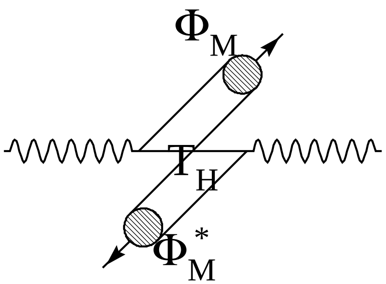
Exclusive Production of Meson Pairs in Two Photon Physics

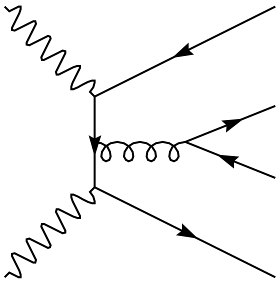
Update of preliminary result shown at Photon 2001.

Now includes all LEP data and systematic errors.

- Theoretical overview
- Selection
- Monte Carlos
- Backgrounds
- Trigger efficiency
- Cross section calculation
- Systematic errors
- Results
- More Theory
- Conclusions

Theoretical Overview





$$M = \int_0^1 dx \int_0^1 dy \Phi^*_M(x,p_t) T_H(x,y,p_t) \Phi_M(y,p_t)$$

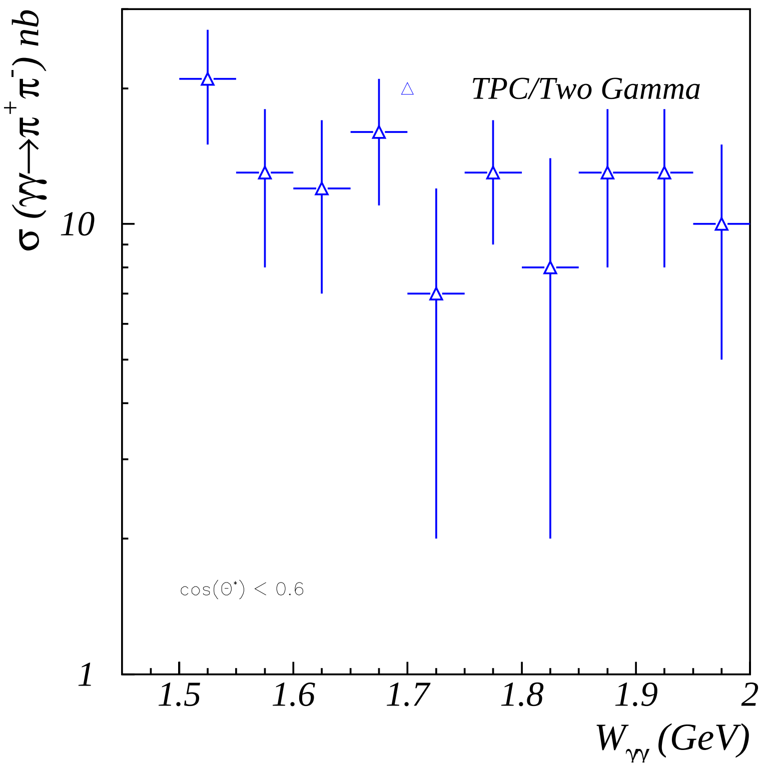
T_H is the hard scattering amplitude (short range, calculable)

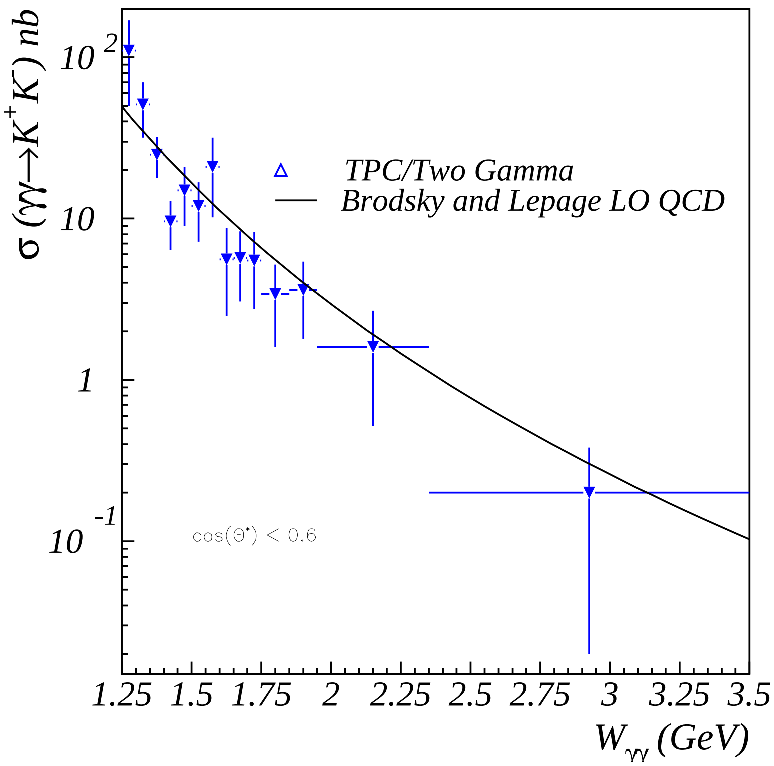
Φ_M is the Meson wave funtion - long range - parameterized by sum rules or lattice calculations

This is the 1981 Brodsky Lepage 'hard scattering' prediction

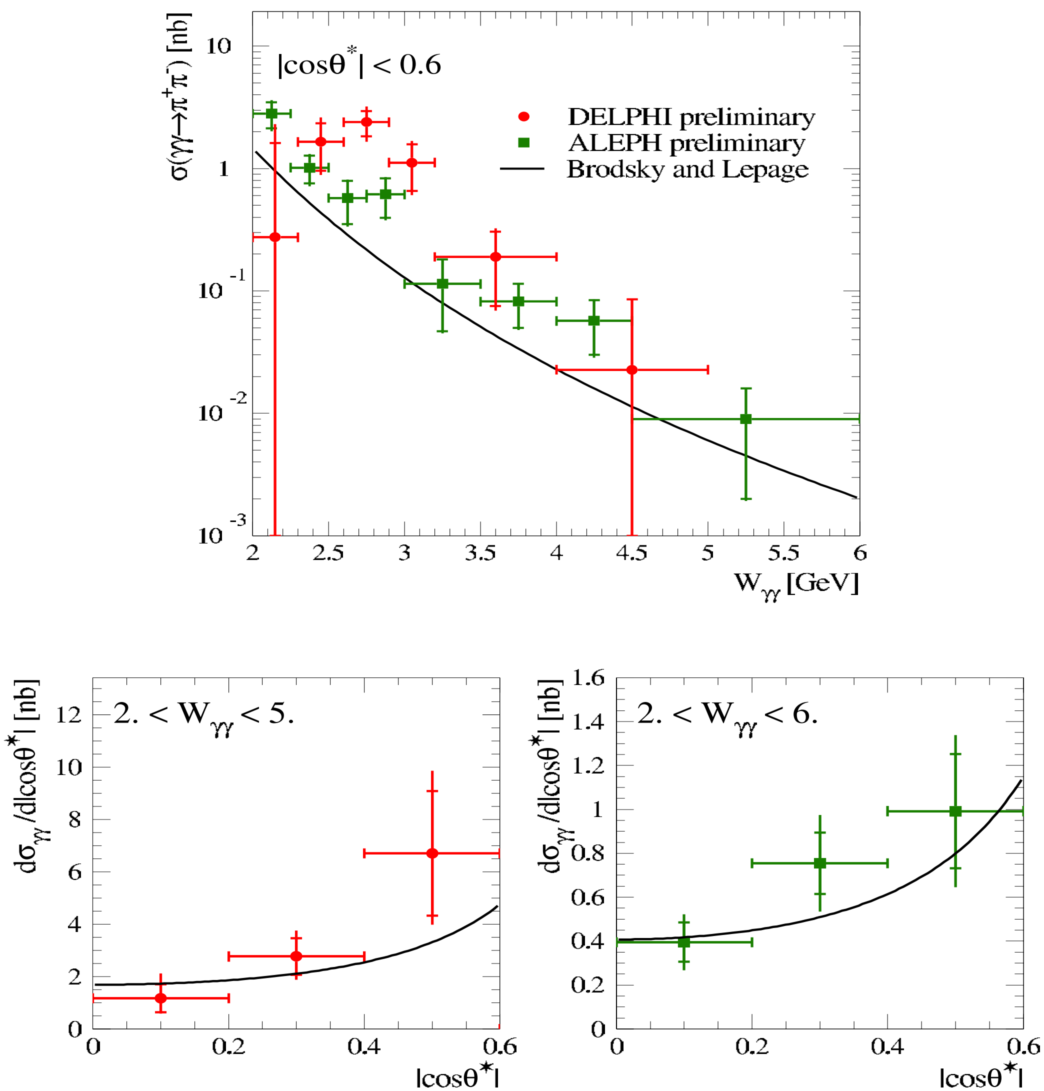
Recently some theorists proposed a soft physics explanation is required

TPC_Two-Gamma

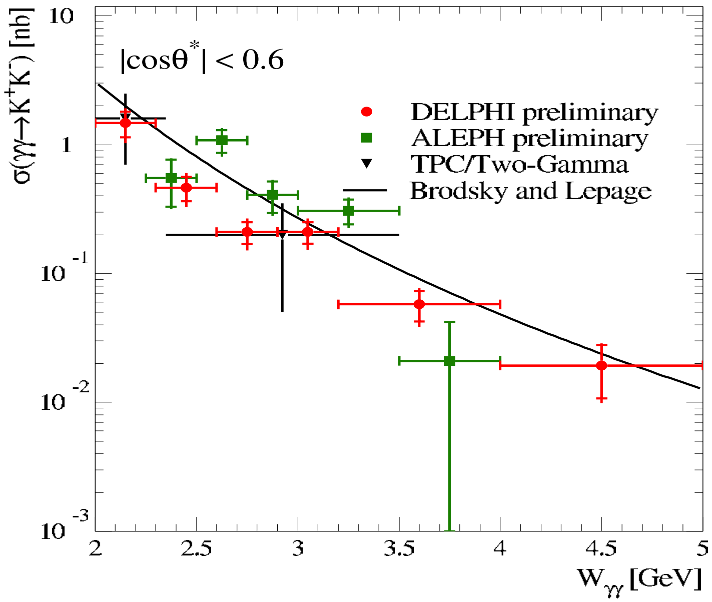


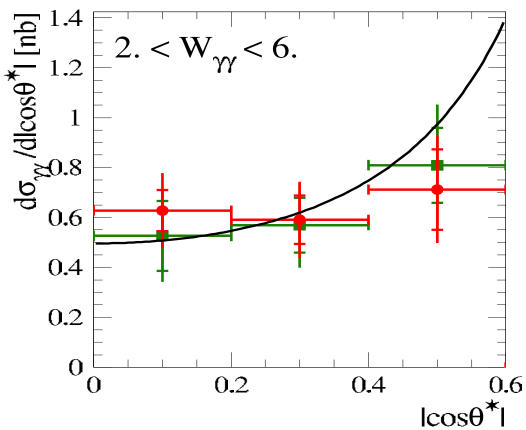


Cross-sections, $\gamma\gamma \longrightarrow \pi^+\pi^-$



Cross-sections, $\gamma\gamma \to K^+K^-$





CLEO

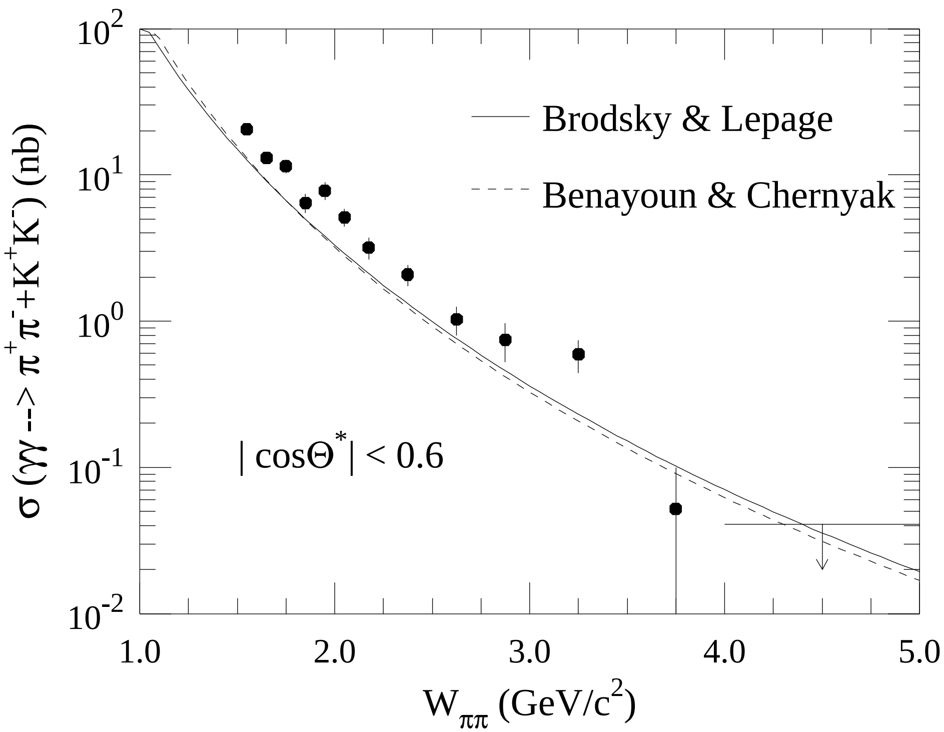


FIG. 5. Measured cross section for the two-photon production of charged pion and kaon pairs as a function of $W_{\pi\pi}$ in the angular region $|\cos\theta^*| < 0.6$. Only statistical errors are shown. The leading order QCD predictions by Brodsky and Lepage, and Benayoun and Chernyak, are shown by the solid and dashed curves respectively.

ALEPH $\gamma\gamma \to \pi^+\pi^- K^+K^-$ Analysis Summary

- Use (almost) all ALEPH data (LEP I and LEP II)
- Select untagged events with just two (oppositely) charged tracks
- Use dE/dx to identify K or π pairs.
- Use calorimeter and muon chamber information to remove muon pair background
- Subtract remaining backgrounds
- Calculate selection and trigger efficiencies
- Calculate Systematic errors
- Calculate cross section versus W and $\cos\theta^*$
- Combine results of each year of LEP data taking

datasets

Year	$\sqrt{s}$	Luminosity Analysed nb^{-1}
1992	91.25	22800.2227
1993	91.27	33156.1211
1994	91.25	47345.4648
1995	91.30	34270.75
1997	177.81	59147.9531
1998	189.00	177073.797
1999	198.00	241607.172
2000	205.89	222109.203

Basic Selection (1)

- Triggered by the Aleph 'back to back' trigger TRK_CNT2 - requires two charged tracks approximately back to back.
- 2 oppositely charged tracks.
- Invariant mass of pair must be between 2.0 and 40.0 GeV.
- p_t of the pair to be less than 0.1 GeV
- Require a vertex within 8cm in Z and 3cm in R of IP.
- Add up energy in all neutral objects, except those close to charged tracks. (Close defined as cosine $<$ 0.95) Require this energy to be no more than 100 MeV

Basic Selection (2)

- Use dE/dx to give probability of each track to be pion, kaon or proton.
- Take the product of these numbers to find the probability of both tracks being pion, kaon or proton.
- For X pair selection, require product X to be greater than 0.05, product for other two both less than 0.05.(X is pion or kaon.)
- For Kaon pairs, recalculate W using Kaon masses for particles.
- At least one track must have its expected ionisation for a pion more than 0.14 different from the corresponding value for a kaon.
- $\cos\theta^*$, the angle of the tracks relative to the beam in their centre of mass, must be less than 0.6.

Signal Monte Carlo

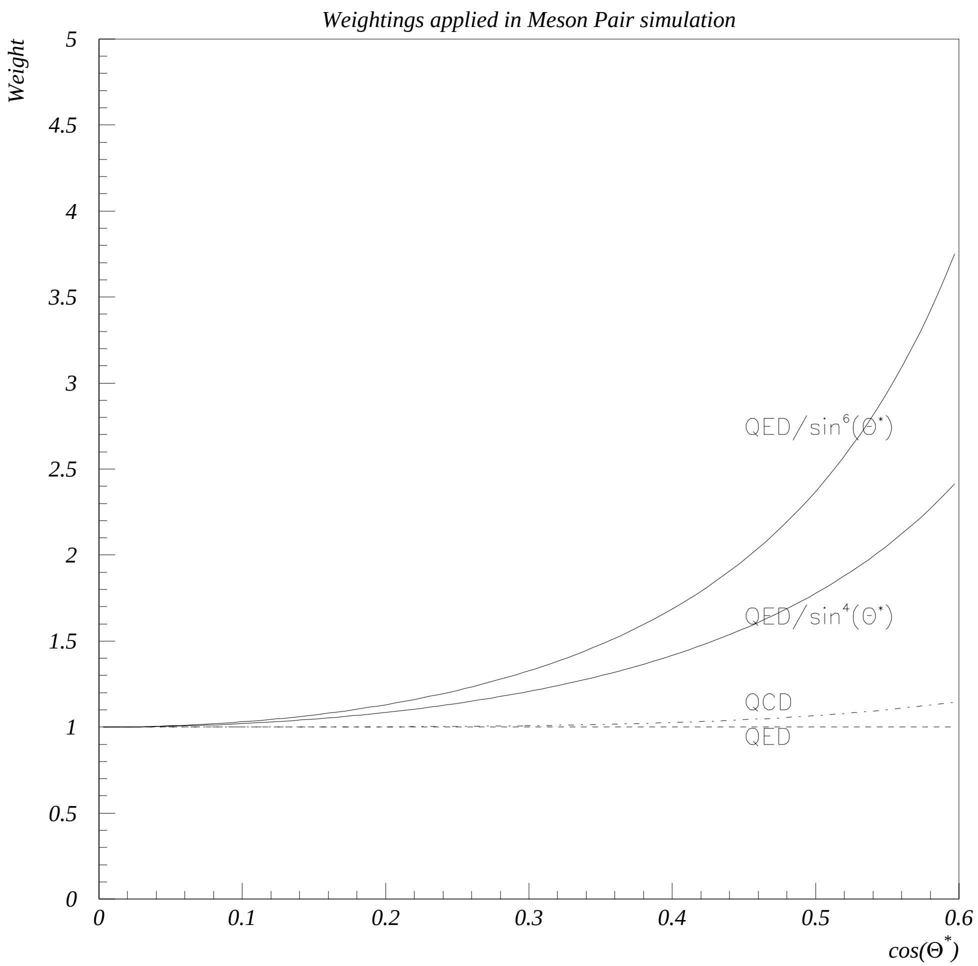
- **Weight Vermasseren QED program for $\gamma\gamma \to$lepton lepton**
- **Brodsky and Lepage stated:**

$$\frac{d\sigma}{d\cos\theta^*}(\gamma\gamma \to M^+M^-) \sim \frac{4|F_M(W^2)|^2}{1-\cos^4\theta^*} d\cos\theta^*(\gamma\gamma \to \mu^+\mu^-)$$

where $F_M(W^2) \sim 1/W^2$

- $1/(1-\cos^4\theta^*) \sim 1.0$ **for** $0.0 < \cos\theta < 0.6$ **so just applied the** W **weighting.**
- **Also generated sets with** $1/\sin^4\theta$ **and** $1/\sin^6\theta$ **weighting.**
- **Used** $1/\sin^4\theta$ **set for measurement as it best described data.**
- **Other two used for systematics.**

MC Weighting



Backgrounds

The following backgrounds sources were considered:

- $\gamma\gamma \rightarrow$hadrons
  - Nonexclusive production - used PHOJET MC
  - Misidentified Exclusive production - used Signal MC, weighted to the data (iterate analysis till stable)
- $\gamma\gamma \rightarrow \mu^+\mu^-$ Used Behrends Darveveldt and Kleiss MC
- $\gamma\gamma \rightarrow \tau^+\tau^-$ Used Vermasseren MC

No background from $p\bar{p}$ or $\tau^+\tau^-$

Special cuts following Background checks

For pion pairs, where there is a large muon contamination:

- p_t of the pair to be less than 0.05
- Tracks to have an angle in ϕ of greater than 3.132 radians.
- Tighter anti-muon cuts in ECAL and HCAL

Trigger efficiency

Measured using e^+e^- pairs triggered independently by ECAL. Parameterized this year on year and applied correction to data.

$d\sigma/\cos\theta^*$ Cross section

$$d\sigma/d\cos\theta^* = \frac{N_{data} - N_{back}}{\epsilon \times L \times L_{\gamma\gamma} \times \delta\cos\theta^*}$$

- $L_{\gamma\gamma}$ **is the luminosity function** $dL_{\gamma\gamma}/dW_{\gamma\gamma}$ **integrated over the range** $2 < W_{\gamma\gamma} < 6$
- $\delta\cos\theta^*$ **is the bin width.**
- ϵ **is the selection efficiency**
- L **is the integrated luminosity**

Luminosity function converts a cross section for a process $e^+e^- \to e^+e^-X$ to a cross section for the process $\gamma\gamma \to X$. Calculated using 'GALUGA'.

σ versus W

$$\sigma = \frac{(N_{data} - N_{back})}{\epsilon \times L \times \delta W_{\gamma\gamma} \times dL_{\gamma\gamma}/dW_{\gamma\gamma}}$$

- $dL_{\gamma\gamma}/dW_{\gamma\gamma}$ **is the luminosity function**
- $\delta W_{\gamma\gamma}$ **is the bin width.**
- $\delta \cos\theta^*$ **is the bin width.**
- ϵ **is the selection efficiency**
- L **is the integrated luminosity**

Systematic Errors

- **Detector Simulation:**
  Vary Monte Carlo and recalculate result.

-dE/dx	:	$\pm$10% resolution
-Charged track momentum	:	$\pm$10% resolution
-noise etc.	:	total energy $\pm$50 MeV.

  Error = half the difference between the largest and smallest value seen in a given bin as a result of these changes.

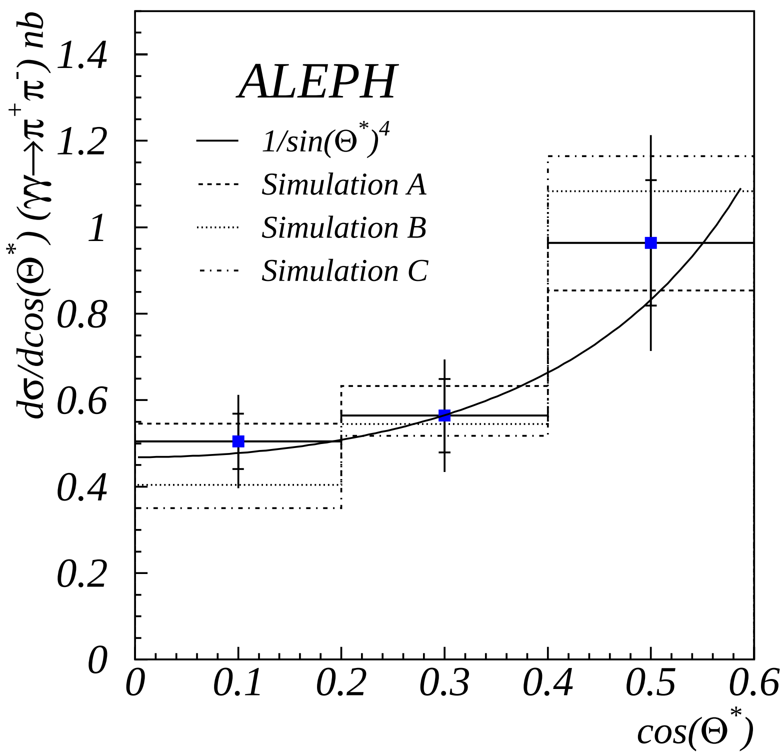
- **Model:**
  Signal MC with steeper / flatter dependance on $\cos\theta^*$ (consistent with data)
  Error = Half difference in efficiency in bin.

- **Monte Carlo statistics**

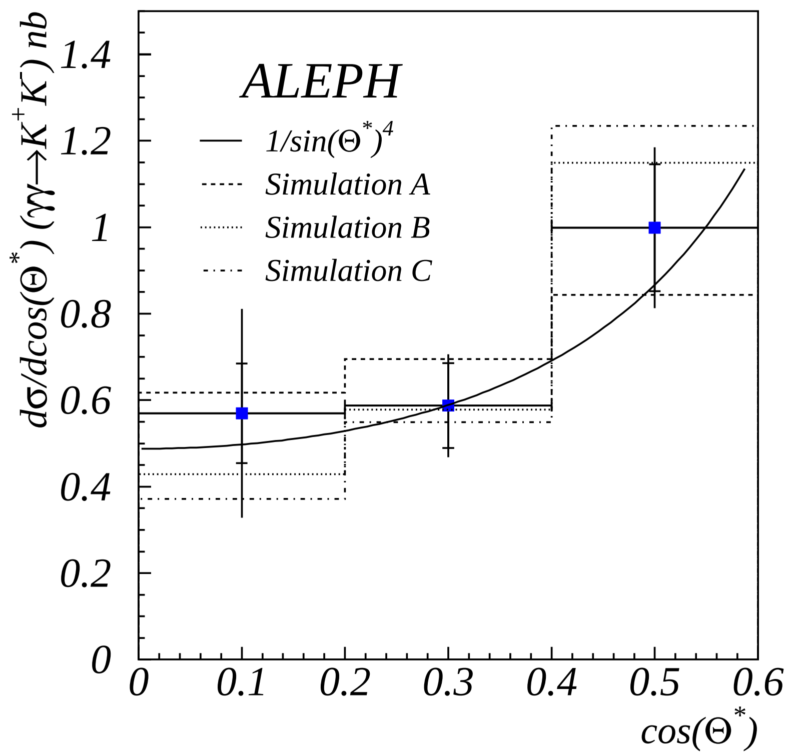
ALEPH $\gamma\gamma \to \pi^+\pi^- K^+K^-$ Results

$\cos\theta^*$

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

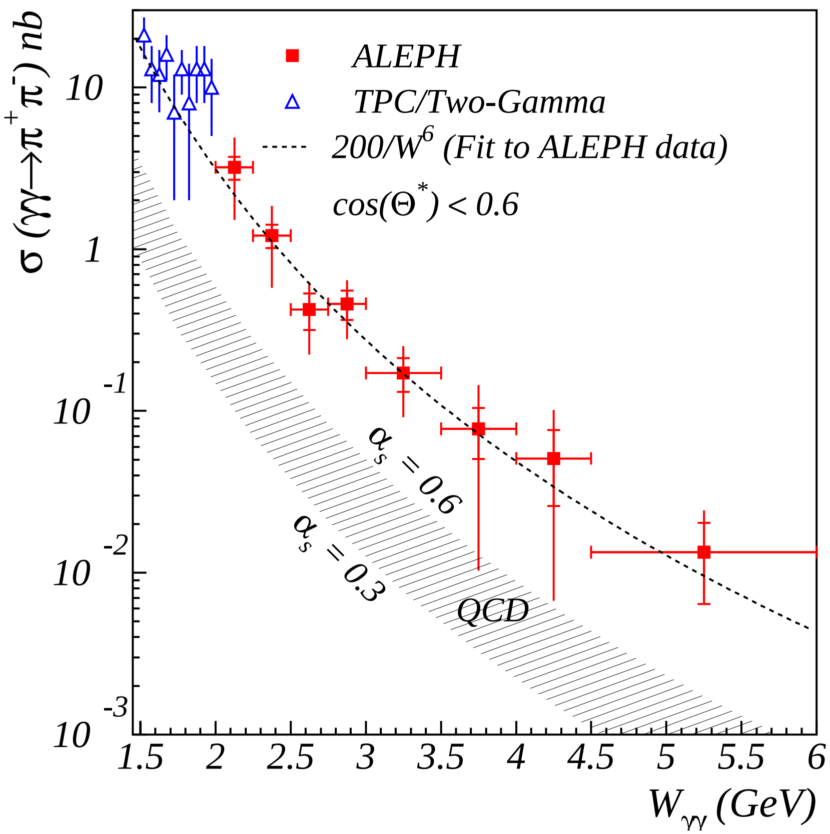


$\gamma\gamma \to K^+K^-$

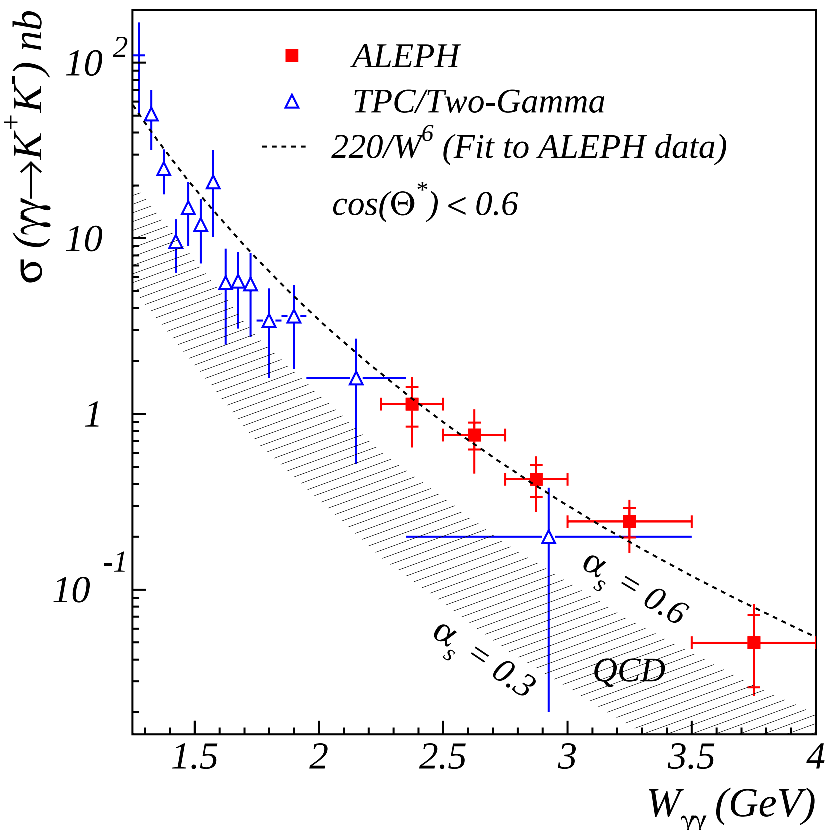


ALEPH $\gamma\gamma \to \pi^+\pi^- K^+K^-$ Results W

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



$\gamma\gamma \to K^+K^-$



What is the QCD Leading Order Prediction?

Following private communication from
Markus Diehl,Peter Kroll, Carsten Vogt

substituted

$$sF_\pi(s) \approx 0.4GeV^2...$$

(from original 1981 Brodsky Lepage paper)

with

$$sF_\pi(s) = 8\pi f_\pi^2 * \alpha_s = \alpha_s * 0.43GeV^2.$$

and vary α_s between 0.3 and 0.6.

ALEPH $\gamma\gamma \to \pi^+\pi^- K^+K^-$ Conclusion

- $\gamma\gamma \to$ $\pi^+\pi^-$ K^+K^- has been measured at higher masses than previously achieved.
- The shapes of the distributions in $d\sigma/d\cos\theta^*$ and $W_{\gamma\gamma}$ are in good agreement with QCD predictions.
- The normalisation of the observed signals disagrees with these predictions.
- $d\sigma/dW_{\gamma\gamma}$ fitted by A/W^6 where

  $200 \pm 40\,\mathrm{nb(GeV/c^2)^6}$ ($\chi^2 = 1.9$ for 7 d.o.f.) pions
  $220 \pm 50\,\mathrm{nb(GeV/c^2)^6}$ ($\chi^2 = 1.5$ for 4 d.o.f.) kaons