

Experimental studies of $\pi^+\pi^-/K^+K^-$ production in two-photon collisions

Photon2003, Frascati



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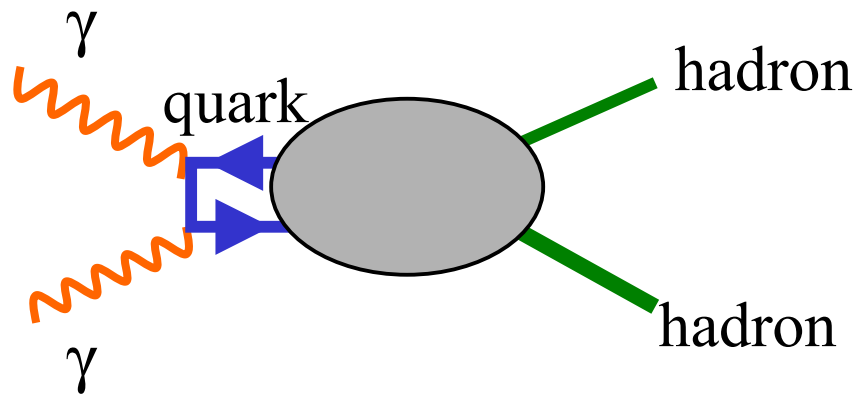
The Belle Collaboration

$\gamma\gamma \rightarrow \pi^+\pi^-$ and $\gamma\gamma \rightarrow K^+K^-$

Measurement of cross sections including angular dependences
Comparison with QCD models

Introduction

$\gamma\gamma \rightarrow$ exclusive hadronic state
in intermediate or high energies (2 - 4 GeV)



QCD – quark-pair production and hadronization
Contribution of resonances (light-quark resonances, $c\bar{c}$)
SU(3) symmetry

$\gamma\gamma \rightarrow \pi^+\pi^-$ and $\gamma\gamma \rightarrow K^+K^-$ in 2.5 - 4.1 GeV

All the Belle data are PRELIMINARY.

KEKB Accelerator

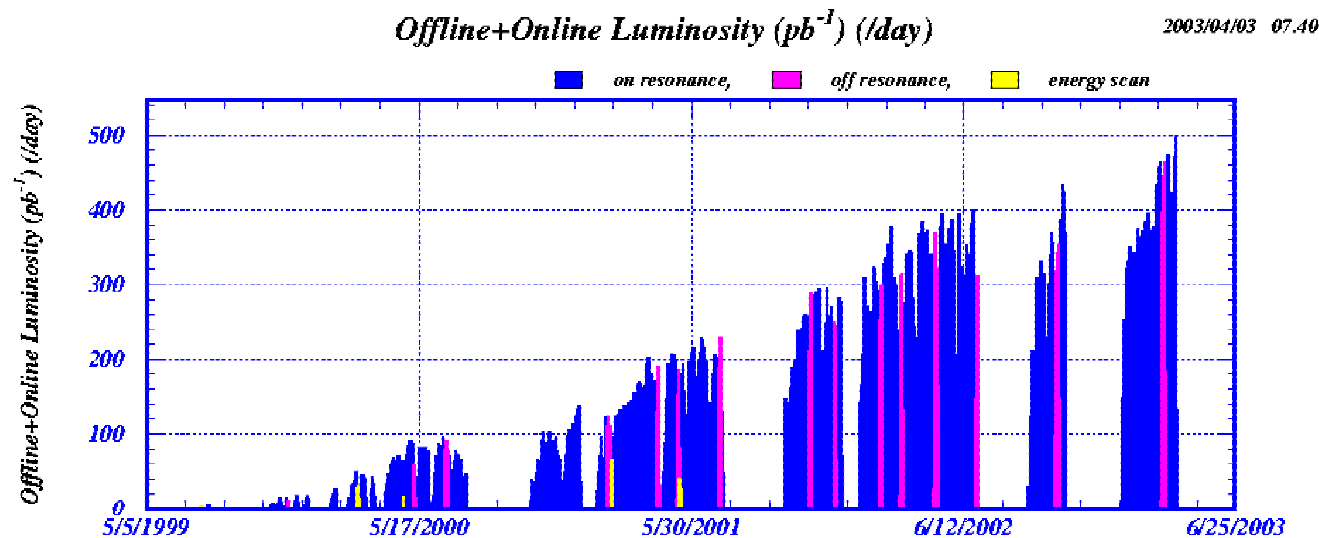
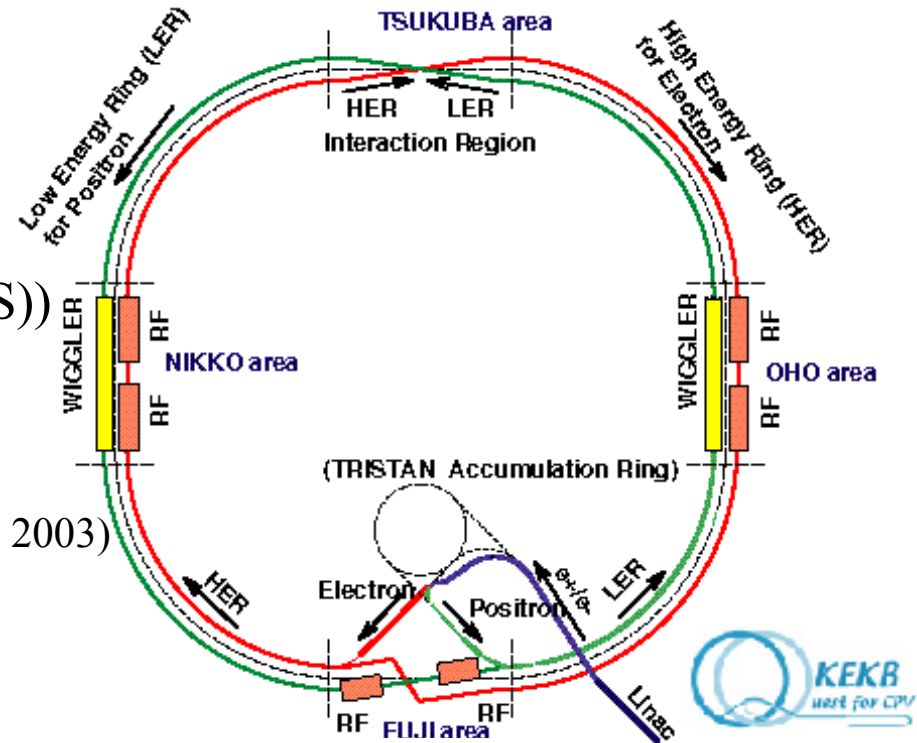
3.5 GeV(e^+), 8 GeV(e^-)

$$E_{\text{cm}}(ee) = 10.6 \text{ GeV} = m(Y(4S))$$

World-highest luminosity

$$L_{\text{max}} = 9.5 \times 10^{33} \text{ cm}^{-2}\text{s}^{-1} \text{ (Apr.2, 2003)}$$

$$\int L dt = 125 \text{ fb}^{-1} \text{ (by Mar.31, 2003)}$$



Belle Detector

Good momentum/energy/vertex resolutions

Drift chamber(CDC)+1.5T solenoid,
CsI EM calorimeters, Silicon vertex detector

Excellent Particle-ID performance

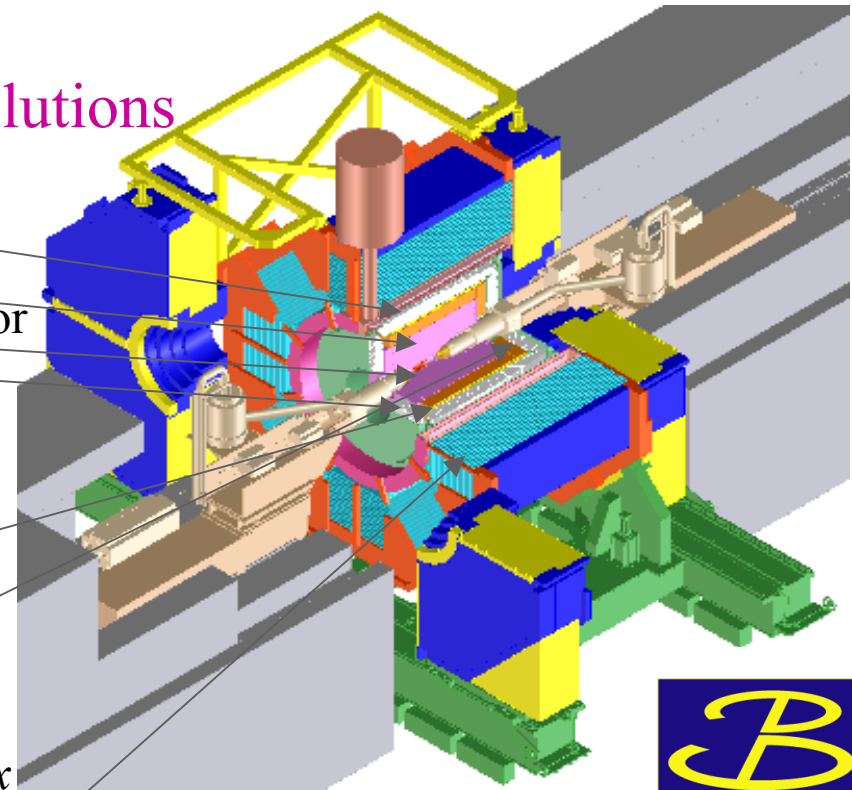
CsI calorimeter – Electron identification

TOF counter, Aerogel-Cherenkov(ACC), dE/dx

-- Excellent performance of $\pi(e,\mu)/K/p$ separation in wide momentum range

High muon detection efficiency

RPC for K_L and muon detections (KLM)



Data and Event selection

Data of **67 fb⁻¹** collected at $\sqrt{s}=10.56$ GeV and 10.50 GeV
in 1999 – 2002 spring

Selection criteria

Two-track exclusive events with

Net charge =0

$p_t > 0.8$ GeV/c, $-0.47 < \cos \theta < +0.82$

Electron rejection (mainly using ECL)

Muon rejection (mainly using KLM)

Tight p_t -balance requirement

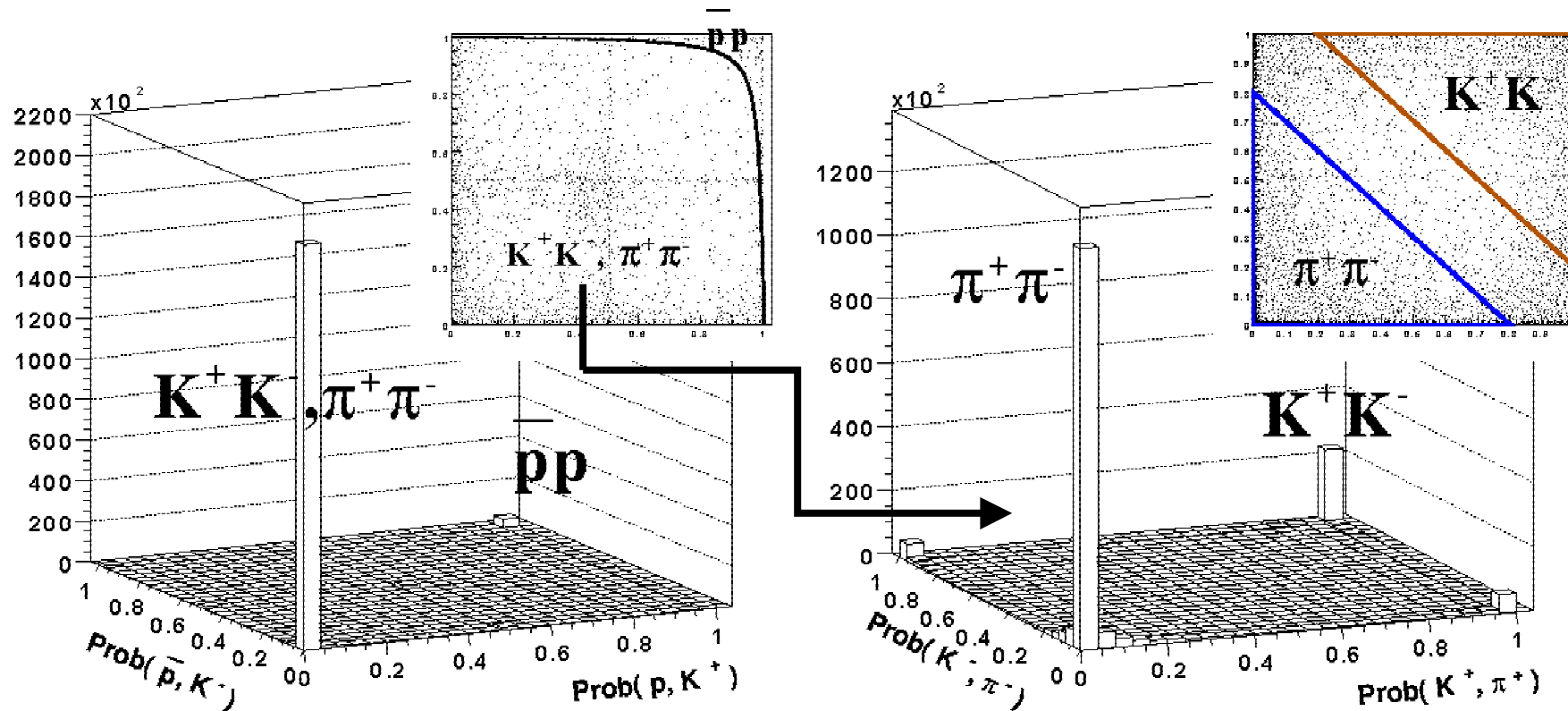
$$|\mathbf{p}_t^*(+) + \mathbf{p}_t^*(-)| < 0.1 \text{ GeV/c}$$

(< 0.05 GeV/c for $\pi^+\pi^-$)

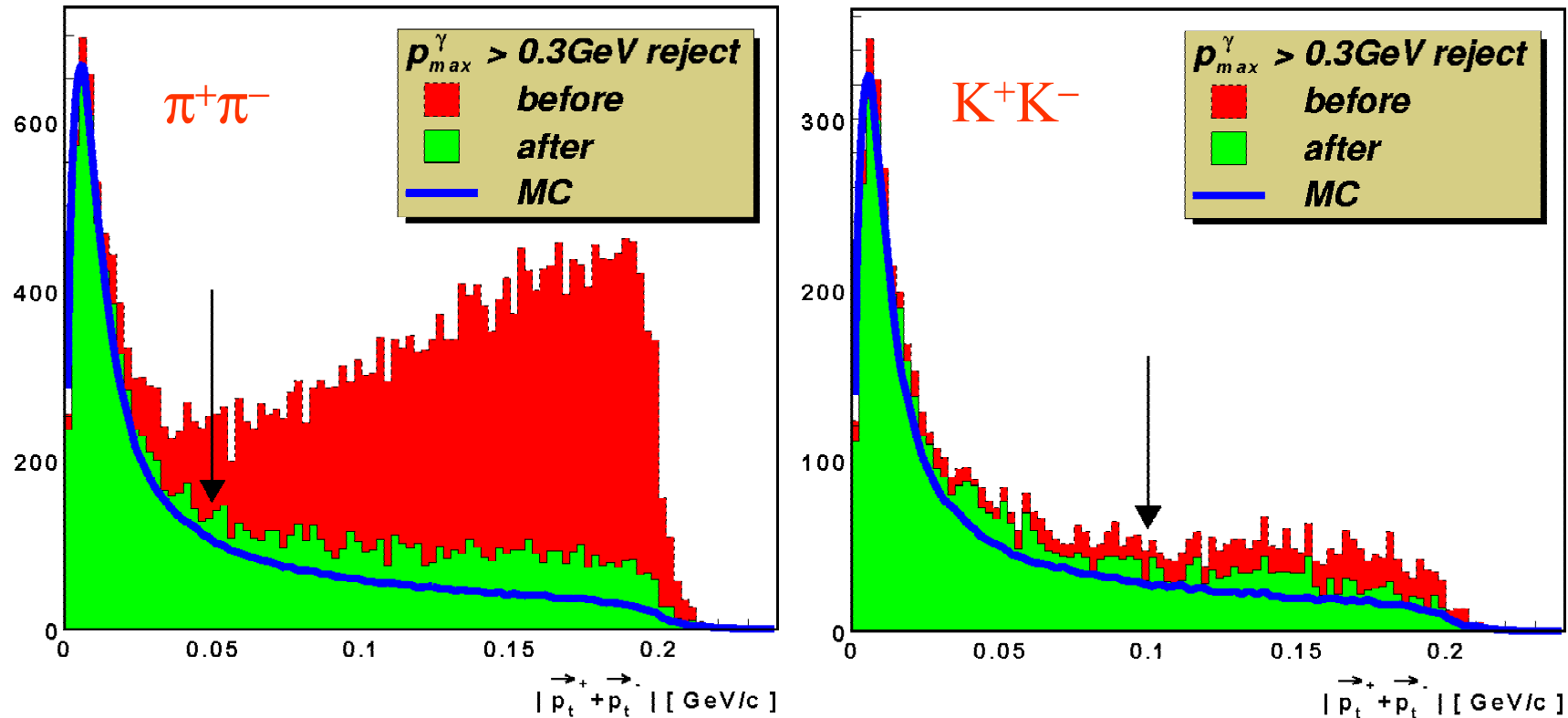
π/K separations and background rejections (next three pages)

Particle identification

$\pi/K/p$ separations using the likelihood ratios from the measurements by TOF, ACC and dE/dx (CDC)



Requirement of p_t -balance and Non-exclusive backgrounds



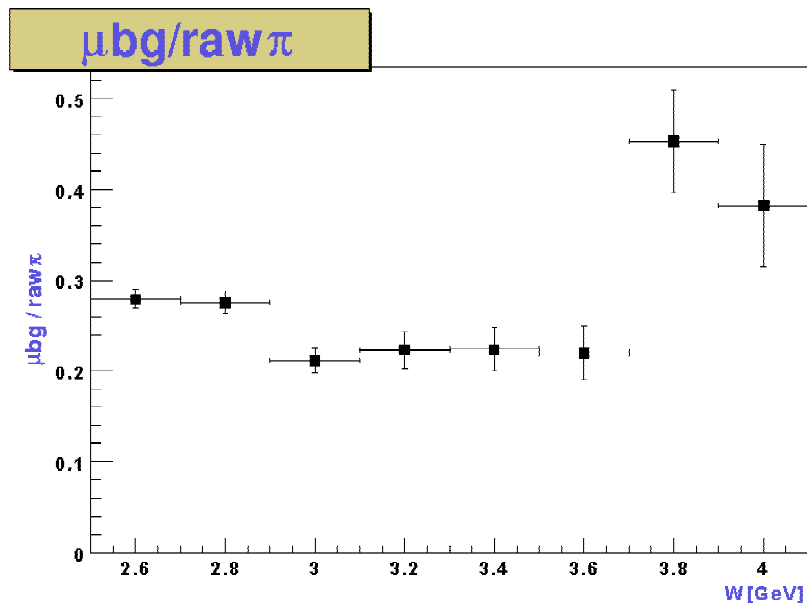
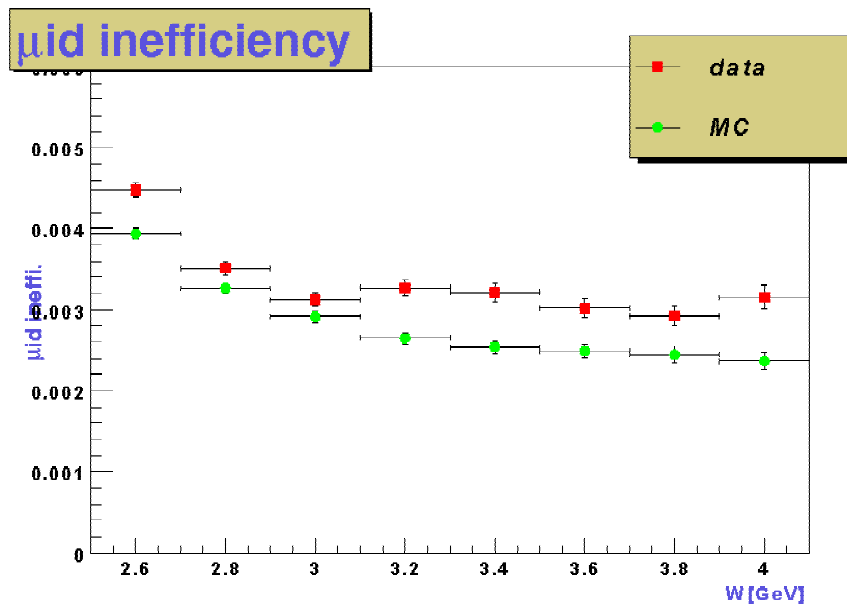
$\pi^+\pi^-$ -- Rather severe backgrounds (mainly from $e^+e^- \rightarrow \tau^+\tau^-$ process)
A tighter cut ($p_t < 0.05\text{ GeV/c}$) and rejection of events with
an energetic photon mainly from a neutral pion ($E_\gamma < 0.3\text{ GeV}$)

K^+K^- -- rather clean ($E_\gamma < 0.3\text{ GeV}$ cut is also applied)

Evaluation of muon background in $\pi^+\pi^-$ sample

$\mu^+\mu^-$ yield is $\sim O(100)$ times larger than the $\pi^+\pi^-$ yield.

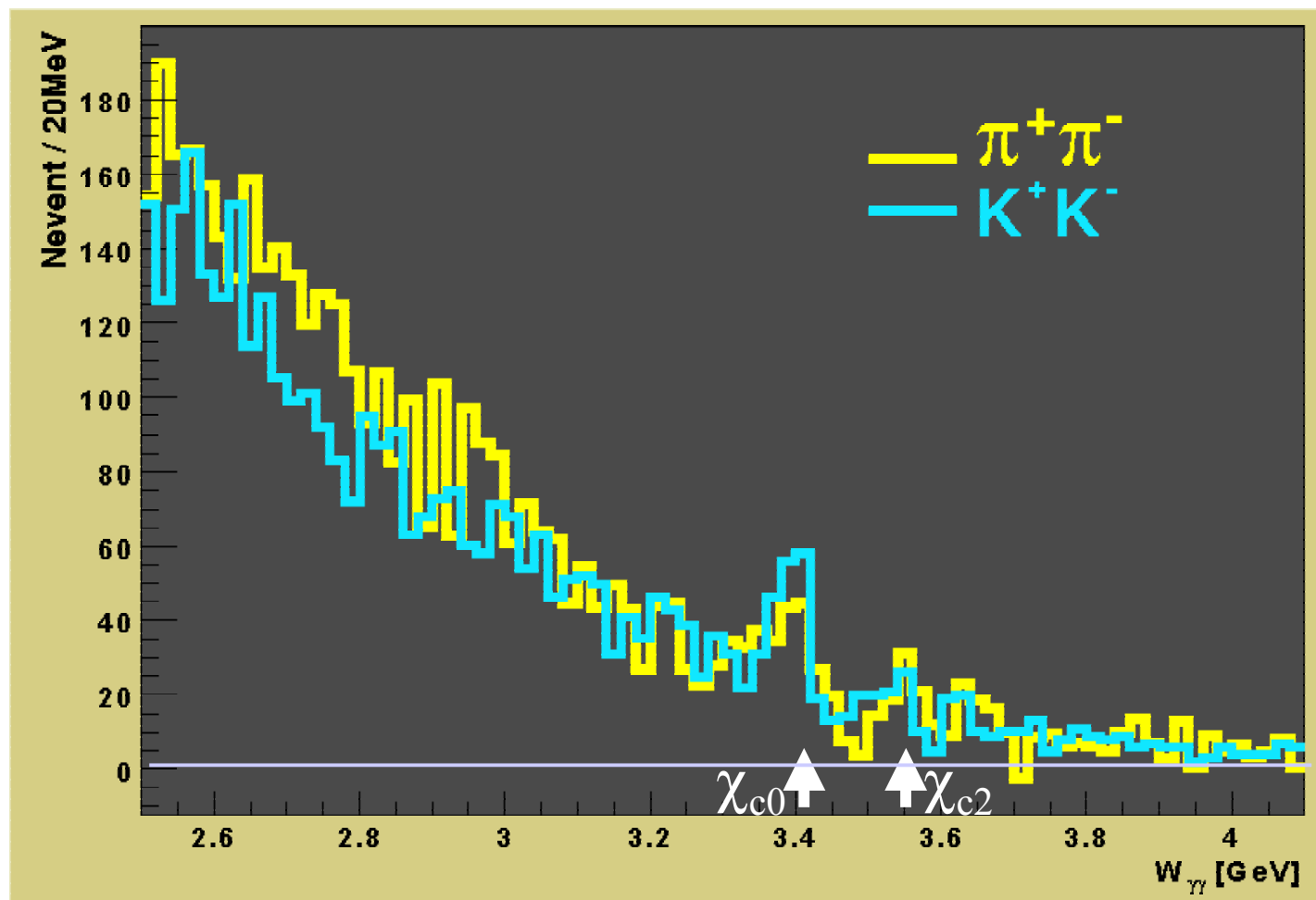
Rejection efficiency of KLM for a single muon -- about 94%



Rejection inefficiency for the two tracks --- about 0.3% of $\mu^+\mu^-$
20 – 45 % for $\pi^+\pi^-$

The background estimation is normalized to the observed $\mu\mu$ yields, and are corrected.

Invariant-mass distributions



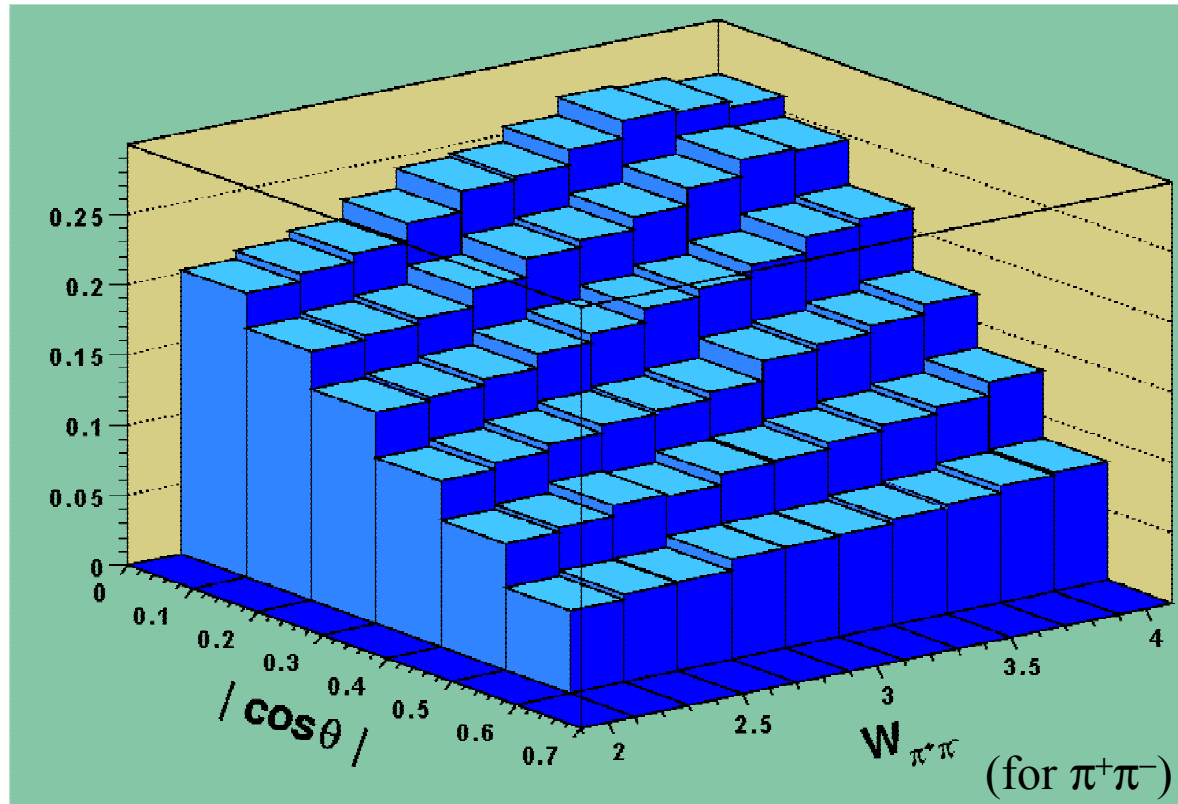
Peaks from $\gamma\gamma \rightarrow \chi_{c0} \rightarrow \pi^+\pi^-, K^+K^-$ are seen. *Belle Preliminary*

Observed numbers of χ_{c0} events:

77 ± 17 in $\pi^+\pi^-$, 103 ± 15 in K^+K^- . (from the fits of distributions)

Their contributions are subtracted in the following analyses.

Efficiencies



Efficiencies (acceptance and trigger efficiency) are determined using the signal Monte-Carlo events and detector & trigger simulators.

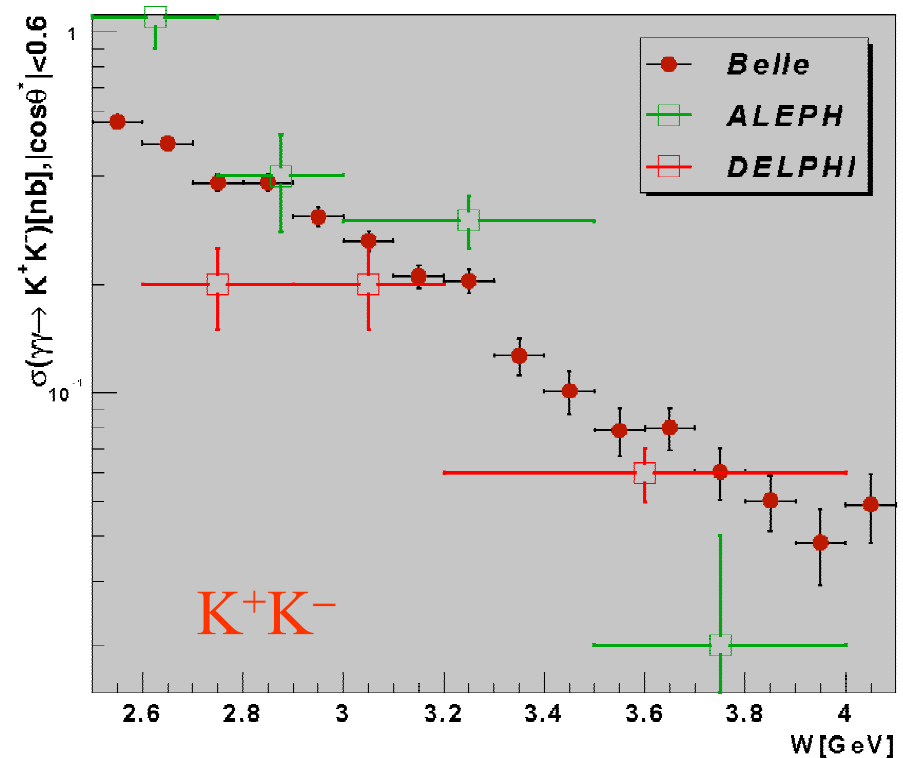
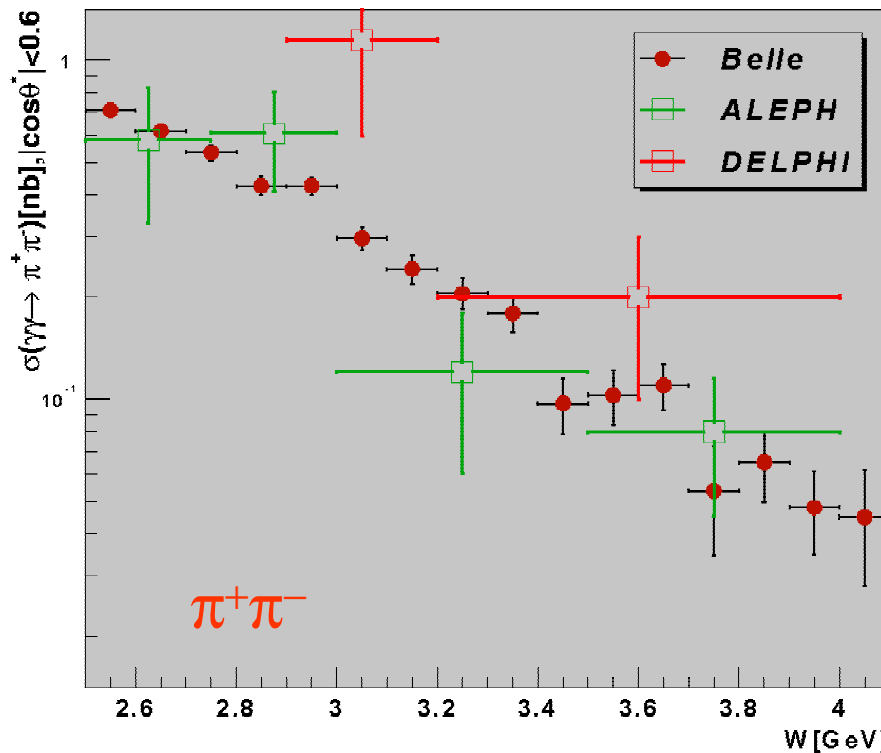
Trigger efficiency is typically 96%.

The $\gamma\gamma\rightarrow\mu^+\mu^-$ yields are used for confirmation of the efficiency.

Systematic errors

	$\gamma\gamma \rightarrow \pi^+\pi^-$	$\gamma\gamma \rightarrow K^+K^-$
Tracking efficiency	4%	4%
Trigger efficiency	4%	4%
K/ π separation	1 – 4%	1 – 4%
$\mu\mu$ background subtraction	2 – 8%	0%
χ_c subtraction	0 – 4%	0 – 10%
Non-exclusive bkg. subtr.	1 – 12%	1 – 2%
Luminosity function	5%	5%
Integrated luminosity	1%	1%
Total systematic error	9 – 17%	8 – 13%

Cross sections (in W dependence)



Belle Preliminary

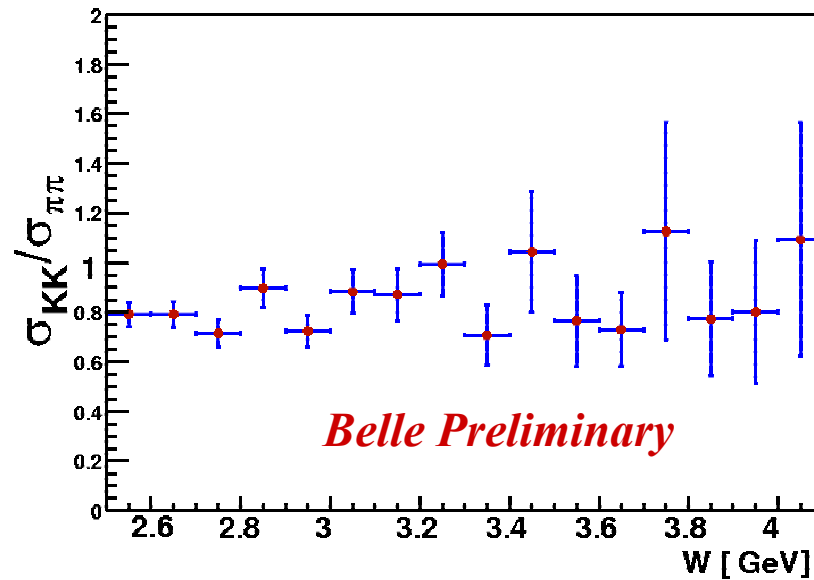
Monotonously decrease with the energy

In good agreements with previous experiments

(LEP2 results presented at Phton2001)

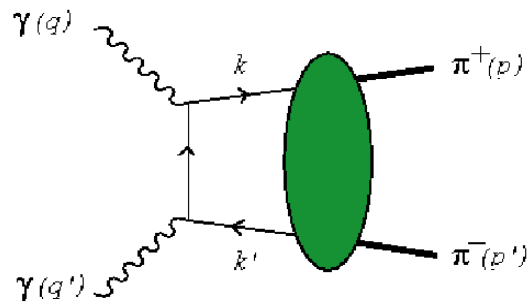
Much better statistical accuracies

Comparison to QCD-based models



The "Handbag model"

M. Diehl, P. Kroll, C. Vogt, Phys.Lett.B532 (2002) 99



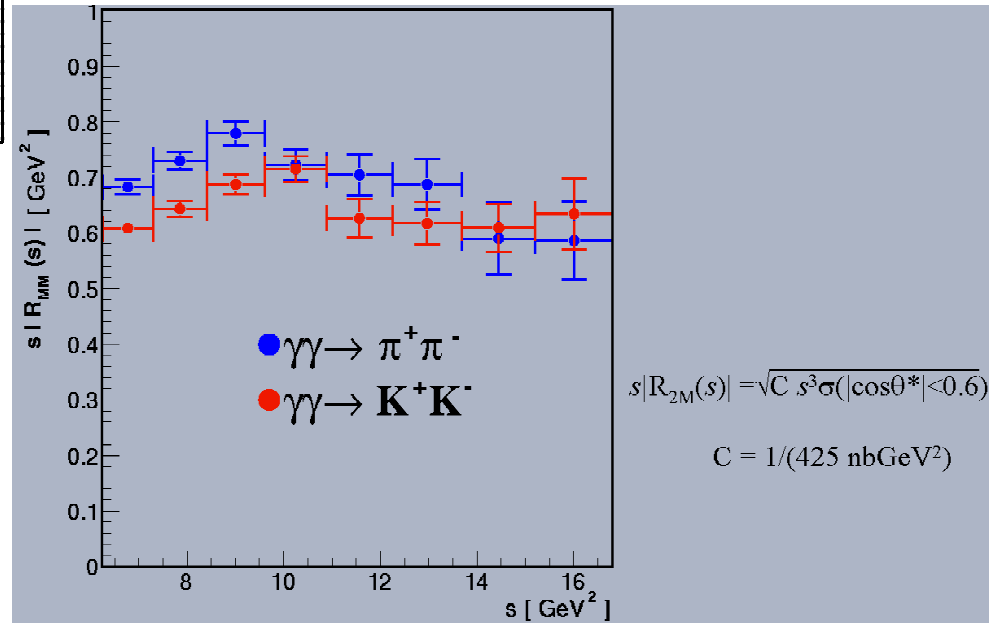
$$\frac{d\sigma}{dt} = \frac{8\pi\alpha^2}{s^2} \frac{1}{\sin^4\theta^*} |R_{2M}(s)|^2$$

$$s = W_{\gamma\gamma}^2$$

$\sigma(K^+K^-)/\sigma(\pi^+\pi^-)$ is 0.7 - 1.1 in the measured energy region.

Does not agree with a prediction of a QCD model by Brodsky and Lepage (~ 2).

The prediction of the **Handbag model** (~ 1 or smaller) is consistent to this result.



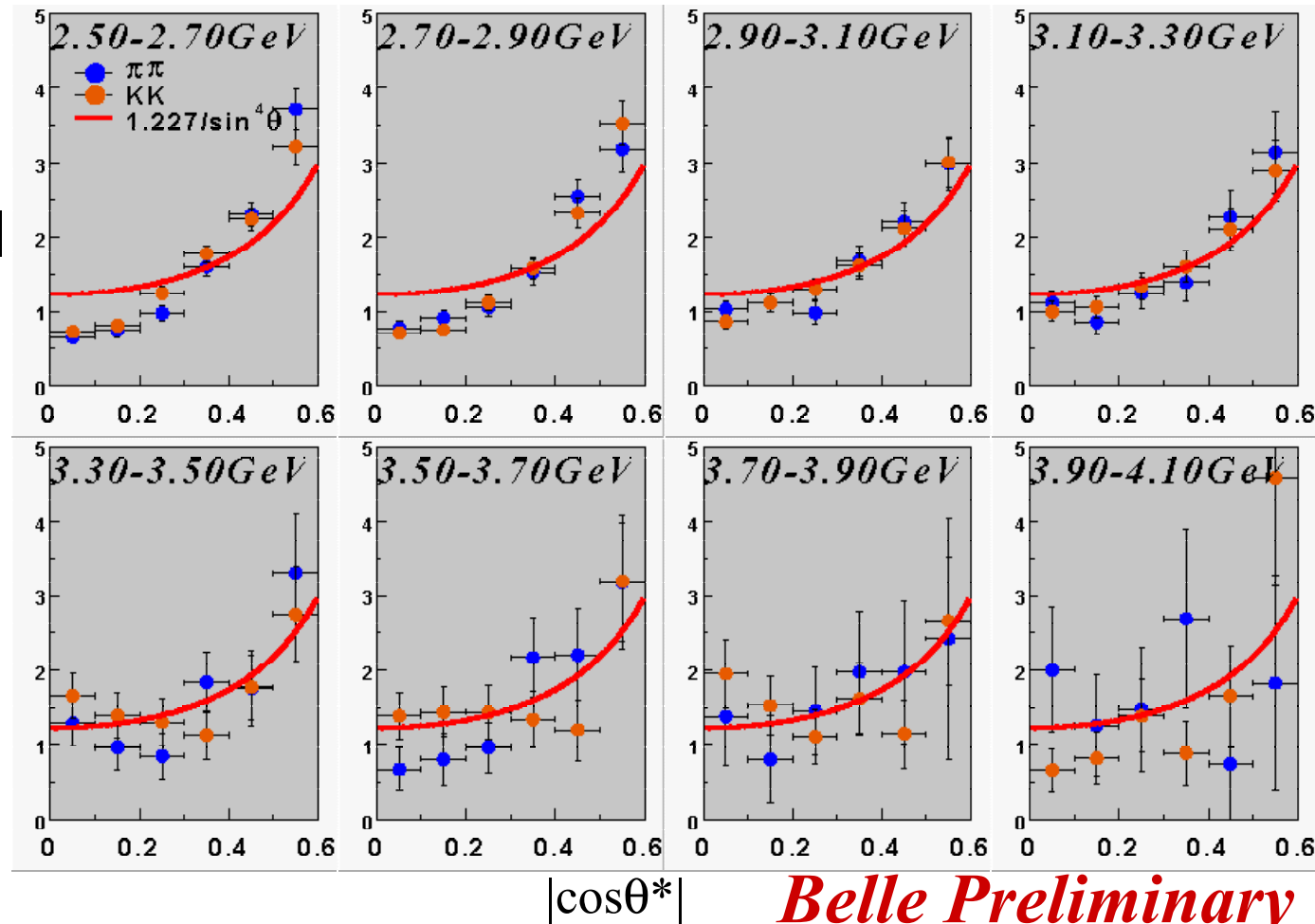
W dependence from dimensional counting rule

$$\frac{d\sigma}{dt} \sim s^{-4} \rightarrow |R_{2M}(s)| \sim 1/s$$

Angular dependences

Normalized angular dependence of the cross sections in $0 < |\cos\theta^*| < 0.6$

$$\frac{d\sigma/d|\cos\theta^*|}{\sigma}$$



Match the $\sim \sin^{-4}\theta^*$ dependence at energies above 3.1 GeV

Conclusions

- ◆ Energy and angular dependences of cross sections for $\gamma\gamma \rightarrow \pi^+\pi^-$ and $\gamma\gamma \rightarrow K^+K^-$ have been measured in the $\gamma\gamma$ c.m. energy region between 2.5 and 4.1 GeV.
- ◆ Good π/K separation are achieved.
Huge muon-pair backgrounds are controlled in the $\pi\pi$ sample.
- ◆ The cross-section ratio $\sigma(K^+K^-)/\sigma(\pi^+\pi^-) = 0.7 - 1.1$ and independent of the energy in the measured energy region.
- ◆ The prediction of a QCD Model on energy and angular dependences, $d\sigma/dt \sim s^{-4} \sin^{-4}\theta^*$, agrees with the data in 3.1 – 4.1 GeV in the two processes.
- ◆ The χ_{c0} is observed in the two processes.

