LHeC: High p_T jets and heavy flavour physics prospects

April 14th 2011, DIS 2011, Newport News, VA, USA

Olaf Behnke (DESY)

This talk will focus on a *new era of QCD tests*
at an LHeC with
high pt Jets and Heavy flavours

HERA ep
27.5 GeV x 920 GeV

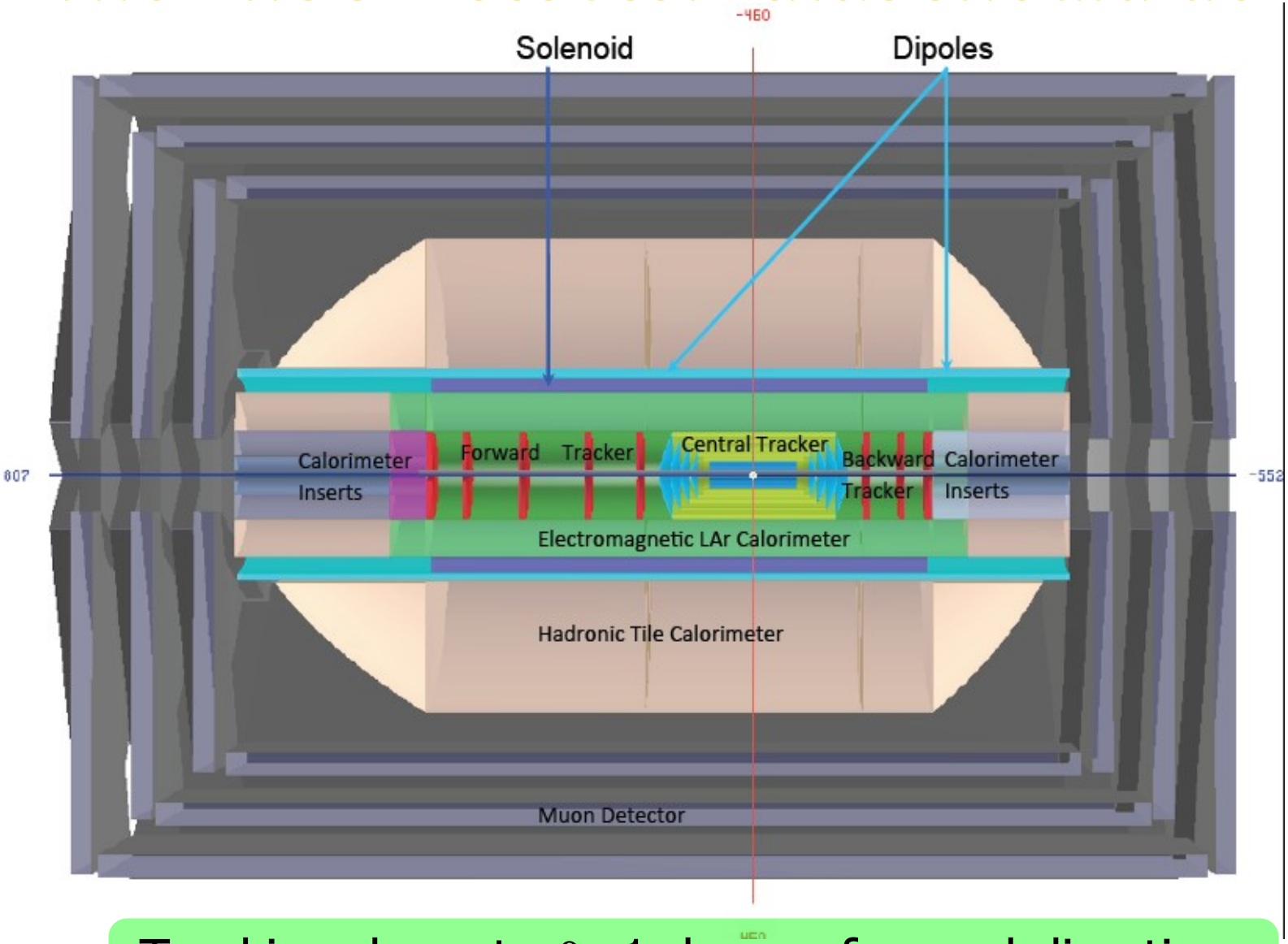
LHeC ep
50-150 GeV x 7 TeV

+ Huge phase space increase
+ Higher cross sections

+ Higher luminosity
+ suitable excellent detector

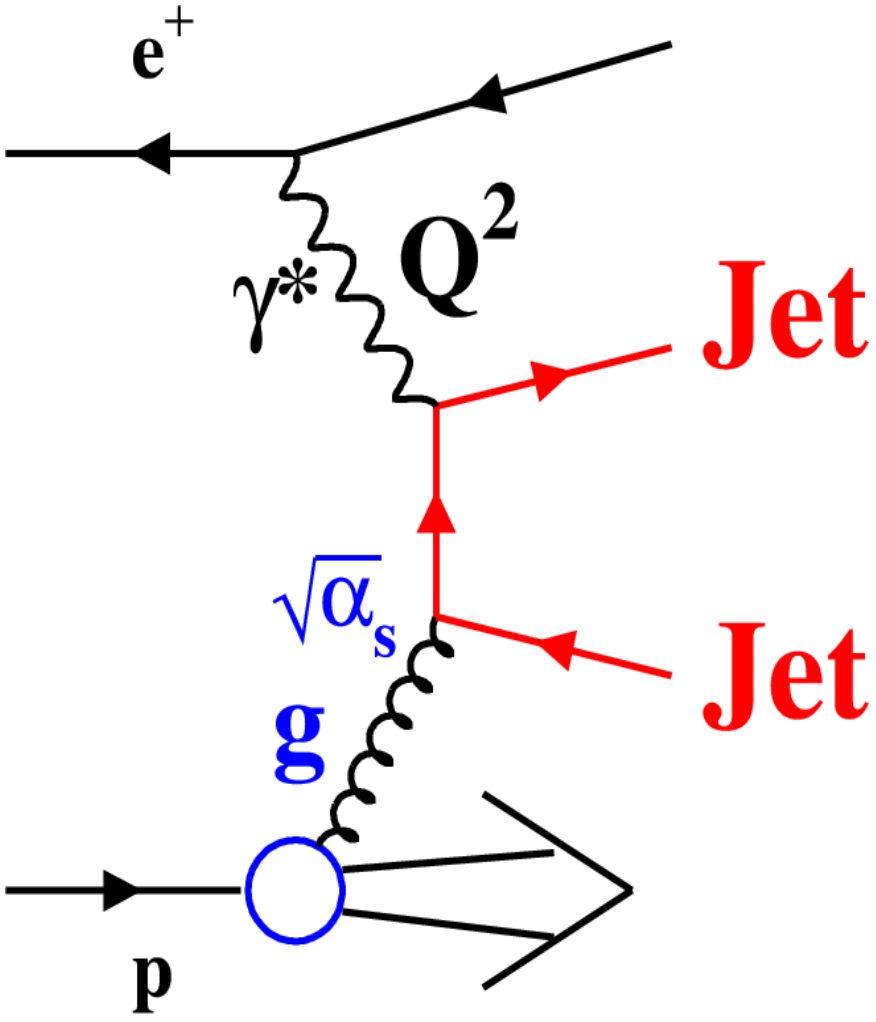
QCD high precision laboratory

The LheC Detector ‘that should do it’:



Tracking down to $\theta \sim 1$ degree forward direction

High p_T Jets



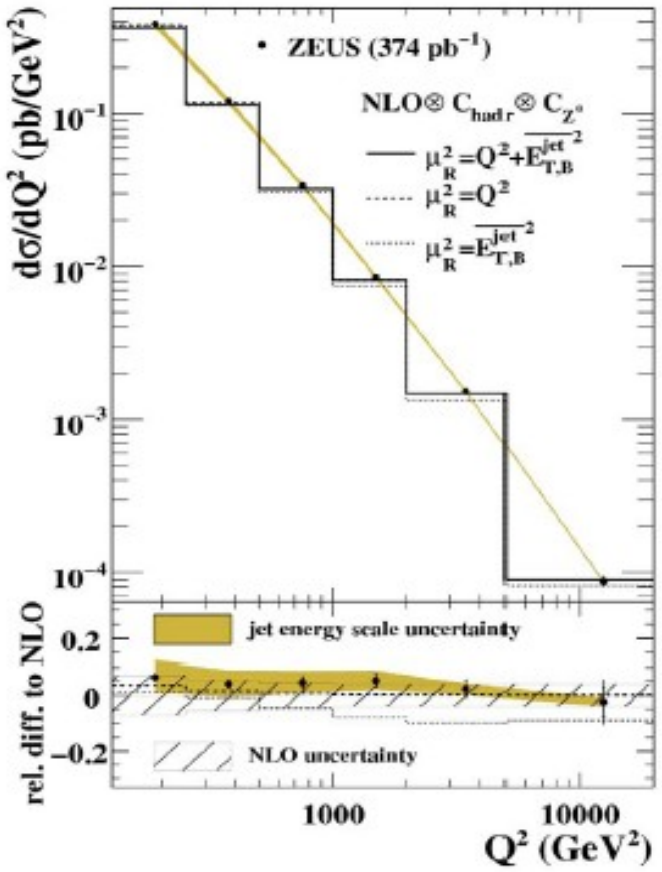
- Check QCD
- Determine running α_s
- Measure gluon density

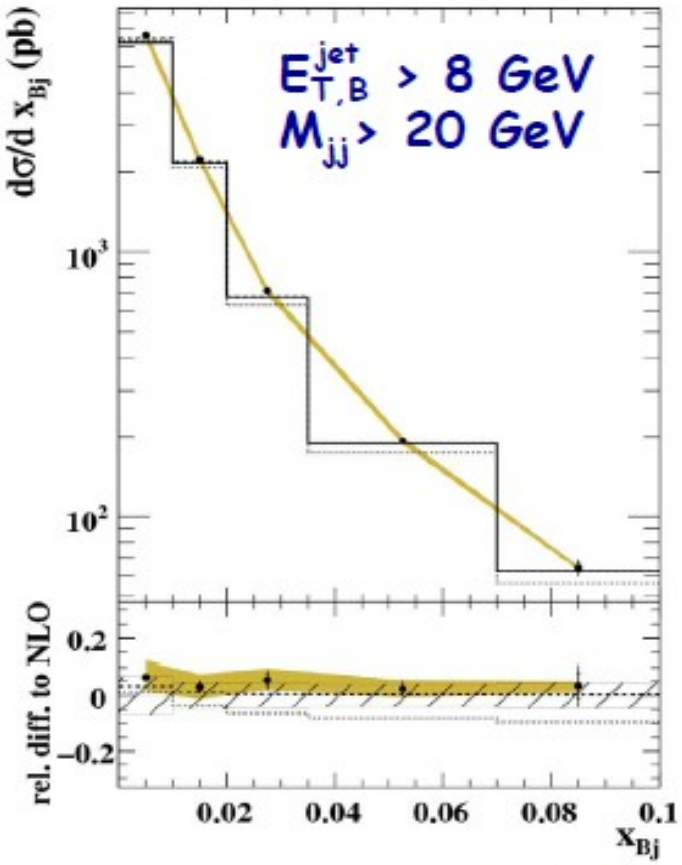
High p_T Jets at HERA

Dijets in DIS

see talk
O. Kuprash

DESY-10-170, Eur. Phys. J. C70 (2010) 965

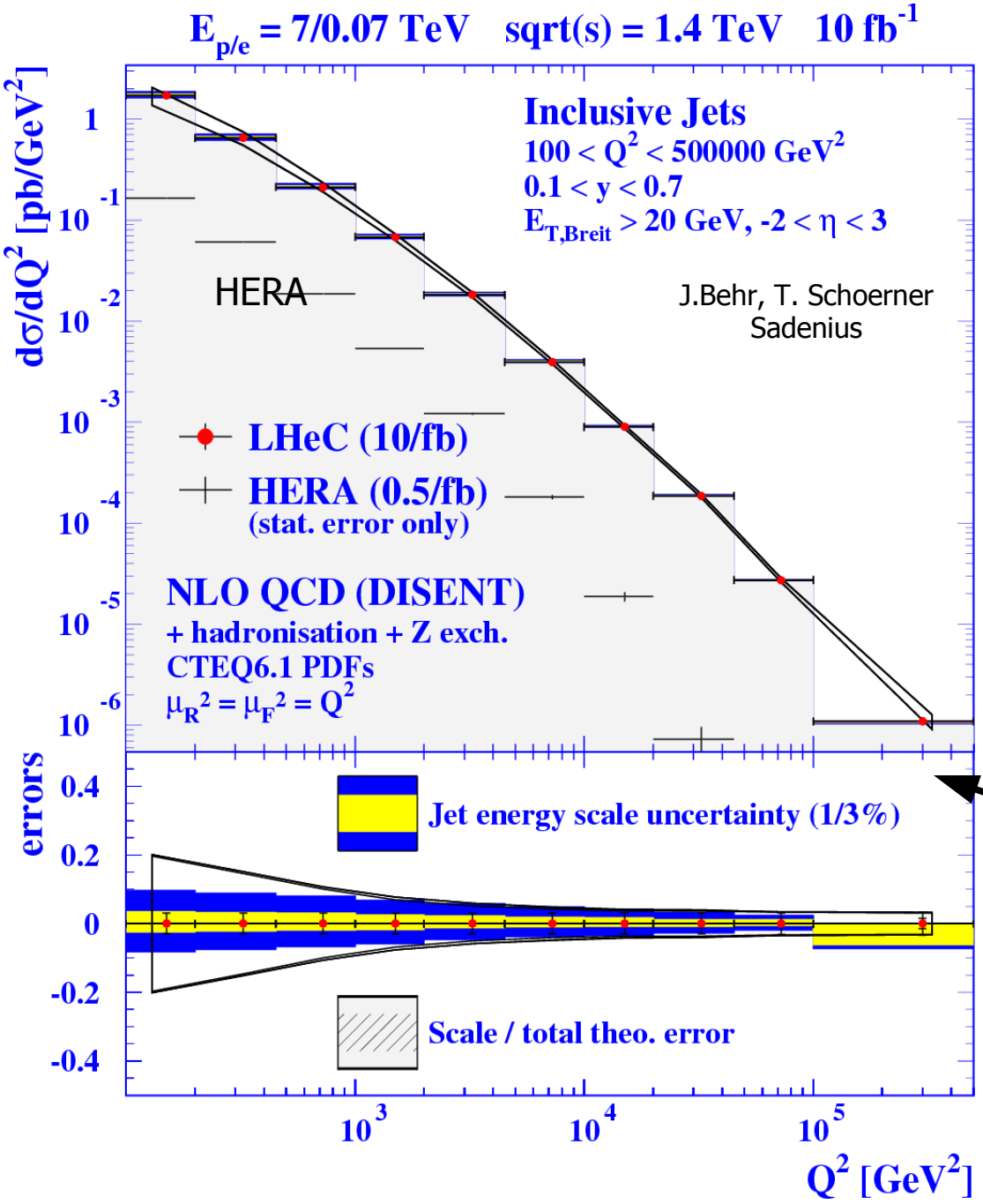


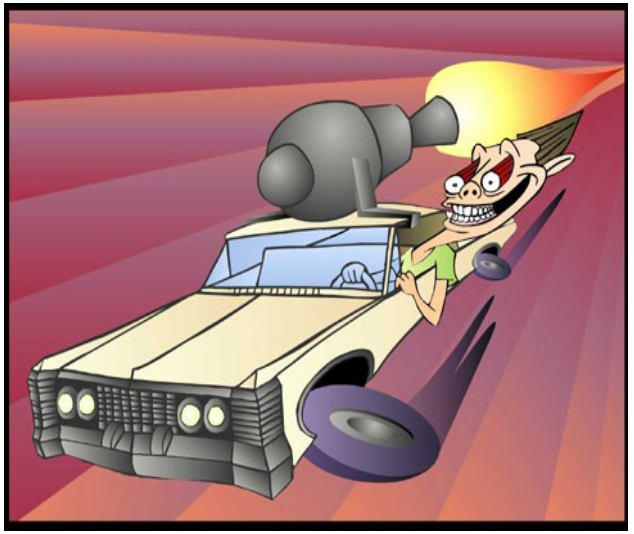


ZEUS

QCD works!

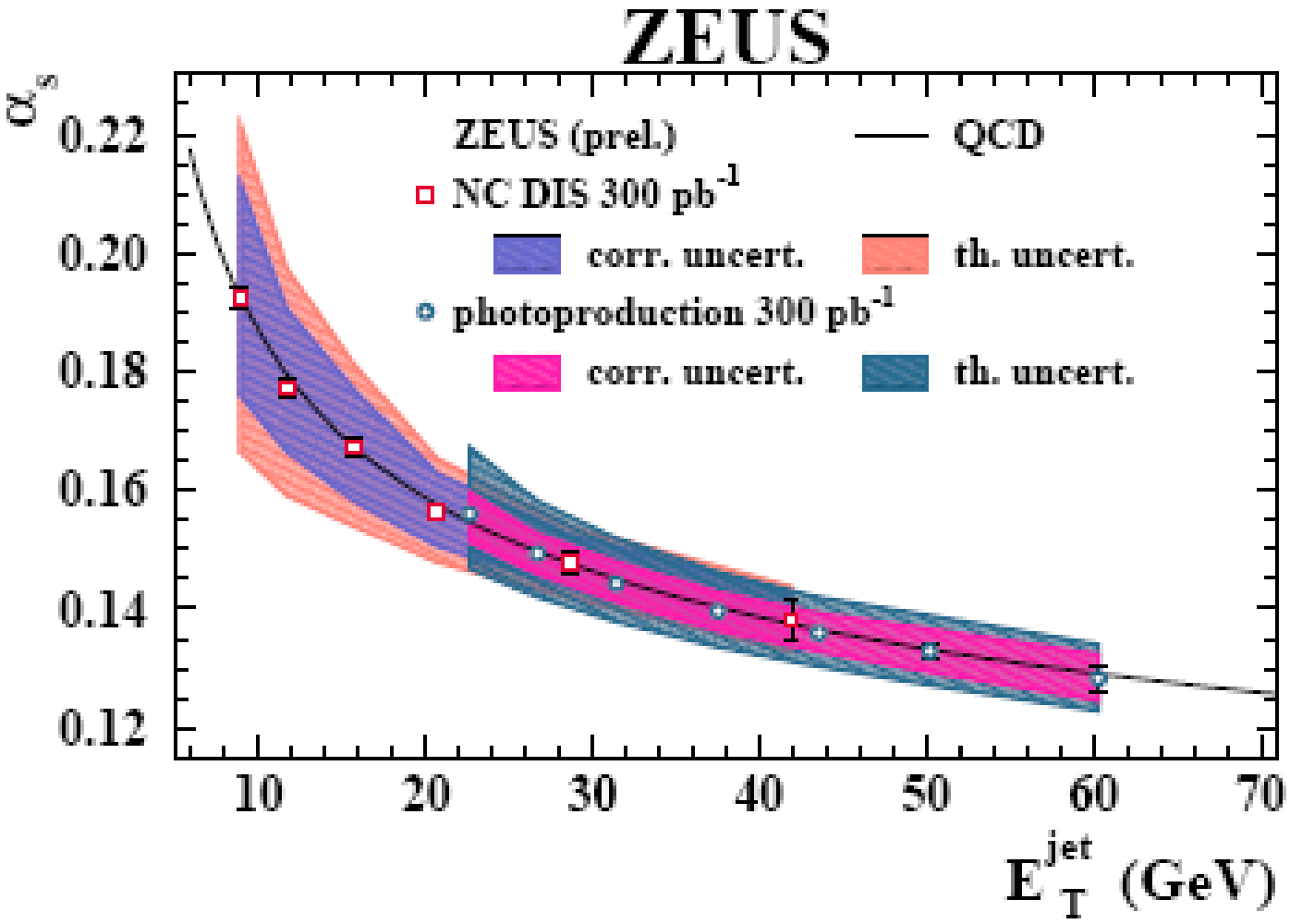
Inclusive Jets in DIS at LHeC (prospects)





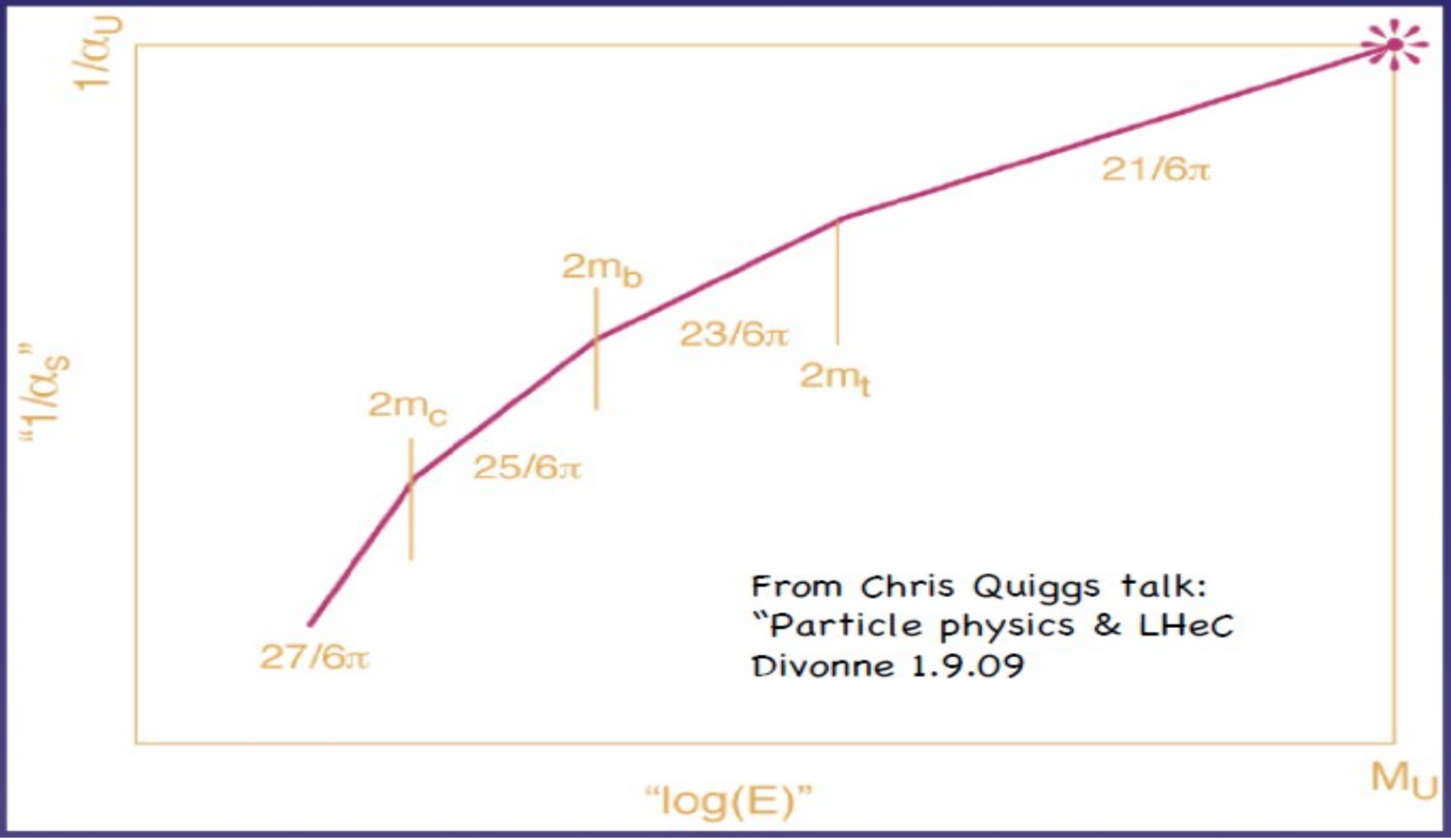
Increase phase space to $Q^2 \sim 400000$ GeV^2

Running α_s from jets at HERA



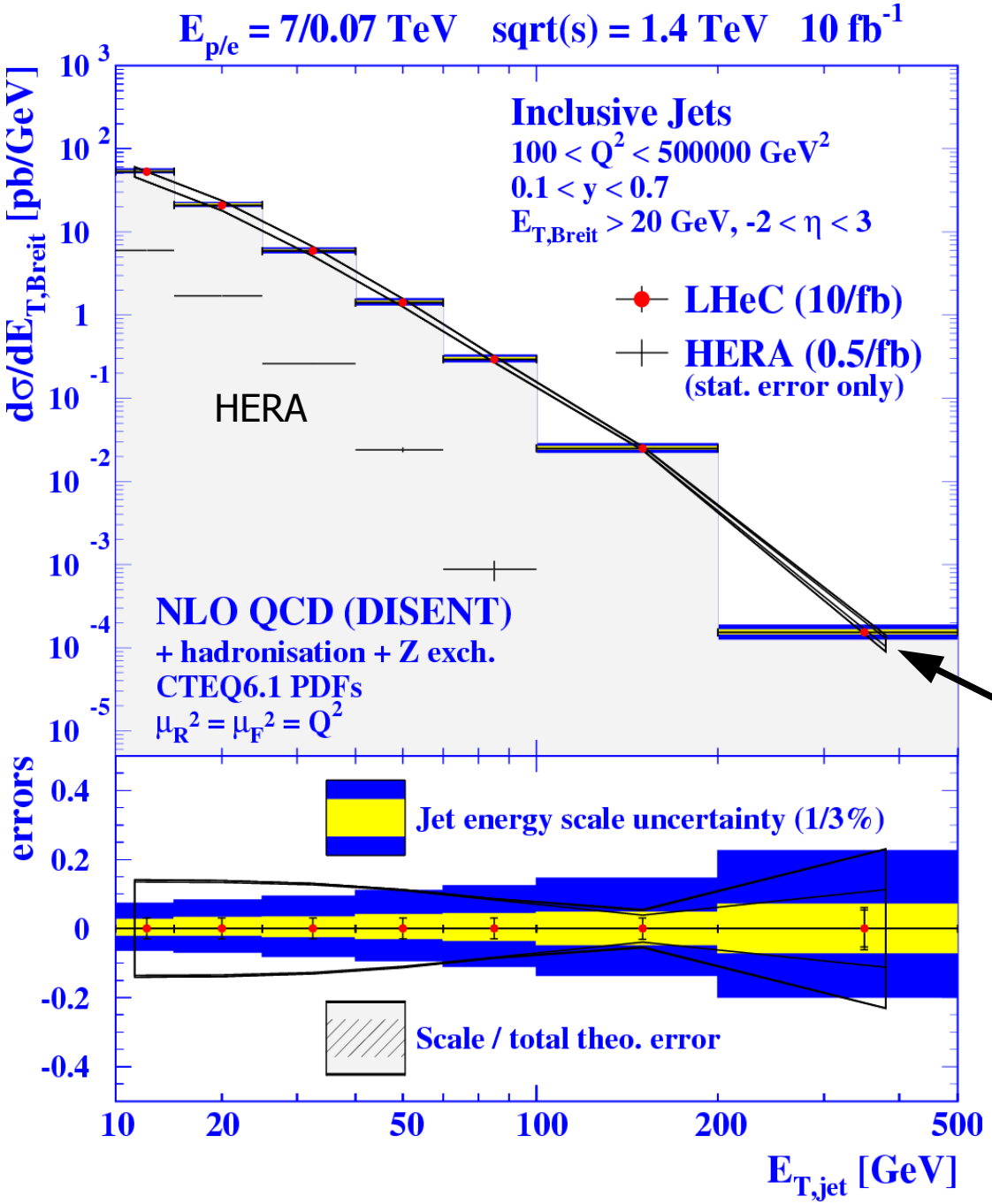
Measurements up to scale ~M_Z

Measure change in slope at top threshold?



Inclusive Jets in DIS at LHeC

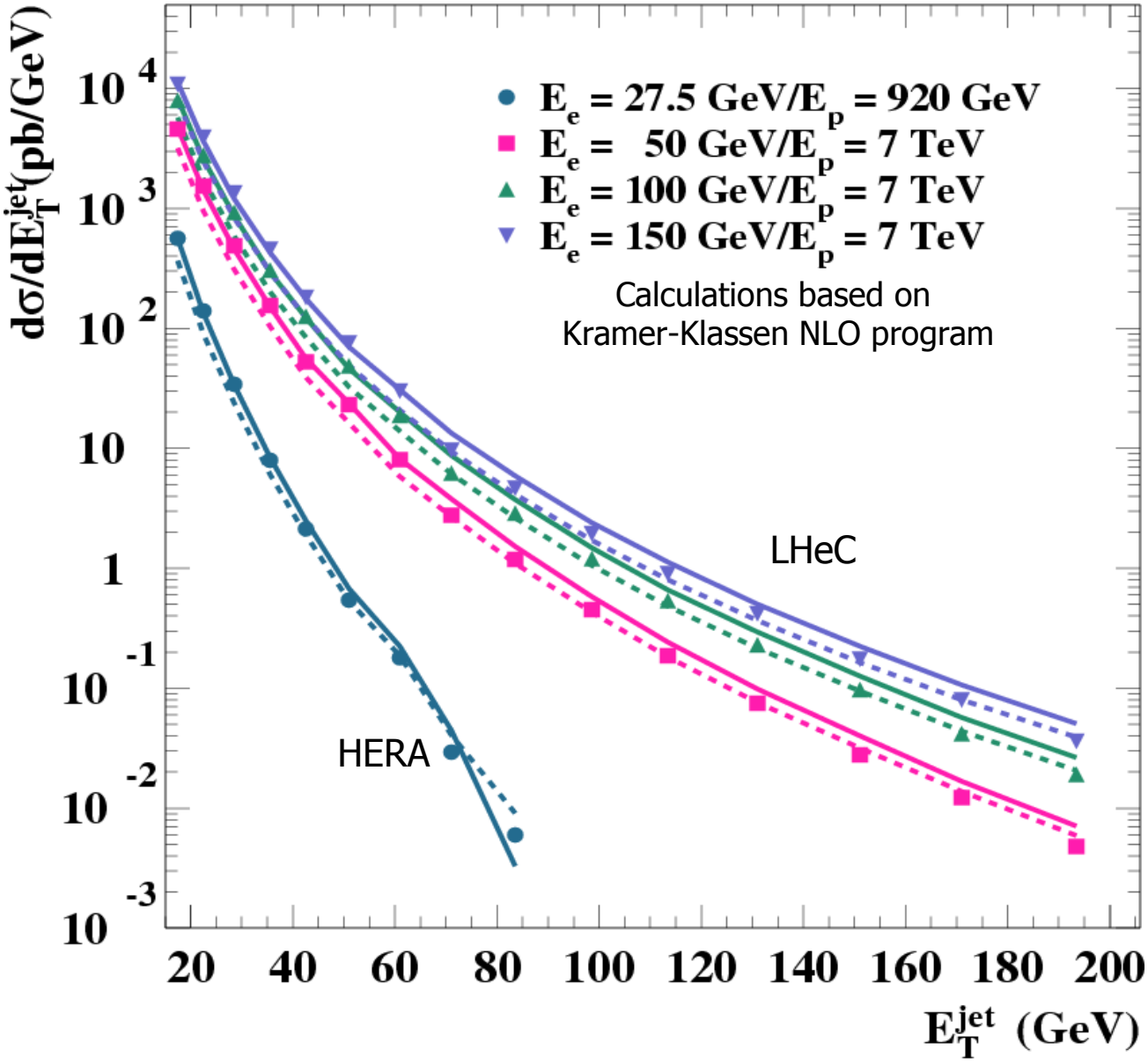
J.Behr, T. Schoerner
Sadenius



study running α_s up to scale $E_{T,jet} \sim 400$ GeV

High p_T Jets in photoproduction (Q^2~0 GeV^2)

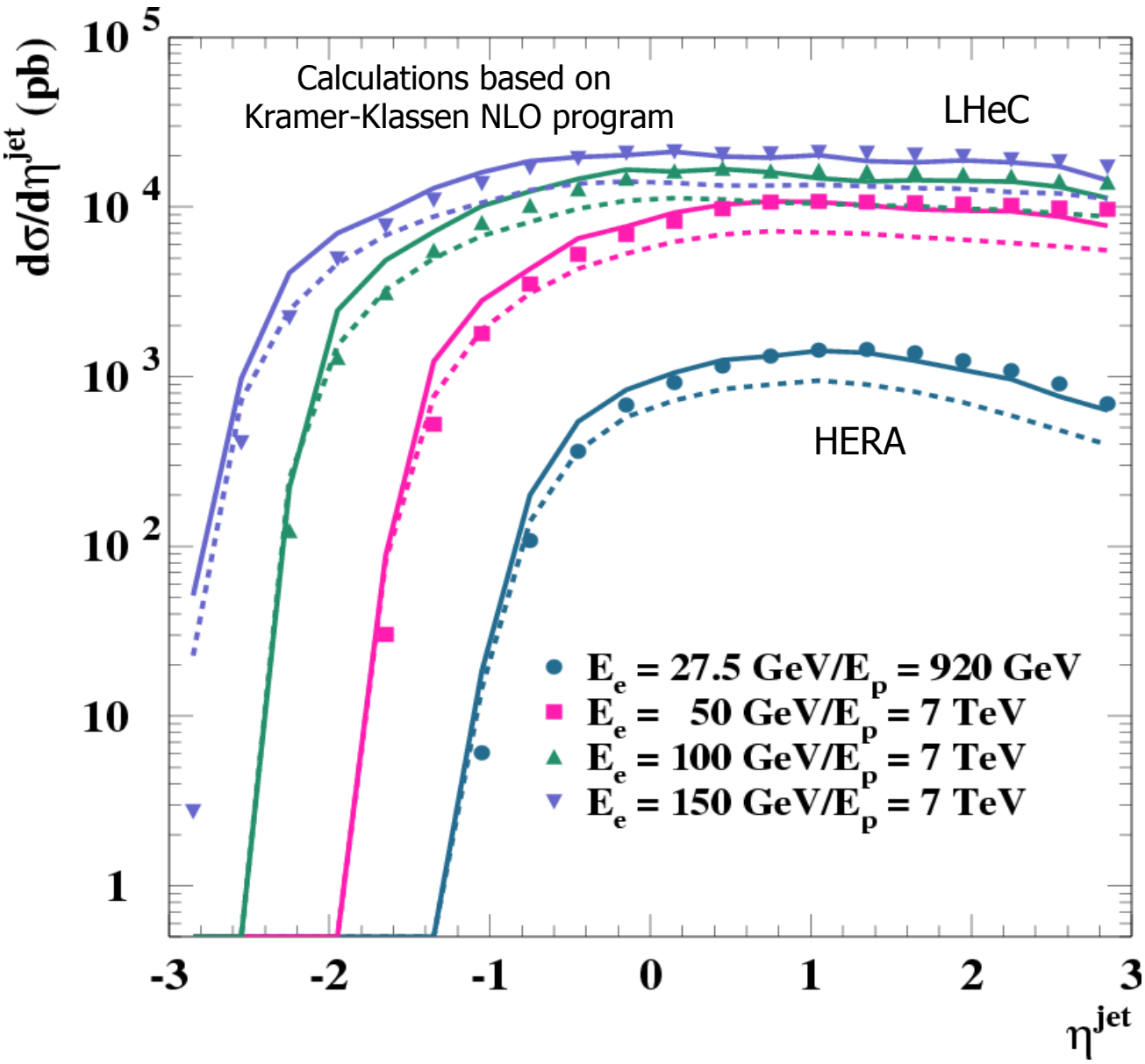
C. Glasman, J. Terron



Similar phase space extension as in DIS +much larger xsecs (compared to HERA)

High p_T Jets in photoproduction (Q^2~0 GeV^2)

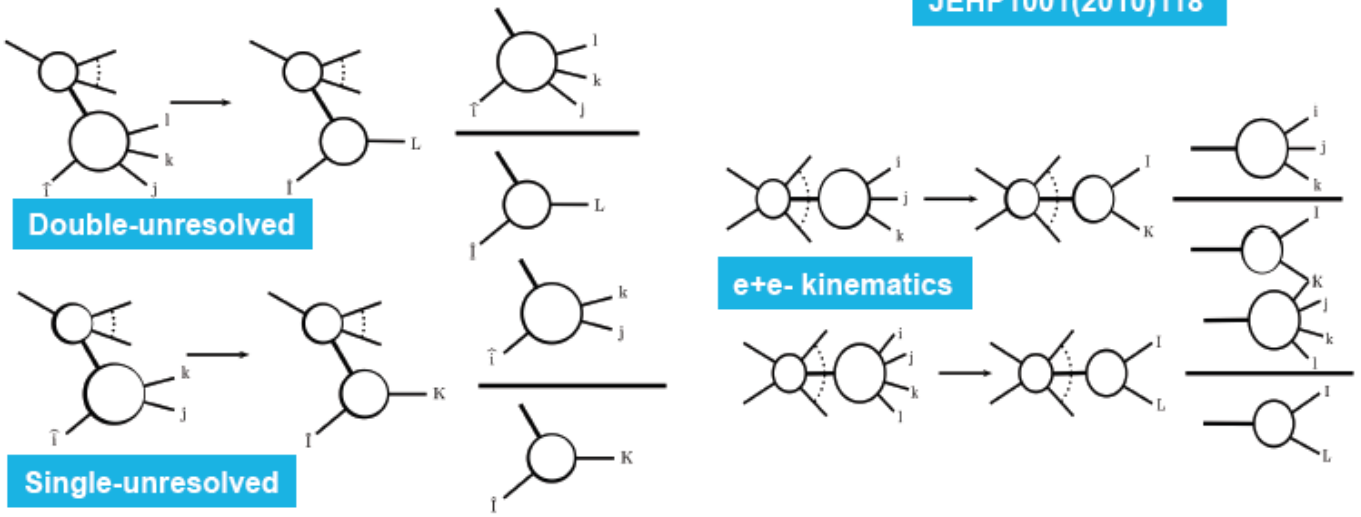
C. Glasman, J. Terron



Cross sections are large in central rapidities

NNLO THEORY (T. Gehrmann et al.) $O(\alpha_s^3)$

- NNLO calculations are ongoing. Matrix elements are either
  - already derived (NLO corrections to 3-jet production in DIS, Z. Nagy, NLOJET++) or
  - Contained in work by Gehrmann/Glover (for the two-loop 2-parton final state). PLB676(2009)146
- Required: subtraction method!
  - Gehrmann et al.: antenna subtraction method (for DIS). JHEP0704*2007)016 JEHP1001(2010)118



- Currently implementing method into program for DIS jet production.

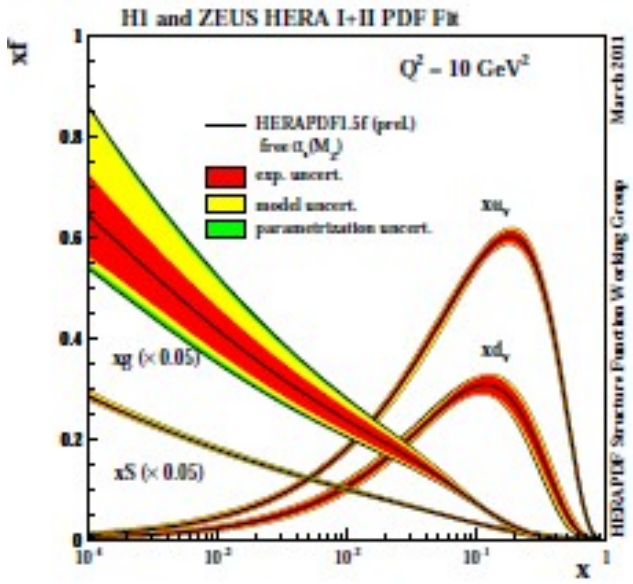
DESY

Will reduce significantly theory (higher order) uncertainty for α_s extraction from jet data

Adding jet data to PDF fits

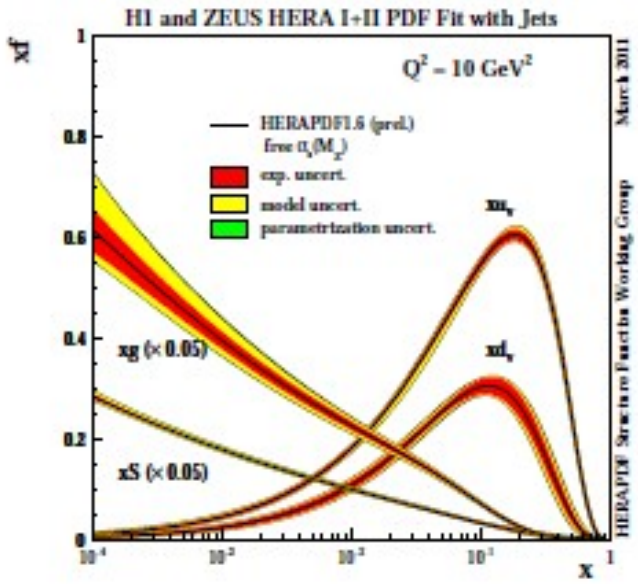
New HERA results, see talk by K. Nowak

PDFs from HERA inclusive ep data



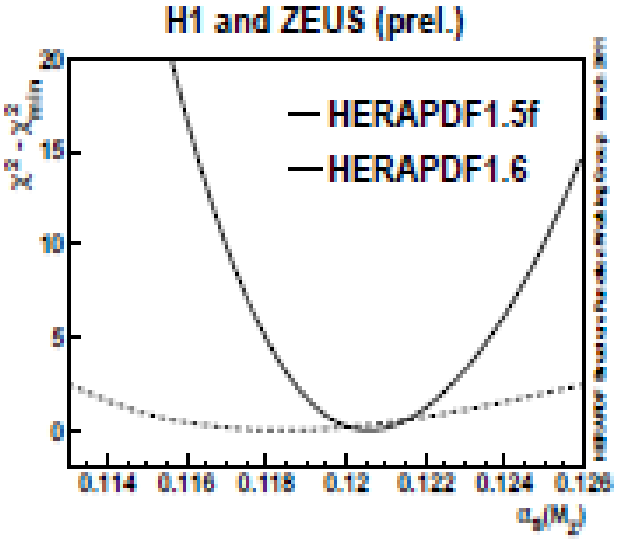
Free α_S, no jets

Adding HERA Jet data



Free α_S, + jets

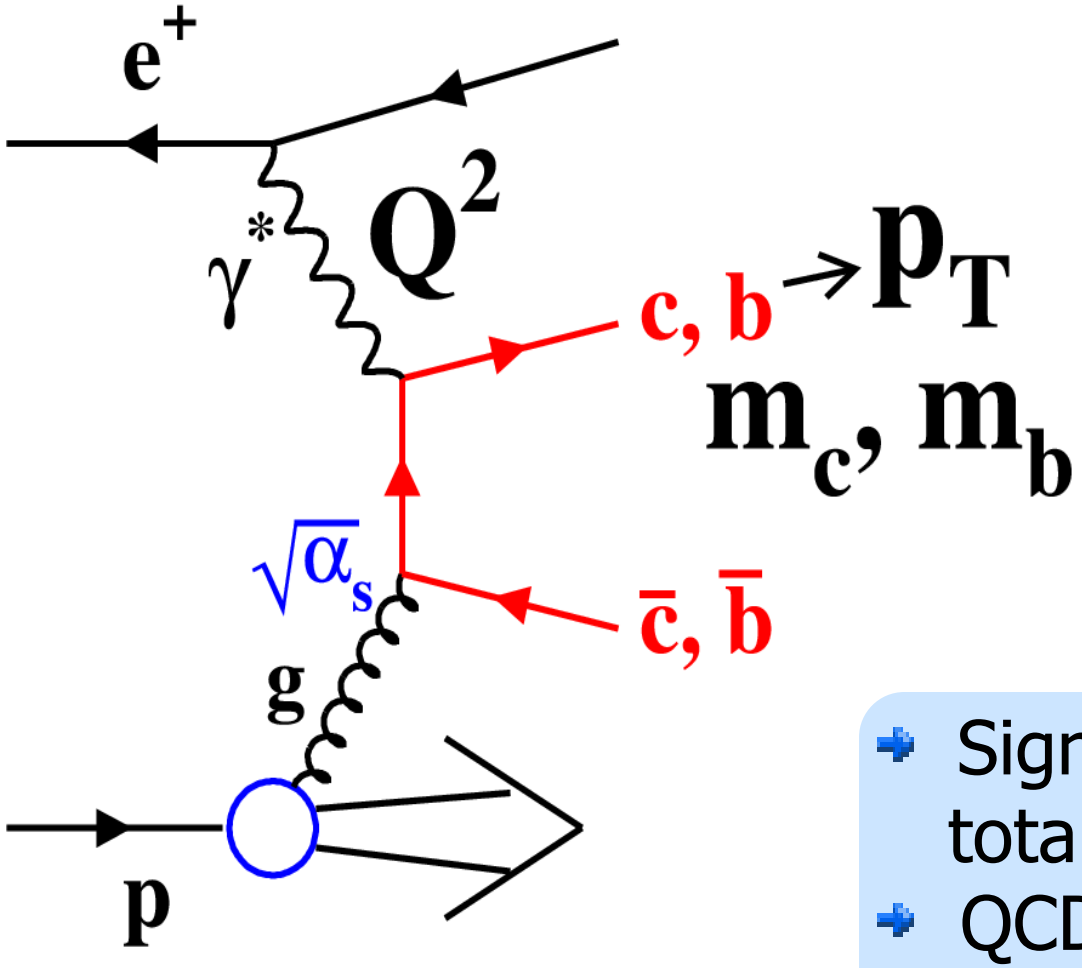
α_s fit



allows to disentangle gluon density and α_s

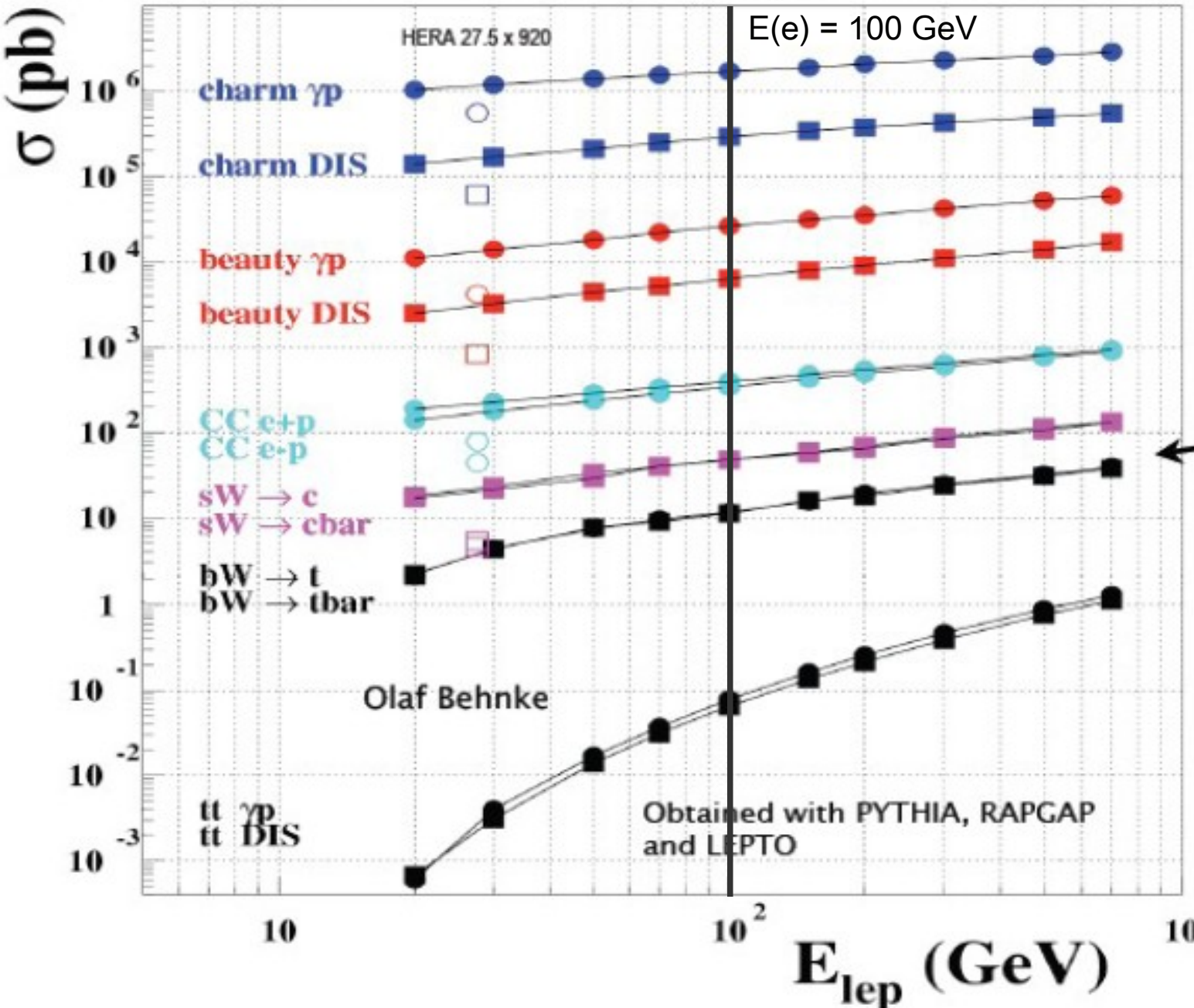
No projections available yet for LHeC

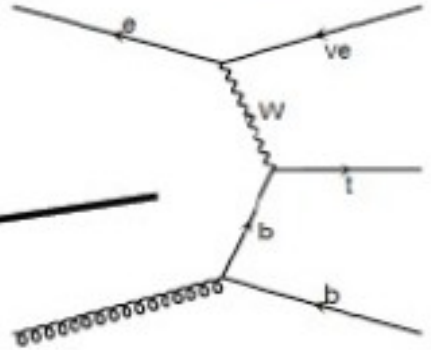
Heavy flavour production



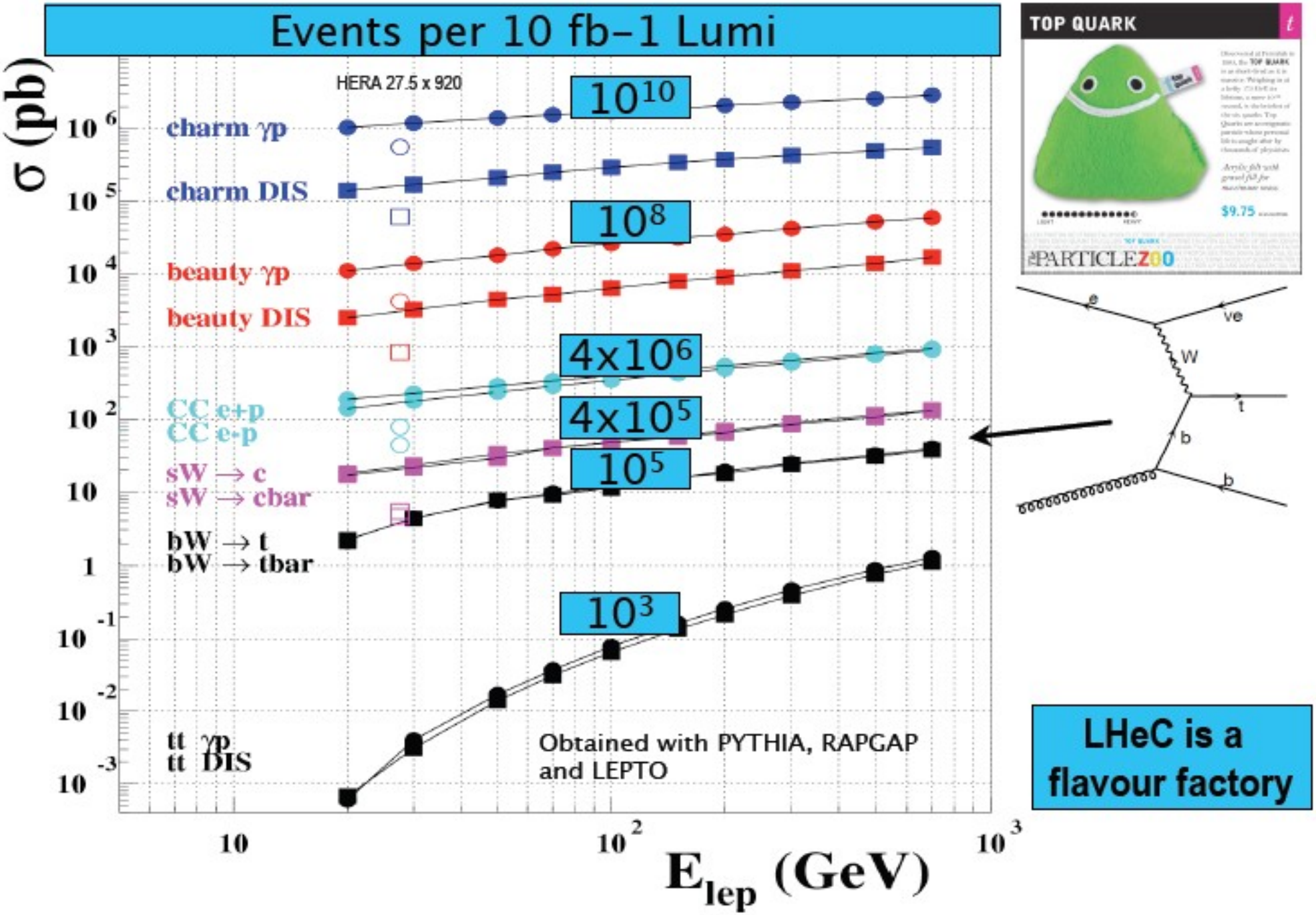
- Significant contributions to total ep cross sections
- QCD multiscale problem
- Sensitive to gluon density

LHeC total cross sections (MC simulated)





LHeC is a flavour factory


Events per 10 fb−1 Lumi
HERA 27.5 x 920
σ (pb)
charm γp
charm DIS
beauty γp
beauty DIS
CC e+p
CC e-p
sW → c
sW → cbar
bW → t
bW → tbar
tt γp
tt DIS
10^10
10^8
4x10^6
4x10^5
10^5
10^3
Obtained with PYTHIA, RAPGAP and LEPTO
E_lep (GeV)
TOP QUARK
PARTICLE ZOO
$9.75
e
ve
W
t
b
b
LHeC is a flavour factory

Heavy quark multiple scale problem:

Massive or Massless Heavy Quarks?

G.Kramer,
H.Spiesberger

$m \neq 0 \longrightarrow$

- correct threshold behavior
  no collinear divergences from $c \longrightarrow c + g$
  but terms $\propto \log(\mu/m)$ with $\mu = Q, p_T, \ldots$
- large corrections at large μ

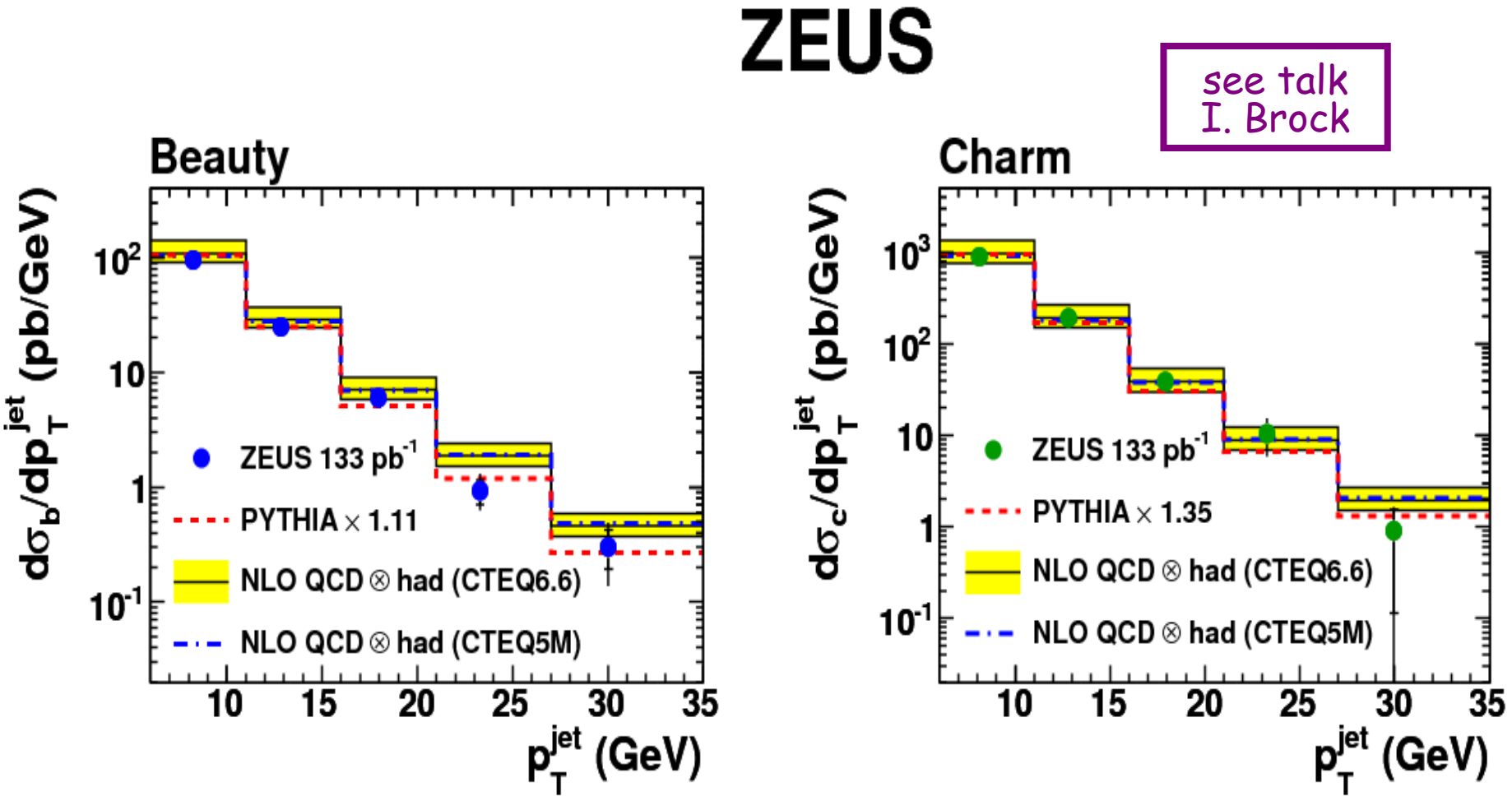
$m = 0 \longrightarrow$

- mass singularities ($1/\epsilon$-poles instead of $\log m^2$-terms)
  absorbed in PDFs and FFs
- QCD prediction: DGLAP (RG) evolution resums
  large logarithms $\log(\mu/m)$
- more reliable at large μ
- not reliable at heavy quark threshold

Goal: combine massive (low scale) and massless (high scale) calculations

- exploit freedom to choose an appropriate
  factorization scheme

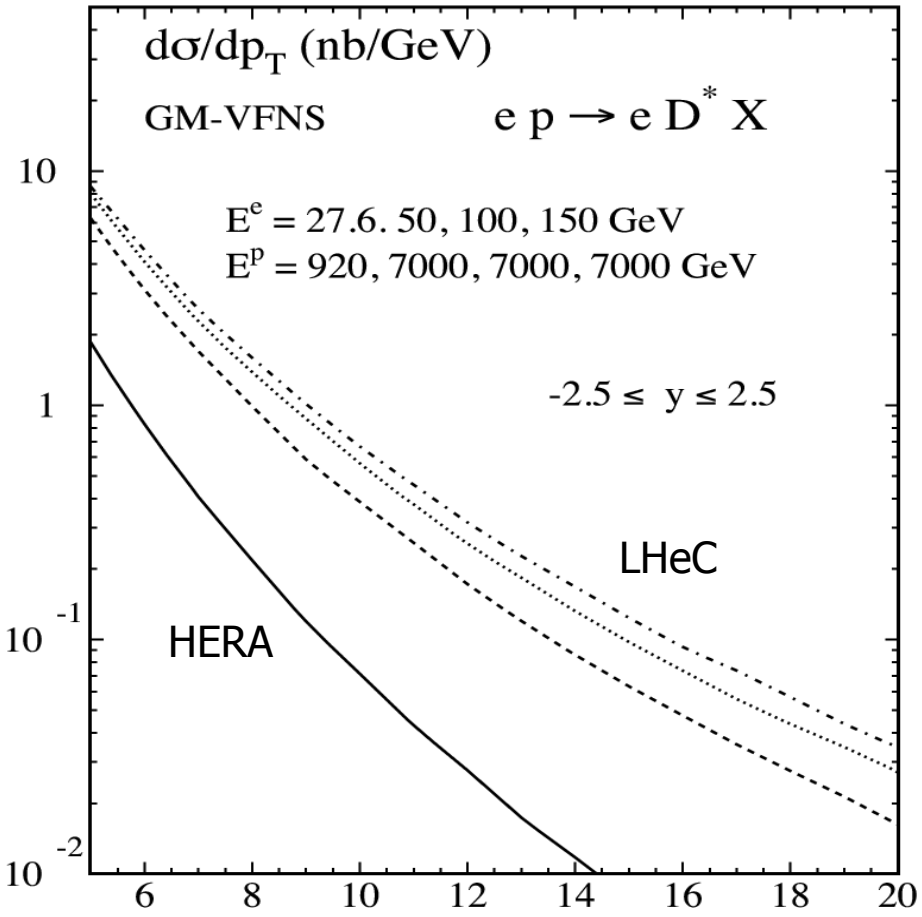
Charm and beauty photoproduction at HERA

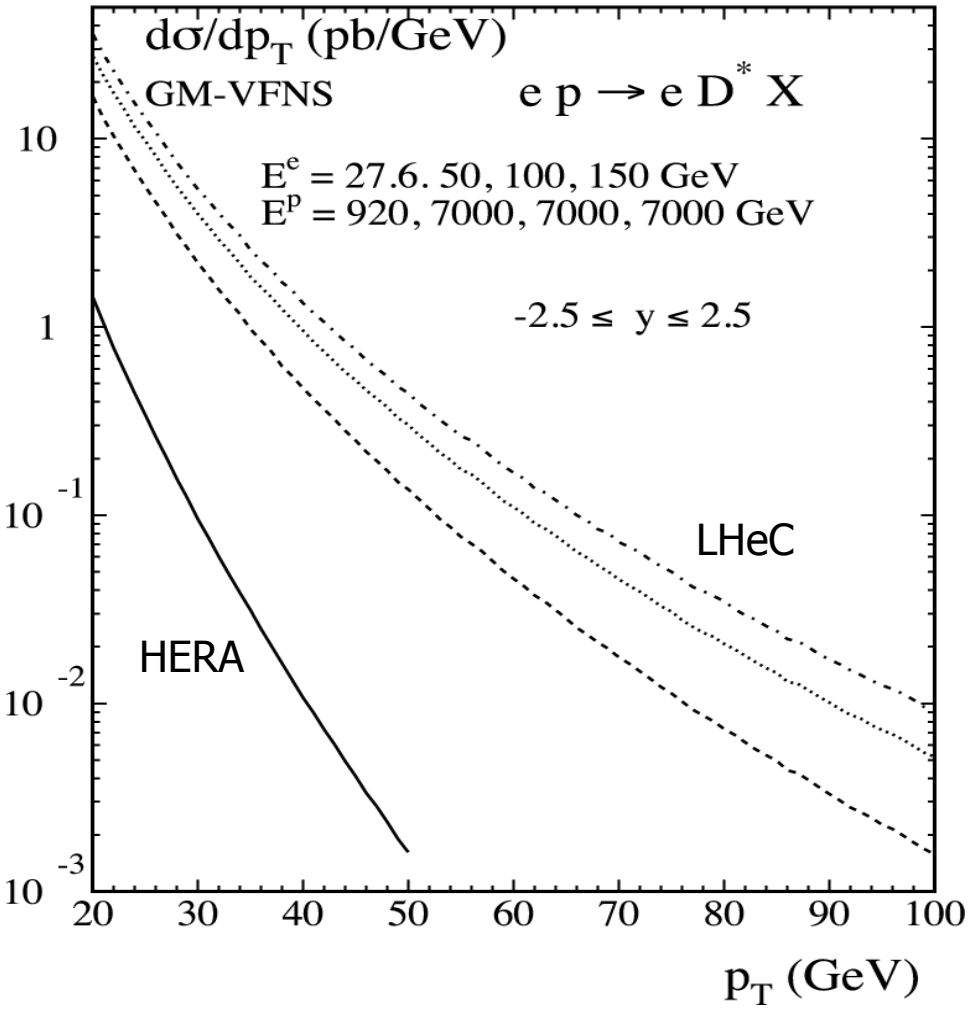


P_T reach up to ~35 GeV,
Well described by massive scheme NLO

D* photoproduction at LHeC

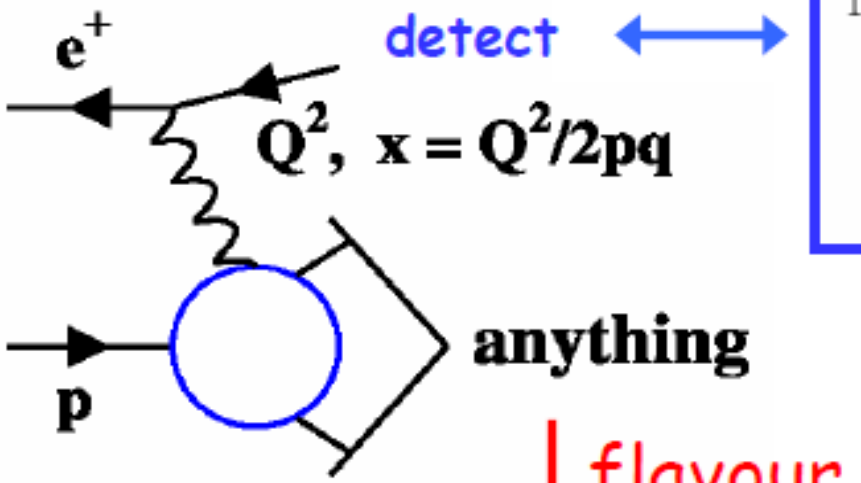
G.Kramer,
H.Spiesberger





LheC will allow to study transition
$p_T \sim m_c$ (massive regime) to $p_T >> m_c$ (massless regime)

Heavy flavour contributions to F_2

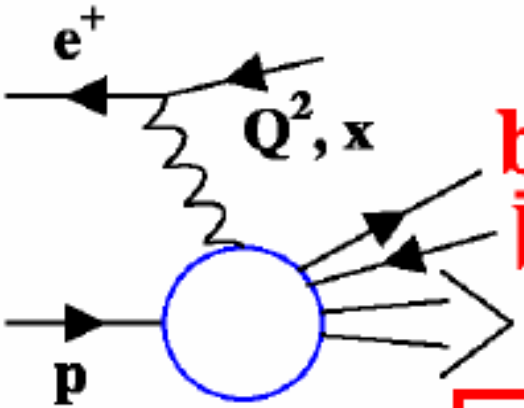


detect ⟷

Measure cross section

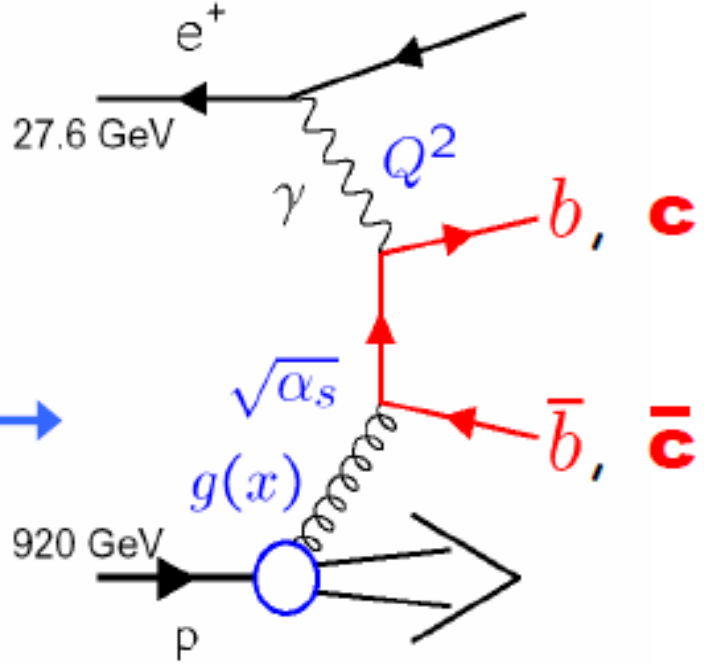
$$\frac{d^2\sigma}{dx\,dQ^2} \cong \frac{2\pi\alpha^2}{Q^4 x}\left\{\left[1+(1-y)^2\right]F_2(x,Q^2)\right.$$

flavour tagging



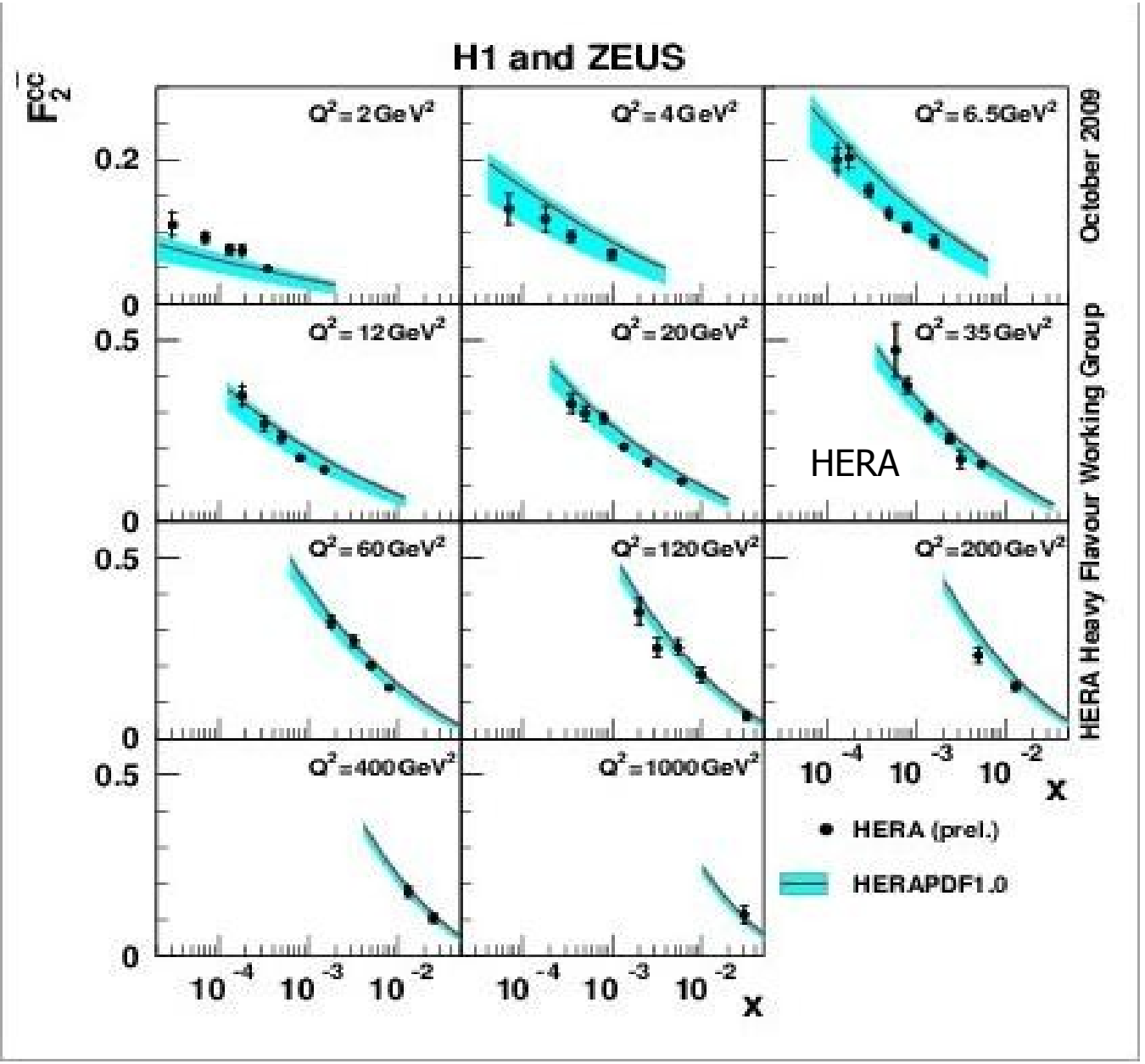
$\mathbf{b\bar{b}}$ or $\mathbf{c\bar{c}}$

QCD ⟷



-> $F_2^{b\bar{b}}$, $F_2^{c\bar{c}}$

F_2^{cc} at HERA

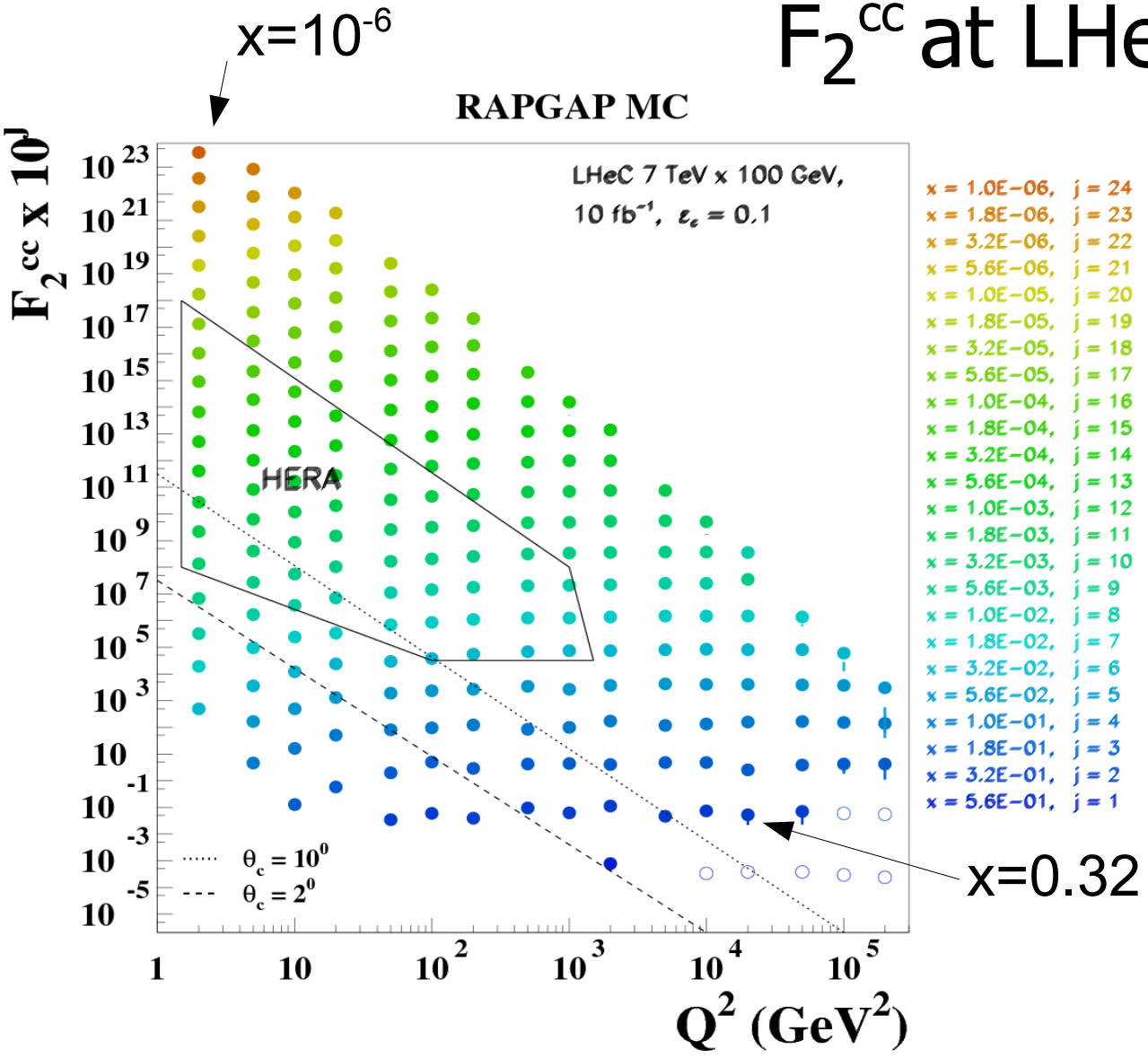


5-10% precision

sensitive to charm quark mass m_c

F_2^{cc} at LHeC

O. Behnke

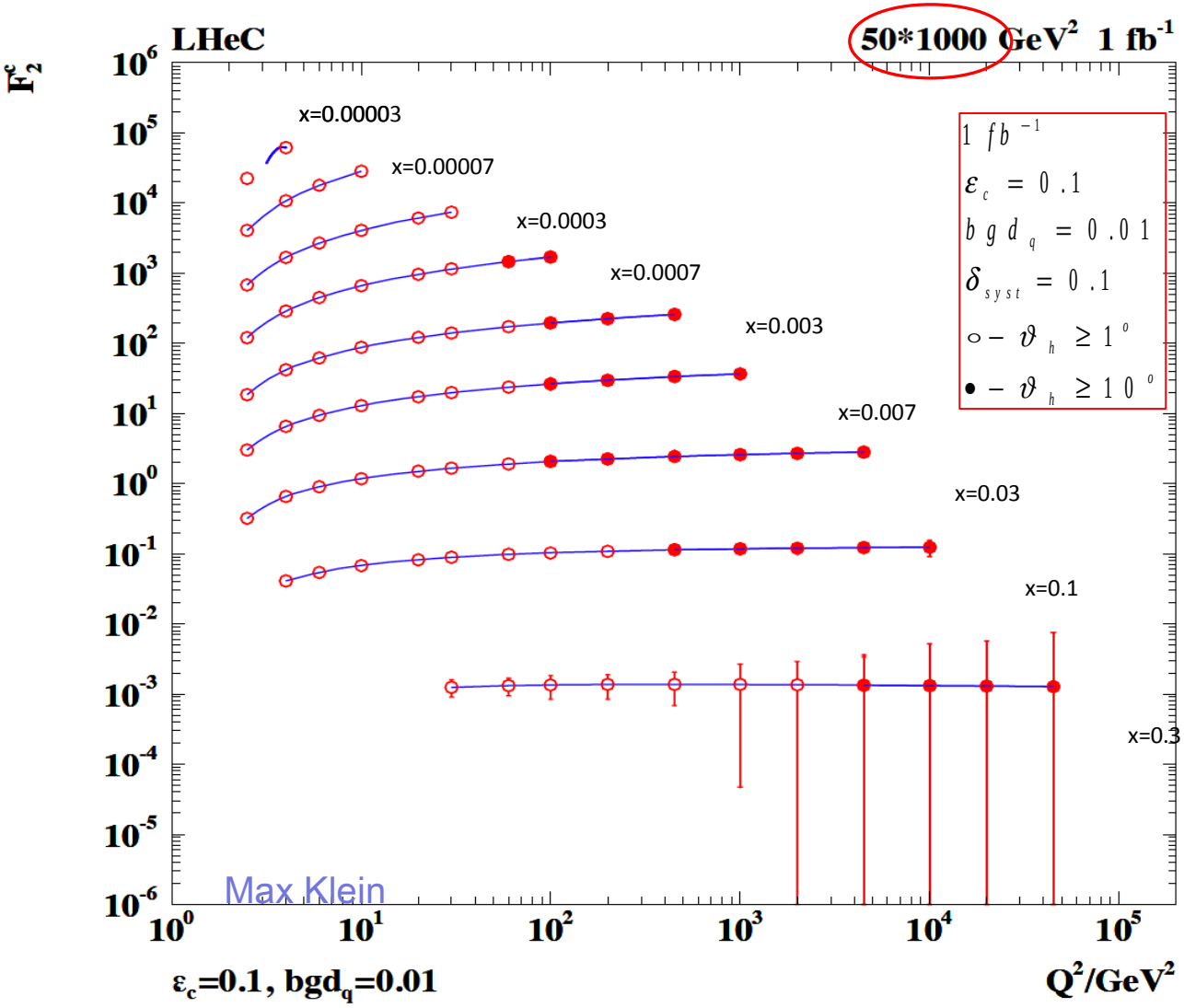


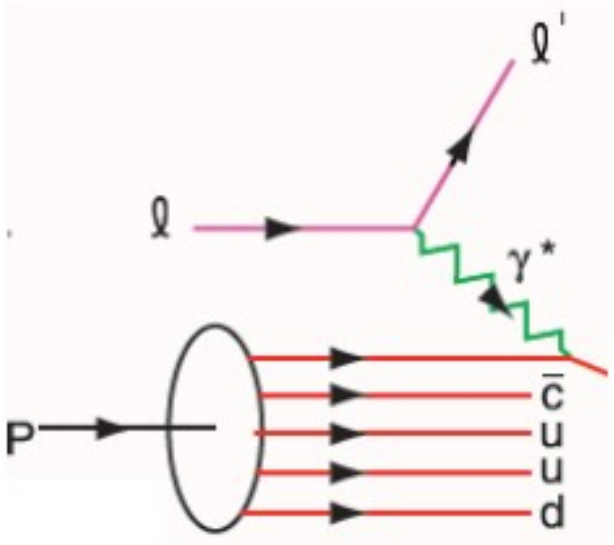
Wanted:

- **For PDF fits**
- **Determination of m_c**
- **Low x: gluon density and parton saturation**
- **High x: intrinsic charm**

LHeC: Much larger phasespace and much better precision compared to HERA

Charm in DIS: test intrinsic charm in proton

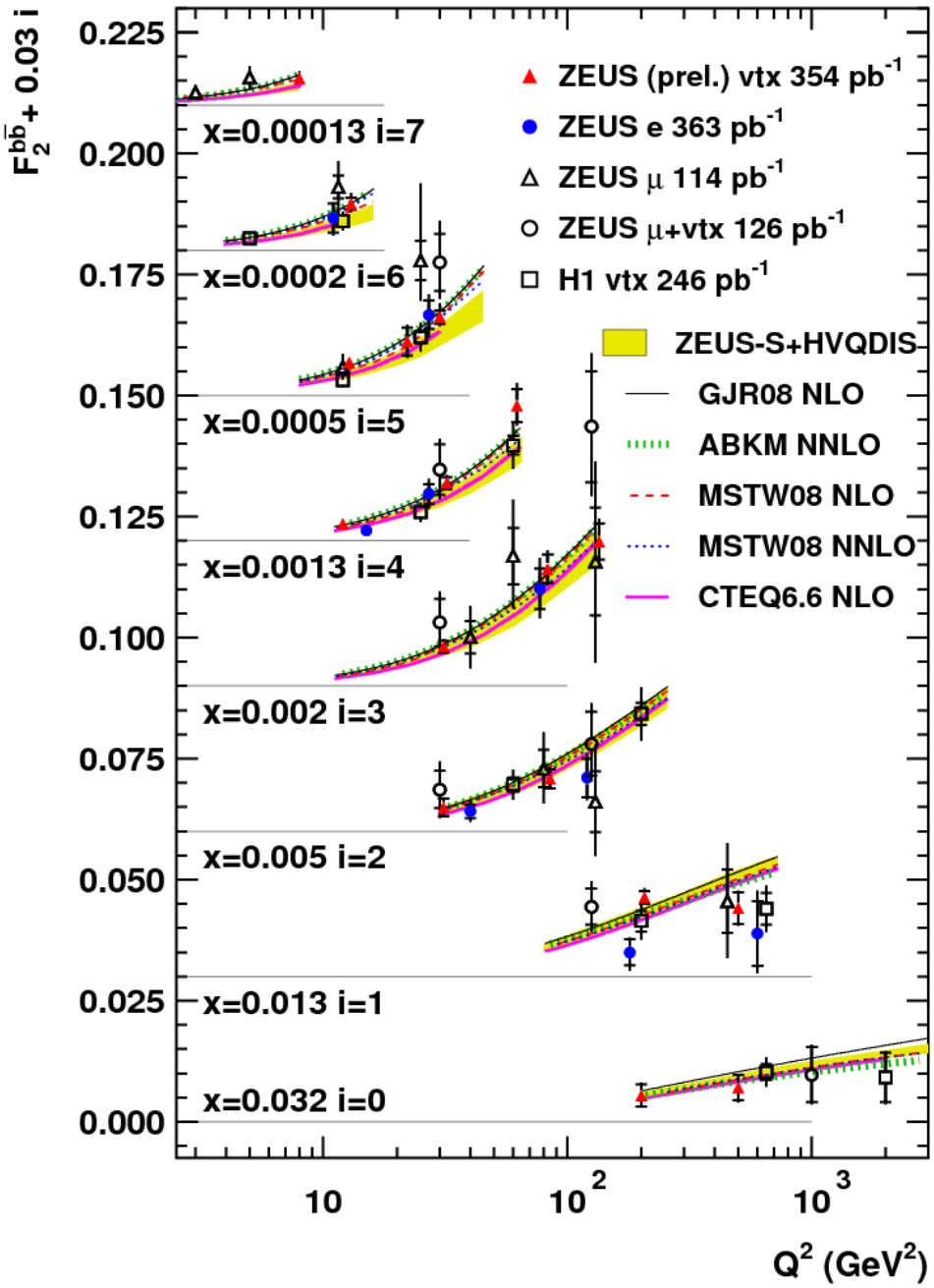




Expected to show up at ~ x_b >0.1

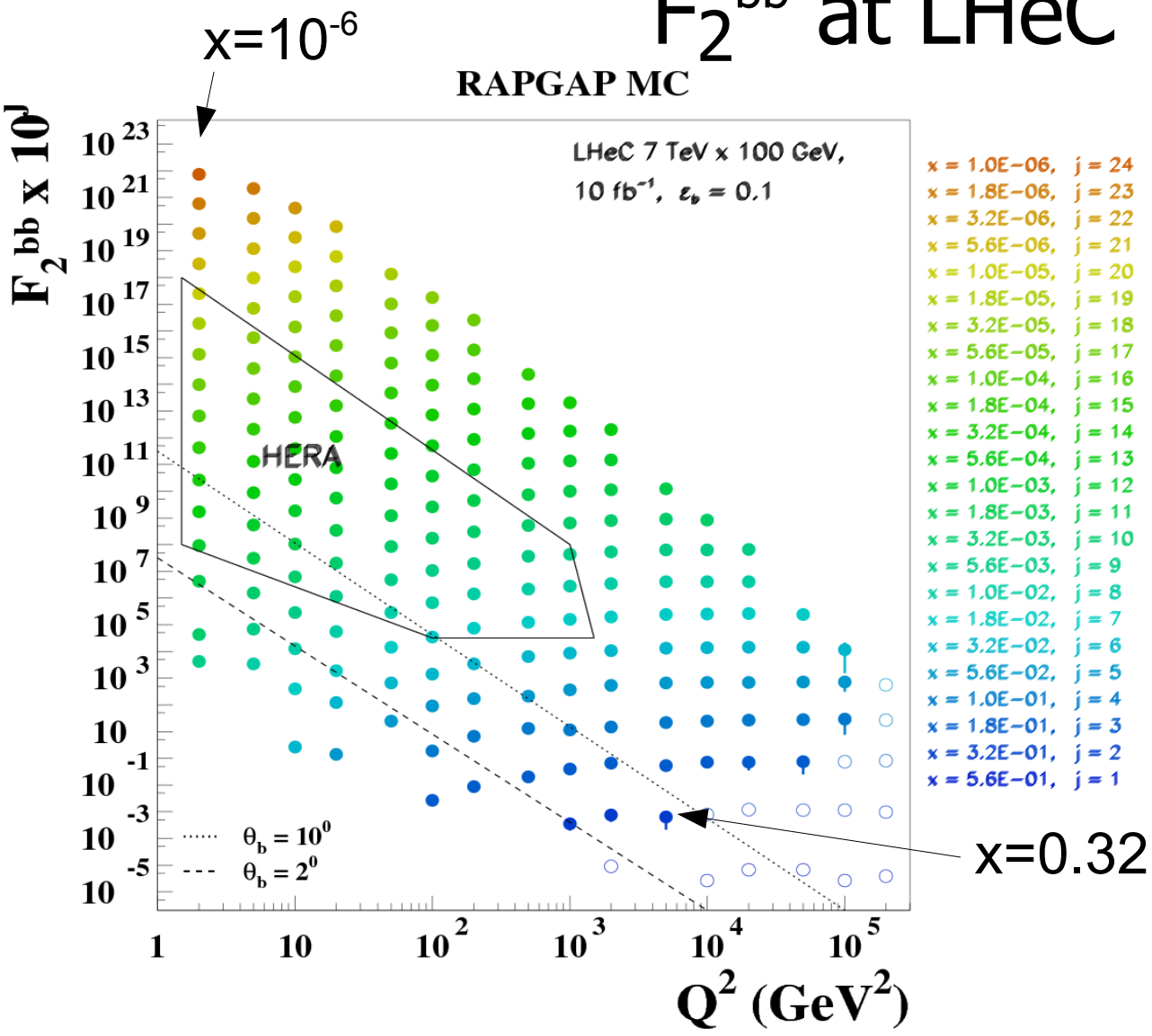
→ Requires c-tagging in very foward direction (θ~1 deg.)

F_2^{bb} at HERA

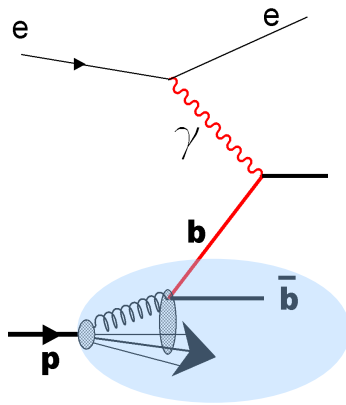


10-50% precision

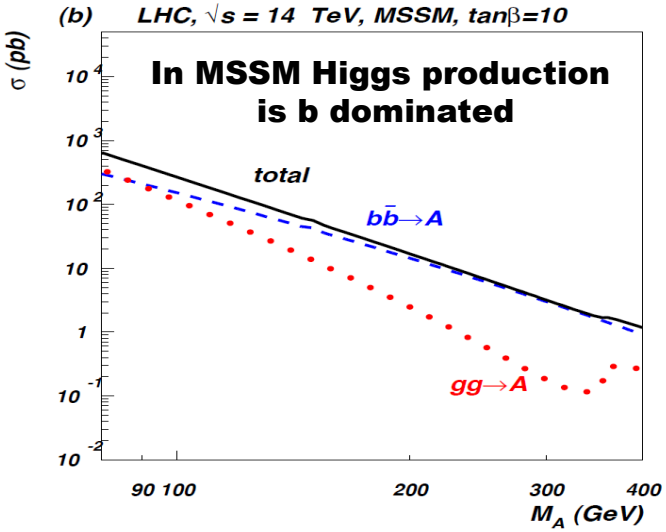
F_2^{bb} at LHeC



High Q^2: determine from F_2^{bb} effective b density in proton



Use for LHC predictions

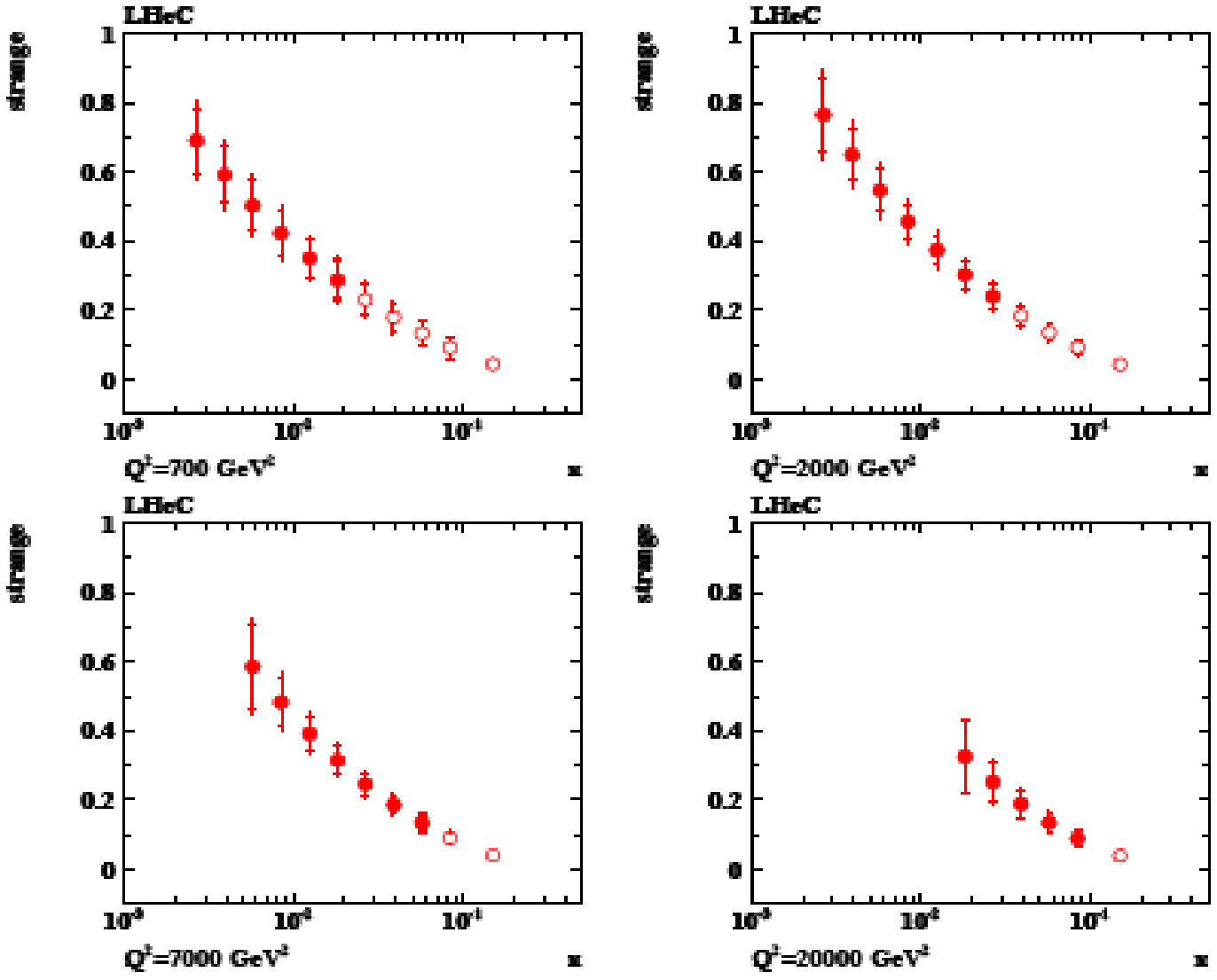


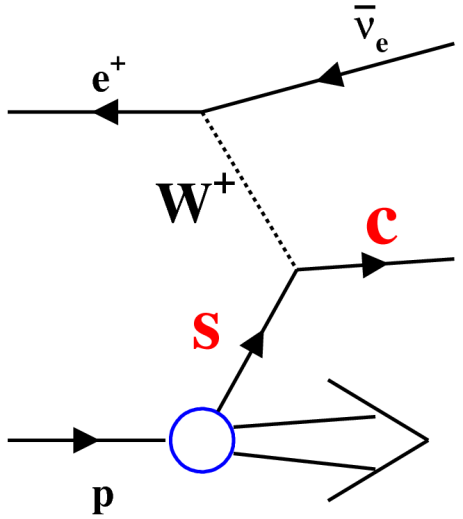
LHeC: Much larger phasespace and much better precision compared to HERA

Summary

- High pt jets and Heavy flavours at LHeC:
  → ideal tools for high precision QCD tests
- Jets:
  - Running alphas up to few 100 GeVs
  - Proton and photon structure: gluon densities!
- Heavy flavours:
  - For the first time top in ep collisions, mostly single
  - Charm and beauty:
    - Understanding of mass treatment in pQCD (massive vs massless)
    - Multi interests: PDF fits, proton gluon density, saturation at low x, intrinsic charm, b density

Strange =? Anti-strange quark density





$W^+ s \rightarrow c$

$1\,fb^{-1}$

$\varepsilon_c = 0.1$

$\varepsilon_q = 0.01$

$\delta_{syst} = 0.1$

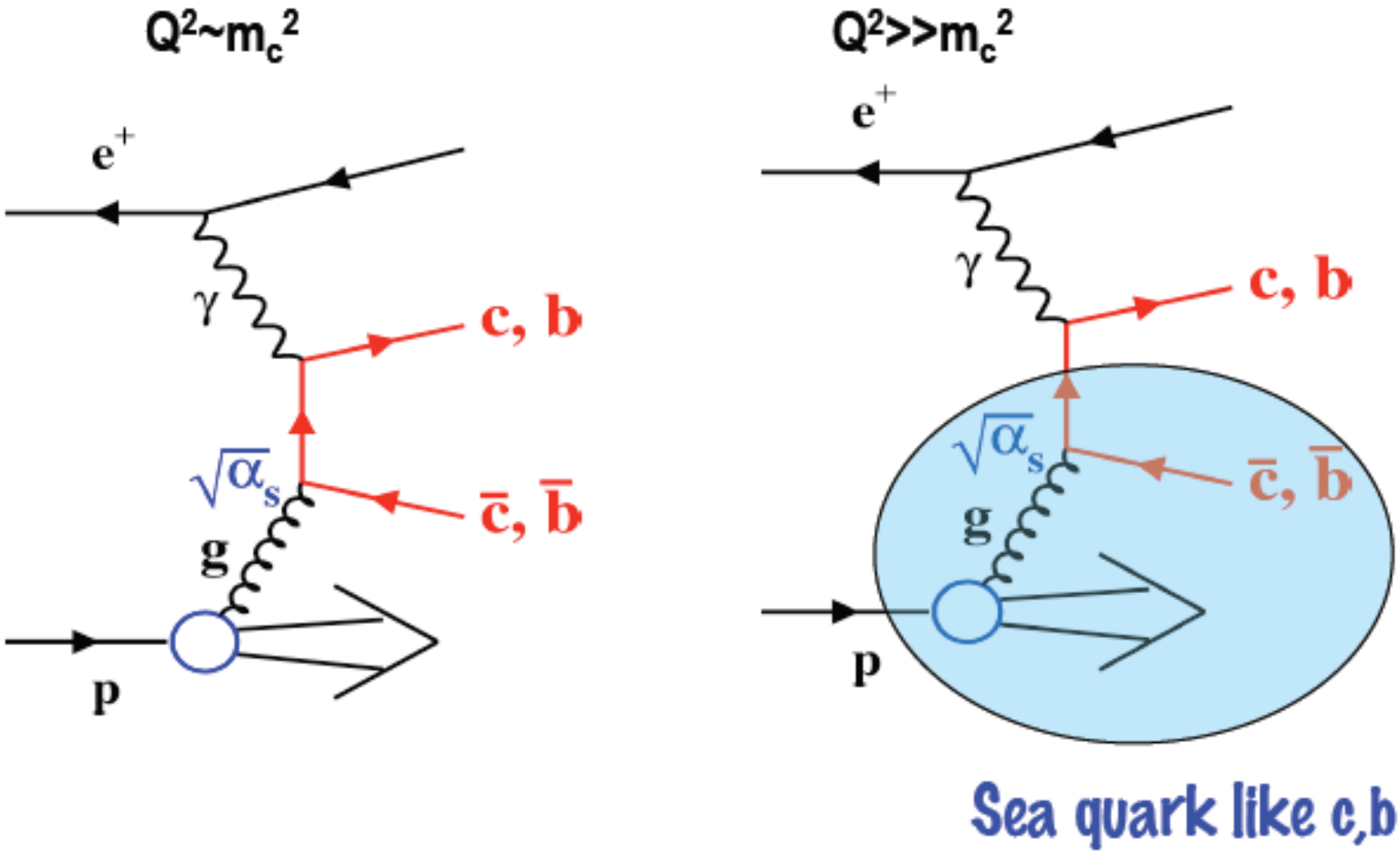
$\circ - \vartheta_h \geq 1^o$

$\bullet - \vartheta_h \geq 10^o$

→ Use e- p data for sbar

Some dimuon and K data, but never properly measured

Subtle topic: correct treatment of heavy flavour masses in pQCD



Sea quark like c,b

How to make properly the transition from left to right picture is a longstanding problem