# Cross-Section Measurements at Belle



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#### Introduction

- Three new Measurements
  - e⁺e⁻ →VP @ √s=10.58 GeV
  - $e^+e^- \rightarrow D^0D^{*-}\pi^+$  in ISR events
  - $\eta \pi^0$ -production in  $\gamma \gamma$  collisions



#### **Processes at a B-Factory**



Reisert EPS09

**Burkard** 

#### **KEKB** at Tsukuba



#### The Belle Detector



Reisert EPS09

#### Exclusive Vector-Pseudoscalar Production in e<sup>+</sup>e<sup>-</sup>-Annihilation

High statistics data samples allow for a study of rare exclusive two-body process in e<sup>+</sup>e<sup>-</sup> annihilation,

example: associated production of Vector & Pseudoscalar Mesons



Special interest as double charm production e<sup>+</sup>e<sup>-</sup>→ J/Ψη<sub>c</sub> (i.e. VP) was observed with unexpectedly high cross sections by Belle (Phys.Rev.Lett.89, 142001) and BaBar (Phys. Rev.D72, 031101)



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- Study ee→φη(φη') i.e. charm quarks replaced by strange quarks and compare to ee→ρη(ρη')
- Measurements (φη, ρη, ρη') of at different center-of-mass exist (DM1, CLEO, BaBar(ISR), BES) → Study energy dependence of cross section

#### $ee \rightarrow VP$ : Selection & Cross Section

#### Selection:

- events with low track multiplicity: n(track) = 2 or 4, veto  $ee \rightarrow \mu\mu$
- all tracks from vertex region with  $\Sigma_{Tr}$  charge = 0
- more than 1 track with  $p_T > 0.5$  GeV/c, all track  $p_T > 0.1$  GeV/c
- photons:  $E_{\gamma}$ >200 MeV, veto  $\gamma$ 's from  $\pi^0$
- VP energy difference in cms  $\Delta E$  within [-0.3 +0.2 GeV]
- V P back-to-back  $\Delta \phi > 175^{\circ}$

Cross Section:



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 $\sigma = \frac{N_{Sig}}{LBr_{V}Br_{P}\varepsilon}$ 

- L: Luminosity on resonance Y(4S) L= 516 fb<sup>-1</sup>, off resonance (-60MeV) L= 58 fb<sup>-1</sup>
- e: Efficiency Simulation of  $ee \rightarrow VP$  with  $J^P=1^-$  initial state
- Br: Branching fractions of V and P to reconstructed final states (PDG)

#### $ee \rightarrow VP$ : Event yields



#### $ee \rightarrow VP$ : Cross Section Extraction

Extraction of number of observed signal events by 2-dimensional fit

Signal on Y(4S) consistent with **Off resonance signals** →Limits for branching fractions  $Y(4S) \rightarrow VP$  (consistent with 0 set upper limits (90% CL)

> Y→\$(1.8 10<sup>-6</sup>) φη' (4.3 10<sup>-6</sup>) ρη (1.3 10<sup>-6</sup>) ρη' (2.5 10<sup>-6</sup>)

 $\rho \eta' (\pi^+ \pi^- \gamma)$ 

on'(comb.)

 $72.1 \pm 15.0$ 

7.6

14.3



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Number of signal events, signal significance efficiencies, cross sections

with tions with 0) -)	Entries / 20 MeV/c <sup>2</sup> Entries / 2.5 MeV/c <sup>2</sup> m(K	$\rightarrow K^{+}$ $^{15} 1^{+}$ $^{+} K^{-} (GeV$ $ 1^{-}$ $ $	$\overline{K}^{-}$	Entries 10 MeV (GeV/c <sup>2</sup> ) $\eta \rightarrow \gamma \gamma$ $\eta \rightarrow \gamma \gamma$ $\eta \rightarrow \gamma \gamma$ $\mu \rightarrow \eta \pi^{+} \eta$ $\eta \rightarrow \eta \pi^{+} \pi^{-}$ $\eta' \rightarrow \eta \pi^{+} \pi^{-}$ $\eta' \rightarrow \eta \pi^{+} \pi^{-}$			
Process	$N_{ m signal}$	Σ	$\varepsilon, \%$	$\sigma$ , fb	$\delta_{\text{sys}}^{\text{tot}}$ (%)	Ē	
$\phi\eta(\gamma\gamma)$	$14.6 \pm 4.3$	8.0	14.1	$1.1 \pm 0.3$	5.3	[	
$\phi \eta' (\eta \pi^+ \pi^-)$	$3.0 \pm 1.7$	12.0	0.917	$2.9\pm1.6$	7.4		
$\phi \eta'(\pi^+\pi^-\gamma)$	$19.6 \pm 4.5$	30.0	5.36	$4.9 \pm 1.1$	6.2		
$\phi \eta'( ext{comb.})$				$4.3\pm0.9$			
$ ho\eta(\gamma\gamma)$	$116.3 \pm 20.2$	9.2	23.2	$2.5 \pm 0.4$	5.0		
$ ho\eta'(\eta\pi^+\pi^-)$	$17.9 \pm 4.8$	7.9	3.58	$2.2 \pm 0.6$	7.0		

 $3.3 \pm 0.7$ 

 $2.7 \pm 0.5$ 

8

5.9



radiative correction:  $\sigma_0 = \frac{\sigma}{1+\delta}$  1+ $\delta = 0.809 (E_{\gamma^{rad}} < 0.3 \text{ GeV})$  applied

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#### $e^+e^- \rightarrow D^0 D^{*-} \pi^+$ in ISR



Possible decay channel for "charmonium like" resonances Y(4260),  $\psi$ (4415) → provides constraints on decay models



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Burkard Reisert EPS09 Full reconstruction on L = 695 fb<sup>-1</sup>: $D^0 \rightarrow K^-\pi^+, K^+K^-, K^-\pi^+\pi^-, K_s\pi^+\pi^-, K^-\pi^+\pi^0$  $D^{*-} \rightarrow D^0$  + slow pion $\pi$ track, no extra tracks

 $\pi^+$ 

#### $e^+e^- \rightarrow D^0 D^{*-} \pi^+$ in ISR

ISR enables scan of  $4 < M(D^0D^{*-}\pi^+) < 5.2 \text{ GeV}$ (threshold to just below B-meson decay)

Events consistent with ISR, but  $\gamma_{ISR}$  not necessarily detected

- 1.) γ<sub>ISR</sub> not detected
   →Recoil against Masszero object
- 2.) γ<sub>ISR</sub> in detector acceptance

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Reisert EPS09  $\rightarrow$  M(D<sup>0</sup>D<sup>\*-</sup> $\pi^+\gamma$ ) ~ E<sub>cm</sub>



#### $e^+e^- \rightarrow D^0 D^{*-} \pi^+$ in ISR



### Fitting the Mass Spectrum





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Burkard Reisert EPS09  $σ(e^+e^- → ψ(4415)) × Br(ψ(4415) → D^0D^{*-}π^+) < 0.8 \text{ nb at } 90\% \text{ CL}$  $Br(ψ(4415) → D^0D^{*-}π^+) < 11\% \text{ at } 90\% \text{ CL}$ 

#### Fitting the Mass Spectrum



	Upper Limit (90% CL)		Y(4350)	Y(4660)	X(4630)
Ŋ	$\sigma(e^+e^- \to X) \times \mathcal{B}(X \to D^0 D^{*-} \pi^+) \ \mathrm{nb}$	0.36	0.55	0.25	0.45
prelimina	$\mathcal{B}_{\rm ee} \times \mathcal{B}(X \to D^0 D^{*-} \pi^+) $ *10 <sup>-6</sup>	0.42	0.72	0.37	0.66
	$\mathcal{B}(X \to D^0 D^{*-} \pi^+) / \mathcal{B}(X \to \pi^+ \pi^- J / \psi)$	9			
	$\mathcal{B}(X \to D^0 D^{*-} \pi^+) / \mathcal{B}(X \to \pi^+ \pi^- \psi(2S))$		8	10	

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Study of  $\gamma\gamma \rightarrow \eta\pi^0 \rightarrow \gamma\gamma \gamma\gamma$ 

EPS09



# Study of $\gamma\gamma \rightarrow \eta\pi^0$ : Cross section



# **Differential Cross section**

Angular dependence of the cross section in selected W regions



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$$\frac{d\sigma}{d\Omega}(\gamma\gamma \to \eta\pi^0) = |SY_0^0 + D_0Y_0^2 + G_0Y_4^0|^2 + |D_2Y_2^2 + G_2Y_4^2|,$$
  
with *SDG* Amplitudes &  $|Y_J^m|$  spherical harmonics

**Good fit already** Without  $G_J^m$ 

 $\gamma\gamma \rightarrow \eta\pi^0$ : Low Mass Region

#### Study of resonances

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### $\gamma\gamma \rightarrow \eta\pi^{0:}$ high mass region



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## Summary

- Measurements of cross sections of exclusive ee→VP processes: ee→ φη, ee→ φη', ee→ ρη, ee→ ρη'
  - No universal energy dependence found
  - Light cone predictions fall short to describe data in all details (energy dependence and relative magnitude)
  - hep-ex 0906.4214 (submitted to PLB)
- First measurement of  $ee \rightarrow D^0 D^{*-}\pi$ + in range 4.0 <m<5.2 GeV
  - values of amplitudes of Y(4260), Y(4350), Y(4660) and X(4630) consistent with 0 within errors
  - □ Present data do not support Y(4260) → D<sup>0</sup>D\*-π<sup>+</sup> decays predicted by hybrid models
  - preliminary study
- Differential cross sections of the process  $\gamma\gamma \rightarrow \eta\pi^0$ measured for 0.84<W<4.0 GeV and  $|\cos\theta^*|<0.8$ 
  - □ Resonances  $a_0(980)$ ,  $a_2(1320)$  and  $a_0(Y)$  near 1320
  - Energy and angular dependencies for high W hep-ex 0906.1464 (submitted to PRD)



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#### Acknowledgement

 High-statistics study of ηπ<sup>0</sup>-production in two photon collisions
 Y. Watanabe, S. Uehara

 Measurement of cross sections of exclusive e<sup>+</sup>e<sup>-</sup>→VP processes at √s=10.58 GeV M. Shapkin, K. Belous



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