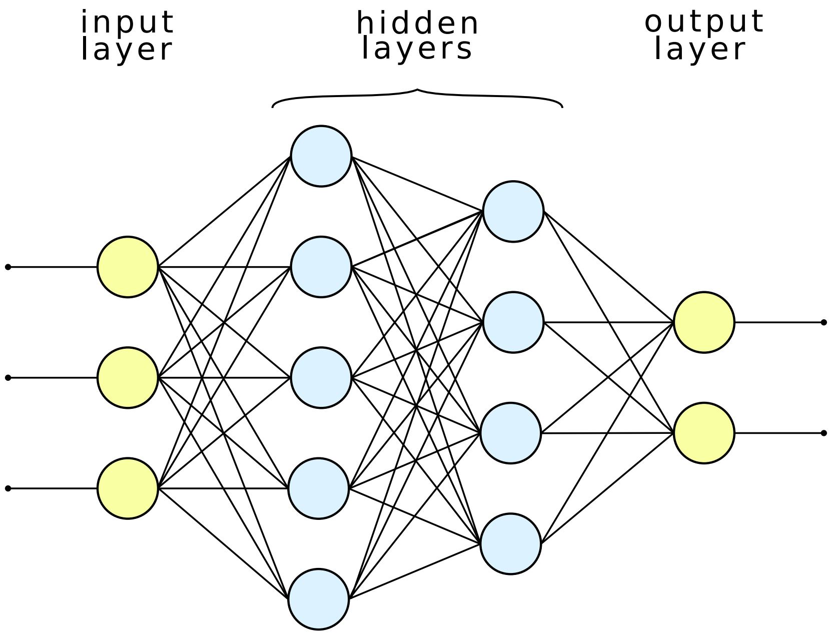
# Proton mechanical properties from global fits to DVCS data

C. Lorcé, H. Moutarde , P. Sznajder, A. Trawiński, J. Wagner

Yellow Report - Physics - Exclusive meeting
April 24, 2020

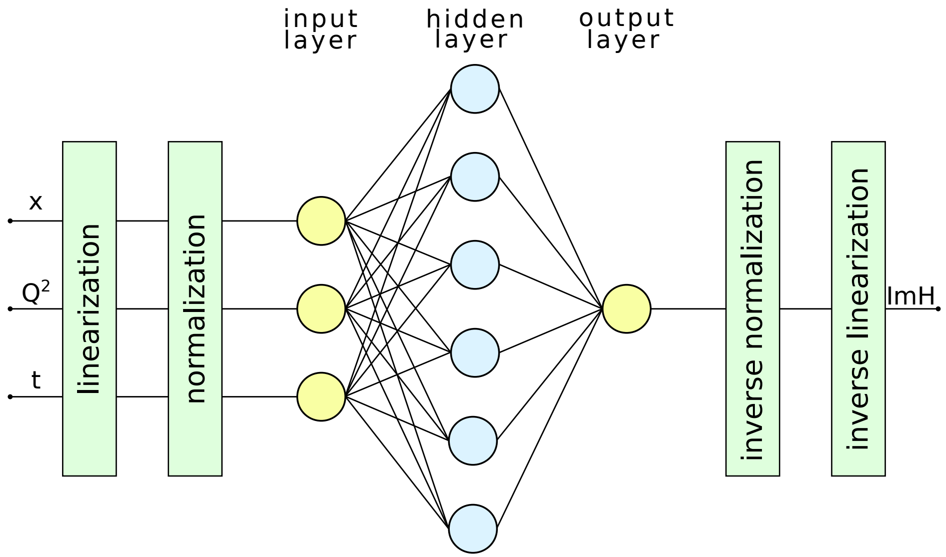



**Artificial neural networks (ANNs)**

- Data processing technique inspired by Nature
- Network made out of simple but highly connected elements → connectionists system
- Many variations, but most popular deep feed-forward ANNs
  - data processed layer by layer
    input layer → hidden layers→ output layer
  - generalisation capability given by consecutive hidden layers
    output of *i-1* layer is more refined than that of *i* layer
- Information containers
- Can be used for approximation of functions

# Neural Networks

H. Moutarde, P. S., J. Wagner
Eur. Phys. J. C 79 (2019) 7, 614



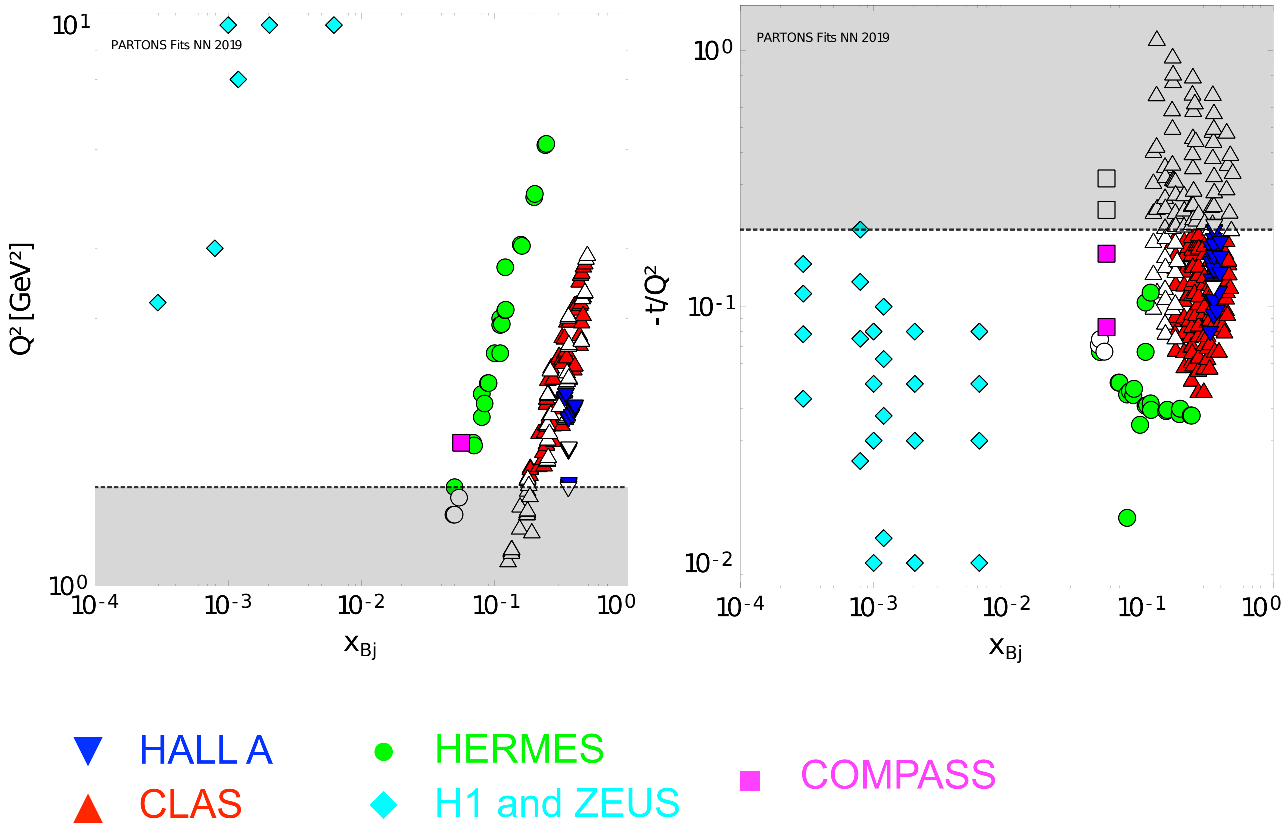

**Features of our analysis:**

- Independent network for each CFF and Re/Im parts
- Functions of $x_B$, $Q^2$ and t
- Network size determined using benchmark sample
- No power-behaviour pre-factors
- Trained with genetic algorithm
- Regularisation method based of early stopping criterion
- Replica method to propagate experimental uncertainties

# Performance

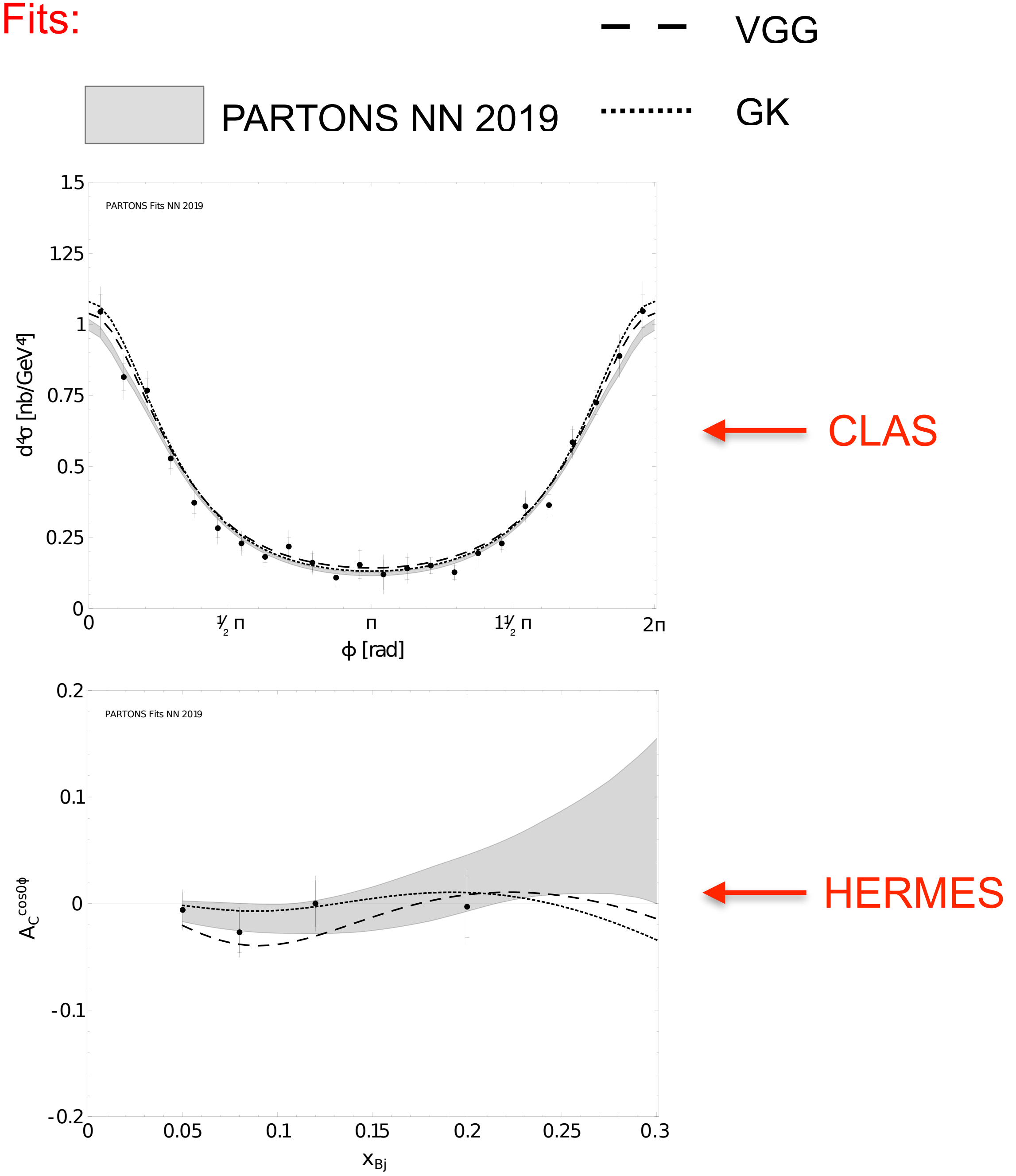
H. Moutarde, P. S., J. Wagner
Eur. Phys. J. C 79 (2019) 7, 614

## Coverage of phase-space:




$$-t/Q^2 < 0.2 \qquad Q^2 > 1.5\ \mathrm{GeV}^2$$

## Fits:



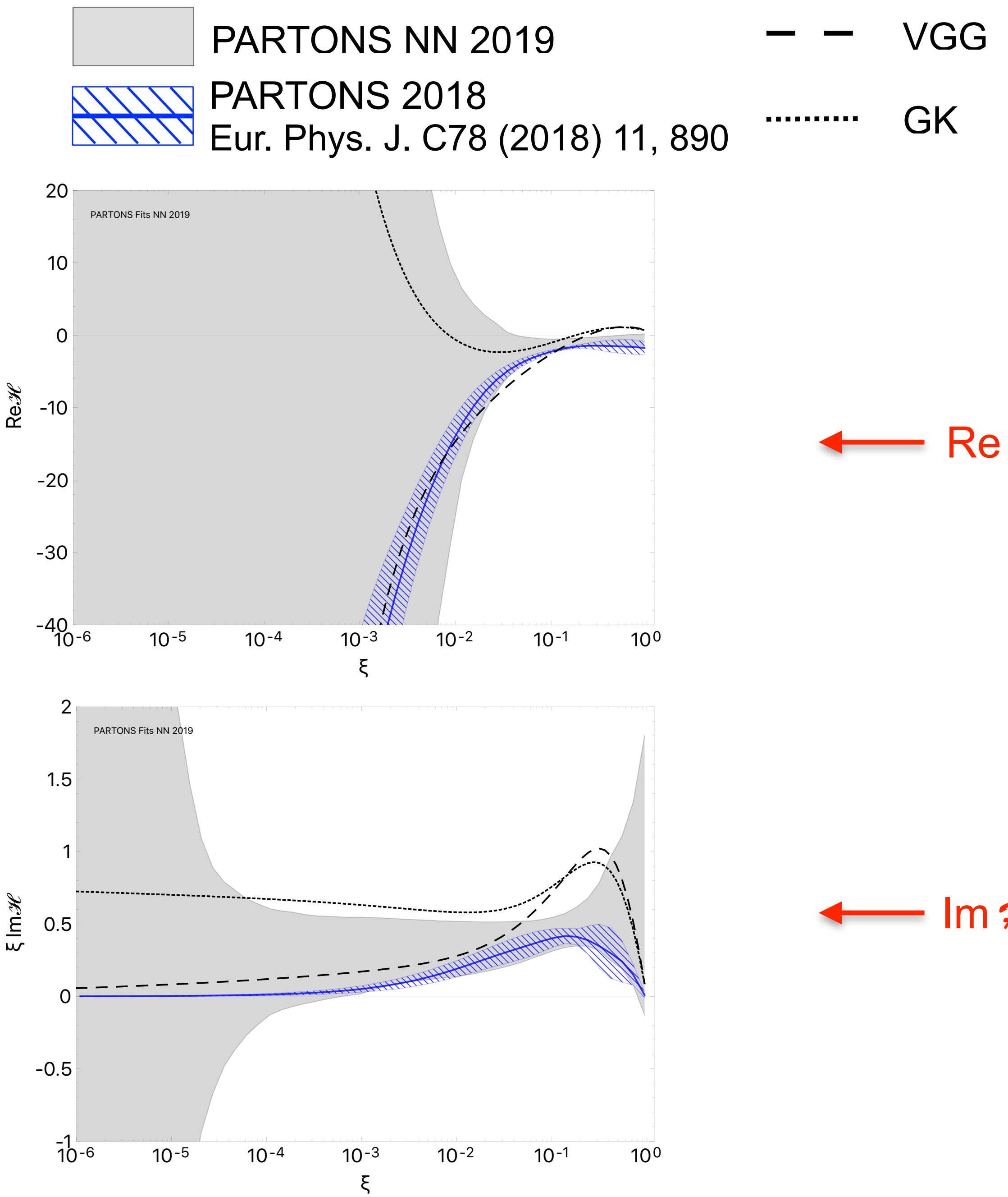
## Performance

H. Moutarde, P. S., J. Wagner
Eur. Phys. J. C 79 (2019) 7, 614

### Quality of fit:

$$\chi^2/\mathrm{nPoints} = 2243.5/2624 \approx 0.85$$

| No. | Collab. | Year | $\chi^2$ | $n$ | $\chi^2/n$ |
|---|---|---|---|---|---|
| 1 | HERMES | 2001 | 10.7 | 10 | 1.07 |
| 2 | | 2006 | 5.5 | 4 | 1.38 |
| 3 | | 2008 | 18.5 | 18 | 1.03 |
| 4 | | 2009 | 34.7 | 35 | 0.99 |
| 5 | | 2010 | 40.7 | 18 | 2.26 |
| 6 | | 2011 | 16.7 | 24 | 0.70 |
| 7 | | 2012 | 22.4 | 35 | 0.64 |
| 8 | CLAS | 2001 | — | 0 | — |
| 9 | | 2006 | 1.0 | 2 | 0.52 |
| 10 | | 2008 | 376.4 | 283 | 1.33 |
| 11 | | 2009 | 28.3 | 22 | 1.29 |
| 12 | | 2015 | 306.6 | 311 | 0.99 |
| 13 | | 2015 | 884.7 | 1333 | 0.66 |
| 14 | Hall A | 2015 | 231.8 | 228 | 1.02 |
| 15 | | 2017 | 211.4 | 276 | 0.77 |
| 16 | COMPASS | 2018 | 3.0 | 2 | 1.50 |
| 17 | ZEUS | 2009 | 5.49 | 4 | 1.38 |
| 18 | H1 | 2005 | 22.2 | 7 | 3.17 |
| 19 | | 2009 | 23.4 | 12 | 1.95 |



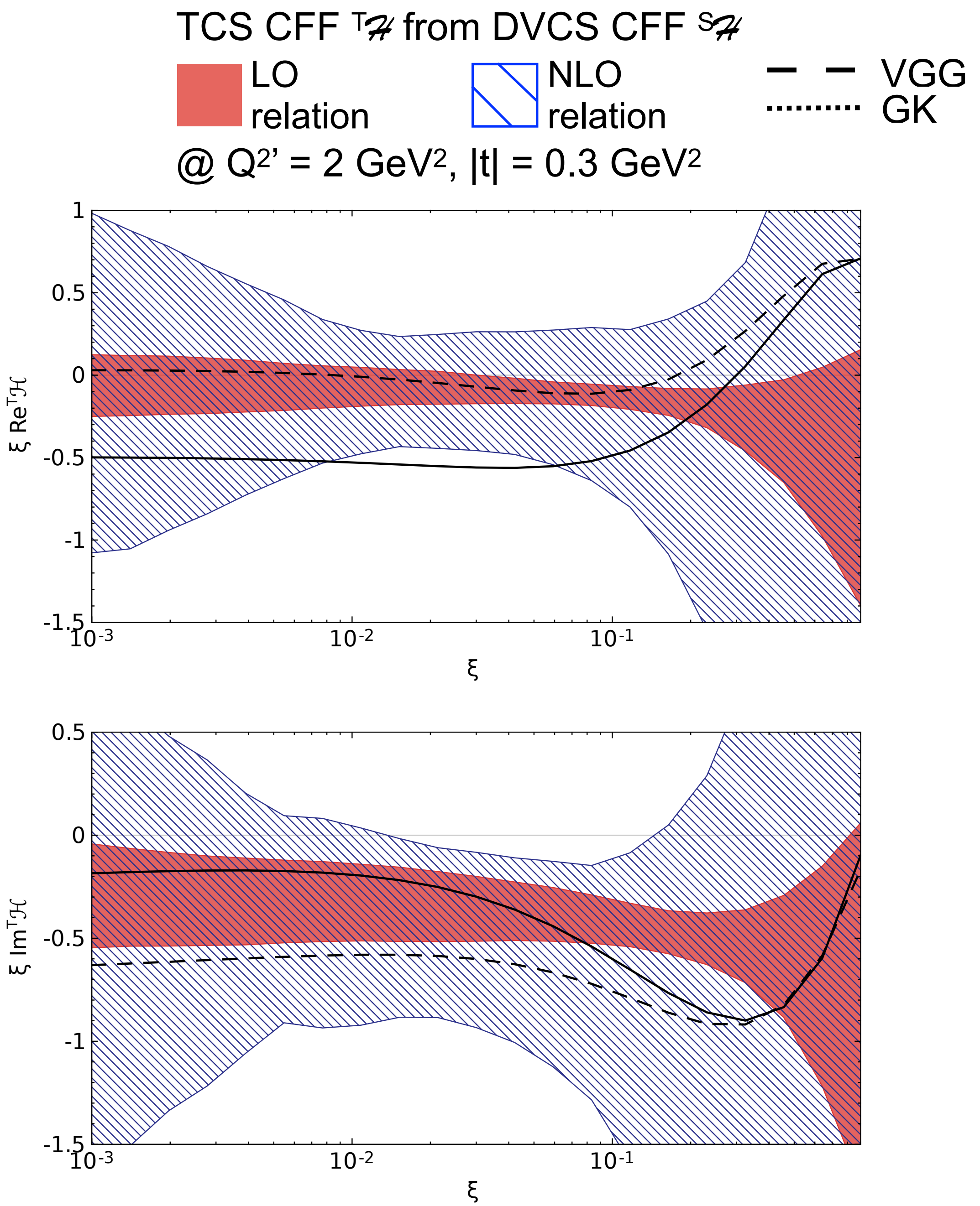

Re $\mathcal{H}$

Im $\mathcal{H}$

# Timelike Compton Scattering

O. Grocholski, H. Moutarde, B. Pire, P. S., J. Wagner
Eur. Phys. J. C 80 (2020) 2, 171
*see Jakub's talk from Temple meeting*

| | **TCS** | | **DVCS** |
|---|---|---|---|
| **LO:** | ${}^{T}\mathscr{H}$ | $=$ | ${}^{S}\mathscr{H}^*$ |
| **NLO:** | ${}^{T}\mathscr{H}$ | $=$ | ${}^{S}\mathscr{H}^* - i\pi\, \mathcal{Q}^2 \dfrac{\partial}{\partial \mathcal{Q}^2} {}^{S}\mathscr{H}^*$ |

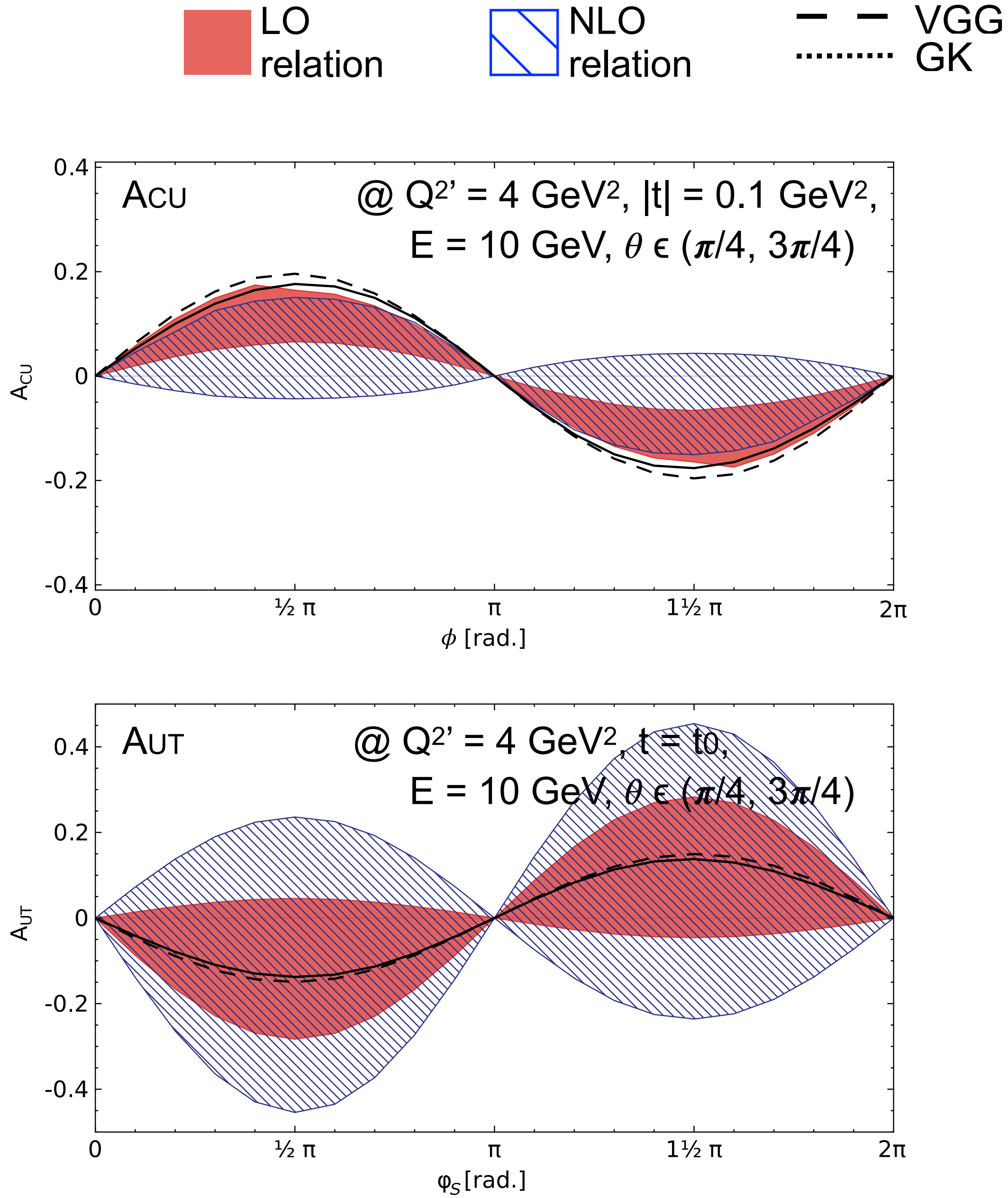


# Timelike Compton Scattering

O. Grocholski, H. Moutarde, B. Pire, P. S., J. Wagner
Eur. Phys. J. C 80 (2020) 2, 171
*see Jakub's talk from Temple meeting*

| | TCS | | DVCS |
|---|---|---|---|
| **LO:** | ${}^{T}\mathcal{H}$ | $=$ | ${}^{S}\mathcal{H}^{*}$ |
| **NLO:** | ${}^{T}\mathcal{H}$ | $=$ | ${}^{S}\mathcal{H}^{*} - i\pi\, Q^2 \frac{\partial}{\partial Q^2}\, {}^{S}\mathcal{H}^{*}$ |

TCS observables from DVCS CFFs



# Subtraction constant

C. Lorcé, H. Moutarde , P. S., A. Trawiński, J. Wagner
*preliminary*

dispersion relation:

$$\mathrm{SC}_H^{\mathrm{DVCS}}(t, Q^2) = \mathrm{Re}\mathcal{H}(\xi, t, Q^2) - \frac{1}{\pi}\mathrm{p.v.}\int_0^1 \mathrm{d}\xi' \, \mathrm{Im}\mathcal{H}(\xi', t, Q^2)\left(\frac{1}{\xi - \xi'} - \frac{1}{\xi + \xi'}\right)$$

thanks to relation between SC and D-term:

$$\mathrm{SC}_H^{\mathrm{DVCS}}(t, Q^2) \overset{\mathrm{LO}}{=} 4\sum_q e_q^2 \sum_{\mathrm{odd}\ n} d_n^q(t, \mu_F^2 \equiv Q^2)$$

relation to EMT form factor:

$$d_1^q(t, \mu_F^2) = 5C^q(t, \mu_F^2)$$

## Modelling of subtraction constant:

- truncation to only d1

$$\mathrm{SC}_H^{\mathrm{DVCS}}(t, Q^2) = 4\sum_q e_q^2 \, d_1^q(t, \mu_F^2 \equiv Q^2)$$

- symmetry of light quark contributions

$$d_1^u(t, \mu_F^2) = d_1^d(t, \mu_F^2) = d_1^s(t, \mu_F^2) \equiv d_1^{uds}(t, \mu_F^2)$$

- radiative generation of gluon and charm contributions

$$d_1^G(t, \mu_{F,0}^2) = 0 \qquad d_1^c(t, m_c^2) = 0 \qquad \mu_{F,0}^2 = 0.1\ \mathrm{GeV}^2$$

- tripole Ansatz for t-dependence

$$d_1^{uds}(t, \mu_F^2) = d_1^{uds}(\mu_F^2)\left(1 - \frac{t}{\Lambda^2}\right)^{-\alpha}$$

$$\alpha = 3$$

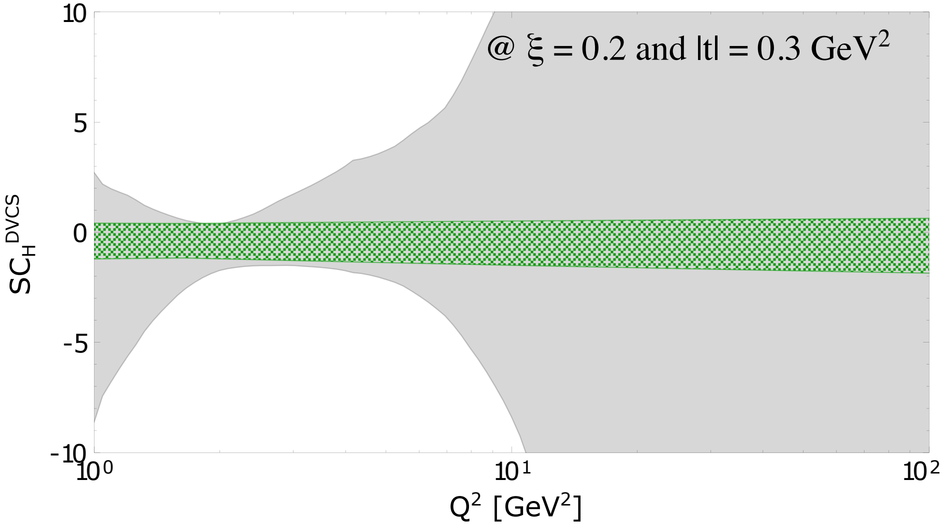
$$\Lambda = 0.8\ \mathrm{GeV}$$

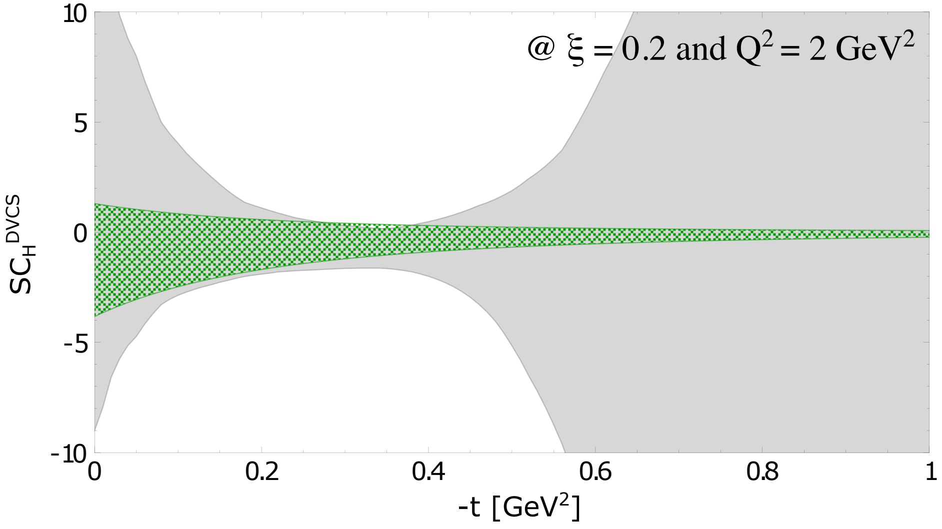
# Subtraction constant

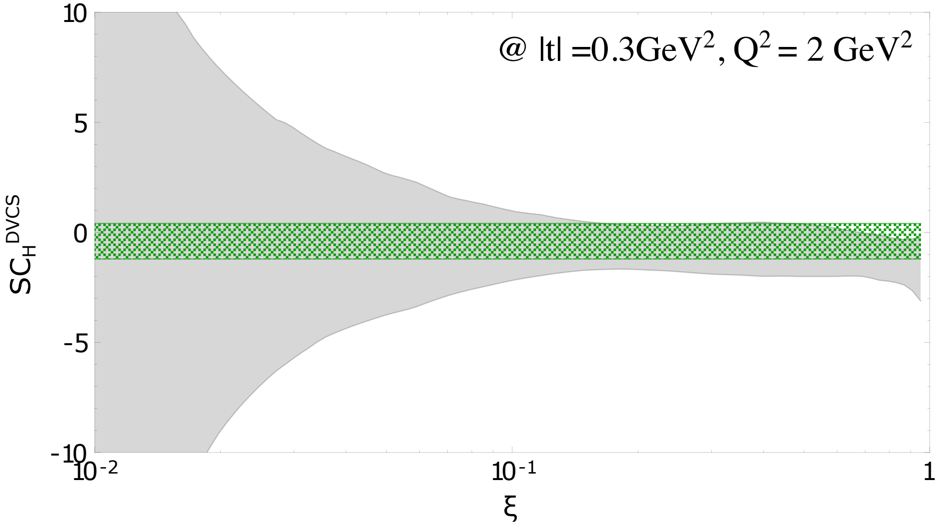
## Results

C. Lorcé, H. Moutarde , P. S., A. Trawiński, J. Wagner

*preliminary*




| Parameter | Value |
|---|---|
| $d_1^{uds}(\mu_F^2)$ | $-0.45 \pm 0.92$ |
| $d_1^{c}(\mu_F^2)$ | $-0.0020 \pm 0.0041$ |
| $d_1^{G}(\mu_F^2)$ | $-0.6 \pm 1.3$ |

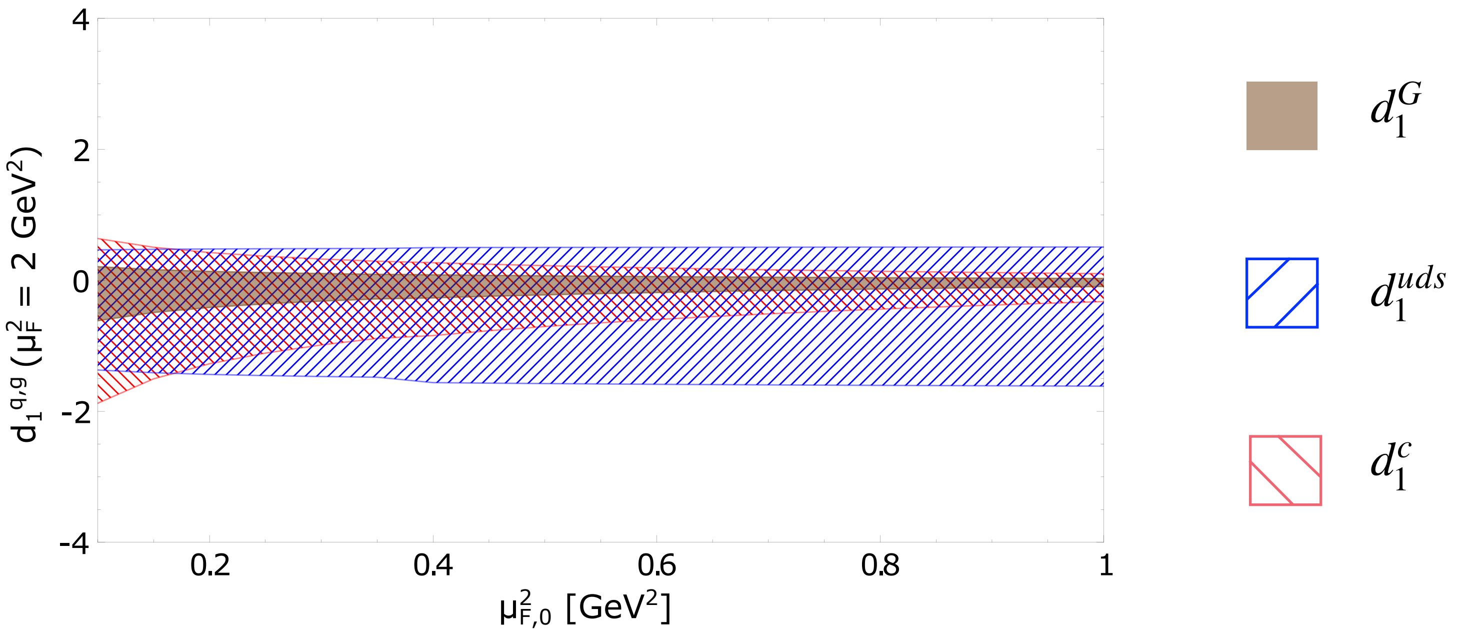
@$\mu_F^2 = 2$ GeV²

# Subtraction constant

**Dependance of initial factorisation scale**

C. Lorcé, H. Moutarde , P. S., A. Trawiński, J. Wagner

*preliminary*



## Subtraction constant

C. Lorcé, H. Moutarde , P. S., A. Trawiński, J. Wagner

*preliminary*

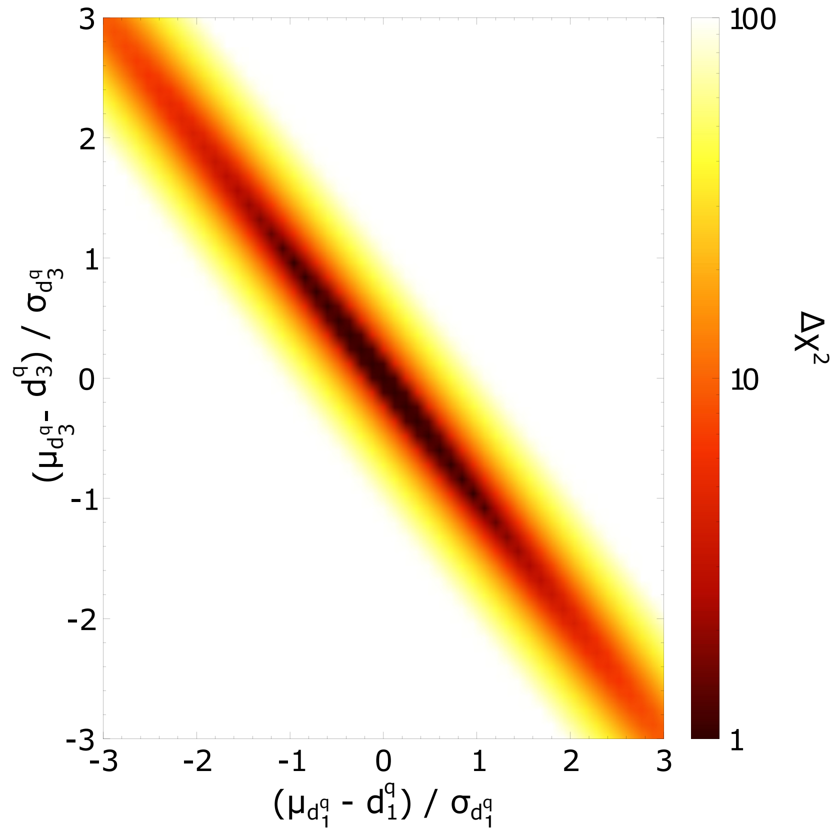
Results when a pair of parameters is extracted at the same time

| No. | Fitted parameters | Value | Allowed range min | max |
|---|---|---|---|---|
| 1 | $d_1^{uds}(\mu_F^2)$ | $-0.8 \pm 1.3$ | | |
| | $d_1^{G}(\mu_F^2)$ | $2 \pm 11$ | | |
| 2 | $d_1^{uds}(\mu_F^2)$ | $0.8 \pm 6.3$ | | |
| | $d_3^{uds}(\mu_F^2)$ | $-1.6 \pm 7.0$ | | |
| 3 | $d_1^{uds}(\mu_F^2)$ | $-0.7 \pm 1.4$ | | |
| | $\Lambda/\mathrm{GeV}$ | $1.4 \pm 0.71$ | 0 | 2 |
| 4 | $d_1^{uds}(\mu_F^2)$ | $-0.5 \pm 1.1$ | | |
| | $\alpha$ | $2.3 \pm 3.2$ | 0 | 10 |

@$\mu_F^2 = 2$ GeV$^2$

**Simultaneous extraction of two parameters**

Correlation between $d_1^{uds}$ and $d_3^{uds}$



## Summary

**Neural network parameterization of CFFs**

→ powerful tool to study GPDs

→ model independent

→ many applications:

→ analysis of TCS:

data driven prediction, multichannel analysis, GPD universality test

→ extraction of subtraction constant:

interpretation too model dependent, large uncertainties → need for more precise data and extended kinematic range covered, what we can learn at EIC?

→ fast generation of DVCS cross sections

→ …