

# **The BESIII experiment at BEPCII**

**Weiguo LI**

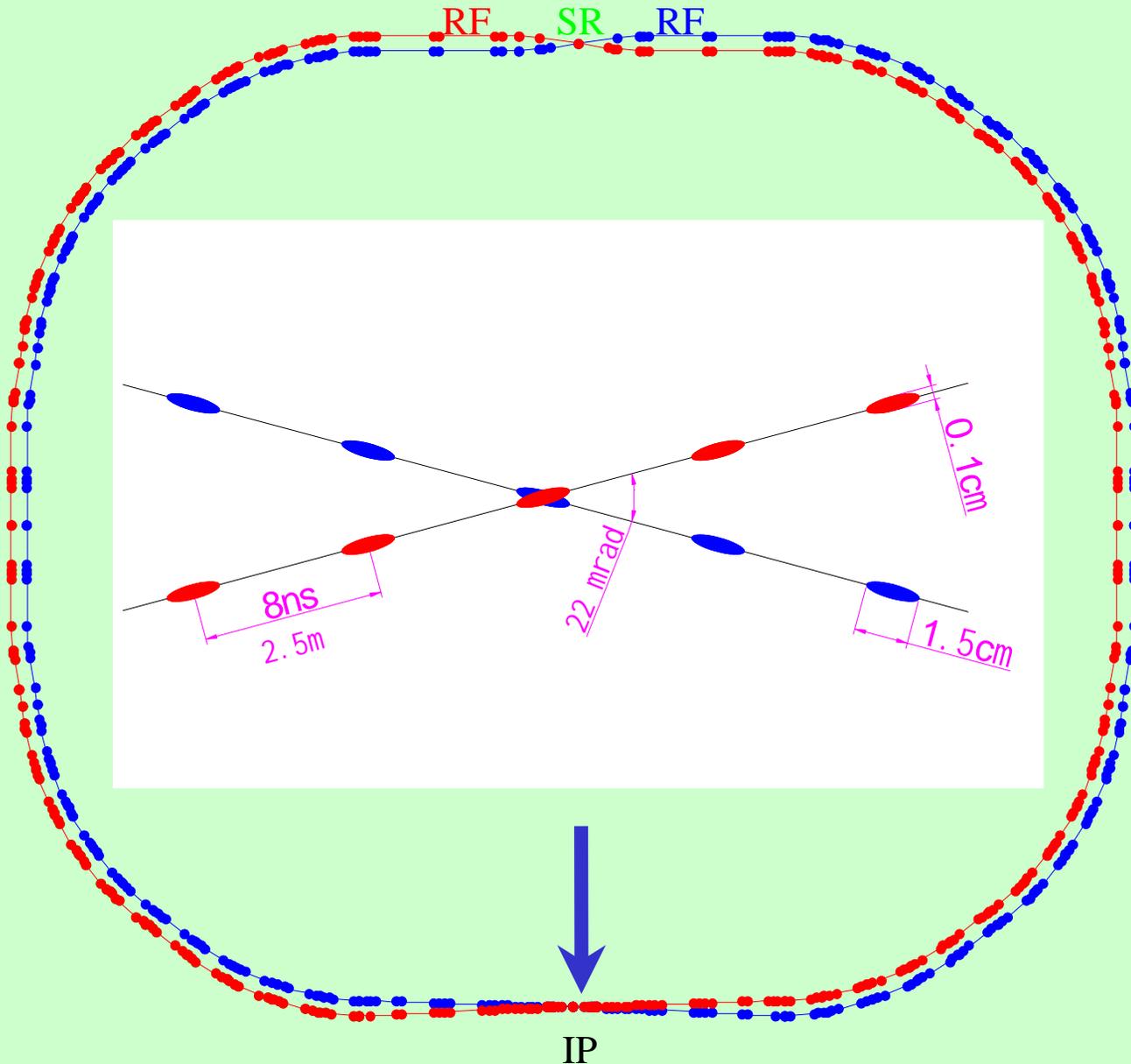
**Institute of High Energy Physics**

**Representing BESIII Collaboration**

**Hadron07**

**Oct. 8-13, 2007, Frascati**

# BEPC II Storage ring: Large angle, double-ring



Beam energy:  
**1.0-2.1 (2.3) GeV**

Magnet, RF power

Luminosity:  
 **$1 \times 10^{33} \text{ cm}^{-2} \text{ s}^{-1}$**

Optimum energy:  
**1.89 GeV**

Energy spread:  
 **$5.16 \times 10^{-4}$**

No. of bunches:  
**93**

Bunch length:  
**1.5 cm**

Total current:  
**0.91 A**

SR mode:  
**0.25 A @ 2.5 GeV**

# Physics at BEPCII/BESIII

- 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

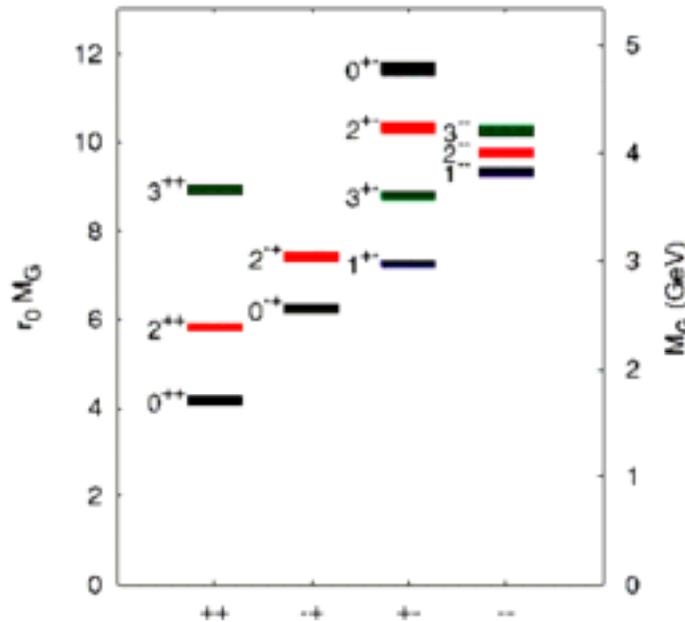
A review book on  
tau-charm physics at BESIII  
~ 800 pages, to be completed  
this year

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

# Light hadron spectroscopy

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

$10^{10}$   $J/\psi$  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)

$0^{++} : 1710 \pm 50 \pm 80$

Also:

$1611 \pm 30 \pm 160$  Michael '98  
 $1550 \pm 50 \pm ?$  Bali *et al.* '93

Spectrum of glueballs from LQCD

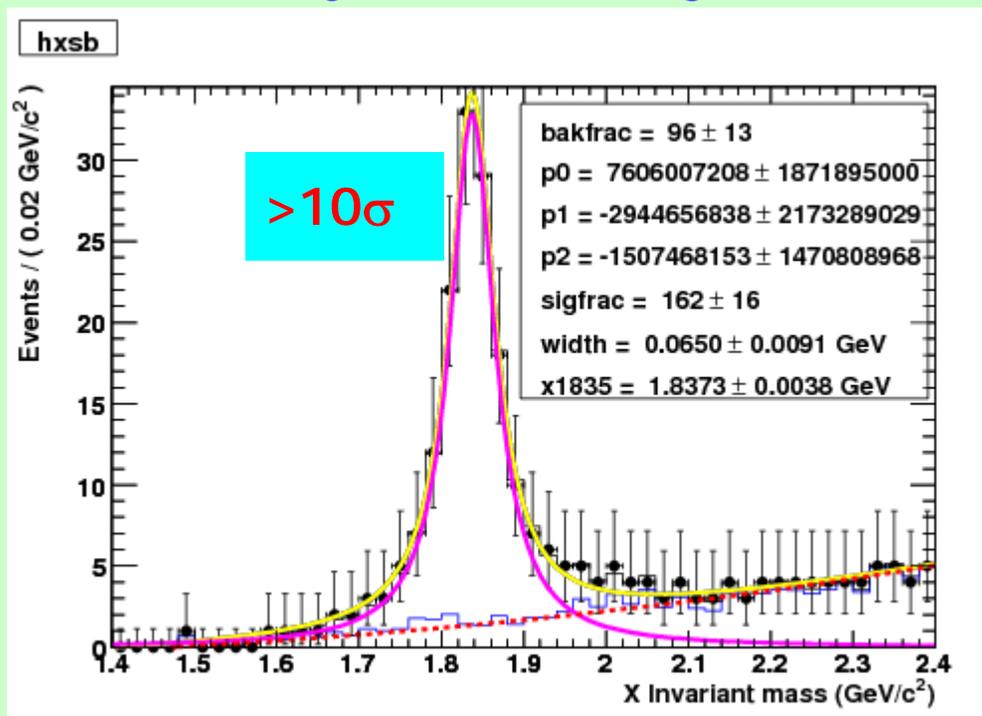
# Example 1

X(1835) at BESIII via  $J/\psi \rightarrow \gamma \eta' \pi^+ \pi^-$ ,  $\eta' \rightarrow \eta \pi^+ \pi^-$

58M  $J/\psi$  data

at BESIII

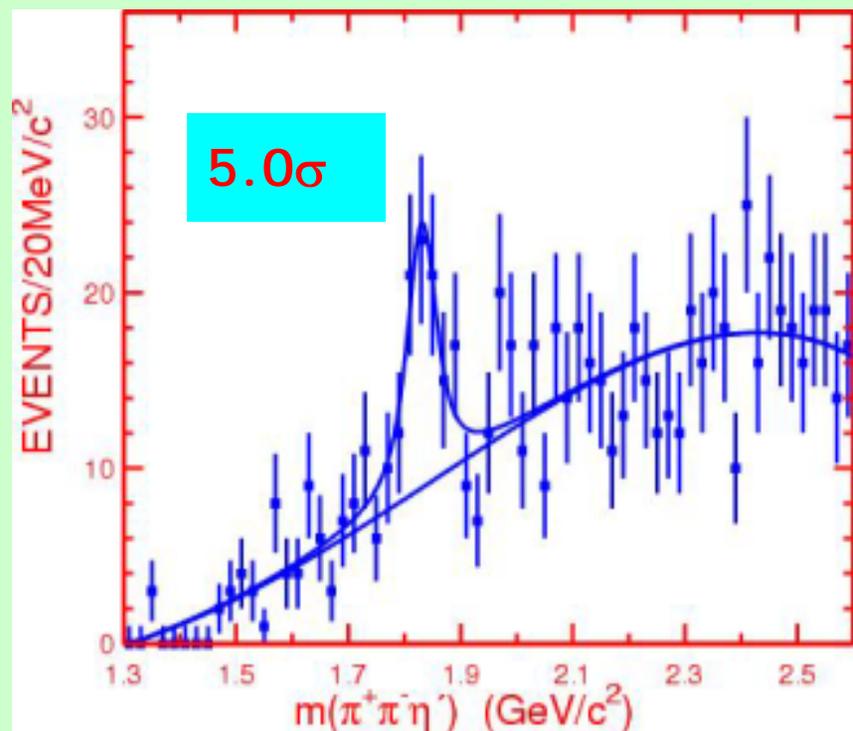
2.5 days' data taking



$M(\eta' \pi \pi)$  GeV/c<sup>2</sup>

at BESII

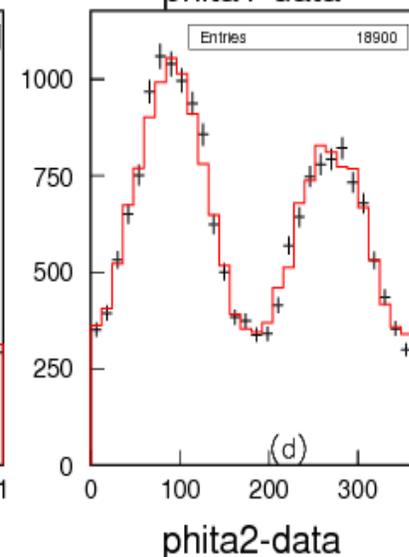
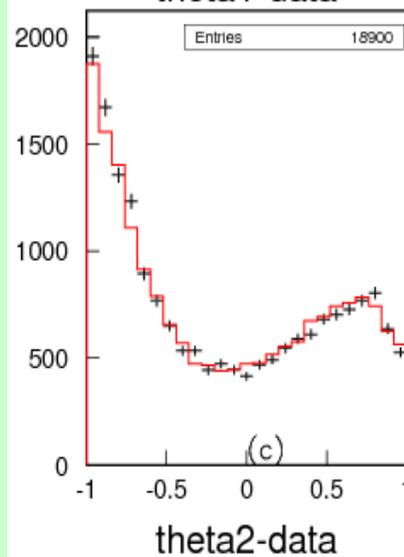
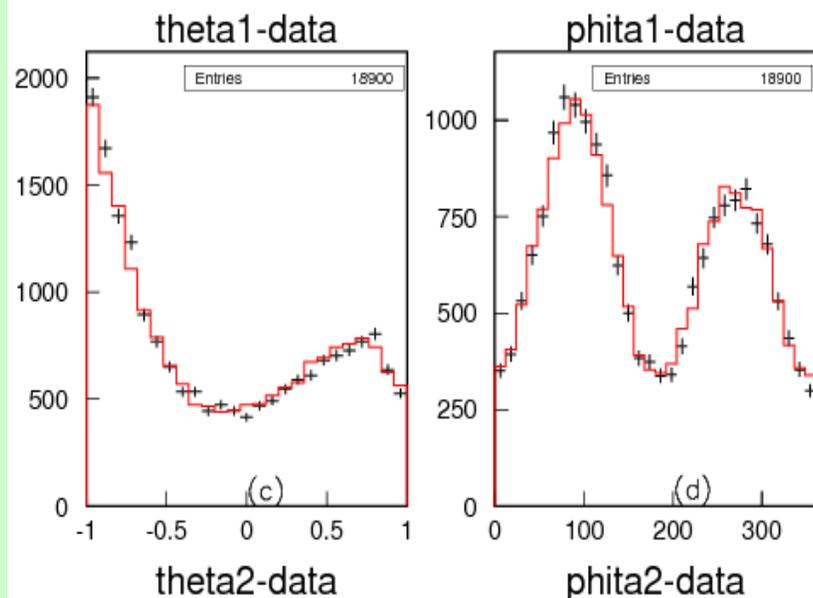
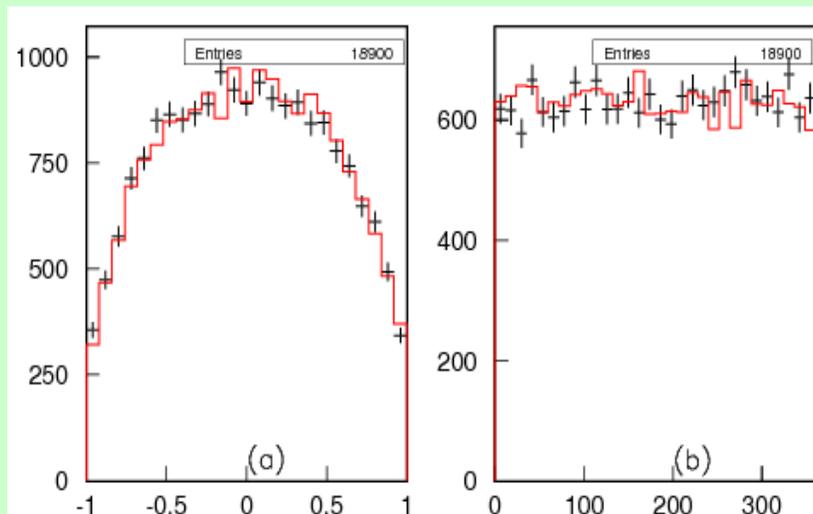
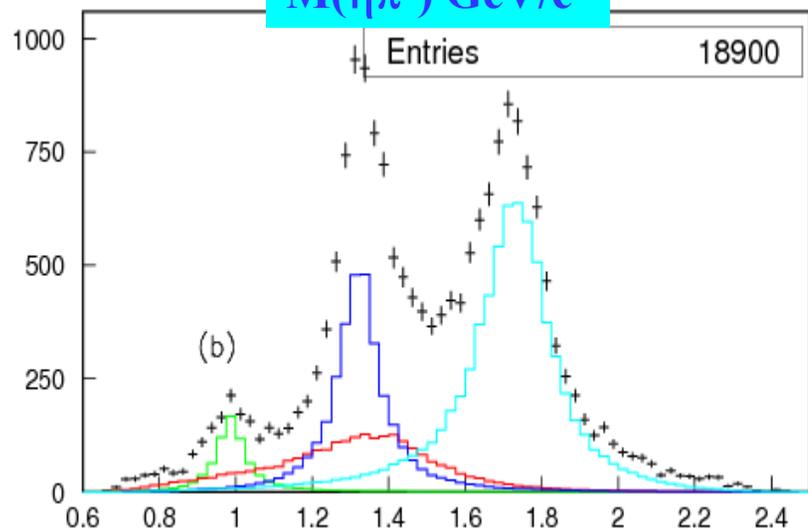
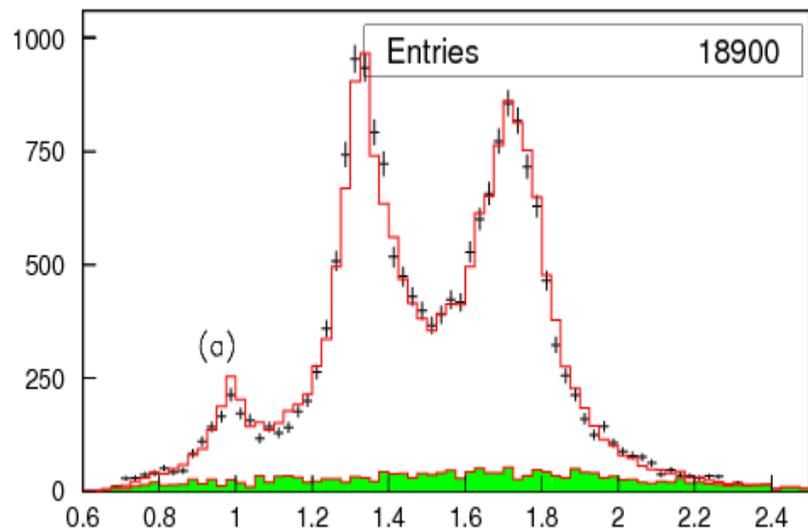
2 years' data taking



$M(\eta' \pi \pi)$  GeV/c<sup>2</sup>

# Example 2

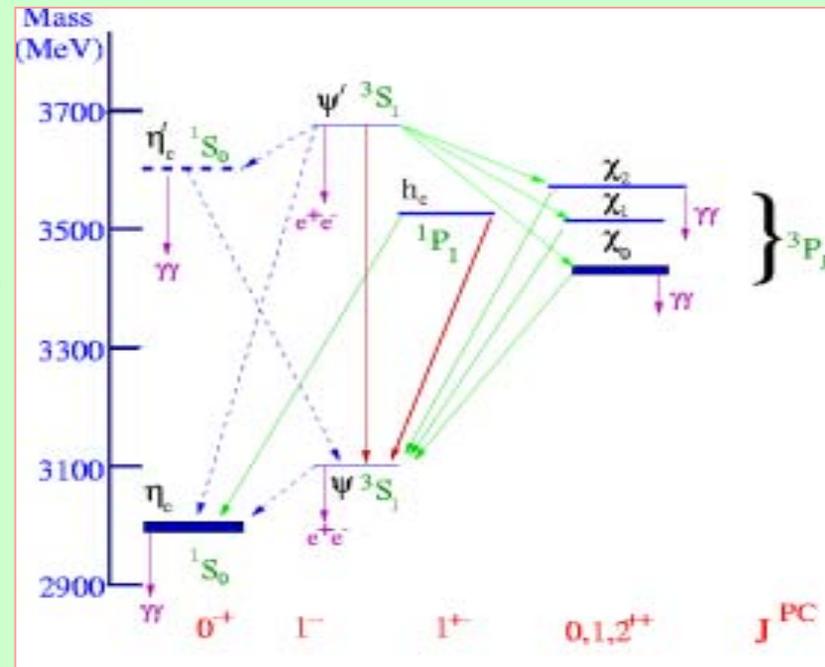
Search for  $1^{-+}$  via  $J/\psi \rightarrow \rho^0 X$ ,  $X \rightarrow \eta \pi^0$



# Charmonium physics

- Understand charmonium spectroscopy and charmonium decay dynamics

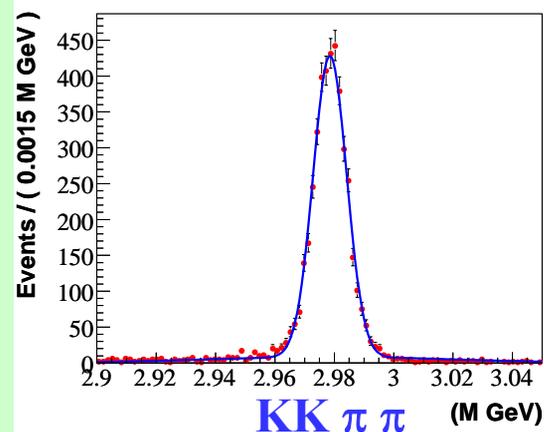
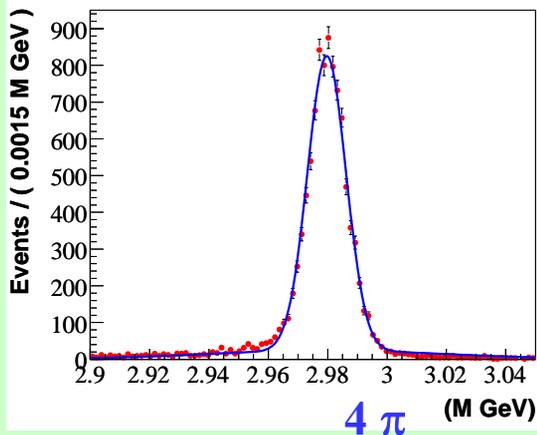
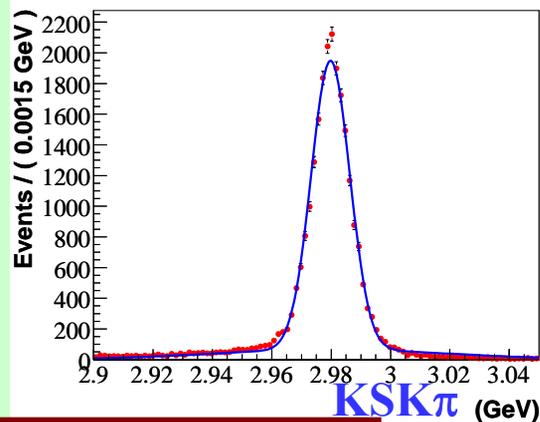
- Hadronic transition
- Radiative transition
- Study of spin-singlets ( $h_c$ ,  $\eta_c$ ,  $\eta_c'$ )
- Hadronic decays and pQCD rule
- Radiative decays and non- $q\bar{q}$  states
- ...



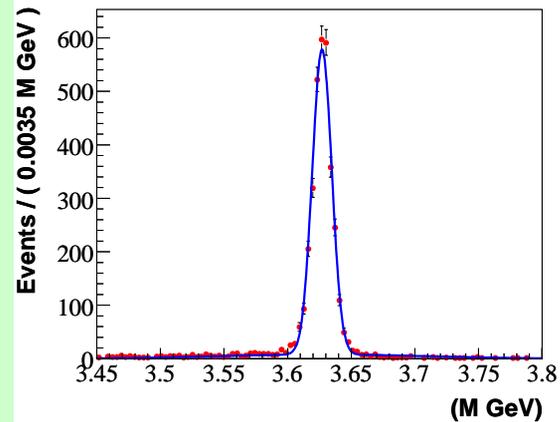
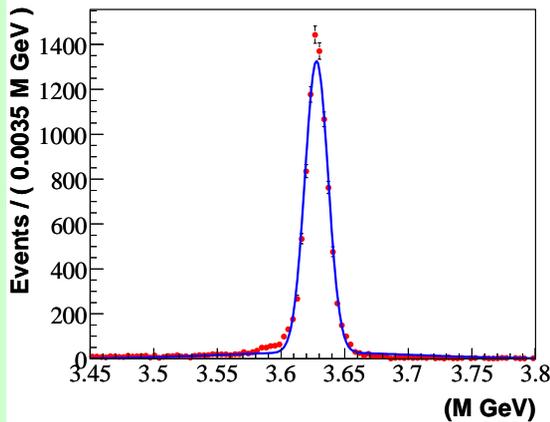
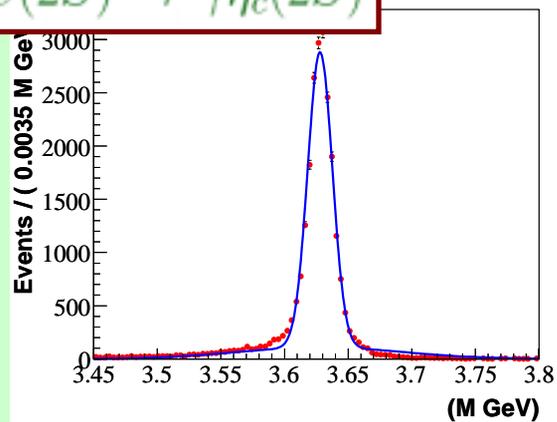
- Search for rare decays and new phenomena

$$\psi(2S) \rightarrow \gamma \eta_c(1S)$$

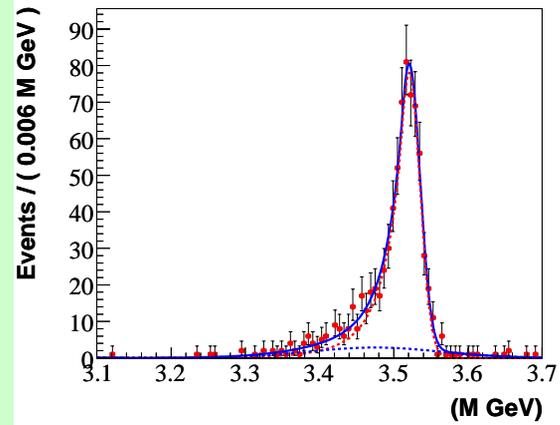
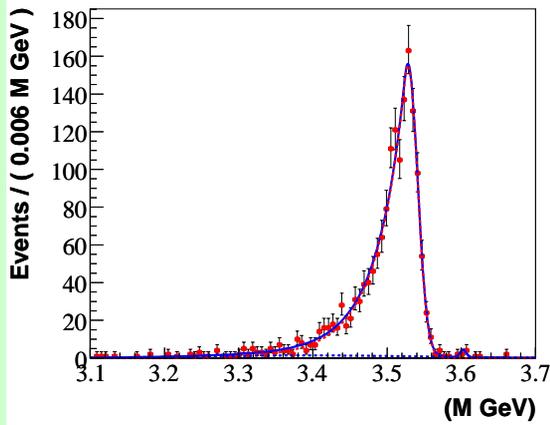
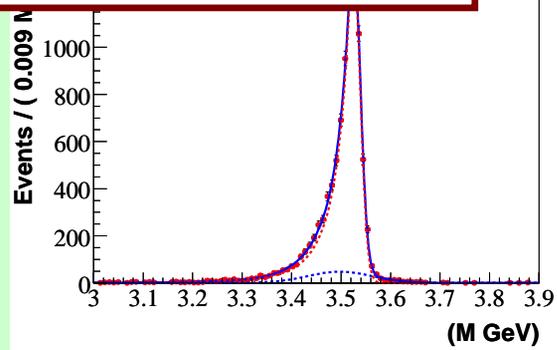
### Example 3



$$\psi(2S) \rightarrow \gamma \eta_c(2S)$$



$$\psi(2S) \rightarrow \pi^0 h_c, h_c \rightarrow \gamma \eta_c(1S)$$



# Precision measurement of CKM

## ----- Branching fractions of charm mesons

Precise measurements of Charm decays will provide inputs directly or indirectly to improve the accuracy of CKM elements determinations

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

**Example 4**

# Some simulation results

## relative errors(%) on the measurements

Mode	$\delta B/B(4\text{fb}^{-1})$	$\delta B/B(20\text{fb}^{-1})$	$\delta B/B(\text{PDG06})$	CLEOc( $281\text{pb}^{-1}$ )
$D^0 \rightarrow K^- \pi^+$	0.5	0.2	1.8	2.0 (3.891 $\pm$ 0.035 $\pm$ 0.059 $\pm$ 0.035)
$D^+ \rightarrow K^- \pi^+ \pi^+$	0.5	0.2	3.6	2.2 (9.15 $\pm$ 0.10 $\pm$ 0.16 $\pm$ 0.007)
$D^0 \rightarrow K^- e^+ \nu$	0.7	0.3	3.1	$\sim 3$
$D^0 \rightarrow \pi^- e^+ \nu$	1.8	0.8	6.8	$\sim 5$
$D^0 \rightarrow K^- \mu^+ \nu$	0.9	0.4	5.0	
$D^0 \rightarrow \pi^- \mu^+ \nu$	2.1	1.0	17	
$D^+ \rightarrow \mu^+ \nu$	4.0	2.0	16	15
$f_{D^+}$	2.0	0.9	7.7	7.5

Mode	$\delta B/B(4\text{fb}^{-1})$	$\delta B/B(20\text{fb}^{-1})$	$\delta B/B(\text{PDG06})$	CLEOc( $281\text{pb}^{-1}$ )
$D_S^+ \rightarrow \phi \pi^+$	4.0	1.8	14	7.5
$D_S^+ \rightarrow \phi e^+ \nu$	5.0	2.2	17	
$D_S^+ \rightarrow \mu^+ \nu$	5.7	2.5	31	8.1
$f_{D_S^+}$	2.8	1.3	9	5

**Systematic errors will be dominant, Dalitz plot analyses**

# Precision test of SM and Search for new Physics

- **DDbar mixing**

DDbar mixing in SM  $\sim 10^{-3} - 10^{-10}$

DDbar mixing sensitive to “new physics”

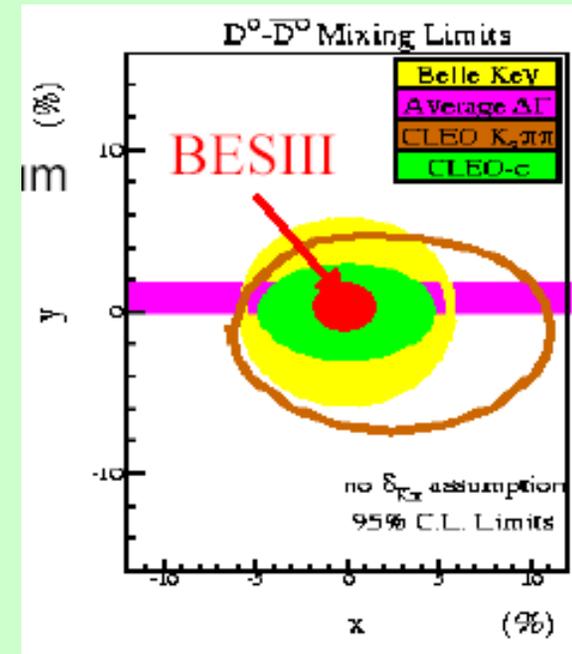
Our sensitivity :  $\sim 10^{-4}$

- **Lepton universality**

- **CP violation**

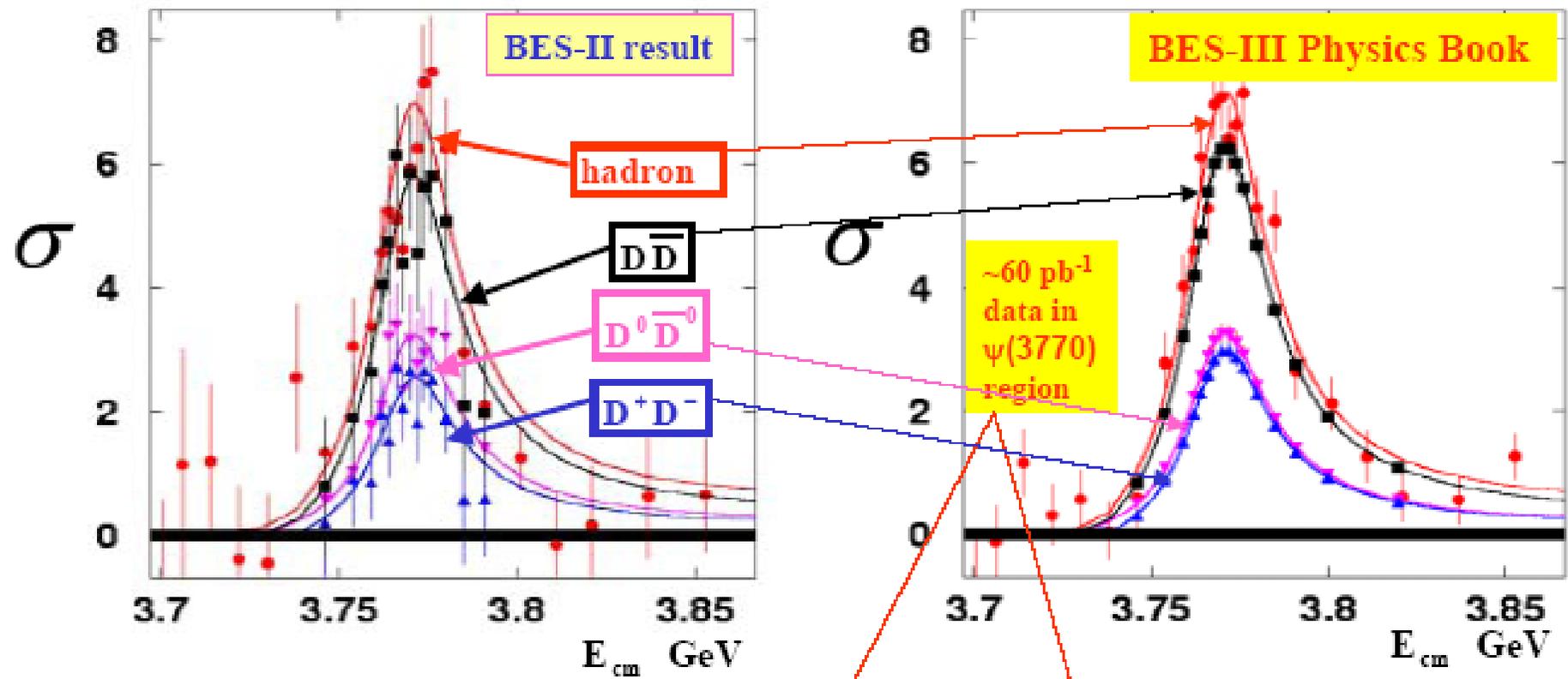
- **Rare decays**

FCNC, Lepton no. violation, ...



$D^0\bar{D}^0$ Mixing		
Reaction	Events Right Sign	Sensitivity of $R_M$
$\psi(3770) \rightarrow (K^- \pi^+)(K^- \pi^-)$	87195	$1 \times 10^{-4}$
$\psi(3770) \rightarrow (K^- e^+ \nu)(K^- e^+ \nu)$	94351	$3.7 \times 10^{-4}$
$\psi(3770) \rightarrow (K^- e^+ \nu)(K^- \mu^+ \nu)$	166808	
$\psi(3770) \rightarrow (K^- \mu^+ \nu)(K^- \mu^+ \nu)$	83404	
$D^{*+}D^- \rightarrow [\pi_s^+(K^+ e^- \bar{\nu})(K^+ \pi^- \pi^-)]$	76000	$4.7 \times 10^{-5}$
$D^{*+}D^- \rightarrow [\pi_s^+(K^+ \mu^- \bar{\nu})(K^+ \pi^- \pi^-)]$	60000	
$D^{*+}D^- \rightarrow [\pi_s^+(K^+ e^- \bar{\nu})(\text{other } D^- \text{ tag})]$	60000	
$D^{*+}D^- \rightarrow [\pi_s^+(K^+ \mu^- \bar{\nu})(\text{other } D^- \text{ tag})]$	60000	

# Scan of $\psi(3770)$ peak



$\Gamma_{\psi(3770)}^{tot}$	$26.8 \pm 0.5$ MeV	26.9 MeV
$\Gamma_{\psi(3770)}^{ee}$	$256 \pm 9$ eV	251 eV
	Measured value	Input value

$B[\psi(3770) \rightarrow D\bar{D}]$	$(88.2 \pm 2.4 \pm \sim 2.0) \%$	Measured value
	89 %	Input value

# QCD and hadron production

- R-value measurement
- Measurement of  $\alpha_s$  at low energies
- Hadron production at  $J/\psi$ ,  $\psi'$ , and continuum
- Multiplicity and other topology of hadron events
- BEC, correlations, form factors, resonance, etc.

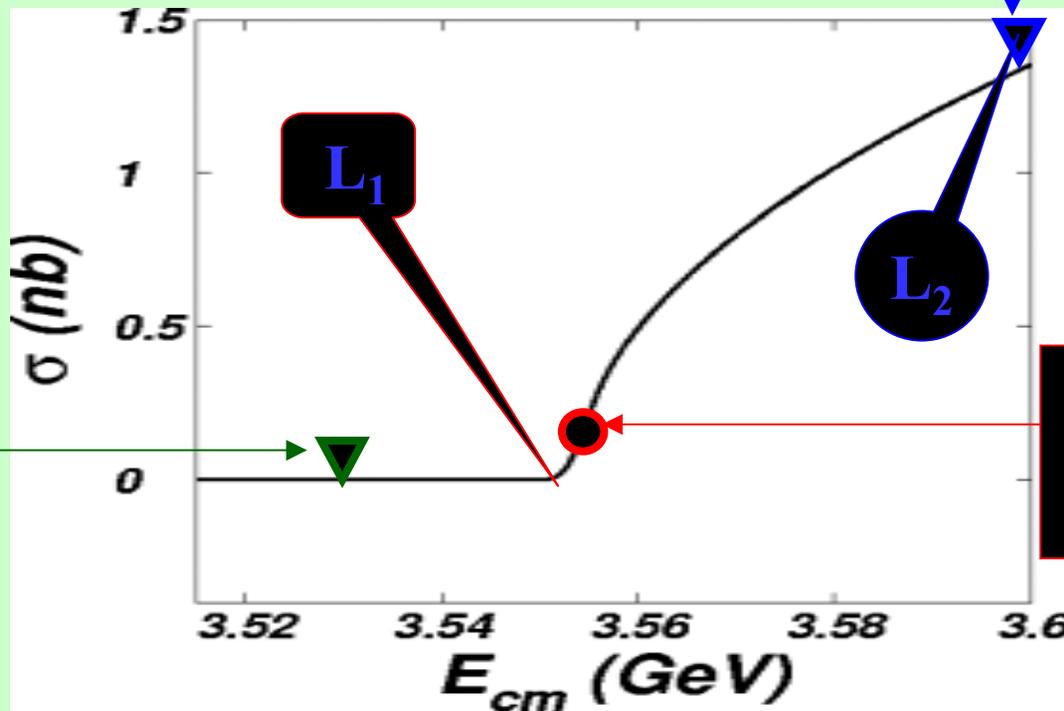
Error on R	$\Delta\alpha_{\text{had}}^{(5)} (M_Z^2)$
6%	$0.02761 \pm 0.00036$
3%	$0.02761 \pm 0.00030$
2%	$0.02761 \pm 0.00029$

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

# Tau mass measurement

**Data taking strategy (~ 2weeks)**

*Event Selection & Eff. determination*



**Current:**

$$m_\tau = 1776.96^{+0.18+0.25}_{-0.21-0.17} \text{ MeV}$$

**BESIII expected:**

$$\Delta m_\tau = \pm 0.05 \pm 0.09 \text{ MeV}$$

Using Compton scattering technique to measure the beam energy

# **Current status of BEPCII/BESIII construction**

# Installation of linac is complete



# Summary of the Linac commissioning

Parameters		Goal	Measured
Beam energy (GeV)		1.89	1.89 (e-); 1.89 (e+)
Beam current (mA)	e <sup>+</sup>	40	40 - 63
	e <sup>-</sup>	500	> 500
Repetition rate (Hz)		50	50
Emittance (1 $\sigma$ ) ( mm·mrad )	e <sup>+</sup>	0.53	0.32 ~ 0.20
	e <sup>-</sup>	0.067	0.080 ~ 0.096
Energy spread (%)	e <sup>+</sup>	$\pm 0.50$	$\pm 0.73 @ 1.30 \text{ GeV}$ $(\pm 0.50 @ 1.89 \text{ GeV})$
	e <sup>-</sup>	$\pm 0.50$	$< \pm 0.80 @ 1.30 \text{ GeV}$ $< (\pm 0.55 @ 1.89 \text{ GeV})$

**The BEPCII storage ring installation was completed in the beginning of Nov. 2006**



# Conventional magnets were installed in IR to start ring commissioning and SR operation



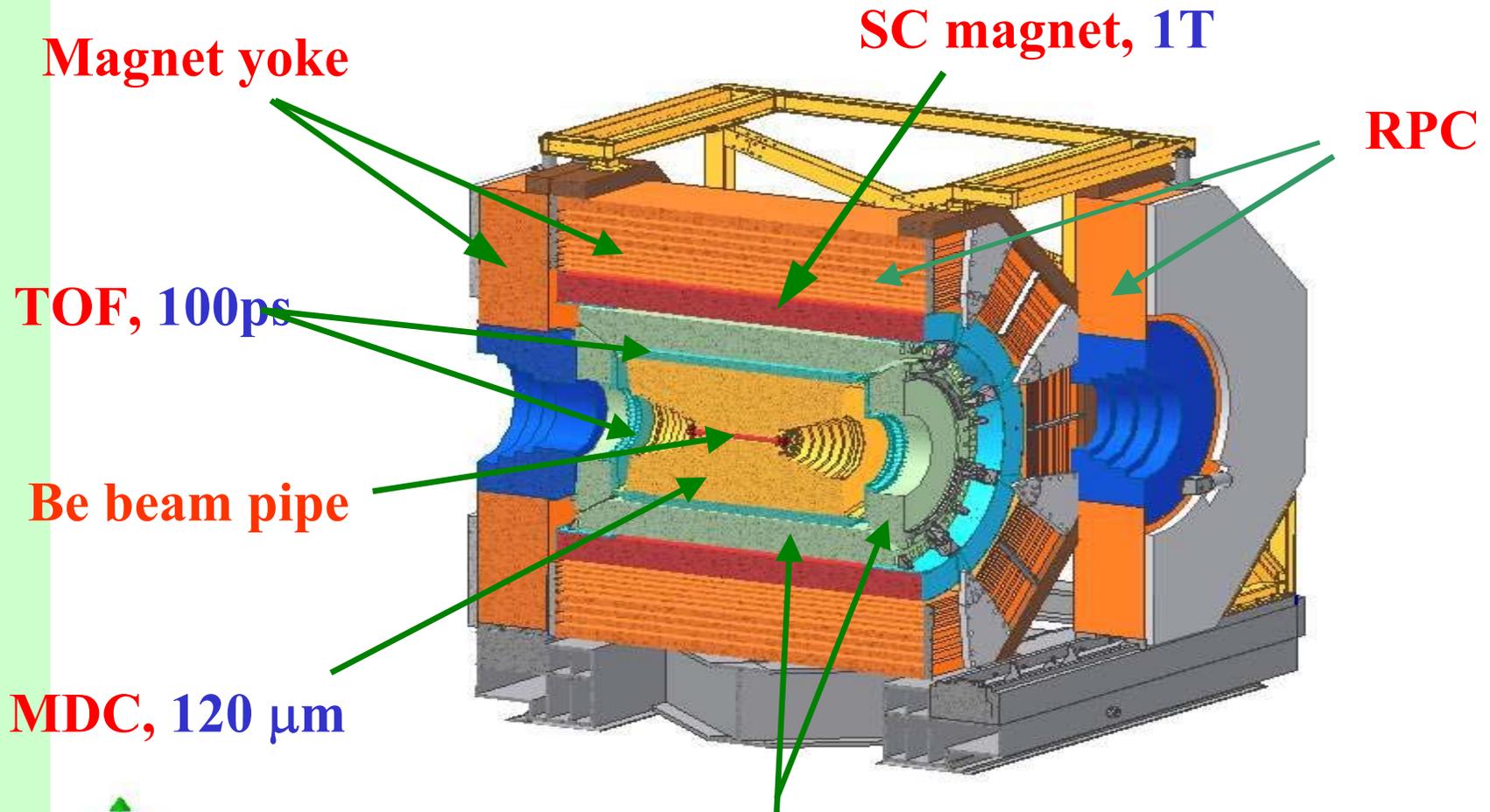
# Milestone of BEPCII storage ring commissioning

- Nov. 2006** Beam commissioning start
- Nov. 2006** Beam was stored in the storage ring
- Dec. 2006** Accumulated beam  $\sim 6$  A·hrs.,  
beam life time  $\sim 1.5$  hrs @ 60mA.
- Dec. 2006** Start to provide SR beams for users
- Mar. 2007** First e<sup>+</sup>e<sup>-</sup> collision, Lumi  $\sim 10^{30}$  cm<sup>-2</sup> s<sup>-1</sup> (normal Q)  
collision of 100 mA + 100 mA , lumi  $\sim 10^{31}$  cm<sup>-2</sup> s<sup>-1</sup>
- June 2007** Provide SR beams for users at 2.5GeV,  
200 mA with a lifetime of 5.5 hr
- Aug. 2007** Beam current reached 500 mA  
SCQ magnet mapped and now at the interaction region  
(was a serious problem)

# Future plan

- Machine study will start Oct. 17, 2007
- Another SR run is planed at the end of 2007
- By march 2008, lumi shall reach  $\sim 10^{32} \text{ cm}^{-2} \text{ s}^{-1}$  and backgrounds acceptable
- The BESIII detector will be moved to the interaction region by March 2008
- The goal is that BEPCII should reach a lumi. around  $3 \times 10^{32} \text{ cm}^{-2} \text{ s}^{-1}$  by the end of 2008

# The BESIII Detector



**CsI(Tl) calorimeter, 2.5 % @ 1 GeV**

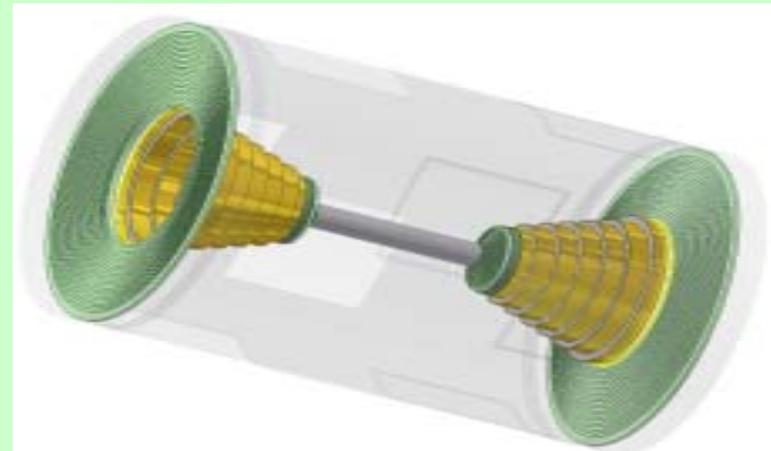
- **Drift chamber and its electronics (IHEP, Sichuan, Tsinghua)**
- **CsI(Tl) calorimeter and its electronics (IHEP, Tsinghua)**
- **TOF ( IHEP, USTC , Tokyo , Hawaii )**
- **TOF electronics ( USTC )**
- **RPC ( IHEP, Uni. of Washington )**
- **RPC electronics ( USTC )**
- **Trigger ( IHEP, USTC )**
- **DAQ & online software (IHEP, Tsinghua)**
- **Offline software ( IHEP, Peking , Shangdong , Nanjing )**
- **Superconducting magnet ( IHEP , Wang NMR )**
- **Mechanics (IHEP)**
- **Technical support ( IHEP, Tsinghua )**

# Drift chamber

- To measure the momentum of charged particles
- Design spec.:

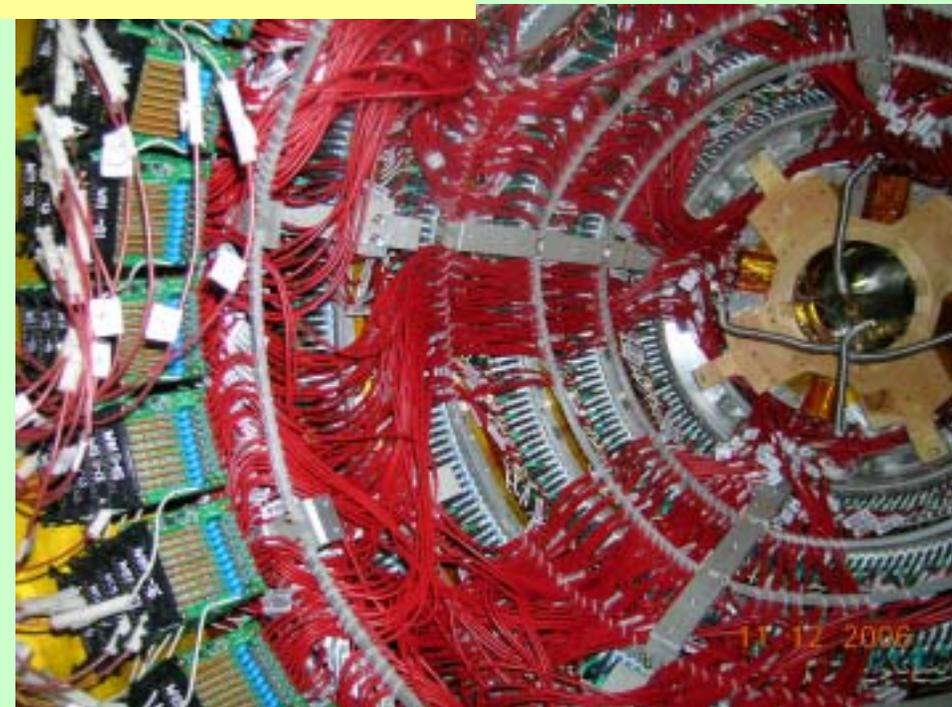
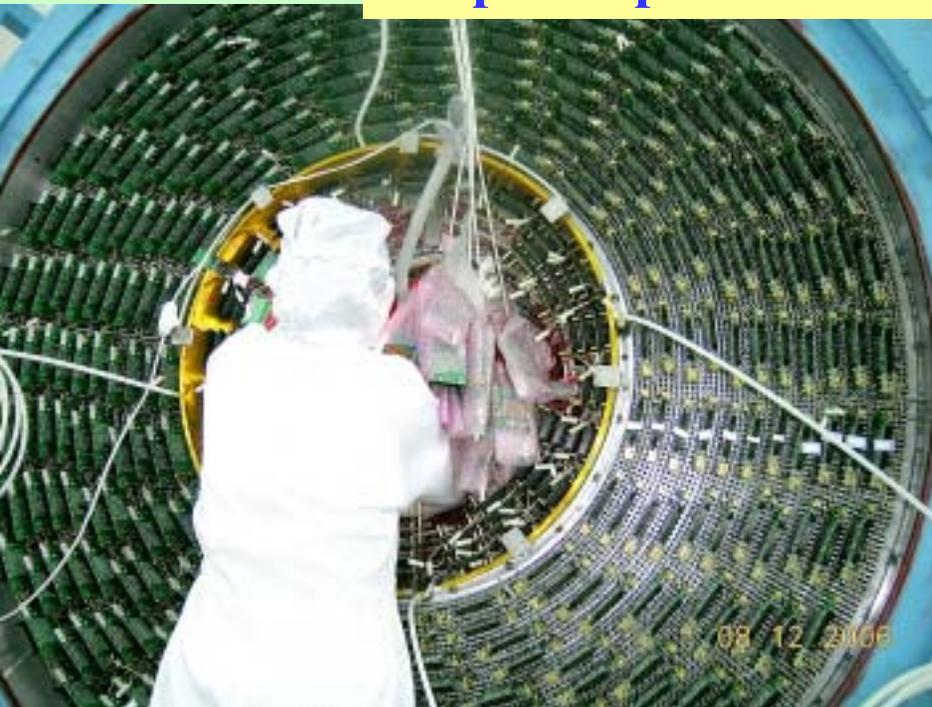
	Single wire reso.	dE/dx reso.
CLEO:	~110 $\mu\text{m}$ ,	5.7%
Babar:	~110 $\mu\text{m}$ ,	6.2%
Belle:	~130 $\mu\text{m}$ ,	5.7%
BESIII	~120 $\mu\text{m}$	6 %
- $R_{\text{in}} = 63\text{mm}$ ;  $R_{\text{out}} = 810\text{mm}$ ; length = 2400 mm
- 7000 Signal wires: 25(3% Rhenium)  $\mu\text{m}$  gold-plated tungsten
- 22000 Field wires: 110  $\mu\text{m}$  Al
- Gas: He + C<sub>3</sub>H<sub>8</sub> (60/40)
- Momentum resolution@1GeV:  
0.5%

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

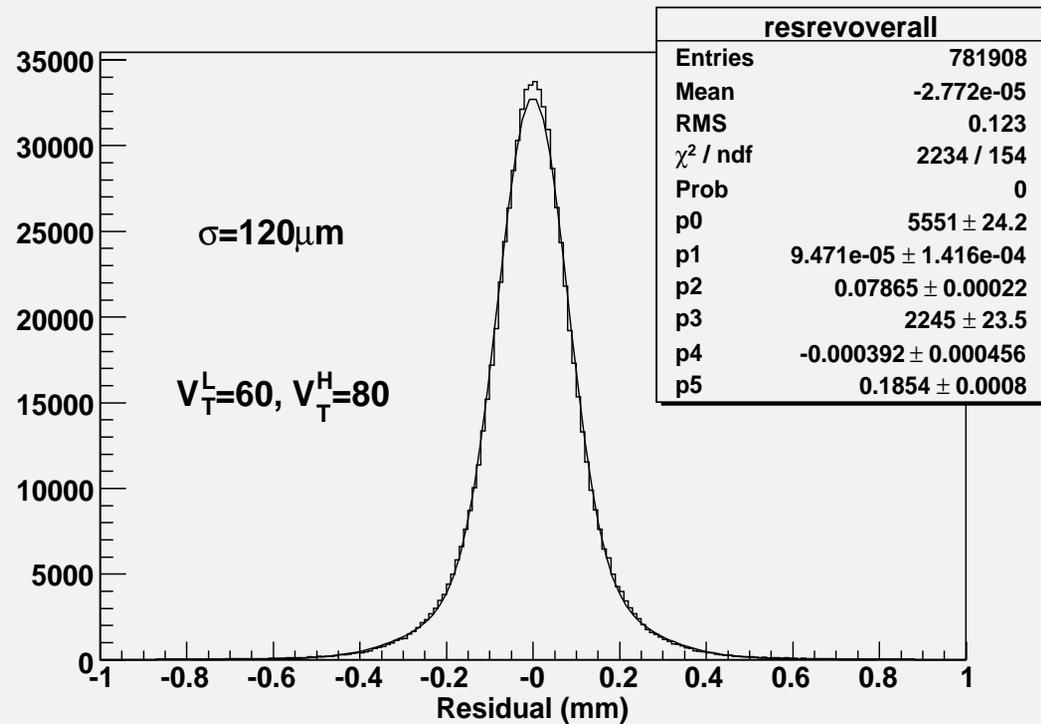
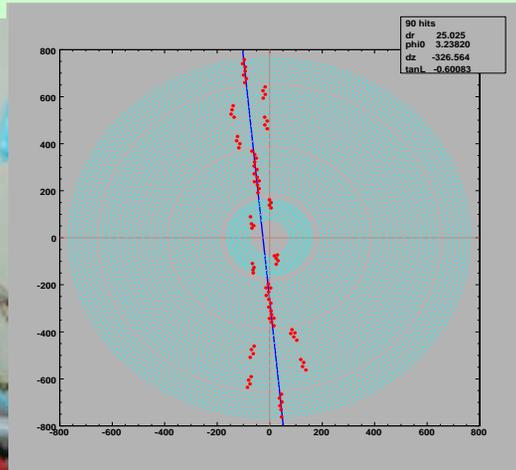




All preamplifiers are mounted and tested



# Cosmic-ray tests completed



# BESIII CsI(Tl) crystal calorimeter

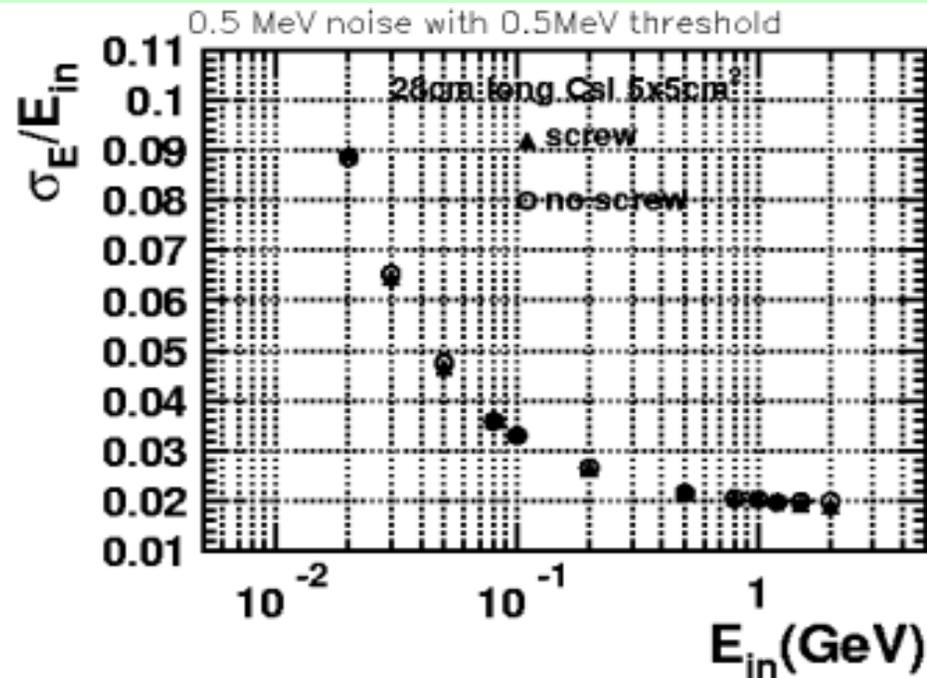
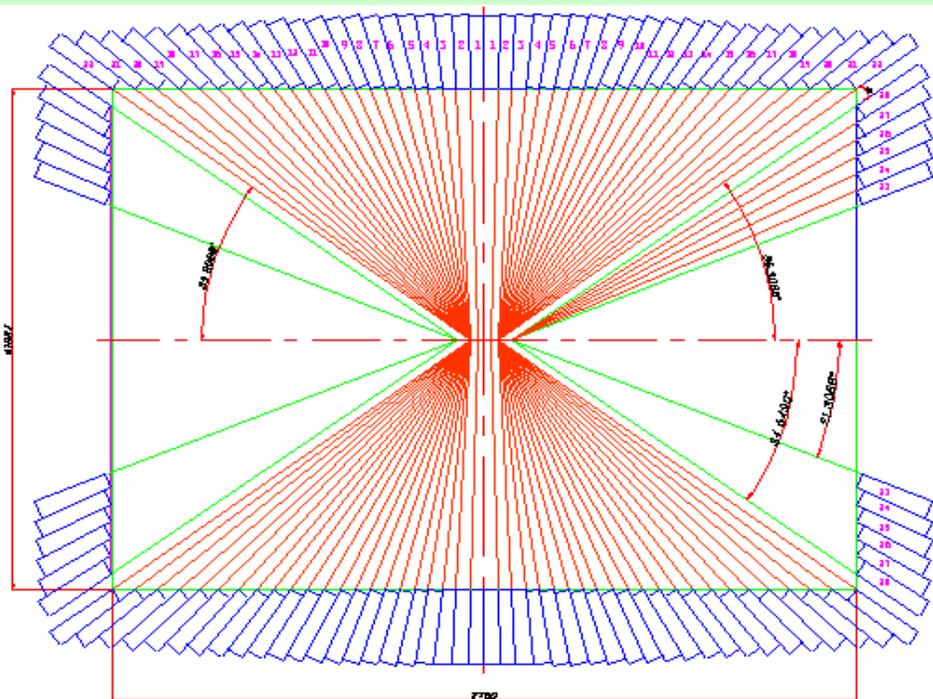
- To measure the energy of electromagnetic particles
- Barrel: 5280 crystals , Endcap: 960 crystals
- Crystal:  $(5.2 \times 5.2 - 6.4 \times 6.4) \times 28 \text{cm}^3$
- Readout:  $\sim 13000$  Photodiodes,  $1 \text{cm} \times 2 \text{cm}$ ,
- Energy range : 20MeV – 2 GeV
- position resolution: 6 mm@1GeV
- Tiled angle: theta  $\sim 1-3^\circ$ , phi  $\sim 1.5^\circ$

Babar: 2.67% @1GeV

BELLE: 2.2% @1GeV

CLEO: 2.2% @1GeV

BESIII: 2.5% @1GeV



# CsI Calorimeter

## Testing:

- Size
- Source tests ( $^{137}\text{Cs}$ )
- LED tests
- PD tests
- Preamp tests
- Cosmic ray tests
- Beam tests (6 x 6 array):

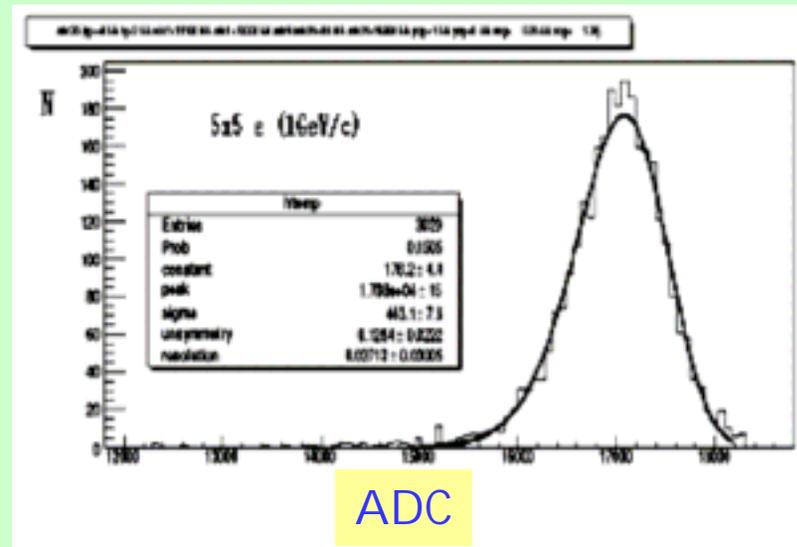
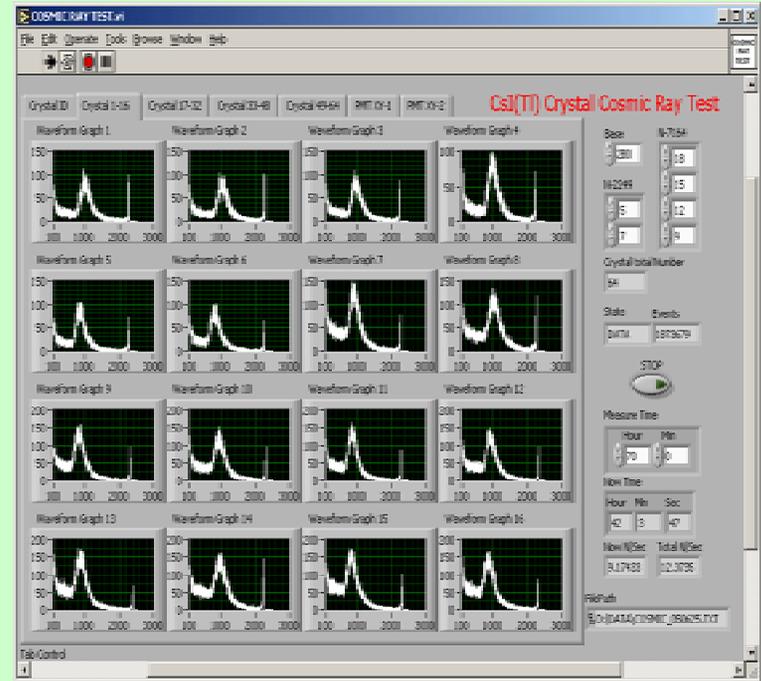
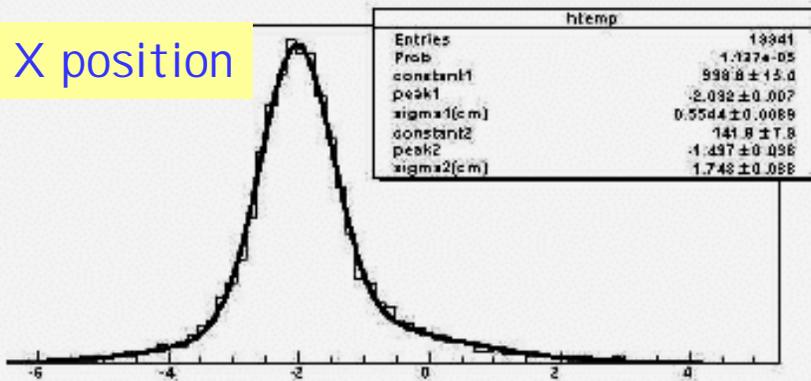
Energy resolution (1GeV)

$$\sigma_E = 2.62 \%$$

position resolution (1GeV)

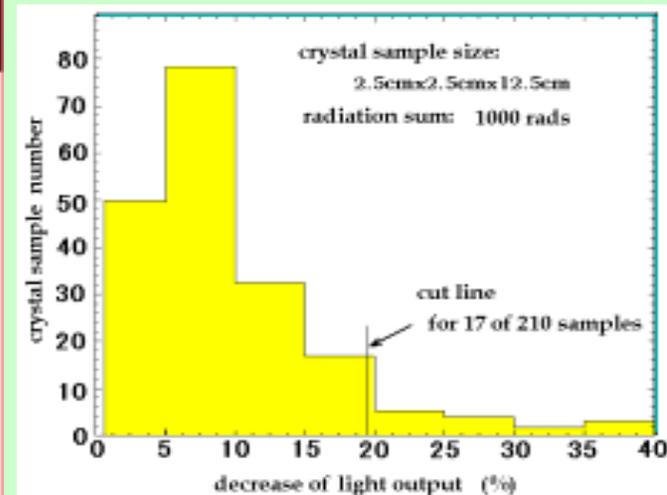
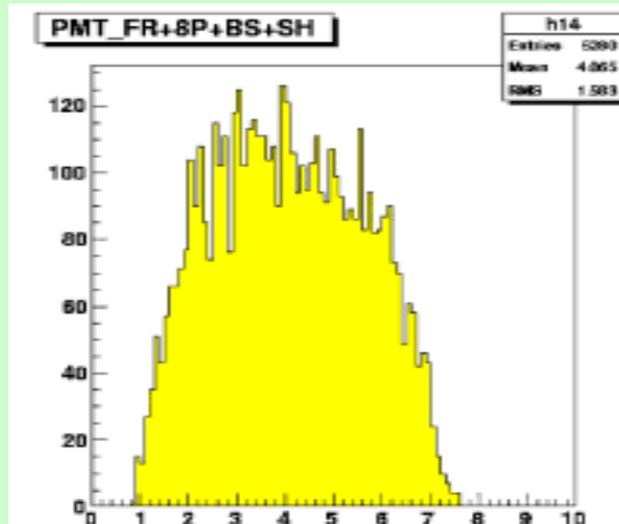
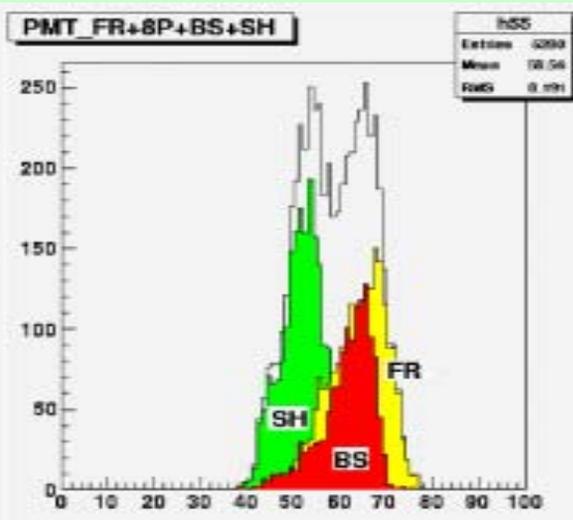
$$\sigma_{x-y} = 6 \text{ mm}$$

X position

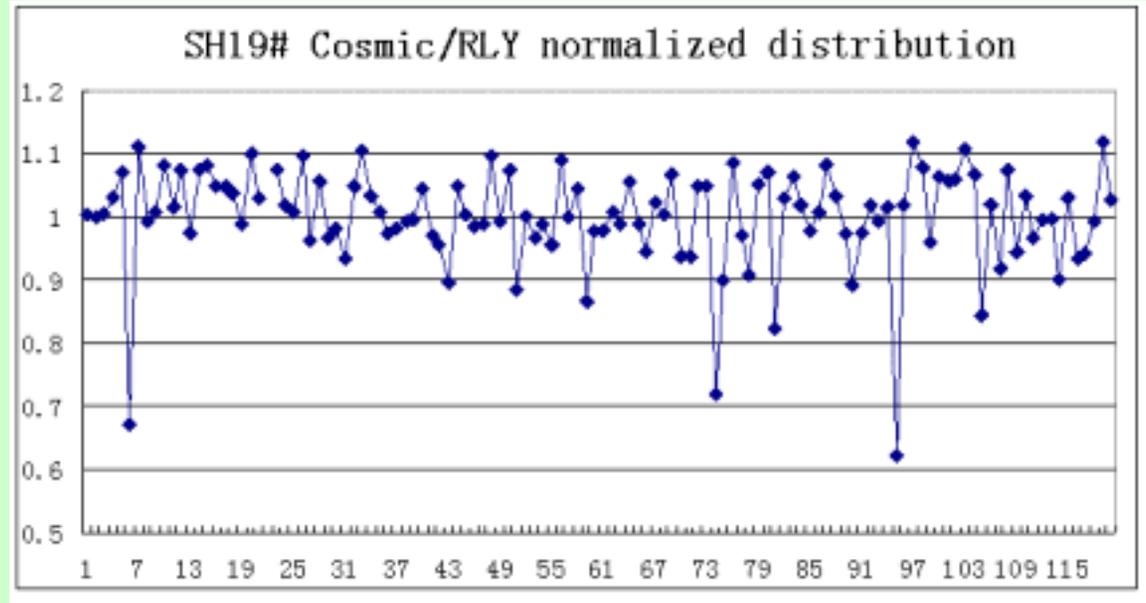


# Crystal production and tests completed

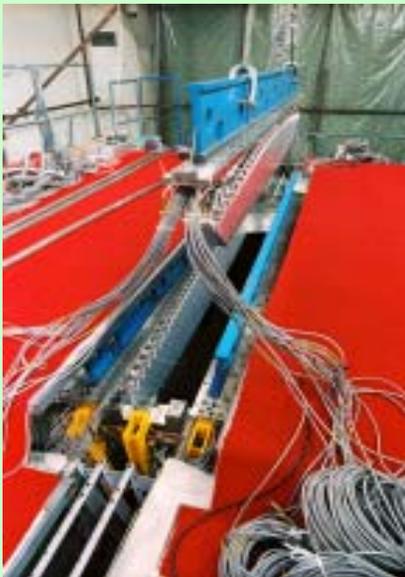
	France Sanit -Gobain	Shanghai Institute of Ceramics	Beijing Hamamatsu	Total
Ordered	2040(960)	1920	1320	5280(960)
Replaced	87(4)	316	79	482(4)



# Crystal assembly completed

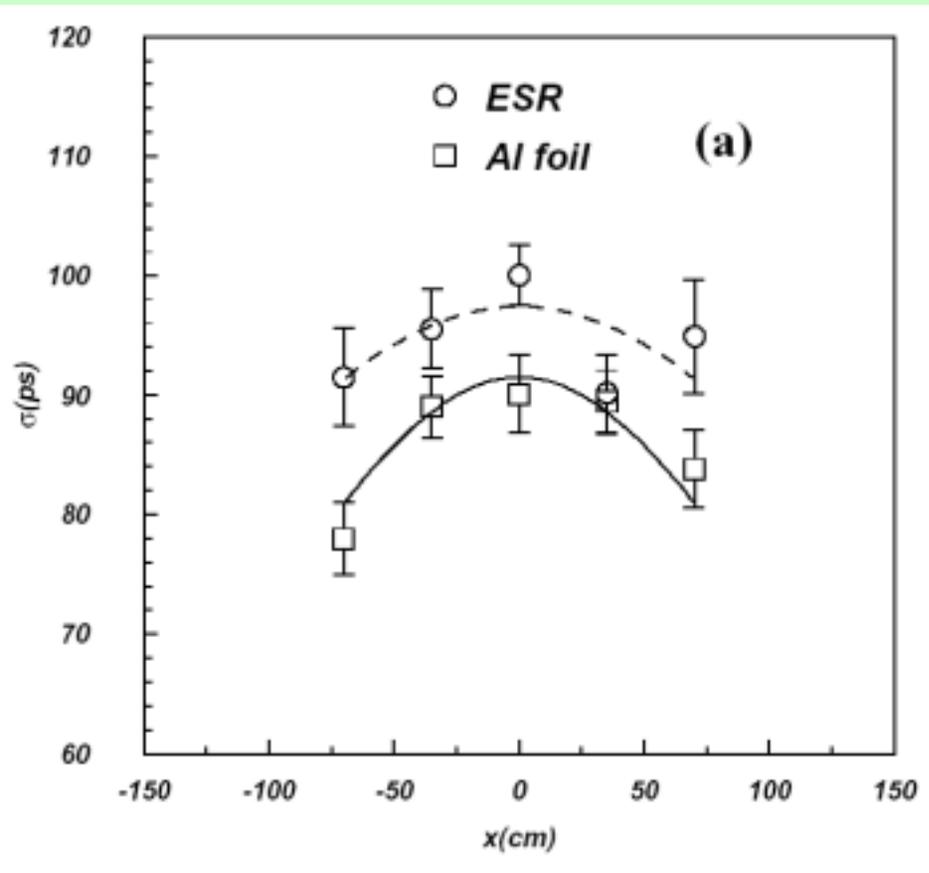


# Barrel assembly completed

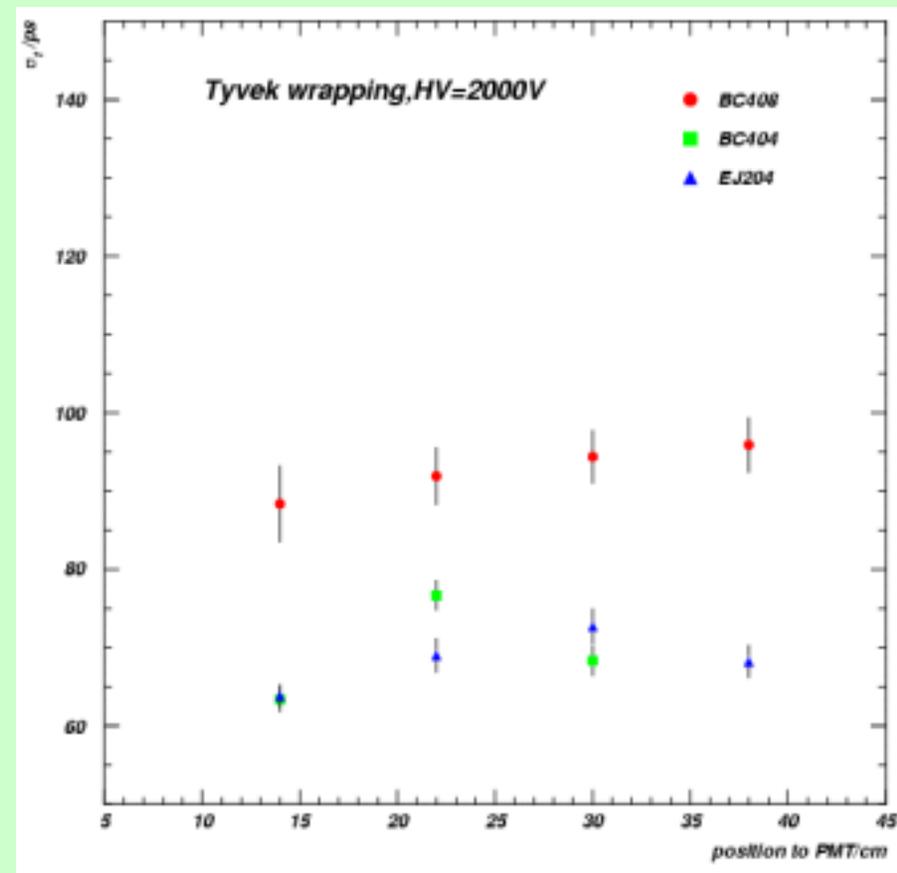




# Test beam at IHEP: for various types of scintillators, thickness, wrapping materials, ...

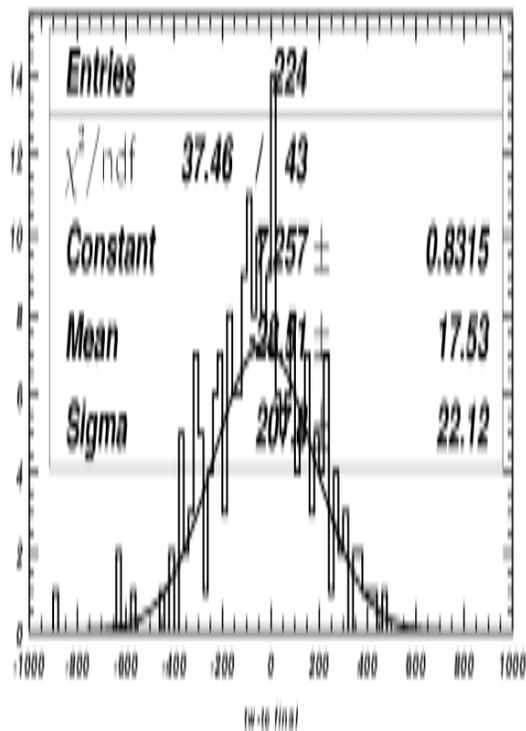


Barrel



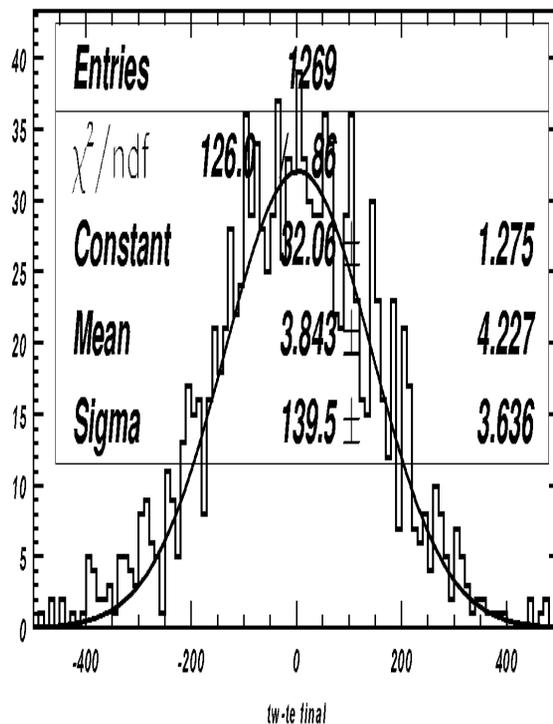
Endcap

# Test beam at IHEP: for various types of scintillators, thickness, wrapping materials, ...



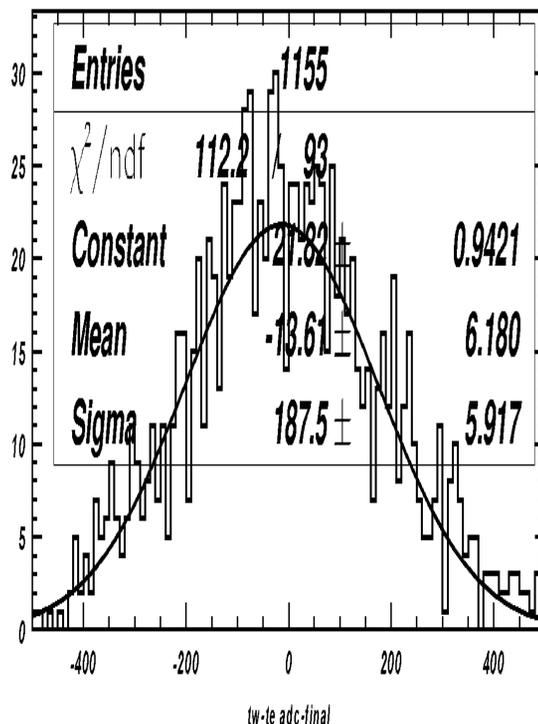
**pions**

**$104 \pm 11 \text{ ps}$**



**protons**

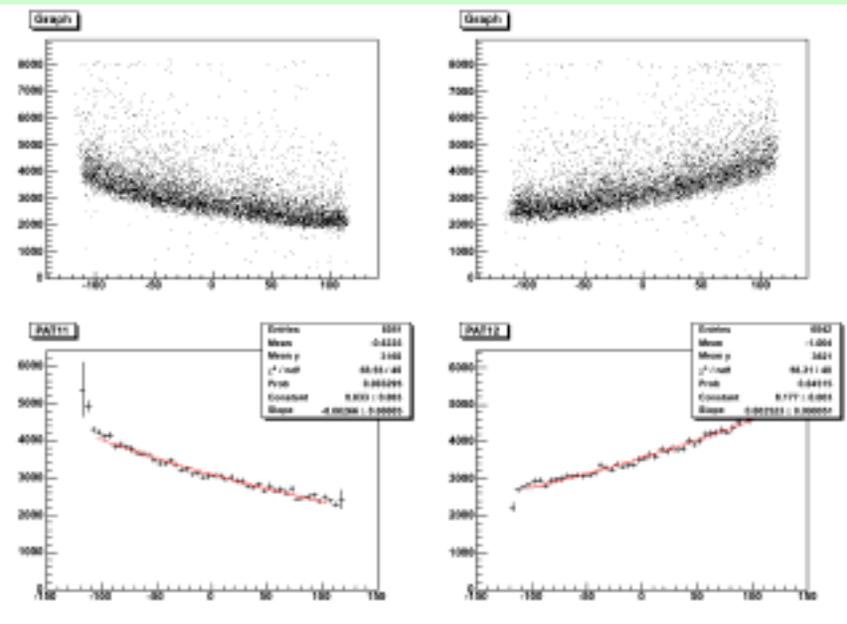
**$70 \pm 2 \text{ ps}$**



**electrons**

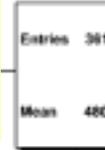
**$94 \pm 3 \text{ ps}$**

# Scintillator tests completed

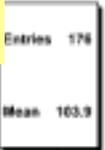


Attenuation length

Average: 4.8m



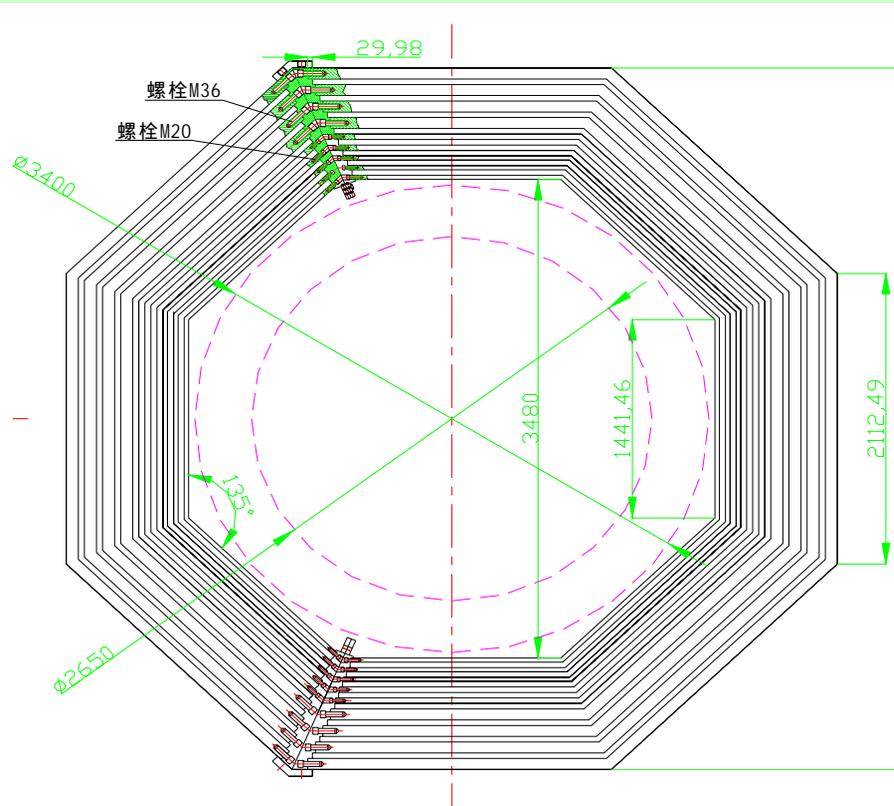
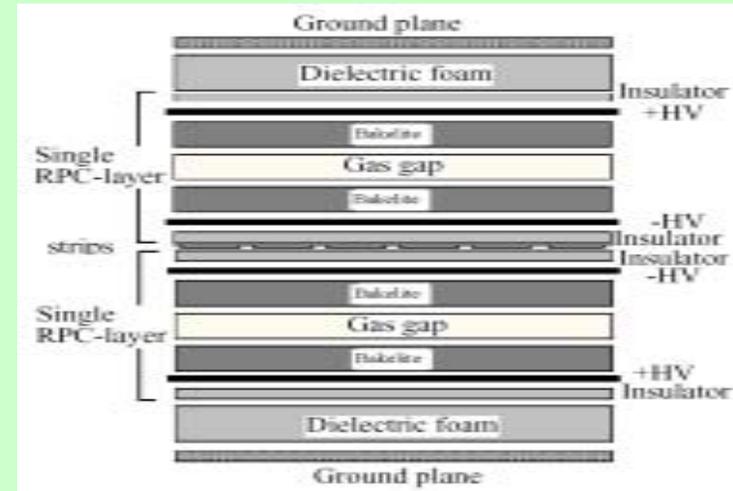
Relative light output



- PMT test completed at Tokyo University
- Preparation for installation completed
- Monitor system by Hawaii University completed

# $\mu$ system : RPC

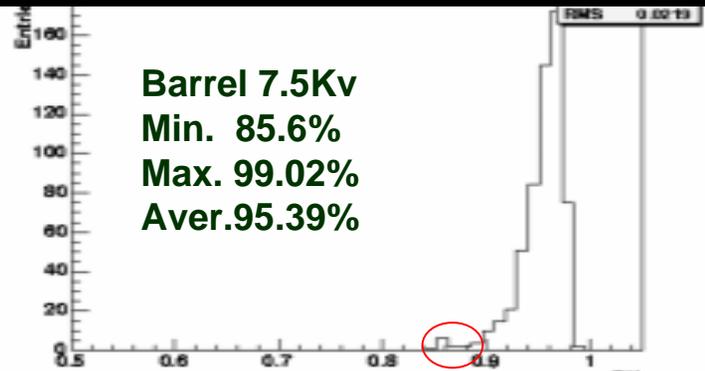
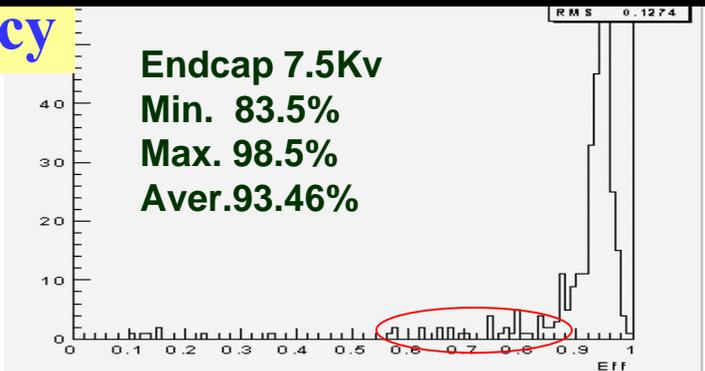
- 9 layer, 2000 m<sup>2</sup>
- Special bakelite plate w/o linseed oil
- 4cm strips, 10000 channels
- Noise less than 0.1 Hz/cm<sup>2</sup>



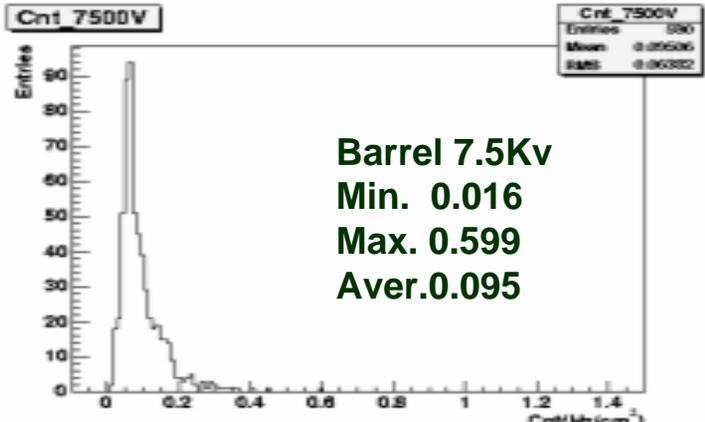
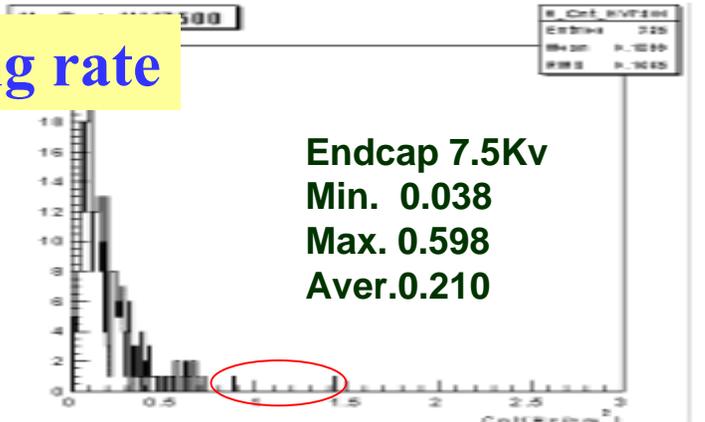
# Mass production ---- Bare chamber test

Training time : 1 - 3days; endcap 320RPCs, barrel 590RPCs

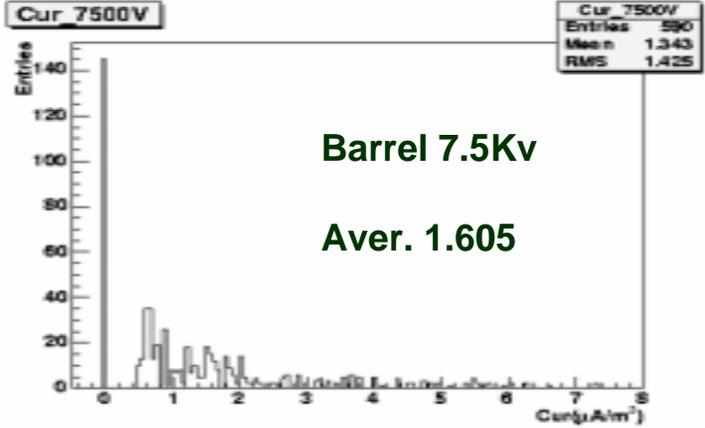
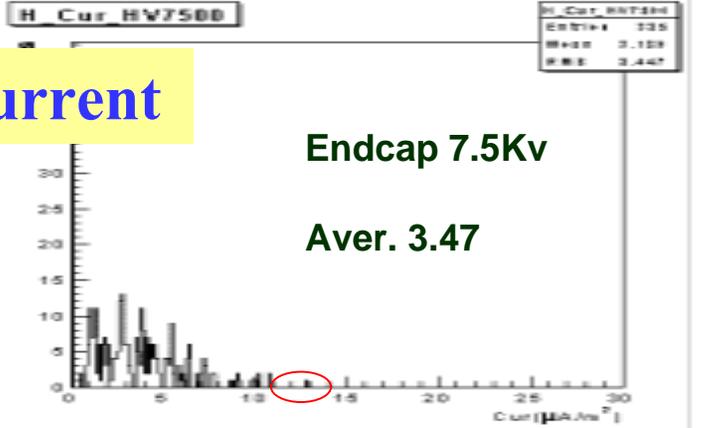
efficiency



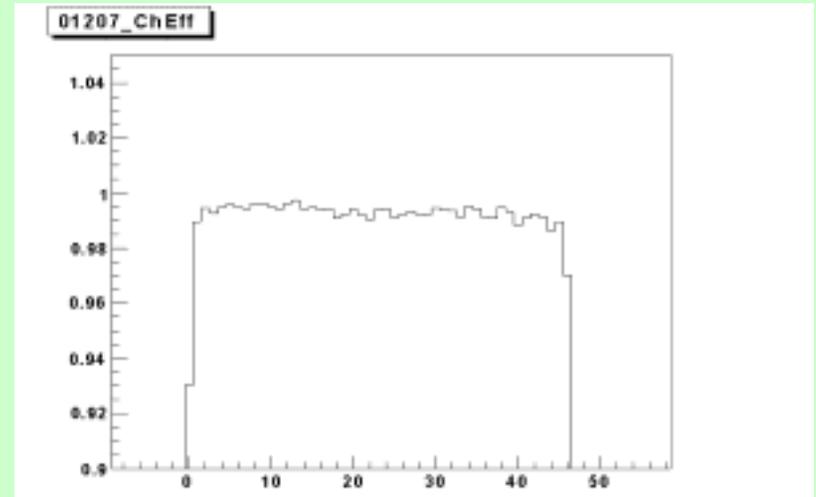
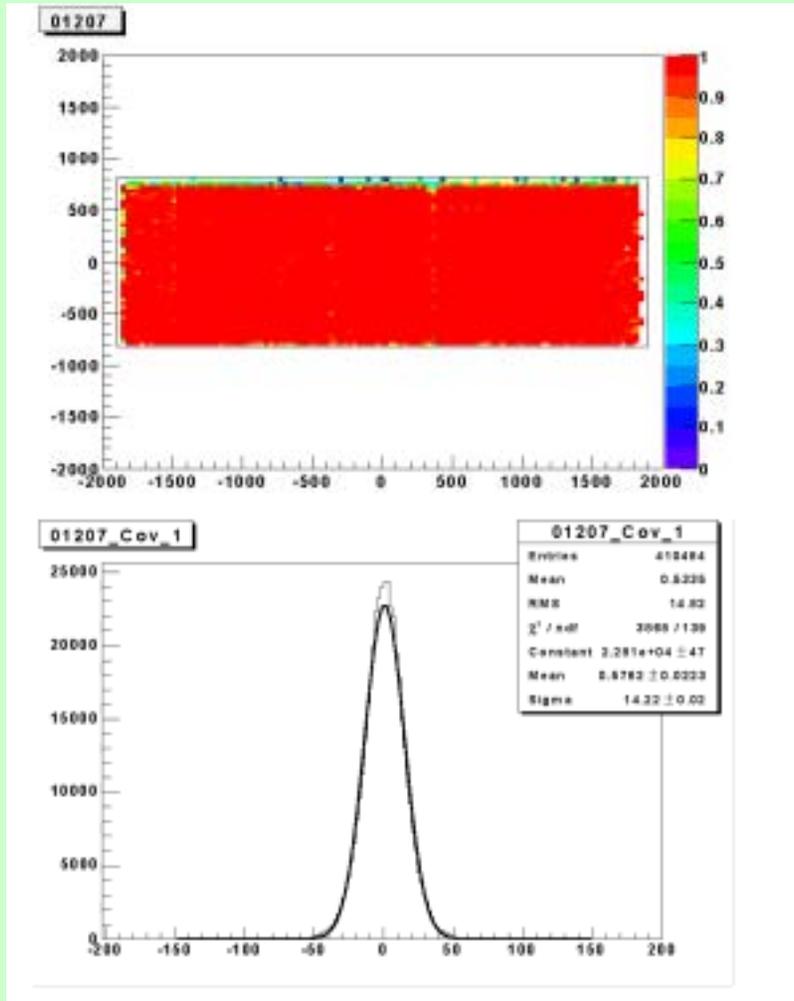
counting rate



Dark current

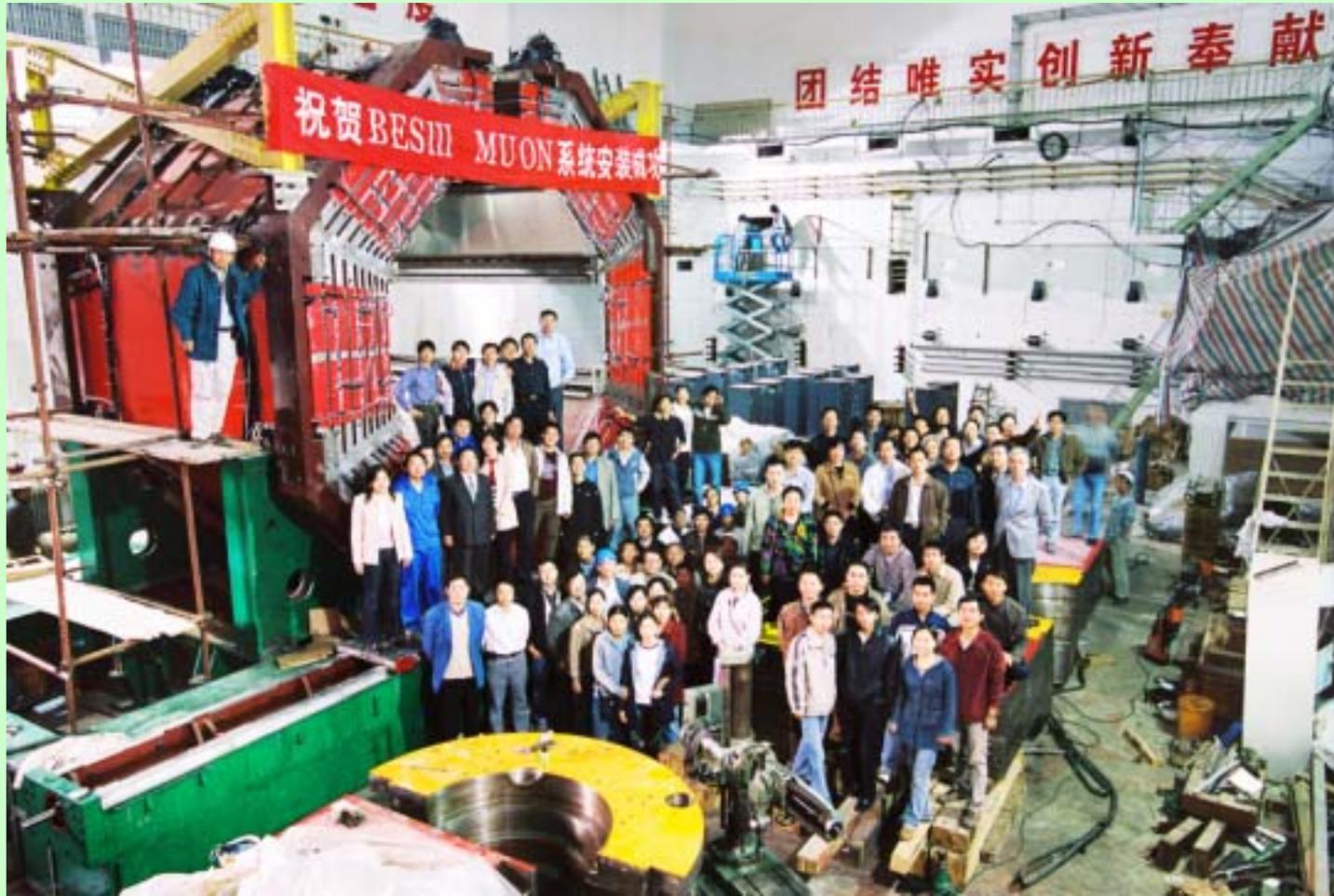


# Test results after installation



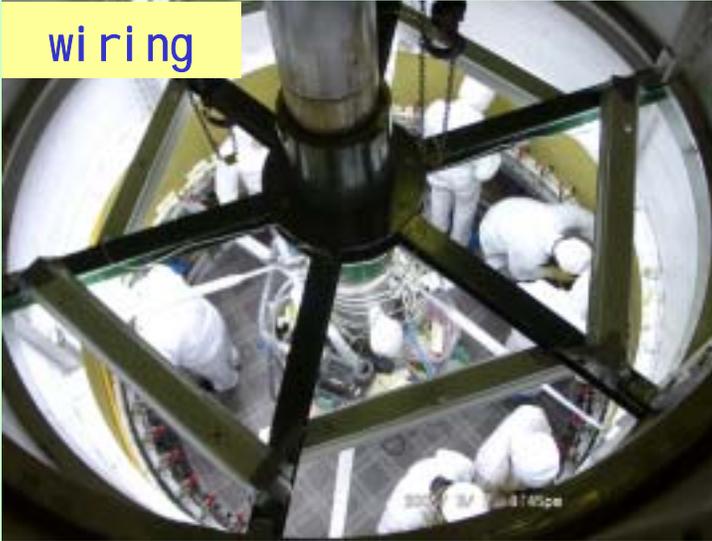
Module size:  
3800mm\*1640mm  
Strip length: 3800mm  
Strip width: 33mm  
Average strip efficiency: 0.99  
Spatial resolution: 14.2mm

# Muon chamber installation completed



# Super-conducting magnet: 1T@3400 A

wiring



Thermal insulation



assembly



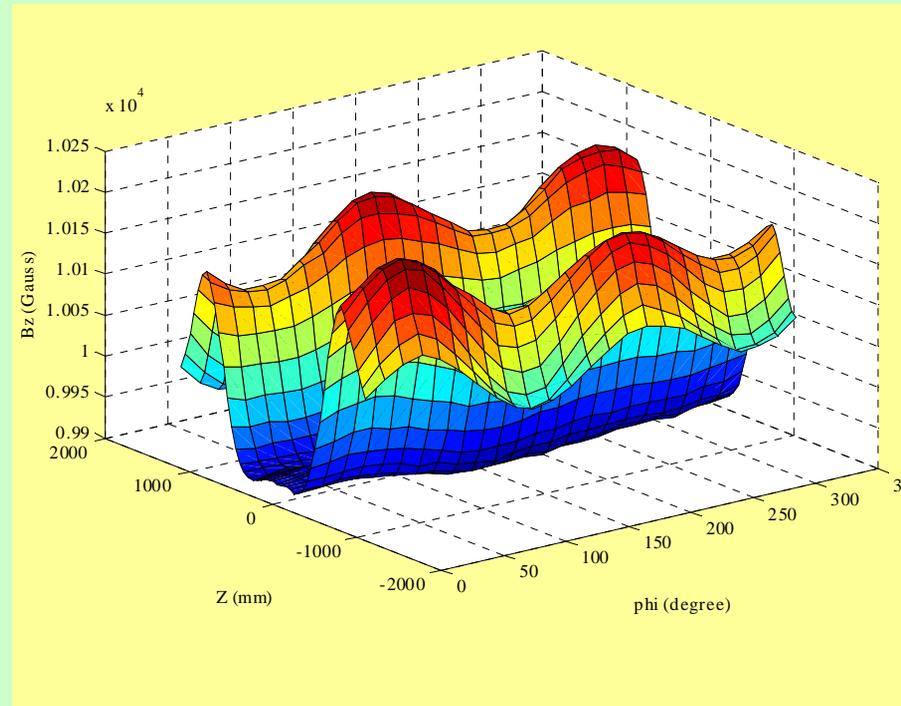
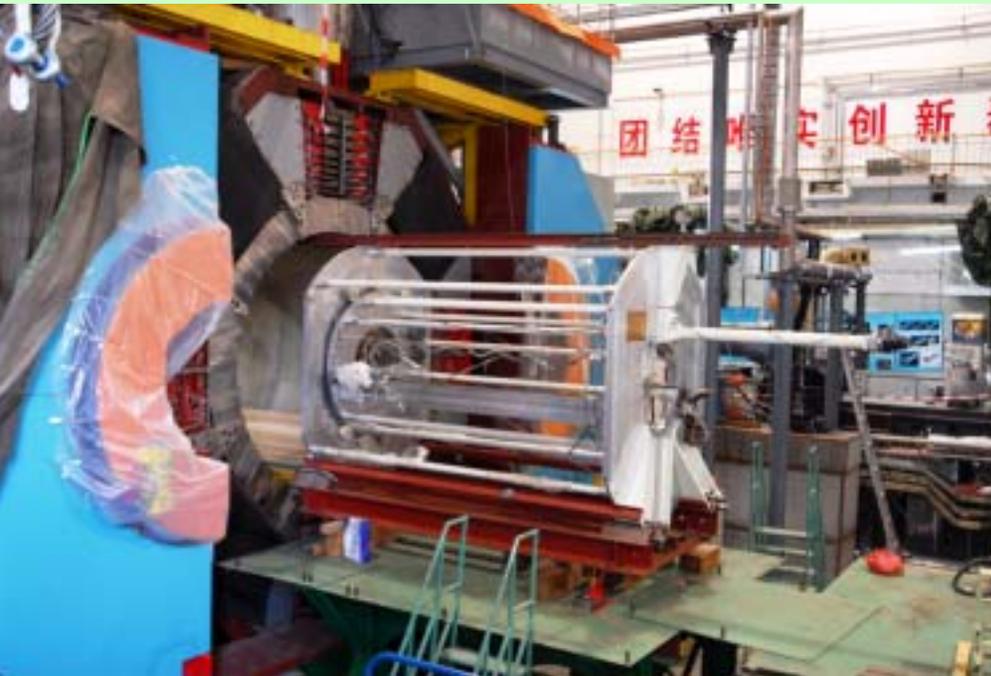
transportation



installation



The magnet reached super-conducting status and 1T magnetic field at 3364A. Field mapping with SCQ completed Aug., 07



# Electronics

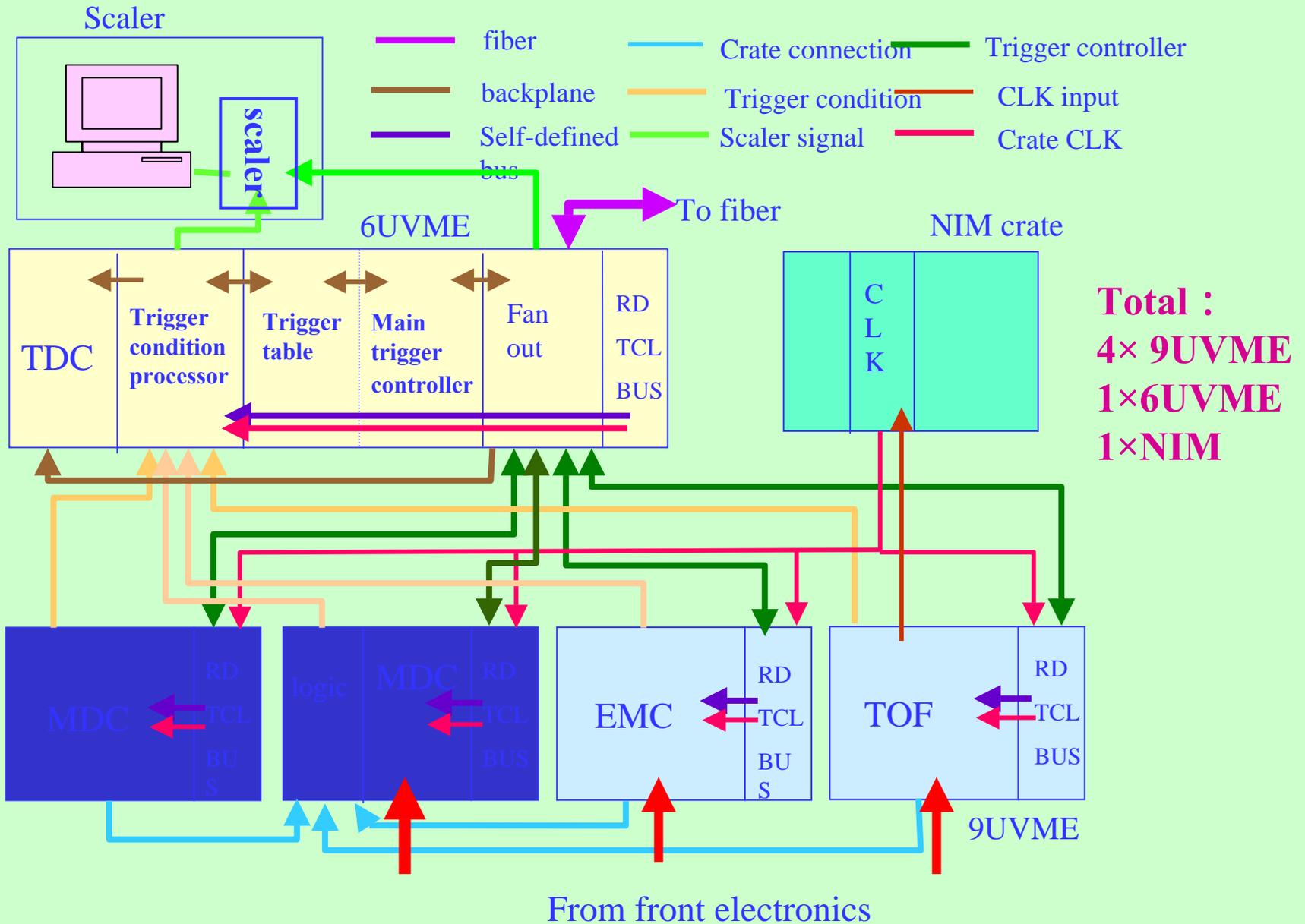
- Drift chamber : 6500ch ,  $s_t \sim 500\text{ps}$ ,  $s_q \sim 5\text{fc}$ , 10bit ADC
- calorimeter: 6300ch,  $s_q \sim 0.5\text{fc}$ ,  $3 \times 10\text{bit ADC}$ , noise  $< 1000\text{ENC}$
- TOF : 500ch ,  $s_t \sim 20\text{ps}$ , 10bit ADC
- RPC : 10000ch , bit map
- Prototype and beam test all meet the design spec.
- Mass production completed
- Some tested with full trigger/DAQ system

IHEP

USTC

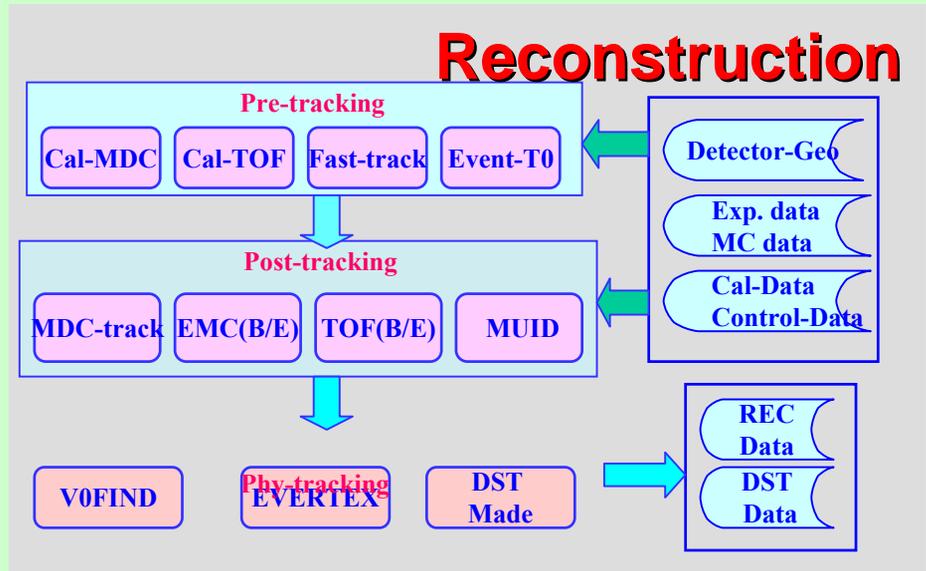
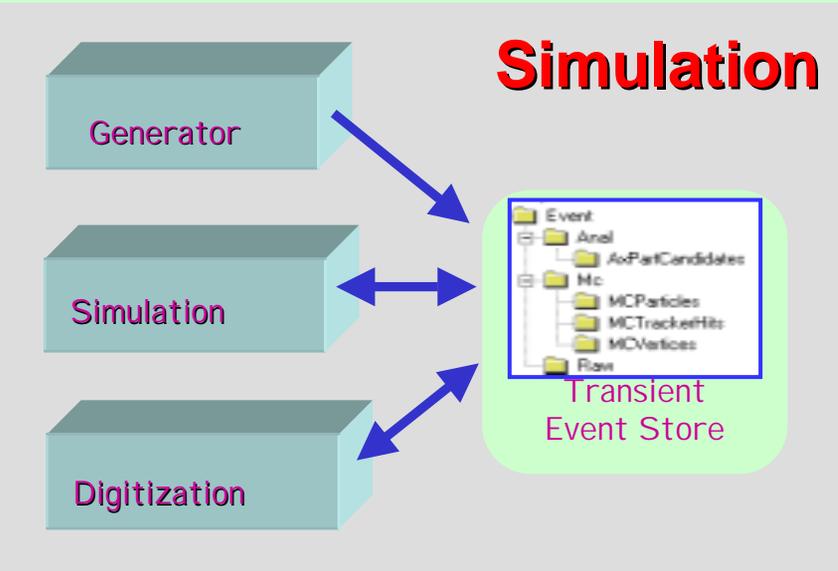
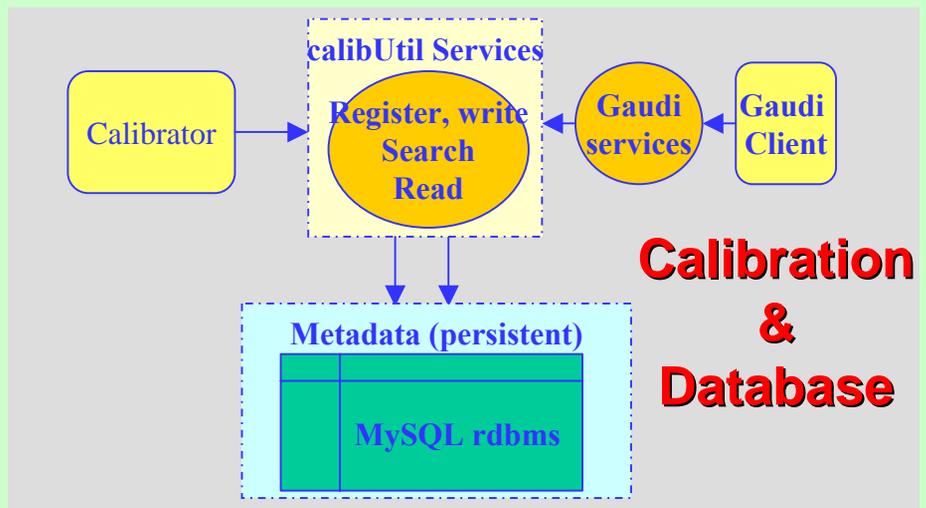
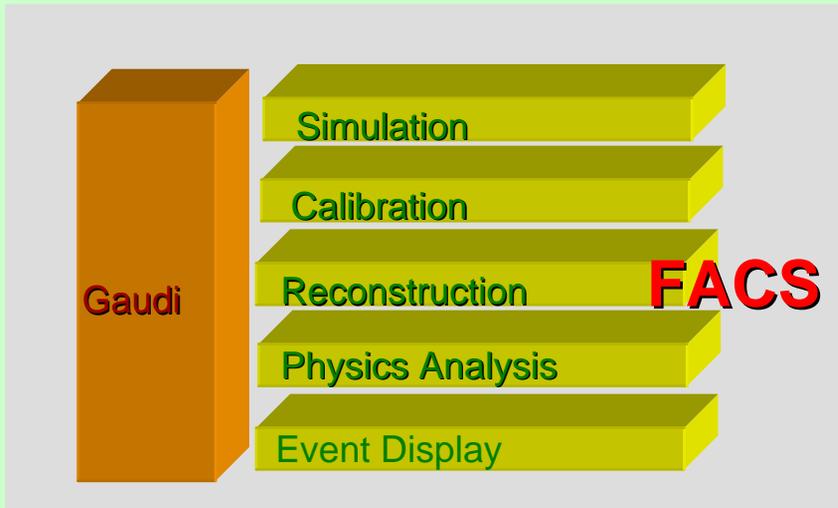


# Trigger system hardware structure



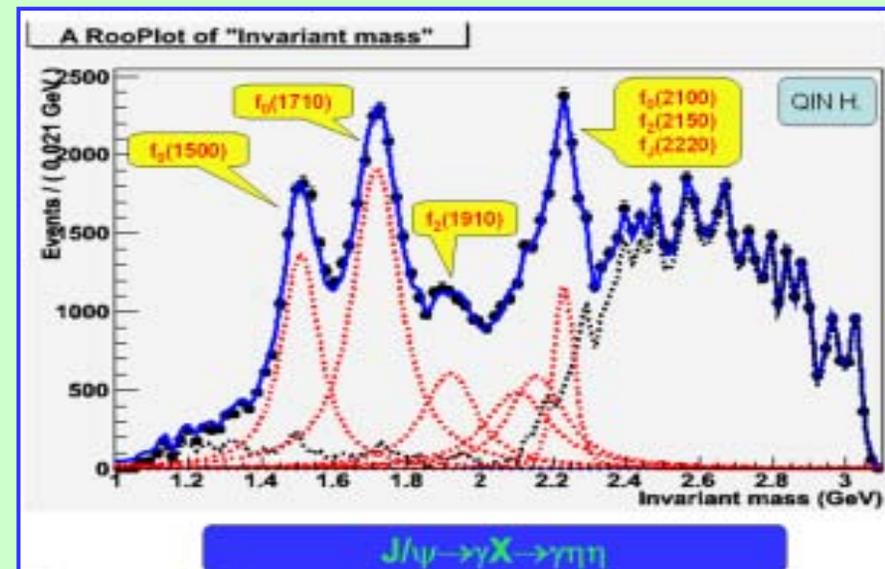
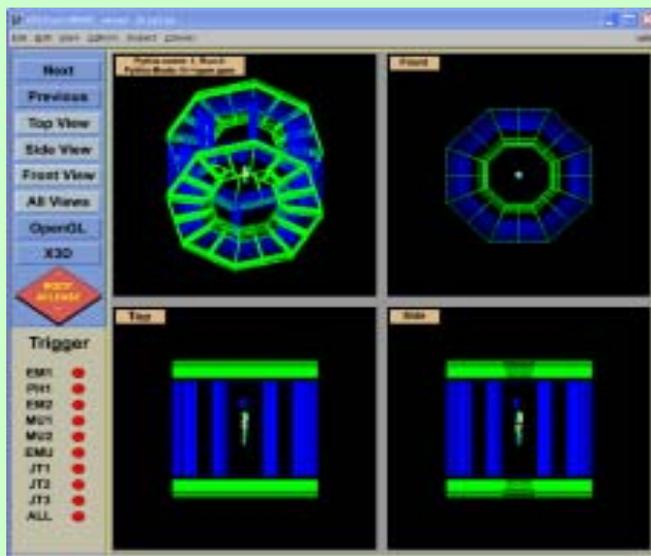


# Offline software system



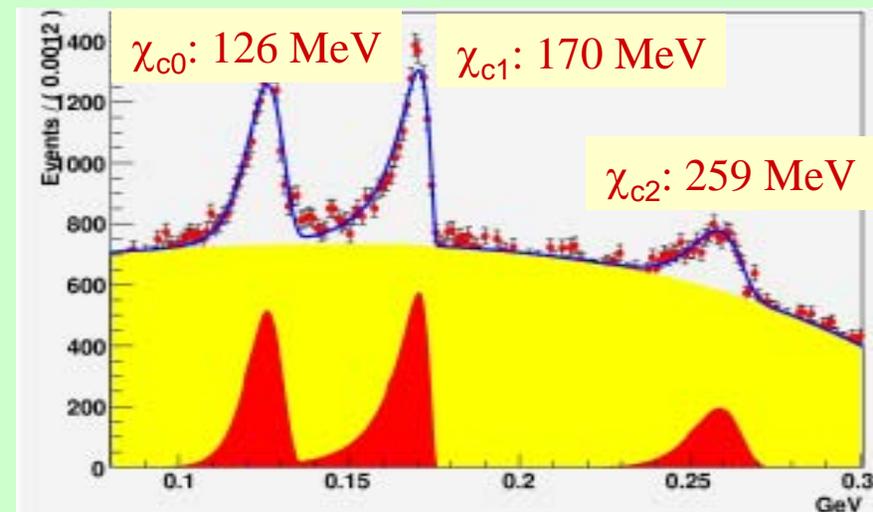
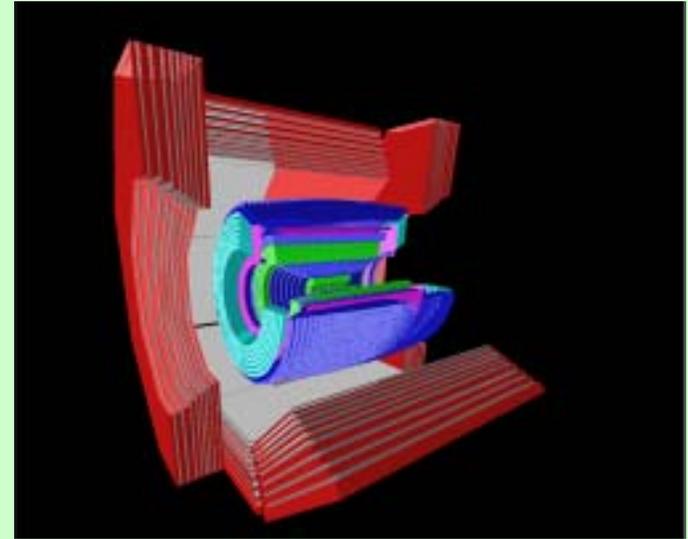
# Monte Carlo simulation

- GEANT4 based simulation framework completed
- Geometry, material and detector response completed
- Real detector response including 3D magnetic field, noise, trigger, bunch size etc completed
- All tested by reconstructed physics events
- Many generators, some are new for tau-charm physics
- Stable operation, large data sample generated



# Event reconstruction and calibration

- Gaudi based framework completed
- Sub-detector reconstruction and calibration almost completed:
  - Kalman-filter based track fitting
  - Basic calibration algorithm established
  - No-bias Event reconstruction
  - Resolution in agreement with specification
  - Timing zero can be reconstructed
  - Secondary vertex can be reconstructed
  - Online event filter
  - Stable operation for physics studies



Inclusive  $\gamma$  spectrum in  $\psi(2S)$  decays

# Schedule

- **2/2003: Official approval of the project**
- **7/2004: BESII detector shutdown**
- **5/2005: Magnet yoke & muon chamber installation**
- **9/2006: Super-conducting magnet cool down**
- **8/2007: Magnetic field mapping finished**
- **10/2007: EMC installation done**
- **10/2007: MDC/TOF installation starts**
- **1/2008: Cosmic-ray tests**
- **3/2008: BESIII detector in beam line**
- **Summer of 08: Start data taking (test run)**



**Barrel EMC installed in the yoke**

**Now mounting barrel TOF to  
MDC, assembling endcap EMC**



# BESIII collaboration

Political Map of the World, June 1999



# Summary

- **BEPCII/BESIII construction is close to the completion**
- **BESIII assembly and installation will be finished this year, physics run will start next summer**
- **Physics and software preparation underway**
- **We are excited about the great physics opportunities of BESIII and welcome new collaborators**

Thanks

# Precision measurement of CKM

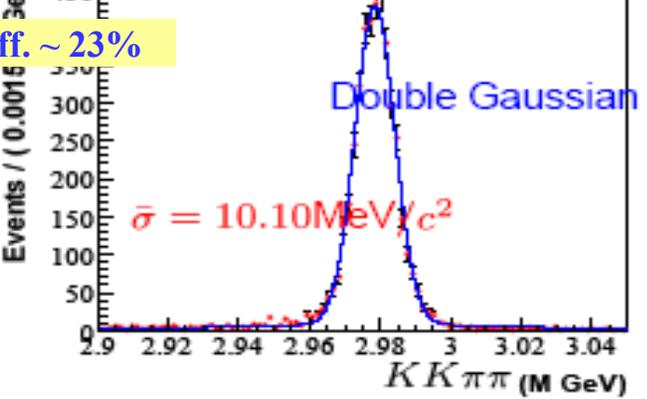
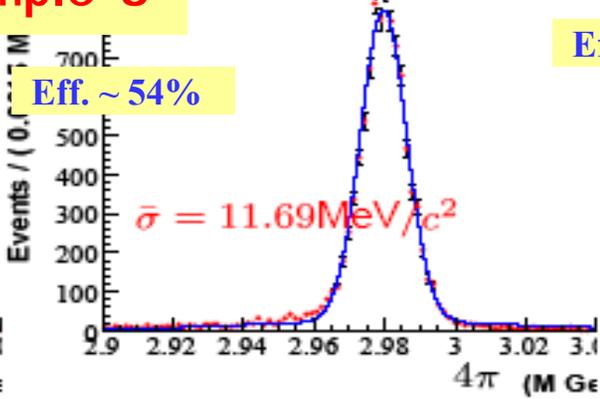
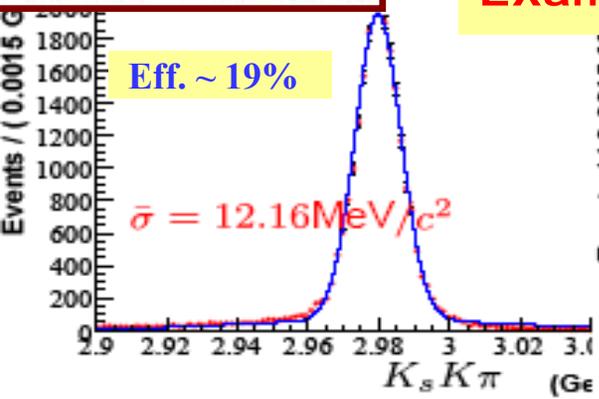
## ---- Branching ratios of charm mesons

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

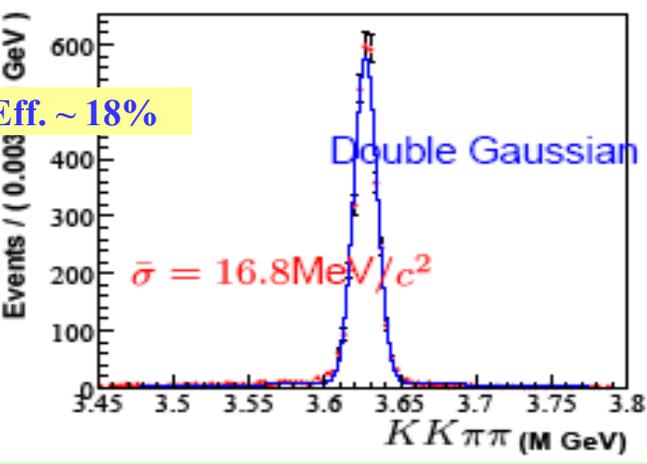
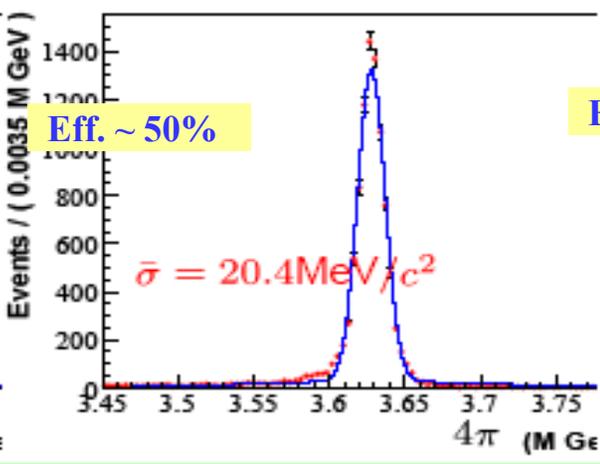
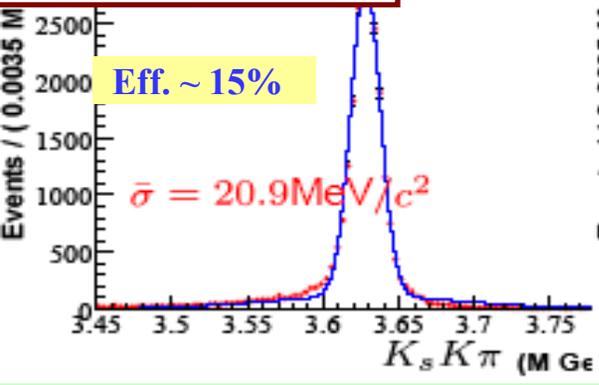
	Current	BESIII
$V_{ub}$	25%	5%
$V_{cd}$	7%	1%
$V_{cs}$	16%	1%
$V_{cb}$	5%	3%
$V_{td}$	36%	5%
$V_{ts}$	39%	5%

$\psi(2S) \rightarrow \gamma\eta_c(1S)$

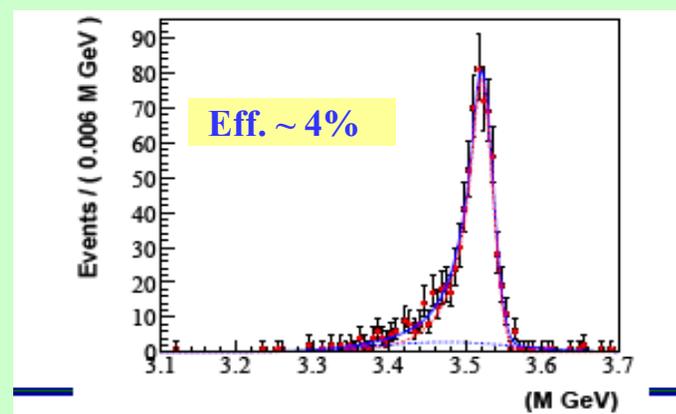
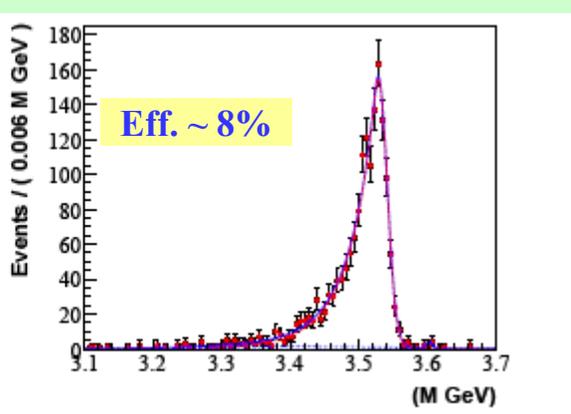
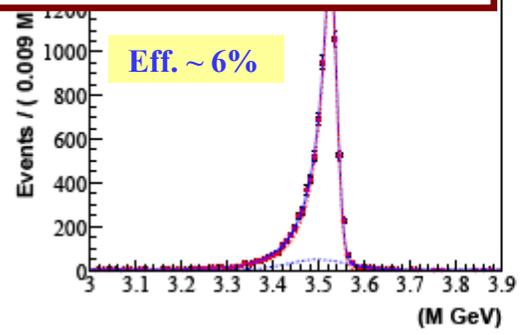
**Example 3**



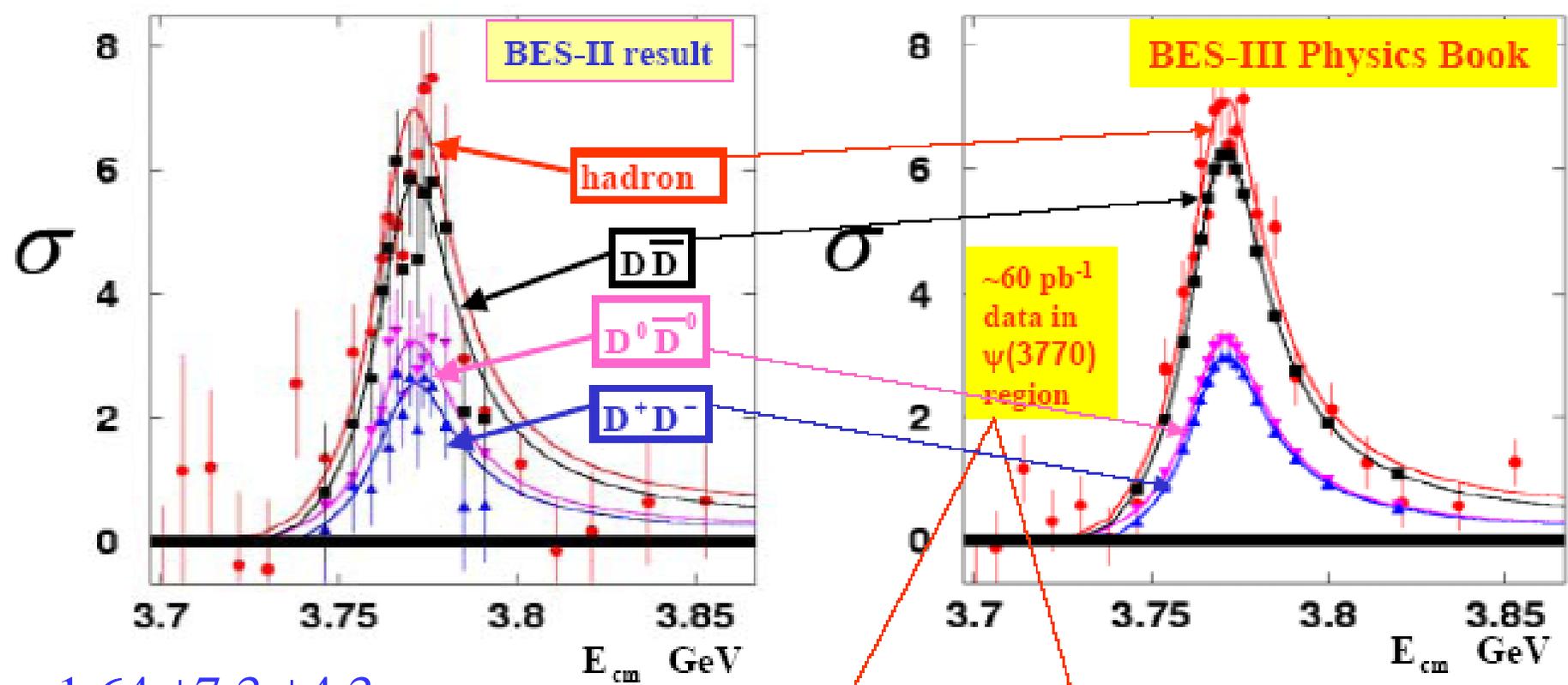
$\psi(2S) \rightarrow \gamma\eta_c(2S)$



$\psi(2S) \rightarrow \pi^0 h_c, h_c \rightarrow \gamma\eta_c(1S)$



# Scan of $\psi(3770)$ peak



$1.64 \pm 7.3 \pm 4.3$

$\Gamma_{\psi(3770)}^{tot}$	$26.8 \pm 0.5$ MeV	26.9 MeV
$\Gamma_{\psi(3770)}^{ee}$	$256 \pm 9$ eV	251 eV
	Measured value	Input value

$B[\psi(3770) \rightarrow D\bar{D}]$	(88.2 $\pm$ 2.4 $\pm$ ~ 2.0) %	Measured value
	89 %	Input value