Nucleon tomography - imaging of partonic structure in 3D

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Odbiory DBP
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QCD group at NCBJ

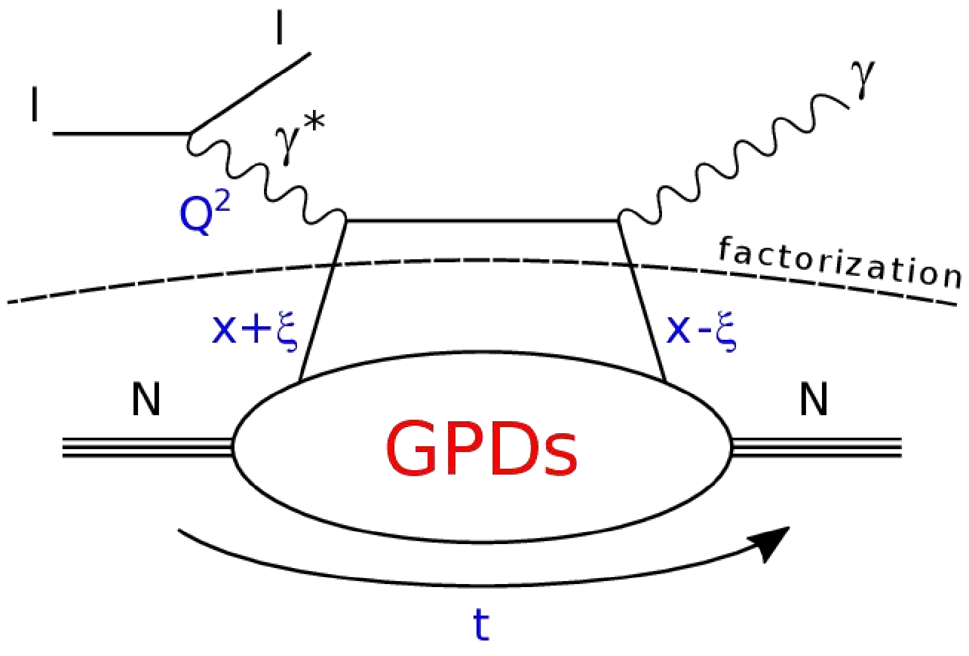
- Tolga Altinoluk, Aleksandra Pędrak, P.S., Lech Szymanowski (coordinator), Jakub Wagner
  Grant Harmonia No. 2017/26/M/ST2/01074 carried out with CEA partners (France)

- Few other grants and collaborations
  (Polonium, CRADA with JLab, scholarship for outstanding young scientists MNiSW (Tolga), H2020, ...)

- Main activities: exclusive reactions and study of Generalized Parton Distributions (GPDs),
  Color Glass Condensate (CGC) and low-x physics

- Both theory and phenomenology

Deeply Virtual Compton Scattering (DVCS)



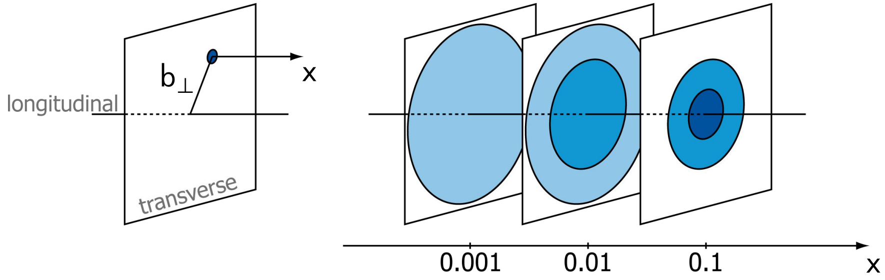
factorization for $|t|/Q^2 \ll 1$

- 3D functions describing partonic structure of nucleon
- Each one defined for specific parton and specific helicity configuration

$H^{q,g}(x,\xi,t)$	$E^{q,g}(x,\xi,t)$	*for sum over parton helicities*
$\widetilde{H}^{q,g}(x,\xi,t)$	$\widetilde{E}^{q,g}(x,\xi,t)$	*for difference over parton helicities*
nucleon helicity conserved	*nucleon helicity changed*	

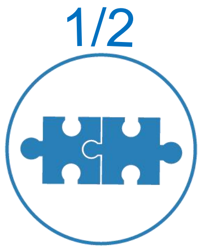
- Nucleon tomography

$$q(x, \mathbf{b}_\perp) = \int \frac{\mathrm{d}^2\mathbf{\Delta}}{4\pi^2} e^{-i\mathbf{b}_\perp \cdot \mathbf{\Delta}} H^q(x, 0, t = -\mathbf{\Delta}^2)$$



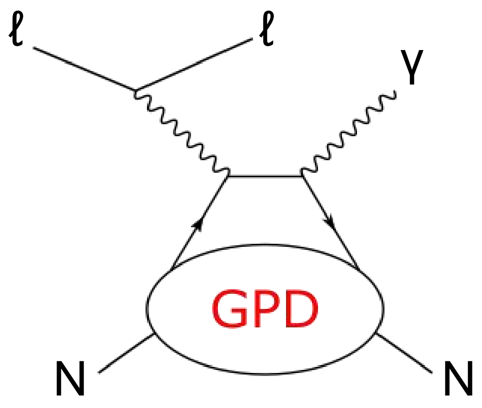
- Access to total angular momentum and forces acting on quarks

$$\underbrace{A^q(0) + B^q(0)}_{\text{EMT form factors @ t = 0}} = \int_{-1}^{1} x \left[H^q(x, \xi, 0) + E^q(x, \xi, 0)\right] = 2J^q$$

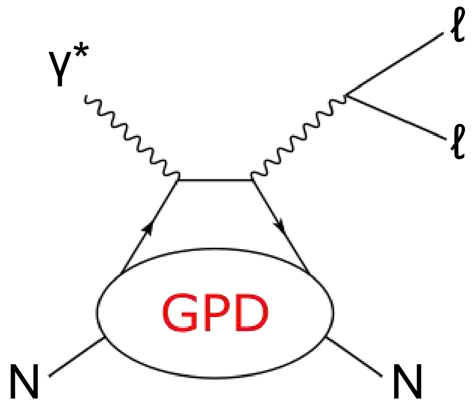


Ji's sum rule

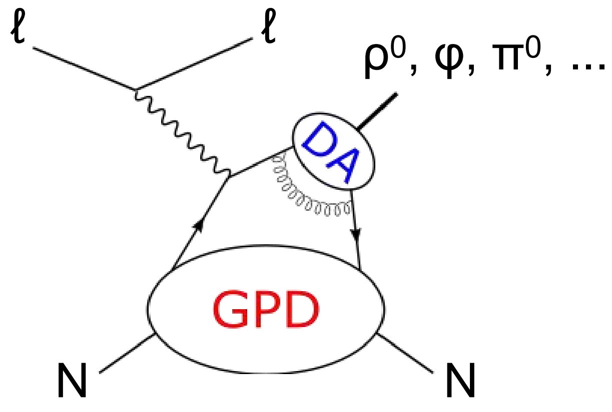
GPDs accessible in various production channels and observables
→ experimental filters



DVCS
Deeply Virtual Compton Scattering



TCS
Timelike Compton Scattering



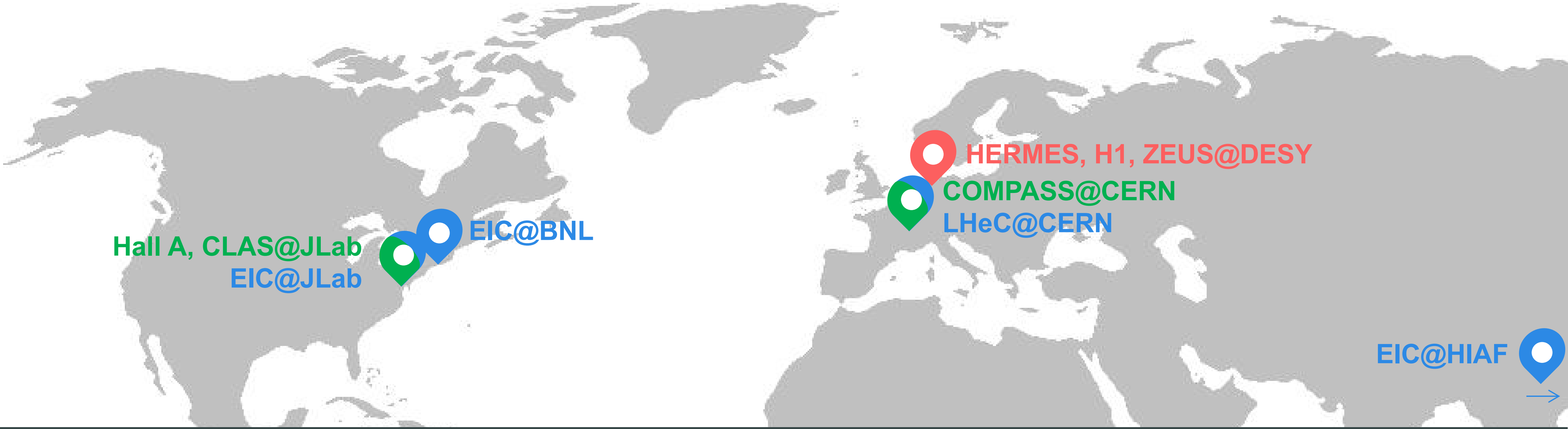
HEMP
Hard Exclusive Meson Production

more production channels sensitive to GPDs exist!

GPDs studied in various laboratories
→ need to cover a broad kinematic range

experiments

closed active planned



Example of recent activities

B. Berthou, P. S., J. Wagner, *et al.* "*PARTONS: PARtonic Tomography Of Nucleon Software. A computing framework for the phenomenology of Generalized Parton Distributions*"
Eur. Phys. J. C78 (2018) no. 6, 478

H. Moutarde, P. S., J. Wagner "*Border and skewness functions from a leading order fit to DVCS data*"
Eur. Phys. J. C78 (2018) no. 11, 890

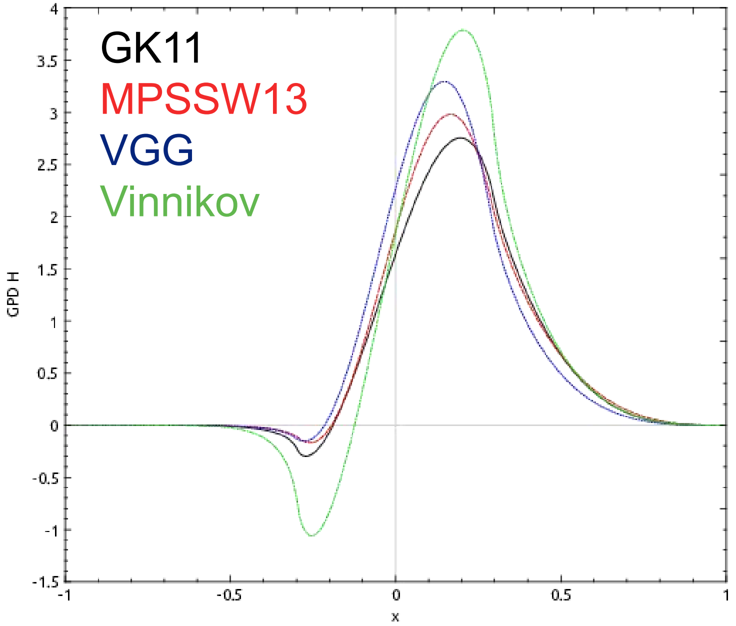
PARTONS project

- PARTONS - platform to study GPDs
- Come with number of available physics developments implemented
- Addition of new developments as easy as possible
- To support effort of GPD community
- Can be used by both theorists and experimentalists

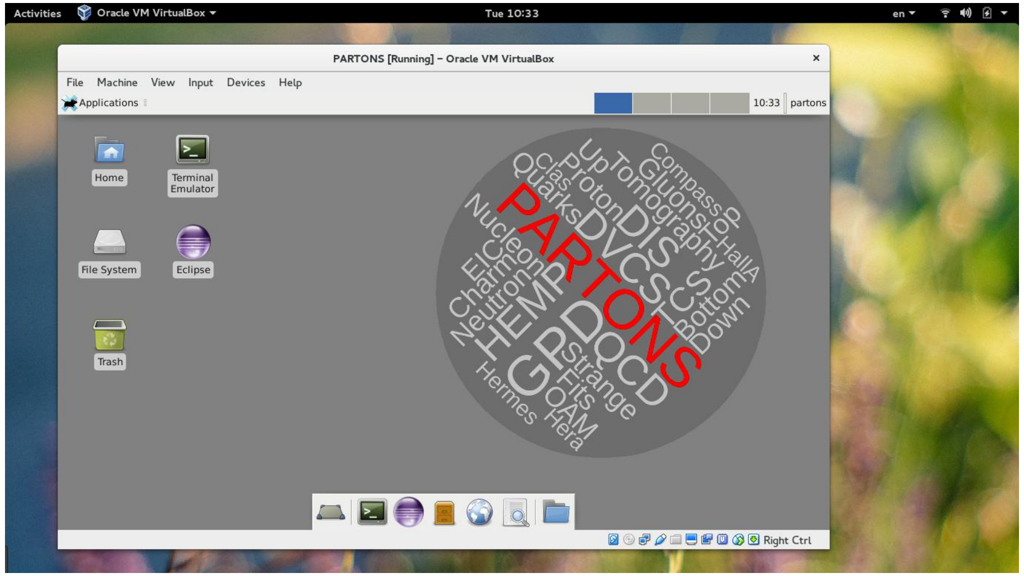
- More info in: Eur. Phys. J. C78 (2018) no. 6, 478

  http://partons.cea.fr

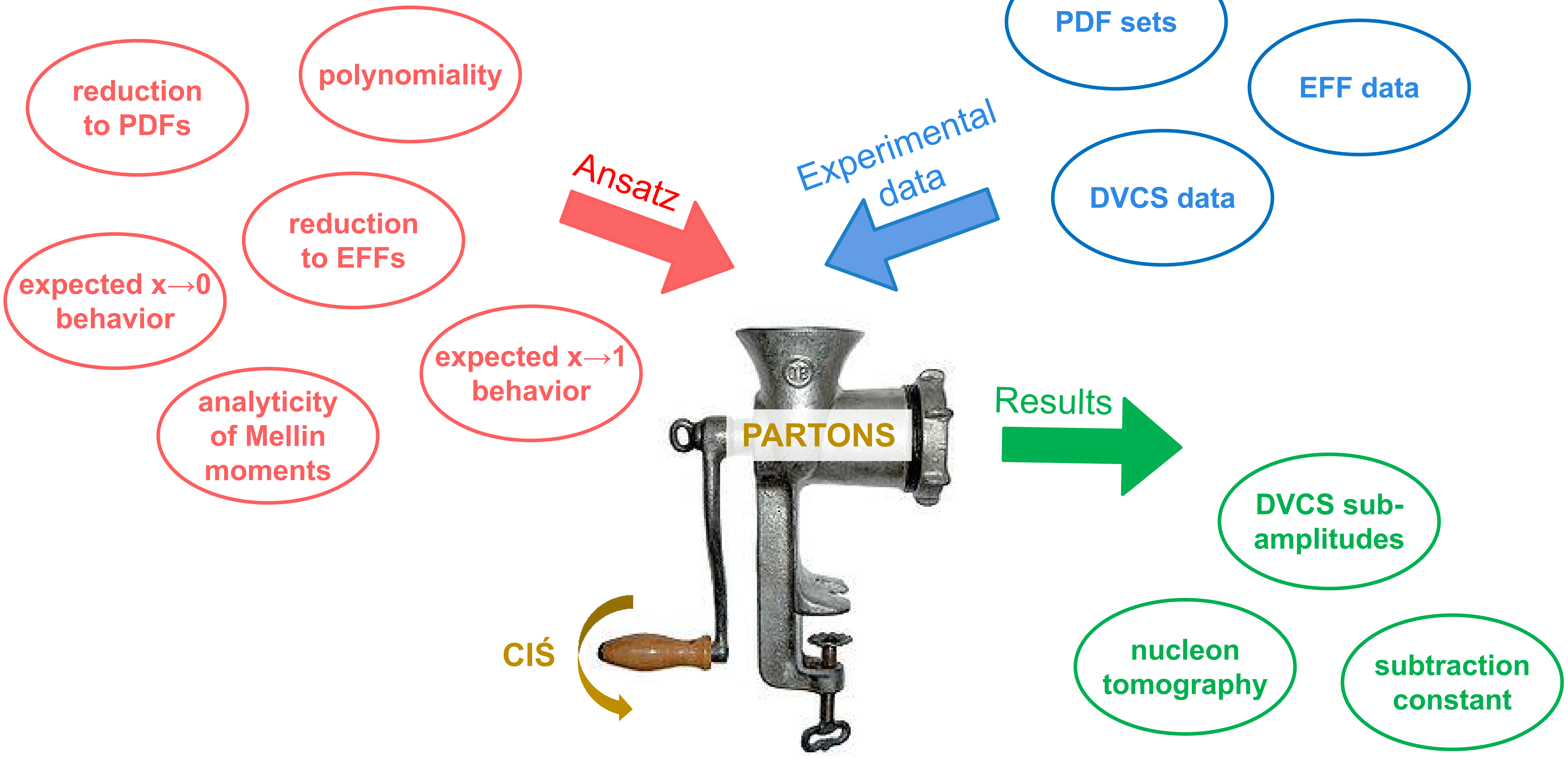
Comparison of GPD models



PARTONS virtual machine



Global analysis of DVCS data



Performance

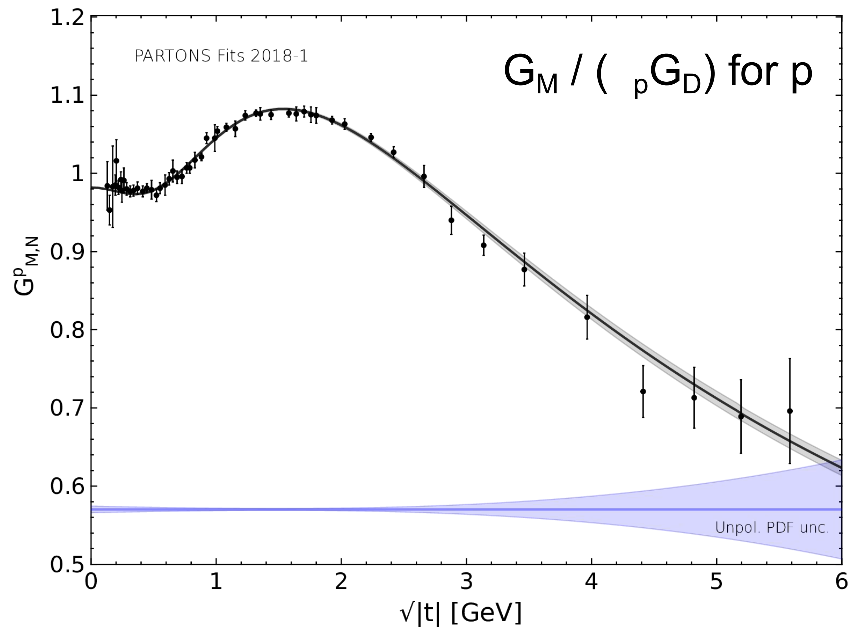
- PDF parameterizations fixed by NNPDF sets
- 178 experimental points for EFFs

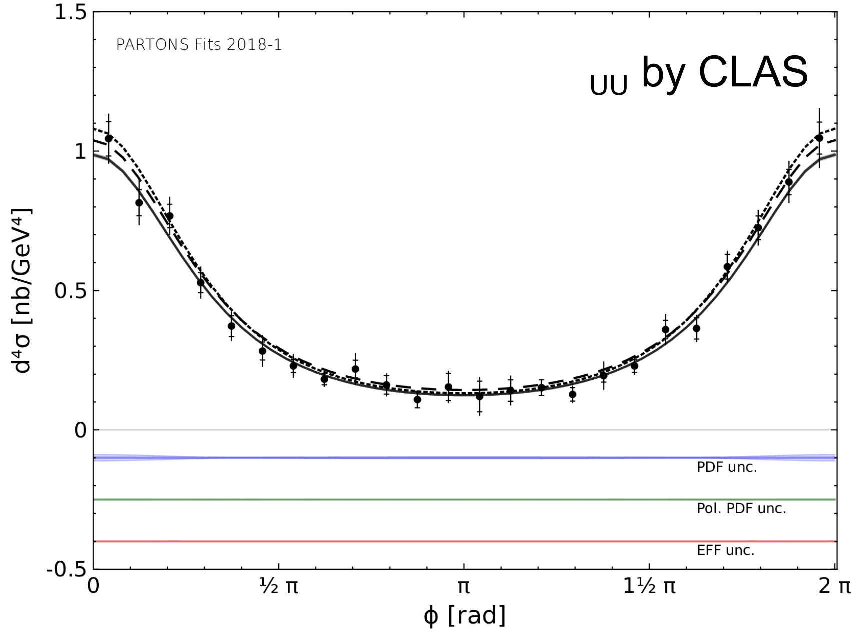
$$\chi^2/\mathrm{ndf} = 129.6/(178-9) \approx 0.77$$

- 2600 experimental points for DVCS

$$\chi^2/\mathrm{ndf} = 2346.3/(2600-13) \approx 0.91$$

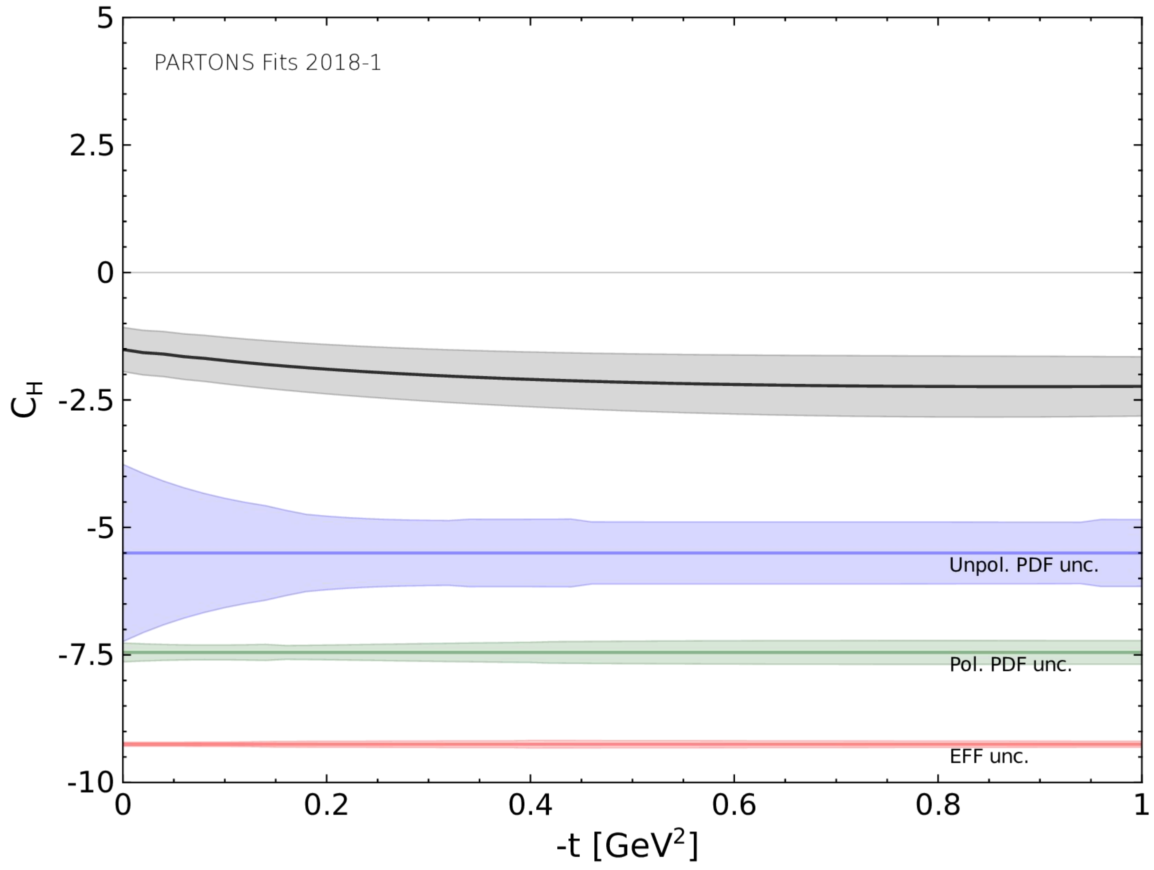
- Replication of experimental data to propagate corresponding uncertainties
- Small number of free parameters



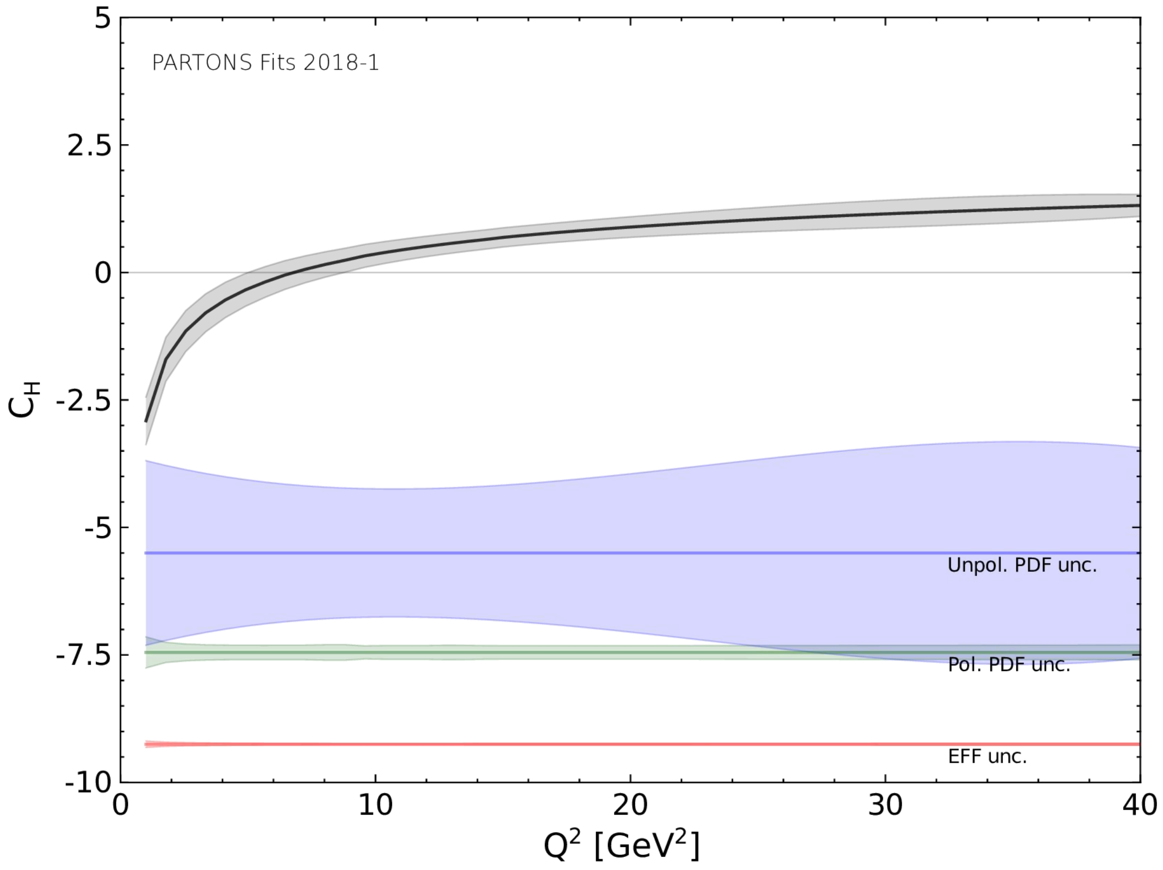


Results

Subtraction constant - relation to distribution of forces acting on quarks in the nucleon

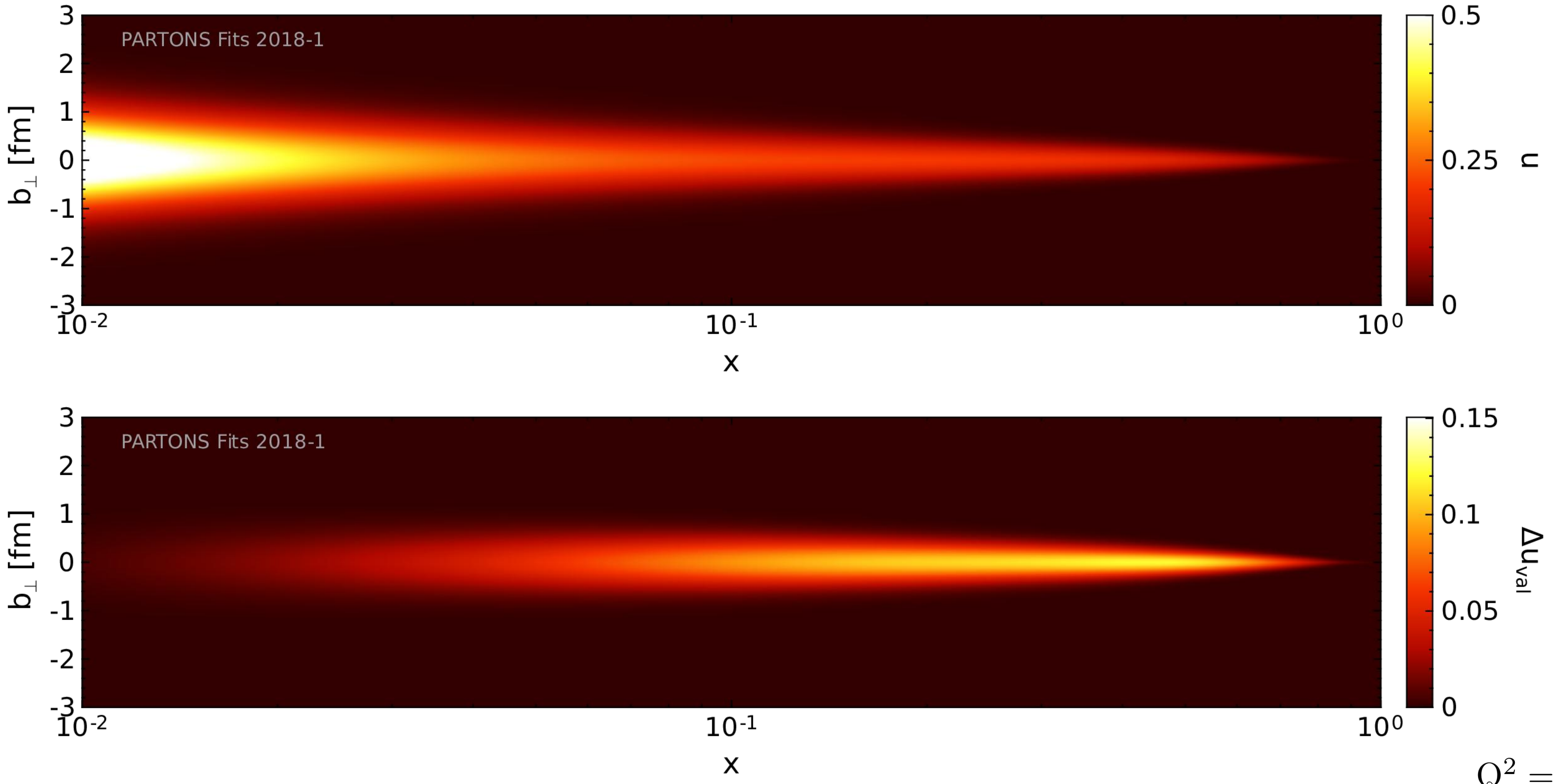


$Q^2 = 2\ \mathrm{GeV}^2$



$t = 0$

Nucleon tomography - proton reverse engineering



$Q^2 = 2 \text{ GeV}^2$

Fits to DVCS data

- New parameterizations of border and skewness function
  - → basic properties of GPD as building blocks
  - → small number of parameters
  - → encoded access to nucleon tomography and subtraction constant
- Successful to fit EFF and DVCS data
  - → replica method for a careful propagation of uncertainties

What next?

- Neural network parameterization of CFFs
- Include other channels and more observables
- Include new and already existing theory developments
- Make consistent analysis of all those ingredients → PARTONS