中国散裂中子源

Target Station and Instruments for Spallation Neutron source

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CSNS CHINESE ACADEMY OF SCIENCES

outline

- **Relationship between structure and property**

  (物质结构与物性)

- **Why neutrons: neutron characteristics and neutron scattering**

  (为什么需要中子：中子特点与中子散射)

- **Target Station of spallation neutron sources**

  (散裂中子源靶站)

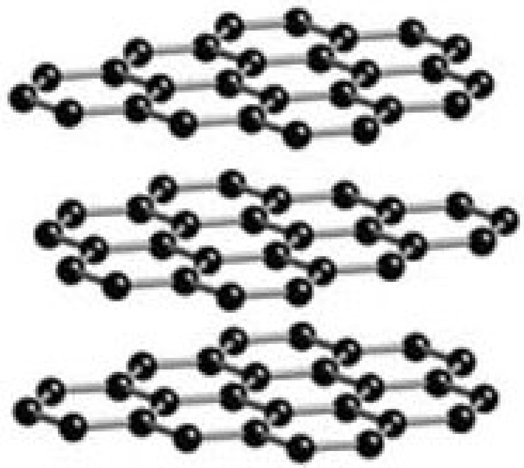
- **Instruments of spallation neutron sources**

  (散裂中子源谱仪)

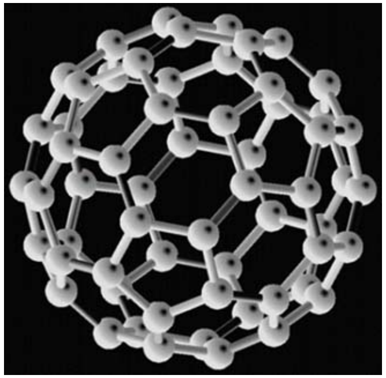
- **CSNS**

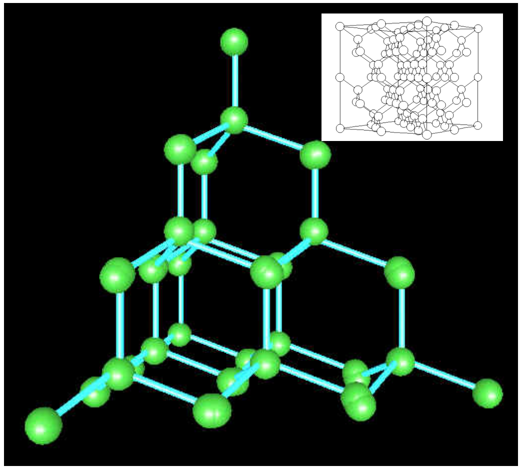
  (中国散裂中子源)

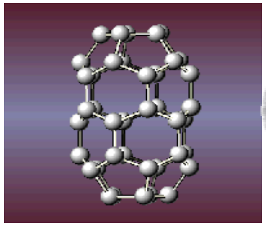
物质结构决定物质性质

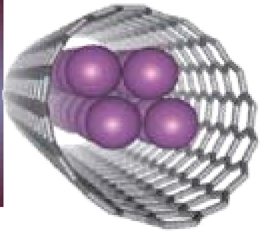


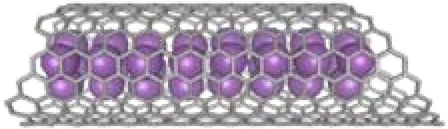
玻璃刀头上镶的金刚石可用来裁玻璃







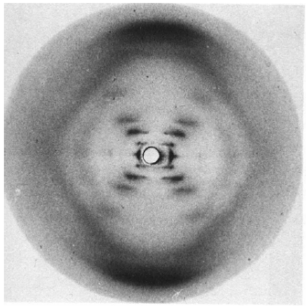




物质结构决定物质性质

- ＤＮＡ双螺旋结构：分子生物学

X-Ray Photograph of DNA Taken by Rosalind Franklin in 1952



James Watson and Francis Crick

1953年Watson and Crick建立了DNA的双螺旋模型结构，并于1958年提出了中心法则。

获1962年度诺贝尔奖

物质结构决定物质性质

结构模型

↓

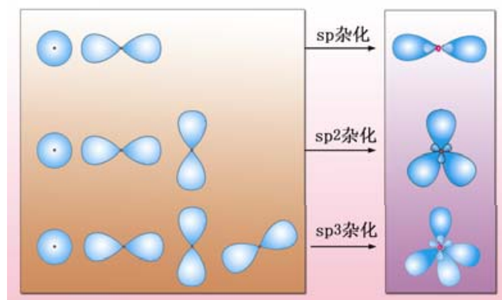
认识相互作用

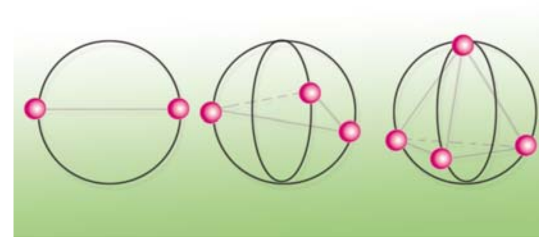
↓

晶体和分子构型

↓

说明物质性质





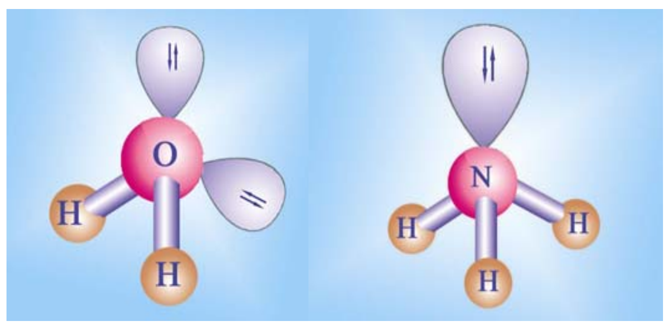
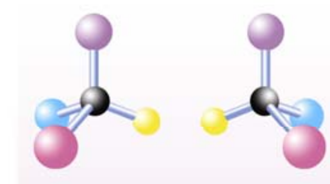


图4-8 NH_3、H_2O分子结构示意图



磁、电、光、热等基本物性

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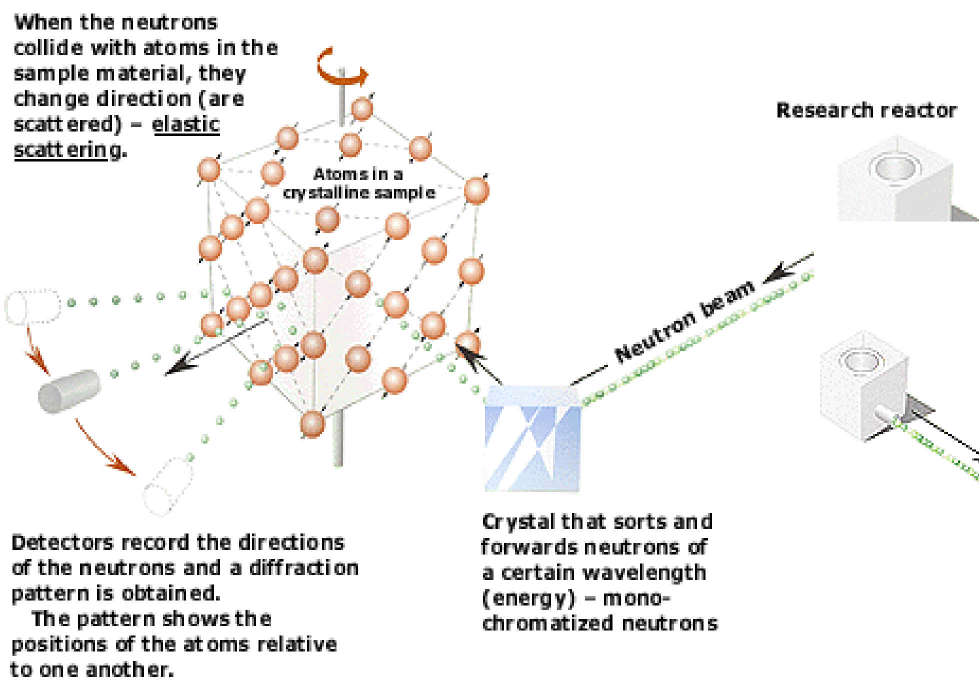
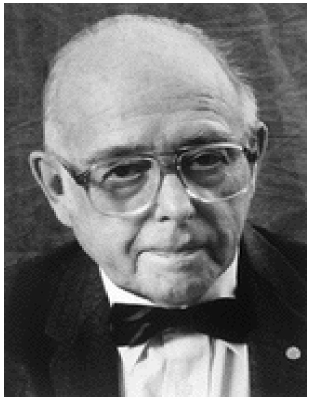
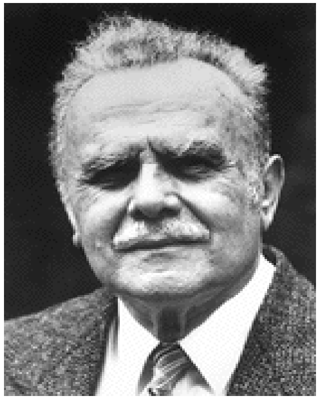
  (中国散裂中子源)

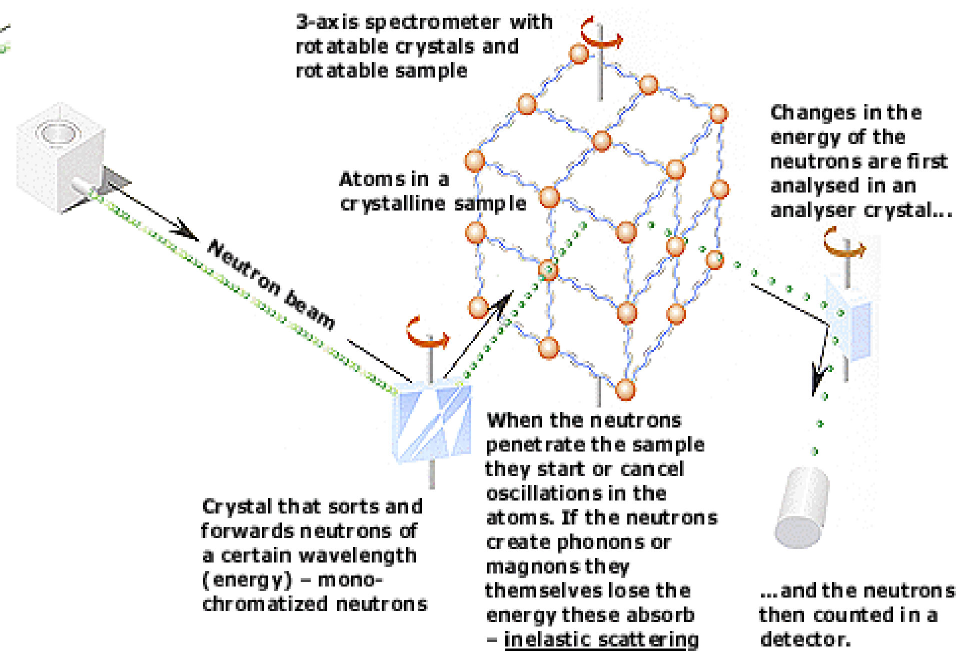
中子散射是探测物质结构的重要手段

中子散射可探测原子、分子和原子分子团簇的位置…



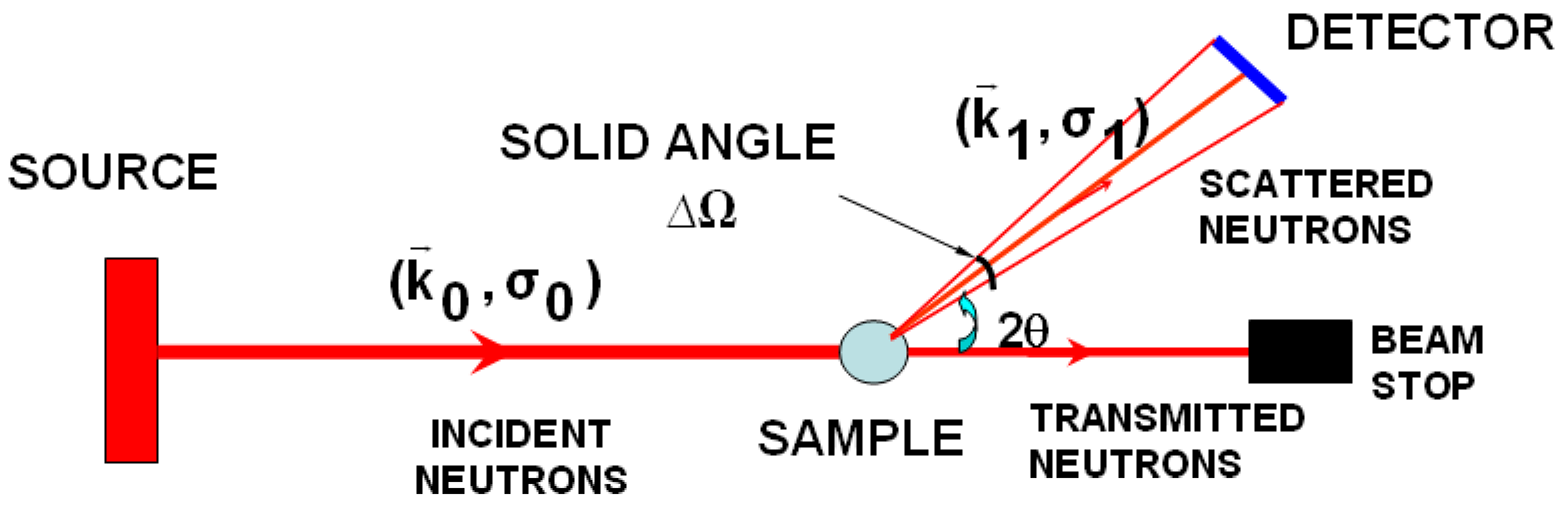






… 以及它们是如何运动的

中子散射基本概念



$$C = \eta \Phi N \left(\frac{d^2\sigma}{d\Omega dE} \right) \Delta\Omega \Delta E$$

中子散射基本概念

Radius of nuclear force: $10^{-12} \sim 10^{-13}$ cm
Wavelength of neutron: 10^{-9} cm
Atomic distance in sample: $\geq 10^{-8}$ cm

Fermi potential:

$$U(\mathrm{r}) = \frac{2\pi\hbar^2}{m} b\delta(\mathrm{r}-\mathrm{R})$$

$$U(\mathrm{Q}) = be^{i\mathrm{Q}\cdot\mathrm{R}}$$

$$\frac{d\sigma}{d\Omega} = b^2$$

a spherical symmetry

b: the scattering length, a property only of the nucleus of the the scattering atom and its spin state.

scattering function：

$$\frac{d^2\sigma}{d\Omega dE} \propto S(Q,E)$$

$$S(Q,E) = \frac{1}{N}\frac{1}{2\pi\hbar}\int_{-\infty}^{\infty}\sum_{ii'}^{i\neq i'}\left\langle e^{-iQ\cdot R_i(0)}e^{iQ\cdot R_{i'}(t)}\right\rangle e^{-iEt/\hbar}dt$$

中子散射基本概念

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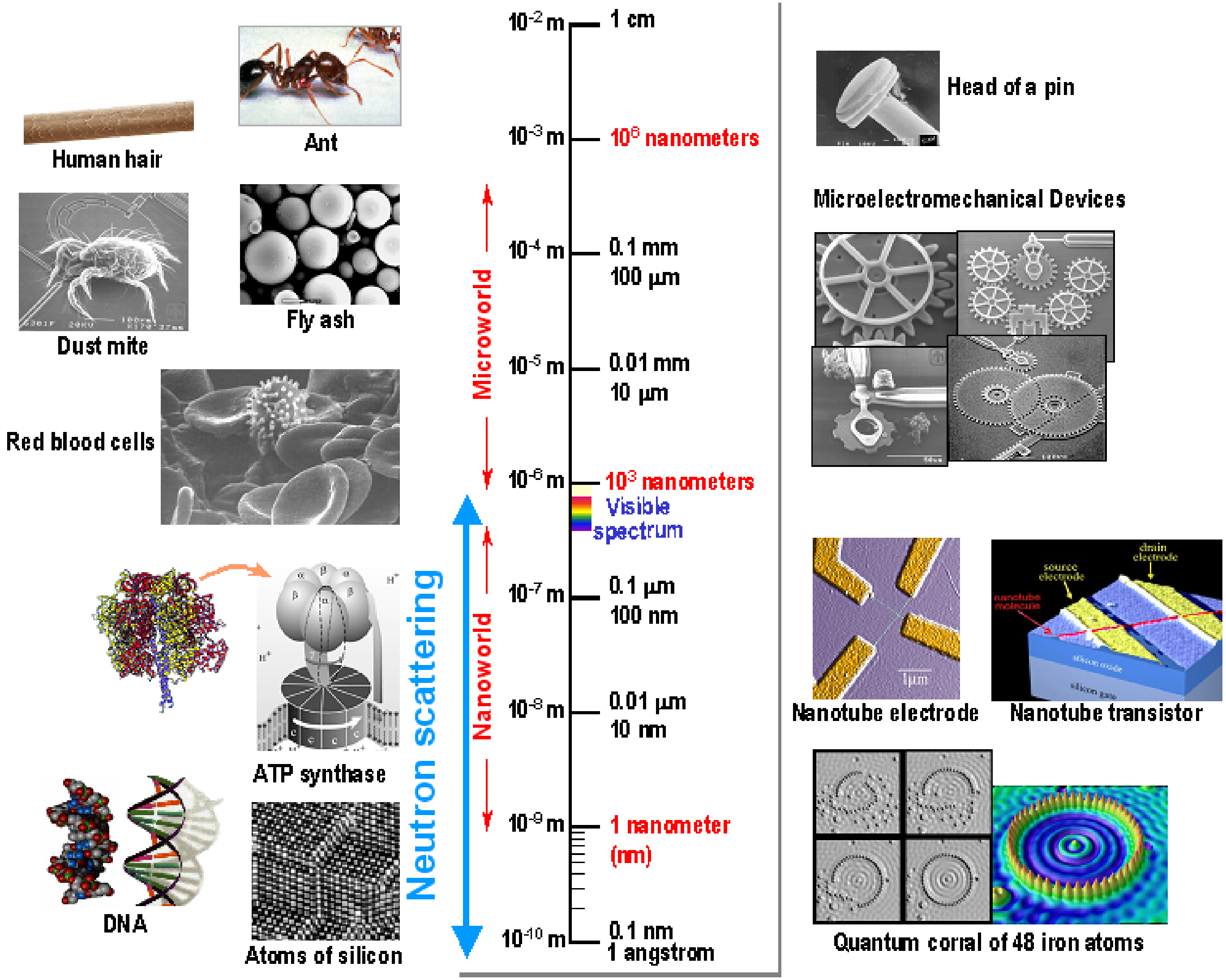
$$I(Q,E) = \iint R(Q-Q',E-E')S(Q',E')dQ'dE'$$

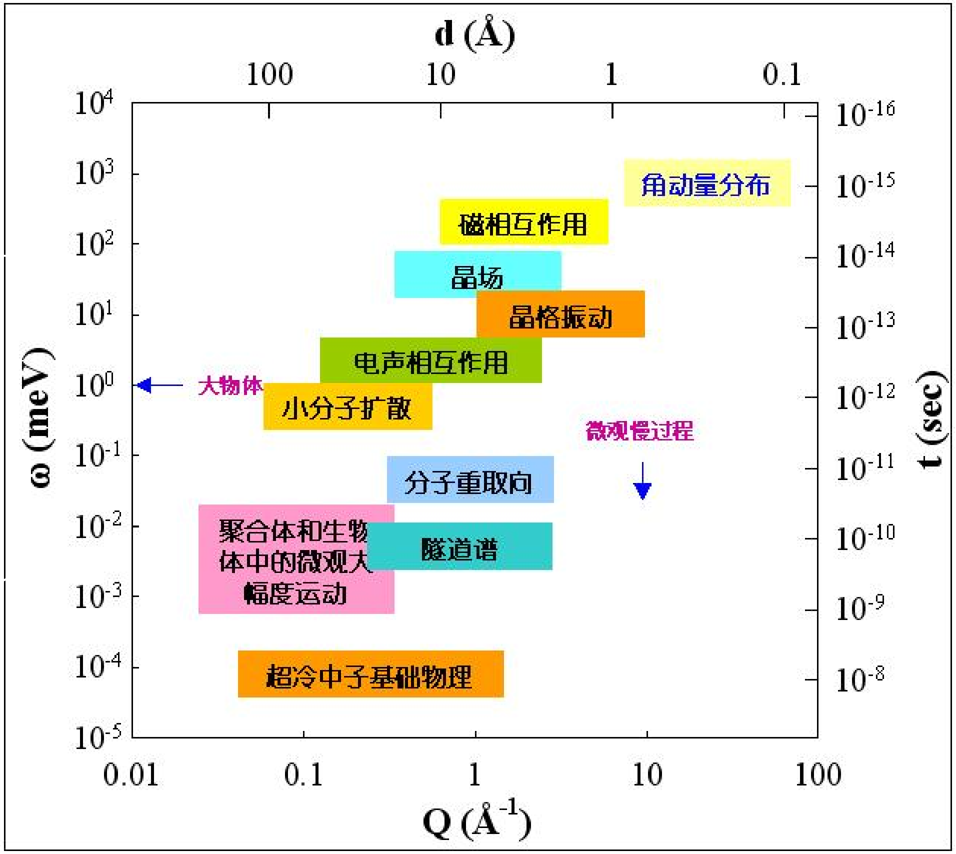
仪器分辨率函数所表达的物理意义是：当谱仪被设定测量动量转移为Q，能量转移为E的散射过程时，在相近的动量、能量空间中探测到中子的概率。

中子特性—波长覆盖宽的微观尺度



中子特性—适合的能量范围

波长 (nm)	X射线 (eV)	中子 (meV)
0.1	12400	82
1	1240	0.82
10	124	0.0082



热中子能量与物质中许多动态过程的激发能量相当

中子特性—电中性

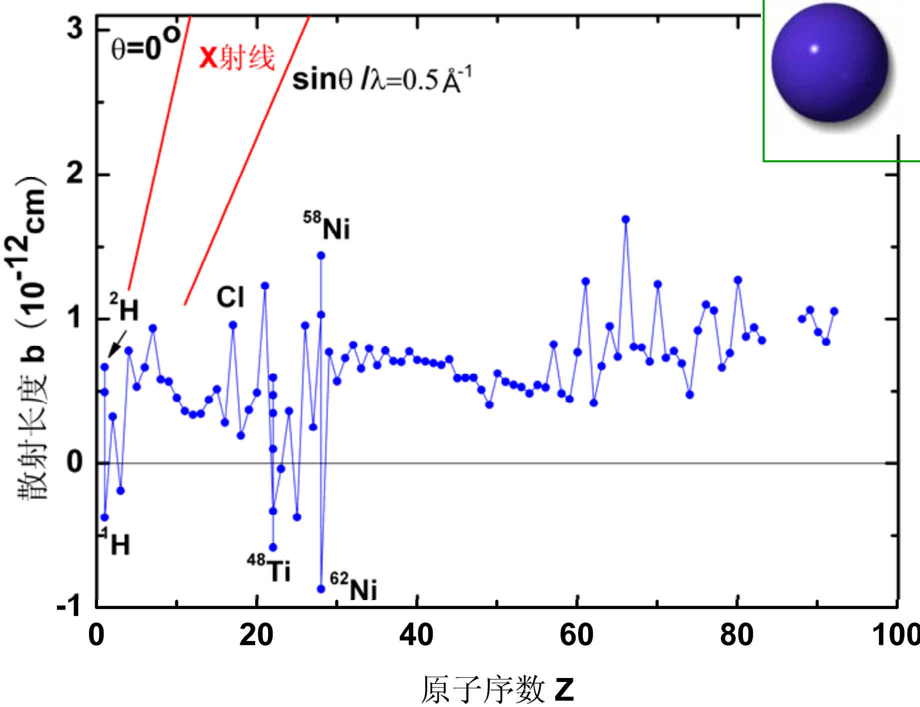
Charge = 0

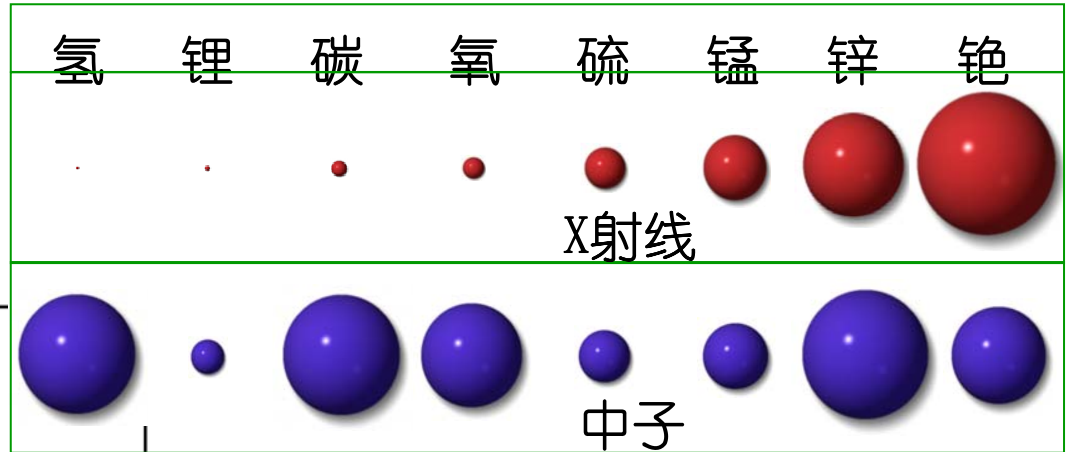
与物质相互作用时，中子几乎不受原子核外电子的影响，被散射的可能性主要取决于原子核的性质。这些带来四个优势：

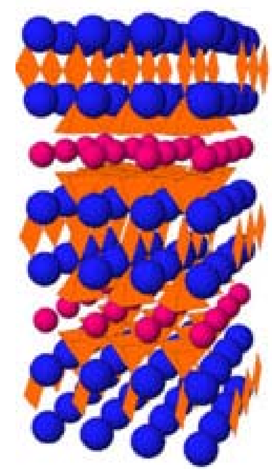
- 中子对轻元素敏感，并可区分同位素。
- 中子的穿透能力较强。研究的是体效应，更容易接近研究对象的本质；易于开展极端条件下物质结构和动态的研究。
- 中子散射结果可在量子力学一级微扰的框架内得到合理的解释，便于与分子（晶格）动力学的数值模拟比较。
- 中子对物质的破坏很小，更有利于研究生物活性体系。

相对于X射线或同步辐射，中子源能提供的中子通量相对较低，局限了中子散射的研究范畴，通常研究能获得**较大样品量**的材料体系。

中子探针特性—对较轻的原子灵敏

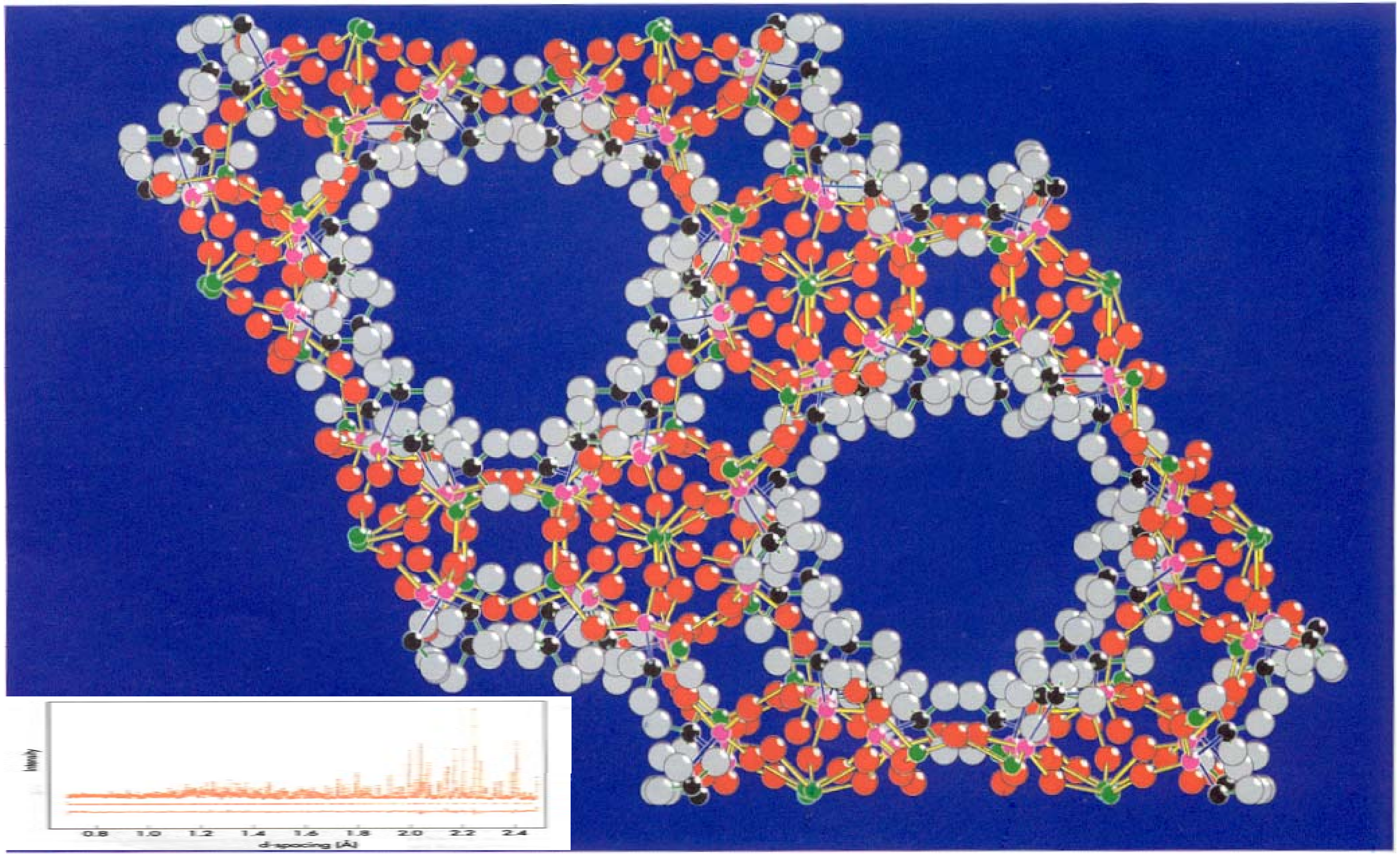






高温超导体中氧的位置和占有率

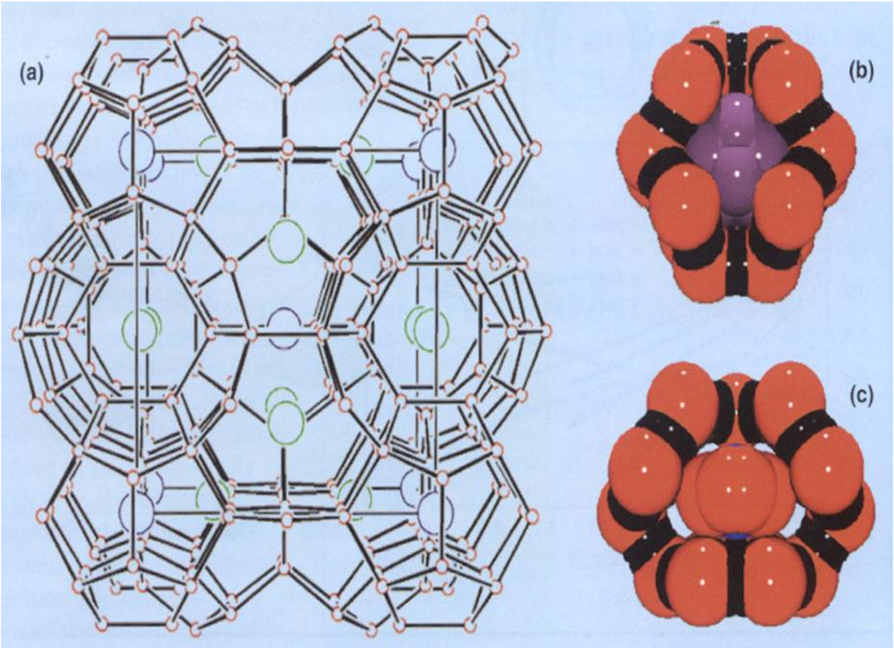
中子与同步辐射在物质结构研究上互补



$Al_2(PO_3CH_3)_3$（甲基沸石）的结构

红，白色部分分别是X射线，中子散射的结构分析结果

中子对轻元素敏感：可燃冰研究

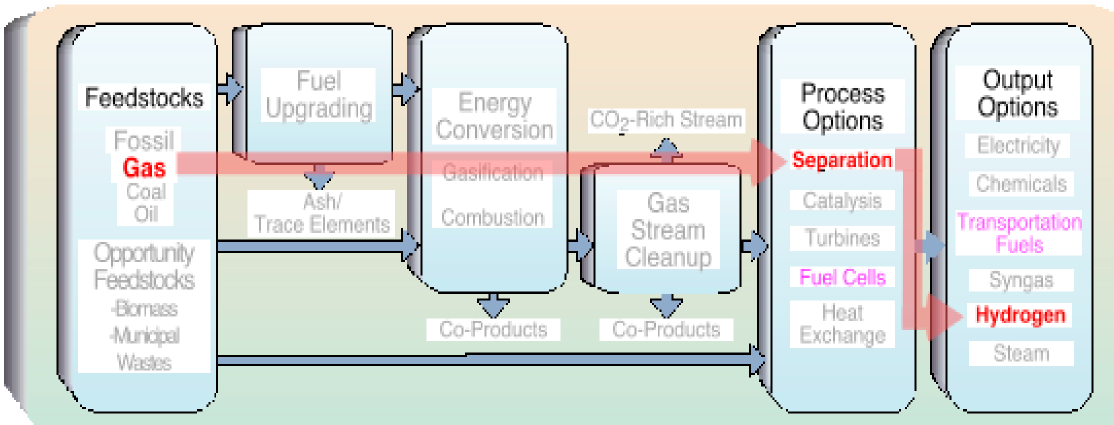


- 美国科学家估计，储存于墨西哥湾海底的可燃冰可供美国使用2000年
- 预计全世界海底的可燃冰可供全人类使用3000年
- 高压、低温下中子散射实验可研究可燃冰性能及形成机制

深海可燃冰的中子散射研究

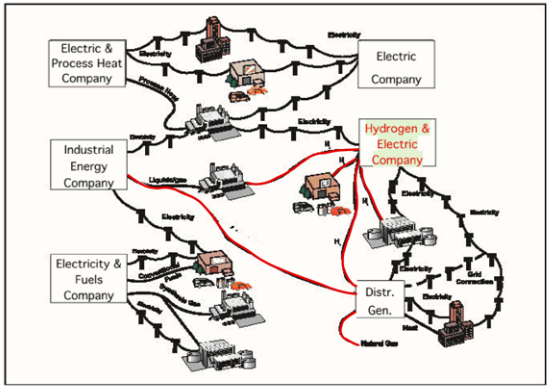
（海底能源－水合天然气）

中子对轻元素敏感：氢能源

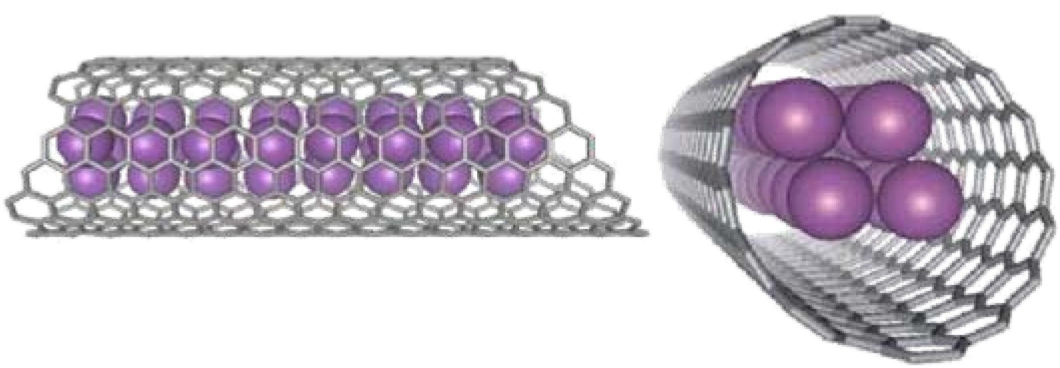


Roadmap: R&D Today ------> Realization ~2010

路线图：今天的研发，明天的应用 （~ 2010）

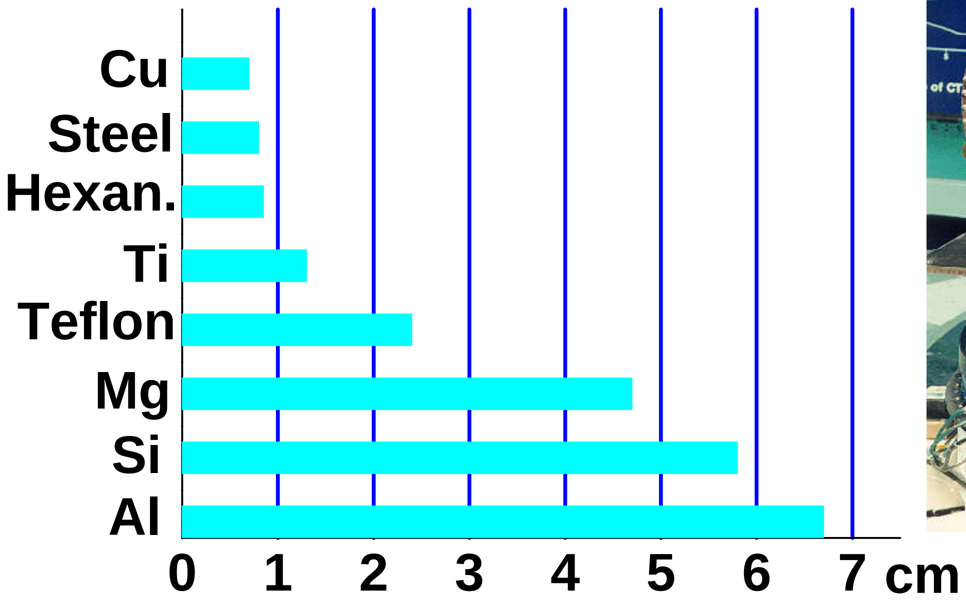


- 美国能源部的21世纪新能源方案
- 石油经济向氢经济过渡
- 相应的科技开发和储备工作
- 需要散裂源这样的大科学平台

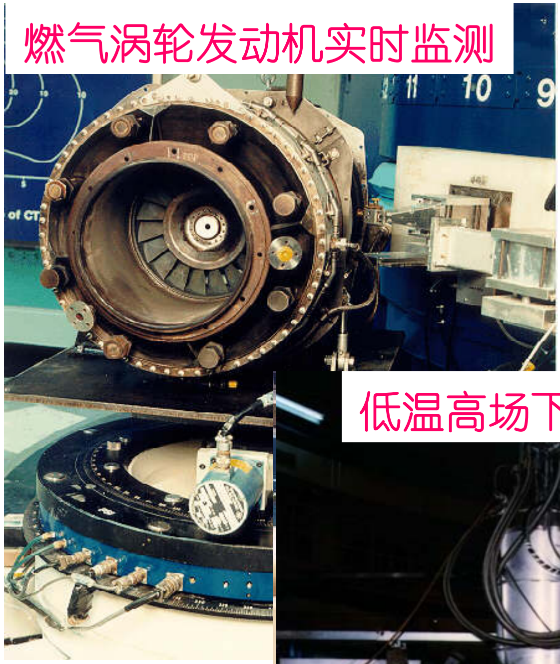


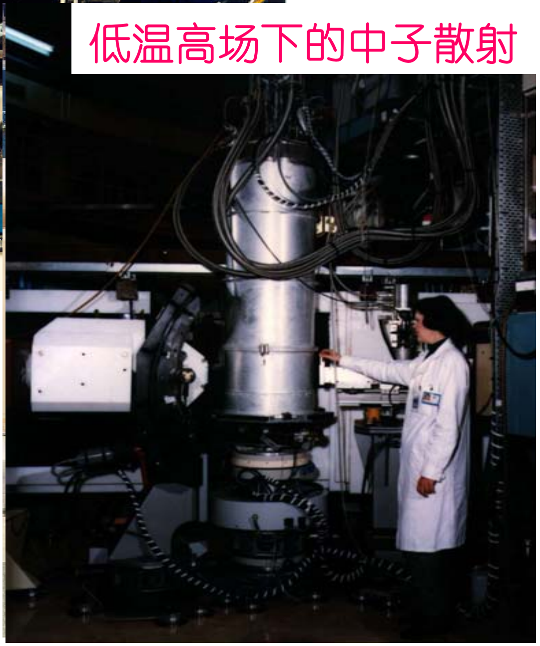
储氢纳米管的中子散射研究

中子探针特性—强穿透能力



热中子在不同材料中的穿透深度

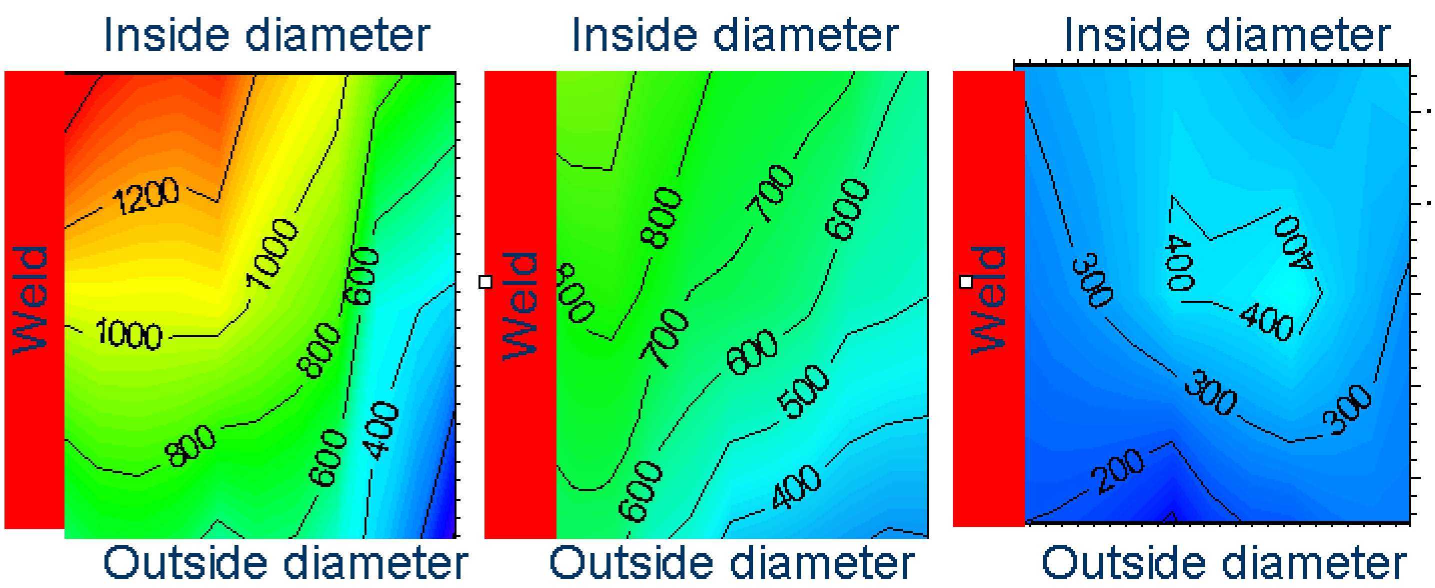




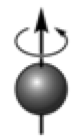
穿透能力强，可以对较大的部件进非破坏性测量，利于加载高温高压及强场等极端条件设备。

中子探针特性—强穿透能力

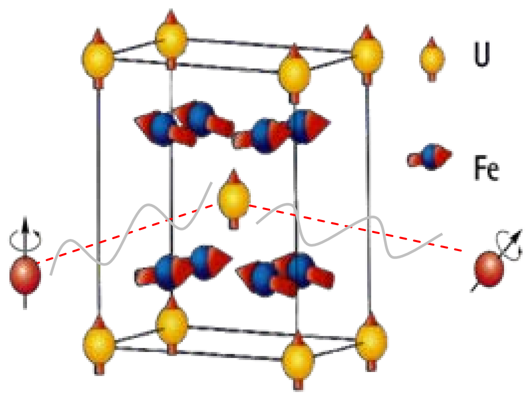
飞机涡轮的叶片与轮盘的焊接应力测量

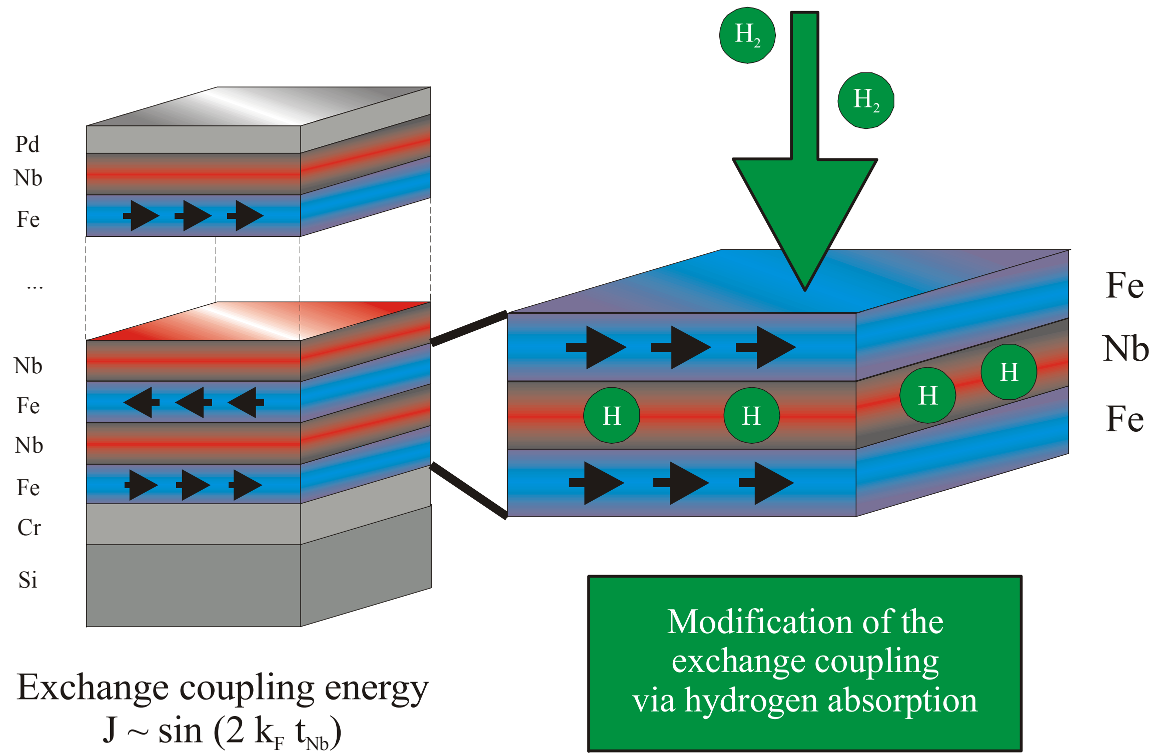


中子探针特性—具有磁矩



Spin = ½　　$\mu_n = -1.913\ \mu_N$



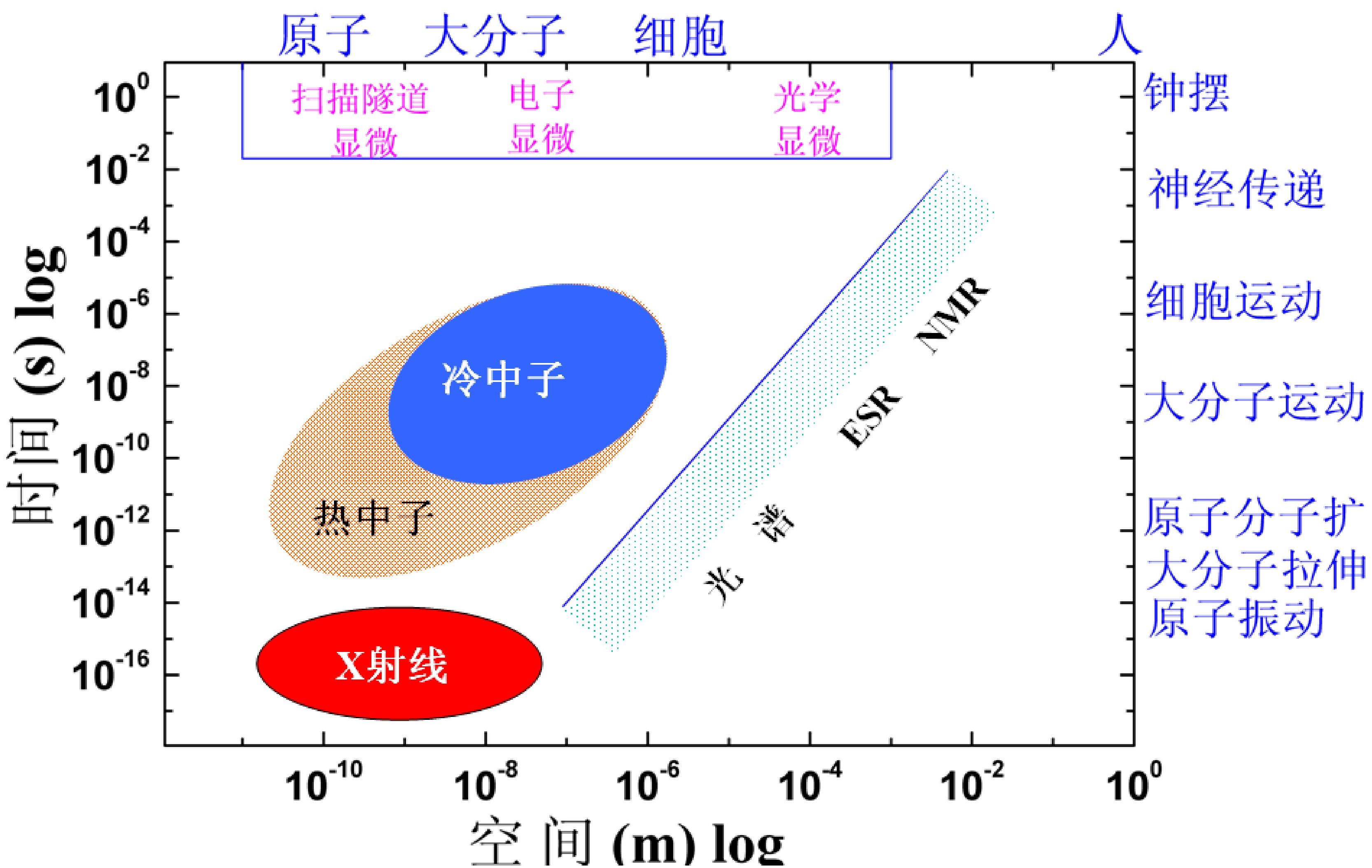


Exchange coupling energy
$J \sim \sin(2\ k_F\ t_{Nb})$

中子是研究材料中磁结构和磁涨落的特有工具


Soft
multidisciplinary
condensed matter science
Hard
1990
1980
1970
1960
Proteins
Surfactants
Polymers
Catalysts
Buckyballs
Water in biology
Minerals
Stress
Superconductivity
Vortex lattice
Hydrogen bonding
Phase transitions
Phonons
Quantum fluids
Spin dynamics
Antiferromagnetism
Achievements of neutron scattering
– the evolution and diversification of neutron scattering over the past 40 years

中子散射在各种微观结构研究手段中的地位



战略意义和社会效益举例

- 新型能源 — 可燃冰、储氢材料
- 航空器材 — 大型客机材料
- 汽车工业 — 电动环保汽车电池
- 医疗技术 — 骨胶、新药研发
- 治病 — 老年痴呆病，基因治疗
- 生物 — 人类基因图，**DNA**和蛋白质结构
- 计算机存储 — 巨阻磁性材料
- 石化工业 — 原油分析、燃油添加剂效率
- 文化遗产 — 考古
- 航天辐照地面模拟；核爆模拟；核废料处理；质子、中子治癌

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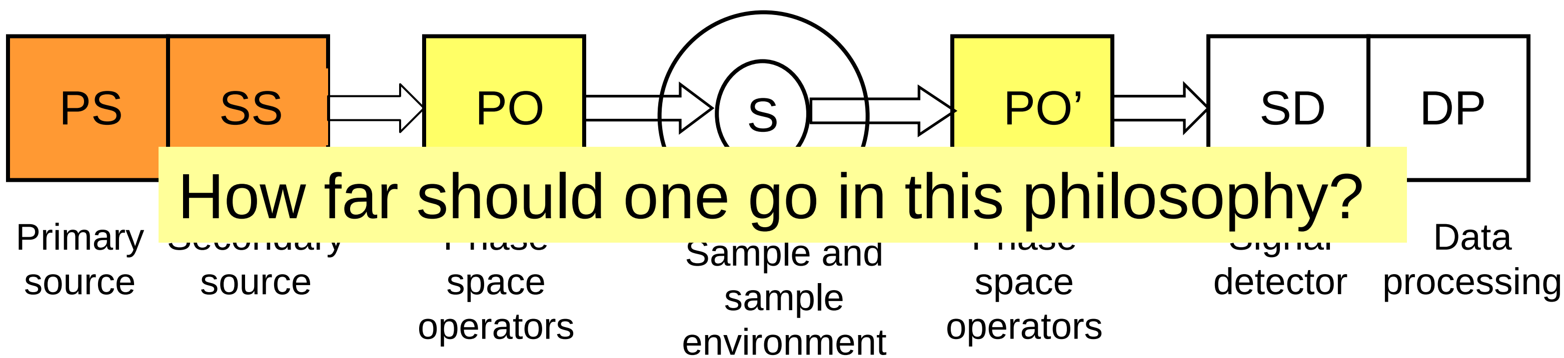
Neutron Source Design

- Neutron scattering instruments can be designed to work in continuous mode or in time of flight mode.
- There is no one instrument that can cover most of the Q-ω space with sufficient resolution and flexibility.
- Instruments have varying requirements with respect to spectral properties and time structure.
- This is why instrument and source designers have come to interact ever more closely in conceiving new systems (not so in the early days of reactor development).

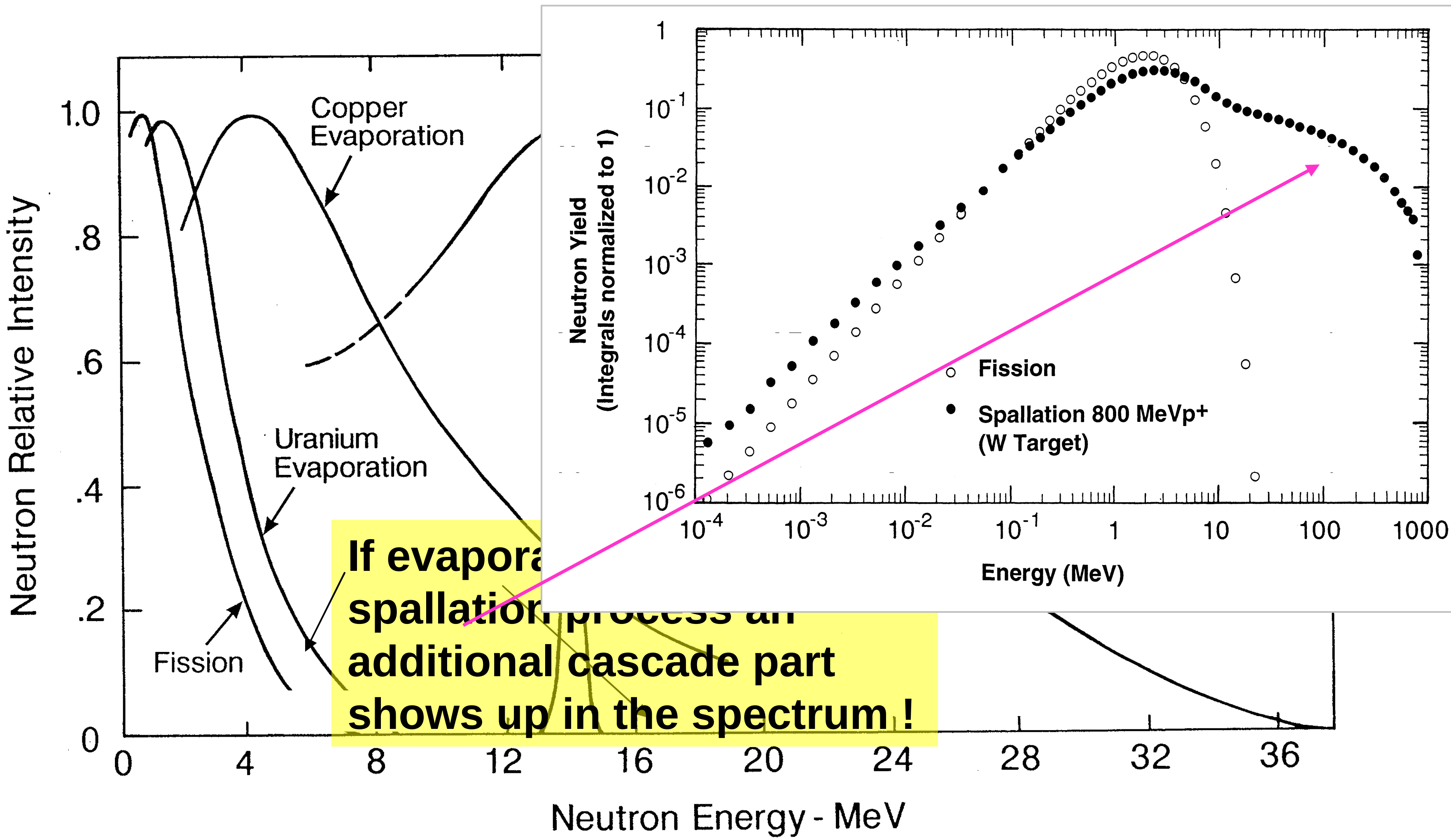


How far should one go in this philosophy?

Neutron Yield of Different Nuclear Reactions

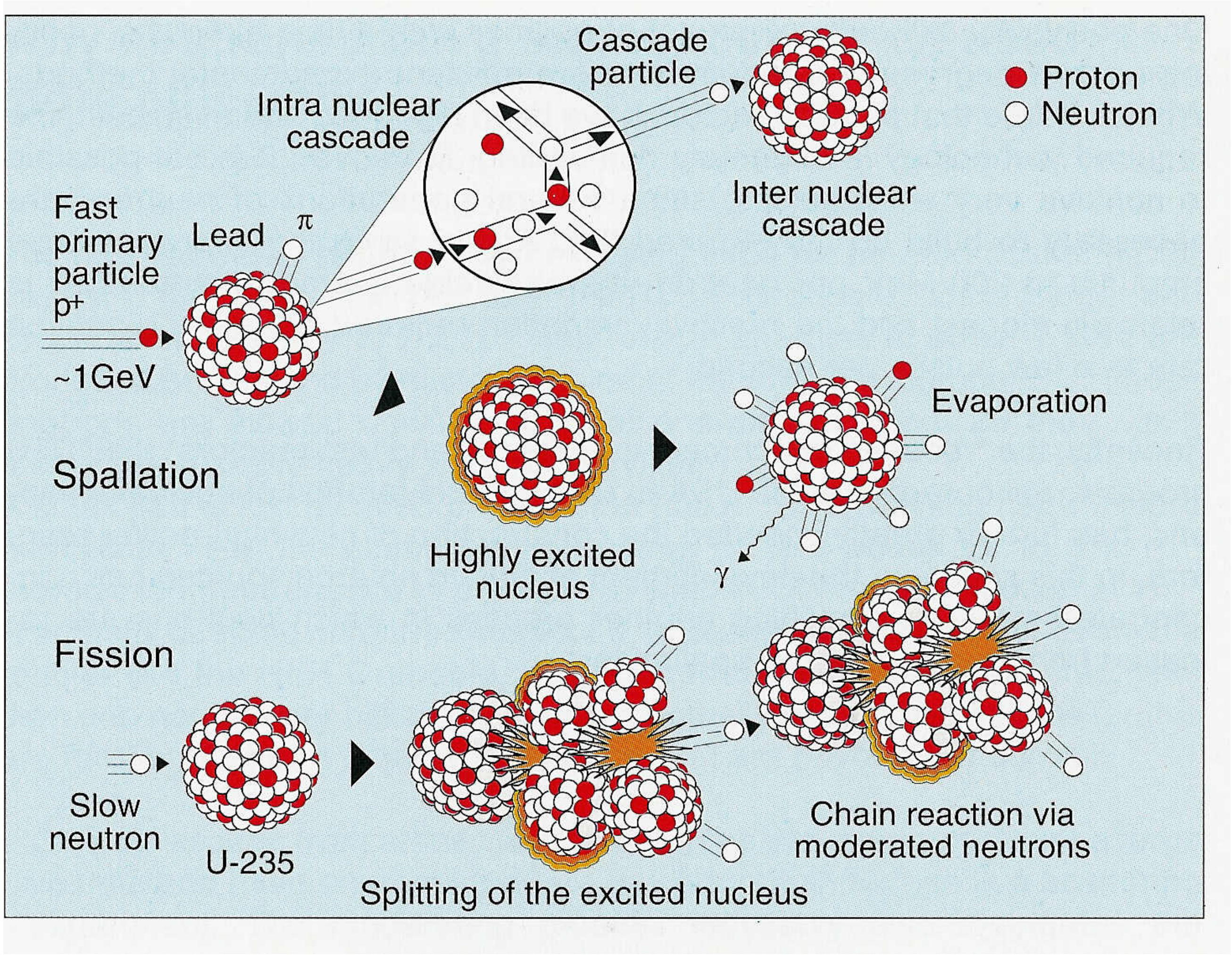
Nuclear process	Example	Neutron yield	Heat release (MeV/n)
D-T in solid target	400 keV deuterons on T in Ti	$4*10^{-5}$ n/d	10 000
Deuteron stripping	40 MeV deuterons on liquid Li	$7*10^{-2}$ n/d	3 500
Nuclear photo effect from e^--bremsstrahlung	100 MeV e^- on ^{238}U	$5*10^{-2}$ n/e^-	2 000
^{9}Be (d,n) ^{10}Be	15 MeV d on Be	1 n/d	1 000
^{9}Be (p,n;p,pn)	11 MeV p on Be	$5*10^{-3}$ n/p	2 000
Nuclear fission	fission of ^{235}U by thermal neutrons	1n/fission	180
Nuclear evaporation (spallation)	800 MeV p+ on ^{238}U on Pb	27 n/p 17 n/p	55 30

Neutron Spectra from Different Nuclear Reactions



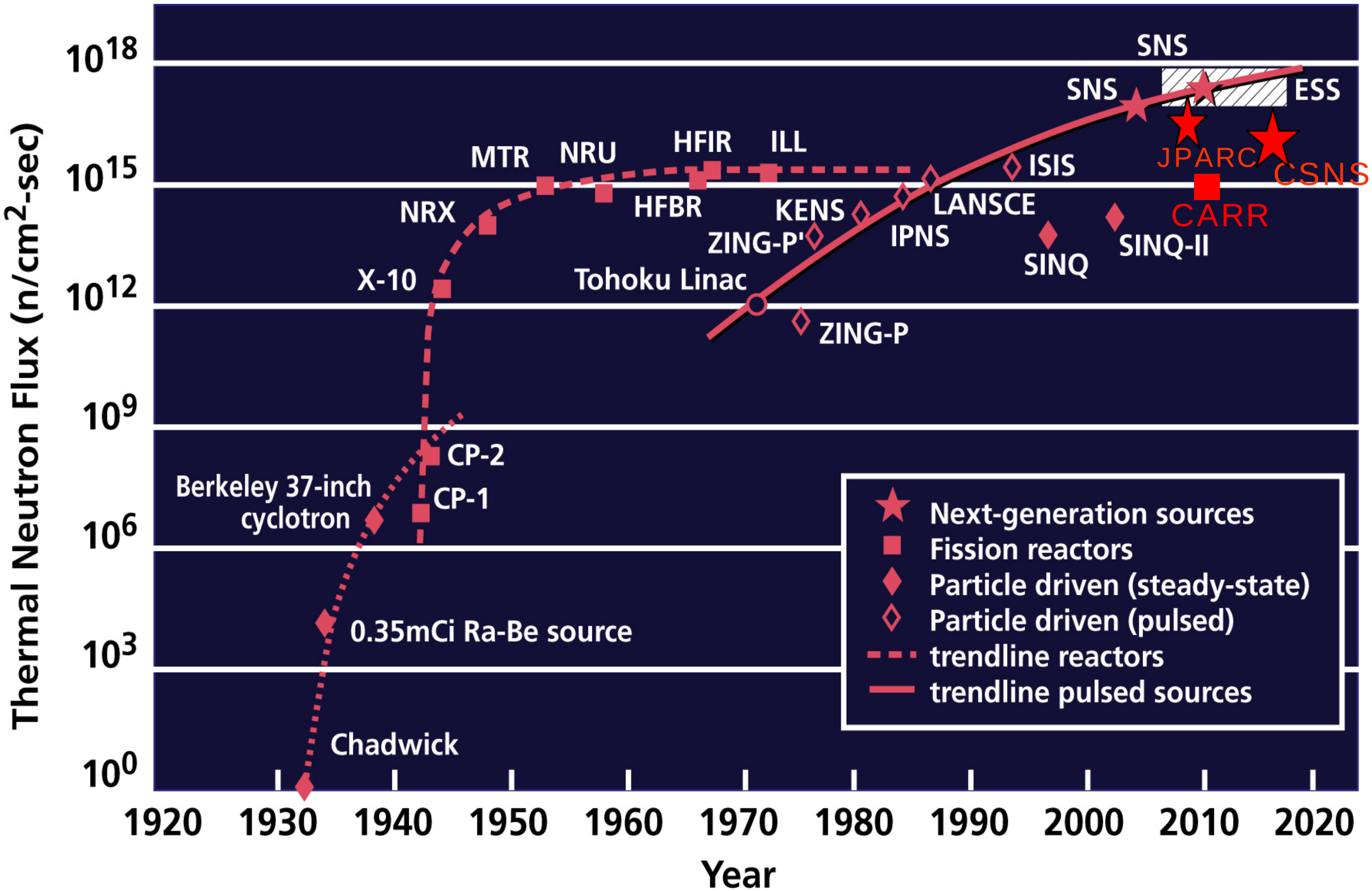
If evaporation … spallation process an additional cascade part shows up in the spectrum !

Visualisation of the Spallation and Fission Processes



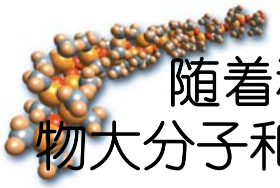
- **Spallation**
  - no chain reaction
  - pulsed operation
  - 35 neutrons/proton
  - ~45 MeV/neutron
- **Fission**
  - chain reaction
  - continuous flow
  - 1 neutron/fission
  - 180 Mev/neutron

中子源发展趋势

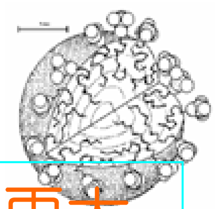


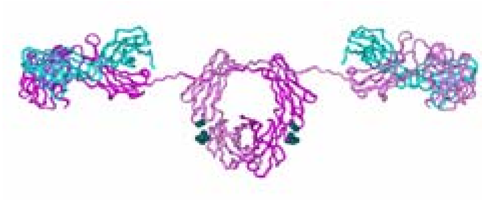
(Updated from *Neutron Scattering*, K. Skold and D. L. Price: eds., Academic Press, 1986)

为什么需要散裂源？



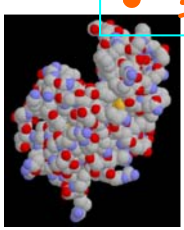
随着科学技术的飞速发展，薄膜、纳米团簇、生物大分子和蛋白质等研究体系成为研究的主要对象。

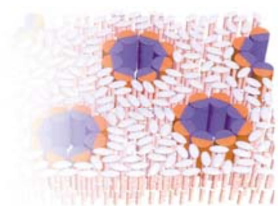


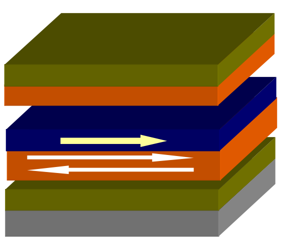


- 周期结构单元更大
- 样品体积更小
- 结构形态变化更快

→ **高通量中子源**







美国散裂中子源-SNS

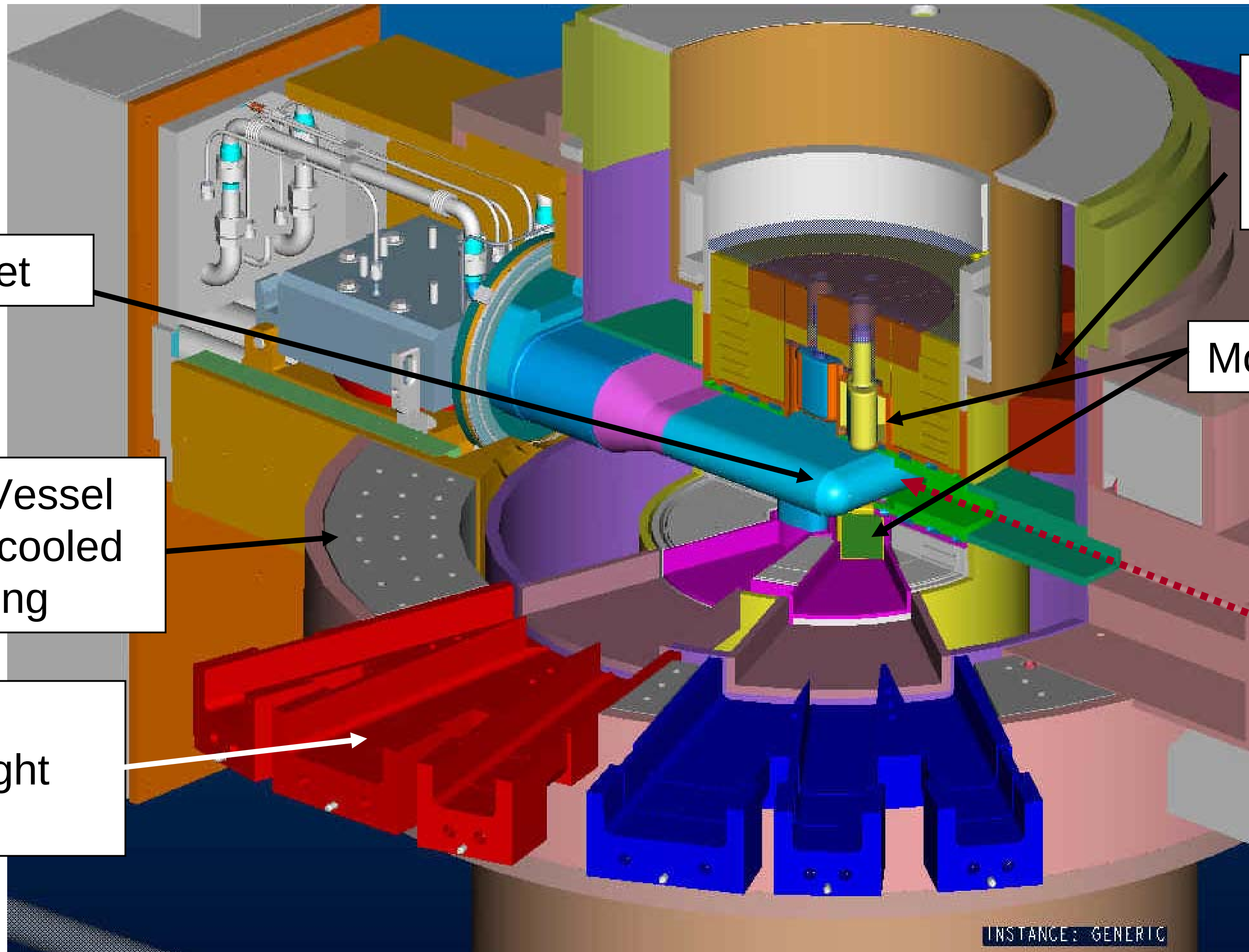
- 2006年运行
- 2 MW时，通量： ~12x ISIS，时间平均通量： ½ ILL
- 峰值热中子通量： ~50-100x ILL
- 世界最好的散裂源，现稳定运行在800kW

日本散裂中子源-JSNS

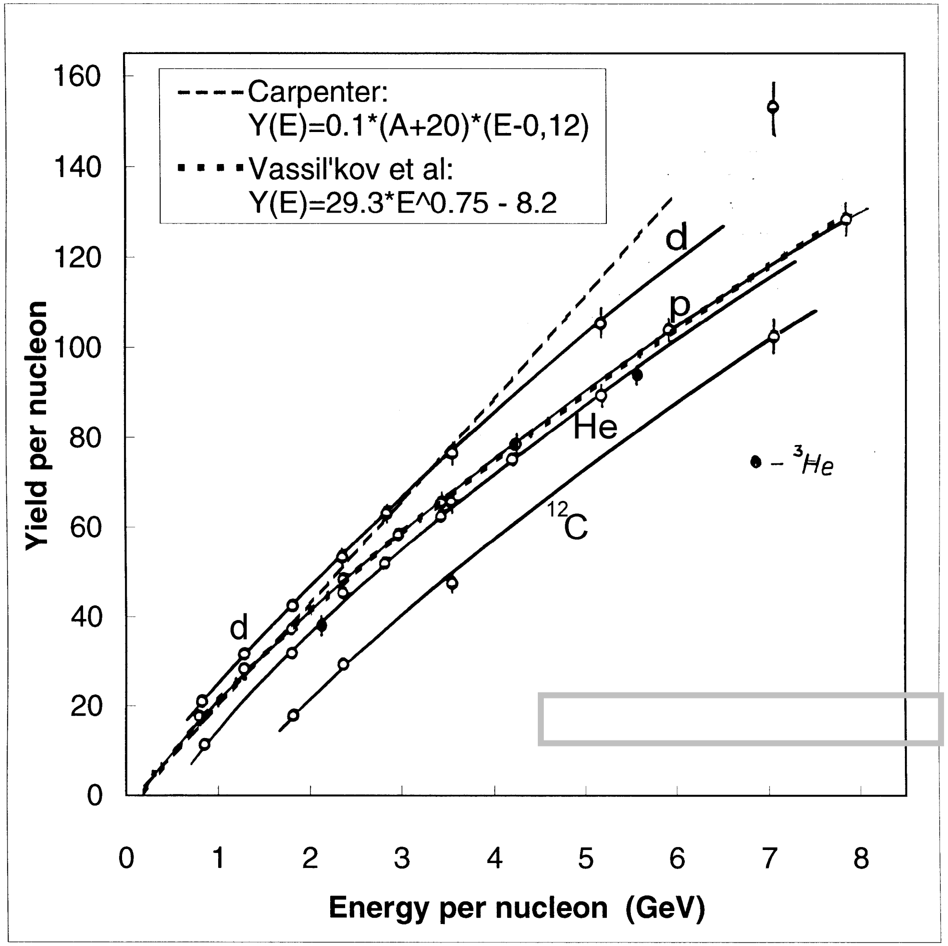
- 自2001年始，一期投资1527亿日元、二期规划363亿日元，2009年建成运行

- 1MW， 25Hz, 3GeV

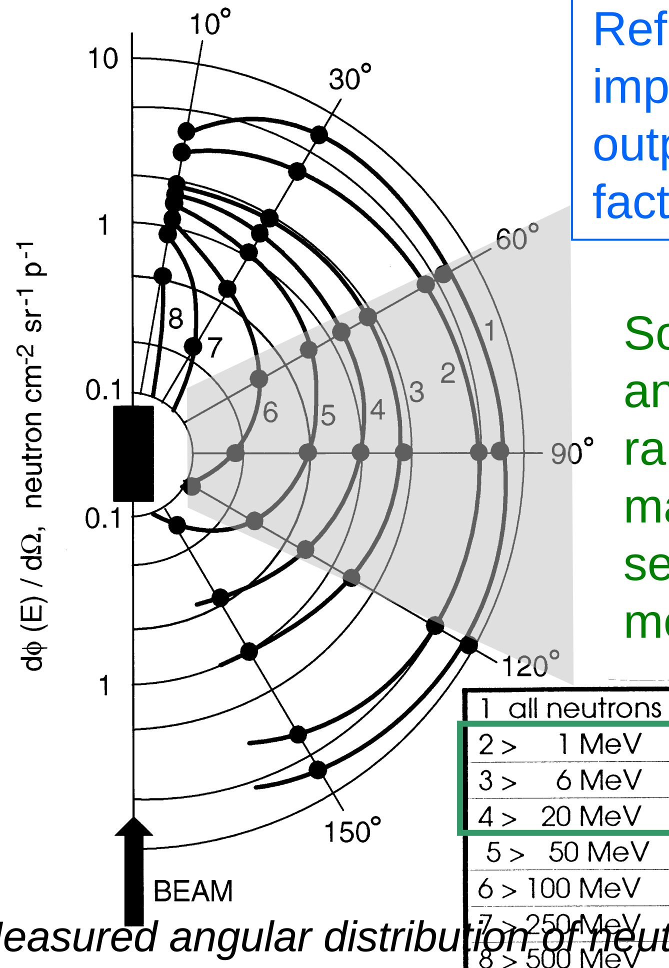
SNS Target System



Spallation neutron yield and angular distribution



Measured neuron yield from thick lead targets

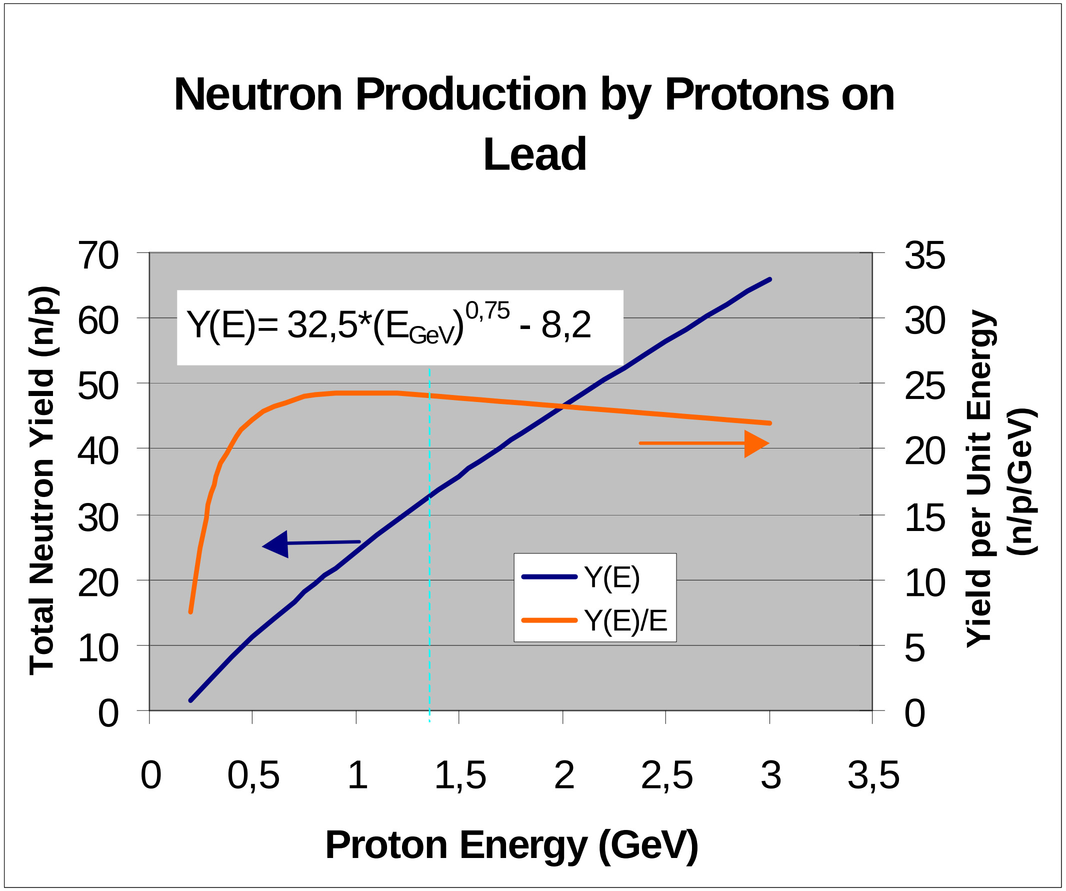


Reflector improves output by factor 2

Solid angular range mainly seen by moderator

Measured angular distribution of neutrons in different energy groups for a 20 cm diameter lead target bombarded by protons of 2 GeV

Choice of proton and its energy



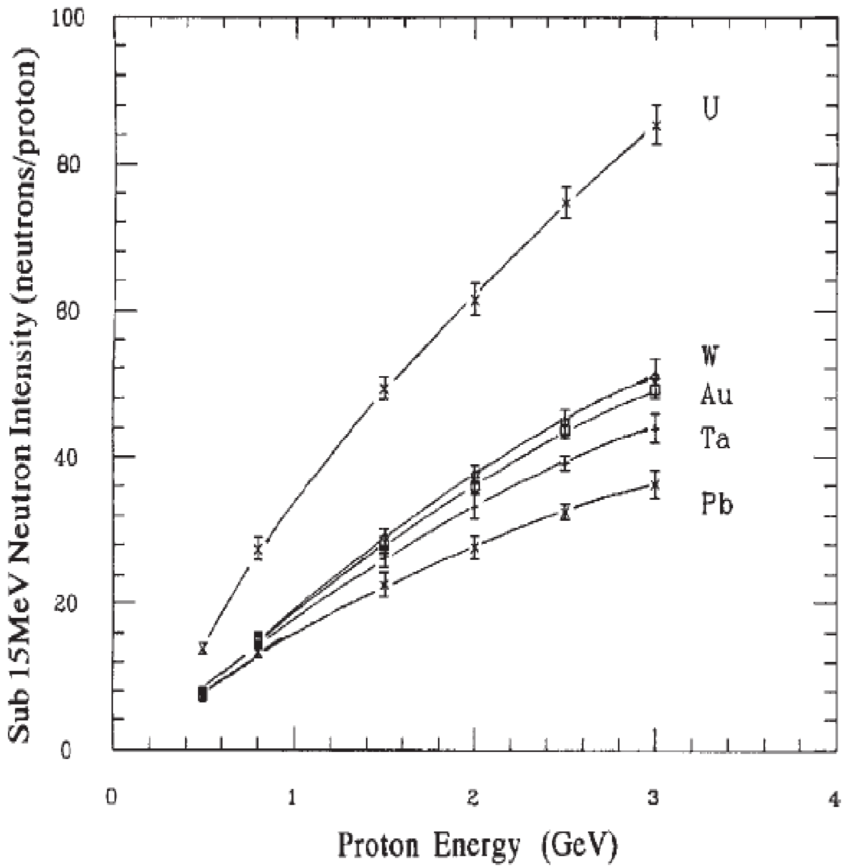
Arguments for higher proton energy:

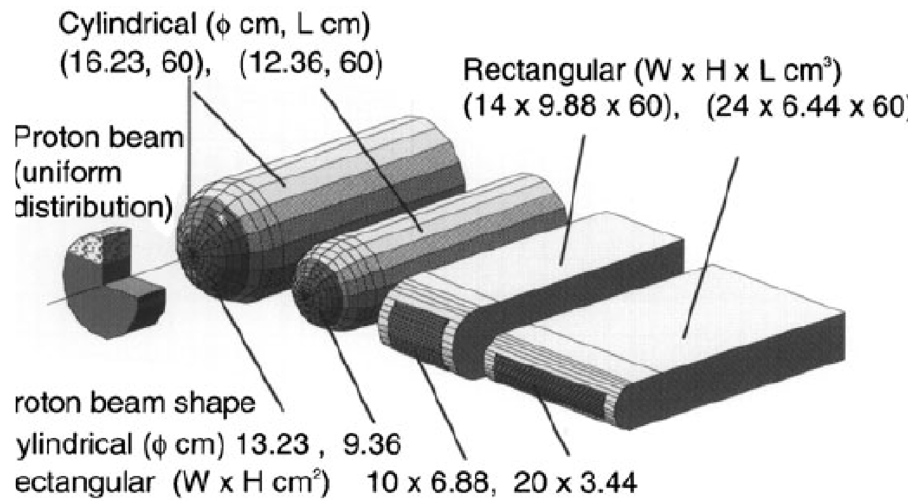
Easier to accelerate to higher energy than to increase current (in particular with circular accelerators)

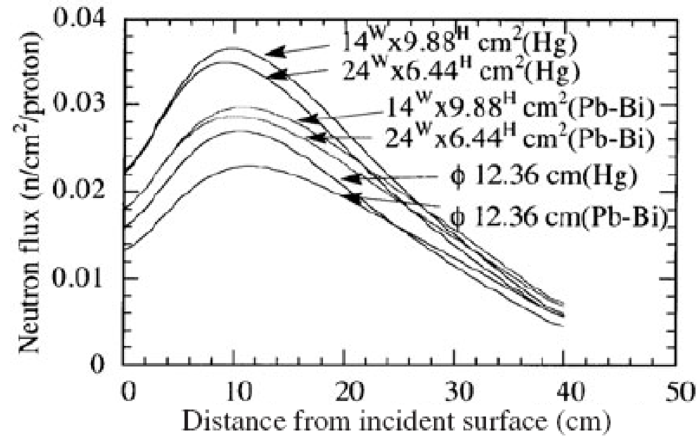
No Bragg peak above 600 Mev

Radiation damage in target and window materials scales roughly with number of protons per unit area, not with beam power.

Target Material and Shape







Neutron Moderation

- Moderation of neutrons occurs by collisions with moderator atoms
- In each collision a constant fraction of the energy is lost
- “Logarithmic energy decrement”:

$$\xi = \ln E_1 - \ln E_2 \begin{cases} = 1 \text{ for } A=1 \\ \approx 2/(A+2/3) \text{ for } A>1 \end{cases}$$

A is the atomic number of the moderator atom

- Number of collisions x required to slow down from energy E_0 to E_f
  $x = 1/\xi * \ln(E_0/E_f)$ for = E_0 2MeV and E_f = 1 eV: $x = 14.5/\xi$

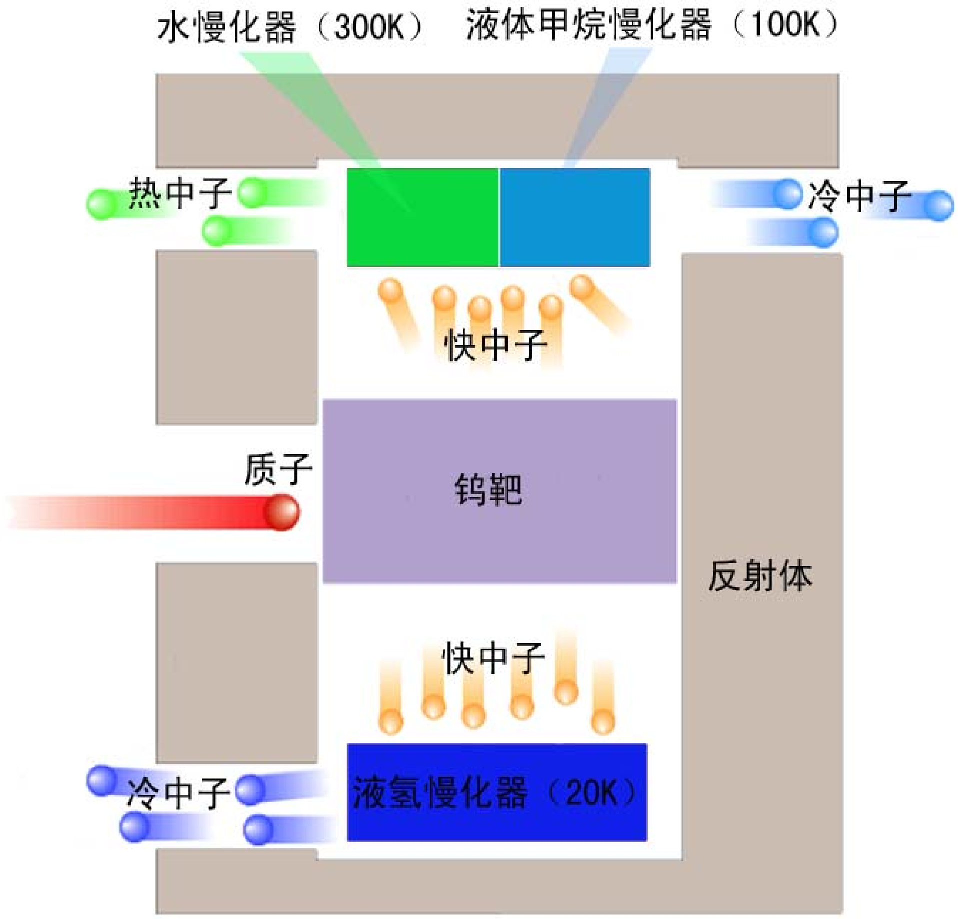
Parameter	Element						
	H	D	Be	C	O	Hg	Pb
A	1	2	9,01	12,01	16	200,6	207,19
σ_{fr} (10^{-24} cm^2)	20,51	3,40	6,18	4,73	3,75	26,53	11,01
ρ (g/cm^3) (*)	0,07	0,163	1,85	2,3	1,13	13,55	11,3
$\Sigma_{fr} = N*\sigma_{fr}$ (cm^{-1})	0,86	0,17	0,76	0,55	0,16	1,08	0,36
ξ	1,000	0,725	0,206	0,158	0,120	0,010	0,010
x (2MeV→1eV)	14,5	20,0	70,3	92,0	121,0	1460,1	1507,9

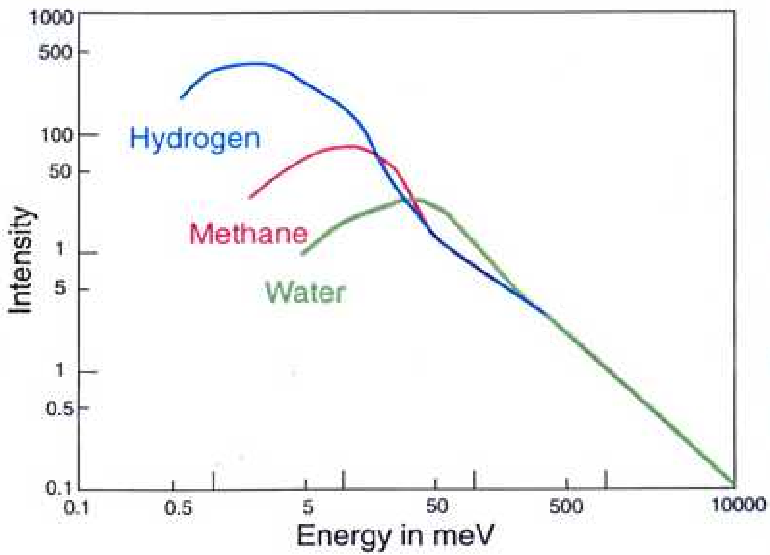
Neutron Reflector

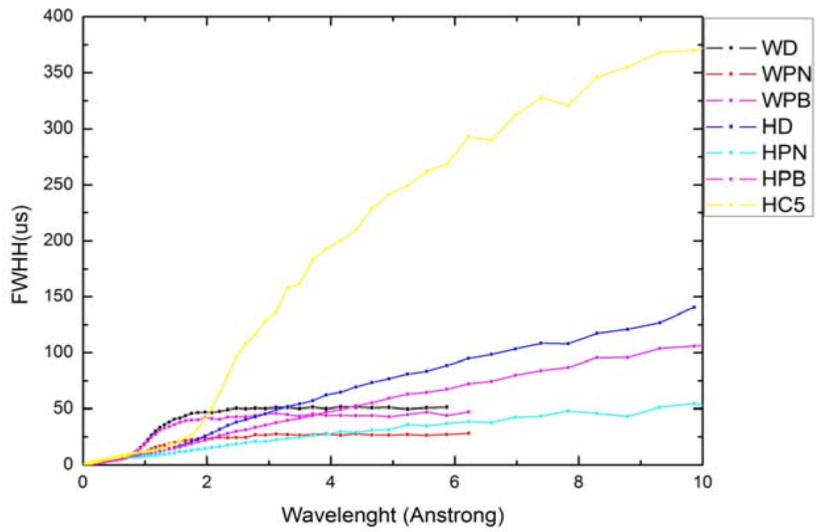
- Similar physical procedure to moderation of neutrons, i.e. reflection occurs by collisions with moderator atoms
- Requirements:
  - Large scattering density
  - Large-angle scattering: larger mass than that of a neutron
  - Large energy loss to shorten the slowing-down time: not too larger mass

	ρ(gcm^{-3})	Mol mass	σ_s(10^{-28}m^2)	$N\sigma_s$(cm^{-1})	ξ
H2O	1.0	18.01	44.4	1.485	0.925
polyethylene	0.918	14.01	45.3	1.765	0.913
D2O	1.1	20.03	10.5	0.347	0.505
Be	1.85	9.013	6.1	0.754	0.206
Graphite	1.6	12.01	4.7	0.377	0.158
Fe	7.86	55.847	11.5	0.930	0.035

散裂中子源原理


水慢化器（300K）
液体甲烷慢化器（100K）
热中子
冷中子
快中子
质子
钨靶
反射体
快中子
冷中子
液氢慢化器（20K）

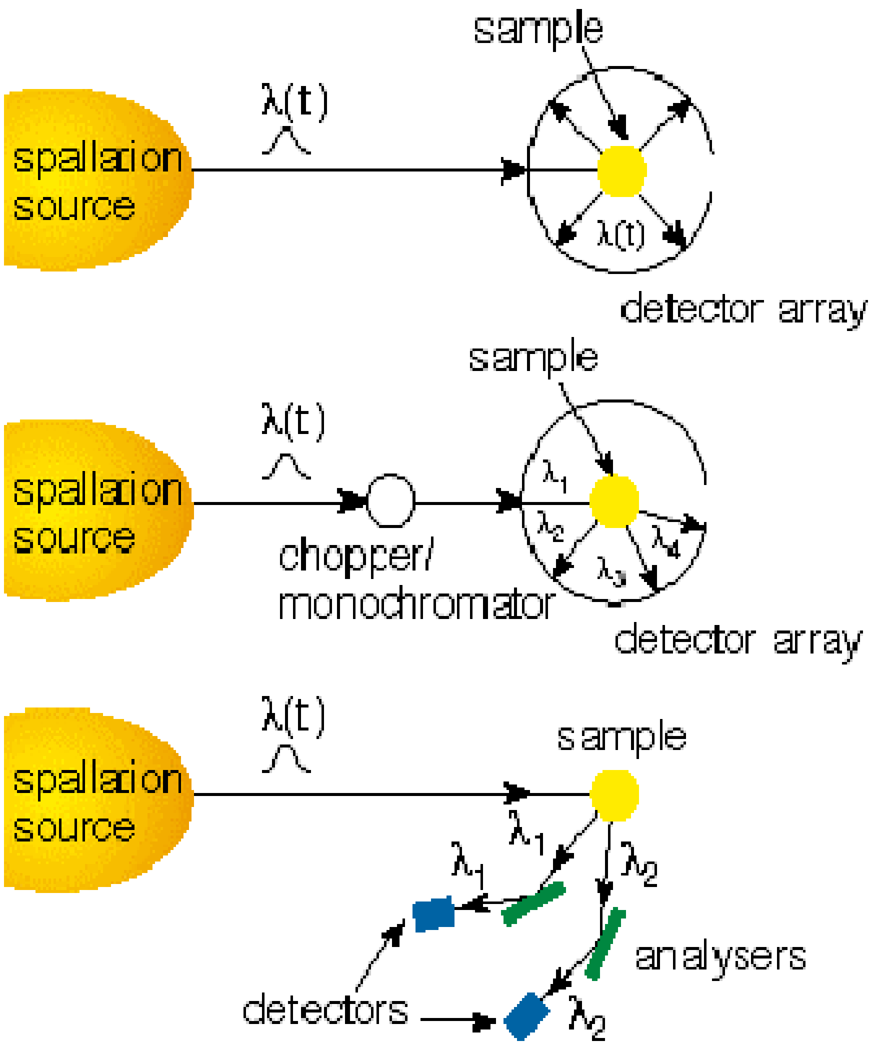

Hydrogen
Methane
Water
Intensity
Energy in meV

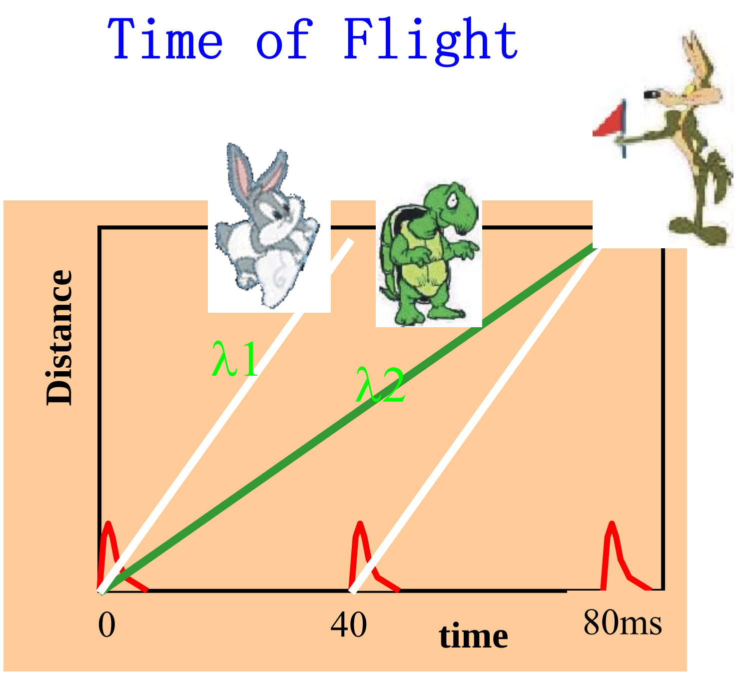

WD
WPN
WPB
HD
HPN
HPB
HC5
FWHH(us)
Wavelenght (Anstrong)

outline

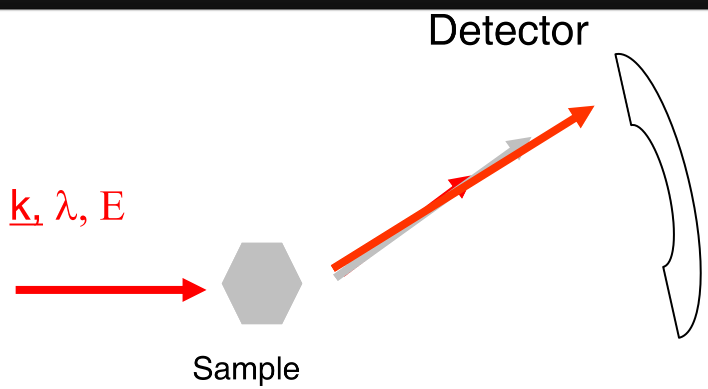
- Relationship between structure and property
  (物质结构与物性)
- Why neutrons: neutron characteristics and neutron scattering
  (为什么需要中子：中子特点与中子散射)
- Target Station of spallation neutron sources
  (散裂中子源靶站)
- **Instruments of spallation neutron sources**
  (散裂中子源谱仪)
- CSNS
  (中国散裂中子源)

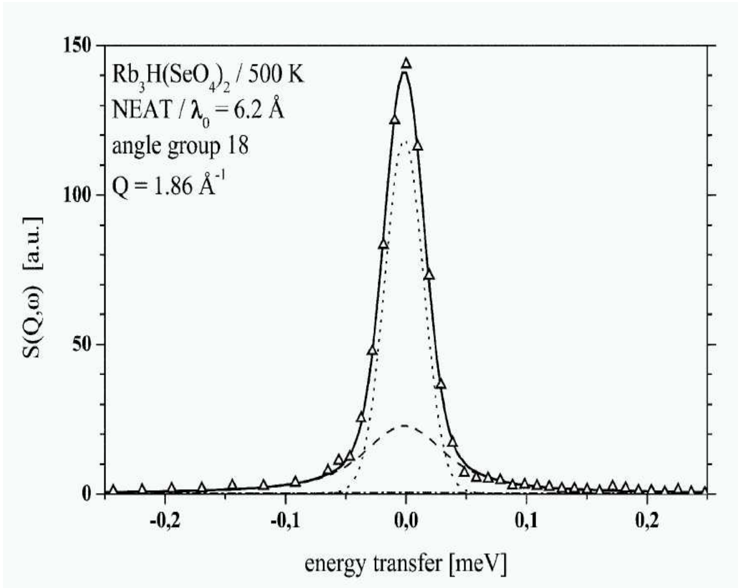
Schematic instrument layout at pulse source

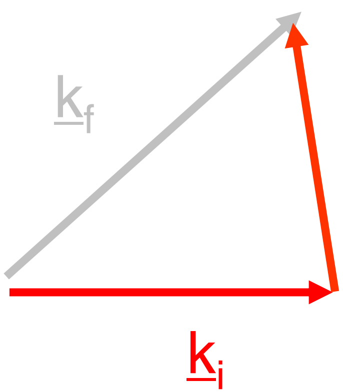




TOF data collection







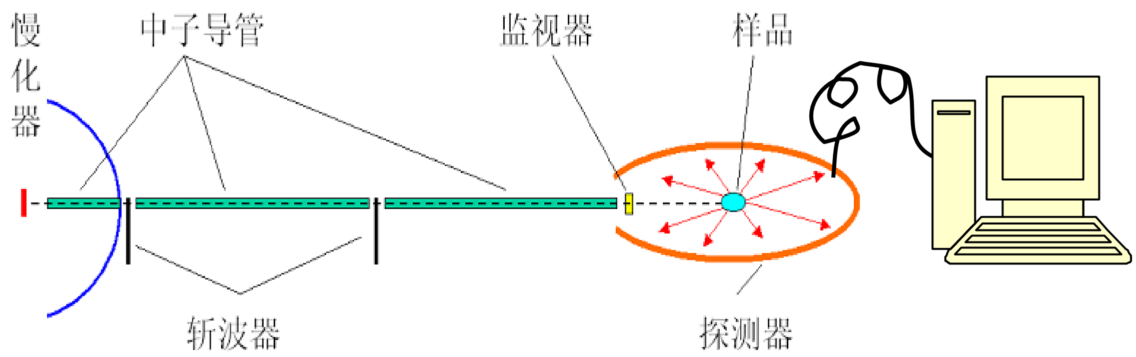
$\underline{Q} = \underline{k}_f - \underline{k}_i$ Wavevector transfer

$\hbar\omega = \underline{E}_f - \underline{E}_i$ Energy transfer

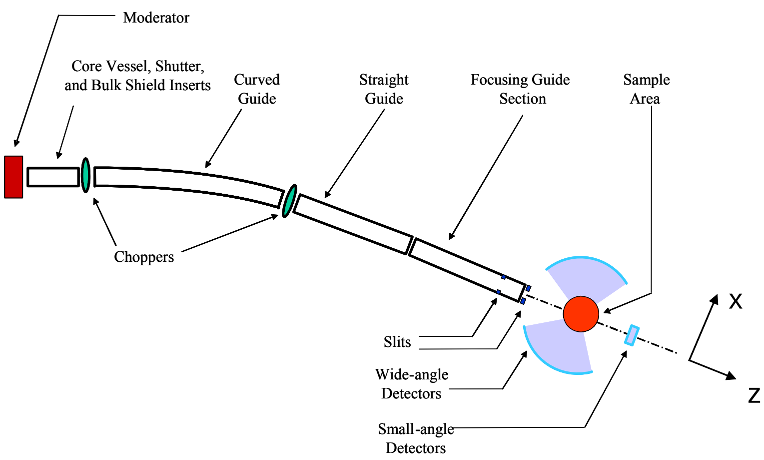
$|k_f| \neq |k_i|$ "Inelastic" scattering $I(\underline{Q}, \omega)$

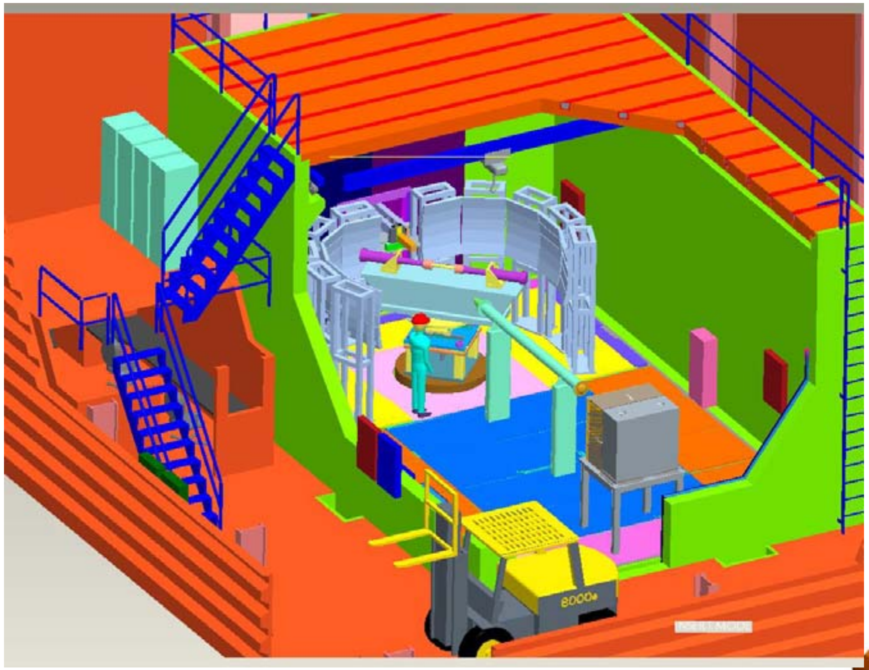
Basic components of TOF spectrometer

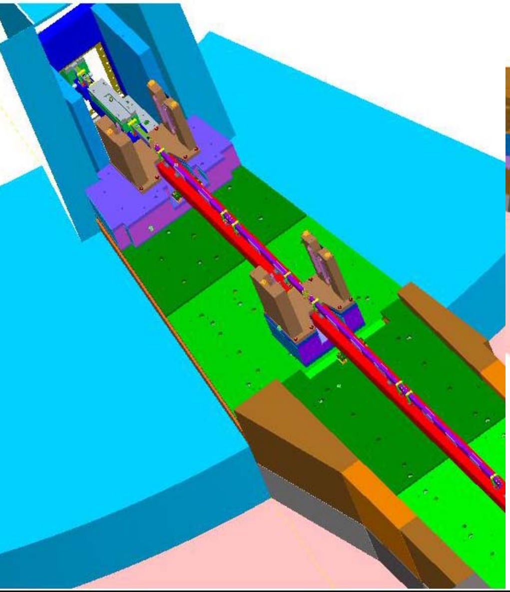
- 转子(Chopper)：又称斩波器、中子能量选择器
  本底转子、盘状转子和费米转子
- 中子导管
- 探测器
- 数据采集和分析系统
- 准直器
- 监测器
- 样品台
- 屏蔽体

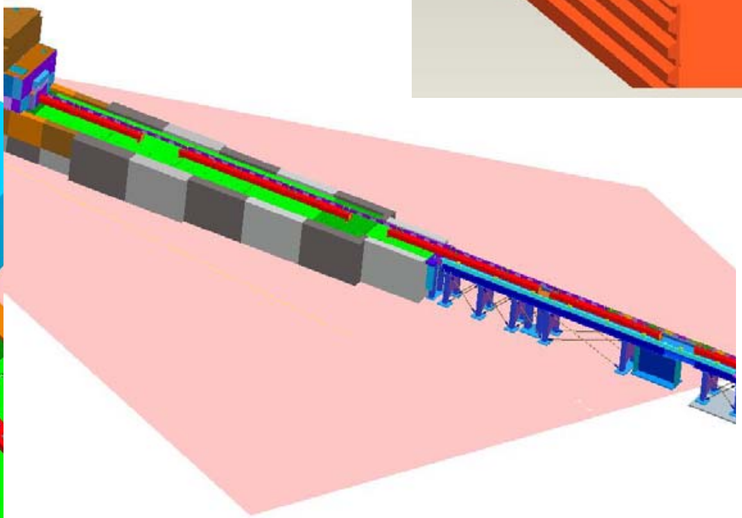


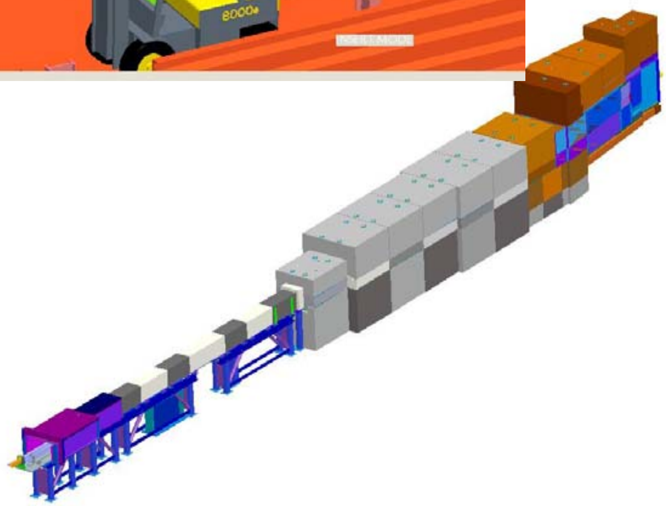
VULCAN (SNS)


Moderator
Core Vessel, Shutter, and Bulk Shield Inserts
Curved Guide
Straight Guide
Focusing Guide Section
Sample Area
Choppers
Slits
Wide-angle Detectors
Small-angle Detectors
X
Z

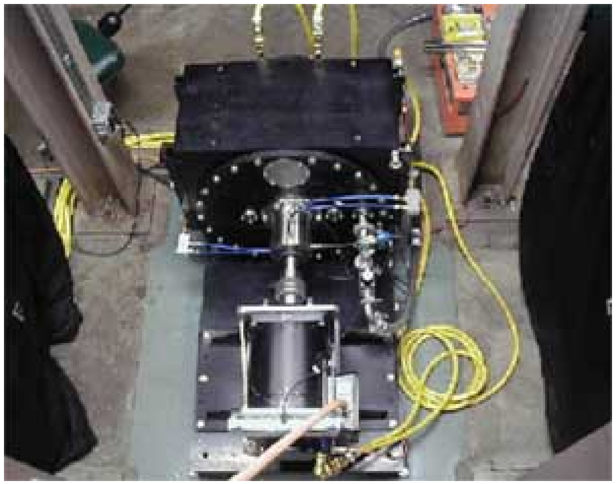




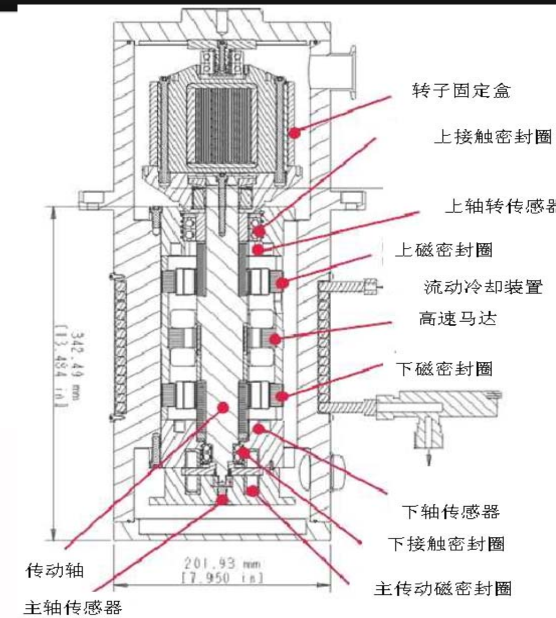




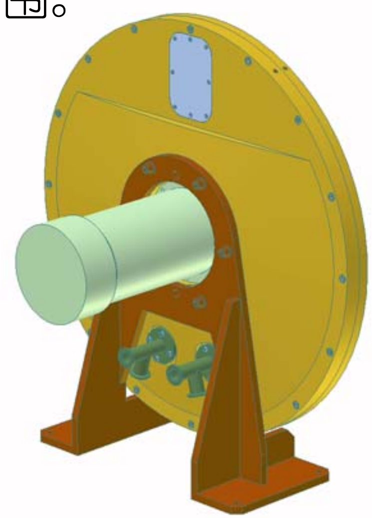
Choppers



带宽限制斩波器 (Bandwidth limited chopper)：厚度只有几个毫米。用来选择中子的波长(能量)范围。



本底斩波器(T_0 chopper)：紧接着慢化器，用来阻挡 γ 射线和部分快中子以清洁本底，也可用于阻挡部分脉冲以改变脉冲频率。

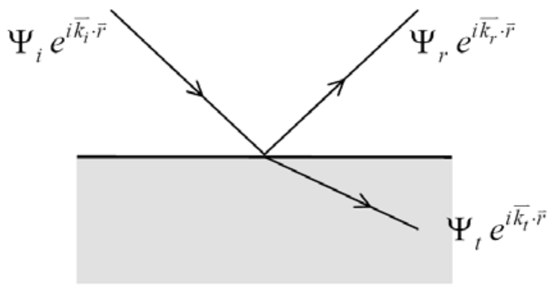


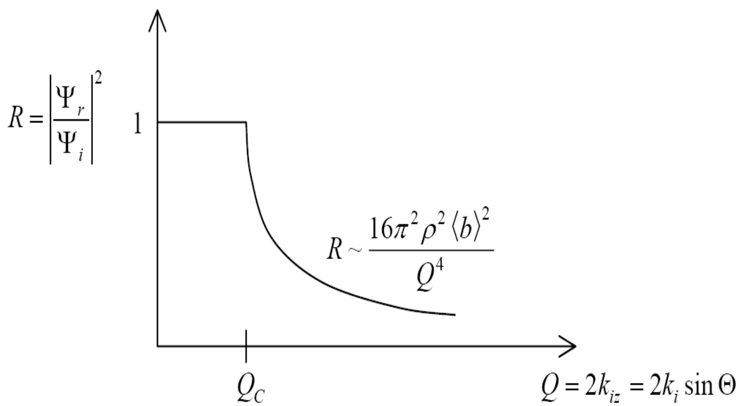
费米斩波器 (Fermi chopper)：仅让脉冲中子束中具有某单一波长(能量)的中子可以通过，起到单色器的作用。

位相控制：与中子脉冲具有特定的相位关系，必须能精确控制；

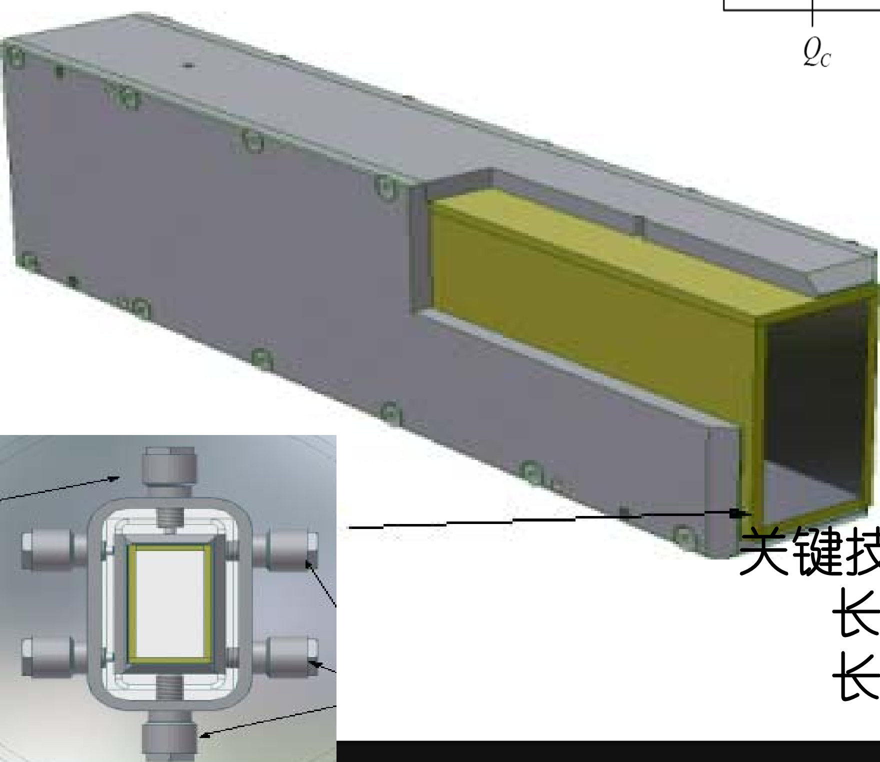
稳定运行：是谱仪中不多的运动部分，必须能长期稳定运行。

Neutron guide





中子导管：利用全反射原理，将波长大于截止波长、发散度低于某一特定值的中子无损耗的引导到样品处，以减少中子通量损失。



产品公司：

法　国	**Cilas**
美　国	**Osmic**
瑞　士	**Swissneutronics**
匈牙利	**Mirrotron**

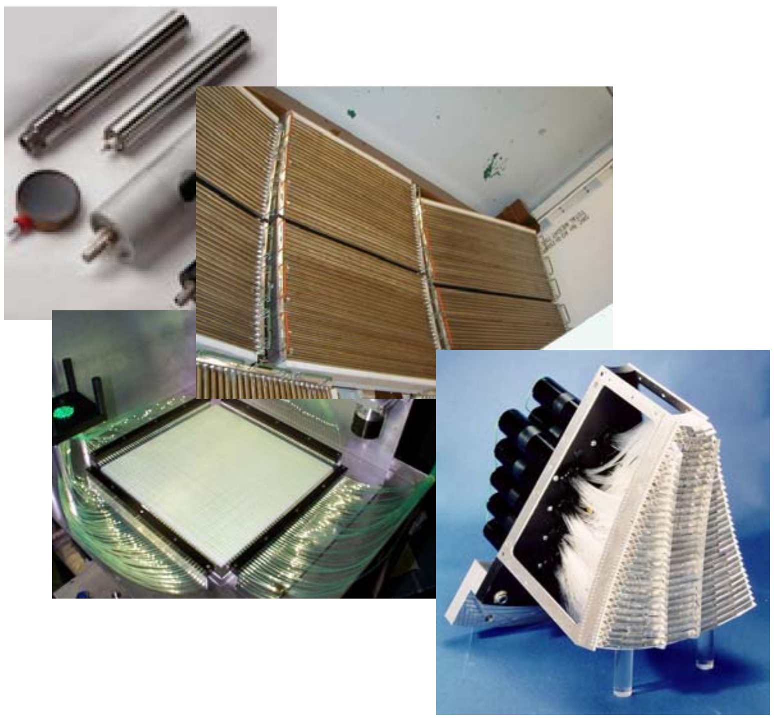
关键技术：

长度在50-100cm的大衬底上多层的均匀生长

长达几十米的导管准直

Neutron detector

探测器：用来接收散射中子，统计中子通量，记录中子飞行时间以得知中子波长(能量)，即记录I(Q, ω)。探测器分为单只探测器、一维和二维位置灵敏探测器等。



种类：

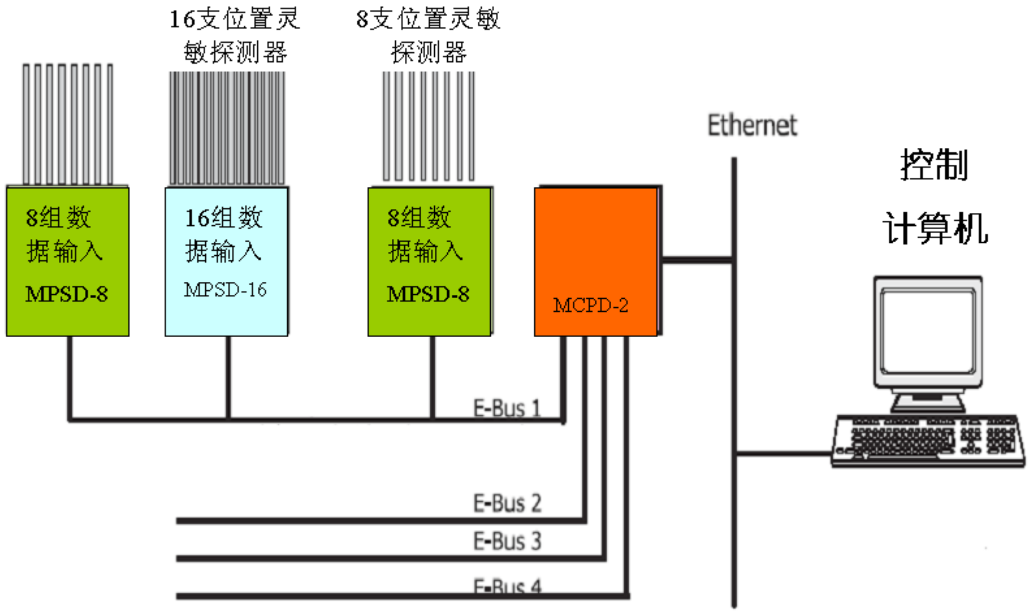
气体探测器
闪烁探测器
半导体探测器

美　国　　Reuter Stokes
美　国　　Canberra

关键技术：中子反应信号的甄别和前级放大；
中子探测效率

Data acquisition

数据采集和分析系统：是获得可靠数据的关键，包括：硬件——数据采集卡；软件——谱仪控制，数据处理。



探测单元： 10,000
时间通道： 6,000

每脉冲数据：6×10^7（每数据占4字节，则数据量达0.25Gb）

分辨率校正
入射通量归一
背底修正
数据合并……

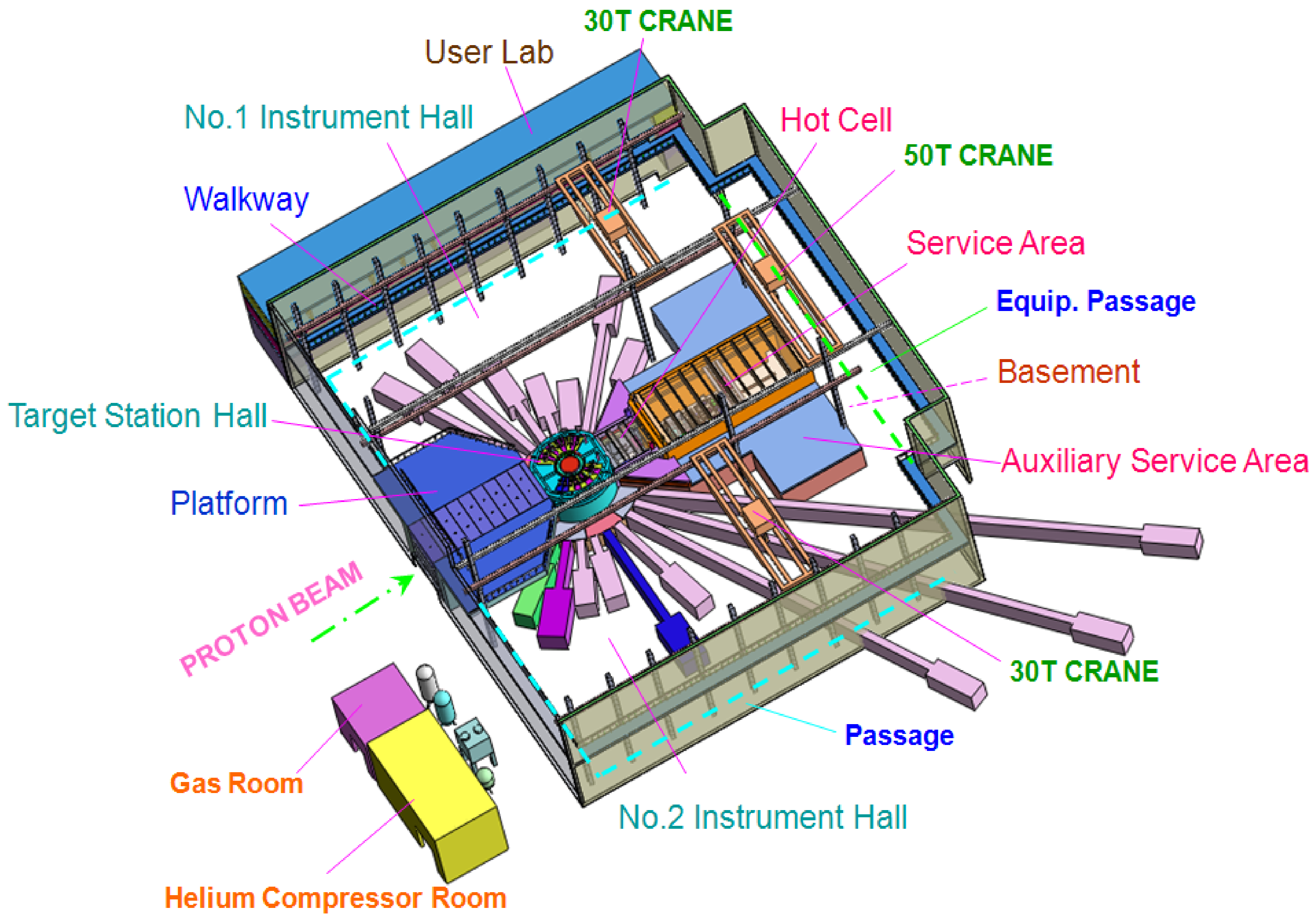
关键技术：谱仪自动化控制集成；海量数据的快速记录、累计和传输

outline

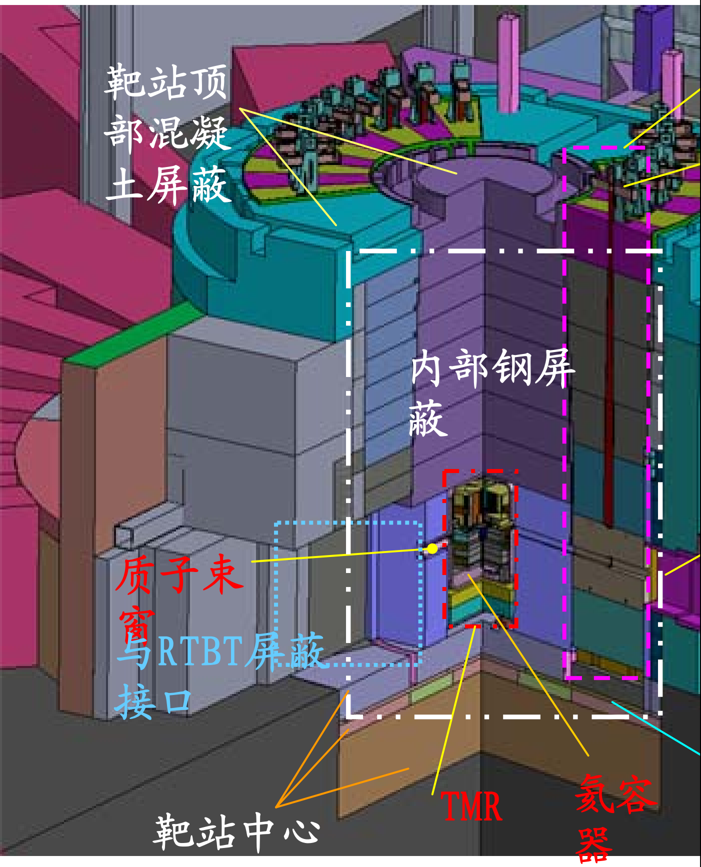
- Relationship between structure and property
  (物质结构与物性)
- Why neutrons: neutron characteristics and neutron scattering
  (为什么需要中子：中子特点与中子散射)
- Target Station of spallation neutron sources
  (散裂中子源靶站)
- Instruments of spallation neutron sources
  (散裂中子源谱仪)
- **CSNS**
  (中国散裂中子源)

中国散裂中子源-CSNS

Target Station and Instruments for CSNS



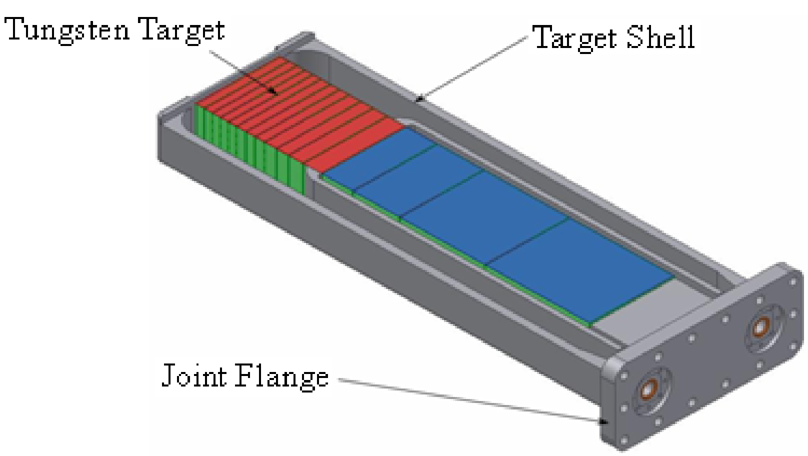
Design parameters



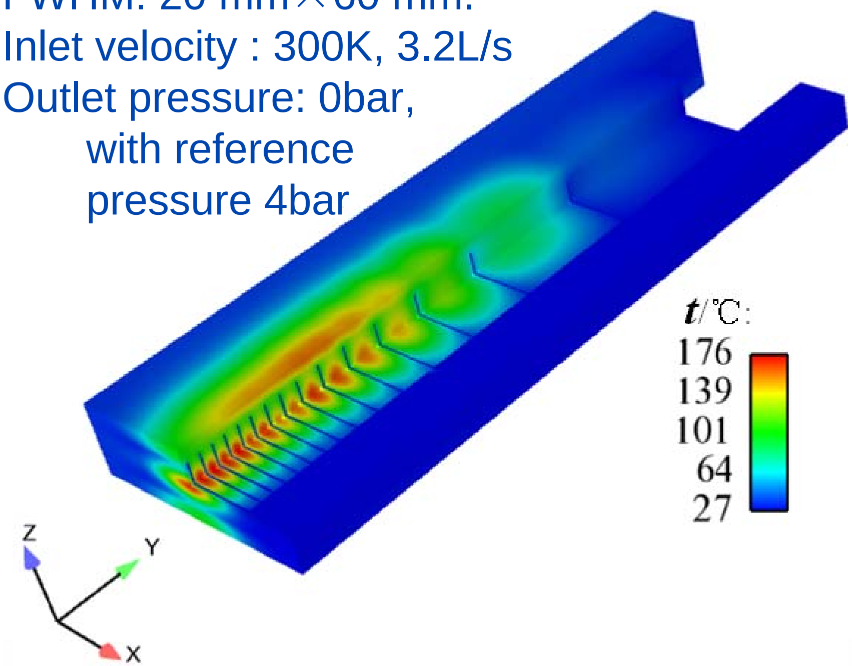
Parameters	Phase I	Phase II	PHASEIII
Beam power on target (kW)	100	200	500
Proton energy on target (GeV)	1.6		
Average beam current (μA)	62.5	125	
Pulse repetition rate (Hz)	25		
Target	1; Tungsten		1or 2
Moderators	3; LH2(C), LH2(DP), H2O(D)		
Reflector	Be		
Beam ports	20		
Neutron instruments	3	20	
Dose control in hall (μSv/h)	2.5		
Operation （hrs/yr)	5000		

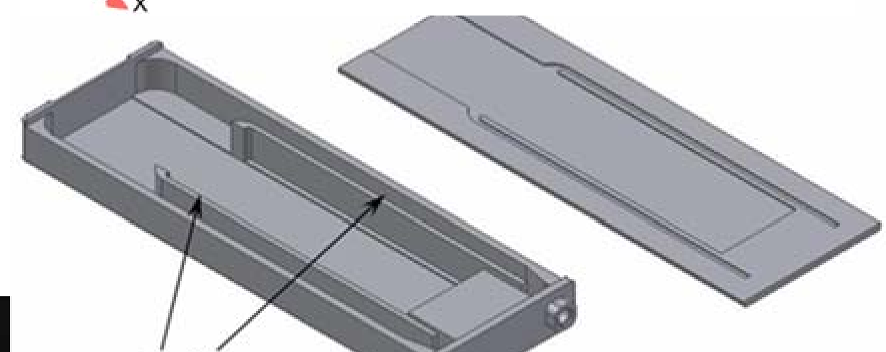
Target Design

Material	Tungsten cladded by 0.5 mm tantalum
Length	607.5 mm (tungsten: 570 mm; tantalum: 15 mm; heavy water: 22.5 mm)
Cross section	50x130 mm
Coolant	D2O/H2O, 1.5mm channel
Target container	8mm SS316 (2/4mm for incident window)

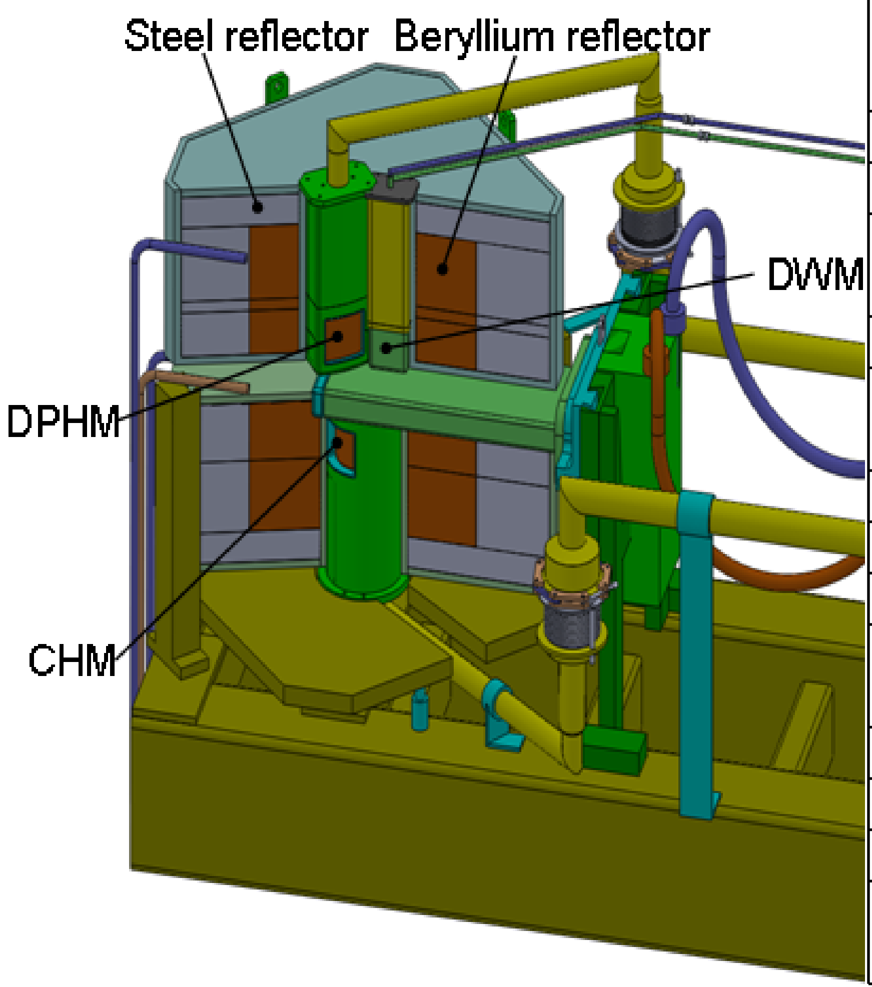


Beam footprint: 40 mm×120 mm,
Gauss distribution in two direction,
FWHM: 20 mm×60 mm.
Inlet velocity : 300K, 3.2L/s
Outlet pressure: 0bar,
with reference
pressure 4bar



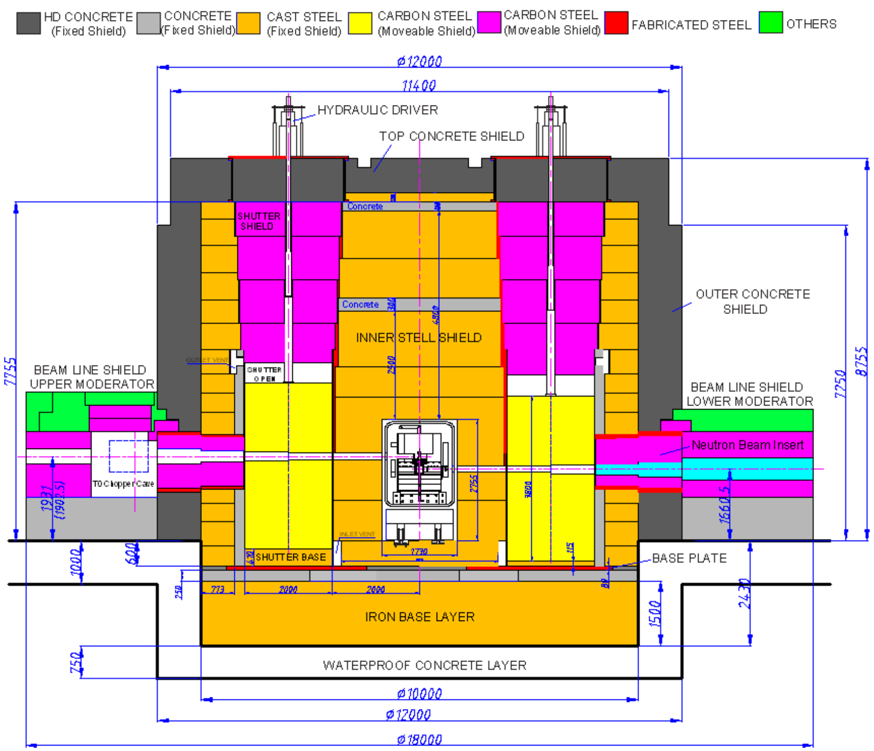


Moderator and Reflector



CHM	hydrogen volume	Φ150x100mm 20K
	Hydrogen vessel thickness	9mm except 5mm for view surface
	water premoderator thickness	20mm
	view surface VxH	100x102.2 mm
DPHM	hydrogen volume	120x120x50 mm 20K
	hydrogen vessel thickness	7mm
	view surface VxH	100x102.2 mm
	poison position offset from center	5mm
	poisoner	Cd/Gd 0.5mm
	decoupler	Cd/ B4C 0.5-2mm
DWM	water volume	110x110x50 mm
	water container thickness	4mm
	decoupler	Cd/ B4C 0.5-2mm
Reflector	Be reflector	Φ700x800mm
	Fe reflector	1000x1000x1000mm
	coolant	D2O/H2O, 10% volume fraction

Shielding

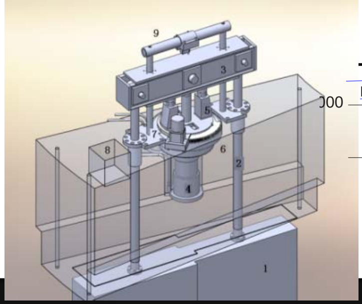


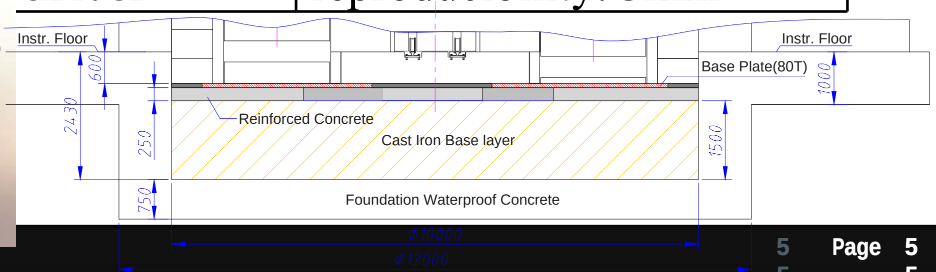
Dose control	< 2.5μSv/h
Installation	50T crane; Gaps: 10mm for the fixed blocks and shutters, 20mm & 30mm for Helium Vessel and side & top shielding
Fixed blocks	Base plate, PBW interface, He-vessel interface, neutron port interface
Shutter	dose control: 10 μ Sv/h at 10 m from the moderator; SS316
Shutter driver	400mm travel in < 2min; reproducibility: 3mm

Block shielding:

5 m steel

+ 1 m heavy concrete

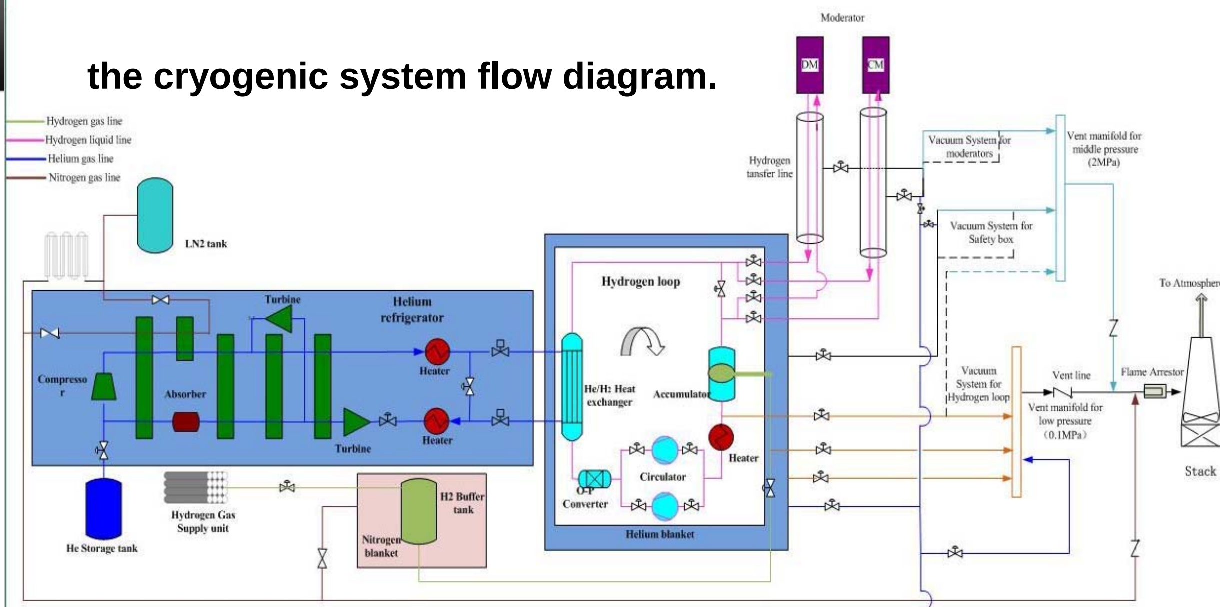




Cryogenic design

- Average temperature : < 20K
  Temperature difference : < 3K
  Para-hydrogen : > 99%
  Operational pressure: 1.5MPa

the cryogenic system flow diagram.

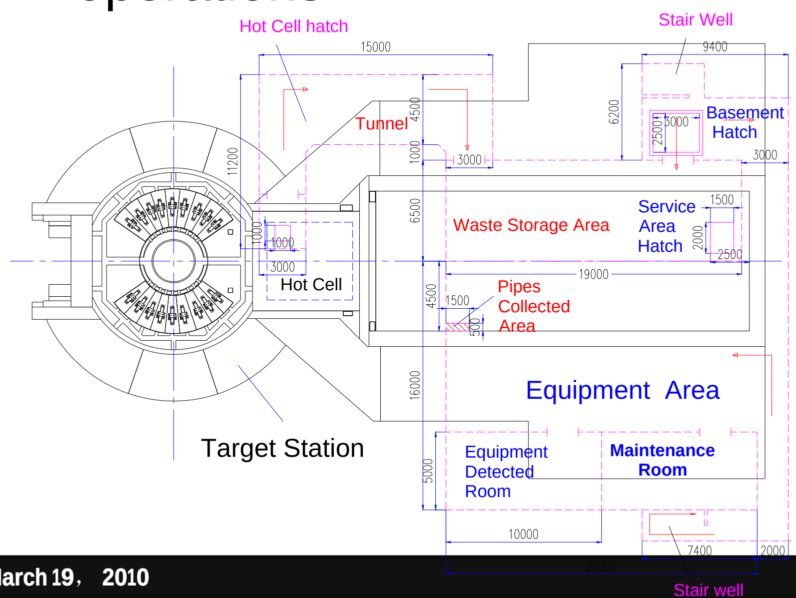


Helium Refrigerator	Flow rate	110g/s	Hydrogen circulation system	Flow rate	87.1g/s
	HX Temperature	14.9-20.9K		HX Temperature	18.5-21.7K
	Operational pressure of compressor	0.12-0.75MPa		Operational pressure of compressor	1.5MPa
	Design pressure	2.5MPa		Design pressure	2.5MPa
	Refrigerator capacity	2500W/21K		Heat removal	2400W

Remote handling design

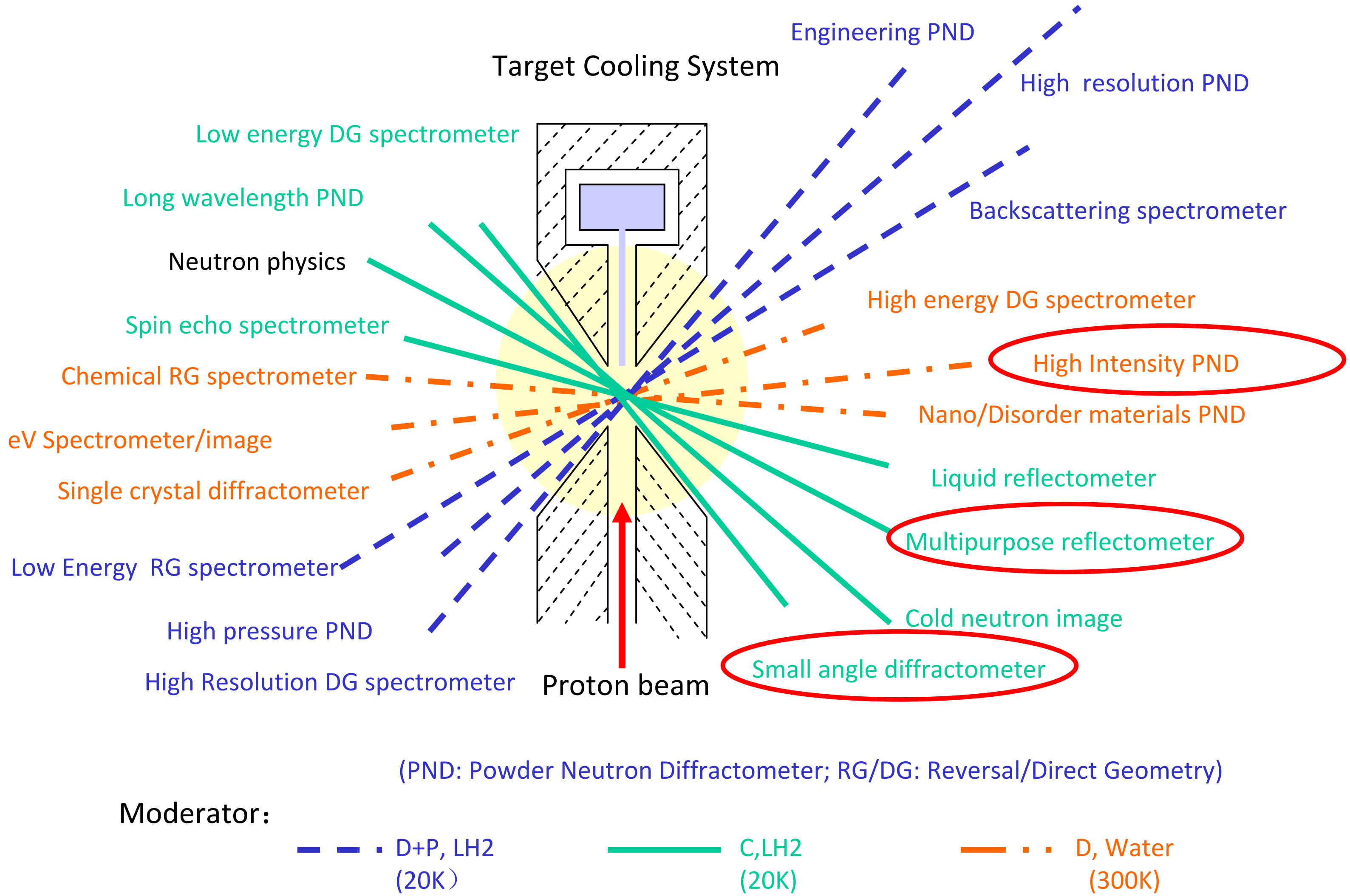
Goal: replacement, transport and final storage of contaminated /activated.

Principle: as low as reasonably achievable (ALARA) , for all personnel and contamination control operations



	Design lifetime	Maintenance time
A: Key Component		
Target	3- 5 years (10 dpa)	10 days
PBW	5 years (10 dpa)	10 days
Shutter	>20 years	10 days
Helium Vessel	>20 years (neutron window)	10 days
Moderator	3-5 years（poison material)	10 days
Reflector	>20 years	15 days
B: Normal maintenance		
Cooling water system	1-2 years	3 days
Monitoring instruments	1-2 years	3 days
Routine maintenance	Half a year	3 days

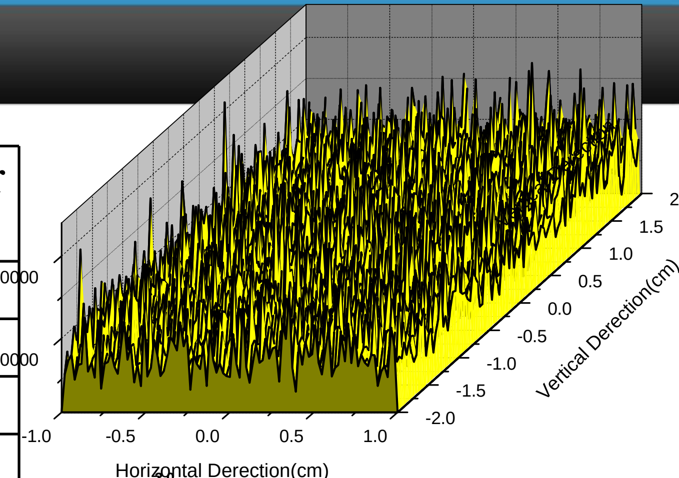
CSNS instrument layout

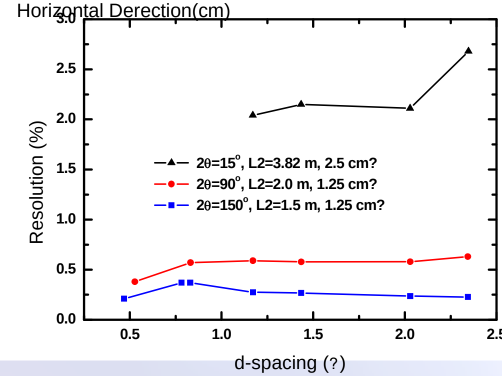


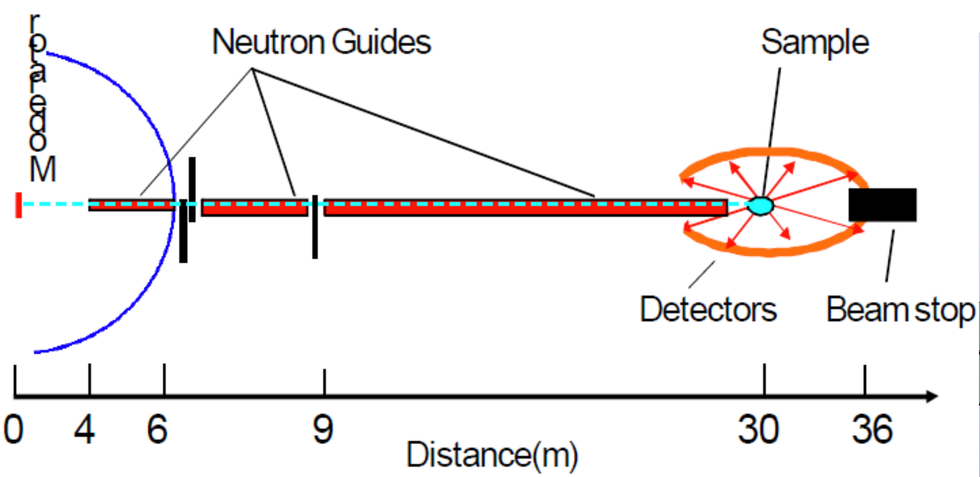
(PND: Powder Neutron Diffractometer; RG/DG: Reversal/Direct Geometry)

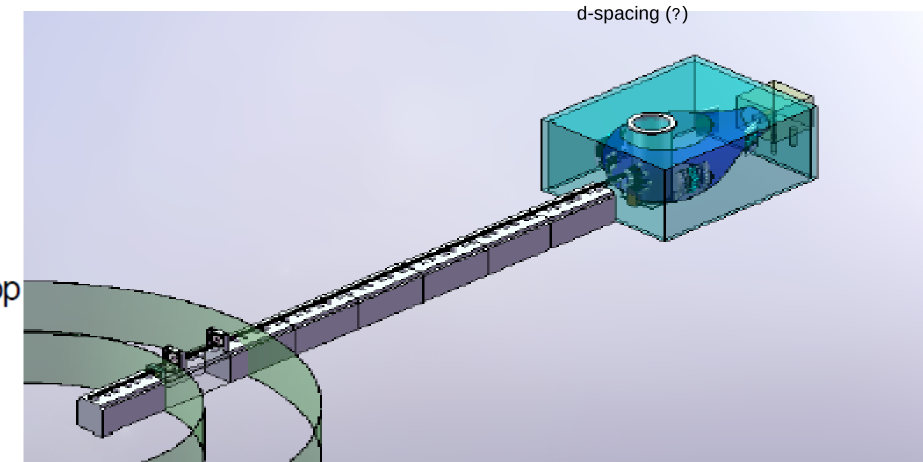
Neutron instrument: HIPD design

Moderator		decoupled water moderator（300 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



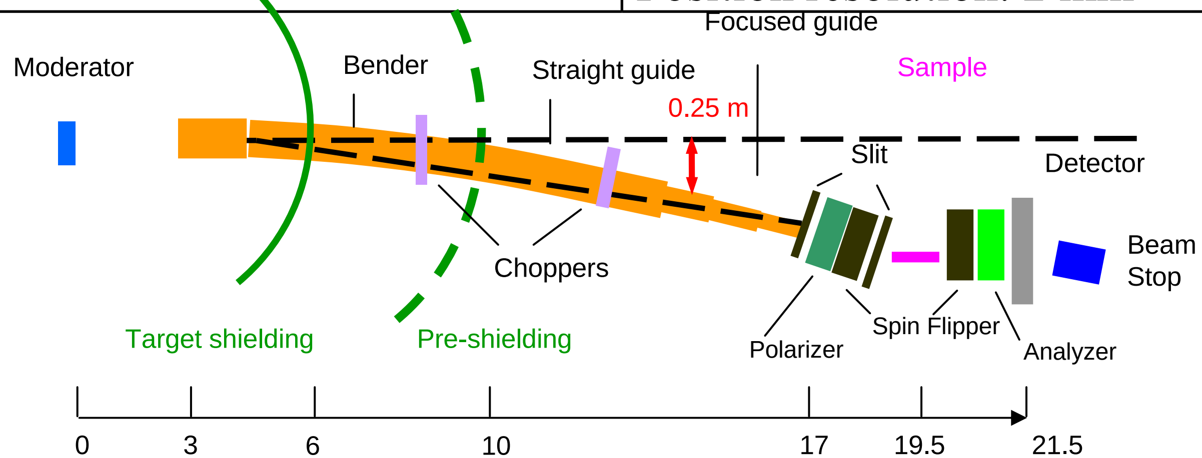






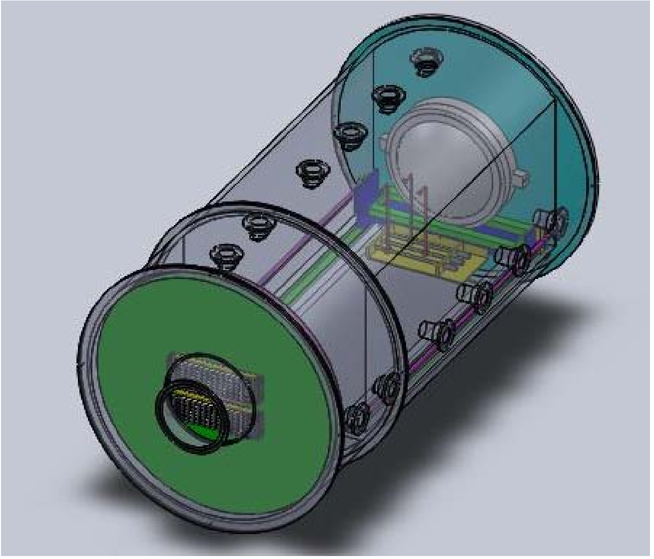
Neutron instruments: REFL design

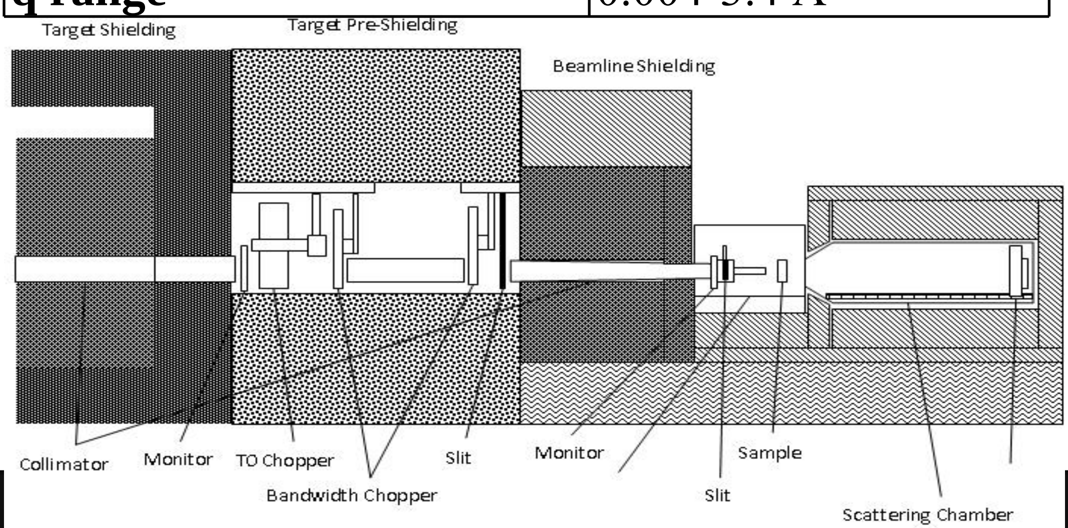
Moderator	Coupled liquid H2 (20 K)
Bandwidth（Δλ）	6 Å
Guide	Bender+Sraight+Taper 40 × 60 → 20 × 30 mm²
Source to sample distance L1	19.5 m
Sample to detector distance L2	2 m
Sample table	6-axis movements
Polarizer/analyzer	Supermirror type
Detector	2D position-sensitive detector Position resolution: 2 mm

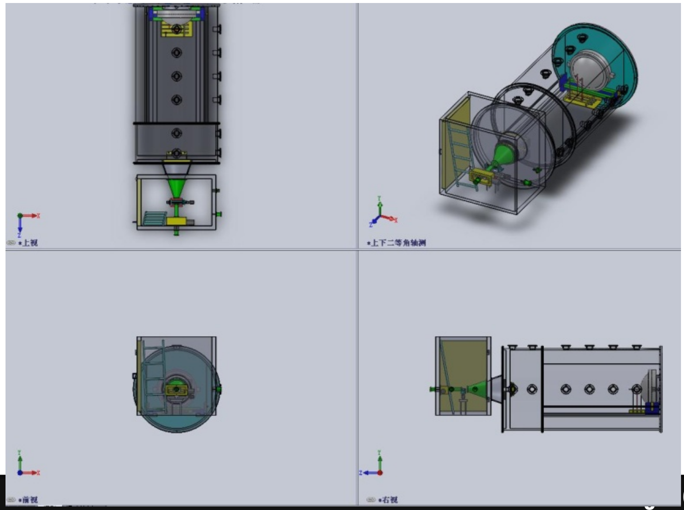


Neutron instruments: SANS

Moderator	Coupled hydrogen（20K）
Moderator to sample distance	14 m
Sample to detector distance	5 m
Detector	
Effective area	50×50 cm^2
Resolution	1 cm (FWHM)
Distance to sample	1~5 m
Working wavelength range	0.4-8 Å
q range	0.004-3.4 Å^{-1}

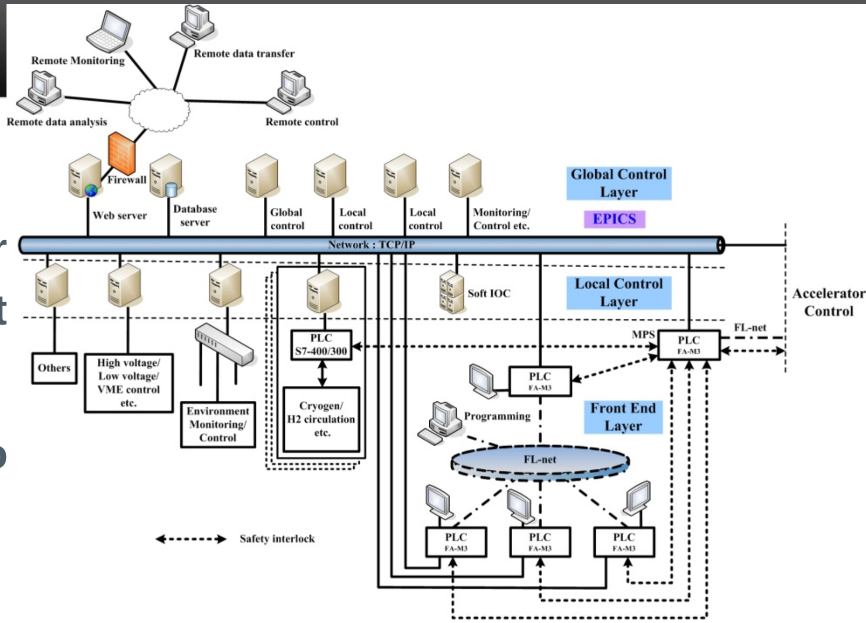


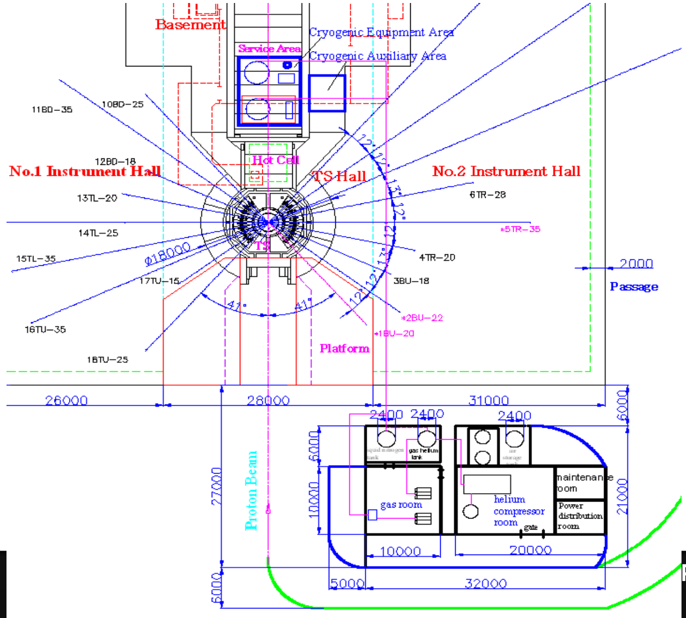




Control and utility

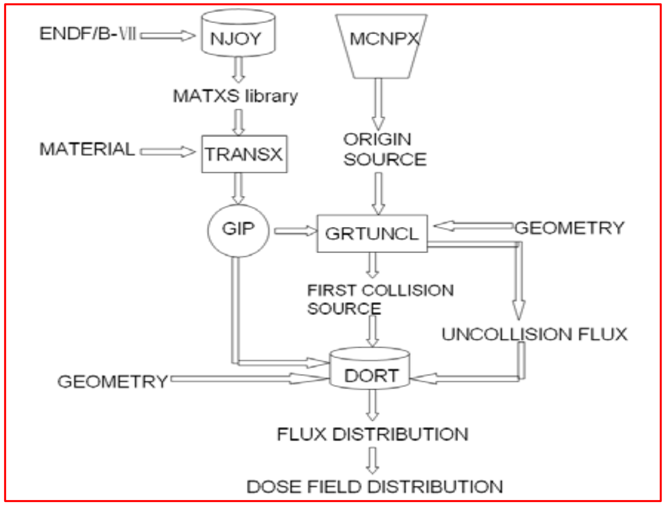
- **Experimental control**
  - To control the behaviors and monitor the status of the devices of the target station and instruments
  - 3 layers:Global Control, Local Contro Front End
  - EPICS:software frame
  - PLC (Yokogawa): frontend unit
- **Experimental utility**
  - water supply & drainage system
  - ventilation & compressed air system
  - power distribution system





Neutronics simulation tools

- **TMR neutronics optimization:**
  - MCNPx
  - database and scattering kernel from ENDF / Sab2002/ La150
- **Shielding:**
  - MCNPx, DOORS
  - Cross section library HILO2K/ HEST1.0

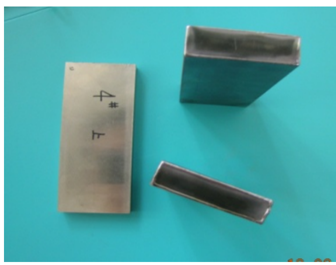


- **Activiation and afterheat**
  - LAHET /MCNP4C or MCNPx:

    spallation reactions and particle Transports;
  - CINDER’90: activity, afterheat and decay gamma rays of the radionuclide,
  - MCNP4C: the dose rate induced

Target Materials

- **HIP**
  - temperature of 1500° C, pressure of 200Mpa
  - Good interface bonding achieved

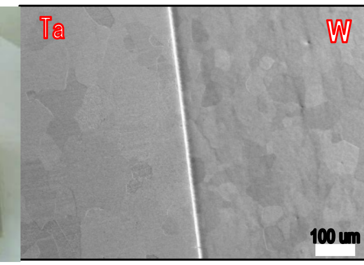


W block

Ta coated

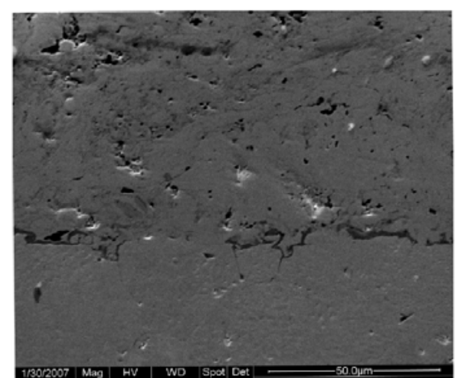
HIP

Ta cladding



SEM interface image

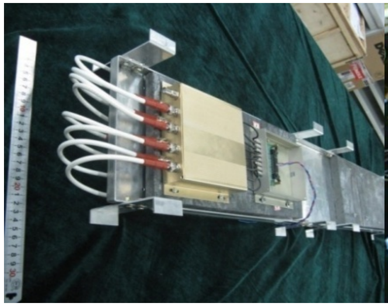
- **Plasma spraying**
  - Small gaps in μm order
  - further process underway



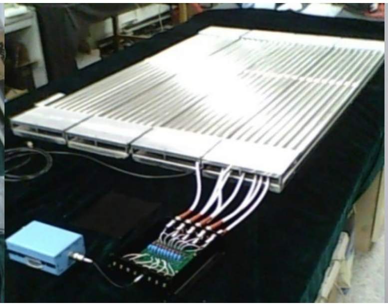
SEM interface image

Detector and electronics

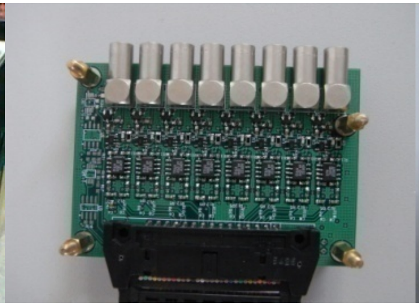
- **LPSD array and its electronics**



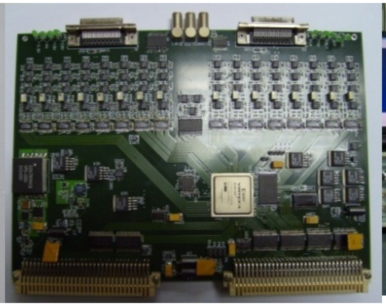
8-tube column



4-column array



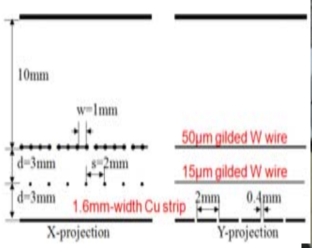
preamplifier



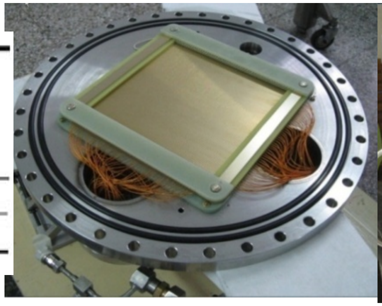
QTC

DAQ test

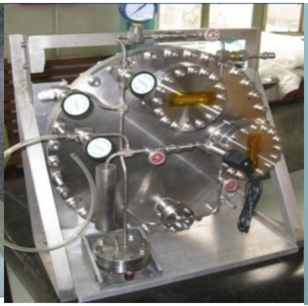
- **2D MWPC and its electronics**



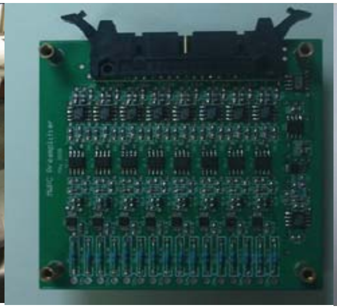
design



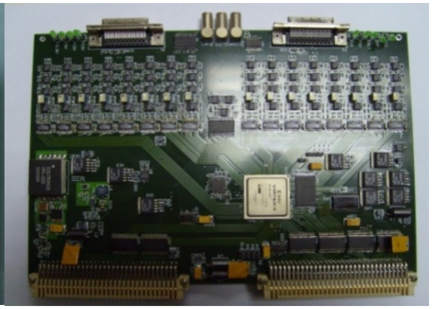
fabrication



MWPC



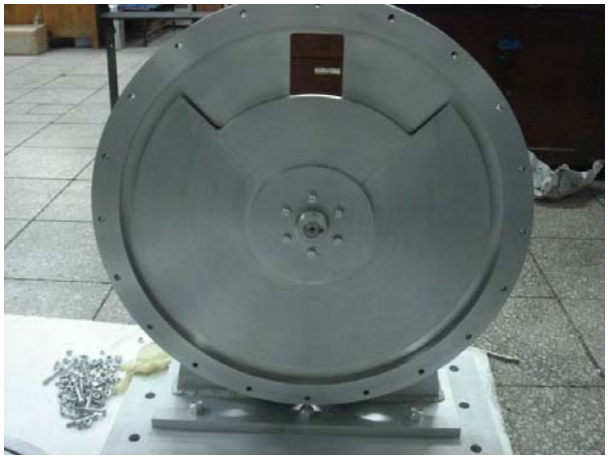
strip readout



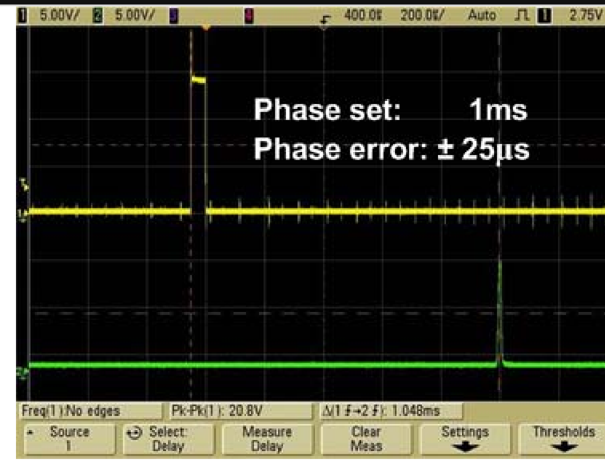
MQ

- **Scintillator detecors**
  - Finish its preliminary design, start scintillator ordering

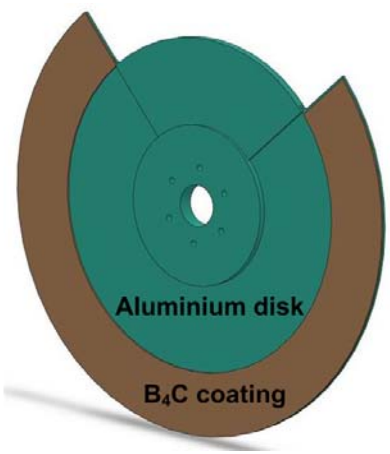
Bandwidth Limited Chopper



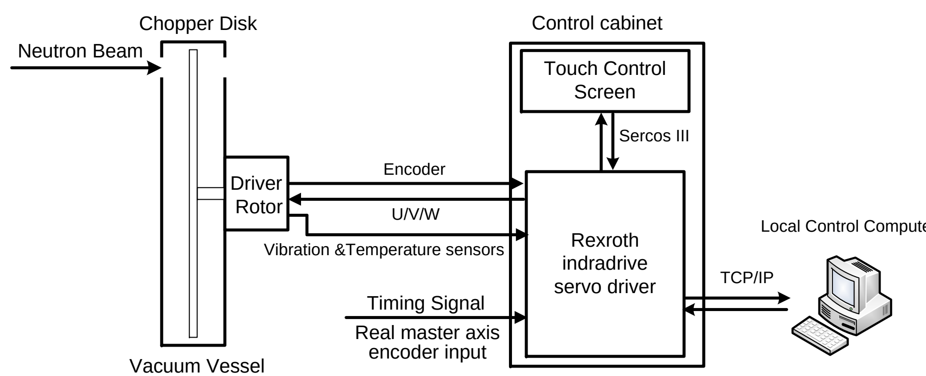
Photograph of the prototype machine



Phase control on the chopper mock-up machine



Mixture of B_4C micro powder and TS811 epoxy resin



Neutron chopper control system on the prototype machine

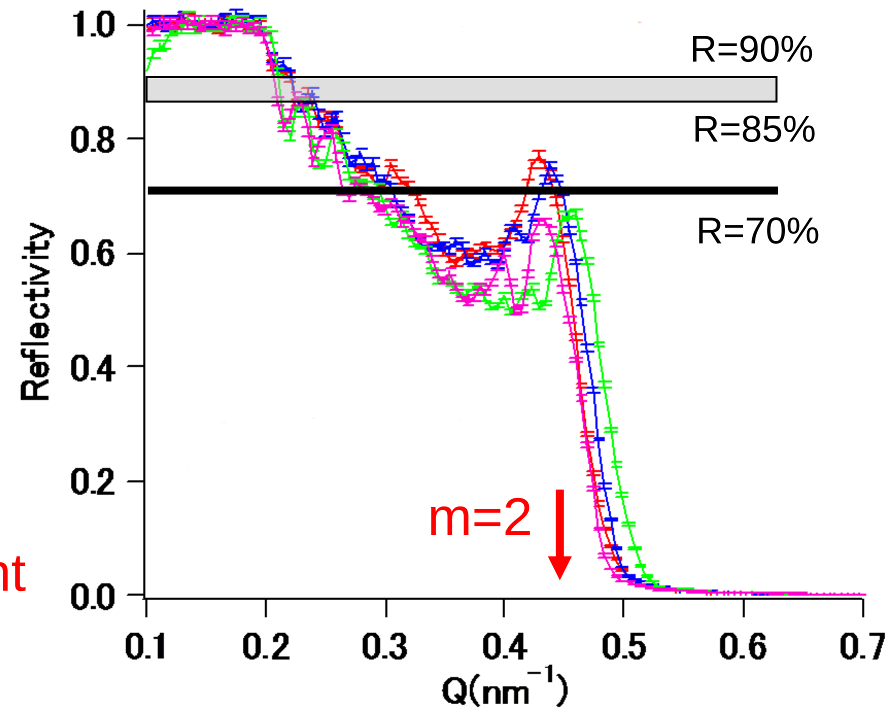
Neutron Guide

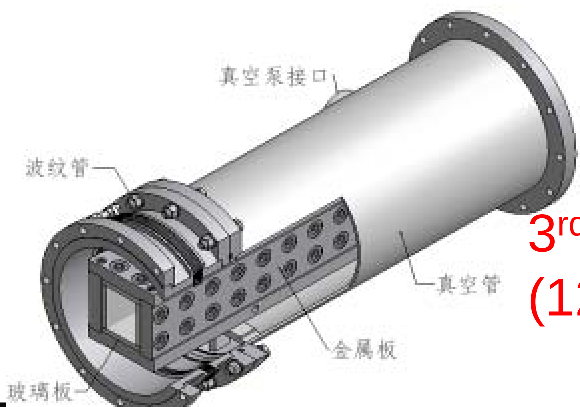
Red: No.4 (08-11-19)

Blue: No.5 (08-11-21)

Green: No.2 (08-06-20)

Pink: No.2 (08-07-04)





3rd measurement (12/2008)

Users Development

- Five CSNS User Meetings/Workshops on Application of Spallation Neutron Source have been held since 2004
  - User Committee has been set up
  - discuss and review the design of 3 instruments for CSNS phase-1 project
  - a better understanding of special needs from the potential users
- CSNS started to support some users for training at foreign neutron sources in 2005.

结束语

- 中子散射是研究位置微观结构与相互作用的不可替代的工具。
- CSNS是目前我国投资最大的多学科研究平台，与同步辐射光源（如上海、北京和合肥光源）及反应堆互补，以其独特性能服务于生命、环境、材料、医药、物理、化学等学科及工业界。
- CSNS是一项艰巨、复杂但值得付出的工程建设和科学研究项目，期待更多的青年才俊。

Thank You !