Parallel Session E:

Low Energy Spin Physics with Lepton, Photon and Hadron Probes

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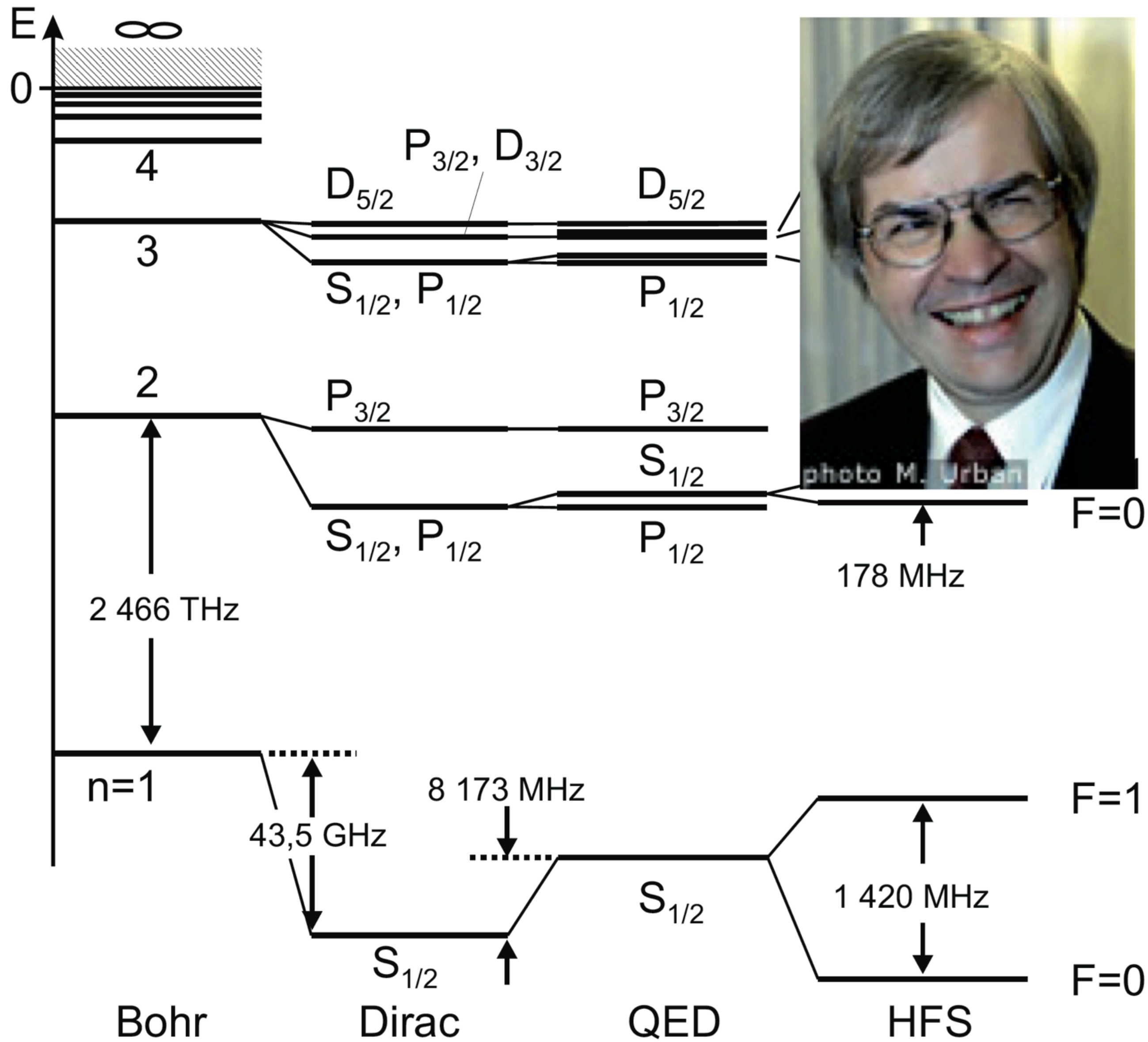
JG-University Mainz)

FERRARA - ITALY

10-14 SEPTEMBER, 2018

Strong force

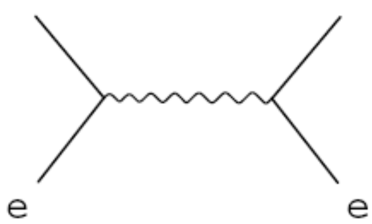
Hydrogen Atom, (g-2)-factor, QED



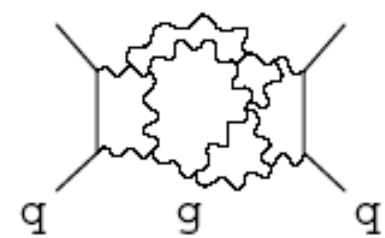
How do Hadrons arise from QCD?

- Fundamental differences relative to QED
  - Self-interaction: highly nonlinear
  - Interaction increases at large distance: Confinement
  - Interaction decreases at small distance: Asymptotic freedom

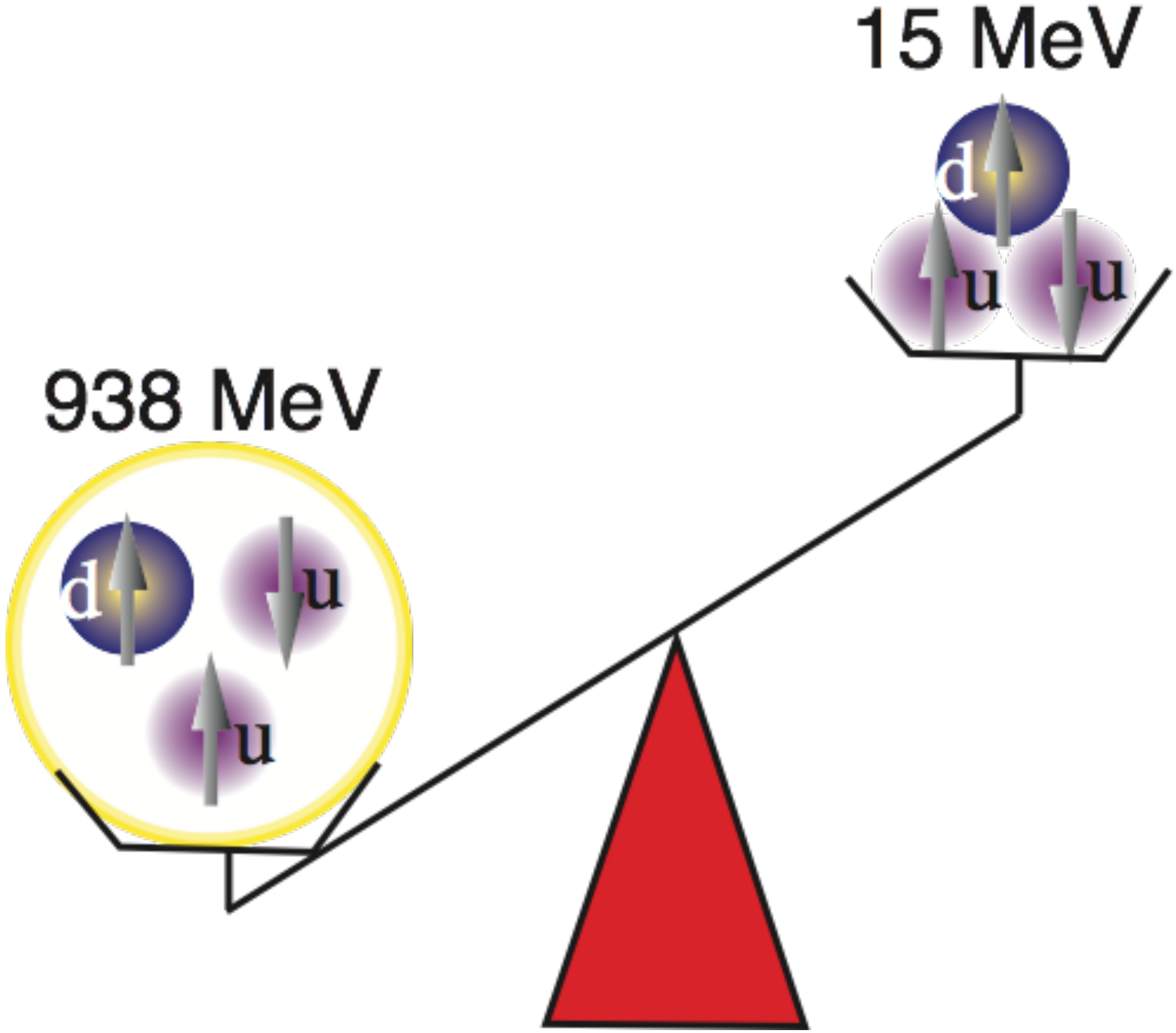
QED



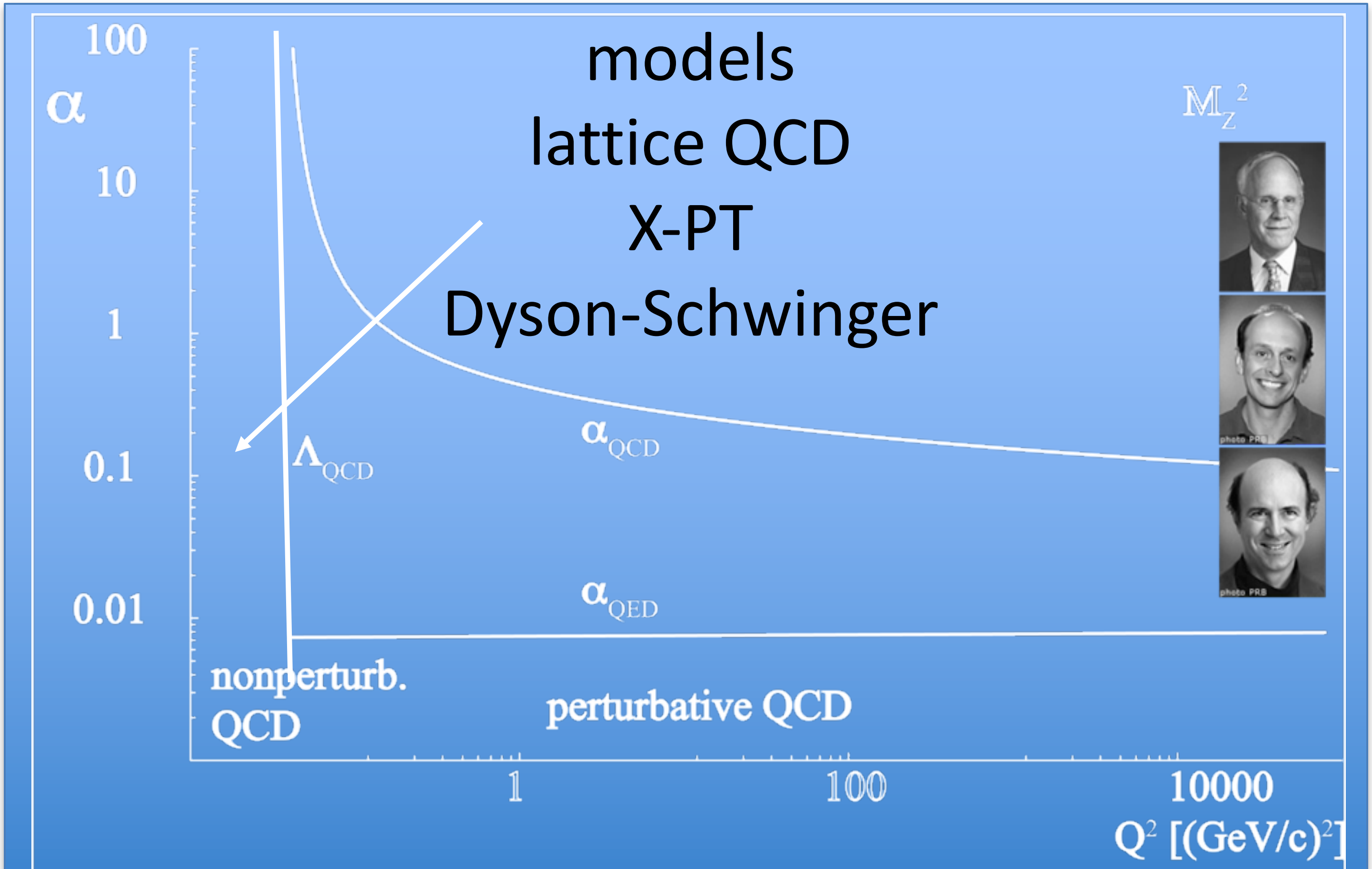
QCD



How do Hadrons arise from QCD?
„Lamb Shift in QCD“

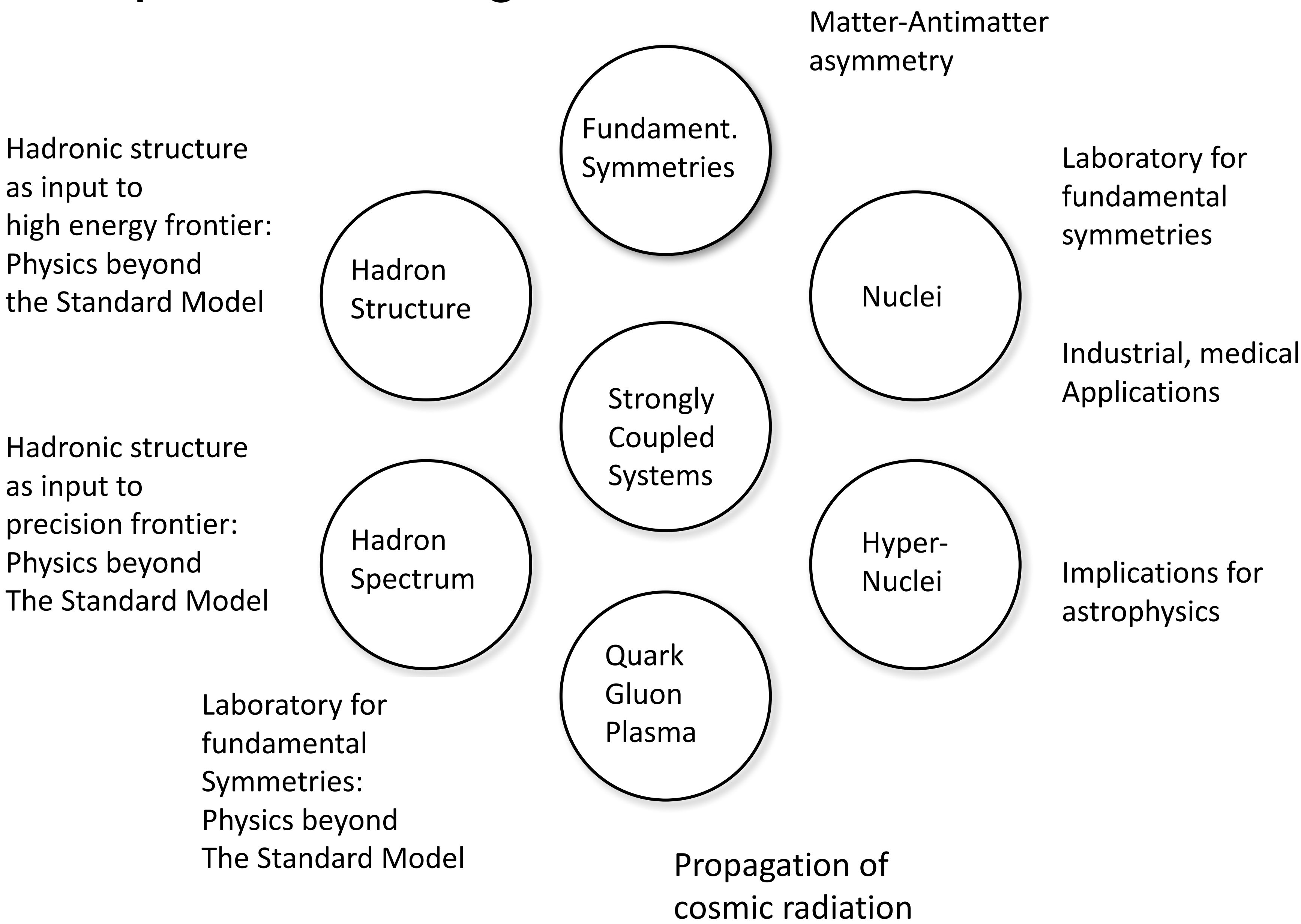


QCD-Renormalisation à la QED

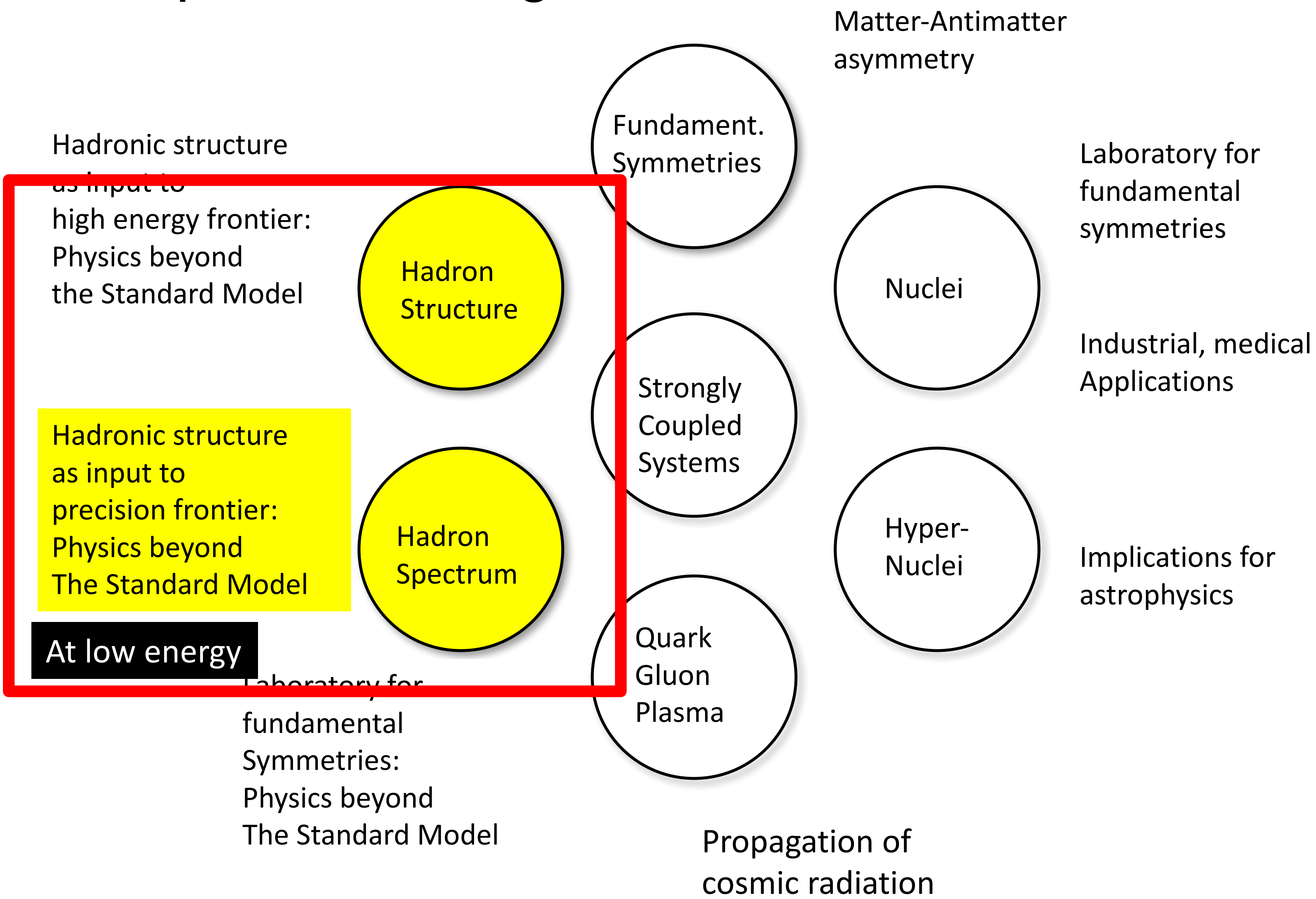


- origin of nucleon mass
- quark and gluon condensates
- structure of the nucleon -> Form Factor

Impact of Strong Interaction Investigations



Impact of Strong Interaction Investigations



- Higher Order QED/electro-weak Processes involving non-perturbative Objects
  - Razvan-Daniel Bucoveanu: QED radiative corrections for PV electron scattering
  - Misha Gorshteyn: Reduced hadronic uncertainty in V_{ud} and CKM unitarity
  - Boxing Gou: Transverse Single Spin Asymmetries, two photon exchange amplitude
- Nonperturbative Observables at low energy:
  - Eugene Chudakov: Measurement of the J/Ψ photoproduction cross section close to threshold, LHCb Pentaquark
  - Isabella Garzia: Baryon electromagnetic from factors at BES-III
  - Paolo Pedroni: Extracting the scalar dynamical polarizabilities from real Compton scattering data
  - S. Dymov: Measurement of the analyzing powers in pd elastic and pn quasi-elastic scattering at small angles at ANKE-COSY
  - Kiyoshi Tanida: Prospects for the spin structure study of hyperons using heavy quark decays at Belle II

- Higher Order QED/electro-weak Processes involving non-p… …tive Objects [New result]
  - Razvan-Daniel Bucoveanu: QED radiative corre… …r PV elect… scattering [New result]
  - Misha Gorshteyn: Reduced hadronic uncertainty i… V_{ud} … …KM unitarity [New result]
  - Boxing Gou: Transverse Single Spin Asymme… …o photon exchange amplitude
- Nonperturbative Observables at low energy:
  - Eugene Chudakov: Measurement of the J/Ψ photo… …n cross … …ion close to threshold, LHCb Pentaquark [New result]
  - Isabella Garzia: Baryon electromagnetic from factors at BES… [New result]
  - Paolo Pedroni: Extracting the scalar dynamical po… …ties from real Compton scattering data [New result]
  - S. Dymov: Measurement of the analyzing pov… …ers in pd … …nd pn quasi-elastic scattering at small angles at ANKE-COSY [New result]
  - Kiyoshi Tanida: Prospects for the spin structure study of hypero… …g heavy quark decays at Belle II [Future]

QED radiative corrections for the P2 experiment

Spin 2018

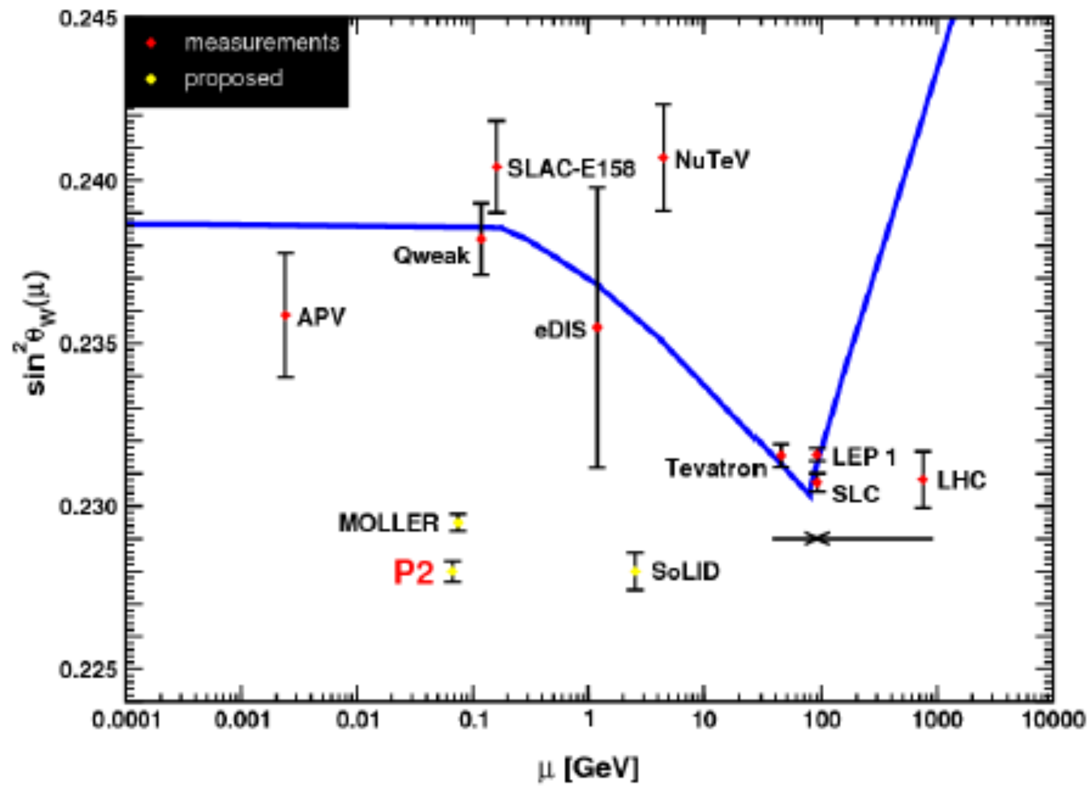
Razvan-Daniel Bucoveanu

PRISMA Cluster of Excellence,
Institut für Physik,
Johannes Gutenberg-Universität Mainz

September 10, 2018

$\sin^2 \theta_W$ is scale dependent

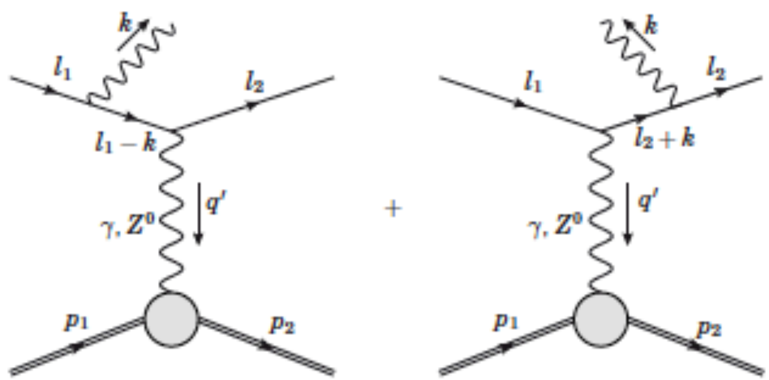
$$\sin^2 \hat{\theta}_W(Q)_{\overline{\text{MS}}} = \kappa(Q)_{\overline{\text{MS}}} \sin^2 \theta_W(M_Z)_{\overline{\text{MS}}}$$



arXiv:1802.04759 (to appear in EPJA)

→ The future P2 experiment at low momentum transfer will complement other high-precision determinations and may thus help to resolve differences between previous measurements, or find interesting new effects.

Shift in momentum transfer due to photon radiation



Shifted kinematics:

$$Q^2 = -(l_1 - l_2)^2 \to Q'^2 = -(l_1 - l_2 - k)^2$$

$\to$ Q'^2 can be on average much smaller than Q^2.

The average shift in momentum transfer squared due to hard-photon bremsstrahlung can be defined as

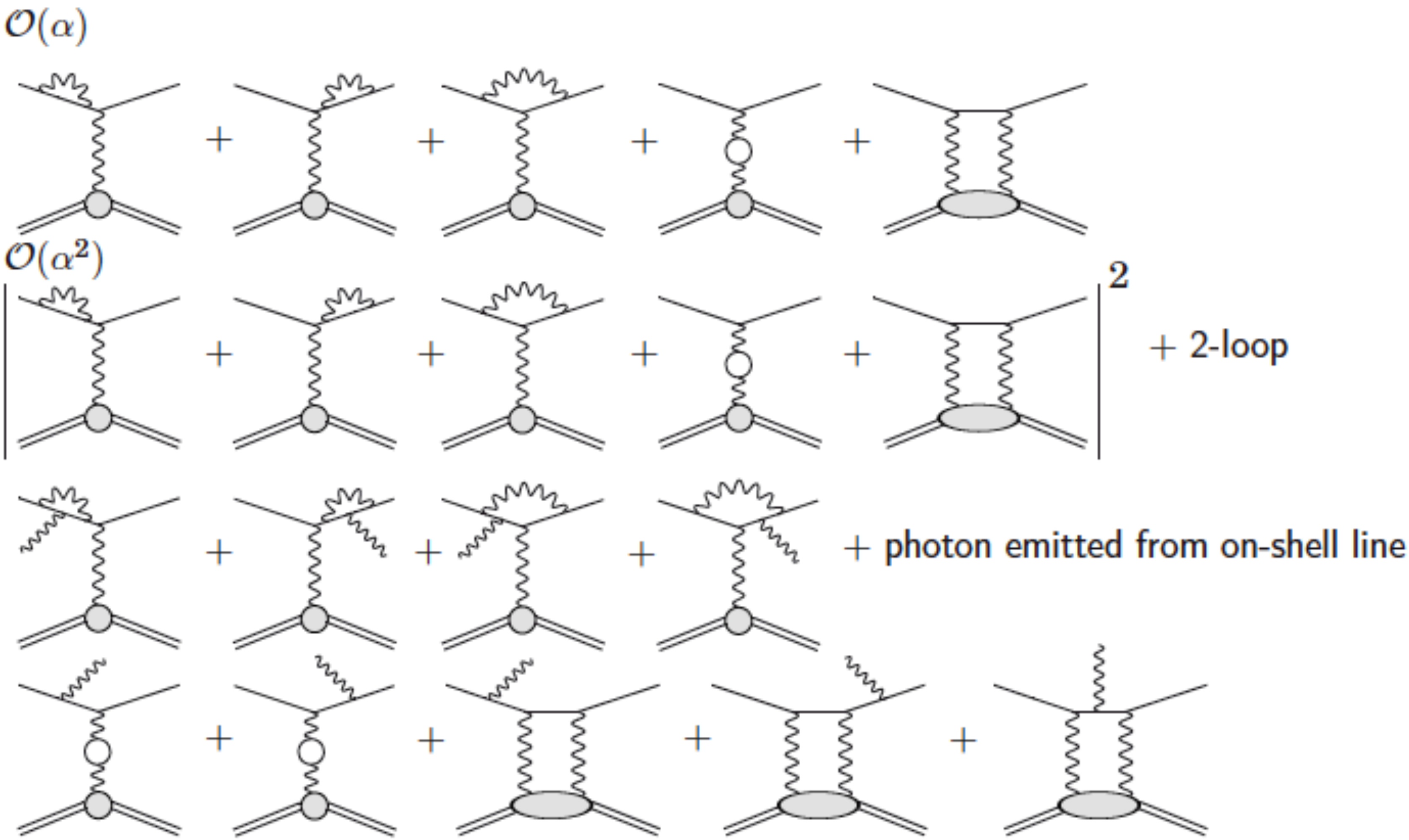
$$\langle \Delta Q^2 \rangle = \frac{1}{\sigma} \int \frac{\mathrm{d}^4 \sigma^{1\gamma}}{\mathrm{d}E' \mathrm{d}\theta_l \mathrm{d}E_\gamma \mathrm{d}\theta_\gamma} \mathrm{d}E' \mathrm{d}\theta_l \mathrm{d}E_\gamma \mathrm{d}\theta_\gamma \Delta Q^2,$$

with

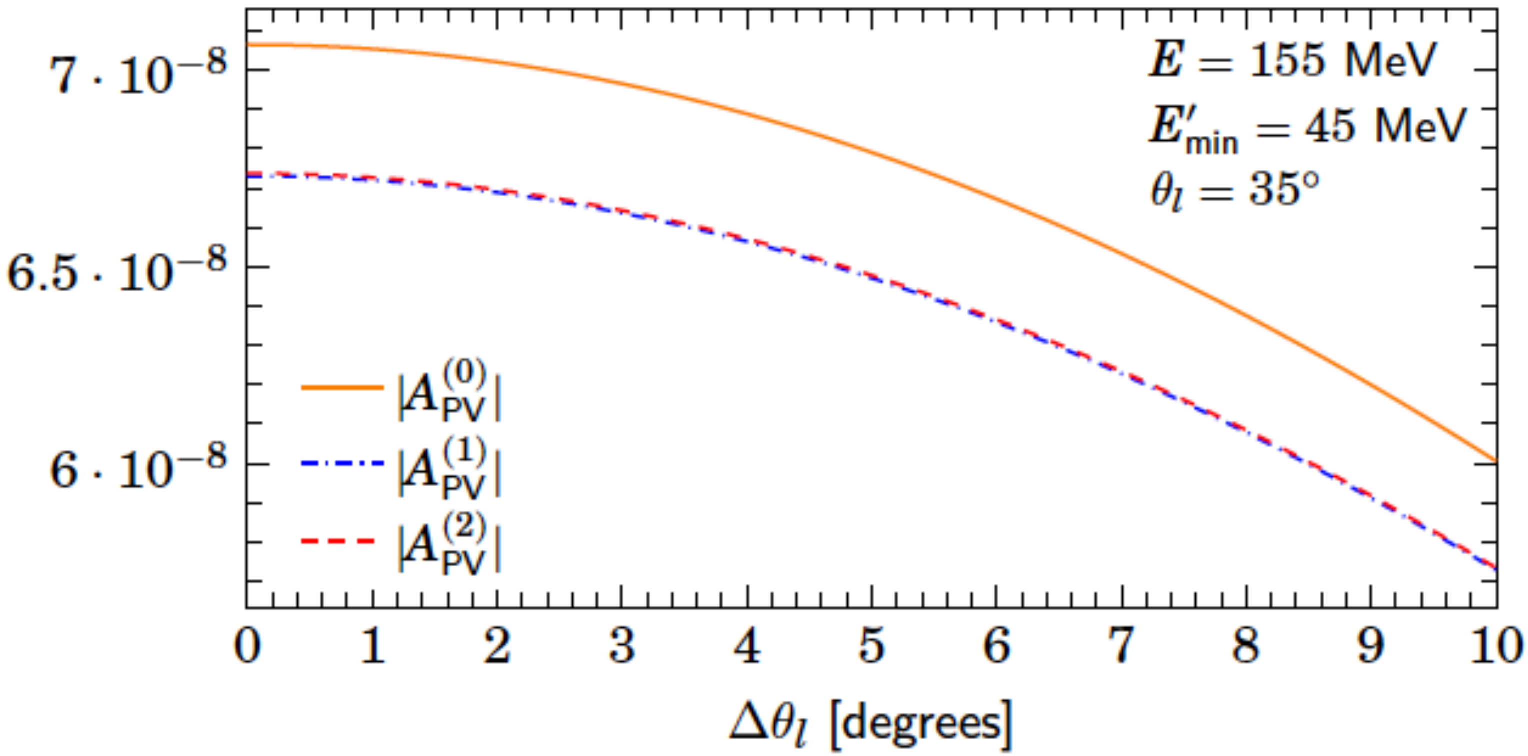
$$\Delta Q^2 = Q'^2 - Q^2,$$

$$\sigma = \sigma^{1\gamma}_{1-\mathrm{loop}}\Big|_{E_\gamma < \Delta} + \sigma^{1\gamma}\Big|_{E_\gamma > \Delta}.$$

QED virtual corrections



$\mathcal{O}(\alpha^2)$ QED corrections to the asymmetry (P2 kinematics)



The shift in Q^2 is a kinematical effect included in 1γ radiation $\rightarrow$ very small $\mathcal{O}(\alpha^2)$ corrections to the asymmetry.

Reduced hadronic uncertainty in V_{ud} and CKM unitarity

Misha Gorshteyn

Universität Mainz

C-Y Seng, MG, H Patel, M J Ramsey-Musolf, arXiv: 1807.10197

Collaborators:
Chien-Yeah Seng (U. Shanghai -> U. Bonn)
Hiren Patel (U. Mass. -> UC Santa Cruz)
Michael Ramsey-Musolf (U. Mass.)

Reduced hadronic uncertainty in V_{ud} and CKM unitarity

Misha Gorchtein Universität Mainz

C-Y Seng, MG, H Patel, M J Ramsey-Musolf, arXiv: 1807.10197

Motivation:

CKM unitarity - stringent test of SM&BSM

$$|V_{ud}|^2 + |V_{ud}|^2 + |V_{ud}|^2 = 0.9994 \pm 0.0005$$

0+-0+ nuclear decays	$\boxed{|V_{ud}|^2 = 0.94906 \pm 0.00041}$
K decays	$|V_{us}|^2 = 0.05031 \pm 0.00022$
B decays	$|V_{ub}|^2 = 0.00002$

V_{ud} is the main contributor to the unitarity test

V_{ud} from 0+-0+ nuclear decays: $|V_{ud}^{0^+-0^+}| = 0.97420 \pm 0.00010^{\rm Exp} \pm \boxed{0.00018^{\rm Rad.\ Corr.}}$

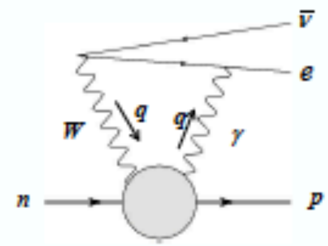
Exp.: Hardy, Towner (2017)
RC: Marciano, Sirlin (2006)

Goal: Reduce uncertainty in RC

Uncertainty - due to hadronic structure effects in γW-box diagram

Lower blob: $\int dx e^{iqx} \langle p|T[J^\mu_{em}(x) J^\nu_W(0)|n\rangle = \frac{i\epsilon^{\mu\nu\alpha\beta} p_\alpha q_\beta}{2(pq)} T_3^{(0)}(\nu, Q^2) + \dots$

Forward Compton amplitude $T_3^{(0)}$ - axial, isovector W × isoscalar γ



$Q^2 = -q^2$
$\nu = (pq)/M$

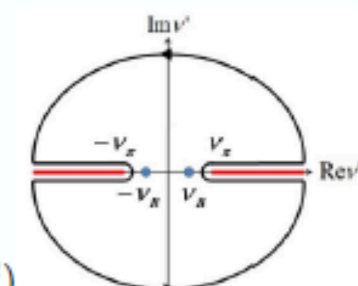
New method: obtain T_3 from a dispersion relation

T_3 - analytic function in the complex ν-plane

Discontinuity along the real axis - on-shell hadronic states:

poles (single particle) + cuts (continuum)

related to an inclusive structure function $\mathrm{Disc}\, T_3^{\gamma W\,(0)}(\nu, Q^2) = 4\pi i F_3^{\gamma W\,(0)}(\nu, Q^2)$



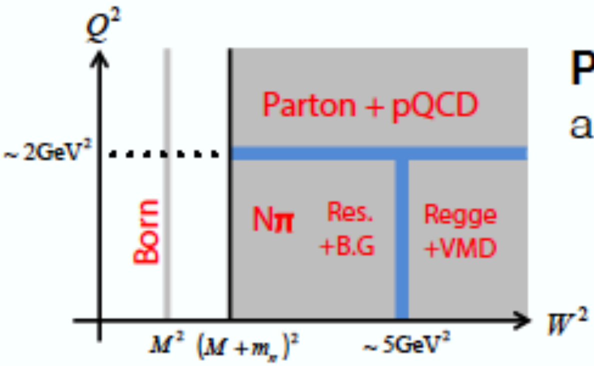
New representation: an integral over first Nachtmann moment of $F_3^{\gamma W(0)}$

$$\boxed{\Box^{VA}_{\gamma W} = \frac{3\alpha}{2\pi}\int_0^\infty \frac{dQ^2}{Q^2} M_3^{(0)}(1,Q^2)\frac{M_W^2}{M_W^2+Q^2}}$$

Nachtmann moment:

$$M_3^{(0)}(1,Q^2) = \frac{4}{3}\int_0^1 dx \frac{1+2\sqrt{1+\frac{4M^2x^2}{Q^2}}}{\left(1+\sqrt{1+\frac{4M^2x^2}{Q^2}}\right)^2} F_3^{\gamma W\,(0)}(x,Q^2)$$

$$x = \frac{Q^2}{2M\nu} = \frac{Q^2}{W^2-M^2+Q^2}$$



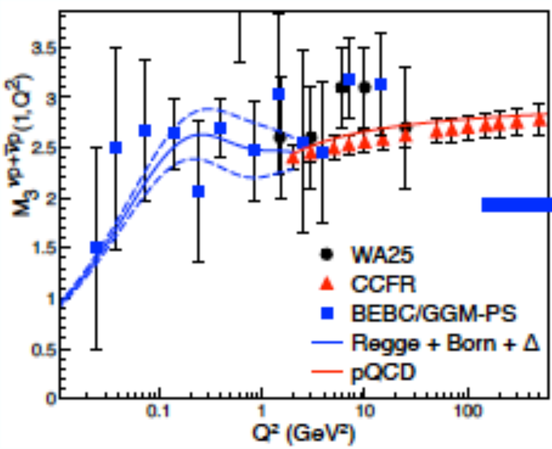
Physics input:

account for leading contributions on the W^2-Q^2 diagram

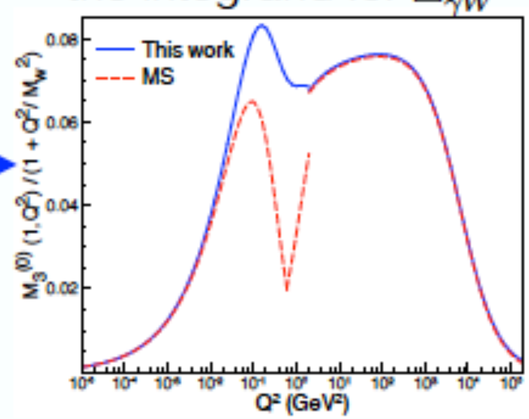
$$F_3^{(0)} = F_{\mathrm{Born}} + \begin{cases} F_{\mathrm{pQCD}}, & Q^2 \gtrsim 2\ \mathrm{GeV}^2 \\ F_{\pi N}+F_{\mathrm{res}}+F_{\mathbb{R}}, & Q^2 \lesssim 2\ \mathrm{GeV}^2 \end{cases}$$

Relate to neutrino data by isospin symmetry → New evaluation of RC; new extraction of V_{ud}

Fit M_3 data from ν scattering



Isospin rotate to obtain the integrand for $\Box^{VA}_{\gamma W}$



Old result: Marciano, Sirlin 2006

$$|V_{ud}^{0^+-0^+}| = 0.97420(10^{Exp})(18^{RC})$$

New result: arXiv: 1807.10197

$$\boxed{|V_{ud}^{0^+-0^+}| = 0.97366(10^{Exp})(10^{RC})}$$

Tension with CKM unitarity (4σ)

$$|V_{ud}|^2 + |V_{us}|^2 + |V_{ub}|^2 = 0.9983(4)$$

Possible explanations:
Nuclear effects in V_{ud} wrong?
V_{us} wrong?
New Physics?

Transverse Single Spin Asymmetries in Electron Scattering on Hydrogen Targets

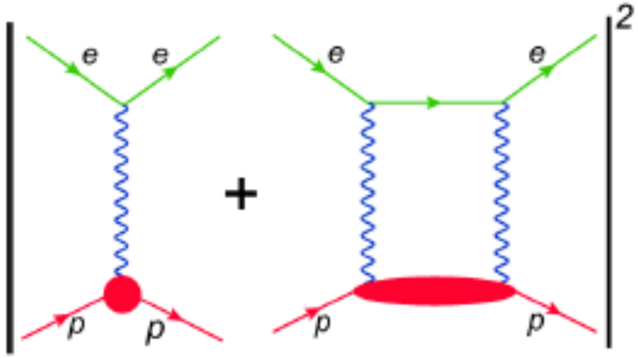
Boxing Gou

11.09.2018

Spin 2018, Ferrara

Two-photon exchange

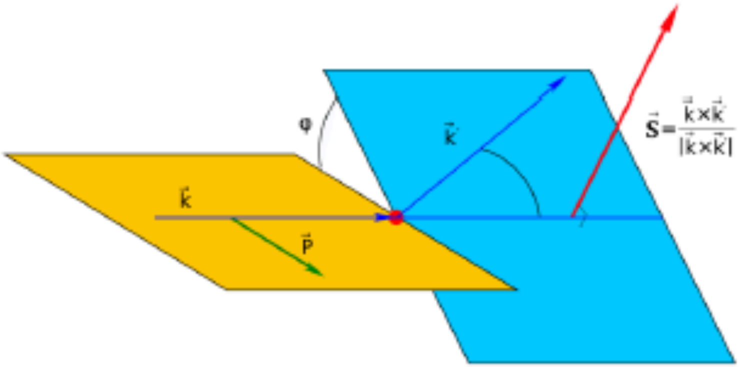
$R(e^+p/e^-p) \Rightarrow Re(\tilde{F}_{1,2,3})$



$$\mathcal{M}_{ep\to ep} = q_e q_p \mathcal{M}_\gamma + q_e^2 q_p^2 \mathcal{M}_{2\gamma}$$
$$\left|\mathcal{M}_{ep\to ep}\right|^2 = q_e^2 q_p^2 \mathcal{M}_\gamma + q_e^3 q_p^3 \mathcal{M}_\gamma \mathcal{M}_{2\gamma}$$
$$\sigma_{e^-p} = \alpha^2 \mathcal{M}_\gamma^2 - \alpha^3 \mathcal{M}_\gamma Re(\mathcal{M}_{2\gamma}) + \cdots$$
$$\sigma_{e^+p} = \alpha^2 \mathcal{M}_\gamma^2 + \alpha^3 \mathcal{M}_\gamma Re(\mathcal{M}_{2\gamma}) + \cdots$$
$$\frac{\sigma_{e^+p}}{\sigma_{e^-p}} \approx 1+2\alpha\frac{Re(\mathcal{M}_{2\gamma})}{\mathcal{M}_\gamma}$$

- VEPP-3@Novosiribisik
- CLAS@JLab
- OLYMPUS@DESY

Single Spin Asymmetry (SSA) $\Rightarrow Im(\tilde{F}_{1-5})$



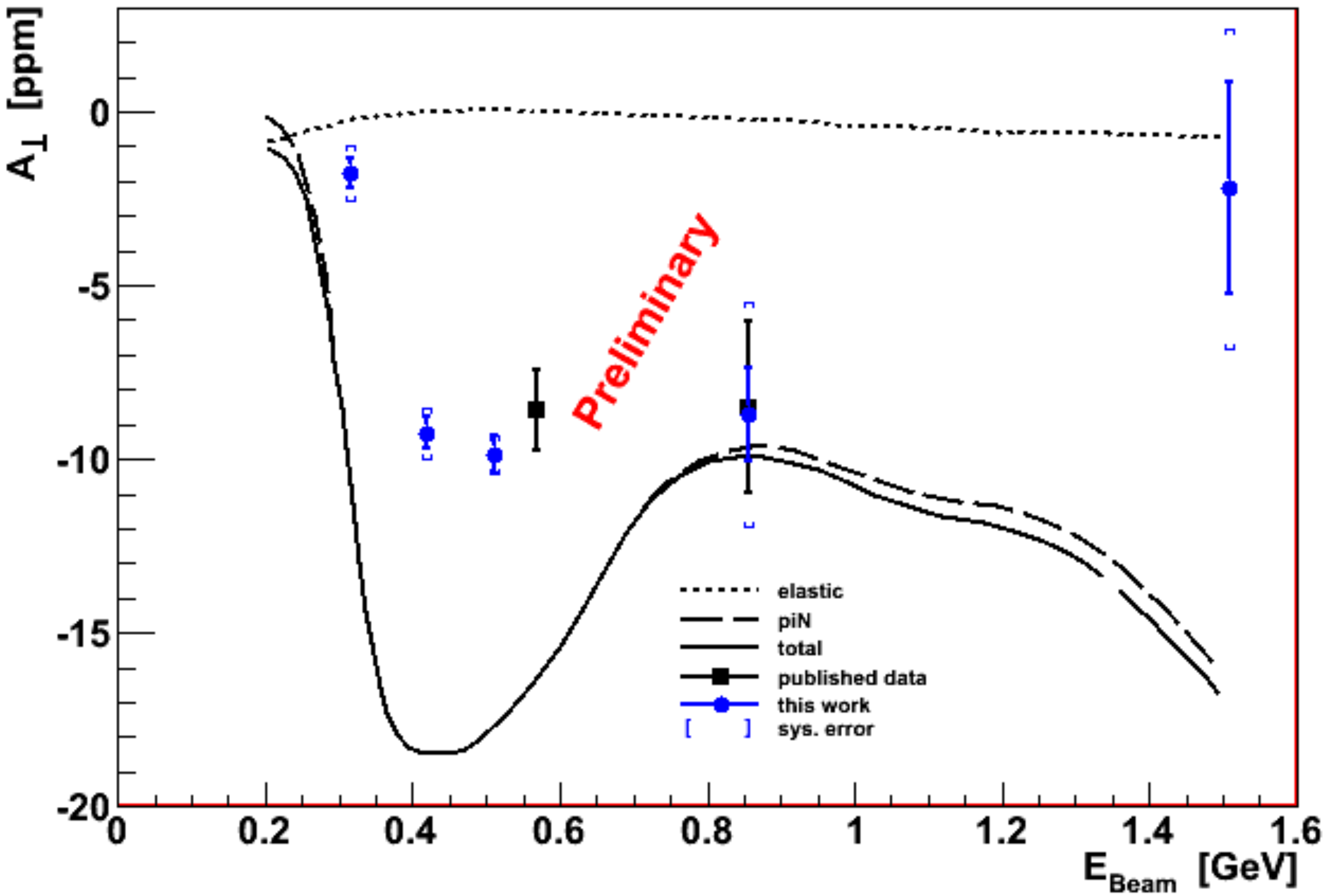
Azimuthal asymmetry

$$A_{exp} = \frac{\sigma_\uparrow - \sigma_\downarrow}{\sigma_\uparrow + \sigma_\downarrow} = A_\perp \frac{\vec{s}\cdot\vec{p}}{|\vec{s}||\vec{p}|} = -A_\perp \cos\varphi$$
$$A_\perp \propto \frac{Im(\mathcal{M}_\gamma^* \mathcal{M}_{2\gamma})}{\left|\mathcal{M}_\gamma\right|^2} \sim \alpha \cdot \frac{m_e}{E} \sim 10^{-5} - 10^{-6}$$

Nucl. Phys. B 35 (1971) 365.

- SAMPLE@MIT-Bates
- HAPPEX, G0, Q_{weak} @JLab
- A4@MAMI

- A systematic two-photon exchange program has been carried out at MAMI-A4.
- New results at forward angle are obtained at 5 energies from 300 MeV to 1.5 GeV.



Prospects for the spin structure study of hyperons using heavy quark decays at Belle II

Kiyoshi Tanida

(Advanced Science Research Center,
Japan Atomic Energy Agency)

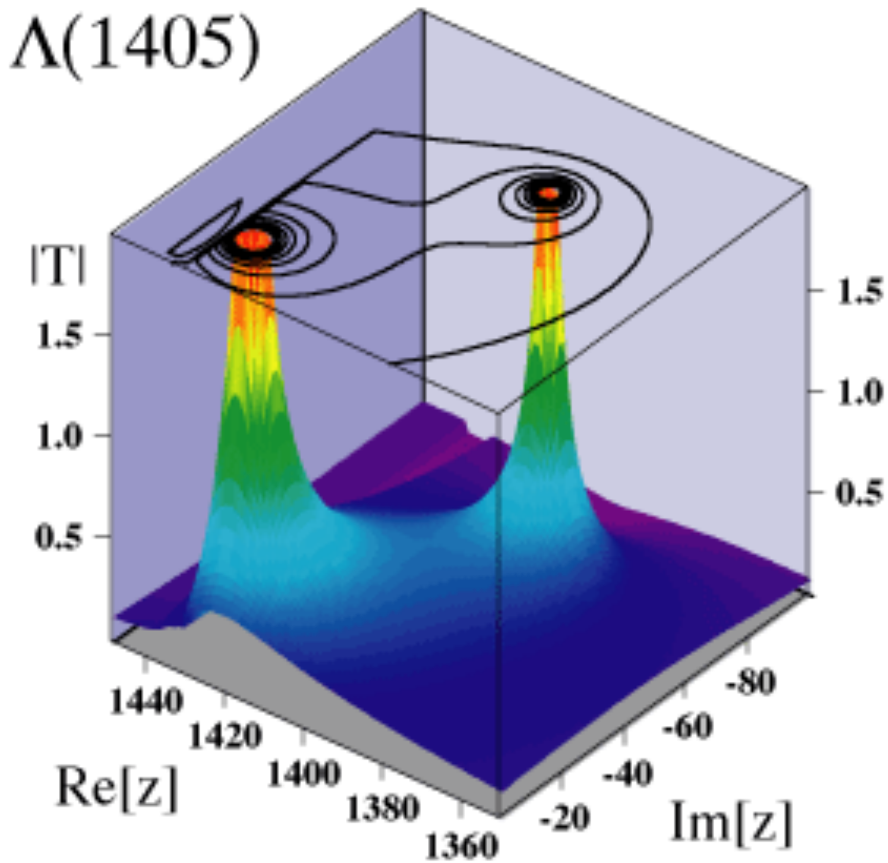
SPIN2018@Ferrara

Sep. 11, 2018

Λ(1405) case

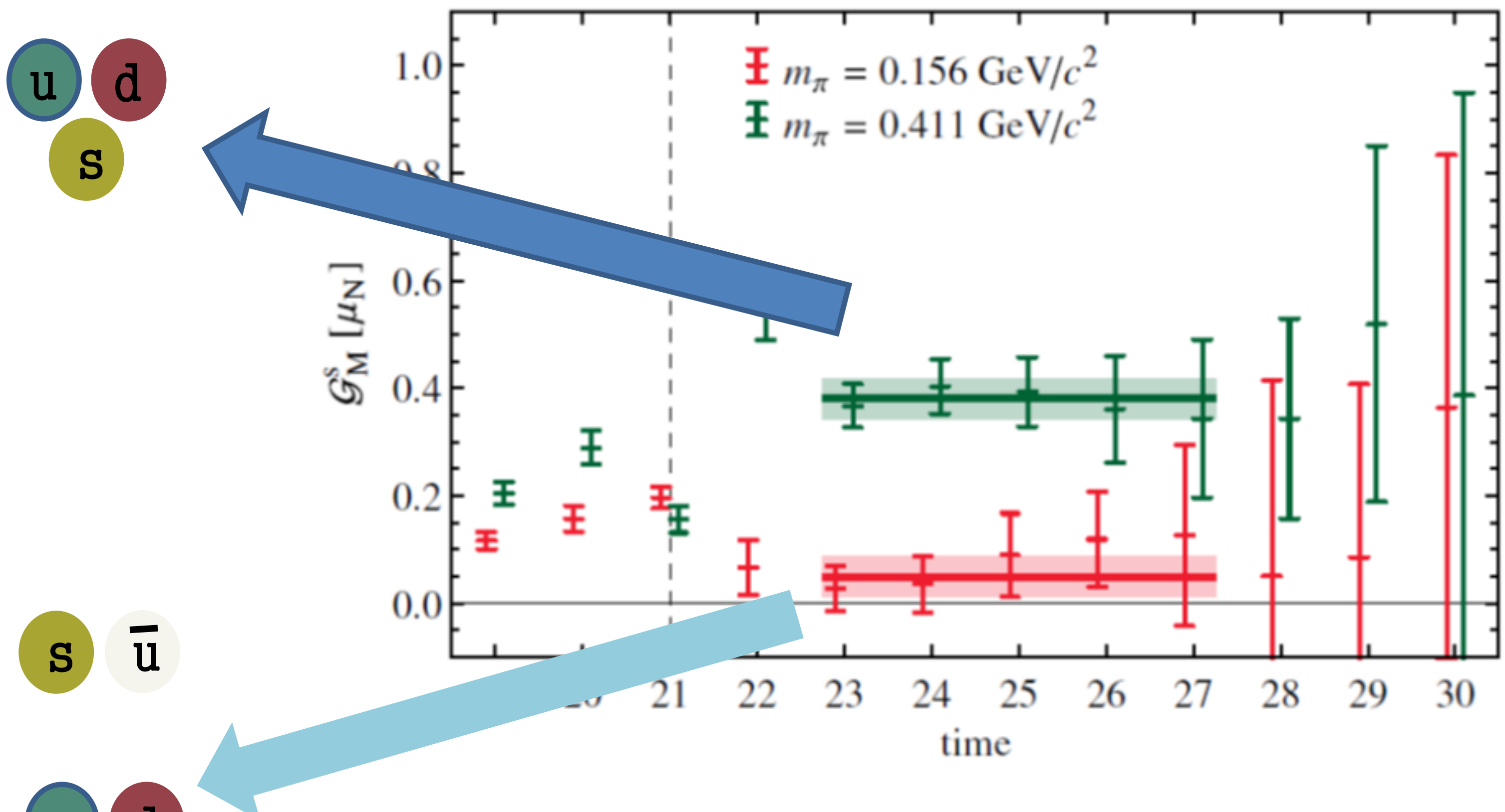
- 3 quark (uds) vs 5 quark?
- Bound state of $\bar{K}N$?
- Double-pole structure?

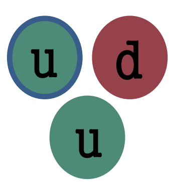
Mysterious & interesting!



- We can distinguish these cases
  - If 3 quark state, P~+0.3
  - If 5 quark state (or $\bar{K}N$ bound state), P~0
  - If there are two poles, P may change with mass

Lattice calculation on $\Lambda(1405)$





J.M.M. Hall et al., Phys. Rev. Lett. 114, 132002 (2015).

$\Lambda(1405)$ spin is not carried by s-quark?

Measurement of the J/ψ photoproduction cross section close to threshold

E.Chudakov[1]

[1] JLab, for GlueX collaboration

Presented at

23-rd International Spin Symposium

SPIN2018, Ferrara, 10-14 Spetember 2018

Measurement of the J/ψ photoproduction cross section close to threshold

E.Chudakov (JLab) for the **GlueX** *Collaboration*

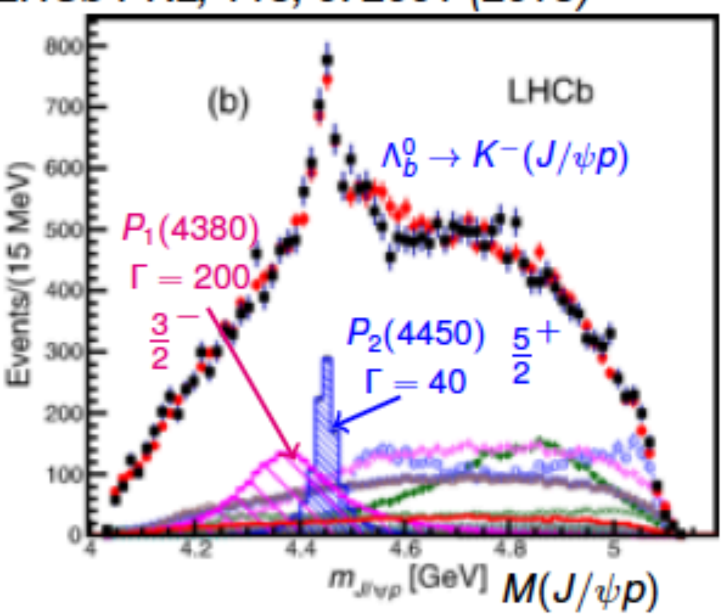
Measured: $\sigma(E_\gamma)$ for $\gamma + p \to J/\psi + p$ at $8.22 < E_\gamma < 12$ GeV

1-st measurement in this energy range

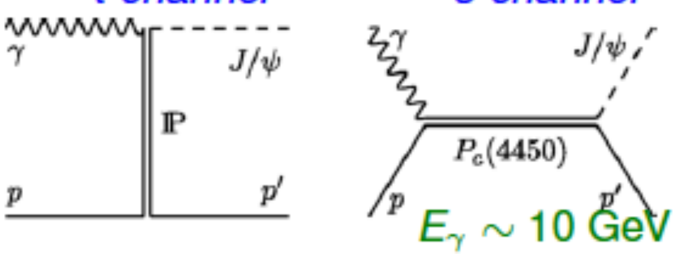
Motivation: Production dynamics, Search for the LHCb Pentaquark

LHCb Pentaquark $P_c \to J/\psi\ p$

LHCb PRL, 115, 072001 (2015)



Predictions for $\gamma p \to P_c \to J/\psi p$

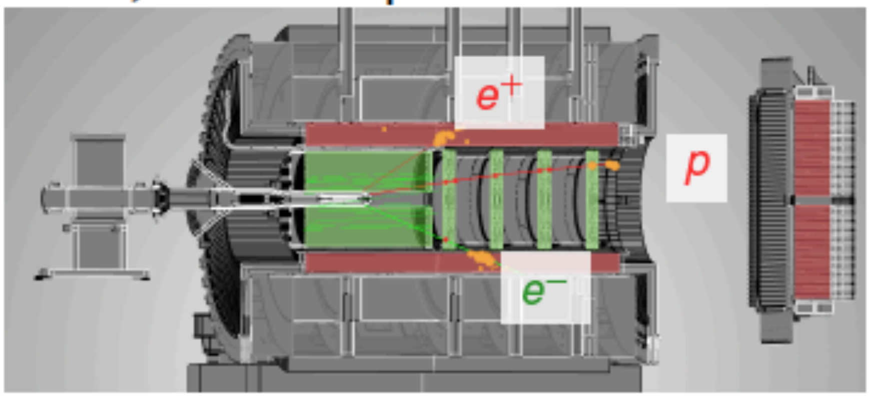


M. Voloshin et al PRD 92, 031502 (2015)
Q. Wang et al PRD 92, 034022 (2015)
M. Karliner et al PL 752, 329 (2016)
A. Hiller Blin et al PRD 94, 034002 (2016) JPAC

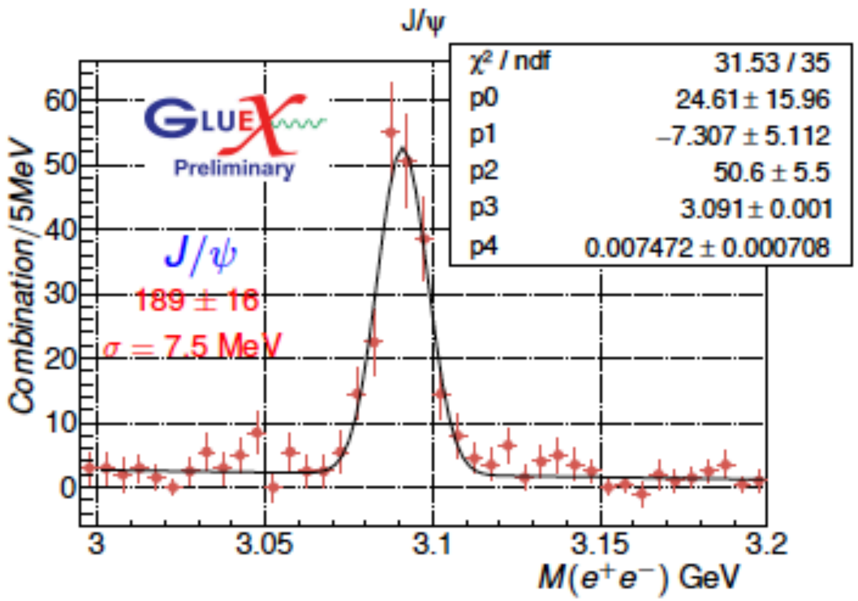
$$\sigma_{\gamma p \to J/\psi p}(E_{peak}) \propto BR(P_c \to J/\psi p)^2$$

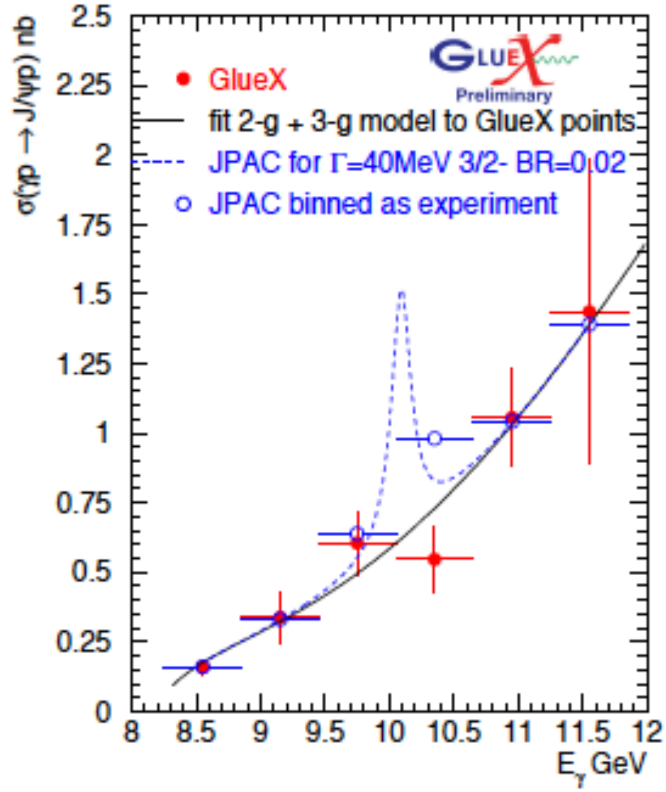
Measurement of the J/ψ photoproduction

JLAB, Hall D Experiment GlueX



$\approx$70% of 2016+2017 data sample





Preliminary results for $\gamma p \to J/\psi p$:

- $\sigma(E_\gamma)$ measured close to threshold
- The data are $\sim 3\sigma(stat)$ below a model-predicted yield for $P_c(4450)\frac{5}{2}^+, BR(J/\psi p) = 0.7\%$

Baryon Electromagnetic Form Factor at BESIII

Isabella Garzia, INFN and University of Ferrara
On behalf of the BESIII Collaboration

INFN
Istituto Nazionale di Fisica Nucleare

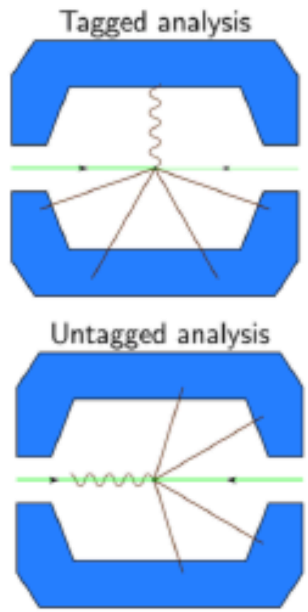
Università degli Studi di Ferrara

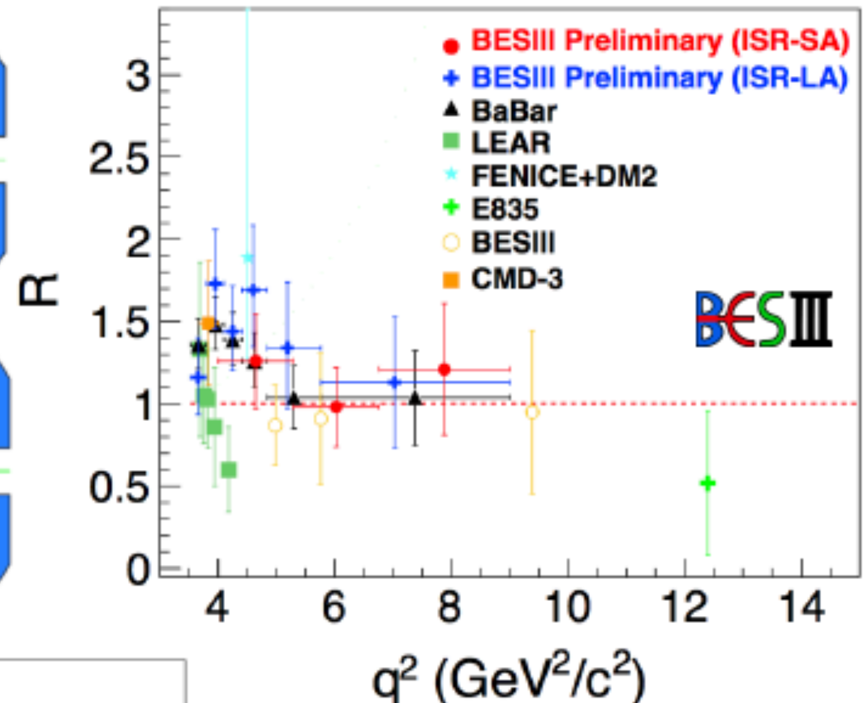
September 10-14, 2018
FERRARA, ITALY

BESIII

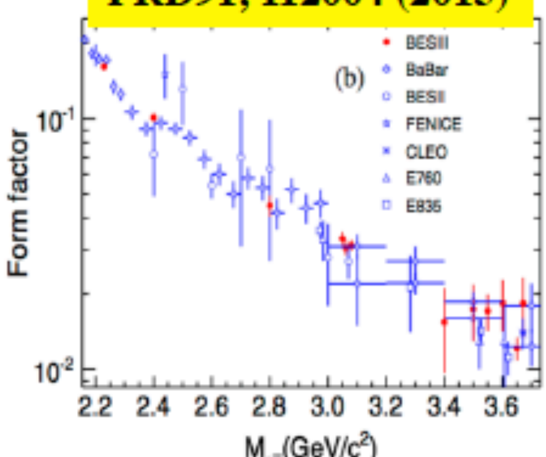
Proton Form Factors at BESIII

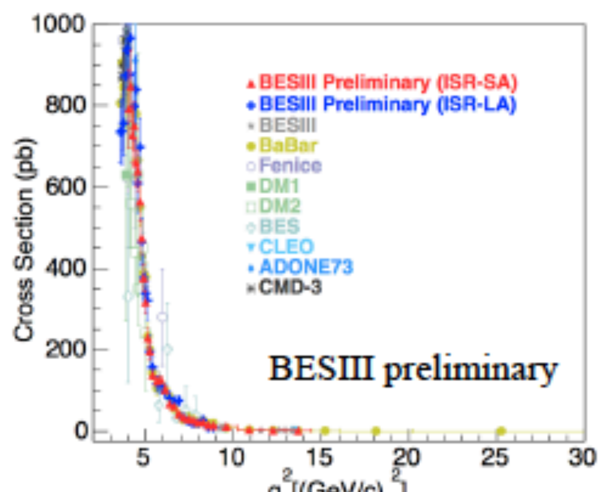
Three different approaches:
- ➢ Energy scan
- ➢ ISR-tagged analysis (Preliminary results)
- ➢ ISR-untagged analysis (Preliminary results)





PRD91, 112004 (2015)

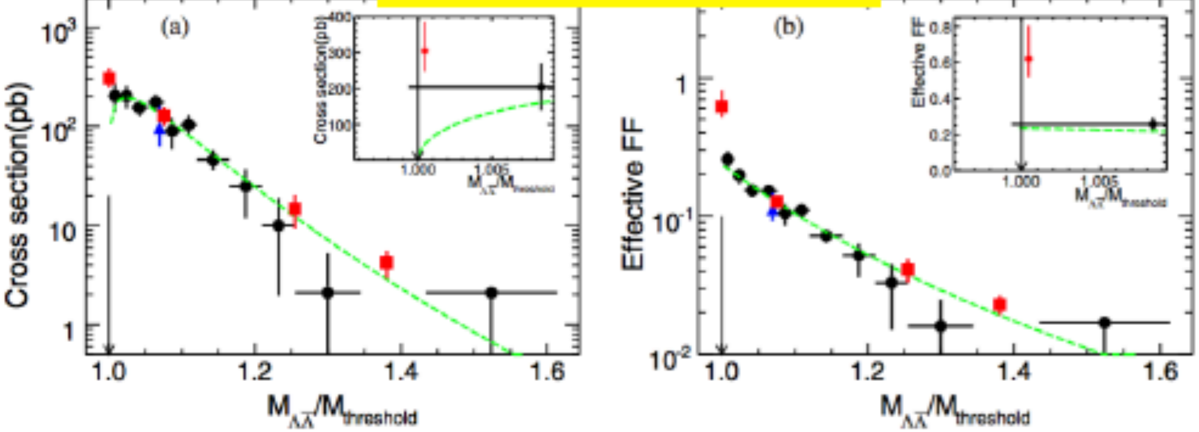




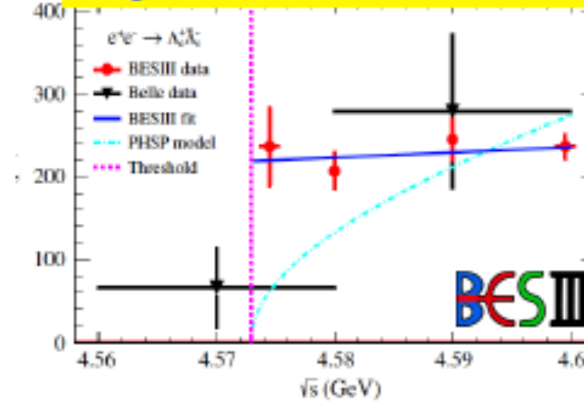
- Consistent results with with BaBar (PRD88,072009; PRD87,092005)
- Competitive uncertainties

Λ and Λ_c Form Factors at BESIII

Λ: PRD97, 032013(2018)

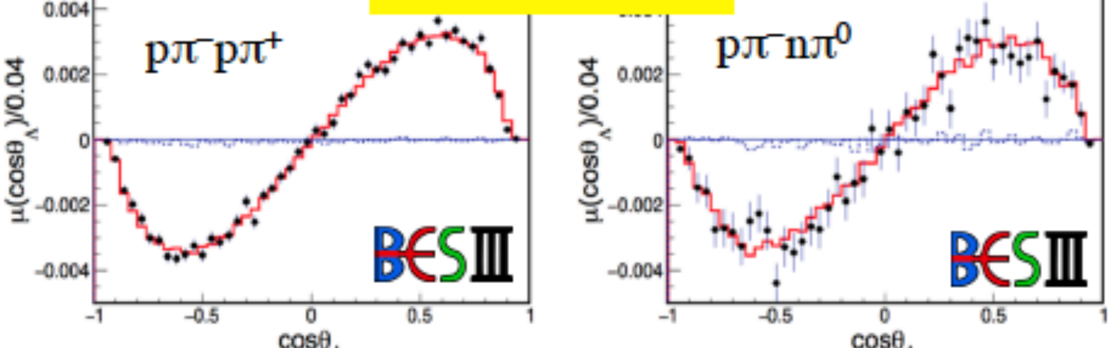


Λ_c: PRL120, 132001(2018)



- $e^+e^- \to \Lambda\Lambda$bar, $\Lambda \to p\pi^-$, Λbar$\to p\pi^+$ (Λbar$\to n\pi^0$, $\Lambda \to X$) @ 2.2324, 2.4, 2.8 and 3.08 GeV
- Λ_c @ 4 c.m. energies: 4.5745, 4.5800, 4.5900, 4.5995 GeV
- No Coulomb effect for neutral baryons BUT **unexpected rise at the threshold :** it underlying a more complicated physics scenario

arXiv:1808.08917



- $J/\psi \to \Lambda\Lambda$bar, $\Lambda \to p\pi^-$, Λbar$\to p\pi^+$ and Λbar$\to n\pi^0$

From polarization measurement:

- **$\Delta\phi = (42.4 \pm 0.6 \pm 0.5)°$**
- ***$\alpha_- = 0.750 \pm 0.09 \pm 0.04$: 5σ deviation from the PDG value***

Extracting the scalar dynamical polarizabilities from real Compton scattering data

Paolo Pedroni

INFN-Sezione di Pavia, Italy

In collaboration with B. Pasquini and S. Sconfietti - University and INFN - Pavia

Istituto Nazionale
di Fisica Nucleare
Sezione Pavia

Extracting the scalar dynamical polarizabilities from real Compton scattering data - 2 page summary

Expansion of the RCS Hamiltonian in incident photon energy (ω)

6 constant parameters (static polarizabilities) connected to the internal nucleon structure

In the PWA framework dynamical polarizabilites dependent on ω can be defined

For the 2 spin-independent polarizabilities α_{E1} β_{M1} the connection between static and dynamic case can be written as

$$\boxed{\alpha_{E1} = \lim_{\omega\to 0} \alpha_{E1-DYN}(\omega) \quad ; \quad \beta_{M1} = \lim_{\omega\to 0} \beta_{M1-DYN}(\omega)}$$

In the Dispersion Relation framework and with a Low energy expansion **(ω < 140 MeV)**

$$\alpha_{E1-DYN}^{DR}(\omega) = f_\alpha(\alpha_{E1}, \beta_{M1}, \boxed{\alpha_{E1,\nu}, \beta_{M1,\nu}}) + \boxed{g_\alpha(\gamma_i)} + \boxed{h_\alpha(\text{any other term})}$$

$$\beta_{M1-DYN}^{DR}(\omega) = f_\beta(\alpha_{E1}, \beta_{M1}, \boxed{\alpha_{E1,\nu}, \beta_{M1,\nu}}) + \boxed{g_\beta(\gamma_i)} + \boxed{h_\beta(\text{any other term})}$$

(up to ω^5)

2 new additional parameters to be fitted

Calculated using measured values

evaluated with DRs

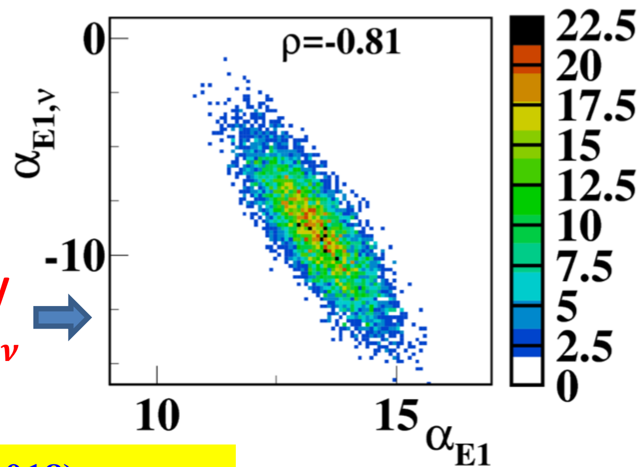
Poor quality of the data set for the proton : only 150 points for ω < 140 MeV; large statistic -and systematical- errors ; possible inconsistencies between subsets.

Due to this poor quality the standard gradient fitting method can not converge (too low sensitivity to the parameters to be fitted

A new fitting method :Combination of **SIMPLEX** method and **BOOTSTRAP** technique
(purely geometrical search) (Monte Carlo)
⇒ inclusions of systematic errors in the fit procedure

		150	55 points
		FULL	TAPS
α_{E1}	$(10^{-4}\mathrm{fm}^3)$	13.3 ± 0.8	11.6 ± 1.1
$\alpha_{E1,\nu}$	$(10^{-4}\mathrm{fm}^5)$	-8.8 ± 2.5	-3.2 ± 3.1
β_{M1}	$(10^{-4}\mathrm{fm}^3)$	0.4 ∓ 0.9	2.2 ∓ 1.1
$\beta_{M1,\nu}$	$(10^{-4}\mathrm{fm}^5)$	10.8 ± 2.8	5.1 ± 3.7

Very low sensitivity of the data to $\alpha_{E1,\nu}$



B. Pasquini, P. Pedroni, S. Sconfietti, Phys. Rev.C 98, 015204 (2018)

Measurement of the analyzing powers in pd elastic and pn quasi-elastic scattering at small angles at ANKE-COSY

S. Dymov
(Ferrara University, Italy,   JINR, Dubna, Russia)

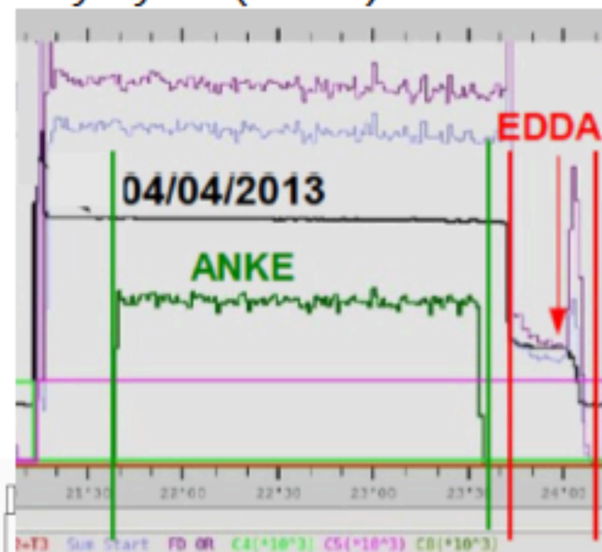
Experiment: ANKE at COSY

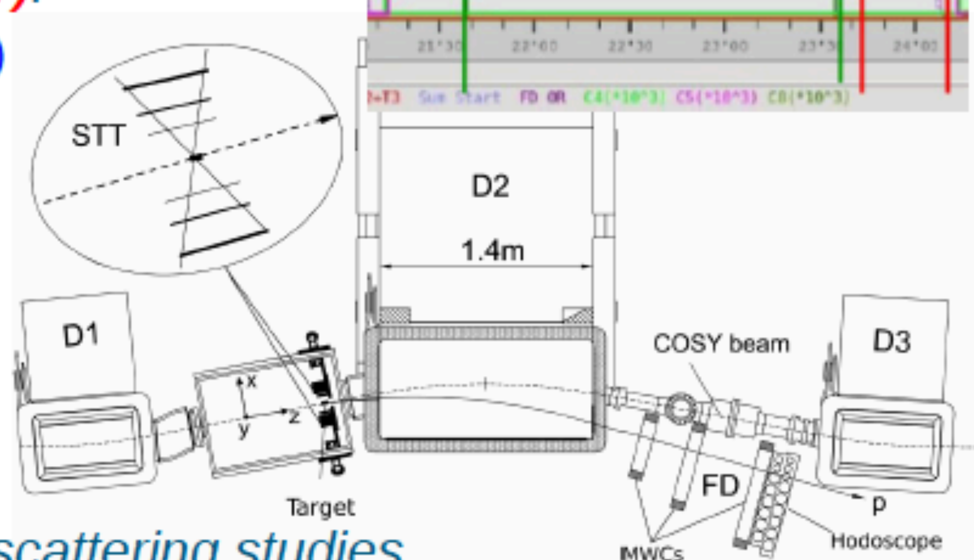
Polarized proton beam: T_p=0.8, 1.6, 1.8, 2.0, 2.2, 2.4 GeV,
Beam polalization : Py~50%, spin flipped every cycle (5 min)
D_2 cluster jet target: *$d=5\cdot10^{14}$ cm^{-2}*

Polarimetry: EDDA detector

Forward detector (FD):
fast proton @ 0-15^0

Silicon Tracking Telescope ***(STT)***:
low energy proton (spectator)
($5^\circ < \Theta^p_{cm} < 30^\circ$)





Triggers:
- Self-triggering STT L2
- FD*STT coincidence

Ideal for small angle elastic scattering studies

Analyzing power in pn quasi-free elastic (3):
Results at 1600 and 2200 MeV

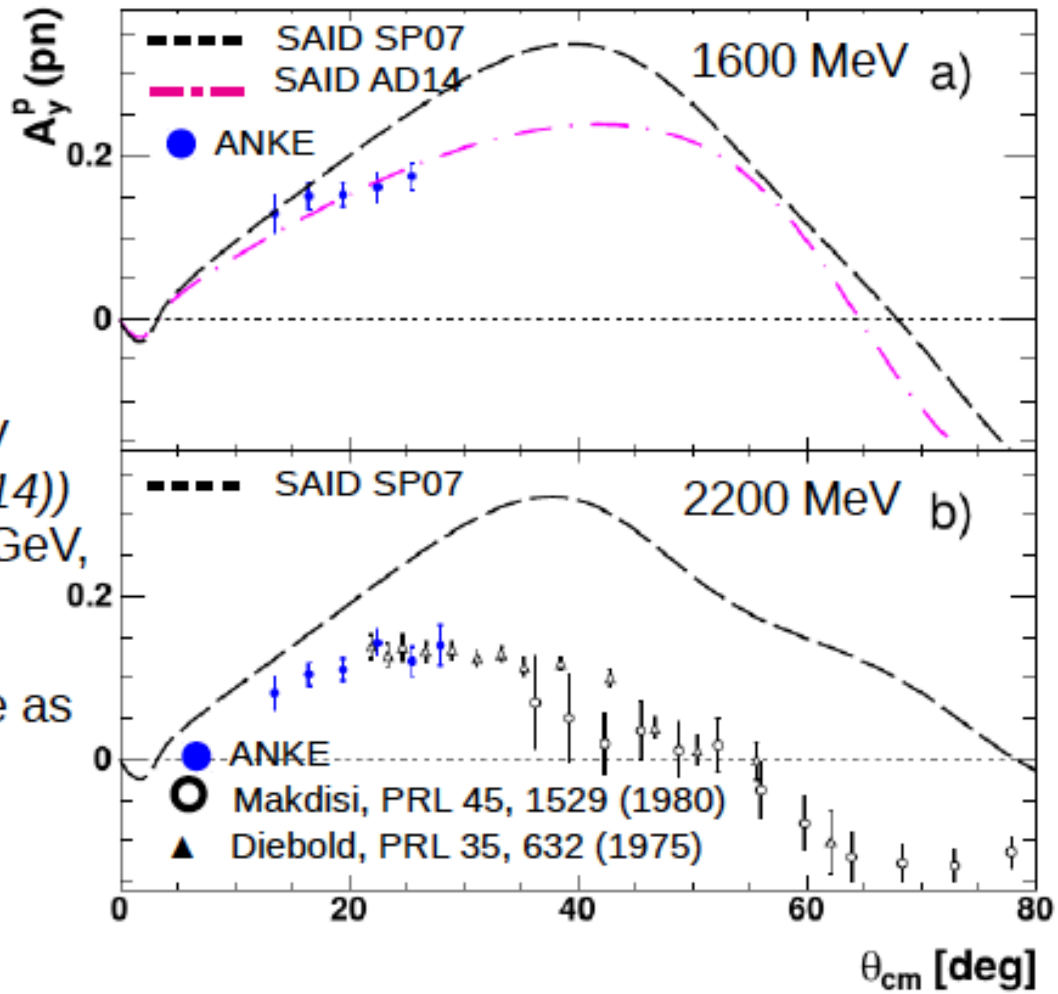
<u>SAID SP07:</u>

based on data < 1.5 GeV,
fails at T_p=1.6-2.4 GeV

<u>SAID AD14:</u>

Includes WASA data at ~1.1 GeV
(Adlarson, PRL 112, 202301 (2014))
Expected to work only up to 1.5 GeV,
But fits ANKE data at 1.6 GeV

A_y^p decreasing with energy same as in pd-elastic



- Low energy spin physics with electromagnetic and hadronic probes
- Very active field, done at low and high energy accelerator facilities
- Strong interaction theory at low energy: substantial progress

- Strong interaction: input, impact and overlap on high precision observables for beyond standard model physics

- Thanks to all speakers for providing slides in advance