Status and Prospects of the BESIII experiment

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(for BESIII collaboration)

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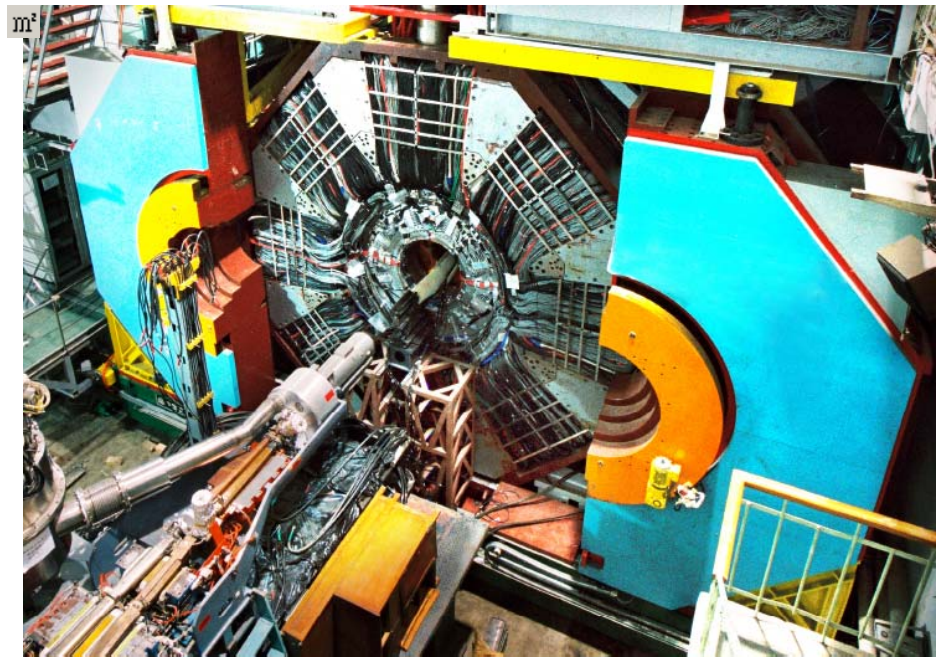
@ SLAC



Lian-Tao: Searching for the Light Dark Gauge Boson

Conclusion:

- Dark matter in the universe could have self-interaction
- Recent evidence can be interpreted as suggesting such self-interaction is mediated by GeV dark sector states.
- Low energy experiments, with high luminosity, is the prime place to look for such states.
- Production of GeV dark sector results in distinct signals: multiple leptons....
- It is exciting to go into this un-explored territory.

Outline

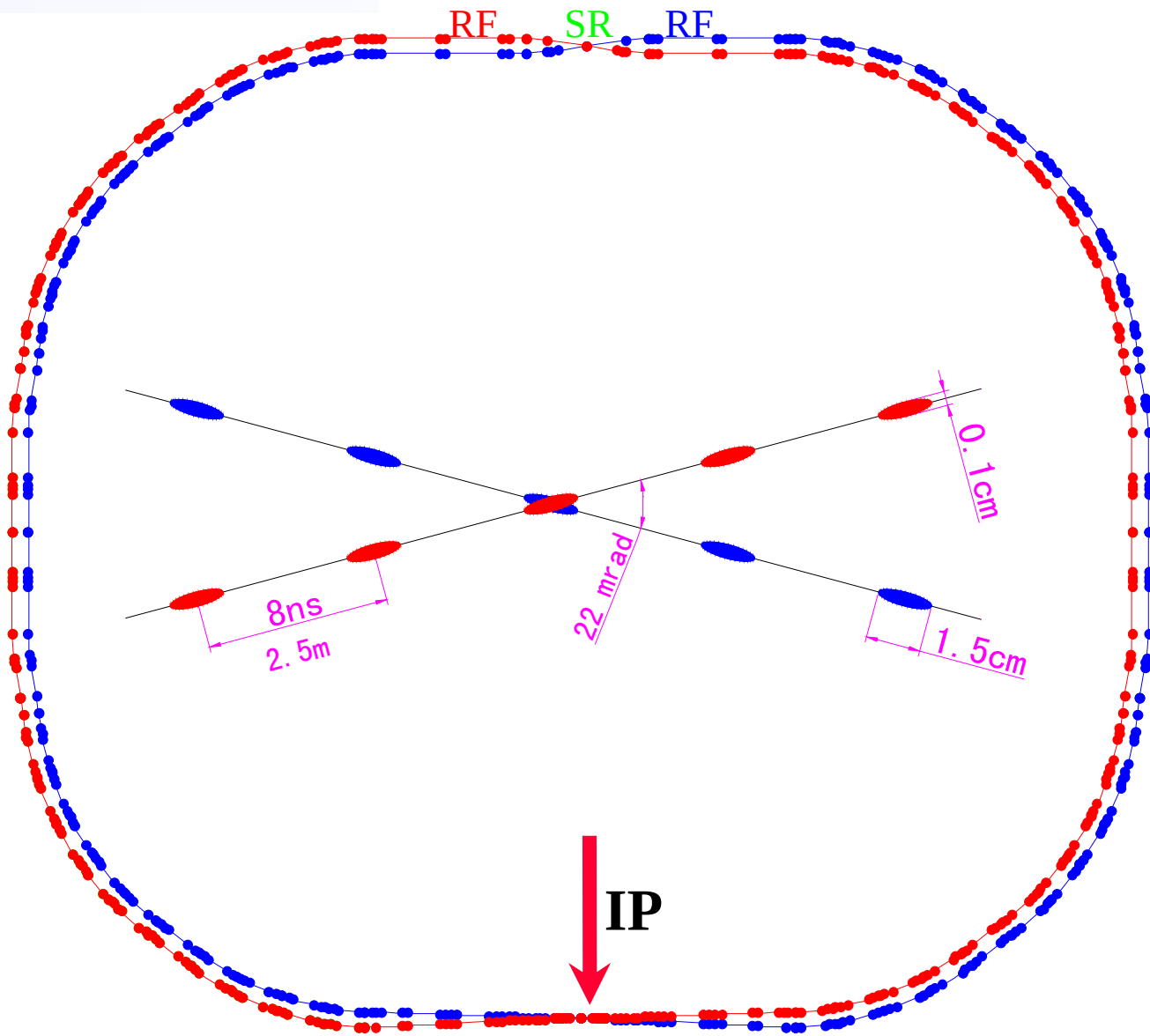
- BESIII/BEPCII experiment status
  - Accelerator and Detector performance
  - Selected preliminary results
- Data taking plan
- Prospects on searching Dark force
  - “invisible” decays
  - Light Dark Gauge Boson (See Hai-Bo’s talk)
- Summary

BESIII experiment

- A mainstream High Energy Physics project in China
  - A major upgrading from BES(II)/BEPC
  - BEPCII : e^+e^- collider
    - ~60% Physics run
    - ~40% Synchrotron radiation run
  - BESIII: particle detector
  - Start testing run on July, 2008
  - Start official data taking on March, 2009
  - Publications in few months

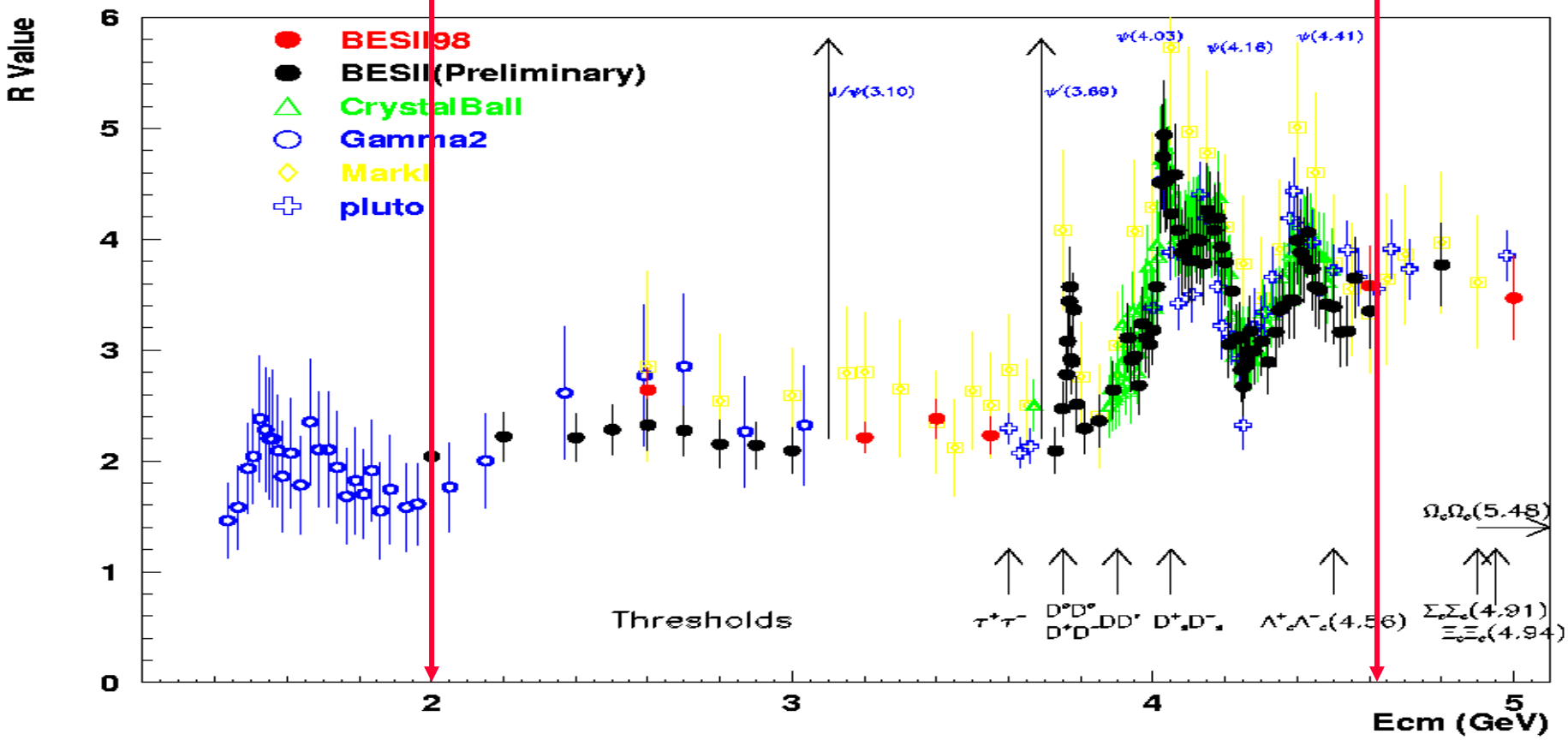
BEPC II Storage ring: Double ring

Beam energy:
1.0-2.3 GeV
Luminosity:
1×10^{33} $cm^{-2}s^{-1}$
Optimum energy:
1.89 GeV
Energy spread:
5.16×10^{-4}
No. of bunches:
93
Bunch length:
1.5 cm
Total current:
0.91 A



τ-Charm productions at BEPCII

2 ~ 4.6 GeV



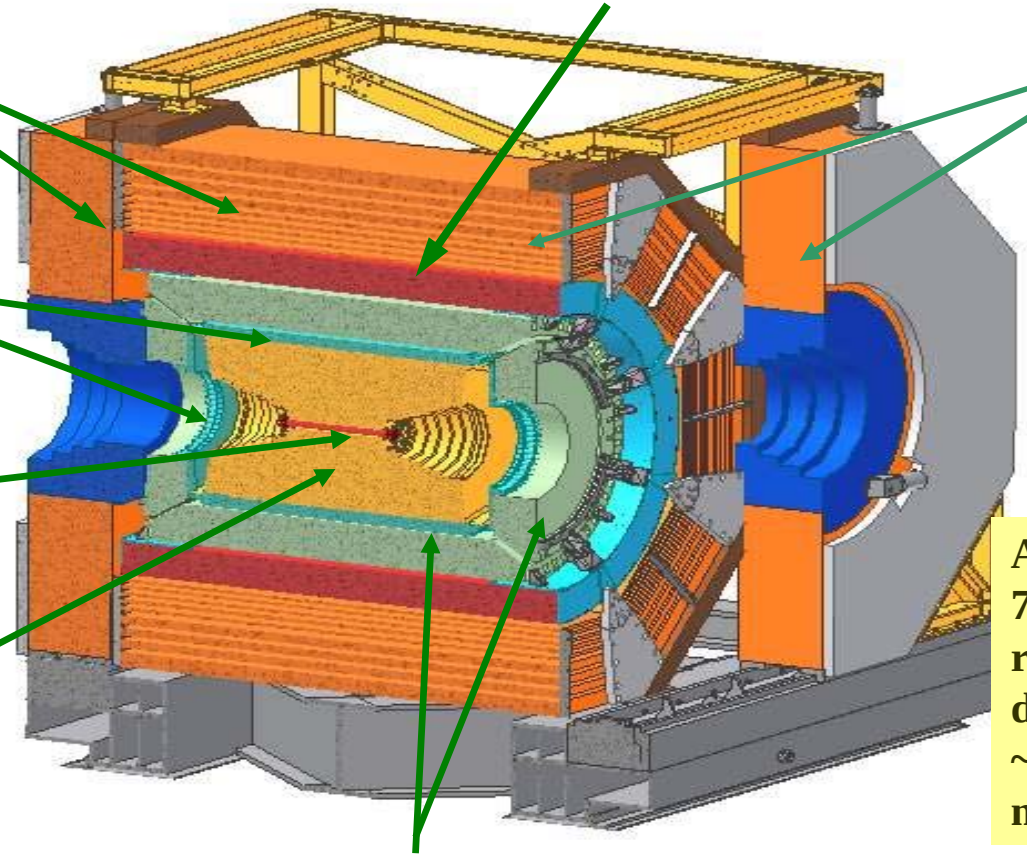
Expected Charm productions at BEPCII

Calculation based on following assumption:
Average Lum: $L = 0.5 \times$ Peak Lum.;
One year data taking time: $T = 10^7 s$

Resonance	Mass(GeV) CMS	Peak Lum. ($10^{33} cm^{-2} s^{-1}$)	Physics Cross Section (nb)	Nevents/yr
J/ψ	3.097	0.6	3400	10×10^9
τ	3.670	1.0	2.4	12×10^6
ψ(2S)	3.686	1.0	640	3.2×10^9
$D^0 D^0$bar	3.770	1.0	3.6	18×10^6
$D^+ D^-$	3.770	1.0	2.8	14×10^6
DsDs	4.030	0.6	0.32	1.0×10^6
DsDs	4.140	0.6	0.67	2.0×10^6

Huge J/ψ and ψ(2S) sample at BESIII

The BESIII Detector



A total weight of 730t, ~40000 readout channels, data rate 6000Hz ~50Mb/s, ~1000 man*year, 30 M$

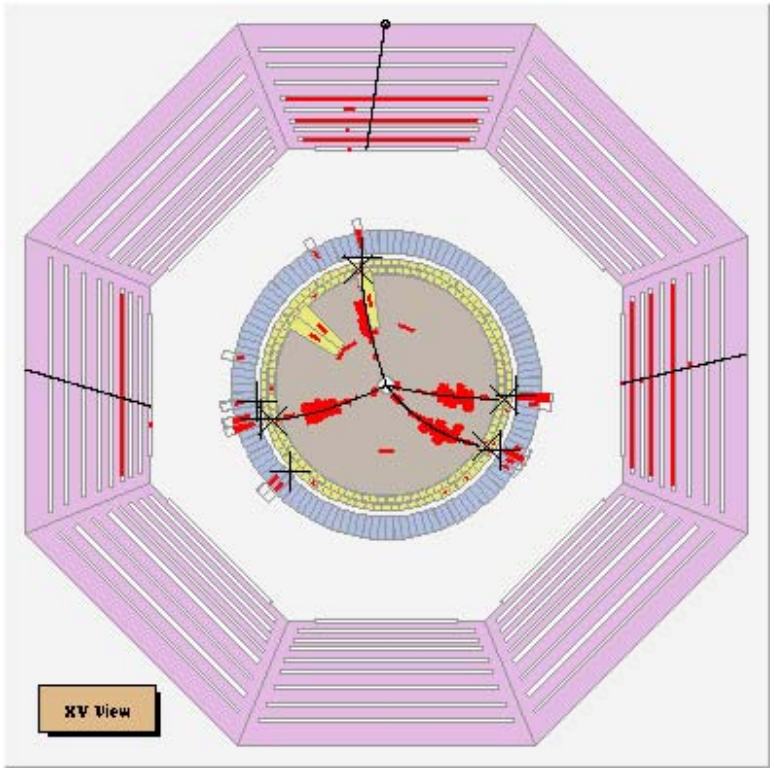
Comparing with recent e^+e^- τ-charm colliders

- **BESII**
  - **BEPC: Luminosity@J/ψ ~ 5x10^{30}/cm^2·s**
  - **Tradition Magnet, magnetic field: 0.4T**
    - **MDC: σ_{xy}~ 220 μm, σ_P ~ 1.2% @1GeV**
  - **Electromagnetic Shower Counter: $\Delta E/\sqrt{E}$ ~ 21 %**
  - **TOF: σ_T~ 180 ps**
  - **Completed on 2003**
- **Cleo-c**
  - **CESR-c: Luminosity@ψ(3770) ~ 7x10^{31}/cm^2·s**
  - **Optimized for B-physics, no Muon detector used for Charm physics**
  - **Not operating on J/ψ resonance**
  - **Completed on 2007**

BESIII Commissioning and data taking milestones

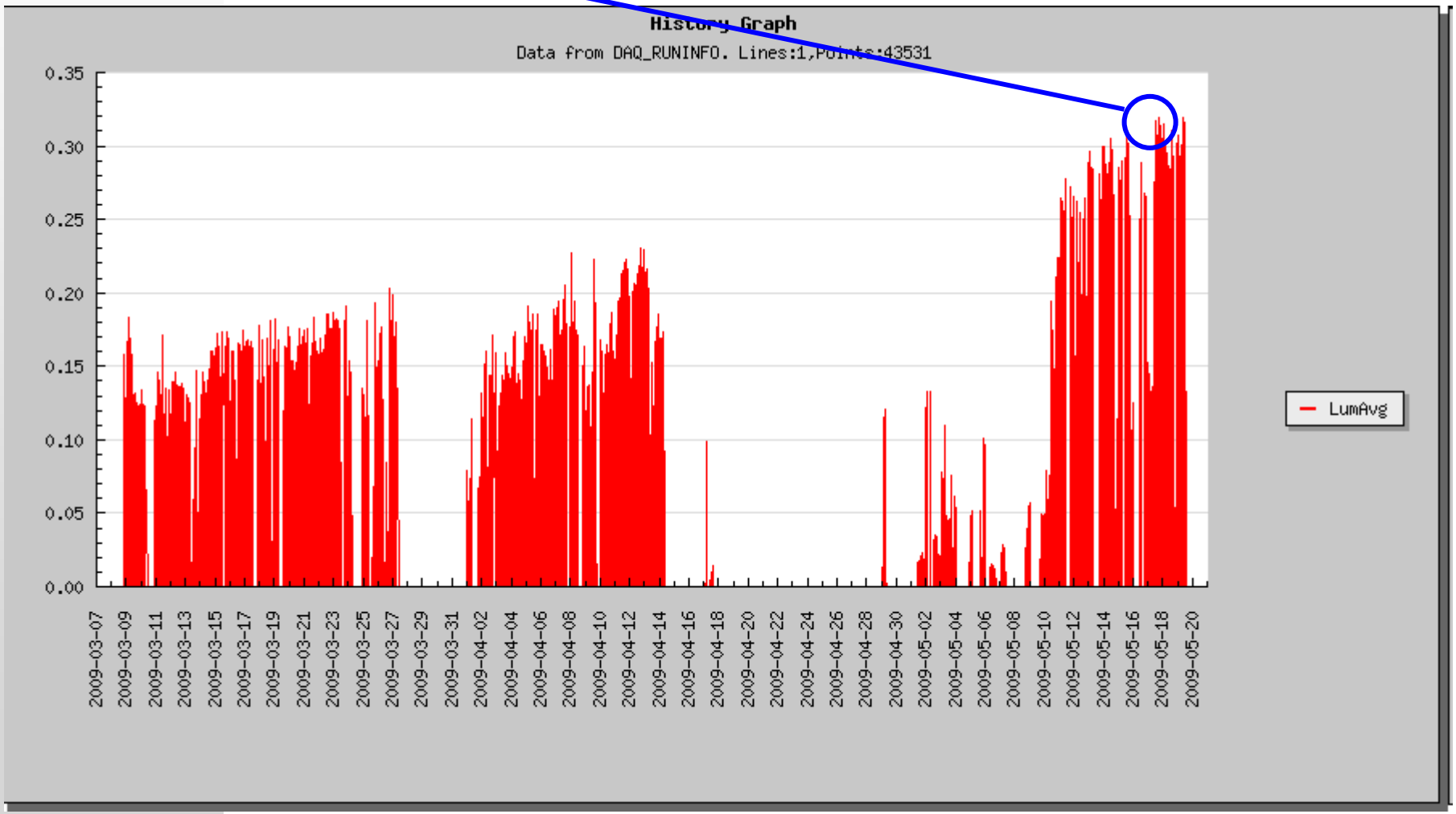
Mar. 2008: first full cosmic-ray event
April 30, 2008: Move the BESIII to IP
July 19, 2008: First e^+e^- collision event in BESIII
Nov. 2008: ~ 14M $\psi(2S)$ events collected
April 14, 2009 ~110M $\psi(2S)$ events collected(×4 CLEOc)
May 30, 2009 42 pb^{-1} at continuum collected
July 28, 2009 ~230M J/ψ events collected(×4 BESII)

Peak Lumi. @ Nov. 2008:
$1.2 \times 10^{32} cm^{-2}s^{-1}$
Peak Lumi. @ May 2009:
$3.2 \times 10^{32} cm^{-2}s^{-1}$ ➔
×5 CESRc
×30 BEPC

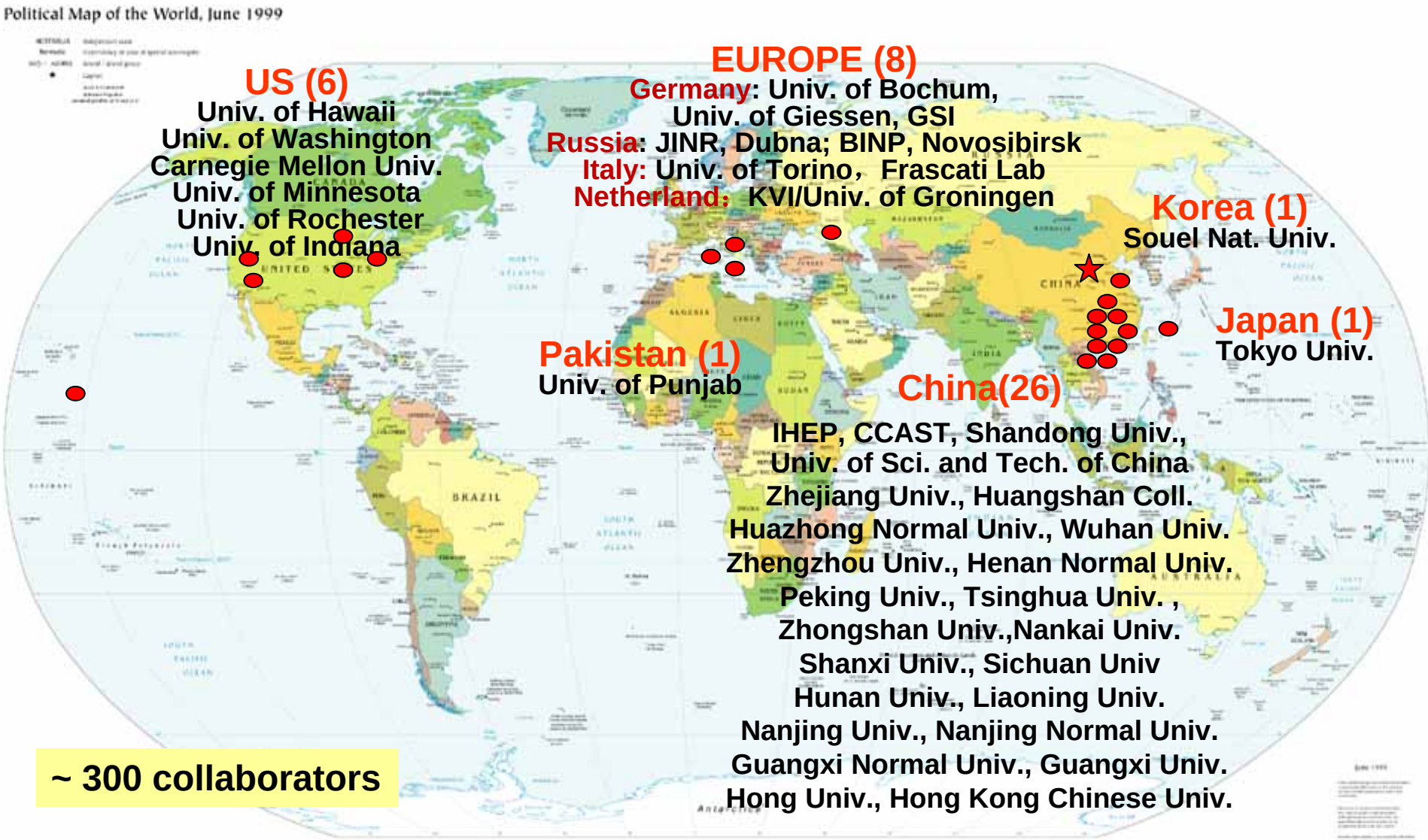


Achieved Luminosity vs Time

Record: 0.32×10^{33} $cm^{-2}s^{-1}$ reached in May 14, 2009

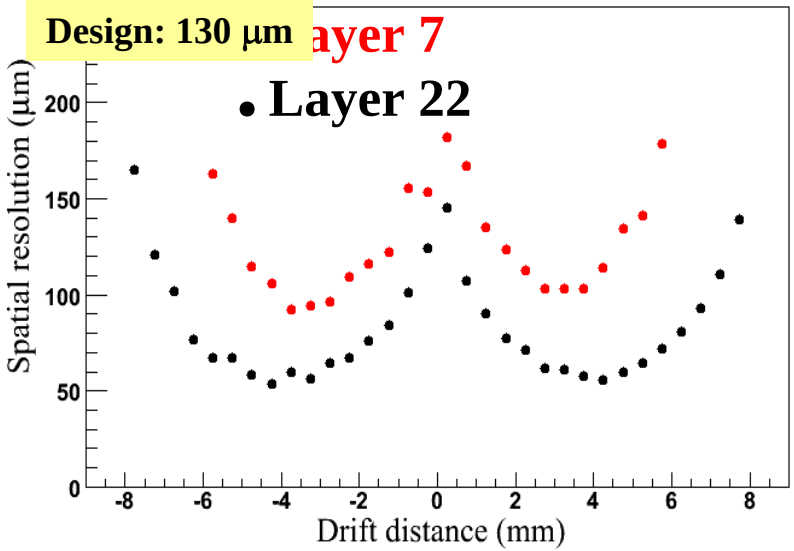


BESIII collaboration

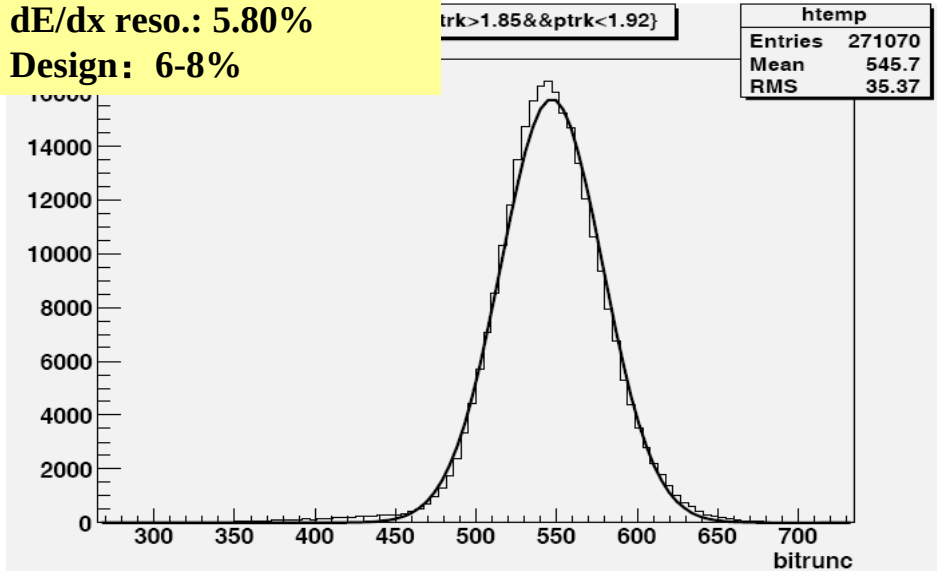


Detector performance and calibration

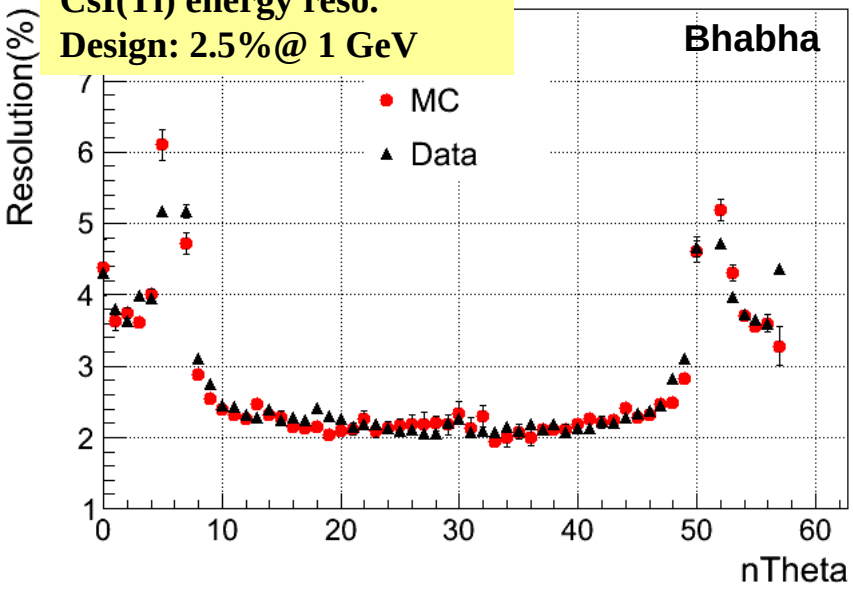
Wire reso.
Design: 130 μm



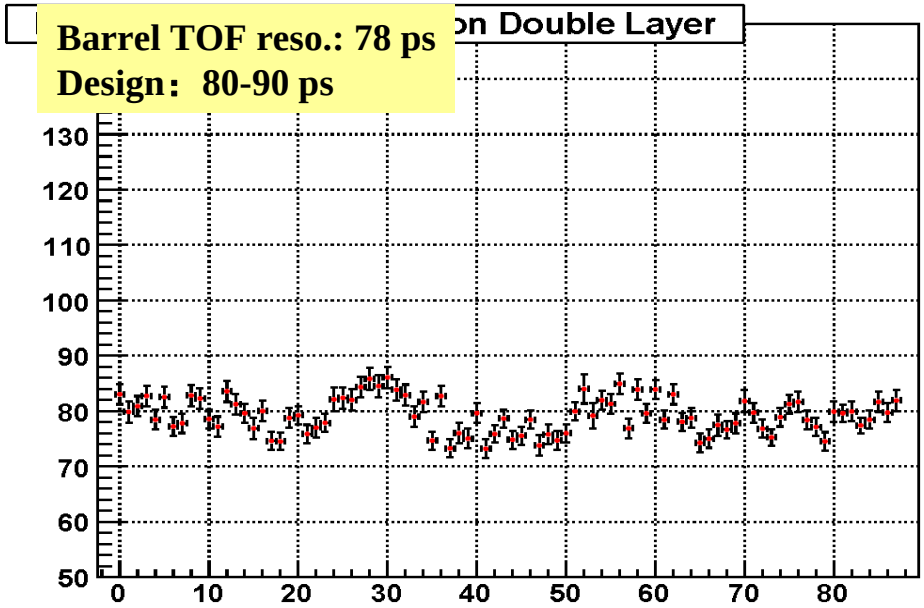
dE/dx reso.: 5.80%
Design：6-8%



CsI(Tl) energy reso.
Design: 2.5%@ 1 GeV



Barrel TOF reso.: 78 ps
Design：80-90 ps



Perspective Physics at BESIII

Many exciting ways to use higher luminosity !

Charmonium states: J/ψ, $\psi(2S)$, $\eta_C(1S)$, $\eta_C(2S)$, χ_{cJ}, and h_C

Exotics: hybrids, glueballs and other exotics in J/ψ and $\psi(2S)$ radiative decays;

Open charm physics: D, D^+, D_s (like CLEO-c)

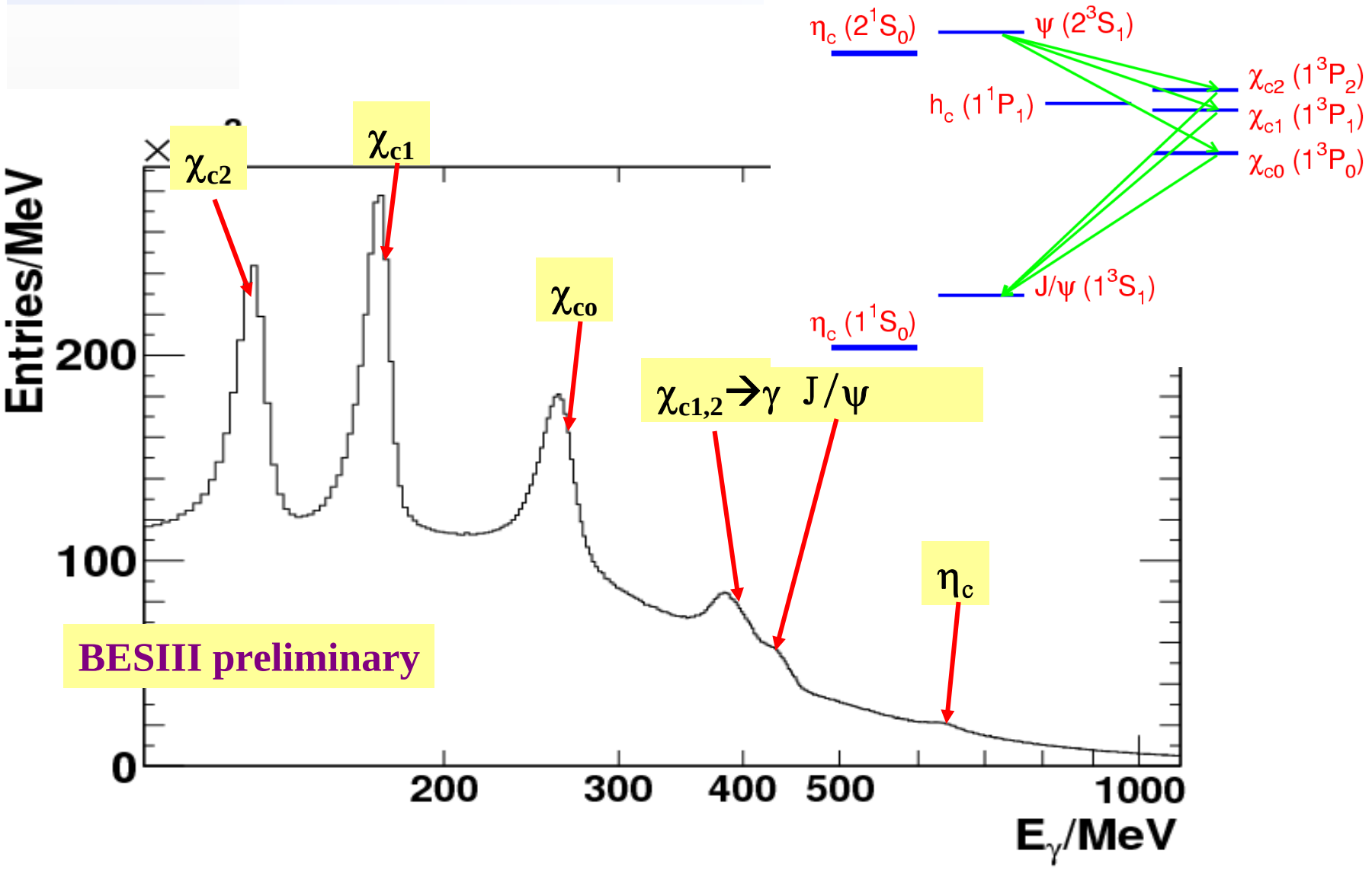
- Improve statistics-hungry analyses
- Improved reach for mixing, rare decays, CP violation
- Quantum correlations, strong $K\pi$ phase, ...
- Spectroscopy via Dalitz plots

Energy scans: R_{had}, resonances, DD composition, ...

Tau Physics

No doubt many more innovations...

EM transitions: inclusive photon spectrum

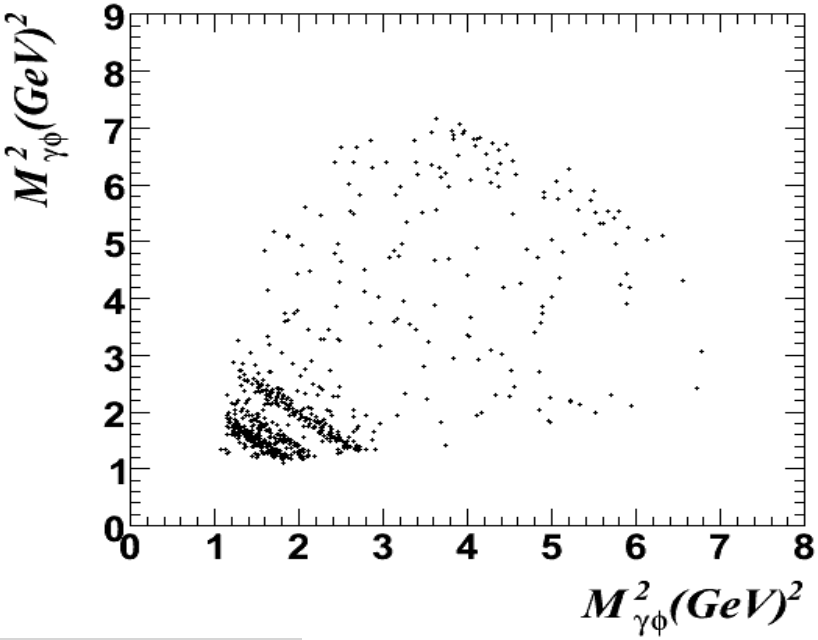


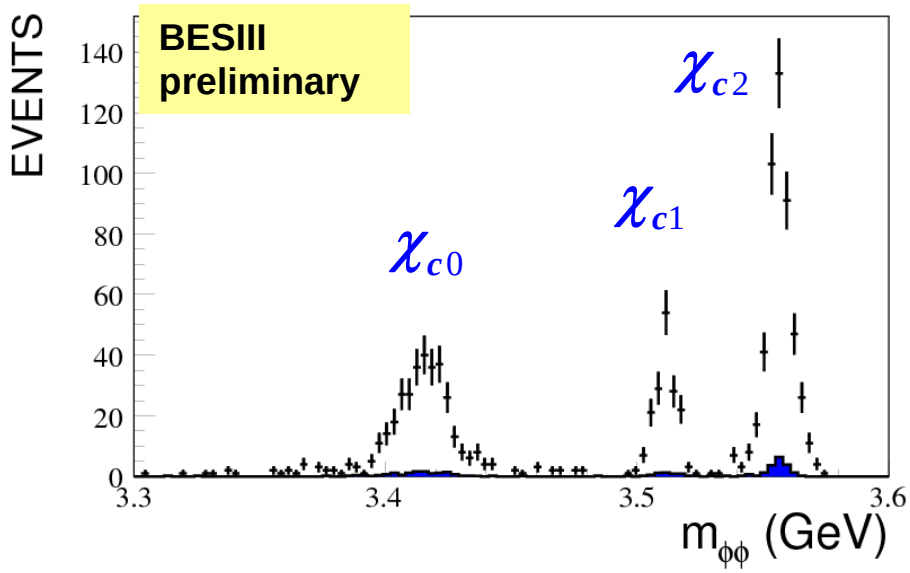
Study of $\chi_{cJ} \rightarrow VV$, V=ω,ϕ

- Test QCD-based theory at χ_{cJ} decays
- Puzzles for $\chi_{c0} \rightarrow$ VV: no helicity suppress
- $\chi_{c1} \rightarrow \phi\phi, \omega\omega$ is only allowed for L=2, suppressed ?
- $\chi_{cJ} \rightarrow \phi\omega$ OZI doubly suppressed

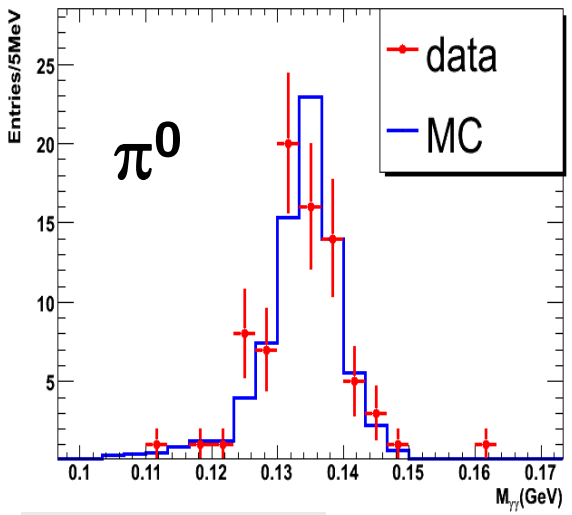
BESII results:		
BR(10^{-3})	χ_{c0}	χ_{c2}
$\phi\phi$	0.93±0.20	1.5±0.3
$\omega\omega$	2.3±0.7	2.0±0.7

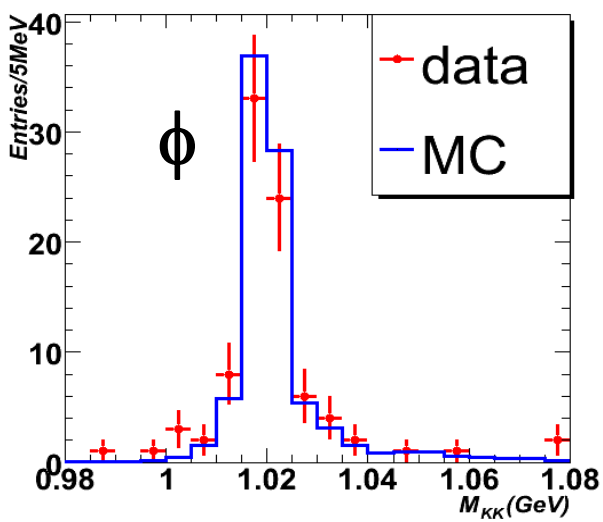
- BK from sideband & 100M MC events
- Clear $\chi_{c1} \rightarrow \phi\phi$ signal

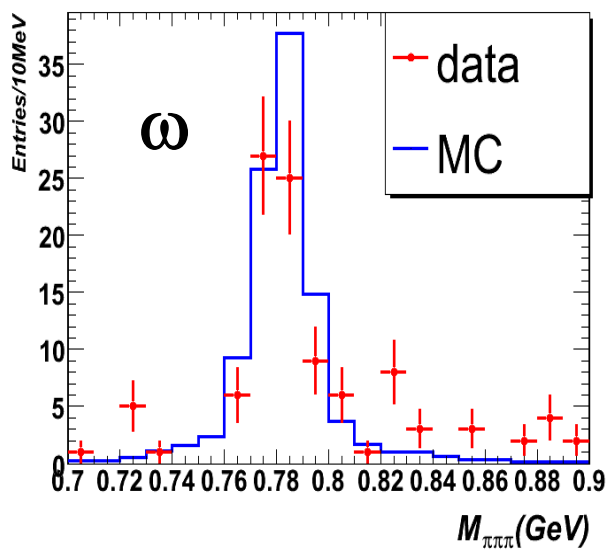


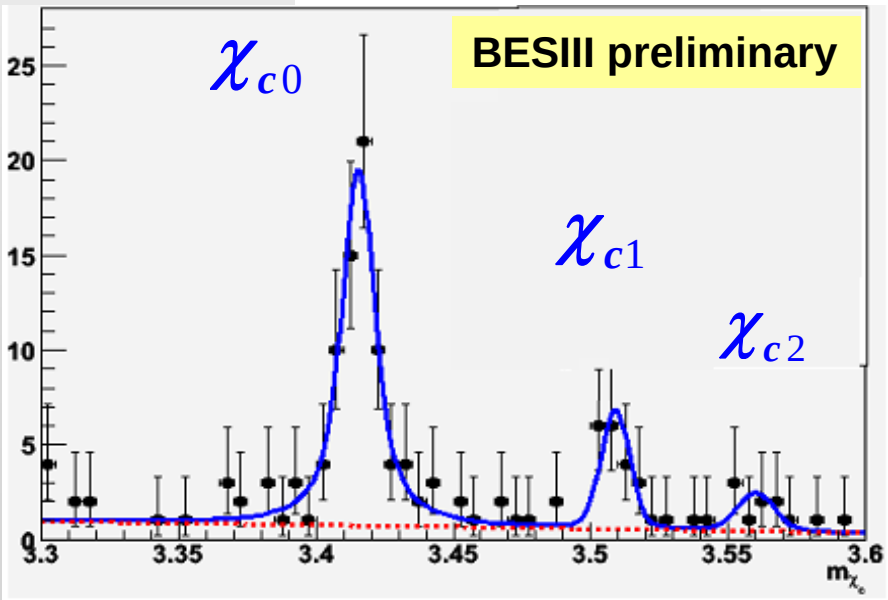


First observation of $\chi_{cJ} \rightarrow \omega\phi$









- **Background from sideband & 100M MC events**
- **Clear signal from**

  χ_{c0} /χ_{c1} → $\omega(\pi^+\pi^-\pi^0)\phi(K^+K^-)$

Publication status

- 5 analysis memos are under the referees review, and will be submitted in few months
- Systematic studies for neutral tracks (γ, π^0, $\eta^{(\prime)}$) are in good shape (MC agrees with data)
- It will take time to fully understand the systematics for the charged tracks
- A lot more exciting results are coming

Proposed data taking plan

- Proposed 5-year running plan. "Higher ψ" indicates ψ(4040) or ψ(4150)
- Motivation: Keeps almost all analysis groups provided with world class data samples as quickly as possible with the potential of maximizing the overall BES-III physics output

year	2009-10	2010-11	2011-12	2012-13	2013-14
$<L_{peak}>$ (10^{33})	0.45	0.65	0.70/0.20	0.85	0.95
# of months	4	6	3/3	6	6
Ecm	ψ(3770)	ψ(3770)	ψ'/J/ψ	higher ψ	higher ψ
$\int Ldt$ (fb^{-1})	1.4	3.1	1.7/0.5	4.1	4.6
# events			10^9/1.6x10^9		

- 2009-2010 decision will be made in November

Philosophies on data taking proposals

- Guarantees that all research groups get competitive data samples in a timely manner
- Gets all BESIII members involved in analyzing real data
- Provides a way that maximizes the efficiency of the psi' & J/psi analyses
- Keeps pressure on the accelerator teams to improve the luminosity
- Long-term goals: ~20 fb^{-1} $\psi(3770)$ and higher ψ states and 10^{10} J/ψ events.

Dark force search at BESIII

- Meson “invisible” decays
- Spin-1 boson in ψ decay:
  - $\psi \rightarrow \gamma U$ $(U \rightarrow e^+e^-, \mu^+\mu^-)$
  - $\psi \rightarrow e^+e^-U$ $(U \rightarrow e^+e^-, \mu^+\mu^-)$
  - $\psi \rightarrow U h_s' \rightarrow$ U + missing Energy $(U \rightarrow e^+e^-, \mu^+\mu^-)$
  - $\psi \rightarrow U h_s' \rightarrow$ 3 U $(U \rightarrow e^+e^-, \mu^+\mu^-)$ (QED background free)

Prospects on Invisible J/ψ decays

- Technical details for BESII analysis can be found in Hai-Bo's talk
- For BESIII estimation: use BESII efficiencies
- Full MC studies need to be done

10^{10} J/ψ Decays

J/ψ decay mode	Branching fraction (10^{-4})	Invisible decay mode	Tagging topology	Number of events in 10 billions J/ψ sample
$J/\psi \to \phi\eta$	6.5 ± 0.7	$\eta \to$ invisible	$\phi \to K^+K^-$	$(31.4 \pm 3.4) \times 10^5$
	6.5 ± 0.7	$\phi \to$ invisible	$\eta \to \gamma\gamma$	$(25.7 \pm 2.8) \times 10^5$
$J/\psi \to \phi\eta'$	3.3 ± 0.4	$\eta' \to$ invisible	$\phi \to K^+K^-$	$(16.2 \pm 1.9) \times 10^5$
	3.3 ± 0.4	$\phi \to$ invisible	$\eta' \to \gamma\rho^0$	$(9.6 \pm 1.2) \times 10^5$
$J/\psi \to \omega\eta$	15.8 ± 1.6	$\eta \to$ invisible	$\omega \to \pi^+\pi^-\pi^0$	$(13.9 \pm 1.4) \times 10^6$
	15.8 ± 1.6	$\omega \to$ invisible	$\eta \to \gamma\gamma$	$(6.2 \pm 0.6) \times 10^6$
$J/\psi \to \omega\eta'$	1.67 ± 0.25	$\eta' \to$ invisible	$\omega \to \pi^+\pi^-\pi^0$	$(1.5 \pm 0.2) \times 10^6$
	1.67 ± 0.25	$\omega \to$ invisible	$\eta' \to \gamma\rho^0$	$(0.7 \pm 0.1) \times 10^6$
$J/\psi \to \rho^0\eta$	1.93 ± 0.23	$\eta \to$ invisible	$\rho^0 \to \pi^+\pi^-$	$(1.9 \pm 0.2) \times 10^6$
	1.93 ± 0.23	$\rho^0 \to$ invisible	$\eta \to \gamma\gamma$	$(0.8 \pm 0.09) \times 10^6$
$J/\psi \to \rho^0\pi^0$	56 ± 7	$\rho^0 \to$ invisible	$\pi^0 \to \gamma\gamma$	$(55.3 \pm 5.8) \times 10^6$

Suppress backgrounds with clean tagging !

Prospects on charmonium invisible decays

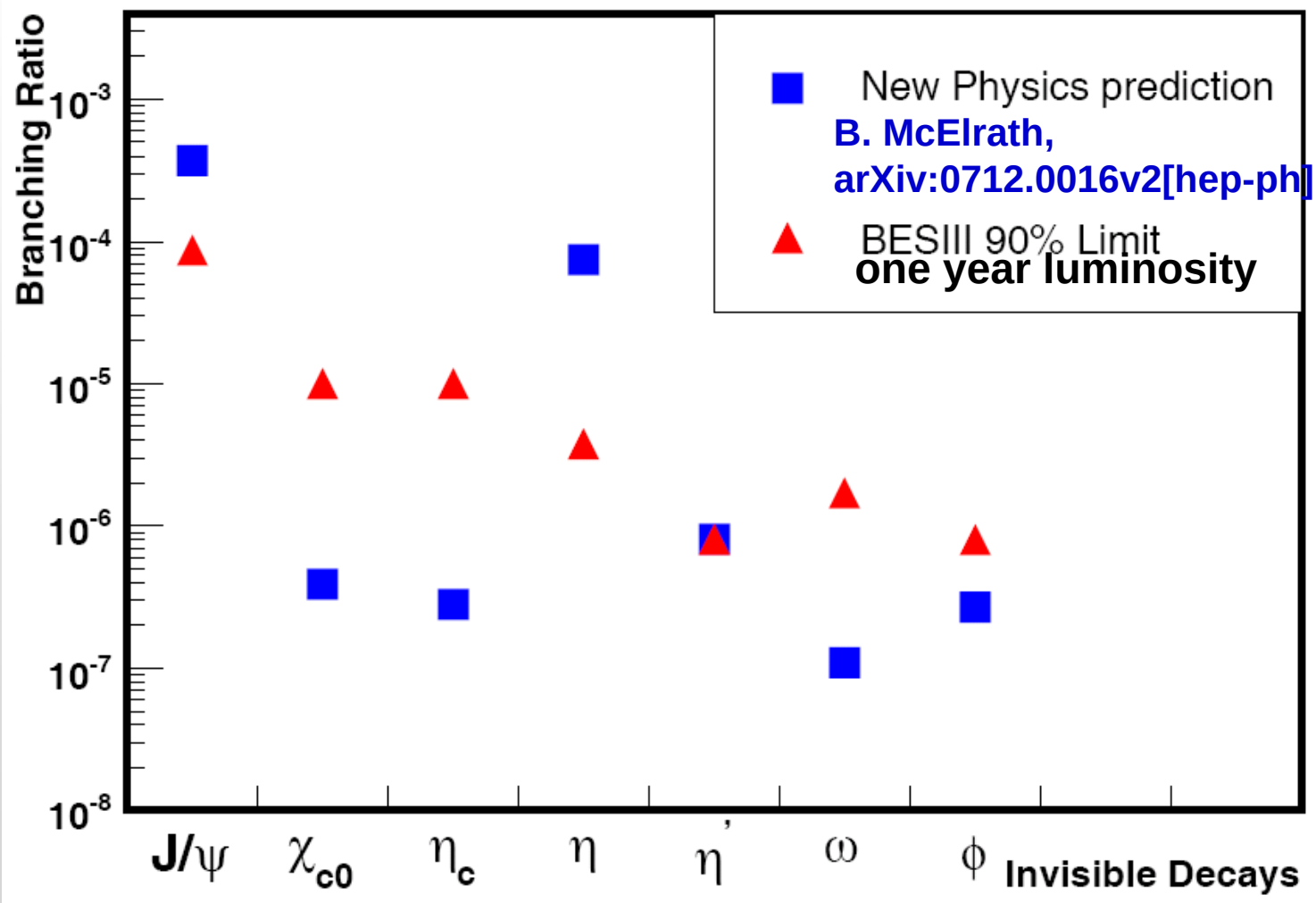
- Technical details for BESII analysis can be found in Hai-Bo's talk
- For BESIII estimation: use BESII efficiencies
- Full MC studies need to be done

3×10^9 $\psi(2S)$ decays

$\psi(2S)$ decay mode	Branching fraction (10^{-2})	Number of events in 3 billions $\psi(2S)$ sample	Invisible decay mode	Tagging topology
$\psi(2S) \to \pi^+\pi^- J/\psi$	31.7 ± 1.1	9.3×10^8	$J/\psi \to$ invisible	$\pi^+\pi^-$
$\psi(2S) \to \pi^0\pi^0 J/\psi$	18.6 ± 0.8	5.6×10^8	$J/\psi \to$ invisible	$\pi^0\pi^0$
$\psi(2S) \to \eta J/\psi$	3.08 ± 0.17	9.3×10^7	$J/\psi \to$ invisible	η
$\psi(2S) \to \pi^0 J/\psi$	0.123 ± 0.018	3.7×10^6	$J/\psi \to$ invisible	π^0
$\psi(2S) \to \gamma\chi_{c0}$	9.0 ± 0.4	2.7×10^8	$\chi_{c0} \to$ invisible	γ
$\psi(2S) \to \gamma\chi_{c1}$	8.7 ± 0.5	2.6×10^8	$\chi_{c1} \to$ invisible	γ
$\psi(2S) \to \gamma\chi_{c2}$	8.2 ± 0.3	2.5×10^8	$\chi_{c2} \to$ invisible	γ
$\psi(2S) \to \gamma\eta_c(1S)$	0.26 ± 0.04	7.8×10^6	$\eta_c(1S) \to$ invisible	γ
$J/\psi \to \gamma\eta_c(1S)$	1.3 ± 0.4	1.3×10^8	$\eta_c(1S) \to$ invisible	γ

The sensitivity at BESIII will be 10^{-4} –10^{-5} for J/ψ, χ_C , η_C → Invisible . The SM backgrounds are high!

Sensitivities of invisible decays of mesons



BESIII Prospects

- BESIII will resume data taking after summer shutdown, ~5 months until next summer.
- Possible data taking plans will be determined in Nov.
- Data taking plan in the future:
  - ~10 Billion J/ψ events (1 year)
  - ~3 Billion ψ(2s) (1 year)
  - ~20 fb^{-1} ψ(3770)+ ψ(4040)+ ψ(4160) (~5 years)
  - R scan/resonance scan: 2.0-4.6 GeV (months)
  - Tau physics (months)
- Possible upgrades:
  - Luminosity: crab waist, bunch spacing, …
  - Beam Energy: E_{max} = 4.6 GeV ➔ 5 GeV
  - e- Polarization
  - Detector: TOF, inner DC, …

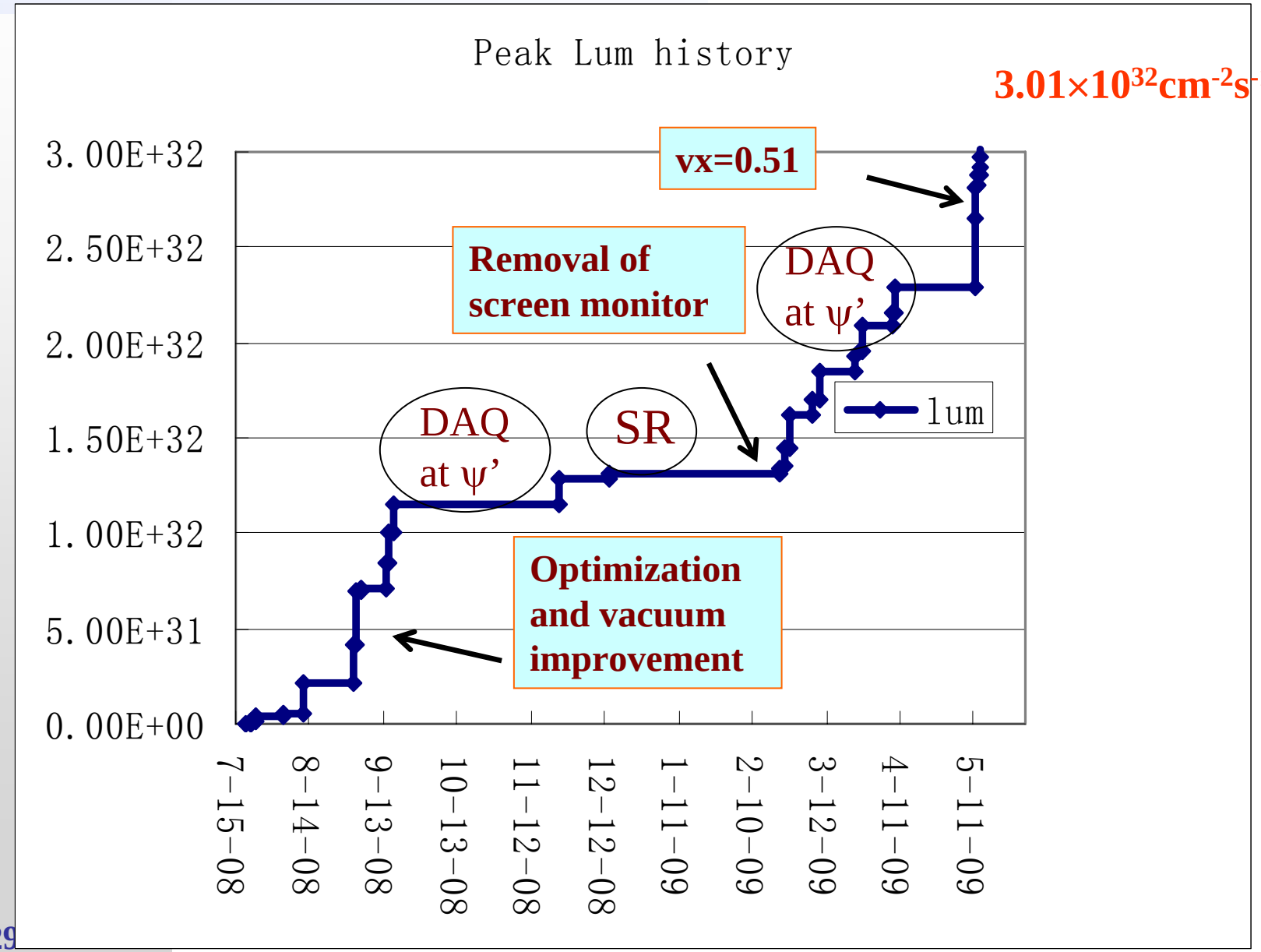
Summary

- BEPCII reached a luminosity of 3.2×10^{32} cm^{-2}s^{-1}
- BESIII/BEPCII has passed government review and shifted from the construction phase to the operation phase
- BESIII detector performance excellent, ready for physics
  - High quality data samples in hand (110 M ψ' and 230 M J/ψ data obtained)
  - Analysis in progress, papers in a few months
  - "Dark force" search will right be launched
- Few billions of J/ψ and ψ' data, 10 – 20 fb^{-1} $\psi(3770)$ data will be accumulated in the future
- We are very exciting about it

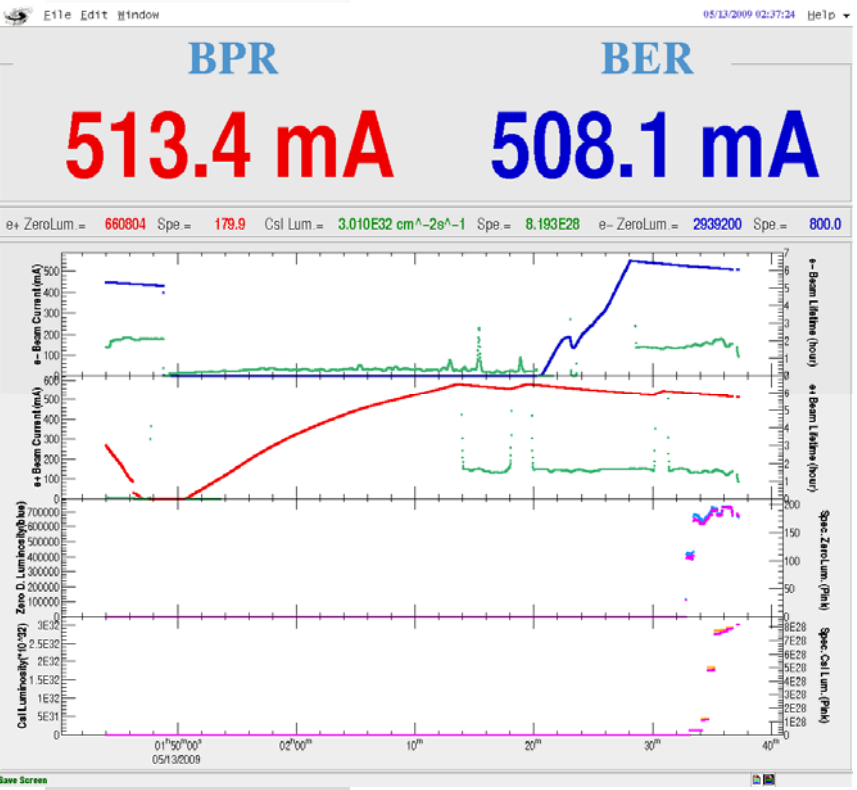
Thank you

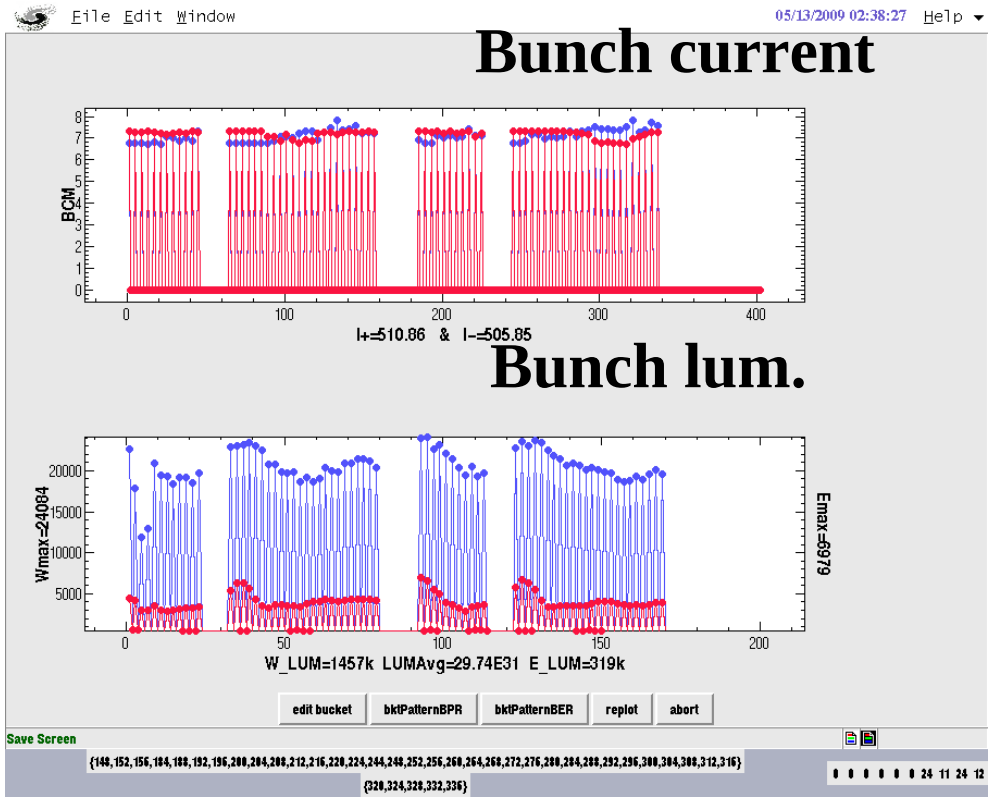
Backup slides

BEPCII Peak Luminosity evolution



Peak Luminosity of $3.0*10^{32}$ achieved on May 13 with ~ 2×500mA and 71 bunches





Main parameters achieved in collision mode

parameters	design	Achieved	
		BER	BPR
Energy (GeV)	1.89	1.89	1.89
Beam curr. (mA)	910	650	700
Bunch curr. (mA)	9.8	>10	>10
Bunch number	93	93	93
RF voltage	1.5	1.5	1.5
$*\nu_s$ @1.5MV	0.033	0.032	0.032
β_x^*/β_y^* (m)	1.0/0.015	~1.0/0.016	~1.0/0.016
Inj. Rate (mA/min)	200 e^-/ 50 e^+	>200	>50
Lum. ($10^{33}cm^{-2}s^{-1}$)	1	0.30	

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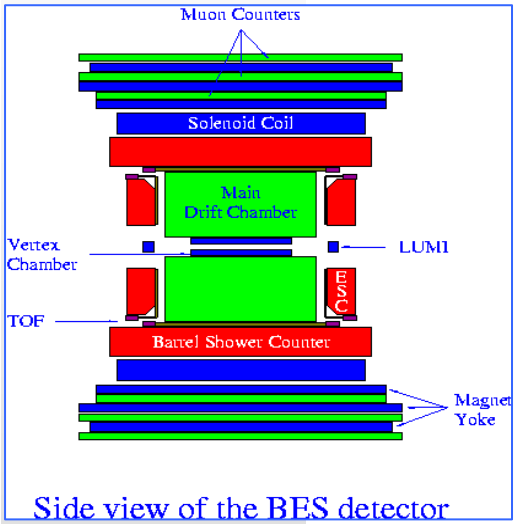
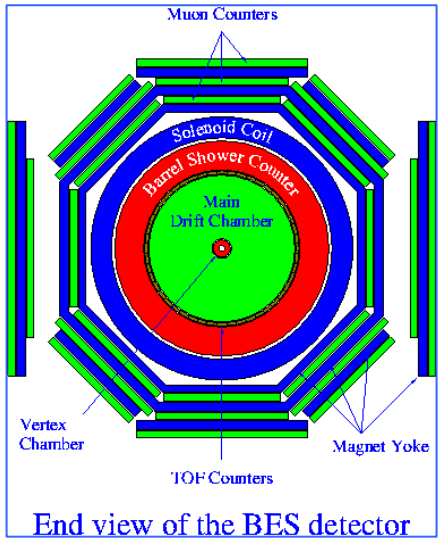
BESII Detector

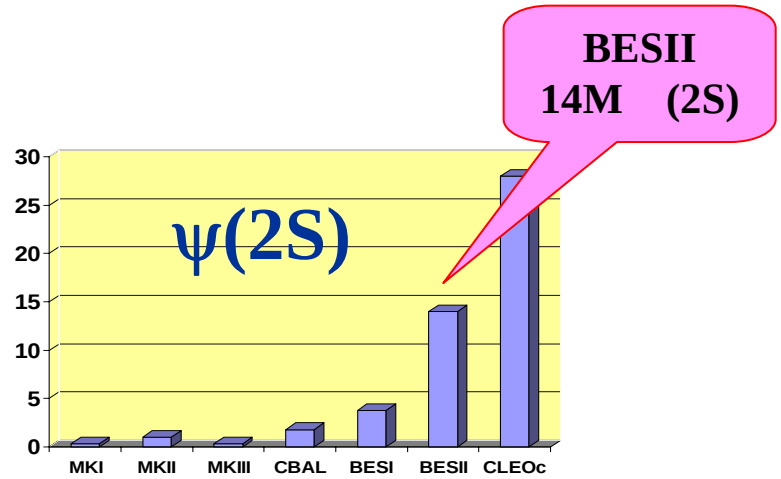
World J/ and (2S) Samples ($\times 10^6$)



Side view of the BES detector



End view of the BES detector



VC: $_{xy}$ = 100 m TOF: $_{T}$ = 180 ps

MDC: $_{xy}$ = 220 m BSC: E/ E= 21 %

$_{dE/dx}$= 8.5 % = 7.9 mr

p/p=1.78 (1+p^2) $_{z}$ = 2.3 cm

m counter: $_{r}$ = 3 cm B field: 0.4 T

$_{z}$ = 5.5 cm