An Overview of the BEPCII Project

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On behalf of the BEPCII Team

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40-th ICFA Advanced Beam Dynamics Workshop on High Luminosity e^+e^- Factories

An Overview of the BEPCII Project

- The BEPCII Project
- The BEPCII Accelerators
- The BESIII Detector

(1) The BEPCII Project

Remains a dual-purpose facility

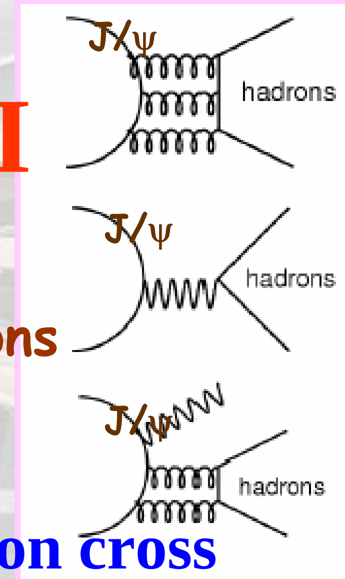
- **Charm and τ physics**
  - **Precision measurement of CKM matrix elements**
  - **Precision test of Standard Model**
  - **QCD and hadron production**
  - **Light hadron spectroscopy**
  - **Charmonium physics**
  - **Search for new physics/new particles ……**
- **Synchrotron radiation research**

Serve as a platform of multi-discipline researches with improved performance.

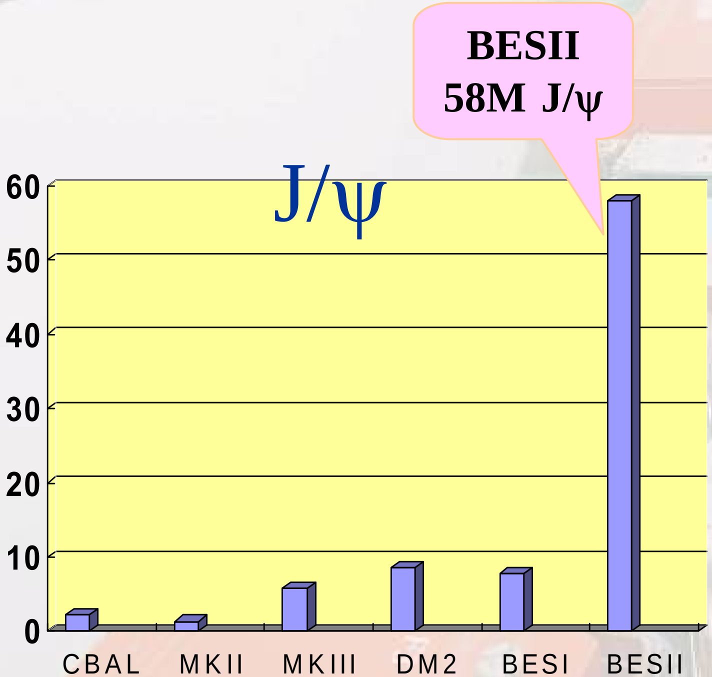
Physics results with BESII

Taking J/ψ decays as example

Ideal place to search for new types of hadrons



World J/ψ Samples (×10⁶)



- **Gluon rich**
- **Very high production cross section**
- **Higher BR to hadrons than that of ψ' ("12% rule").**
- **Larger phase space to 1-3 GeV hadrons than that of Y**
- **Clean background environment compared with hadron collision experiments, e.g., "*J^P, I*" filter**

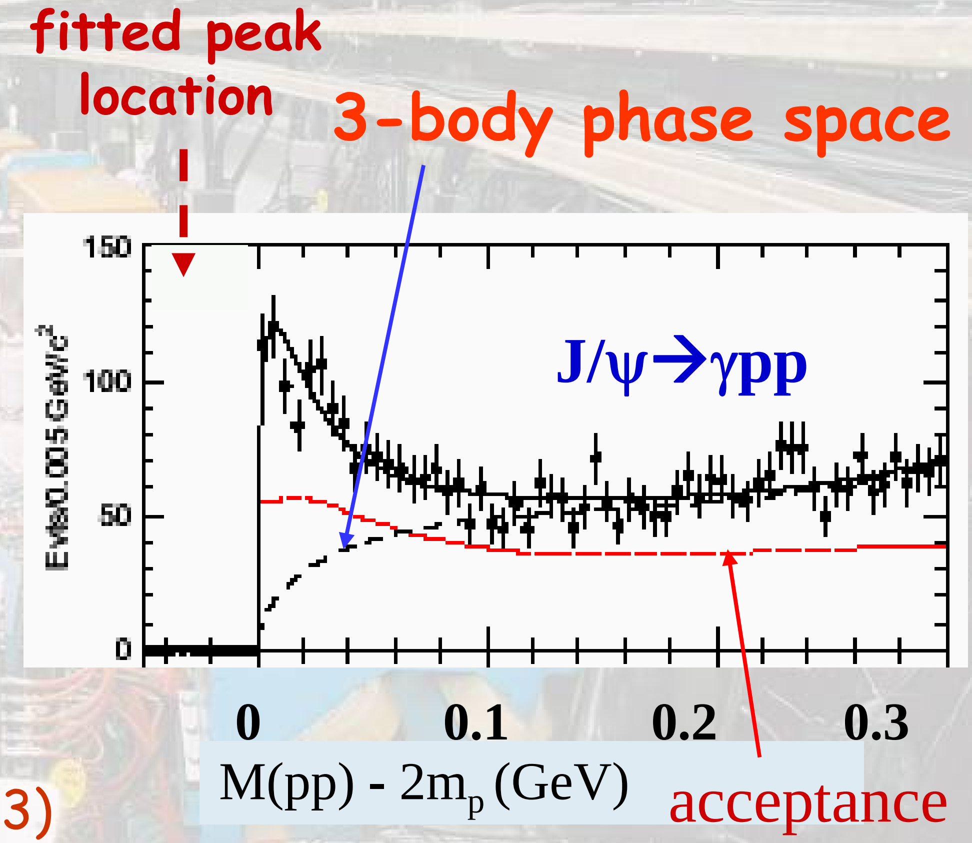
Threshold enhancement in $J/\psi \to \gamma p\bar{p}$

- **BES: enhancement seen near threshold in M_{pp} in $J/\psi \to \gamma p \bar{p}$.**
- **If fitted with an *S*-wave resonance:**

$$M = 1859^{+3}_{-10}\,{}^{+5}_{-25}\ \mathrm{MeV}/c^2$$

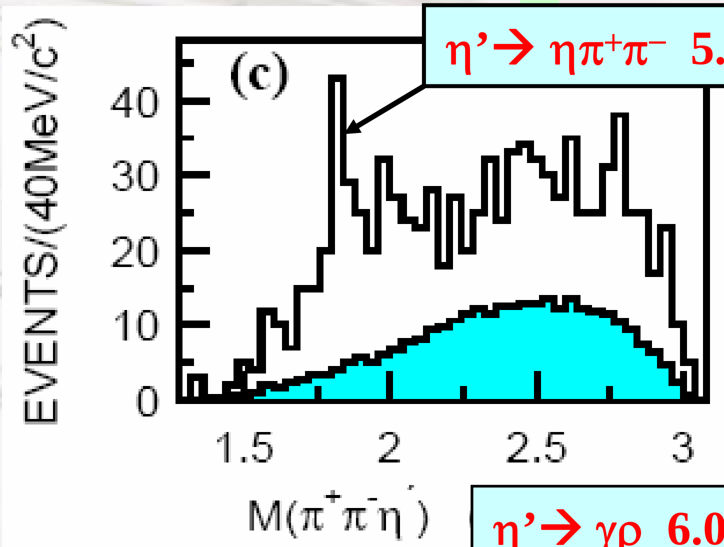
$$\Gamma < 30\ \mathrm{MeV}/c^2\ (90\%\ \mathrm{CL})$$

Phys. Rev. Lett. 91, 022001 (2003)

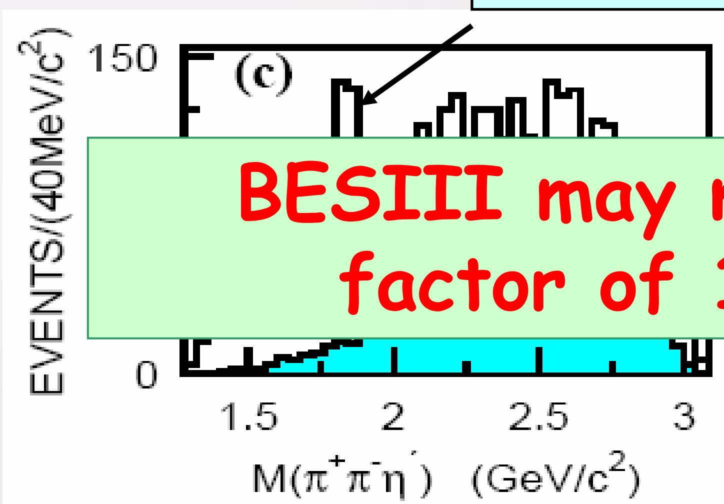


If Ppbar molecules, looking for other decay modes, such $J/\psi \to \gamma\pi^+\pi^-\eta'$
G.J. Ding and M.L. Yan, PRC 72 (2005) 015208

Observation of X(1835) in $J/\psi \rightarrow \gamma\eta'\pi^+\pi^-$



$\eta' \rightarrow \eta\pi^+\pi^-$ 5.1 σ



$\eta' \rightarrow \gamma\rho$ 6.0 σ

Phys. Rev. Lett. 95, 262001 (2005)

Combine two η' decay modes

BESIII may measure its J^{PC} with a factor of 100 more statistics

$M = 1833.7 \pm 6.1 \pm 2.7\ \mathrm{MeV}/c^2$

$\Gamma = 67.7 \pm 20.3 \pm 7.7\ \mathrm{MeV}/c^2$

$$B(J/\psi \rightarrow \gamma X) B(X \rightarrow \pi^+\pi^-\eta') = (2.2 \pm 0.4 \pm 0.4) \times 10^{-4}$$

BESIII Data acquisition plan

Physics Channel	Energy (GeV)	Luminosity (10^{33} $cm^{-2}s^{-1}$)	Events/year
J/ψ	3.097	0.6	1.0×10^{10}
τ	3.67	1.0	1.2×10^{7}
ψ'	3.686	1.0	3.0×10^{9}
D*	3.77	1.0	2.5×10^{7}
Ds	4.03	0.6	1.0×10^{6}
Ds	4.14	0.6	2.0×10^{6}

Strategy of luminosity upgrade

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

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

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

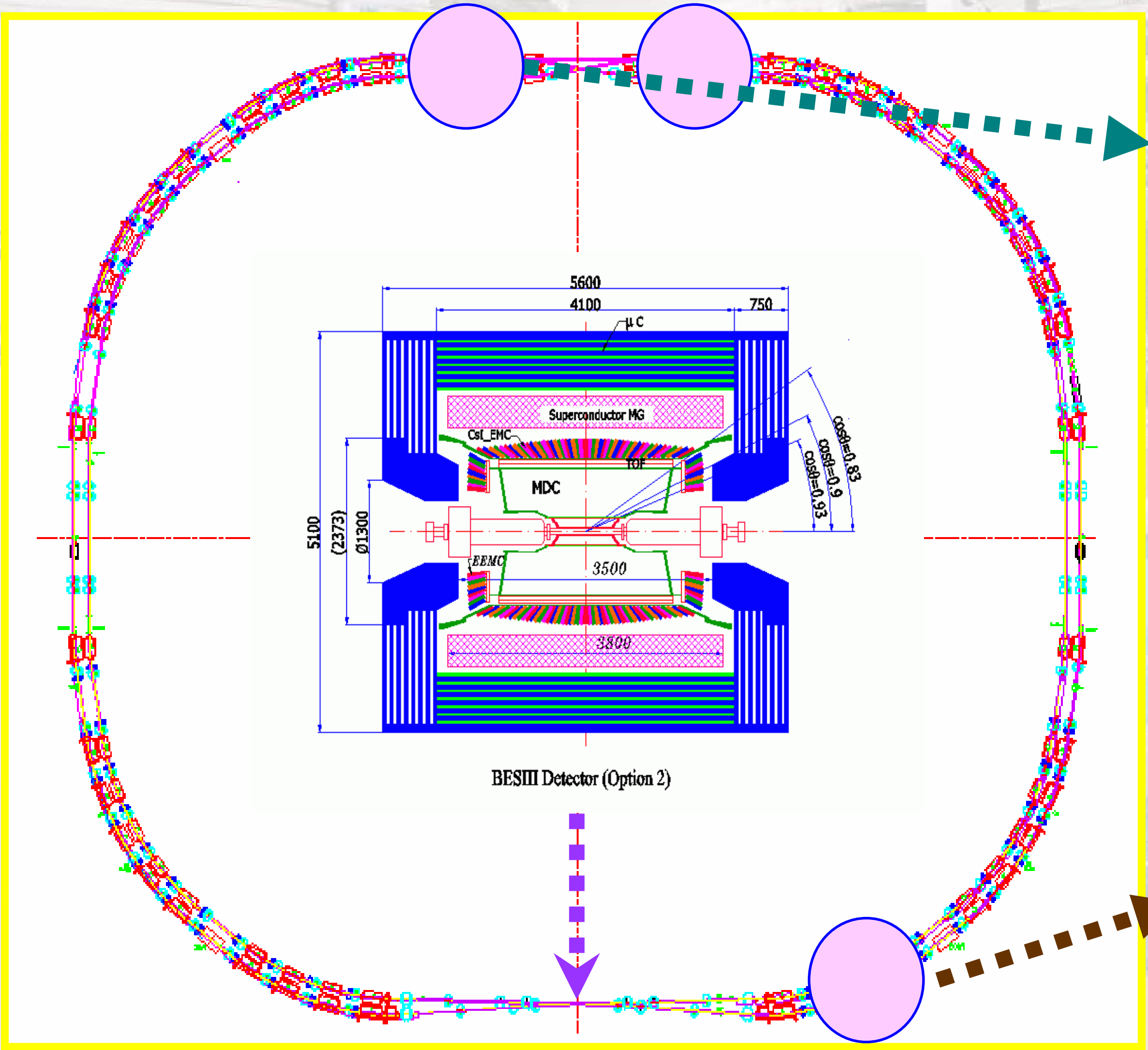
Micro-β: β_y^* =5cm ➔ 1.5 cm
SC insertion quads

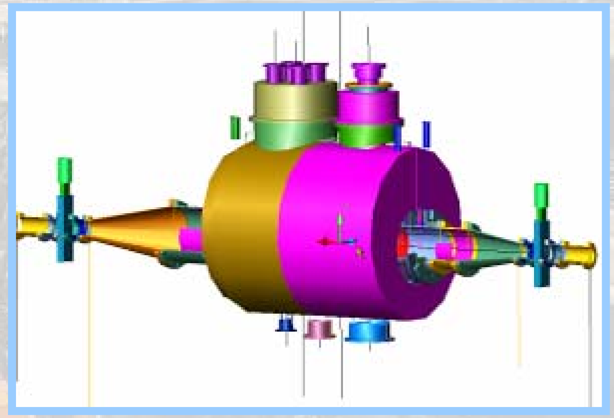
Reduce impedance +SC RF
σ_z =5cm ➔ <1.5cm

$(L_{BEPCII}/ L_{BEPC})_{D.R.}$=(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}

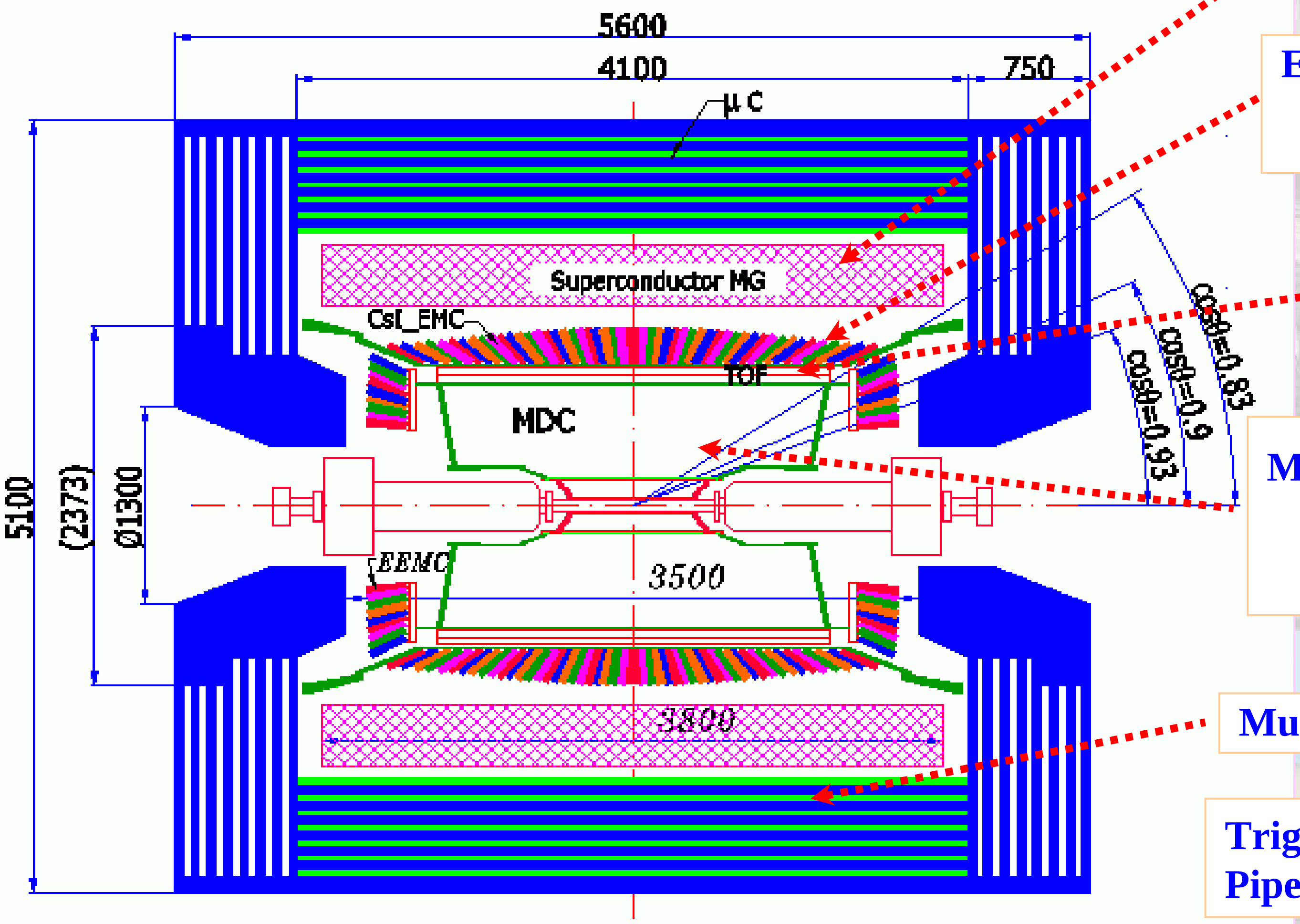
BEPCII: *a high luminosity double–ring collider*





BESIII Detector

Magnet: 1 T Super conducting



EMCAL: CsI crystal
$\Delta E/E$ = 2.2% @1 GeV
σz = 0.5 cm/$\sqrt{E}$

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%

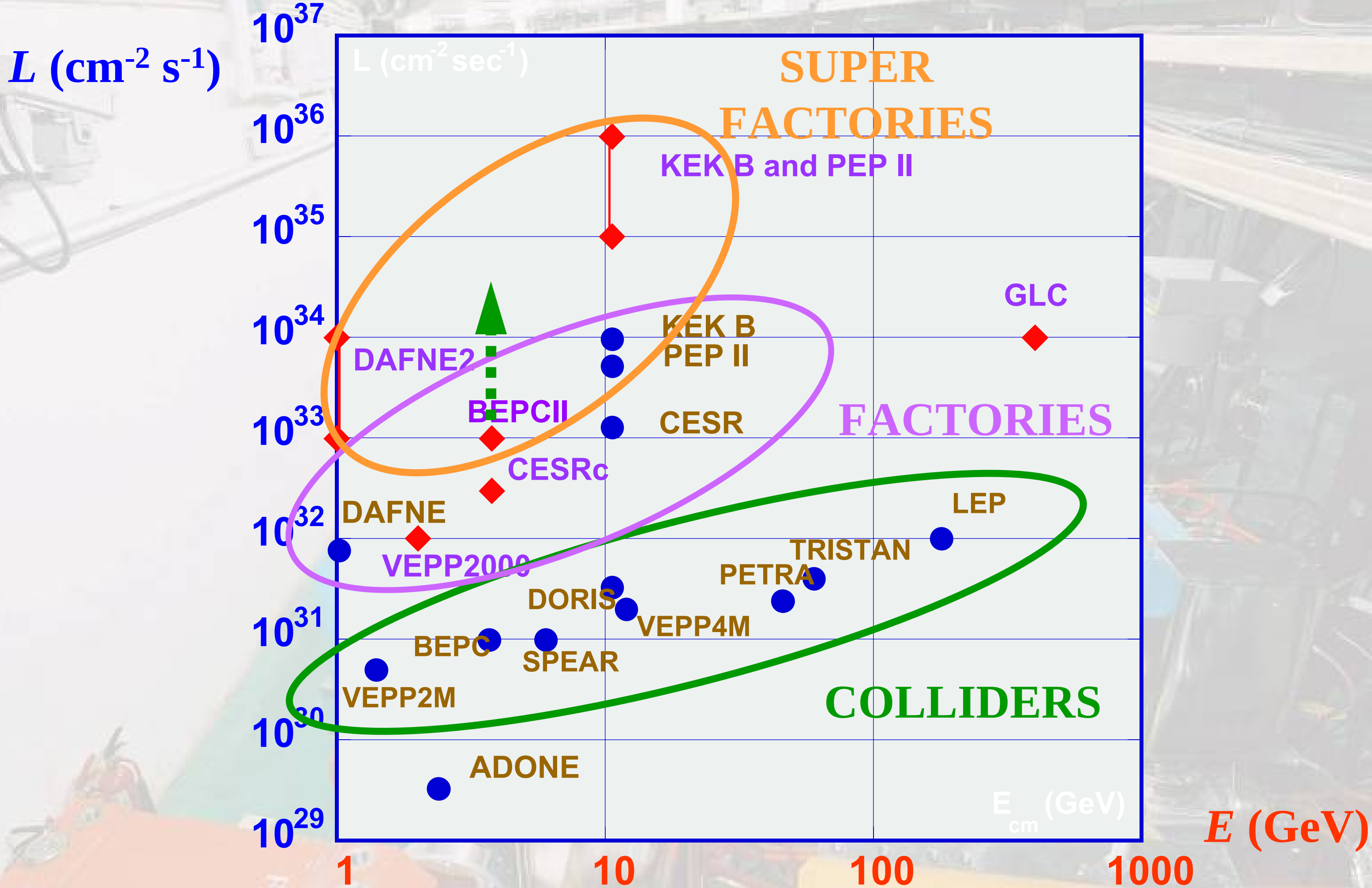
Muon ID: 9 layer RPC

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**

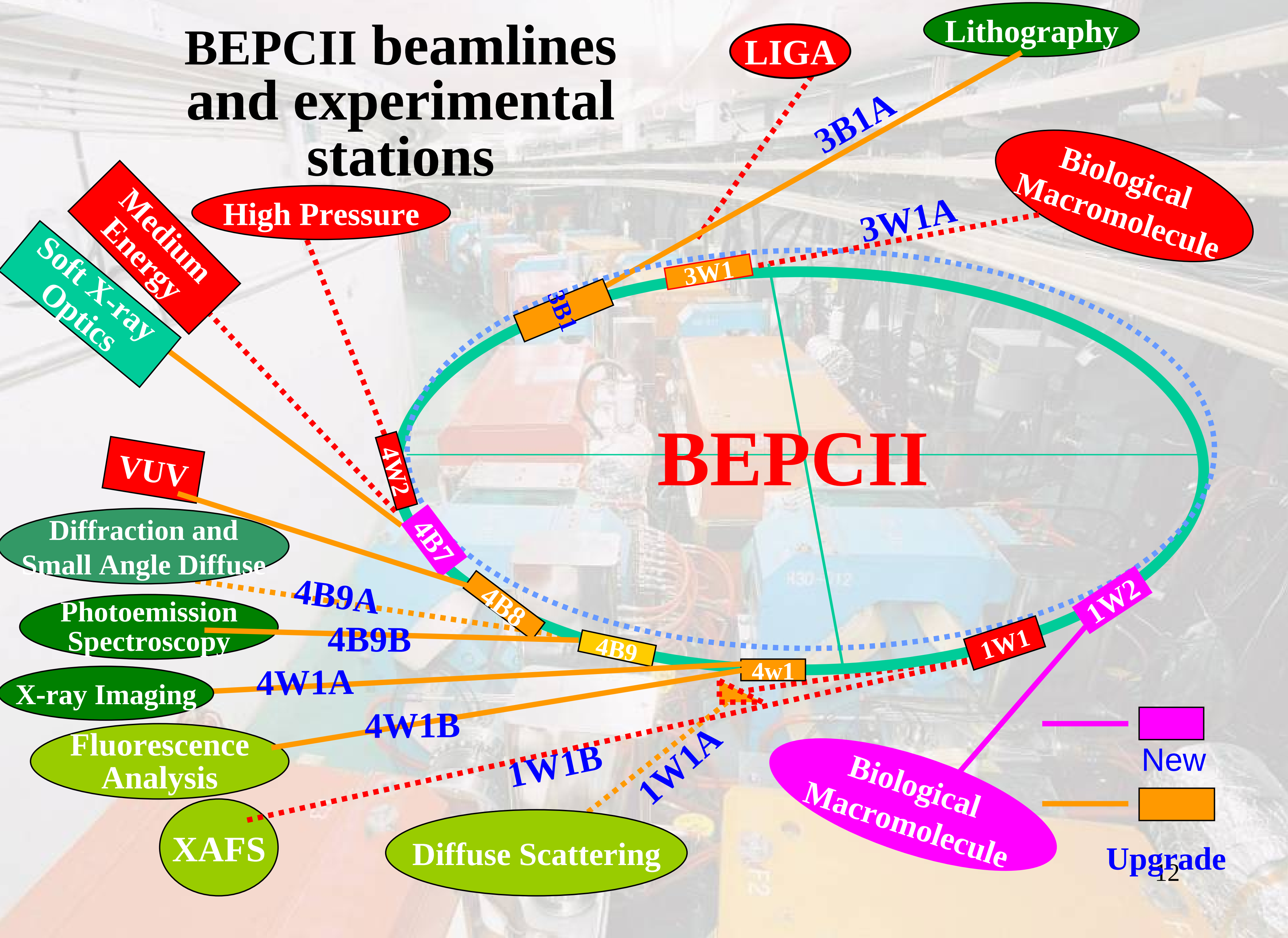
Data Acquisition:
Event rate = 3 kHz
Thruput ~ 50 MB/s

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



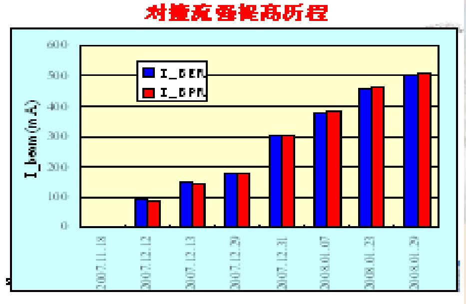
C. Biscari, Workshop on e^+e^- in 1-2 GeV Range, September 10-13, 2003, Italy

BEPCII beamlines and experimental stations



The Milestones

January 2004	Construction started
May. 4, 2004	Dismount of 8 linac sections started
Dec. 1, 2004	Linac delivered e^- beams for BEPC
July 4, 2005	BEPC ring dismount started
Mar. 2, 2006	BEPCII ring installation started
Nov. 13, 2006	Phase 1 commissioning started
Aug. 3, 2007	Shutdown for installation of IR-SCQ's
Oct. 24, 2007	Phase 2 commissioning started
Jan. 29, 2008	2×500mA collision, $L > 1\times10^{32}cm^{-2}s^{-1}$



(2) The BEPCII Accelerators

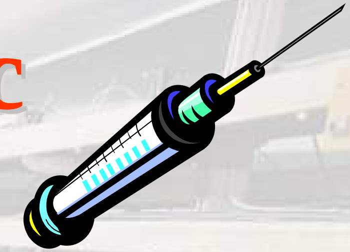
The BEPCII serves the purposes of both high energy physics experiments and synchrotron radiation applications.

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 Positron injection rate > 50 mA/min
Dedicated SR operation	250 mA @ 2.5 GeV

Main Parameters

Parameters		Unit	BEPCII	BEPC
Operation energy (E)		GeV	1.0–2.1	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 ($\nu_x/\nu_y/\nu_s$)			6.53/5.58/0.034	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
	SR		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

2.1 The Injector Linac



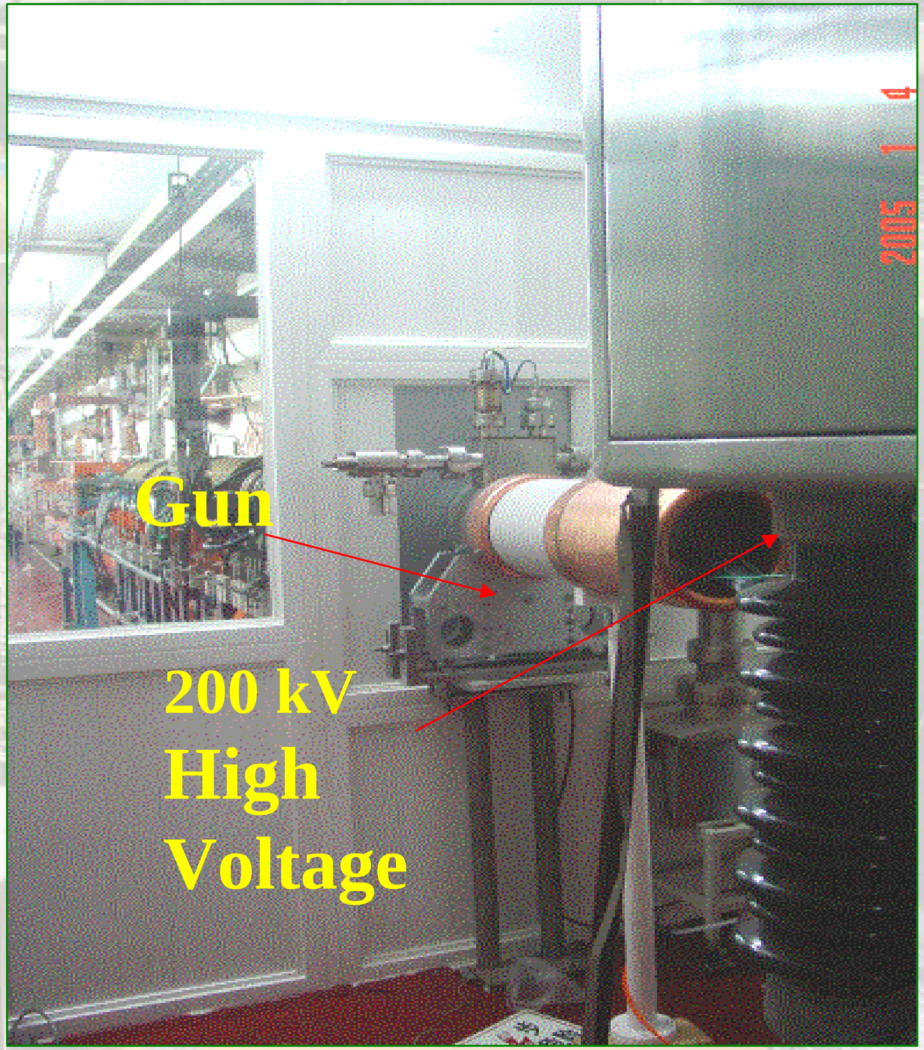
- **Basic requirement:**
  - **Higher intensity: e^+ injection rate ≥ 50 mA/min.;**
  - **Full energy injection with E=1.55 ~ 1.89 GeV;**
- **To enhance the current and energy of the electron beam bombarding the target and to reduce the beam spot;**
- **To design and produce a new positron source and 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

New e^- Gun	High current ; low emittance
New e^+ Source	High e+ yield; Large capture acceptance
New RF System with phasing loop	High RF power output; Stable phasing loops
New Beam Tuning Devices	Orbit correction; Optimum optics
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

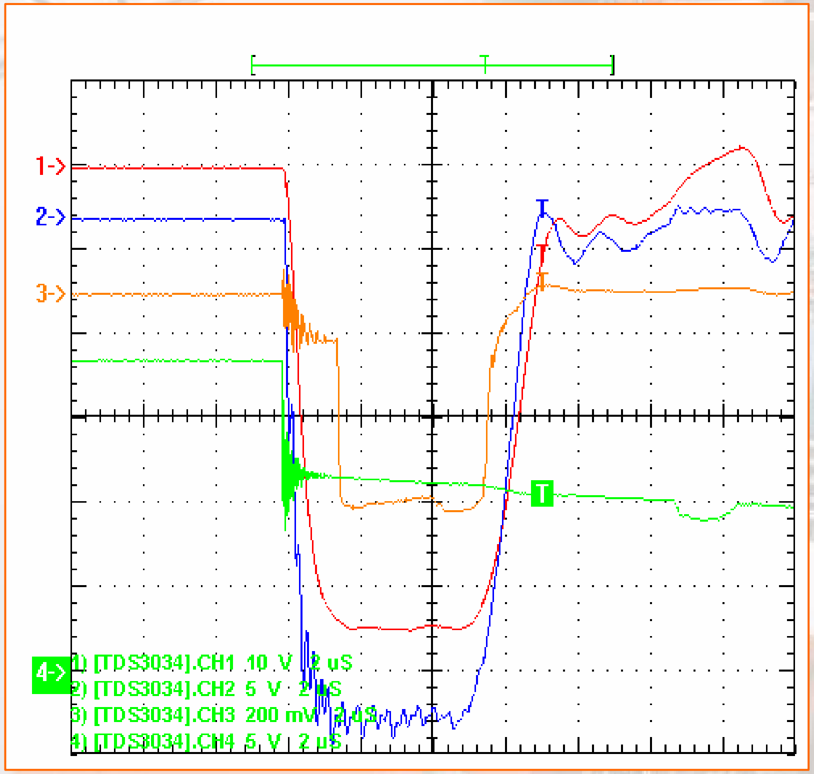
A flux concentrator is employed to have a large e^+ acceptance:
L = 10 cm , B = 5.3 T ↘0.50 T, Φ = 7 mm →52 mm.

New RF Power Sourse

50MW new klystrons

New modulators with high power 320 kV × 360 A.

High voltage stability ≤ ±0.15%



Performance of the BEPCII Linac

Parameters		Design (BEPC)	Achieved
Beam energy （GeV）		1.89 (1.55)	1.89
current (mA)	e+	37 (4)	62.5
	e-	500 (50)	510
Repetition rate (Hz)		50 (12.5)	50
ε_x / ε_y (mm·mrad)	e+	0.40 (1.70)	0.346/0.269
	e-	0.10 (0.58)	0.097/0.079
Energy spread (%)	e+	0.5 (0.8)	0.37
	e-	0.5 (0.8)	0.30
e^+ Inj. rate (mA/min.)		50	62

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



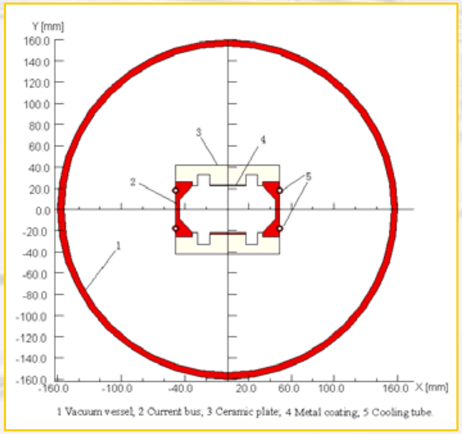
Magnet type	Number
Dipole (Leff.=1.4135m)	40+1
Dipole (Leff.= 1.2277m)	2
Dipole (Leff.= 1.0339m)	2
Weak dipole (Leff.=1.0321m)	2
Weak dipole (Leff.=0.7453m)	2
Quadrupole	88+2
Old quadrupoles with modified coils	28
160Q quadrupole (Old)	6
Sextupole	72+1
Vertical corrector	48+1
Special vertical corrector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



Power Supplies

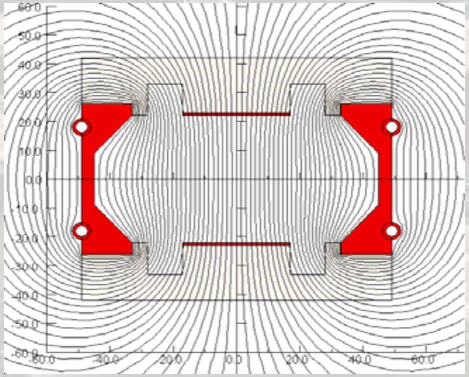
P.S.	No.	Design Stability	Tested Stability
Q & S	165	1×10^{-4}	4×10^{-5}
OQ2,OQ3, IQ2, IQ3	16	1×10^{-4}	5×10^{-5}
B	4	1×10^{-4}	5×10^{-5}
BH,BV	144	1×10^{-4}	4×10^{-5}
T.Q	34	1×10^{-4}	4×10^{-5}
T.B	2	1×10^{-4}	4×10^{-5}
SC magnets	16	1×10^{-4}	1×10^{-4}
Q1a,Q1b,ISPB	3	1×10^{-4}	1×10^{-4}

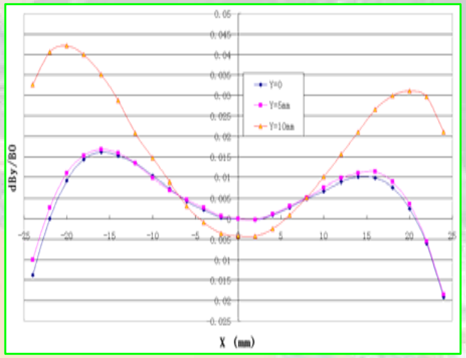
Injection Kickers



1 Vacuum vessel, 2 Current bus, 3 Ceramic plate, 4 Metal coating, 5 Cooling tube

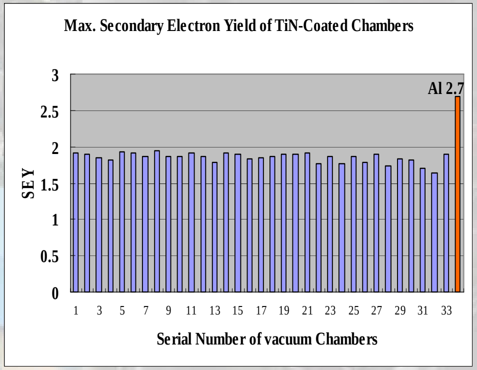
Number of Kickers	4
Length	1.9m
Integral field	200Gs·m
Aperture	90mm×38mm
Good field region	±20mm
Field uniformity	±1%
The pulse repetition	50Hz
Stability of current	1%
Waveform	Half-sine wave
Pulse Width	600ns
Time jitter	<5ns
impedance	<0.025Ω



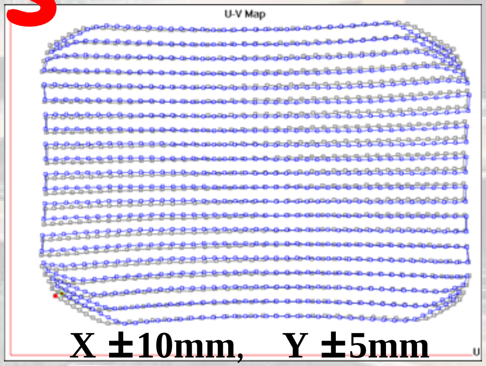


Vacuum System

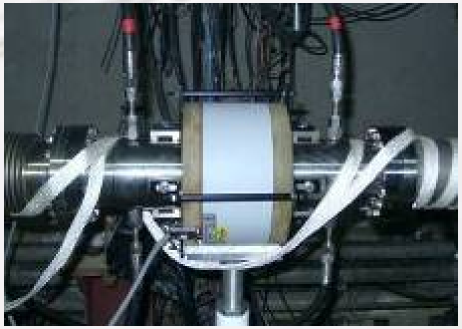
- The design dynamic vacuum pressure are 8×10^{-9} Torr in the arc and 5×10^{-10} Torr in the IR.
- Antechambers are chosen for both e^+ and e^- rings.
- 80 arc chambers,120 straight section chambers; 175 discrete photon absorbers 180 RF shielded bellows
- TiN coating for e+ ring chambers to reduce SEY

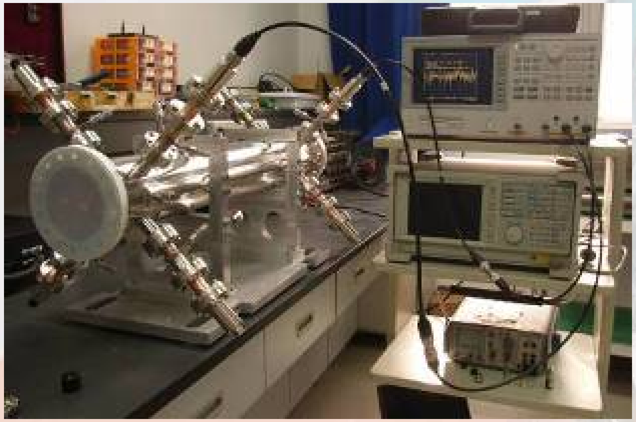


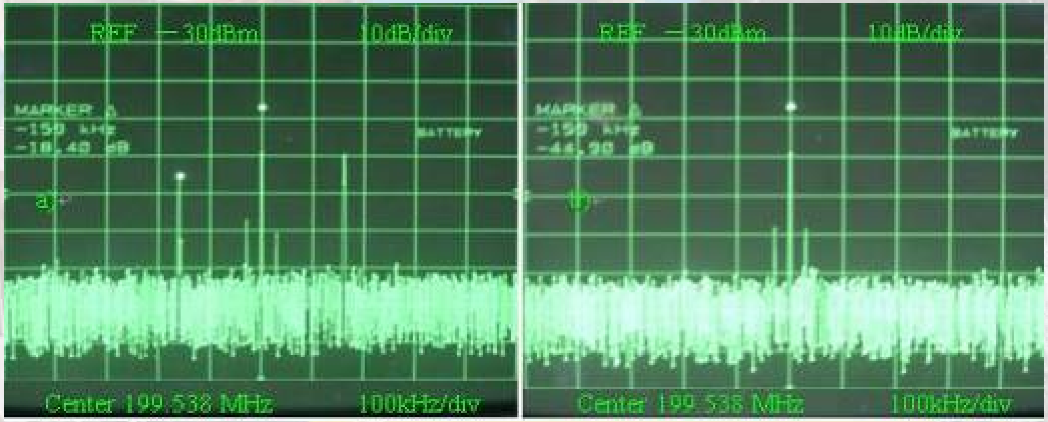
Beam Diagnosis



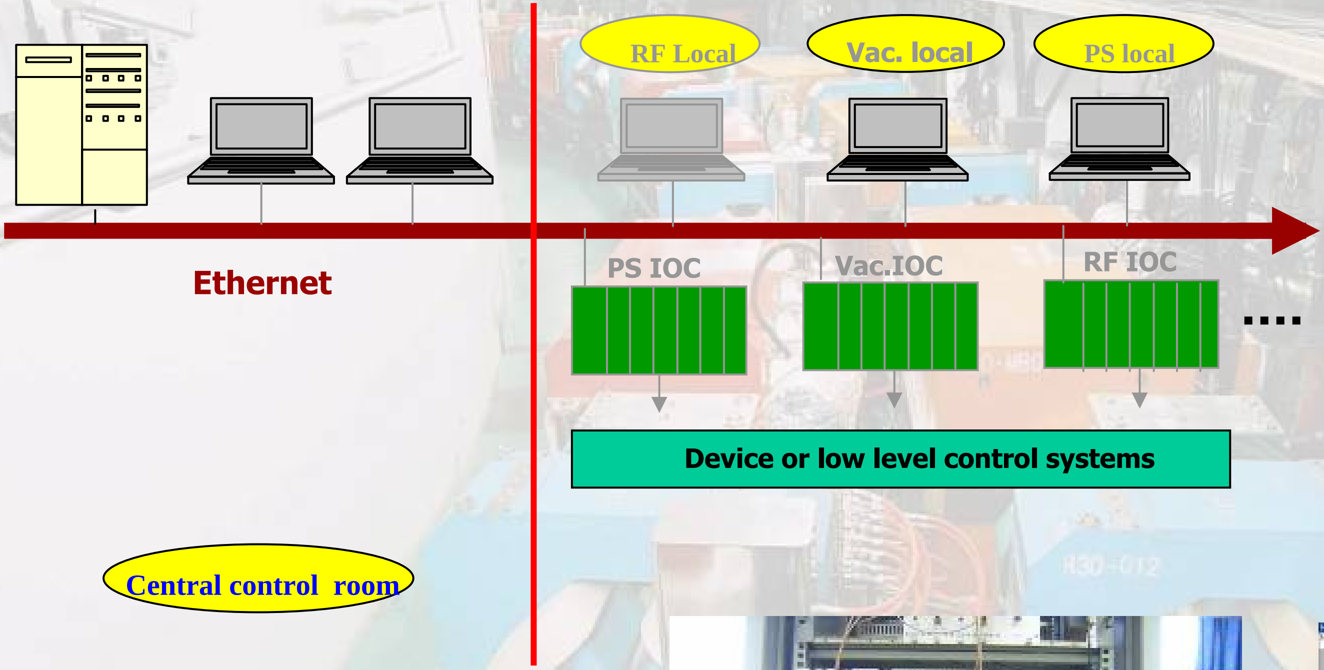
- Beam Position Monitor
- Bunch Current Monitor
- SR monitor
- DCCT
- Transverse Feedback
- Tune measurement
- Beam Loss Monitor

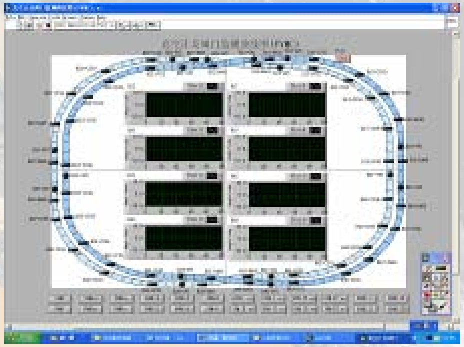




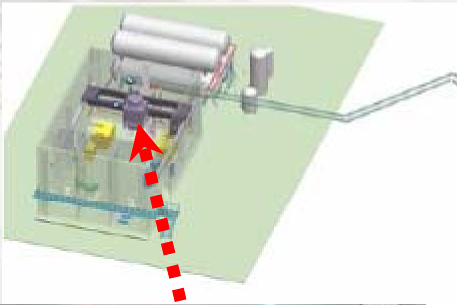


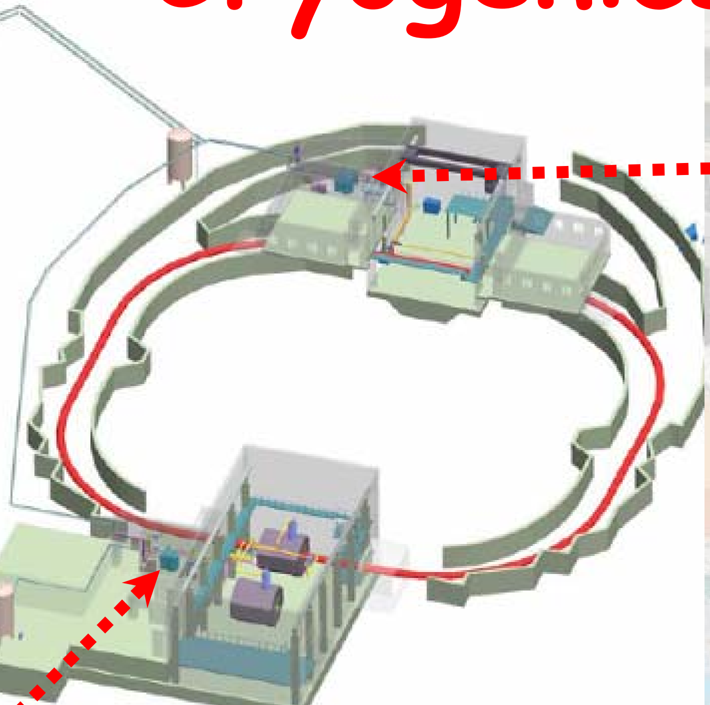
Control System

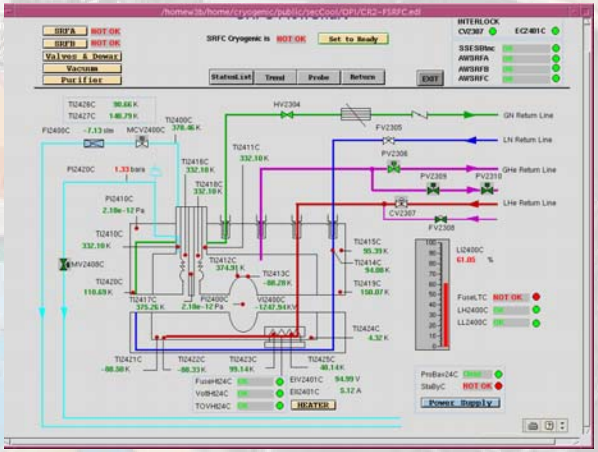


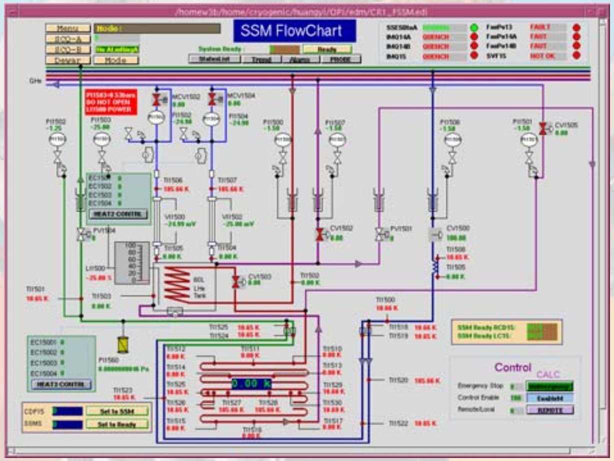


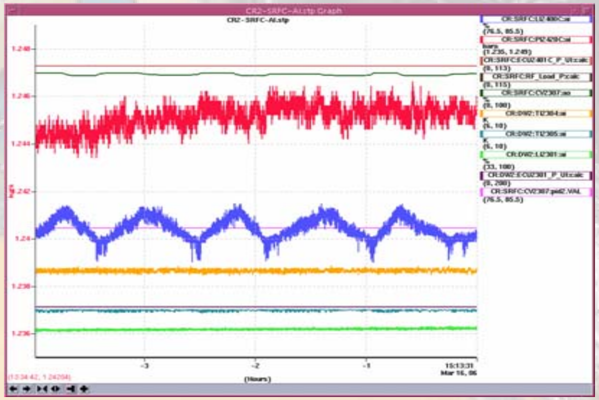
Cryogenics



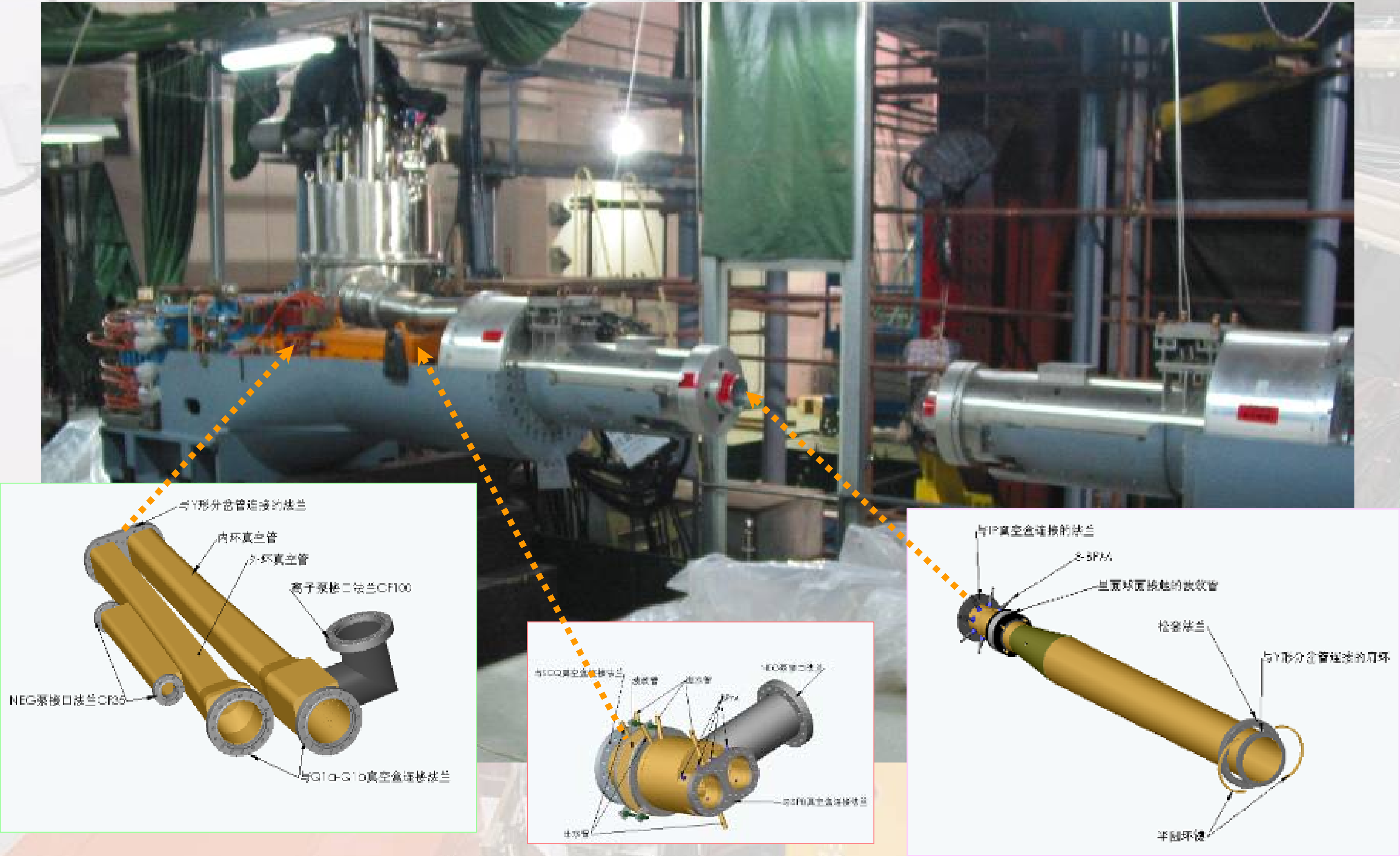




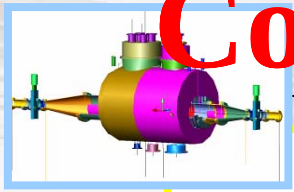


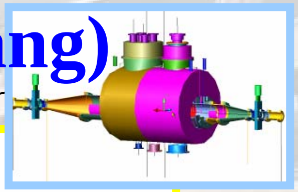


Interaction Region



Commissioning (J.Q.Wang)





Collision: e⁻ ring (BER) + e⁺ ring (BPR)

SR Operation: Outer ring (BSR)

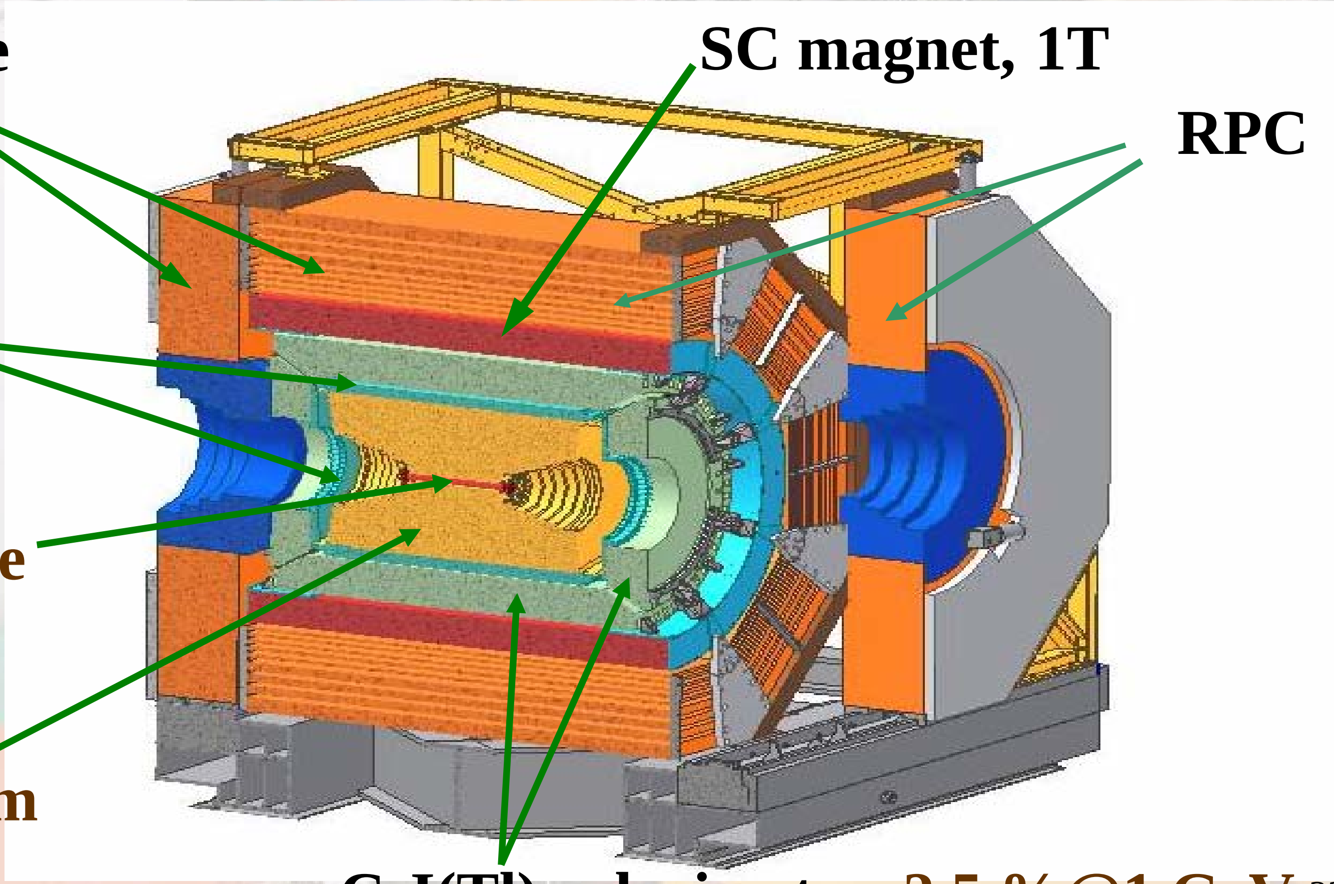
Phase 1：IR with Conventional magnets

Phase 2：IR With SCQ's

Phsse 3：BEPCII + BESIII

(3) The BESIII Detector

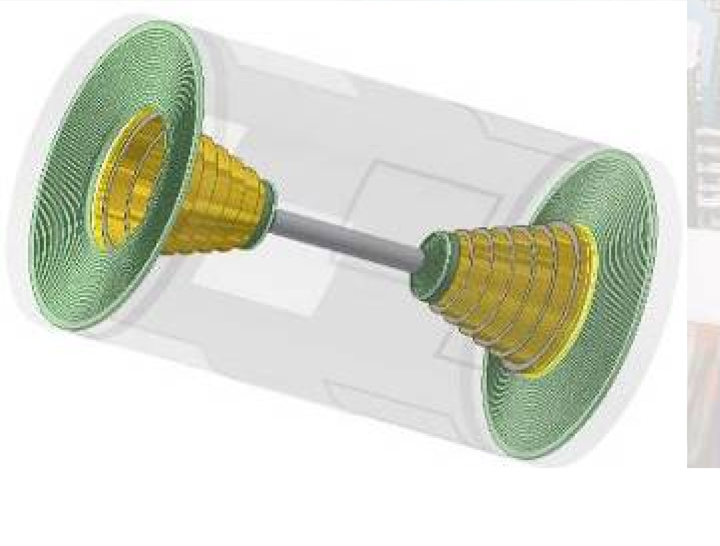
— Adapt to high event rate : $10^{33}cm^{-2}\,s^{-1}$ and bunch spacing 8ns
— Reduce sys. errors for high statistics: photon measurement, PID…
— Increase acceptance, and give space for SC quads



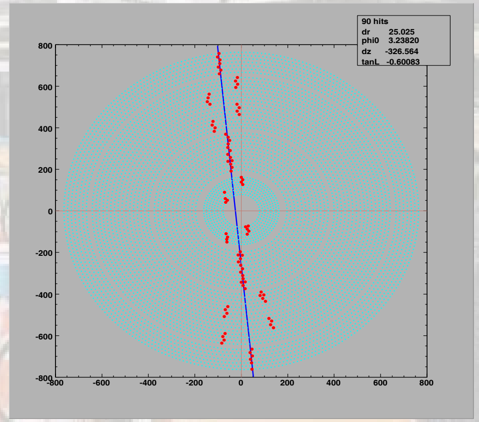
Main Drift Chamber

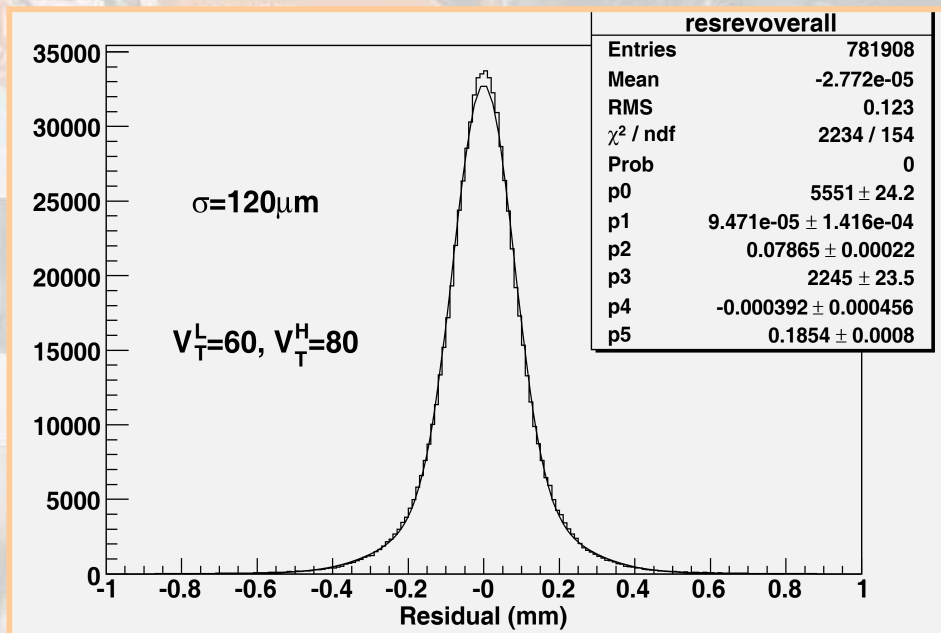
- **Small cell**
- **7000 Signal wires: 25μm gold-plated tungsten**
- **22000 Field wires: 110 μm gold-plated Aluminum**
- **Gas: He + C_3H_8 (60/40)**
- **Momentum resolution@1GeV:**
- **dE/dX resolution: ~ 6%.**

$$\frac{\sigma_{P_t}}{P_t} = 0.32\% \oplus 0.37\%$$



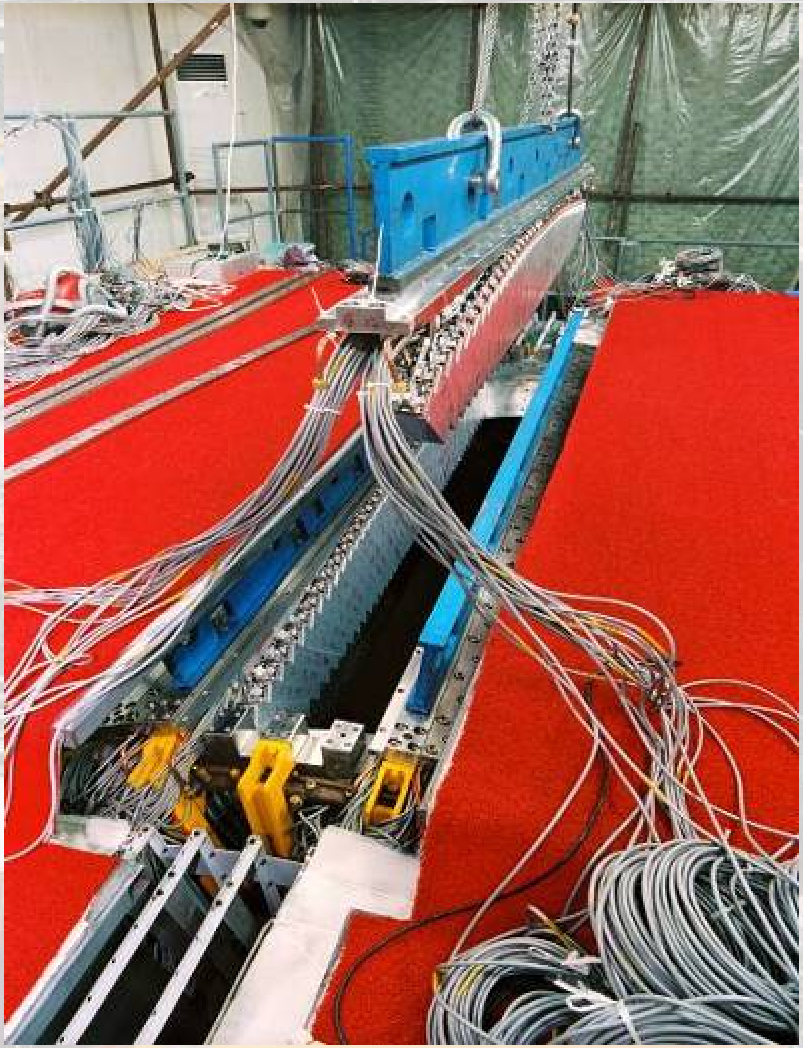
Separate cosmic ray test：meet design





Support Structure of EMC Barrel

EMC Barrel assembly



CsI(Tl) crystal calorimeter