Baryon Form Factors: Where do we stand?

668. WE-Heraeus-Seminar

April 23 - 27, 2018
at the Physikzentrum Bad Honnef/Germany

WILHELM UND ELSE
HERAEUS-STIFTUNG

Subject to alterations!

Introduction

The Wilhelm and Else Heraeus Foundation (Wilhelm und Else Heraeus-Stiftung) is a private foundation which supports research and education in science, especially in physics. A major activity is the organization of seminars. To German physicists the foundation is recognized as the most important private funding institution in their fields. Some activities of the foundation are carried out in cooperation with the German Physical Society (Deutsche Physikalische Gesellschaft).

Scope of the 668. WE-Heraeus-Seminar:

Electromagnetic form factors are basic quantities containing the dynamical information of the hadron structure. Although form factors constitute one of the main fields of research on hadron physics since many years, recent technical developments and discoveries modified essentially our understanding of the nucleon and opened new questions. The surprising results obtained by the JLab-GEp Collaboration, using the Akhiezer-Rekalo polarization method, have shown a decreasing of the ratio of electric to magnetic form factor of the proton, contrary to what currently assumed. Electron-positron colliders, using the initial state radiation have given precise results in the time-like region, showing the presence of regular structures. Questions on the reaction mechanism and on the size and dependence of radiative corrections on the kinematical variables are open. New, sophisticated tools start to be available, as dedicated Monte Carlo and a web site for data basis. Active developments of methods and phenomenology aim to a global understanding in time-like and space-like regions. Gathering experimentalists and theoreticians seems timely for a critical discussion of the recent results and reanalysis of data obtained at DESY, VEPPII, JLab, BABAR and BESIII, before the future measurements such as the upgraded JLab experiments, and at the future facility FAIR. The aim of this seminar is to:

- clarify past and recent experimental results and critically compare different analysis and interpretations
- discuss the present data from two photon exchange experiments and the applied corrections
- deepen the understanding of the reaction amplitudes for the crossed elementary processes involving electrons and protons, through a unified analysis in space and time-like regions.

Introduction

Scientific Organizers:

Prof. Egle Tomasi-Gustafsson	IRFU, CEA, Université Paris-Saclay, France E-mail egle.tomasi@cea.fr
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Registration:

Jutta Lang (WE-Heraeus Foundation)
at the Physikzentrum, reception office
Sunday (17:00 h – 21:00 h) and
Monday morning

Door Code:

(Key symbol button) 2 6 6 8 #
For entering the Physikzentrum
during the whole seminar

Program

Program

Sunday, April 22, 2018

17:00 – 21:00	Registration	
18:30	*BUFFET SUPPER / Informal get together*	

Monday April 23, 2018

08:00	*BREAKFAST*	
09:00 – 09:20	Scientific organizers	**Opening and welcome**
09:20 – 10:10	Eduard Brash	**Elastic electromagnetic form factors in the space-like region: Recent results and future experiments**
10:10 – 10:40	*COFFEE BREAK*	
10:40 – 11:30	Monica Bertani	**An experimental overview of time-like electromagnetic baryon form factors**
11:30 – 12:20	Egle Tomasi-Gustafsson	**On the physical meaning of time-like electromagnetic form factors**
12:20	**Conference Photo** (in the foyer of the lecture hall)	
12:30	*LUNCH*	

Program

Monday, April 23, 2018

14:30 – 15:20	Andrej Arbuzov	**Higher order QED radiative corrections to elastic electron-proton scattering**
15:20 – 16:10	Alexander Dorokhov	**The contribution of light mesons to hyperfine structure of muonic hydrogen**
16:10 – 16:40	*COFFEE BREAK*	
16:40 – 17:20	Carlo Carloni Calame	**The BabaYaga event generator**
17:20 – 17:40	Stefan Jorda	**About the Wilhelm and Else Heraeus Foundation**

17:40 – 18:15 **Poster flash presentations** (3 min. / 2 slides each)

18:30 *DINNER*

Program

Tuesday, April 24, 2018

08:00	*BREAKFAST*	
09:00 – 09:50	Evegny Solodov	**The NNbar and multihadron production at the nucleon threshold at VEPP2000**
09:50 – 10:40	Alexandr Milstein	**Fine structure of the nucleon electromagnetic form factors in the vicinity of the threshold of e^+e^- annihilation into nucleon-antinucleon pair**
10:40 – 11:10	*COFFEE BREAK*	
11:10 – 12:00	Christoph Rosner	**Proton time-like electromagnetic form factor measurements at BESIII**
12:00 – 12:30	Xiaorong Zhou	**Cross section measurement of Lambda Lambdabar production at BESIII**
12:30	*LUNCH*	
14:30 – 15:20	James Ritman	**Investigation of the transition form factors of excited hyperons with HADES**
15:20 – 16:10	Karin Schönning	**Electromagnetic form factors of hyperons - Present and future**
16:10 – 16:40	*COFFEE BREAK*	
16:40 – 18:30	**Poster session**	
18:30	*DINNER*	

Program

Wednesday, April 25, 2018

08:00	*BREAKFAST*	
09:00 – 09:50	Elena Santopinto	**Form factors in three quark models and in quark diquark models**
09:50 – 10:40	Rinaldo Baldini Ferroli	**Anomalies in time-like baryon form factors**
10:40 – 11:10	*COFFEE BREAK*	
11:10 – 12:00	Cédric Mezrag	**Partons distributions amplitudes and form factors at large momentum transfer**
12:00 – 12:30	**Discussions**	
12:30	*LUNCH*	
14:30 – 18:30	**Excursion** (leisurely hike in the vicinity)	
18:30	*HERAEUS DINNER* *(cold & warm buffet, free beverages)*	

Program

Thursday, April 26, 2018

08:00	*BREAKFAST*	
09:00 – 09:50	Eric Voutier	**The low-Q^2 experimental effort for the measurement of the proton radius**
09:50 – 10:40	Mostafa Hoballah	**Constraints on low Q^2 data for the extraction of the proton charge radius**
10:40 – 11:10	*COFFEE BREAK*	
11:10 – 12:00	Michael Kohl	**Results and implications of OLYMPUS**
12:00 – 12:30	**Discussions**	
12:30	*LUNCH*	
14:30 – 15:20	Nikolay Piskunov	**Measurement of analyzing powers of the np charge exchange reaction in the GeV region**
15:20 – 16:10	John Annand	**Charge-exchange neutron scattering: Extending recoil-polarimetry measurements of G_{En}/G_{Mn} to high values of Q^2**
16:10 – 16:40	*COFFEE BREAK*	
16:40 – 17:30	Frank Maas	**Antiproton annihilation studies with the PANDA experiment at FAIR**
18:00	*DINNER*	

Program

Friday, April 27, 2018

08:00	*BREAKFAST*	
09:00 – 09:50	Inti Lehmann	**FAIR – Where do we stand?**
09:50 – 10:40	Iris Zimmermann	**Feasibility studies for the measurement of time-like electromagnetic form factors of the proton at PANDA-FAIR**
10:40 – 11:00	*COFFEE BREAK*	
11:00 – 11:30	Marco Maggiora	**Perspectives in Hadron Physics, an example of international collaboration**
11:30 – 12:00	Scientific organizers	**Poster awards, summary and closing remarks**
12:00	*LUNCH*	

End of the seminar *and FAREWELL COFFEE* ***/ Departure***

Please note that there will be ***no*** *dinner at the Physikzentrum on Friday evening for participants leaving the next morning.*

Posters

Posters

1.	Samer Ahmed	**Measurements of neutron electromagnetic form factors at BESIII**
2.	Boxing Gou	**Study of the transverse beam spin asymmetries at forward angles in $\vec{e}$ -p scattering at A4**
3.	Philippe Legou	**High rate applications of micromegas for: Time projection chambers, trackers, and wide range neutrons detectors**
4.	François Gildas Nizery	**Technological aspects for high rate capabilities**
5.	Simone Pacetti	**Sensitivity of the elastic cross section to the proton radius**
6.	Susan Schadmand	**Time-like form factors of hadrons**
7.	Weiping Wang	**Measurement of the $e^+e^-\to\Lambda_c^+\bar{\Lambda}_c^-$ cross section near threshold and the Λ_c^+ form factor**

Abstracts of Lectures

(in chronological order)

Elastic Electromagnetic Form Factors in the Space-like Region: Recent Results and Future Experiments

E.J Brash[1,2]

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Precise proton and neutron elastic electromagnetic form factor measurements in the space-like region ($Q^2 > 0$) at Jefferson Lab, in particular using spin observables, have recently made a significant contribution to the unraveling of the internal structure of the nucleon. Accurate experimental measurements of the nucleon form factors are a test-bed for understanding how the nucleon's static properties and dynamical behavior emerge from QCD - the theory of strong interactions between quarks. At the same time, there has been enormous theoretical progress since the publication of the Jefferson Lab proton form factor ratio data aimed at reevaluating the picture of the nucleon. I will review the experimental and theoretical developments in this field and discuss the outlook for the future.

References

[1] V. Punjabi, C.F. Perdrisat, M.K. Jones, E.J. Brash, C.E. Carlson, Eur. Phys. J. **A51**, 79 (2015)

An Experimental Overview of time-like Electromagnetic Baryon Form Factors

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The baryon time-like form factors are reviewed from an experimental point of view. They are mainly studied in electron-positron annihilation into baryon-antibaryon pairs or vice versa.

Proton form factors have been extensively measured in the time-like region, while the neutron form factor measurements are still poor. New measurements on Hyperon form factor close to threshold, showing a very interesting behavior, will be discussed.

On the physical meaning of time-like electromagnetic form factors

A. Bianconi[1] and E. Tomasi-Gustafsson[2]

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It is well known that space-like proton form factors may be interpreted in the Breit frame as Fourier transform of static space distributions of the electromagnetic current. In the time-like region we suggest that form factors represent the time evolution of the forming or annihilating quark-antiquark pairs in the center of mass system. From a generalization of the definition of form factors as Fourier transform of a unique function depending on both time and space coordinates [1], time-like form factors are interpreted as the amplitude for the distribution in time of the charge coupling related to the 'photon-q qbar' vertex that allows the pair creation from the annihilation vacuum [2]. In this sense, time-like form factors allow to investigate the fourth dimension of the hadron: the time dimension, and to get information of the first instants of the hadron formation. We show that simple functions allow to qualitatively reproduce the regular oscillations pointed out in Ref. [3] from a reanalysis of the data from the BaBar collaboration [4].

References

[1] E.A. Kuraev, E. Tomasi-Gustafsson, A. Dbeyssi, Phys. Lett. **B581**, 75 (2004)
[2] A. Bianconi, E. Tomasi-Gustafsson, Phys. Rev. **C95**, 015204 (2017)
[3] A. Bianconi, E. Tomasi-Gustafsson, Phys. Rev. Lett. **114**, 232301 (2015)
[4] J. Lees et al., [the BaBar Collaboration] Phys. Rev. **D87**, 092005 (2013)

Higher order QED radiative corrections to elastic electron-proton scattering

A.B. Arbuzov[1,2] **and T.V. Kopylova**[2]

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[2] *Dubna State University, Dubna, Russia*
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QED radiative corrections to elastic electron-proton scattering at low energies are discussed [1,2]. Corrections to the electron line and effects due to vacuum polarization are computed. Higher order effects are estimated for the conditions of the experiment on the electric and magnetic proton form factors by A1 Collaboration at MAMI. Analytic results are obtained within the next-to-leading approximation. Critical remarks on the treatment of QED corrections in the modern experiments on ep scattering are done. It is demonstrated that inclusion of the higher order effects can considerably affect the value of the proton charge radius and proton form factors extracted from the experimental data. Magnitudes of radiative corrections are estimated for different experimental set-ups. In particular, it is shown that in the future experiment with measurement of the momentum transfer from the proton recoil, there will be a substantial reduction of QED radiative corrections in comparison with the set-up where the scattered electron energy and momentum are used.

References

[1] A.B. Arbuzov and T.V. Kopylova, Eur. Phys. J. C **75**, 603 (2015)
[2] A.B. Arbuzov and T.V. Kopylova, EPJ Web Conf. 125, 04005 (2016)

The contribution of light mesons to hyperfine structure of muonic hydrogen

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In the framework of the quasipotential method in quantum electrodynamics we calculate the contribution of light pseudoscalar (PS) and axial-vector (AV) mesons to the interaction operator of a muon and a proton in muonic hydrogen atom. The coupling of mesons with the muon is via two-photon intermediate state. The parametrization of the transition form factor of two photons into PS and AV mesons, based on the experimental data on the transition form factors and QCD asymptotics, is used. Numerical estimates of the contributions to the hyperfine structure of the spectrum of the S and P levels are presented. It is shown that such contribution to the hyperfine splitting in muonic hydrogen is rather important for a comparison with precise experimental data.

References

[1] A.E. Dorokhov, N.I. Kochelev, A.P. Martynenko, F.A. Martynenko and R.N. Faustov, Phys. Part. Nucl. Lett. **14** 857 (2017)

[2] A.E. Dorokhov, N.I. Kochelev, A.P. Martynenko, F.A. Martynenko and A.E. Radzhabov, Phys. Lett. **B776** 105 (2018)

The BabaYaga event generator

Carlo M. Carloni Calame[1] , **Guido Montagna**[2] , **Oreste Nicrosini**[1] **and Fulvio Piccinini**[1]

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In the last two decades, the event generator BabaYaga [1-5] has been developed for the simulation of QED processes (*i.e.* Bhabha scattering, $e^+e^- \to \mu^+\mu^-$ and $e^+e^- \to \gamma\gamma$) at flavour factories. In order to reach an accurate theoretical description of the processes, the generator includes QED radiative corrections by means of a Parton Shower in QED, which solves numerically the QED DGLAP equation. The generator has been further improved by matching the Parton Shower to exact one-loop (NLO) radiative corrections, achieving a theoretical accuracy at the 0.1% level. The generator is widely used by all the experimental collaborations for a precise determination of the machine luminosity, within realistic event selection criteria.
In this general framework, part of the development of the generator consisted in adding the simulation of few hadronic final states (pp, $\pi^+\pi^-$, K^+K^-, $\Lambda\Lambda$) with the effects of initial state radiation within the Parton Shower approach, to be used for data analysis.
The talk will overview the status of the BabaYaga event generator, discussing its general features and some phenomenological results. An emphasis will be given on how its theoretical accuracy has been assessed.

References

[1] C. M. Carloni Calame, C. Lunardini, G. Montagna, O. Nicrosini and F. Piccinini, Nucl. Phys. **B 584** 459 (2000)
[2] C. M. Carloni Calame, Phys. Lett. **B 520** 16 (2001)
[3] C. M. Carloni Calame, G. Montagna, O. Nicrosini and F. Piccinini, Nucl. Phys. Proc. Suppl. **131** 48 (2004)
[4] G. Balossini, C. M. Carloni Calame, G. Montagna, O. Nicrosini and F. Piccinini, Nucl. Phys. **B 758** 227 (2006)
[5] G. Balossini, C. Bignamini, C. M. C. Calame, G. Montagna, O. Nicrosini and F. Piccinini, Phys. Lett. **B 663** 209 (2008)

The NNbar and multihadron production at the nucleon threshold at VEPP2000

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The proton-antiproton and neutron-antineutron productions in the e+e- annihilation are studying with the CMD-3 and SND detectors at VEPP2000 e+e- collider in Novosibirsk. Both detectors have special equipment for the slow nucleon registration. Both detectors have observed a sharp increase of the cross section in ppbar and nnbar production [1,2]. Also a "dip" in the six-pion production at the NNbar threshold was confirmed [3]. Special energy scan around the NNbar threshold production was performed with a tiny step with less than machine energy spread of 1.2 MeV, and large integrated luminosity. Preliminary analysis of the ppbar production demonstrates an extremely fast cross section rise, smaller than the difference in the ppbar and nnbar production thresholds. A corresponding cross section drop has been observed in the six-charged-pions production, when no indication of such a drop is shown in the four-charged-pions cross section. We continue analysis for the nnbar reaction and other multihadron states around NNbar threshold, and plan to take more data in this region. New preliminary results are presented.

References

[1] R. R. Akhmetshin *et al.*, (CMD-3 Collaboration), Phys. Lett. B **759**, 634 (2016).
[2] M. N. Achasov *et al.*, (SND Collaboration), Phys. Rev. D **90**, 112007 (2014).
[3] R. R. Akhmetshin *et al.*, (CMD-3 Collaboration), Phys. Lett. B **723**, 82 (2013).

Fine structure of the nucleon electromagnetic form factors in the vicinity of the threshold of e^+e^- annihilation into nucleon - antinucleon pair

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At present, the interest of researchers is attracted by the unusual behavior of the cross section of nucleon-antinucleon pair production near the threshold and the corresponding electromagnetic form factors in various reactions. A natural explanation of this behavior is the strong effect of the final-state interaction of nucleon and antinucleon near the threshold of the pair production. Now, the first preliminary results have been obtained at the CMD-3 detector at the VEPP-2000 collider on the production of the proton-antiproton pair in e + e- annihilation at energies only slightly higher than the pair production threshold. The energy resolution of the facility allows one to obtain data between the thresholds of the proton-antiproton and neutron-antineutron pair production. For a theoretical description of the production of a proton-antiproton pair in this region, it is necessary to take into account both the electromagnetic interaction of proton and antiproton and the difference of proton and neutron masses. This is also important for the calculation of the cross section of neutron-antineutron pair production near the threshold due to the existence in strong interaction of the charge exchange reaction (proton + antiproton -> neutron + antineutron). The results of such calculations are discussed in my talk. Our previous results, obtained without account for the electromagnetic interaction and proton-neutron mass difference,
are published in Refs. [ ]

References

[1] V. F. Dmitriev and A. I. Milstein, Phys. Lett. B 658, 13 (2007).
[2] V. F. Dmitriev, A. I. Milstein, S. G. Salnikov, Phys. Rev. D 93, 034033 (2016).
[3] V. F. Dmitriev, A. Milstein, S.G. Salnikov, Phys. Lett. B 760, 139 (2016).
[4] A. I. Milstein, and S. G. Salnikov; Nuclear Physics A 966, 54 (2017).

Proton Time-Like Electromagnetic Form Factor Measurements at BESIII

S. Ahmed[1], A. Dbeyssi[1], P. Larin[1], D. Lin[1], F. Maas[1, 2, 3], C. Morales[1], C. Rosner[1] and Y. Wang[1]

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BESIII is a multi-purpose detector operating at the electron-positron collider BEPCII in Beijing. Time Like Electromagnetic Form Factors can be explored using both the direct scan method as well as the ISR method, both with (tagged) and without (untagged) detecting the ISR photon.
This contribution reports on the ongoing analysis at BESIII for all three approaches. In the case of the ISR method, the analysis of 7.408 fb^{-1} collected at seven center of mass energies between 3.773 and 4.600 GeV is presented. Preliminary results on both the effective Form Factor as well as the ratio of the electric and magnetic Form Factor are shown for both tagged and untagged case. In addition, efforts to analyse a dedicated scan dataset of 651 pb^{-1} taken at 22 center of mass energies between 2.0 and 3.08 GeV are presented.

Cross section measurement of Lambda Lambdabar production at B ESIII

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The process e+e- to Lambda anti-Lambda is studied using data samples at sqrt(s)=2.2324, 2.400, 2.800 and 3.080 GeV collected with the BESIII detector operating at the BEPCII collider. The Born cross section is measured at sqrt(s)=2.2324 GeV, which is 1.0 MeV above the Lambda anti-Lambda mass threshold, to be 305+-45^+66_-36 pb, where the first uncertainty is statistical and the second systematic. The cross section near threshold is larger than that expected from theory, which predicts the cross section to vanish at threshold. The Born cross section at sqrt(s)=2.400, 2.800 and 3.08 GeV are measured and found to be consistent with previous experimental results, but with improved precision. Finally, the corresponding effective electromagnetic form factors of Lambda are deduced.

References

[1] M. Ablikim, Phys. Rev. D 97, 032013 (2018).

Investigation of the transition form factors of excited hyperons with HADES

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Detailed information on the structure of hyperons can be determined from precise measurements of the transition form factor describing the decay of hyperon resonances to the Lambda. For the first time, high statistics measurements of these processes will be possible with the newly upgrades HADES detector. This will not only enable significantly enhanced abilities to investigate dilepton production via the RICH upgrade, but also greatly increase the acceptance for hyperon reconstruction by including a RPC-TOF and PANDA-Phase0 tracking detectors at small polar angles. This talk will present the physics program as well as simulated results for the projected upcoming experiments.

Electromagnetic Form Factors of hyperons - present and future

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Hyperons is a powerful diagnostic tool that sheds light on some of the most challenging questions in contemporary physics. One is how and why the strong force confines quarks and gluons into composite systems, e.g. protons. The central question is: What happens if we replace one of the light quarks in a proton, with a heavier quark?

Electromagnetic form factors (EMFF's) is currently the best way to study hyperon structure. In the time-like region, the EMFF's can be complex with a relative phase. This phase polarises the final state even in the case of an unpolarised initial state. Hyperons have the advantage compared to protons that their polarisation is experimentally accessible by the angular distributions of their decay products. However, due to experimental challenges, the phase has not been measured until now.

In this talk, I will outline how to measure the phase between the electric and the magnetic form factor and present the latest results from the BESIII experiment. In addition, I will review future prospects at future facilities, e.g. PANDA at FAIR.

Form factors in three quark models and in quark diquark models.

E. Santopinto[1]

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Different results for form factors as obtained with three quark models versus quark diquark models will be critically revised and discussed.

References

. [1] E. Santopinto, F. Iachello and M.M. Giannini, Eur. Phys. J. A**1** 307-315 (1998)
[2] M. De Sanctis, M.M. Giannini, E. Santopinto, A. Vassallo, Phys.Rev. C**76** 062201 (2007)
[3] M. De Sanctis, J. Ferretti, E. Santopinto, Phys. Rev C **84**, 055201 (2011)

Anomalies in Time-like Baryon Form Factors

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Many anomalies or peculiar unexpected behaviours have been observed in various $e^+ e^-$ -> Baryon $Baryon_{bar}$ cross sections, close to the relative threshold and in charmonium decay. They will be pointed out and summarized.

Partons Distributions Amplitudes and Form Factors at large momentum transfer.

Cédric Mezrag[1]

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Unravelling the structure of hadrons in terms of quarks and gluons remains today one of the main goal of hadron physics. Being key objects to reach this goal, Form Factors are usually thought as a way to probe experimentally the structure of hadron in the transverse plan. However, it has been known since almost four decades now that, at large momentum transfer, collinear factorisation allows us to understand form factors in terms of partons distributions amplitudes (PDAs), and therefore to probe the longitudinal structure of hadrons.

In this talk I will described our recent model of the nucleon PDAs [1], based on both Perturbative Integral Representation (PTIR) and a quark-diquark approximation with both scalar and pseudo-vector degrees of freedom. Our PDA is broad and concave, decreasing monotically from its peak, skewed with respect to the conformal limit. Within our approximations, our results are in fair agreement with lattice QCD predictions of the first Mellin moments of the PDA. I will explain how the form factors can be computed, what are our current limitations and what to expect from existing and future experimental data.

References

[1] Cédric Mezrag *et al.*, arXiv:1711.09101 (2017).

The low-Q^2 experimental effort for the measurement of the proton radius

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The difference between the measurements of the proton radius as obtained from the spectroscopy of muonic hydrogen [1] and the elastic scattering of an electron off a proton [2] questions our understanding and practice of Quantum Electrodynamics and lepton scattering. A large number of hypotheses ranging from experimental issues up to physics beyond the Standard Model have been proposed to solve this puzzle. However, the existing world data set does not allow for a consensus and calls for new experimental data investigating on the one hand lepton non-universality, and on the other hand the precision frontier.
A world-wide effort of both the atomic and subatomic physics community is currently developing. The low-Q^2 experimental effort aiming at very accurate measurements of the electric form factor of the proton intends to provide a more robust determination of the proton radius, ultimately confirming or not the previous difference. This presentation will review the low-Q^2 electron scattering program and more specifically the ProRad experiment [3] at the PRAE facility [4] of Orsay.

References

[1] (CREMA Collaboration) R. Pohl et al. Nature **466**, 213 (2010)
[2] (A1 Collaboration) J.C. Bernauer et al. Phys. Rev. Lett. **105**, 242001 (2010)
[3] (PRAE Collaboration) D. Marchand, EPJ Web of Conf. **138**, 01012 (2017)
[4] (PRAE Collaboration) S. Barsuk et al. IPAC 2017 JaCoW, THPVA079 (2017)

Constraints on low Q^2 data for the extraction of the proton charge radius

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The proton charge radius is defined as the slope of the proton electric form factor at a four-momentum transfer $Q^2 = 0$. The extraction of the proton charge radius from electron-proton elastic scattering data has been questioned [1,2]. The extracted value of the radius depends on the data extrapolation scheme and the Q^2 domain in consideration. The fact that current experimental data exist in a domain in Q^2 where the electric form factor of the proton is non-linear lead to the belief that the proton radius puzzle [1] -the difference between the radius obtained from electron-proton scattering data and muonic hydrogen spectroscopy- might be a consequence of an imperfect extraction. Therefore, several experiments are trying to reach the low Q^2 region [3,4,5,6] with the aim to reduce the sensitivity of the measurement to the extrapolation method. The ProRad experiment at PRAE in Orsay [6] is part of this effort.

This presentation will address the different problematics that face the extraction of the proton charge radius from electron-proton scattering data. In particular, the benefits of low Q^2 experiments and the related precision constraints will be discussed.

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Results and implications of OLYMPUS

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The famous discrepancy between measurements of the proton electric-to-magnetic form factor ratio with polarized and unpolarized methods has generated significant interest both experimentally and theoretically. The widely preferred explanation of the discrepancy has been hard two-photon exchange, which had been a neglected piece of the radiative corrections. Several experiments have been carried out to investigate the effects of two-photon exchange. The OLYMPUS experiment at DESY has been one of three dedicated experiments to use comparisons of positron-proton and electron-proton scattering to unequivocally determine the effects of two-photon exchange [1]. Results from the OLYMPUS experiment and their implications will be presented.
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Measurement of Analyzing Powers of the np Charge Exchange Reaction in the GeV Region

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Analyzing powers for polarized **neutrons** have been measured only for thin hydrogen targets. Cross sections and analyzing powers for np, for both elastic scattering and charge exchange are known up to 29 GeV/c. No data exist for thick analyzers.

During two beam runs in the years 2016 and 2017, the analyzing powers for protons and neutrons scattering on CH2, CH, C and Cu targets were measured at the nucleon momentum from 3.0 to 4.2 GeV/c with the ALPOM2 setup at the Nuclotron accelerator. The data for polarized neutron beam are obtained for the first time, thanks to the unique polarized deuteron beam that is presently available up to 13 GeV/c.

The measurement of the angular dependence of Ay for the neutron is essential to the continuation of the neutron form factor measurements to the highest possible transferred momentum-Q^2 at the Jefferson Laboratory. The reaction p+Cu(W), with the detection of a neutron in the forward direction by a hadron calorimeter, can be used for the measurement of the proton polarization at the future NICA collider.

Charge-Exchange Neutron Scattering: Extending Recoil-Polarimetry measurements of G_{En}/G_{Mn} to high values of Q^2

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Neutron electromagnetic form factor measurements at high values of Q^2 are an important part of the experimental programme at Jefferson Lab. In Hall A four measurements of the neutron and proton Sachs form factors have been approved, using the Super BigBite spectrometer and associated apparatus. With data on the proton and neutron form factors, a u/d flavour decomposition of F_1 and F_2 [1] can be performed. The behaviour of G_E/G_M at $Q^2 >> 1$ $(GeV/c)^2$, specifically the zero crossing points of the proton and neutron ratios (if they exist) have important implications for QCD-inspired models of nucleon structure.

This talk will focus on a double polarised measurement of G_{en}/G_{mn} [2], using quasi-elastic scattering of polarised electrons from an unpolarised deuterium target and measuring the polarisation transfer to the recoiling neutron (RP). This experiment was approved in 2017 with an A- rating and is novel in that the neutron polarimeter will use charge exchange np→pn scattering.

Charge exchange np→pn scattering from the free proton exhibits a very large analysing power, compared to standard np→np, at neutron momenta above a few GeV/c. A liquid hydrogen analyser would be very difficult technically at Jefferson Lab and thus the polarimeter will employ a Cu or CH_2 analyser. Recent measurements at JINR Dubna have shown that good analysing power is obtained in np→pn scattering from CH_2, C, and Cu at incident neutron momenta in the 3-4 GeV/c range. This new information has proved crucial in demonstrating that a RP G_{En}/G_{Mn} experiment can achieve excellent precision in a feasible measurement time. Eventually it is hoped that the present technique will enable G_{En}/G_{Mn} measurements out to Q^2 ~ $10(GeV/c)^2$. This is totally unexplored territory, where different theoretical models of nucleon structure predict very different behaviour.

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Antiproton annihilation studies with the PANDA experiment at FAIR

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In the framework of the upcoming PANDA experiment at the future FAIR facility in Darmstadt, a multipurpose modern high energy physics detector will be operated at the High Energy Storage Ring. Stored and cooled antiproton beams will be available in the momentum range between 1.5 GeV/c and 15 GeV/c and will allow for nuclear structure studies in the time like domainand for spectroscopy studies of the meson and baryon spectrum for strange and charmed hadrons. The physics program for the initial stage will be discussed.

FAIR – Where do we stand?

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The Facility for Antiproton and Ion Research (FAIR) is an international accelerator facility under construction which will use antiprotons and ions to perform research in the fields of: nuclear, hadron and particle physics, atomic and anti-matter physics, high density plasma physics, and applications in condensed matter physics, biology and the bio-medical sciences. I will give an overview of the project and report about the current status of planning and construction.

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

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One of the main goals of the future PANDA experiment at FAIR [1] (Darmstadt, Germany) is the investigation of the proton structure. Electromagnetic form factors (FF's) are fundamental quantities, which parameterize the electric and magnetic structure of hadrons. In the time-like region, proton FF's can be accessed experimentally in $\bar{p}p \rightarrow \ell^+\ell^-$, $(\ell = e,\mu)$ annihilation processes, assuming that the interaction takes place through the exchange of one virtual photon. The expected statistical precision for the measurement of time-like electromagnetic proton form factors with PANDA was investigated in the framework of the PANDARoot software [2] for detector simulation and event reconstruction for both muon and electron channels [3]. These studies investigated the possibility to achieve an optimal signal-background separation and sufficient background suppression of the relevant background channels. Different methods have been used to generate and analyse the processes of interest. The results show, that time-like electromagnetic proton form factors can be measured at PANDA with high statistical accuracy over a large kinematical region.

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Perspectives in Hadron Physics, an example of international collaboration

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The BESIII Collaboration will soon host the new Cylidrical GEM Inner Tracker. The design, validation and construction of this innovative detector, going far beyond the pre-existing state of the art and reaching unprecedented resolutions in large magnetic fields (B=1T), is a vivid example of a successful International Collaboration, involving Germany, Italy, Sweden and People's Republic of China, and funded by EU within the framework of the H2020-MSCA-RISE-2014 call.

The Collaboration within BESIII is only one of the joint research activities performed within the framework of the IHEP-INFN Joint Laboratory. A brief overview and perspectives on the possible future Collaborations will be provided as well.

Abstracts of Posters

(in alphabetical order)

Measurements of Neutron Electromagnetic Form Factors at BESIII

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The neutron structure and dynamics can be understood via the study of its electromagnetic form factors. In the time-like region few experiments had been performed so far [1,2], none of them had the possibility to determinate the ratio of the electric and magnetic form factors. Therefore, a large data sample in a wide range of center of mass energies [2.0 - 3.08 GeV] has been collected in Beijing Spectrometer III (BESIII) at the Beijing Electron Positron Collider II (BEPCII). With the collected data, it is expected to determine the electric and the magnetic FFs of neutron separately, determine Born cross section with higher precision and therefore enhance the knowledge of neutron structure. In this contribution, we will present our strategy of selecting $e^+e^- \rightarrow n\bar{n}$ signal and the expected precision in the determination of Born cross section and electromagnetic form factors.

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Study of the transverse beam spin asymmetries at forward angles in $\vec{e}$-p scattering at A4

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The one-photon exchange approximation in the electron-nucleon scattering had been regarded as sufficient in probing the nucleon structure, until the discrepancy between the Rosenbluth separation and the polarization transfer methods in measuring the proton form factor ratio arose. The two-photon exchange process has been proposed to account for this discrepancy[1]. It is imperative to study the two-photon exchange amplitudes quantitatively, in order to understand how the two-photon exchange process may affect various observables. The imaginary parts of the two-photon exchange amplitudes are accessible via the single normal spin asymmetries in the polarized electron-nucleon scattering[2]. The A4 collaboration has embarked on a systematic study of the transverse beam spin asymmetries in the intermediate energy regime using polarized electron beams scattering on hydrogen/deuterium targets. Measurements have been performed at both forward and backward angles at energies between 210 MeV and 1.5 GeV. In this poster we present the investigation of the forward measurements.

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High rate applications of Micromegas for: Time Projection Chambers, trackers, and wide range Neutrons detectors

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In the heart of stars in laboratories, plasmas constitute one of the major objects of the physics in many research institutes. Very big research infrastructures aim at big advances in the understanding of the physics of plasmas. Some Fields of application of science, as inertial confinement fusion experiment or Magnetic confinement fusion for energy, produce very energetics particles that can create nuclear fusion reactions. Many of these reactions lead to the creation of very fast neutrons. Detection of very fast neutrons remains also a challenge for particles accelerators safety diagnostics (beam loss monitor ...).

We developed a new wide energy neutrons detector able to work in a large gamma background. This concept is based on a very fast electronics associated to a Micromegas detector and a charged to particle converter. The detector can be configured according to energy spectrum of neutrons, it can sustend very high flux and with a good efficiency.

Technological aspects for high rate capabilities

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Micromegas detectors are widely used for physics experiments, for tracking, but also in beam instrumentation diagnostics. We present here the Micromegas technology, and the construction of such detectors. Applications are shown and performances are presented. These detectors are low cost, reliable, and present very high rate capabilities in difficult environments. Possible improvements to work in very high radiative environments will be presented.

Sensitivity of the elastic cross section to the proton radius

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The proton radius has been determined by exploiting directly data in terms of the derivative of the electric form factor, extracted by recent high-precision, electron-proton elastic scattering measurement. It is shown that the relative precision on the derivative, at zero momentum squared, is, as expected, two orders of magnitude lower han that on the form factor itself.

Such unavoidable loss of precision in transforming the data on the form factor to physical information on its first derivative, that is the quantity of interest, prevents the possibility of reaching a meaningful precision for the radius extracted from scattering cross section. The precision on the radius achieveble from electron-proton scattering experiments, is anyway much lower compared to that obtained from laser spectroscopy of muonic, as well as electronic, hydrogen.

Timelike Form Factors of Hadrons

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From the status of time-like form factors of mesons with WASA and CLAS to time-like form factors of hyperons with HADES and PANDA.

Measurement of the $e^+e^- \rightarrow \Lambda_c^+\bar{\Lambda}_c^-$ cross section near threshold and the Λ_c^+ form factor

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The cross section of the $e^+e^- \rightarrow \Lambda_c^+\bar{\Lambda}_c^-$ is measured with unprecedented precision using data collected with BESIII detector at $\sqrt{s} = 4575.5,\ 4580.0,$ 4590.0 and 4599.5 MeV. The measured results are listed in following table.

$\sqrt{s}$ (MeV)	σ (pb)
4575.5	$236 \pm 11 \pm 46$
4580.0	$207 \pm 17 \pm 13$
4590.0	$245 \pm 19 \pm 16$
4599.5	$237 \pm 3 \pm 15$

where the first uncertainties are statistical and the second are systematic and the non-zero cross section near the $\Lambda_c^+\bar{\Lambda}_c^-$ production threshold is cleared. At the center-of-mass energy $\sqrt{s} = 4575.5$ and 4599.5 MeV, the higher statistics data enable us to measure the Λ_c polar angle distribution. From these, the Λ_c electric over magnetic form factor ratios ($|G_E/G_M|$) are measured for the first time. They are found to be $1.14 \pm 0.14 \pm 0.07$ and $1.23 \pm 0.05 \pm 0.03$ respectively, where the first uncertainties are statistical and the second are systematic.