The BEPCII: Construction and Initial Commissioning

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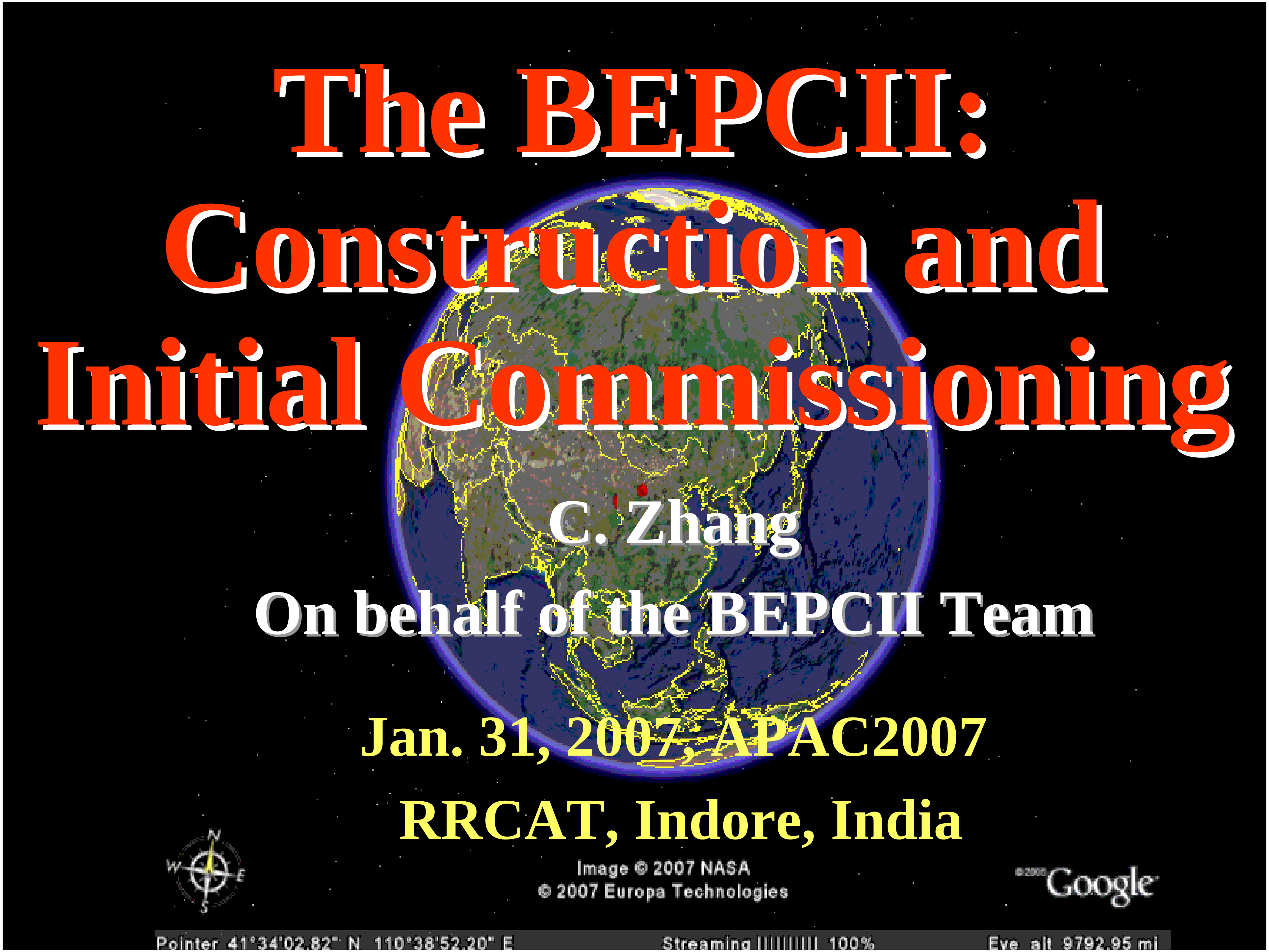
On behalf of the BEPCII Team

Jan. 31, 2007, APAC2007

RRCAT, Indore, India



Performance of BEPC and Progress of BEPCII

The construction of the BEPCII has started since beginning of 2004. In the next APAC, APAC07, we should be able to report some results of BEPCII commissioning.

- **Summary**

The BEPCII: Construction and Initial Commissioning

Jan. 31, 2007, APAC2007, RRCAT, Indore, India

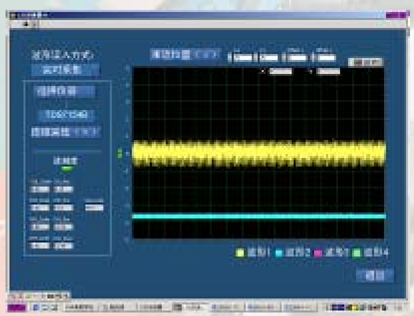
- General Description
- Construction
- Commissioning
- Conclusion

The Milestones



January 2004	**Construction started**
May. 4, 2004	**Dismount of 8 linac sections started**
Dec. 1, 2004	**Linac delivered e^- beams for BEPC**
Mar. 19, 2005	**First e^+ beam of 50mA obtained**
July 4, 2005	**BEPC ring dismount started**
Mar. 2, 2006	**BEPCII ring installation started**
Nov. 13, 2006	**BEPCII ring commissioning started**
Nov. 18, 2006	**First e^- beam stored in the ring**
Dec. 25, 2006	**Beams provided for SR users**



(1) General Description

The BEPCII serves the purposes of both high energy physics experiments and synchrotron radiation applications.

Beam energy range	**1–2 GeV**
Optimized beam energy region	**1.89GeV**
Luminosity @ 1.89 GeV	**1×10^{33} cm^{-2}s^{-1}**
Injection from linac	**Full energy injection: E_{inj}=1.55–1.89GeV**
Dedicated SR operation	**250 mA @ 2.5 GeV**

Main Parameters

Parameters	Unit	BEPCII	BEPC
Operation energy (E)	GeV	1.0–2.0	1.0–2.5
Injection energy (E_{inj})	GeV	1.55–1.89	1.3
Circumference (C)	m	237.5	240.4
β^*-function at IP (β_x^*/β_y^*)	cm	100/1.5	120/5
Tunes ($\nu_x/\nu_y/\nu_s$)		6.57/7.61/0.034	5.8/6.7/0.02
Hor. natural emittance (ε_{x0})	mm·mr	0.14 @1.89 GeV	0.39 @1.89 GeV
Damping time ($\tau_x/\tau_y/\tau_e$)		25/25/12.5 @1.89 GeV	28/28/14@1.89 GeV
RF frequency (f_{rf})	MHz	499.8	199.533
RF voltage per ring (V_{rf})	MV	1.5	0.6–1.6
Bunch number (N_b)		93	2×1
Bunch spacing	m	2.4	240.4
Beam current — Colliding	mA	910 @1.89 GeV	~2×35 @1.89 GeV
Beam current — SR	mA	250 @2.5GeV	130
Bunch length (cm) σ_l	cm	~1.5	~5
Impedance $\|Z/n\|_0$	Ω	~ 0.2	~4
Crossing angle	mrad	±11	0
Vert. beam-beam param. ξ_y		0.04	0.04
Beam lifetime	hrs.	2.7	6–8
luminosity@1.89 GeV	$10^{31}cm^{-2}s^{-1}$	100	1

The luminosity strategy

DR: multi-bunch k_{bmax}~400, k_b=1 ➔ 93

Choose large ε_x & optimum param.: I_b=9.75mA, ξ_y=0.04

$$L(\mathrm{cm}^{-2}\mathrm{s}^{-1}) = 2.17\times10^{34}(1+R)\xi_y \frac{E(GeV)k_b I_b(A)}{\beta_y^*(cm)}$$

Micro-β: β_y^* =5cm ➔ 1.5 cm
SC insertion quads

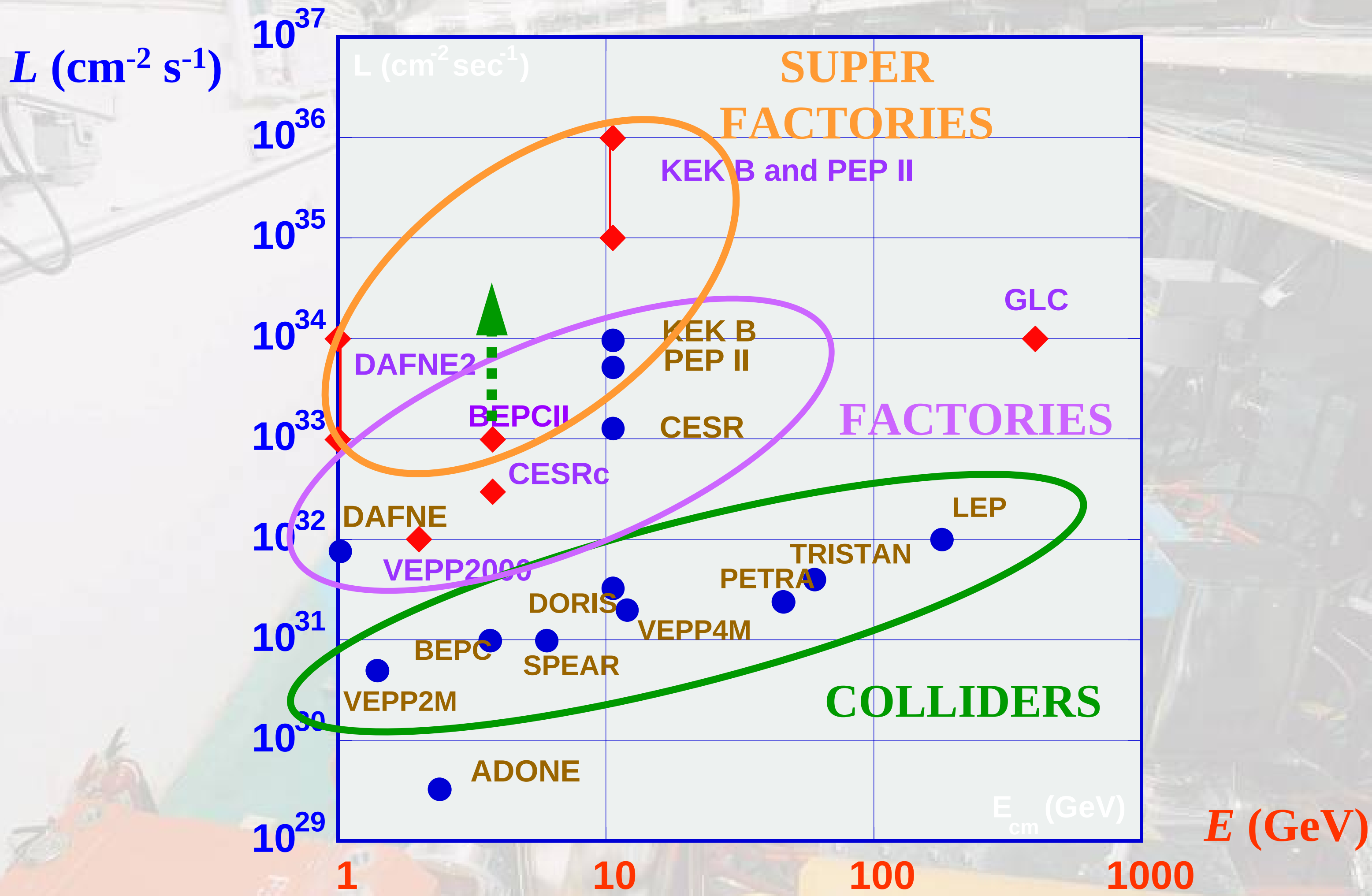
Reduce impedance +SC RF
σ_z =5cm ➔ <1.5cm

$(L_{BEPCII}/ L_{BEPC})_{D.R.}$=(5.5/1.5) ×93 × 9.8/35=96

L_{BEPC}=1.0×10 ^{31} cm^{-2}s^{-1} ➔ L_{BEPCII} =1×10 ^{33} cm^{-2}s^{-1}

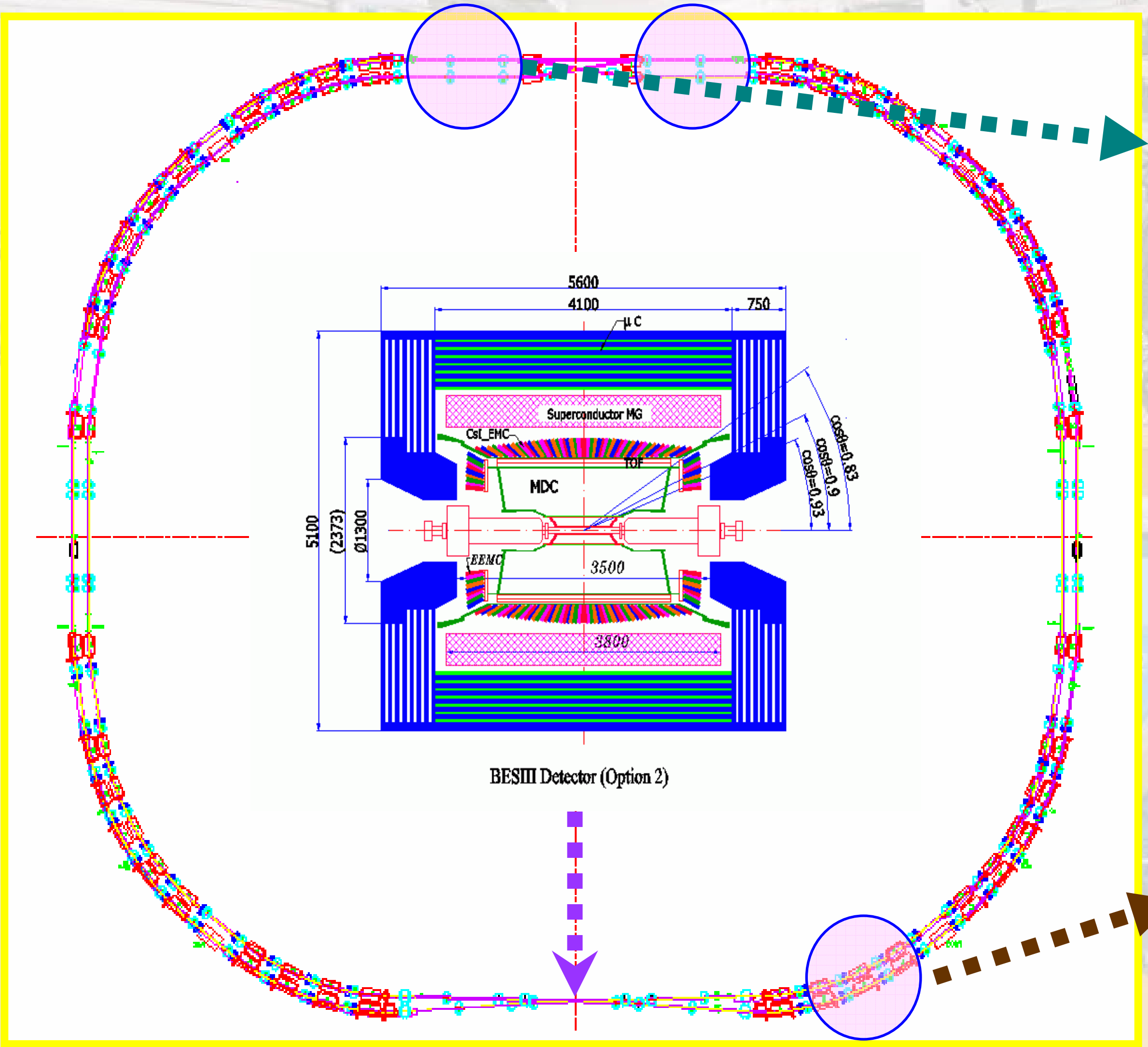
Detail machine physics issues refer to G. Xu, et al, Proc. of EPAC 2004, July 2004.

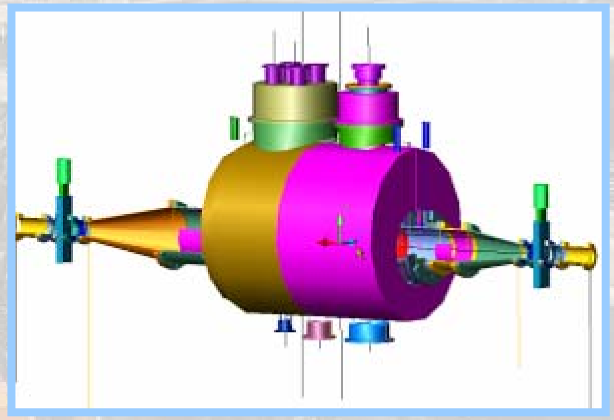
e^+-e^- Colliders: Past, Present and Future



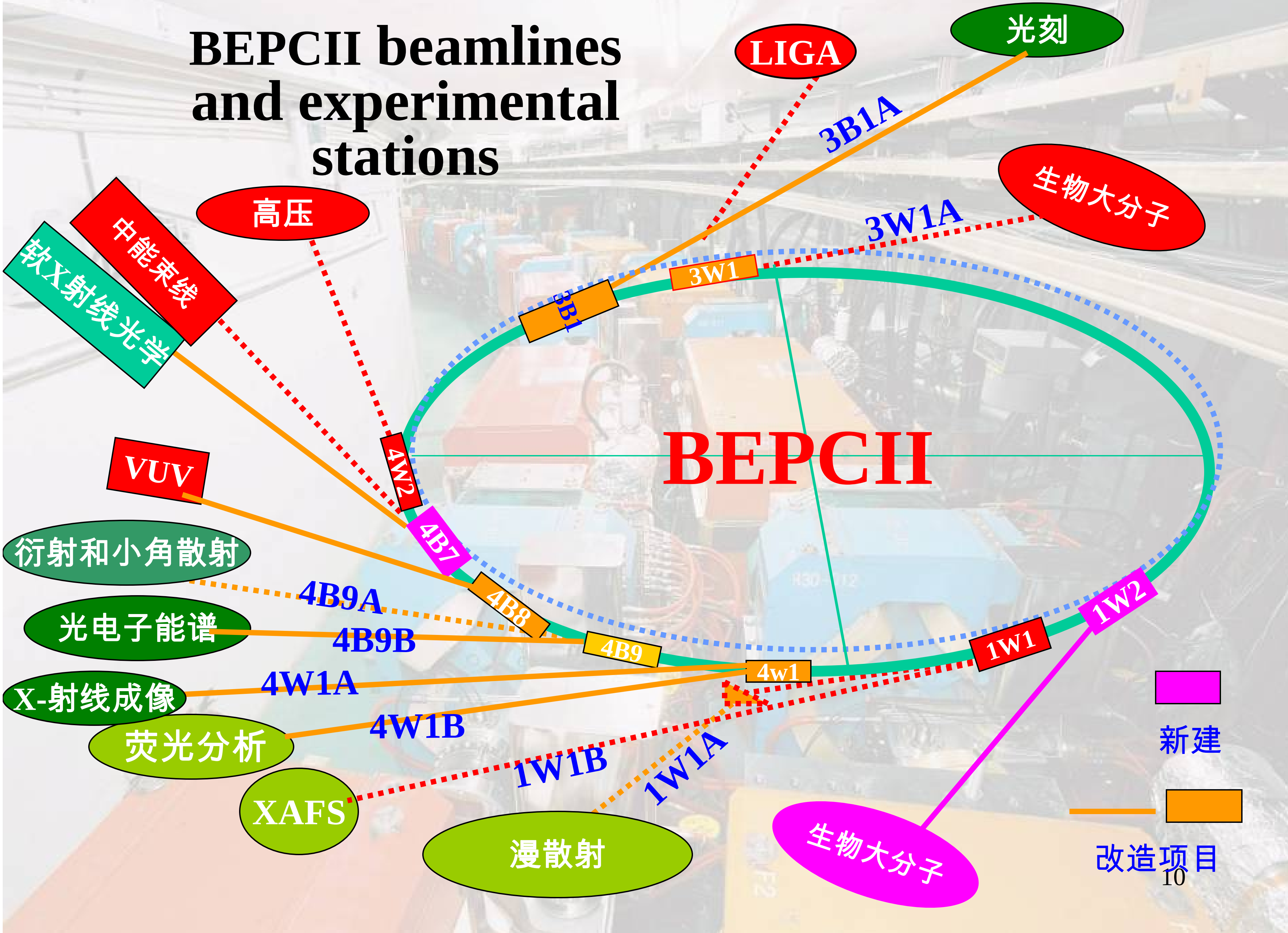
C. Biscari, Workshop on e^+e^- in 1-2 GeV Range, September 10-13, 2003, Italy

Three ring structure





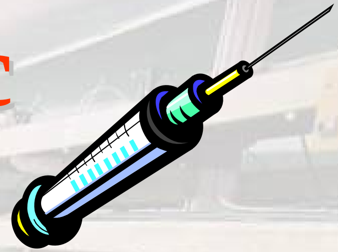
BEPCII beamlines and experimental stations



(2) Construction

- **Injector Linac**
- **Storage Rings**
- **BESIII & BSRF**

2.1 The Injector Linac



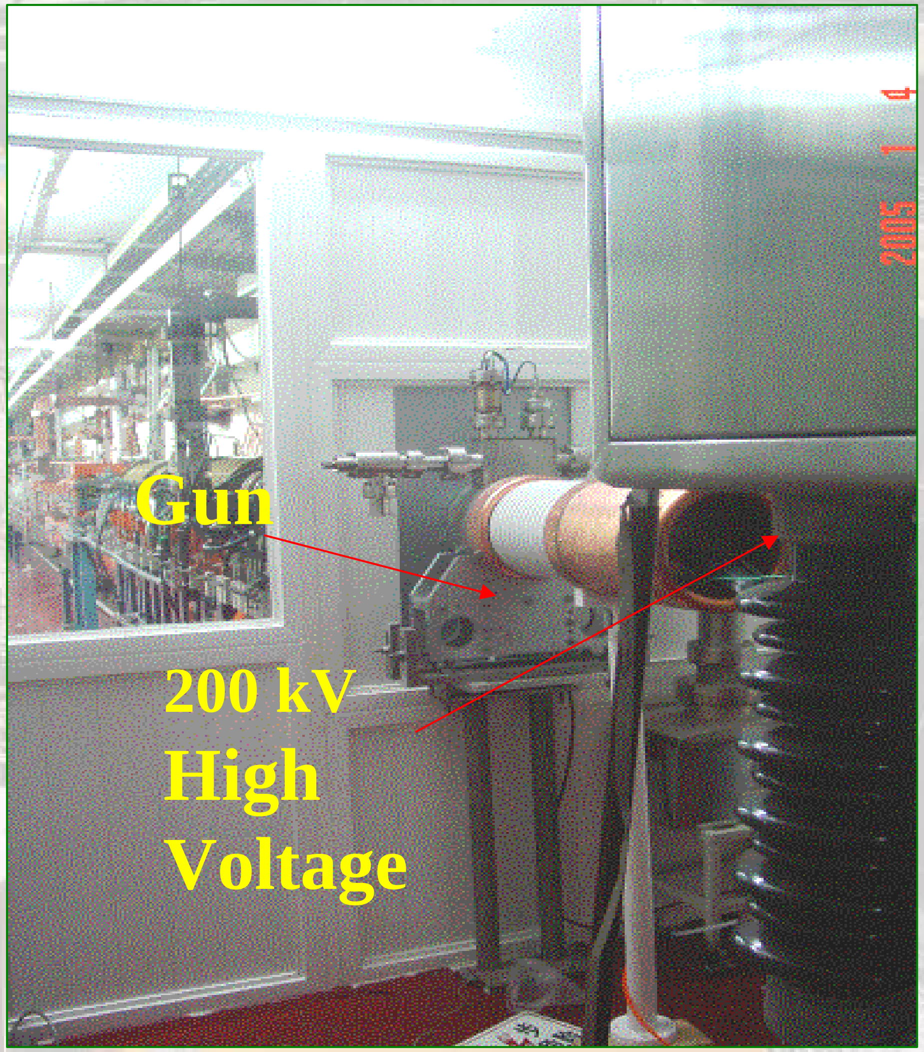
- **Basic requirement:**
  - **Higher intensity: e^+ injection rate ≥ 50 mA/min.;**
  - **Full energy injection with E=1.55 ~ 1.89 GeV;**
- **To enhance the current and energy of the electron beam bombarding the target and to reduce the beam spot;**
- **To design and produce a new positron source and to improve its focusing;**
- **To increase the repetition rate from present 12.5 Hz to 50 Hz.**
- **To apply multi-bunch injection (f_{RF}/f_{Linac}=7/40);**

Measures to reach the goals

1) **New e^- Gun**	High current ; low emittance
2) **New e^+ Source**	High e+ yield; Large capture acceptance
3) **New RF System with phasing loop**	High RF power output; Stable phasing loops
4) **New Beam Tuning Devices**	Orbit correction; Optimum optics
5) **Other System's Upgrade**	Microwave system, Vacuum, Instrumentation, Control.

New Electron Gun

Parameters	Unit	BEPCII
Cathode		EIMAC Y796
Beam current Pulse length	A ns	10 1 (FWHM)
Emittance (norm.)	μm	14
Accelerating voltage	kV	120~200 Pulse / 3μs
Heater volt. /current	V/A	6 ~ 8 / 5 ~ 7.5
Grid voltage	V	0~250
Grid pulse	V	-300 ~ -700
Bias voltage	V	+150 ~ +300
Operating Mode		1 or 2 Bunches
Repetition Rate	Hz	50



New Positron Source

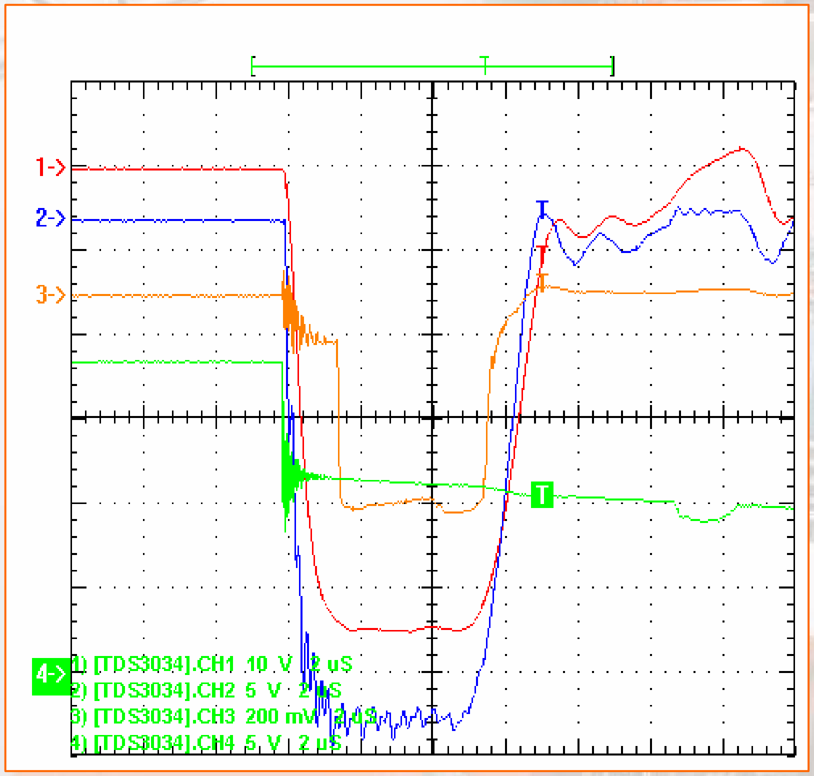
A flux concentrator is employed to have a large e^+ acceptance:
L = 10 cm , B = 5.3 T ↘0.50 T, Φ = 7 mm →52 mm.

New RF Power Sourse

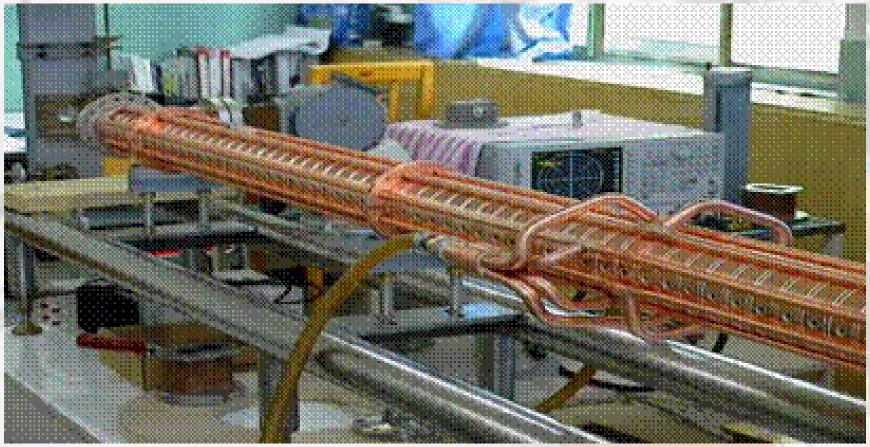
50MW new klystrons

New modulators with high power 320 kV × 360 A.

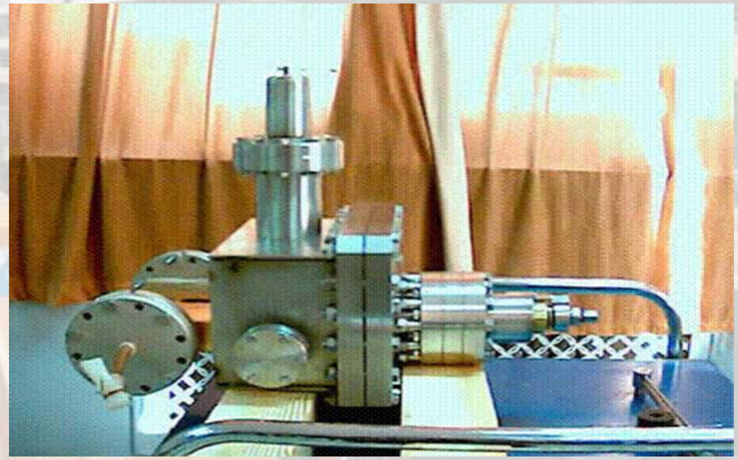
High voltage stability ≤ ±0.15%



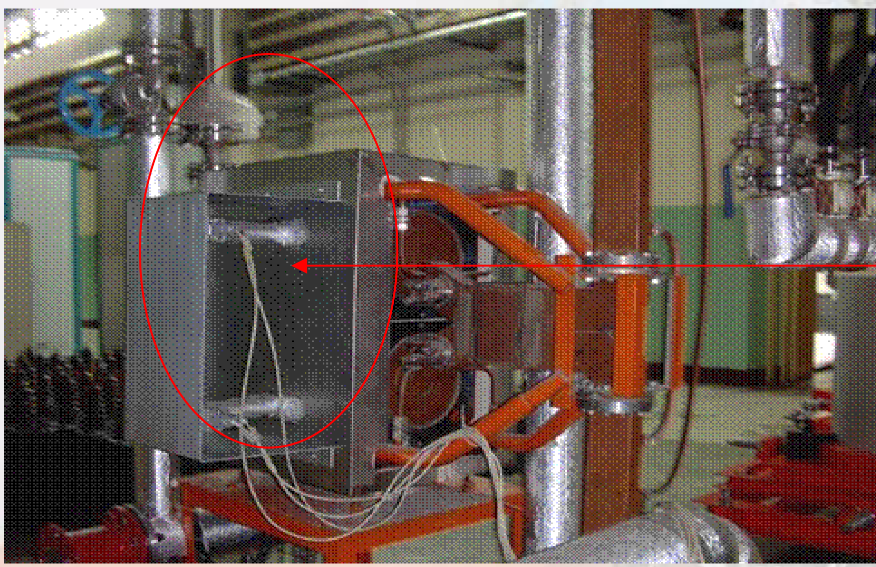
Microwave system

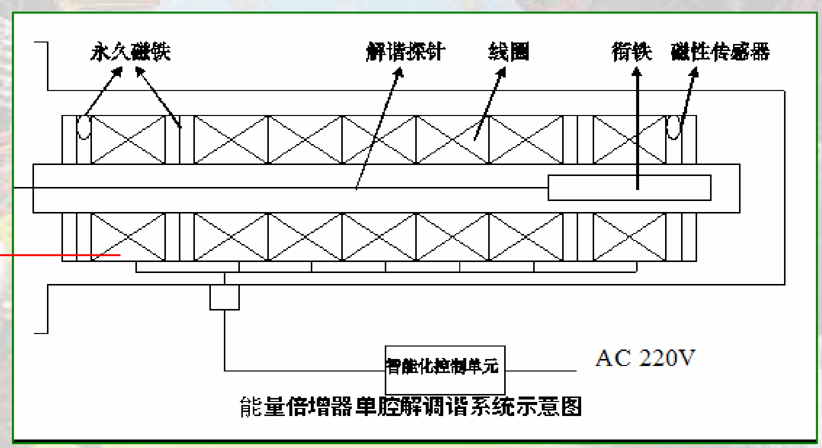


New Accelerating Structure (20 MV/m)



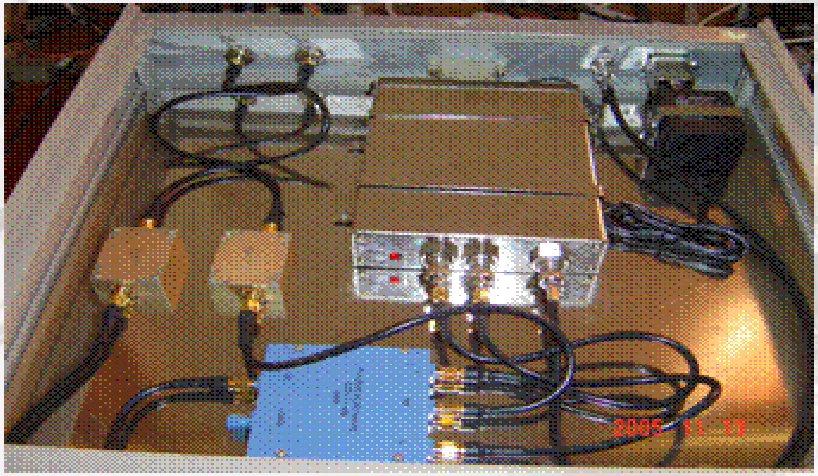
High power Wave Guide valve





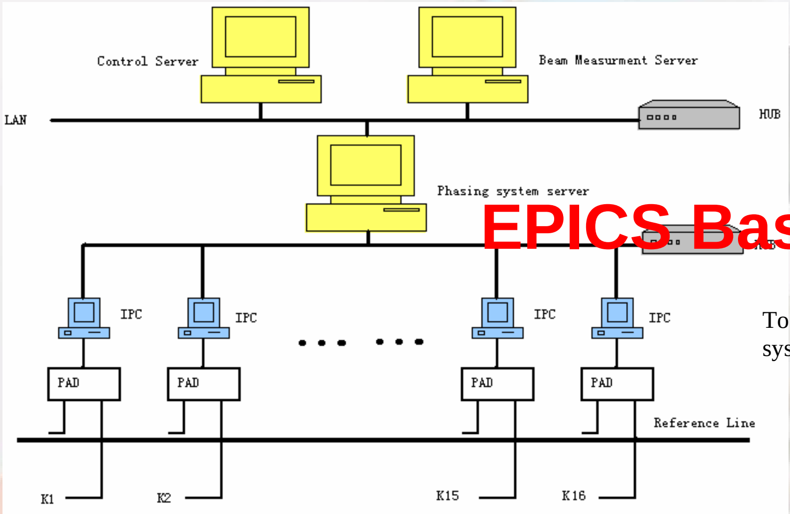
SLED & New Detuning device

Phase control system

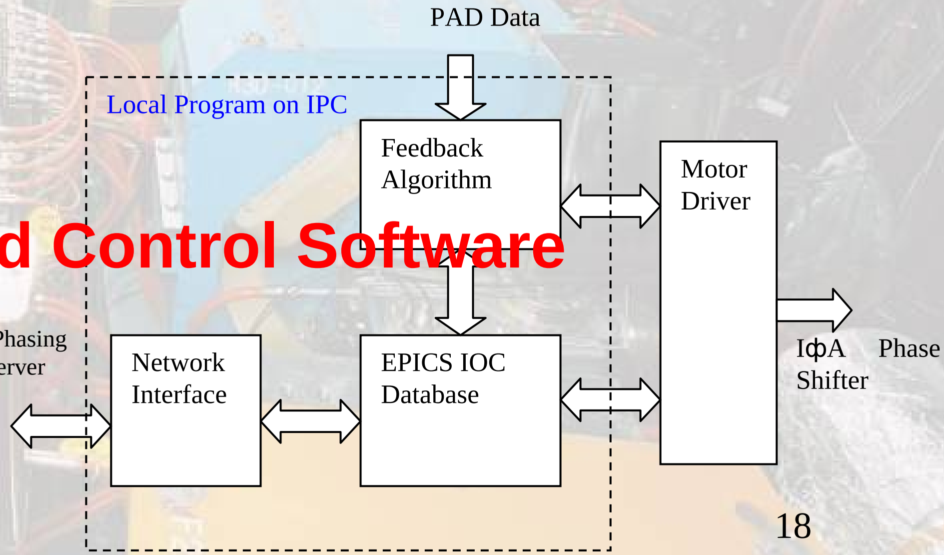


I/Q demodulator based PAD

IΦA unit

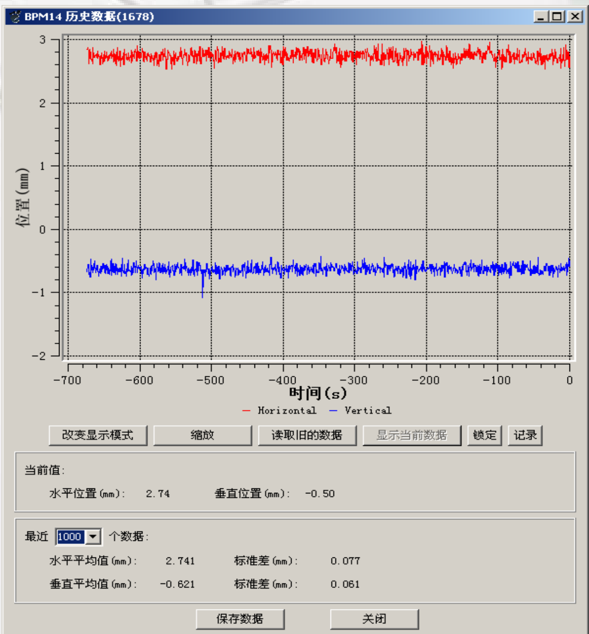


EPICS Based Control Software

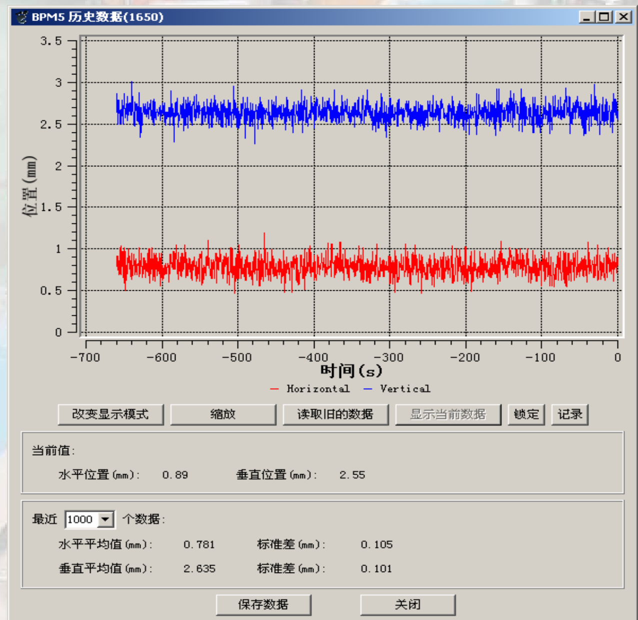


Beam orbit stable in operation

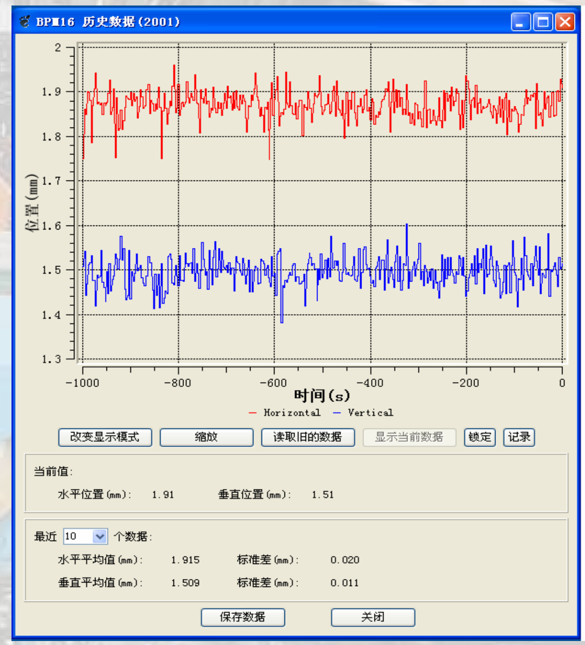
Last 3 BPMs in the Linac jitter ≤ 0.1 mm (1σ)



BPM 14



BPM 15



BPM 16

Summary of the Linac commissioning

Parameters		Goal	Measured
Beam energy (GeV)		1.89	1.89
Beam current (mA)	e^+	40	61
	e^-	500	> 500
Repetition rate (Hz)		50	50
Emittance (1σ) (mm·mrad)	e^+	0.4	0.4
	e^-	0.1	0.1
Energy spread (%)	e^+	± 0.50	±0.4
	e^-	± 0.50	±0.4

2.2 Storage Rings

- RF System
- Injection Kickers
- Magnet System
- Power Supply
- Vacuum System
- Beam Diagnosis
- Control System
- Cryogenics
- Interaction Region
- Installation

RF System

RF Frequency	**f_{rf}**	**499.8 MHz**
RF Voltage	**V_{rf}**	**1.5 MV**
Q Value		**$>5\times10^{8}$@2MV**
Number of cavities	**N_{rfc}**	**2×1**
SR loss per turn @ 1.89 GeV	**U_{rf}**	**123 keV/ring**
Total RF loss @ 1.89 GeV	**P_b**	**124 kW/ring**
Power of RF transmitters	**P_{rf}**	**2× 250 kW**

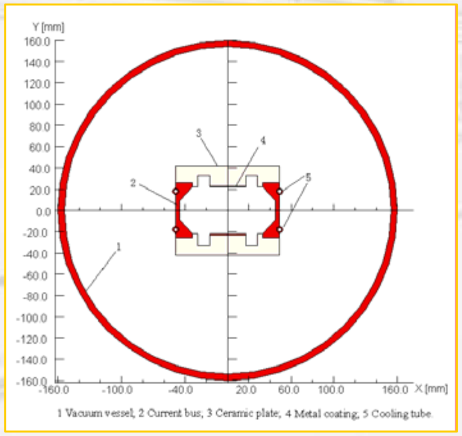
Magnet System

Magnet type	Number
Dipole (Leff.=1.4135m)	40+1
Dipole (Leff.= 1.2277m)	2
Dipole (Leff.= 1.0339m)	2
Weak dipole (Leff.=1.0321m)	2
Weak dipole (Leff.=0.7453m)	2
Quadrupole	88+2
Old quadrupoles with modified coils	28
160Q quadrupole (Old)	6
Sextupole	72+1
Vertical corrector	48+1
Special vertical corrector	6
Quadrupole of the SR mode	1
Skew quadrupole	4+4
70B dipole (Old)	40+4
Octupole (Old)	2
Total	356

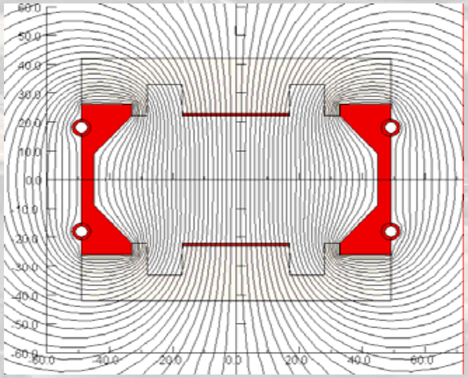
Power Supplies

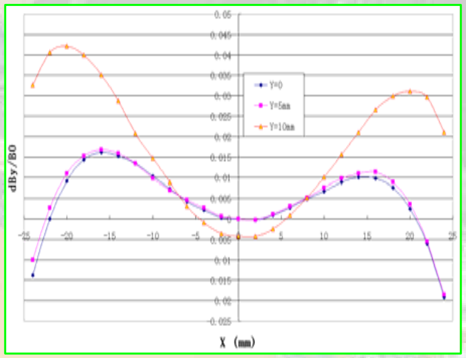
P.S.	No.	Design Stability	Tested Stability
Q & S	165	1×10^{-4}	4×10^{-5}
OQ2,OQ3, IQ2, IQ3	16	1×10^{-4}	5×10^{-5}
B	4	1×10^{-4}	5×10^{-5}
BH,BV	144	1×10^{-4}	4×10^{-5}
T.Q	34	1×10^{-4}	4×10^{-5}
T.B	2	1×10^{-4}	4×10^{-5}
SC magnets	16	1×10^{-4}	1×10^{-4}
Q1a,Q1b,ISPB	3	1×10^{-4}	1×10^{-4}

Injection Kickers



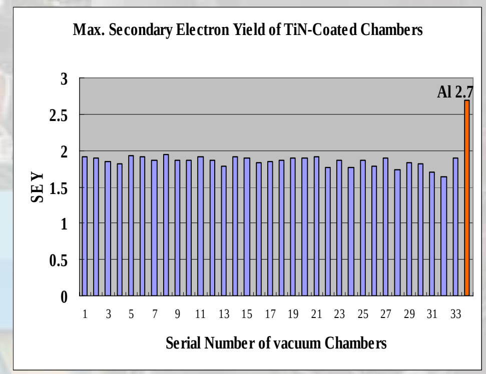
Number of Kickers	4
Length	1.9m
Integral field	200Gs·m
Aperture	90mm×38mm
Good field region	±20mm
Field uniformity	±1%
The pulse repetition	50Hz
Stability of current	1%
Waveform	Half-sine wave
Pulse Width	600ns
Time jitter	<5ns
impedance	<0.025Ω



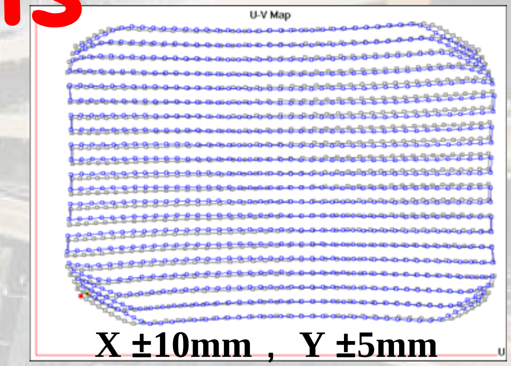


Vacuum System

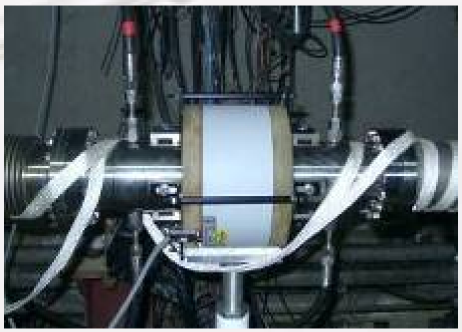
- The design dynamic vacuum pressure are 8×10^{-9} Torr in the arc and 5×10^{-10} Torr in the IR.
- Antechambers are chosen for both e^+ and e^- rings.
- 80 arc chambers,120 straight section chambers; 175 discrete photon absorbers 180 RF shielded bellows
- TiN coating for e+ ring chambers to reduce SEY

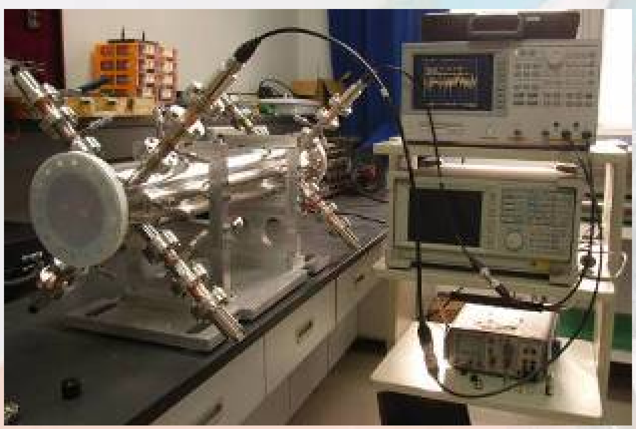


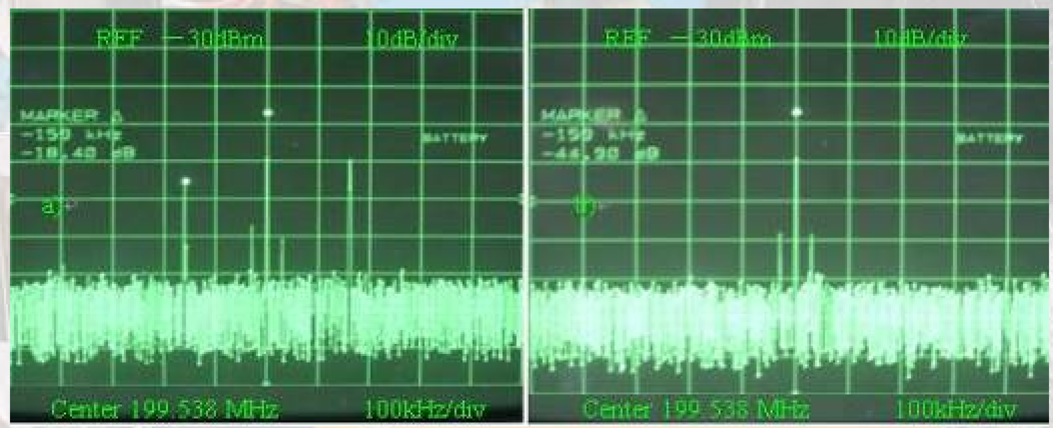
Beam Diagnosis



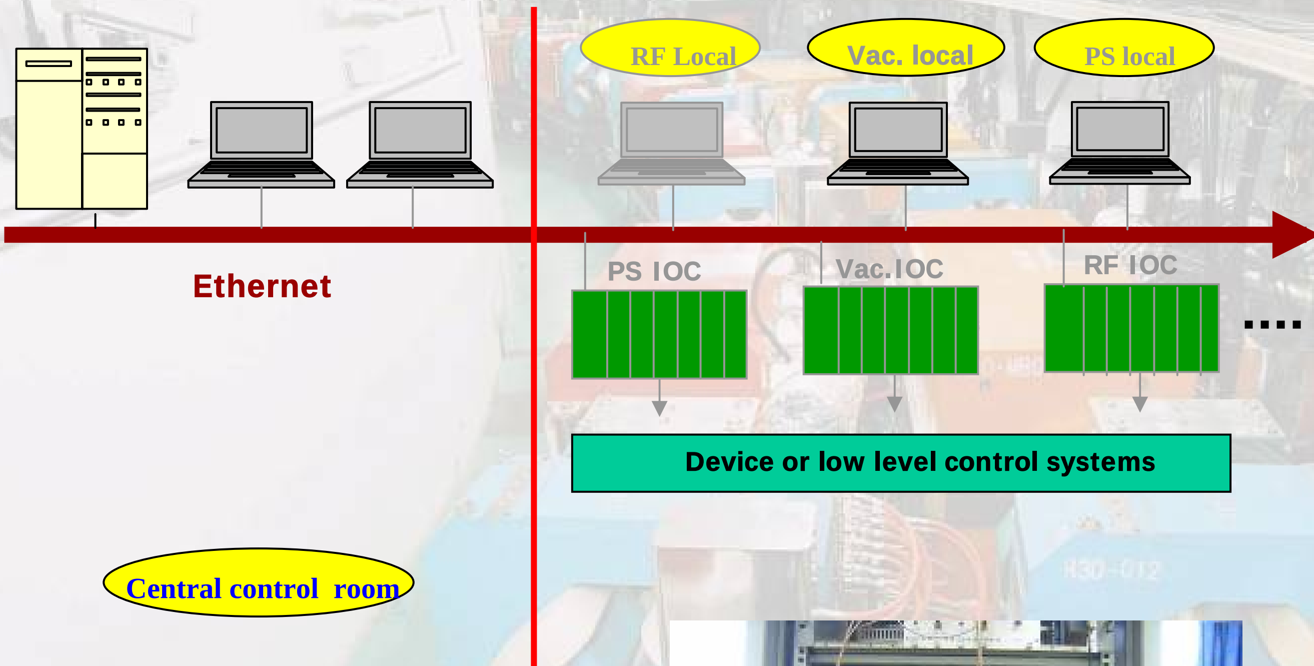
- Beam Position Monitor
- Bunch Current Monitor
- SR monitor
- DCCT
- Transverse Feedbake
- Tune measurement
- Beam Loss Monitor

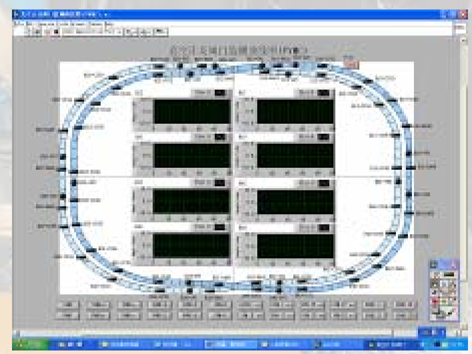




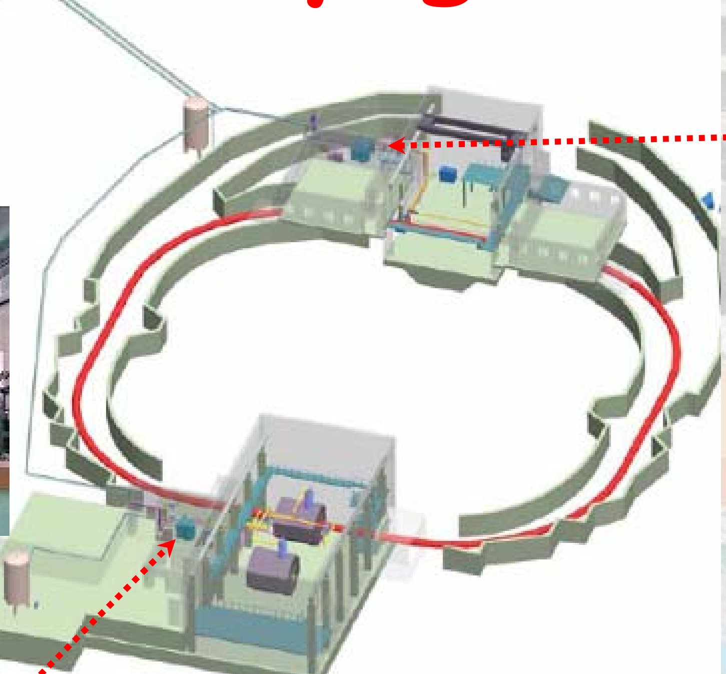


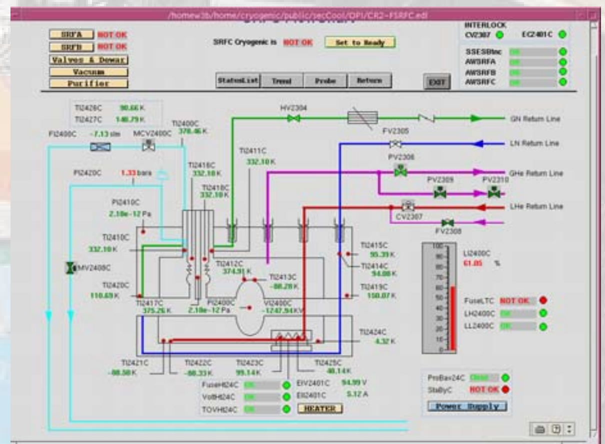
Control System

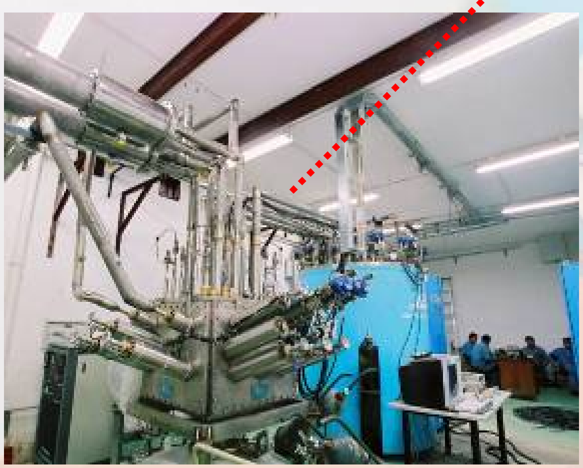


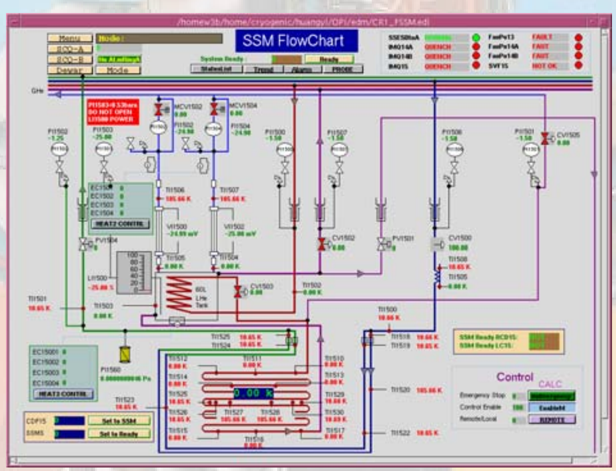


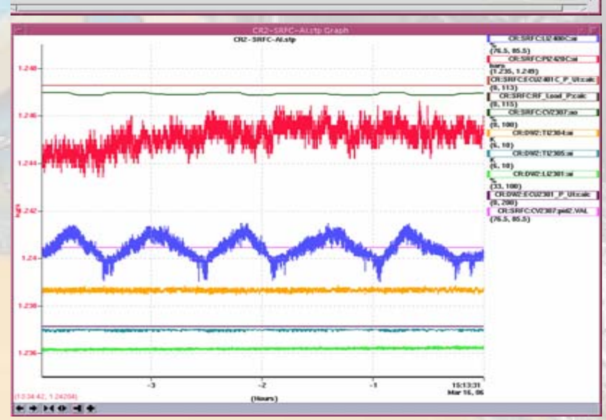
Cryogenics



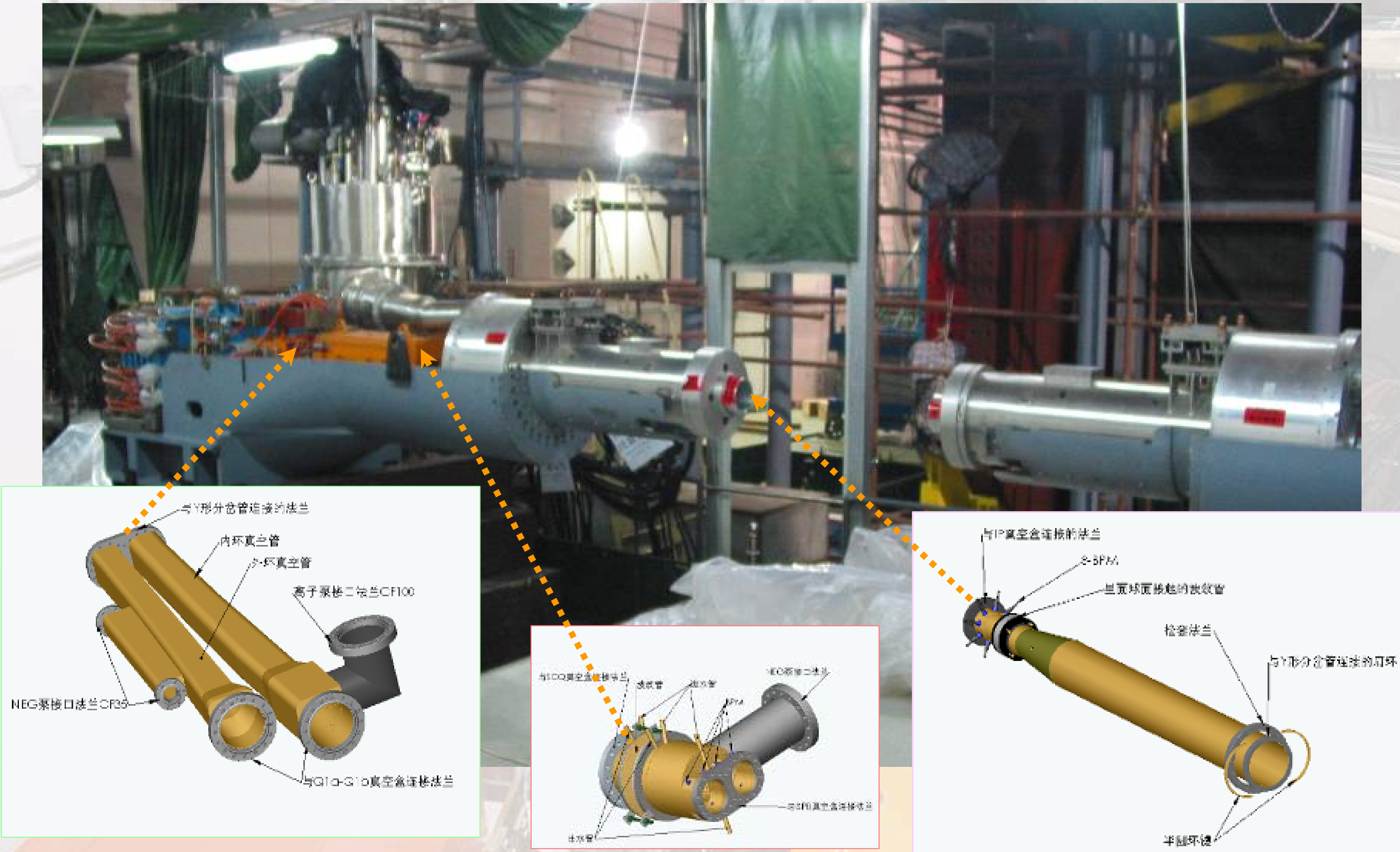




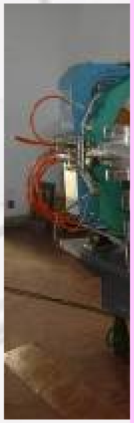




Interaction Region



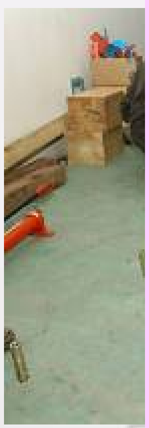
Installation



Preasse

ir cushion

	Δx(mm)	Δy(mm)	Δz (mm)	θ_x(mr)	θ_y(mr)	θ_z(mr)
SC magnet	0.15	0.15	0.2	0.1	0.1	0.1
B	0.4	0.4	0.3	0.2	0.2	0.1
Q	0.15	0.15	0.5	0.5	0.5	0.2
S	0.2	0.2	0.5	0.5	0.5	0.5
BV, BH	0.5	0.5	1.0	1.0	1.0	0.5
RF	0.15	0.15	0.5	-	-	-
Kicker	0.3	0.3	1.0	1.0	1.0	0.5
Lambertson	0.3	0.3	1.0	1.0	1.0	0.5

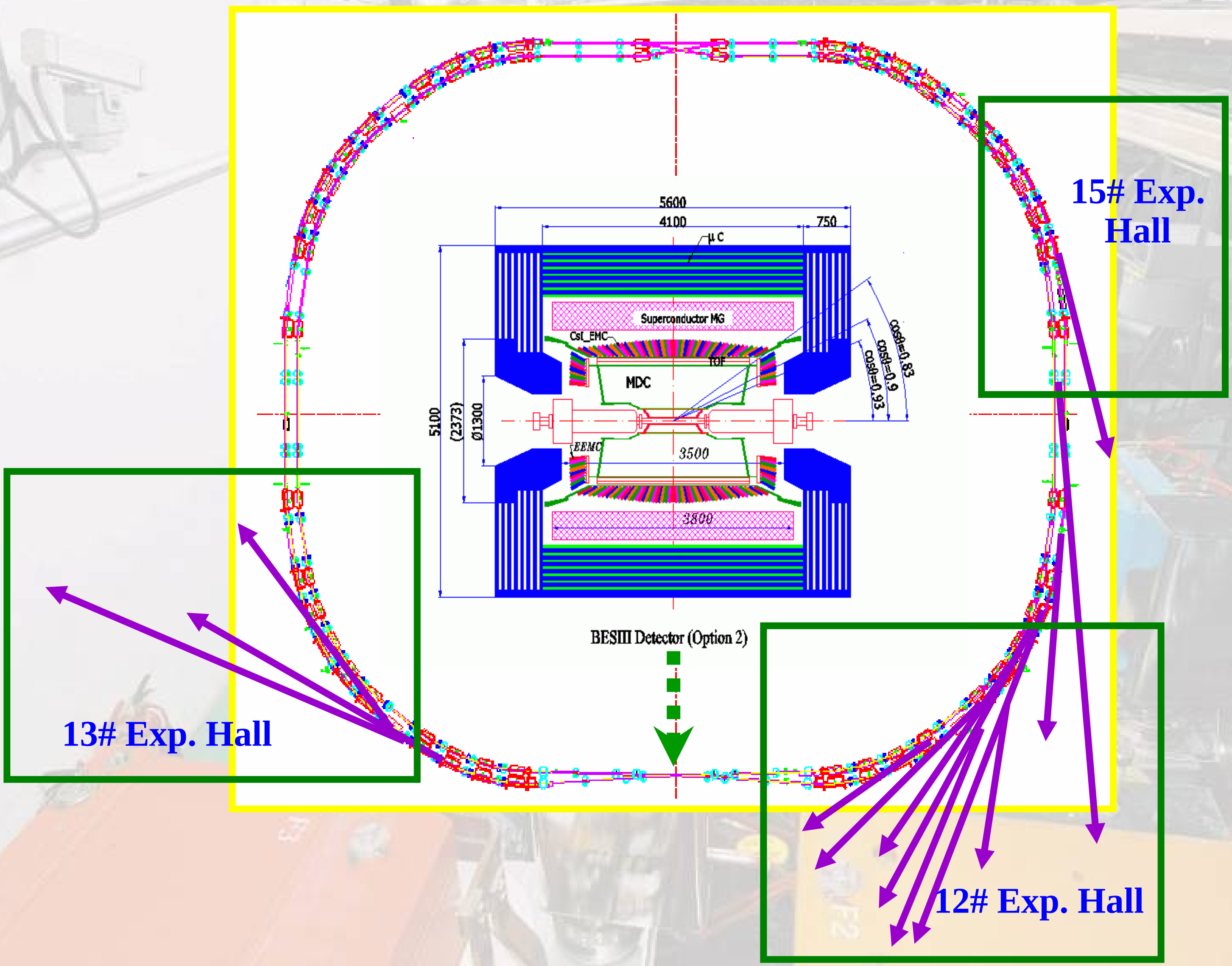


Putting the foot screws on floor

The installed outer ring in R3

Aligning and adjusting

2.3 BESIII and BSRF

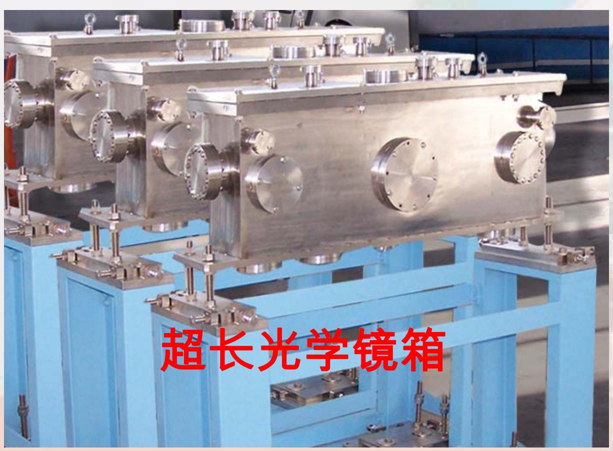


BESIII Detector

Y.F.Wang, Inter. Journal of Modern Physics A, Vol.21(2006), 5371-5381.

BSRF

- Commissioning together with SR beam lines was carried out.
- Beams have been provided for SR users since Dec. 25,



BEPCII: *a double-rings high luminosity e^--e^+ collider*

(3) Commissioning

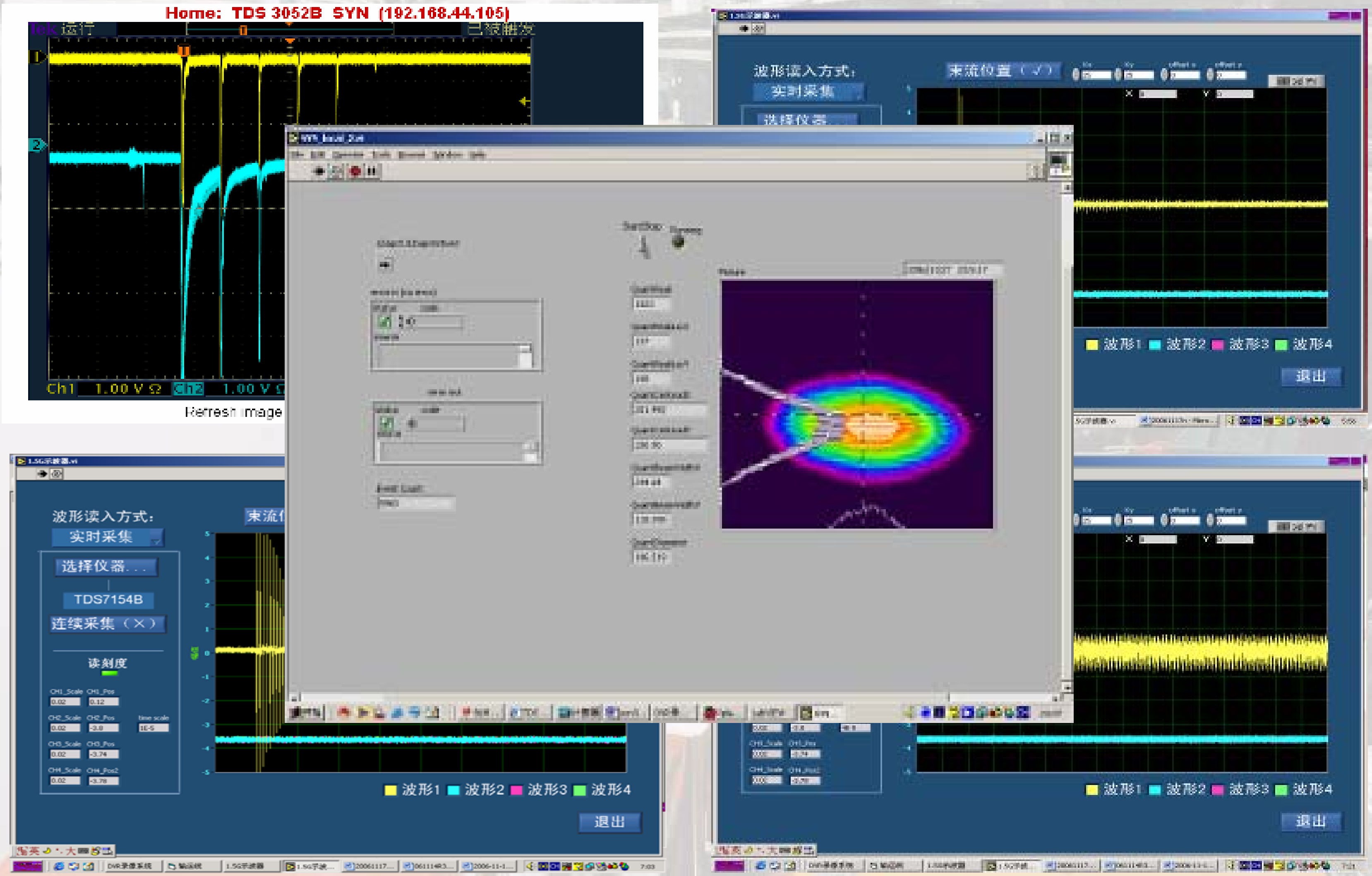
- **The operation of the BEPC completed on July 4, 2005, dismount of the old ring started.**
- **After 16 months' hard work, the storage ring installation was finished in early November 2006 except the cryogenics of the magnets.**
- **It was decided to install conventional magnets in the IR to start storage ring commissioning and SR operation.**
- **In the meantime, improvement of the cryogenics system and measurement of the SC magnets are being carried out at the BESIII off-line position.**

IR with conventional magnets

Some Results of the SR ring commissioning

Parameters	Unit	Measured	Design
Operation Energy	GeV	2.5	2.5
Injection energy	GeV	1.89	1.89
Circumference	m	241.130	241.127
RF voltage	MV	1.5	1.5~3.0
Tunes ($\nu_x/\nu_y/\nu_s$)		7.269/5.399/ 0.0242	7.270/5.370/ 0.0249
Beam emittance	nm·rad	100	
Bunch number		~100	200-300
Beam current	mA	200	250

The early commissioning



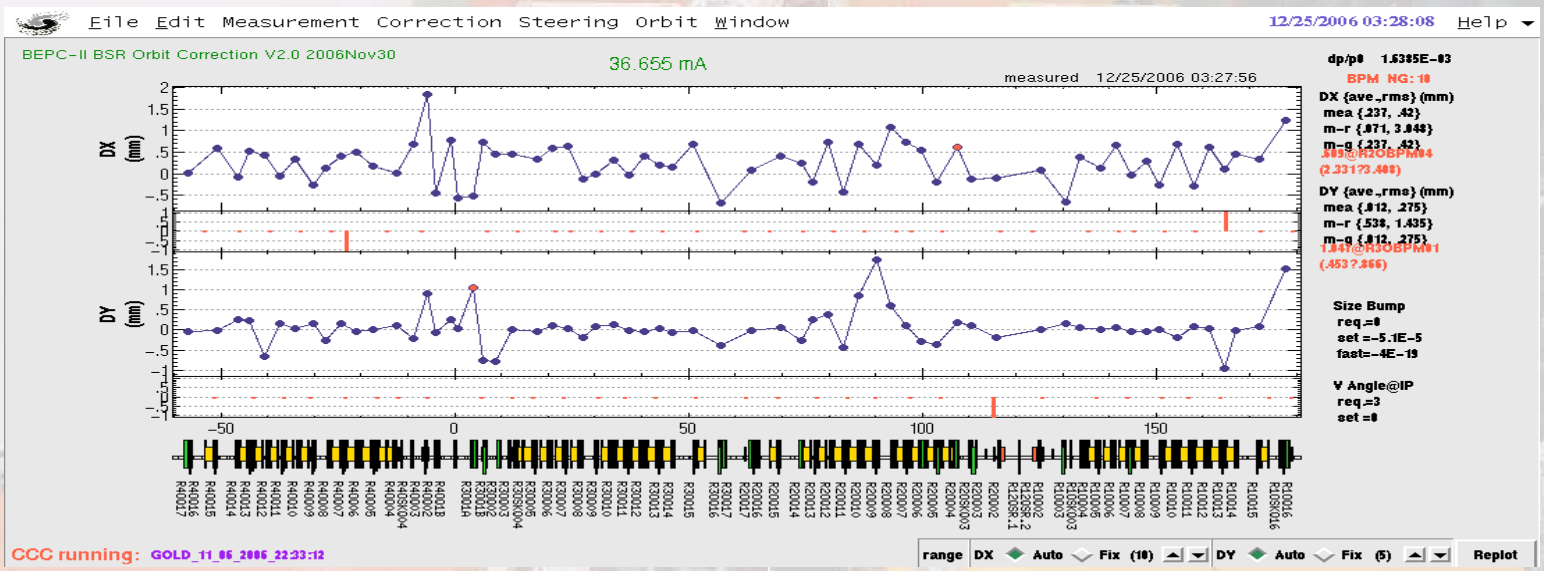
When the first electron beam stored in the ring…

Hardware systems debug

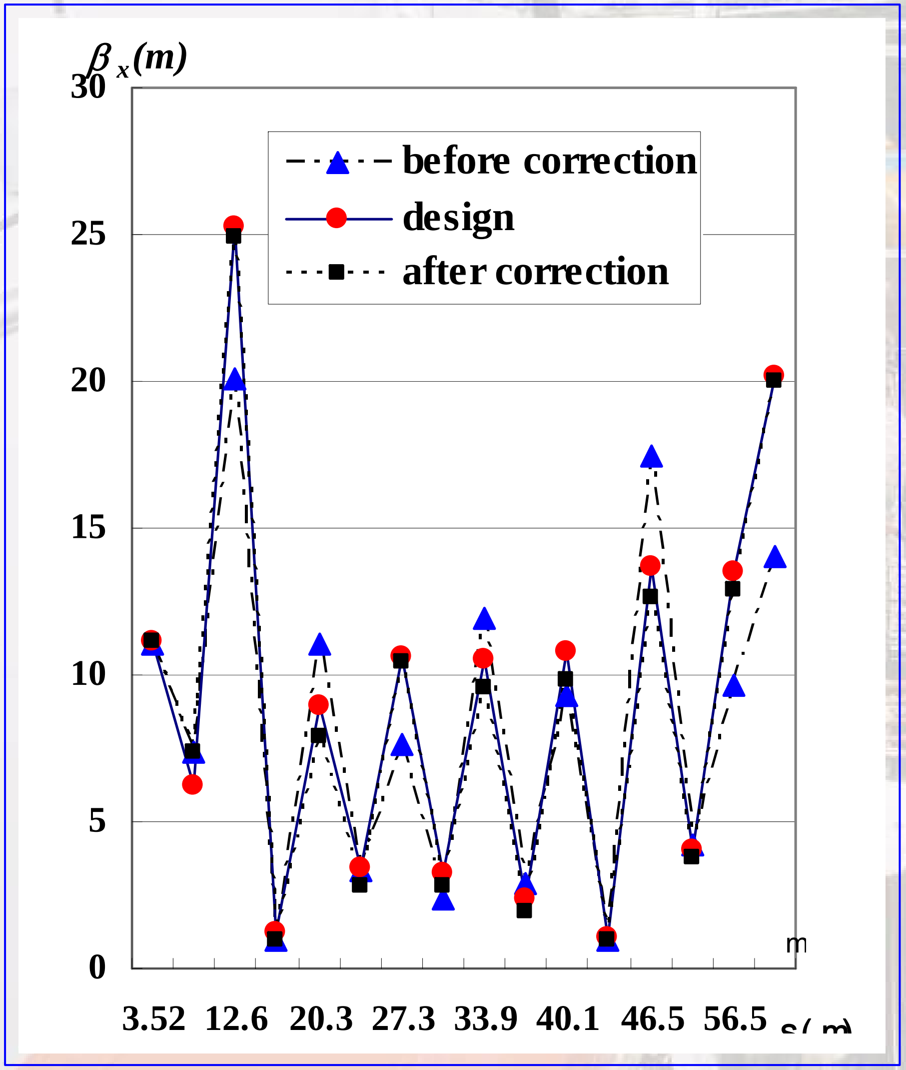
- **Power supply re-calibration with a larger current range;**
- **Misconnection of some corrector power supplies found and amended;**
- **Cables of the BPM’s re-calibrated;**
- **Offsets of the BPM’s were measured with beam based alignment;**
- **Some “bad” BPM’s, judged by 3-button check, were disabled.**

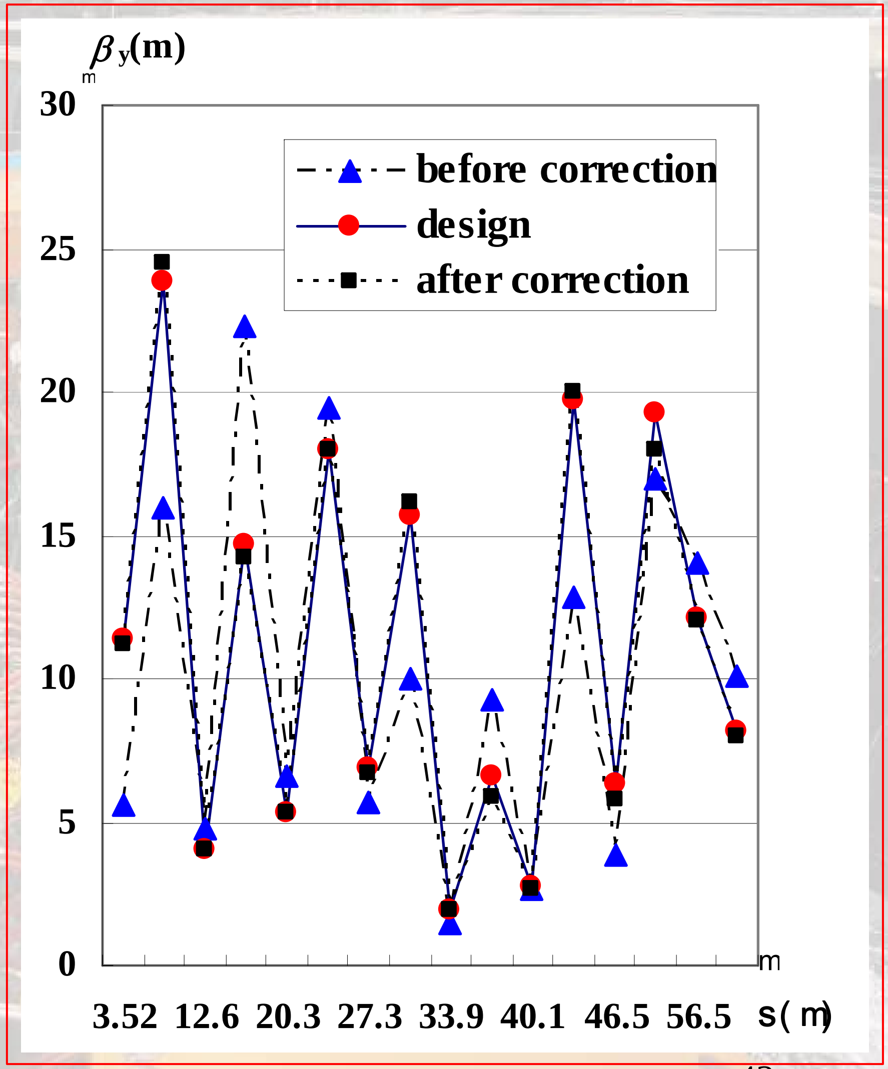
Orbit Correction

The orbit correction with transfer functions was performed. The residual rms orbit distortion after correction can be reduced to 0.42mm and 0.27mm on the horizontal and vertical planes, respectively

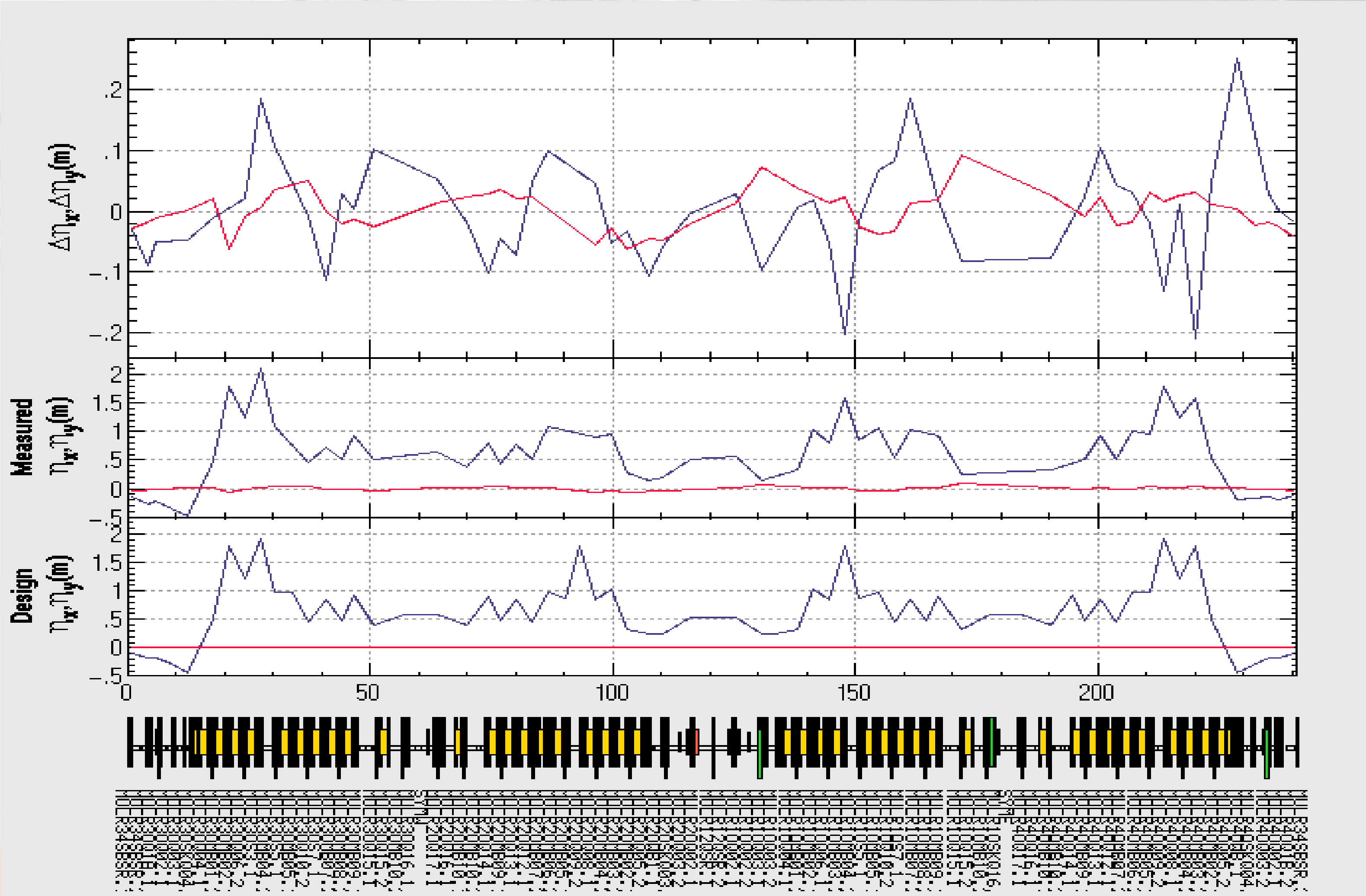


Twiss parameter measurement



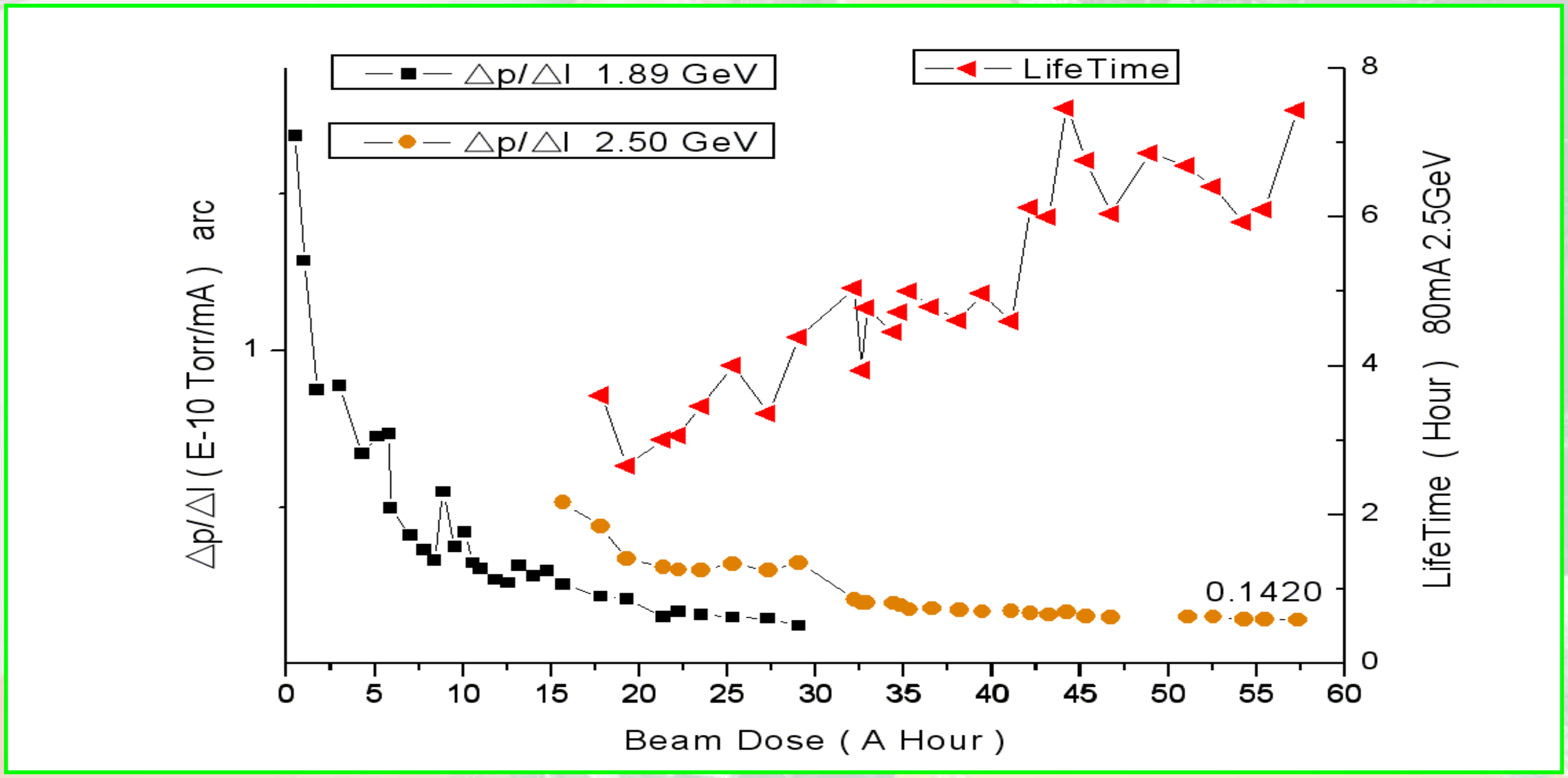


Dispersion function measurement

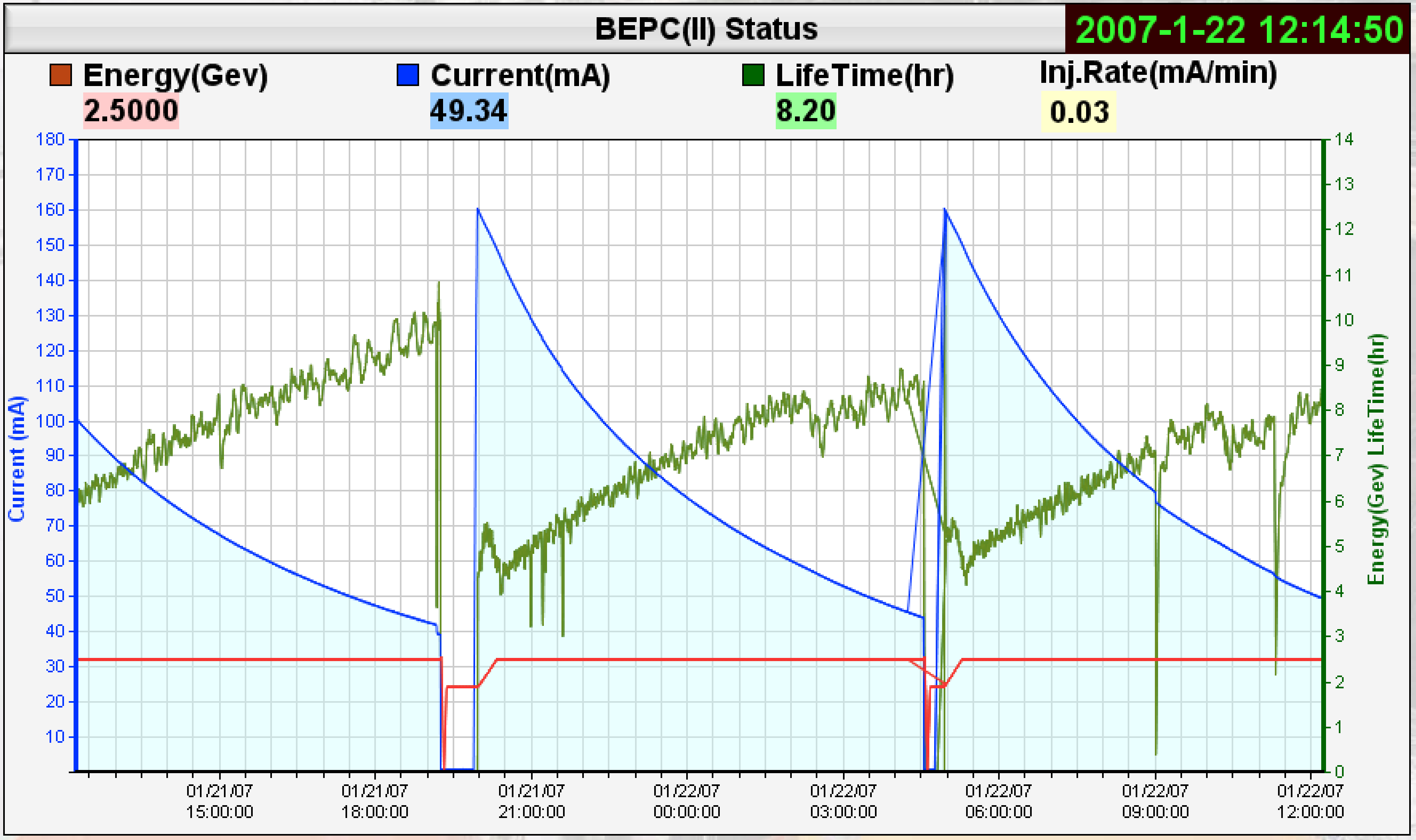


Beam current and lifetime

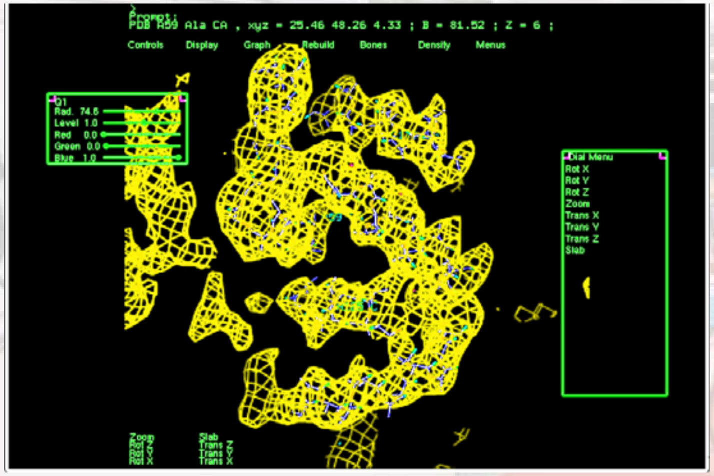
- Maximum beam current reached 250 mA at 1.55 GeV and 1.89 GeV with no limit indicated.
- By improving the vacuum pressure with the accumulated beam dose, beam lifetime increases smoothly.



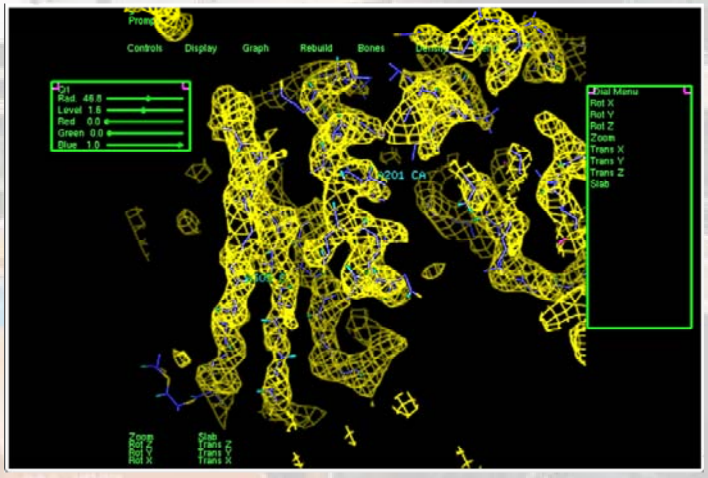
Joint commissioning & SR operation



SR user experiments, examples

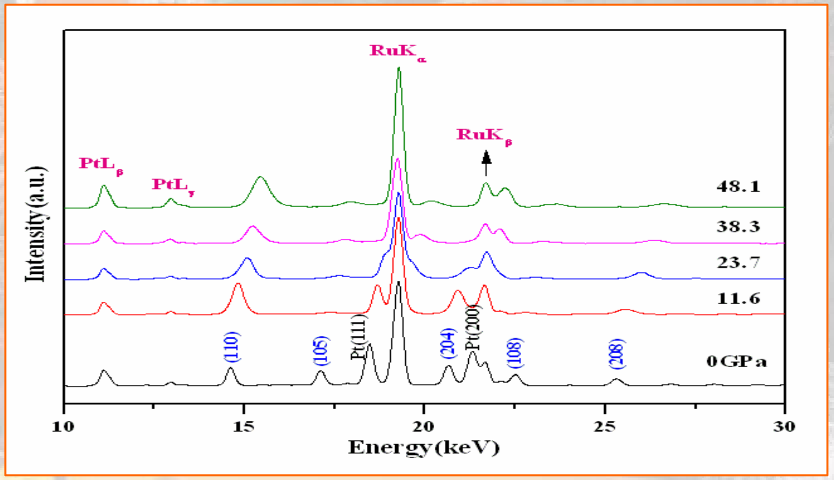


A structure and function unknown protein



Sm423 – a protein in Serine degradation pathway

Sm424 – a protein in Serine degradation pathway



X-ray diffraction of BaRuO3 under high pressure

BEPCII Schedule

2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 201
Q1 Q2 Q3 Q4 Q1 Q2 Q3 Q4 Q1 Q2 Q3 Q4 Q1 Q2 Q3 Q4 Q1 Q2 Q3 Q4 Q1 Q2 Q3 Q4 Q1 Q2

★ Start Construction

- The first round SR operation will be ended on Feb. 1, 2007.
- Commissioning for the e- ring, the e+ ring and e+-e- collision will be followed.
- The second round SR operation of one month will be arranged in June.
- The SCQ’s tested in the off-line position during the commissioning should be ready for installation in July.
- After the SCQ’s are installed, the BEPCII commissioning will be contin-ued.
- It is expected that the luminosity would be high enough for the BESIII detector to start up by end of 2007.

07-8-31 Move BESIII into IR

07-9-19 BEPC/BESIII commissioning

Concluding Remarks

- As a natural extension of the BEPC, the BEPCII is a double ring e^{-}-e^{+} collider with design luminosity of $1\times10^{33}cm^{-2}\,s^{-1}$ in 1-2.1 GeV and a SR source of 2.5 GeV, 250 mA.
- Significant progress has been made since the project started construction in the beginning of 2004;
- The success of the initial commissioning and early operation encourage us to go ahead;
- There is still a long way to go before taking about the full success.
- The success will of enable us for the future projects, such as CSNS, XFEL and ILC.
- The challenges and physical prospects of the BEPCII call for further cooperation Asia- & World-wide.

Thank You

Institute of High Energy Physics

Jan. 31, 2007, APAC2007

RRCAT, Indore, India