Proton polarizabilities and polarizability radii

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NREC 2024 Workshop

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Temple
University

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Outline

Introduction to the GPs

Status

Recent experiments / Jlab & MAMI

Spatial information & polarizability radii

Prospects

Proton Polarizablities

Fundamental structure constants
(such as mass, size, shape, …)

Response of the nucleon to external EM field

Sensitive to the full excitation spectrum

Accessed experimentally through Compton Scattering

RCS: static polarizabilities → net effect on the nucleon

PDG

150 Baryon Summary Table

N BARYONS
$(S = 0,\ I = 1/2)$
$p,\ N^+ = uud;\quad n,\ N^0 = udd$

p $\quad I(J^P) = \frac{1}{2}(\frac{1}{2}^+)$

Mass $m = 1.00727646681 \pm 0.00000000009$ u
Mass $m = 938.272046 \pm 0.000021$ MeV [a]
$|m_p - m_{\overline{p}}|/m_p < 7 \times 10^{-10}$, CL = 90% [b]
$|\frac{q_{\overline{p}}}{m_{\overline{p}}}|/(\frac{q_p}{m_p}) = 0.99999999991 \pm 0.00000000009$
$|q_p + q_{\overline{p}}|/e < 7 \times 10^{-10}$, CL = 90% [b]
$|q_p + q_e|/e < 1 \times 10^{-21}$ [c]
Magnetic moment $\mu = 2.792847356 \pm 0.000000023\ \mu_N$
$(\mu_p + \mu_{\overline{p}}) / \mu_p = (0 \pm 5) \times 10^{-6}$
Electric dipole moment $d < 0.54 \times 10^{-23}$ e cm
$\boxed{\text{Electric polarizability } \alpha = (11.2 \pm 0.4) \times 10^{-4} \text{ fm}^3}$
$\boxed{\text{Magnetic polarizability } \beta = (2.5 \pm 0.4) \times 10^{-4} \text{ fm}^3}$ (S = 1.2)
Charge radius, μp Lamb shift $= 0.84087 \pm 0.00039$ fm [d]
Charge radius, $e p$ CODATA value $= 0.8775 \pm 0.0051$ fm [d]
Magnetic radius $= 0.777 \pm 0.016$ fm
Mean life $\tau > 2.1 \times 10^{29}$ years, CL = 90% [e] ($p \to$ invisible mode)
Mean life $\tau > 10^{31}$ to 10^{33} years [e] (mode dependent)

Virtual Compton Scattering:

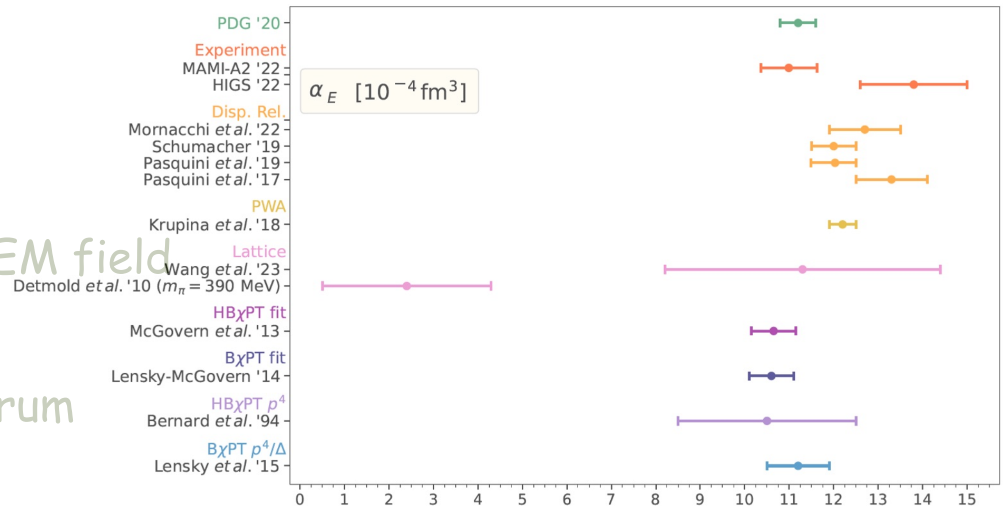
Virtuality of photon gives access to the GPs : $\alpha_E(Q^2)$ & $\beta_M(Q^2)$ + spin GPs

→ spatial distribution of the polarization densities
→ electric & magnetic polarizability radii

Fourier transform of densities of electric charges and magnetization of a nucleon deformed by an applied EM field

Proton Polarizablities

Fundamental structure constants
(such as mass, size, shape, …)



Response of the nucleon to external EM field

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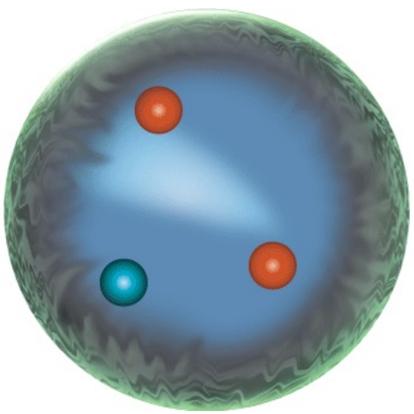
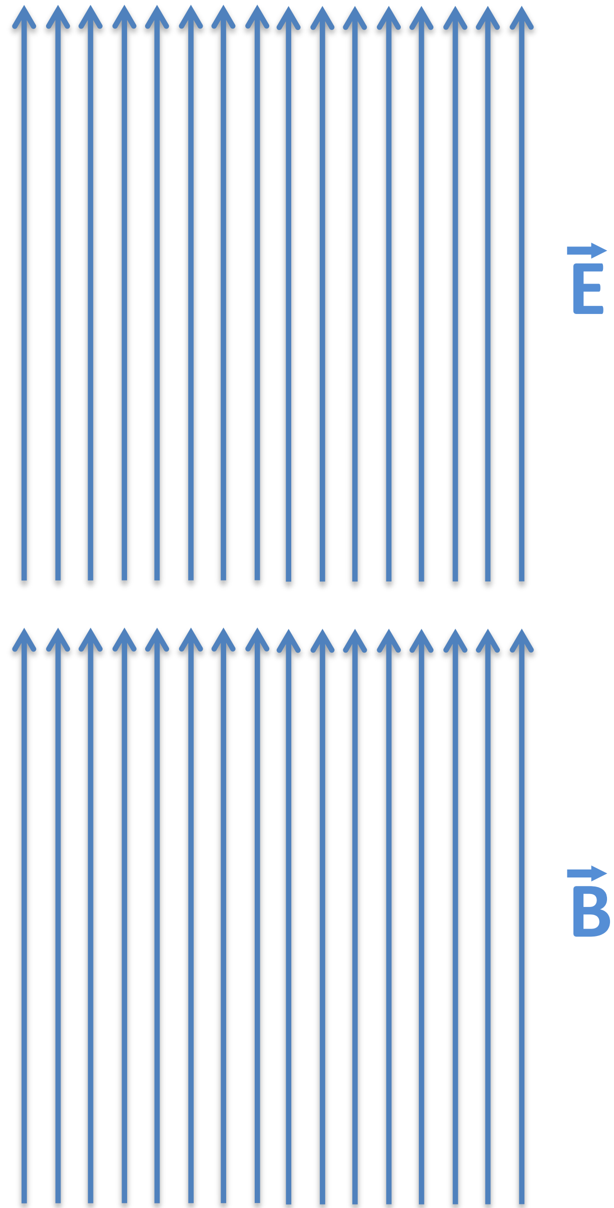
Scalar Polarizablities

Response of internal structure to an applied EM field

Interaction of the EM field with the internal structure of the nucleon

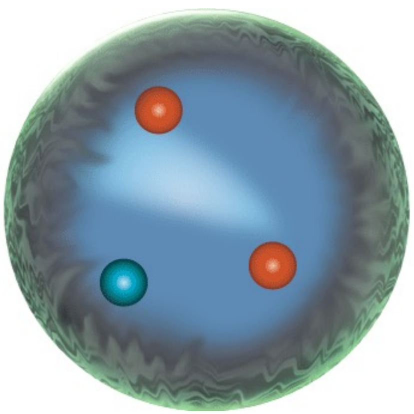


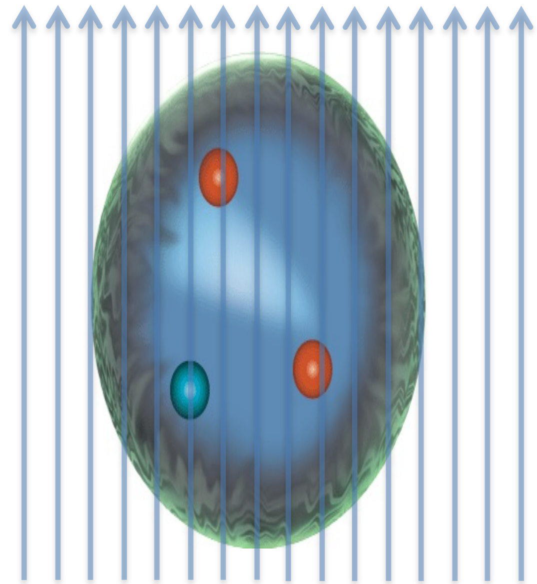


Scalar Polarizablities

Response of internal structure to an applied EM field

Interaction of the EM field with the internal structure of the nucleon



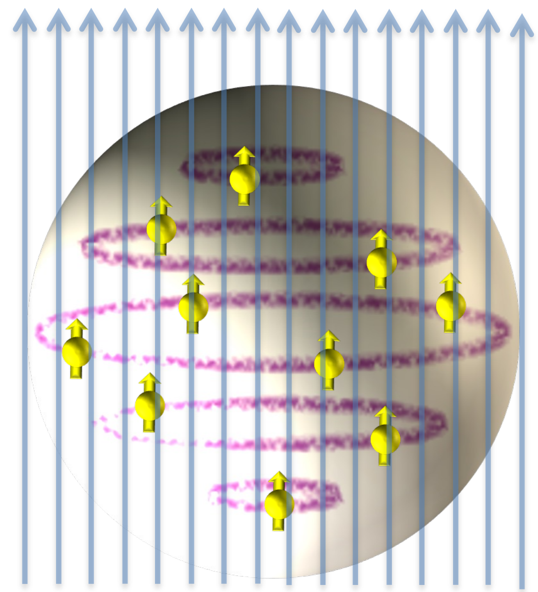


$\vec{E}$

"stretchability"

$\vec{d}_{E\ \mathrm{induced}} \sim \alpha\, \vec{E}$

External field deforms the charge distribution



$\vec{B}$

"alignability"

$\vec{d}_{M\ \mathrm{induced}} \sim \beta\, \vec{B}$

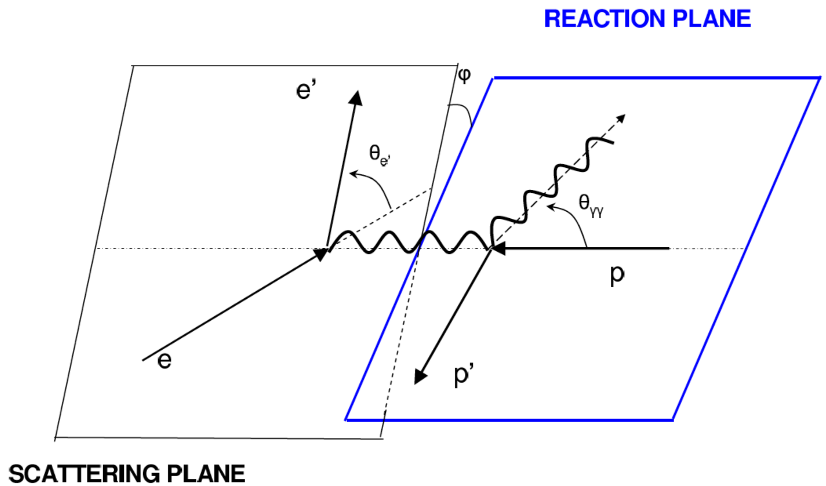
$\beta_{para} > 0$

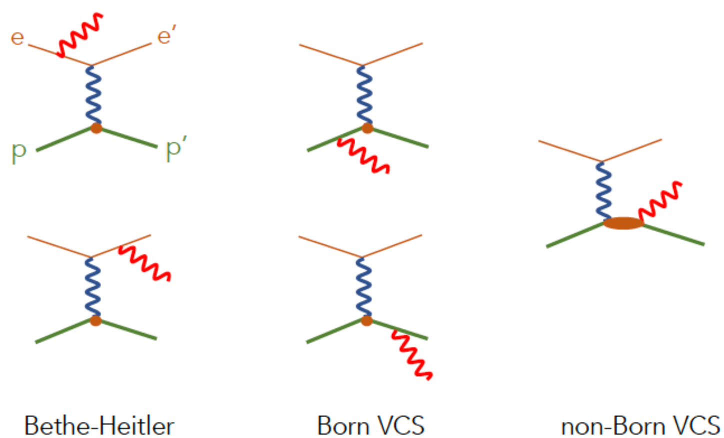
$\beta_{diam} < 0$

Paramagnetic: proton spin aligns with the external magnetic field

Diamagnetic: π-cloud induction produces field counter to the external perturbation

Virtual Compton Scattering





Elastic FFs

GPs

Virtual Compton Scattering

DR

valid below & above
Pion threshold

Dispersive integrals
for Non Born amplitudes

Spin GPs are fixed

Scalar GPs have
an unconstrained part

Fit to the experimental
cross sections at each Q^2

LEX

valid only below
Pion threshold

Response functions

$$d^5\sigma \;=\; d^5\sigma^{BH+Born} \;+\; q'_{cm}\cdot\phi\cdot\Psi_0 \;+\; \mathcal{O}(q'^2_{cm})$$

$$\Psi_0 \;=\; v_1\cdot(P_{LL} - \frac{1}{\epsilon}P_{TT}) \;+\; v_2\cdot P_{LT}$$

Subtract the spin part

$$P_{TT} \;=\; [P_{TT\ spin}]$$

$$P_{LT} \;=\; -\frac{2M}{\alpha_{em}}\sqrt{\frac{q^2_{cm}}{Q^2}}\cdot G_E^p(Q^2)\cdot\beta_M(Q^2) + [P_{LT\ spin}]$$

utilize DR

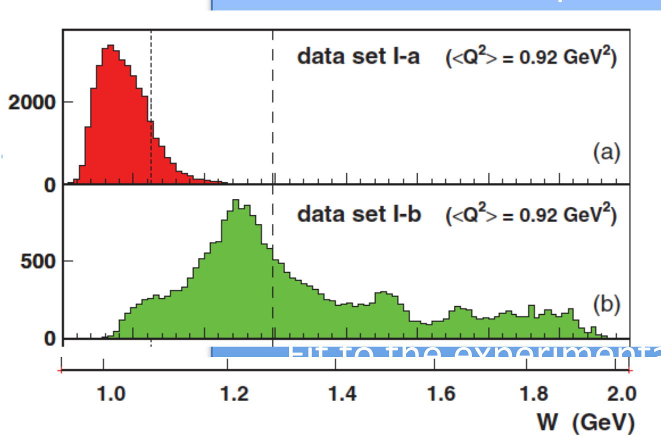
scalar GPs α_E and β_M

Virtual Compton Scattering

DR

valid below & above Pion threshold

Dispersive integrals for Non Born amplitudes



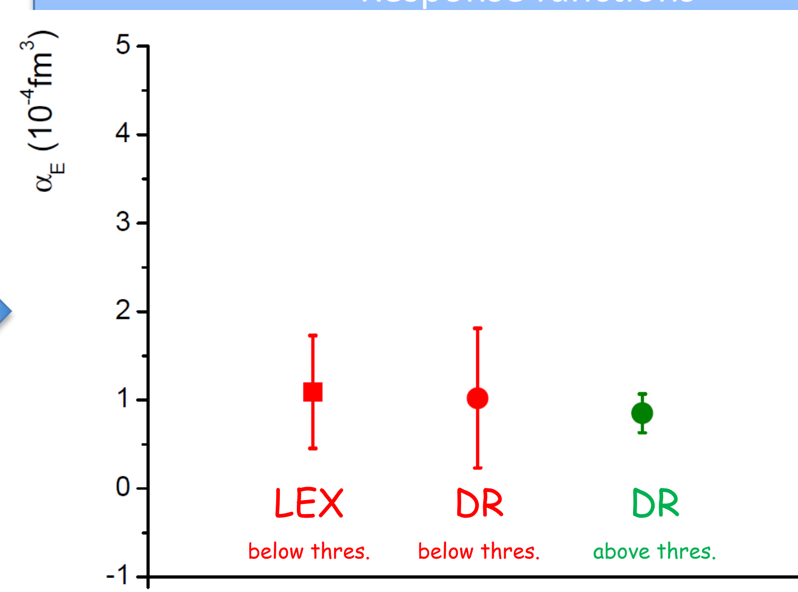
Fit to the experimental

LEX

valid only below Pion threshold

Response functions

$\mathcal{O}(q'^2_{cm})$

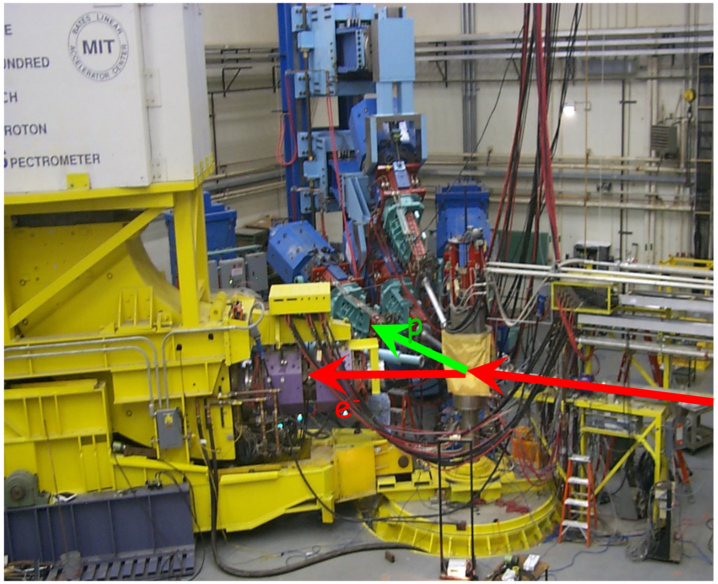


utilize DR

scalar GPs α_E and β_M

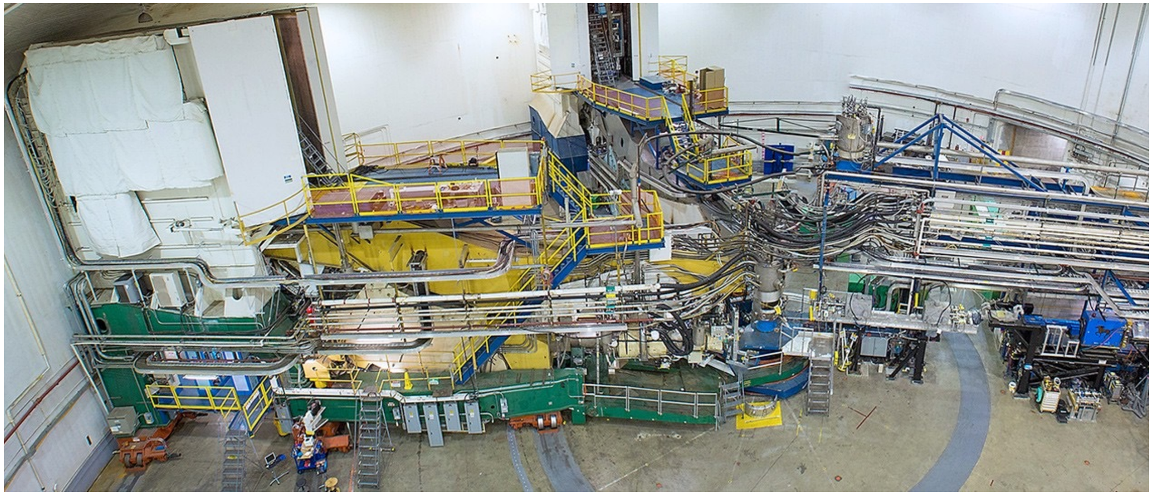
Early Experiments

MIT-Bates @ Q^2=0.06 GeV^2



MAMI-A1 @ Q^2=0.33 GeV^2

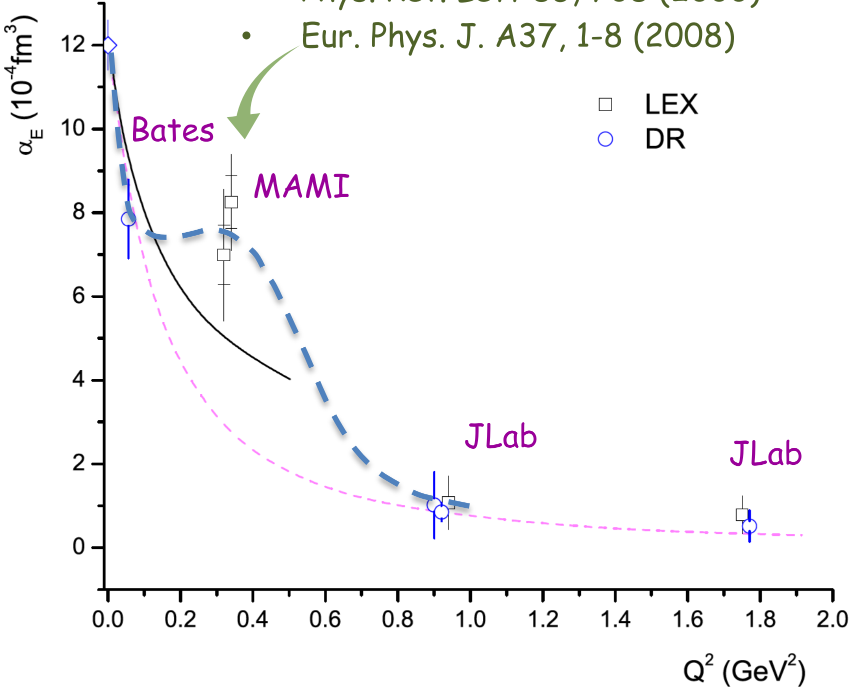
Jlab-Hall A @ Q^2=0.9 & 1.8 GeV^2

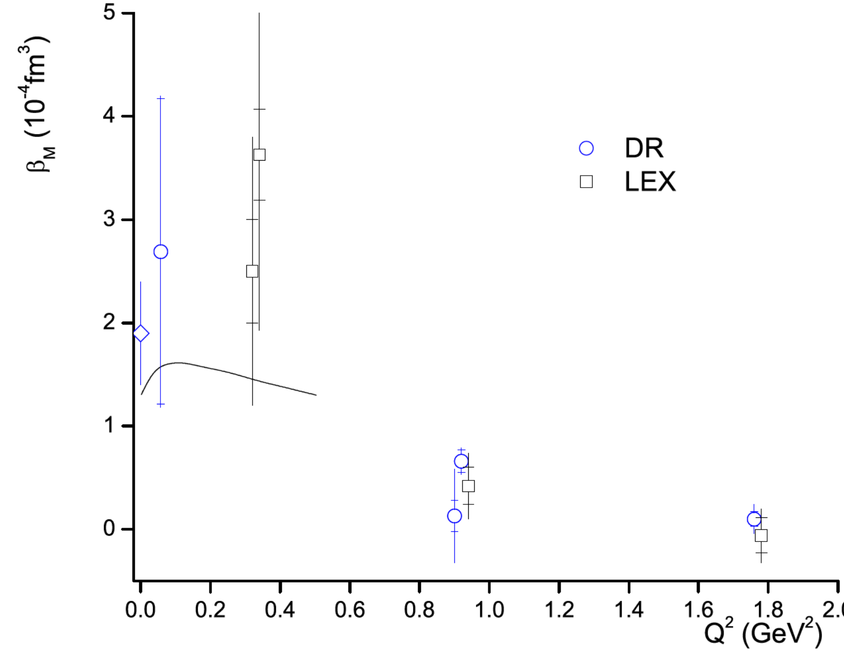


Early Experiments

$Q^2 = 0.33\ (GeV/c)^2$ measured twice at MAMI:

- Phys. Rev. Lett 85, 708 (2000)
- Eur. Phys. J. A37, 1-8 (2008)

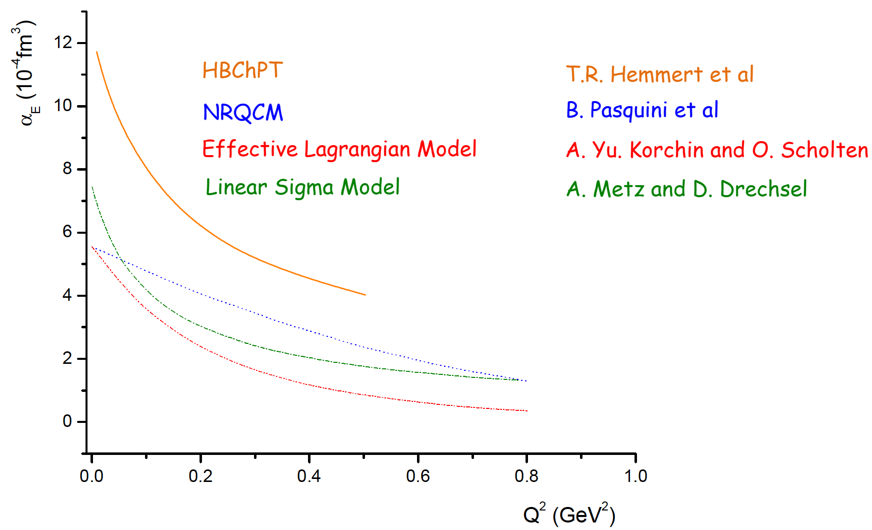




$a_E \approx 10^{-3}\ V_N$ (stiffness / relativistic character)

Data: non-trivial Q^2 dependence of a_E (?)

Theory: monotonic fall-off



β_M small ←→ cancellation of competing mechanisms

Large uncertainties

Higher precision measurements needed

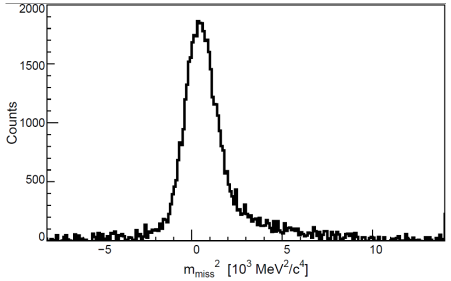
➔ Quantify balance between dia/para-magnetism

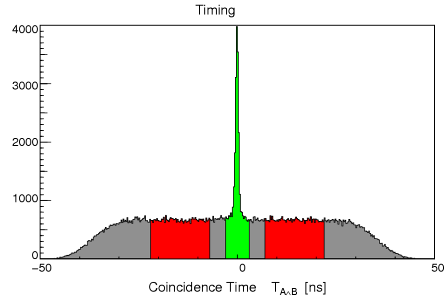
Recent Experiments

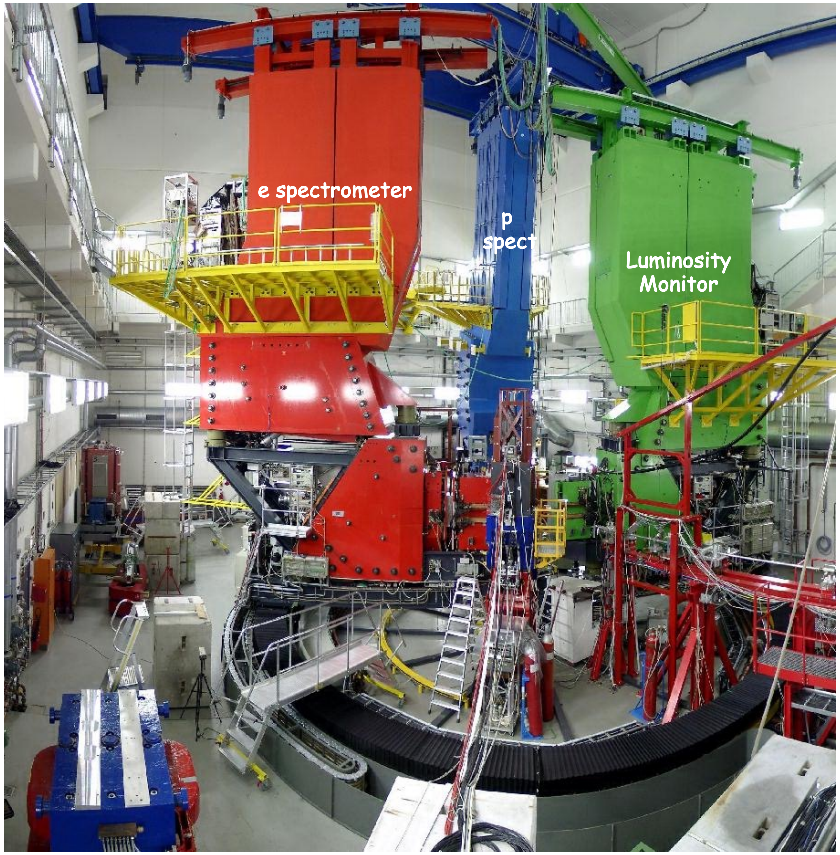
Recent Measurements: MAMI

MAMI	A1/1-09 (vcsq2)	below threshold
MAMI	A1/3-12 (vcsdelta)	above threshold

Both experiments utilized
the A1 setup at MAMI







A1/1-09 @ MAMI

For LEX the higher order terms have to be kept small / under control

$$d^5\sigma \;=\; d^5\sigma^{BH+Born} \;+\; q'_{cm}\cdot\phi\cdot\Psi_0 \;+\; \mathcal{O}(q'^2_{cm})$$

Refined analysis procedure / phase space masking to keep these terms smaller than ~ 2%-3% level

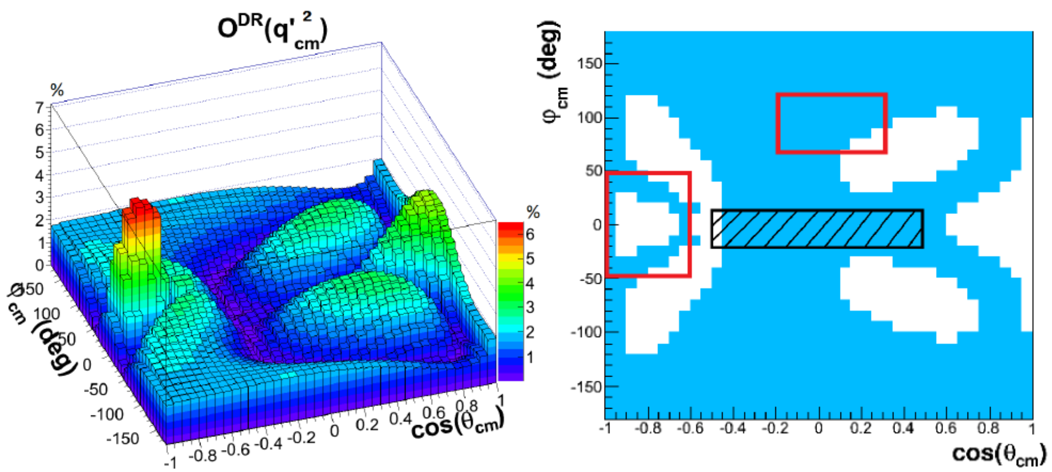
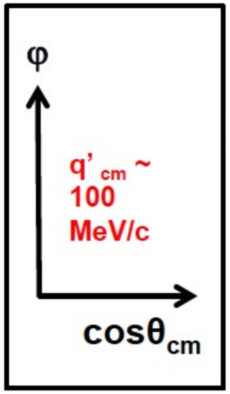


Figure 3.13: (Left) behavior of $\mathcal{O}^{DR}({q'_{cm}}^2)$ in the $(cos(\theta_{cm}),\varphi_{cm})$-plane at $q'_{cm} = 87.5\ MeV/c$ and (right) two-dimensional representation of the angular region where $\mathcal{O}^{DR}({q'_{cm}}^2) < 2\%$ (blue), the red squares correspond to the two areas of interest to perform the GP extraction.

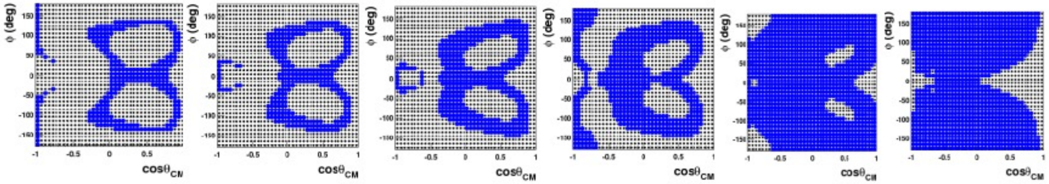
Figure from PhD thesis of L. Correa, Mainz / Cl. Ferrand

Blue bins = where the higher-order estimator is < 3%
(LEX truncation « valid »)



VCS expt : Bates MAMI MAMI MAMI MAMI JLab

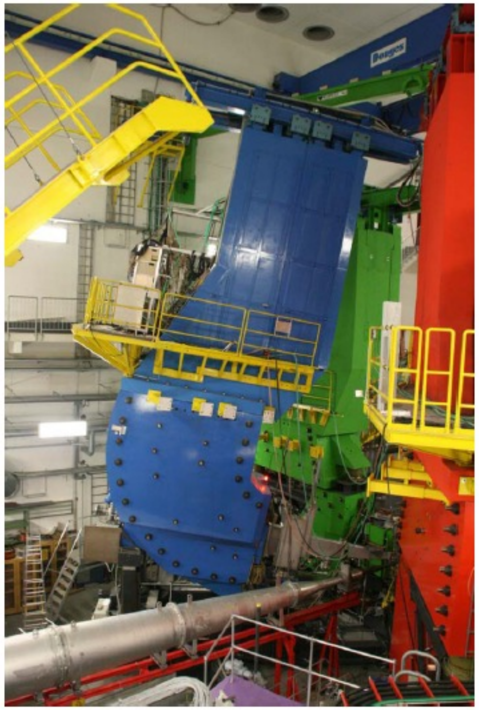
Q2 (GeV2) = 0.06 0.10 0.20 0.33 0.45 0.92



New « vcsq2 » data:

- **OOP kinematics (to access the blue region)**
- **LEX Fit done with bin selection at Q^2 = 0.1 and 0.2 GeV^2.**
- **was found not necessary at Q^2 = 0.45 GeV^2.**

In-plane



8.5 deg OOP

(material from H. Fonvieille)

A1/1-09 @ MAMI

~ 1.0 GeV beam

Q^2 = 0.1 $(GeV/c)^2$, 0.2 $(GeV/c)^2$, and 0.45 $(GeV/c)^2$

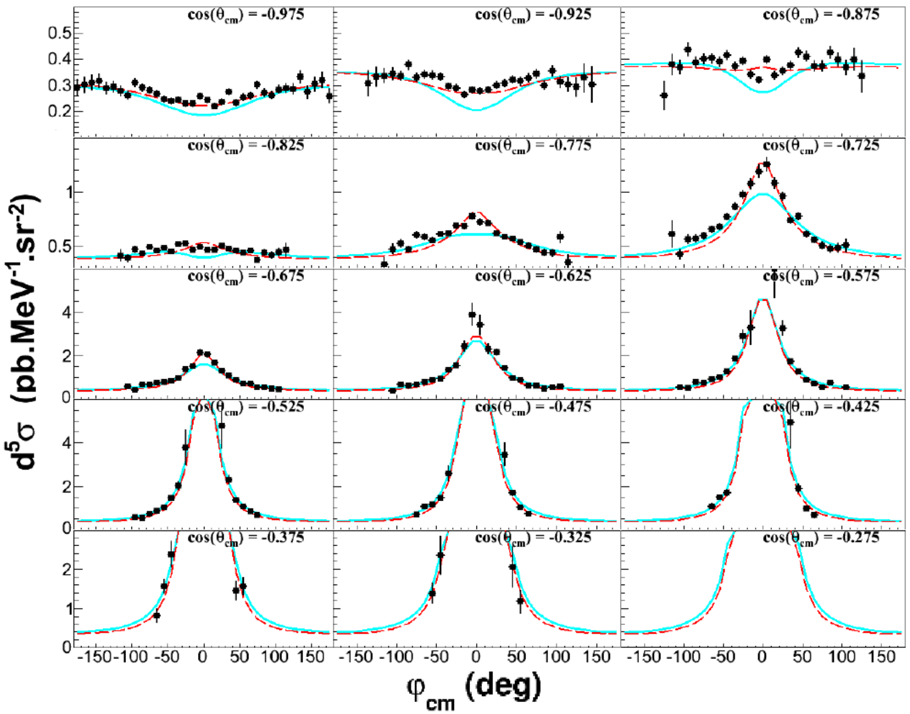


Figure 5.8: Setting INP: measured $ep \to ep\gamma$ cross section at fixed q'_{cm} = 112.5 MeV/c with respect to φ_{cm} for all the $cos(\theta_{cm})$-bins. The curves follow the convention of figure 5.6.

Figure from PhD thesis of L. Correa, Mainz / Cl. Ferrand

BH+B ---

Polarizability effect ---

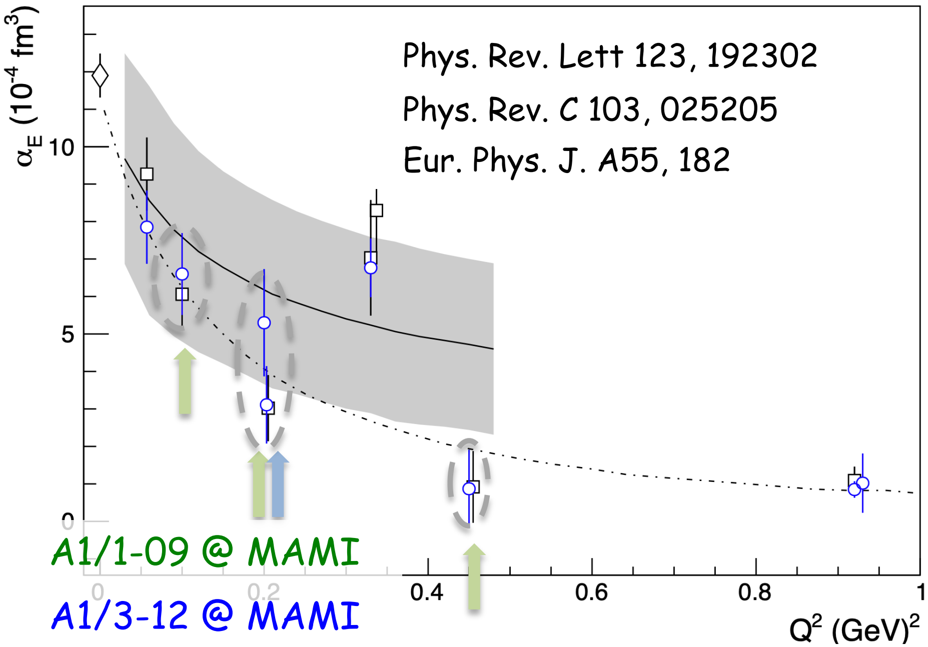
GP effect typically 5% - 15% of the cross section

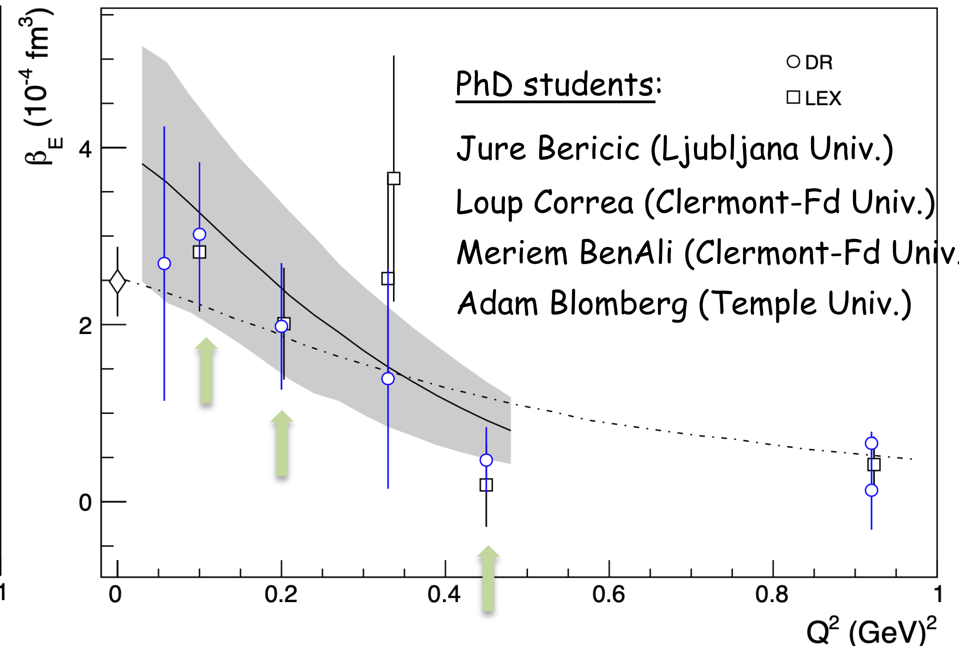
Polarizability fits:

DR fit:
DR calculation includes full dependency in q'_{cm}

LEX fit:
truncated in q'cm. Suppress contribution from higher order terms

MAMI Results

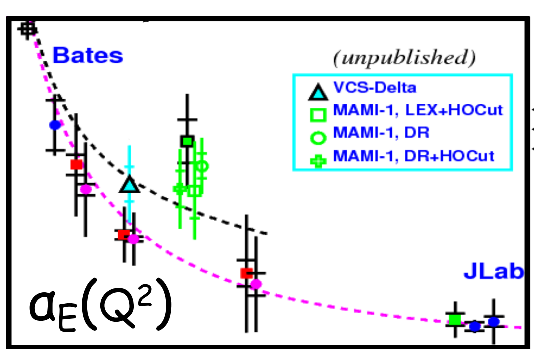




Revisiting the Q^2=0.33 GeV^2 data

Analysis revisited (unpublished):

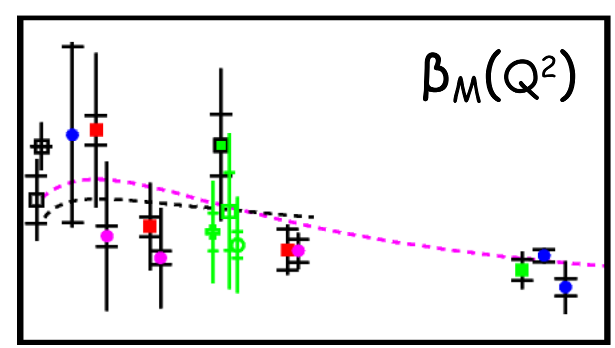
The α_E puzzle still holds



Re-fits at Q^2=0.33 GeV^2 (H.F.)

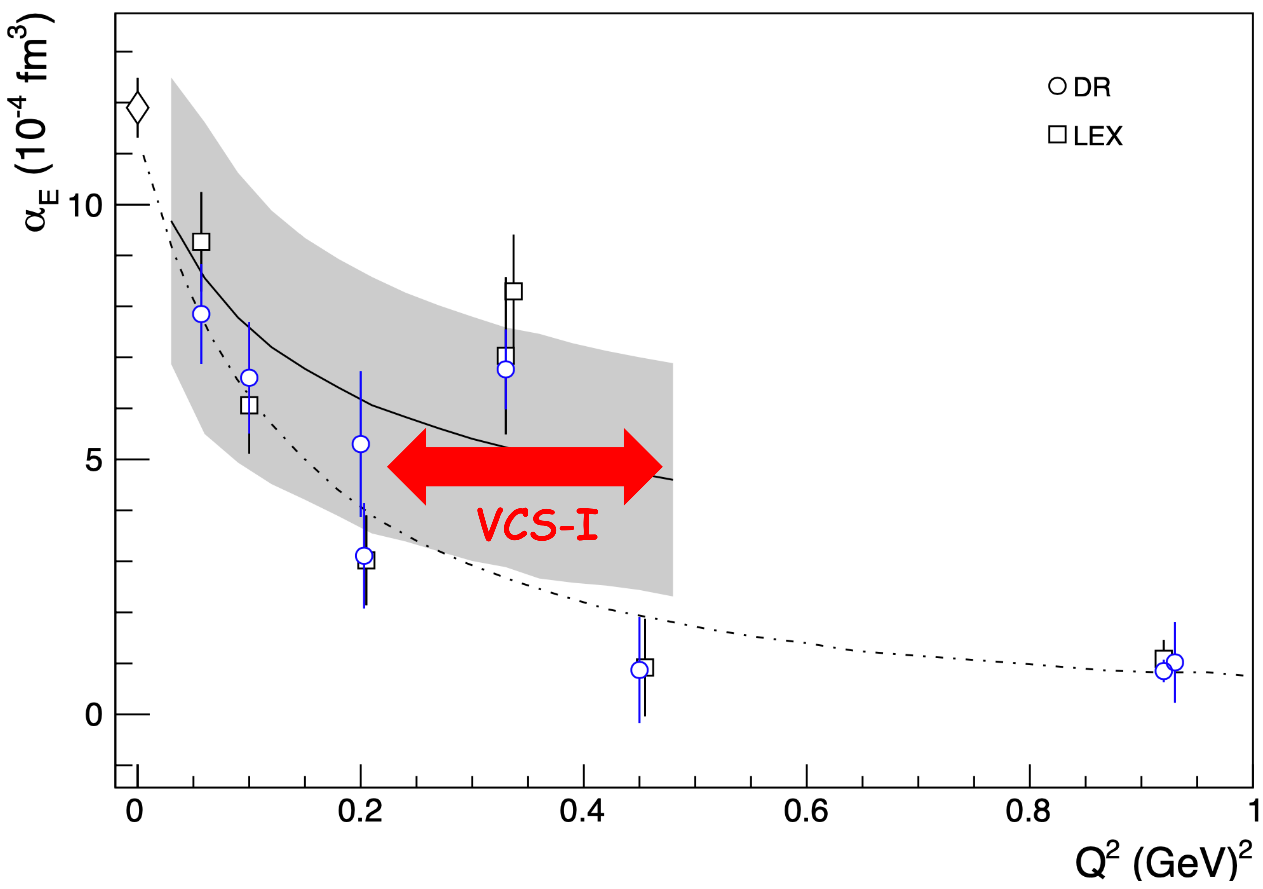
LEX and DR

Updated HO-cut

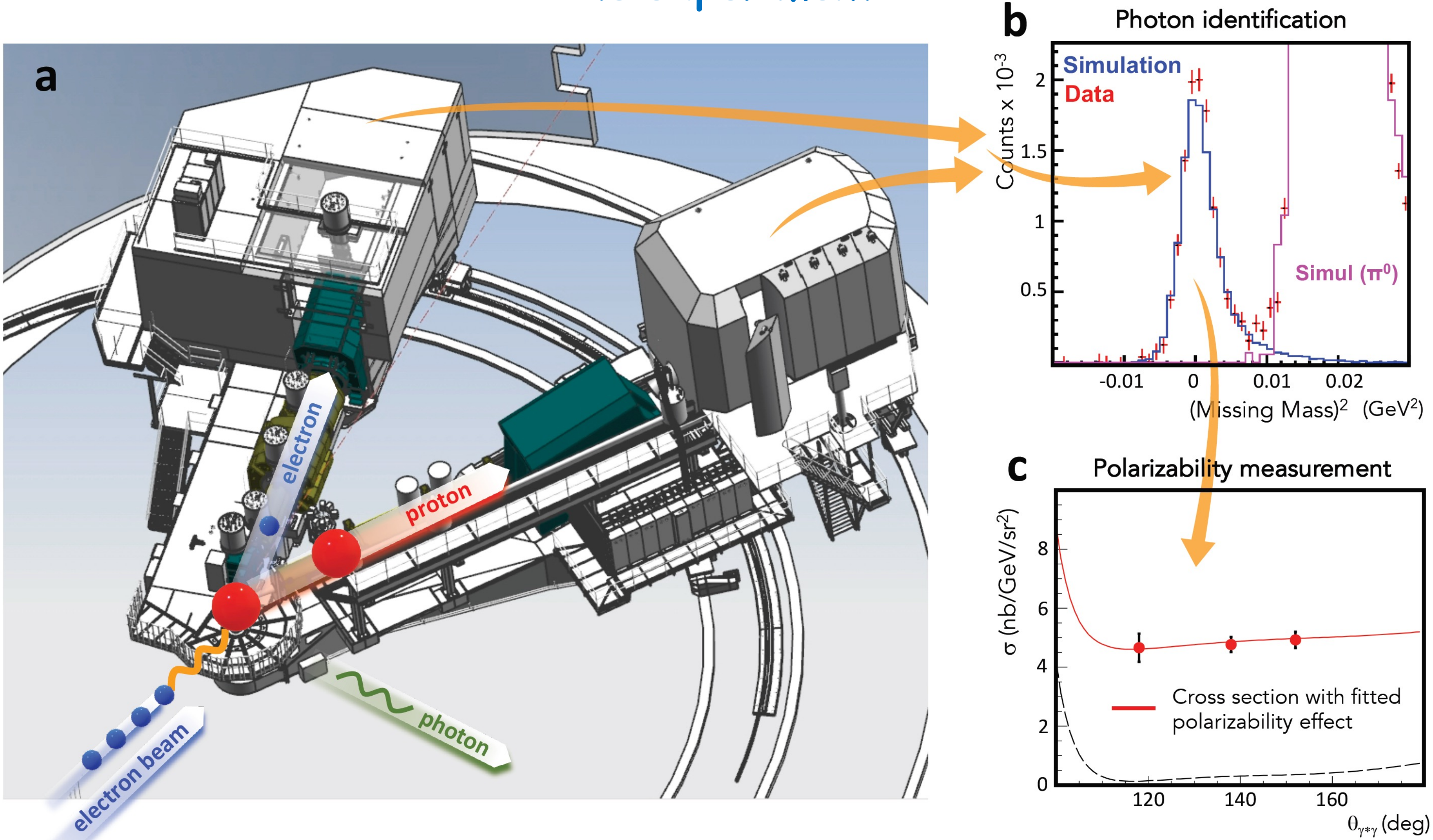


Jlab : VCS-I Experiment (E12-15-001) in Hall C

High precision measurements targeting
explicitly the kinematics of interest for α_E



The experiment



Hall C: SHMS, HMS

4.56 GeV

20 μA

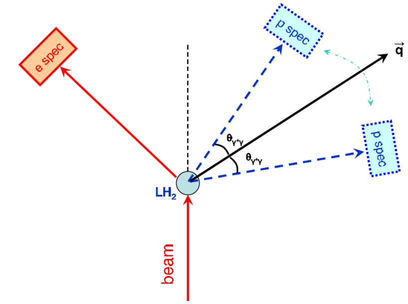
Liquid hydrogen 10 cm

cross sections & azimuthal asymmetries

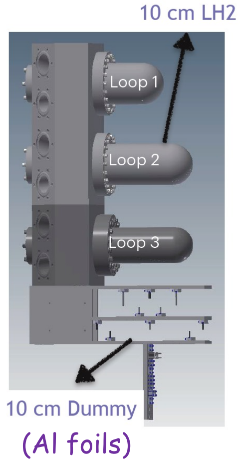
$$A_{(\phi_{\gamma^*\gamma}=0,\pi)} = \frac{\sigma_{\phi_{\gamma^*\gamma}=0} - \sigma_{\phi_{\gamma^*\gamma}=180}}{\sigma_{\phi_{\gamma^*\gamma}=0} + \sigma_{\phi_{\gamma^*\gamma}=180}}$$

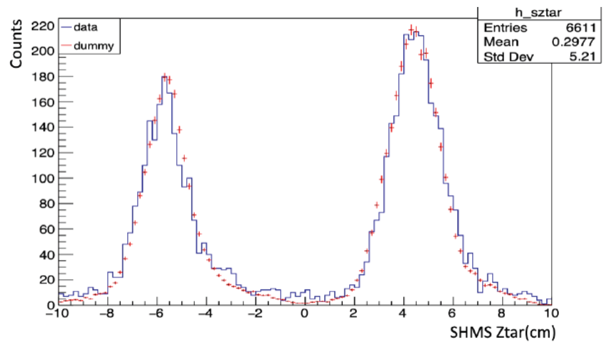
sensitivity to GPs

suppression of systematic asymmetries

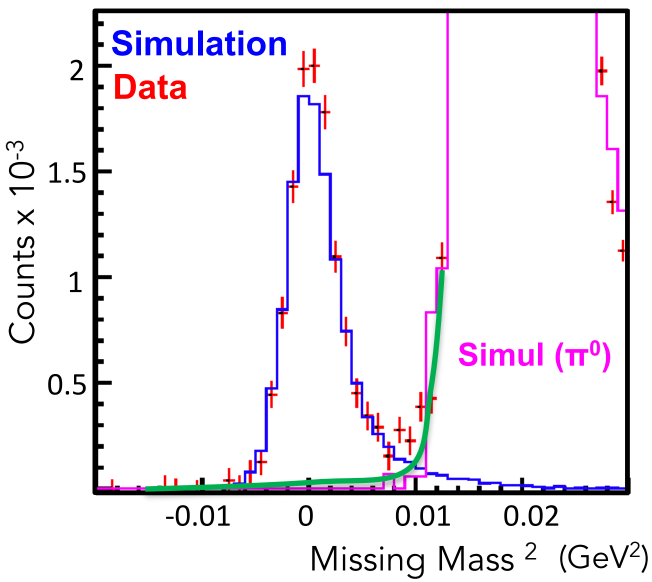


Contribution from (Al) target walls



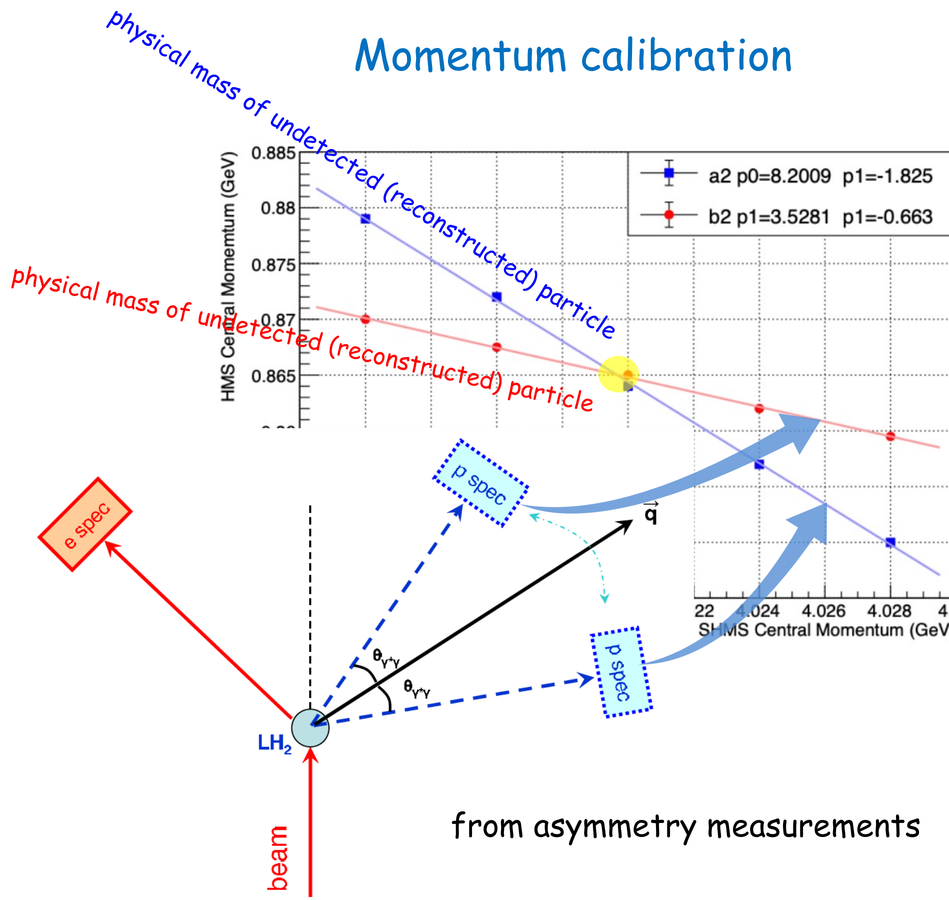


Pion contamination

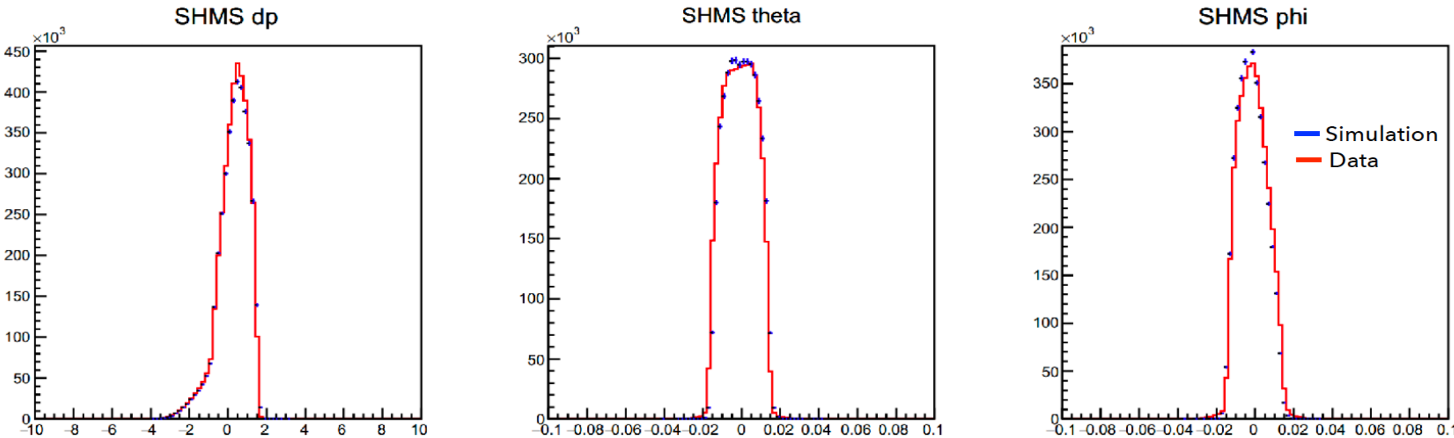


Simulation & Phenomenological fits

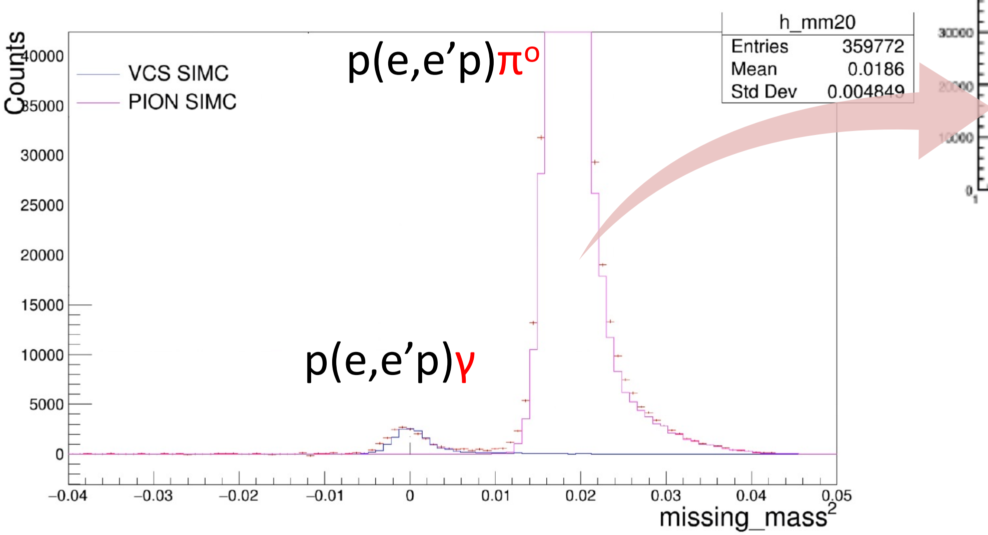
Momentum calibration

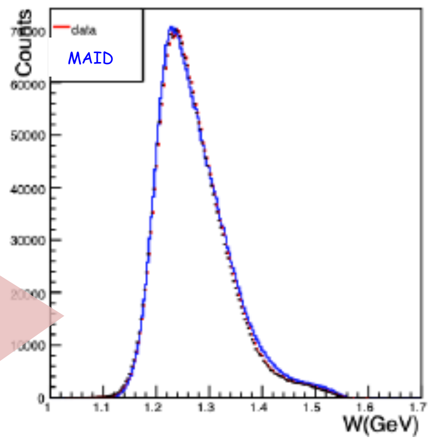


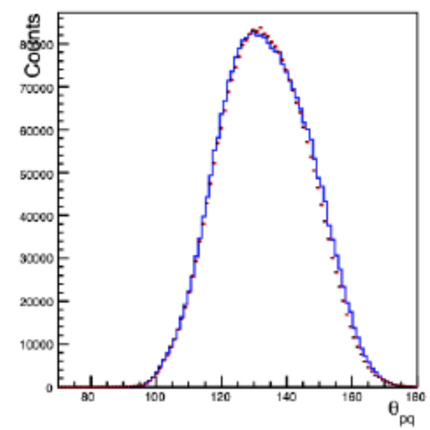
Elastic data

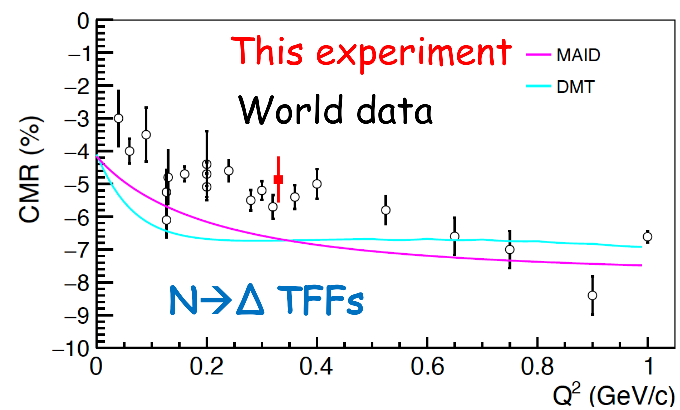


p(e,e′p)π^0



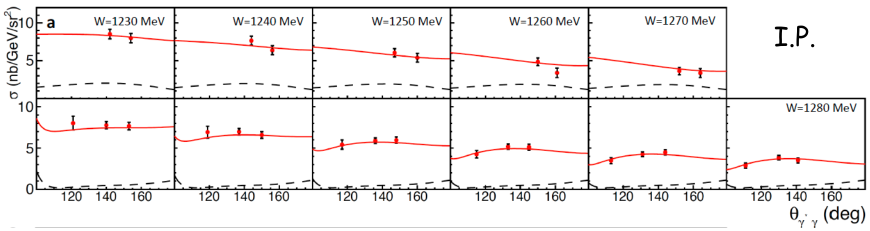




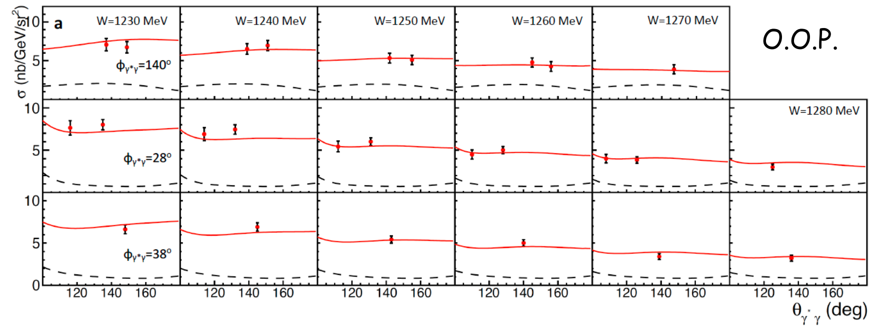


VCS-I results: cross sections

Q^2=0.27 GeV^2

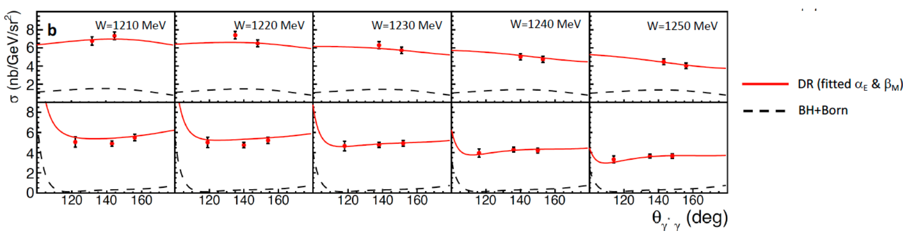


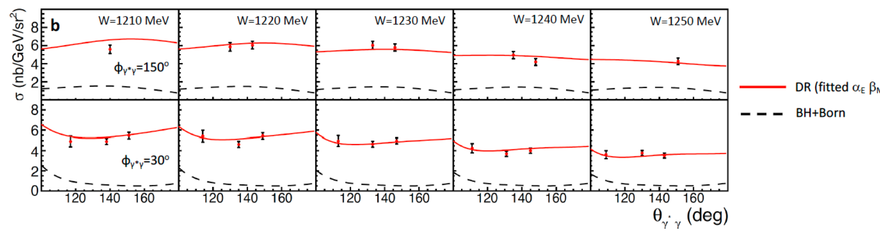
I.P.



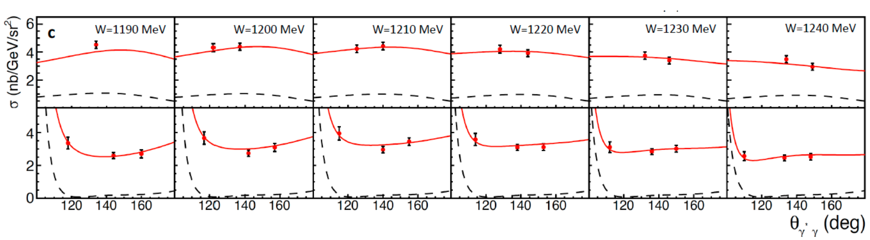
O.O.P.

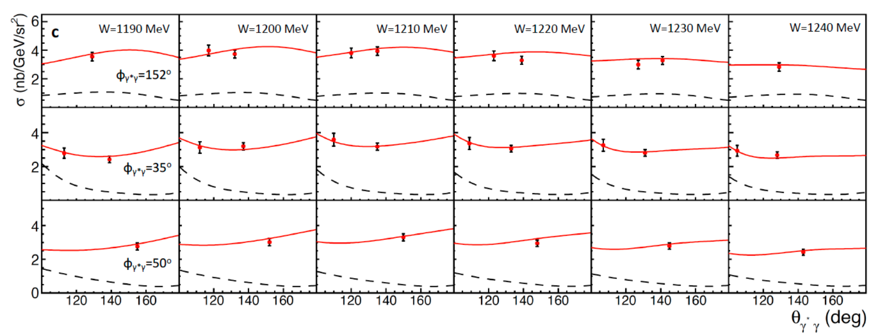
Q^2=0.33 GeV^2





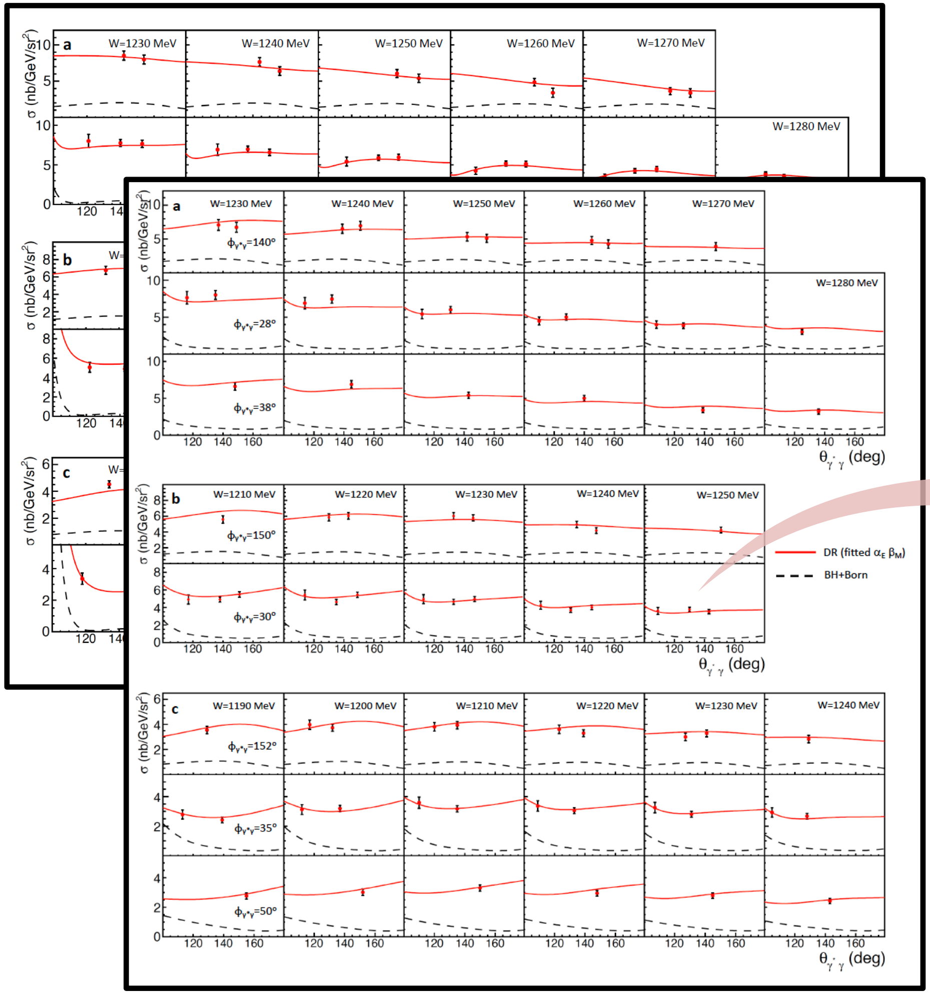
Q^2=0.40 GeV^2



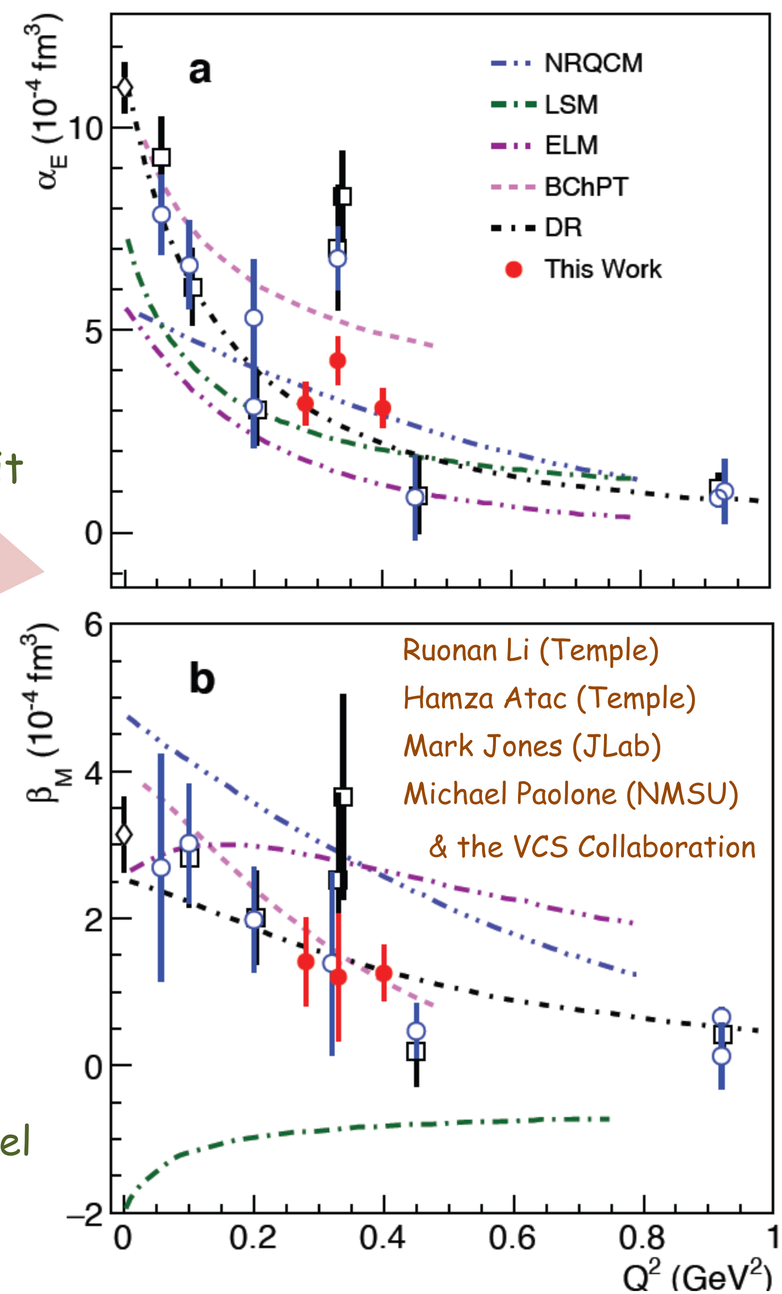


VCS-I results: GPs

Nature 611, 265 (2022)



DR fit



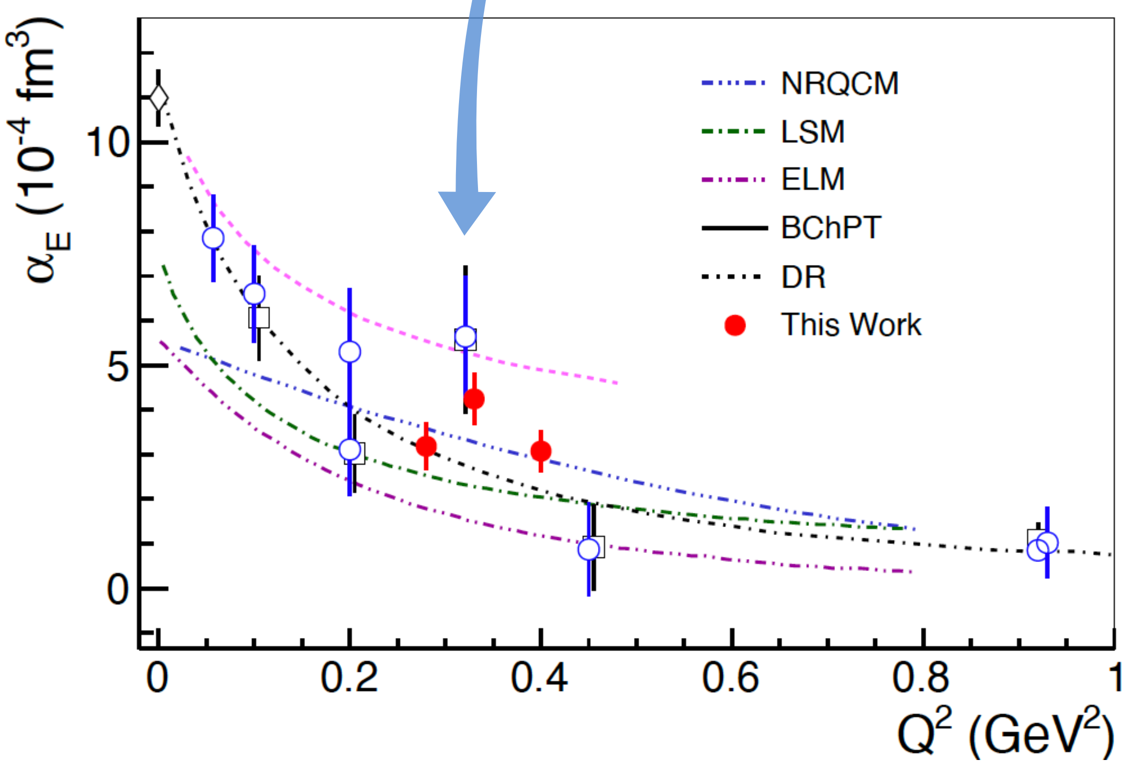
Experimental cross sections are compared to the DR model predictions for all possible values for the GPs

→ $\alpha_E(Q^2)$ and $\beta_M(Q^2)$ are fitted by a χ^2 minimization

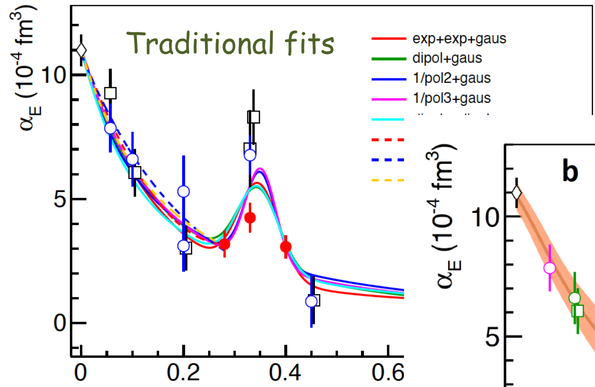
Electric GP (Q^2)

Is there a non-trivial structure?

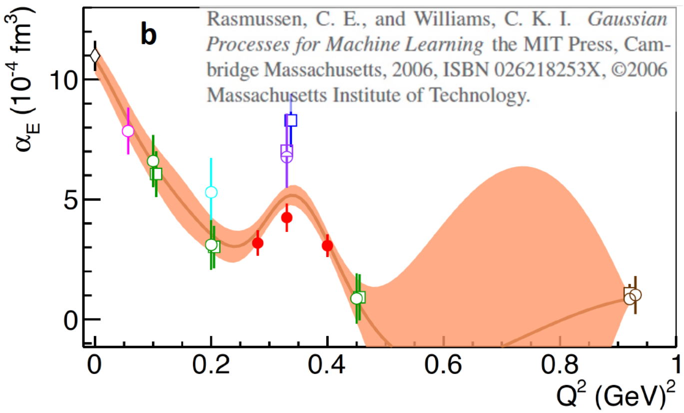
MAMI-I re-analysis (unpublished)



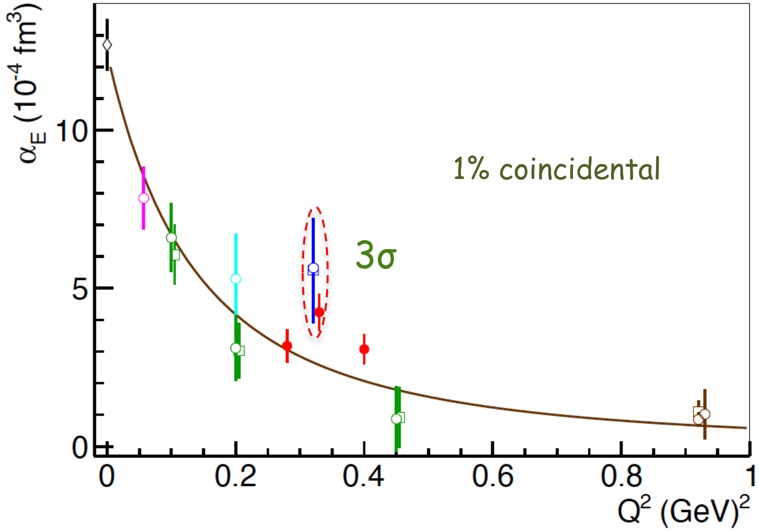
Electric GP



Data-driven techniques:
no underlying functional form is assumed



Rasmussen, C. E., and Williams, C. K. I. *Gaussian Processes for Machine Learning* the MIT Press, Cambridge Massachusetts, 2006, ISBN 026218253X, ©2006 Massachusetts Institute of Technology.



Is the observed α_E structure coincidental or not?

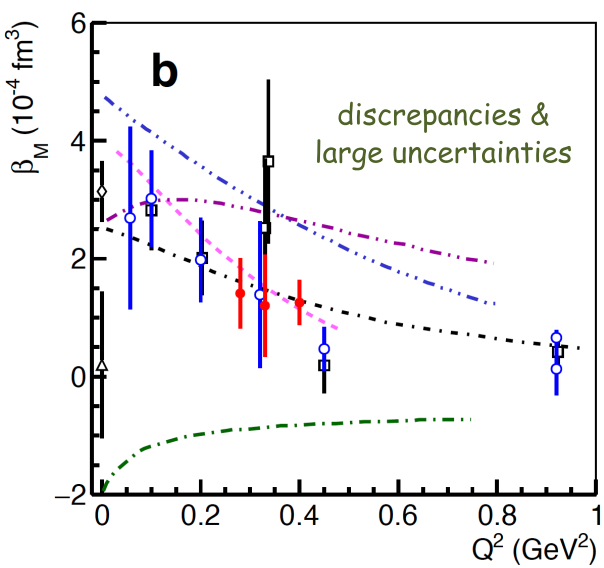
If true: Measure the shape precisely → input to theory

If not: We are able to show it with more measurements

Strong tension between world data (?)

Things we do not yet understand well?
Underestimated uncertainties? …

Magnetic GP



Magnetic GP: Large uncertainties & discrepancies

Disentangle para/dia-magnetism in the proton

Ability to measure α_E and β_M with superb precision
and with consistent systematics across Q^2

Theory: BχPT

Eur. Phys. J. C (2017) 77:119
DOI 10.1140/epjc/s10052-017-4652-9

THE EUROPEAN PHYSICAL JOURNAL C

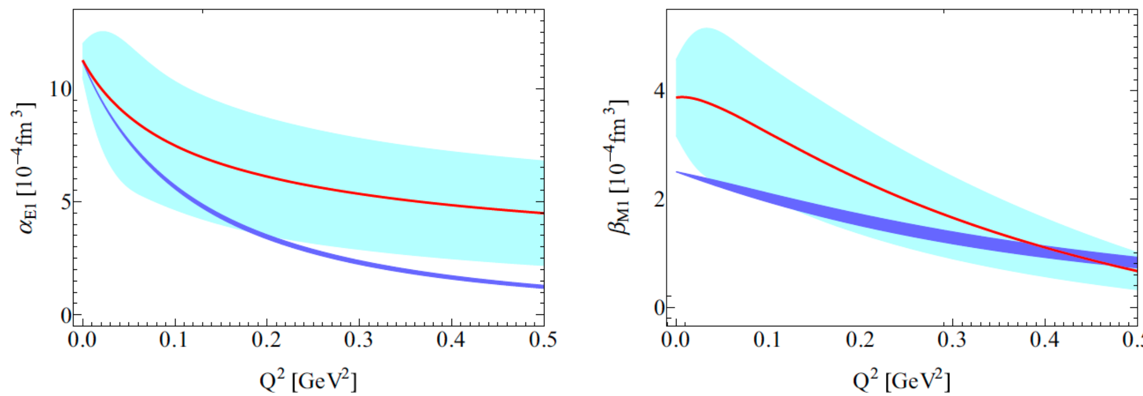
Regular Article - Theoretical Physics

Generalized polarizabilities of the nucleon in baryon chiral perturbation theory

Vadim Lensky[1,2,3,a], **Vladimir Pascalutsa**[1], **Marc Vanderhaeghen**[1]
[1] Institut für Kernphysik, Cluster of Excellence PRISMA, Johannes Gutenberg Universität Mainz, 55128 Mainz, Germany
[2] Institute for Theoretical and Experimental Physics, Moscow 117218, Russia
[3] National Research Nuclear University MEPhI (Moscow Engineering Physics Institute), Moscow 115409, Russia

BχPT calculation to NLO
in the δ-counting scheme

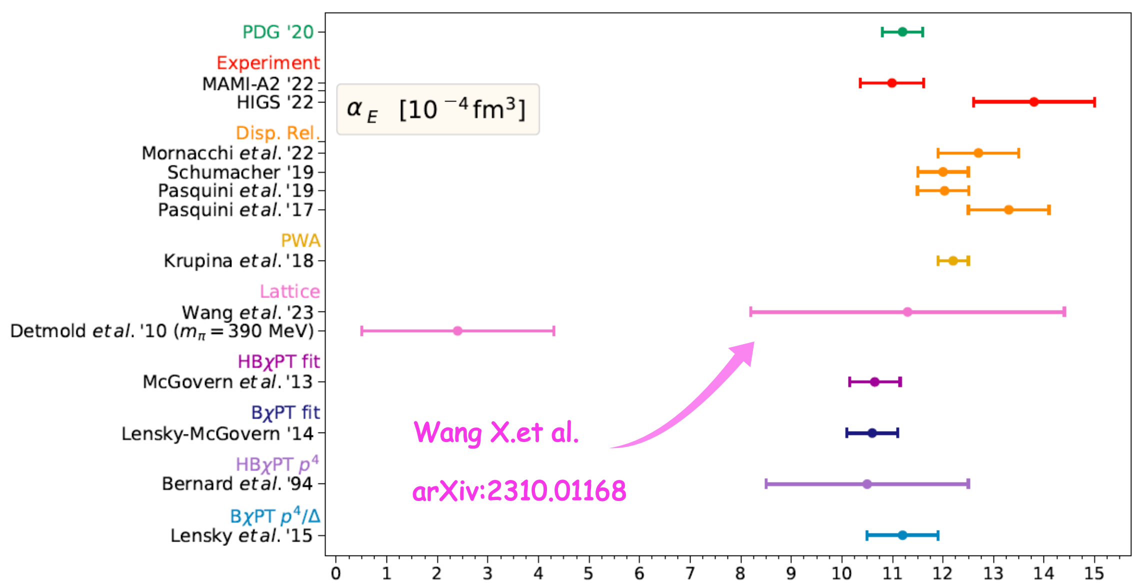

DR calculation
D. Drechsel, B. Pasquini, M. Vanderhaeghen,
Phys. Rep. 378,99 (2003)



Theory: Lattice QCD

Lattice QCD results for
the static polarizabilities

Next step: Lattice QCD
calculations for the GPs



Analysis of the resonance contributions to the low-energy behavior of $\alpha_E(Q^2) + \beta_M(Q^2)$ within holographic QCD

Nucleon electric and magnetic polarizabilities in Holographic QCD

Federico Castellani[a,b]

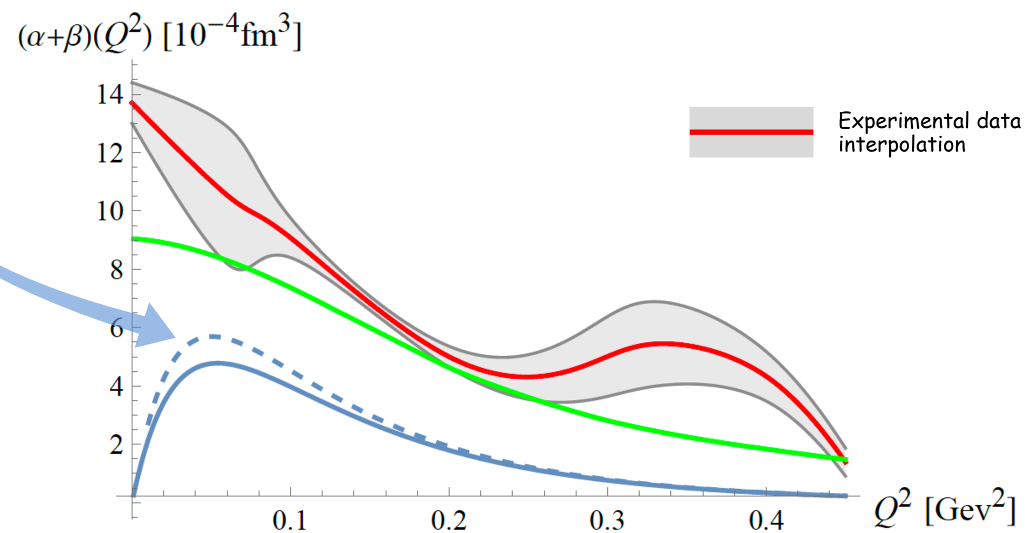
[a] *INFN, Sezione di Firenze, Via G. Sansone 1, I-50019 Sesto Fiorentino (Firenze), Italy.*

[b] *Dipartimento di Fisica e Astronomia, Università di Firenze, Via G. Sansone 1, I-50019 Sesto Fiorentino (Firenze), Italy.*

E-mail: federico.castellani@unifi.it

ABSTRACT: Novel experimental results for the proton generalized electric polarizability, suggest an unexpected deviation from current theoretical predictions at low momentum transfer squared Q^2. Motivated by this puzzle, we analyze the resonance contributions to the sum of the generalized electric and magnetic nucleon polarizabilities $\alpha_E(Q^2)$ and $\beta_M(Q^2)$, within the Holographic QCD model by Witten, Sakai, and Sugimoto (WSS). In particular, we account for the contributions from the first low-lying nucleon resonances with spin 1/2 and 3/2 and both parities. After having extrapolated the WSS model parameters to fit experimental data on baryonic observables, our findings suggest that the resonance contributions alone do not solve the above-mentioned puzzle. Moreover, at least for the proton case, where data are available, our results are in qualitative agreement with resonance contributions extracted from experimental nucleon-resonance helicity amplitudes.

Resonance contributions follow a smooth Q^2 dependence



Spatial information & polarizability radii

Spatial dependence of induced polarizations

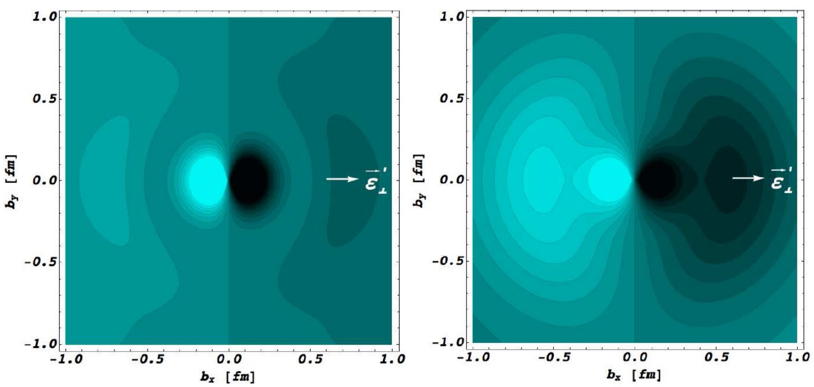
Nucleon form factor data ➔ light-front quark charge densities

Formalism extended to the deformation of these quark densities when applying an external e.m. field:

GPs ➔ spatial deformation of charge & magnetization densities under an applied e.m. field

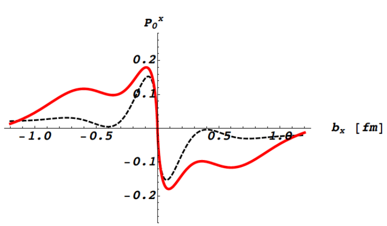
Induced polarization in a proton when submitted to an e.m. field

GP I GP II



Light (**dark**) regions ➔ largest (**smaller**) values

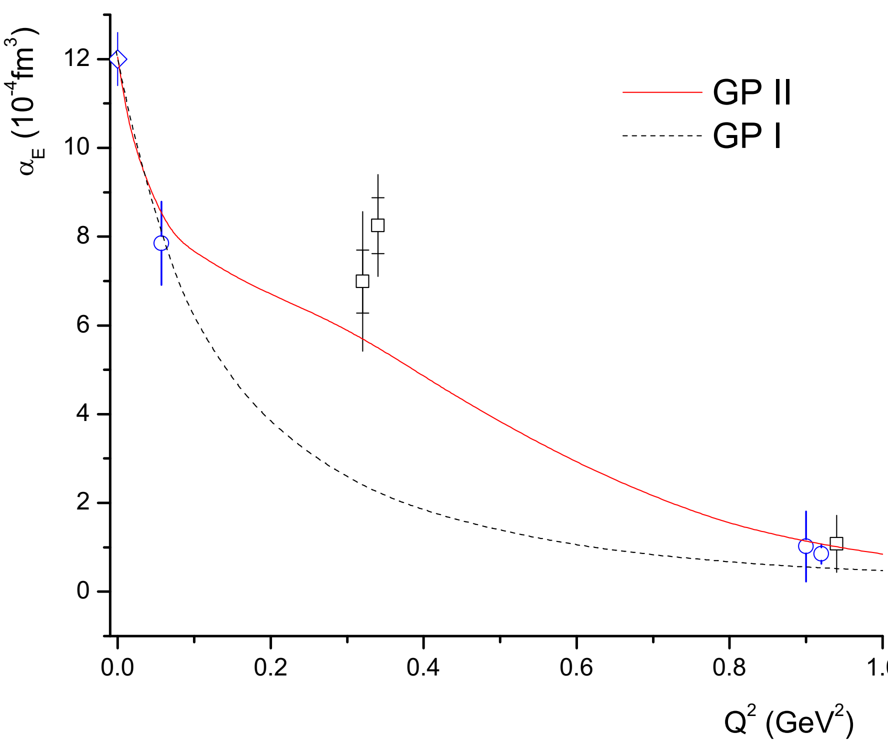
(photon polarization along x-axis, as indicated)



Induced polarization along b_y=0

Phys. Rev. Lett. 104, 112001 (2010)

M. Gorchtein, C. Lorce, B. Pasquini, M. Vanderhaeghen



Spatial dependence of induced polarizations

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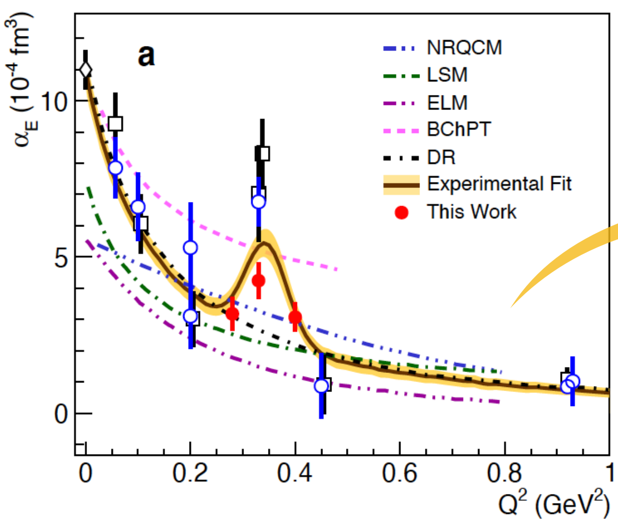
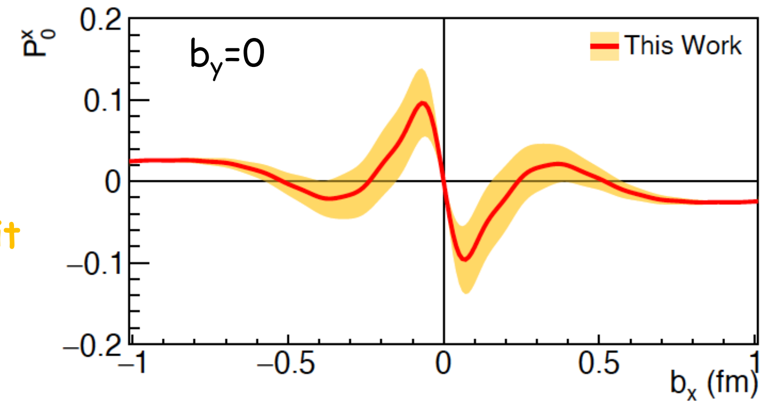
Induced polarization in a proton when submitted to an e.m. field



Experimental Fit



x-y defines the transverse plane with the z-axis being the direction of the fast-moving proton

Polarizability radii

$$\langle r^2_{\alpha_E} \rangle = \frac{-6}{\alpha_E(0)} \cdot \frac{d}{dQ^2} \alpha_E(Q^2) \Big|_{Q^2=0}$$

$$\langle r^2_{\beta_M} \rangle = \frac{-6}{\beta_M(0)} \cdot \frac{d}{dQ^2} \beta_M(Q^2) \Big|_{Q^2=0}$$

Polarizability radii

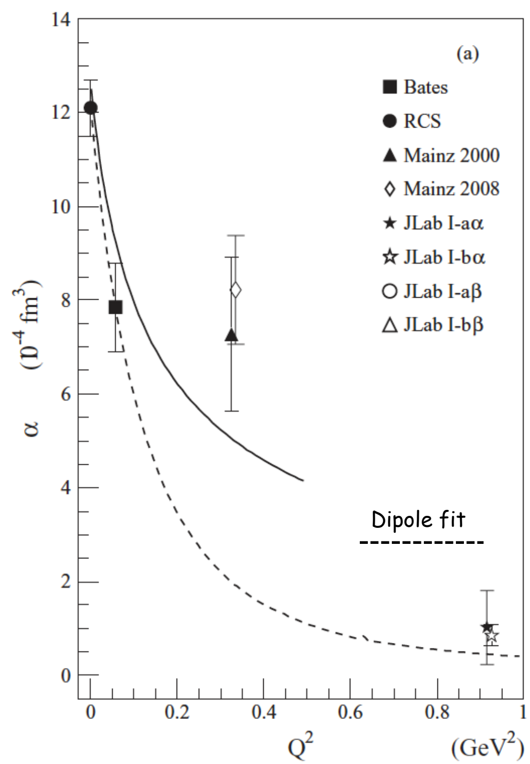
$$\langle r^2_{\alpha_E} \rangle = \frac{-6}{\alpha_E(0)} \cdot \frac{d}{dQ^2} \alpha_E(Q^2) \Big|_{Q^2=0}$$

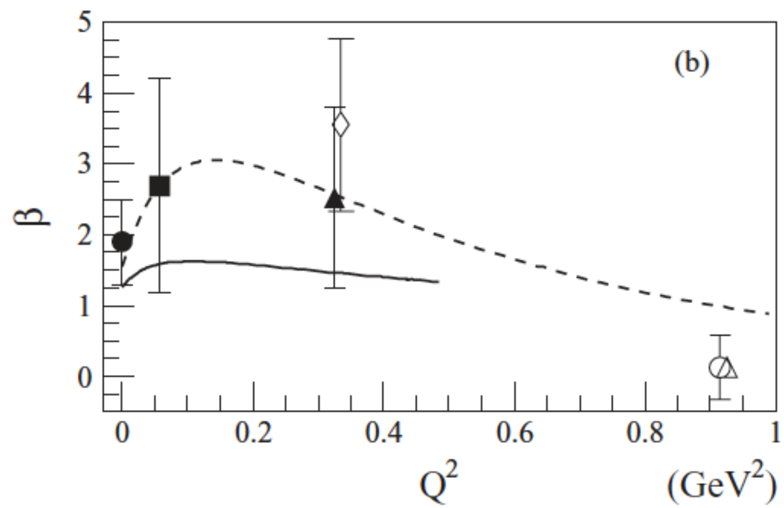
$$\langle r^2_{\beta_M} \rangle = \frac{-6}{\beta_M(0)} \cdot \frac{d}{dQ^2} \beta_M(Q^2) \Big|_{Q^2=0}$$

First extraction made possible with the MIT-Bates measurement (Q^2=0.06 GeV^2)

PRL **97,** 212001 (2006)

PHYSICAL REVIEW C **84**, 035206 (2011)





$$\langle r^2_\alpha \rangle = 2.16 \pm 0.31 \text{ fm}^2$$

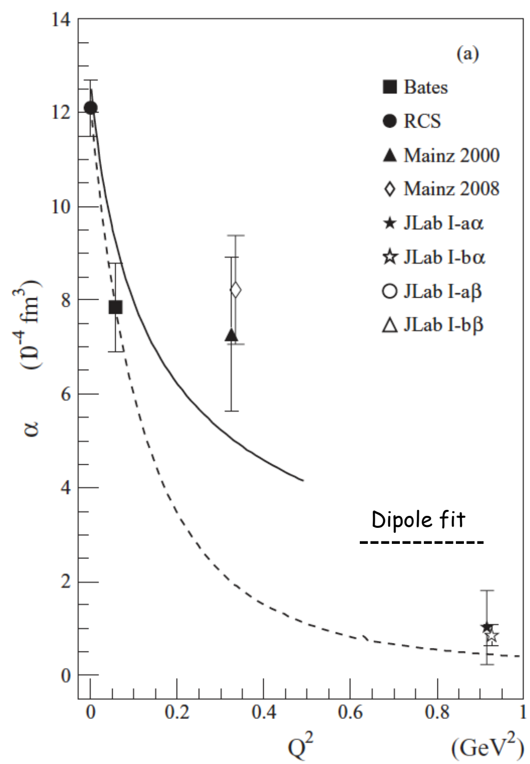
$$\langle r^2_\beta \rangle$$

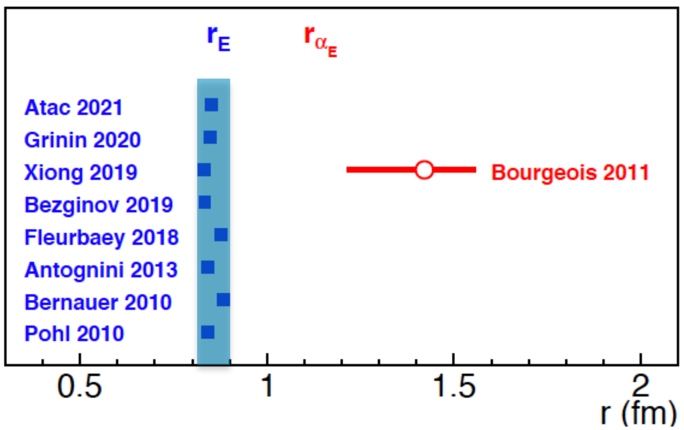
$$-4.67^{+5.36}_{-13.04}$$

Polarizability radii

$$\langle r^2_{\alpha_E} \rangle = \frac{-6}{\alpha_E(0)} \cdot \frac{d}{dQ^2} \alpha_E(Q^2) \Big|_{Q^2=0}$$

First extraction made possible with the MIT-Bates measurement (Q^2=0.06 GeV^2)

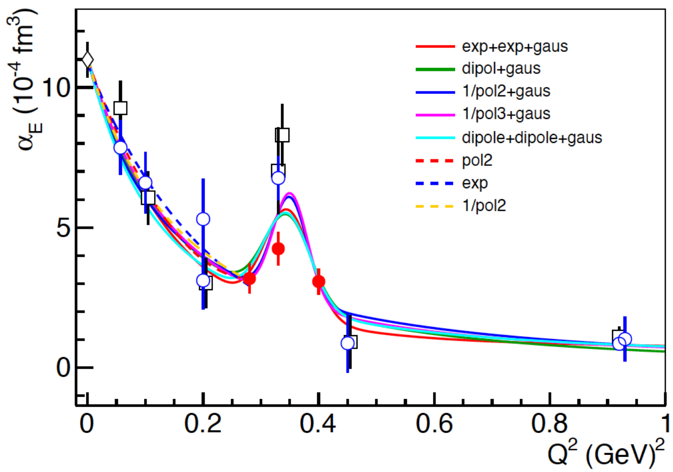




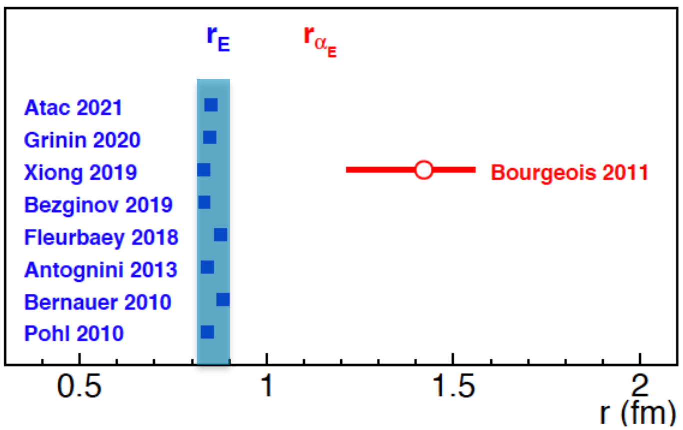
$$\langle r^2_{\alpha} \rangle = 2.16 \pm 0.31 \ \text{fm}^2$$

Polarizability radii

$$\langle r^2_{\alpha_E} \rangle = \frac{-6}{\alpha_E(0)} \cdot \frac{d}{dQ^2} \alpha_E(Q^2) \Big|_{Q^2=0}$$

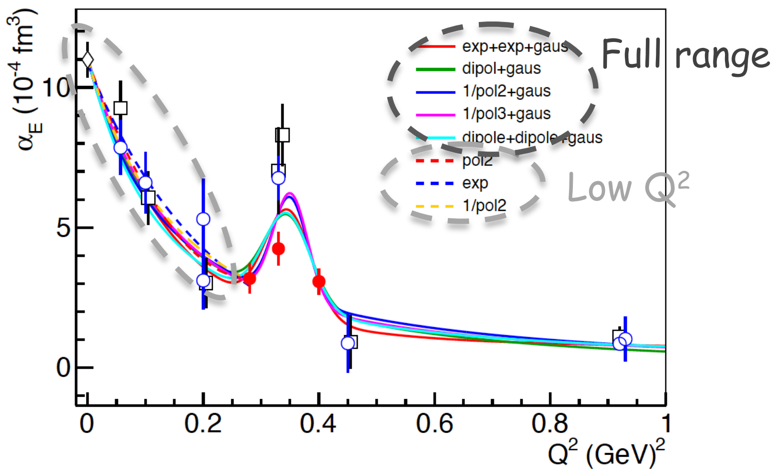


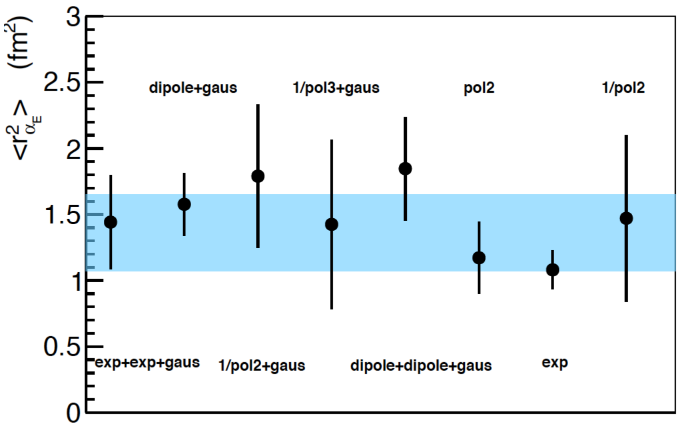
Since then: more data and more comprehensive treatment of the radius extraction



Polarizability radii

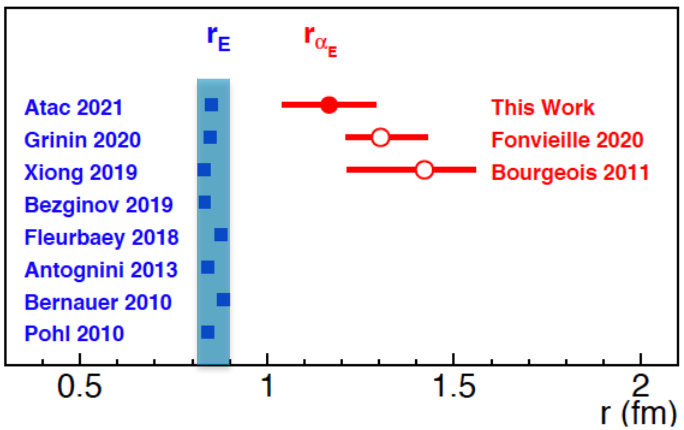
$$\langle r^2_{\alpha_E} \rangle = \frac{-6}{\alpha_E(0)} \cdot \frac{d}{dQ^2} \alpha_E(Q^2) \Big|_{Q^2=0}$$





$$\langle r^2_{\alpha_E} \rangle = 1.36 \pm 0.29 \text{ fm}^2$$

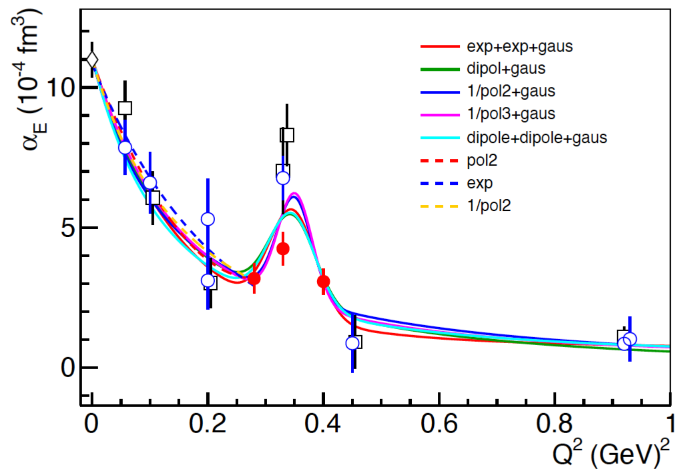
Since then: more data and more comprehensive treatment of the radius extraction

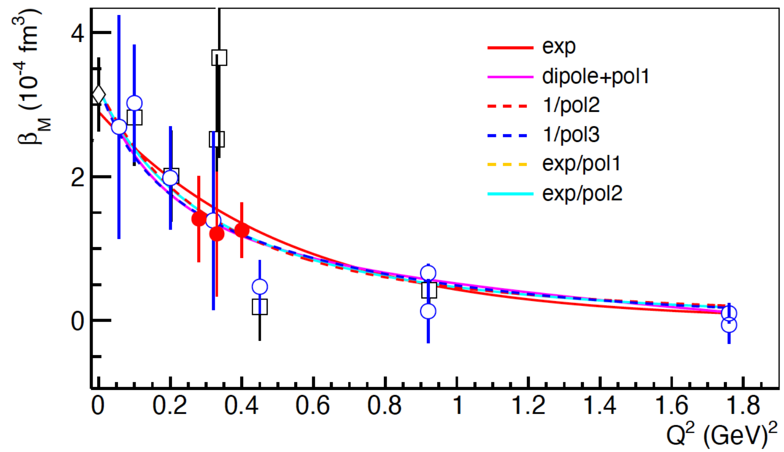


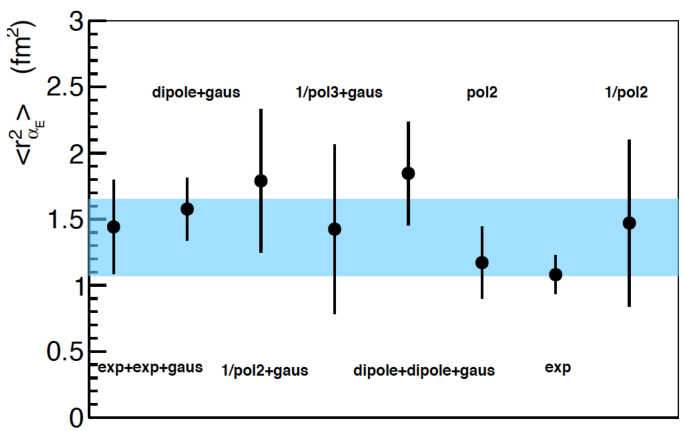
Polarizability radii

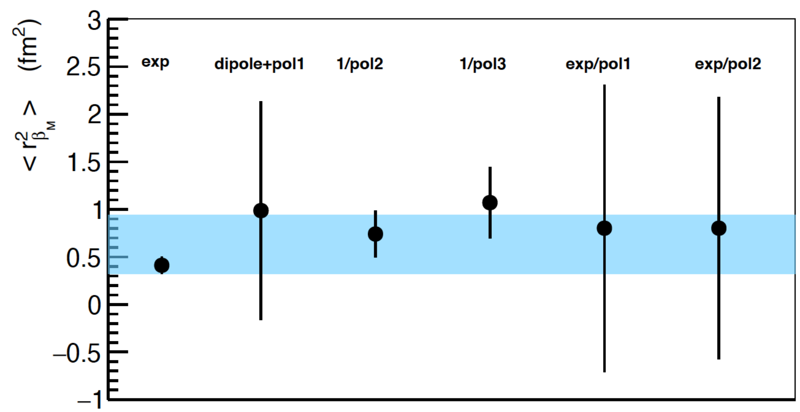
$$\langle r^2_{\alpha_E} \rangle = \frac{-6}{\alpha_E(0)} \cdot \frac{d}{dQ^2} \alpha_E(Q^2) \Big|_{Q^2=0}$$

$$\langle r^2_{\beta_M} \rangle = \frac{-6}{\beta_M(0)} \cdot \frac{d}{dQ^2} \beta_M(Q^2) \Big|_{Q^2=0}$$





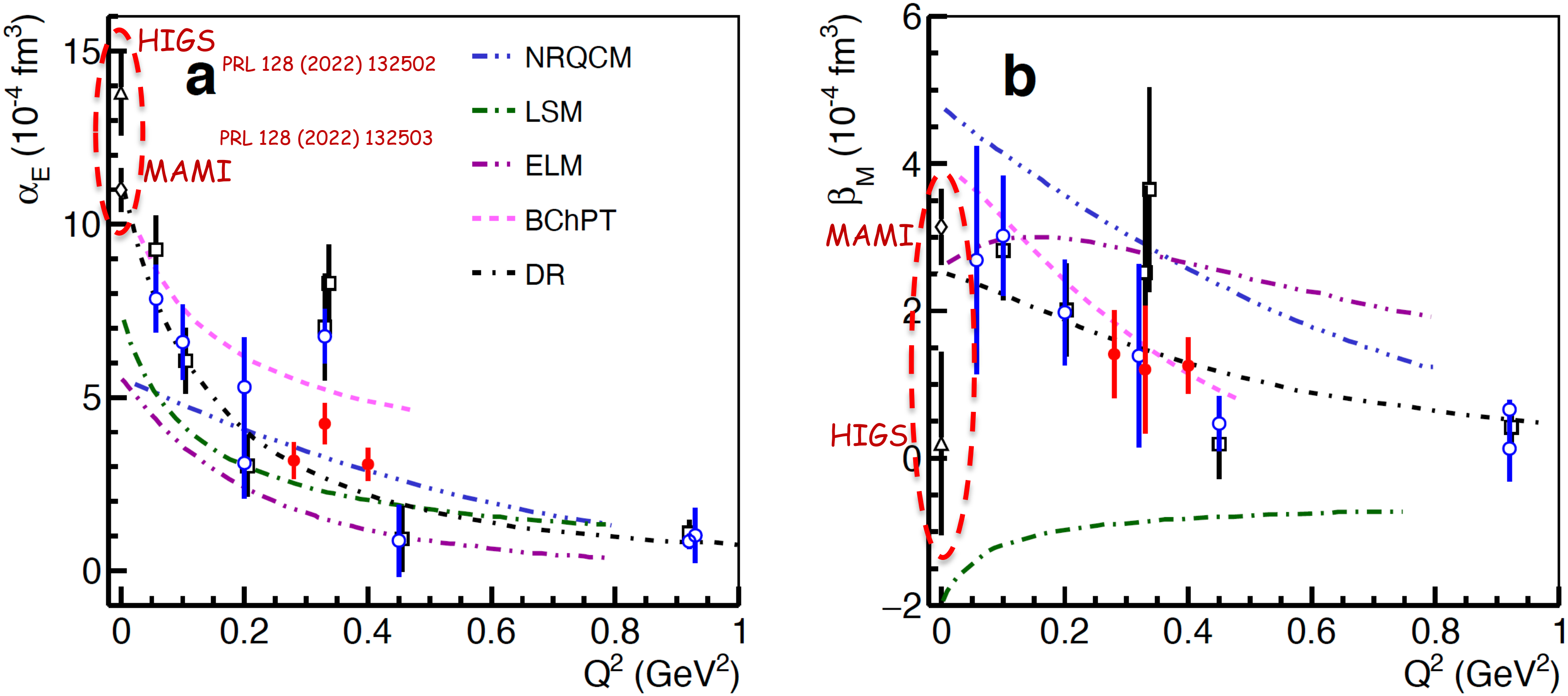




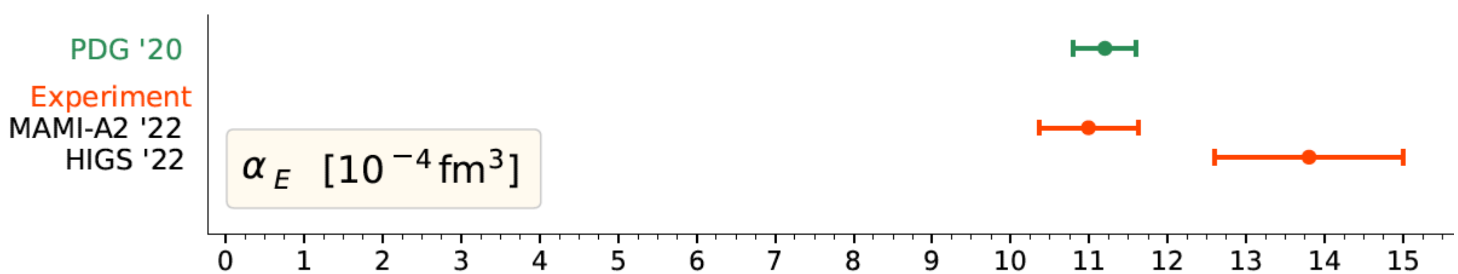
$$\langle r^2_{\alpha_E} \rangle = 1.36 \pm 0.29 \text{ fm}^2$$

$$\langle r^2_{\beta_M} \rangle = 0.63 \pm 0.31 \text{ fm}^2$$

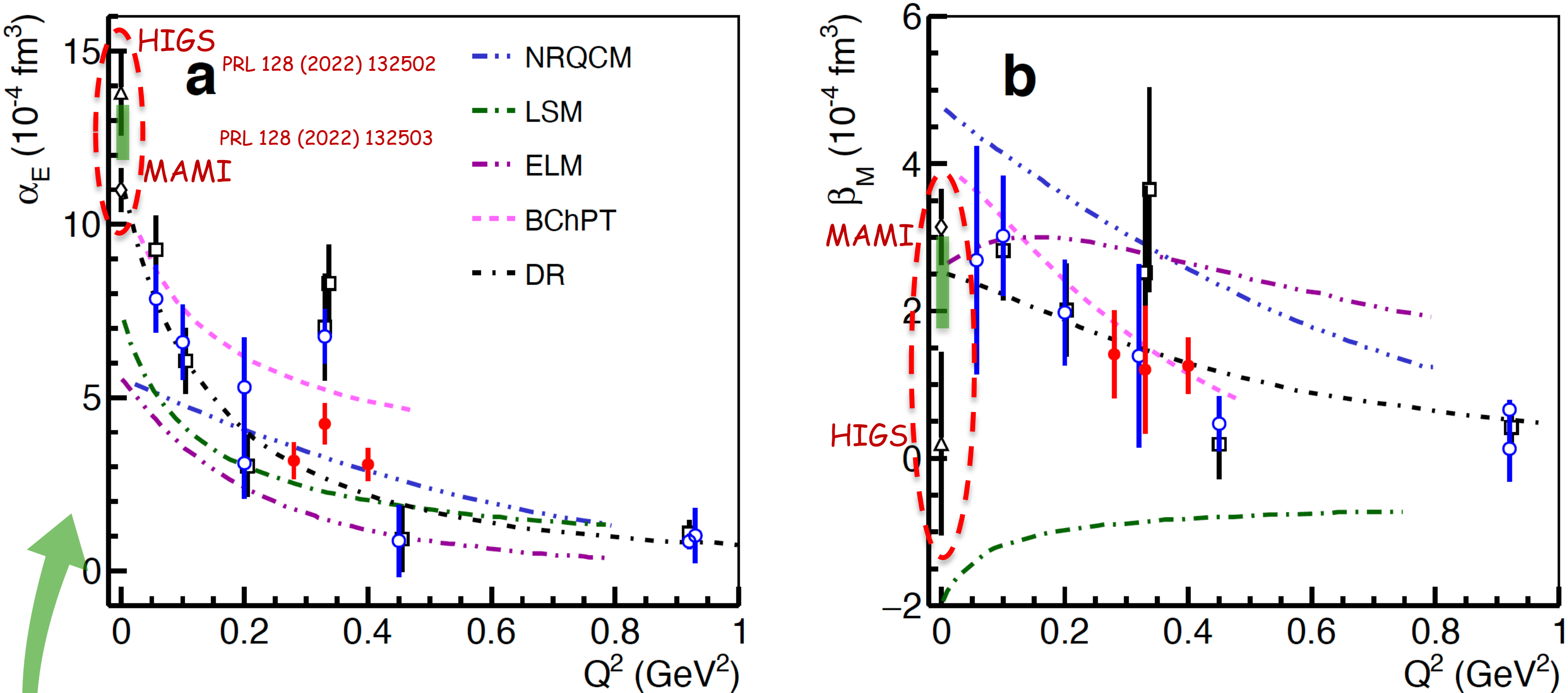
Static Polarizabilities



Recent measurements exhibit tension → affects the pol. radius extraction



Static Polarizabilities



PHYSICAL REVIEW LETTERS 129, 102501 (2022)

First Concurrent Extraction of the Leading-Order Scalar and Spin Proton Polarizabilities

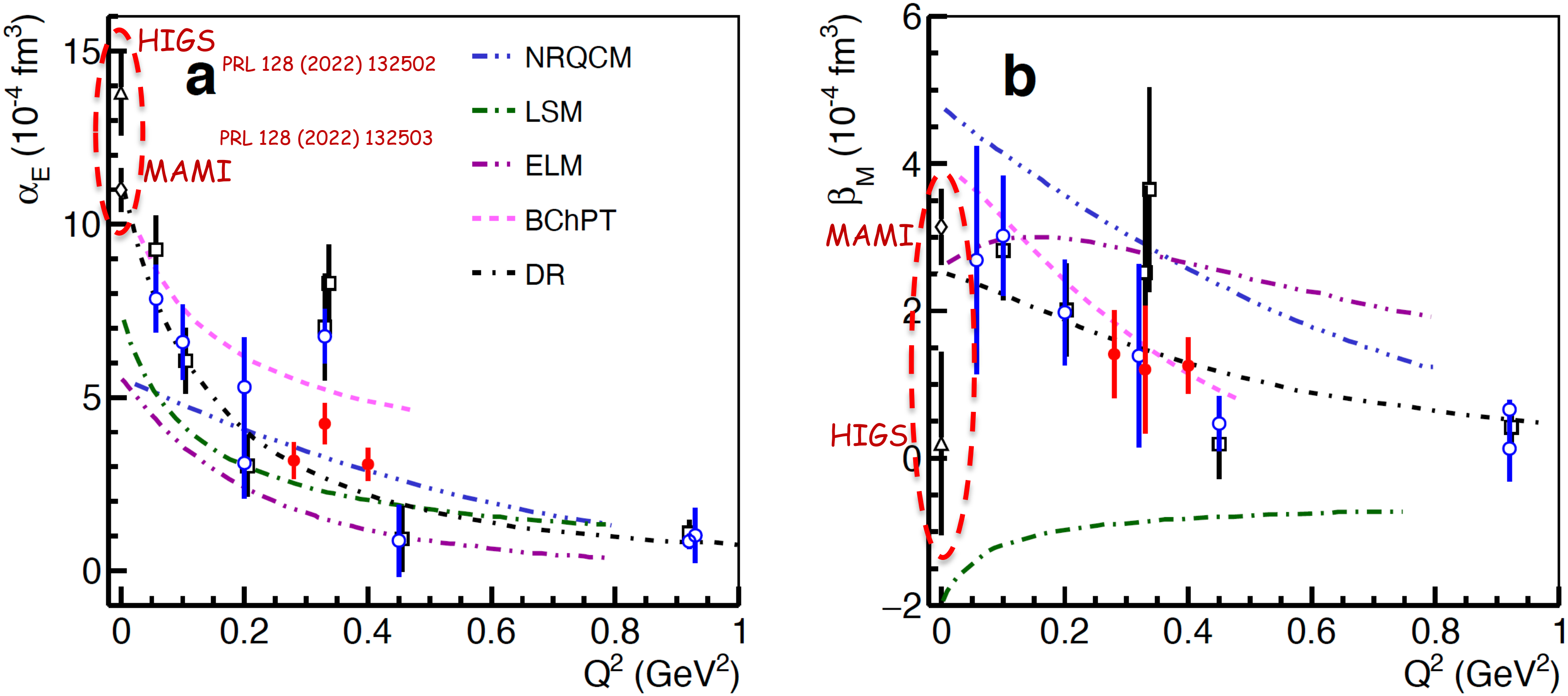
E. Mornacchi,[1,*] S. Rodini,[2] B. Pasquini,[3,4] and P. Pedroni[4]
[1]*Institut für Kernphysik, Johannes Gutenberg-Universität Mainz, D-55099 Mainz, Germany*
[2]*Institut für Theoretische Physik, Universität Regensburg, D-93040 Regensburg, Germany*
[3]*Dipartimento di Fisica, Università degli Studi di Pavia, I-27100 Pavia, Italy*
[4]*INFN Sezione di Pavia, I-27100 Pavia, Italy*

(Received 3 May 2022; revised 11 July 2022; accepted 2 August 2022; published 31 August 2022)

We performed the first simultaneous extraction of the six leading-order proton polarizabilities. We reached this milestone thanks to both new high-quality experimental data and an innovative bootstrap-based fitting method. These new results provide a self-consistent and fundamental benchmark for all future theoretical and experimental polarizability estimates.

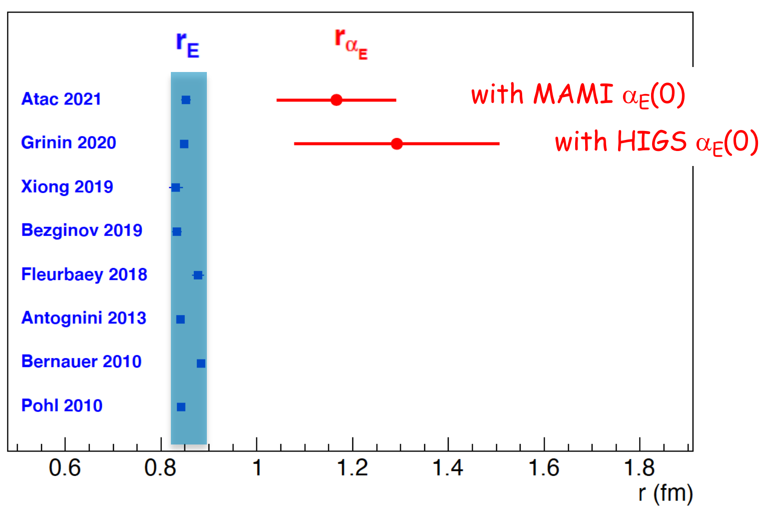
$$\alpha_{E1} = [12.7 \pm 0.8(\text{fit}) \pm 0.1(\text{model})] \times 10^{-4}\ \text{fm}^3,$$
$$\beta_{M1} = [2.4 \pm 0.6(\text{fit}) \pm 0.1(\text{model})] \times 10^{-4}\ \text{fm}^3,$$
$$\gamma_{E1E1} = [-3.0 \pm 0.6(\text{fit}) \pm 0.4(\text{model})] \times 10^{-4}\ \text{fm}^4,$$
$$\gamma_{M1M1} = [3.7 \pm 0.5(\text{fit}) \pm 0.1(\text{model})] \times 10^{-4}\ \text{fm}^4,$$
$$\gamma_{E1M2} = [-1.2 \pm 1.0(\text{fit}) \pm 0.3(\text{model})] \times 10^{-4}\ \text{fm}^4,$$
$$\gamma_{M1E2} = [2.0 \pm 0.7(\text{fit}) \pm 0.4(\text{model})] \times 10^{-4}\ \text{fm}^4,$$

Polarizability radii - Static Polarizabilities



$$\langle r^2_{\alpha_E} \rangle = 1.36 \pm 0.29 \ fm^2$$

$$\langle r^2_{\alpha_E} \rangle = 1.67 \pm 0.50 \ fm^2$$

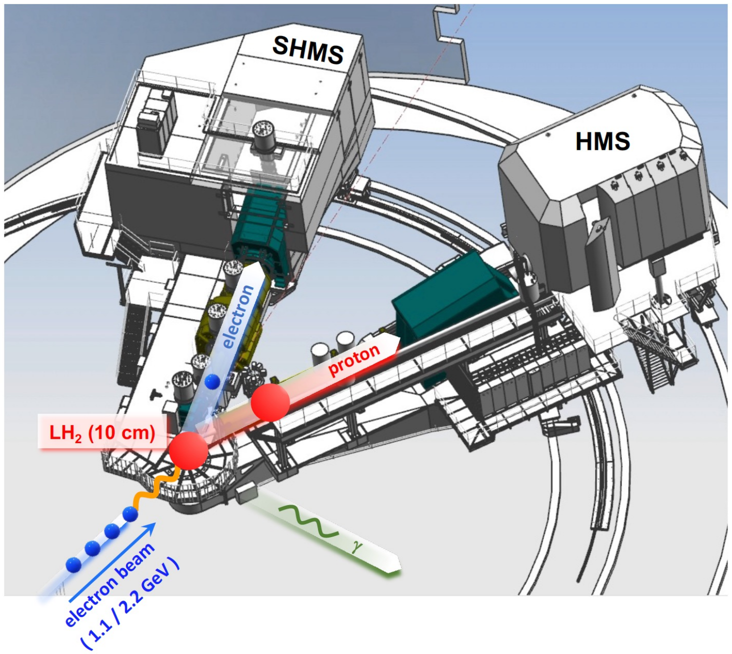


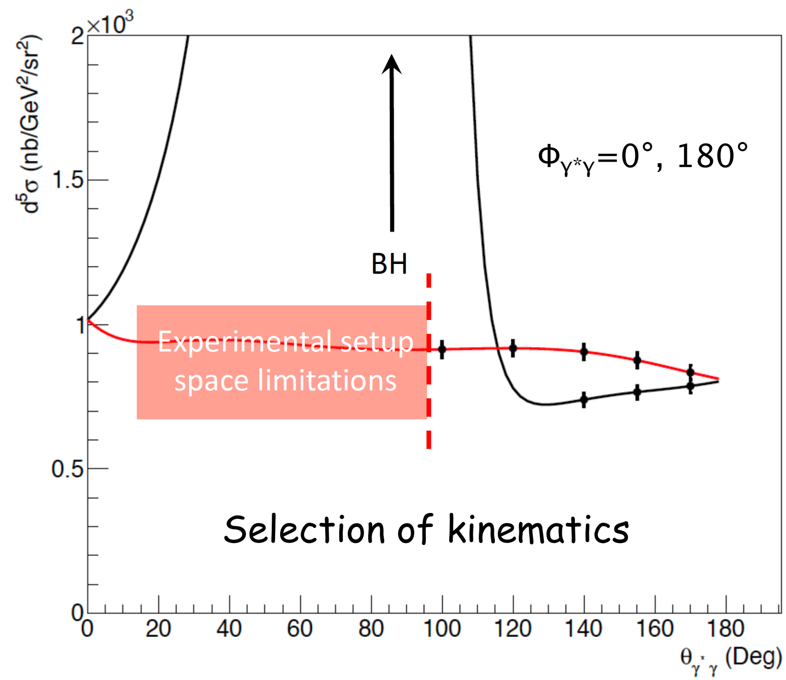
$$\langle r^2_{\beta_M} \rangle = 0.63 \pm 0.31 \ fm^2$$

$$\langle r^2_{\beta_M} \rangle = 0.20 \pm 0.36 \ fm^2$$

Moving Forward

VCS-II (E12-23-001) @ JLab



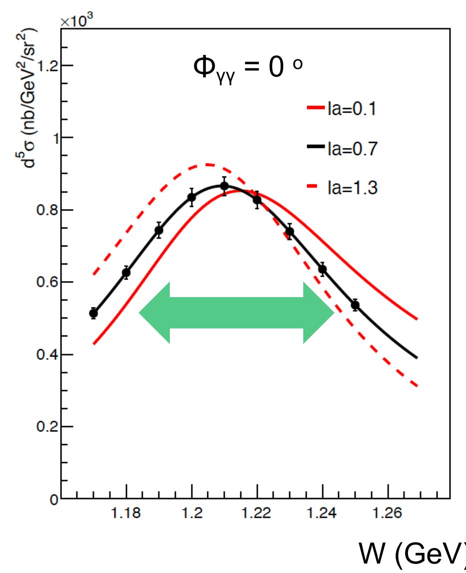


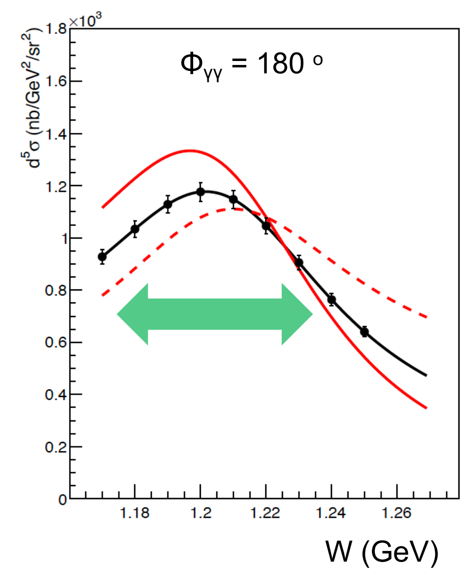
Extend Q^2 range & targeted measurements to fully exploit the sensitivity to the EM GPs

APPROVED
PAC 51

Production (E_0 = 1.1 GeV) :	6 days
Production (E_0 = 2.2 GeV) :	53 days
Studies (optics/dummy/calibrations) :	3 days

Total: 62 days

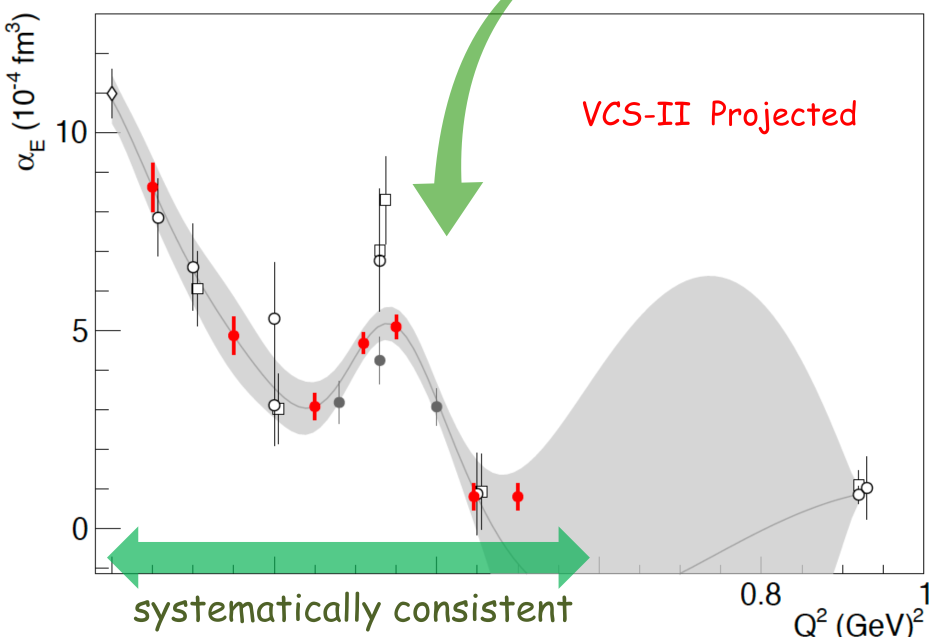




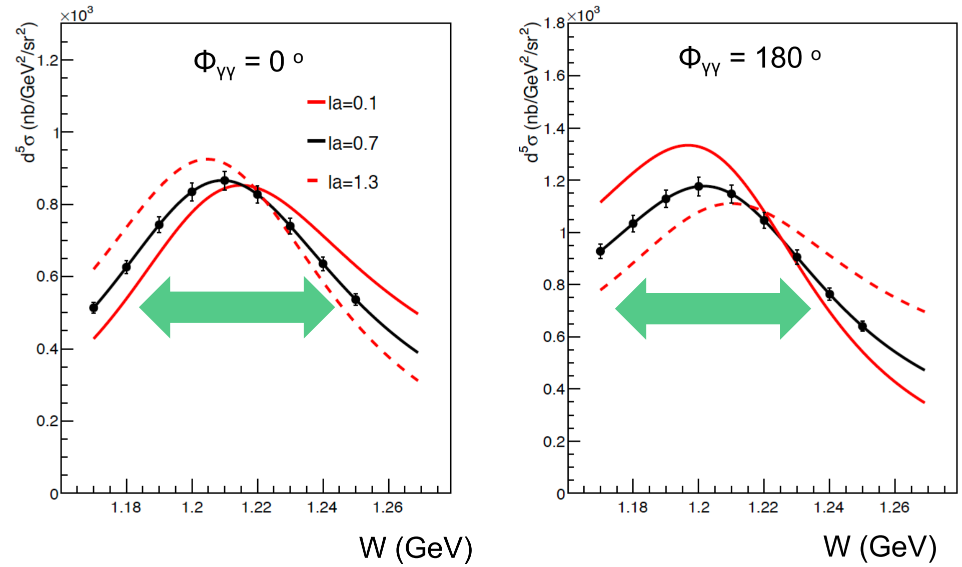
VCS-II Projected Measurements

High precision measurements
combined with a fine mapping in Q^2

Targeted measurements to fully
exploit the sensitivity to the GPs

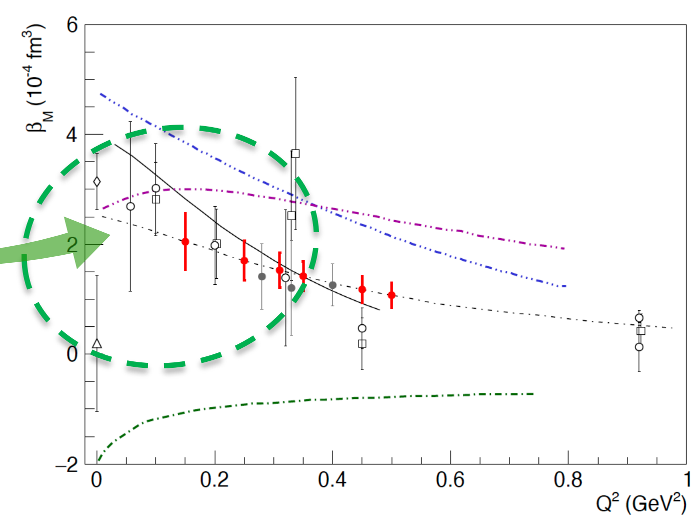


systematically consistent
measurements throughout Q^2



Improve upon β_M :

Pin down the competing
para/dia-magnetic contributions
in the nucleon



Can we measure with a different method ?

Yes: positrons and/or beam spin asymmetries

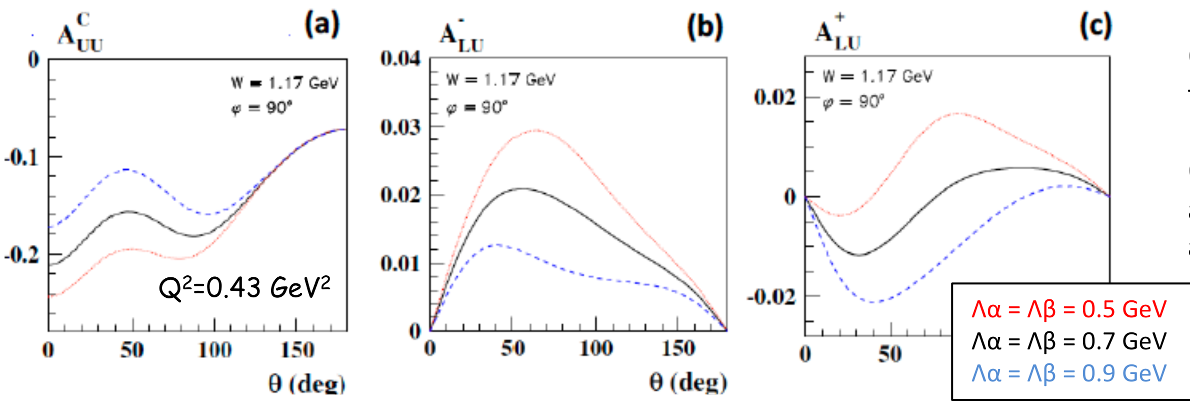
Positrons allow for an independent path to access experimentally the GPs

Eur. Phys. J. A 57 (2021) 11, 316

Virtual Compton scattering at low energies with a positron beam

Barbara Pasquini[a,1,2], Marc Vanderhaeghen[b,3]

[1]Dipartimento di Fisica, Università degli Studi di Pavia, 27100 Pavia, Italy
[2]Istituto Nazionale di Fisica Nucleare, Sezione di Pavia, 27100 Pavia, Italy
[3]Institut für Kernphysik and PRISMA+ Cluster of Excellence, Johannes Gutenberg Universität, D-55099 Mainz, Germany



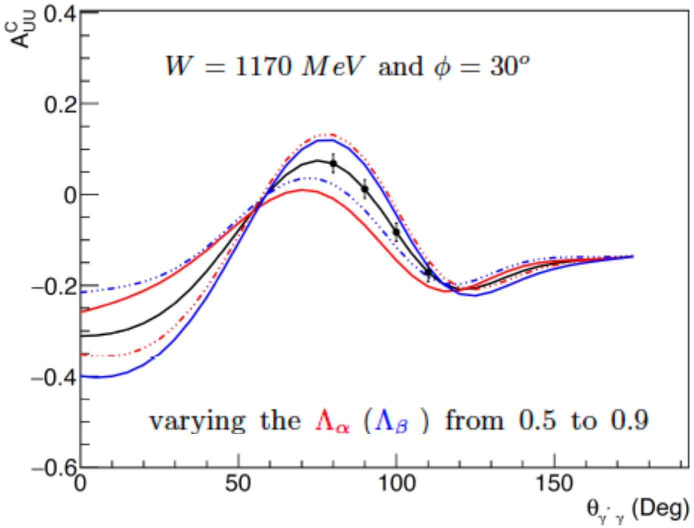
(a): The beam-charge asymmetry as a function of the photon scattering angle at Q2 = 0.43 GeV 2.

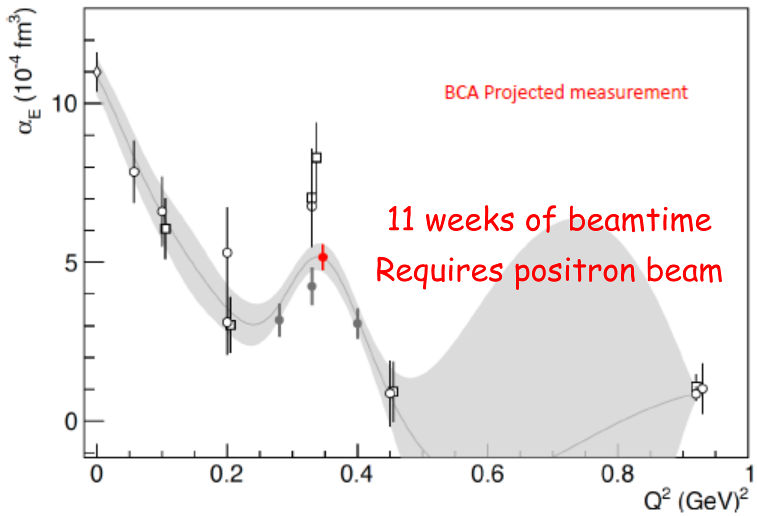
(b) & (c): The electron and positron beam-spin asymmetry as a function of the photon scattering angle for out-of-plane kinematics.

Unpolarized beam charge asymmetry (BCA) : $A^C_{UU} = \frac{(d\sigma^+_+ + d\sigma^+_-) - (d\sigma^-_+ + d\sigma^-_-)}{d\sigma^+_+ + d\sigma^+_- + d\sigma^-_+ + d\sigma^-_-}$

Lepton beam spin asymmetry (BSA) : $A^e_{LU} = \frac{d\sigma^e_+ - d\sigma^e_-}{d\sigma^e_+ + d\sigma^e_-}$

BCA (electrons & positrons)





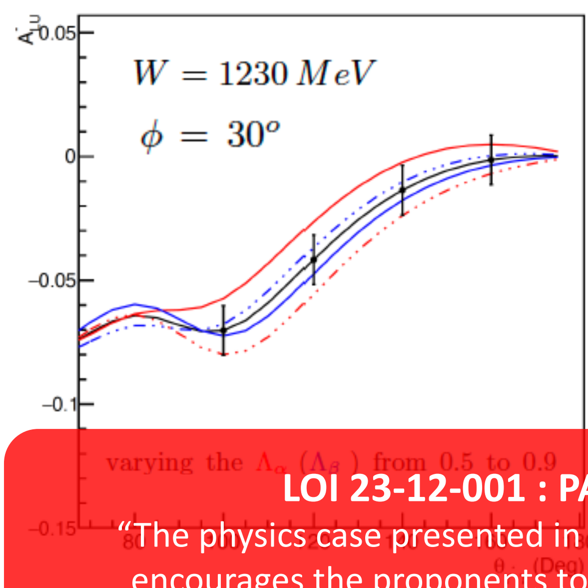
Hall C (SHMS / HMS)

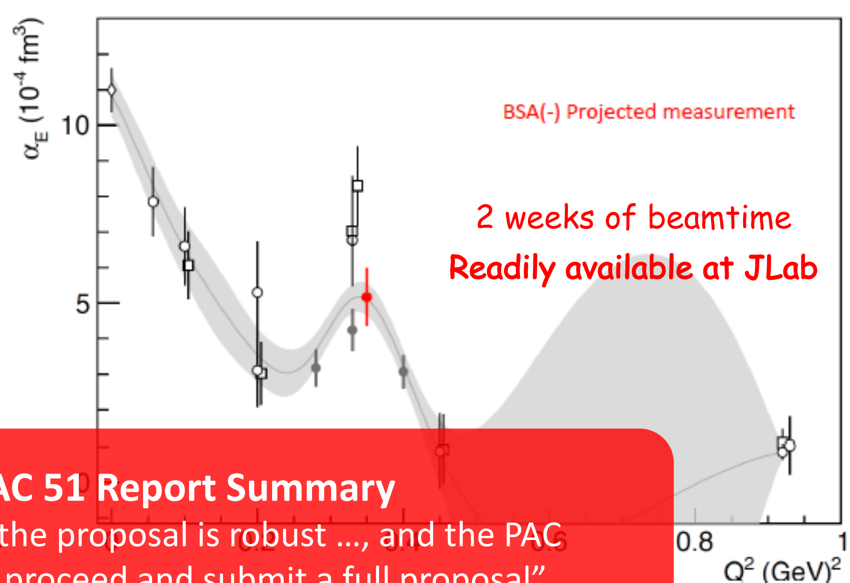
e^- : ~ 1 week @ 50 μA

and

e^+ : ~ 10 weeks @ 5 μA

BSA (electrons or positrons)





e^- (pol. 85% @ 70 μA)

~ 2 weeks of beamtime

or

e^+ (pol. 60% @ 50 nA)

~ 3 orders of magnitude more beamtime

LOI 23-12-001 : PAC 51 Report Summary

"The physics case presented in the proposal is robust ..., and the PAC encourages the proponents to proceed and submit a full proposal"

Summary

Progress in measuring fundamental properties of the proton

Insight to spatial deformation of the nucleon densities under an applied EM field,
interplay of para/dia-magnetism in the proton, polarizability radii, …

Electric GP:

- possibility for a non-trivial (non-monotonic) behavior in $\alpha_E(Q^2)$
(albeit with a smaller magnitude than originally suggested)

or

- at minimum: strong tension between world data

Experiment is ahead of theory:

Stringent constraints to theoretical predictions

High precision benchmark data for upcoming LQCD calculations

Future experiments:

Shape of the α_E structure (if it exists)
pin down with precision - important input for the theory

Conduct independent cross-check
Measure via a different channel (BS asymmetries & positrons)

Thank you!