中国科学院高能物理研究所
Institute of High Energy Physics Chinese Academy of Sciences

Status of China Spallation Neutron Source

Tianjiao Liang

On behalf of CSNS Team

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Outline

- CSNS project overview
- Status of civil constructions
- Progress of accelerator system
- CSNS target station and instruments
- Closing Remarks

Institute of High Energy Physics

- Institute of Modern Physics（predecessor of IHEP）: established at 1950
- Institute of High Energy Physics: independent Institute for Particle physics at 1973

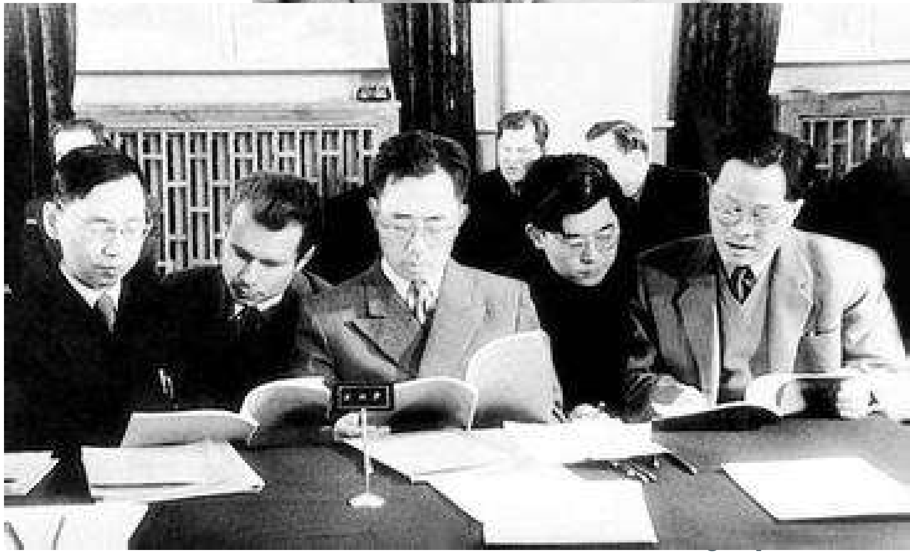
→ Comprehensive and largest fundamental research center in China

  - 1500 employees
  - 500 PhD Students and 60 postdoctors

- Goal of IHEP:
  - International center of particle physics
  - Multiple discipline research center based on large scientific facilities （neutron/synchrotron).

Wang Ganchang 1907-1998

- One of the founders of JINR
- Deputy director of JINR (1958-1960)
- Academician of CAS
- Worked at the Veksler & Baldin Lab. Of high energies of JINR from Sep. 1956 to Dec. 1960
- Discovery of anti-sigma minus hyperon at JINR



Tang Xiaowei 1931-

- Academician of CAS
- Worked at http://t12.baidu.com/it/u=3437736242,3041320908&fm=58the Dzhelepov Lab. of Nuclear Problem of JINR from Oct. 1956 to Dec. 1959
- Development of total absorption Cerenkov Counter & sampling electro-magnetic calorimeter at JINR

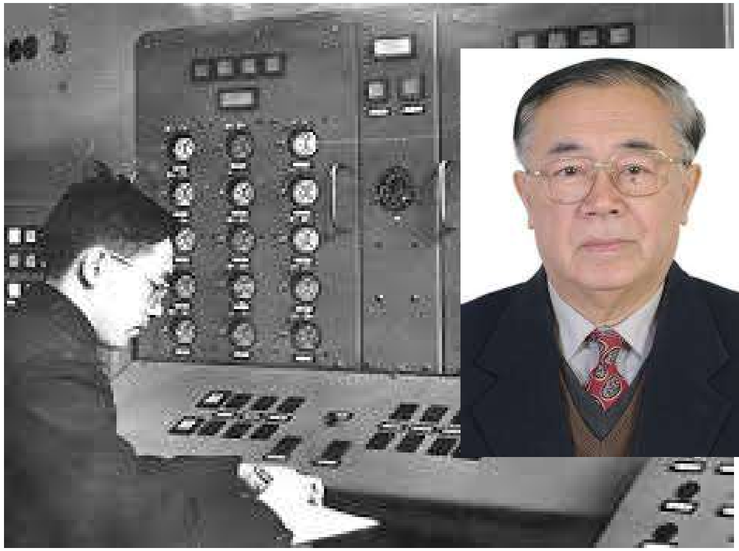
Ю.Д. Прокошкин, Тан Сяо-вэй: Измерение энергии электронов и гамма-квантов счетчиком с малой эффективностью, Приб. и тех. Экспер., 3(1959)32.

Ю.Д. Прокошкин,Тан Сяо-вэй: Ливни, образованные позитронами с энергей от 100 до 400MeV. ЖЭТФ,36(1959),10.

A.Dunaitsev, Y. Prokoshkin,X.W.Tang:π^- star detector, Nucl. Instr. Meth.,8(1960)11.

В.Вишияков, А. Тяпкин,Тан Сяо-вэй: Низковольтные галогенные счетчики, Усп. Физ. Наук, 72(1960)133.

Wang Naiyan 1935-



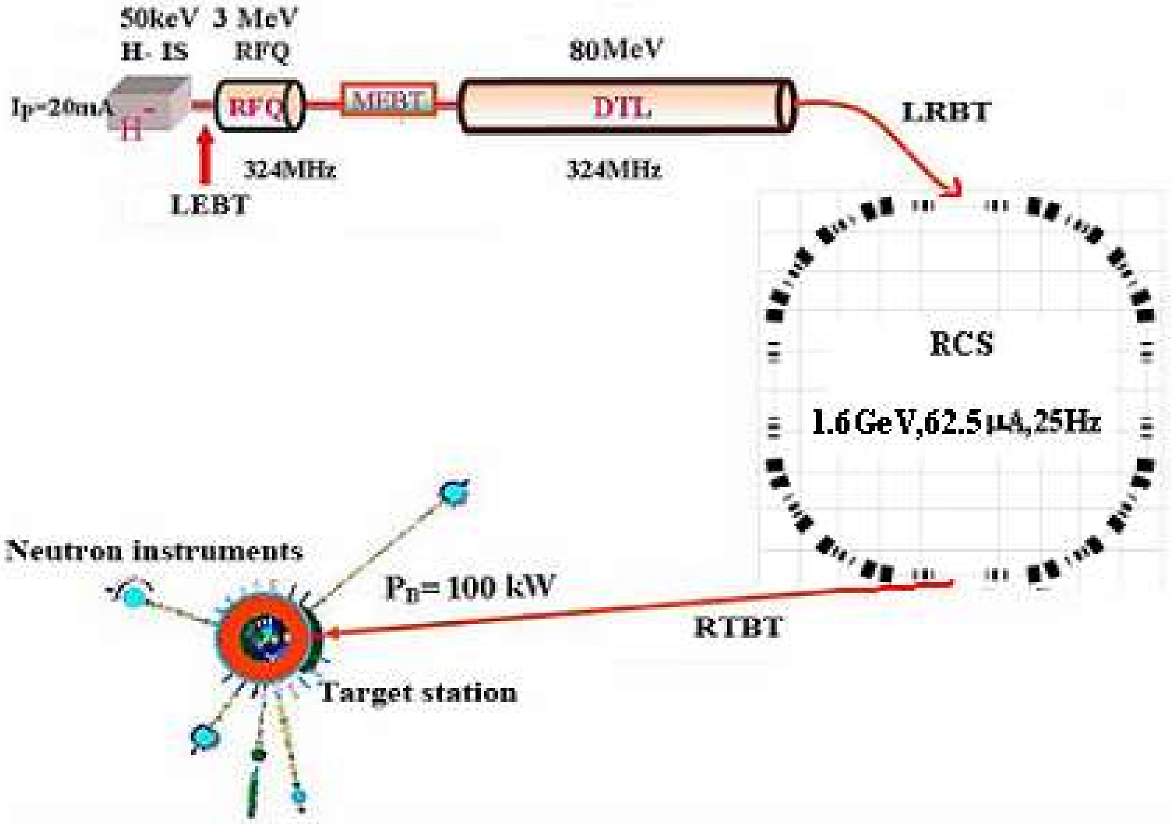
- Academician of CAS
- Worked at the Frank Lab.of Neutron Physics of JINR from 1959 to 1965
- Chairman of China Nuclear Society 2001-2009

Wang Shiji 1932-

- Academician of CAS
- Worked at the Frank Lab. Of Neutron Physics of JINR from 1959 to 1964

CSNS Project Overview

Chinese Spallation Neutron Source (CSNS)



	CSNS-I	CSNS-II
Beam power (kW)	100	500
Repetition rate (Hz)	25	25
# of Target	1	1
current (μA)	62.5	312
beam energy (GeV)	1.6	1.6
Linac energy (MeV)	80	250

Site: Dongguan, Guangdong
IHEP in charge the project,
in cooperation with Inst. of Physics

Design Philosophy

- Build facility within the approved budget and time schedule
  - phase-I budget 1.82B CNY (~US$281M)+marching fund
  - 6.5 year construction duration
- Build advanced facility with upgrade potential: 100kW beam power at phase I (with minimum initial cost, lower energy linac + high energy RCS), expandable to 500kW at Phase II (Using SC cavities to increasing energy of Linac to 250MeV, R&D is finished)
- Adopt proven technology to reduce risk
  - first high-power proton beam facility in China
  - high operational reliability for user facility
- Develop domestic technology to control cost
  - keep final fabrication in China as much as possible
  - closely collaborate with world leaders

Strong supports from the local governments

- 500M RMB match fund
- Land of 0.67km^2：0.27-km^2 land for phase-I. slope protection
- 3.6-km dedicated road to the site was finished.
- 110kV/10kV transform station: ready
- in charge of the management of civil engineering and will take care the deficit of the budget of the civil engineering if any.
- 50 min. by car from the Shenzhen Airport; 70 min. by train from Hongkong+25min. of car.

Key Milestones

Feb. 2001	Idea of CSNS discussed
June 2005	proposal approved in principle (CD-0)
Jan. 2006-Dec. 2013	Prototyping R&D
Dec. 2007	proposal reviewed
Sept. 2008	proposal approved
October 2009	feasibility study reviewed
February 2011	feasibility study approved (CD-1)
May 2011	preliminary design approved (CD-2)
Sept. 2011	construction start (CD-3)
May 2012 – June 2016	civil construction
Sept. 2011–May 2017	component fabrication
Oct. 2014- Sept. 2017	installation & tests
Jan. 2017	RCS commissioning start
Sept. 2017	First beam on target
March 2018	project complete/operation start (6.5 years)

CSNS: Dongguan Branch of IHEP

- CAS opened 400 positions for CSNS.
- About 270 persons were hired for the Dongguan Branch.
- There about 78 physicists and engineers from IHEP working at Dongguan, most of them are senior, backbone.
- IHEP Beijing provides strong supports to the construction, commissioning and research in CSNS.

Status of Civil Construction

Layout of CSNS

The civil construction near finish

June, 2012

March, 2016

Civil Constructions

Linac surface building

Ring Building

Target building & Experimental halls


Testing Building 1


Testing Building 1


Testing Building 2


Testing Building 2


Central Utility Building


Supporting Building

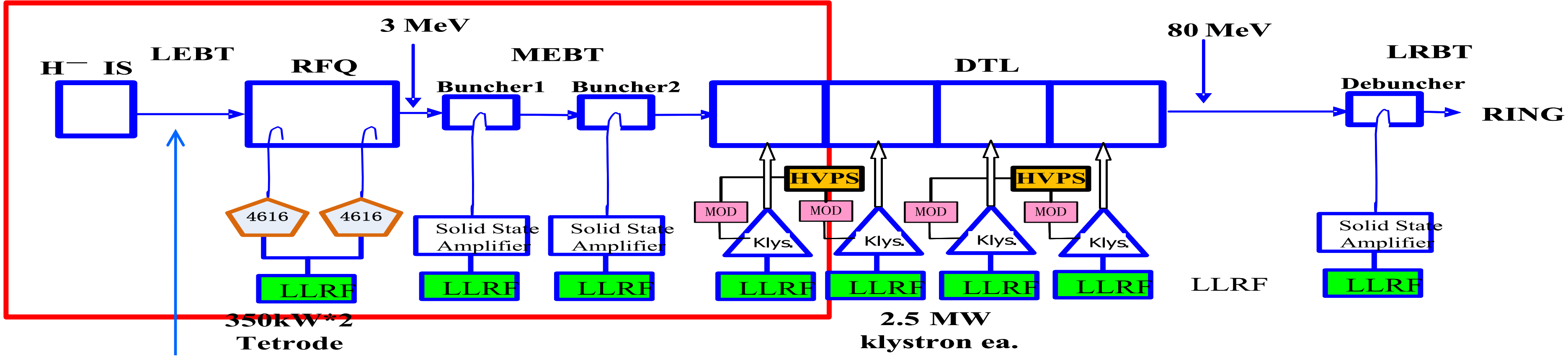

CSNS Campus

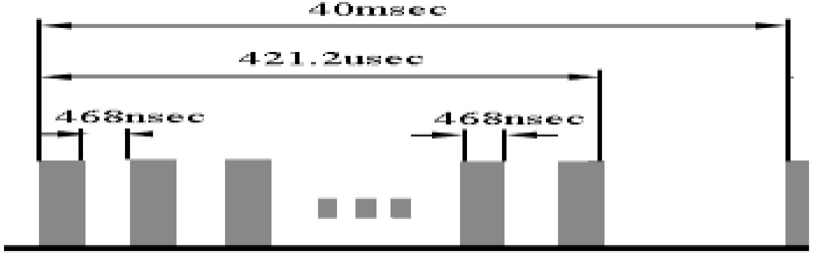
Birds View of CSNS

May, 2016

Progress of Accelerator System

Linac Design





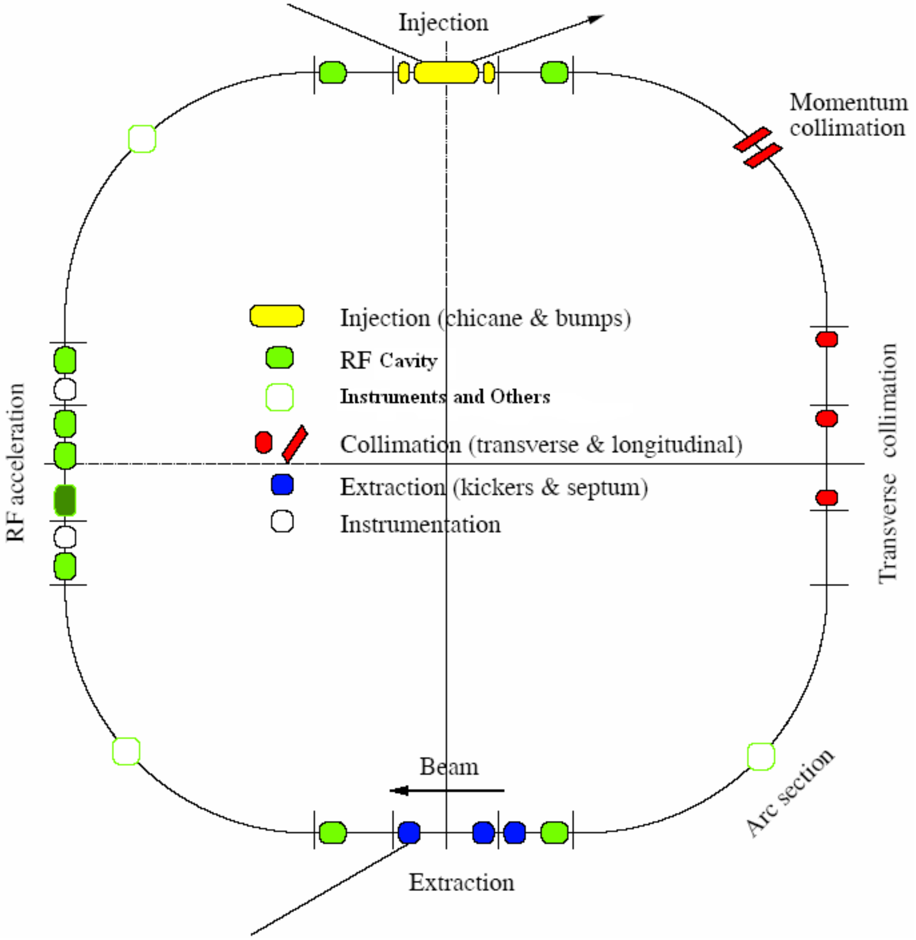
EMQ option in FFDD lattice for DTL

Electrostatic chopper in LEBT

	Ion Source	RFQ	DTL
Input Energy（MeV)		0.05	3.0
Output Energy(MeV)	0.05	3.0	80
Pulse Current (mA)	20/40	20/40	15/30
RF frequency (MHz)		324	324
Chop rate (%)		50	50
Duty factor (%)	1.3	1.05	1.05
Repetition rate (Hz)	25	25	25

RCS Design

- Lattice of 4-fold symmetry, triplet.
- 227.92m circumference.
- Four long straight sections for injection, acceleration, collimation and extraction.
- 24 main dipoles with one power supply.
- 48 main quadruples with 5 power supplies.
- Ceramic vacuum chambers for the AC&pulsed magnets.
- 8 RF ferrite loaded cavities to provide 165 kV.

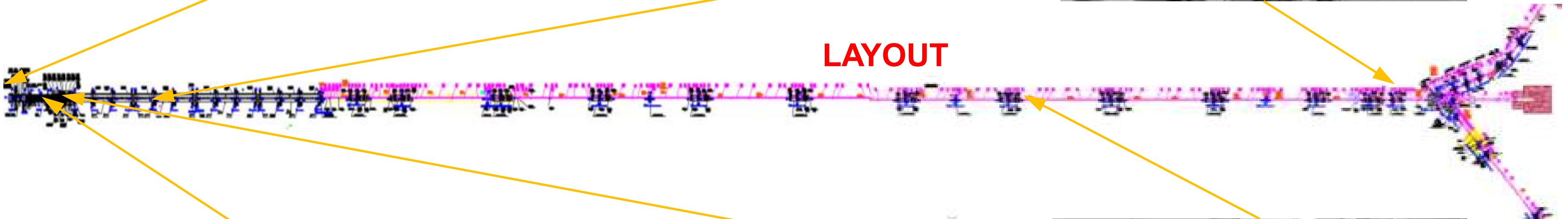


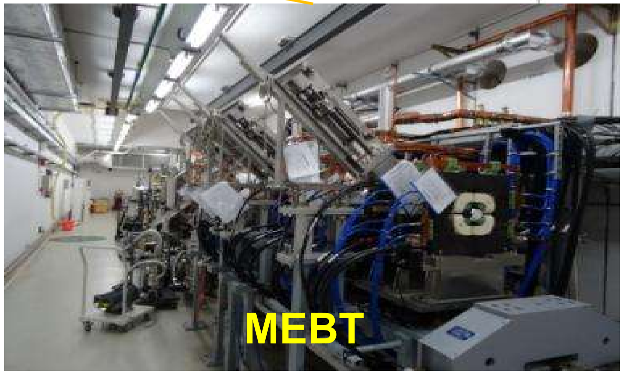
Linac Tunnel

Ring Tunnel

Linac Accelerator Installation

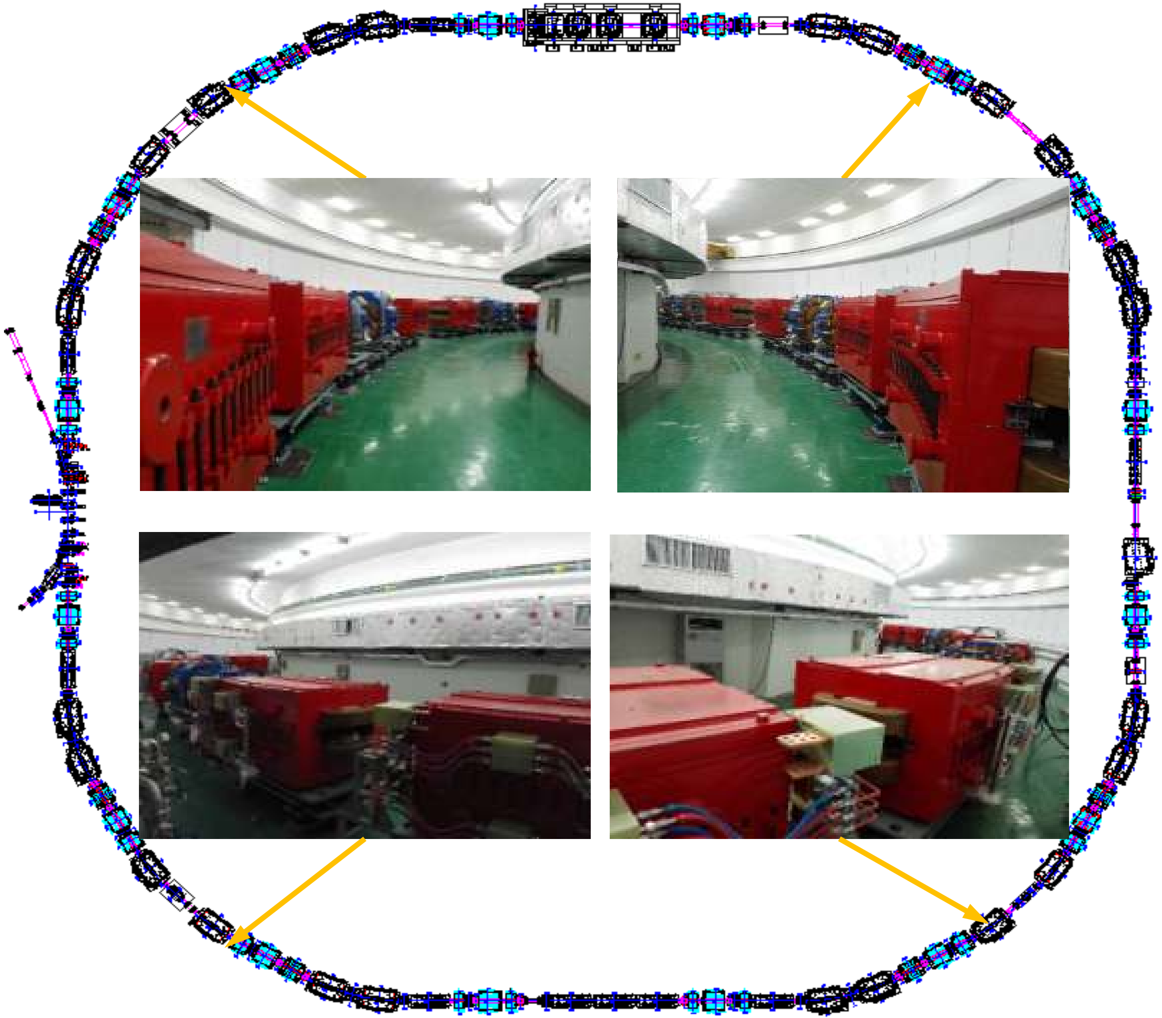
Finish commissioning with beam by Dec. 30,2016





RCS Installation

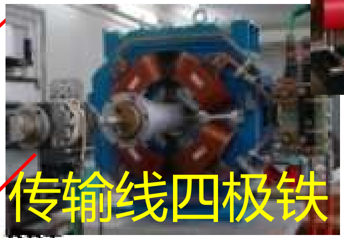
Complete cold commissioning by Nov. 30,2016

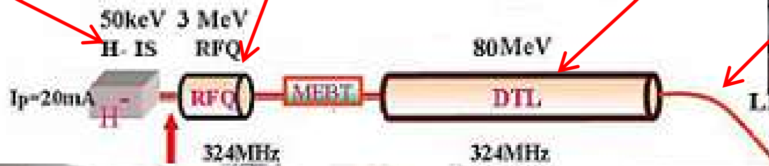


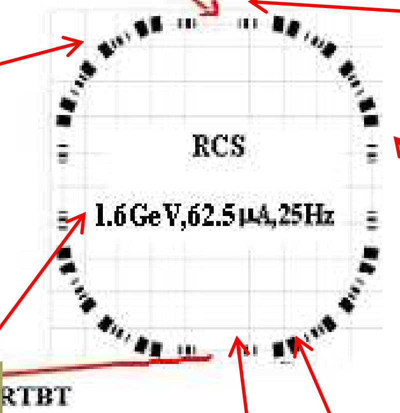

负氢离子源


RFQ及其功率源


DTL及其速调管


传输线四极铁






注入剥离膜


主磁铁电源

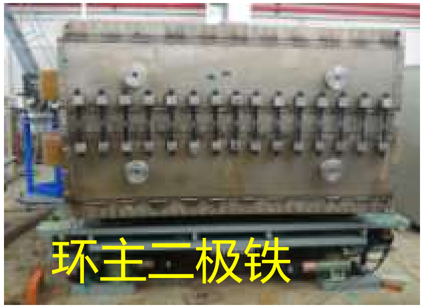

环主四极铁


主准直器


环高频腔


引出冲击铁

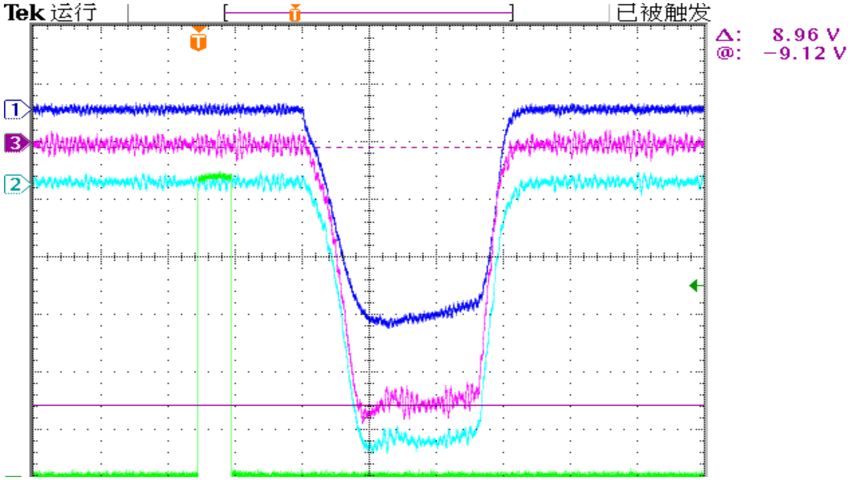

环高频功率源


环主二极铁

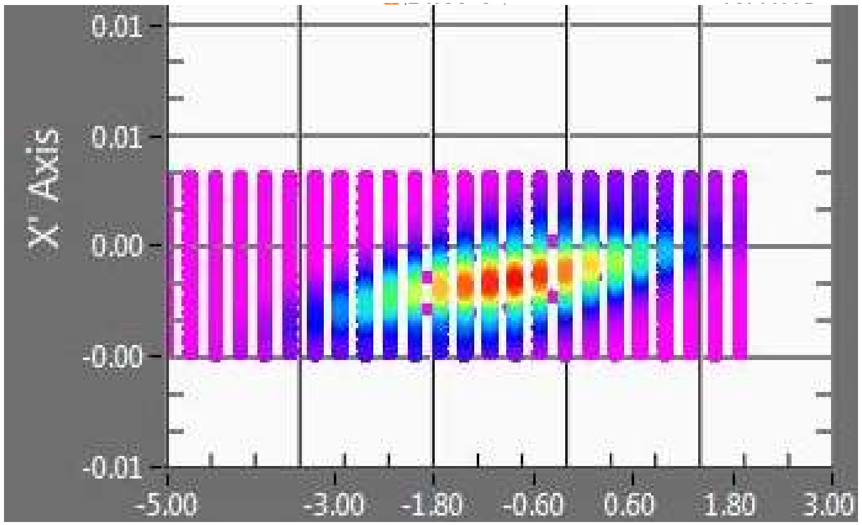
加速器设备研制顺利

Linac Front End Commissioning

- Front end installation completed 6 Apr. 2015,
- First H- beam from RFQ 21 Apr. with peak current of 28mA at 3MeV.
- The front end commissioning finished 13 July, and reached the design specification.



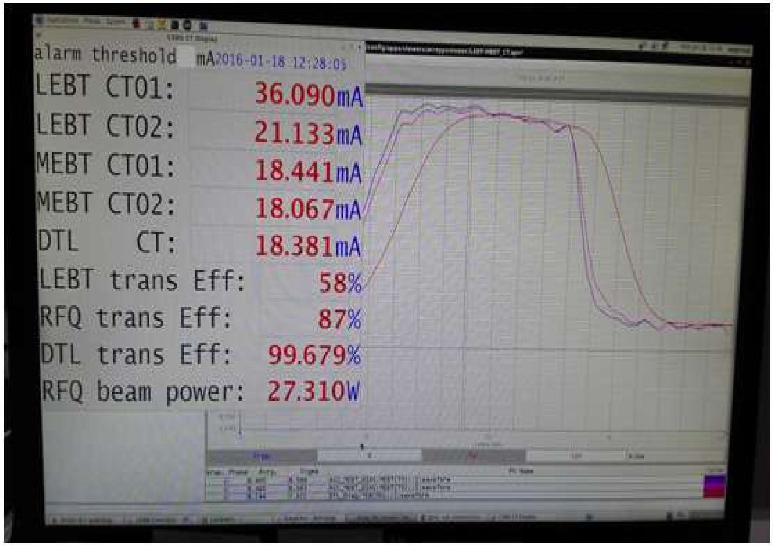
BEAM signal measured by CT at MEBT



The emittance measured at MEBT

DTL-1 Beam Commissioning

Jan.2016 negative hydrogen ion beam was successfully accelerated to the design energy of 21.6MeV with the first Drift Tube Linac. The peak pulsed current reaches 18mA, higher than the design value of 15mA. Almost all the beam go through the linac with 99.7% beam transmission rate.



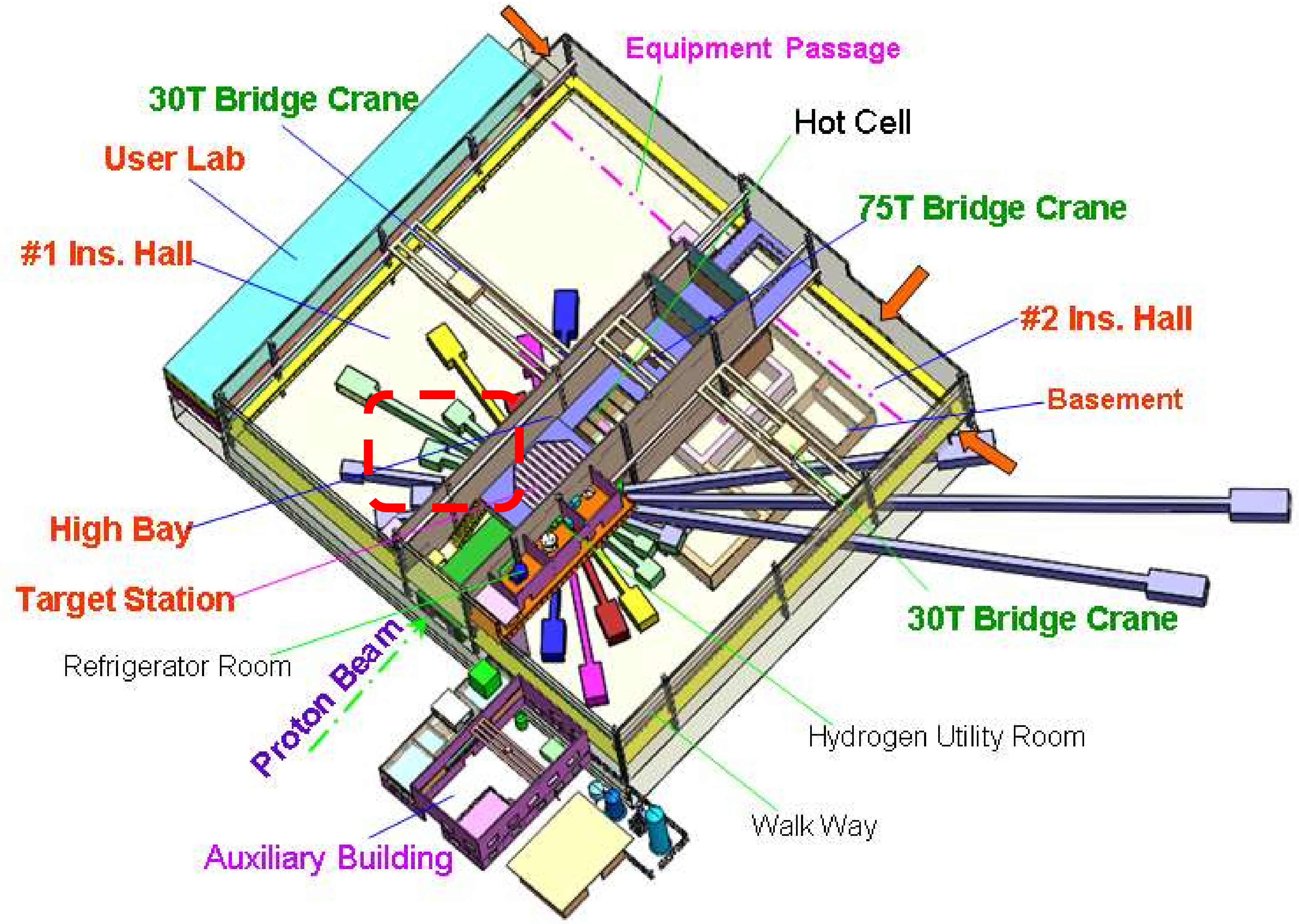
```
alarm threshold    mA2016-01-18 12:28:05
LEBT CT01:          36.090mA
LEBT CT02:          21.133mA
MEBT CT01:          18.441mA
MEBT CT02:          18.067mA
DTL     CT:         18.381mA
LEBT trans Eff:        58%
RFQ trans Eff:         87%
DTL trans Eff:     99.679%
RFQ beam power:    27.310W
```

CSNS target station and instruments

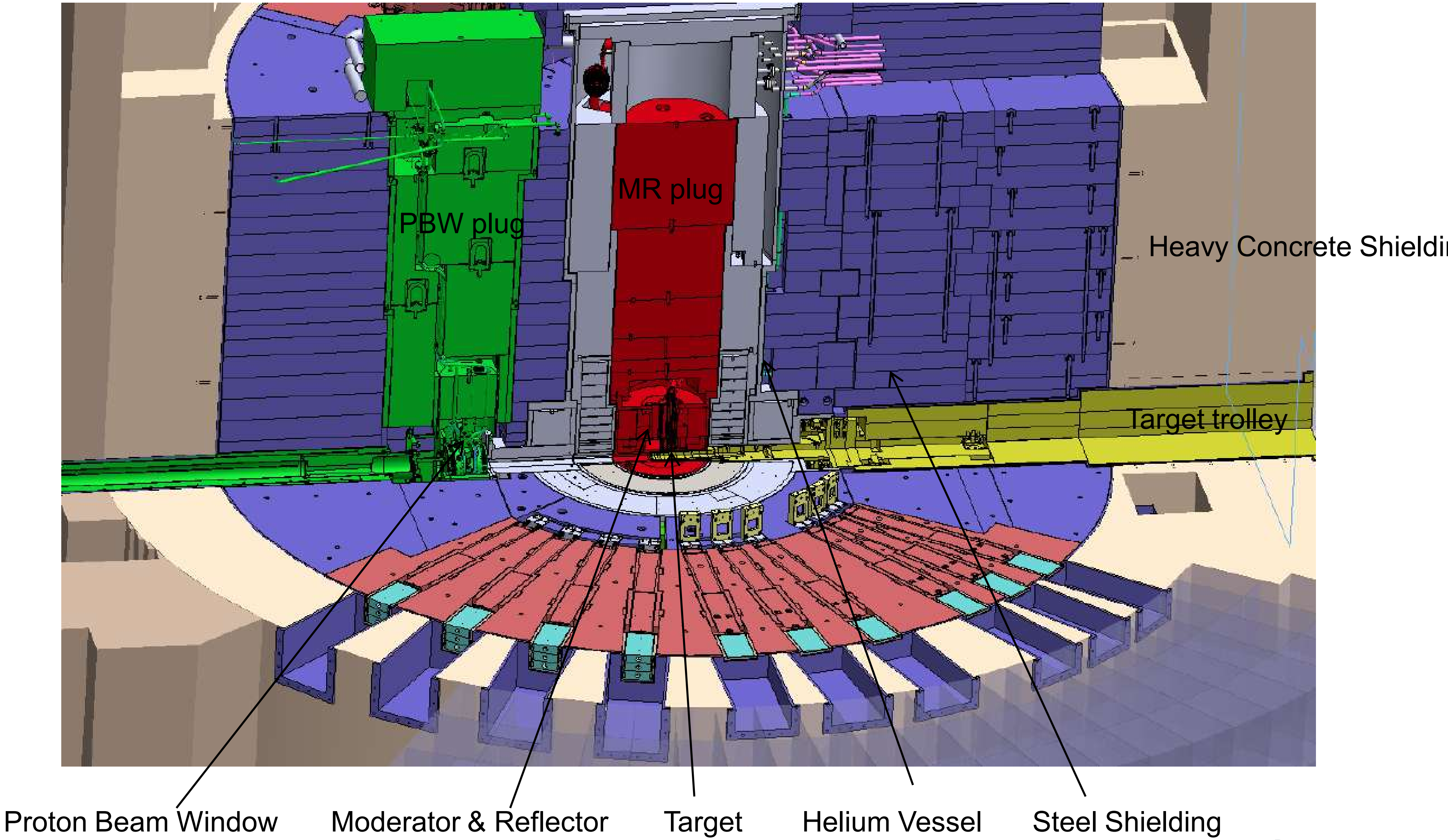
Major design consideration

- High neutron production
  - 1.6GeV proton beam; cladding W target; Be reflector; heavy water cooling (light water at beginning due to budget limit)
- Diverse neutron performance
  - 3 wings moderators: H_2O (300K, decoupled), H_2 (20K, decoupled+poisoned), H_2 (20K, coupled)
- High neutron utilization
  - compact configuration between TMR and bulk shielding; moderation by para-hydrogen; supermirror neutron guide; efficient position sensitive neutron detector with large coverage
- Optimization for 100 kW, but keeping upgrade capacity to 500 kW
  - Optimize the TMR for the beam power of 100 kW
  - Design shields with dose control < 2.5 μSv/h up to 500 kW
  - Embedded coolant pipes and tanks meet to requirement of 500 kW

Main design parameters



CSNS Target Station



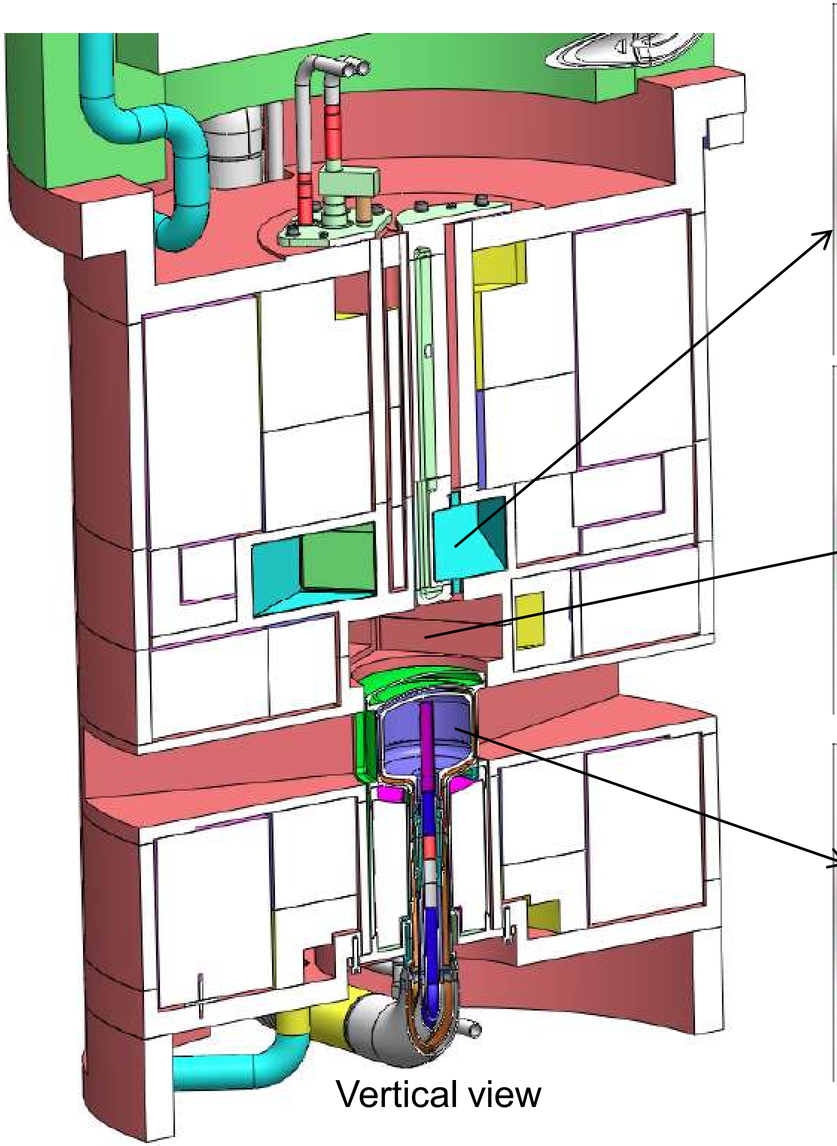
Shielding Installation 2015/10/20

Target station

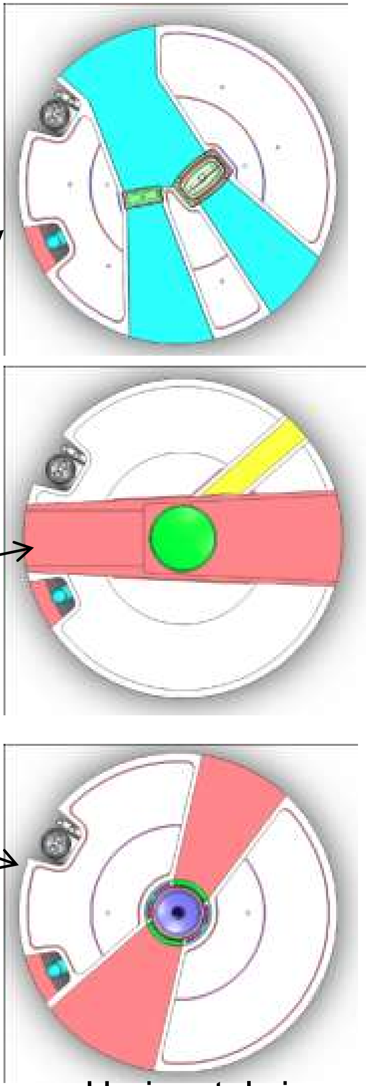
TMR maintenance: the horizontal target plug plus vertical MR plug, similar to the SNS/JPARC type.

- Feasible for 500 kW upgrade
- More compacted configuration between Target and Moderators/Reflector
- Small seal between trolley and helium vessel
- Separated room for liquid hydrogen system at the building roof
- High-bay to define a radiation control area for target station out from scattering hall

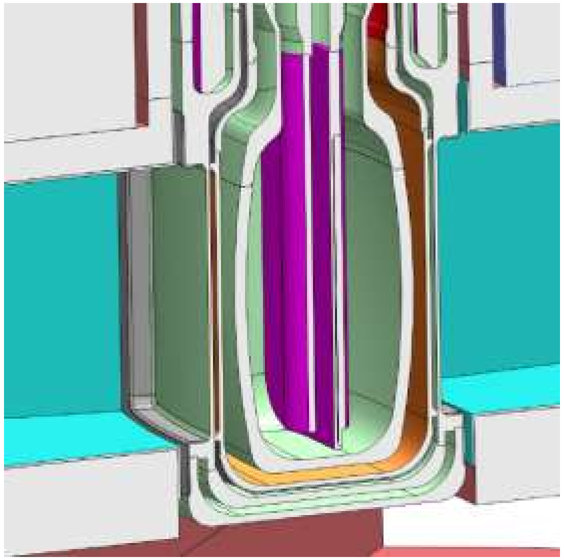
Engineering design of CSNS MR



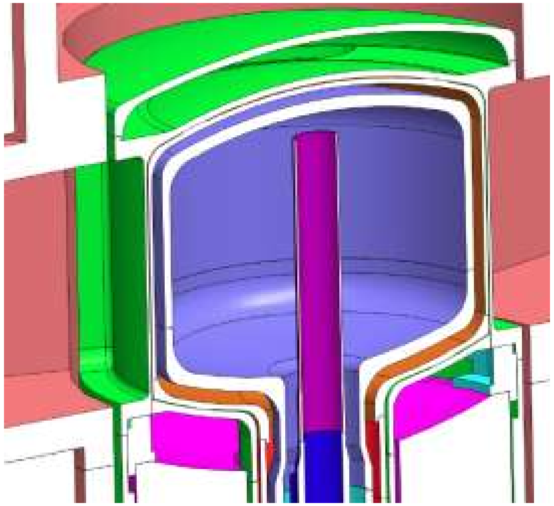
Vertical view



Horizontal view



Decouple & poison hydrogen moderator



Couple hydrogen moderator

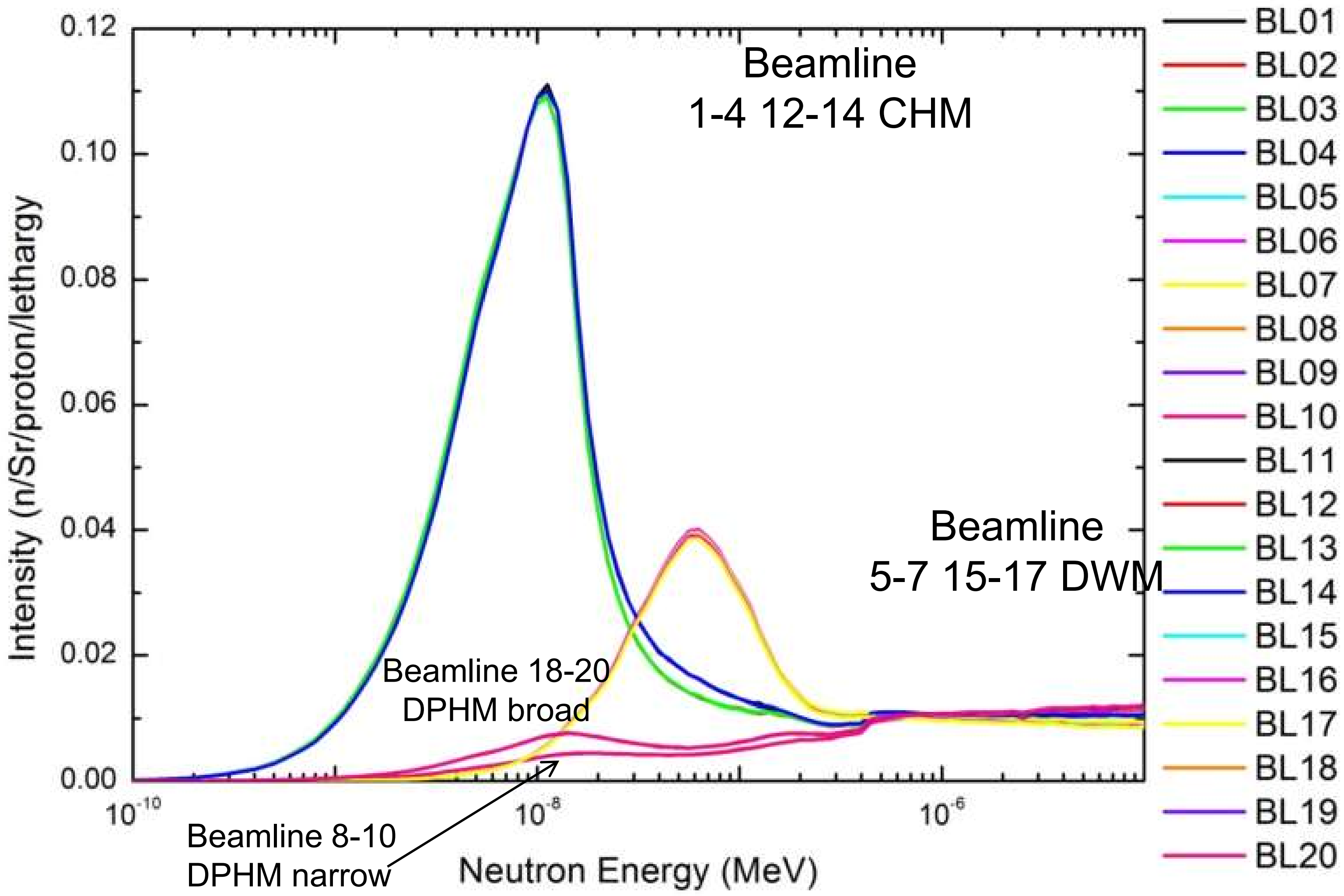
Baseline parameters of CSNS TMR

proton beam	energy	1.6 GeV
	beam footprint VXH	**40x120/60x160** mm(100/500kW)
	Beam profile	Gaussian, 2 sigma
target	material	Tungsten cladded by **0.3**mm tantalum
	length	570mm for W
	cross section VXH	**70x170 mm**
	coolant	D2O/H2O, 1.2mm channel
	target container	8mm SS316 (3mm for incident window)
CHM	hydrogen volume	Φ150x106mm 20K 100% para
	Hydrogen vessel thickness	**6mm** except **4mm** for view surface
	water premoderator thickness	20mm for target side 10mm other side
	view surface VxH	100x102.2 mm

Baseline parameters of CSNS TMR

DPHM	hydrogen volume	120x120x50 mm 20K 100% para
	hydrogen vessel thickness	**5mm**
	view surface VxH	100x102.2 mm
	poison position offset from center	5mm
	poisoner	Gd 0.2mm
	decoupler	Cd 0.5mm
DWM	water volume	120x120x50 mm
	water container thickness	4mm
	decoupler	Cd 0.5mm
reflector	Be reflector ((**S-200-F**))	Φ700x800mm
	Fe reflector (**SS316**)	Φ1000x1000mm
	coolant	D2O/H2O, **10%** volume fraction for Be reflector, **5%** for Fe reflector

Lethargy Spectra



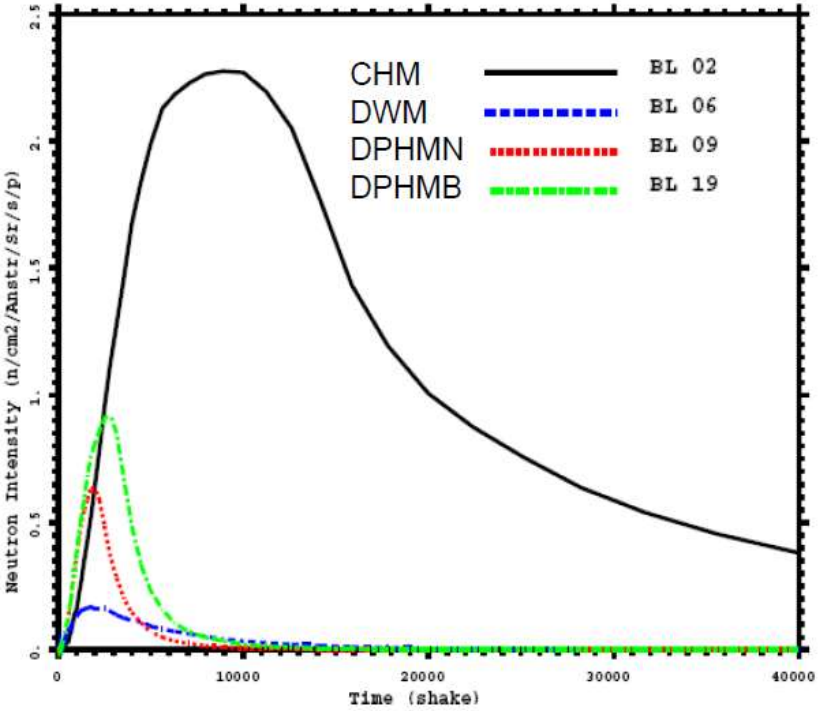
Beamline
1-4 12-14 CHM

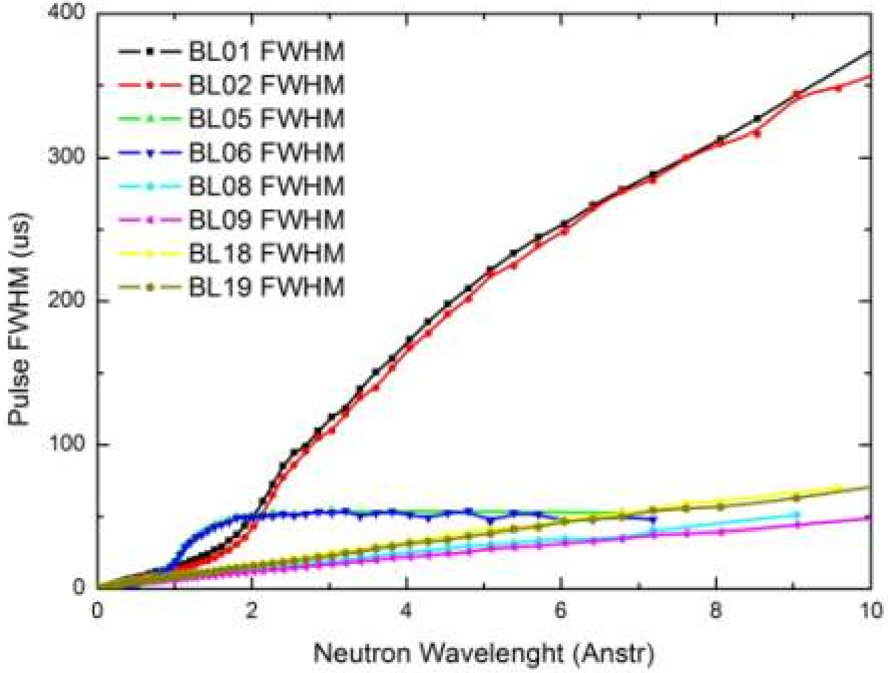
Beamline
5-7 15-17 DWM

Beamline 18-20
DPHM broad

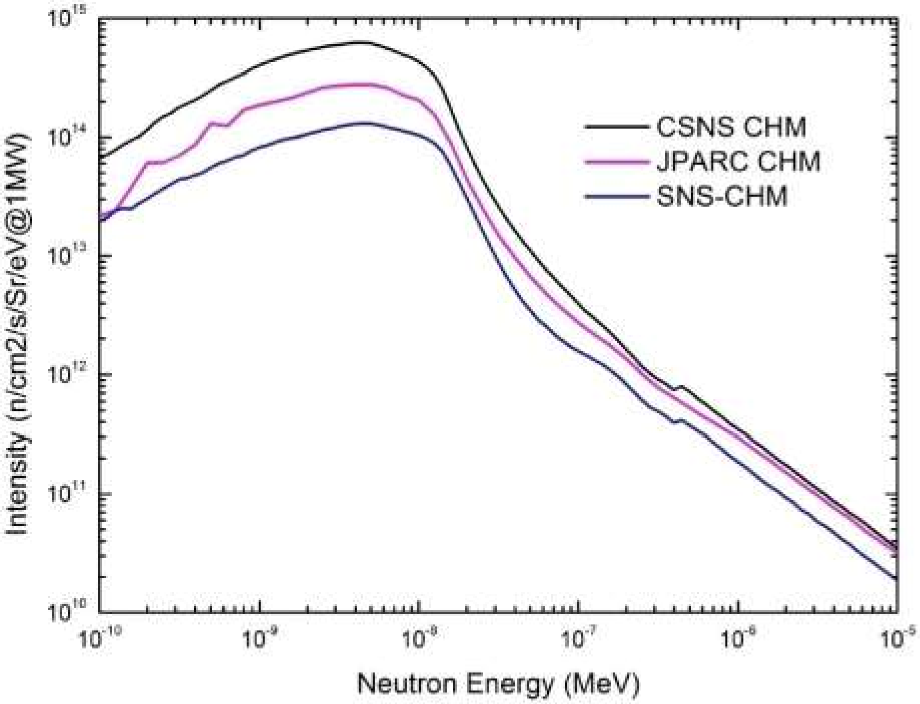
Beamline 8-10
DPHM narrow

Pulse shape @ 4A & pulse width

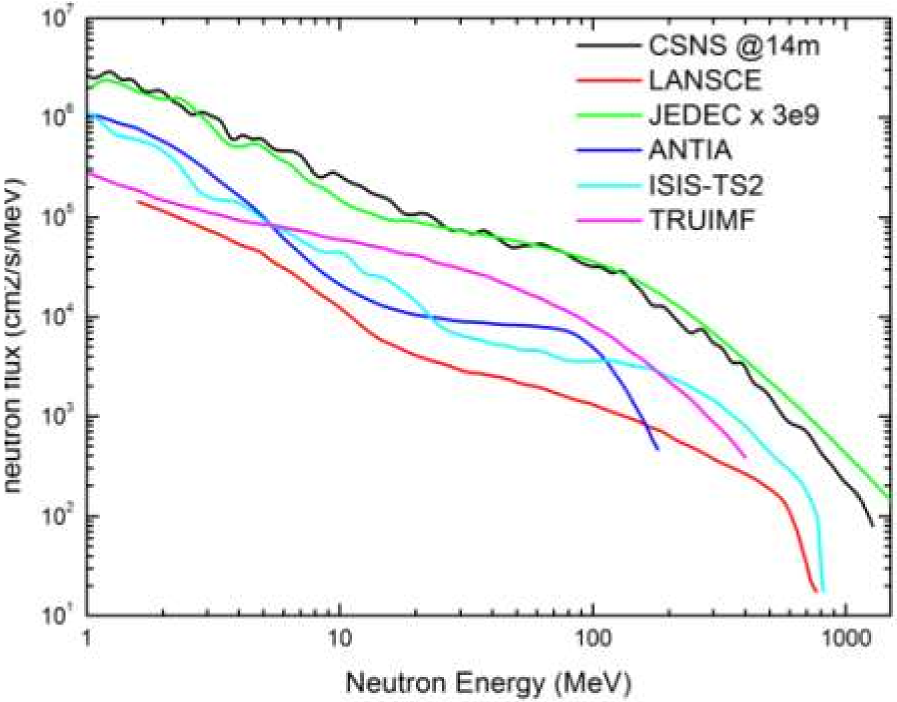




Neutronics performance

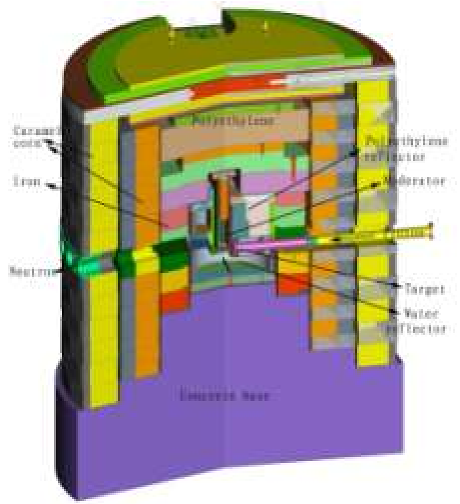


Couple Hydrogen Moderator spectra comparison (normalized to same proton beam power)



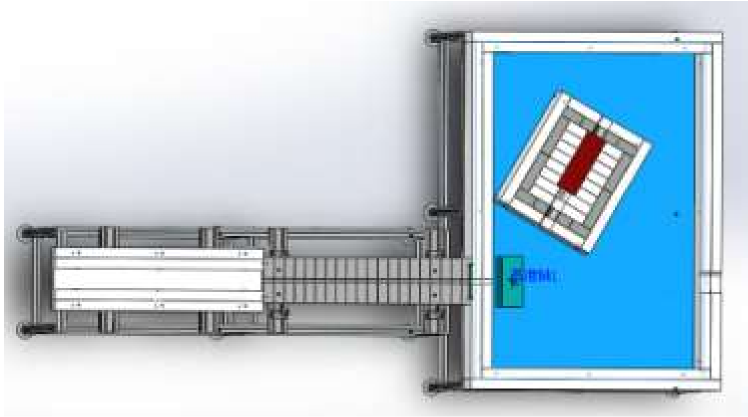
Atmospheric neutron spectra comparison

Test of neutronics measurement instruments

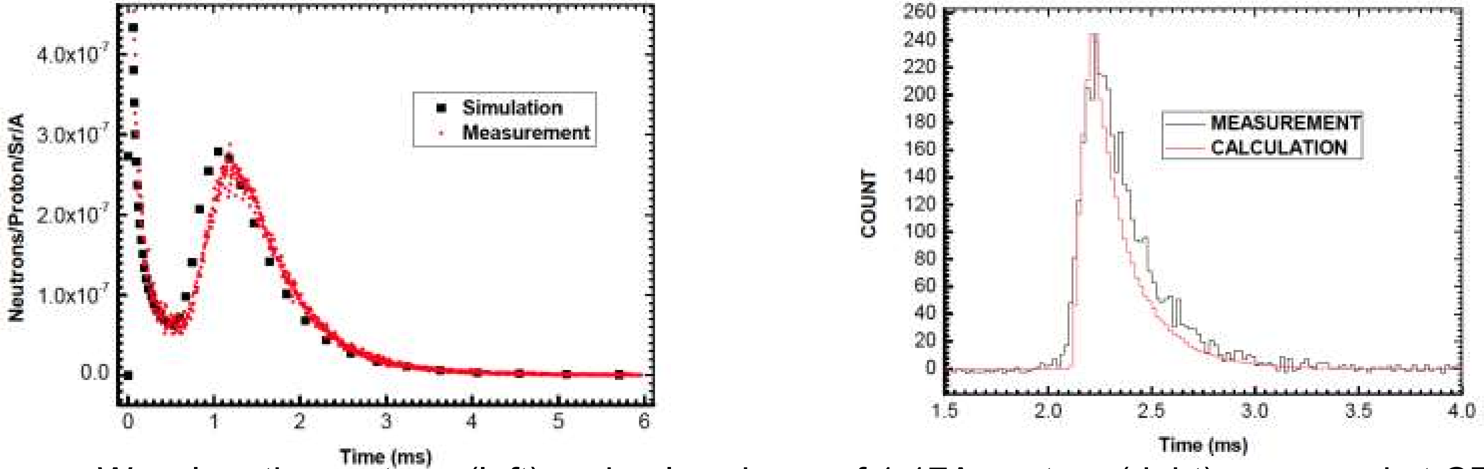


CPHS TMR layout

Neutronics test beamline



layout for pulse shape measurement



Wavelength spectrum (left) and pulse shape of 1.17A neutron (right) measured at CPHS

Target-moderator-reflector


CSNS target before welding


CSNS target after assembling


Coupled hydrogen moderator

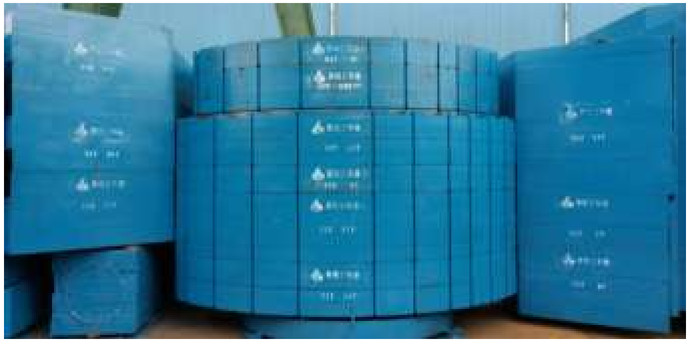

Beryllium reflector


Reflector vessel under fabrication

Shielding system

- The first set of **shutter** had passed acceptance check in January, 2015.
- The **fixed shielding** below the helium vessel and the **shutter base plates** had been installed and passed the acceptance check in April, 2015.
- All other **fixed shielding** had passed acceptance check in September, 2015.

The first set of shutter



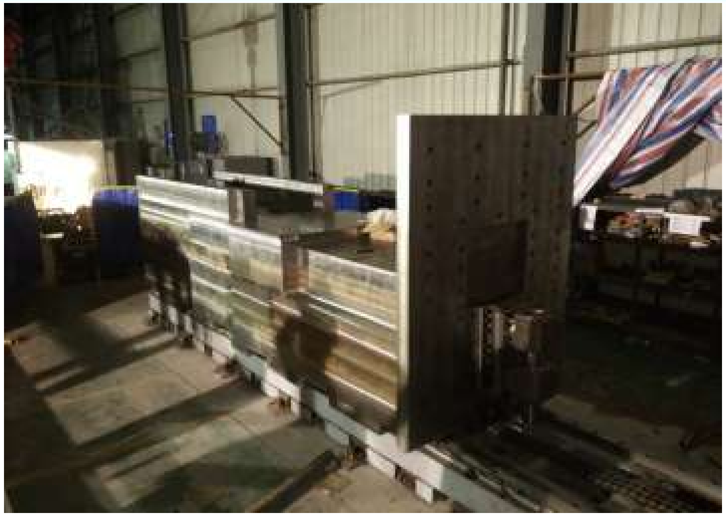
Pre-installation of fixed shielding

Machining

site installation of fixed shielding

Installation of shutter base plate

Helium vessel were manufactured and installed on site.



Target Trolley under fabrication

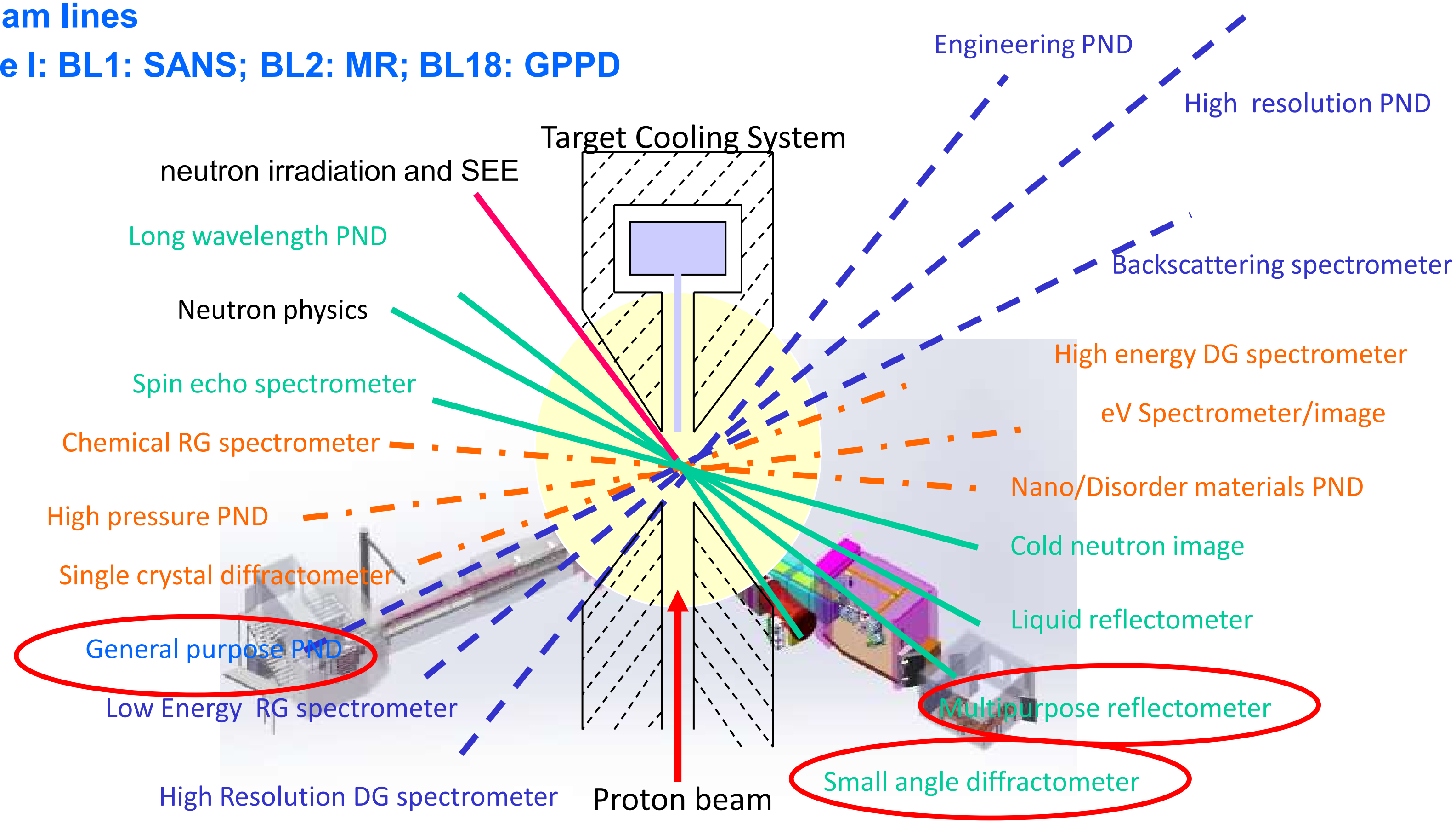
Neutron Shutter installation

Pressure vessel of TS cooling system accepted

Cryogenic equipment installation

Neutron instruments

- **20 beam lines**
- **Phase I: BL1: SANS; BL2: MR; BL18: GPPD**



(PND: Powder Neutron Diffractometer; RG/DG: Reversal/Direct Geometry)

Moderator：

- - - D+P, LH2 (20K）
—— C,LH2 (20K)
— · · D, Water (300K)

Neutron instruments

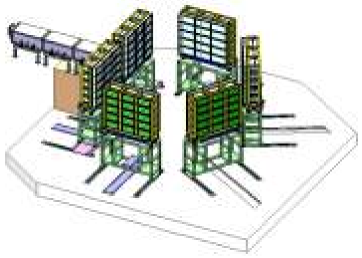
- **Engineering design of three day-one instruments fixed. Control and data management/analysis are partially tested.**
- **Detailed time schedule of instrument construction and installation has been determined.**
- **New state-of-the-art instruments**: still looking for other fund
  - the 13th national five-year plan
  - the probability to collaborate with local institutes and universities
- **User meeting:**
  - Annual national user meeting with training course.
  - Workshops on day one experiments every year

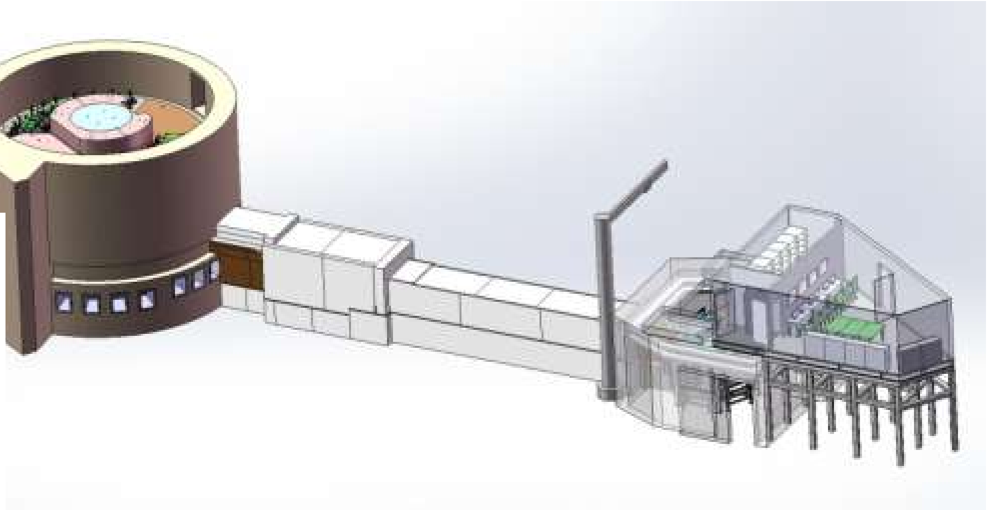
1. General Purpose Powder Diffractometer

Performance:

- For most users to determine crystallographic and magnetic structures in general purposes
- Best resolution Δd/d ~ 0.2 %.
- ~ mimutes for a diffraction histogram used by Rietveld refinement on ~ 1-g-weight sample
- Easily loading the ancillary equipment such as cryostat, furnace and pressure cell

Moderator		DPHM（20 K）
Bandwidth(Δλ)		4.5 Å
Max. Beam Size		40(h)×20(w) mm
Flux at sample position		~10^7 n/cm^2/s
Best Resolution(Δd/d)		0.2 % at 2θ=150°
Guide		Taper focus, m=3
Source to sample distance L1		30 m
Sample-detector distance L_2	2θ=150°	1.5 m
	2θ=90°	2.0 m
	2θ=15°	3.8 m



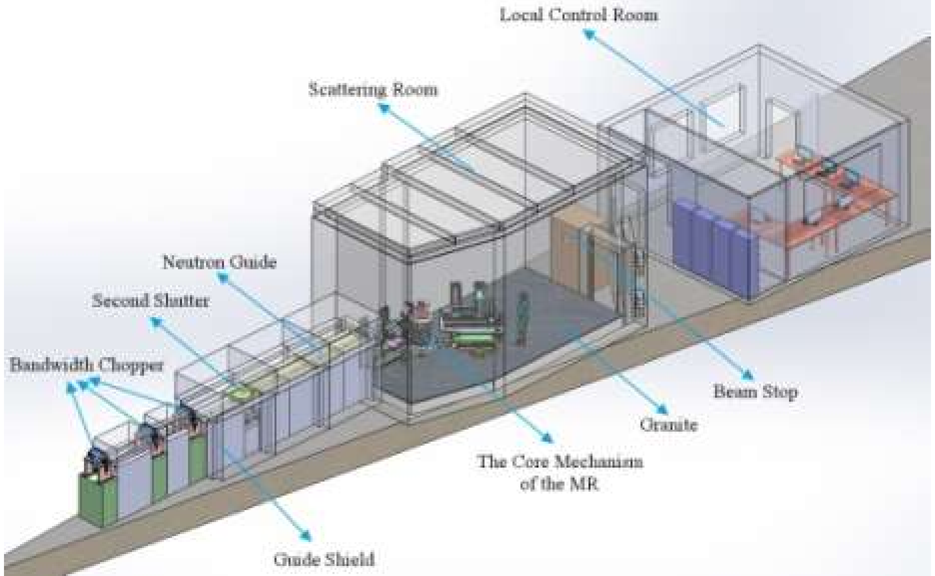


2. Multiple Purpose Reflectometer

Moderator	CHM (20 K)
Bandwidth（Δλ）	6 Å
Guide	Bender+Sraight+Taper $40 \times 60 \rightarrow 20 \times 30$ mm^2
SS distance L1	19.5 m
SD distance L2	2 m
Sample table	6-axis movements
Polarizer/analyzer	Supermirror type
Detector	2D position-sensitive detector Position resolution: 2 mm

Performance:

- **Vertical sample geometry: solid film**
- **Reflectivity/diffraction**
- **Best resolution ΔQ/Q < 1%**
- **Polarizing analysis for spinoelectronics.**
- **In-suit study on growing films**
- **In-suit MOKE magnetic analysis**
- **Off-specular scattering**
- **Grazing-incidence small-angle scattering**

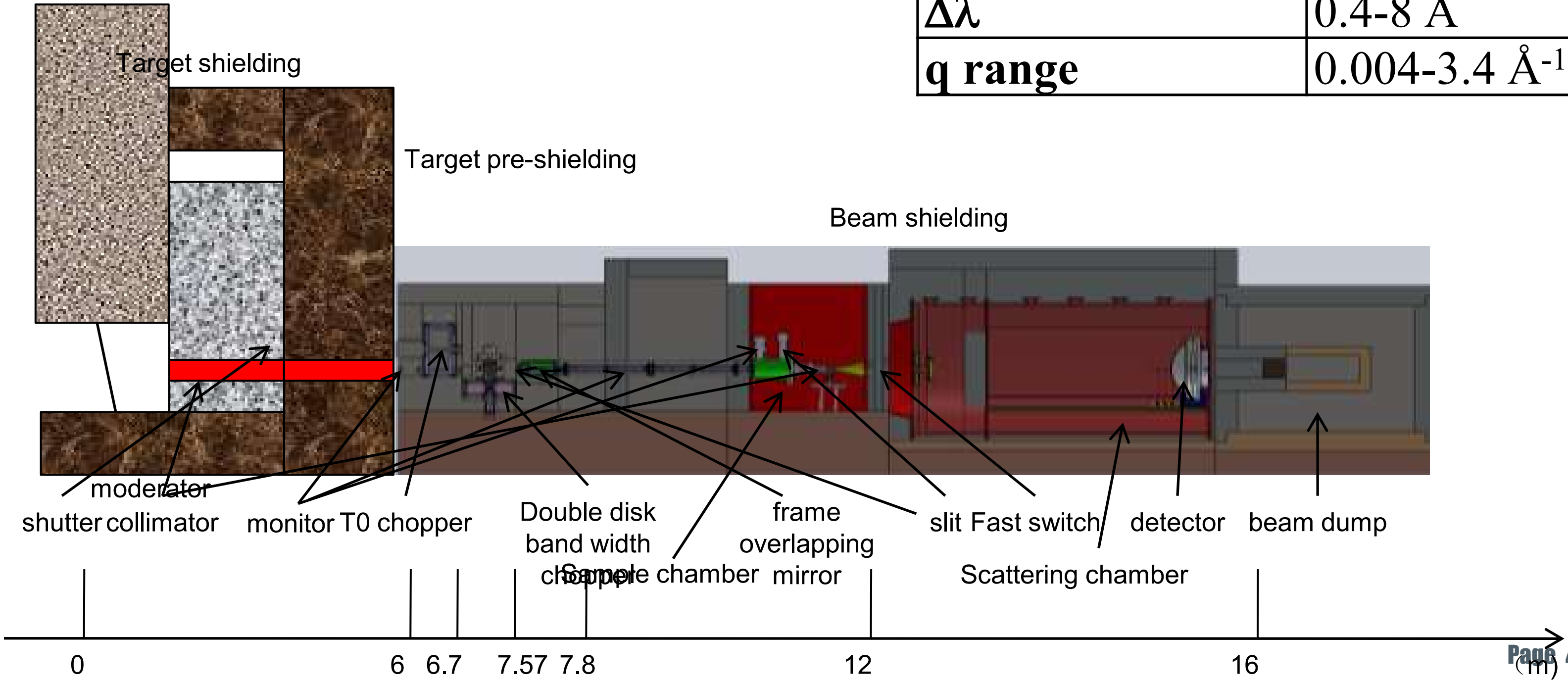


3. Small Angel Neutron Scattering

Performance:

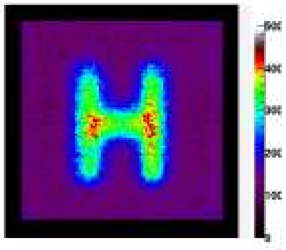
- Reliable SANS data between 0.01~0.5 Å^{-1}
- Instrument resolution better than ~30% around Q_{min}
- Good dynamic range, sample space
- Variable sample size

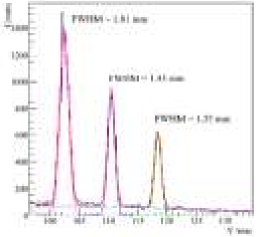
Moderator	CHM（20K）
MS distance	14 m
SD distance	1~5 m
Detector	
Effective area	50×50 cm^2
Resolution	1 cm (FWHM)
Δλ	0.4-8 Å
q range	0.004-3.4 Å^{-1}



^{3}He-MWPC- 200mm*200mm

- Active area: 200mm*200mm
- Detection efficiency: ~50%@ 2Å
- Pixel size: 2mm*2mm
- Max Counting rates: 10^5 n/s

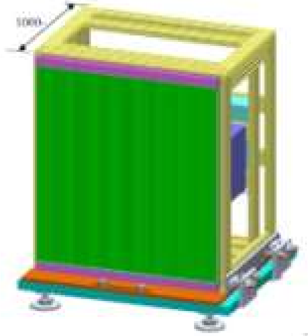




- Neutron beam test @ CARR
  - Position resolution(FWHM)
    X : 1.23mm, Y: 2mm
- The detector will be ready by the end of October 2016

^{3}He tube-LPSD for SANS

Effective area	1m×1m
Diameter	8mm
Effective length	1000mm
Detection efficiency	>60%@1.8Å
Maximum counting rate @ single tube	10 kHz
Pixel size	<1cm×1cm
Time resolution	2μs

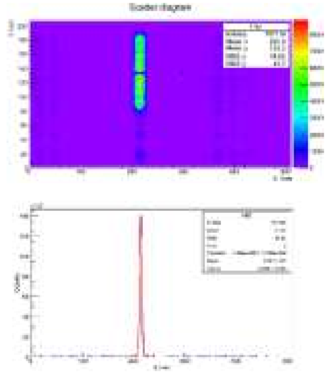


- 3He tube will arrive in July, 2016
- The design of HV system finished and be tested.

Shifting Scintillator Neutron Detector (SSND)

- Module size 500mm × 250mm
- Pixel size is 5mm × 10mm
- Detection efficiency: over 50%@ 2Å

Testing with neutron beam @ Mianyang

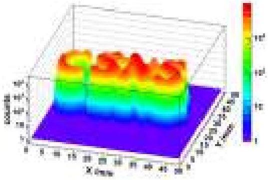


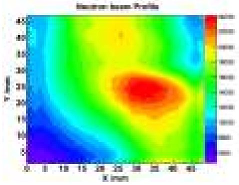
Position Reso. 4.1mm*4.1mm(FWHM)
Efficiency @2.6 Å : 54.3% / layer

- **Mass production**
  - Lab. In Sun Yat-sen university
  - 6 peoples, one year

Neutron beam monitor Based on GEM detector

Parameter	Specification
Active Area	50mm*50mm
Neutron Flux	<10^8n/cm^2.s
Spatial Resolution	<3mm
Timing Resolution	<1μs
Efficiency@1.8Å	～4%
Max Counting Rate	>1MHz
Working mode	Real-time

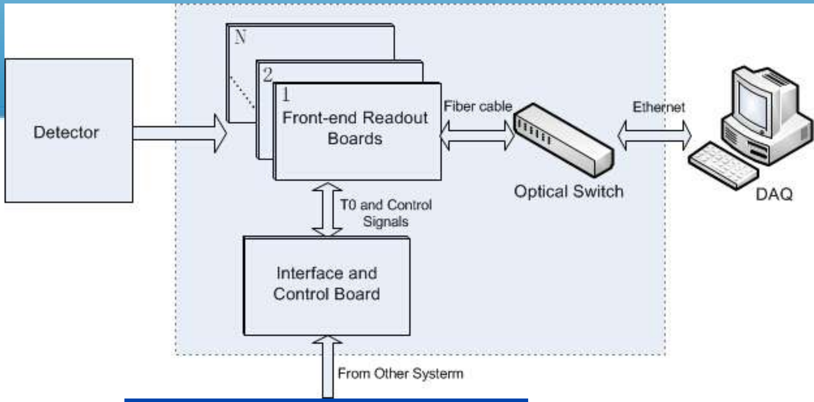




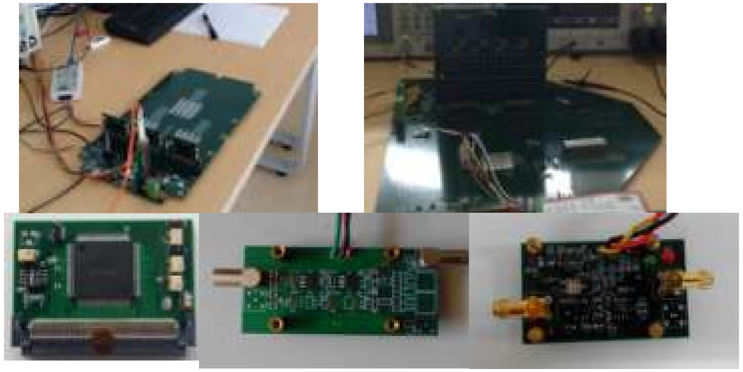
- **Successful Application**
  - Beam monitor @ CMRR
  - Beam monitor @ CARR

Electronics and DAQ System

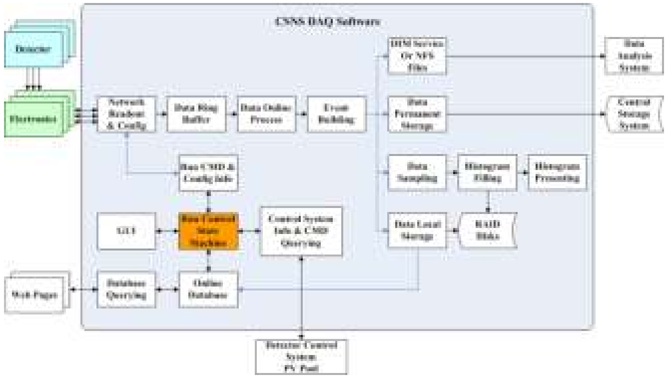
- Design the data acquisition system of 3 types of detectors in the same structure
- Finished the Prototype of the FEB of GPPD. The key IC is designed by ourselves.
- Finished the prototype of the FEB of MR, under testing .
- The testing board of the FEE of SANS is finished, and the prototype will be done next step.
- Finished the most DAQ software design



Electronics system



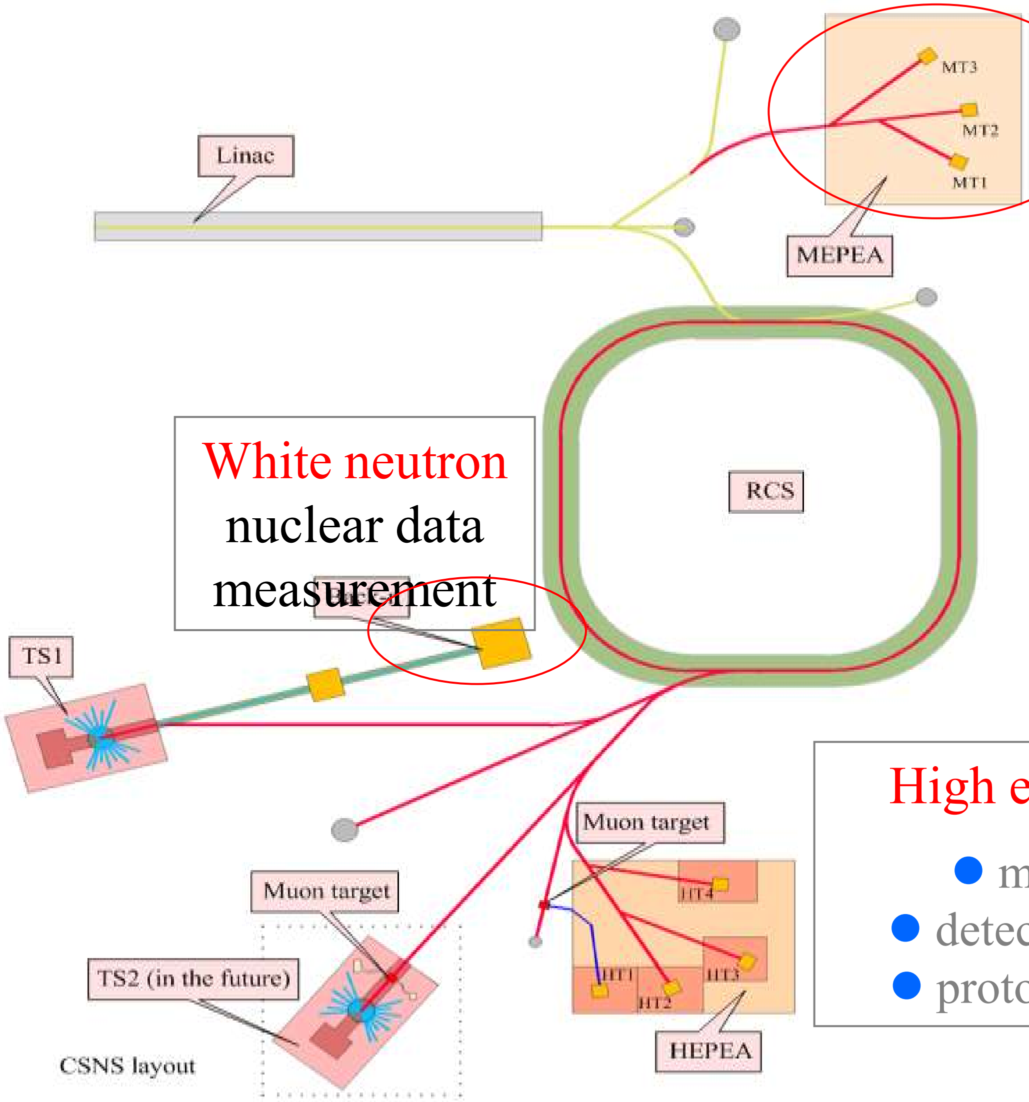
Electronics FEB



Function of DAQ

The 7th international review meeting of accelerator technology advisory committee (ATAC) and neutron technology advisory committee (NTAC) of CSNS was held 10-12 Oct. 2015 in CSNS, Dongguan.

Other application



Middle energy proton
Radiation effect test
Proton therapy

White neutron
nuclear data measurement

High energy proton

- muon source
- detector calibration
- proton radiography

Closing Remark

- CSNS civil construction will be finished. Utility installation goes well.
- The installation of accelerators started Oct. 2014. RFQ and the first DTL reached the design requirements.
- We expect the first neutron beam by Sept. 2017, and open to users by Spring 2018.
- Great efforts to promote the user community and to prepare the day-one experiments.
- Proposal of Phase II (more spectrometers +Power upgrade) are under discussion.
- Look forward for cooperation with JINR in CSNS upgrade and the neutron scattering applications.

Many thanks for your attention