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

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ISNP Erice
September 16-24, 2011

Outline

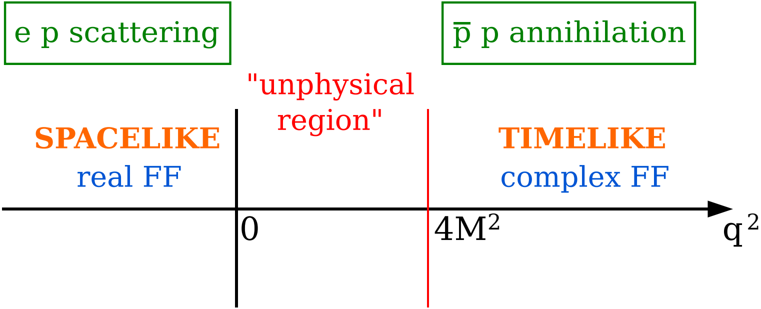
Introduction: goal

- Form Factors (FF) parametrize structure of the nucleon: G_E, G_M (Sachs FF) or F_1, F_2 (Pauli-Dirac FF)
  - functions of the four-momentum transfer q^2
  - related by $G_M = F_1 + F_2$ and $G_E = F_1 + \tau F_2$, with $\tau = q^2/4M^2$

our goal:

make feasibility studies of proton electromagnetic form factors with the $\bar{P}$ANDA detector

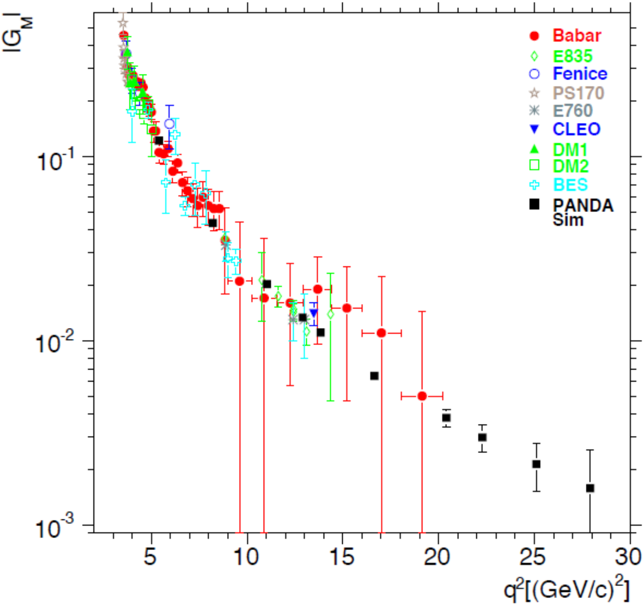
Introduction: overview



$\bar{p}p \to e^+e^-$: FF modulus

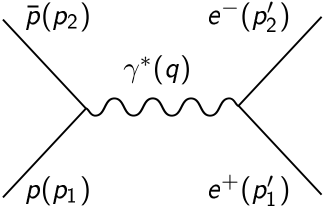
$\bar{p}p \to \pi^+\pi^-$: main background

Introduction: overview



Introduction: basics

Signal channel: $\bar{p}p \to e^+e^-$



- one-photon exchange approximation
  A. Zichichi et. al.,
  Nuovo Cimento XXIV, 170 (1962)
- in $\bar{p}p$ CM frame, cross section given by

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

where $C = \frac{\pi\alpha^2(\hbar c)^2}{8m_p^2\sqrt{\tau(\tau-1)}}$, $\tau = q^2/4m_p^2$ and

$\theta = angle(e^-\bar{p})$ in $\bar{p}p$ CM frame

- sensitive to G_E and G_M
- $q = p_1 + p_2 \Rightarrow$ kinematic threshold $q^2 > 4M^2$

Introduction: basics

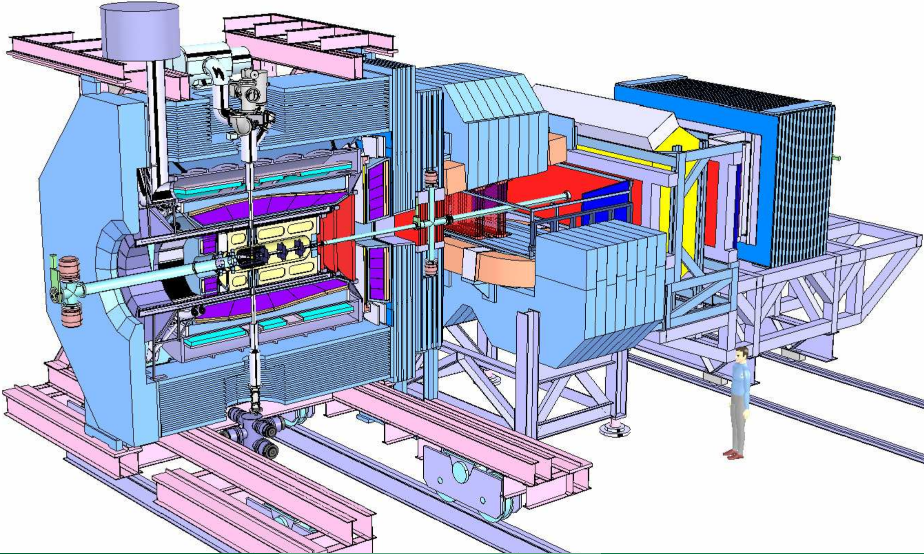
Background channel: $\bar{p}p \to \pi^+\pi^-$

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

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

- No unique cross section parametrization valid in the full kinematic range
  - low energy range: $1 < p(\bar{p}) < 2.5 GeV$ data
    Eisenhandler et. al., Nucl. Phy. B96 (1975) 109
  - high energy range: $2.5 < p(\bar{p}) < 12 GeV$ Regge model
    J. Van de Wiele and S. Ong: Eur. Phy. J. A46(2010) 291

$\bar{P}$ANDA detector



Monte Carlo Simulations

Full MC simulation:

- physics simulation: model "true-level" physics
  event generators for both signal and backround developed in Mainz
  (M. Zambrana and D. Khaneft)
- detector simulation:
  model detector response to all particles in final state

Simulation:

$$p(\bar{p}) = 4GeV/c : \begin{array}{l} N_{\bar{p}p \to e^+e^-} = 10^5 \\ N_{\bar{p}p \to \pi^+\pi^-} = 10^7 \end{array}$$

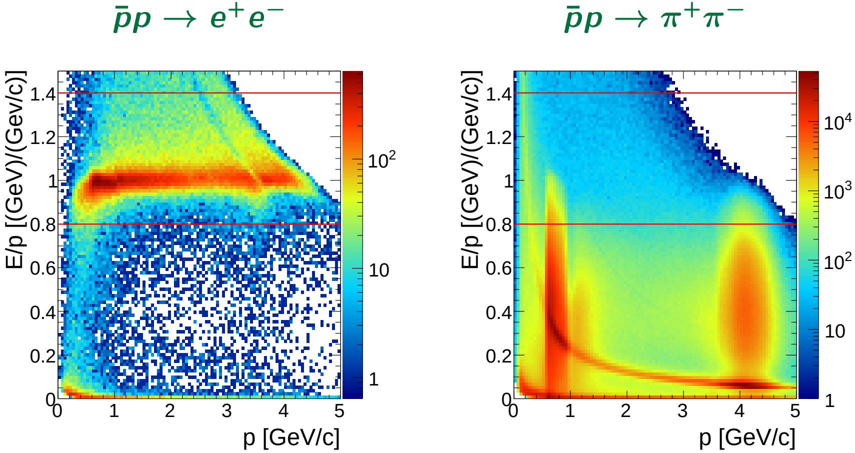
Selection criteria for e^+e^-

- Event must have **only one** positive and one negative particle after reconstruction
- Both positive and negative particle in CM frame

$$\sqrt{s}/2 - \lambda < E_{RECO} < \sqrt{s}/2 + \lambda,$$

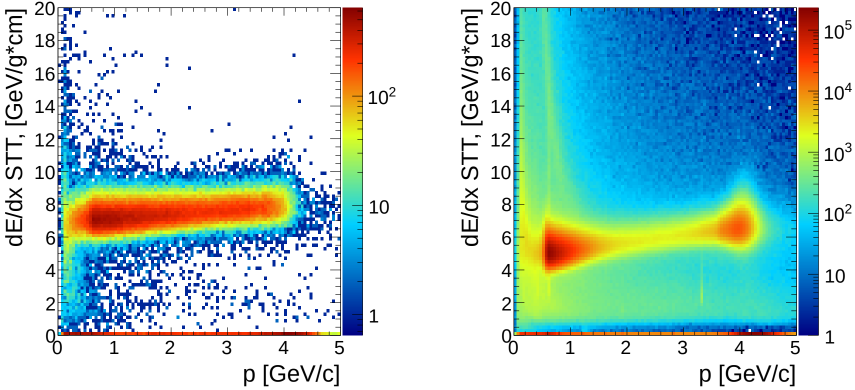
  where $\lambda = 0.2(\sqrt{s}/2)$
  For $P(\bar{p}) = 4GeV/c$, $\sqrt{s}/2 = 1.54GeV, \lambda = 0.31GeV$
- Both positive and negative particle $0.8 < E/p < 1.4[(GeV)/(GeV/c)]$
- Both positive and negative particle $\frac{dE}{dx}_{STT} > 5.8[GeV/g * cm]$

Results of the simulation using deposited energy from EMC and momentum provided by tracking



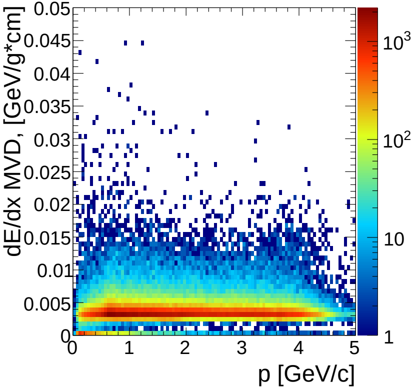
Energy loss in STT

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

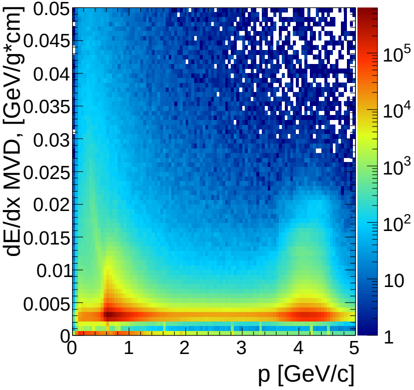


Energy loss in MVD

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

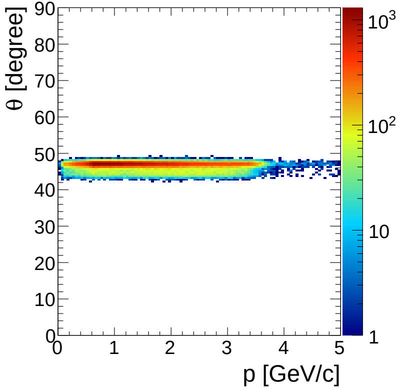


$\bar{p}p \rightarrow \pi^+\pi^-$

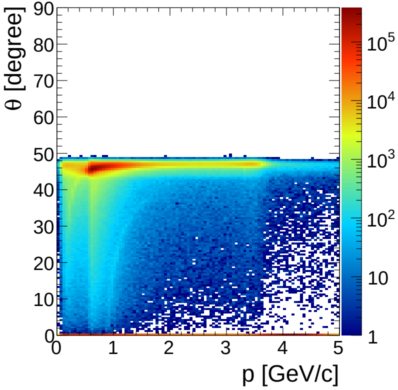


Cherenkov angle provided by barrel DIRC

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

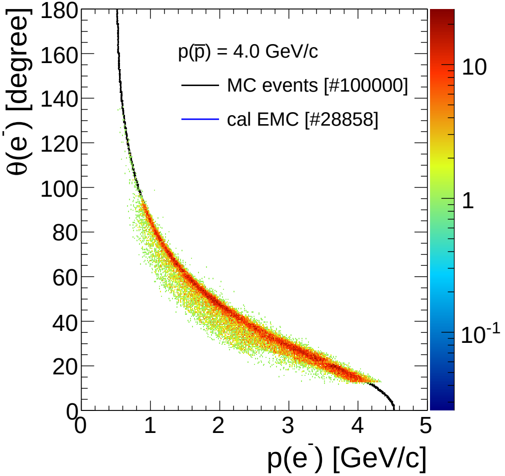


$\bar{p}p \to \pi^+\pi^-$



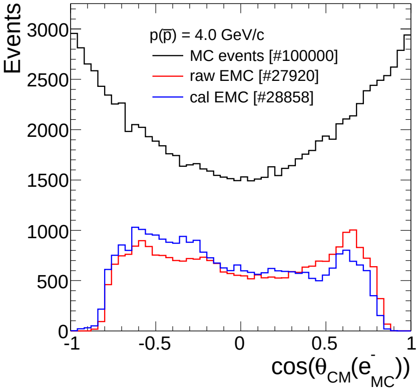
θ angle of generated and reconstructed particles

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

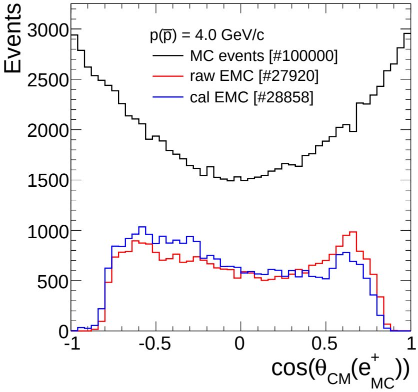


$cos(\theta_{CM})$ of generated and reconstructed particles

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



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



Number of e^+e^- and $\pi^+\pi^-$ pairs left after the cuts

type of event	e^+e^-	$\pi^+\pi^-$
MC events	10^5	10^7
raw EMC + E/p cut	57840	3186
cal EMC + E/p cut	56930	4650
raw EMC + all cuts	27920	3
cal EMC + all cuts	28858	3

Signal (e^+e^-) efficiency $27 - 28\%$
Background ($\pi^+\pi^-$) suppression almost 100% for 10^7 events

Summary and Outlook

Summary

- Developed set of cuts gives signal efficiency about $27 - 28\%$
- Achived background rejection factor about 10^7

Outlook

- New methods of background suppression
- Is it possible to get background rejection factor 10^8?
- Larger stastics for background
- Realistic statistics