Target diffraction simulation in Geant4

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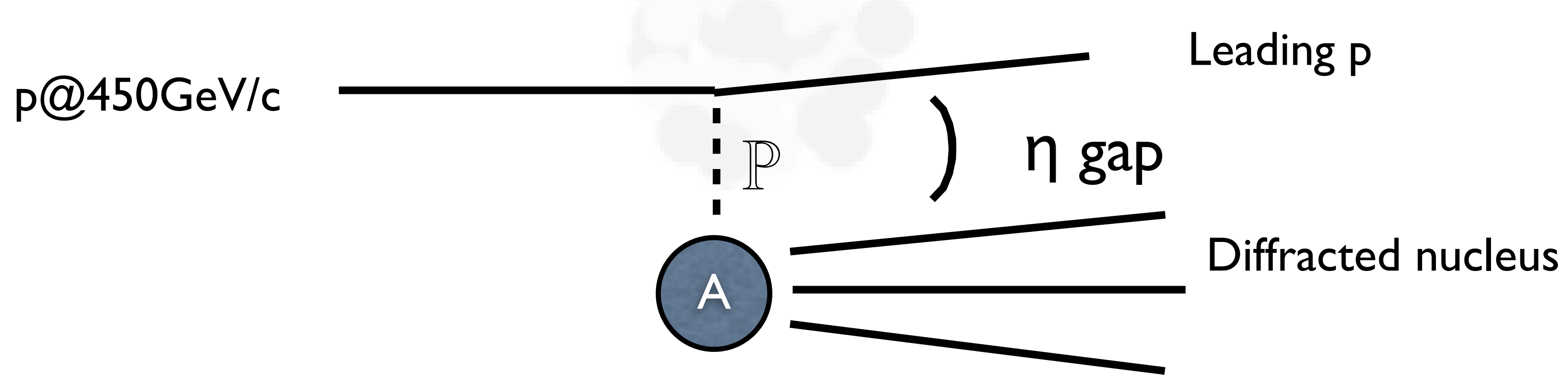
Target diffraction

- Diffraction dissociation of nuclei in reaction pA→pX
  - Less known than pp diffraction
  - Only one experiments
- The process is interesting since it can give clues on:
  - the parton structure of nucleons inside the nucleus
  - the dynamics of Pomeron interaction with nuclear matter
- Experiment:
  - HELIOS spectrometer
  - SpS (1991)

Target diffraction

- Accounts for ~10% of total production cross section
- Experimental signature:
  - Leading proton with small momentum transfer to nuclei
  - Diffracted nucleus: backward activity (in c.m.s.)
  - Rapidity gap

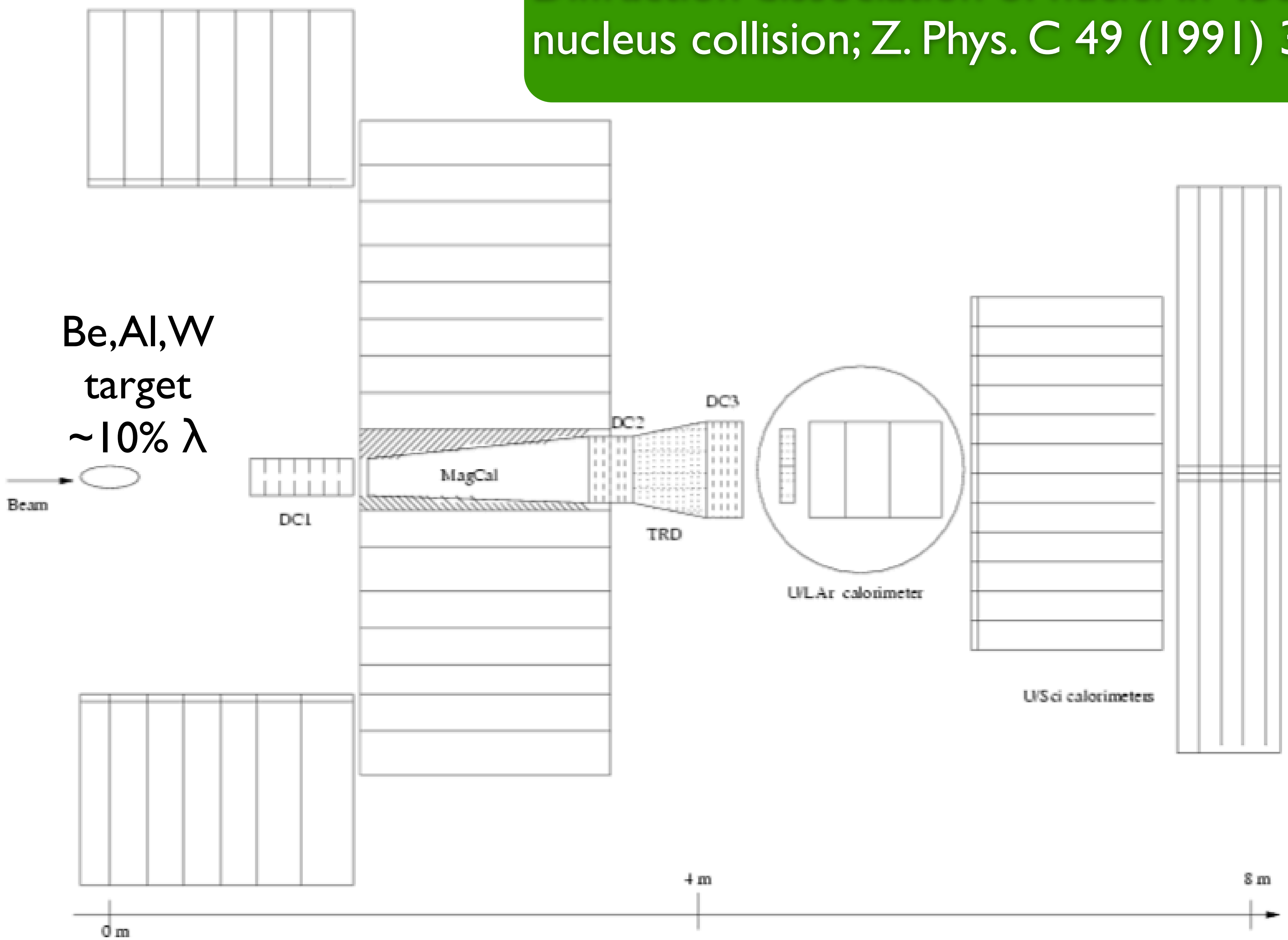


- Process important at high energies
- Since leading proton loses only small fraction of its momentum and fragments are relatively soft:
  - It can affect longitudinal shower shapes
- Geant4 simulation:
  - Does not have "target diffraction" process
  - It is part of inelastic and quasi-elastic process
- We compare experimental data with "pseudo simulations" of the same interaction (i.e. w/o detector simulation)
- Based on A. Ribon's Analysis (2007): 4th simple benchmark

HELIOS Experiment

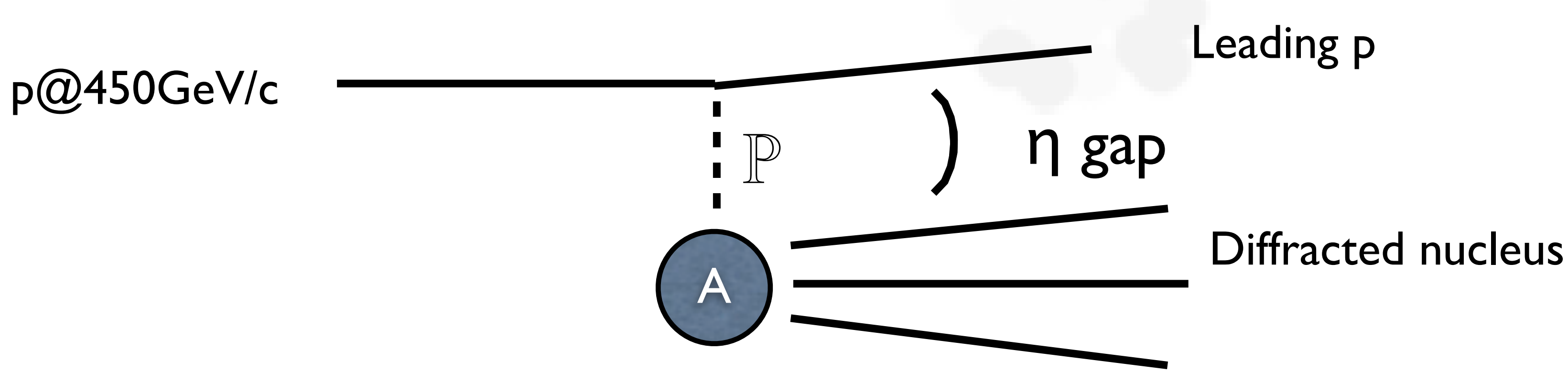
Diffraction dissociation of nuclei in 450 GeV/c proton-nucleus collision; Z. Phys. C 49 (1991) 355

Be,Al,W
target
~10% λ



Analysis and Results

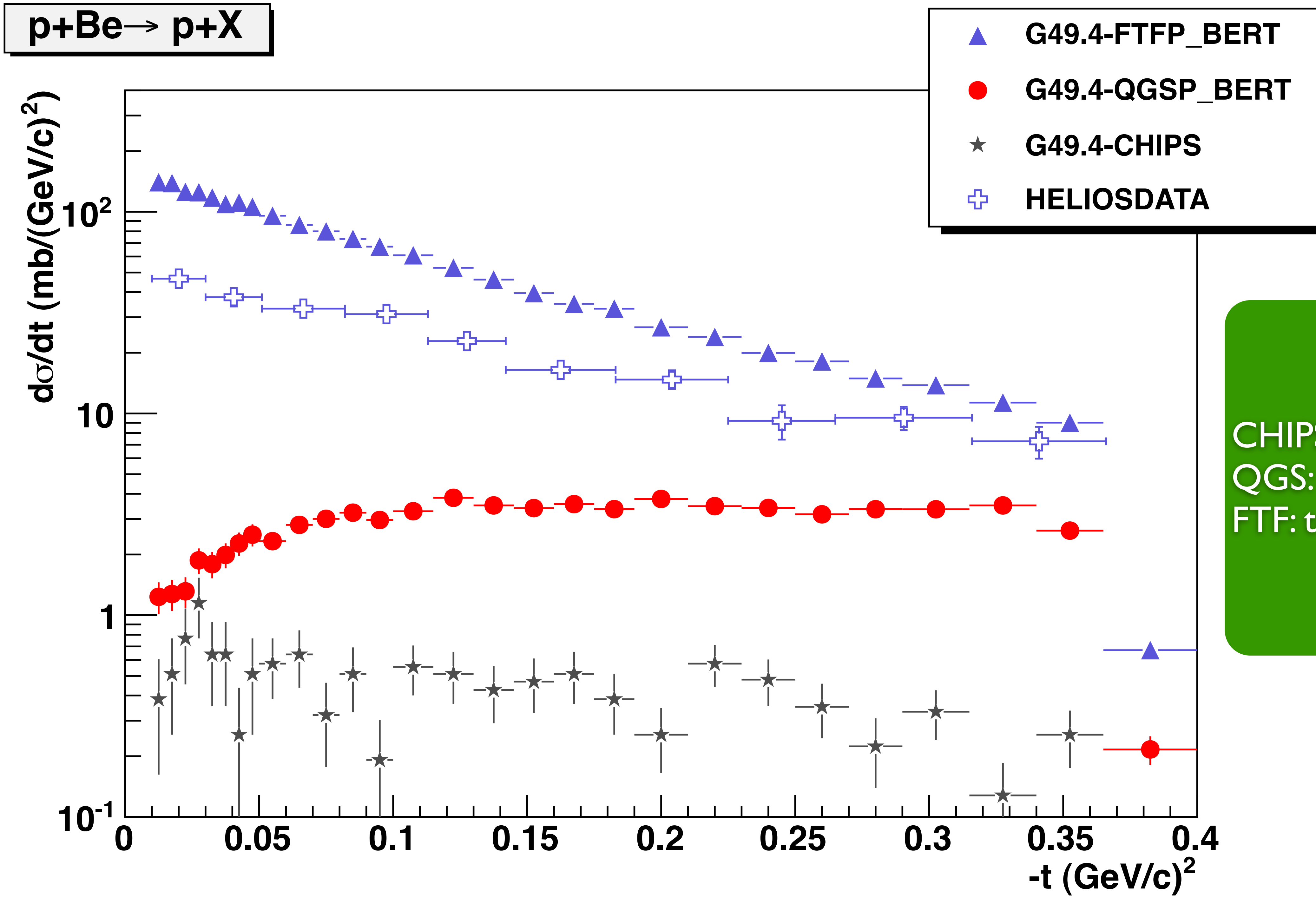
- Single-diffractive differential σ as a function of -t
- Single-diffractive differential σ as a function of (1-xF)
- Analysis based on cuts on tracking chamber and calorimeters
  - Leading proton identification: $\Delta p_{||}<35$ GeV/c , $0.1<p_{\perp}<0.6$ GeV (suppress hadron-elastic & quasi-elastic)
  - E>0.5 GeV for $\eta<2.9$ (backward activity)
  - rapidity gap ($4.75<\eta<6.0$ with no tracks, no neutral particles E<30 GeV in $\eta>3.0$



Simulation

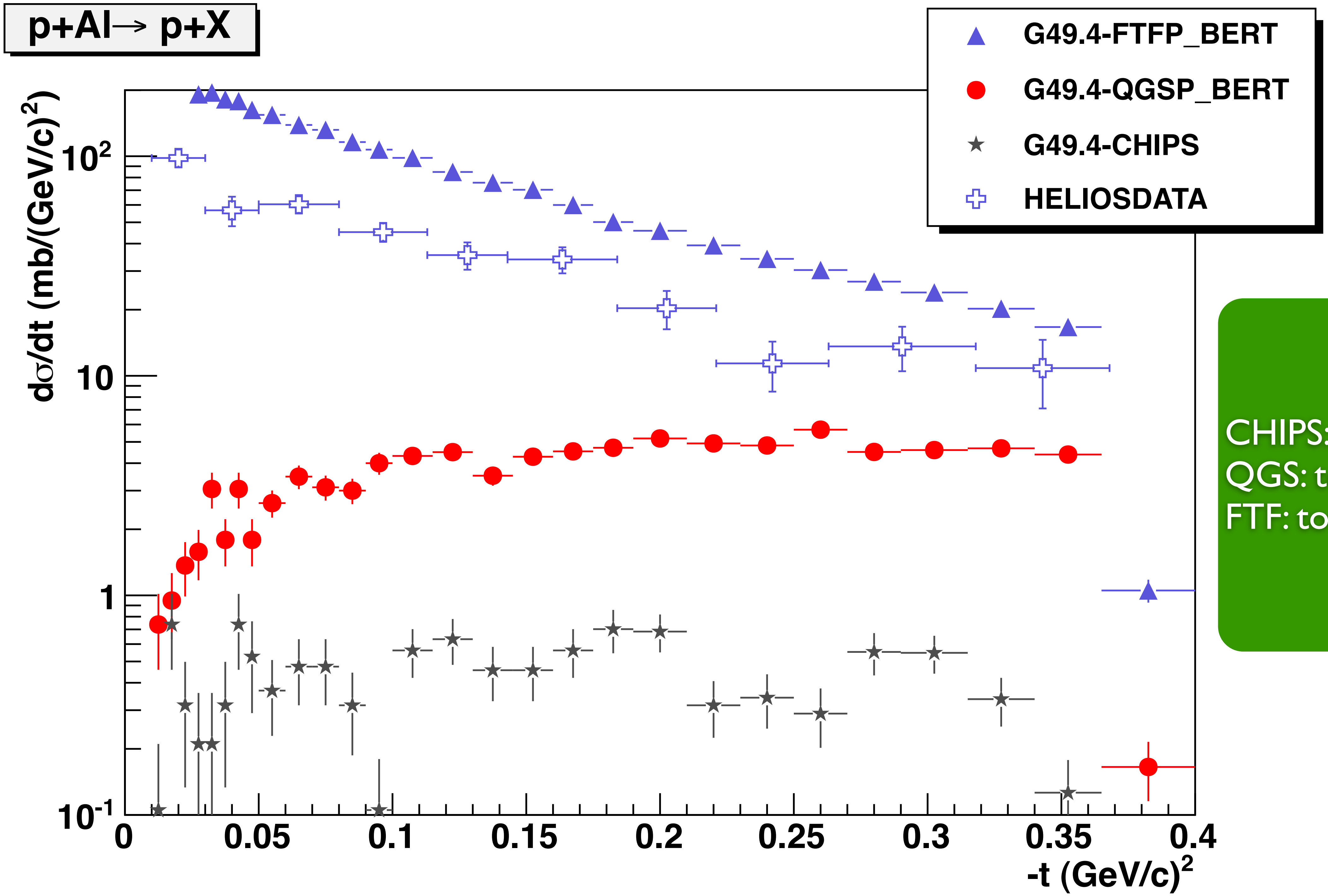
- Interactions of protons on target
- Apply analysis cuts to the secondaries produced
  - Do not simulate detector
  - Experimental corrections not applied
- Experimental corrections applied on HELIOS data:
  - ε_{vertex} : absent in MC
  - $\varepsilon_{forward}$: experiment use toy MC: O(20%)
  - $\varepsilon_{backward}$: experiment use special MC: ≤20% affects mainly low 1-x_F
  - ε_{gap} : experiment use a (tuned) special MC , unfortunately most important O(60%), but much is due to experimental readout
- Experimental results are "unfolded"

Results: dσ/dt Be



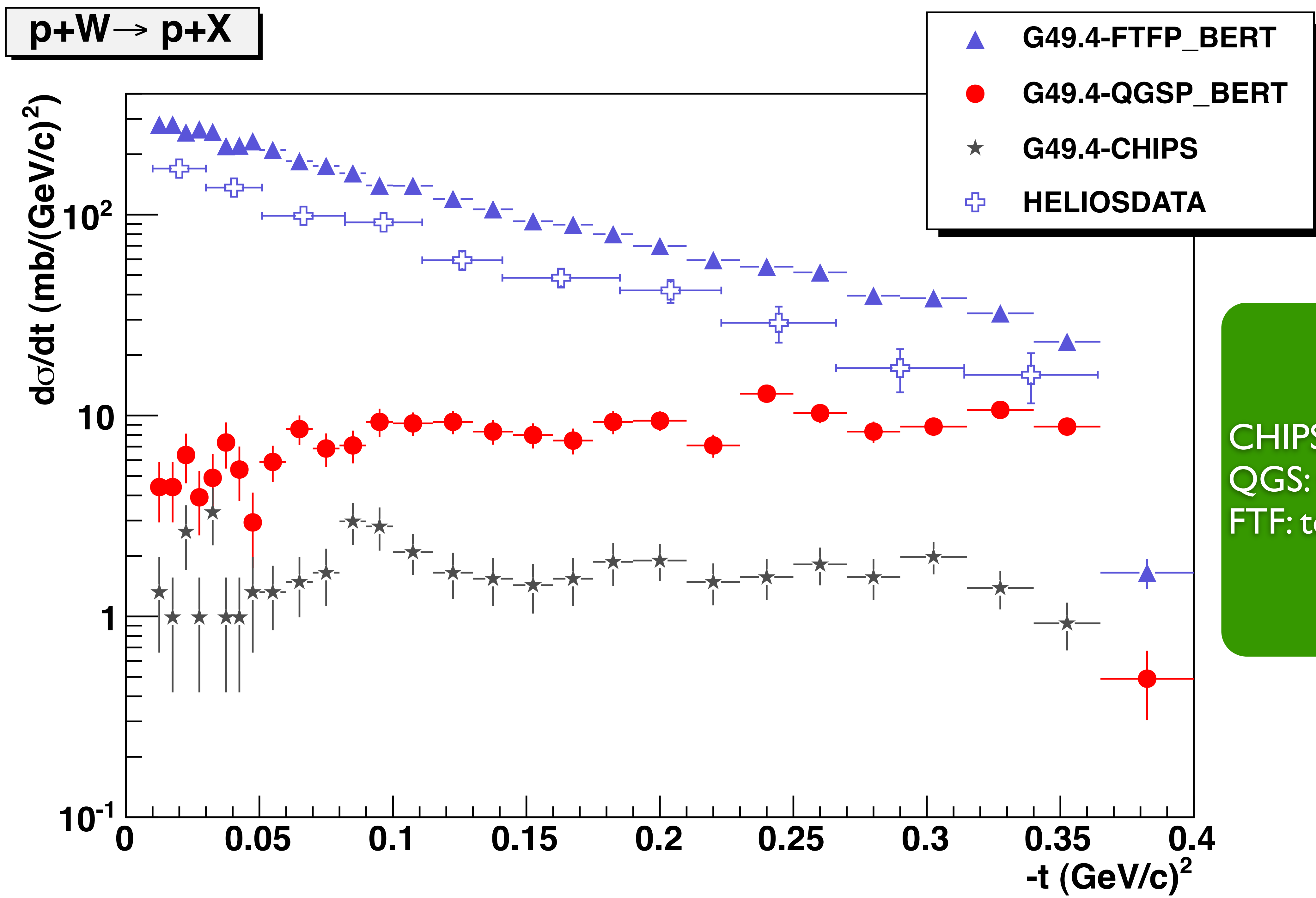
CHIPS: very low
QGS: too low, wrong shape
FTF: too large, correct shape

Results: dσ/dt Al



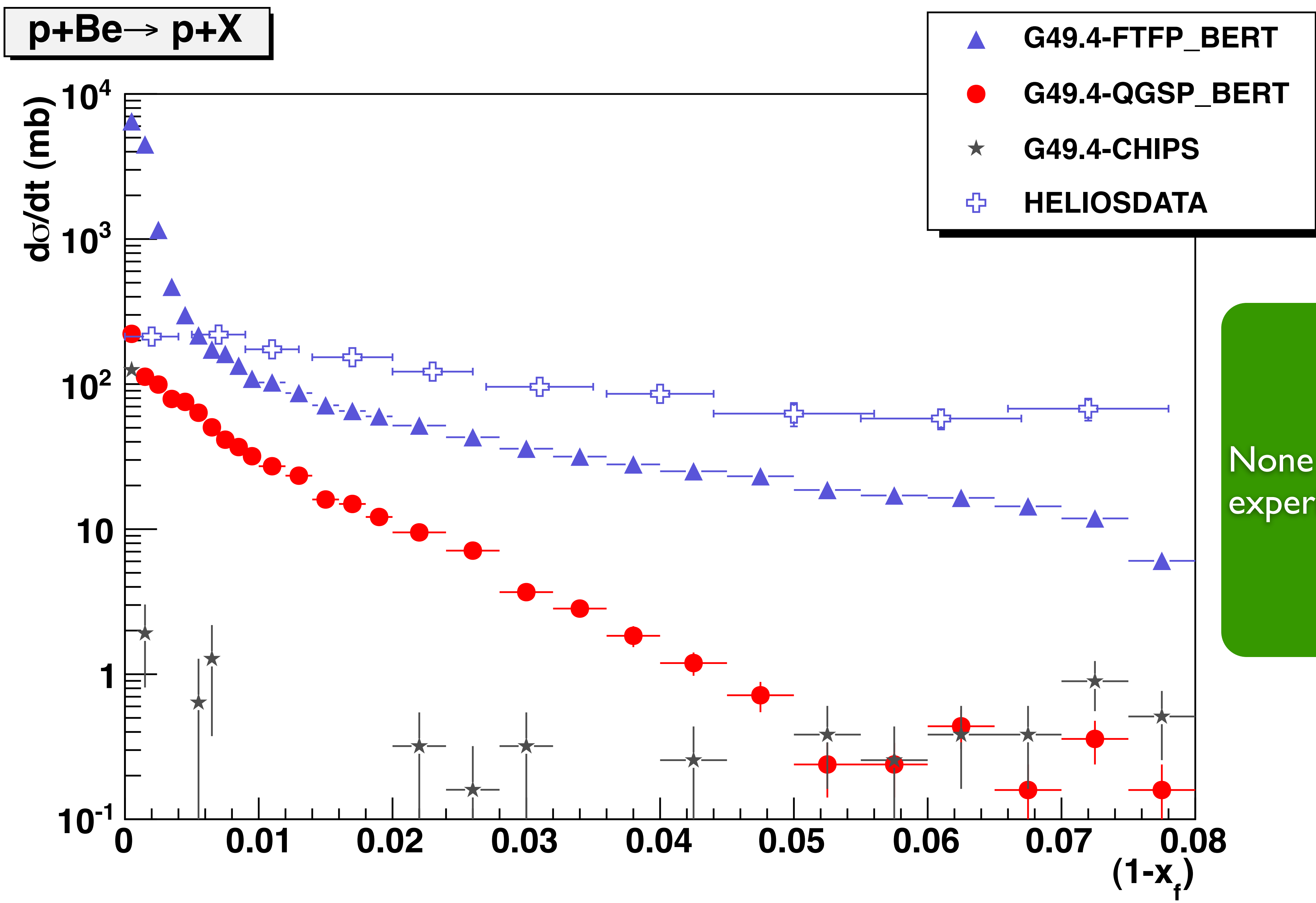
CHIPS: very low
QGS: too low, wrong shape
FTF: too large, correct shape

Results: dσ/dt W



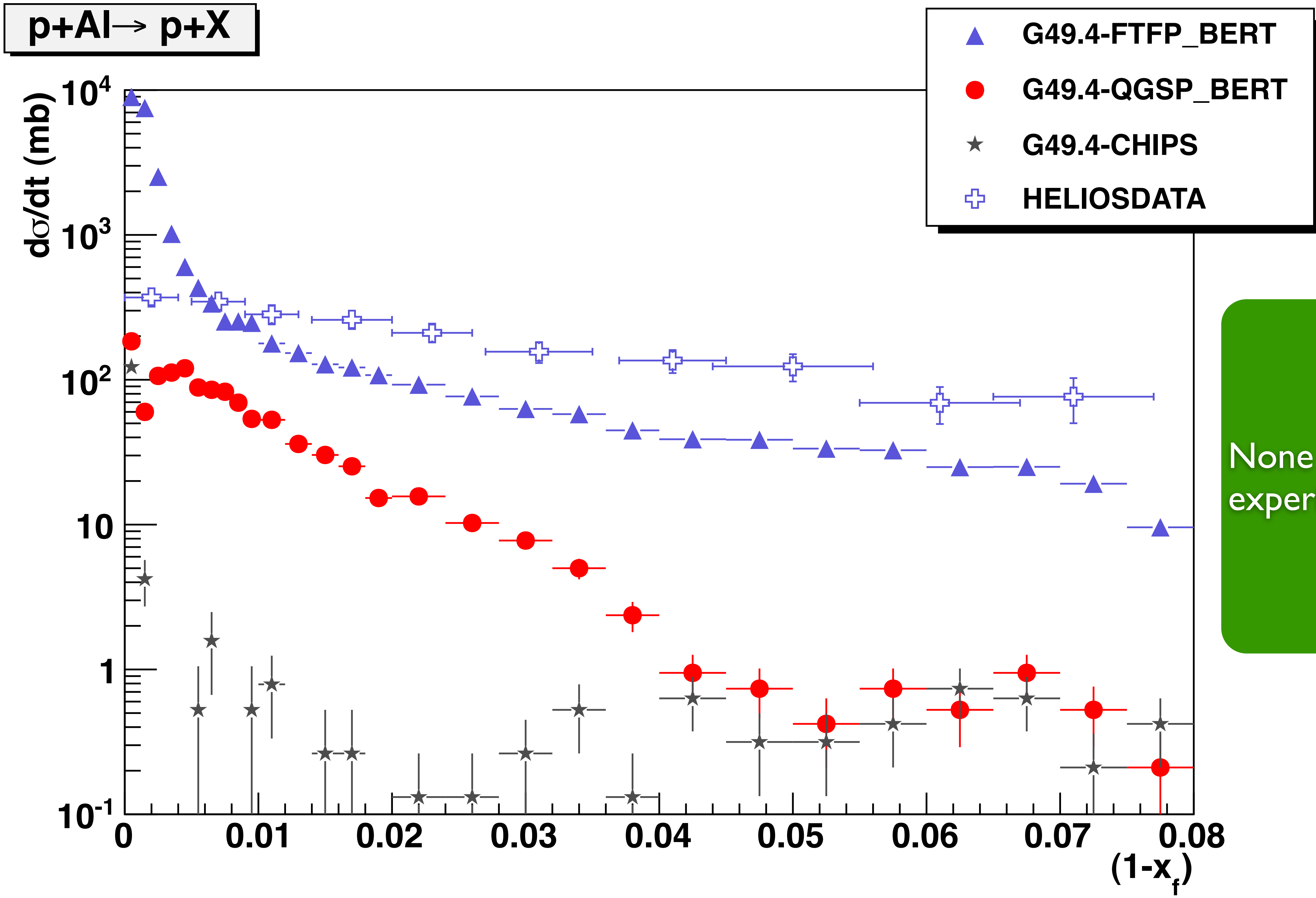
CHIPS: very low
QGS: too low, wrong shape
FTF: too large, correct shape

Results: $d\sigma/dx_F$ Be



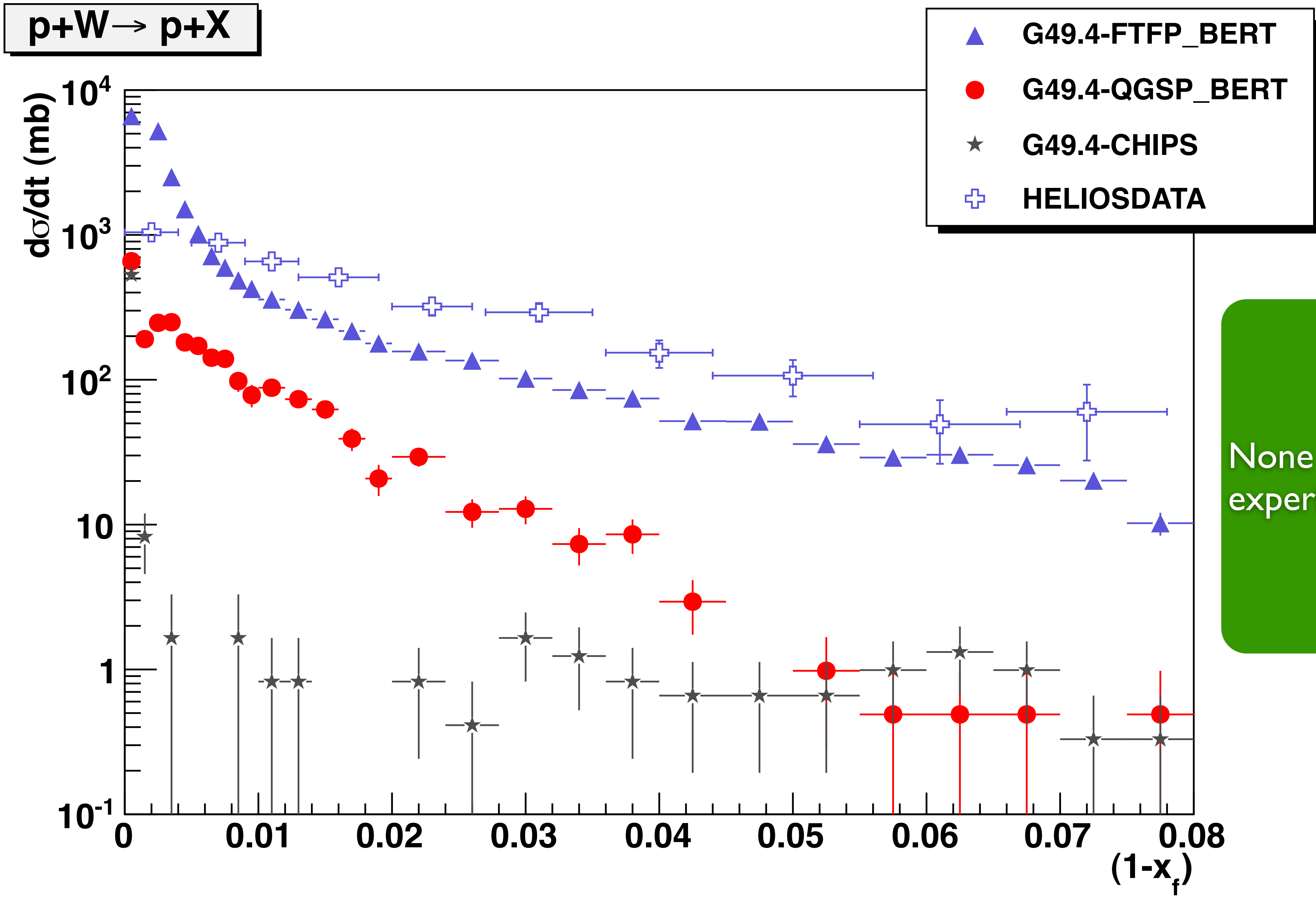
None can reproduce experimental shape

Results: $d\sigma/dx_F$ Al



None can reproduce experimental shape

Results: $d\sigma/dx_F$ W



None can reproduce experimental shape

Integrated Cross section

(mb)	Be	Al	W
DATA	8.21±0.32±1.18	13.29±0.80±1.84	23.52±1.09±3.36
G4 9.4 QGSP_BERT	1.11±0.01	1.47±0.03	3.03±0.09
G4 9.4 FTFP_BERT	15.85±0.06	25.91±0.11	37.34±0.8
G4 9.4 CHIPS	0.14±0.01	0.16±0.03	0.81±0.11

Functional Form

- $d\sigma/dt$ fit with exponential (only FTF for G4 has correct shape)

exp(-b|t|)	Be	Al	W
DATA	b= 6.22±0.36 (χ2/NDF)=9.89/10	b= 7.62±0.62 (χ2/NDF)=11.08/10	b= 7.91±0.47 (χ2/NDF)=10.52/10
FTF 9.4	b= 8.30±0.04 (χ2/NDF)=155/25	b= 7.96±0.05 (χ2/NDF)=122/25	b= 7.18±0.08 (χ2/NDF)=60/25

Interpretation

- Zoller has shown that the data are not completely consistent with the theoretical interpretation
- The process is dominated by:
  - Diffraction of single nucleon
  - Cross-section enhanced by elastic knock-out of other nucleons (10-20%)
- Slope parameter should decrease with A (as seen in MC)
- Effect of analysis cuts should be studied in detail
  - Difficult to imagine that they completely explain factor 2
  - Simulation of calorimeter response may play a role

Conclusions I

- Geant4 best model to describe target diffraction is FTF:
  - Overestimates integrated cross-section of a factor 2 w.r.t. HELIOS data
  - MC analysis does not have acceptance corrections, however it is difficult to explain the observed discrepancy even considering these
- Other models QGS and CHIPS are inadeguate for this particular process

Conclusions II

- Several issues in data interpretation
- Need additional studies...
  - ... future developments in FTF should consider Zoller's calculation and HELIOS data
- Zoller gives two very important conclusion:
  - Process dominated by single-nucleon scattering: study p-p interactions (more data available)
  - Need to add re-scattering in nuclear matter in string models (10% of cross section)
- LCG-AA note will be prepared