Current and Future Charm Experiments

Yangheng Zheng
Graduate University of Chinese Academy of Sciences

Sep. 7, 2010

@ Univ. of Warwick

Outline

- Introduction to the Charm experiments
- Status of BEPCII/BESIII experiment
  - Accelerator and Detector performance
  - Selected results
  - Data taking plan & Future upgrade
- Charm experiments in the future
- Summary

Charm from dedicated colliders

ADONE, FRASCATI ’69-’90

SPEAR, SLAC, ’72-’90

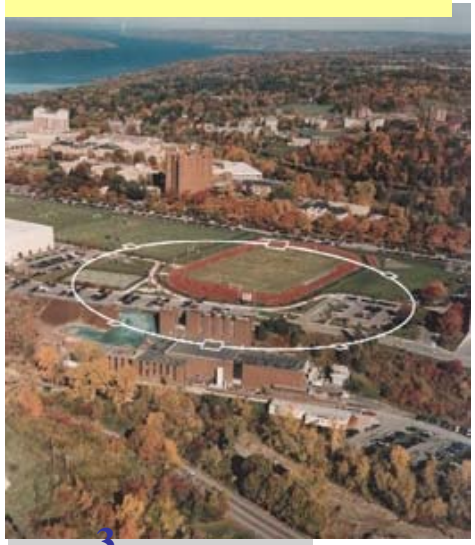
6×10^{29} cm^{-2}.s^{-1}

BEPC, IHEP, ’90-’04

5×10^{30} cm^{-2}.s^{-1}

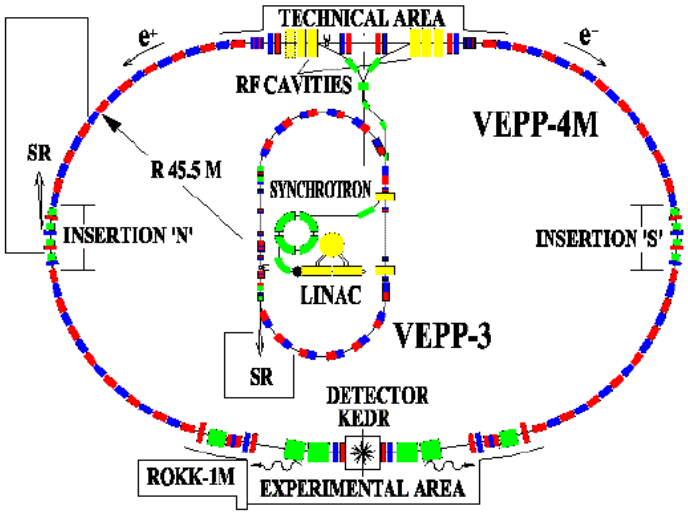
CESRc, Cornell, ’04-’08

7×10^{31} cm^{-2}.s^{-1}



VEPP-4M, Novosibisk, ’02-’12(?)

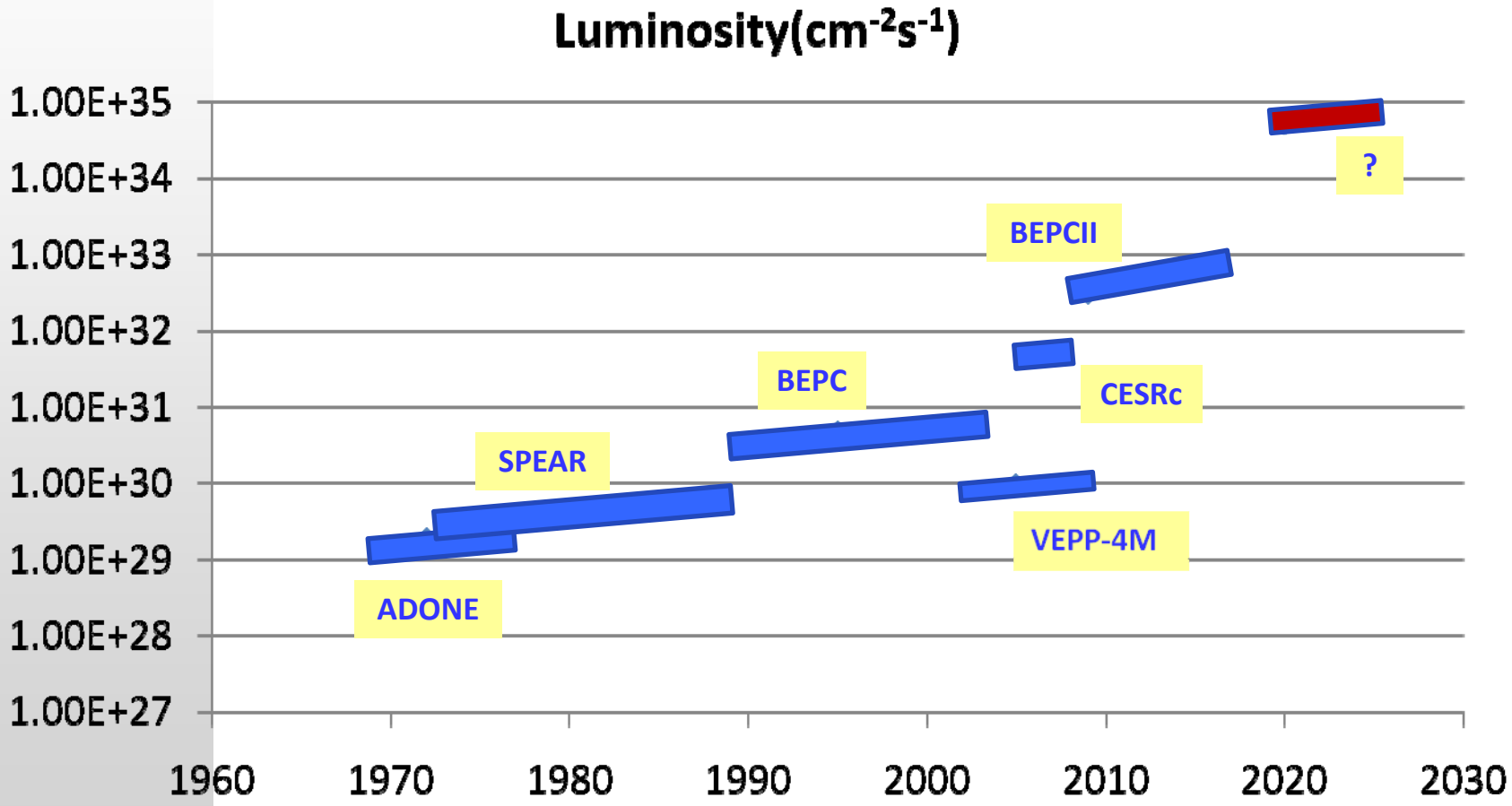
1×10^{30} cm^{-2}.s^{-1}



BEPCII, IHEP, ’08-’18(?)

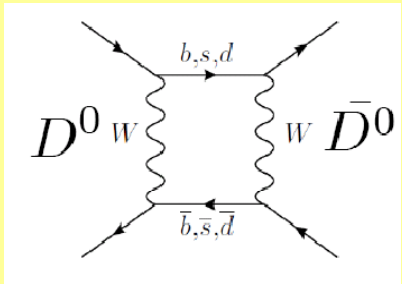
1×10^{33} cm^{-2}.s^{-1}

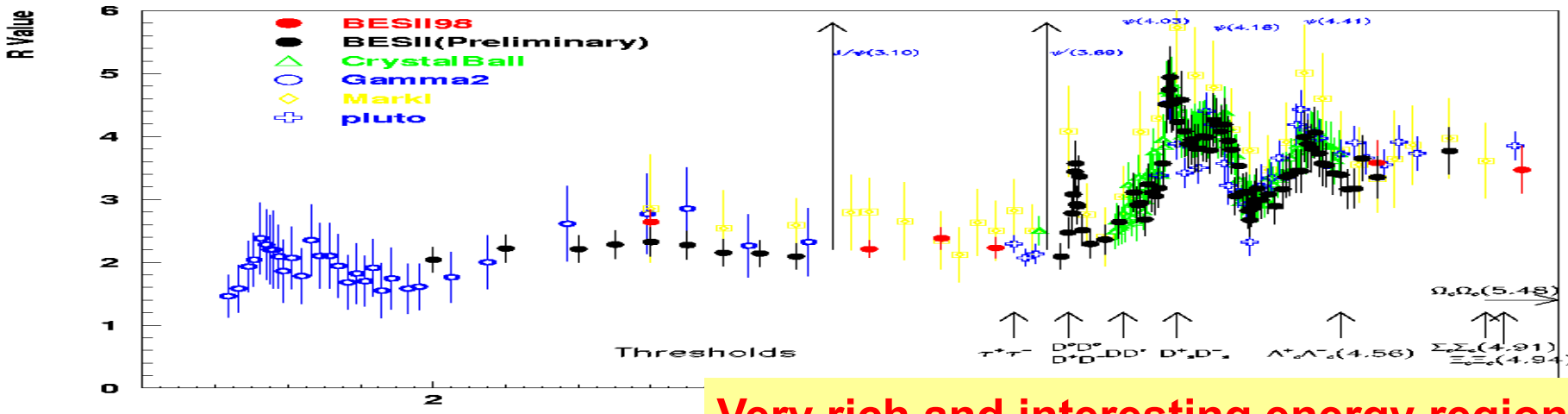
A very long history



Physics of tau – charm region

- **Open charm factory :**
  - precise measurement (~1.6%) of CKM (Vcd, Vcs)
  - f_{D+}, f_{Ds}, form factors in leptonic D decays
  - D^0 - D^0bar mixing
  - CP violation, strong phase.
  - Quantum correlations (ψ“)
  - Absolute BR measurements of D and Ds decays
  - Rare D decay
  - Can provide calibrations and tests of lattice QCD.
  - light meson spectroscopy in D^0 and D^+ Dalitz plot analyses.
- **Search for new physics.**





Very rich and interesting energy region.

Charm meson productions

- Hadron colliders (huge cross-section, energy boost)
  - Tevetron
  - LHC (LHCb, CMS, ATLAS)
- e^+e^- Colliders (clean environment, ~100% trigger efficiency)
  - B-factories (Belle, BaBar)
  - Threshold production (CLEOc, BESIII)
    - Quantum correlations and CP-tagging are unique
    - Double Tag techniques: (partial-) reconstruct both D mesons
    - Ratio of signal to background is optimum
    - Lots of systematic uncertainties cancellation while applying double tag method

BEPCII/BESIII experiment

- A mainstream High Energy Physics project in China
  - A major upgrading from BEPC/BES(II)
  - BEPCII : e^+e^- collider
    - ~60% Physics run
    - ~30% Synchrotron radiation run
  - BESIII: particle detector
  - Start testing run on July, 2008
  - Start official data taking on March, 2009
  - In 2010, 3 Published papers and 5 – 7 more expected

BEPC II Storage ring: Double ring

Beam energy:
1.0-2.3 GeV

Design Luminosity:
1×10^{33} $cm^{-2}s^{-1}$

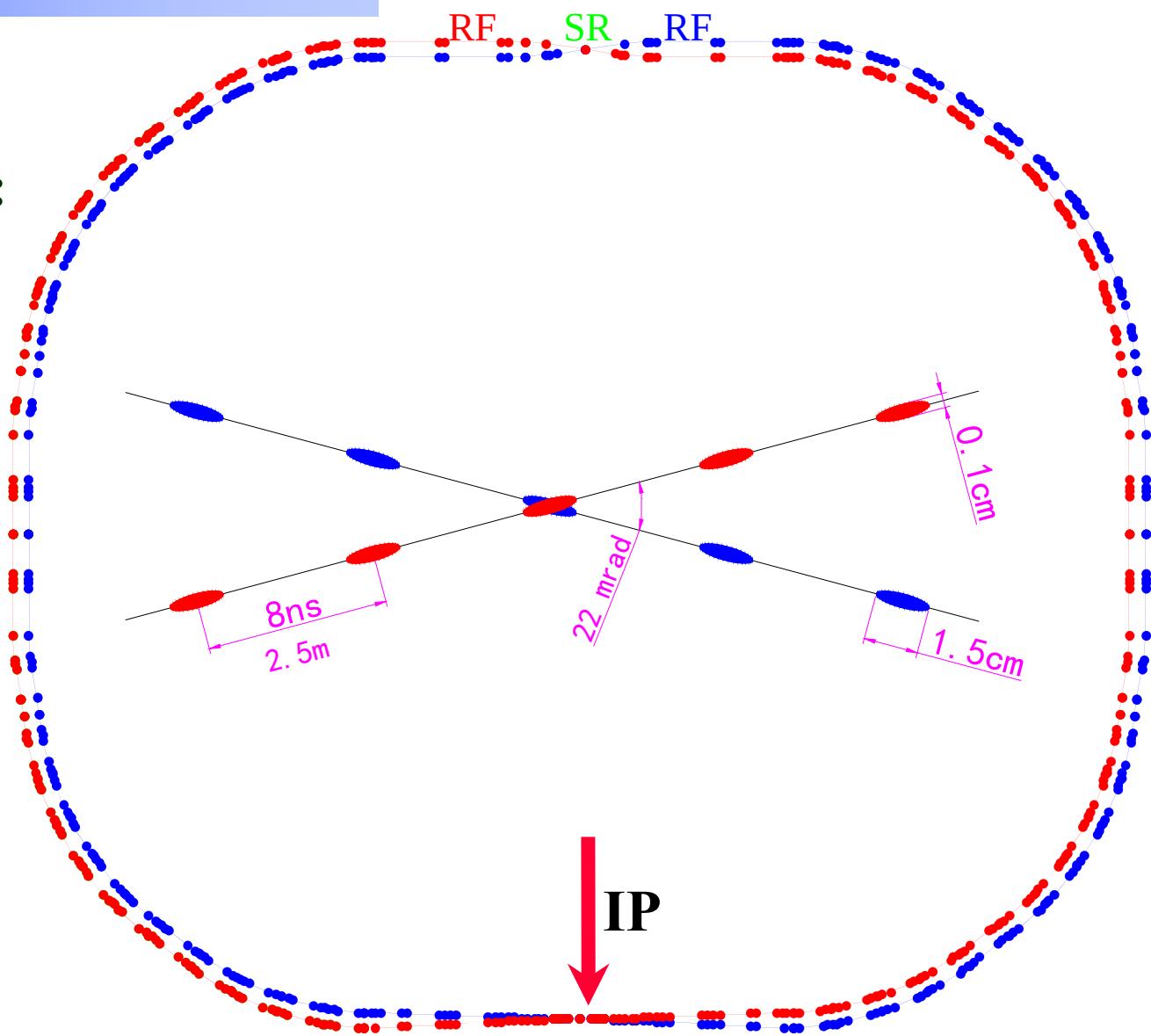
Optimum energy:
1.89 GeV

Energy spread:
5.16×10^{-4}

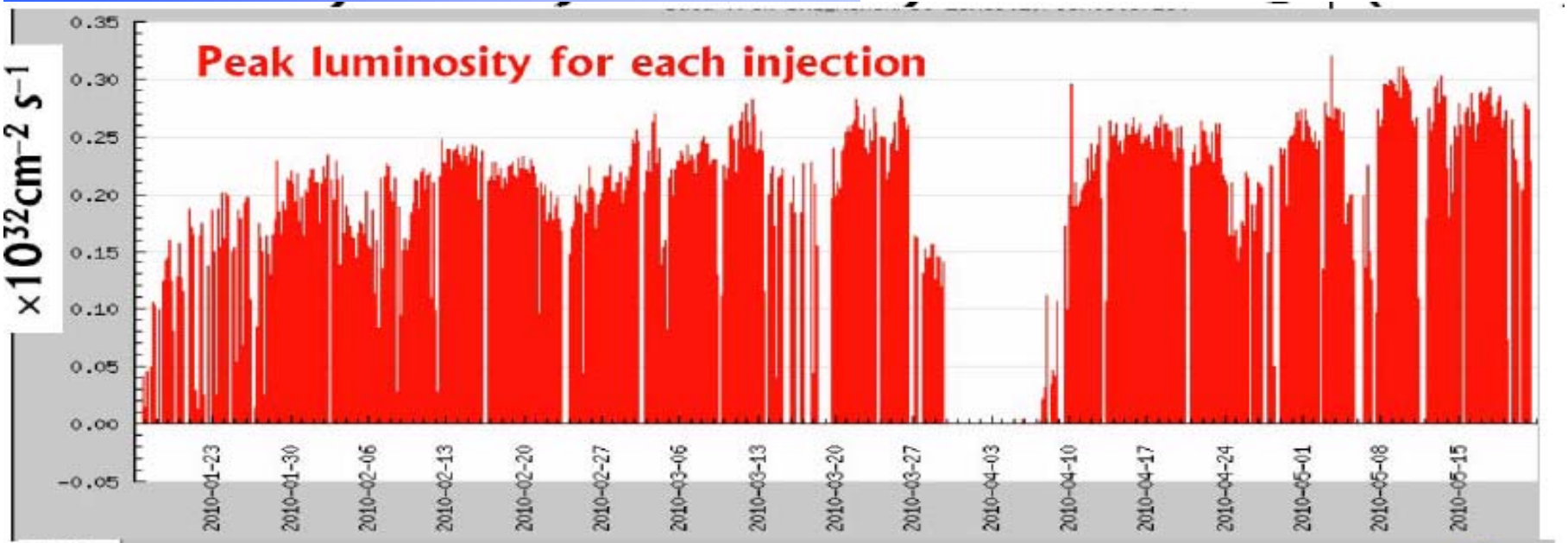
No. of bunches:
93

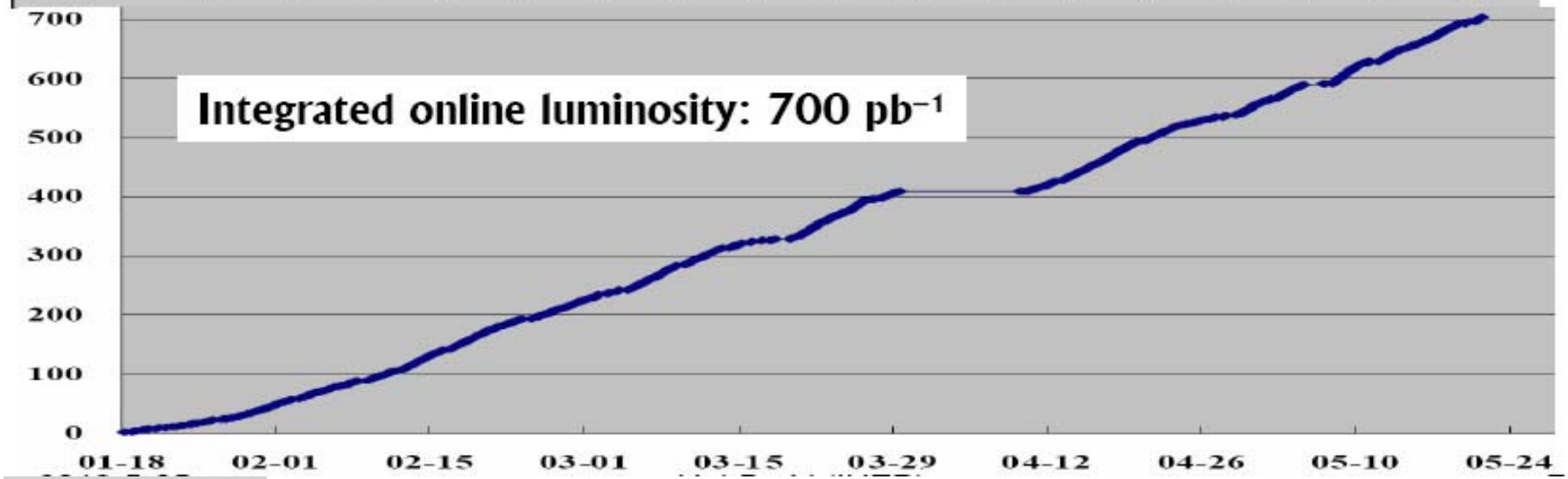
Bunch length:
1.5 cm

Total current:
0.91 A

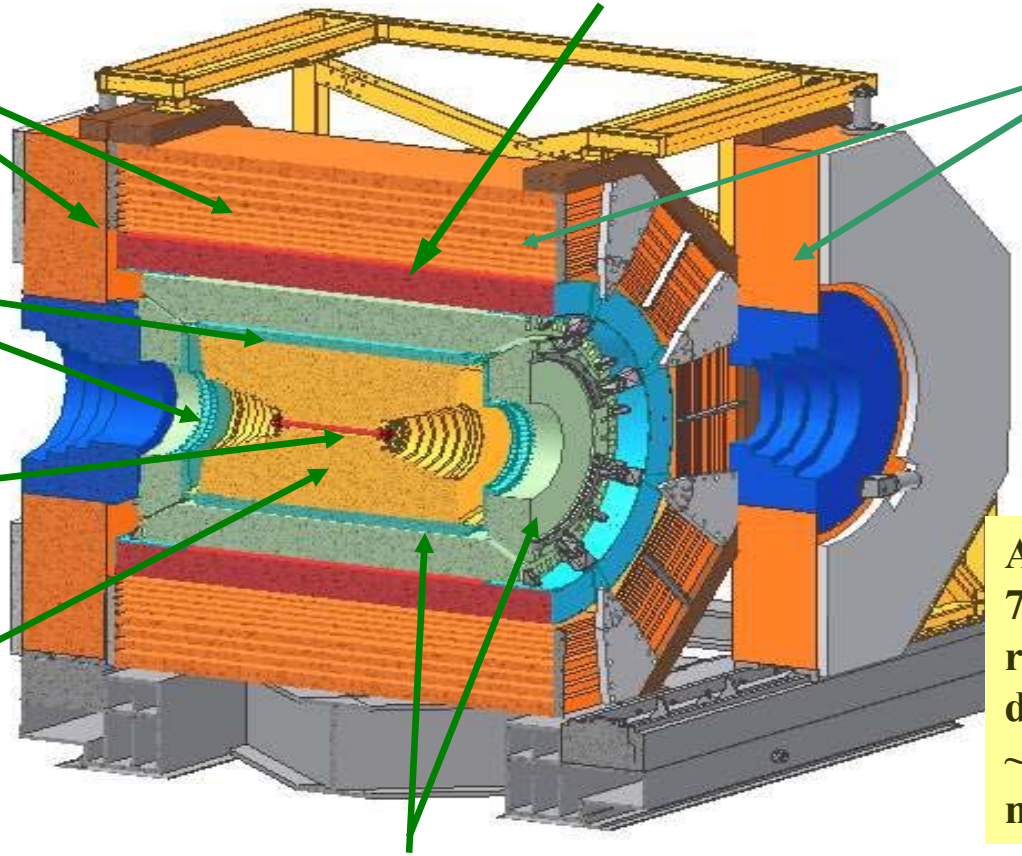


BEPCII Luminosity (Up to May)





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^- Charm colliders

- BESII
  - BEPC: Luminosity@J/ψ ~ $5\times10^{30}/cm^2\cdot s$
  - 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
- CLEOc
  - CESR-c: Luminosity@ψ(3770) ~ $7\times10^{31}/cm^2\cdot s$
  - 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

July 19, 2008: First e^+e^- collision event in BESIII

Nov. 2008: ~ 14M ψ(2S) events collected

April 14, 2009 ~110M ψ(2S) events collected(×4 CLEOc)

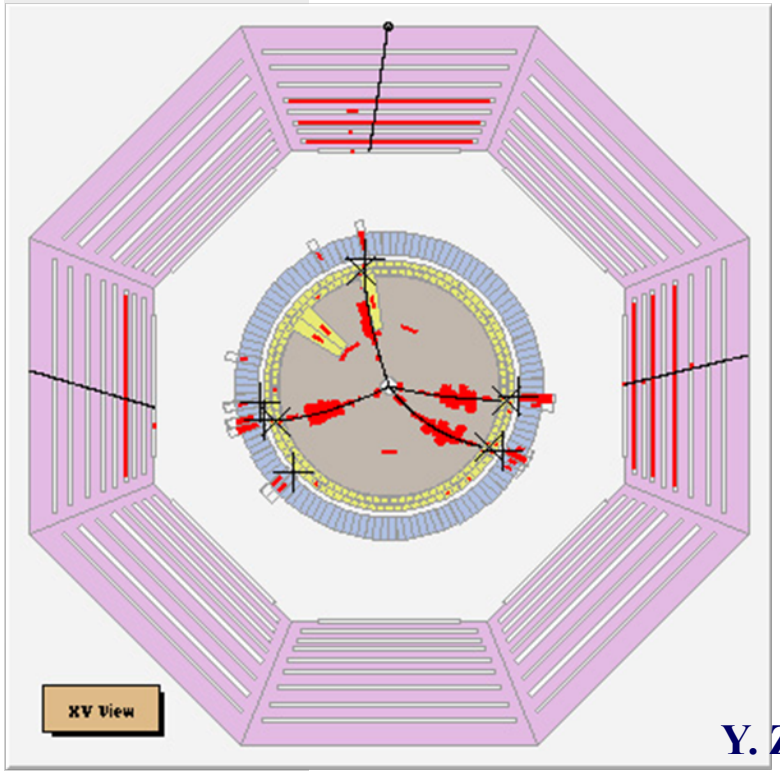
May 30, 2009 42 pb^{-1} at continuum collected

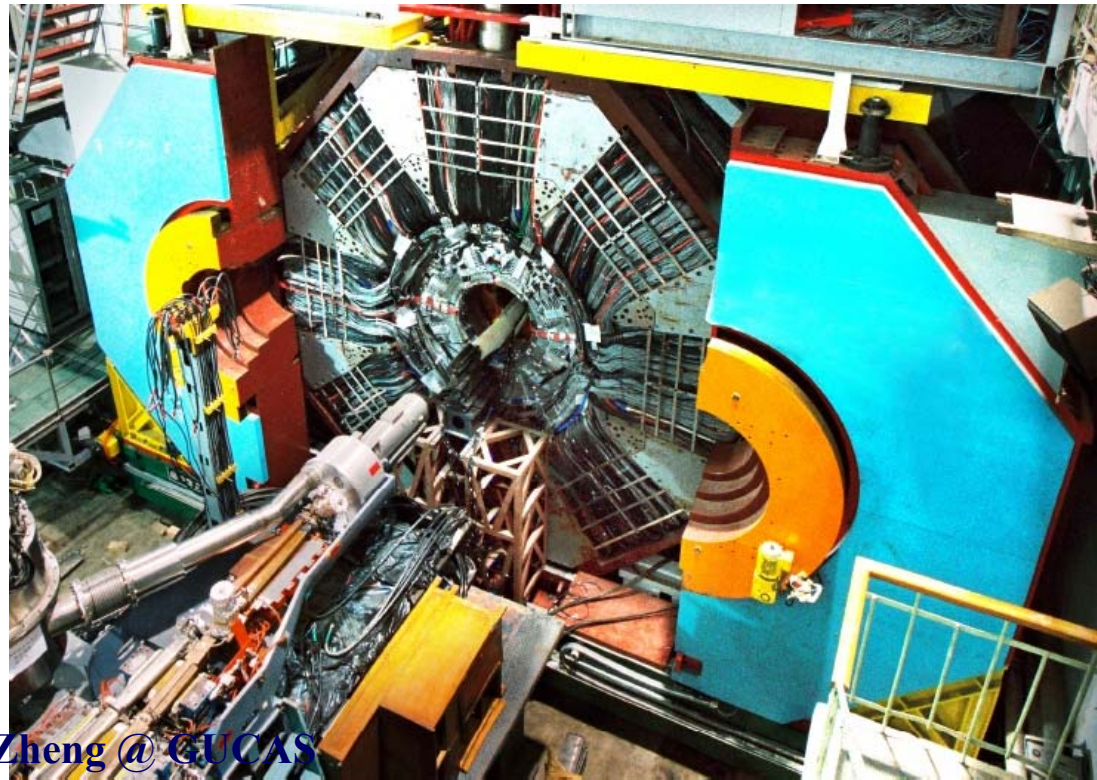
July 28, 2009 ~230M J/ψ events collected(×4 BESII)

February, 2010 3 journal paper published

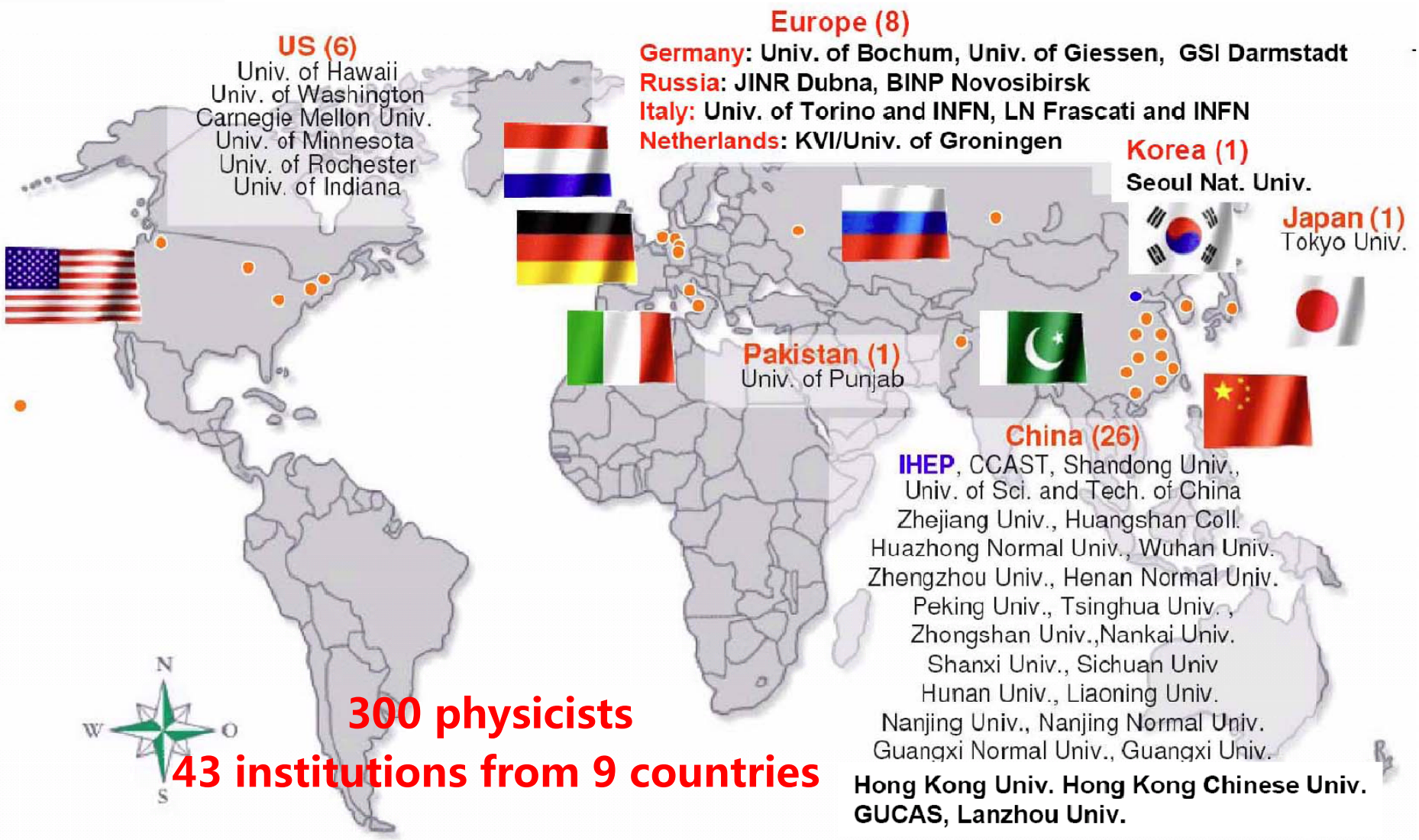
June 28, 2010 950 pb^{-1} ψ(3770) data collected

Peak Lumi. @ Nov. 2008:
$1.2 \times 10^{32} cm^{-2}s^{-1}$
Peak Lumi. @ May 2010:
$3.3 \times 10^{32} cm^{-2}s^{-1}$ ➔
×5 CESRc
×30 BEPC





BESIII Collaboration



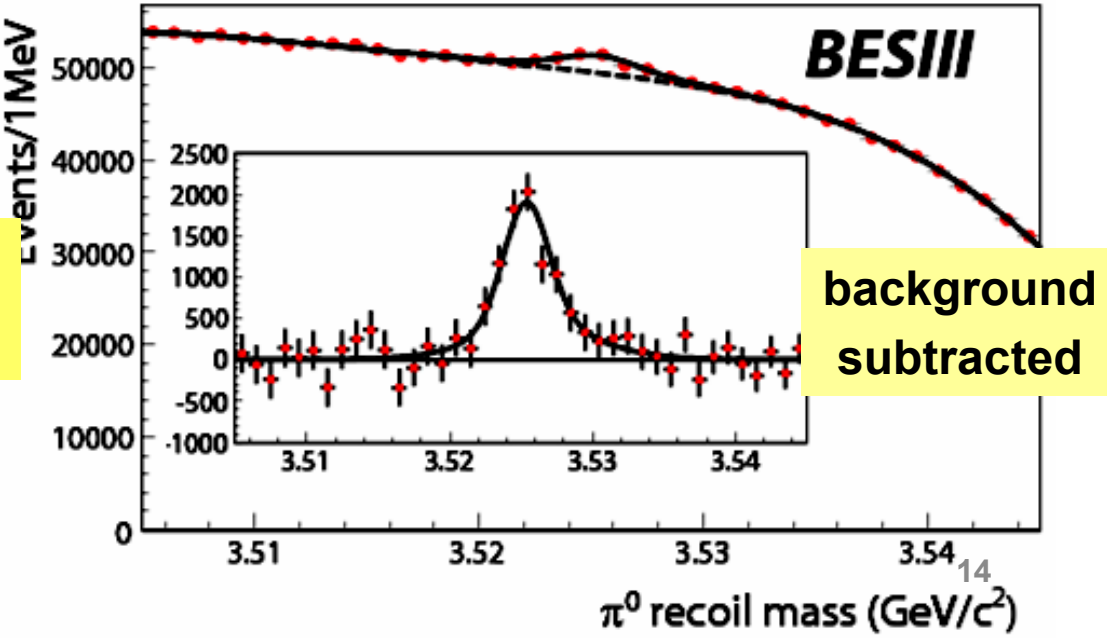
Observation of h_c : Inclusive $\psi(2S)\rightarrow\pi^0 h_c$

- Select inclusive π^0 (untagged)
- Plot mass recoiling against π^0.
- Fit with double-Gaussian x BW signal + 4th Poly. bkg (mass and width fixed to tagged values)
- Combine with tagged results to determine:

$Br(\psi'\rightarrow\pi^0 h_c) = (8.4 \pm 1.3 \pm 1.0) \times 10^{-4}$ (First measurement)

$Br(h_c\rightarrow\gamma\eta_c) = (54.3 \pm 6.7 \pm 5.2)\ \%$ (First measurement)

BESIII Collaboration, PRL 104, 132002 (2010)



14

Data taking plan

- 6-year running plan (Approved by the Collaboration).
- Philosophy: Keeps 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	Running
2010	$\psi(3770)$ and $\psi((3770)$ scan
2011	J/ ψ (+ ψ (2S))
2012	$\psi(3770)$ or $\psi(2S)$
2013	Ds + R (E > 4 GeV) or $\psi(2S)$
2014	$\psi(2S)$ or Ds + R (E > 4 GeV)
2015	R (E < 4 GeV) and τ

- Up to June 28, 2010, 950 pb^{-1} $\psi(3770)$ data collected (Including ~70 pb^{-1} $\psi(3770)$ line shape scan data)
- 10 fb^{-1} open charm data expected in total

Status of BEPCII/BESIII

- **BEPCII**
  - Commissioning and stable running of Linac necessary
  - 1/3 of the luminosity design value was reached, further studies are needed.
  - The dark current of detector limits the beam current right now, and needs to be improved.
- **BESIII**
  - 15 analysis memos are under the referees review, and 5 - 7 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 (expecting <1% per track)

To enhance luminosity

- **Conventional ways:**
  - ✓ Increase bunch current, beam current
  - ✓ Shorten bunch spacing to get more bunches collision
  - ✓ Squeeze β_y^*
  - ✓ Move transverse tunes closer to half integers
- **Possible peak luminosity:**

  $L \sim 5\times10^{32}\ cm^{-2}s^{-1}$ @ 1.89GeV

Long term upgrade

- BEPCII
  - Crab-waist for higher luminosity
    - Some changes in the IR (crossing angle of collision beams, magnets' positions near the IP, etc.)
    - Limit from the constraints of BESIII solenoid
  - Beam Energy: Emax = 4.6 GeV $\Rightarrow$ 5 GeV
  - Collision with (e^-) polarized beam
- BESIII
  - PID system
  - Inner Drift Chamber

Future Charm Experiment(s)

- Hadron Colliders
  - FAIR/PANDA Experiment (Under construction, operating on 2015?)
  - Fermilab proposals
- e^+e^- Colliders (Running at threshold?)
  - Super tau-Charm factory
  - Super B factory (Approved, complete on 2014?)
  - Super Flavor factory (Linear collider?)
- Other ideas…

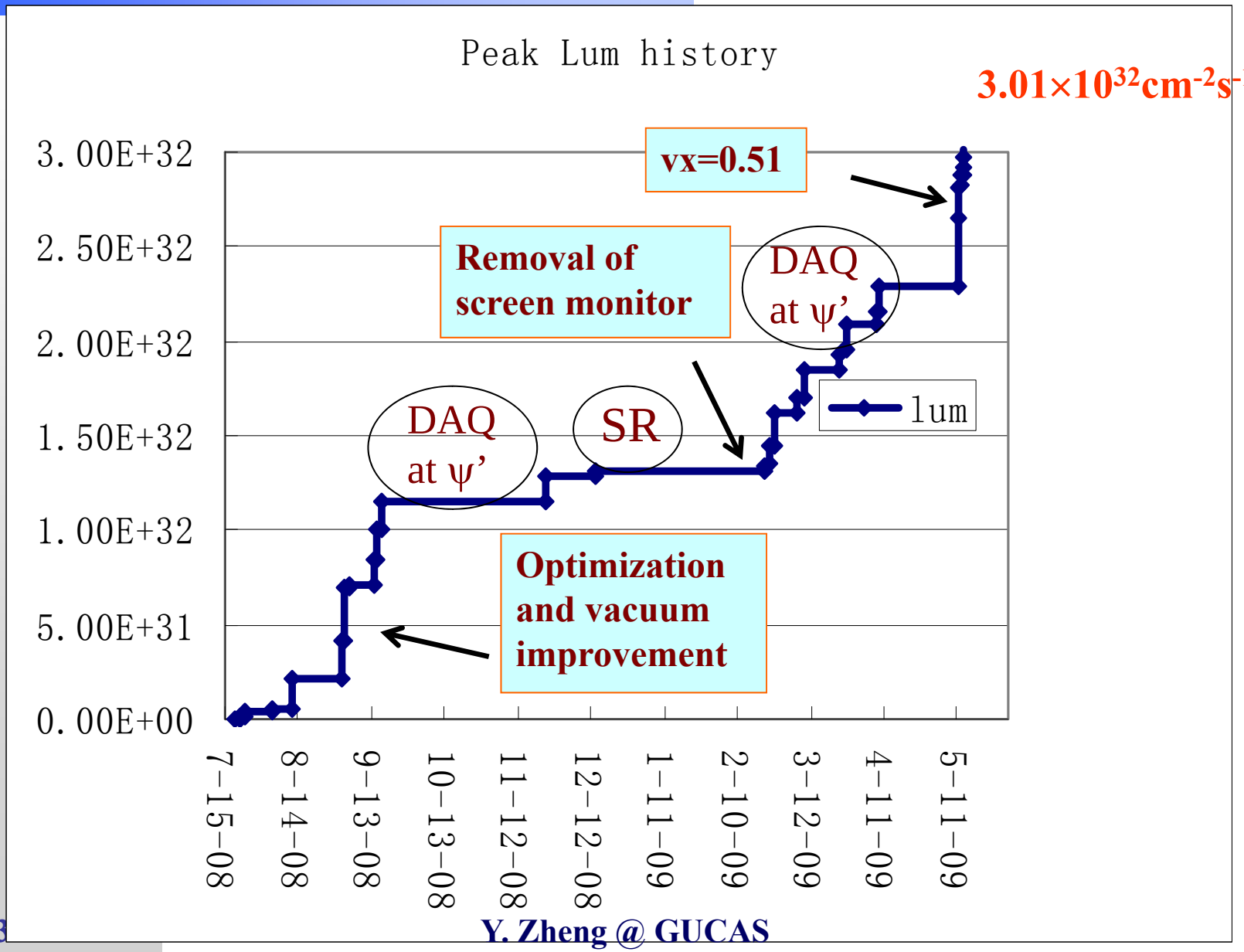
Summary

- BEPCII reached a luminosity of 3.3×10^{32} cm^{-2}s^{-1}
- BESIII detector performance excellent, physics results published
  - High quality data samples in hand (110 M ψ' and 230 M J/ψ, 950pb^{-1} $\psi(3770)$ data obtained)
  - Analysis in progress, more publications in a few months
  - "Open Charm" analyses have already be launched, expect more exciting results
- Few billions of J/ψ and ψ' , ~10 fb^{-1} open charm data will be accumulated in the future
- Rich physics topics in Charm sector. More experiments are coming.

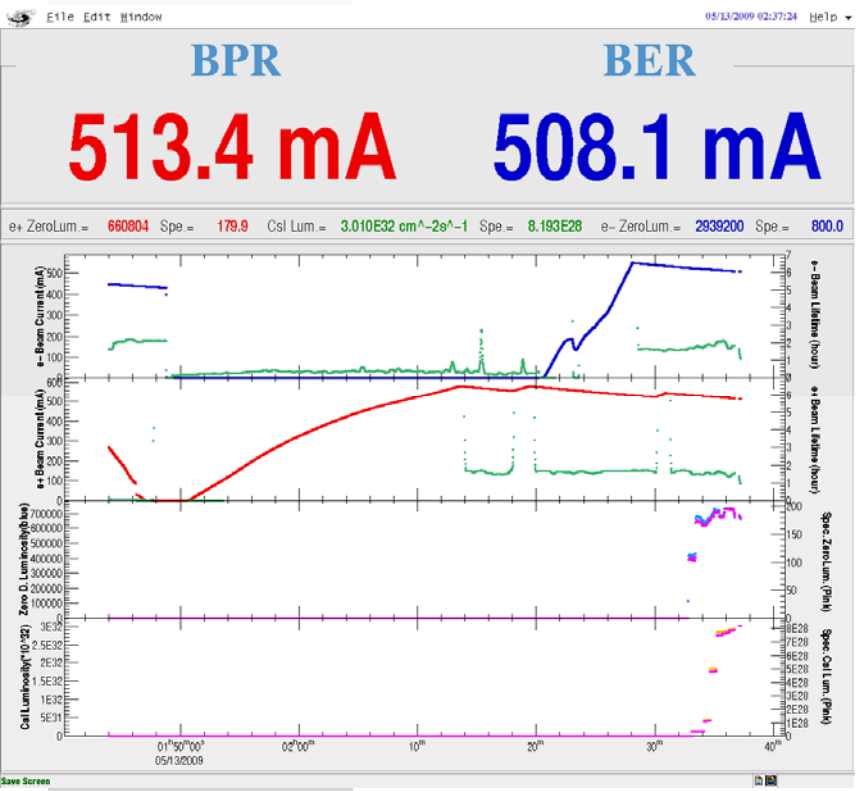
Thank you

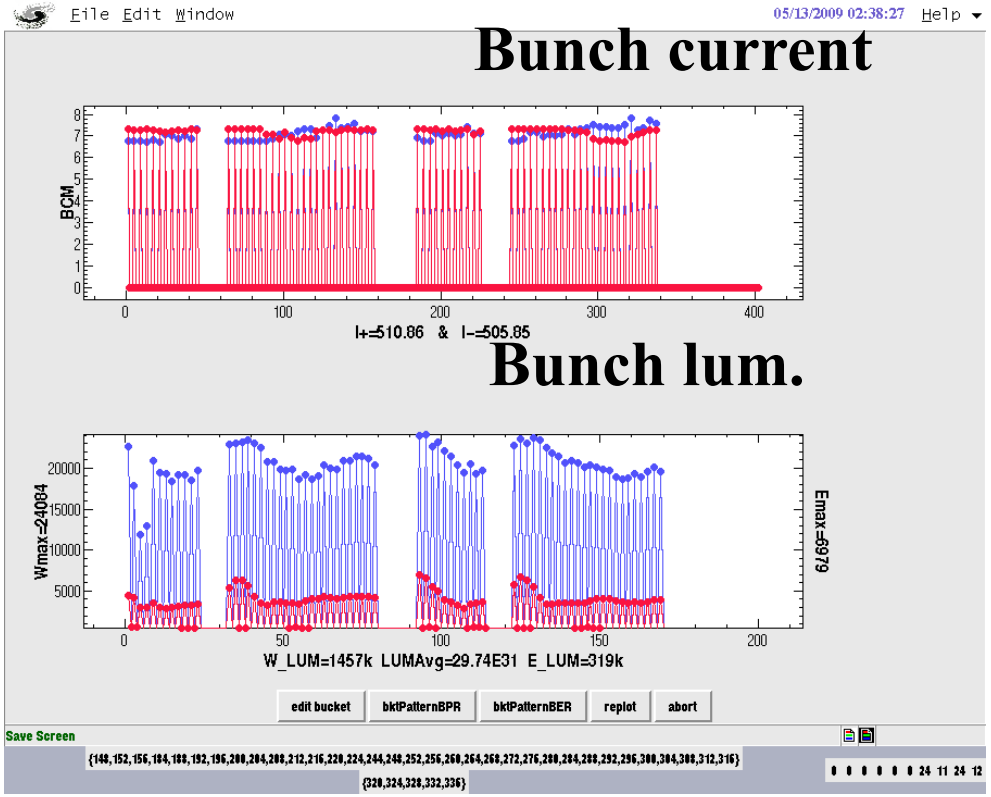
Backup slides

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	

Problems on the way of further upgrades

- Heating of bellows, vacuum chamber, etc.
- Background when bunch current increases
- Possible ECI after bunch current increases or bunch spacing shortening
- Longitudinal instabilities after bunch spacing shortening
- Etc, etc.

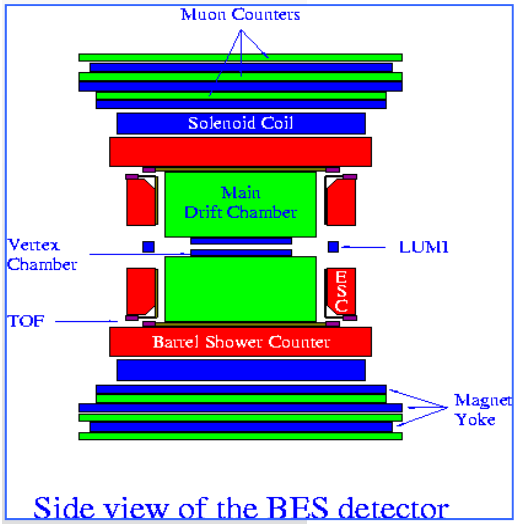
Long term upgrade of the BEPC-II

- ✦ Crab-waist for higher luminosity
- ✓ Some changes in the IR (crossing angle of collision beams, magnets' positions near the IP, etc.)
- ✓ Limit from the constraints of BES solenoid

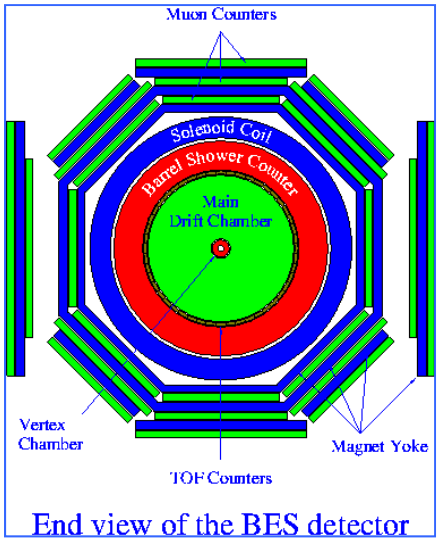
- ✦ Collision with polarized beam
- ✓ Physics requirement
- ✓ Possibility of realization (e- beam? Location for rotators?)
- ✓ Budget limitation
- ✓ Other problems…

BESII Detector

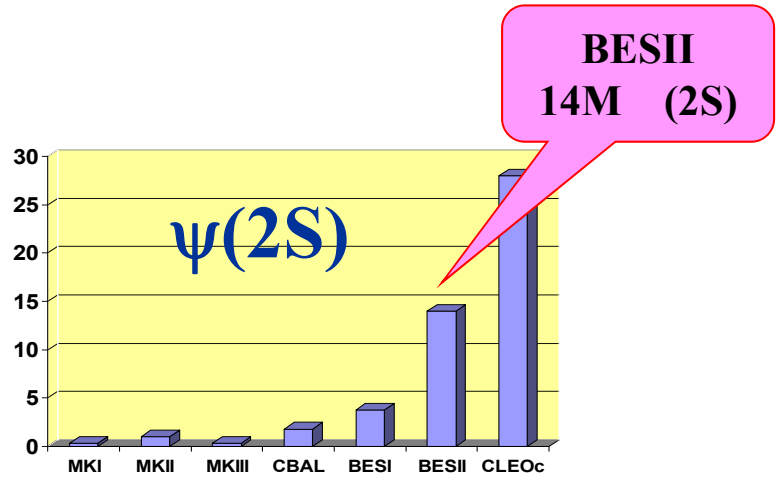
World J/ and (2S) Samples ($\times 10^6$)



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