Charm, beauty and (a little on) top at the LHeC

LHeC workshop, Divonne, 2 Sep 2009
Olaf Behnke, DESY

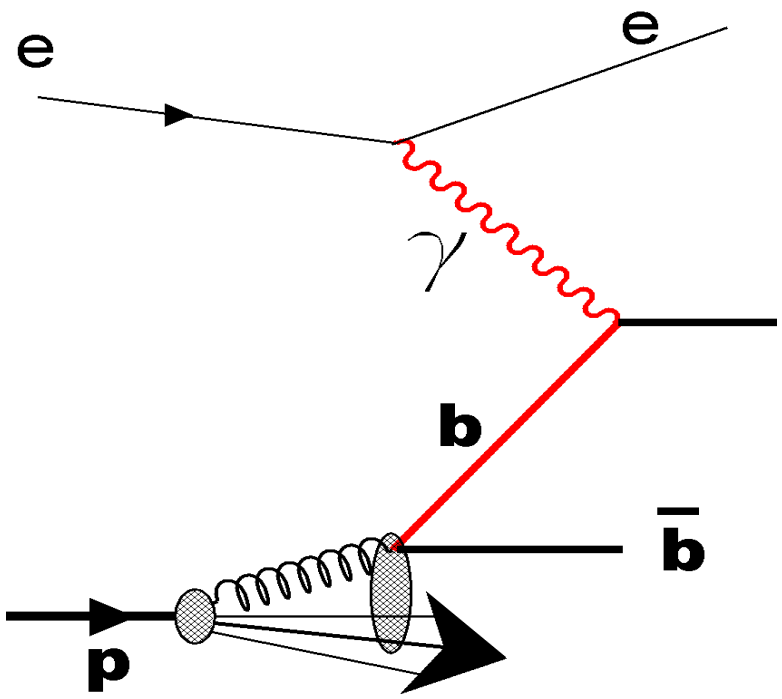
- Charm and beauty production in DIS (RAPGAP)
- Beauty in Photoproduction (PYTHIA)
- Total cross sections for charm, beauty and top production (RAPGAP, PYTHIA, LEPTO)

Motivation

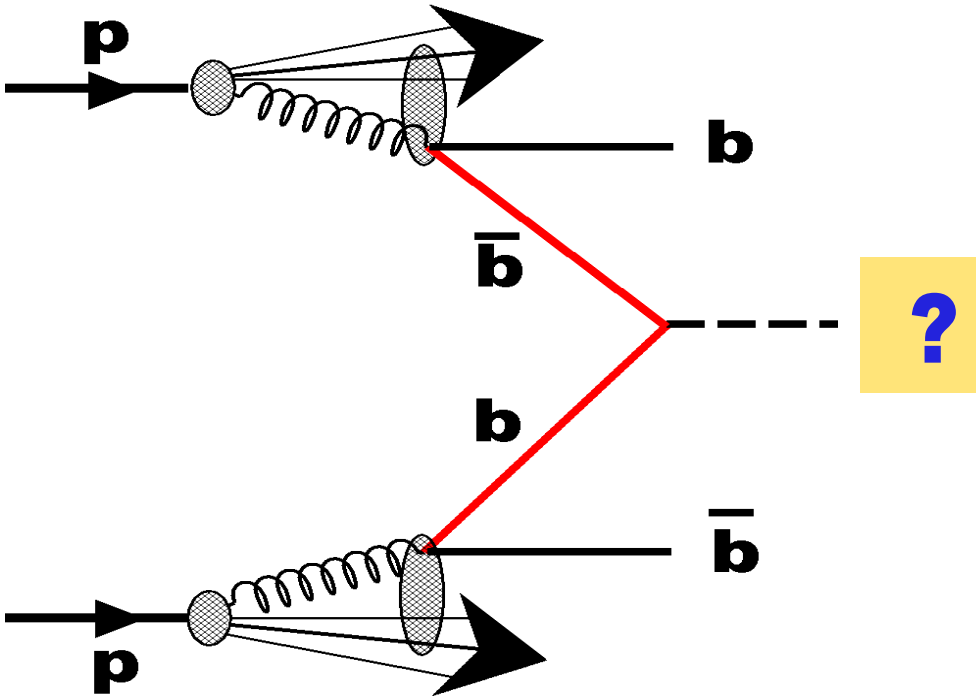
- Understand quark properties: **Top**
- Look for enhanced production due to new physics: **Top, Beauty**
- Tool for measuring proton strange density via sW $\rightarrow$ c: **Charm**
- Tool for measuring proton gluon density: **F2cc, F2bb**
- To predict bb $\rightarrow$ H and other b-initiated processes at LHC: **F2bb**

F2bb one motivation: determine 'b-density' in proton

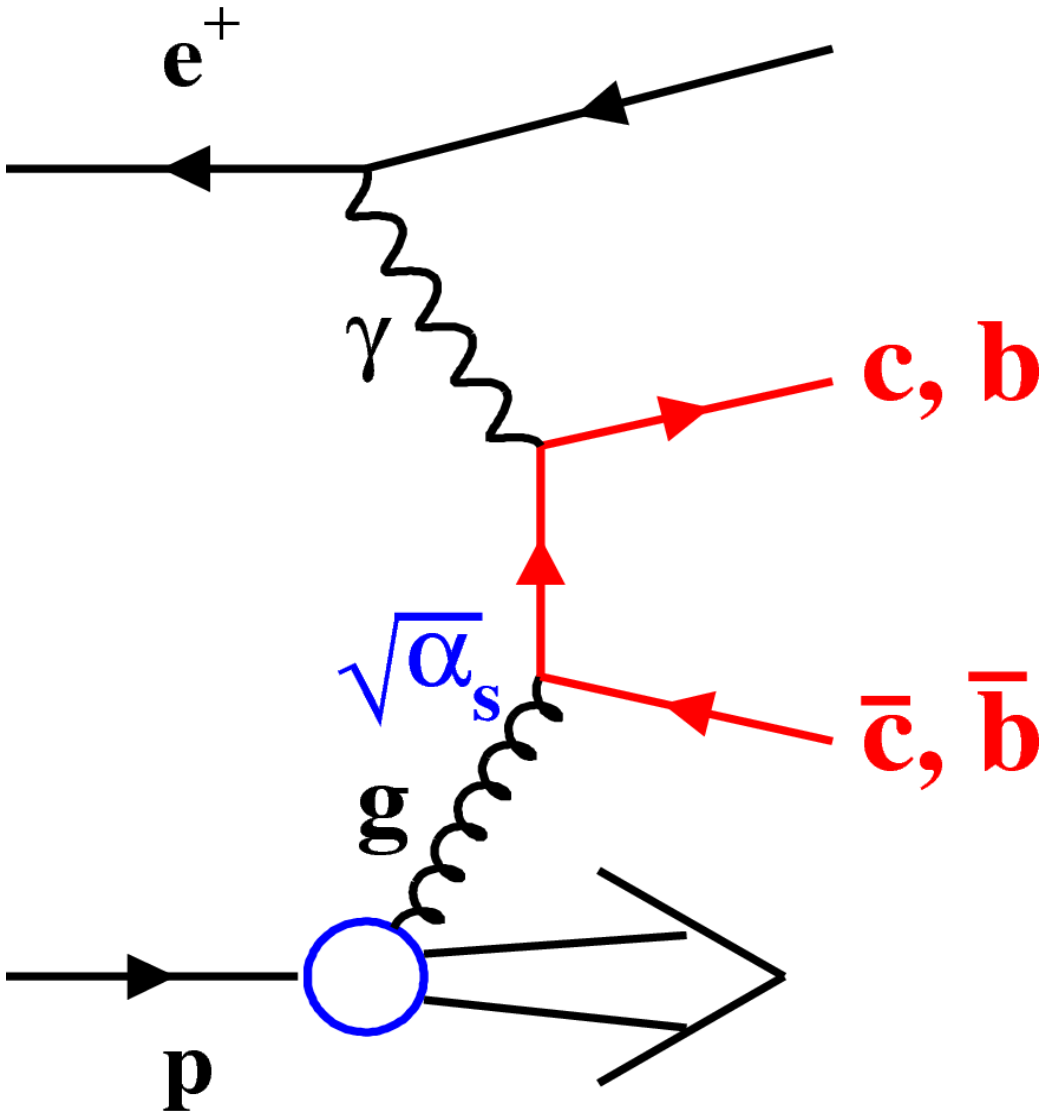
LheC



LhC



Charm and beauty in DIS with RAPGAP31 MC



Used steering:

- LO BGF + PS (ipro=14)
- Used PDF: CTEQ5L
- mc=1.5, mb=4.75 GeV
- 0.01<y<0.95

Note: all MC predictions shown are on parton level

Fiducial cuts

HERA :

- pt_c>1.5 GeV
  |eta_c|<1.5↔ 25<θ<155

LHeC :

- No cut scenario ***"all inclusive"***
- pt_c>1.5 GeV
  - |eta_c|<4 ↔ 2<θ<178
  - |eta_c|<2.5 ↔10<θ<170
  - |eta_c|<1.5 ↔25<θ<155

|eta|<4 or at least |eta|<2.5 should be reachable

Energy, luminosity and tagging efficiencies

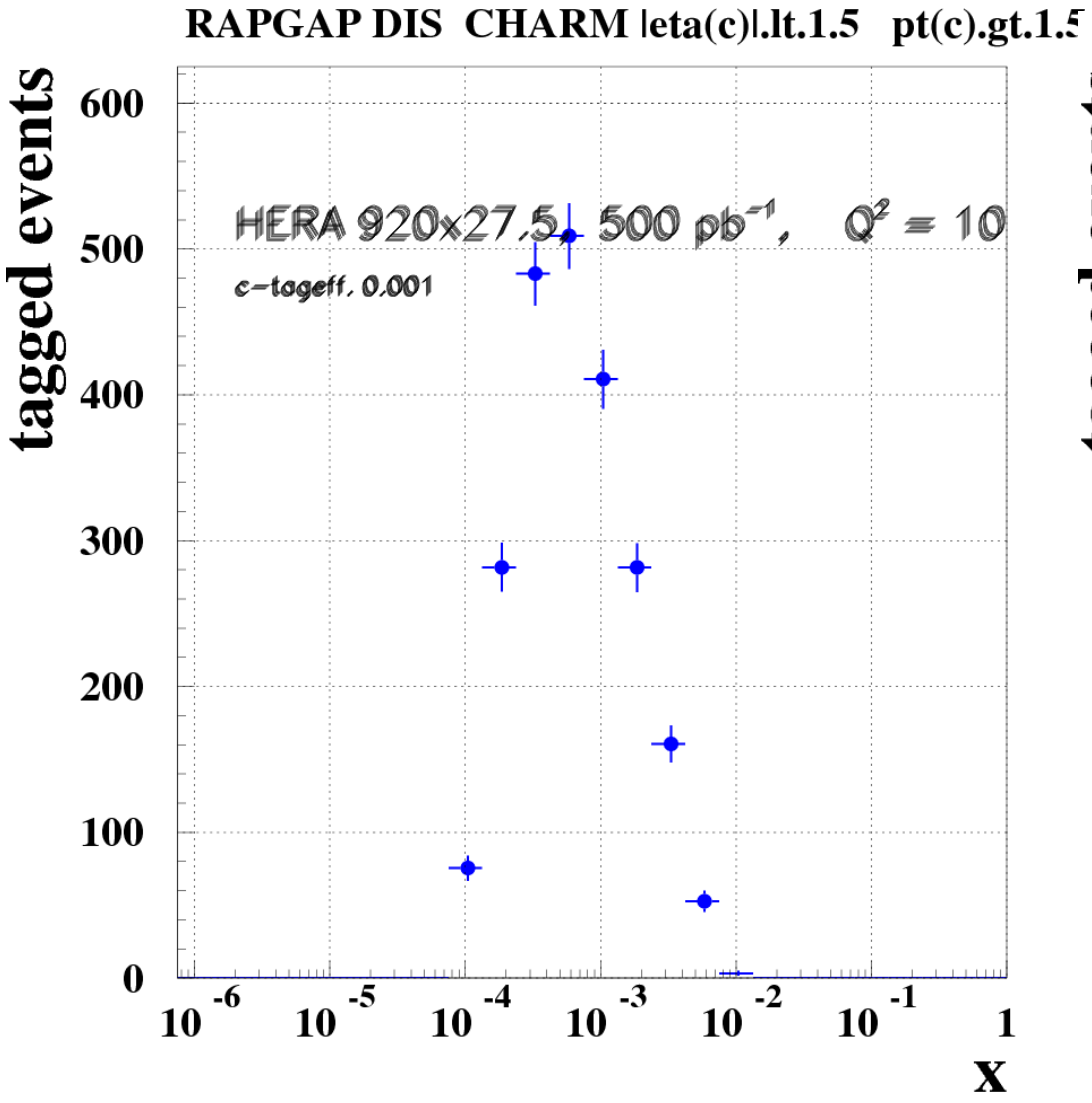
HERA :

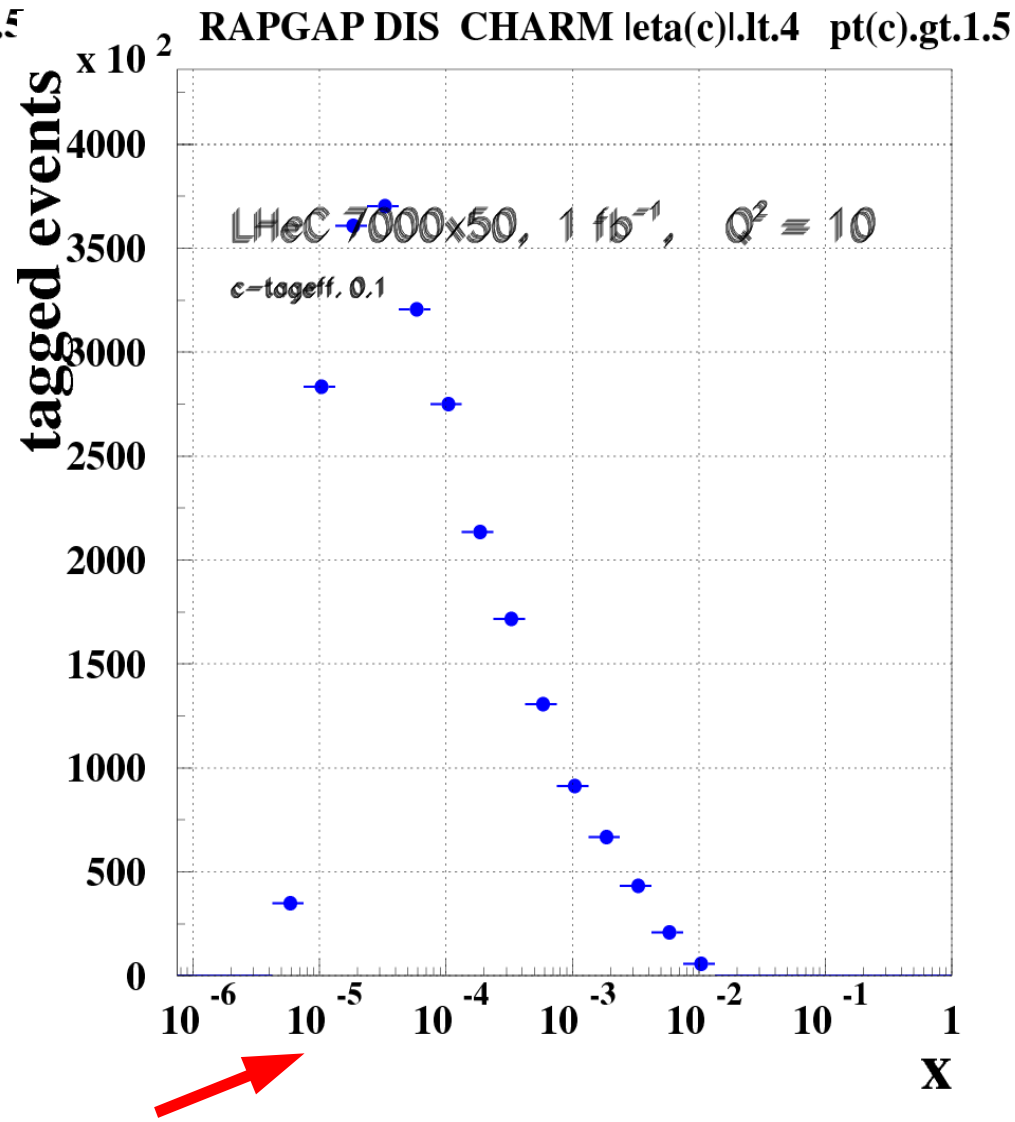
- L = 500 pb-1
- Effective tagging efficiencies (corresponding to background free events):
  - Charm: 0.001
  - Beauty: 0.01

LHeC :

- Charm: scenario C, Ring Ring low x
  - 7000 GeV x 50 GeV
  - L = 1 fb-1
- Beauty: scenario D Linac Ring
  - 7000 GeV x 100 GeV
  - L = 10 fb-1
- Effective tagging efficiencies:
  - Charm: 0.1
  - Beauty: 0.1

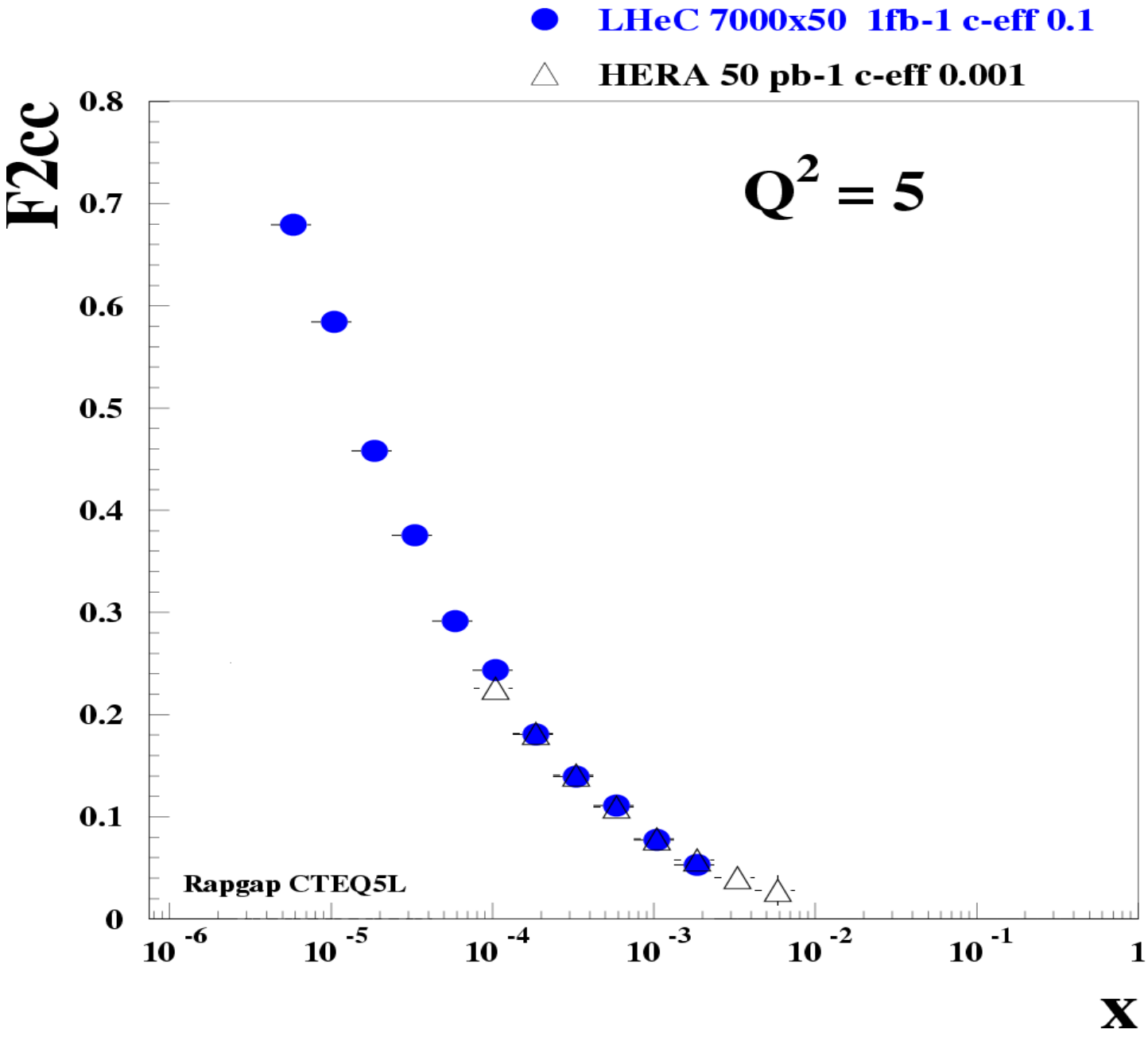
Expected tagged charm events (corresponding to background free #events)





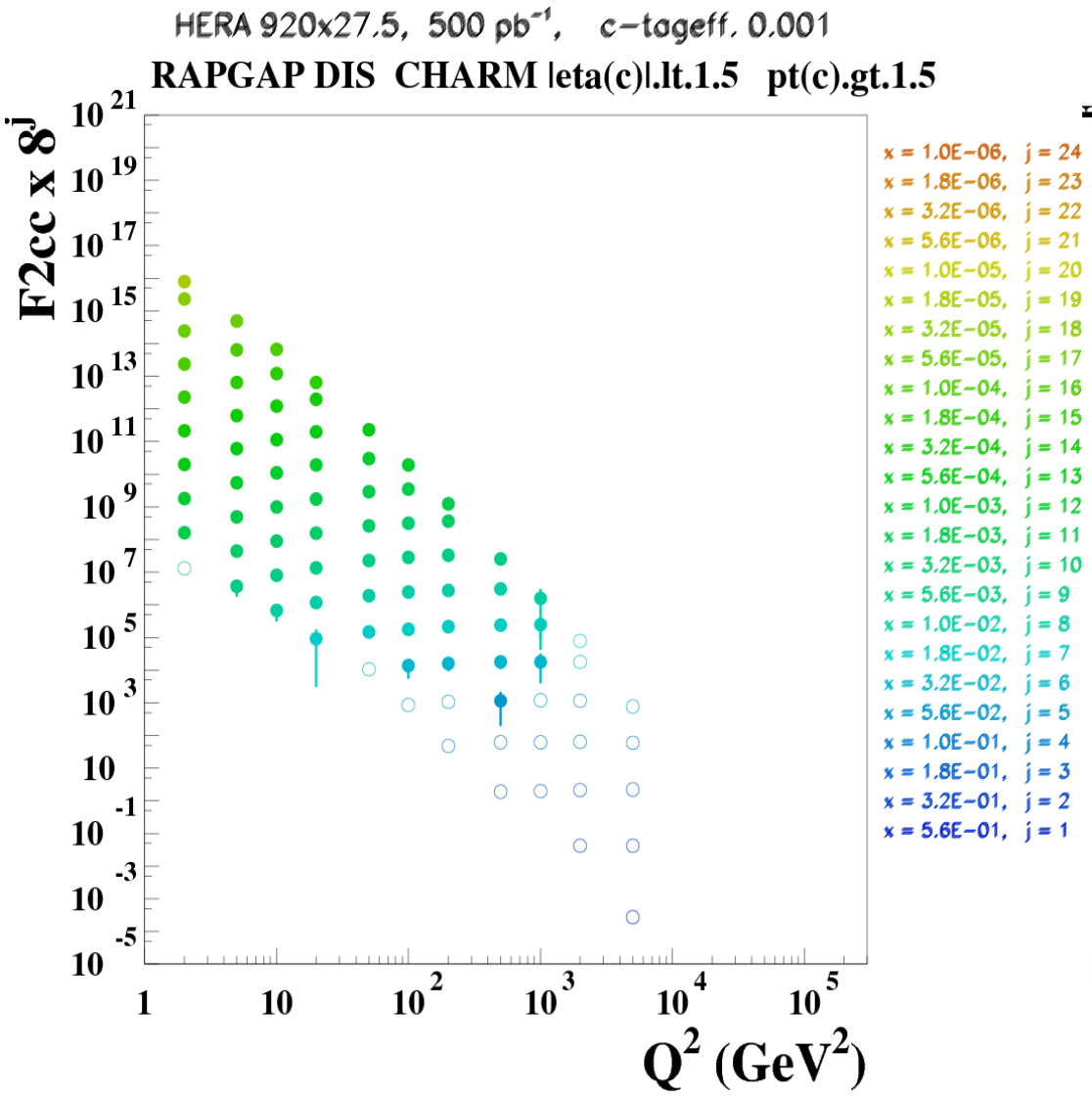
➔ LHeC extends to much smaller x values (as expected!)

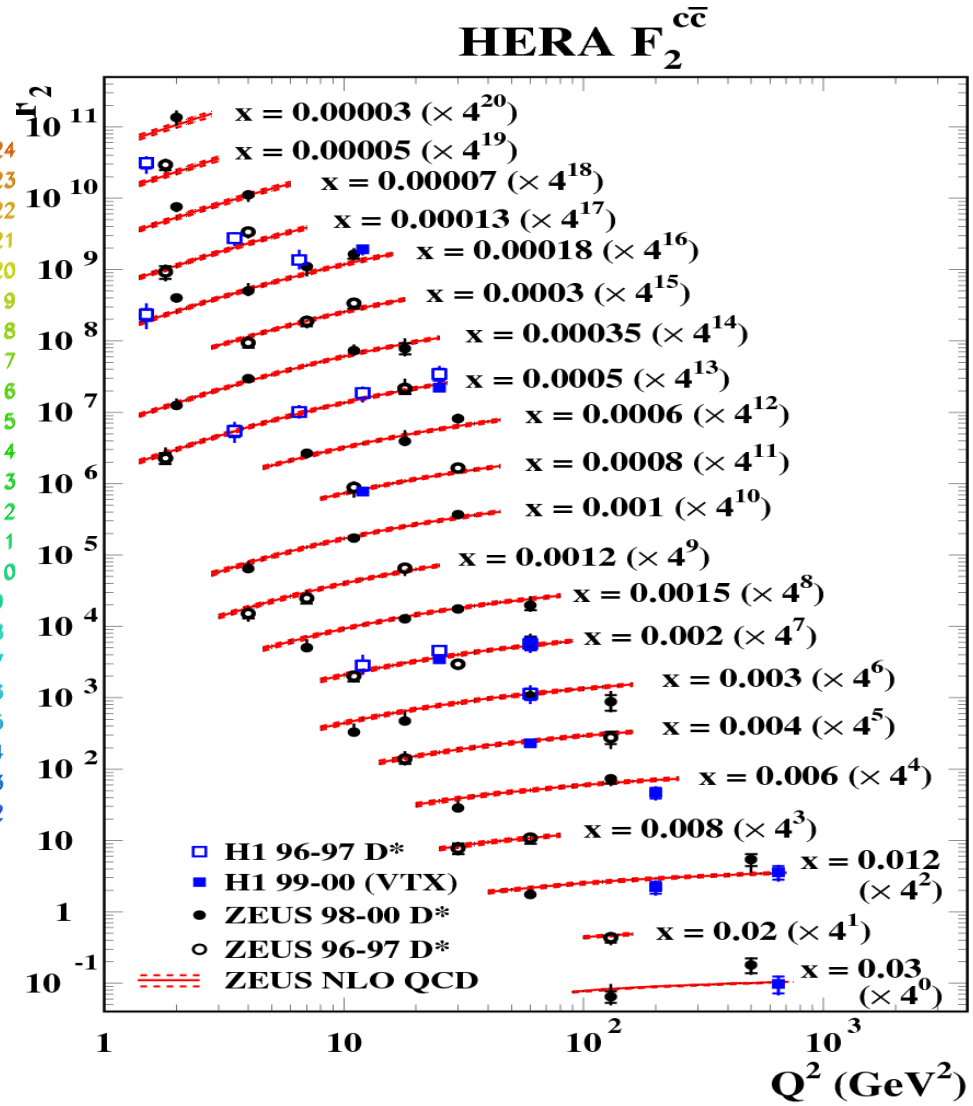
Expected F2cc: LheC vs HERA



➔ Again:
for same Q2
LHeC extends to
much lower x

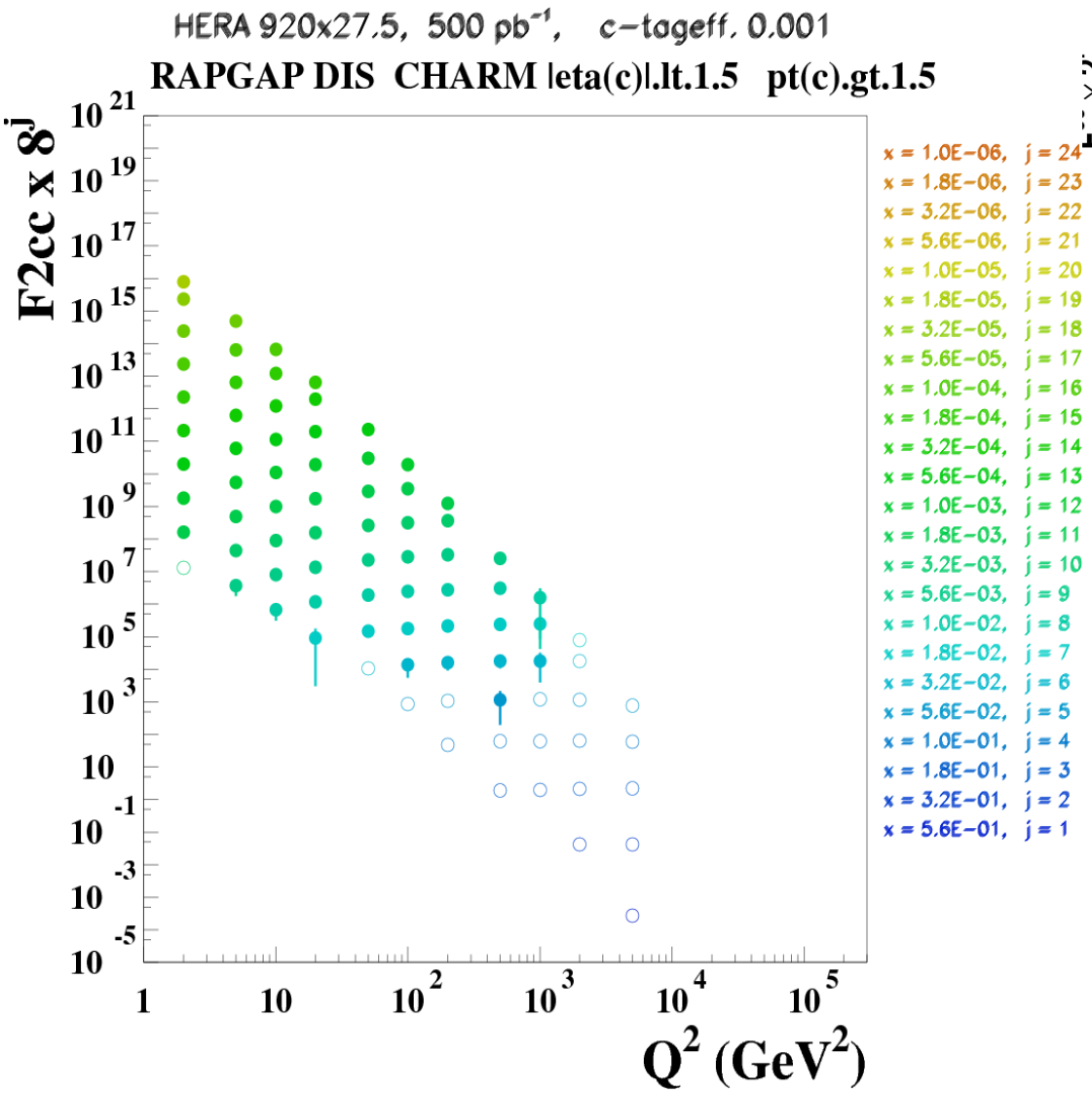
F2cc: Can we 'reproduce' HERA with our simulation?

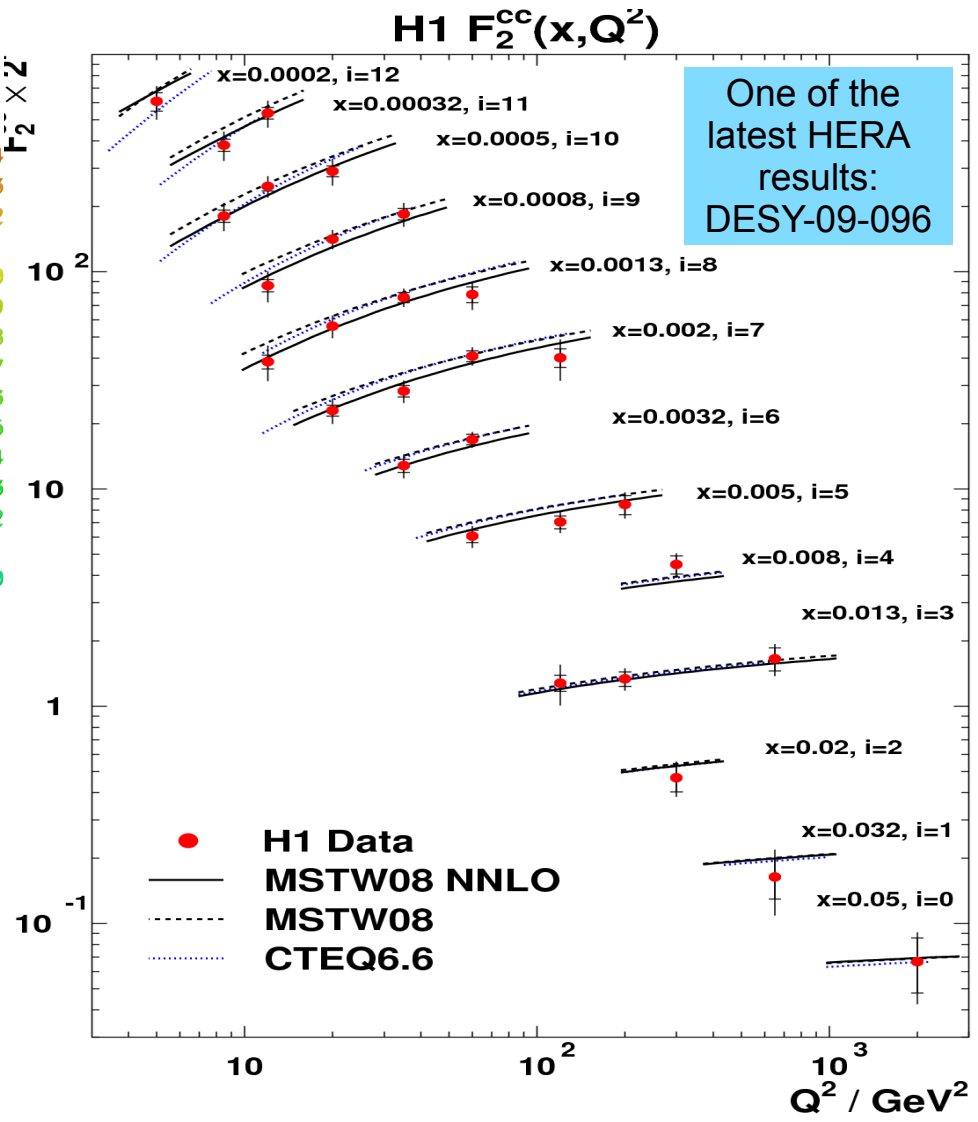




➔ Yes, at least roughly

F2cc: Can we 'reproduce' HERA with our simulation?

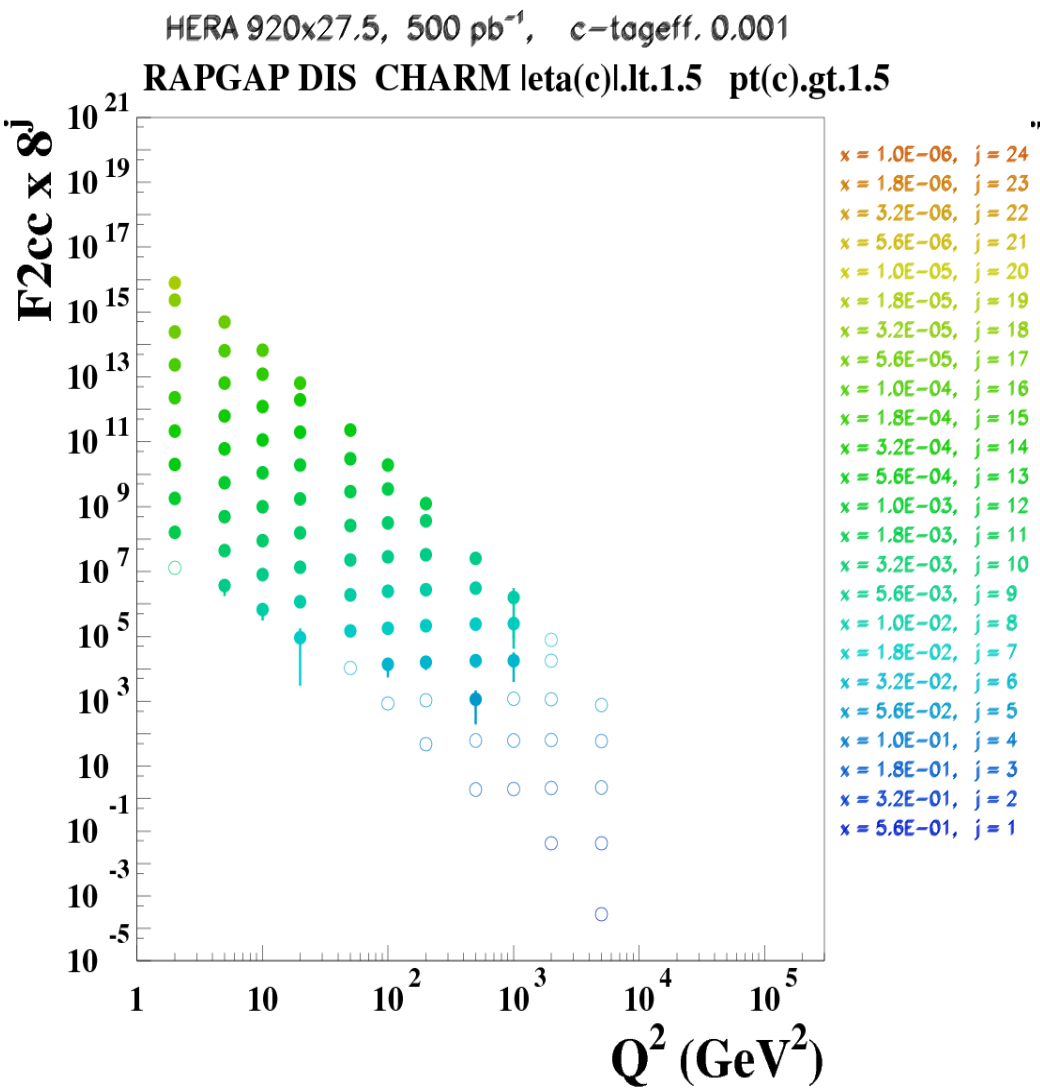


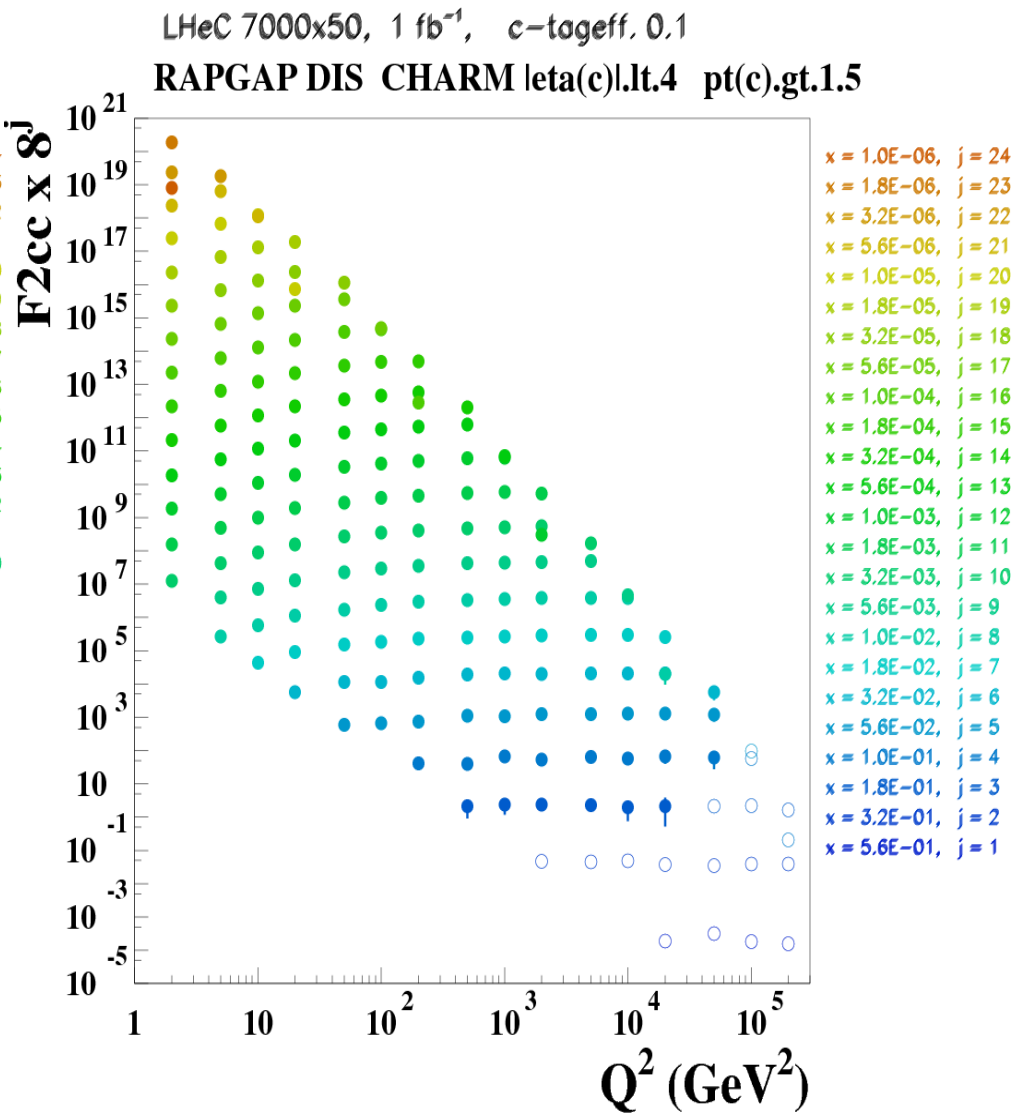


One of the latest HERA results: DESY-09-096

➔ Yes, at least roughly

F2cc: HERA vs LHeC

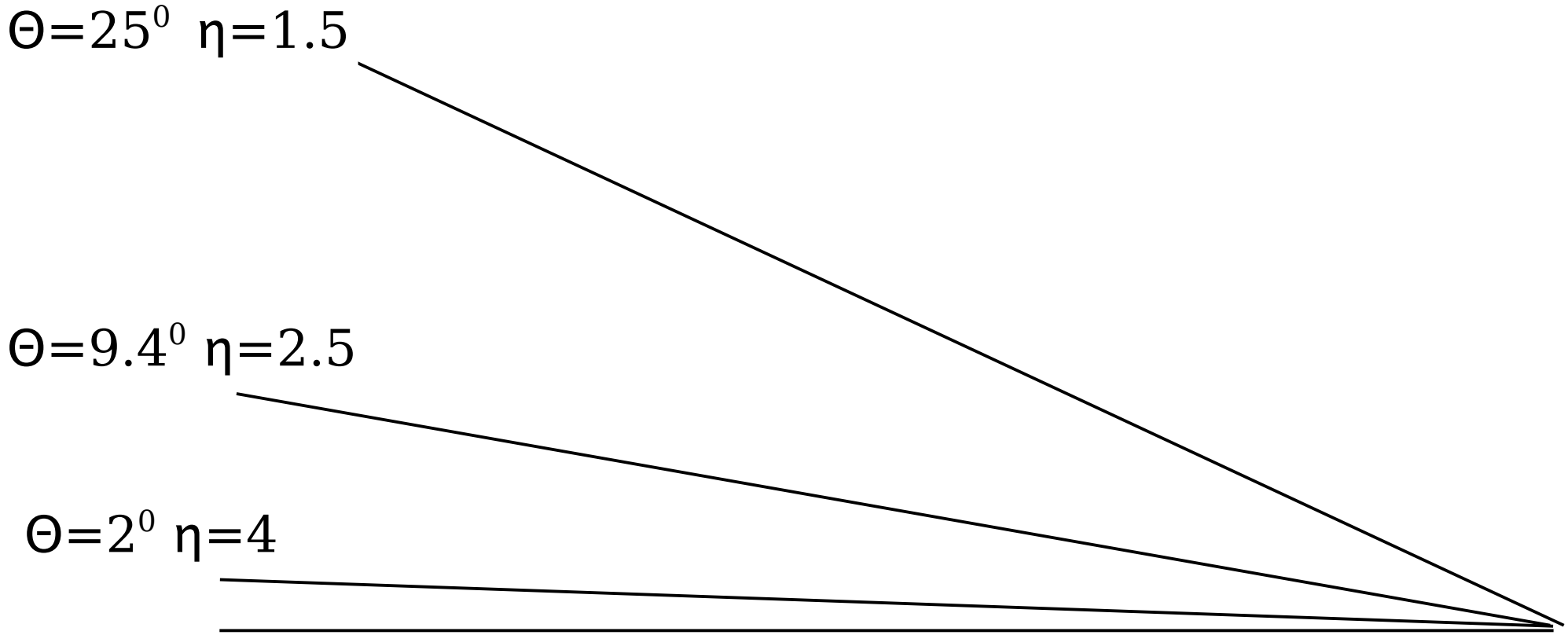


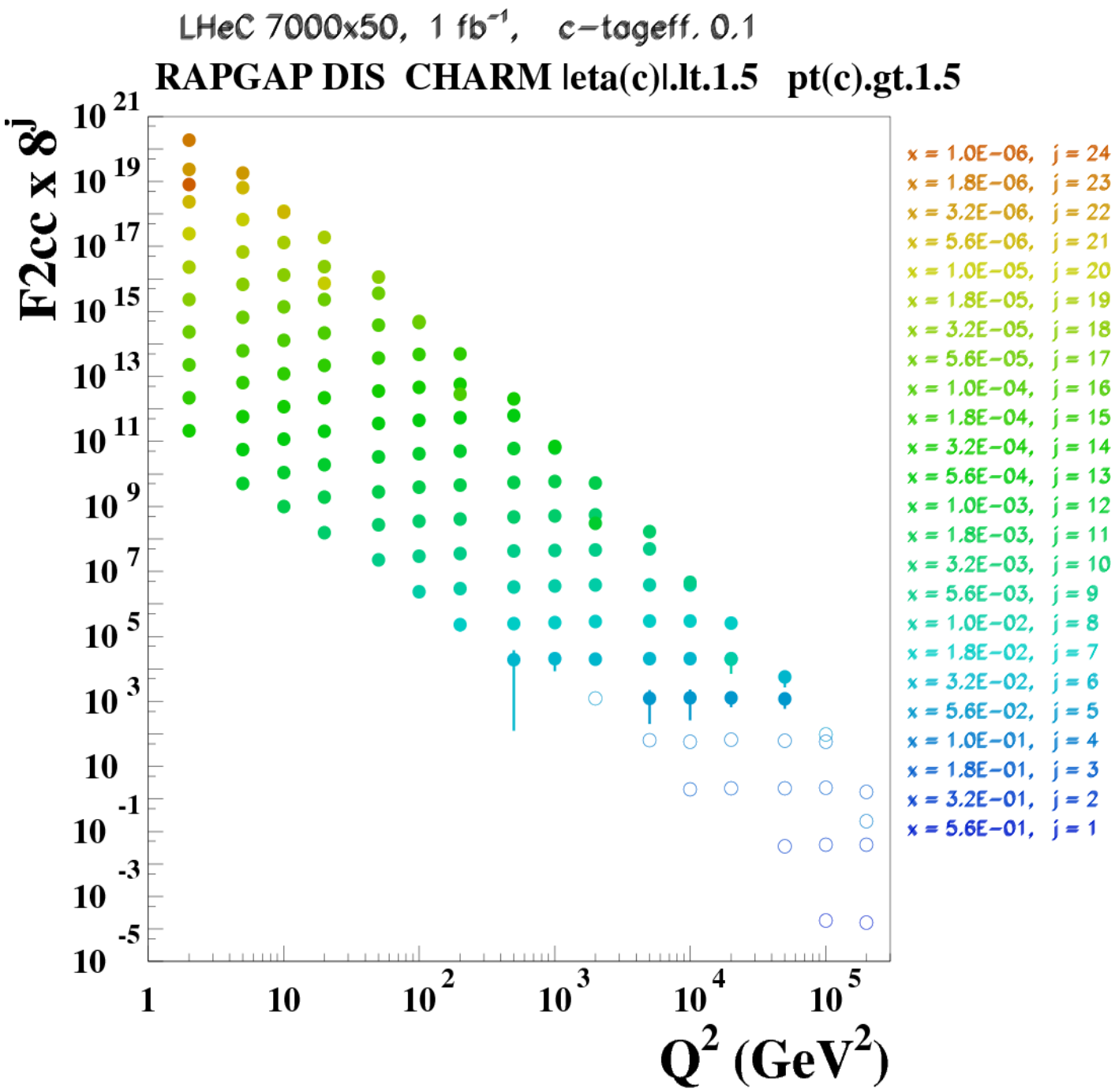


➔ LheC increases visible phasespace to $10^{-6}<x<0.1$

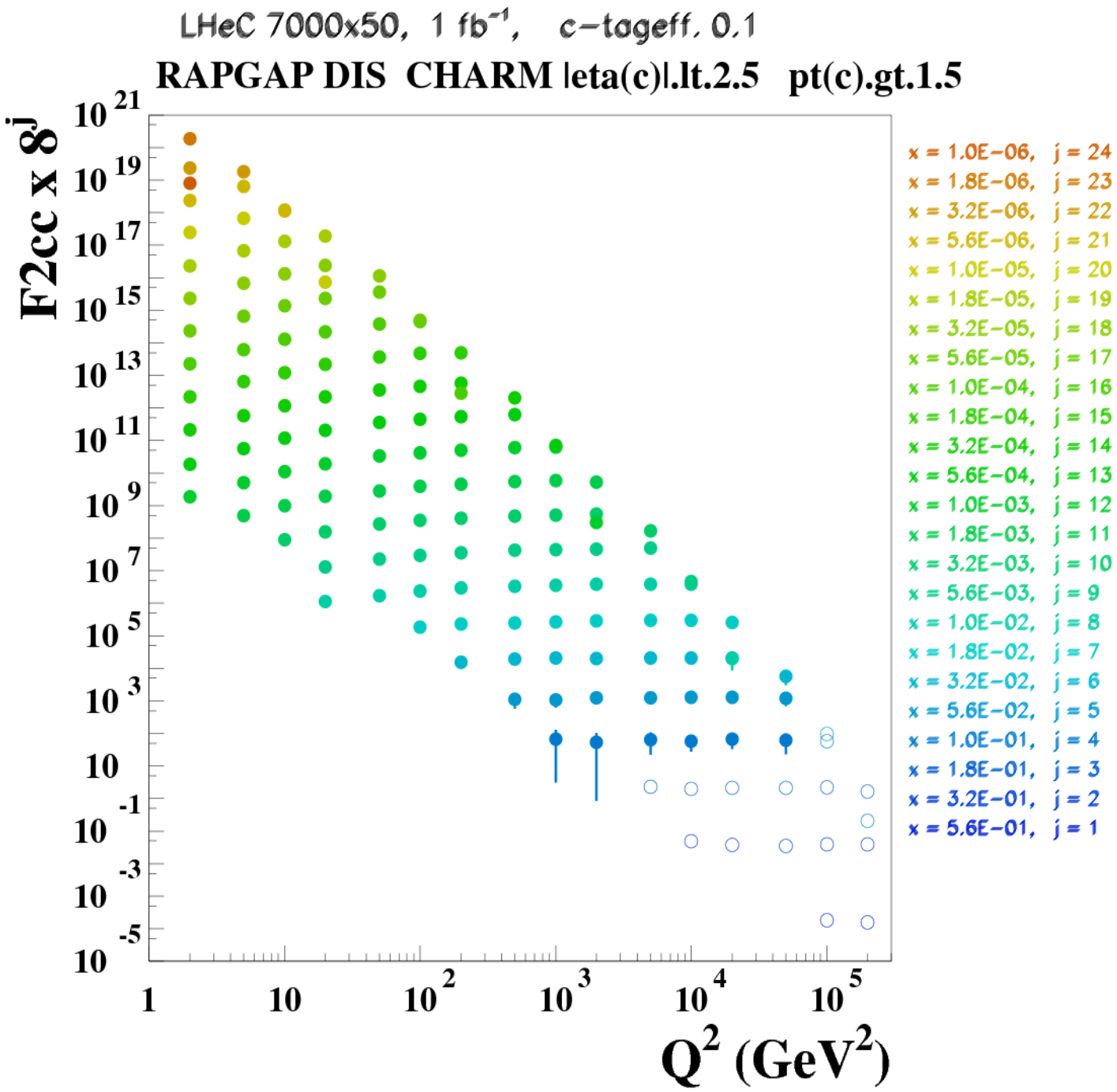
F2cc: LHeC

Next: check dependence of expected F2cc @LHeC on the detector polar angle acceptance

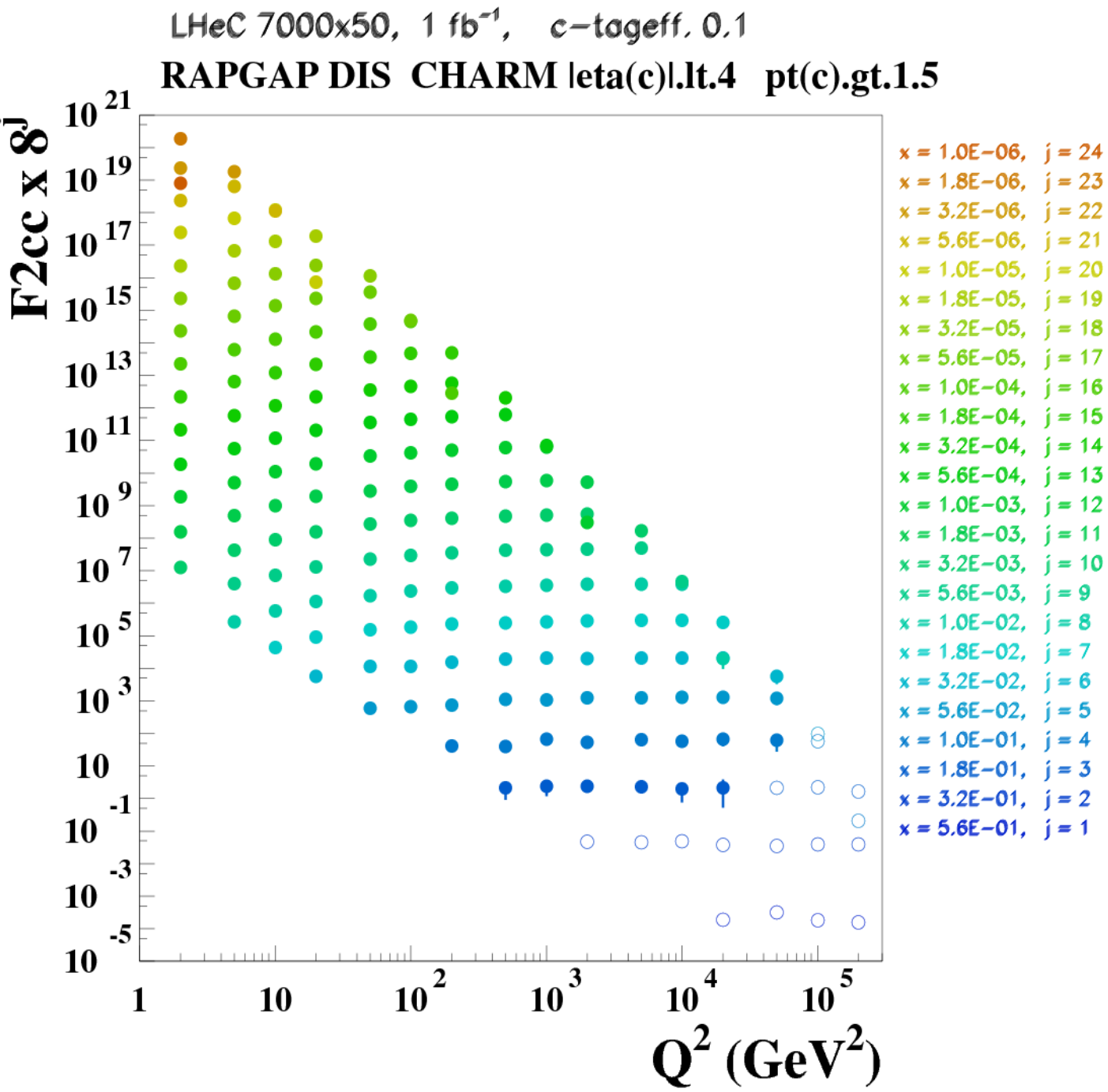




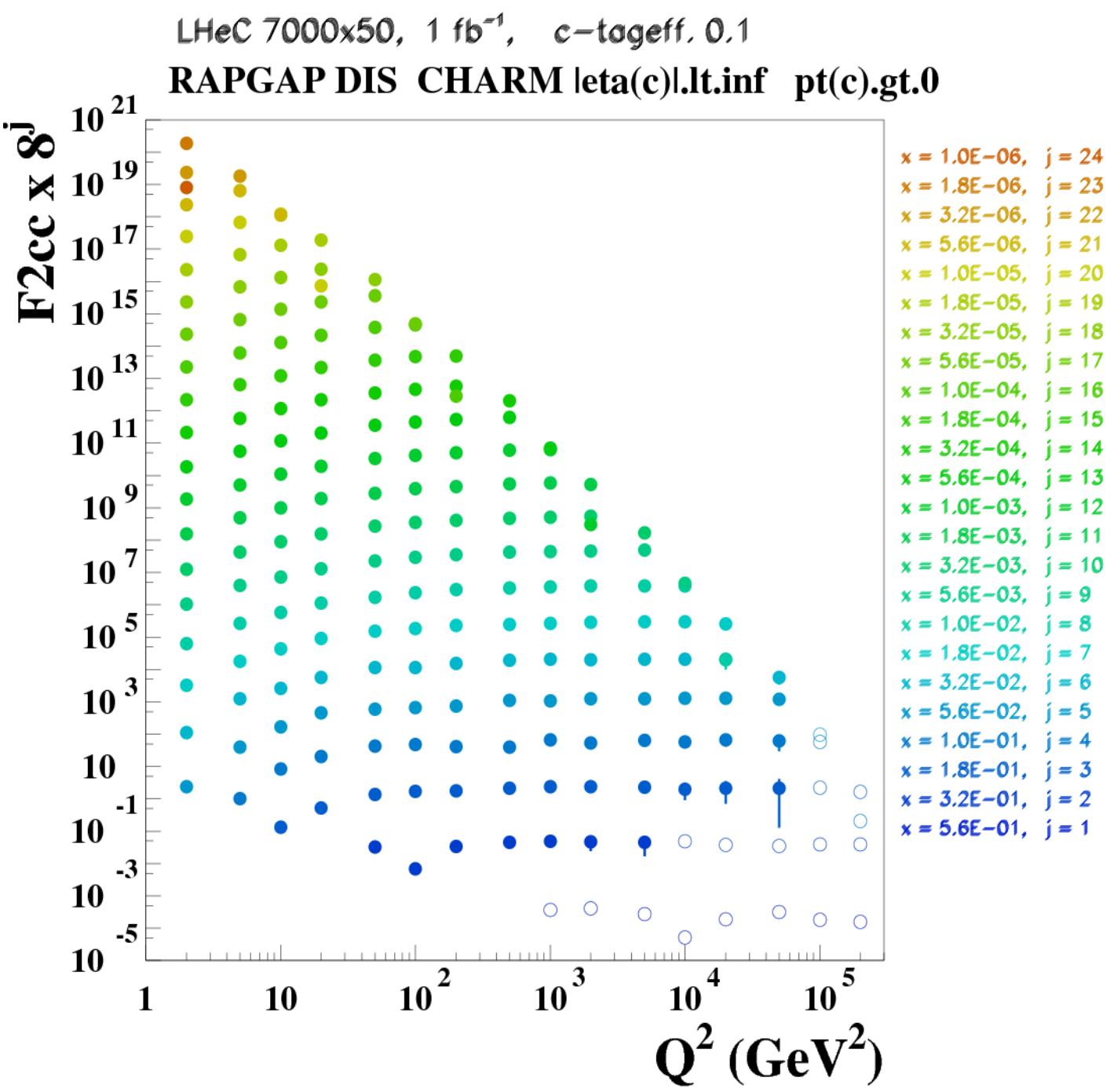
F2cc: LHeC
|eta_c|<1.5



F2cc: LHeC
|eta_c|<2.5

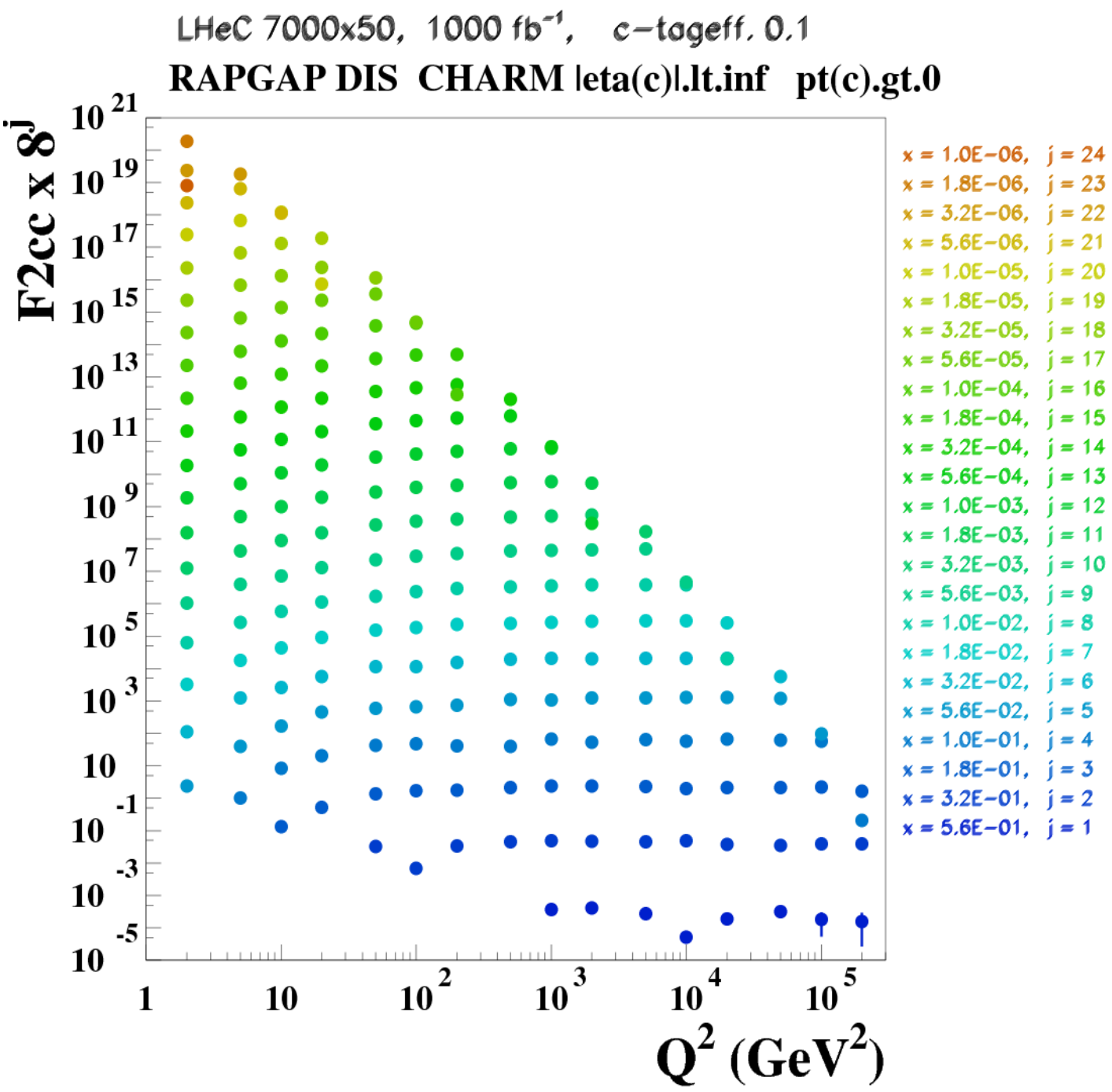


F2cc: LHeC
|eta_c|<4



F2cc: LHeC
no eta_c cuts

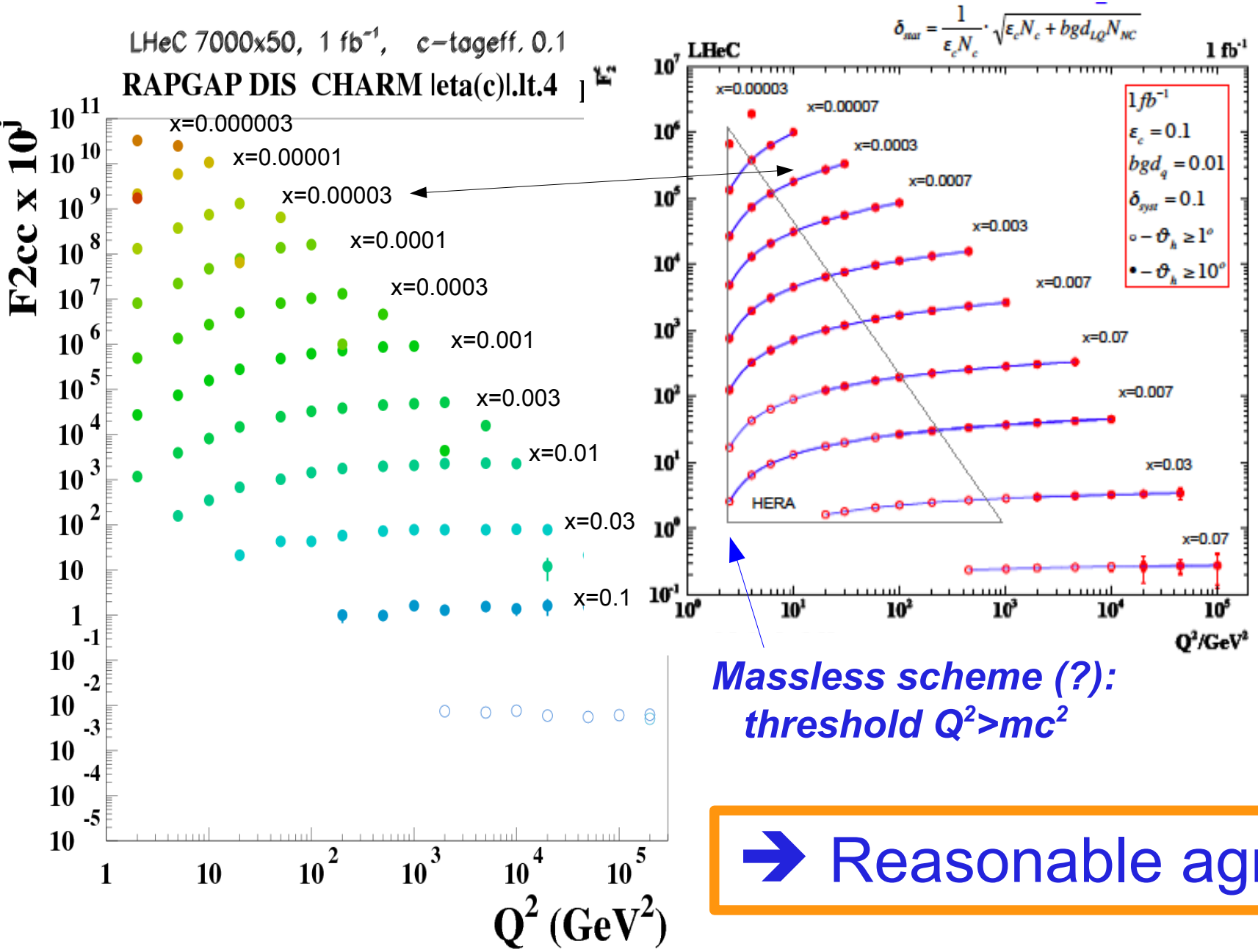
➔ Detector coverage down to $\theta=1^0$
crucial for large x physics



F2cc: LHeC
no eta_c cuts
with 1000 fb^{-1}

➔ Detector coverage down to $\theta=1^0$
crucial for large x physics

F2cc: Comparing to Max and Andys LHeC simulation

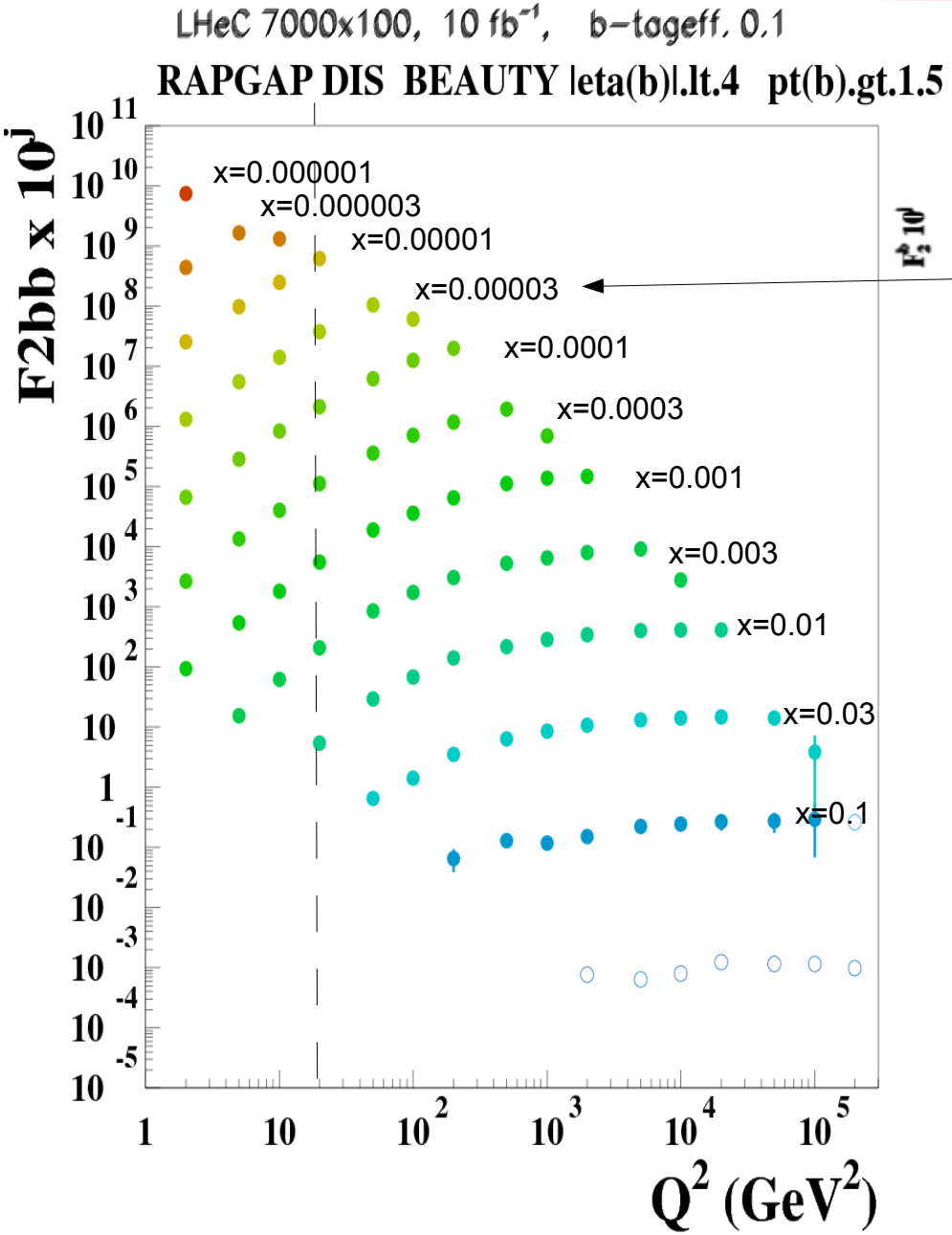


Max Klein,
Andy Mehta
LheC 7000 x 70

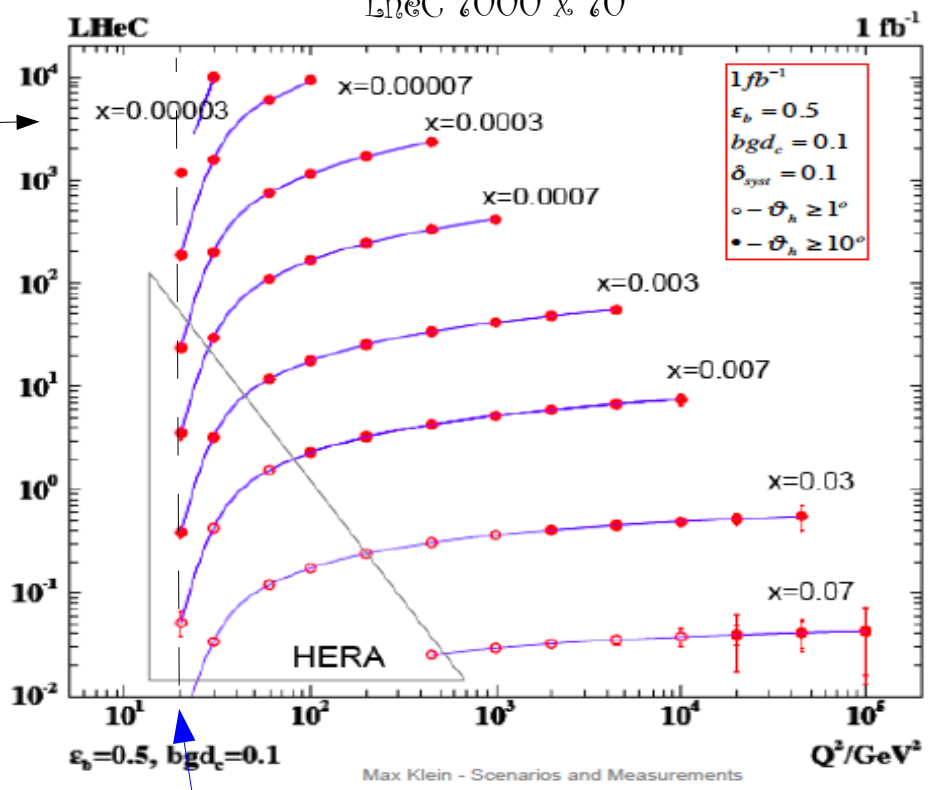
Massless scheme (?): threshold $Q^2 > mc^2$

➔ Reasonable agreement

F2bb: Comparing to Max and Andys LHeC simulation



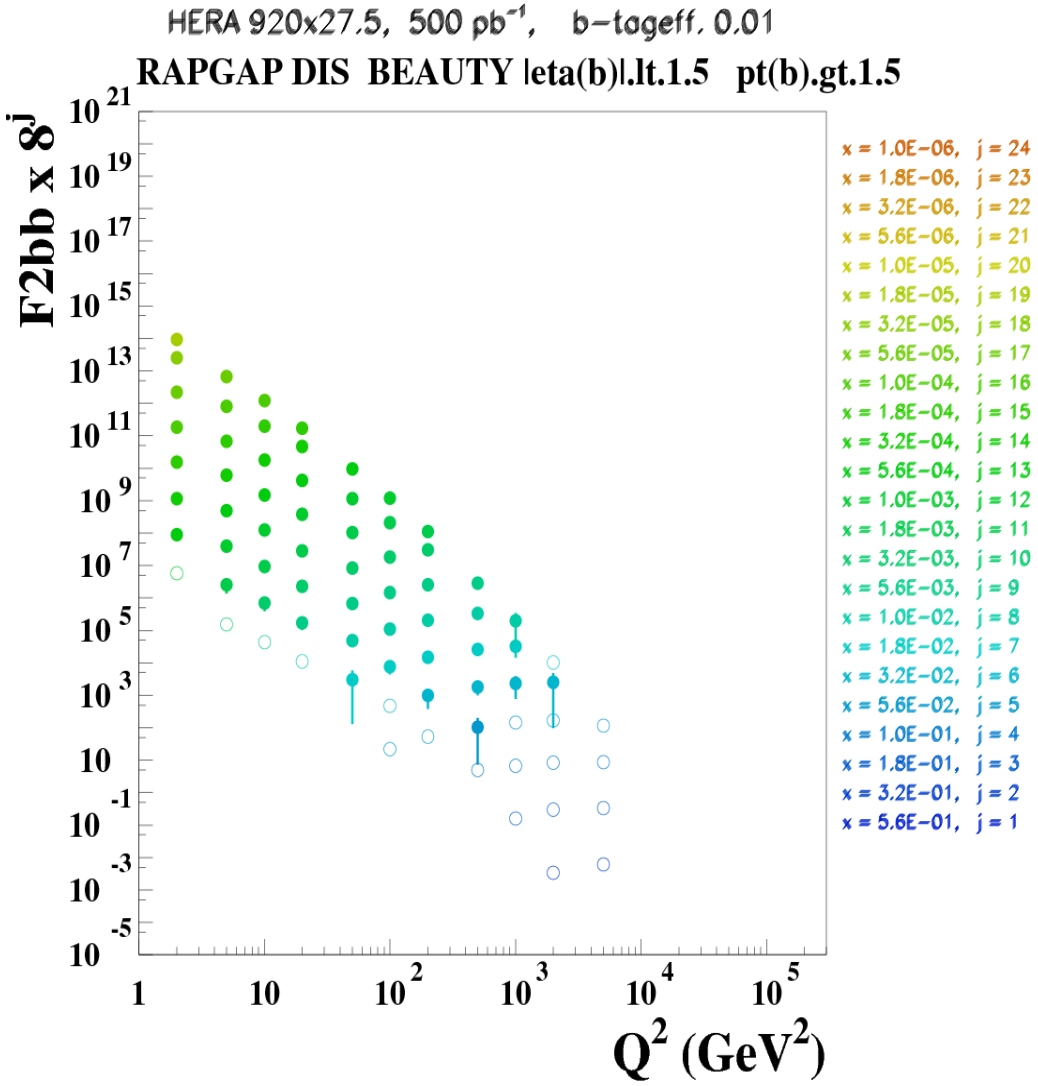
Max Klein, Andy Mehta

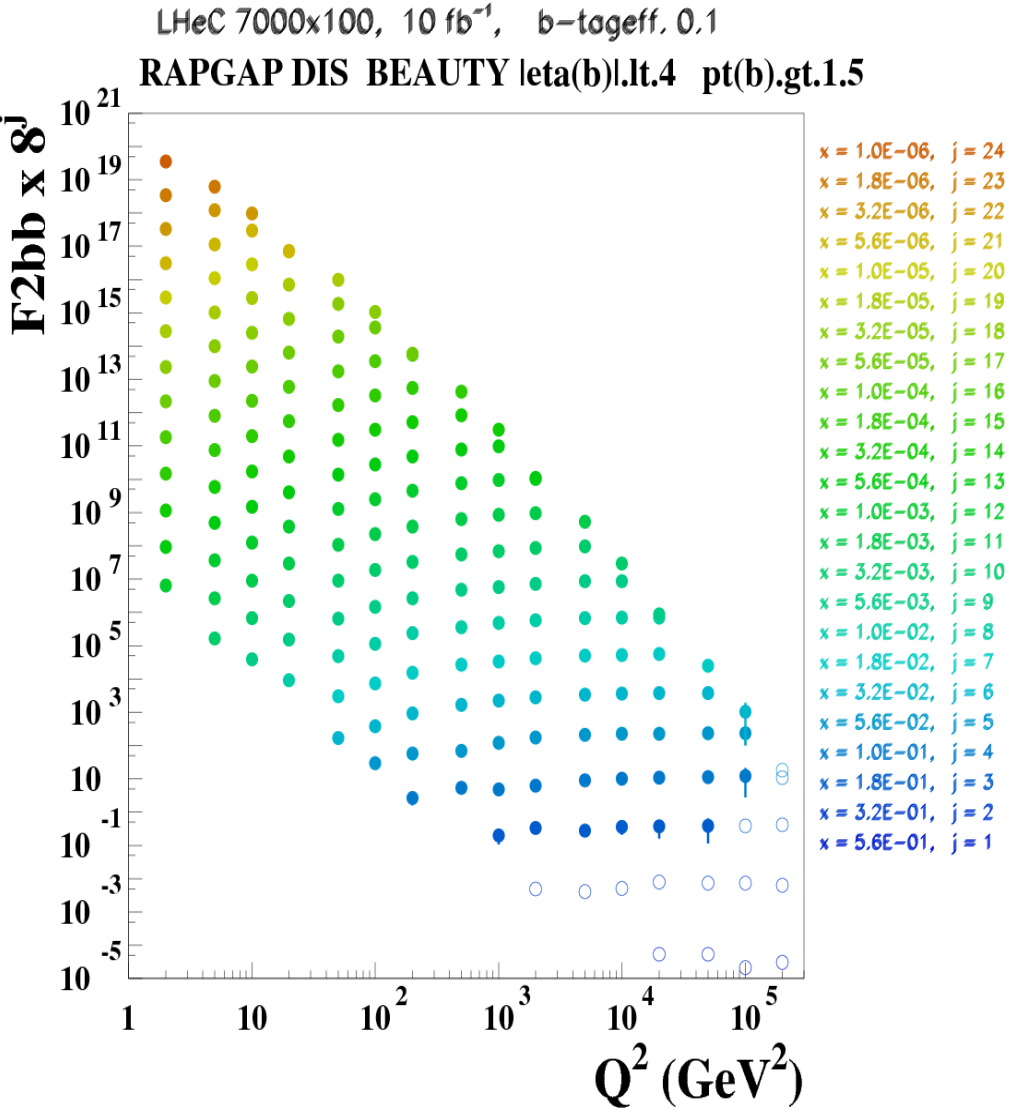


Threshold $Q^2 > mb^2$

➔ RAPGAP simulation in massive scheme extends to lower x and Q^2

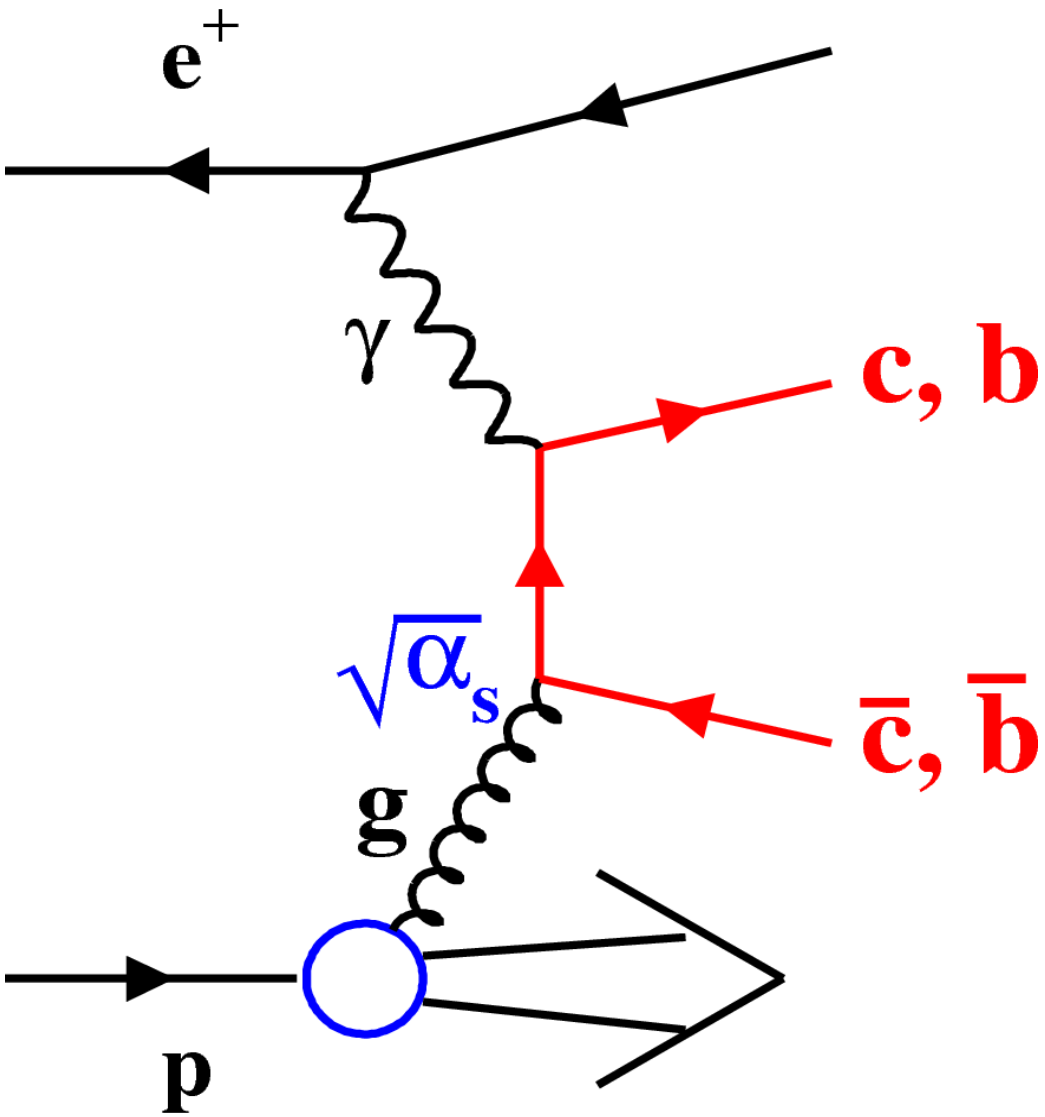
F2bb: HERA vs LHeC





➔ Again: LHeC increases visible phasespace to $10^{-6}<x<0.1$

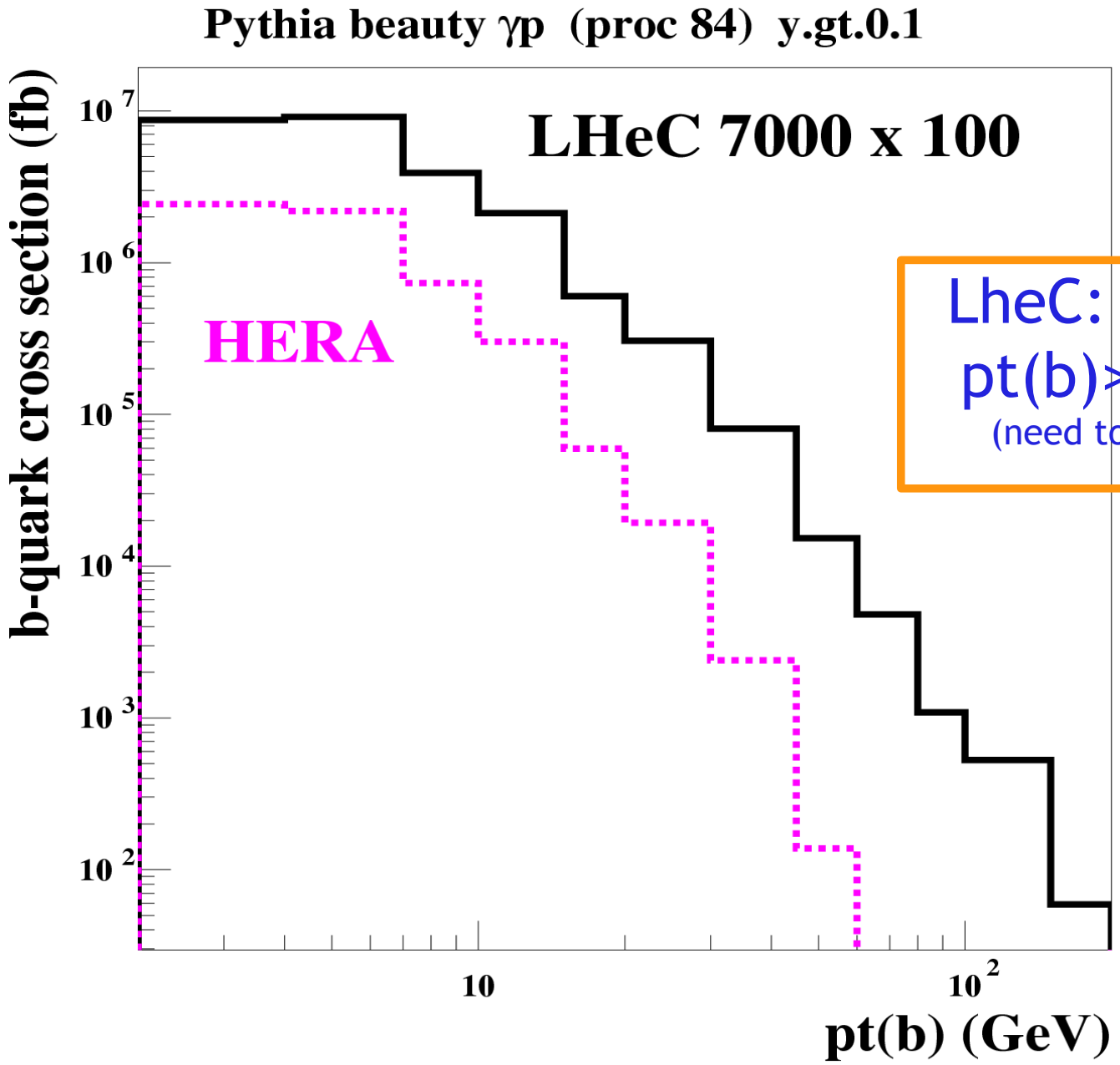
Used tool for **Top**, **Beauty** and **Charm** photoproduction: PYTHIA 6.4



Used steering:

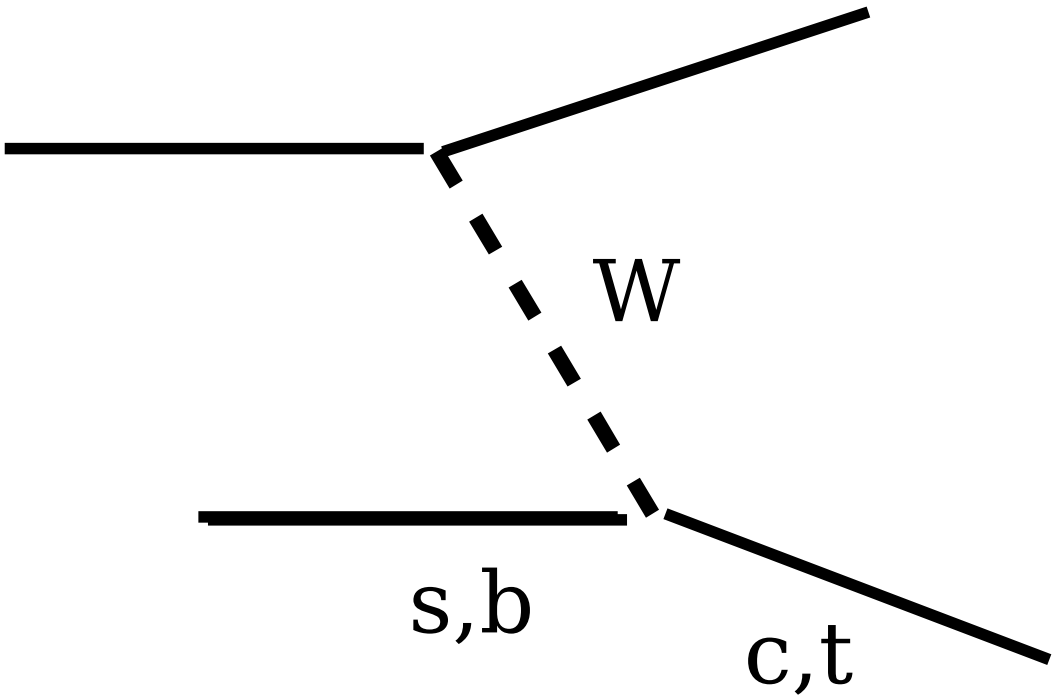
- LO BGF + PS (Proc 84)
- Used PDF: CTEQ6L
- mc=1.5, mb=4.75 GeV
- 0.1<y<0.9

Beauty □p: LheC vs HERA



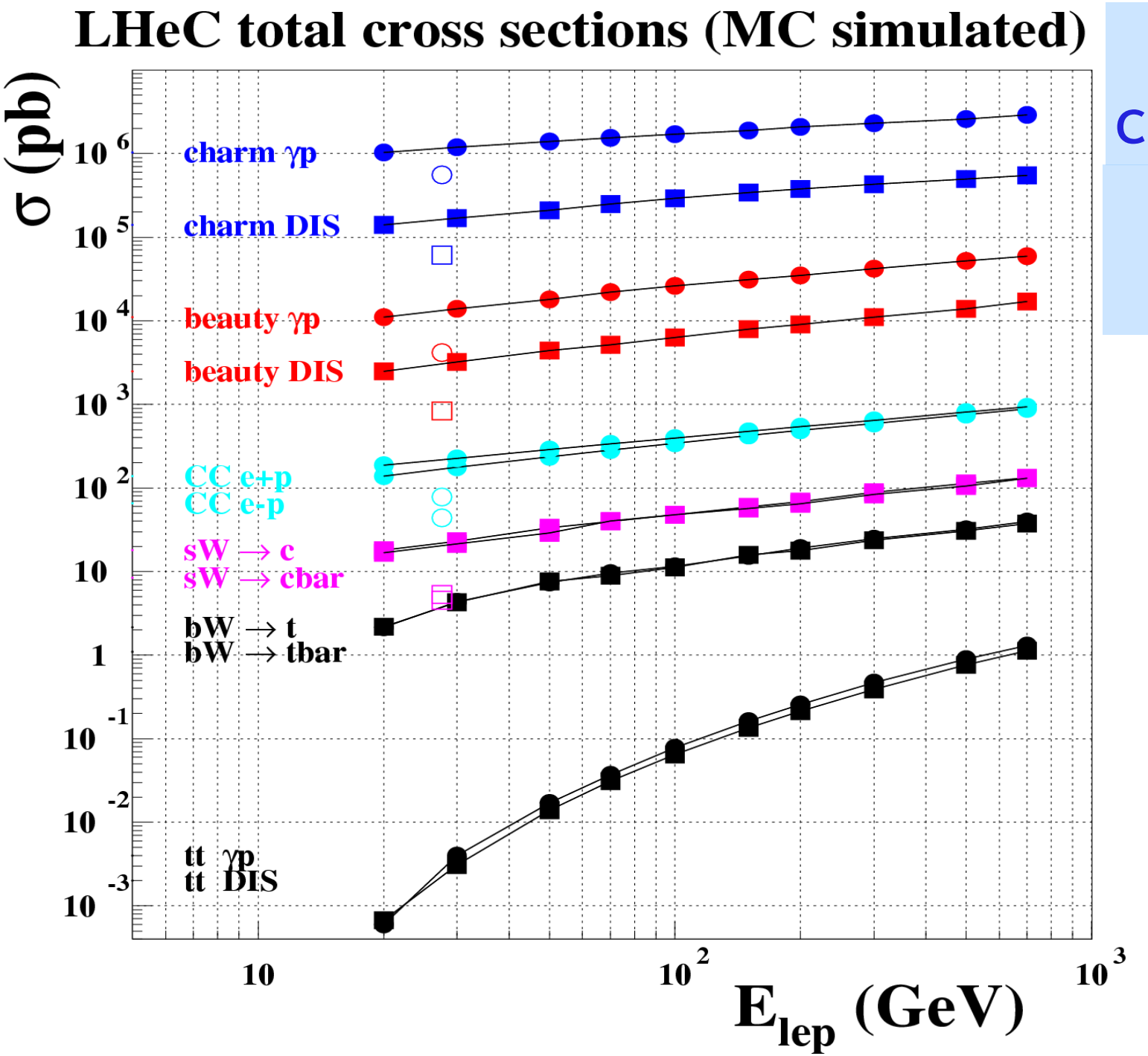
LheC: ~1000 b-events for pt(b)>100 GeV per $1fb^{-1}$
(need to multiply with tagging eff.)

Used tool for **incl cc, sW → c and bw → t:** Lepto6.5 MC



Used steering:

- Lepto CC mode
- QCD 'switched off'
- Used PDF: CTEQ5L
- For top: mtop=170 GeV, y>0.1



Total LHeC cross sections

vs E_{lep} (E_p=7 TeV)

Conclusions

Assuming LheC 7 TeV x 50-100 GeV with L~ 1-10 fb-1:

✔ Expect factor o(100-1000) larger tagged charm and beauty samples compared to HERA, requires c and b tagging efficiencies >= 10%

✔ F2cc and F2bb: LHeC extends coverage down to $x=10^{-6}$, while x>0.1 will be (again) difficult, polar angle acceptance $<10^{0}$ crucial

✔ Single top cross-section bW → t of order 5-10 pb (but Lepto inappropriate (?) since probably doesn't have correct matrix elements (quote Hubert Spiesberger))

✔ Total cross section for sW → c of order 40 pb

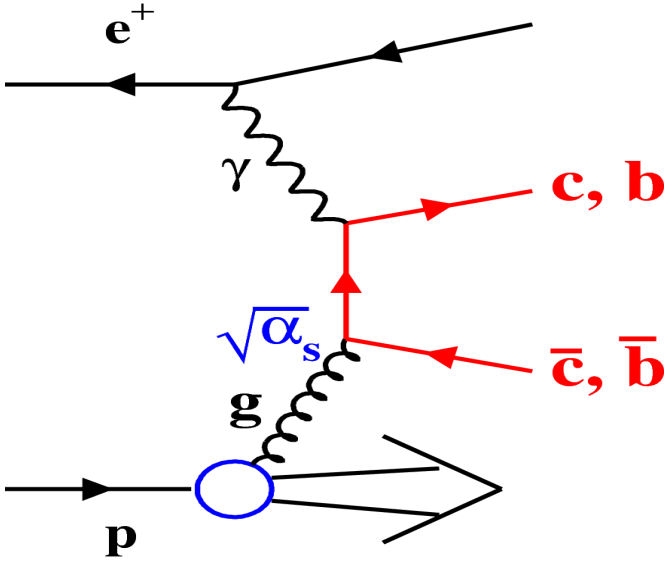
✔ Future: c and b studies – not only on parton level but also including final state particles (e.g. b-> μ X) and their detector acceptance

✔ ***More detailed comparison of physics potentials and complementarity to LHC/ILC prospects would be nice, e.g. comparing impact on proton effective beauty density from: F2bb at LheC vs Z+b production at LHC***

Backup slides

Lets have some fun !

To obtain errors on **F2cc**



Calculate expected number N of charm tagged events in bins of Q2 and x

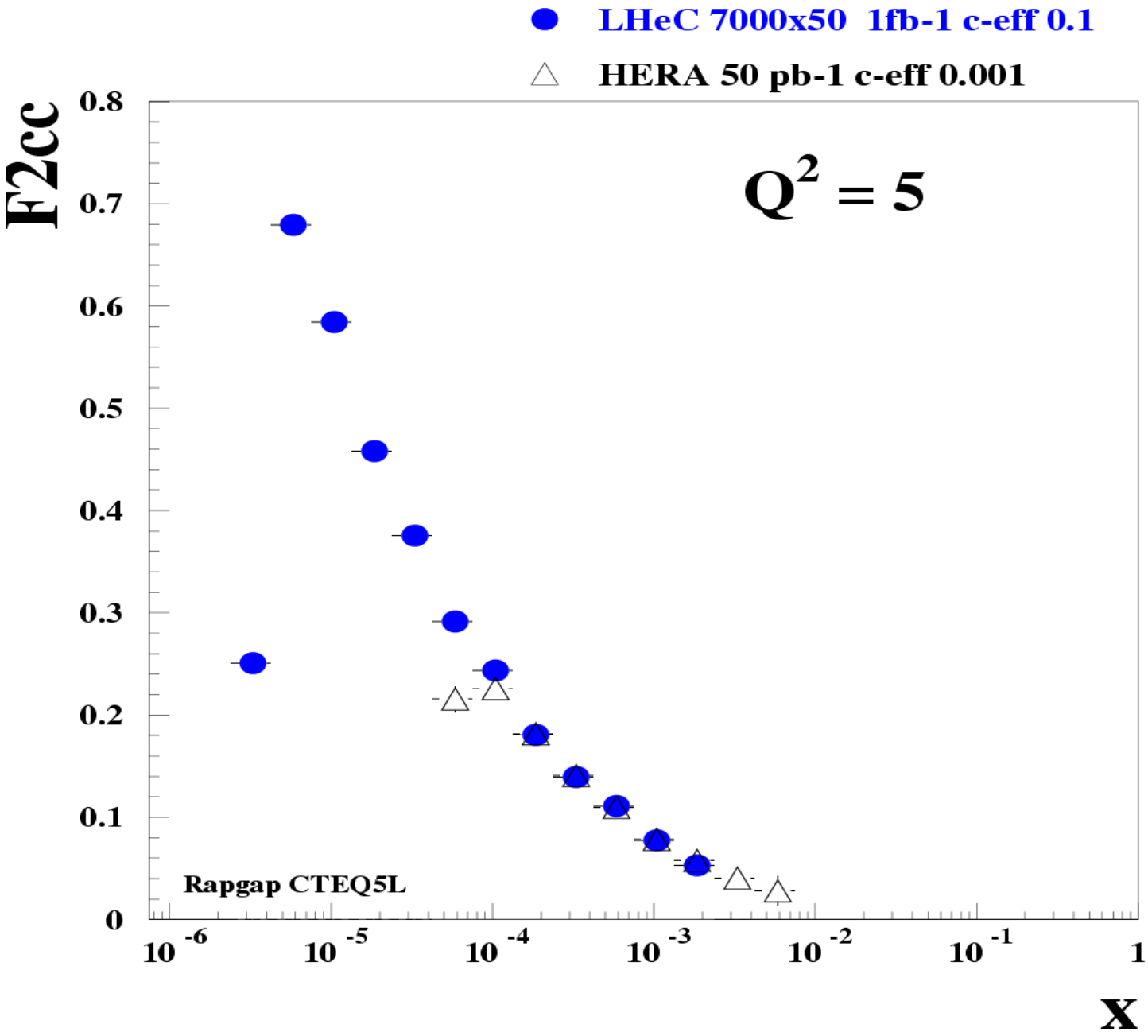
$$\mathbf{N = L * \Delta\sigma * tageff}$$

→ Δσ is charm cross section obtained from RAPGAP

→ Assumed effective tagging efficiency is product of **branching ratios (e.g. c-> D*), acceptances, and takes background contamination into account**

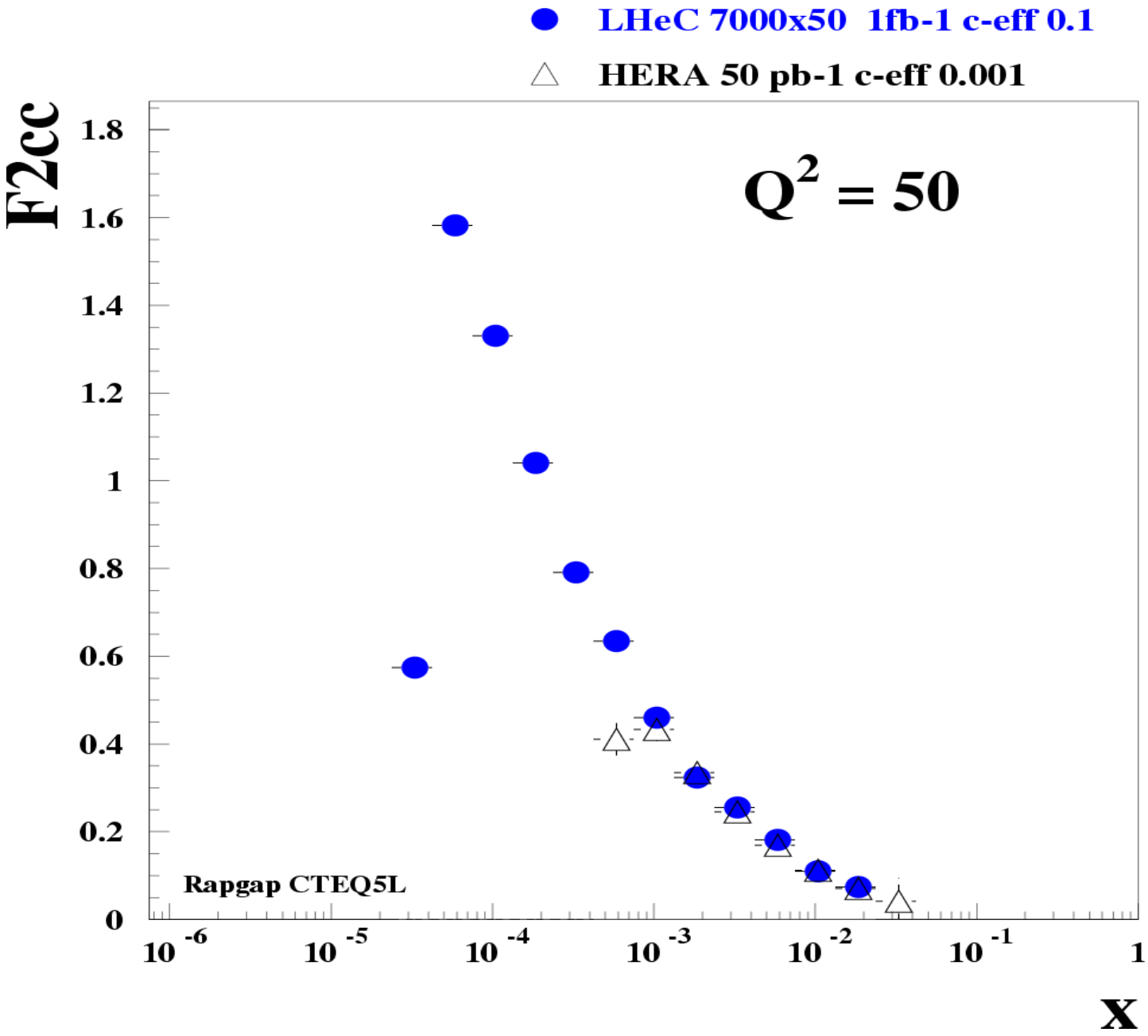
→ Obtain fractional error on F2cc from 1/sqrt(N)

Simulation results **F2cc:** LheC vs HERA



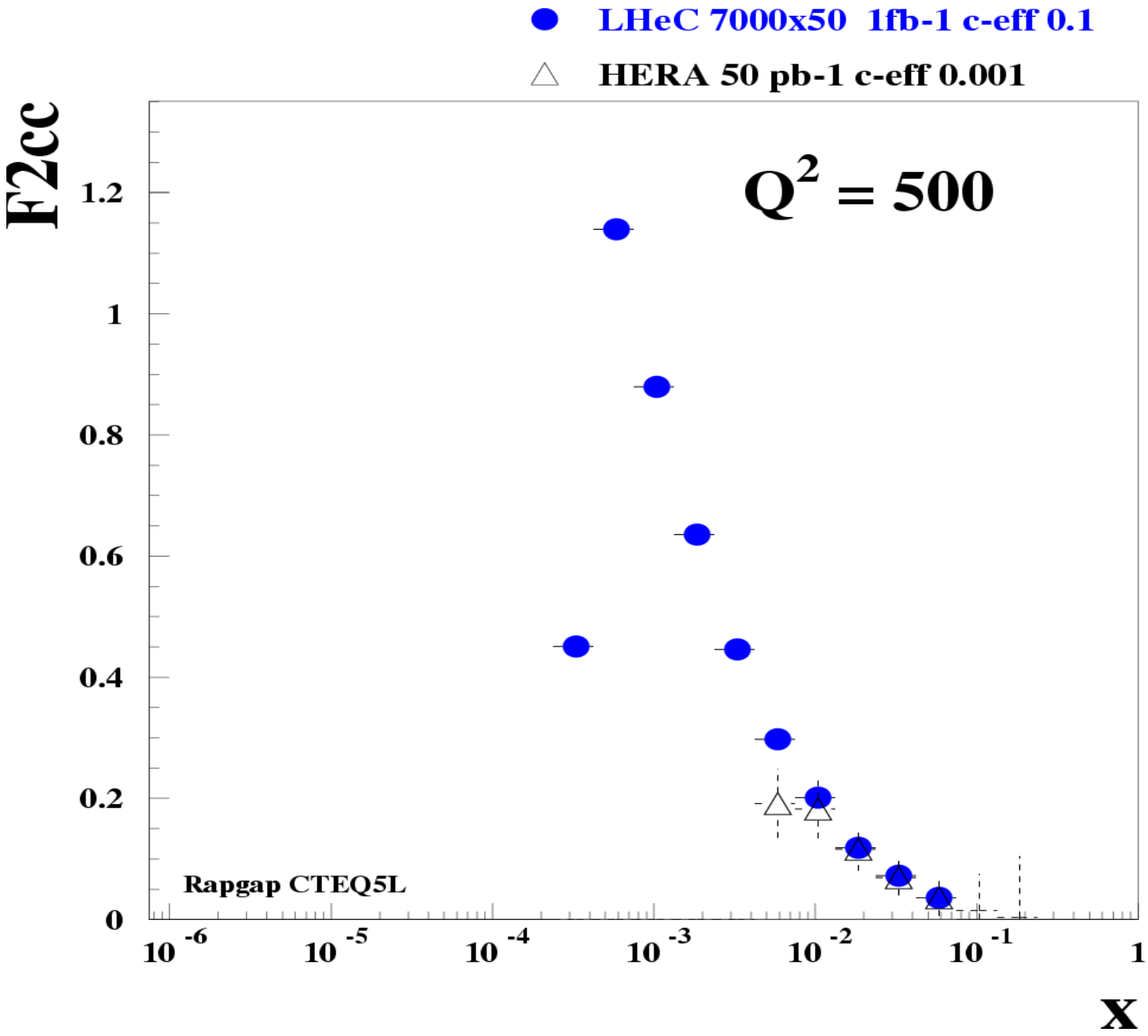
➔ For same Q2 LHeC extends to much lower x

Simulation results **F2cc:** LheC vs HERA



➔ For same Q2 LHeC extends to much lower x

Simulation results **F2cc:** LheC vs HERA



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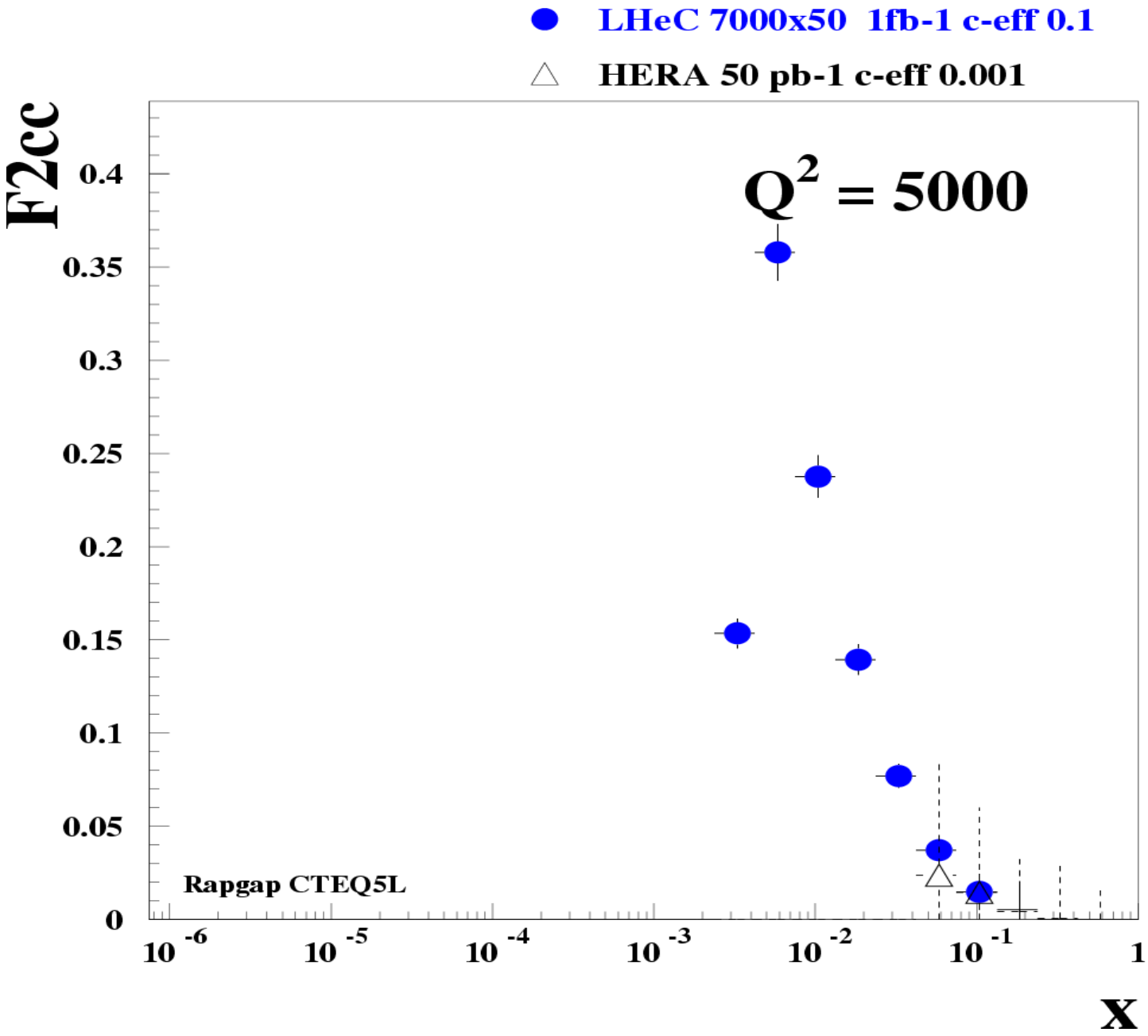
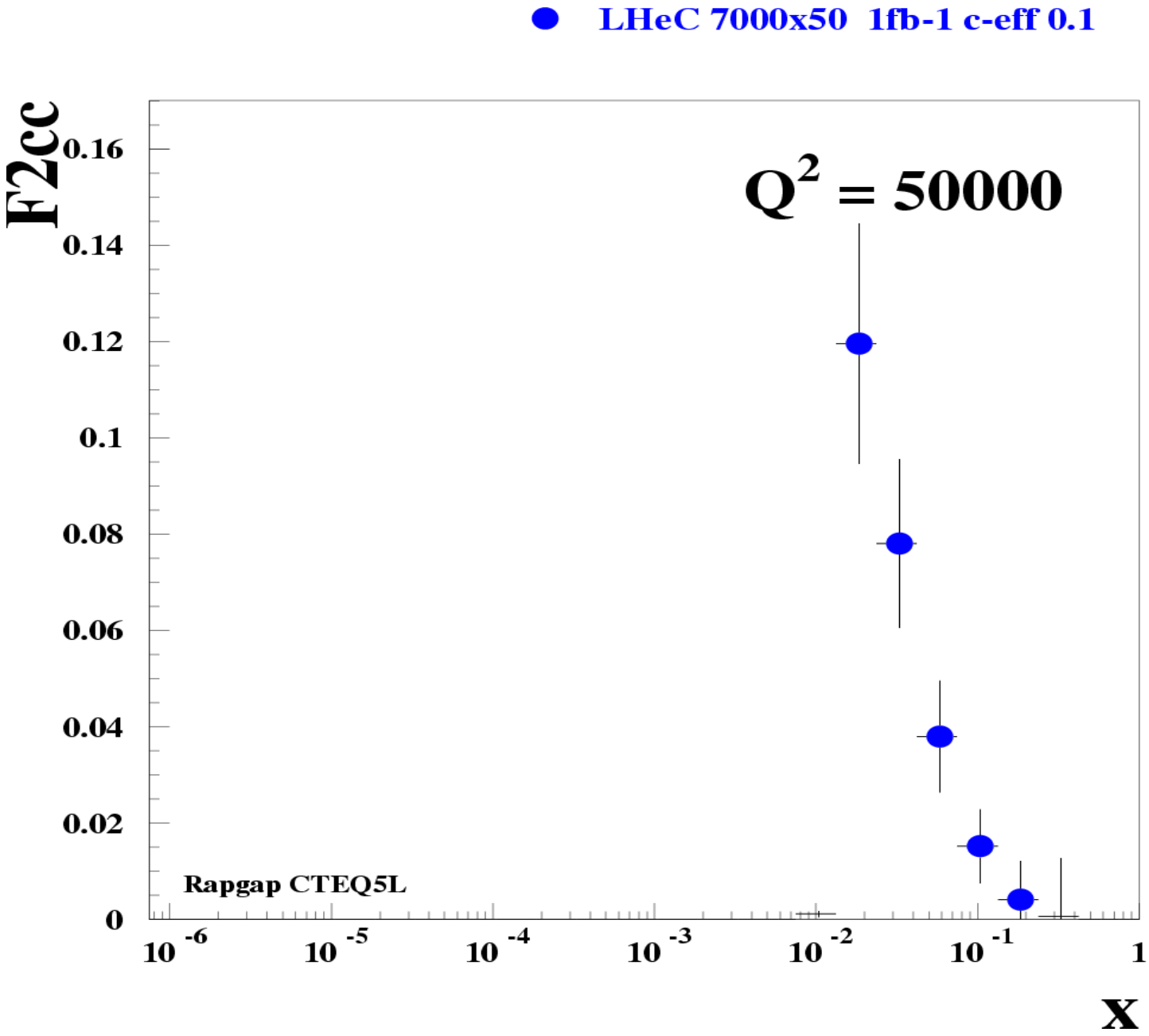
Simulation results **F2cc:** LheC vs HERA



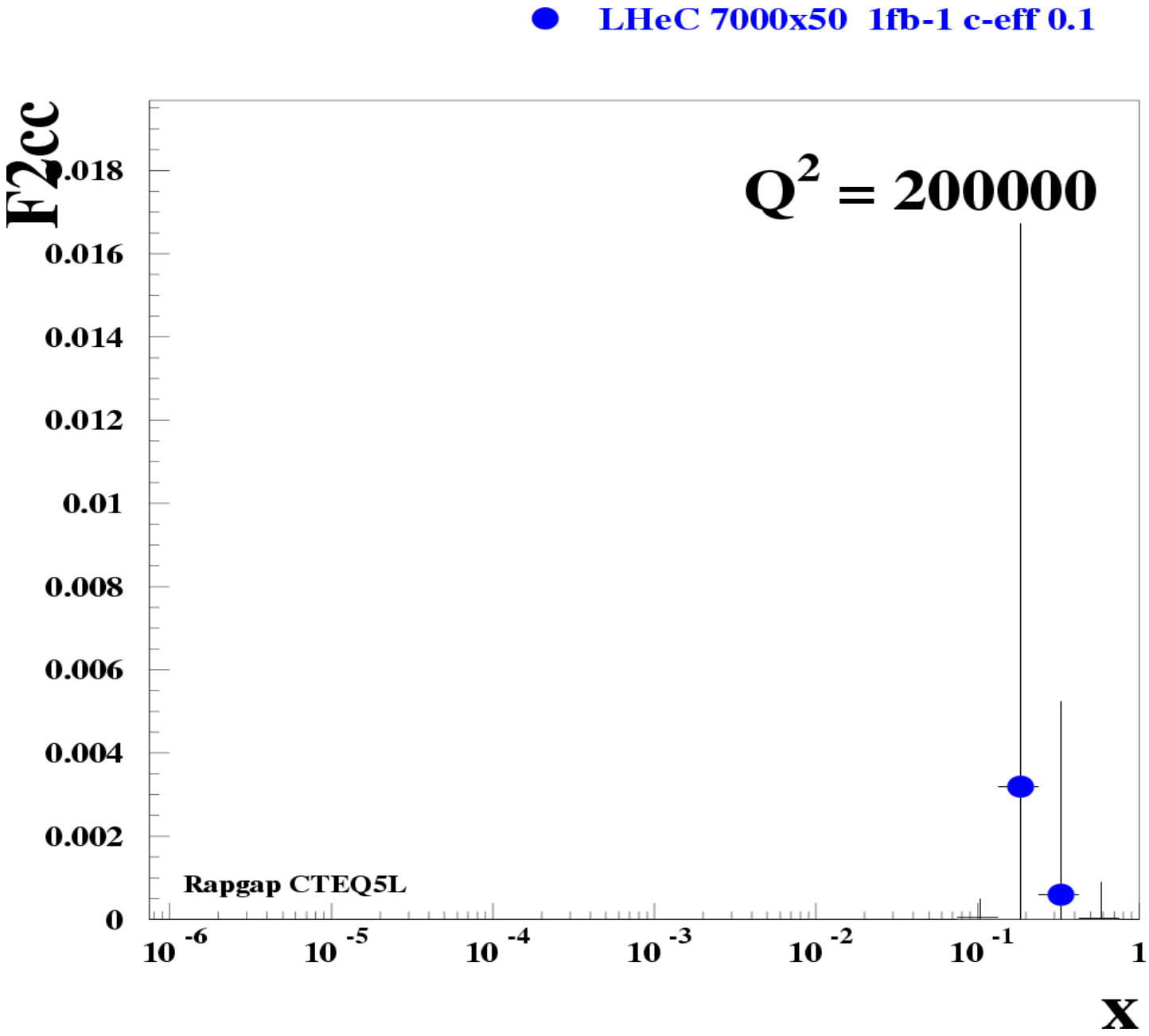
➔ No HERA here (almost)

Simulation results **F2cc**: LheC vs HERA



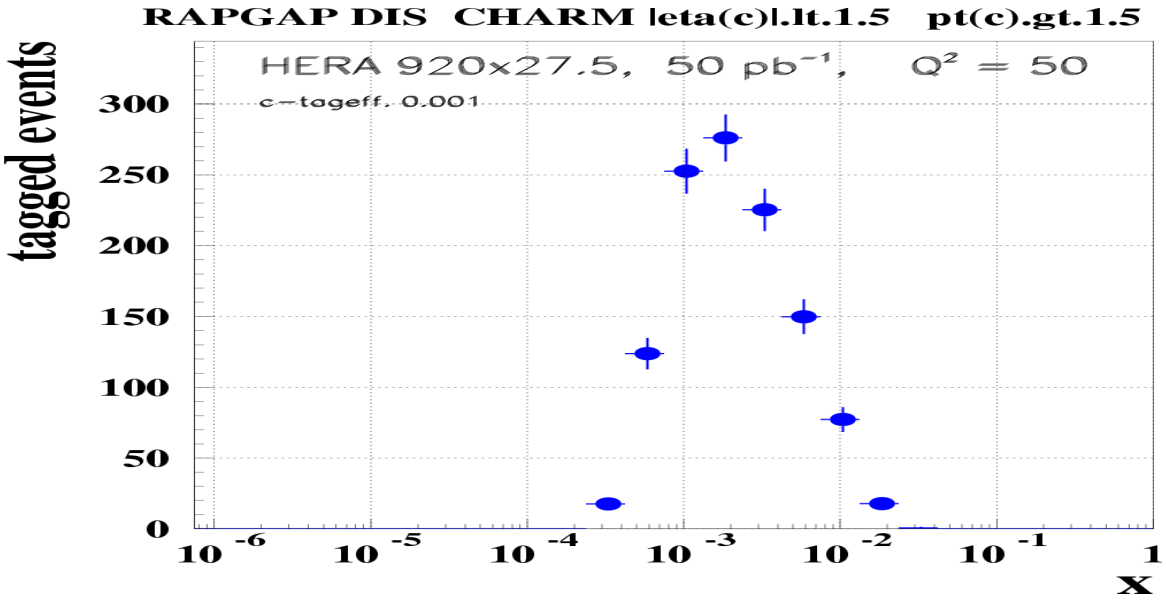
➔ Up to where we go…

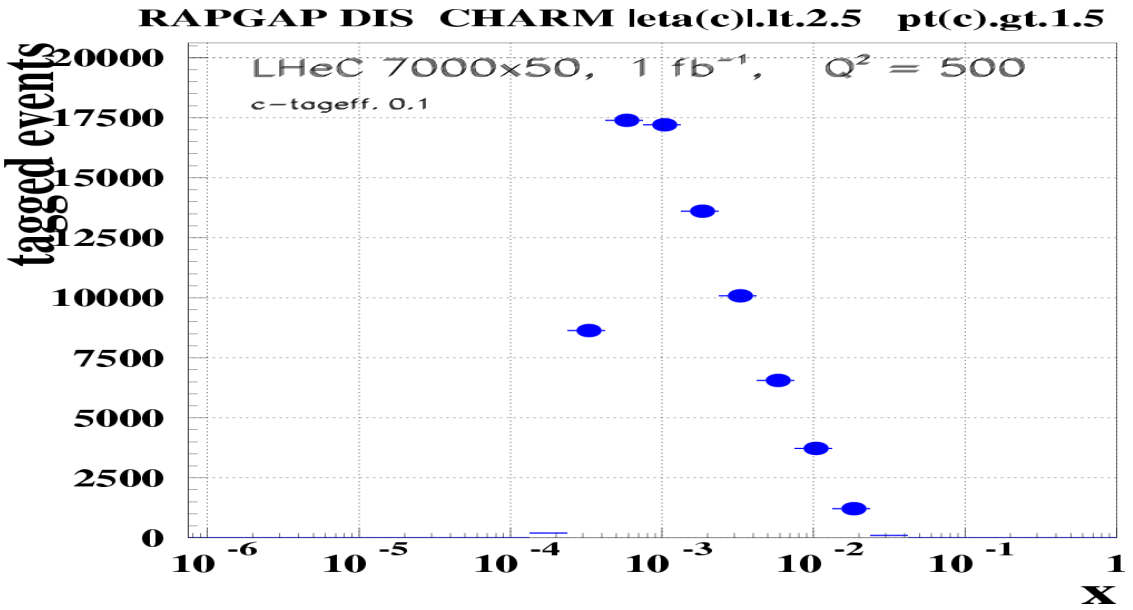
Simulation results **F2cc**: LheC vs HERA



➔ NO, that's too far, sorry

#charm tagged events for same x: LheC vs HERA



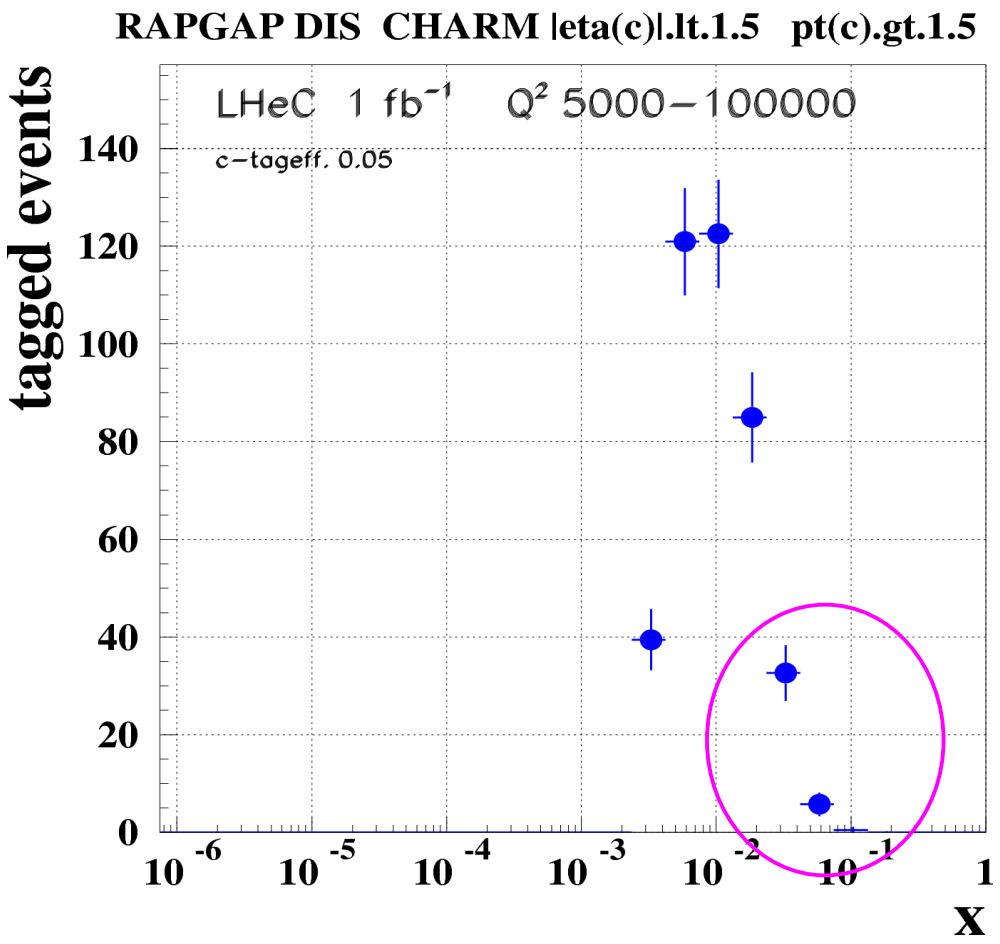


LheC/HERA rate factor ~100 from:
20 x lumi, 100 x tageff
higher gluon density
$1/Q^4$ suppression

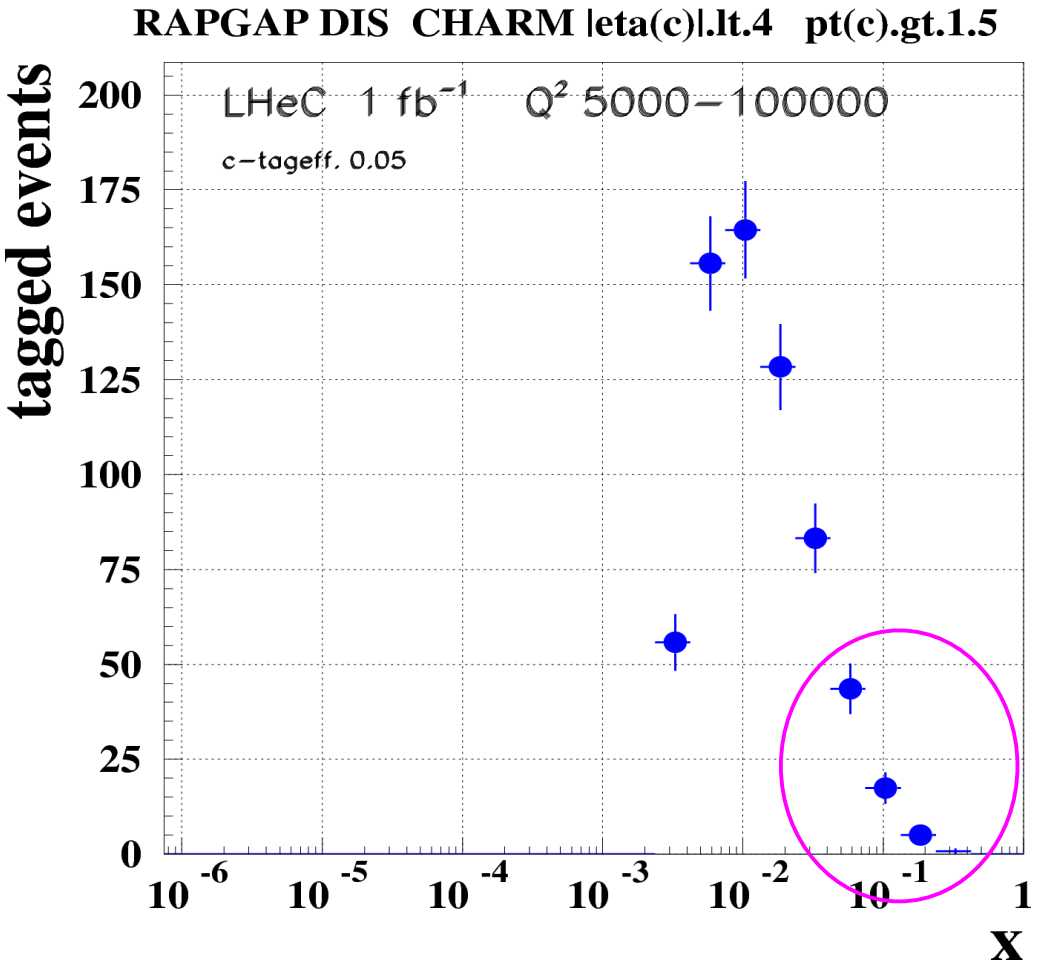
Charm: improvement with forward tagging

7 TeV x 70 GeV simulation

LheC |eta_c|<1.5



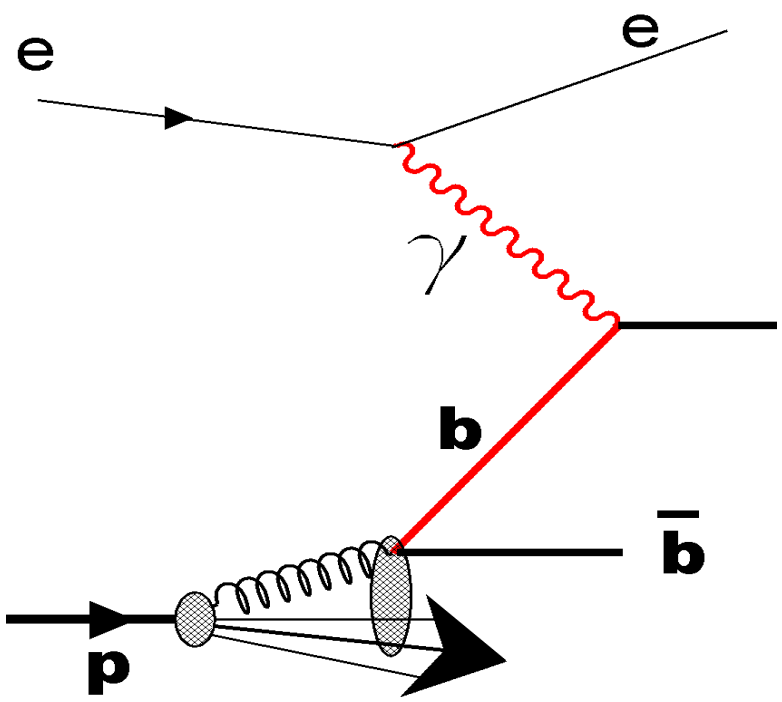
LheC |eta_c|<4



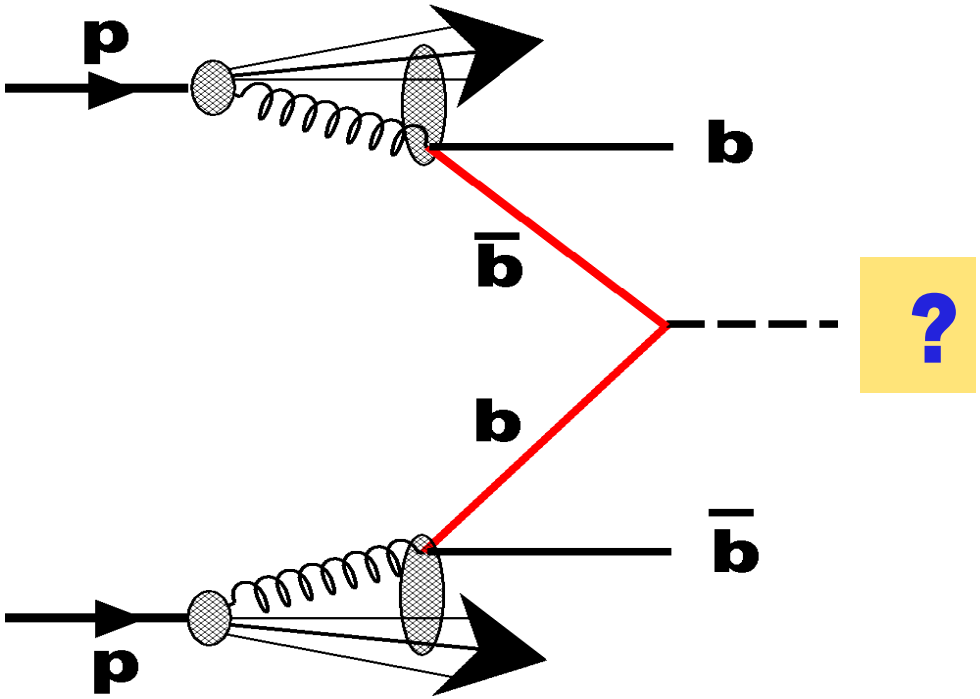
➔ Intrinsic charm (x>~0.1) will be difficult (again)

F2bb one motivation: determine 'b-density' in proton

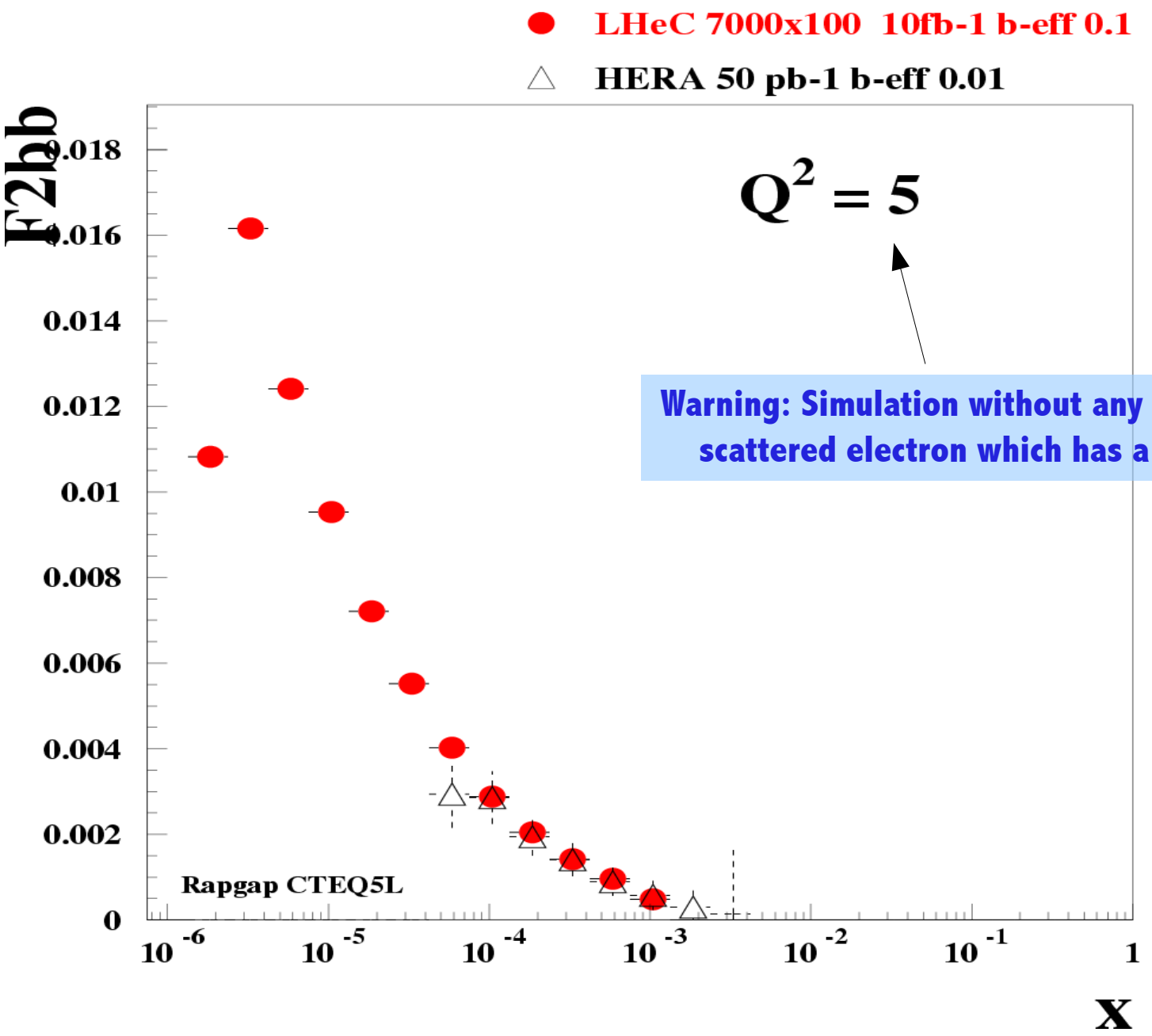
LheC



LhC



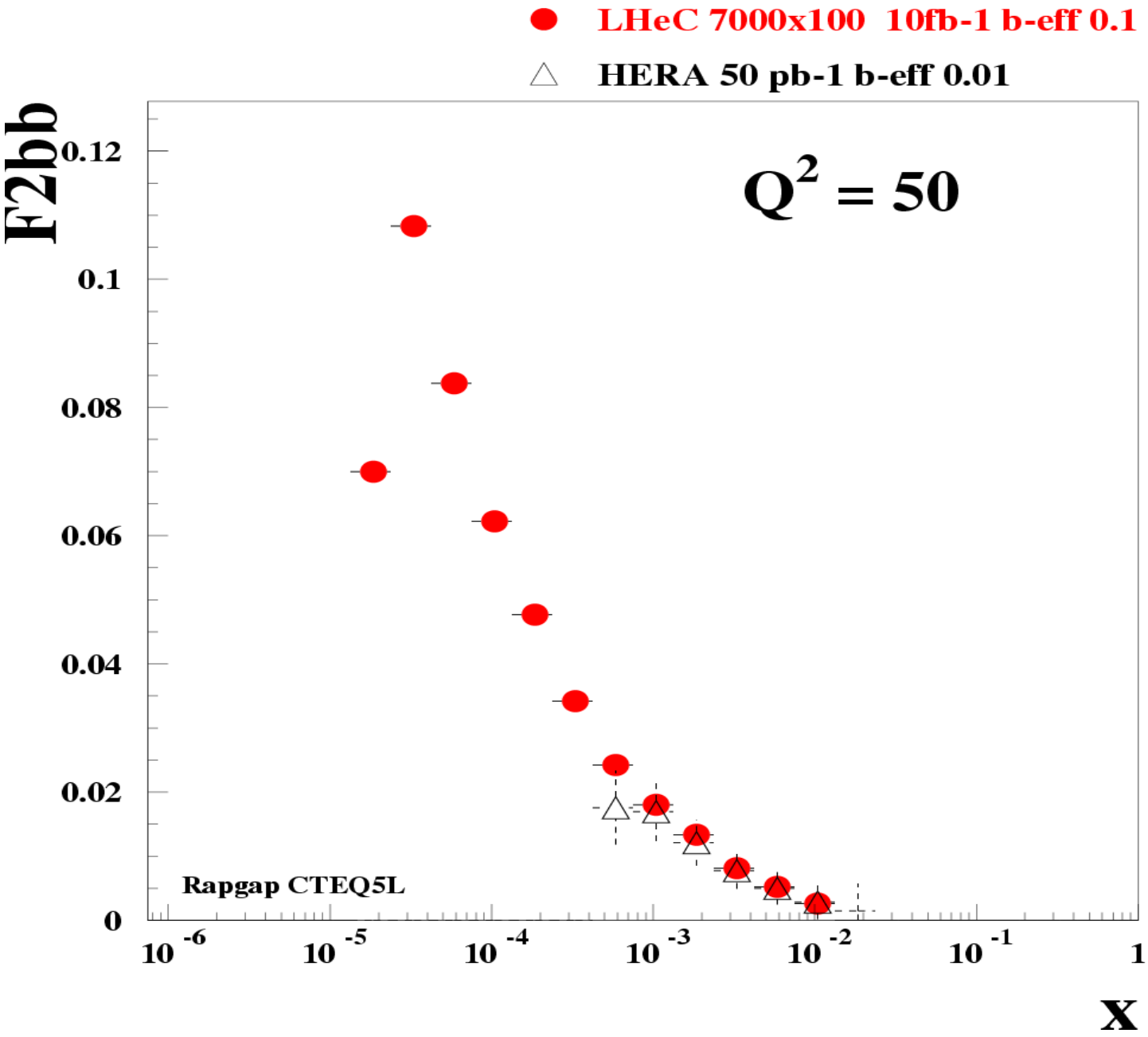
Simulation results **F2bb**: LheC vs HERA



Warning: Simulation without any acceptance restriction on scattered electron which has a typical theta of ~178^0

➔ For same Q2 LHeC extends to much lower x

Simulation results **F2bb**: LheC vs HERA



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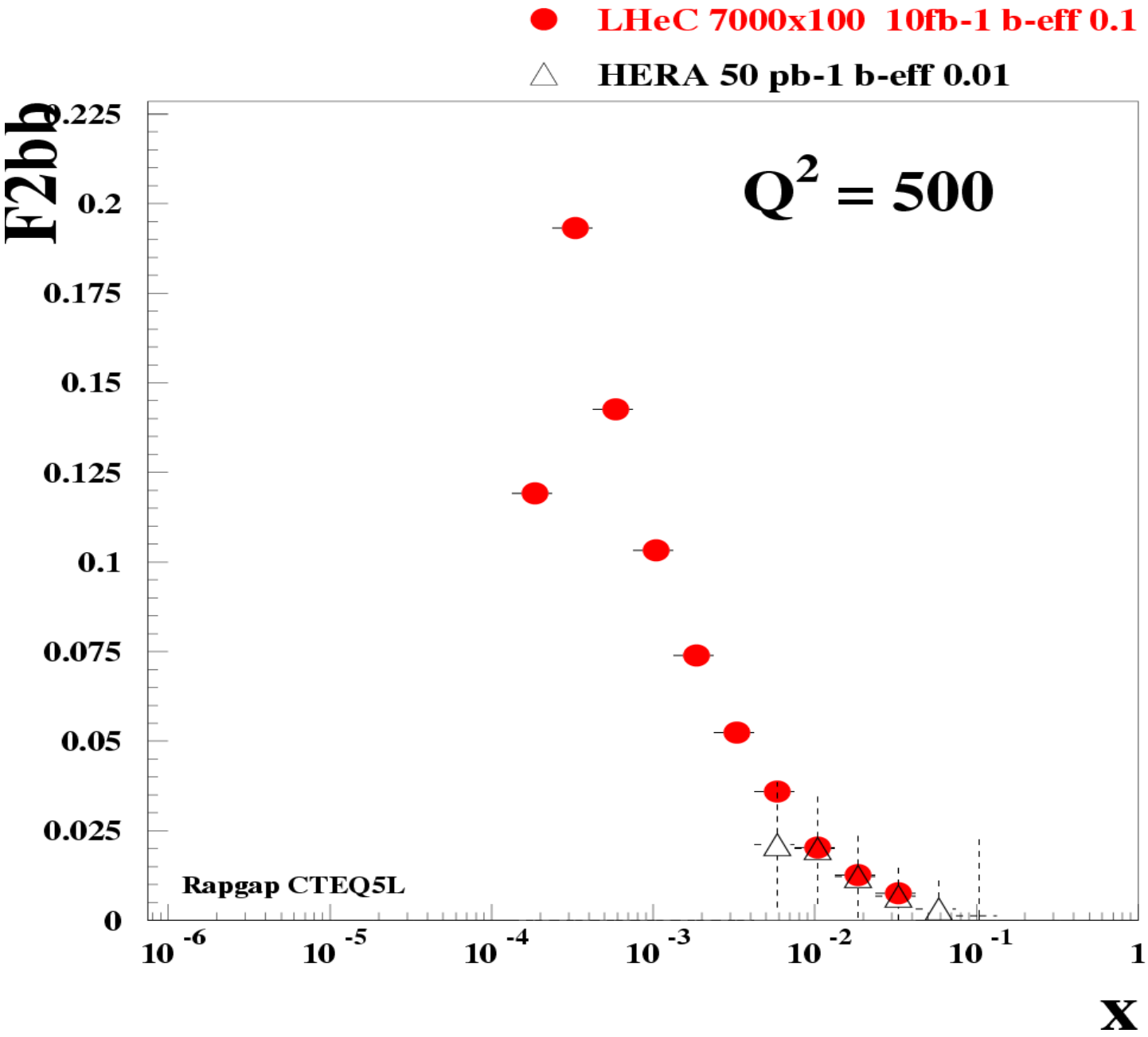
Simulation results **F2bb**: LheC vs HERA



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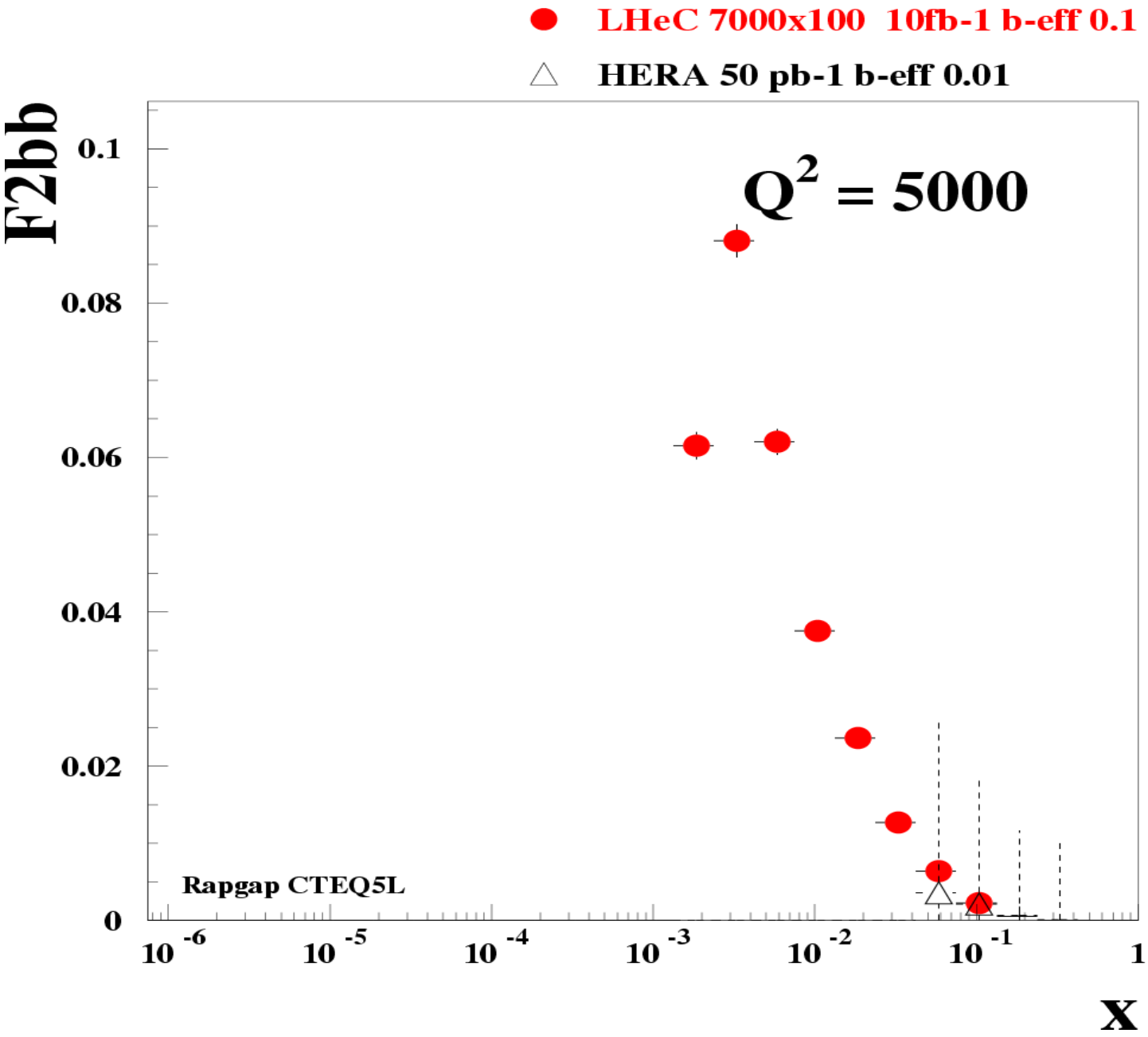
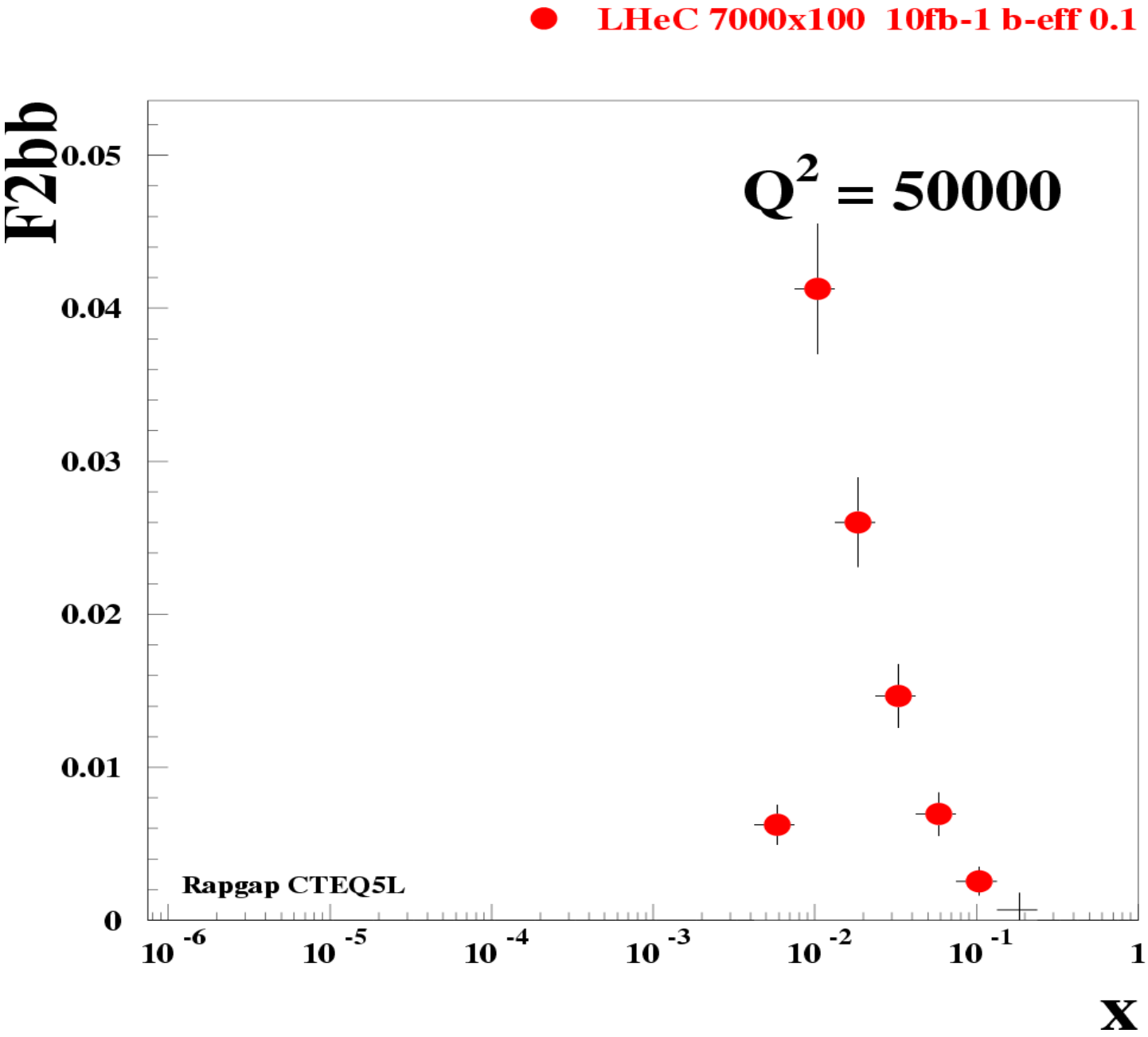
Simulation results **F2bb**: LheC vs HERA



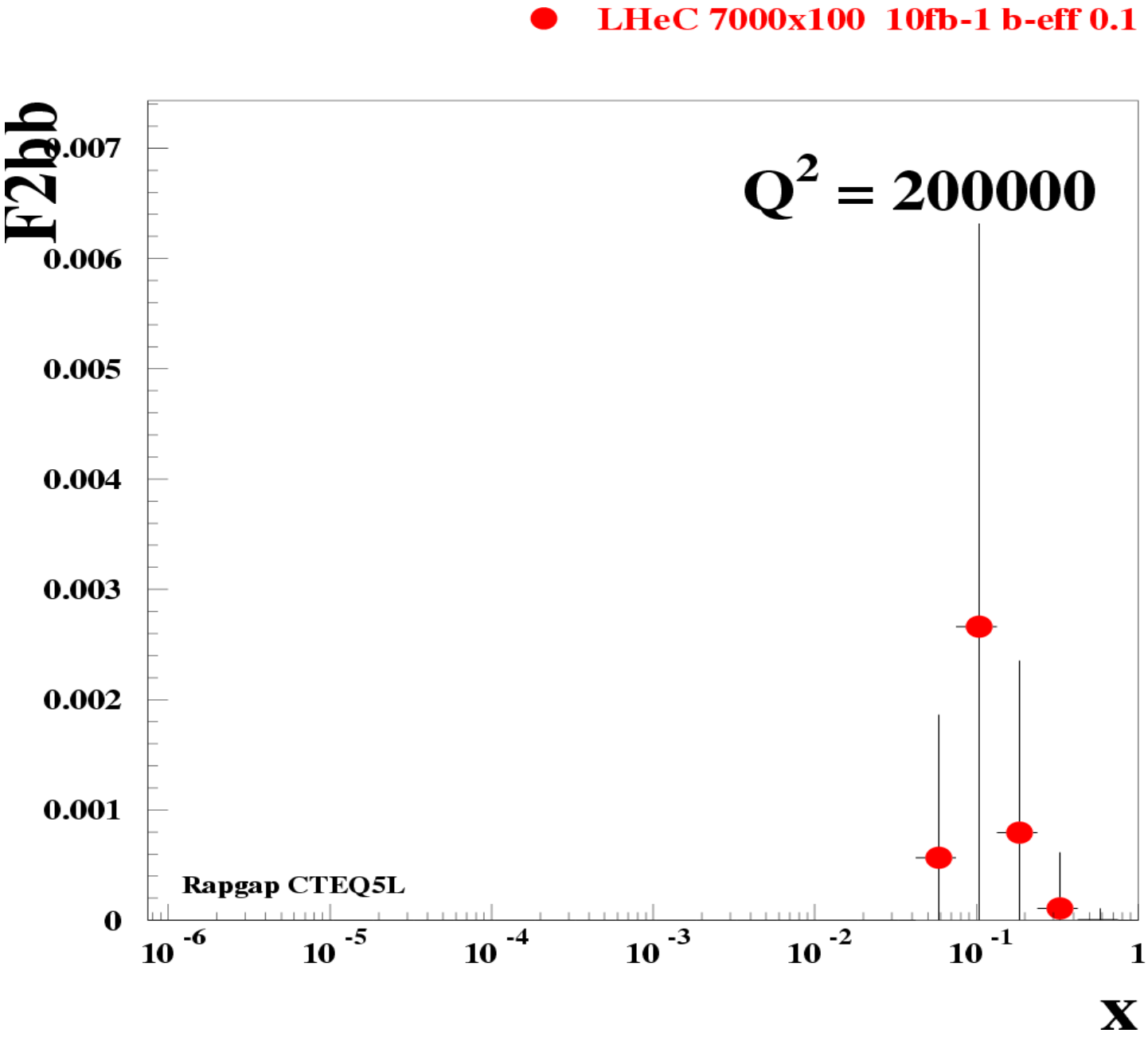
➔ Sorry for HERA!

Simulation results **F2bb**: LheC vs HERA



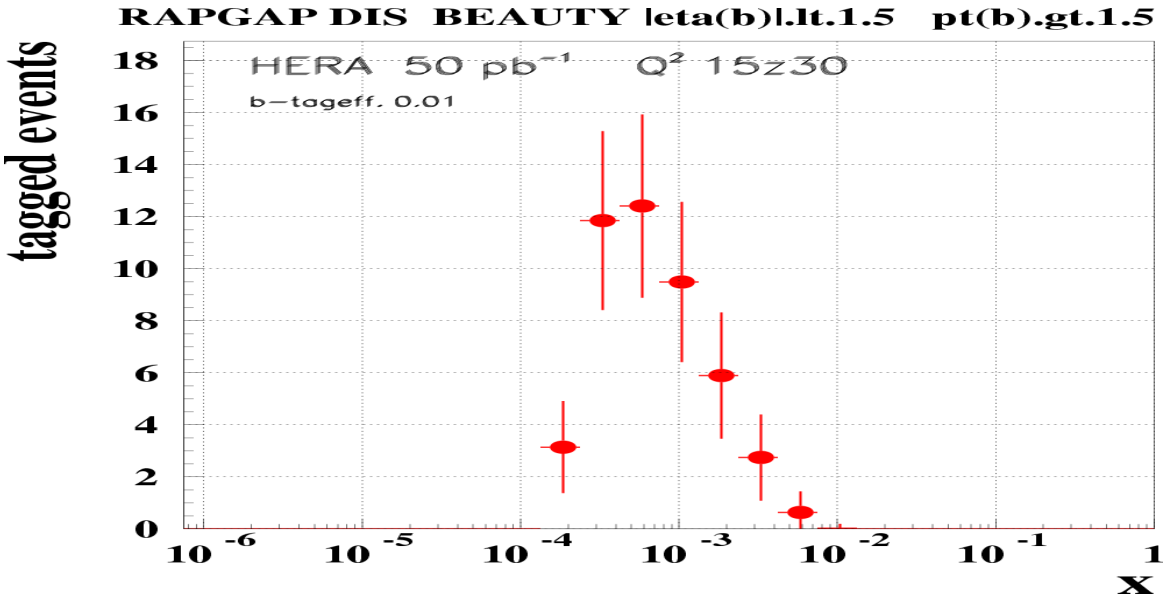
➔ Here we go

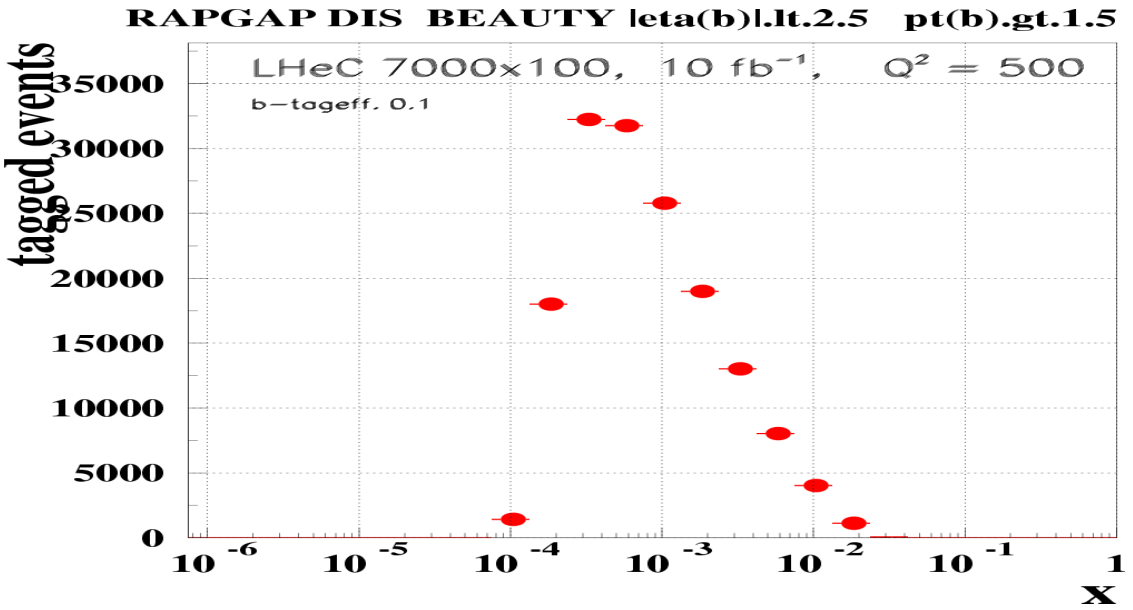
Simulation results **F2bb**: LheC vs HERA



➔ Oooooops, too far again

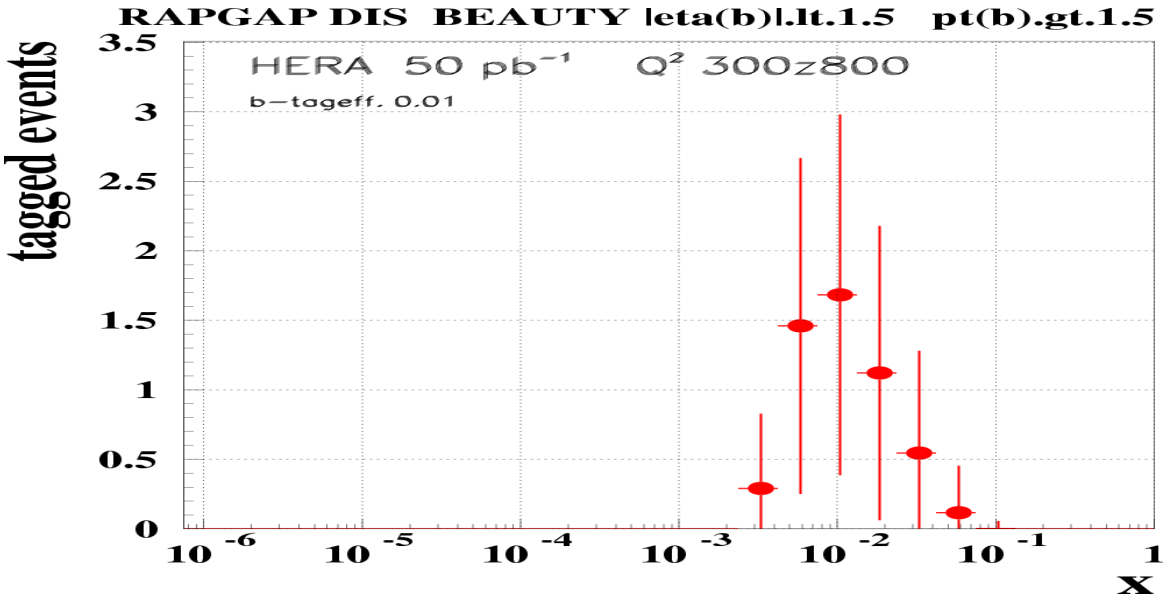
#beauty tagged events for same x: LheC vs HERA

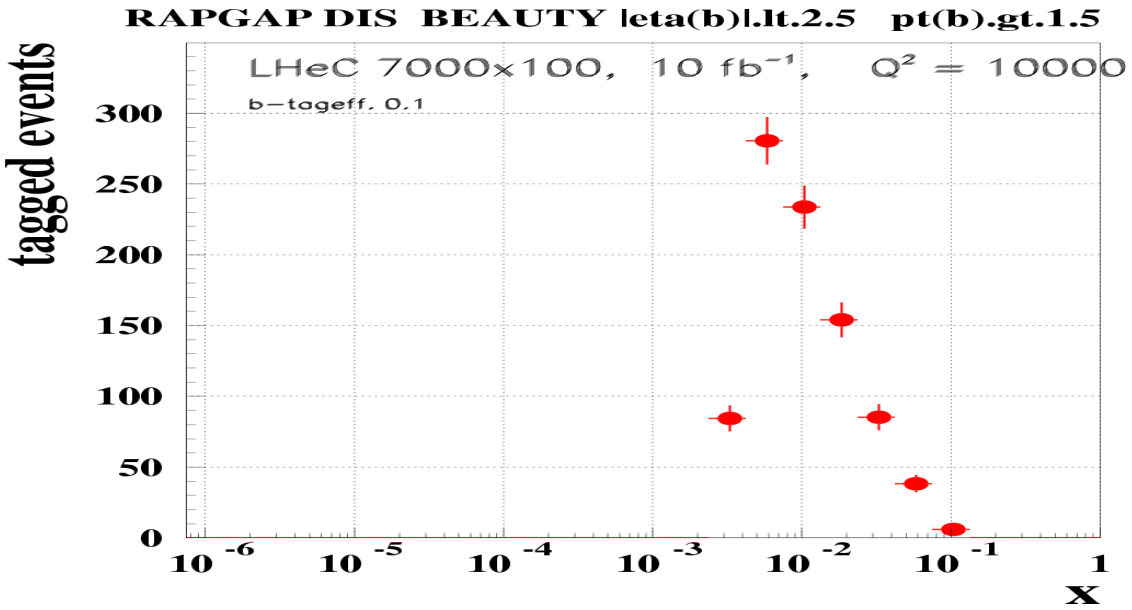




LheC/HERA rate factor 2000 from:
200 x lumi, 10 x tageff, much larger kin. phase space,
$1/Q^4$ suppression

#beauty tagged events for same x, high Q2: LheC vs HERA





LheC/HERA rate factor ~100 from:
200 x lumi, 10 x tageff, $1/Q^4$ suppression