THE BEPC AND ITS SECOND PHASE CONSTRUCTION

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2. Basic Design of the BEPCII
3. Key Technologies and Systems
4. Budget and Schedule
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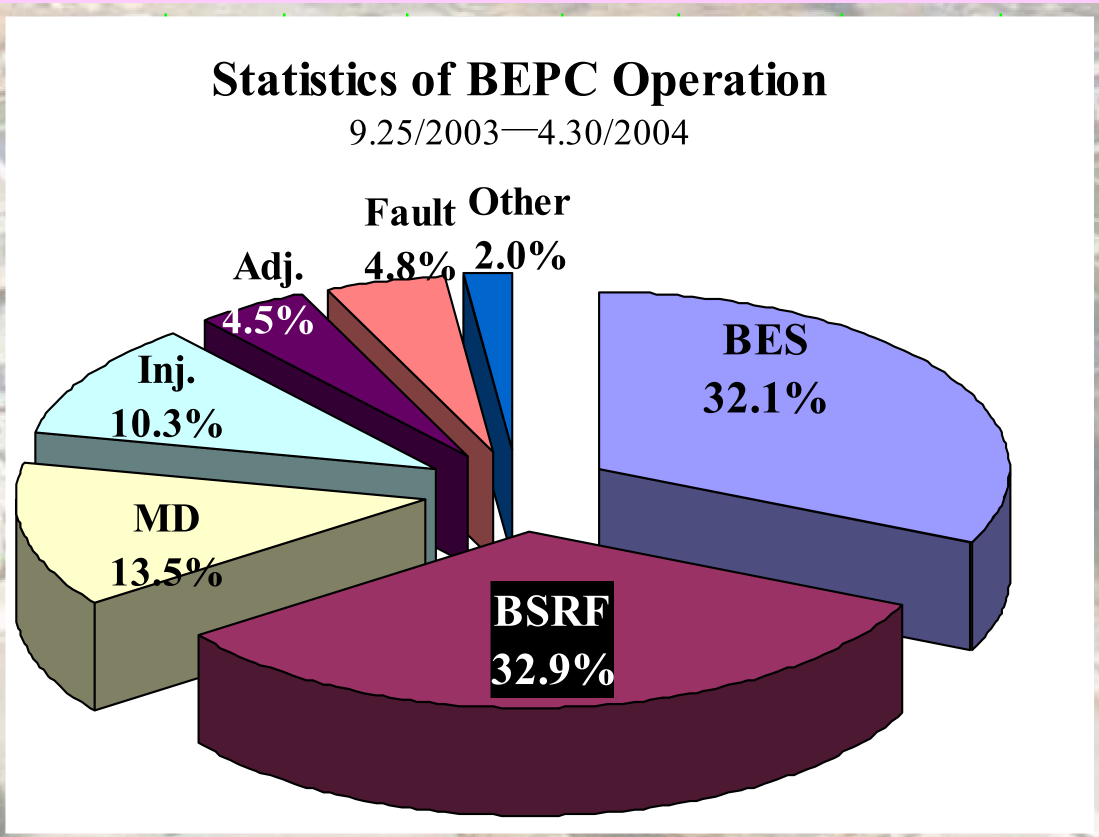
1. A Brief Introduction on BEPC

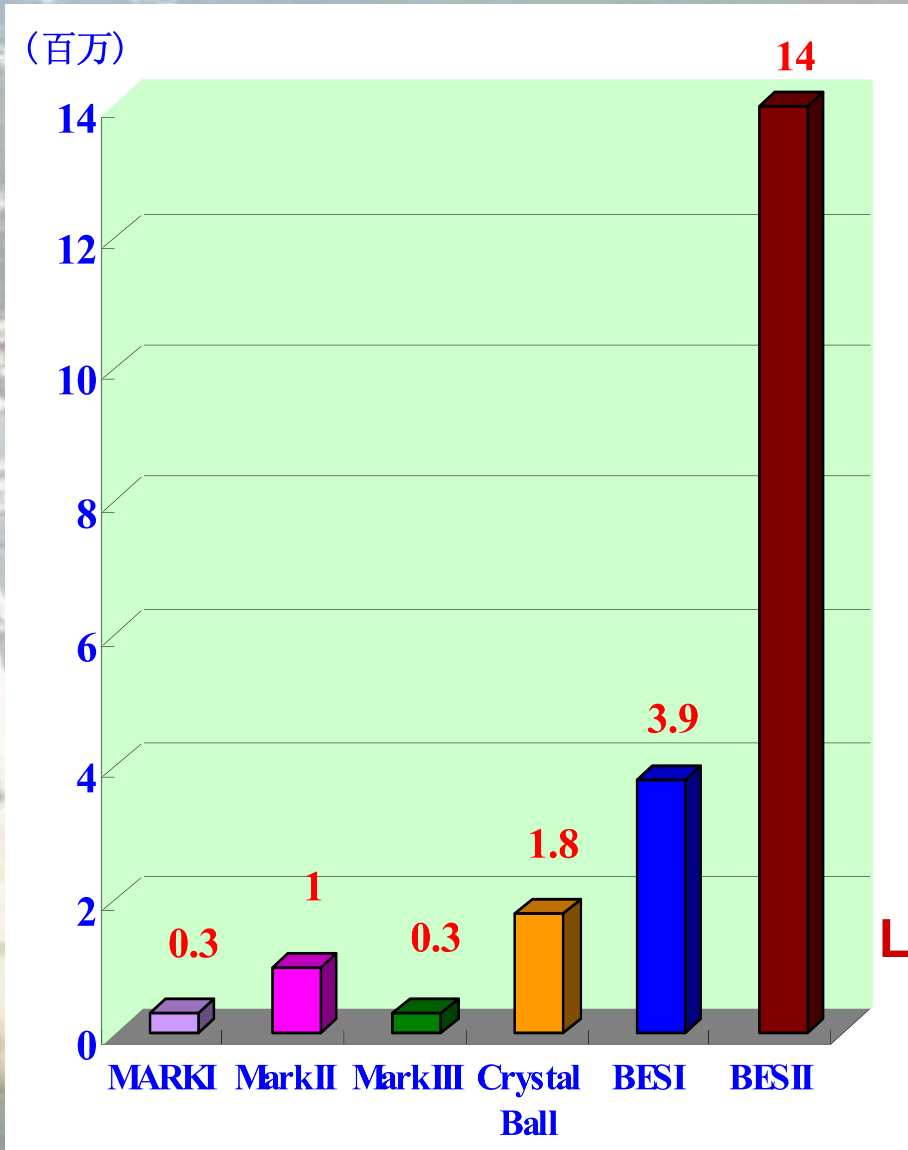
- **The Beijing Electron-Positron Collider (BEPC) was constructed (1984-1988) for both high energy physics and synchrotron radiation research.**
- **The machine has been well operated for more than 15 years since it was put into operation in 1989.**
- **BEPC finished running on April 30, 2004, when the removal of BES and the upgrade of the linac mark the beginning of the BEPCII installation.**

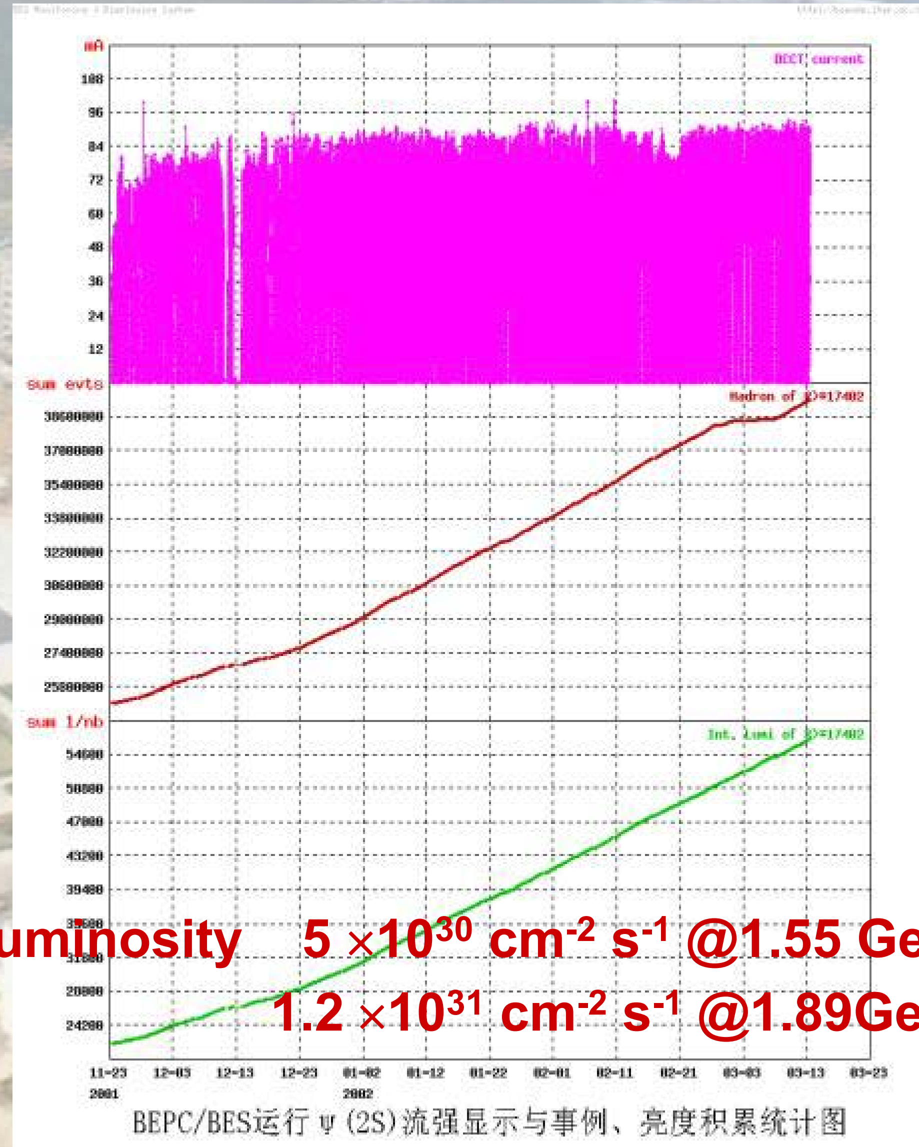
BEPC Operation and Performance

Year	BES	BSRF	MD	Inj	Adj.	Fault	Other	Total
2003	2324	992	656	804	923	313	18	6030 hrs
2004	1678	1721	706	539	233	249	106	5232 hrs



BEPC/BES ψ(2s) Operation



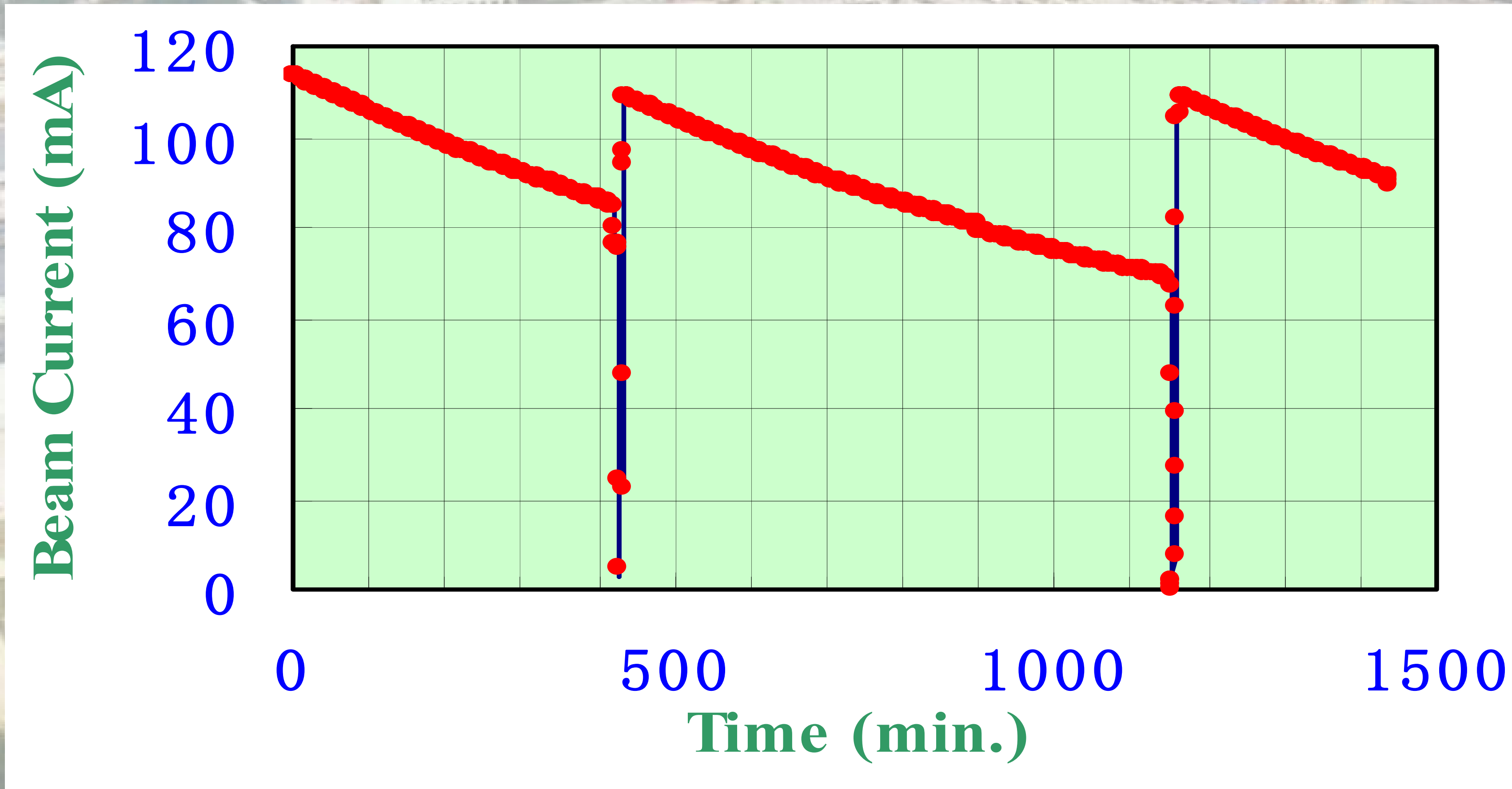


Luminosity 5×10^{30} cm^{-2} s^{-1} @1.55 GeV,
1.2×10^{31} cm^{-2} s^{-1} @1.89GeV

BSRF dedicated operation

70 days with three times for about 300 users every year

I_{max}=140 mA, ε_{x0}=76 nm, τ=20~30 hrs., N_{inj}=2



2. From BEPC to BEPCII

Remains as dual-purpose facility

- **Rich HEP: Charm and τ physics**
  - Light hadron spectroscopy, charmed mesons and τ at the thresholds; Hadron production mechanism;
  - Precision R values, ambiguous' structures in 3.8-4.2 GeV.
  - Searches for glueball, hybrids and exotic states;
  - ...
- **SR research with improved performance**

To meet the challenges in the precision measurement:

6×10^9 J/ψ, 2×10^9 ψ' per year are expected

➔➔➔ BEPCII/BESIII was approved in 2003.

Luminosity Strategy of BEPCII

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

Choose large ε_x & optimum param.: I_b=9.8mA, ξ_y=0.04

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

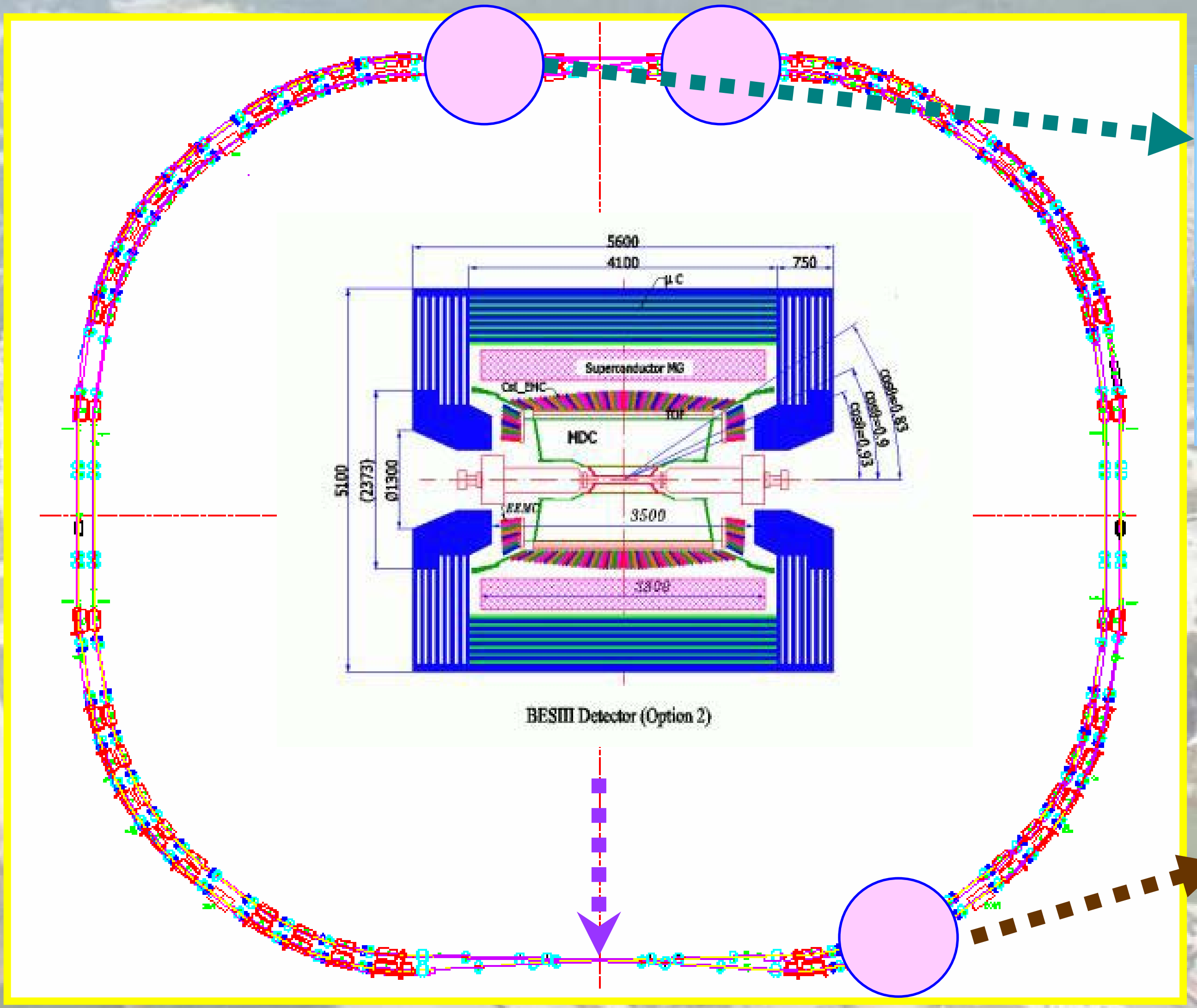
Micro-β: β_y^* =5cm ➔ 1.5 cm
SC insertion quads

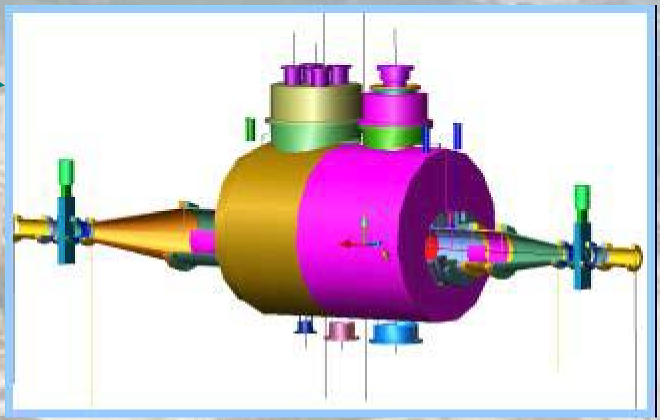
Reduce impedance +SC RF
σ_z =5cm ➔ <1.5cm

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

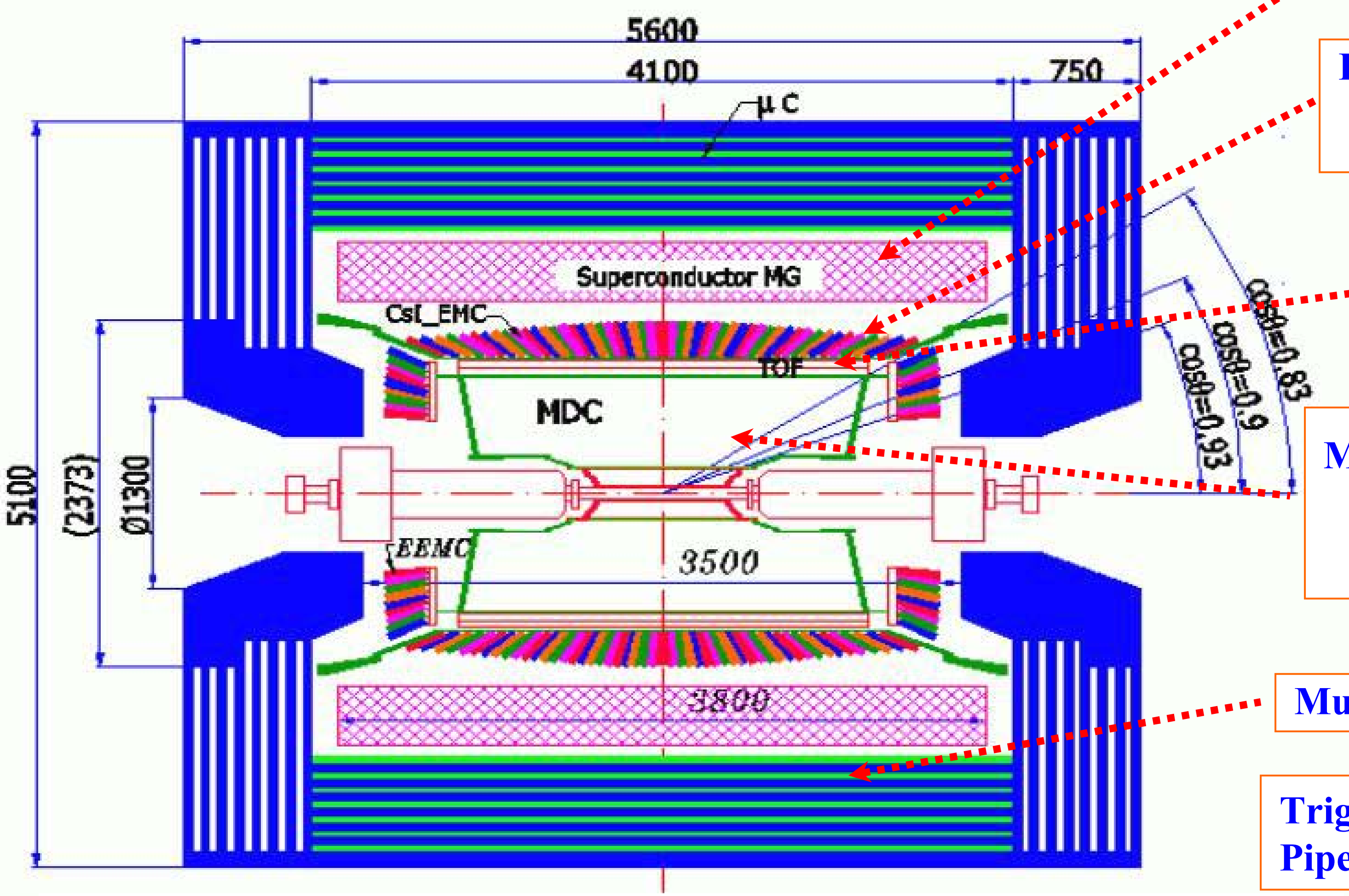
L_{BEPC}=1.0×10^{31} cm^{-2}s^{-1} ➔ L_{BEPCII} =1×10^{33} cm^{-2}s^{-1}

BEPCII: *a high luminosity double–ring collider*





BESIII Detector



Magnet: 1 T Super conducting

EMCAL: CsI crystal
ΔE/E = 2.2% @1 GeV
σz = 0.5 cm/√E

TOF:
σT = 100 ps Barrel
110 ps Endcap

MDC: small cell & He gas
σ_{xy}=130 μm
s_p/p = 0.5% @1GeV
dE/dx=6%

Muon ID: 9 layer RPC

Trigger: Tracks & Showers
Pipelined; Latency = 2.4 ms

- **Adapt to high event rate of BEPCII:**
  10^{33}cm^{-2} s^{-1} and bunch spacing 8ns
- **Reduce sys. errors to match high statistics**
  Photon measurement, PID…
- **Increase acceptance**

Data Acquisition:
Event rate = 3 kHz
Thruput ~ 50 MB/s

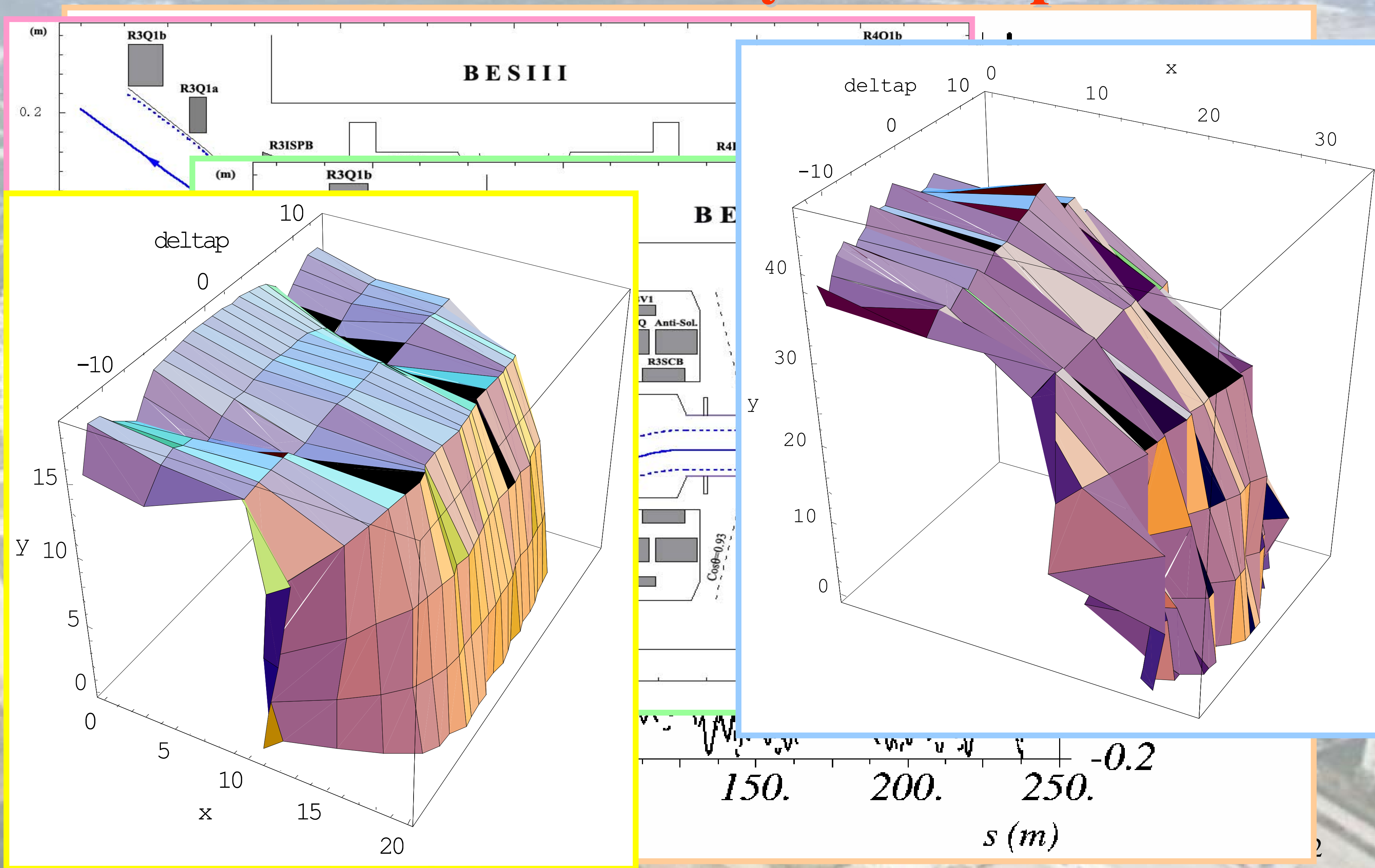
2.1 Design Goals and Main Parameters

Beam energy range	1–2 GeV
Optimized beam energy	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 of BEPCII

Parameters	Unit	Collision	SR
Operation energy (E)	GeV	1.0–2.0	2.5
Injection energy (E_{inj})	GeV	1.55–1.89	1.89
Circumference (C)	m	237.53	241.13
β^*-function at IP (β_x^* / β_y^*)	cm	100/1.5	-
Tunes ($\nu_x / \nu_y / \nu_s$)		6.53/7.58/0.034	8.28/5.18/0.035
Hor. natural emittance (ε_{x0})	mm·mr	0.14 @1.89 GeV	~0.10
Damping time ($\tau_x / \tau_y / \tau_e$)		25/25/12.5 @1.89 GeV	12/12/6
RF frequency (f_{rf})	MHz	499.8	499.8
RF voltage per ring (V_{rf})	MV	1.5	3.0
Bunch number (N_b)		93	multi
Bunch spacing	m	2.4	0.6
Beam current	mA	910 @1.89 GeV	250
Bunch length (cm) σ_l	cm	~1.5	-
Crossing angle	mrad	11×2	-
beam-beam param. ξ_y		0.04	-
Beam lifetime	hrs.	2.7	>10
luminosity@1.89 GeV	$10^{31}cm^{-2}s^{-1}$	100	-

2.2 The lattice and dynamic aperture



2.3 Single beam collective effects

- Strict impedance budget to control bunch lengthening

$Z/n|_{eff}$~0.2Ω, $I_{th} = 37\text{mA}$ ➔ $I_b = 9.8\text{mA}$, σ_l <1.5 cm

- Bunch to bunch feedback system to damp the coupled bunch instability due to HOMs of RF cavity, resistive-wall and ion effect:

τ_L=5 ms, τ_T =1 ms

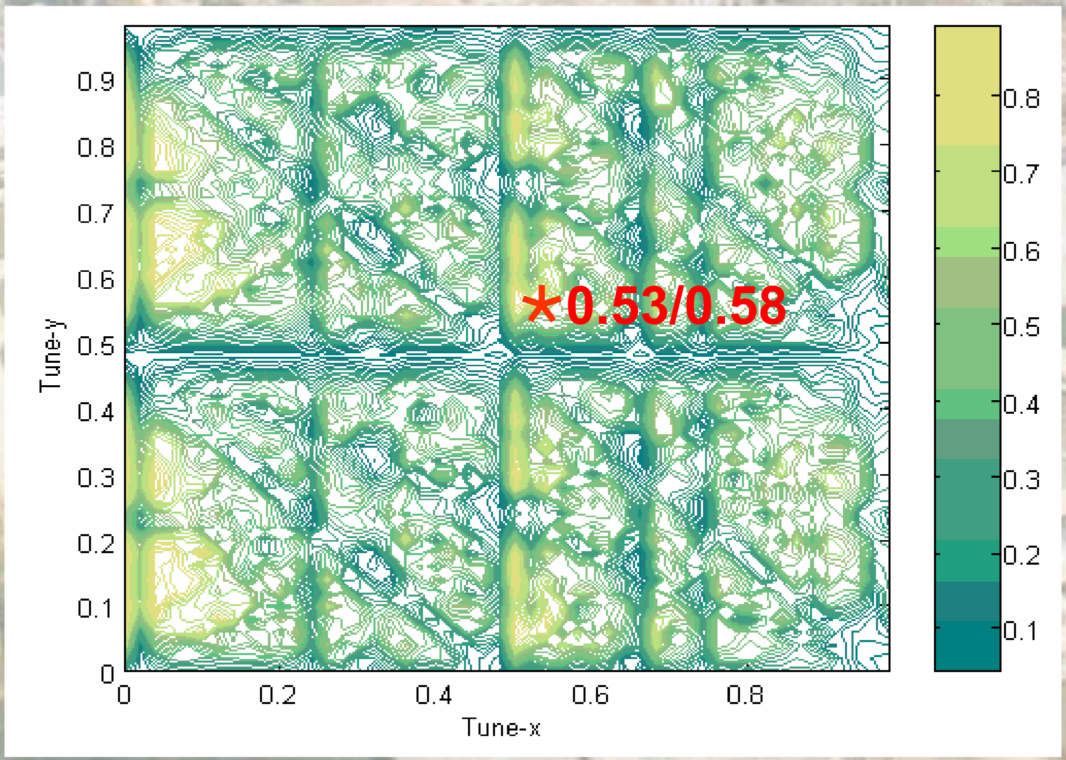
- Electron cloud instability:

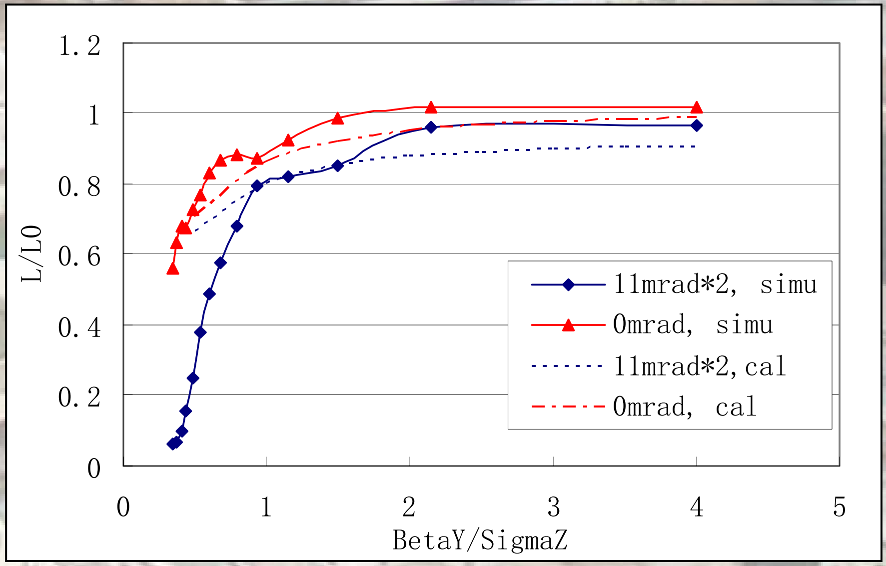
Antechamber with TiN coating for e^+ ring

Single beam instabilities can be controlled!

2.4 Beam-beam effects

- **Beam-beam simulation with BBC code has shown that the beam-beam parameters of 0.04 and crossing angle of 11mrad×2 are acceptable.**





2.5 Beam Lifetime and Average Luminosity

Effect	Condition	Lifetime (hrs.)
Beam-gas interaction	P= 5×10^{-9} Torr; 80% H_2, 20% CO	26
Quantum effect	$A_x \sim 10\ \sigma_x$	>10^5
Beam-beam bremsstrahlung	$\xi_{x,y}$=0.04, β_y^*=1.5 cm	5.1
Touschek effects	I_b = 9.8 mA, V_{rf} = 1.5 MV	7.1
Overall lifetime	$\tau^{-1}=\Sigma\tau_i^{-1}$	~3

$$\langle L \rangle = \frac{\int_0^{t_c} L(t)dt}{t_c + t_f} = L_0 \tau_L \frac{1 - e^{-t_c/\tau_L}}{t_c + t_f}$$

Taking τ_L =1.5 hrs., t_f= 0.4 hr. and L_0=1×10^{33} $cm^{-2}s^{-1}$, With top-off injection, the average luminosity:

$<L>_{max}$> 0.6×10^{33}.

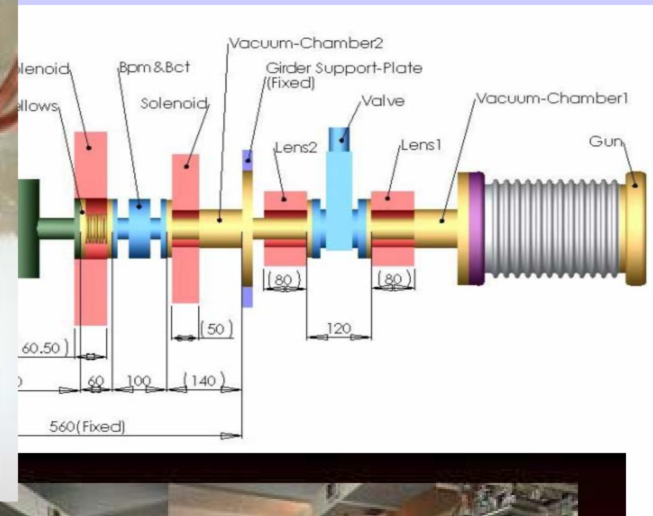
3. Key Technologies & Systems

- Injector Upgrades
- RF System
- Injection Kickers
- Magnet & Power Supply
- Vacuum System
- Beam Instrumentation & Control
- Interaction Region
- Cryogenics

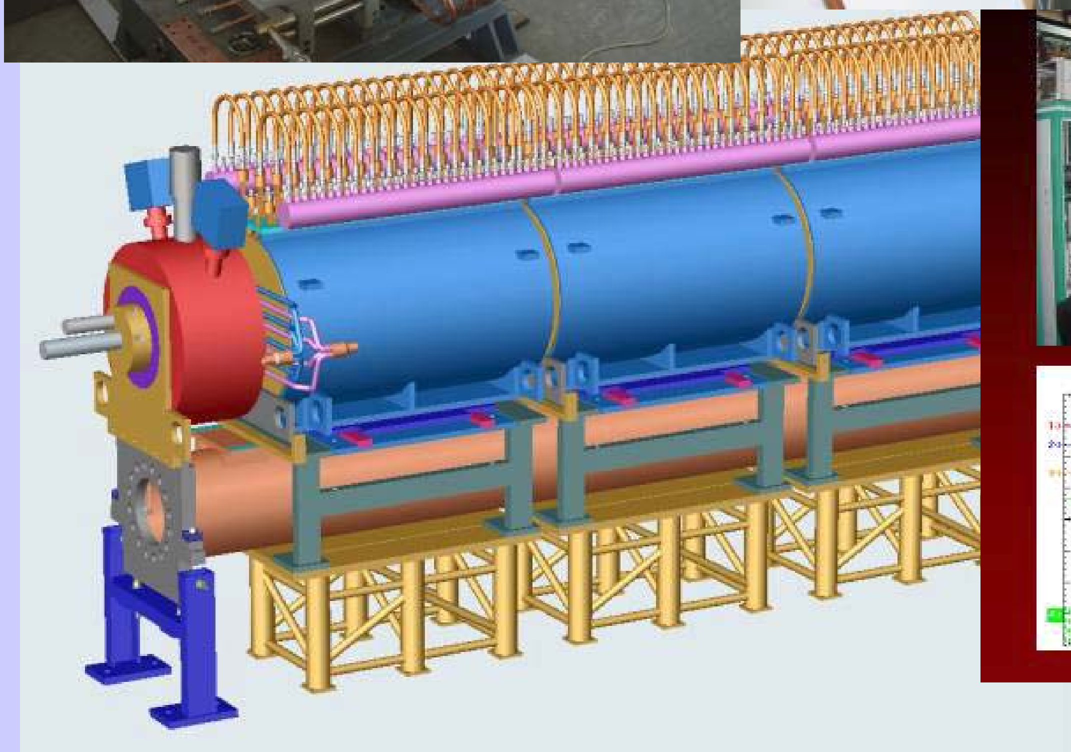
3.1 Injector upgrading

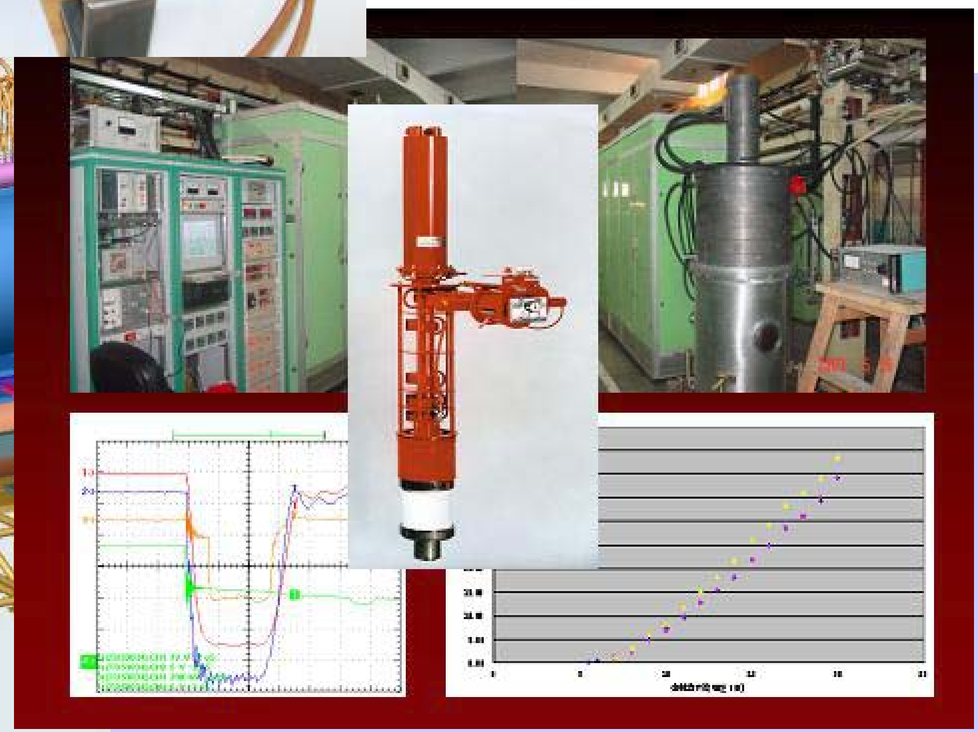
1. Upgrade Goal

	BEPC	BEPCII
Injection Energy	1.30 GeV	1.89 GeV
Beam Current (e+)	4.0 mA	40 mA
Energy Spread (e+)	±0.8 %	±0.5 %
Emittance (e+) (e-)	1.70 mm-mrad 0.58 mm-mrad	1.60 mm-mrad 0.20 mm-mrad
Pulse Repe. Rate	12.5 Hz	50 Hz
Injection Rate (e+)	3 mA/min	50 mA/min



Vacuum-Chamber2
Bpm & Bct
Girder Support-Plate
(Fixed)
Solenoid
Valve
Vacuum-Chamber1
Lens2
Lens1
Gun
80
80
50
120
60.50
60
100
140
560(Fixed)



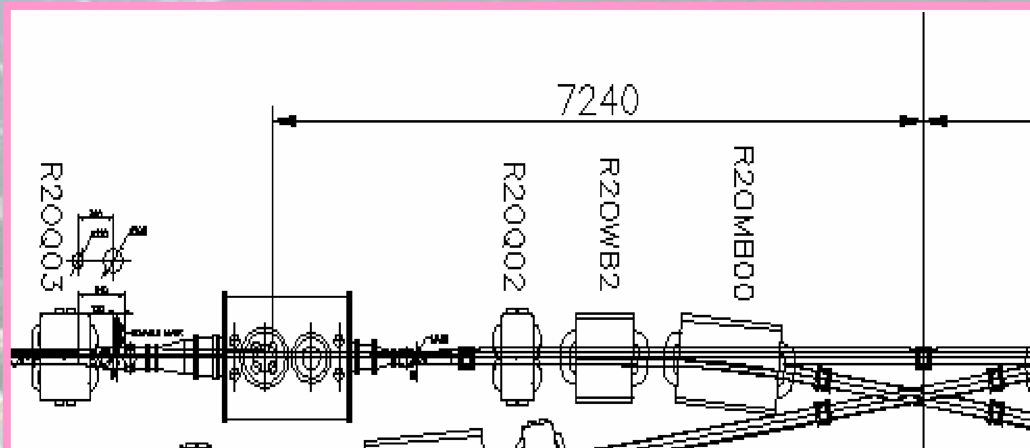


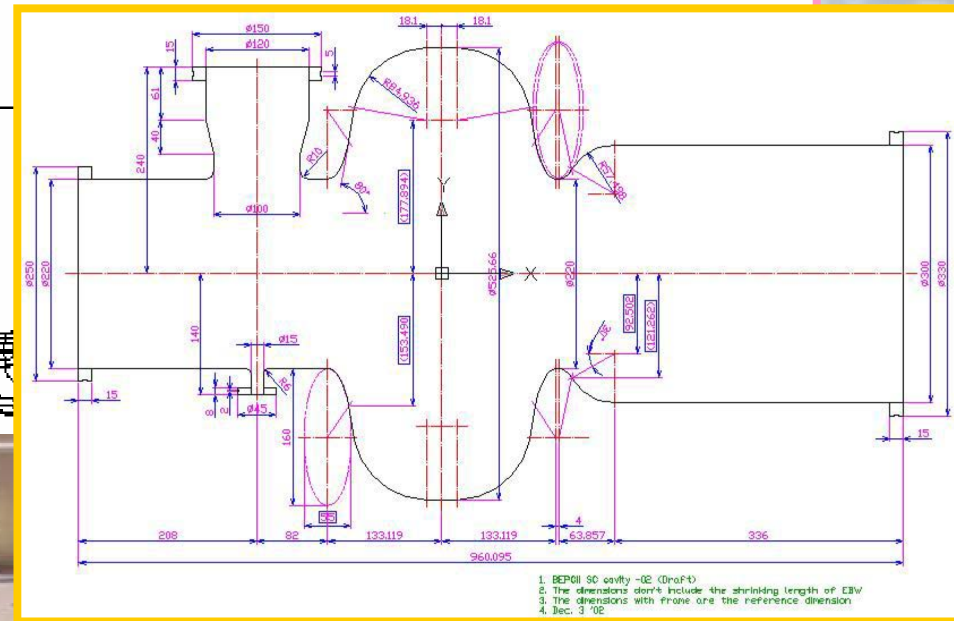
3.2 RF System with Superconducting cavity

RF frequency	f_{rf}	$7/40 \times 2856 = 499.8$ MHz
RF voltage	V_{rf}	1.5 MV
Number of Cavities	N_{rfc}	2×1
Energy Loss per Turn @ 1.89 GeV	U_{rf}	123 keV/ring
Total Beam SR Power @ 1.89 GeV	P_b	131 kW/ring
Total Power of RF transmitters	P_{rf}	$2 \times$ 250 kW

- **Superconducting Cavity is adopted for high voltage and low HOMs.**
  - **Strategy: to take advantage of collaboration with SSRF, Cornell and KEK and to apply the existing industrial technology.**

Superconducting cavity





3.3 Injection Kickers

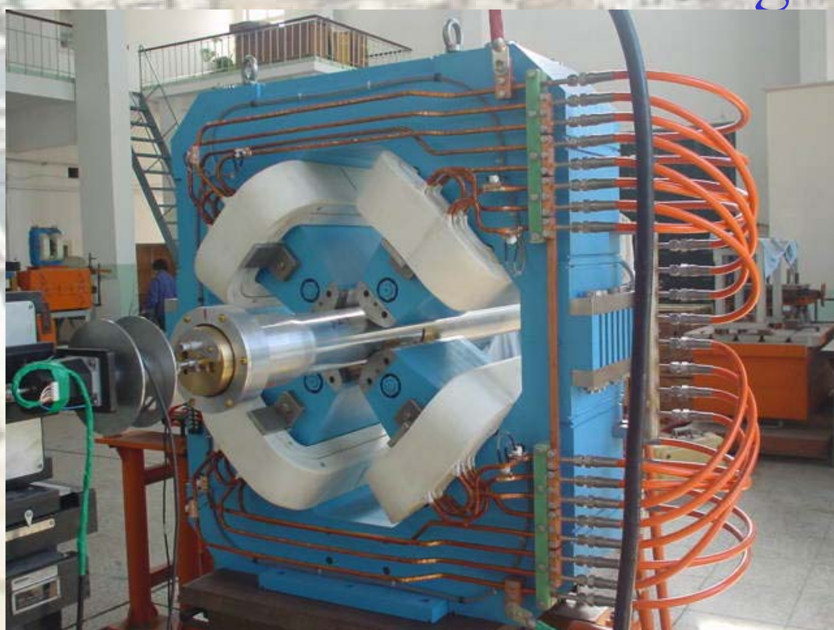
- To meet the challenges both on the field uniformity and low beam impedance. A modified slotted-pipe kicker is designed combining advantages of the slotted-pipe and ceramic vacuum chamber kickers.
- The prototype of power source and the field measurement are being developed.

eform
e
plane
plane

3.4 Magnet & Power Supply

- **Magnet**

  Challenges : to meet space limit…
  but with large apert…
  and …



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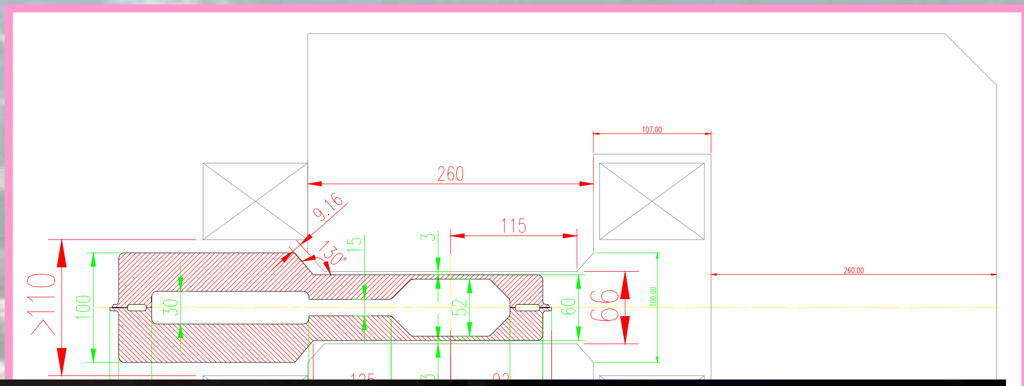
  … numb… (4)
  … hase-…
  … er ; S…)
  Prototypes being made and teste…

3.5 Vacuum System

- Two challenges: Vacuum pressure & Impedance.
- The dynamic vacuum at a high beam current should satisfy the requirements of sufficient beam lifetime, low background in the detector. The design vacuum pressure:
  5×10^{-9} Torr in the arc and 5×10^{-10} Torr in the IR.
- In order to improve vacuum and save the longitudinal space, the antechamber structure will be used for both e^+ and e^- rings.
- To reduce the impedance, the vacuum chamber should be as smooth as possible.
- Inner surface of the arc vacuum chambers for the e+ ring will be coated with 100-nm of TiN to reduce SEY. A test setup using DC sputtering has been developed.

Progress on vacuum system



3.6 Beam Instrumentation & Control

- **Beam Instrumentation will adopt the state-of – the-art technologies**
  - **Beam Position Monitors**
  - **Bunch Current Monitors**
  - **Beam loss monitors**
  - **Synchrotron Light Monitors**
  - **Beam Feedback System**
  - **IP beam position control**
- **Control System will base on EPICS environment, prototype system being created**

3.7 Interaction Region

- **Collision Mode**
  - **Separate two beams rapidly into the two rings with**

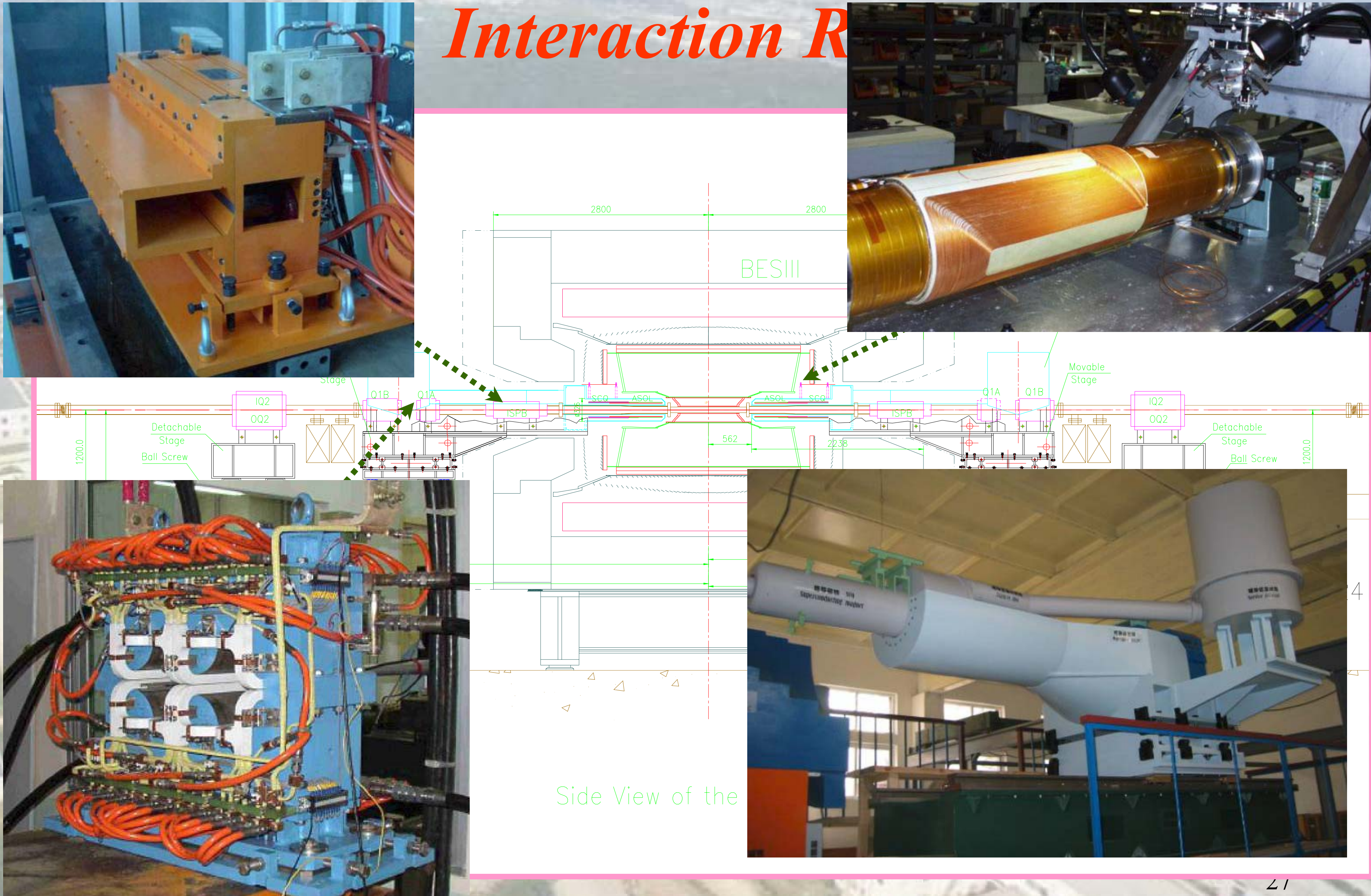
Crossing angle	11 mrad × 2
SCQ	26 mrad × 2
ISPB (inner ring)	65.5 mrad

  - **β-functions at IP are 1.0m/0.015m.**
  - **Compensating detector solenoid field with anti-solenoid and skew quadrupole in the SC magnet package.**
- **SR Mode**

  Connect two half outer rings with SCB 27 mrad

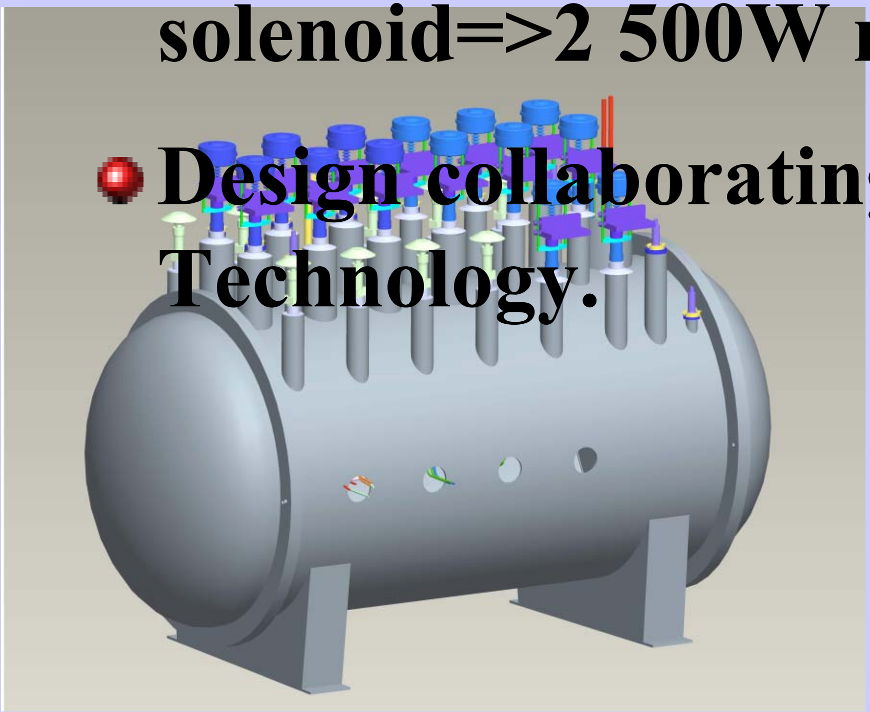
- **Very limited space=>challenging on design of magnets and vacuum chambers**

Interaction R



3.8 Cryogenics System

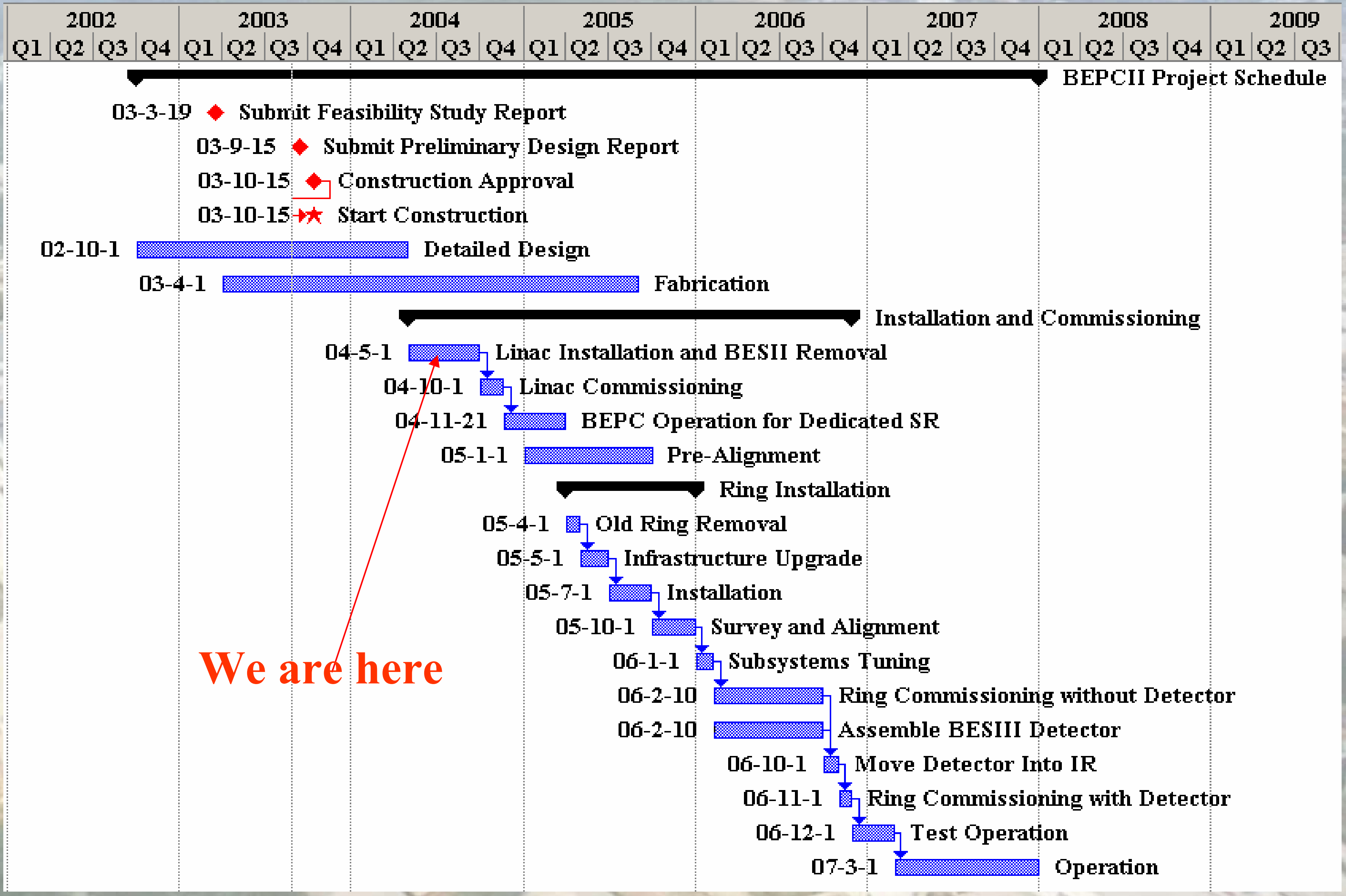
- The system is composed of four sub-systems: the central cryogenic plant and the three satellite cryogenic systems for the SRF cavities, the SCQ magnets, and the SSM solenoid=>2 500W refrigerators required
- Design collaborating with Harbin Institute of Technology.



4. Budget and Schedule

Linac Upgrading	44
Storage Rings	240
Detector	230
Utilities	80
Others	14
Contingency	32
Grand total	640M (77M$)

The project is expected to be finished in 4 years after its approval



5. Summary

- The BEPC has been well operated with many exciting HEP and SR results for 15 years since 1989.
- The BEPCII is designed as two-ring collider and its design luminosity is two order of magnitude higher than BEPC.
- Some key technologies and prototype have been developed, bidding for its equipments has been carrying out.
- International collaboration is promoted to accomplish the challenging and exciting project on schedule and budget.
- The installation of BEPCII started out since Apr. 30, 2004.
  The upgrade of linac will be finished in Oct. 2004;
  Installation of storage rings will be from Apr. 2005;
  Commissioning of the storage rings scheduled in Feb. 2006;
  Moving BESIII into IR will be in Oct. 2006.


Thank You
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