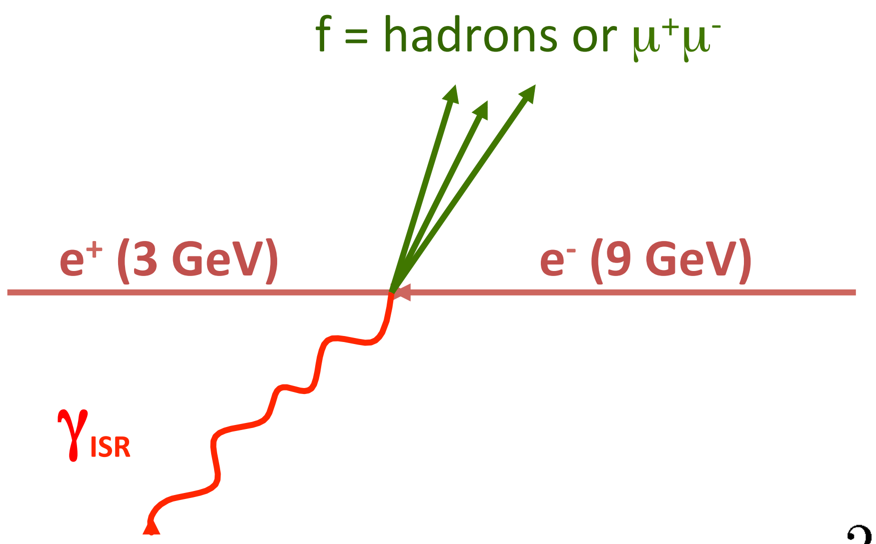
Measurements of branching fractions of J/ψ and $\psi(2S)$ to hadrons via ISR

E.P.Solodov
Budker INP, NSU
For BaBar Collaboration

Charm2018, Novosibirsk, Russia

ISR Method at BaBar : $e^+e^- \to \gamma f$



Arbuzov 98', Binner 99', Benayoun 99'

$$\frac{d\sigma(s,x)}{dx} = W(s,x)\sigma_f\left[s(1-x)\right]$$

$$x = \frac{2E^*_\gamma}{\sqrt{s}}$$

at lowest order
$$W(s,x) = \frac{2\alpha}{\pi \cdot x} \cdot (2ln\frac{\sqrt{s}}{m_e} - 1) \cdot (1 - x + \frac{x^2}{2})$$

Cross Section for final state f (normalized to radiative dimuons)

$$\sigma_f(s') = \frac{dN_{f\gamma} \cdot \varepsilon_{\mu\mu} \cdot (1+\delta^{\mu\mu}_{FSR})}{dN_{\mu\mu\gamma} \cdot \varepsilon_f \cdot (1+\delta^f_{FSR})} \cdot \sigma_{e^+e^-\to\mu^+\mu^-}(s')$$

"effective c.m. energy-squared" = s(1-x)

dL(s') ISR luminosity

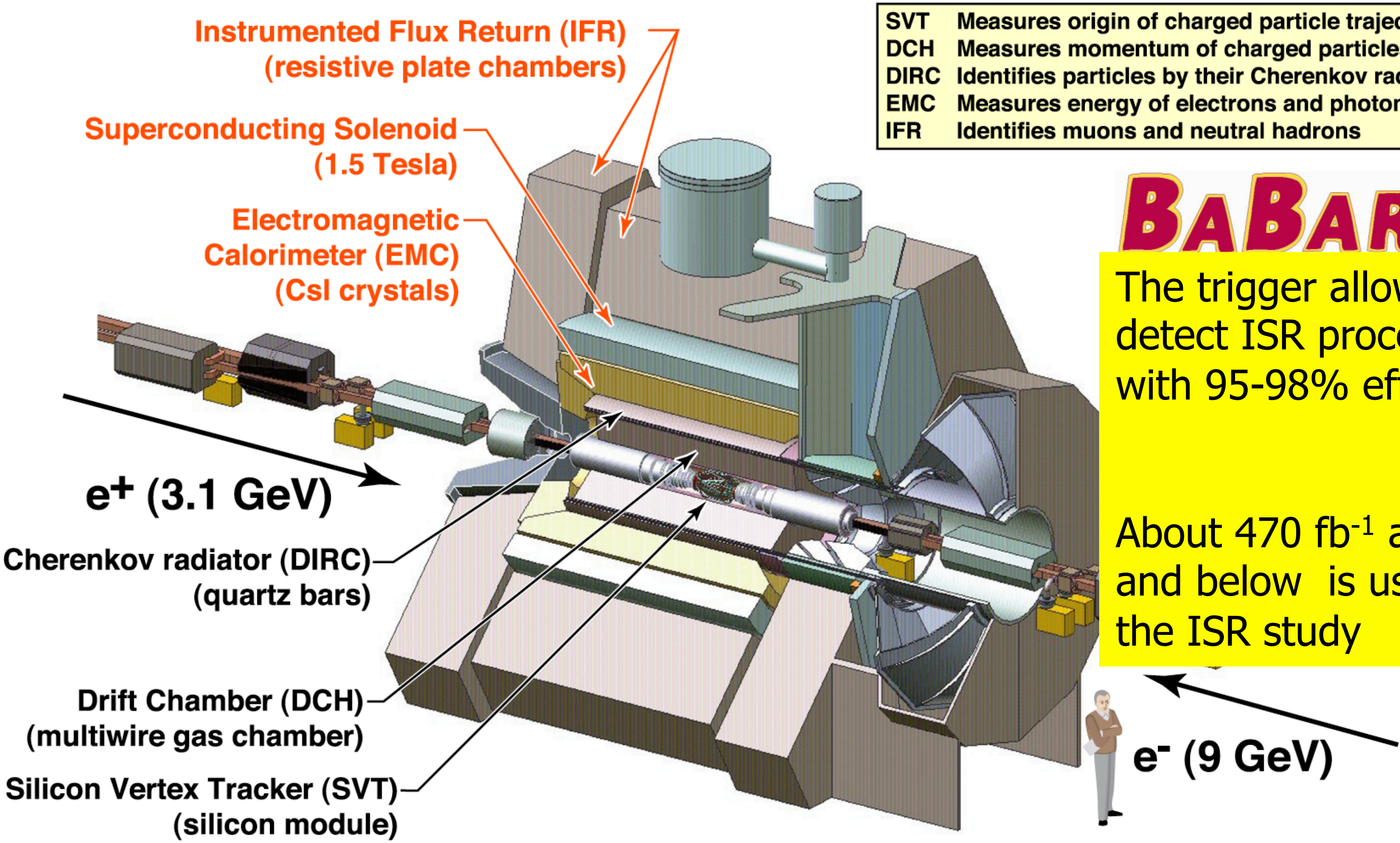
Detection efficiencies

Corrections for final state radiation

γ detected at large angle in BaBar

BaBar

SVT	Measures origin of charged particle trajectories
DCH	Measures momentum of charged particles
DIRC	Identifies particles by their Cherenkov radiation
EMC	Measures energy of electrons and photons
IFR	Identifies muons and neutral hadrons



The trigger allows to detect ISR processes with 95-98% efficiency !

About 470 fb^{-1} at Y(4S) and below is used for the ISR study

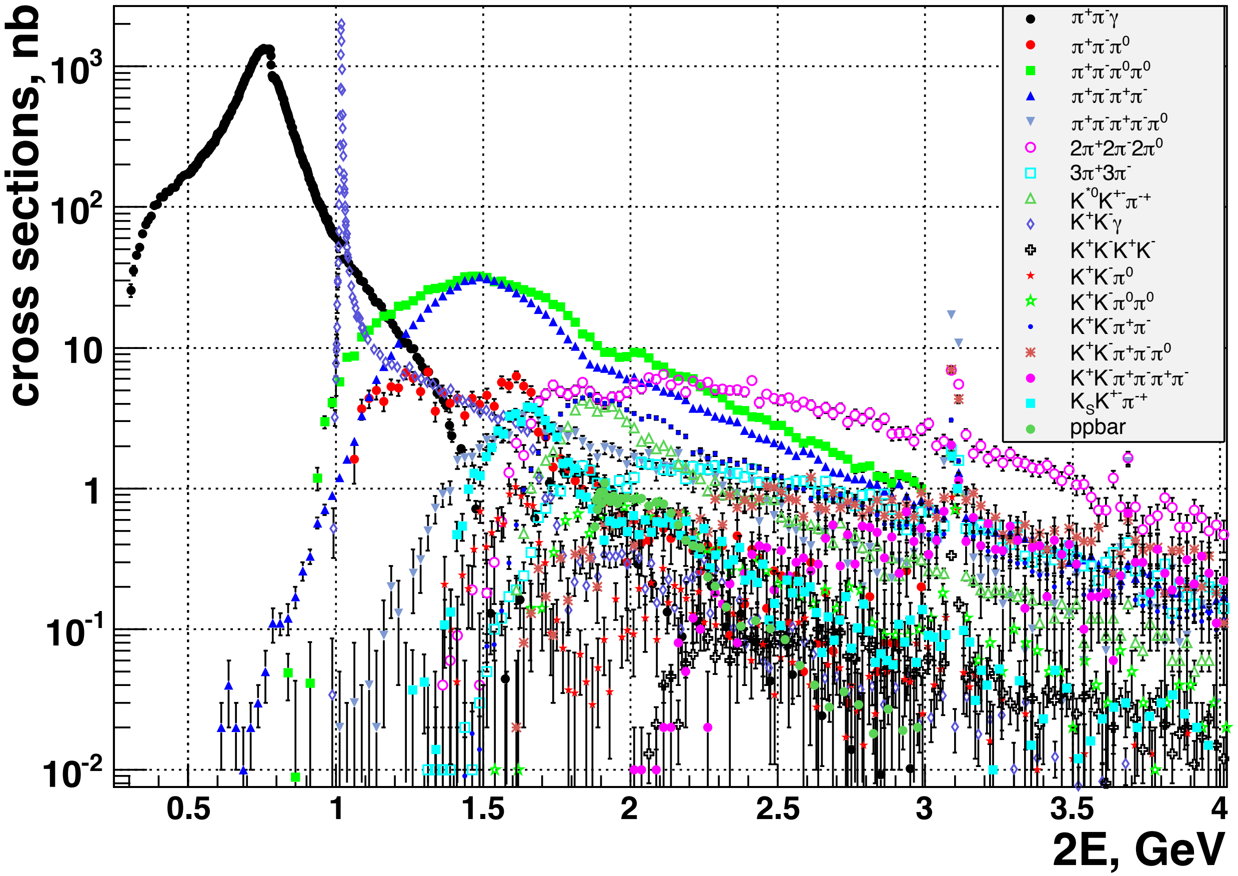
SVT: 97% efficiency, 15 μm z hit resolution

SVT+DCH: $\sigma(p_T)/p_T = 0.13\ \% \times p_T + 0.45\ \%$

DIRC: K-π separation 4.2 σ @ 3.0 GeV/c → 2.5 σ @ 4.0 GeV/c

EMC: $\sigma_E/E = 2.3\ \% \cdot E^{-1/4} \oplus 1.3\ \%$

BaBar measurements summary



0.5-2% syst. errors 4-15% syst. errors

About 30 final states has been studied. BaBar data dominates now in calculation of hadronic contribution to G-2 of muons.

J/ψ and ψ(2S) signals are seen in almost all channels

$e^+e^- \to \gamma\ J/\psi$

For a narrow state such as J/ψ:

$$\sigma_{J/\psi}(s) = \frac{12\pi^2 \Gamma_{ee} B_{\mu\mu}}{m \cdot s} \cdot W(s, x_0),\ x_0 = (1 - \frac{m^2}{s})$$

Total J/ψ ISR production cross section is 0.036 nb for s= $(10.58)^2$ GeV^2

$\Rightarrow$ 1.7 10^7 J/ψ's for ~470 fb^{-1} of BaBar luminosity

(acceptance for ISR photon in EMC is 0.1)

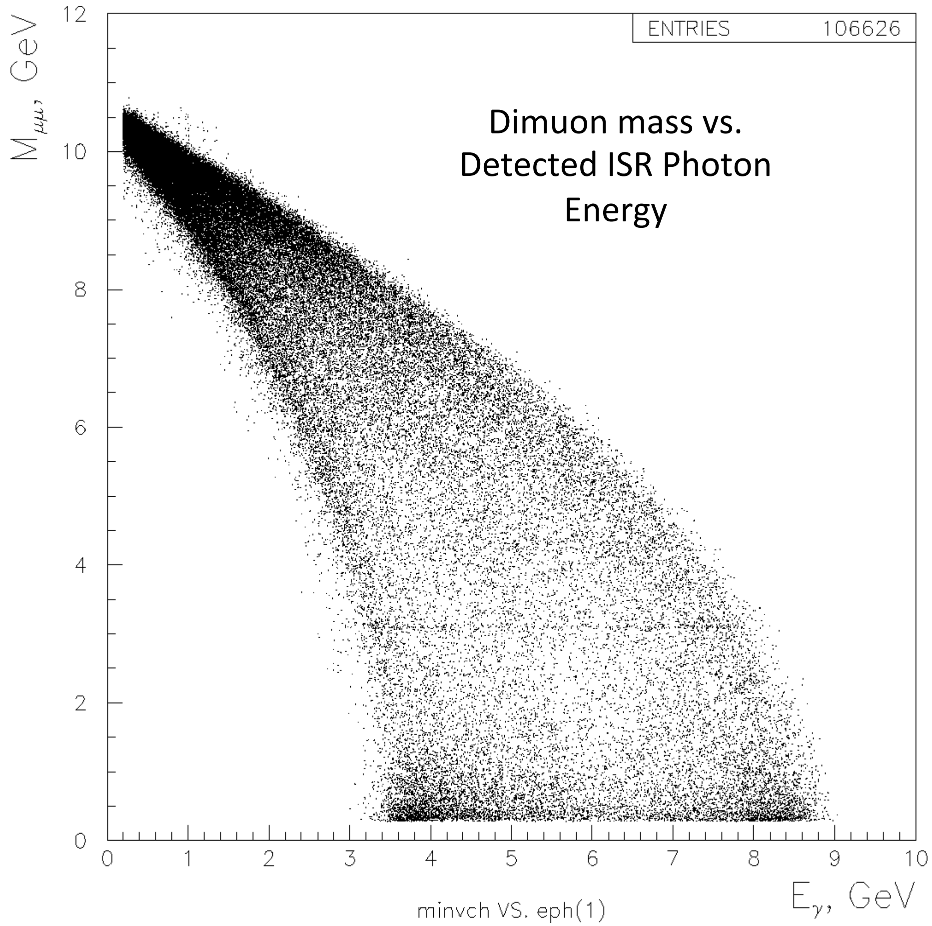
For a decay final state **f**: Number of detected events is proportional to $\Gamma_{ee} B_f$

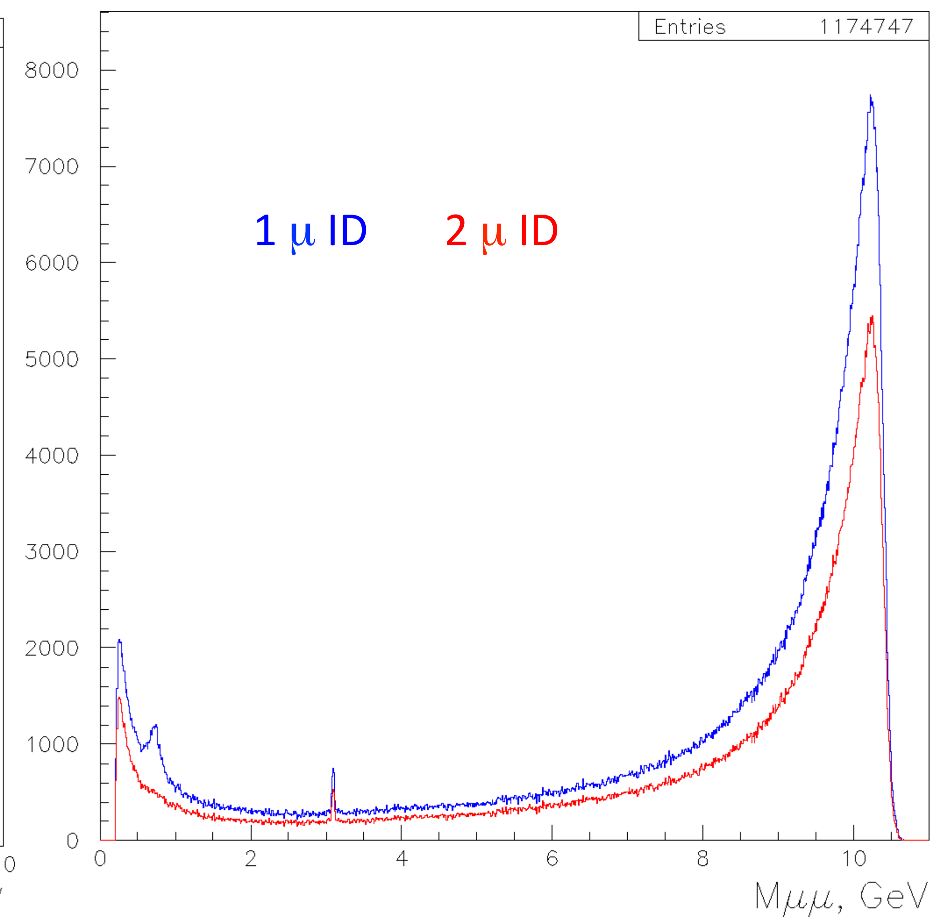
$$\mathcal{B}_{J/\psi \to f} \cdot \Gamma_{ee}^{J/\psi} = \frac{N_{J/\psi \to f} \cdot m^2_{J/\psi}}{6\pi^2 \cdot d\mathcal{L}/dE \cdot \epsilon_f(m_{J/\psi}) \cdot C}$$

PDG has included this measured parameter into particle listing

$e^+e^- \rightarrow \gamma\, \mu^+\mu^-$: kinematics

used for normalization and important test sample

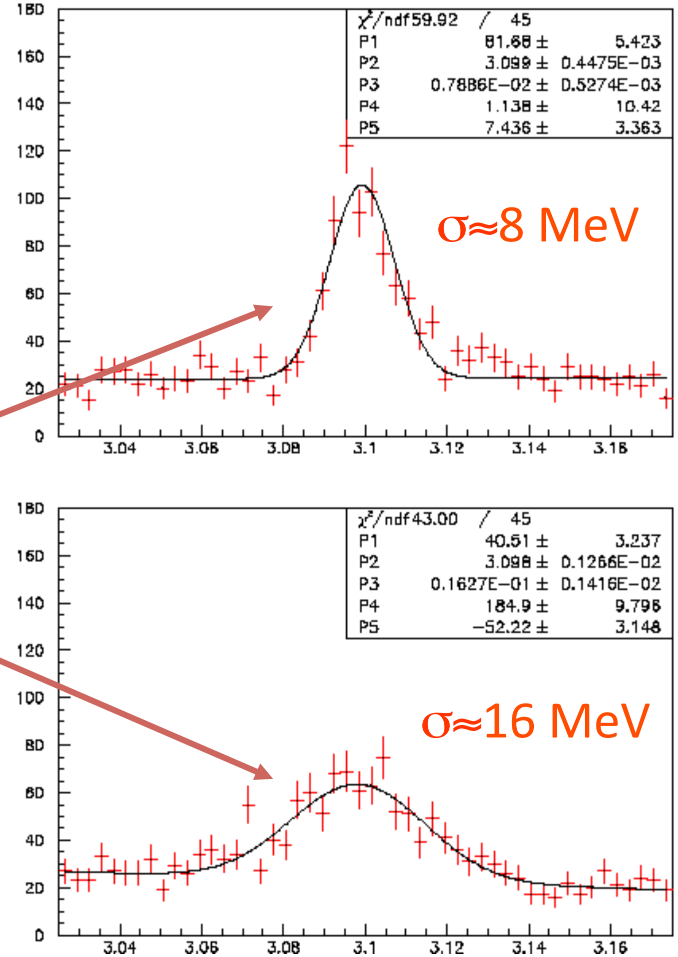




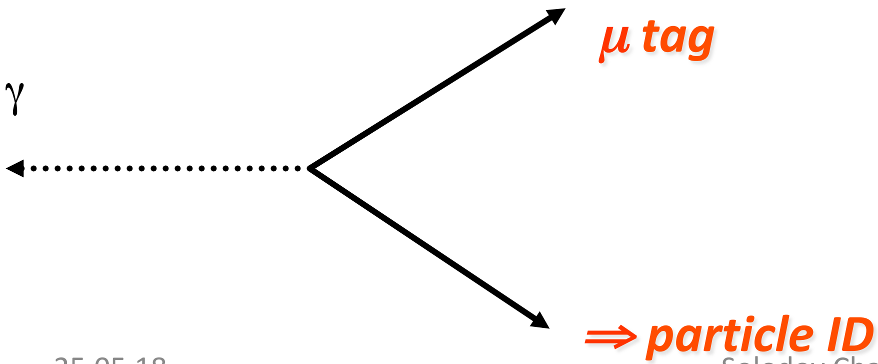
$e^+e^- \to \gamma\, \mu^+\mu^-$: efficiency and resolution

- muon sample purity > 99.9 % ($M_{\mu\mu}$ > 2 GeV)
- measurement of μ ID efficiency
- measurement of tracking efficiency
- measurement of photon detection efficiency
- kinematic fit improves resolution:
  16 → 8 MeV at J/ψ

After fit



Before fit

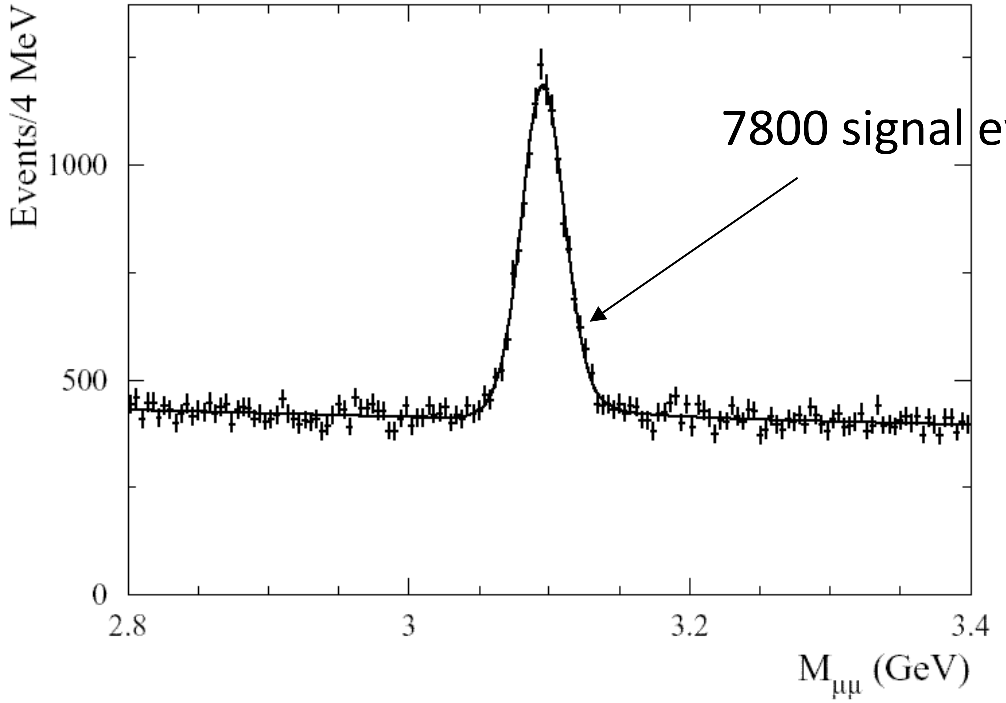


$e^+e^- \to \gamma\, J/\psi \to \gamma\, \mu^+\mu^-$

First ISR publication by BaBar using 90 fb-1. B. Aubert et al. PR D69 011103 (2004)

Test of method, tuning of simulation, development of tools.

Ratio to non-resonant cross section cancels most of systematic errors – good method for precision measurement of narrow resonance width.



7800 signal events

- interference effect 0.3%
- J/ψ line shape simulation 1.4%
- uncertainty in background 0.5%
- K factor cut dependence 1.3%
- MC statistics 0.9%

Total systematic error	2.2%
Statistical error	2.3%

$e^+e^- \to \gamma\ J/\psi \to \gamma\ \mu^+\mu^-$

Ratio to non-resonant XS, K is correction to FSR

$$K \cdot R = 21.03 \pm 0.49 \pm 0.46 \quad \to \quad \sigma_{J/\psi} = (2124 \pm 49 \pm 47)\ \text{fb}$$

PDG2018
333±4 eV

$$\Rightarrow \quad \Gamma_{ee} \cdot B_{\mu\mu} = 0.3301 \pm 0.0077 \pm 0.0073\ \text{keV}$$

← **Our result**

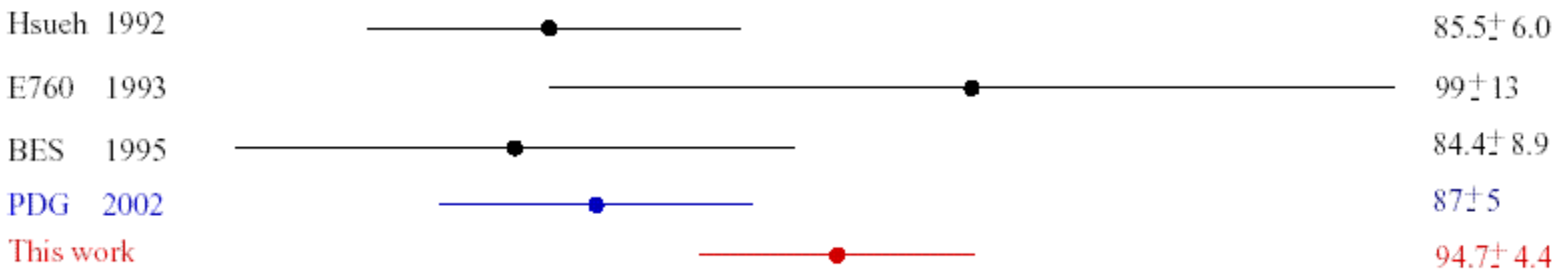
$$B_{\mu\mu} = (5.88 \pm 0.10)\% \qquad B_{ee} = (5.93 \pm 0.10)\%$$

Derived using PDG →

$$\Gamma_{ee} = 5.61 \pm 0.20\ \text{keV}$$

$$\Gamma = 94.7 \pm 4.4\ \text{keV}$$

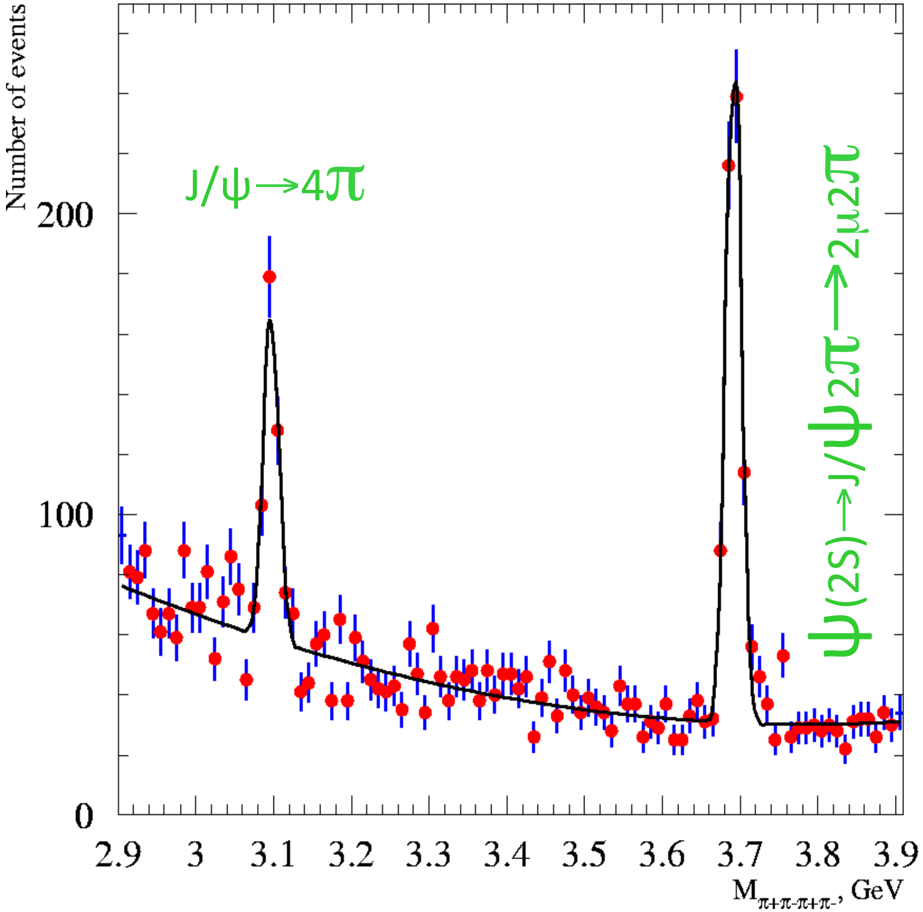
5.26 ± 0.37 keV
PDG2002:
87 ± 5 keV



Firt ISR result from B-factories! 90 fb^{-1}

$e^+e^- \to \gamma\ J/\psi \to \gamma\ 4\ \pi$

First hadronic channel, measured via ISR! 90 fb^{-1}
B. Aubert *et al*. PR D71 052001 (2005)



$B_{J/\psi \to 4\pi}\, \Gamma_{J/\psi ee}$=(1.95 ± 0.14 ± 0.13) 10^{-2} keV

Systematic errors:	Luminosity	3%
	Background	5%
	Efficiency	3%

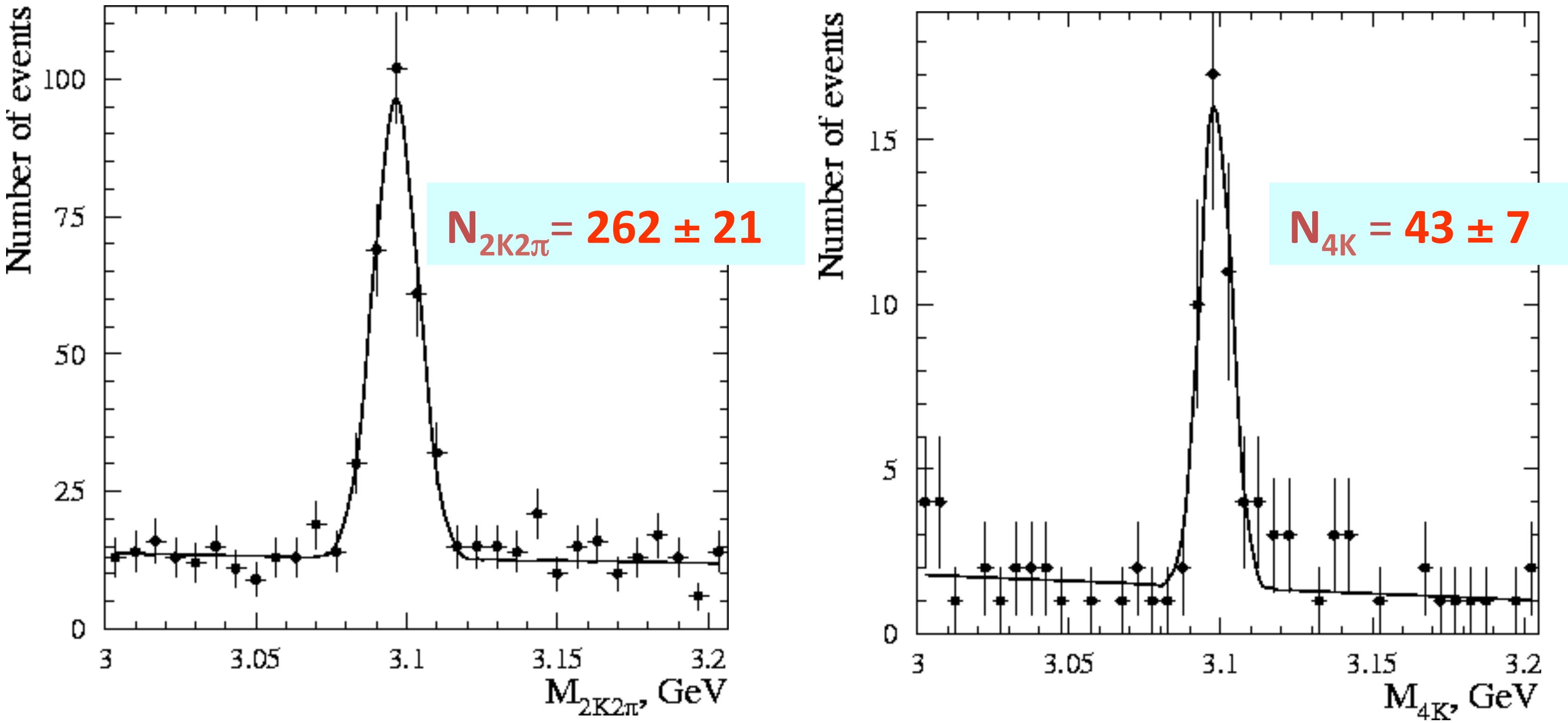
Using $\Gamma_{J/\psi ee}$ from PDG:

$B_{J/\psi \to 4\pi}$ (BaBar) = (3.70 ± 0.27 ± 0.36) x 10^{-3}

$B_{J/\psi \to 4\pi}$(PDG) = (4.0 ± 1.0) x 10^{-3} PDG2004

Improved with full data set: **$B_{J/\psi \to 4\pi}\, \Gamma_{J/\psi ee}$= (2.04 ± 0.09 ± 0.04) 10^{-2} keV**
J.P. Lees *et al*. PR D85 112009 (2012)

$e^+e^- \to \gamma\, J/\psi \to \gamma\, K^+K^-\pi^+\pi^-,\ 2K^+2K^-$



$B_{J/\psi\to 2K2\pi}\,\Gamma_{J/\psi ee}=(3.29 \pm 0.27 \pm 0.27)10^{-2}$ keV

$B_{J/\psi\to 4K}\,\Gamma_{J/\psi ee}=(3.6 \pm 0.6 \pm 0.5)\ 10^{-2}$ keV

Using $\Gamma_{J/\psi ee}$ from PDG:

$B_{J/\psi\to 2K2\pi}=(6.25 \pm 0.50 \pm 0.62)*10^{-3}$

$B_{J/\psi\to 2K2\pi}$(PDG) = $(7.2 \pm 2.3)\ *10^{-3}$

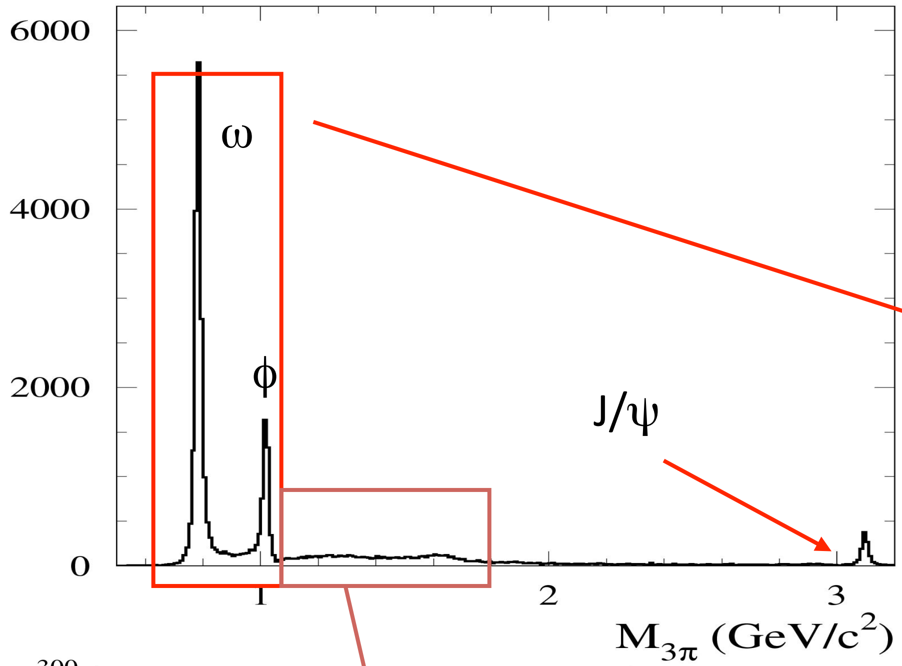
$B_{J/\psi\to 4K} = (6.9 \pm 1.2 \pm 1.1)*10^{-4}$

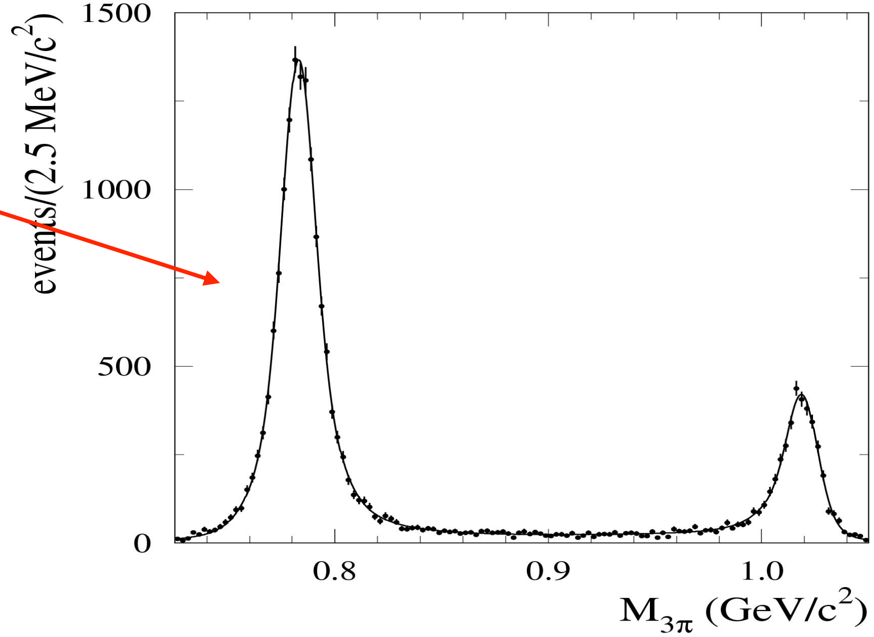
$B_{J/\psi\to 4K}$(PDG) = $(7.0 \pm 3.0)\ *10^{-4}$

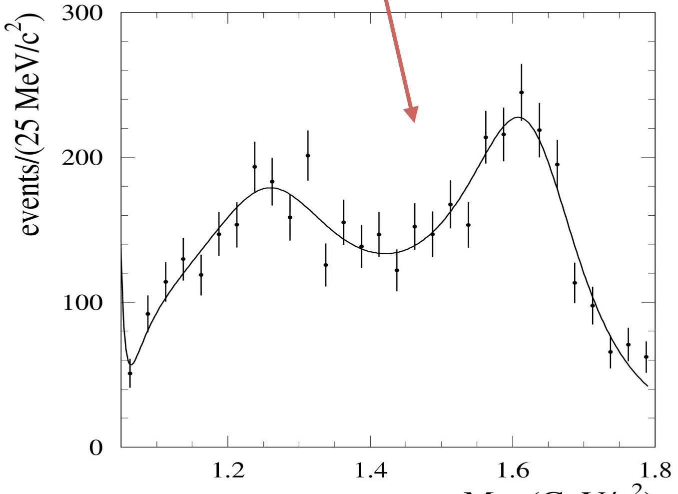
Still only BaBar data, improved with full data set: B. Aubert *et al*. PR D76 012008 (2007)

$e^+e^- \to \pi^+\pi^-\pi^0\gamma$

Key process for studing excited ω-like state: first surprise!   B. Aubert *et al*. PR D70 072004(2004)

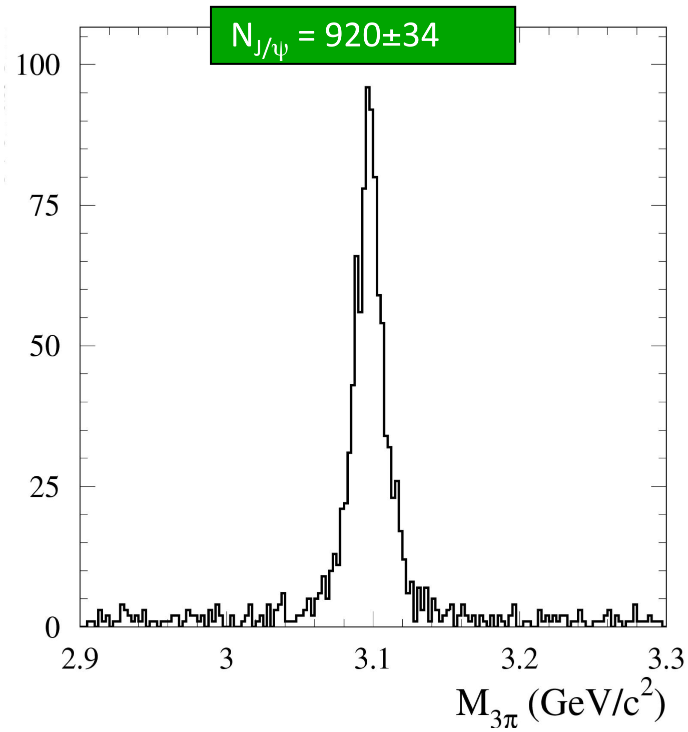


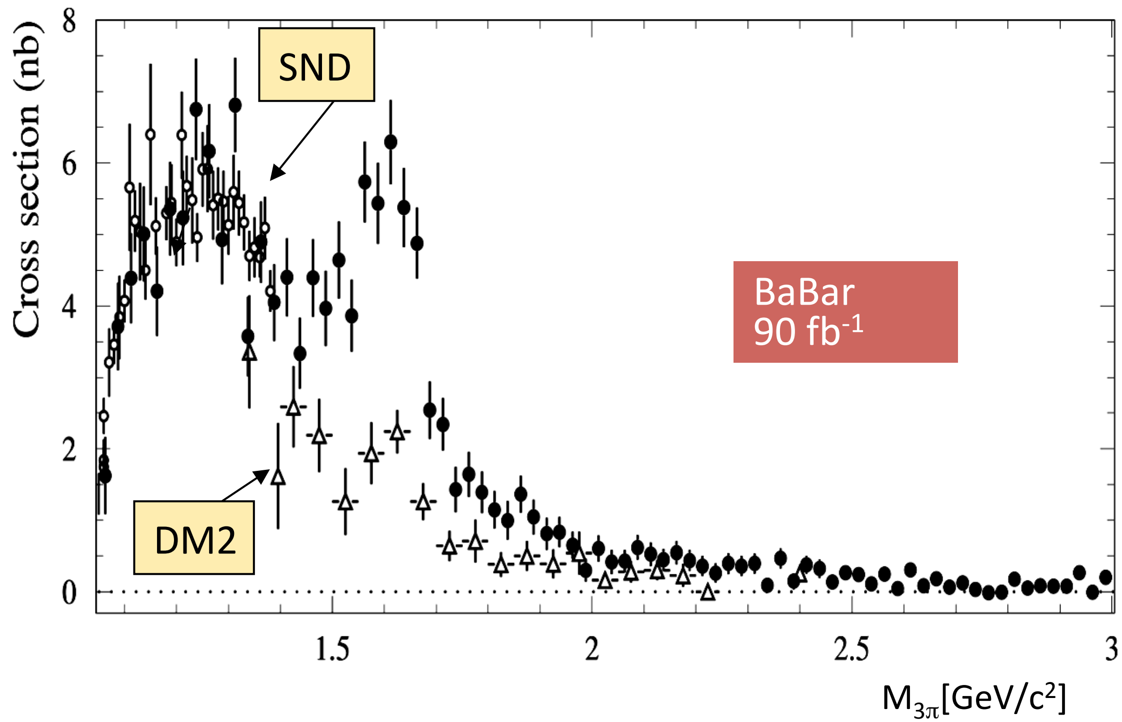




$M_{\omega'} = 1350 \pm 20 \pm 20$ MeV/c^2	PDG: 1400-1450 МэВ/c^2
$\Gamma_{\omega'} = 450 \pm 70 \pm 70$ MeV	PDG : 180-250 МэВ
$M_{\omega''} = 1660 \pm 10 \pm 2$ MeV/c^2	PDG: 1670 ± 30 МэВ/c^2
$\Gamma_{\omega''} = 230 \pm 30 \pm 20$ MeV	PDG: 315 ± 35 МэВ

$e^+e^- \to \pi^+\pi^-\pi^0\gamma$





$B(J/\psi \to \pi^+\pi^-\pi^0)\%$

BABAR	PDG 2004	BES 2003
2.18±0.19	1.50±0.20	2.10±0.12

- systematic error - 5%
- ω and ϕ-meson parameters are in agreement with world averages
- Consistent with SND data for M<1.4 GeV
- Inconsistent with DM2 results
- Inconsistent with MARK3 J/ψ result!

J/ψ and $\psi(2S)$ decays (2005-2006 view)

Mode	BaBar BF	PDG 2004
$J/\psi \to \pi^+\pi^-\pi^0$	$(2.18\pm0.19)\%$	$(1.50\pm0.20)\%$
$J/\psi \to \pi^+\pi^-\pi^+\pi^-$	$(3.61\pm0.26\pm0.26)\times10^{-3}$	$(4.0\pm1.0)\times10^{-3}$
$J/\psi \to K^+K^-\pi^+\pi^-$	$(6.09\pm0.50\pm0.53)\times10^{-3}$	$(7.2\pm2.3)\times10^{-3}$
$J/\psi \to 2K^+2K^-$	$(6.7\pm1.0\pm1.1)\times10^{-4}$	New
$J/\psi \to 3\pi^+3\pi^-$	$(4.40\pm0.29\pm0.29)\times10^{-3}$	$(4.0\pm2.0)\times10^{-3}$
$J/\psi \to 2\pi^+2\pi^-2\pi^0$	$(1.65\pm0.10\pm0.18)\times10^{-2}$	New
$J/\psi \to \omega\eta$	$(1.47\pm0.41\pm0.15)\times10^{-3}$	$(1.58\pm0.16)\times10^{-3}$
$J/\psi \to K^+K^-2\pi^+2\pi^-$	$(5.09\pm0.42\pm0.35)\times10^{-3}$	$(3.1\pm1.3)\times10^{-3}$
$J/\psi \to \phi 2\pi^+2\pi^-$	$(1.77\pm0.35\pm0.12)\times10^{-3}$	$(1.60\pm0.32)\times10^{-3}$
$J/\psi \to p\bar{p}$	$(2.22\pm0.16)\times10^{-3}$	$(2.17\pm0.08)\times10^{-3}$

BES $(2.10\pm0.12)\%$

Mode	BaBar BF	PDG 2004
$\psi(2S) \to 2\pi^+2\pi^-\pi^0\pi^0$	$(5.3\pm1.6\pm0.6)\times10^{-3}$	New
$\psi(2S) \to K^+K^-2\pi^+2\pi^-$	$(2.1\pm1.0\pm0.2)\times10^{-3}$	New
$\psi(2S) \to p\bar{p}$	$(3.3\pm0.9)\times10^{-4}$	$(2.36\pm0.24)\times10^{-4}$

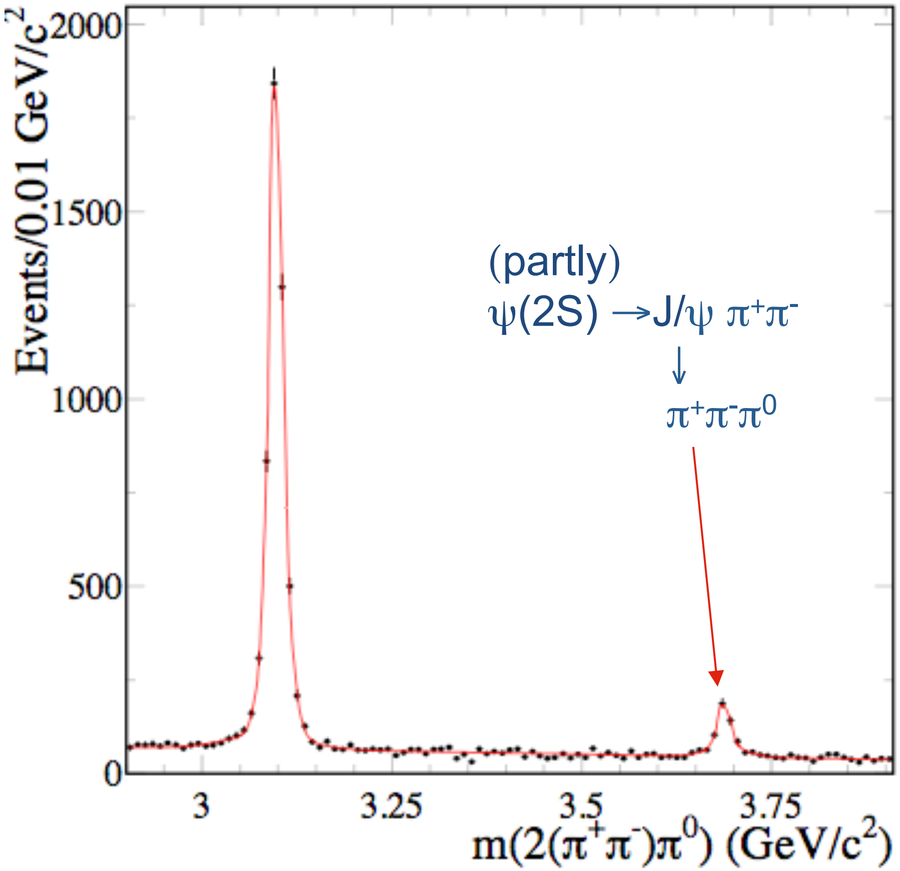
We actually measure
$BF(J/\psi\to f)\times\Gamma_{ee}$

Branching fractions are obtained using
$\Gamma_{ee} = (5.40\pm0.18)$ keV [PDG]

better

worse

J/ψ region for $2(\pi^+\pi^-)\pi^0$ – 232 fb^{-1}



$N_{J/\psi}$ = 4990 ± 79, ε = 0.1045 dL/dE = 65.6

$\Gamma_{ee} \bullet B_{5\pi} = (3.03 \pm 0.05 \pm 0.18) \times 10^{-1}$ keV
$B_{J/\psi\to5\pi} = (5.46 \pm 0.09 \pm 0.34) \times 10^{-2}$

$B_{J/\psi\to5\pi} = (3.37 \pm 0.26) \times 10^{-2}$ PDG2006
$B_{J/\psi\to5\pi} = (3.17 \pm 0.49) \times 10^{-2}$ DM2
$B_{J/\psi\to5\pi} = (3.17 \pm 0.42) \times 10^{-2}$ MARK2
$B_{J/\psi\to5\pi} = (3.64 \pm 0.52) \times 10^{-2}$ PLUTO

$N_{\psi(2S)}$ = 410 ± 30, ε = 0.0965 dL/dE = 84.0

$\Gamma_{ee} \bullet B_{5\pi} = (2.97 \pm 0.22 \pm 0.18) \times 10^{-2}$ keV
$B_{\psi(2S)\to5\pi} = (1.20 \pm 0.09 \pm 0.07) \times 10^{-2}$

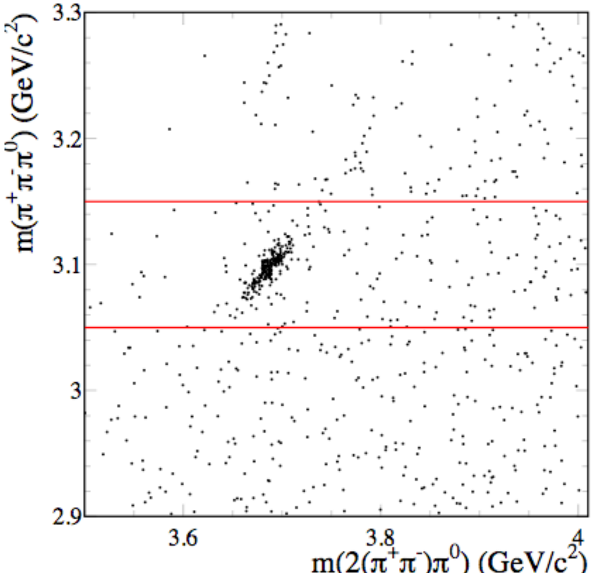
$B_{\psi(2S)\to5\pi} = (0.266 \pm 0.029)\times10^{-2}$ PDG2006

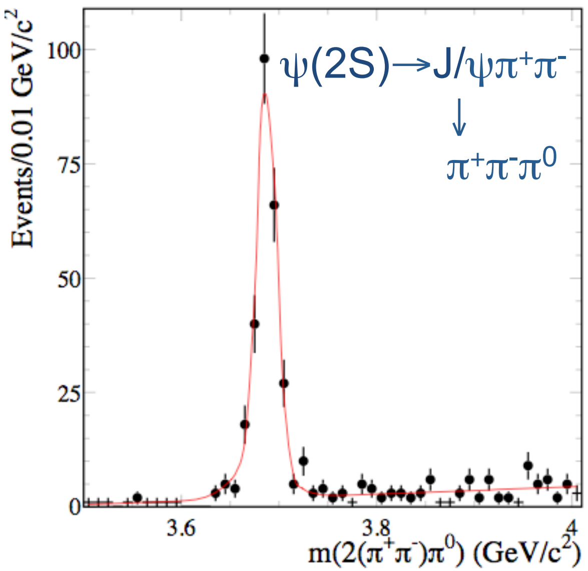
Huge discrepancy ! ?

Another example of discrepancies in largest decay mode!
B. Aubert *et al*. PR D76 092005 (2007) No other measurements! Still exists in PDG2018

About 6% systematic error from efficiency (5%) and luminosity (3%)

The $\psi(2S) \rightarrow J/\psi\, \pi^+\pi^- \rightarrow 2(\pi^+\pi^-)\pi^0$





$N_{\psi(2\Sigma)}$ = 256 ± 17, ε = 0.0965 dL/dE = 84.0

$\Gamma_{ee} \bullet B_{J/\psi\pi\pi} \bullet B_{J/\psi\rightarrow 3\pi}$ = (1.86 ± 0.12 ± 0.11) × 10^{-2} keV

Γ_{ee} = 2.48 ± 0.06 keV, $B_{J/\psi\pi\pi}$ = 0.318 ± 0.006 PDG2006

$B_{J/\psi\rightarrow 3\pi}$ = (2.36 ± 0.16 ± 0.16) × 10^{-2}

$B_{J/\psi\rightarrow 3\pi}$ = (2.02 ± 0.14)×10^{-2} S=1.7 PDG2006

$B_{J/\psi\rightarrow 3\pi}$ = (2.18 ± 0.19)×10^{-2} BaBar 2004

$B_{J/\psi\rightarrow 3\pi}$ = (2.18 ± 0.20)×10^{-2} BES 2004

$B_{J/\psi\rightarrow 3\pi}$ = (2.09 ± 0.12)×10^{-2} BES 2004

$B_{J/\psi\rightarrow 3\pi}$ = (1.42 ± 0.19)×10^{-2} MARK3 1988

We are in agreement with BaBar and BES !

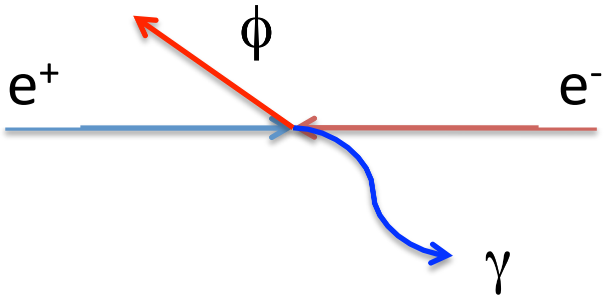
Use ϕ mass to get $E_{\gamma ISR}$

Assuming $e^+e^- \to \phi\gamma$ reaction

$E_0 = E^+ + E^-$

$\vec{p}_0 = \vec{p}^+ + \vec{p}^-$

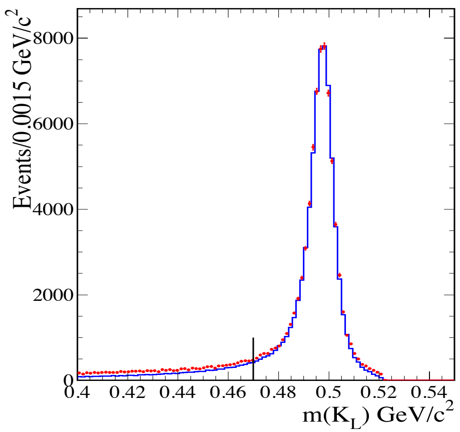
$\vec{p}_\gamma = \vec{n}\, E_\gamma$



$$E^c_\gamma = \frac{E_0^2 - p_0^2 - m_\phi^2}{2\left(E_0 - \vec{p}_0 \cdot \vec{n}_\gamma\right)}$$

Using energy-momentum conservation, ϕ mass constrain and detected K_S we determine K_L mass and direction:

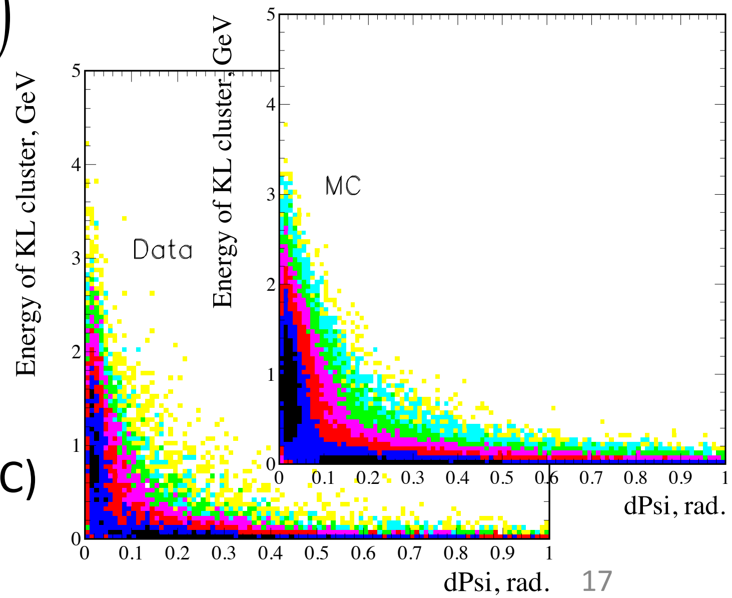
$$m^2(K_L) = \left(E^+ + E^- - E^c_\gamma - E_{K_S}\right)^2 - \left(p^+ + p^- - p^c_\gamma - p_{K_S}\right)^2$$



Very clean sample without KL detection!

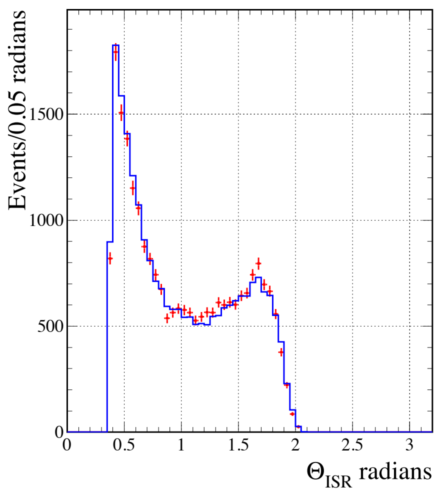
MC normalized to two bins at peak

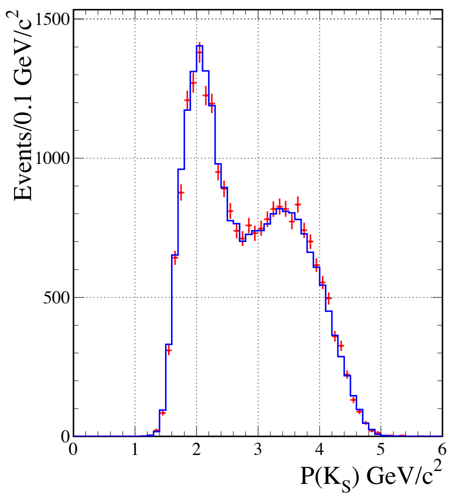
83247 (413401) events for data (MC)

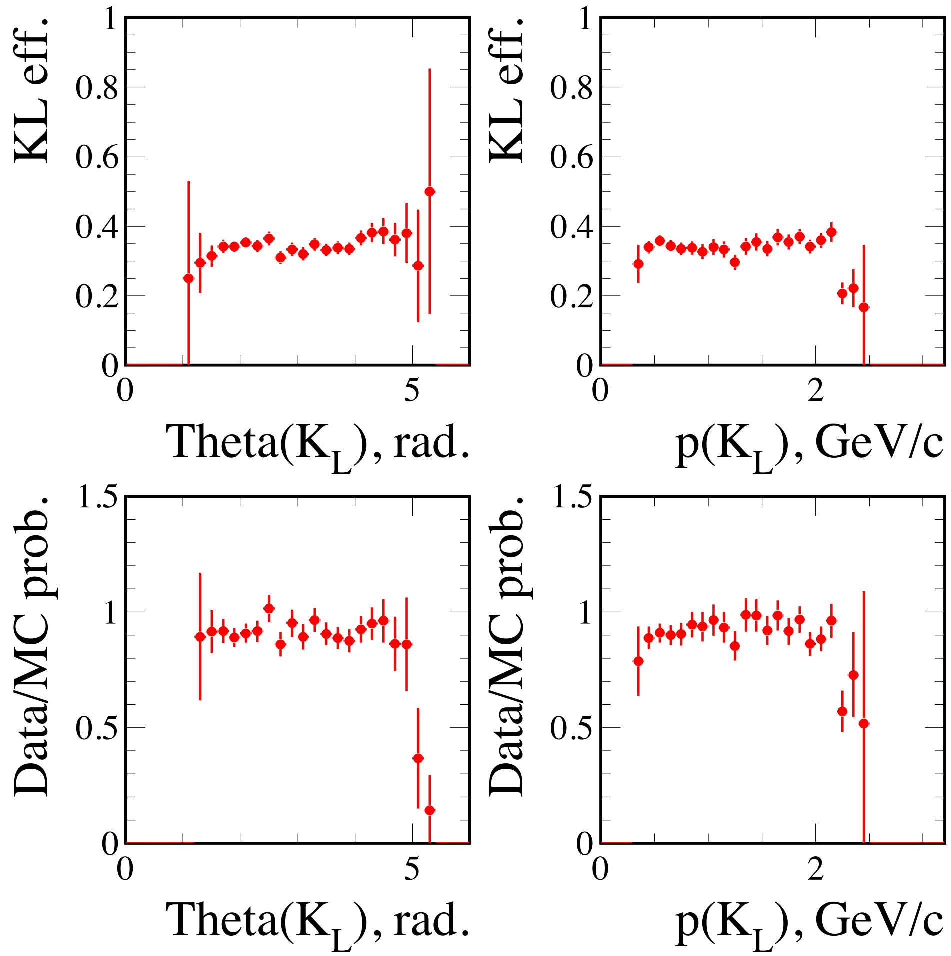


K_L EMC detection probability

The KL detection efficiency for kinematic fit in $\phi\gamma$ hypothesis is ~35%



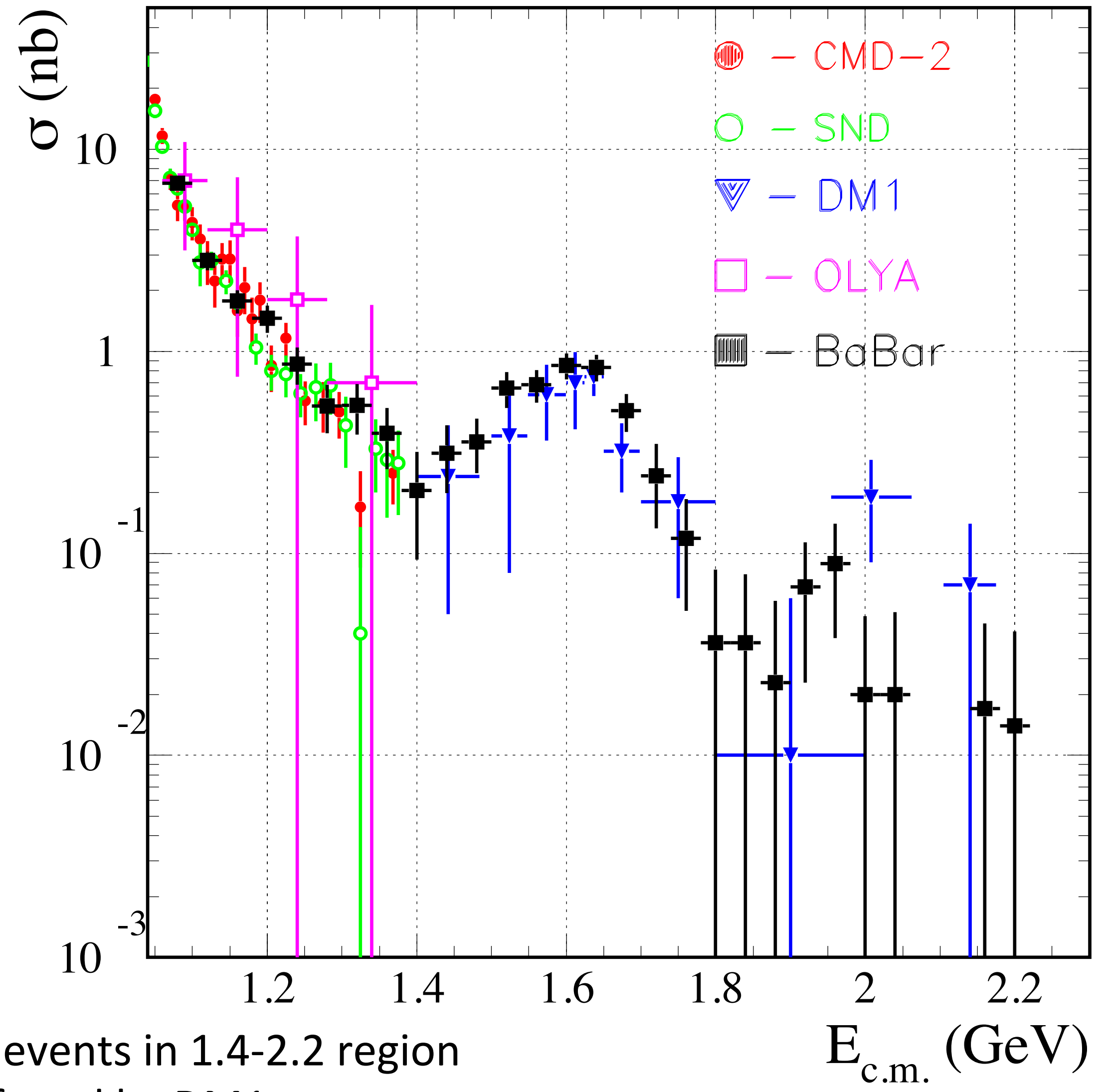




Data/MC = 0.9394 ± 0.0052 (includes also χ^2 cut efficiency)

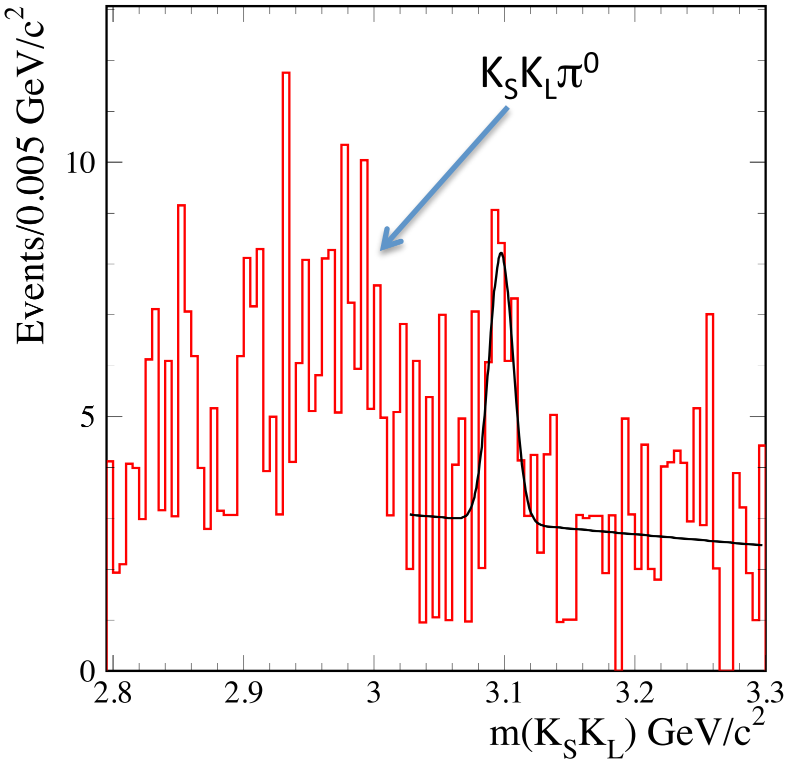
Open possibility to study reactions with KL!

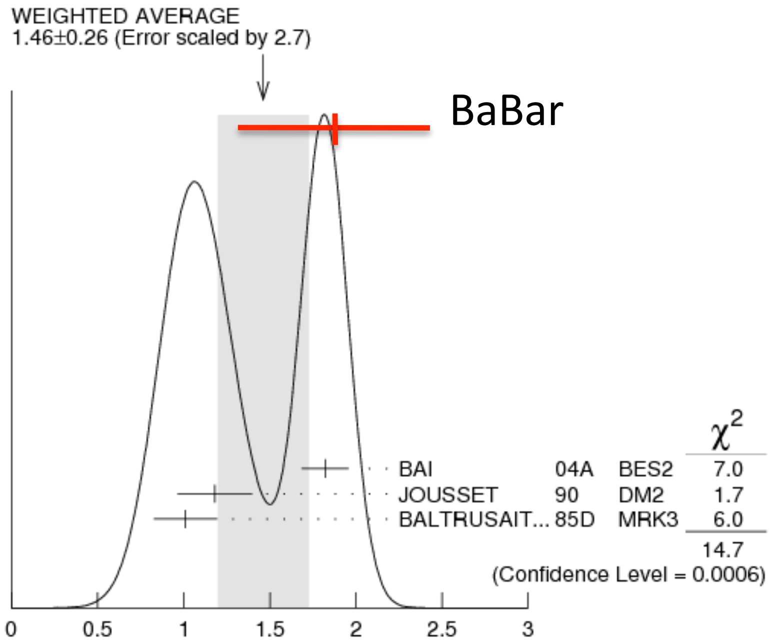
Compare $e^+e^- \to K_SK_L$ to other data



We have ~1000 events in 1.4-2.2 region
Compare to 58 found by DM1

J/ψ -> $K_S K_L$





N = 24.6 ± 7.5

Gee• B(J/ψ -> $K_S K_L$) = 1.13±0.34±0.11 eV

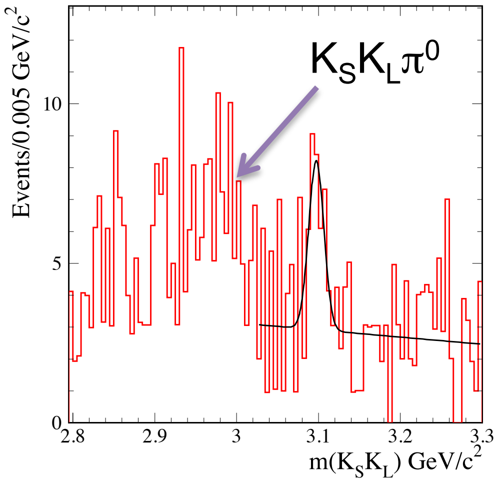
B(J/ψ -> $K_S K_L$) = (2.0±0.6±0.2)•10^{-4}

From PDG

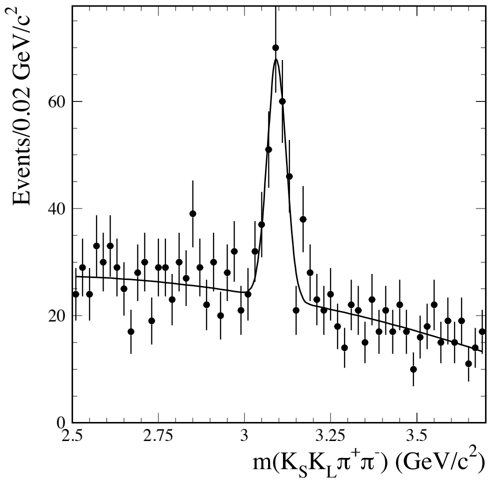
B(J/ψ -> $K_S K_L$) = (1.46 ± 0.26)•10^{-4} S=2.7

J/ψ decays with $K_{S,L}$

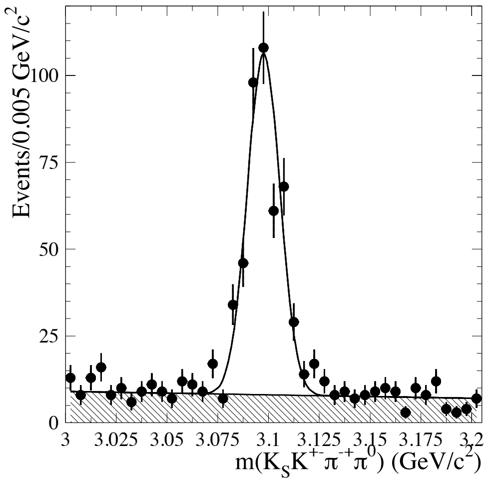
J.P. Lees *et al*. PR D86 012008 (2012)
J.P. Lees *et al*. PR D86 092002 (2014)
J.P. Lees *et al*. PR D95 092005 (2017)



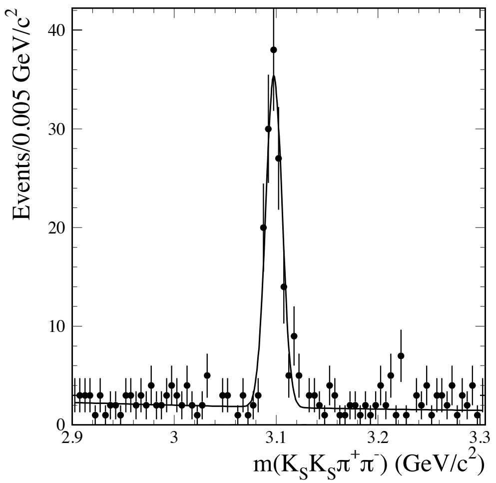
N = 24.6 ± 7.5



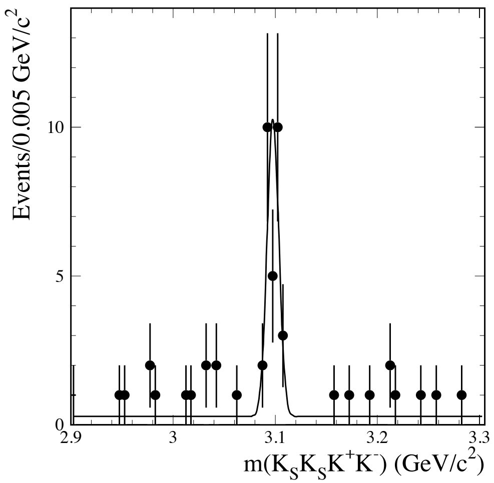
N = 154 ± 19



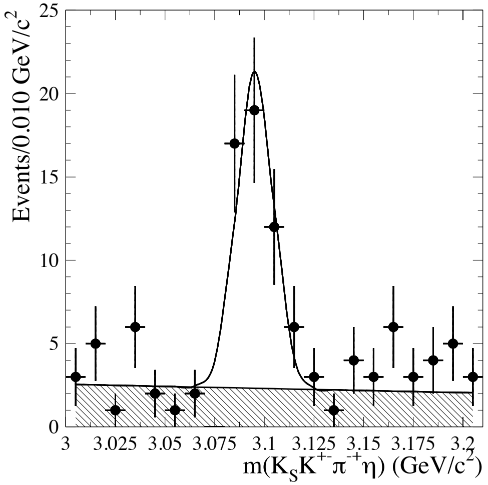
N = 393 ± 23



N = 248 ± 27



N = 28.5 ± 5.1



N = 44 ± 7

J/ψ decay results

Measured Quantity	Measured value (eV)	This work Br (10^{-3}) Γ_{ee} = 5.55 ± 0.14 keV	PDG 2014 Br (10^{-3})
Γ_{ee}•Br(J/ψ -> $K_S K_L$)	1.13±0.34±0.11	0.20 ± 0.06± 0.02	0.146 ± 0.026 S=2.7
Γ_{ee}•Br(J/ψ -> $K_S K_L \pi^+\pi^-$)	20.9±2.7±2.1	3.7 ± 0.6 ± 0.4	no entry
Γ_{ee}• Br(J/ψ -> $K_S K_S \pi^+\pi^-$)	9.3±0.9±0.5	1.68 ± 0.16 ± 0.08	no entry
Γ_{ee}• Br(J/ψ -> $K_S K_S K^+ K^-$)	2.3±0.4±0.1	0.42 ± 0.08 ± 0.02	no entry
Γ_{ee}• Br(J/ψ->$K_S K_S \phi$)•Br(φ ->K^+K^-)	1.6±0.4±0.1	0.58 ± 0.14 ± 0.03	no entry
Γ_{ee}• Br(J/ψ->f_2' φ)•Br(φ->K^+K^-) •B(f_2'->$K_S K_S$)	0.88±0.34±0.04	0.45±0.17 ± 0.02	0.8 ± 0.4 S=2.7
Γ_{ee}• Br(J/ψ -> $K_S K^{-+} \pi^{+-} \pi^0$)	31.7±1.9±1.8	5.7 ± 0.3 ± 0.4	no entry
Γ_{ee}• Br(J/ψ -> $K_S K^{-+} \pi^{+-} \eta$)	7.3±1.4±0.4	1.30 ± 0.25 ± 0.07	2.2 ± 0.4

We measure:

$$\mathcal{B}_{J/\psi\to f} \cdot \Gamma_{ee}^{J/\psi} = \frac{N_{J/\psi\to f} \cdot m_{J/\psi}^2}{6\pi^2 \cdot d\mathcal{L}/dE \cdot \epsilon_f(m_{J/\psi}) \cdot C}$$

B(J/ψ -> φ f_2') = (0.48 ± 0.18)•10^{-3} (MarkII)
B(J/ψ -> φ f_2') = (1.23 ± 0.026 ± 0.20)•10^{-3} (DM2)

J/ψ Branching Fractions

Latest measurements: J.P. Lees *et al*. PR D95 052001 (2017)

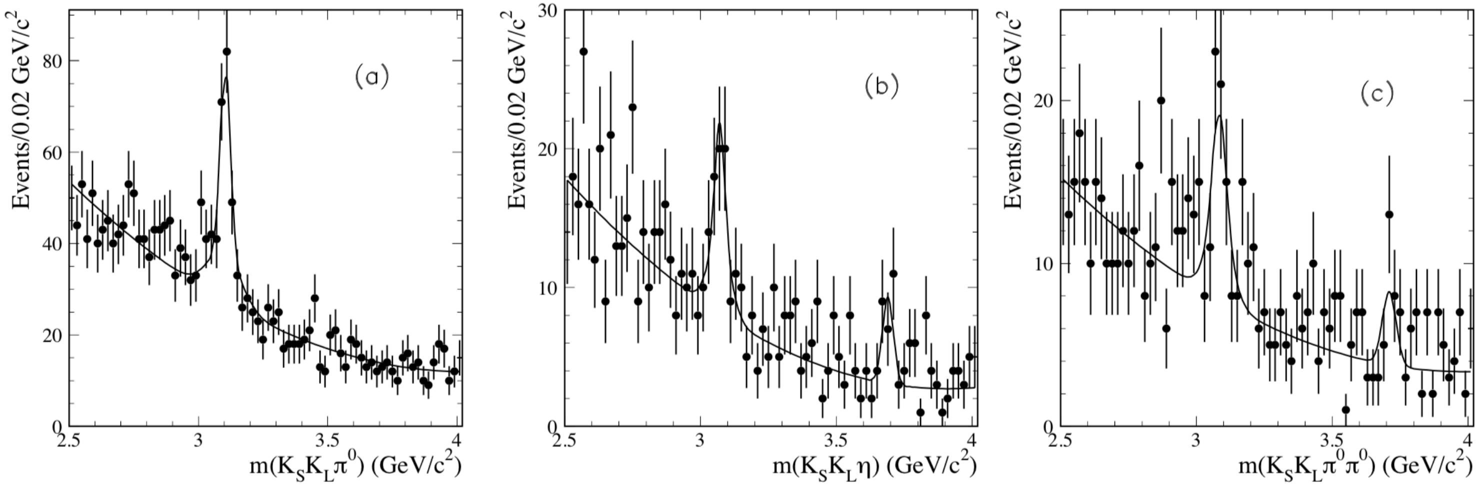


FIG. 16: Expanded views of the invariant mass distributions in the charmonium mass region for the (a) $K_S^0 K_L^0 \pi^0$, (b) $K_S^0 K_L^0 \eta$, and (c) $K_S^0 K_L^0 \pi^0\pi^0$ final states. The lines represent the results of the fits described in the text.

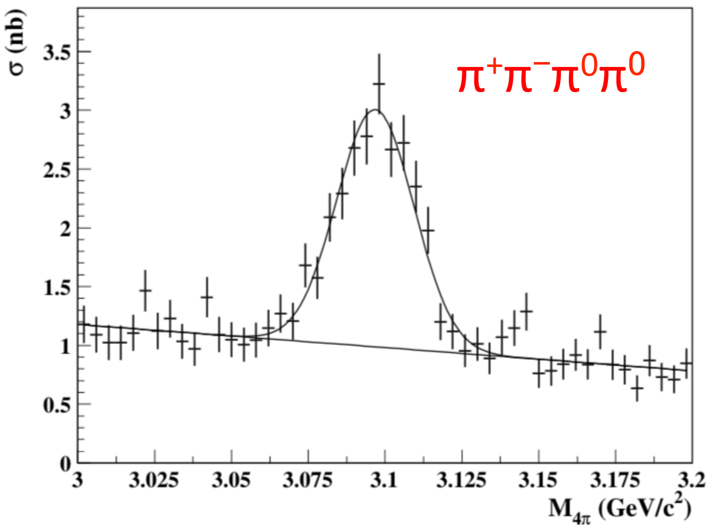
TABLE V: Summary of the J/ψ and $\psi(2S)$ branching fractions obtained in this analysis.

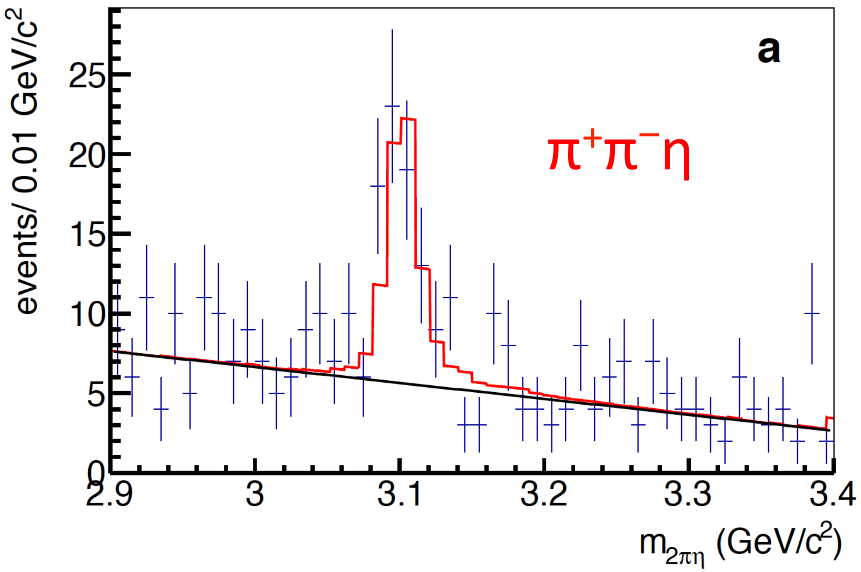
Measured Quantity	Measured Value (eV)	Calculated Branching Fractions (10^{-3}) This work	Previous
$\Gamma_{ee}^{J/\psi} \cdot \mathcal{B}_{J/\psi \to K_S^0 K_L^0 \pi^0}$	$11.4 \pm 1.3 \pm 0.6$	$2.06 \pm 0.24 \pm 0.10$	–
$\Gamma_{ee}^{J/\psi} \cdot \mathcal{B}_{J/\psi \to K_S^0 K_L^0 \eta}$	$8.0 \pm 1.8 \pm 0.4$	$1.45 \pm 0.32 \pm 0.08$	–
$\Gamma_{ee}^{J/\psi} \cdot \mathcal{B}_{J/\psi \to K_S^0 K_L^0 \pi^0\pi^0}$	$10.3 \pm 2.3 \pm 0.5$	$1.86 \pm 0.43 \pm 0.10$	–
$\Gamma_{ee}^{J/\psi} \cdot \mathcal{B}_{J/\psi \to K^*(892)^0 \bar{K}^0 + c.c.} \cdot \mathcal{B}_{K^*(892)^0 \to K^0\pi^0}$	$6.7 \pm 0.9 \pm 0.4$	$1.20 \pm 0.15 \pm 0.06$	–
$\Gamma_{ee}^{J/\psi} \cdot \mathcal{B}_{J/\psi \to K_2^*(1430)^0 \bar{K}^0 + c.c.} \cdot \mathcal{B}_{K_2^*(1430) \to K^0\pi^0}$	$2.4 \pm 0.7 \pm 0.1$	$0.43 \pm 0.12 \pm 0.02$	< 4 [26]
$\Gamma_{ee}^{\psi(2S)} \cdot \mathcal{B}_{\psi(2S) \to K_S^0 K_L^0 \pi^0}$	< 0.7	< 0.3	–
$\Gamma_{ee}^{\psi(2S)} \cdot \mathcal{B}_{\psi(2S) \to K_S^0 K_L^0 \eta}$	$3.14 \pm 1.08 \pm 0.16$	$1.33 \pm 0.46 \pm 0.07$	–
$\Gamma_{ee}^{\psi(2S)} \cdot \mathcal{B}_{\psi(2S) \to K_S^0 K_L^0 \pi^0\pi^0}$	$2.92 \pm 1.27 \pm 0.15$	$1.24 \pm 0.54 \pm 0.06$	–

J/ψ Branching Fractions

Latest measurements: J.P. Lees *et al*. PR D96 092009 (2017)
J.P. Lees *et al*. PR D97 052007 (2018)

J/ψ branching fractions	PDG
$B(J/\psi \to \pi^+\pi^-\eta)$ = $(0.42\pm0.8)\times10^{-3}$	$(0.40\pm0.17)\times10^{-3}$
$B(J/\psi \to \pi^+\pi^-\pi^0\pi^0)$ = $(5.1\pm0.5)\times10^{-3}$	$\pi^+\pi^-\pi^+\pi^-$: $(3.57\pm0.30)\times10^{-3}$





Two different approaches

- Detection of all final particles, including ISR photon

  10% of ISR events due to ISR photon acceptance

  background from $e^+e^- \to$ hadrons at E=10 GeV, asymmetric π^0 decay mimic ISR photon

  weak efficiency dependence from mass and process dynamics, full kinematic fit

  cross sections can be measure up to 3-5 GeV

- Without ISR photon detection

  masses above 3 GeV

  5-8 time more effective luminosity starting from 3.5 GeV

  background from $e^+e^- \to$ hadrons low, but exists $e^+e^- \to e^+e^-$ + hadron

  rare processes above 3.5 GeV can be studied

Advantage of B-factories: at 10 GeV all exclusive processes are small and final state radiation (FSR) background is small

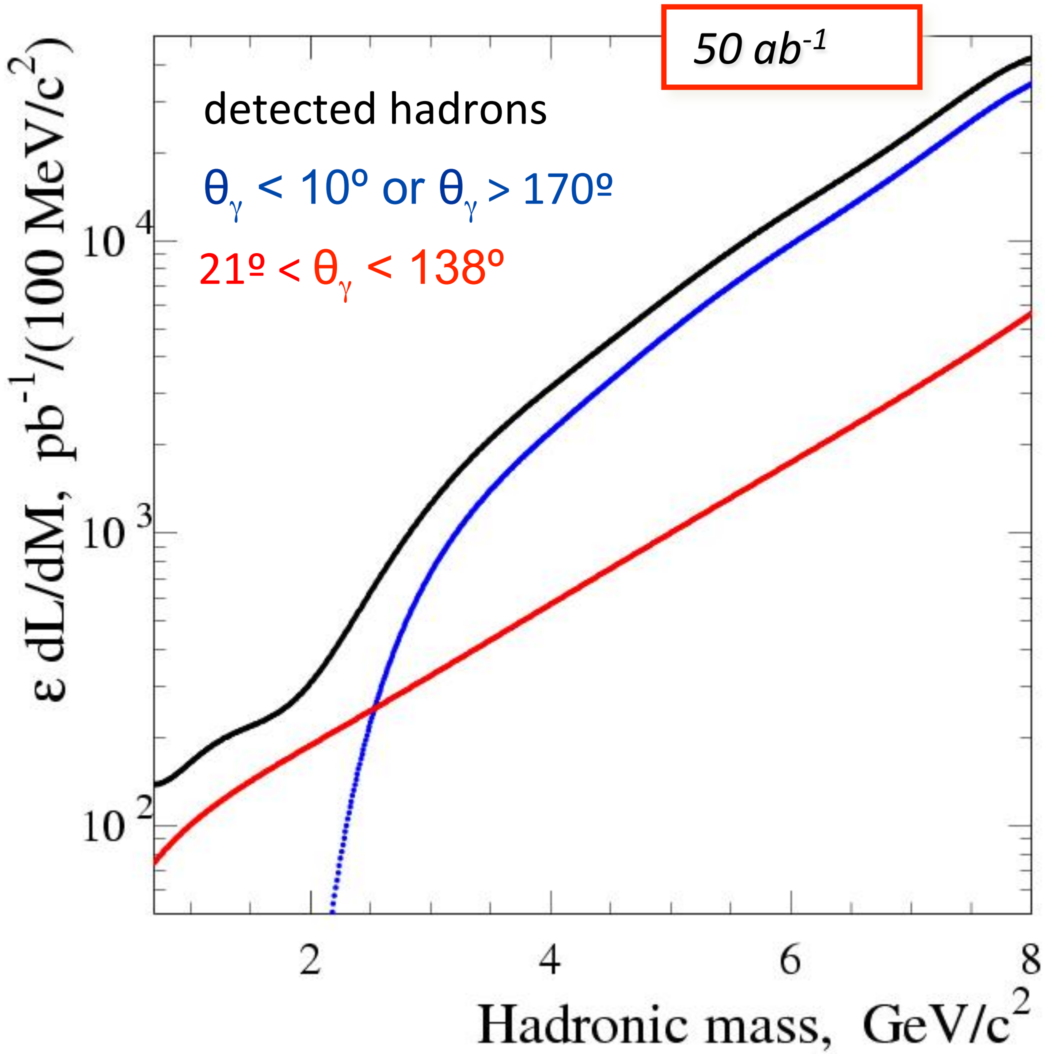
Example without ISR photon detection

Dalitz plot analyses of $J/\psi \to \pi^+\pi^-\pi^0$, $J/\psi \to K^+K^-\pi^0$**, and** $J/\psi \to K^0_S K^\pm \pi^\mp$ **produced via** e^+e^- **annihilation with initial-state radiation.**

BaBar Collaboration (J. P. Lees (Annecy, LAPP) *et al.)*

Published in **Phys.Rev. D95 (2017) no.7, 072007**

ISR luminosity for **50 ab⁻¹**



√s, GeV	$\varepsilon \cdot IL, fb^{-1}$
0.3-0.6	0.4
0.6-1.0	0.4
1.0-2.0	2.2
2.0-3.0	6.8
3.0-4.2	28
4.2-5.0	40
5.0-8.0	60

VEPP-2000
2 fb-1

BES-III
20 fb-1

Resonances produced and detected:

J/ψ - 0.25×10^9
ψ (2S) – 0.14×10^9
Υ(1S) – 0.6×10^9
Υ(2S) – 0.5×10^9
Υ(3S) – 0.8×10^9

Summary

- ISR is a powerful method to study low energy resonances at (super) B e+e- factories
- BaBar has wide ISR program and has studied many e+e- -> hadrons channels
- More than 30 exclusive final states of J/ψ and $\psi(2S)$ have been studied by BaBar – many of them for the first time and ~60 BF with intermediate resonances are measured.
- Still less than 50% of J/ψ decays are detected and studied now and study should be continued