CHINA SPALLATION NEUTRON SOURCE

STATUS OF A HIGH CURRENT LINEAR ACCELERATOR AT CSNS

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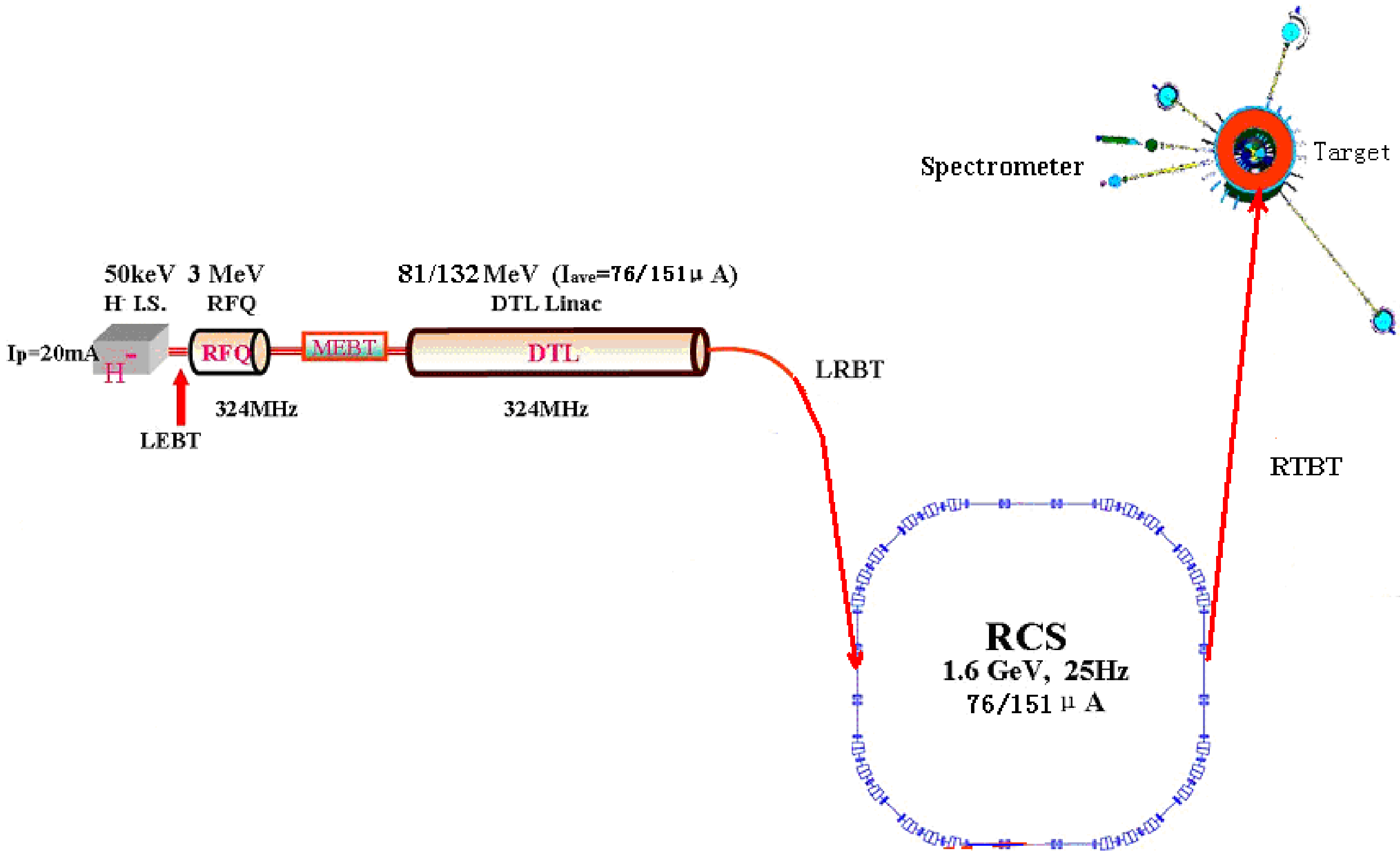
Outline

- 1, Brief introduction to CSNS
- 2, Design of CSNS Linac
- 3, R&D for key technology
- 4, Conclusions

1, Brief introduction to CSNS

Schematic view of CSNS

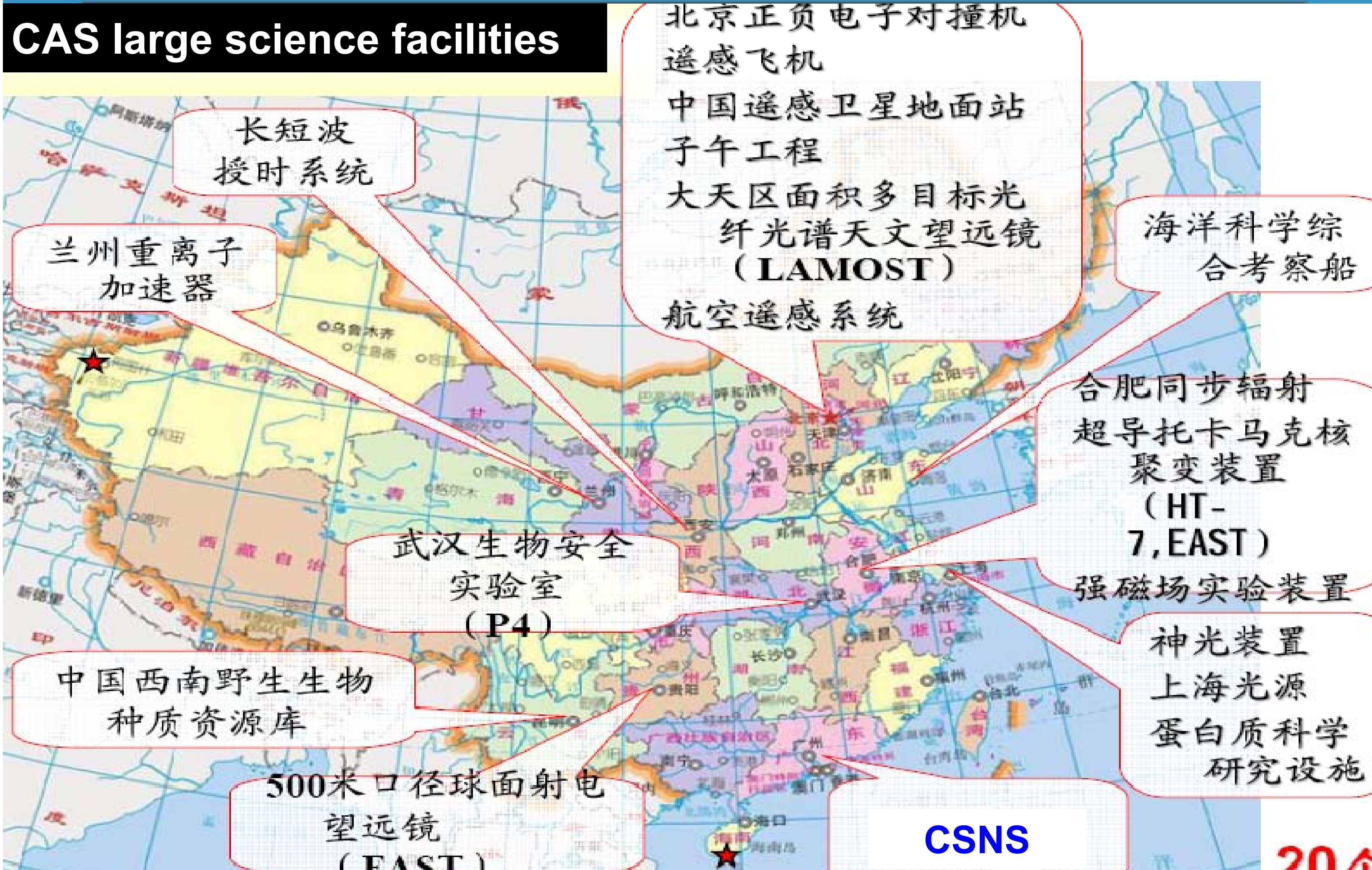
- 100kW fits in China's present economical situation, but upgradable to world class (200-500kW).



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	132	230
Linac type	DTL	DTL	DTL+SCL
Target number	1	1	2
Target material	Tungsten		
Moderators	H_2O (300K), CH_4(100K), H_2(20K)		
Number of spectrometers	3	18	>18

CAS large science facilities



Milestones

- 2005. 6: “Political approval” (CD0)
  - central government approval & fund allocation
- 2006.1 -: CAS funded R&D 1 (35 M CNY)
- 2007.7 -: Guangdong funded R&D 2 (40 M CNY)
- 2007.12 -: “Project establishment review”
  - Budget baseline: 1.4 B CNY + 0.5 B CNY (Guangdong) + land
- 2008.6: Environmental impact assessment completed
- 2008.9. Establishment approval(financial approval). (CD1)
- 2009: ground breaking expected
  - Need to pass feasibility review and preliminary design reviews

2, Design of CSNS Linac

Ion source

❖ Main parameters of CSNS ion source (phase I)

➢ Ion	H^-
➢ Energy (keV)	45-50 (40-50) (the input energy of RFQ is 50keV)
➢ Current (mA)	20 (75% transmission required for Linac)
➢ Emittance (π mm-mrad, norm, rms)	<0.20 (decided by input emittance of RFQ)
➢ Repetition Rate (Hz)	25
➢ Beam Width (us)	443.475 + 100 (space charge neutralization time)
➢ Lifetime (month)	>1

Ion source

❖ Type of the chosen H- ion source

- ISIS ion source (Penning Surface Plasma H^- Source)

❖ Reasons of the choice

- Completely satisfy CSNS (phase I) requirements
- Comparatively cheaper (comparing to RF cusped volume H^- ion source(SNS); hot cathode cusped volume H^- ion source (JPARC) etc.)
- Good collaboration with and kind helps from RAL

✓ provided us with the ion source mechanical drawings

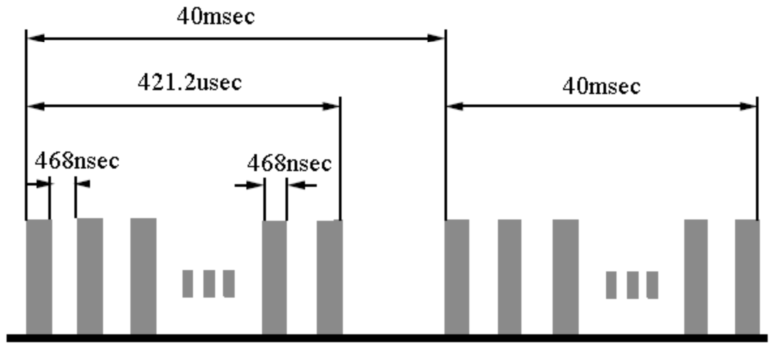
✓ helped us on the experiments of several sets of discharge chambers

✓ Gave us many technical instructions on H- ion source

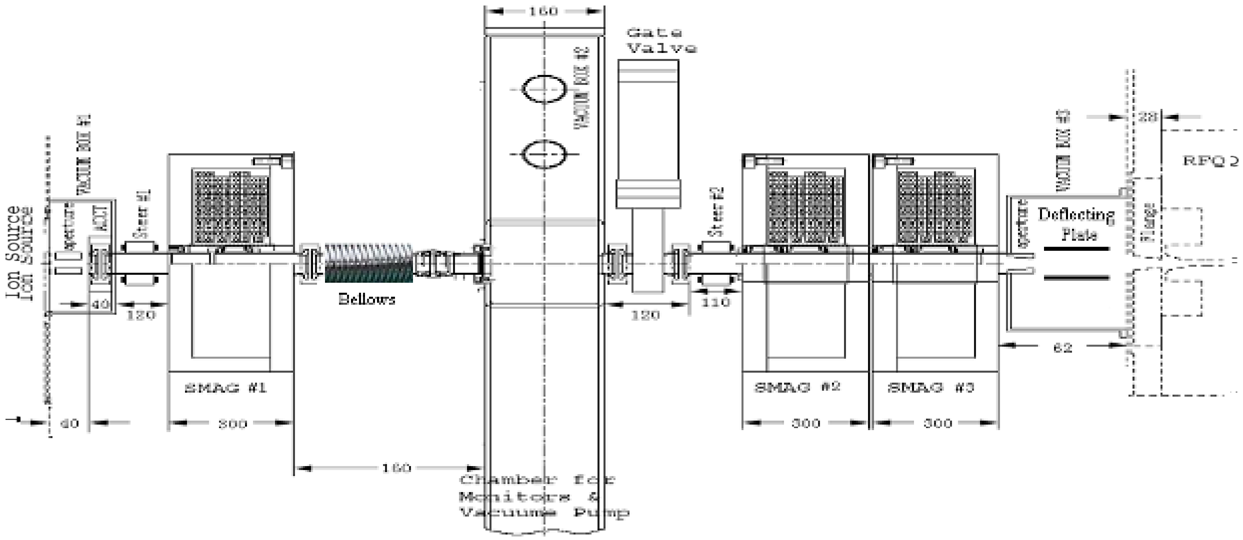
✓ ....

LEBT

- Pulse structure for low beam loss in the ring.

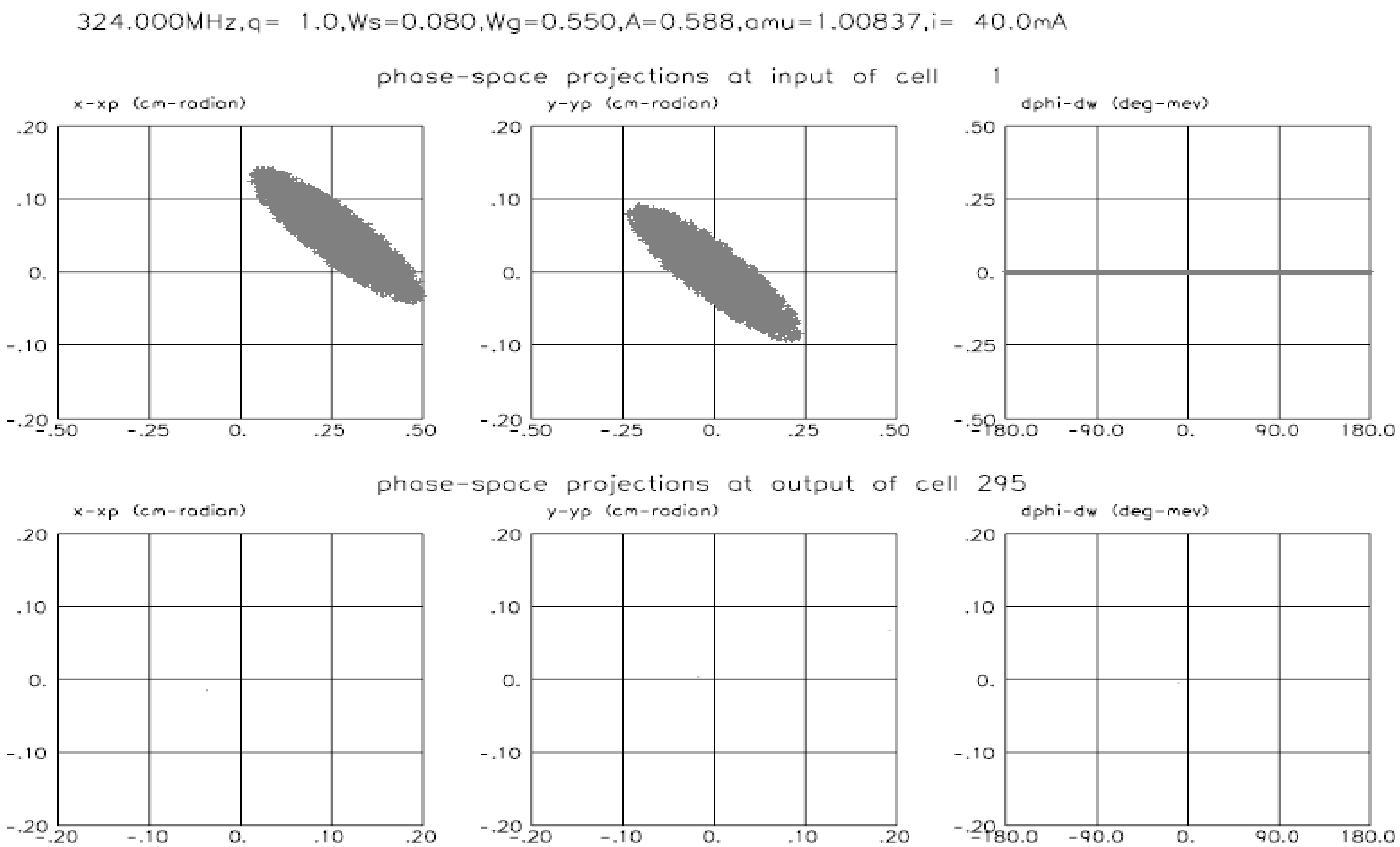


- Induction cavity replaced with electrostatic deflector



LEBT

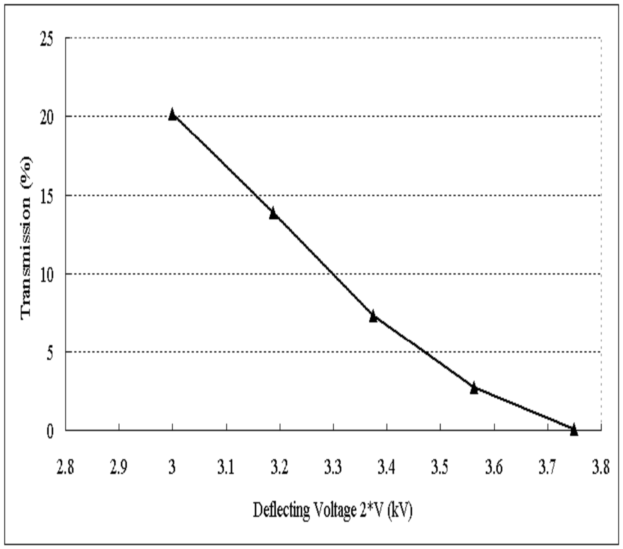
- Injection condition: x_c=2.65mm x_c'=50mrad



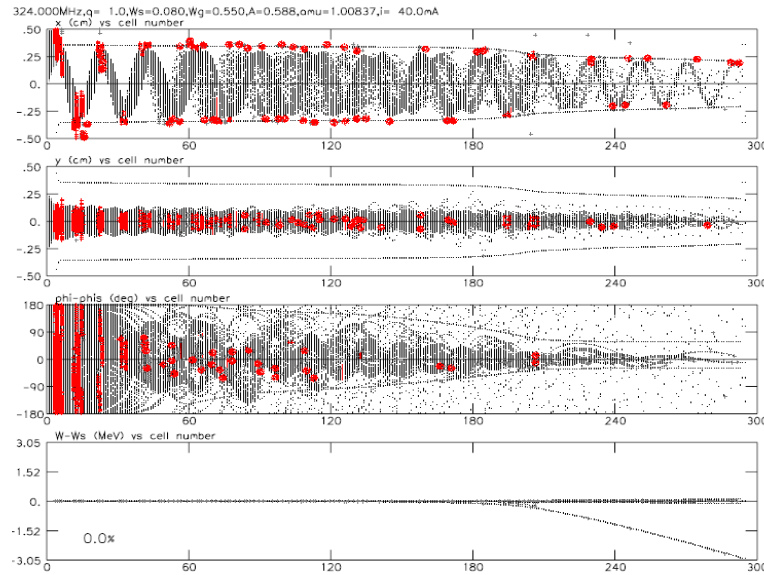
The initial and final particle distributions in phase space

LEBT

➢The needed deflecting voltage 2V: 3.75kV



The beam transmission versus the deflecting voltage

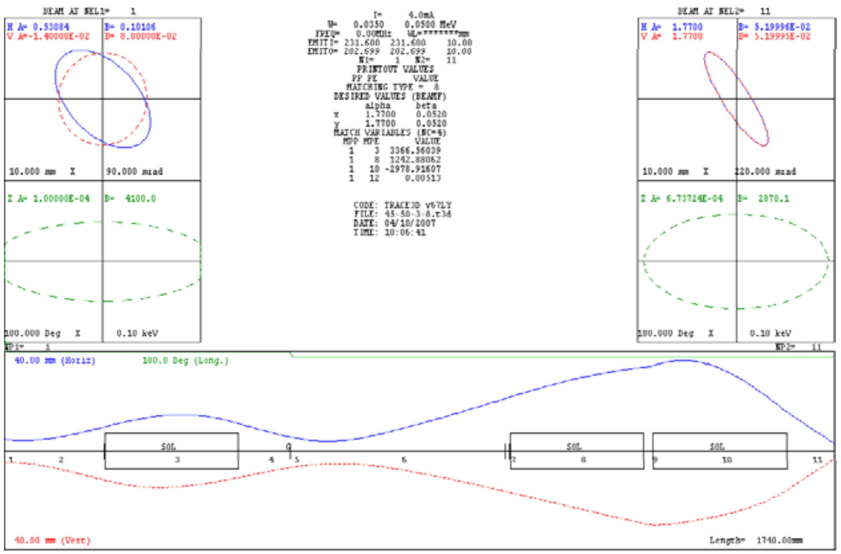


The beam transmission is 0 at 2*V is 3.75kV

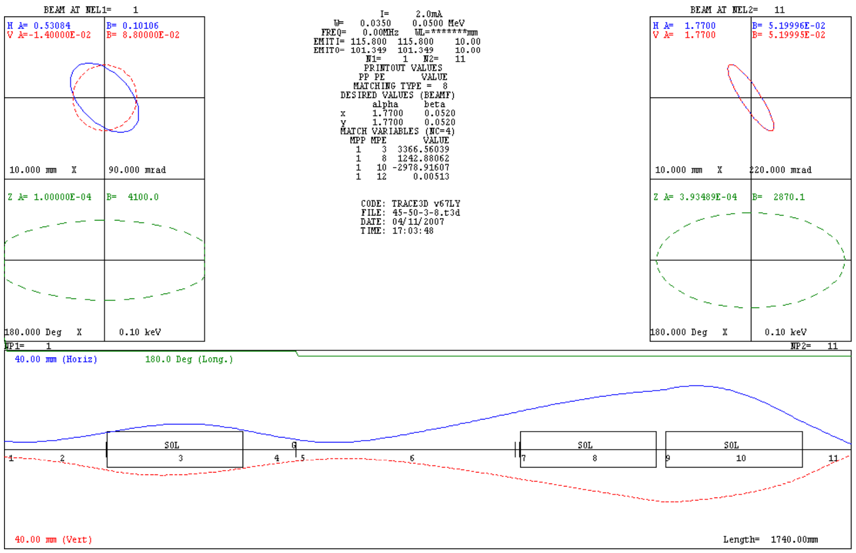
- **➢The peak beam power deposited in RFQ cavity: 2.495kW**
- **➢The average beam power deposited in RFQ cavity is about 25W**

LEBT

Design for I=40mA



Design for I=20mA

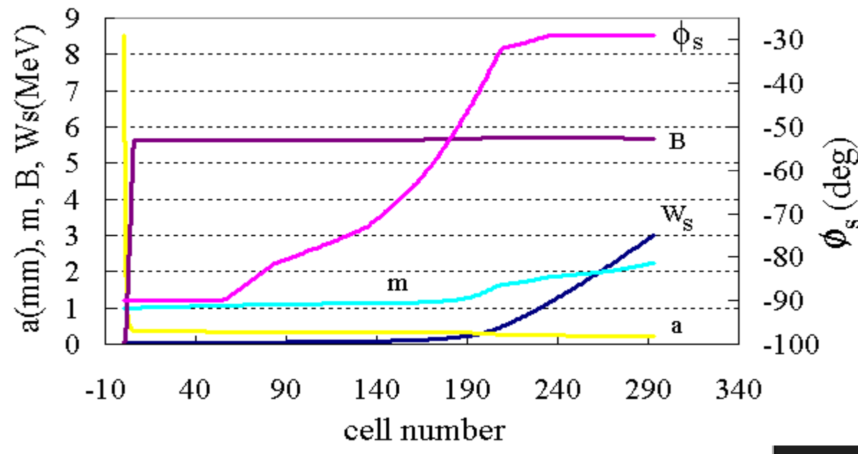


- **The initial beam Twiss parameters from ISIS ion source**
- **90% space charge neutralization, emittance: 0.4 π mm.mrad (40mA) 0.2 π mm.mrad (20mA)**

RFQ

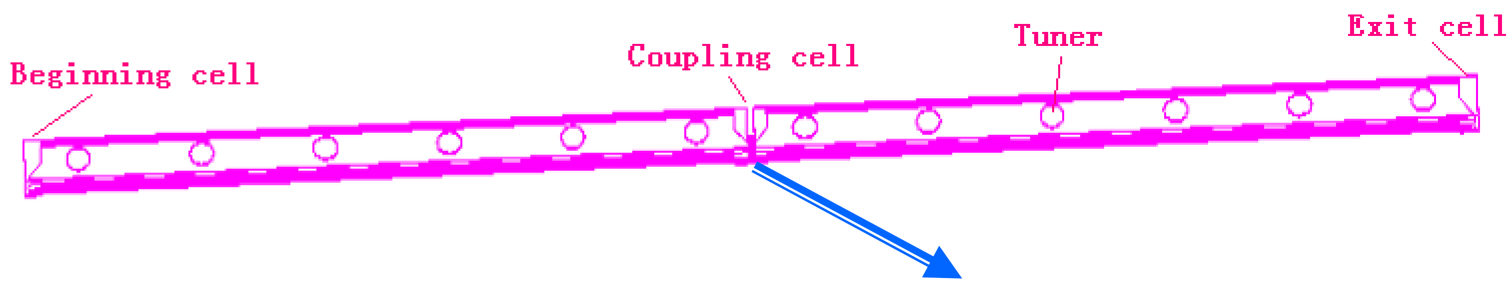
- Four vane type with two resonantly coupled cavities, following the experience gained in ADS RFQ.

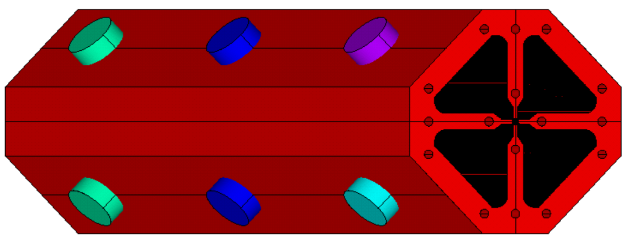
Frequency(MHz)	324
Injection Energy (keV)	50
Output Energy (MeV)	3.0
Pulsed beam current (mA)	40
Beam duty factor	1.05%
Vane length (m)	3.603
Norm. rms emittance (πmm.mrad)	0.2
Maximum surface field (MV/m)	31.68(1.78Kilp)
Power dissipation (kW)	410

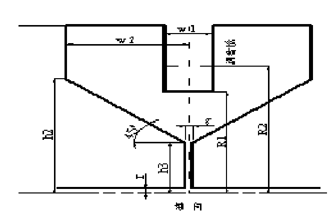


RFQ

- **Beam dynamics and structure design without dipole stabilized rod**



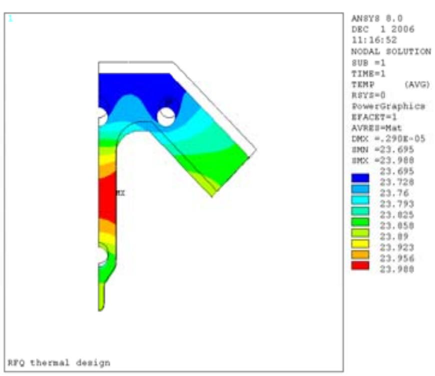


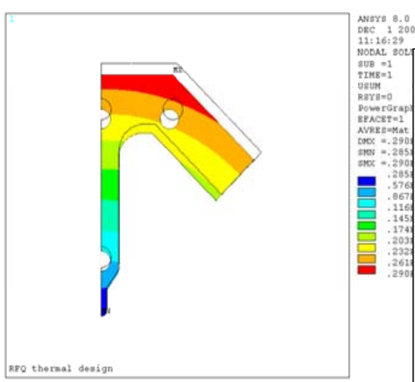


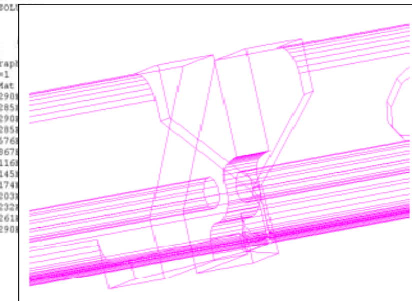
The two-dimensional schematic of the coupling cell

The geometric parameter value of the coupling cell

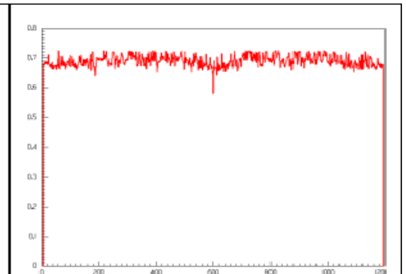
Parameters	Value
h1	104.238 mm
h2	65.50 mm
h3	25.09 mm
w1	18.00 mm
w2	40.5 mm
r	3.173 mm
R1	41.6 mm
R2	48.60 mm
g	1.8 mm







The 3-dimensional figure of the coupling cell

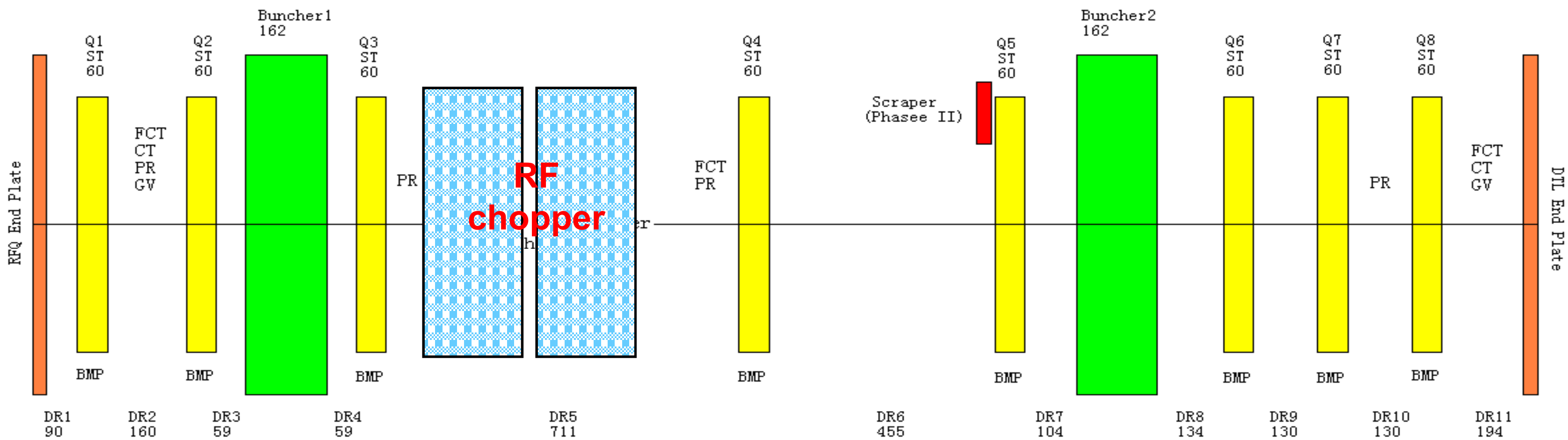


The distribution of the amplitude of E along the longitudinal direction at x,y=3.565 mm

The coupling cell

MEBT

- Total length =3030 mm
- 8 Q magnets combined with ST magnets
- 2 bunchers for longitudinal beam match
- 2 RF deflectors as a chopper will be added **in phase-II**
- Two tasks of matching and chopping lead to emittance growth and halo formation.

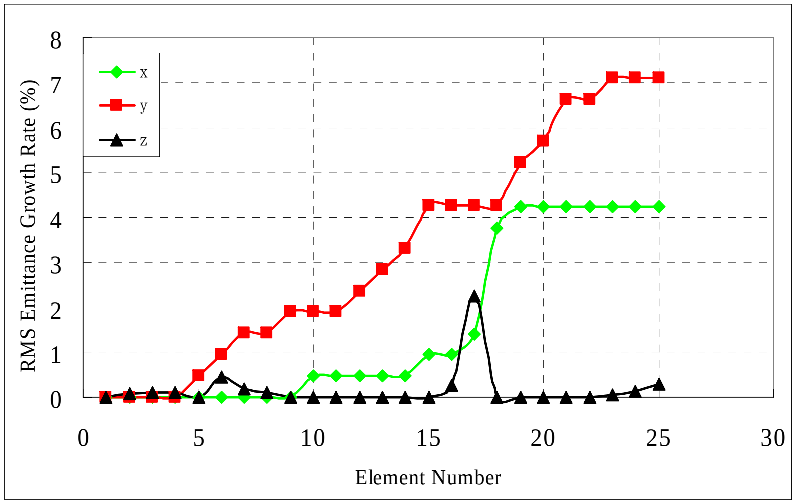


BPM=beam position monitor
PR=profile monitor
FCT=fast current monitor
CT=current monitor
Q=quadrupole magnet
ST=steering magnet
GV=gate vale

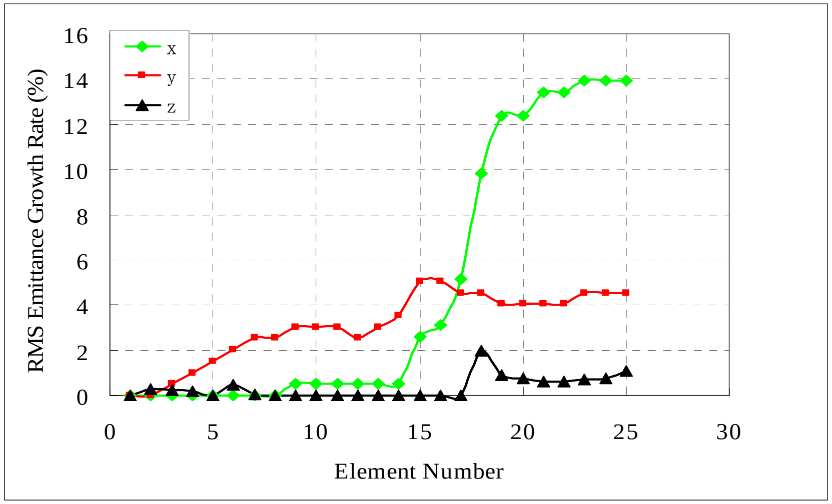
MEBT

- **A large Emittance growth in simulations**

I=20mA



I=40mA



The RMS emittance growths in the x, y, z directions are respectively about 7.1%, 4.25% and 0.3%

The RMS emittance growths in the x, y, z directions are respectively about 14%, 4. 5% and 1.1%

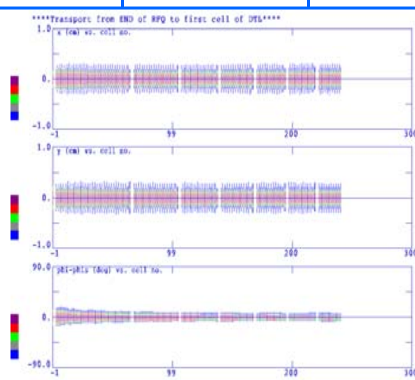
DTL

- **DTL design**

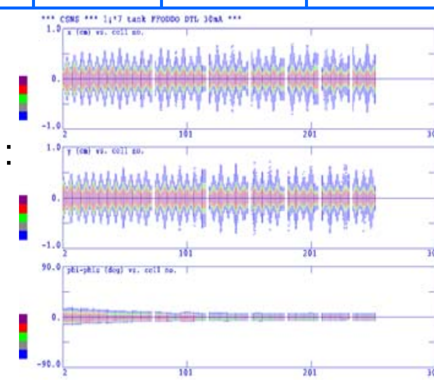
Tank number	1	2	3	4	5	6	7	total
Output energy (MeV)	21.76	41.65	61.28	80.77	98.86	115.8	132.2	132.2
Tank length (m)	7.99	8.34	8.5	8.85	8.69	8.57	8.67	59.6
Space between tanks (m)	0.2	0.27	0.32	0.36	0.39	0.42		
Number of cell	61	36	29	26	23	21	20	216
RF driving power (MW)	1.41	1.41	1.39	1.45	1.45	1.45	1.49	10.05
Total RF power (MW)	1.97	2.01	1.98	2.03	1.99	1.96	1.98	13.92
Accelerating field (MV/m)	2.06 to 3.1	3.1	3.1	3.1	3.1	3.1	3.1	
Synchronous phase	-30 to -25	-25	-25	-25	-25	-25	-25	

FD lattice with EMQ

chosen for strong focusing with small emitt. growth



FFODDO with PMQ :



3, R&D for key technology

Ion Source

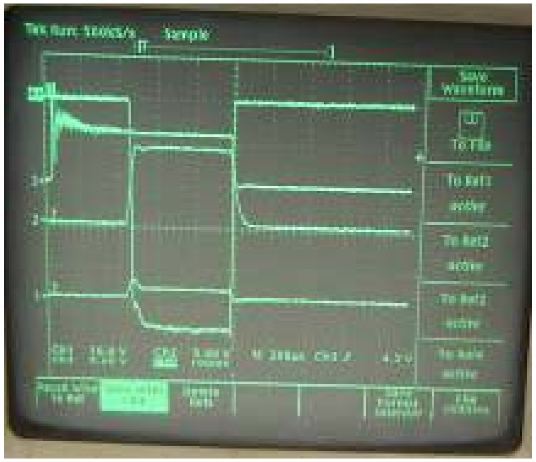
- **Collaboration with ISIS**

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

→ Dan Faircloth with Dr He Wei of IHEP

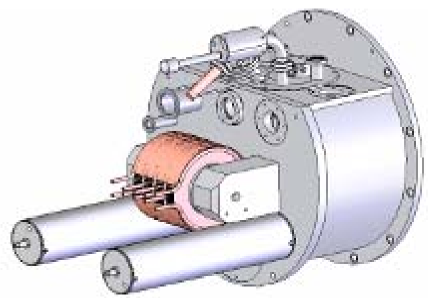
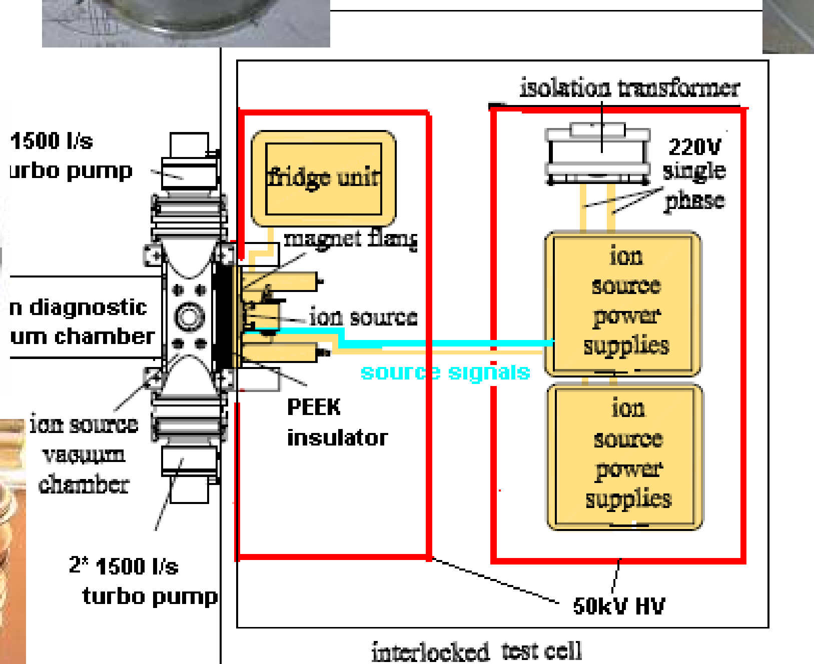


CSNS ion source body tested at ISIS with a beam current of 55mA 50Hz, 500us. The emittance measurement gave almost the same value as that of ISIS operating ion source.

Ion Source

- A test stand is building up at IHEP





Schematic of ion source layout.

LEBT

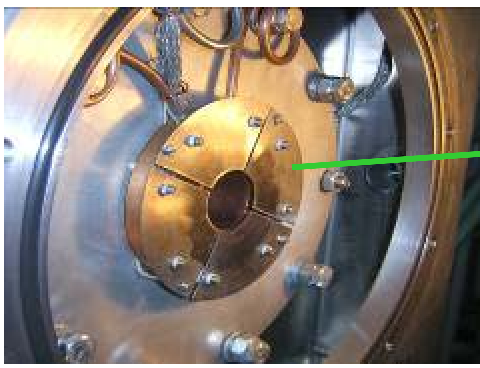
- **Electrostatic chopper is gong to test on ADS RFQ**

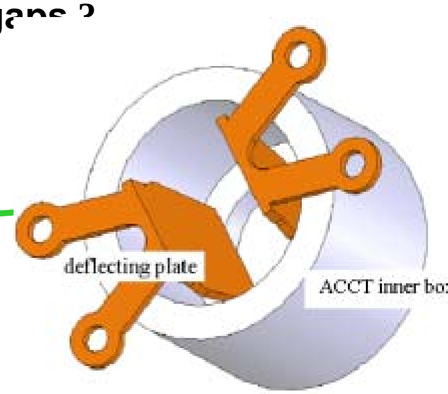
replace beam collimator with deflecting plates

Q1: the RFQ vane damaged by the dumped beam?

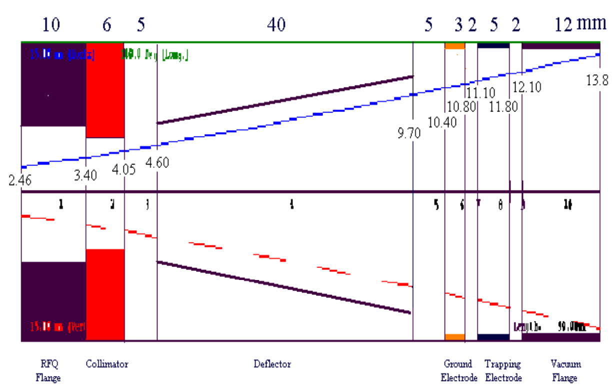
Q2: spark occurs in the electrostatic chopper?

Q3: chopping is fast enough for clear gaps ?





LEBT for ADS RFQ



Tapered deflector for higher effect (1.3 times)

RFQ

- RFQ technology has been developed in an ADS program

Four vane structure RFQ

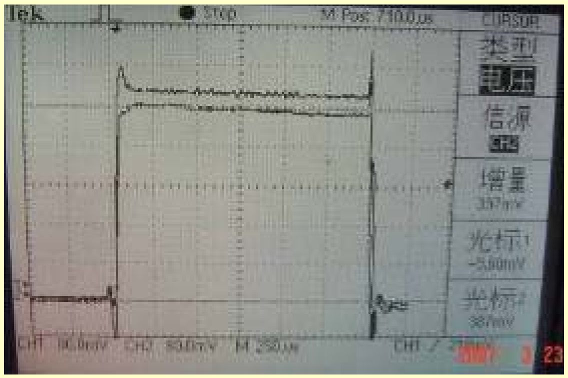
Four RF feeders

Frequency(MHz)	352.2
Injection Energy (keV)	75
Output Energy (MeV)	3.5
Pulsed beam current (mA)	50
Beam duty factor	6-100%
Vane length (m)	4.731
Norm. rms emittance (πmm.mrad)	0.2
Maximum surface field (MV/m)	33(1.8Kilp)
Power dissipation (kW)	630

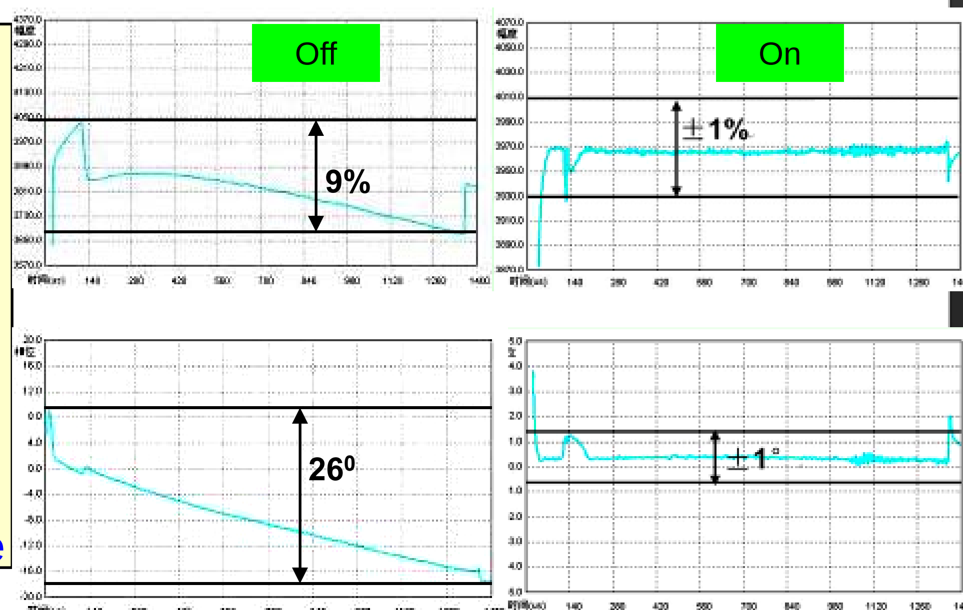
LEP-II RF power source

RFQ

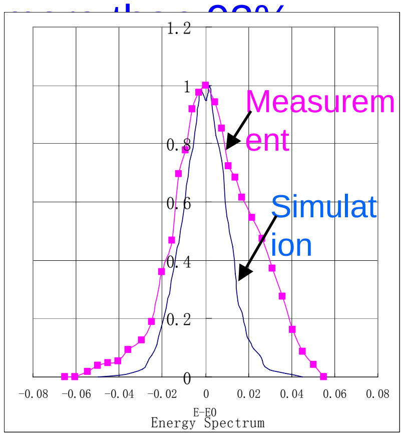
- **93% transmission rate of 46mA output beam at 7% duty**



46mA output beam at duty 7% with 1.43ms pulse length at 50Hz was obtained with a beam transmission rate



Digital feed-back and feed-forward LLRF system off and on



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

RF conditioning at duty factor to 15%. Beam duty to 15% this year.

DTL

- **A prototype DTL tank of 2.9m in length. It is the first section of the first tank. It is the most difficult section.**

Short tank for explosive bonding test. It is successful, but the port was found to be uneasy for welding.

Electroforming method was successfully adopted by the domestic vendor in the tank fabrication.

DTL


DTL tank under final machining of the drift tube holes

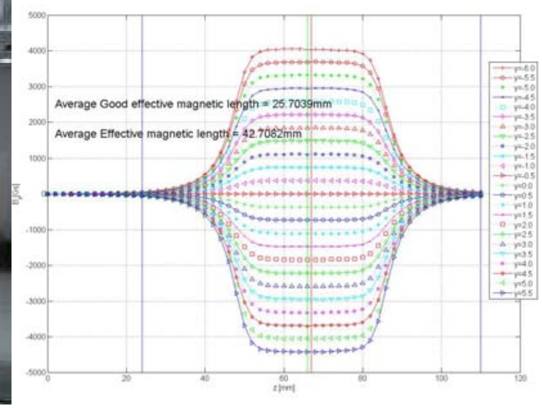


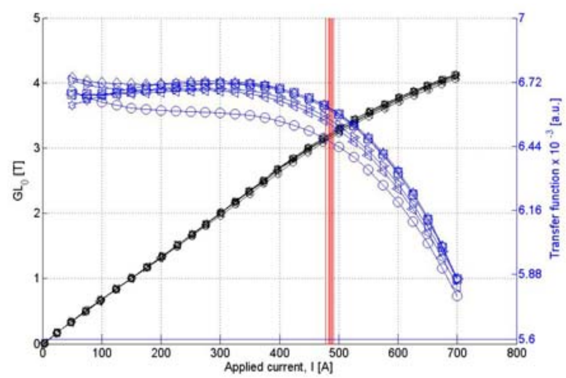
J-PARC type electromagnetic quadrupoles

Bulk copper for drift tube by EBW

DTL

- **Hall plate, single stretched wire and rotating coil**





RF Power Source

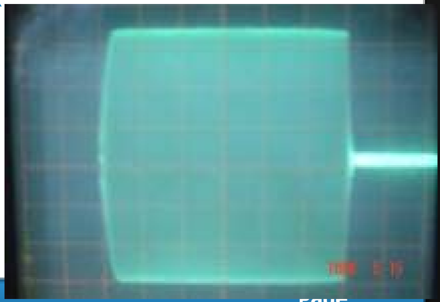
- A novel HV pulse power supply has been demonstrated

t pulse

RF Power Source

Basic parameters of prototype

AC resonance charging voltage	120 kV（peak）
AC resonance charging current	120 A（peak）
Resonance frequency	100 Hz
High voltage discharging pulse	0 ~ 1ms
Rep. rate of High voltage discharging pulse	25 Hz or 50 Hz
Resonance inductor	1.6 H, Q0≥ 350
Resonance capacitor bank	1.585 uF ± 1%
Energy storage capacitor bank	6.34 uF
Maximum temperature rise	65 K



Klystron output pulse (1ms, 420kW) driven by the prototype pulse power supply

THANKS !