Status and Challenges of China Spallation Neutron Source

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Institute of High Energy Physics, Beijing

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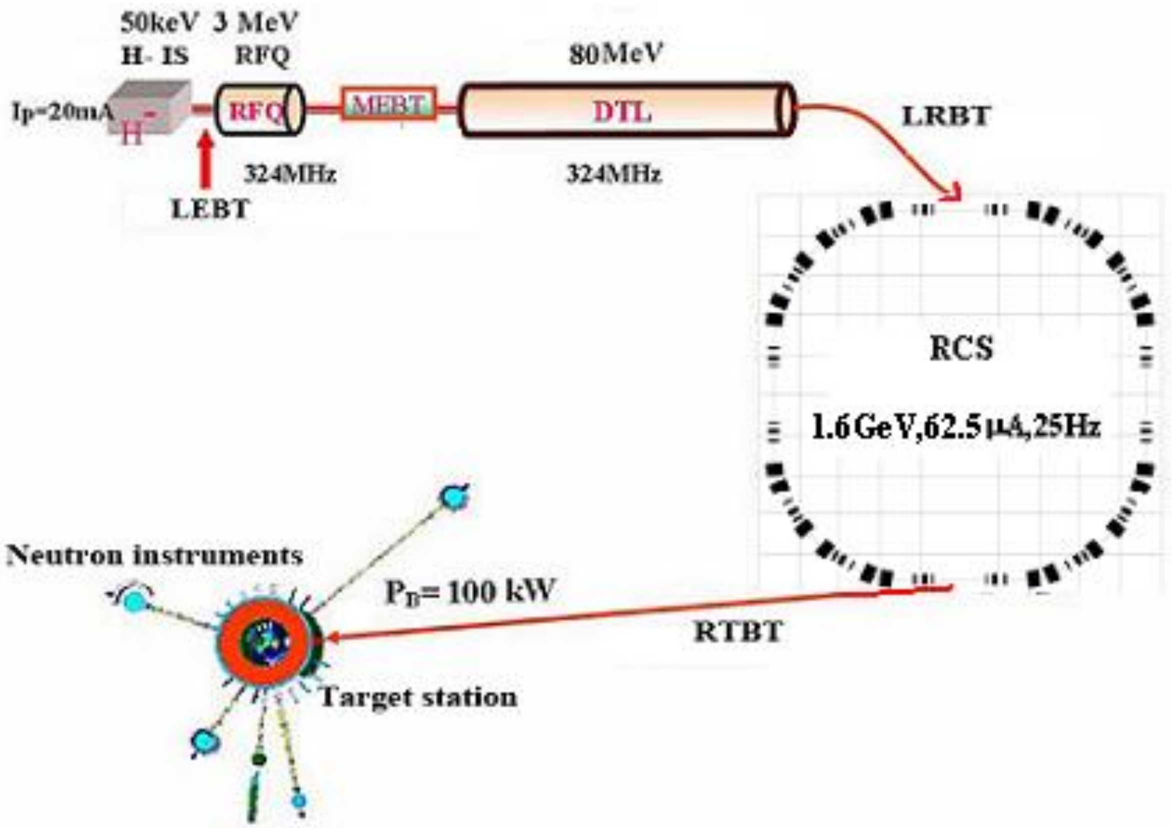
Project Overview

CSNS Project



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

Design Goal

Beam power (kW)	Repetition (Hz)	Beam current (μA)	Energy (GeV)	Max neutron flux* ($n/cm^2/s$)
100	25	63	1.6	10^6

* Measured at 14m from modulator

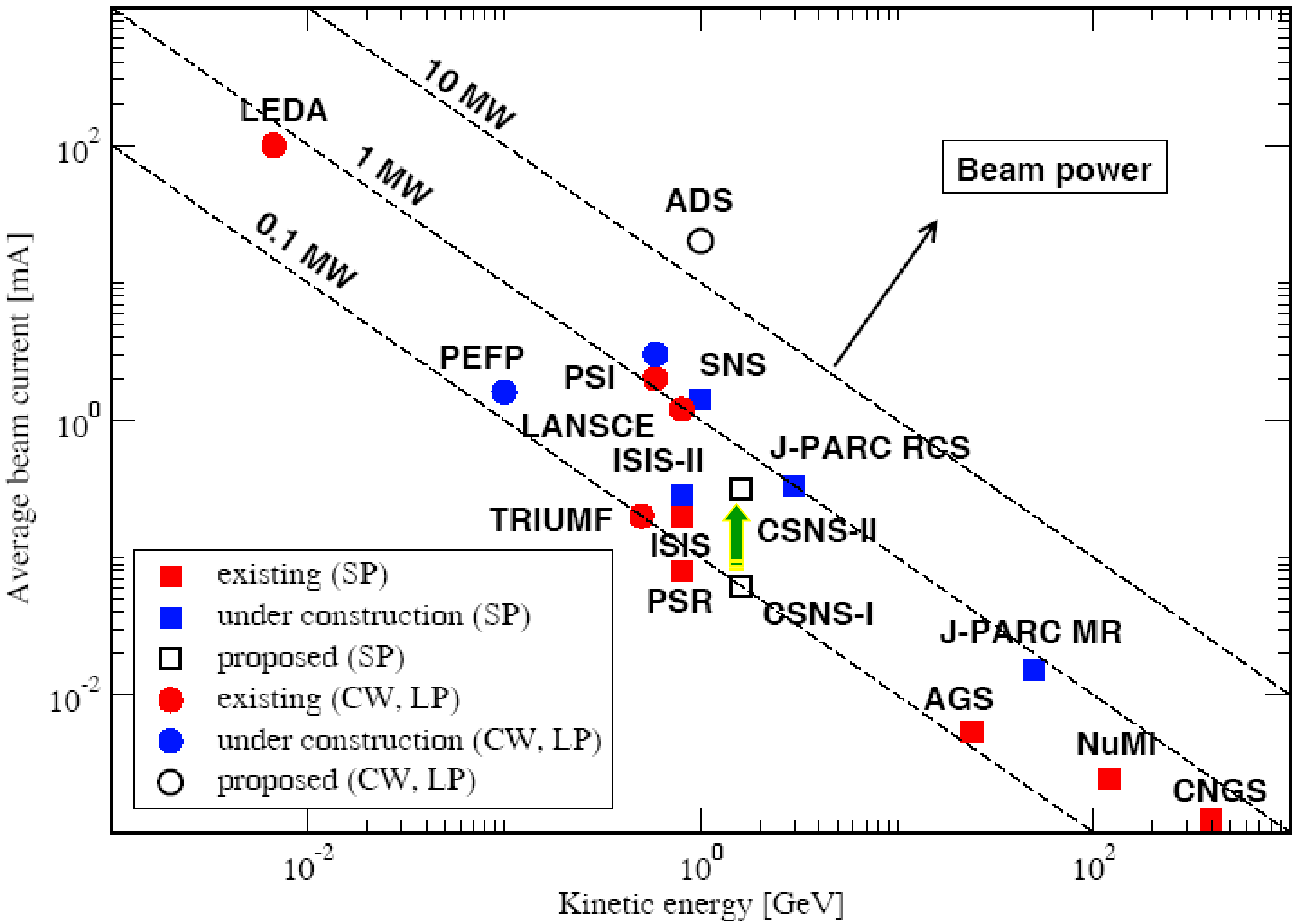
- Design goal will be met three years after acceptance.
- Project acceptance goal is 1/10 beam power goal.

Acceptance Goal

Beam power (kW)	Repetition (Hz)	Beam current (μA)	Energy (GeV)	Max neutron flux* ($n/cm^2/s$)
10	25	6.3	1.6	10^5

- Upgradeable to 500kW at 25Hz in the second phase.

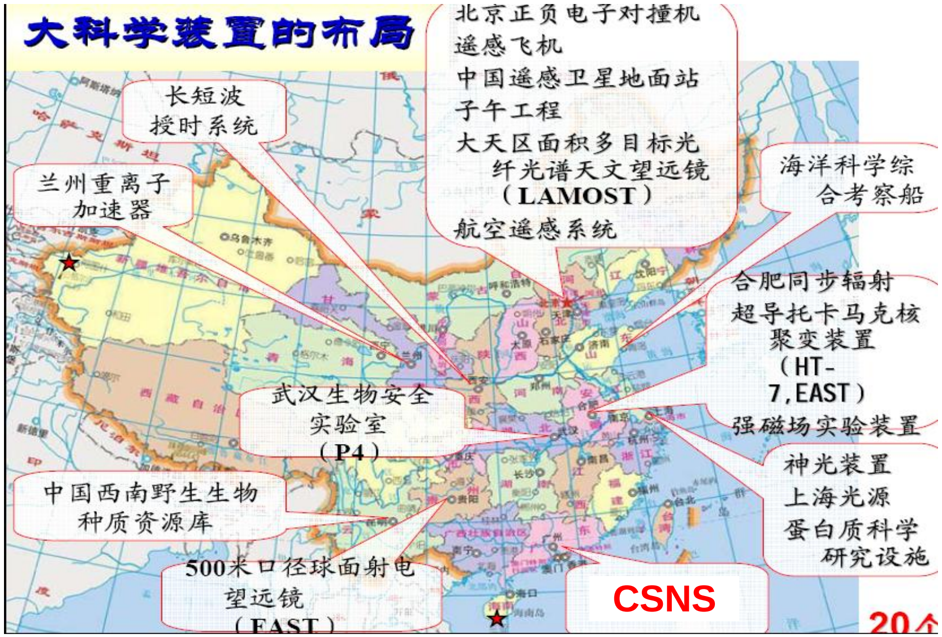
Power Map of Proton Accelerators



Key Milestones

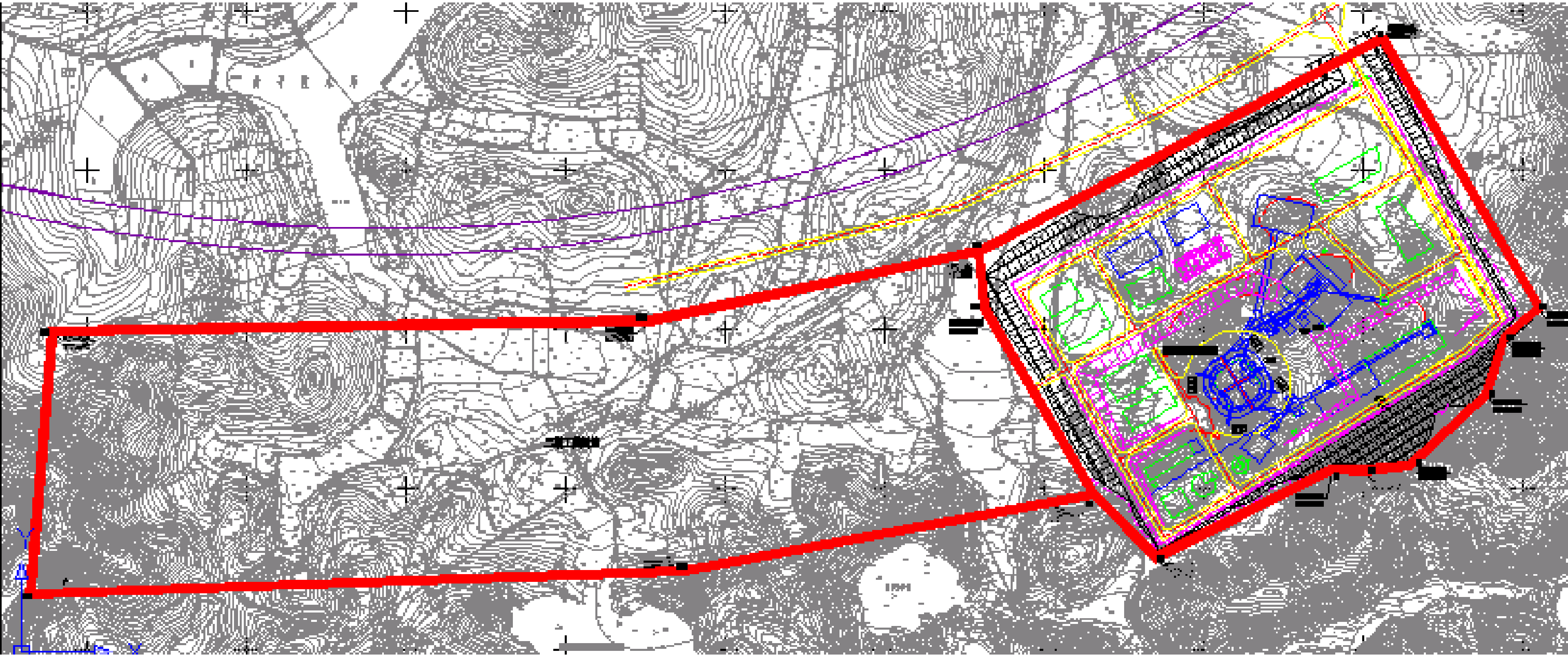
- **Feb. 2001: Idea of CSNS discussed**
- **Jun. 2005: Project proposal approved in principle by central government**
- **Jan. 2006 : CAS funded (35M CNY) for R&D 1**
- **Jul. 2007 : Guangdong funded (40M CNY) for R&D 2**
- **Dec. 2007: Project proposal review**
- **Sep. 2008: Project proposal approved by central government**
- **Oct. 2009: Project feasibility study review**
- **May 2010: Project design review**
- **Sep. 2011: Project construction start**
- **Mar. 2018: Project completion**

Site Selection



- The site of CSNS has been selected at Dongguan, Guangdong Province.
- CSNS is the first large scientific facility in southern part of China. It can balance the present uneven distribution of the facilities, and promote advanced researches in the economic developed zone of Guangdong-Hongkong.

Site Area



The Guangdong/Dongguan local government provides a free land of about 0.667km^2 for CSNS. 0.267km^2 is planned for the phase-I construction.

IHEP will set up a new branch at Dongguan for CSNS construction. Artificial view of the campus of the site.

Land preparation (upper: before; bottom: now)

the 70m-high slop protection laid on the hill have almost completed.

Two dedicated high-ways are under construction.

5 Apartment buildings with 230 rooms is under construction at Songshan Lake, and some other apartment buildings (430rooms) will be built soon.

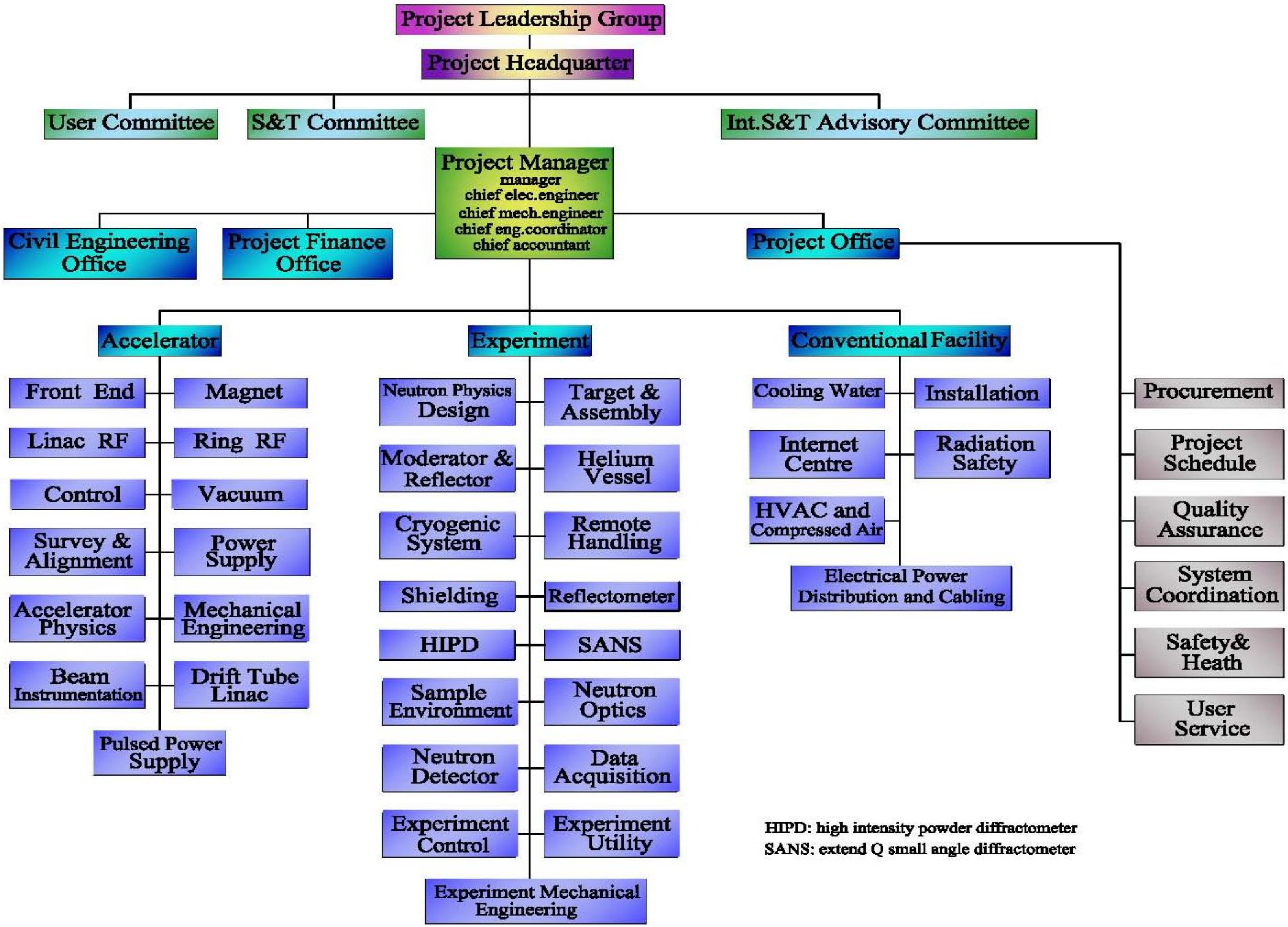
Budget

- **Baseline--- the largest big-science project in China**
  - **1.7B CNY from central government for project construction**
  - **0.5B CNY and land from Guangdong/Dongguan local government for additional supports**
- **R&D**
  - **35M CNY (received) from CAS for R&D 1**
  - **40M CNY (received) from Dongguan government for R&D 2 (included in 0.5B CNY additional supports)**
- **Operation**
  - **0.14B CYN per year from central government**

Personnel Needs

No.	Division	Peak (FTE)	Present (FTE)
1	Accelerator	160	110
2	Experiment	136	49
3	Conventional Facility	95	11
Total		391	141

Organization Chart



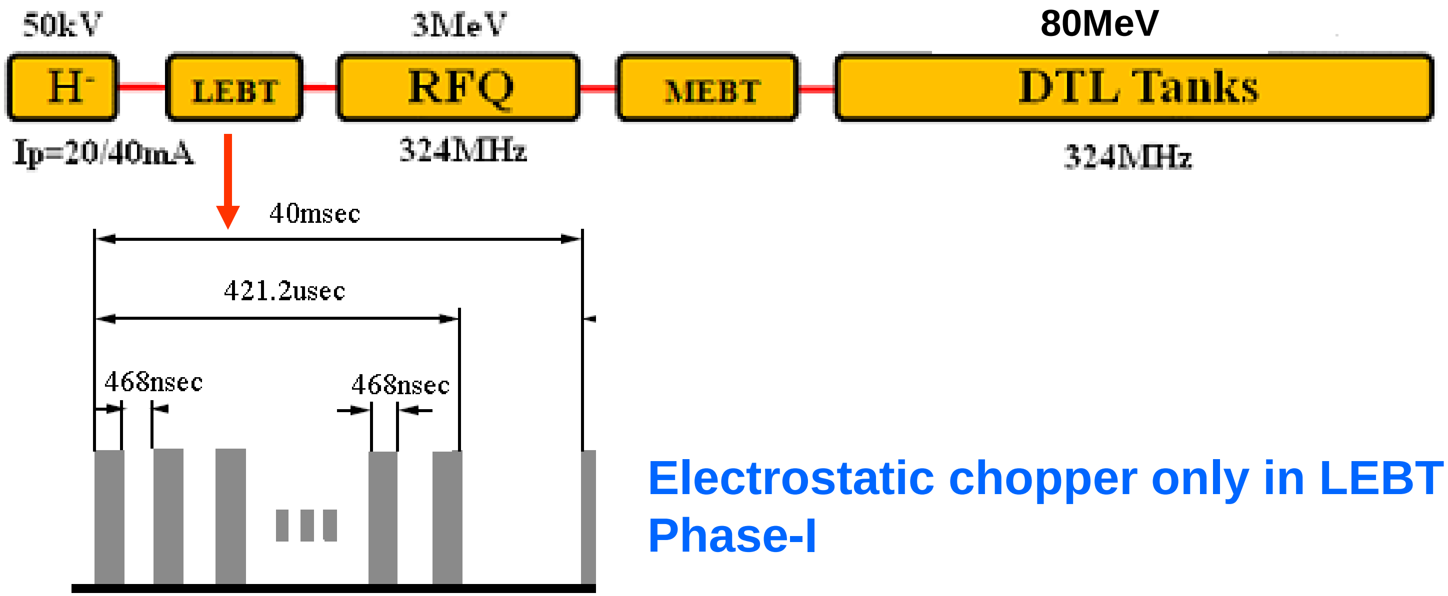
HIPD: high intensity powder diffractometer
SANS: extend Q small angle diffractometer

The Second International Accelerator Technology Advisory Committee Review Meeting was held in January, 2010.

The 3rd ATAC is going to be held in 22-24, Sept. 2011

Accelerator Design

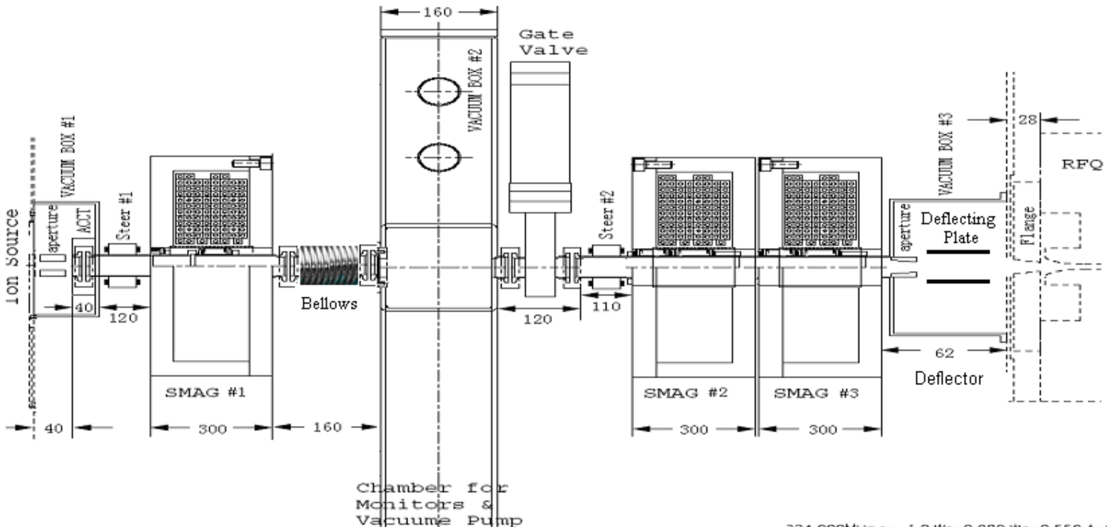
- **Linac design :**



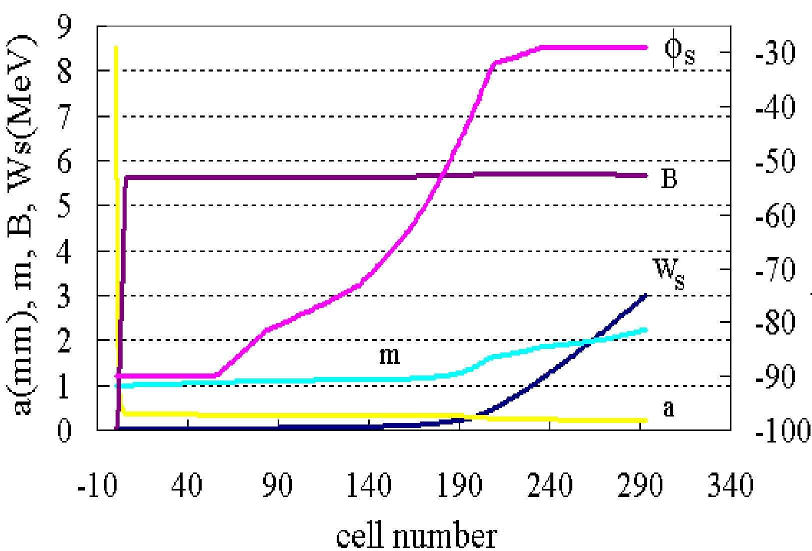
Electrostatic chopper only in LEBT in Phase-I

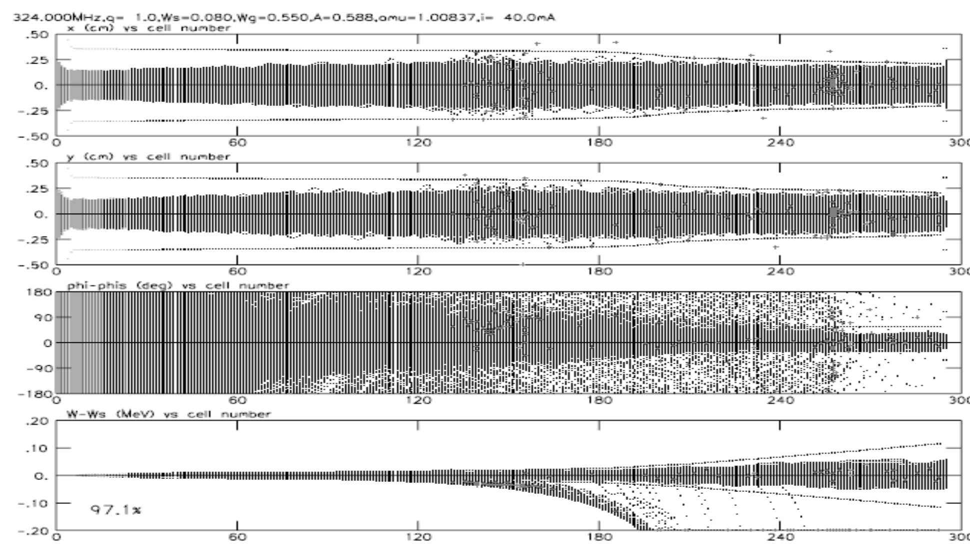
	Ion Source	RFQ	DTL
Input Energy（MeV)		0.05	3.0
Output Energy(MeV)	0.05	3.0	80
Pulse Current (mA)	20/40	20/40	15/30
RF frequency (MHz)		324	324
Chop rate (%)		50	50
Duty factor (%)	1.3	1.05	1.05
Repetition rate (Hz)	25	25	25

Front-end design



A Penning H- ion source and a three-solenoids LEBT with space charge neutralization.





97% transmission rate in design

DTL design

Tank parameters of CSNS DTL

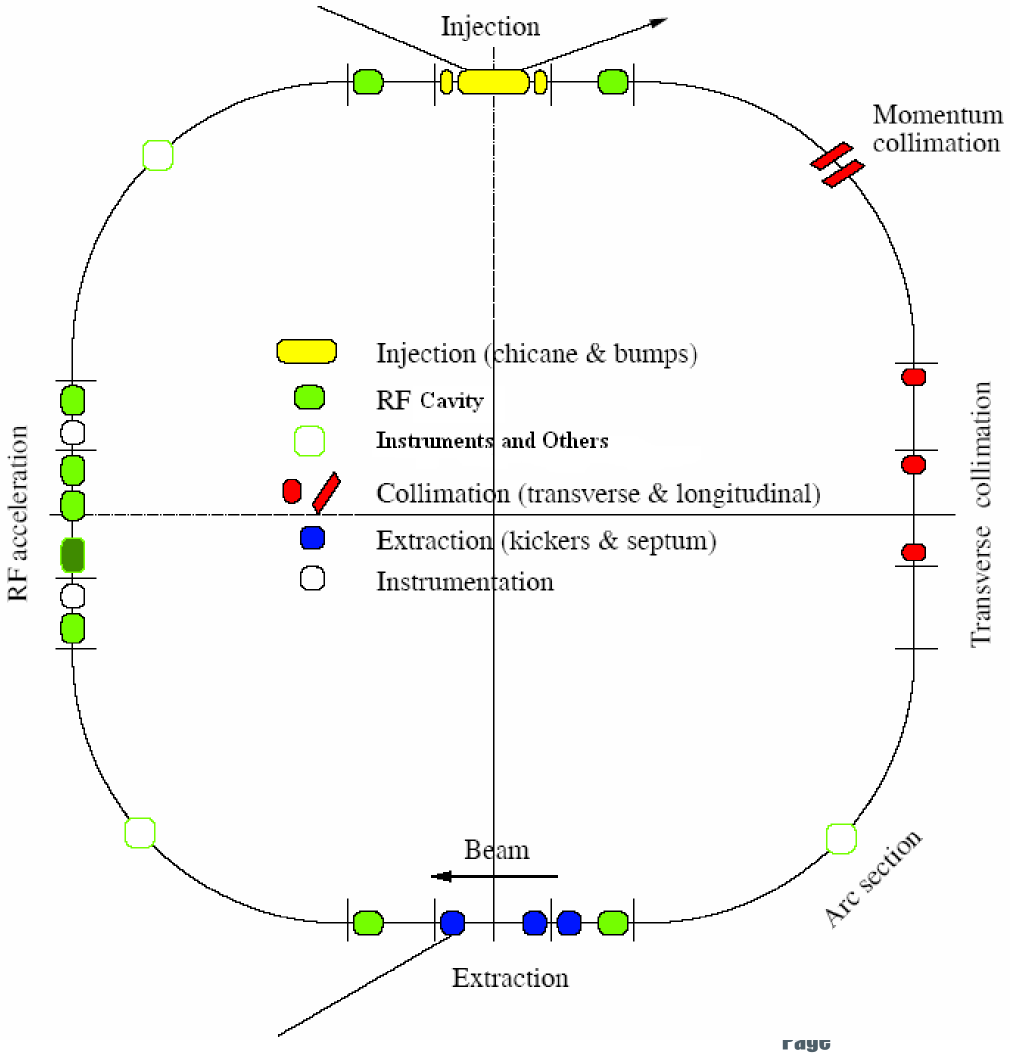
Tank number	1	2	3	4
Output energy (MeV)	21.67	41.41	61.07	80.1
Length (m)	8.51	8.56	8.78	8.8
Number of cell	64	37	30	26
RF driving power (MW)	1.35	1.32	1.32	1.34
Total RF power (MW)	1.91	1.92	1.92	1.93
Accelerating field (MV/m)	2.86	2.96	2.96	3.0
Synchronous phase (degree)	-35 to -25	-25	-25	-25

- The total RF power with a 30mA beam in a tank is about 2MW. Each tank is fed by a 2.5MW klystron.
- FFDD lattice is used.

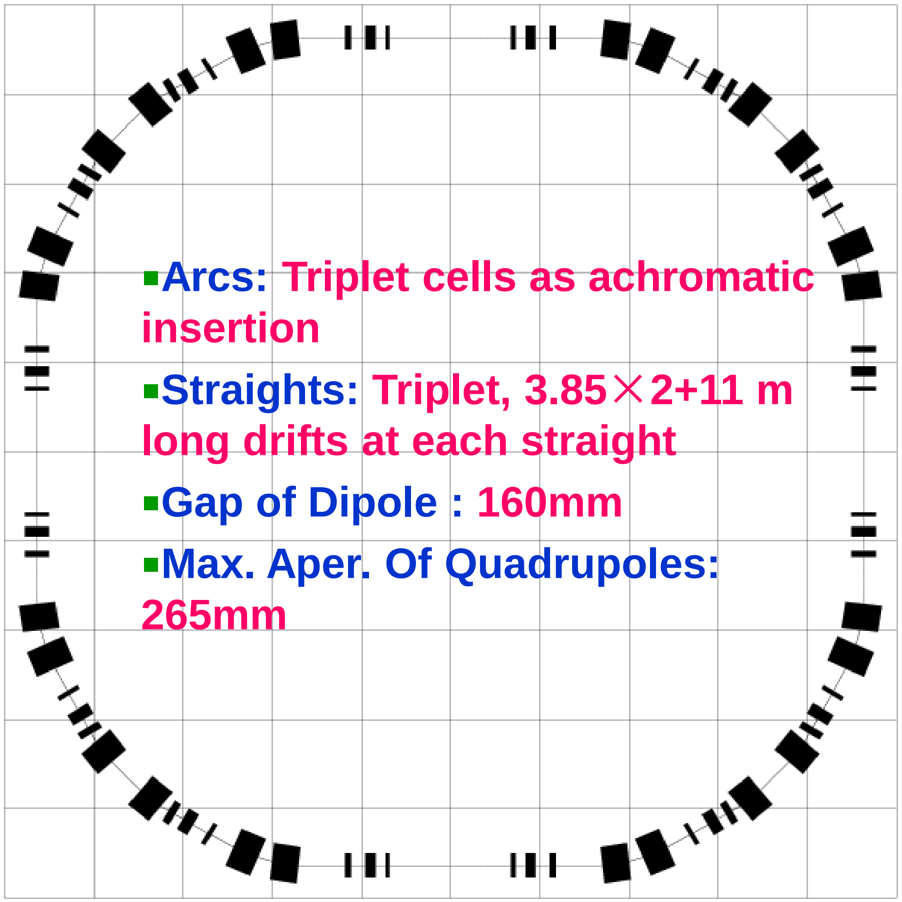
RCS Design

Lattice design—4-fold Structure

- Separated-function design
- The collimation can be performed in a separate straight section.
- The superperiodicity of 4 is better for reducing the impact of low-order structure resonance than superperiodicity of 3.



RCS major parameters

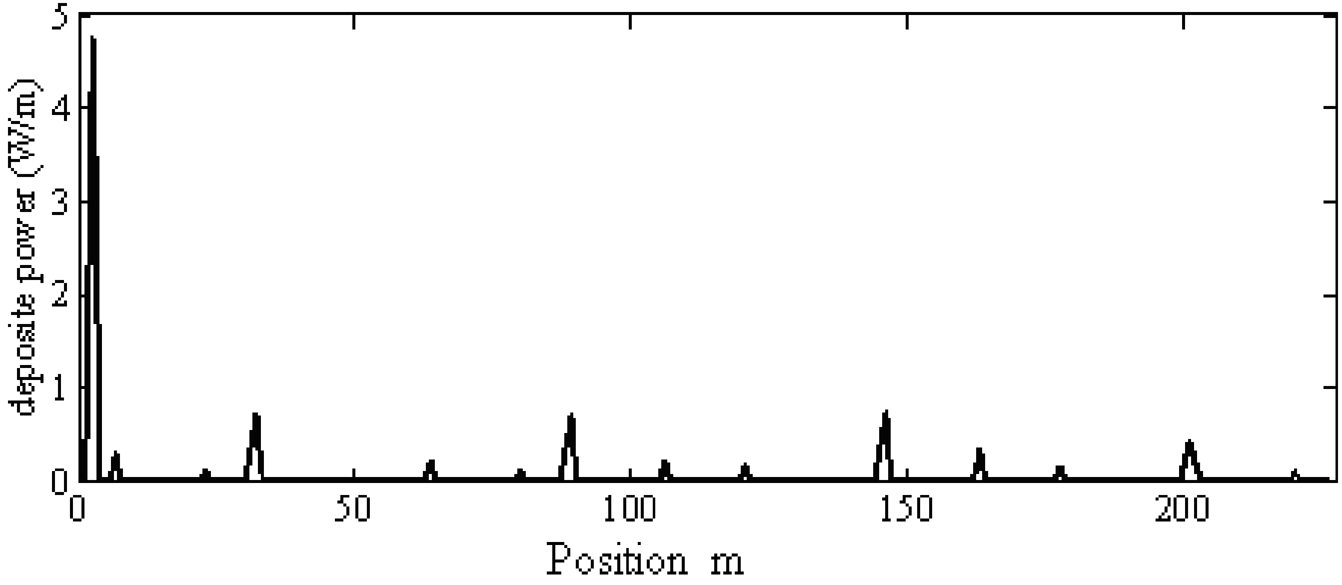


- Arcs: Triplet cells as achromatic insertion
- Straights: Triplet, 3.85×2+11 m long drifts at each straight
- Gap of Dipole : 160mm
- Max. Aper. Of Quadrupoles: 265mm

Lattice consists of 16 triplet cells, with a gap in the middle of arc and dispersion free straight section .

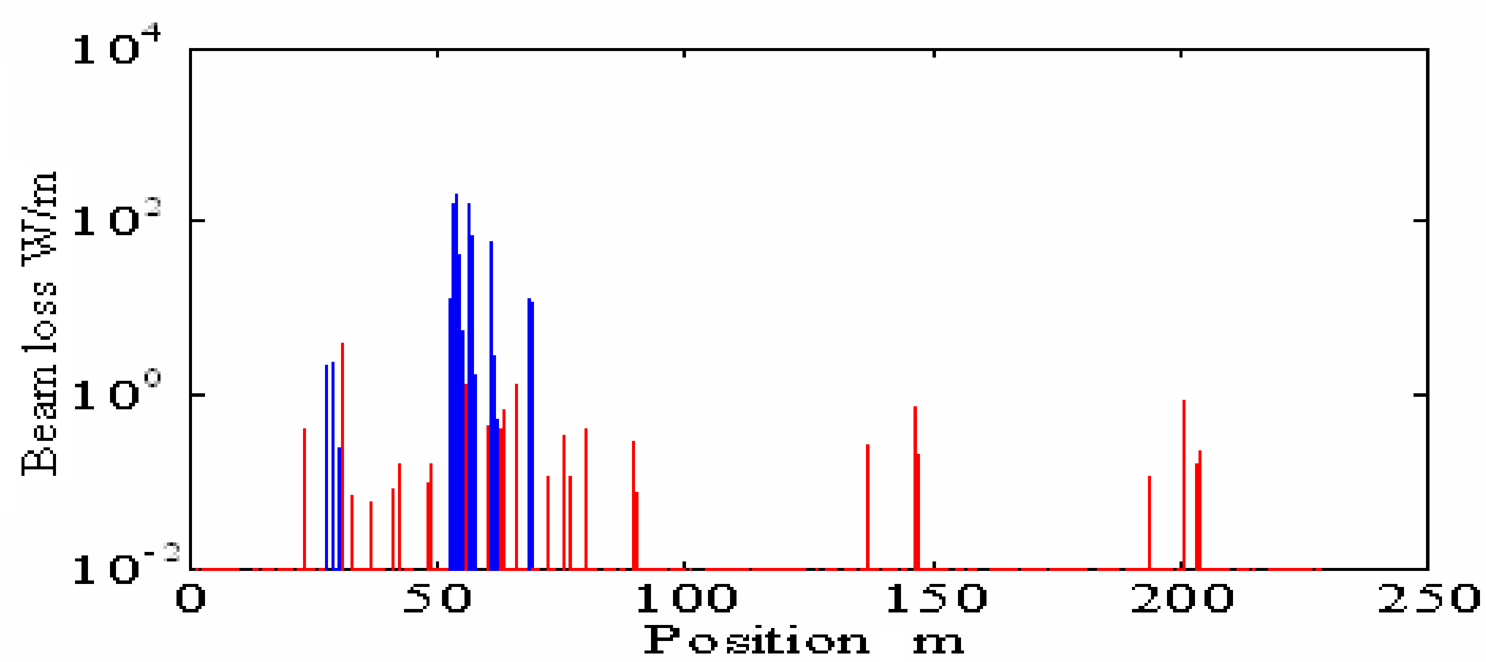
Circumference (m)	227.92
Superperiod	4
Number of dipoles/quadrupoles	24/48
Number of long drift	12
Total Length of long drift (m)	75
Betatron tunes (h/v)	4.82/4.80
Chromaticity (h/v)	-4.3/-8.2
Momentum compaction	0.041
RF harmonics	2
RF Freq. (MHz)	1.0241~2.44
RF Voltage (kV)	165
Trans. acceptance (πμm.rad)	540

Beam loss without collimation



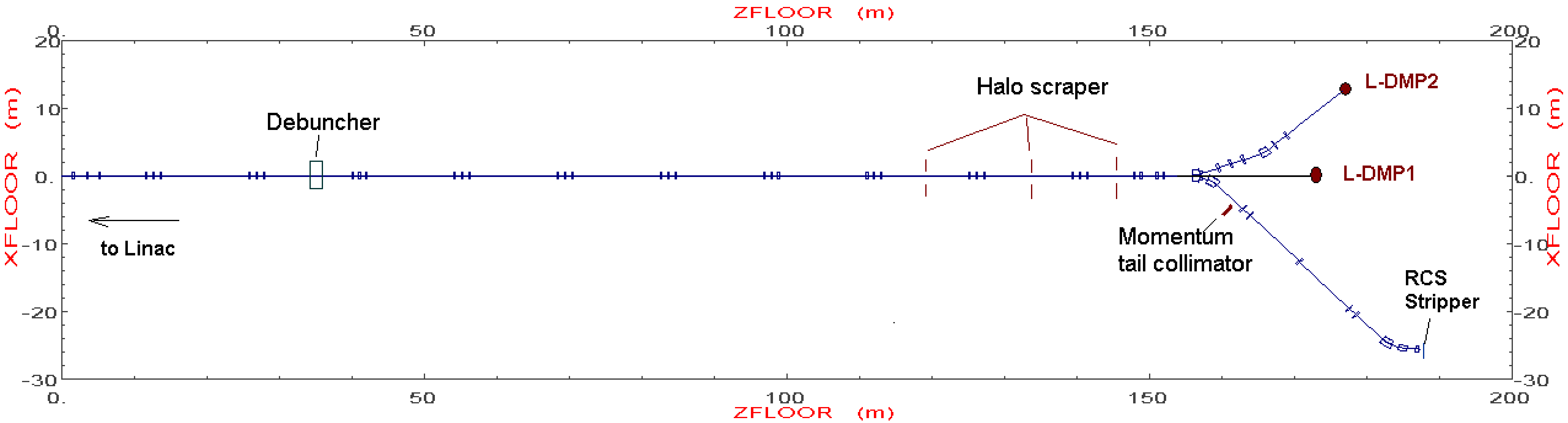
In case of no beam collimation, the total beam loss is small, but the maximum local beam loss is over 5W/m.

Beam loss with collimation



Beam loss distribution in the RCS with transverse and momentum beam collimation, total beam loss is about 5%, and the collimation efficiency is more than 96%

LRBT layout

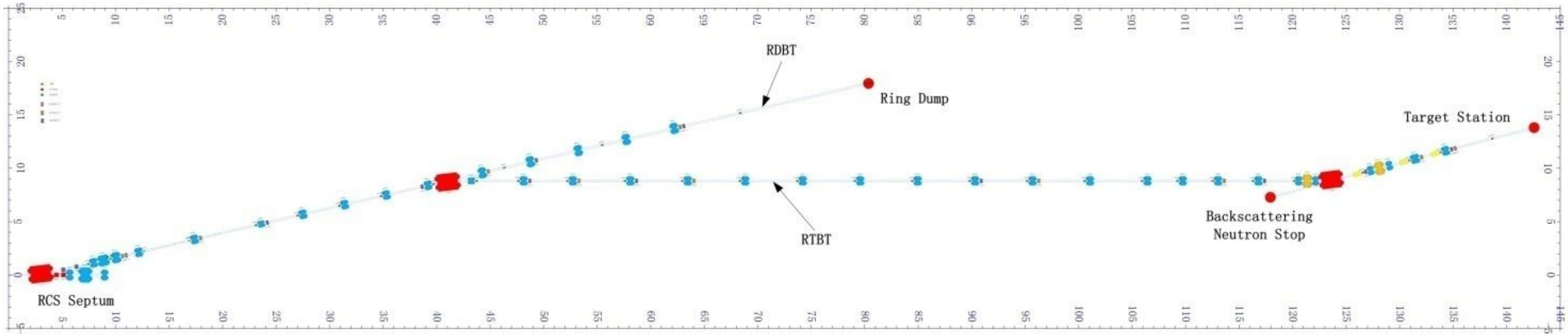


85m reserved for upgrade linac energy to 250MeV

Superconducting spoke cavity will be used from 80 to 250 MeV linac

RTBT Layout

W.Liu: THPS041



•RTBT transport extracted beam from RCS to target.

•Matching and tailoring the beam to get the required profile and beam density in the target by means of two octupole magnets.

• Beam loss control: collimation at RTBT for protection of the target and shielding of back scattering neutrons.

•A beam dump for beam commissioning.

•Proton beam window: separating accelerator vacuum from outside.

• Back scattering neutron beam line is design for future applications.

Key Technology R&D

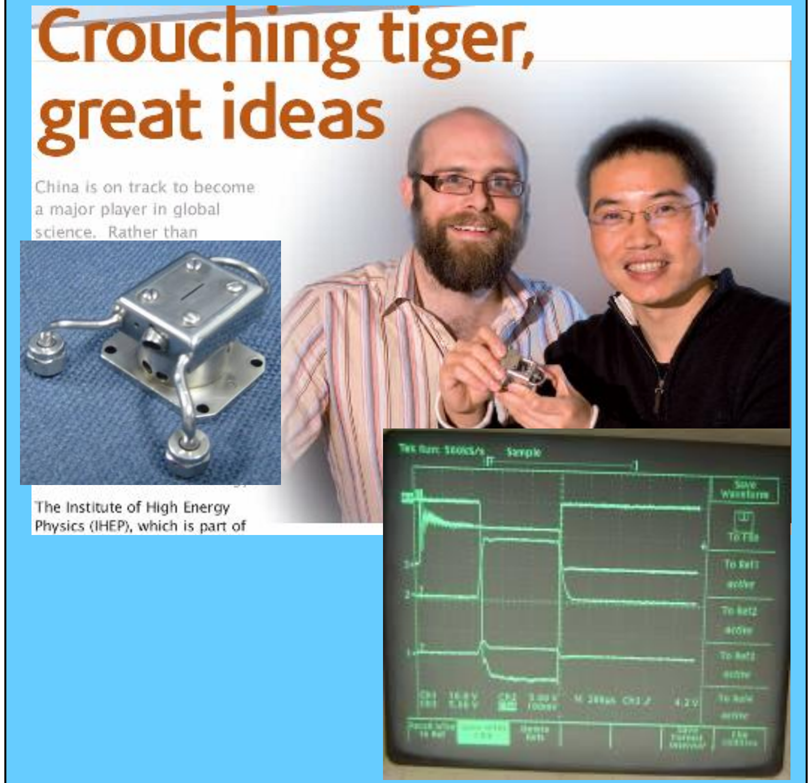
Key Technology Identification

1. H- ion source (20mA, 0.2πmm-mrad, long lifetime)
2. Ion source control system (EMC)
3. Fast chopper in LEBT(fast rise time and space-charge neutralization)
4. DTL tank (high RF freq. , small DT with EMQ, electroform)
5. Digital linac LLRF (1^0/1% , long flattop)
6. HV pulsed power supply for RF power source (innovative)
7. Modulator and Crowbar (high V and quick protection)
8. AC dipole magnet (Big gap, AC, eddy current)
9. AC quadrupole magnet (Big bore radius, AC, eddy current)
10. Magnet measurement (AC, curved)
11. Power supplies for D and Q magnets (AC+DC, high power, High tracking accuracy)
12. Ceramic chamber and its RF cage (Ceramic, Joining, crack)

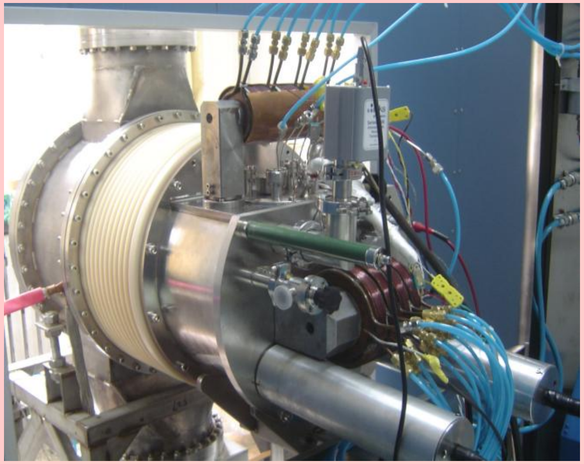
Key Technology Identification

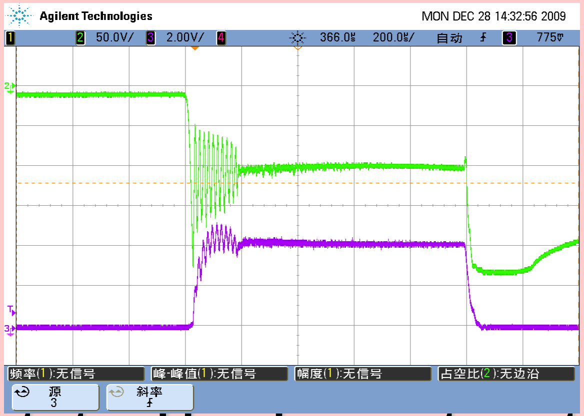
13. **Ferrite-loaded RF cavity** (High-power dissipation,Cooling plate:0.05mm)
14. **Biased current source for RF cavity** (High stabl: 0.2%, ramp:200A/ms)
15. **RF power supply** (wide swing:1-2.4MHz, high duty:50%, high power:500kW)
16. **Digitalized LLRF** (Varying f + Varying V+varying Φs, heavy beam loading,FB/FF)
17. **Inj/Ext magnets** (Good-field region, vibration, quick rise time)
19. **In/Ext power supplies** (High current:18kA, Prog. Slop, quick rise time:250nS))
20. **Beam diagnostics** (BLM, BPM, WS)
21. **Control** (Digitalized power-supply controller, waveform collector for power supply, timing system, XAL)
22. **Collimator**

Prototype



H- ion source: four H- ion source bodies were fabricated at IHEP and test at ISIS with a satisfactory results (55mA pulse current).



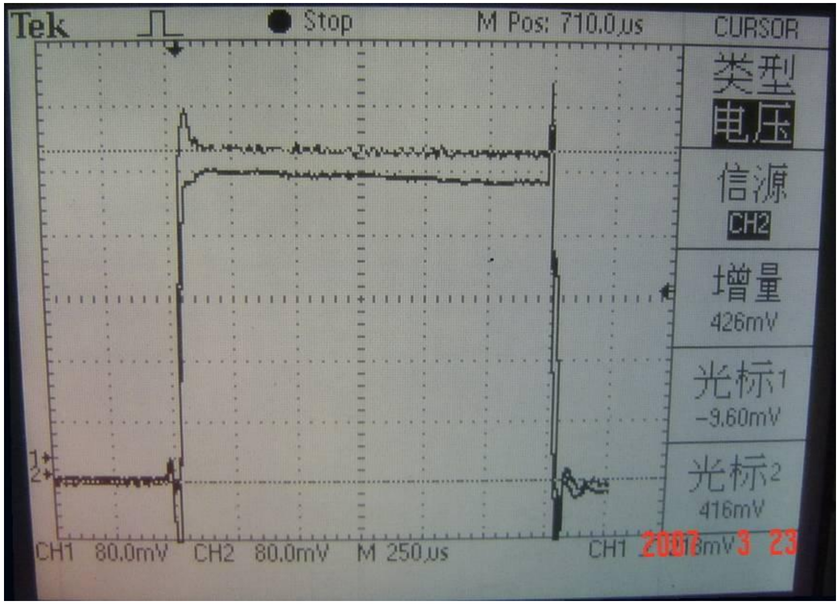


A test stand has been set up at IHEP for long-term reliability verification of the ion source.

Prototype

- **RFQ technology has been developed in an ADS program**

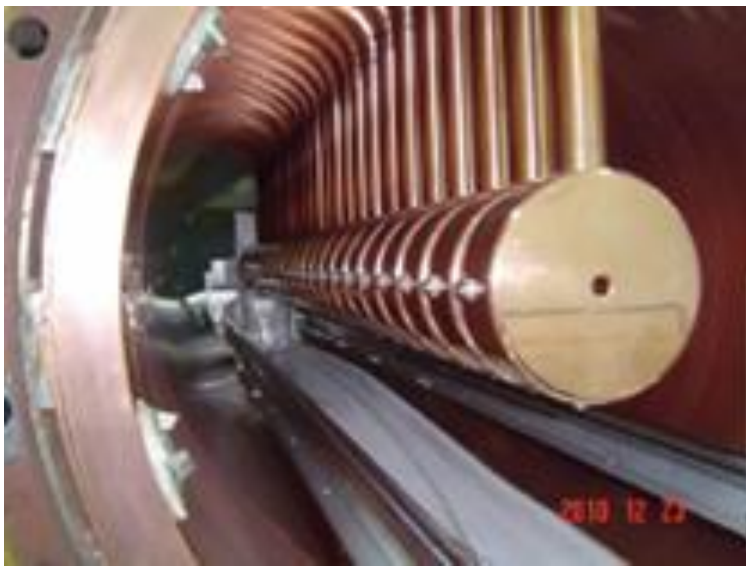
A 3.5MeV RFQ has been commissioned at IHEP with the kind support of the RF power system from CERN.

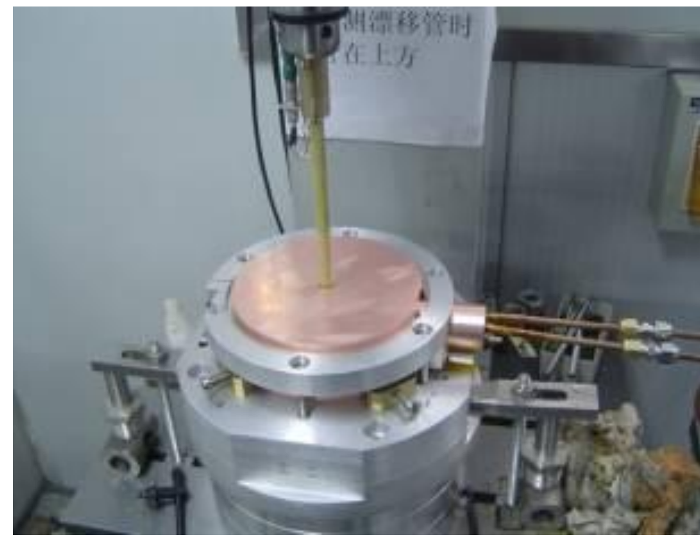


46mA output beam at 7% duty factor, transmission rate>93%. Now to 15% duty, CW in future.

Prototype

- DTL tank: electroform technologies are developed for tank copper liner.
- Electroformed coil， the same as J-PARC.



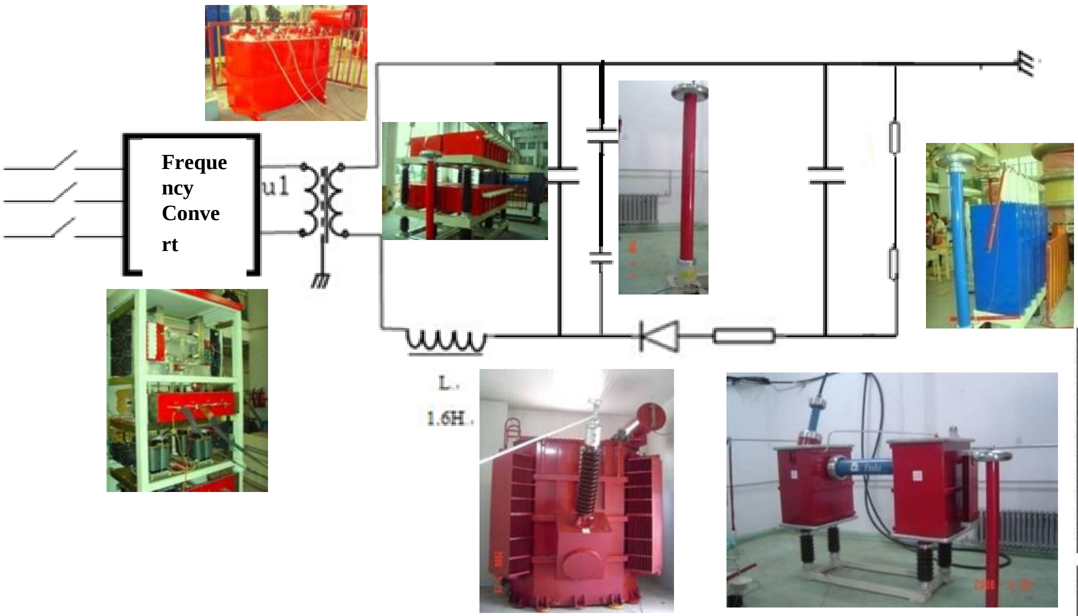


The first module of the first tank has been fabricated for field tuning.

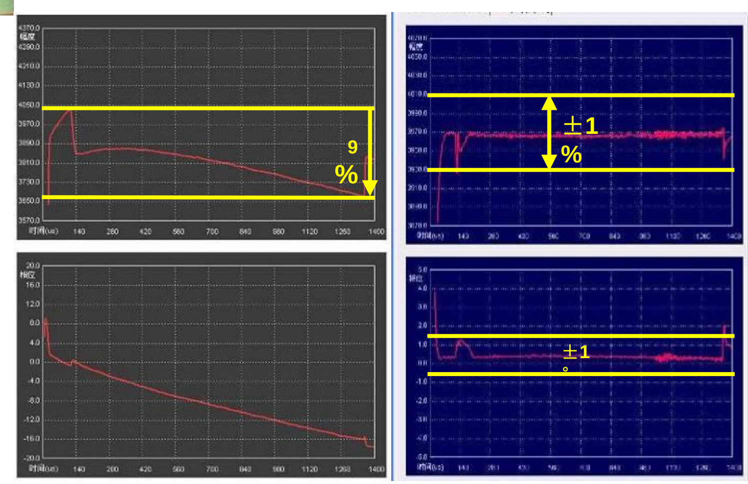
Sakae coil and quadrupole at rotating coil measurement

Prototype

Linac RF power system



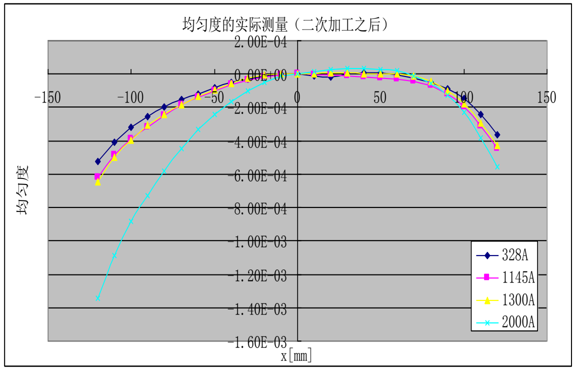
AC resonant HV pulsed power supply for klystron was proposed and devised.

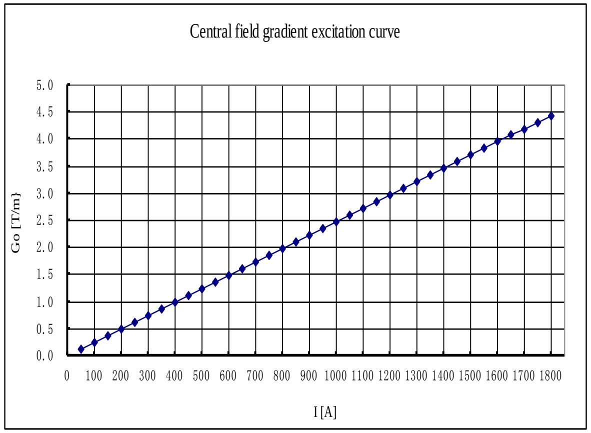


FPGA based digital LLRF control system with effective control of ph & ampl.

Prototype

- Dipole and quadrupole are prototyped. AC measurement system developed for dipole, with a good preliminary result.





Prototype

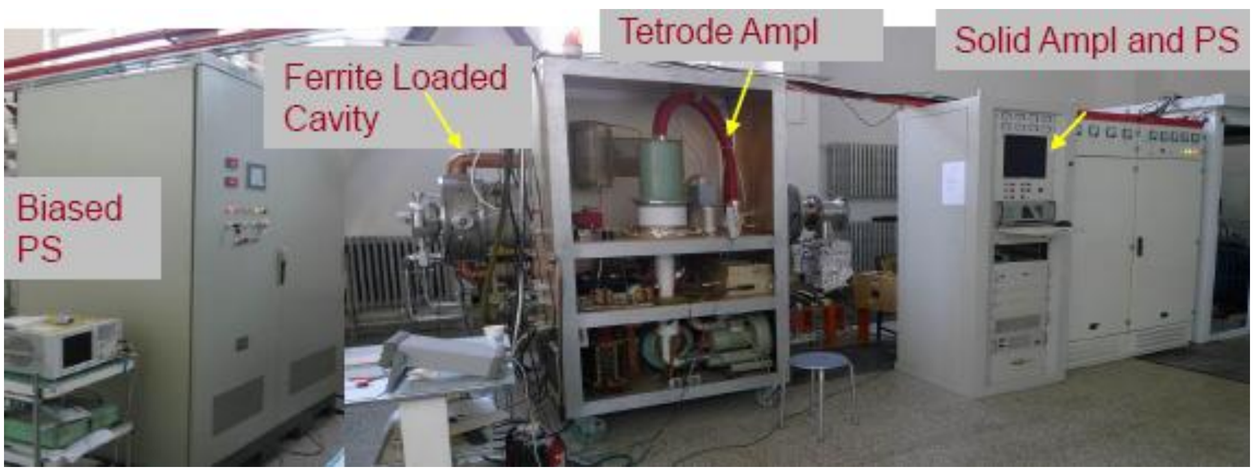
- **Power supply for dipole magnet**

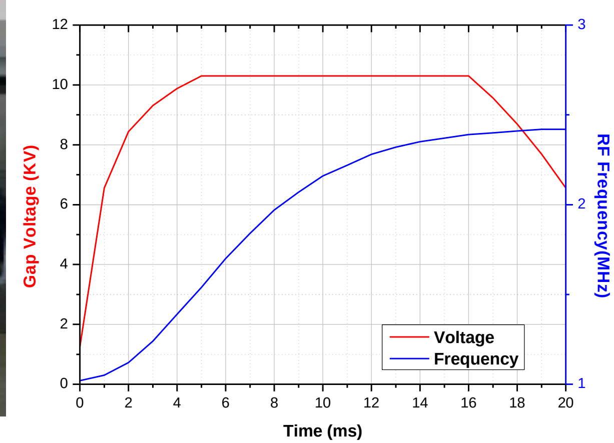
White resonant circuit was chosen as the power supply for the magnets with a large conductivity. It is composed of DC (1260A)+ AC(900A) sources, choke, and capacitor bank.

One of the key technology is high tracking accuracy. With the harmonics injection technology, magnet tracking accuracy meets design demand.

Prototype

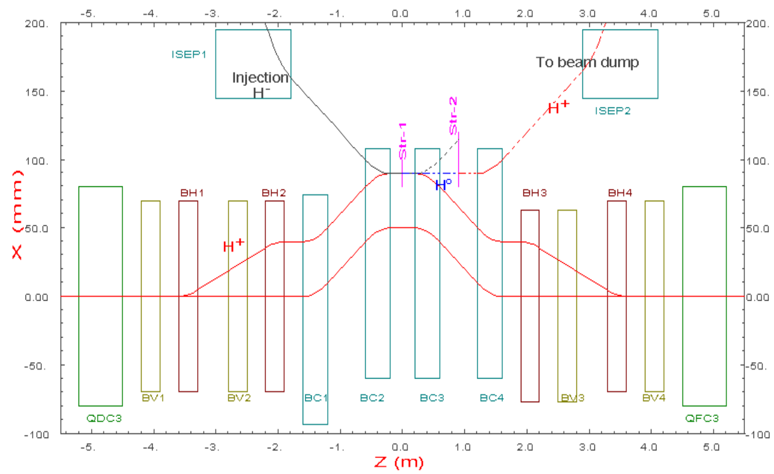
- **Complete RF system high power test**
  - Sweeping range: 1.02~2.44MHz
  - Repetition rate: 25Hz
  - Gap voltage: according to the curve of RF voltage provided by the physicist
  - The maximum gap volts can reach to 12kV.
- **Through 24 hours operation continuously, cavity and all devices works well.**





Prototype

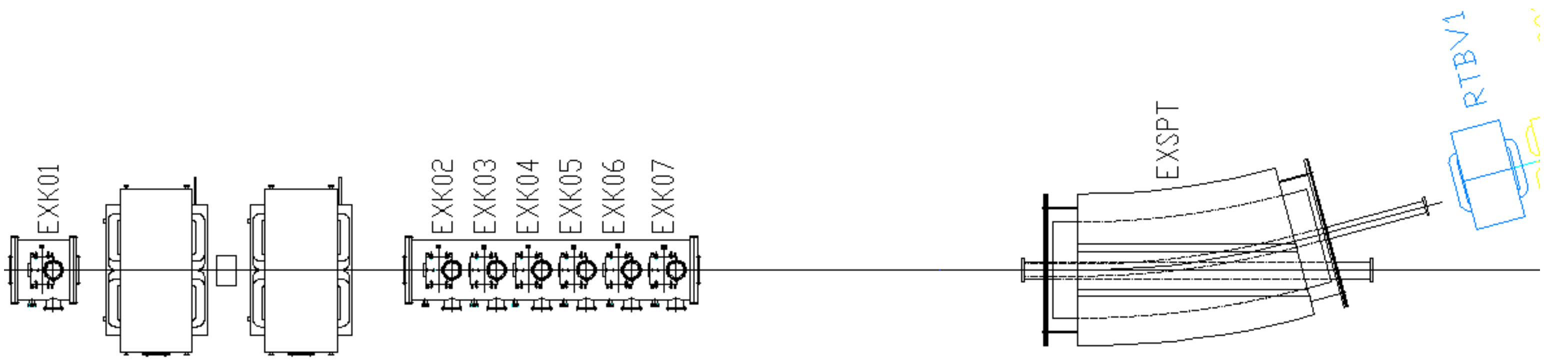
- **Injection bumper magnet and power supply are prototyped**



A pulsed power supply with 18kA output current in maximum during injection time of 500μs connected with the bump magnet for the magnet measurement.

Prototype

Extraction fast kicker and its pulse power supply.



The pulse power supply uses Blumlein type pulse forming network to get a short pulse with a current of 5840A and a flattop of better than ±1.5%

Summary

- CSNS is the largest big-science facility in China
- The CSNS accelerator design can meet the project requirement.
- Optimization of the design has been done for low beam loss and low cost.
- Most of the key technology have been developed for low technology risk.
- CSNS will start construction in the end of Sept. 2011 and complete in 2018.

Thank you very much for your attention