From BESI, BESII to BESIII

Celebration of the 500 Publications of BESIII Collaboration

May 31, 2023

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From BESI, BESII to BESIII

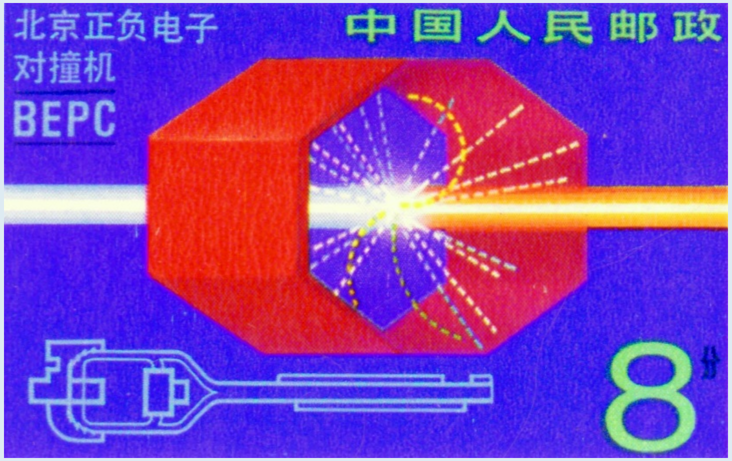
- Thank you for the invitation. It is great to be back at IHEP and see old friends.
- Haibo: “Please kindly review the history of the BES experiment and its achievements.”
- Since most other talks will mostly concentrate on results from BESIII, I will concentrate on BESI and BESII but show some comparisons with BESIII.

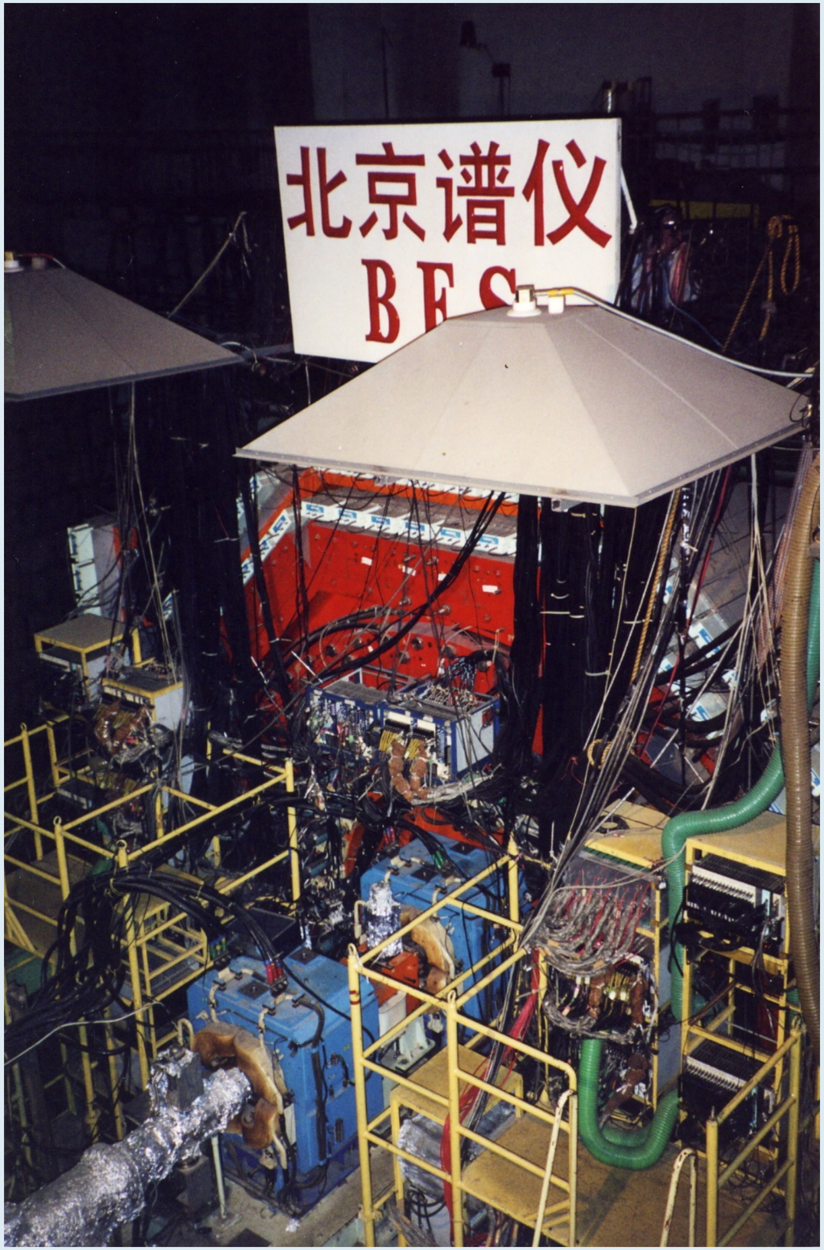
From BESI, BESII to BESIII

- First, I would like to recognize Yifang's role in the success of BESIII. He was involved in the design of every aspect. During BESII, he was continuously in meetings on detector components, electronics, software, and collaboration management.

OUTLINE

- BEPC/BES beginnings and the US-China connection.
- BESI Experiment
- BESII Experiment
- BESI, BESII, and BESIII comparisons
- Summary





BEPC/BES beginnings and The US-China connection

BEPC/BES beginnings and the US-SLAC connection

- 1972: Chinese physicists visit US to consult on future major facility. Return to China with idea of 40 – 50 GeV proton accelerator.

- 1976 Pief Panofsky invited to visit China, suggests e^+e^- collider better choice.

Zhang Wenyu visits SLAC in 1972 (from Panofsky on Physics, Politics, and Peace)

An aside: Pief was deeply involved in advising on and promoting nuclear disarmament and emphasized the importance of academic exchanges in furthering peace.

BEPC/BES beginnings and the US-China connection

- 1981 T.D. Lee and Panofsky both suggest e^+e^- collider.

- 1982 Deng Xiaoping endorses.

- 1982 30 engineers and physicists go to SLAC to make preliminary design.

- 1984 Construction begins.
- First collisions, Oct. 16, 1988
- Inaugural celebration, Oct. 24, 1988.

Wang T.C.

From Jean Deken, SLAC Archives and History Office

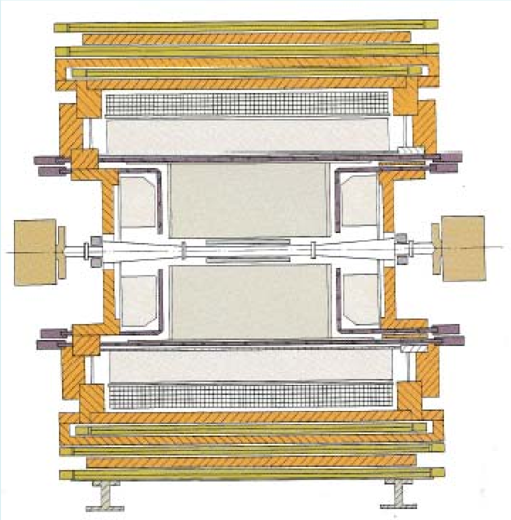
Deng at ground breaking (Oct. 7, 1984)

BEPC/BES beginnings and the SLAC connection

- BESI detector modeled on Mark III with improvements.
- 10 M J/Ψ events accumulated (May 1991).
- American scientists join in 1991 to measure τ mass:

  (Boston University, Caltech, UC Irvine, Colorado State, MIT, SLAC, SSC, University of Texas at Dallas, and University of Washington).

- τ threshold scan Nov. 91 – Jan. 92



BESI detector


BESI Experiment
Zhangjiajie

BESI: 1989 - 1995

BEPC:

Beam energy 1.1 – 2.7 GeV

Luminosity 7 x 10^{30} cm^{-2} s^{-1} @2.2 GeV

BESI Detector:

MDC:

σ_p/p at 1 GeV: 2.4 %

$\sigma_{dE/dx}/dE/dx$ 8.5 %

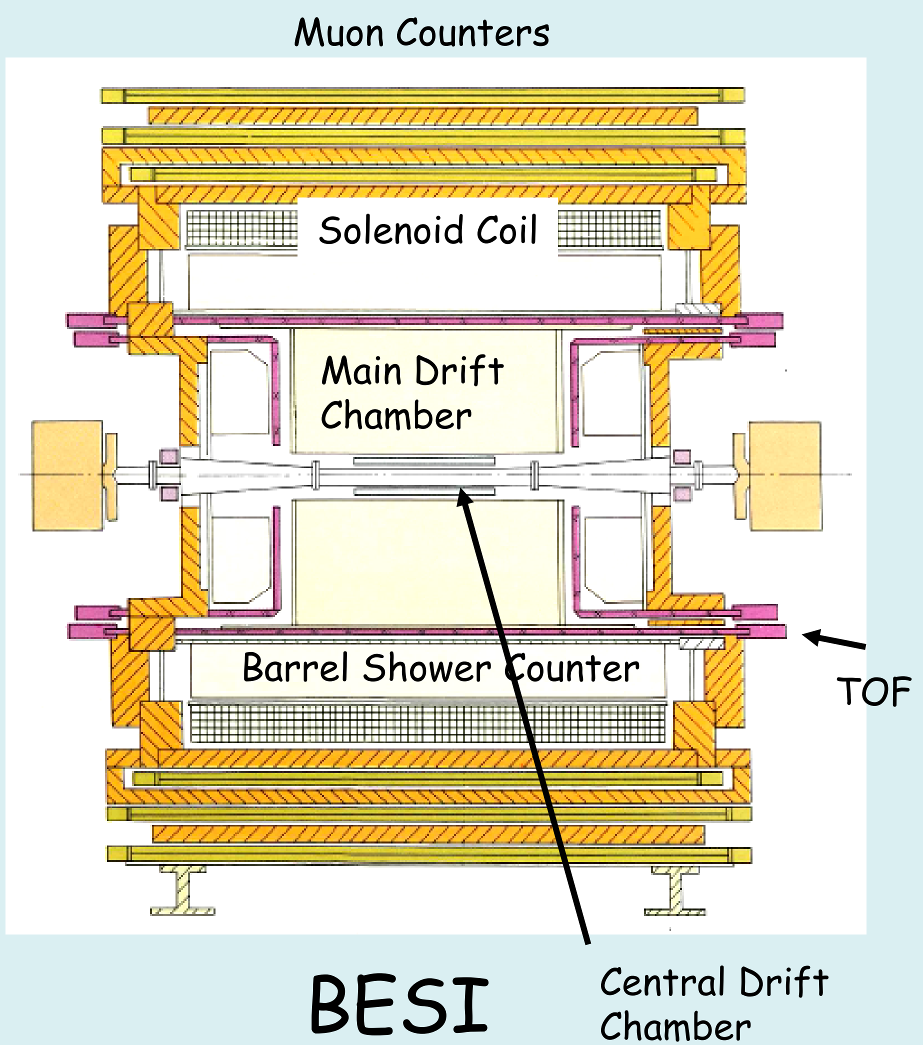
TOF barrel:

σ_t 330 ps

EMC barrel:

σ_E/E at 1 GeV 24%

Conventional magnet 0.4 T



BESI

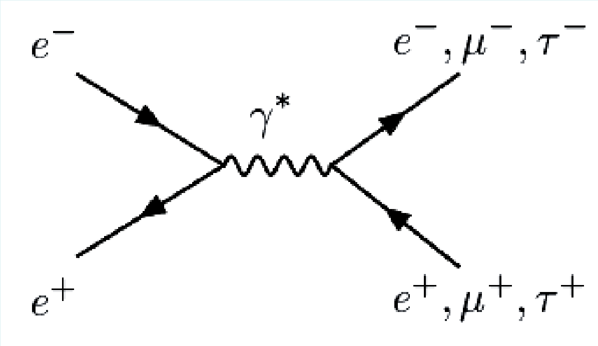
Data:

10 M J/Ψ events, 3.8 M Ψ(2S) events, 10 pb^{-1} D_S

BESI Experiment

BESI most cited papers: mass of τ lepton

M(τ) is fundamental parameter of the SM.
Precision important to test universality



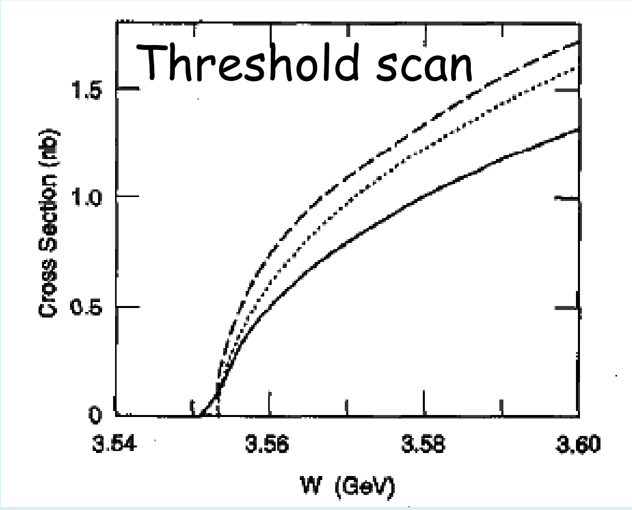
$$\left[\frac{G_{\tau\to e\upsilon\bar{\upsilon}}}{G_{\mu\to e\upsilon\bar{\upsilon}}}\right]^2 = \left[\frac{m_\mu}{m_\tau}\right]^5 \frac{B_\tau^e}{B_\mu^e}\frac{\tau_\mu}{\tau_\tau}$$

G – weak coupling constant

Before BESI:

$$m_\tau = 1784.1^{+2.7}_{-3.6}\ \mathrm{MeV}$$

$$\left(\frac{G_{\tau\to e\nu\bar{\nu}}}{G_{\mu\to e\nu\bar{\nu}}}\right)^2 = 0.941 \pm 0.025$$

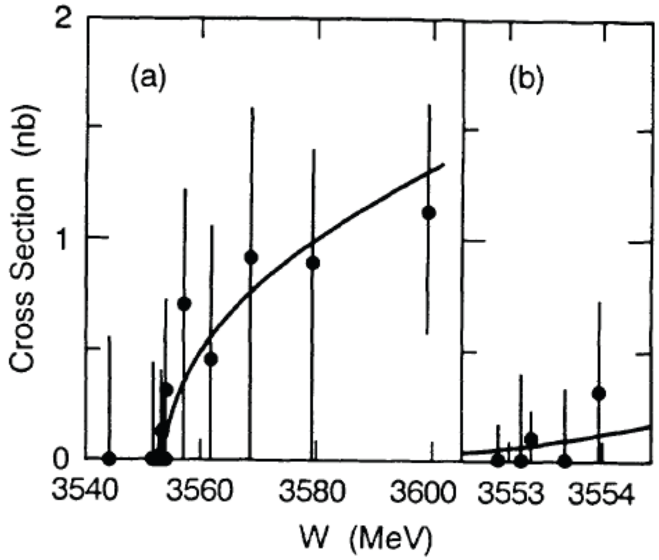


Possible lepton flavor violation

τ threshold scan
Nov. 91 – Jan. 92

BESI Experiment

First measurement of the τ mass at BESI
PRL 69, 3021 (1992)



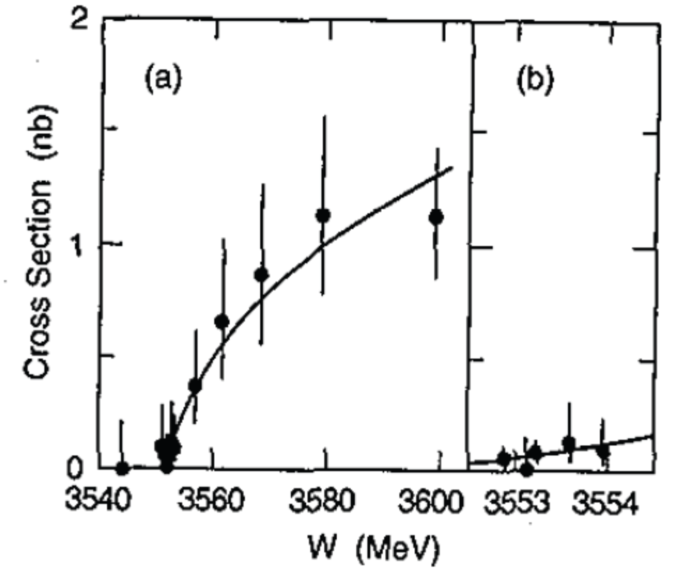
12 points (data-driven), Nov. 91 to Jan. 92 , 5pb^{-1}.
One channel: eμ + neutrinos

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

147 citations

$$\left(\frac{G_{\tau\to e\nu\bar{\nu}}}{G_{\mu\to e\nu\bar{\nu}}}\right)^2 = 0.960 \pm 0.024$$

Second measurement of the τ mass at BESI
PRD 53, 20 (1996)



12 points (data-driven), Nov. 91 to Jan. 92 , 5pb^{-1}.
Many channels.

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

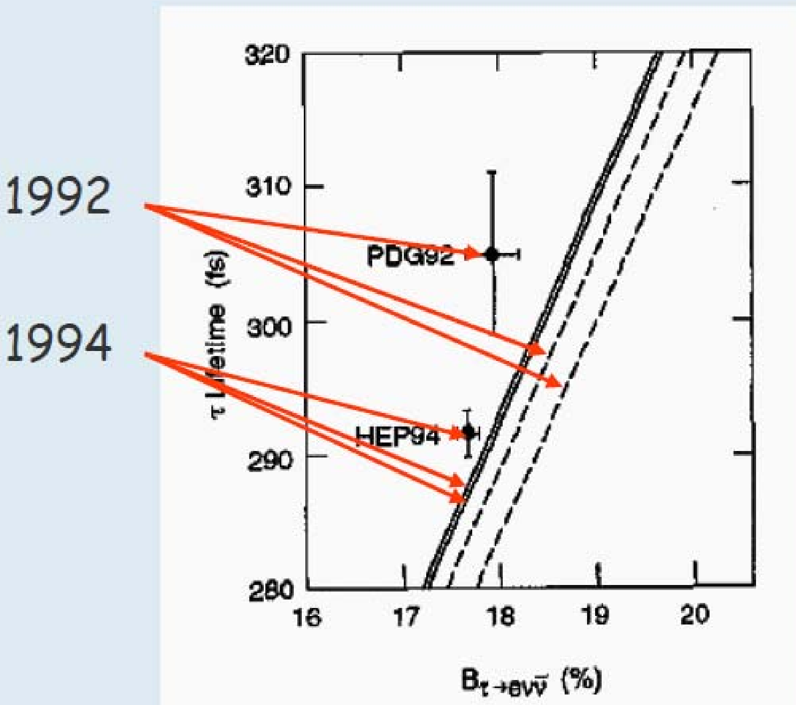
152 citations

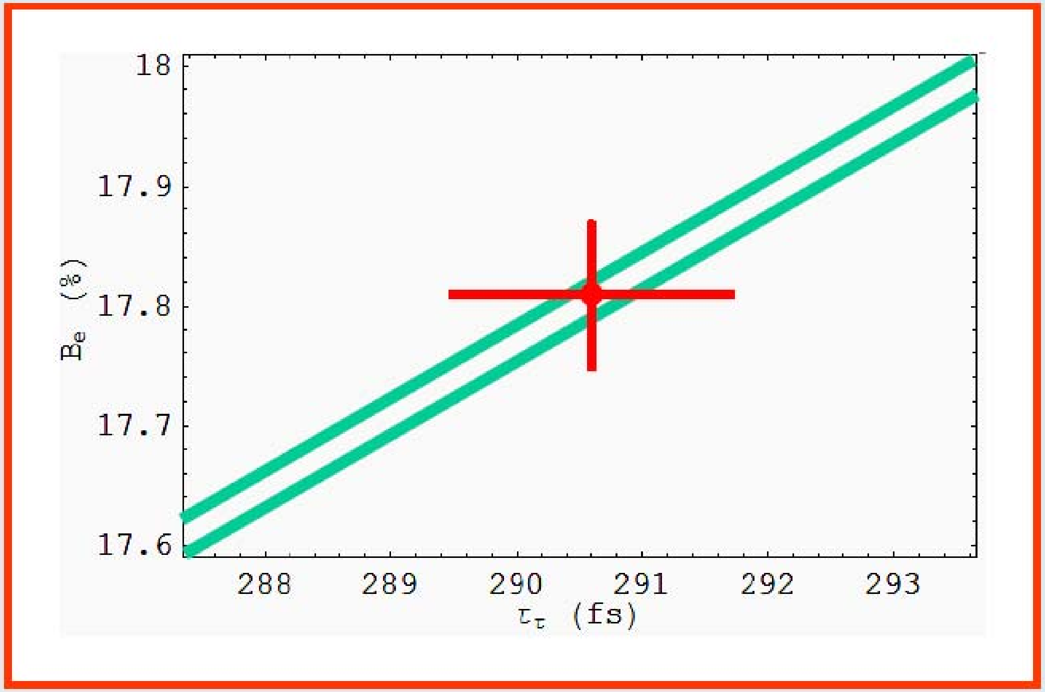
$$\left(\frac{G_{\tau\to e\nu\bar{\nu}}}{G_{\mu\to e\nu\bar{\nu}}}\right)^2 = 0.9886 \pm 0.0085$$

BESI -- Tau mass measurement

- Lifetime, leptonic branching ratio, and mass are related in Standard Model:

$$\Gamma(\tau \to e\upsilon_\tau\overline{\upsilon}_e) = \frac{B(\tau \to e\upsilon_\tau\overline{\upsilon}_e)}{\tau(\tau \to e\upsilon_\tau\overline{\upsilon}_e)} = \frac{G_F^2 m_\tau^5}{192\pi^3} F_{cor}(m_\tau, m_e)$$





Status 1992 (2.4 σ) and 1994 (1.3 σ)

Status 2006

A. Pich, Charm06 talk

BESI Experiment

Top ten hits

Published	Title	Cite
PRD 53, 20 (1996)	Measurement of the mass of the tau lepton	152
PRL 69, 3021 (1992)	Measurement of the mass of the tau lepton	147
PRL 76, 3502 (1996)	Studies of Xi(2230) in J/psi radiative decays	142
PRD 62, 032002 (2000)	psi(2s) to pi pi J/psi decay distributions	92
PRL 74, 4599 (1995)	A direct measurement of the pseudoscalar decay constant, f(Ds)	81
PLB 472, 200 (2000)	Partial wave analysis of J/psi →gamma k+k-pi+pi-	66
PRL 77, 3959 (1996)	Structure analysis of the f(j)(1710) in radiative decay J/psi → gamma K+K-	49
PRD 60, 072001 (1999)	Study of hadronic decays of chic states	48
PLB 446, 356 (1999)	Partial wave analysis of J/psi → gamma eta pi+ pi-	45
PRL 81, 3091 (1998)	Partial wave analysis of J/psi → gamma eta pi+ pi-	45

BESI Experiment

- Another major accomplishment of BESI was the Publication Policy.
- Important to insure quality of publications.
- For example, only one preliminary result can be reported.
- Credit goes to Joe Izen, the US co-spokesman at the time.

Publication Policy of the Beijing Spectrometer Collaboration

(Updated June 23, 1996)

New physics analyses to be presented in conferences or to be submitted for publications should satisfy following requirements:
A presentation should be given in IHEP or at a U.S. group meeting. There must be consensus that the physics results are presentable before the physics results are shown outside the BES group. The Chinese and U.S. Spokespersons must give their explicit approval before new physics results are presented at a conference or submitted for publication.
It is desirable but not required that an analysis be done by both the Chinese and U.S. sides. All parties involved in an analysis subject are encouraged to communicate openly from the early stages of the analysis.
The Chinese and U.S. Spokespersons will update each other at regular intervals concerning analysis work in progress on their respective sides.
An analysis document in English should be made available to all BES members prior (>1 month) to a conference presentation to allow sufficient time for responses. In practice this should be done before a group meeting to allow discussion. If there changes in the analysis and/or changes in the final results due to reanalysis, these new cuts and new results should appear in an appendix to the analysis document.
The analysis document should contain all analysis cuts, data sets used, relevant plots, and numerical results. The document should be sufficiently detailed to make it possible for other BES members to reproduce the same results. The document should be available on line to enable all BES members to easily print out a copy. The document can be in postscript or html with plots.

Response to the analysis document from the collaboration needs to be sent to the authors within a reasonable time, two (2) weeks, excluding holidays to allow time for proper responses.
A necessary condition for paper writing for publication is the availability of the corresponding analysis document.
For publication, a Referee Committee of 3 people with both Chinese and U.S. members should be formed to evaluate the analysis results and the paper to be published. The committee members will be chosen by the Spokespersons after discussion with the relevant people. The Referee Committee's duty is to raise questions, correct errors, suggest modifications, and require necessary checks or changes. It is the responsibility of the Referee Committee to respond to the analysis note within two (2) weeks of the formation of the committee.
After the Referee Committee reaches a consensus that a paper is ready, the paper draft should be made available to the collaboration for written responses and public discussion. A discussion of the paper should be done in a collaboration meeting at IHEP if the authors reside in China or in the U.S. if the authors reside in the U.S. The collaboration should mainly comment on scientific and technical aspects of the paper. The stylistic aspects of the paper should be controlled by the authors. All responses should be returned to the authors within four (4) weeks of the time the paper was distributed to the collaboration.

Draft publications should be clearly identified as drafts and should be circulated only among BES collaborators. A Publication Timeline and Checklist has been prepared to help BES authors comply with this publication policy.

BESIII Publication Policy.

First page of 9 pages.

2 December 2020

BESIII Publication Policy

Preamble

The BESIII collaboration is committed to bring results to publication quickly while maintaining the highest quality of scientific content and presentation. All collaboration members are expected to contribute to this goal. Group leaders have a special responsibility to ensure that students and postdocs are appropriately mentored in effective communication in all relevant forms, including oral presentations, internal documents and journal publications. The Physics Coordinator and Deputy Physics Coordinator play leadership roles in the publication process. They have the responsibility to oversee and monitor all physics analyses and to help guide papers through the internal review process. The Physics Coordinators monitor the work of referees and provide necessary reminders of expectations and deadlines. It is also the responsibility of the Physics Coordinators to manage the BESIII publication web pages, containing all analysis memos, talks, papers, and a list of current analyses with their authors, referees and publication status.

Responsibilities and Composition of the BESIII Publication Committee

The BESIII Publication Committee has three principal responsibilities:

Develop and maintain the BESIII Publication Policy defining the requirements for authors, referees and management for journal publications, conference talks and other aspects of the preparation and dissemination of BESIII results.

Upon referral by the Physics Coordinators and/or Spokespersons, resolve analysis and publication disputes that arise among authors, referees and management.

Directly participate in ensuring the quality of BESIII papers by carrying out editing of manuscripts in the final stages of collaboration review.

The Publication Committee consists of ten members. The chair and four additional members constitute the standing Publication Committee, nominated for renewable three-year terms (staggered so that no more than two members change each year) by the Spokespersons in consultation with the Executive Board and with the approval of the Institutional Board. The standing Publication Committee is responsible for developing and maintaining the BESIII Publication Policy and for dispute resolution. The Physics Coordinator, Deputy Physics Coordinator and Spokespersons are all *ex officio* members of the Publication Committee.

The final editing of manuscripts is the responsibility of the full Publication Committee, which consists of the five standing committee members and five additional members whose only responsibility is editing. These additional members are nominated by BESIII institutions and selected by the Standing Committee for one-year terms.

BESII Experiment

BESII: 1998 - 2004

BEPC upgrade:

Beam energy 1.0 – 2.8 GeV

Luminosity 49 x 10^{30} cm^{-2} s^{-}

@1.55 GeV

BESII Detector upgrade:

MDC:

σ_p/p at 1 GeV: 2.5 %

$\sigma_{dE/dx}/dE/dx$ 8 %

TOF barrel:

σ_t 180 ps

EMC barrel:

σ_E/E at 1 GeV 21%

Conventional Magnet 0.4 T

Data:

51 M J/Ψ events, 14 M Ψ(2S) events, other.

BESII Upgrade: Replace MDC, TOF, and Central Drift Chamber replaced with revamped MARKI vertex detector

BESII R Measurement

Beijing tests complete precision measurement

The BES II spectrometer at the Beijing electron–positron collider (BEPC) has completed a measurement of hadron production rates over the 2–5 GeV energy range which is valuable input for Standard Model calculations.

Three vital input parameters in the elec-

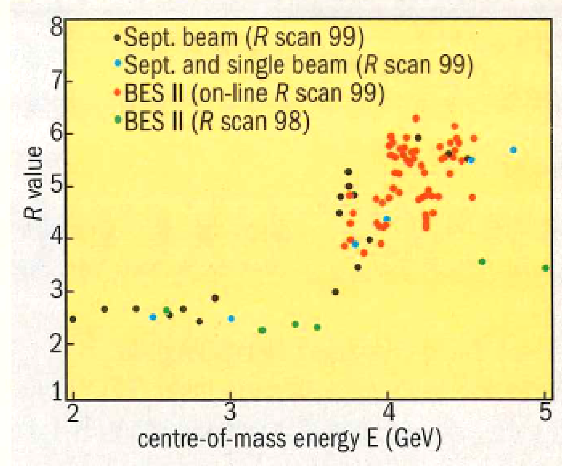
…

indirect determination of the mass of the Higgs particle. A more accurate value narrows the mass window for Higgs particle searches.

Of particular importance in the extrapola-tion of α is the hadronic contribution to the vacuum, such as virtual quark–antiquark pairs, which cannot be calculated reliably but can be related to a factor known as *R* – the ratio of hadron to muon pair production in electron–positron annihilation. Uncertainties

…

at 7 energy points. Special runs were taken at the J/psi resonance to determine the trigger efficiency and calibrate the detector. These runs show that the 12-tracking-layer vertex



Comparing hadrons and muon production at the BES II spectrometer at the BEPC.

…C, as well as the good co-operation and hard work of the BEPC staff, were essential for the success of the scan, which continued even through the traditional Chinese Spring Festival.

Zhengguo Zhao and Frederick A Harris.

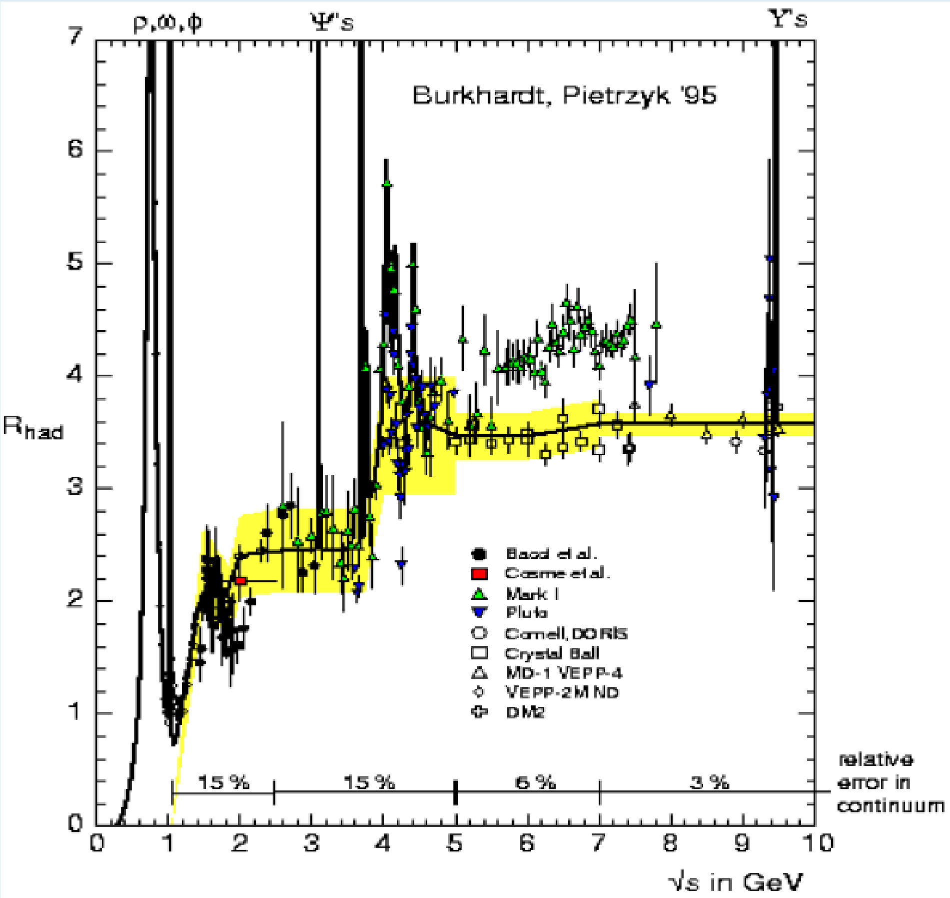
After returning from Switzerland in 1997, Zhao Zhengguo convinced collaboration of the importance of an R-scan.
Coordinated data taking in 1998 and 1999 and formed group to do analysis of R-scan data.

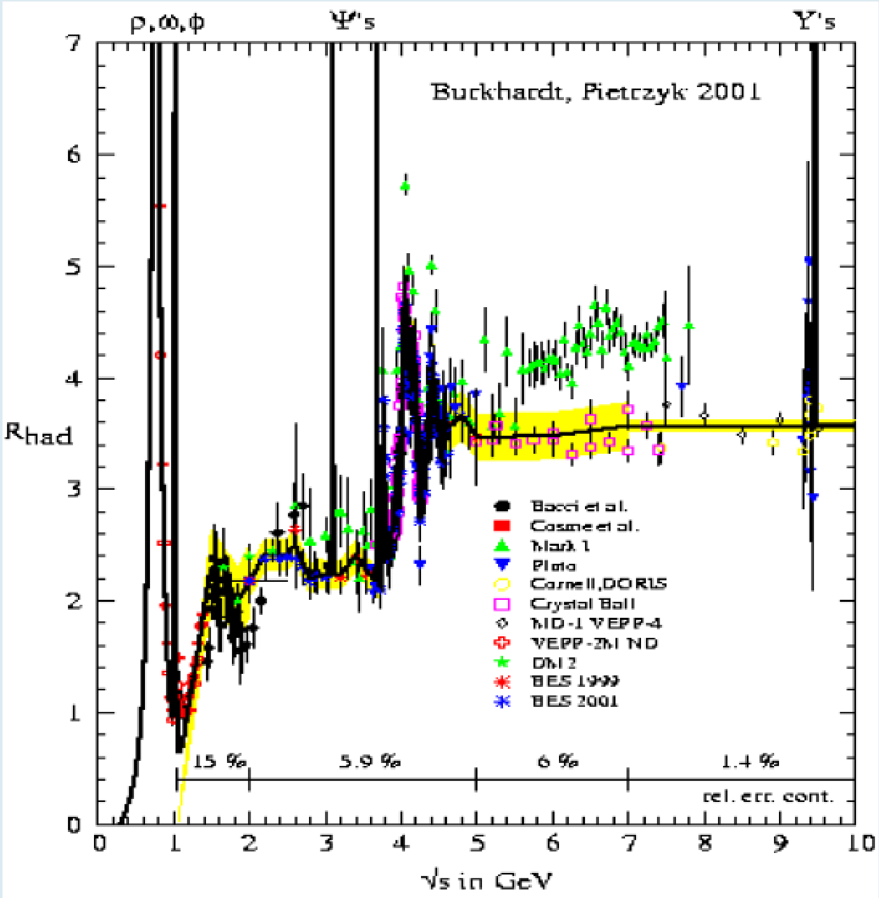
Cern Courrier, September 1999

BESII: R

$R = \sigma(e^+e^- \to hadrons)/\sigma(e^+e^- \to \mu^+\mu^-)$

BES reduces R errors from 15 - 20 % to an average of 6% in the 2 - 5 GeV region. Important region!





Before BES R Scan

PRL **84**, 594 (2000)
PRL **88**, 101802 (2002)
191 + 393 citations

After BES R Scan

Highest cited BESII papers

R measurement

- Needed to improve precision of $\alpha(M^2_Z)$:
  - Uncertainties in α introduced when it is extrapolated to the Z-pole:

$$\alpha(q^2) = \frac{\alpha_0}{1 - \Delta\alpha(q^2)}$$

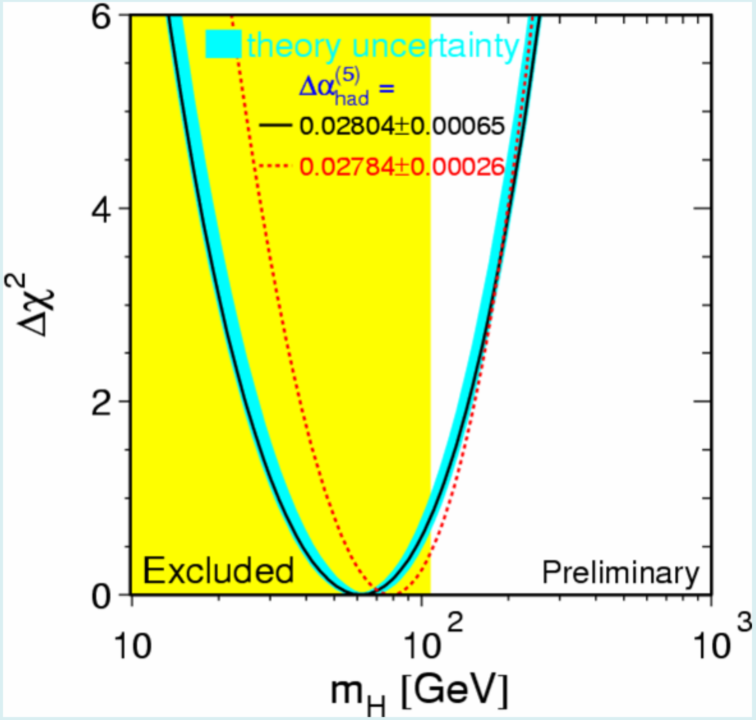
$$\Delta\alpha(q^2) = \Delta\alpha_l(q^2) + \Delta^{(5)}_{\mathrm{had}}\alpha(q^2) + \Delta_{\mathrm{top}}\alpha(q^2)$$

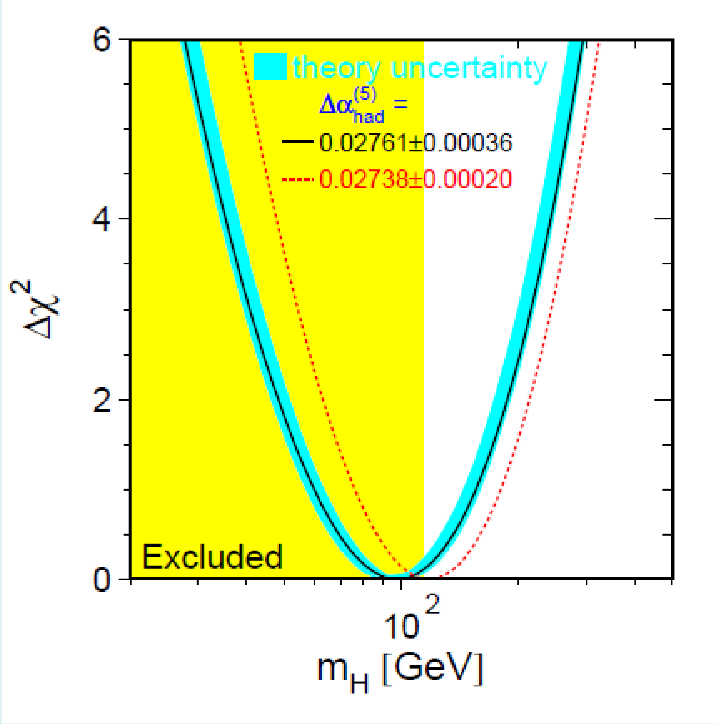
  - Dominant uncertainty due to hadronic vacuum polarization.
  - This is determined from R values using a dispersion relation.

$$\Delta\alpha_{\mathrm{had}}(s) = -\frac{\alpha\, s}{3\pi}\ P \int_{4m_\pi^2}^{\infty} \frac{R_{\mathrm{had}}(s')}{s'(s'-s)} ds'$$

- The Higgs mass determined from radiative corrections in the SM is very sensitive to $\alpha(M^2_Z)$.

SM Fit to M_H





Before BESII:

$\Delta\alpha_{had} = 0.02804 \pm 0.00065$

$M_H = 62^{+53}_{-30}$ GeV/c²

$M_H < 170$ GeV/c² @ 95% CL

LEP lower limit = 112 GeV/c²

After BESII:

$\Delta\alpha_{had} = 0.02761 \pm 0.00036$

$M_H = 98^{+58}_{-38}$ GeV/c²

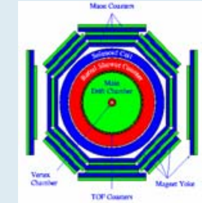
$M_H < 212$ GeV/c² @ 95% CL

Burkhardt and Pietryzk, PLB 513, 46 (2001)

Data from tau-mass region important for SM fits.

$M_H = 125.25 \pm 0.17$ GeV/c² PDG

BESII Threshold enhancement in $J/\psi \rightarrow \gamma p \bar{p}$

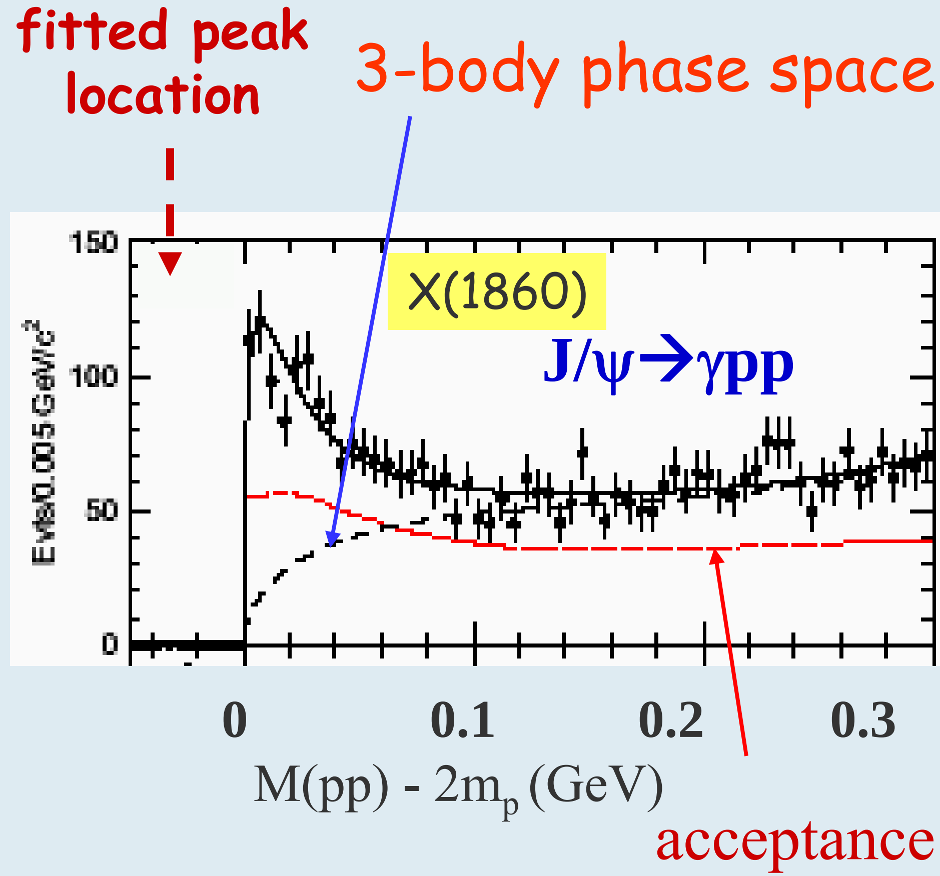


- Enhancement seen near threshold in $M_{p\bar{p}}$ in $J/\psi \rightarrow \gamma p \bar{p}$.

- If fitted with an *S*-wave resonance:

$$M = 1859 \,^{+3}_{-10}\,^{+5}_{-25}\ \mathrm{MeV}/c^2$$

$$\Gamma < 30\ \mathrm{MeV}/c^2\ (90\%\ \mathrm{CL})$$

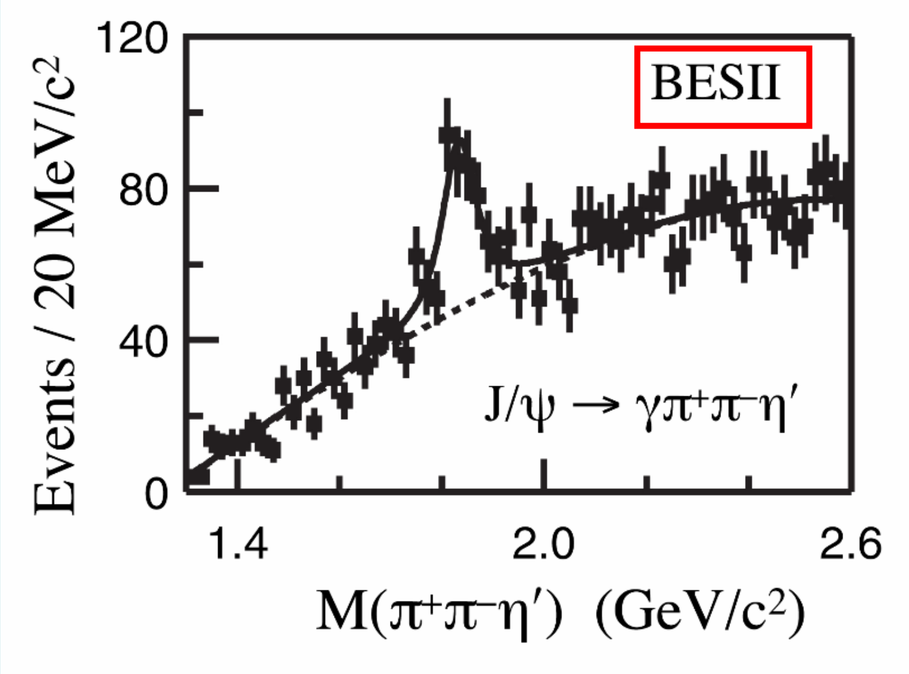


$p\bar{p}$ boundstate (baryonium)?
Many other possibilities suggested.

Phys. Rev. Lett. 91, 022001 (2003)
378 citations – Second highest

X(1835) at BESII

- The X(1860) should be detected in other decay modes.
- G.J. Ding and M.L. Yan suggest η'ππ to be a favorable mode. (PRD C72, 015208 (2005).)
  - there is gluon content in $p\bar{p}$
  - η' has strong coupling to gluons



$\eta' \to \pi^+\pi^-\eta$ and $\eta' \to \gamma\rho$

$M = 1833.7 \pm 6.1 \pm 2.7\ \mathrm{MeV}/c^2$
$\Gamma = 67.7 \pm 20.3 \pm 7.7\ \mathrm{MeV}/c^2$

PRL 95, 262001 (2005)

226 citations

BESI, BESII, & BESIII Comparison

BES Detectors

Sub-system	Parameter	BESI	BESII	BESIII
Beam pipe	Material	Al		Be
MDC	# layers σ_p/p @ 1 GeV/c $\sigma_{dE/dx}$	40 2.4% 8.5%	40 2.5% 8%	43 0.5% 6% @ 1 GeV/c
TOF-barrel	# scint. σ_t	48 330 ps	48 180 ps	2 layers/88 in each 80 ps
TOF-end-cap	# scint. (each end) σ_t	24	24	48 110 ps
EMC-barrel	Construction σ_E/E @ 1 GeV σ_{pos} (cm)	Str. tubes/Pb 24% 3.0	Str. tubes/Pb 21%	CsI(Tl) 2.5% 0.6
EMC-end-cap	Construction σ_E/E @ 1 GeV σ_{pos} (cm)	Str. tubes/Pb 21% 2.3	Str. tubes/Pb 21% 2.3	CsI(Tl) 5% 0.9
Magnet	Type Field (T)	conventional 0.4	conventional 0.4	superconducting 1
Muon-barrel	# layers σ_{pos} (cm)	3 6	3 6	9 RPCs 2
Muon-end-cap	# layers			8 RPCs

BESIII similar overall, but subsystems much improved over BESI and BESII.

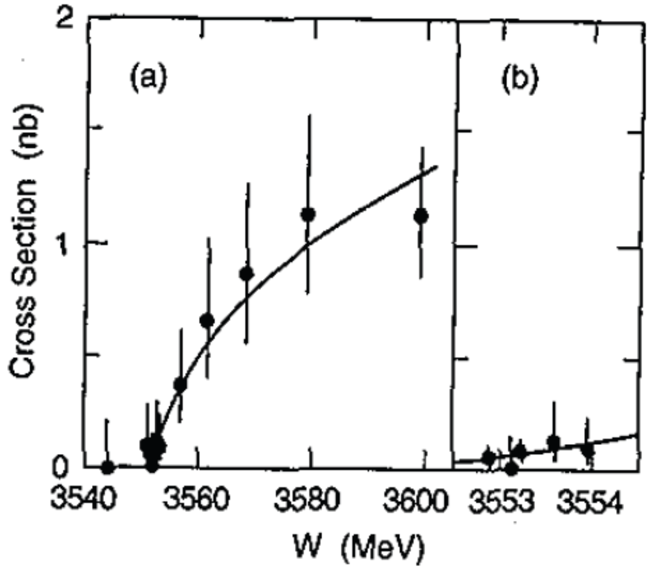
BESI, BESII, and BESIII

	BES	BESII	BESIII
Institutions	14	19	79
Authors	200	204	607
Papers	37	121	> 500
Beam Energy (GeV)	1.1-2.7	1.0-2.8	1.0-2.5
Luminosity (x 10^{33})($cm^{-2}s^{-1}$)	0.007	0.049	1.00
at beam energy (GeV)	2.2	1.55	1.89
MDC σ_p/p at 1 GeV	2.4%	2.5%	0.5%
MDC $\sigma_{dE/dx}/E/dx$	8.5%	8%	6% @ 1GeV
TOF barrel σ_t (ps)	330	180	80
EMC barrel σ_E/E	24%	21%	2.5%

BESIII much improved.

BESI, BESII, and BESIII Comparison

Second measurement of the τ mass at BESI
PRD 53, 20 (1996)



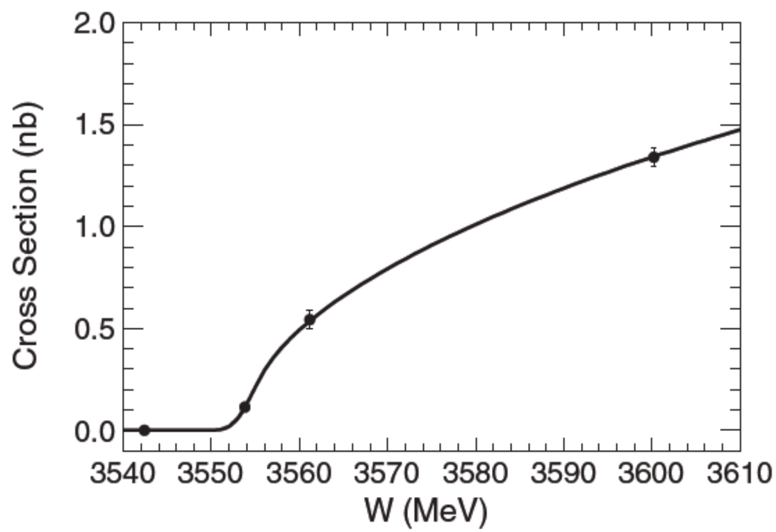
12 points (data-driven), Nov. 91 to Jan. 92 , 5pb⁻¹.
Many channels.

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

$$\left(\frac{G_{\tau\to e\nu\bar{\nu}}}{G_{\mu\to e\nu\bar{\nu}}}\right)^2 = 0.9886 \pm 0.0085$$

152 citations

Measurement of the τ mass at BESIII
PRD 90, 012001 (2014)



4 points, Dec. 2011, 24pb⁻¹.
Many channels, implementing BEMS.

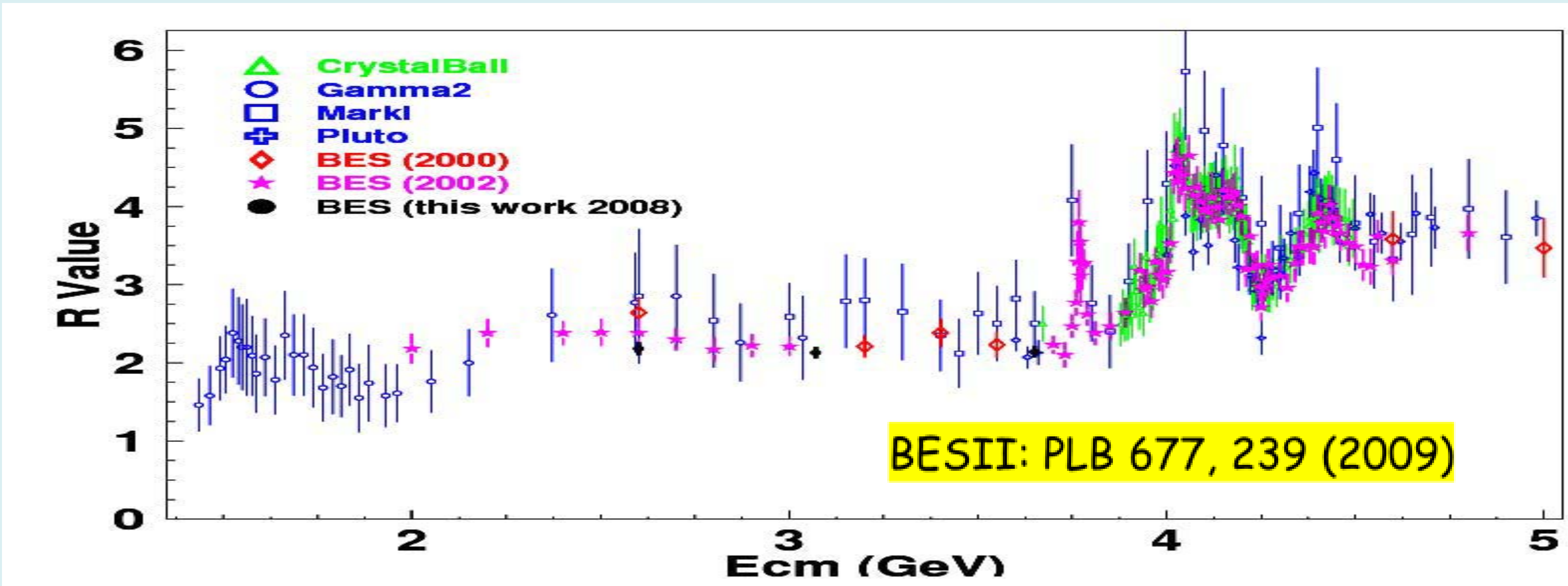
$$m_\tau = 1776.91 \pm 0.12^{+0.10}_{-0.13}\ \mathrm{MeV}$$

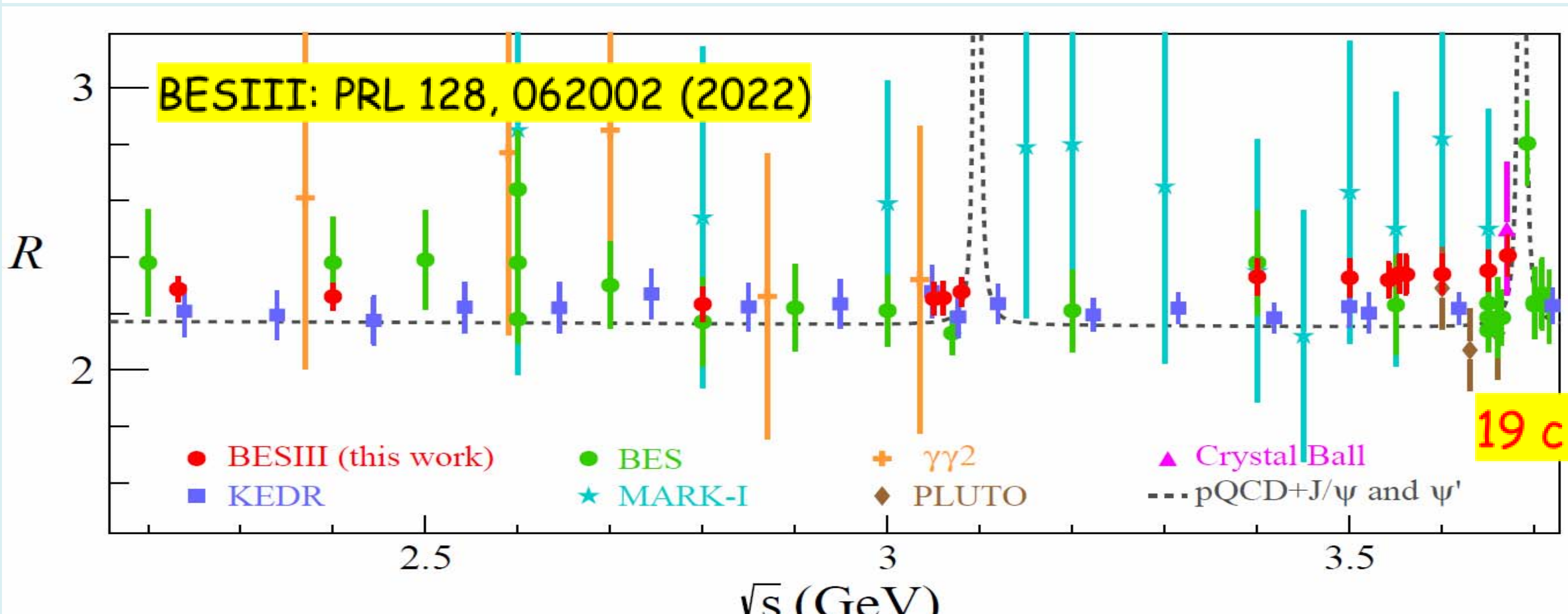
$$\left(\frac{G_{\tau\to e\nu\bar{\nu}}}{G_{\mu\to e\nu\bar{\nu}}}\right)^2 = 1.0016 \pm 0.0042$$

42 citations

BESI, BESII, and BESIII Comparison

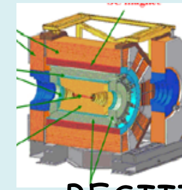
R value





19 citations

BESI, BESII, and BESIII Comparison

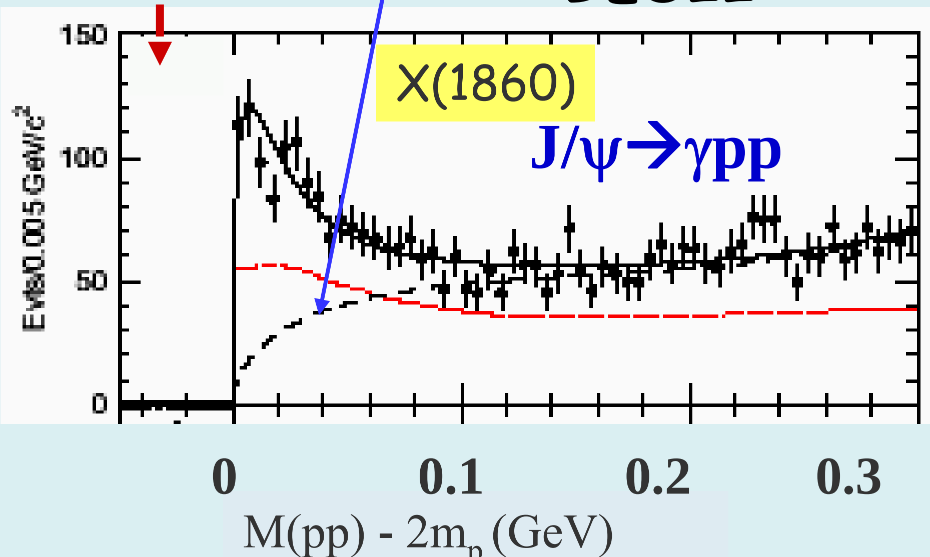


$p\bar{p}$ threshold enhancement @ BESIII

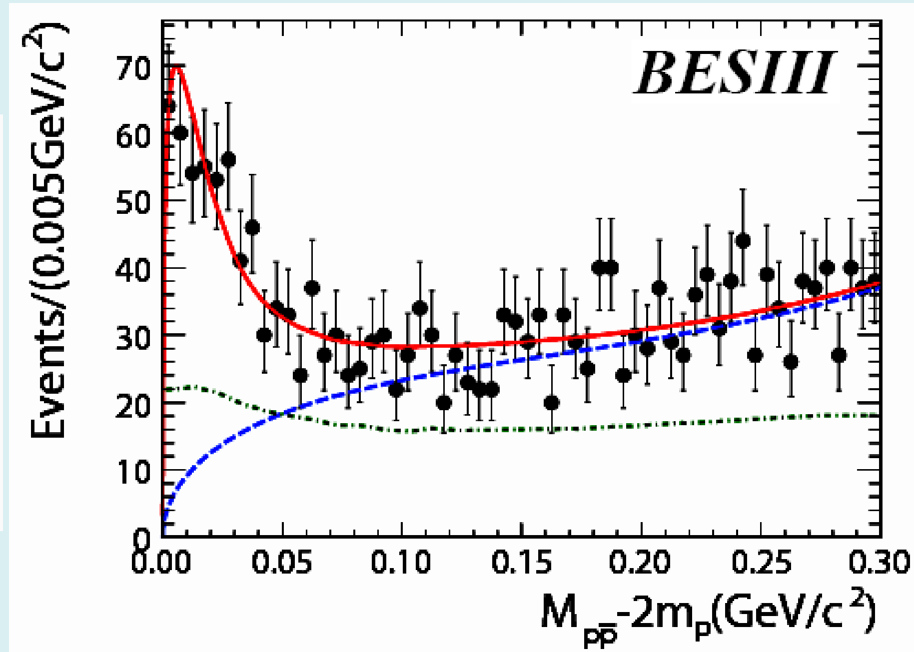
fitted peak location

3-body phase space

BESII



$\psi' \to \pi^+\pi^- J/\psi, J/\psi \to \gamma p\bar{p}$



$M = 1859 ^{+3}_{-10} {}^{+5}_{-25}$ MeV/c²

$\Gamma < 30$ MeV/c² (90% CL)

Phys. Rev. Lett. 91, 022001 (2003)

$M = 1861 ^{+6}_{-13} {}^{+7}_{-26}$ MeV/c²

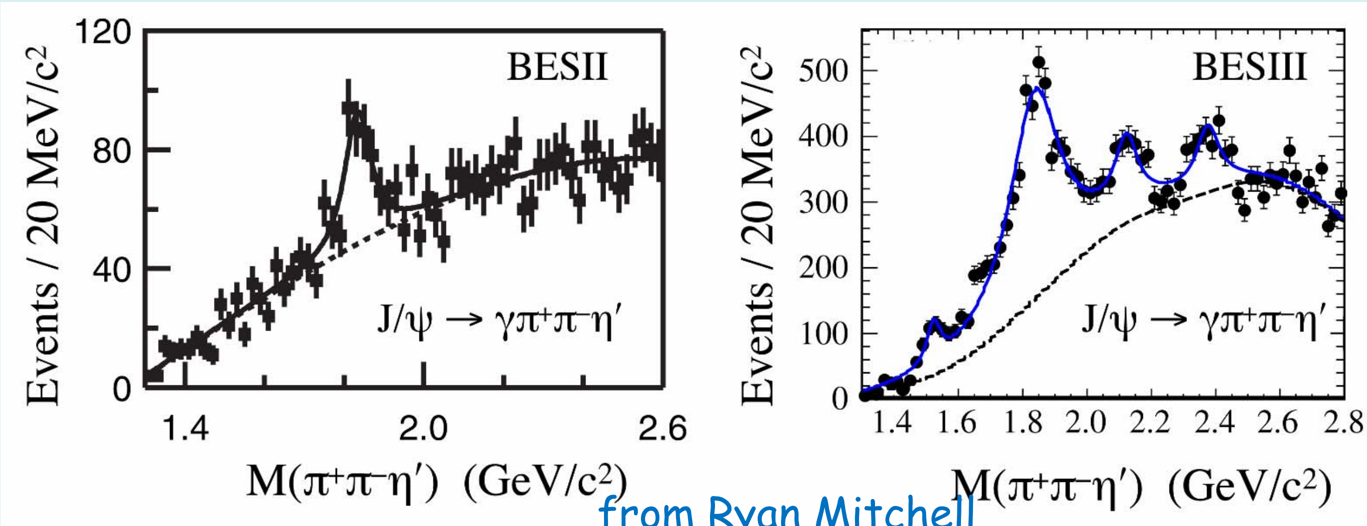
$\Gamma < 38$ MeV/c² (90% CL)

Chinese Physics C 34, 421 (2010)
69 citations

Consistent observation by BESIII !

BESI, BESII, and BESIII Comparison

Observation of X(1835) in $J/\Psi \rightarrow \gamma X(1835) \rightarrow \gamma \pi^+ \pi^- \eta'$



from Ryan Mitchell

$\eta' \rightarrow \pi^+\pi^-\eta$ and $\eta' \rightarrow \gamma\rho$

$\eta' \rightarrow \pi^+\pi^-\eta$ and $\eta' \rightarrow \gamma\rho$

M = 1833.7 $\pm$ 6.1 $\pm$ 2.7 MeV/

Γ = 67.7 $\pm$ 20.3 $\pm$ 7.7 MeV/c

PRL 95, 262001 (2005)

226 citations

resonance	M(MeV/c^2)	Γ(MeV/c^2)	N_{event}
$f_1(1510)$	1522.7 ± 5.0	48 ± 11	230 ± 37
$X(1835)$	1836.5 ± 3.0	190.1 ± 9.0	4265 ± 131
$X(2120)$	2122.4 ± 6.7	83 ± 16	647 ± 103
$X(2370)$	2376.3 ± 8.7	83 ± 17	565 ± 105

PRL 106, 072002 (2011)

169 citations

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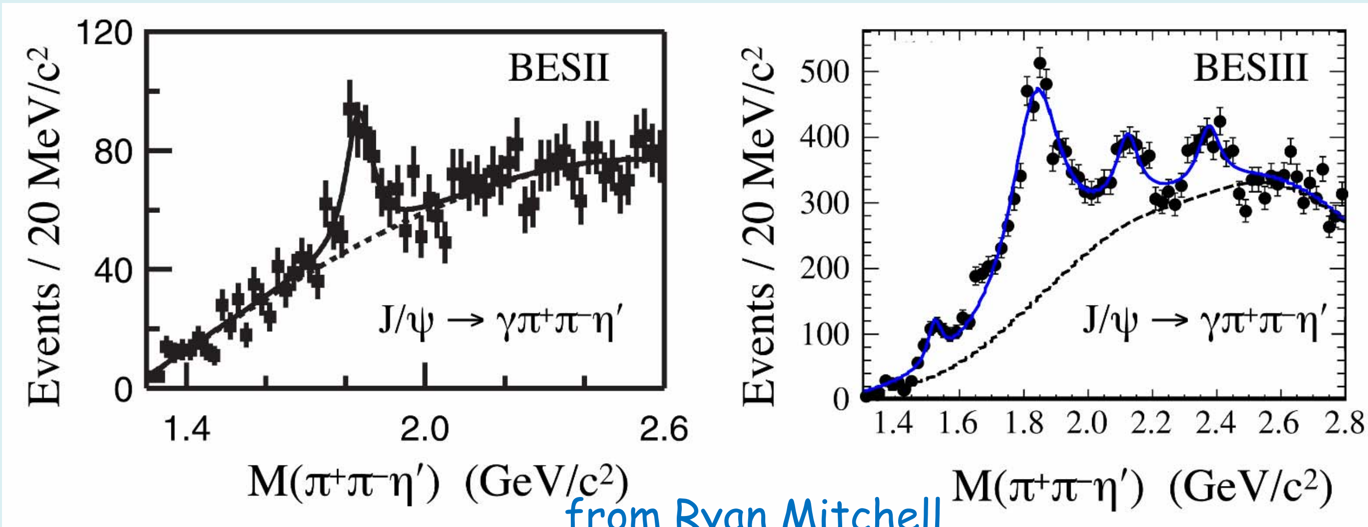

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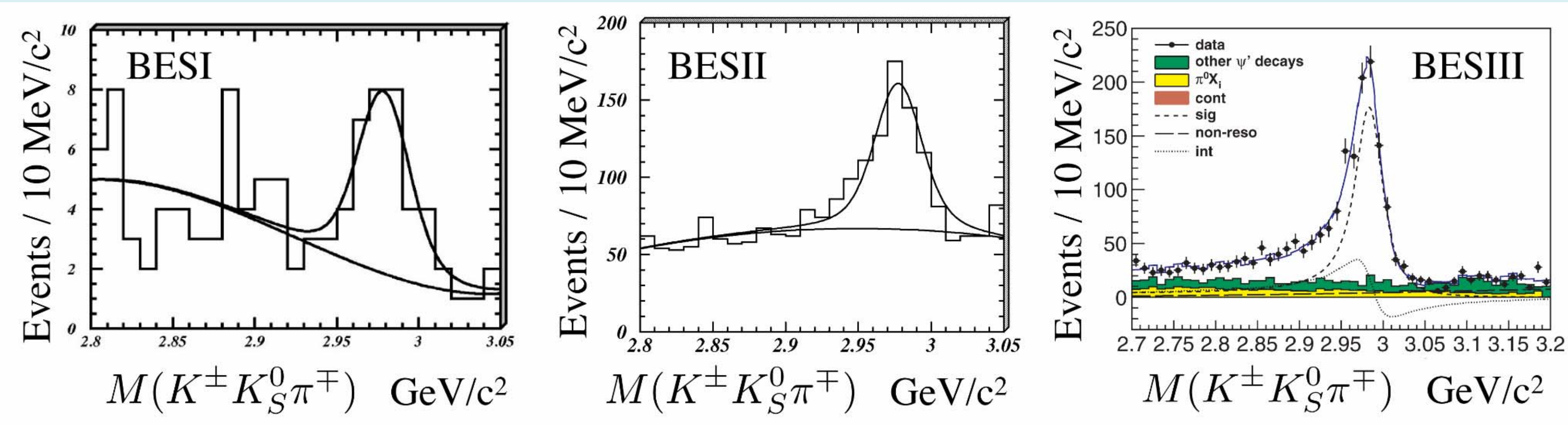
But BESIII with more data [PRL 117 (2016) 4, 042002] finds that main peak is made from the interference of two resonances. The story gets even more intriguing.

BESI, BESII, and BESIII Comparison

Measurement of $\eta_c(1S)$ mass using $\eta_c(1S) \to K^{\pm}K^{0}\pi$



Above from Ryan Mitchell

BESI using $J/\Psi \to \gamma\, \eta_c$ from 7.8 M J/Ψ events.

BESII using $J/\Psi \to \gamma\, \eta_c$ from 58 M J/Ψ events.

BESIII using $J/\Psi \to \gamma\, \eta_c$ from 106 M $\Psi(2S)$ events.

Using above and 3.8 M $\Psi(2S)$ decays,
$M(\eta_c)$ = 2976.3 $\pm$2.3$\pm$1.2 MeV/c^2

$M(\eta_c)$ = 2977.3$\pm$1.0$\pm$1.2 MeV/c^2

$M(\eta_c)$ = 2984.3 0.6$\pm$0.6 MeV/c^2

BESIII: Accounting for the distorted line shape and including interference with background, mass shifted considerably higher. Now consistent with other production mechanisms.


Summary
West Lake, Hangzhou, China

Summary and Comments

- Cooperation of US and China was important for the early development of BES. Many thanks to Pief and T.D. Lee for their early efforts on behalf of BES.
- BESI and BESII produced many interesting results and were very important stepping stones to BESIII.
- BEPCII and BESIII much improved over previous.
- The great increase in data of BESIII has allowed much more detailed analyses of many processes.
- Having 500 publications is a great achievement and is due to the great efforts of both BEPCII and BESIII physicists and engineers.
- Let's get the next 500.

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