Chinese Efforts in High Intensity Accelerators, ADS and Waste Transmutation

Shinian Fu, Shouxian Fang, Jiuqing Wang

Institute of High Energy Physics, CAS

Beijing, China

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1, Introduction

- **Two applications of High Intensity Proton Accelerators in China:**

1. **ADS for nuclear waste transmutation:**

   A 1GeV superconducting linac

2. **China Spallation Neutron Source and its upgrade program.**

   Present 100kW CSNS: a 80MeV NC linac and a RCS

   Upgrade 500kW CSNS: add SC linac to 250MeV and a RCS

ADS basic study

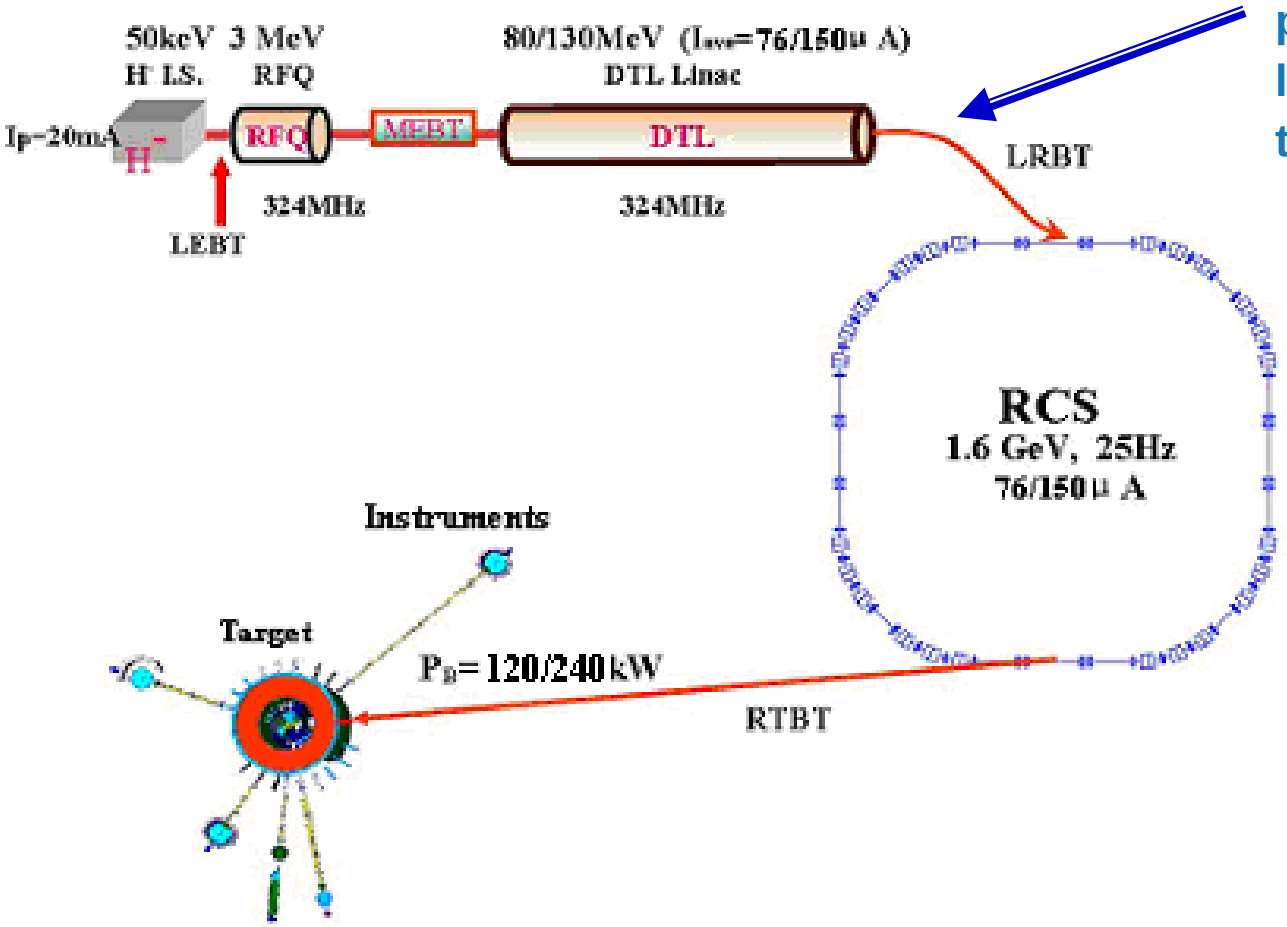
Rapid economy growth in China demands for energy resource 4 billion tons standard coal in 2050, and the electricity will be 1200 GWe, 20% contributed from nuclear power.

Nuclear waste accumulated up to 2050 in China:

Year	2000	2010	2020	2050
Power（GW)	6	20	40	240
Spend fuel（T)			7200	>50000
MA（T)			4	>30
LLFP (T)			17	>120

Nuclear waste will be a bottleneck for nuclear power development. ADS has been recognized as a good option for nuclear waste transmutation. As a long-term program, basic study and some R&D has been supported by the MOST of Chinese government since 1999.

CSNS and its upgrade



In the LRBT a tunnel length is now reserved for future upgrade to 500kW beam power with additional SC linac to rise linac energy to 250MeV from 130MeV.

CSNS project has been approved by Chinese government and will start construction in 2010 and completion in 2016.

Schematics of CSNS with a 324MHz NC linac as an injector to a RCS

2, Study on High Intensity Proton Accelerator

Five study fields in ADS programs

1. **A high intensity injector**
2. **A high intensity RFQ accelerator**

   supported by the Ministry of Science and Technology in ADS basic study programs
3. **Medium beta SC cavity study**

   supported by the Chinese Academy of Sciences
4. **A SC lab for vertical test**

   supported by IHEP, Beijing
5. **Low beta SC cavity study**

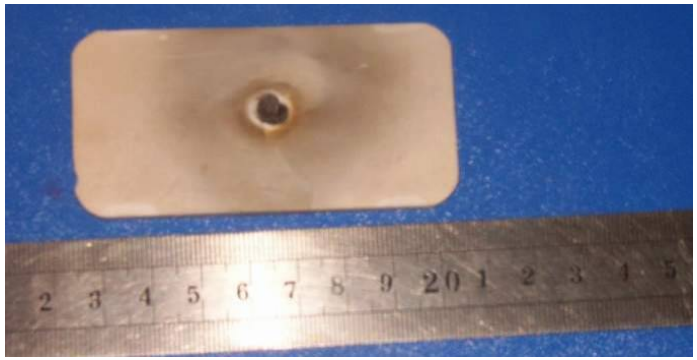
   supported by CAS

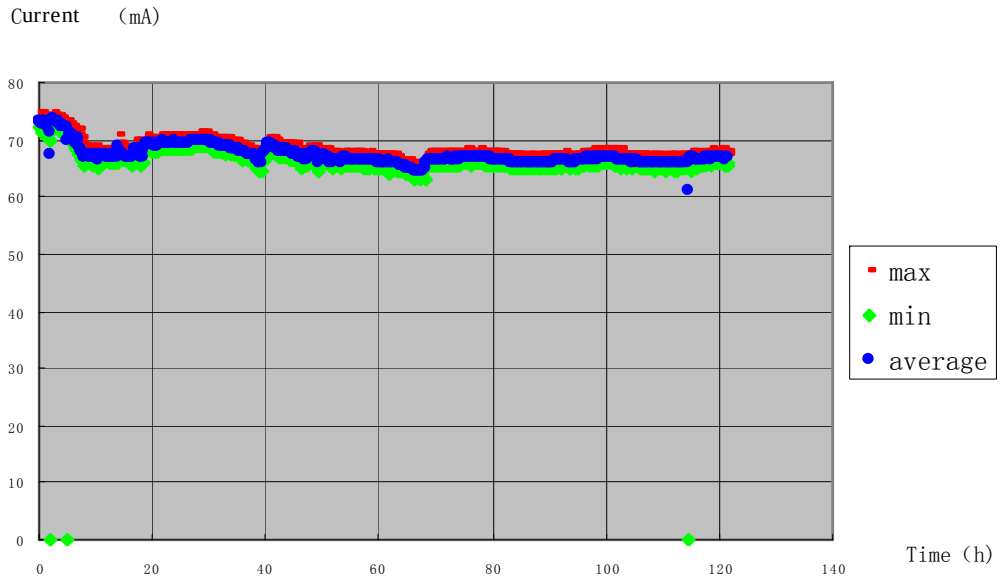
(1) High Intensity injector

An ECR proton source at 2.45GHz was built and tested with LEBT.

Cuurent(mA)	85
Energy (keV)	75
Proton ratio	>90%
Normalized Emittance pi mm mrad	0.13
Reliability	2 trips in 120 hours

Injector reliability is very crucial for ADS because most of the beam trips of the whole accelerator come from injector.





120 hours reliability test run

- **Reliability and stability:**

  long life time & rare spark

Improvement on the chamber material

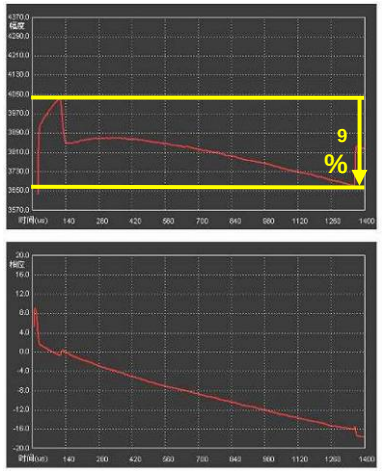
(2) A high intensity RFQ accelerator

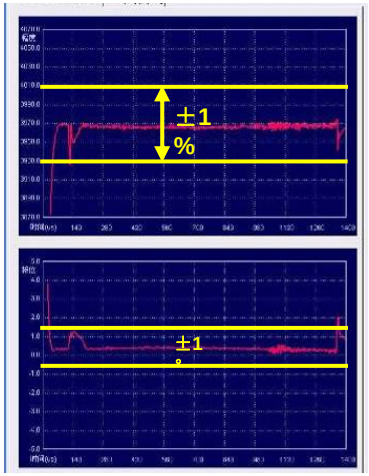
A 3.5MeV RFQ has been commissioned at IHEP with the ECR ion source, the LEBT and a post beam line for diagnostics.

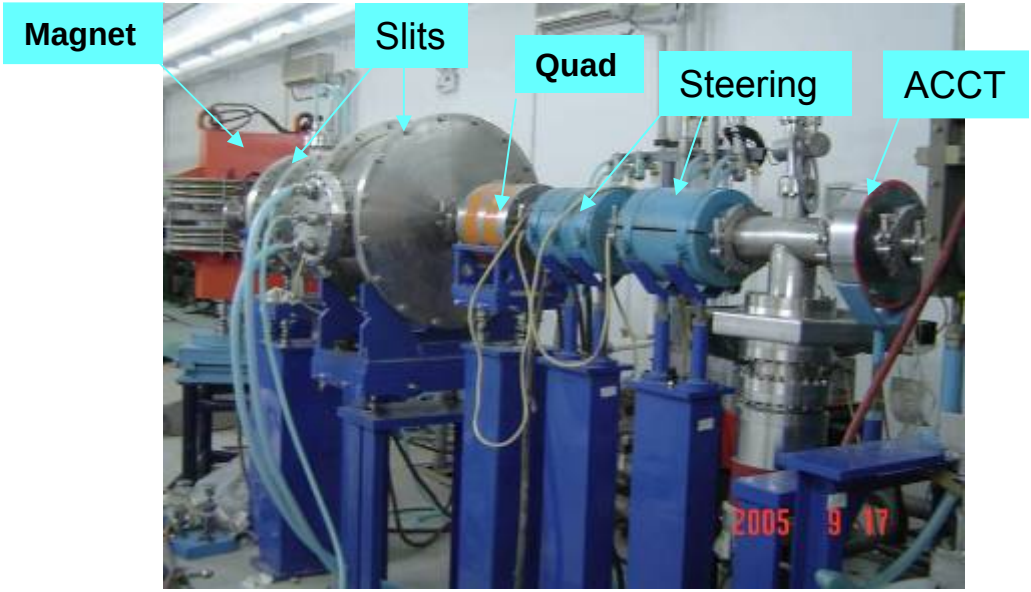
A four-vane RFQ with a total length of 4.8m long at 352MHz. It is consists of two resonant segments with coupling cell between them. One RF power coupler in each quadrant. It was made in Shanghai, China.

Thanks CERN for providing the 325MHz power system. The modulator was reformed at IHEP for pulse mode operation.

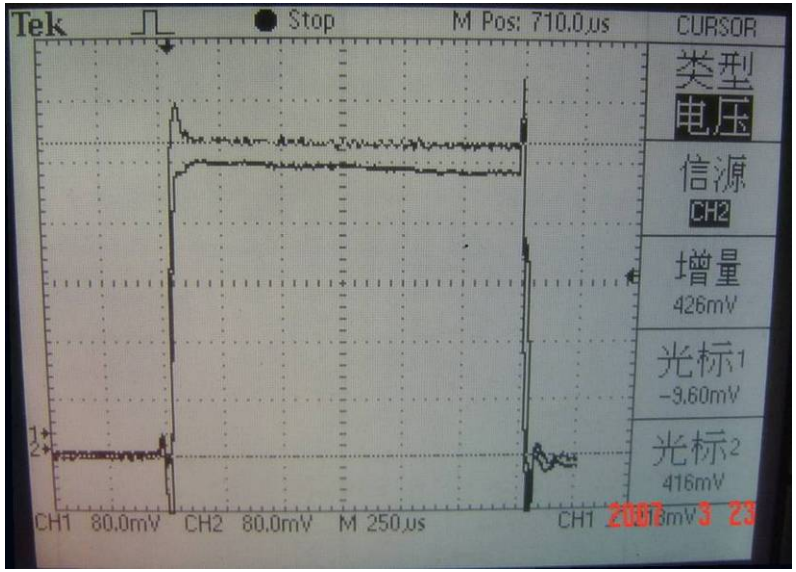
FPGA based LLRF control system has been developed with a satisfactory results.



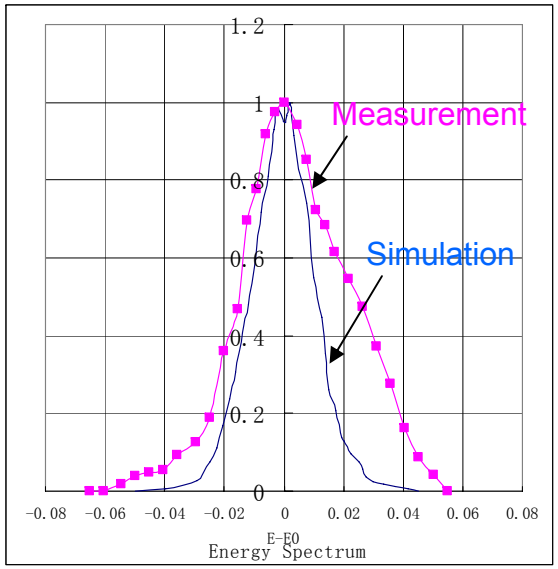




The diagnostics beam line

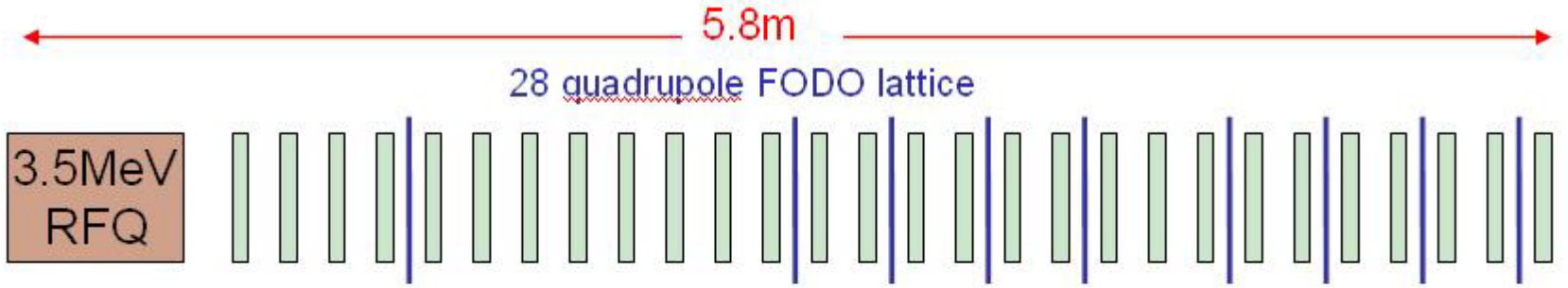


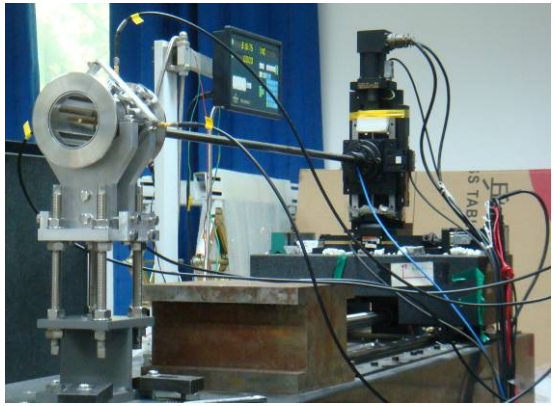
46mA output beam at 7% duty factor, transmission rate>93%. Now we are raising up to 15% duty factor.

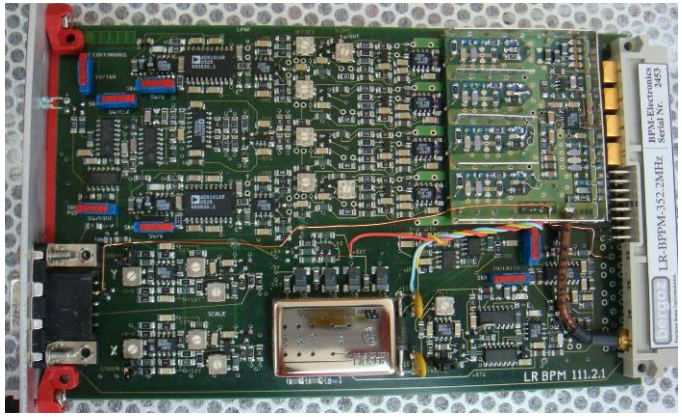


The measured beam energy is only 0.04MeV higher than the simulation from PARMTEQ.

Intense beam physics experimental study is undergoing with the output beam from the RFQ. A periodical channel will be set up for beam halo study. Some diagnostic elements are developed.







(3) Medium beta SC cavity study

1.3GHz、β=0.45 single cells as a scale down prototype of 700MHz cavity was first developed to master the manufacture and surface treatment technology .

Three 1.3GHz/ β =0.45 scaled cavities are fabricated, and the dies of 700MHz cavities are machined. The process of cavity fabrication is explored in China.

Dies of 700Hz cavities

Deep drawing

Half cells after drawing

Electron-beam welding

Beam pipe rolling (Step 1)

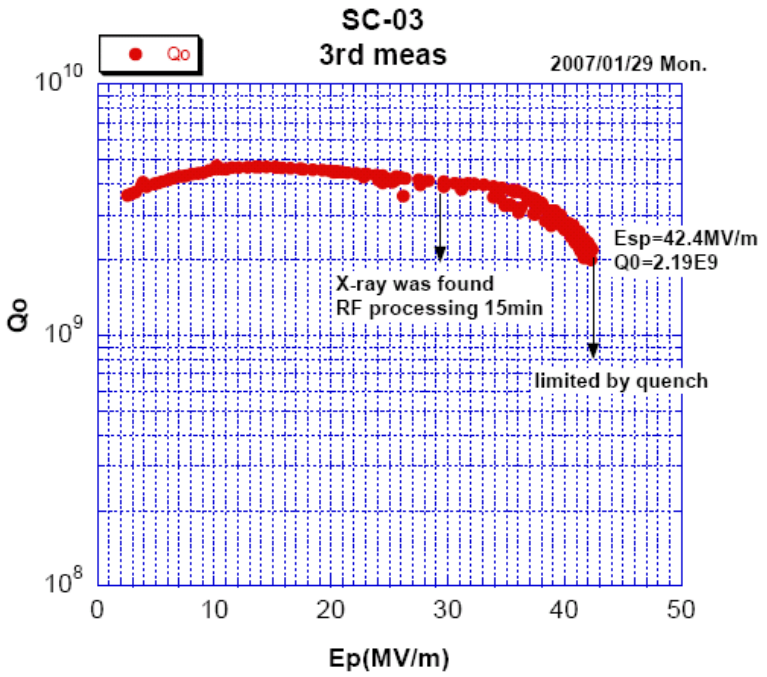
Beam pipe rolling (Step 2)

Parts after machining

1.3GHz/ β =0.45 cavities

Scale-down model cells were built in cooperation with KEK

The whole set of SCC waiting for measurement

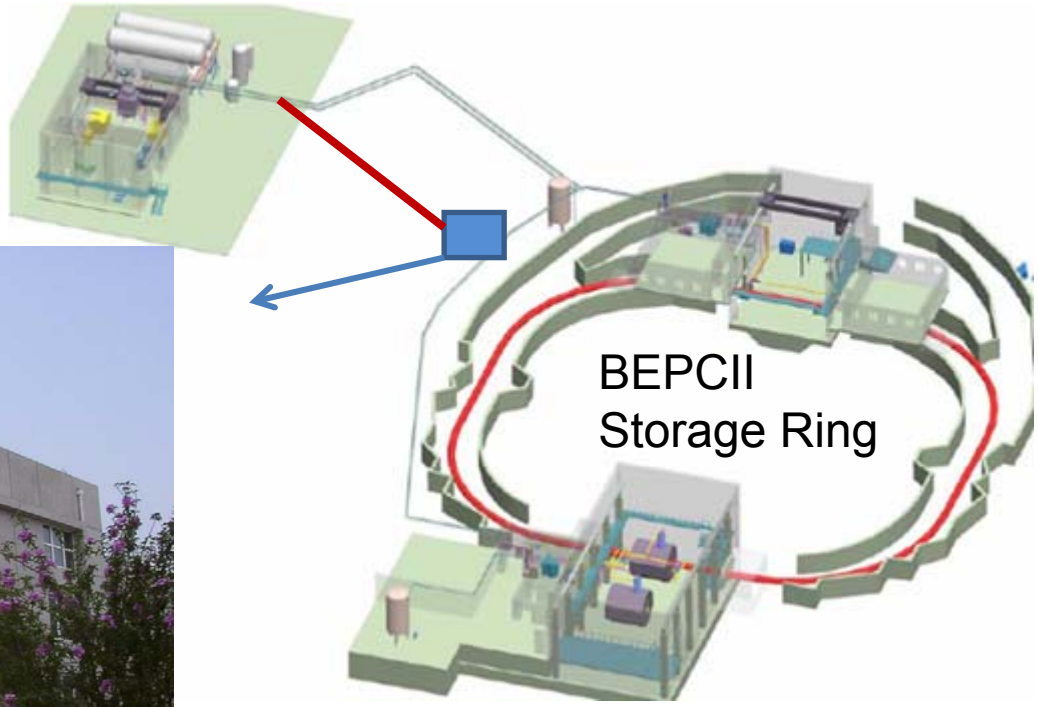


1.3GHz、β=0.45 single cell

Measured data of 1.3GHz cell

Surface field *E*p ＝ 42.4 MV / m（*E*acc＝ 10 MV / m）

(4) SC lab for vertical test



SC lab of 250m^2

Helium Cycling System will be built for SRF Lab soon to make the vertical test cheaper and easier.

SC Laboratory equipments

The area of the SRF lab is about 250m², the facilities in which can meet the demand of surface preparation and vertical test for single cell superconducting cavities. Presently, Surface preparation and vertical test for several type of cavities have been done in the lab. Those include 1.3G/ β =0.45 cavities for High Intensity Proton Linac, 1.3GHz high gradient cavities for International Linear Collider, and 1.3GHz 2-cell cavity for Photo Cathode Injector. The spare cavities for BEPCII storage ring are also about to be treated and tested in the lab. The facilities are proved to have nice performance.

Ultra pure water system

Cavity mount stage

Cavity setting for vertical test

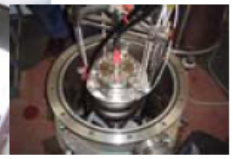
Control room

HPR stand HPR

SRF laboratory layout

CP Room

CP



Test pit for 1.3GHz cavities

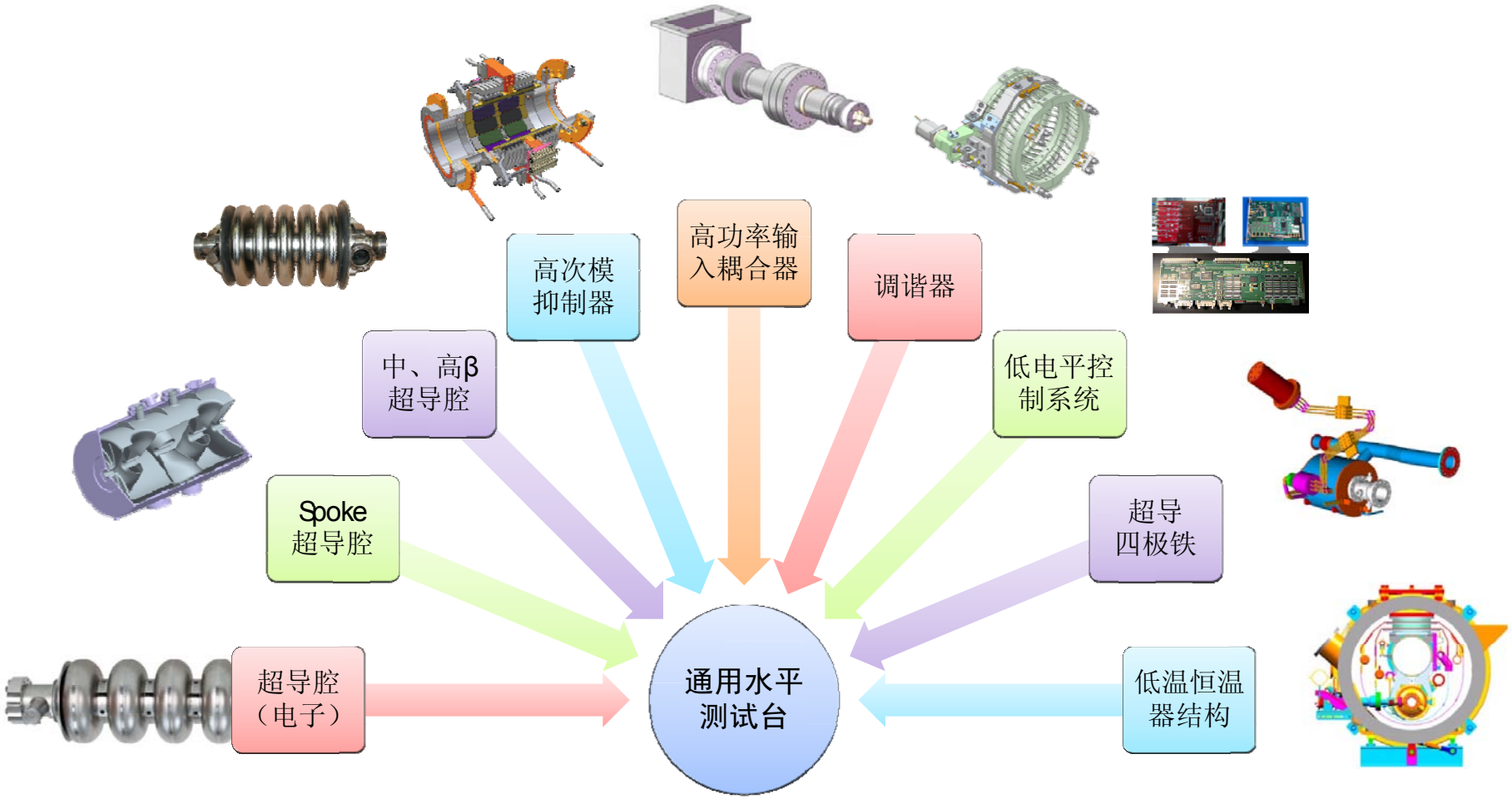
Assembly area class 10

Evacuating and baking system in Class 10000 area

CBP equipment

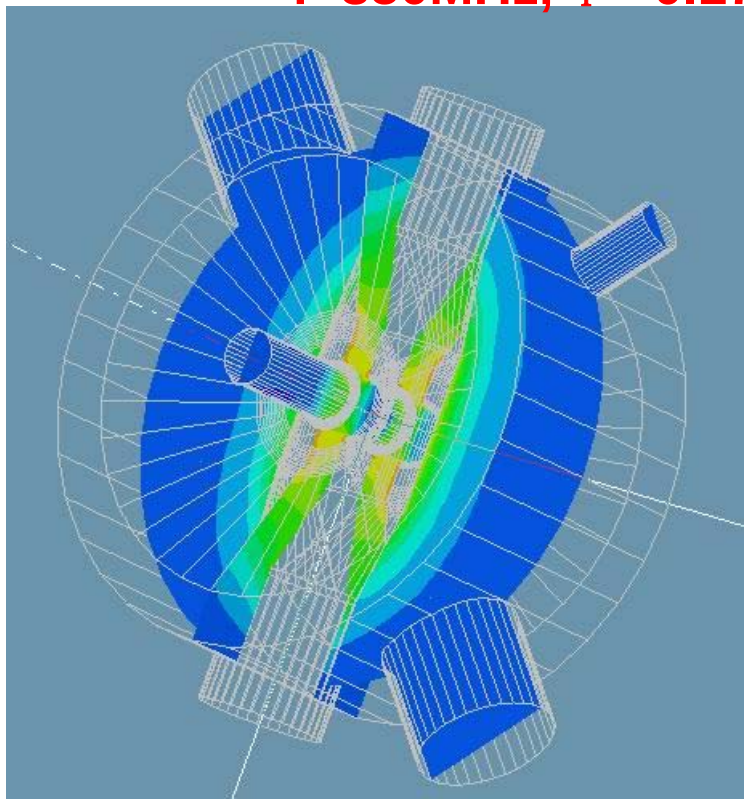
Pumping system

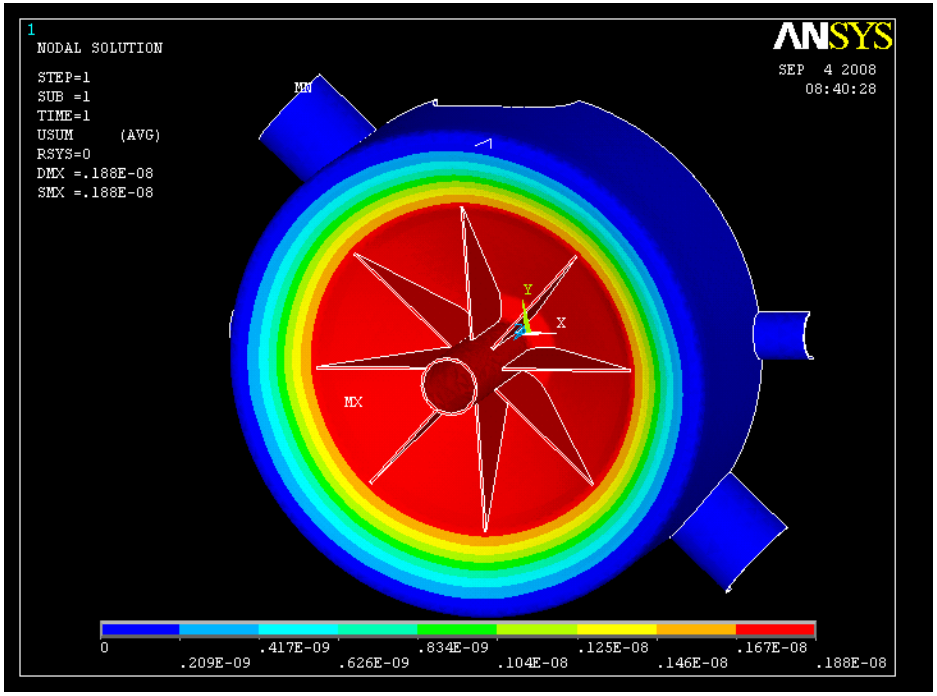
A larger SC lab planed at IHEP—A synthesize horizontal test stand for multipurpose



(5) Low beta SC cavity study

f=350MHz, β=0.17, Eacc=10MV/m

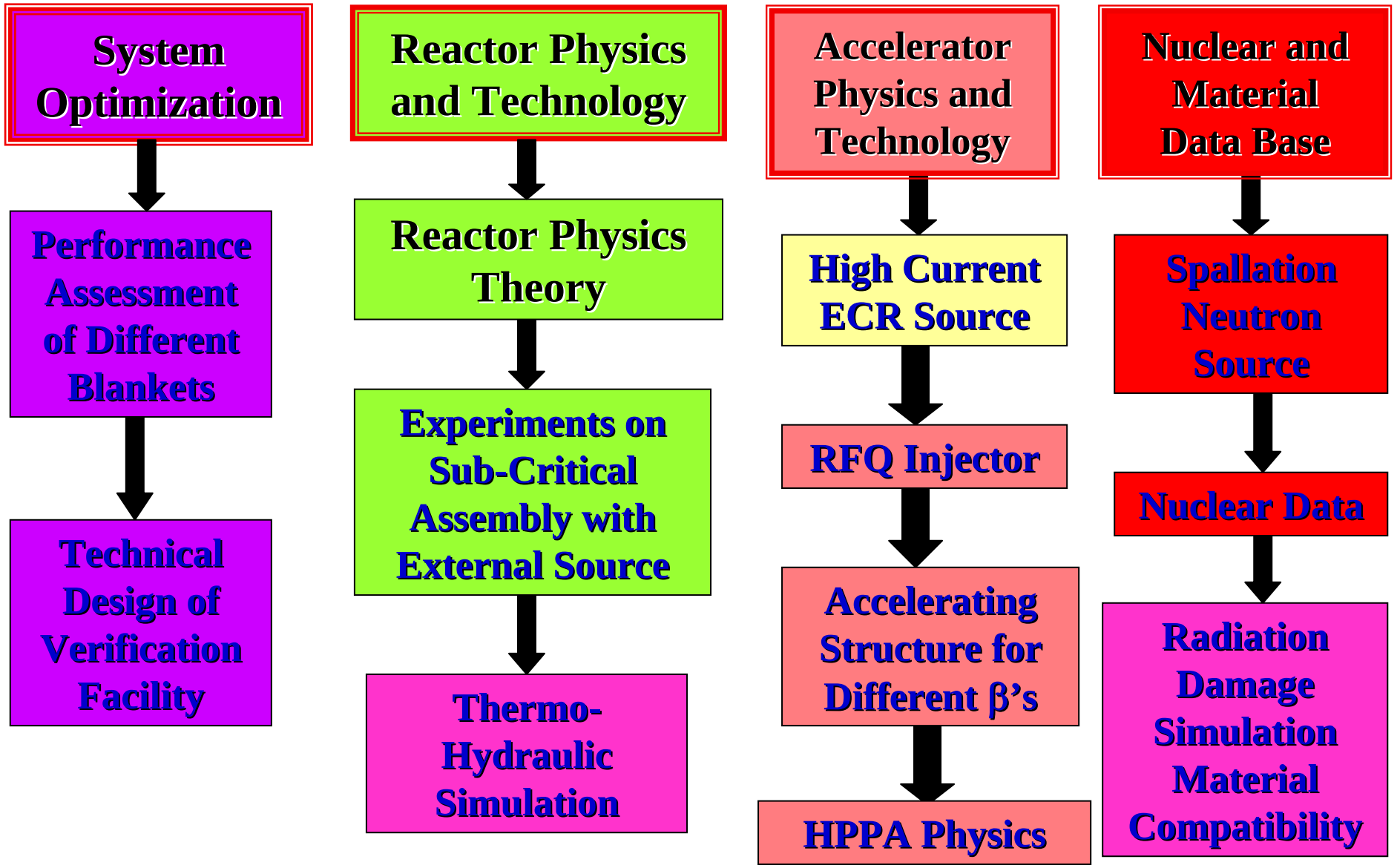


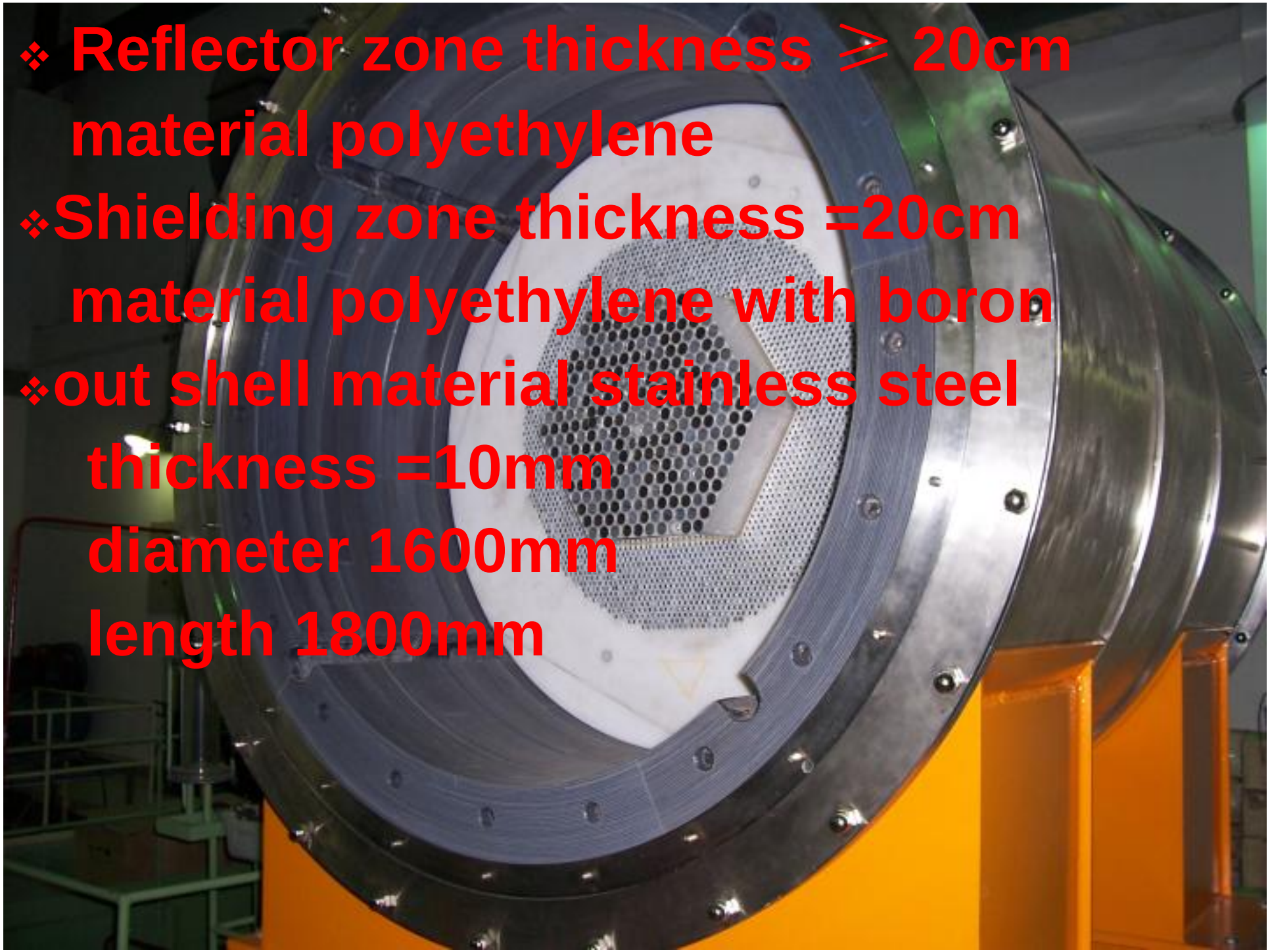


- SC spoke cavity design study is also carried out for the low beta section of the ADS linac, just after the 3.5MeV RFQ. Cavity R&D is going to be carried out in the CAS ADS program soon.

ADS Study for Transmutation

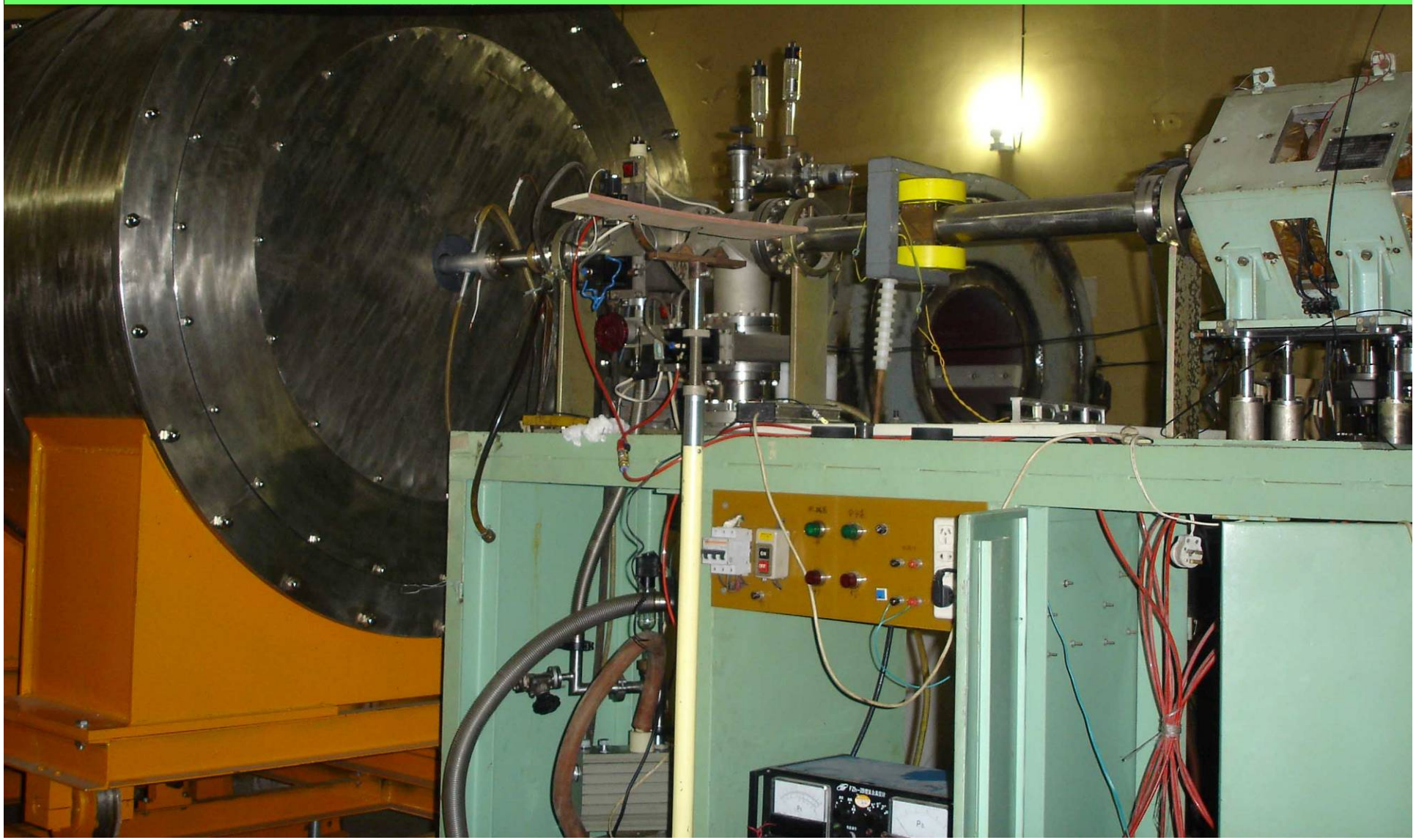
ADS Work Packages in Phase 1



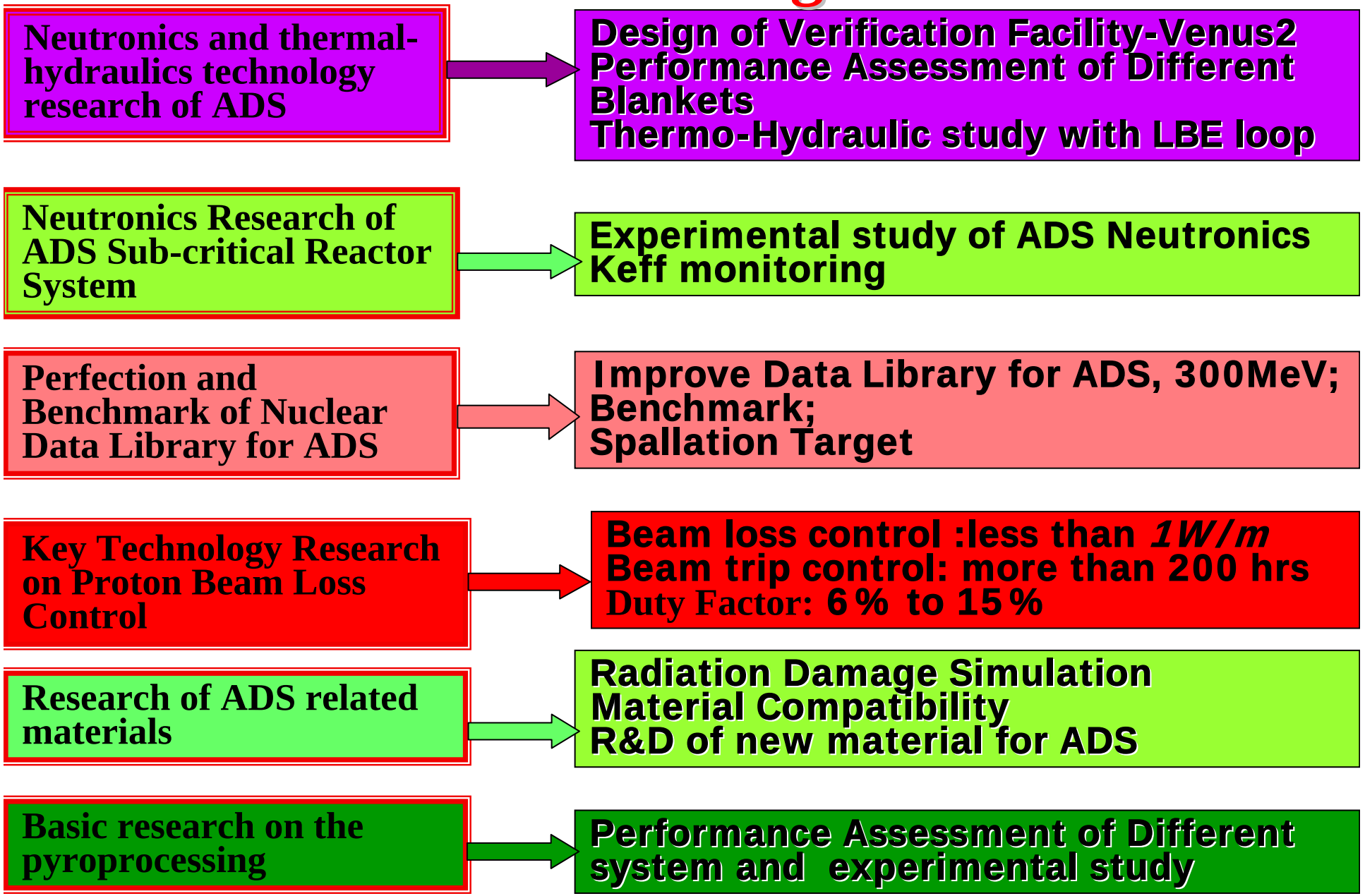


- Reflector zone thickness ≥ 20cm material polyethylene
- Shielding zone thickness =20cm material polyethylene with boron
- out shell material stainless steel thickness =10mm diameter 1600mm length 1800mm

The Venus 1 coupled with 300 kV pulsed neutron generator

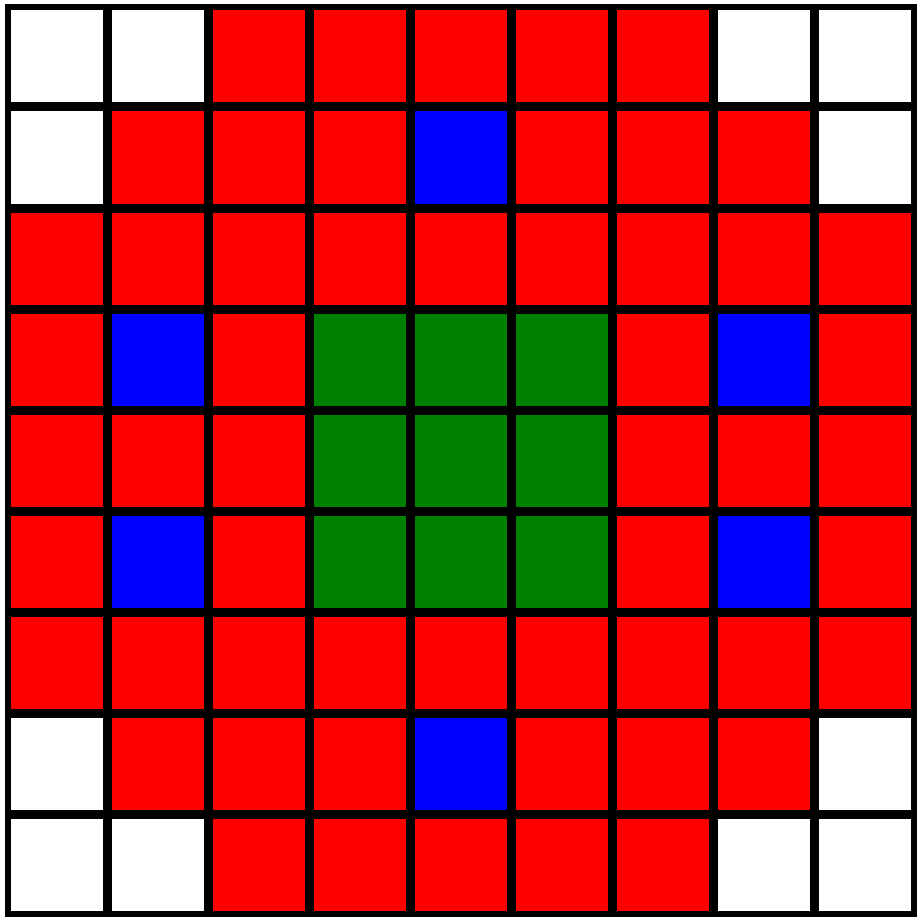


ADS Work Packages in Phase 2



Neutronics and thermal-hydraulics technology research of ADS –Venus 2

Fuel	**Spent fuel of CARR, U3Si2-Al , 149.3kg**
Keff	**0.982**
Spallation Target	**Solid W**
Energy of Proton Beam	**100MeV**
Yield of spallation neutron	**0.3 n/p**
Beam Intensity	**0.3 mA**
Beam Power	**30 kW**
Thermal Power of the Core	**200kW**



Primary Parameters for Our LBE loop

Highest Temperature	**550 ℃**
Maximum Flux	**6 m^3/h,（velocity 3 m/s）**
Pressure	**0.3 MPa**
Oxygen Control	**Ar＋5%H_2/H_2O**
LBE capacity	**100～150 l**
Height of Loop	**5 m**
Experimental Segment	**2**
Height of Segment	**1.5～2 m**
Velocity of Flux	**1 m/s**
Temperature Difference	**100 ℃**

Consideration in near future

A moderate style multi-purpose verification system is under consideration. In the conceptual study, we consider:

- **Low energy accelerator**
- **MW swimming pool light water sub-critical reactor**

Step by Step

1st，R&D of key technology：

ECR ion source、RFQ、

Super conducting cavity etc

2nd，Integral Test：150MeV, 50mA, 6％

3rd，CW，300MeV，Sub-critical reactor。

4th，1GeV，ADS Demo

SUMMARY

1, High intensity proton accelerator has two applications in China: ADS and CSNS.
2, Five key technologies in high intensity proton accelerator for ADS are under development.
3, ADS basic study has gained support in two phases from the Ministry of Science and Technology.
4, CAS presented an ADS new proposal to the government in recent to speed up ADS from the present basic study to small-scale system construction. Five institutes of CAS joined in the new proposal.

Thank you very much for your attention