First Results from BESIII: Charmonium à la Carte

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(+ CLEO & BESIII)

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NSF

Outline

Introduction: Collaborating in Beijing

Status: The BEPCII Accelerator & BESIII Detector

Charmonium Physics

1) h_c studies: absolute BF — **PRL 104,132002 (2010)**

2) $\chi_{c0}, \chi_{c2} \rightarrow \pi^0\pi^0, \eta\eta$ — **PRD 81, 052005 (2010)**

3) Low-mass p pbar enhancement in tagged $J/\psi \rightarrow \gamma p \bar{p}$ — **CPC, to appear (?)**

2010: First Open Charm Data Run

Conclusions

[more info: http://bes3.ihep.ac.cn/]

Introduction:
Collaborating in Beijing

BESIII Collaboration

25 Chinese groups (IHEP host lab + Universities)

8 European (3 German, 2 Italian, 2 Russian, 1 Dutch)

6 US groups (see next page)

3 other Asian (Japan, Korea, Pakistan)

Still adding new groups...

First papers: 36 groups (of 42 listed above)

293 Authors; 148 from IHEP

CLEOns @ IHEP

Carnegie Mellon: Briere + postdoc Chunlei Liu

dE/dx calibration (both); DTag software (Liu);
(open) Charm co-convener (RAB)

U. Minn: Poling, Cronin-Hennessy + pdoc Zweber + grads

MC Farm; DTag Coordinator (Zweber -> industry soon)

U. Rochester: Thorndike + many

Indiana U.: Shepherd, Mitchell, + ?

Past Interest from:

RPI (no $$), Florida (Yelton settled on CMS)

Other US groups: Hawaii (F. Harris only PI; S. Olsen now in Korea),
U. Washington (small: 1 author)

More on (sic) Working in Beijing

Collaboration meetings

- 2 per year; 1 @ IHEP, 1 @ Chinese university
  "typically" Jan & summer; in some flux
- 2 additional software workshops per year

Lots of "video"conference meetings (or just audio +pdf)

- Beijing is EDT+12 hrs (EST+13) easy to remember, hard to do !
- ~bi-weekly Physics/Software meeting
- ~bi-weekly "PTA" meetings (charm, charmonium, light hadrons)

I tried to take Chinese last fall, on sabbatical

- Characters and a tonal language: tough combination
- I did learn a lot more than I had picked up on the fly
- I can bargain while shopping with Chinese numbers now
- But... the single biggest thing I learned:

All teaching faculty should take a course every 10 years or so ! (it's my 11th year)

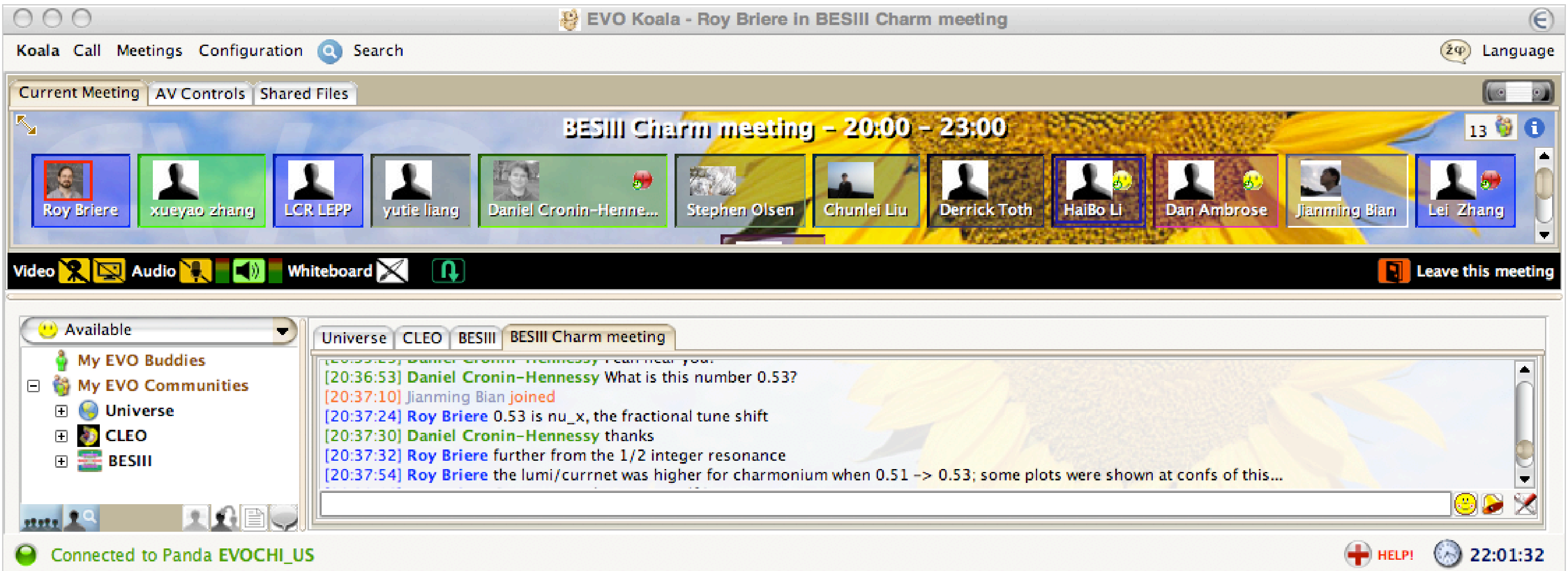
- It's hard to learn something you *<u>don't already know</u>*
- I suspect it's even harder to do 4-5 at once
- I kind of gave up 1/2 way through
  (ironically, when I missed some classes due to being in Beijing…)

But I can say things like:

Nihao! Wo jiao Roy; wo shi wu li laoshi.

(and I'm ever-so-slightly nicer to my students)

Large EVO-based Meeting…



Organization: CLEO-esque

Officers

Conveners ("PTA" chairs)

Standing committees

Paper committees

Different: Executive Board, Institutional Board

Status:
The BEPCII Accelerator
& BESIII Detector

BEPC II

Key features vs. CESR-c

- Two-Ring machine (BEPC → BEPCII)
- Smaller radius (built for low energy)

  So equal stored *current* is fewer particles than CESR…
  But, *collision frequency* is correspondingly higher

What I miss:

- Control room is not as close to counting room
- Can't read an online machine log

So… it's hard to get a good feeling of what's happening in real time !

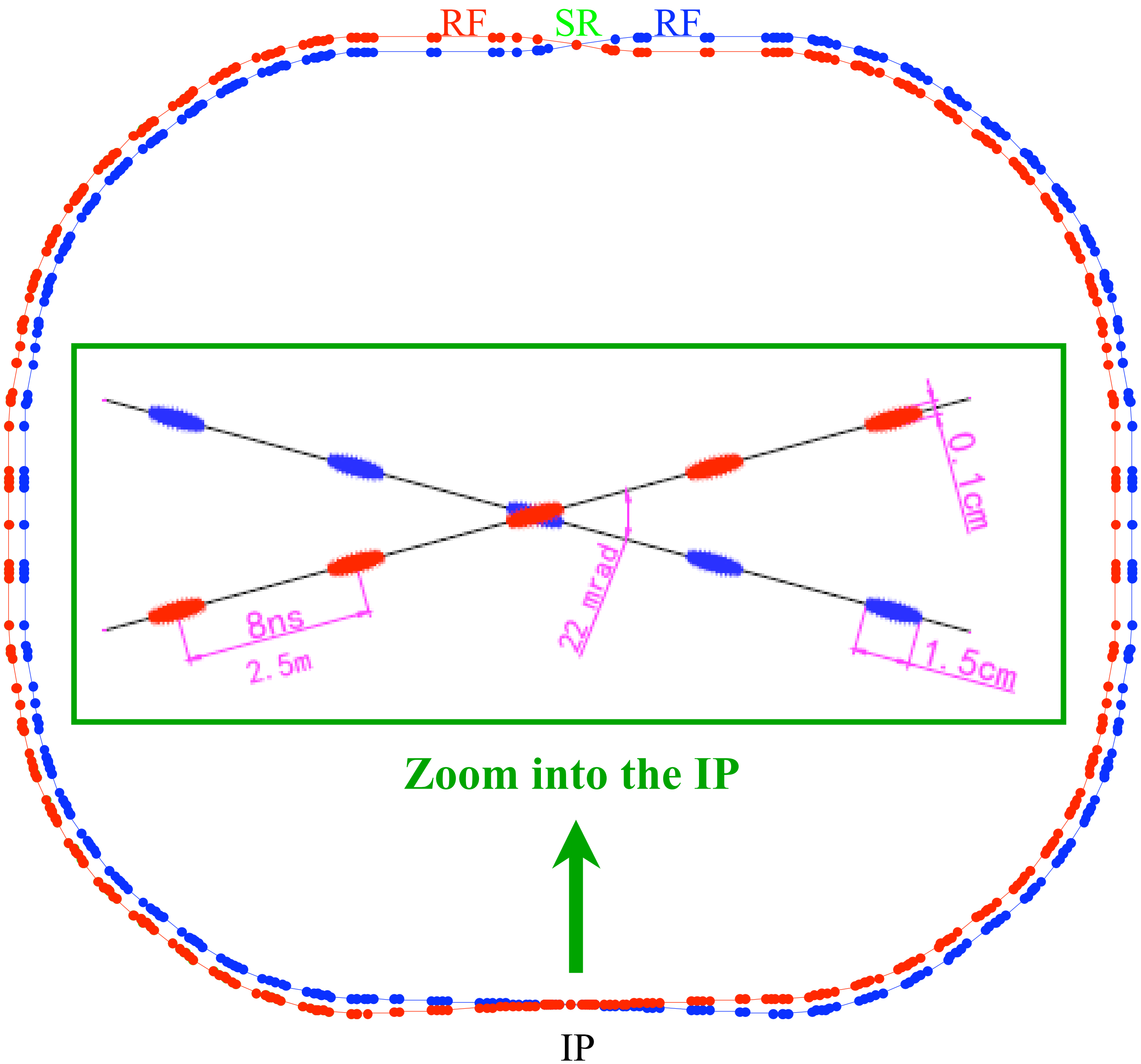
Have lately been trying to have Chinese speakers in US groups translate Chinese minutes of weekly "runman" meetings…

But I can see currents, luminosity, etc. in real time

(some plots a bit later on… and as a database, unlike CESR scoreboard)

BEPC II Storage ring:

Large crossing angle, double-ring



Beam energy:
1 - 2 GeV

Luminosity:
1×10^{33} $cm^{-2}s^{-1}$

Optimum energy:
1.89 GeV

Energy spread:
5.16×10^{-4}

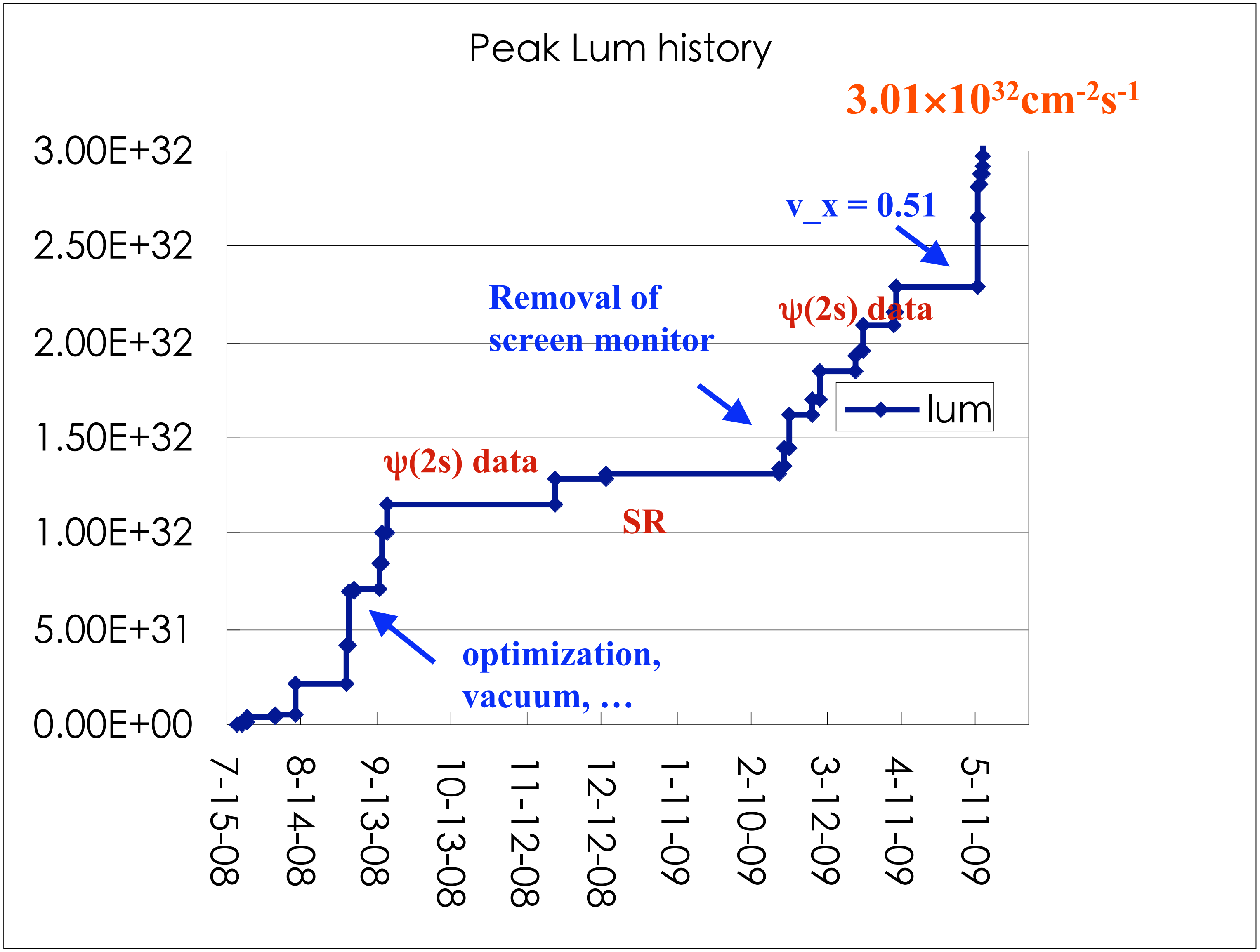
No. of bunches:
93

Bunch length:
1.5 cm

Total current:
0.91 A

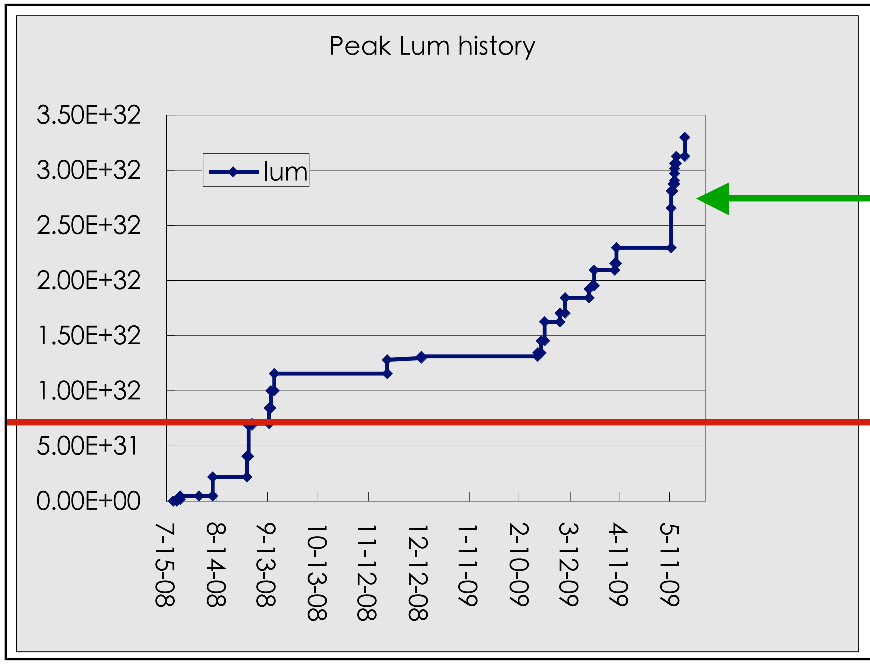
SR mode:
0.25A @ 2.5 GeV

BEPCII Peak Luminosity trend (2008-7-15 to 2009-5-13)



Peak Luminosity History

Luminosity



July '08 May '09

Rapid rise:
response to a government mandate to meet a goal

CESR-c maximum achieved
[CESR-c accelerator with CLEO-c detector]

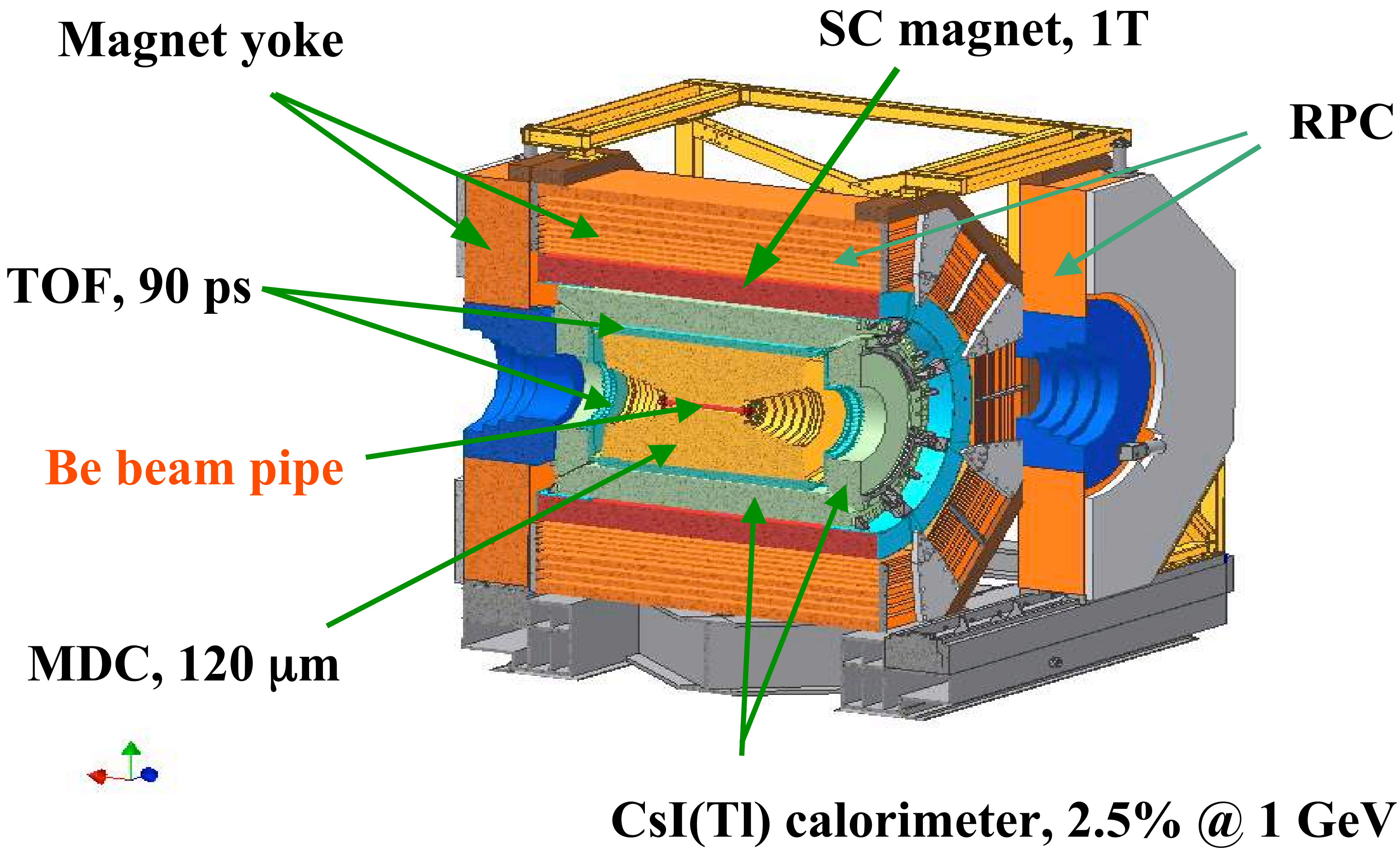
After less than one year, new BEPCII accelerator provided more than four times the best collision rate from CESR-c !

Main parameters achieved in collision mode

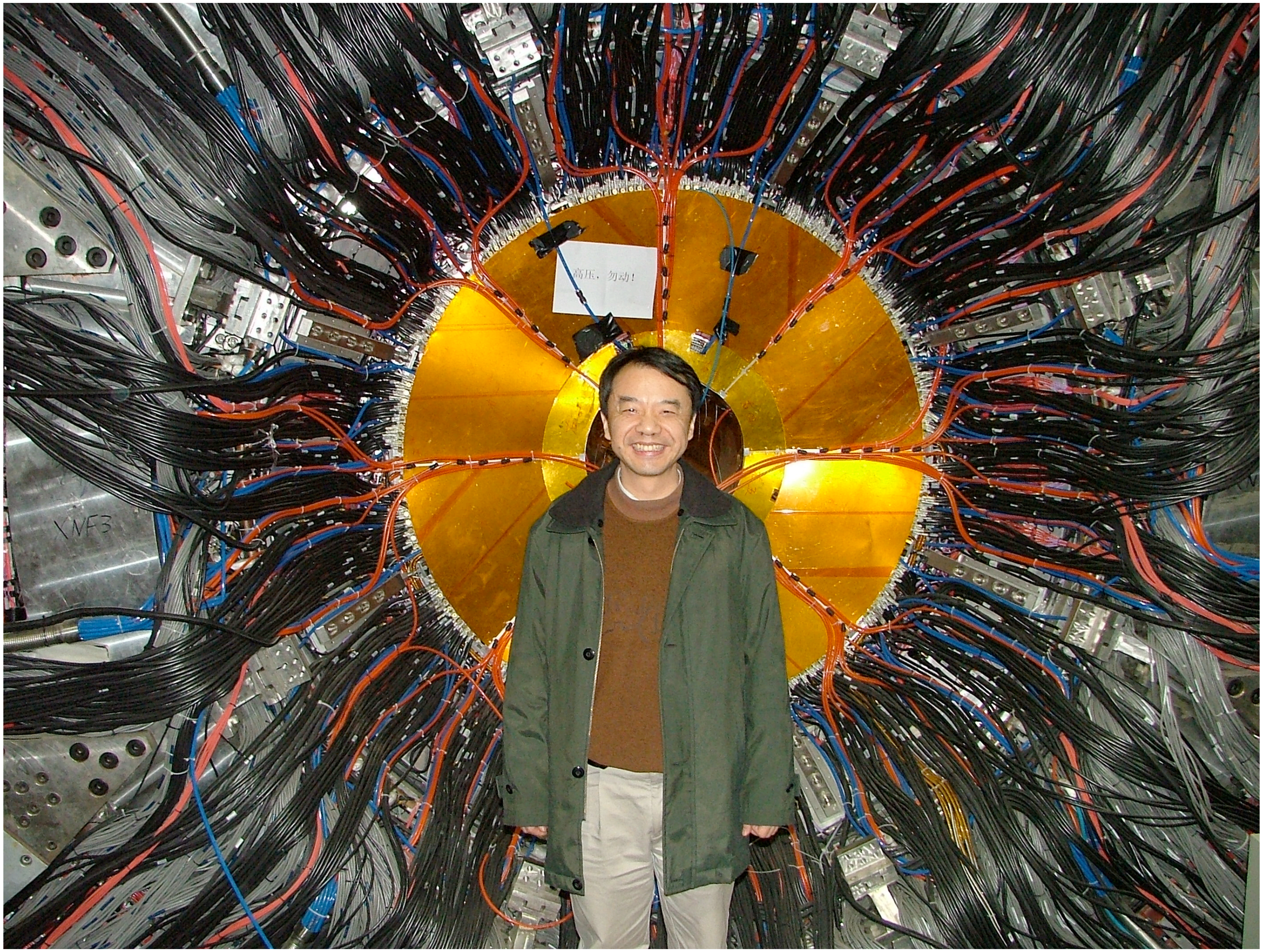
(may be a bit dated now…)

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	

BESIII detector



Spokesperson Yifang Wang in front of BESIII (Jan'08)



BESIII Detector, vs. CLEO-c

Key features vs. CLEO-c

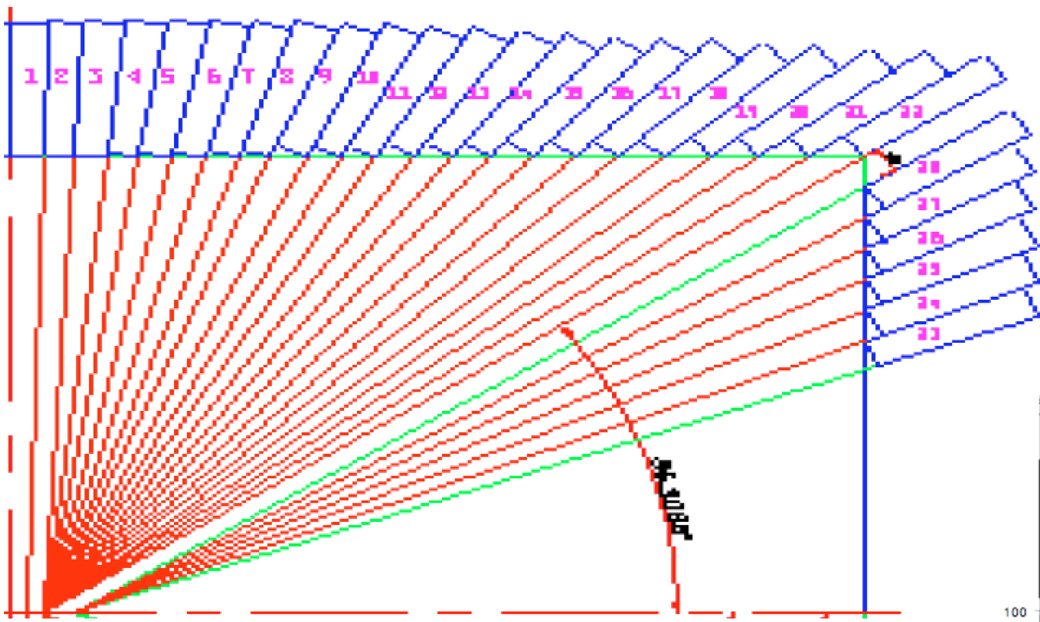
- All-in-one drift chamber
- TOF, not RICH, to aid dE/dx
- Gap between CsI barrel and endcap
- More ambitious muon system

Design and Construction of the BESIII Detector
NIM A614 (2010) 345-399

Chinese Physics C also has many (~20) articles on tests, software, calibration, MC studies, etc.

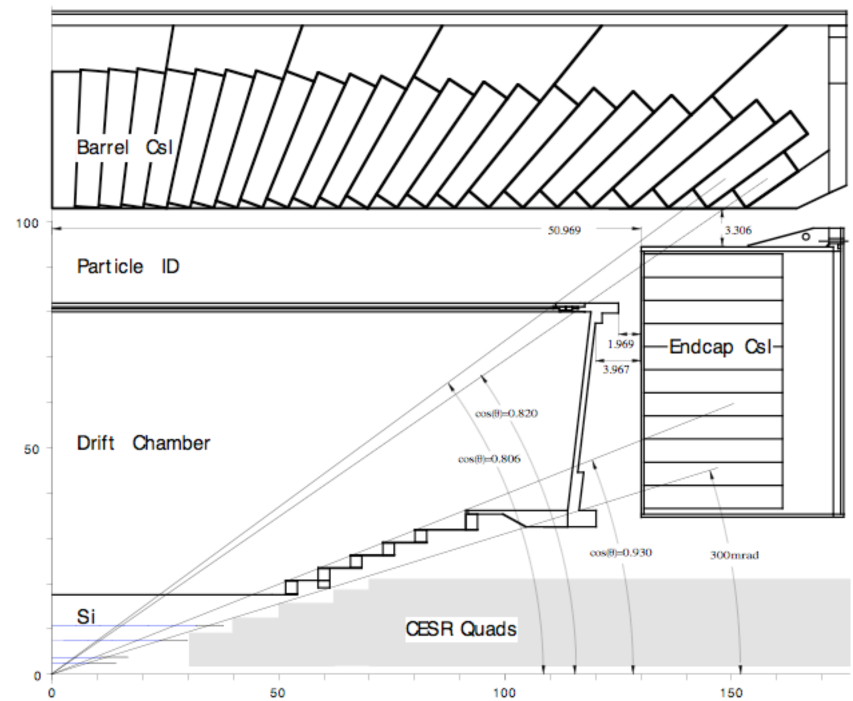
EMC: Projective Endcap, but w/ gap

A bit different than CLEO



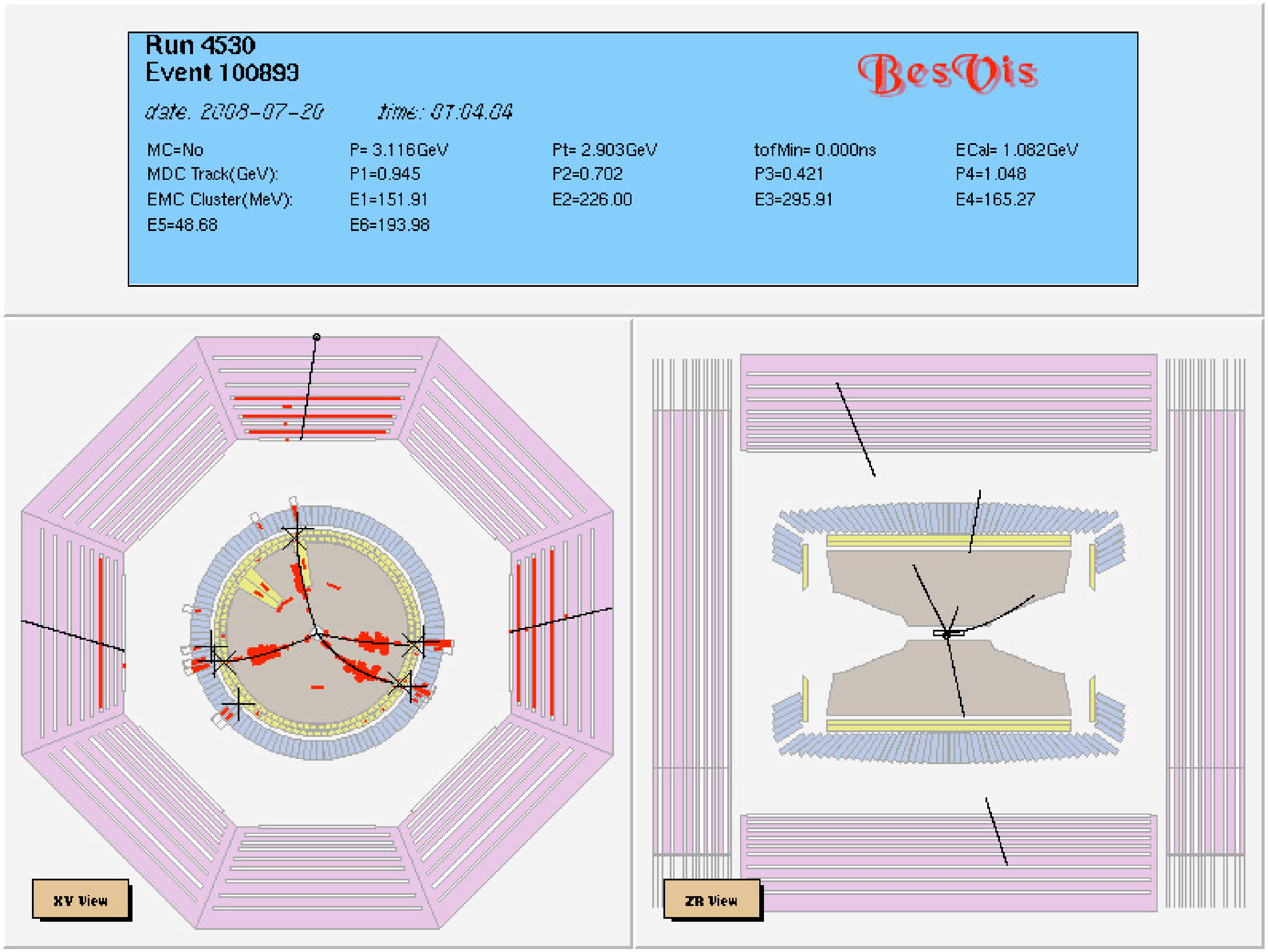
BESIII

CLEO-c



BESIII Counting Room

First collision event on July 19, 2008



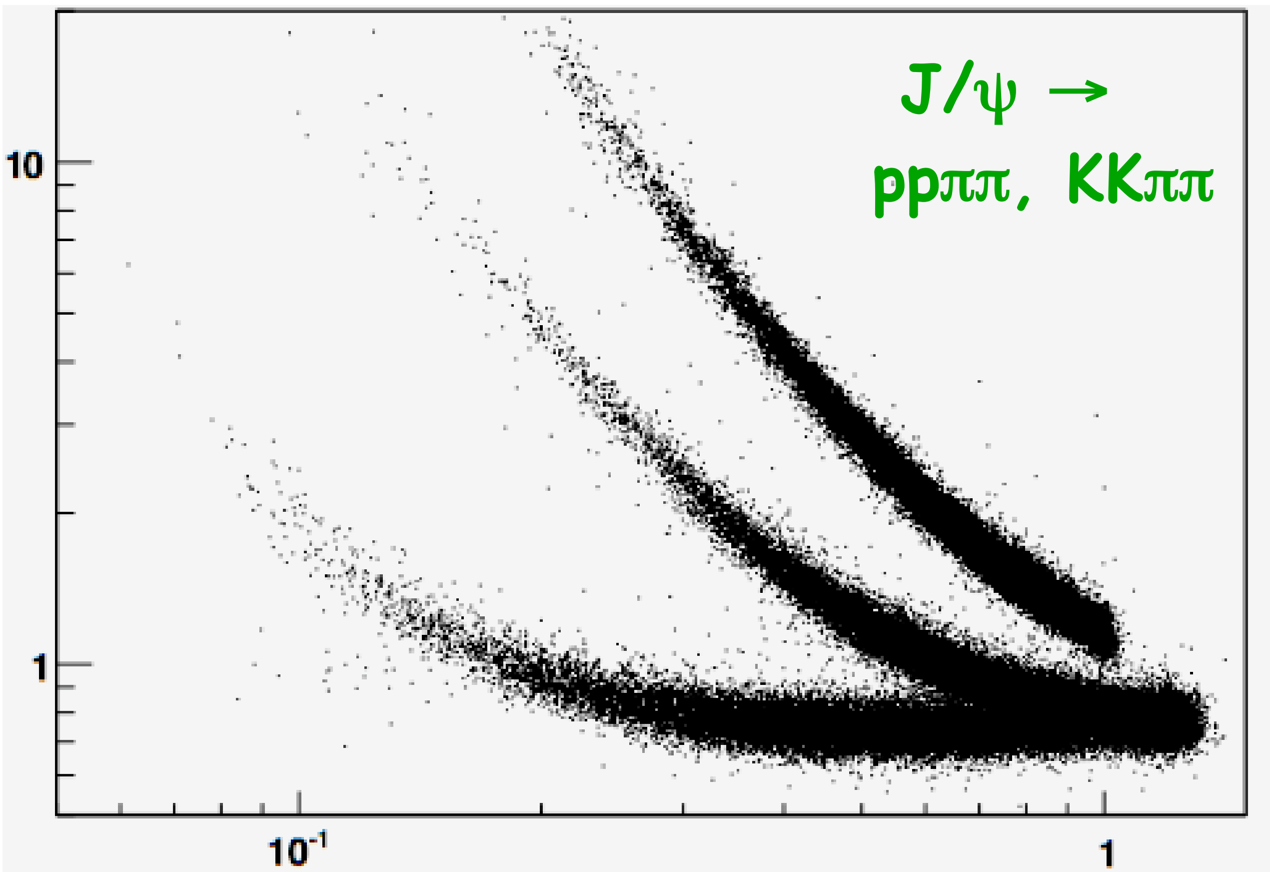
13 Million ψ(2S) events collected in 2008 (engineering data)

dE/dx Calibration

Manpower:

Chunlei & I from CMU [see, Ed? I wrote "I" !]

Student(s) from IHEP + (busy!) supervisor



Note: I look at J/ψ data with 2 undergrads; good practice for me…

Flies in the Ointment

Overall, a very smooth start-up, but…

Drift chamber noise limits currents; some reduced HV

Muon endcap has never really functioned properly

(conveniently, the least important detector)

One bad experience w/ cooling water & electronics

Positron injection slow… improving

limits turning peak lumi into integrated lumi

Equipment breakdowns:

> quite rare overall

> quenches mostly only early on

> misc. magnet issues (only one serious recently)

Charmonium Physics

Charmonium Samples

2008:

Startup in July, engineering data

2009:

~105 M ψ' (vs. 27 M @ CLEO-c)

~225 M J/ψ (vs. 57 M @ BESII: w/ poor EMC)

Beam-energy spread a bit smaller than CESR-c, so effective cross-section is a bit higher… [~10% ?]

Synchrotron runs are separate; about 5 months of HEP physics running per calendar year

(some things never change…)

h_c Introduction

Last low-lying charmonium state; found by CLEO-c

BES analysis:

- Inclusive: $\psi' \to \pi^0 h_c$ using π^0 recoil mass
- E1-tagged: inclusive plus see γ from $h_c \to \gamma \eta_c$

Use both to get separate absolute Branching Fractions

Data Samples:

- (106 ± 4) Million ψ'
- 42.6 pb^{-1} @ 3.65 GeV

h_c Analysis Cuts

Barrel γ: $E_\gamma > 25$ MeV $|\cos\theta| < 0.80$

Endcap γ: $E_\gamma > 50$ MeV $0.86 < |\cos\theta| < 0.92$

Isolation: $>10^o$ from any track

π^0: 120 - 145 MeV (about -1.5 to +2.0 σ)

1-*C* kinematic fit improves E resolution

raise barrel cut to $E_\gamma > 40$ MeV

[also "no other π^0 veto" for all transition γ, plus π^0 in incl. analysis]

Candidate events:

a) at least two tracks, at least one passing:

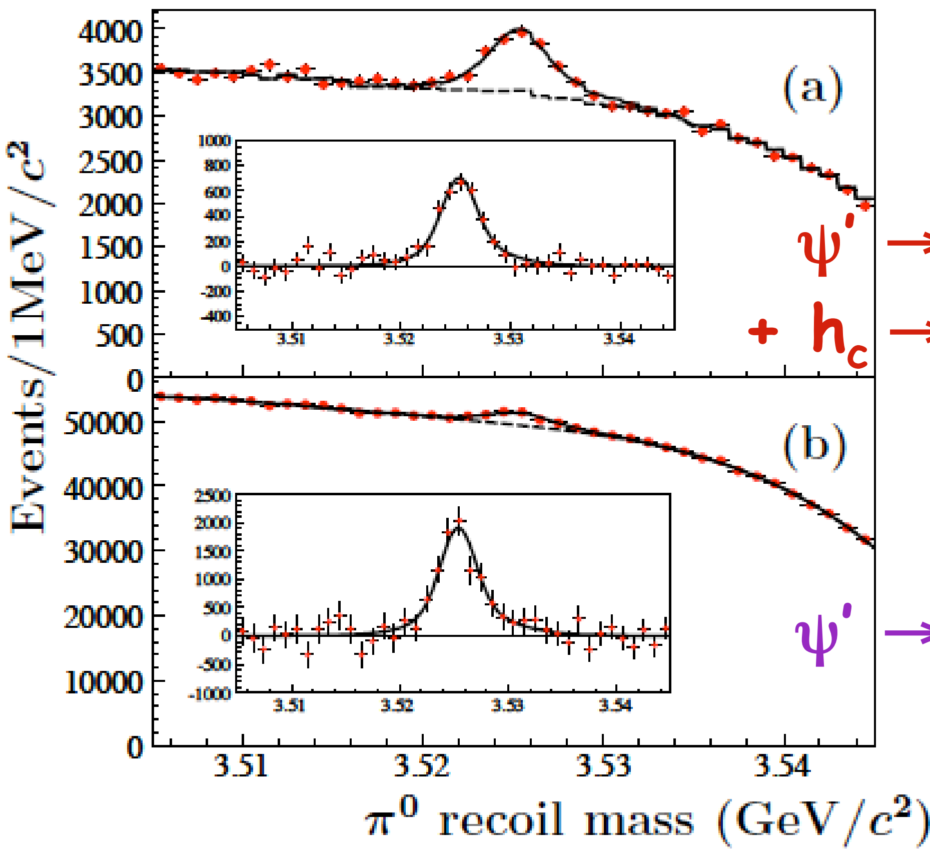
$|\cos\theta| < 0.93$ $|\Delta z| < 10$ cm $|\Delta r| < 1$ cm

b) >0.6 GeV in EMC

Background suppression:

$\pi^+\pi^-$ ($\pi^0\pi^0$) recoil mass >7 (>15) MeV from J/ψ mass

h_c Recoil-Mass Plots



$\psi' \rightarrow \pi^0\ h_c$

$+\ h_c \rightarrow \gamma\ \eta_c$

$\psi' \rightarrow \pi^0\ h_c$

FIG. 1: (a) The π^0 recoil mass spectrum and the fit for the $E1$-tagged analysis of $\psi' \rightarrow \pi^0 h_c, h_c \rightarrow \gamma\eta_c$; (b) The π^0 recoil mass spectrum and fit for the inclusive analysis of $\psi' \rightarrow \pi^0 h_c$. Fits are indicated by solid lines, background by dashed lines. The respective background-subtracted spectra are shown in the insets.

E1-tagged:

3679 ± 319 events

fit χ^2 = 33.5/36

efficiency = 7.57 %

Gives product BF

Inclusive:

10353 ± 1097

fit χ^2 = 24.5/34

efficiencies:

12.89% (E1 h_c)

10.02% (hadr. h_c)

Gives h_c production BF, but efficiency weighting depends on h_c decay BF!

h_c Systematics

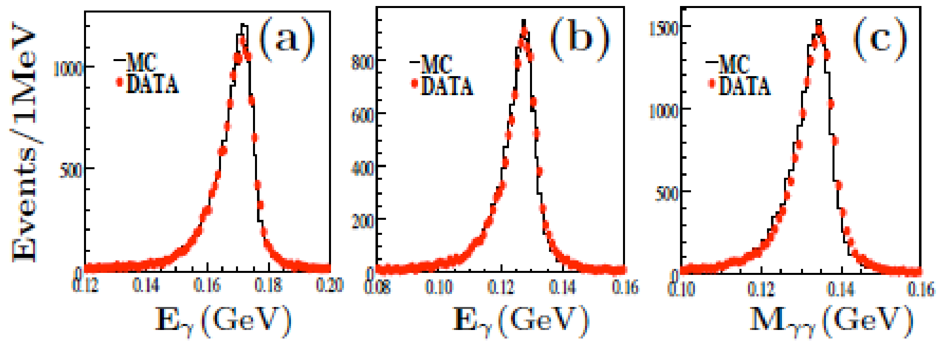


FIG. 2: Comparisons between MC (lines) and data (dots): (a) energy distribution of the radiative photon in $\psi' \to \gamma\chi_{c1}, \chi_{c1} \to \gamma J/\psi, J/\psi \to l^+l^-$; (b) energy distribution of the radiative photon in $\psi' \to \gamma\chi_{c2}, \chi_{c2} \to \gamma J/\psi, J/\psi \to l^+l^-$; (c) invariant mass distribution of π^0 in $\psi' \to \pi^0\pi^0 J/\psi, J/\psi \to l^+l^-$;

Study Samples:

π^0 efficiency, resolution

$\psi' \to \pi^0\pi^0 J/\psi$, $J/\psi \to ll$

E1 photon selection:

$e^+ e^- \to e^+ e^- \gamma$

(normalize with recoil mass)

TABLE I: Summary of systematic errors.

Source	$M(h_c)$(MeV/c^2)	$\Gamma(h_c)$(MeV/c^2)	$\mathcal{B}_1(10^{-4})$	$\mathcal{B}_1 \times \mathcal{B}_2(10^{-4})$	$\mathcal{B}_2(\%)$
Background shape and fit range	0.11	0.23	0.4	0.22	4.4
Energy scale, position reconstruction and 1-C fit	0.13	0.06	0.5	0.10	2.1
Energy resolution	0.00	0.15	0.2	0.03	1.0
Background veto	0.05	0.03	0.0	0.03	0.3
π^0 efficiency	0.00	0.00	0.3	0.14	0.0
$E1$ photon efficiency	0.00	0.00	0.0	0.10	1.2
Number of π^0	0.00	0.00	0.6	0.35	0.6
Number of charged tracks	0.00	0.00	0.1	0.06	0.1
$N(\psi')$	0.00	0.00	0.4	0.19	0.0
$M(\psi')$	0.03	0.02	0.0	0.00	0.0
$M(\eta_c)$ and $\Gamma(\eta_c)$	0.00	0.00	0.0	0.01	0.3
Total systematic error	0.18	0.28	1.0	0.50	5.2

h_c Results

$B(\psi' \to \pi^0 h_c) = (8.4 \pm 1.3 \pm 1.0) \times 10^{-4}$

$B(h_c \to \gamma \eta_c) = (54.3 \pm 6.7 \pm 5.2)\ \%$ **

$M(h_c) = (3525.40 \pm 0.13 \pm 0.18)$ MeV

[CLEO: $3525.20 \pm 0.18 \pm 0.12$]

Hyperfine splitting:

$\langle M^3P_1 \rangle - M(^1P_1) = -0.10 \pm 0.13 \pm 0.18$

$\Gamma(h_c) < 1.44$ MeV 90% CL (0.73 ± 0.45) **

** Similar to values for $B(\chi_{c1} \to \gamma\ J/\psi)$ and $\Gamma(\chi_{c1})$

$\chi_{c0}, \chi_{c2} \rightarrow \pi^0\pi^0, \eta\eta$: Analysis

χ_{c1} modes forbidden by spin-parity

Cuts generally similar to h_c analysis...'

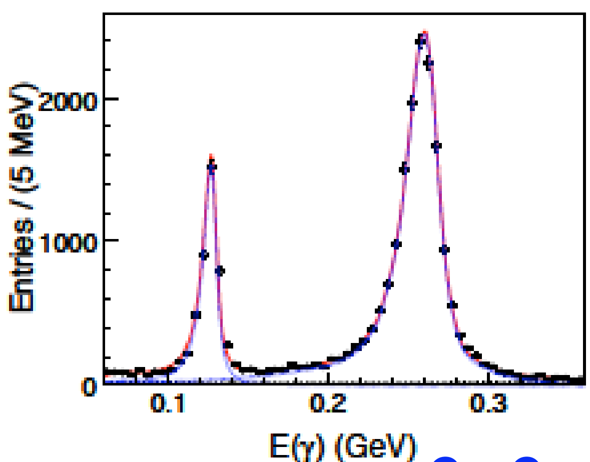
Use decay angle cuts on π^0, η

5 or 6 photons, no charged tracks

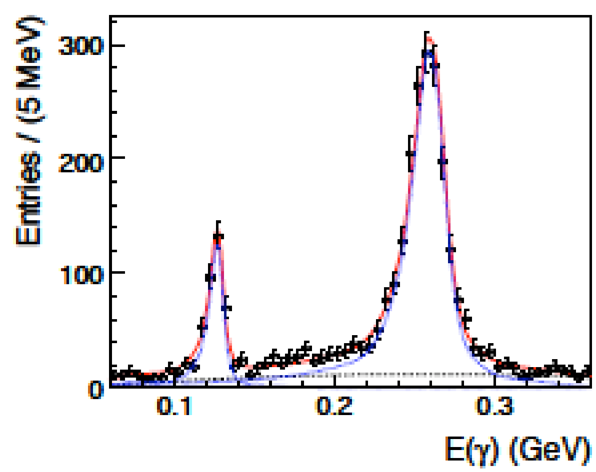
efficiencies ~ 50% (no need for isoliaton cuts!)

A "p_t^2" cut reduces missing particle background

(based on angle between $\pi^0\pi^0$ recoil and radiative photon)



$\chi_c \rightarrow \pi^0\pi^0$



$\chi_c \rightarrow \eta\eta$

χ_{c0}, $\chi_{c2} \to \pi^0\pi^0$, $\eta\eta$: Systematics

TABLE II: Systematic uncertainties expressed in percent.

Mode	$\chi_{c0} \to \pi^0\pi^0$	$\chi_{c2} \to \pi^0\pi^0$	$\chi_{c0} \to \eta\eta$	$\chi_{c2} \to \eta\eta$
photon detection	5	5	5	5
$\pi^0(\eta)$ reconstruction	2	2	2	2
$p^2_{t\gamma}$	0.9	1.2	0.1	0.3
$\chi_{\eta\eta}$	-	-	0.6	2.6
signal shape	1.6	1.2	1.4	1.5
background shape	0.5	0.5	0.2	0.3
fitting range	0.3	0.3	0.8	1.3
trigger	0.1	0.1	0.1	0.1
$N_{\psi'}$	4	4	4	4
Total	7.0	6.9	6.9	7.5

Study Samples:

π^0,η selection:

$J/\psi \to \pi^+\pi^-\pi^0$

$J/\psi \to \eta\ p\ \bar{p}$

(recoil mass)

photon detection, conversion:

$J/\psi \to \rho^0\pi^0$

& $e^+e^- \to \gamma\gamma$

χ_{c0}, χ_{c2} → $\pi^0\pi^0$, $\eta\eta$: Results

TABLE III: Branching fraction results (in units of 10^{-3}) for each decay mode. The uncertainties are statistical, systematic due to this measurement, and systematic due to the branching fractions of $\psi' \to \gamma\chi_{cJ}$, respectively. CLEOc results are determined using their own branching fractions for $\psi' \to \gamma\chi_{cJ}$, while ours are determined using branching fractions from the PDG. If we use the CLEOc branching fractions, we find $Br(\chi_{c0} \to \pi^0\pi^0) = 3.29 \times 10^{-3}$, $Br(\chi_{c0} \to \eta\eta) = 3.51 \times 10^{-3}$, $Br(\chi_{c2} \to \pi^0\pi^0) = 0.78 \times 10^{-3}$, and $Br(\chi_{c2} \to \eta\eta) = 0.58 \times 10^{-3}$.

Mode		χ_{c0}	χ_{c2}
$\pi^0\pi^0$	This Work	$3.23 \pm 0.03 \pm 0.23 \pm 0.14$	$0.88 \pm 0.02 \pm 0.06 \pm 0.04$
	CLEOc [2]	$2.94 \pm 0.07 \pm 0.32 \pm 0.15$	$0.68 \pm 0.03 \pm 0.07 \pm 0.04$
	PDG [10]	2.43 ± 0.20	0.71 ± 0.08
$\eta\eta$	This Work	$3.44 \pm 0.10 \pm 0.24 \pm 0.13$	$0.65 \pm 0.04 \pm 0.05 \pm 0.03$
	CLEOc [2]	$3.18 \pm 0.13 \pm 0.31 \pm 0.16$	$0.51 \pm 0.05 \pm 0.05 \pm 0.03$
	PDG [10]	2.4 ± 0.4	< 0.5

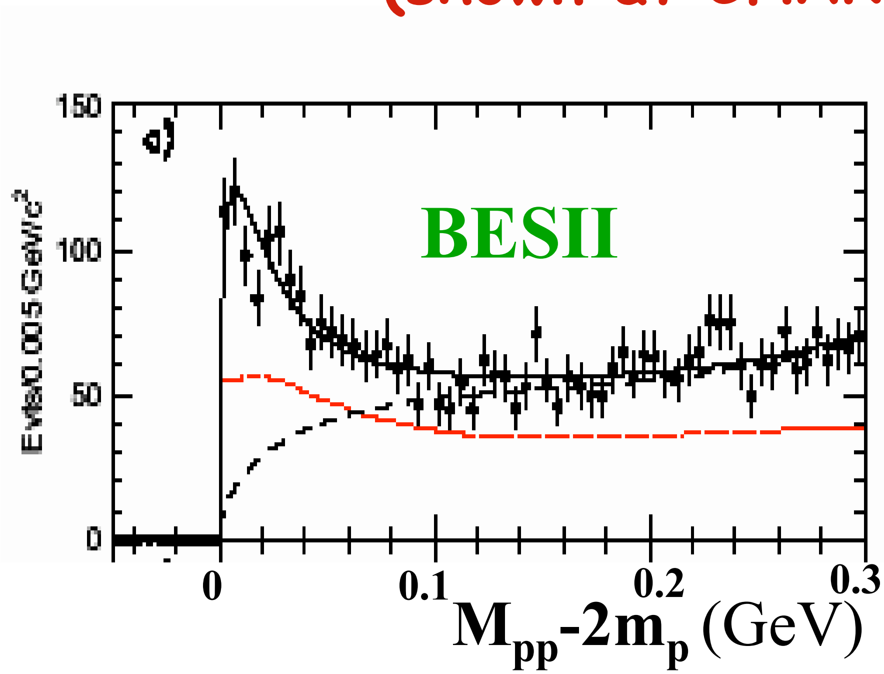
3 errors

Bit higher than CLEO; closer when consistent $\psi' \to \gamma\chi_c$ BF used

BUT: we both agree old PDG is mostly too low… (3 of 4 cases)

$J/\psi \rightarrow \gamma\, p\, \bar{p}$: "Teaser Plots"

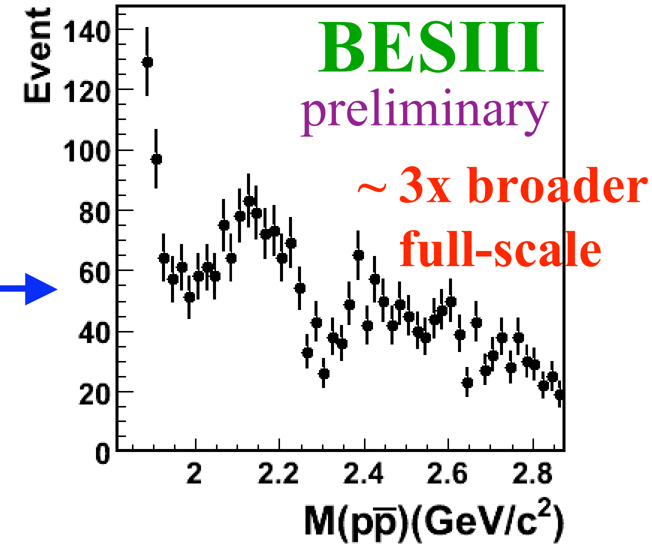
(shown at CHARM 2009, FPCP2009)

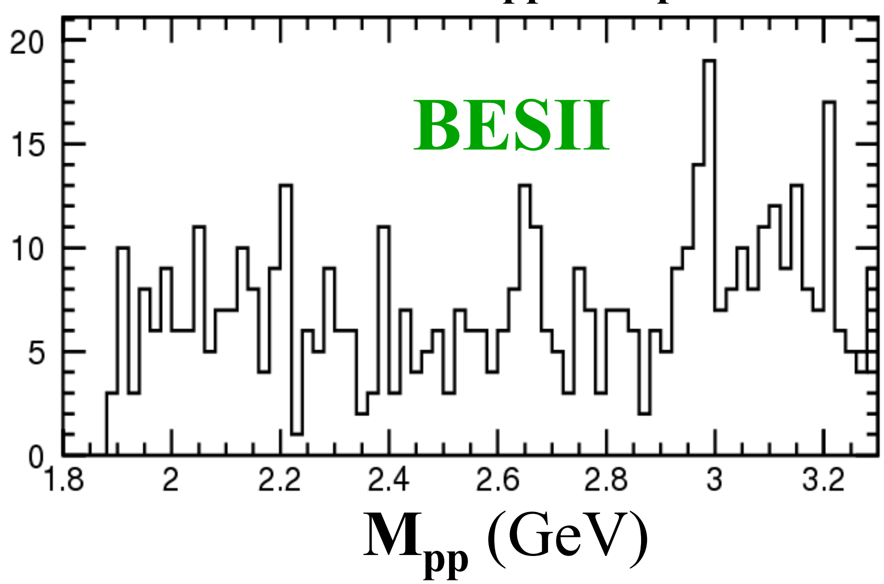


J/ψ

↔

Threshold resonance!

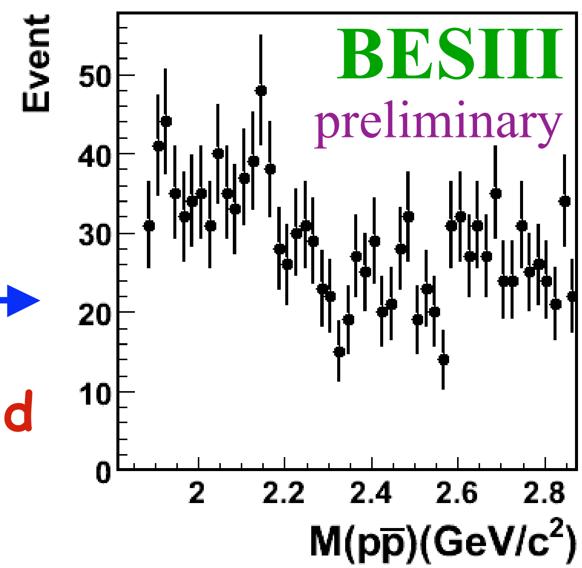




ψ'

↔

NO threshold resonance!



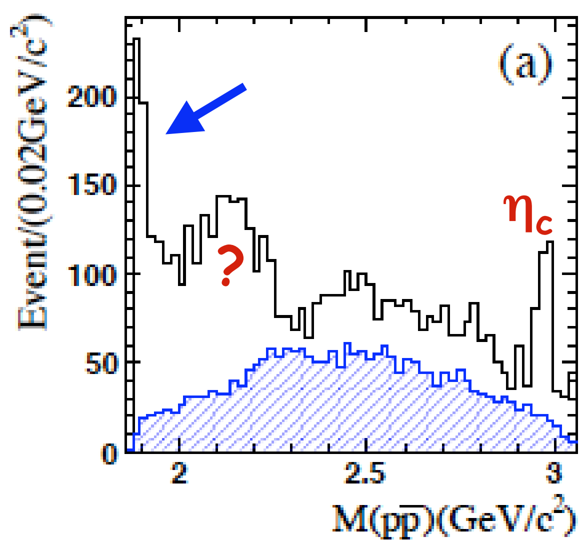
$J/\psi \rightarrow \gamma\ p\ \bar{p}$

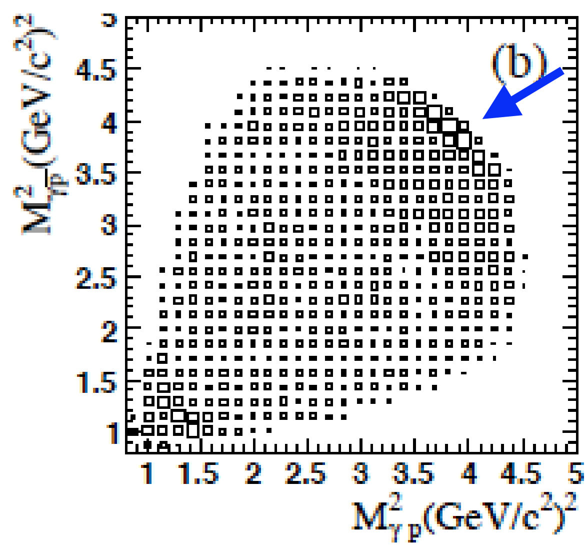
Low-mass ppbar enhancement seen in BESII
But, NOT seen in ψ' decays

Ironically, we confirm with ψ'-tagged J/ψ , with no mention of analogous ψ' decay in the paper…
(but it's still absent! You saw "teaser plots" from '09 confs)

Also NOT observed in other cases:
$p\bar{p}$ cross-sections, B decays, $\Upsilon \rightarrow \gamma\ p\ \bar{p}$ $J/\psi \rightarrow \omega\ p\ \bar{p}$
Dis-favors a pure final-state interaction (FSI) explanation

New BESIII data:





$J/\psi \rightarrow \gamma\, p\, \bar{p}$

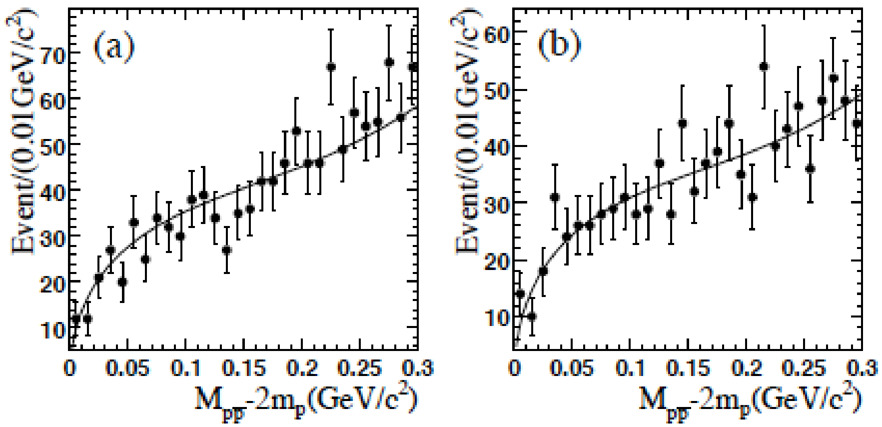


FIG. 2: The $p\bar{p}$ mass spectrum near threshold for: (a) selected $\psi' \rightarrow \pi^+\pi^- J/\psi (J/\psi \rightarrow \pi^0 p\bar{p})$ events for the same real data sample. (b) phase-space MC $\psi' \rightarrow \pi^+\pi^- J/\psi (J/\psi \rightarrow \gamma p\bar{p})$ events that satisfy the $\gamma p\bar{p}$ selection criteria. The smooth curves are the results of the fit described in the text.

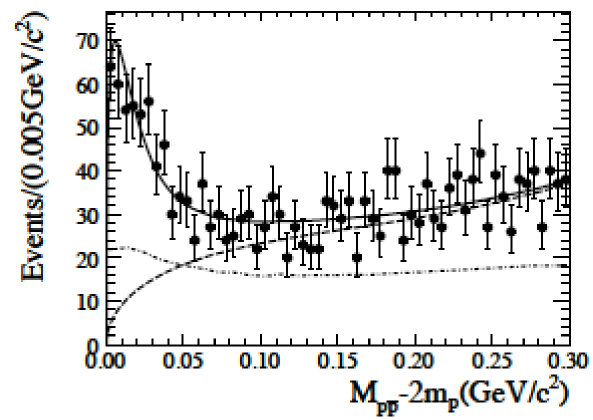


FIG. 3: The $p\bar{p}$ invariant mass spectrum for the $\psi' \rightarrow \pi^+\pi^- J/\psi (J/\psi \rightarrow \gamma p\bar{p})$ after final event selection. The solid curve is the fit result; the dashed curve shows the fitted background function, and the dash-dotted curve indicates how the acceptance varies with $p\bar{p}$ invariant mass.

Control sample:

$J/\psi \rightarrow \pi^0\, p\, \bar{p}$

S-wave B-W fit:

$M = 1861^{+6}_{-13}{}^{+7}_{-26}$ MeV

$\Gamma < 38$ MeV

It's certainly fair to discuss the best way to fit this, but clearly something is happening

2010:
First Open Charm Data Run

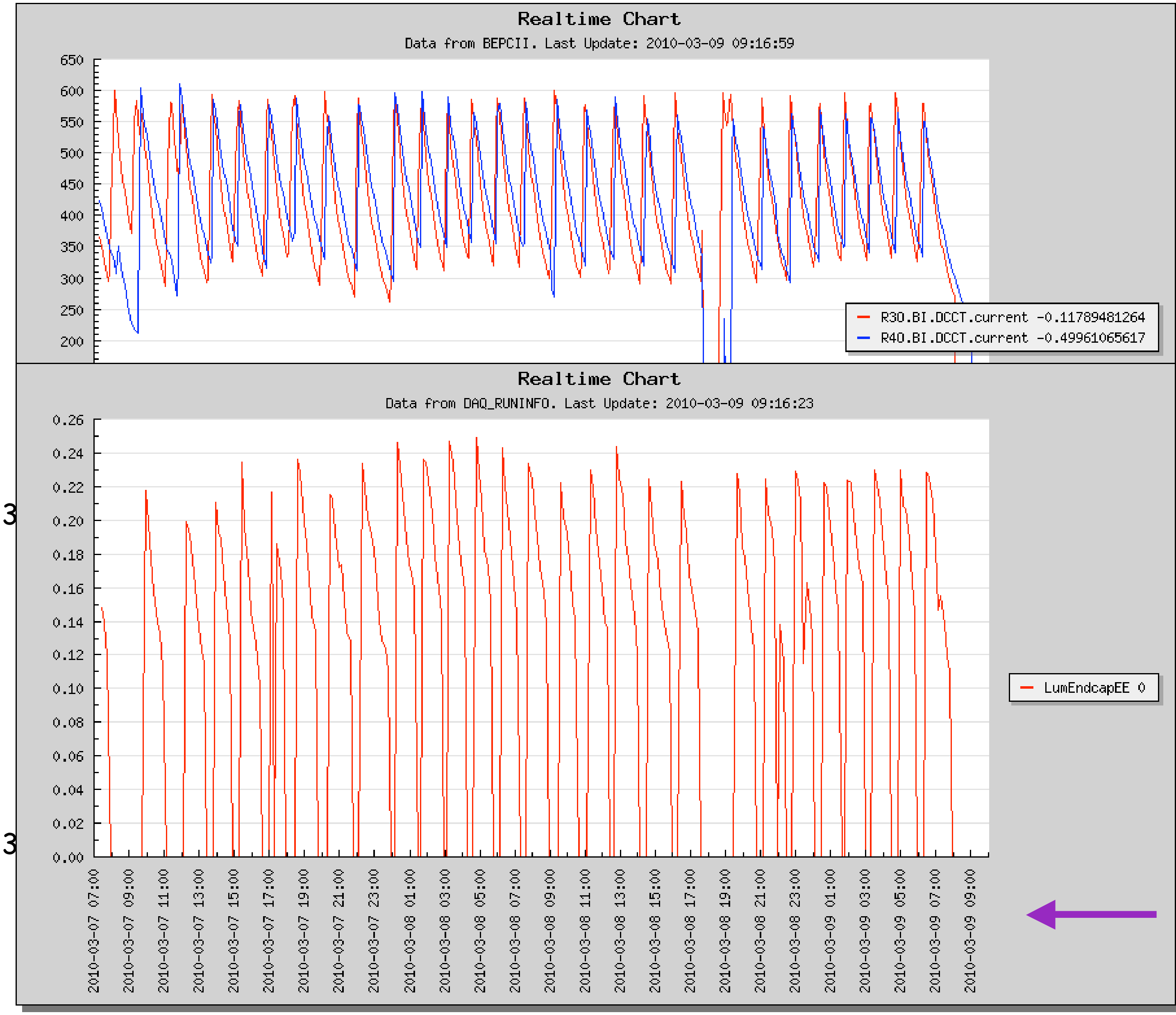
Current and Inst. Lumi. Cycles

600 mA

200mA

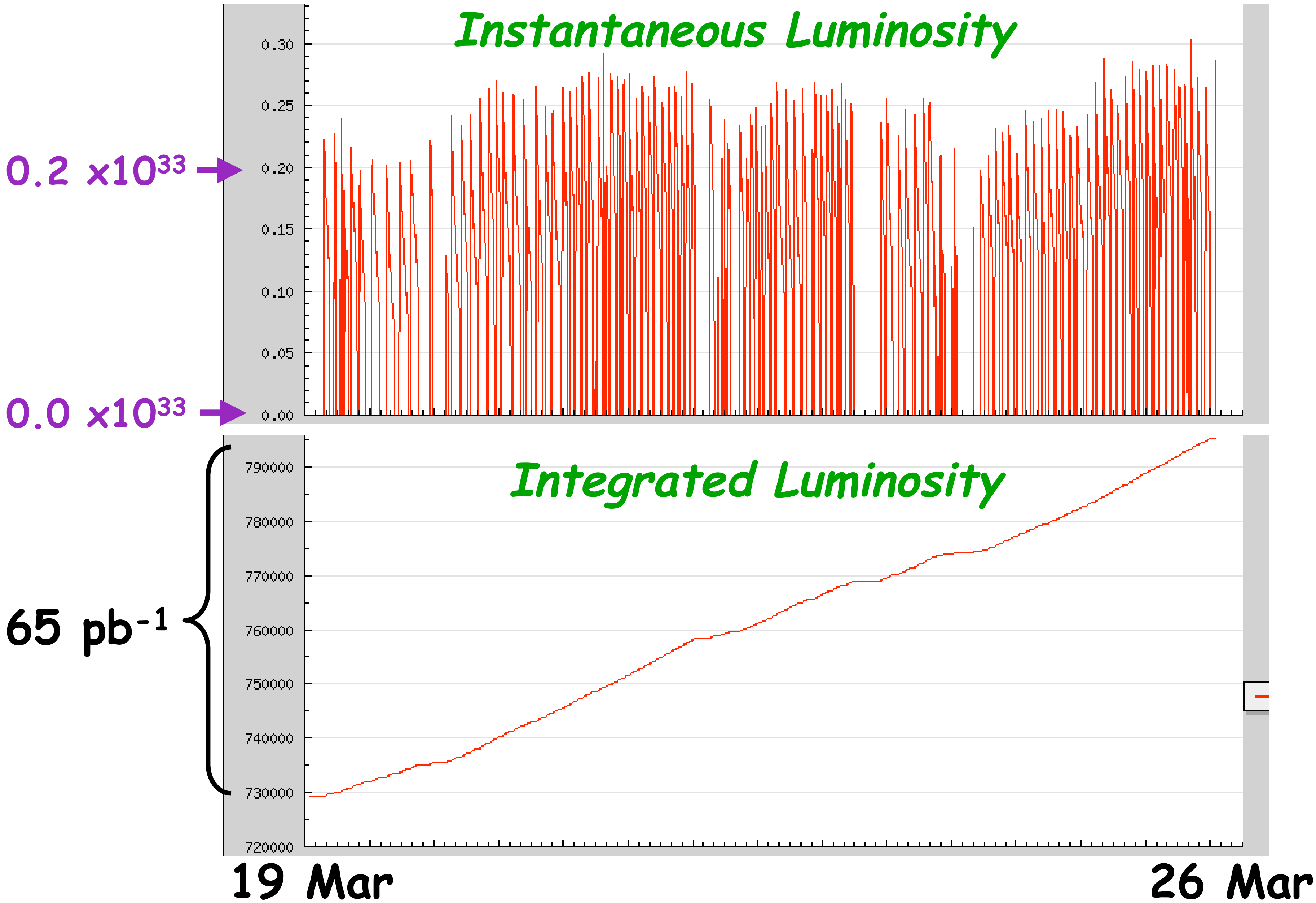
0.2×10^{33}

0.0×10^{33}

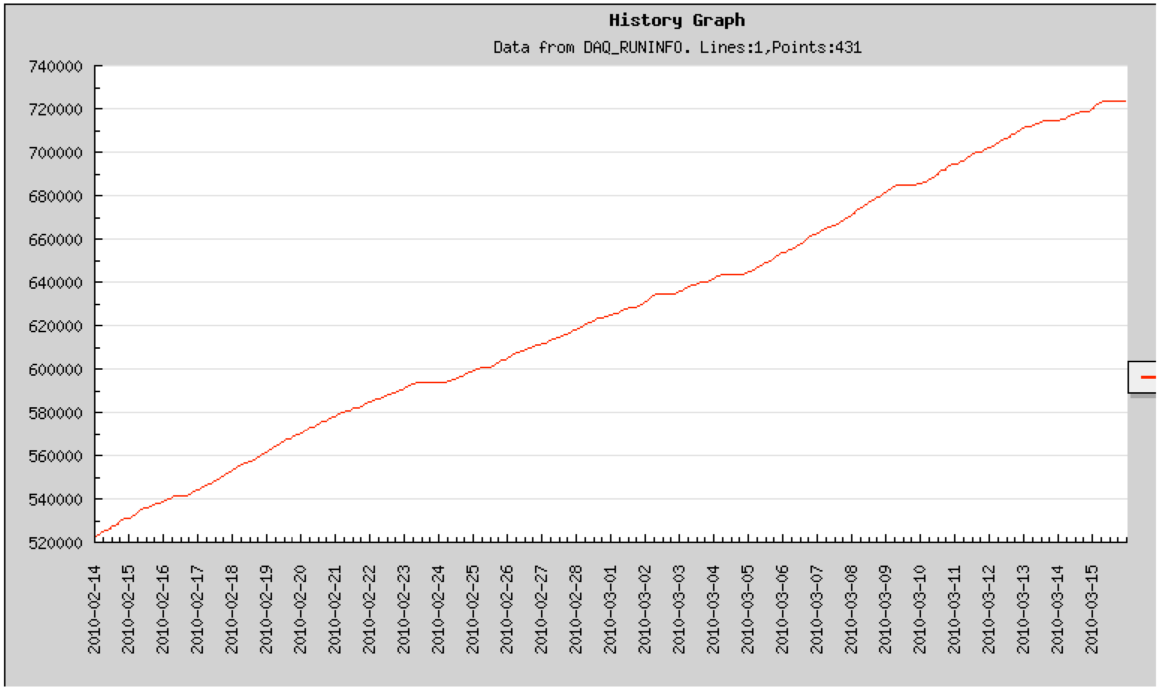


2 hours between labels

Best Week in Current Run



Integrated Luminosity

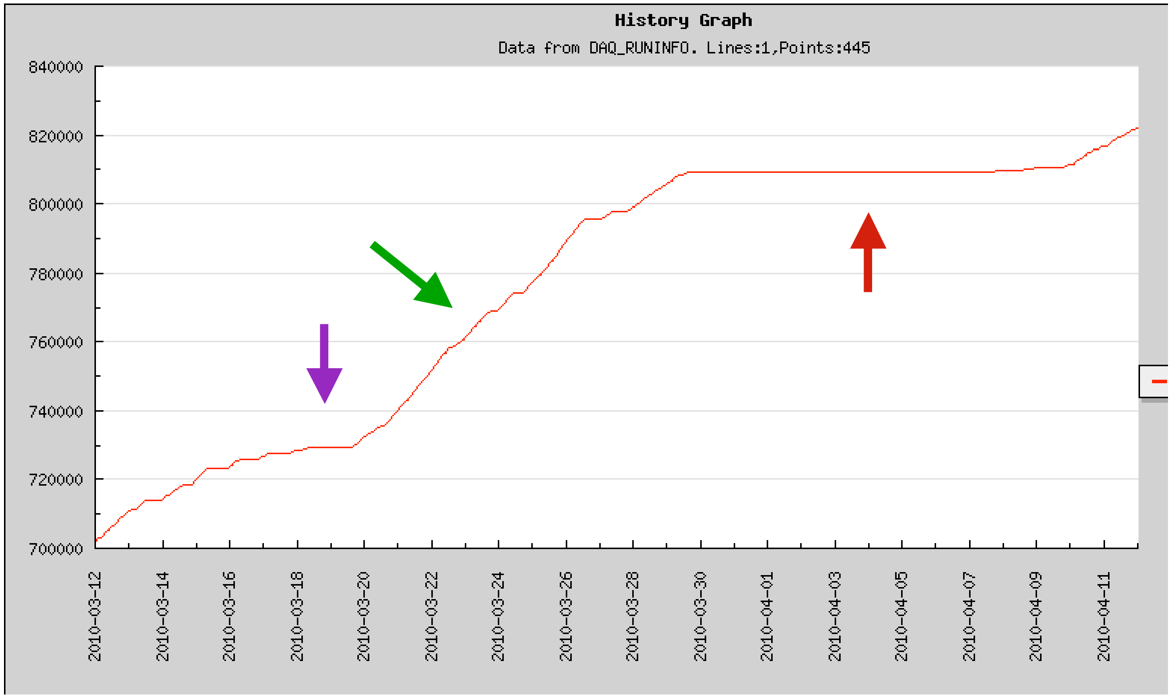


30 days
with 200 pb^{-1}

Issues:

- Top-off + start/stop: can be 30 min. !!!
  Recent improvements, but still variable
- Consistency
- Peak lumi and lifetime

Reality…



A small lull…

Best rate ever… (10 pb^{-1}/day)

Kicker magnet fails !!! (almost 2 weeks)

Open Charm: Statistics

Run in progress now !

Data sample:

375 pb^{-1} from mid-Jan mid-April

[includes 2 weeks of kicker magnet downtime;
150/month for rest of time…]

Should be able to take ~250 pb^{-1} /month now

[all-out push at end of CLEO-c 3770: ~100/month
Have 3.5x peak, can get >2.5x integrated?]

Rest of run:

Approved until about mid-June, perhaps more?

Would like to exceed CLEO-c [it's doable]

Possibly take a two-week (3770) scan…

(1 fb^{-1} now tough, w/o luck & extension & no scan)

Conclusions

Detector and accelerator successfully commissioned;
a few teething pains, but no show-stoppers

World's best Charmonium data samples;
already publishing results

Open-charm physics data run in progress

Stay tuned for more! Should be a big wave of results
for summer conferences…