Chinese Plan for ADS and CSNS

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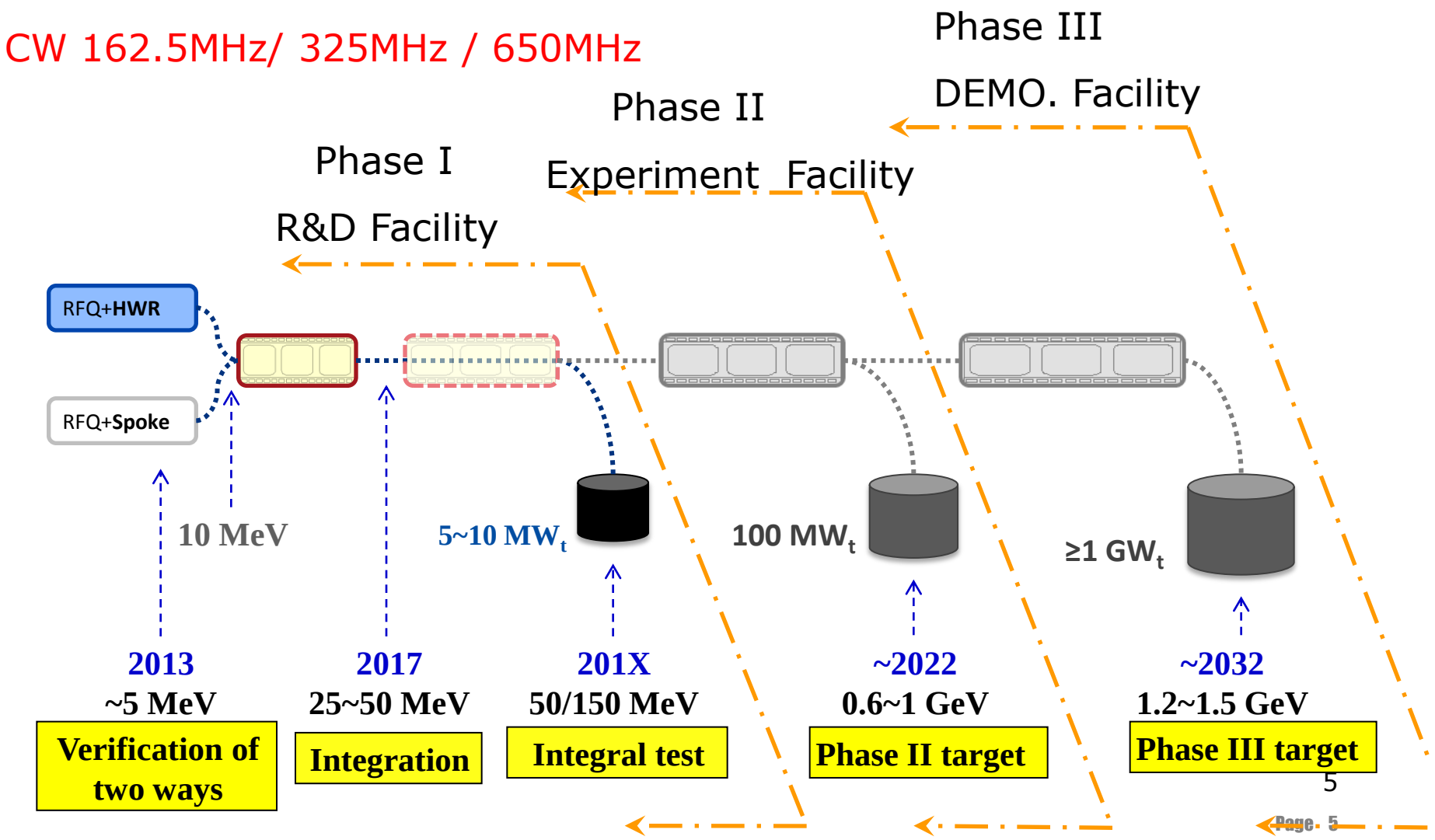
1, ADS & CSNS Plan

Nuclear Power in China

- **To 2010.10**
  - Operation reactor 13 sets, 10.23GWe
  - Constructing reactor 23 sets, 25.90GWe， is the largest in construction scale over the world
- **According to some information:**
  - **2020**: >70 GWe NPP in operation and 30GWe NPP under construction; >5% of NP to total installed capacity
  - **2030**: ~10% of NP to total installed capacity
  - **2050**: >400 GWe NPP 」 **almost same as the scale of the total in the world todays!**

ADS Roadmap in China



Phase I - CIADS

- Schedule: 2011-2017
- Budget: &260M approved ($98M for accelerator), plus free land & Infrastructure from local government.
- Site Candidate: Inner Mongonia
- Accelerator Task:

a) 2011-2013: 2 Injectors at 5MeV

b) 2013-2017: S.C. Spoke Linac: 50MeV

- Accelerator Team: IHEP&IMP
- Accelerator Key Technology:

a) R.T. RFQ and low-beta S.C. spoke&HWR

b) S.C. laboratory

CSNS Plan

- It consists of a H- linac, a rapid-cycling synchrotron, a target station and 3 neutron spectrometers in Phase-I (Max. Num.=20)
- Its approved budget is $260, with additional free land & infrastructure plus $76 from the local government.
- It is going to start construction in September 2011 and completed in 6.5 years.

- **Land preparation has been finished.**

中国散裂中子源


Heilongjiang
Jilin
Liaoning
ADS
BEIJING
Xinjiang
Inner Mongolia
Gansu
Tianjin
Hebei
Ningxia
Qinghai
Shanxi
Shandong
Henan
Jiangsu
Shaanxi
Tibet
Shanghai
Sichuan
Anhui
Hubei
Zhejiang
Chongqing
Jiangxi
Hunan
Guizhou
Fujian
Yunnan
Guangxi
Taiwan
Guangdong
Hong Kong
Mocau
CSNS
Hainan
Islands of South China Sea

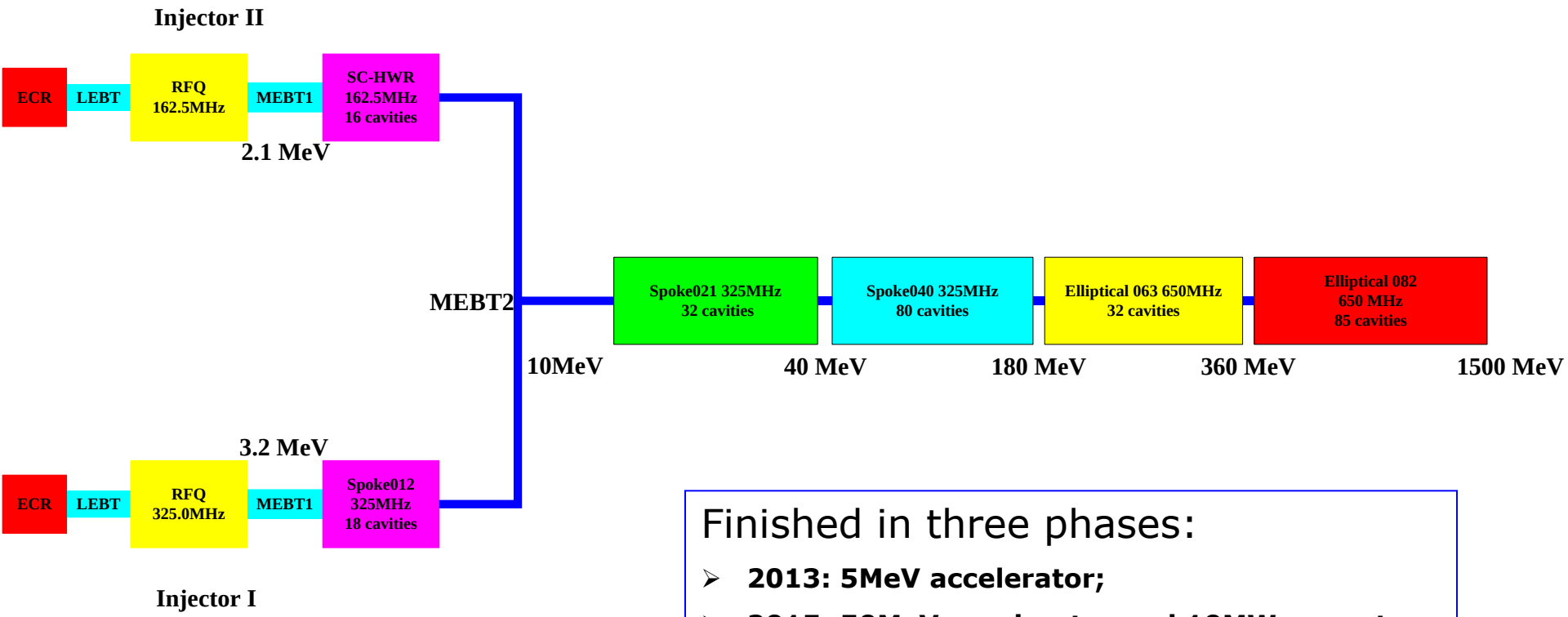
2. ADS Accelerator

1, ADS Linac Preliminary Design

Major Parameters

Particle	Proton	
Frequency	162.5/325/650	MHz
Energy	1.5	GeV
Current	10	mA
Beam power	15	MW
Duty factor	100	%

Layout

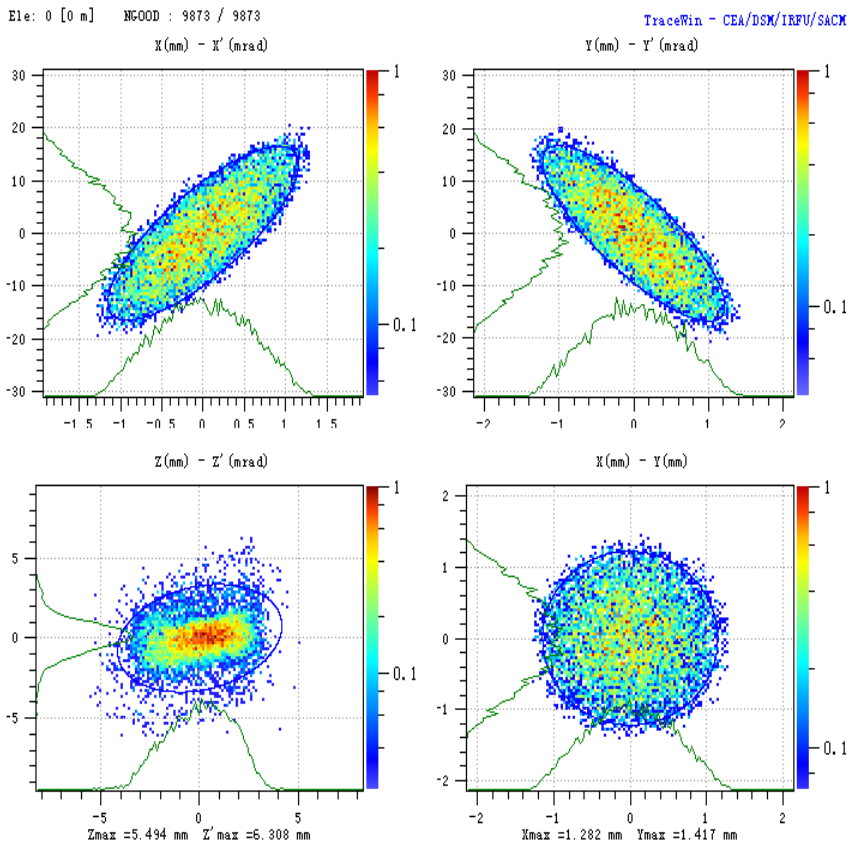


Finished in three phases:

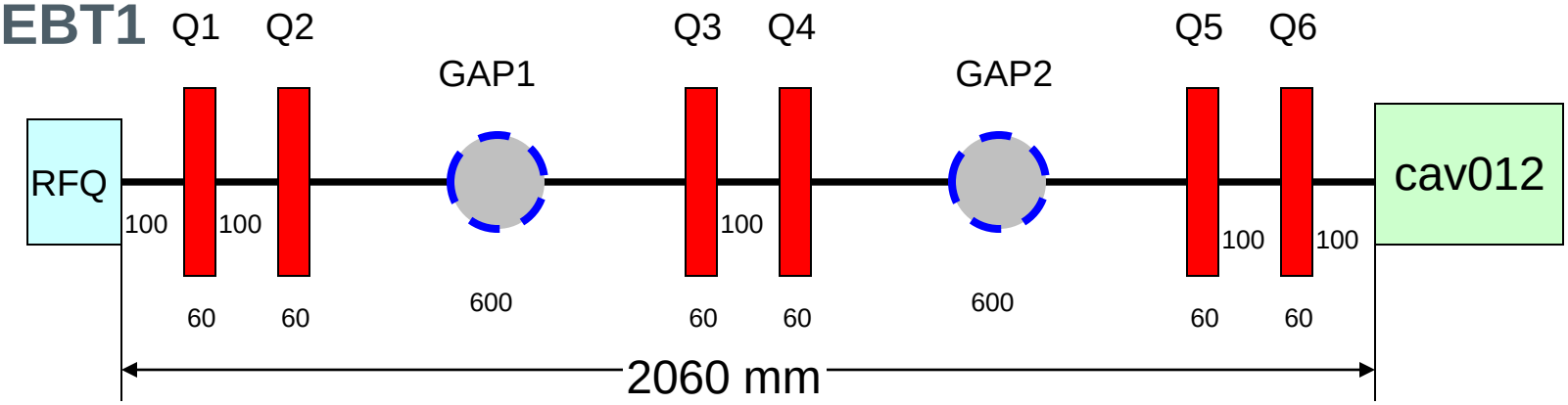
- **2013: 5MeV accelerator;**
- **2015: 50MeV accelerator and 10MW reactor, target;**
- **2020: 600MeV accelerator and 100MW reactor, target;**
- **2030: 1.5GeV and 1000MW reactor, target;**

IS & RFQ (Injector-I)

Ion source	
Out put current	20 mA
Trans. RMS. Nor. Emittance	0.2 πmm.mrad
RFQ	
Type	4 vane
Input energy	55keV
Transmission efficiency	98%
Output energy	3.2 MeV
Length	4.67m
Cavity Power	272 kW



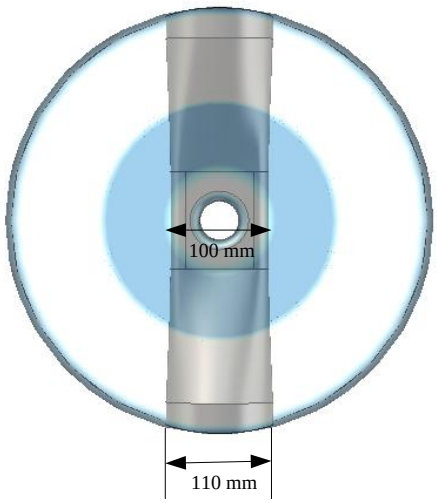
MEBT1

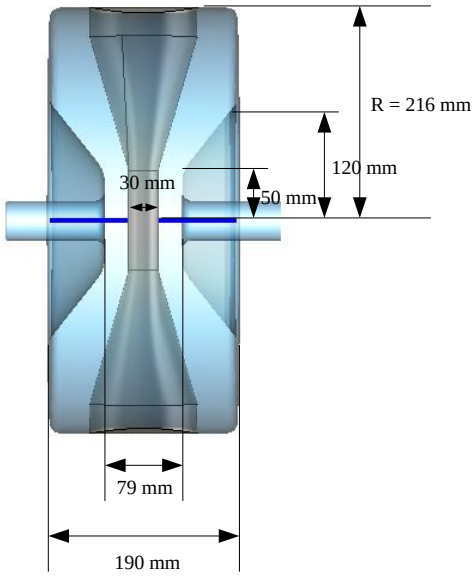


Element	Length (mm)	Magnetic field gradient (T/m) /Effective electric field (kV)
Q1	60	41.0
Q2	60	-26.5
Q3	60	19.3
Q4	60	-18.8
Q5	60	13.2
Q6	60	-11.9
Buncher-1	600	117.5
Buncher-2	600	114.3

Injector I

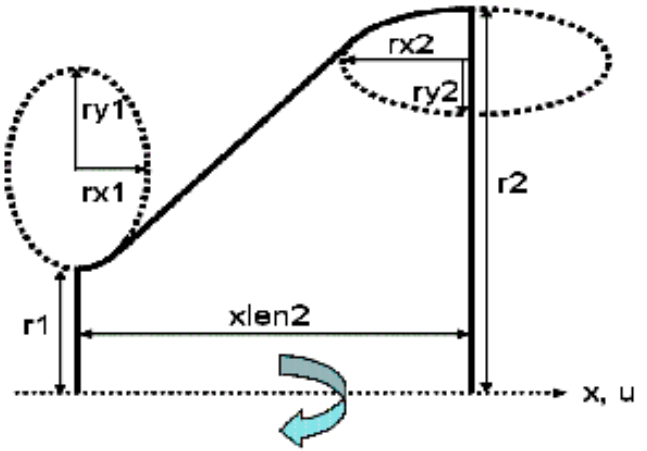
- **Spoke012 cavity:**
  - Geometry beta: 0.12
  - Acceleration gradient: (active length: βλ)
    - 5.75 MV/m (scheme1)
    - 8.6MV/m (scheme2)
  - Cavity number:
    - 18 for scheme1 in two cryomodules;
    - 13 for scheme2 in one cryomodules;
  - Epeak/Eacc=4.38
  - Bpeak/Eacc=7.76 mT/MeV/m





Elliptical cavity

- 5 cell;
- Gradient:
  - Eacc=10MV/m for β=0.63
  - Eacc=15MV/m for β=0.82
- Changing end cell length to get smooth field distribution;

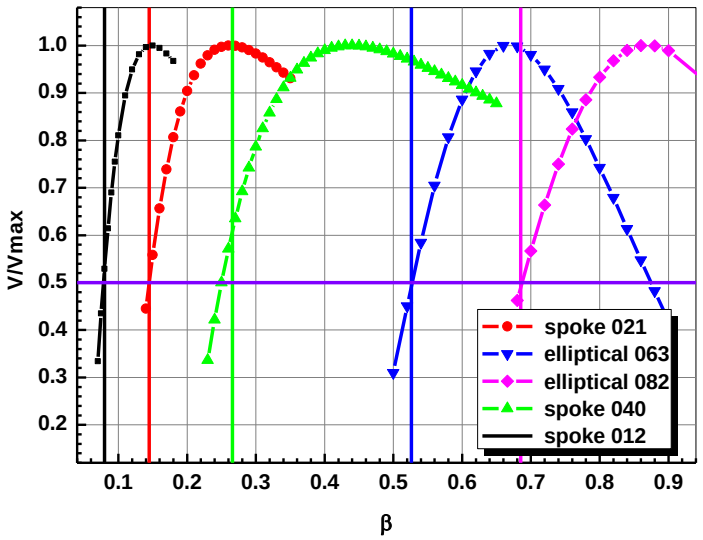


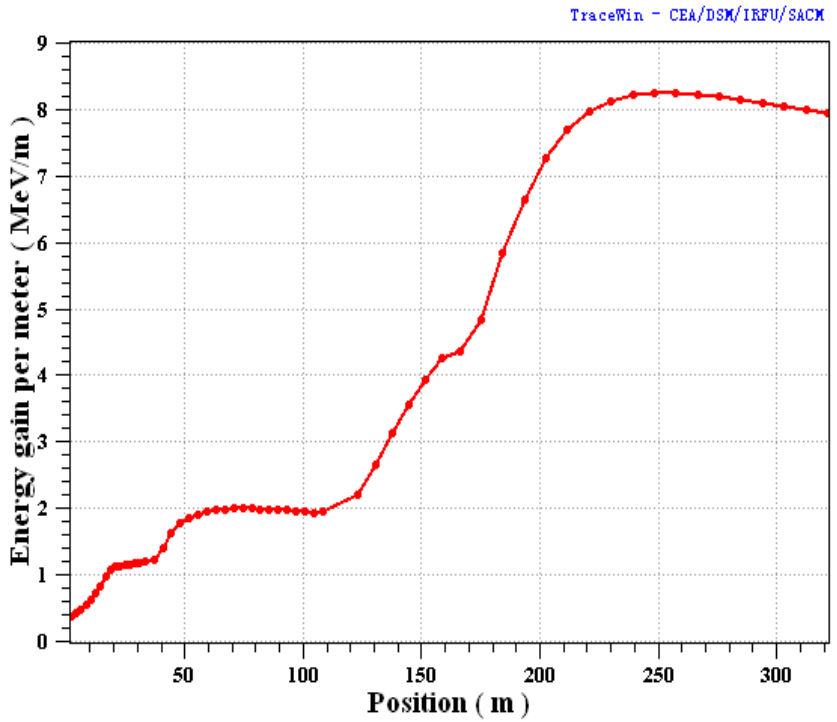
	β=0.63		β=0.82	
	middle cell	end cell	middle cell	end cell
rx1	18	18	18	18
ry1	36	36	38	38
rx2	51	53	71	73.1
ry2	53	53	73	73.1
r1	40	40	47.5	47.5
r2	195.5	195.5	199.7	199.7
xlen2	72.64	75.1	94.55	98.6

Cavity characters along the accelerator

Cavity type	S-spoke	S-spoke	S-spoke	5 cell ell.	5 cell ell.
Geometry β	0.12	0.21	0.40	0.63	0.82
E_p / E_{acc}	4.38	3.67	3.70	3.13	2.13
B_p / E_{acc}	7.76	6.59	7.22	4.57	4.30
Acc. Grad. /MV/m	5.75	6.97	7.56	10.56	16.36
	325MHz E_{peak}=25MV/m Acctive length=βλ			650MHz E_{peak}=35MV/m Active length=5βλ/2	

Acceleration efficiency and acceleration gradient



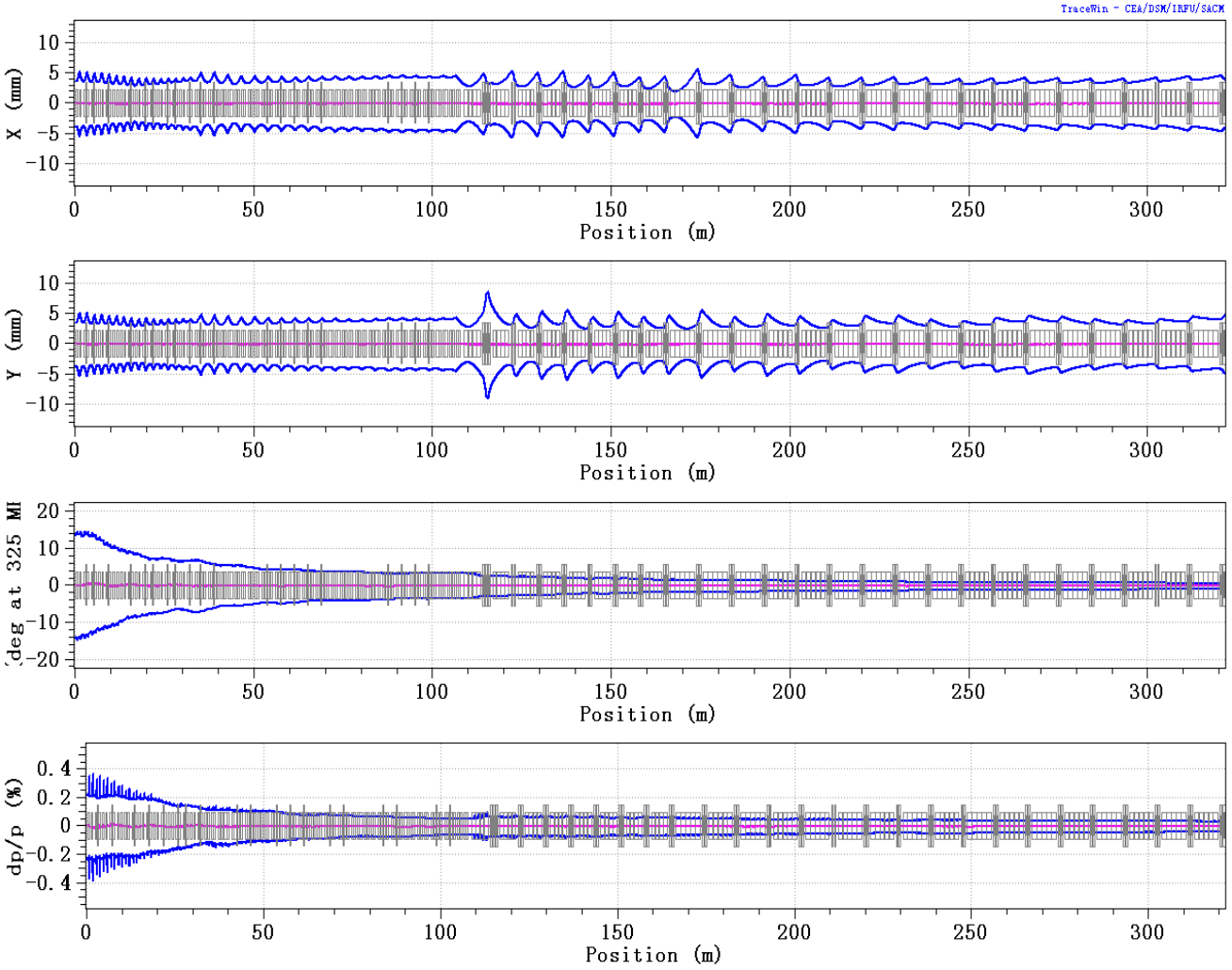


Asymmetry acceleration efficiency for each cavity type about active velocity range:

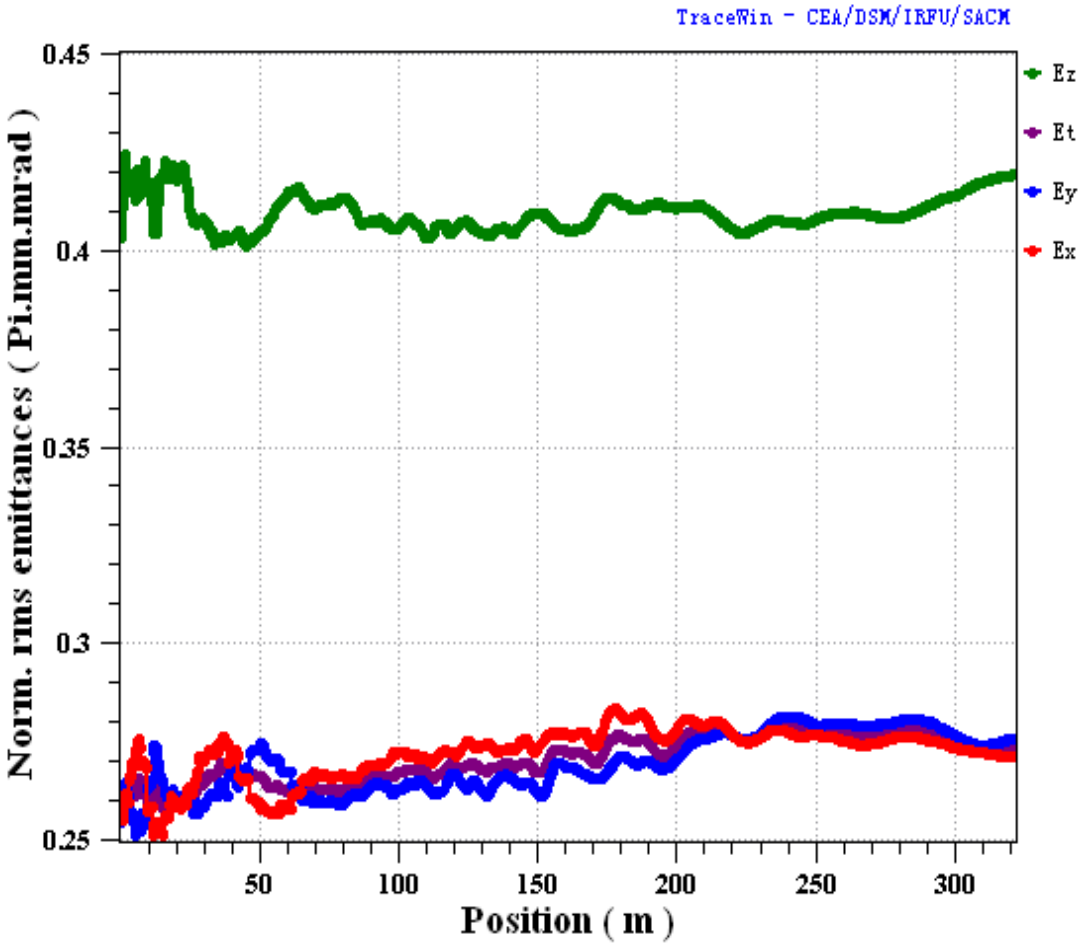
1、Efficiency for each cavity is greater than 0.5;

2、Acceleration gradient is smoothly change at the transition between different sections;

Dynamic results of the main linac



RMS emittance growth

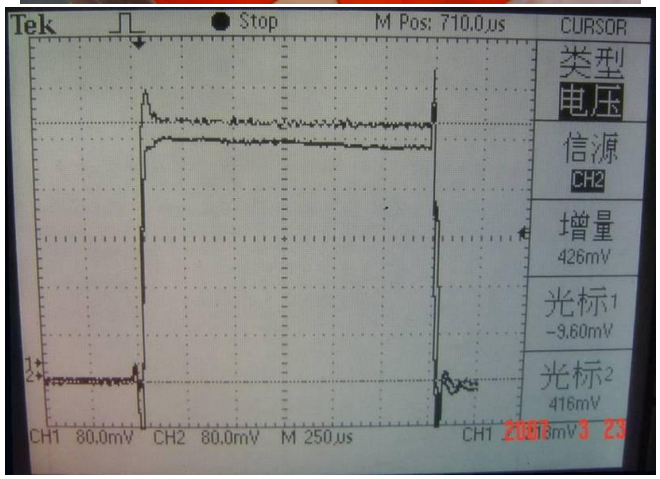


2, Key Technology in the ADS Linac

1. *Accelerator Physics -- low beam loss*
2. *Ion Source -- Reliability*
3. *CW RFQ – Heat release*
4. *SC Spoke* (β=0.12, 0.21, 0.40) and *Elliptical cavity(*β= 0.63,0.82, 5-cell*) -- welding*
5. *High power couplers – Ceramic window*
6. *Cryomodule*
7. *RF source* (CW Klystron, CW SSA, LLRF)
8. *Control & Instrumentation*
9. *…*

3, R&D Activities - RFQ accelerator

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



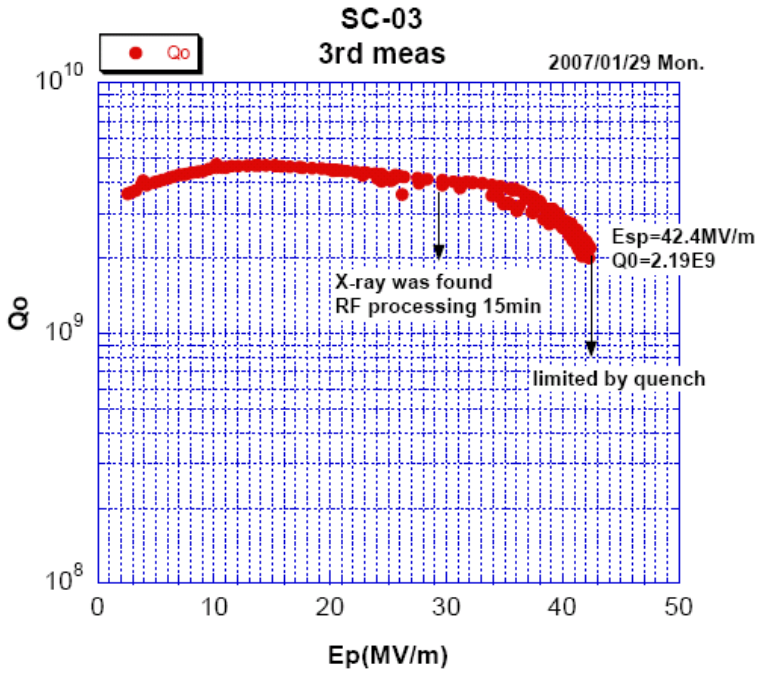
46mA output beam at 7% duty factor, transmission rate>93%, now up to 15% duty factor and then to CW.

4, R&D Activities - 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 .

The whole set of SCC waiting for measurement

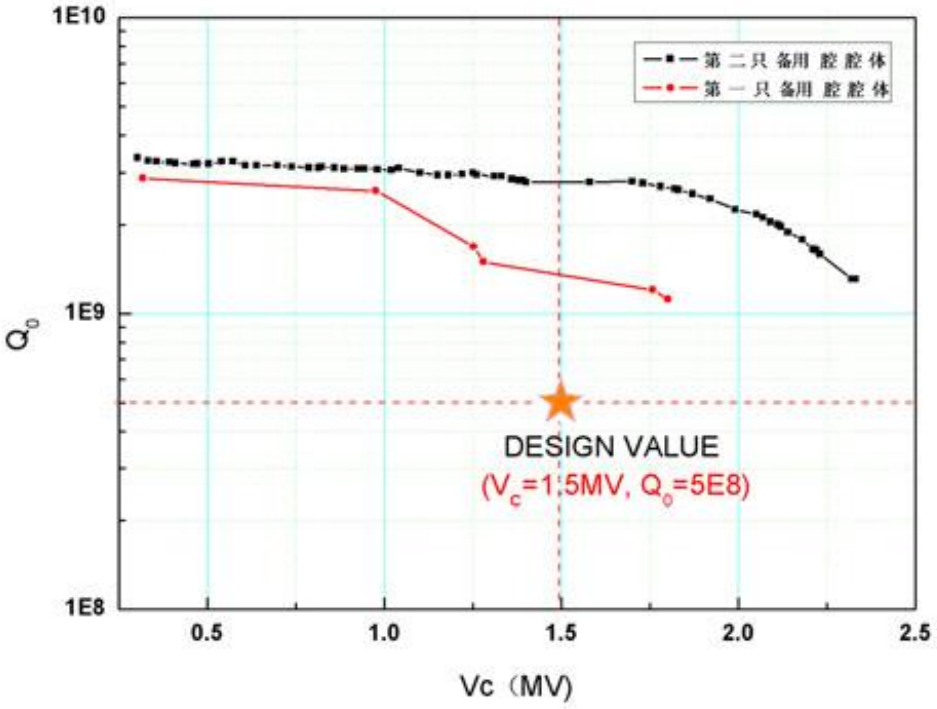
1.3GHz、β=0.45 single cell



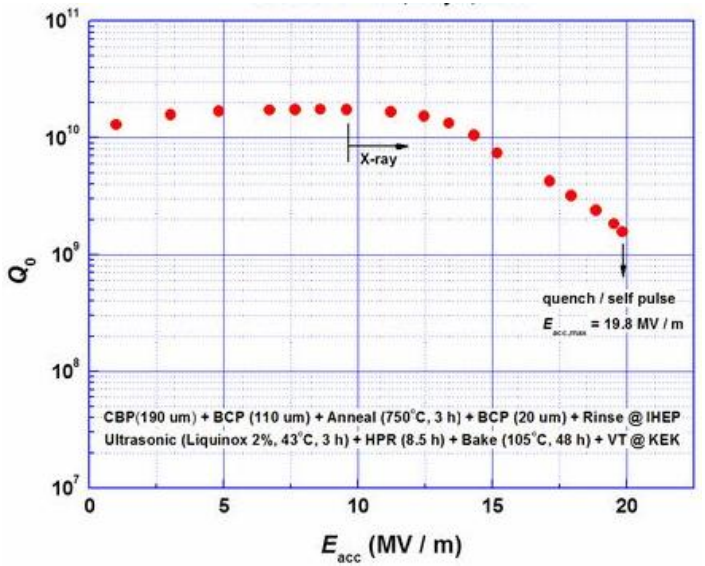
Measured data of 1.3GHz cell

Surface field *Ep* = 42.4 MV / m（*Eacc*= 10 MV / m）

In recent the second BEPC-II backup cavity of 500MHz(KEKB type) reached 2.3MV cavity voltage, with Q0=1.2E+9，better than the design specification---1.5MV and Q0=5E+8.



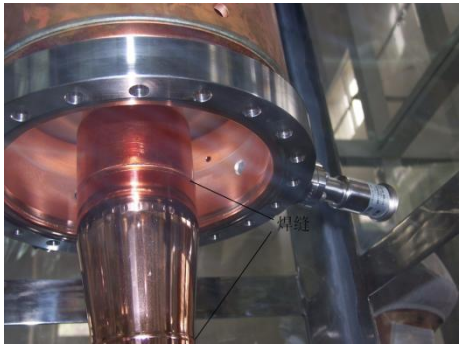
4, R&D Activities- SC cavity study



IHEP-01 Low-Loss Large Grain 9-cell Cavity Vertical Test (ILC)


Cryostat for EXFEL- PXFEL1

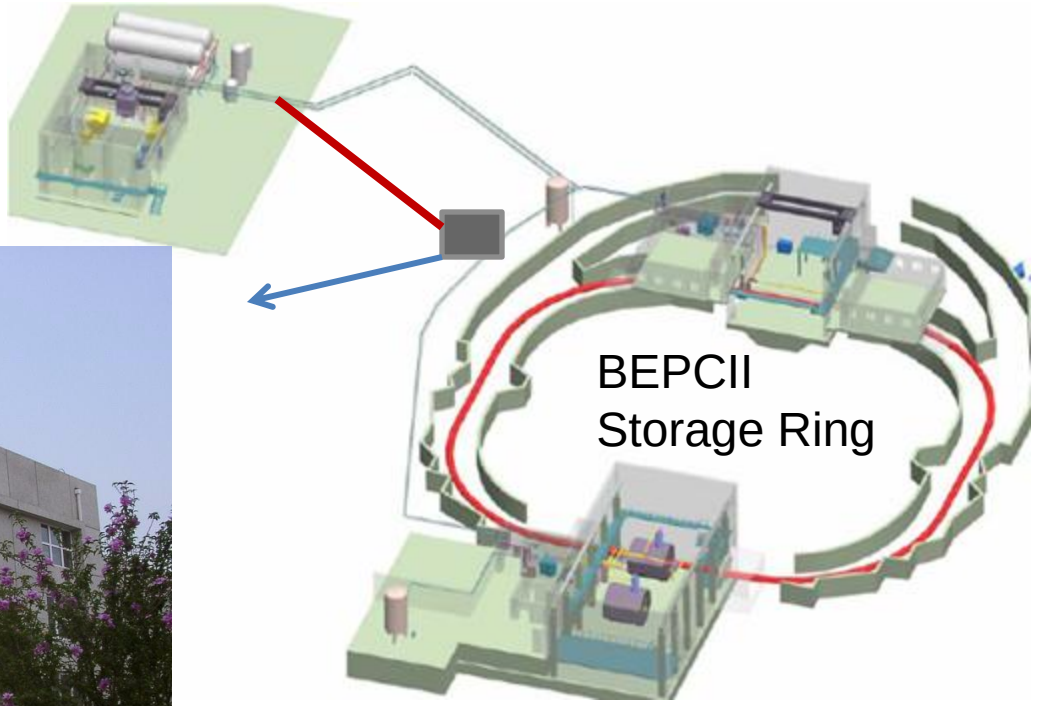
4, R&D Activities- High power coupler



≥400kW

4, R&D Activities- SC lab for vertical test

Cryogenic Plant

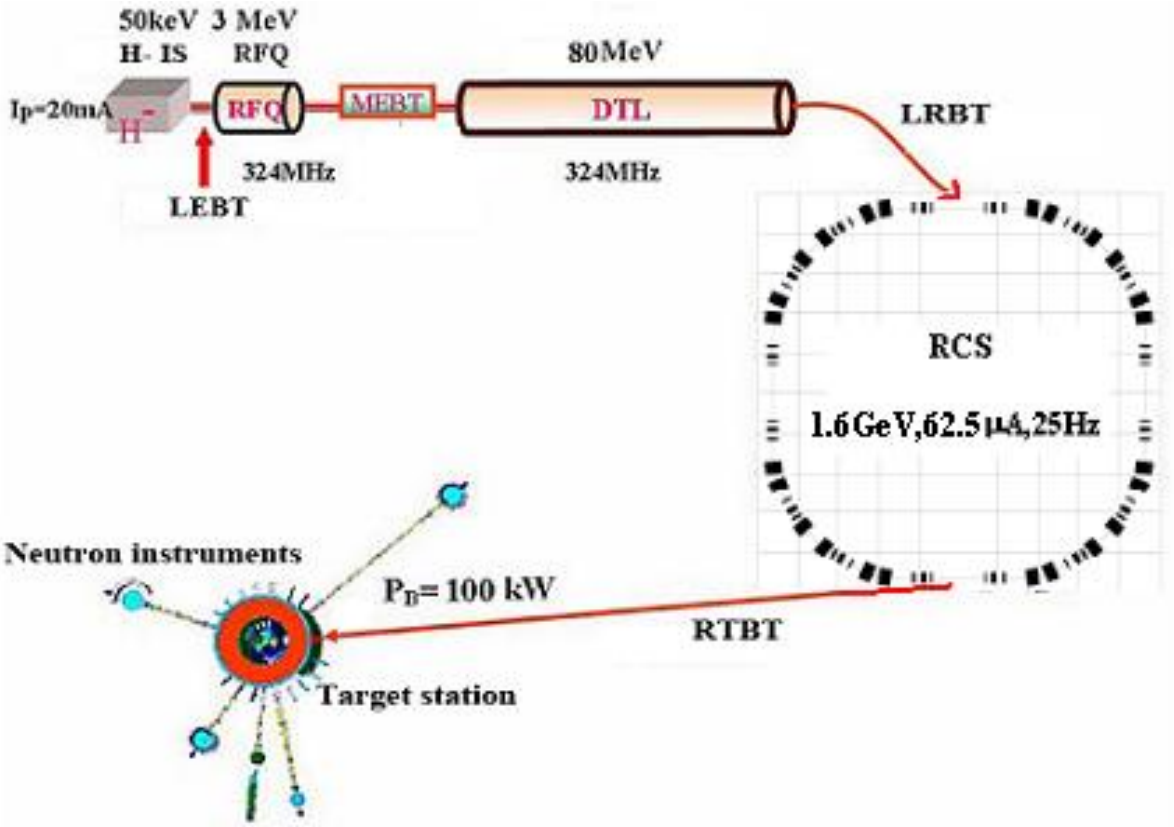


SC lab of 250m^2

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

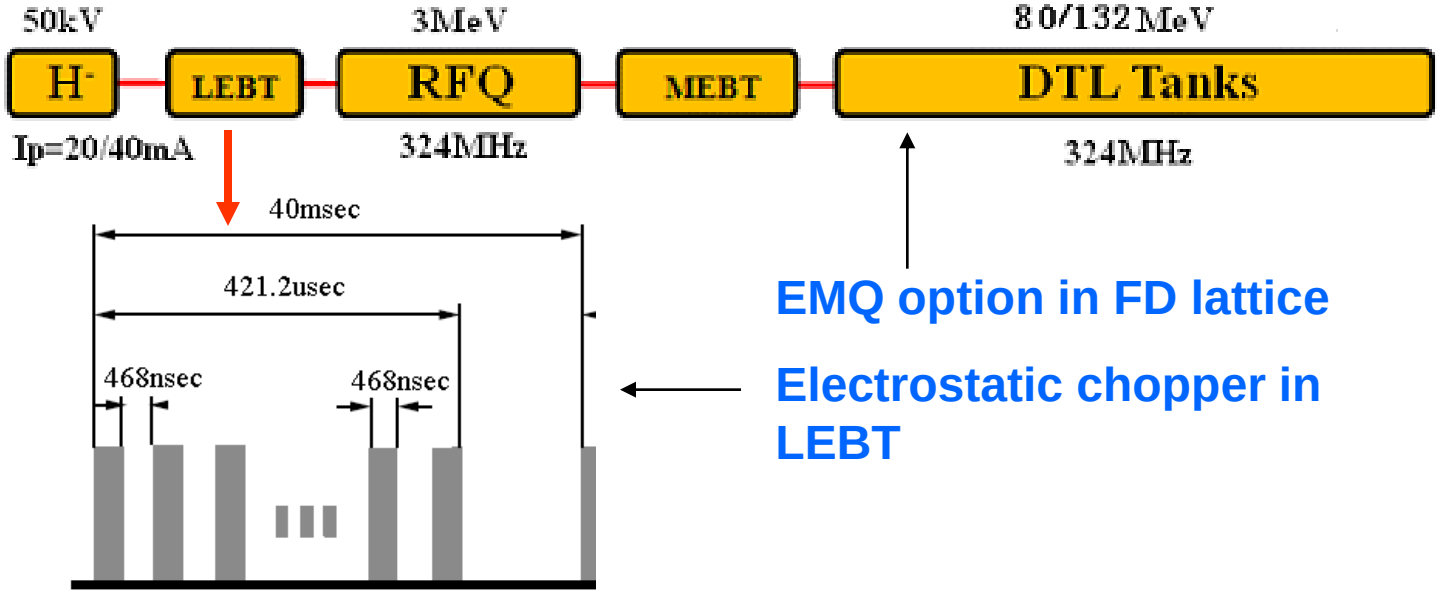
CSNS Accelerator

1, CSNS Overview



	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

2, Linac Design



	Ion Source	RFQ	DTL
Input Energy（MeV)		0.05	3.0
Output Energy(MeV)	0.05	3.0	80/132
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

3, Linac Upgrade Options-superconducting linac

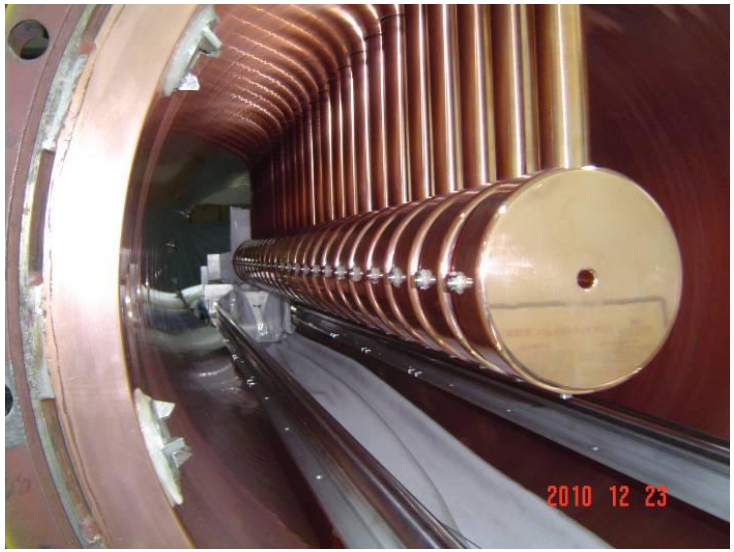
Elliptical Cavity from 130-250MeV

Energy Range (MeV)	130-250
RF frequency (MHz)	972
Geometry βg	0.52
Particle β range	0.48-0.61
E_{acc} (MV/m)	13.02
Energy gain (MeV/m)	1.92
E_{pk}/E_{acc}	3.72
B_{pk}/E_{acc}(mT/(MV/m))	6.7
Cell No/ Cavity	6
Cell No/ Cryo	6
Cell No.	240
Length (m)	62

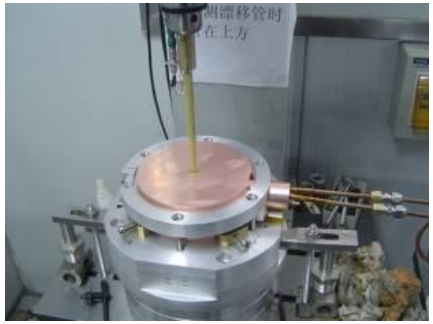
Spoke Cavity from 80-250MeV

Energy Range (MeV)	80-250
RF frequency (MHz)	324
Geometry βg	0.5
Particle β range	0.39-0.61
E_{acc} (MV/m)	5.6
Energy gain (MeV/m)	3.1
E_{pk}/E_{acc}	4.46
B_{pk}/E_{acc}(mT/(MV/m))	7.1
Cell No./ Cavity	3
Cell No/ Cryo	9
Cell No.	108
Length (m)	56

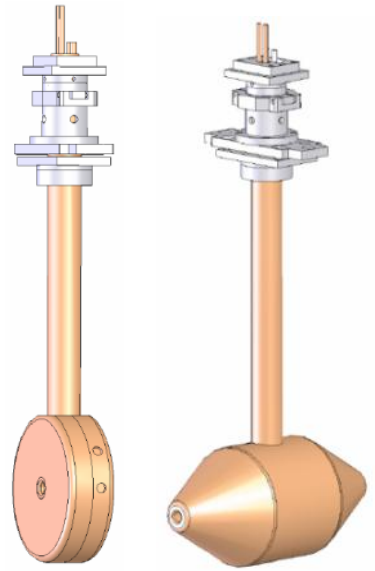
4, Linac R&D: DTL

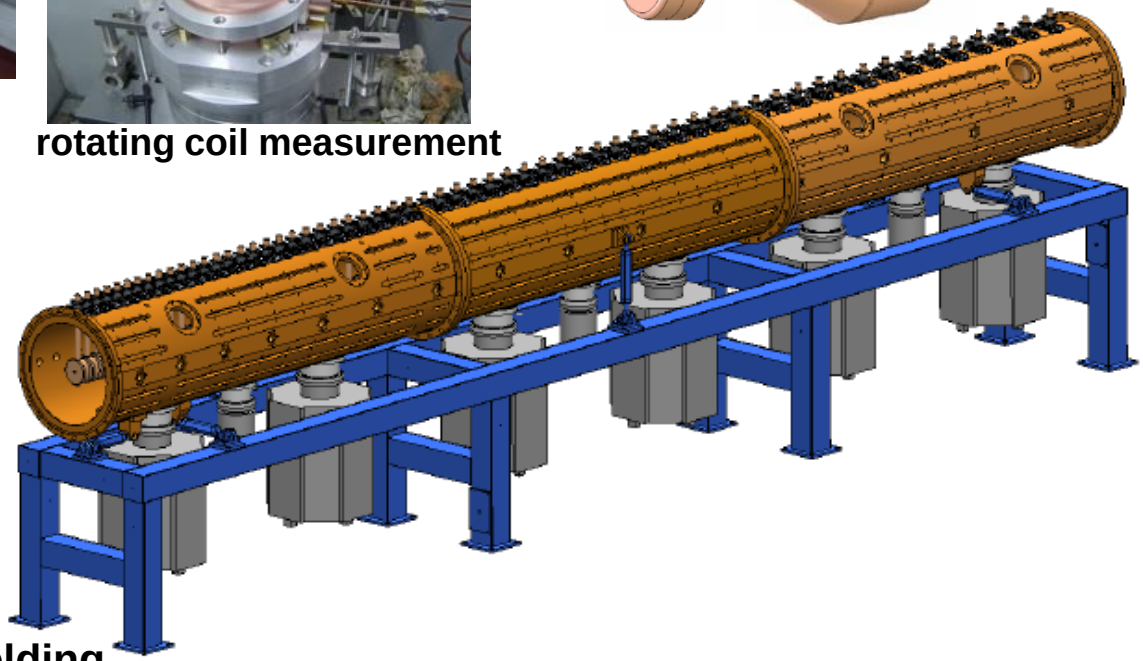


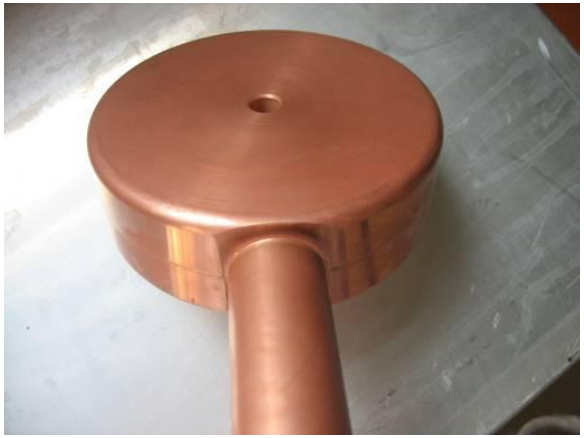
The first module of the first tank has been fabricated as a prototype.



rotating coil measurement



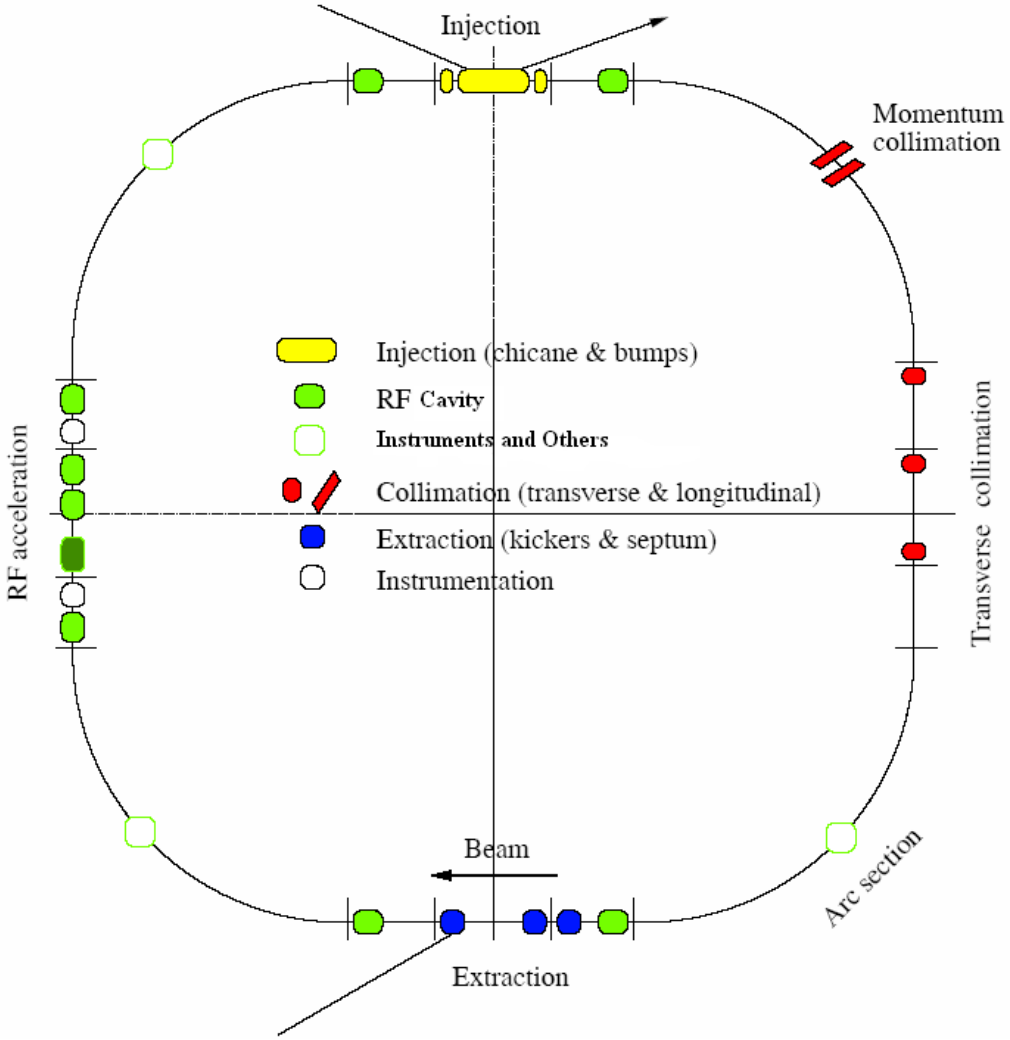




Bulk copper drift tube by electron welding.

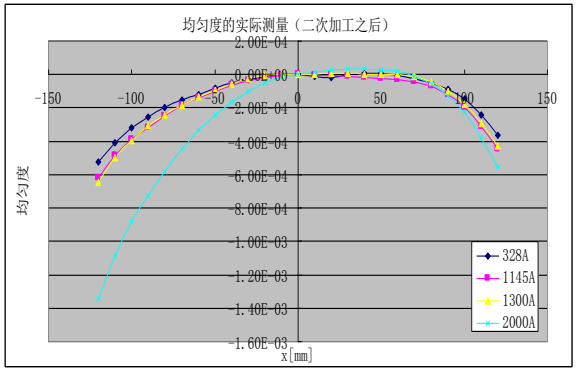
5, RCS Design

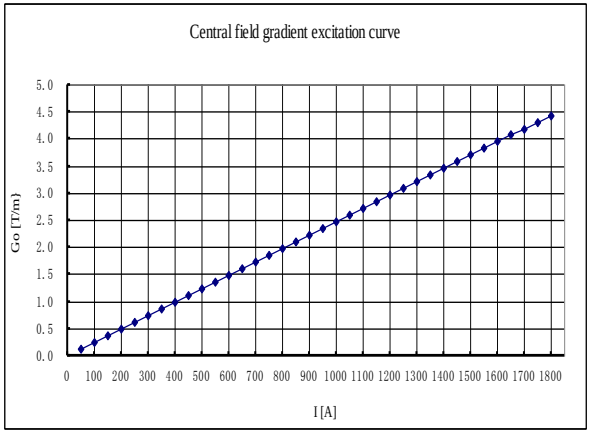
- Lattice of 4-fold symmetry, triplet
- 227.92m circumference
- 1.6GeV at 25Hz
- 80MeV injection energy for phase I
- four long straight sections for injection, acceleration, collimation and extraction
- Upgradeable with increased injection energy (beam current)



6, RCS R&D

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





6, RCS R&D

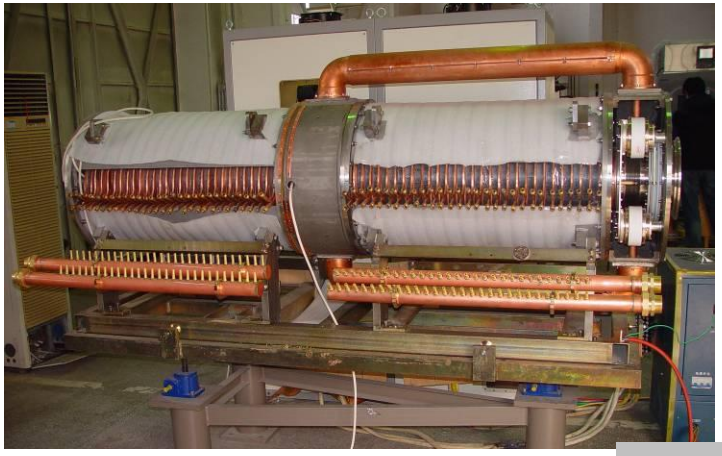
- **Power supply for dipole magnet**

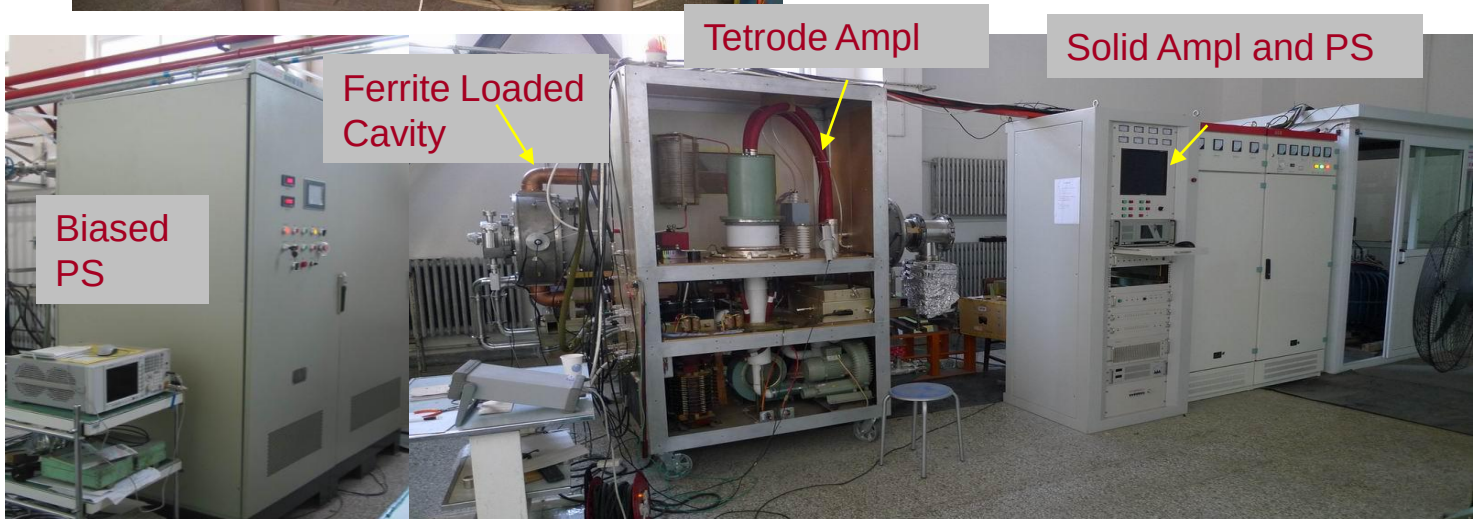
White resonant circuit was chosen as the power supply for the magnets with a large conductivity. It is composed of DC (1260A)+ AC(900A) sources, choke, and capacitor bank.

One of the key technology is high tracking accuracy.

6, RCS R&D

- **A prototype of the ferrite loaded RF cavity: 1 – 2.5 MHz, RF power source of 500kW at 50% duty factor.**





6, RCS R&D

Ceramic chamber has to be used in the 25Hz AC magnets to avoid heat from addy current. Inside surface with TiN; outside surface with RF cage.

Section prototype have been fabricated

Two whole size prototypes for dipole magnet are under fabrication in two vendors in China

6, RCS R&D

- Injection and extraction magnets and their power supply are prototyped




SUMMARY

1, High intensity proton accelerator has two applications in China: CSNS and ADS.

2, ADS long-term road map has been plotted, and its first phase has been funded and started in 2011.

3, CSNS will start construction in 2011 and will be completed in 6.5 years.

4, High-current proton accelerators will be intensively studied for CSNS and ADS in China.

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Thank you very much for your attention