PROGRESS OF NUCLEAR DATA MEASUREMENT IN CHINA (2013)

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CHINA NUCLEAR DATA CENTER

I. Institutes involve in nuclear data measurement in China

中国原子能科学研究院 CHINA INSTITUTE OF ATOMIC ENERGY

Excitation function, FY, gamma production yields, DX and DDX, benchmark experiments, etc

北京大学 PEKING UNIVERSITY

(n,LCP) reaction

蘭州大學 LANZHOU UNIVERSITY

Excitation function around 14 MeV

中国科学院近代物理研究所 Institute of Modern Physics, Chinese Academy of Sciences

ADS related (proton induced)

中国科学院上海应用物理研究所 Shanghai Institute of Applied Physics, Chinese Academy of Sciences

Th-U cycle related

中国工程物理研究院 CHINA ACADEMY OF ENGINEERING PHYSICS

Integral experiments

Neutron sources in China

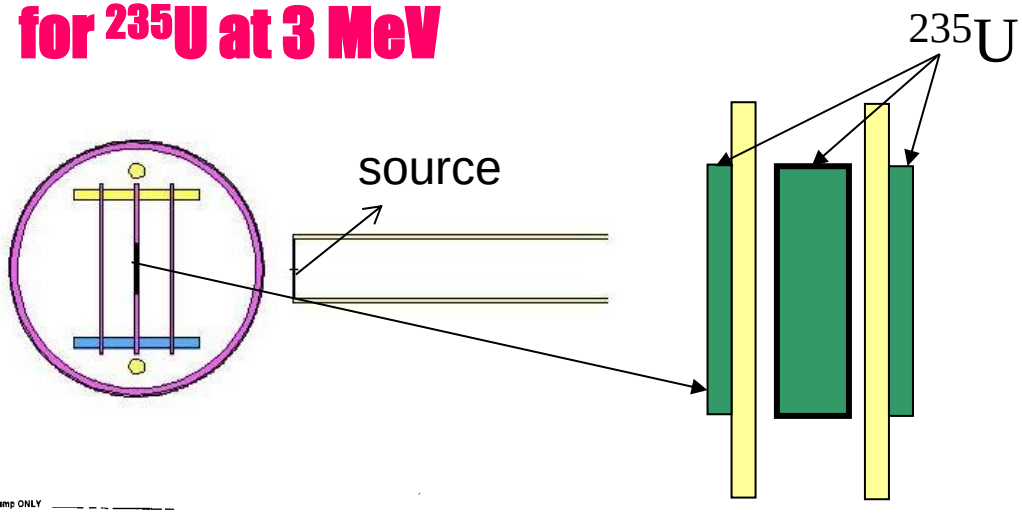
CIAE

Facilities	Neutron energy	Intensity (1/s/sr)
reactor	thermal	10^{14} n/cm^2/s
HI-13 Tandem	8-26 MeV (d+D) 4-23 MeV (p+T) 22-42 MeV (d+T)	10^8 10^7 10^6
2×1.7 MV Small tandem	3-6 MeV (d+D) 14-20 MeV (d+T) 0.07-2.0 MeV (p+T) 0.03-1.3 MeV (p+Li)	10^9 10^8 10^9 10^8
Neutron generator	2.5, 14 MeV	10^8 , 10^{10}
Neutron generator in LZU	2.5, 14 MeV (DC)	10^{11}

Other facilities in china will not exceed this list in neutron energy and intensity

II. Recent Progress of Nuclear Data Measurement in China

Fission yield for ^{235}U at 3 MeV



Sample irradiation

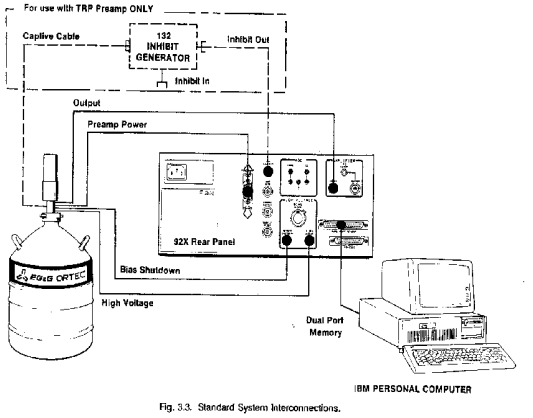
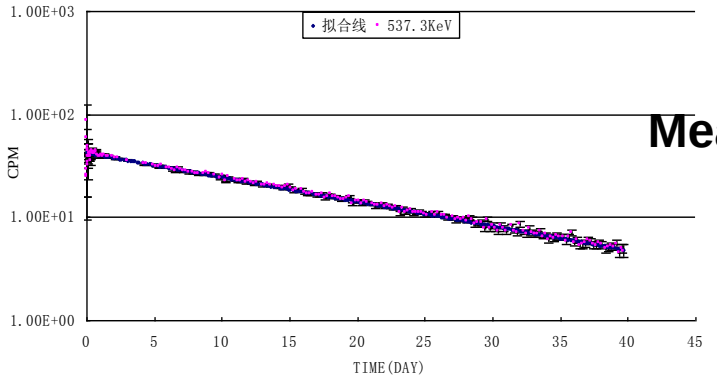


Fig. 3.3. Standard System Interconnections.



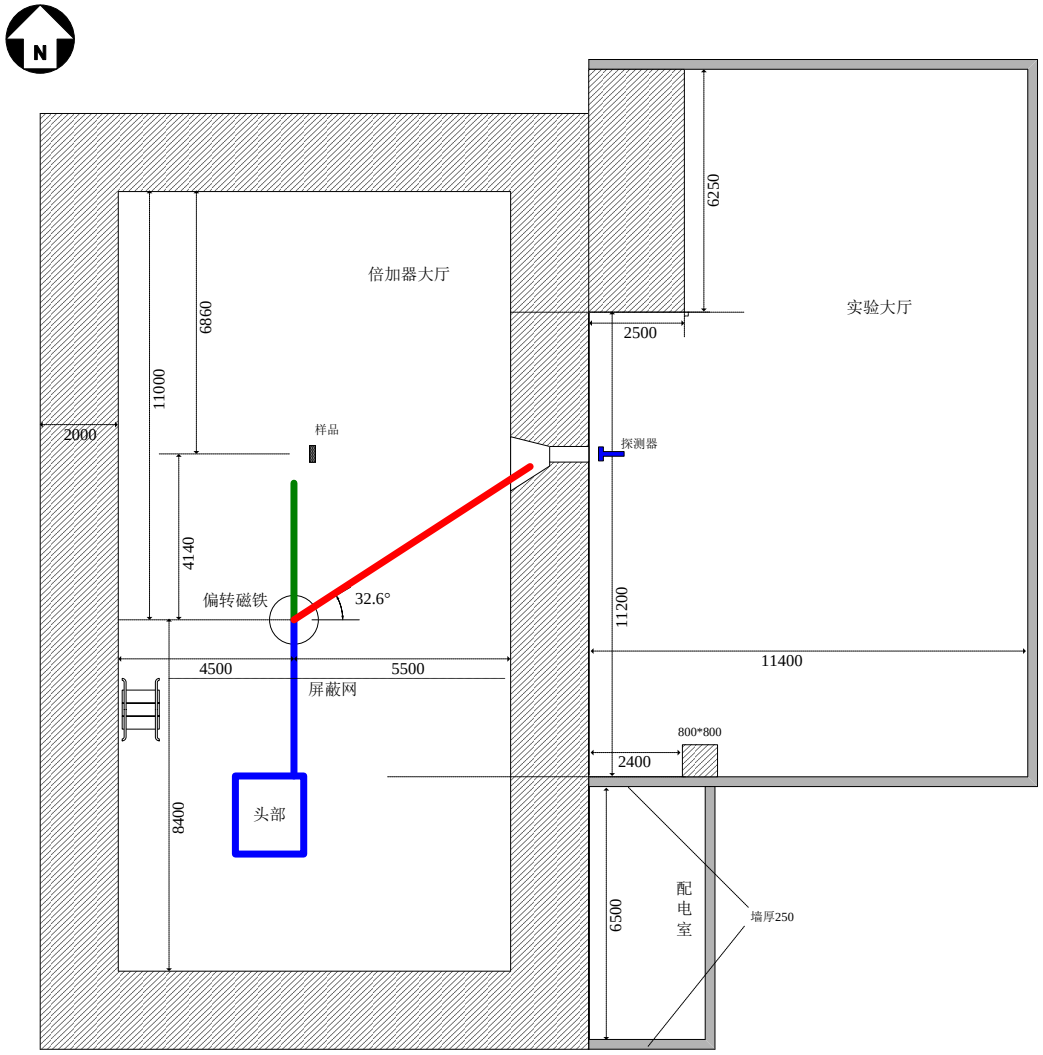
Measurement

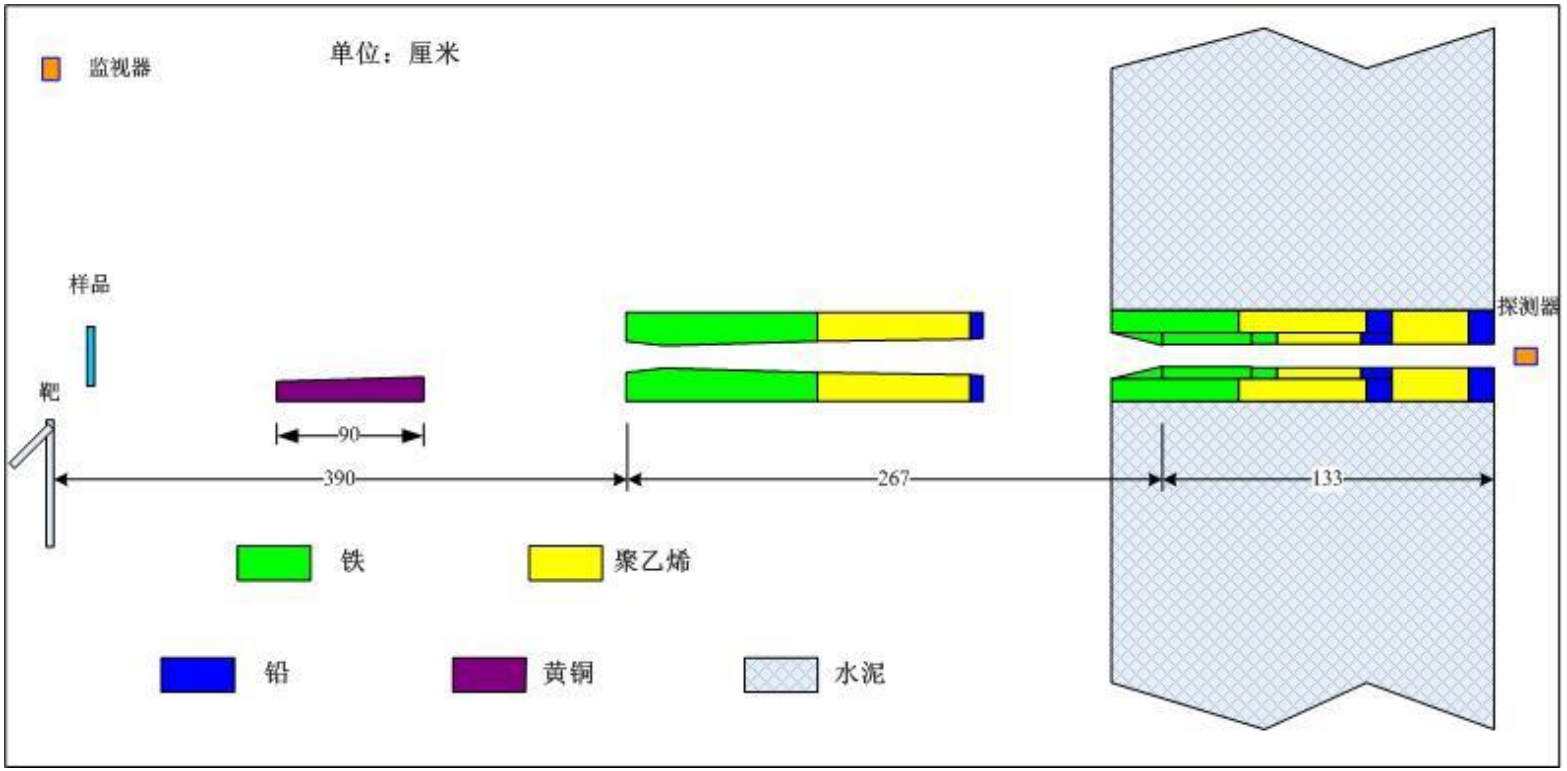
Measured results. All data are normalized to ^{140}Ba(5.8%)

Products	1st measurement	2nd measurement	Averaged yields	Absolute uncertainty	Relative uncertainty
Zr-95	6.18	6.21	6.20	0.30	4.8%
	0.30	0.30			
Zr-97	6.00	6.12	6.06	0.25	4.1%
	0.25	0.30			
Mo-99	5.86	6.24	6.05	0.25	4.1%
	0.25	0.30			
Ru-103	3.36	3.29	3.33	0.12	3.6%
	0.12	0.15			
Ba-140	5.8	5.8	5.8		0.0%
Nd-147	2.39	2.30	2.35	0.10	4.3%
	0.09	0.10			

Nuclear data benchmark experiment

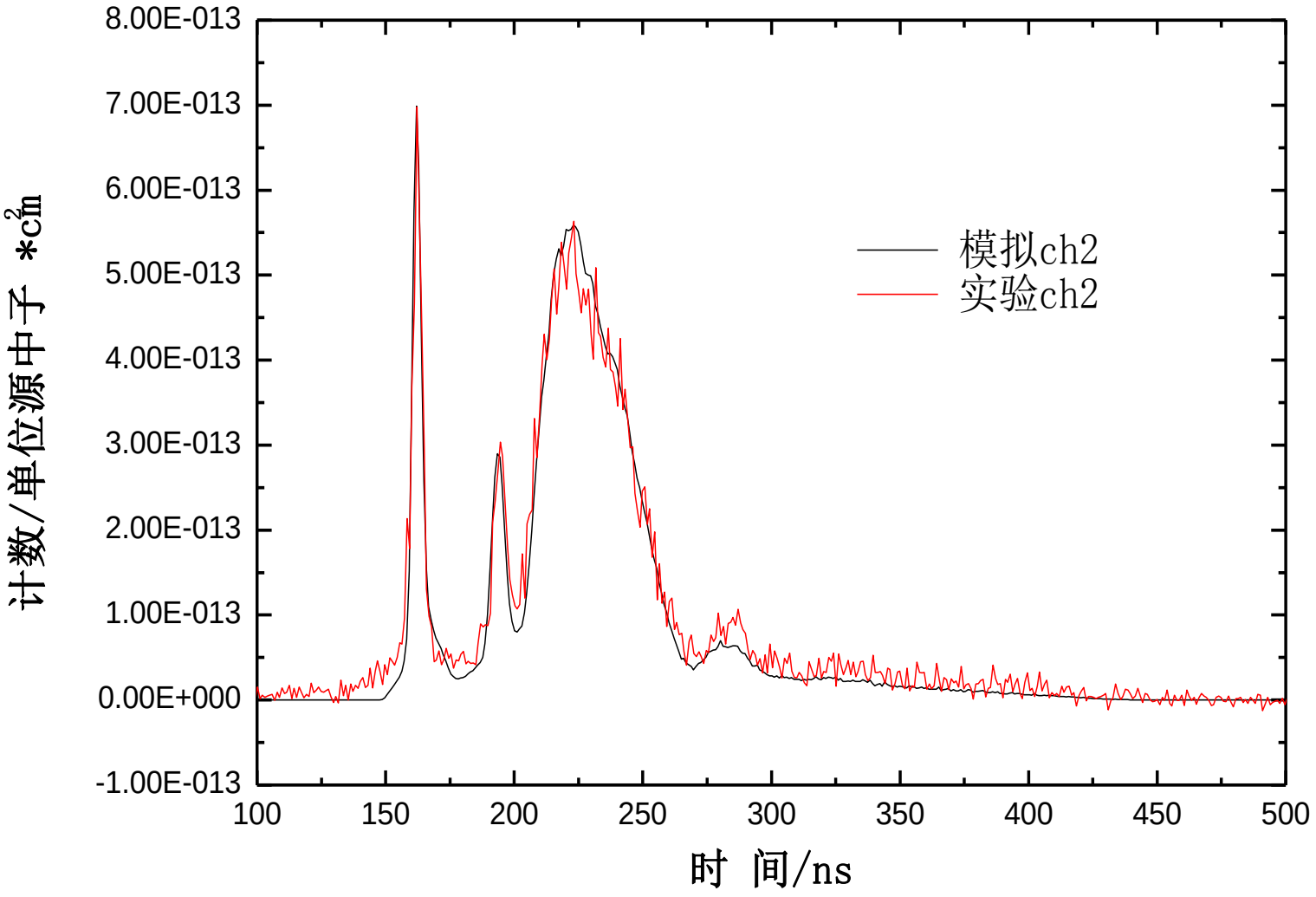
Measure the neutron leakage spectrum from slab samples for different angles with a 14 MeV d-T neutron source



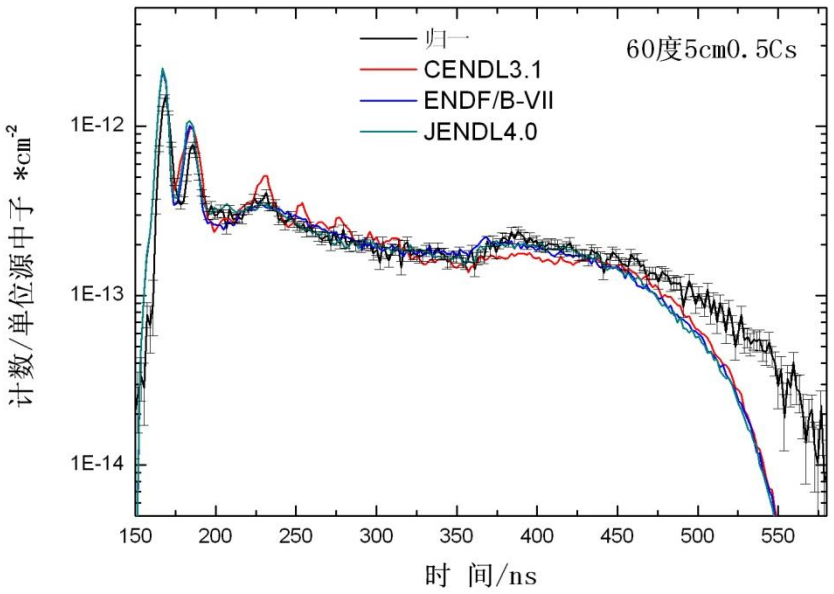


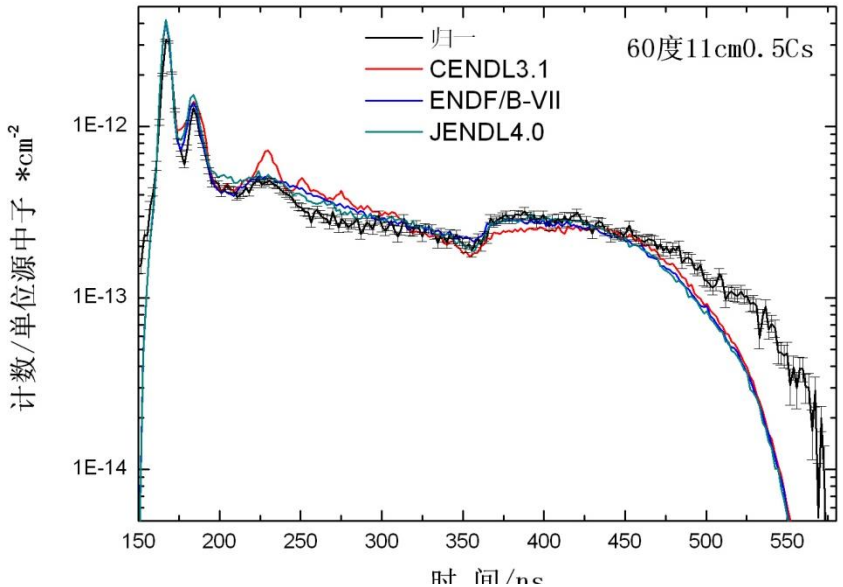
2011-2012, experimental system improved
2013, data taken for Be, Ga, ^{nat}Fe and liquid Pb-Bi alloy
2014, Th and W

Verify the experimental system with a PE sample

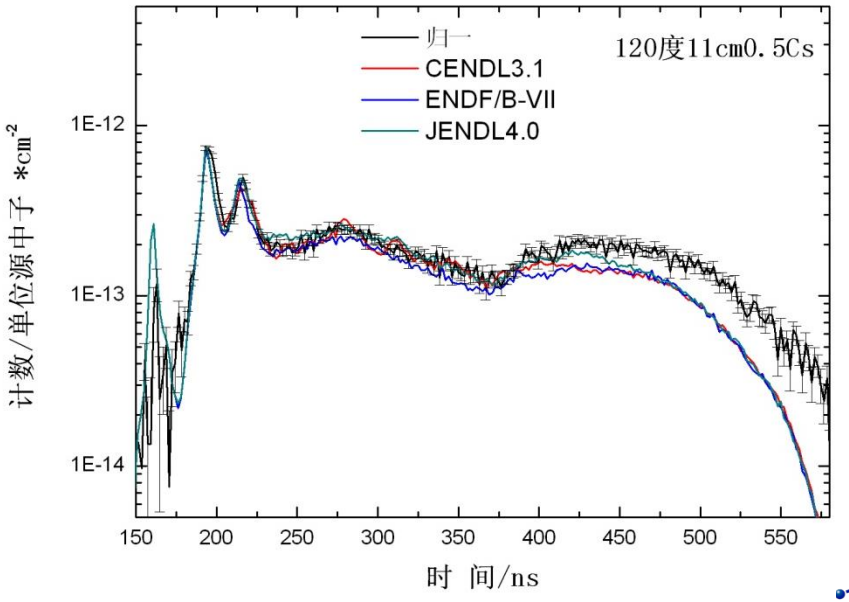


Preliminary result for Be

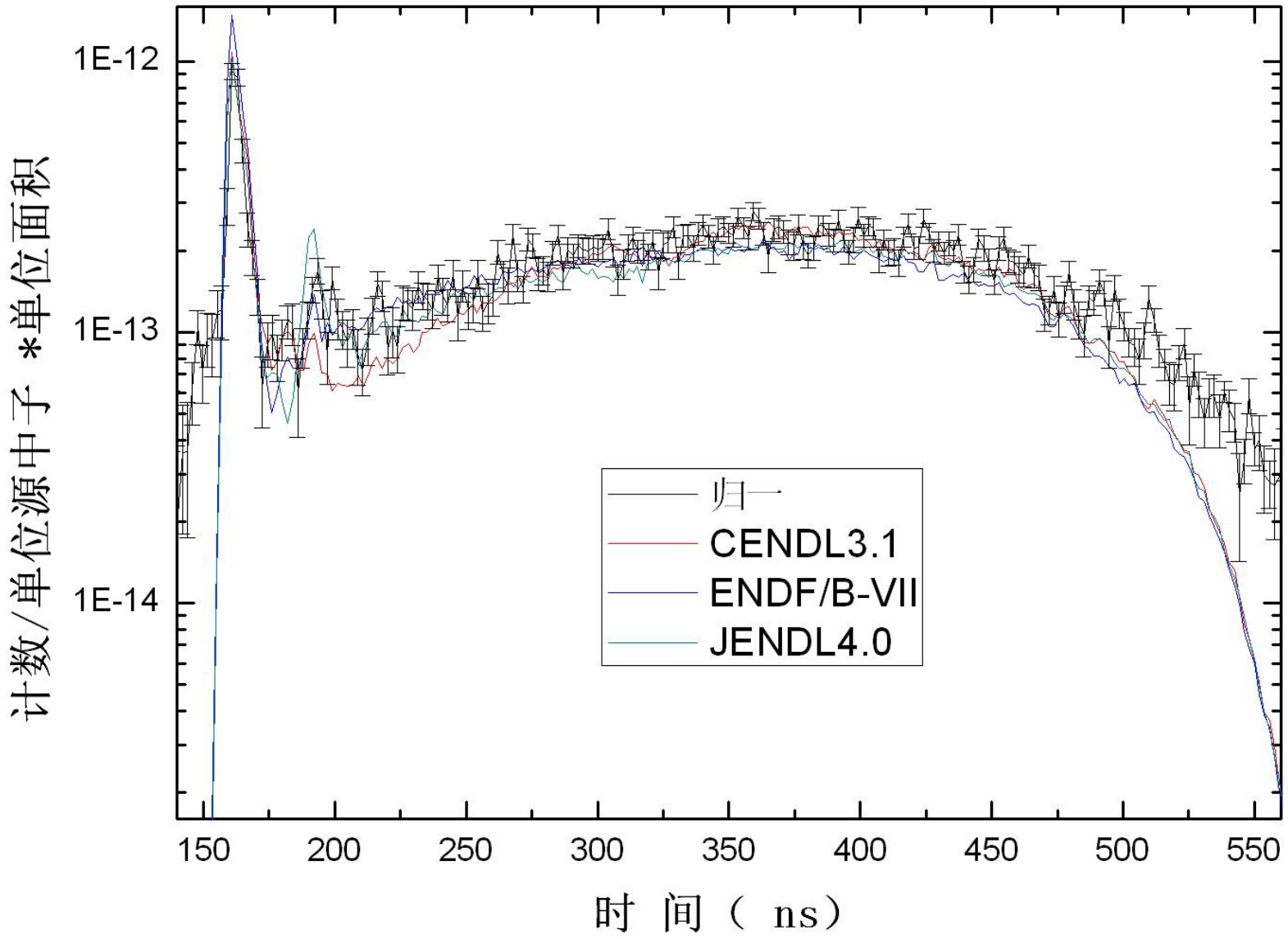




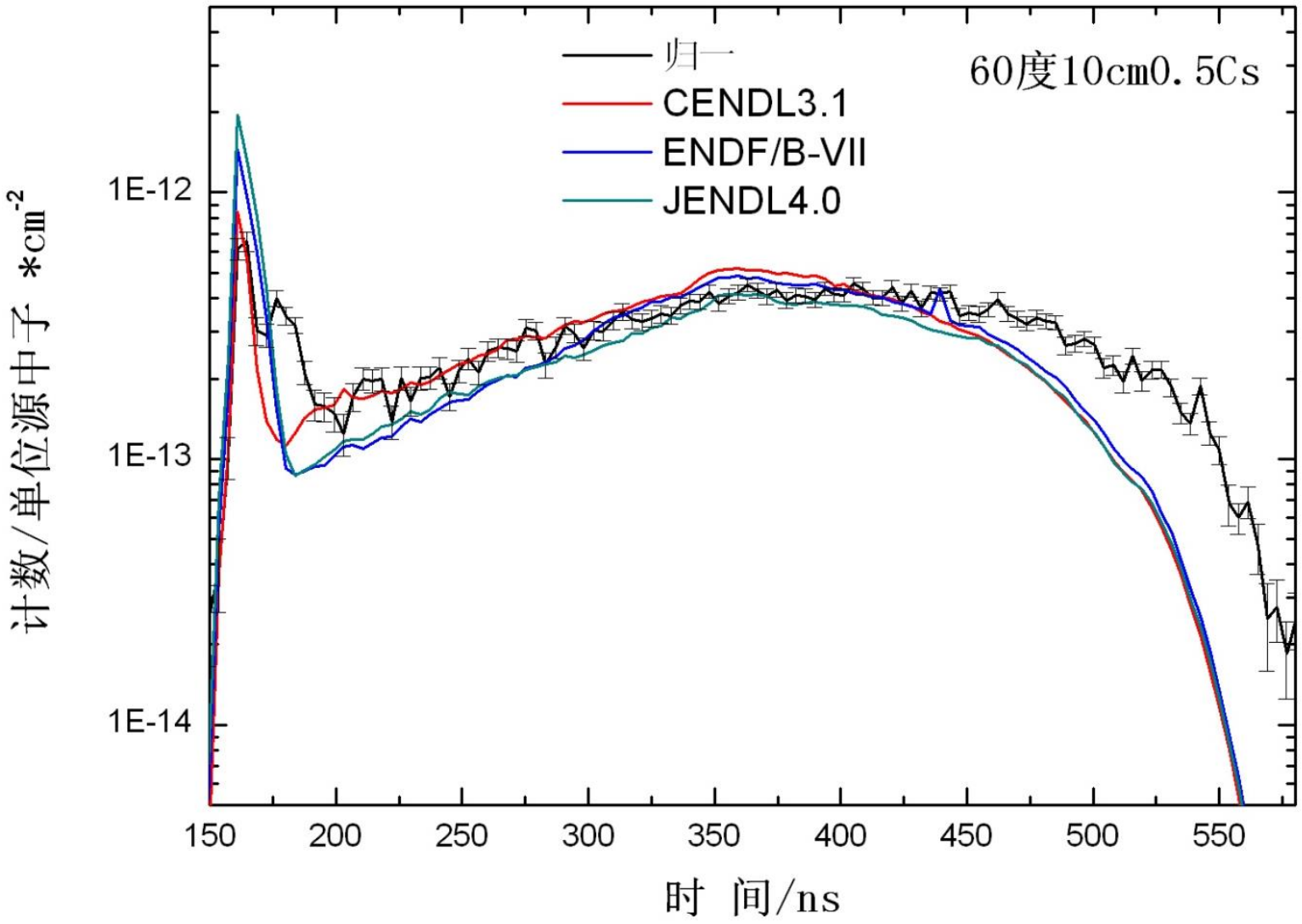
Discrepancies at low energy region are caused by improper detection efficiency (a new detector before calibration)



Iron sample

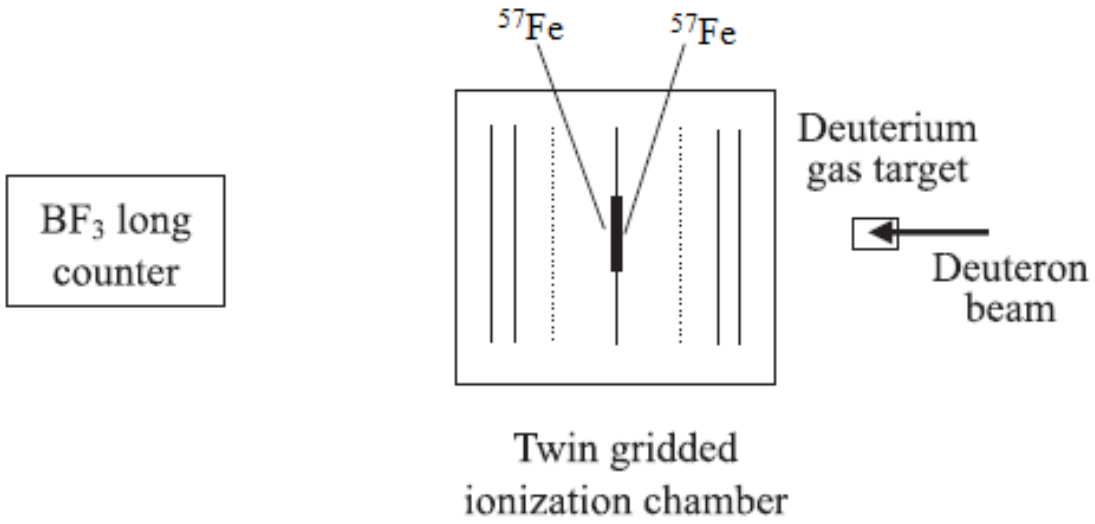

1E-12
1E-13
1E-14
计数/单位源中子 *单位面积
150
200
250
300
350
400
450
500
550
时 间（ ns）
归一
CENDL3.1
ENDF/B-VII
JENDL4.0

Ga sample

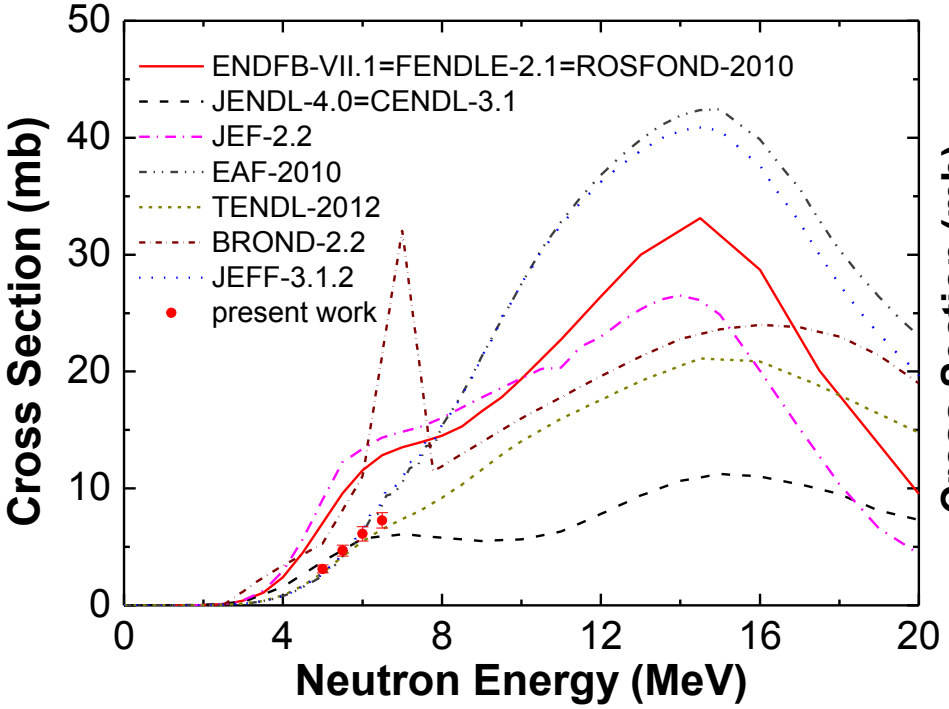

归一
CENDL3.1
ENDF/B-VII
JENDL4.0
60度10cm0.5Cs
计数/单位源中子 *cm-2
1E-12
1E-13
1E-14
150
200
250
300
350
400
450
500
550
时 间/ns

(n, x) measurement at Peking University

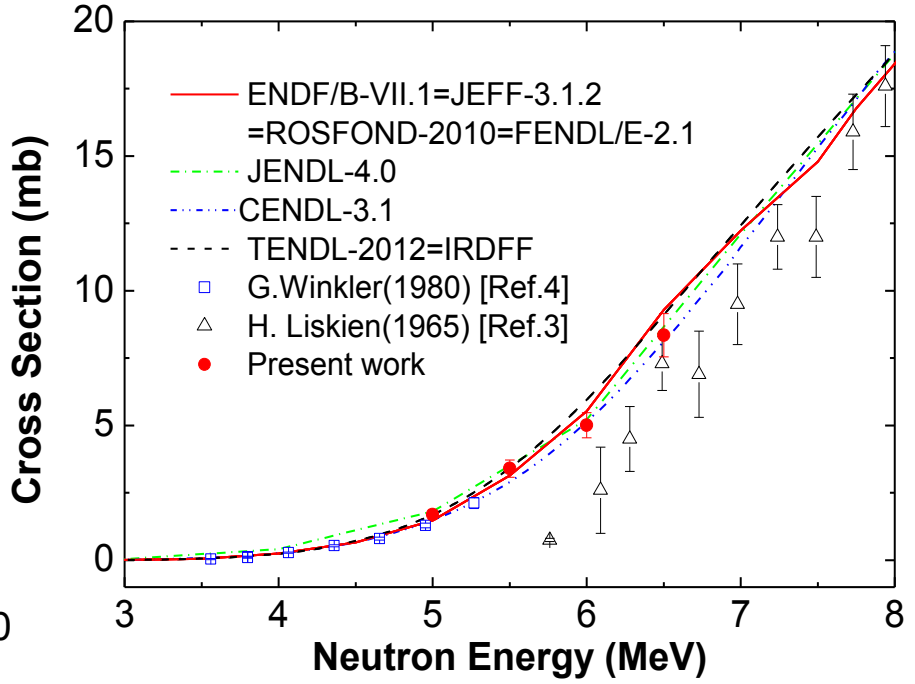
The reaction cross sections of **^{57}Fe(*n*,*a*)^{54}Cr and ^{63}Cu(*n*,*a*)^{60}Co** *were measured with the 4.5 MV Van de Graaff accelerator of Peking University at 5.0, 5.5, 6.0 and 6.5 MeV. Alpha particles were detected with a double-section gridded ionization chamber having two back-to-back samples attached to the common cathode. Absolute neutron flux was measured using a small ^{238}U fission chamber and monitored by a BF3 long counter. The measured results were compared with TALYS calculations, evaluated data and other measurements.*



Experimental apparatus of (n,x) measurement at Peking University.



$^{57}Fe(n,\alpha)^{54}Cr$ reaction.



$^{63}Cu(n,a)^{60}Co$ reaction

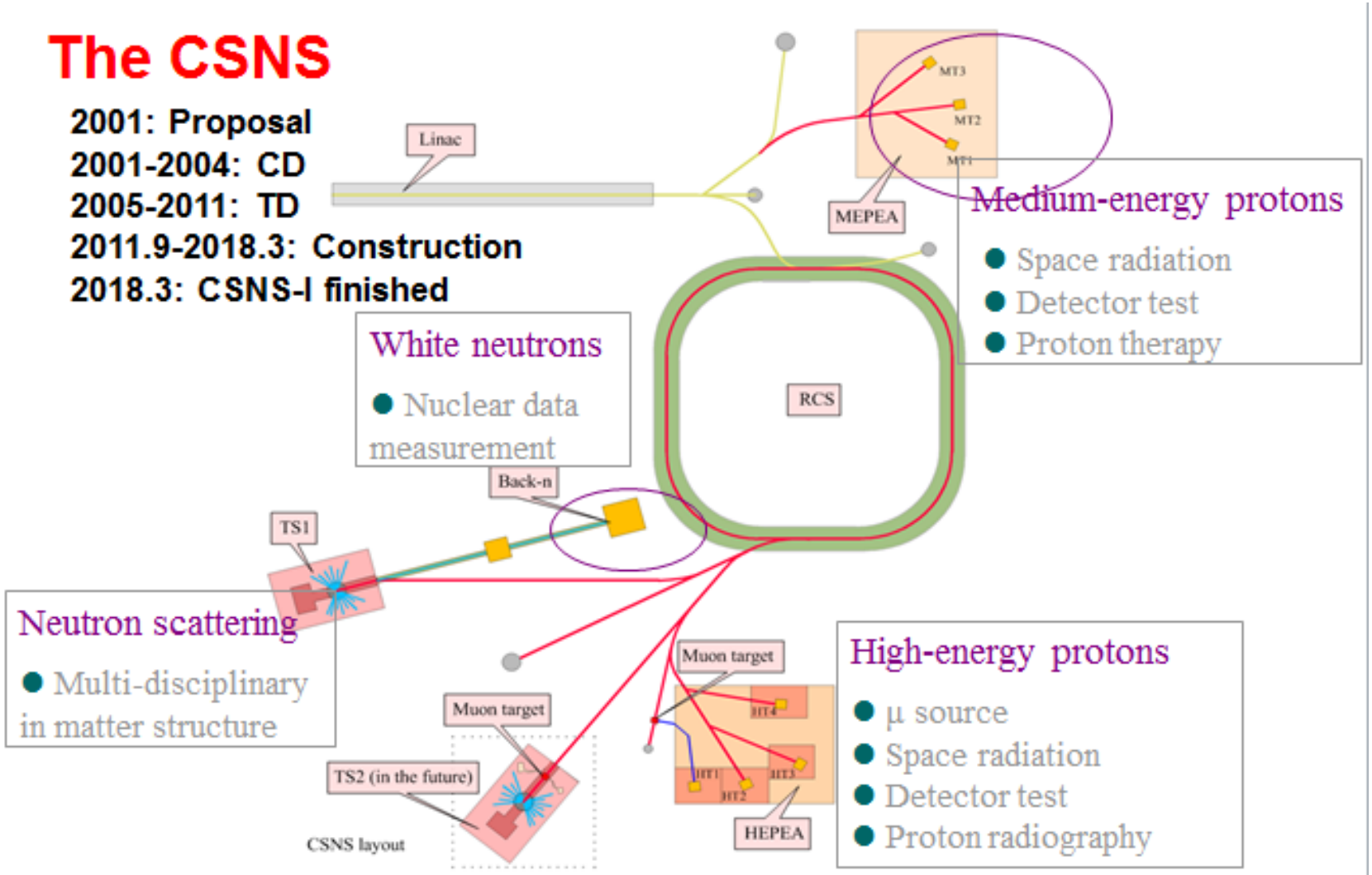
III. New facilities for ND measurement

☆ China Spallation Neutron Source (CSNS)

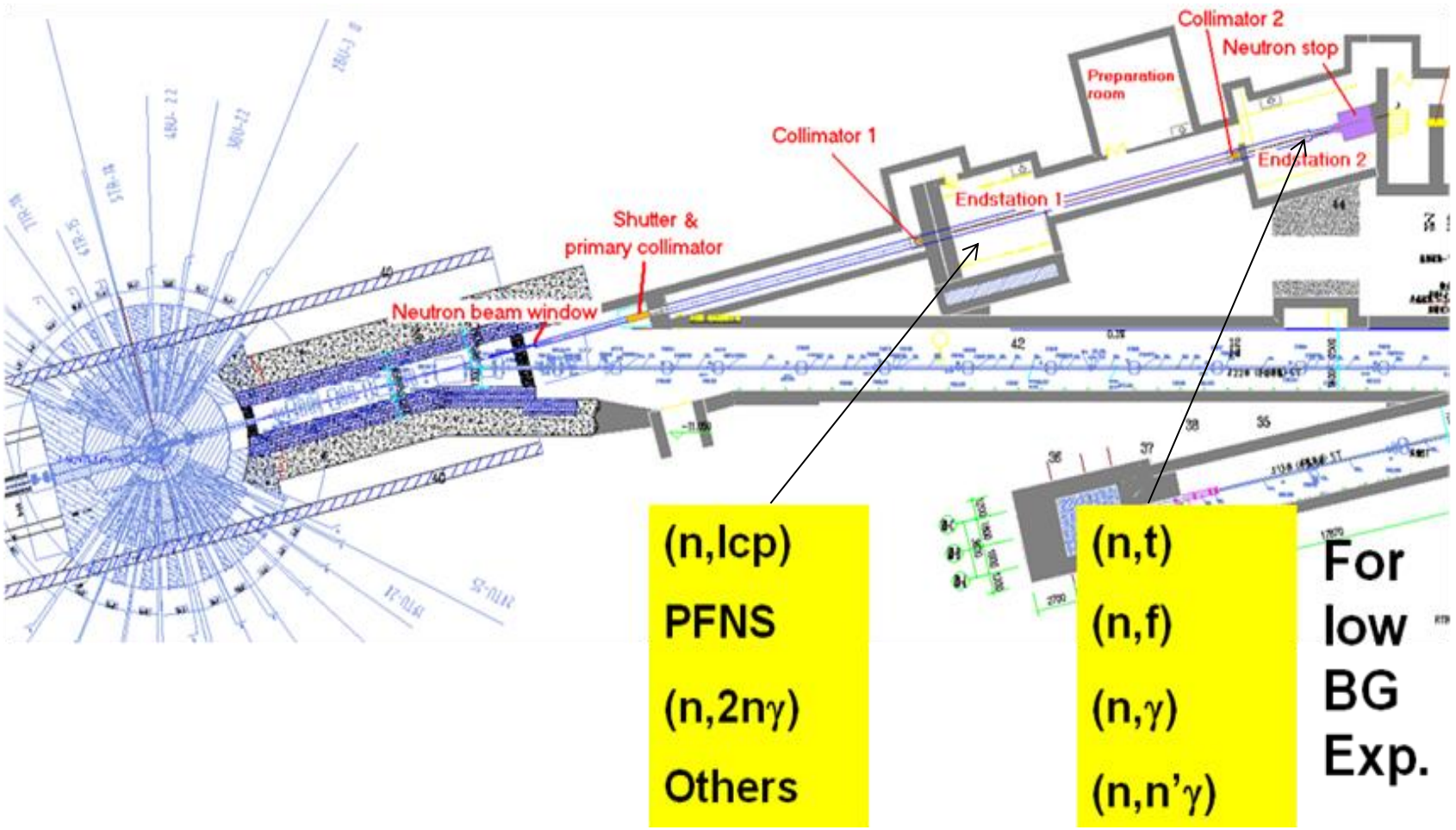
☆ LINAC at SINAP

☆ PISA at IMP

The back streaming neutron source of CSNS



Schematic for CSNS multiple platforms



Endstation 1: 55 meters
Endstation 2: 80 meters

The CSNS parameters

Parameters	United States				Europe		China
	ORELA	LANSCE WNR		RPI	GELINA	CERN n_TOF	CSNS-I Back-n
Accelerator	e- linac	p-Synch	p-linac	e- linac	e- linac	p-Synch	p-Synch
Energy (GeV)	0.14	0.8	0.8	>0.06	0.12	24	1.6
Flight (m)	10-200	7-55	7-90	10-250	8-400	185	55, 80
Pulse (ns)	2-30	125	0.15	15	1	7	52 (6)
B. Power (kW)	50	48	1.6	>10	11	45	100
Rep. rate (Hz)	1-1000	20	32k	1-500	Max. 900	0.28-0.42	25
Time res. (ns/m)	0.01	3.9		0.06	0.0025	0.034	0.65
n yield (n/s)	1×10^{14}	6.4×10^{13}	2.1×10^{12}	4×10^{13}	3.2×10^{13}	8.1×10^{14}	2.0×10^{16}

Back-n: The most intensive neutron source

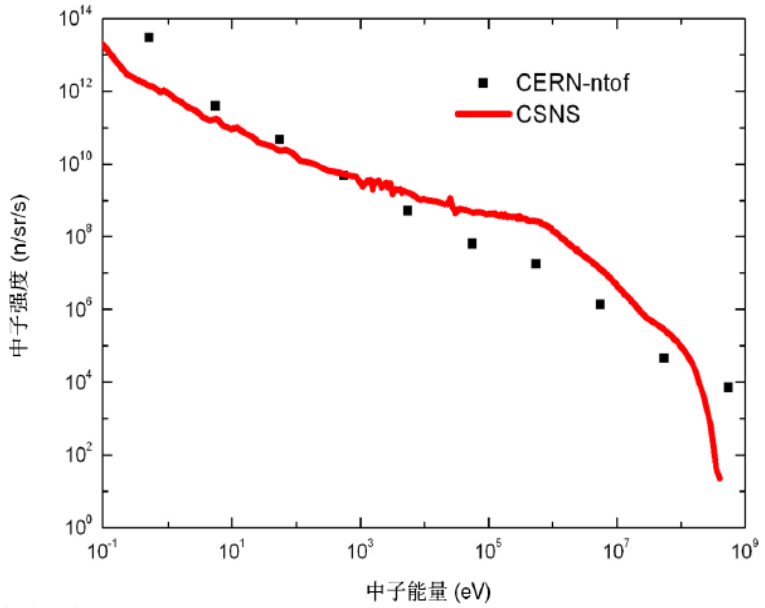


图2　拟建的CSNS核数据测量专用管道的中子能谱及强度与CERN n-TOF的比较。

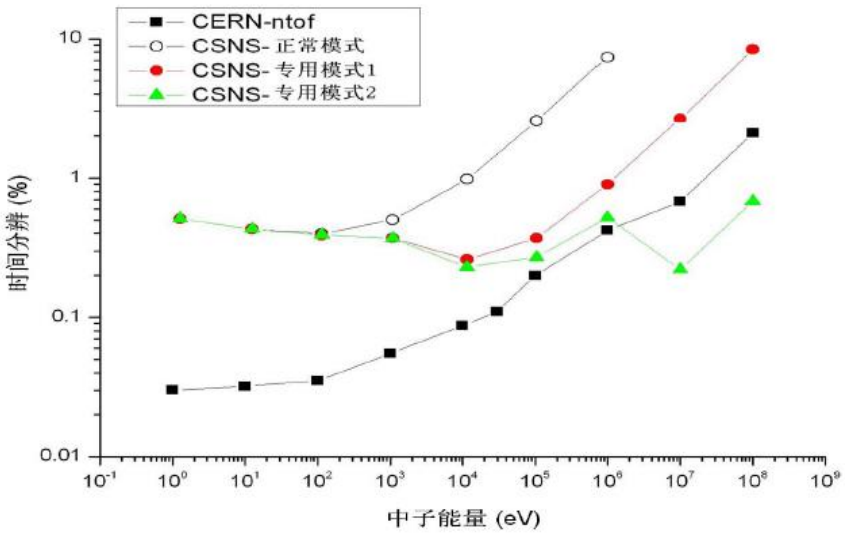


图 3　拟建的 CSNS 核数据测量专用管道 80 米处时间分辨与 CERN n-TOF 的比较。其中：○是 CSNS 的正常运行模式，●是核数据专用模式 1，▲是核数据专用模式 2，■为 CERN n-TOF 的时间分辨。

Comparing with CERN nTOF:

1. **Source intensity and energy range: the CSNS is good**
2. **Resolution: not good but acceptable**

The CSNS can provide two special operation modes to get better resolution

The following neutron cross section measurements are planed at CSNS

(n,t): neutron total cross section

(n,f): fission cross section

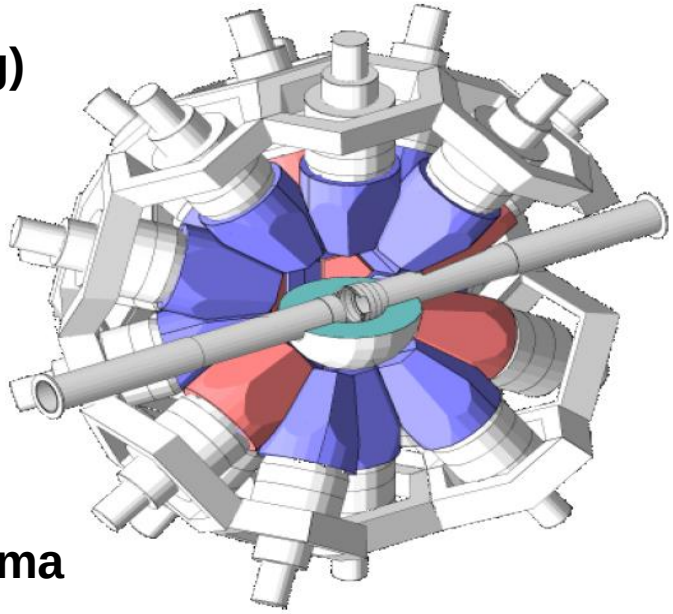
(n,γ): neutron capture cross section

(n,x): neutron induced charged particle emission

PFNS: prompt fission neutron spectra

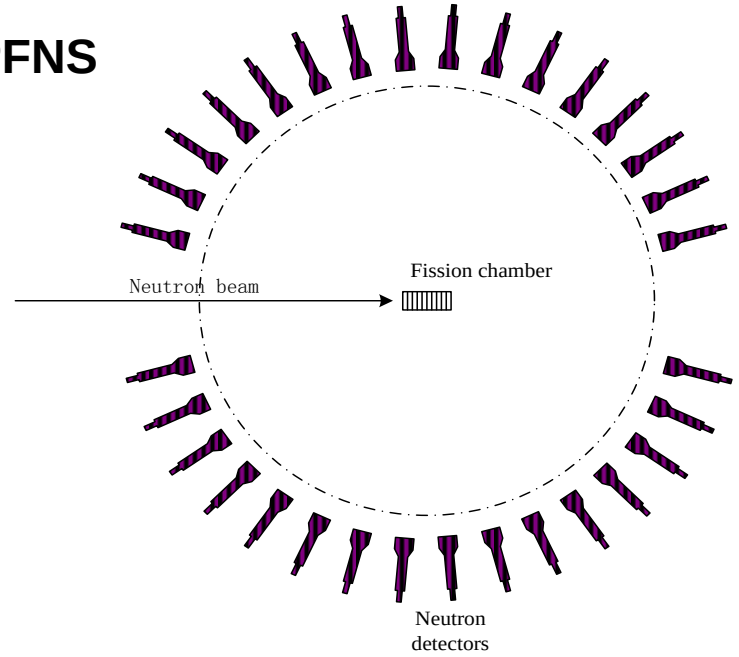
(n,n'γ) and (n,2nγ): inelastic scattering and gamma production cross sections from neutron induced reactions

(n,g)

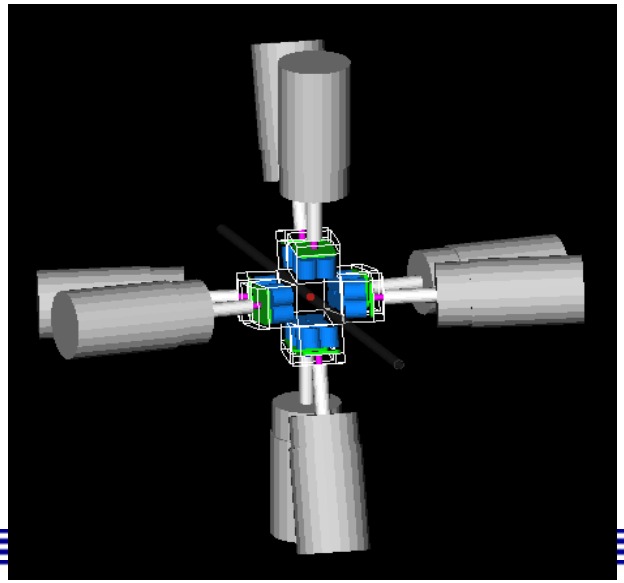


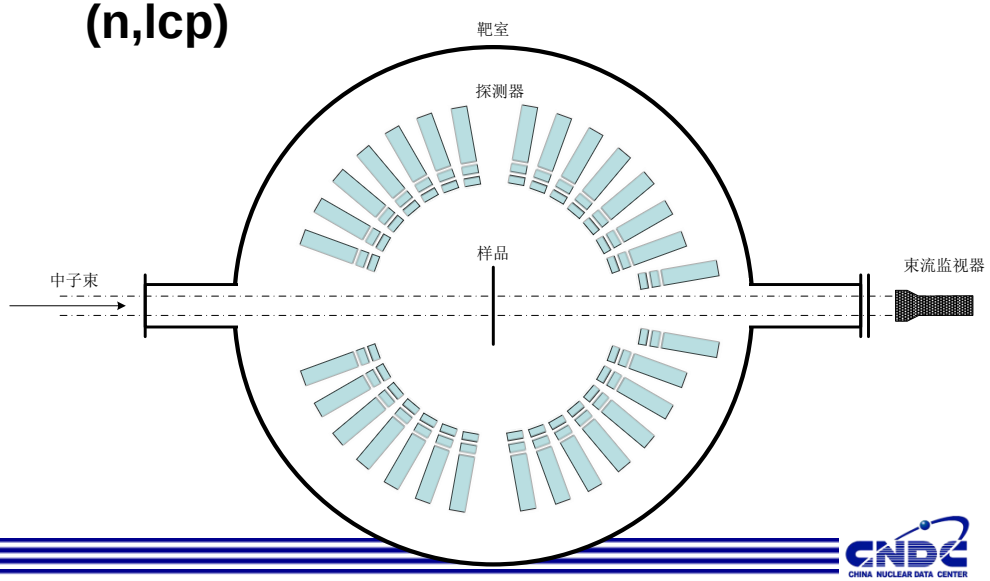
gamma

PFNS



(n,lcp)

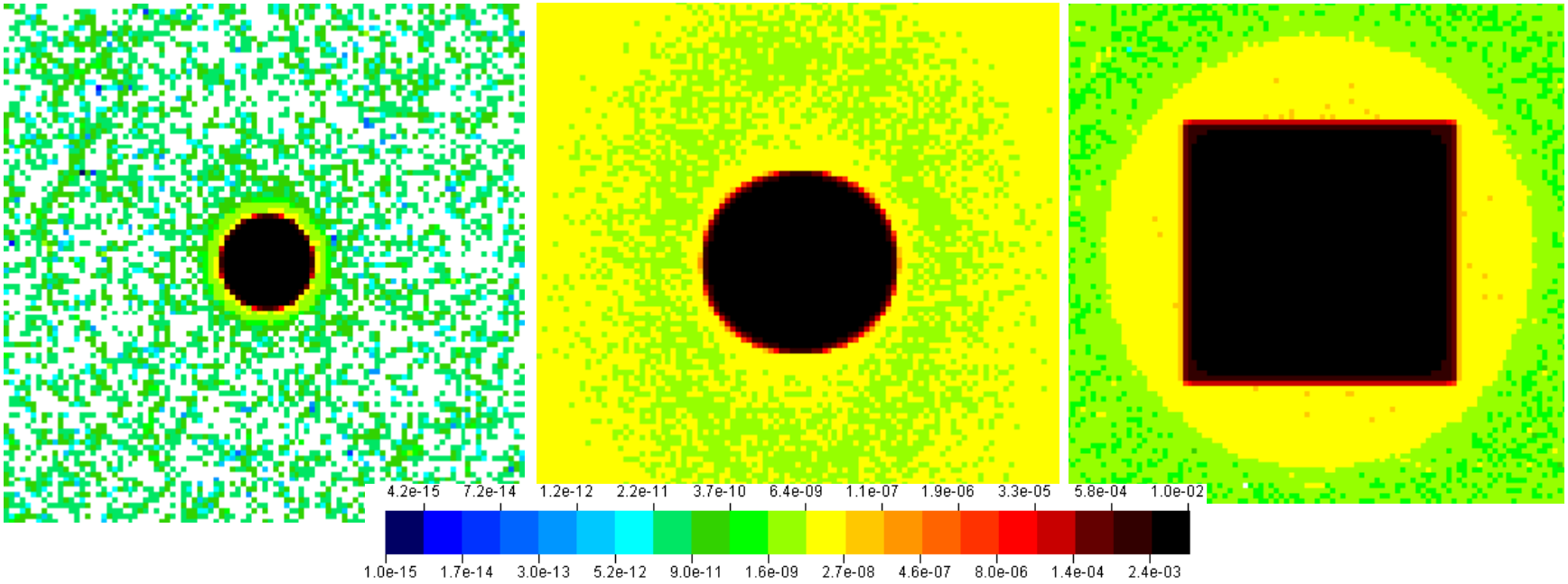


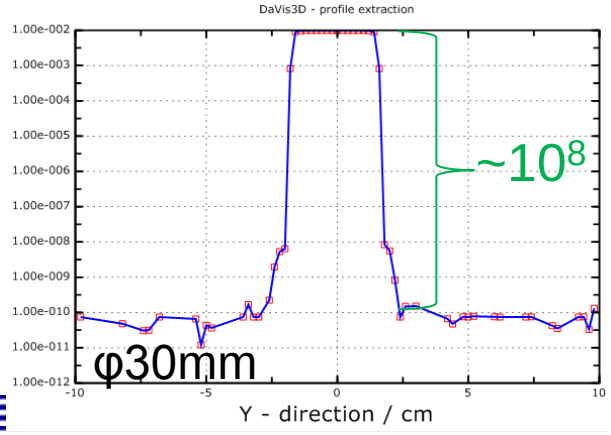


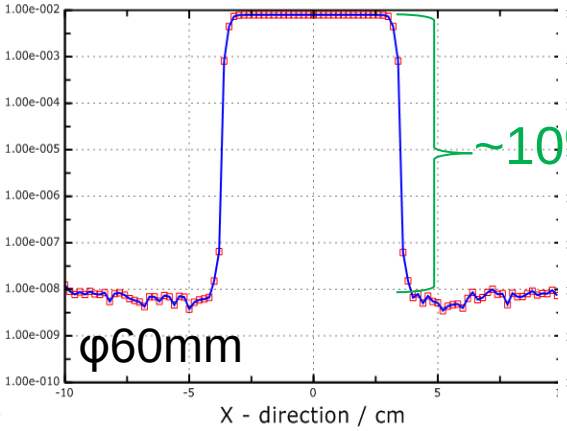
Progress

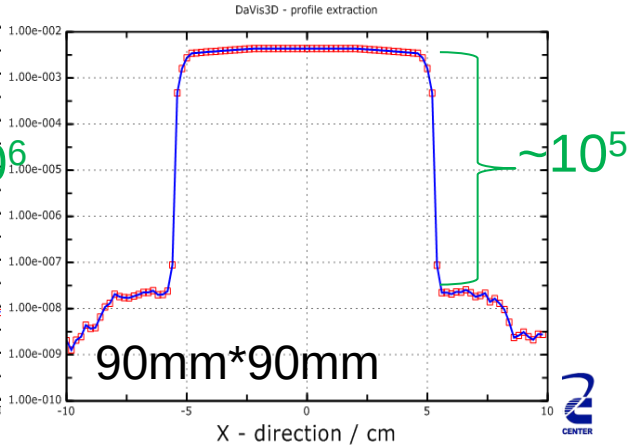
- Civil construction undergoing
- Physical design of the neutron beamline, shutter, collimator and beam dump finished. Technical design started
- Design of the detectors started
- Hope the source and the detector systems can be ready in 2018

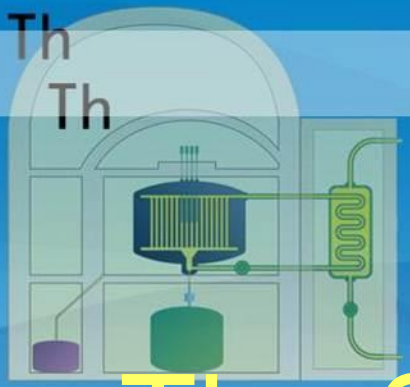
3 beam profiles are designed for different measurements









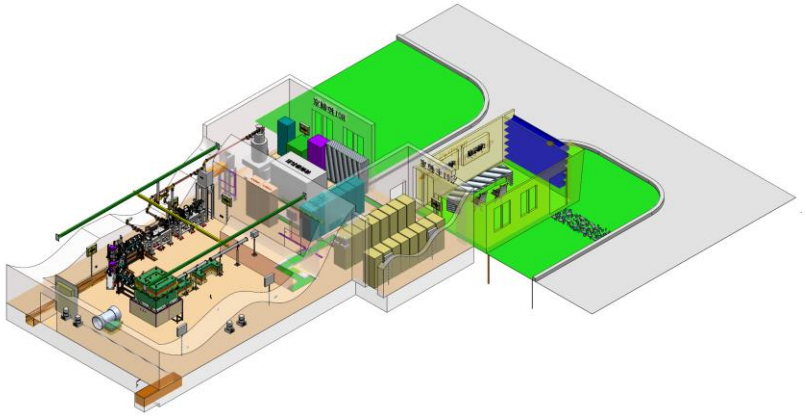


The Study of the Th/U Cycle Nuclear Data in TMSR

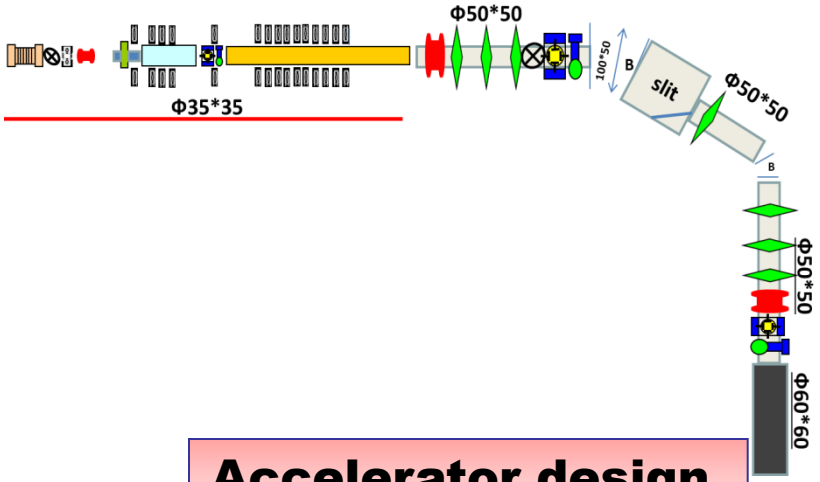
Reactor Physics Division,
Center for Thorium Molten Salt Reactor System,
SINAP,CAS

The LINAC at SINAP

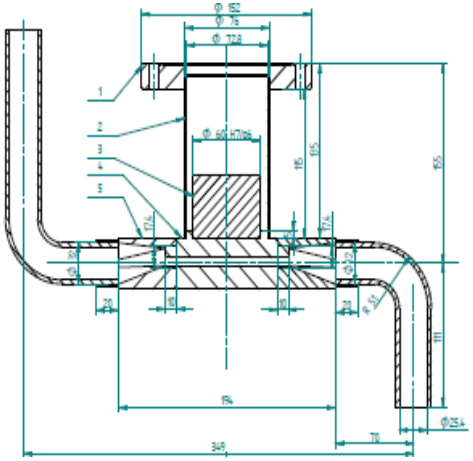
☐ The Important progress - 15MeV Photon-neutron source I

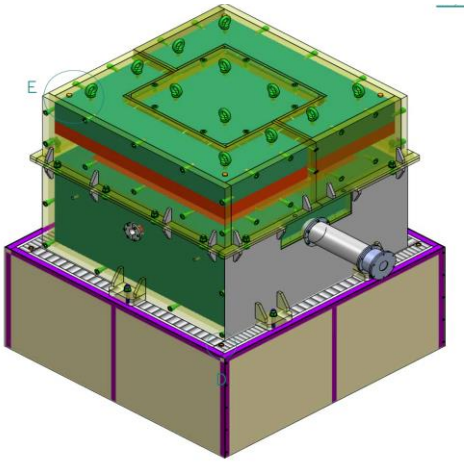


Project layout



Accelerator design

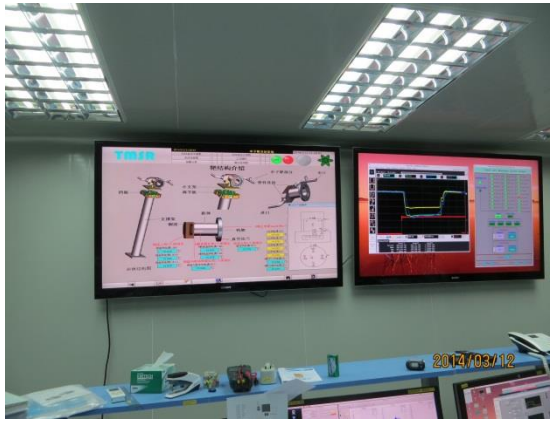


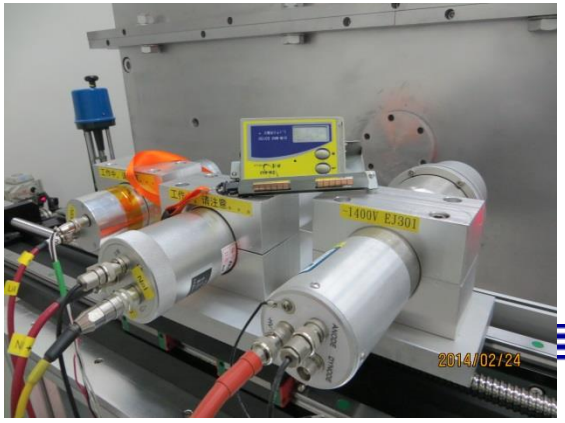


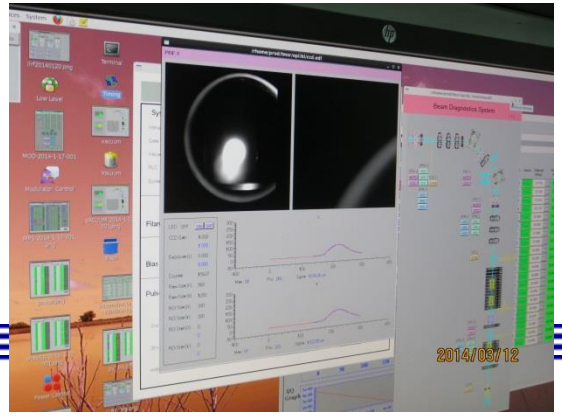
Neutron target system Design

Detector system

- Recent commissioning







Comparison with other neutron source facility based on the electron LINAC

	ORNL ORELA	IRMM GELINA	ELBE	ELBE -SRF	Osaka KURRI	PAL PNF	SINAP I	SINAP II
Average Current /mA	0.045	0.065	0.125	1	0.13-0.22		0.0005-0.1	0.5
Electron Energy /MeV	180	110	40	40	46	60	15	100
Beam Power /kW	8	7	5	40	6-10	0.2-7	0.0075-1.5	50
靶	Ta	U	Pb	Pb	Ta	Ta	Ta，W	Ta
Pulse frequency /Hz	500	800	1.6×10^{6}	5×10^{5}	300	12	10-266	1500
Pulse Width /ns	>4	>1	<0.4	<0.4	2	1500	3-3000	3-3000
TOF path/m	40	20	4	4	5-22	5.4	1-5	20-30
Resolution (@1MeV) %	<1	<2	≈1	≈1	-	-	<1	<1
Neutron flux $/s^{-1}\ cm^{-2}$	$\approx10^{4}$	4×10^{4}	4×10^{5}	3×10^{6}	-	-	1×10^{5}	5×10^{6}
Neutron yield $10^{13}/s^{-1}$	2.2	3.4	1	1	2.0	0.2	0.4	1.0

Neutron & photon flux（n/s/cm^2) at 90° direction relative to electron beam

15MeV Electron(2kW)+W	0.5m/(n/s/cm2)	5m/(n/s/cm2)
Neutron	1.51E+07	1.43E+05
Photon	1.81E+10	1.64E+08

Planed measurements:

Th/U cycle related materials

1. Transmission measurements
2. Capture measurements

ADS related nuclear data measurements for spallation target at IMP,CAS

Zhiqiang Chen

ADS Nuclear Data Laboratory

Institute of Modern Physics, Chinese Academy of Sciences(IMP,CAS)

HIRFL-CSR Complex in Lanzhou

SSC(K=450)
100 AMeV (H.I.), 110 MeV (p)

SFC (K=69)
10 AMeV (H.I.), 17~35 MeV (p)

RIBLL2
RIBs at hundreds of AMeV

CSRe

RIBLL1
RIBs at tens of AMeV

PISA

Proton:2.5GeV

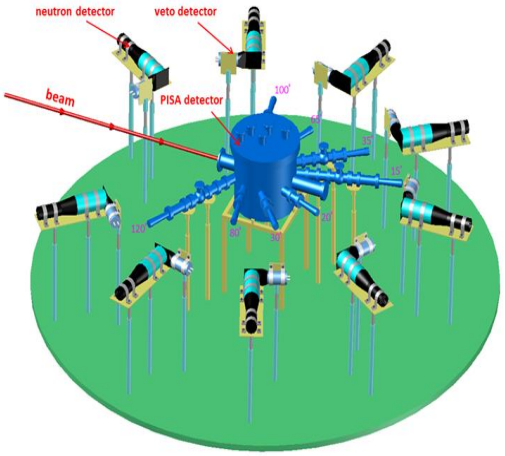
Cancer Therapy

CSRm
1000 AMeV (H.I.), ≤ 2.8 GeV (p)

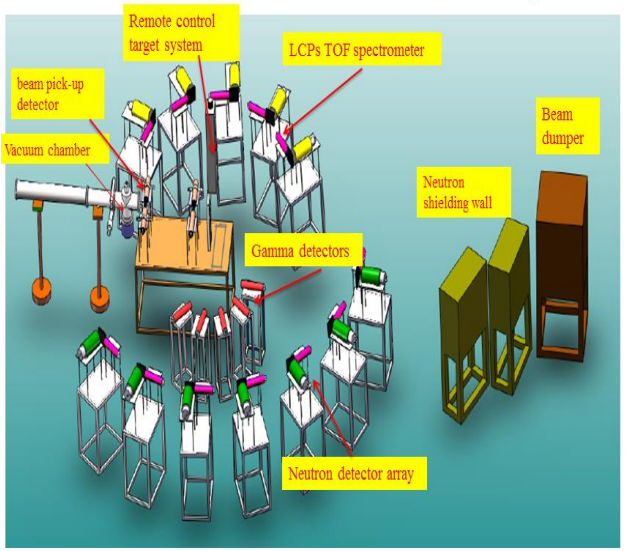
PISA terminal is used for ADS Nuclear data measurements.

Nuclear data measurement facilities

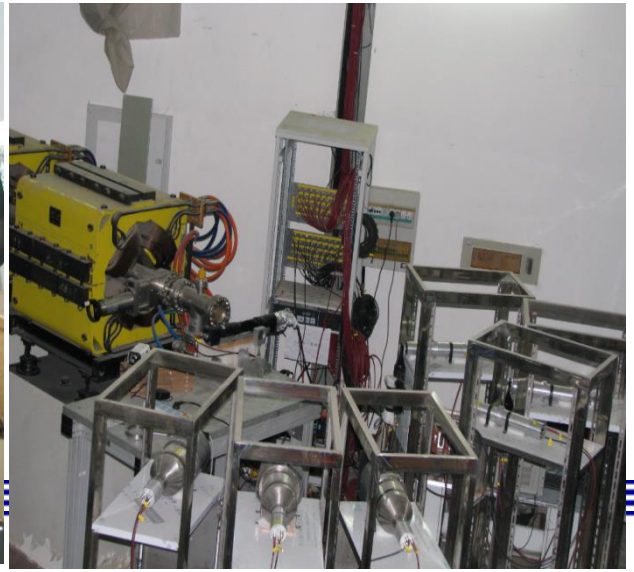
PISA (Proton Induced SpAllation)



Nuclear data measurement facility



Neutron activation method



Experiments performed in recent years

2012:

- 400 AMeV ^{12}C + Pb (thick targets,naked targets)
- Neutron activation method

2013:

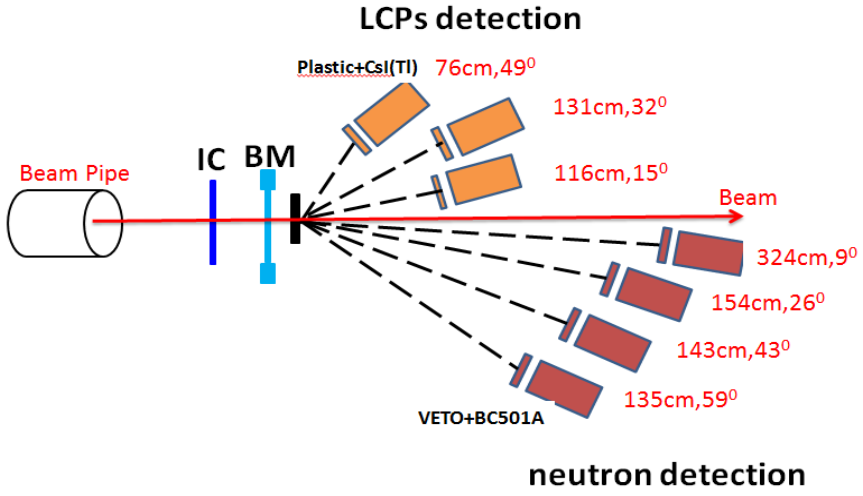
- 400 AMeV ^{12}C + Pb/W (thick targets, targets in water tanker)
- neutron activation method
- 165-350 AMeV ^{12}C + H_2O
- LCPs detector tests

2014:

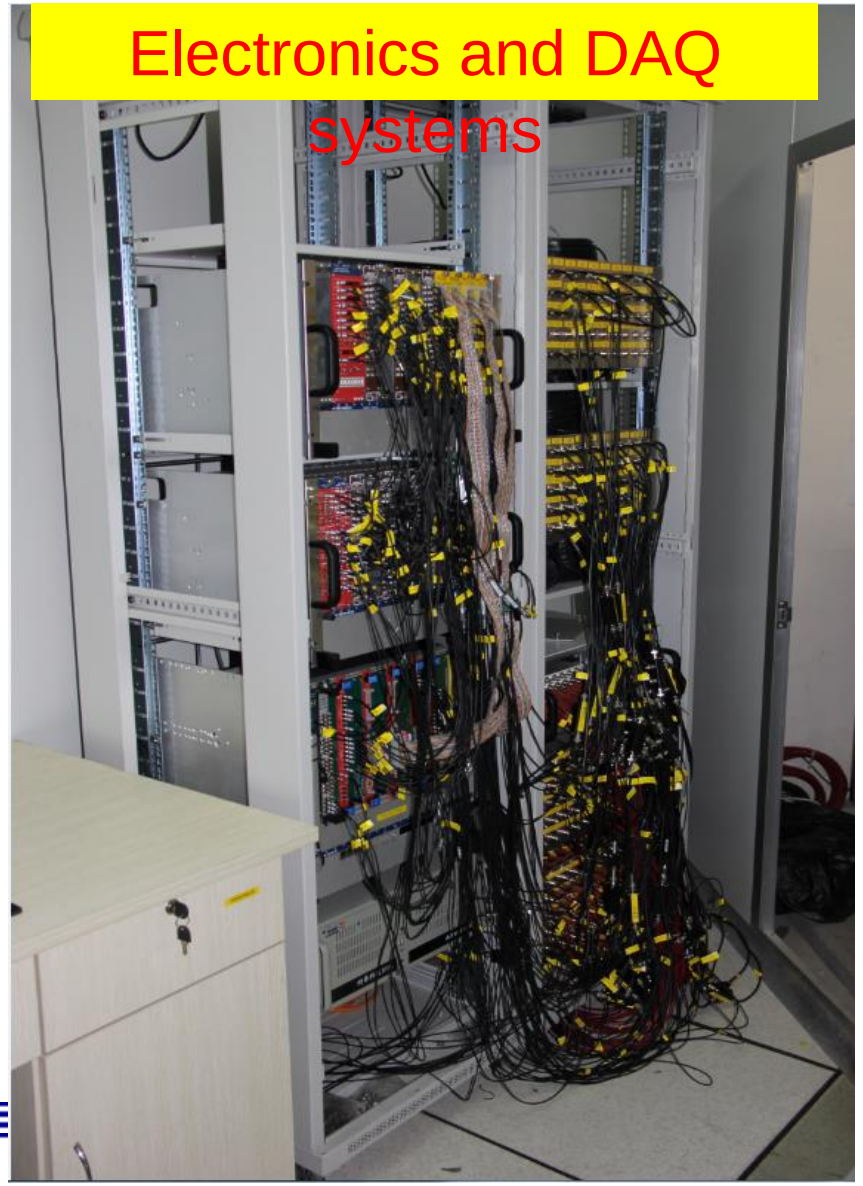
- 250 AMeV H_2^+ + Pb/W (thick targets)
- Neutron activation method
- 400 AMeV ^{16}O + Pb/W (thin,thick targets)
- Online measurement detectors and DAQ system test
- BC501A neutron detectors for neutron measurements
- Plastic + CsI(Tl) detectors for LCPS.

400 AMeV 16O + Pb/W experiments

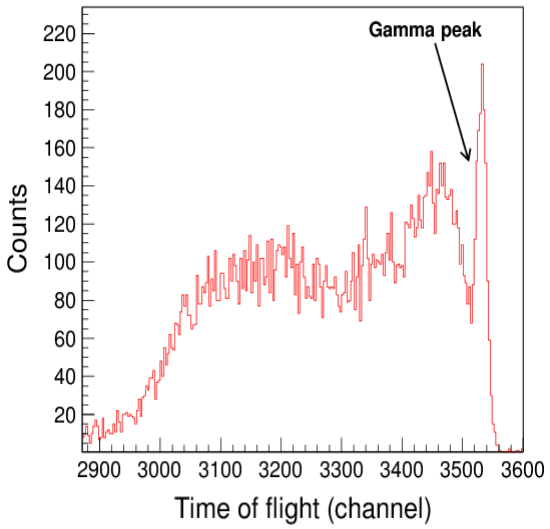
Experimental setup

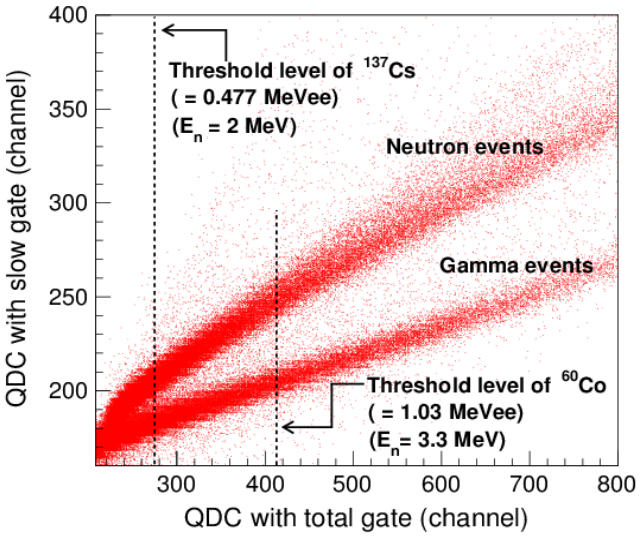


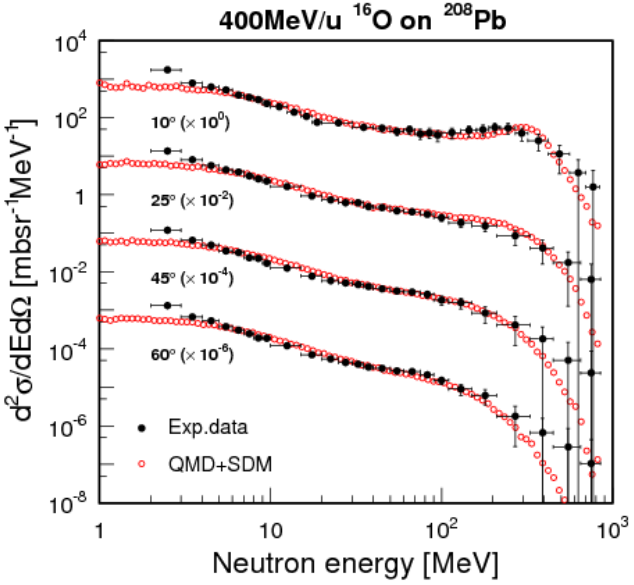
Electronics and DAQ systems

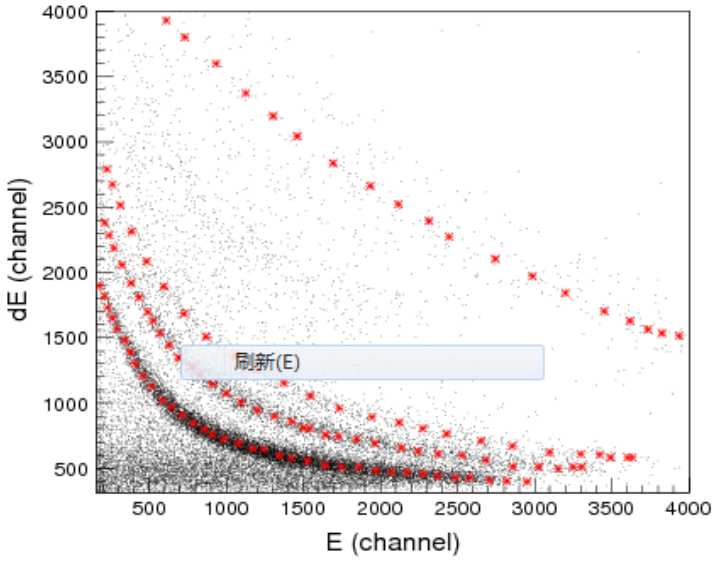


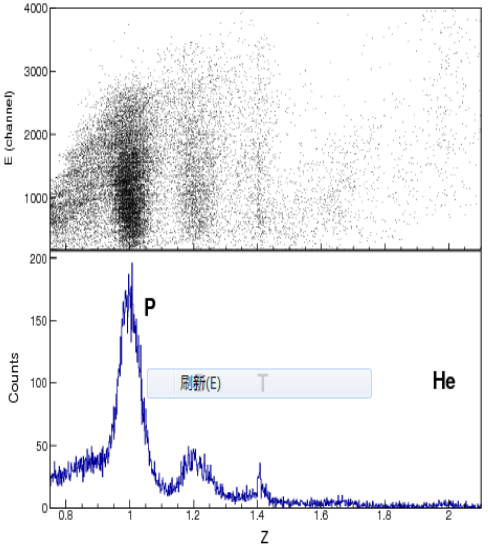
Results for neutron and LCPs measurements

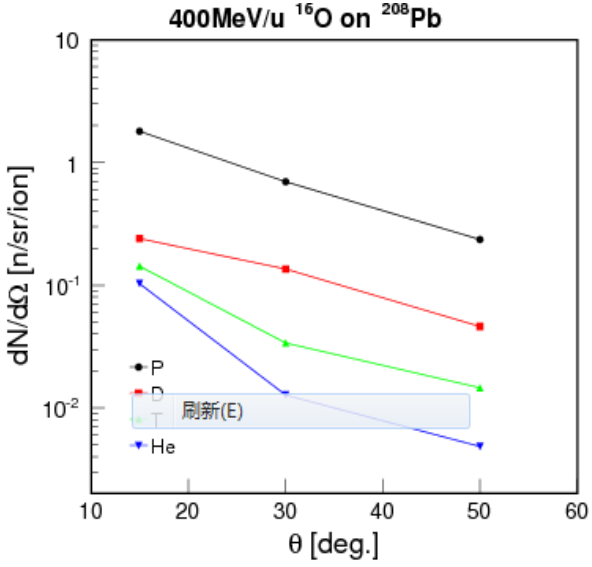




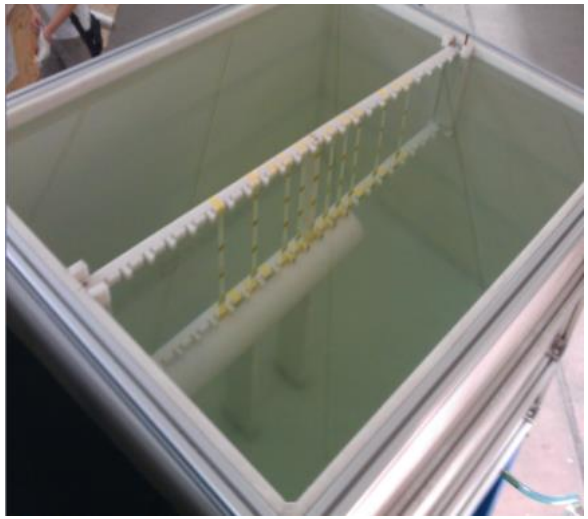


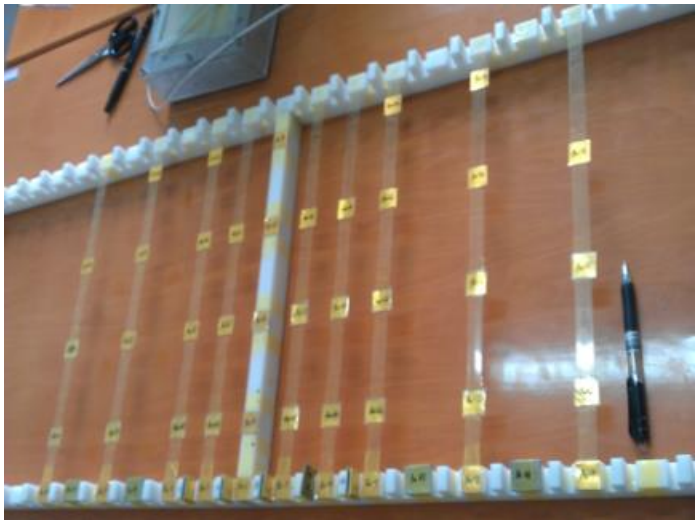


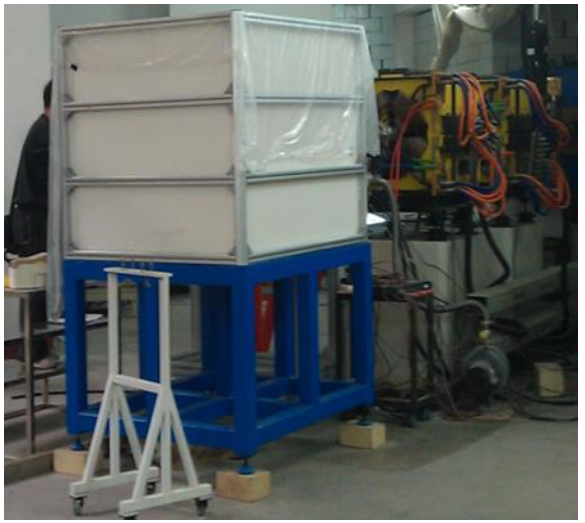


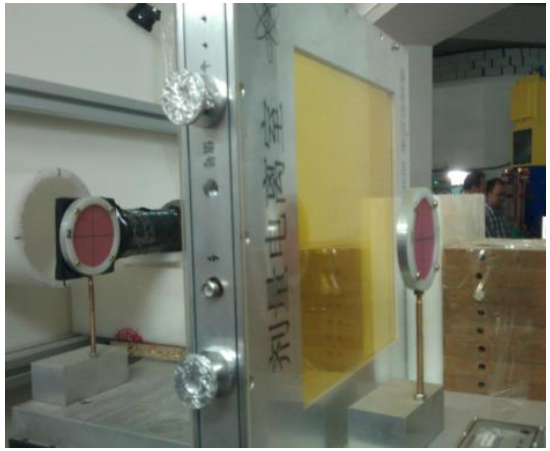


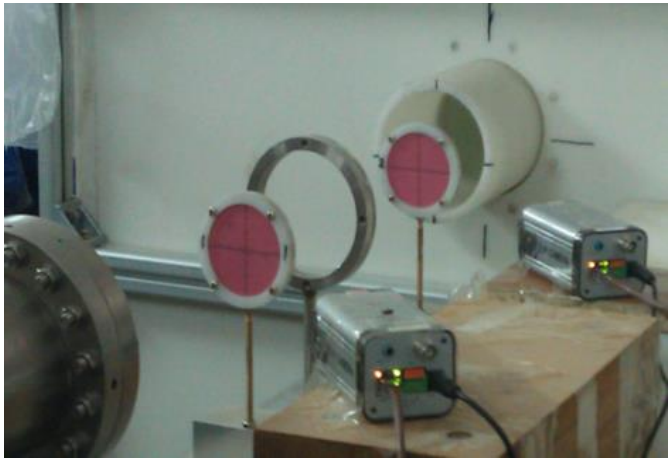
400 AMeV 12C + Pb experiment (neutron activation method)











Results for radioactivity

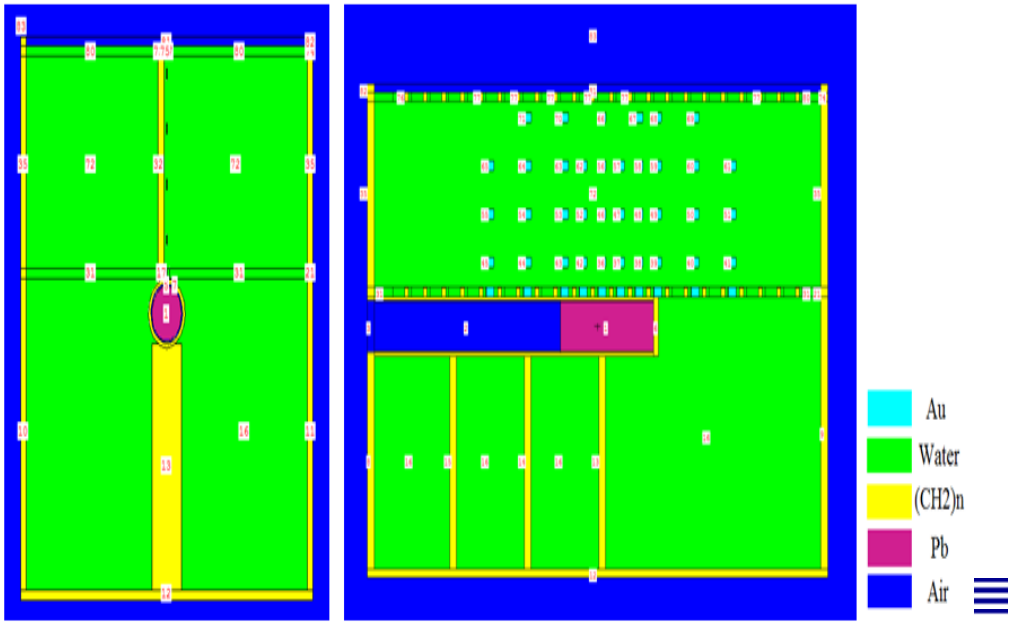
Activation foil arrangement

束流条件：
1. 能量：400MeV/u C束；
2. 脉冲宽度：约5s；
3. 脉冲重复周期：约20s；
4. 辐照时间：22小时；
5. 加速器终端：PISA；

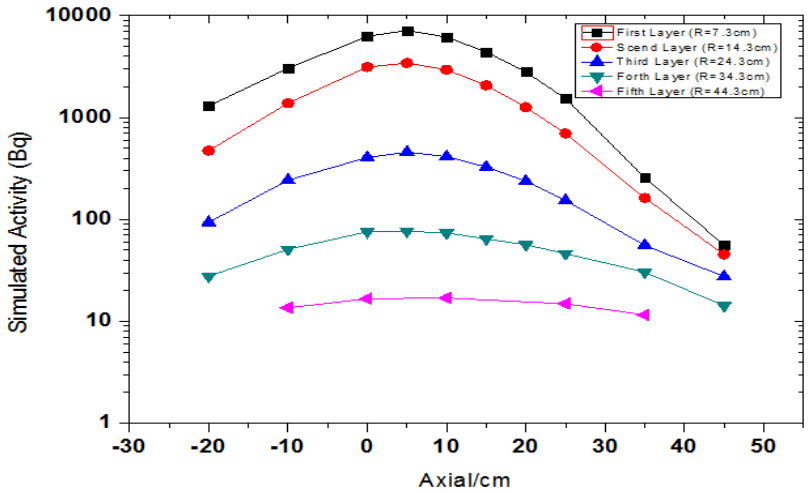
水浴盛器：长120cm，宽96cm，高100cm；

铅靶规格：直径10cm，长度25cm；

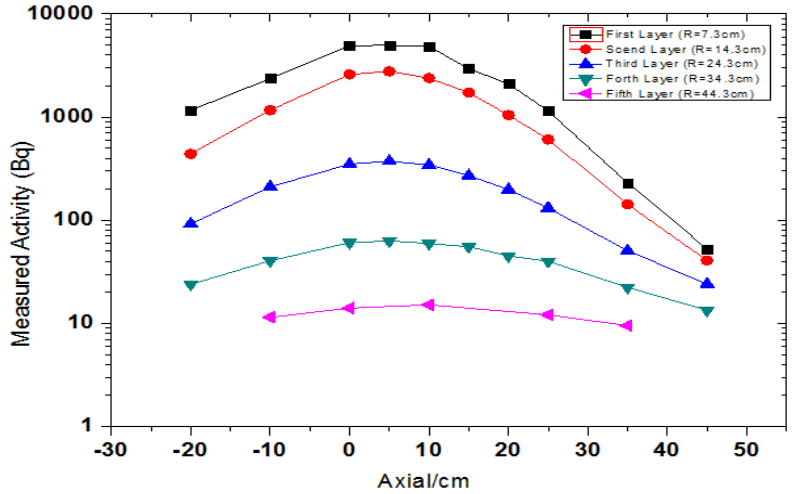
Au活化片：1. 体积：2×2×0.004cm^3；
2. 数目：45片；



MCNPX simulation



Experimental data



Thank you for your attention !
Comments and suggestion welcome !