CHINA SPALLATION NEUTRON SOURCE

A HIGH-DUTY FACTOR RADIO-FREQUENCY QUADRUPOLE ACCELERATOR FOR ADS STUDY IN CHINA

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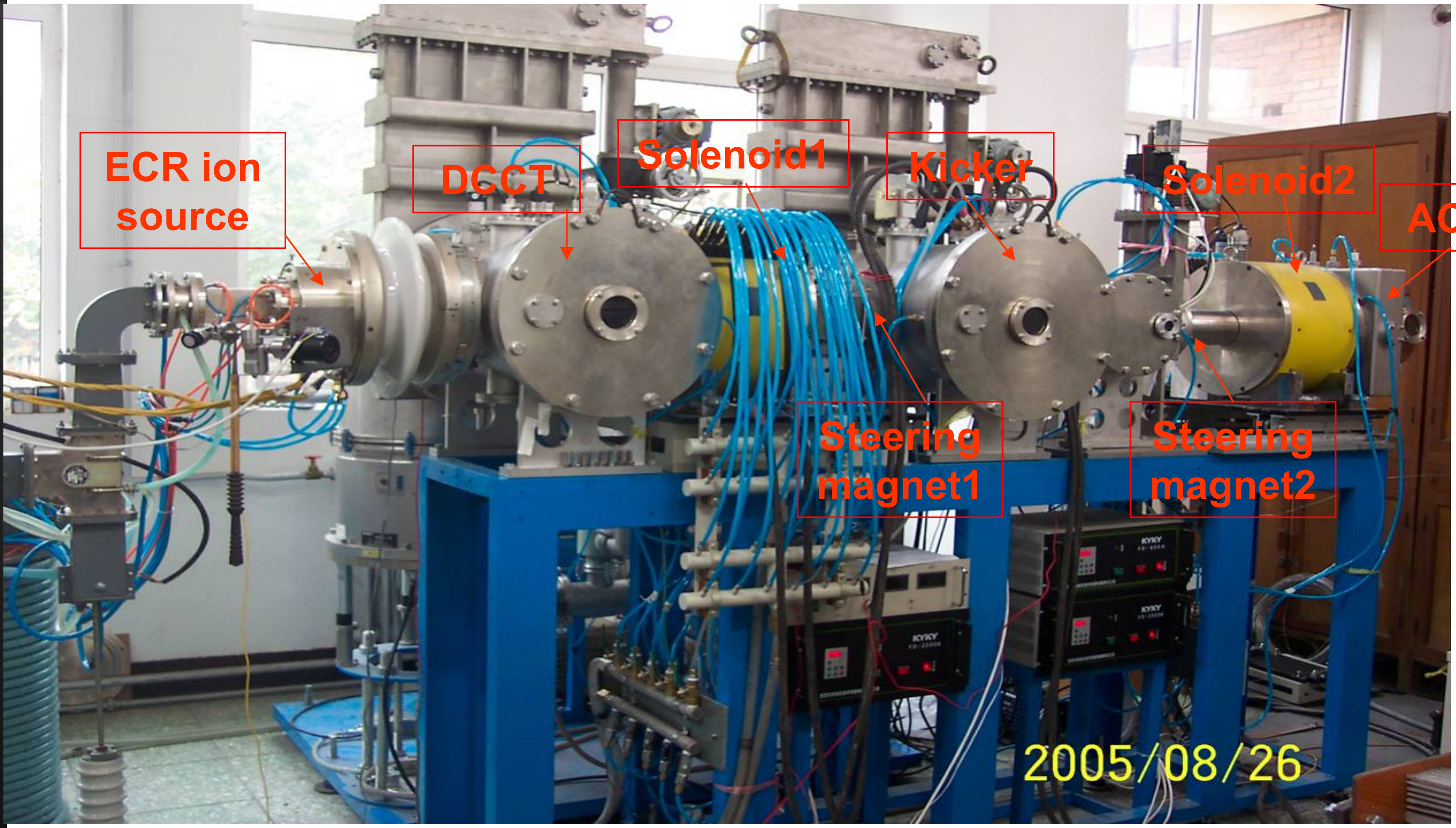
Introduction-layout of the RFQ accelerator

Layout of the RFQ accelerator

Introduction-ECR ion source and LEBT



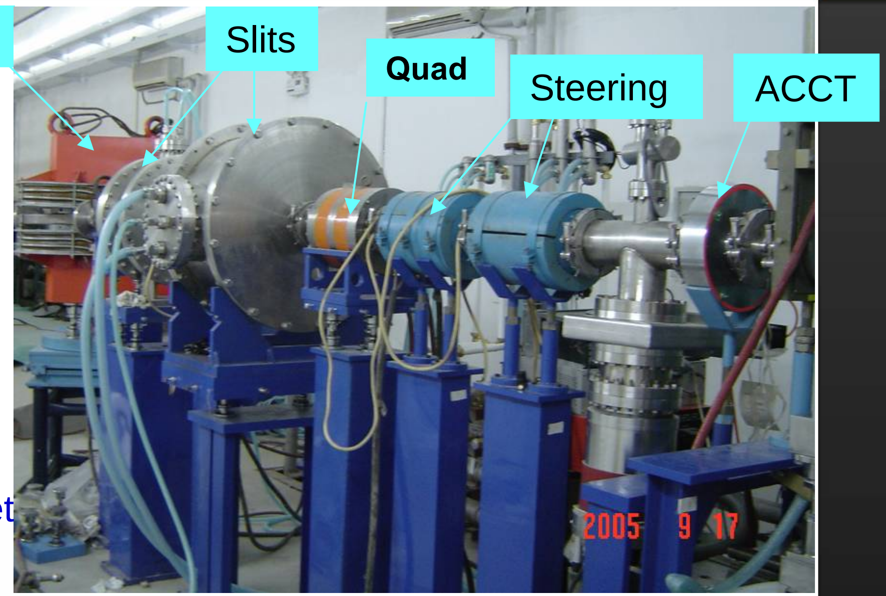
ECR ion source and LEBT (about 2.6m long)

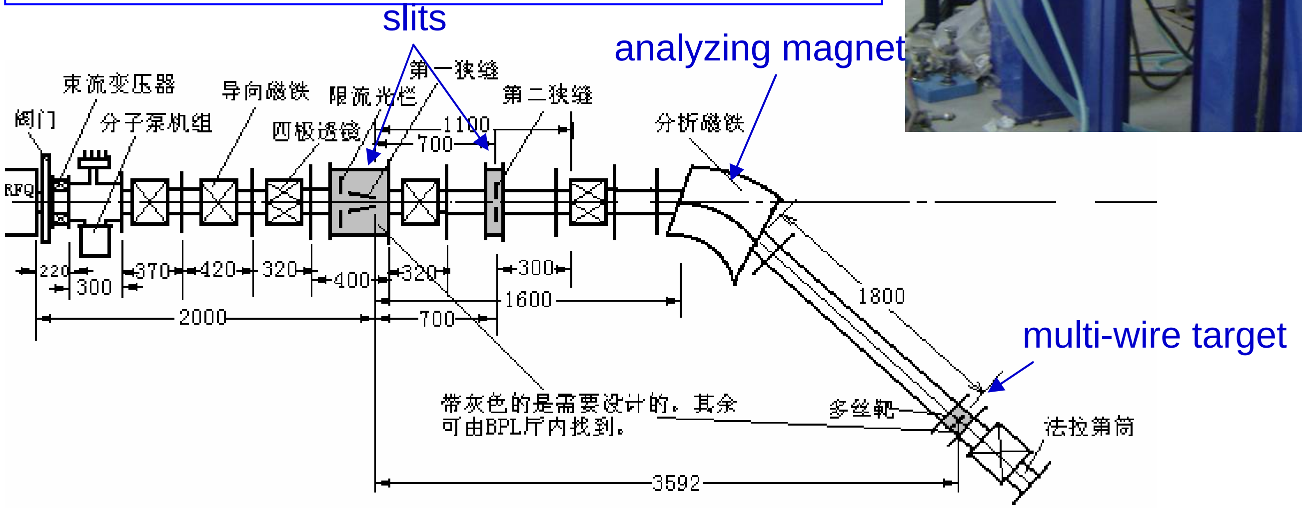
Introduction-RFQ

RFQ in installing process

Introduction-HEBT

Two slits , an analyzing magnet and a multi-wire target, are used to carry out beam energy spectrum measurement. Two slits align the beam and define the beam trace in the magnet . The first slits also acts as the beam dumper.





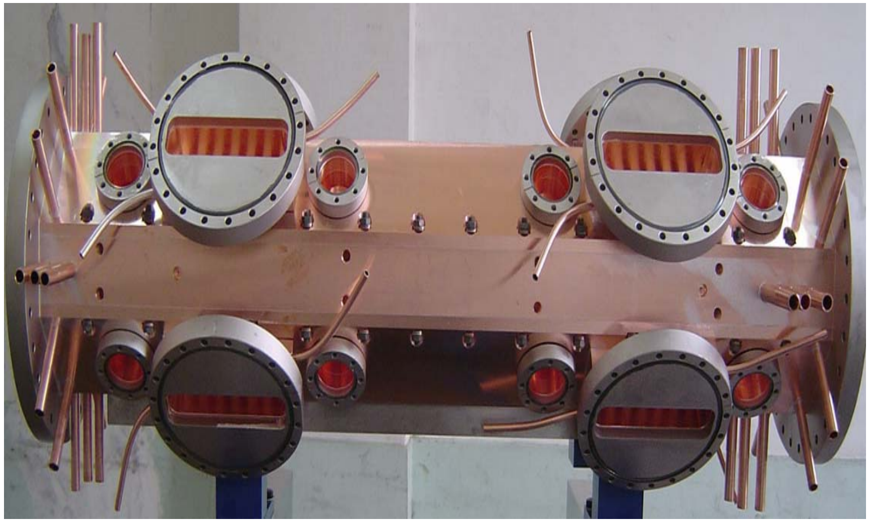
HEBT

Introduction-main RFQ parameters

Main RFQ parameters

Input Energy	75keV
Output Energy	3.5MeV
Peak Current	50mA
Structure Type	4-Vane
RF Frequency	352.2MHz
Maximum Surface E	33MV/m (1.8Kilp)
Structure Power	420kW
Beam Power	175kW
Total Power	595kW
Total Length	4.75m

- This 4.75 long RFQ consists of two segments, which are resonantly coupled by a coupling cell. Each segment is formed by two technological modules.



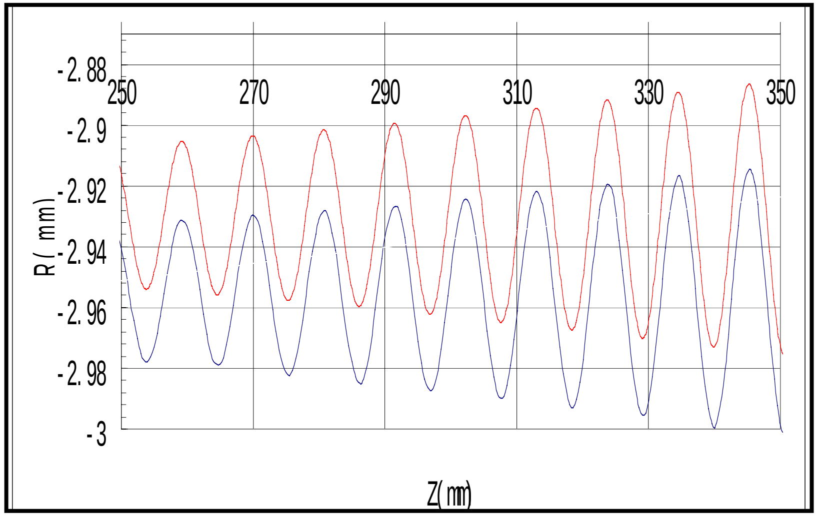
One technological module (1.2m long)

Introduction-milestone of the RFQ

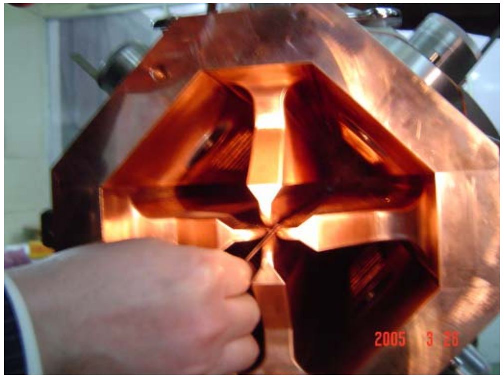
- In 2000 , RFQ design and construction was started.
- In 2002, RFQ measurement and tuning code was developed together by LNL (INFN) Italia and IHEP (CAS) China.
- At the end of 2005, RFQ fabrication and brazing was finished.
- In July of 2006, first beam from RFQ was got.
- In March of 2007, an output current 44.5mA with beam duty factor about 7%, and transmission of 93% was got.
- In June of 2008, an output current of 29mA with Beam duty factor of 15% was got.

RFQ fabrication, assembly, brazing and field tuning

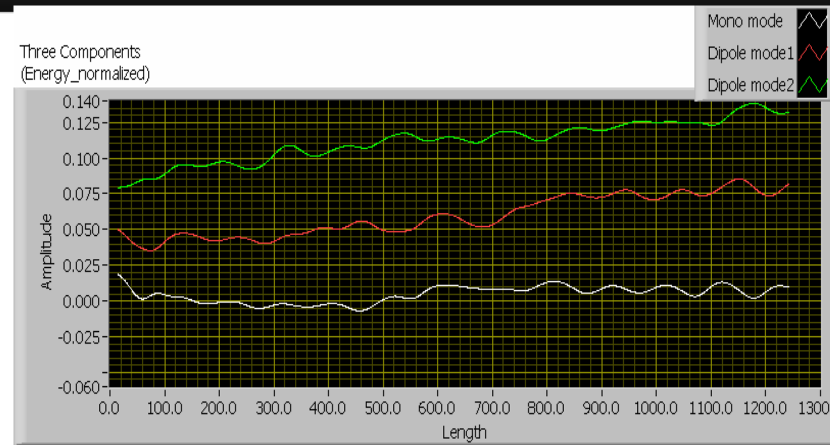
- Following the R&D experiences in the technological models, we started mass fabrication of the RFQ cavity: only one formed cutter for the final machining of all 16 vanes.
- The cavity vanes were fabricated and measured with (coordinate measuring machine) CMM.
- The measured modulation curve was compared with design curve.



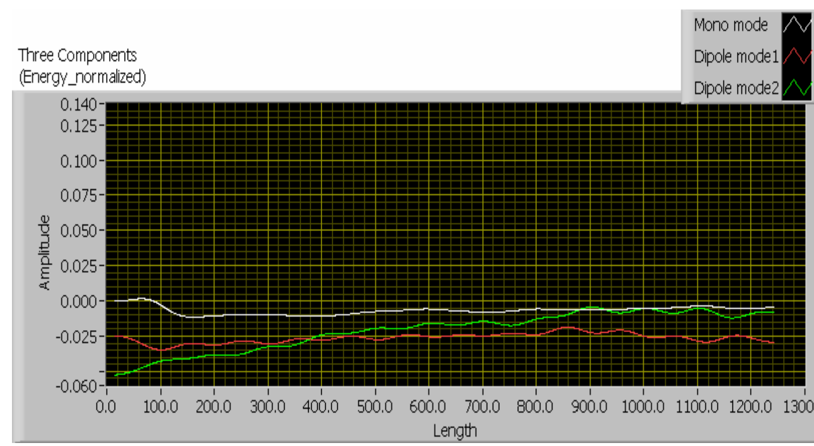
RFQ fabrication, assembly, brazing and field tuning



- Before brazing ,the four vanes were assembled and measured geometrically (pin gauge) and electrically (bead-pull), and the horizontal vanes were adjusted to get a good field distributions and a right frequency.



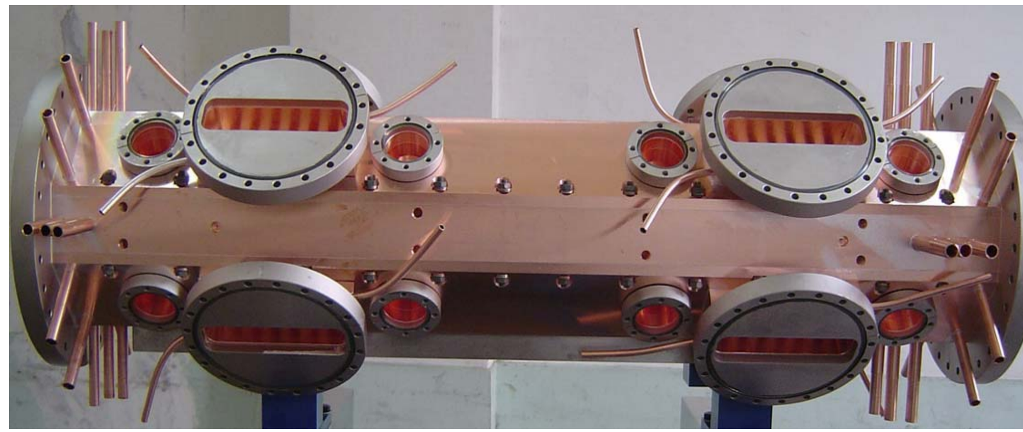
Dipole component (13%) before adjustment



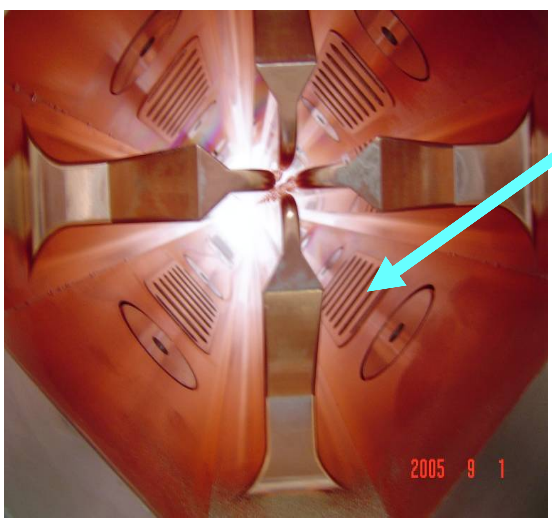
Dipole component (3%) after adjustment

RFQ fabrication, assembly, brazing and field tuning

The RFQ cavity after the first braze



The RFQ cavity after the final braze



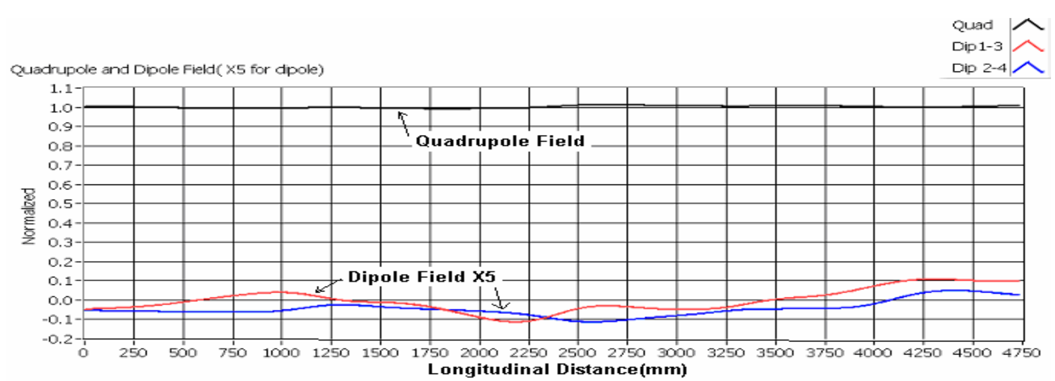
Repair brazing of the vacuum grill due to insufficient insertion.

Vacuum leakage check

RFQ fabrication, assembly, brazing and field tuning

4 sections of the cavity were aligned with a laser tracker to reach an alignment accuracy of 30μm.

Bead-pull measurement for tuning the field with 64 movable Al tuners.



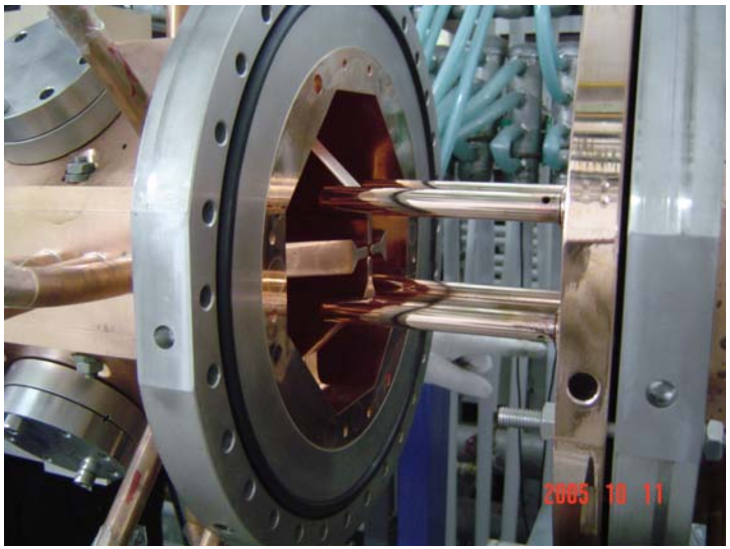
By using RFQ tuning code, a satisfactory field was reached.

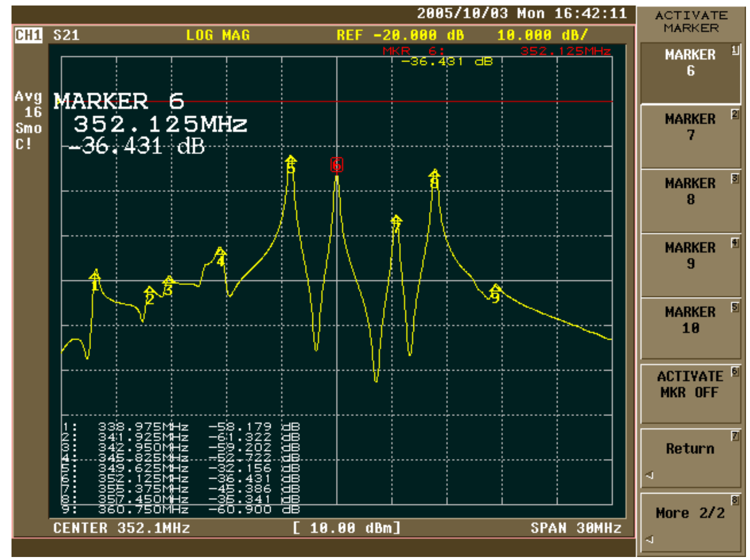
f_Q=352.123MHz,

Quadrupole field error<1 %

Dipole field<2%

RFQ fabrication, assembly, brazing and field tuning





Dipole stabilizer rods are inserted into the cavity at the ends and the coupling cell.

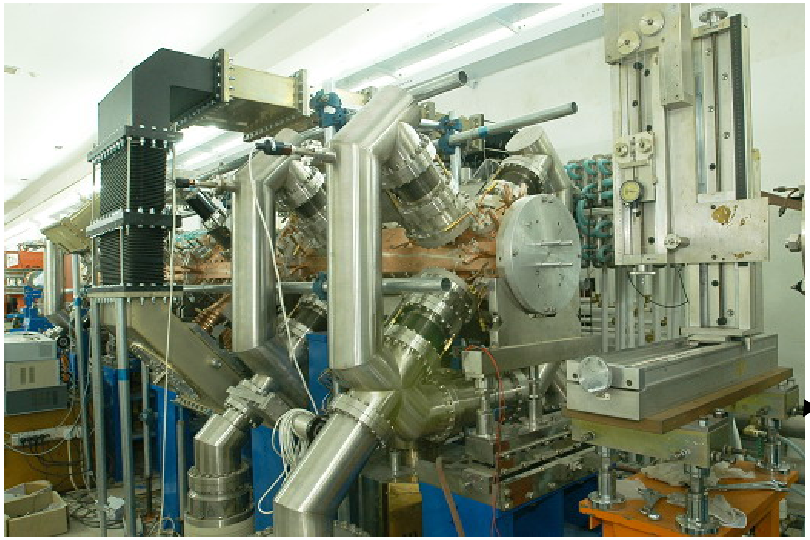
Spectrum of dipole modes are shifted by the dipole stabilizer rods.

Δf=5MHz (neighbouring dipoles from the operating quadrupole mode)

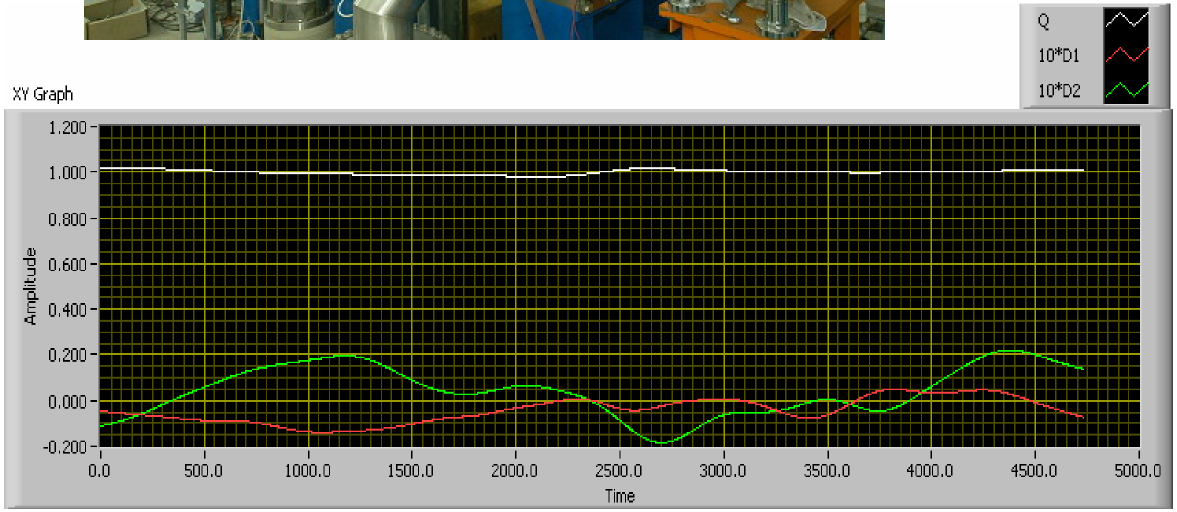
Δf=3MHz (neighbouring quadrupoles from the operating quadrupole mode)

RFQ fabrication, assembly, brazing and field tuning

The Al tuners were replaced with copper slug tuners in three batches.



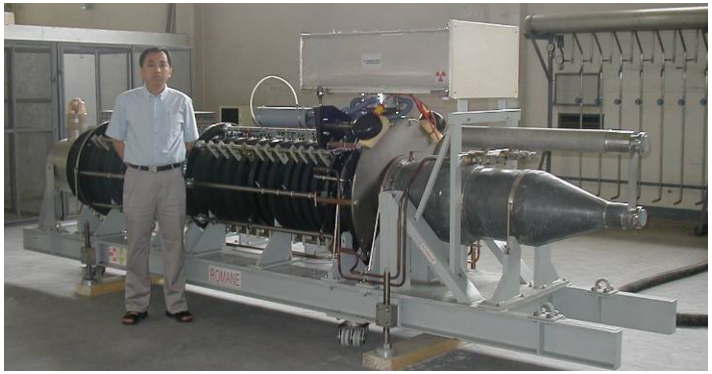
Bead pull measurement after the cavities are fully installed with all ports, except the end plates.



Quadrupole tilt: 2 % in max.

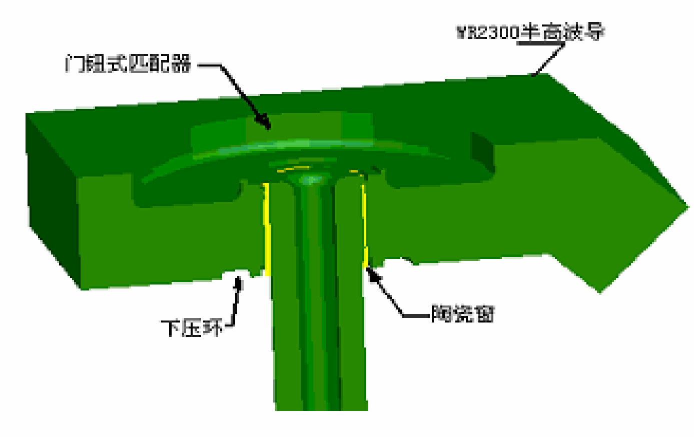
Dipole : ±2% in max.

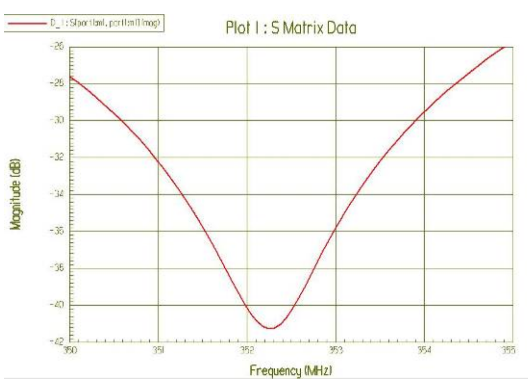
RF power source and input coupler

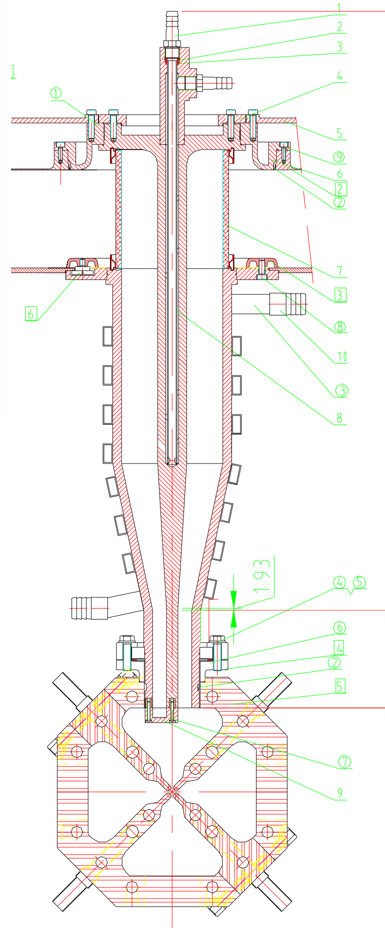


The RF power source for the RFQ from CERN has been installed at IHEP. It is a CW RF power source of 352.2MHz/1.2MW, decommissioned from LEPII. We reinstalled it at IHEP, and the modulator was modified to adapt to our pulse operation mode.

RF power source and input coupler







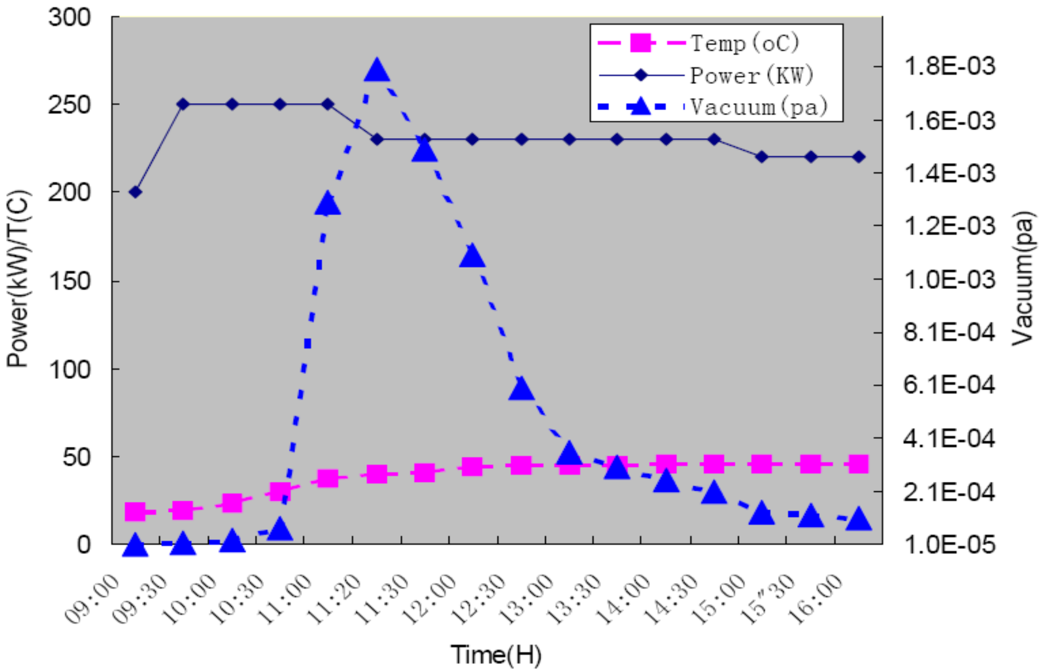
RF power coupler

Initial beam commissioning with a low duty factor

➢RFQ conditioning with a low RF duty factor but full RF power was rapidly accomplished through the following two steps:

1, Bake for vacuum conditioning without cooling water;

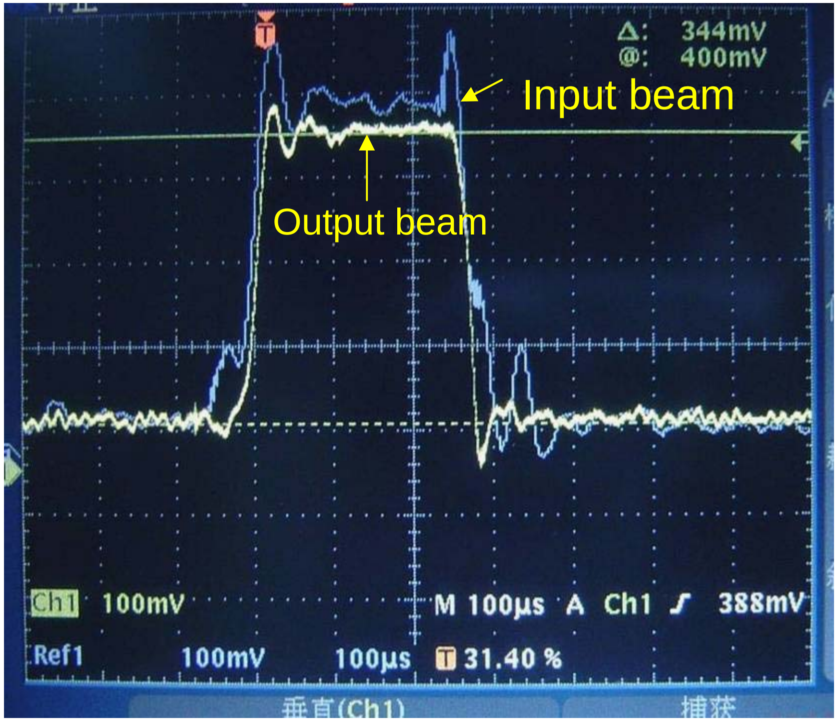
2, High power conditioning with cooling water.



Time diagram of the initial RFQ conditioning

Initial beam commissioning with a low duty factor

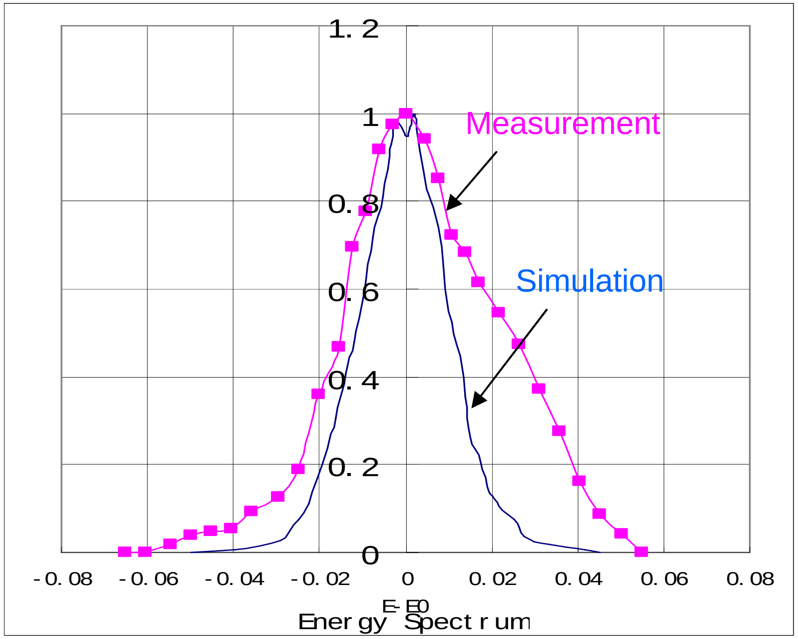
➢Initial beam commissioning started at a low beam duty (0.5%) but a higher RF duty (1.5%). We reached a transmission rate of 92% with an input beam of 44mA .



a transmission rate of 92% with an input beam of 44mA .

Initial beam commissioning with a low duty factor

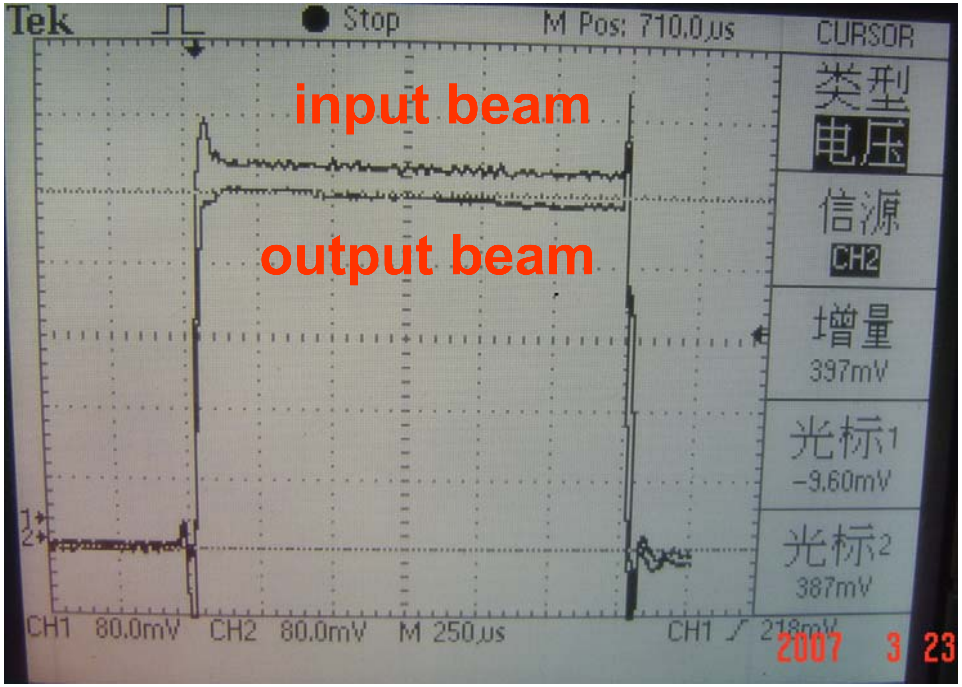
- The measured beam energy is only 40keV higher than the simulation from PARMTEQ.
- The measured energy spectrum is similar to the simulation result from PARMTEQM



Energy spectrum

Initial beam commissioning with a low duty factor

Later on, the beam duty factor was boosted to 7.15%. The main performance is as follows: the output pulsed beam current 44.5mA, the beam pulse width 1.43ms, the repetition rate 50Hz, the beam duty factor 7.15%, the beam transmission about 93%.

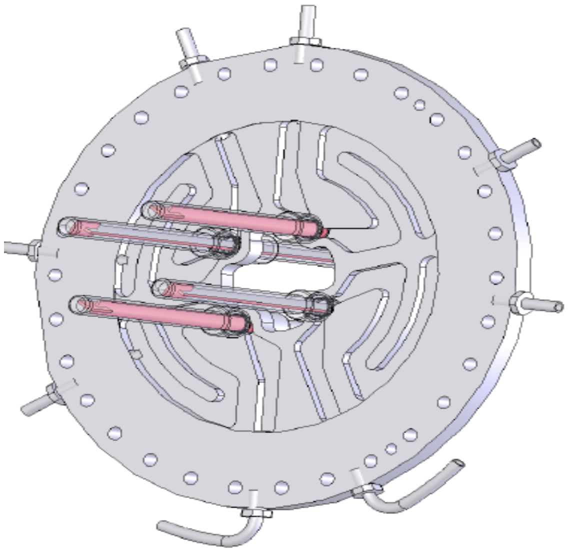


a transmission rate of 93% with an output beam of 44.5mA .

Beam commissioning with a higher duty factor

In order to extend the beam duty factor to a higher level, some systems or components need to be replaced, improved or examined.

1 . To add water-cooling channels in rods installed on the coupling plate and end



The mechanical drawing of the coupling plate, on which the rods are installed and embedded with water-cooling channels.

Beam commissioning with a higher duty factor

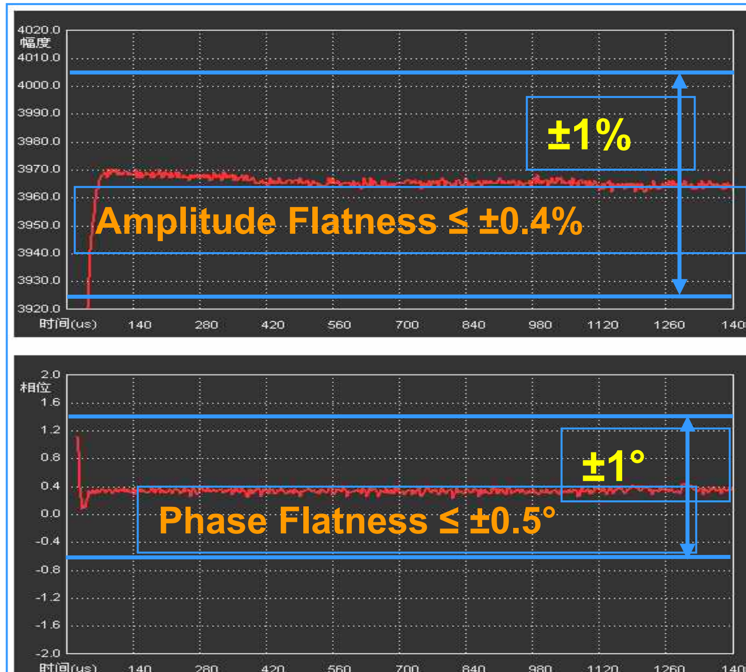
2. A new VME frame 6U timing trigger system is made to replace the original CAMAC frame timing trigger system. The maximum work repetition rate is **50Hz** provided by the original timing system. But for a beam pulse width **1.4ms**, we need at least a **110Hz** work repetition rate to obtain a beam duty factor higher than **15%.**

The VME frame timing trigger system

Beam commissioning with a higher duty factor

3 . To construct and develop digital LLRF control system. Both the feed-forward control and feedback control are incorporated into the digital LLRF control system, and the RFQ field variation can be maintained within ±1% in amplitude and ±1° in phase during the beam experiments.

19'' standard racks profile



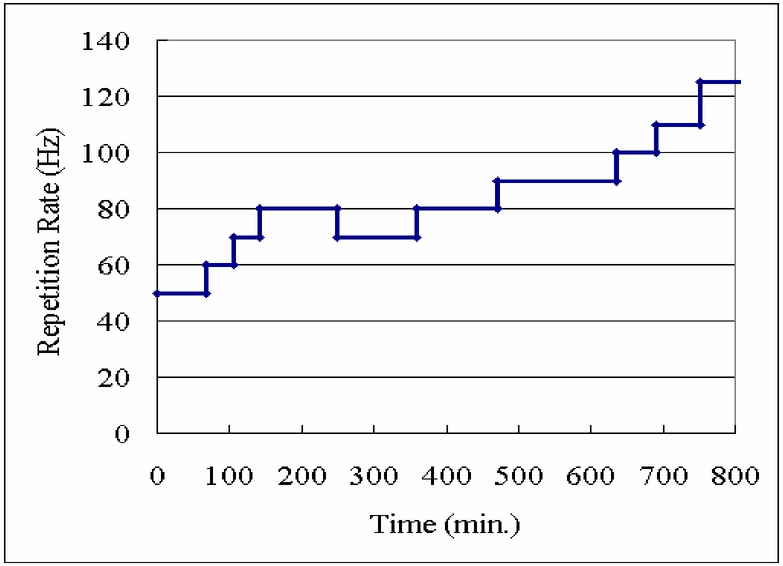
Beam commissioning with a higher duty factor

4. In order to afford a beam duty factor higher than 15%, a new dumper is machined. For the new copper dumper, the water-cooling channel of the plane has a fish-bone structure. Its surface is plated with aluminium to decrease nuclear activation.

The new dumper with two slope plates

Beam commissioning with a higher duty factor

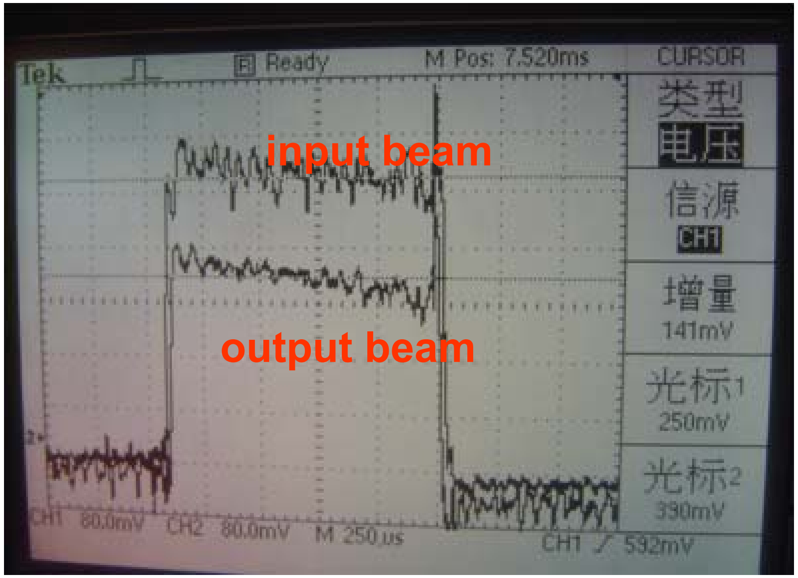
- RF conditioning was carried out by increasing the repetition rate from 50Hz to 125Hz while keeping pulse width 1.4ms unchanging.
- only takes about 750 minutes to extend the RF duty factor from 7% to 17.5%.



Time diagram of the RF conditioning

Beam commissioning with a higher duty factor

- **Beam commissioning with a beam duty factor of 15% (a repetition rate of 125Hz and a beam pulse width 1.2ms) is also underway. An output pulsed beam current of 29mA from the RFQ was got at the initial commissioning.**



Output beam current of 29mA with beam duty factor of 15%

Summary

- We have succeeded to construct a high-duty factor proton RFQ. And a transmission of 93% and output current of 43mA was got in the initial beam commissioning with a beam duty factor about 7%. RF conditioning with a duty factor of 17.5% was also finished. Beam commissioning with beam duty factor of 15% is underway, and an output pulsed beam current of 29mA was got. But more work is still needed for a higher beam transmission.

Thank you very much

for your attention