China high-intensity accelerator technology developments for Neutron Sources & ADS

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Outline

- Introduction
- High-intensity proton accelerator programs
  - ADS accelerator program
  - China Spallation Neutron Source project
  - Compact Pulsed Hadron Source project
- Accelerator technology developments
- Discussions & summary

Introduction

Major existing/proposed accelerator & neutron sources

SSRF: the 4th light source in China

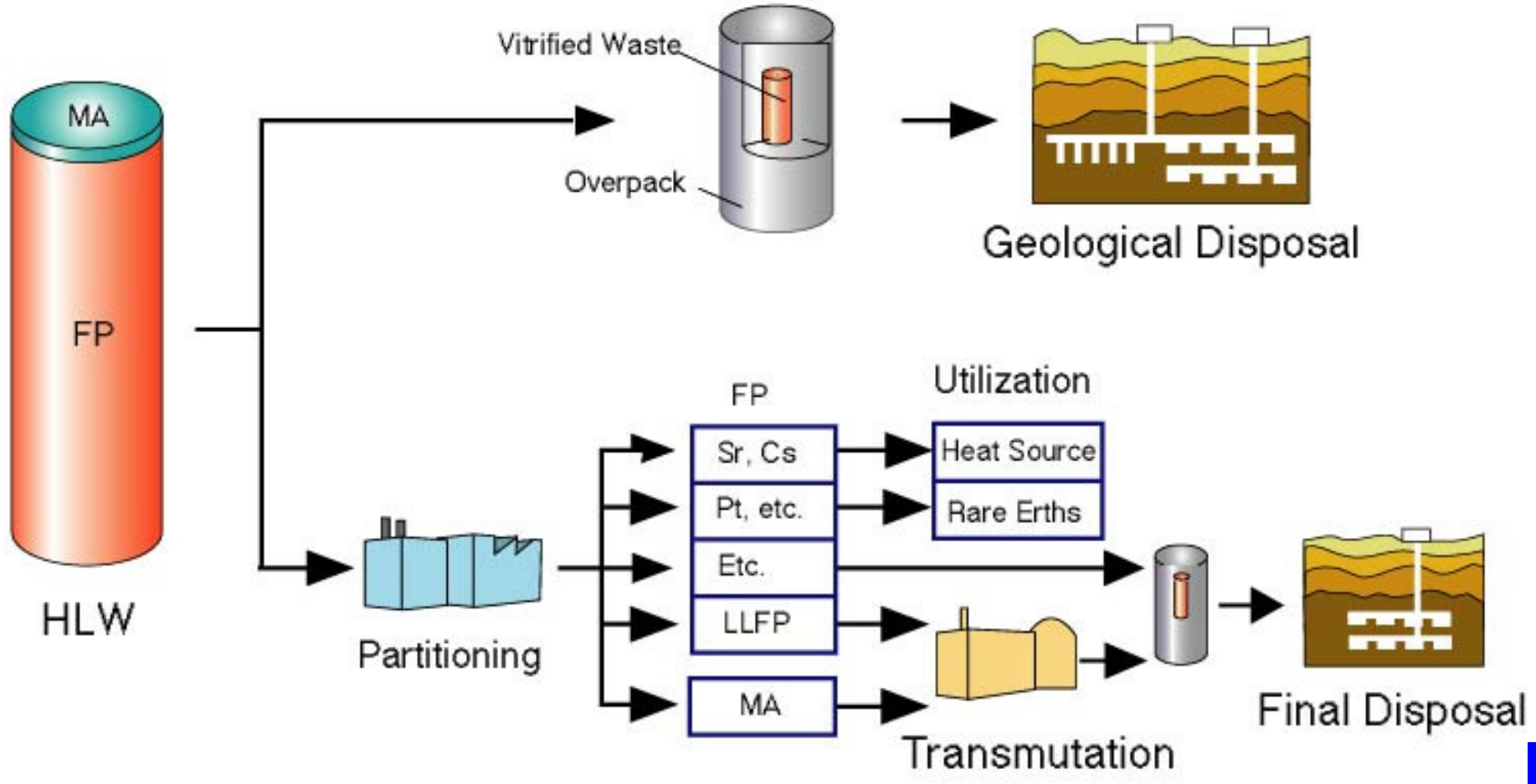
- Shanghai synchrotron light source, 2008

Major demands for hadron accelerator

- ADS for nuclear waste transmutation
- Thorium fueled accelerator driven subcritical reactor (ADS) for power generation
- multi-disciplinary platform neutron source
- ion beam therapy
- compact neutron and proton sources

ADS for waste transmutation

- By 2020, addition of nuclear power of 40 GWe, by 2050 reaching 240 GWe. 25 tons of waste per 1 GWe reactor plant.
- Transmutation of MA and LLFP material.



Neutron scattering applications

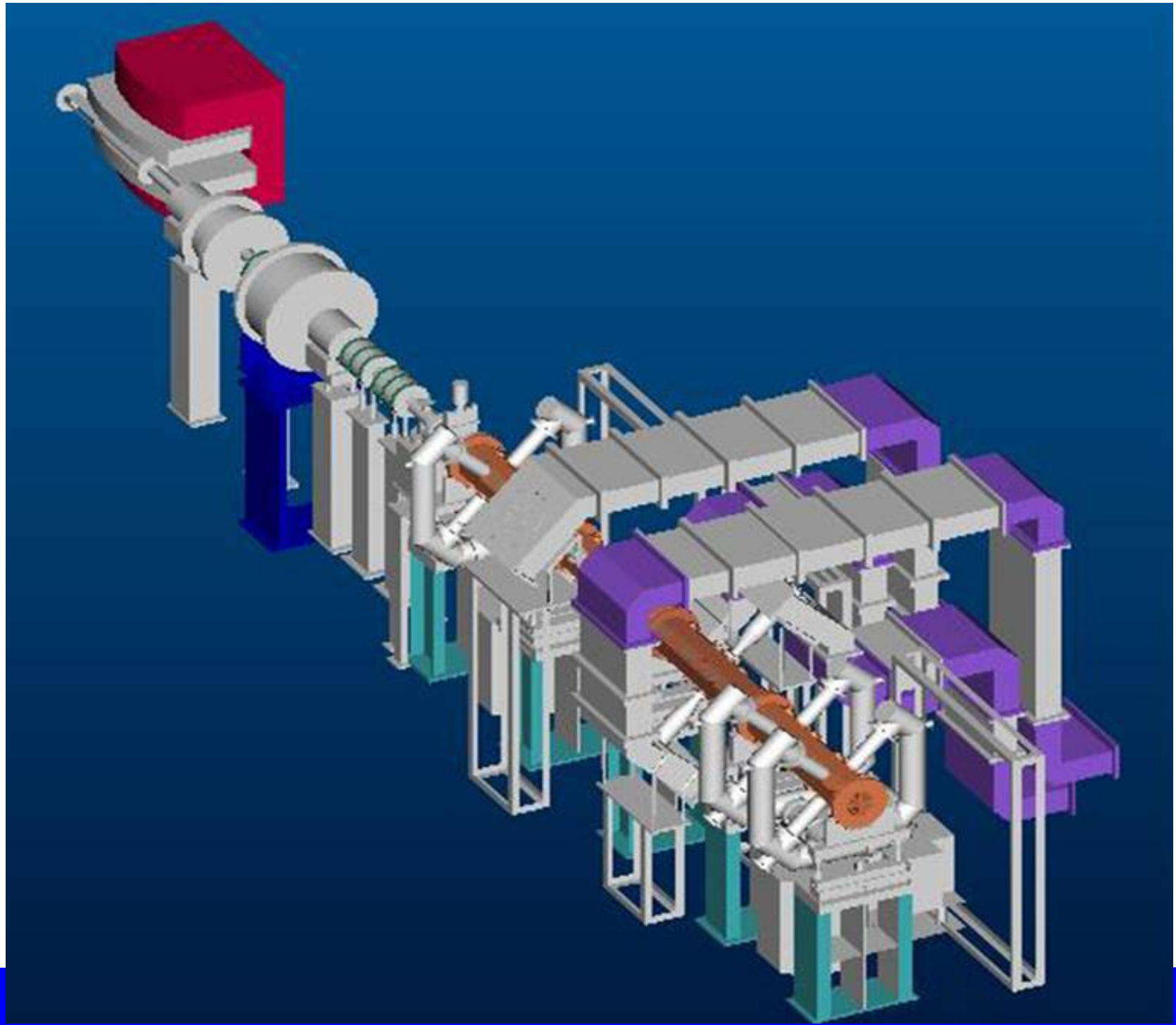
中子散射的研究成果

——过去40年间中子散射的发展与革新

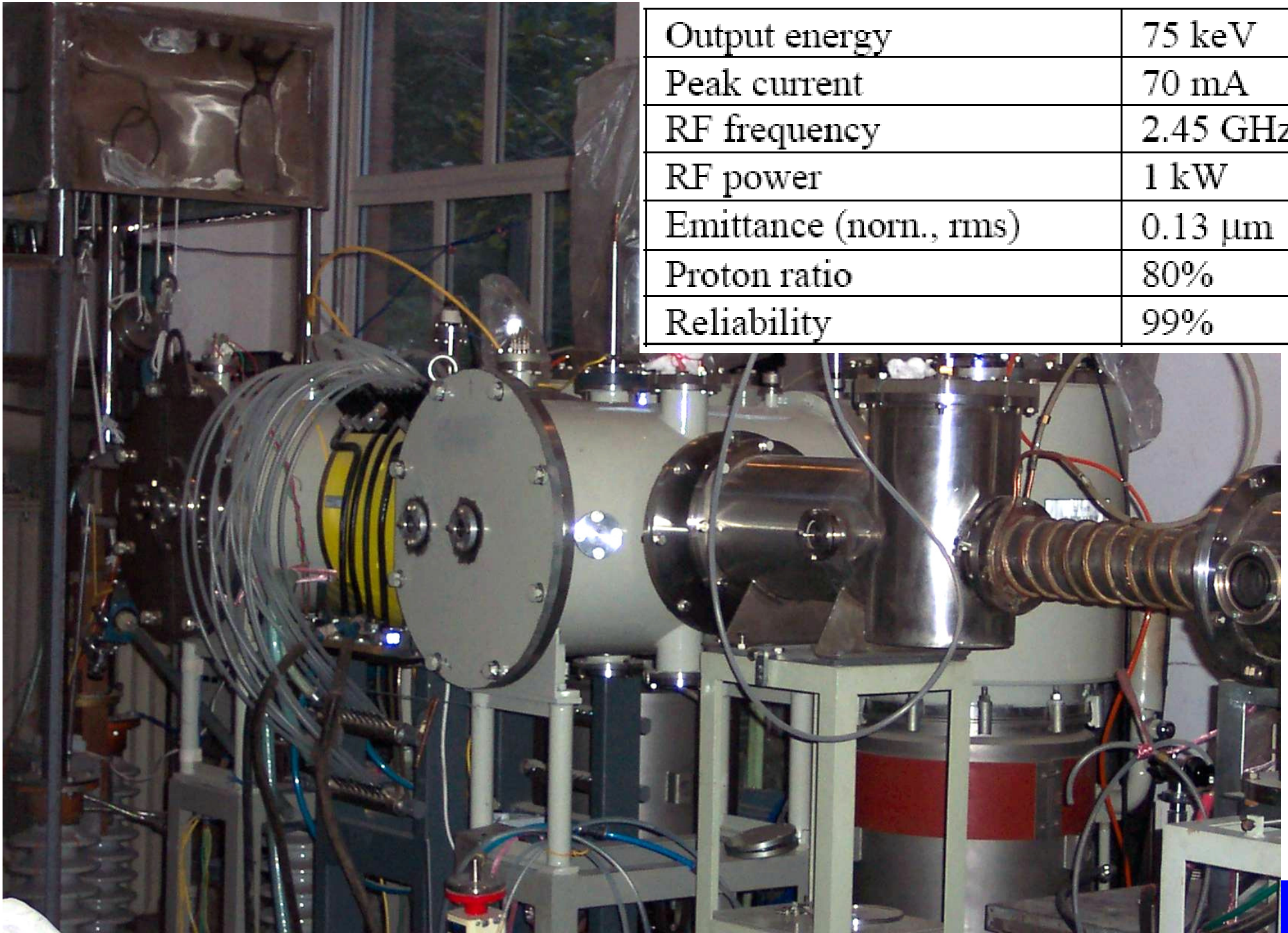
High-intensity proton accelerator programs

– ADS accelerator program

ADS program 3.5 MeV front end

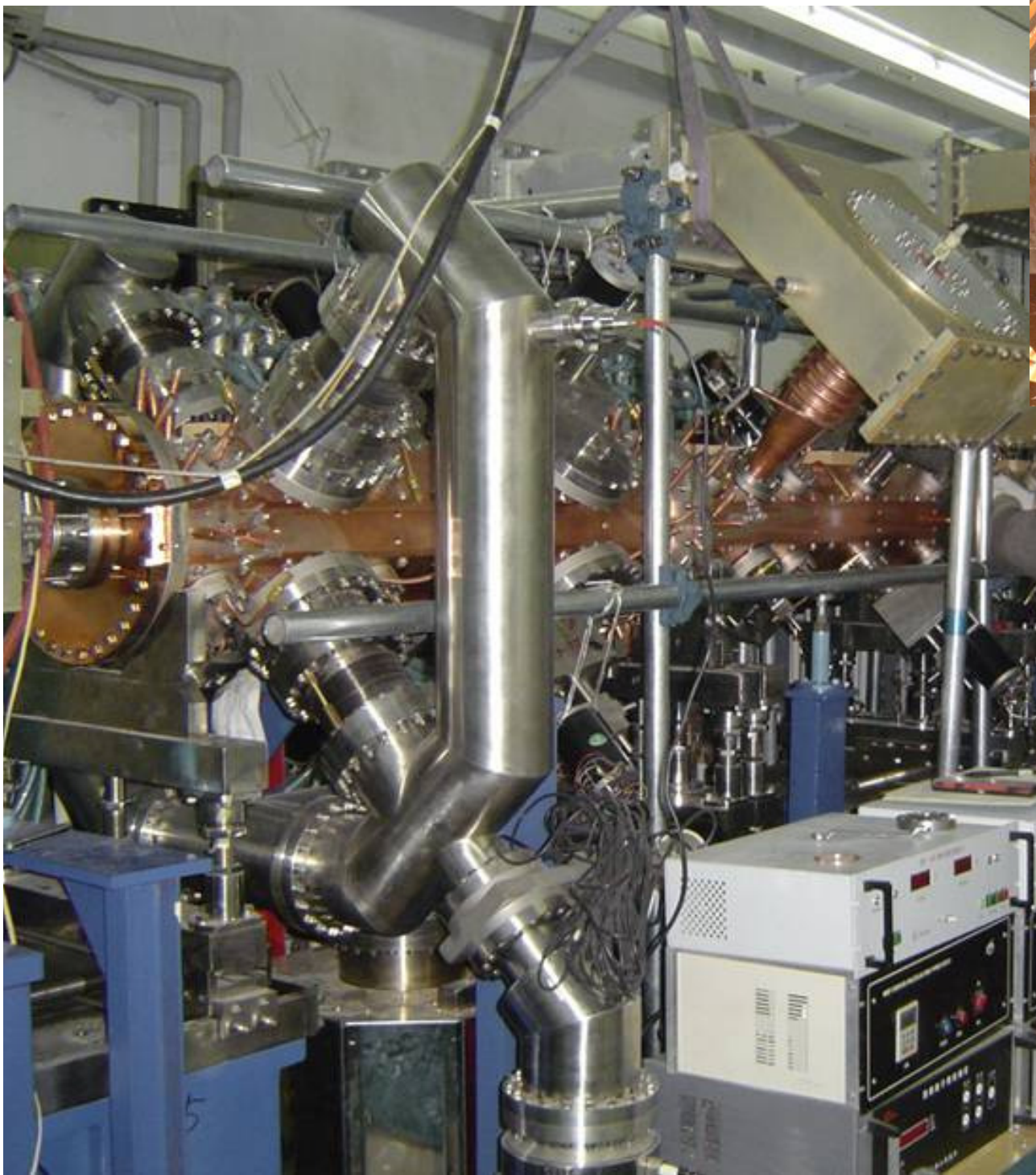


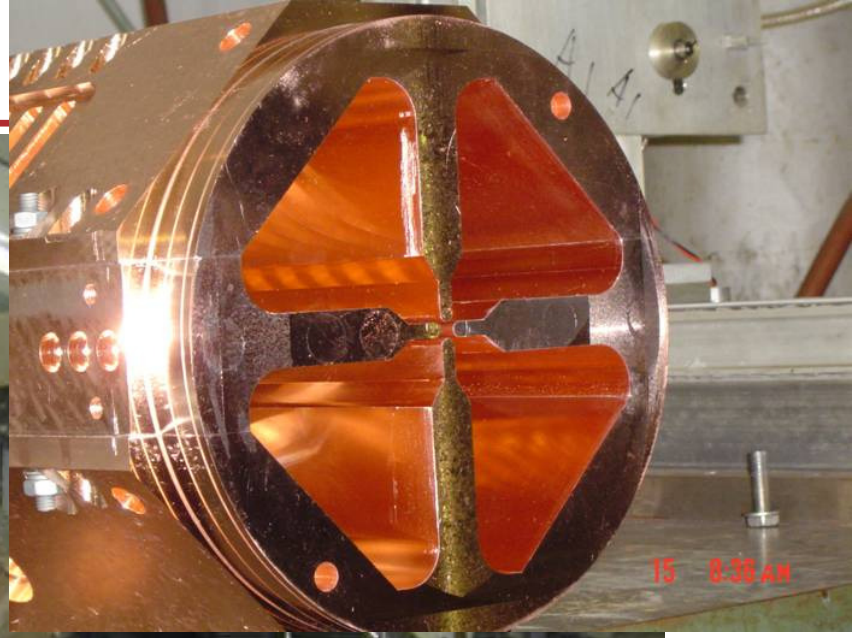
ECR ion source



Output energy	75 keV
Peak current	70 mA
RF frequency	2.45 GHz
RF power	1 kW
Emittance (norn., rms)	0.13 μm
Proton ratio	80%
Reliability	99%

4-vane RFQ





- achieved:
  - 3.5 MeV
  - 49 mA @ 93%
  - 15% rf duty
  - 7% beam duty
  - RF: ±1%, ±1°

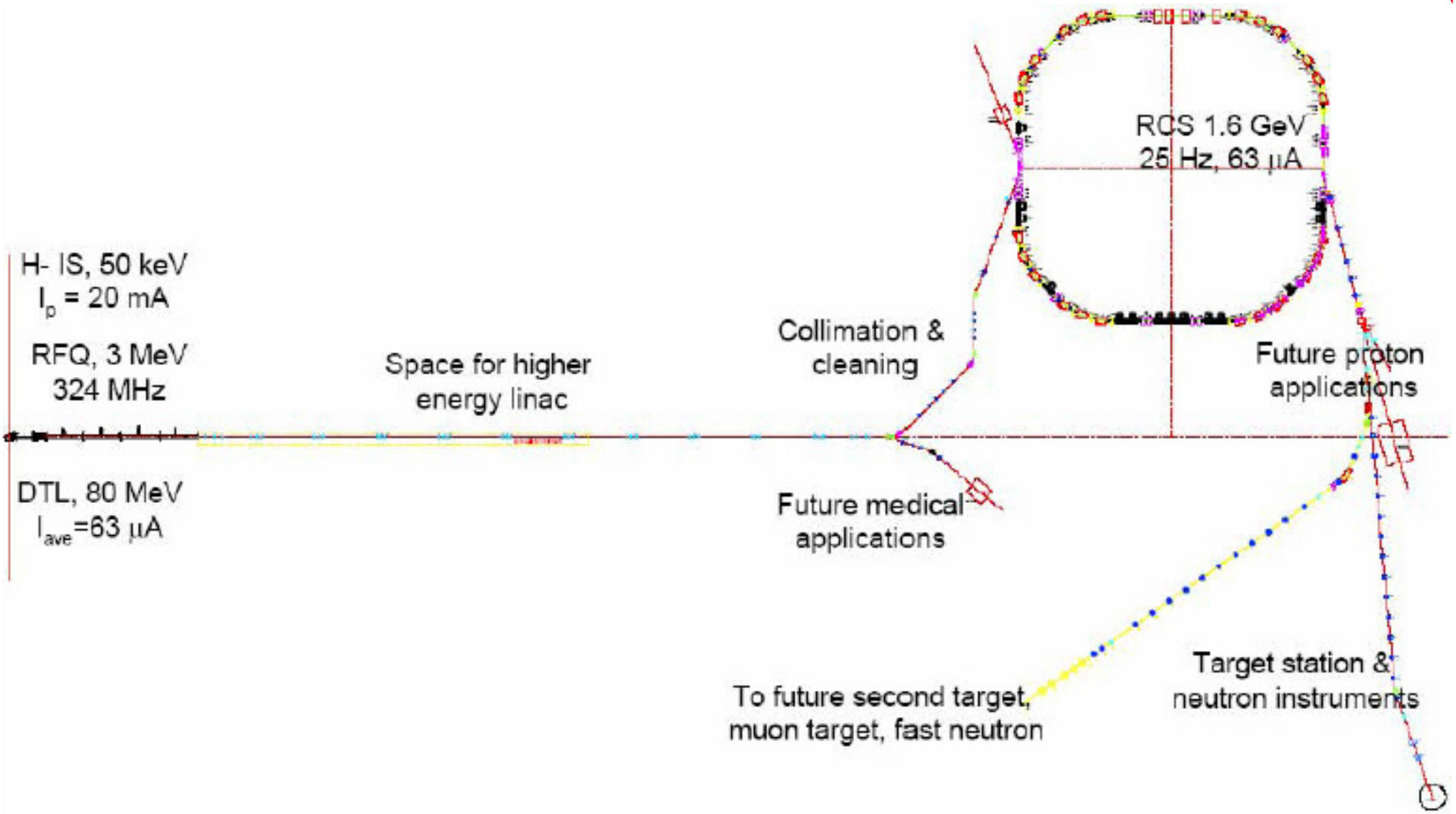
– CSNS project

China Spallation Neutron Source layout

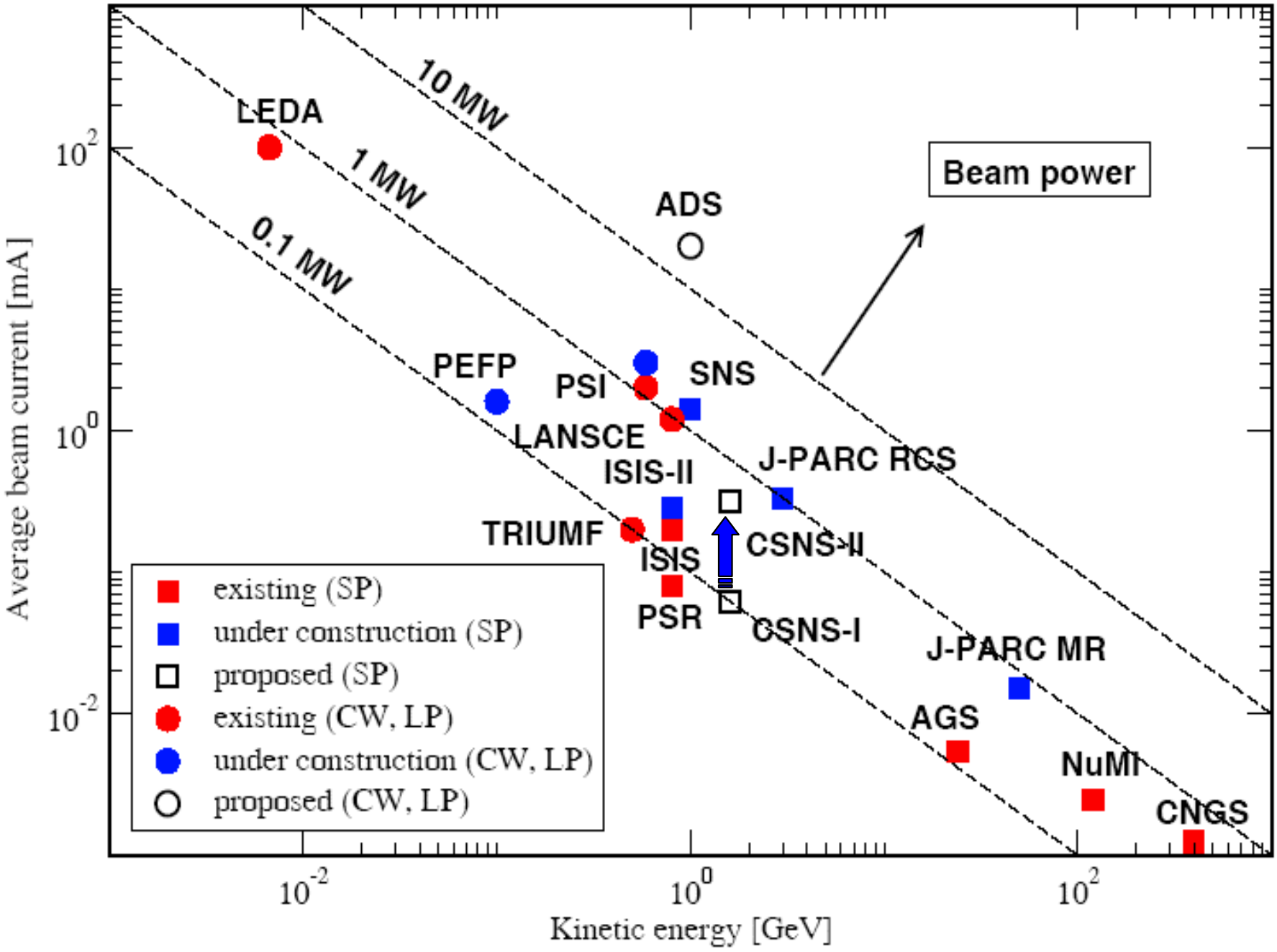
- facility site: Dongguan, Guangdong

2007 5 13

CSNS layout to scale



High beam power frontier & CSNS



CSNS primary design parameters

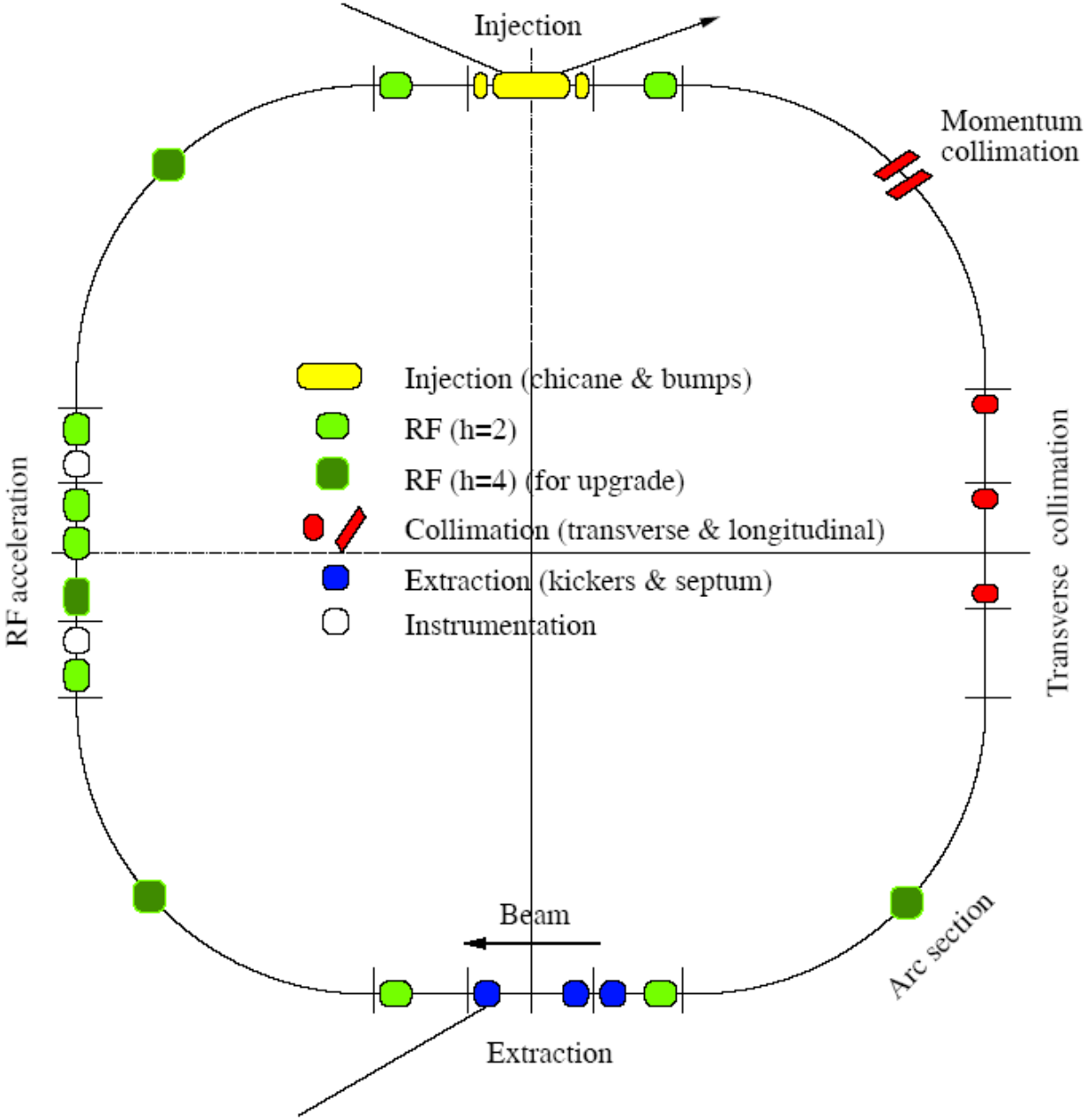
Phase	I	II	ultimate
Beam power on target [kW]	120	240	500
Beam energy on target [GeV]	1.6	1.6	1.6
Ave. beam current [μA]	76	151	315
Pulse repetition rate [Hz]	25	25	25
Protons per pulse [10^{13}]	1.9	3.8	7.8
Linac energy [MeV]	81	130	230
Linac type	DTL	DTL	DTL+SCL
Target number	1	1	2
Target material	Tungsten		
Moderators	H_2O (300K), L-H_2(20K) coupled & decoupled		
Number of spectrometers	3	18	>18

CSNS proposal

- proposal accepted on Sept. 2008

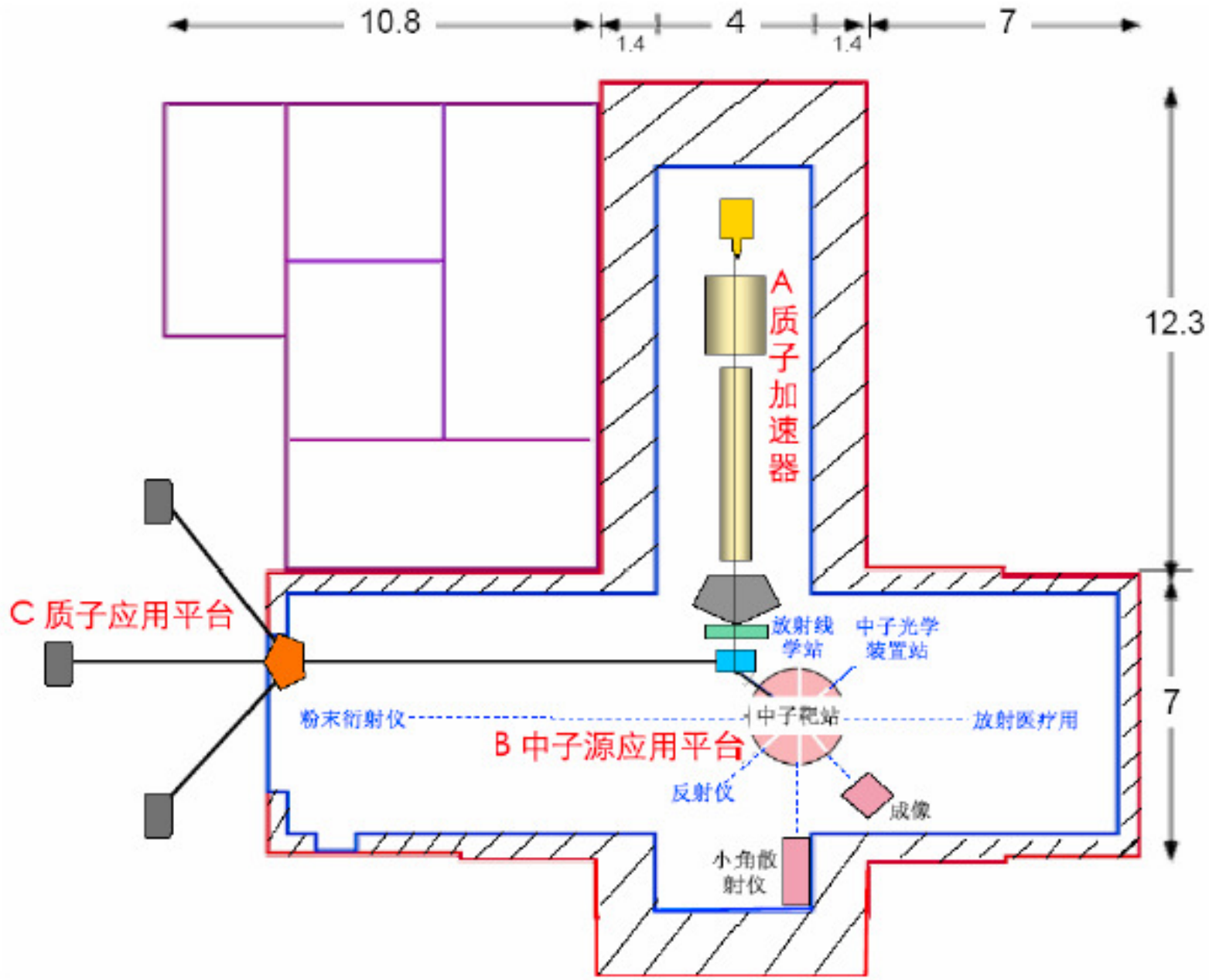
主管部门	中国科学院
共建部门	广东省人民政府
项目法人单位	中国科学院高能物理研究所
共建单位	中国科学院物理研究所
项目性质	新建
建设地点	广东省东莞市大朗镇水平村
建设投资及来源	建设总投资估算为 14 亿元，其中 11 亿元申请国家投资，中国科学院联合相关单位负责筹集 3 亿元；广东省提供土地及七通一平条件，并提供配套建设资金 5 亿元。
运行经费及来源	CSNS 每年运行费 14300 万元，国家财政拨款
建设周期	6 年 6 个月 （78 个月）

CSNS rapid cycling synchrotron

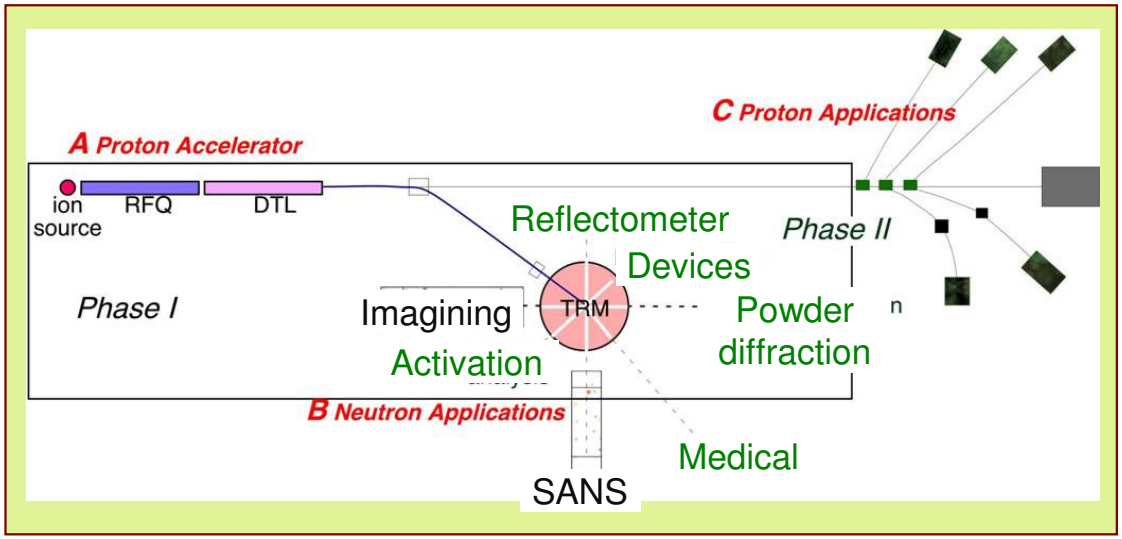


– CPHS project

Compact Pulsed Hadron Source



CPHS in phases



Phase I

SANS: Large (~1-100nm) structure of assemblies in solid, liquid, powder forms

- Micro-to-nano structures of composites
- Biology, nanobiotechnology
- Polymers and soft matters
- Complex systems

Imaging: Non-destructive of internal elements—structure & motion—in large structures & devices

- Materials engineering design
- Device testing & standardization
- Tomography & radiology (Medical, materials)
- Cultural heritage & artifacts

Phase II

Reflectometry: Films & (internal) surfaces including liquid interfaces

- Sensor & device heterostructures
- Biology, nanobiotechnology
- Polymers and soft matters
- Complex systems

Devices: Frontiers of neutron optics

- Beam filters
- Detector development
- Neutron polarization

Medical: Neutron therapy

- BNCT
- Nuclear medicine

Powder diffraction: Crystal structure

- Solid-state chemistry & physics
- Novel materials

Activation: Chemical analysis of materials

- Elementary analysis
- Nuclear materials, security

CPHS major parameters

Table 1: Primary parameters of CPHS

Proton power on target	16	kW
Proton energy	13	MeV
Average beam current	1.25	mA
Pulse repetition rate	50	Hz
Protons per pulse	1.56×10^{14}	Protons
Pulse length	0.5	ms
Peak beam current	50	mA
Target material	Be	
Moderator type	H_2O (300K), CH_4 (20K)	

- ion source, RFQ, DTL, RF
- Be target
- neutron scattering
- neutron imaging
- proton application

- Phase I program in 3 years
- Existing building on main campus
- Starting funds available

Accelerator technology developments

Collaboration worldwide

- Tremendous help from ISIS, J-PARC, KEK, BNL, SNS, CERN, PSI, IPNS, LBNL … MOST, NSFC, JSPS …

Crouching tiger, great ideas

China is on track to become a major player in global science. Rather than designing and building their facilities from scratch, the Chinese Academy of Sciences (CAS) has been collaborating with some of the world's leading science labs to develop new ideas, and building partnerships which will enable Chinese facilities to benefit from tried and tested technology.

The Institute of High Energy Physics (IHEP), which is part of the CAS, is planning to build a spallation neutron source. Its scientists and engineers have naturally turned to ISIS for advice and expertise.

IHEP has chosen to implement designs of several parts of ISIS including the ion source, the very first stage in the production of ISIS neutrons and muons. Last year Dr Ouyang and Prof Zhang from IHEP made an initial visit to gather information, and more recently, their colleague, Dr He Wei has been to ISIS to test ion sources that were manufactured in China to the ISIS design.

Dan Faircloth (ISIS) has been working with IHEP. "The Chinese ion sources were manufactured to an impressively high standard. They ran very well and gave a very high output current. We're still carrying out tests to determine the lifetime of the sources but this collaboration has already provided new directions for the development of our own ion source."

You can learn more about the ISIS ion source at OPB events on 20 and 21 June. Book your place via the OPB web site.

→ Dan Faircloth with Dr He Wei of IHEP

e-Science goes global

e-Science has been extending it's strategic role beyond the UK.

Over the last few months the department has contributed to an EU workshop on the future of grid technology and been awarded an EU grant to provide expert guidance. The department has also received a grant to encourage liaison between Europe and China on the future of grid technologies.

20 years of muons

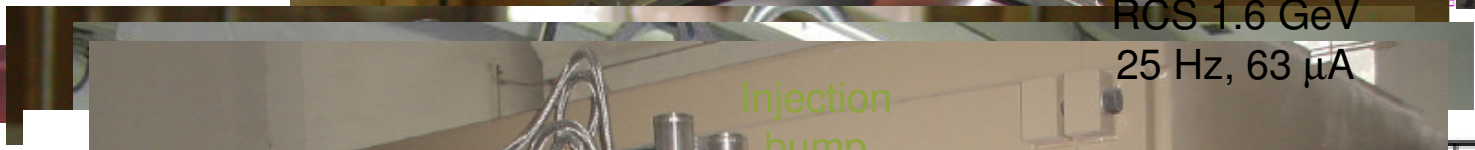
The first muons were produced at ISIS on 23 March 1987.

A muon is a subatomic particle, very much like an electron but heavier. Muons provide an alternative to the neutron as a probe of condensed matter and are frequently used in complementary experiments. The ISIS muon facility attracts users from 18 different countries as there are only four muon sources around the world.

→ Left to right: Adrian Hillier, Philip King, Francis Pratt, Steve Cox, James Lord

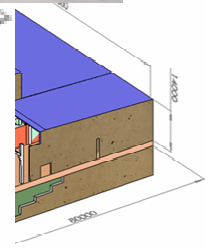
If you want to know more, sign up for one of our OPB events.

CSNS component prototyping



RCS 1.6 GeV
25 Hz, 63 μA

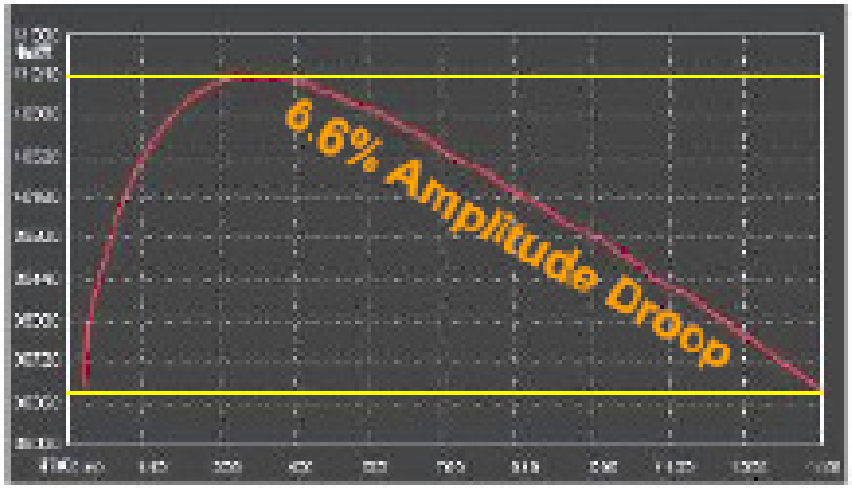
To future second target,
muon target, fast neutron

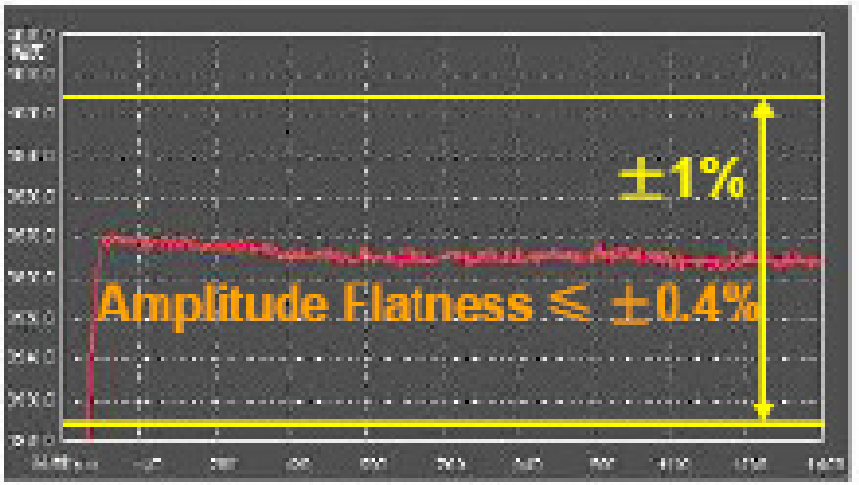


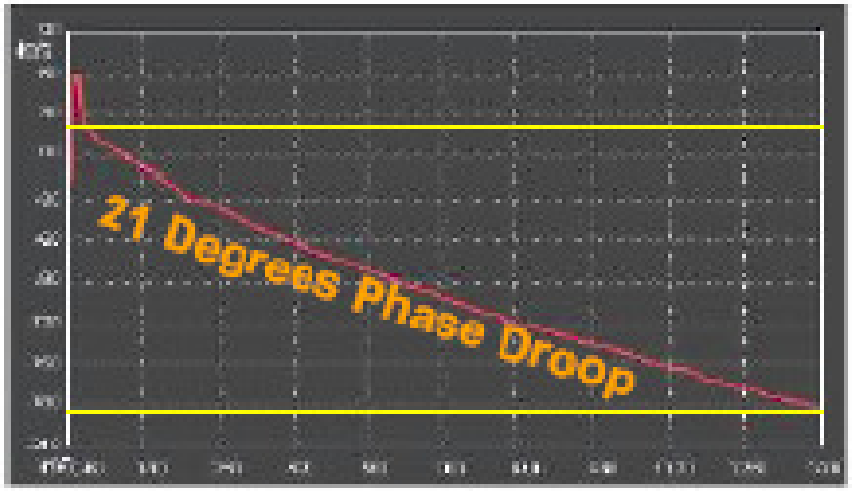
effect

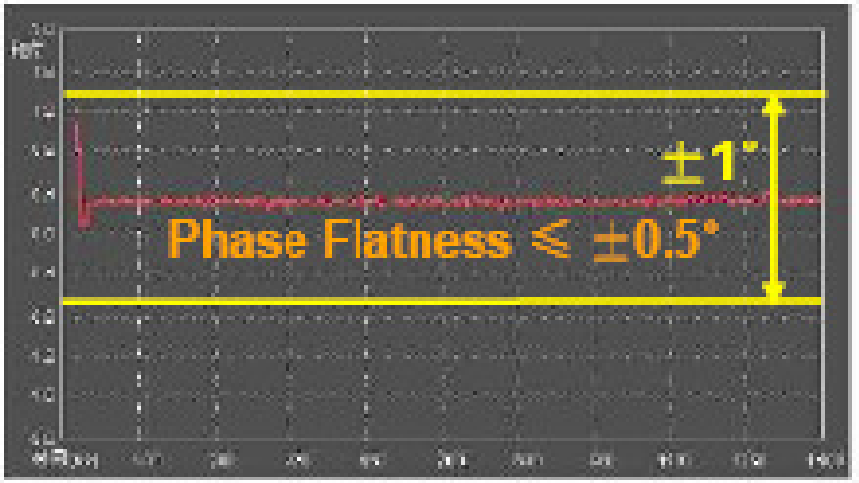
No Feedback Control

With Feedback Control



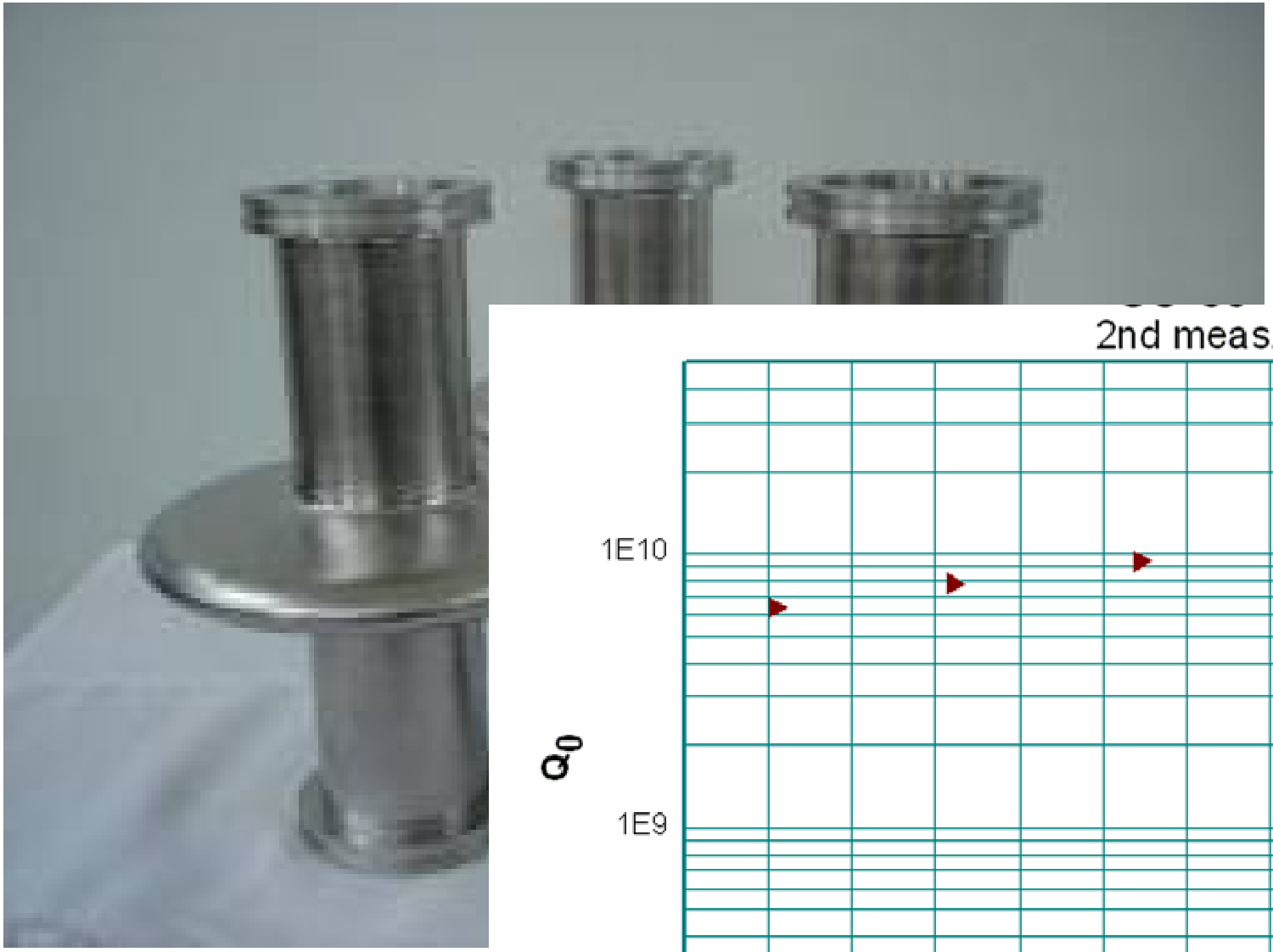




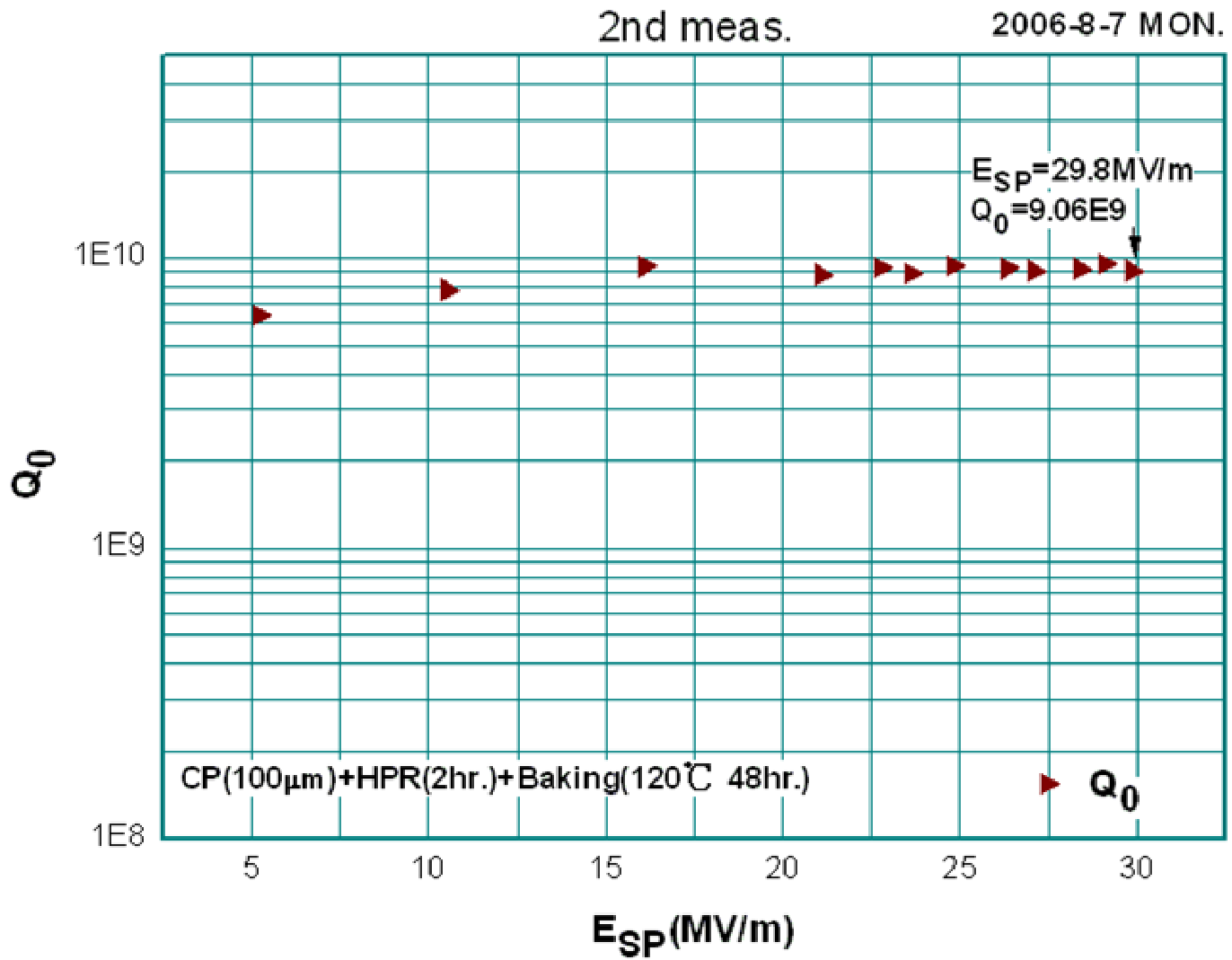


Klystron beam voltage sag leads to amplitude and phase droop.

1.3 GHz, β=0.45 superconducting RF cavity

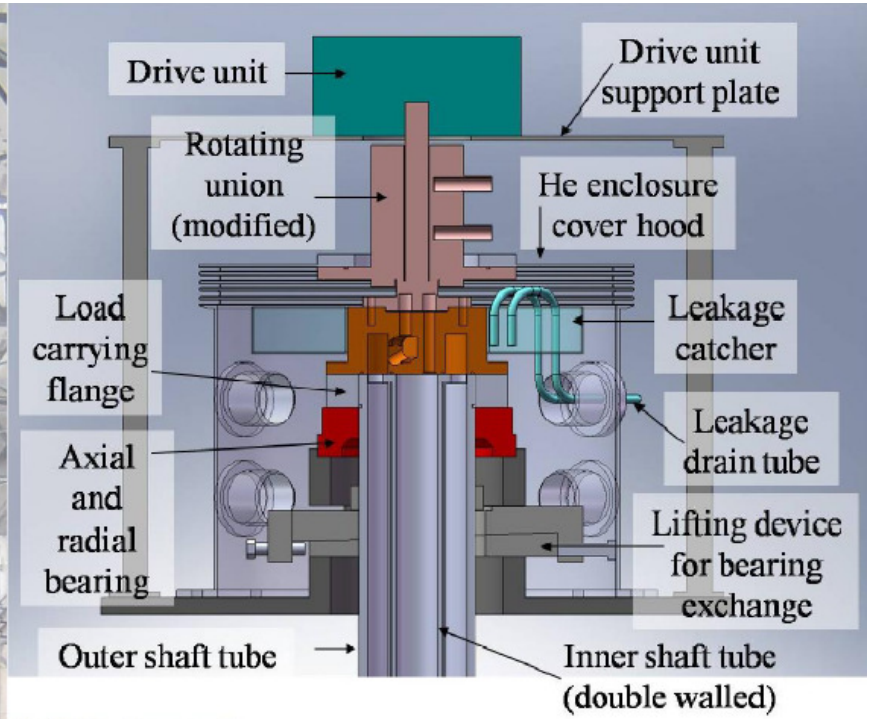


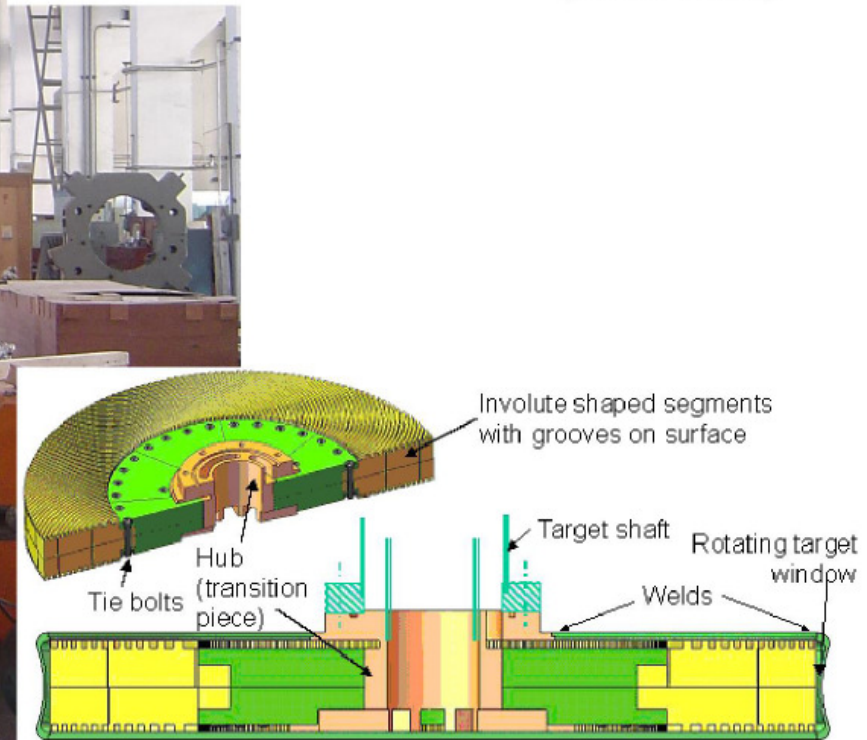
IHEP, CAS
Beijing Univ.



RCS magnet & measurement system

Rotating target mock-up

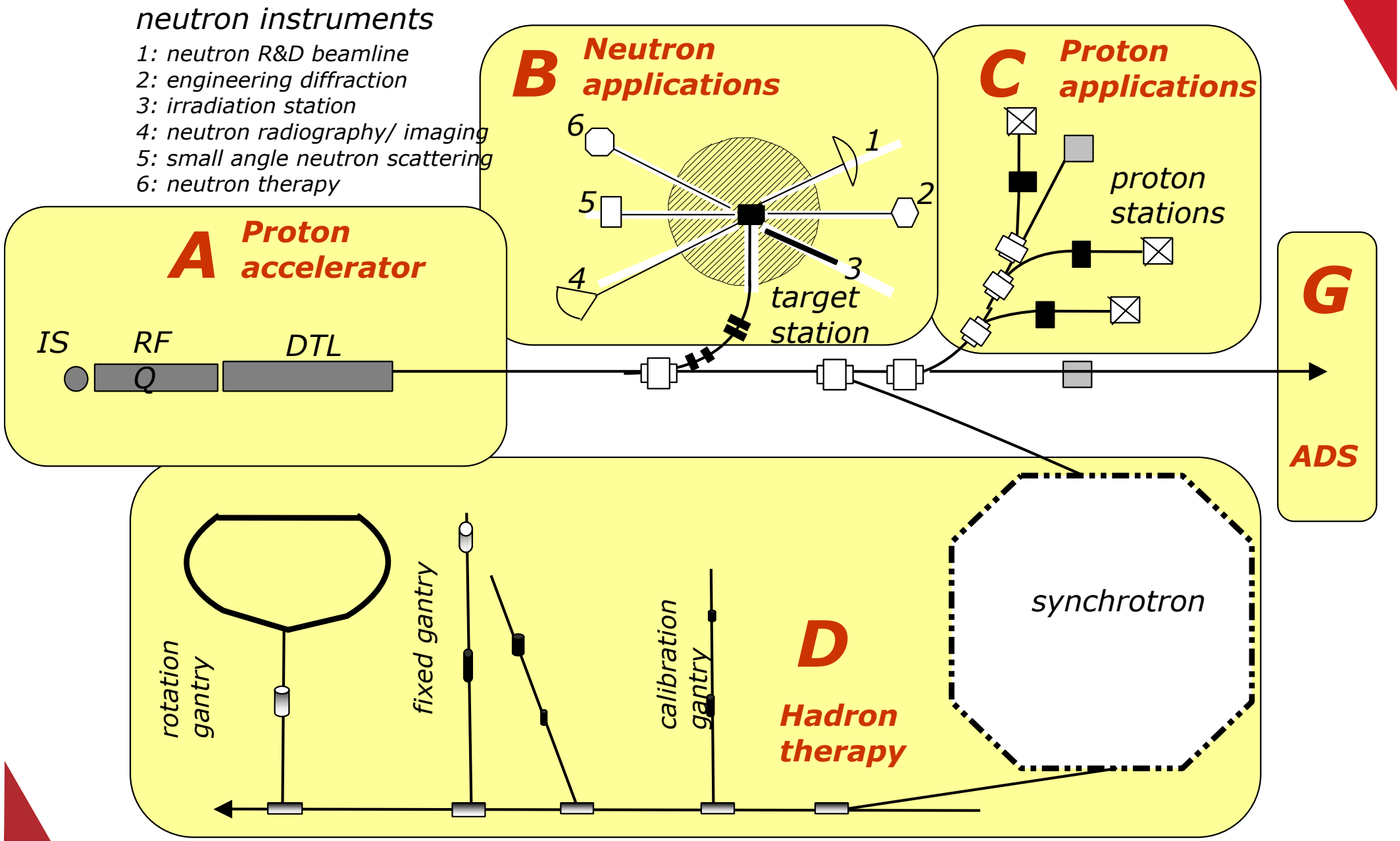




IHEP &
Inst. of Physics
CAS

Discussions & summary

A possible hadron facility layout



small …

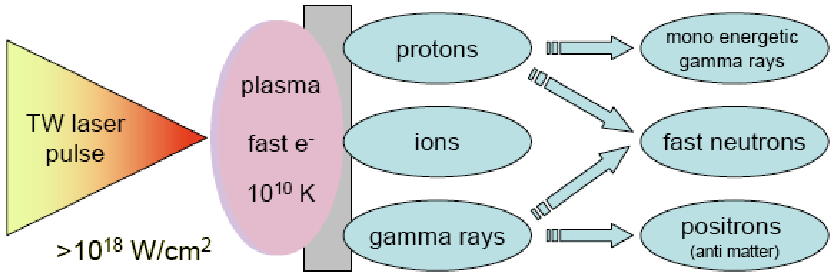
Pistol

Grenade Simulant

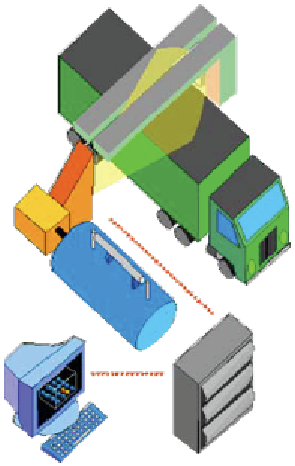
Smuggling Cultural Relic

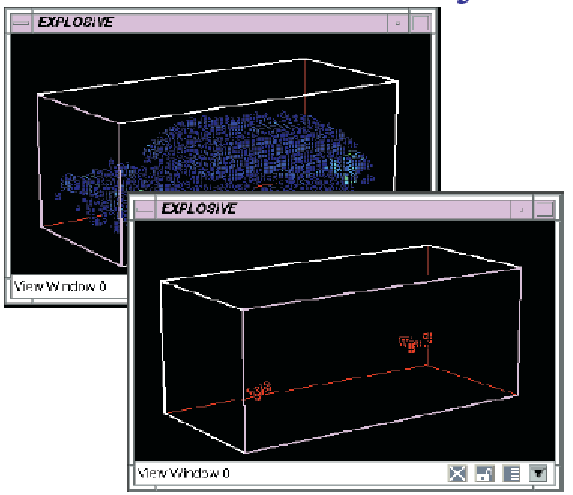
PFNA - Pulsed Fast Neutron Analysis

Laser-generated nanosecond pulsed neutron sources: scaling from VULCAN to table-top, *Zager et al, New J. Phys.(2005)*

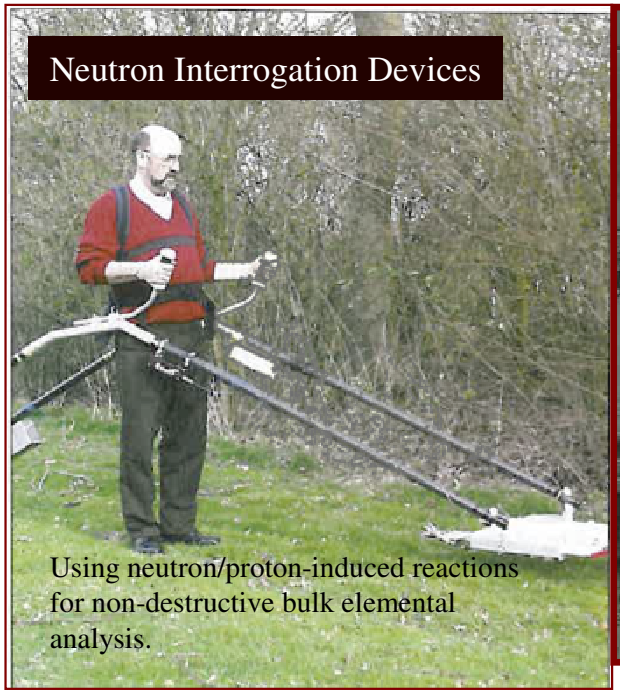


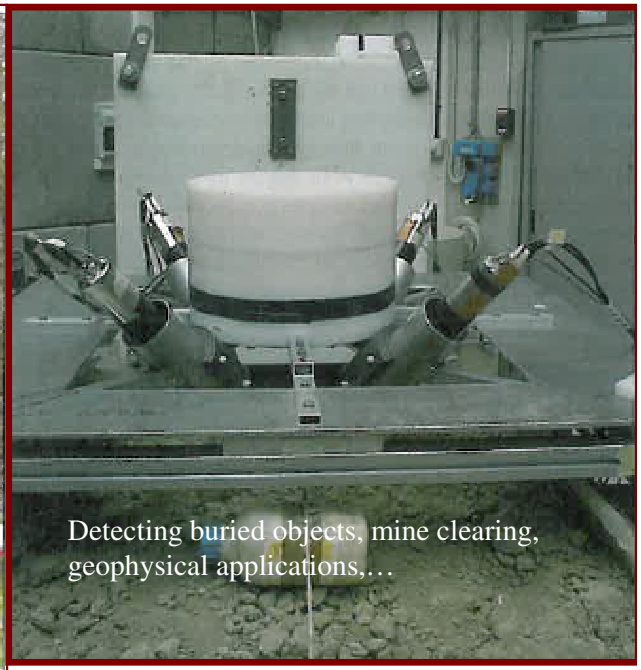
- Compact, table-top sources yet producing useful neutron fluxes for practical applications
- Broad fast neutron spectrum
- Forward directed beams
- Pulsed operation, short pulse and high repetition rates





Ancore Corporation, Santa Clara, USA





Courtesy C. K. Loong

Key challenges

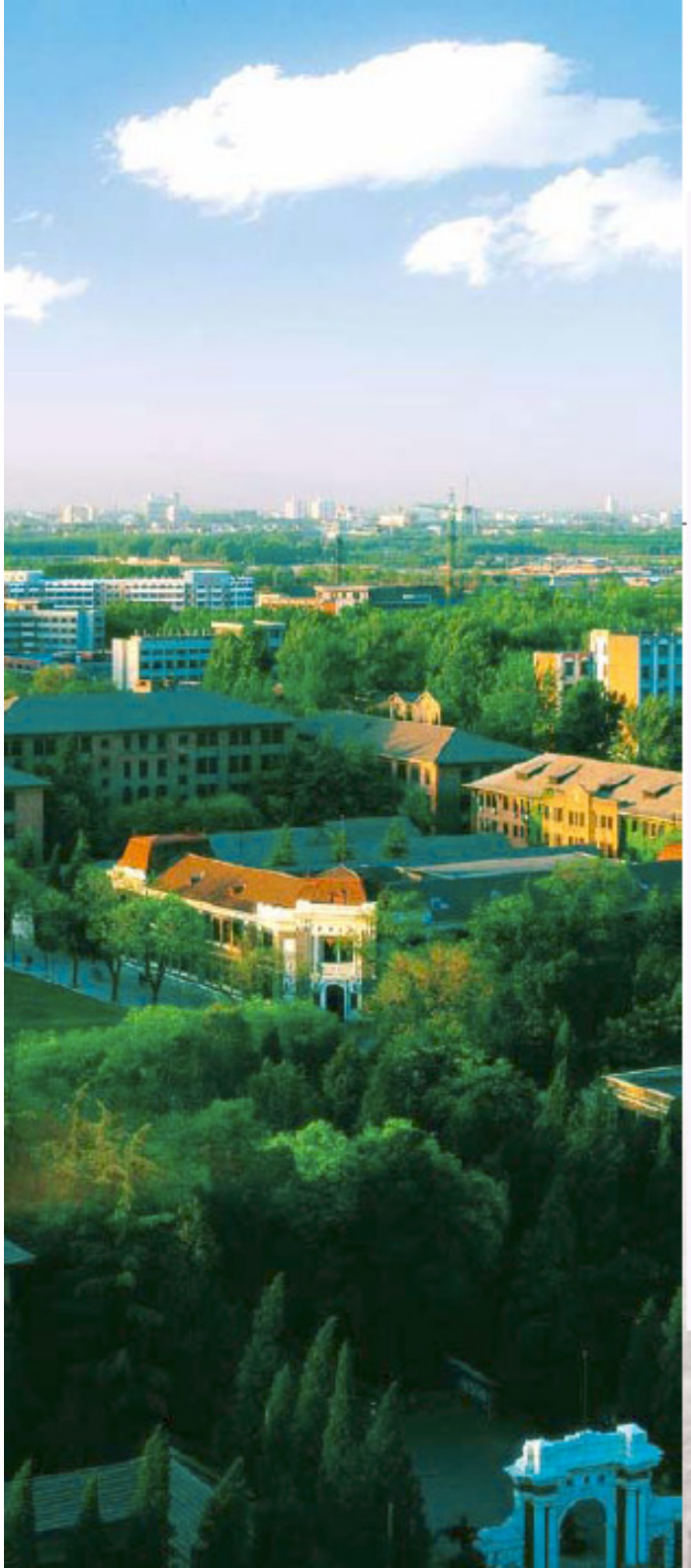
- A common challenge in pursuing hadron accelerator facilities in China is the extremely low level of funding and a lack of expertise
  - Projects typically cost less than 1/2 of non-labor cost of USA

→Solution: extensive R&D and prototyping

  - Import & improve advanced technology; collaborate worldwide
  - Develop domestic, industrial vendors to control project cost

Summary

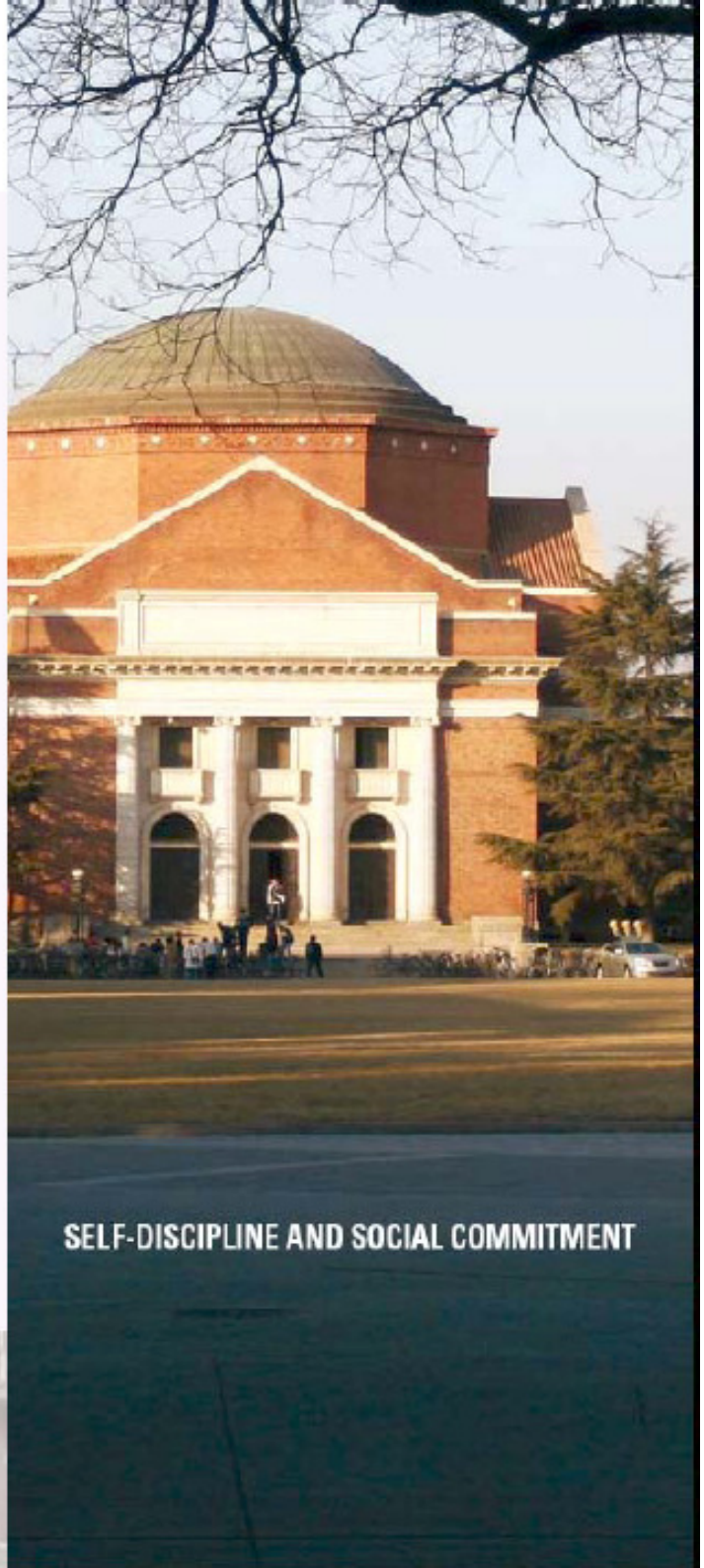
- In China, there are great interests in:
  - ADS programs for nuclear waste transmutation and power generation
  - multi-disciplinary platform neutron source
  - Ion-beam therapy
  - compact neutron and proton sources
- Keys to the success: collaborate worldwide, and develop domestic industry



清華大學

Tsinghua University

THANK YOU!



Acknowledgements

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  - Dept. Engineering Physics, Tsinghua University; C.K. Loong
- To the ADS program team
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