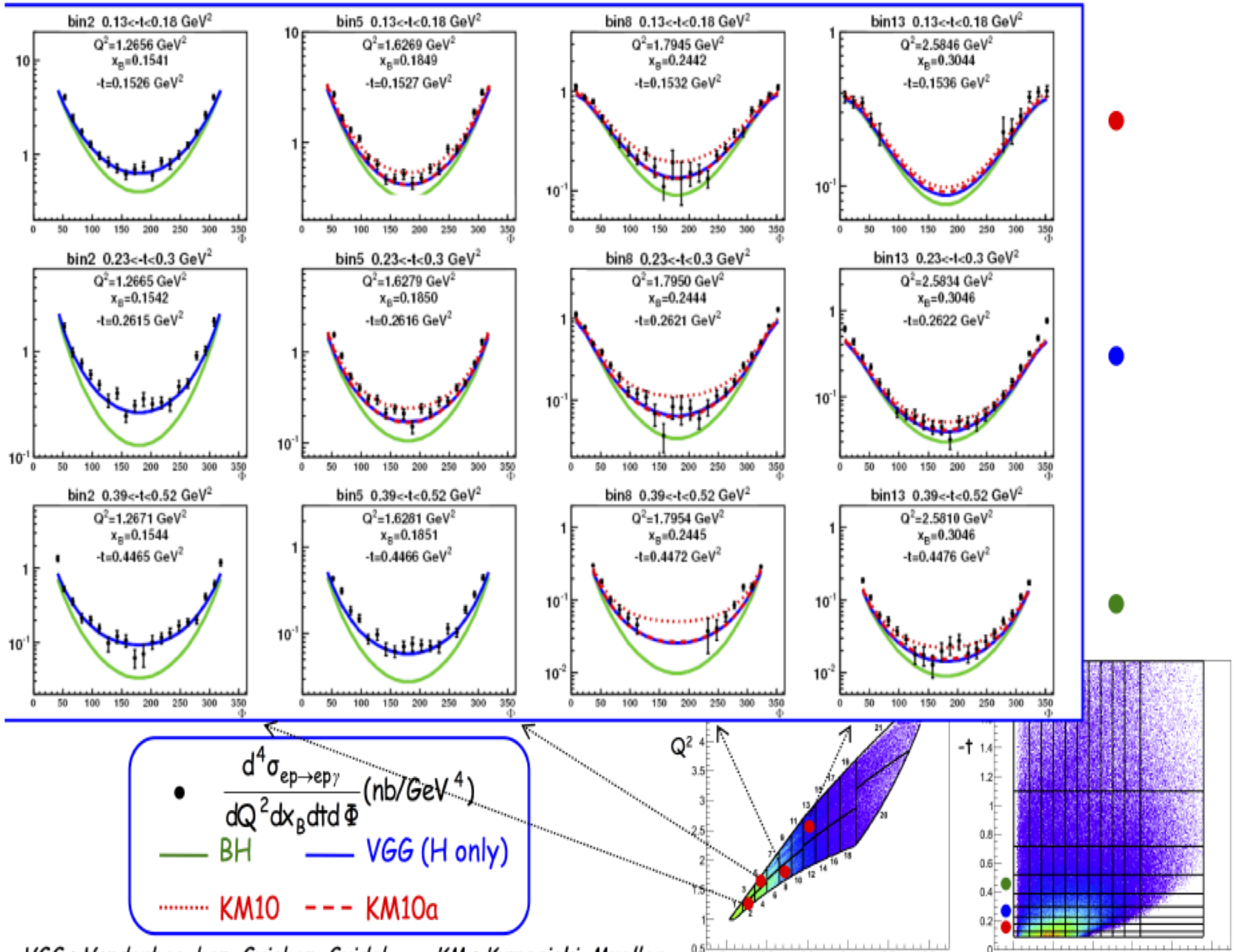
Panel discussion 1

Question: "How can future experiments with electromagnetic probes improve our knowledge on the pressure distribution within the nucleon? How should these results be used for the exploration of the strong QCD dynamics that underlie the pressure part of the energy-momentum tensor?"

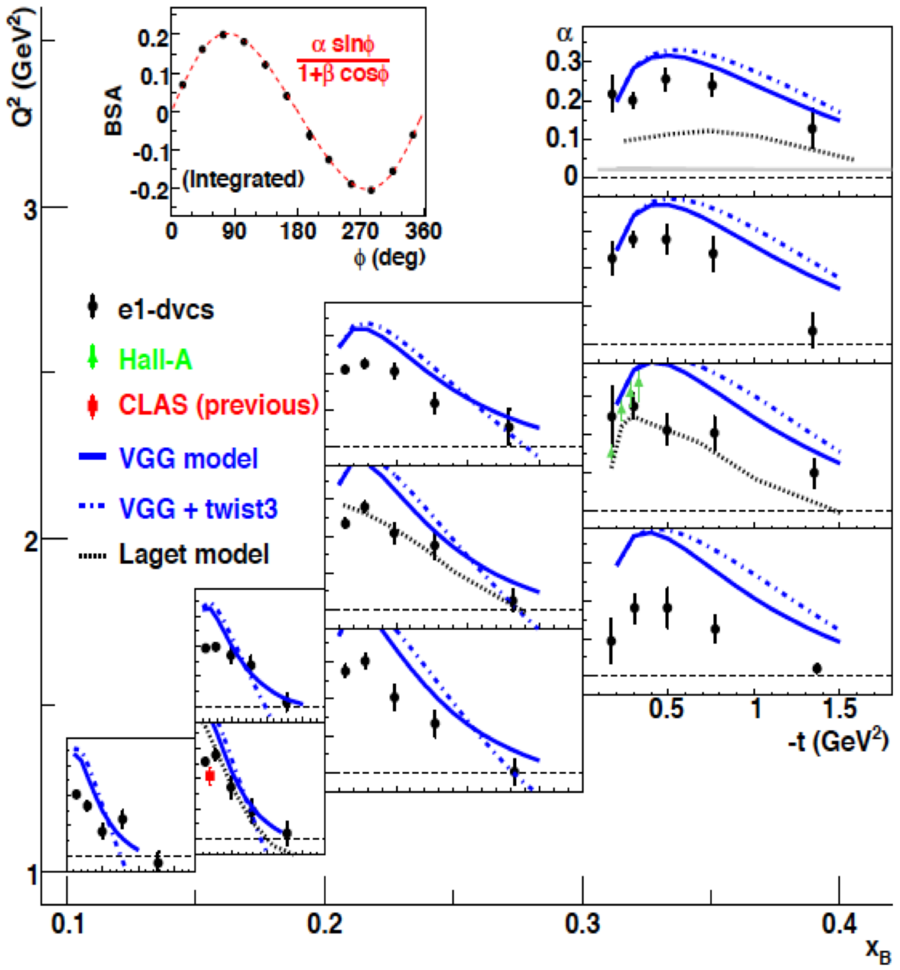
- The pressure distribution is just one aspect of the new avenue of "Gravitational structure of particles", and the first data-based results have been limited in precision and kinematics reach as they were the results of making use of existing and published works.
- The existing data can also be used to extract other mechanical properties such as normal and shear stress, which may tell us about quark-gluon binding forces, and may be relevant for understanding the binding forces inside the proton (confinement??)
- Another topic is the gravitational or mechanical radius of the proton. This is of interest to people who do Chiral EFT and study the cores of neutron stars.
- D(t) can be computed in LQCD/sQCD w/ ~300-MeV pions. Improved calculations with/close-to physical pion mass may soon be available?
- Major improvement may come with the extended kinematic reach and higher precision available in the 12 GeV era.
- In the following slides I show a simulation of DVCS data with the Compton FF $\mathcal{H}(\xi, t)$ and the extraction of the $D^Q(t)$ in 12 GeV era.

DVCS-BH BSA & Cross sections



VGG : Vanderhaeghen, Guichon, Guidal KM : Kumericki, Mueller

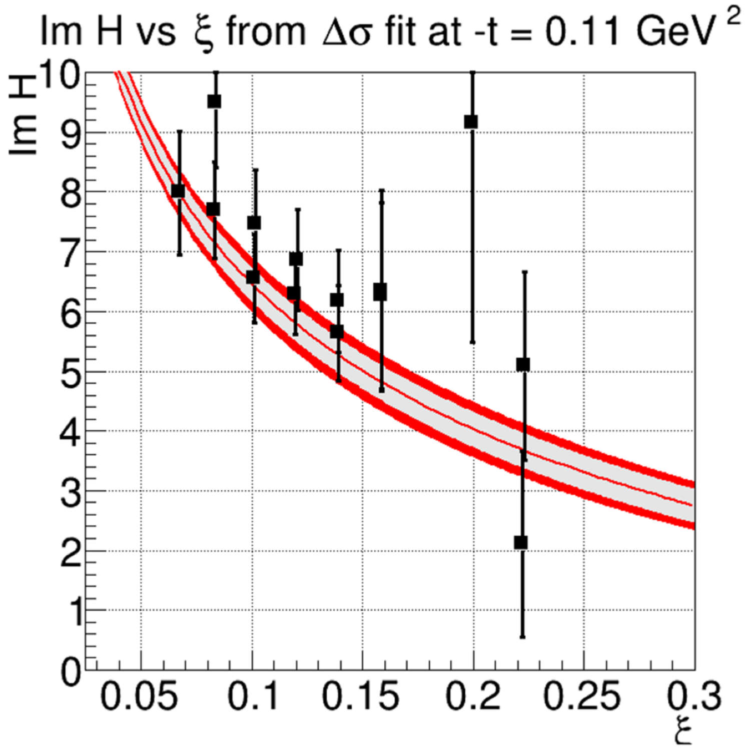
H.-S. Jo *et al.*, PRL 115 212003 (2015)

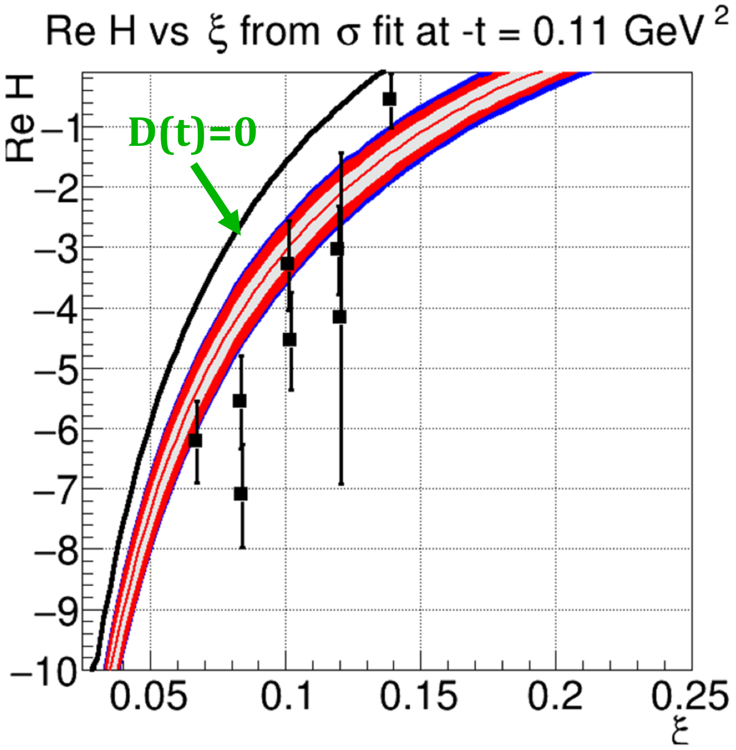


F.X. Girod et al. Phys.Rev.Lett. 100 162002 (2008)

Extraction of Compton Form Factor $\mathcal{H}(\xi,t)$

Data point closest to t=0



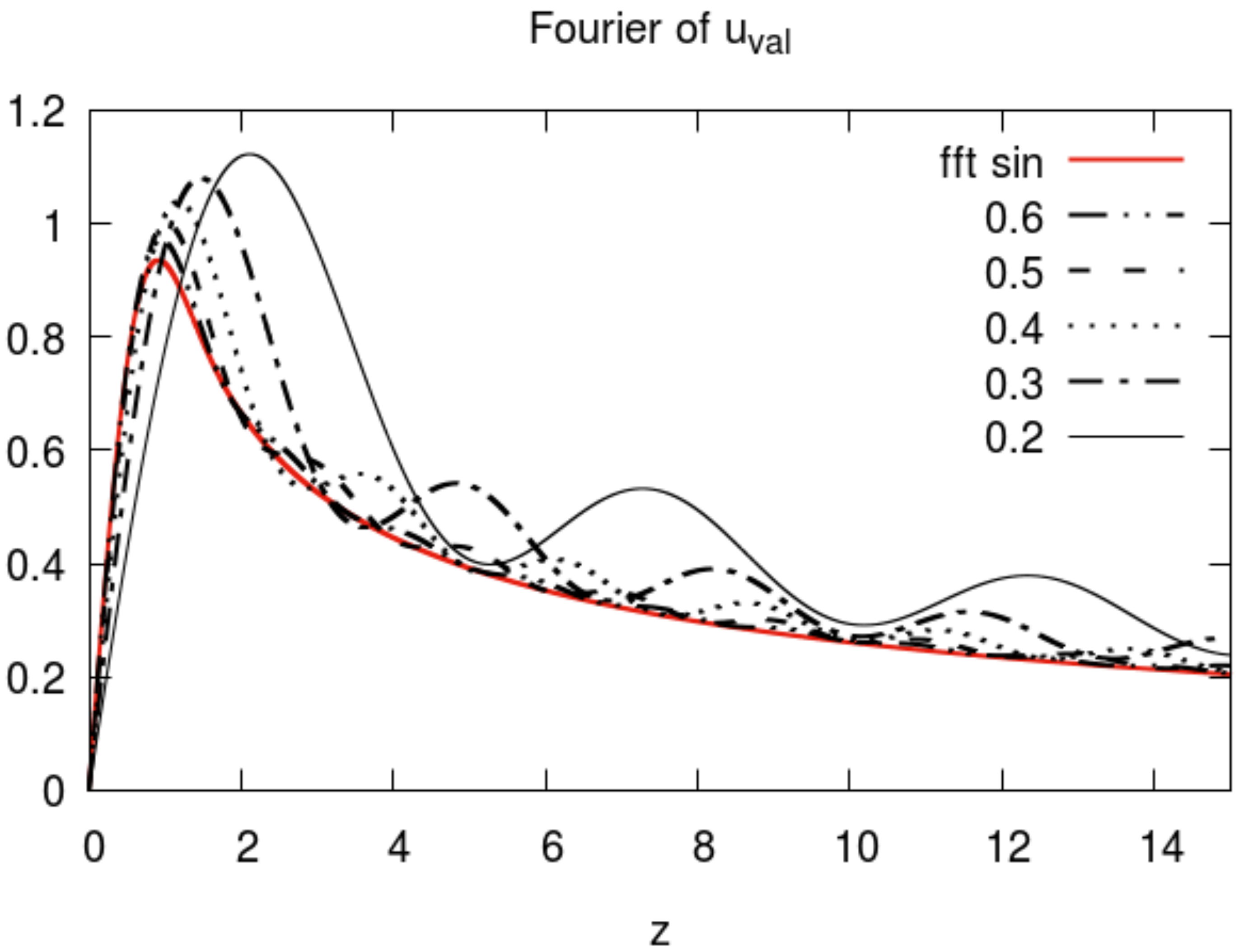


Use subtracted fixed-t dispersion relation to determine $D(t)$

$$\mathrm{Re}\mathcal{H}(\xi,t) \stackrel{\mathrm{LO}}{=} D(t) + \mathcal{P}\int_{-1}^{1} dx \left(\frac{1}{\xi - x} - \frac{1}{\xi + x}\right) \mathrm{Im}\mathcal{H}(x,t)$$

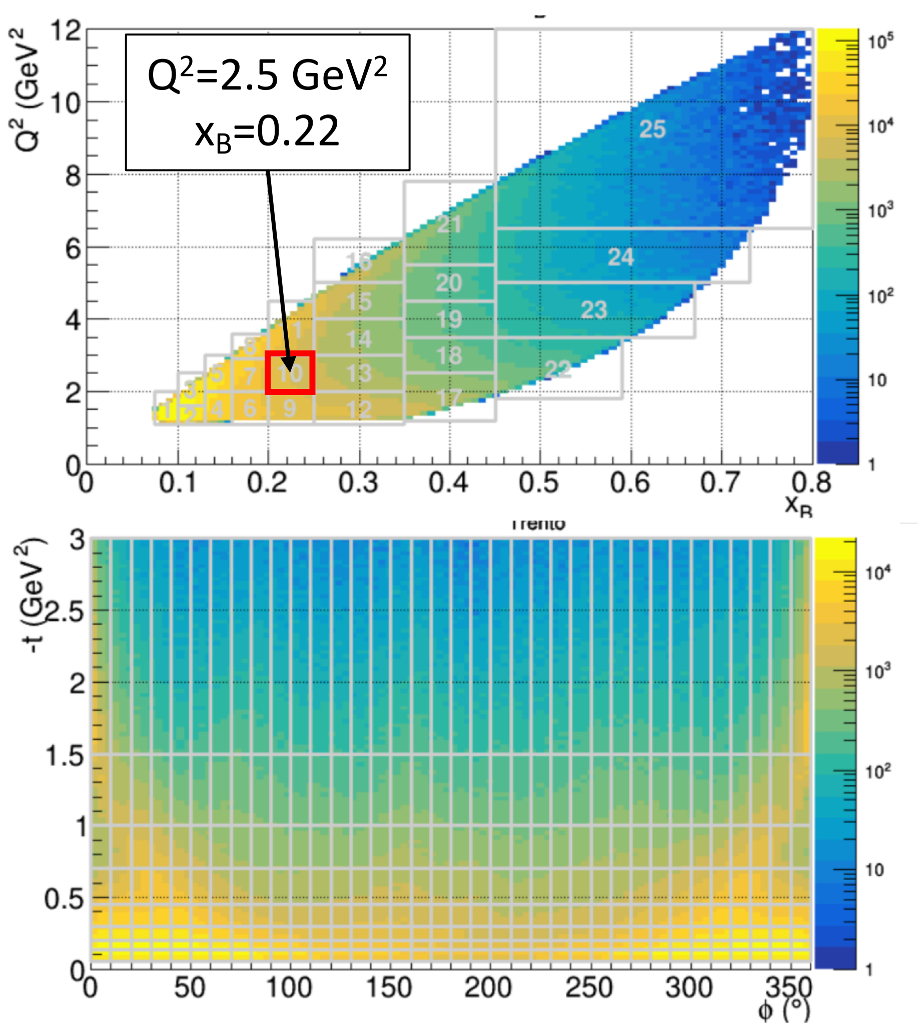
Comment frim Simonetta Liuti

Upper limit cuts in transverse momentum generate oscillations in the Fourier transform to b space



Simulating DVCS observables with $\mathcal{H}(\xi, t)$

Kinematics

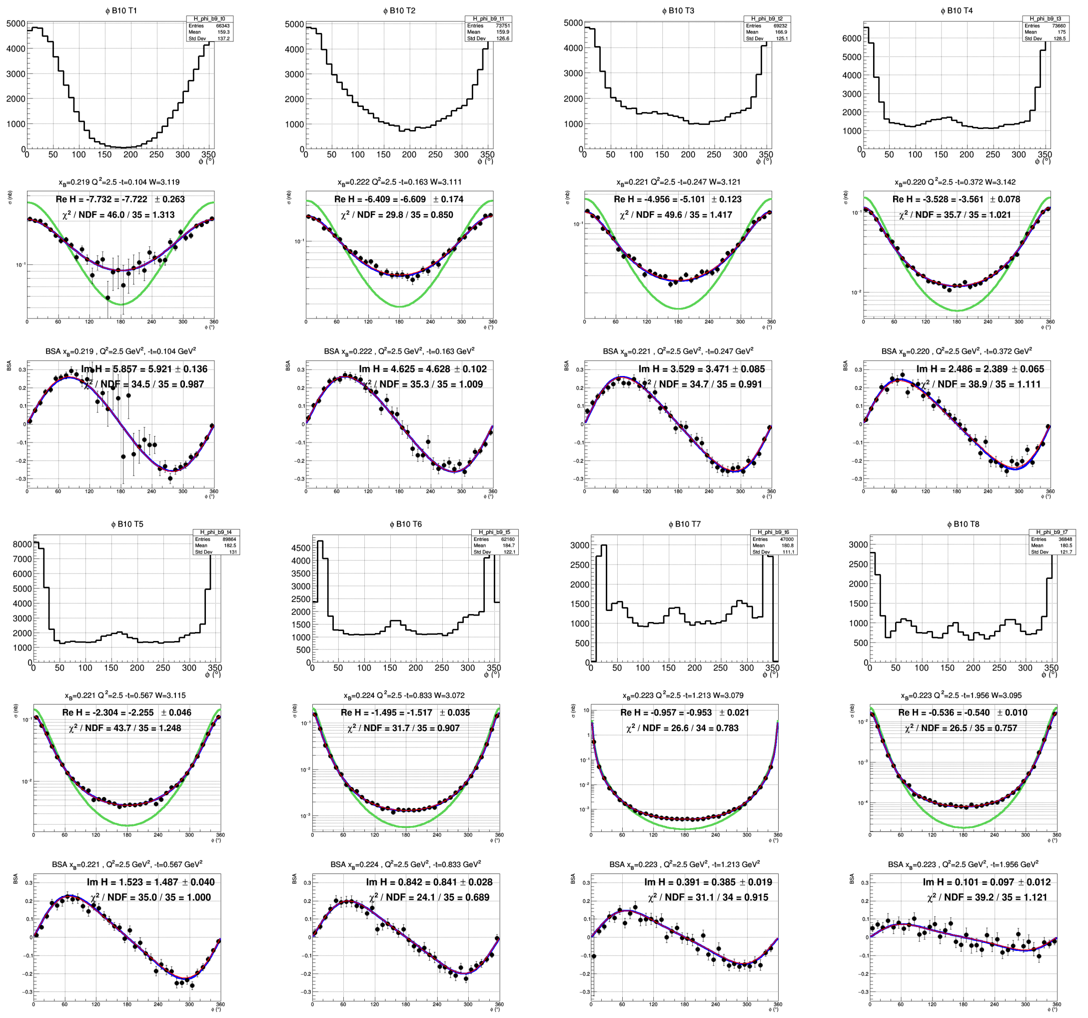


Extract Re($\mathcal{H}$) and Im($\mathcal{H}$)

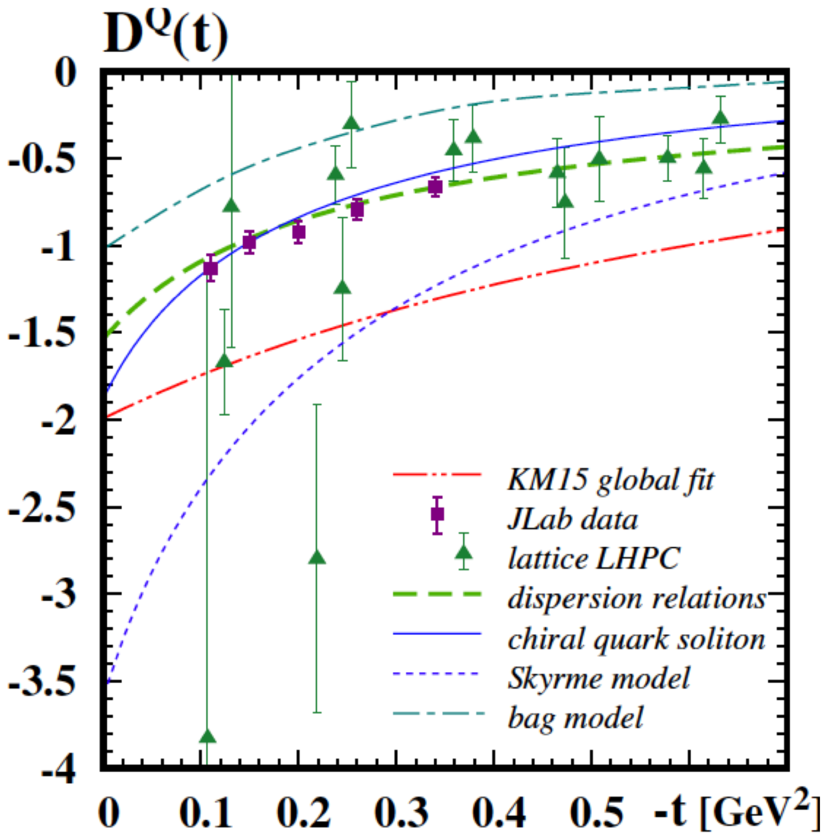
Rate(ϕ)

Diff crs(ϕ)

BSA(ϕ)

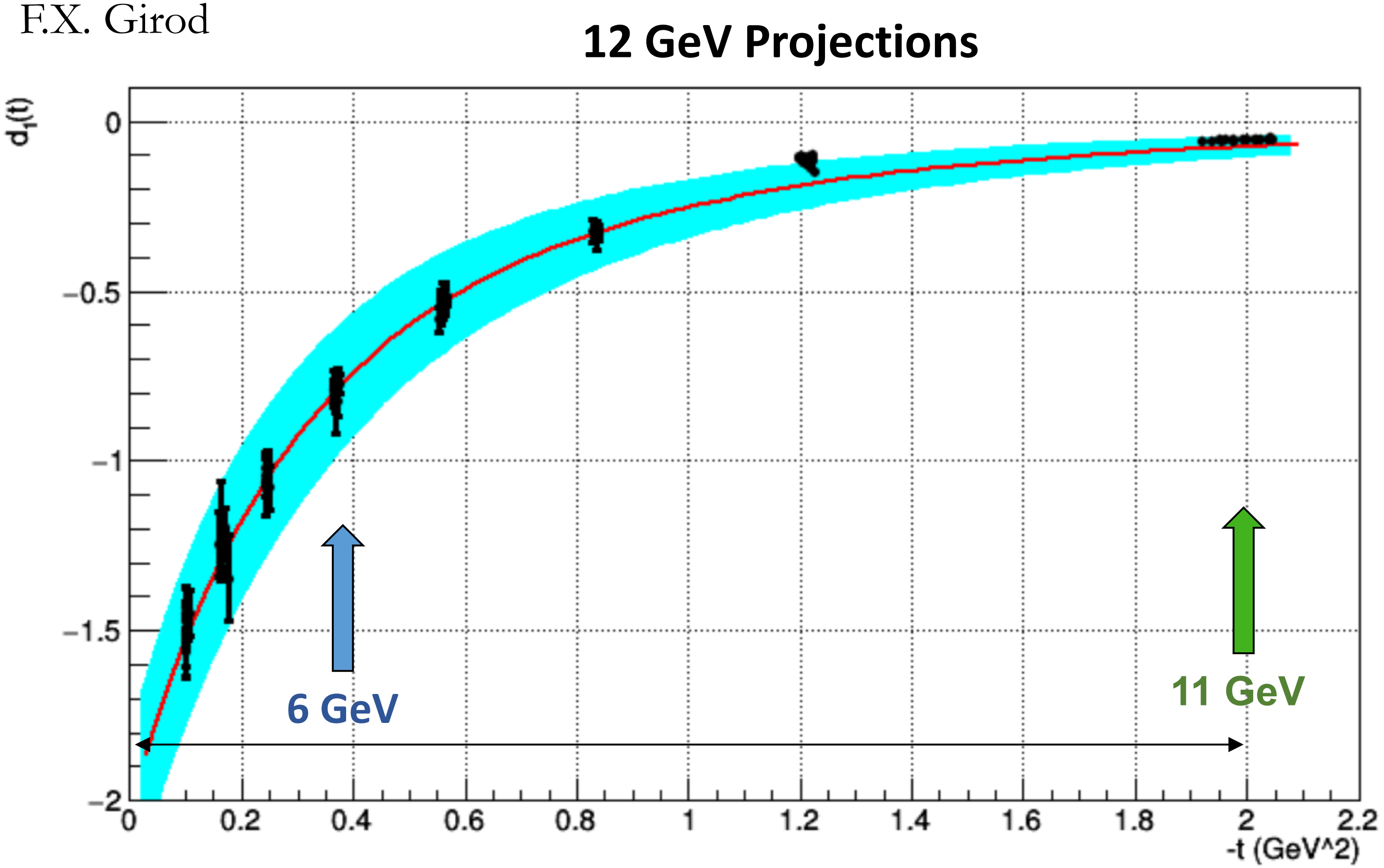


Gravitational Form Factor D(t)



M. Polyakov, P. Schweitzer, Int.J.Mod.Phys. A33 (2018

F.X. Girod

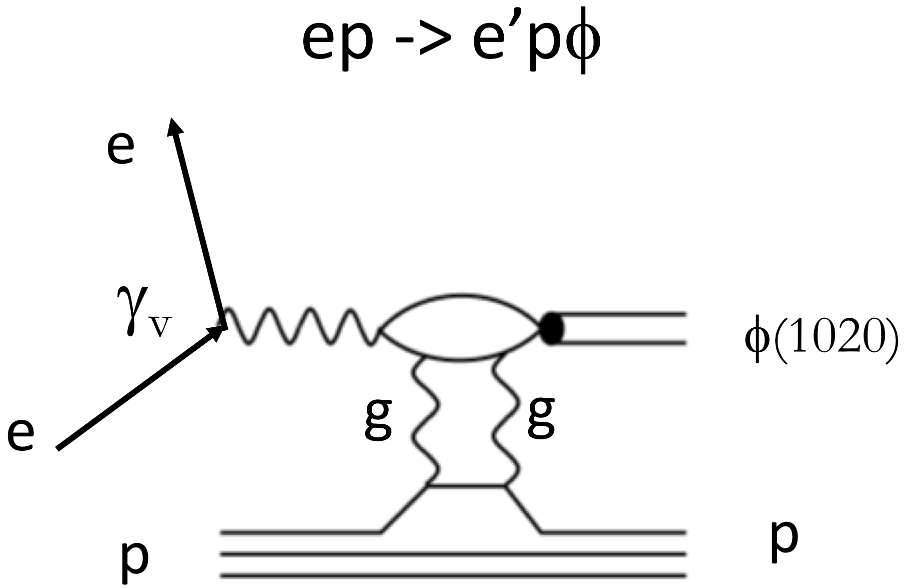


With CLAS12 the t-range increases significantly reducing systematics

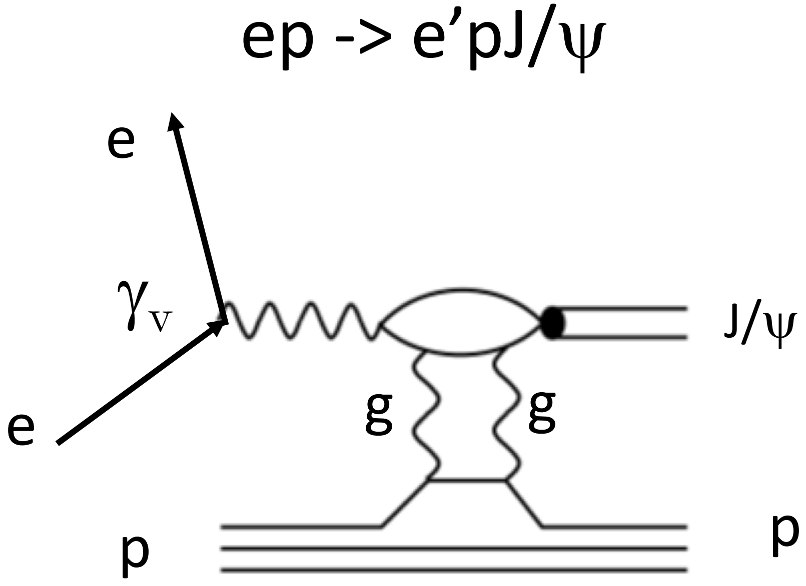
D(t) has been computed in LQCD – higher precision and physical pion mass needed

Access $D^G(t)$ in $\phi(1020)$ and J/Ψ production

Further extension with EIC to determine the gluonic part of D(t) to fully extract pressure distribution from DVCS to $\phi(1020)$, J/ψ production.



JLab@12GeV



EIC

Panel discussion 2

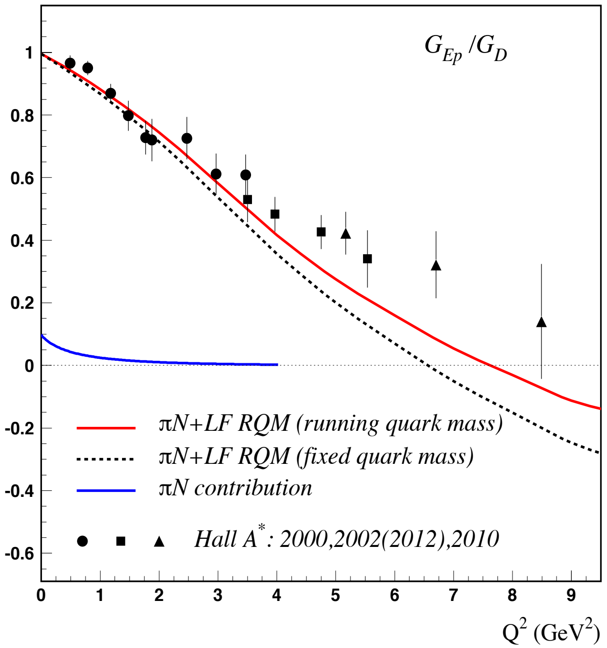
1. What can be learned about strong QCD from the combined investigation of the ground and excited state nucleons? How can the results on N* structure affect the exploration of the ground state nucleon structure, and vice versa?

Differences in effective dof. e.g. different magnitudes in the meson-baryon contributions and in what Q^2 range they are relevant. e.g. the proton elastic FF has a small amplitude of pion contributions to FF (10%) , Delta(1232) has much larger (35%) and more extended MB cloud, Roper is more MB than N(1535). When analyzing the MB part we learn something about the extension of the "cloud".

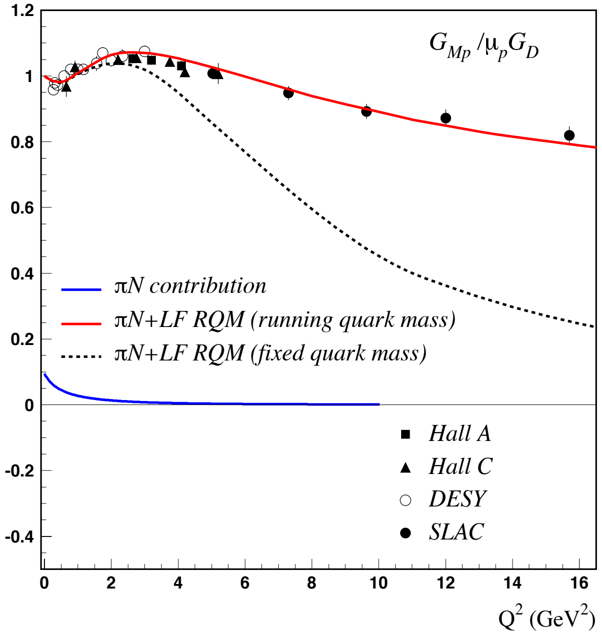
How to interpret this different behavior?

Meson clouds for elastic form factors

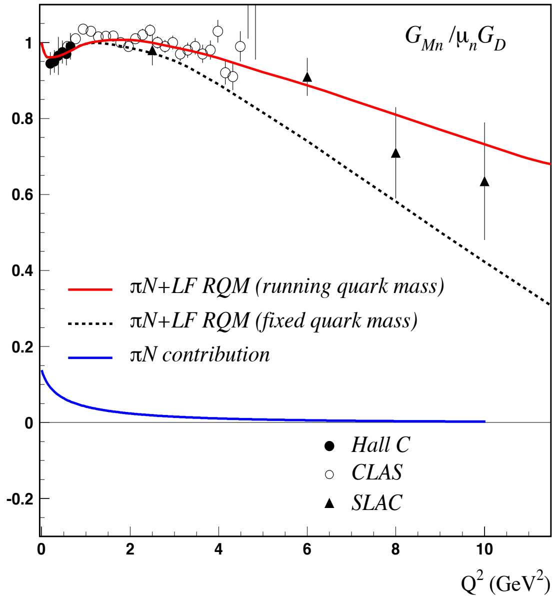
The proton electric form factor G_{Ep}



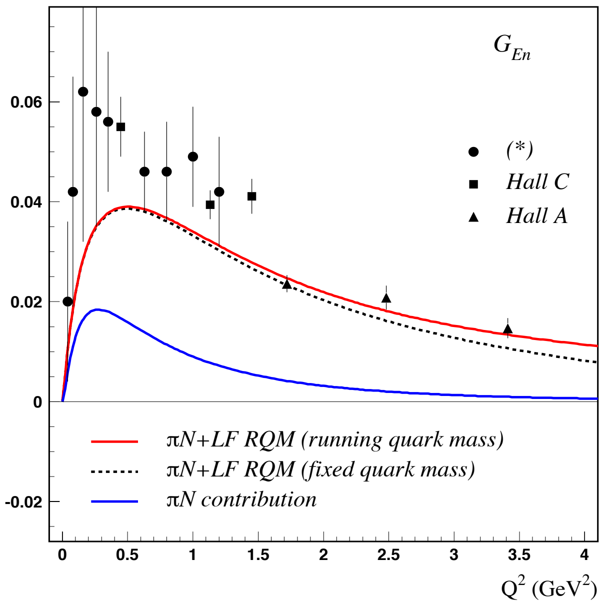
The proton magnetic form factor G_{Mp}



The neutron electric form factor G_{Mn}

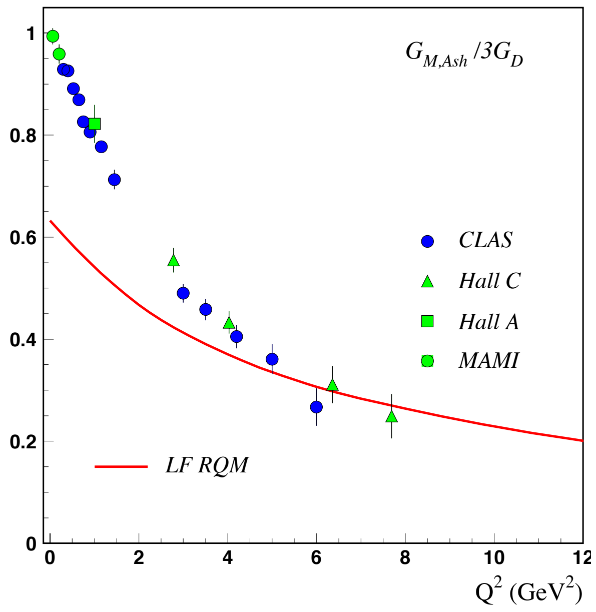


The neutron electric form factor G_{En}

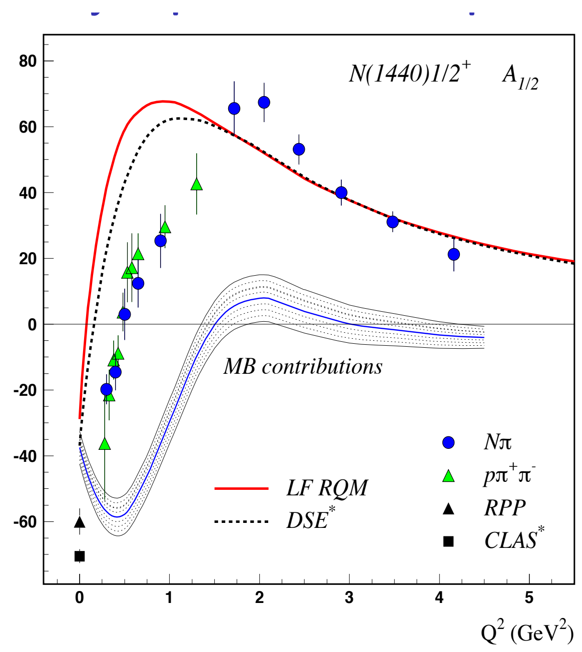


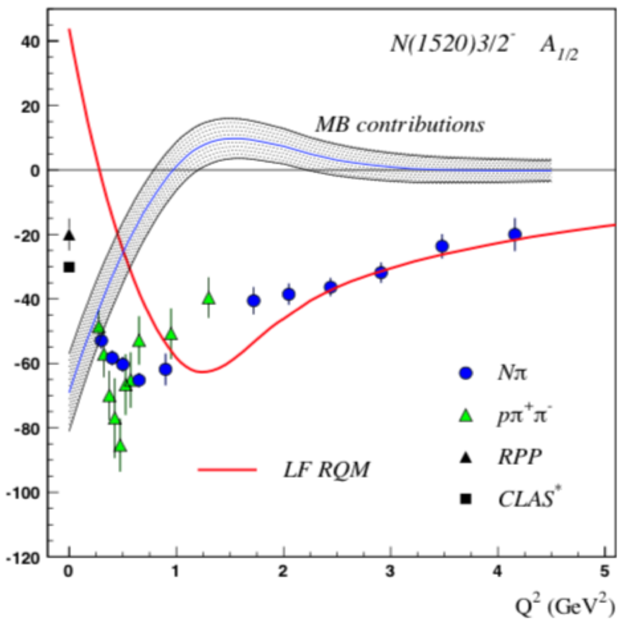
Elastic ep/en FF MB/q^3 ~ 10% at small Q^2, and dropping with Q^2.

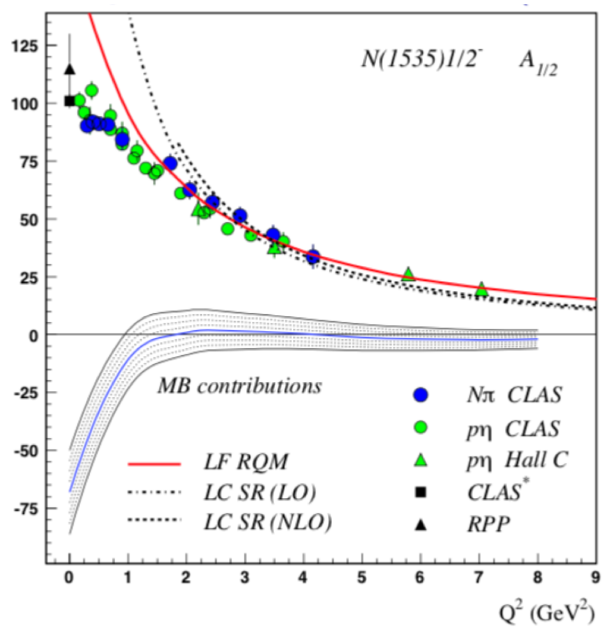
Meson-baryon effects on $\gamma_v NN^*$ transitions



Δ(1232)







Resonance Transition FF have large MB contributions at $Q^2 < 2\text{-}3$ GeV^2

Panel discussion 2, cont'd

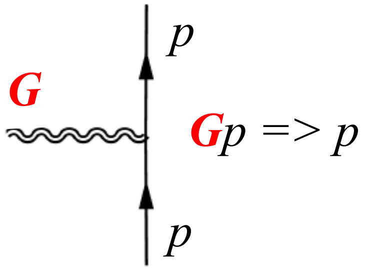
1. What can be learned about strong QCD from the combined investigation of the ground and excited state nucleons? How can the results on N* structure affect the exploration of the ground state nucleon structure, and vice versa?

How to interpret this different behavior of elastic and transition MB contributions?

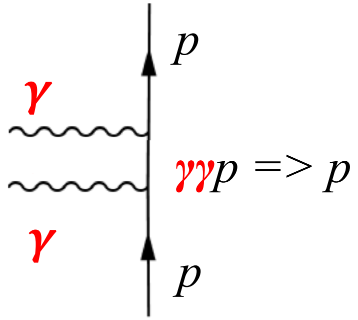
Talk by Hyun-Chul Kim emphasized that nucleon ground state stability is governed by chiral symmetry breaking forces, while excited states may be sensitive to confinement forces.

Is there an analogy to the ground state?

Gp -> p scattering

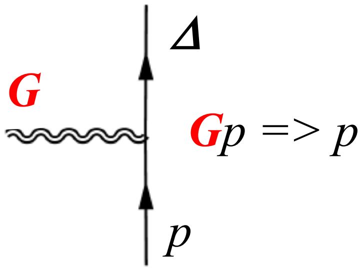


DVCS

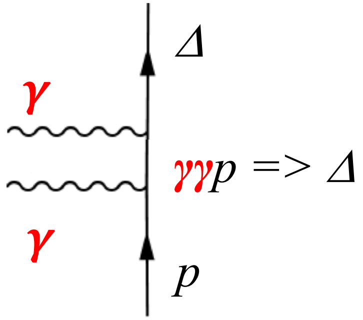


Dominant Chiral forces?

Gp -> Δ resonance transition



ΔVCS



Dominant Confining forces?

What can we do with resonance transition GPDs ?

Can we extract the **chiral forces** from elastic gravitational D(t).

Can we extract the **resonance transition gravitational form factors**, e.g. $D^{N\Delta}(t)$ or $D^{NN^*}(t)$.

Can we determine the **transition forces** to excited states?

And can these forces then be related to the **confinement forces** of QCD?