A high luminosity experiment at tau-charm region

--- BEPCII/BESIII upgrade program

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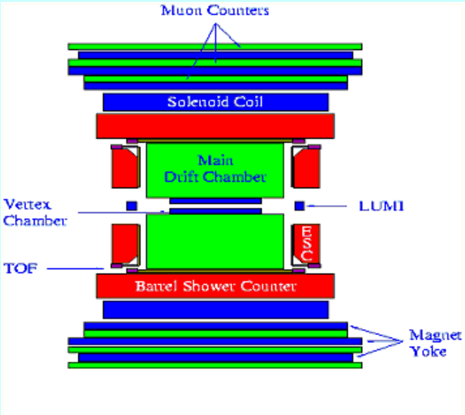
Beijing e^+e^- collider(**BEPC) consists of Linac**, Storage Ring, Spectrometer(BES) and Synchrotron Radiation Facility (**BSRF**)
It started construction in 1984 and completed in 1988

Beam Energy: 1 – 2.8 GeV Luminosity： $10^{31}cm^{-2}s^{-1}$ @ 1.89 GeV

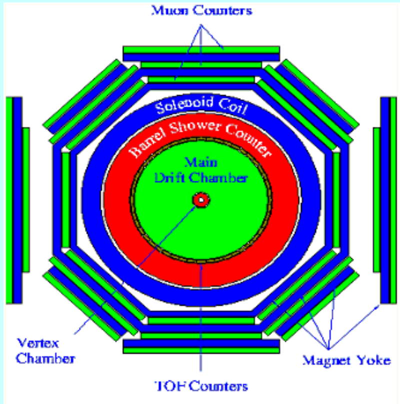
Collider physics：5 months；SR：3 months；machine study：2 months

The BES Collaboration

BESII Detector (1995-1997 upgrade)



Side view of the BES detector



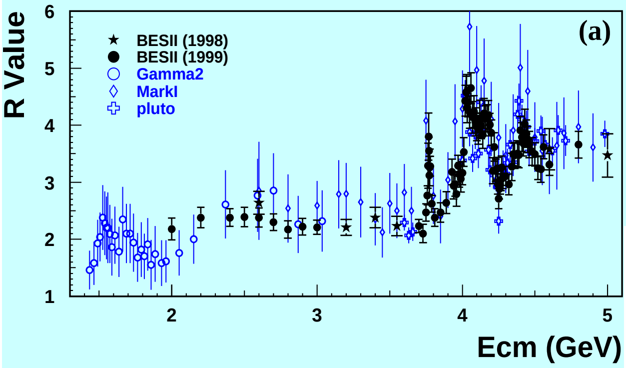
End view of the BES detector

VC: σ_{xy} = 100 μm
MDC: σ_{xy} = 200 μm
$\sigma_{dE/dx}$ = 8.4 %
$\Delta p/p = 1.8\sqrt{(1+p^2)}$

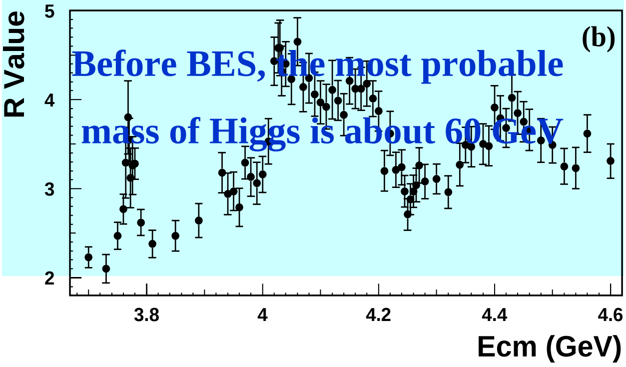
TOF: σ_T = 180 ps
BSC: $\Delta E/\sqrt{E}$ = 22 %
σ_ϕ = 7.9 mr
σ_z = 2.3 cm

μ counter: $\sigma_{r\phi}$ = 3 cm
σ_z = 5.5 cm
B field: 0.4 T
Dead time/event: 10 ms

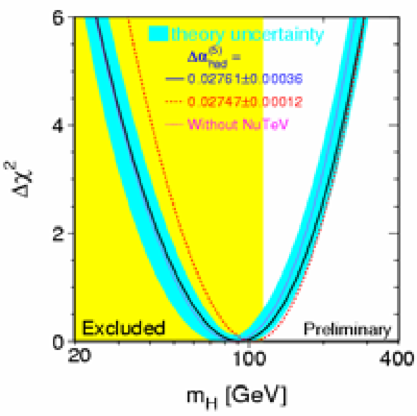
Main results: R value measurement



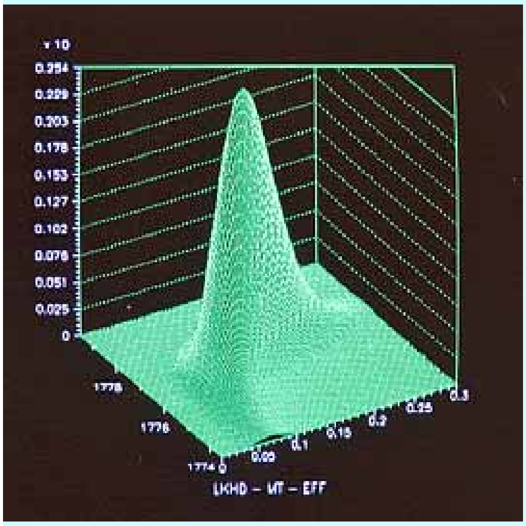
$$R = \frac{\sigma(e^+e^- \to \text{hadrons})}{\sigma(e^+e^- \to \mu^+\mu^-)}$$



Before BES, the most probable mass of Higgs is about 60 GeV



Tau mass measurement



BES results reduced the error by a factor 8, and shifted the central value by 3σ, improved lepton universality(2.4σ→1.5σ)

$m_\tau = 1776.9\,^{+0.4}_{-0.5} \pm 0.2$ MeV

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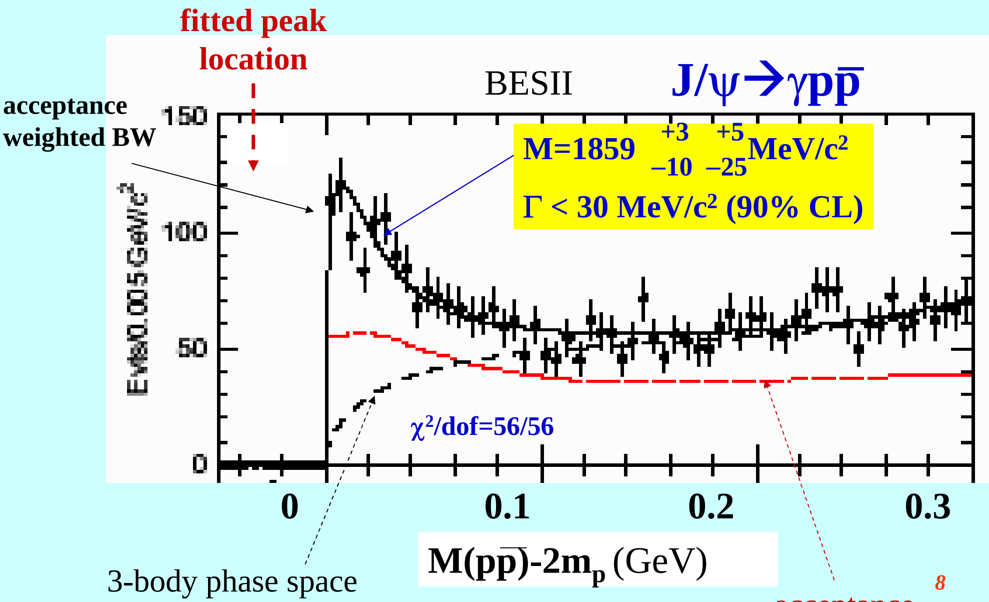
An enhancement near $p\bar{p}$ threshold



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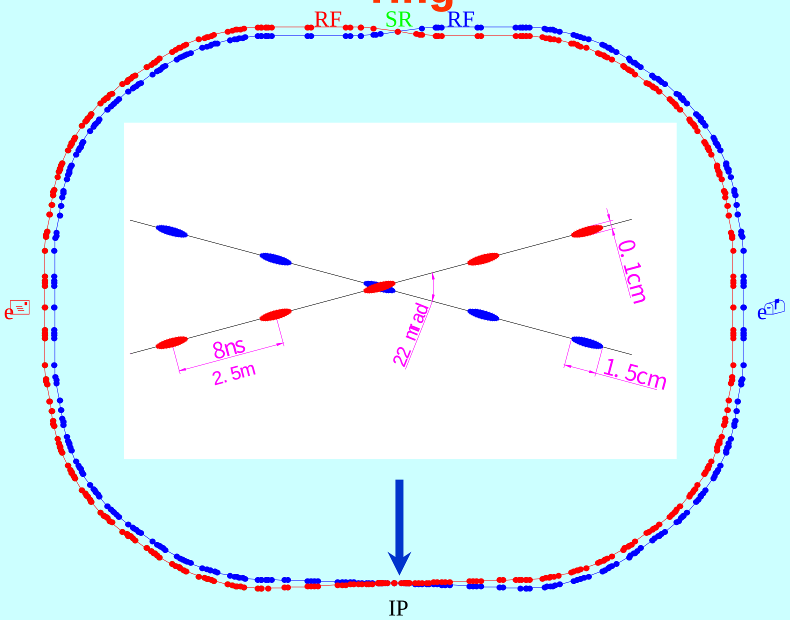
The need for upgrade

- Interesting physics limited by statistics:
  glueball/hybrid searches, CKM matrix elements DDbar mixing, $\rho\pi$ puzzle, non-pQCD…
- Systematic error is also large due to poor resolution
- Detector is aging
- Multi-bunch mode

On Feb. 10, 2003, the chinese government, the state council, approved officially the BEPCII/BESIII upgrade project

BEPC II Storage ring: Large angle, double-ring



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Double ring installation – Wood model

No spacing problems

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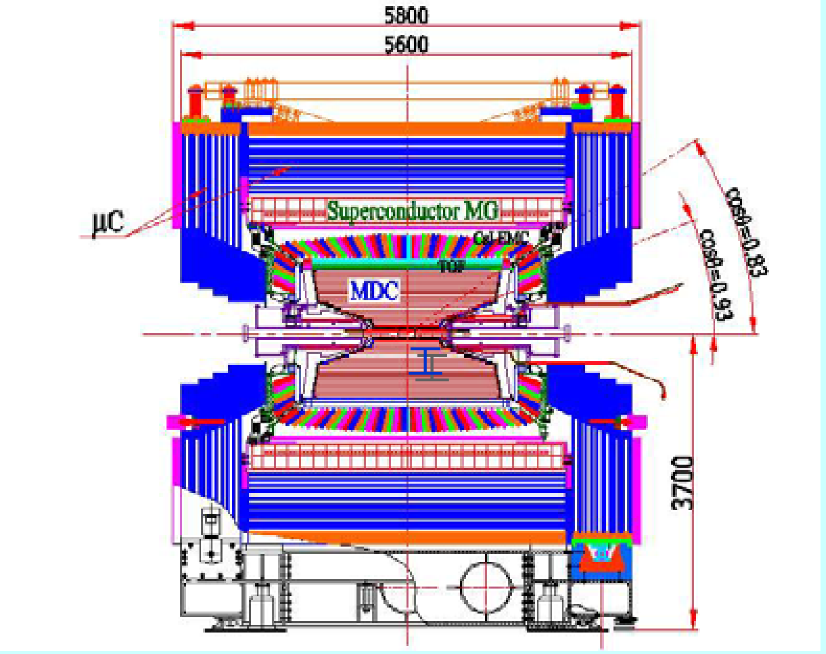
BEPCII Design goal

Energy range	1 – 2 GeV
Optimum energy	1.89 GeV
Luminosity	1×10^{33} $cm^{-2}s^{-1}$ @ 1.89 GeV
Injection	Full energy injection: 1.55 – 1.89 GeV Positron injection speed > 50 mA/min
Synchrotron mode	250 mA @ 2.5 GeV

BEPCII main parameters

Energy E(GeV)	1.89	Energy spread(10^{-4}) σ_e	5.16
Circumference C(m)	237.53	Emittance $\varepsilon_x/\varepsilon_y$(nm)	144/2.2
Harmonic number h	396	Momentum compact α_p	0.0235
RF frequency f_{rf}(MHz)	499.8	β^*_x/β^*_y(m)	1/0.015
RF Voltage V_{rf}(MV)	1.5	Tunes $\nu_x/\nu_y/\nu_z$	6.57/7.6/0.034
Energy loss/turn U_0(keV)	121	Chromaticities ν'_x/ν'_y	-11.9/-25.4
Damping time $\tau_x/\tau_y/\tau_z$(ms)	25/25/12.5	Natural bunch length σ_{z0}(cm)	1.3
Total current/beam I(A)	0.91	Crossing angle ϕ(mrad)	±11
SR Power P(kW)	110	Piwinski angle Φ(rad)	0.435
Bunch number N_b	93	Bunch spacing S_b(m)	2.4
Bunch current I_b(mA)	9.8	Beam-beam parameter ξ_x/ξ_y	0.04/0.04
Particle number N_t	4.5×10^{12}	Luminosity($10^{33}cm^{-2}s^{-1}$) L_0	1.0



The BESIII Detector

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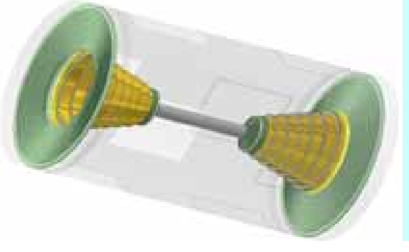
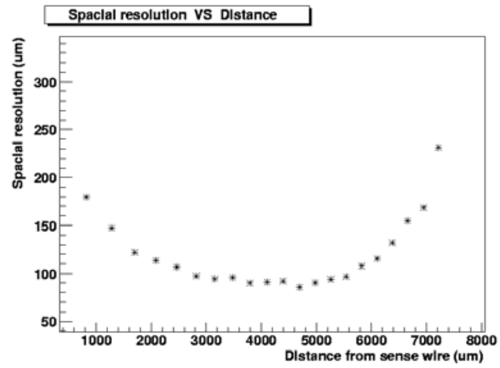
Main drift chamber

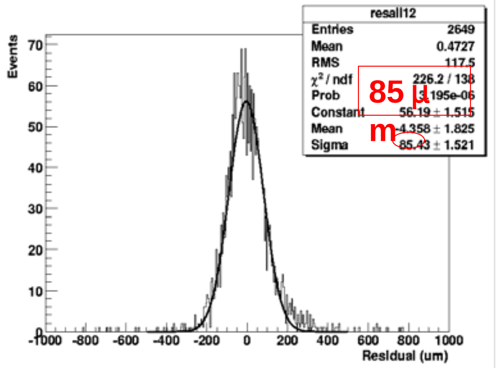
- **Inner diameter: 63mm; Outer diameter: 810mm; length: 2400 mm**
- **Inner cylinder: 1 mm Carbon fiber, outer cylinder: 10 mm CF with 8 windows**
- **End flange: 18 mm thick Al 7075 (6 steps)**
- **7000 Signal wires : 25(3% Rhenium) μm gold-plated tungsten**
- **22000 Field wires: 110 μm gold-plated Aluminum**
- **Small cell: inner---6*6 mm2, outer--- 8.2 *8.2 mm2,**
- **Gas: He + C_3H_8 (60/40)**
- **Momentum resolution@1GeV:**

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

- **dE/dX resolution: 6-7%.**

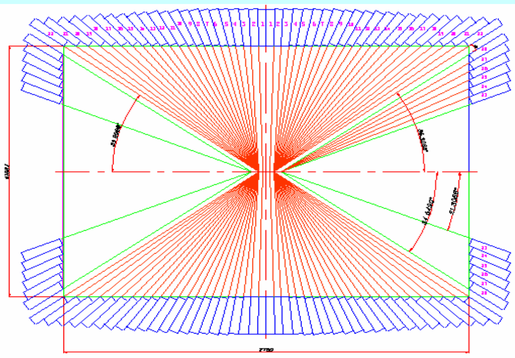


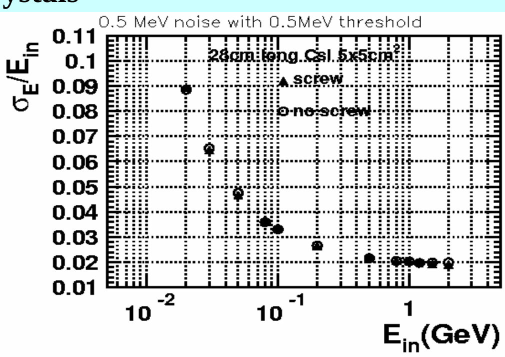




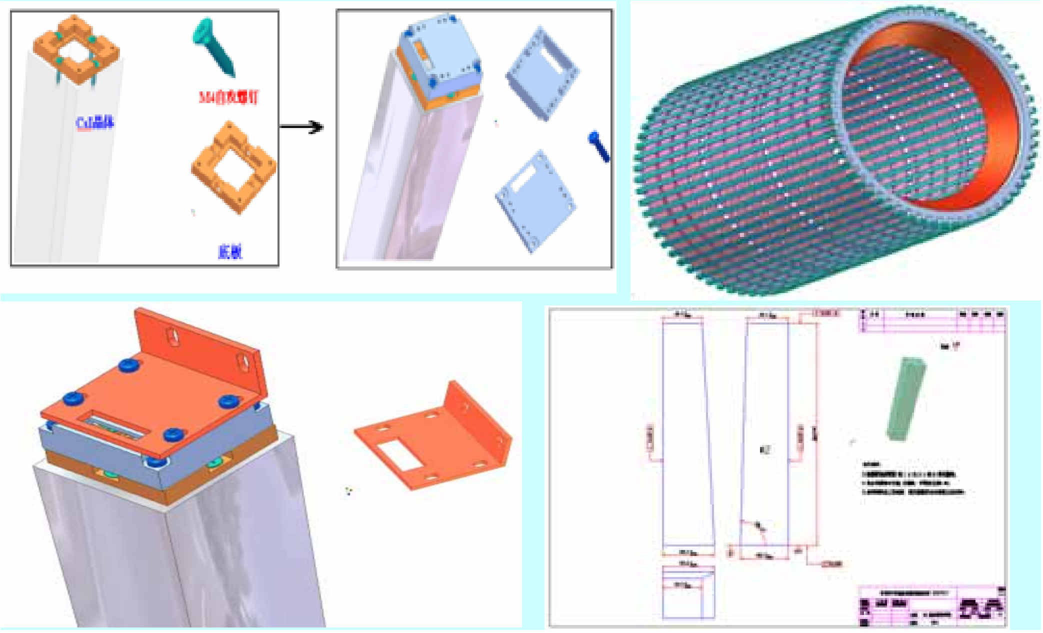
EMC: CsI(Tl) crystals

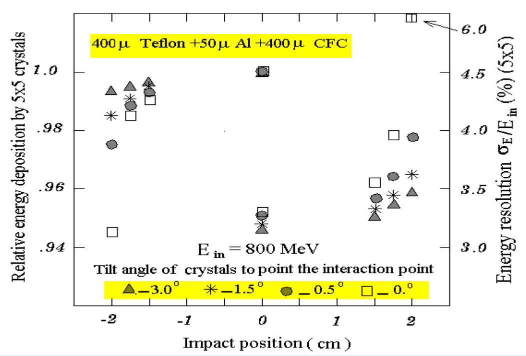
- 6300 crystals, (5.2x 5.2 – 6.4 x 6.4) x 28cm^3
- PD readout, noise ~1100 ENC
- Energy resolution: 2.5%@1GeV
- Position resolution: 5mm@1GeV
- Tiled angle: theta ~ 1-3^o, phi ~ 1.5^o
- Minimum materials between crystals

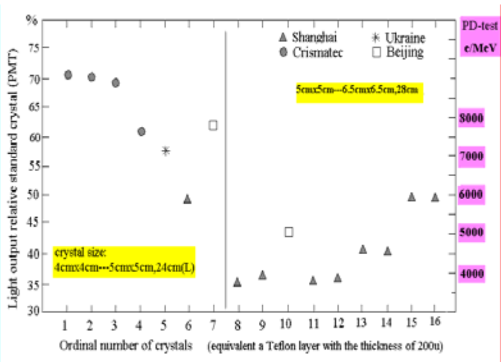


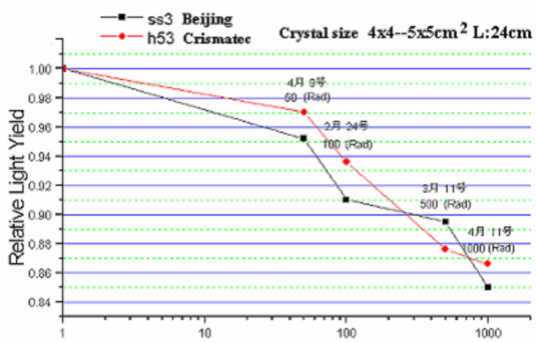


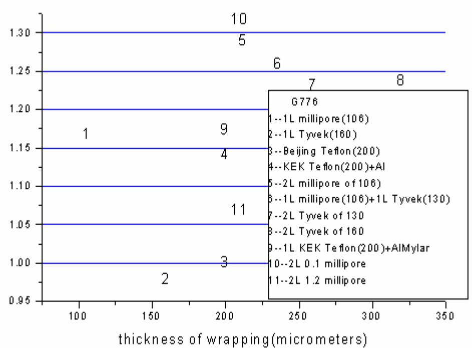
no partition wall Mechanical support structure





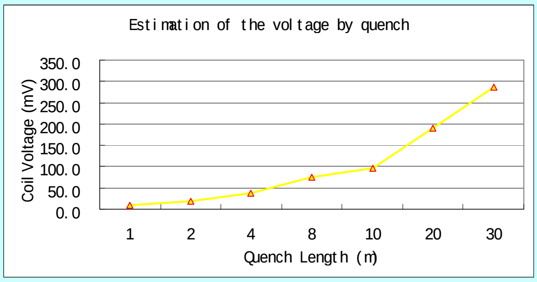


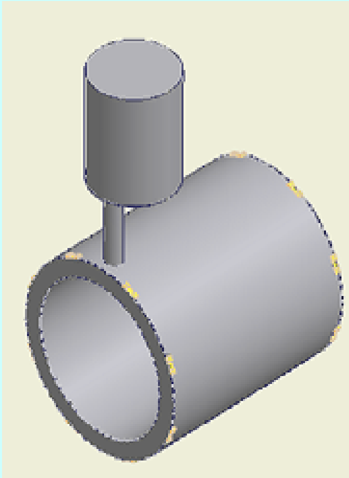




Super-conducting magnet

- Al stabilized NbTi/Cu conductor from Hitachi
- 1.0 T, <5% non-uniformity
- 921 turns, 3150A @4.5K
- R = 1.475 m, L=3.52m, cold mass 3.6t
- Thickness: 1.92 X_0
- Inner-winding method





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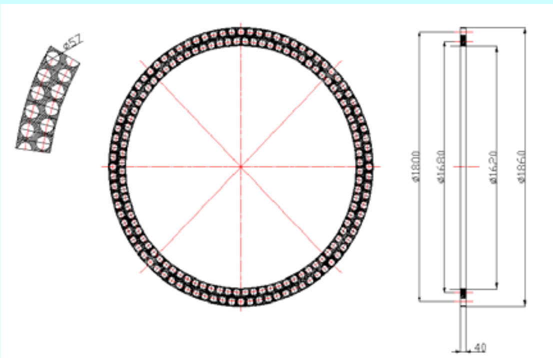
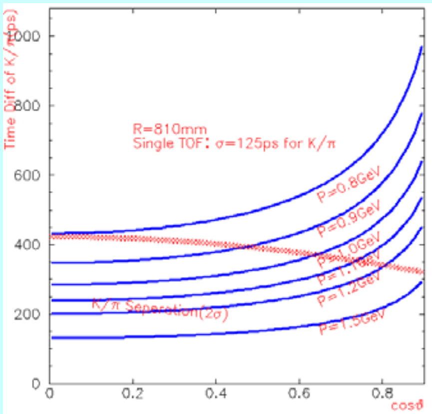
Particle ID: TOF system

- 392 pieces BC408, 2.4 m long, 5cm thick
- Time resolution 100-110 ps/layer
- PMT: Hamamatzu R5942





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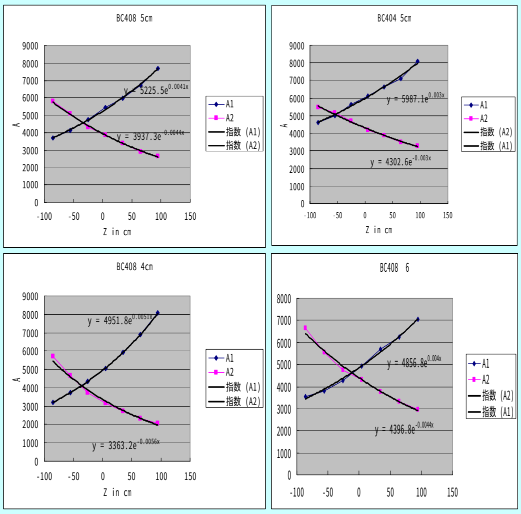
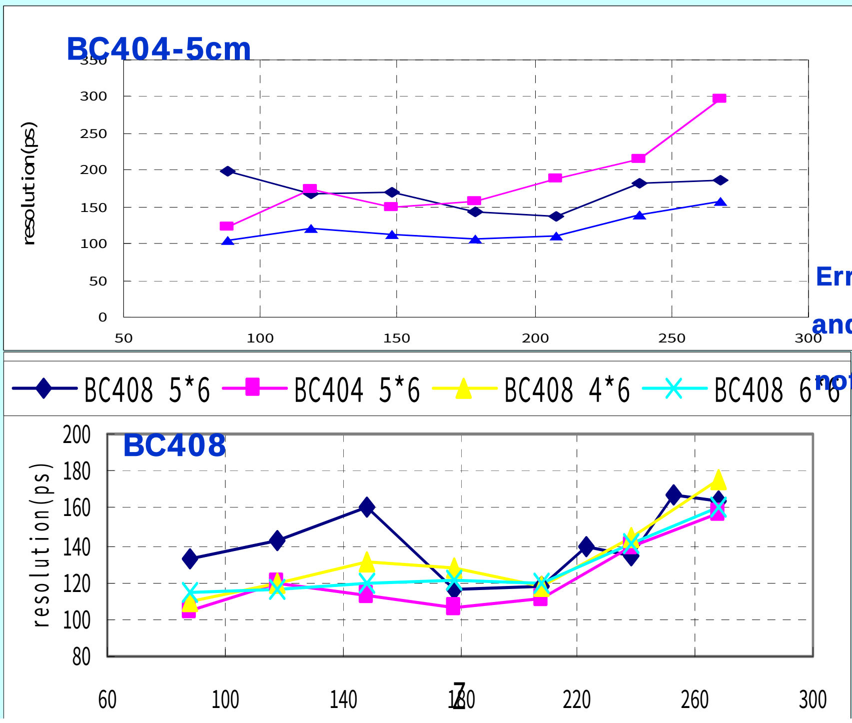
Test beam results

Eff. Atten. Length(cm)：

	East	West
BC404-5cm	333.3	333.3
BC408-5cm	243.9	227.2
BC408-4cm	196.1	178.5
BC408-6cm	250	227.3

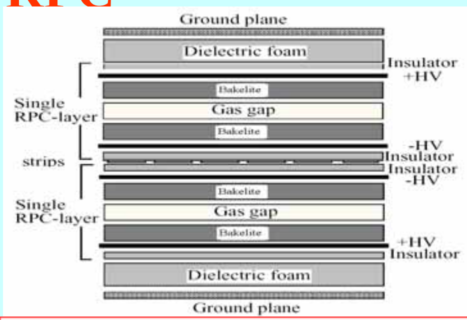


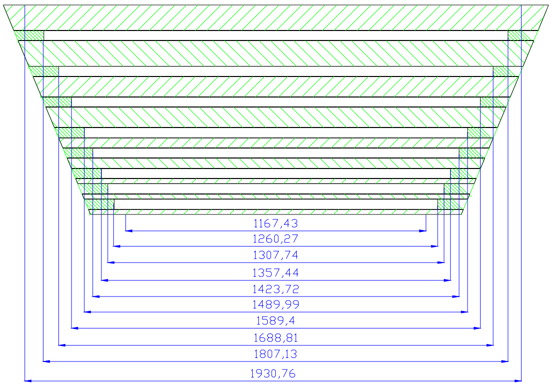


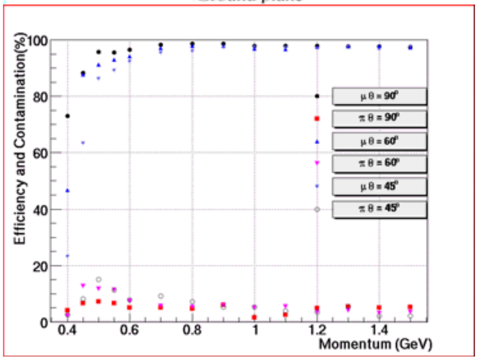
Errors from T0 and electronics not subtracted

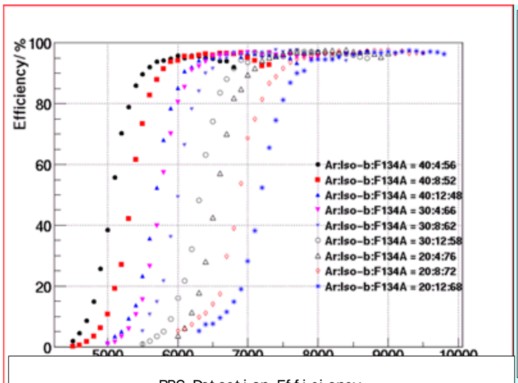
μ system : RPC

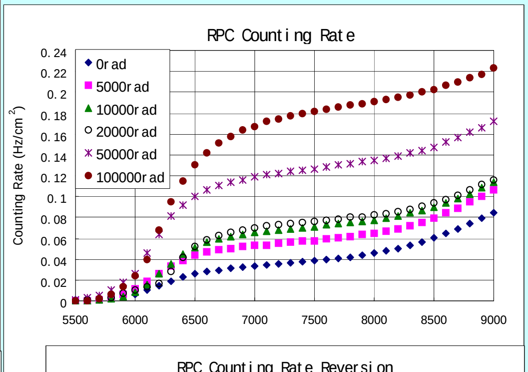
- 9 layer, 2000 m^2
- Bakelites and glass, no lineseed oil
- 4cm strips, 10000 channels
- Tens of prototypes (up to 1*0.6 m^2)
- Noise less than 0.2 Hz/cm^2

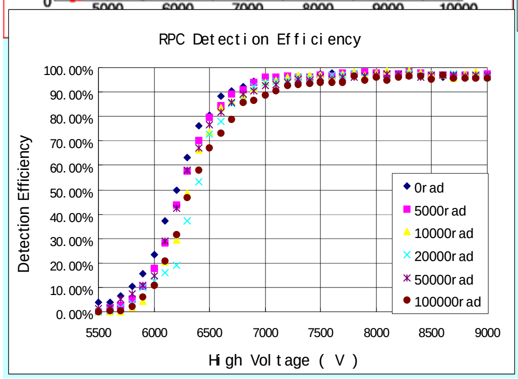


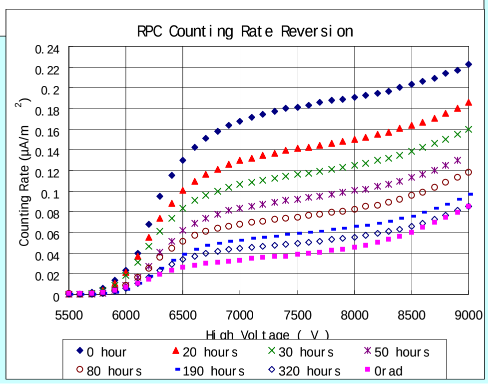












Other systems

- Electronics design have been almost finished, several prototypes have been successfully tested
- Trigger system largely based on FPGA technology have been designed, prototypes underway
- DAQ system based on VME/PowerPC and PC farm have been designed, mini-version setup, software underway
- Offline computing environment based on a large scale PC farm is under study
- MC based on GEANT4, first reconstruction framework released, sub-detector reconstruction code underway

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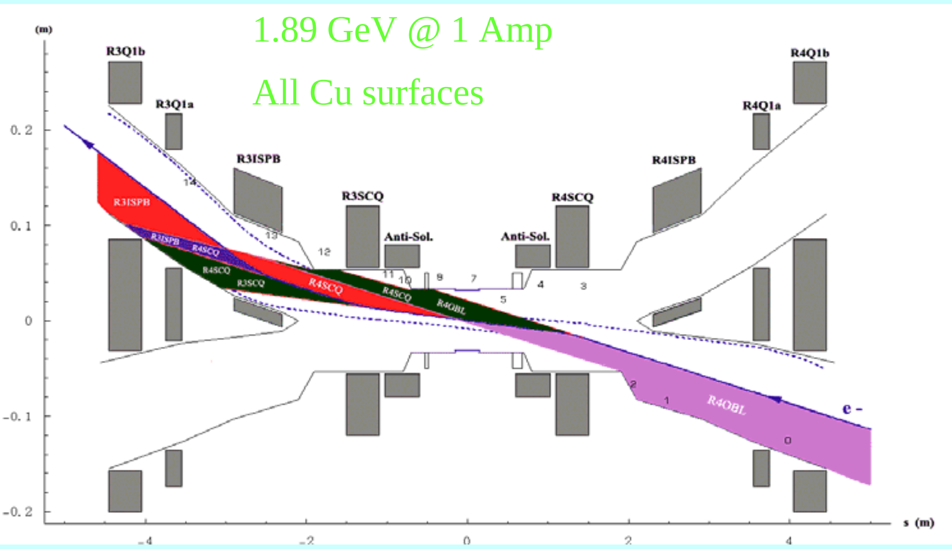
Beam background: a serious issue



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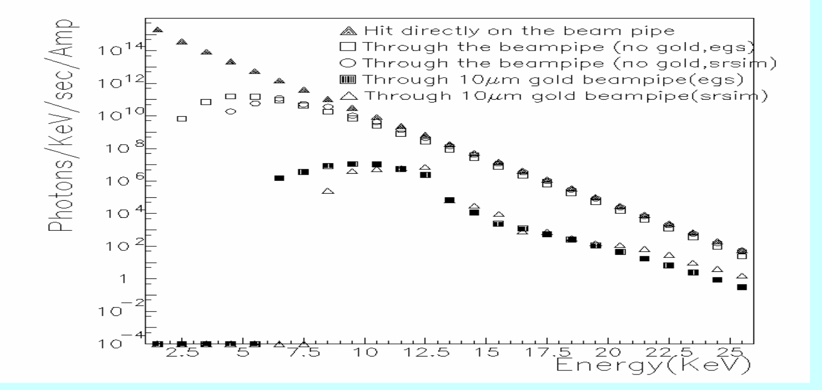
Direct SR photons on Be pipe/LUMI/MDC elec.



- **Normal case on Be pipe: 1.6 W, worst case 20 W**
- **All have E_c < 1 KeV, No masks possible**
- **Dose < 100 rad/year@MDC electronics**
- **Rate < 20 KHz/wire**

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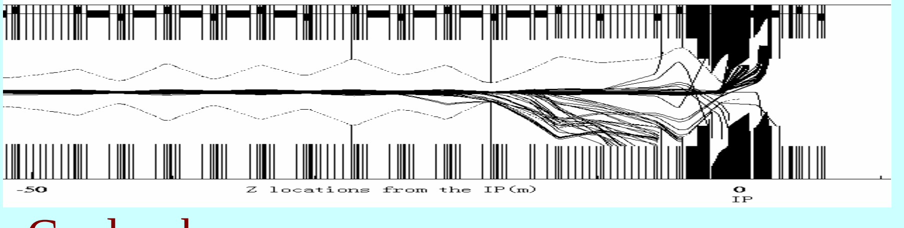
Bremsstrahlung

1.89GeV@0.9A, 5nT vacuum



Coulomb

A total of 6 pairs of masks

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Beam-Gas background

- Total dose near the interaction region ~ 150 MeV/μs
- < 20 rad/year @ CsI crystals
- < 20 rad/year @ MDC electronics
- < 1 rad/year @ TOF
- OK for safety

MDC < 20 KHz/wire

TOF < 5 KHz/ch @E>500 KeV

EMC < 2 KHz/ch @E>100 KeV

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Schedule

- **7/2004: BESII detector shutdown**
- **11/2004: supporting structure/york installation**
- **3/2005: muon chamber installation**
- **5/2005: magnet installation**
- **10/2005: magnetic field mapping**
- **2/2006: EMC installation**
- **3/2006: MDC/TOF installation**
- **6/2006: Cosmic-ray run**
- **9/2006: BESIII detector in place**
- **12/2006: tuning of detector/machine**

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Physics at BEPCII/BESIII

- **Precision measurement of CKM matrix**
- **Precision test of Standard Model**
- **QCD and hadron production**
- **Light hadron spectroscopy**
- **Charmonium physics**
- **Search for new physics**

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We are unique

- In a regime of transition between pQCD and non-pQCD
- Provide calibrations and tests for LQCD
- Rich spectra of light hadrons for Quark model test
- Threshold production of tau-charm

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Event statistics at BESIII

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}

*CLEO took 10 nb D production cross section while we took 5 nb

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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**

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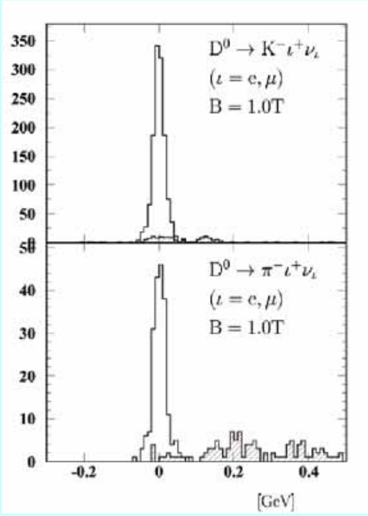
Semi-leptonic decays

Decay Mode	Input Br(%)	Detection Efficiency	Statistics Errors	CKM Elements
$D^0 \rightarrow K^- e^+ \nu_e$	3.4%	54.6%	0.6 %	V_{cs}
$D^0 \rightarrow K^- \mu^+ \nu_\mu$		30.5%		
$D^0 \rightarrow \pi^- e^+ \nu_e$	0.4%	62.2%	1.6%	V_{cd}
$D^0 \rightarrow \pi^- \mu^+ \nu_\mu$		44.3%		
$D^+ \rightarrow \overline{K}^0 e^+ \nu_e$	8.5%	6.7%	1.6%	V_{cs}
$D^+ \rightarrow \overline{K}^0 \mu^+ \nu_\mu$		3.7%		



$\Delta V_{cs} / V_{cs} = 1.6\%,$

$\Delta V_{cd} / V_{cd} = 1.8\%$

$E_{missing}$-$P_{missing}$

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Pure Leptonic decays

Decay Modes	Decay Constant	Branching ratios	Life time	CKM Elements	Precision of decay constants
$D^+ \rightarrow \mu^+ \nu$	f_D	2.4%	1.2%	1.8%	3.0%
$D^+_s \rightarrow \mu^+ \nu$	f_{Ds}	1.7%	1.8%	0.1%	2.5%

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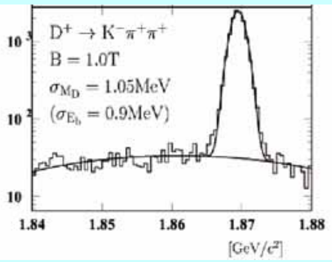
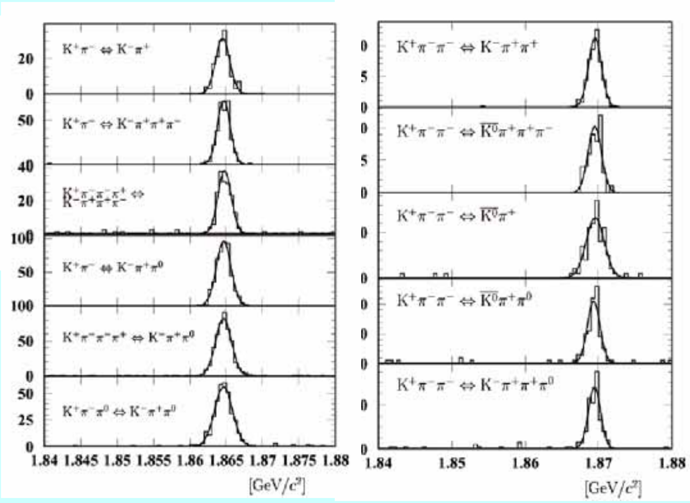
Absolute Br measurement: clear D tagging





beam energy spread important

Non-leptonic decays

Decay Mode	Input Br(%)	Detection efficiency	Statistics Error (ΔB/B)
$D^0 \to K^-\pi^+$	3.7	72.2%	~ 0.4%
$D^0 \to K^-\pi^+\pi^+\pi^-$	~7.8	34.0%	
$D^0 \to K^-\pi^+\pi^0$	~12.0	32.0%	
$D^+ \to K^-\pi^+\pi^+$	~7.7	52.0%	~ 0.6%
$D^+ \to \overline{K^0}\pi^+$	2.8	12.5%	
$D^+ \to \overline{K^0}\pi^+\pi^+\pi^-$	~5.6	9.2%	
$D^+ \to \overline{K^0}\pi^+\pi^0$	~8.6	7.9%	
$D^+ \to K^-\pi^+\pi^+\pi^0$	~5.0	22.5%	
$D^+_s \to \phi\pi^+$	~3.0	60.0%	~ 1.2%

CKM matrix elements measurement

	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%

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Precision test of SM and Search for new Physics

- DD mixing
- Lepton universality
- CP violation
- Rare decays

  FCNC, Lepton no. violation, ...

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DDbar Mixing at BESIII

- DDbar mixing in SM ~ 10^{-3} - 10^{-10}
- DDbar mixing sensitive to "new physics"
- Our sensitivity : ~ 10^{-4}
- $D^0 D^0 \rightarrow (K^- \pi^+)(K^+ \pi^-)$

  Acceptance: ~ 40%

  Background: ~ 10^{-4}

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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
- BEC, correlations, form factors, resonance, etc.

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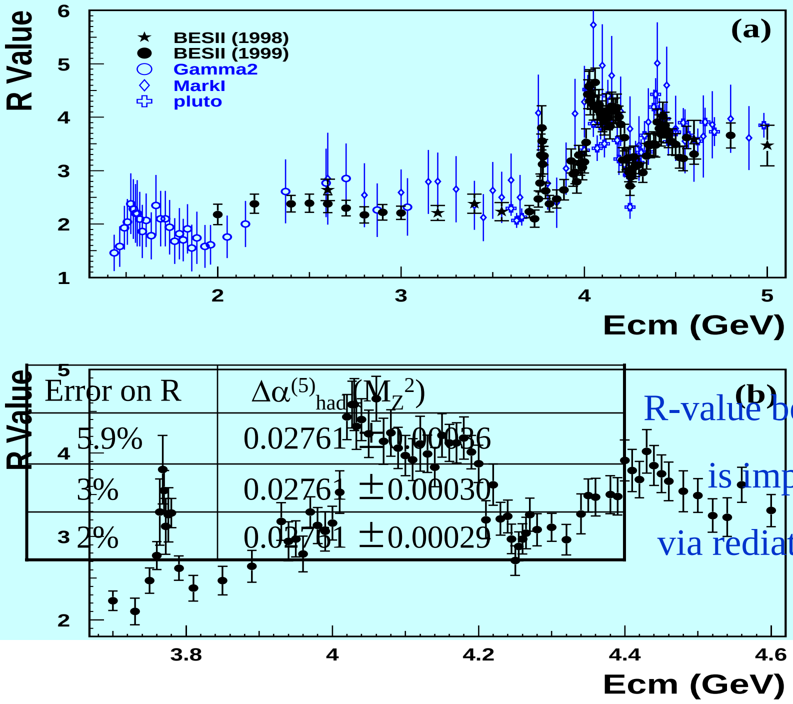
R-value measurement



Error on R	$\Delta\alpha^{(5)}_{had}(M_Z^2)$
5.9%	0.02761 ± 0.00036
3%	0.02761 ± 0.00030
2%	0.02761 ± 0.00029

R-value below 2GeV is important, via rediative returns

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Errors on R at BESIII

Error sources	BESII (%)	BESIII (%)
Luminosity	2 - 3	1
Detection efficiency	3 - 4	1 - 2
Trigger efficiency	0.5	0.5
Radiative corrections	1 - 2	1
Hadron decay model	2 - 3	1 – 2
Statistics	2.5	--
Total	6 – 7	2 - 3

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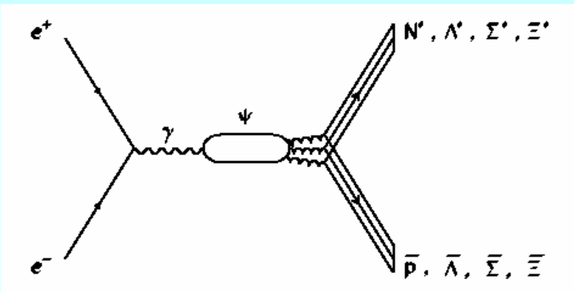
Light hadron spectroscopy

- Baryon spectroscopy
- Charmonium spectroscopy
- Glueball searches
- Search for non-qqbar states
- Search for $^1P_1$

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

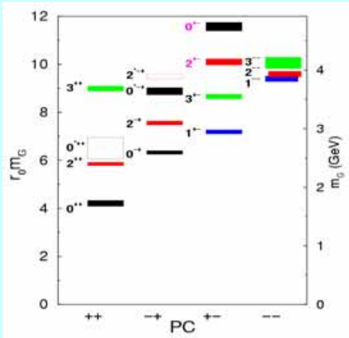
Excited Baryons from J/ψ and ψ(2s) Decays

- **Test of QCD and confinement**
- **Reveal the quark-gluon structure of matter**
- **Only 10% excited baryons(N^*, Λ^*, Σ^* and Ξ^*) observed**
- **Complementary to CEBAF, GRAAL and SPRING8**



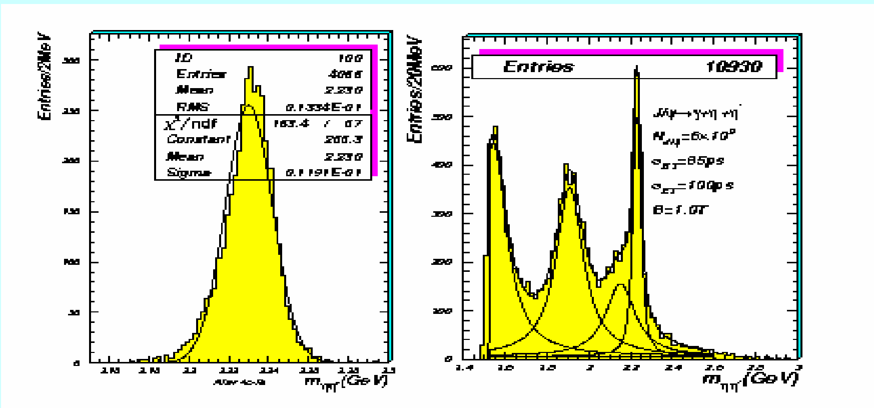
Search for glueballs

- no place in nonet
- enhanced in J/ψ decays
- branching ratios incompatible with SU(3) predictions
- reduced γγ couplings



Candidates: $f_0(1500)$, $f_0(1700)$,ξ(2230), ….

Good energy/mass resolution



J/ψ –> γξ(2230)–>γηη'--> $\gamma\gamma\gamma\gamma\pi^+\pi^-$

Non qqbar exotic 1^{-+} state

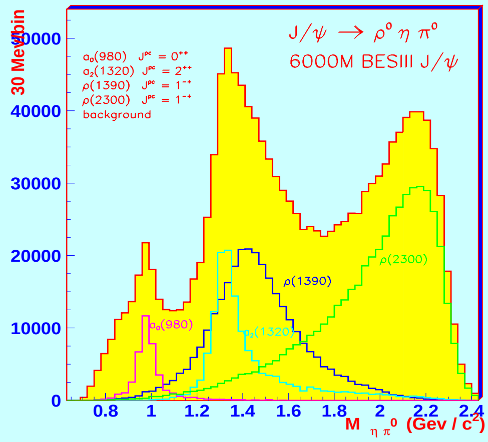
- $J/\psi \rightarrow \rho^0\eta\pi^0$

Well identified

$\rho(1390)$

$\rho(2300)$

via partial wave analysis



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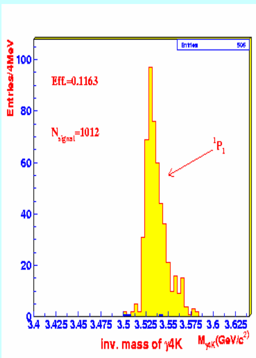
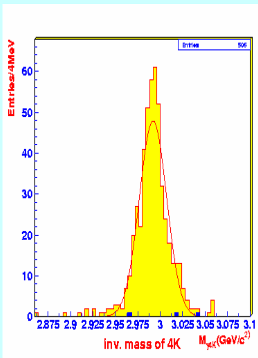
Search for $^1P_1$





Br = (1.2 – 3.3) × 10^{-6}

450-1200 evts/year

$\psi(2S) \rightarrow \pi^0\ {}^1P_1 \rightarrow \gamma\gamma\gamma\ \eta_c \rightarrow \gamma\gamma\gamma\ 4K$

Background: $\psi(2S) \rightarrow \gamma\ \chi_{c1}, \gamma\chi_{c2,}, \eta\psi, \pi^0\pi^0\psi$

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Event Statistics: BESIII vs CLEO-c

Physics Channel	Energy (GeV)	Luminosity (10^{33} $cm^{-2}s^{-1}$)		Events/year (10^9)	
		BEPCII	CLEO	BEPCII	CLEO
J/ψ	3.097	0.6	0.15	10.0	1.0
τ	3.67	1.0	0.30	0.012	—
ψ'	3.686	1.0	0.30	3.0	—
D	3.77	1.0	0.30	0.025	0.03 *
Ds	4.03	0.6	0.50	0.001	—
Ds	4.14	0.6	0.50	0.002	0.0015

*CLEO took 10 nb D production cross section while we took 5 nb

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Comparison with other facilities

	B-Factories	CLEO-C	BEPCII
	400 fb^{-1}	3fb^{-1}	5fb^{-1}
$Br(D^0 \to K^- \pi^+)$		< 1%	<1%
$Br(D^+ \to K^- \pi^+ \pi^+)$	3-5%	<1%	<1%
$Br(D^+_s \to \phi^- \pi^+)$	5-10%	<2%	~ 2%
f_D	>10 %	~2%	~3%
f_{Ds}	6-9%	~2%	~2.5%
V_{cs}	16%	~1%	~1.5%
V_{cd}	7%	~1.5%	~2%

*CLEO took 10 nb D production cross section while we took 5 nb

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International collaboration

IHEP, Beijing
Beijing University , Beijing
Tsinghua University , Beijing
USTC, Hefei
National Central University, Taipei
KEK, Tokyo University, Tokyo
Hawaii University, Honolulu
Washington University, Seattle

Welcome more collaborators

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Summary

- **The BEPCII/BESIII has been approved officially by the Chinese government**
- **The BESIII detector design is finished, prototyping is underway, some of the mass production have been started**
- **Rich physics after CLEO-c(upgrade of BEPCII to $3*10^{33}$ $cm^{-2}s^{-1}$ is possible)**

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