Feasibility studies of proton time-like electromagnetic form factors with the $\bar{\text{P}}$ANDA detector

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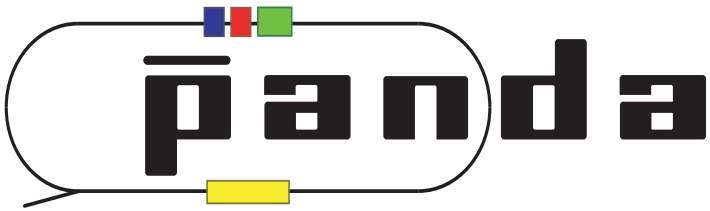

JOHANNES GUTENBERG UNIVERSITÄT MAINZ

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Outline

Introduction

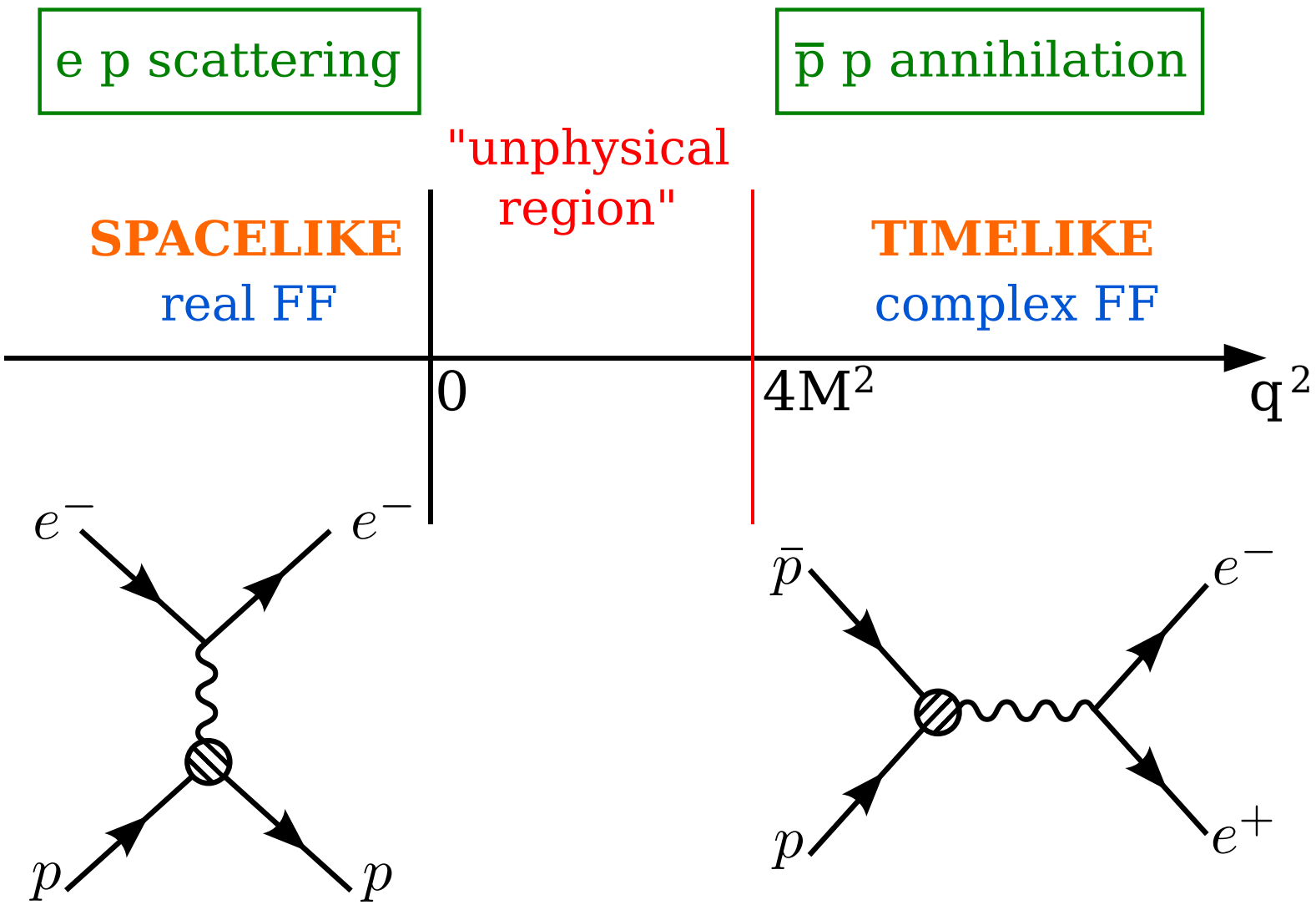
Efficiency and suppression studies

Selection criteria

G_E and G_M extraction

Conclusions

Nucleon structure: form factors measurement



Challenge: background

Background channel: $\bar{p}p \to \pi^+\pi^-$

- Main background source to e^+e^- production

$$\boxed{\frac{\sigma(\bar{p}p \to \pi^+\pi^-)}{\sigma(\bar{p}p \to e^+e^-)} \sim 10^6} \Rightarrow \text{need suppression factor} \sim 10^8$$

data: Eisenhandler et. al., NP B96 (1975)

A. Eideetal. NP B60(1973)
T. Buranetal. NPB 116(1976)
C. Whiteetal. PRD 49(1994)

model: Legendre polynomial fit ⟵ interpolation ⟶ Regge Theory
J. Vande Wiele and S. Ong, EPJA 46 (2010)

Expected number of events for $\bar{p}p \to e^+e^-$

$p_{beam}[GeV/c]$	$s[GeV/c]^2$	$N_{G_E/G_M=0}$	$N_{G_E/G_M=1}$
1.7	5.4	$8.0 \cdot 10^5$	$1.1 \cdot 10^6$
2.78	7.27	$1.2 \cdot 10^5$	$1.4 \cdot 10^5$
3.3	8.21	$5.3 \cdot 10^4$	$6.4 \cdot 10^4$
4.9	11.0	$7.4 \cdot 10^3$	$9.1 \cdot 10^3$
5.9	12.9	$2.7 \cdot 10^3$	$3.2 \cdot 10^3$
6.4	13.8	$1.7 \cdot 10^3$	$2 \cdot 10^3$
7.9	16.7	517	580

for integrated luminosity $L = 2fb^{-1}$

E. Tomasi-Gustafsson and M. P. Rekalo, Phys. Lett. B 504, (2001) 291.

Efficiency and suppression studies with $\bar{\text{P}}$ANDAroot

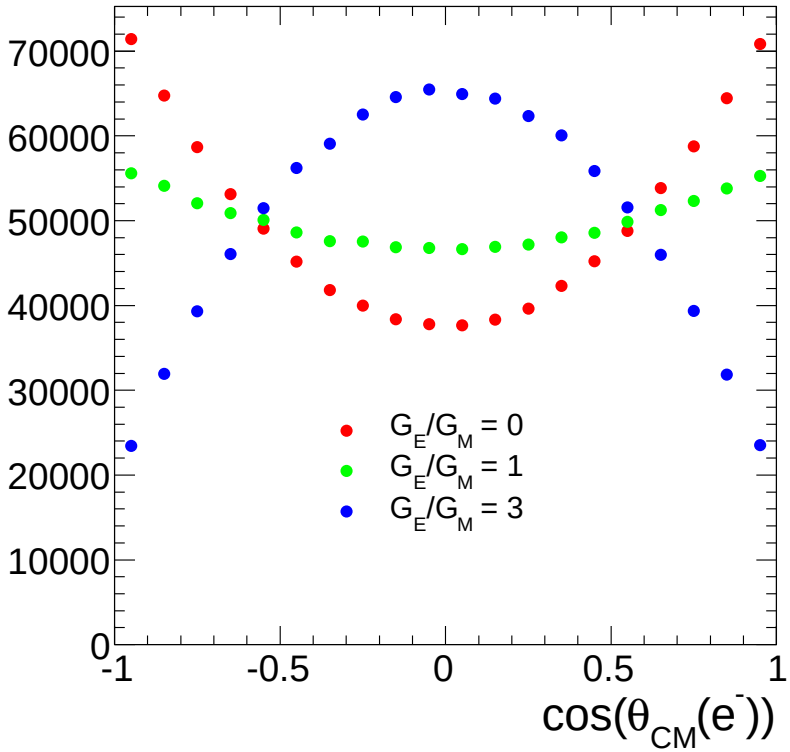
Number of events simulated

	$\bar{p}p \to e^+e^-$	$\bar{p}p \to \pi^+\pi^-$
$p_{beam}[GeV/c]$	$G_E/G_M = 0, 1, 3$	
1.7	10^6	10^8
2.78	10^6	-
3.3	10^6	10^8
4.9	10^6	-
5.9	10^6	-
6.4	10^6	*soon*
7.9	10^6	-

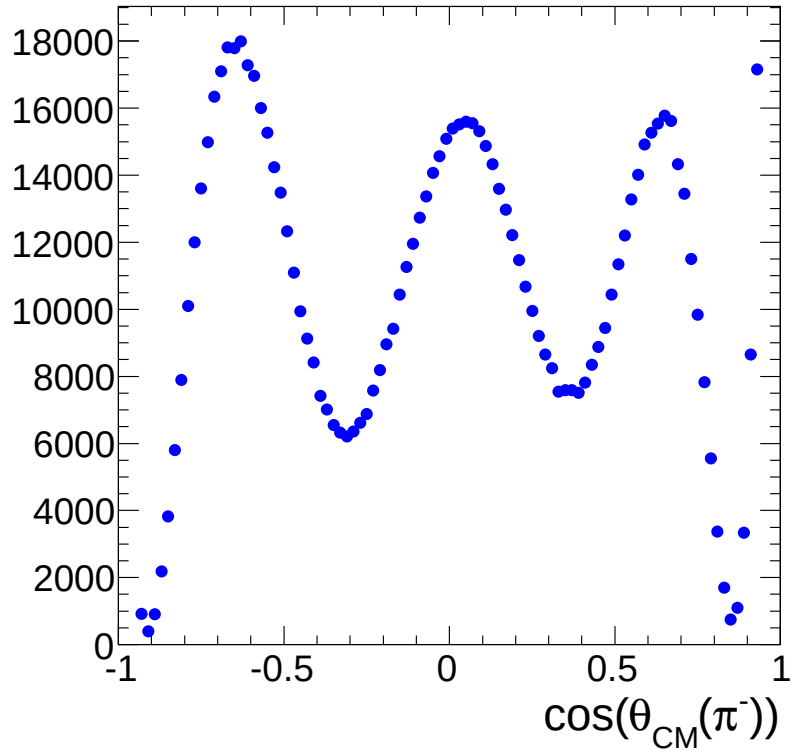
Simulation was performed **@HIMSTER** cluster of **Helmholtz-Institut Mainz**

Monte-Carlo $cos(\theta_{CM})$ at $p_{beam} = 1.7[GeV/c]$

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



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



event generator developed by M. Zambrana in Mainz
http://panda-wiki.gsi.de/cgi-bin/view/PANDAMainz/EventGenerators
(PANDA report)

Selection criteria

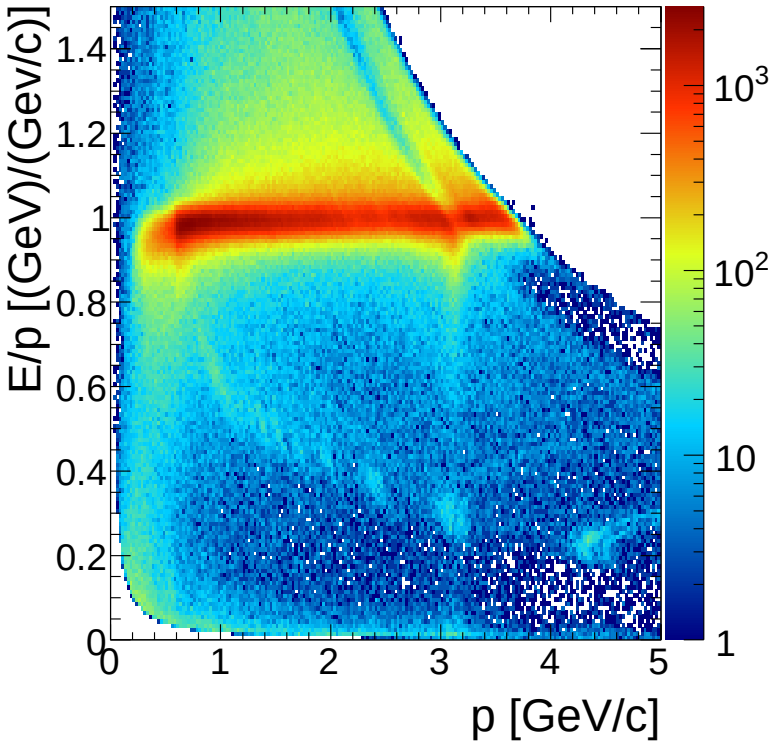
- PID : $p(e^{-/+}) > 99.9\%$
  - EMC
  - STT
  - DRC
  - DISC

Selection criteria

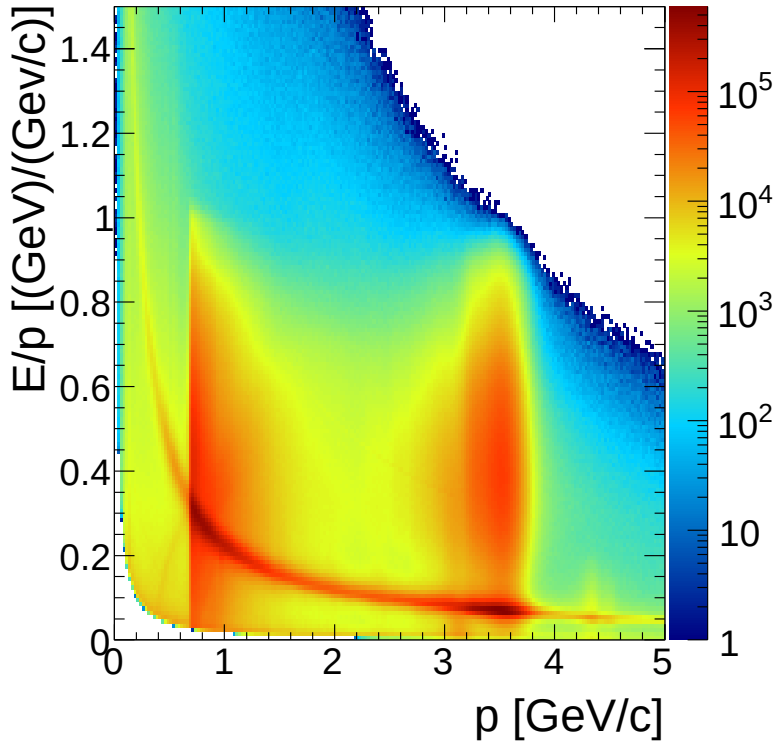
- 1 positive 1 negative event
- $E/p > 0.8$
- MDT - no hits
- $dE/dx_{STT} > 5.8$
- $N_{crystals} > 5$
- $S \pm 20\%$
- $178^\circ < \theta^+ + \theta^- < 182^\circ$
- $178^\circ < \phi^+ - \phi^- < 182^\circ$
- $|Vertex(x, y)| < 3mm$

E/p vs p for $p_{beam} = 3.3[GeV/c]$

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

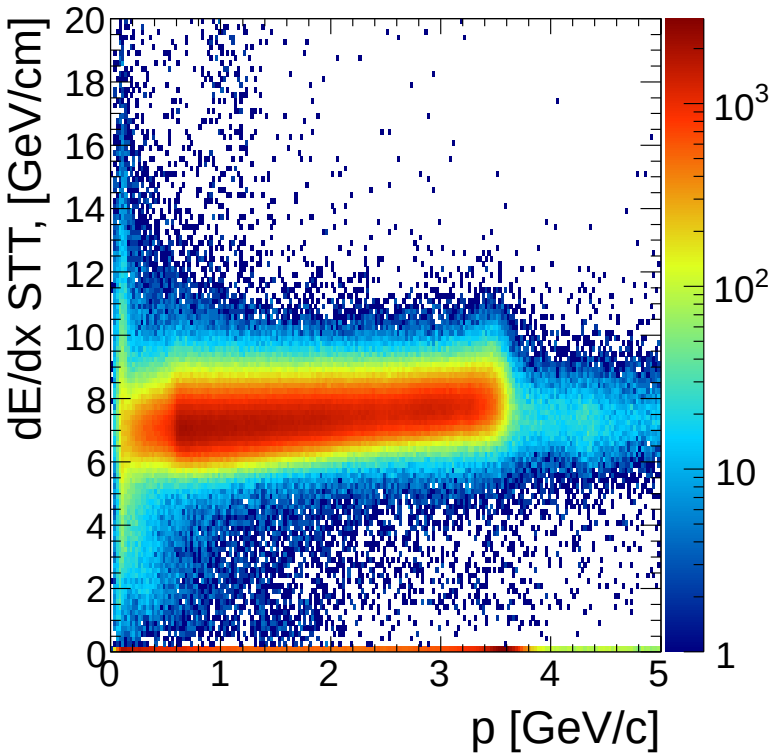


$\bar{p}p \to \pi^+\pi^-$

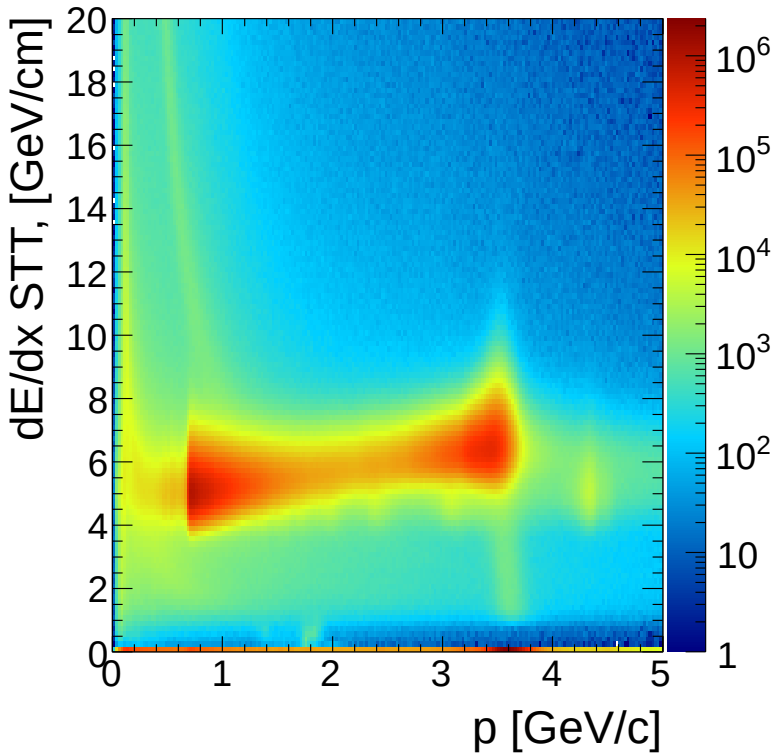


STT dE/dx for $p_{beam} = 3.3[GeV/c]$

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

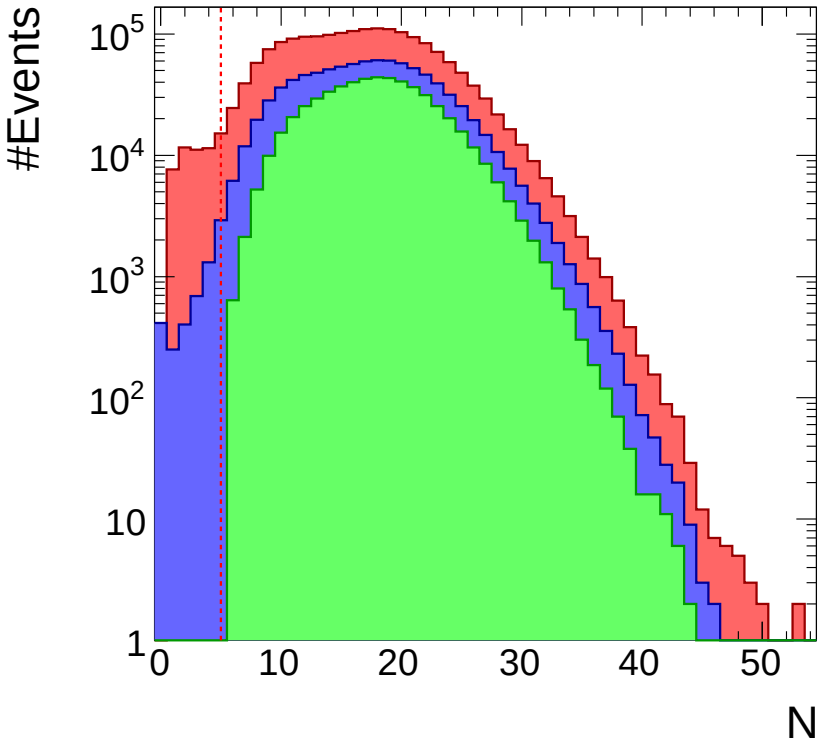


$\bar{p}p \to \pi^+\pi^-$

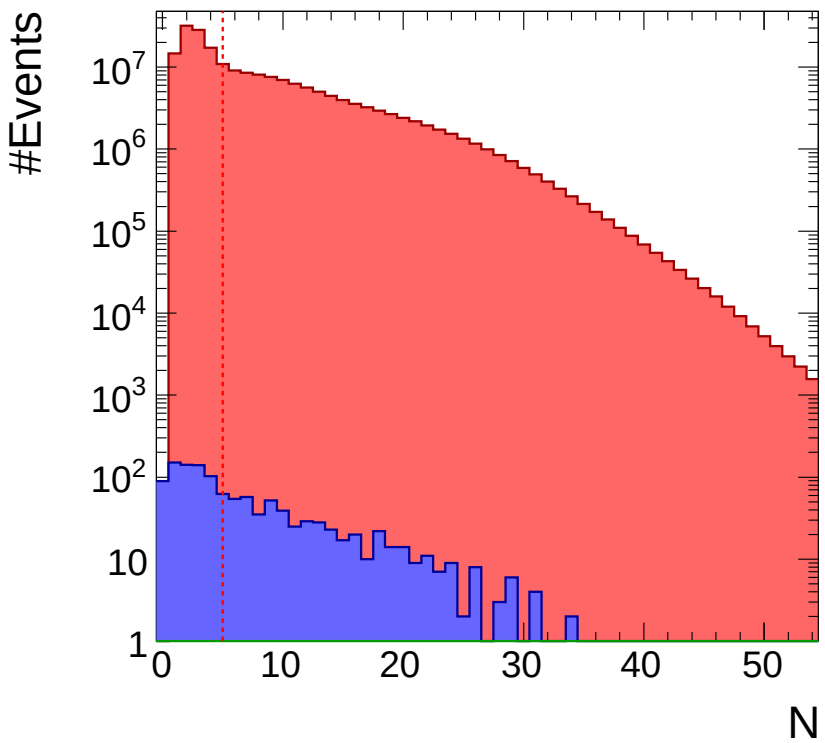


EMC cluster size for $p_{beam} = 3.3[GeV/c]$

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



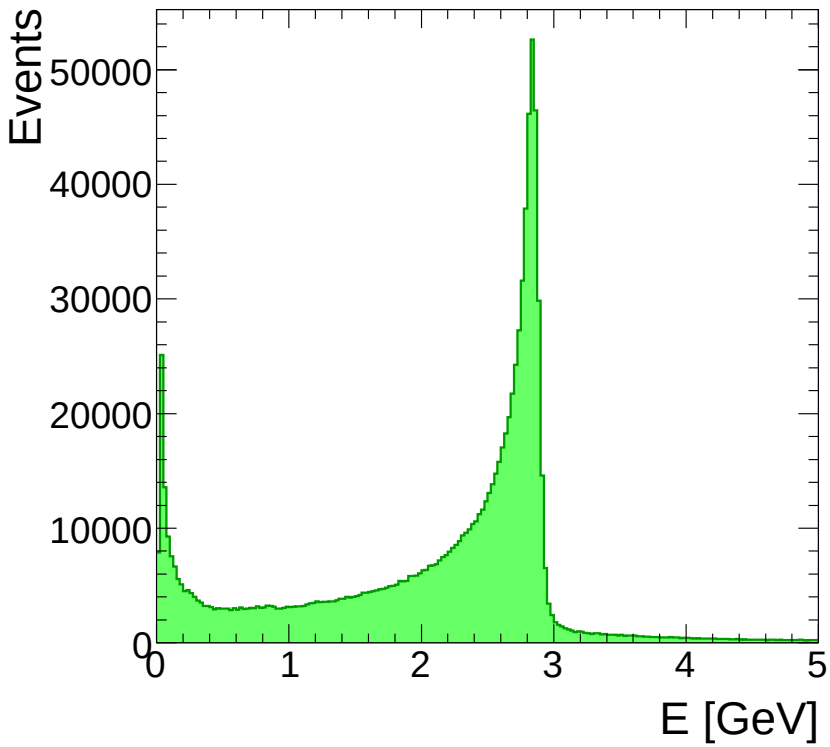
$\bar{p}p \to \pi^+\pi^-$



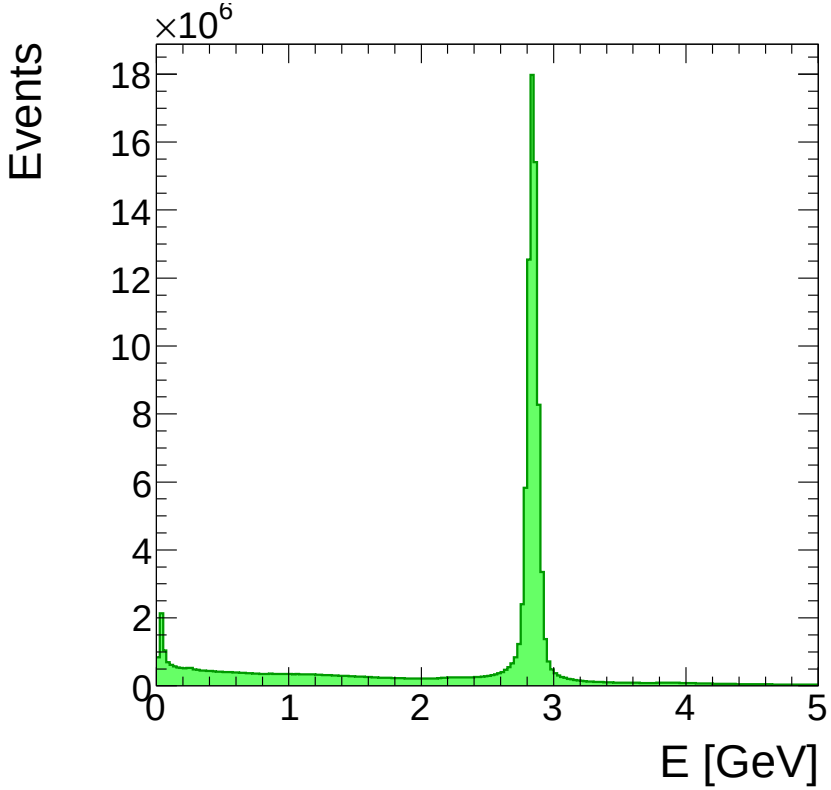
Red all events **Blue** intermediate stage **Green** after all cuts

Total energy of reconstructed pairs (4-momentum) for $p_{beam} = 3.3[GeV/c]$

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

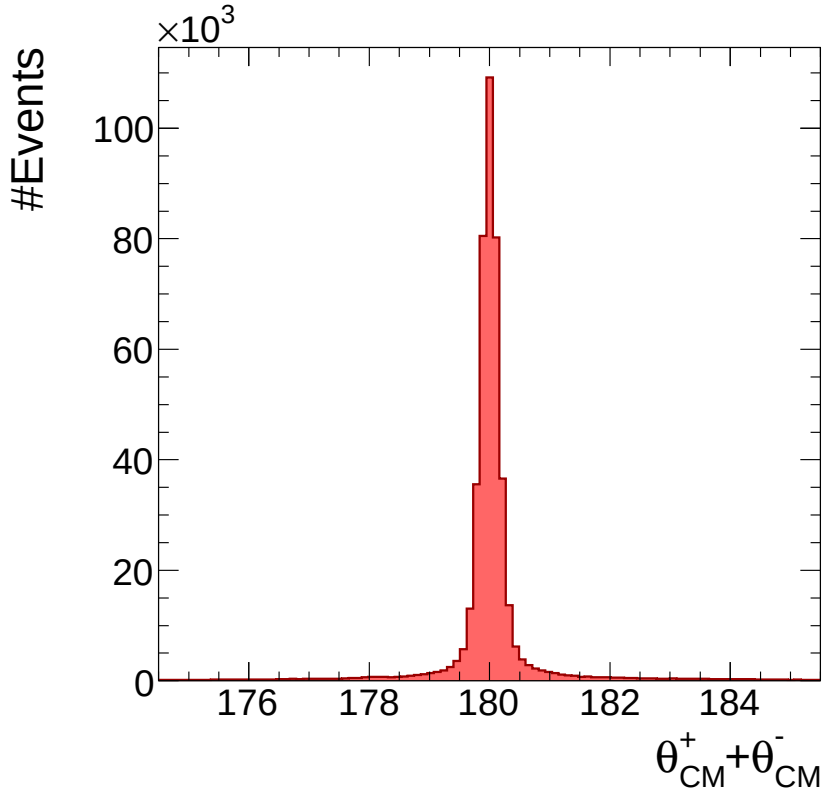


$\bar{p}p \to \pi^+\pi^-$

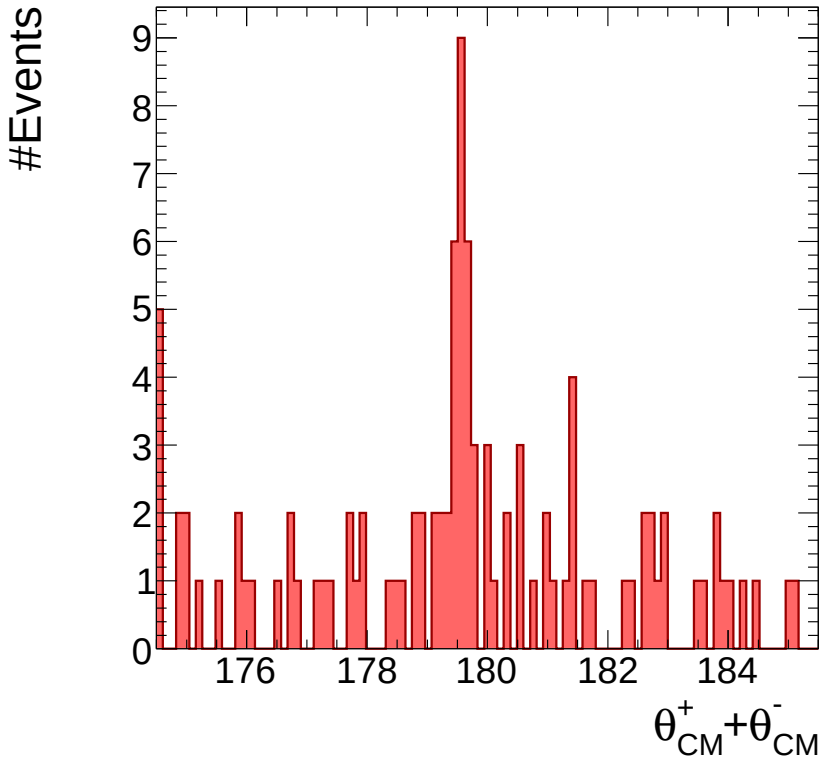


$\theta^+ + \theta^-$ for $p_{beam} = 3.3[GeV/c]$

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



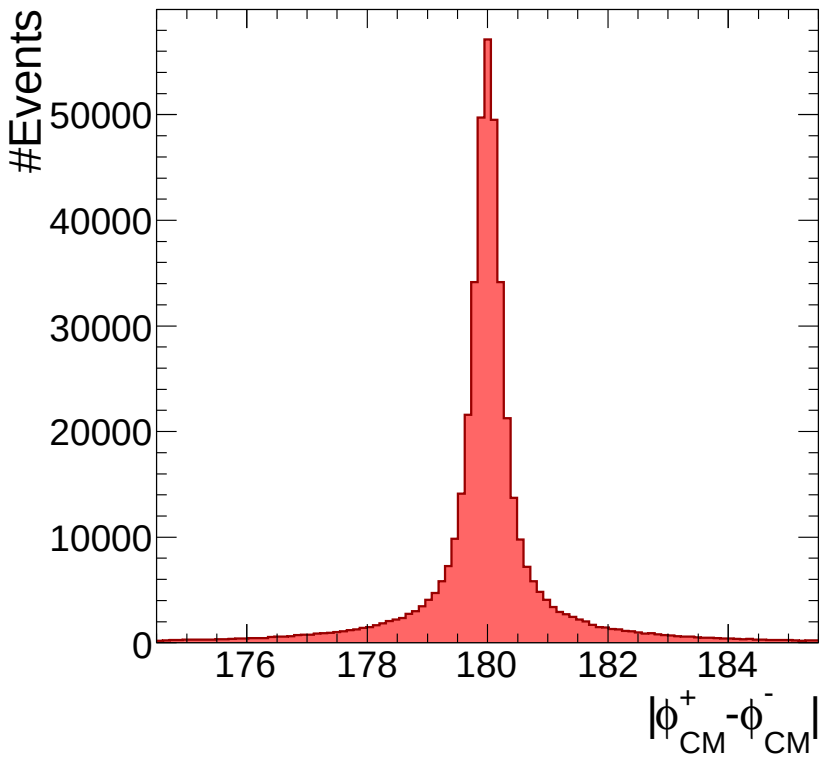
$\bar{p}p \to \pi^+\pi^-$



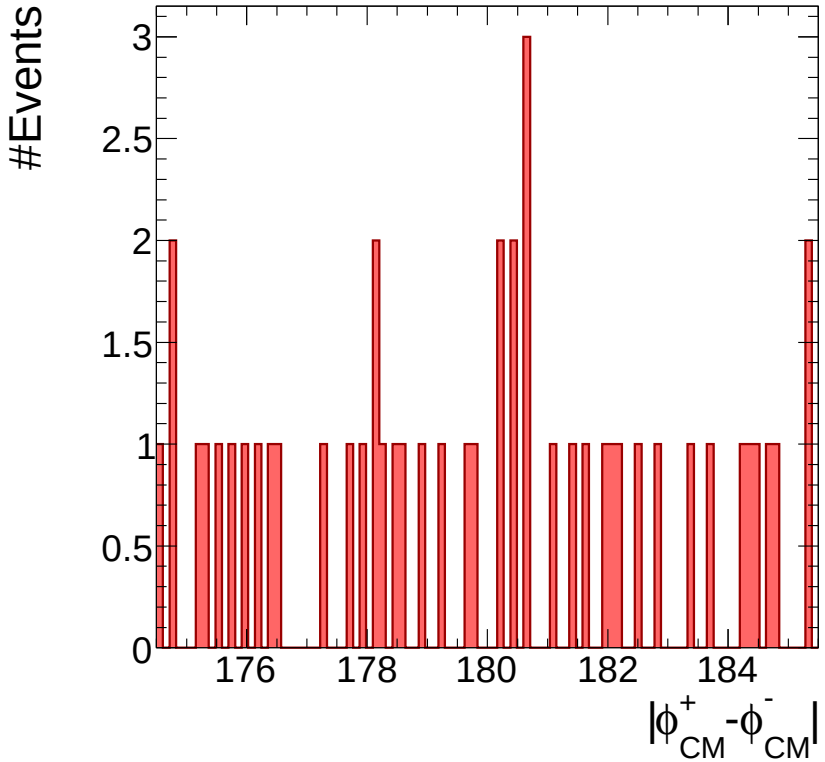
*after applying probability cut

$\phi^+ - \phi^-$ for $p_{beam} = 3.3[GeV/c]$

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



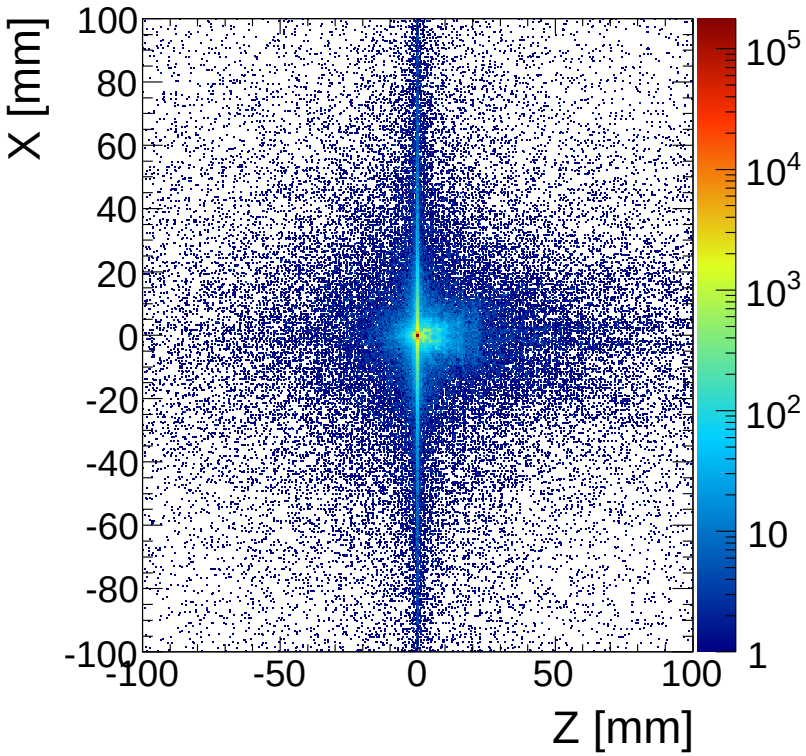
$\bar{p}p \to \pi^+\pi^-$



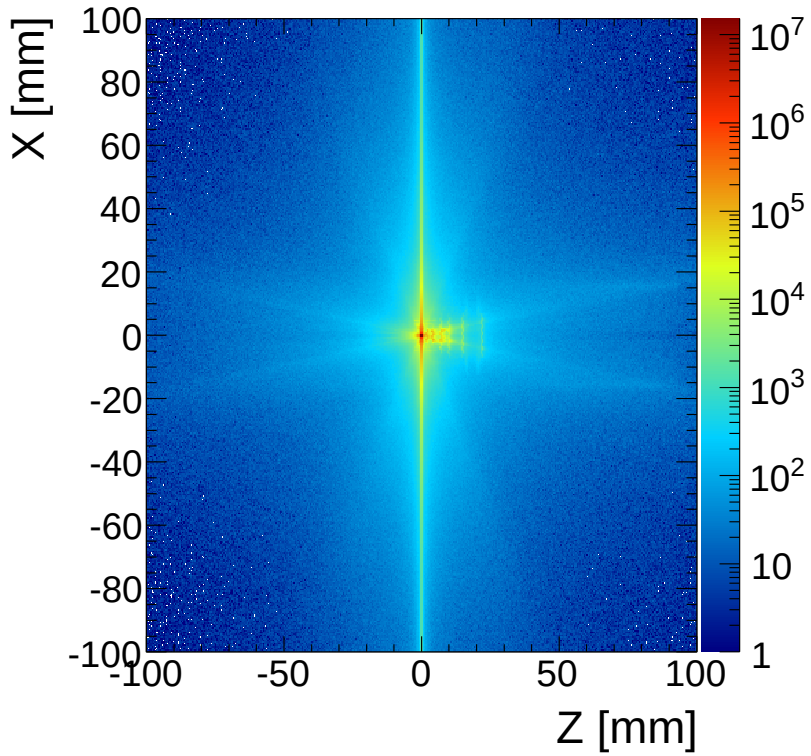
*after applying probability cut

Vertex distribution for $p_{beam} = 3.3[GeV/c]$

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



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



Signal (e^+e^-) reconstruction efficiency and background ($\pi^+\pi^-$) suppression

	$e^+e^-(10^6)$			$\pi^+\pi^-(10^8)$
$p_{beam}[GeV/c]$	$G_E/G_M = 0, 1, 3$			–
1.7	32.0%	33.6%	36.6%	0.0%
2.78	28.4%	29.6%	32.9%	–
3.3	26.8%	27.8%	31.1%	0.0%
4.9	21.5%	22.5%	25.8%	–
5.9	18.5%	19.3%	22.6%	–
6.4	17.0%	17.9%	20.9%	
7.9	12.8%	13.4%	15.8%	–

$\Rightarrow$ with a $CL = 95\%$ the upper limit of the rejection factor $\boldsymbol{R = 0.7 * 10^{-8}}$

G_E and G_M extraction

1. Efficiency correction
   - Sample with expected number of events
   - Independent sample for the efficiency correction
2. Angular distribution fit
3. Extraction of G_E and G_M from the fit function

Zichichi cross section

Fit function for G_E and G_M extraction

$$\frac{d\sigma}{d\cos\theta} = C[|G_M|^2(1+\cos^2\theta) + \frac{|G_E|^2}{\tau}(1-\cos^2\theta)]$$

$$\frac{d\sigma}{d\cos\theta} = C|G_M|^2[(1+\cos^2\theta) + \frac{|R|^2}{\tau}(1-\cos^2\theta)]$$

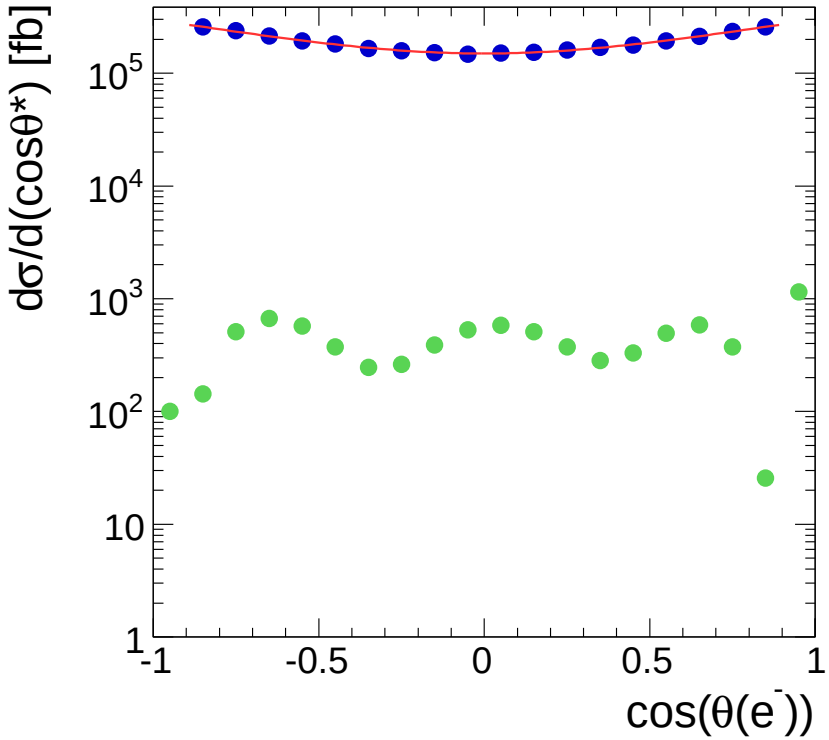
A. Zichichi et. al., Nuovo Cimento XXIV, 170 (1962)
Input into the fit tunction:

$$|G_M| = \frac{22.5}{(1+q^2/0.71)^2(1+q^2/3.6)}$$

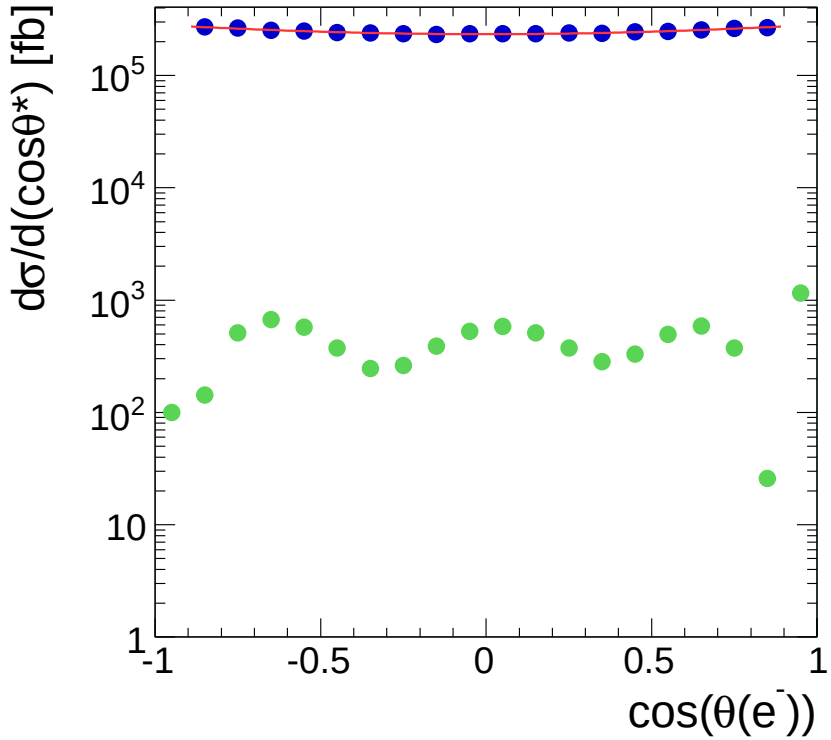
E. Tomasi-Gustafsson and M. P. Rekalo, Phys. Lett. B 504, (2001) 291.

G_E and G_M extraction
$p_{beam} = 1.7[GeV/c]$

$G_E/G_M = 0$



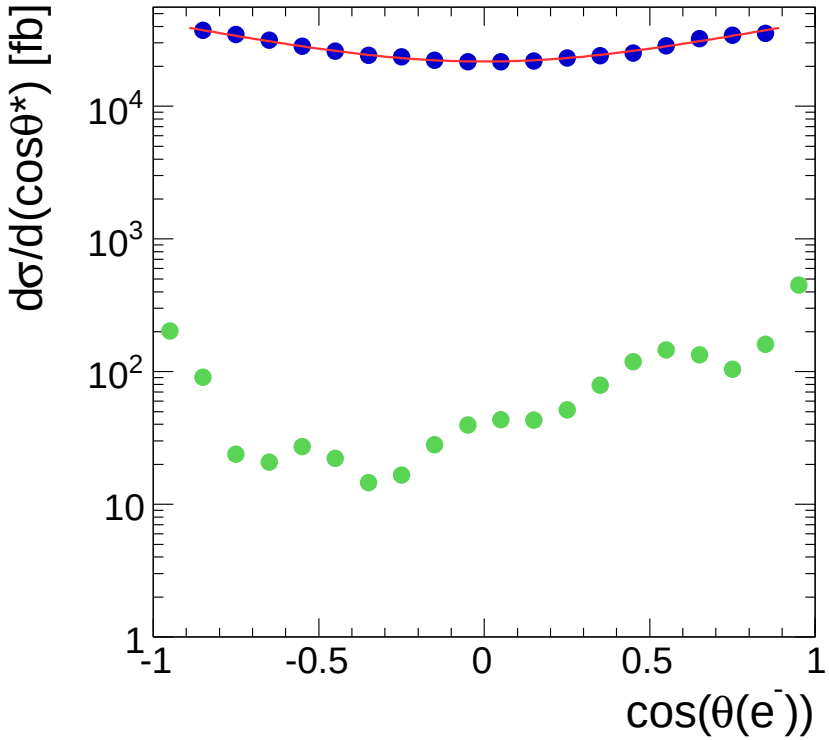
$G_E/G_M = 1$



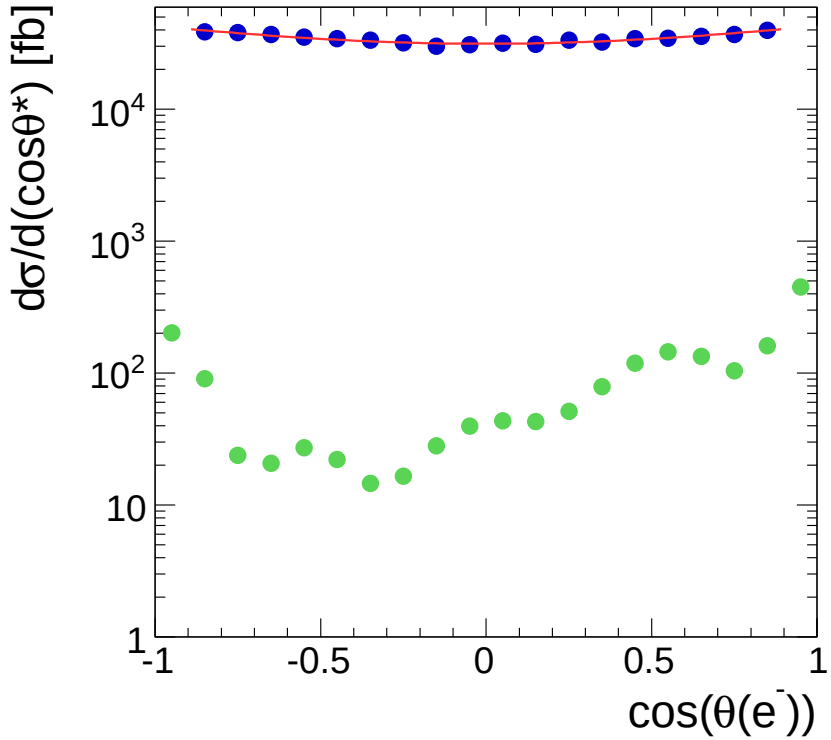
- Measured e^+e^- cross section
- Fit
- $\pi^+\pi^-$ cross section scaled by the rejection factor

G_E and G_M extraction
$p_{beam} = 2.78[GeV/c]$

$G_E/G_M = 0$



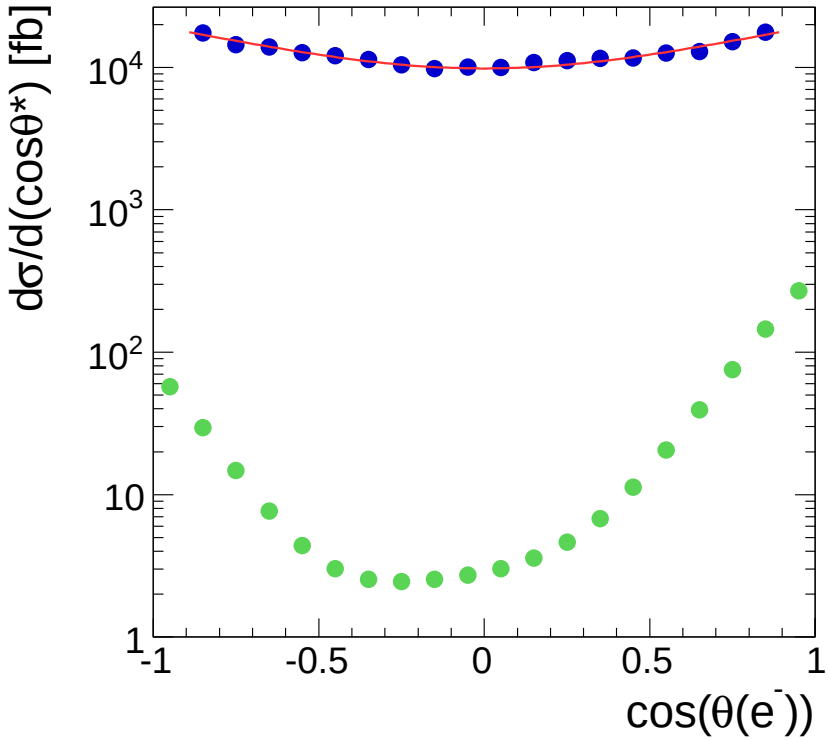
$G_E/G_M = 1$



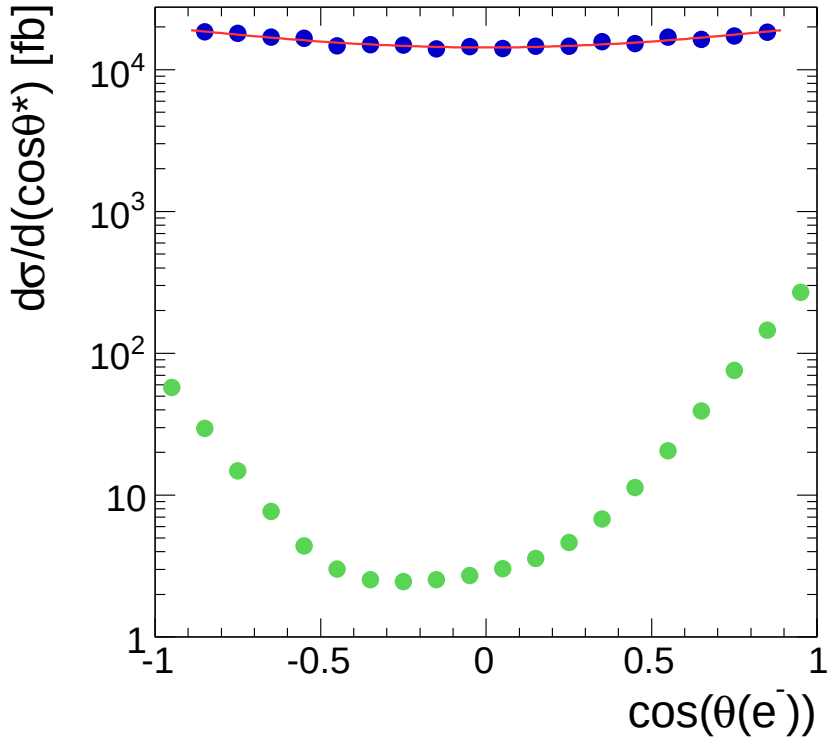
- Measured e^+e^- cross section
- Fit
- $\pi^+\pi^-$ cross section scaled by the rejection factor

G_E and G_M extraction
$p_{beam} = 3.3[GeV/c]$

$G_E/G_M = 0$



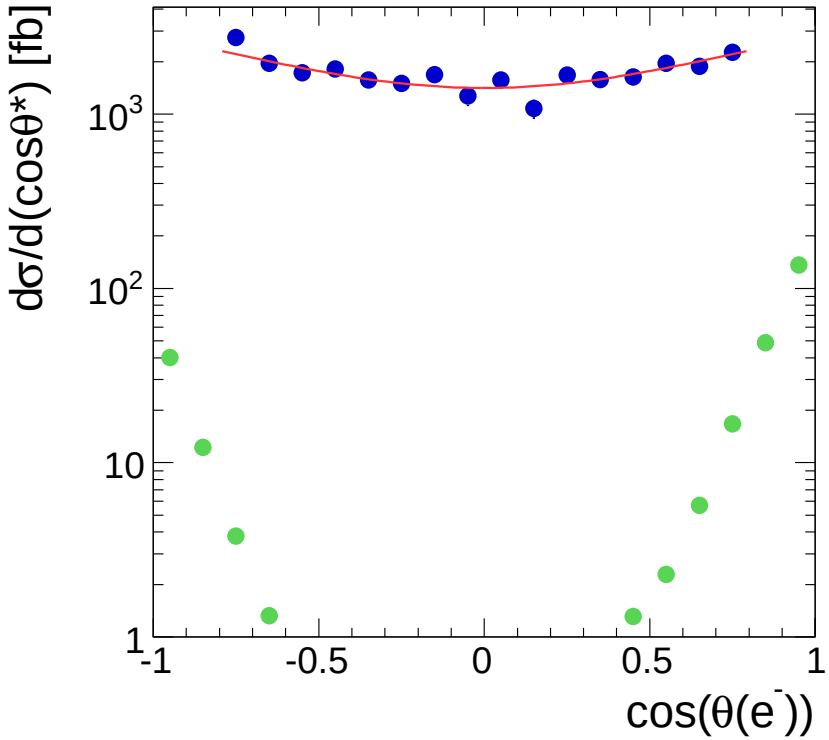
$G_E/G_M = 1$



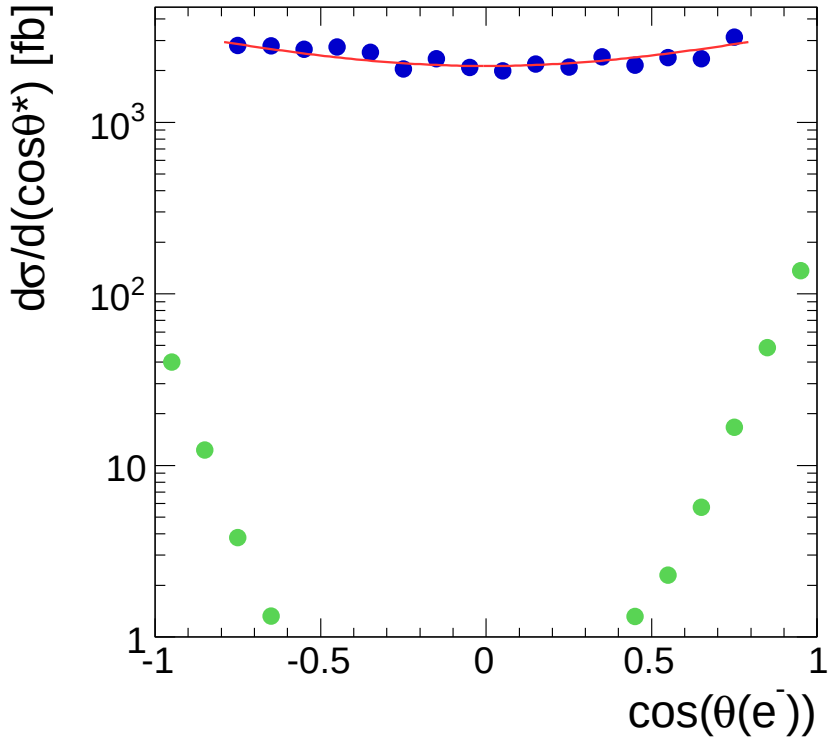
- Measured e^+e^- cross section
- Fit
- $\pi^+\pi^-$ cross section scaled by the rejection factor

G_E and G_M extraction
$p_{beam} = 4.9[GeV/c]$

$G_E/G_M = 0$



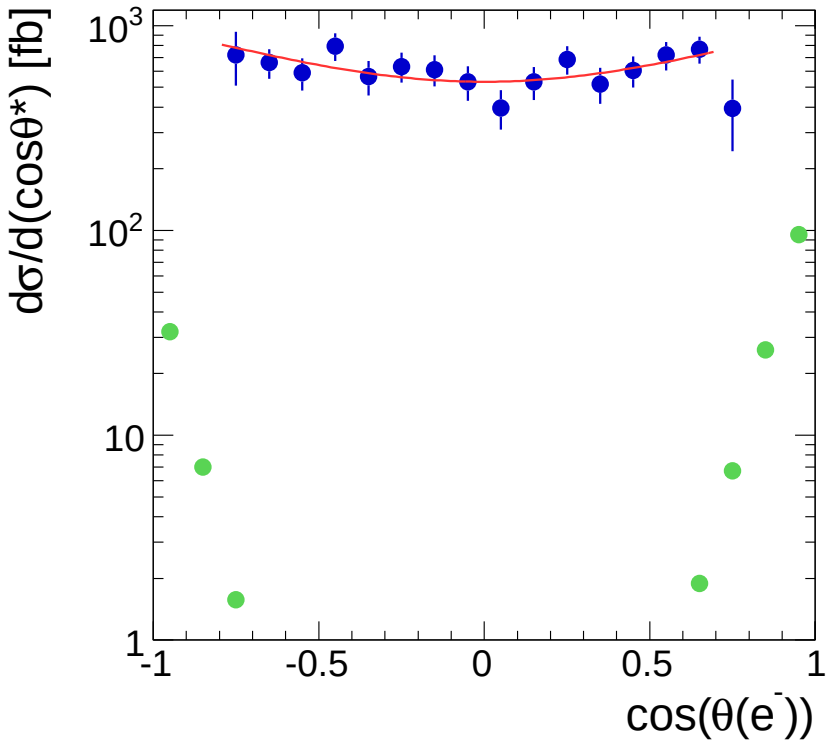
$G_E/G_M = 1$



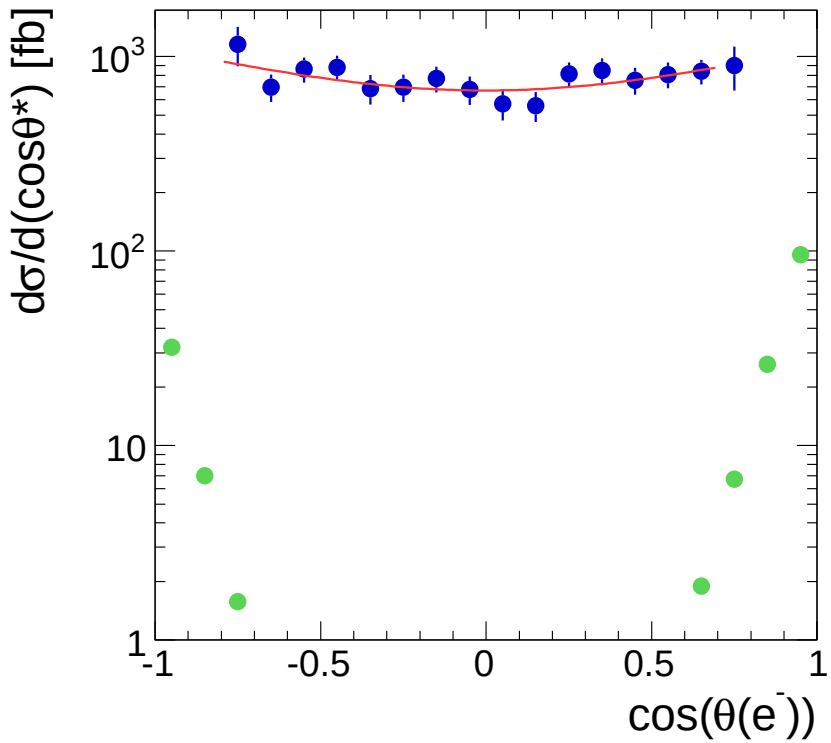
- Measured e^+e^- cross section
- Fit
- $\pi^+\pi^-$ cross section scaled by the rejection factor

G_E and G_M extraction
$p_{beam} = 5.9[GeV/c]$

$G_E/G_M = 0$



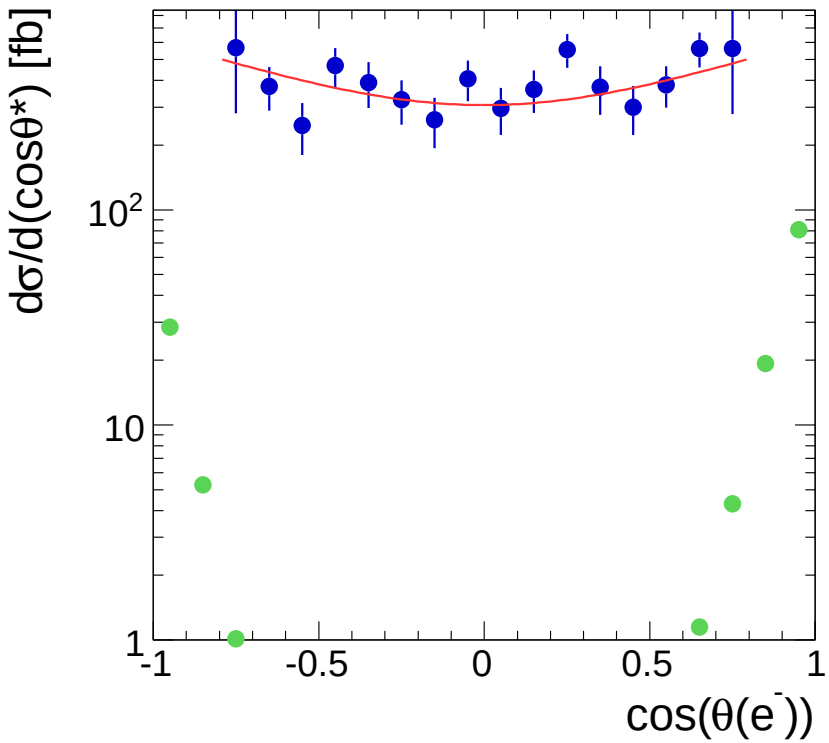
$G_E/G_M = 1$



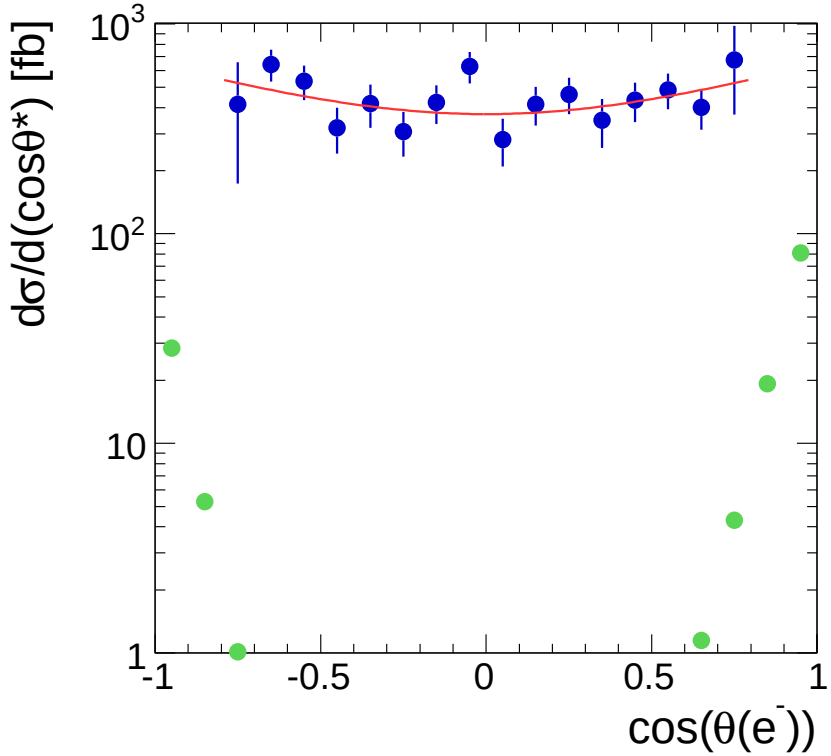
- Measured e^+e^- cross section
- Fit
- $\pi^+\pi^-$ cross section scaled by the rejection factor

G_E and G_M extraction
$p_{beam} = 6.4[GeV/c]$

$G_E/G_M = 0$



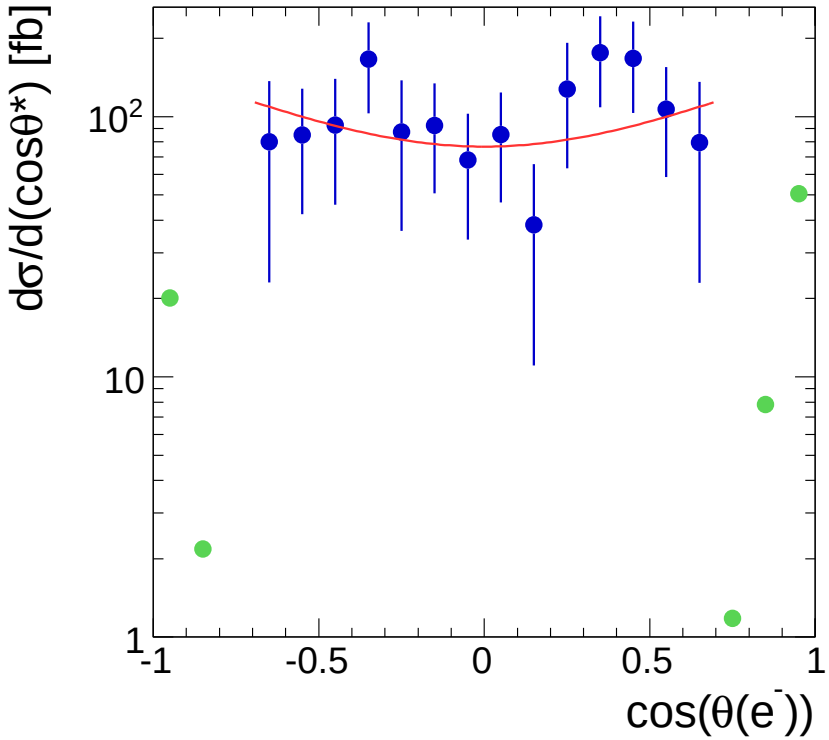
$G_E/G_M = 1$



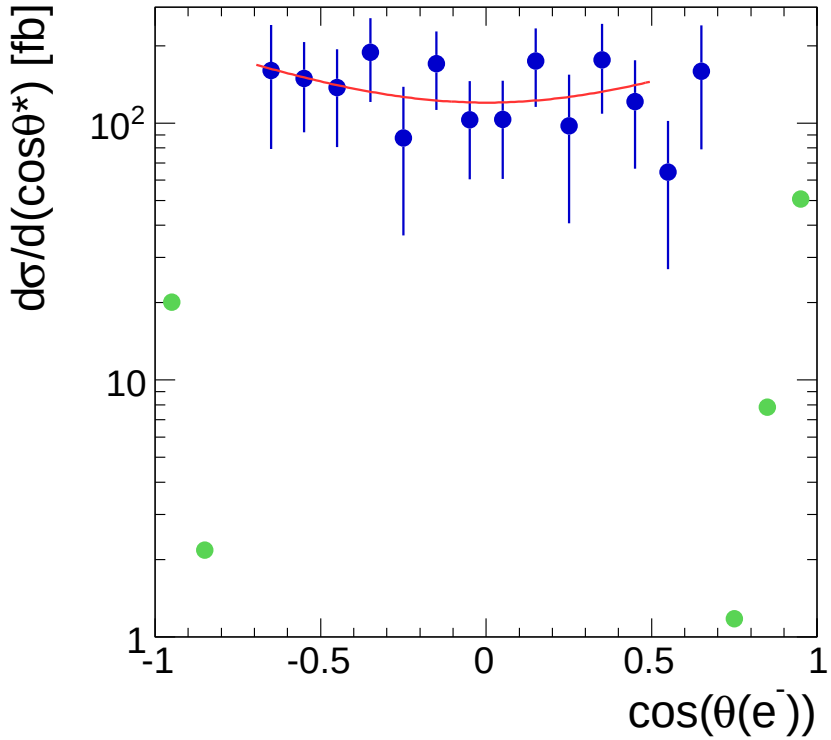
- Measured e^+e^- cross section
- Fit
- $\pi^+\pi^-$ cross section scaled by the rejection factor

G_E and G_M extraction
$p_{beam} = 7.9[GeV/c]$

$G_E/G_M = 0$

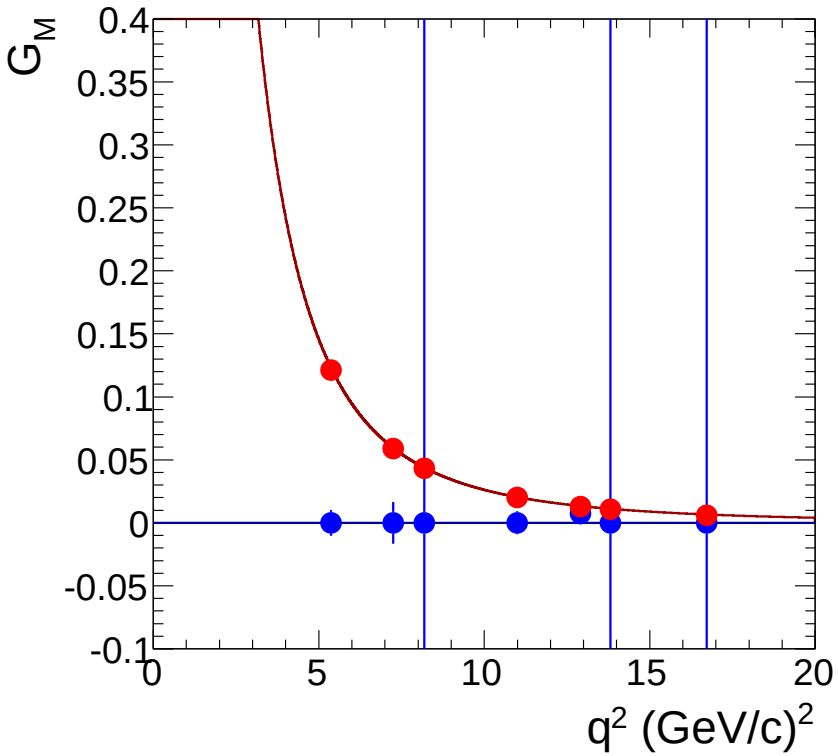


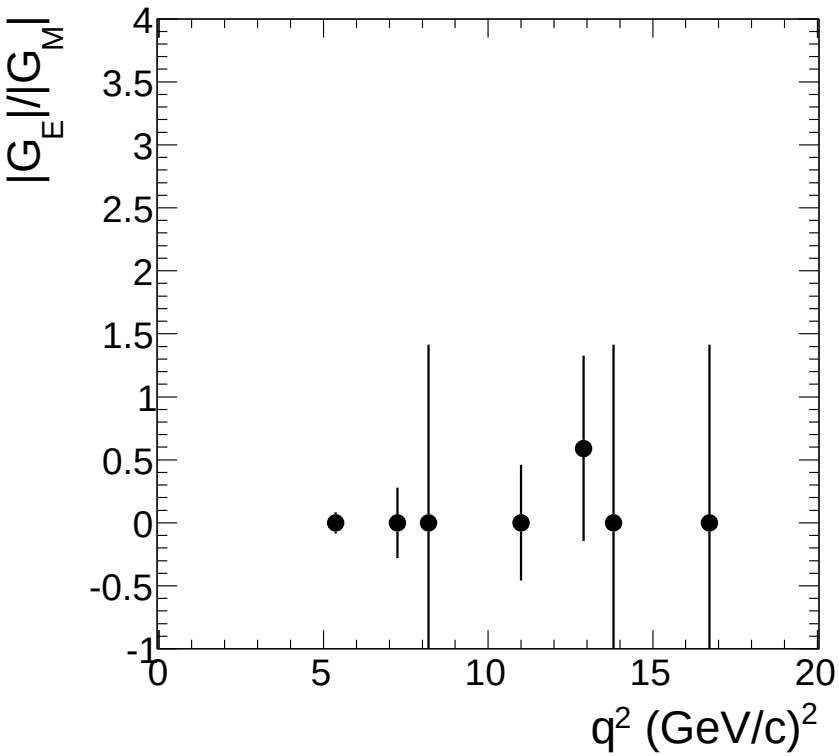
$G_E/G_M = 1$



- Measured e^+e^- cross section
- Fit
- $\pi^+\pi^-$ cross section scaled by the rejection factor

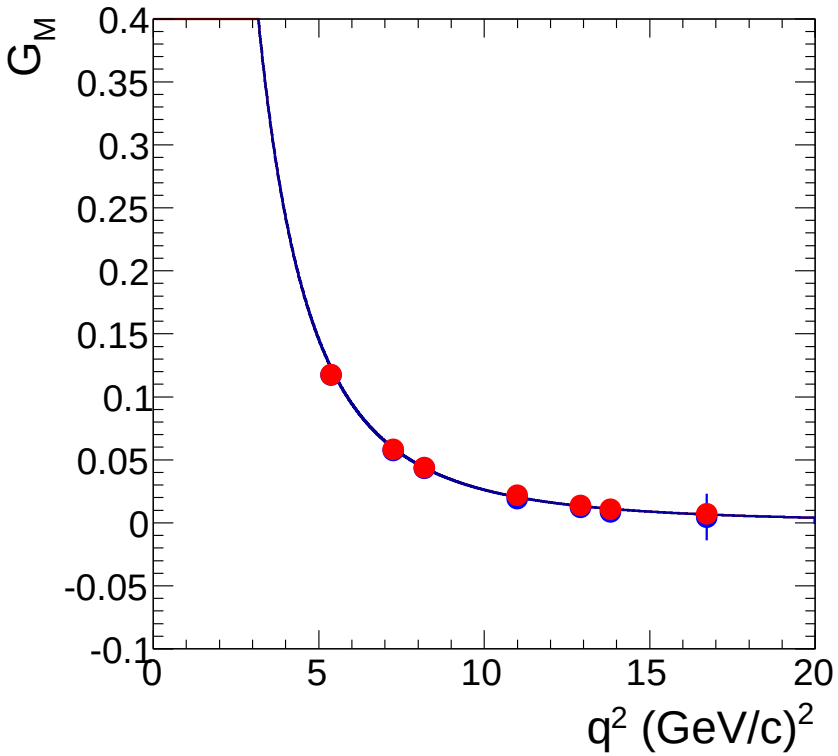
Values of G_E and G_M extracted from the fit for $G_E/G_{Minit} = 0$

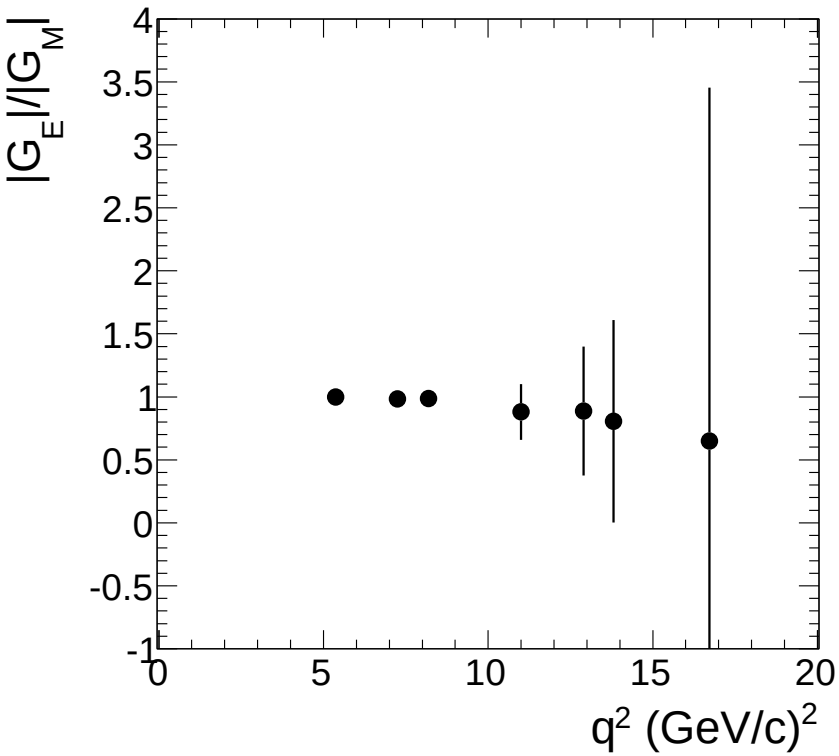




(left side)**line** - model prediction for G_M, **dots** - G_M from the fit, **line** - model prediction for G_E, **dots** - G_E from the fit, (right side)**dots** - ratio from the fit

Values of G_E and G_M extracted from the fit for $G_E/G_{Minit} = 1$





(left side)**line** - model prediction for G_M, **dots** - G_M from the fit, **line** - model prediction for G_E, **dots** - G_E from the fit, (right side)**dots** - ratio from the fit

Conclusions

- Statistical errors are expected to be of the order of few percent
- Signal efficiency sufficient for the extraction of G_E and G_M
- Background suppression factor of 10^8 achieved (background pollution $< 1\%$)