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Feasibility studies for the measurement of the time-like electromagnetic form factors of the proton at PANDA

HK 45.3

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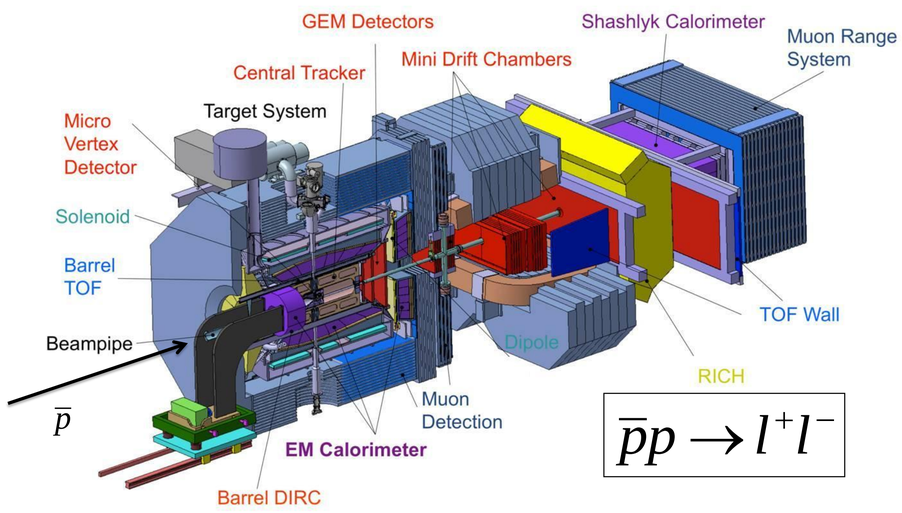
The PANDA-Detector



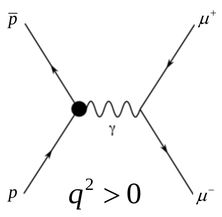
Setup of the PANDA-Detector[1]: Target and Forward Spectrometer

Simulations with PANDA Root on HIMster (Mainz)

- The process of **annihilation of antiproton and proton into a pair of charged leptons** can be used to investigate the **inner structure of the proton**
- The **high luminosity** at PANDA allows **direct extraction of the time-like electromagnetic form factors** from the angular distribution of the differential cross section
- **Simulations** using the software package **PANDA Root** can provide information about the feasibility of using such processes

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

The differential cross section for $\bar{p}p \to l^+l^-$ gives access to the moduli of the time-like electromagnetic form factors G_E and G_M.



$$\frac{d\sigma}{d\cos\theta_{CM}}(s,\theta) = \frac{\alpha^2\pi}{2\cdot s}\cdot\frac{p_{l^-}}{\bar{p}}\cdot|G_M|^2\left[\frac{4M_p^2}{s}\left(1-\beta^2\cos^2\theta_{CM}\right)\cdot R^2+\left(1+\frac{4m_l^2}{s}+\beta^2\cos^2\theta_{CM}\right)\right]$$

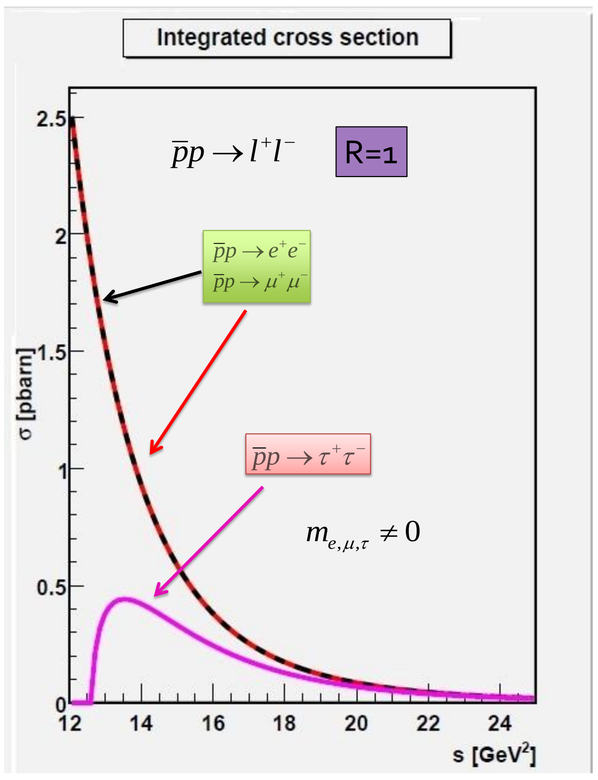
with $R = \frac{|G_E|}{|G_M|}$

- Several studies for e^+e^- have been done so far
- The **muonic channel** contains the **same information about the nucleon structure as the other channels**
- Challenge: **Separation of muon signal events from the strong hadronic background** (mostly pairs of charged pions):

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

Integrated Cross Section[2]

$$\sigma(s) = \frac{\alpha^2\pi}{s}\cdot\frac{p_{l^-}}{\bar{p}}\cdot|G_M|^2\left[\frac{4M_p^2}{s}\left(1-\frac{1}{3}\beta^2\right)\cdot R^2+\left(1+\frac{4m_l^2}{s}+\frac{1}{3}\beta^2\right)\right]$$



with parametrization for the magnetic form factor

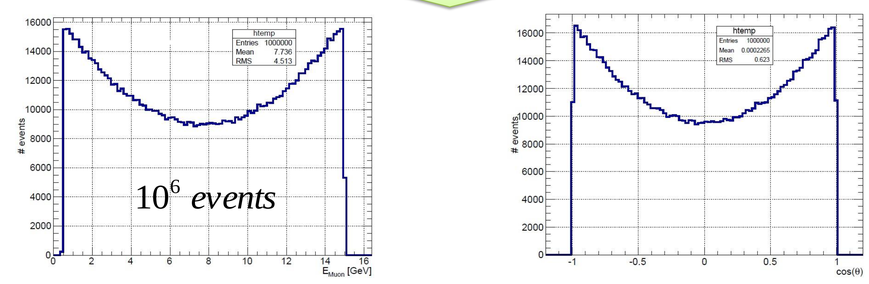
$$|G_M| = 22.5\cdot\left(1+\frac{s}{0.71}\right)^{-2}\cdot\left(1+\frac{s}{3.6}\right)^{-1}$$

- Electronic and muonic processes have high rates at low center-of-mass energies (allows precise measurement of the angular distribution)
- Tau channel has a poor cross section → not enough statistics

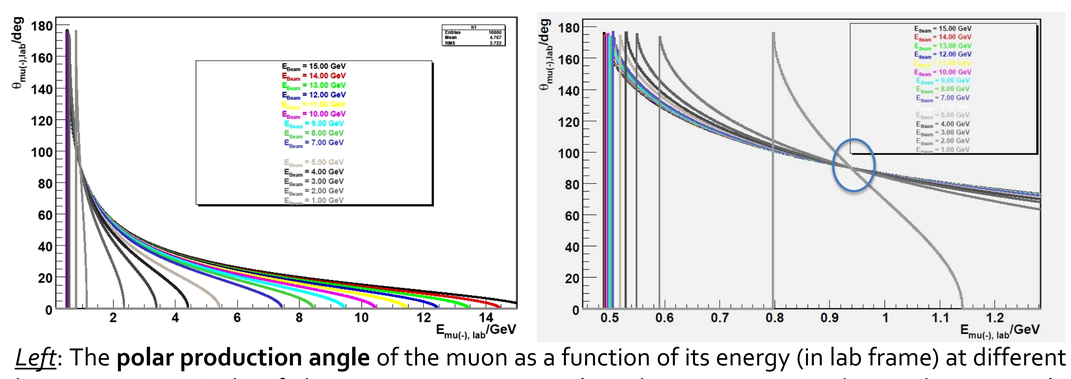
Primary Studies: Kinematical studies of $\bar{p}p \to \mu^+\mu^-$

Event Generator based on real cross section

A first **event generator for the muonic channel** for test usage based on the cross section[2] for muon production has been developed



Left: **Muon energy distribution** at a very high beam momentum of 14.5 GeV. *Right:* **Angular distribution in center-of-mass system** of the muons. Both cases contain one million events.



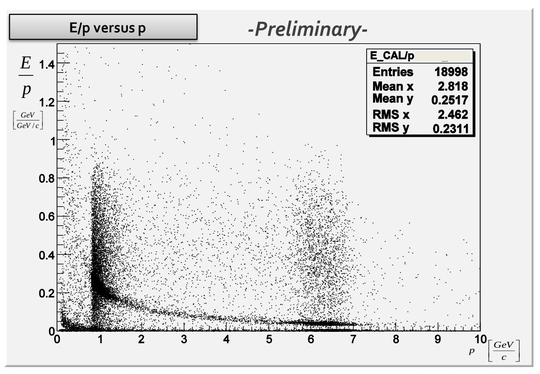
Left: The **polar production angle** of the muon as a function of its energy (in lab frame) at different beam energies. *Right*: If the muon energy is equal to the proton mass, the production angle becomes 90° (Intersection point of the curves for different beam energies).

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

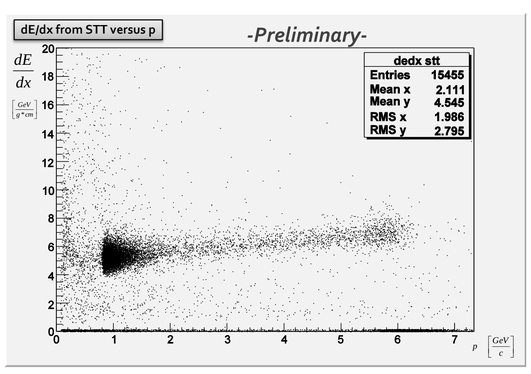
Simulation of the **main background process** using PANDA Root at a **beam momentum of 6.4 GeV** is in progress.

First preliminary results are shown below. The analysis for 10^6 events was performed using PANDA Root.

MC Simulation → Digitization → Reconstruction → Particle Identification



E/p vs. p for deposited energy in EMC after reconstruction and particle identification using PANDA Root.



Mean energy loss inside the Straw Tube Tracker (STT) versus momentum. The analysis was made for 10^4 MC events for test usage.

For the **separation of signal and background** detailed simulation and analysis of both channels are needed. A **muon event generator** has been developed[3] and will be implemented into the PANDA Root framework.

1) PANDA Collaboration, 2) Cross section derived by J. Van de Wiele, June 2011 IPN Orsay, 3) Manuel Zambrana, Institut für Kernphysik Mainz