F_L and F_2 - theory model comparison with HERA data

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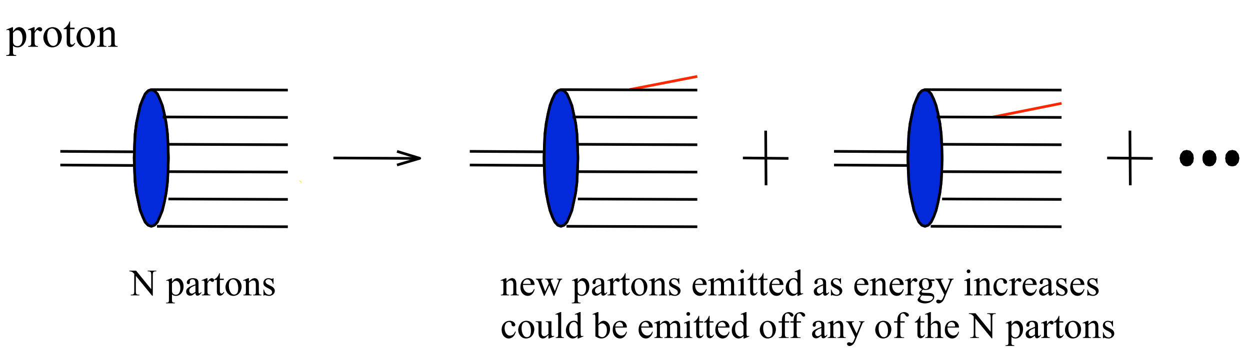
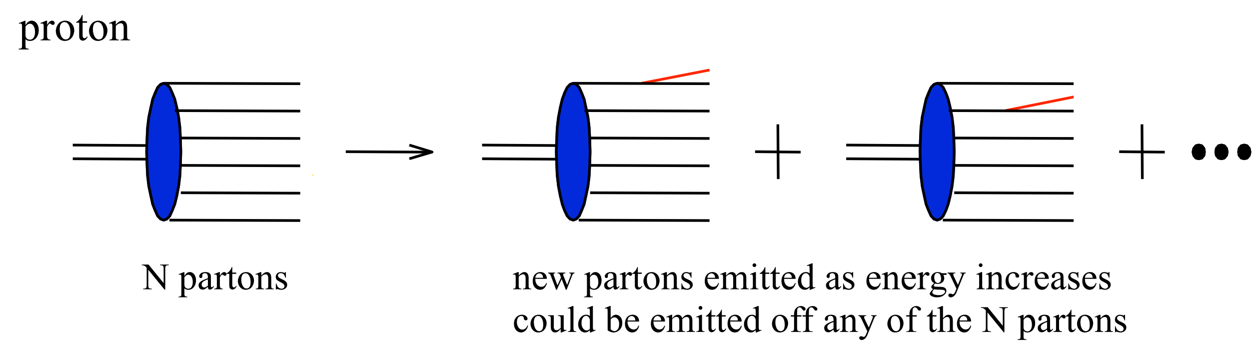
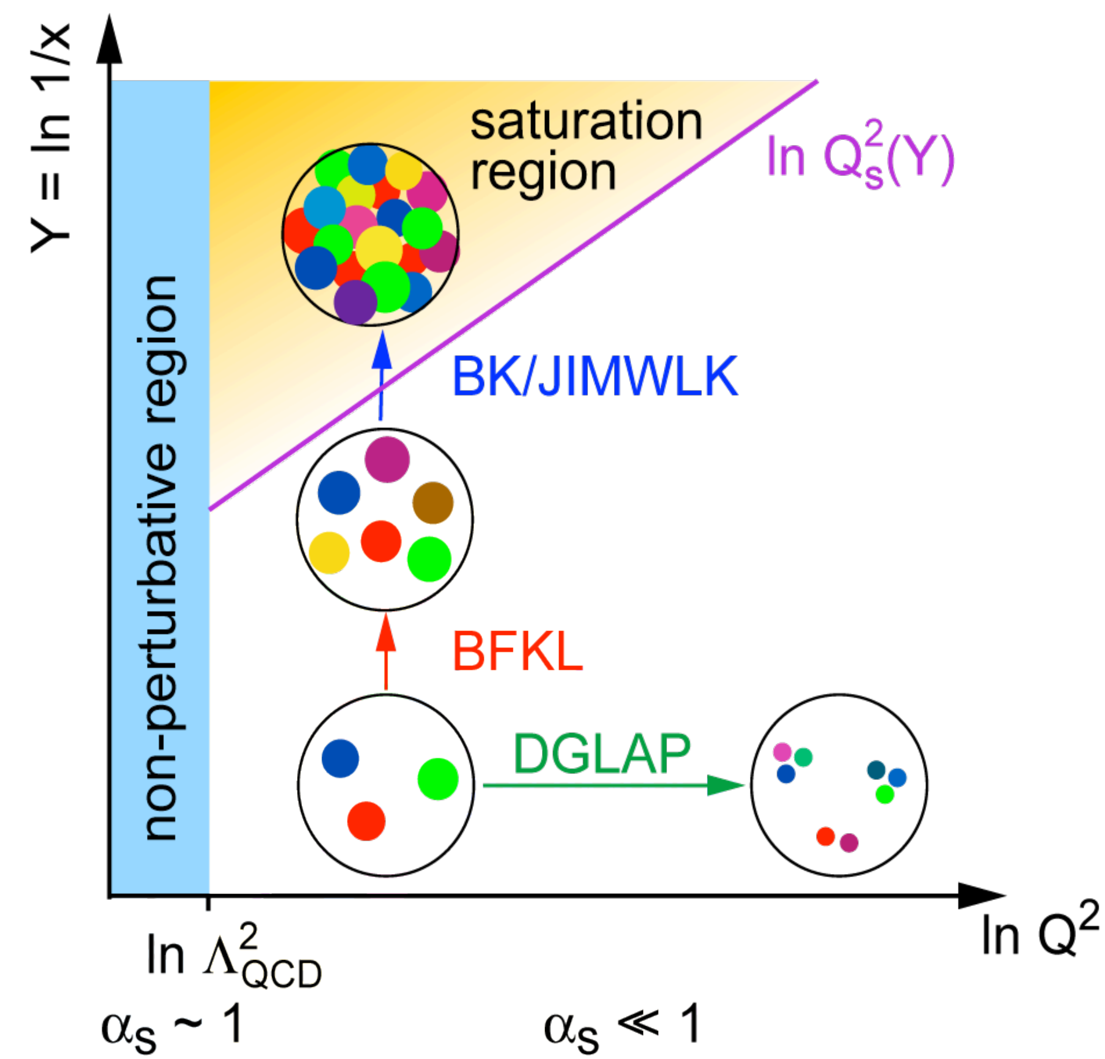
Non-linear QCD - Saturation



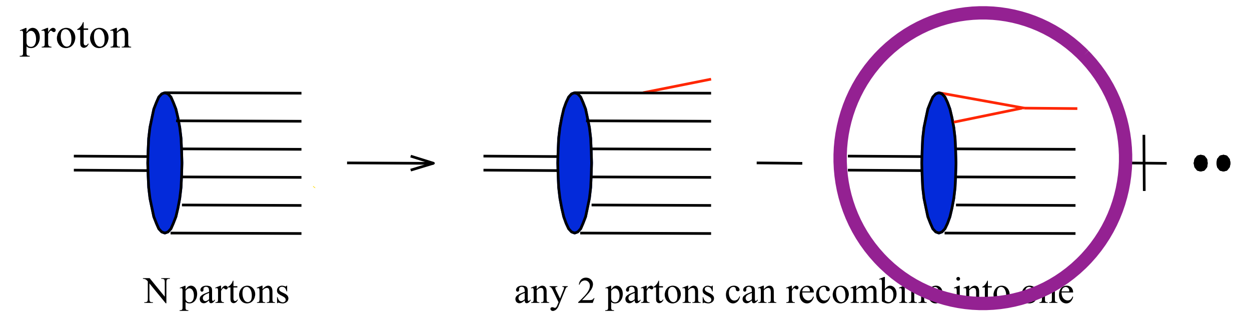
Non-linear QCD - Saturation

- BFKL: evolution in x
  - ➡ linear
    - explosion in colour field at low-x

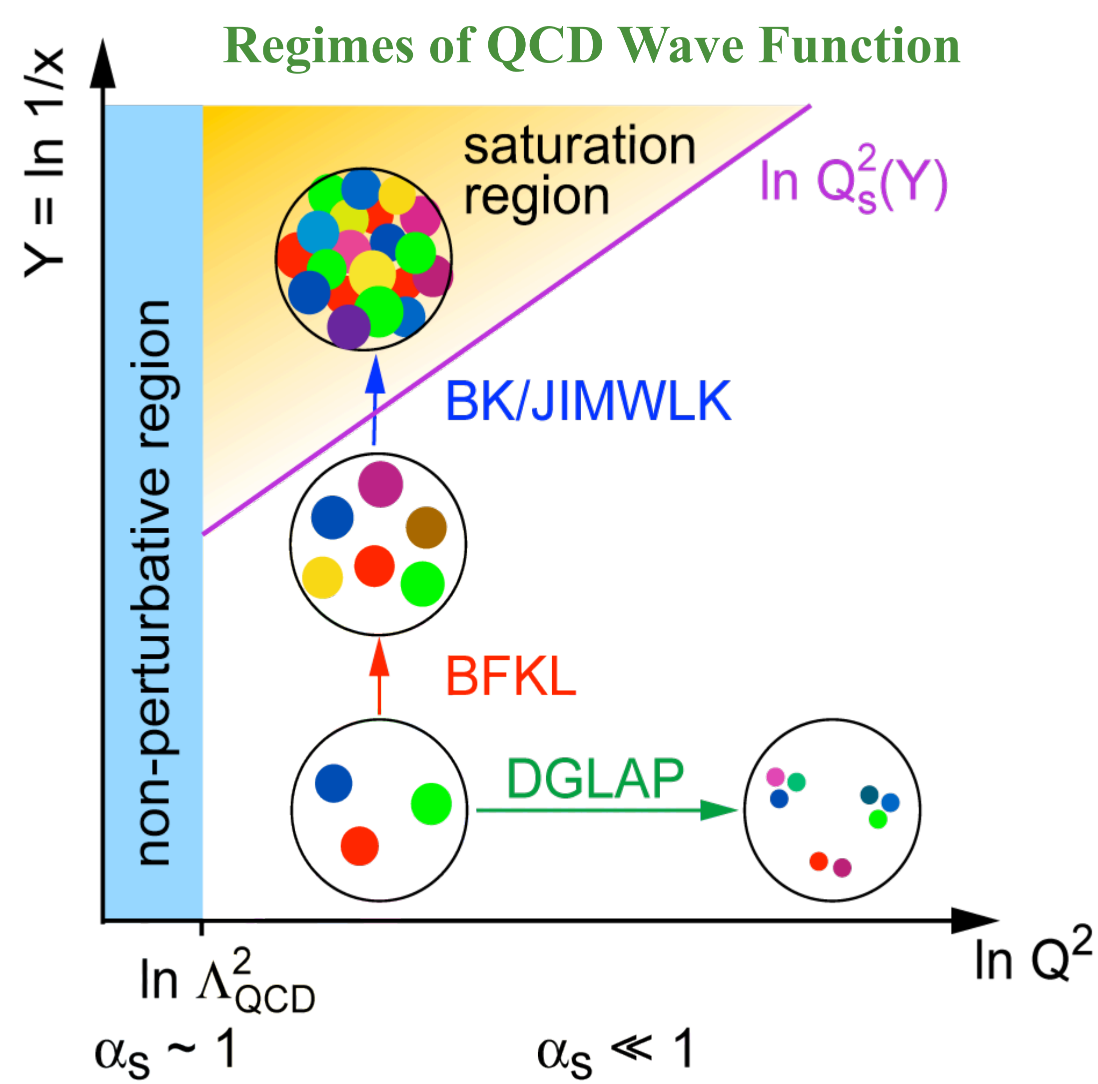




Non-linear QCD - Saturation



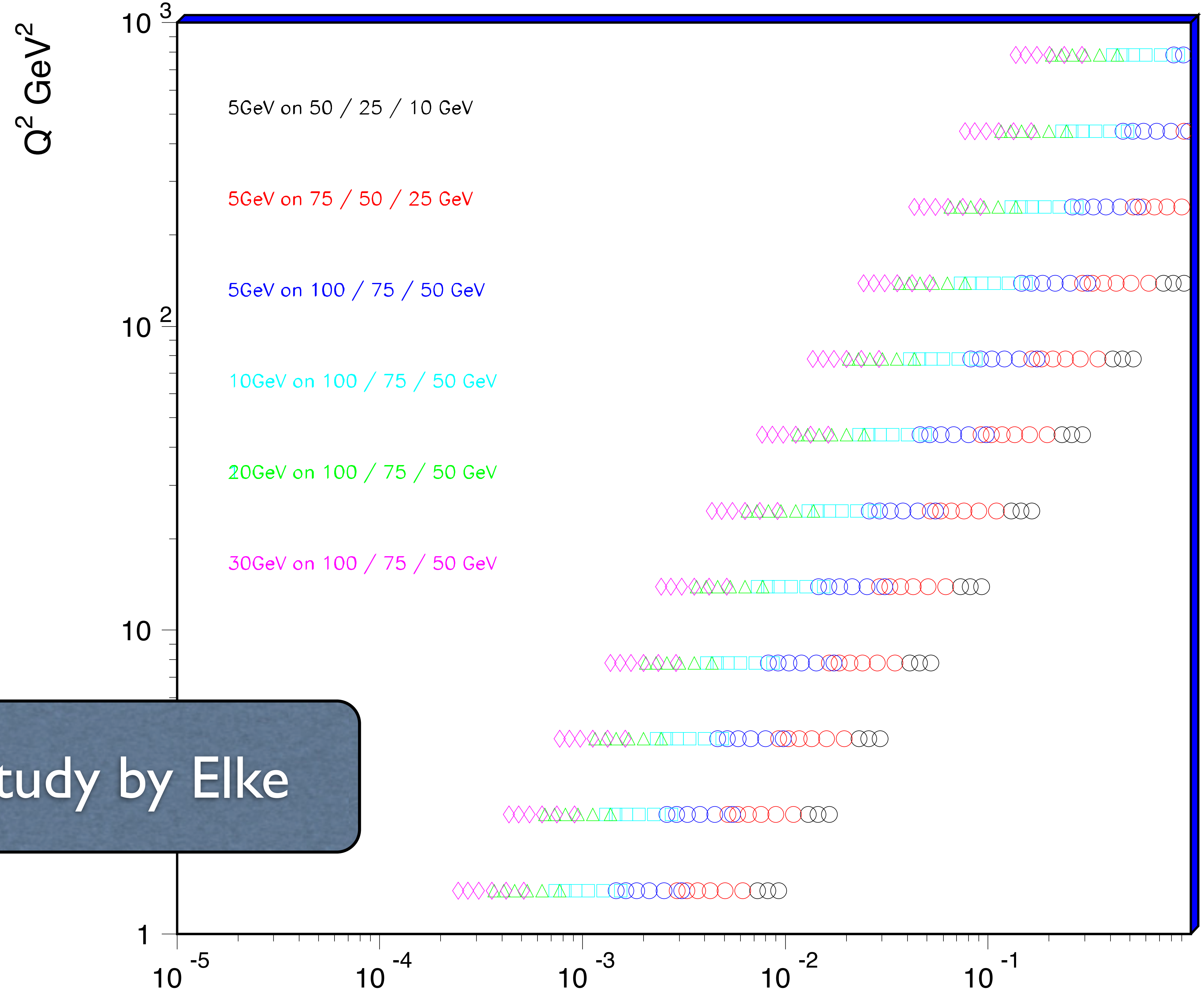
- BFKL: evolution in x
  - ➡ linear
    - explosion in colour field at low-x
- Non-linear BK/JIMWLK equations
  - ➡ non-linearity ⇒ saturation
    - Allows for the recombination of gluons in a dense gluonic medium
  - ➡ characterised by the saturation scale, $Q_S(x,A)$



Explanation of what's on the plots..

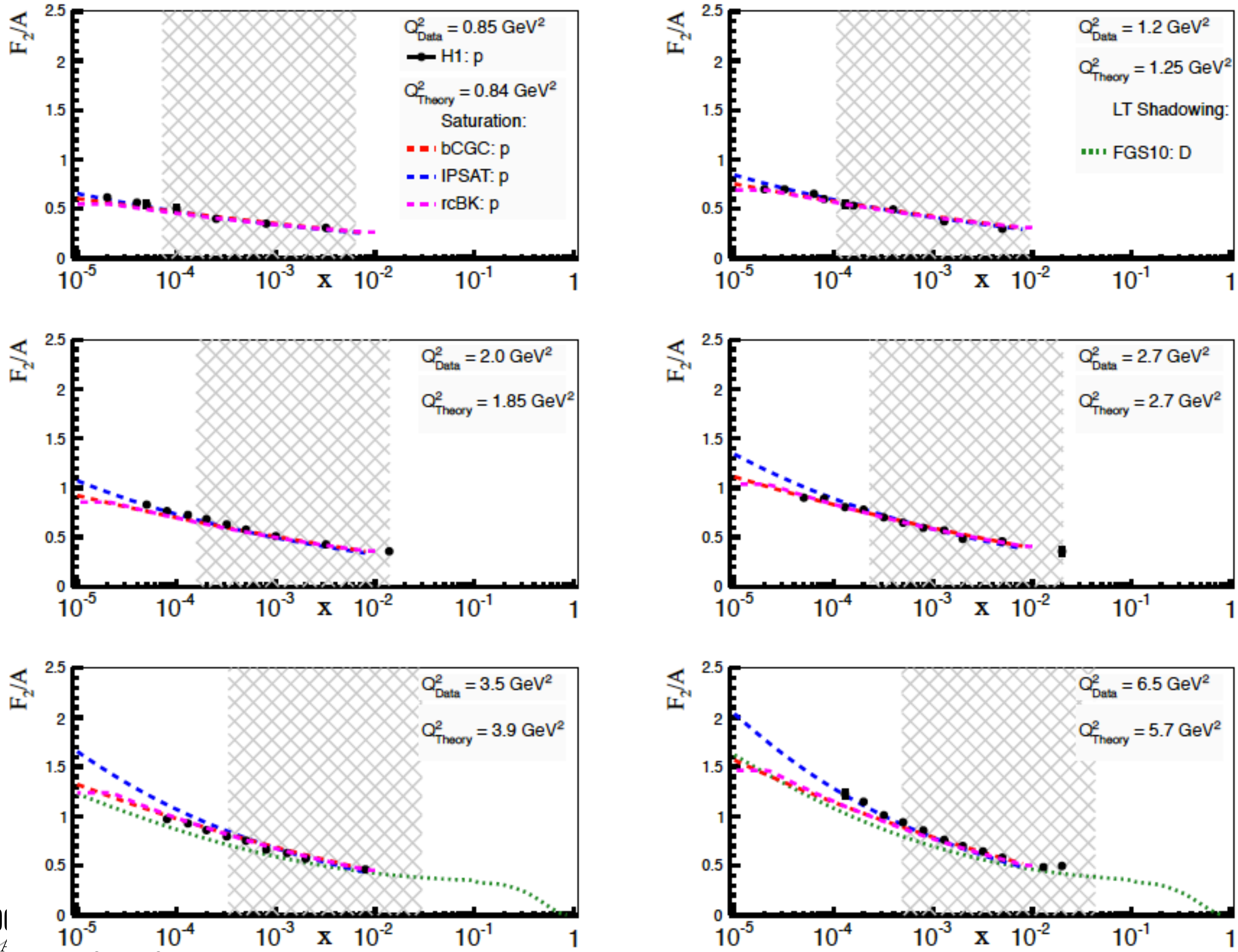
- Theory
  - ➡ Leading-Twist Shadowing
    - **FGS10** provided by Vadim Guzey
      - Evolved with a DGLAP evolution
  - ➡ Saturation, dipole models
    - **IPSat** provided by Tuomas Lappi (work by Henri Kowalski, Graeme Watt)
      - Evolved with a DGLAP evolution
      - Fit to ZEUS 96 data - χ^2/d.o.f. ~ 1.2
    - **bCGC** provided by Tuomas Lappi (work by Henri Kowalski, Graeme Watt)
      - "ad-hoc" approach to evolution but based on BK
      - Fit to ZEUS 96 data - χ^2/d.o.f = 1.62
    - **rcBK** provided by Javier Albacete (AAQMS model)
      - Evolution along x with BK equation
      - Fit to H1+ZEUS combined 2006 data
- Experimental Data
  - ➡ F_2: H1&ZEUS combined data from: http://www-h1.desy.de/psfiles/papers/desy09-158.pdf
  - ➡ F_L: H1&ZEUS combined data from: http://www-h1.desy.de/psfiles/papers/desy10-228.pdf

Hatched region - our x-Q^2 acceptance for F_L and F_2



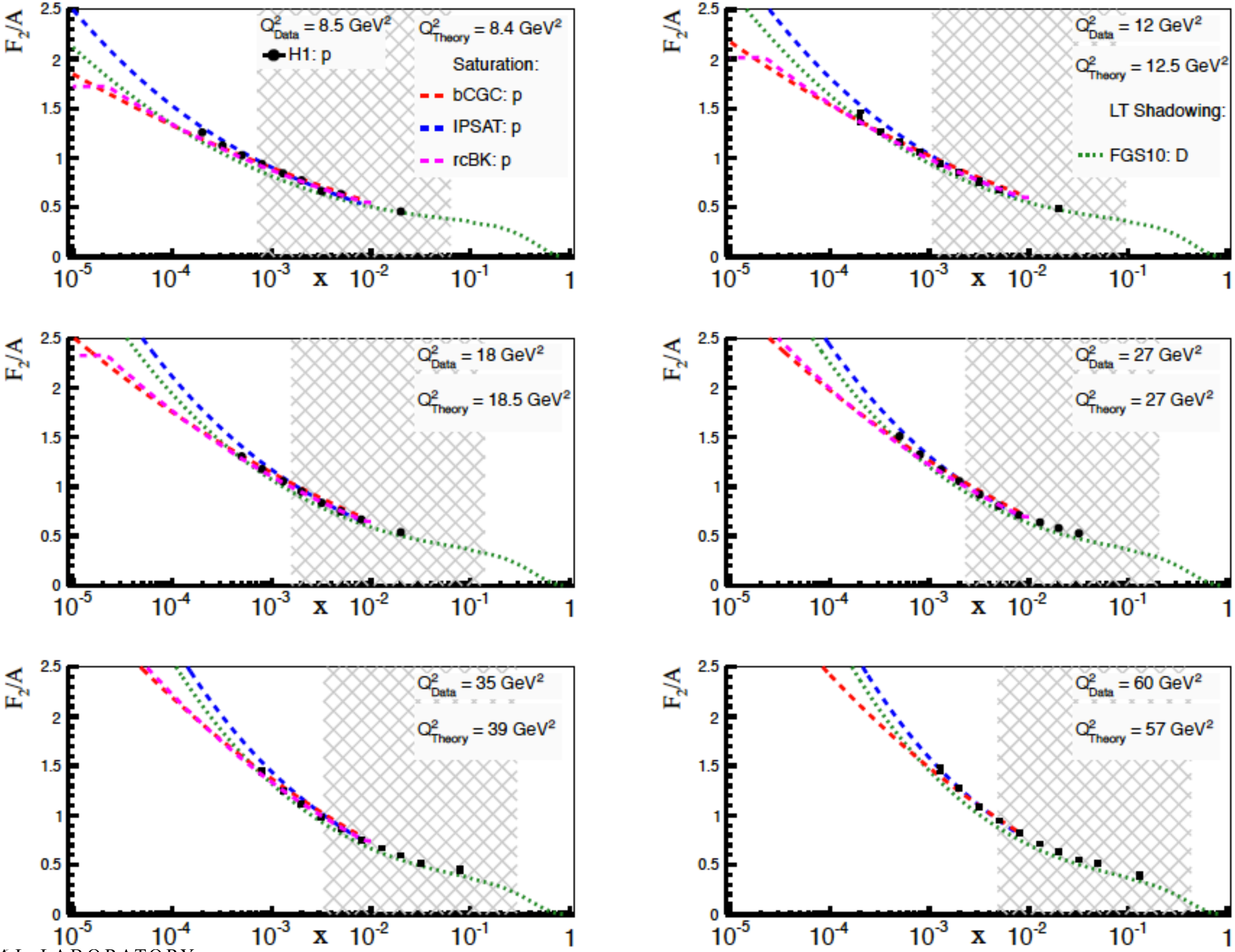
Study by Elke

$F_2(p,D)$ - 0.8 < Q^2 < 6



F2/A
x
Q^2_{Data} = 0.85 GeV²
H1: p
Q^2_{Theory} = 0.84 GeV²
Saturation:
bCGC: p
IPSAT: p
rcBK: p
Q^2_{Data} = 1.2 GeV²
Q^2_{Theory} = 1.25 GeV²
LT Shadowing:
FGS10: D
Q^2_{Data} = 2.0 GeV²
Q^2_{Theory} = 1.85 GeV²
Q^2_{Data} = 2.7 GeV²
Q^2_{Theory} = 2.7 GeV²
Q^2_{Data} = 3.5 GeV²
Q^2_{Theory} = 3.9 GeV²
Q^2_{Data} = 6.5 GeV²
Q^2_{Theory} = 5.7 GeV²

$F_2(p,D)$ - 8 < Q^2 < 60



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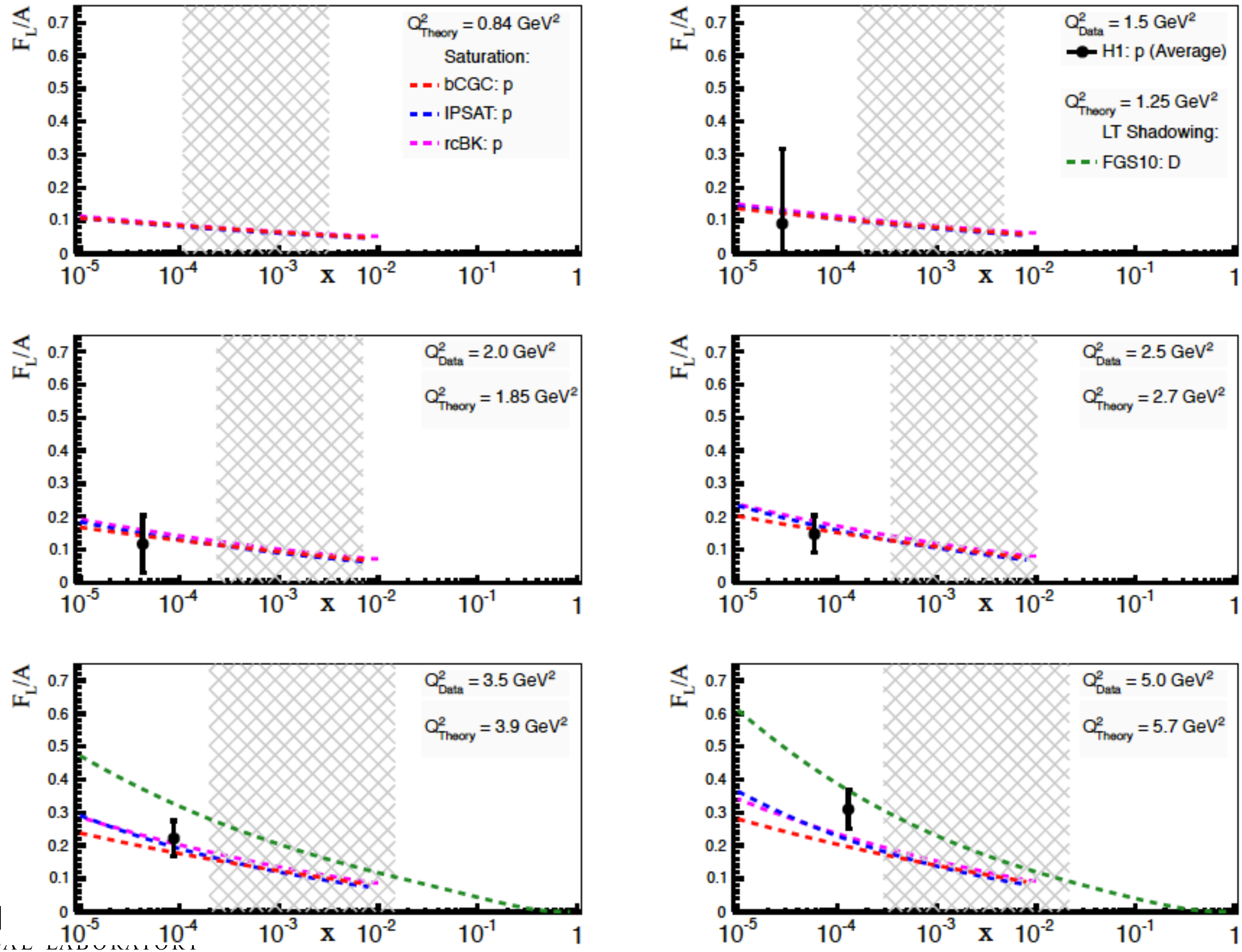
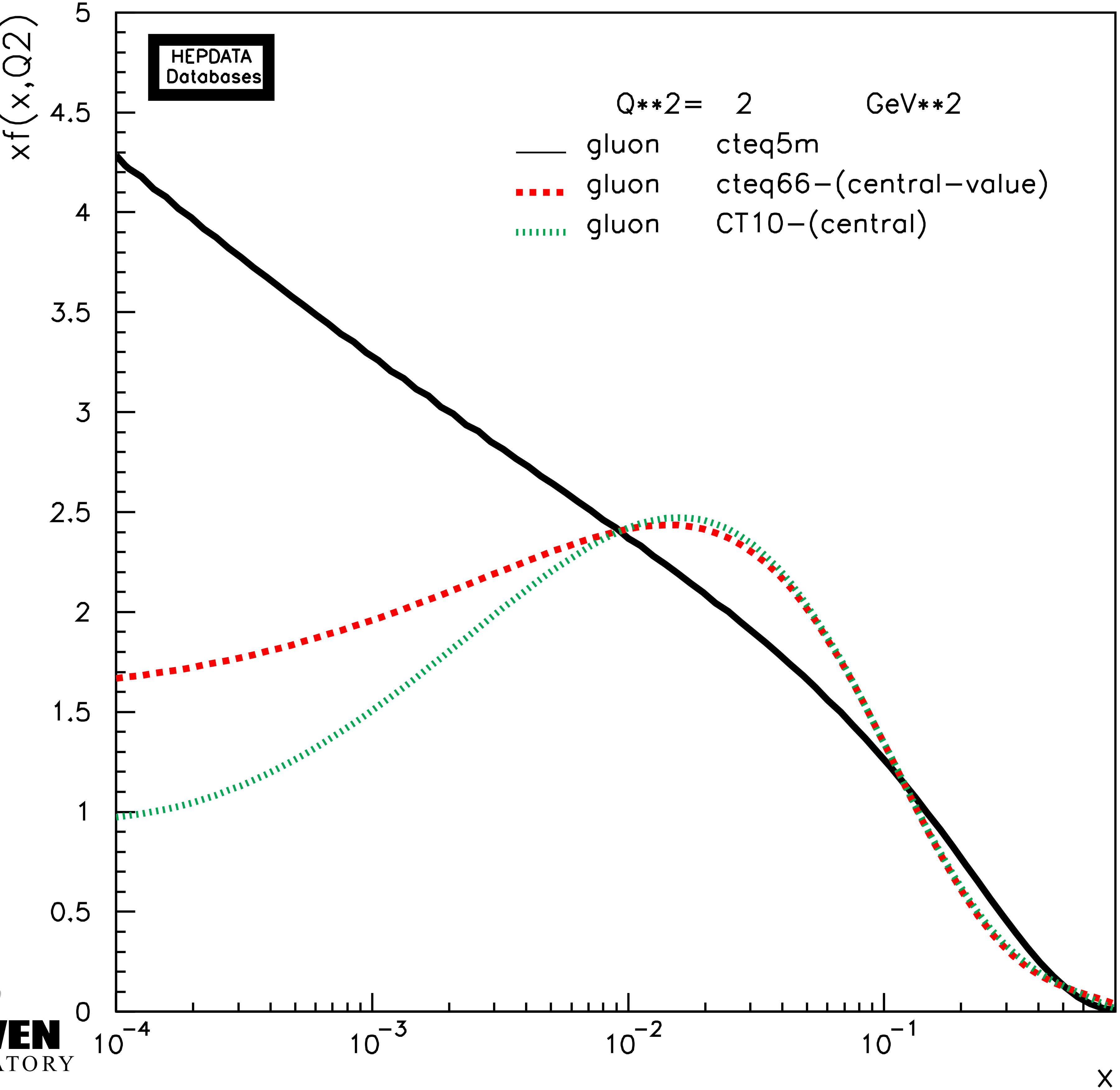
$F_L(p,D)$ - $0.8 < Q^2 < 6$



F_L/A
x
Q^2_{Theory} = 0.84 GeV^2
Saturation:
bCGC: p
IPSAT: p
rcBK: p
Q^2_{Data} = 1.5 GeV^2
H1: p (Average)
Q^2_{Theory} = 1.25 GeV^2
LT Shadowing:
FGS10: D
Q^2_{Data} = 2.0 GeV^2
Q^2_{Theory} = 1.85 GeV^2
Q^2_{Data} = 2.5 GeV^2
Q^2_{Theory} = 2.7 GeV^2
Q^2_{Data} = 3.5 GeV^2
Q^2_{Theory} = 3.9 GeV^2
Q^2_{Data} = 5.0 GeV^2
Q^2_{Theory} = 5.7 GeV^2

Input PDFs in FGS10 model



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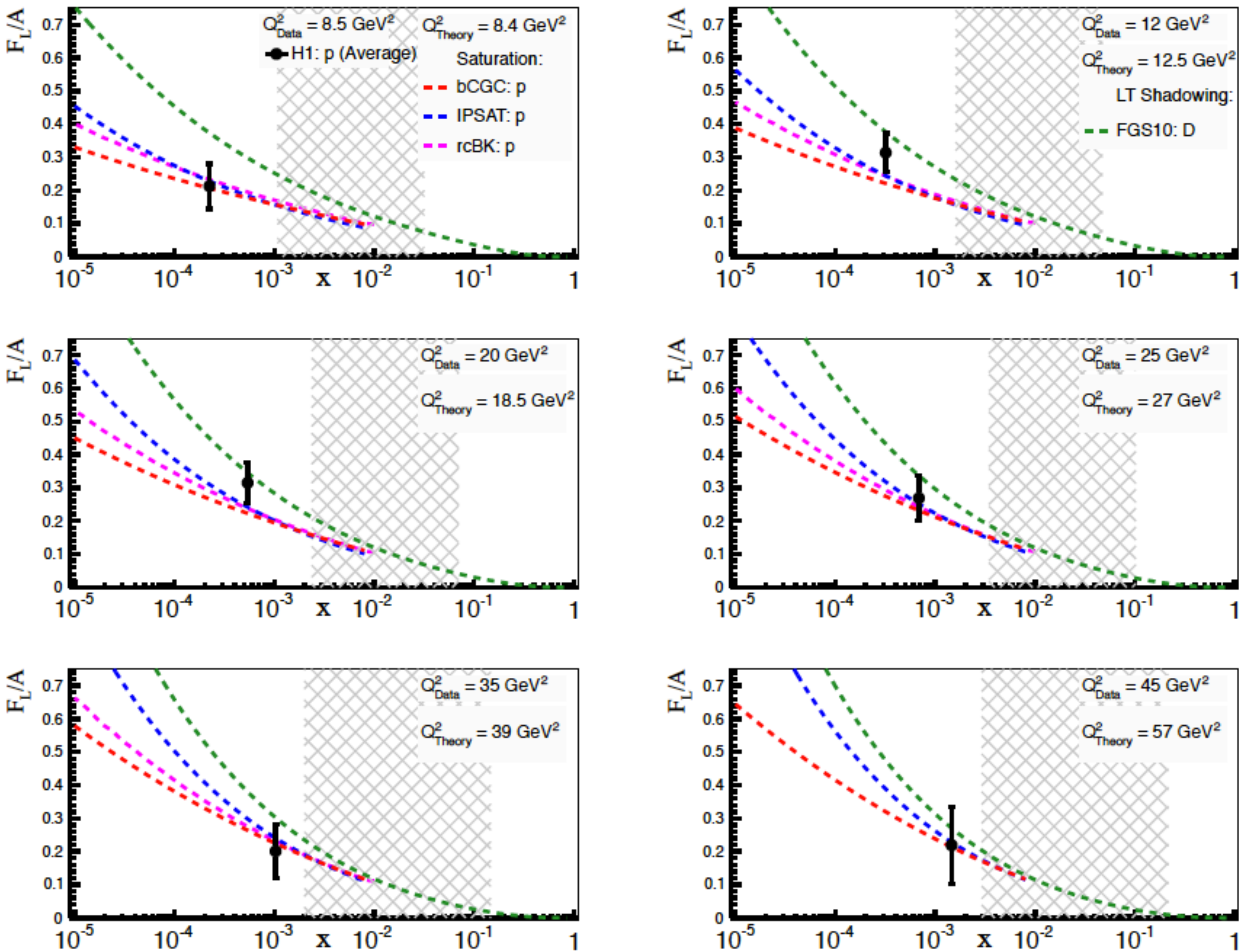
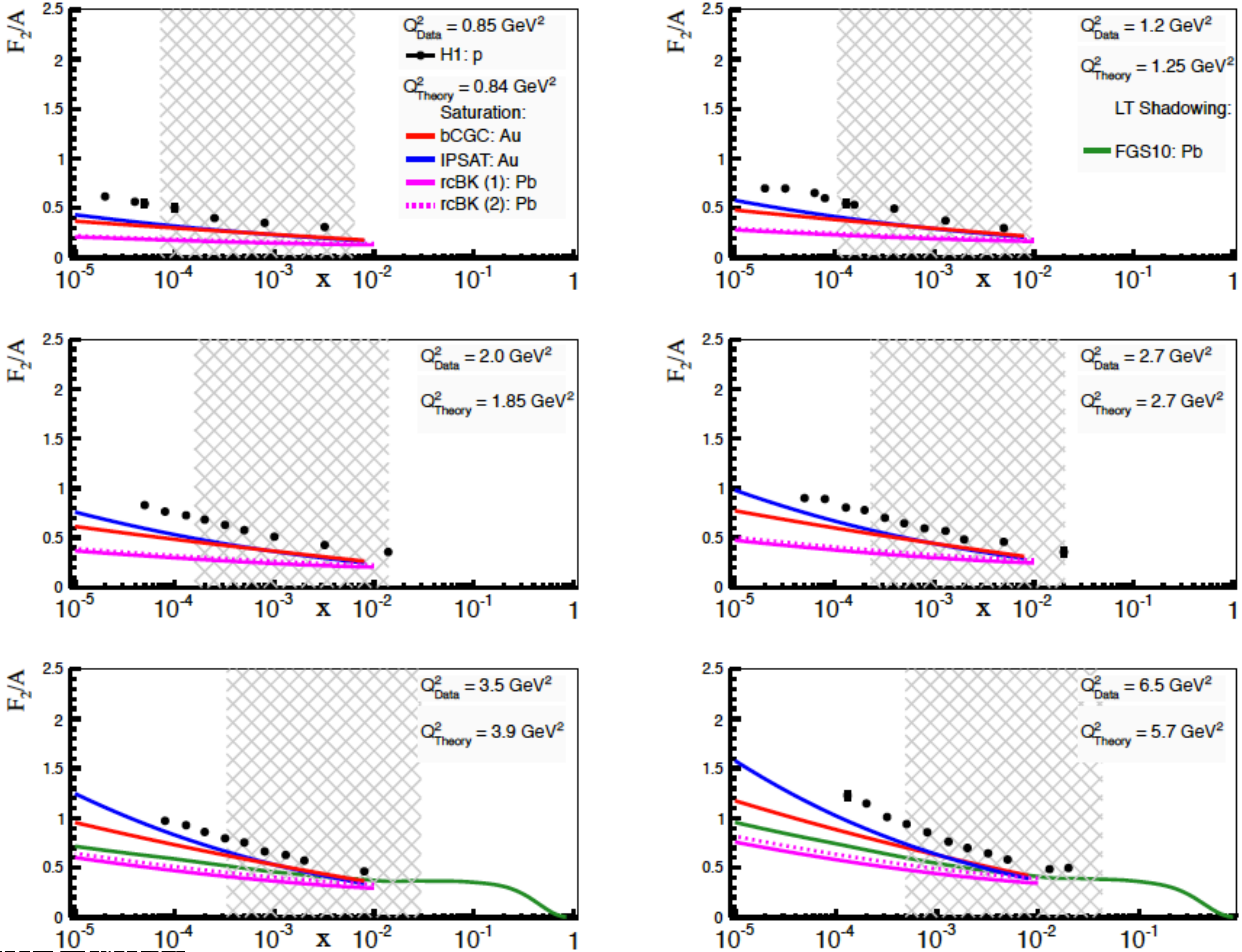
$F_L(p,D)$ - $8 < Q^2 < 60$



F_L/A
x
Q²_Data = 8.5 GeV²
Q²_Theory = 8.4 GeV²
H1: p (Average)
Saturation:
bCGC: p
IPSAT: p
rcBK: p
Q²_Data = 12 GeV²
Q²_Theory = 12.5 GeV²
LT Shadowing:
FGS10: D
Q²_Data = 20 GeV²
Q²_Theory = 18.5 GeV²
Q²_Data = 25 GeV²
Q²_Theory = 27 GeV²
Q²_Data = 35 GeV²
Q²_Theory = 39 GeV²
Q²_Data = 45 GeV²
Q²_Theory = 57 GeV²

$F_2(A)/A$ - $0.8 < Q^2 < 6$



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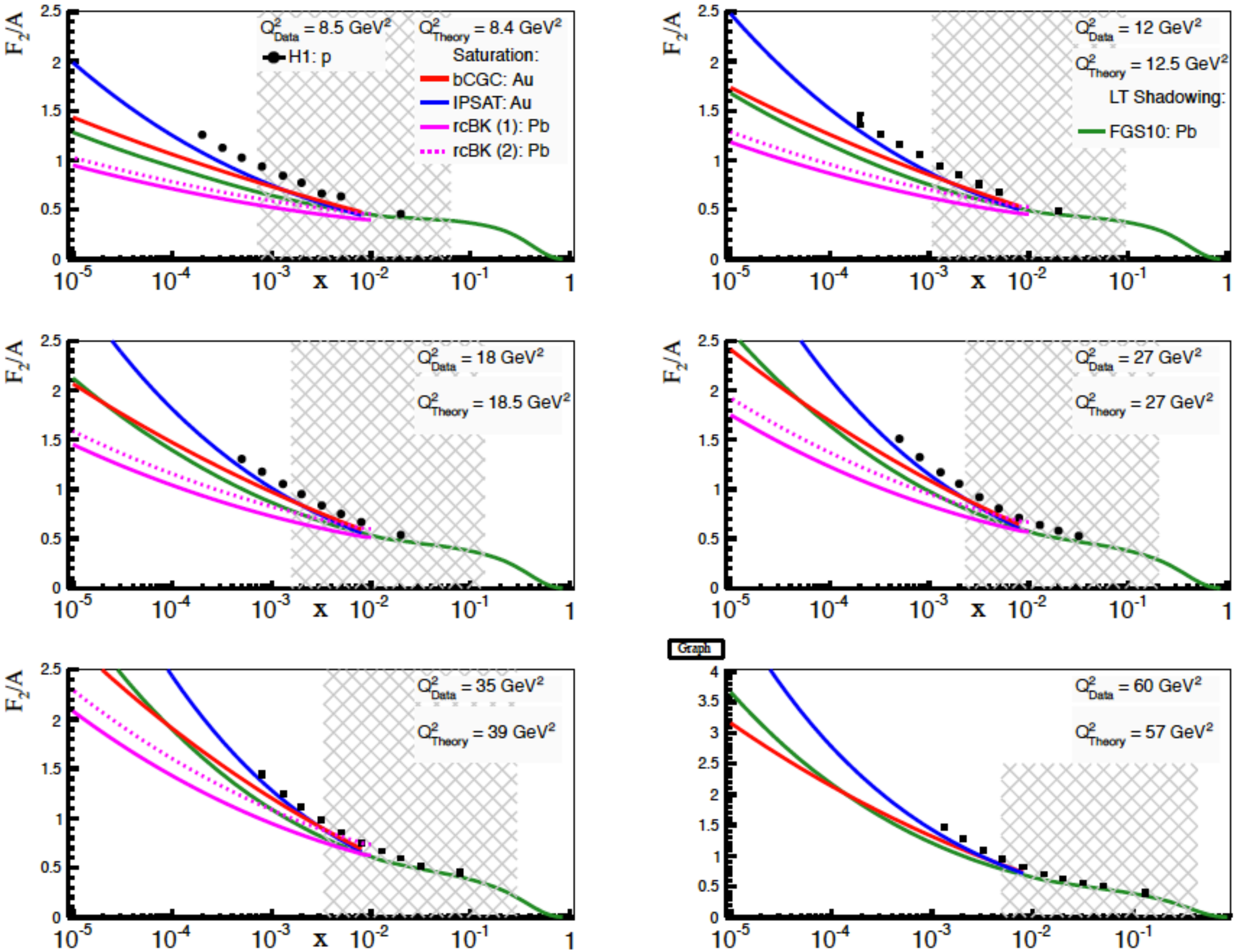
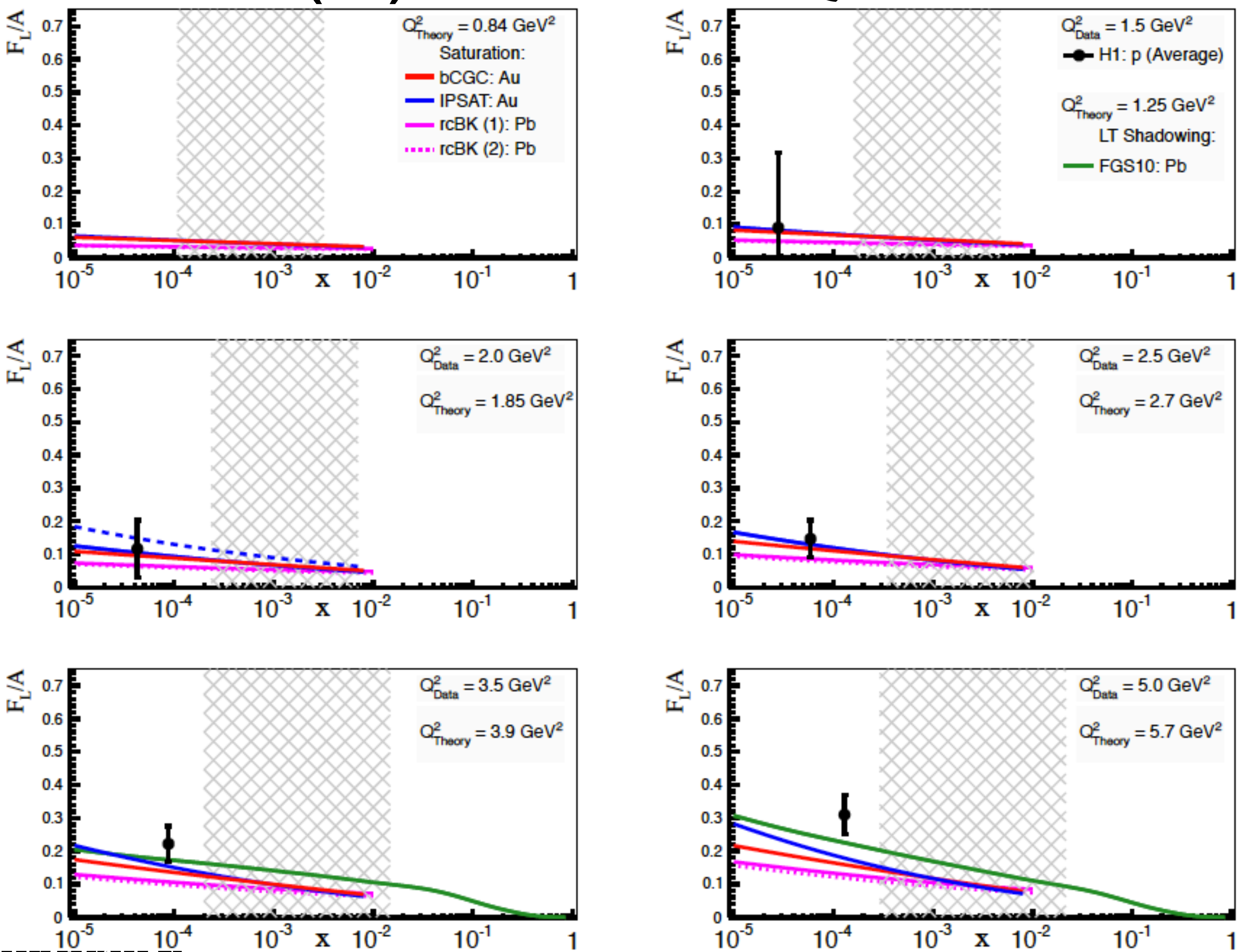
$F_2(A)/A$ - $8 < Q^2 < 60$



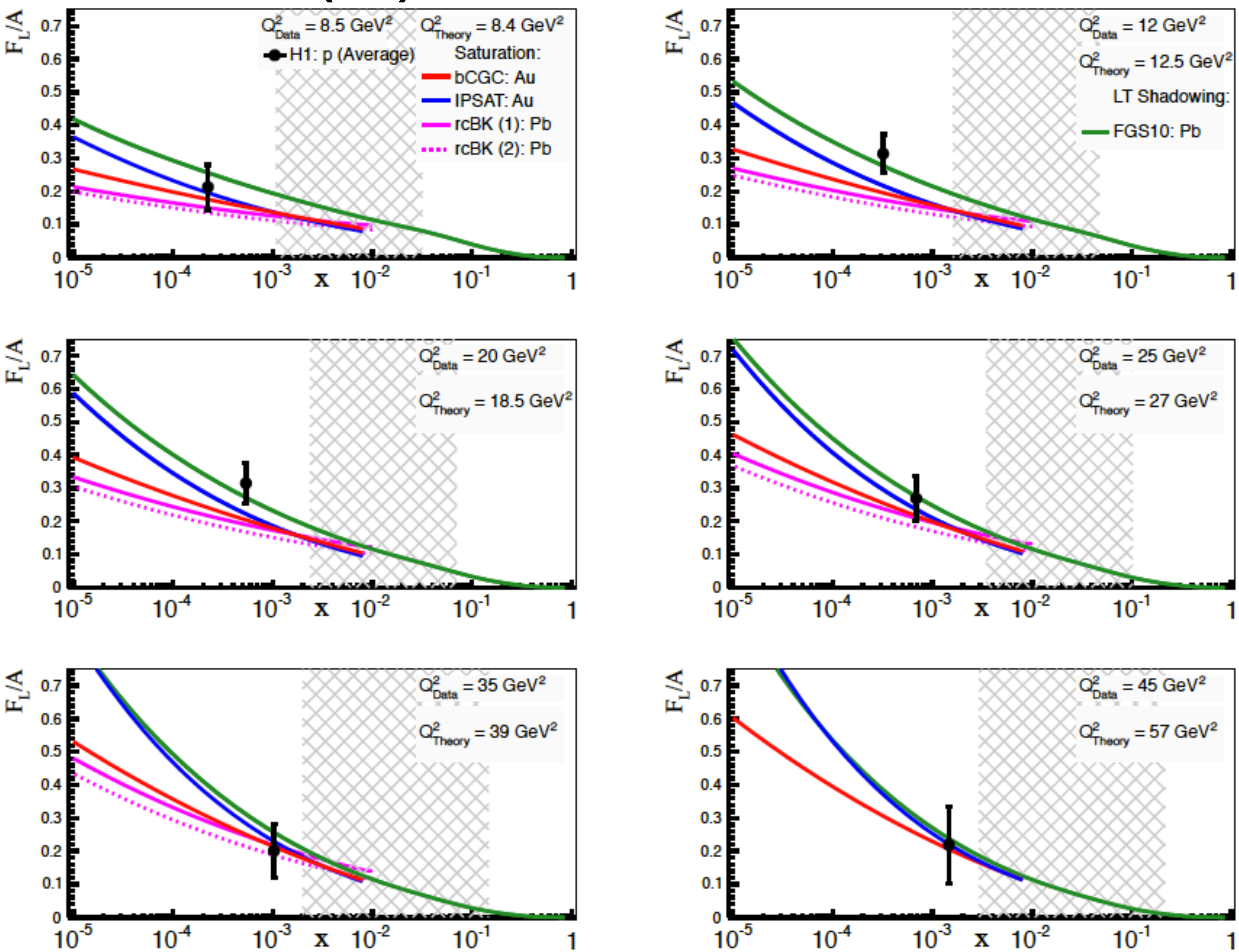
F2/A
Q²Data = 8.5 GeV²
Q²Theory = 8.4 GeV²
H1: p
Saturation:
bCGC: Au
IPSAT: Au
rcBK (1): Pb
rcBK (2): Pb
Q²Data = 12 GeV²
Q²Theory = 12.5 GeV²
LT Shadowing:
FGS10: Pb
Q²Data = 18 GeV²
Q²Theory = 18.5 GeV²
Q²Data = 27 GeV²
Q²Theory = 27 GeV²
Q²Data = 35 GeV²
Q²Theory = 39 GeV²
Graph
Q²Data = 60 GeV²
Q²Theory = 57 GeV²
x
10⁻⁵ 10⁻⁴ 10⁻³ 10⁻² 10⁻¹ 1

$F_L(A)/A$ - $0.8 < Q^2 < 6$



F_L/A
Q^2_{Theory} = 0.84 GeV²
Saturation:
bCGC: Au
IPSAT: Au
rcBK (1): Pb
rcBK (2): Pb
Q^2_{Data} = 1.5 GeV²
H1: p (Average)
Q^2_{Theory} = 1.25 GeV²
LT Shadowing:
FGS10: Pb
Q^2_{Data} = 2.0 GeV²
Q^2_{Theory} = 1.85 GeV²
Q^2_{Data} = 2.5 GeV²
Q^2_{Theory} = 2.7 GeV²
Q^2_{Data} = 3.5 GeV²
Q^2_{Theory} = 3.9 GeV²
Q^2_{Data} = 5.0 GeV²
Q^2_{Theory} = 5.7 GeV²
x

$F_L(A)/A$ - 8 < Q^2 < 60



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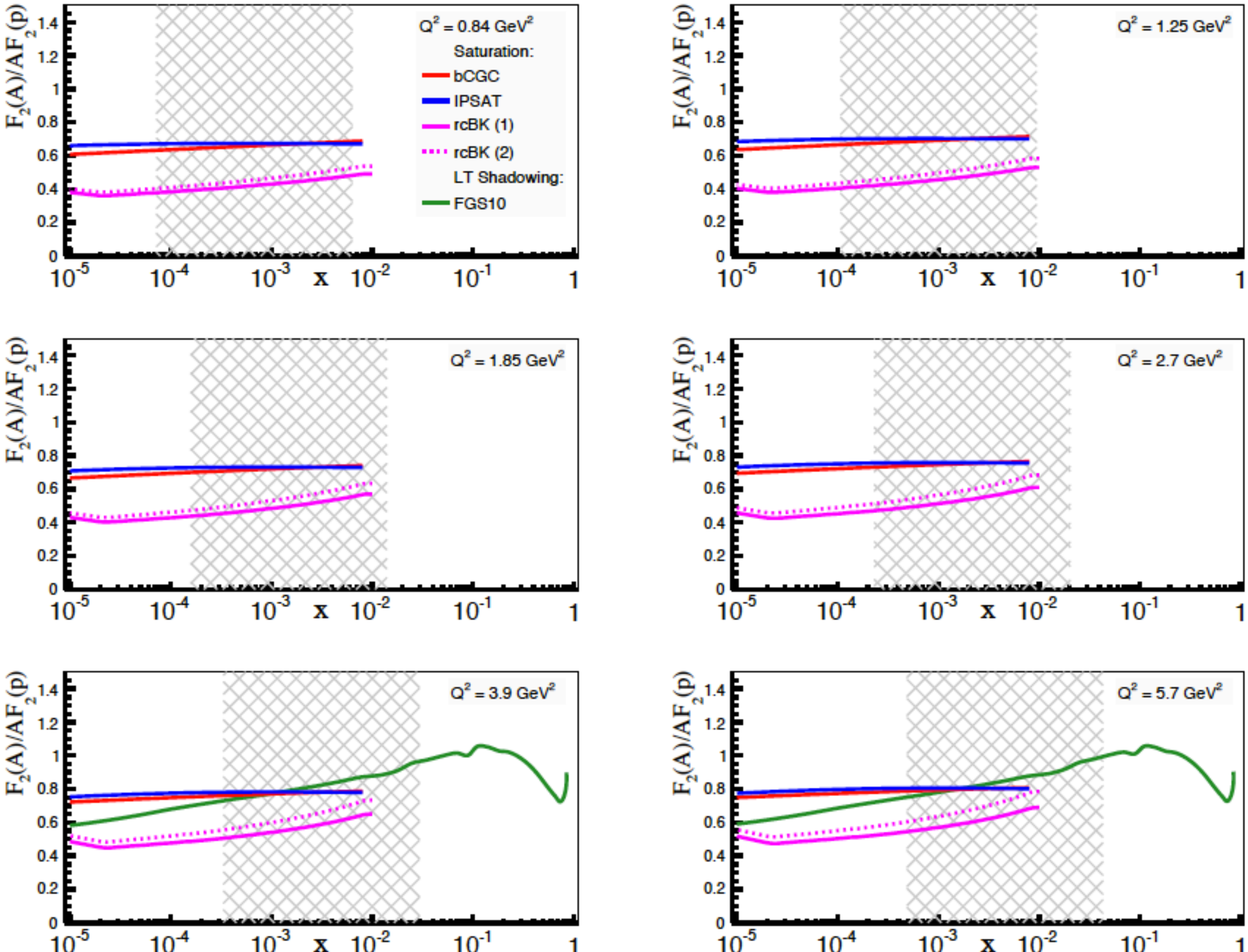
$F_2(A)/AF_2(p)$ - $0.8 < Q^2 < 6$



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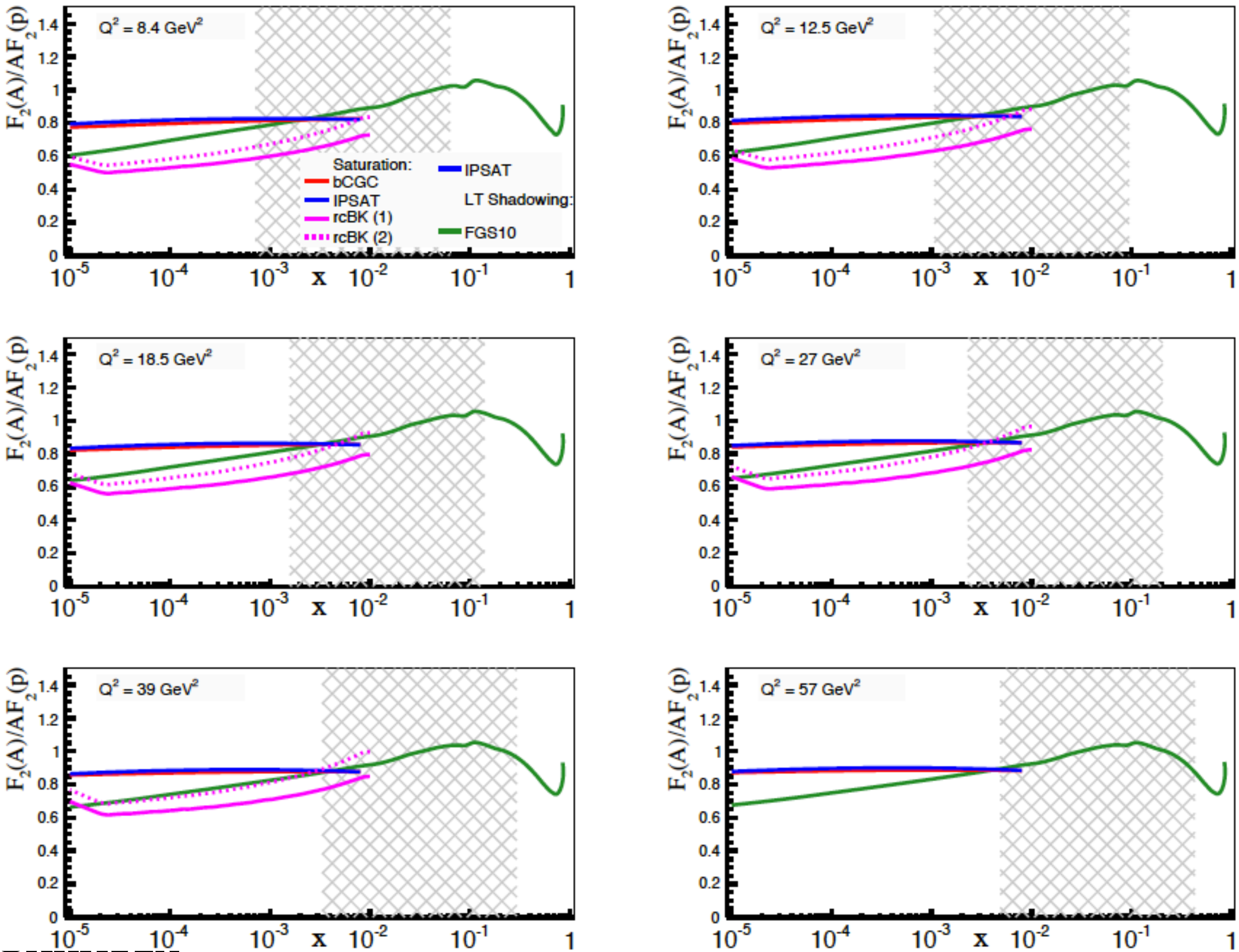
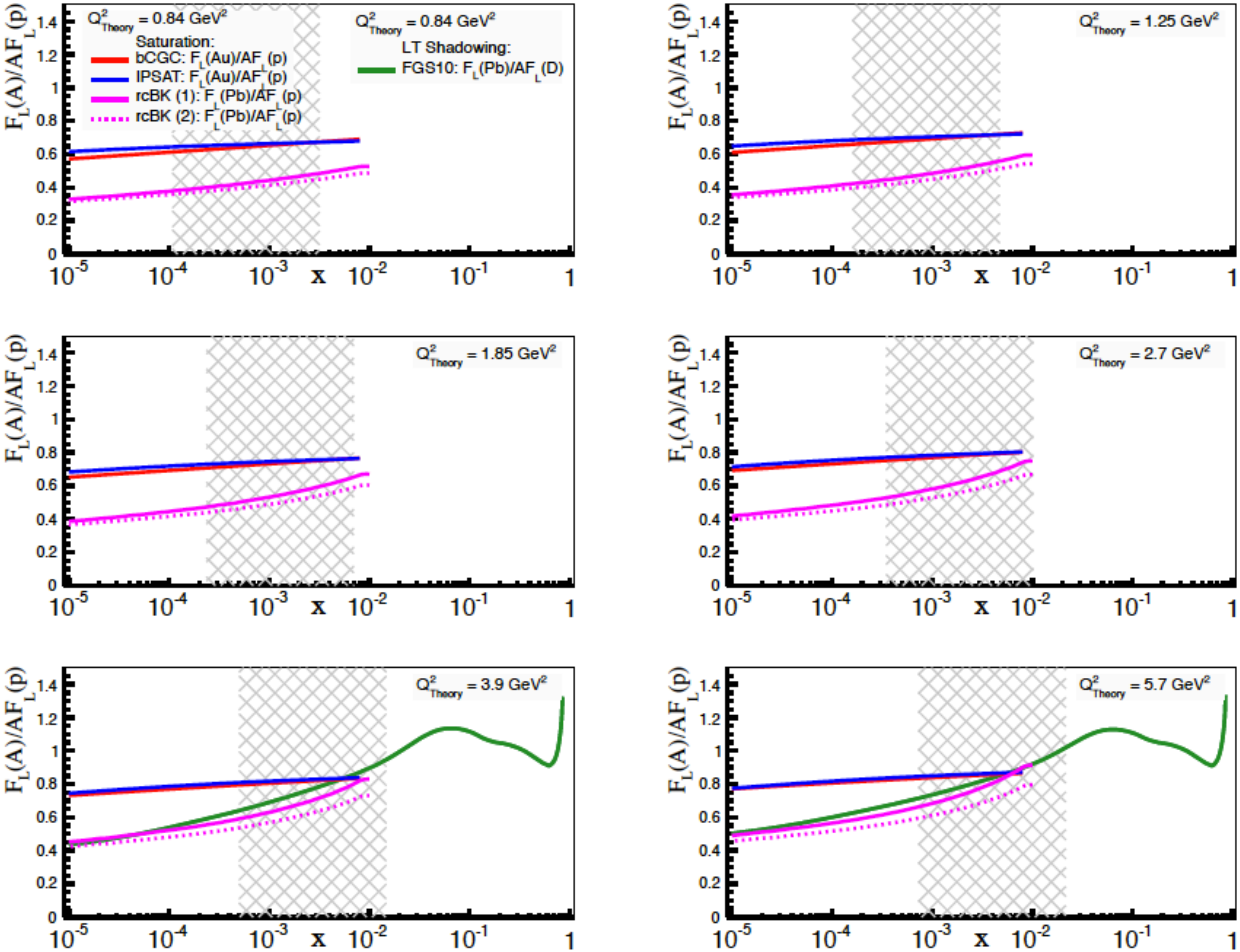
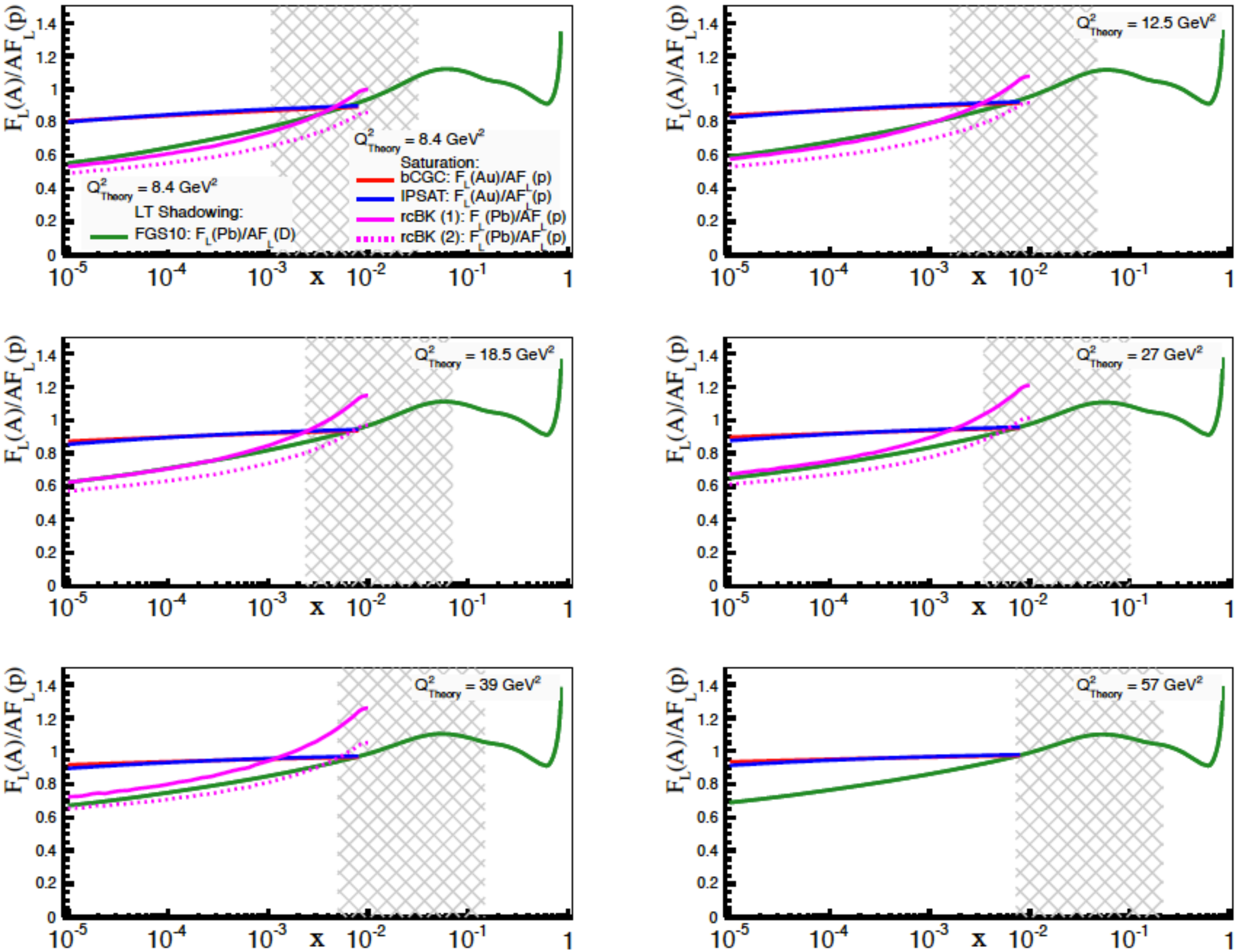
$F_2(A)/AF_2(p)$ - $8 < Q^2 < 60$



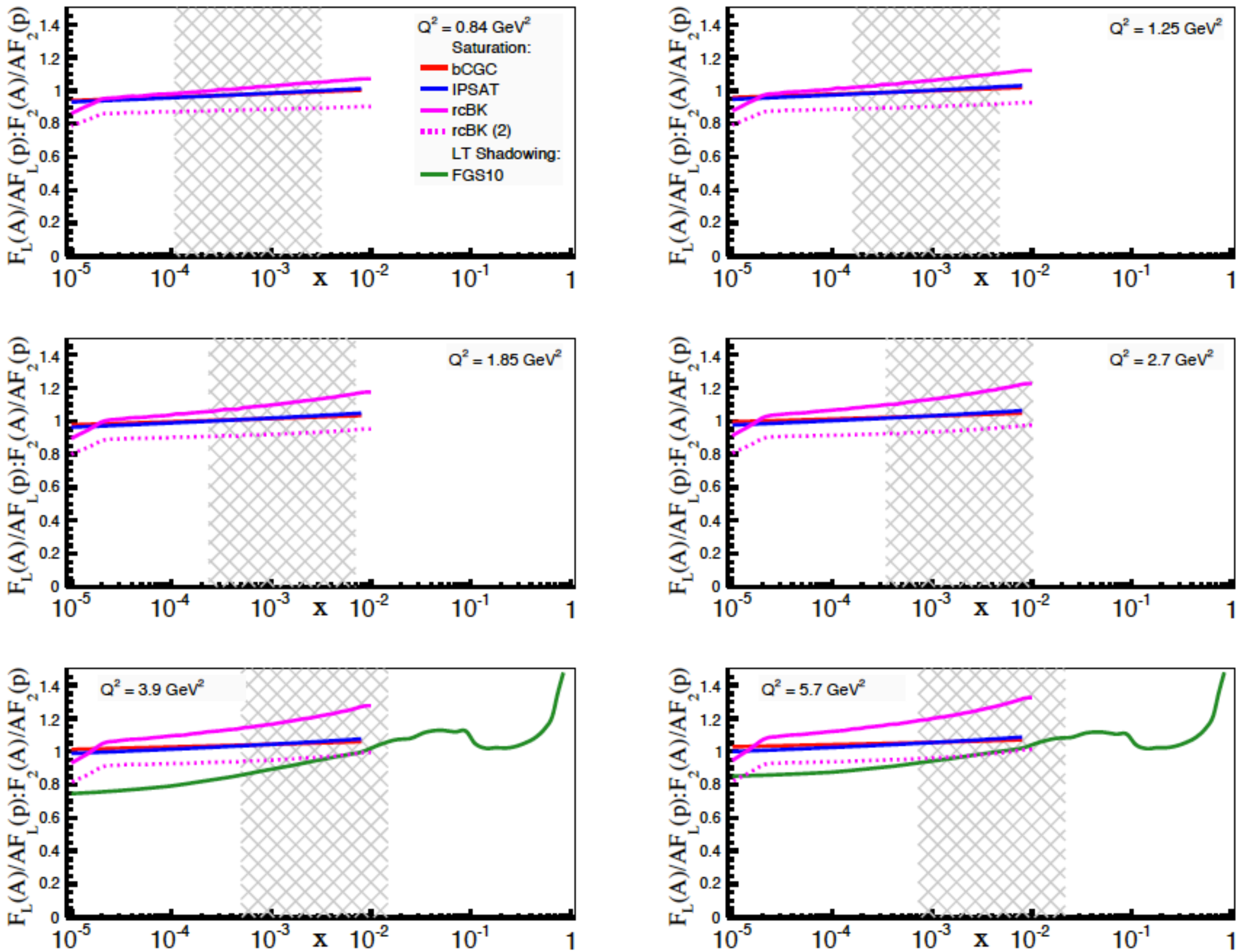
$F_L(A)/AF_L(p)$ - 0.8 < Q^2 < 6



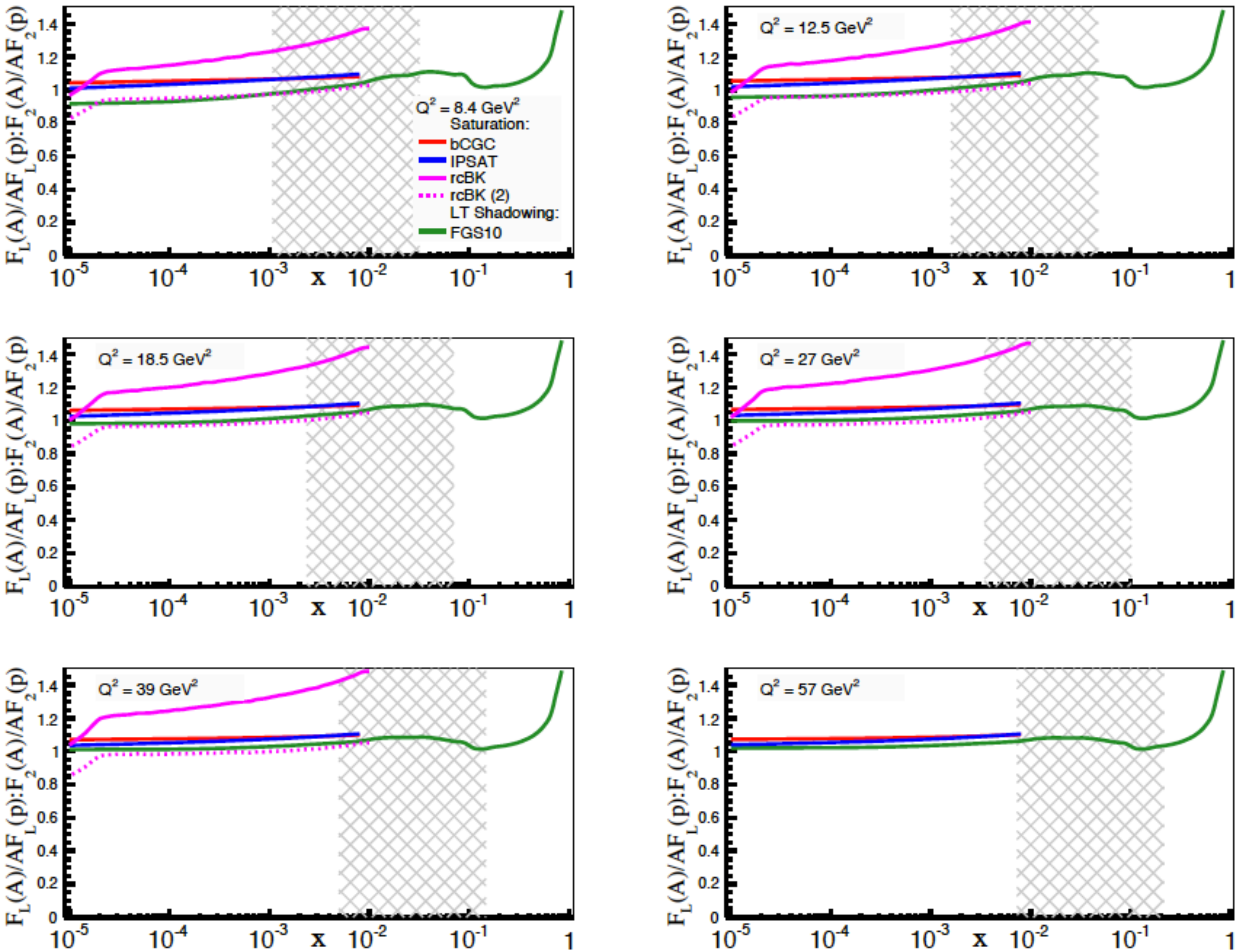
$F_L(A)/AF_L(p)$ - $8 < Q^2 < 60$



$F_L(A)/AF_L(p)$: $F_2(A)/AF_2(p)$ - 0.8 < Q^2 < 6



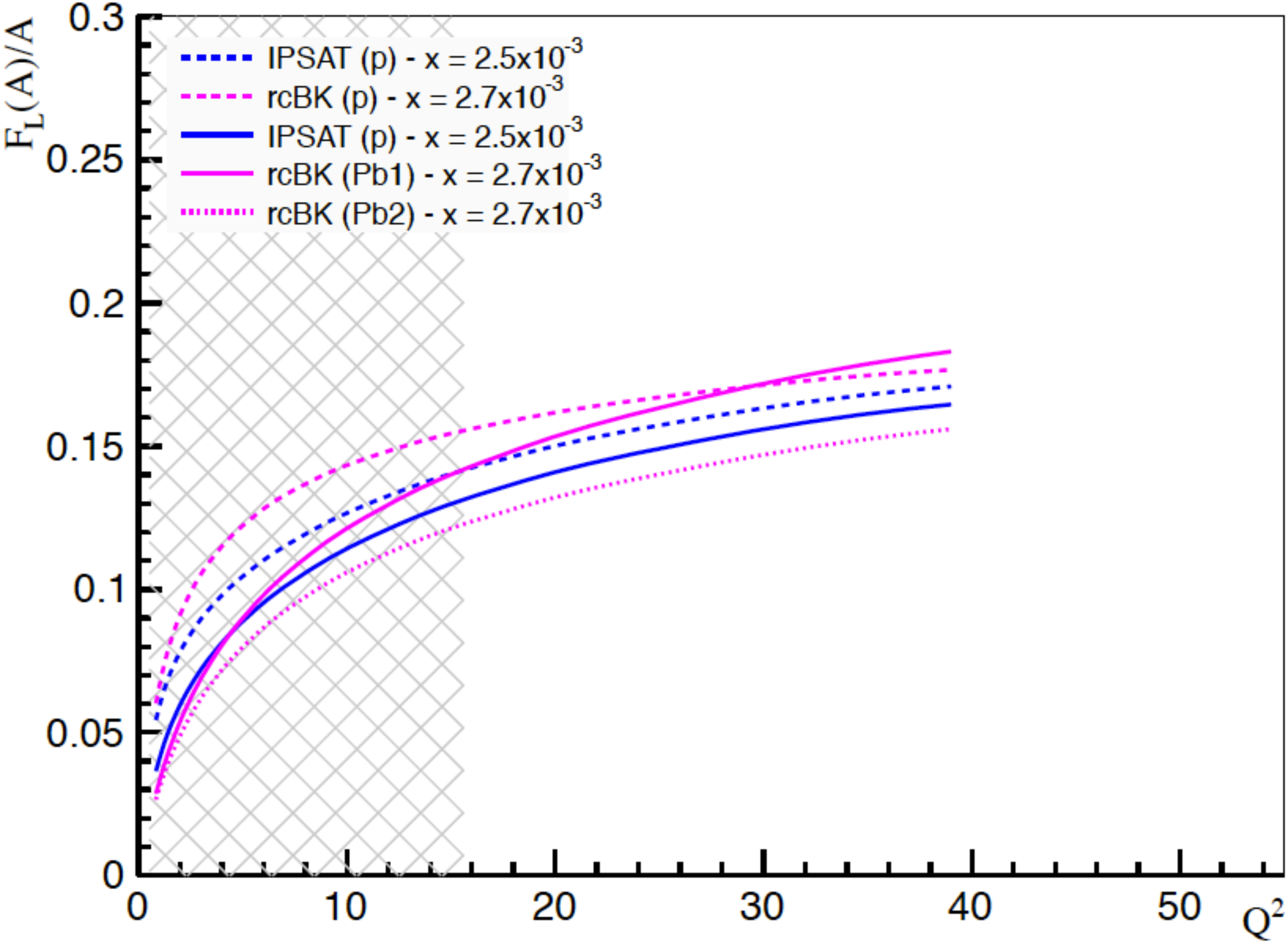
$F_L(A)/AF_L(p)$: $F_2(A)/AF_2(p)$ - $8 < Q^2 < 60$



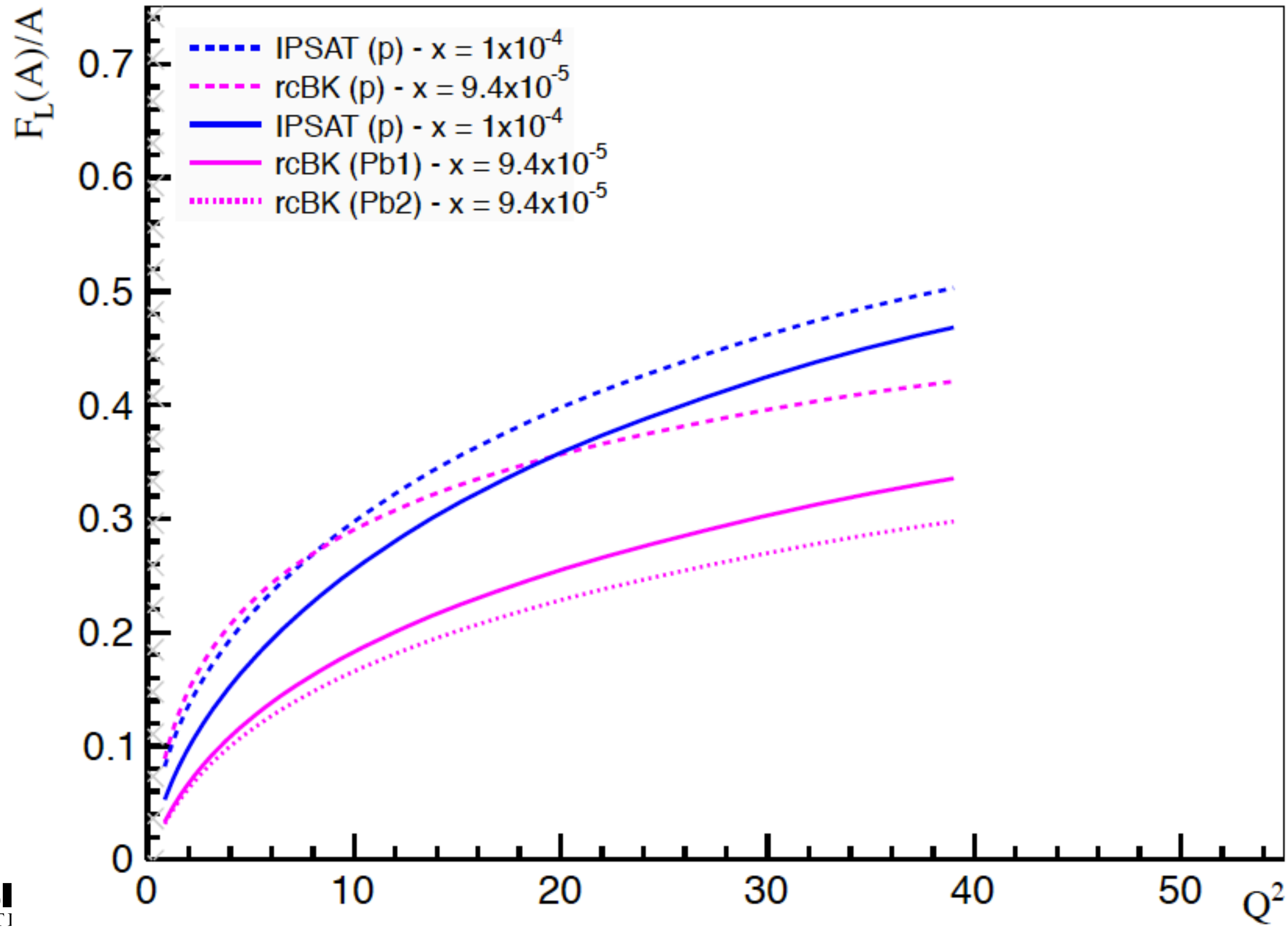
Some Questions, Points, Thoughts

- The bCGC and IPSat models are different for F_2(p) and rcBK and bCGC are on top of each other
  - ➡ bCGC and rcBK are based on BK - IPSat on eikonalised DGLAP…. Was the bCGC re-fit to the combined H1&ZEUS data?
- There are 10% differences between IPSat and the F2(p) HERA data
  - ➡ If IPSat was re-fit (not a small effort, who would do it?), would this have any significant affect on the F_L data?
- What do we make of the difference in evolutions of F_2(A)/AF_2(p) and F_2(A)/AF2(p) in the saturation models?
  - ➡ Must be dependent on what order the saturation is implemented in the model
- The double ratios are hard to interpret, can we use this though to constrain the normalisations in the rcBK model?
- Vadim is currently updating his code to use CTEQ6/10 instead of CTEQ5
  - ➡ How will this affect the plots?
  - ➡ Will the ratios be unchanged (or at least minor changes)?
- Finally, we want some clean plots for the white paper, what do we want to show?

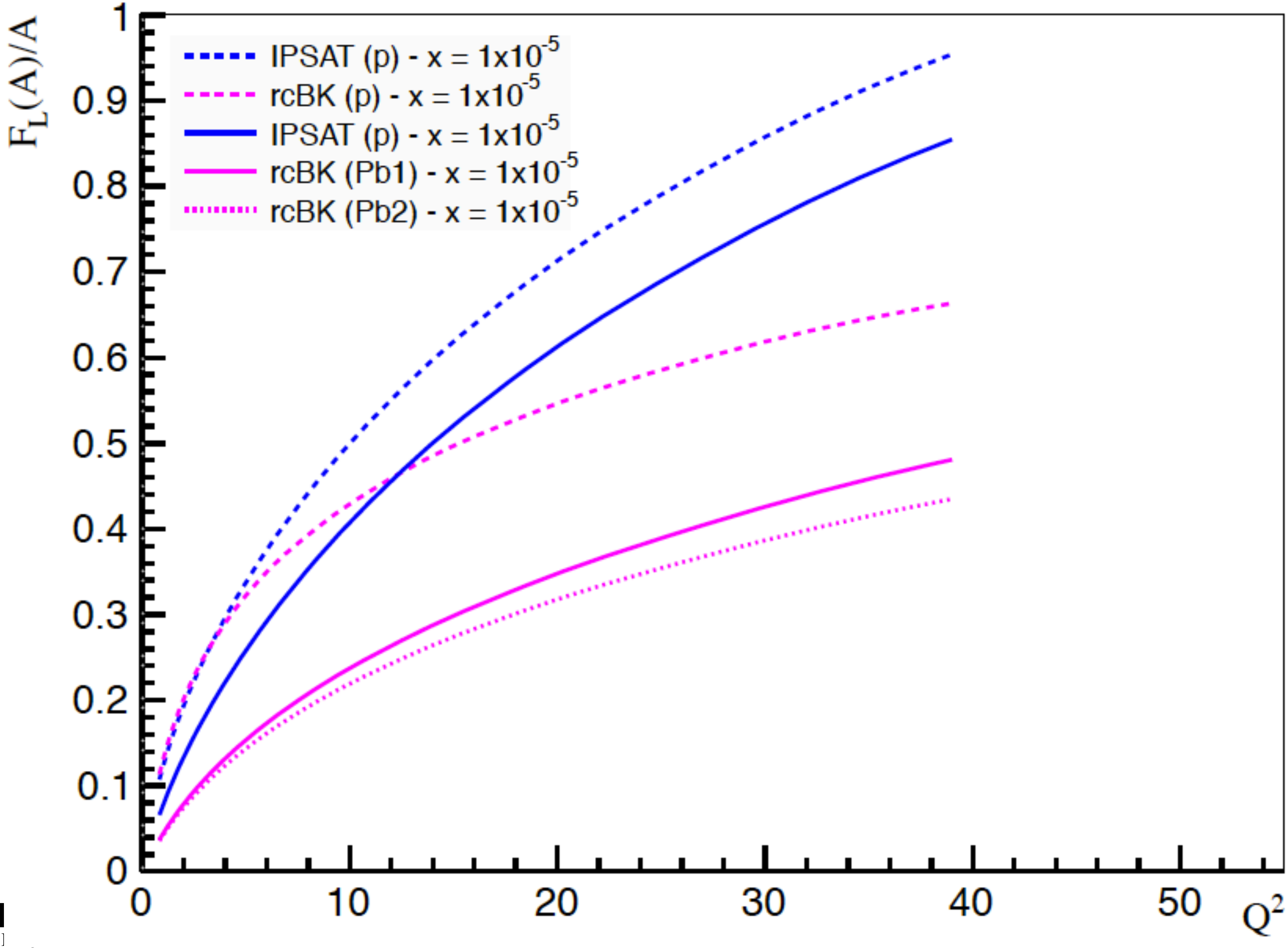
Keep x fixed: x = 2x10^{-3}



Keep x fixed: $x = 1\times10^{-4}$



Keep x fixed: $x = 1 \times 10^{-5}$



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