xFitter ACOT: NC at NLO, N2LO, N3LO

…

Updates and advice needed

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SMU

Heavy Quark Production in the ACOT Scheme at NNLO and N3LO

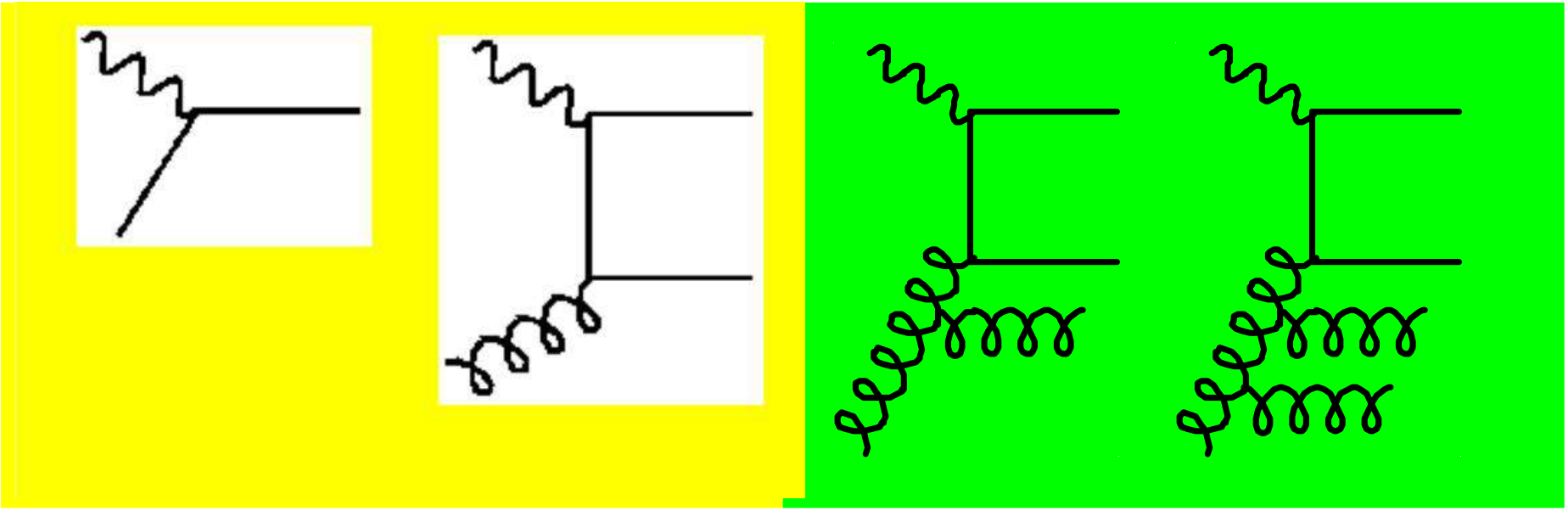
T. Stavreva, F. I. Olness, I. Schienbein, T. Jezo, A. Kusina, K. Kovarik, J. Y. Yu

https://doi.org/10.48550/arXiv.1203.0282
Phys. Rev. D 85, 114014 (2012)

xFitter
09 Aug 2023

ACOT Extension to Higher Orders

LO **NLO** **N2LO** **N3LO**



Full ACOT *Extensible to any order*

$$\sigma = f(\xi(x, m_{ps}), Q) \otimes \hat{\sigma}(m_{dyn})$$

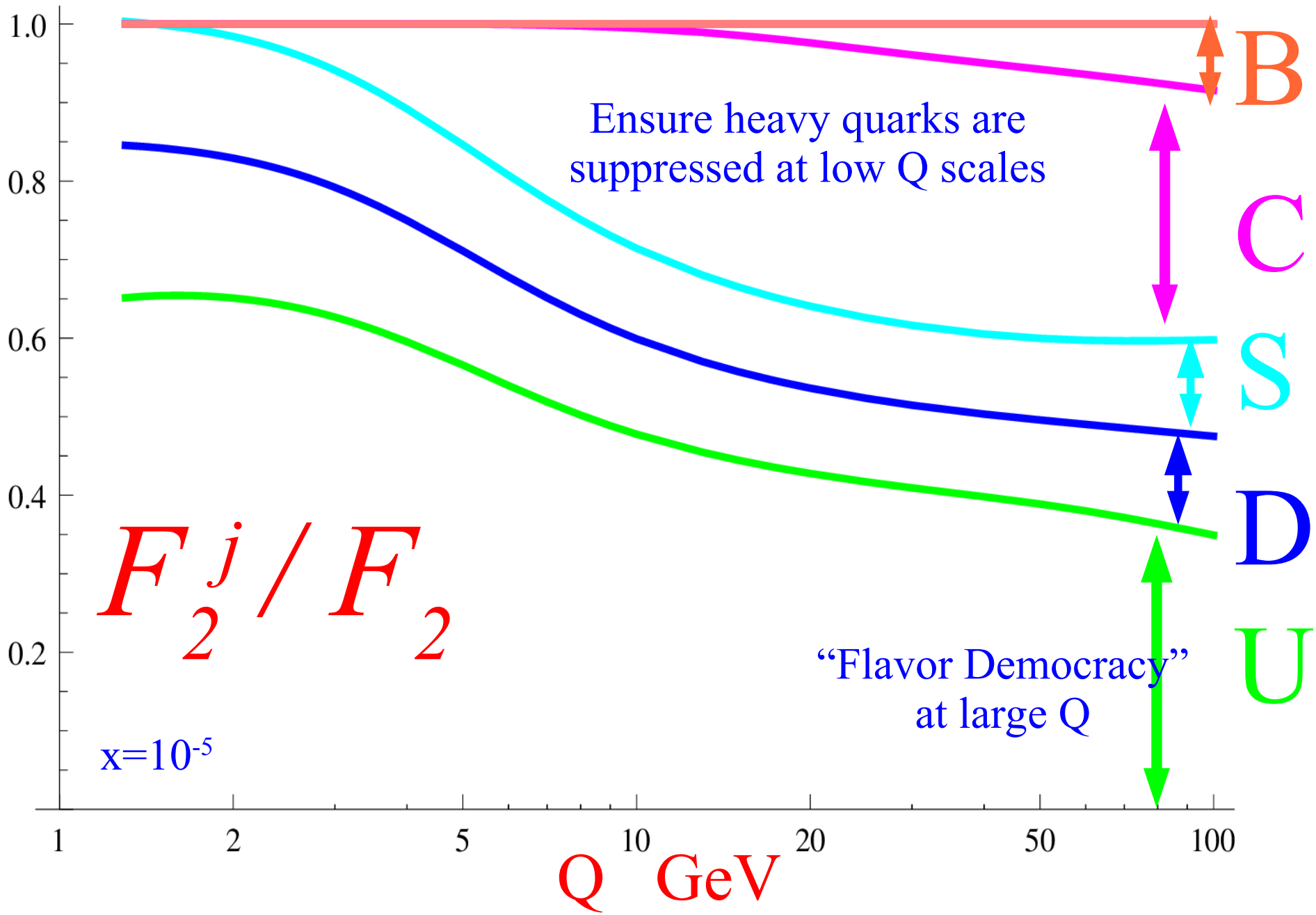
$$\xi(x, m_{ps}) = x\left(1 + \left[\frac{n\, m_{ps}}{Q}\right]^2\right)$$

$$n = \{0, 1, 2\}$$

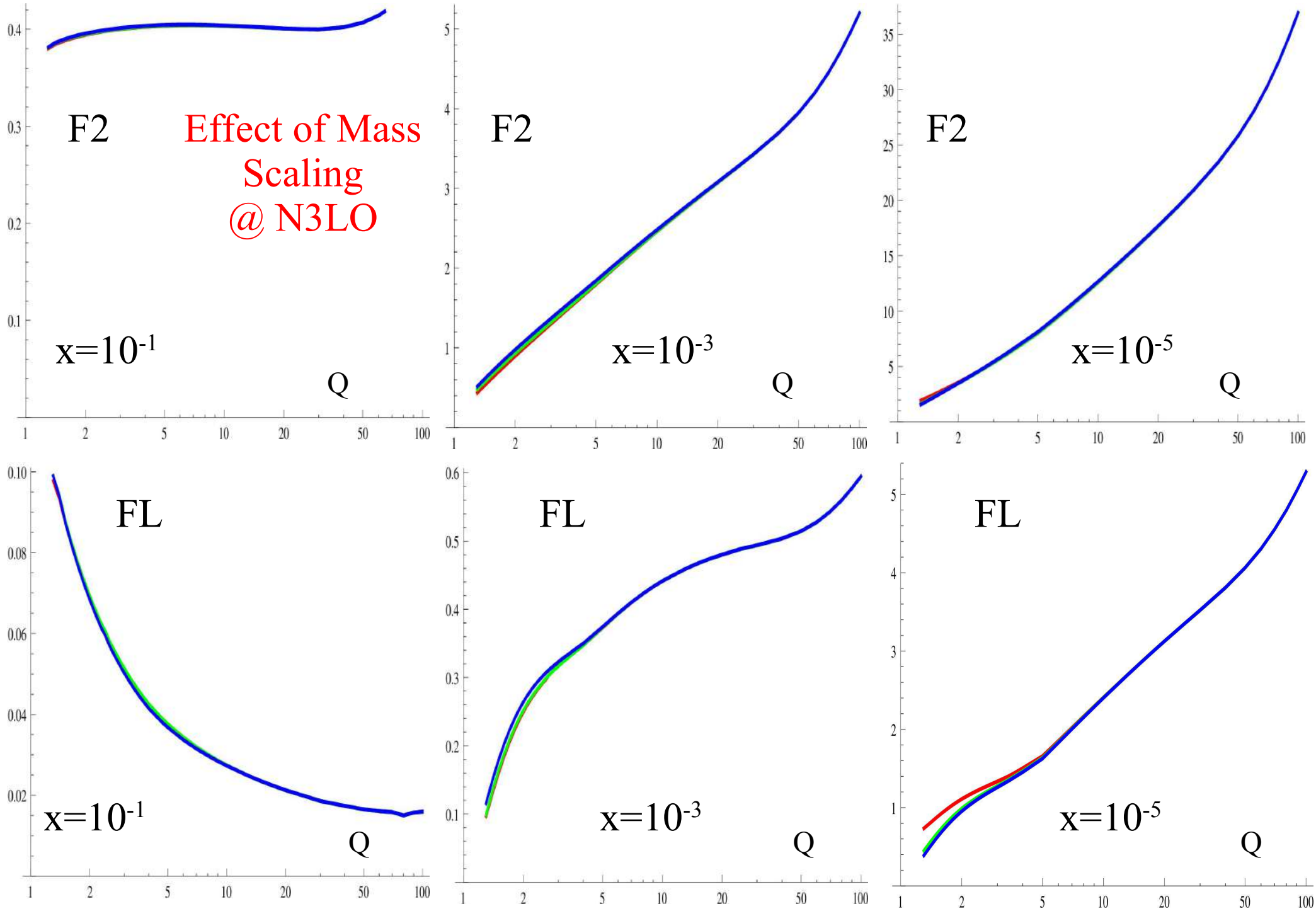
Distinguish:
"phase space" mass
"dynamic" mass

Demonstrate:
1) PS mass dominates
2) Estimated Error small

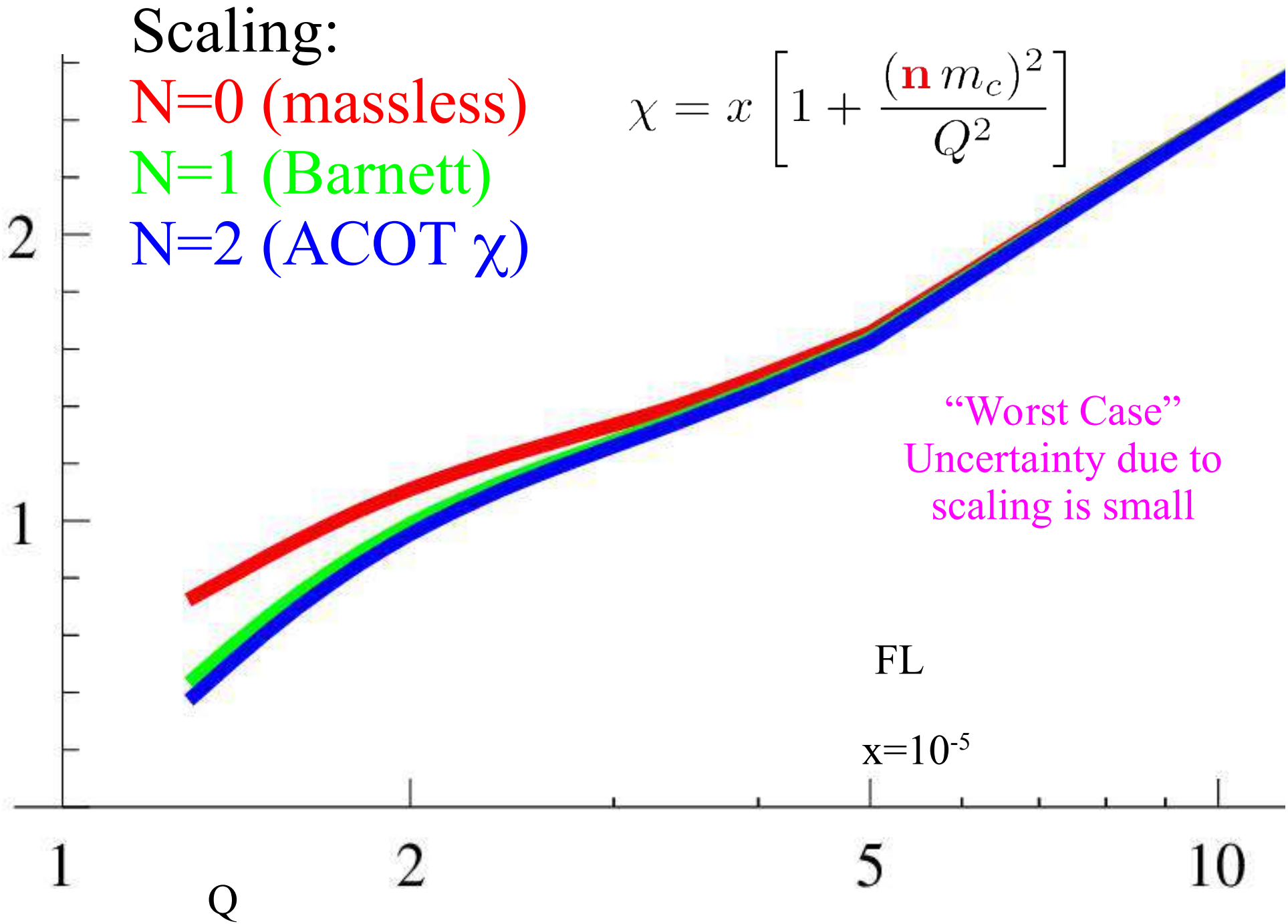
FLAVOR DECOMPOSITION



EFFECT OF MASS SCALING @ N3LO (Phase Space Mass)



EFFECT OF MASS SCALING @ N3LO (Phase Space Mass)



Questions/Advice:

- Input controlled by ACOT.yaml (need to re-compile)
  - ischeme=9 ACOT-Chi
  - iKfactor: used K-factors to speed up
  - iQCDNUM: For {F2,FL}use QCDNUM for denominator
  - {Kmin,Kmax} limit K-factor

```
#ACOT:              # Reaction-specific settings
  varinacot0 : 0.5      # K-factor min
  varinacot1 : 1.5      # K-factor-max
  varinacot2 : 0.0      # unused
  varinacot3 : 0.0      #  unused

  intvarin0 : 1   #  NORD for calcululation: = [1,2,3]  Note, 2,3 are approximate
  intvarin1 : 9   #  IScheme: 9= preferred ACOT-CHI; [Not used: HFSCHEME_IN ]
  intvarin2 : 1   #  Use K-Factor 1=yes, 0=no
  intvarin3 : 1   #  Use QCDNUM for K-factor denominator: 1=yes,
                          [ 0=no not implemented]
```

Need Advice:

"index" is used to keep track of the K-factor for each experimental point.
We need to reset "index" for each fcn.f call.
Need to do this more elegantly.

fcn.f

```
*     ---------------------------------------------------------
*     Initialise various c++ code per iteration
*     ---------------------------------------------------------
      call init_at_iteration
*     ---------------------------------------------------------
*     ACOT TEMP PATCH
*     ---------------------------------------------------------
      WRITE(6,*) "=========================”
      CALL ACOTindexRESET()
*     ---------------------------------------------------------
*     Calculate theory for datasets:
*     ---------------------------------------------------------
      do idataset=1,NDATASETS
        if(NDATAPOINTS(idataset).gt.0) then
          call GetTheoryForDataset(idataset)
```

ACOTindexRESET()

```
      subroutine ACOTindexRESET()
      implicit none
      integer index
      common /acotIndex/  index

      index=0
      return
      end
```

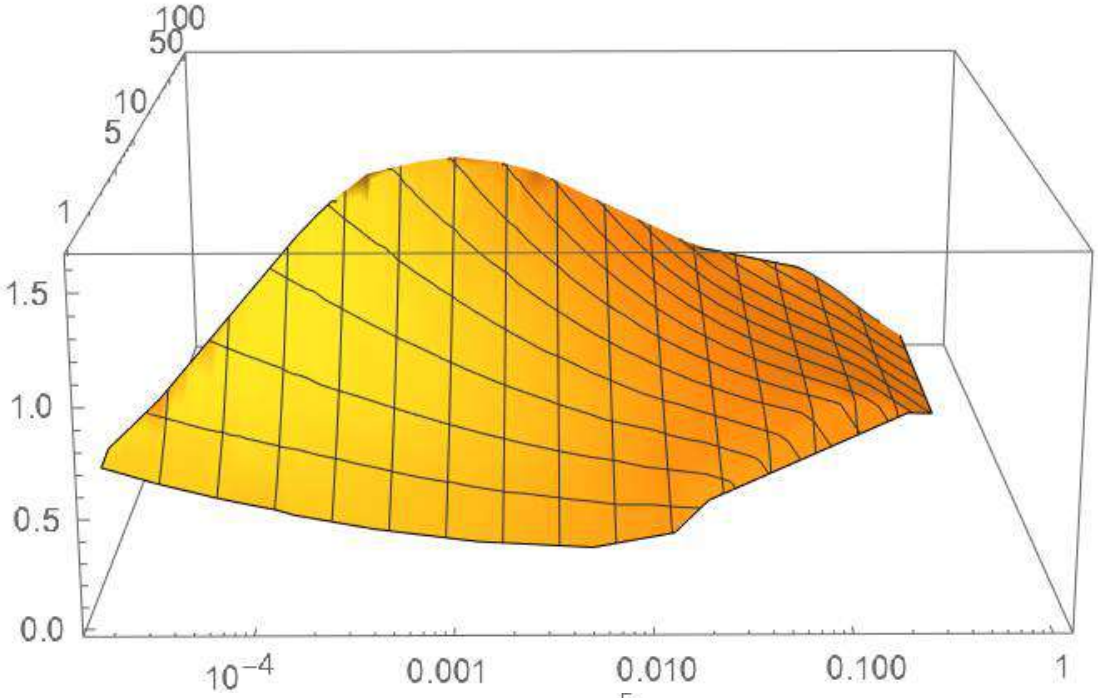
Note: Subroutine ACOT_Set_Input()
is called for EACH data set, so this will not quite work.

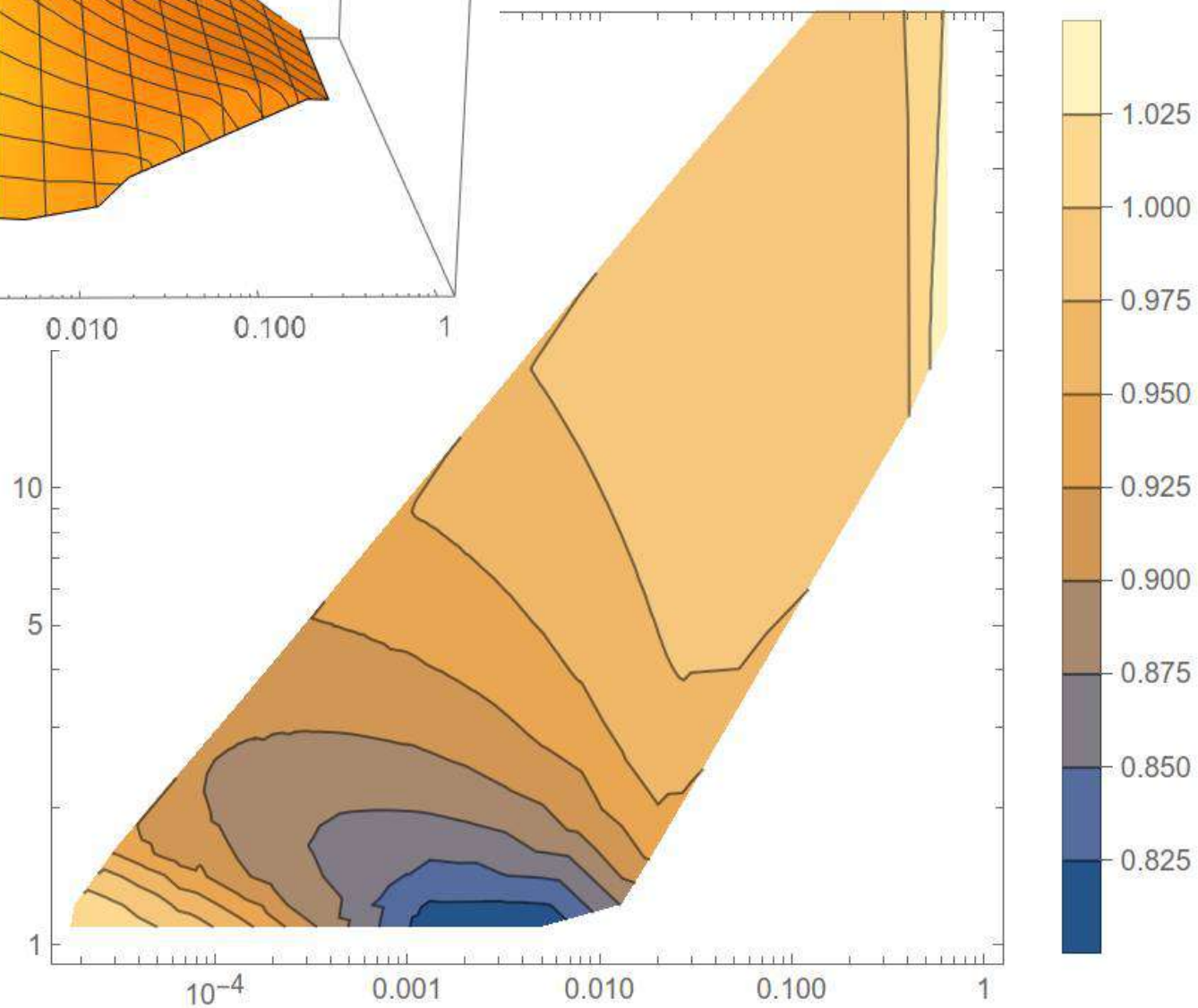
Sanity Checks:

- Check agains MSTW
- Compare nOrd={1,2,3} …. NLO, N2LO, N3LO

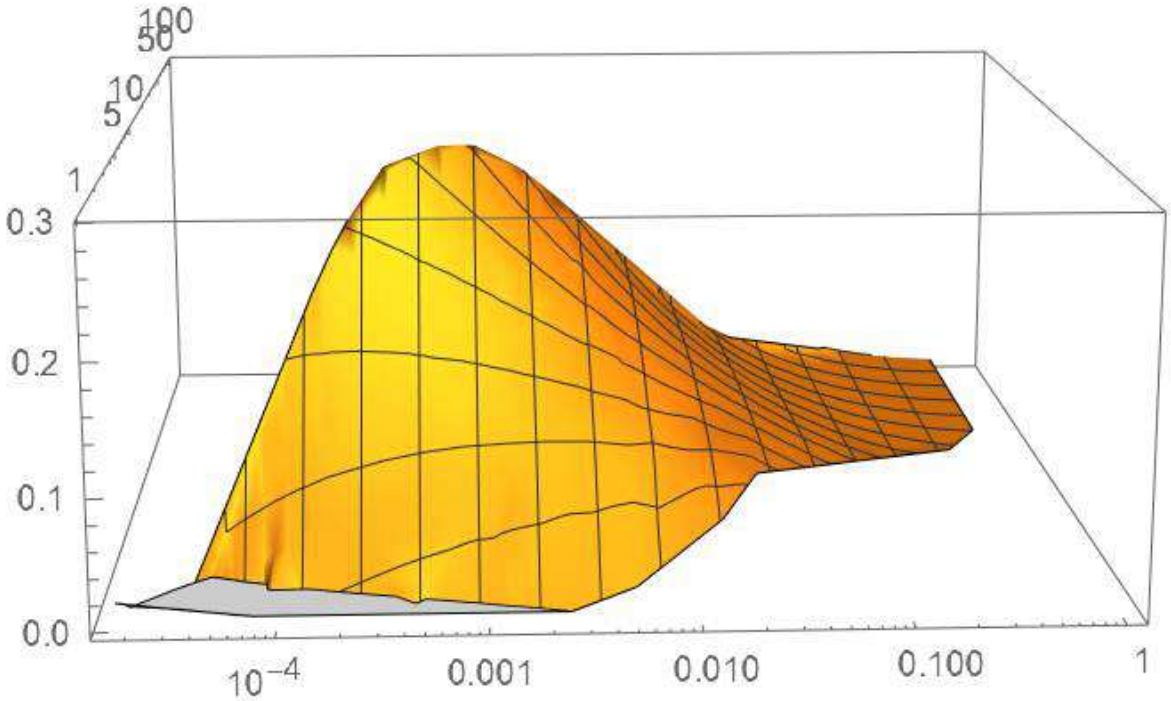
- NC available NLO, N2LO, N3LO
- CC available (not implemented) NLO

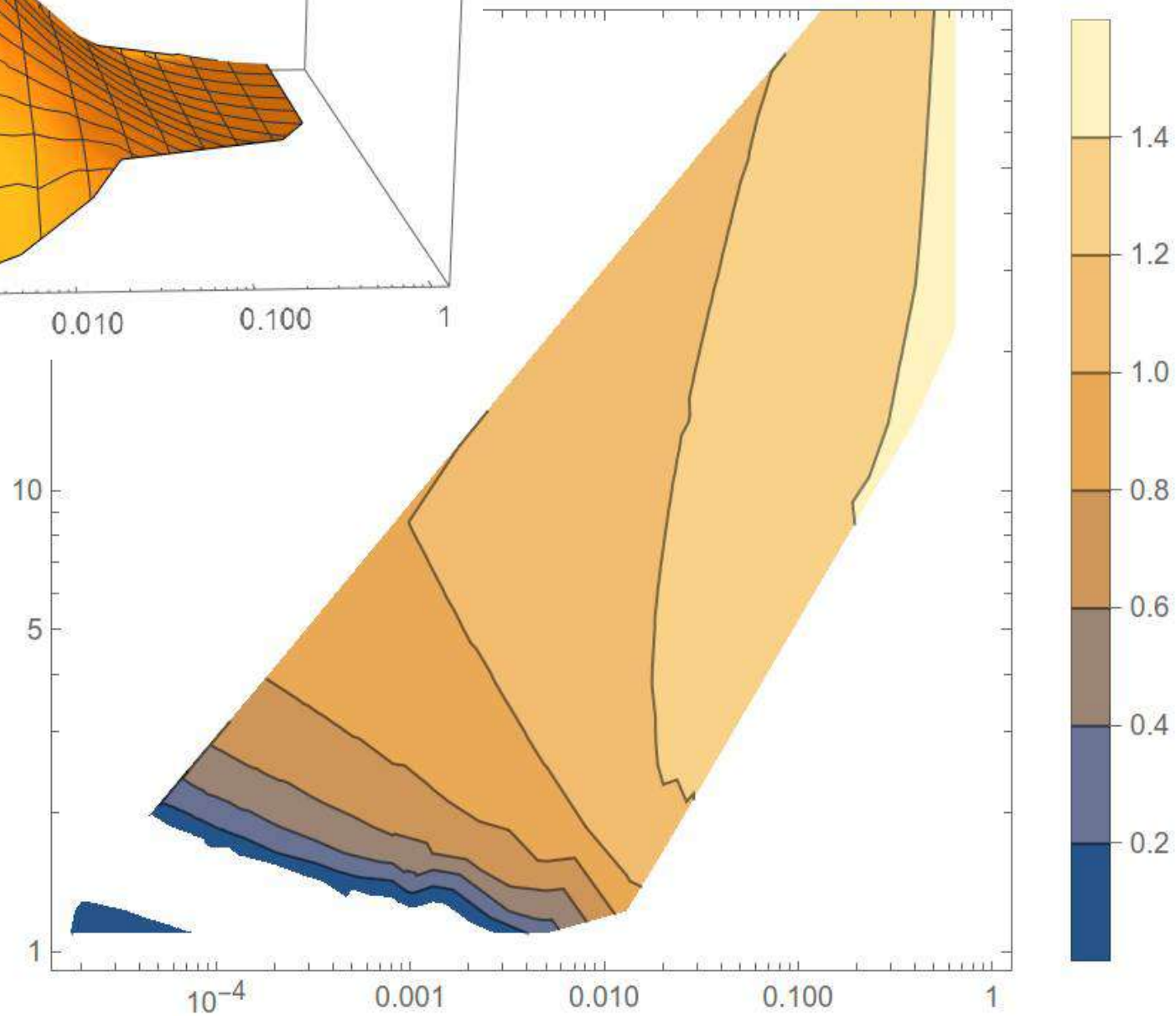
F2 N2LO: Ratio to NLO



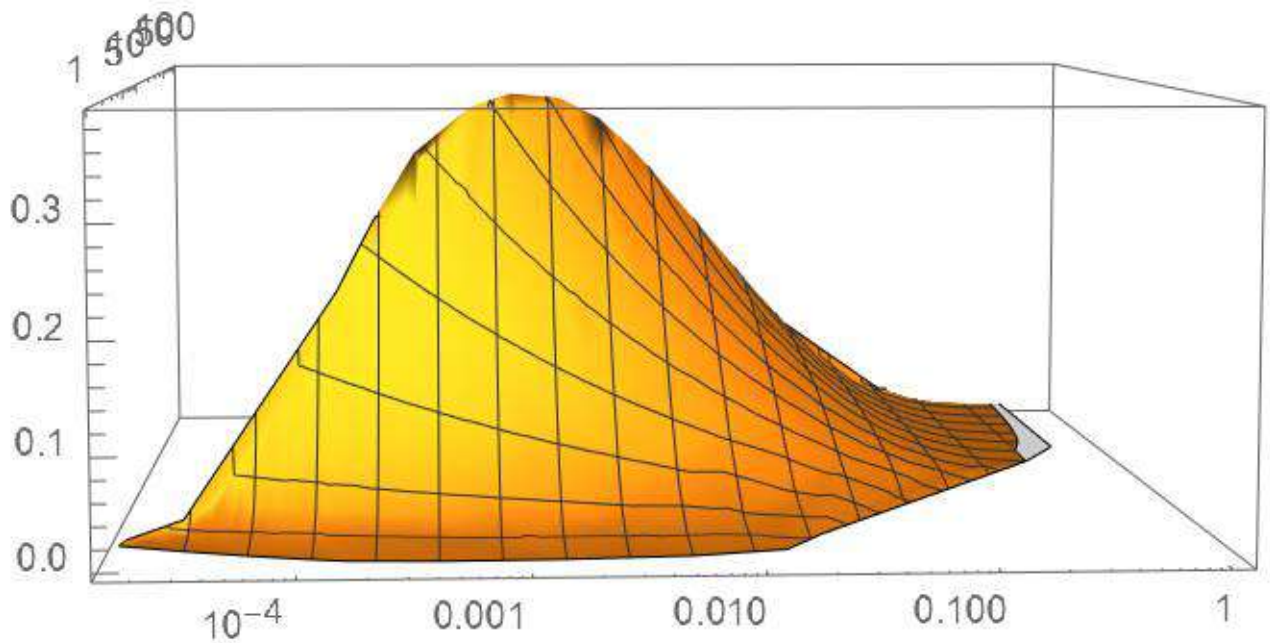


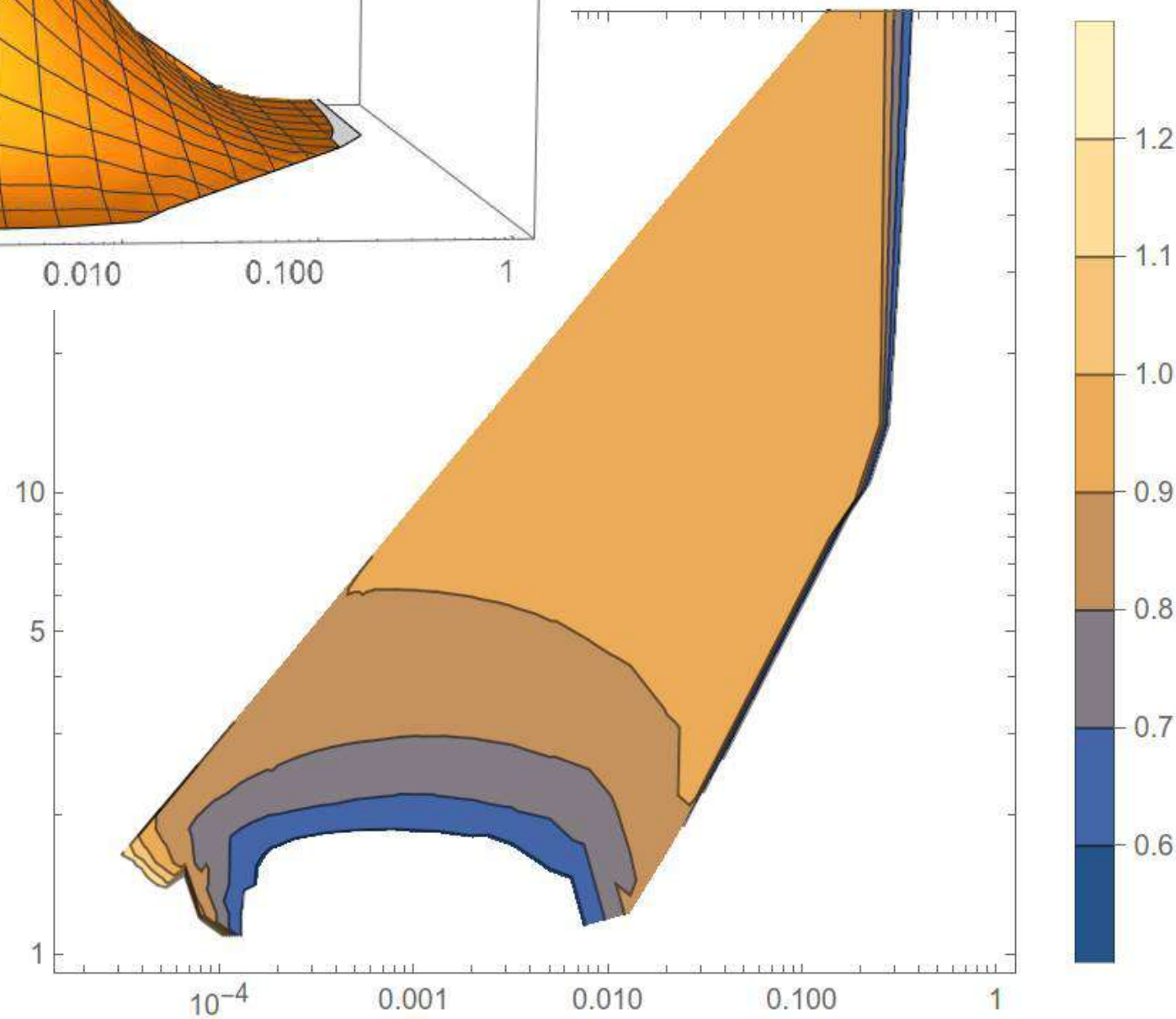
FL N2LO: Ratio to NLO



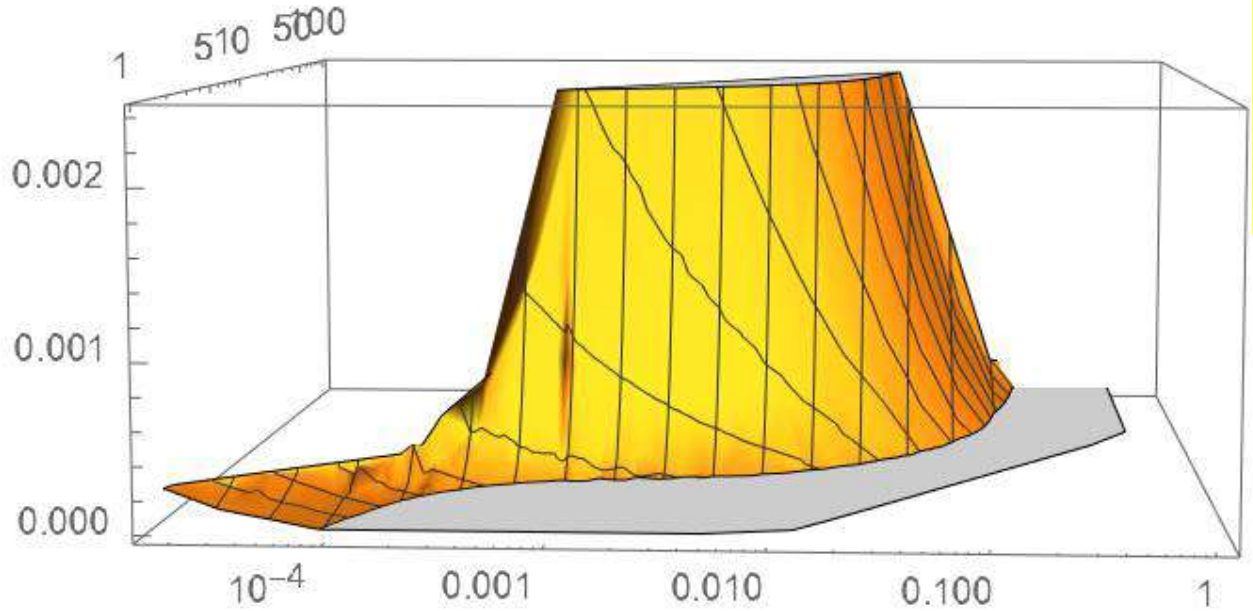


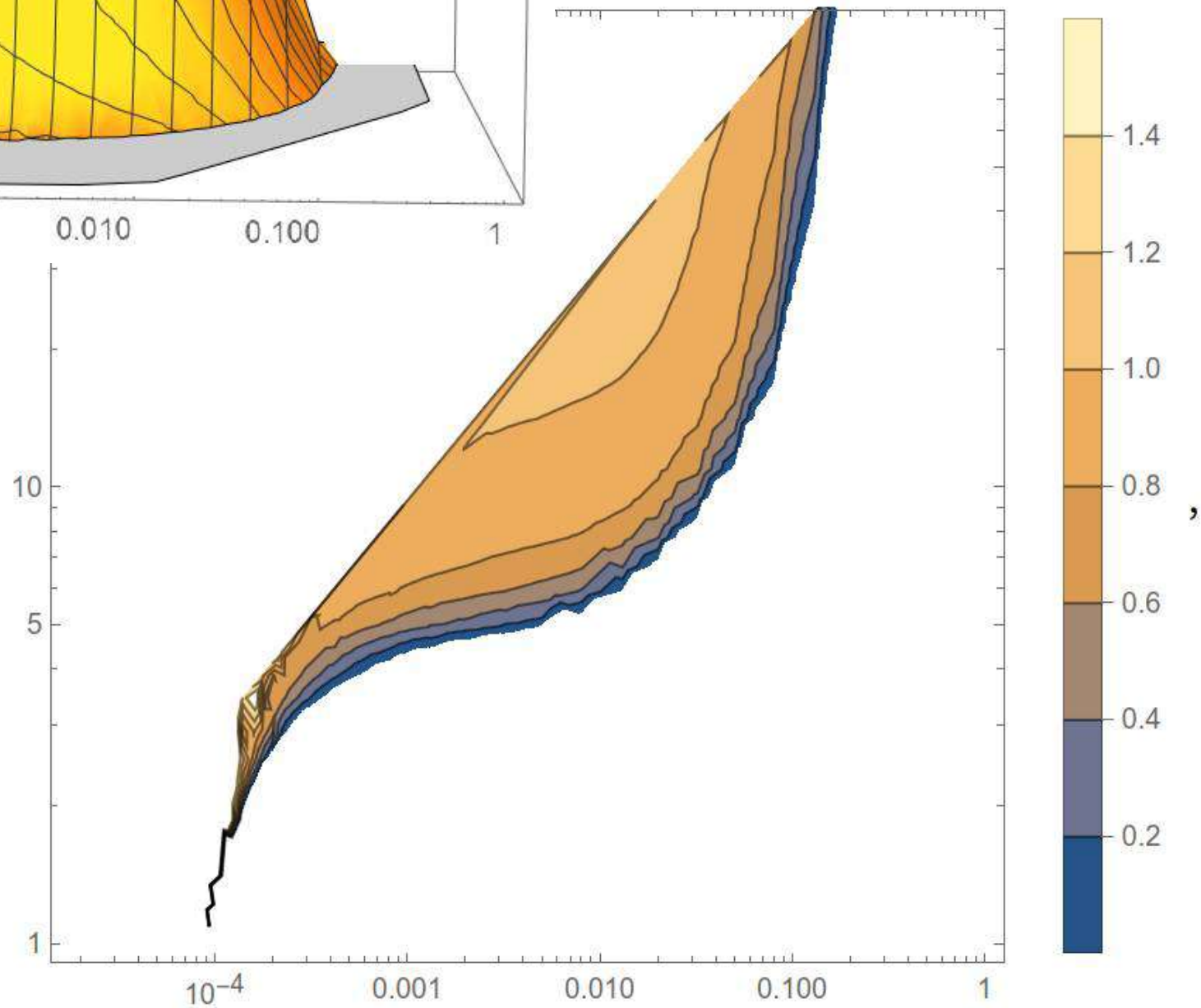
F2c N3LO: Ratio to NLO



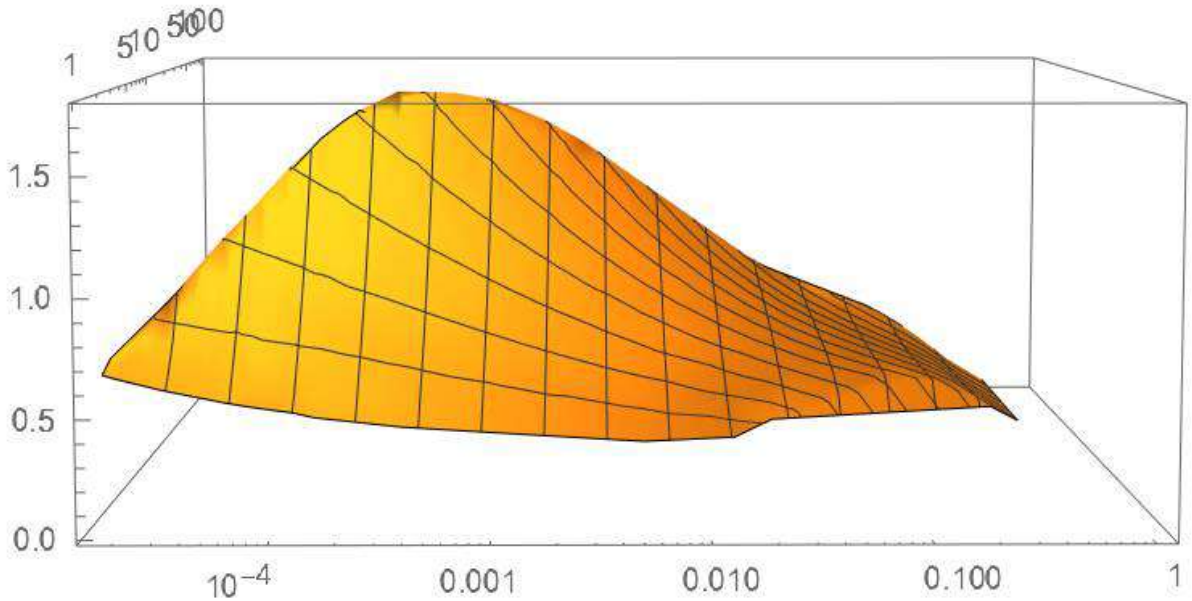


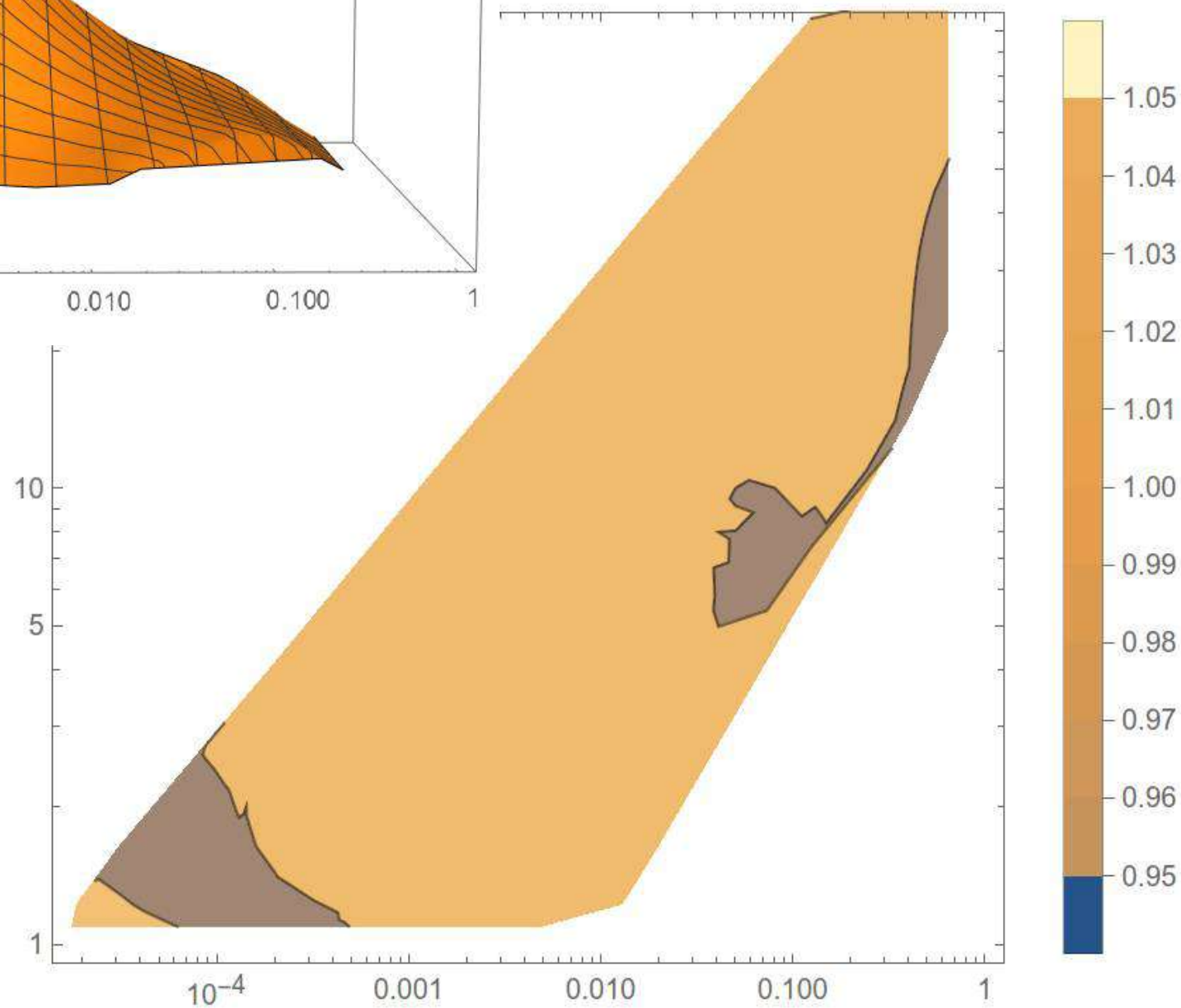
FbL N3LO: Ratio to NLO





F2 NLO: Ratio to MSTW



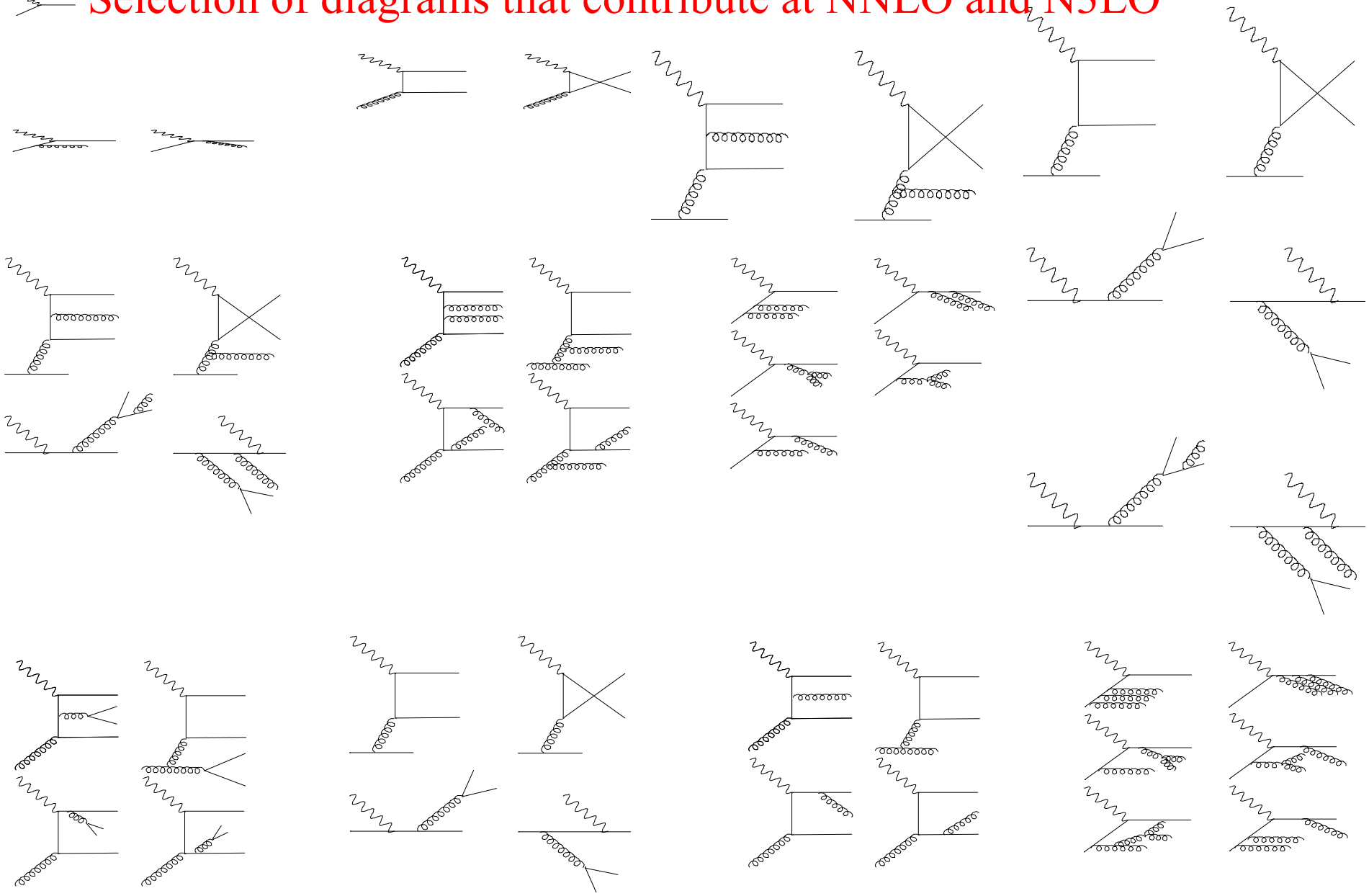


BACKUP

ACOT

Phase Space & Dynamic Mass

Selection of diagrams that contribute at NNLO and N3LO



Laenen, Riemersma, Smith, van Neerven, Nucl. Phys. B392, 162.
Vermaseren, Vogt, Moch, Nucl. Phys. B724, 3.
Moch, Vermaseren, Vogt, Nucl. Phys., B646, 181.
Moch, Vermaseren, Vogt, Phys. Lett., B606, 123.
Blumlein, Hasselhuhn, Kovacikova, Moch, Phys.Lett. B700, (2011) 294.

Master formula for decomposing the flavor components

T.P. Stavreva, I Schienbein

$$F = \sum_{i,j}^{6} F^{ij}$$

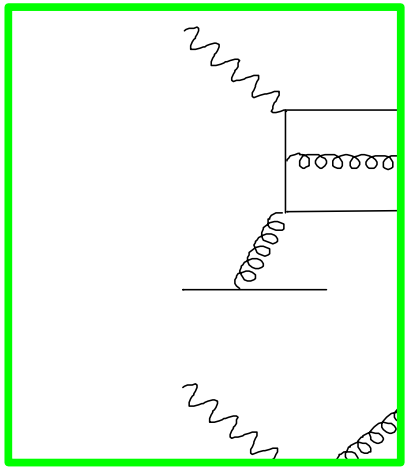
The Goal: Convert from {s, ns, ps} to {q,g, ...}

$$x^{-1} F_a^{ij} = q_i^+ \otimes \Big\{ e_i^2 \Big[C_{a,q}^{\rm ns}(n_f = 0)\ \delta_{ij} + C_{a,q}^{\rm ns}(j) - C_{a,q}^{\rm ns}(j-1) \Big] - \langle e^2 \rangle^{(j)}\ C_{a,q}^{\rm ps}(j) - \langle e^2 \rangle^{(j-1)}\ C_{a,q}^{\rm ps}(j-1) \Big\}$$

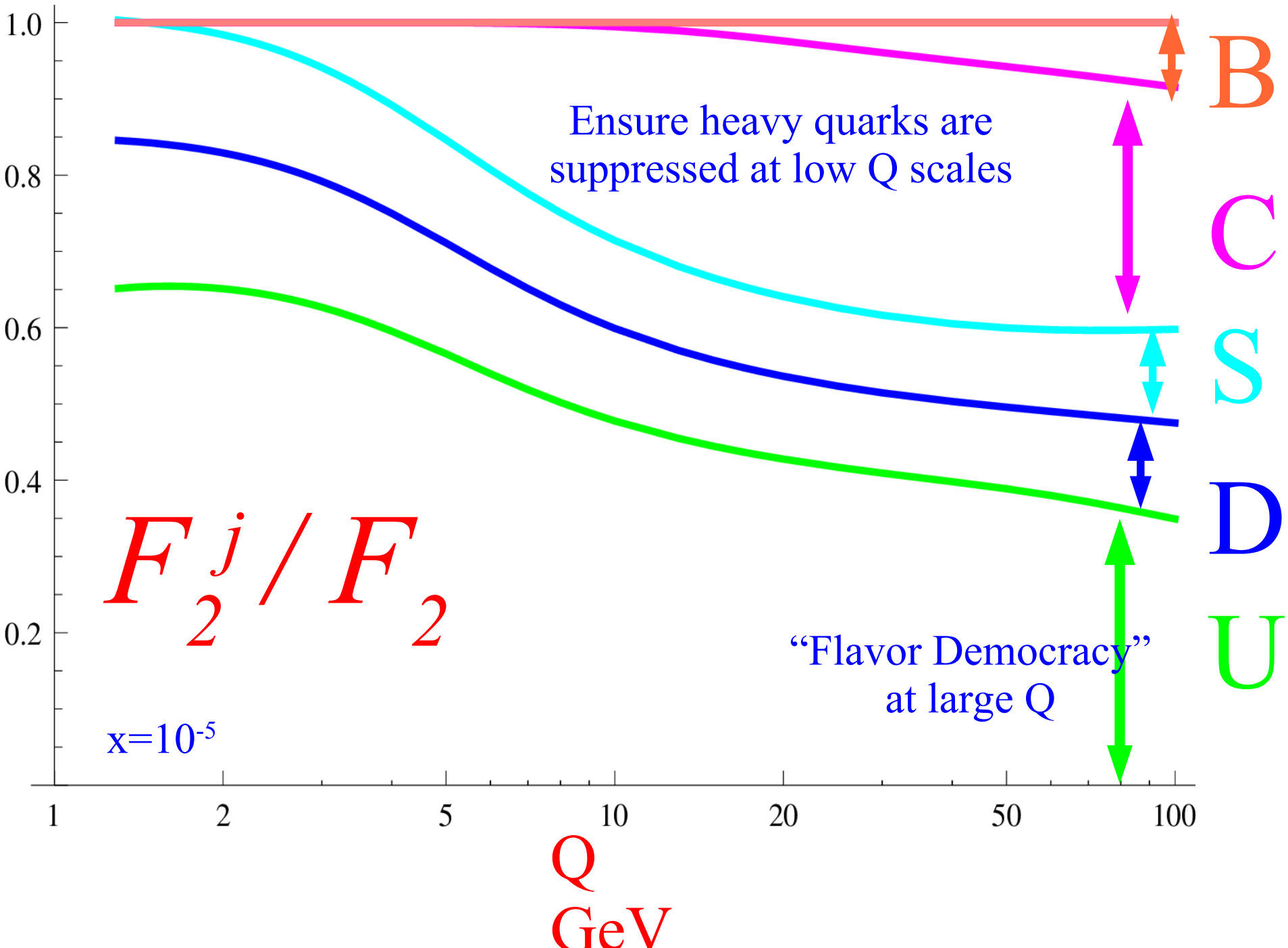
Issues: Flavor separation:

New diagrams at this order

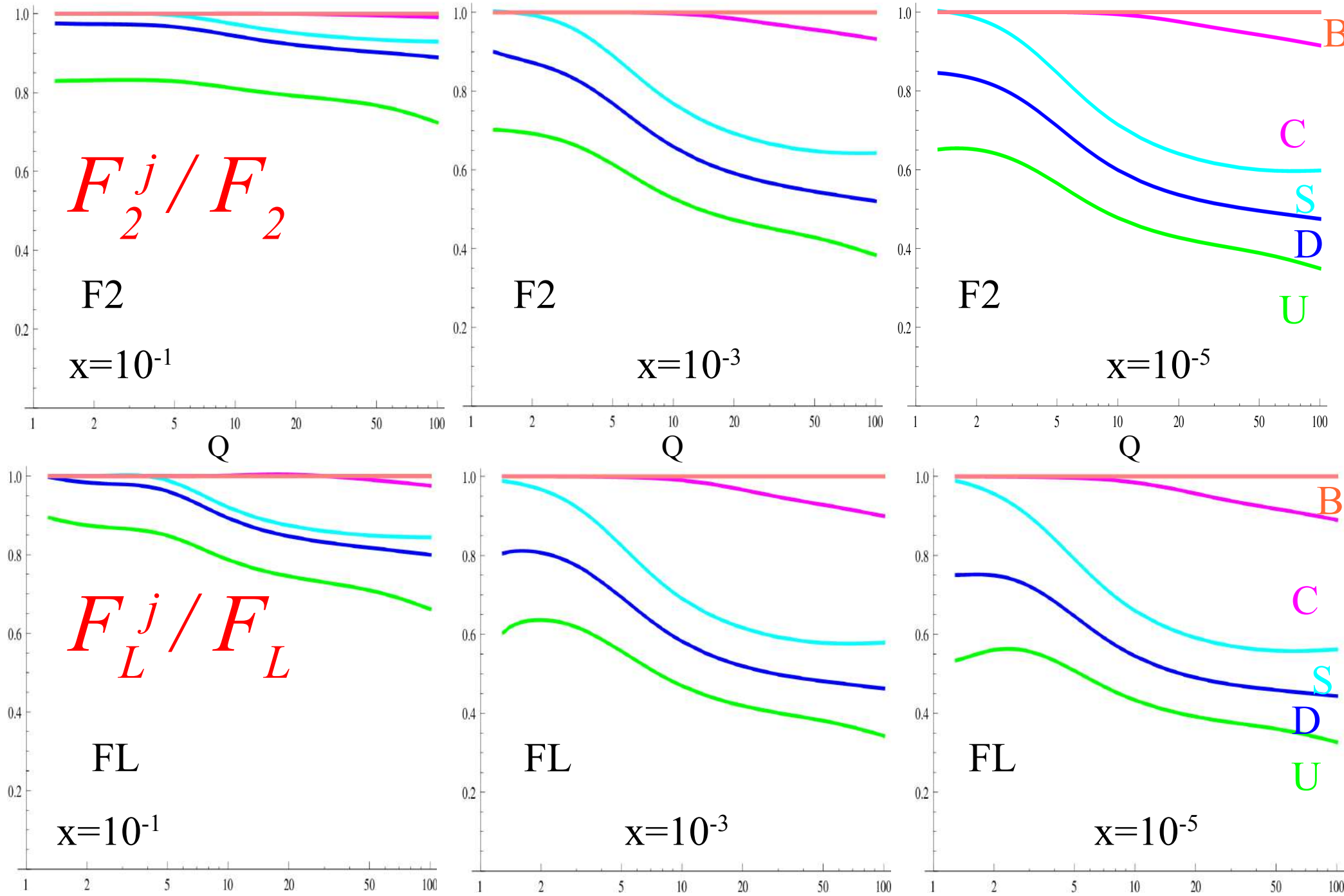
- c,b, goes down beam pipe
- both c & b in final state



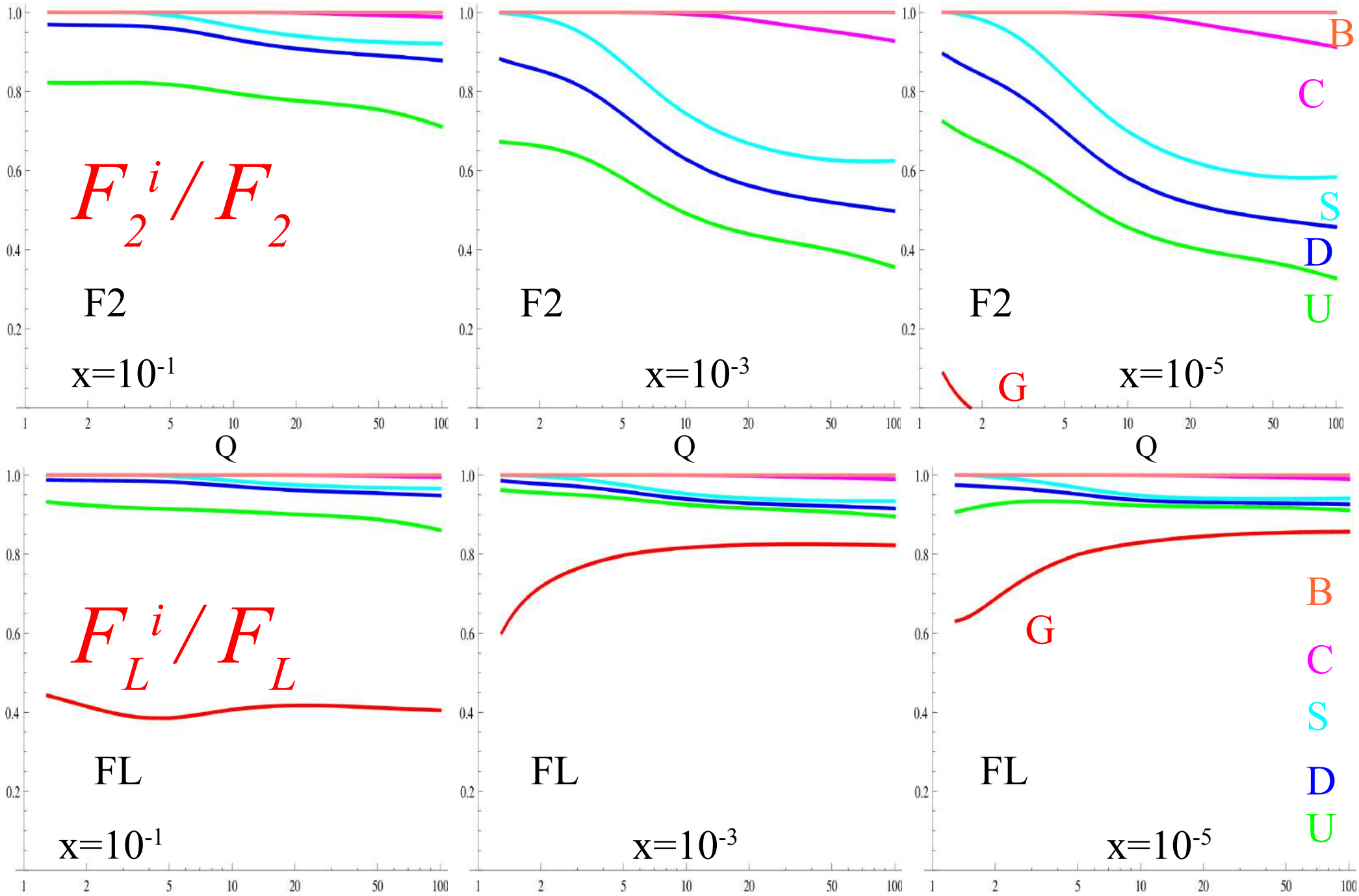
FLAVOR DECOMPOSITION



FLAVOR DECOMPOSITION: Final State Quark:

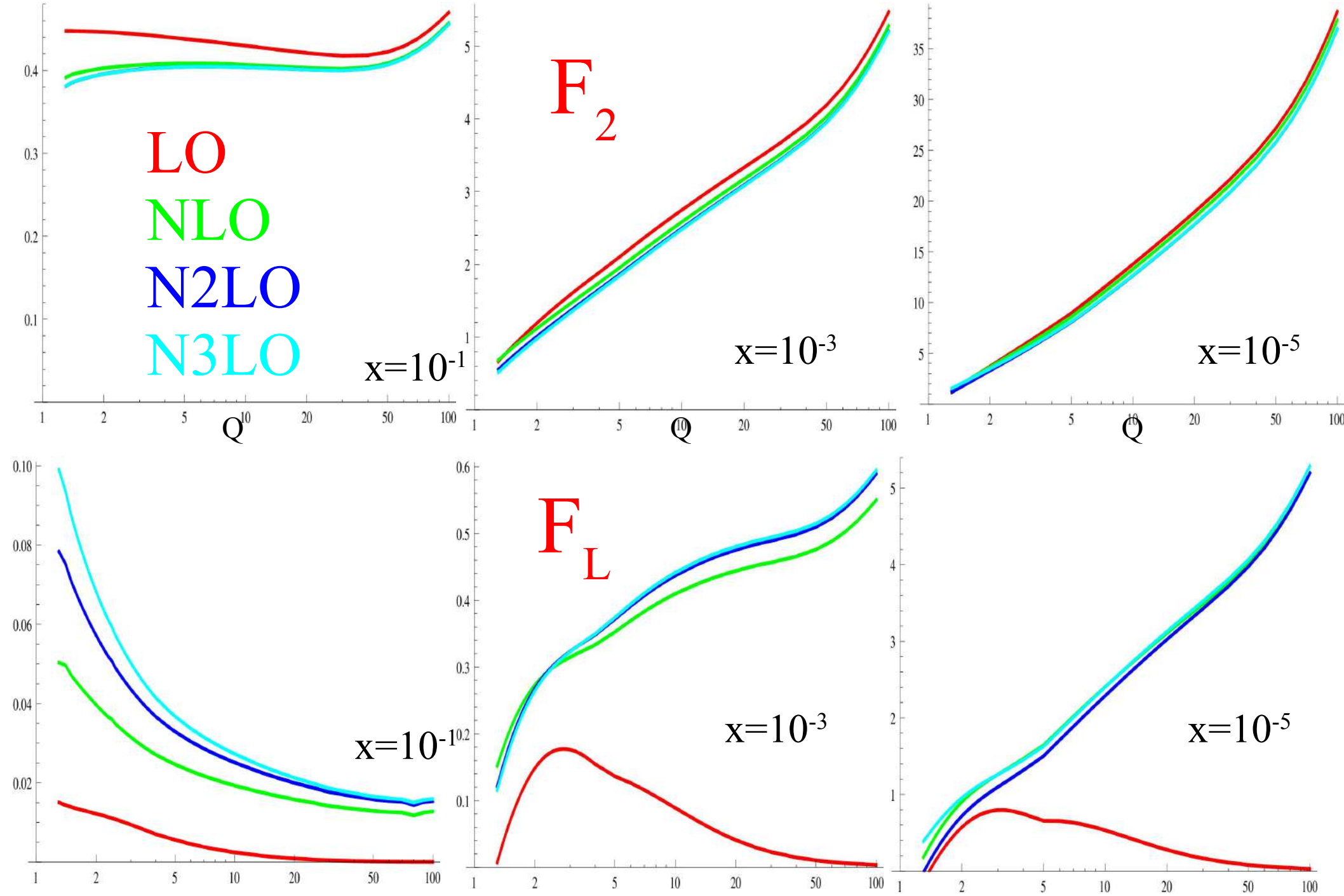


FLAVOR DECOMPOSITION: Initial State Quark:

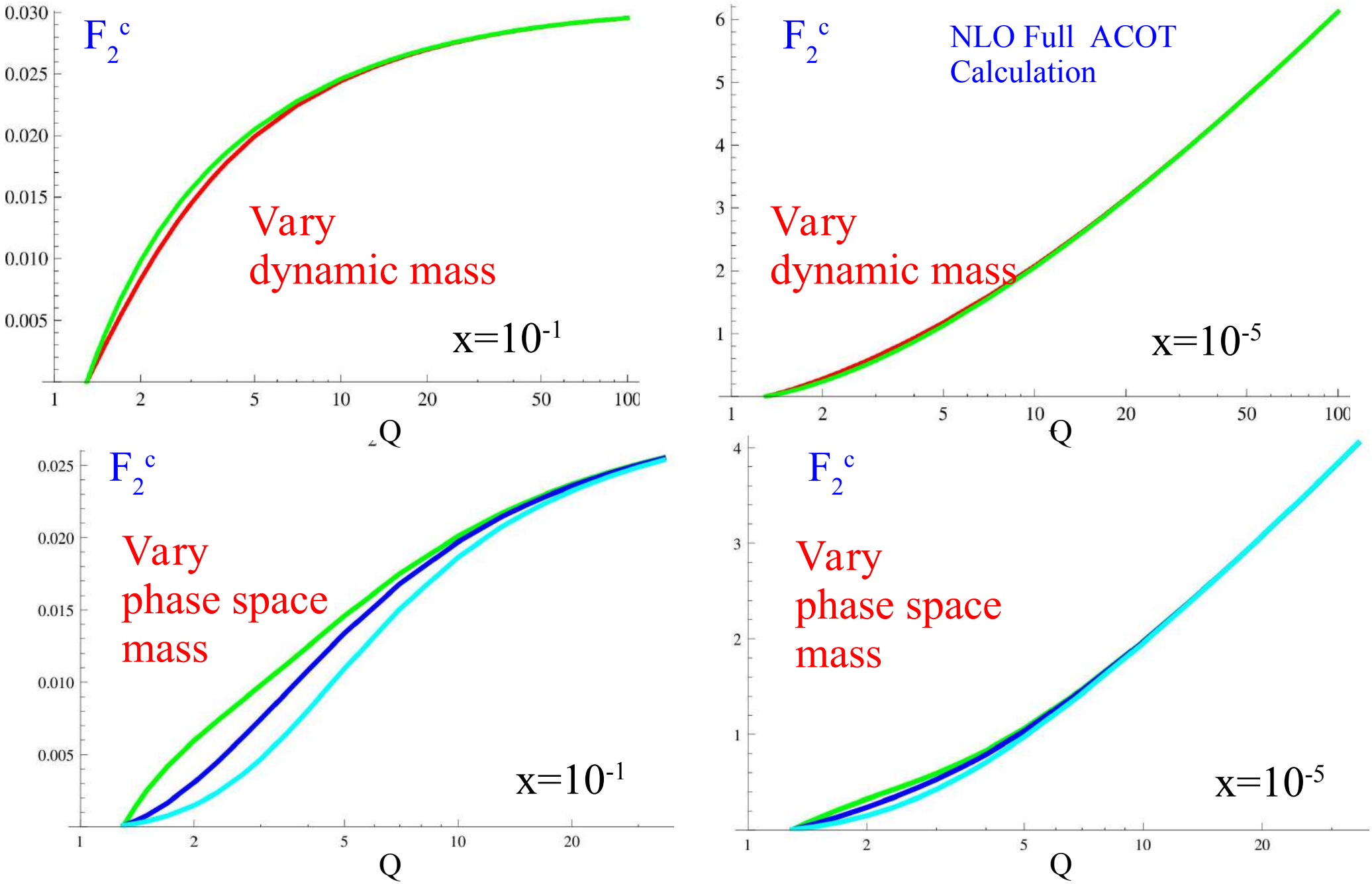


$F_{2,L}$ @ N3LO

$F_{2,L}$ @ N3LO



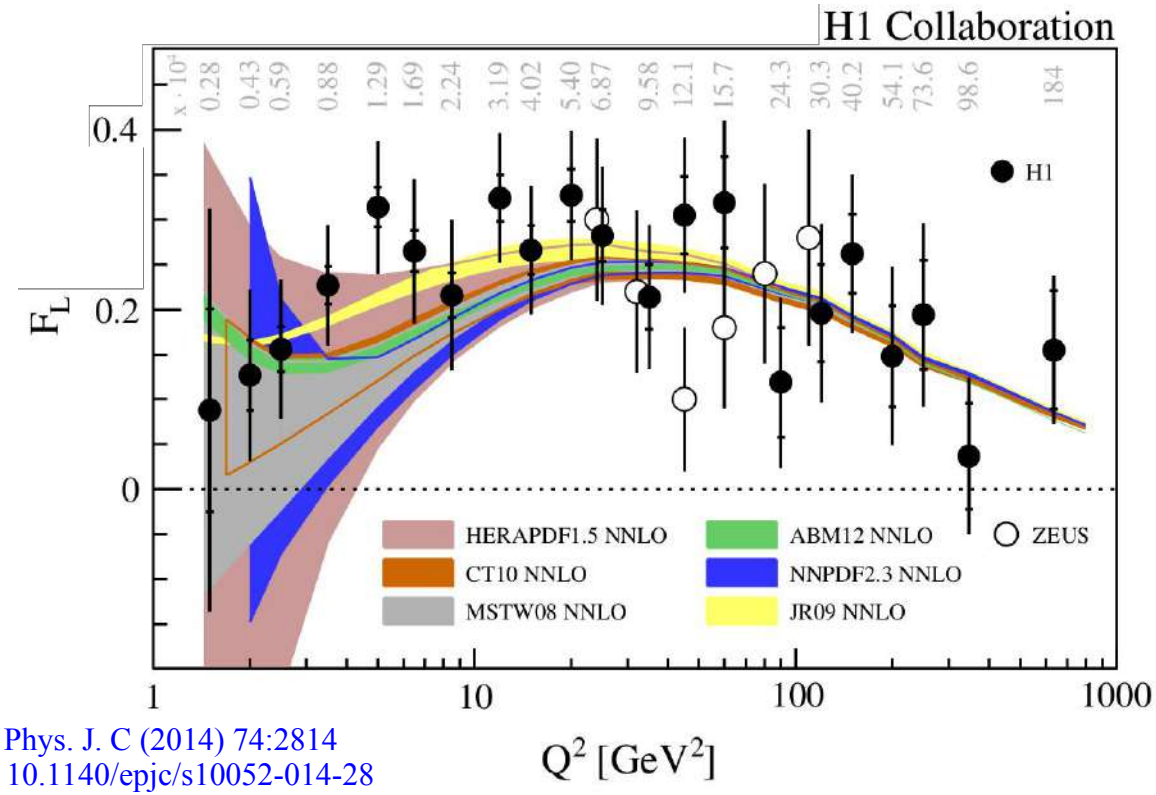
Identify Two Types of Mass Depencence: "dynamic" & "phase space"



"phase space" mass yields larger variation. Not a proof, but ….

BACKUP

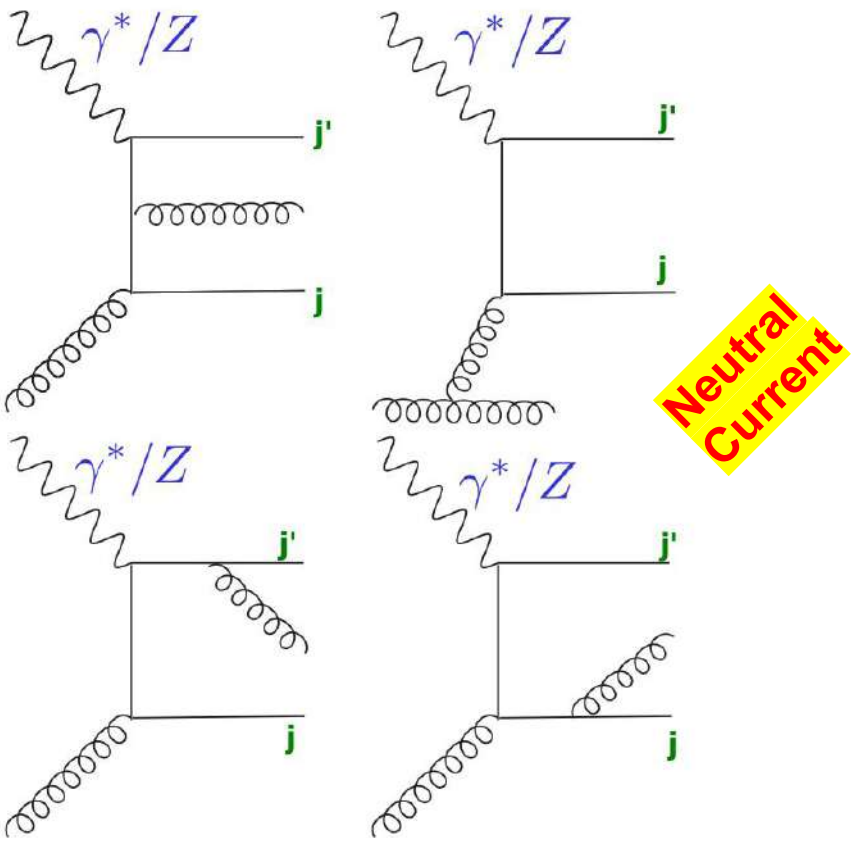
Heavy Quark Production



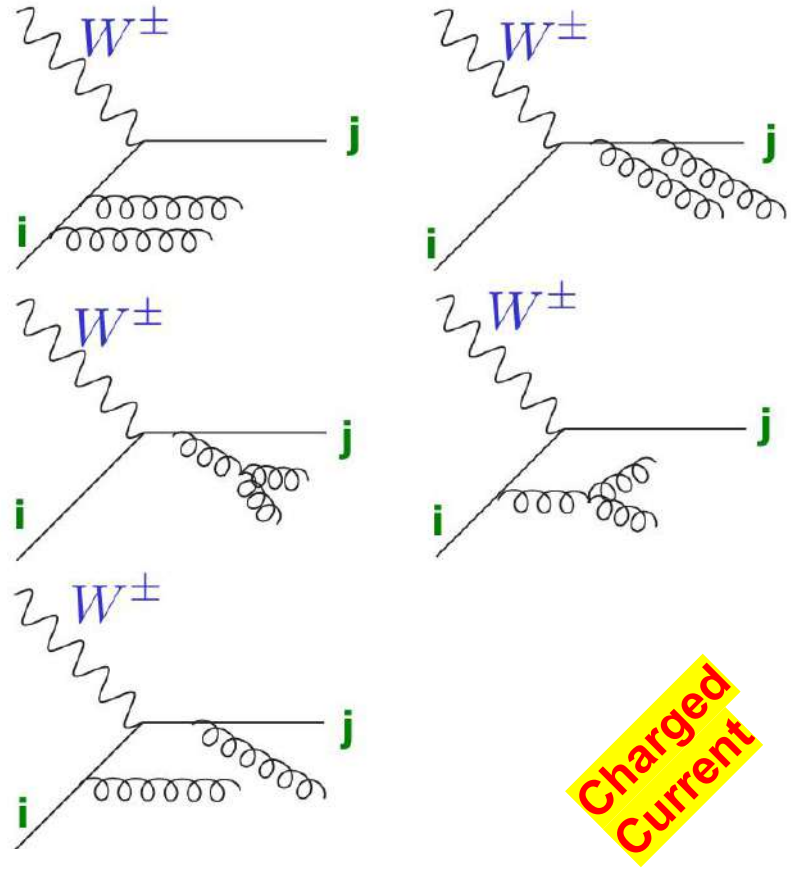
Eur. Phys. J. C (2014) 74:2814
DOI 10.1140/epjc/s10052-014-28

sACOT-χ – NNLO gluon

Stavreva *et al*, arXiv:1203.0282



sACOT-χ – NNLO non-singlet



Precompute observables

$$F_\lambda(x,Q^2) = \sum_k \sum_\alpha \underbrace{\int_\chi^1 \frac{\mathrm{d}\xi}{\xi} C_k^\lambda\left(\frac{\chi}{\xi}, \frac{Q}{mu}, \frac{M_i}{\mu}, \alpha_s(\mu)\right) w_\alpha(\xi)}_{\text{Precompute}} f_k(\xi_\alpha, \mu)$$

APFEL++ – A PDF evolution library in c++

Bertone, arXiv:1708.00911

- main author: **V. Bertone**
- rewrite of the Fortran APFEL code
  - used by the NNPDF collaboration

Available schemes in APFEL++

scheme	$\mathcal{O}(\alpha_s)$		NC: F_2	NC: F_3	NC: F_L		CC: F_2	CC: F_3	CC: F_L
ZM	N2LO		✓	✓	✓		✓	✓	✓
FONLL-C	N2LO		✓	✗	✓		✗	✗	✗
ACOT	NLO		✓	✓	✓		✗	✗	✗
sACOT-χ	NLO		✓	✓	✓		✓	✓	✓
approx. sACOT-χ	N2LO		✓	✓	✓		✓	✓	✓