Baryon Antibaryon Pair Production in Two-Photon collisions at LEP

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Outline:

- Introduction
- $\gamma\gamma \rightarrow p\overline{p}$ production
- $\gamma\gamma \rightarrow \Lambda\overline{\Lambda}$ and $\gamma\gamma \rightarrow \Sigma^0\overline{\Sigma}^0$ channels
- $\gamma\gamma \rightarrow \Delta^{++}\Delta^{--}$ analysis (ongoing)
- Summary

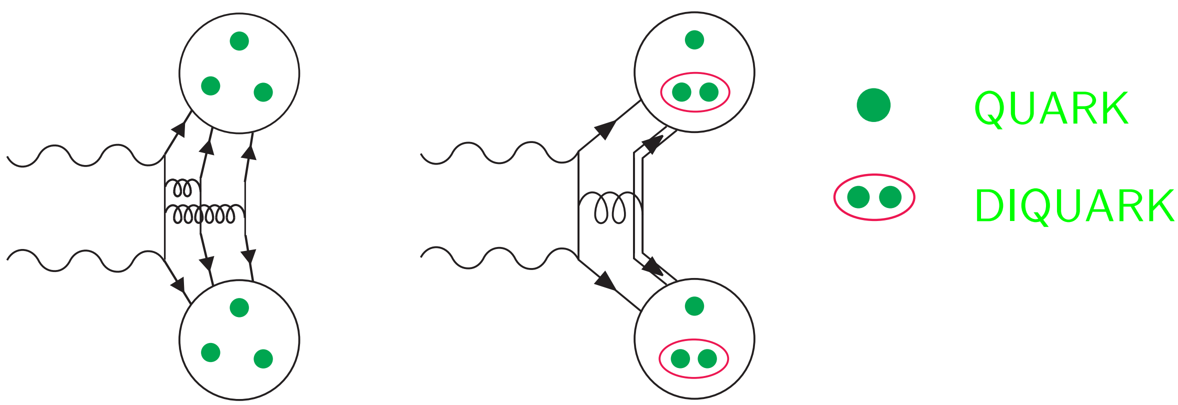
Motivation

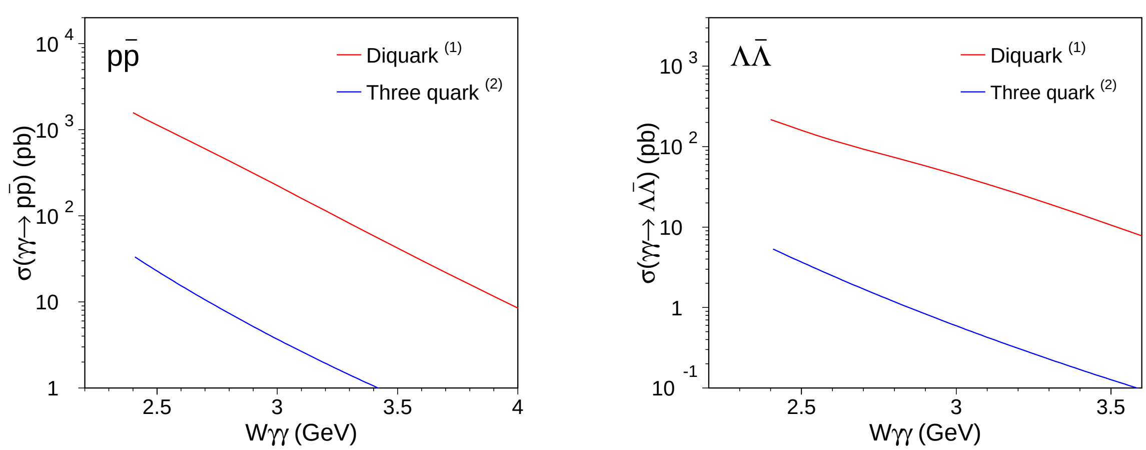
Measure the cross section $\gamma\gamma \rightarrow \mathrm{H}\overline{\mathrm{H}}$ $(\mathrm{H} = \mathrm{p}, \Lambda, \Sigma^0)$

➪ compare with **three-quark** predictions

➪ compare with **quark-diquark** predictions

Three quark **Diquark**



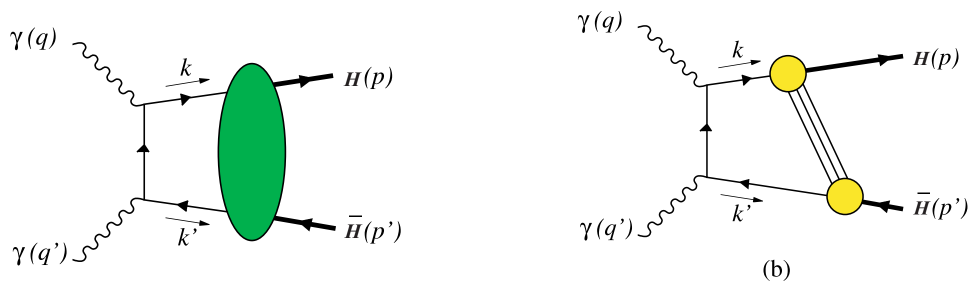


(1) C. Berger, B. Lechner and W. Schweiger, Fizika **B 8** (1999) 371;
C. Berger and W. Schweiger, hep-ph/0212066.
(2) G. Farrar *et al.*, Nucl. Phys. **B 259** (1985) 702.

Motivation bis

Also test the **handbag model**[1]. In this model, the amplitude of the process $\gamma\gamma \to \mathrm{H\overline{H}}$ is factorized into:

- **hard part:** $\gamma\gamma \to \mathrm{q\overline{q}}$ **scattering.**
- **soft part:** $\mathrm{q\overline{q}} \to \mathrm{H\overline{H}}$ **transition** described by form factors (which represents moment of time-like generalized parton distribution).



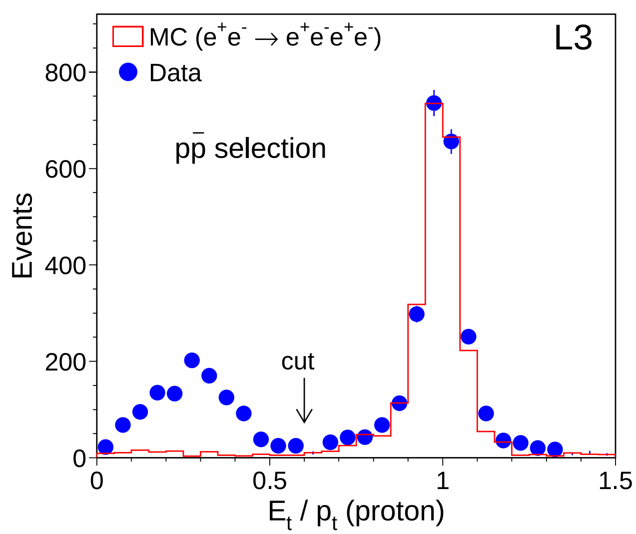
In this framework:

- assume that (anti)quark carries almost the full momentum of (anti)baryon.
- use $\gamma\gamma \to \mathrm{p\overline{p}}$ measurement to fit the parameters of the model.
- predictions for all other baryon octet members depend only on one parameter ρ, a ratio of form factors of the proton.

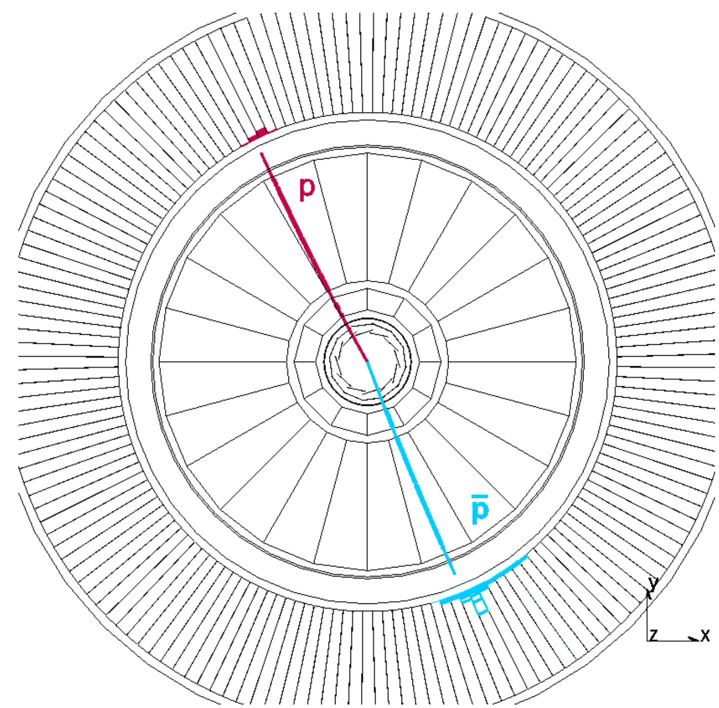
(1) M. Diehl, P. Kroll and C. Vogt, hep-ph/0206288.

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

- 2 tracks of opposite charge.
- Antiproton identification Neural networks, use P, dE/dx, Et/pt, shower shape.
- Proton identification dE/dx and Et/pt.
- Exclusive event no photons and $|\sum \vec{p}_t^{\,2}|$ cut.



Typical event



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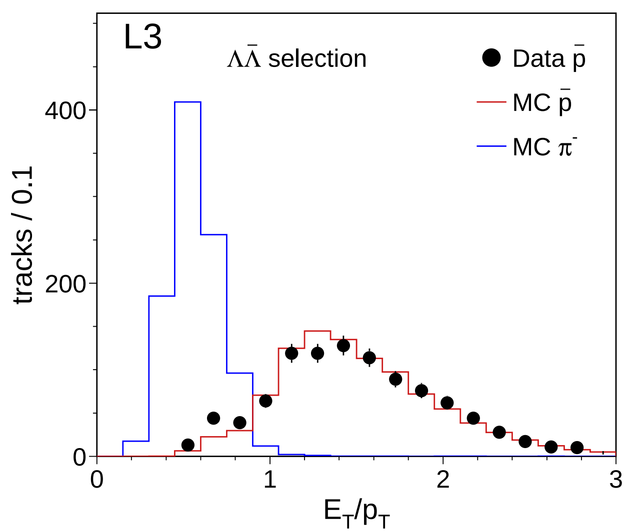
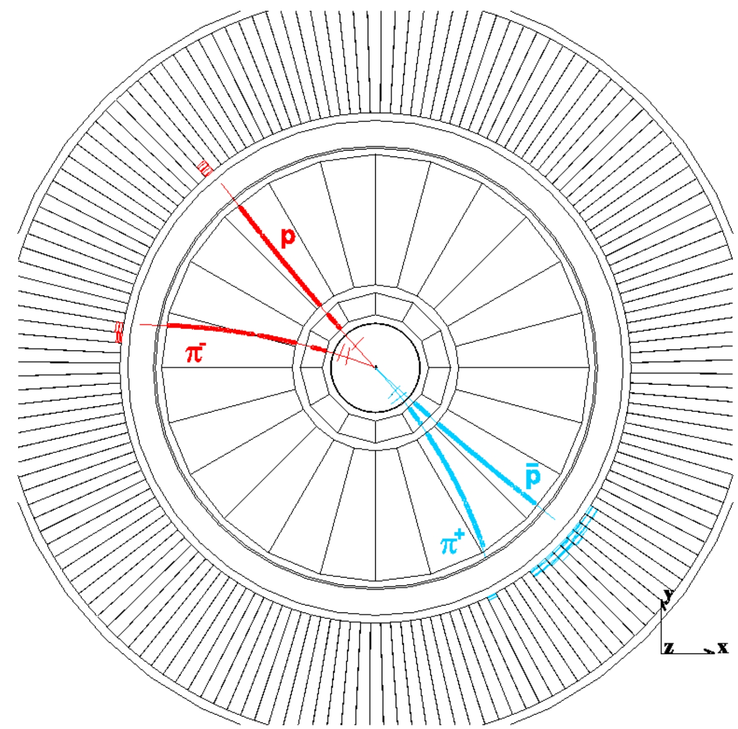
$e^+e^- \to e^+e^-\Lambda\overline{\Lambda}, \Sigma^0\overline{\Sigma}^0$ *event selection*

$e^+e^- \to e^+e^-\Lambda\overline{\Lambda}, \Sigma^0\overline{\Sigma}^0$

- Decays $\Lambda \to p\pi^-$ $\overline{\Lambda} \to \overline{p}\pi^+$ $\Sigma^0 \to \gamma\Lambda$
- Antiproton identification Et/pt .
- Proton and pion identification dE/dx.
- Exclusive event $|\sum p_t^2|$ cut.



Typical event



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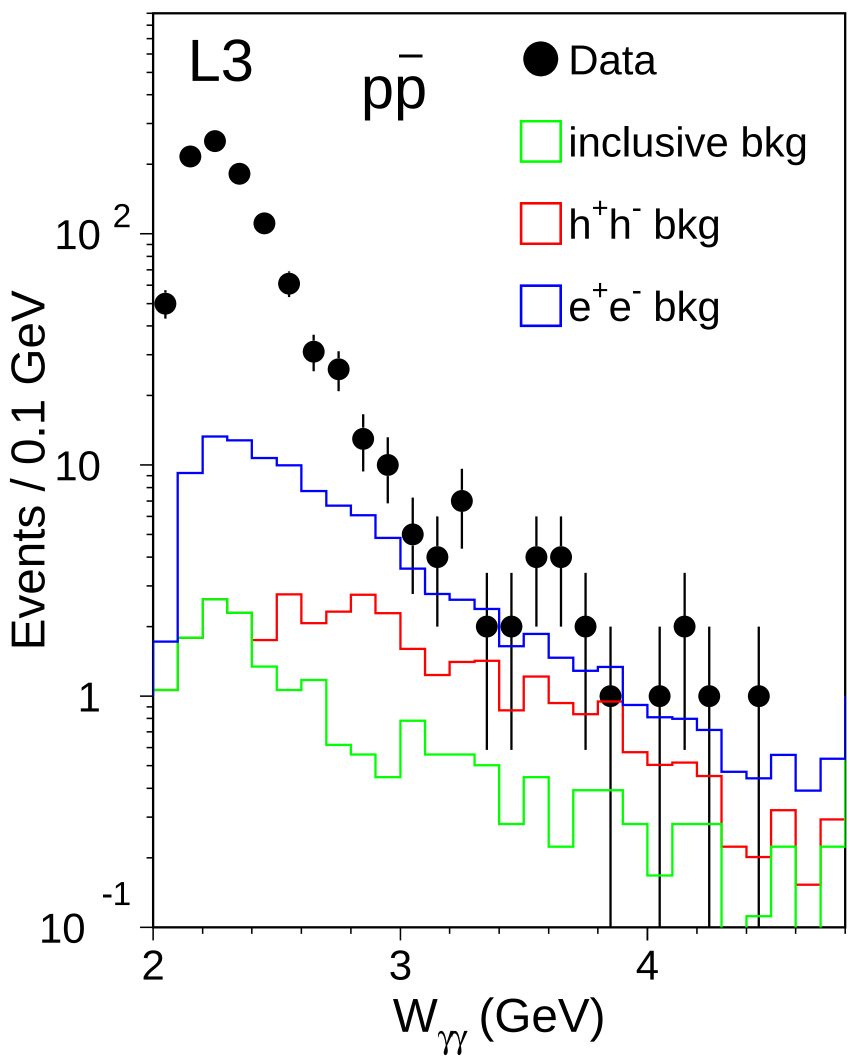
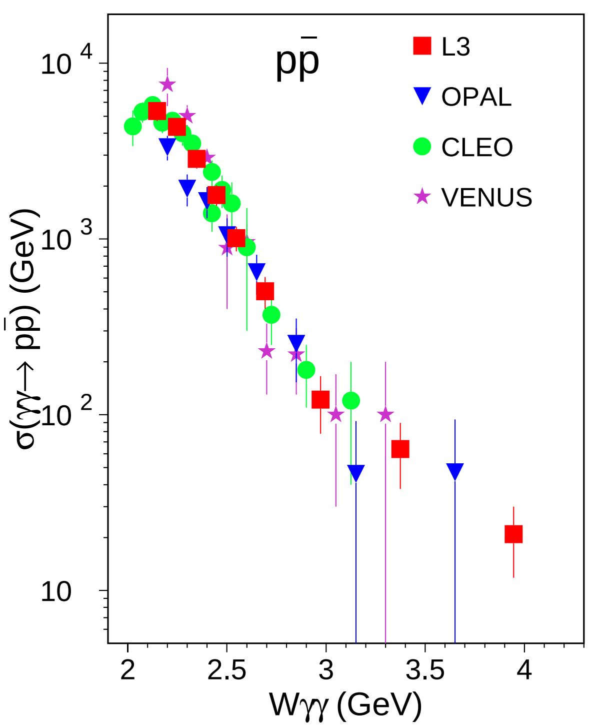
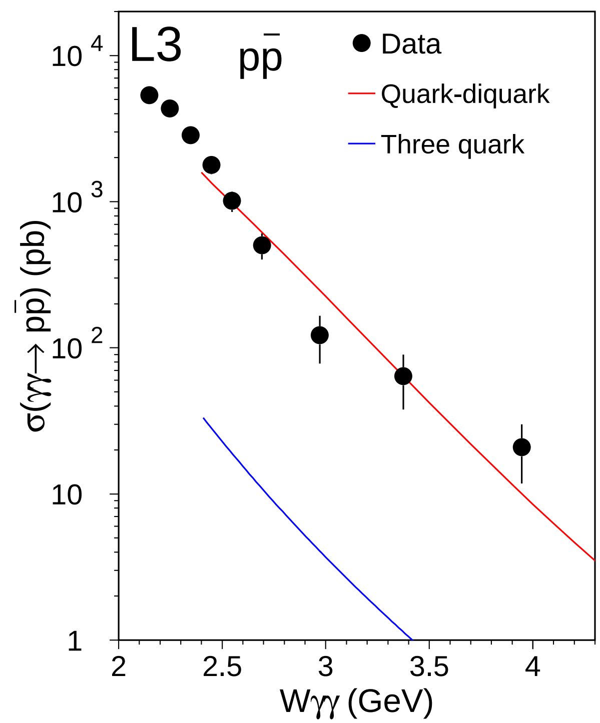
$\gamma\gamma \rightarrow \mathrm{p}\overline{\mathrm{p}}$ *results*



- 989 events found ($\mathcal{L} = 667\ \mathrm{pb}^{-1}$).
- $\mathrm{W}_{\gamma\gamma}$ range : $2.0 < \mathrm{W}_{\gamma\gamma} < 4.5$ GeV.
- Background level: between 4% and 69%.

$\gamma\gamma \rightarrow p\bar{p}$ *results*

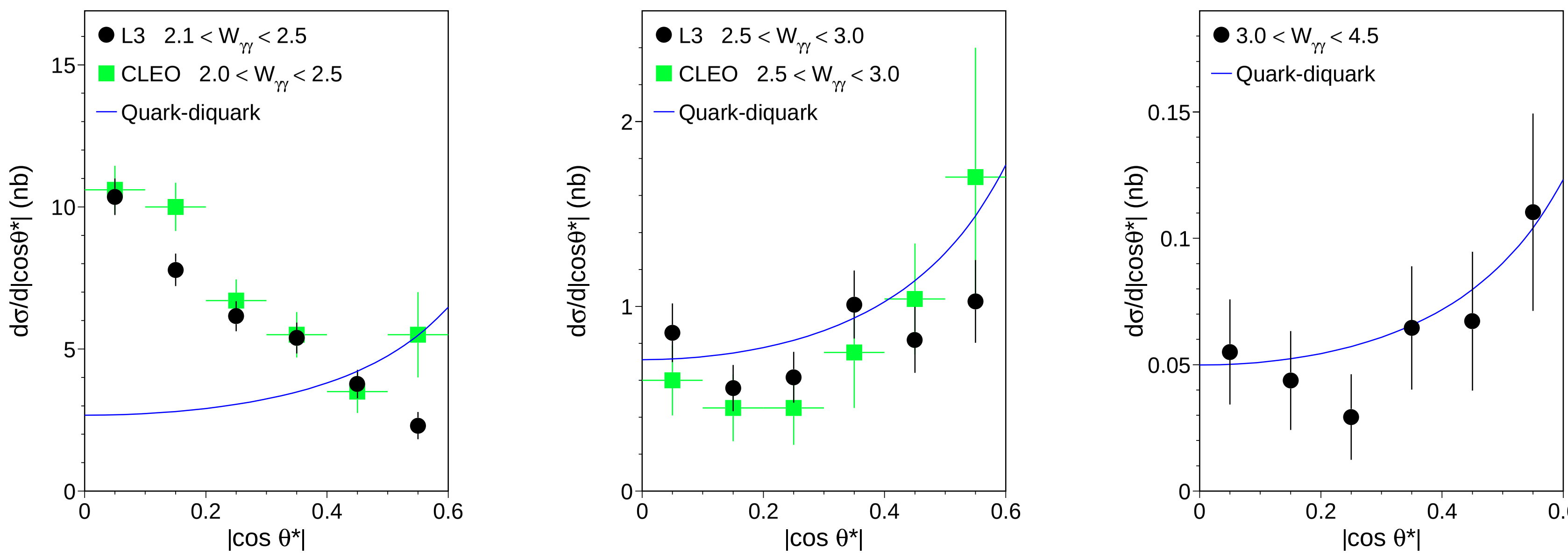




- Good agreement with previous experiments
- Extend $W_{\gamma\gamma}$ range

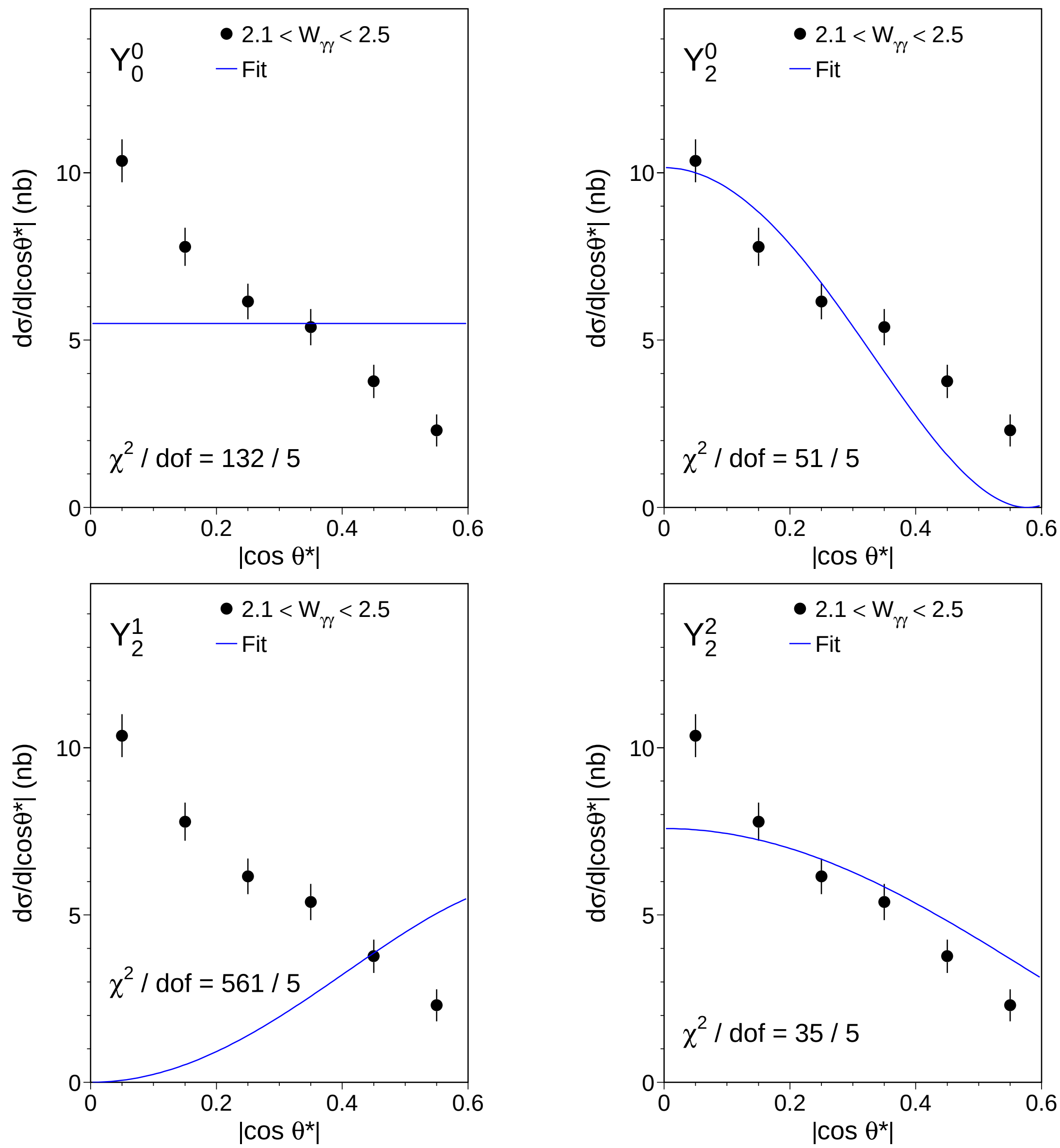
- Data globally described by the diquark model.
- Three-quark model excluded.

Differential cross sections $d\sigma/d|\cos\theta^*|$



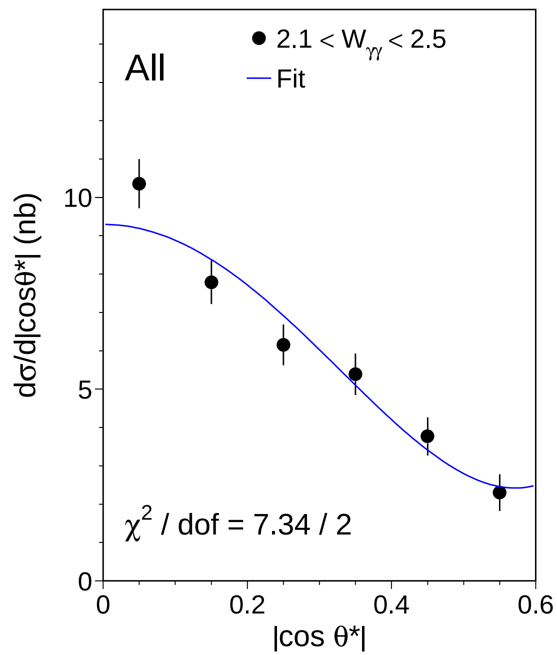
Striking disagreement with the quark-diquark predictions in the low $W_{\gamma\gamma}$ region !!

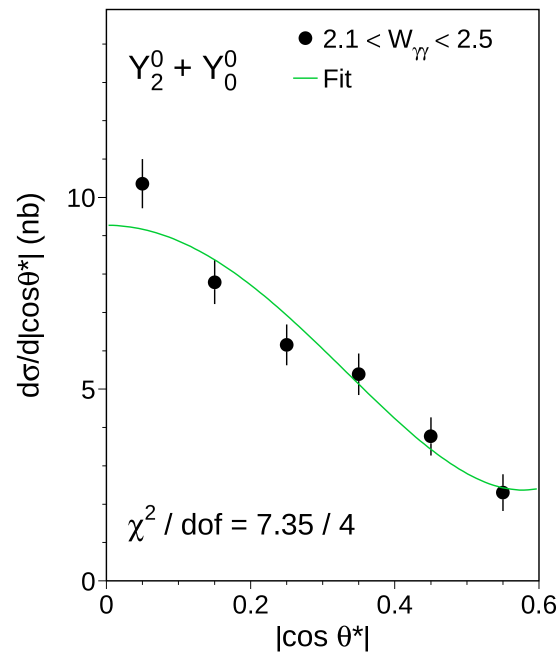
Differential cross sections $d\sigma/d|\cos\theta^*|$



A single spherical harmonic is not sufficient to describe the data !!

Differential cross sections $d\sigma/d|\cos\theta^*|$



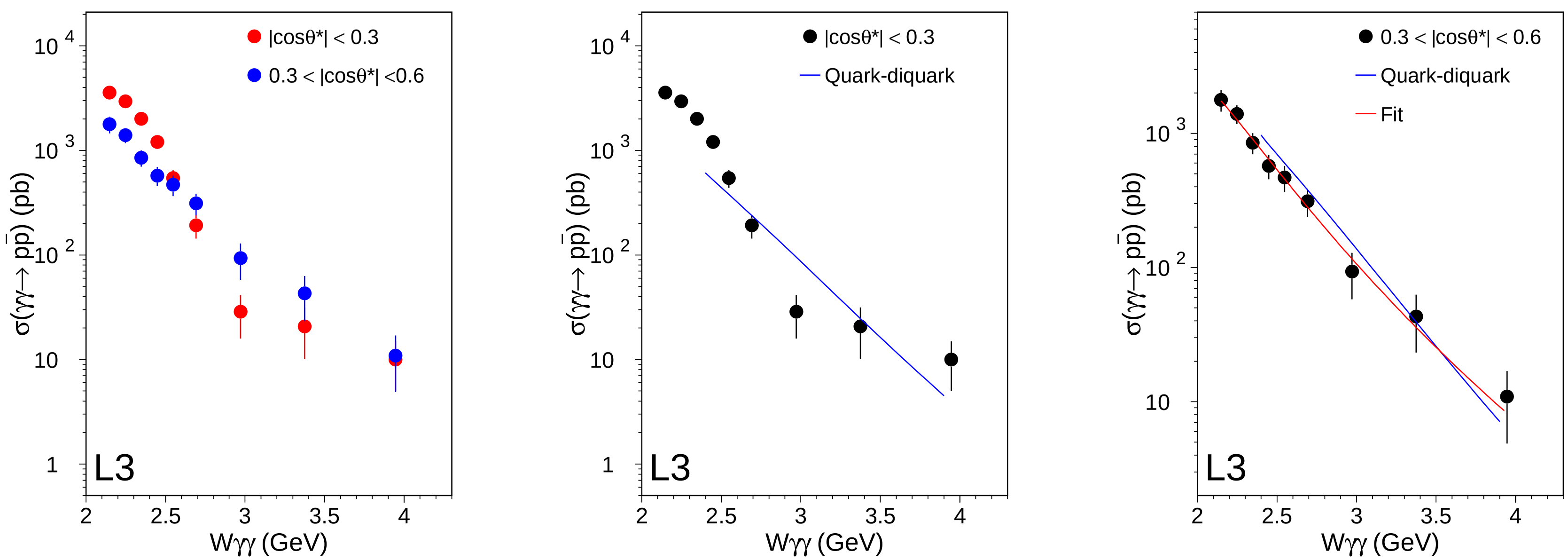


Good fit with all harmonics (left)

OR

Good fit with 92% Y_2^0 and 8% Y_0^0 (right).

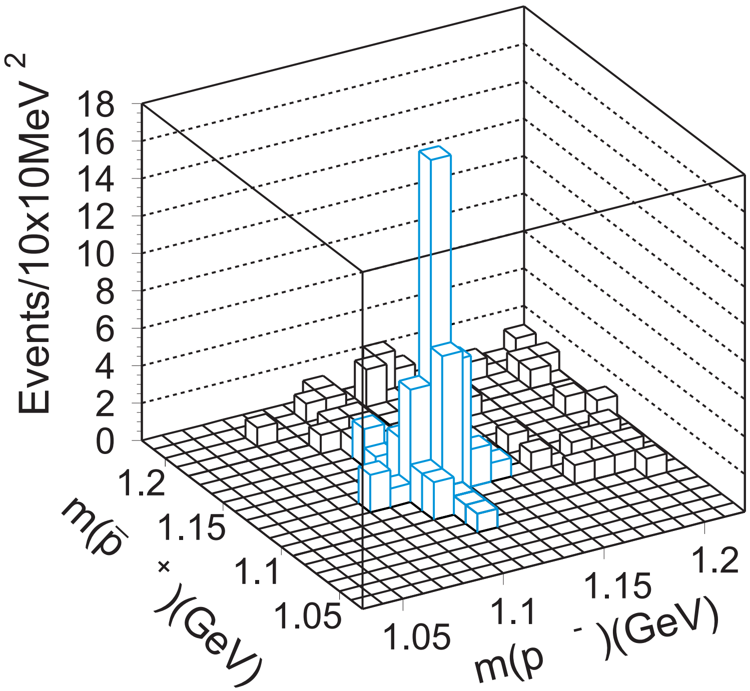
$\gamma\gamma \rightarrow p\bar{p}$ *cross section*

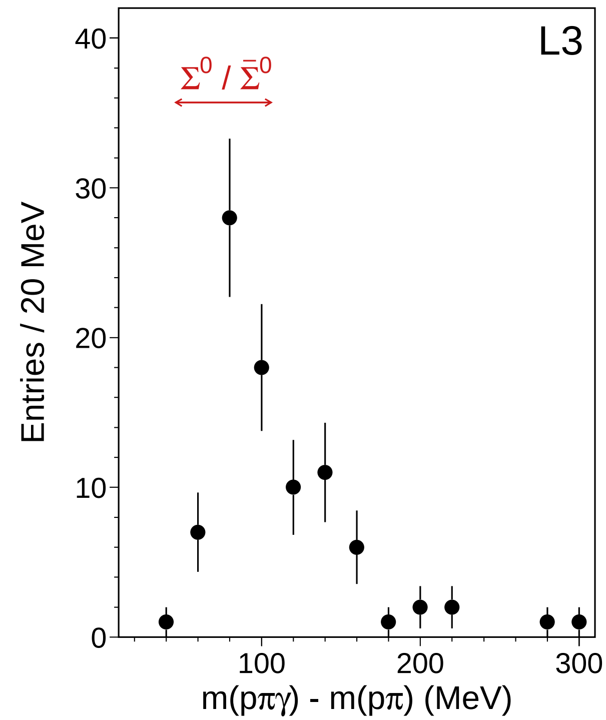


Large angle Clear change of shape at $W_{\gamma\gamma} \sim 3$ GeV and the quark-diquark model fails to reproduce the data.

Small angle Data are reproduced by the quark-diquark model, fit with a power law $\sigma \propto W^{-n}$ gives $n = 9.8 \pm 0.3$.

$\gamma\gamma \rightarrow \Lambda\overline{\Lambda}$ *and* $\gamma\gamma \rightarrow \Sigma^0\overline{\Sigma}^0$ *results*





- ❑ Clean peak, 33 events selected.
- ❑ Estimated background $< 1\%$.

- ❑ Clear $\Sigma^0/\overline{\Sigma}^0$ peak.

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$\Lambda\overline{\Lambda}$, $\Lambda\overline{\Sigma}^0 + \overline{\Lambda}\Sigma^0$ and $\Sigma^0\overline{\Sigma}^0$ separation

$\Lambda\overline{\Lambda}$, $\Lambda\overline{\Sigma}^0 + \overline{\Lambda}\Sigma^0$ and $\Sigma^0\overline{\Sigma}^0$ all mixed

➪ Separate the three contributions

Procedure:

1. Classify events:

$\Sigma^0\overline{\Sigma}^0$	if a Σ^0 **and** $\overline{\Sigma}^0$ are found
$\Lambda\overline{\Sigma}^0 + \overline{\Lambda}\Sigma^0$	if a Σ^0 **or** $\overline{\Sigma}^0$ is found
$\Lambda\overline{\Lambda}$	otherwise

2. Use a maximum extended likelihood fit to find the fractions $\mathrm{r_i}$ of different channels.

3. Results:

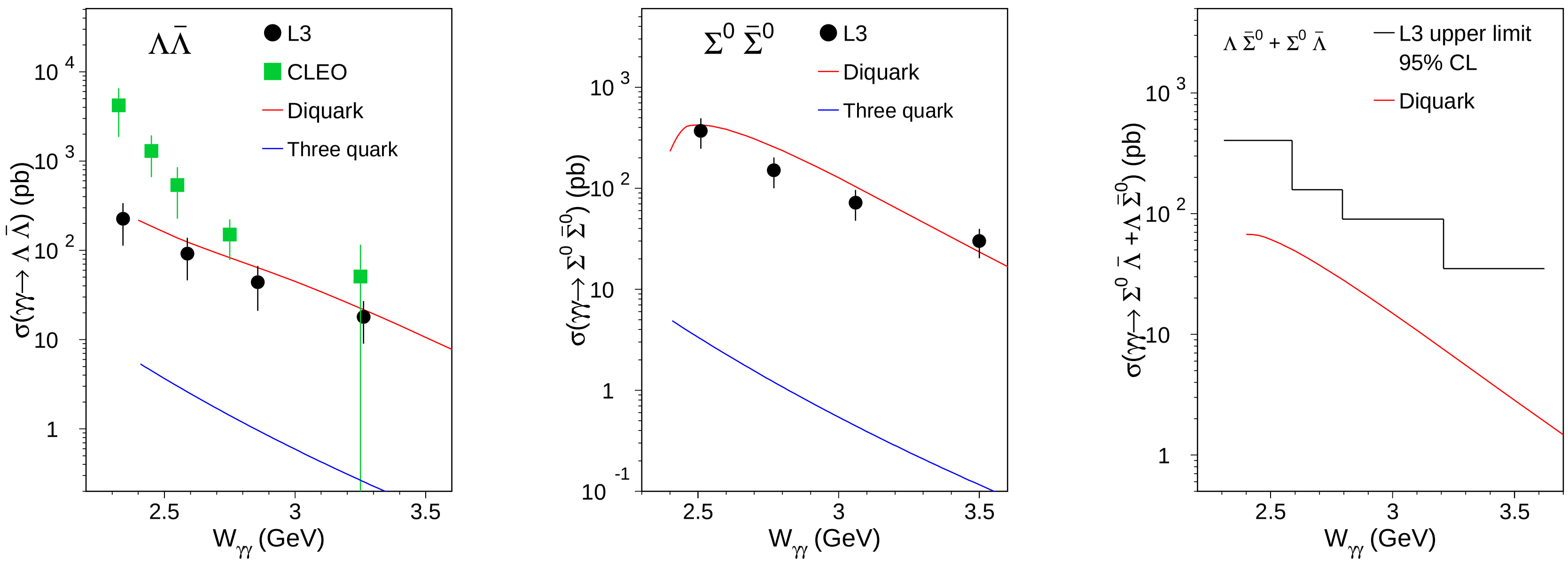
$$\mathrm{r}_{\Lambda\overline{\Lambda}} = 0.38 \pm 0.18 \quad (r_{\Lambda\overline{\Sigma}^0+\overline{\Lambda}\Sigma^0} = 0)$$

$$\mathrm{r}_{\Sigma^0\overline{\Sigma}^0} = 0.62 \pm 0.18 \quad (r_{\Lambda\overline{\Sigma}^0+\overline{\Lambda}\Sigma^0} = 0)$$

$\mathrm{r}_{\Lambda\overline{\Sigma}^0+\overline{\Lambda}\Sigma^0}$ compatible with 0

< 0.58 at 95% CL

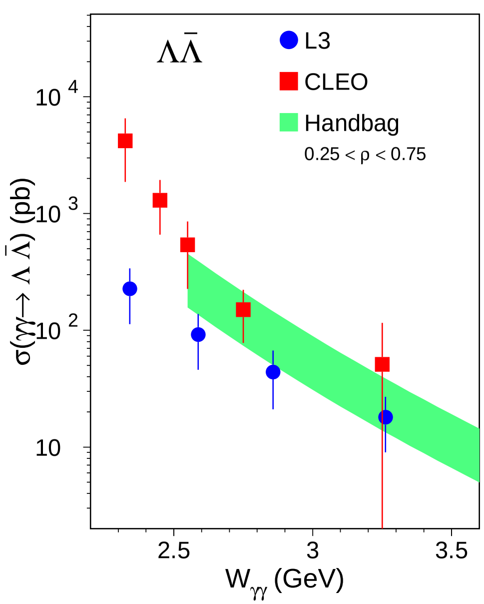
$\gamma\gamma \rightarrow \Lambda\overline{\Lambda}$ *and* $\gamma\gamma \rightarrow \Sigma^0\overline{\Sigma}^0$ *results*

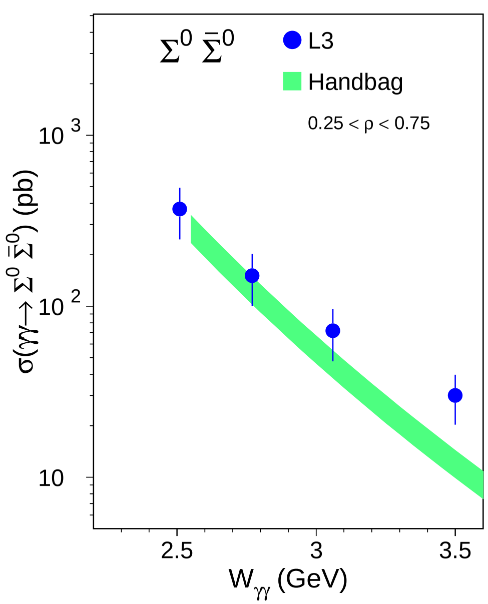


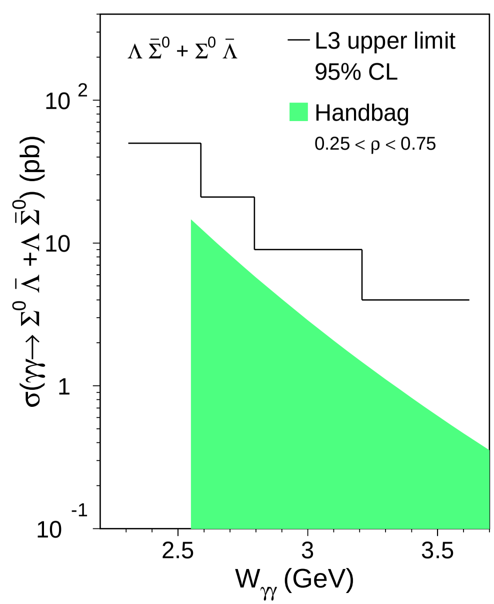
- Limited statistics.
- Disagreement with CLEO at low $W_{\gamma\gamma}$.
- Three quark model excluded.

- Good agreement with diquark predictions for $\Lambda\overline{\Lambda}$ and $\Sigma^0\overline{\Sigma}^0$.
- Diquark predictions compatible with $\sigma(\Lambda\overline{\Sigma}^0 + \overline{\Lambda}\Sigma^0)$

$\gamma\gamma \to \Lambda\overline{\Lambda}$ *and* $\gamma\gamma \to \Sigma^0\overline{\Sigma}^0$ *results*







- Predictions for the range $0.25 < \rho < 0.75$.
- Good agreement with $\Lambda\overline{\Lambda}$ and $\Sigma^0\overline{\Sigma}^0$.
- Handbag predictions compatible with $\sigma(\Lambda\overline{\Sigma}^0 + \overline{\Lambda}\Sigma^0)$

$\Delta^{++}\Delta^{--}$ *channel*

Can we measure the $\gamma\gamma \to \Delta^{++}\Delta^{--}$ cross section ?

➪ With the naive three quark picture:

$$\sigma(\gamma\gamma \to \Delta^{++}\Delta^{--}) = 16 \cdot \sigma(\gamma\gamma \to \mathrm{p\overline{p}})$$

BUT upper limit measurement[1] excludes this model: $\sigma(\gamma\gamma \to \Delta^{++}\Delta^{--})/\sigma(\gamma\gamma \to \mathrm{p\overline{p}}) = 1$ at 95% CL for 2.6 GeV $< W_{\gamma\gamma} <$ 2.8 GeV.

➪ With the diquark model, calculations have not been done yet, but a rough estimation[1] gives for $W_{\gamma\gamma} \simeq 2.8$ GeV:

$$\sigma(\gamma\gamma \to \Delta^{++}\Delta^{--}) \simeq 0.1 \cdot \sigma(\gamma\gamma \to \mathrm{p\overline{p}})$$

Interesting challenge and can provide information to improve models

(1) ARGUS, H. Albrecht *et al.*, Z. Phys. **C 42** (1989) 543.
(2) M. Anselmino *et al.*, Int. J. Mod. Phys. **A 4** (1989) 5213.

Event Selection

Decays: $\Delta^{++} \rightarrow \mathrm{p}\pi^{+} \quad \Delta^{--} \rightarrow \overline{\mathrm{p}}\pi^{-}$

Selection:

- 4 tracks from interaction point.
- Proton (antiproton) is identified as the positive (negative) track with the largest momentum.
- dE/dx identification: CL > 0.05 for p, $\overline{\mathrm{p}}$ and CL > 0.01 for $\pi^{\pm}$.

At this point:

Configuration correctly identified: 98.5%

Main background: $\gamma\gamma \rightarrow \pi^{+}\pi^{-}\pi^{+}\pi^{-}$.

➪ Antiproton identification:

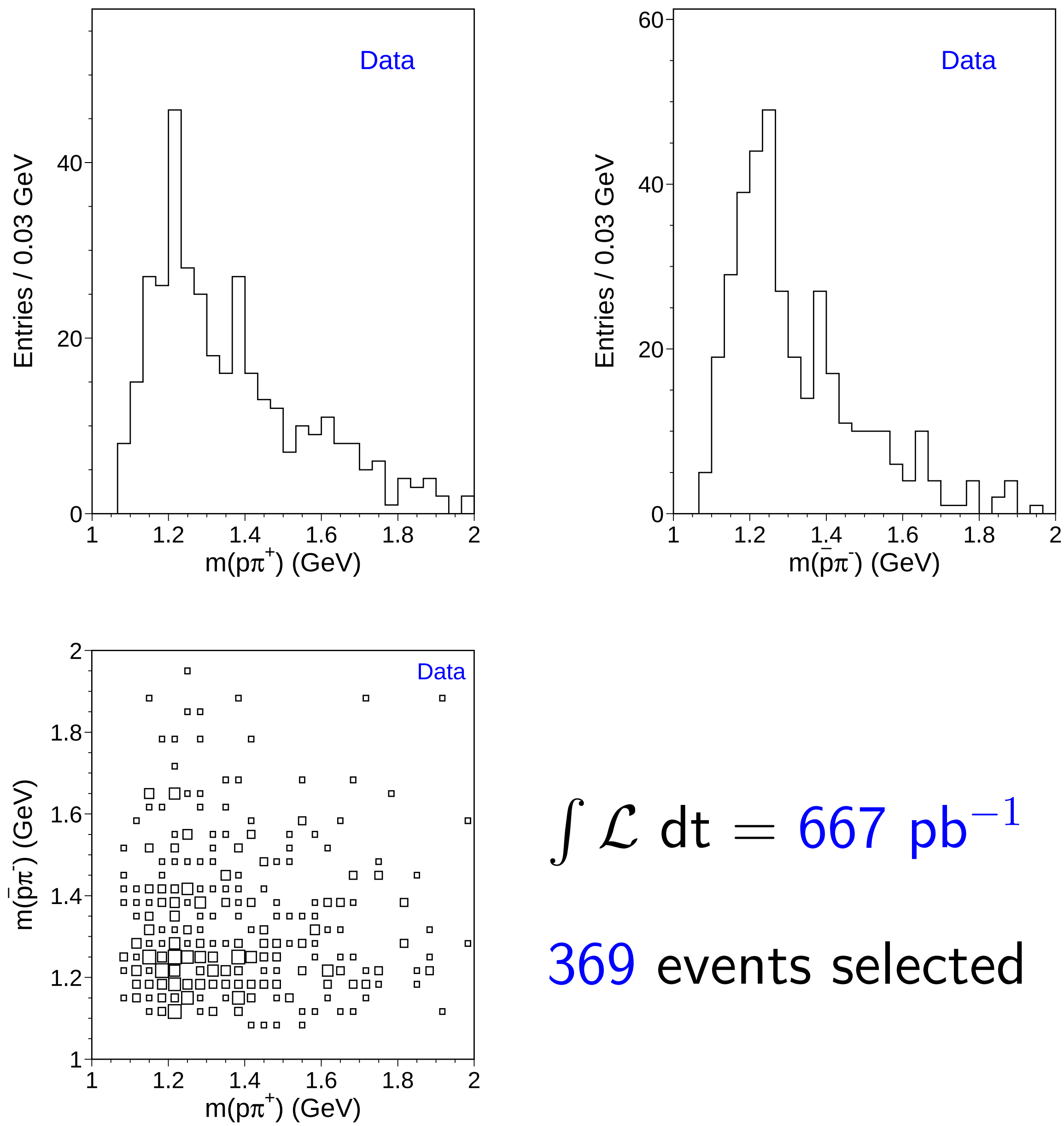
dE/dx : CL(p) / (CL(p) + CL(K) + CL(π)) $>$ 0.95

$\overline{\mathrm{p}}$ annihilation in calorimeter : Et/pt $>$ 0.8

Finally, apply cut to select exclusive events :

No photons and $|\sum p_t^2| <$0.02 GeV^2.

Data Results



$\int \mathcal{L}\, dt = 667\ pb^{-1}$

369 events selected

Seems there is something...

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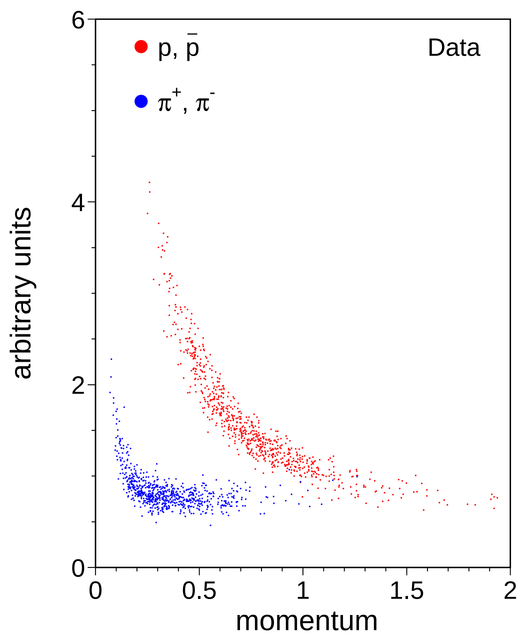
$\gamma\gamma \to p\bar{p}\pi^+\pi^-$ *candidates*

Background?



$\sim 100\% \quad p\bar{p}\pi^+\pi^-$

In data:

- $\gamma\gamma \to \Delta^{++}\Delta^{--}$
- $\gamma\gamma \to \Delta^0\overline{\Delta}^0$
- $\gamma\gamma \to p\bar{p}\pi^+\pi^-$ non resonant

Next step:

➪ Separate the three contributions and extract cross sections $\sigma(\gamma\gamma \to \Delta^{++}\Delta^{--})$ and $\sigma(\gamma\gamma \to \Delta^0\overline{\Delta}^0)$.

Summary

$\gamma\gamma \rightarrow \mathbf{p\overline{p}}$:

- Striking disagreement with the three quark model.
- Data globally described by the diquark model.
- Differential cross section is not reproduced by the diquark model at low $W_{\gamma\gamma}$.
- Large angle and small angle cross sections have different $W_{\gamma\gamma}$ dependence.

$\gamma\gamma \rightarrow \Lambda\overline{\Lambda}$, $\gamma\gamma \rightarrow \Lambda\overline{\Sigma}^{\mathbf{0}} + \Sigma^{\mathbf{0}}\overline{\Lambda}$ and $\gamma\gamma \rightarrow \Sigma^{\mathbf{0}}\overline{\Sigma}^{\mathbf{0}}$:

- Striking disagreement with the three quark model.
- Good agreement with the diquark predictions.
- Good agreement with the handbag calculations.

$\gamma\gamma \rightarrow \Delta^{++}\Delta^{--}$:

- Ongoing analysis with promising results.

Systematic uncertainties

$W_{\gamma\gamma}$ (GeV)	Selection cuts (%)	Back- (%)	Other ground(%)	Total (%)
2.1 – 2.2	7.3	1.0	7	10.3
2.2 – 2.3	7.3	1.3	6	9.5
2.3 – 2.4	7.3	1.7	6	9.6
2.4 – 2.5	7.3	2.4	6	9.7
2.5 – 2.6	7.3	3.8	6	10.2
2.6 – 2.8	14.3	5.8	6	16.5
2.8 – 3.1	30.5	12.4	6	33.5
3.1 – 3.6	30.5	12.8	6	33.7
3.6 – 4.5	30.5	15.0	6	34.5

Background

$W_{\gamma\gamma}$ (GeV)	inclusive (%)	h^+h^- (%)	e^+e^- (%)
2.1 – 2.2	0.3	3.4	0
2.2 – 2.3	0.4	4.2	0
2.3 – 2.4	0.4	5.8	0
2.4 – 2.5	0.4	8.1	0.4
2.5 – 2.6	0.6	11.9	2.8
2.6 – 2.8	1.1	17.5	4.6
2.8 – 3.2	2.6	29.3	17.2
3.2 – 3.6	4.2	23.9	20.8
3.6 – 4.5	6.3	25.5	25.1

Background subtraction:

- uncertainty of 50% on $\gamma\gamma \to \pi^+\pi^-$ and $\gamma\gamma \to K^+K^-$ cross sections.
- uncertainty of 30% on the $e^+e^- \to e^+e^-e^+e^-$ cross section due to MC statistic.
- 50% on the inclusive background due to the fitting procedure.

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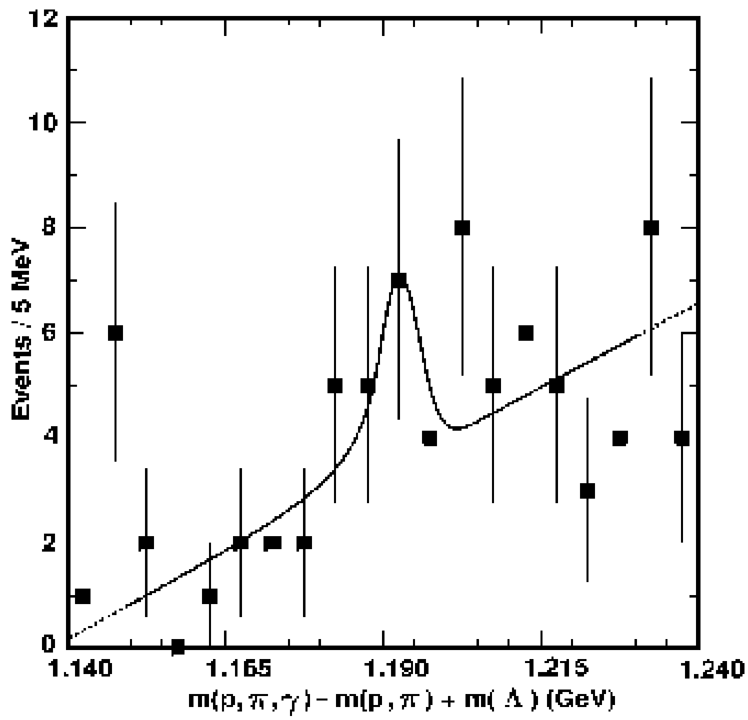
$\gamma\gamma \rightarrow \Lambda\overline{\Lambda}$ *and* $\gamma\gamma \rightarrow \Sigma^0\overline{\Sigma}^0$ *results*



- Fit to determine the Σ^0 contamination.
- Assume $\sigma(\Lambda\overline{\Sigma}^0 + \overline{\Lambda}\Sigma^0) \simeq \sigma(\Sigma^0\overline{\Sigma}^0)$.
- 22% $(\Sigma^0/\overline{\Sigma}^0)$ contamination