High Energy Physics and Accelerators Projects in China

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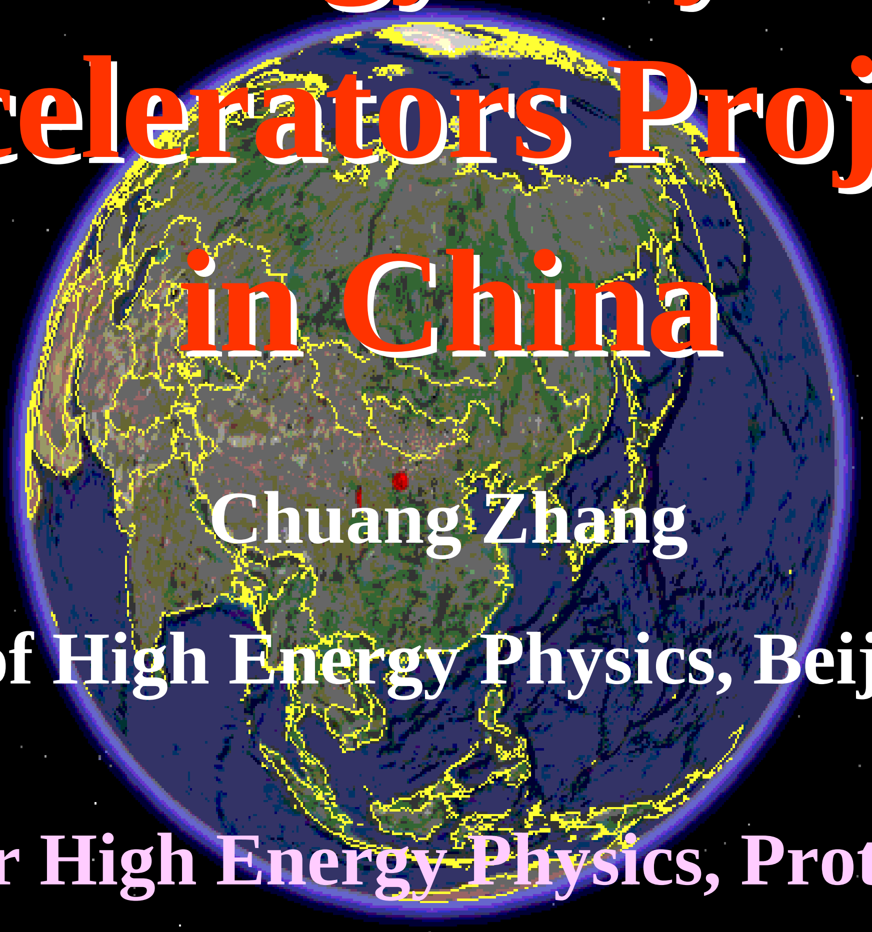


High Energy Physics and Accelerator Projects in China

- Beijing Electron-Positron Collider (BEPC)
- BEPCII Project
- Daya Bay neutrino oscillation experiment
- Other Accelerator Projects in China

(1) Beijing Electron-Positron Collider (BEPC)

- A brief introduction
- Operation and performance
- Physics results with BES
- From BEPCI to BEPCII

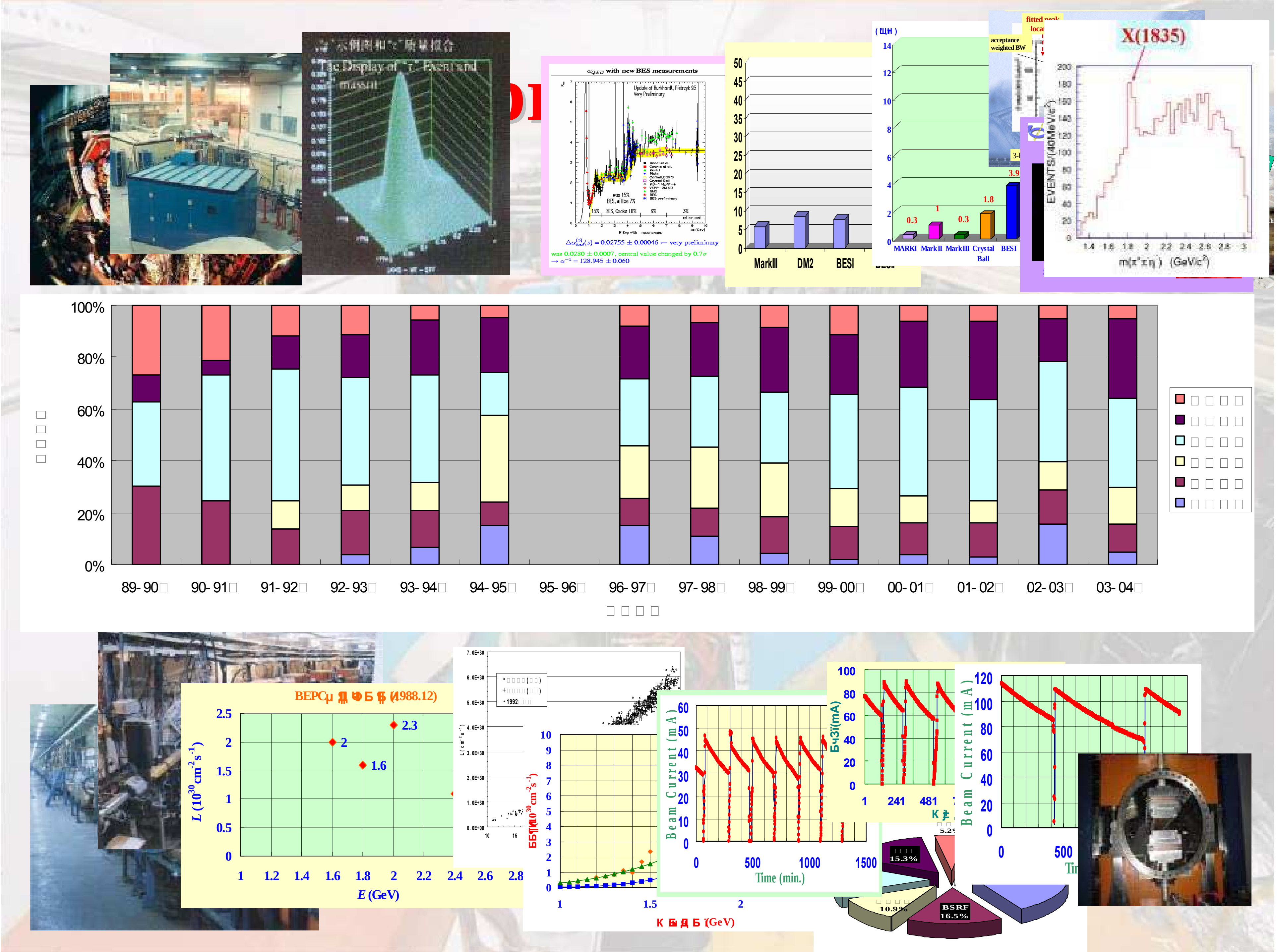
1.1 *A Brief Introduction*

- The Beijing Electron-Positron Collider (BEPC) was constructed (1984-1988) for both high energy physics and synchrotron radiation research.
- The machine well operated for 16 years after it was put into operation in 1989.
- The BEPC consists of a 202-meter long linac injector, a 210-meter long beam transport line and a 240.4 m circumference storage ring and the BEijing Spectrometer (BES).

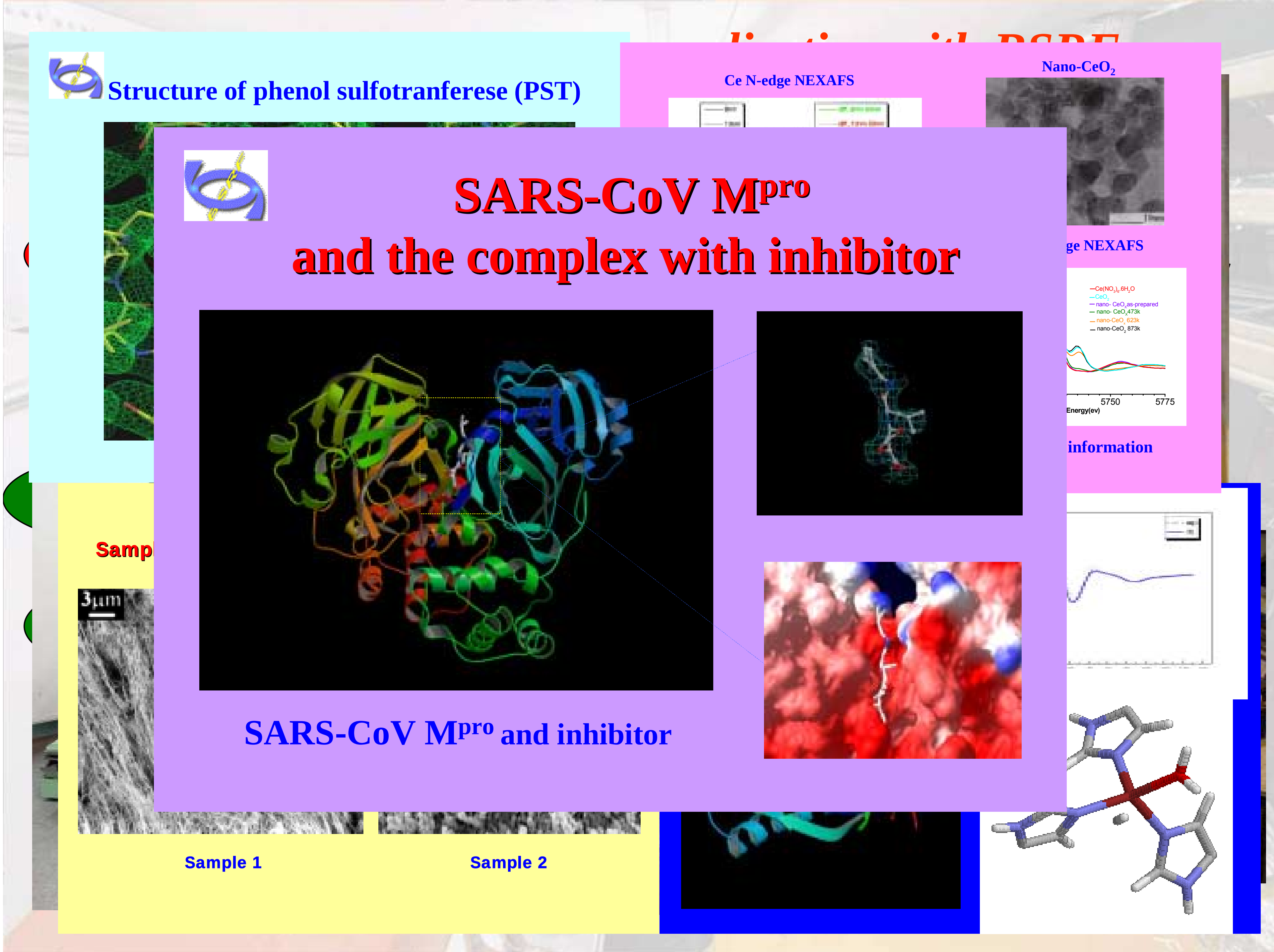
The Beijing Electron-Positron Collider

1.2 *Performance and Operation*

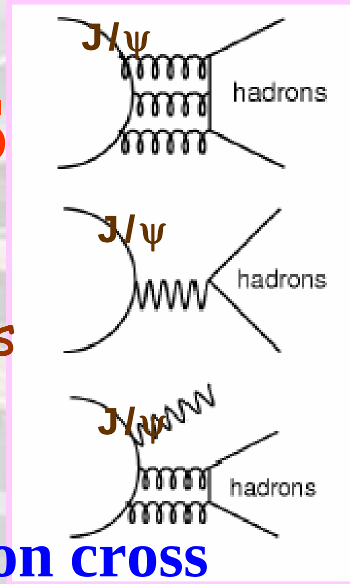
Beam Energy (E)	1.0 ~ 2.5 GeV
Revolution frequency (f_r)	1.247 MHz
Lattice Type	FODO + Low-β Insertions
β^*_x -function at IP (β^*_x / β^*_y)	1.3/0.05 m
Transverse Tune (ν_x/ν_y)	5.8/6.8 (Col. Mode) 8.72/4.75 (SR Mode)
Natural Energy Spread (σ_e)	$2.64E \times 10^{-4}$
Momentum Com. Factor (α_p)	0.042 (Col. Mode) 0.016 (SR Mode)
Hor. Natural Emittance (ε_{x0}) mm·mr	0.4@1.55 GeV, 0.076@2.2GeV(SR)
RF Frequency (f_{rf})	199.533 MHz
Harmonic Number (h)	160
RF Voltage (V_{rf})	0.6~1.6 MV
Bunch Number (N_b)	1*1 (Col.), 60~80 (SR)
Maximum Beam Current	50mA@1.55 GeV (Col.,) 130mA (SR)
Luminosity (10^{31} cm^{-2} s^{-1})	0.5 @1.55 GeV, 1.2 cm^{-2} s^{-1}@1.89GeV



The Display of "τ" Event and mass
X(1835)
MarkIII
DM2
BESI
MARKI
MarkII
Crystal Ball
100%
80%
60%
40%
20%
0%
89-90
90-91
91-92
92-93
93-94
94-95
95-96
96-97
97-98
98-99
99-00
00-01
01-02
02-03
03-04
E (GeV)
Time (min.)
Beam Current (mA)
BSRF 16.5%


Structure of phenol sulfotranferese (PST)
Ce N-edge NEXAFS
Nano-CeO2
SARS-CoV Mpro
and the complex with inhibitor
ge NEXAFS
5750
5775
Energy(ev)
information
Samp
3μm
SARS-CoV Mpro and inhibitor
Sample 1
Sample 2

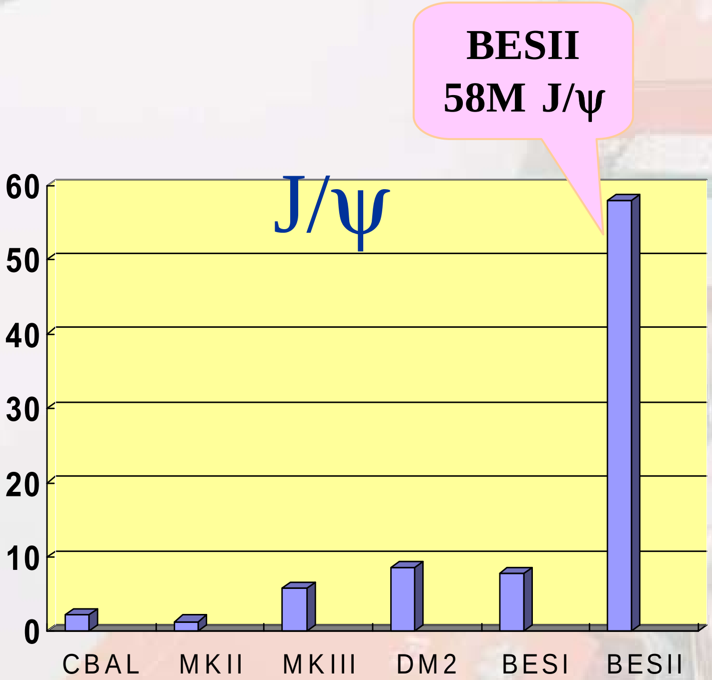
1.3 Physics results with BES



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**

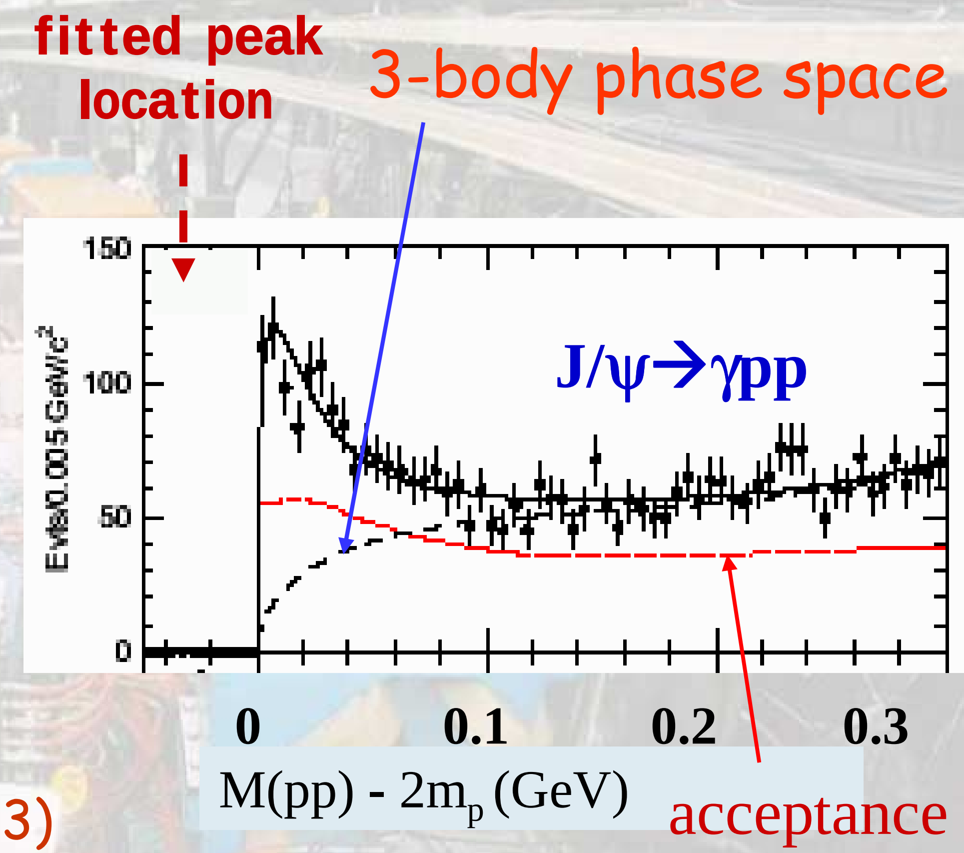
Threshold enhancement in $J/\psi \rightarrow \gamma p\bar{p}$

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

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

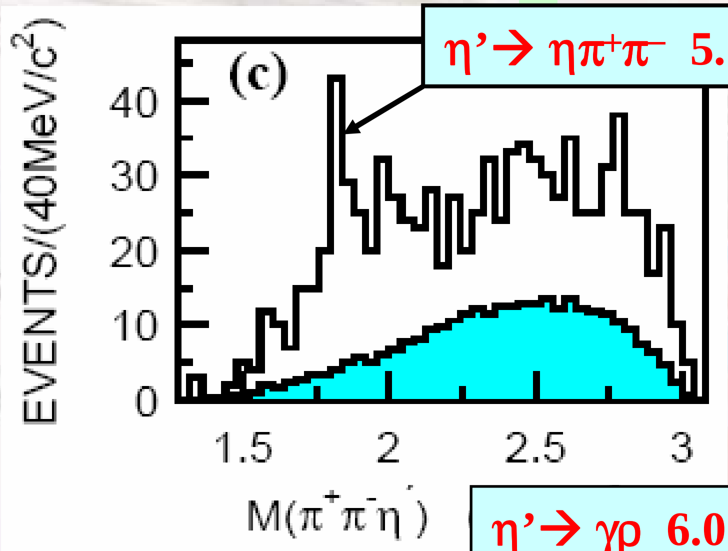
$$\Gamma < 30\ \text{MeV}/c^2\ (90\%\ \text{CL})$$

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



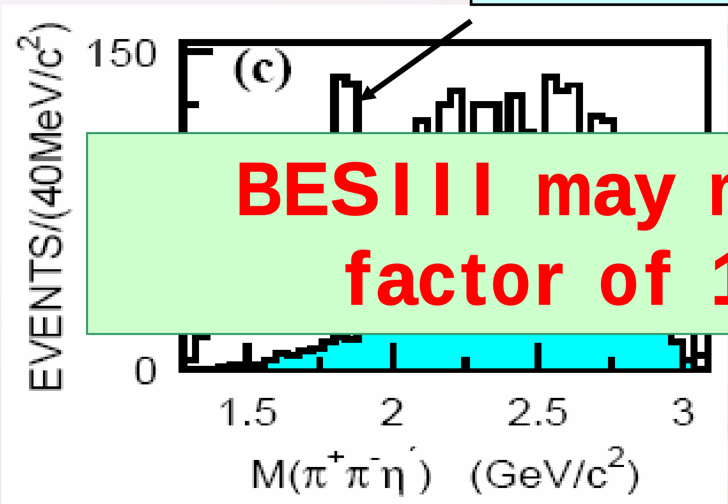
If Ppbar molecules, looking for other decay modes, such $J/\psi \rightarrow \gamma\pi^+\pi^-\eta'$
G.J. Ding and M.L. Yan, PRC 72 (2005) 015208

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



$\eta' \to \eta\pi^+\pi^-$ 5.1 σ

$\eta' \to \gamma\rho$ 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

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

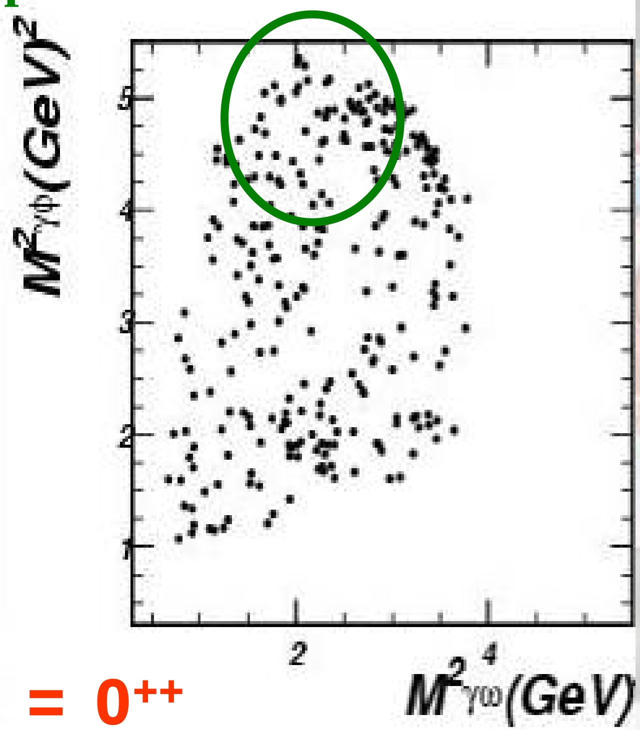
$\Gamma = 67.7 \pm 20.3 \pm 7.7$ MeV/c^2

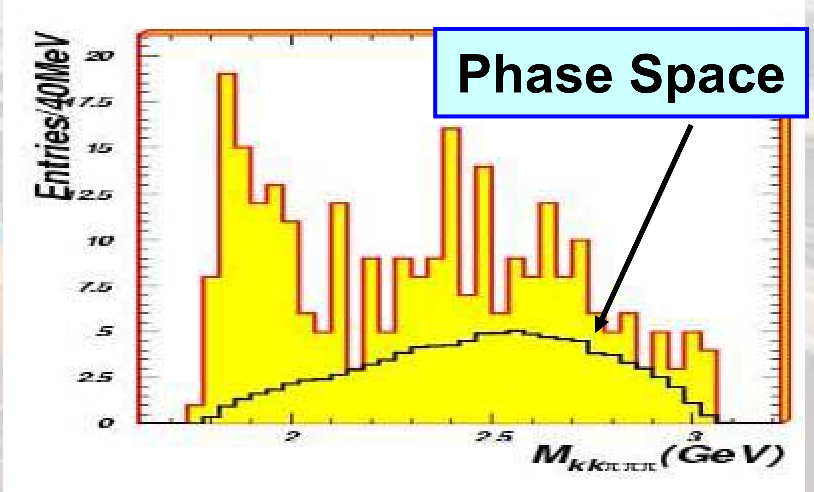
$$B(J/\psi \to \gamma X)B(X \to \pi^+\pi^-\eta') = (2.2 \pm 0.4 \pm 0.4) \times 10^{-4}$$

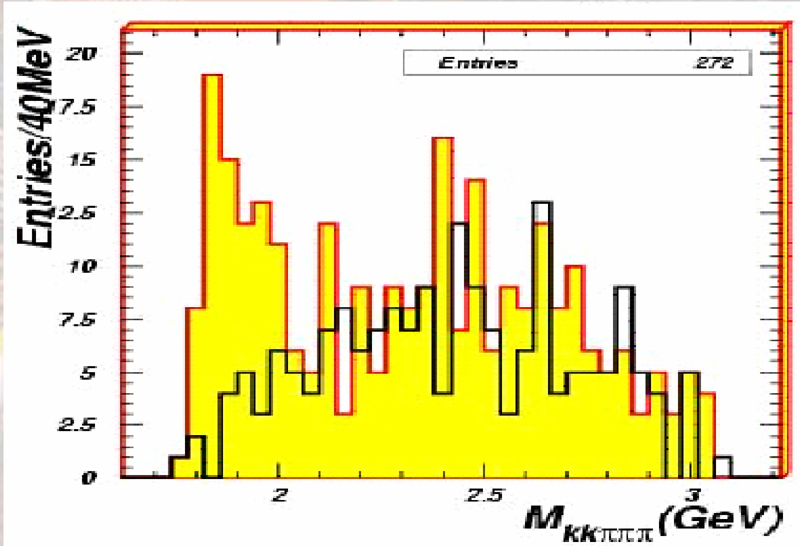
Observation of $\omega\phi$ threshold enhancement in $J/\psi \to \gamma\omega\phi$

Phys. Rev. Lett. 96, 162002 (2006)

DOZI process







$J^{PC} = 0^{++}$

M = $1812^{+19}_{-26} \pm 18 MeV$

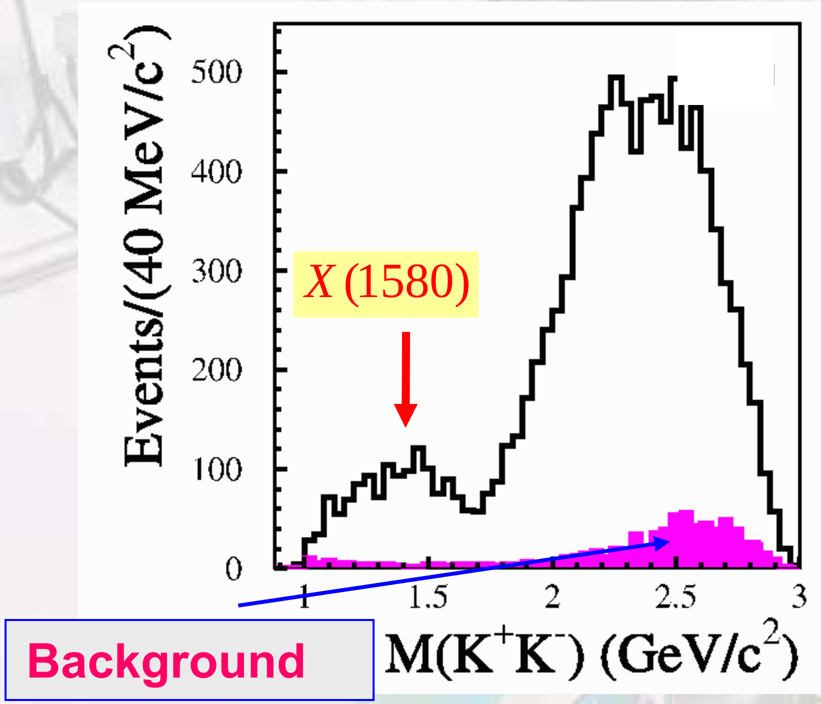
Γ = 105±20±28 MeV

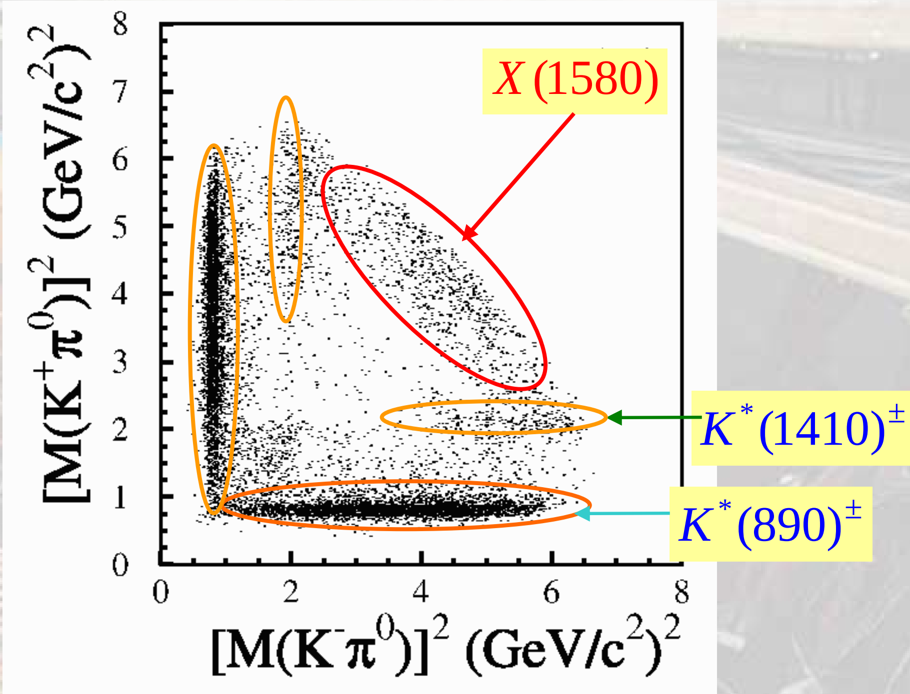
BR = $(2.61\pm0.27\pm0.65)\times10^{-4}$

relation with $f_0(1710)$, $f_0(1790)$?
multiquark/hybrid/glueball ?

New observation of a broad resonance in $J/\psi \to K^+K^-\pi^0$

Phys. Rev. Lett. 97 (2006) 142002





- **X pole position:** $(1576^{+49+98}_{-55-91}) - i(409^{+11+32}_{-12-67})\ MeV/c^2$

$$Br(J/\psi \to X\pi^0)\cdot Br(X \to K^+K^-) = (8.5 \pm 0.6^{+2.7}_{-3.6})\times 10^{-4}$$

PWA analysis and parity conservation considerations yield: $J^{PC} = 1^{--}$

Too many 1^{--}, width is much broader than other mesons; multiquark state ?

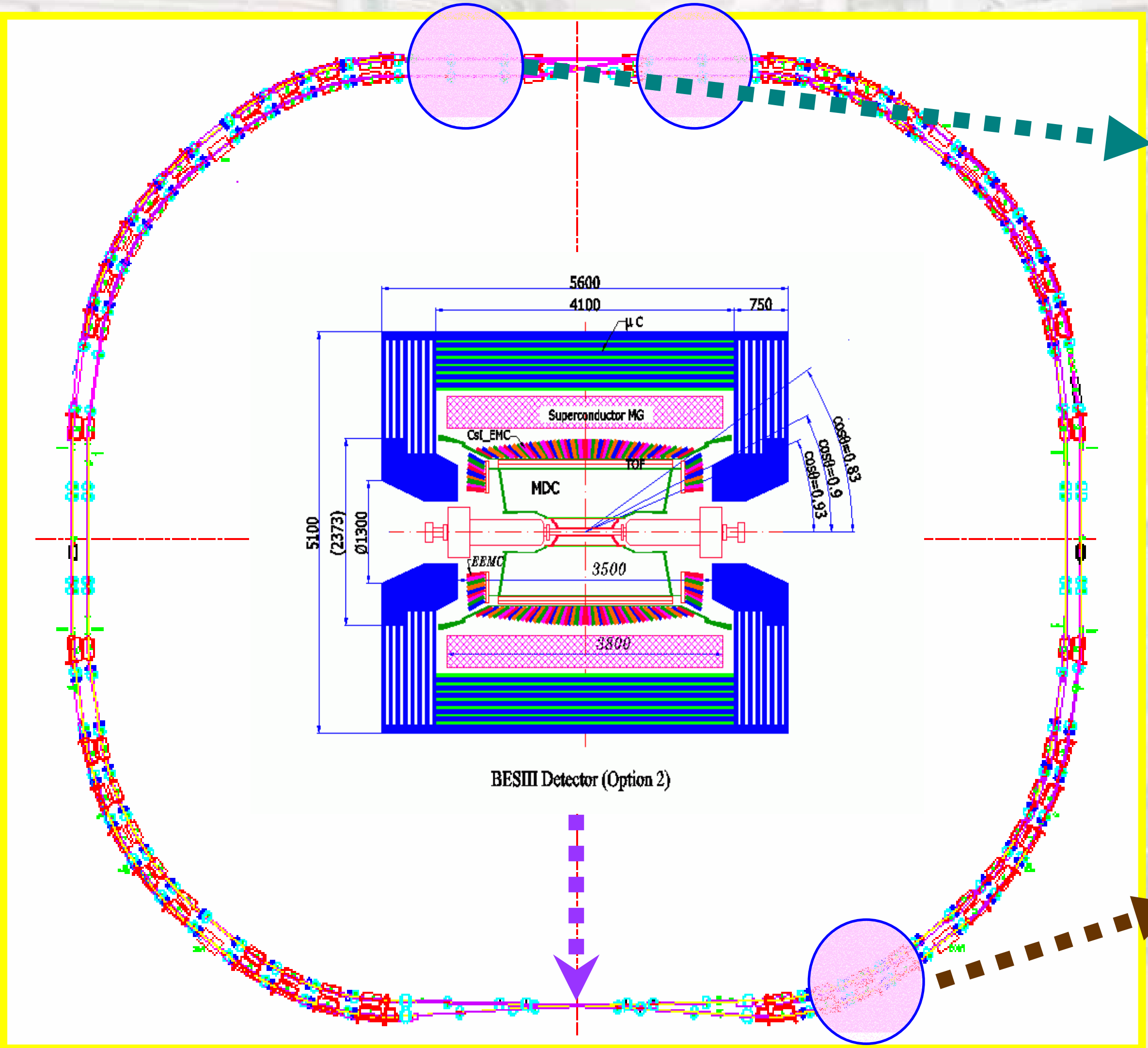
1.4 From BEPC to BEPCII

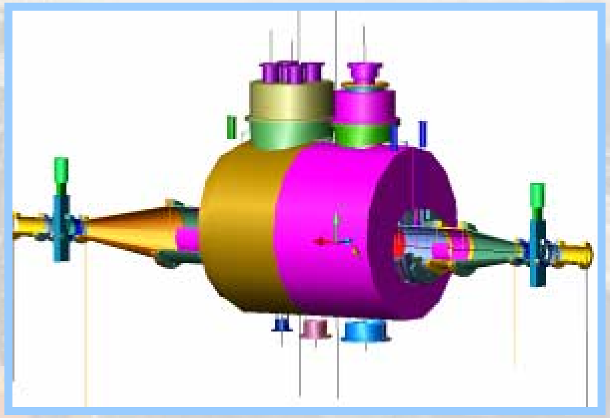
- **In early 80's, the decision to build BEPC was a great success:**
  - **Rich physics opportunities with limited investment:**
    - ✓ **A total of ~ 100 papers published in PRL, PRD, PLB, …**
    - ✓ **A total of ~300 records in particle data book**
    - ✓ **Several highlights well known in the community**
  - **Established the foundation of particle physics and its related technology in China: accelerator, detector, electronics, …**
  - **Started the era of synchrotron radiation application in China**
  - **Technology transfer**
- **In early 90's, the community started the discussion for the future. The conclusion was to continue the τ-charm physics study by a major upgrade of the accelerator and detector (BEPCII / BESIII)**
- **The physics window is precision charm physics and search for new physics:**
  - **High statistics: high luminosity machine + high quality detector**
  - **Small systematic error: high quality detector**

(2) BEPCII Project

- General Description
- Physics at BEPCII/BESIII
- BEPCII Accelerators
- BESIII Detector
- Beijing Synchrotron Facility

2.1 General Description





What is BEPCII

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

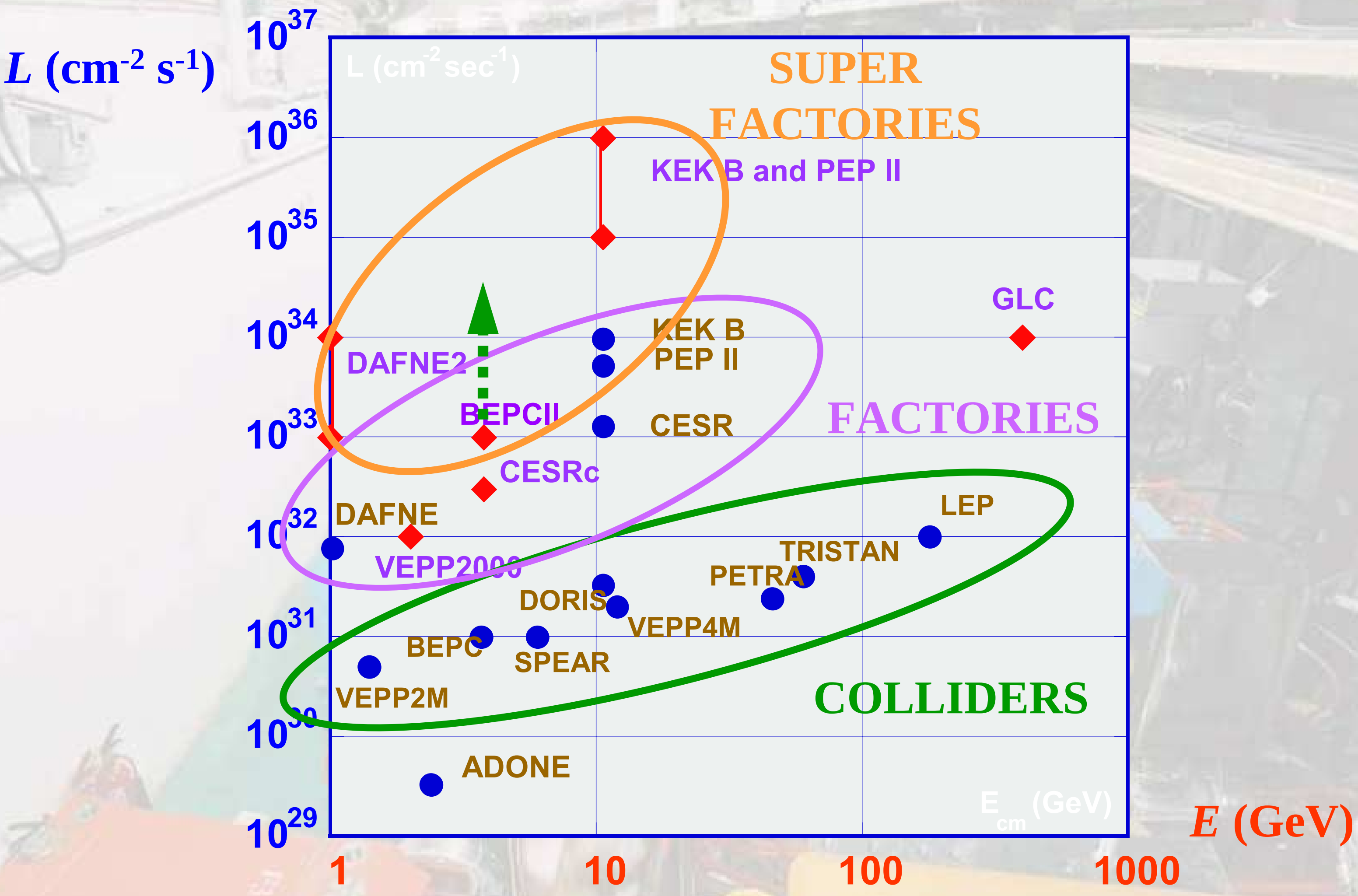
$(L_{BEPCII}/L_{BEPC})_{D.R.}=(5.5/1.5)\times 93\times 9.8/35=96$

$L_{BEPC}=1.0\times10^{31}$ cm^{-2}s^{-1} ➔ $L_{BEPCII}=1\times10^{33}$ cm^{-2}s^{-1}

Design Goals

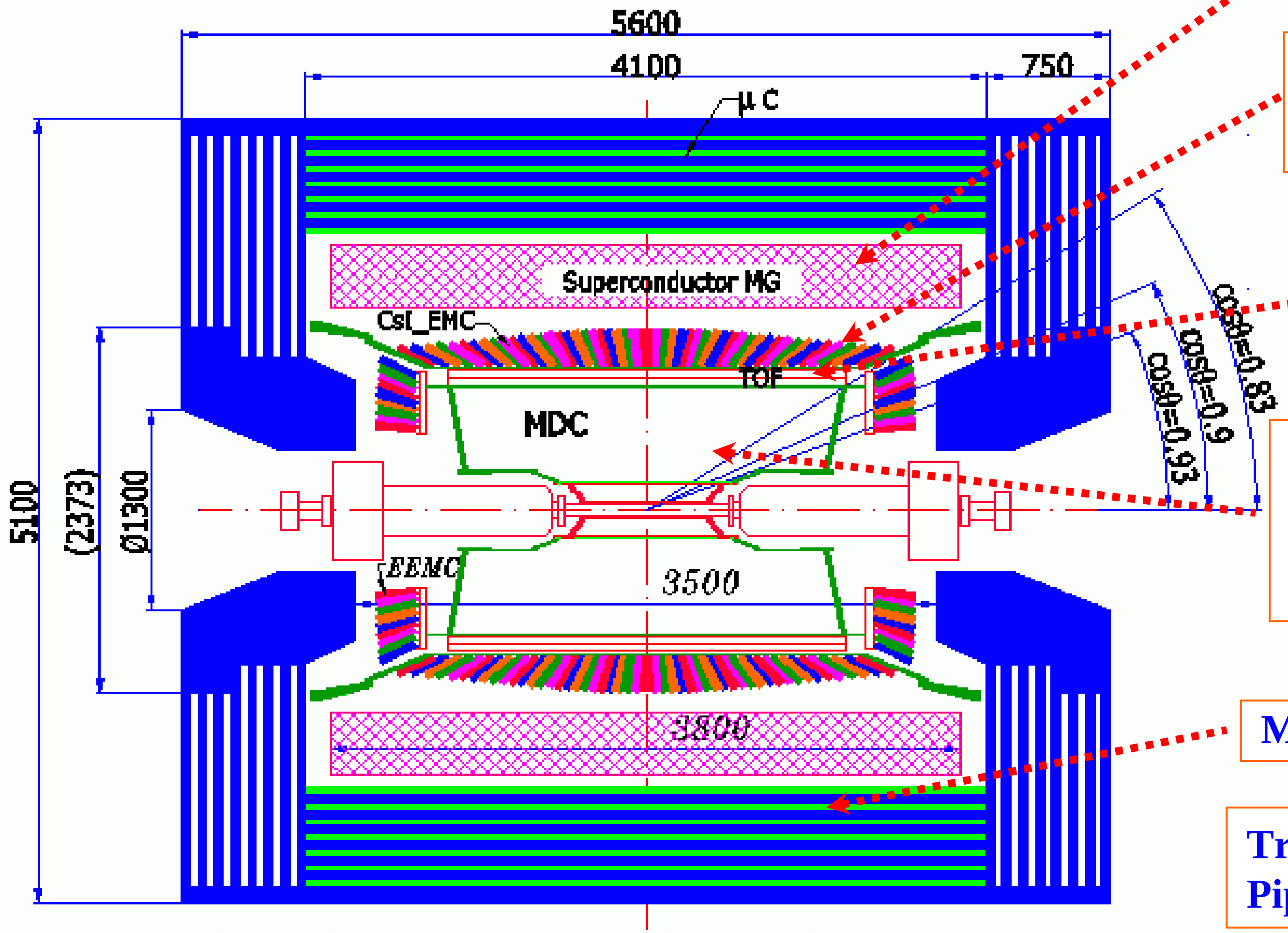
Beam energy range	1–2.1 GeV
Optimized beam energy region	1.89GeV
Luminosity @ 1.89 GeV	1×10^{33} $cm^{-2}s^{-1}$
Injection from linac	Full energy injection: E_{inj}=1.55–1.89GeV
Dedicated SR operation	250 mA @ 2.5 GeV

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



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

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

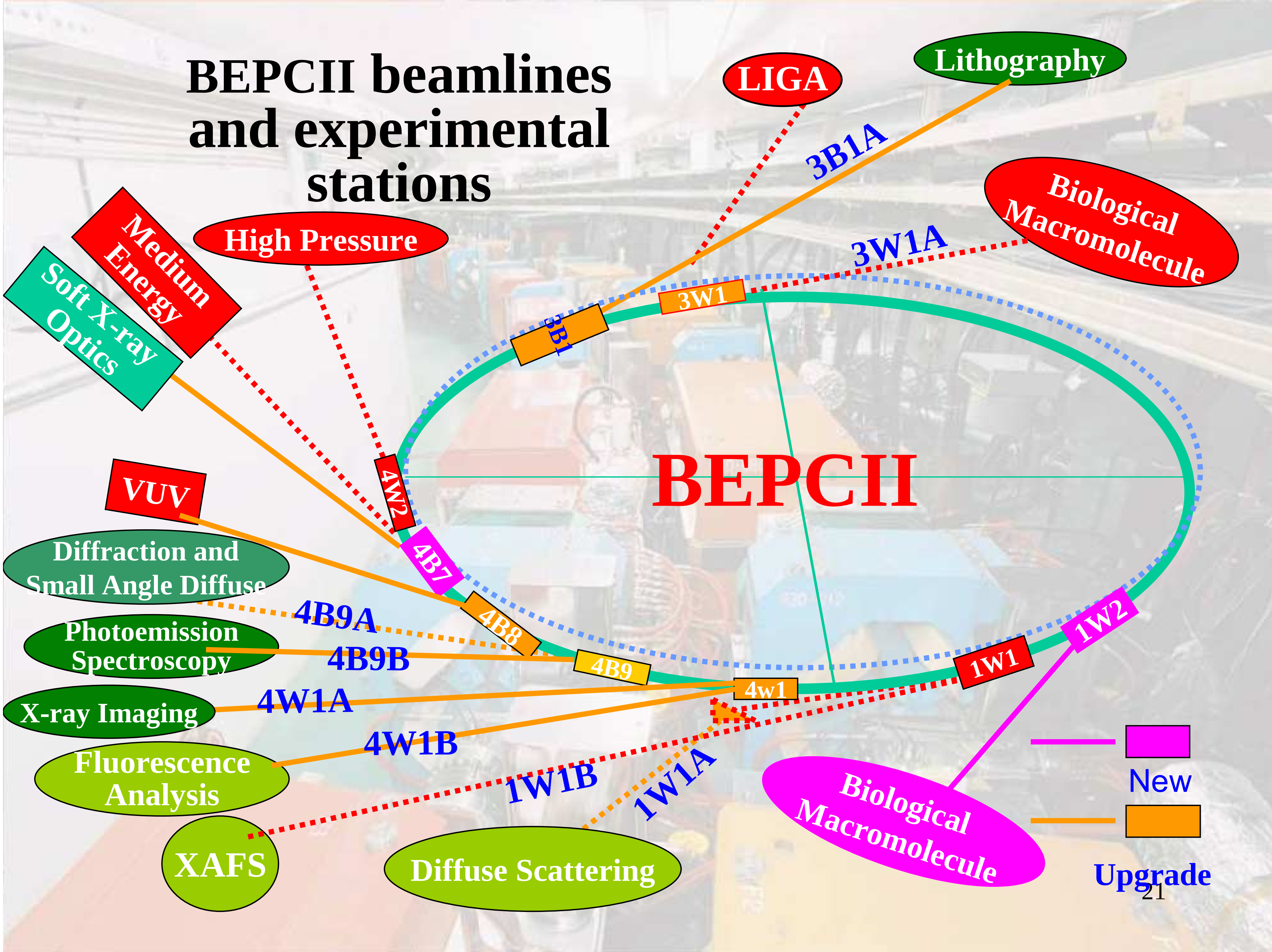
MDC: small cell & He gas
σ_{xy}=130 μm
s_p/p = 0.5% @1GeV
dE/dx=6%

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


BEPCII beamlines and experimental stations
LIGA
Lithography
3B1A
Biological Macromolecule
3W1A
High Pressure
Medium Energy
Soft X-ray Optics
3W1
3B1
4W2
BEPCII
VUV
4B7
Diffraction and Small Angle Diffuse
4B9A
4B8
Photoemission Spectroscopy
4B9B
4B9
4w1
1W1
1W2
X-ray Imaging
4W1A
4W1B
Fluorescence Analysis
1W1B
1W1A
XAFS
Diffuse Scattering
Biological Macromolecule
New
Upgrade

2.2 Physics at BEPCII/BESIII

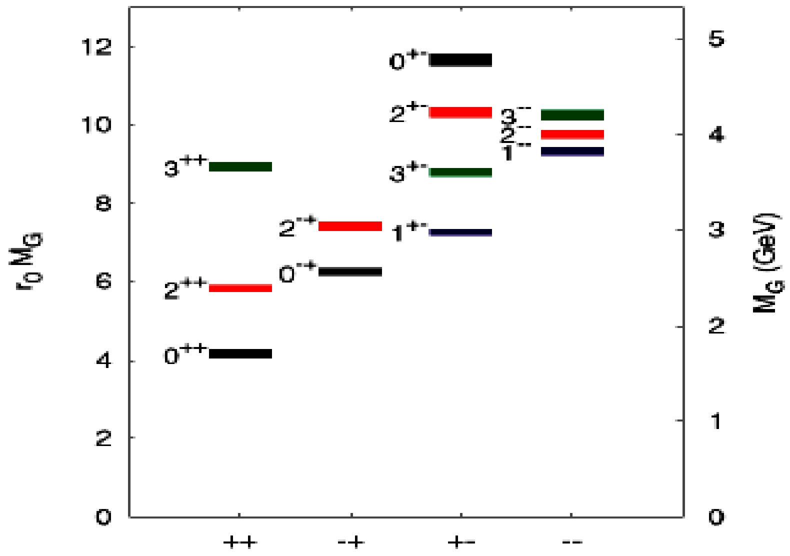
Remains a dual-purpose facility

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}

Light hadron spectroscopy

- **Baryon spectroscopy**
- **Charmonium spectroscopy**
- **Glueball searches**
- **Search for non-$q\bar{q}$ states**

10^{10} J/ψ events is probably enough to pin down most of problems of light hadron spectroscopy



Y. Chen *et al.*
PRD73:014516,2006
(updates Morningstar & Peardon, '99)

0^{++} : 1710 ± 50 ± 80

Also:
1611 ± 30 ± 160 Michael '98
1550 ± 50 ± ? Bali et al. '93

Spectrum of glueballs from LQCD

Precision measurement of CKM

- *Branching rations of charm mesons*

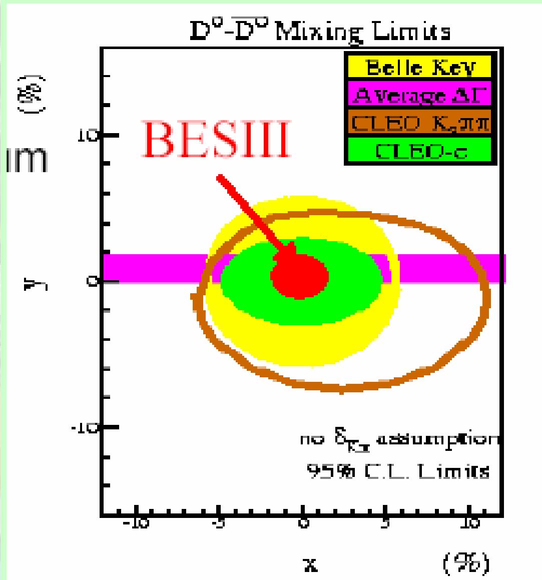
- **V_{cd} /V_{cs}: Leptonic and semi-leptonic decays**
- **V_{cb}: Hadronic decays**
- **V_{td} /V_{ts}: f_D and f_{Ds} from Leptonic decays**
- **V_{ub}: Form factors of semi-leptonic decays**
- **Unitarity Test of CKM matrix**

	Current	BESIII
V_{ub}	25%	5%
V_{cd}	7%	1%
V_{cs}	16%	1%
V_{cb}	5%	3%
V_{td}	36%	5%
V_{ts}	39%	5%

Precision test of SM and Search for new Physics

- **$\bar{D}D$ mixing**
  - $D\bar{D}$ mixing in SM ~ 10^{-3} - 10^{-10}
  - $D\bar{D}$ mixing sensitive to "new physics"
  - Our sensitivity : ~ 10^{-4}
- **Lepton universality**
- **CP violation**
- **Rare decays**

  FCNC, Lepton no. violation, …



$D^0\overline{D}^0$ Mixing

Reaction	Events Right Sign	Sensitivity of R_M
$\psi(3770) \to (K^-\pi^+)(K^-\pi^+)$	87195	1×10^{-4}
$\psi(3770) \to (K^-e^+\nu)(K^-e^+\nu)$	94351	
$\psi(3770) \to (K^-e^+\nu)(K^-\mu^+\nu)$	166808	3.7×10^{-4}
$\psi(3770) \to (K^-\mu^+\nu)(K^-\mu^+\nu)$	83404	
$D^{*+}D^- \to [\pi_s^+(K^+e^-\overline{\nu})(K^+\pi^-\pi^-)]$	76000	
$D^{*+}D^- \to [\pi_s^+(K^+\mu^-\overline{\nu})(K^+\pi^-\pi^-)]$	60000	
$D^{*+}D^- \to [\pi_s^+(K^+e^-\overline{\nu})(\text{other } D^- \text{ tag})]$	60000	4.7×10^{-5}
$D^{*+}D^- \to [\pi_s^+(K^+\mu^-\overline{\nu})(\text{other } D^- \text{ tag})]$	60000	

QCD and hadron production

- R-value measurement
- pQCD and non-pQCD boundary
- Measurement of α_s at low energies
- Hadron production at J/ψ, ψ', and continium
- Multiplicity and other topology of hadron event
- …

Error on R	$\Delta\alpha^{(5)}_{had}(M_Z^2)$
6%	0.02761 ±0.00036
3%	0.02761 ±0.00030
2%	0.02761 ±0.00029

Errors on R will be reduced to 2% from currently 6%

2.3 The BEPCII Accelerators

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

Beam energy range	1–2.1 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	1.0–2.1	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 ($\nu_x/\nu_y/\nu_s$)		6.57/7.61/0.034	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

2.3.1 The Injector Linac

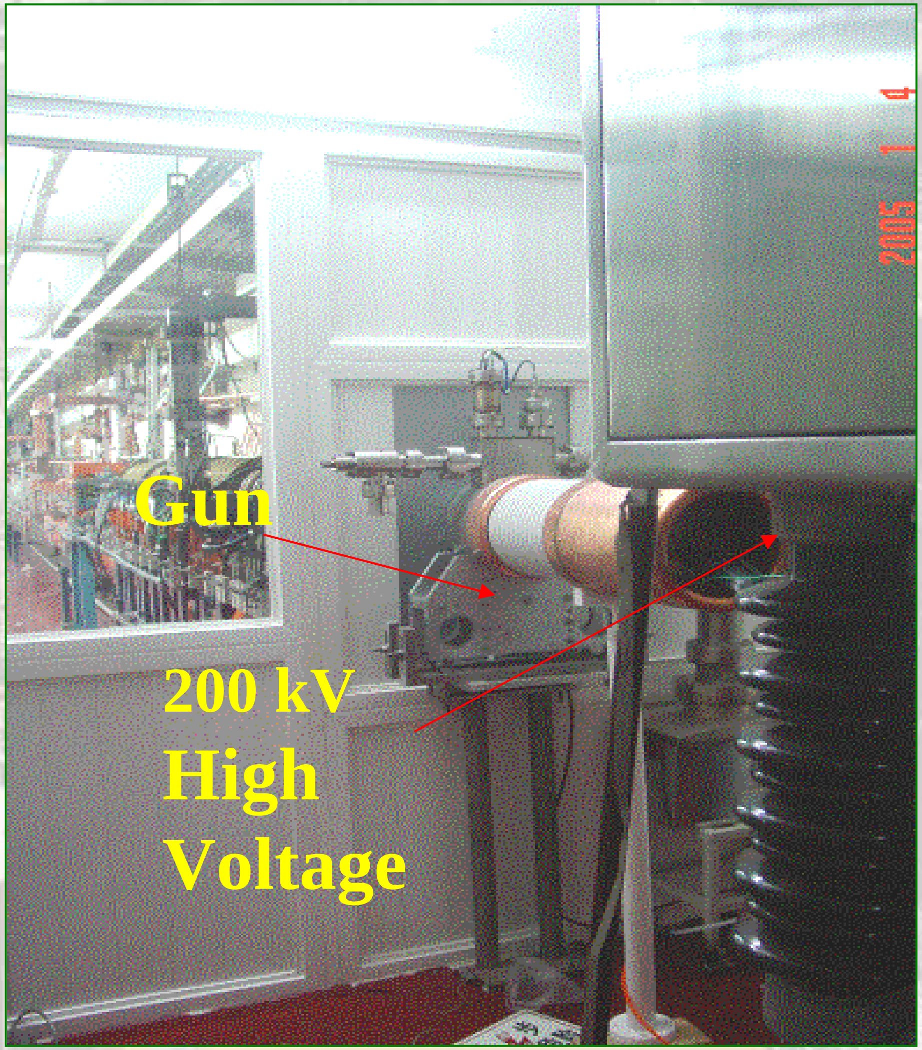
- **Basic requirement:**
  - **Higher intensity: e^+ injection rate ≥ 50 mA/min.;**
  - **Full energy injection with E=1.55 ~ 1.89 GeV;**
- **To enhance the current and energy of the electron beam bombarding the target and to reduce the beam spot;**
- **To design and produce a new positron source and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

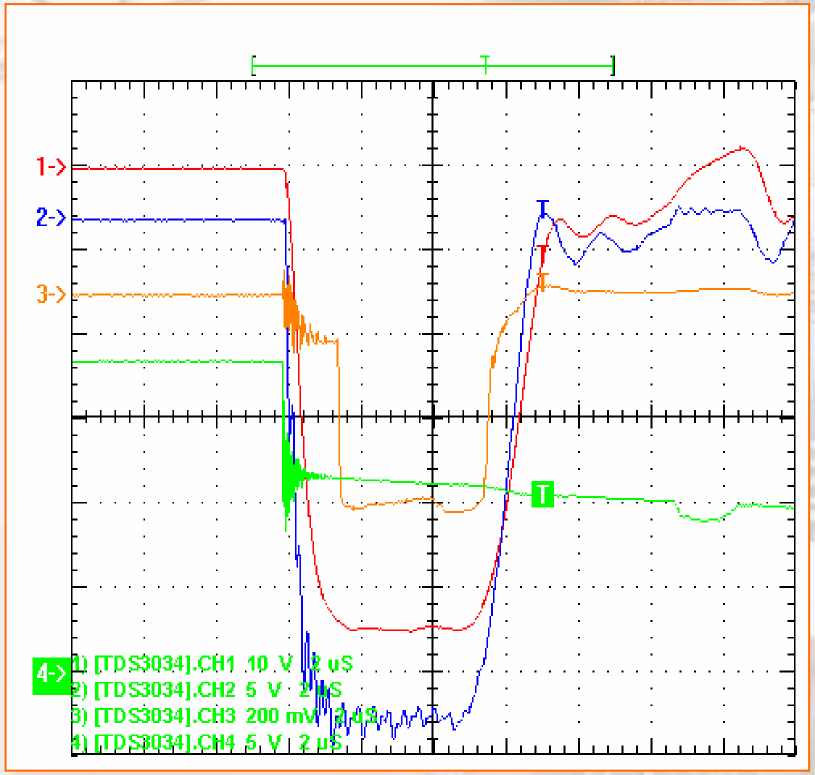
A flux concentrator is employed to have a large e^+ acceptance:
L = 10 cm , B = 5.3 T □0.50 T, Φ = 7 mm →52 mm.

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
$\varepsilon_x / \varepsilon_y$ (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

2.3.3 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



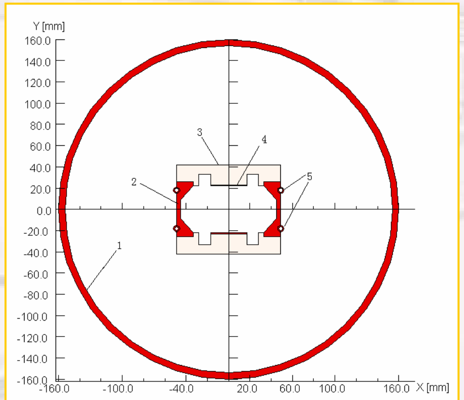
Magnet type	Number
Dipole (Leff.=1.4135m)	40+1
Dipole (Leff.= 1.2277m)	2
Dipole (Leff.= 1.0339m)	2
Weak dipole (Leff.=1.0321m)	2
Weak dipole (Leff.=0.7453m)	2
Quadrupole	88+2
Old quadrupoles with modified coils	28
160Q quadrupole (Old)	6
Sextupole	72+1
Vertical corrector	48+1
Special vertical corrector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



Power Supplies

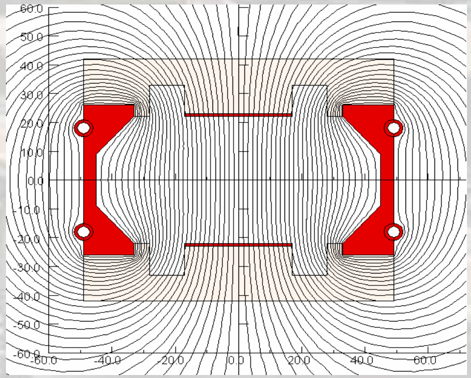
P.S.	No.	Design Stability	Tested Stability
Q & S	165	1×10^{-4}	4×10^{-5}
OQ2,OQ3, IQ2, IQ3	16	1×10^{-4}	5×10^{-5}
B	4	1×10^{-4}	5×10^{-5}
BH,BV	144	1×10^{-4}	4×10^{-5}
T.Q	34	1×10^{-4}	4×10^{-5}
T.B	2	1×10^{-4}	4×10^{-5}
SC magnets	16	1×10^{-4}	1×10^{-4}
Q1a,Q1b,ISPB	3	1×10^{-4}	1×10^{-4}

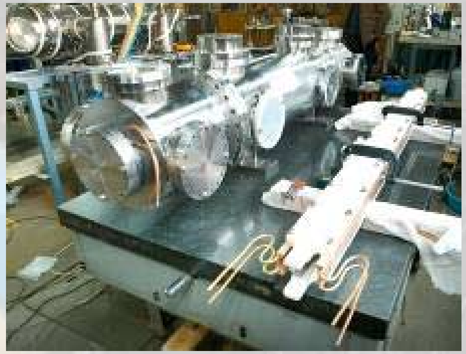
Injection Kickers

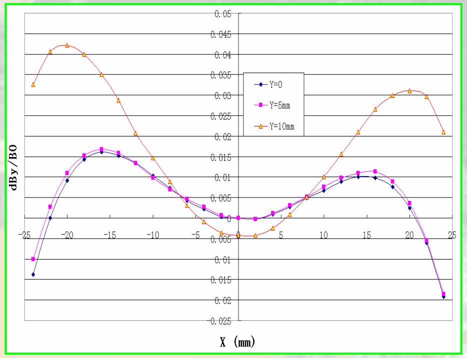


1 Vacuum vessel; 2 Current bus; 3 Ceramic plate; 4 Metal coating; 5 Cooling tube.

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

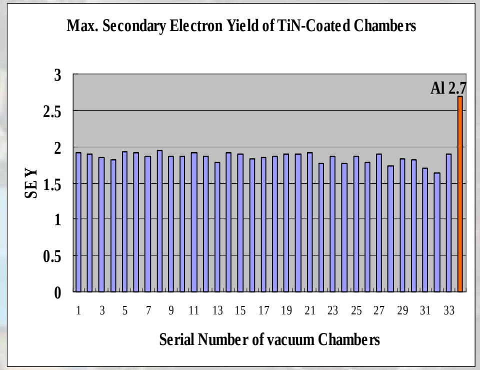




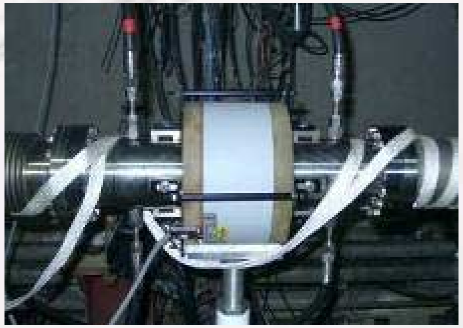


Vacuum System

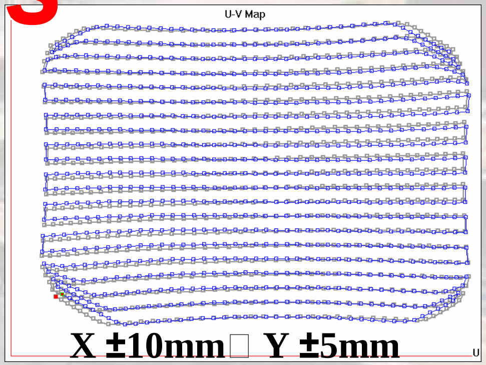
- The design dynamic vacuum pressure are 8×10^{-9} Torr in the arc and 5×10^{-10} Torr in the IR.
- Antechambers are chosen for both e^+ and e^- rings.
- 80 arc chambers,120 straight section chambers; 175 discrete photon absorbers 180 RF shielded bellows
- TiN coating for e+ ring chambers to reduce SEY

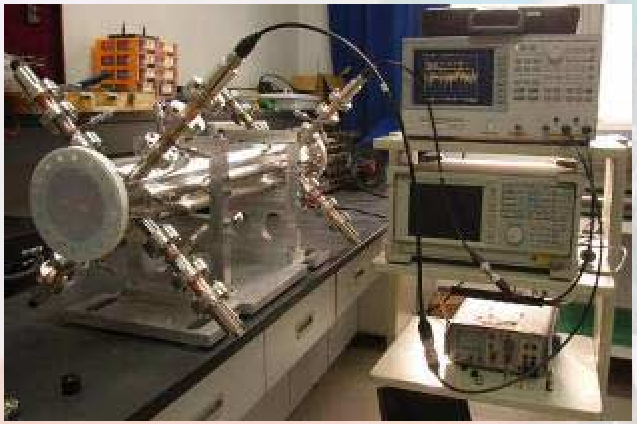


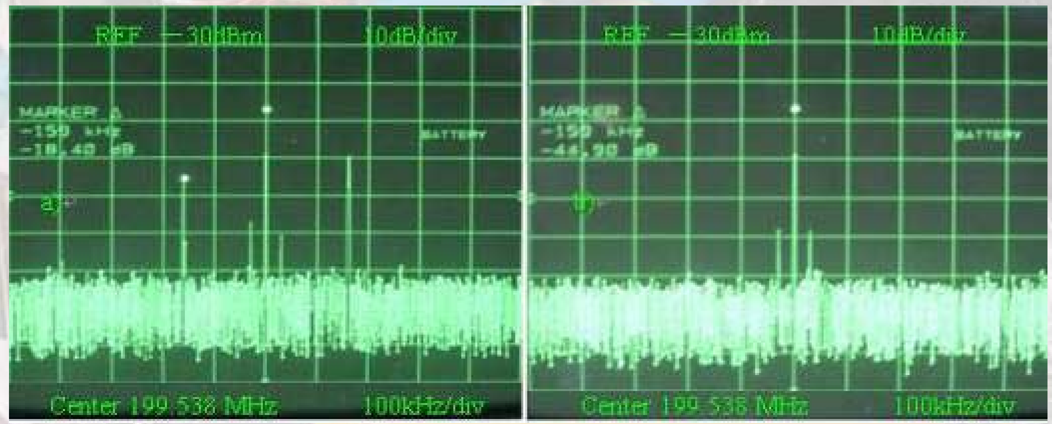
Beam Diagnosis



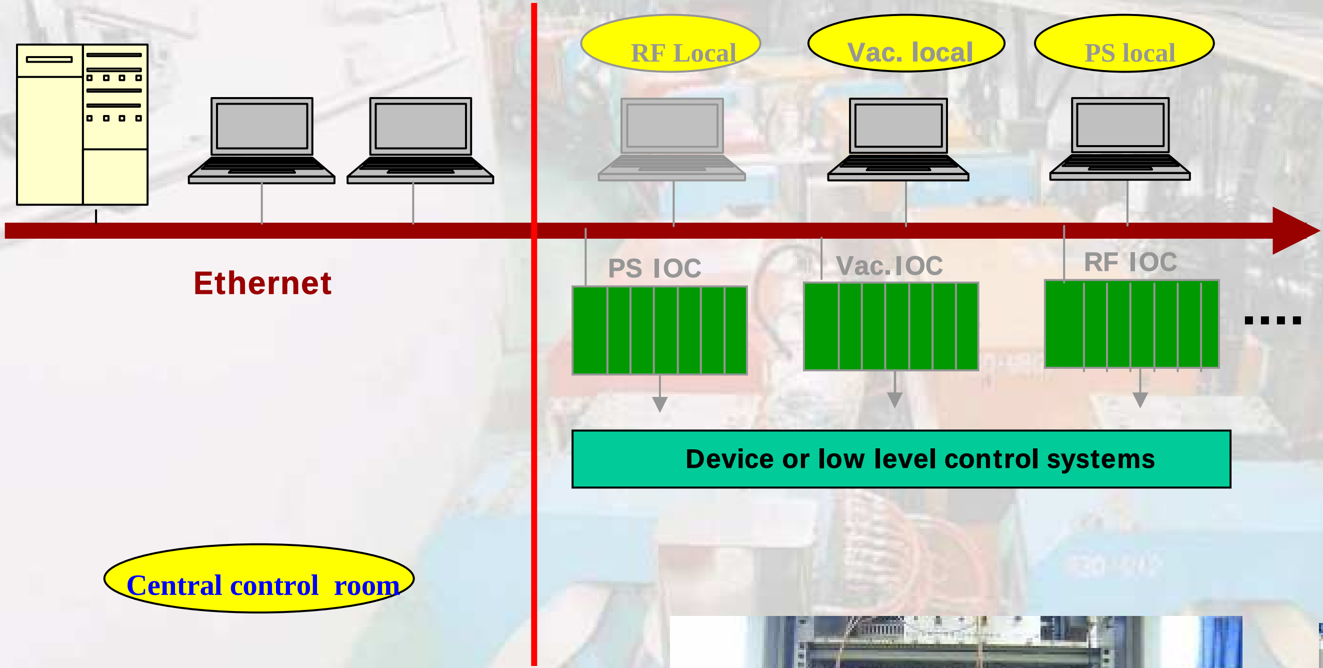
- Beam Position Monitor
- Bunch Current Monitor
- SR monitor
- DCCT
- Transverse Feedbake
- Tune measurement
- Beam Loss Monitor

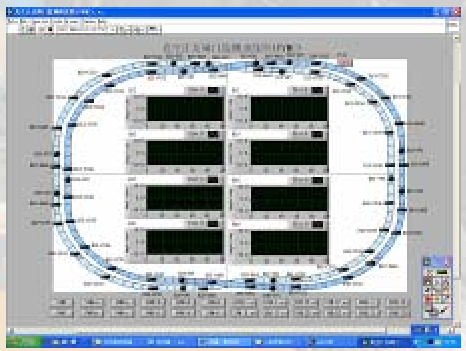




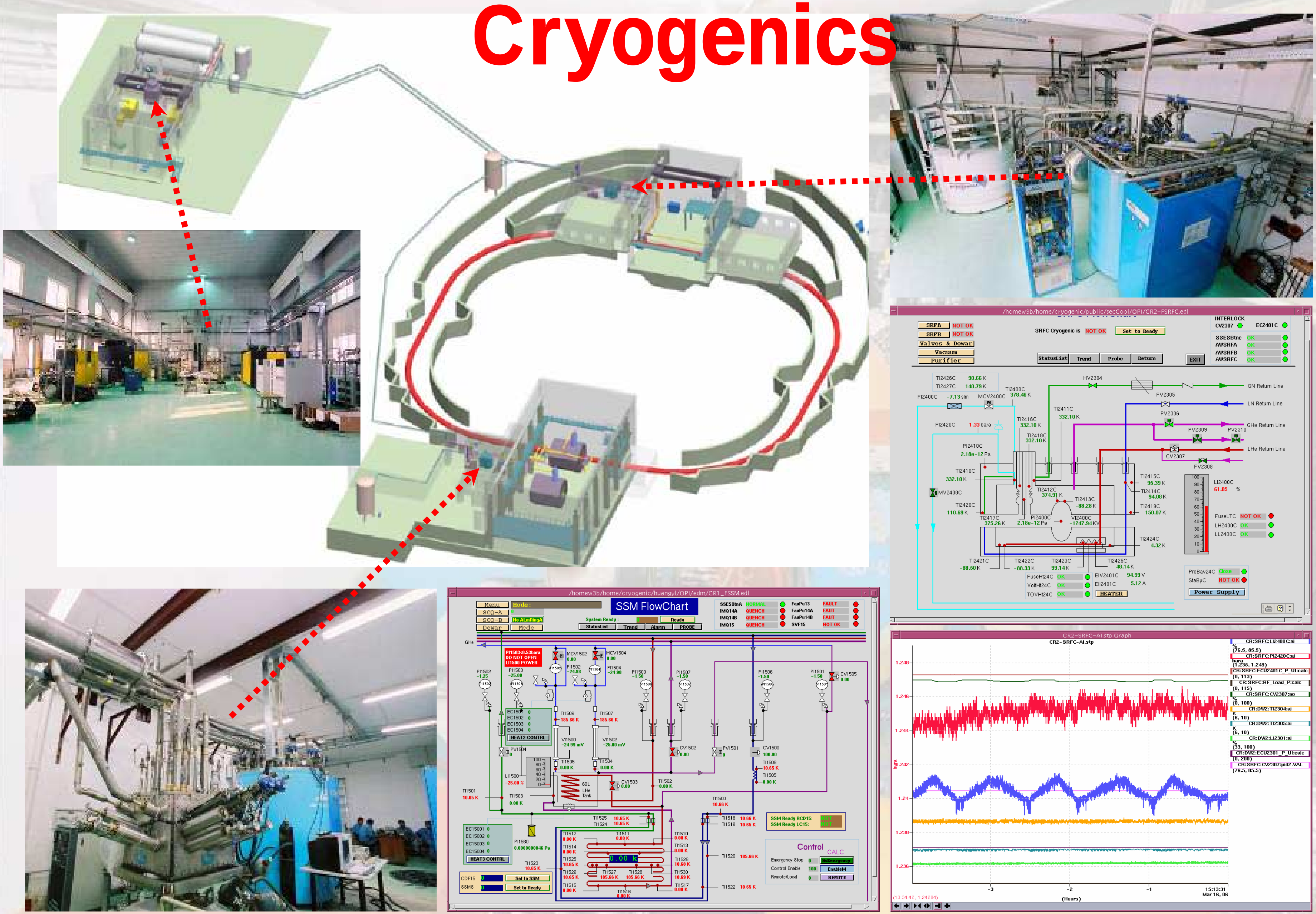


Control System

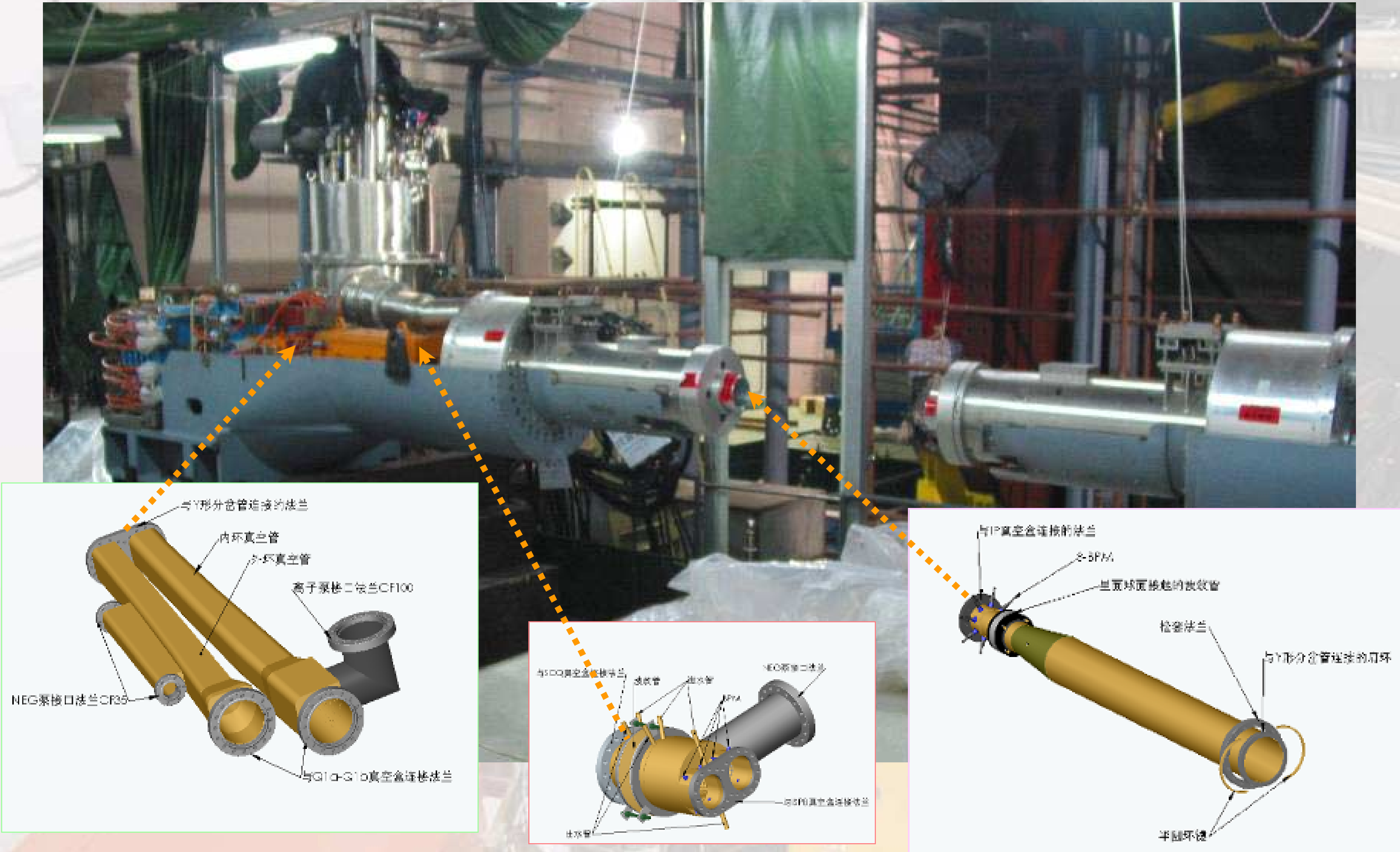




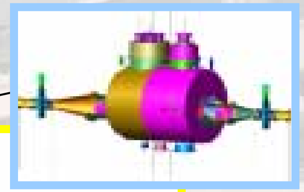
Cryogenics


SSM FlowChart
GN Return Line
LN Return Line
GHe Return Line
LHe Return Line
Control

Interaction Region



Commissioning



Collision: e^- ring (BER) + e^+ ring (BPR)

SR Operation: Outer ring (BSR)

Phase 1□IR with Conventional magnets

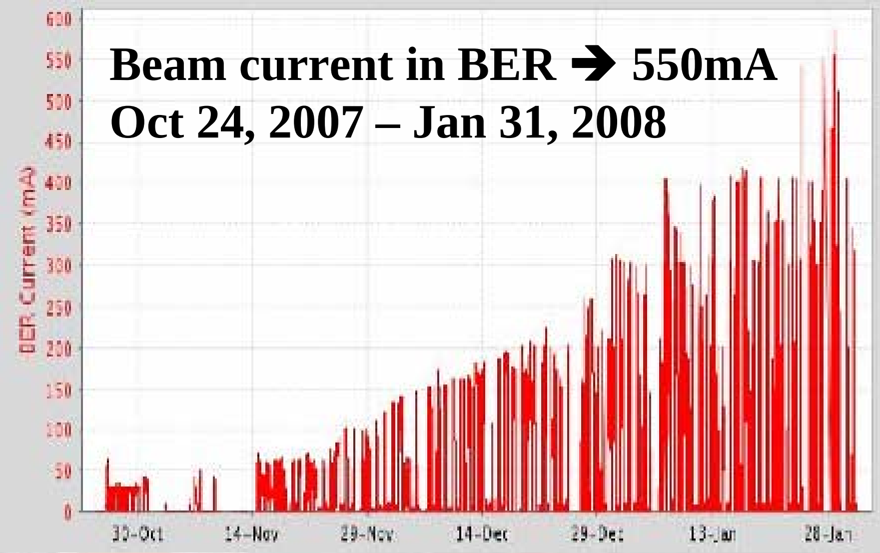
Phase 2□IR With SCQ's

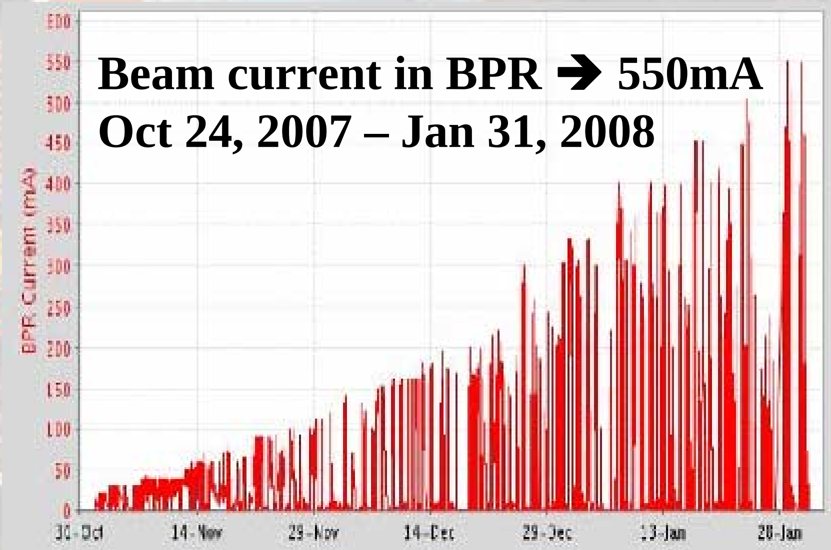
Phsse 3□BEPCII + BESIII

The road to high beam current

- **Optics optimization□Twiss parameter corrected to design velues, orbit correction, etc.**
- **High beam current: Beam dose cleaning vacuum, RF conditioning, bunch-by-bunch feedback, cooling in beam dusts, etc.**
- **High luminosity□tune scan, collision optimization, single bunch current, more bunches□etc.**

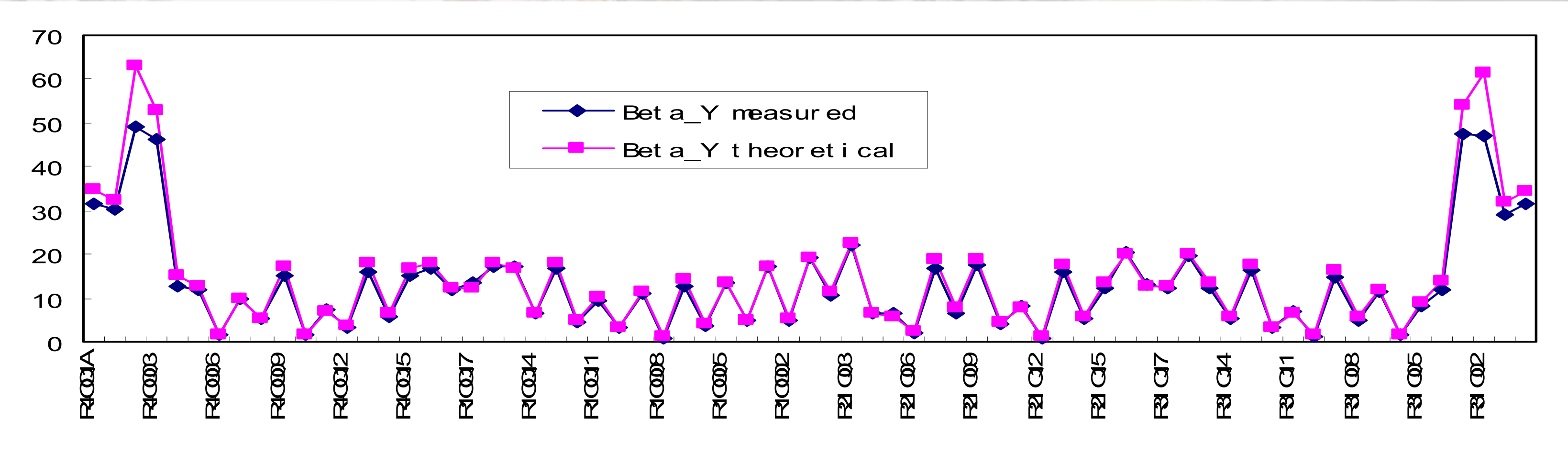
As the result, the beam current in collision get higher than 530mA.

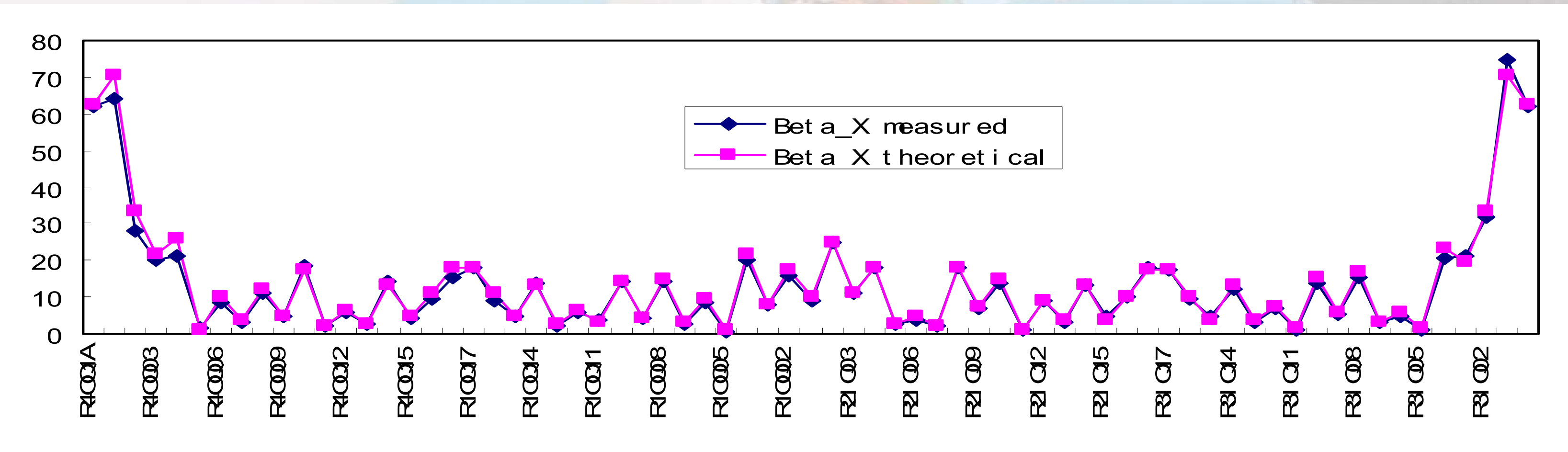




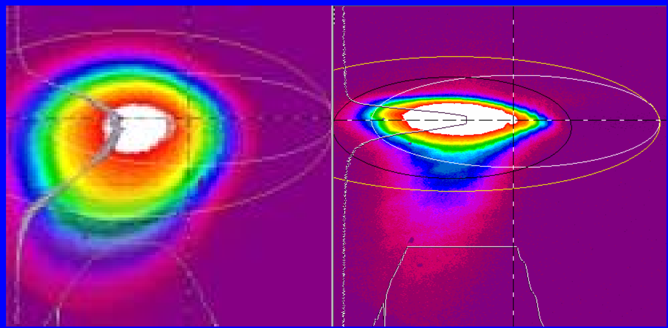
Optics Correction

Design ν_x/ν_y= 6.54, 5.59 measured ν_x/ν_y= 6.544, 5.599

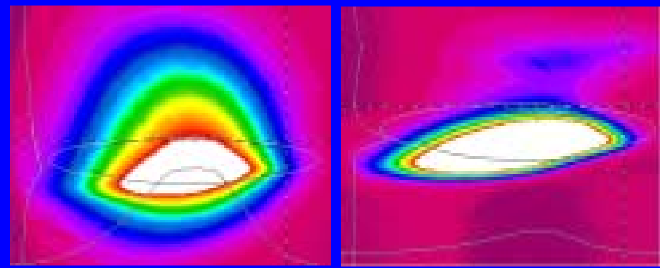




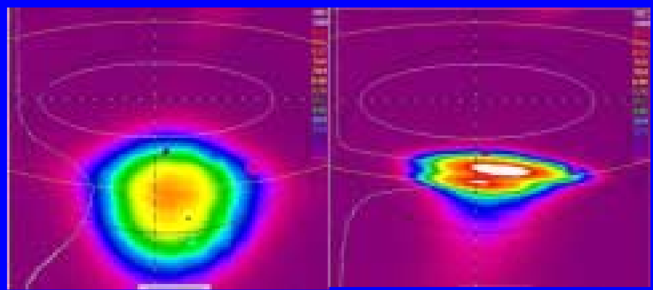
Test of transverse feedback



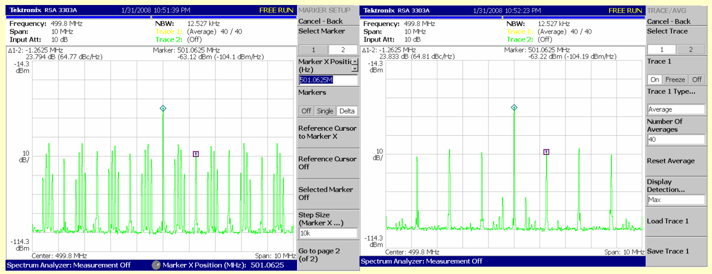
Feedback off feedback on



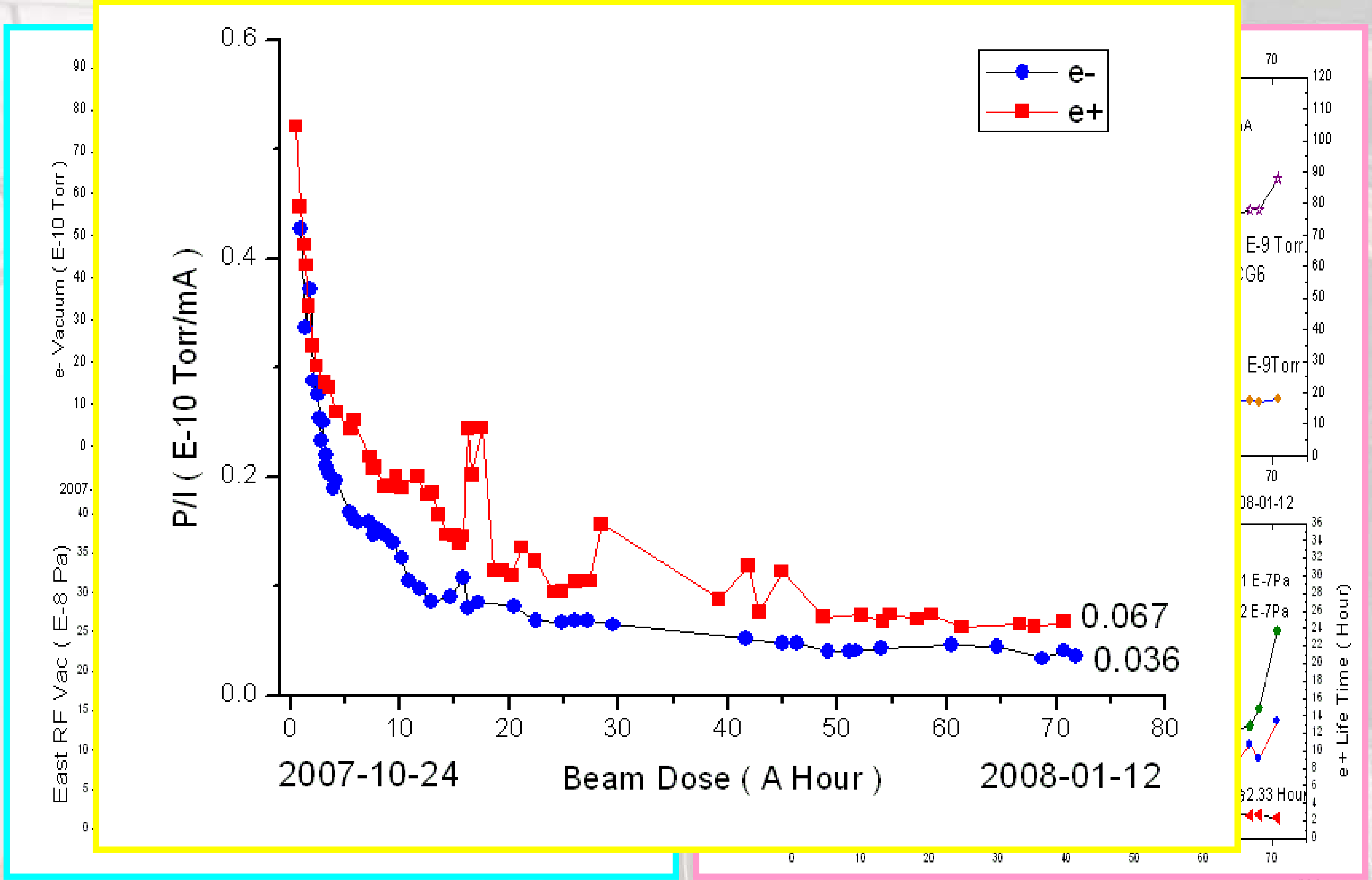
Feedback off feedback on



Feedback off feedback on

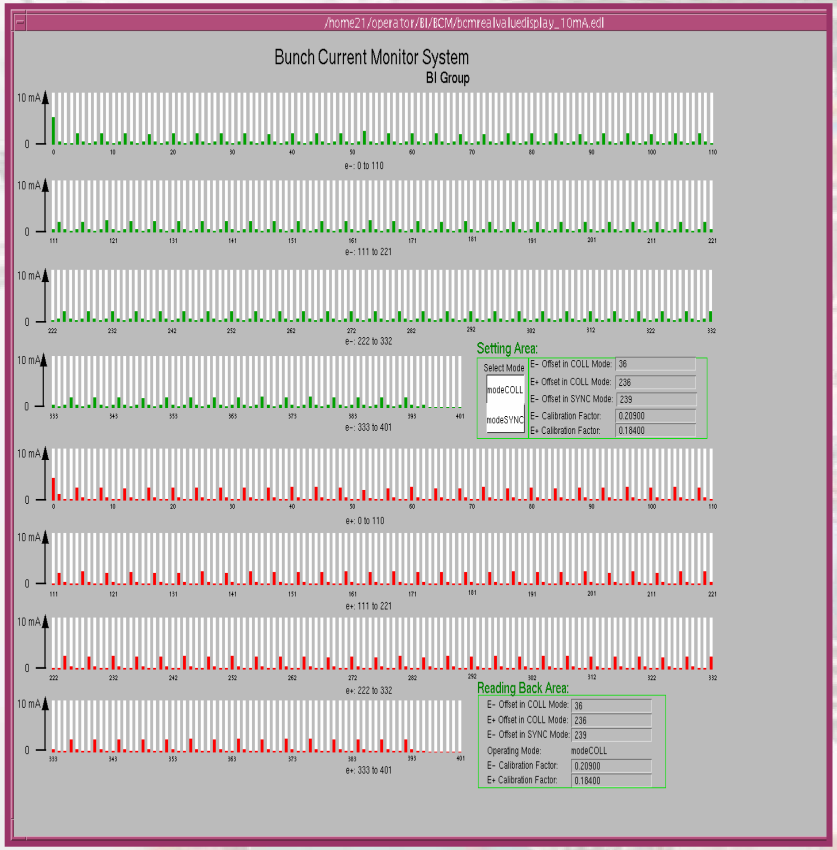


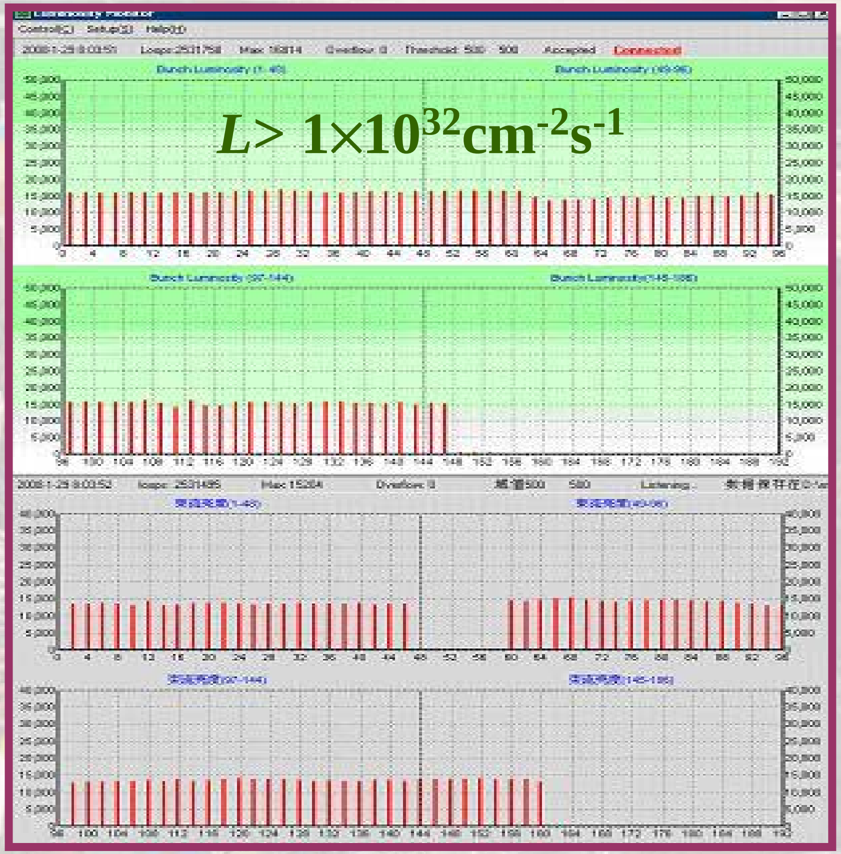
Vacuum pressure & lifetime vs. beam dose



L> 1×10^{32}cm^{-2}s^{-1} with 530mA×530mA Collision

Bunch current and luminosity





Bunch current display with BCM

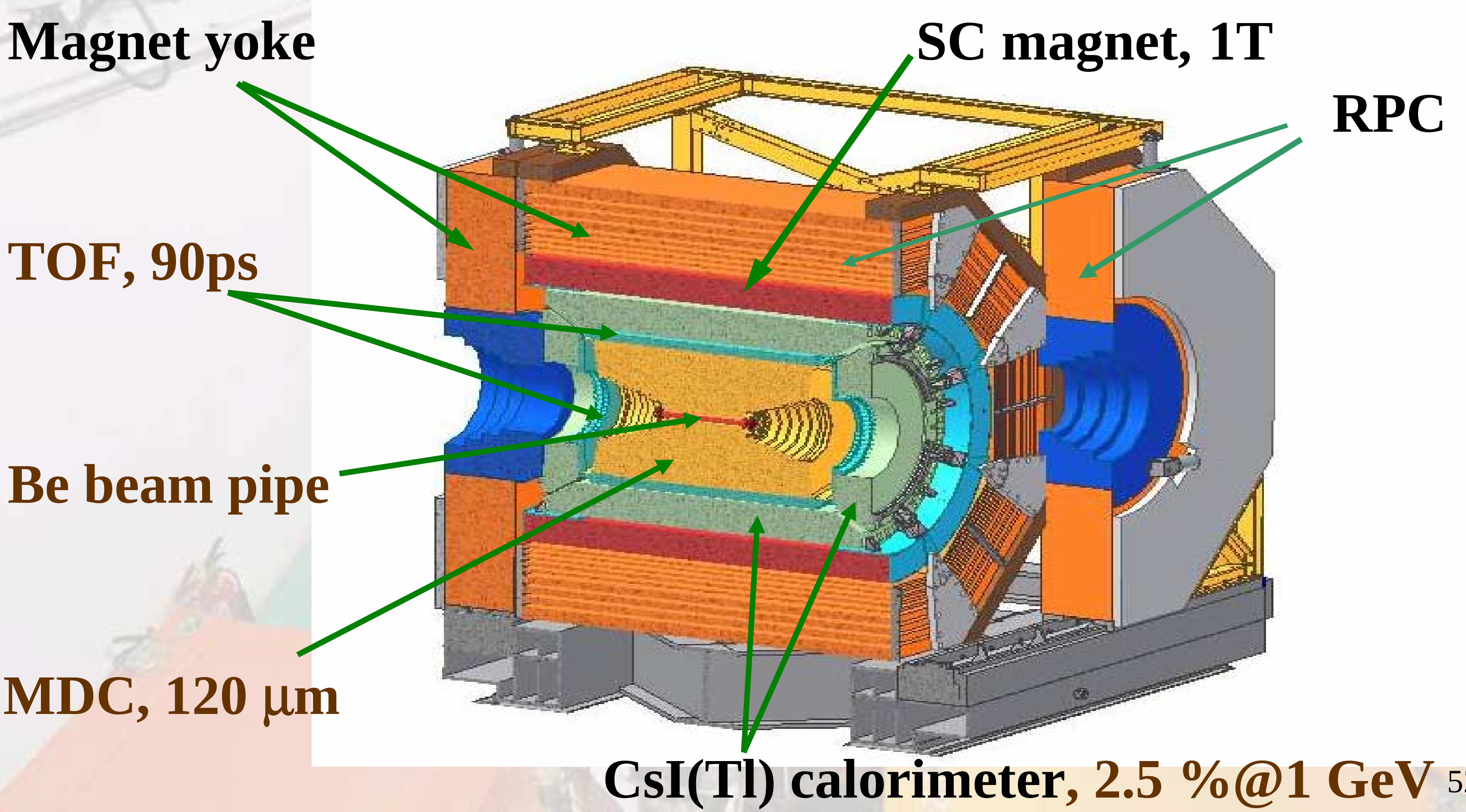
Bunch-bunch luminosity with zero-degree γ-detector

2.2 The BESIII Detector

— Adapt to high event rate : $10^{33}cm^{-2}\,s^{-1}$ and bunch spacing 8ns

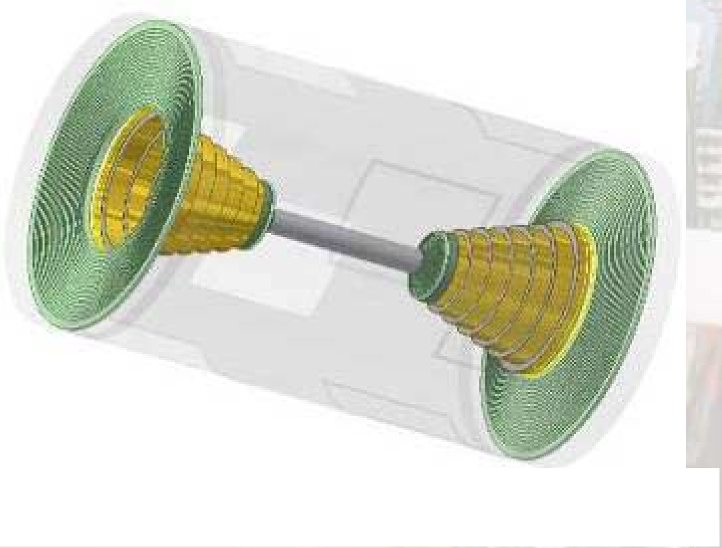
— Reduce sys. errors for high statistics: photon measurement, PID…

— Increase acceptance and give space for SC quads

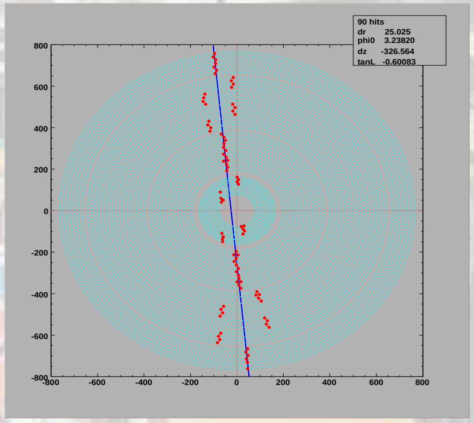


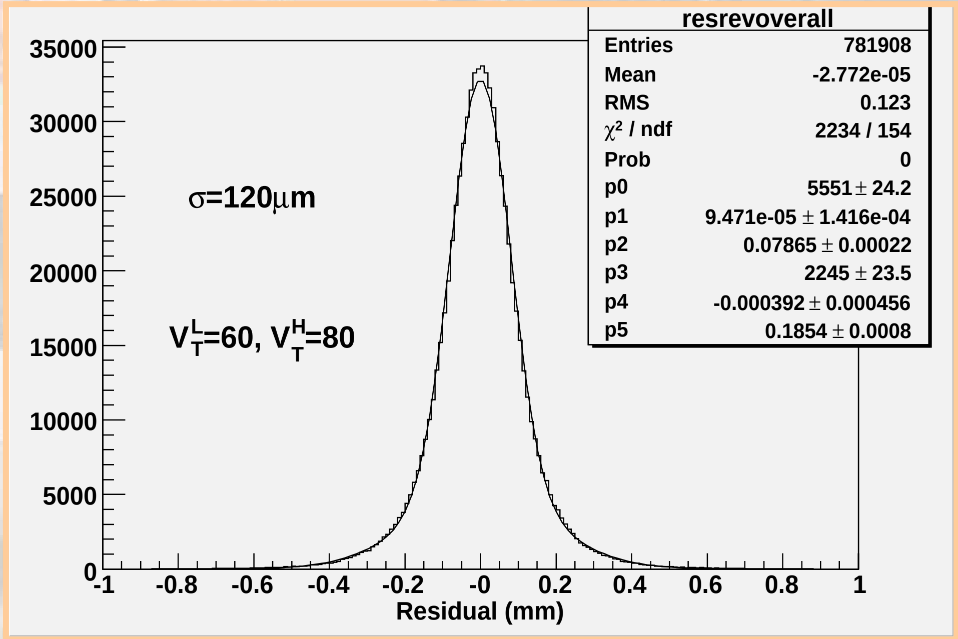
Main Drift Chamber

- 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: $$\frac{\sigma_{P_t}}{P_t} = 0.32\% \oplus 0.37\%$$
- dE/dX resolution: ~ 6%.



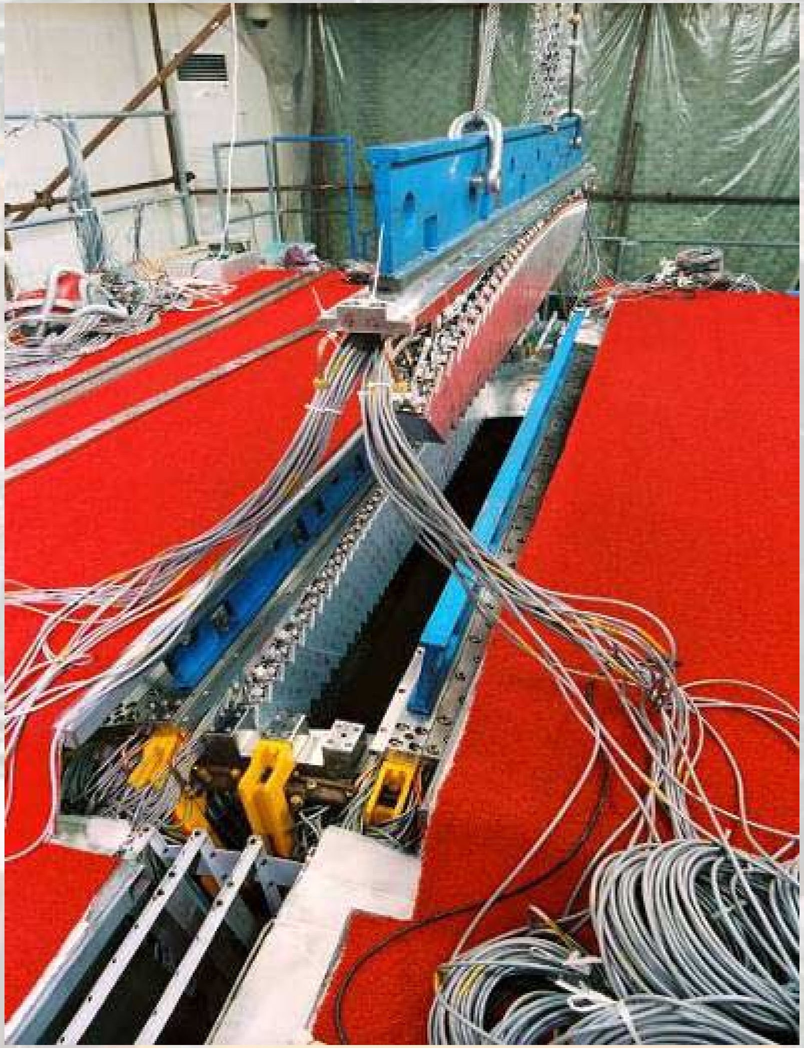
Separate cosmic ray test□meet design





Support Structure of EMC Barrel

EMC Barrel assembly



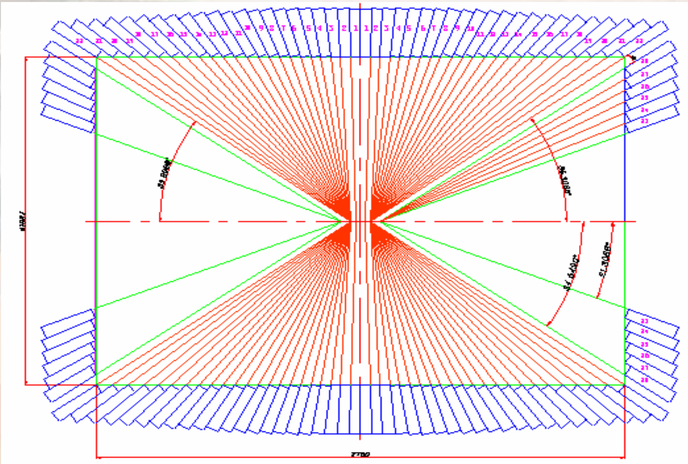
CsI(Tl) crystal calorimeter

Design goals:

- Energy: 2.5% @ 1GeV
- Spatial: 0.6cm @ 1GeV

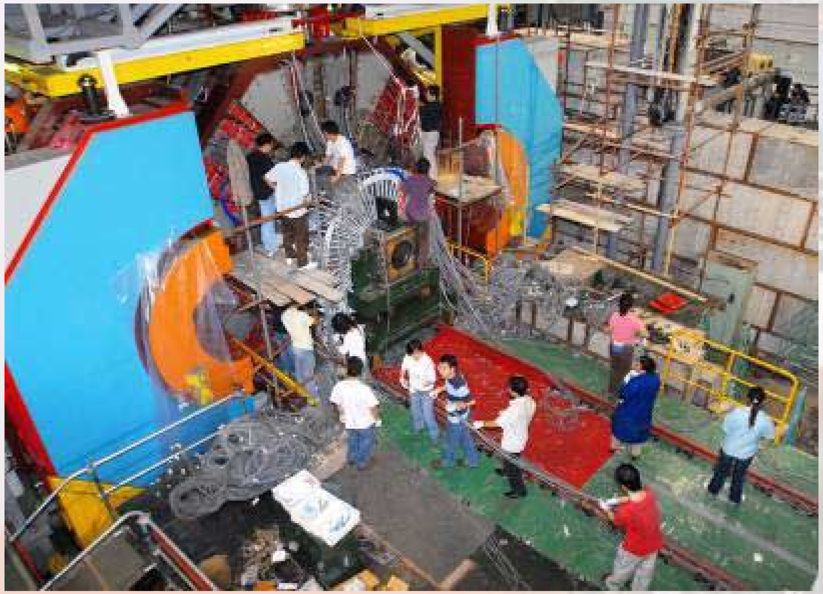
Crystals:

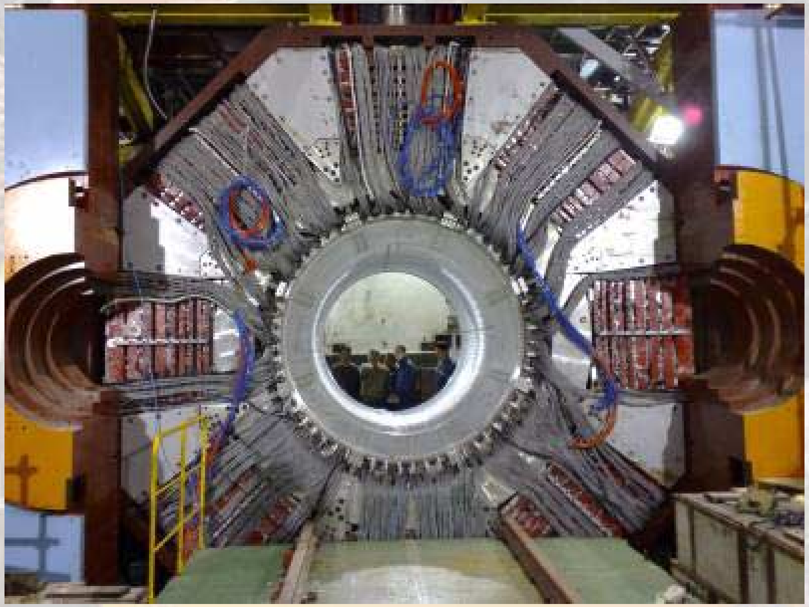
- Barrel: 5280 w: 21564 kg
- Endcaps: 960 w: 4051 kg
- Total: 6240 w: 25.6 T



France Sanit -Gobain	Shanghai Inst. of Ceramics	Beijing Hamamatsu	Total
2040	1920	1320	5280

Barrel EMC installation





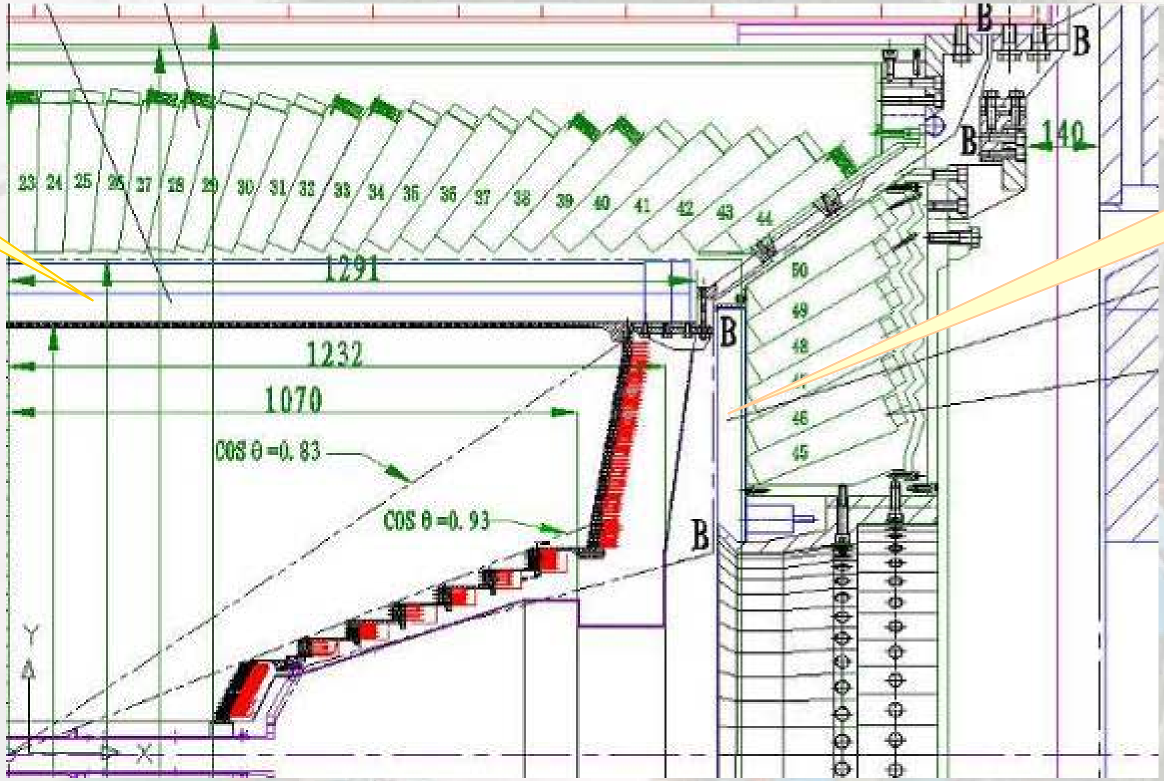
EMC endcap

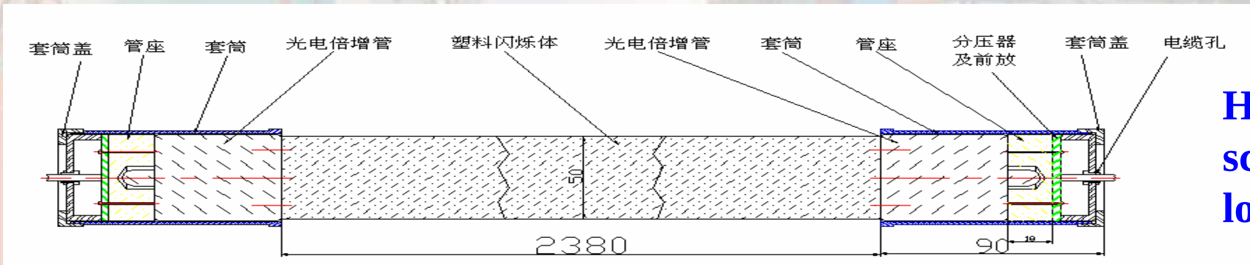
Time-Of-Flight counters

To measure the flight time of particles in order to identify them: m=P/(L/t)

Barrel TOF

Endcap TOF





High quality plastic scintillator: 2.4 m long, 5cm thick

Time-Of-Flight counters

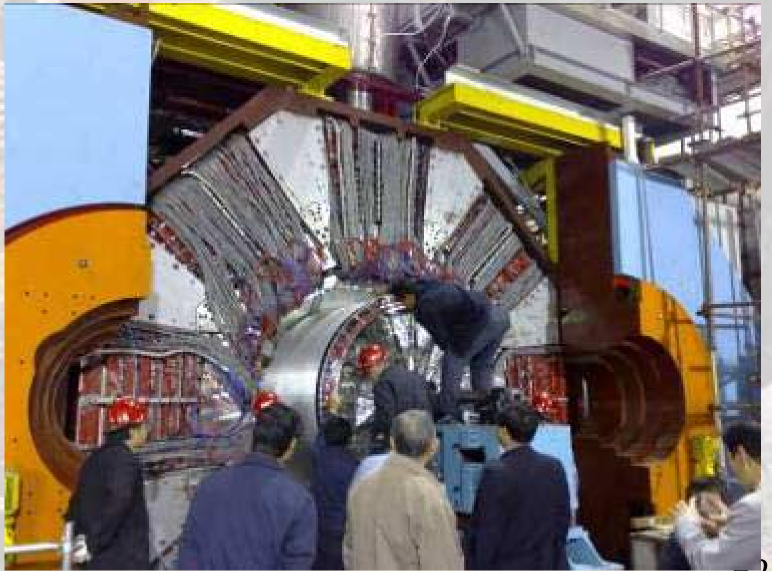
- All scintillator bars arrived from Bicron. BC408 at barrel, BC404 at endcap, PMT:R5924;
- Laser light monitor system;
- All counters are assembled, tested and installed.
- Cosmic ray test shows the system works.

Unit assembly and test

System test

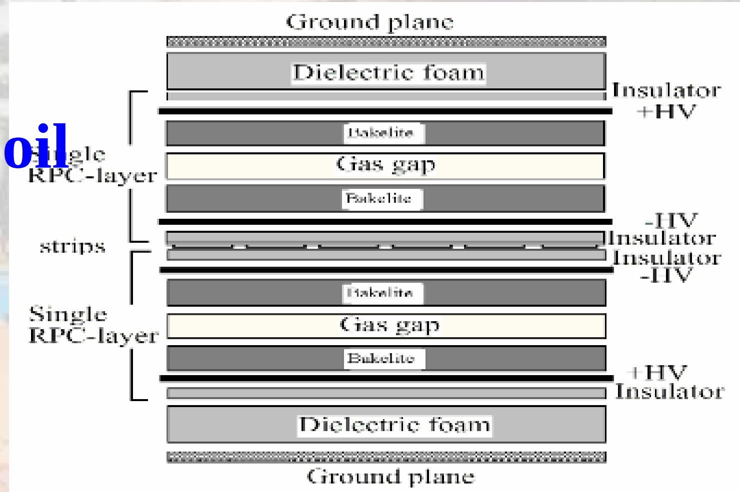
Barrel TOF installation

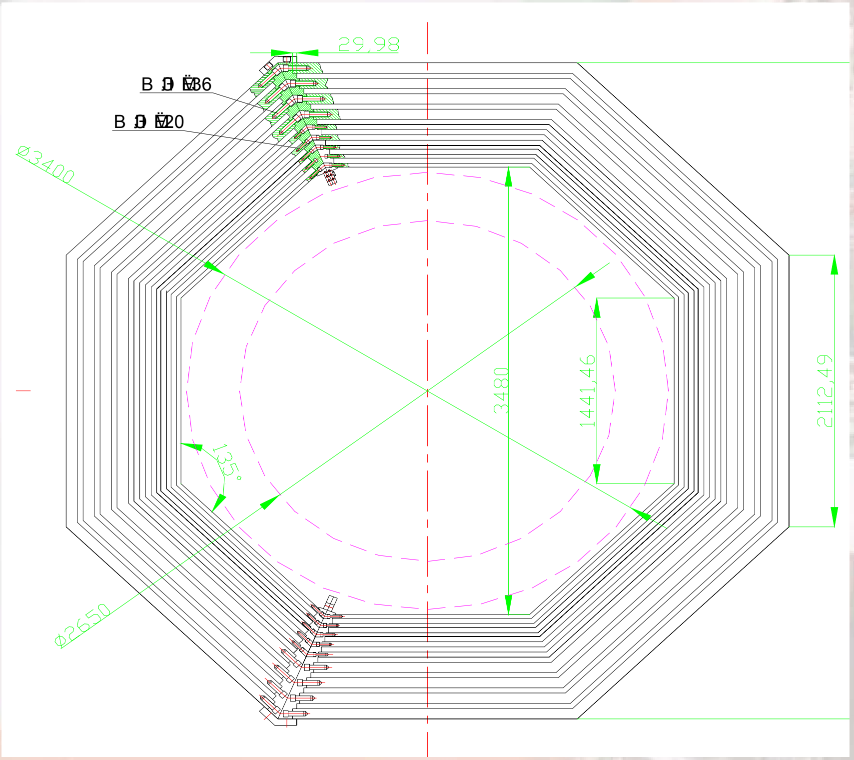
TOF/MDC installation



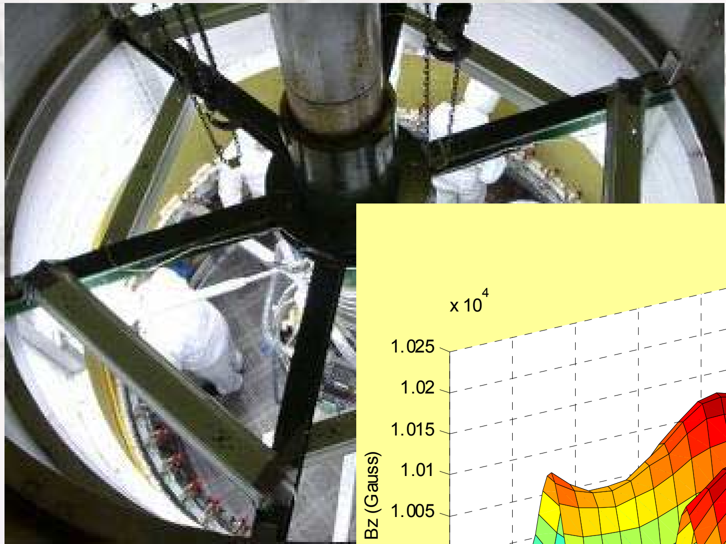
μ-detector : RPC

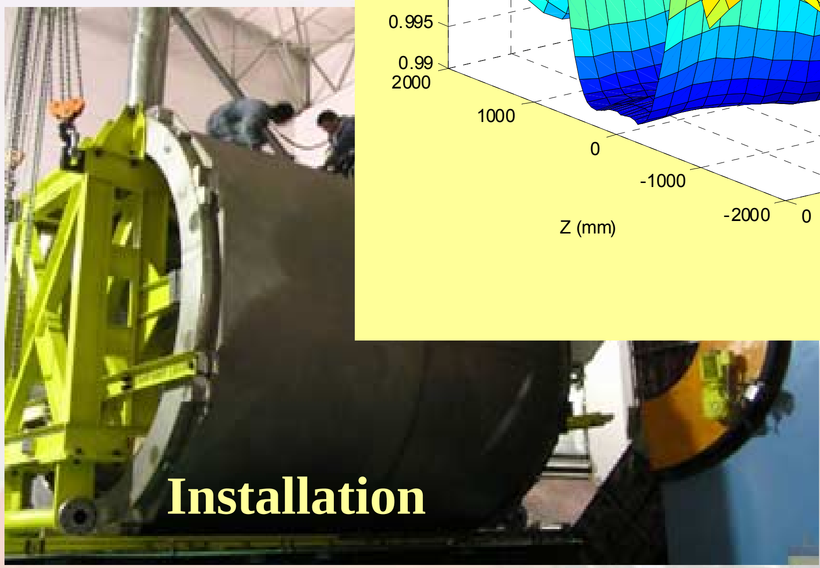
- **9 layer, 2000 m^2**
- **Special bakelite plate w/o lineseed oil**
- **4cm strips, 10000 channels**
- **Noise less than 0.1 Hz/cm^2**

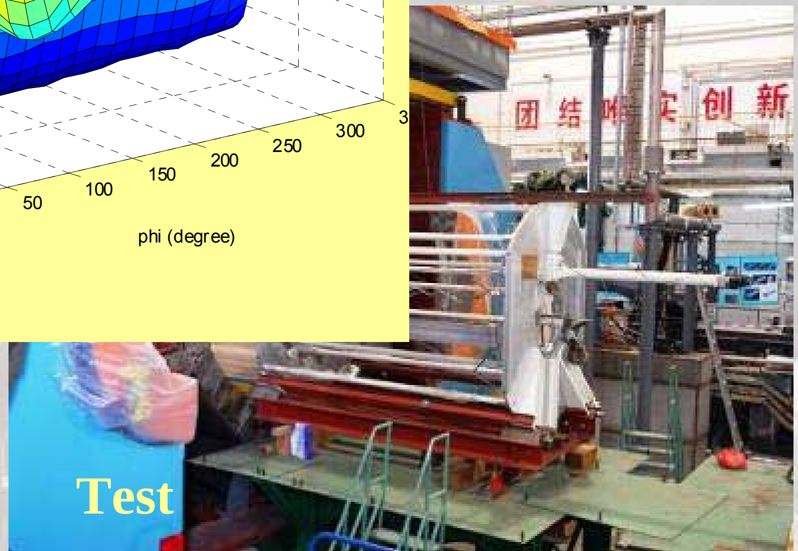


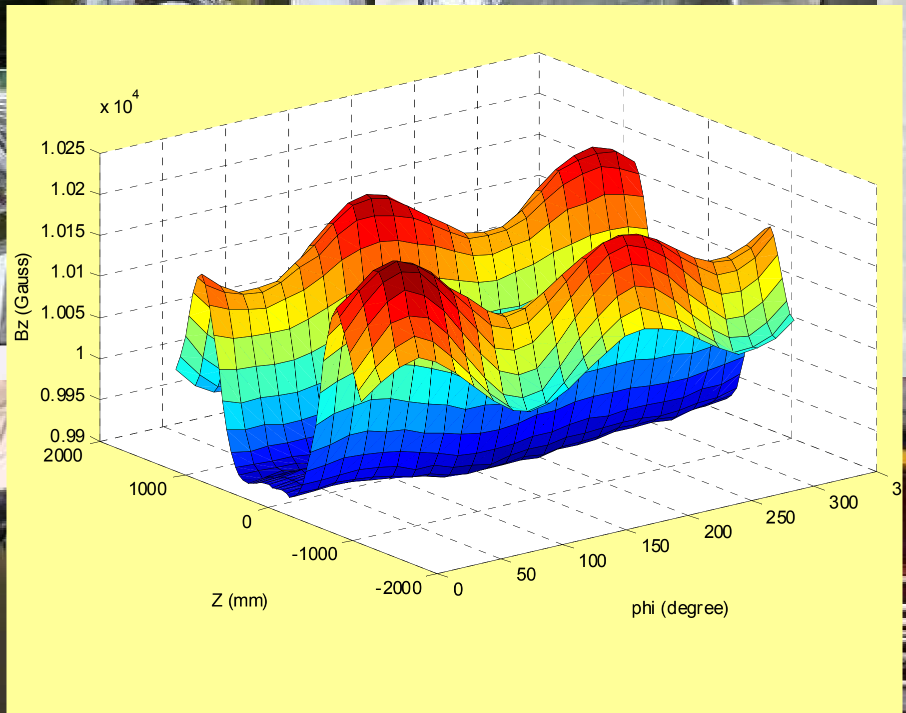


Superconducting magnet

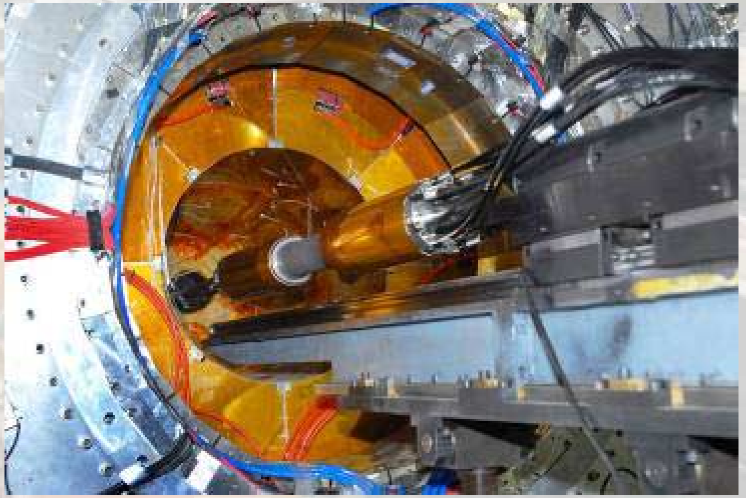


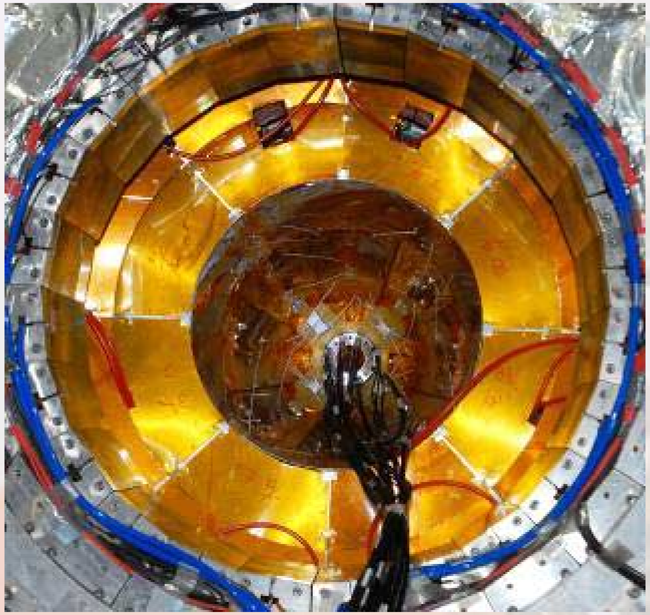




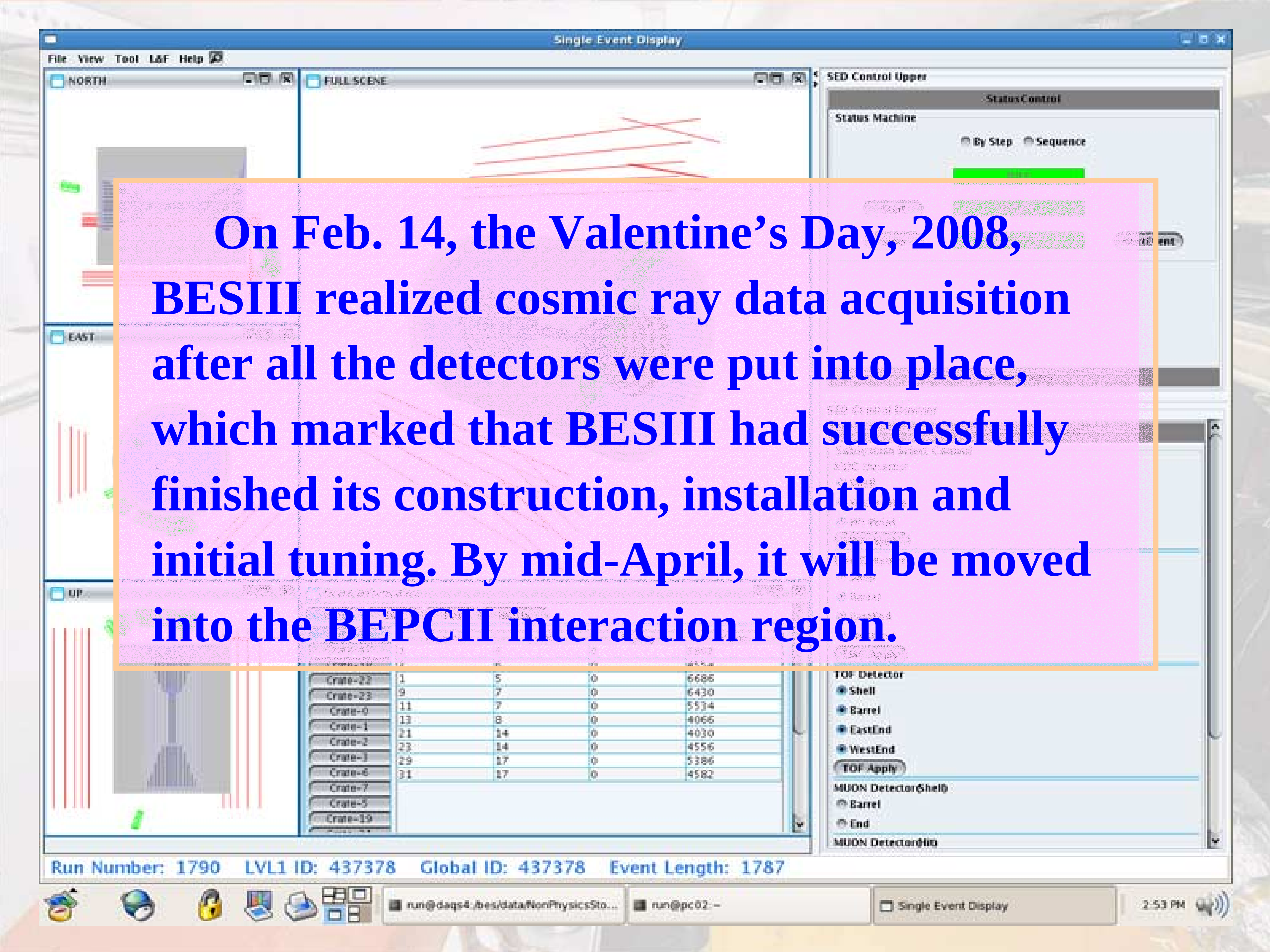


Be beam pipe



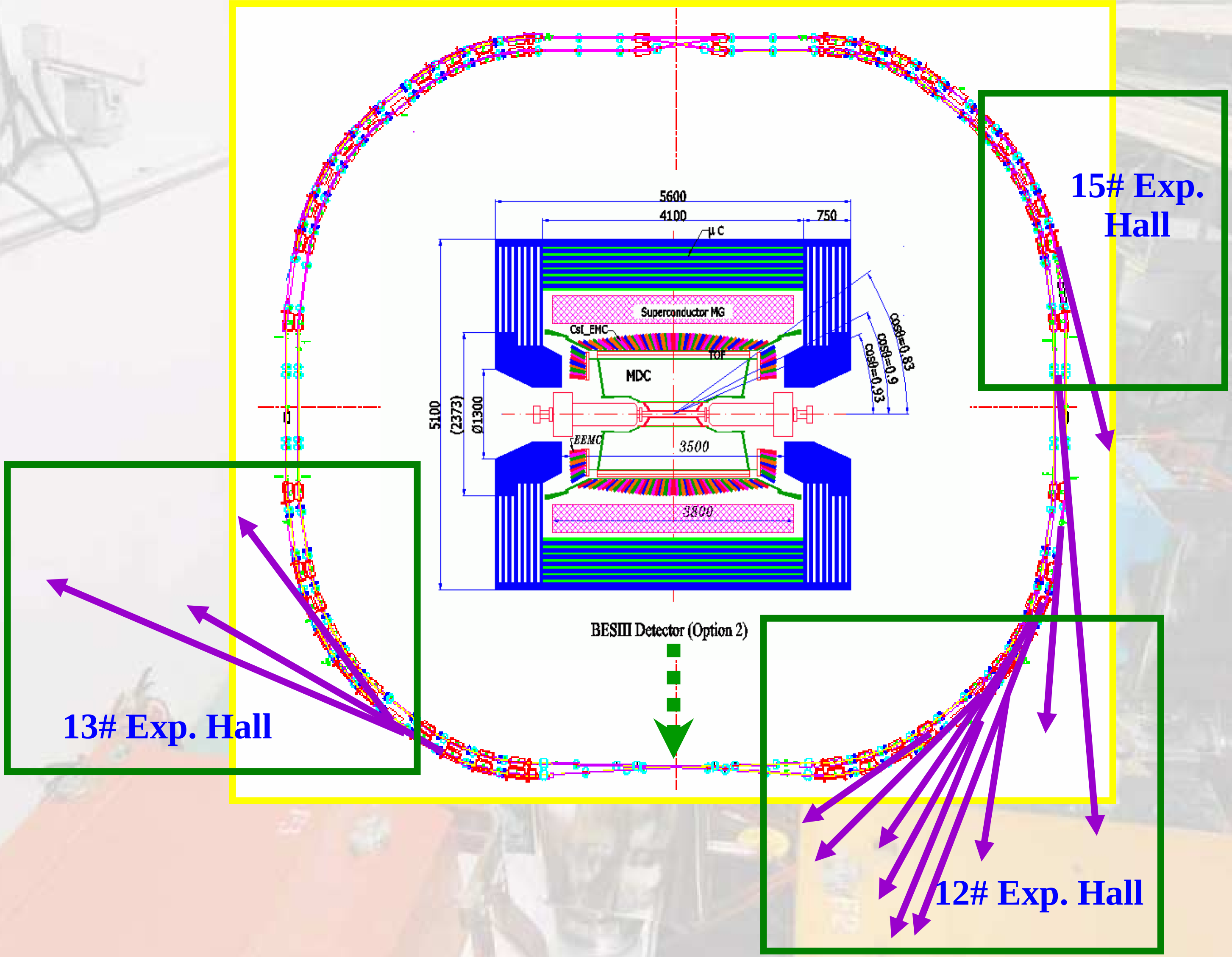


- Two Be cylinders (0.8 mm and 0.5 mm thick, 0.8mm gap), cold by paraffine-1
- 14.6 μm gold at inner surface.
- All welded together and installed in the BESIII on March 27.



On Feb. 14, the Valentine's Day, 2008, BESIII realized cosmic ray data acquisition after all the detectors were put into place, which marked that BESIII had successfully finished its construction, installation and initial tuning. By mid-April, it will be moved into the BEPCII interaction region.

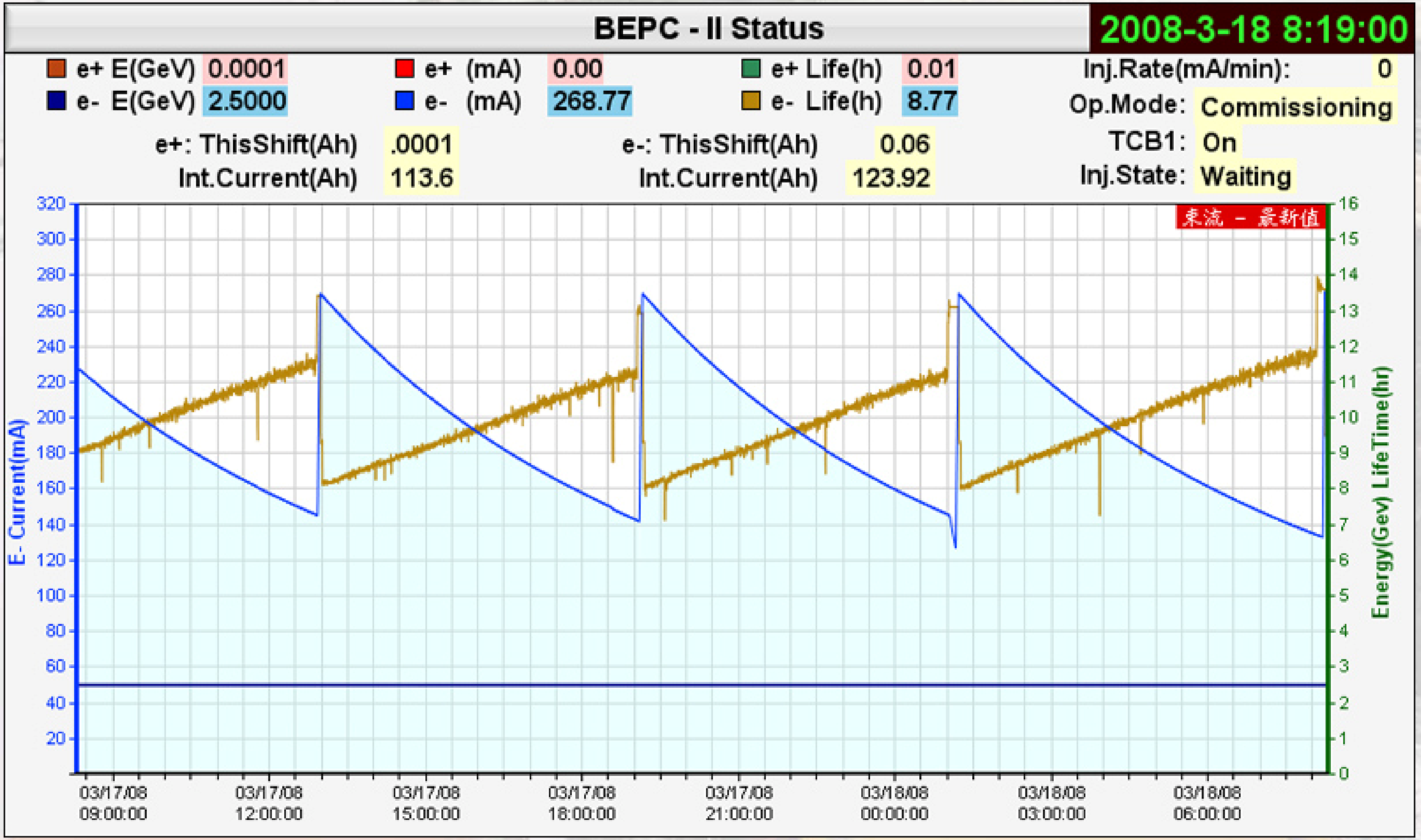
2.3 Beijing Synchrotron Radiation Facility



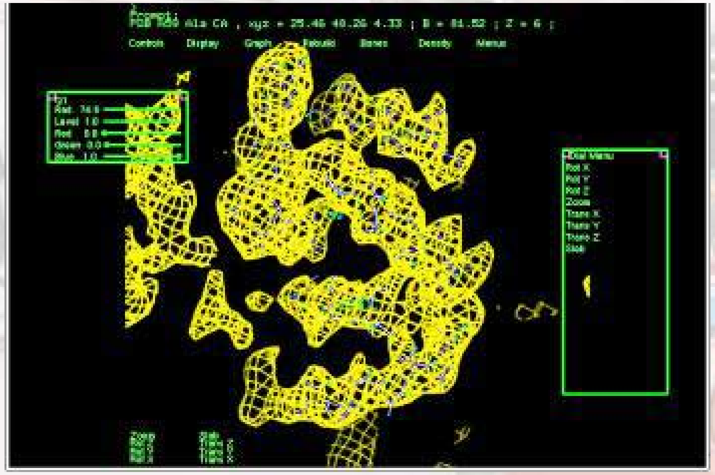
BSRF

- Commissioning together with SR beam lines was carried out.
- Beams have been provided for SR users since Dec. 25, 2006.

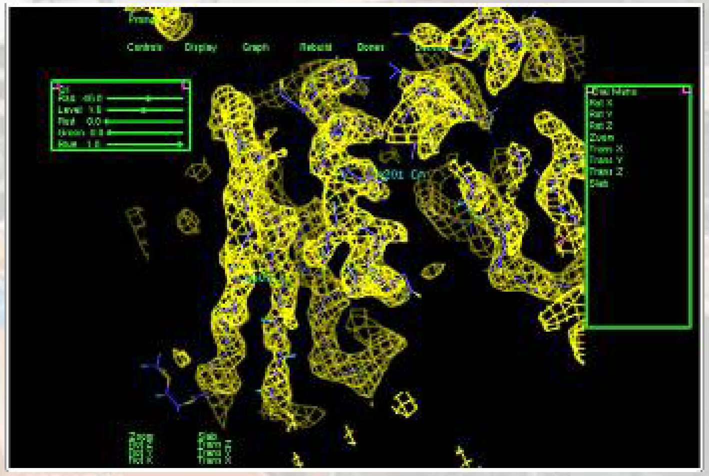
BSRF Operation



SR user experiments, examples

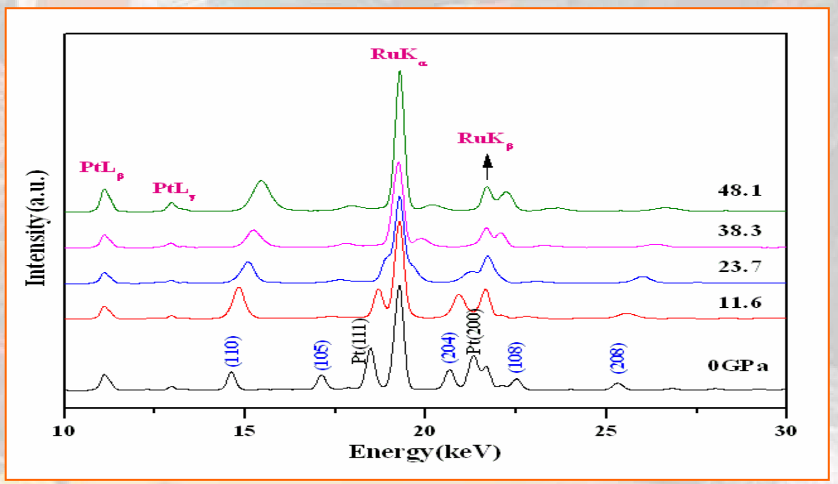


A structure and function unknown protein



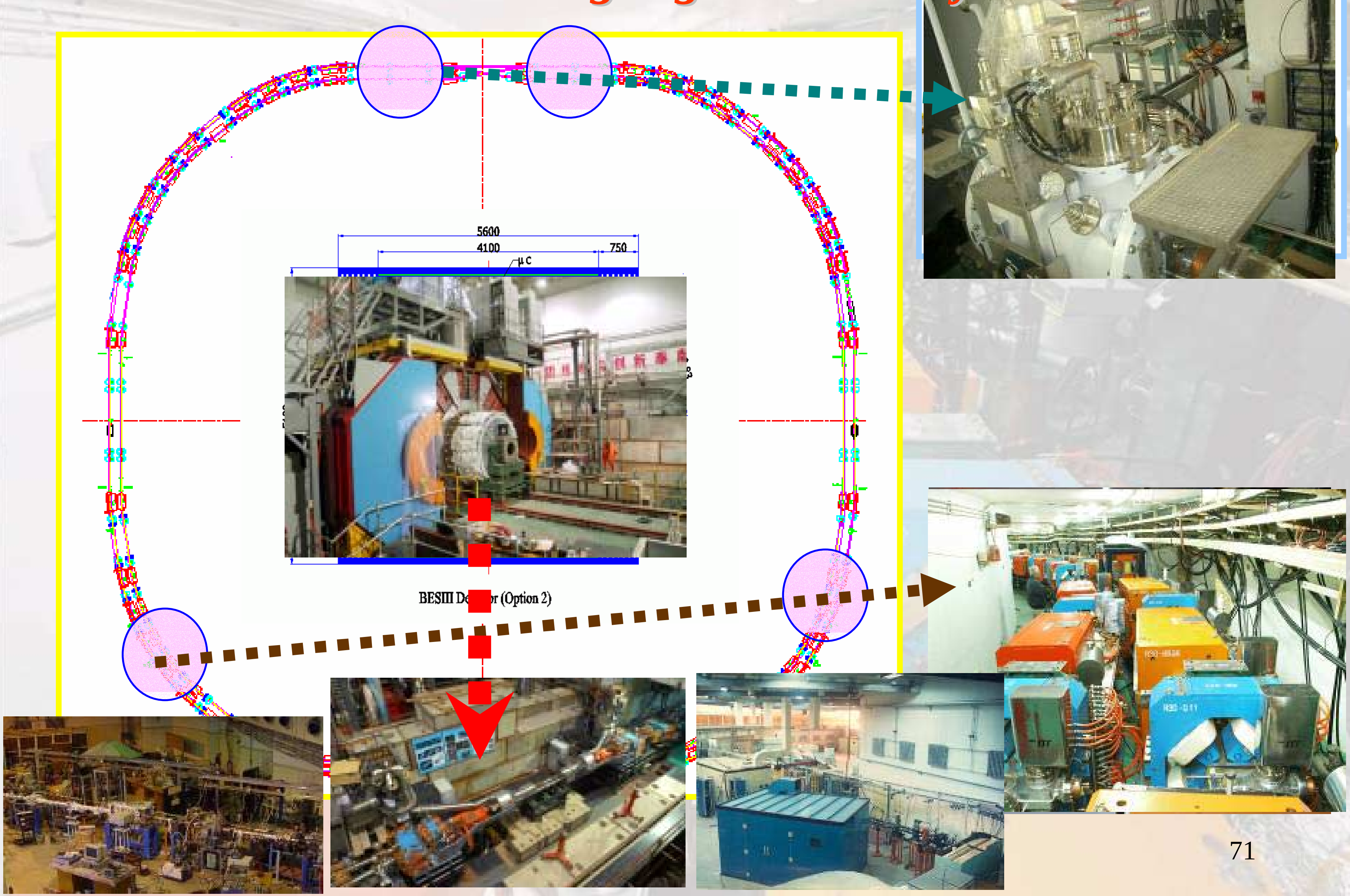
Sm423 – a protein in Serine degradation pathway

Sm424 – a protein in Serine degradation pathway



X-ray diffraction of BaRuO3 under high pressure

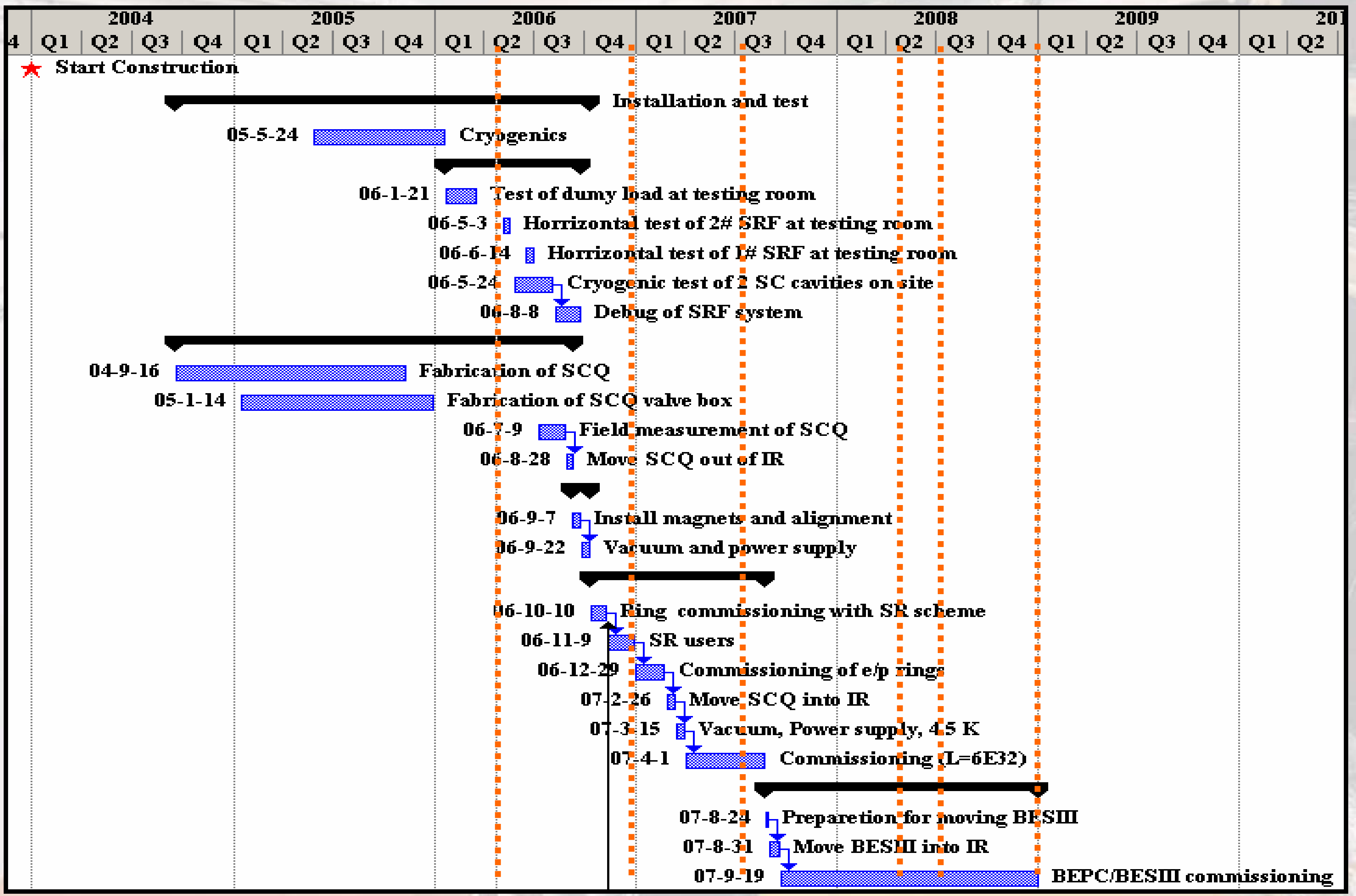
BEPCII: *a double-ring high luminosity e^{-}-e^{+} collider*



Budget and Schedule

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

BEPCII Schedule



BESIII collaboration

USA (2)

University of Hawaii

University of Washington

Europe (4)

GSI, Germany

University of Bochum, Germany

University of Giessen, Germany

JINR, Dubna, Russia

China (21)

IHEP, CCAST,

Univ. of Sci. and Tech. of China

Shandong Univ., Zhejiang Univ.

Huazhong Normal Univ., Wuhan Univ.

Zhengzhou Univ., Henan Normal Univ.

Peking Univ., Tsinghua Univ. ,

Zhongshan Univ.,Nankai Univ.

Shanxi Univ., Sichuan Univ

Hunan Univ., Liaoning Univ.

Nanjing Univ., Nanjing Normal Univ.

Guangxi Normal Univ., Guangxi Univ.

Japan (1)

Tokyo University

(3) Daya Bay reactor neutrino oscillation experiment

- Motivation
- Daya Bay nuclear power plant
- Baseline detector design
- Plan and schedule

3.1 Motivation

Neutrino oscillation: PMNS matrix

If Mass eigenstates ≠ Weak eigenstates ➔ Neutrino oscillation

Oscillation probability□

$$P(\nu 1 \rightarrow \nu 2) \propto \sin^2(1.27 \Delta m^2 L/E)$$

Atmospheric	crossing□CP & θ_{13}	solar	ββ decays

$$V = \begin{pmatrix} 1 & 0 & 0 \\ 0 & c_{23} & s_{23} \\ 0 & -s_{23} & c_{23} \end{pmatrix} \begin{pmatrix} c_{13} & 0 & s_{13} \\ 0 & e^{-i\delta} & 0 \\ -s_{13} & 0 & c_{13} \end{pmatrix} \begin{pmatrix} c_{12} & s_{12} & 0 \\ -s_{12} & c_{12} & 0 \\ 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} e^{i\rho} & 0 & 0 \\ 0 & e^{i\sigma} & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

Super-K	Daya Bay	Homestake	EXO
K2K	Double	Gallex	Genius
Minos	Chooz	SNO	CUORE
T2K	NOVA	KamLAND	NEMO

A total of 6 parameters: 2 Δm^2, 3 angles, 1 phases + 2 Majorana phases

Importance to know θ_{13}

1、A fundamental parameter.

2、Important to understand the relation between leptons and quarks, in order to have a grand unified theory beyond the Standard Model.

$$\begin{pmatrix} d' \\ s' \\ b' \end{pmatrix} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} \begin{pmatrix} d \\ s \\ b \end{pmatrix} \Longleftrightarrow \begin{pmatrix} \nu_e \\ \nu_\mu \\ \nu_\tau \end{pmatrix} = \begin{pmatrix} U_{e1} & U_{e2} & U_{e3} \\ U_{\mu 1} & U_{\mu 2} & U_{\mu 3} \\ U_{\tau 1} & U_{\tau 2} & U_{\tau 3} \end{pmatrix} \begin{pmatrix} \nu_1 \\ \nu_2 \\ \nu_3 \end{pmatrix}$$

3、Important to understand matter-antimatter asymmetry

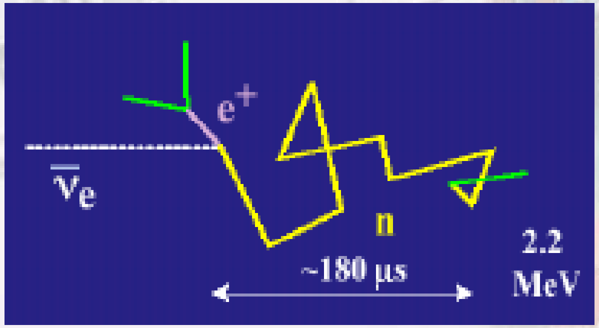
- If $\sin^2 2\theta_{13} > 0.01$，next generation LBL experiment for CP
- If $\sin^2 2\theta_{13} < 0.01$, next generation LBL experiment for CP ???

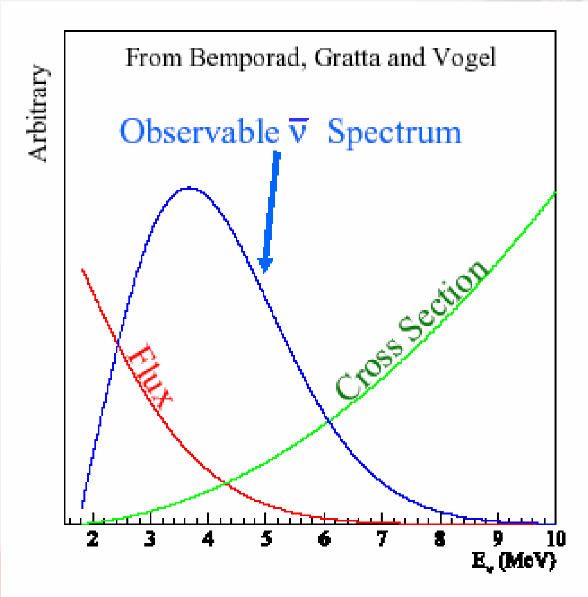
4、Provide direction to the future of the neutrino physics: super-neutrino beams or neutrino factory ?

Neutrino detection:

Inverse-β reaction in liquid scintillator

$$\bar{\nu}_e + p \rightarrow e^+ + n$$





τ ≈ 180 or 28 μs(0.1% Gd)

n + p → d + γ (2.2 MeV)

n + Gd → Gd* + γ (8 MeV)

Neutrino Event: coincidence in time, space and energy

Neutrino energy:

$$E_{\bar{\nu}} \cong T_{e^+} + T_n + (M_n - M_p) + m_{e^+}$$

10-40 keV (under T_n)   **1.8 MeV: Threshold** (under $(M_n - M_p) + m_{e^+}$)

How to reach 1% precision ?

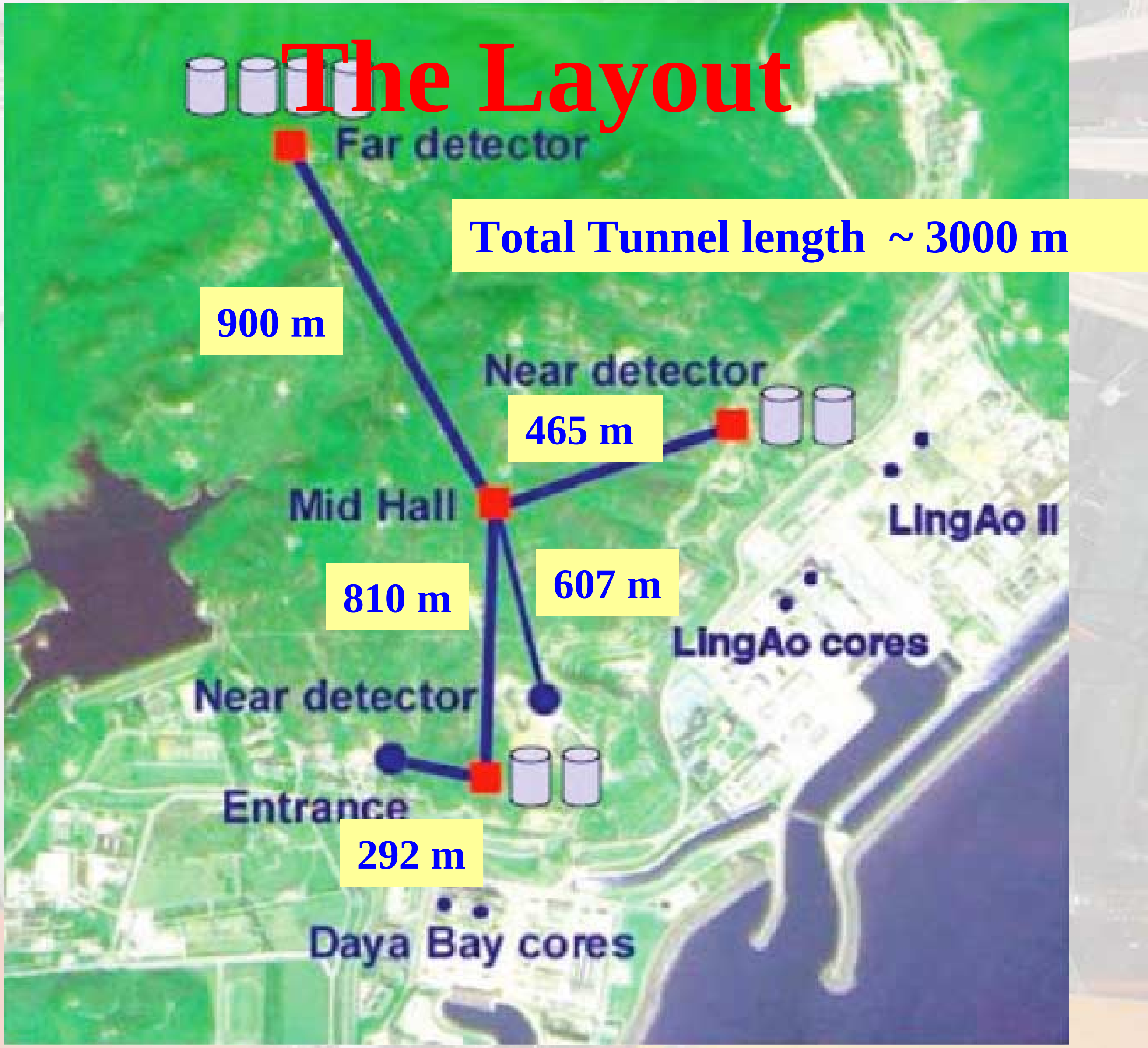
- **Increase statistics:**
  - **Powerful nuclear reactors(1 GW_{th}: 6 x 10^{20} $\bar{\nu}_e$/s)**
  - **Larger target mass**
- **Reduce systematic uncertainties:**
  - **Reactor-related:**
    - ✓ **Optimize baseline for best sensitivity and smaller residual errors**
    - ✓ **Near and far detectors to minimize reactor-related errors**
  - **Detector-related:**
    - ✓ **Use "Identical" pairs of detectors to do *relative* measurement**
    - ✓ **Comprehensive program in calibration/monitoring of detectors**
    - ✓ **Interchange near and far detectors (optional)**
  - **Background-related**
    - ✓ **Go deep to reduce cosmic-induced backgrounds**
    - ✓ **Enough active and passive shielding**

Proposed Reactor Neutrino Experiments

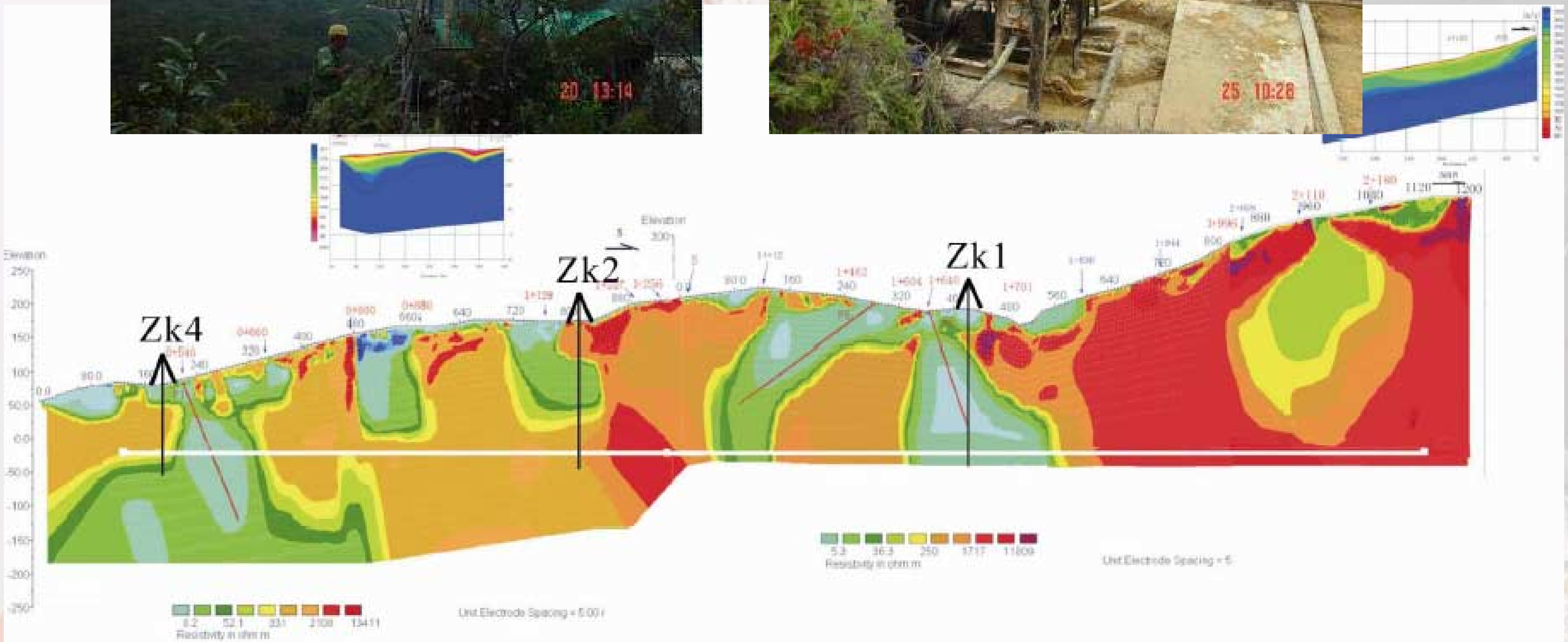
3.2 Daya Bay nuclear power plant

- **4 reactor cores, 11.6 GW**
- **2 more cores in 2011, 5.8 GW**
- **Mountains near by, easy to construct a lab with enough overburden to shield cosmic-ray backgrounds**

The Layout

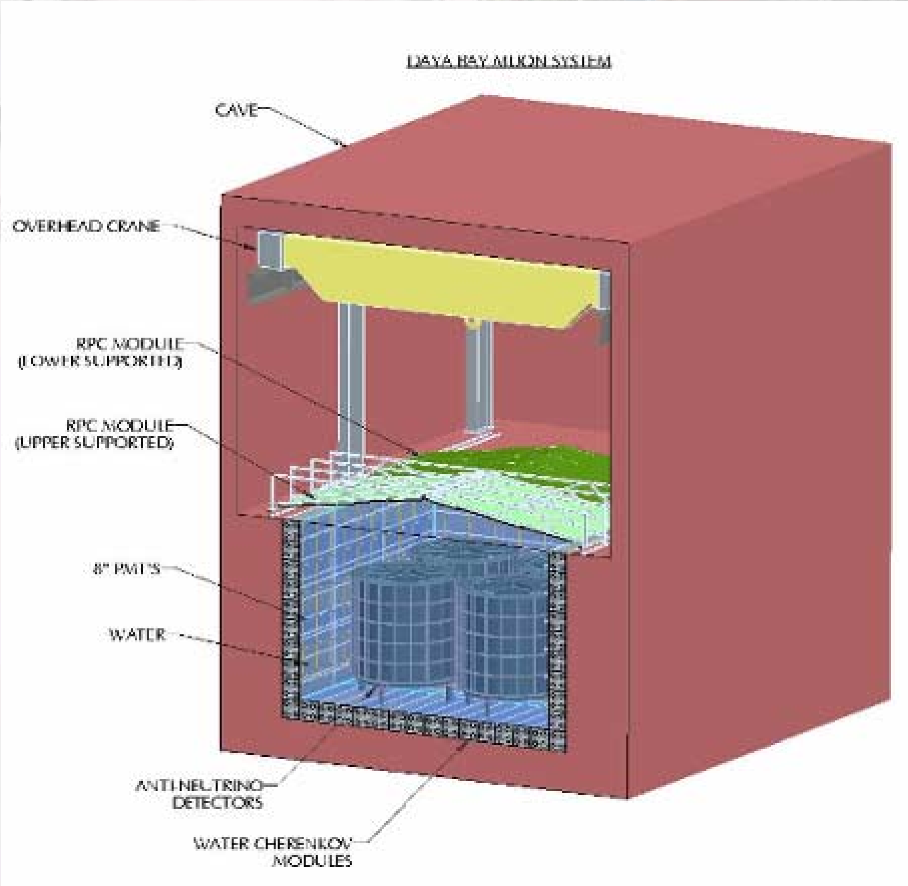

Far detector
Total Tunnel length ~ 3000 m
900 m
Near detector
465 m
Mid Hall
LingAo II
810 m
607 m
LingAo cores
Near detector
Entrance
292 m
Daya Bay cores

Site investigation completed: very good rocks conceptual design of tunnel completed, engineering design of the tunnel will start soon



3.3 Baseline detector design

multiple neutrino modules and multiple vetos



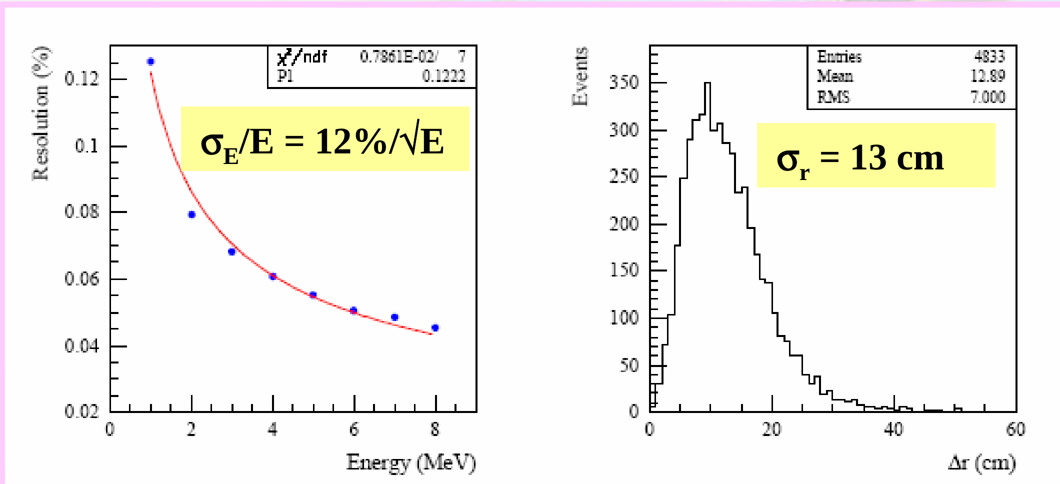
- Multiple anti-neutrino detector modules for side-by-side cross check
- Multiple muon tagging detectors:
  - Water pool as Cherenkov counter
  - Water modules along the walls and floor as muon tracker
  - RPC at the top as muon tracker
  - Combined efficiency > (99.5 ± 0.25) %

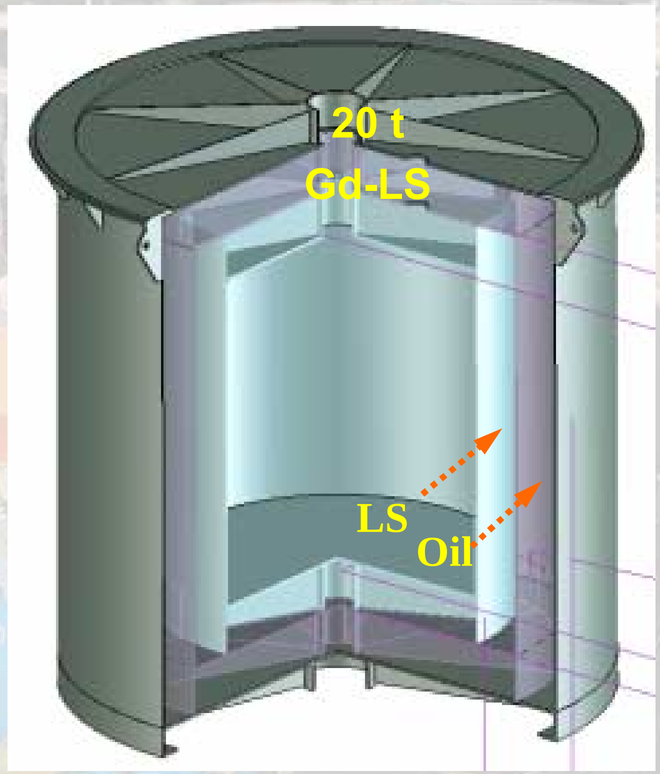
Redundancy is a key for the success of this experiment

Central Detector modules

- Three zones modular structure:
  - I. target: Gd-loaded scintillator
  - II. γ-catcher: normal scintillator
  - III. Buffer shielding: oil
- Reflector at top and bottom
- 224 8" PMT/module
- Photocathode coverage:

  5.6 % ➔ 12%(with reflector)

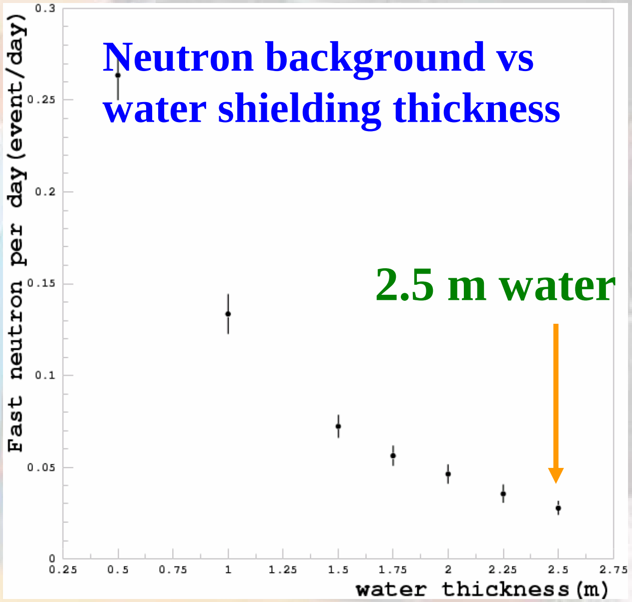




Target: 20 t, 1.6m
γ-catcher: 20t, 45cm
Buffer: 40t, 45cm

Water Buffer & VETO

- **2.5 m water buffer to shield backgrounds from neutrons and γ's from lab walls**
- **Cosmic-muon VETO Requirement:**
  - **Inefficiency < 0.5%**
  - **known to <0.25%**
- **Solution: multiple detectors**
- **Multiple detectors can also cross check each other to control uncertainties**



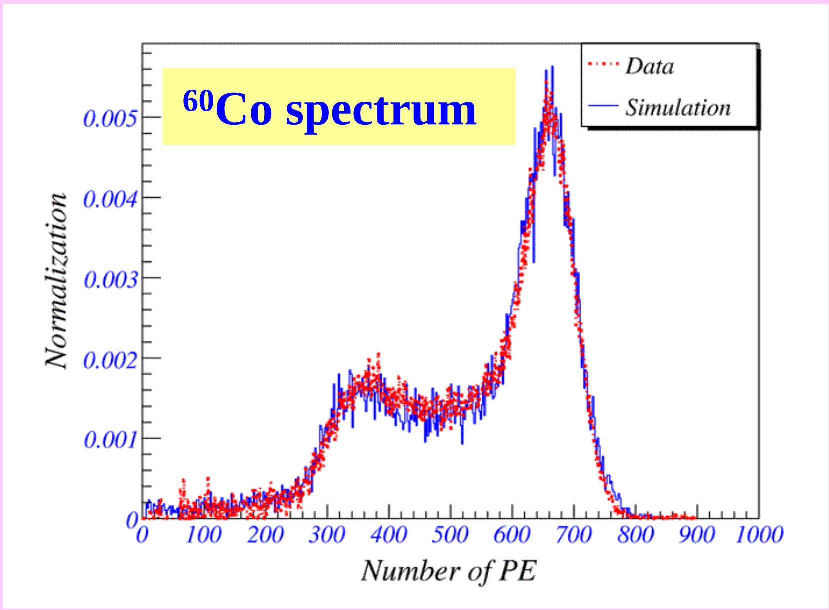
Summary of Systematic Uncertainties

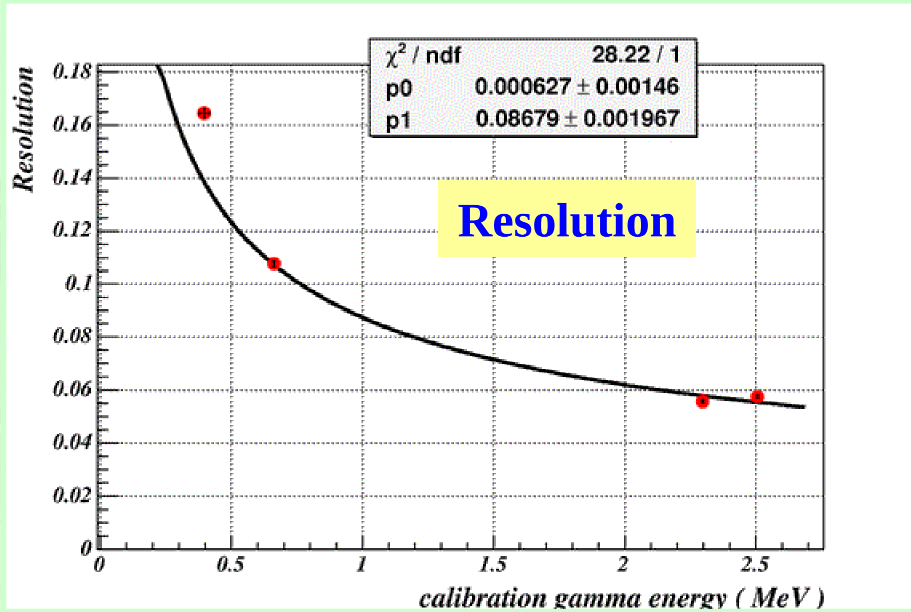
sources	Uncertainty
Reactors	0.087% (4 cores) 0.13% (6 cores)
Detector (per module)	0.38% (baseline) 0.18% (goal)
Backgrounds	0.32% (Daya Bay near) 0.22% (Ling Ao near) 0.22% (far)
Signal statistics	0.2%

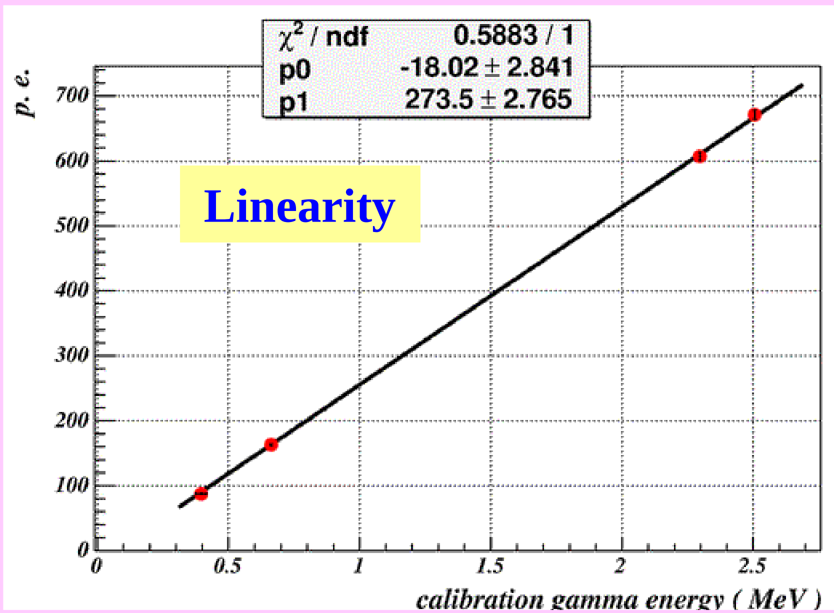
Prototype:

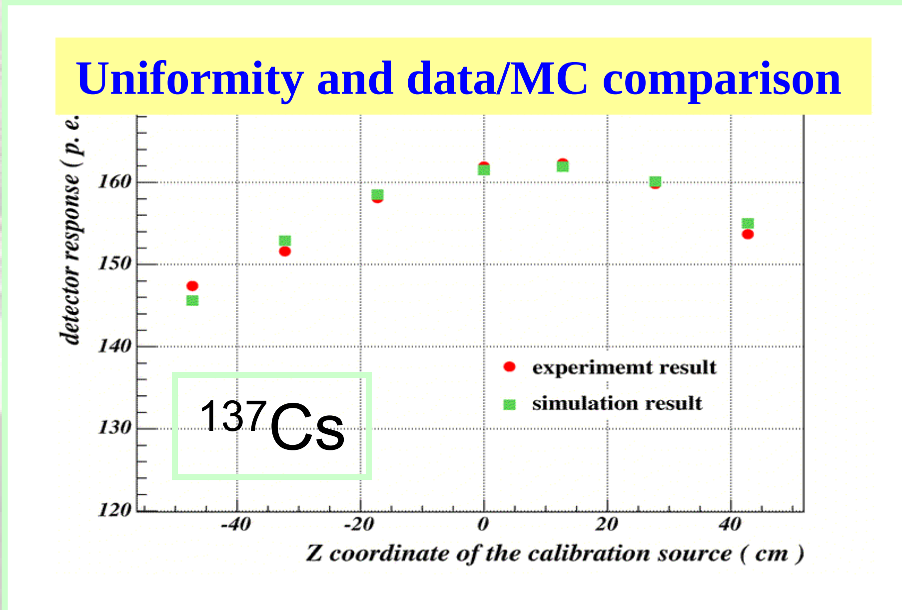
2m×2m, 0.6 t LS

45 PMT

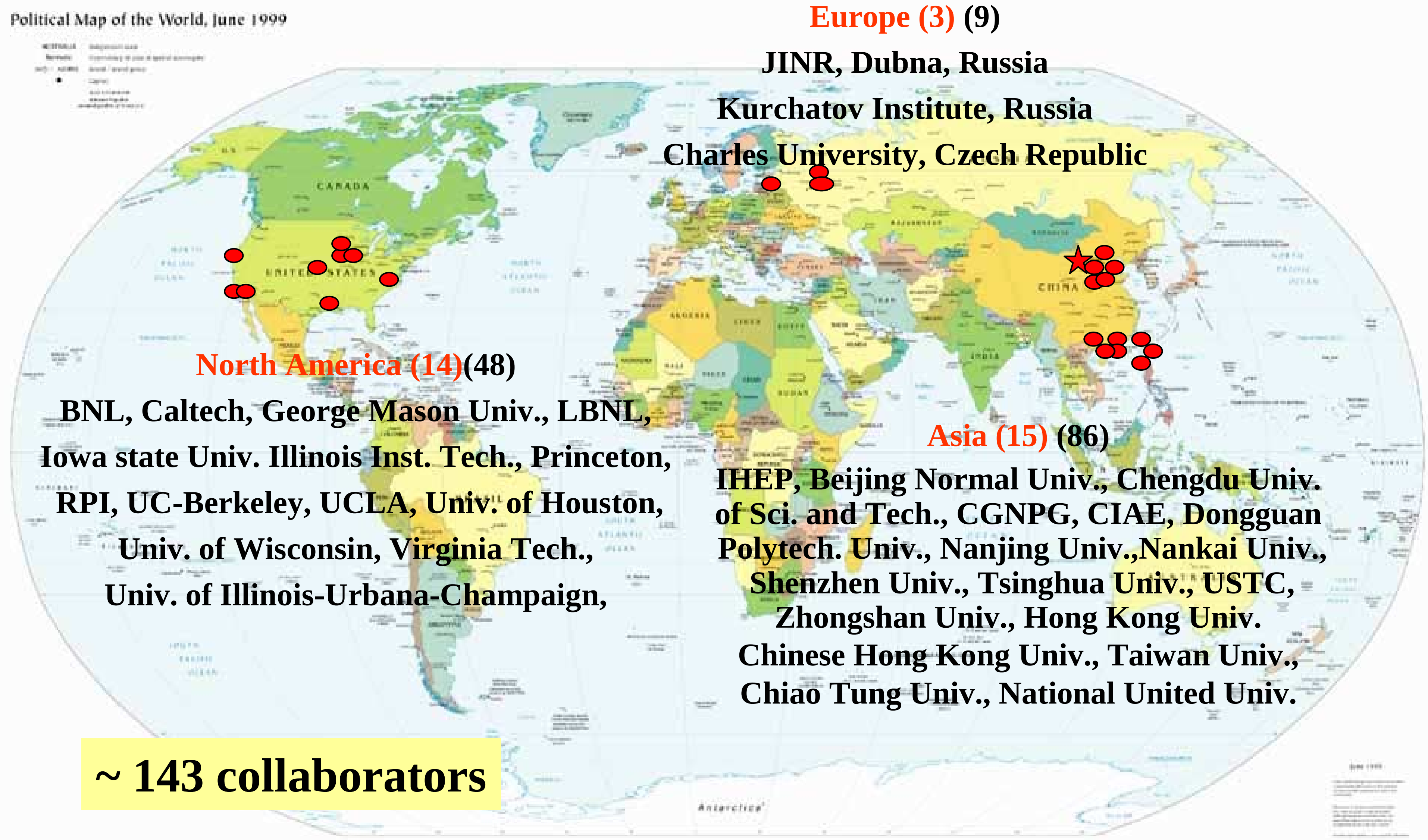

60Co spectrum
Data
Simulation
Normalization
0.005
0.004
0.003
0.002
0.001
0
0
100
200
300
400
500
600
700
800
900
1000
Number of PE


χ2 / ndf 28.22 / 1
p0 0.000627 ± 0.00146
p1 0.08679 ± 0.001967
Resolution
Resolution
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
0
0.5
1
1.5
2
2.5
calibration gamma energy (MeV)


χ2 / ndf 0.5883 / 1
p0 -18.02 ± 2.841
p1 273.5 ± 2.765
Linearity
p. e.
700
600
500
400
300
200
100
0
0
0.5
1
1.5
2
2.5
calibration gamma energy (MeV)


Uniformity and data/MC comparison
detector response (p. e.
160
150
140
130
120
137Cs
experimemt result
simulation result
-40
-20
0
20
40
Z coordinate of the calibration source (cm)

Daya Bay collaboration



Europe (3) (9)

JINR, Dubna, Russia
Kurchatov Institute, Russia
Charles University, Czech Republic

North America (14)(48)

BNL, Caltech, George Mason Univ., LBNL, Iowa state Univ. Illinois Inst. Tech., Princeton, RPI, UC-Berkeley, UCLA, Univ. of Houston, Univ. of Wisconsin, Virginia Tech., Univ. of Illinois-Urbana-Champaign,

Asia (15) (86)

IHEP, Beijing Normal Univ., Chengdu Univ. of Sci. and Tech., CGNPG, CIAE, Dongguan Polytech. Univ., Nanjing Univ.,Nankai Univ., Shenzhen Univ., Tsinghua Univ., USTC, Zhongshan Univ., Hong Kong Univ. Chinese Hong Kong Univ., Taiwan Univ., Chiao Tung Univ., National United Univ.

~ 143 collaborators

3.4 Schedule and Funding

Begin civil construction	**June 2007**
Bring up the first pair of detectors	**June 2009**
Begin data taking with full detector	**June 2010**

Funding and other supports

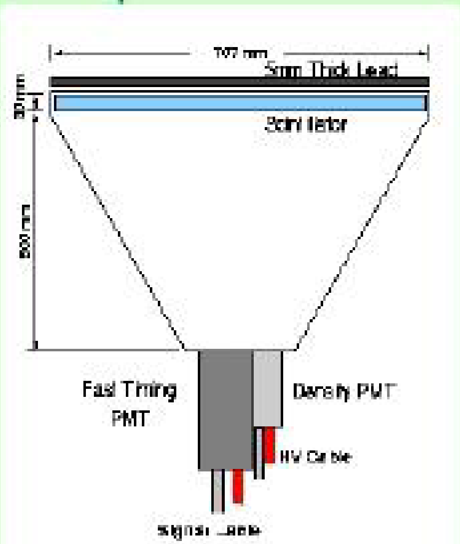
- Funding Committed from
  - Chinese Academy of Sciences,
  - Ministry of Science and Technology
  - Natural Science Foundation of China
  - China Guangdong Nuclear Power Group
  - Shenzhen municipal government
  - Guangdong provincial government
- Gained strong support from:
  - China Guangdong Nuclear Power Group
  - China atomic energy agency
  - China nuclear safety agency
- Supported by BNL/LBNL seed funds
- Supported by DOE $800K R&D fund
- Support by funding agencies from other countries & regions
- China plans to provide civil construction and ~half of the detector systems; U.S.plans to bear ~half of the detector cost

Yangbajing Cosmic Ray Observatory

(a.s.l. 4300m)

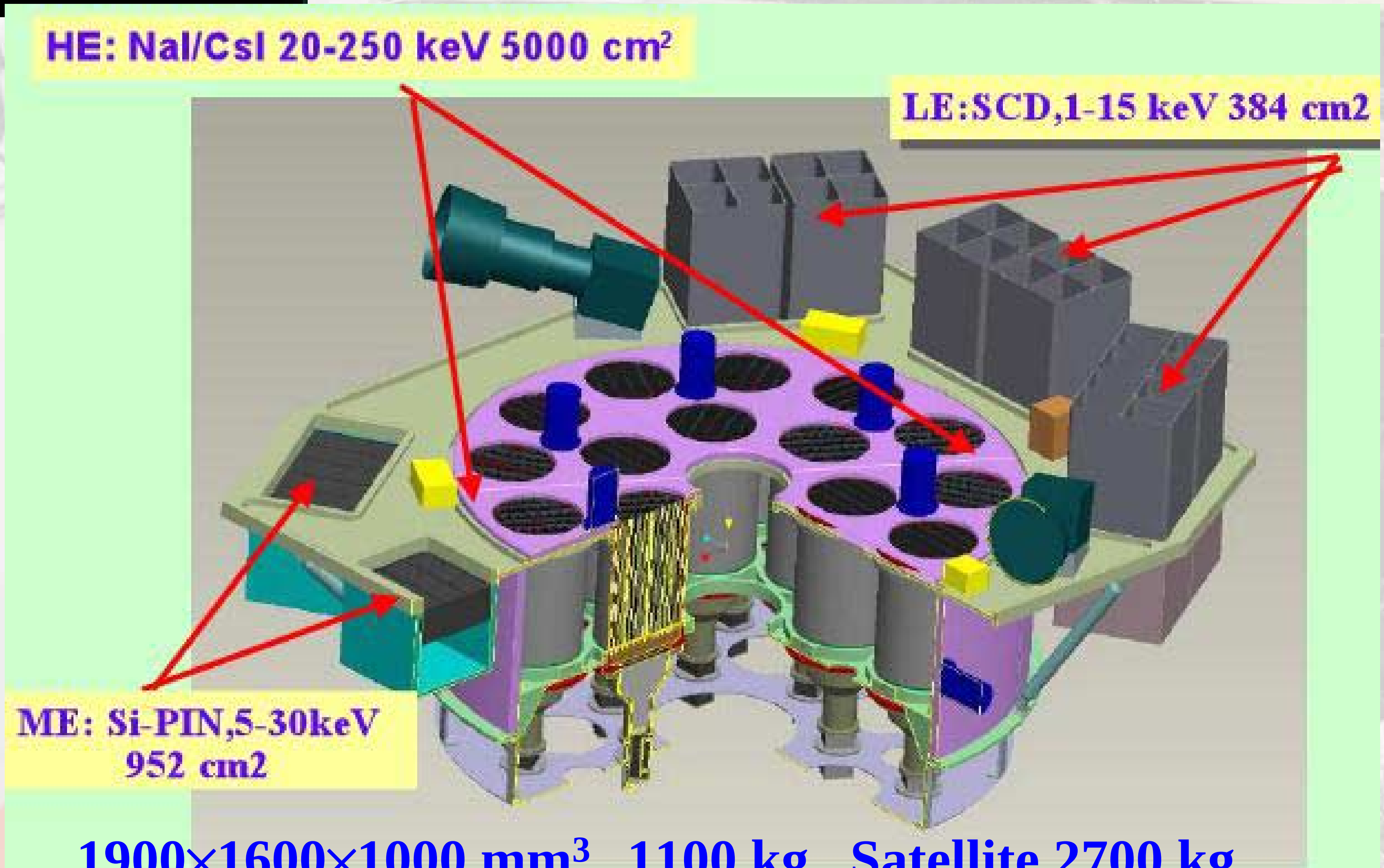
~3TeV ~300GeV

ASγ scintillation detector



Sino-Italian ARGO experiment (part of RPC carpet)

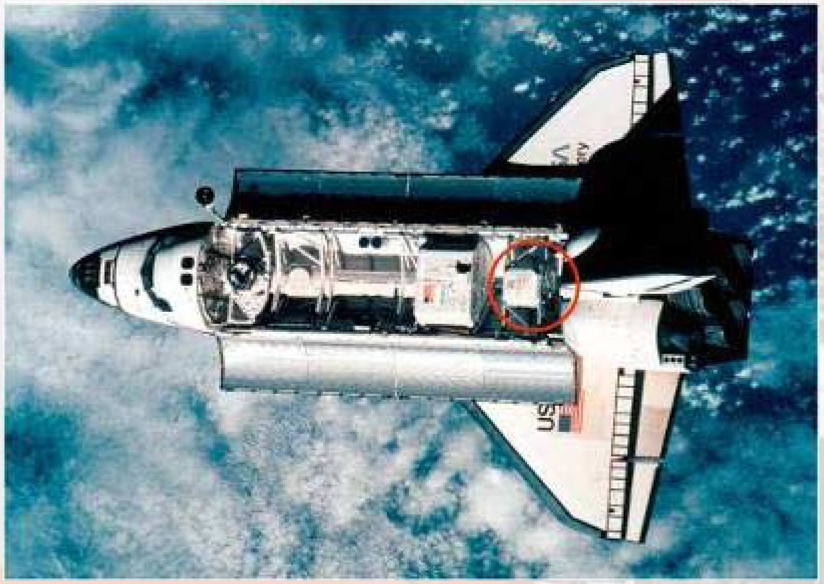
Hard X-ray Modulation Telescope (HXMT)



1900×1600×1000 mm^3 1100 kg Satellite 2700 kg

Alpha Magnetic Spectrometer

AMS01 permanent magnet and structure were built at Beijing, and became the first big magnet in space as payload of Discovery June 1998.



AMS02:

ECAL/IHEP/LAPP/Pisa

Flight module is ready.

Remarks

- Particle physics in China is in phase transition: the experiments discussed above will bring it to a new stage;
- Great progress has been seen on the design and construction, as well as industrial supports;
- Physics potential of the experiments are great, but remains to be demonstrated;
- Welcome new collaborators!

(4) Accelerator Projects in China

- HIRFL-CSR
- CBRIF of CIAE
- NSRL Upgrades
- SSRF Project
- CSNS Project
- ILC Activities
- Advanced Accelerator Research

4.1 HIRFL-CSR

Main Parameters

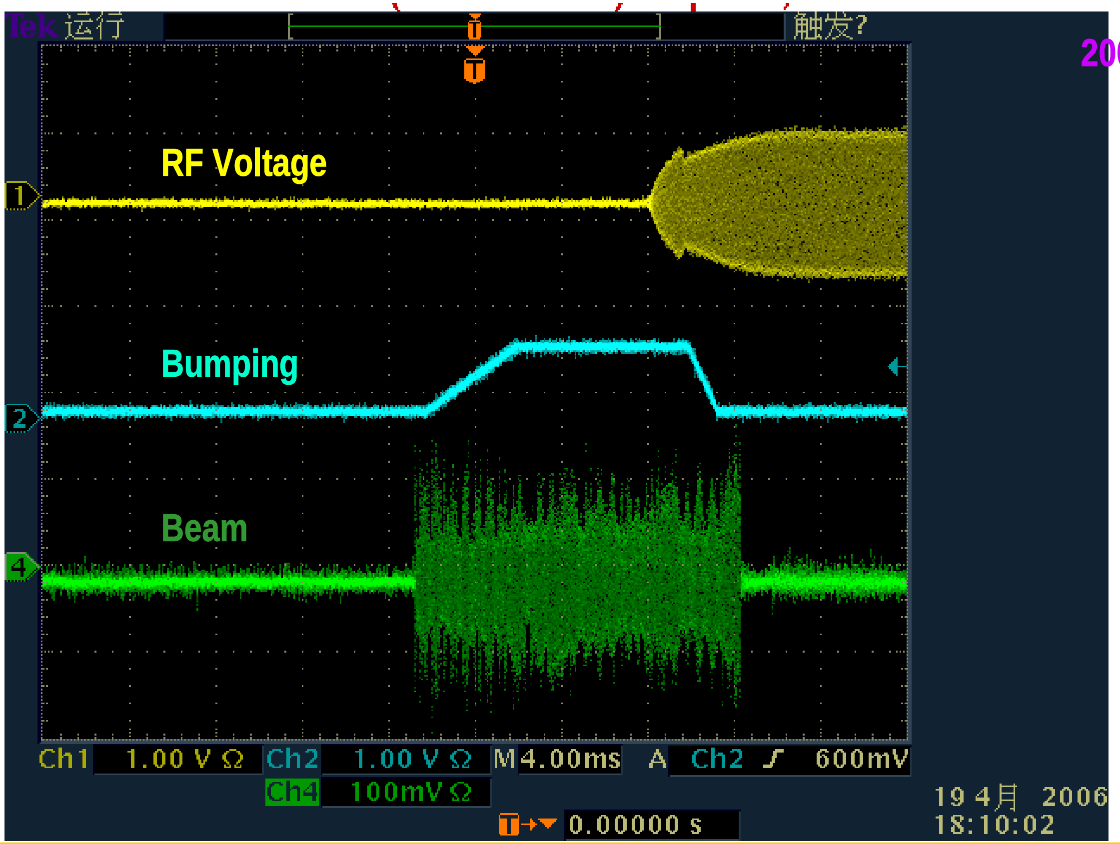
	CSRm	CSRe
Particle Species	P, C-U	P, C-U, RIB, …
Energy (MeV/u) (B_{max}=1.4~1.6 T)	2350~2800 (P) 900~1110($^{12}C^{6+}$) 400~510($^{238}U^{72+}$)	2000 (P) 600~770($^{12}C^{6+}$) 400~500($^{238}U^{>90+}$)
Resolution $\Delta p/p$	$<10^{-4}$	$<10^{-5}$
Momentum Acceptance	±0.15%	±0.25~0.5%
Emittance	≤ 5 π mm-mrad	≤ 1 π mm-mrad

HIRFL-CSR Project at Langzhou

Signals of beam + bump + RF for multi-turn injection

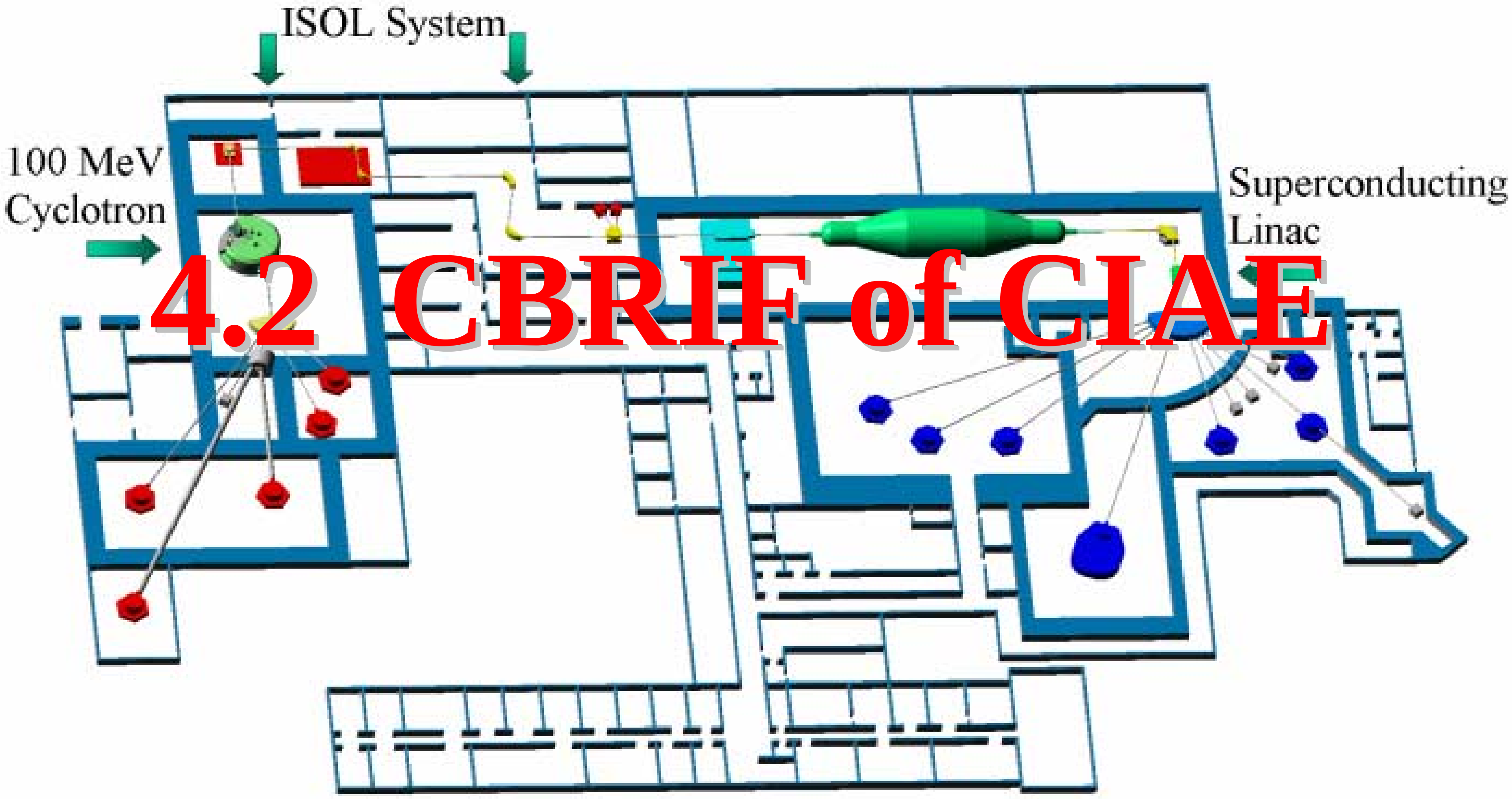
PS of bumps, dipoles and quadruples were controlled by the new DSP

2006.04/20



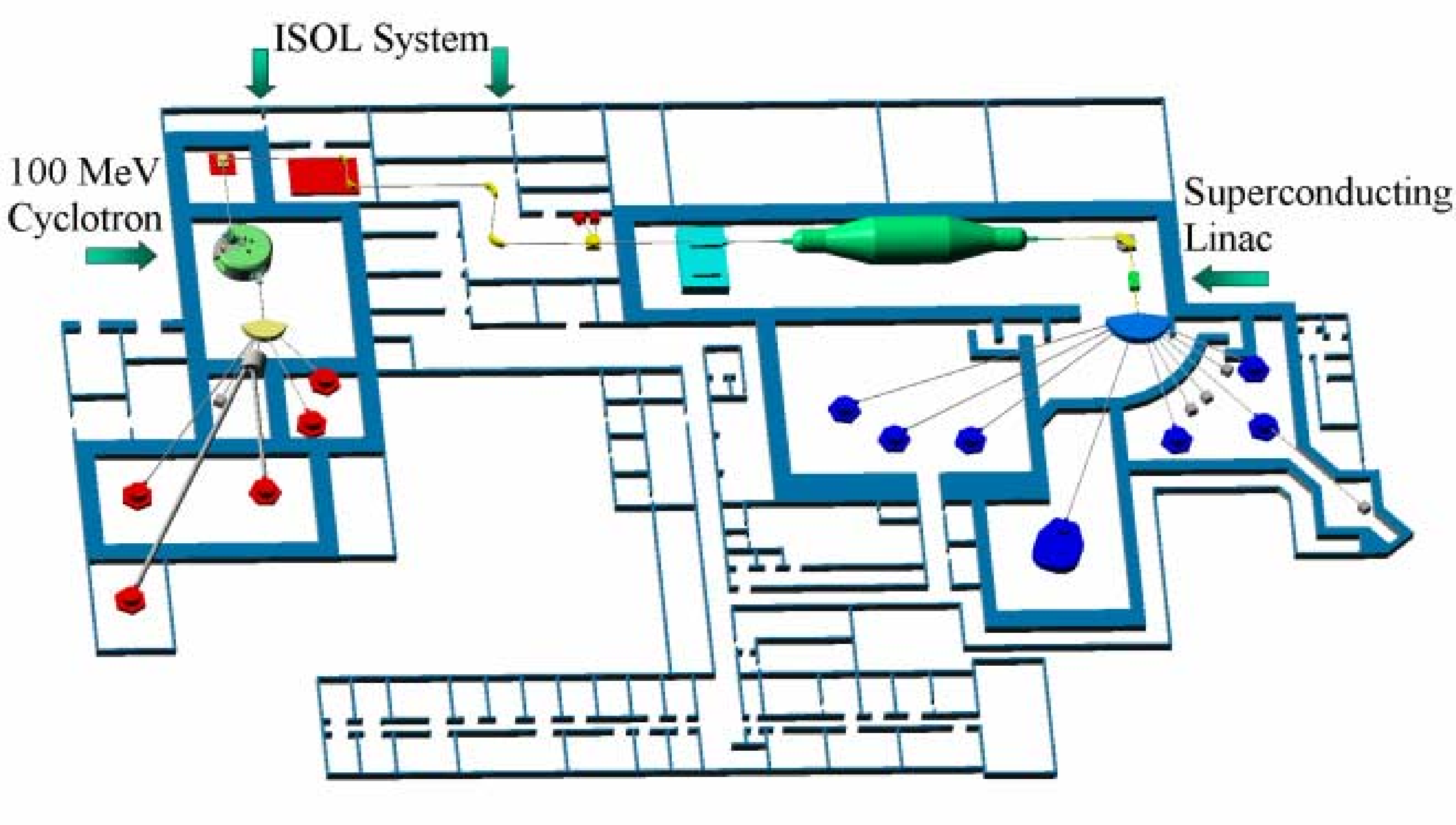
Cyclotron Based Radioactive Ion Facility

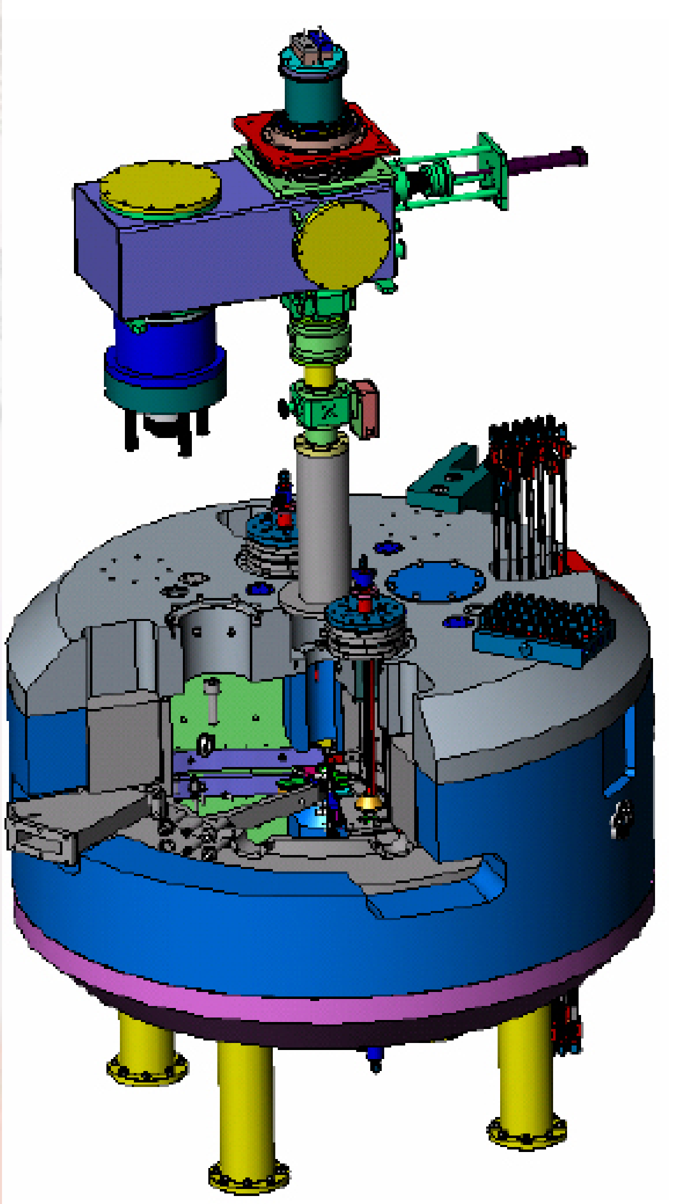
4.2 CBRIF of CIAE



Approved in July 2003, the project is in its construction. More than 40 proton-rich and 80 neutron-rich radioactive ion beams with beam intensity higher than 10^6 pps will be provided by

CBRIF





The Cyclotron

Energy

75 MeV ~ 100 MeV

Max Current

200 μA ~ 500 μA

For a final energy of 100 MeV or below, and beam intensity of less than 1 mA, a compact magnet and H^- acceleration with stripping extraction might lead to a smaller and cheaper machine.

Superconducting Linac

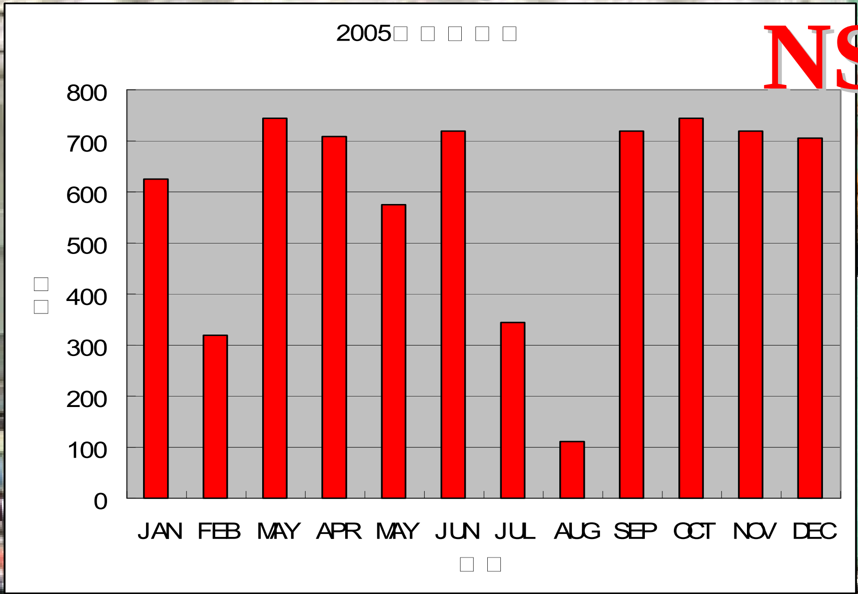
4.3 NSRL Upgrades

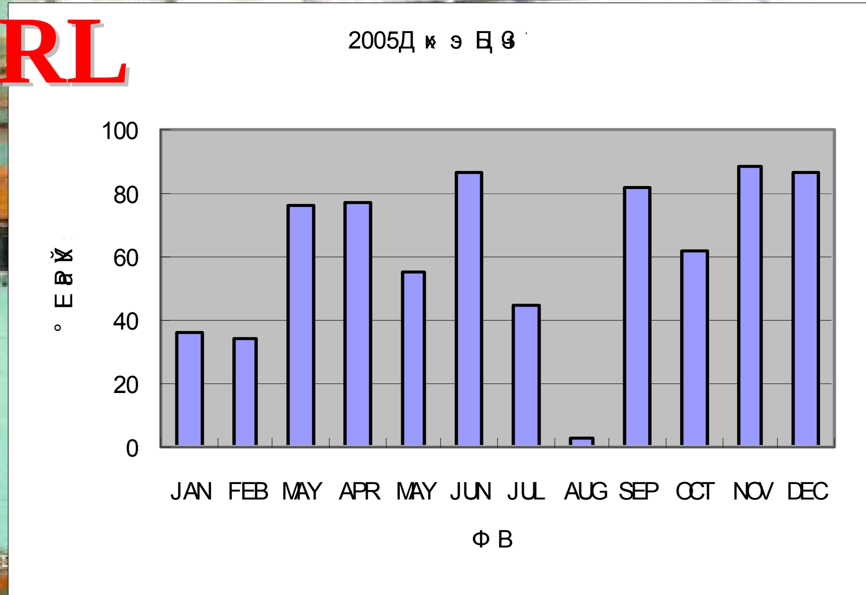
Completed in 1990, the NSRL has well operated for synchrotron radiation users for 14 years.

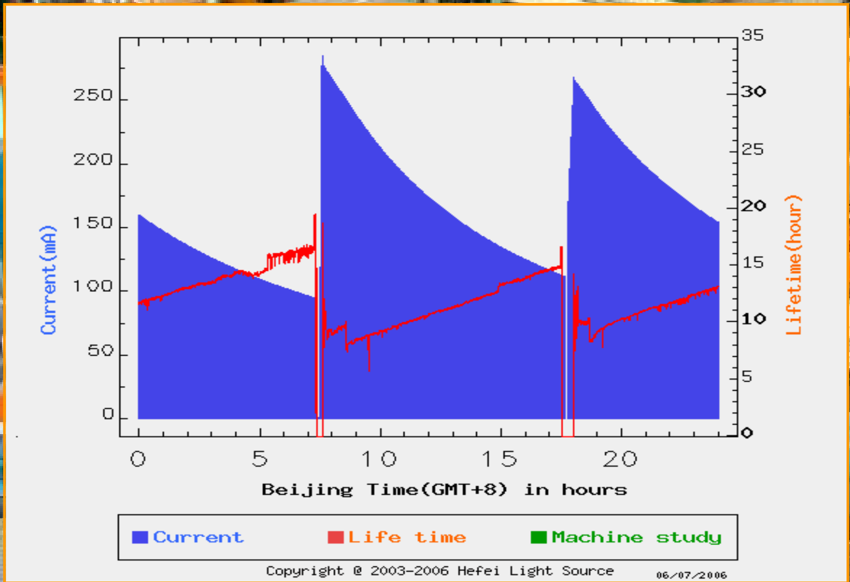
Goal of NSRL upgrades

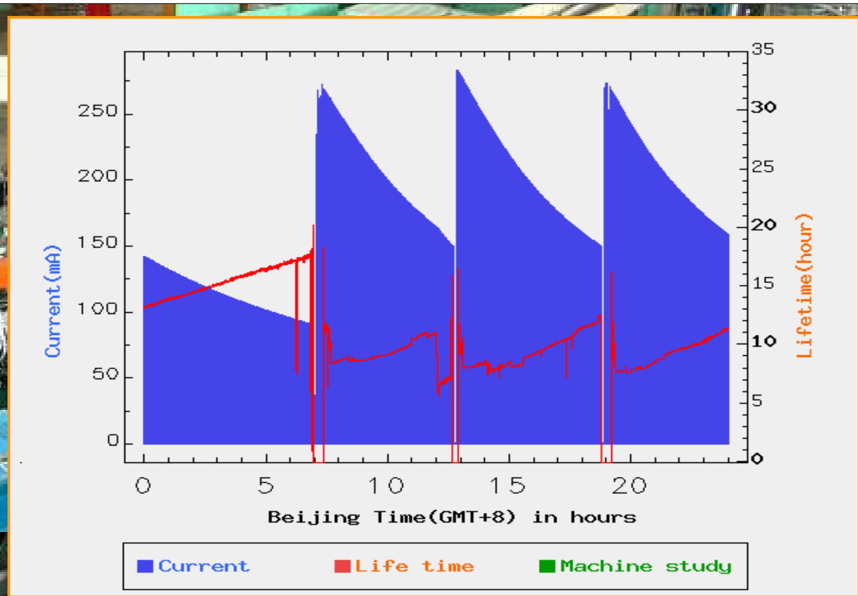
- **To increase number of beamlines**
- **To improve machine performance**
- **To satisfy growing needs of users**

National Synchrotron radiation Laboratory NSRL









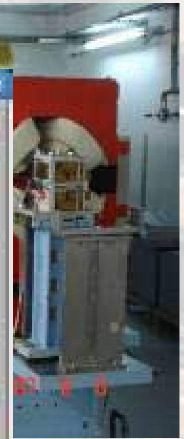
4.4 SSRF Project

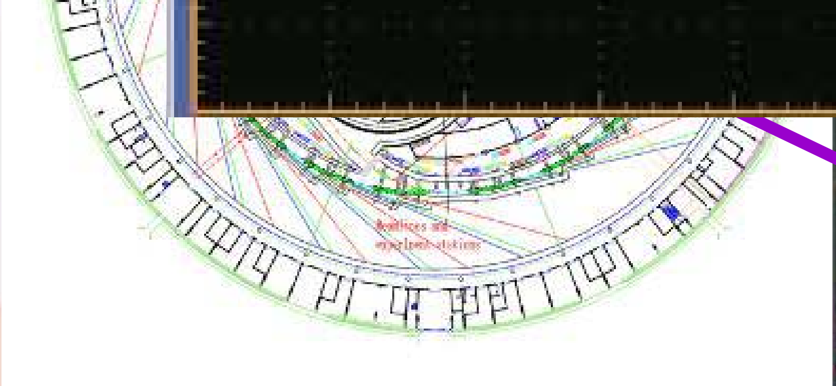
方案5鸟瞰图

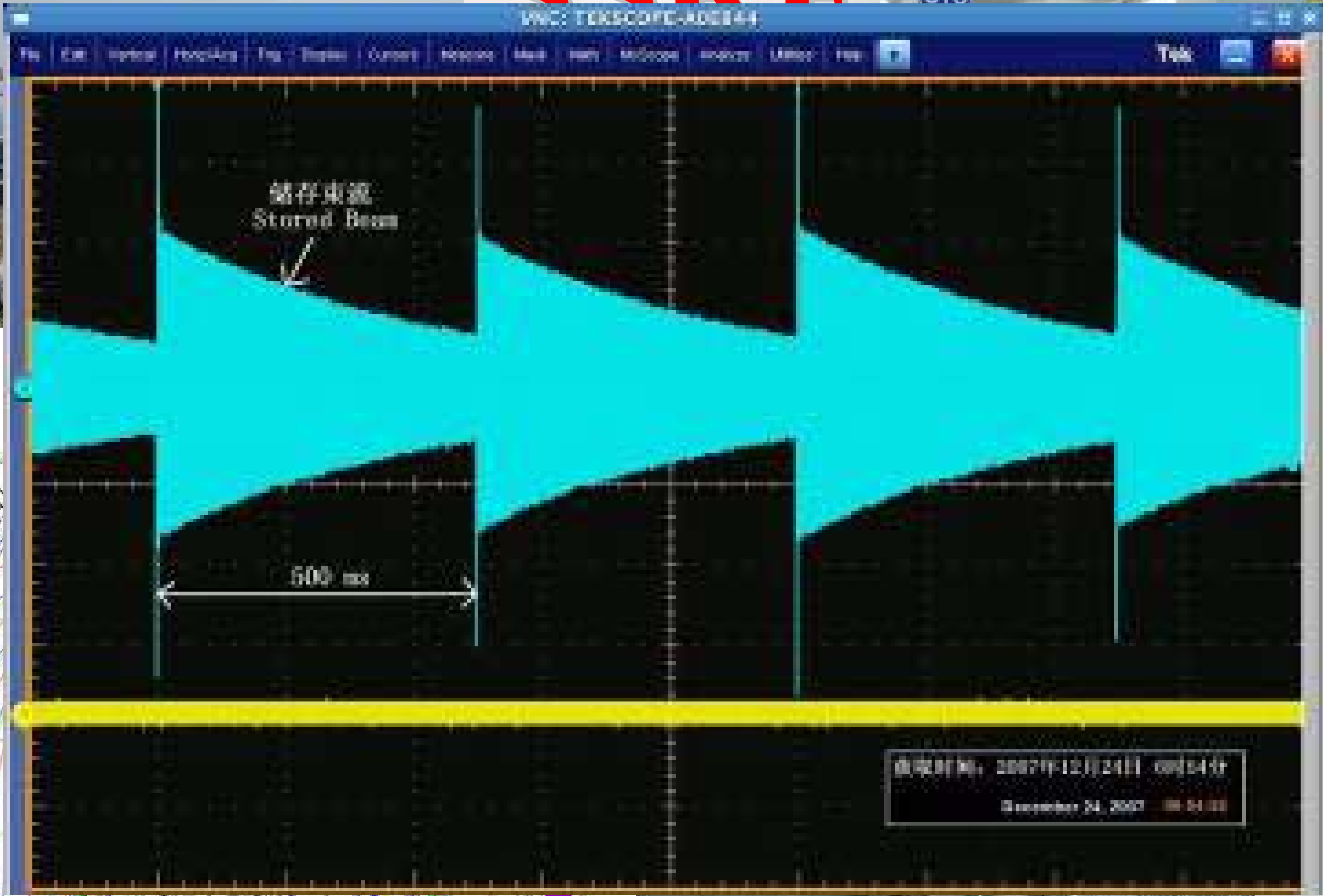
Main Parameters of SSRF

Beam Energy		GeV	3.5
Circumference		m	432
Number of cells			20
Straight sections (*L*×*N*)		m	4×12m, 16×6.7m
Beam current		mA	200~300
Natral emittance		nm·rad	3.0
Beam lifetime		hrs	>10
SR beam stability		μm	~±0.1σ
Injection Booster	Energy	GeV	0.1~3.5
	Circumference	m	180
	Natral emittance		110 nm×rad

SSRF







150MeV Linac

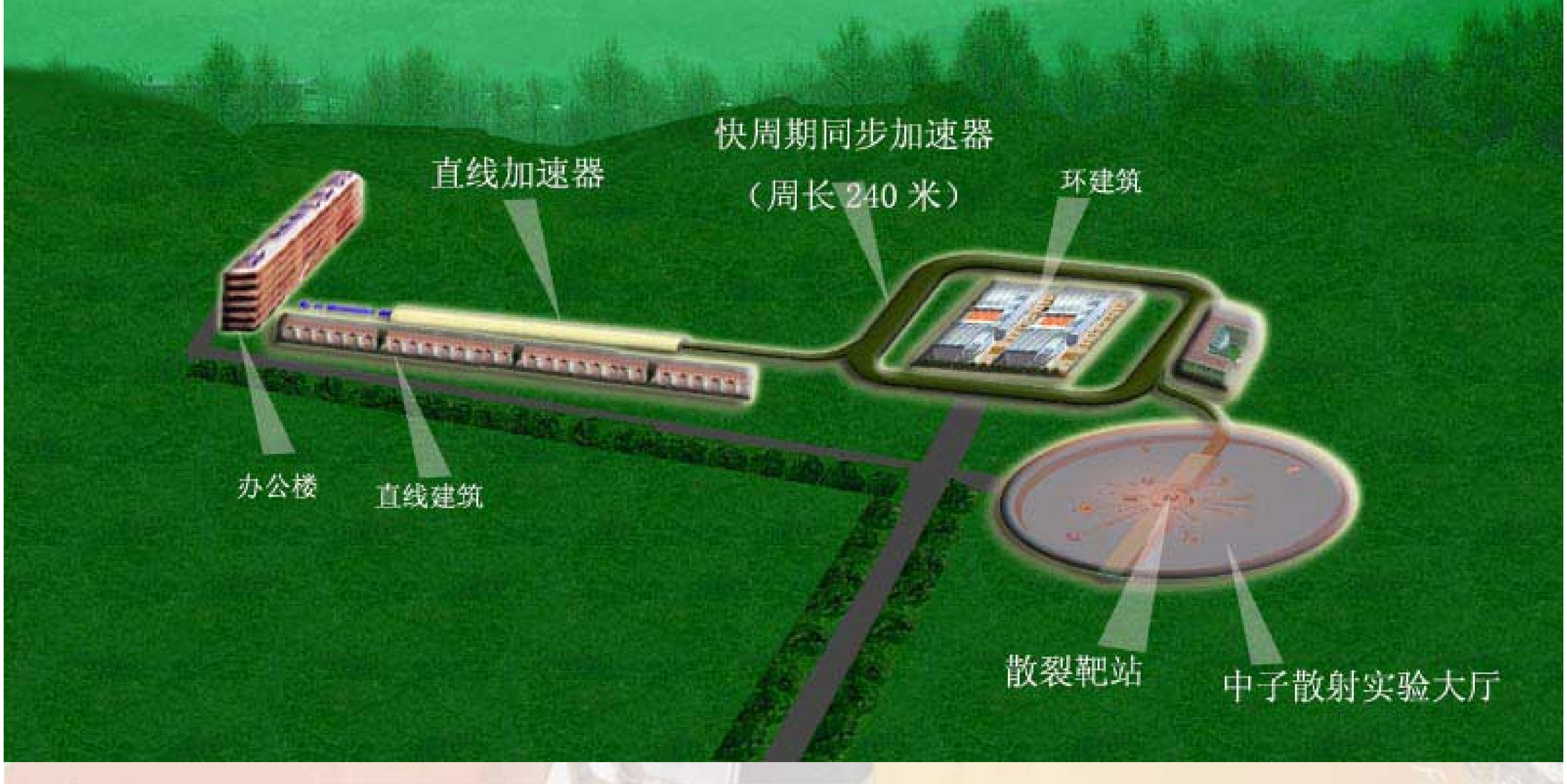
Schedule and Budget

Schedule

Jan.7 2004	**SSRF project approval**
Feb. 2004 – June 2004	**Feasibility study**
July 2004 – Nov. 2004	**Design**
Dec. 2004 – Apr. 2007	**Civil construction**
Dec. 2001 – Oct. 2007	**Manufacture and test**
May 2005 – Mar. 2008	**Installation and test**
Apr. 2009 – Mar. 2009	**Commissioning & Operation**
Mar. 2009 —	**Operation**

Budget □1300 MRMB

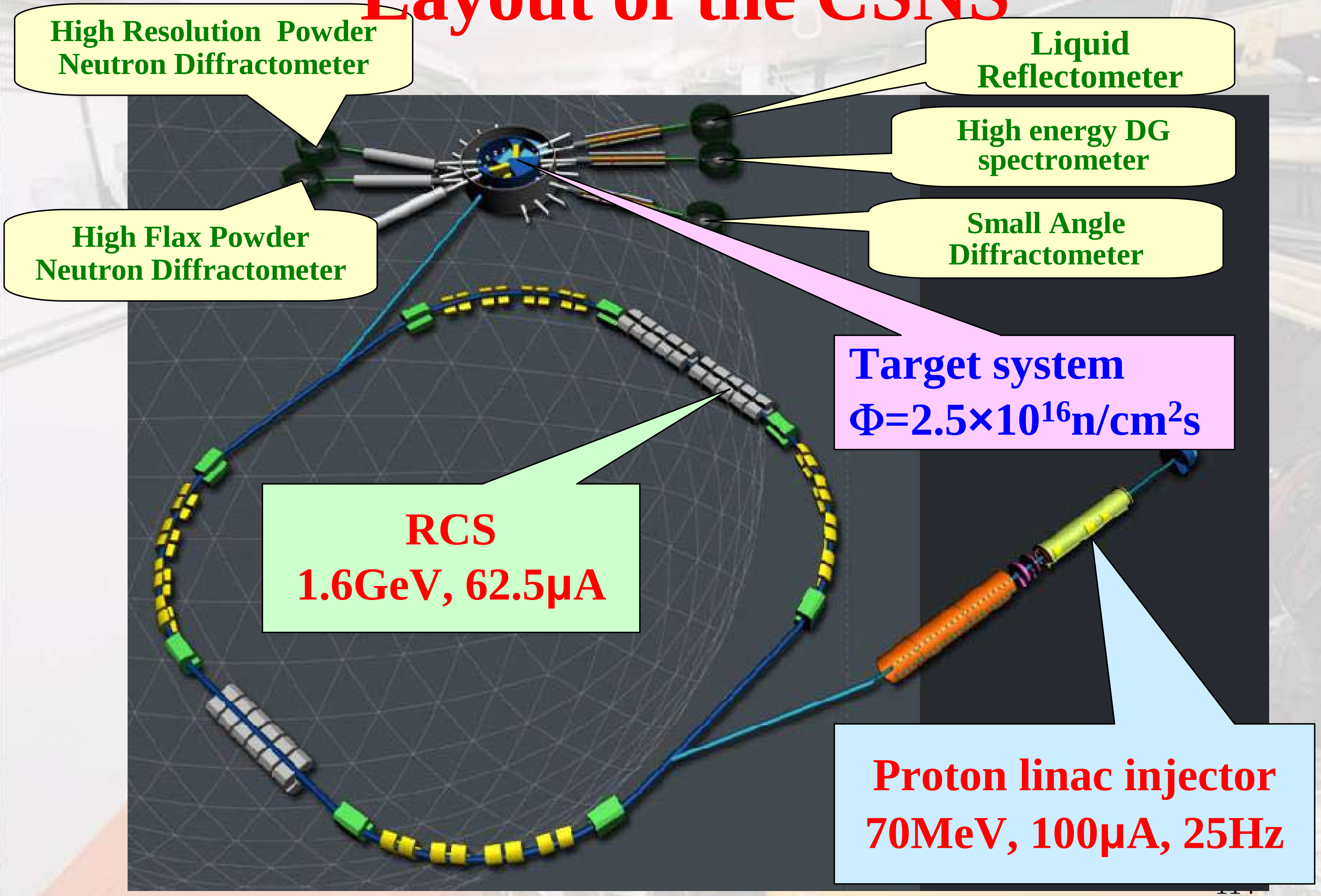
4.5 CSNS Project



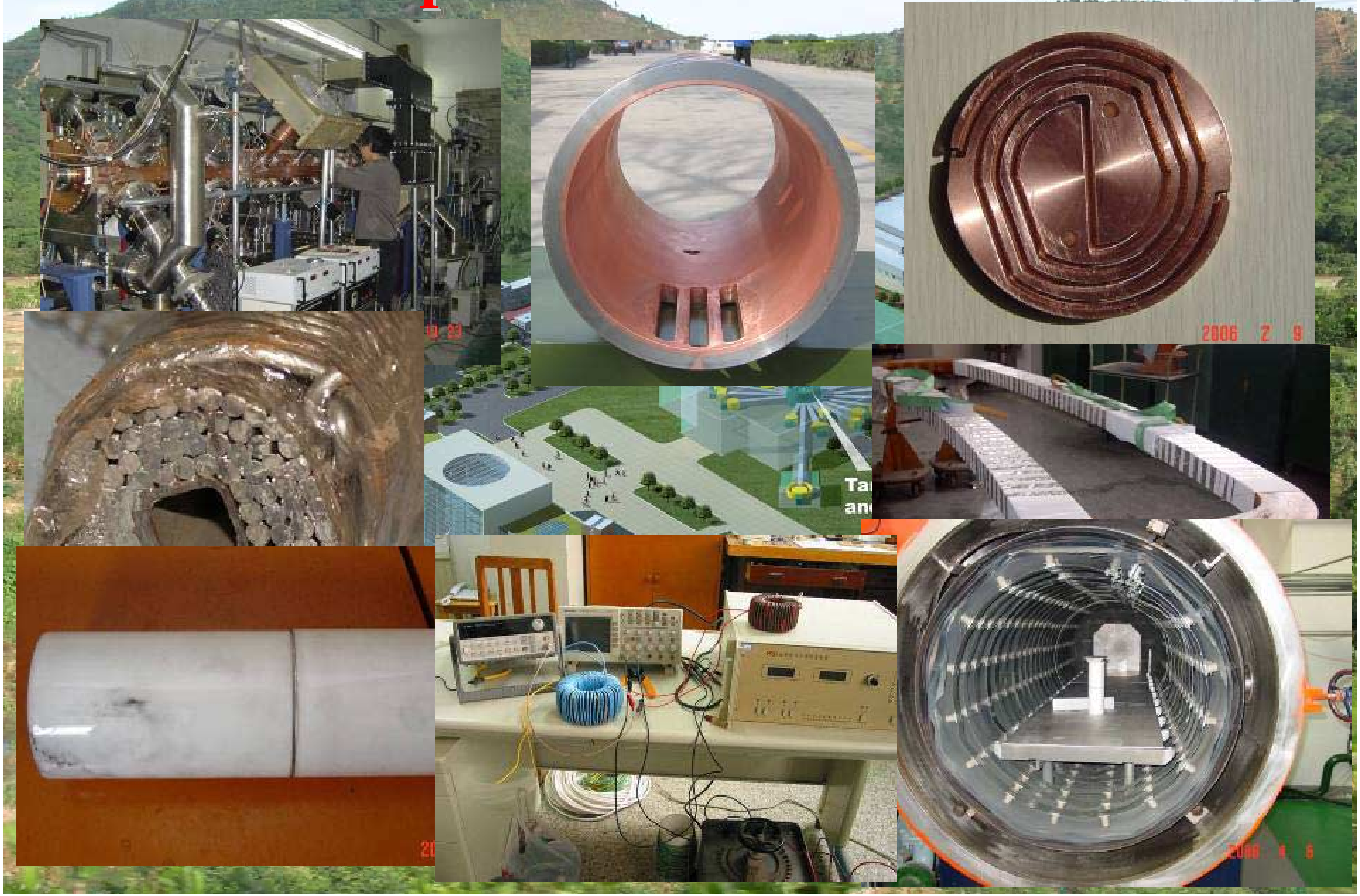
Main Parameters of the CSNS

RFQ injection energy (keV)	75
DTL injection energy (MeV)	3.5
RCS injection energy (MeV)	80 → 130
Beam energy on target (GeV)	1.6
Repetition frequency of RCS (Hz)	25
Average beam current (μA)	75→125
Average beam power (kW)	120→200

Layout of the CSNS



China Spallation Neutron Source



4.6 ILC Activities

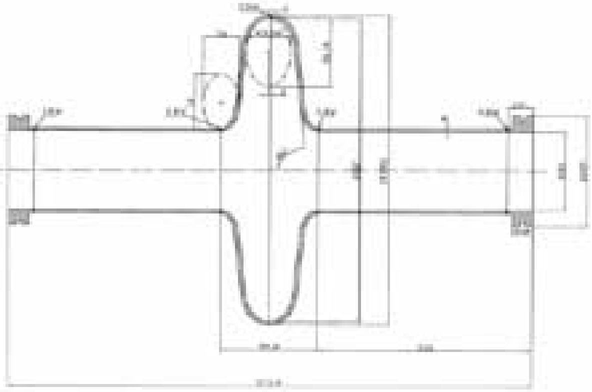
- Join the Asia-wide and World-wide collaboration on ILC;
- Forming China-collaboration team (IHEP, Peiking U., Tsinghua U., Etc.);
- Join activities of Working Groups;
- Xiangshan meeting on ILC;
- Organizing the ACFA ILC Physics and Detector Workshop & ILC GDE Meeting
- ILC Schools;
- ……

Superconducting laboratory in IHEP

700MHz/β=0. 45
超导腔 腔型设计结果

电磁场特性@2 k):

- F_{rf}=696.812 MHz;
- R_s=14.8265nΩ ;
- Q_0=7.7336E+09;
- Γ=114.655 Ω;
- R_{sh}=1.8442E+06 MΩ/m;
- R/Q=19.396 Ω;
- Esp/Eacc=3.319;
- Bsp/Eacc=8.15[mT/(Mv/m)。



腔形尺寸(单cell带束管) :

D=387mm; R_i=50mn
L_{eq}=4mm; L_b=210r
A=21.69mm,; B=43.3
a=18mm,; b=36mn

超导腔实验

IHEP-ILC Group Works on Single LLSC R&D

IHEP made 6 single LLSC cavities with three different types of materials. Experiments start with Chinese Ning Xia Large Grain LLSC.

IHEP made Saito-type CBP

Z.G. Zhong, J. Gao, J. Gu, H. Sun, Q. J. Xu, J.Y. Zhai, M.Q. Ge

IHEP-ILC in collaboration with KEK Saito's group on China Large Grain Single Cell LLSC

1. Motivation and Significance of the Research of Large Grain Niobium Cavity
2. Large Grain Pieces From Ningxia, China
3. Fabrication of Large Grain Cavities by Standard techniques
4. Surface treatment and Preparation for Vertical Test
5. Comparison of cryogenic vertical test results of the three cavities.
6. Summary


China Large Grain Niobium Cavities

4.7 Advanced Accelerator Research

JG-II: 20TW fs laser facility at IOP and CAEP

For laser-plasma acceleration experiments

640mJ/30fs, 20TW, focused intensity > $3x10^{19}W/cm^2$

Contrast ratio better than 10^6, 1.5xdiffraction limit

Target area

JG-II laser facility

Compressor

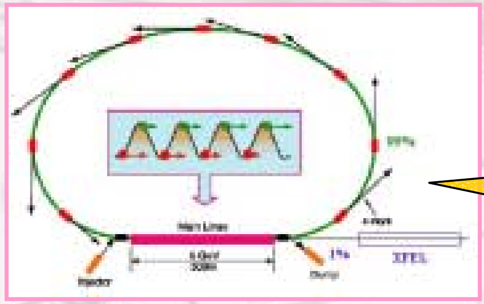
Beam complexing

Adaptive optics

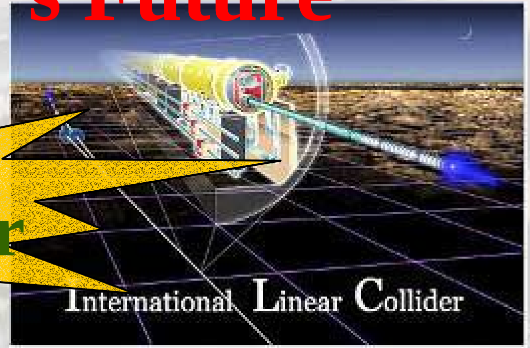
Target chamber

Diagnostics

The long march towards IHEP's Future



Inter. Linear Collider

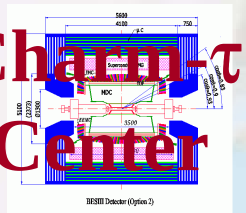


Test Beam

Slow Positron

XFEL

Charm-τ Center



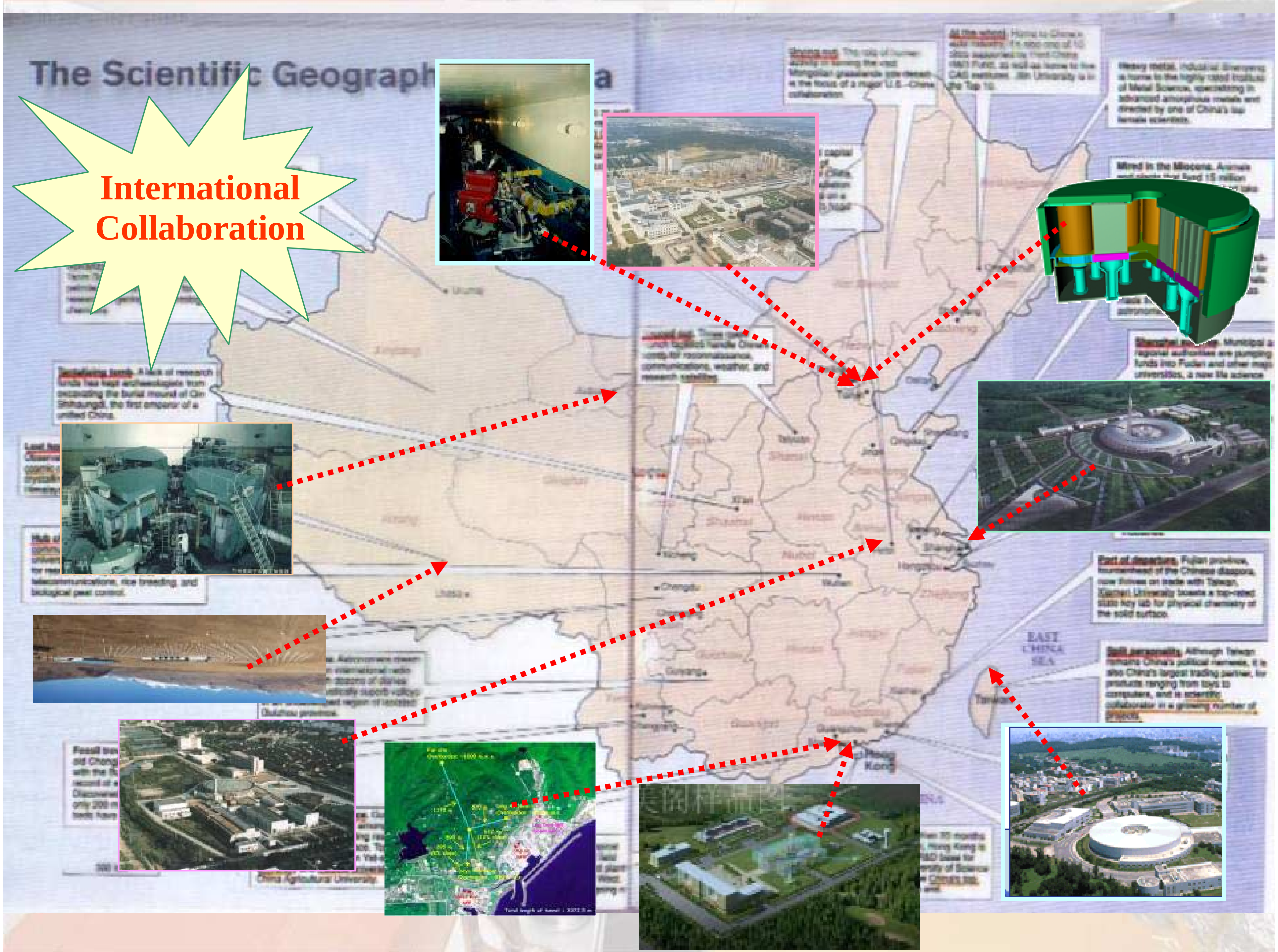
SR- Center

Neno-Center

Bio-Center

CSNS &ADS

Application


The Scientific Geograph a
International Collaboration
EAST CHINA SEA

Concluding Remarks

- High energy physics and accelerator projects have been in rapid development in China, aiming at such fundamental scientific researches, as high energy physics, nuclear physics, material science, bio-science and many other fields, as well as their application;
- Chinese scientists are devoting themselves to these projects. If they succeed, their contribution will not only benefit their own nation, but entire of the world.
- There is every reason for our two IHEP's of Russia and China to work together for the bright future of our nations and, in the same time, the whole world.

Thank You for Attention