

BES-II Recent Results on $\psi(3770)$ and D Mesons Production and Decays

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Outline

- ◆ **Introduction**
- ◆ **Inclusive Decays of D Mesons**
- ◆ **Measurements of R**
- ◆ **Measurements of Parameters of $\psi(3770)$**
- ◆ **Measurements of $B[\psi(3770) \rightarrow \text{non-}D\bar{D}]$**
- ◆ **Search for Charmless Decays of $\psi(3770)$**
- ◆ **Summary**

Introduction

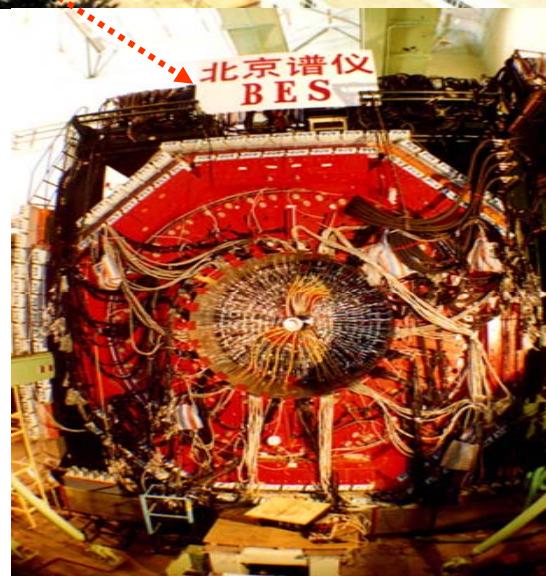
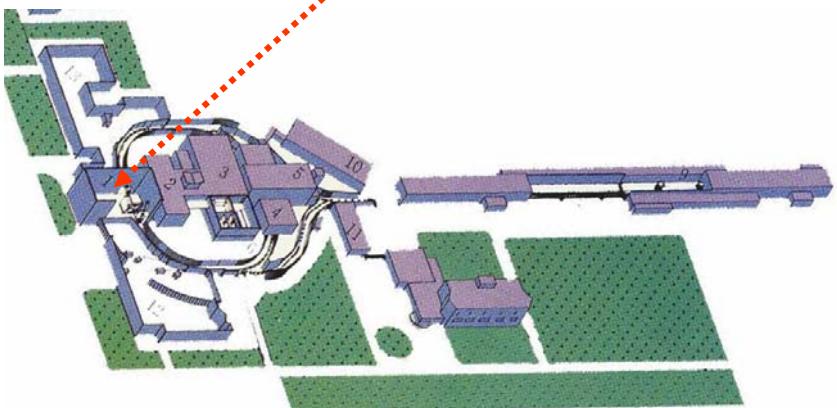
BES-II/BEPC

The bird-view of Beijing Electron Positron Collider

$L \sim \sim 1 \times 10^{31} / \text{cm}^2 \cdot \text{s}$

at $\psi(3770)$ peak

$E_{\text{cm}} \sim 2\text{-}5 \text{ GeV}$



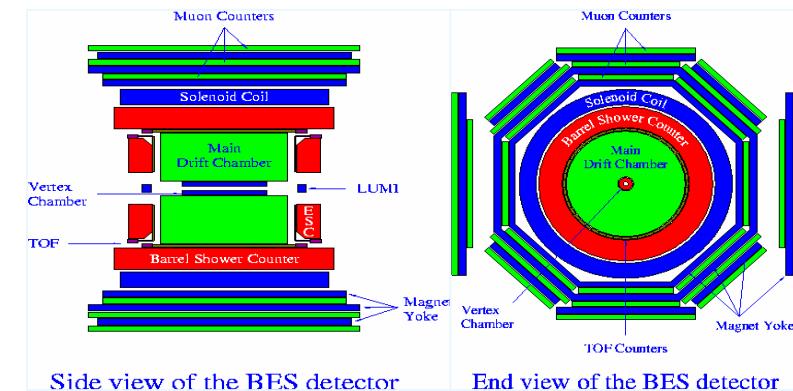
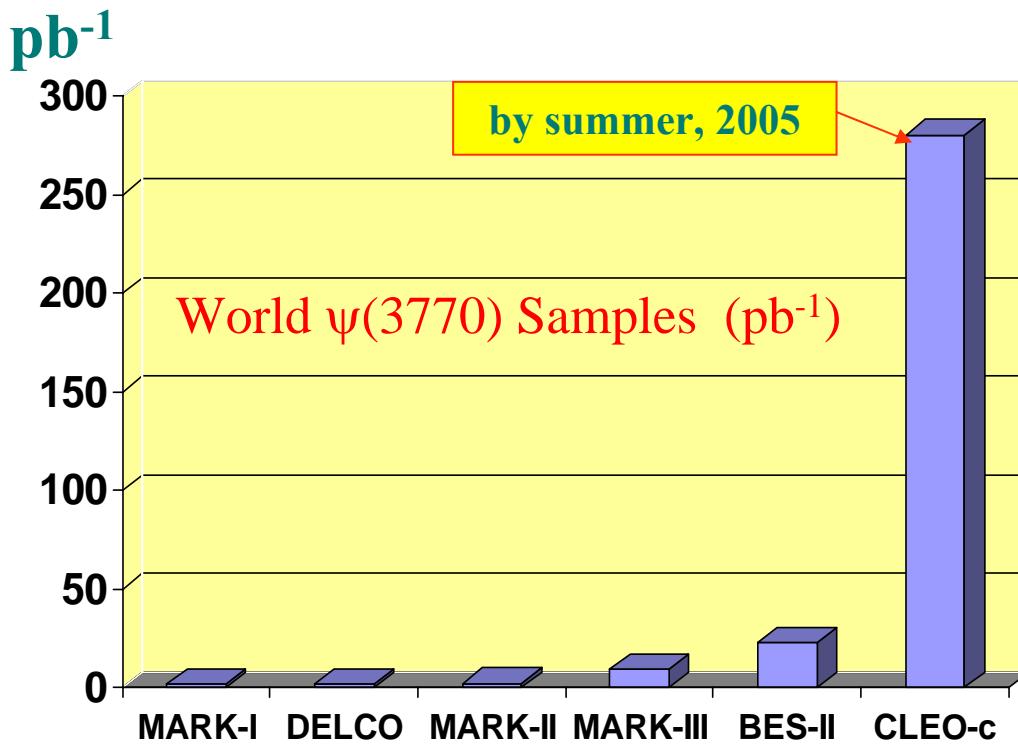
Introduction

Data Samples

- ❖ about 17.3 pb^{-1} data taken at 3.773 GeV
- ❖ about 7 pb^{-1} data taken from 3.768 GeV to 3.778 GeV
- ❖ about 8 pb^{-1} data taken from 3.665 to 3.878 GeV
 - about 6.5 pb^{-1} data taken at 3.650 GeV
 - about 1 pb^{-1} data taken at 3.665 GeV

BESII $\psi(3770)$
data sample of
about 33 pb^{-1}

cross
section
scan data



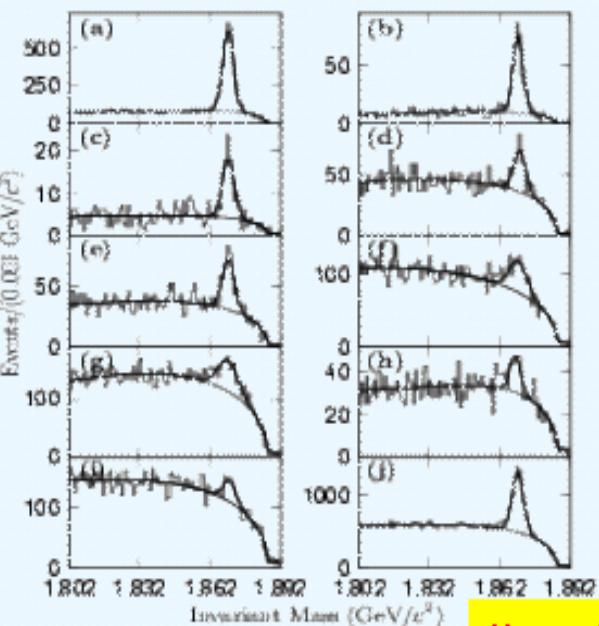
VC: $\sigma_{xy} = 100 \mu\text{m}$ TOF: $\sigma_T = 180 \text{ ps}$ μ counter: $\sigma_{r\phi} = 3 \text{ cm}$
MDC: $\sigma_{xy} = 220 \mu\text{m}$ BSC: $\Delta E/\sqrt{E} = 22 \%$ $\sigma_z = 5.5 \text{ cm}$
 $\sigma_{dE/dx} = 8.5 \%$ $\sigma_\phi = 7.9 \text{ mr}$ B field: 0.4 T
 $\Delta p/p = 1.78\% \sqrt{(1+p^2)}$ $\sigma_z = 3.1 \text{ cm}$

D⁻ and D⁰ tags

Double tag analysis

Singly tagged D̄ samples

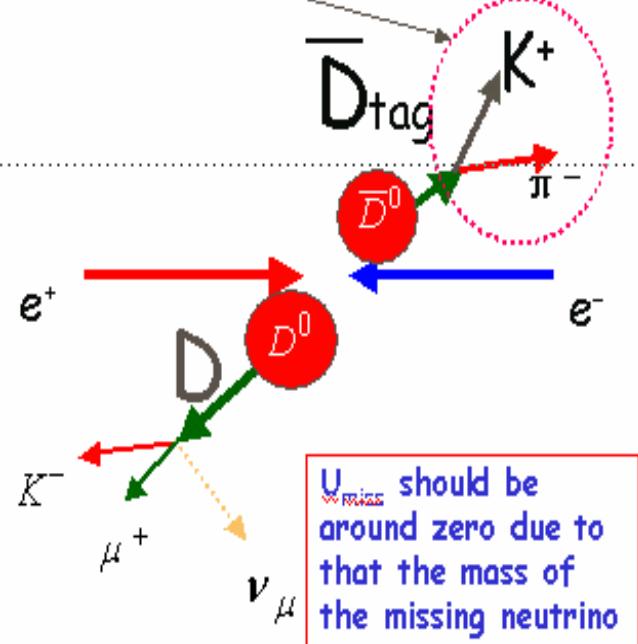
$$N_{D^- \text{ Tag}} = 5321 \pm 125 \pm 160$$



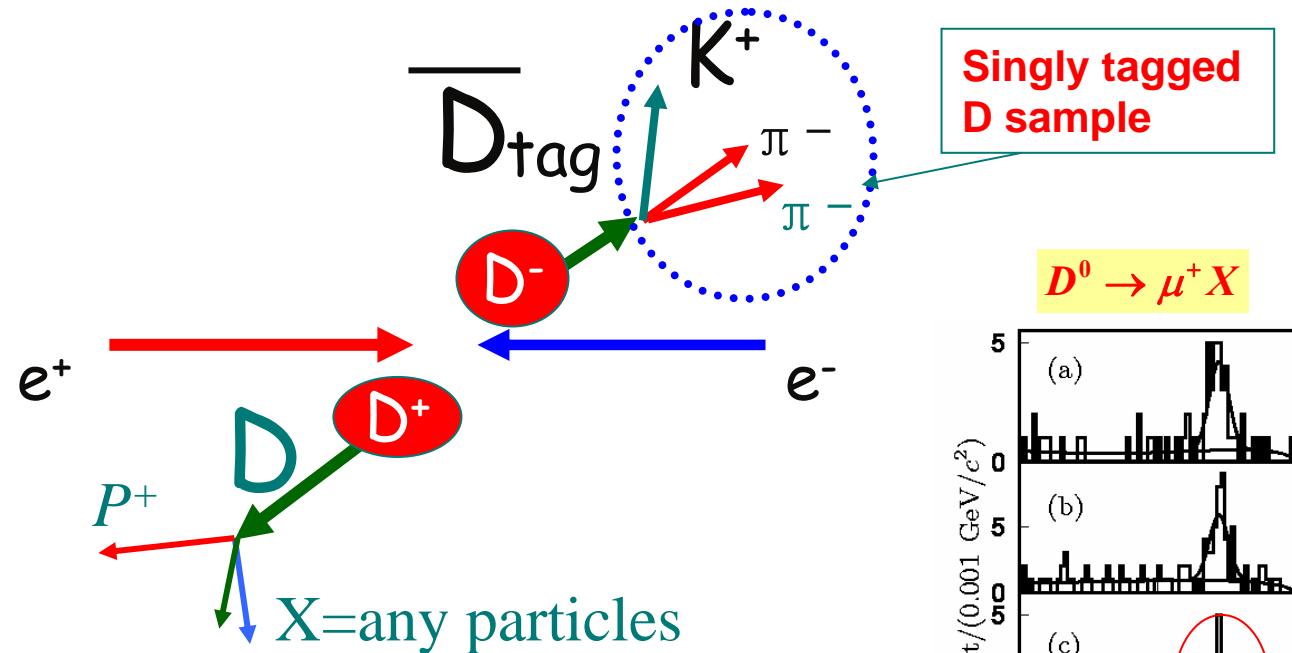
$$N_{D^0 \text{ Tag}} = 7584 \pm 198 \pm 241$$

Absolute measurements

Singly tagged D sample



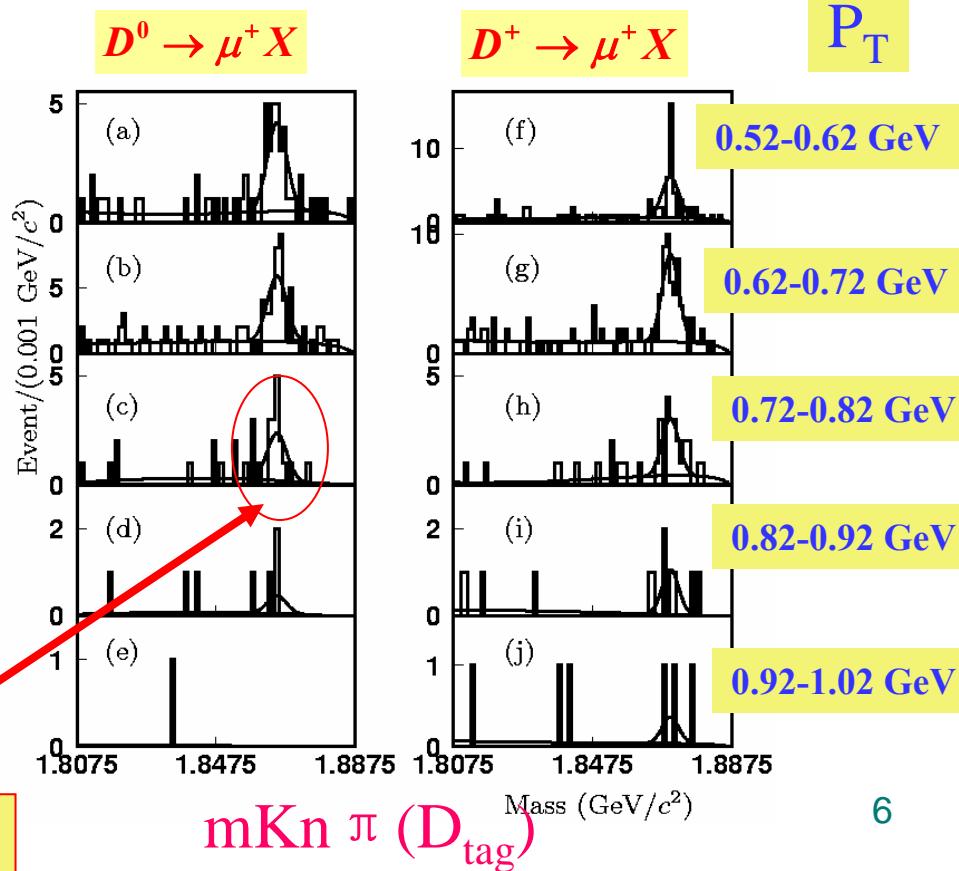
$D \rightarrow \mu^+ X$



P^+ is any charged particle (μ , e , π and K)

N_{μ}^{obs}

With the singly tagged \bar{D} sample, we can do some absolute measurements of D decays on the side recoiling against the tags .



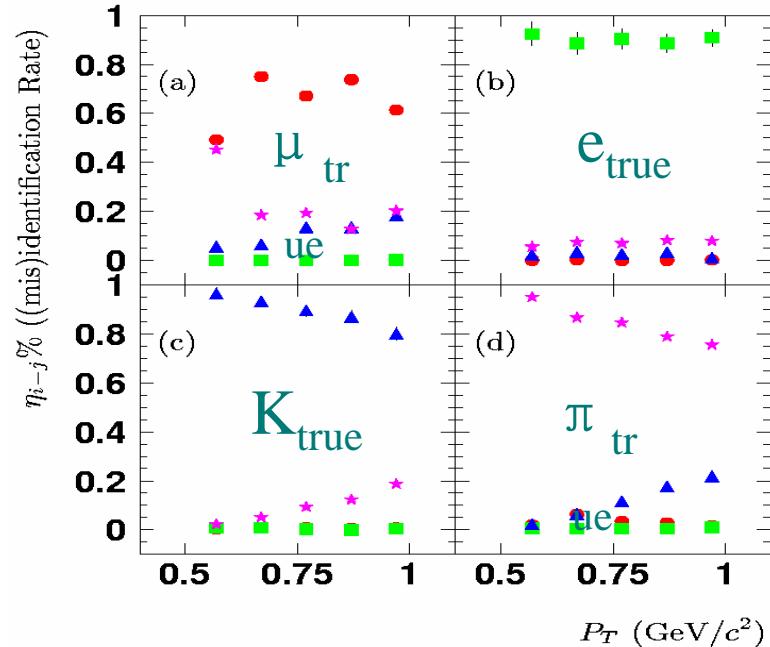
D \rightarrow μ^+X

$$\begin{aligned} N_{obs}^\mu &= N_{true}^\mu \epsilon_{\mu\mu} + N_{true}^e \epsilon_{e\mu} + N_{true}^k \epsilon_{k\mu} + N_{true}^\pi \epsilon_{\pi\mu} \\ N_{obs}^e &= N_{true}^\mu \epsilon_{\mu e} + N_{true}^e \epsilon_{ee} + N_{true}^k \epsilon_{ke} + N_{true}^\pi \epsilon_{\pi e} \\ N_{obs}^k &= N_{true}^\mu \epsilon_{\mu k} + N_{true}^e \epsilon_{ek} + N_{true}^k \epsilon_{kk} + N_{true}^\pi \epsilon_{\pi k} \\ N_{obs}^\pi &= N_{true}^\mu \epsilon_{\mu\pi} + N_{true}^e \epsilon_{e\pi} + N_{true}^k \epsilon_{k\pi} + N_{true}^\pi \epsilon_{\pi\pi} \end{aligned}$$

$$\begin{pmatrix} N_{true}^\mu \\ N_{true}^e \\ N_{true}^k \\ N_{true}^\pi \end{pmatrix} = \begin{pmatrix} \epsilon_{\mu\mu} & \epsilon_{e\mu} & \epsilon_{k\mu} & \epsilon_{\pi\mu} \\ \epsilon_{\mu e} & \epsilon_{ee} & \epsilon_{ke} & \epsilon_{\pi e} \\ \epsilon_{\mu k} & \epsilon_{ek} & \epsilon_{kk} & \epsilon_{\pi k} \\ \epsilon_{\mu\pi} & \epsilon_{e\pi} & \epsilon_{k\pi} & \epsilon_{\pi\pi} \end{pmatrix}^{-1} \begin{pmatrix} N_{obs}^\mu \\ N_{obs}^e \\ N_{obs}^k \\ N_{obs}^\pi \end{pmatrix}$$

N_{obs}^i =observed particle I; N_{true}^i =true particle i

	$B(D^0 \rightarrow \mu^+ X)(\%)$	$B(D^+ \rightarrow \mu^+ X)(\%)$
ARGUS	$6.0 \pm 0.7 \pm 1.2$	-
CHORUS	$6.5 \pm 1.2 \pm 0.3$	-
BES-II	$6.8 \pm 1.5 \pm 0.6$	$17.6 \pm 0.7 \pm 1.3$
PDG	6.6 ± 0.6	



ϵ_{im} = ratio of a particle “i” to be identified as “m”

the first measurement

$$\frac{B(D^+ \rightarrow \mu^+ X)}{B(D^0 \rightarrow \mu^+ X)} = 2.59 \pm 0.70 \pm 0.15$$

$$\frac{\tau_{D^+}}{\tau_{D^0}} = 2.54 \pm 0.02$$

PDG

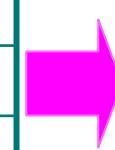
D \rightarrow e $^+$ X and D \rightarrow KX

B(D \rightarrow e $^+$ X)

	$B(D^0 \rightarrow e^+ X)(\%)$	$B(D^+ \rightarrow e^+ X)(\%)$
CLEO-c	$6.46 \pm 0.17 \pm 0.13$	$16.13 \pm 0.20 \pm 0.33$
MarkIII	$7.5 \pm 1.1 \pm 0.4$	$17.0 \pm 1.9 \pm 0.7$
BES-II	$6.3 \pm 0.7 \pm 0.4$	$15.2 \pm 0.9 \pm 0.8$
PDG2007	6.55 ± 0.17	16.1 ± 0.4

Comparison of Results

Preliminary



$$\frac{\Gamma(D^+ \rightarrow e^+ X)}{\Gamma(D^0 \rightarrow e^+ X)} = 0.95 \pm 0.12 \pm 0.07$$

B(D \rightarrow K $^{+/-}$ X)

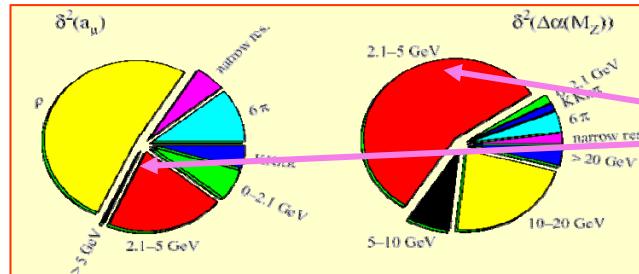
	$B(D^+ \rightarrow K^- X)(\%)$	$B(D^+ \rightarrow K^+ X)(\%)$	$B(D^0 \rightarrow K^- X)(\%)$	$B(D^0 \rightarrow K^+ X)(\%)$
BES-II	$24.7 \pm 1.3 \pm 1.2$	$6.1 \pm 0.9 \pm 0.4$	$57.8 \pm 1.6 \pm 3.2$	$3.5 \pm 0.7 \pm 0.3$
PDG2007	27.5 ± 2.4	5.5 ± 1.6	53 ± 4	$3.4^{+0.6}_{-0.4}$

The quantity R

◆ Why are we interested in R(s) ?

- Vacuum polarization correction needs the R(s) values, which plays an important role in the precision test of the Standard Model.
- For evaluation of the electromagnetic coupling at the Z mass scale, $\alpha_{QED}(M_Z)$.
- For determination of $a_\mu = (g_\mu - 2)/2$ of the muon.

$$a_\mu^{\text{had, LO}} = \frac{\alpha^2(0)}{3\pi^2} \int_{4m_\pi^2}^\infty ds \frac{K(s)}{s} R(s)$$



- Evaluate $\alpha_s(s)$
- Non-DD decays of $\psi(3770)$

$\alpha_{QED}(M_Z)$ affects the determination of the mass of Higgs boson from the measurement of $\sin^2 \theta_w$ indirectly.

The R values at all energies is needed to calculate the effects of vacuum polarization on the parameters of Standard Model. [for example, $\alpha_{QED}(M_Z)$ and a_μ]. A large uncertainty in this calculation arises from the uncertainties in the measured R values in the open charm threshold region (3.7 GeV to 5.0 GeV).

The quantity R

- Precision measurements of the R values in open charm region are also important in understanding 1^- resonance production, for searching for new states, study of dynamics ...

◆ $\psi(3770)$ production & decays

It is believed to be a mixture of 1^3D_1 and 2^3S_1 waves of $c\bar{c}$ system. It is thought to decay almost entirely to pure DD-bar.

Long-standing puzzle of $\psi(3770)$ production and decays

Before BES-II & CLEO-c, previously published data indicate that more than about 35% of $\psi(3770)$ does not decay to DD-bar ? This conflicts with theoretical prediction.

The quantity R

◆ New Measurements

Recently BES and CLEO-c measured the $D\bar{D}$ and $\psi(3770)$ production at 3.773 GeV based on the data taken below $D\bar{D}$ threshold and at 3.773 GeV.

To uncover the puzzle, a better way is to make cross section scan

A better way to measure the cross sections, the widths of the resonance and the $D\bar{D}$ branching fractions of $\psi(3770)$ is to analyze the line-shapes of $\psi(3770)$, $\psi(3686)$ and $D\bar{D}$ production simultaneously.

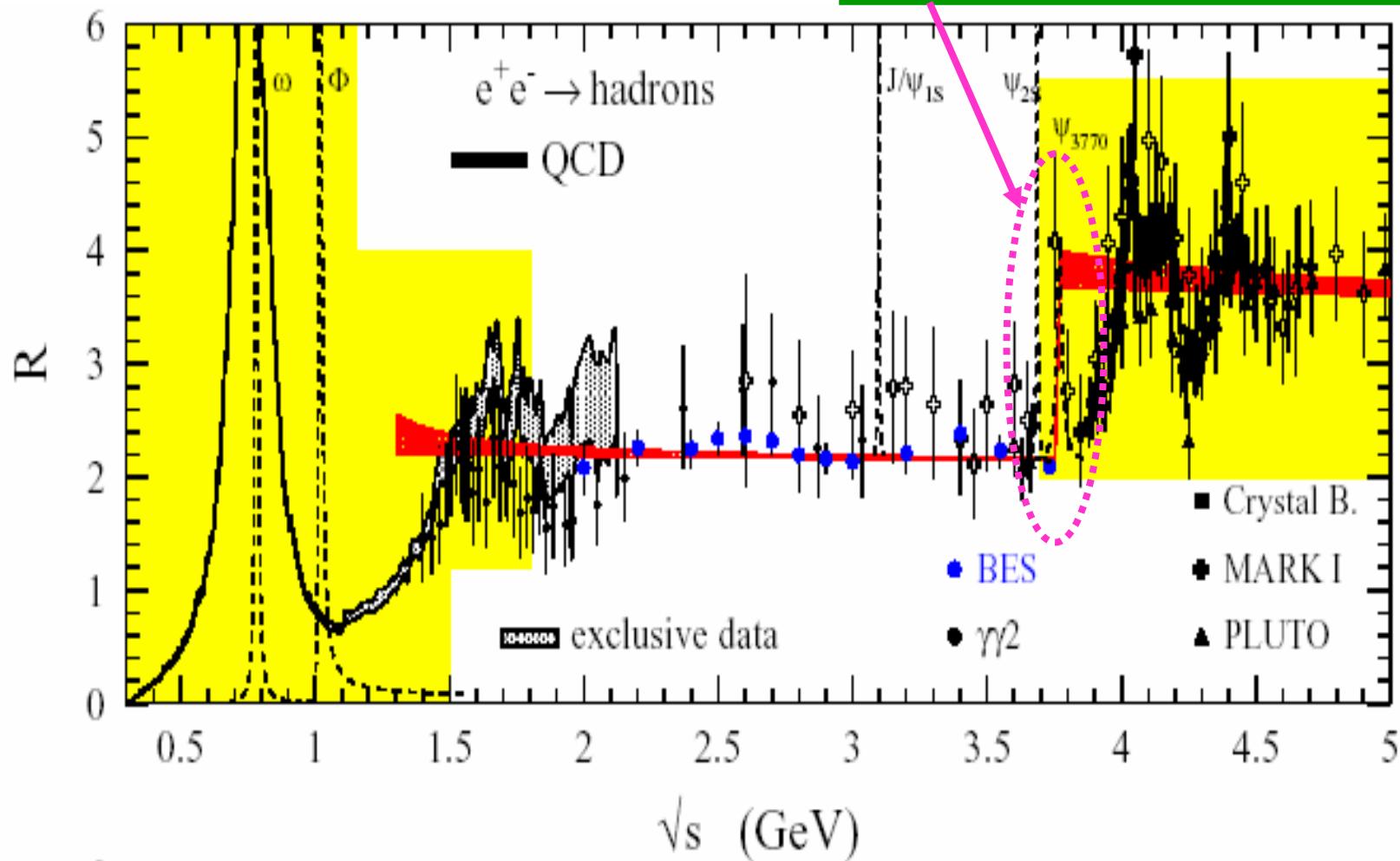
BES made several fine cross section scans covering both the $\psi(3686)$ and $\psi(3770)$ to measure the resonance parameters, branching fractions and search for non- $D\bar{D}$ decays ...

The quantity R

The Previously Measured quantity R

Including all hadrons

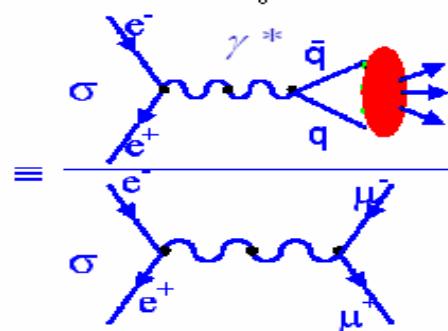
Precision measurement of the cross sections in this region



The quantity R

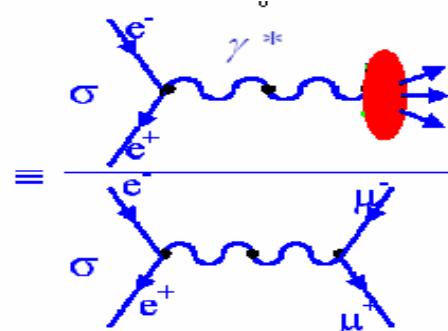
Definition & measurements of different R

$$R_{uds(c)+\psi(3770)}(s) = \begin{cases} R_{uds(c)}(s) + R_{\psi(3770)}(s) & (\text{above DD-bar threshold}) \\ R_{uds} & (\text{below DD-bar threshold}) \end{cases}$$



$$R_{\text{had}}(s) = R_{uds(c)}(s) + \sum R_{\text{res}, i}(s),$$

$R_{\text{res}, i}(s)$ are R values due to all 1^{--} resonances decay to hadrons.



calculate

$$\alpha_{QED}(M_Z)$$

$$a_\mu = (g_\mu - 2)/2$$

Results

$$R_{uds} = 2.141 \pm 0.025 \pm 0.085$$

Below DD-bar threshold

$$R^{\text{pQCD}}_{uds} = 2.15 \pm 0.03$$

PRL 97, 262001 (2006)

The quantity R

R_{had} , $R_{\text{uds}(c)}$ and $R_{\text{uds}(c)+\psi(3770)}$

Results

PRL 97, 262001 (2006)

Table 1. Systematic uncertainties in the determination of R values

Sources	$\Delta_{\text{SYS}} (\%)$
Luminosity	1.8
Hadron selection	2.5
M. C. modeling	2.0
ISR	1.5
$\psi(3770)$ resonance parameters	2.7
Total (off $\psi(3770)$ region)	3.9
Total (within $\psi(3770)$ region)	4.9

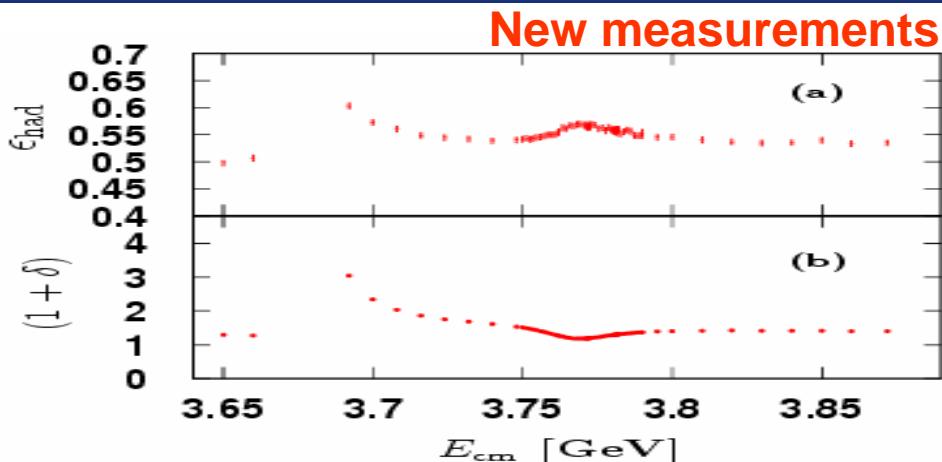
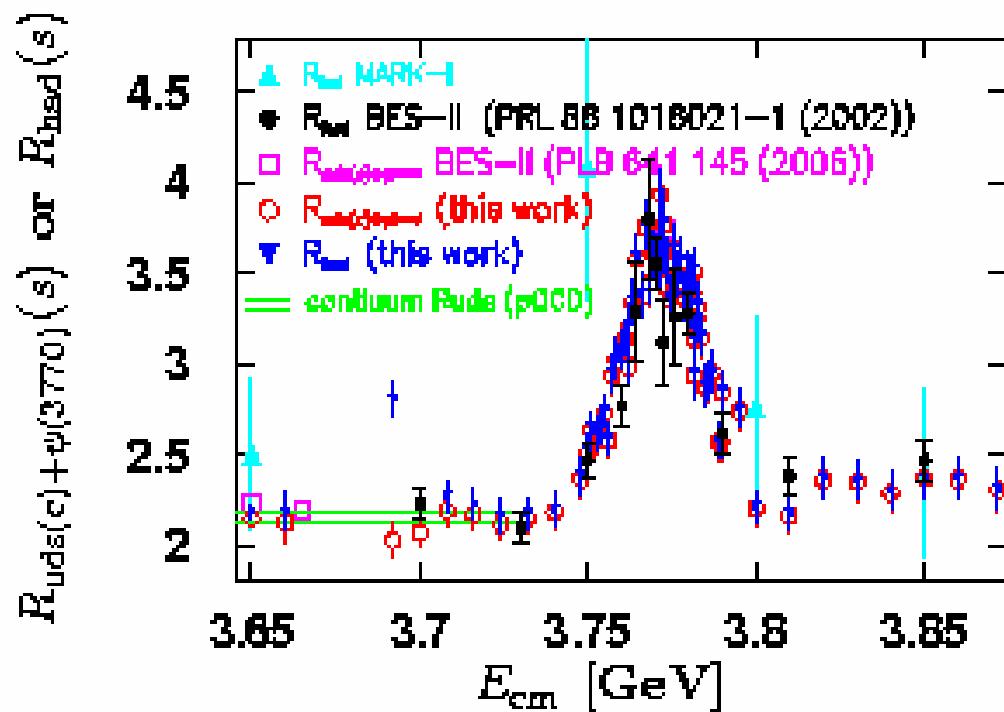
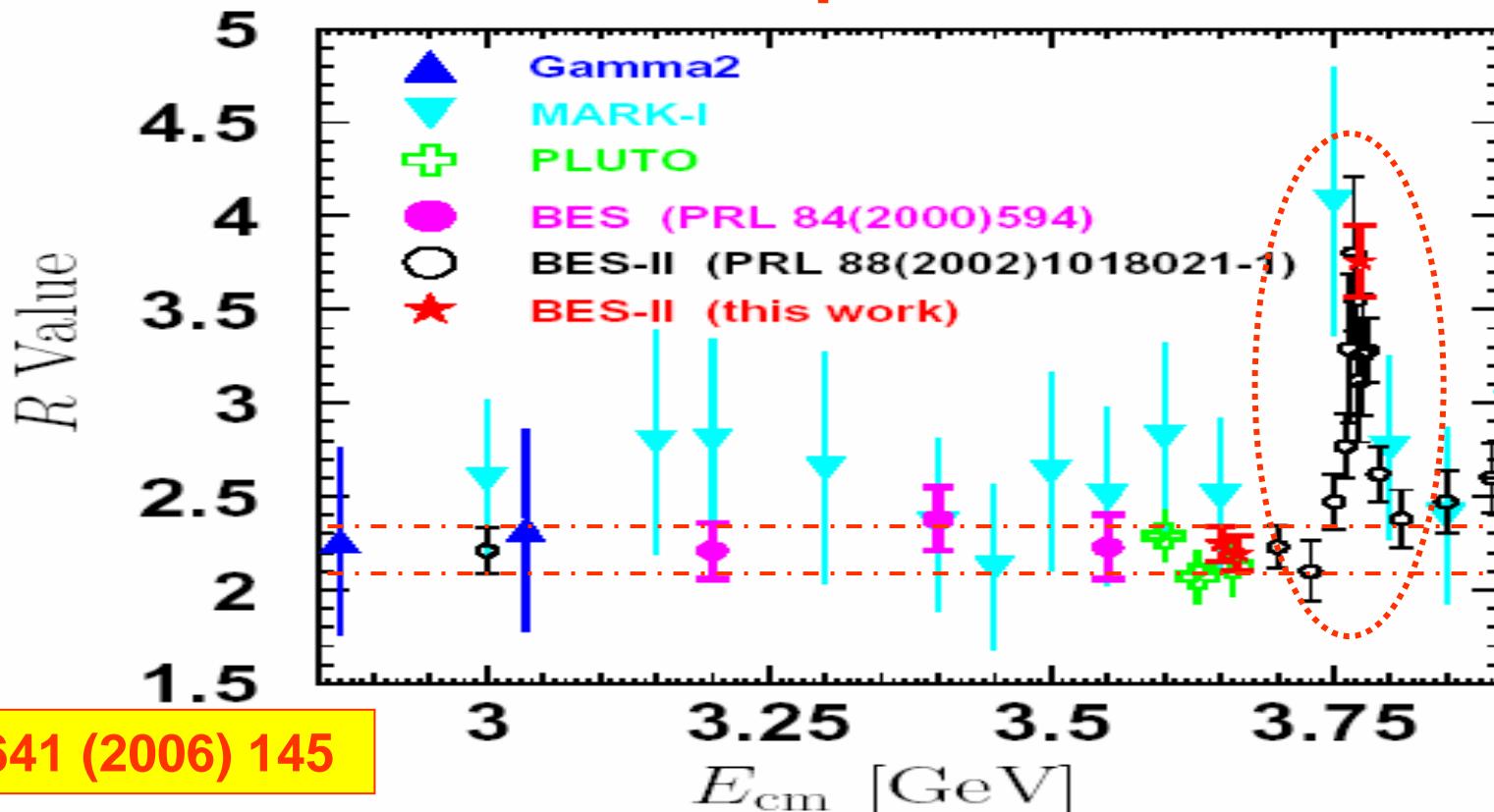


FIG. 2: (a) The efficiency versus the nominal c.m. energy; (b) The ISR factor versus the nominal c.m. energy (see text).



The quantity R

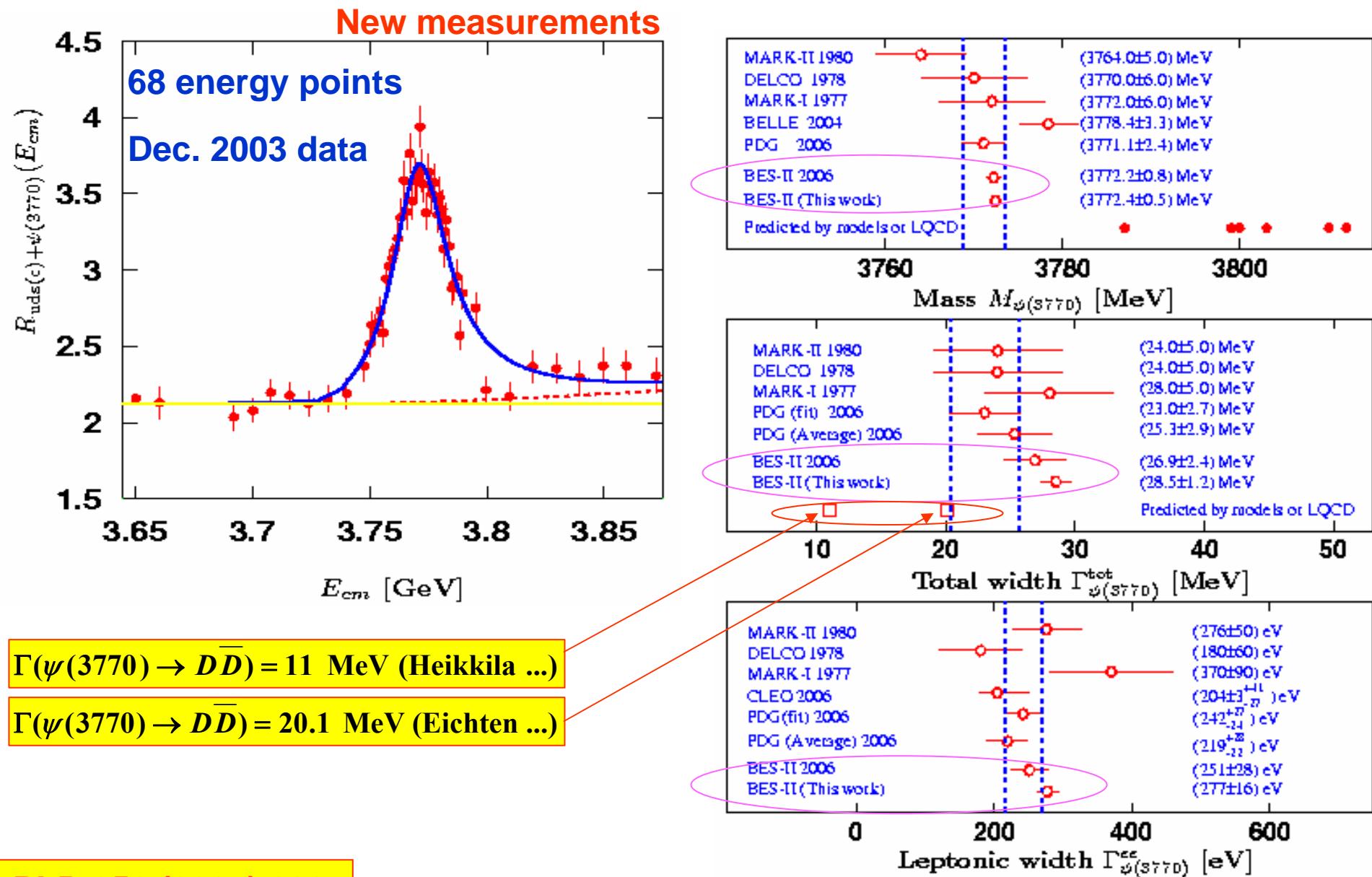
Comparison of R measurements from different experiments



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FIG. 4: The values of R measured by BES Collaboration, MARK-I Collaboration, $\gamma\gamma 2$ Collaboration and PLUTO Collaboration in the energy region between 2.85 and 3.90 GeV, where the error bars show the combined statistical and systematic errors in quadrature.

Resonance Parameters of $\psi(3770)$



Resonance Parameters of $\psi(3770)$

New measurements

Comparison with those measured by other experiments (energy scan)

Experiment	$\sigma^{\text{prd}}[e^+e^- \rightarrow \psi(3770)][\text{nb}]$	$\sigma^{\text{obs}}[e^+e^- \rightarrow \psi(3770)][\text{nb}]$	
BES (PLB 625 (2007) 238)	$10.0 \pm 0.3 \pm 0.5$	$7.2 \pm 0.2 \pm 0.4$	Dec. 2003 data
BES [PRL 97(2006)121801]	$9.6 \pm 0.7 \pm 0.4$	$6.9 \pm 0.5 \pm 0.3$	Mar. 2003 data
MARKII		9.3 ± 1.4	

$M_{\psi(3770)}(\text{MeV})$	$\Gamma^{\text{tot}}_{\psi(3770)}(\text{MeV})$	$\Gamma^{\text{ee}}_{\psi(3770)}(\text{eV})$	Note
$3772.4 \pm 0.4 \pm 0.3$	$28.5 \pm 1.2 \pm 0.2$	$277 \pm 11 \pm 13$	PLB 625 (2007) 238
$3772.2 \pm 0.7 \pm 0.3$	$26.9 \pm 2.4 \pm 0.3$	$251 \pm 26 \pm 11$	PRL 97(2006)121801

Experiment	BES [PLB 652(2007) 238]	BES [PRL 97(2006)121801]	PDG
$B[\psi(3770) \rightarrow e^+e^-][\times 10^{-5}]$	$0.97 \pm 0.03 \pm 0.05$	$0.93 \pm 0.06 \pm 0.03$	1.05 ± 0.14

Dec. 2003 data

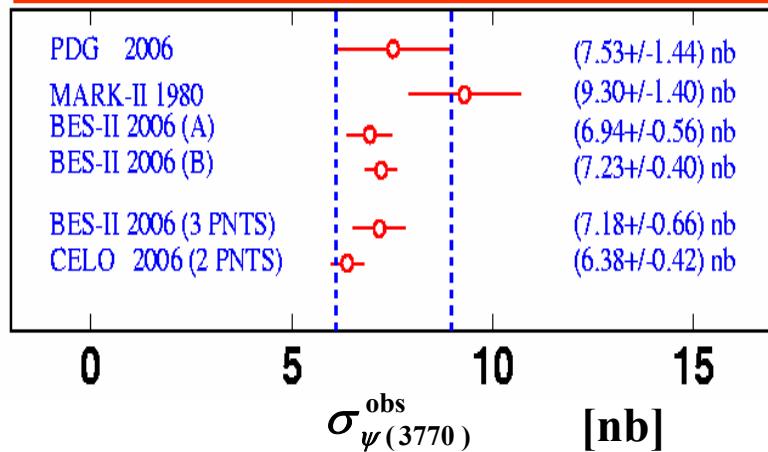
Mar. 2003 data

$R_{uds} = 2.121 \pm 0.023 \pm 0.084$ (fit to cross sections at 68 energy points) 17

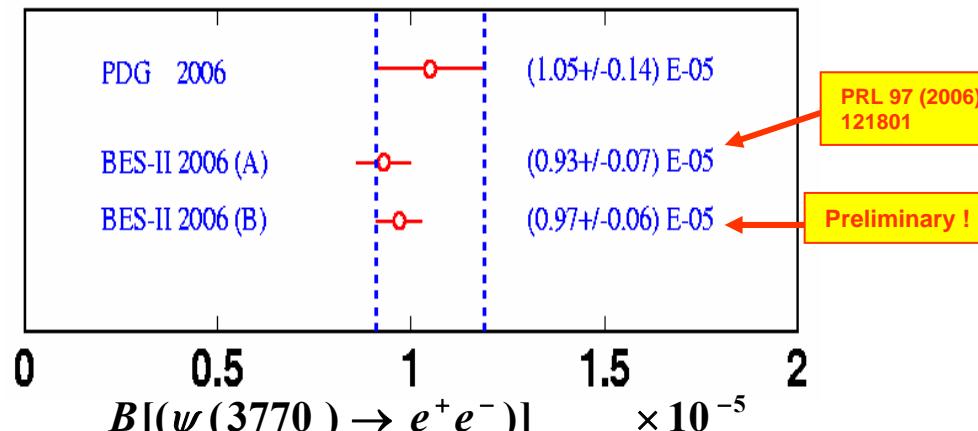
Resonance Parameters of $\psi(3770)$

What about World Average

Comparison of measurements of the cross section for $\psi(3770)$ production



Leptonic branching fraction



$$B[\psi(3686) \rightarrow e^+e^-] = (0.704 \pm 0.122 \pm 0.033)\%$$

PRL 97 (2006) 121801

$$B[\psi(3686) \rightarrow e^+e^-] = (0.735 \pm 0.018)\%$$

PDG04

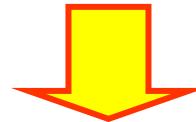
B[$\psi(3770) \rightarrow$ non-DD]

Branching fractions

$$BF(\psi(3770) \rightarrow D^0 \bar{D}^0) = (46.7 \pm 4.7 \pm 2.3)\%$$

$$BF(\psi(3770) \rightarrow D^+ D^-) = (36.9 \pm 3.7 \pm 2.8)\%$$

$$BF(\psi(3770) \rightarrow D\bar{D}) = (83.6 \pm 7.3 \pm 4.2)\%$$



$$BF(\psi(3770) \rightarrow \text{non-}D\bar{D}) = (16.4 \pm 7.3 \pm 4.2)\%$$

where the first error is statistical and second systematic, which arises from the un-canceled systematic uncertainties in hadron cross sections (~4.4 %), neutral DD-bar cross sections (~4.5 %) and charged DD-bar cross sections (~7.4 %).

PRL 97 (2006) 121801

Mar. 2003 data set

Obtained from fitting to the inclusive hadron and the DD-bar production cross sections simultaneously.

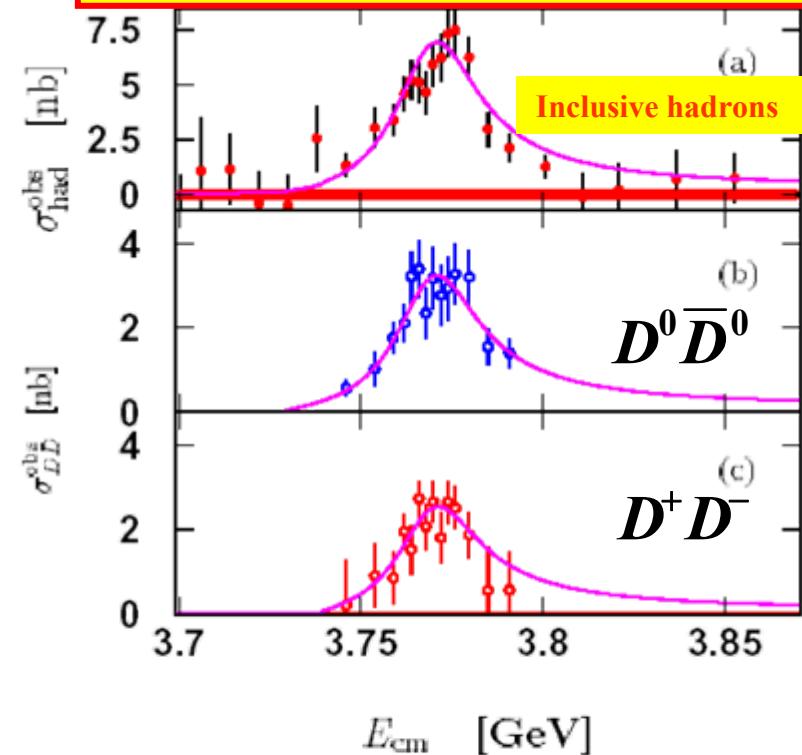


FIG. 4: The observed cross sections versus the nominal center-of-mass energies, where (a) shows the inclusive hadronic event production, (b) and (c) show the $D^0 \bar{D}^0$ and $D^+ D^-$ event production, respectively; the points with error are the data, while the lines are the fits to the data. ¹⁹

B[ψ(3770)→non-DD]

Measurements of $\sigma_{ψ(3770)}$ and $\sigma_{D\bar{D}}$

◆ $R_{ψ(3770)}$ & $\sigma_{ψ(3770)}^{\text{Born}}$
determined with

Taking the R for light hadron production to be a constant, then

$$R_{ψ(3770)} = R(E_{cm})|_{E_{cm}=3.773 \text{ GeV}} - \overline{R}_{uds}$$

Including ψ(3770)

We obtain

$$R_{ψ(3770)} = 1.53 \pm 0.04 \pm 0.13$$

$$\sigma_{ψ(3770)}^{\text{Born}} = 9.32 \pm 0.25 \pm 0.80 \text{ nb}$$

Preliminary

It is consistent with

$$\sigma_{ψ(3770)}^{\text{Born}} = \frac{12\pi}{(1+\delta_{ψ})M_{ψ(3770)}^2} \times BF(ψ(3770) \rightarrow e^+e^-) = 11.08 \pm 1.74 \text{ nb}$$

$$(1+\delta_{ψ}) = (1.047 \pm 0.024)$$

PLB 603(2004) 130

obtained based on PDG04 ψ(3770)
resonance parameters

37

My calculation

PLB 641 (2006) 145

$$BF(ψ(3770) \rightarrow D^0\bar{D}^0) = (49.9 \pm 1.3 \pm 3.8)\%$$

$$BF(ψ(3770) \rightarrow D^+D^-) = (35.7 \pm 1.1 \pm 3.4)\%$$

$$BF(ψ(3770) \rightarrow D\bar{D}) = (85.5 \pm 1.7 \pm 5.8)\%$$

With BES previously measured cross sections for $D\bar{D}$ production.
PLB 603(2004) 130



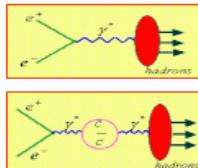
These result in the non-DD branching fraction

$$BF(ψ(3770) \rightarrow \text{non-}D\bar{D}) = (14.5 \pm 1.7 \pm 5.8)\%$$

$$\sigma_{ψ(3770)}^{\text{Born}} = (9.22 \pm 0.25 \pm 0.80) \text{ nb}$$

$$\sigma_{ψ(3770)}^{\text{obs}} = (7.09 \pm 0.19 \pm 0.63) \text{ nb}$$

(1+δ) Is calculated with the $\psi(2S)$ resonance parameters measured by scanning the $\psi(2S)$ peak. PLB 641 (2006) 145



Considering the possible interference
between the two amplitudes ...

$$BF(ψ(3770) \rightarrow D^0\bar{D}^0) = (52.4 \pm 1.3 \pm 4.1)\%$$

$$BF(ψ(3770) \rightarrow D^+D^-) = (37.4 \pm 1.2 \pm 3.6)\%$$

$$BF(ψ(3770) \rightarrow D\bar{D}) = (89.8 \pm 1.8 \pm 6.1)\%$$

$$BF(ψ(3770) \rightarrow \text{non-}D\bar{D}) = (10.2 \pm 1.8 \pm 6.1)\%$$

$$R_{uds} = 2.26 \pm 0.02 \pm 0.09$$

$$\sigma_{ψ(3770)}^{\text{Born}} = (8.88 \pm 0.25 \pm 0.79) \text{ nb}$$

$$\sigma_{ψ(3770)}^{\text{obs}} = (6.84 \pm 0.19 \pm 0.62) \text{ nb}$$

(1+δ) Is calculated with the $\psi(2S)$ resonance parameters measured by scanning the $\psi(2S)$ peak. PLB 641 (2006) 145

B[$\psi(3770) \rightarrow$ non-DD]

What is the branching fraction from PDG07 ?

Branching fraction for $\psi(3770) \rightarrow$ non-DD-bar

BES-II Results

PDG07

used

used

$$BF(\psi(3770) \rightarrow D^0 \bar{D}^0) = (50.1 \pm 1.3 \pm 3.9)\%$$

$$BF(\psi(3770) \rightarrow D^+ D^-) = (35.9 \pm 1.1 \pm 3.5)\%$$

$$BF(\psi(3770) \rightarrow D \bar{D}) = (86.0 \pm 1.7 \pm 6.0)\%$$

$$BF(\psi(3770) \rightarrow \text{non-}D\bar{D}) = (14.0 \pm 1.7 \pm 6.0)\%$$

Determined from analysis of R values and DD-bar cross sections

Obtained by fitting to the inclusive hadron and the DD-bar production cross sections simultaneously.

→ $BF(\psi(3770) \rightarrow D \bar{D}) = (85 \pm 5)\%$ PDG07

→ $BF(\psi(3770) \rightarrow \text{non-}D\bar{D}) = (15 \pm 5)\%$

B[ψ(3770)→non-DD]

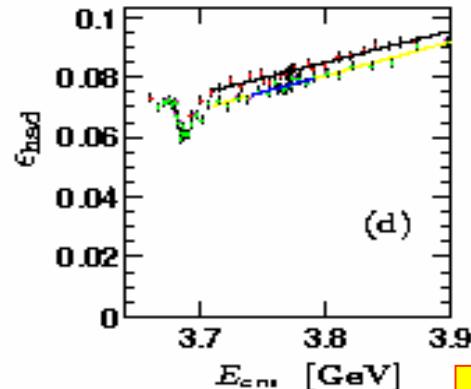
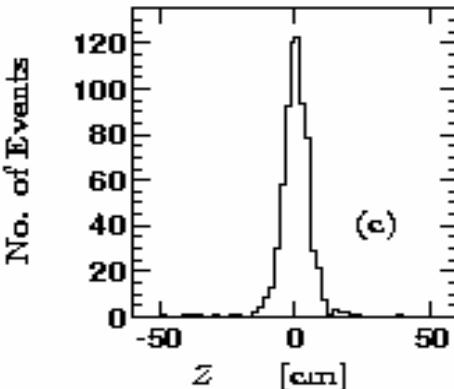
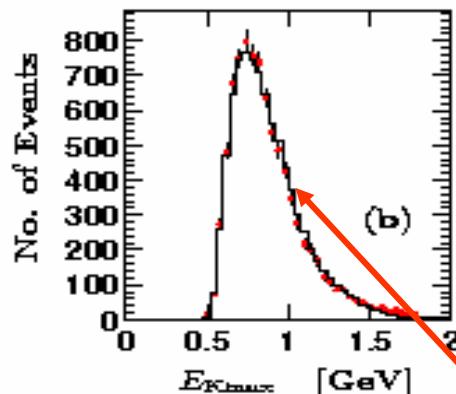
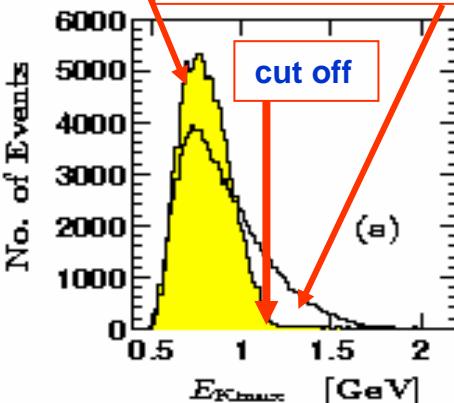
cross sections measured at 156 energy points

New measurements

From MC DD-bar events

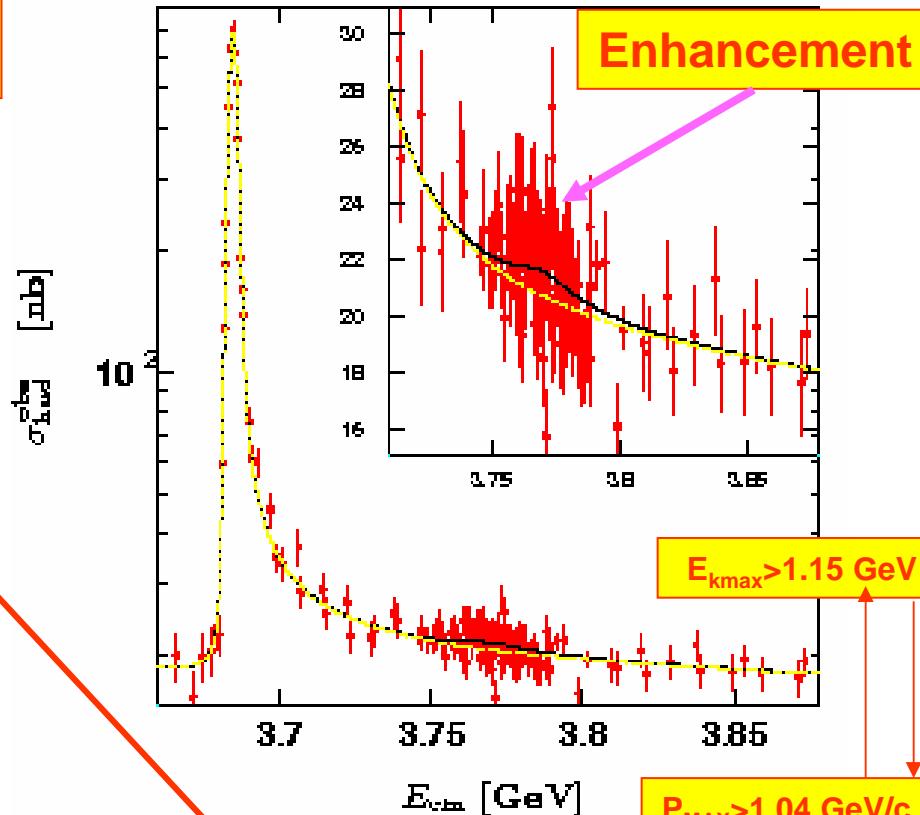
All kinds of hadrons including non-DDbar events

From MC $e^+e^- \rightarrow \text{hadrons}$



Observed non-DDbar cross section

Enhancement



histogram is MC, point with error bars is data

The largest momentum of the charged particle from D decays is about 0.92 GeV/c.

The largest momentum of the charged track in the final states

Selection of the non-DD-bar hadronic events by tagging the largest energy of the assumed Kaon in the final states of e^+e^- annihilation

B[$\psi(3770) \rightarrow \text{non-}D\bar{D}$]

$$BF(\psi(3770) \rightarrow \text{non-}D\bar{D}) = (15.4 \pm 5.7 \pm 1.7)\%$$

$$\sigma_{\text{non-}D\bar{D}}^{\text{obs}} = (1.10 \pm 0.41 \pm 0.13) \text{ nb}$$

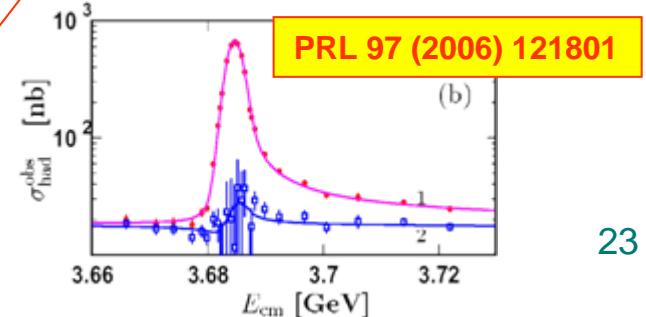
$$R_{uds} = 2.195 \pm 0.053 \pm 0.119$$

(From the fit)
Preliminary !

M(MeV)	$\Gamma^{\text{tot}}(\text{keV})$	$\Gamma^{ee}(\text{keV})$
$3685.5 \pm 0.0 \pm 0.3$	$356 \pm 89 \pm 4$	$2.39 \pm 0.04 \pm 0.11$

Consistent with

experiment	M_{ψ} (MeV)	$\Gamma_{\psi}^{\text{tot}}$ (keV)	Γ_{ψ}^{ee} (keV)
E760	$3686.0 \pm 0.1 \pm 0.3$	$306 \pm 36 \pm 16$	
BES-II	N/A	264 ± 27	2.44 ± 0.21
PDG04	3686.09 ± 0.03	281 ± 17	2.12 ± 0.12
PRL 97(2006) 121801	$3685.5 \pm 0.0 \pm 0.3$	$331 \pm 58 \pm 2$	$2.33 \pm 0.04 \pm 0.11$



B[ψ(3770)→non-DD]

Analyzing 17.3 pb⁻¹ of data @ 3.773 GeV;
 5.65 pb⁻¹ data @ 3.650 GeV and 1 pb⁻¹
 data @ 3.6648 GeV yields

$$R_{uds} = 2.214 \pm 0.031 \pm 0.094$$

$$\sigma_{\psi(3770)}^{obs} = (7.07 \pm 0.36 \pm 0.48) \text{ nb}$$

$$\sigma_{non-DD}^{obs} = (0.95 \pm 0.35 \pm 0.31) \text{ nb}$$

$$\sigma_{DD}^{obs} = (6.12 \pm 0.37 \pm 0.23) \text{ nb}$$

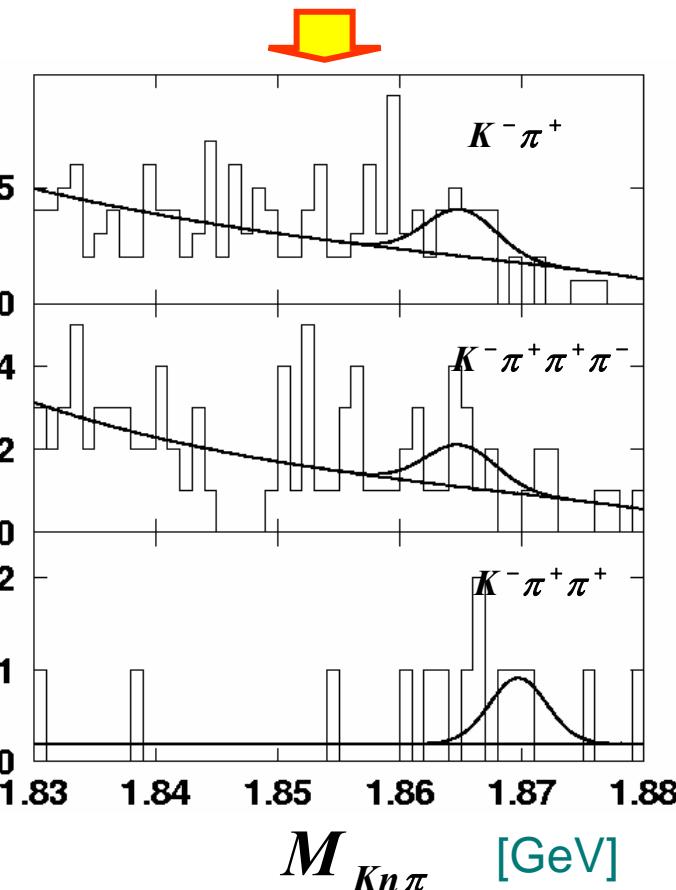
$$BF[\psi(3770) \rightarrow non-DD] = (13.4 \pm 5.0 \pm 3.6)\%$$

These results are Preliminary !

N# of singly tagged D satisfying selection criterion of Ekmax>1.15 GeV

Mode	D ⁰ →K ⁻ π ⁺	D ⁰ →K ⁻ π ⁺ π ⁺ π ⁻	D ⁺ →K ⁻ π ⁺ π ⁺
N _{obs}	14.6±6.5	7.3±5.0	4.2±2.7
N _{expected}	13.5	10.6	17

Analyzing the non-DD-bar hadronic events satisfied Ekmax>1.15 GeV, we observed



Direct measurements of the branching fraction

Search for Charmless Decays of $\psi(3770)$

Mode	$\sigma^{3.773} [\text{pb}]$	$\sigma^{3.650} [\text{pb}]$	$B^{\text{up}} [\times 10^{-3}]$
$\phi\pi^0$	<3.5	<8.9	<0.5
$\phi\eta$	<12.6	<18.0	1.9
$2(\pi^+\pi^-)$	$173.7 \pm 8.4 \pm 18.4$	$177.7 \pm 13.3 \pm 18.8$	4.8
$K^+K^-\pi^+\pi^-$	$131.7 \pm 10.1 \pm 14.1$	$161.7 \pm 17.9 \pm 17.1$	4.8
$\phi\pi^+\pi^-$	<11.1	<22.9	1.6
$2(K^+K^-)$	$19.9 \pm 3.6 \pm 2.1$	$24.1 \pm 6.5 \pm 2.6$	1.7
ϕK^+K^-	$15.8 \pm 5.1 \pm 1.8$	$17.4 \pm 9.2 \pm 2.0$	2.4
$p\bar{p}^{\text{bar}}\pi^+\pi^-$	$33.2 \pm 3.4 \pm 3.8$	$42.1 \pm 6.1 \pm 4.8$	1.6
$p\bar{p}^{\text{bar}}K^+K^-$	$7.1 \pm 2.0 \pm 0.8$	$6.1 \pm 3.1 \pm 0.7$	1.1
$\phi p\bar{p}^{\text{bar}}$	<5.8	<9.1	0.9
$3(\pi^+\pi^-)$	$236.7 \pm 14.7 \pm 33.4$	$234.9 \pm 23.8 \pm 33.1$	9.1
$2(\pi^+\pi^-)\eta$	$153.7 \pm 40.1 \pm 18.4$	$86.6 \pm 40.3 \pm 10.4$	24.3
$2(\pi^+\pi^-)\pi^0$	$80.9 \pm 13.9 \pm 10.0$	$124.3 \pm 21.7 \pm 14.9$	6.2
$K^+K^-\pi^+\pi^-\pi^0$	$171.6 \pm 26.0 \pm 20.9$	$222.8 \pm 37.7 \pm 27.2$	11.1
$2(K^+K^-)\pi^0$	$18.1 \pm 7.7 \pm 2.1$	<23.0	4.6
$p\bar{p}^{\text{bar}}\pi^0$	$10.1 \pm 2.2 \pm 1.0$	$9.2 \pm 3.4 \pm 1.0$	1.2
$p\bar{p}^{\text{bar}}\pi^+\pi^-\pi^0$	$53.1 \pm 9.2 \pm 6.8$	$29.0 \pm 11.1 \pm 3.7$	7.3
$3(\pi^+\pi^-)\pi^0$	$105.8 \pm 34.4 \pm 16.9$	$126.6 \pm 47.1 \pm 19.2$	13.7

Search for
Charmless
decays of
 $\psi(3770)$

We have searched for
more than 40 modes
for the light hadron
decays.

PLB650(2007)111

Search for Charmless Decays of $\psi(3770)$

Preliminary Results

Mode	$\sigma^{3.773}[\text{pb}]$	$\sigma^{3.650}[\text{pb}]$	$B^{\text{up}}[\times 10^{-3}]$
$K^+K^-2(\pi^+\pi^-)$	$168.0 \pm 18.2 \pm 23.$ 7	$164.9 \pm 30.3 \pm 23.$ 2	< 10.3
$2(K^+K^-)\pi^+\pi^-$	$11.9 \pm 5.8 \pm 1.7$	< 49.1	< 3.2
$p\bar{p}2(\pi^+\pi^-)$	$23.5 \pm 5.0 \pm 3.5$	$22.8 \pm 8.4 \pm 3.4$	< 2.6
$4(\pi^+\pi^-)$	$131.8 \pm 19.5 \pm 23.6$	$76.2 \pm 24.4 \pm 13.9$	< 16.7
$K^+K^-2(\pi^+\pi^-)\pi^0$	$231.5 \pm 63.6 \pm 37.5$	< 375.2	< 52.0
$4(\pi^+\pi^-)\pi^0$	< 206.9	< 119.4	< 30.6
$\rho^0\pi^+\pi^-$	$111.9 \pm 13.1 \pm 13.1$	$113.6 \pm 21.3 \pm 13.1$	< 6.9
$\rho^0K^+K^-$	$34.2 \pm 11.5 \pm 4.4$	$57.6 \pm 17.9 \pm 6.3$	< 5.0
$\rho^0 p\bar{p}$	$13.1 \pm 3.2 \pm 1.8$	$17.7 \pm 6.2 \pm 2.8$	< 1.7
$K^{*0}K^-\pi^+$	$94.7 \pm 15.5 \pm 10.4$	$85.5 \pm 26.3 \pm 14.4$	< 9.7
$\Lambda\Lambda^{\bar{b}ar}$	< 2.5	< 6.1	< 0.4
$\Lambda\Lambda^{\bar{b}ar}\pi^+\pi^-$	< 26.7	< 42.9	< 4.4

Search for light-hadron decays of $\psi(3770)$

Search for Charmless Decays of $\psi(3770)$

Search for light-hadron decays of $\psi(3770)$

Mode	$\sigma^{3.773} [\text{pb}]$	$\sigma^{3.650} [\text{pb}]$	$B^{\text{up}} [\times 10^{-3}]$
$\omega\pi^+\pi^-$	<37.1	<50.8	5.5
ωK^+K^-	<44.4	<53.2	6.6
$\omega p\bar{p}$	<20.3	<30.9	3.0
$\phi\pi^+\pi^-\pi^0$	<25.5	<66.7	3.8
$K^{*0}K^-\pi^+\pi^0$	$116.3 \pm 32.7 \pm 20.0$	$128.1 \pm 59.5 \pm 17.9$	16.3
$K^{*+}K^-\pi^+\pi^-$	$173.9 \pm 73.3 \pm 26.1$	$189.0 \pm 116.3 \pm 28.2$	32.4
$K^+K^-\rho^0\pi^0$	<5.6	$47.6 \pm 33.4 \pm 10.7$	0.8
$K^+K^-\rho^+\pi^-$	$94.2 \pm 31.6 \pm 11.7$	$141.9 \pm 53.3 \pm 19.7$	14.6
$\Lambda\Lambda^{\bar{p}}\pi^0$	<7.9	<21.4	1.2

Preliminary Results

Upper limits are set at 90% CL

We searched for $\psi(3770) \rightarrow$ light hadrons over 40 channels, but no significant signals were found. This does not mean that $\psi(3770)$ does not decay into light hadrons. To extract the branching fractions for $\psi(3770) \rightarrow$ light hadrons from the observed cross sections, one need to make finer cross section scan covering both $\psi(3686)$ and $\psi(3770)$ with larger data samples (BES-III can do this well).²⁷

SUMMARY

- Inclusive decays of D mesons

Measured $\text{BF}(D^+ \rightarrow \mu^+ X) = (17.6 \pm 2.7 \pm 1.3)\%$

the first measurement

Measured $\text{BF}(D^+ \rightarrow K^- X) = (24.7 \pm 1.3 \pm 1.2)\%$

Measured $\text{BF}(D^+ \rightarrow K^+ X) = (6.1 \pm 0.9 \pm 0.4)\%$

Measured $\text{BF}(D^0 \rightarrow K^- X) = (57.8 \pm 1.6 \pm 3.4)\%$

Improved measurements

- The quantity R

Improved measurements of R in the range from 3.65 to 3.88 GeV

Measured $R_{uds} = 2.121 \pm 0.023 \pm 0.085$

Measured $R_{uds(c)+\psi(3770)}$ for the first time

- $\psi(3770)$ parameters

Precisely measured $M_{\psi(3770)} = 3772.3 \pm 0.5 \text{ MeV}$; $\Gamma_{\text{tot}} = 28.5 \pm 1.2 \text{ MeV}$;
 $\Gamma_{ee} = 277 \pm 16 \text{ eV}$

Precisely measured $\text{BF}[\psi(3770) \rightarrow e^+e^-] = (0.97 \pm 0.08 \pm 0.05) \times 10^{-5}$

$\sigma_{\psi(3770)}^{\text{obs}} = 7.15 \pm 0.25 \pm 0.25 \text{ nb}$ [combined two measurements]

SUMMARY

Combined 49 energy point cross section scan results and 3 energy point cross section results (inclusive hadron and DD-bar cross sections)

- **BF[$\psi(3770) \rightarrow$ non-DDbar]**

Measured BF[$\psi(3770) \rightarrow$ non-DDbar] = (15+5)%

Measured BF[$\psi(3770) \rightarrow$ DDbar] = (85+5)% PDG07 [BES]

$BF(\psi(3770) \rightarrow \text{non-}D\bar{D}) = (15.4 \pm 5.7 \pm 1.7)\%$

$BF[\psi(3770) \rightarrow \text{non-}D\bar{D}] = (13.4 \pm 5.0^{+3.5}_{-3.7})\%$

Assuming that there is only one $\psi(3770)$

- **Light hadron decays of $\psi(3770)$**

No significant signals for $\psi(3770) \rightarrow$ light hadron were found in about 40 channels.

- **How to solve this problem ?**

Finer cross section scan over $\psi(3686)$ and $\psi(3770)$ to measure the cross sections for exclusive modes and fitting the cross sections to extract out the branching fractions (My comment only !)

Need to more precisely measure $\psi(3770)$ parameters

Thank You !

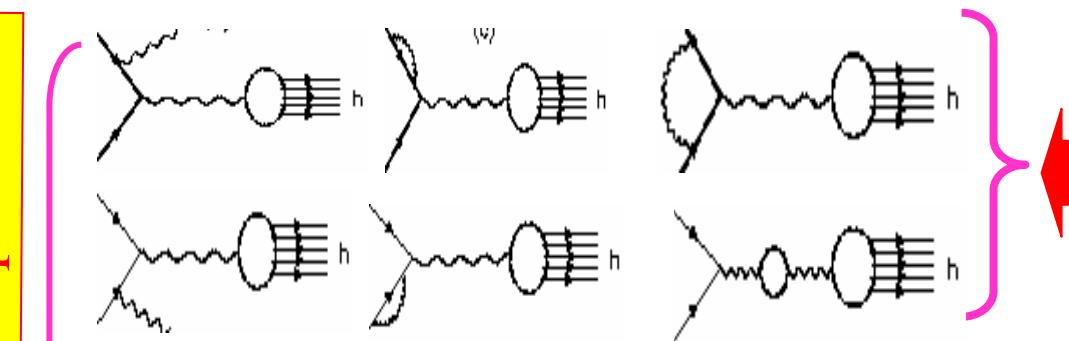
Backup slides

Gang RONG

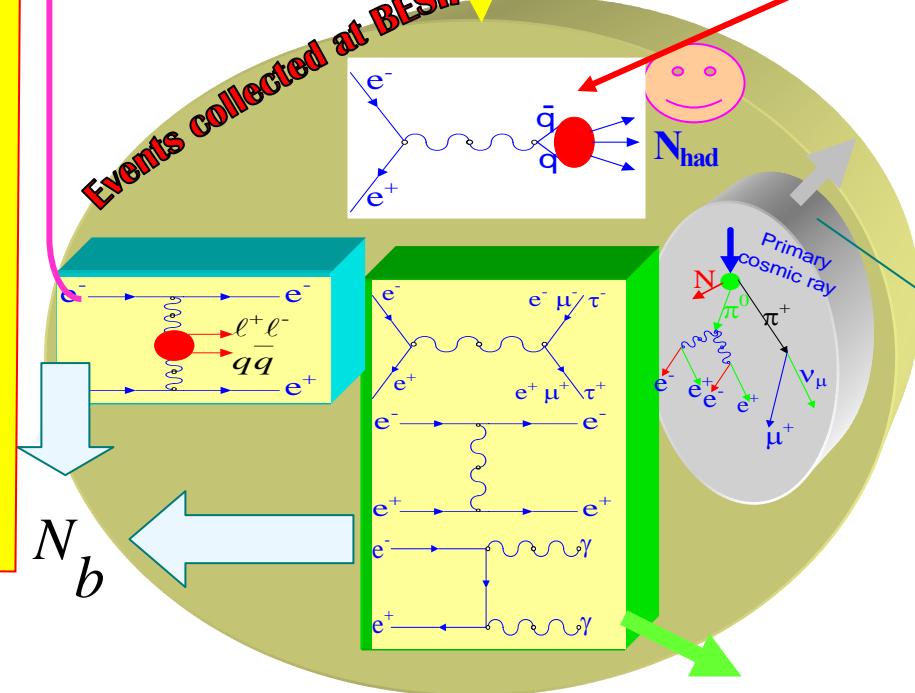
Institute of High Energy Physics, Beijing 100049, P.R. China

The quantity R

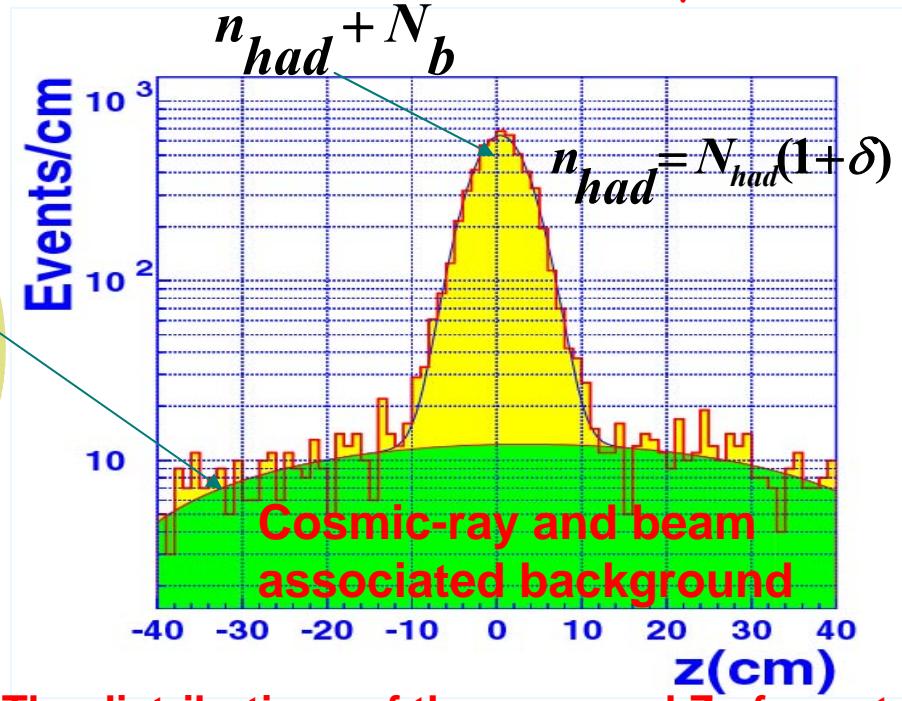
The events observed in the experiment



Radiative correction could remove the effects of high order processes from the observed cross section, and gives $\sigma^B(e^+e^- \rightarrow \text{hadrons})$



Events Recorded by BESII



The distributions of the averaged Z of events

N_b could be estimated based on cross sections, luminosity and acceptance

The quantity R

ISR corrections

$$\sigma_{\text{had}}^{\text{expect}}(s) = \int_0^{x_{\max}} dx \ F(x, s) \ \sigma^B(s(1-x)) |1 - \Pi(s(1-x))|^{-2}$$

$\sigma^B(s)$ is Born order cross sections

$$x = 1 - \frac{s'}{s}$$

Effective
c.m. energy

Moninal c.m.
energy

$F(x, s)$ is sampling function

Kuraev
& Fadin

$$F(x, s) = \beta x^{\beta-1} \delta^{V+S} + \delta^H$$

$$\beta = \frac{2\alpha}{\pi} \left(\ln \frac{s}{m_e^2} - 1 \right)$$

the electron equivalent
radiator thickness

$$\delta^{V+S} = 1 + \frac{3}{4}\beta + \frac{\alpha}{\pi} \left(\frac{\pi^2}{3} - \frac{1}{2} \right) - \frac{\beta^2}{24} \left(\frac{1}{3} \ln \frac{s}{m_e^2} + 2\pi^2 - \frac{37}{4} \right)$$

$$\delta^H = \delta_1^H + \delta_2^H$$

$$\delta_1^H = -\beta \left(1 - \frac{x}{2} \right)$$

$$\delta_2^H = \frac{1}{8} \beta^2 \left[4(2-x) \ln \frac{1}{x} - \frac{1+3(1-x)^2}{x} \ln(1-x) - 6 - x \right]$$

The quantity R

Vacuum polarization correction

$$\frac{1}{1-\Pi(s)} = 1 + \Pi(s) + \Pi^2(s) + \dots$$

$$\Pi = \Pi_h + \Pi_l$$

$$\Pi_h = \frac{s}{4\pi^2\alpha} [PV \int \frac{\sigma^B(s')}{s-s'} ds' - i\pi\sigma^B(s)]$$

$$\Pi_l = 1 + \frac{1}{2}\delta_{vac}^{l^+l^-}$$

$$\delta_{vac}^{l^+l^-}(s) = \frac{2\alpha}{\pi} f(x), \quad (x = \frac{4m_l^2}{s})$$

$$f(x) = -\frac{5}{9} - \frac{x}{3} + \frac{\sqrt{1-x}(2+x)}{6} \log \left[\frac{1+\sqrt{1-x}}{1-\sqrt{1-x}} \right], \quad (x \leq 1)$$

$$f(x) = -\frac{5}{9} - \frac{x}{3} + \frac{\sqrt{x-1}(2+x)}{3} \tan^{-1} \frac{1}{\sqrt{x-1}}, \quad (x > 1)$$

$$(1 + \delta) = \frac{\sigma_{had}^{expect}}{\sigma^B}$$

Vacuum polarization change
the photon propagator

$$\frac{-ig_{\mu\nu}}{q^2} \Rightarrow \frac{-ig_{\mu\nu}}{q^2(1-\Pi(q^2))}$$

results in 

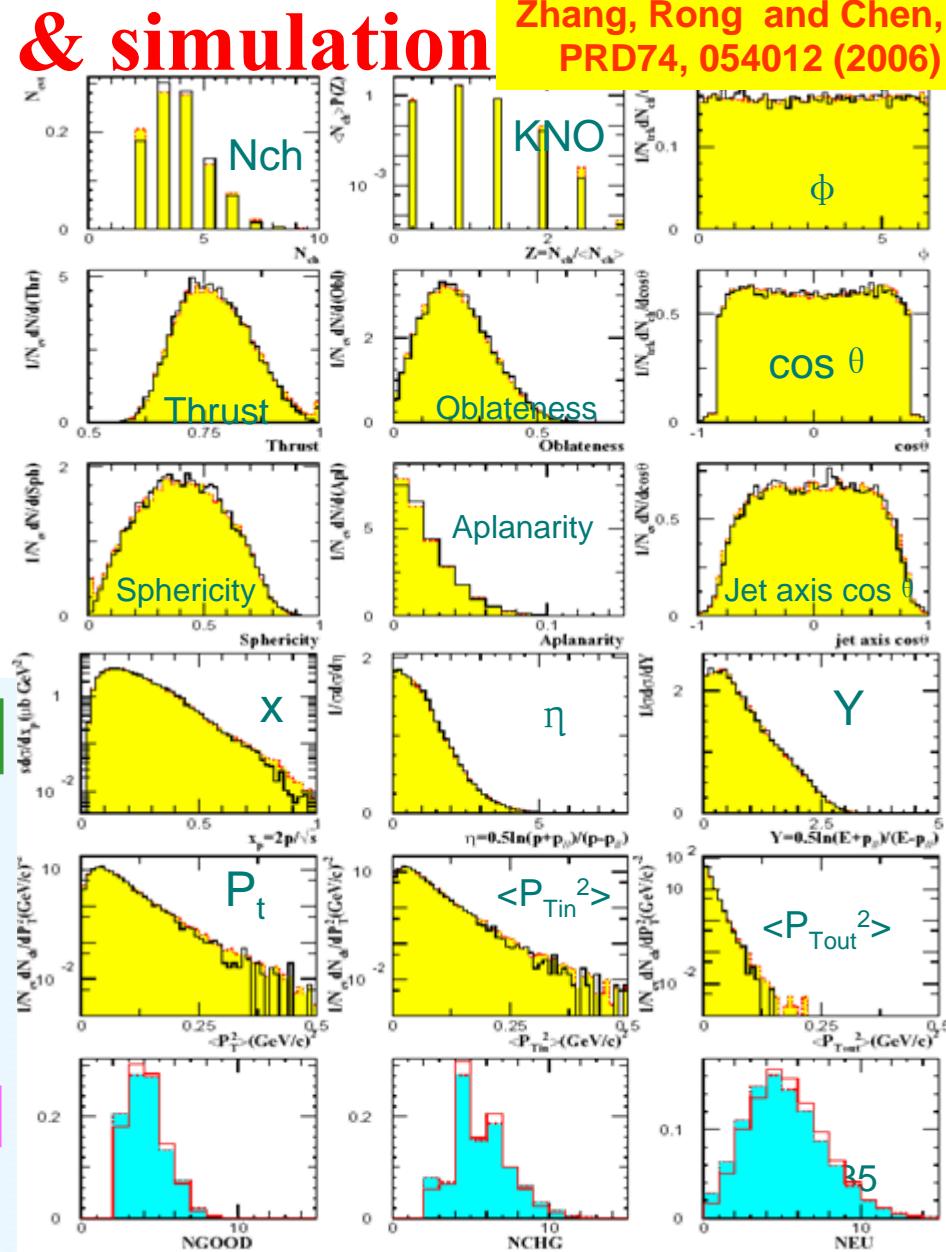
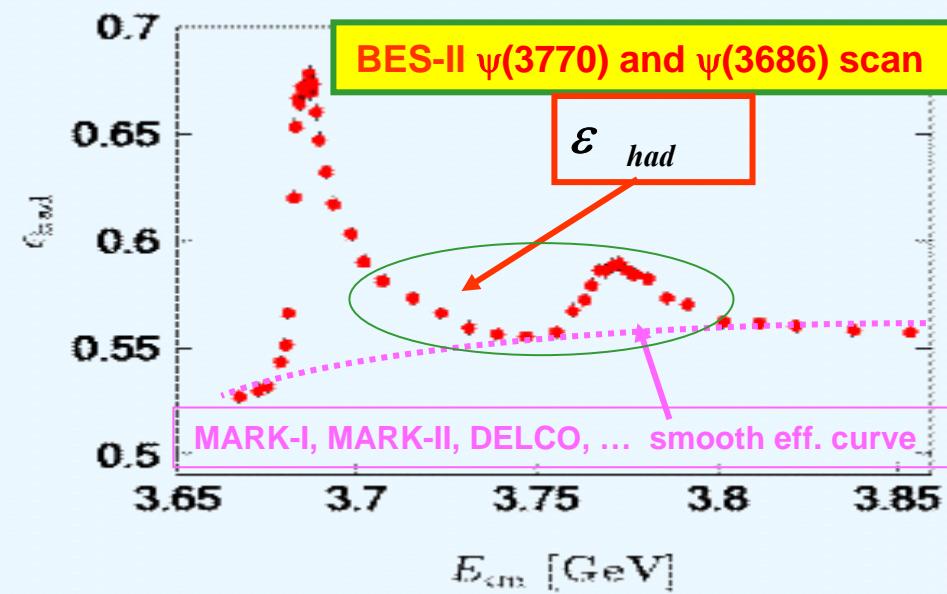
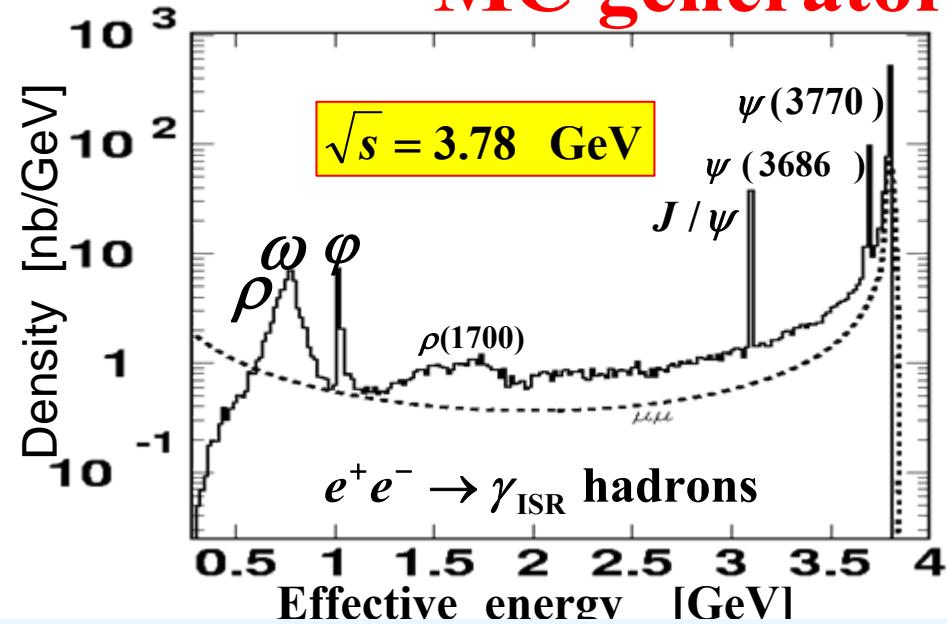
$$\sigma^B \Rightarrow \frac{\sigma^B}{|1-\Pi(s)|^2}$$

Radiative correction factor

The quantity R

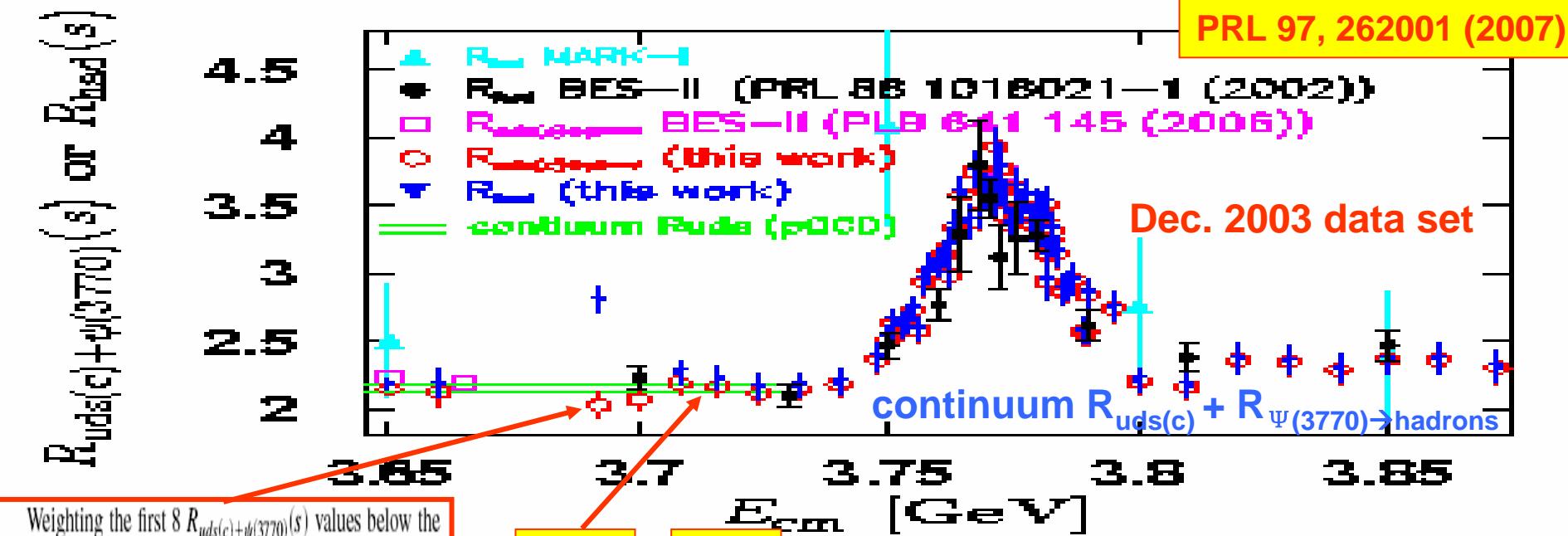
MC generator & simulation

Zhang, Rong and Chen,
PRD74, 054012 (2006)



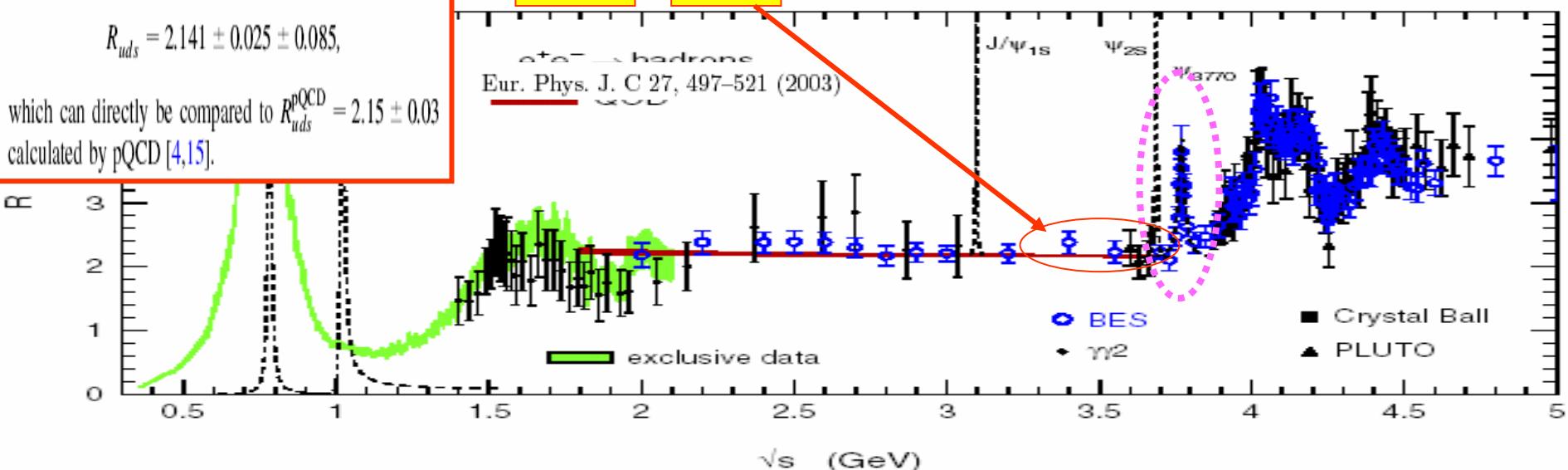
The quantity R

PRL 97, 262001 (2007)



$$R_{uds} = 2.141 \pm 0.025 \pm 0.085,$$

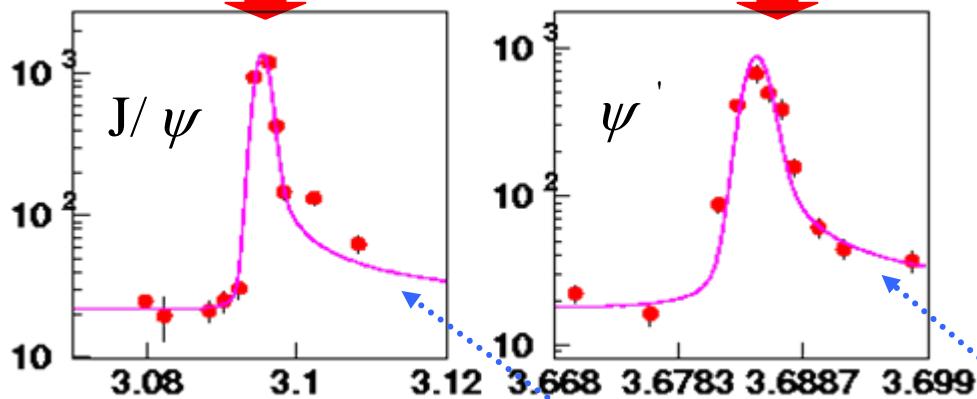
which can directly be compared to $R_{uds}^{\text{pQCD}} = 2.15 \pm 0.03$ calculated by pQCD [4,15].



The quantity R

During the cross section experiments, we performed 9 fast cross section scans over J/ψ and ψ' resonances to calibrate the BEPC energy and monitoring the variation of the energy with time

Just before the scan experiment

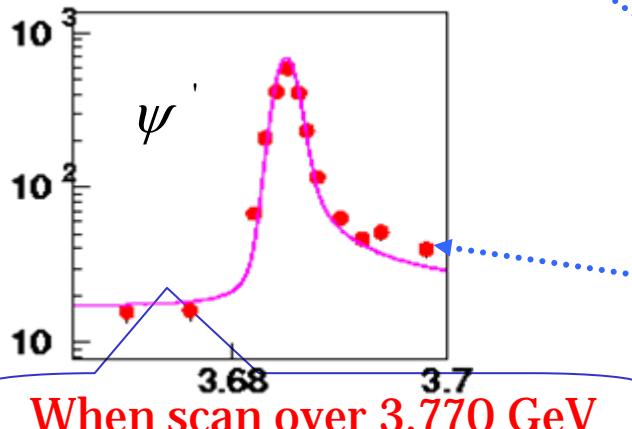


$$E^{\text{true}} = M_{J/\psi}^{\text{PDG02}} - (E^{\text{BEPC}} - 3095.3) \times \frac{M_{\psi'}^{\text{PDG}} - M_{J/\psi}^{\text{PDG}}}{3684.8 - 3095.3}$$

E^{BEPC} is the energy of BEPC set in the experiment,

E^{true} is the true energy

$$\frac{3684.7 + 3684.9}{2} = 3684.8$$



Mass [MeV]	J/ψ	ψ'
PDG04	3096.916 ± 0.011	3686.093 ± 0.034
BEPC	3095.30 ± 0.05	3684.70 ± 0.01
BEPC		3684.90 ± 0.01
BEPC		3684.50 ± 0.02^{37}

BEPC energy calibration

B[$\psi(3770) \rightarrow$ non-DD]

Branching fraction for $\psi(3770) \rightarrow$ non-DD-bar

Citation: W.-M. Yao et al. (Particle Data Group), J. Phys. G 33, 1 (2006) and 2007 partial update for edition 2007



$$I^G(J^{PC}) = 0^-(1^{--})$$

PDG07

$\psi(3770)$ MASS

From $m_{\psi(2S)}$ and mass difference below.

VALUE (MeV)	DOCUMENT ID
3772.4±1.1 OUR FIT Error includes scale factor of 1.8.	

$$m_{\psi(3770)} - m_{\psi(2S)}$$

VALUE (MeV)	EVTS	DOCUMENT ID	TECN	COMMENT
86.3±1.1 OUR FIT Error includes scale factor of 1.8.				
86.3±1.1 OUR AVERAGE Error includes scale factor of 1.9. See the ideogram below.				
86.7±0.7		ABLIKIM 06L	BES2 $e^+e^- \rightarrow$ hadrons	
92.3±3.0±1.3	34	CHISTOV 04	BELL $B^+ \rightarrow \psi(3770)K^+$	
80 ±2		SCHINDLER 80	MRK2 e^+e^-	
86 ±2		¹ BACINO 78	DLCO e^+e^-	
88 ±3		RAPIDIS 77	MRK1 e^+e^-	

$\psi(3770)$ WIDTH

VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
25.2±1.8 OUR FIT			
26.3±1.9 OUR AVERAGE			
26.9±2.4±0.3	ABLIKIM 06L	BES2 $e^+e^- \rightarrow$ hadrons	
24 ±5	SCHINDLER 80	MRK2 e^+e^-	
24 ±5	BACINO 78	DLCO e^+e^-	
28 ±5	RAPIDIS 77	MRK1 e^+e^-	

$\psi(3770)$ DECAY MODES

In addition to the dominant decay mode to $D\bar{D}$, $\psi(3770)$ was found to decay into the final states containing the J/ψ (BAI 05, ADAM 06). ADAMS 06 and HUANG 06A searched for various decay modes with light hadrons and found a statistically significant signal for the decay to $\phi\eta$ only (ADAMS 06).

Mode	Fraction (Γ_i/Γ)	Scale factor/ Confidence level
$\Gamma_1 D\bar{D}$	(85 ± 5) %	
$\Gamma_2 D^0\bar{D}^0$	(48.7 ± 3.2) %	
$\Gamma_3 D^+\bar{D}^-$	(36.1 ± 2.8) %	

Comparison with those measured by CLEO-c

BES-II

$$\sigma_{D\bar{D}}^{obs} = 6.14 \pm 0.12 \pm 0.50 \text{ nb}$$

$$BF(\psi(3770) \rightarrow non-D\bar{D}) = (14.0 \pm 1.7 \pm 6.0)\%$$

Taking $\sigma_{\psi(3770)}^{obs} \approx 6.95 \text{ nb}$

$$[\sigma_{\psi(3770)}^{obs} = (9.35 \times 0.764 + 6.8) / 2 = 6.95 \text{ nb}]$$

$$\sigma_{\psi(3770) \rightarrow non-D\bar{D}} \approx 0.97 \pm 0.44 \text{ nb}$$

Based on measured R values.

Method:

BES measured \bar{R}_{uds} near DD-bar threshold and R at 3.773 GeV with traditional method, then calculate the Born order cross section for $\psi(3770)$ production. By comparing the cross sections for DD-bar and $\psi(3770)$ production, BES obtained the branching fraction. BES used an ISR generator to simulate the decay $\psi(3770) \rightarrow$ hadrons and obtain the efficiency for $\psi(3770) \rightarrow$ hadrons.

CLEO-c

$$\sigma_{D\bar{D}}^{obs} = 6.39 \pm 0.10 {}^{+0.17}_{-0.08} \text{ nb}$$

$$\sigma_{\psi(3770) \rightarrow hadrons}^{obs} = 6.38 \pm 0.08 {}^{+0.41}_{-0.30} \text{ nb}$$

$$\sigma_{\psi(3770) \rightarrow non-D\bar{D}} = -0.01 \pm 0.08 {}^{+0.41}_{-0.30} \text{ nb}$$

Method:

CLEO-c directly count the number of hadronic events observed at 3.773 GeV, and subtract the backgrounds from J/ ψ , $\psi(2S)$ radiative tails and continuum QED background. CLEO-c used the efficiency for the decay $\psi(3770) \rightarrow J/\psi \pi^+ \pi^-$ to estimate the efficiency for $\psi(3770) \rightarrow$ hadrons.

Comparison with those measured by CLEO-c

BES-II

$$BF(\psi(3770) \rightarrow non-D\bar{D}) = (16.2 \pm 6.8 \pm 6.4)\%$$

Taking $\sigma_{\psi(3770)}^{\text{obs}} \approx 7 \text{ nb}$

$$[\sigma_{\psi(3770)}^{\text{obs}} = (9.35 \times 0.764 + 6.8) / 2 = 6.95 \text{ nb}]$$



$$\sigma_{\psi(3770) \rightarrow non-D\bar{D}} \approx 1.1 \pm 0.7 \text{ nb}$$

(the error in $\sigma_{\psi(3770)}^{\text{obs}}$ is ignored)

Based on analysis of inclusive hadron
and DD-bar cross section scan data.

CLEO-c

$$\sigma_{D\bar{D}}^{\text{obs}} = 6.39 \pm 0.10^{+0.17}_{-0.08} \text{ nb}$$

$$\sigma_{\psi(3770) \rightarrow \text{hadrons}}^{\text{obs}} = 6.38 \pm 0.08^{+0.41}_{-0.30} \text{ nb}$$



$$\sigma_{\psi(3770) \rightarrow non-D\bar{D}} = -0.01 \pm 0.08^{+0.41}_{-0.30} \text{ nb}$$

(hep-ex/0512038)

Actually, considering the errors, the two results are not in contradiction.

Comparison with those measured by CLEO-c

Discussion

BES-II

Method:

BES did not consider the possible effect of interference between the final states of resonance decays (i.e. Res. $\rightarrow \gamma^* \rightarrow q\bar{q} \rightarrow$ hadrons) and non-resonance annihilation of e^+e^- (i.e. $e^+e^- \rightarrow q\bar{q} \rightarrow$ hadrons).

This possible effect may reduce the branching fraction by about 4%.

If we consider this possible effect, the branching fraction and cross section would be reduced to

$$BF(\psi(3770) \rightarrow \text{non-}D\bar{D}) \approx (10.0 \pm 1.7 \pm 6.0)\%$$

$$\sigma_{\psi(3770) \rightarrow \text{non-}D\bar{D}} \approx 0.70 \pm 0.44 \text{ nb}$$

In this case, if we use $\sigma_{D\bar{D}}^{obs} = 6.39 \pm 0.10^{+0.17}_{-0.08}$ nb measured by CLEO-c, the branching fraction and cross section would be reduced to

$$BF(\psi(3770) \rightarrow \text{non-}D\bar{D}) \approx 7\%$$

$$\sigma_{\psi(3770) \rightarrow \text{non-}D\bar{D}} \approx 0.49 \text{ nb}$$

CLEO-c

Method:

CLEO-c considered the possible effect of interference between the final states of resonance decays (i.e. Res. $\rightarrow \gamma^* \rightarrow q\bar{q} \rightarrow$ hadrons) and non-resonance annihilation of e^+e^- (i.e. $e^+e^- \rightarrow q\bar{q} \rightarrow$ hadrons).

$$\sigma_{\psi(3770) \rightarrow \text{non-}D\bar{D}} = -0.01 \pm 0.08^{+0.41}_{-0.30} \text{ nb}$$

B[ψ(3770)→non-DD]

What about world average ?

PDG06

$$BF(\psi(3770) \rightarrow e^+e^-) = (1.05 \pm 0.14) \times 10^{-5}$$

World average

$$M_{\psi(3770)} = 3771.1 \pm 2.4 \text{ MeV}$$

My estimation based on PDG06 parameters of ψ(3770)

World average

$$(1 + \delta_{ISR})|_{E_{cm} = 3.771 \text{ GeV}} \approx 0.72$$

$$\langle \sigma_{D\bar{D}}^{\text{obs}} \rangle|_{\text{single-and-double-tag}} = 6.08 \pm 0.14 \text{ nb}$$

$$BF(\psi(3770) \rightarrow D\bar{D}) = \frac{\sigma_{D\bar{D}}^{\text{obs}}}{(1 + \delta_{ISR}) \cdot \sigma_{\psi(3770)}^{\text{produced}}}$$

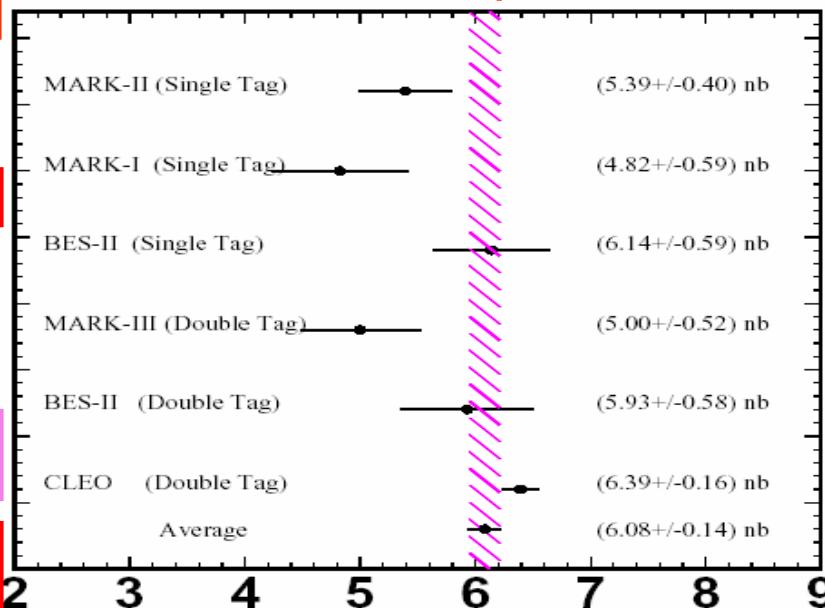


$$BF(\psi(3770) \rightarrow D\bar{D}) = (73.4 \pm 11.2)\%$$

$$BF(\psi(3770) \rightarrow \text{non-}D\bar{D}) = (26.6 \pm 11.2)\%$$

Which are obtained based on the measurements from MARK-I, MARK-II, MARK-III, BES-II and CLEO-c.

Comparison of measurements of the cross sections for DD-bar production



My estimation, Input with PDG04 BF

$\sigma_{D\bar{D}}^{\text{obs}}$ [nb]

My estimation

$$\langle \sigma_{D\bar{D}}^{\text{obs}} \rangle|_{\text{CLEO double-tag}} = 6.39 \pm 0.16 \text{ nb}$$

If using CLEO-c DD-bar cross section, the BF would be

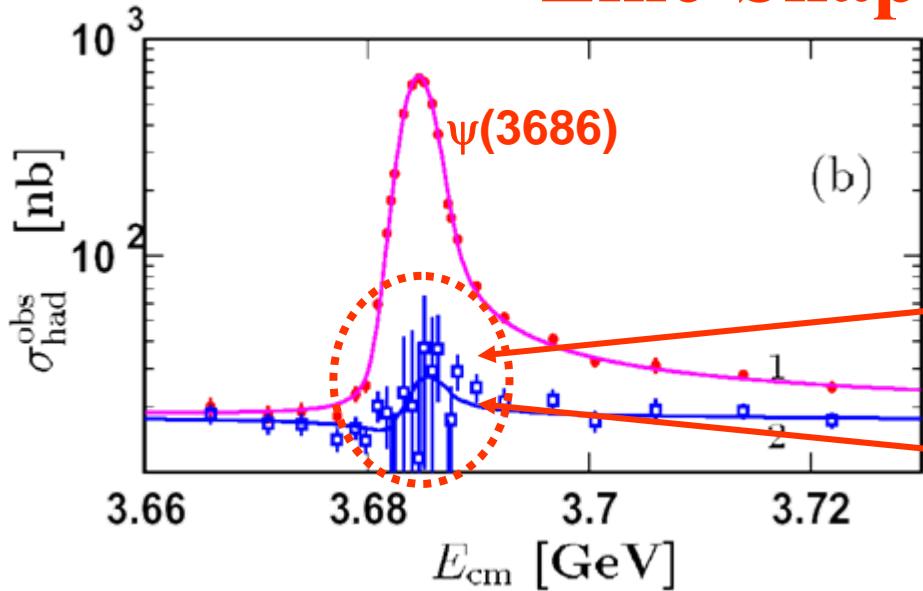
$$BF(\psi(3770) \rightarrow D\bar{D}) = (77.2 \pm 10.3)\%$$

$$BF(\psi(3770) \rightarrow \text{non-}D\bar{D}) = (22.8 \pm 10.3)\%$$

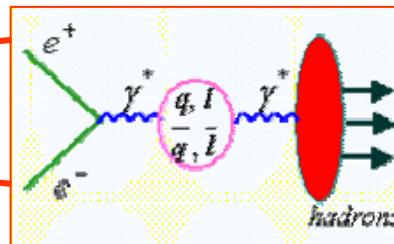
Resonance Parameters of $\psi(3686)$

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Line-Shape of $\psi(2s)$



If one do not consider the effects of vacuum polarization corrections on the observed cross sections in the data reduction, the total width of $\psi(3686)$ would decrease by about 40 keV!



Mar. 2003 data set

Mainly due to vacuum polarization corrections

experiment	M_{ψ} (MeV)	$\Gamma_{\psi}^{\text{tot}}$ (keV)	Γ_{ψ}^{ee} (keV)
E760	$3686.0 \pm 0.1 \pm 0.3$	$306 \pm 36 \pm 16$	
BES-II	N/A	264 ± 27	2.44 ± 0.21
PDG04	3686.09 ± 0.03	281 ± 17	2.12 ± 0.12
This work	$3685.5 \pm 0.0 \pm 0.3$	$331 \pm 58 \pm 2$	$2.33 \pm 0.04 \pm 0.11$

After subtraction of $\psi(3686)$, $\psi(3770)$ and J/ψ from the observed cross sections, one obtains the expected cross sections of the continuum hadron production.

Conclusion: Ruds in the resonance regions below 3.9 GeV is the same as the one in continuum region !!

Resonance Parameters of $\psi(3686)$

Table 1: The measured $\psi(3770)$ and $\psi(2S)$ parameters, where M is the mass, Γ_{tot} the total width [$\Gamma_{\text{tot}} = \Gamma_0$ for $\psi(3770)$], Γ_{ee} the partial leptonic width and ΔM the measured mass difference of the $\psi(3770)$ and the $\psi(2S)$.

Res.	M (MeV)	Γ_{tot} (MeV)	Γ_{ee} (eV)	ΔM (MeV)
$\psi(3770)$	$3772.2 \pm 0.7 \pm 0.3$	$26.9 \pm 2.4 \pm 0.3$	$251 \pm 26 \pm 11$	
$\psi(2S)$	$3685.5 \pm 0.0 \pm 0.3$	$0.331 \pm 0.058 \pm 0.002$	$2330 \pm 36 \pm 110$	86.7 ± 0.7

$\psi(2S)$ WIDTH

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obtained from
analyzing the
line-shapes

DOCUMENT ID

TECN

COMMENT

VALUE (keV)

327 ± 11 OUR FIT

284 ± 21 OUR AVERAGE

$331 \pm 58 \pm 2$

264 ± 27

$306 \pm 36 \pm 16$

ABLIKIM

06L

BES2

$e^+ e^- \rightarrow$ hadrons

⁶ BAI

02B

BES2

$e^+ e^-$

ARMSTRONG

93B

E760

$p\bar{p} \rightarrow e^+ e^-$

PDG07

$\Gamma(e^+ e^-)$

VALUE (keV)

2.43 ± 0.05 OUR FIT

2.29 ± 0.10 OUR AVERAGE

$2.330 \pm 0.036 \pm 0.110$

2.14 ± 0.21

• • • We do not use the following data for averages, fits, limits, etc. • • •

2.44 ± 0.21

2.0 ± 0.3

2.1 ± 0.3

DOCUMENT ID

TECN

COMMENT

Γ_4

ABLIKIM

06L

BES2

$e^+ e^- \rightarrow$ hadrons

ALEXANDER

89

RVUE

See γ mini-review

⁷ BAI

02B

BES2

$e^+ e^-$

BRANDELIK

79C

DASP

$e^+ e^-$

⁸ LUTH

75

MRK1

$e^+ e^-$

To obtain the correct
values of the resonance
parameters, it is
important to make the
vacuum polarization
corrections !