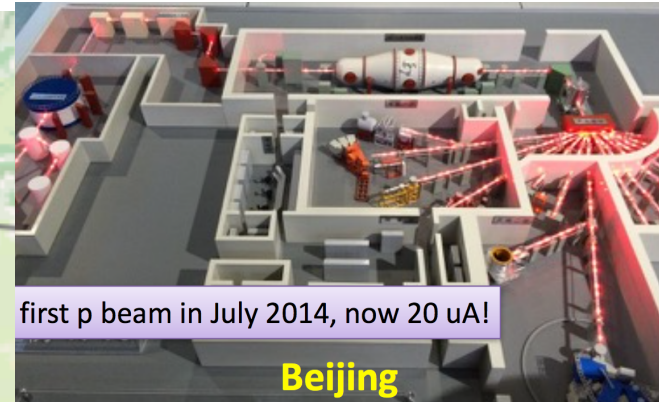
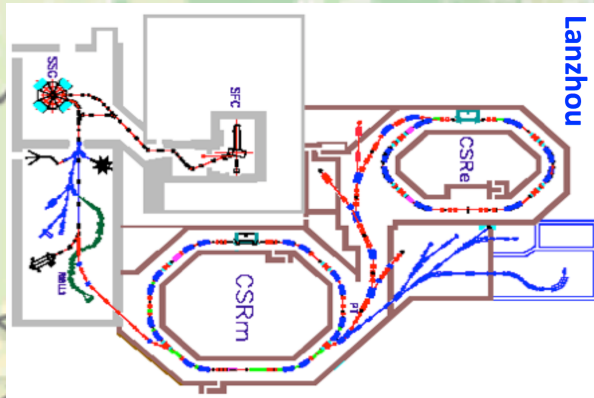
China JinPing Underground Laboratoy (CJPL)



JUNA

HIAF

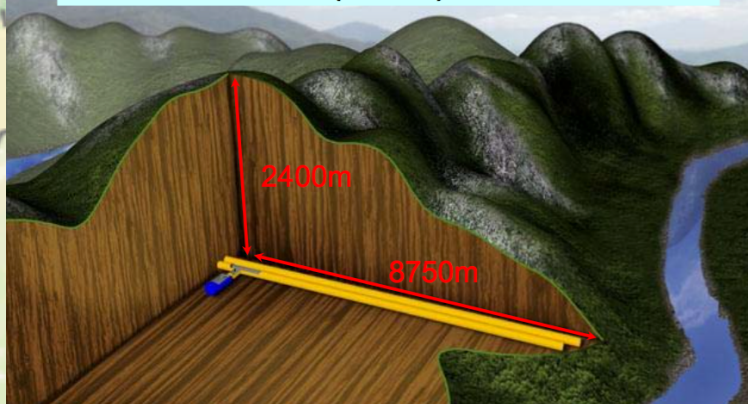
RIB facilities



CIAE (ISOL)

HIRFL-CSR(In-Flight)

China JinPing Underground Laboratoy (CJPL)



JUNA

HIAF



- | | | |
|-------------------|---------------------------------|-----------------------|
| ① Nucl. Structure | ④ Exp. Storage Ring | ⑦ e- nucleus colider |
| ② Irridiation | ⑤ External target terminal | ⑧ H.E irradiation |
| ③ Ribl | ⑥ e- lon resonance spectrometer | ⑨ High energy density |

Heavy Ion Research Facility in Lanzhou

HIRFL(1997) → HIRFL+CSR(2008)

SSC (K=450)

100 AMeV (H.I.), 110 MeV (p)

Operated in 1988

SFC (K=69)

10 AMeV (H.I.), 17~35 MeV (p)

Operated in 1963

RIBLL1

RIBs at tens of AMeV

Operated in 1997

CSRe

(2008)

RIBLL2

RIBs at hundreds of AMeV

CSR(Cooling Storage Ring)

1000 AMeV (H.I.), ≤ 2.8 GeV (p)

Circumference: 160 m

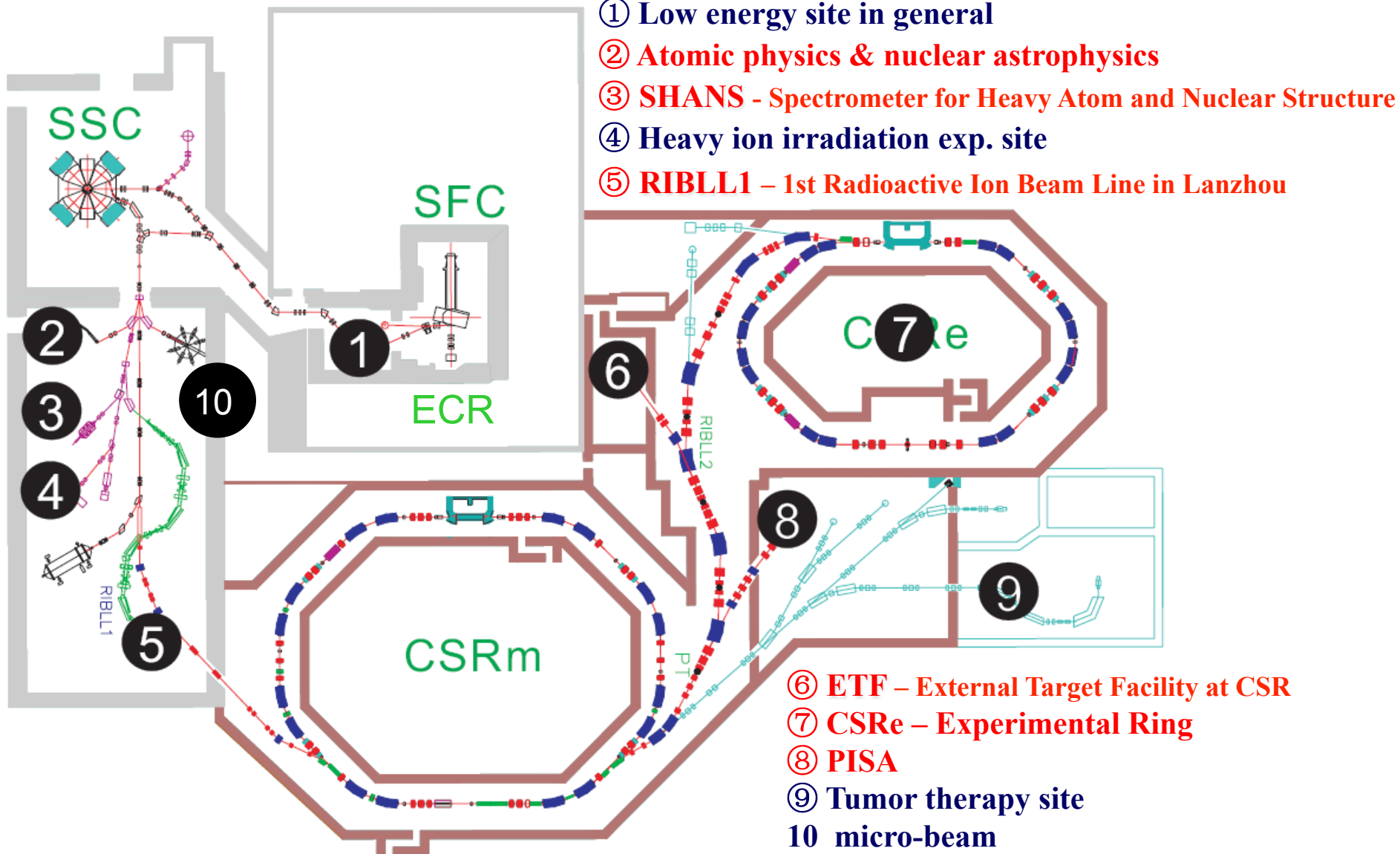
Operated in 2005

Clinical trial for Skin-tumor therapy started in 2006

Clinical trial for deep-seated tumor therapy started in 2009

HIRFL-CSR

~25 new isotopes discovered



Experiments @ RIBLL1

研究手段:

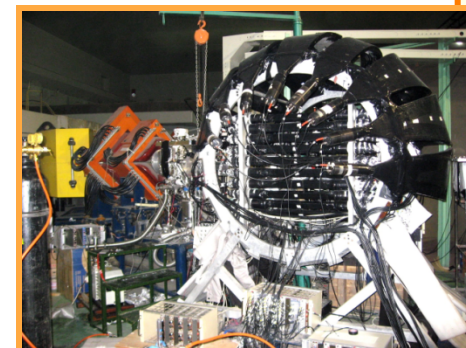
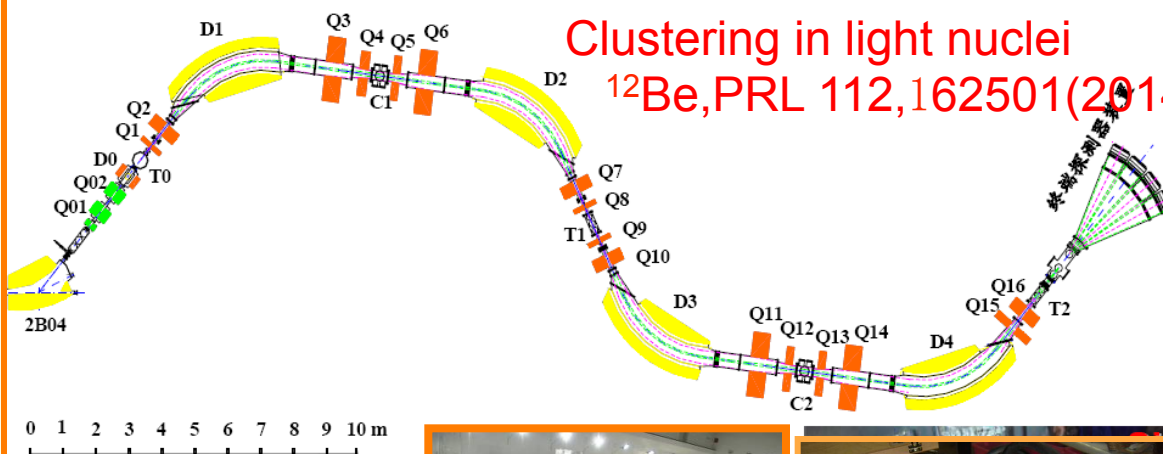
- **反应手段:** 总反应截面测量、动量分布测量、弹性散射测量、敲出反应、“丢失质量”方法、核子-核子关联函数方法等
- **谱学手段:** β -延迟中子、 β -质子发射、直接质子发射、 γ 谱学等

探测器系统

Clover det. for γ detection

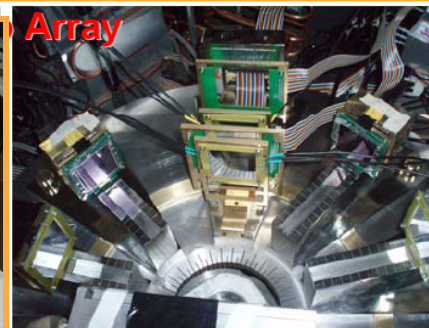
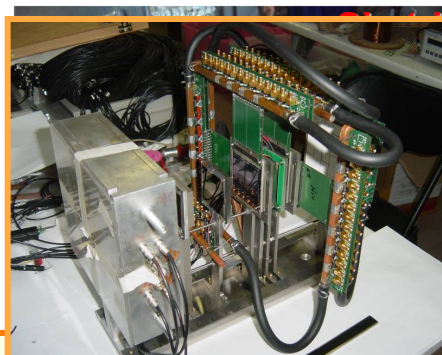


Clustering in light nuclei
 ^{12}Be , PRL 112, 162501 (2014)



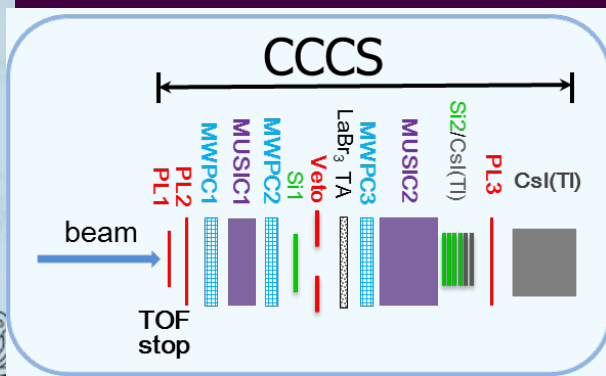
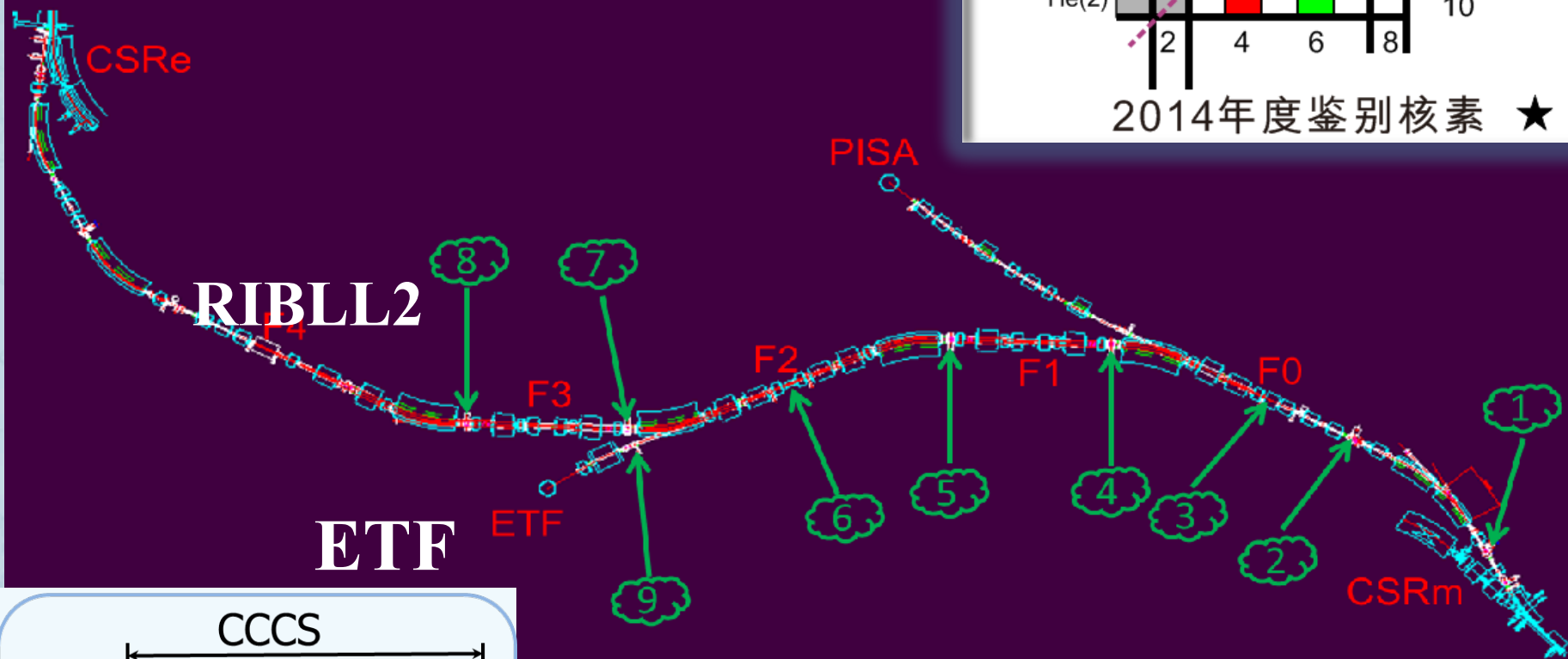
Main Parameters

$\Delta\Omega$	$>7\text{msr}$
$\Delta P/P$	$\sim 10\%$
$B\rho_{\text{max}}$	$\sim 4.2\text{Tm}$
$A/\Delta A$	~ 300

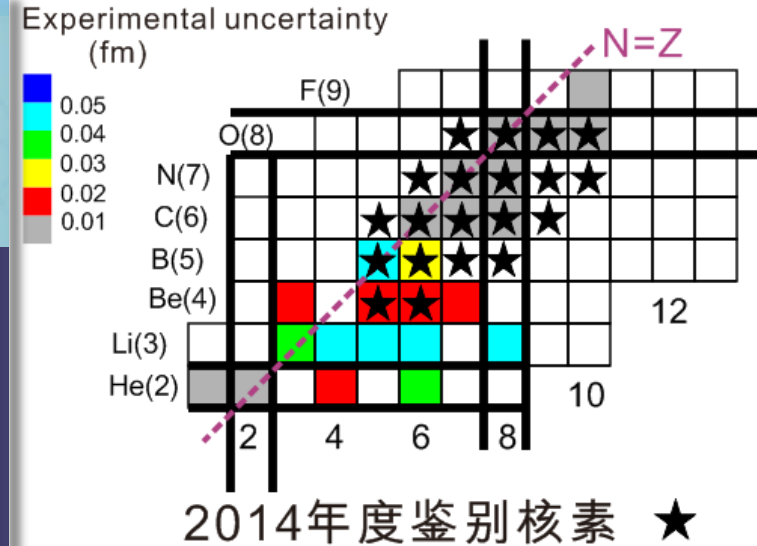


RIBLL2 + ETF

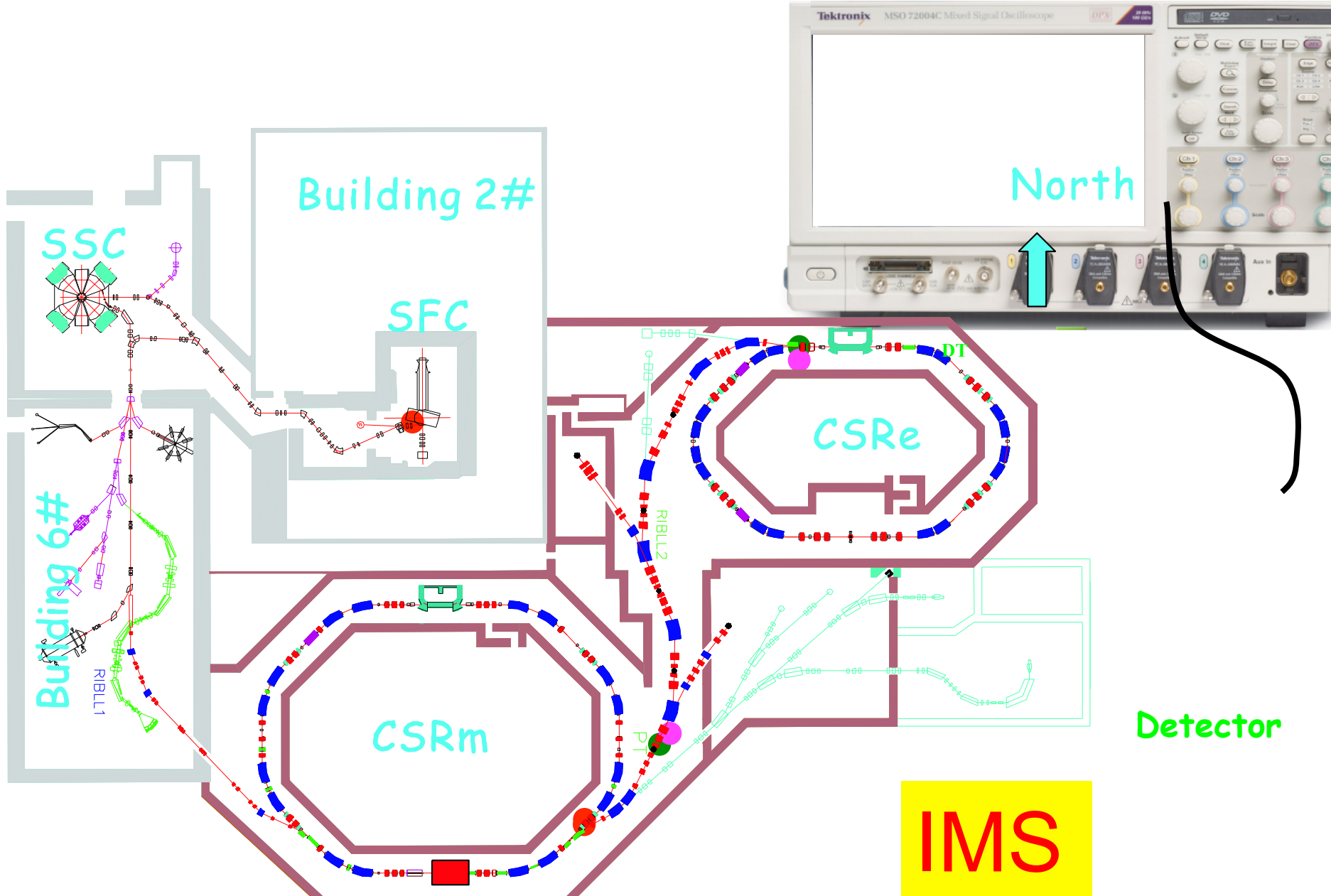
共9套探测器



Charge-changing cross section (Jan. 2015)



Mass measurement at CSRe



Mass measurement results at CSRe-Lanzhou

1. B. Mei et al., NIM A 624, 109 (2010)
2. X. L. Tu et al., PRL 106, 112501 (2011)
3. X. L. Tu et al., NIM A 654, 213 (2011)
4. Y. H. Zhang et al., PRL 109, 102501 (2012)
5. X. L. Yan et al. Astrophys. J. Lett. 766, L8 (2013)
6. H. S. Xu et al., IJMS 349, 162 (2013)
7. X. L. Tu et al., J. Phys. G41, 025104 (2014)
8. W. Zhang et al., NIM A 756, 1 (2014)
9. B. Mei et al., Phys. Rev. C 89, 054612 (2014)
10. P. Shuai et al., Phys. Lett. B 735,327 (2014)

Beams: ^{56}Ni , ^{78}Kr , ^{86}Kr , ^{112}Sn , ^{36}Ar

Precision
 $10^{-6} \sim 10^{-7}$
(20-200 keV)

Nuclear Astrophysics:

- ^{65}As : on the waiting point nuclide ^{64}Ge ,
PRL 106, 112501 (2011)
- ^{45}Cr : on the Ca-Sc cycle in the rp-process
Astrophys. J. Lett. 766, L8 (2013)
- ^{82}Zr : on the reaction path of vp-process at $A=80-86$
in progress

Nuclear Structure:

- ^{53}Ni : on the isospin multiplet mass equation
PRL 109, 102501 (2012)
- ^{51}Co : on isospin non-conserving forces
Phys. Lett. B 735,327 (2014)
- ^{52}Co , ^{56}Cu : np interaction at $N=Z=28$ closed shell
- ^{53}Sc : on the new $N=32$ magic number
in progress

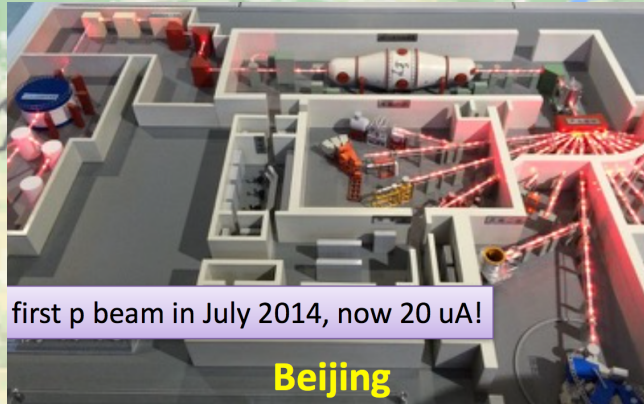
■ **Remeasured**

■ Newly measured

张玉虎

Double ToF

Nuclear physics related facilities



← **CIAE (ISOL)**

HIRFL-CSR(In-Flight)

JUNA



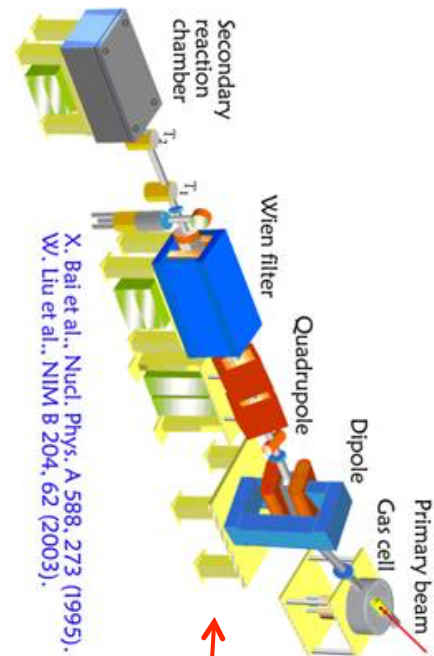
Beijing Rare Ion-beam Facility (BRIF)

100MeV proton cyclotron

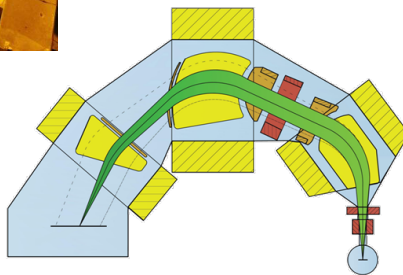
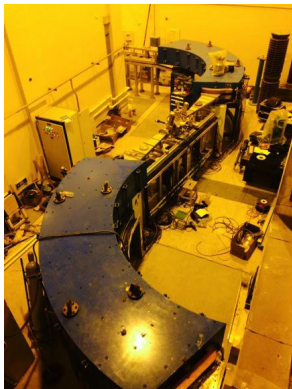
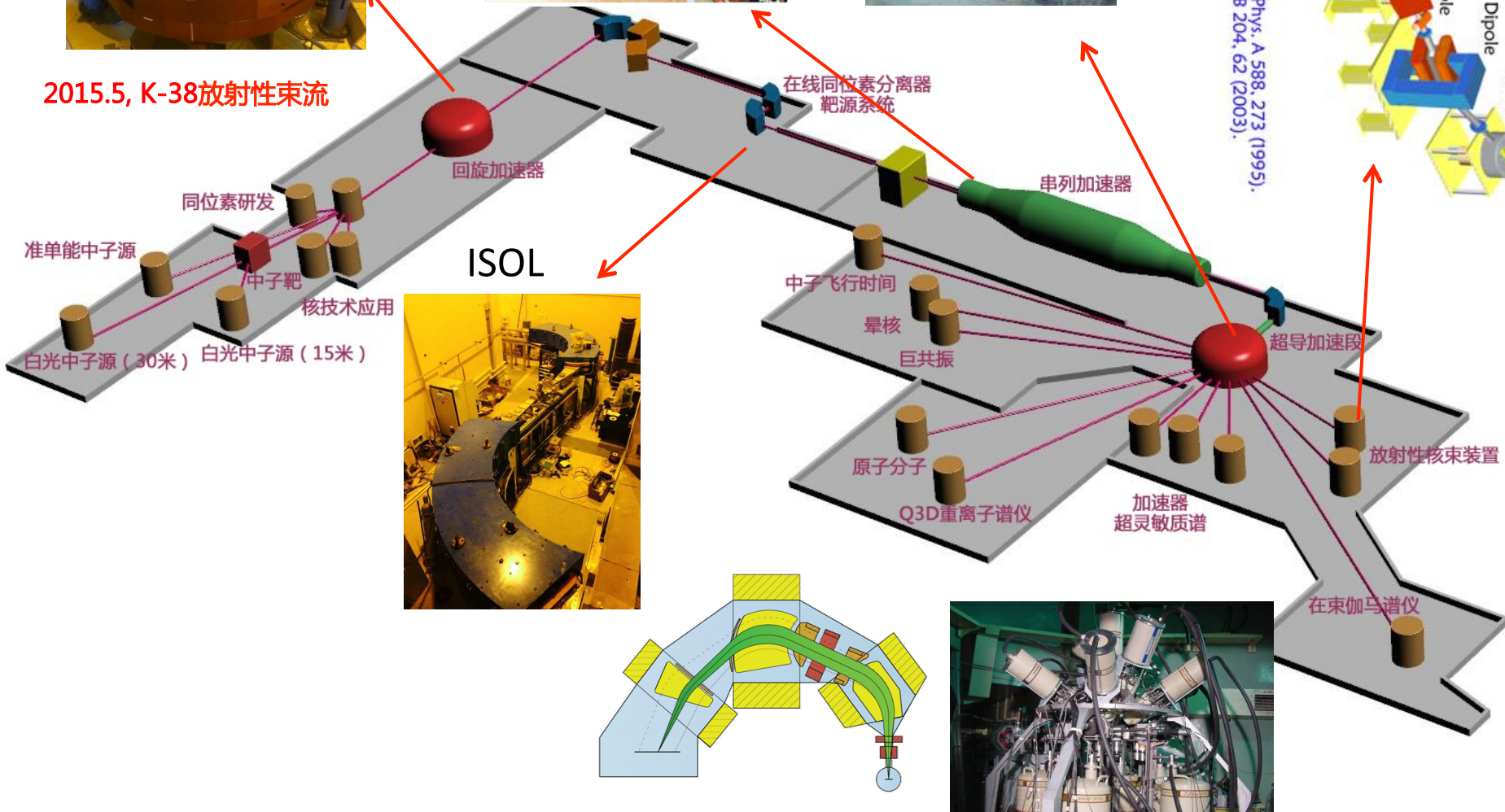


15MV tandem

Superconducting cavity



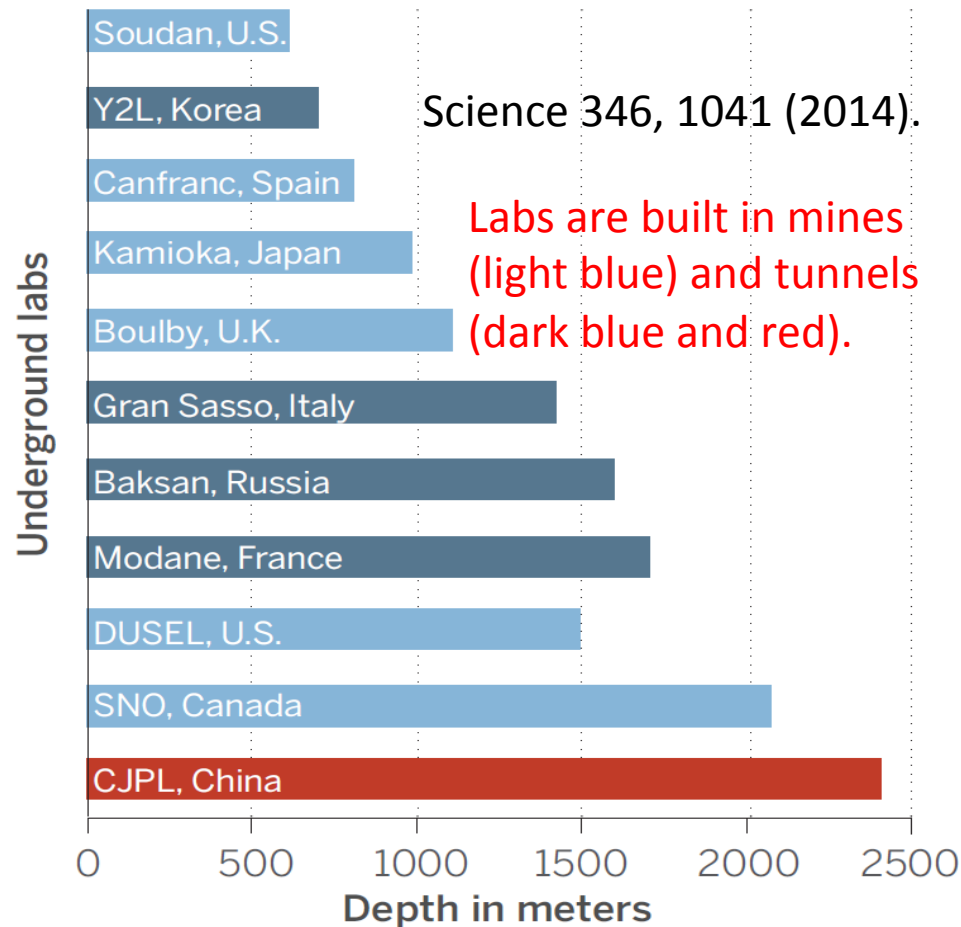
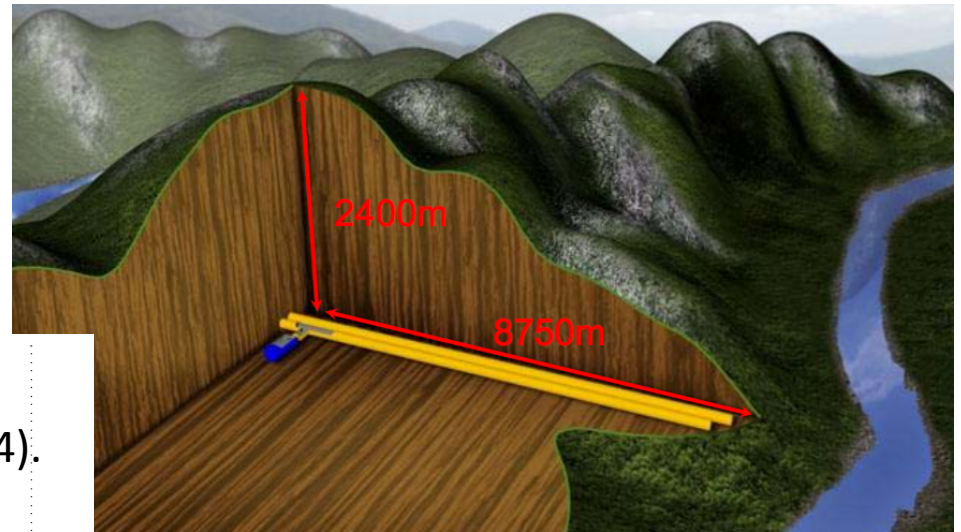
2015.5, K-38放射性束流



Nuclear physics related facilities



CJPL (China Jinping Underground Laboratory)



Dec. 12, 2010 Opening Ceremony



Dark matter searching

JUNA (Jinping Underground laboratory for Nuclear Astrophysics)

JUNA, 400kV accelerator,
2019

Detectors (Major \$1.3M)
Electronics, shielding (Major \$1.0M)
Ion source (CAS \$0.8M), accelerator (CNNC \$0.5M)
Lab CJPL II (Tsinghua, group \$0.3M, Major \$0.9M)
total \$4.8+ M

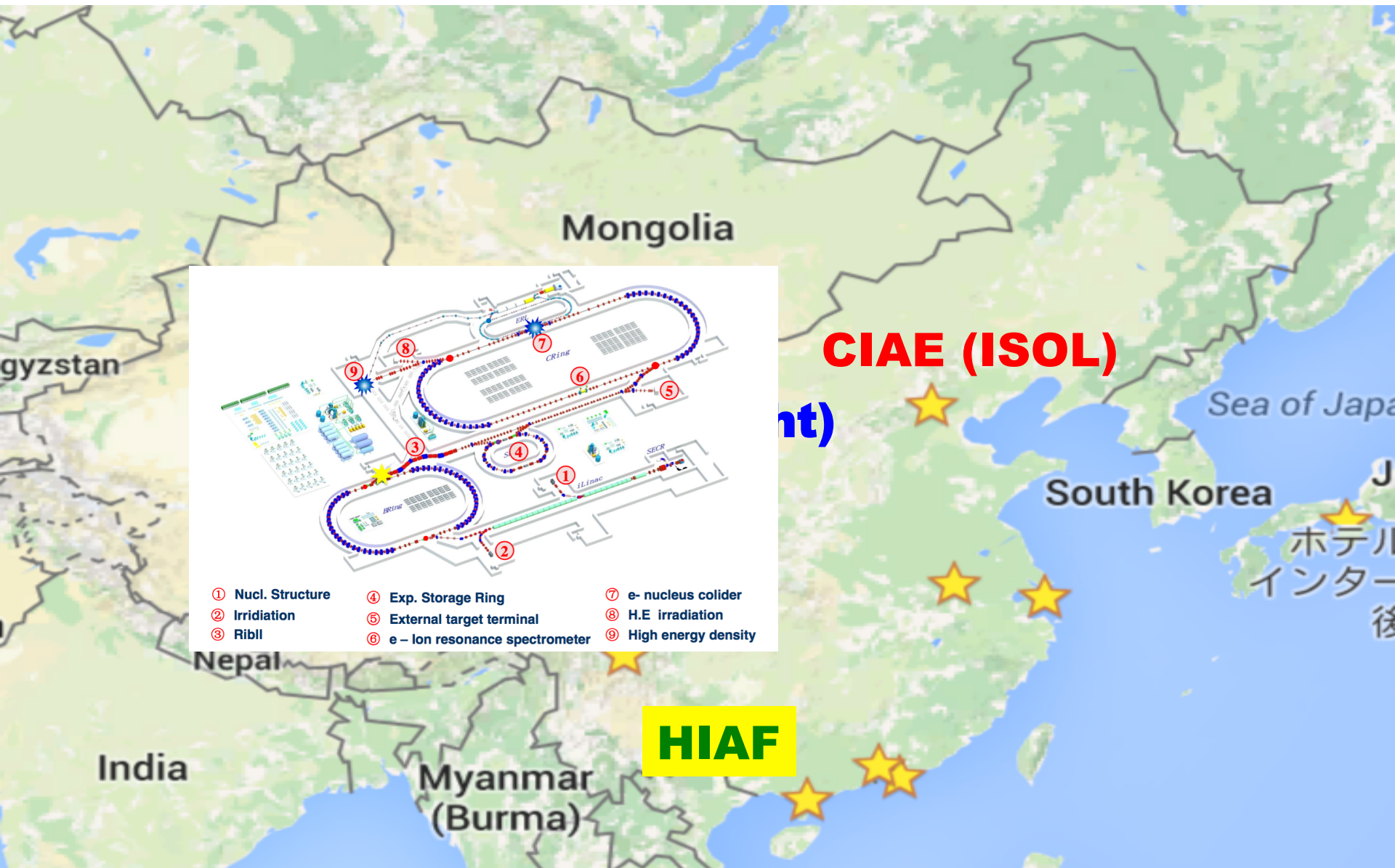
Reaction Chamber
& detectors

ECR source

JUNA-II, MV accelerator,
to be proposed

Beams		Intensity (mA)	Energy(keV)
	H ⁺	~10	50~400
	He ⁺	~10	50~400
	He ²⁺	~5	100~800

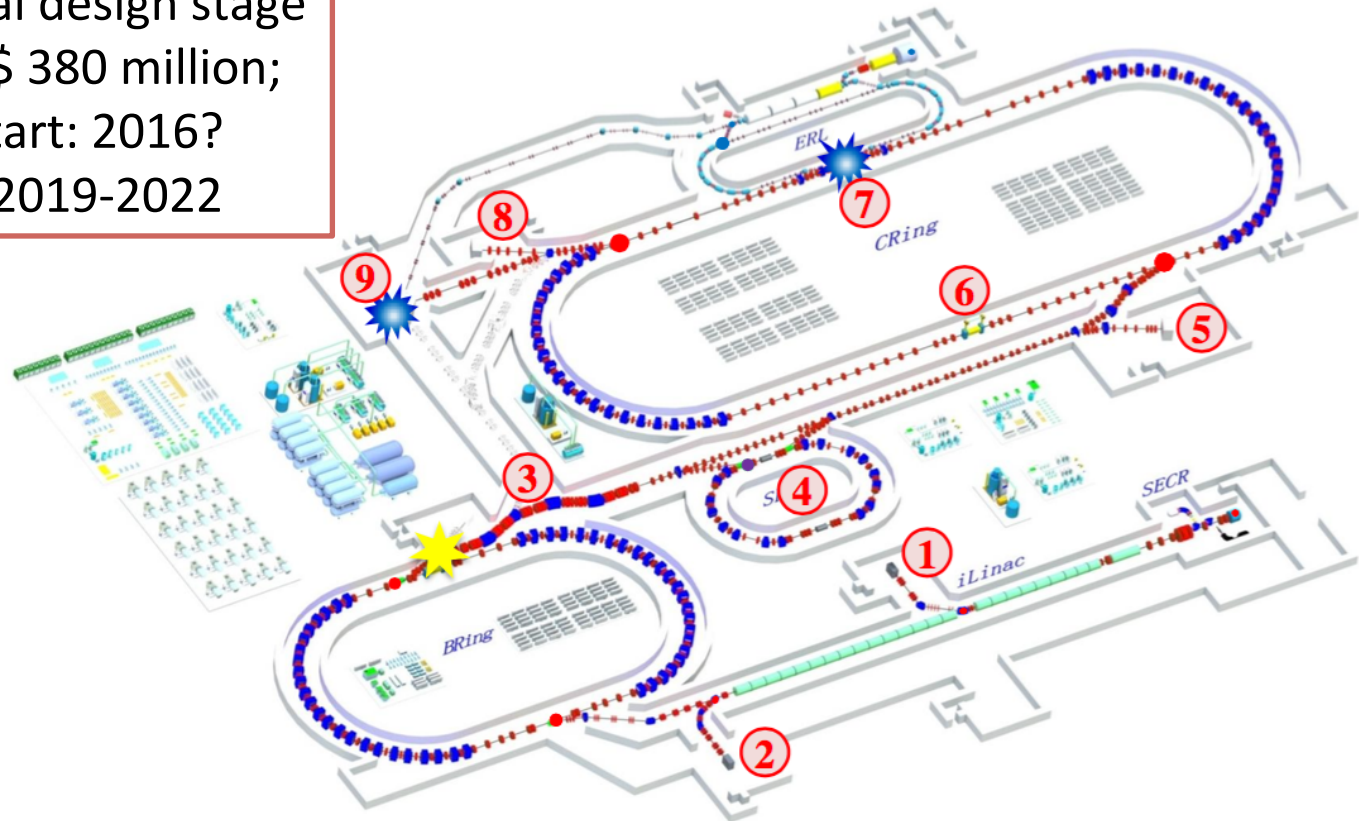
RIB facilities



Heavy ion accelerate facilities (HIAF)

Proposed in 2009,
approved in 2012
Now conceptual design stage
Total budget~ \$ 380 million;
Construction start: 2016?
Completion: ~ 2019-2022

High energy / high intensity / pulse
Cooled intense primary/RIBs



- | | | |
|-------------------|----------------------------------|-----------------------|
| ① Nucl. Structure | ④ Exp. Storage Ring | ⑦ e- nucleus colider |
| ② Irridiation | ⑤ External target terminal | ⑧ H.E irradiation |
| ③ Ribll | ⑥ e - Ion resonance spectrometer | ⑨ High energy density |

Main parameters and operation modes

Fast Extraction

Matter States
(Dense plasma research,
High-Energy-Density Matter)

Slow Extraction

Material irradiation
Space electronic device
Application in bioscience

Atomic physics
Mass measurement

CBR-35

9.5 GeV (p)
 1.0×10^{12}

ER

3.0 GeV (e)
 7.5×10^{13}

Merging

ICR-35

0.8 GeV/u ($^{238}\text{U}^{34+}$)
 $(0.6-2.4) \times 10^{11} \times 4$ Stacking
2.5 GeV/u ($^{238}\text{U}^{76+}$)
 $(1.2-4.8) \times 10^{10} \times 4$ Stacking
9.5 GeV (p)
 1.0×10^{12}

Electron injector

Electron-Ion
collision

High Purity &
Quality RIBs Station

ABR-35

0.8 GeV/u ($^{238}\text{U}^{34+}$)
 $(0.6-2.4) \times 10^{11}$
2.5 GeV/u ($^{238}\text{U}^{76+}$)
 $(1.2-4.8) \times 10^{10}$

RIBs line

25 MeV/u
(U^{34+})

0.04-0.15 pA
2 Hz, 500 μs

SC-LINAC

0.05-0.2 pA,
2 Hz

ECR

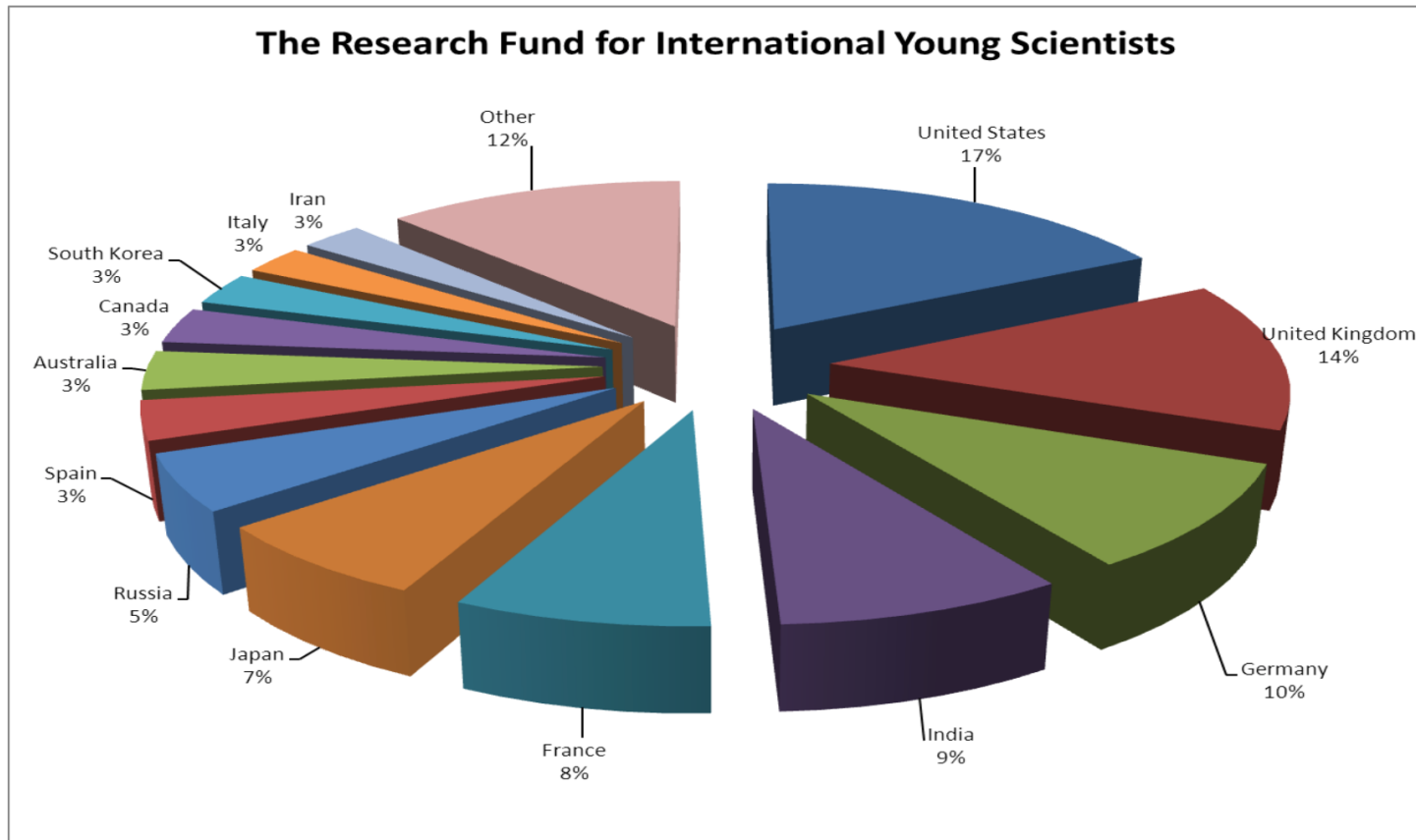
LIS

$\bar{p}$

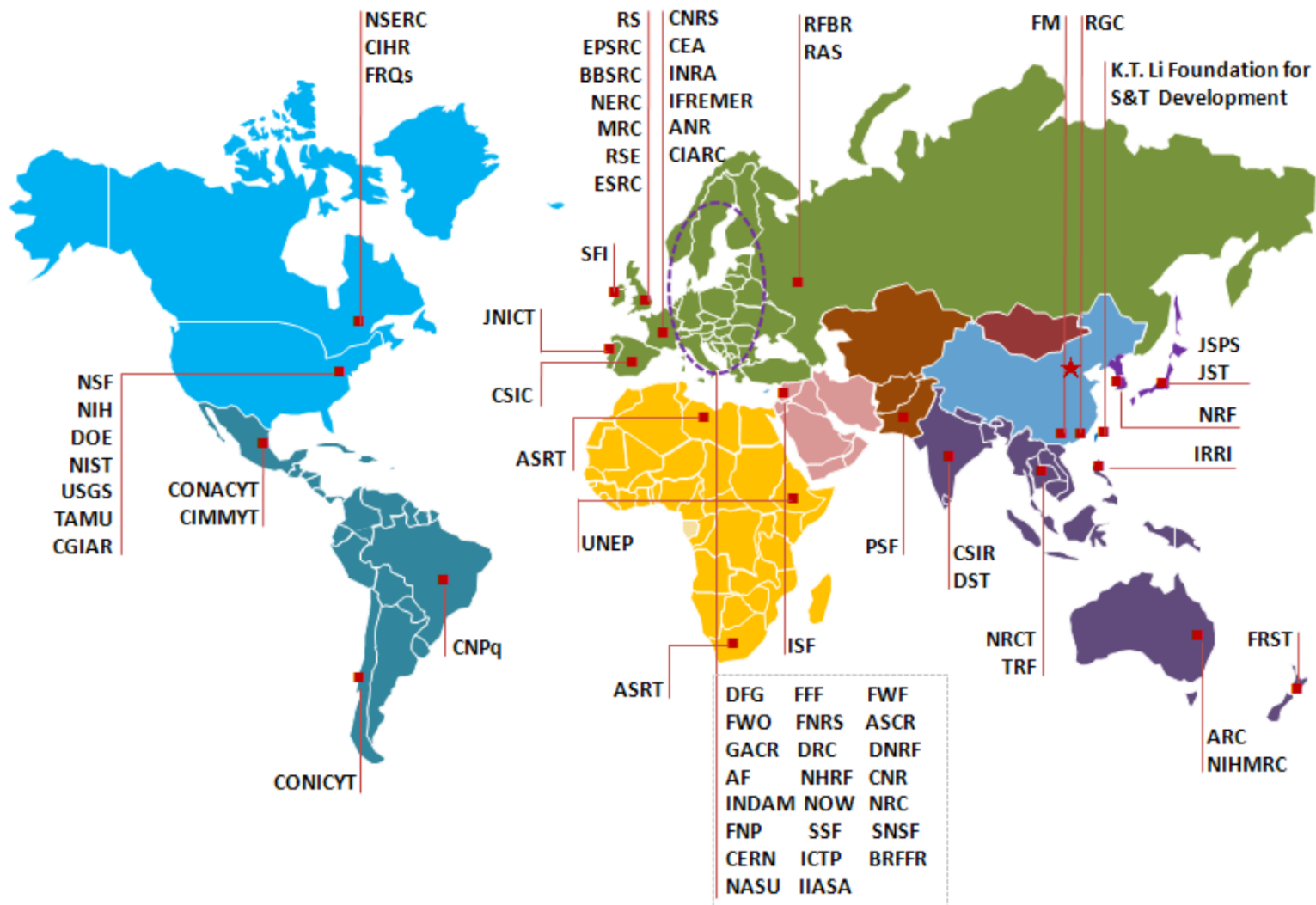


Opportunity

**Scholarship from (almost) every national universities/institute;
NSFC funding: Research Fellowship for International Young Scientists**



Institutional Joint Funding



74 Agreements or MoUs with Institutions in 36 Countries and Regions
Exchange of Personnel, Workshops and Joint Research Projects

Nuclear physics related facilities

Thank you for your attention!



Bao-Hua SUN
bhsun@buaa.edu.cn