Measurements of the Magnetic Form Factor of the Proton for Large Timelike Momentum Transfers

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E835 Collaboration Meeting
Irvine, July 01 2002

- Results of the analysis
- Evaluation of background contamination

Energy ranges for the form factor analysis

We find the form factor events at the following energy:

- Data at background above and below energy peak of χ_0 (out of about $1.5 - 2\Gamma_{\chi_0}$)
- All data at h_c energy
- Data at two high energies ($\sim$ 3.8 GeV and $\sim$ 4.2 GeV)

summarized in the following table:

Sample	$\sqrt{s}$ Interval (GeV)	Mean$\pm$Rms (GeV)	$\int Ldt$ (pb^{-1})	N
1	3.340-3.392	3.379$\pm$0.014	8.52	8
2	3.430-3.470	3.455$\pm$0.019	3.95	3
3	3.523-3.529	3.526$\pm$0.006	50.50	31
4	3.770-3.836	3.795$\pm$0.050	5.17	0
5	4.267-4.270	4.268$\pm$0.002	2.10	0

Measurements of the $\overline{p}p \to e^+e^-$ cross section

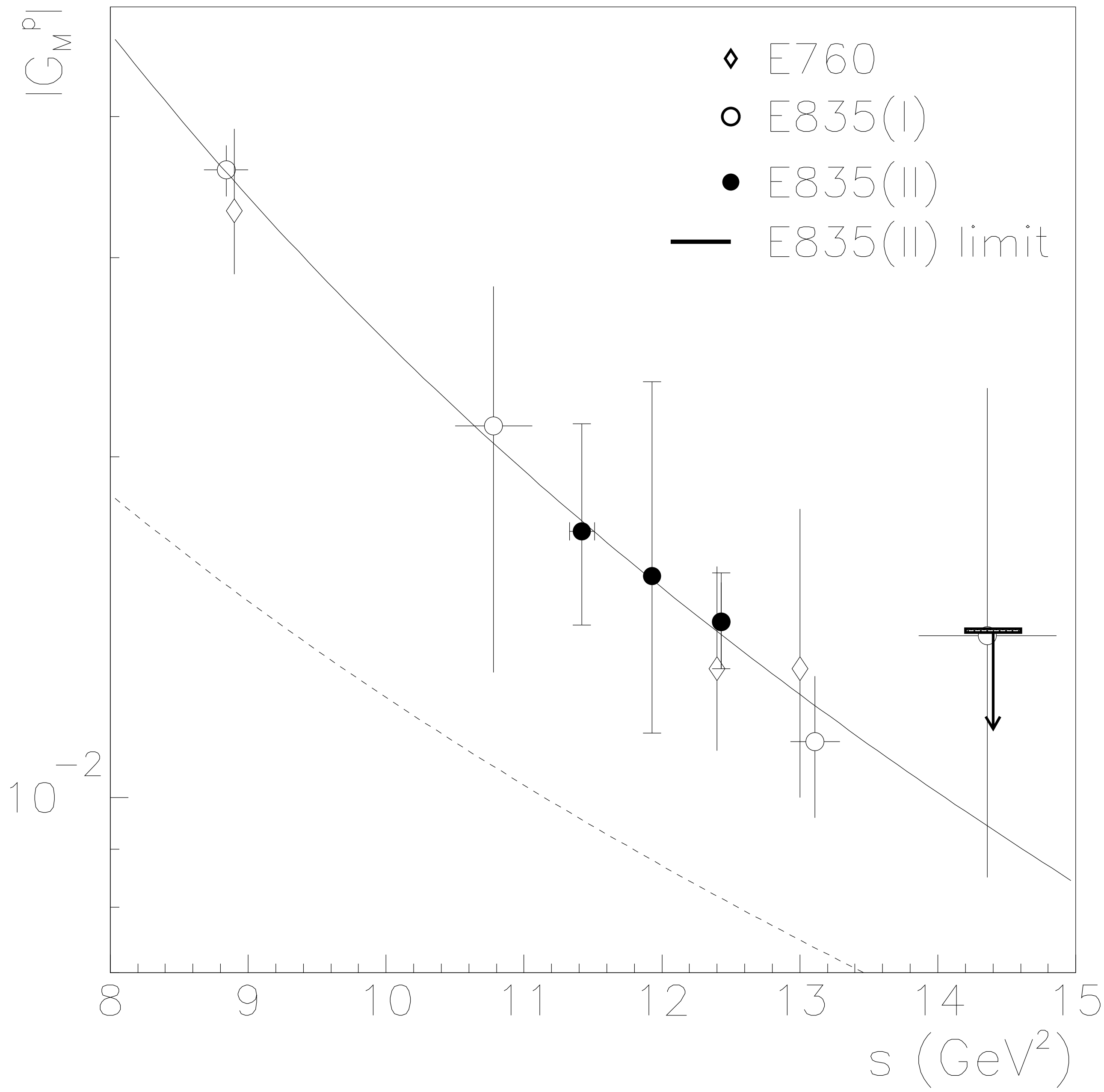
From N, L and ϵ we measure: $\sigma_{acc} = \frac{N}{\epsilon L}$

s (GeV^2)	L (pb^{-1})	N	σ_{acc} (pb)	$\mid \cos\theta^* \mid_{max}$
11.42±0.09	8.52	8	$1.64^{+0.81+0.11}_{-0.57-0.10}$	0.568
11.93±0.13	3.95	3	$1.33^{+1.29+0.09}_{-0.72-0.08}$	0.585
12.43±0.01	50.50	31	$1.07^{+0.23+0.07}_{-0.20-0.07}$	0.601
14.40±0.19	5.17	0	< 0.85	0.603
18.22±0.01	2.10	0	< 2.10	0.512

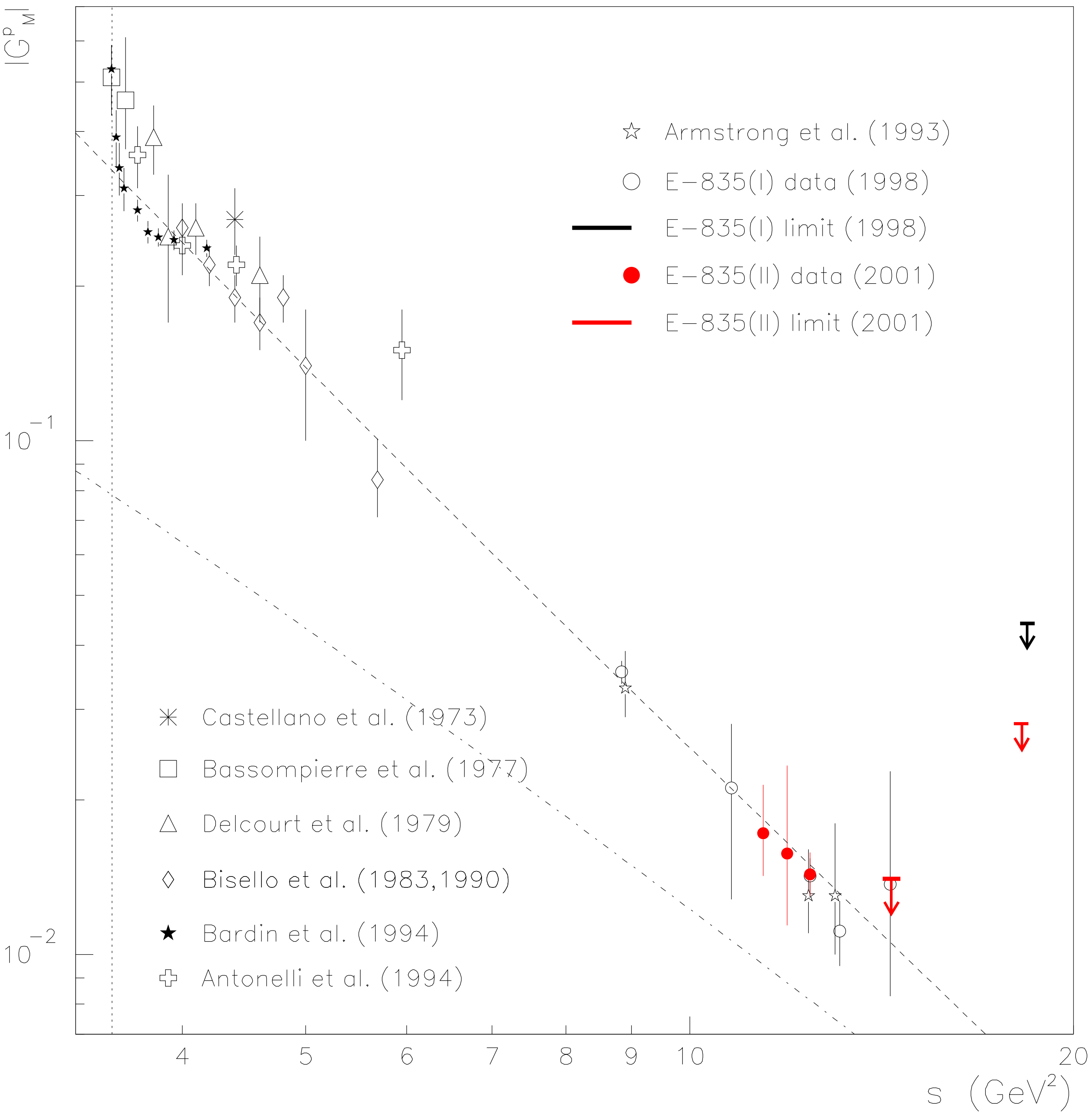
Results of the form factor analysis

s (GeV^2)	$10^2 \times \vert G_M\vert$ (a)	(b)
11.42 ± 0.09	$1.74^{+0.43+0.06}_{-0.30-0.05}$	$1.95^{+0.48+0.07}_{-0.34-0.05}$
11.93 ± 0.13	$1.59^{+0.77+0.06}_{-0.43-0.05}$	$1.77^{+0.86+0.06}_{-0.48-0.06}$
12.43 ± 0.01	$1.45^{+0.15+0.05}_{-0.13-0.04}$	$1.60^{+0.17+0.06}_{-0.15-0.05}$
14.40 ± 0.19	< 1.42	< 1.56
18.22 ± 0.01	< 2.85	< 3.08

Magnetic form factor from E760, E835(I) and E835(II)



All existing measurements of the magnetic form factor



Evaluation of background contamination

The reaction which could simulate the same signal of e^+e^- final state are:

- J/ψ inclusive reactions:
  - contamination from $J/\psi\gamma$ at the χ_0 energy.
  - contamination from $J/\psi\pi^0$ at the h_c energy.

- Photon conversions and π^0 Dalitz decays:

$$\bar{p}p \rightarrow \pi^0\pi^0$$
$$\bar{p}p \rightarrow \pi^0\gamma$$
$$\bar{p}p \rightarrow \gamma\gamma$$

- Hadronic two body final state, mainly:

$$\bar{p}p \rightarrow \pi^+\pi^-$$

Evaluation of $\chi_0 \to J/\psi\gamma$ contamination

- At χ_0 peak $(M_{\chi_0} - \frac{\Gamma_{\chi_0}}{2} \leqslant E_{cm} \leqslant M_{\chi_0} - \frac{\Gamma_{\chi_0}}{2})$ form factor analysis selects 10 events, with $L = 11.07$ pb^{-1}.

- Considering all these events as due to $J/\psi\gamma$ background

  and

  rescaling with Breit-Wigner formula we calculate the background contribution to cross section at different energy.

- The background contribution to the cross section at the two energy out of the χ_0 peak results:

$$\sigma_{J/\psi\gamma} \approx 10^{-2} \text{ pb}$$

Evaluation of $J/\psi\pi^0$ contamination at h_c

$$\sigma'_{J/\psi\pi^0} = \alpha \times \sigma(\bar{p}p \to J/\psi\pi^0)$$

- $\alpha = 10^{-3}$ is the fraction of $J/\psi X$ (X not detected) events at χ_1, which satisfy the form factor analysis.

- $\sigma(\bar{p}p \to J/\psi\pi^0) < 5$ pb from E760.

$$\sigma'_{J/\psi\pi^0} \approx 10^{-2} \text{ pb}$$

Same upper limit is used at 14.40 GeV^2 and 18.22 GeV^2.

Evaluation of photon conversions and π^0 Dalitz decays background contamination

$$\sigma_p < \omega \left[(\delta + 2\eta)^2 \sigma'_{\pi^0\pi^0} + (\delta + 2\eta)\eta\sigma'_{\pi^0\gamma} + \eta^2 \sigma_{\gamma\gamma} \right]$$

- $\delta = 1.2 \times 10^{-2}$: probability for Dalitz decay
- $\eta < 1.7 \times 10^{-2}$: probability for $\gamma \to (e^+e^-)$ before H1, calculated from a sample of $\pi^0\pi^0$ events.
- $\omega < 10^{-2}$: probability that a background event (with 2 e^+e^- pairs) satisfy the cut on the EW.
- $\sigma'_{\pi^0\pi^0}$ and $\sigma'_{\pi^0\gamma}$ feed-down background from $\pi^0\pi^0$ and $\pi^0\gamma$ to $\gamma\gamma$. (from E760)

$$\sigma_p \approx 10^{-3} \text{ pb}$$

$\pi^+\pi^-$ background contamination

$$\sigma_h = (\alpha_{acc} \times \sigma_{\pi^+\pi^-}) \times \xi^2 \times k^2$$

- $\xi = 10^{-2}$ CCAL rejection power.
- $k = 6 \times 10^{-3}$ Čerenkov rejection power.
- $\alpha_{acc} \times \sigma_{\pi^+\pi^-}$ taken from literature.

Above values have been extracted from a sample of $\pi^+\pi^-$ events.

$$\sigma_h \approx 10^{-3}\ \mathrm{pb}$$

All backgrounds together

s (GeV^2)	$\sigma_{J/\psi X}$ (pb)	σ_p (pb)	σ_h (pb)
11.42	3.0×10^{-2}	3.1×10^{-3}	4.3×10^{-3}
11.93	2.3×10^{-2}	2.0×10^{-3}	3.6×10^{-3}
12.43	1.5×10^{-2}	1.7×10^{-3}	2.9×10^{-3}
14.40	$< 1.5 \times 10^{-2}$	$< 0.9 \times 10^{-3}$	$< 0.7 \times 10^{-3}$
18.22	$< 1.5 \times 10^{-2}$	$< 0.9 \times 10^{-3}$	$< 0.7 \times 10^{-3}$

Summing all backgrounds:

s (GeV^2)	σ_{ff} (pb)	σ_B (pb)
11.42	$1.64^{+0.81+0.11}_{-0.57-0.10}$	3.7×10^{-2}
11.93	$1.33^{+1.29+0.09}_{-0.72-0.08}$	2.9×10^{-2}
12.43	$1.07^{+0.23+0.07}_{-0.20-0.07}$	2.0×10^{-2}
14.40	< 0.85	1.7×10^{-2}
18.22	< 2.10	1.7×10^{-2}

Why do we use E760 data rather than E835(I) data to evaluate the contamination from $\pi^0\pi^0$, $\pi^0\gamma$ and $\gamma\gamma$?

- $\sigma^{'}_{\pi^0\pi^0}$, $\sigma^{'}_{\pi^0\gamma}$ and $\sigma_{\gamma\gamma}$ from E835(I) are integrated over a limited angular region:

$$\text{E835(I)} \implies |\cos\theta^*| < 0.40 \div 0.45$$

- while from E760 we used the cross section integrated over E835 fiducial volume:

$$\text{E760} \implies |\cos\theta^*| = |\cos\theta^*|_{FF}$$

Comparison between E760 and E835(I) integrated in the same angular region $|\cos\theta^*| < 0.45$:

E_{CM} (MeV)	$\sigma^{'}_{\pi^0\pi^0} + \sigma^{'}_{\pi^0\gamma}$ (pb)		$\sigma_{\gamma\gamma}$ (pb)	
	E760	E835(I)	E760	E835(I)
3526	25	20	28	21
3686	16	11	22	12