EMP current activities

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PANDA CM 27.10.2020 (EMP session)

Publications/release notes in progress

Feasibility studies for the measurement of time-like proton electromagnetic form factors from $\bar{p}p \to \mu^+\mu^-$ at PANDA at FAIR
[arXiv:2006.16363 [hep-ex]].

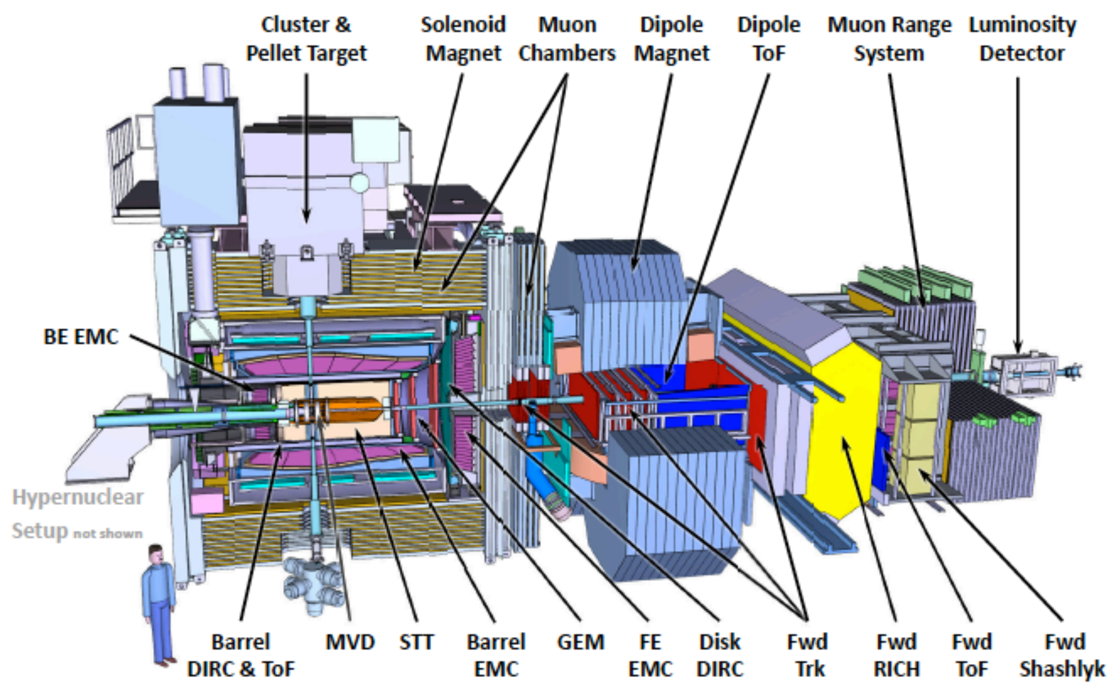
- Submitted to EPJA on June 30, 2020
- Answer from EPJA received on October 14, 2020 :
  - clear and appreciated paper;
  - the final result appears quite impressive: the form factor ratios have errors lower or similar to those of the other existing data;
  - minor modifications are suggested;
- Revised version need to be submitted within 6 weeks

Iris Zimmermann et al., HIM

Publications/release notes in progress

Main suggested modifications and questions (EPJA muon paper):

- Figure 1: for which measurement is the shown set-up meant, why is there a reference to "Hypernuclear Setup“. In the description of the experiment and the references to figure 1, it is quite annoying that different names or abbreviations are used e.g. in the text muon system is used, which I do not find in the figure, e.g. is the Forward range system the muon range system in the figure?



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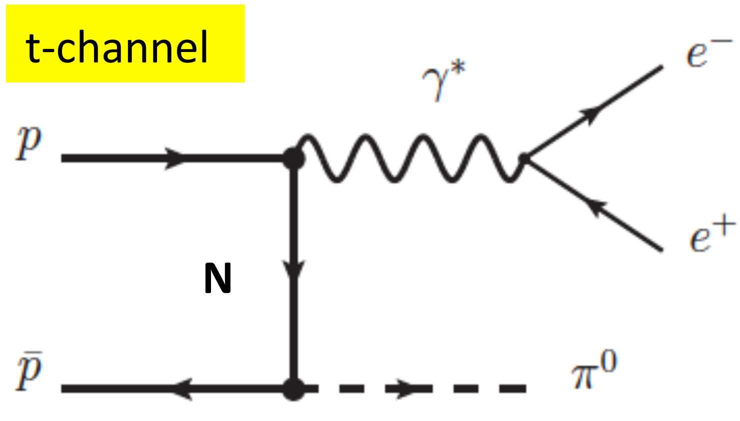
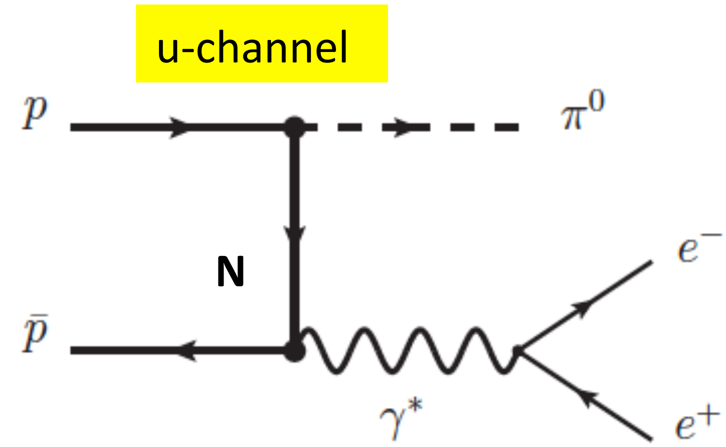
- In a recent talk it was commented that the discrepancy (between polarized elastic ep scattering data and Rosenbluth data) is largely resolved due to multiple photon exchange, you do not agree to this statement?

- how is the total systematic uncertainty calculated? are the syst. uncertain. correlated for the different energies? how is this treated in the analysis

Iris Zimmermann et al., HIM

Study of the process pbar+p -> $e^+e^-\pi^0$ at low q^2



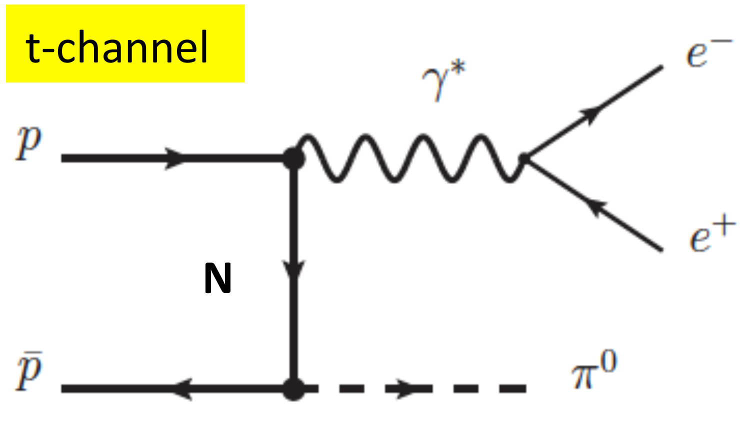


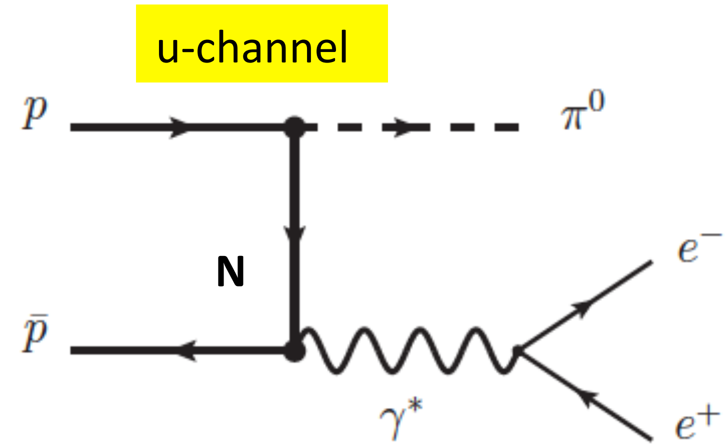
- Give access to the proton form factors in the unphysical region

- M. P. Rekalo, Sov. J. Nucl. Phys. 1 (1965) 760
- A.Z. Dubnickova , S. Dubnicka , M.P. Rekalo, Z. Phys. C 70, 473—481 (1996)
- C. Adamuscin et al., Phys. Rev. C 75, 045205 (2007)
- G. I. Gakh et al. PHYSICAL REVIEW C 83, 025202 (2011)
- Feasibility studies by J. Boucher; PhD thesis (BaBar Framework)
- J. Guttmann, M. Vanderhaeghen, PLB B 719 (2013) 136–142

Feasibility study with PANDARoot using the one-nucleon exchange model presented in June 2020:
Precision on the form factor ratio and relative phase at the order of few percent can be achieved

Study of the process pbar+p -> $e^+e^-\pi^0$ at low q^2





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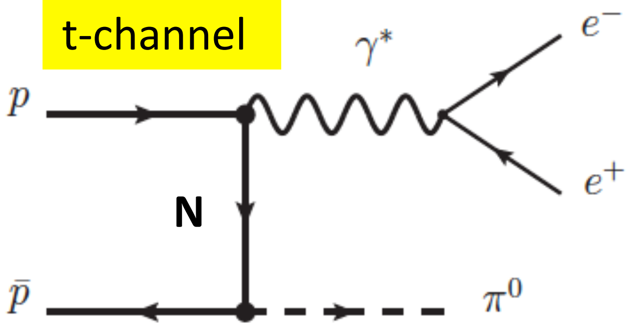
Regge pole description, which is based on the exchange of dominant baryon Regge trajectories (N and $\Delta(1232)$) at forward (|t|<<s) and backward (|u|<<s) angles.

Differential cross section within Regge framework

J. Guttmann, M. Vanderhaeghen / PLB 719 (2013) 136–142

t-channel



- Modification of the exchanged nucleon propagator:

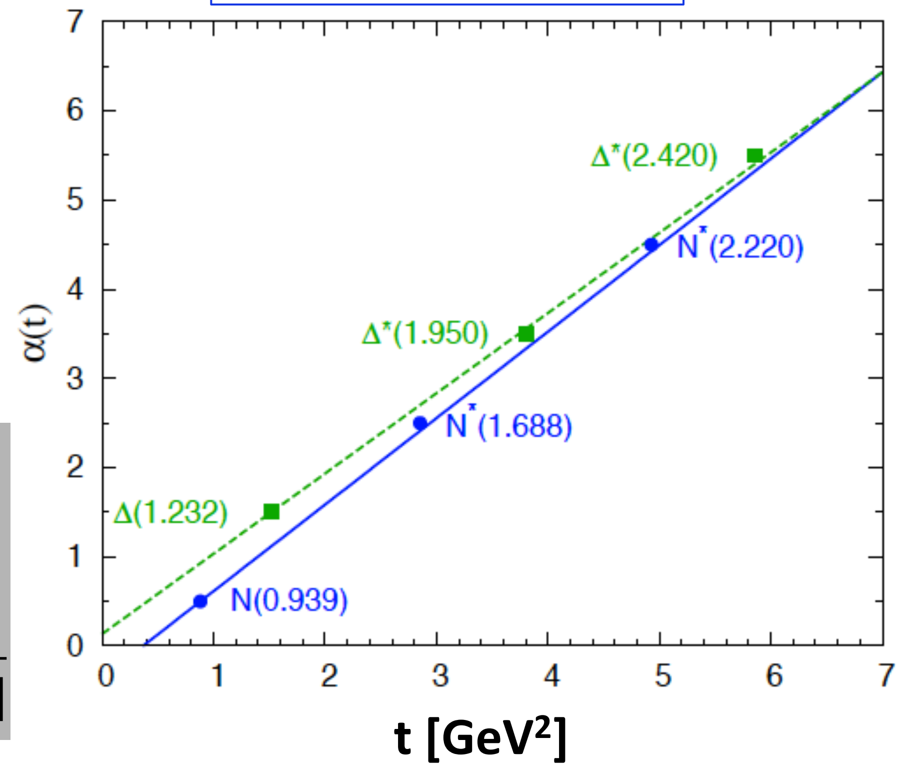
$$t-channel: \frac{1}{t-m_N^2} \rightarrow$$

$$D_N^{Regge}(t,s) = \frac{s^{\alpha_N(t)-0.5}}{\Gamma[\alpha_N(t)+0.5]} \pi\alpha_N' \frac{e^{-i\pi(\alpha_N(t)+0.5)}}{\sin[\pi(\alpha_N(t)+0.5)]}$$

- $\Gamma_{\gamma NN}$ remain unchanged - no additional unknown parameters are introduced

Regge trajectory for the nucleon

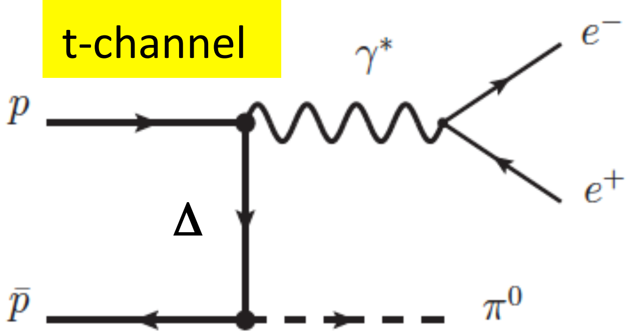
$$\alpha_N(t) = 0.5 + 0.97(t - m_N^2)$$



$$\Gamma^{\mu}_{\gamma NN}(q) = e\left[F_1(q^2)\gamma^{\mu} - \frac{i}{2m_N}F_2(q^2)\sigma^{\mu\nu}q_{\nu}\right]$$

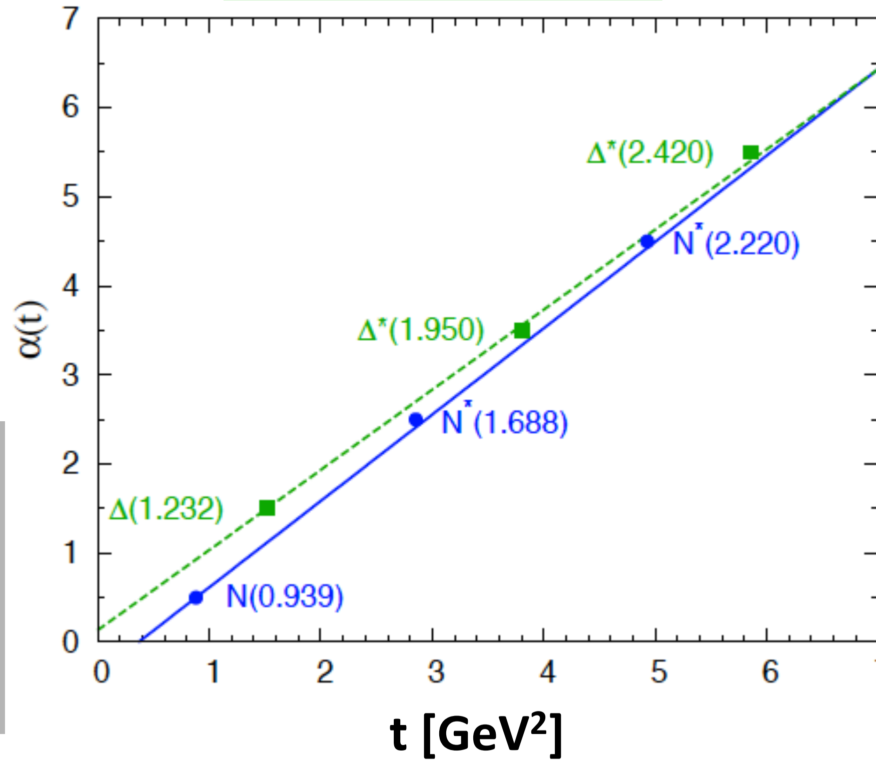
Differential cross section within Regge framework

J. Guttmann, M. Vanderhaeghen / PLB 719 (2013) 136–142



Regge trajectory for the nucleon

$$\alpha_\Delta(t) = 1.5 + 0.9(t - m_\Delta^2)$$



- Modification of the exchanged $\Delta(1232)$ propagator:

$$t - channel : \frac{1}{t - m_\Delta^2} \rightarrow$$

$$D_\Delta^{\mathrm{Regge}}(t,s) = \frac{s^{\alpha_\Delta(t)-1.5}}{\Gamma[\alpha_\Delta(t)+0.5]} \pi\alpha_\Delta^{'} \frac{e^{-i\pi(\alpha_\Delta(t)-0.5)}}{\sin[\pi(\alpha_\Delta(t)-0.5)]}$$

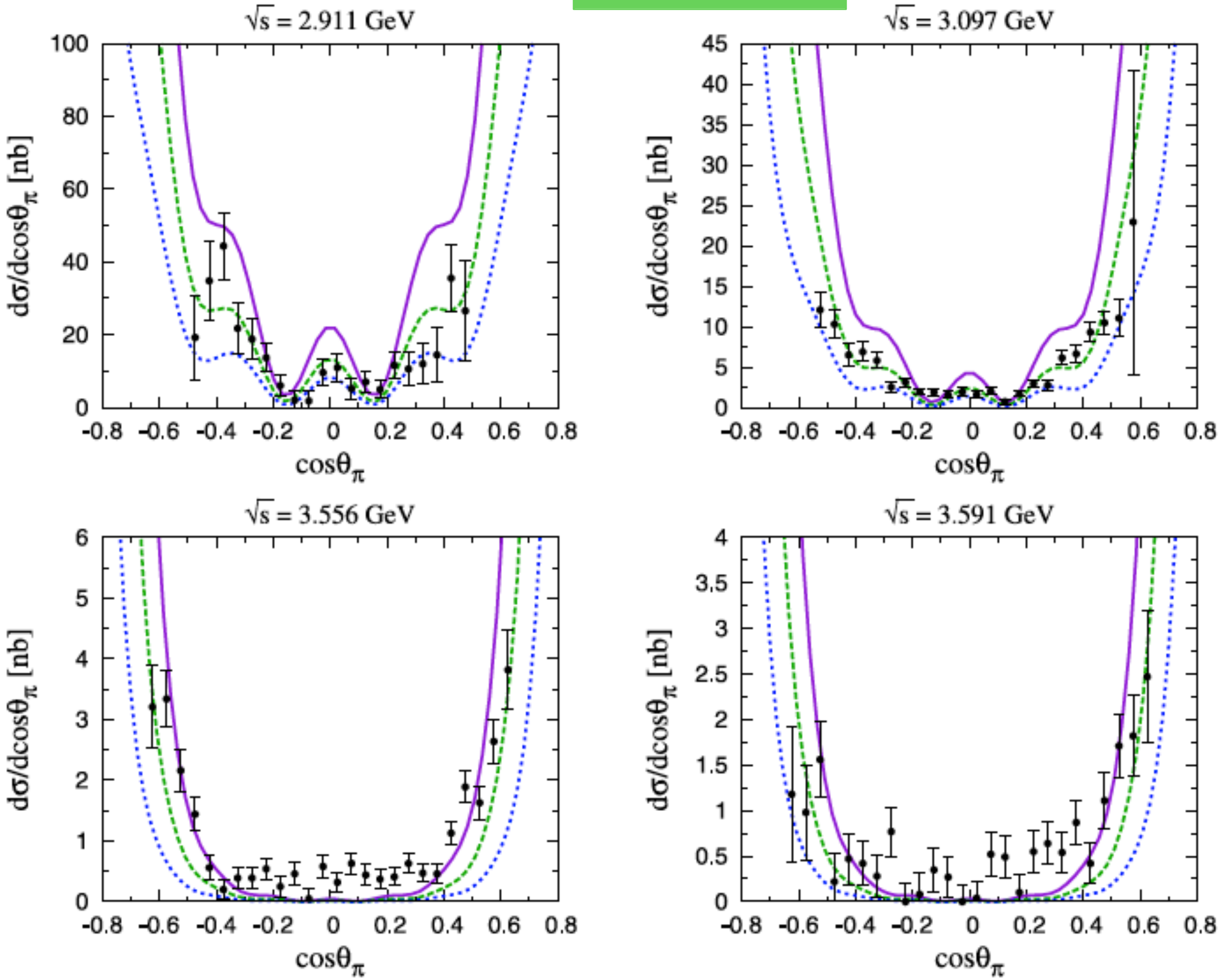
- $\Gamma_{\gamma N\Delta}$ introduces the magnetic dipole form factor G_D

$$\Gamma_{\gamma N\Delta}^{\alpha} = i\sqrt{\frac{2}{3}} \frac{3e(m_\Delta + m_N)}{2m_N((m_\Delta + m_N)^2 - q^2)} G_D(q^2)\varepsilon^{\alpha\mu\rho\sigma} p_\Delta q_\sigma$$

Differential cross section within Regge framework

J. Guttmann, M. Vanderhaeghen / PLB 719 (2013) 136–142

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



Regge (N)
Regge (N+Δ)
Regge (N+0.5Δ)

Differential cross section within Regge framework

$$\bar{p}p \to \pi^0 e^+ e^-$$

$$\frac{d\sigma}{dq^2 d\cos\theta_{\pi^0} d\Omega_e^*} = 4\pi e^2 q^2 (H_{11} + H_{22} + H_{33}) - 8e^2 p_e^{*2} \left(\frac{H_{11} + H_{22}}{2} \right.$$

$$\left. + \frac{H_{11} - H_{22}}{2} \sin^2\theta_e^* \cos 2\varphi_e^* + 2H_{13} \sin\theta_e^* \cos\theta_e^* \cos\varphi_e^* + \frac{1}{2}(2H_{33} - H_{11} - H_{22}) \cos^2\theta_e^* \right)$$

- $\theta_{\pi 0}$ pion polar angle in the laboratory frame
- θ_e^*, φ_e^* electron polar and azimuthal angle in the virtual photon rest frame (*)

$$H_{\mu\nu} = |G_M|^2 \left[\alpha_{\mu\nu} R^2 + \beta_{\mu\nu} + \gamma_{\mu\nu} R \cos(\phi_E - \phi_M) \right]$$ ← N-exchange

$$+\eta_{\mu\nu} |G_D|^2$$ ← Δ(1232)-exchange

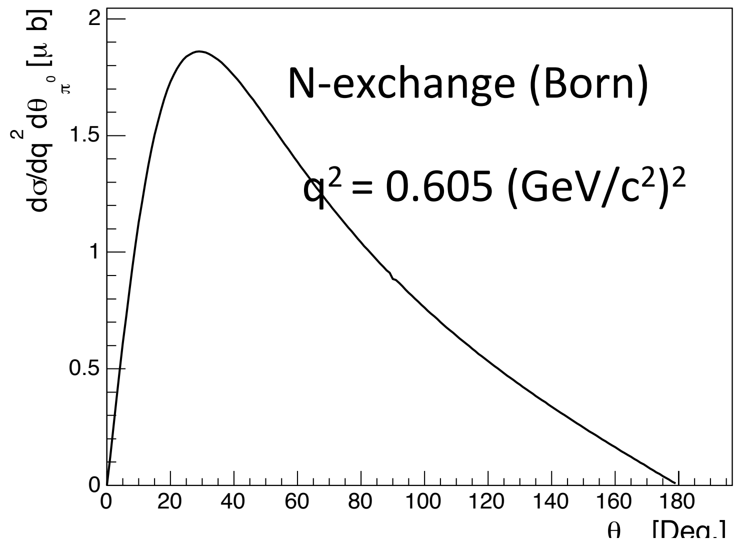
$$+|G_D||G_E| \left[\tau_{\mu\nu} \cos(\phi_E - \phi_D) + \xi_{\mu\nu} \sin(\phi_E - \phi_D) \right]$$

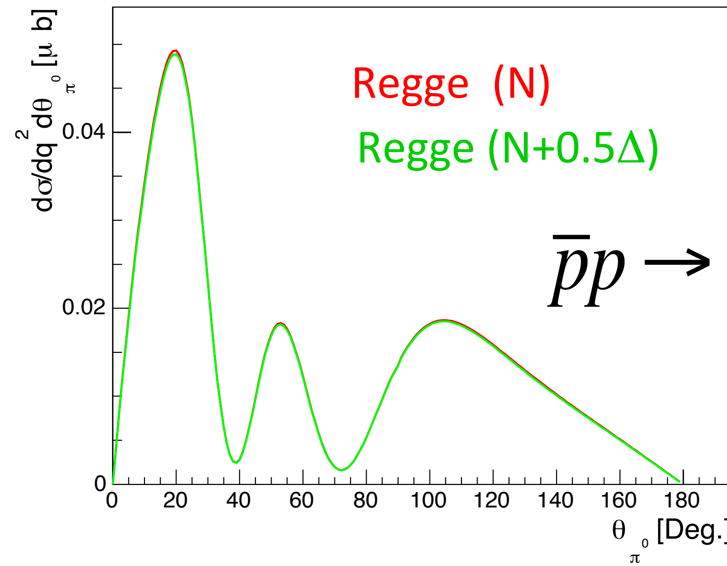
$$+|G_D||G_M| \left[\kappa_{\mu\nu} \cos(\phi_M - \phi_D) + \rho_{\mu\nu} \sin(\phi_M - \phi_D) \right]$$ ← N−Δ(1232)- interference

- $\alpha_{\mu\upsilon}$, $\beta_{\mu\upsilon}$, $\gamma_{\mu\upsilon}$, $\tau_{\mu\upsilon}$, $\xi_{\mu\upsilon}$, $\kappa_{\mu\upsilon}$, $\rho_{\mu\upsilon}$, $\gamma_{\mu\upsilon}$ depend on s, q^2 and $\theta_{\pi 0}$

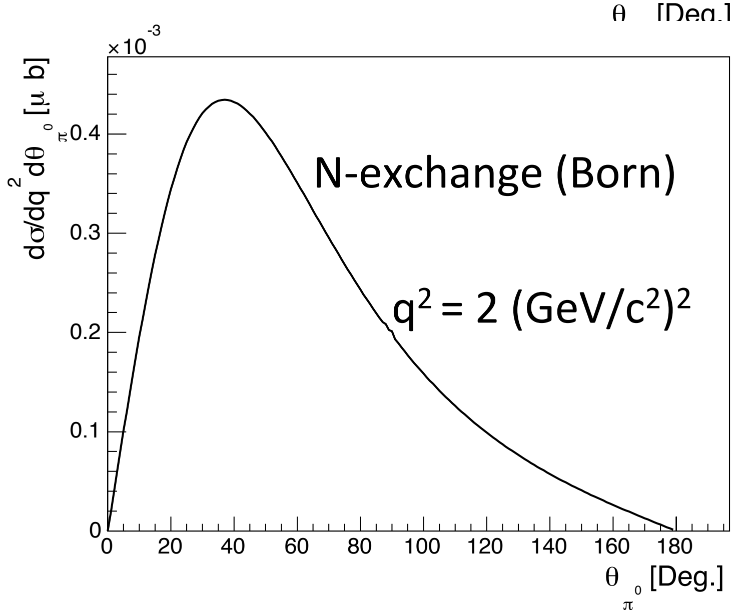
Differential cross section at plab=1.7 GeV/c

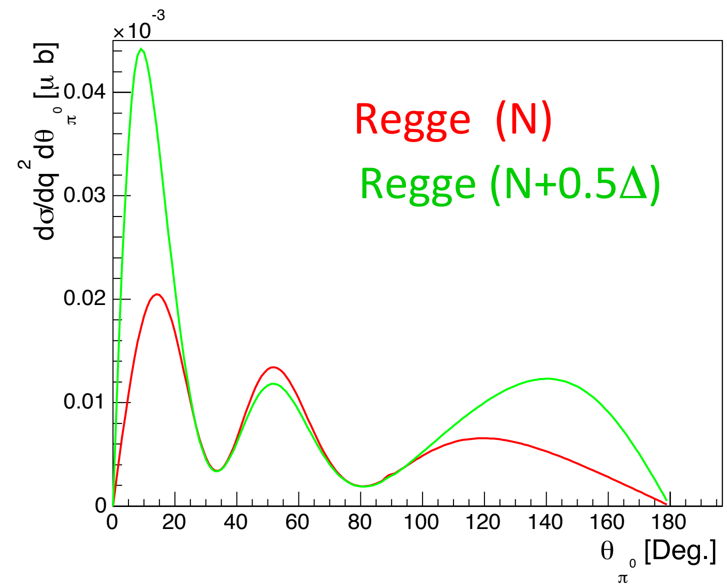
Proton form factors VMD- F. Iachello, PRC 69, 055204 (2004)



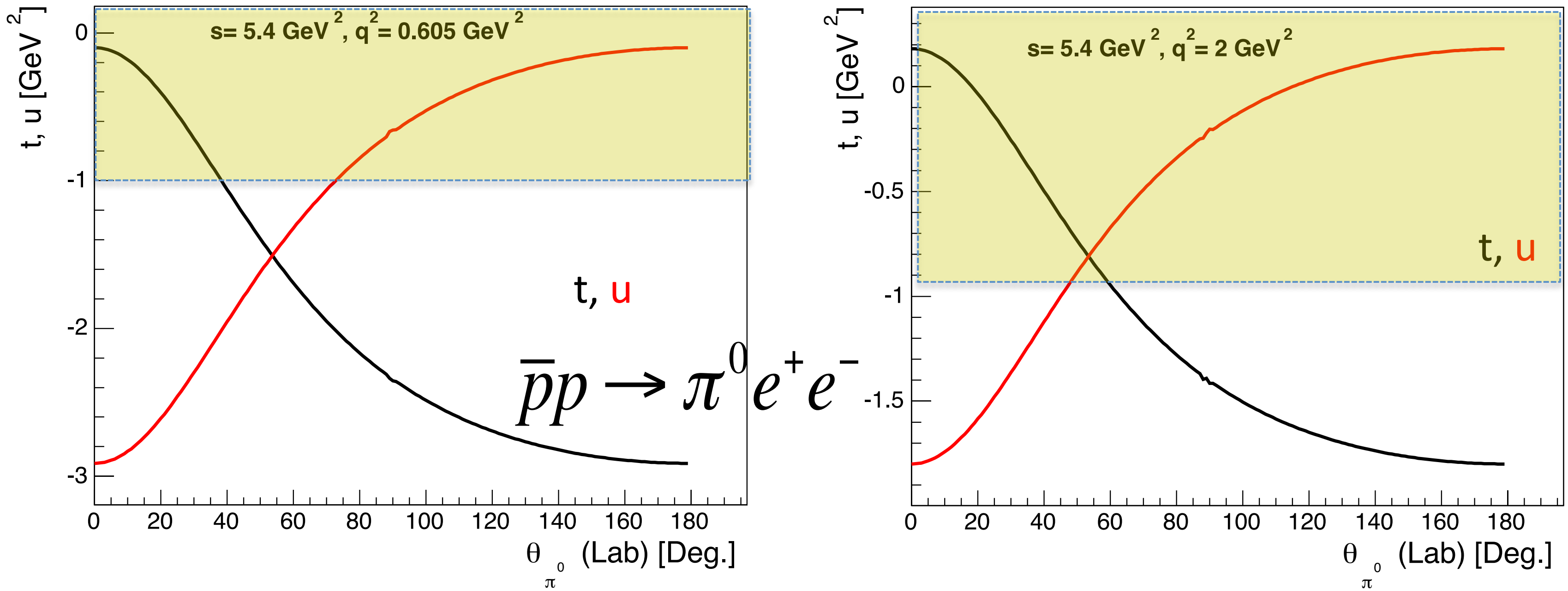


$$\bar{p}p \rightarrow \pi^0 e^+ e^-$$





Domain of measurements and number of counts



$$\bar{p}p \rightarrow \pi^0 e^+ e^-$$

L=2 fb^{-1}, proton form factors VMD- F. Iachello, PRC 69, 055204 (2004)

$s=5.4\ GeV^2$	$q^2=0.605\pm0.005\ (GeV/c^2)^2$	$q^2 = 2\pm0.125\ (GeV/c^2)^2$
$10^o < \theta_{\pi 0} < 30^o$	$2.9 . 10^7$	$1.6 . 10^4$
$30^o < \theta_{\pi 0} < 50^o$	$6.0 . 10^6$	$4.7 . 10^3$
$90^o < \theta_{\pi 0} < 100^o$	$9.2 . 10^6$	$2.2 . 10^3$
$120^o < \theta_{\pi 0} < 140^o$	$8.9 . 10^6$	$8.0 . 10^3$
$140^o < \theta_{\pi 0} < 160^o$	$5.3 . 10^6$	$7.9 . 10^3$

Other ongoing analyses

- Hard exclusive processes for GDAs/GPDs measurements at PANDA (Stefan Diehl)
- Drell-Yan processes at PANDA (Anna Skachkova)

Next steps (??) …

- Extend the nucleon-to-pion TDA studies at PANDA to other light or heavy mesons

$$\bar{p}p \to \gamma^{*} M -> e^{+}e^{-} M \qquad \bar{p}p \to J/\psi M -> e^{+}e^{-} M$$

- Radiative corrections to the electron pair production at PANDA (higher order corrections)
- Polarized target at PANDA
- Production of light mesons pairs
- ....

- *C. Adamuscin et al., Phys. Rev., C75:045205, 2007.*
- *J. P. Lansberg et al., Phys. Rev., D76:111502, 2007.*
- *B. Pire et al., Phys. Lett., B724:99-107, 2013.*
- *Y. Wang et al., Phys.Rev.C 96 (2017) 2, 025204*
- *Y. Wang et al., Phys.Rev.C 95 (2017) 4, 045202*
- *A. T. Goritschnig et al., J. Phys. Conf. Ser. 503 (2014), 012032*

Status of Drell-Yan study 2020

- Initial intention of writing a brief Note on Background studies based on pure PYTHIA simulation was refused after discussion with colleagues who deal with the similar subject.
- 10^9 background events were simulated using DPM & PandaRoot.
- During processing of the results some strange deviations on muons momenta determintaion were observed.
- In order to study such deviations -- the box generator was used to study efficiency of muon reconstruction at different angles and accuracy of known momenta determination.
  Some deviations were observed again. Their nature is not yet understood — under Investigation.
  If we will not find the reason of such a bug — we will post it later to the forum.

Further plans

- Further analisys of simulated data
- Comparison of pure Pythia signal results with the ones obtained after PandaRoot simulation.
- Possibly simulation of background events with use of PYTHIA & PandaRoot.
- Comparison and analysis of results.

Anna Skachkova 27.10.2020