LHCP 22/05/23

Simultaneous determination of SMEFT parameters and PDFs

Luca Mantani

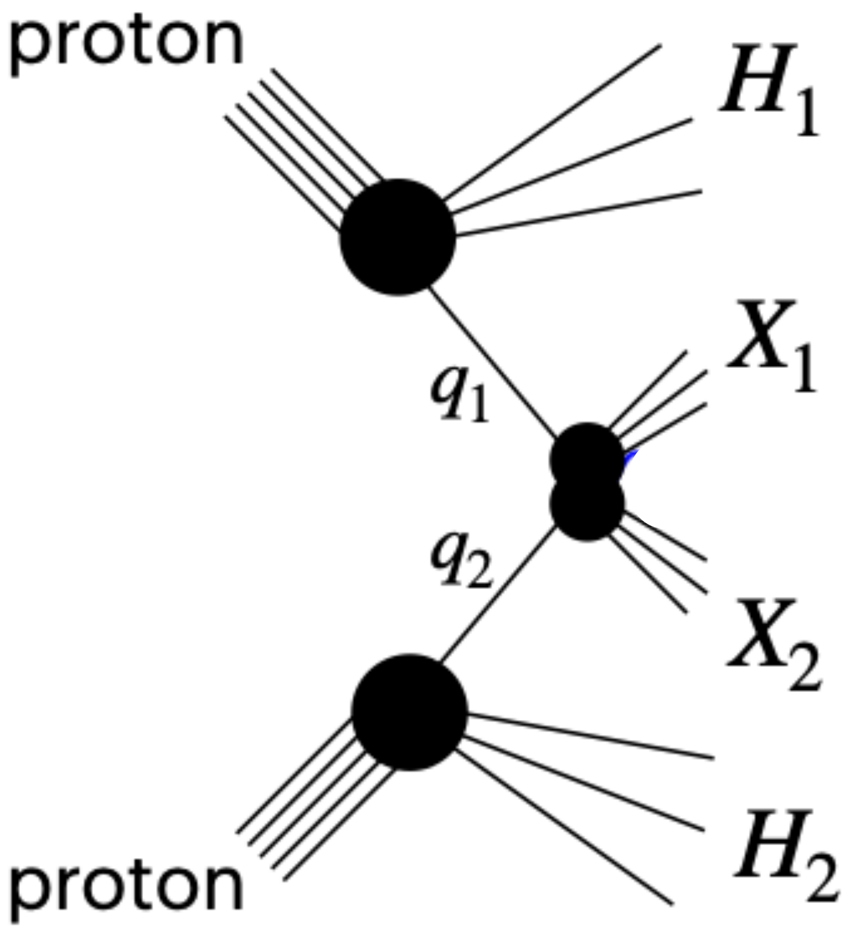
European Research Council
Established by the European Commission

UNIVERSITY OF CAMBRIDGE

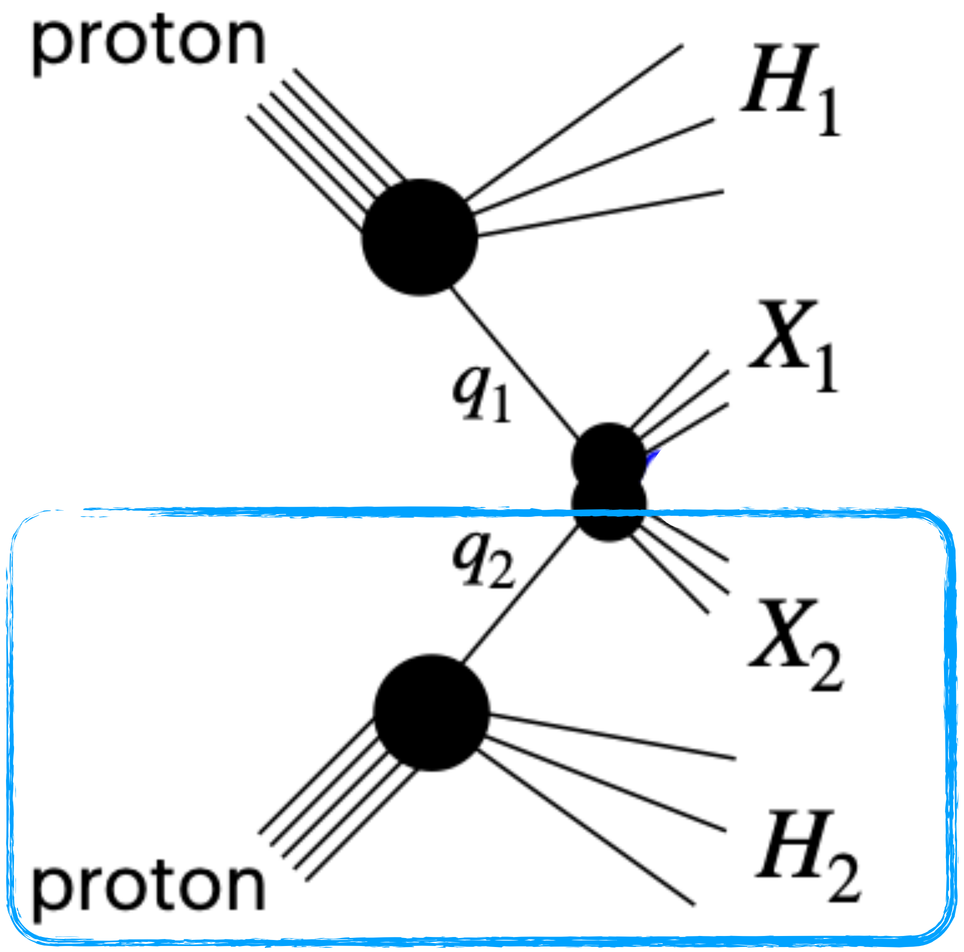
PBSP

At the LHC we smash protons

At the LHC we smash protons

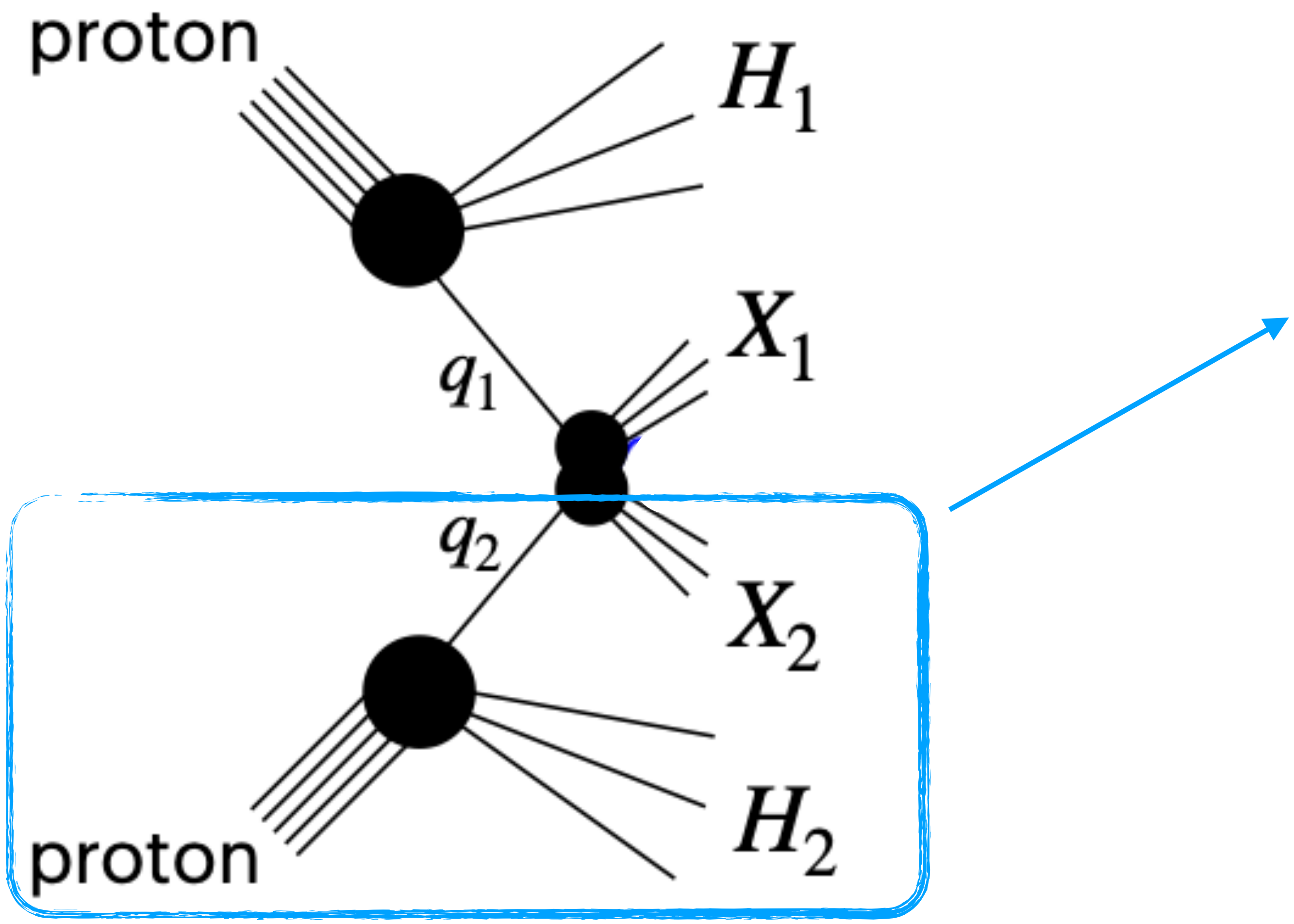


At the LHC we smash protons



parton distribution function (PDF)

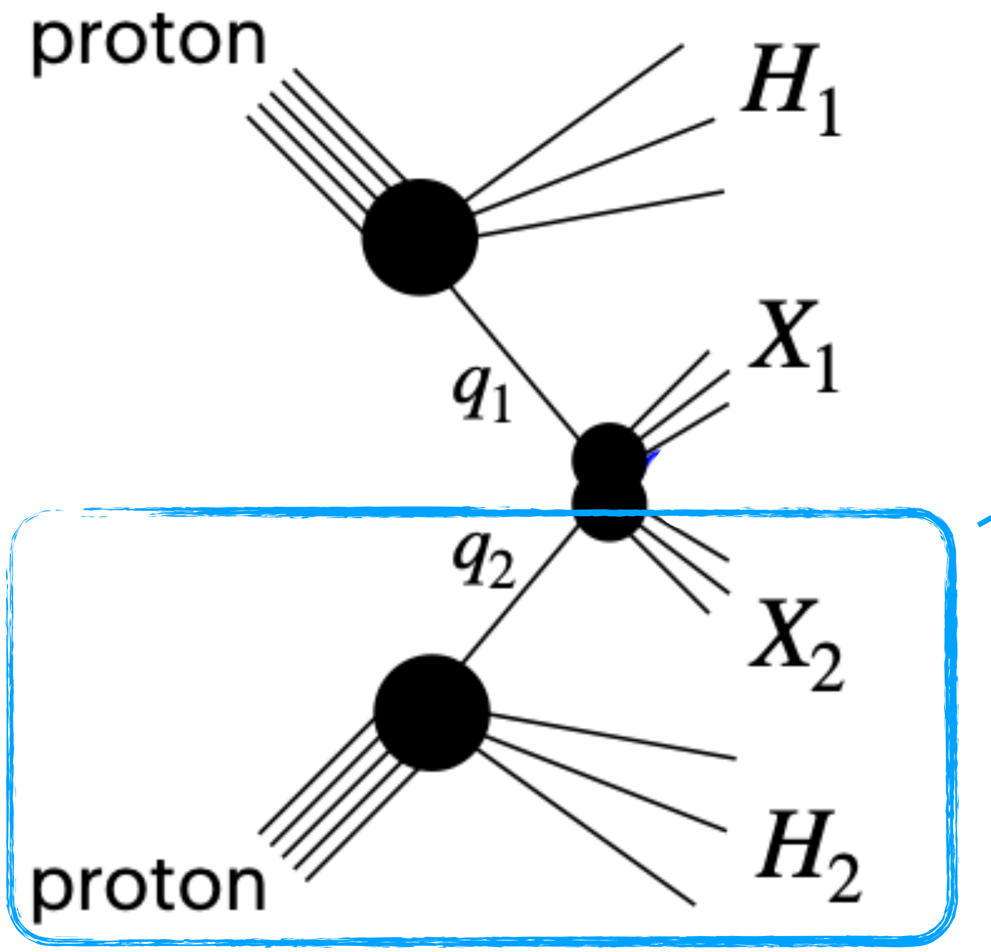
At the LHC we smash protons



parton distribution function (PDF)

Difficult to determine
on theoretical basis
(obtained through fits)

At the LHC we smash protons



parton distribution function (PDF)

Difficult to determine
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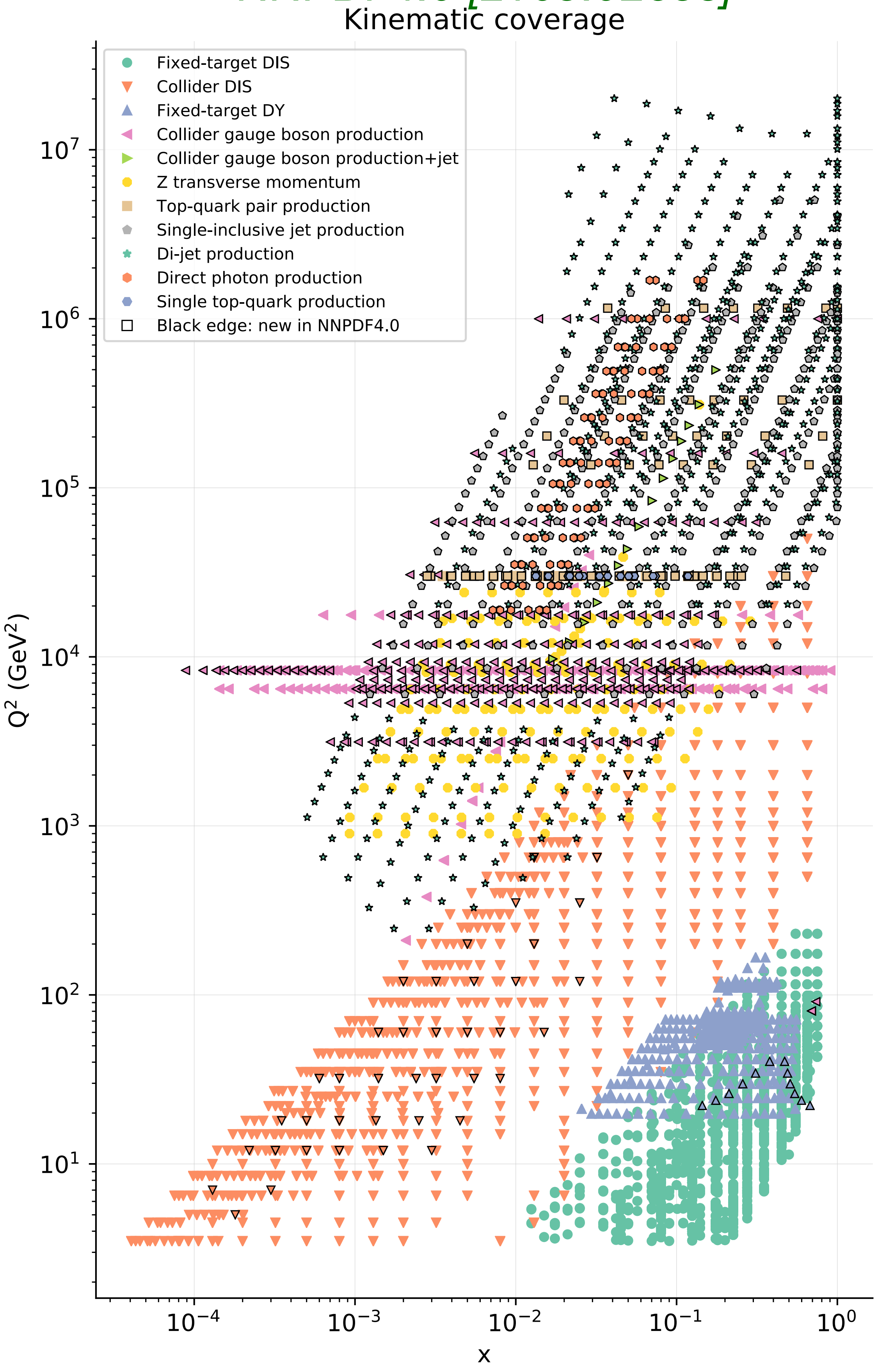
$$\sigma = \int_0^1 dx_1 \int_0^1 dx_2 \sum_{q_1,q_2} f_{q_1}(x_1) f_{q_2}(x_2) \hat{\sigma}(x_1, x_2)$$

Data overlap

Often data used in SMEFT interpretations and PDF extraction coincide

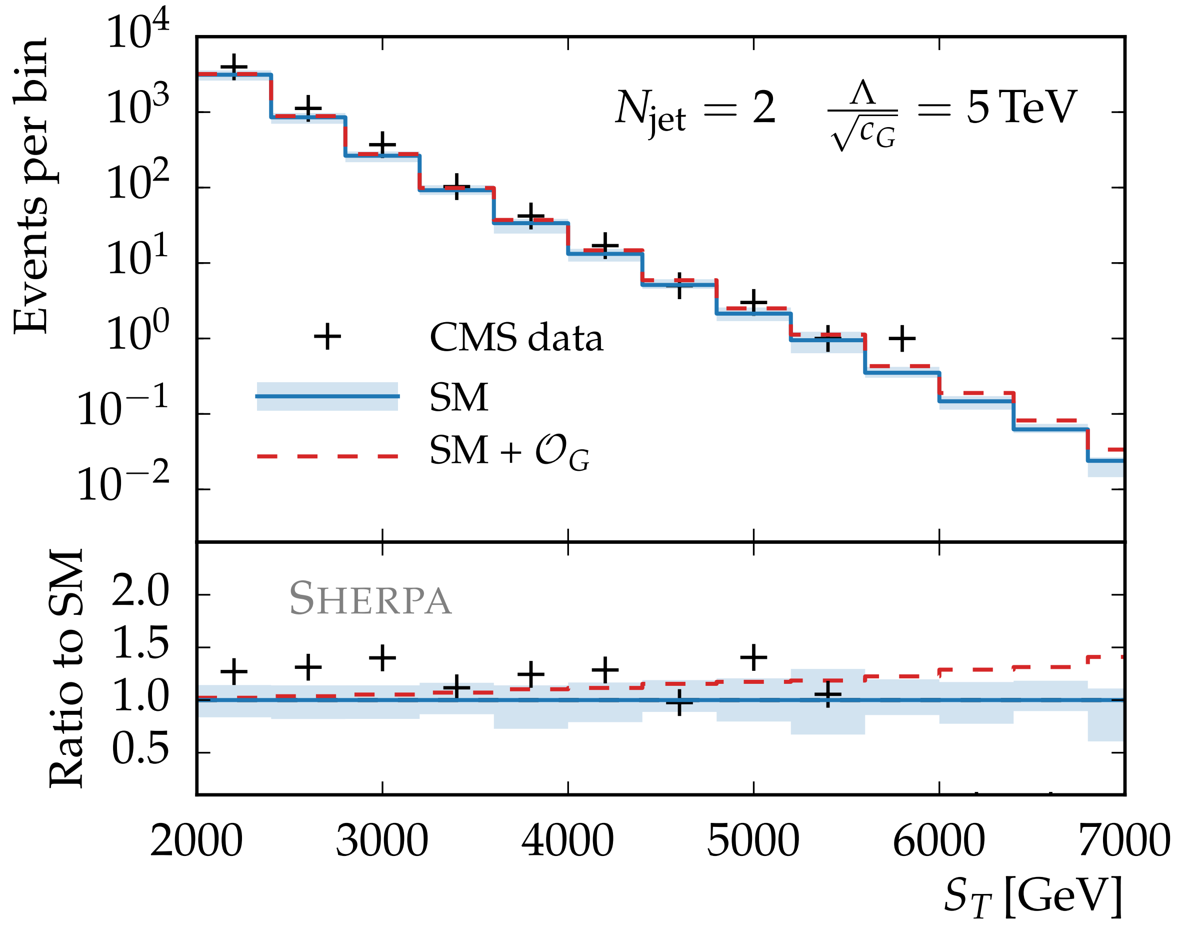
NNPDF4.0 [2109.02653]



Data overlap

Often data used in SMEFT interpretations and PDF extraction coincide

e.g. Dijet data used to fit the SMEFT operator in *F. Krauss et. al, 1611.00767*



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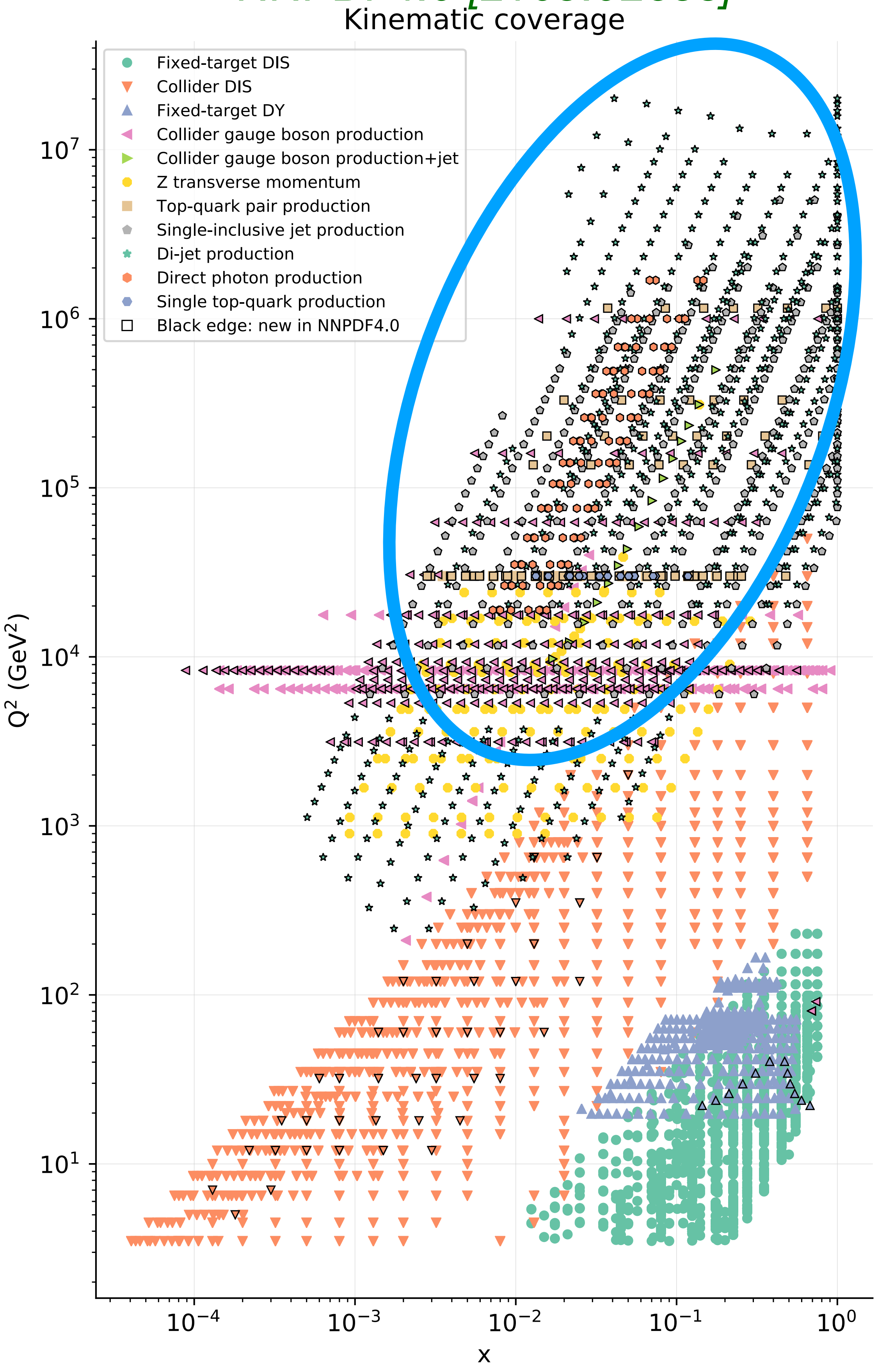

Typically fits of physics parameters and PDFs do not talk

$$\sigma(C,\theta) = f_1(C,\theta) \otimes f_2(C,\theta) \otimes \hat{\sigma}(C)$$

The current status

Typically fits of physics parameters and PDFs do not talk

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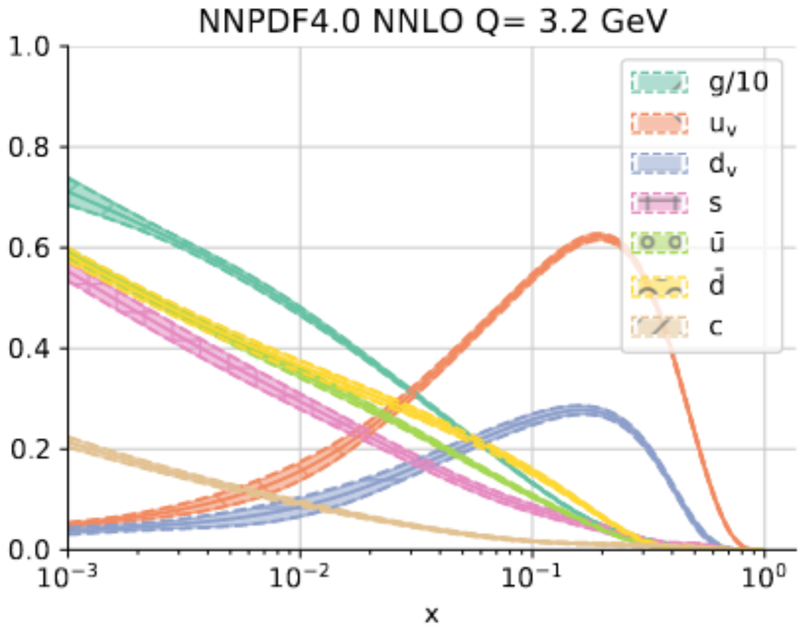
PDFs extraction

- Fix physics parameters $\bar{C}$

$$\sigma(\bar{C},\theta) = f_1(\bar{C},\theta) \otimes f_2(\bar{C},\theta) \otimes \hat{\sigma}(\bar{C})$$

We extract the PDFs from data,
we have implicit dependence $\theta^* = \theta^*(\bar{C})$



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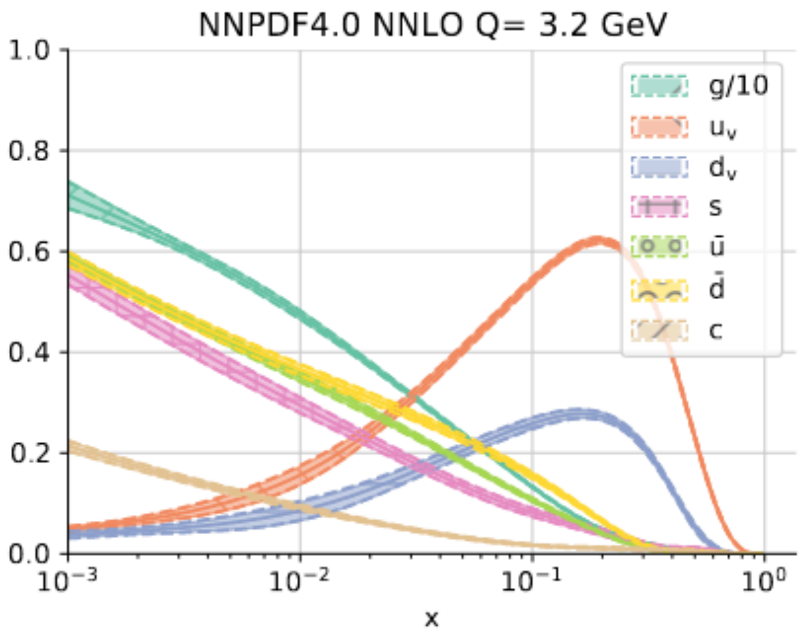

Physics parameters

- Fix PDFs parameters $\bar{C}, \bar{\theta}$

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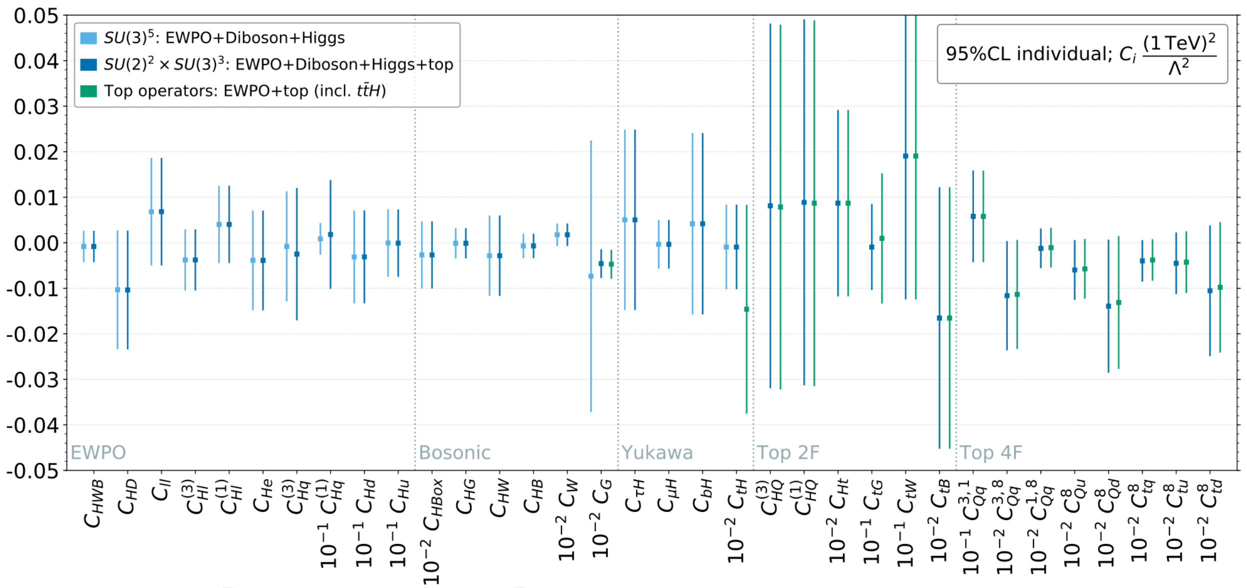
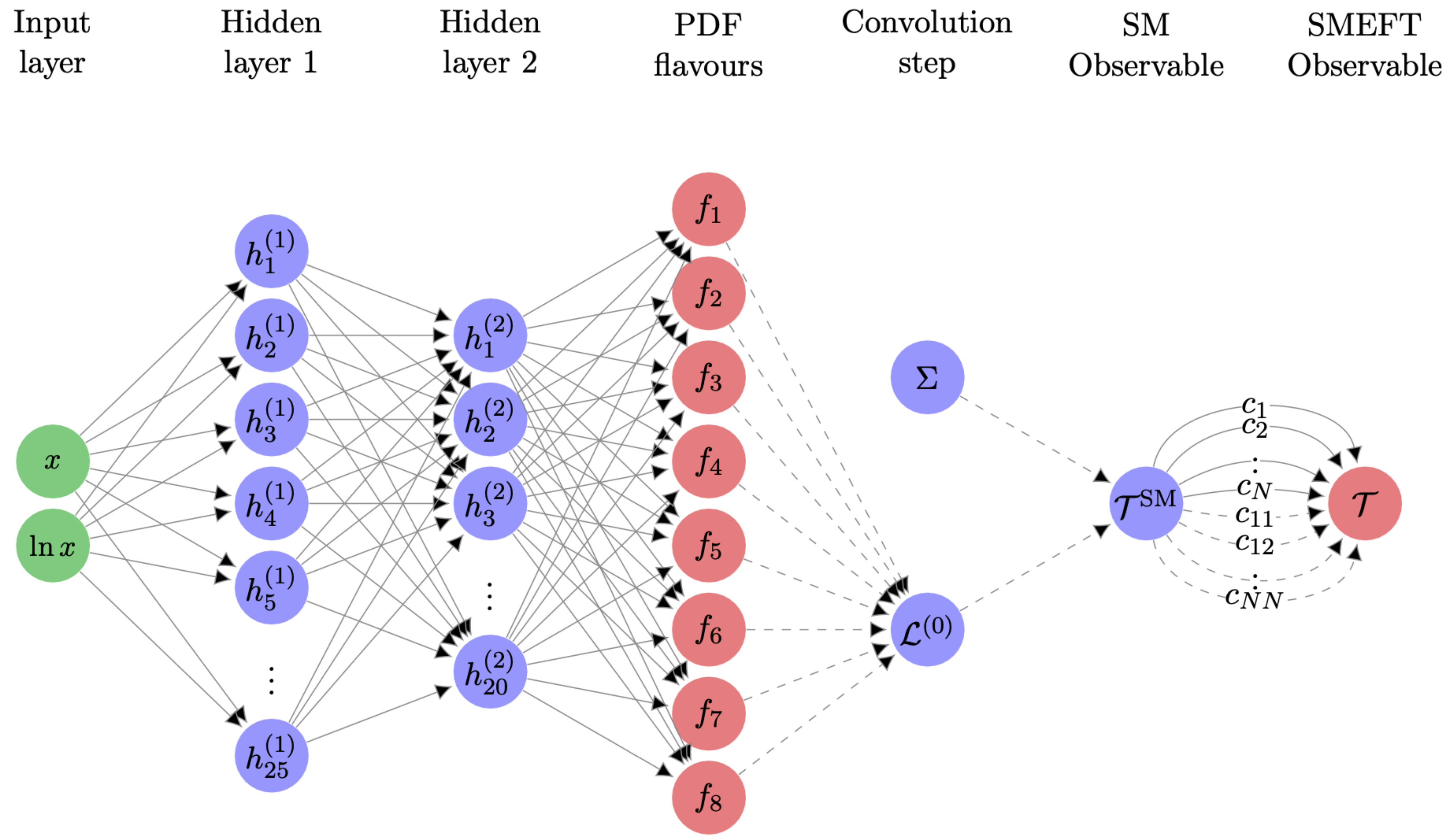


FitMaker [2012:02779]

SIMUnet

S. Iranipour, M. Ubiali, [2201.07240]

“A new methodology that is able to yield a simultaneous determination of the PDFs alongside **any set of parameters that determine the theory predictions**”



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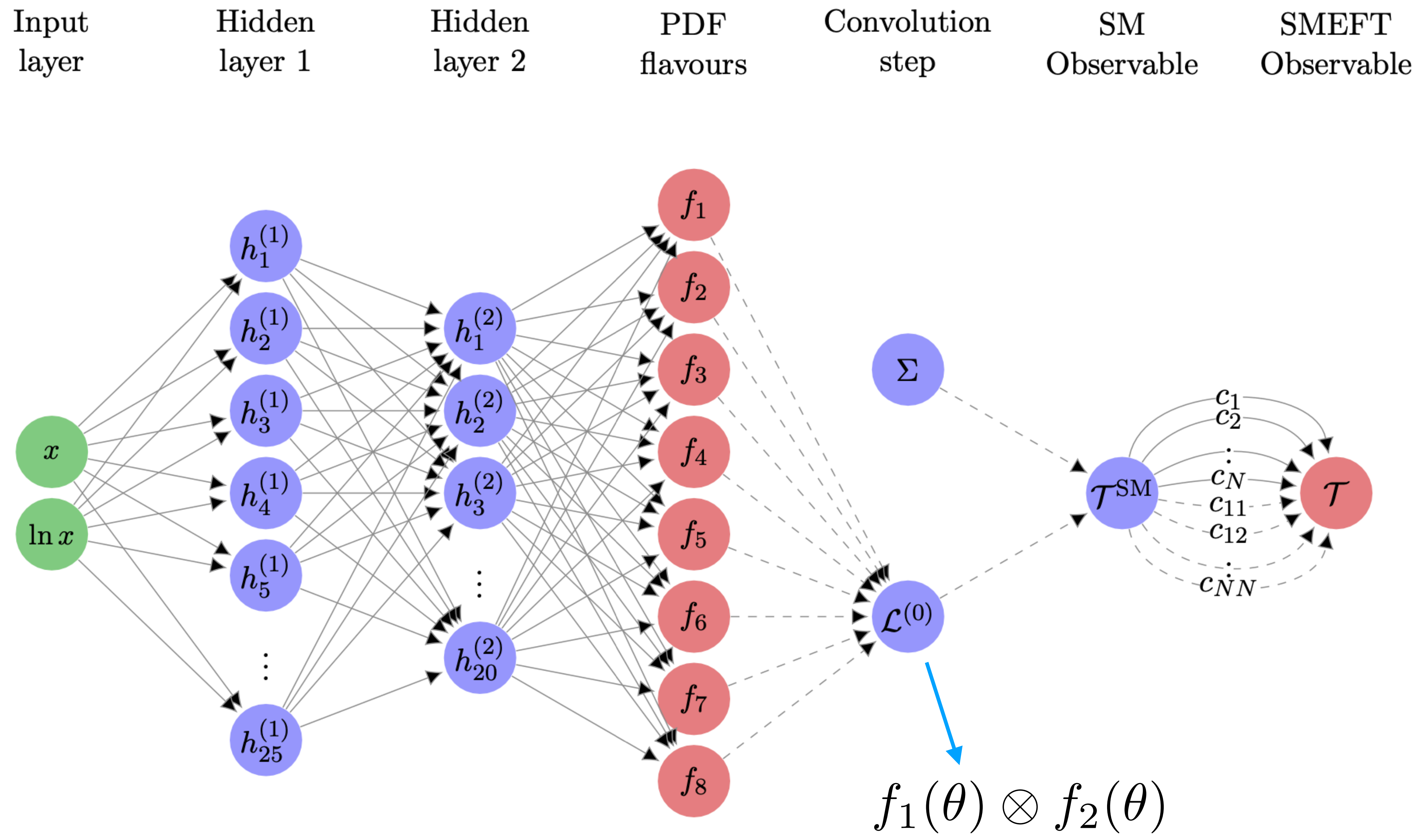

$$f_1(\theta) \otimes f_2(\theta)$$

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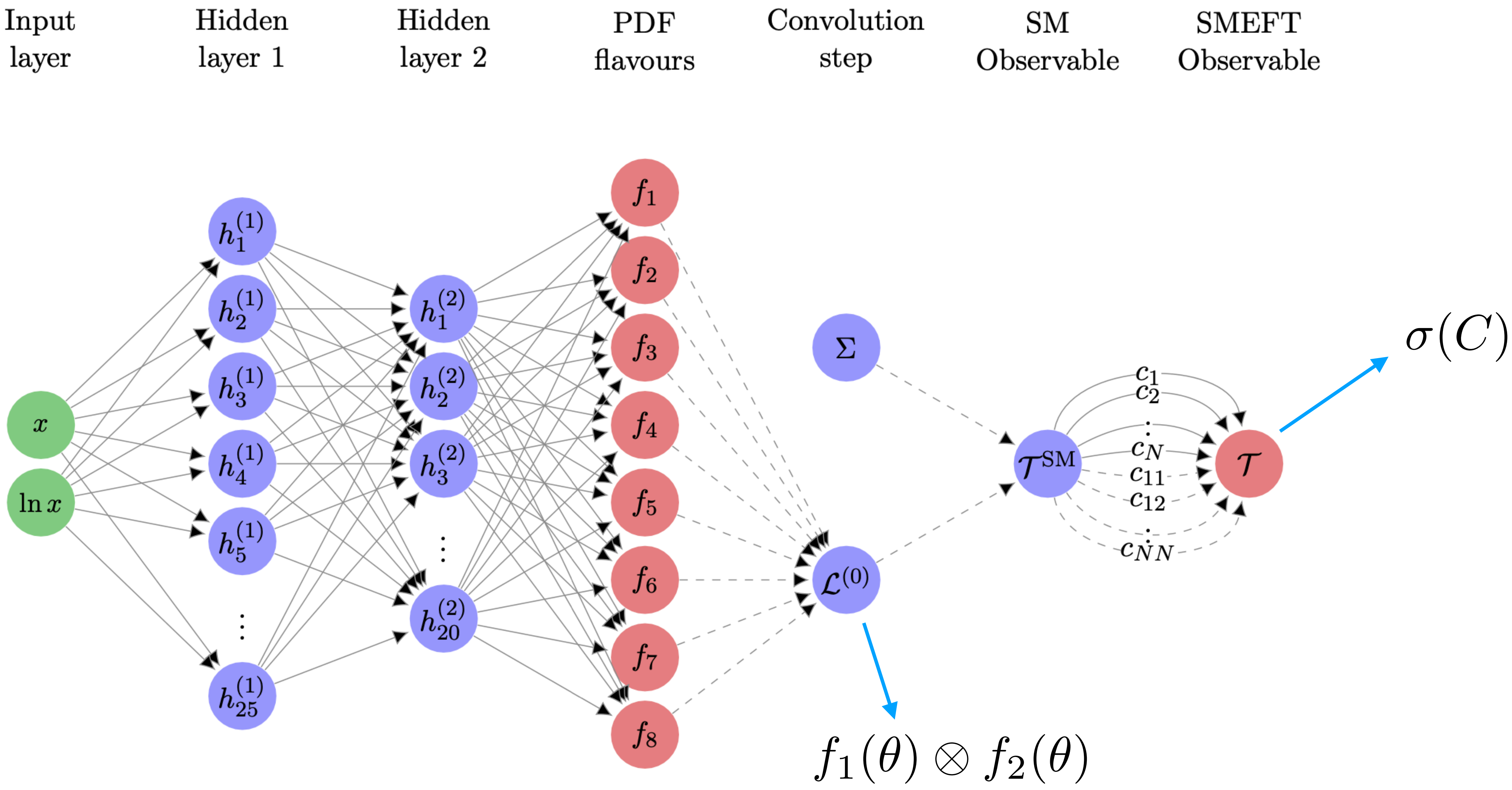


$\sigma(C)$

$f_1(\theta) \otimes f_2(\theta)$

SMEFT-PDF interplay in top

arXiv:2303.06159

The **top sector** has been used in multiple EFT analyses, including **SMEFiT** (2105.00006) and **FitMaker** (2012.02779).

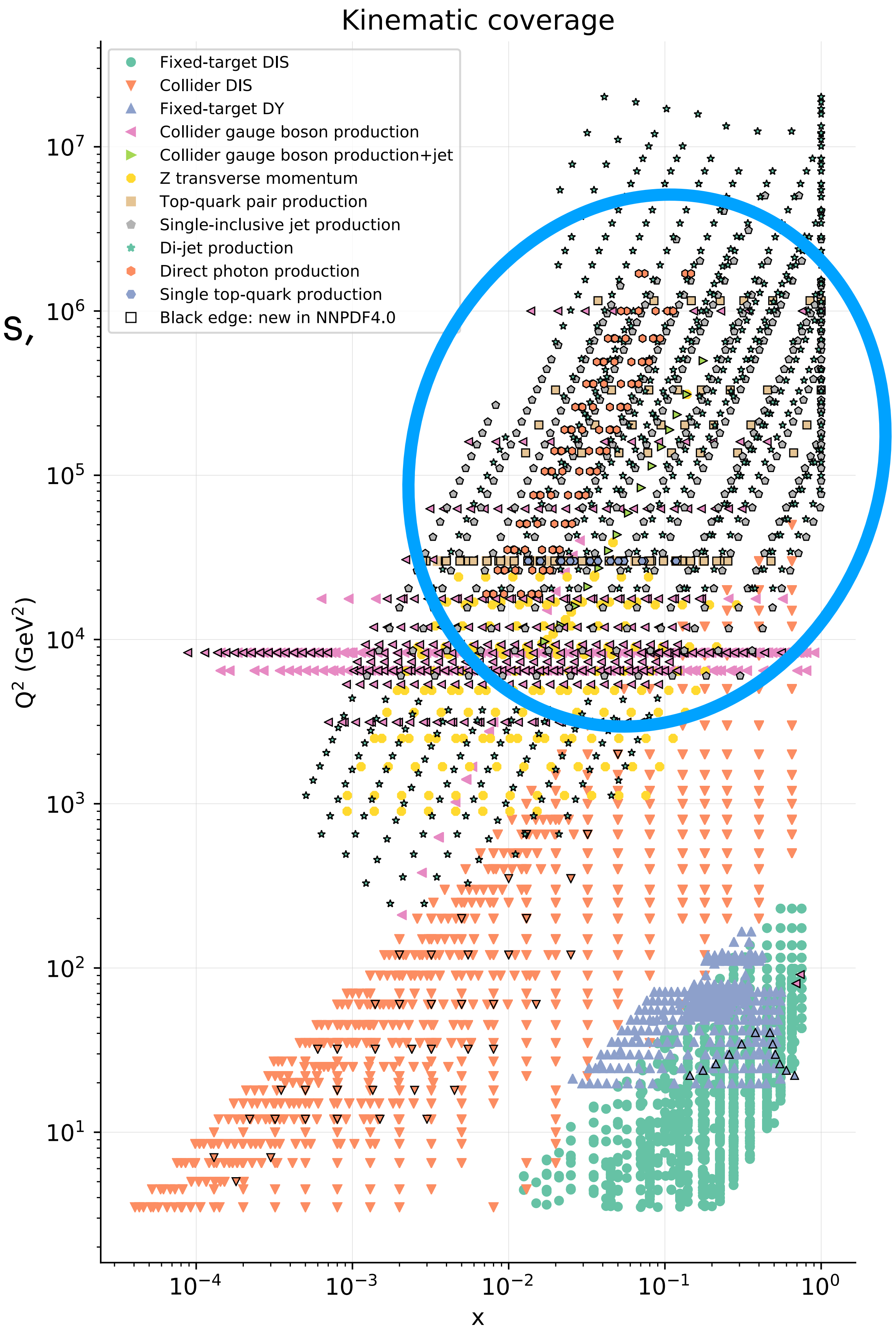
PDFs: the top sector is relevant for **high-x** $\bar{q}q$ lumi + **gluon** lumi

EFT: ~ 20 operators affect top processes

Dataset superset of SMEFiT & FitMaker

$$t\bar{t}\ (\text{incl. } A_C), \qquad t\bar{t} + X,$$

$$\text{single } t, \qquad tZ, tW, \ldots$$



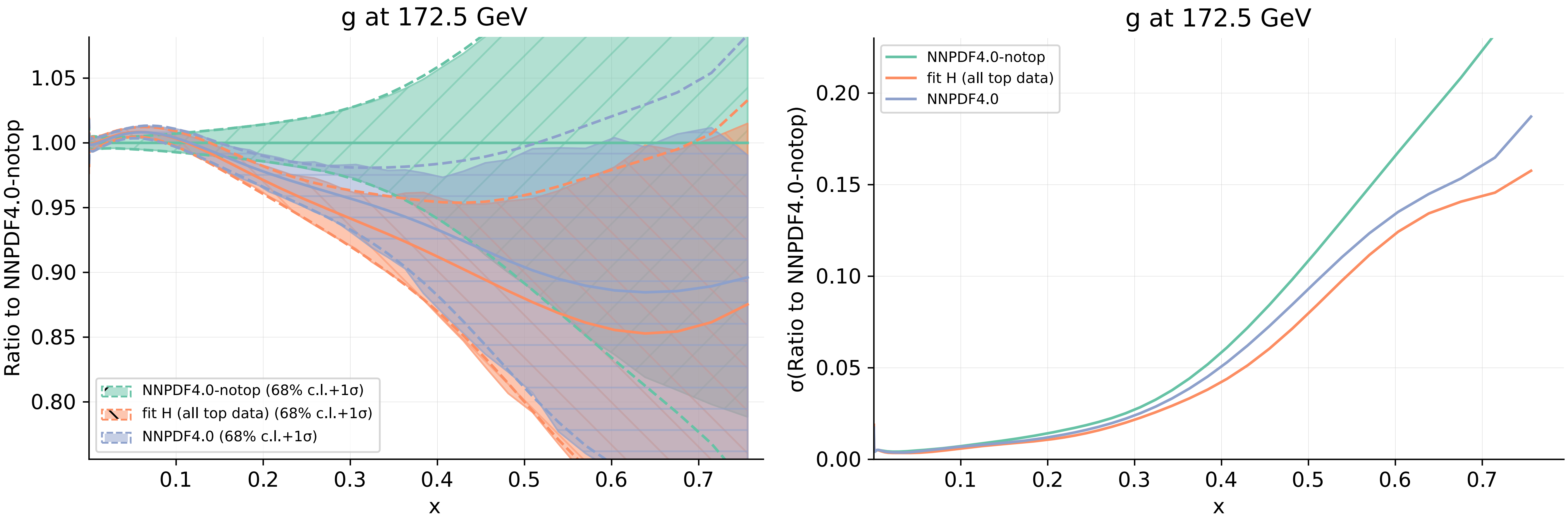
Top data is important especially for the gluon PDF

SM PDF fit, all top data

SM PDF fit, no top data

NNPDF 4.0

Additional data include: DIS, DY, jets, V + jets



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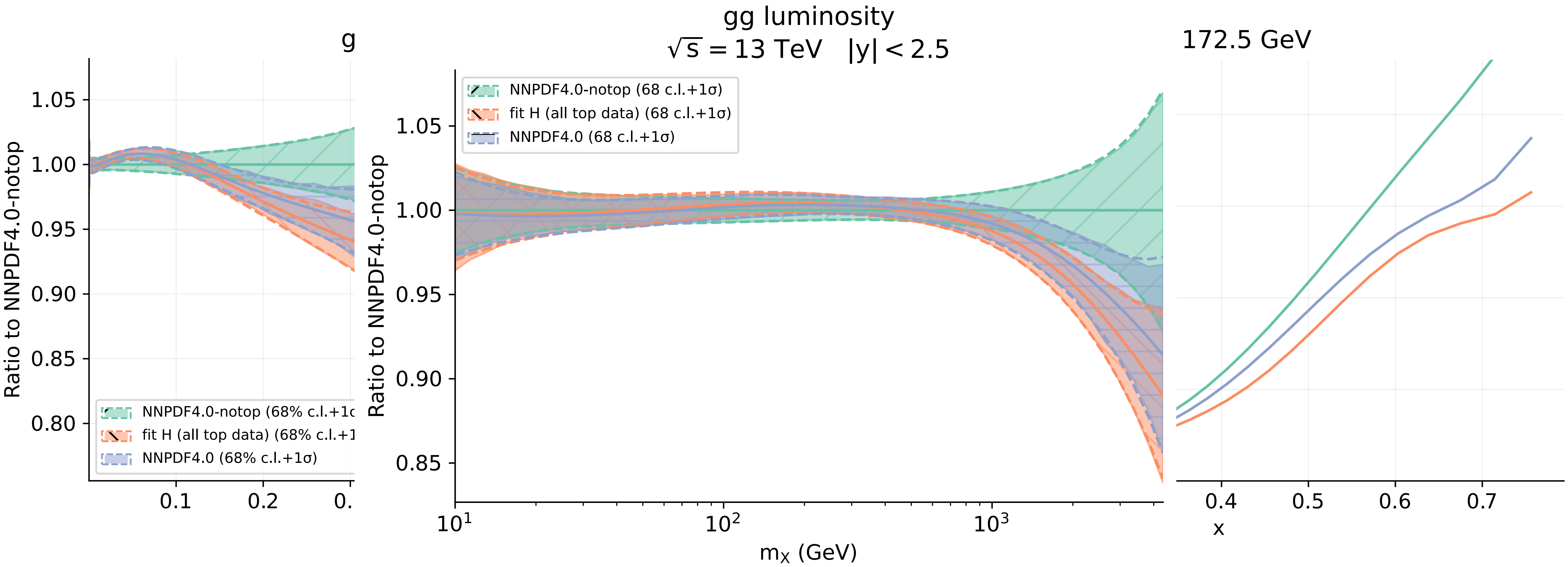

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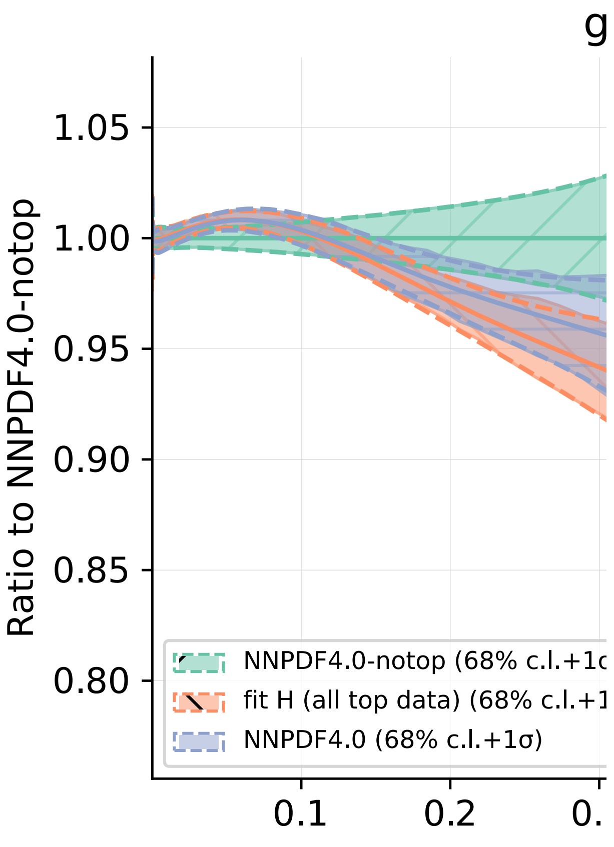

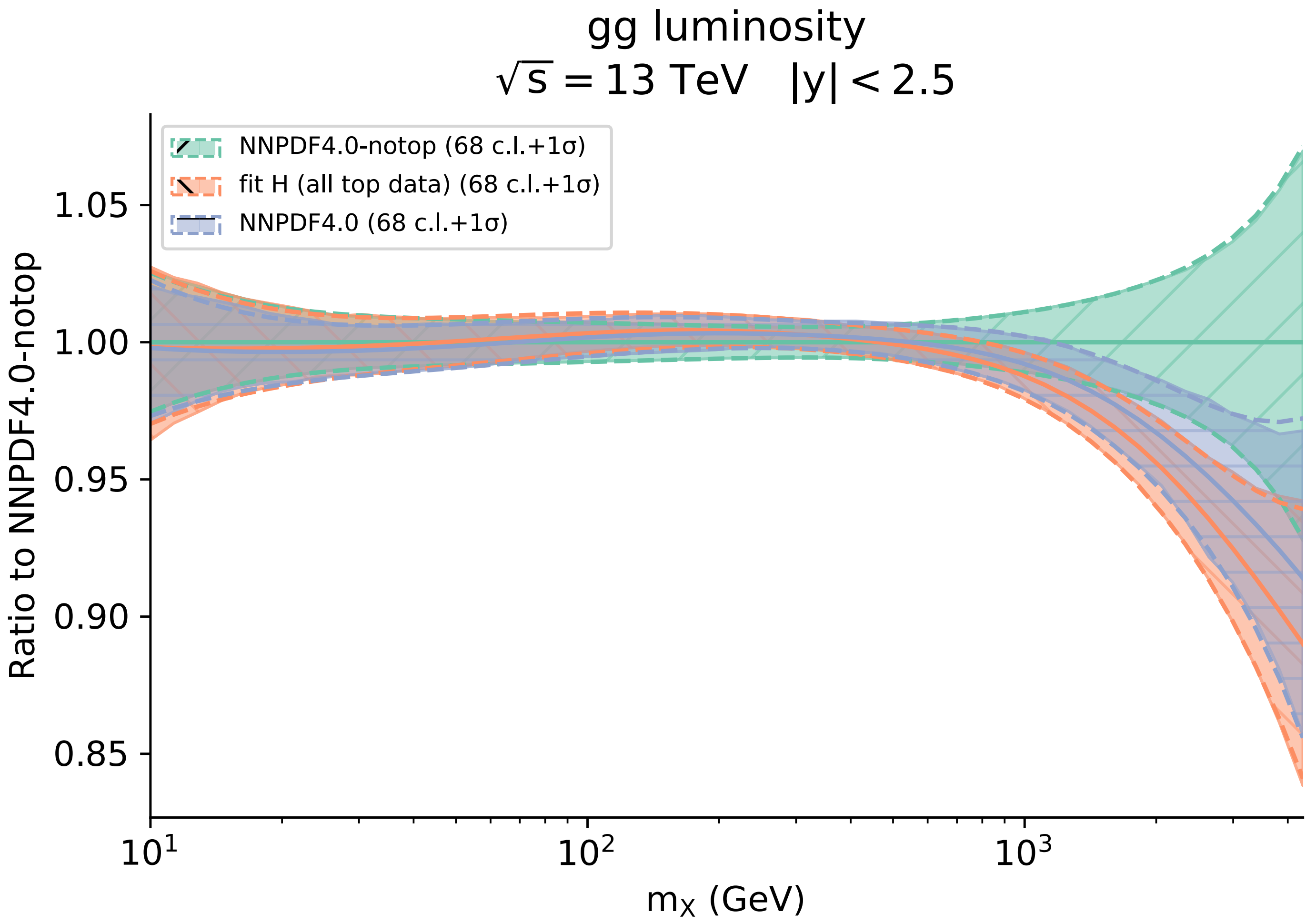

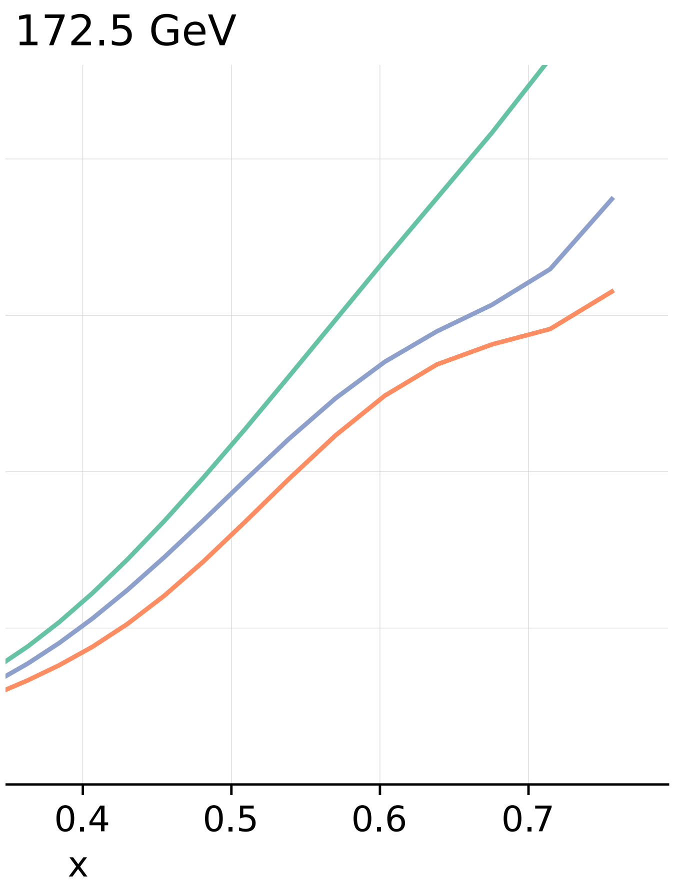

Impact mostly from ttbar data

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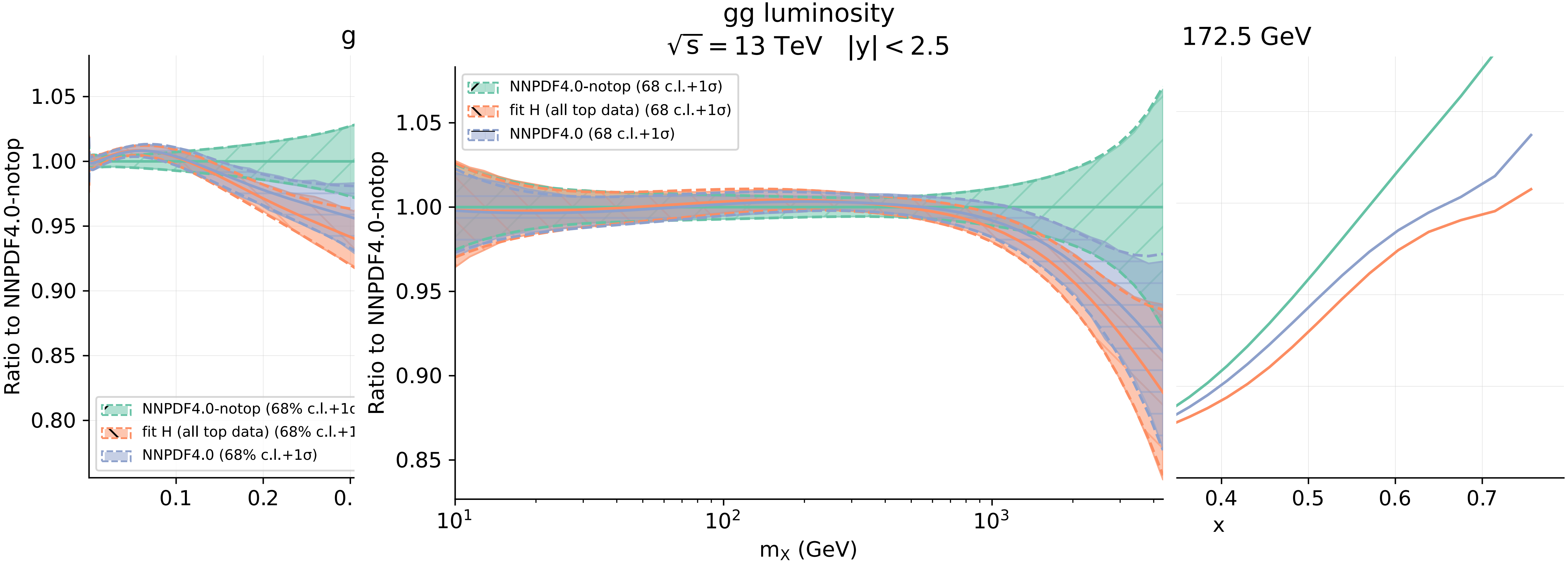
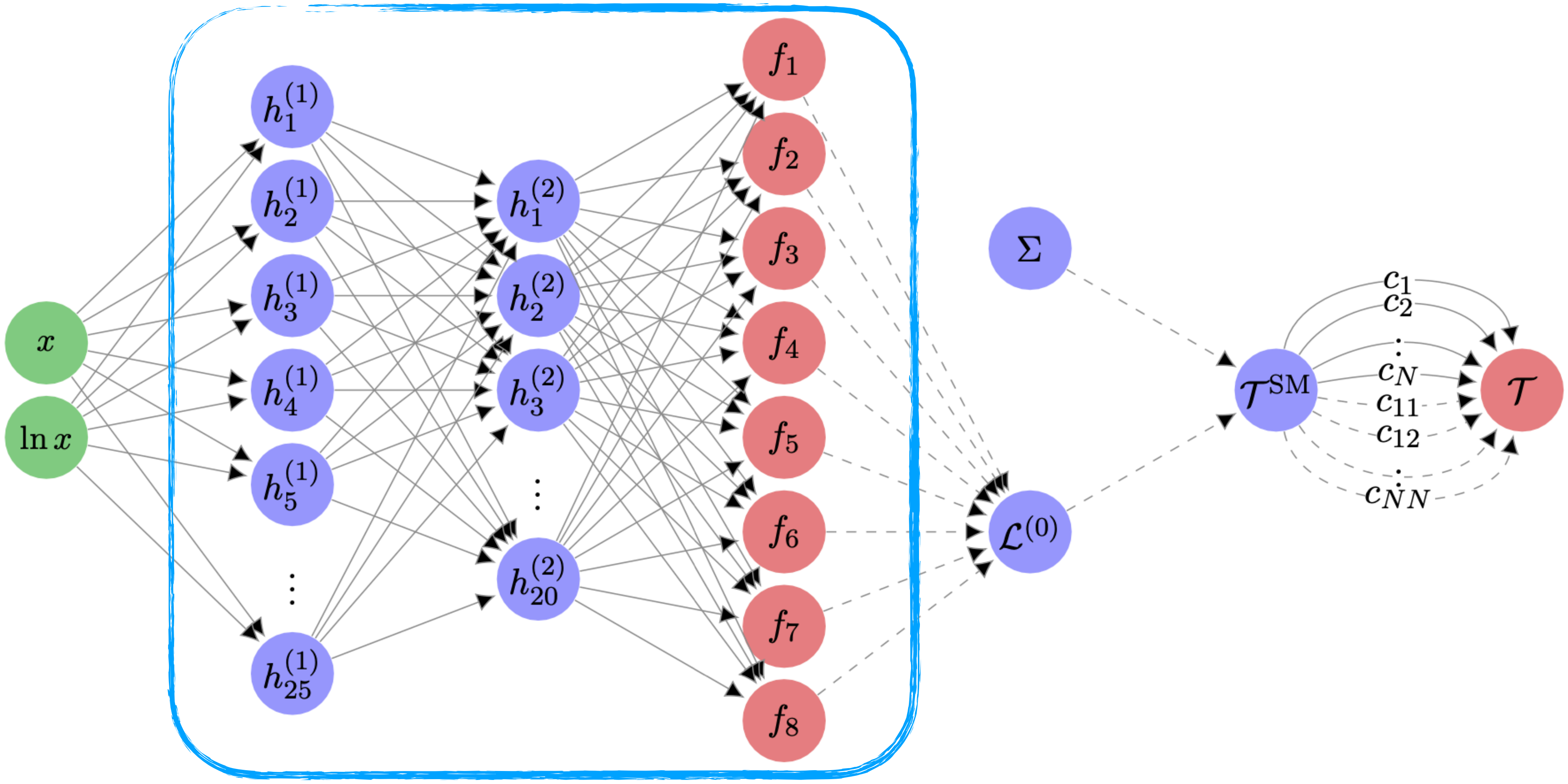


Impact mostly from ttbar data

Likely interplay
gluon PDF - EFT operators

Conservative fixed PDF fit

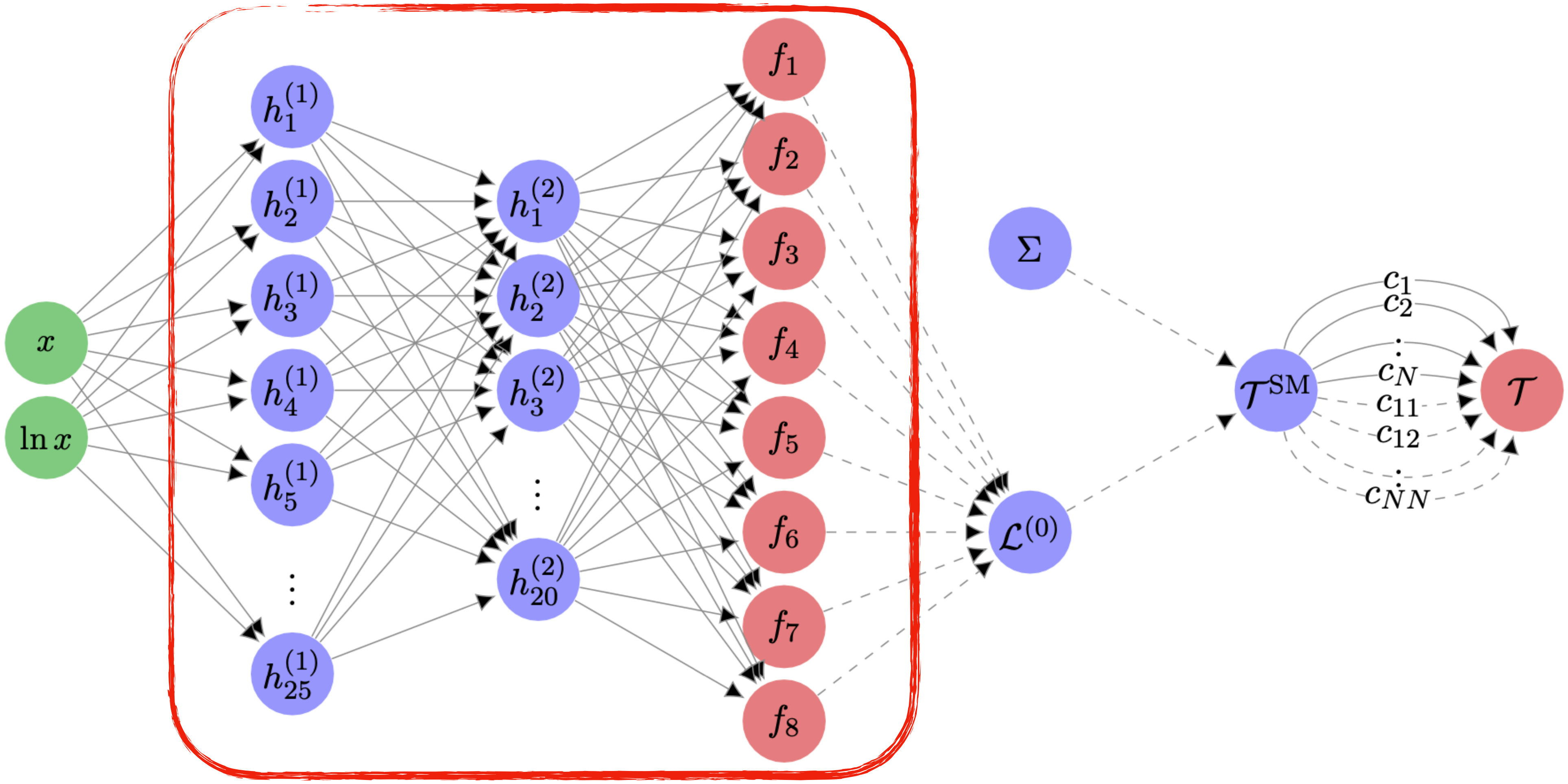
NN weights fixed, no top PDF



Conservative fixed PDF fit

Improper fixed PDF fit

NN weights fixed, all top PDF



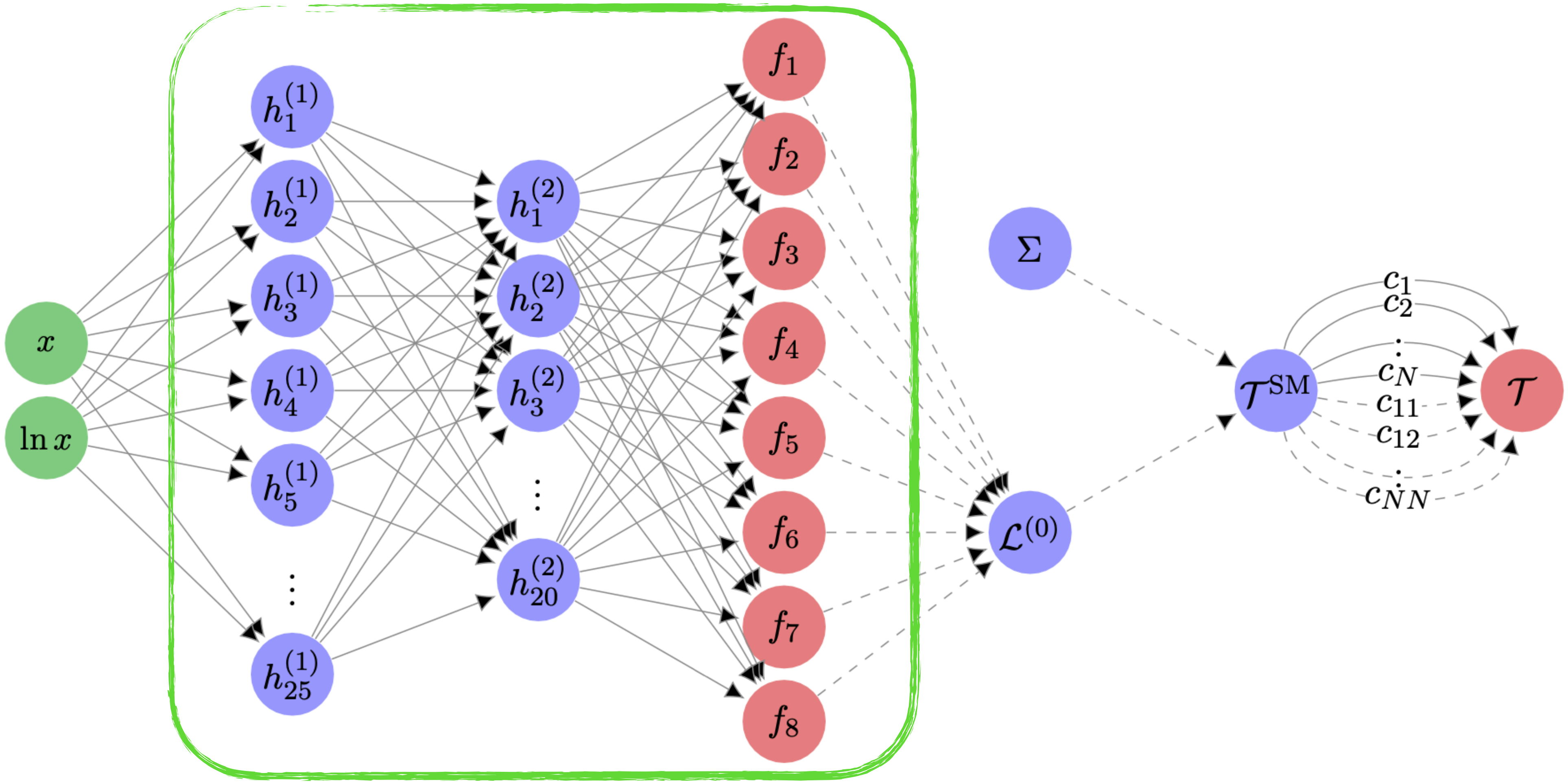
EFT fits

Conservative fixed PDF fit

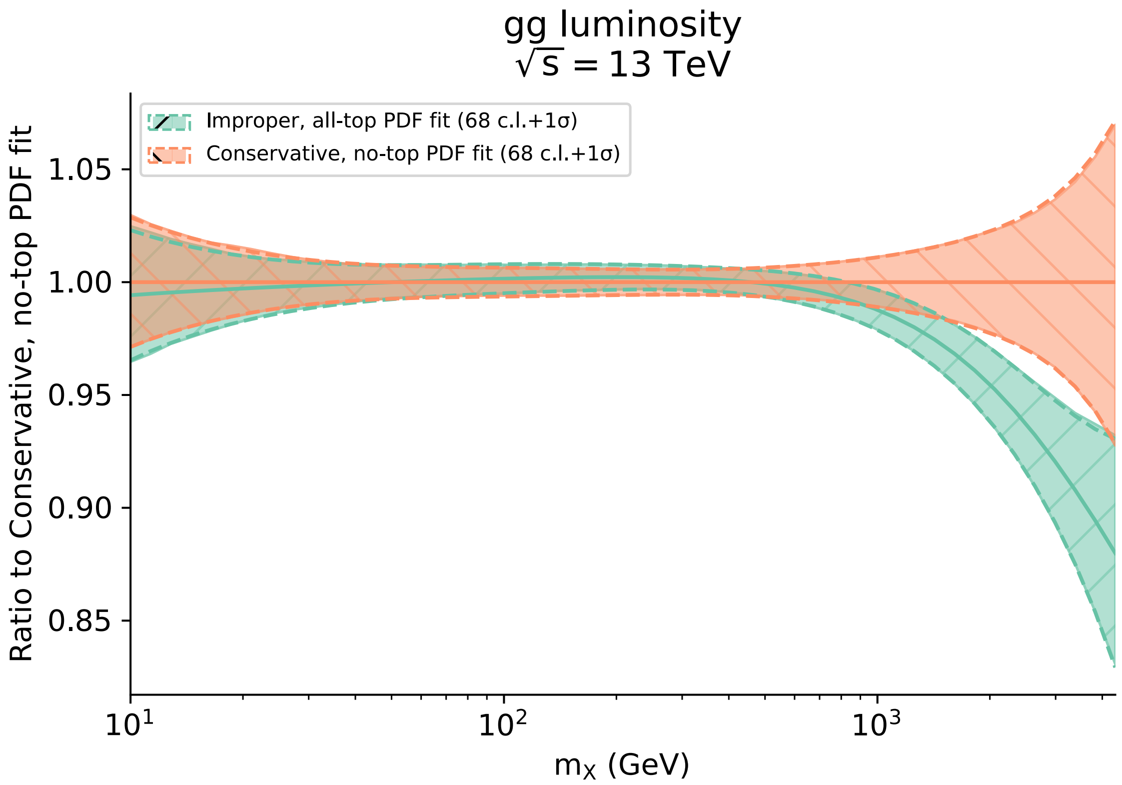
Improper fixed PDF fit

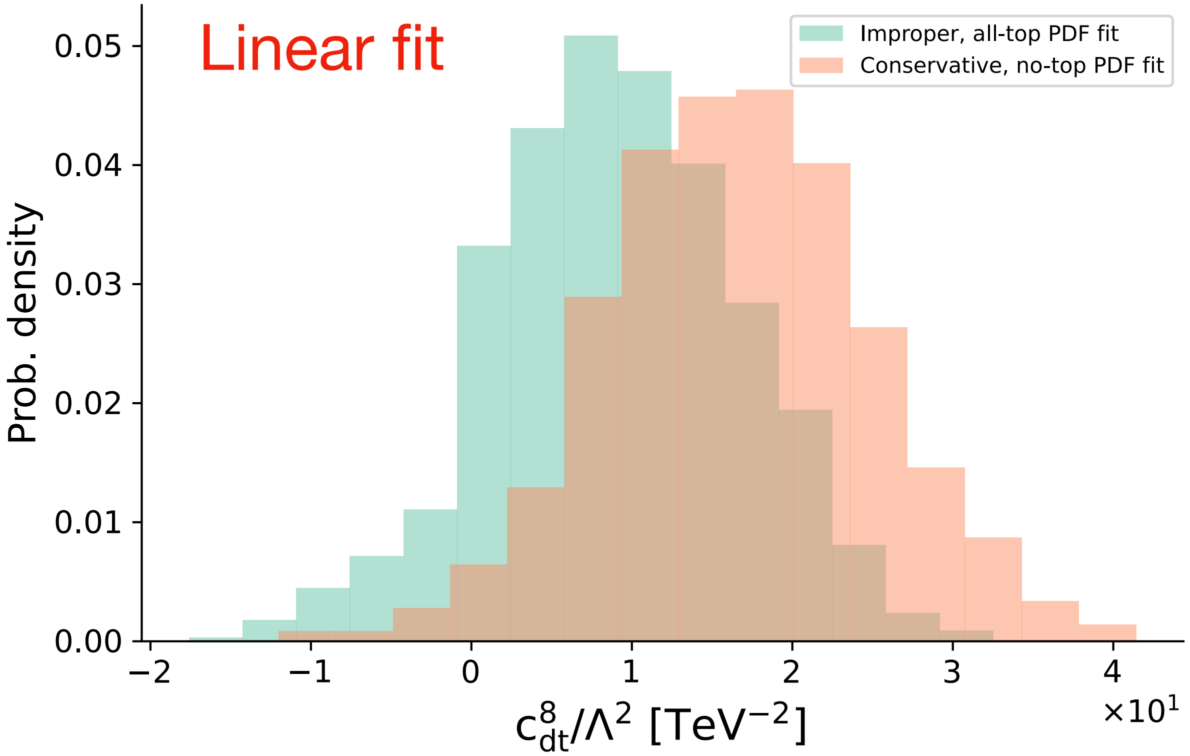
Simultaneous PDF-EFT fit

NN weights trainable

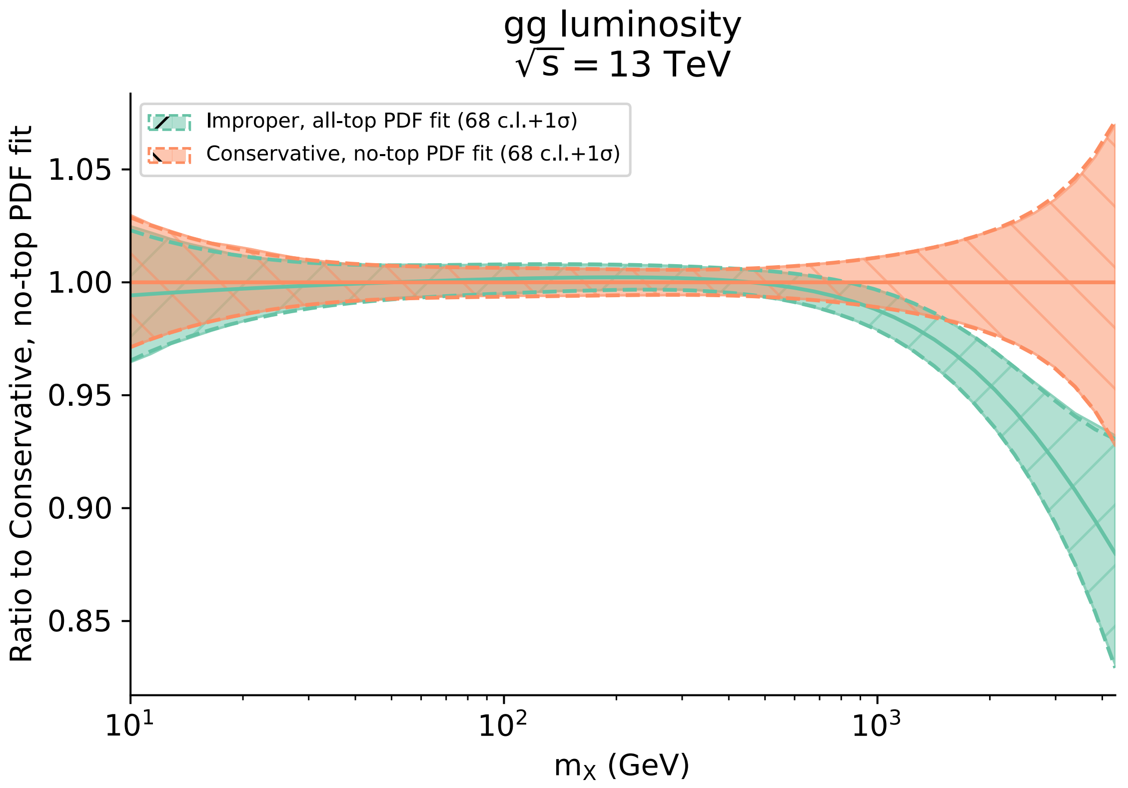


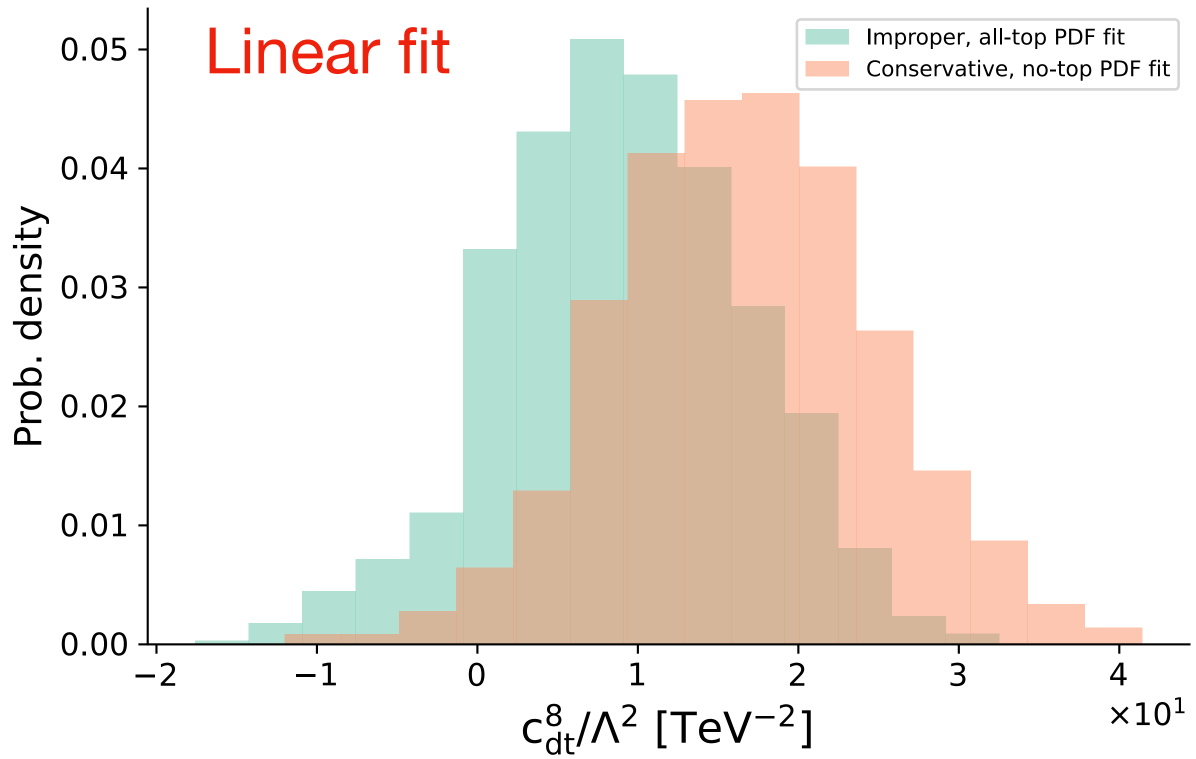
Conservative vs improper




Linear fit

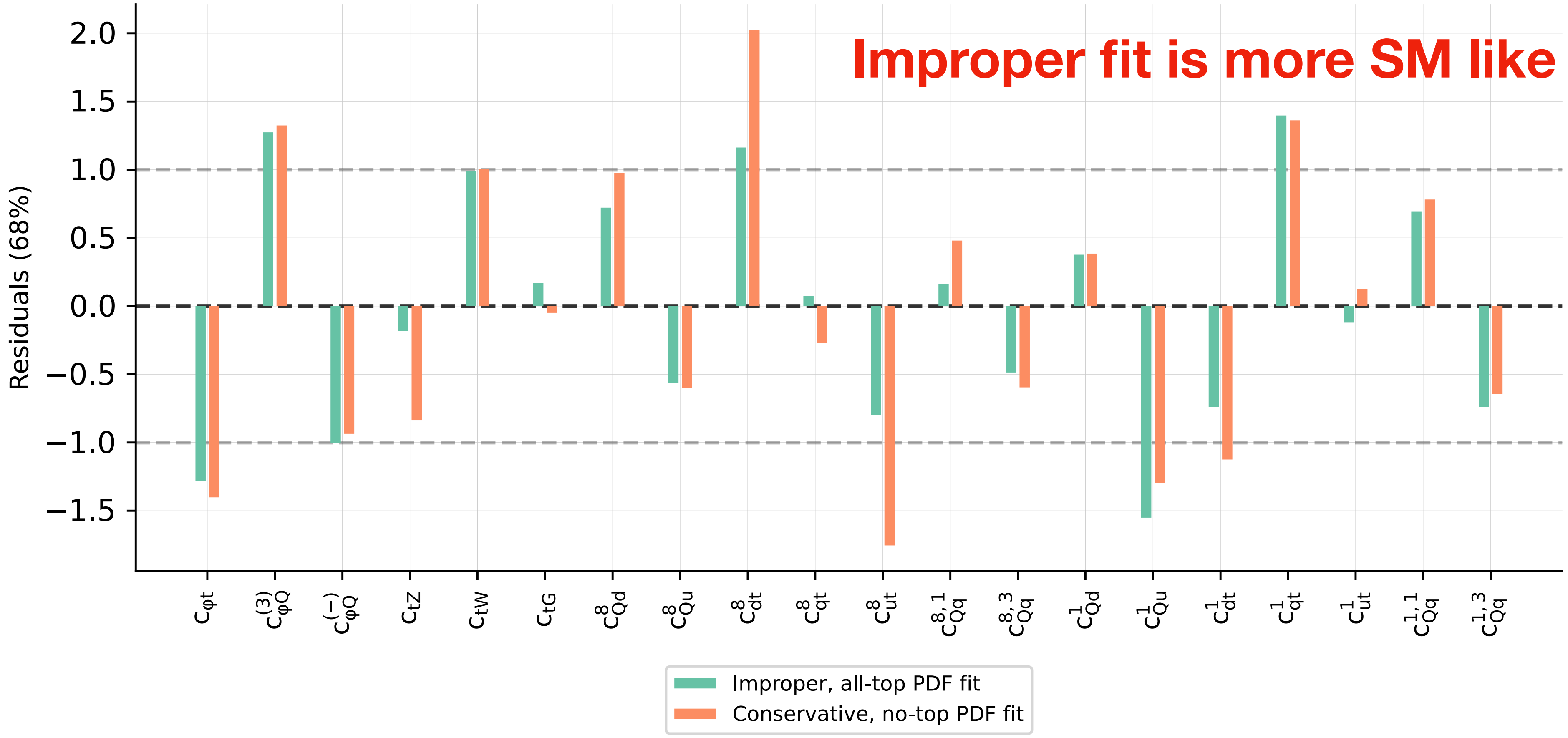
Conservative vs improper





Linear fit

$$R_n = \frac{c_n^*}{\sigma_n}$$



Improper fit is more SM like

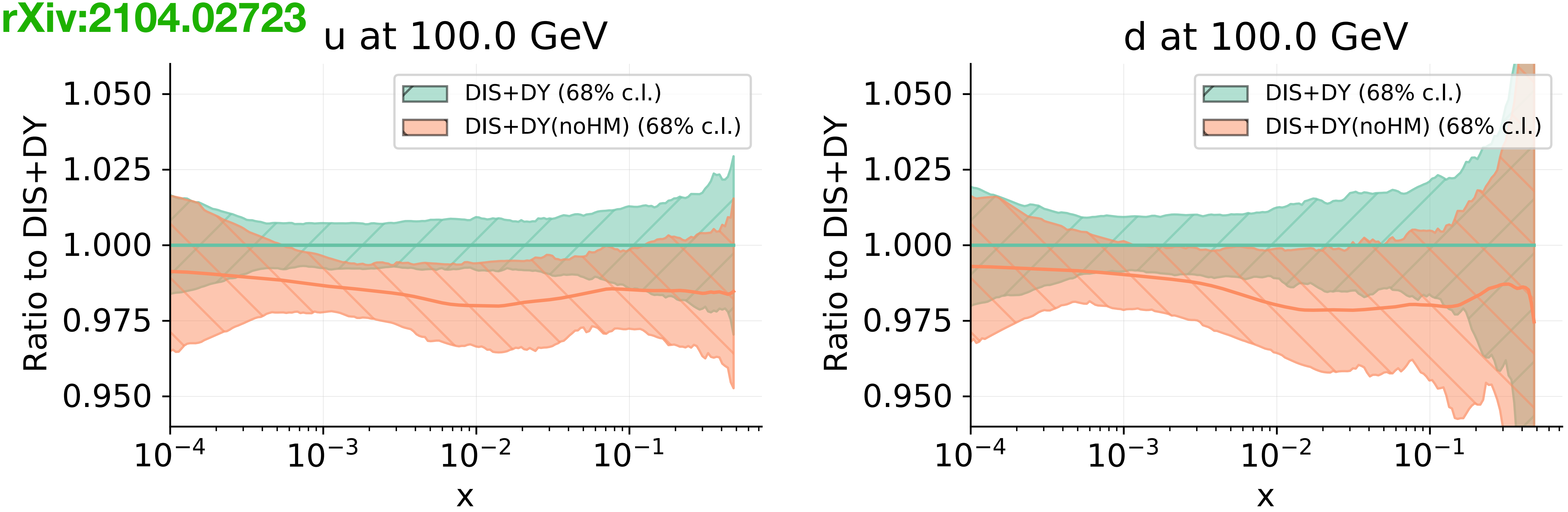
Conservative fit

Luca Mantani

Why not simply use a conservative PDF fit?

Why not simply use a conservative PDF fit?

arXiv:2104.02723



Conservative fit

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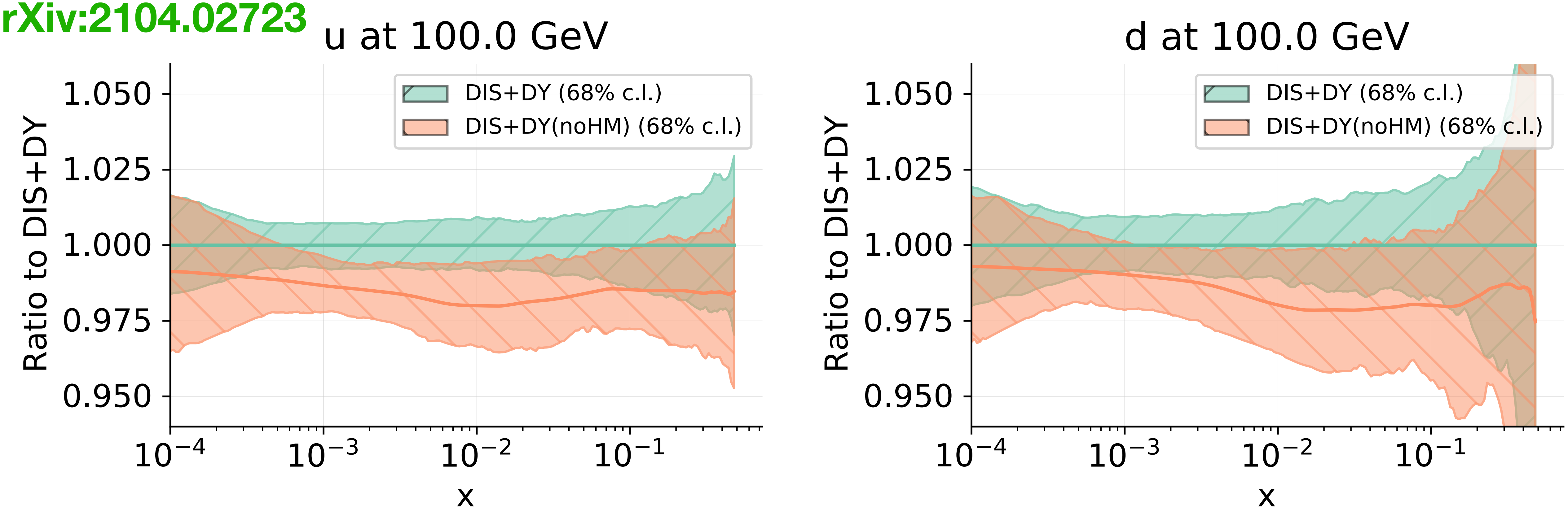

Increased PDF uncertainties in high-x region for several processes interesting for NP:

- diboson
- VBF
- high mass ttbar
- high mass jets
- etc..

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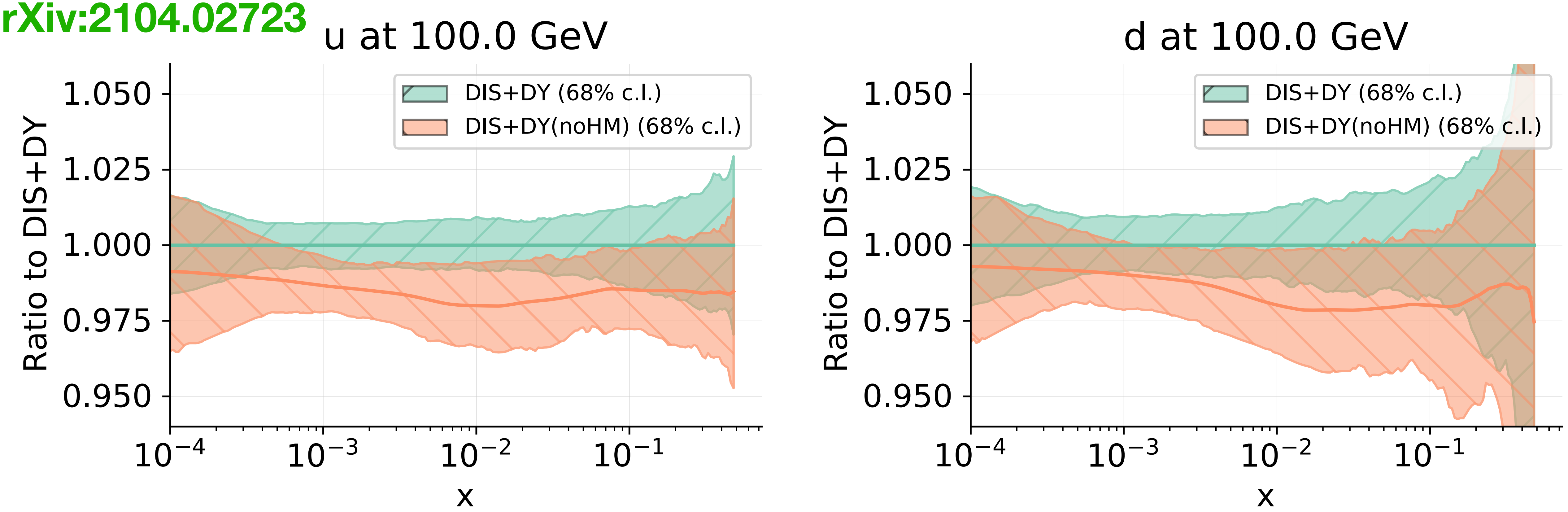

Increased PDF uncertainties in high-x region for several processes interesting for NP:

- diboson
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- etc..

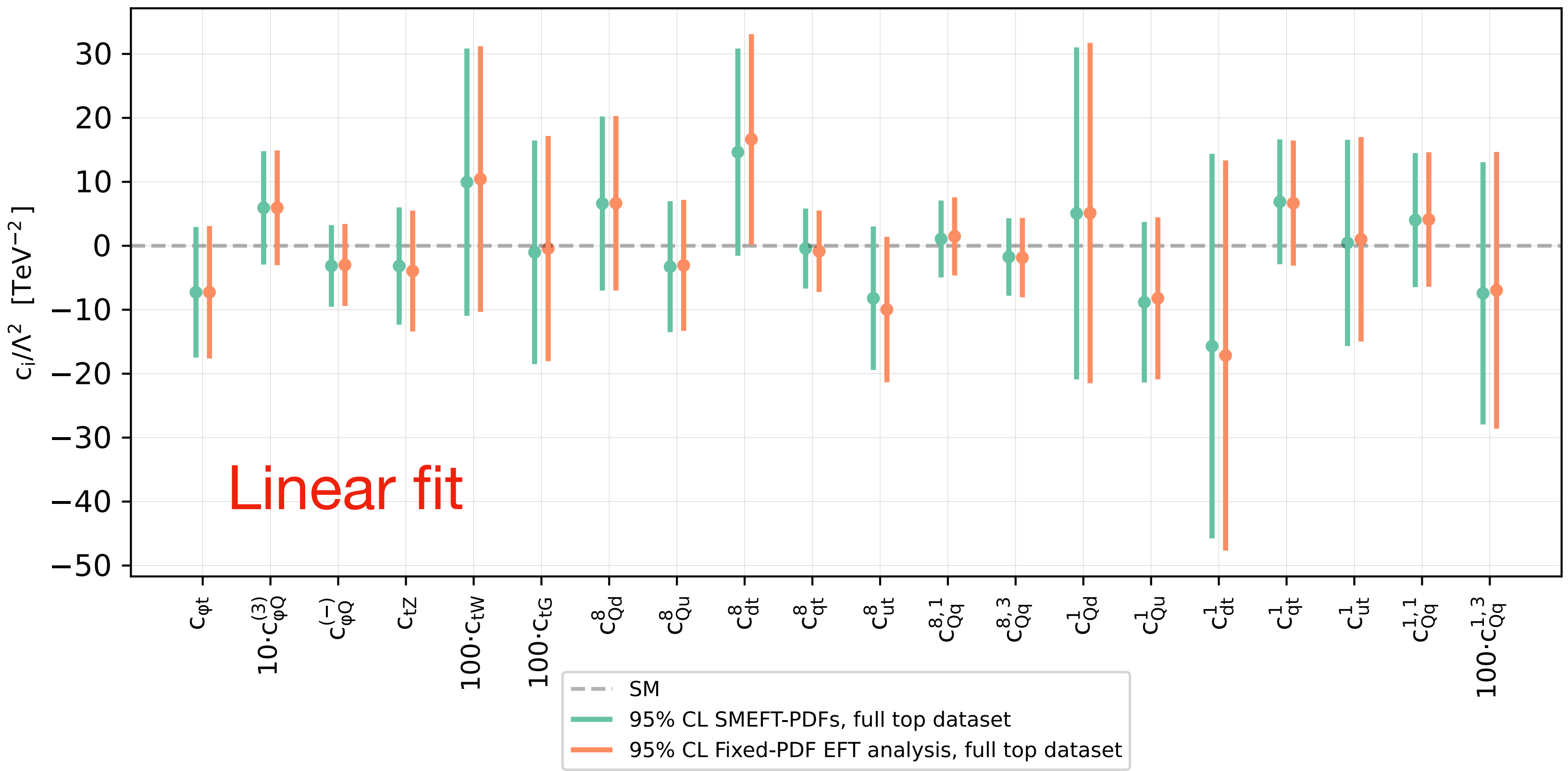
Also: NN good at interpolating, bad in extrapolation

Simultaneous fit

Conservative fit

Simultaneous fit

Moderate effect on WC, ~ 5-10%



Linear fit

Simultaneous fit

Conservative fit

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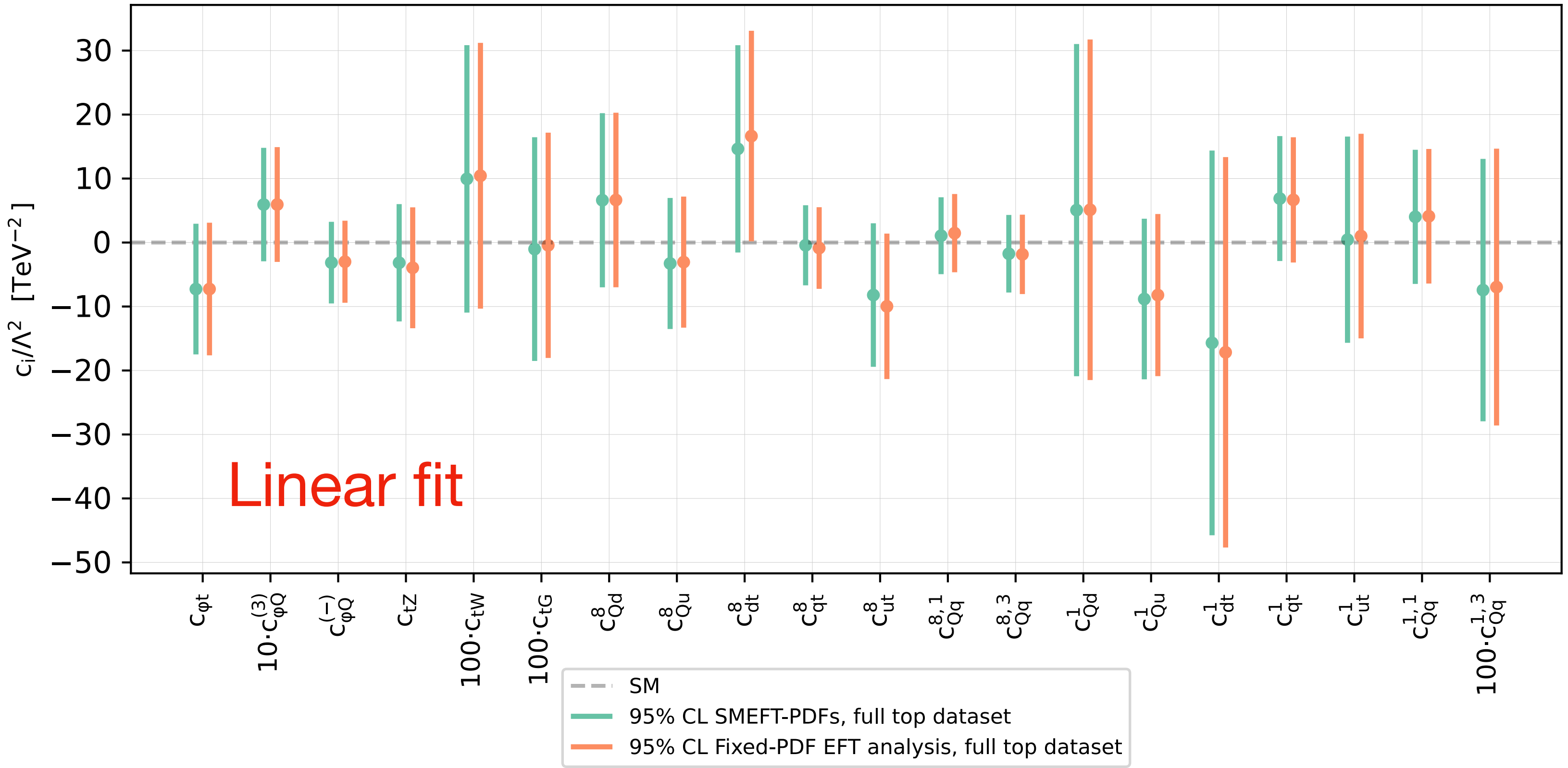
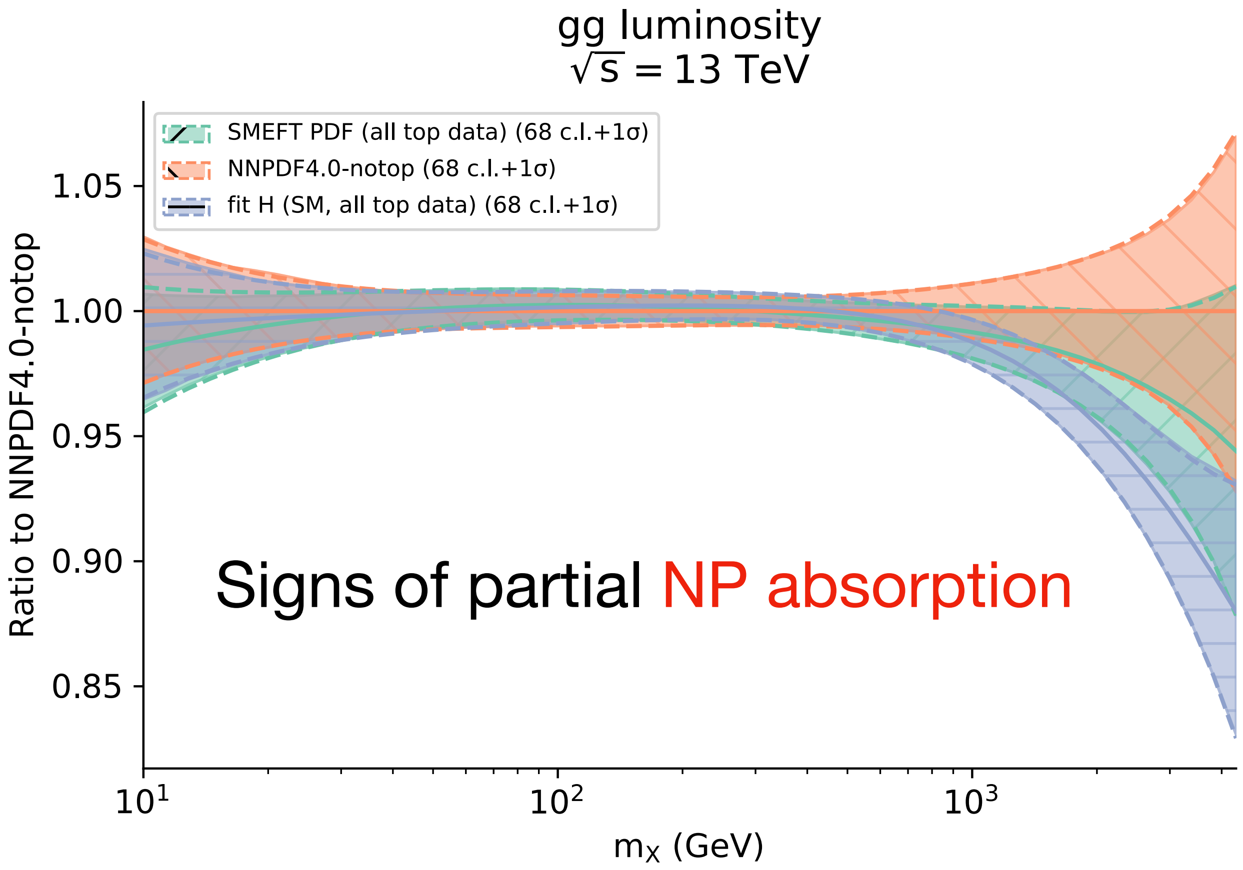


Linear fit

Shift in PDF not as dramatic as SM



Signs of partial NP absorption

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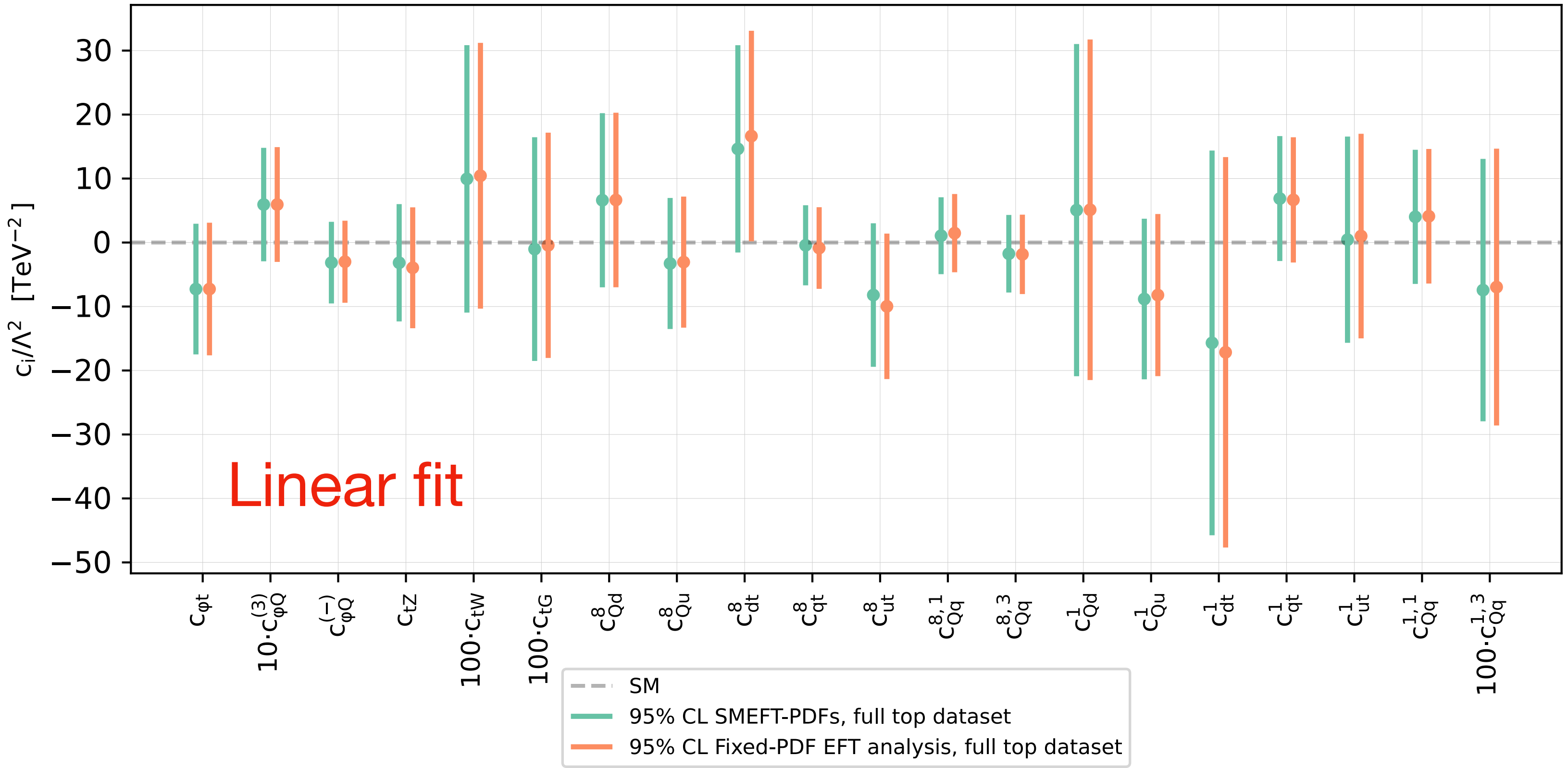

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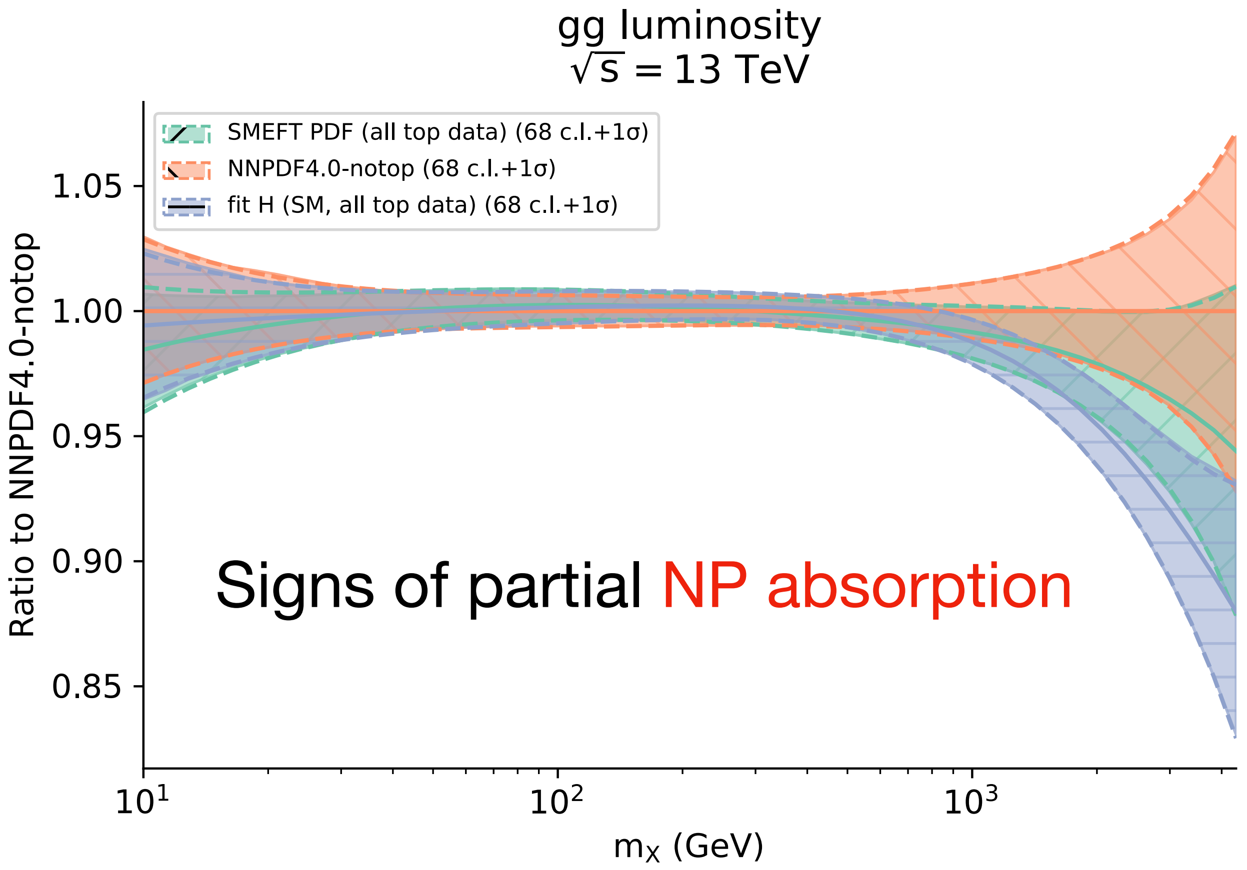
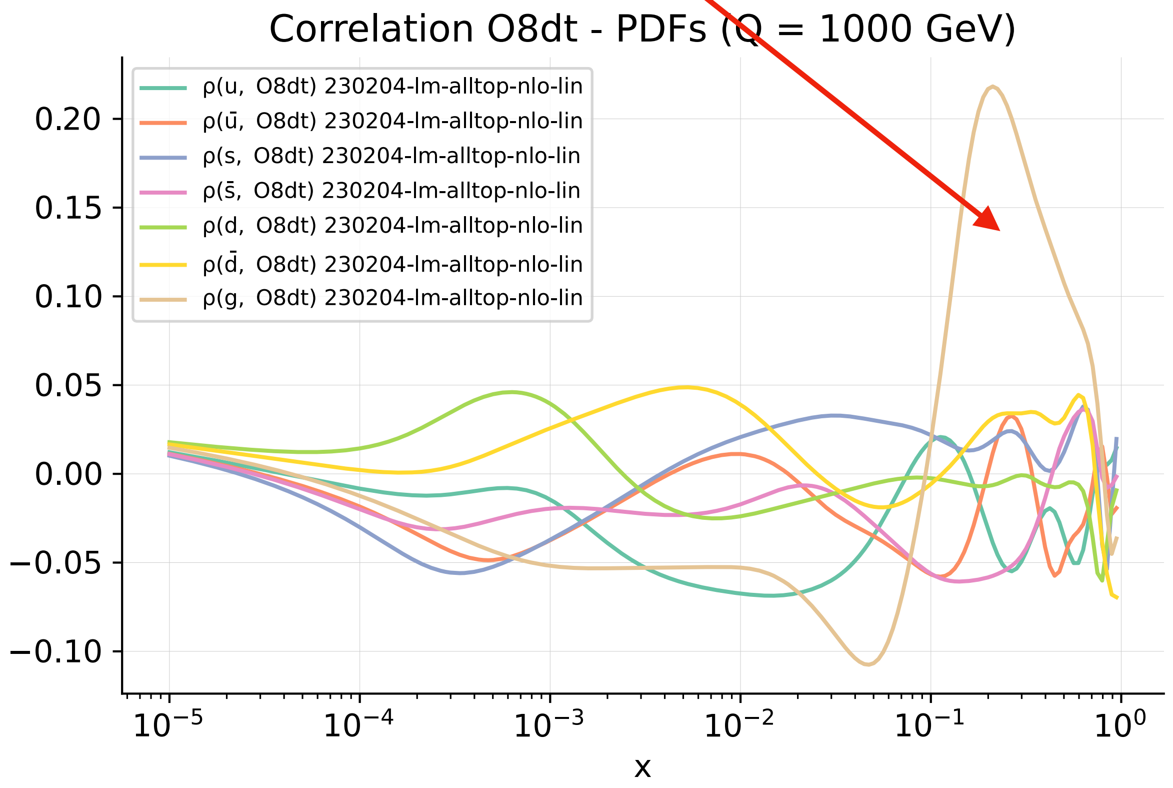


Signs of partial NP absorption

Correlation gluon-EFT



We now have a 4th option to perform a SMEFT fit

SMEFT PDF

Luca Mantani

We now have a 4th option to perform a SMEFT fit

From the simultaneous fits we now have a SMEFT PDF

SMEFT PDF

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EFT degrees of freedom → **Enhanced PDF uncertainties**

SMEFT PDF

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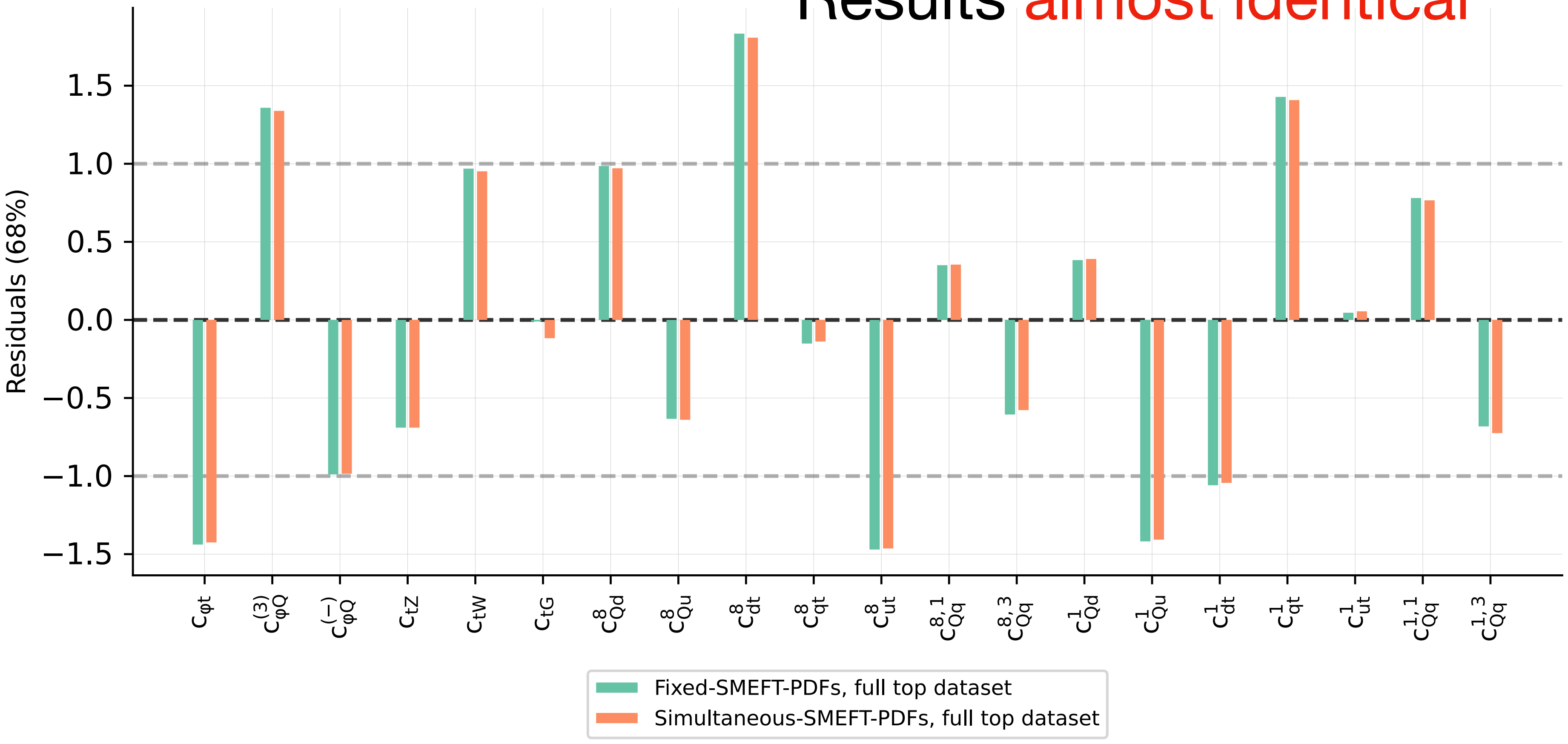
EFT degrees of freedom → **Enhanced PDF uncertainties**

Results almost identical

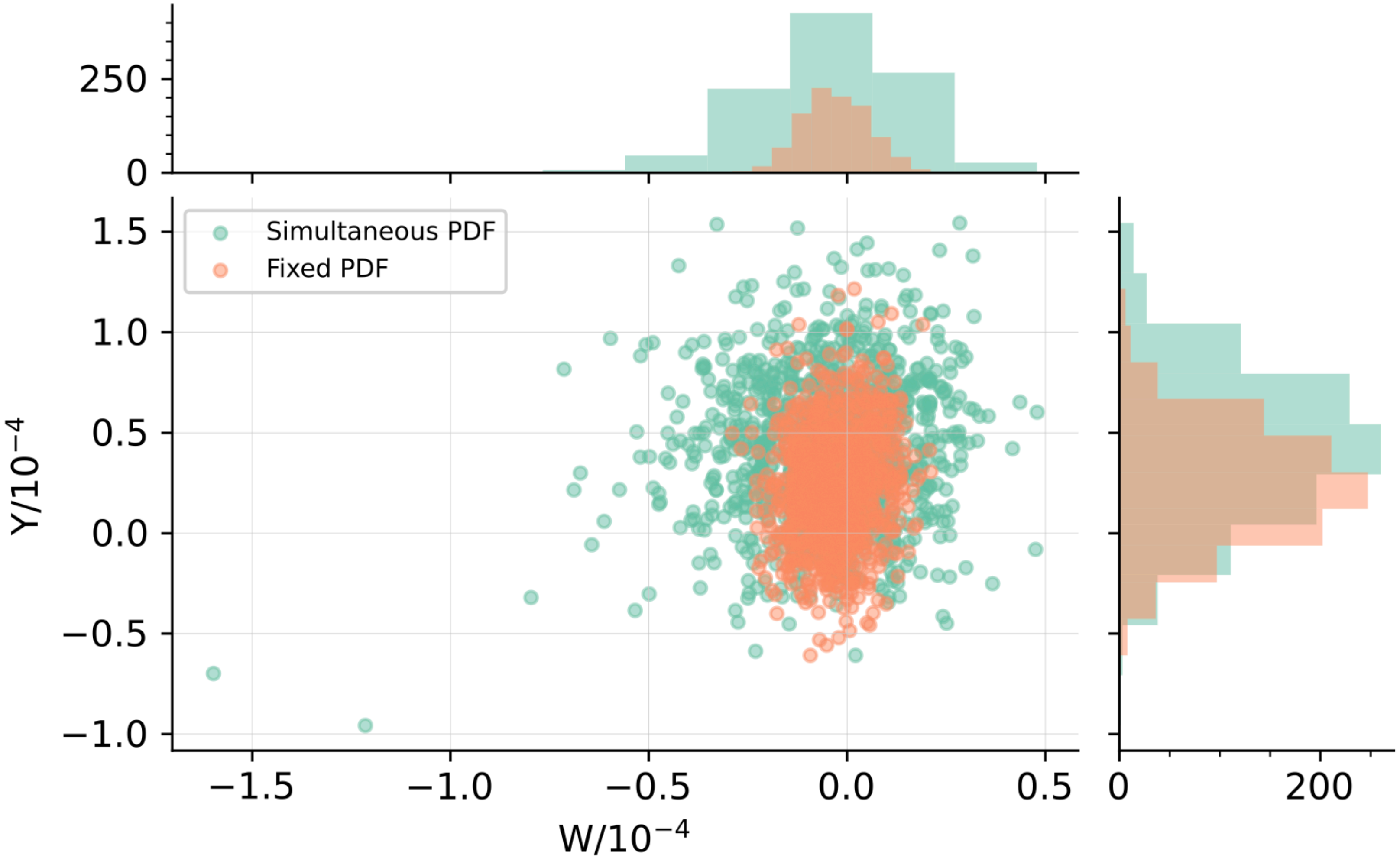
Simultaneous fit

fixed-SMEFT PDF fit

$$R_n = \frac{c_n^*}{\sigma_n}$$



arXiv:2104.02723 Things become more relevant at HL-LHC



HL-LHC: DY projection

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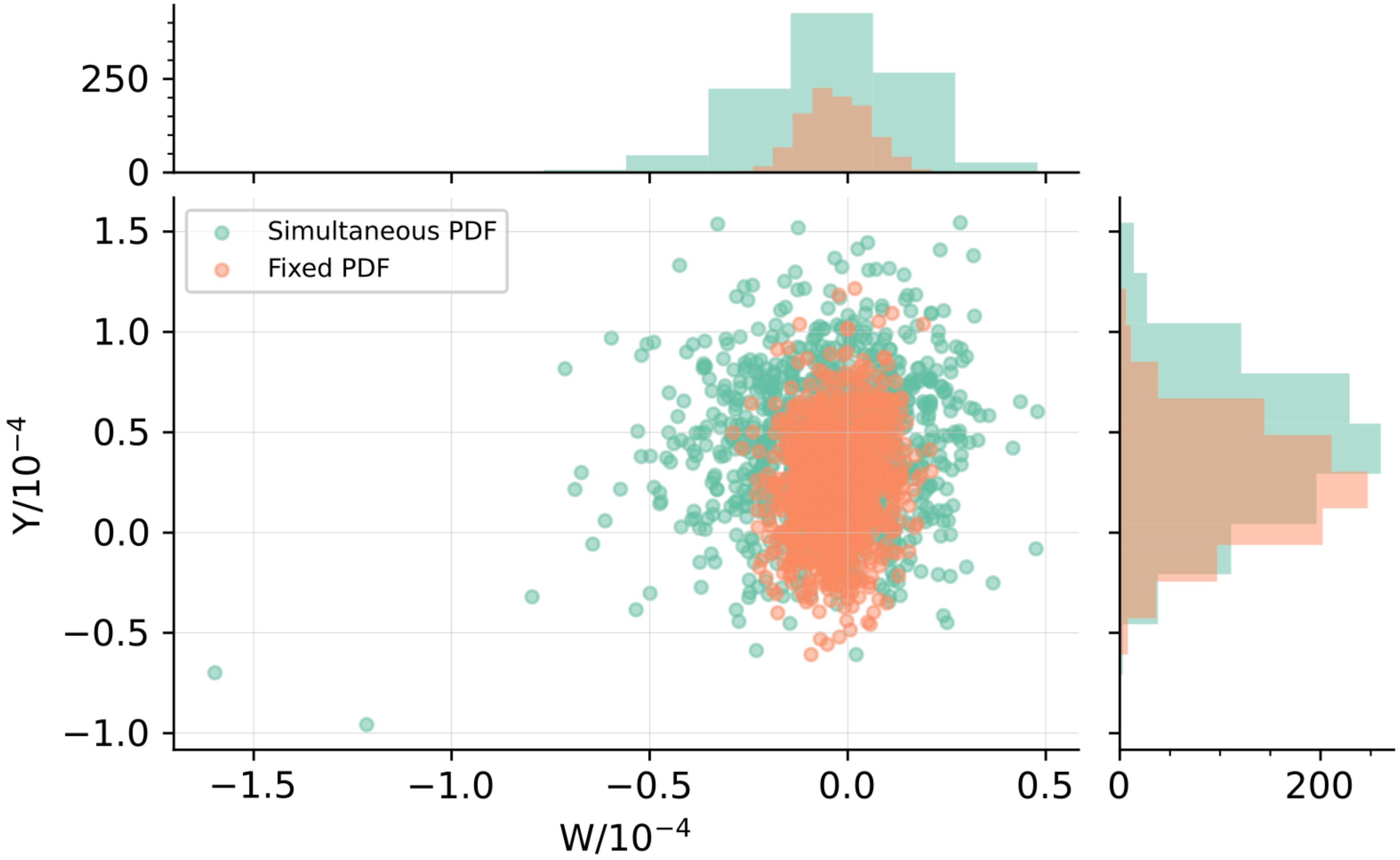

	SM PDFs	SMEFT PDFs	best-fit shift	broadening
$W \times 10^5$ (68% CL)	$[-1.1, 0.5]$	$[-2.4, 1.5]$	-0.2	$+144\%$
$W \times 10^5$ (95% CL)	$[-2.0, 1.4]$	$[-4.3, 3.4]$	-0.2	$+126\%$
$Y \times 10^5$ (68% CL)	$[-0.4, 5.2]$	$[0.6, 8.0]$	$+1.9$	$+32\%$
$Y \times 10^5$ (95% CL)	$[-3.2, 8.1]$	$[-3.1, 11.7]$	$+1.9$	$+31\%$

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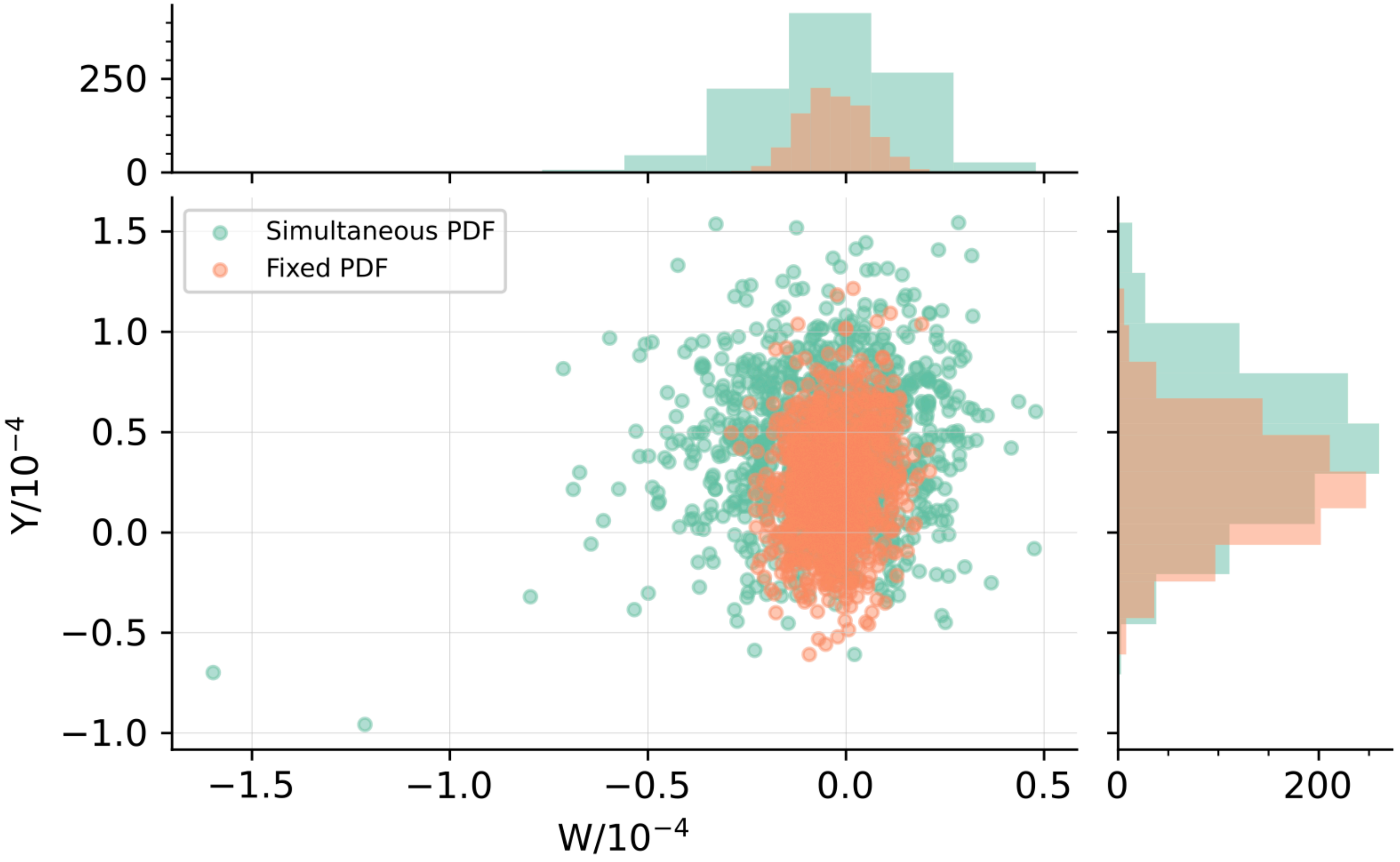
Things become more relevant at HL-LHC



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Conclusions

- PDF fitting is currently done by assuming the SM. This could lead to problems in estimation of NP parameters.
- The **SMEFT** is a powerful framework to parametrise NP, but global studies are necessary.
- Interplay PDFs-EFT needs to be understood, could be crucial in HL-LHC.
    - NP effects can be at least partially absorbed during PDF fits
    - SMEFT coefficient bounds can be both biased and underestimated
    - SMEFT PDFs could be viable proxy to simultaneous fits
    - Identification of smoking gun observables (e.g. forward W/Z in LHCb) to disentangle PDF and EFT effects

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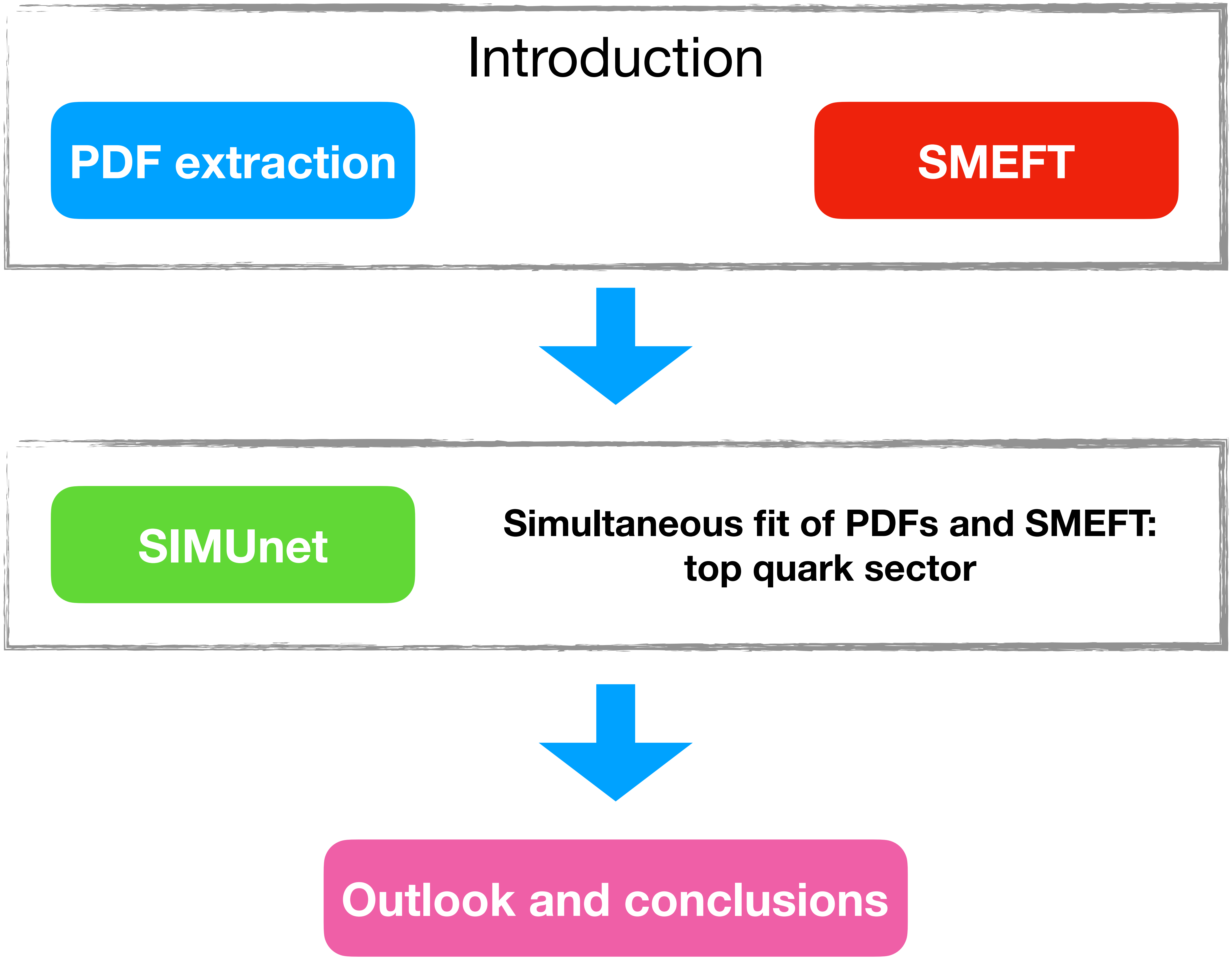
Thanks!

Backup

Outline



Introduction

PDF extraction

SMEFT

SIMUnet

Simultaneous fit of PDFs and SMEFT: top quark sector

Outlook and conclusions

Proton structure

Idea: use data to infer the structure of the proton

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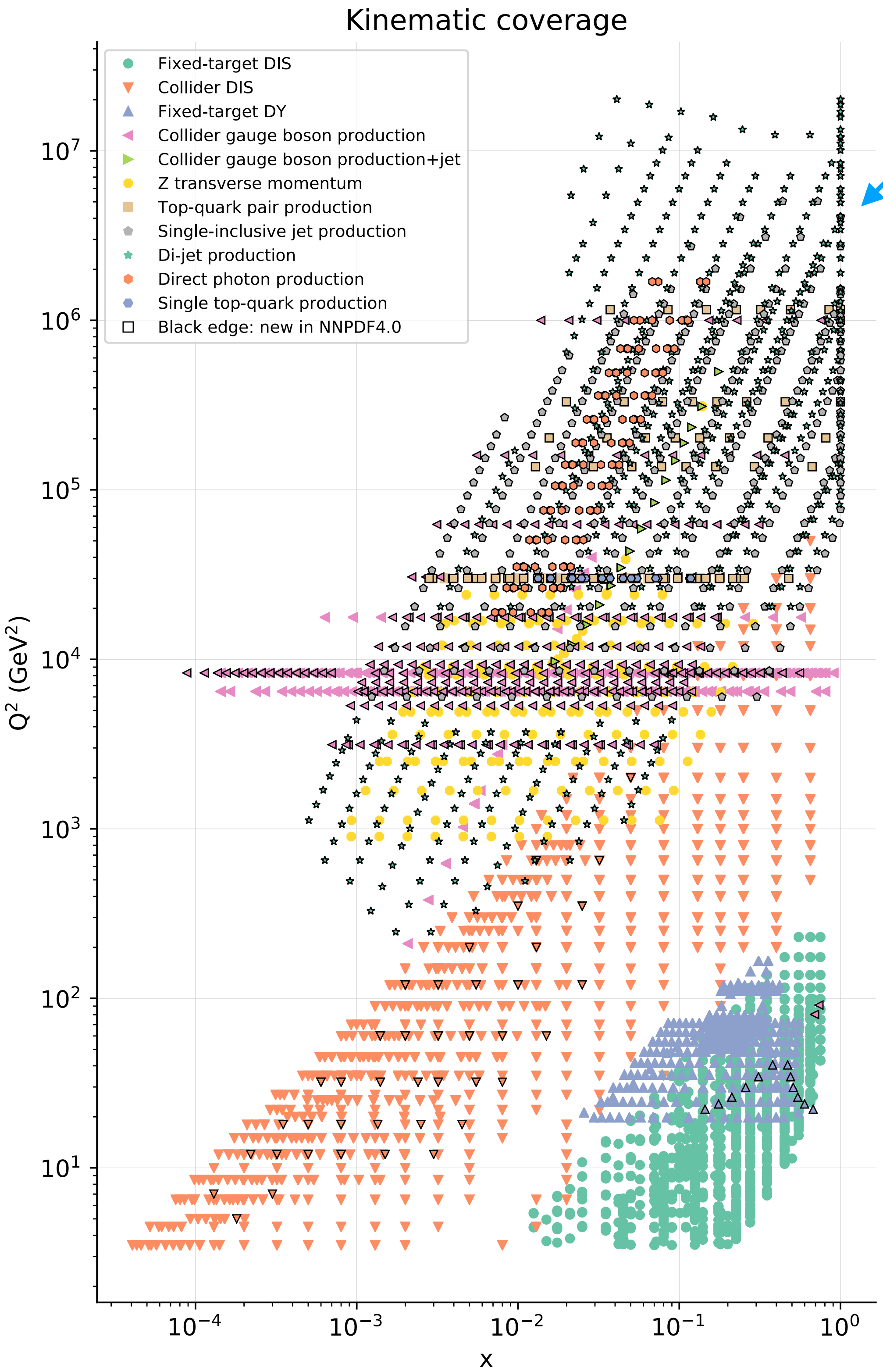
$$f(x, \mu^2)$$



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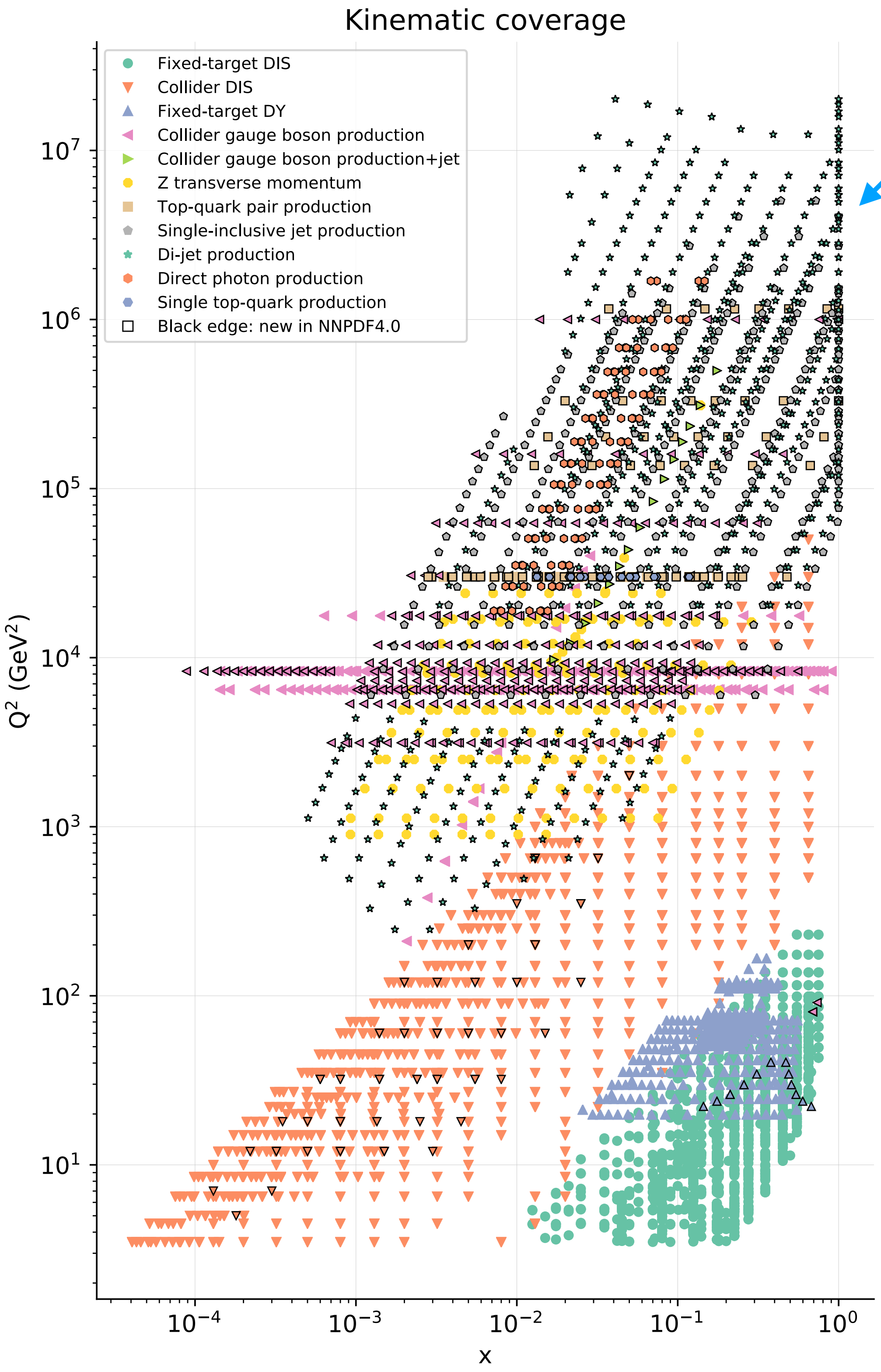

DGLAP equations

$$\frac{\partial}{\partial \log(\mu^2)} \begin{pmatrix} q(x,\mu^2) \\ g(x,\mu^2) \end{pmatrix} = \frac{\alpha_S(\mu^2)}{2\pi} \int_x^1 \frac{dz}{z} \begin{pmatrix} P_{qq}(z) & P_{qg}(z) \\ P_{gq}(z) & P_{gg}(z) \end{pmatrix} \begin{pmatrix} q(x/z,\mu^2) \\ g(x/z,\mu^2) \end{pmatrix}$$

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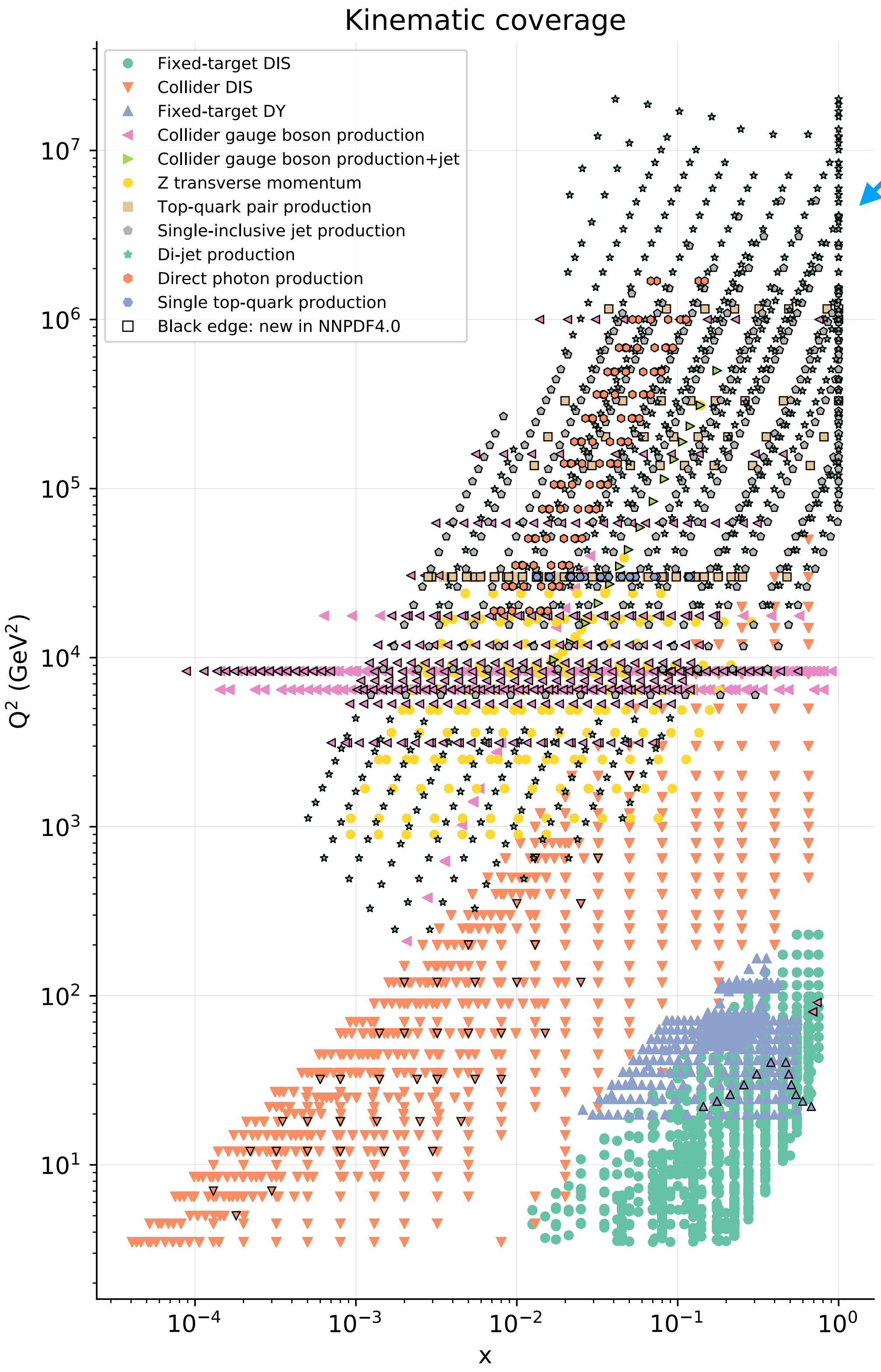

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We just need a functional form for the PDFs

Data driven determination

Theory assumptions

Measurements

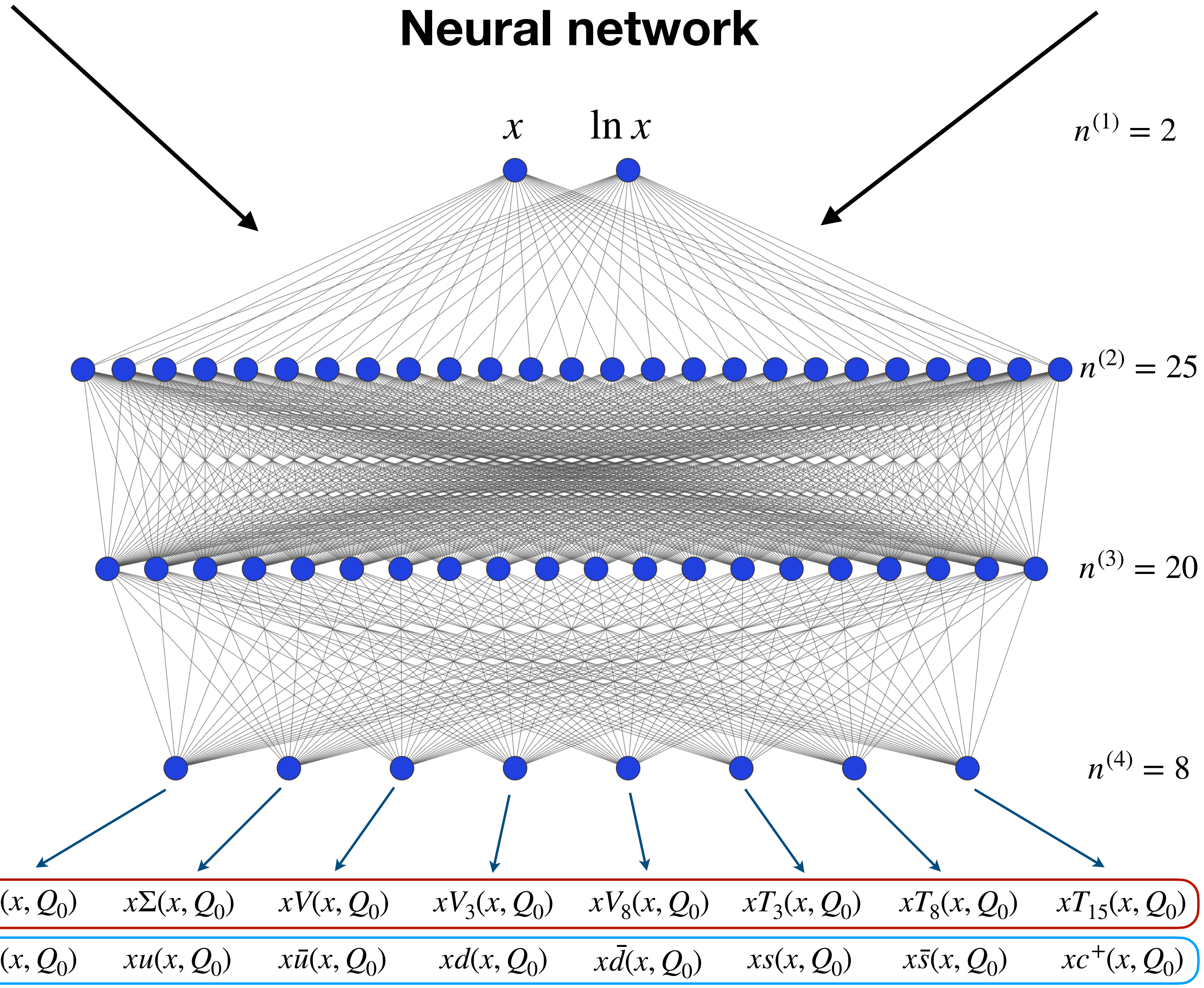
Model the proton

Data driven determination

Theory assumptions

Measurements

Neural network



$xg(x, Q_0)$ $x\Sigma(x, Q_0)$ $xV(x, Q_0)$ $xV_3(x, Q_0)$ $xV_8(x, Q_0)$ $xT_3(x, Q_0)$ $xT_8(x, Q_0)$ $xT_{15}(x, Q_0)$

$xg(x, Q_0)$ $xu(x, Q_0)$ $x\bar{u}(x, Q_0)$ $xd(x, Q_0)$ $x\bar{d}(x, Q_0)$ $xs(x, Q_0)$ $x\bar{s}(x, Q_0)$ $xc^+(x, Q_0)$

Monte Carlo method

Experimental uncertainties are propagated to the PDFs via Monte Carlo

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N pseudodata samples $\{x_i\}$

$$N \sim 1000$$

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Final PDF is the ensemble of N Neural Networks

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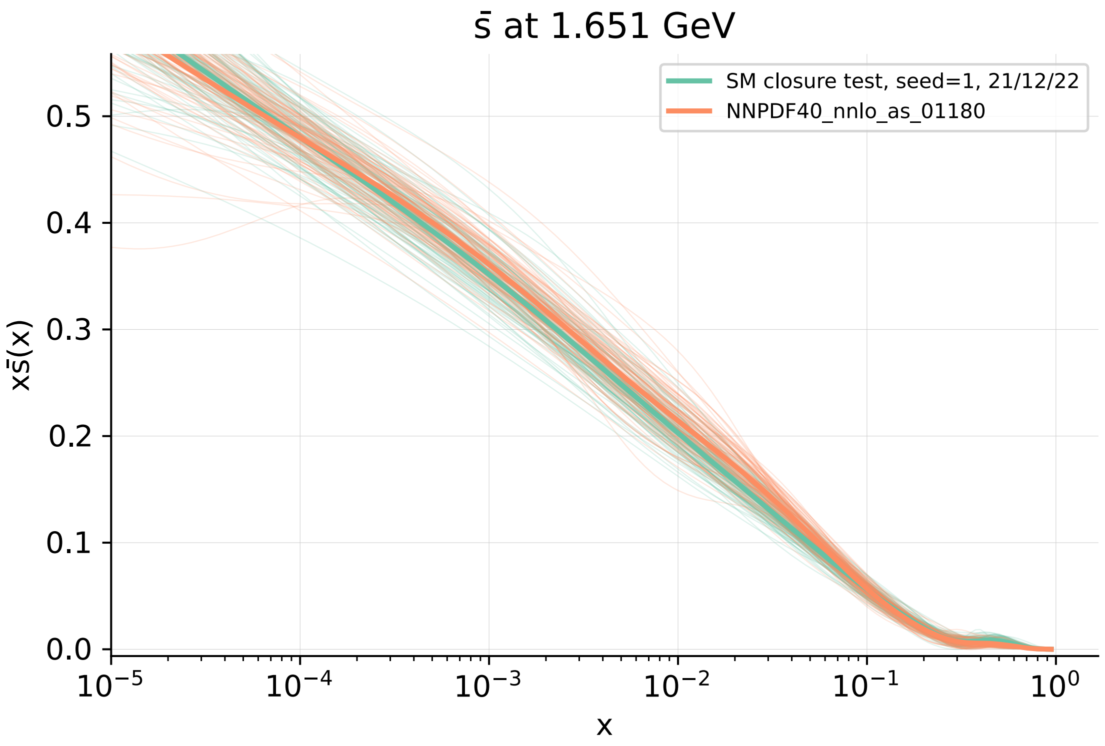

Monte Carlo method

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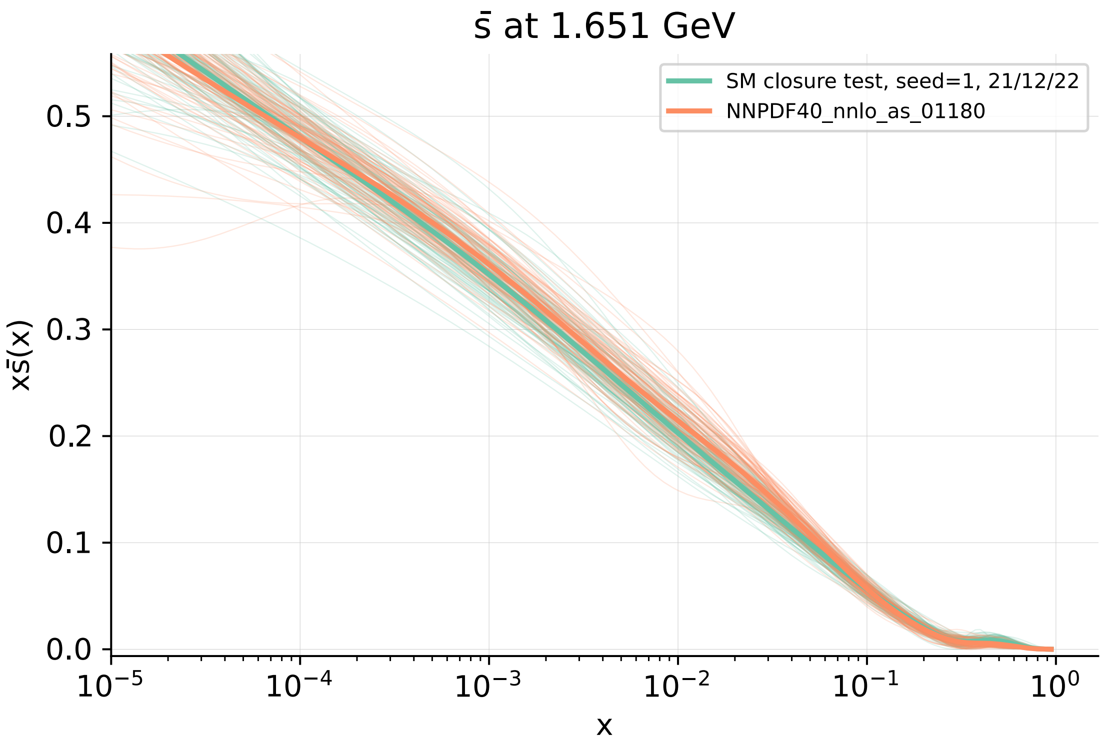
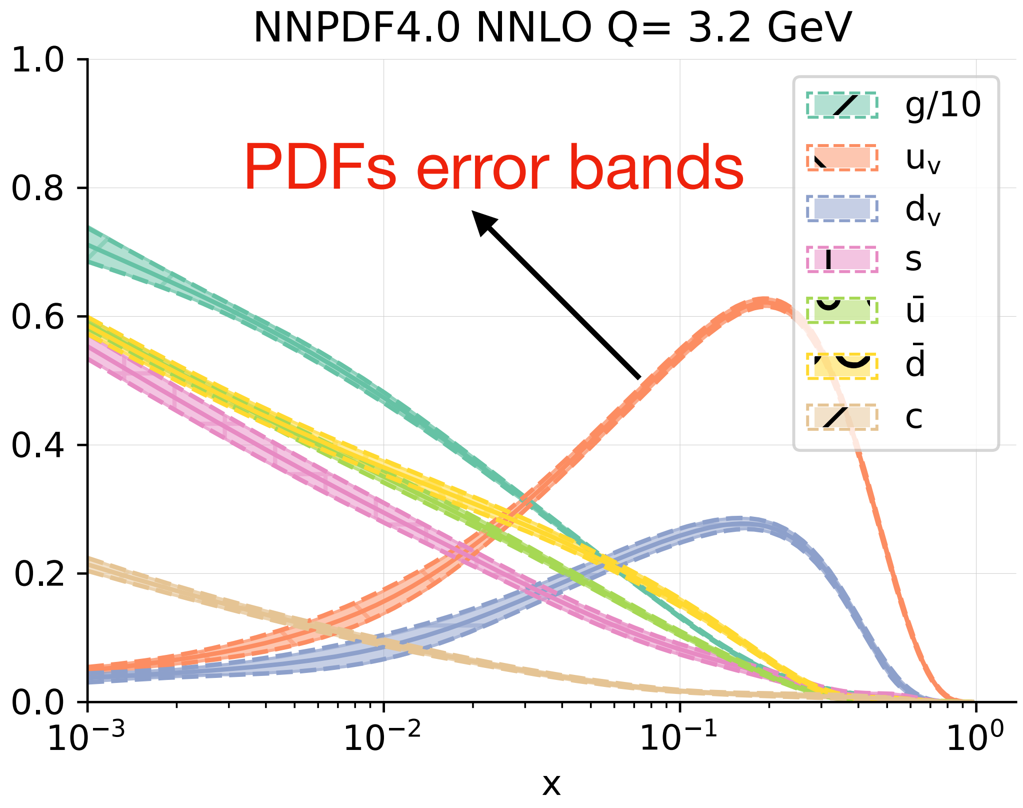


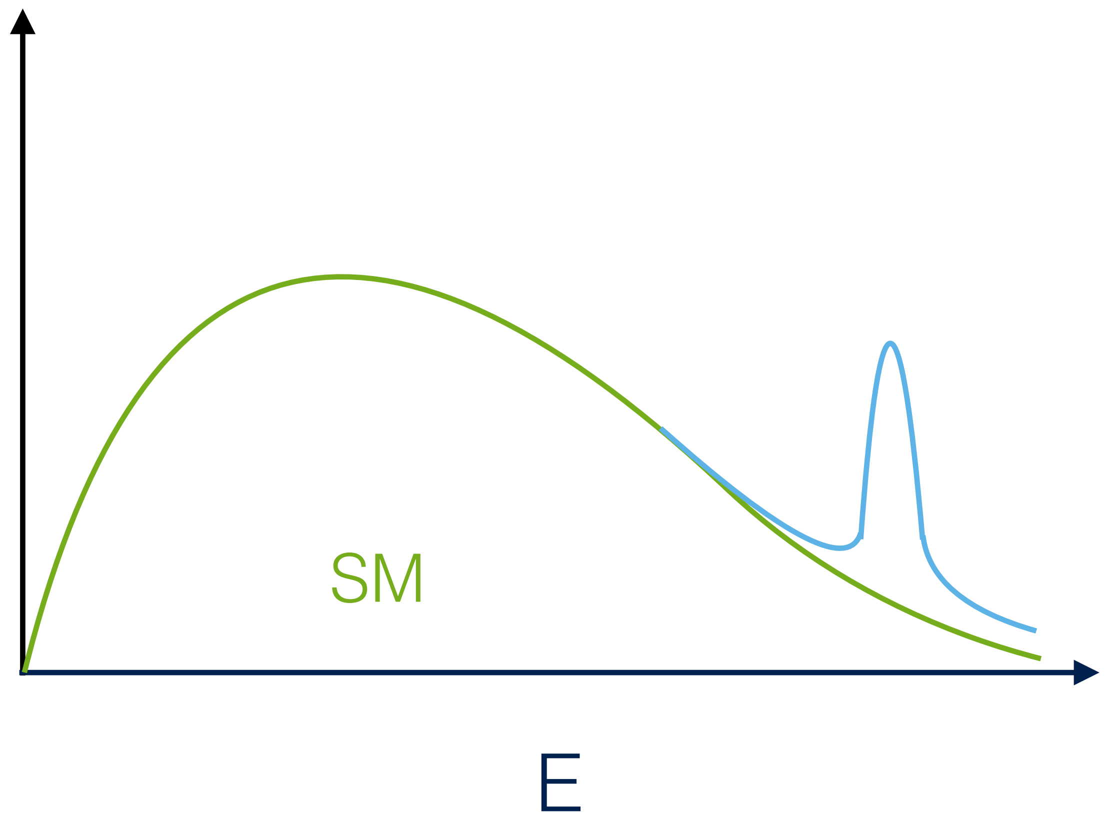


PDFs error bands

Ball et. al, NNPDF4.0, 2109.02653

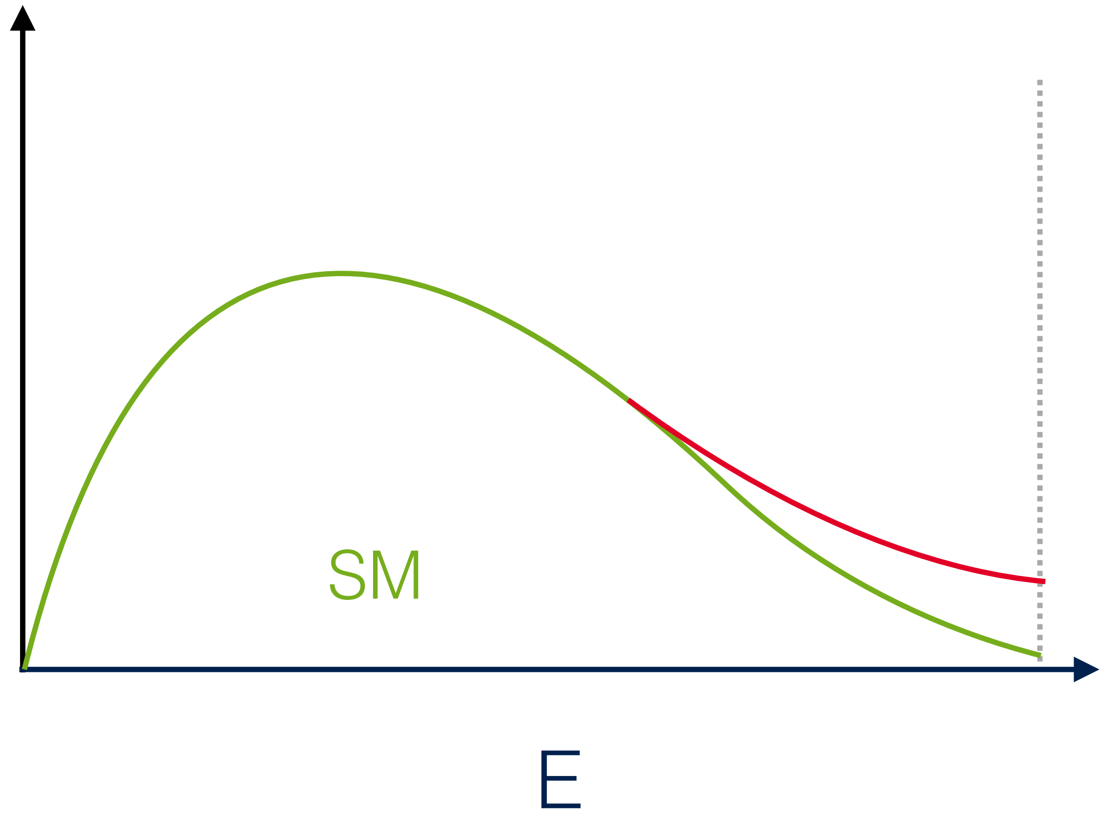
The Standard Model Effective Field Theory

Direct search (Bumps)



Direct search (Bumps)

Indirect (scouting tails)



Direct search (Bumps)

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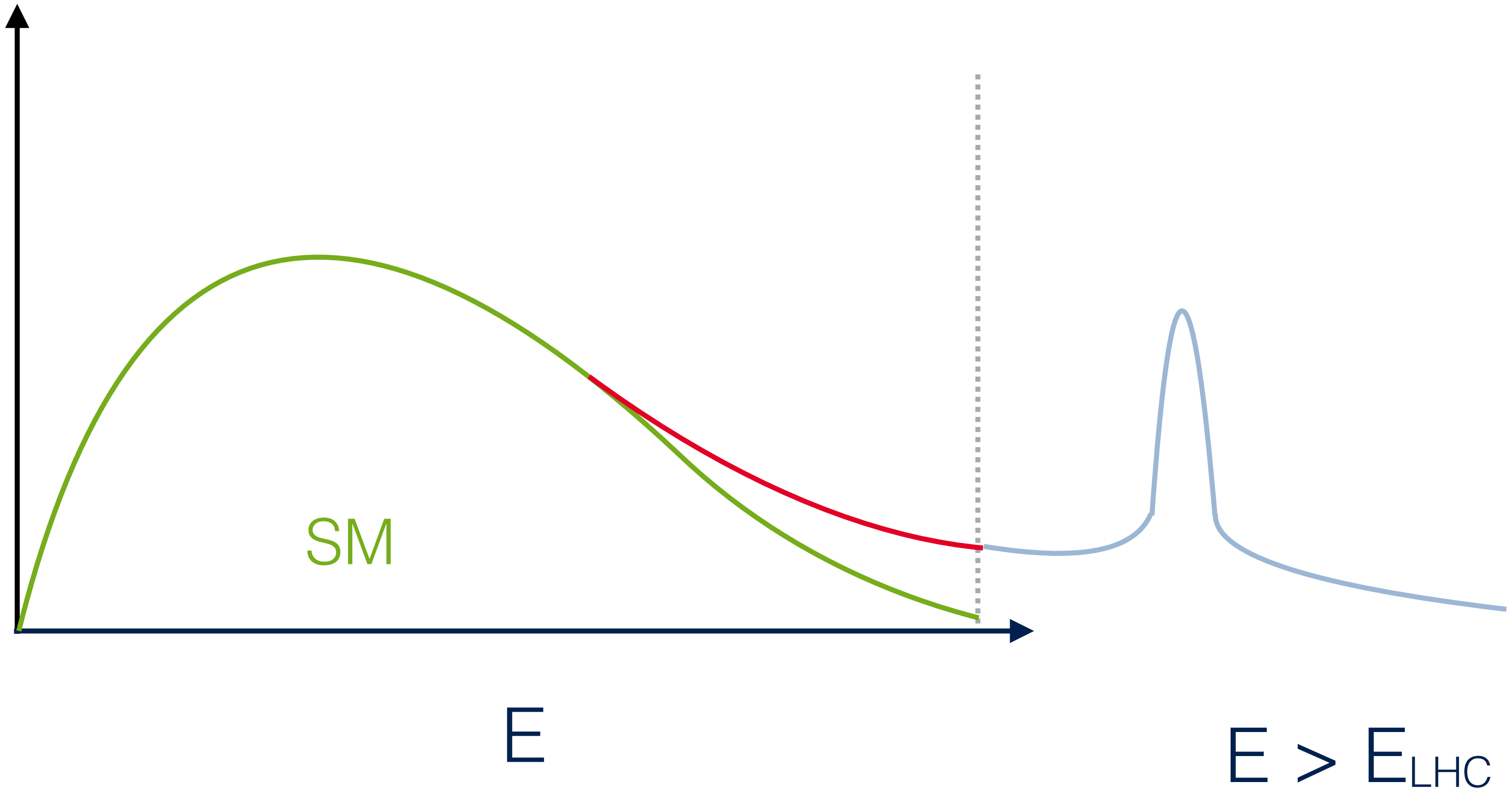
⇒ New physics is heavy



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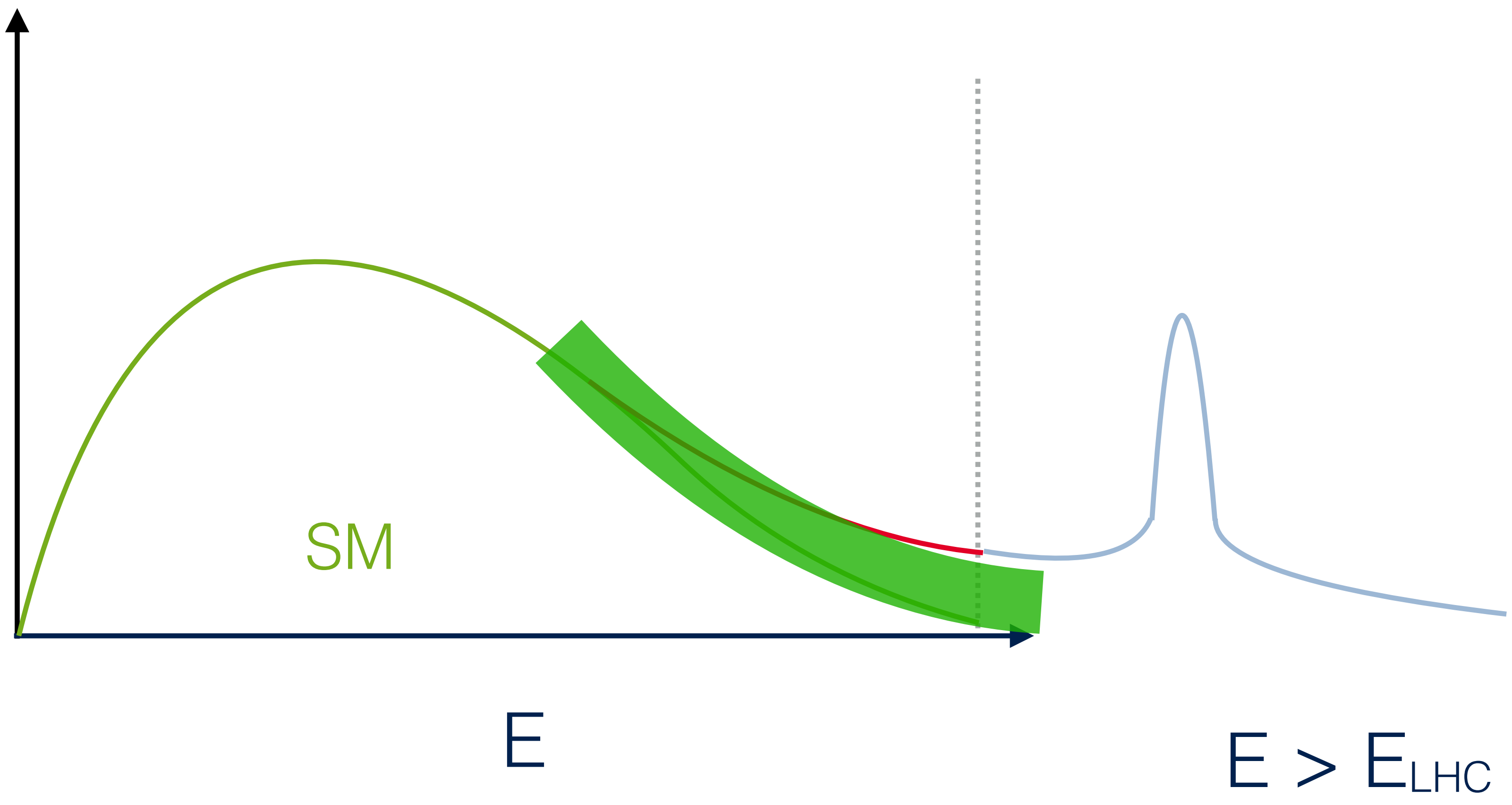

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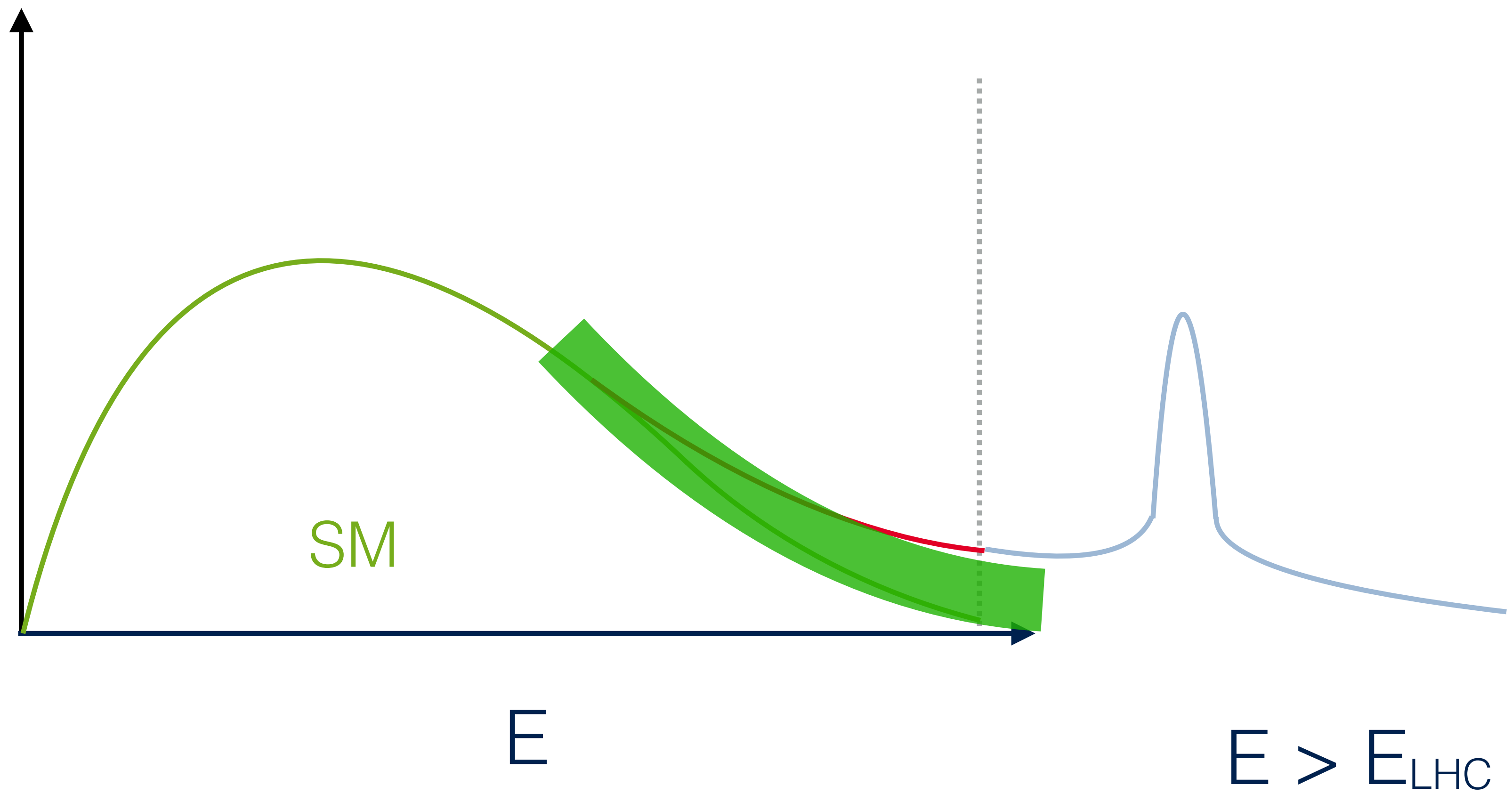

Framework to describe both precision physics and Heavy New Physics.

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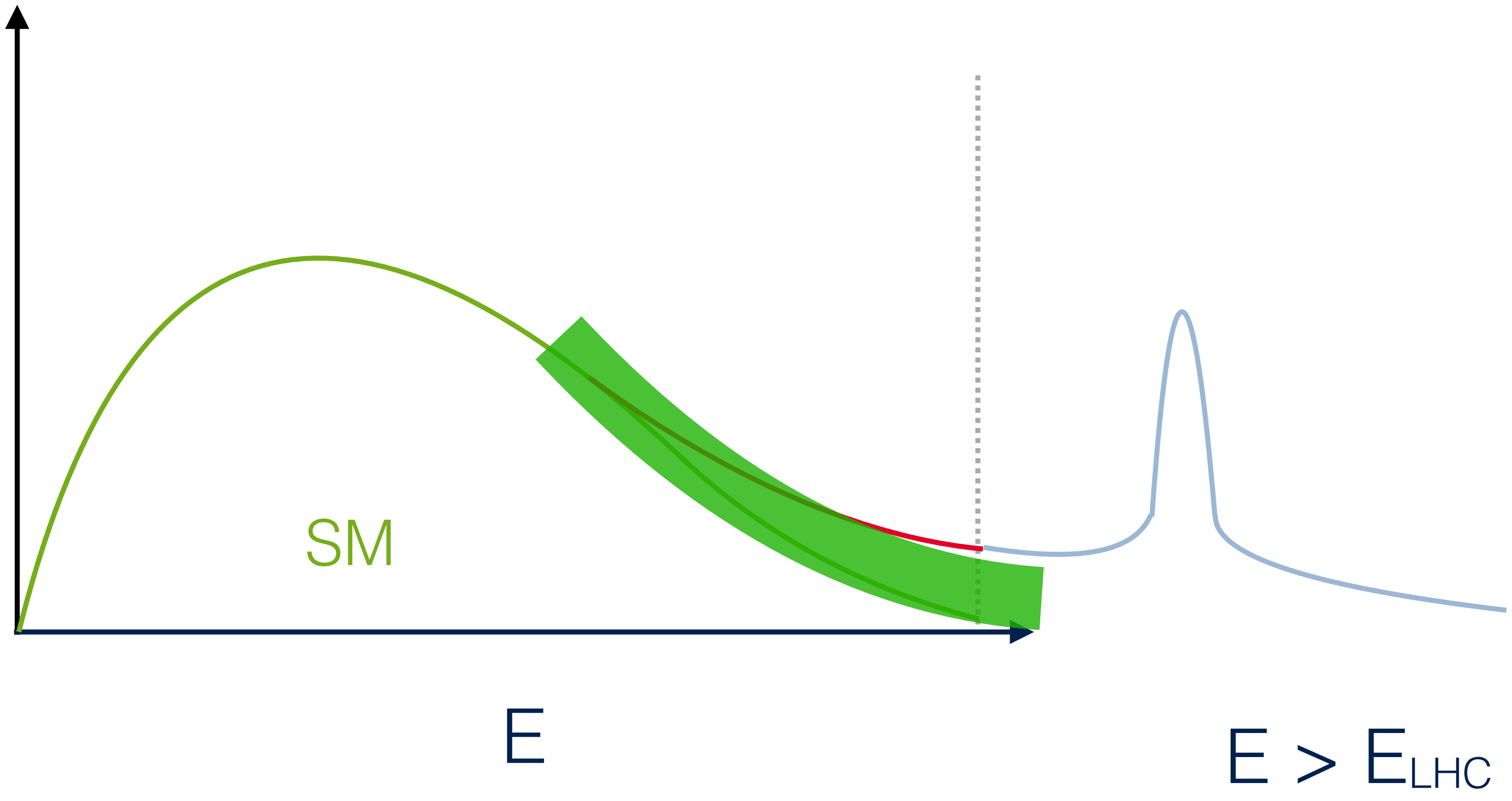

Framework to describe both precision physics and Heavy New Physics.

Standard Model Effective Field Theory (SMEFT)

The framework: SMEFT

$$\mathcal{L} = \mathcal{L}_{SM} + \sum_i \frac{1}{\Lambda}\mathcal{O}_i^5 + \sum_i \frac{1}{\Lambda^2}\mathcal{O}_i^6 + \dots$$

- ❖ **Modified interactions among SM particles**
- ❖ **Higher dimensional operators preserve SM symmetries.**
- ❖ **Mappable to a large class of BSM models.**
- ❖ **Truncate at dim 6: leading corrections**

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EFT to-do list

- **Define target operators: e.g. top-philic EFT** [arXiv:1802.07237]
- **Find optimal observables to probe them**
- **Compute with precision theoretical predictions (both SM and EFT)**
- **Make accurate measurements**

59 operators flavour universal

2499 operators flavour general

X^3		φ^6 and $\varphi^4 D^2$		$\psi^2\varphi^3$	
Q_G	$f^{ABC} G_\mu^{A\nu} G_\nu^{B\rho} G_\rho^{C\mu}$	Q_φ	$(\varphi^\dagger\varphi)^3$	$Q_{e\varphi}$	$(\varphi^\dagger\varphi)(\bar l_p e_r \varphi)$
$Q_{\widetilde G}$	$f^{ABC} \widetilde G_\mu^{A\nu} G_\nu^{B\rho} G_\rho^{C\mu}$	$Q_{\varphi\Box}$	$(\varphi^\dagger\varphi)\Box(\varphi^\dagger\varphi)$	$Q_{u\varphi}$	$(\varphi^\dagger\varphi)(\bar q_p u_r \widetilde\varphi)$
Q_W	$\varepsilon^{IJK} W_\mu^{I\nu} W_\nu^{J\rho} W_\rho^{K\mu}$	$Q_{\varphi D}$	$\left(\varphi^\dagger D^\mu\varphi\right)^\star \left(\varphi^\dagger D_\mu\varphi\right)$	$Q_{d\varphi}$	$(\varphi^\dagger\varphi)(\bar q_p d_r \varphi)$
$Q_{\widetilde W}$	$\varepsilon^{IJK} \widetilde W_\mu^{I\nu} W_\nu^{J\rho} W_\rho^{K\mu}$				

$X^2\varphi^2$		$\psi^2 X\varphi$		$\psi^2\varphi^2 D$	
$Q_{\varphi G}$	$\varphi^\dagger\varphi\, G^A_{\mu\nu} G^{A\mu\nu}$	Q_{eW}	$(\bar l_p \sigma^{\mu\nu} e_r)\tau^I \varphi W^I_{\mu\nu}$	$Q^{(1)}_{\varphi l}$	$(\varphi^\dagger i\overleftrightarrow{D}_\mu \varphi)(\bar l_p \gamma^\mu l_r)$
$Q_{\varphi \widetilde G}$	$\varphi^\dagger\varphi\, \widetilde G^A_{\mu\nu} G^{A\mu\nu}$	Q_{eB}	$(\bar l_p \sigma^{\mu\nu} e_r)\varphi B_{\mu\nu}$	$Q^{(3)}_{\varphi l}$	$(\varphi^\dagger i\overleftrightarrow{D}^I_\mu \varphi)(\bar l_p \tau^I \gamma^\mu l_r)$
$Q_{\varphi W}$	$\varphi^\dagger\varphi\, W^I_{\mu\nu} W^{I\mu\nu}$	Q_{uG}	$(\bar q_p \sigma^{\mu\nu} T^A u_r)\widetilde\varphi\, G^A_{\mu\nu}$	$Q_{\varphi e}$	$(\varphi^\dagger i\overleftrightarrow{D}_\mu \varphi)(\bar e_p \gamma^\mu e_r)$
$Q_{\varphi \widetilde W}$	$\varphi^\dagger\varphi\, \widetilde W^I_{\mu\nu} W^{I\mu\nu}$	Q_{uW}	$(\bar q_p \sigma^{\mu\nu} u_r)\tau^I \widetilde\varphi\, W^I_{\mu\nu}$	$Q^{(1)}_{\varphi q}$	$(\varphi^\dagger i\overleftrightarrow{D}_\mu \varphi)(\bar q_p \gamma^\mu q_r)$
$Q_{\varphi B}$	$\varphi^\dagger\varphi\, B_{\mu\nu} B^{\mu\nu}$	Q_{uB}	$(\bar q_p \sigma^{\mu\nu} u_r)\widetilde\varphi\, B_{\mu\nu}$	$Q^{(3)}_{\varphi q}$	$(\varphi^\dagger i\overleftrightarrow{D}^I_\mu \varphi)(\bar q_p \tau^I \gamma^\mu q_r)$
$Q_{\varphi \widetilde B}$	$\varphi^\dagger\varphi\, \widetilde B_{\mu\nu} B^{\mu\nu}$	Q_{dG}	$(\bar q_p \sigma^{\mu\nu} T^A d_r)\varphi\, G^A_{\mu\nu}$	$Q_{\varphi u}$	$(\varphi^\dagger i\overleftrightarrow{D}_\mu \varphi)(\bar u_p \gamma^\mu u_r)$
$Q_{\varphi WB}$	$\varphi^\dagger \tau^I \varphi\, W^I_{\mu\nu} B^{\mu\nu}$	Q_{dW}	$(\bar q_p \sigma^{\mu\nu} d_r)\tau^I \varphi\, W^I_{\mu\nu}$	$Q_{\varphi d}$	$(\varphi^\dagger i\overleftrightarrow{D}_\mu \varphi)(\bar d_p \gamma^\mu d_r)$
$Q_{\varphi \widetilde W B}$	$\varphi^\dagger \tau^I \varphi\, \widetilde W^I_{\mu\nu} B^{\mu\nu}$	Q_{dB}	$(\bar q_p \sigma^{\mu\nu} d_r)\varphi\, B_{\mu\nu}$	$Q_{\varphi ud}$	$i(\widetilde\varphi^\dagger D_\mu \varphi)(\bar u_p \gamma^\mu d_r)$

Dim-6 operators

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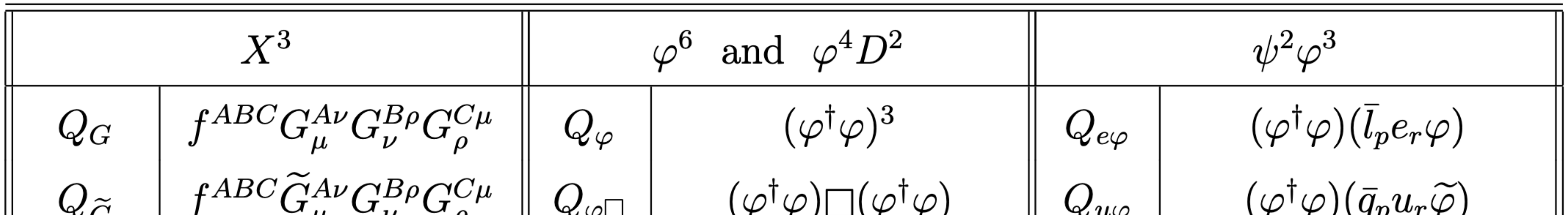
2499 operators flavour general



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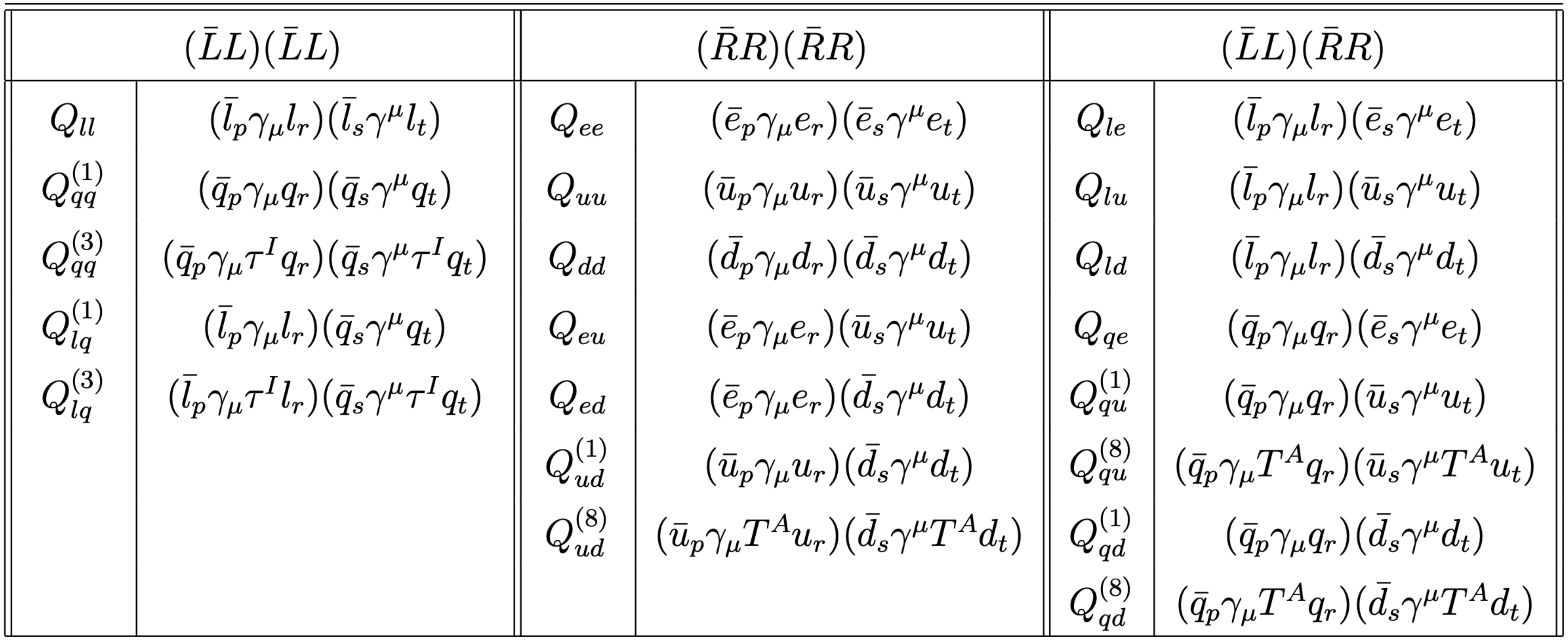
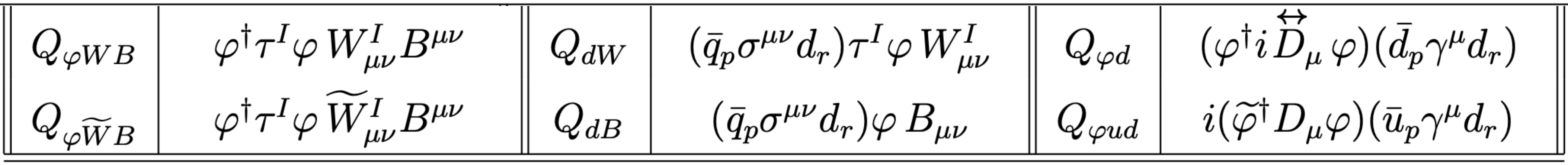


$(\bar LL)(\bar LL)$		$(\bar RR)(\bar RR)$		$(\bar LL)(\bar RR)$	
Q_{ll}	$(\bar l_p\gamma_\mu l_r)(\bar l_s\gamma^\mu l_t)$	Q_{ee}	$(\bar e_p\gamma_\mu e_r)(\bar e_s\gamma^\mu e_t)$	Q_{le}	$(\bar l_p\gamma_\mu l_r)(\bar e_s\gamma^\mu e_t)$
$Q_{qq}^{(1)}$	$(\bar q_p\gamma_\mu q_r)(\bar q_s\gamma^\mu q_t)$	Q_{uu}	$(\bar u_p\gamma_\mu u_r)(\bar u_s\gamma^\mu u_t)$	Q_{lu}	$(\bar l_p\gamma_\mu l_r)(\bar u_s\gamma^\mu u_t)$
$Q_{qq}^{(3)}$	$(\bar q_p\gamma_\mu\tau^I q_r)(\bar q_s\gamma^\mu\tau^I q_t)$	Q_{dd}	$(\bar d_p\gamma_\mu d_r)(\bar d_s\gamma^\mu d_t)$	Q_{ld}	$(\bar l_p\gamma_\mu l_r)(\bar d_s\gamma^\mu d_t)$
$Q_{lq}^{(1)}$	$(\bar l_p\gamma_\mu l_r)(\bar q_s\gamma^\mu q_t)$	Q_{eu}	$(\bar e_p\gamma_\mu e_r)(\bar u_s\gamma^\mu u_t)$	Q_{qe}	$(\bar q_p\gamma_\mu q_r)(\bar e_s\gamma^\mu e_t)$
$Q_{lq}^{(3)}$	$(\bar l_p\gamma_\mu\tau^I l_r)(\bar q_s\gamma^\mu\tau^I q_t)$	Q_{ed}	$(\bar e_p\gamma_\mu e_r)(\bar d_s\gamma^\mu d_t)$	$Q_{qu}^{(1)}$	$(\bar q_p\gamma_\mu q_r)(\bar u_s\gamma^\mu u_t)$
		$Q_{ud}^{(1)}$	$(\bar u_p\gamma_\mu u_r)(\bar d_s\gamma^\mu d_t)$	$Q_{qu}^{(8)}$	$(\bar q_p\gamma_\mu T^A q_r)(\bar u_s\gamma^\mu T^A u_t)$
		$Q_{ud}^{(8)}$	$(\bar u_p\gamma_\mu T^A u_r)(\bar d_s\gamma^\mu T^A d_t)$	$Q_{qd}^{(1)}$	$(\bar q_p\gamma_\mu q_r)(\bar d_s\gamma^\mu d_t)$
				$Q_{qd}^{(8)}$	$(\bar q_p\gamma_\mu T^A q_r)(\bar d_s\gamma^\mu T^A d_t)$



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Dim 6: Large number of operators and therefore degrees of freedom

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Many observables and final states → **Break degeneracies in parameter space**

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$$\mathcal{O} = \mathcal{O}_{SM} + \frac{C_i}{\Lambda^2}\,\mathcal{O}_i^{INT} + \frac{C_i\,C_j}{\Lambda^4}\,\mathcal{O}_{ij}^{SQ}$$

NLO-QCD
with SMEFT@NLO

Degrande et al,
arXiv:2008.11743

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Linear contribution: leading correction

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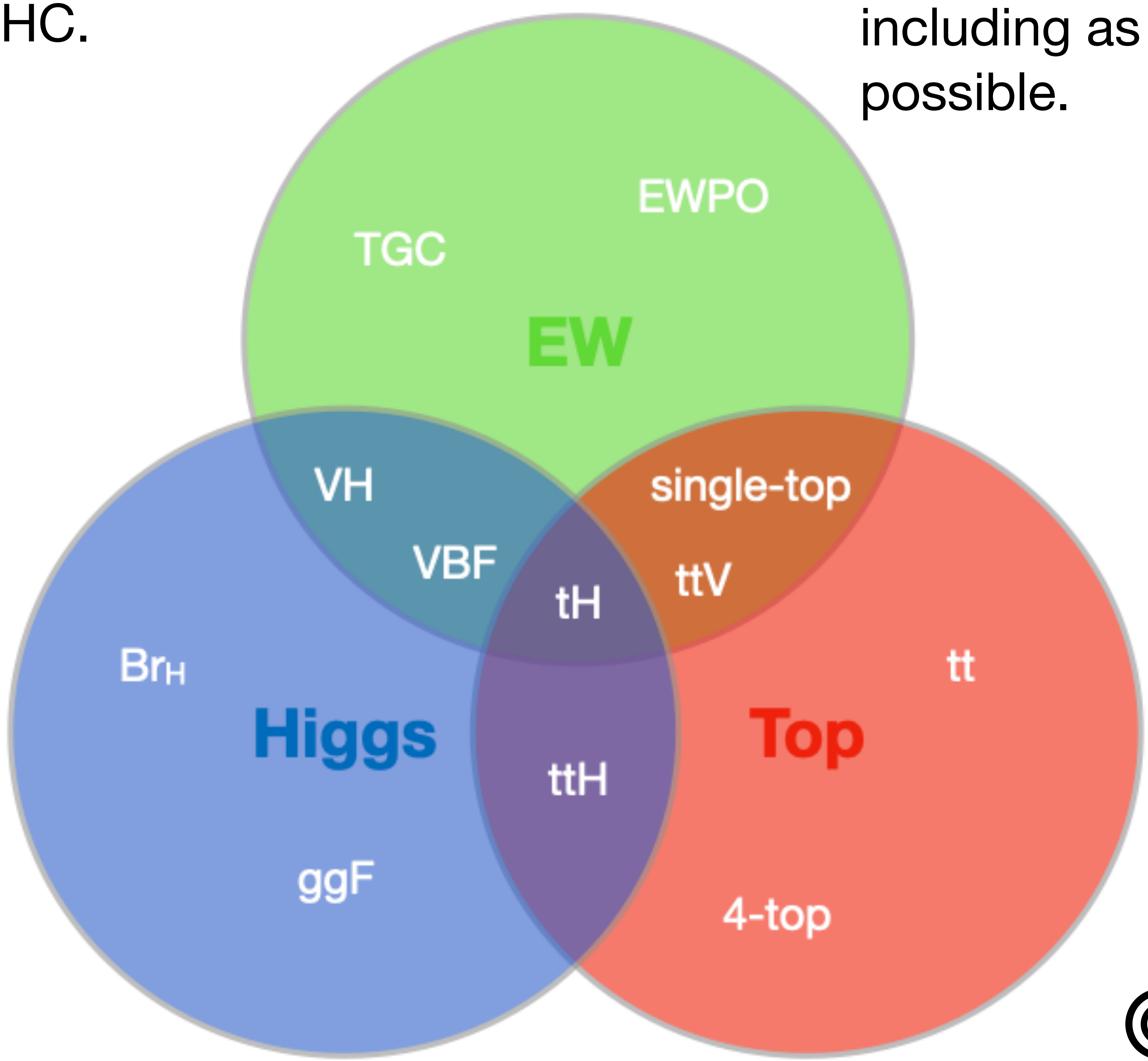
Linear contribution: leading correction

Quadratic contribution: useful information in many instances

The SMEFT framework connects different sectors of observables measured at the LHC.

We can probe the SMEFT by taking a **global approach,** including as many datasets as possible.



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Fitting the SMEFT

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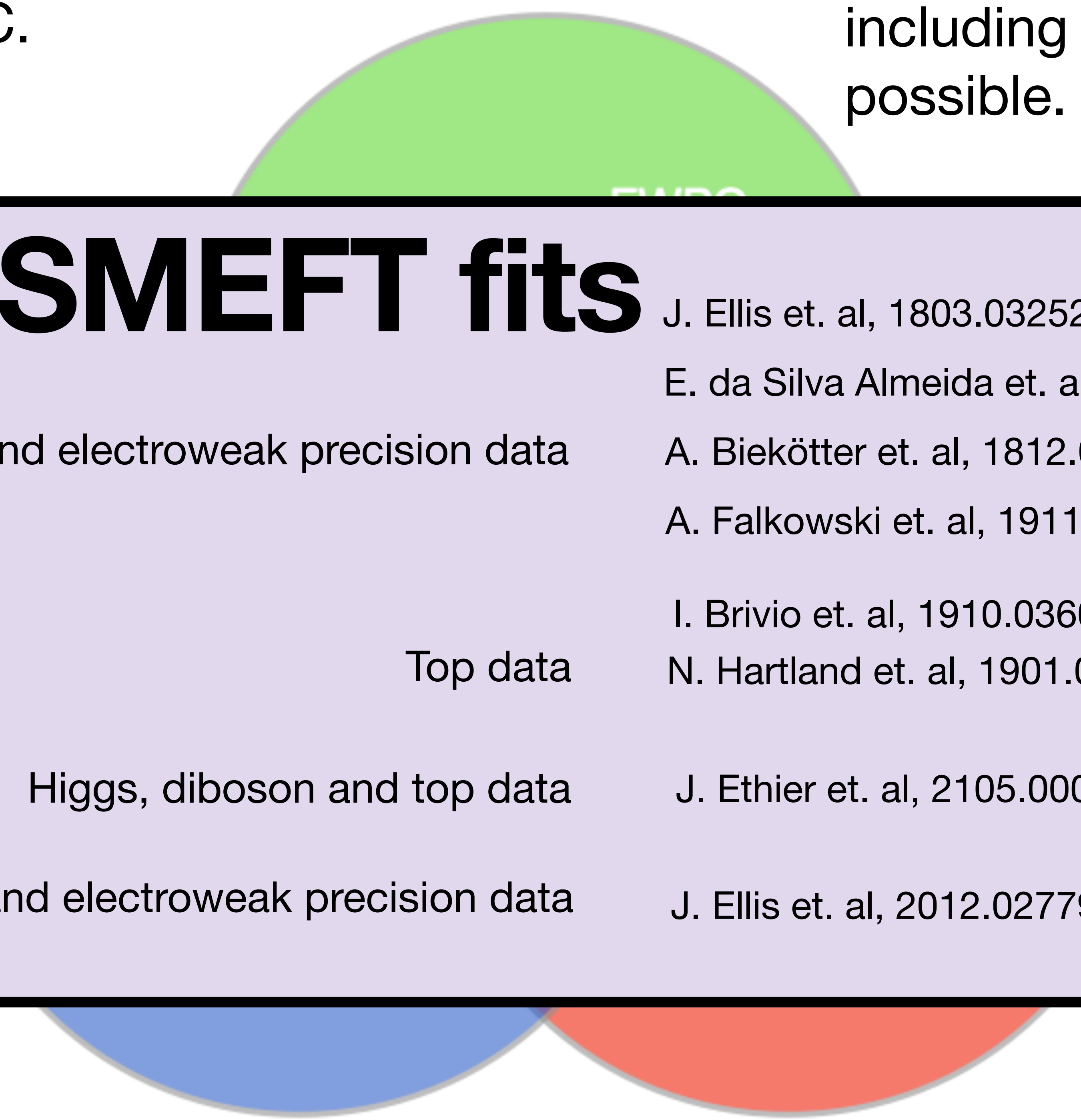

Global SMEFT fits

Higgs, diboson and electroweak precision data	J. Ellis et. al, 1803.03252 E. da Silva Almeida et. al, 1812.01009 A. Biekötter et. al, 1812.07587 A. Falkowski et. al, 1911.07866
Top data	I. Brivio et. al, 1910.03606: N. Hartland et. al, 1901.05965:
Higgs, diboson and top data	J. Ethier et. al, 2105.00006
Higgs, diboson, top and electroweak precision data	J. Ellis et. al, 2012.02779

+ many others….

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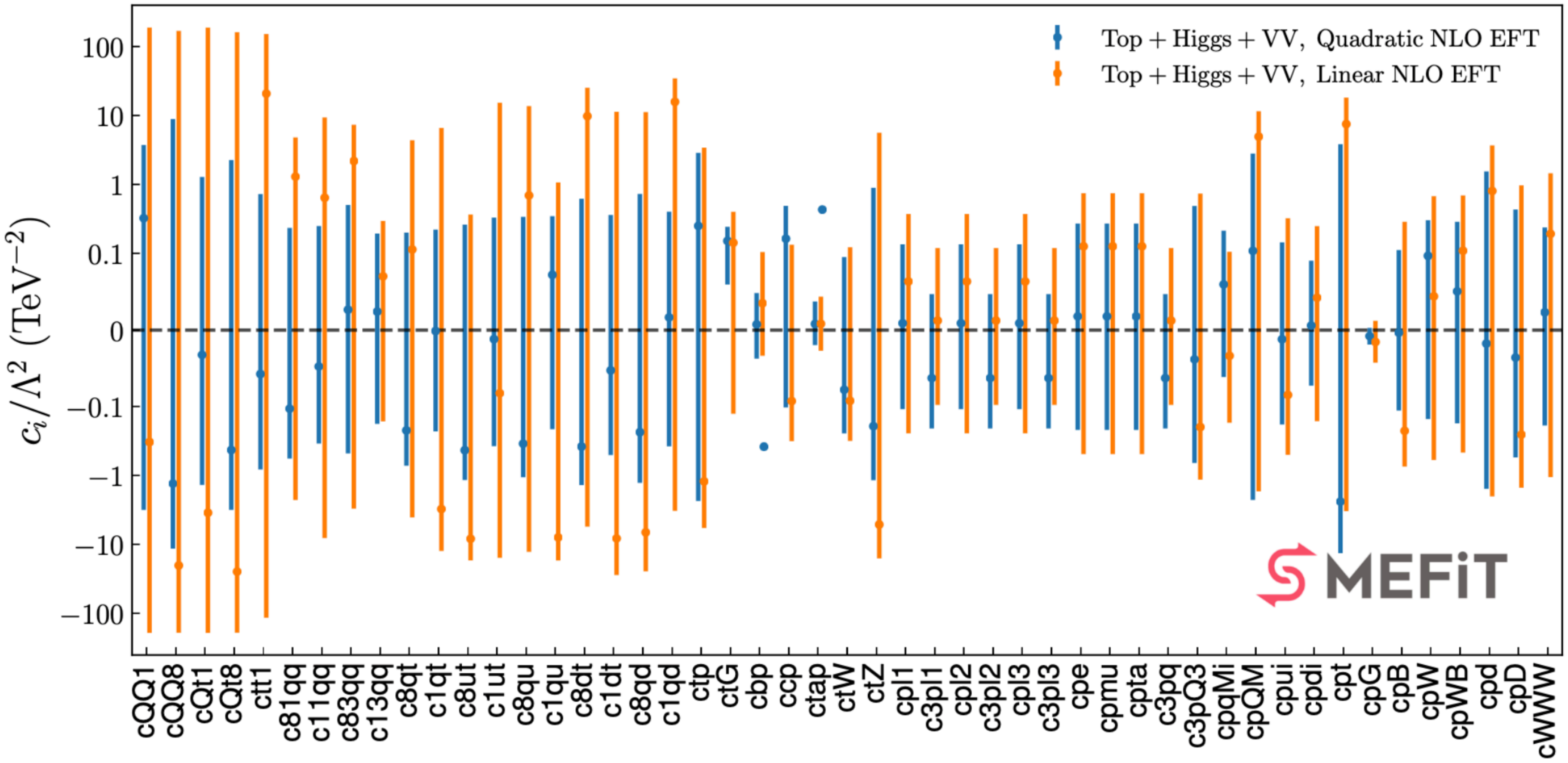
Global fit result



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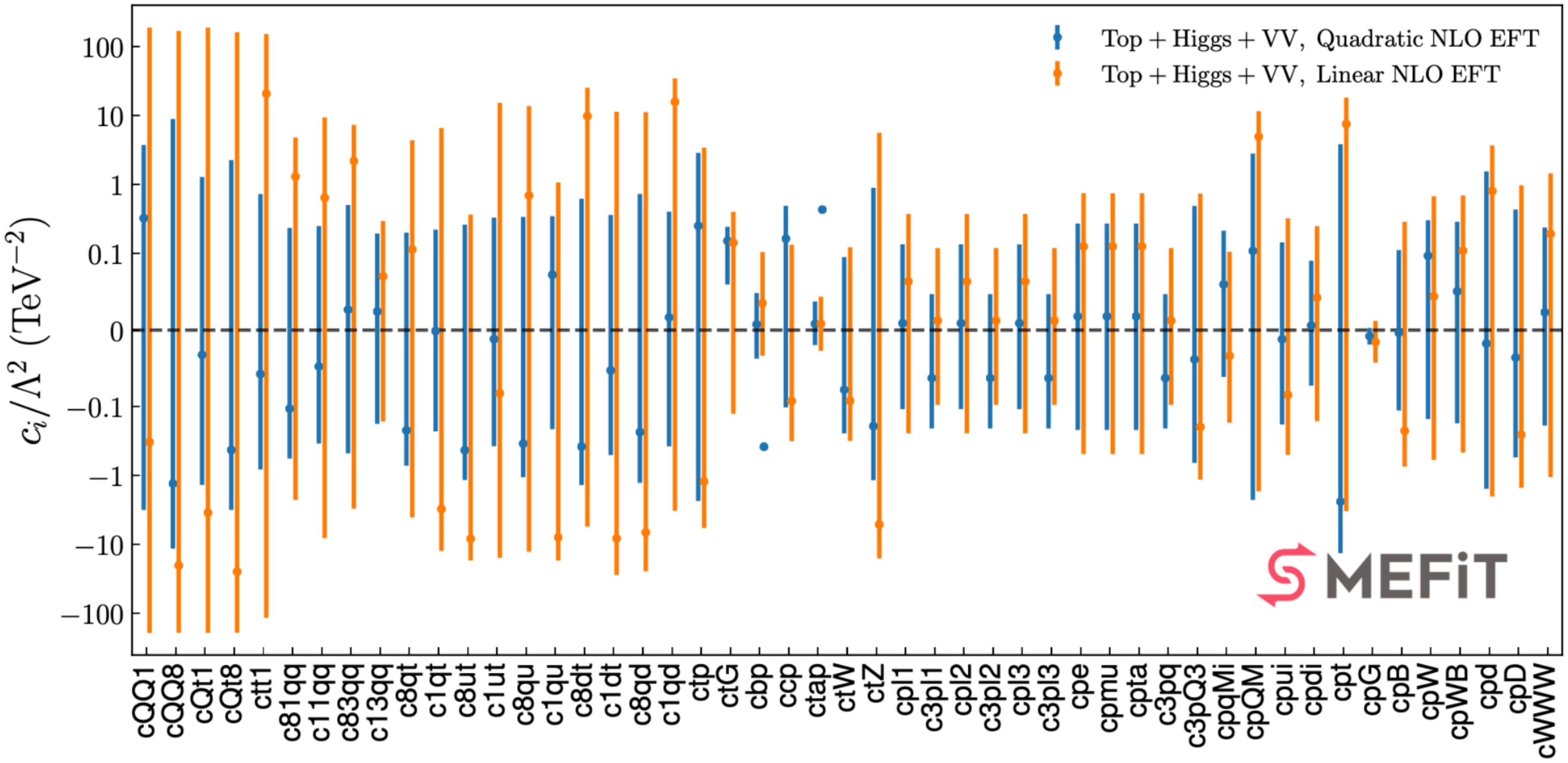
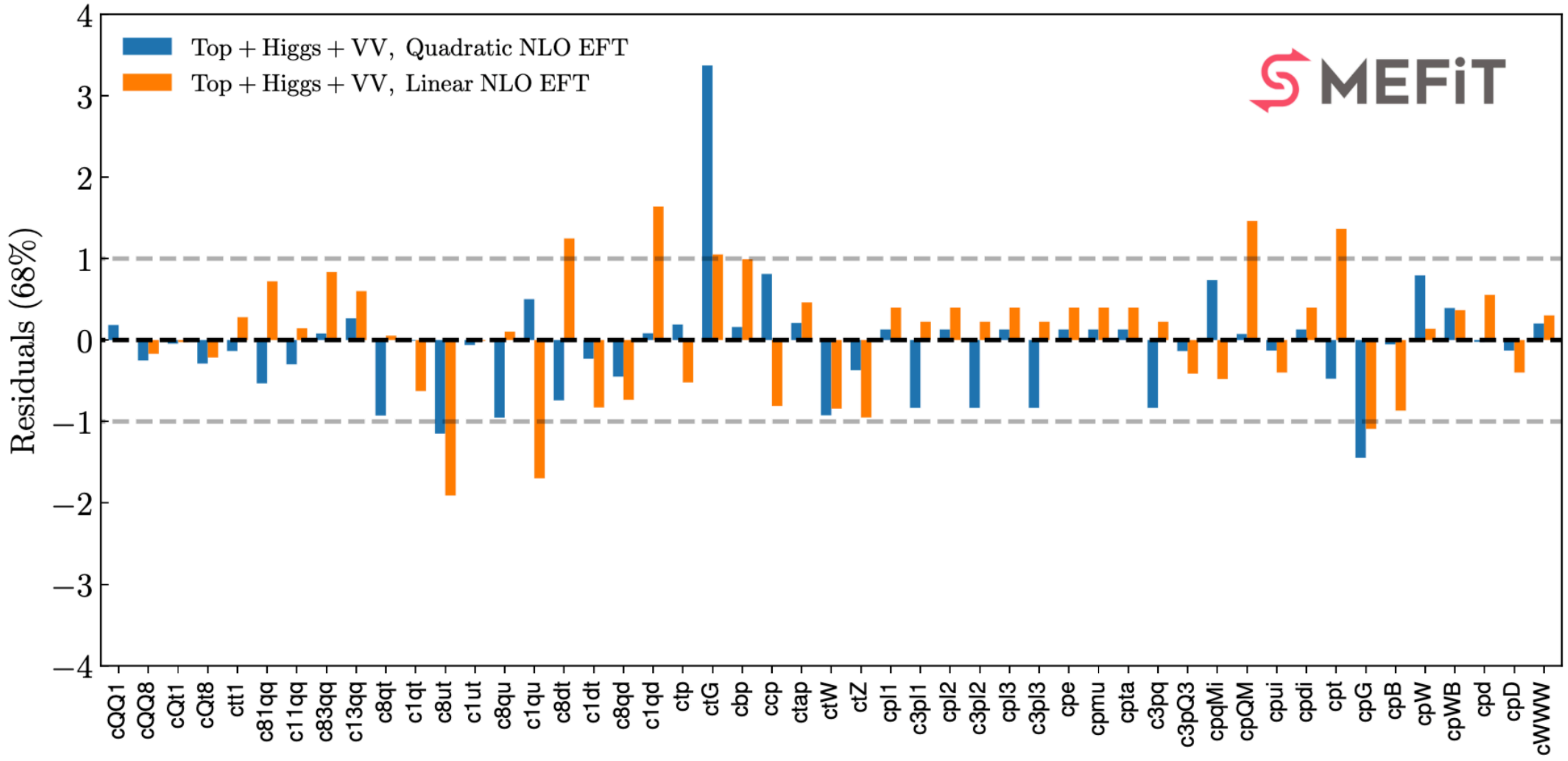
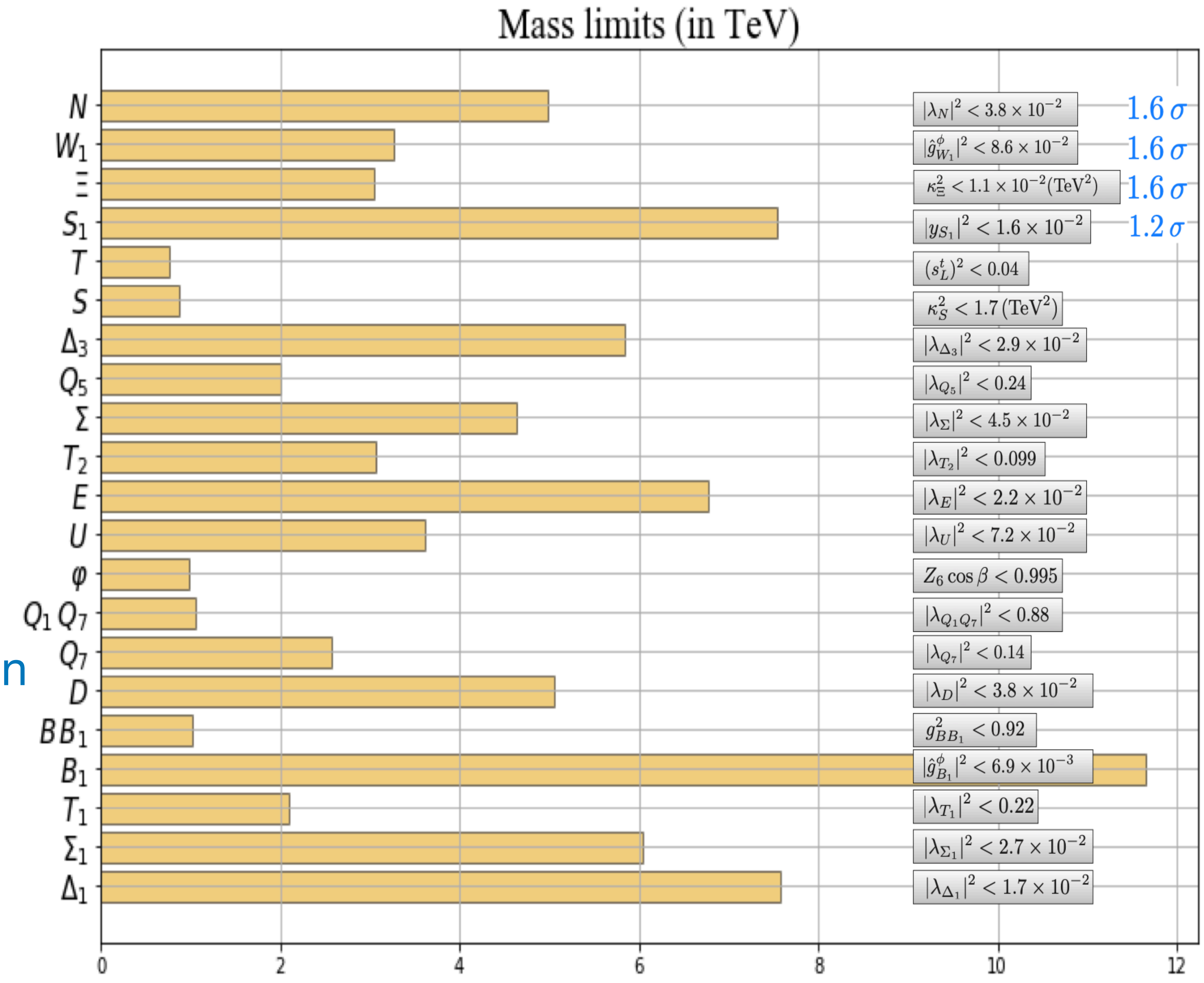




What do we learn?

- ❖ Fits can be interpreted in UV completion models
- ❖ Bounds on coefficient translate on bounds on mass or couplings
- ❖ Simple case: single field extension



Ellis et al: arXiv:2012.02779

The SMEFT proton

EFT quality of fit

Process	$n_{\rm dat}$	$\chi^2_{\rm exp+th}$ [SM]	$\chi^2_{\rm exp+th}$ [SMEFT $\mathcal{O}(\Lambda^{-2})$]	$\chi^2_{\rm exp+th}$ [SMEFT $\mathcal{O}(\Lambda^{-4})$]
$t\bar{t}$	86	1.71	1.11	1.69
$t\bar{t}$ AC	18	0.58	0.50	0.60
W helicities	4	0.71	0.45	0.47
$t\bar{t}Z$	12	1.19	1.17	0.94
$t\bar{t}W$	4	1.71	0.46	1.66
$t\bar{t}\gamma$	2	0.47	0.03	0.59
$t\bar{t}t\bar{t}$ & $t\bar{t}b\bar{b}$	8	1.32	1.06	0.49
single top	30	0.504	0.33	0.37
tW	6	1.00	0.82	0.82
tZ	5	0.45	0.30	0.31
Total	**175**	**1.24**	**0.84**	**1.14**

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For a linear fit, χ^2 improves across the board

For a quadratic fit, χ^2 improves only mildly

EFT quality of fit

Process	n_{dat}	$\chi^2_{\text{exp+th}}$ [SM]	$\chi^2_{\text{exp+th}}$ [SMEFT $\mathcal{O}(\Lambda^{-2})$]	$\chi^2_{\text{exp+th}}$ [SMEFT $\mathcal{O}(\Lambda^{-4})$]
$t\bar{t}$	86	1.71	1.11	1.69
$t\bar{t}$ AC	18	0.58	0.50	0.60
W helicities	4	0.71	0.45	0.47
$t\bar{t}Z$	12	1.19	1.17	0.94
$t\bar{t}W$	4	1.71	0.46	1.66
$t\bar{t}\gamma$	2	0.47	0.03	0.59
$t\bar{t}t\bar{t}$ & $t\bar{t}b\bar{b}$	8	1.32	1.06	0.49
single top	30	0.504	0.33	0.37
tW	6	1.00	0.82	0.82
tZ	5	0.45	0.30	0.31
Total	**175**	**1.24**	**0.84**	**1.14**

For a linear fit, χ^2 improves across the board

For a quadratic fit, χ^2 improves only mildly

→

Model is less flexible and unable to accomodate deviations

Assess the interplay

How do the constraints on the SMEFT change if we perform a consistent joint determination of the PDFs and SMEFT?

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Could we be absorbing signs of new physics into the PDFs?

New Physics

The SM does not explain everything.

ν masses

Gravity

Dark Matter

Baryon asymmetry

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We look for New Physics or BSM to explain the deficiencies.

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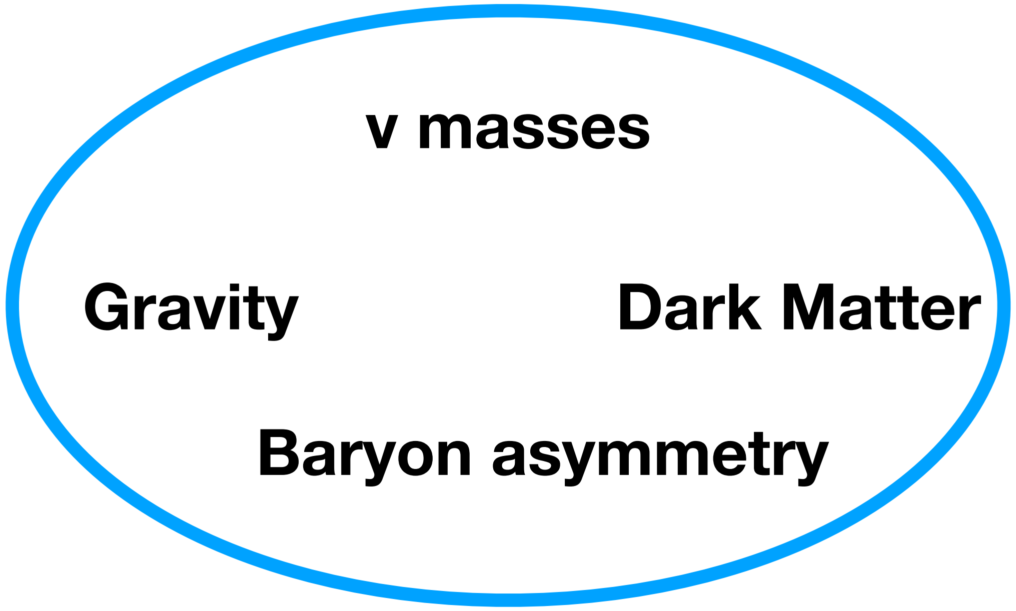

ν masses

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Baryon asymmetry

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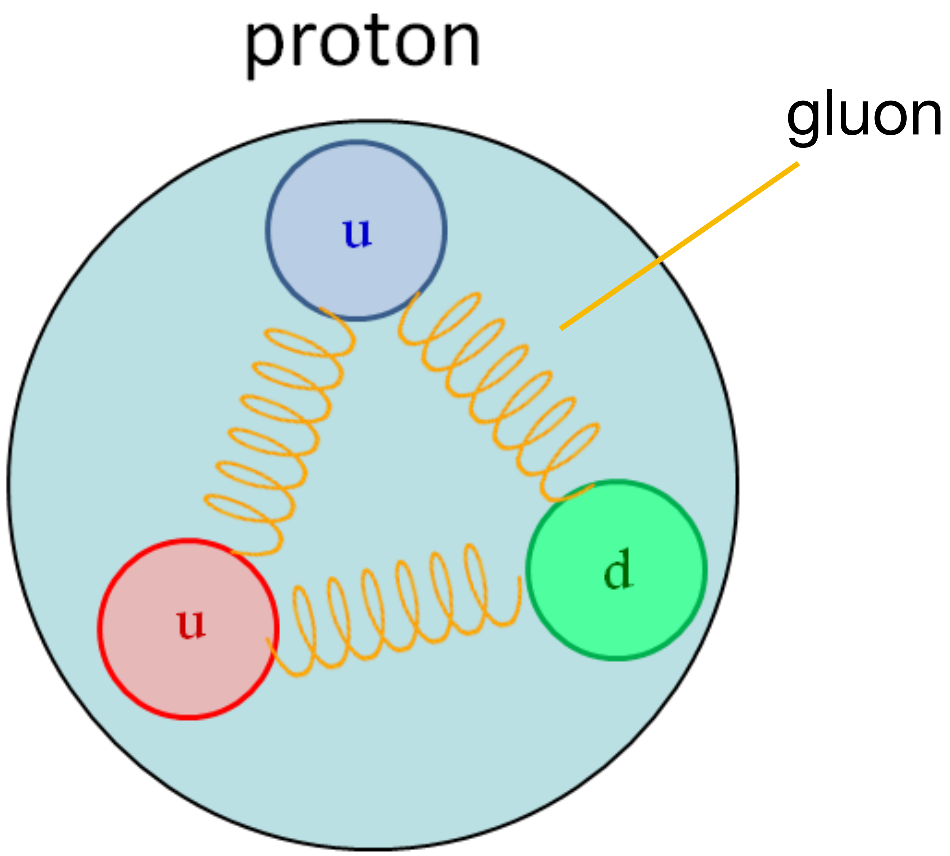
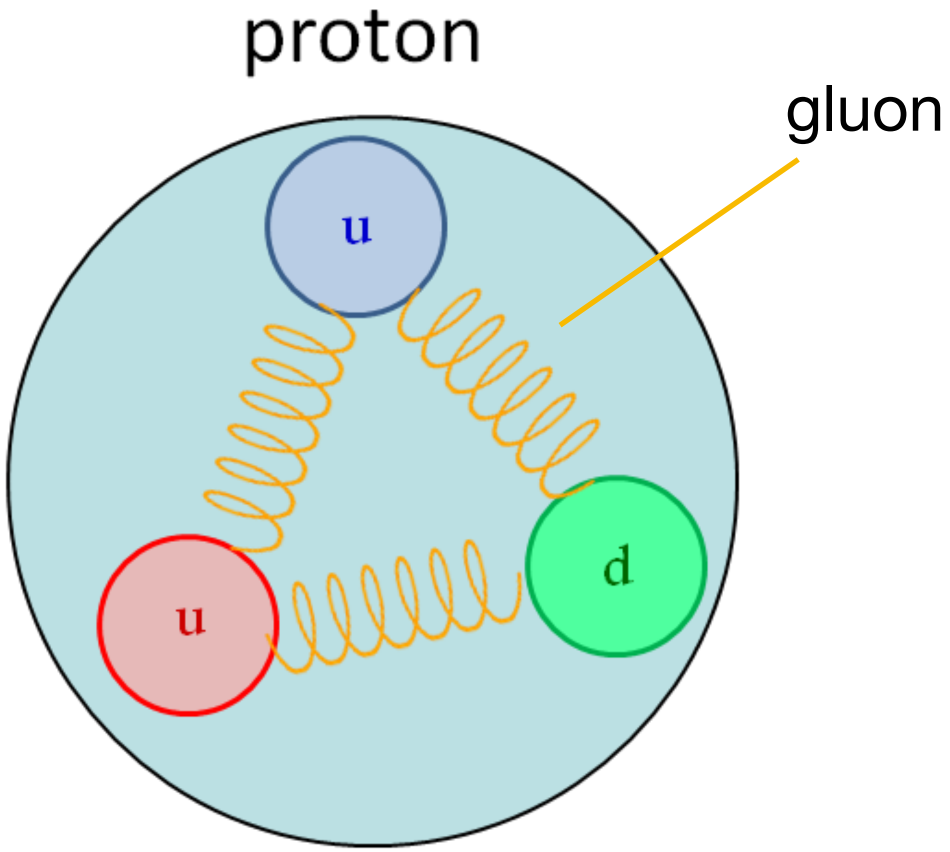
Where do we go from here?

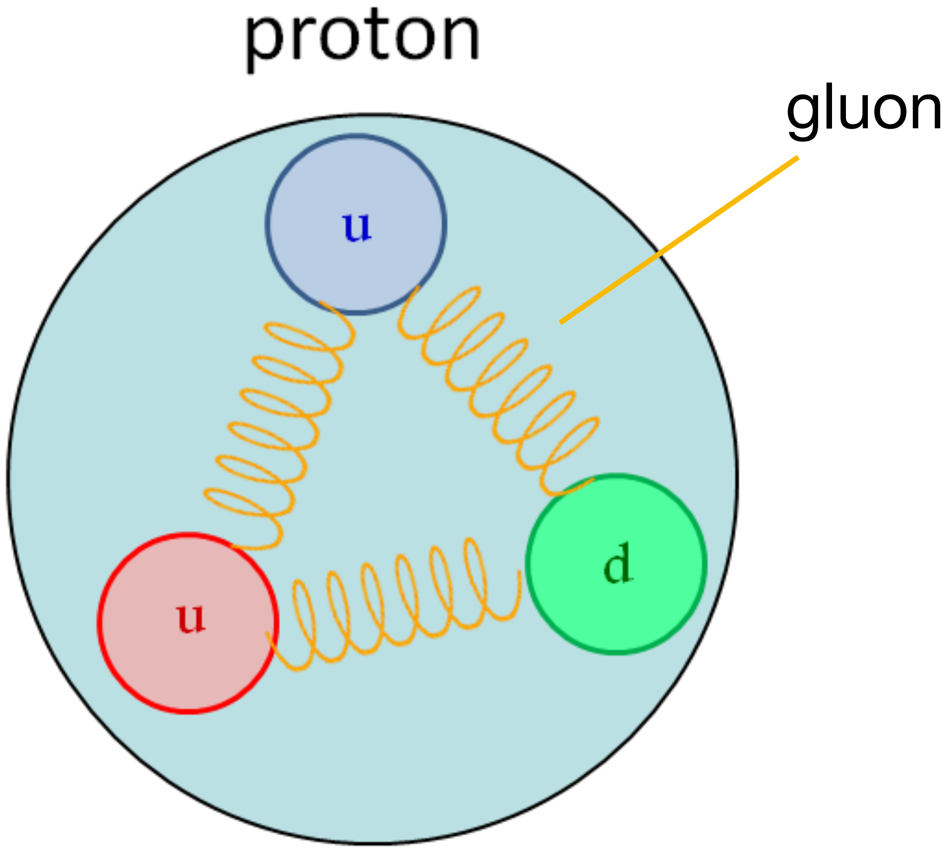
Inside the proton





Zoom in

Inside the proton



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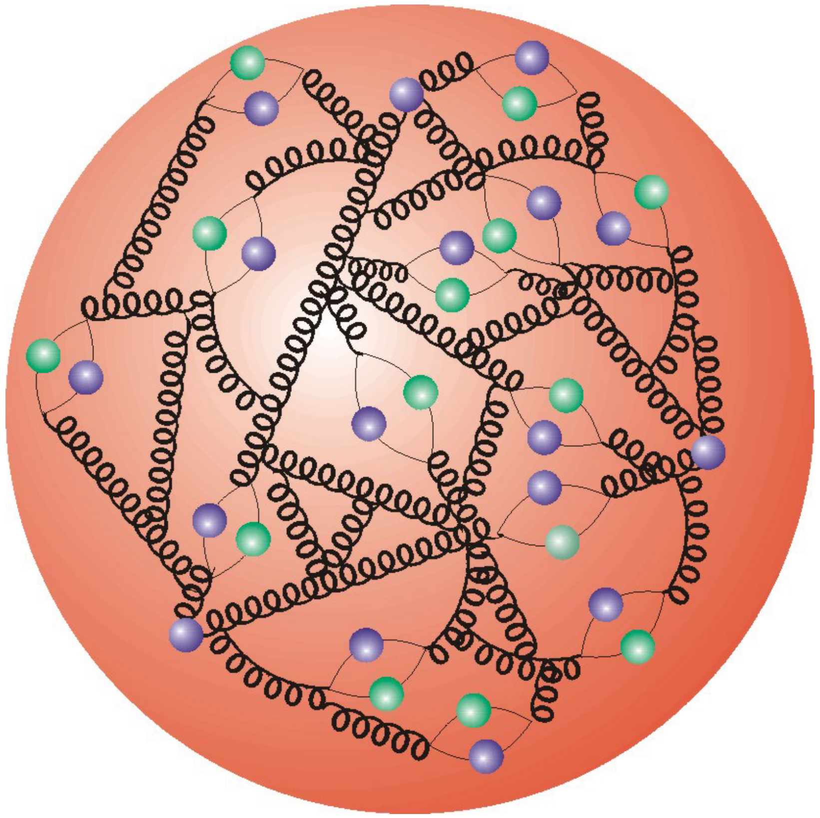

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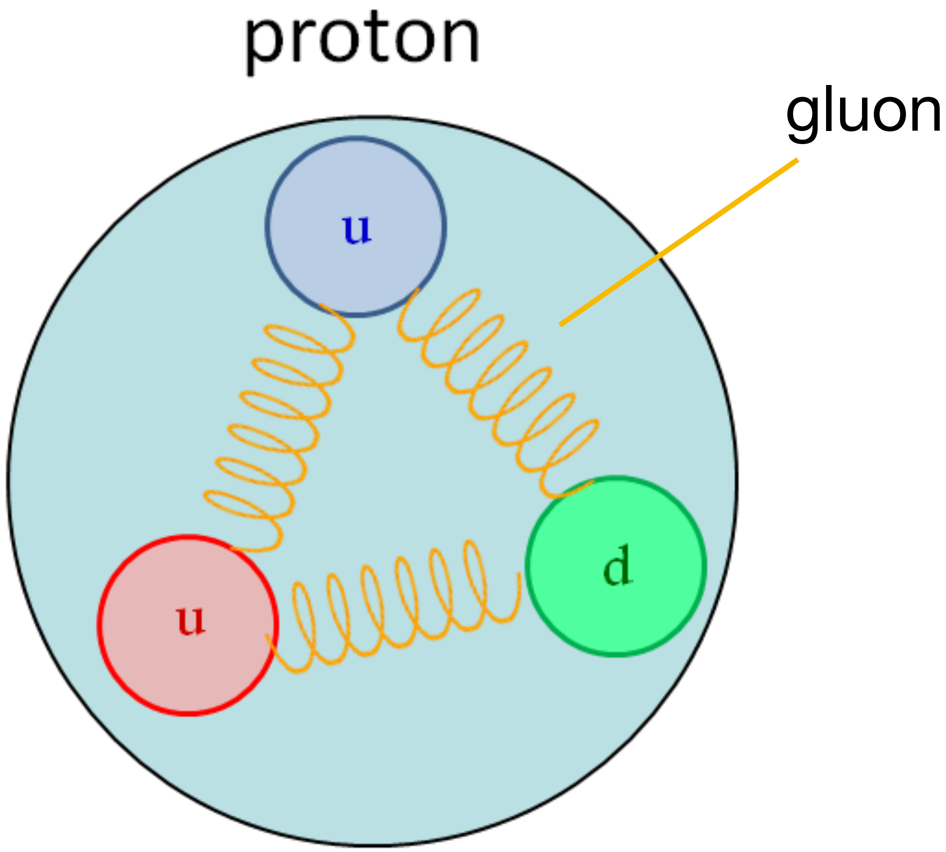

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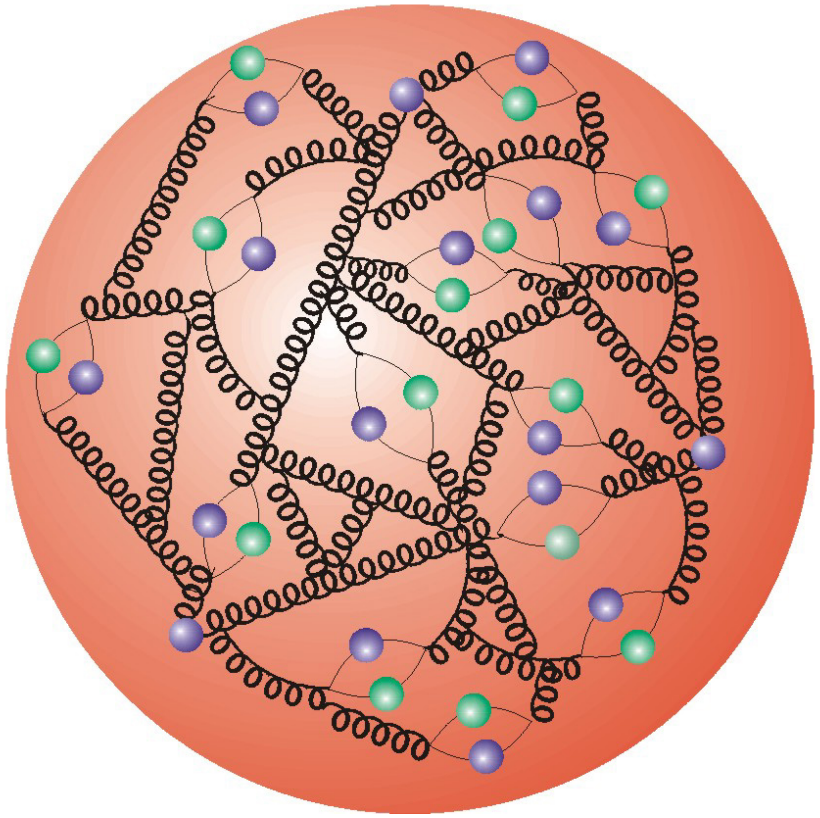

There is A LOT of dynamics inside a proton!

Current status

(16 zeros)

LHC operations started around 2010 → 10000000000000000 proton collisions!!

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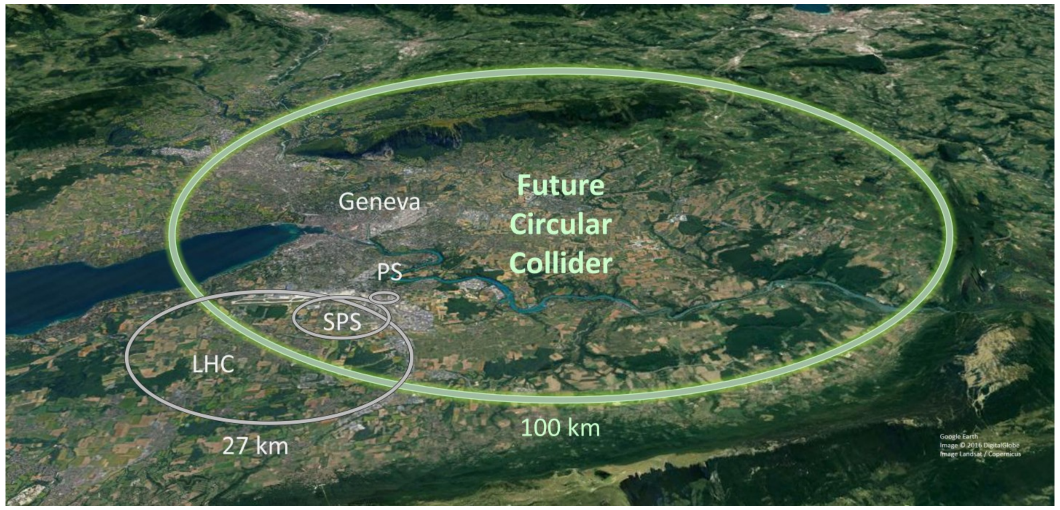
New collider!



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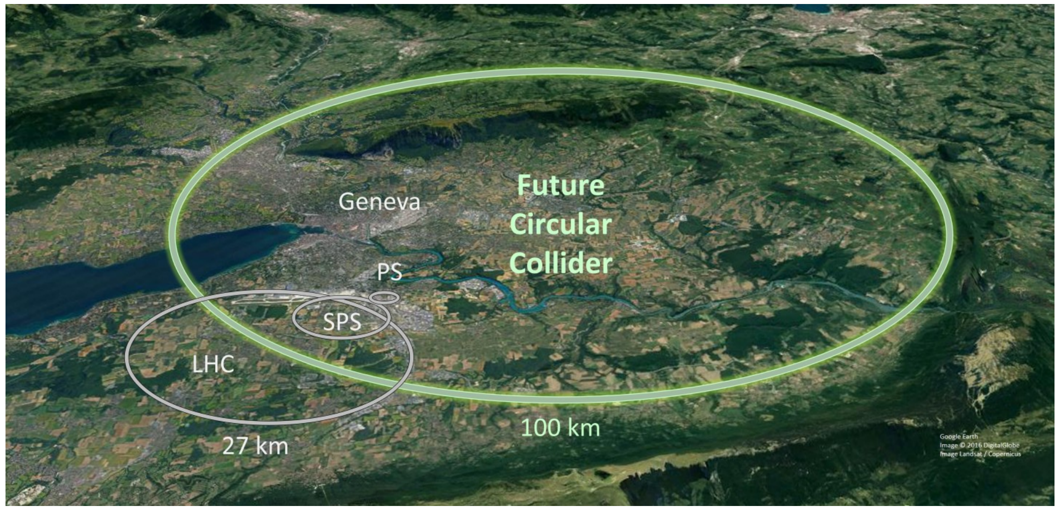

Many years to wait…
We are impatient

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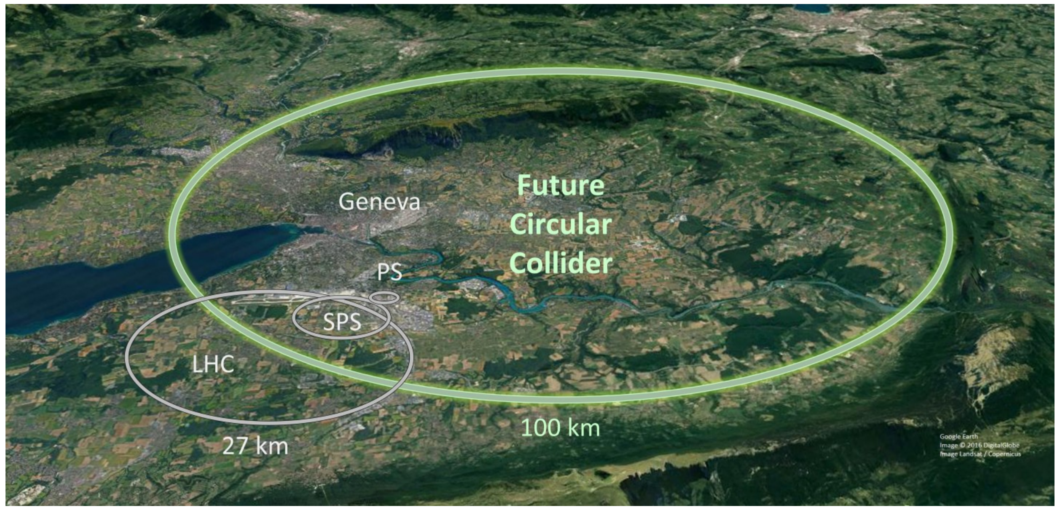
Precision



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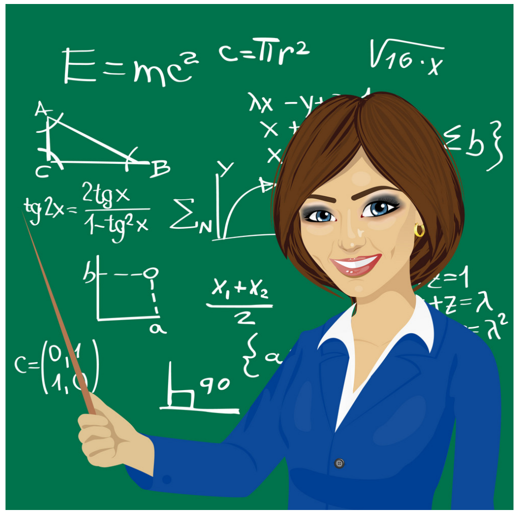
Precise measurements



Accurate calculations

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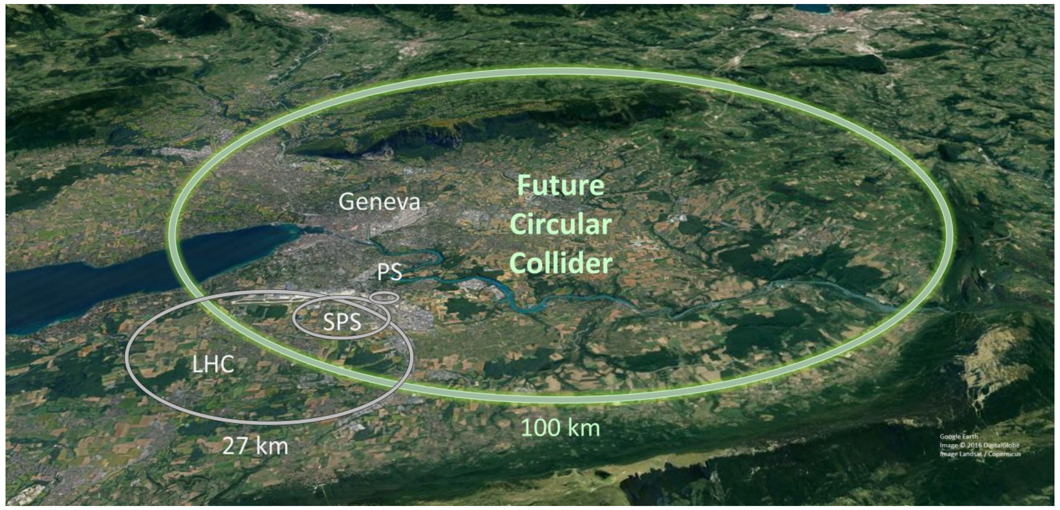
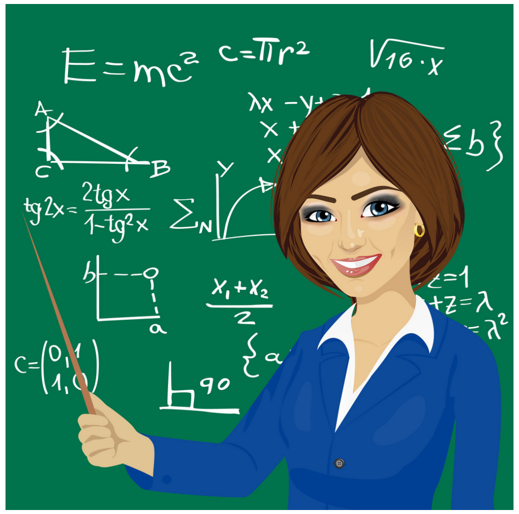
Precision





Precise measurements

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Indirect discovery!

How can we describe the presence of new interactions?

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New particles being exchanged in collisions

New interactions

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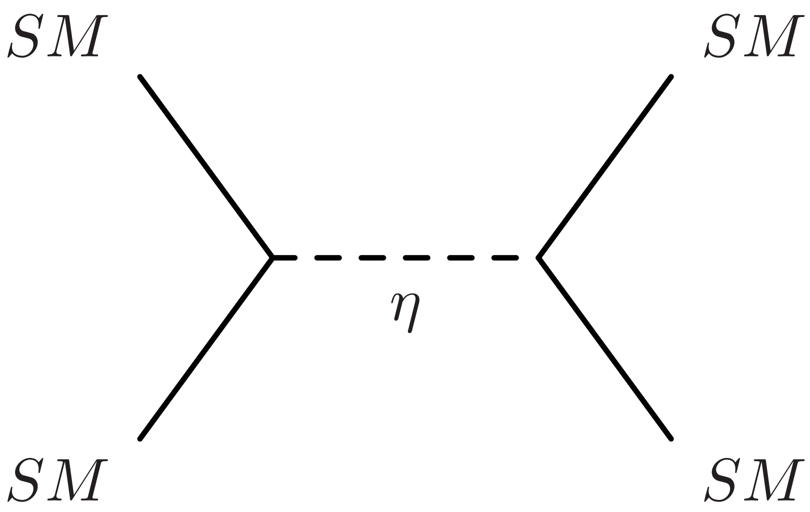
New particles being exchanged in collisions

$$\frac{g^2}{p^2 - M^2}$$



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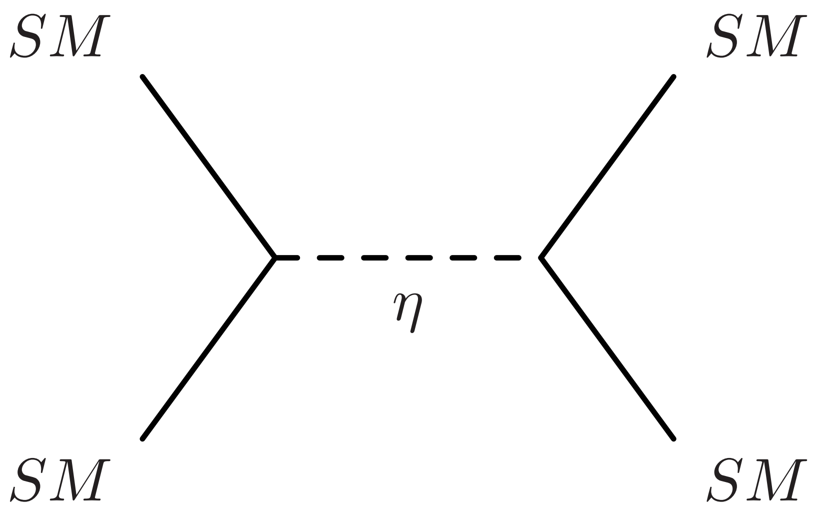

$$M \equiv \Lambda$$
$$p^2 \ll \Lambda^2$$

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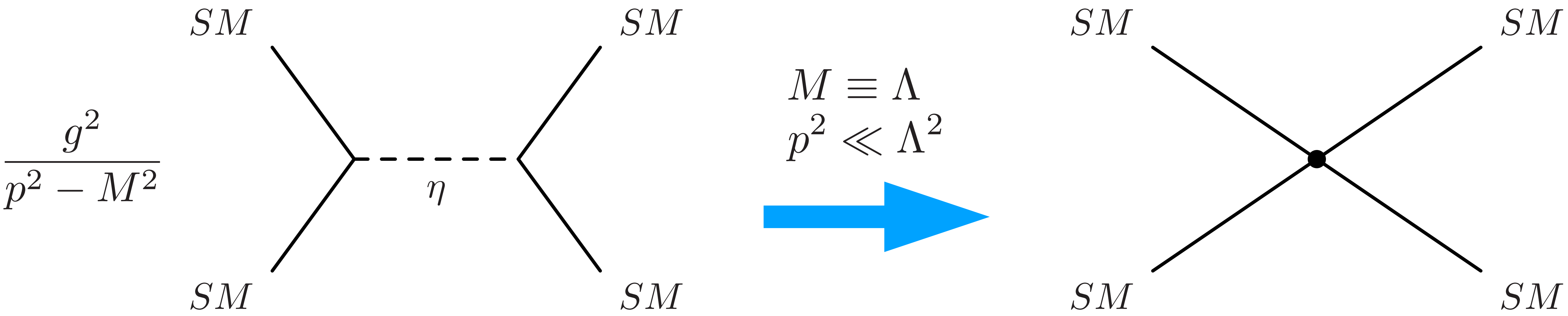

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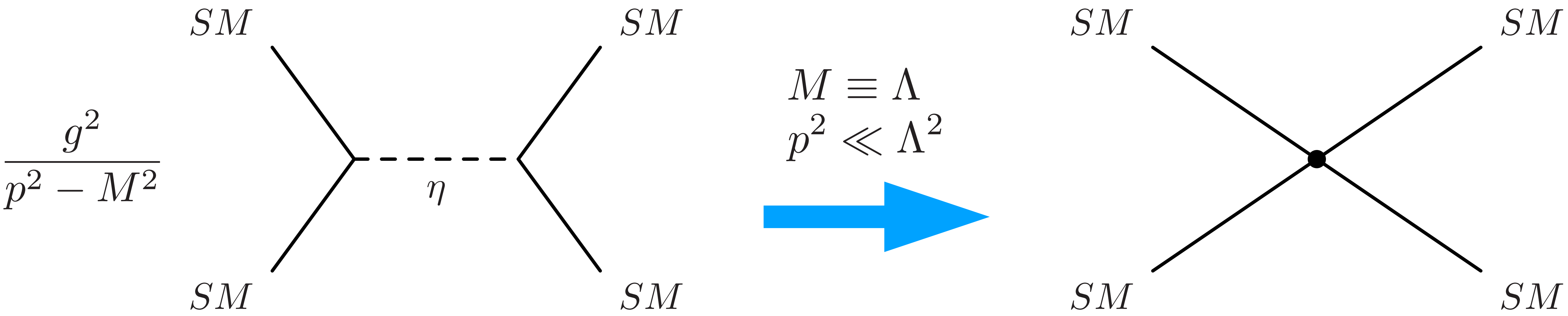

Interaction can be described without explicit presence of new states!

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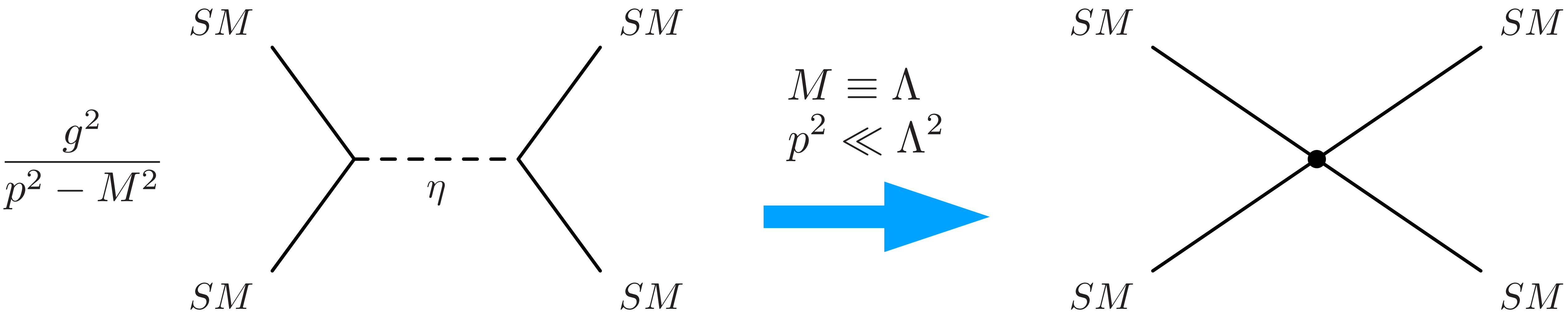

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$$M \equiv \Lambda$$
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Interaction can be described without explicit presence of new states!

New framework → **Effective Field Theory**

Input assumptions

SMEFT fits are highly dependent on several input assumptions

Flavour assumptions

EW input scheme

EFT truncation

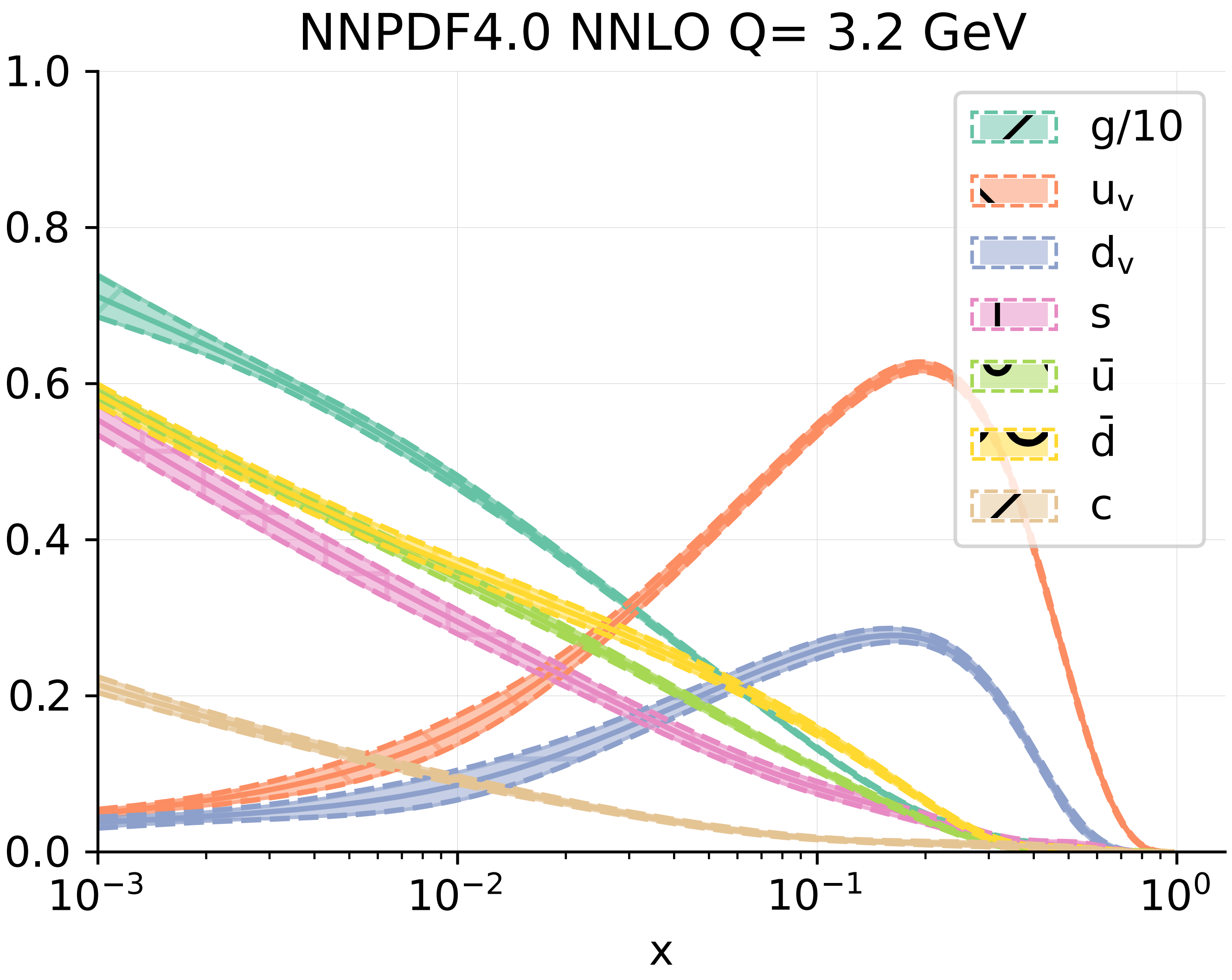
SMEFT fits are highly dependent on several input assumptions

Flavour assumptions

EW input scheme

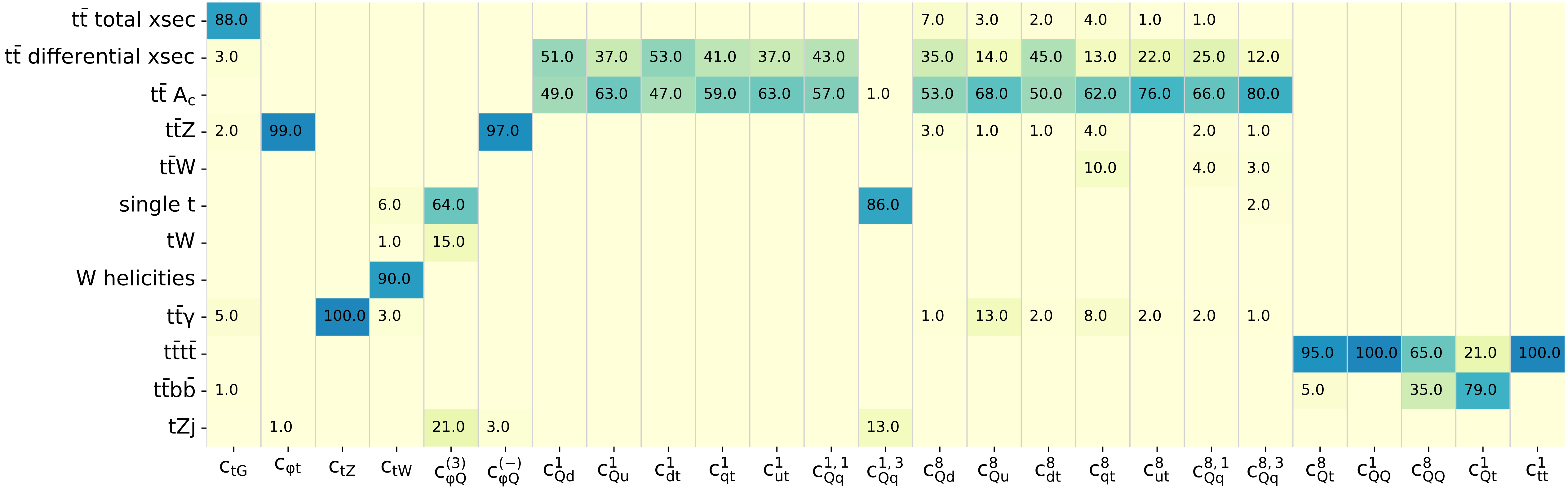
EFT truncation

Parton distribution functions



Ball et. al, NNPDF4.0, 2109.02653

fixed-PDF EFT fit



	c_{tG}	$c_{\varphi t}$	c_{tZ}	c_{tW}	$c_{\varphi Q}^{(3)}$	$c_{\varphi Q}^{(-)}$	c_{Qd}^{1}	c_{Qu}^{1}	c_{dt}^{1}	c_{qt}^{1}	c_{ut}^{1}	$c_{Qq}^{1,1}$	$c_{Qq}^{1,3}$	c_{Qd}^{8}	c_{Qu}^{8}	c_{dt}^{8}	c_{qt}^{8}	c_{ut}^{8}	$c_{Qq}^{8,1}$	$c_{Qq}^{8,3}$	c_{Qt}^{8}	c_{QQ}^{1}	c_{QQ}^{8}	c_{Qt}^{1}	c_{tt}^{1}
$t\bar{t}$ total xsec	88.0													7.0	3.0	2.0	4.0	1.0	1.0						
$t\bar{t}$ differential xsec	3.0						51.0	37.0	53.0	41.0	37.0	43.0		35.0	14.0	45.0	13.0	22.0	25.0	12.0					
$t\bar{t}$ A_c							49.0	63.0	47.0	59.0	63.0	57.0	1.0	53.0	68.0	50.0	62.0	76.0	66.0	80.0					
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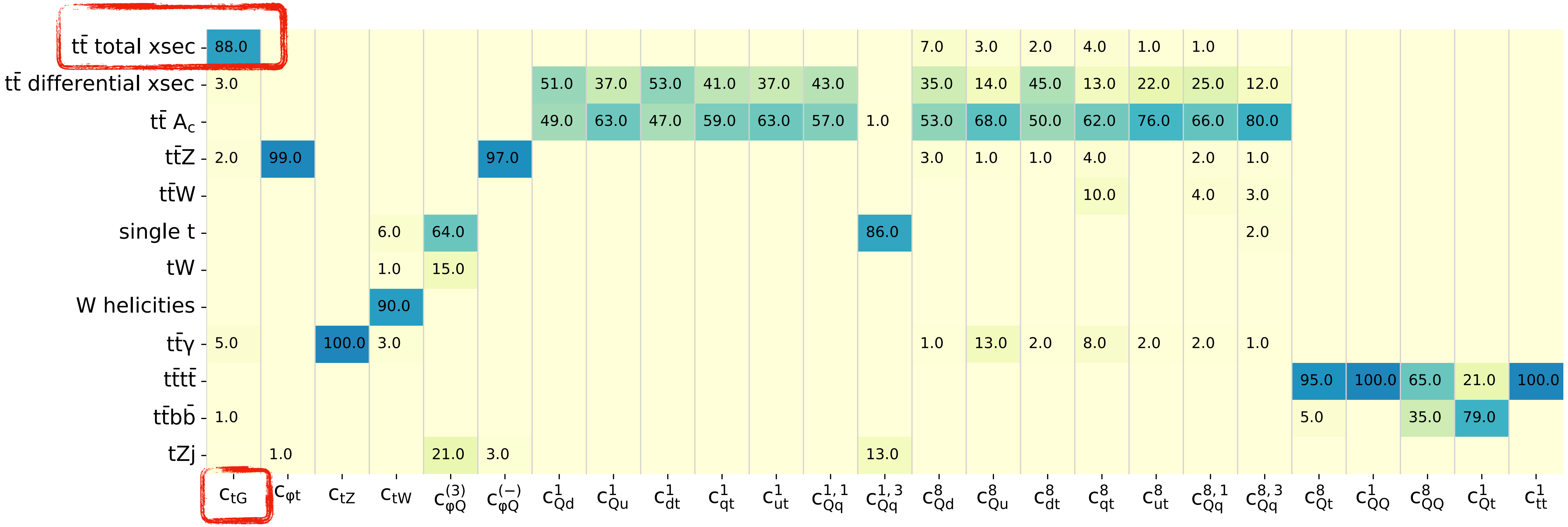
tZj		1.0			21.0	3.0							13.0												

$$F_{ii}(D)\Big/\sum_{\text{sectors }D'}F_{ii}(D')$$

fixed-PDF EFT fit



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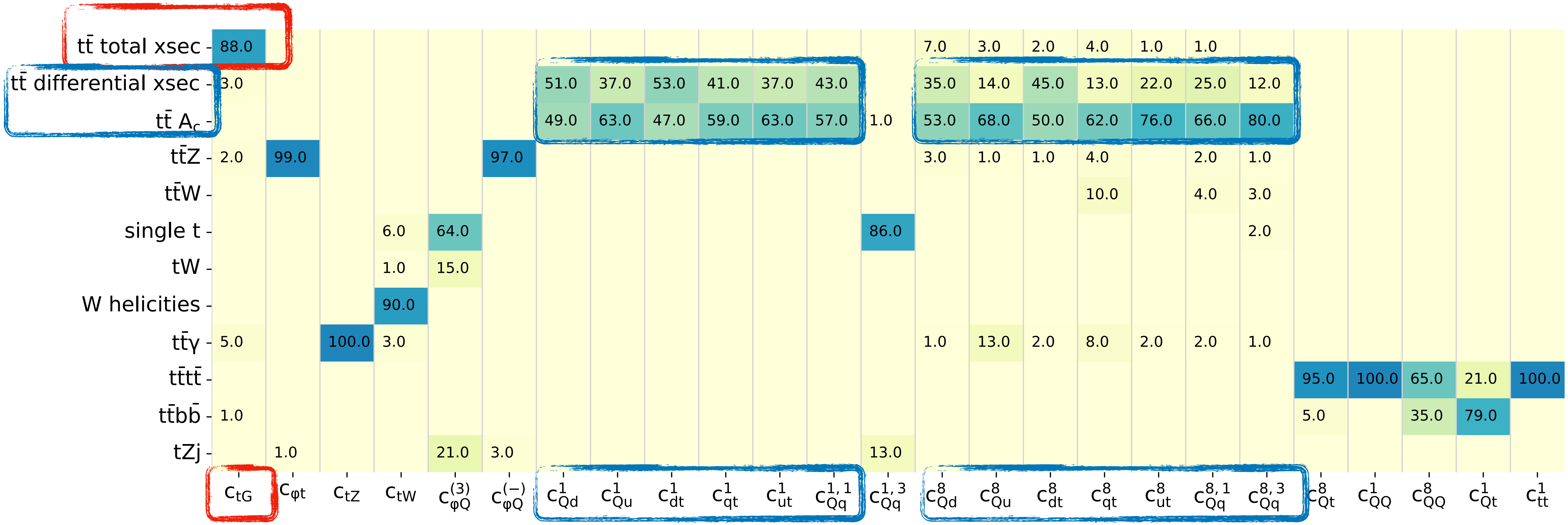
fixed-PDF EFT fit

Luca Mantani



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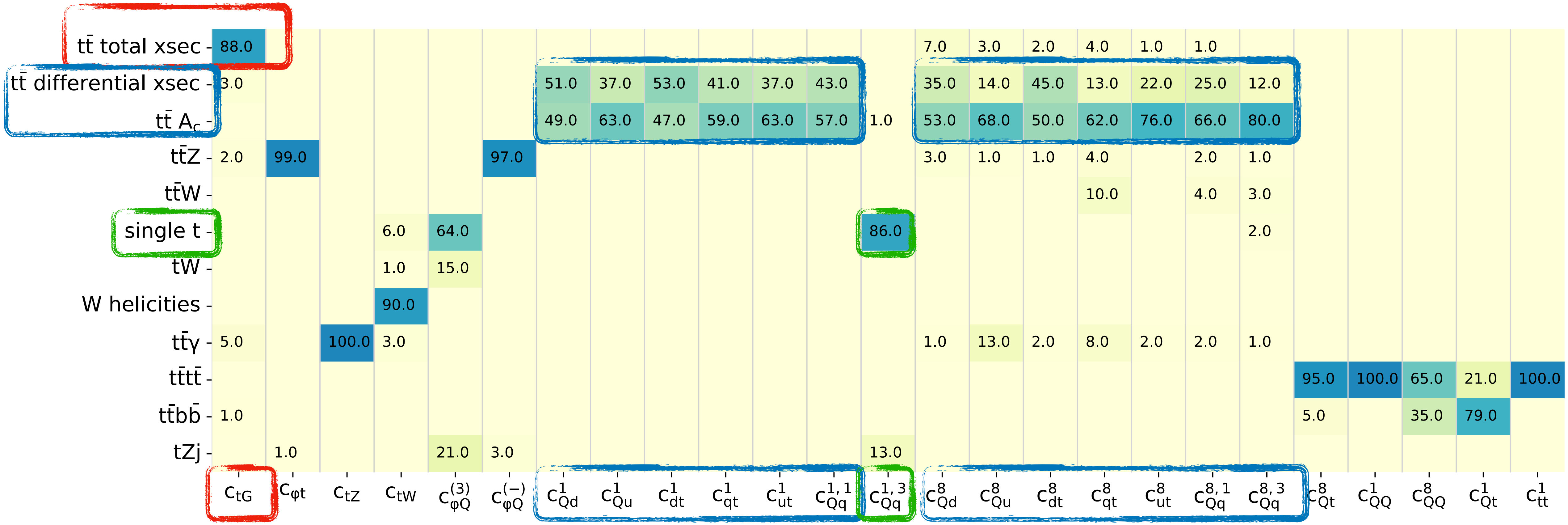
fixed-PDF EFT fit



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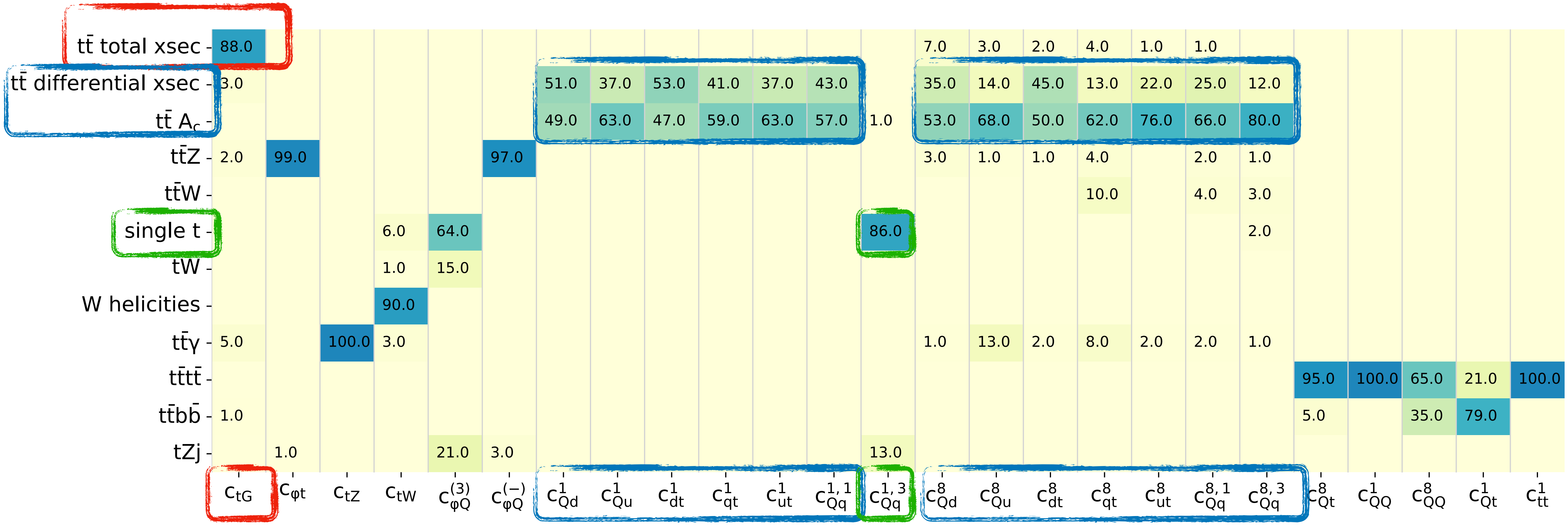
fixed-PDF EFT fit

Luca Mantani



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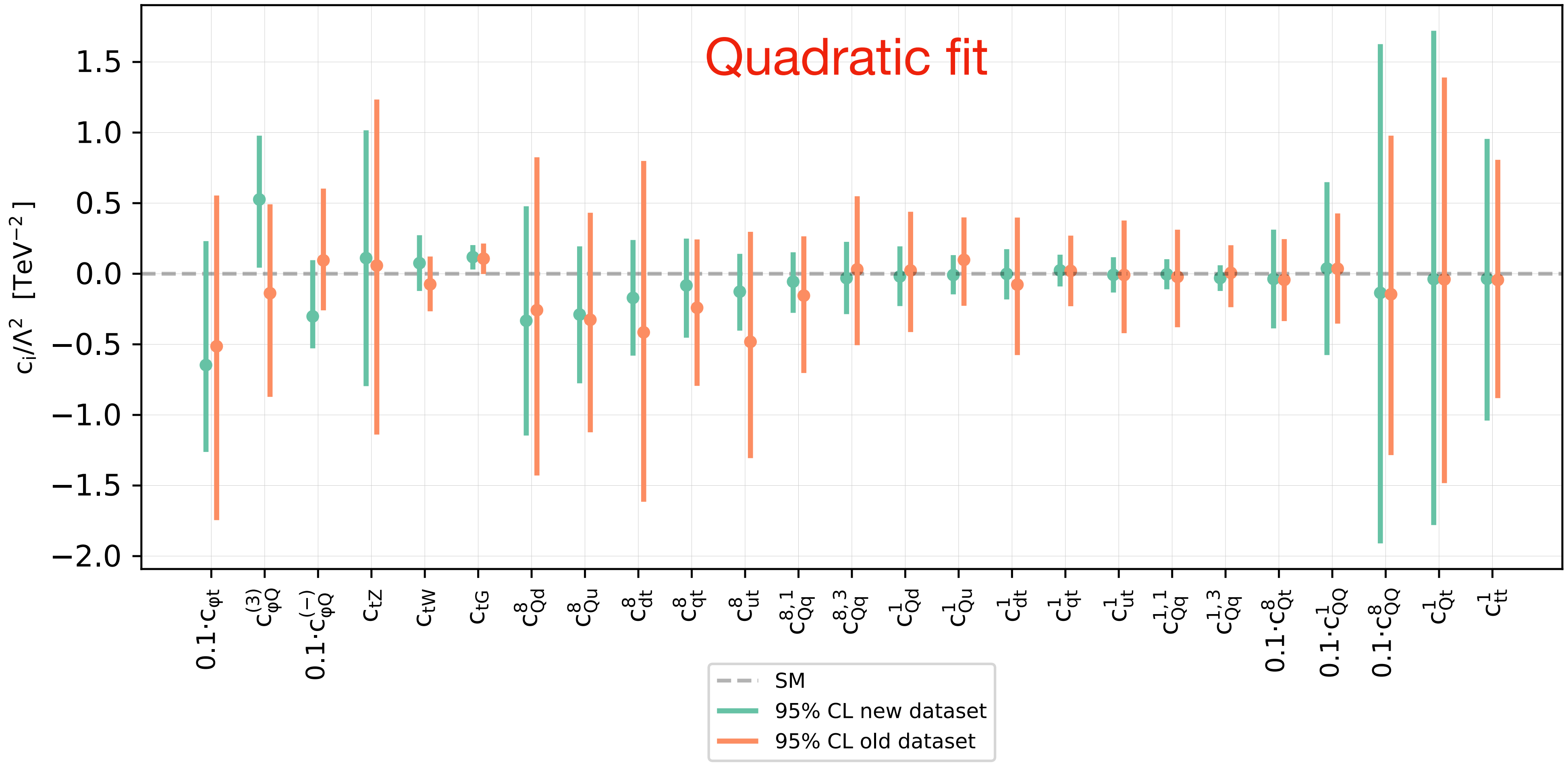

Performed with NS in SMEFiT

High mass DY tails

Particularly interesting sector: **Drell-Yan**

- Used in PDFs to extract information on high-x valence quarks
- Used in SMEFT interpretations to constrain 4F operators

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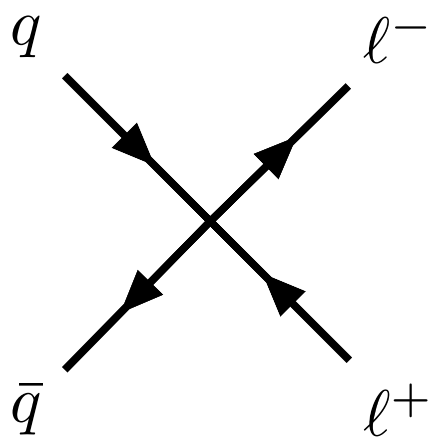
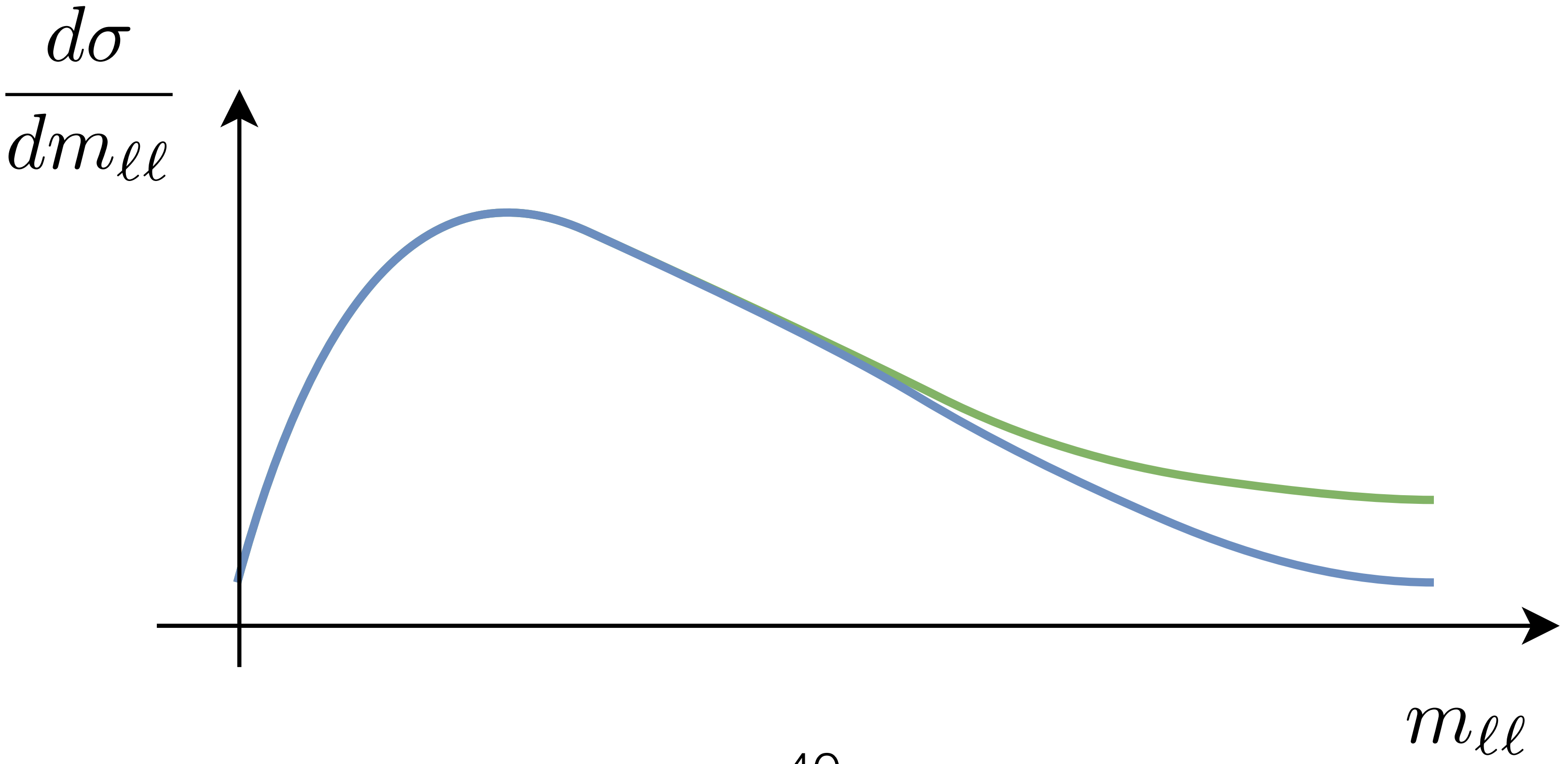


$$\mathcal{A} \sim \mathcal{A}_{\mathrm{SM}} + C\,\frac{E^2}{\Lambda^2}$$



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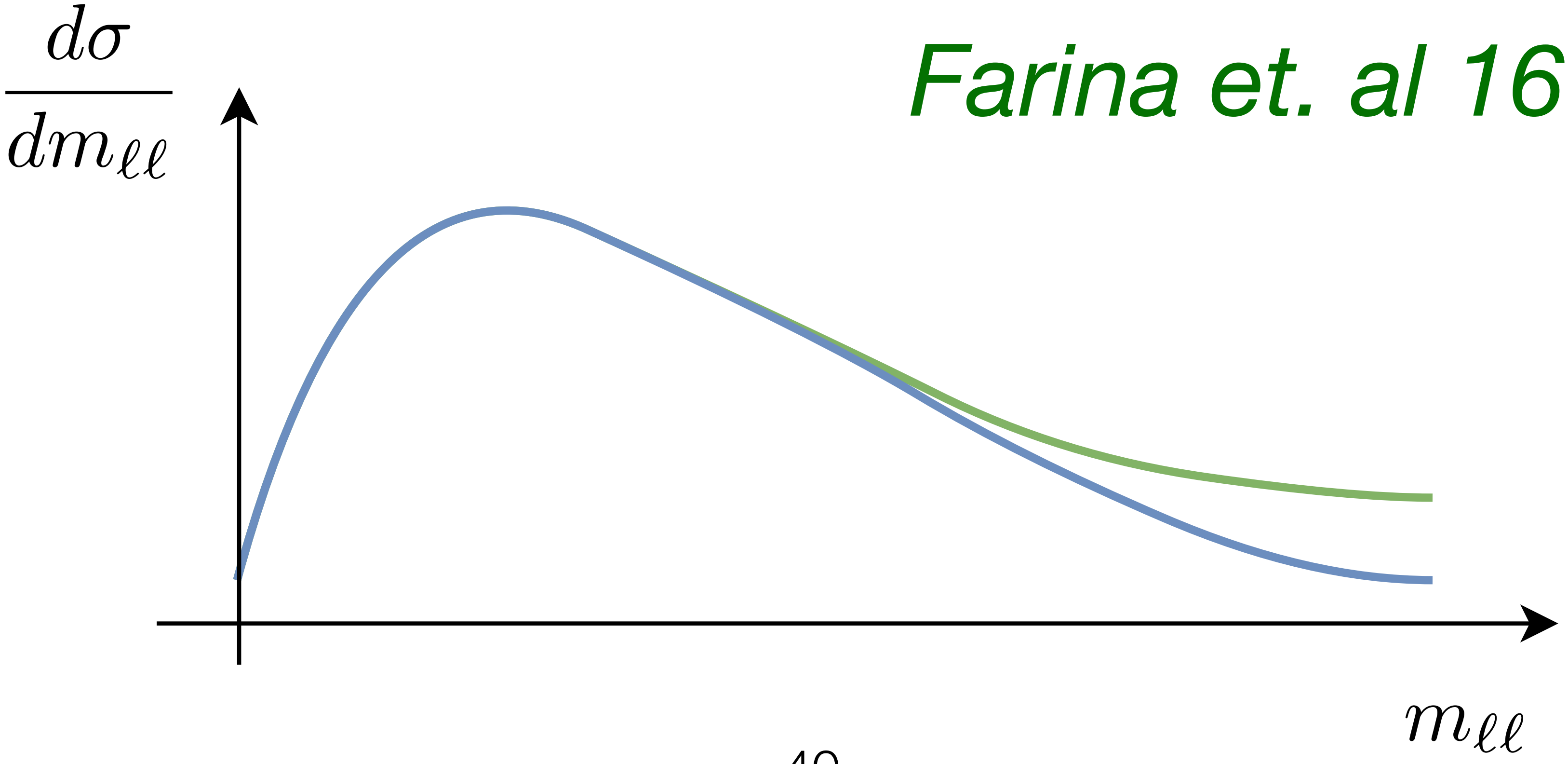
- Used in SMEFT interpretations to constrain 4F operators

Energy helps accuracy

Farina et. al 1609.08157



Quadratic fits: a challenge

Let’s consider a simple scenario: 1 operator, 1 datapoint

$$\chi^2 = \frac{(\sigma(c) - \sigma_{exp})^2}{\delta\sigma^2} \qquad \Delta\chi^2 = \chi^2 - \chi_{min} = 1$$

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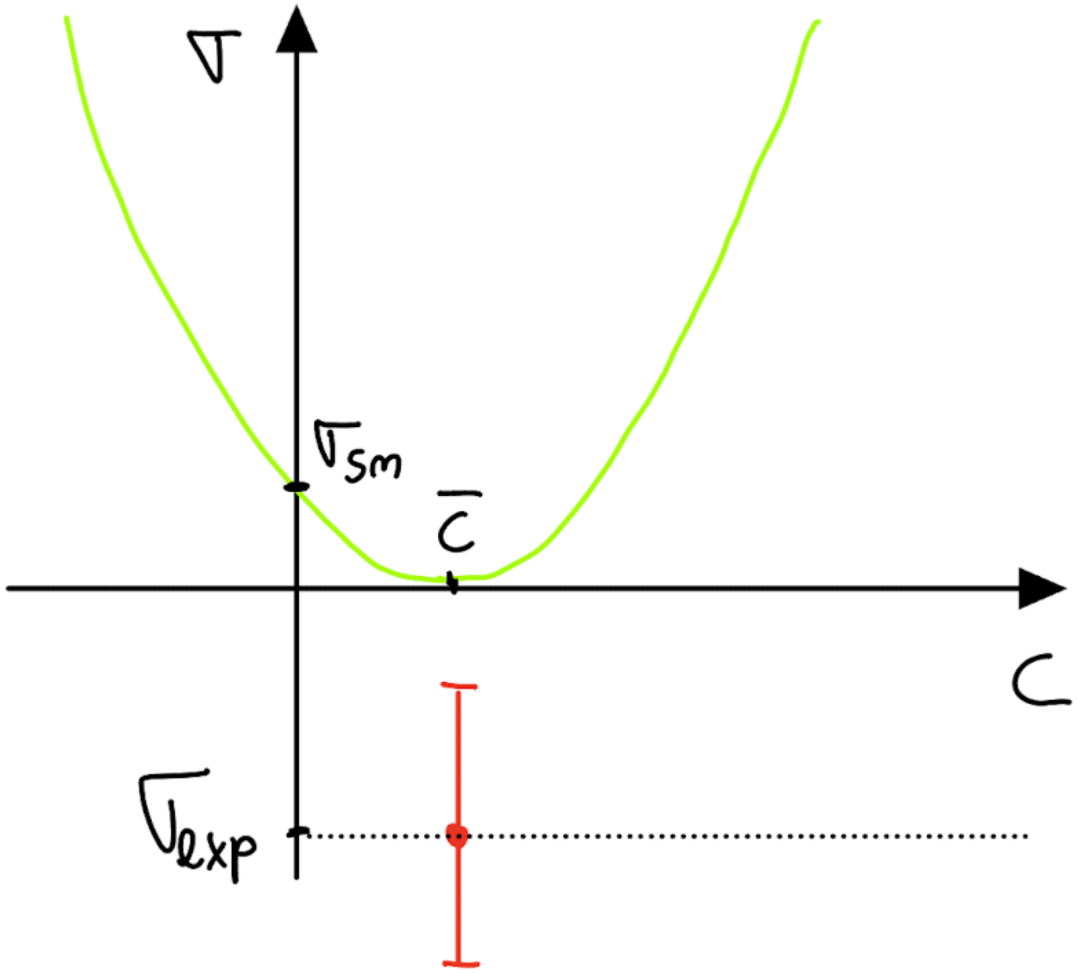

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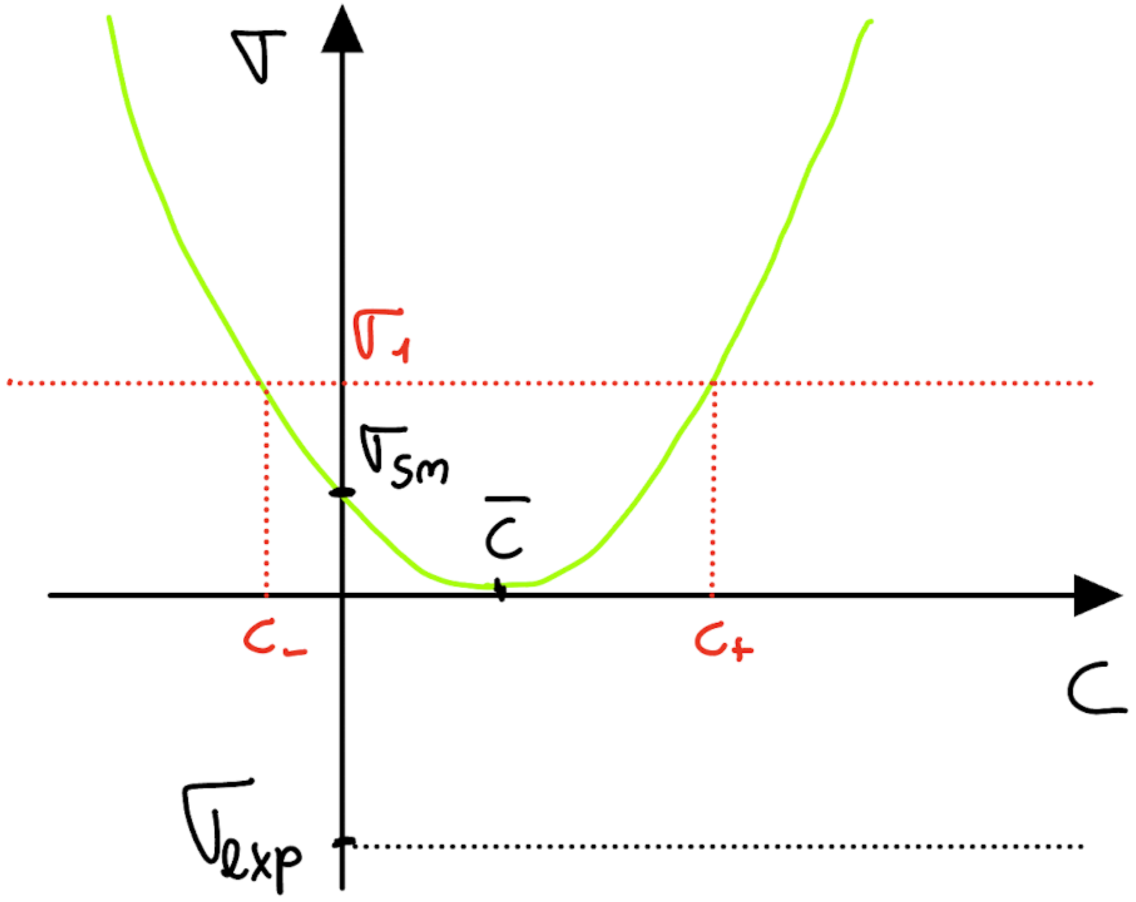
Monte Carlo replica 1



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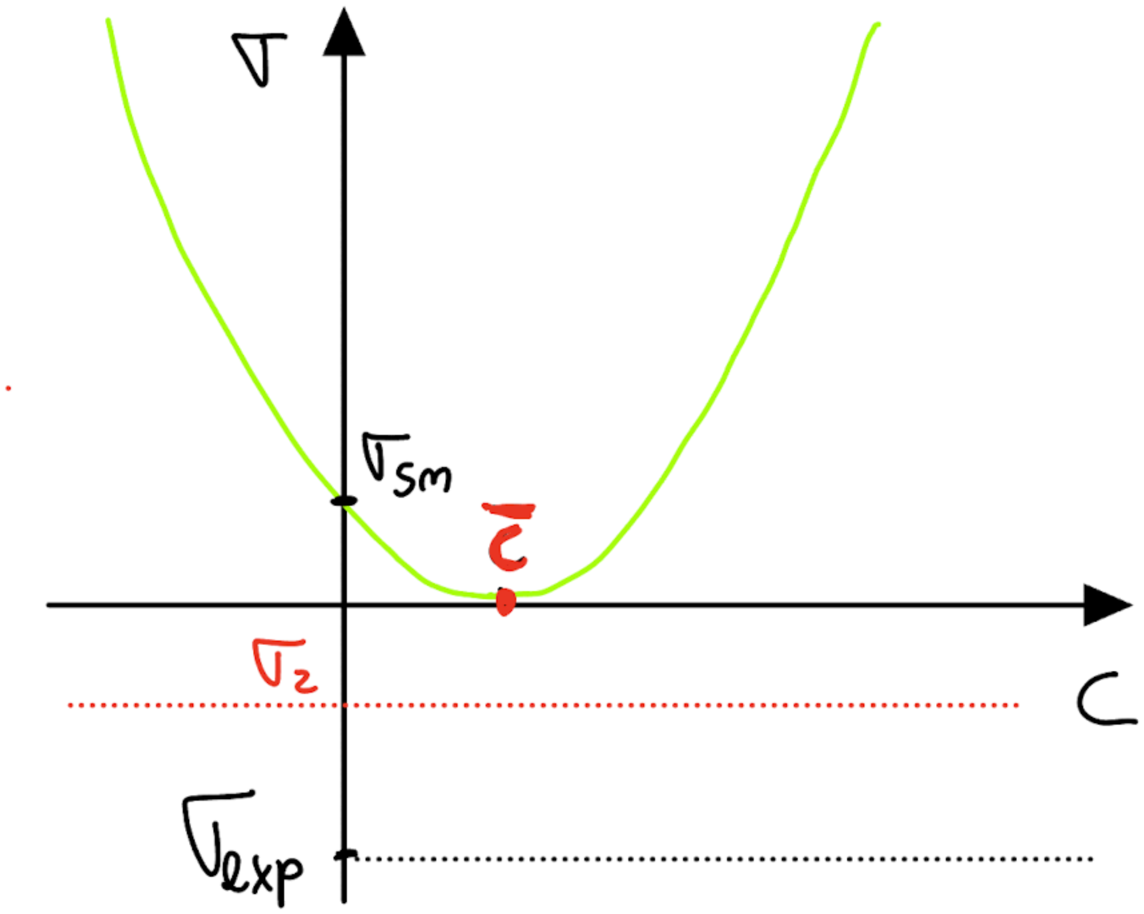
Monte Carlo replica 2



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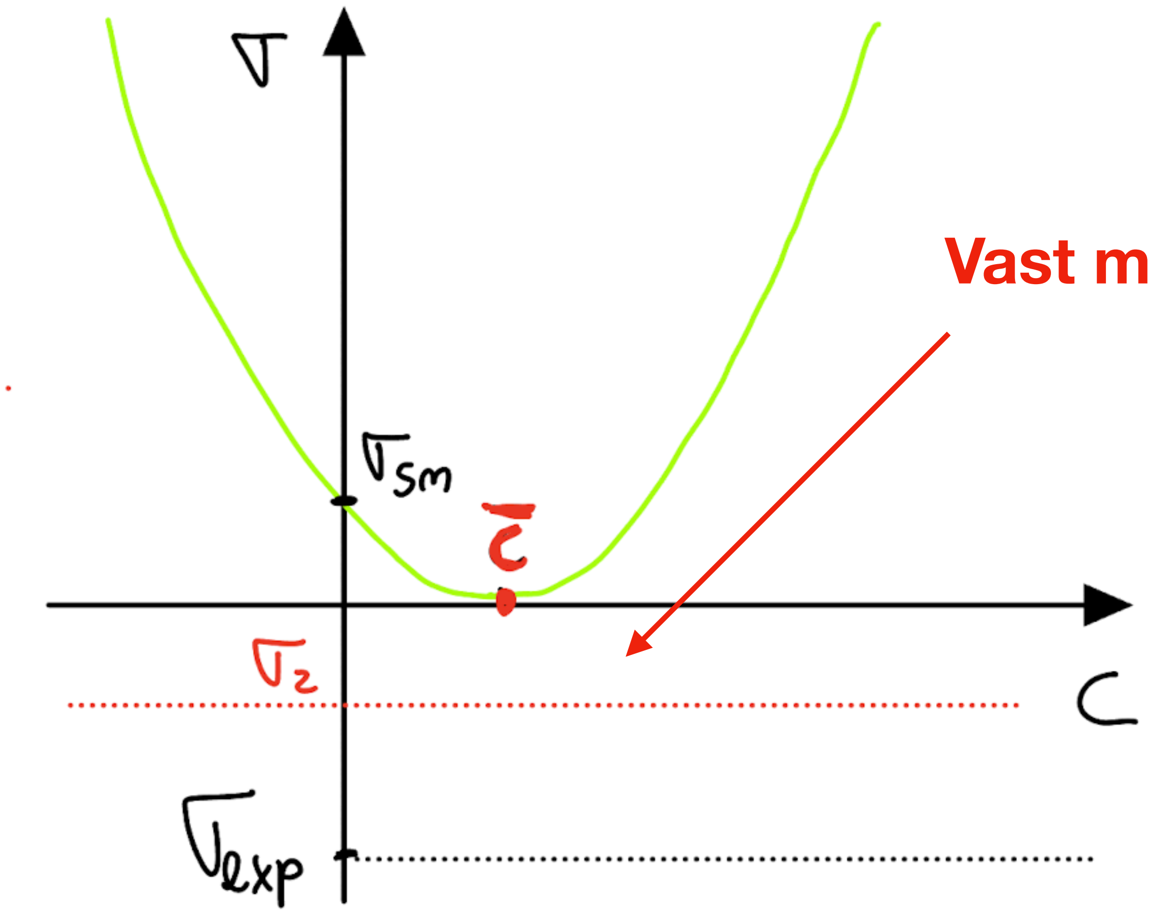
Monte Carlo replica 2



Vast majority

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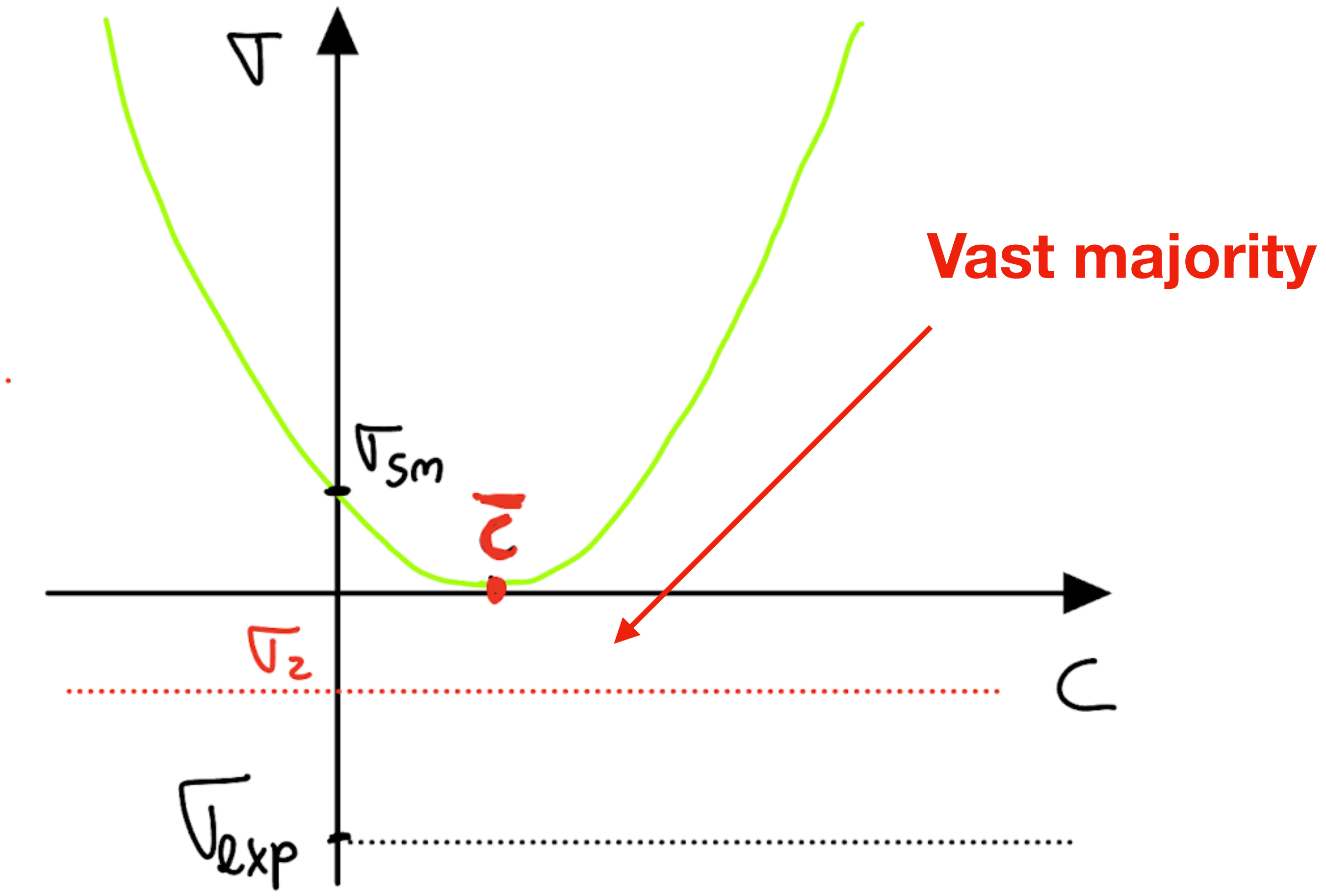
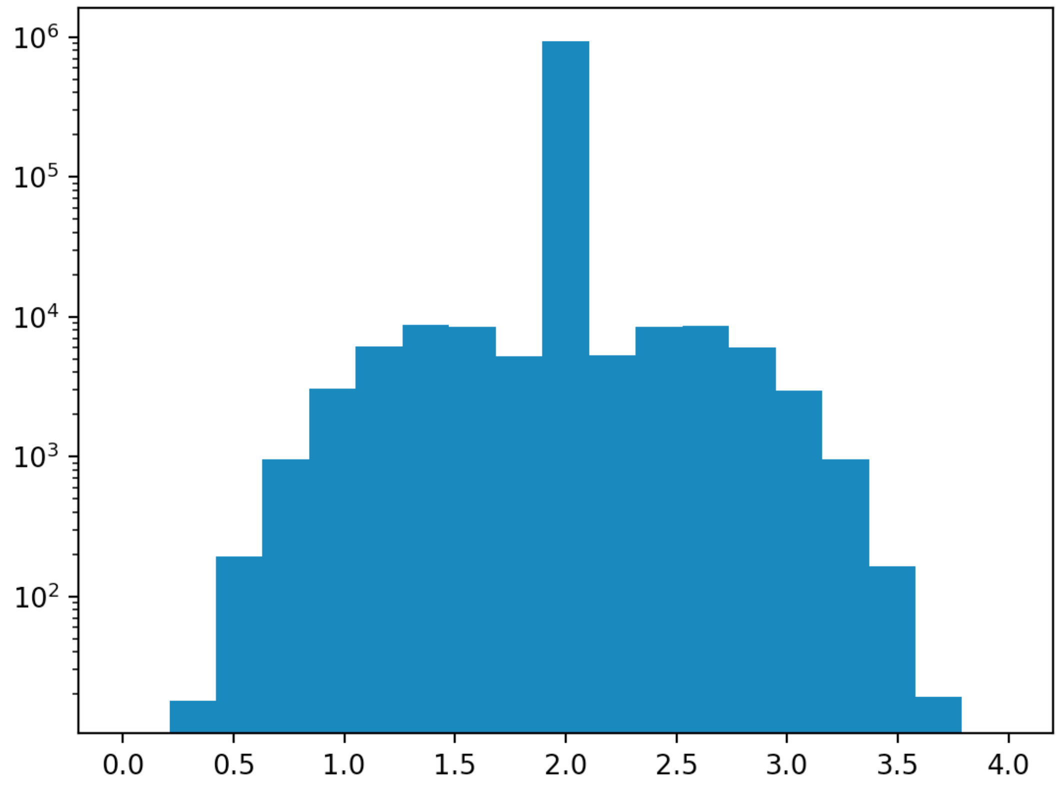
Monte Carlo replica 2



Computed bounds completely wrong:
the spike dominates



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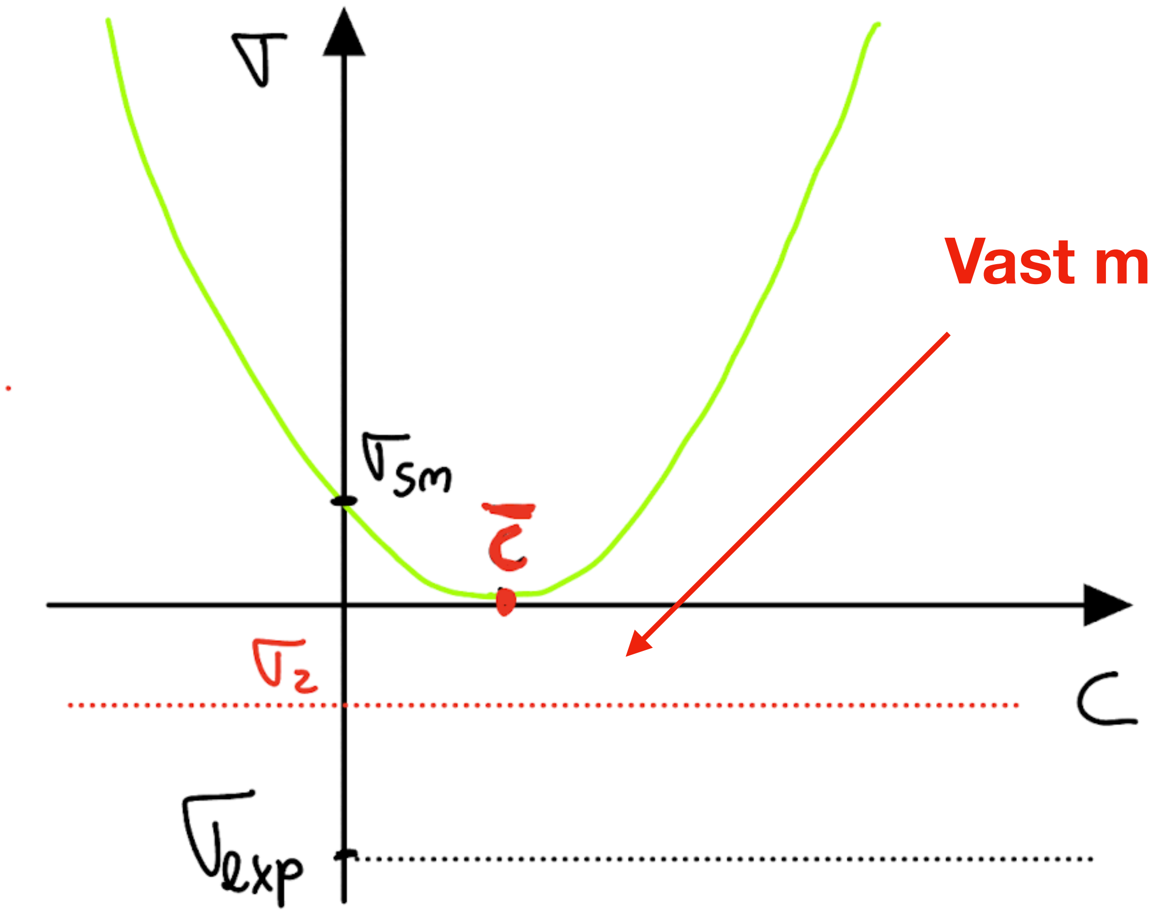

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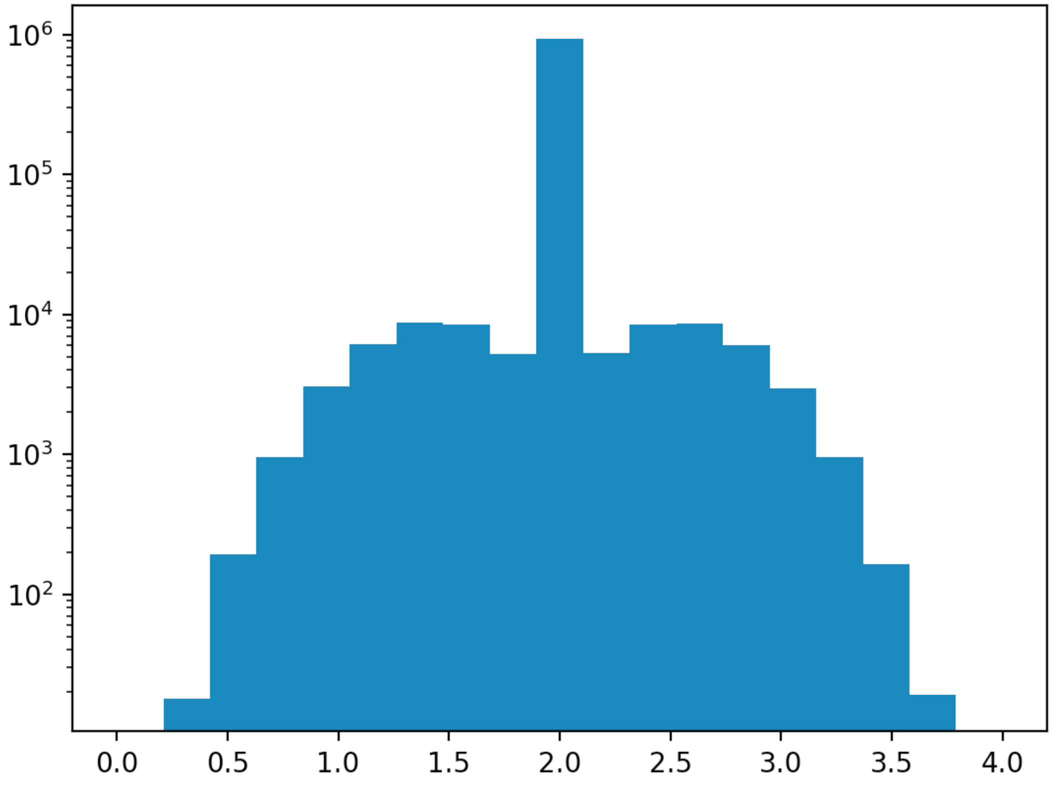
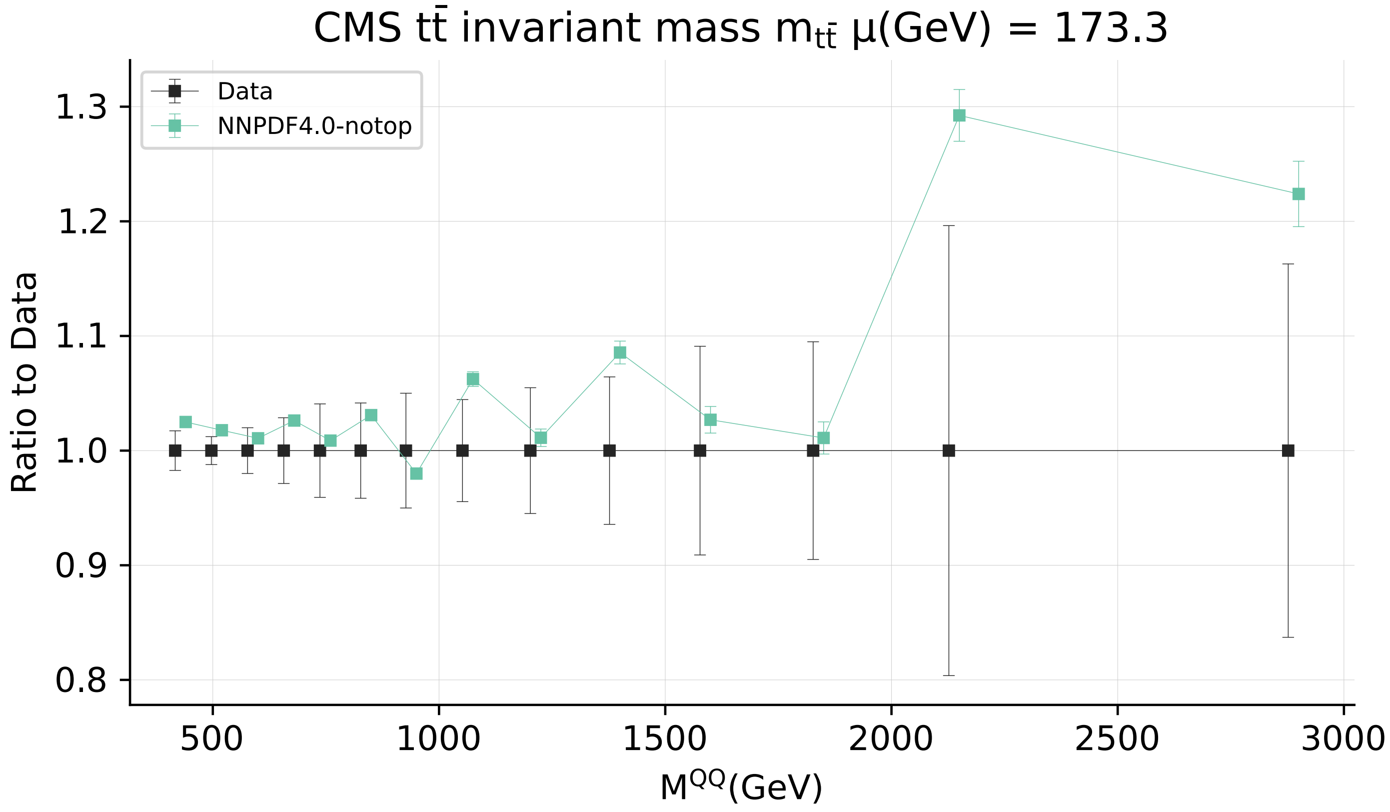


Different approach is needed

Example: CMS Mtt dataset

Luca Mantani



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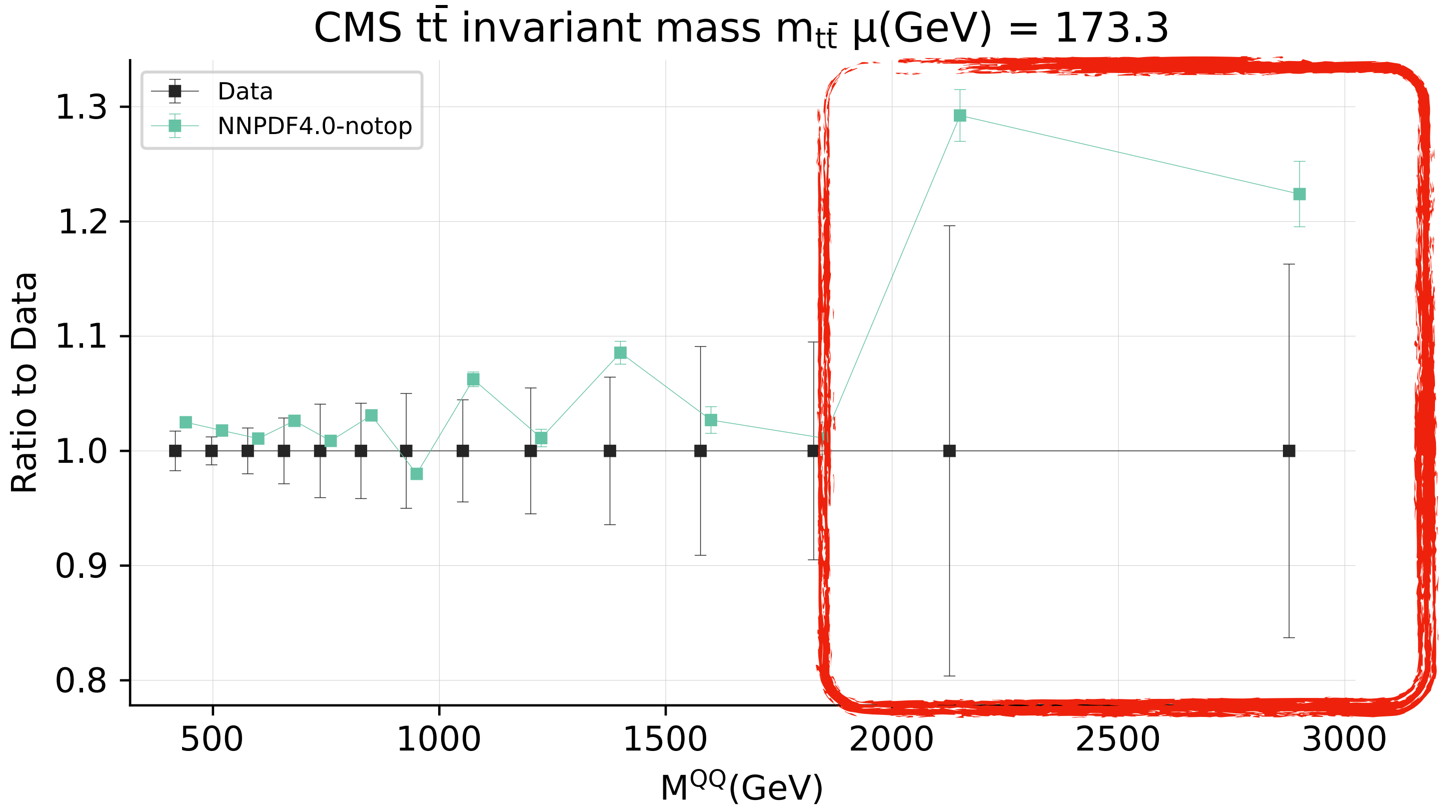
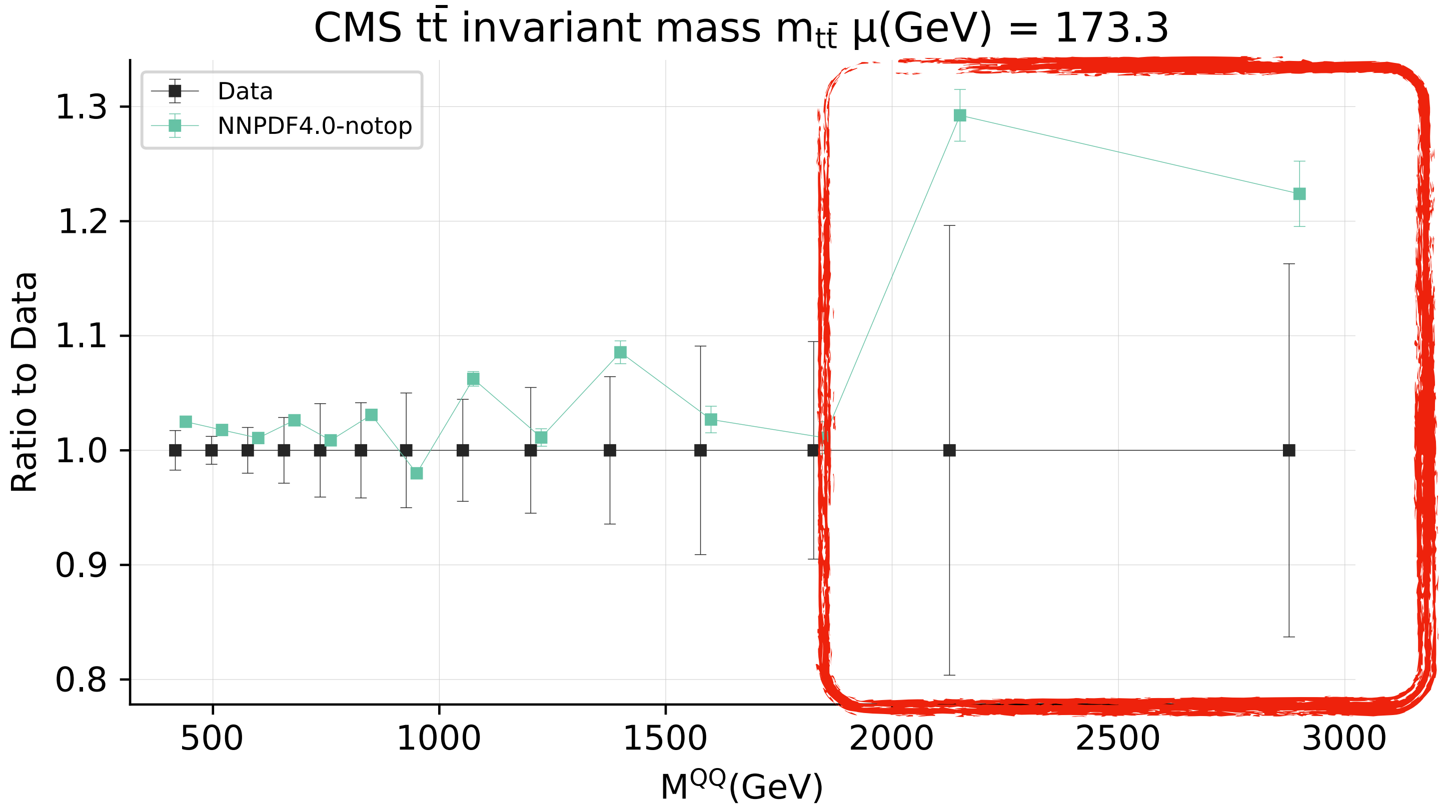


SM overshoots

Example: CMS Mtt dataset



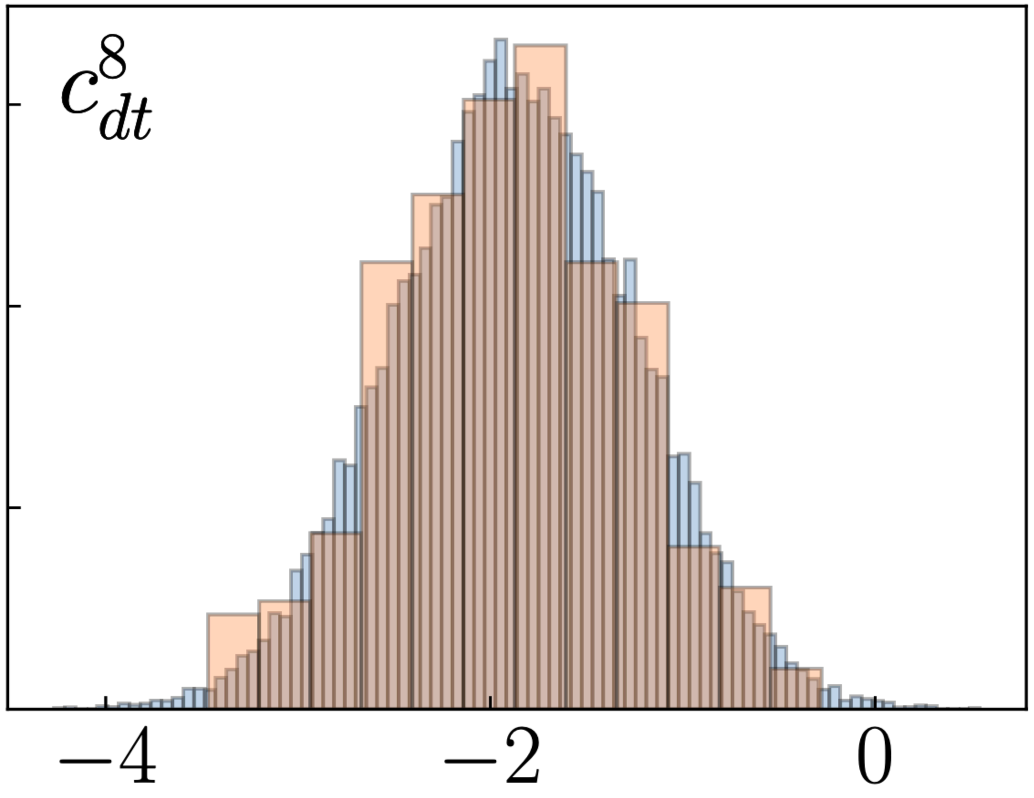
CMS $t\bar{t}$ invariant mass $m_{t\bar{t}}$ μ(GeV) = 173.3

SM overshoots

MC fit

NS fit

Linear fit



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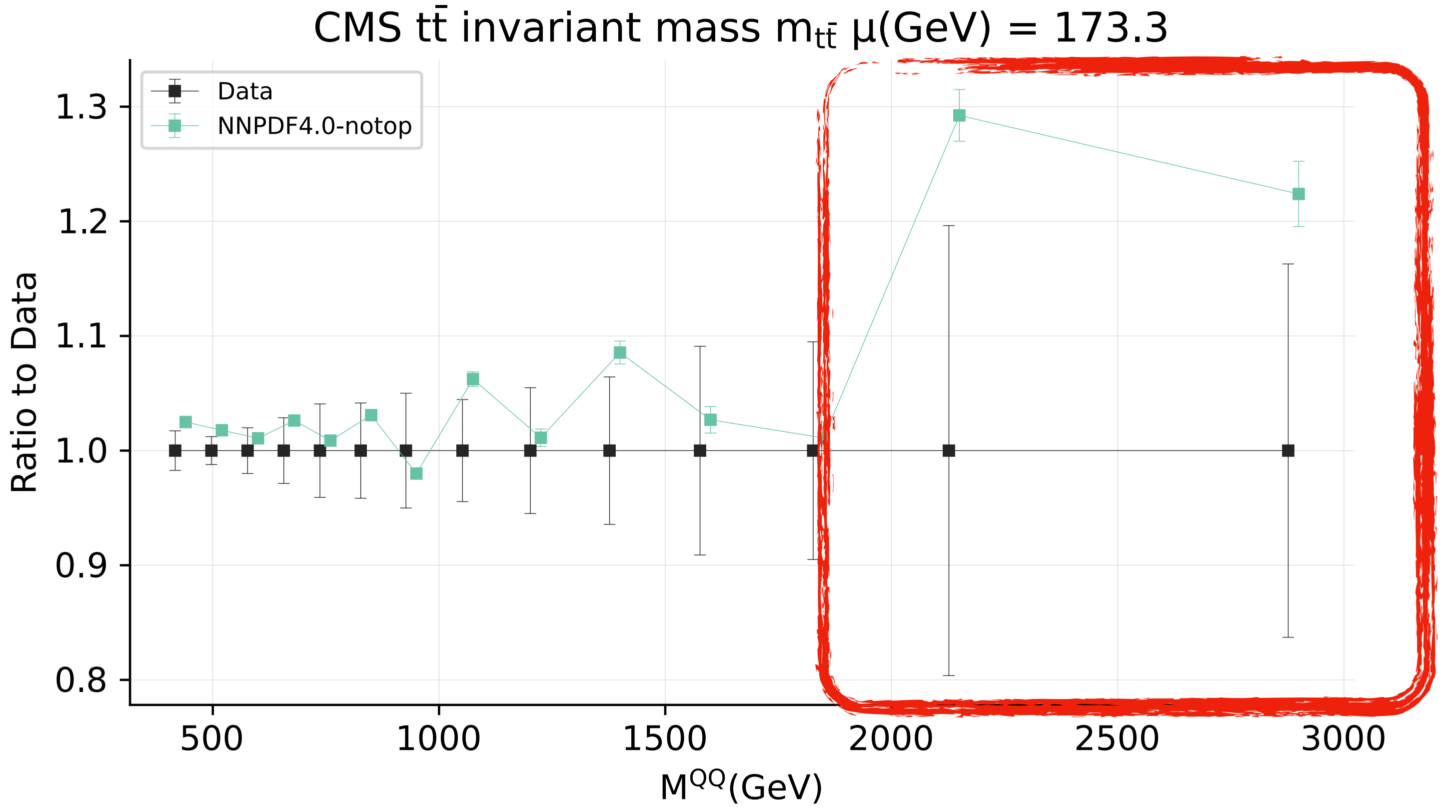

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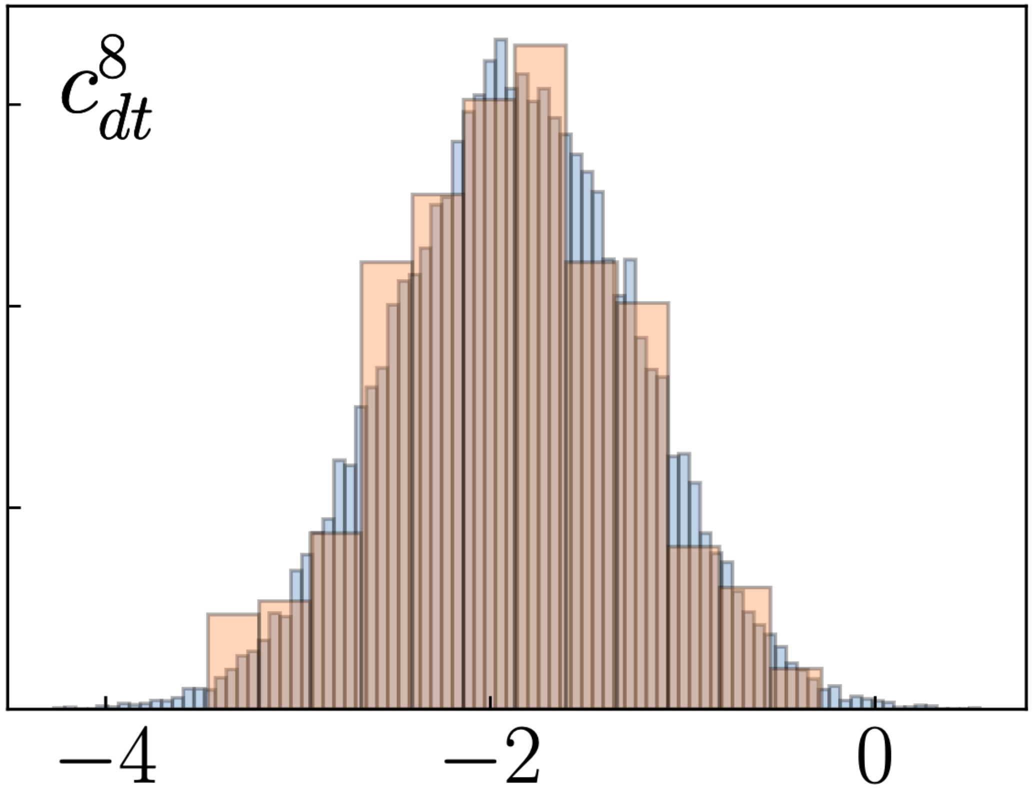

Quadratic fit