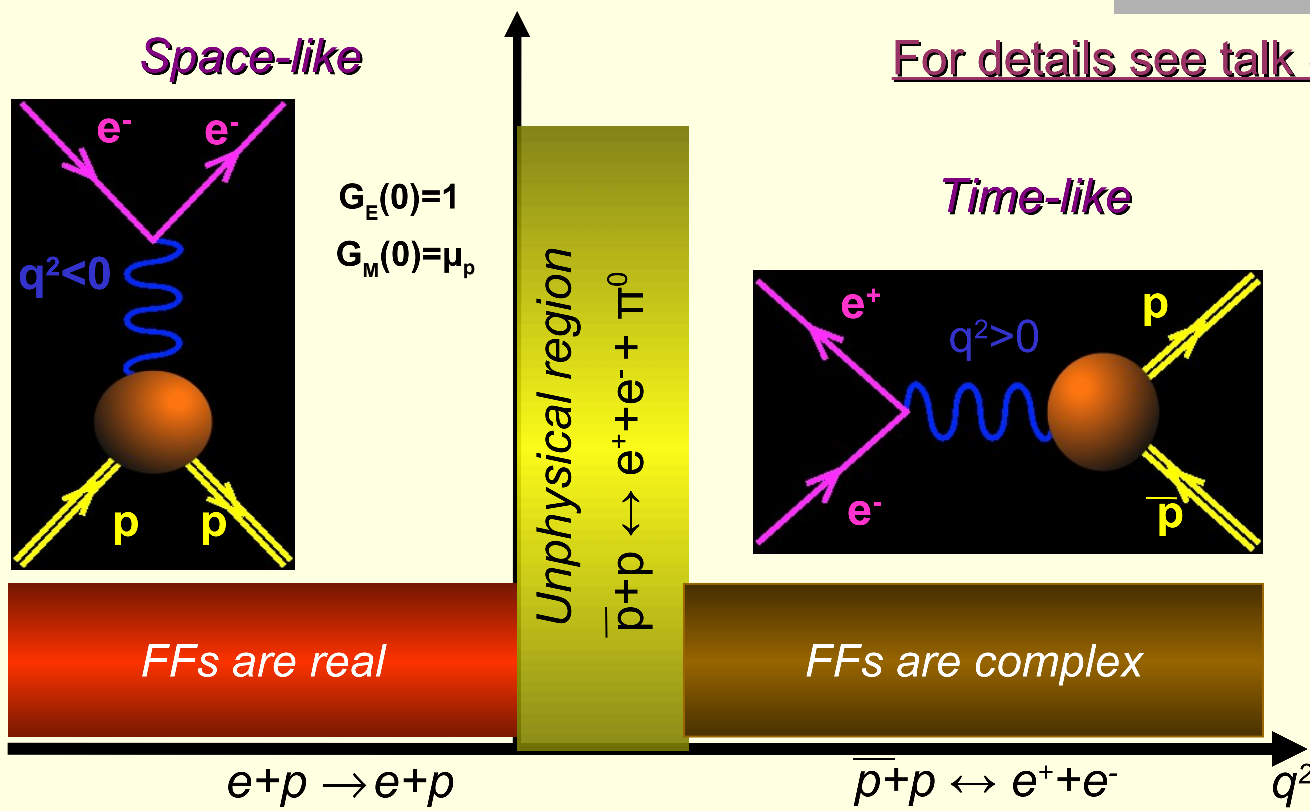
Time-like nucleon form factors measurements at PANDA

Małgorzata Sudoł

IPNO/CNRS, France

Proton form factors

<u>For details see talk S.Pacetti</u>



$\sigma\left(\bar{p}\,p \rightarrow e^{+}e^{-}\right)$ in 1 photon exchange:

$$\frac{d\sigma}{d\cos\theta_{CM}} = \pi \frac{\alpha^{2}}{8M_{p}^{2}\sqrt{\tau\left(\tau-1\right)}}\left[\left(G_{M}\right)^{2}\left(1+\cos^{2}\theta_{CM}\right)+\frac{\left(G_{E}\right)^{2}}{\tau}\sin^{2}\theta_{CM}\right]$$

$$\tau = \frac{q^{2}}{4m_{p}^{2}}$$

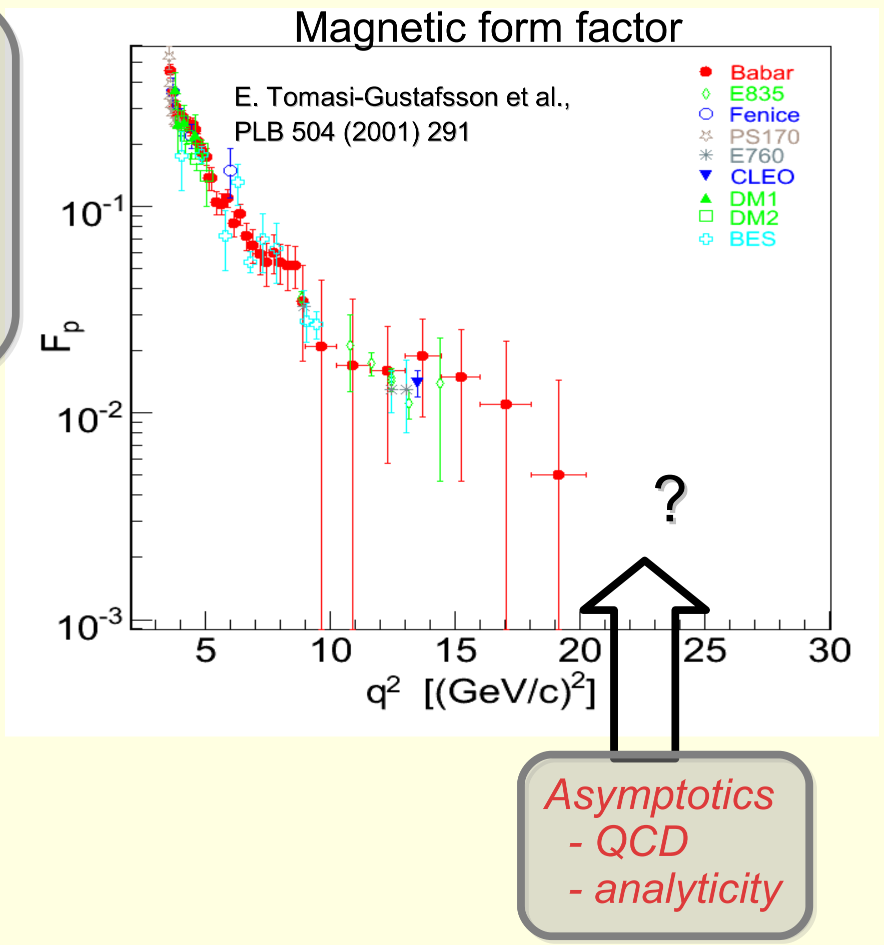
magnetic form factor

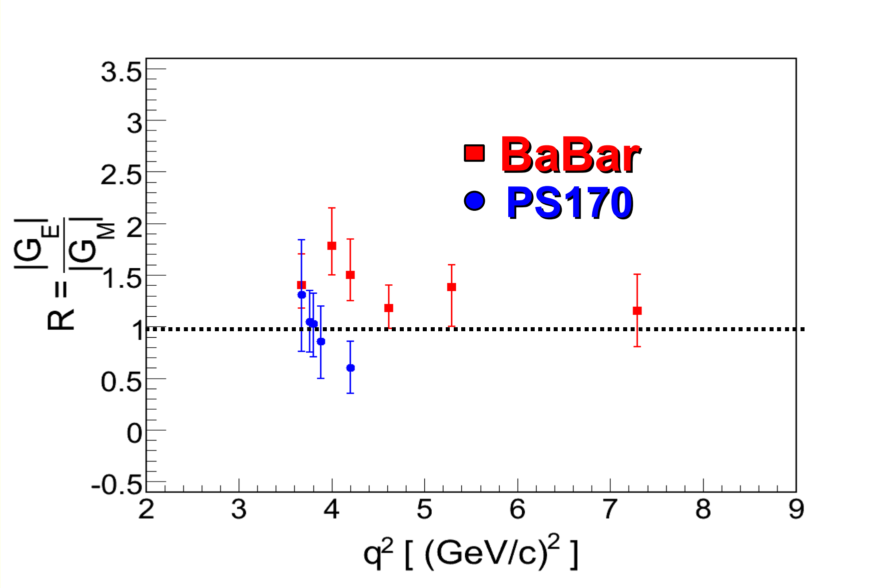
electric form factor

Status of the experimental data

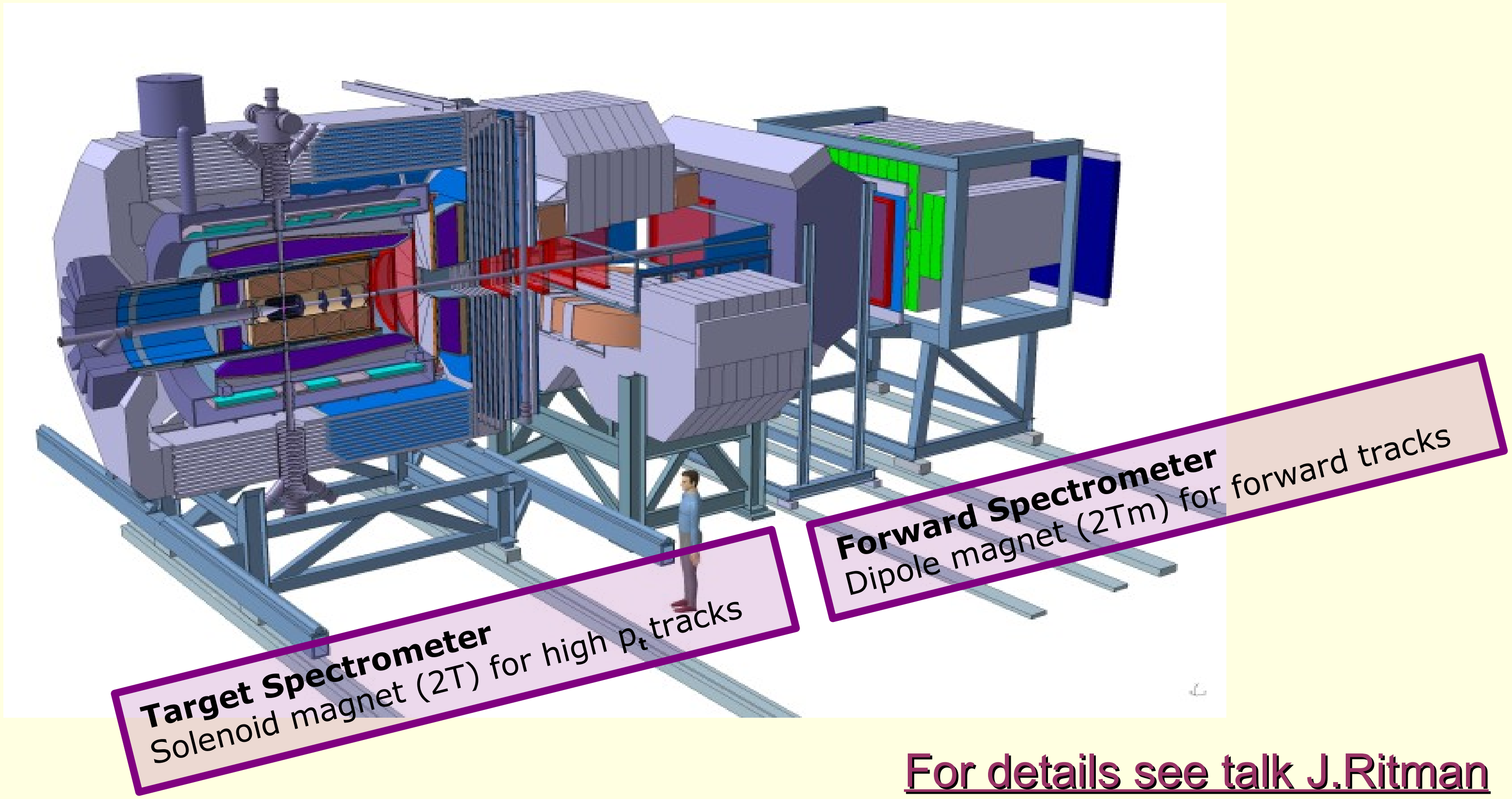
Experimental status:

- New, precise, surprising data in space-like
- All existing data in the time-like region were analyzed under assumption of $|G_E| = |G_M|$ (F_p) or $|G_E| = 0$.





PANDA detector @ FAIR



For details see talk J.Ritman

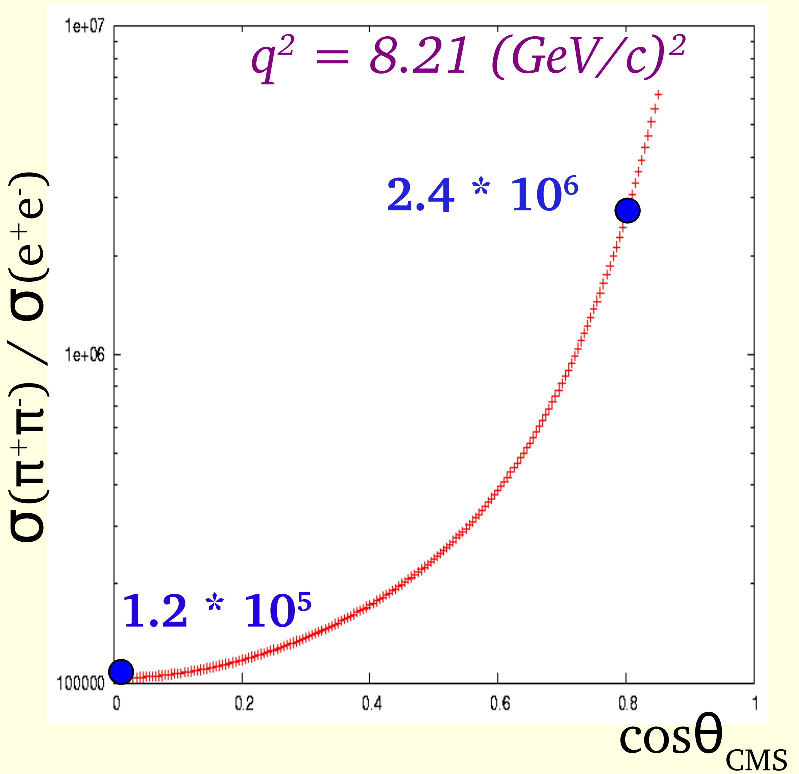
Detector requirements:

- nearly 4π solid angle for PWA;
- high rate capability: 2×10^7 interactions/s;
- efficient event selection;
- good momentum resolution $\Delta p/p \approx 1\%$;
- vertex resolution < 100 μm
  for K^0, Σ, Λ, ($D^{\pm}$, $c\tau \approx 317$ μm);
- good PID (γ, e, μ, π, K, p);
- γ detection -> few MeV < E_γ < 10 GeV.

Feasibility study

Important aspects in the determination of the proton form factors:

- Background contamination
- Sensitivity to G_E and G_M



Background reactions

➔ **3 body reactions** ('easy' to eliminate)
  ➔ Tracking in magnet, θ and φ correlations,
  ➔ Missing or invariant mass cuts, PID

➔ **2 charged body reactions**
  (e.g. $\pi^+\pi^-$, $\mu^+\mu^-$, K^+K^-)
  ➔ Most important background is $\pi^+\pi^-$,
  ➔ Kinematical correlation $p=f(\theta)$,
  ➔ PID very important,

Background suppression, signal efficiency

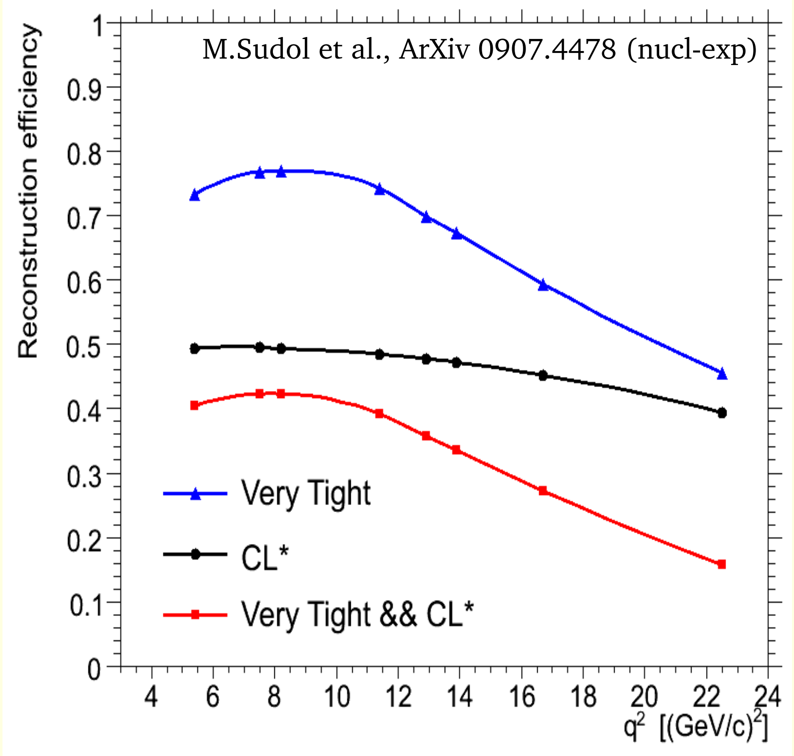
Background suppression after **Very Tight** PID cuts:

- 8.2 $(GeV/c)^2$: $2/10^8$
- 12.9 $(GeV/c)^2$: $5/10^8$
- 16.7 $(GeV/c)^2$: $6/10^8$

Additional factor ~ 100 applying the kinematic fit

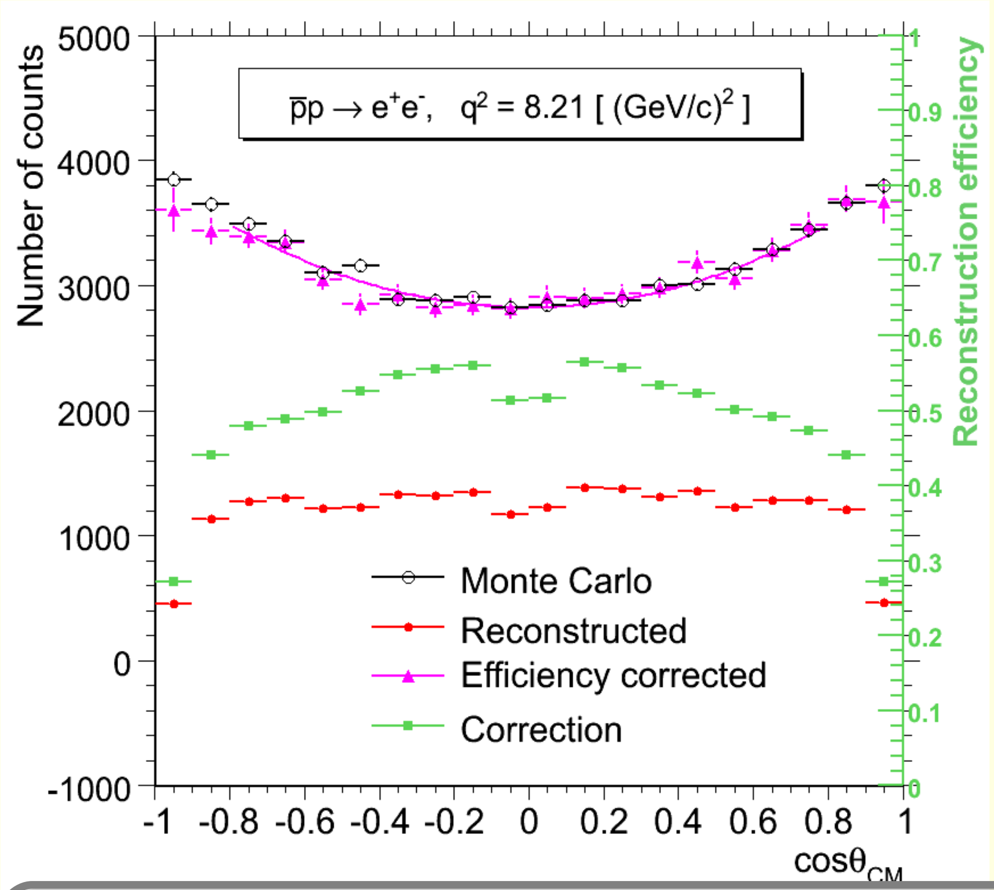
Background suppression factor is at least of the order of 10^{-9} taking into account PID & kinematic fit !!

Efficiency integrated ($|G_E|=|G_M|$) over $|\cos\theta| < 0.8$



- Efficiency decreasing with the q^2 value.
- The efficiency of the CL* cut constant over the full q^2 value.

Monte Carlo, reconstructed, efficiency corrected spectra

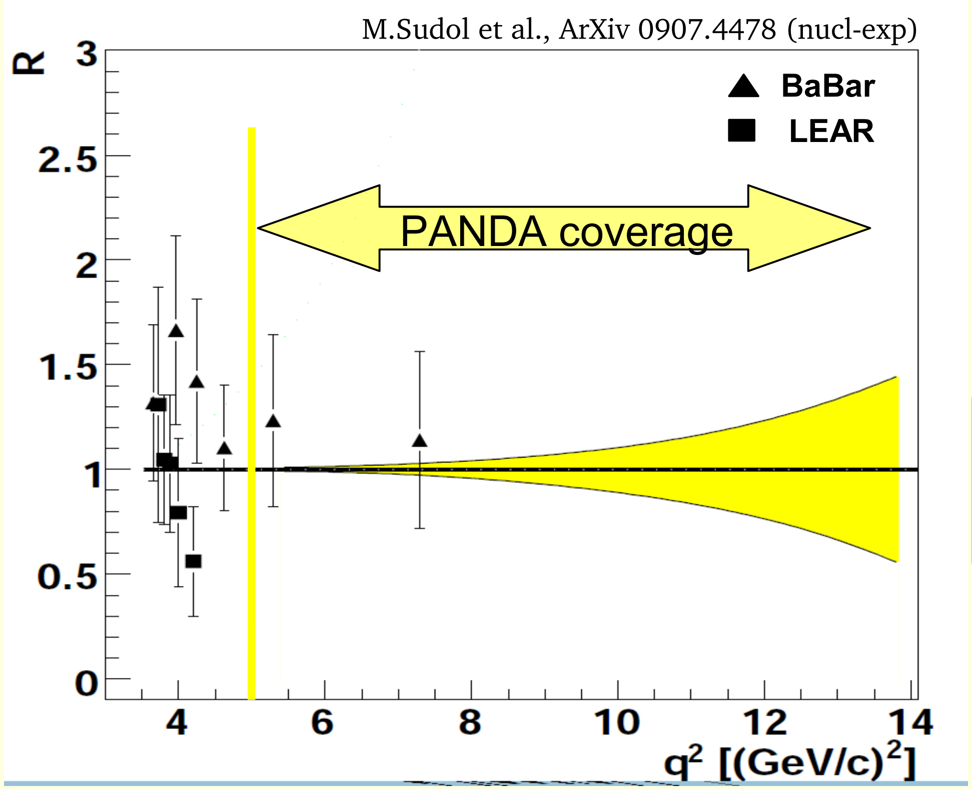


For the efficiency correction determination isotropic distributions with high statistics have been used.

We fitted every resulting efficiency corrected e+e- angular distributions in order to determine the error on the ratio $|G_E|/|G_M|$ with a linear 2 parameter fit.

$$N(\cos\theta) = C * \left[\tau\left(1+\cos^2\theta\right) + R^2\sin^2\theta\right]$$

Comparison with the BaBar and PS170 results



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

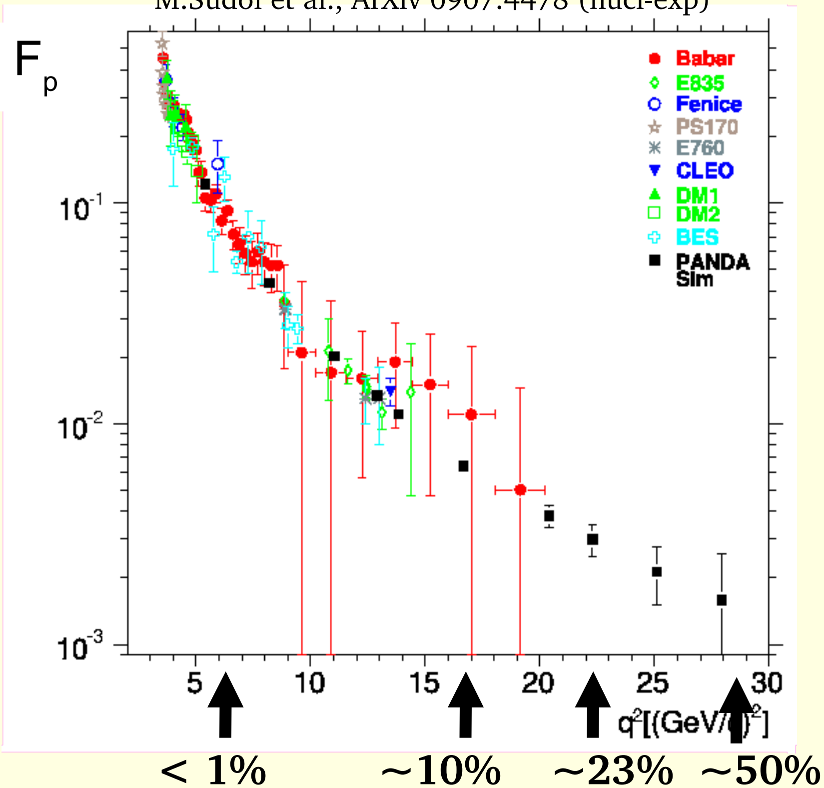
Yellow band represents the errors from the fits to the efficiency corrected data.

Measurement of G_E/G_M ratio with PANDA can be done with

- much better precision than BaBar or LEAR.
- will improve the error bars at the low q^2

Effective proton form factor : world data

M.Sudol et al., ArXiv 0907.4478 (nucl-exp)



PANDA: 120 days, L=2 fb^{-1}

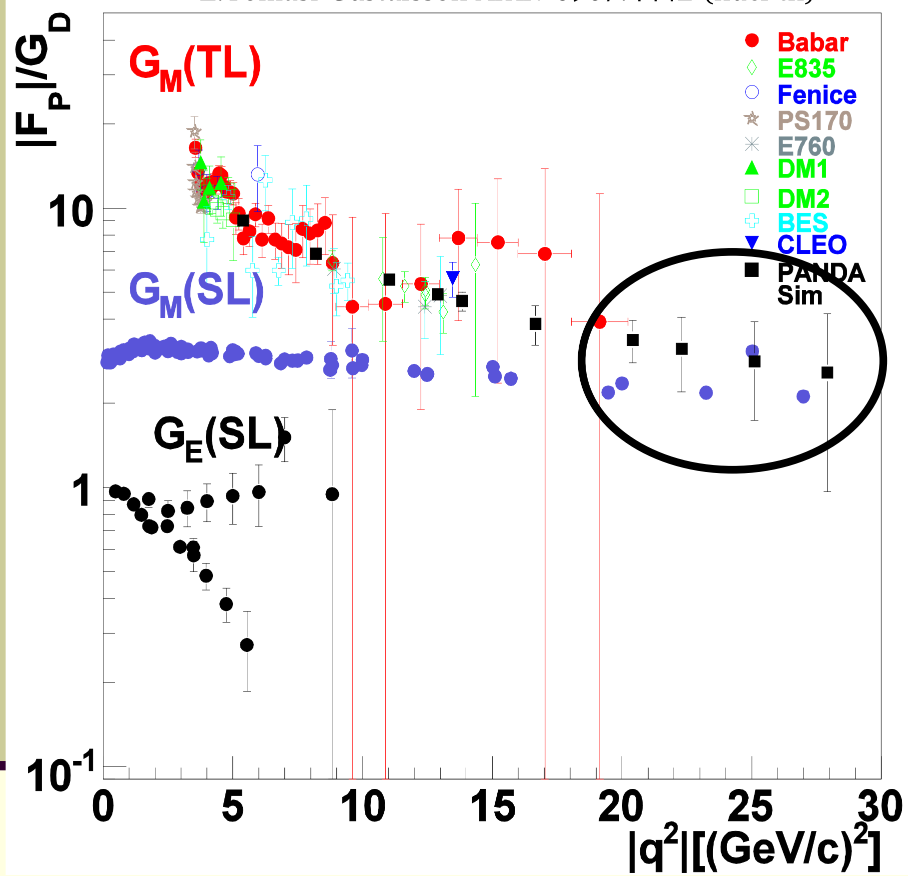
Effective proton form factor extracted from different experiments using:

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

In all cases, the hypothesis of $|G_E| = |G_M|$ has been used to analyze the data.

Effective proton form factor : world data

E.Tomasi-Gustafsson ArXiv 0907.4442 (nucl-th)



pQCD predicts asymptotic behavior of G_M

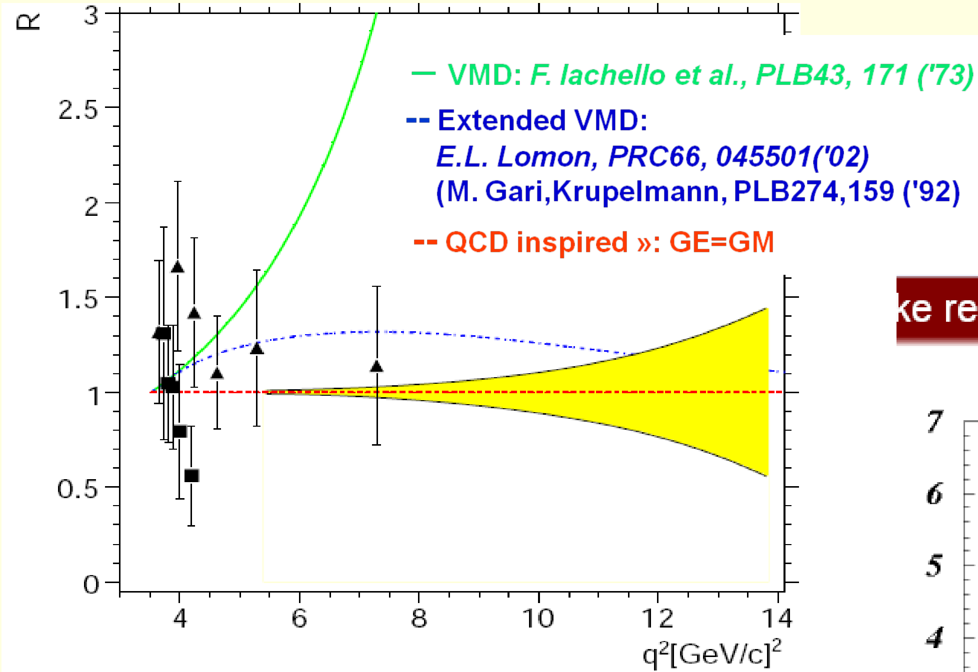
$$\lim_{q^2\to\infty} G_M\left(q^٢\right) \propto \frac{١}{q^٤}$$

Phargmen-Lindeloef theorem (asymptotic properties of FFs):

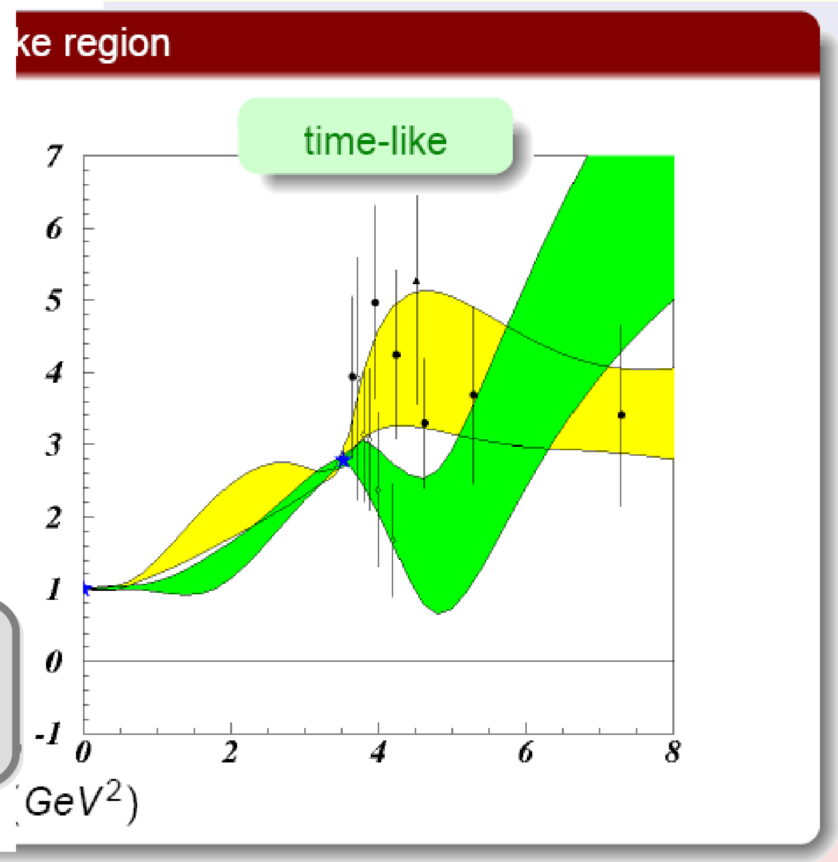
$$\lim_{q^2\to-\infty} F^{SL}\left(q^2\right) = \lim_{q^2\to+\infty} F^{TL}\left(q^2\right)$$

PANDA will provide a new set of good quality data that can be compared to the SL data in a region where the asymptotic behavior of form factors might show up.

Theoretical models



@ S. Pacetti



PANDA will discriminate between models and will add more constrains to dispersion relation

Outlook & conclusion

PANDA will improve measurement of:

- Proton magnetic AND electric form factors up to $q^2 = 14\ (\text{GeV}/c)^2$,
- Cross sections (dominated by the magnetic form factors) up to $q^2 = 30\ (\text{GeV}/c)^2$

- Sensitivity to odd cosθ contribution have been studied (>5%),
- Unphysical region can be accessed via $\bar{p}\, p \rightarrow e^+ e^- \pi^0$