Precision QCD and electroweak physics at the LheC

Dis 2010, 20 Apr 2010, Florence

Olaf Behnke, DESY

Need for LHeC

27.5 GeV x 920 GeV ep HERA

with integrated L~0.5 fb^{-1} was a

- high precision machine for QCD
- modest precision machine for electroweak physics

Where could we go with a

20-150 GeV x 7 TeV ep LHeC

with integrated L~1-10 fb^{-1} ?

Precision QCD & electroweak physics at LHeC

Selected highlights presented in this talk :

Inclusive DIS: Complete flavour decomposition of proton: u,d,s,c,b (+antiquarks), valence & sea, gluon, precision α_s

Electroweak tests in t channel:
Light quark couplings to Z0: a_u, v_u, a_d, v_d

Single top production (Test of SM)

Charm and Beauty: mass treatment in pQCD

Jet production: Precision QCD tests in clean environment at high(est) p_t

For many more interesting results see talks at http://www.ep.ph.bham.ac.uk/exp/LHeC//talks.html

1. Physics using inclusive ep measurements at LHeC

Simulated Default Scenarios, April 2009

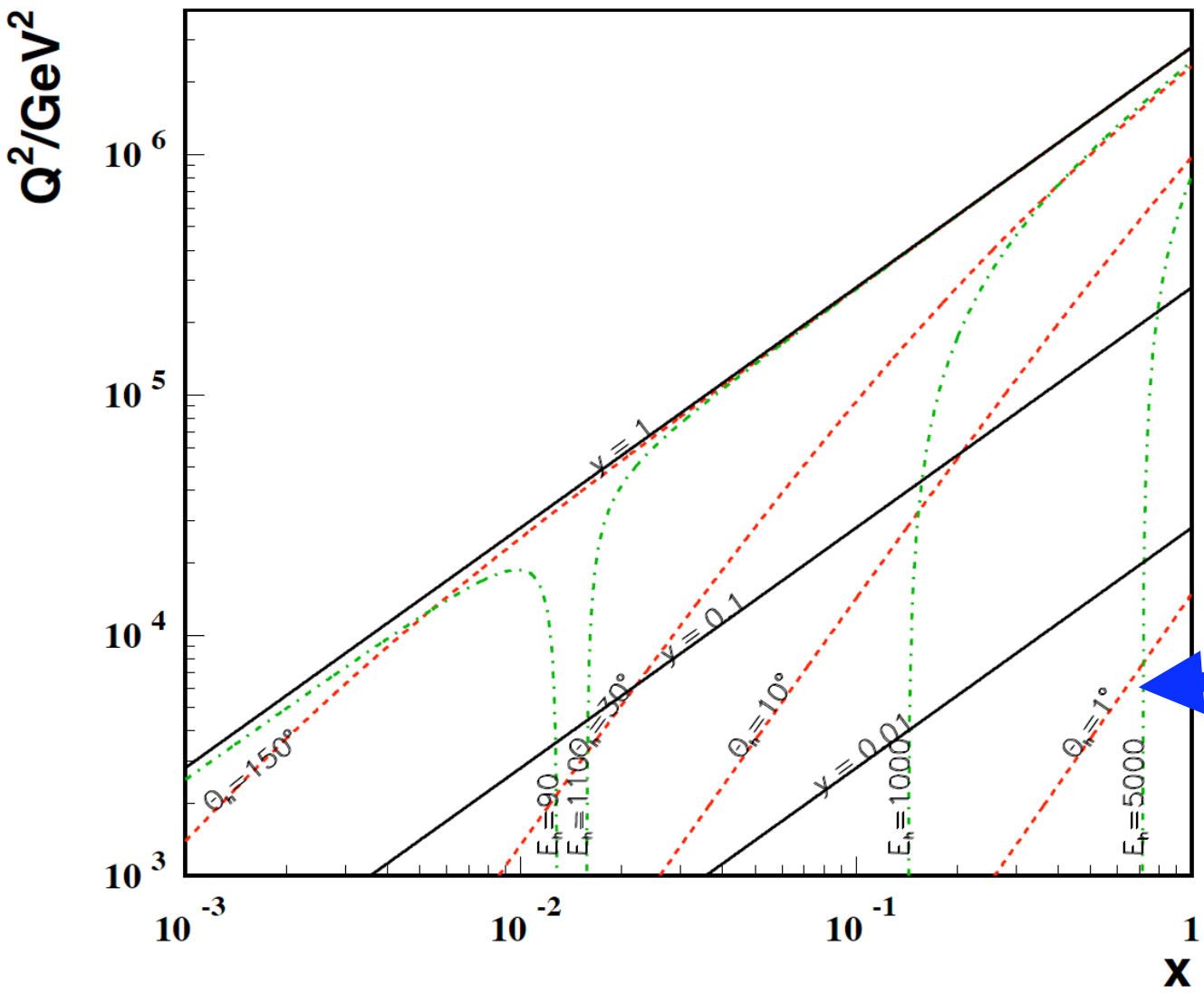
Max Klein

http://hep.ph.liv.ac.uk/~mklein/simdis09/lhecsim.Dmp.CC, readfirst

config.	E(e)	E(N)	N	$\int L(e^+)$	$\int L(e^-)$	|Pol|	$L/10^{32}$	P/MW	years	type
A	20	7	p	1	1	-	1	10	1	SPL
B	50	7	p	50	50	0.4	25	30	2	RR hiQ^2
C	50	7	p	1	1	0.4	1	30	1	RR lo x
D	100	7	p	5	10	0.9	2.5	40	2	LR
E	150	7	p	3	6	0.9	1.8	40	2	LR
F	50	3.5	D	1	1	--	0.5	30	1	eD
G	50	2.7	Pb	0.1	0.1	0.4	0.1	30	1	ePb
H	50	1	p	--	1	--	25	30	1	lowEp

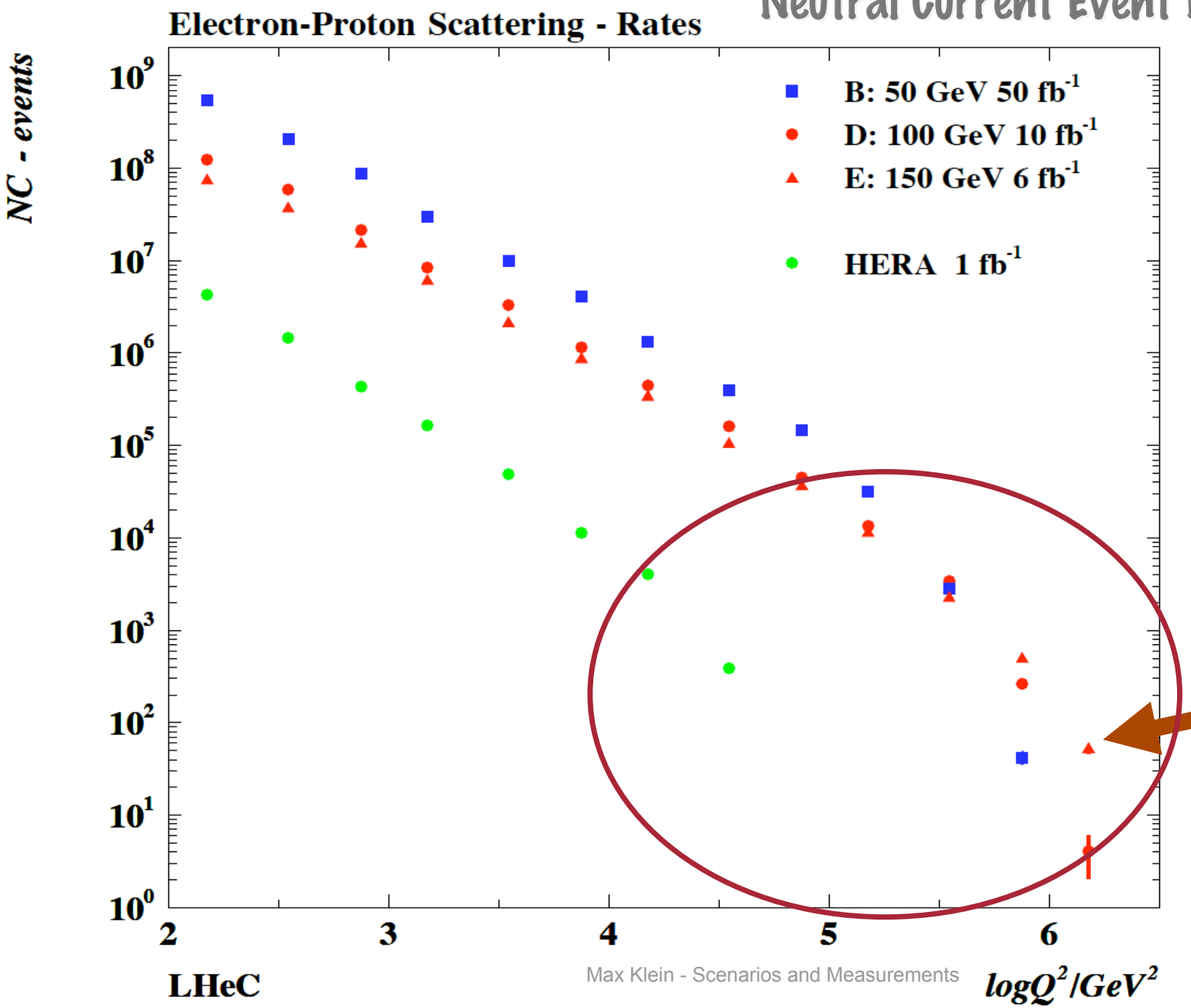
Not simulate

Kinematics – high Q^2



Need excellent forward hadron calorimetry & calibration

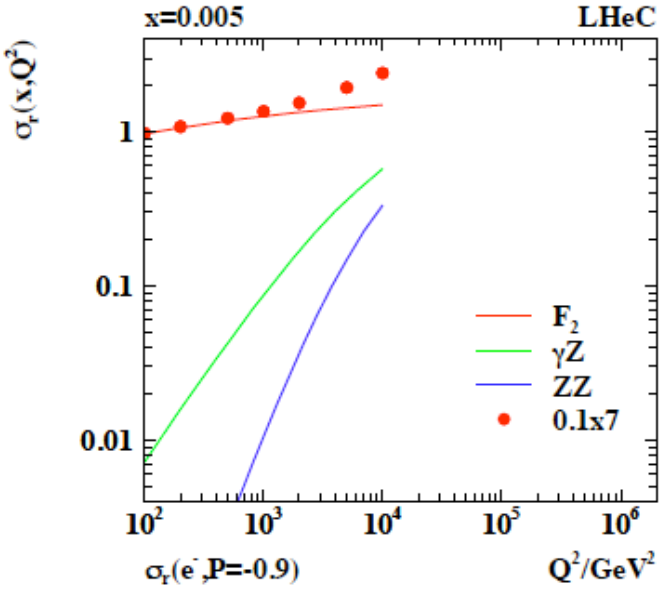
Neutral Current Event Rates

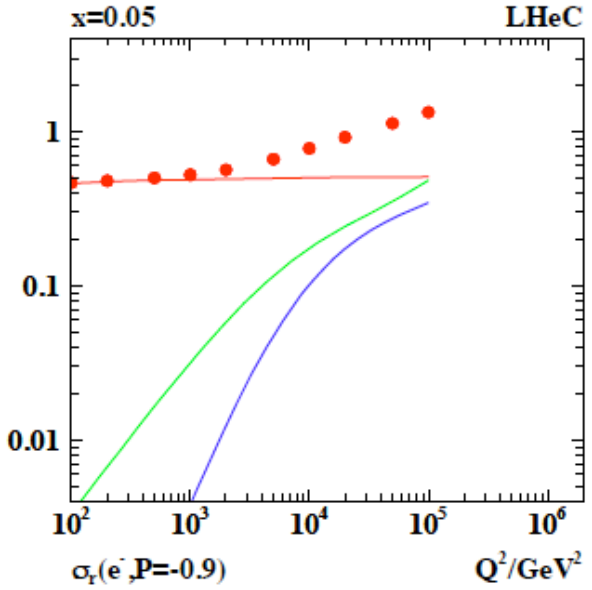


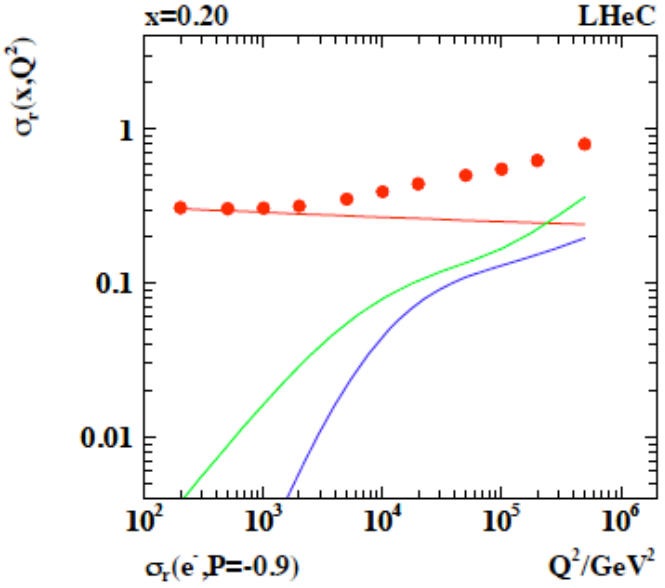
Trivial, but important: largest E_{lep} allows highest Q^2 scales

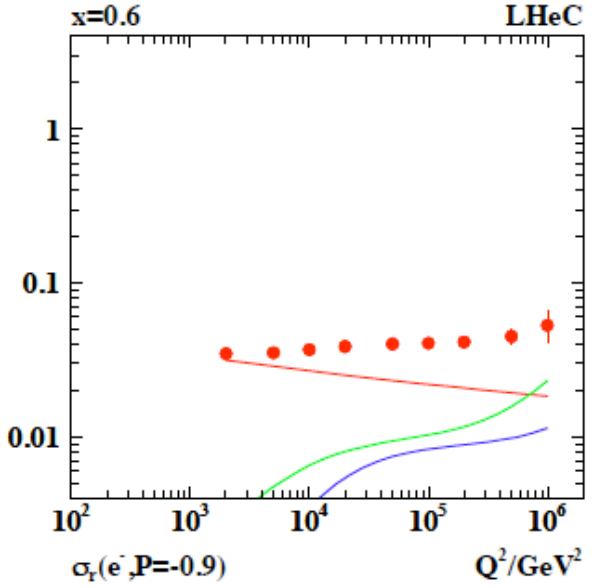
Electroweak NC Cross Section Measurements

Max Klein









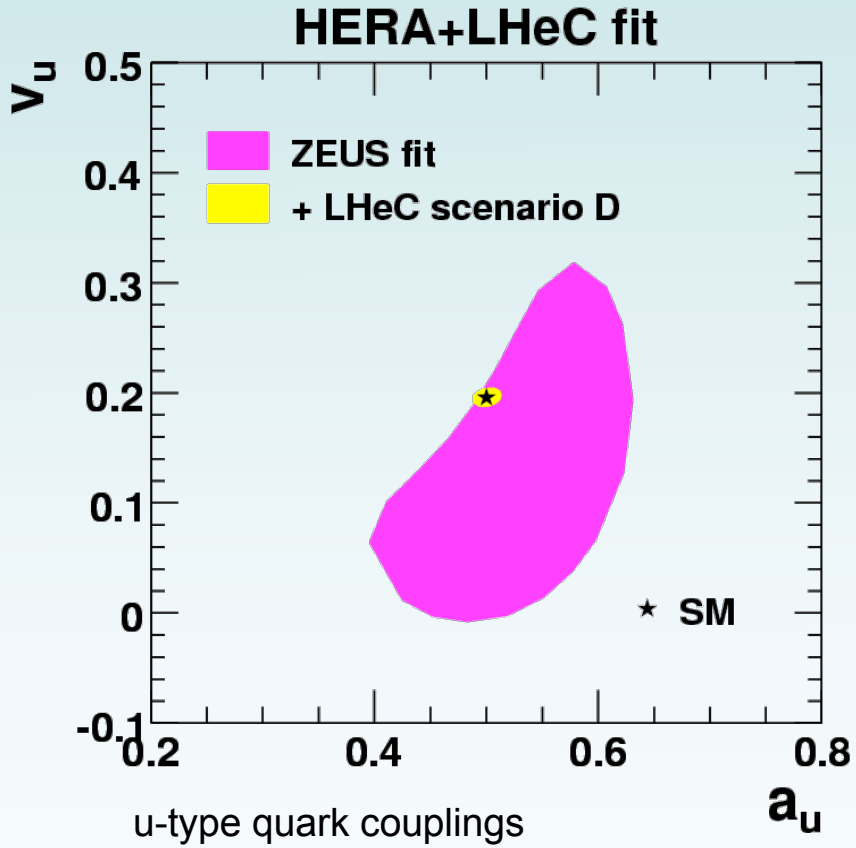
2 charges and
2 polarisations
very desirable
for electroweak
physics and the
new spectroscopy
should that appear.

Z effects depend
on charge and
polarisation.

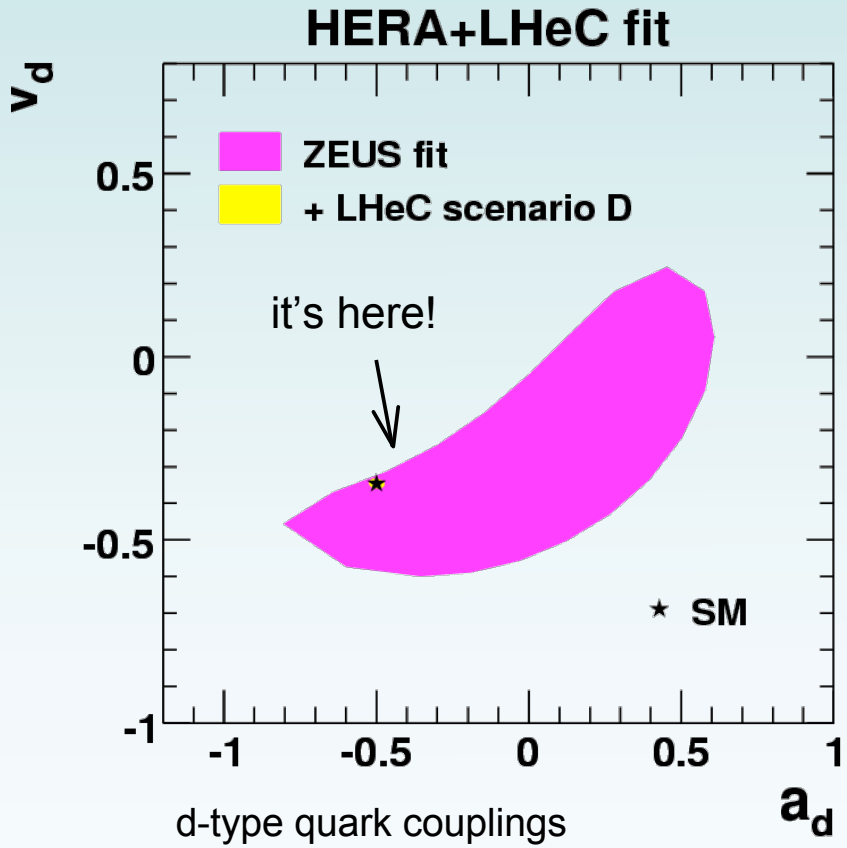
Electroweak physics: quark couplings to Z0

scenario D:
$P_e = \pm 0.9$

comparison with **ZEUS fit** (base to which LHeC pseudo-data added)



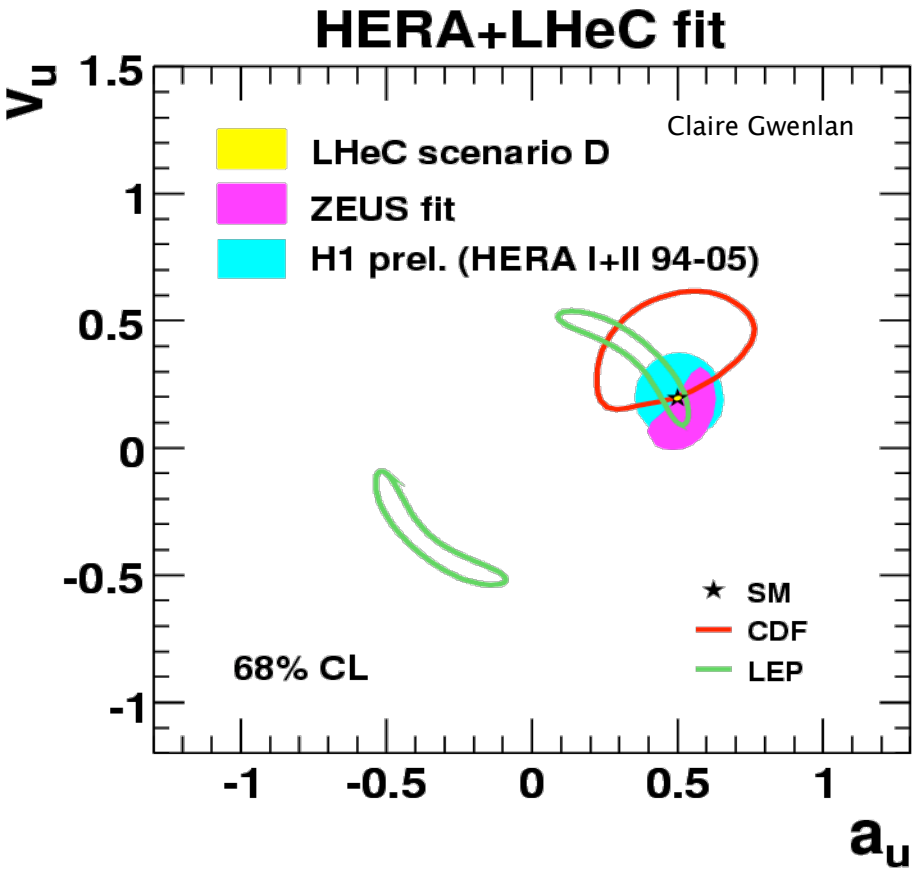
u-type quark couplings

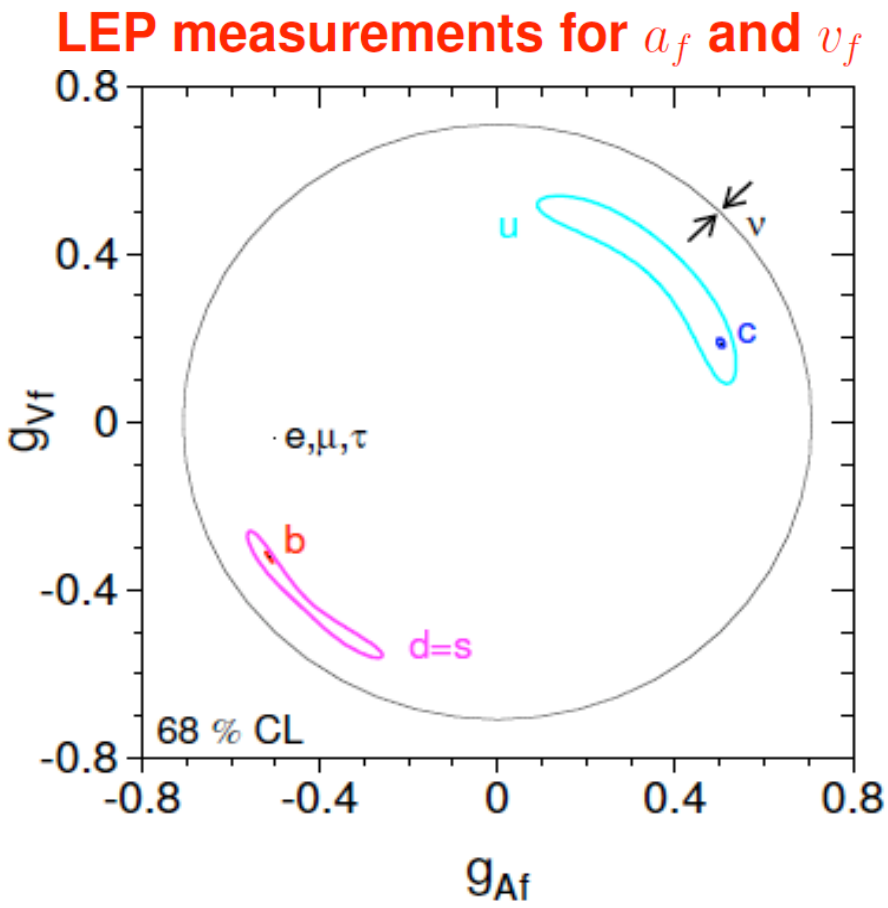


d-type quark couplings

Electroweak physics: quark couplings to Z0

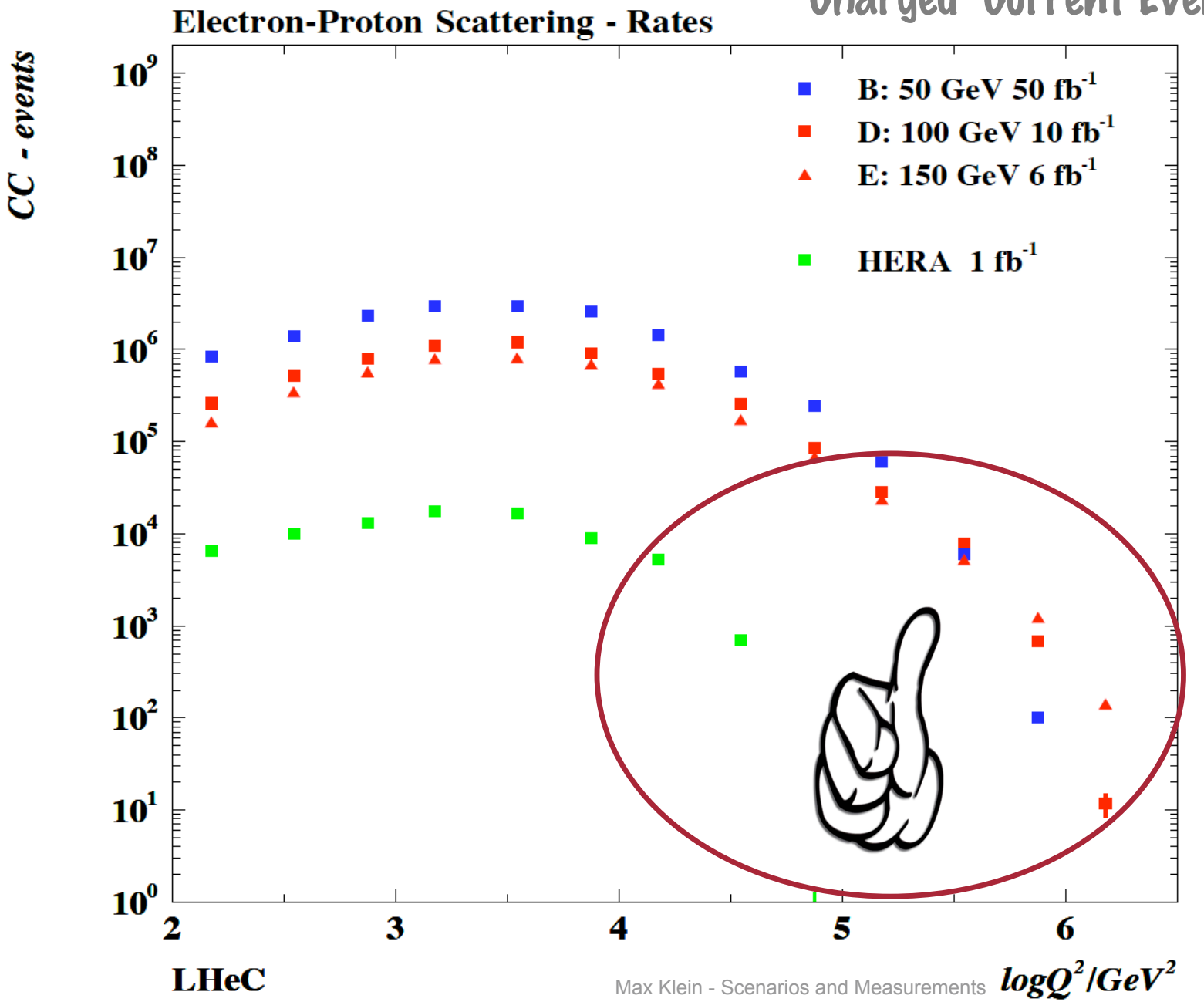
Soumitra Nandi,
Paolo Gambino





LHeC (and HERA) especially sensitive to u and d couplings: expect deviations from SM for these couplings e.g in Leptophobic Z' models

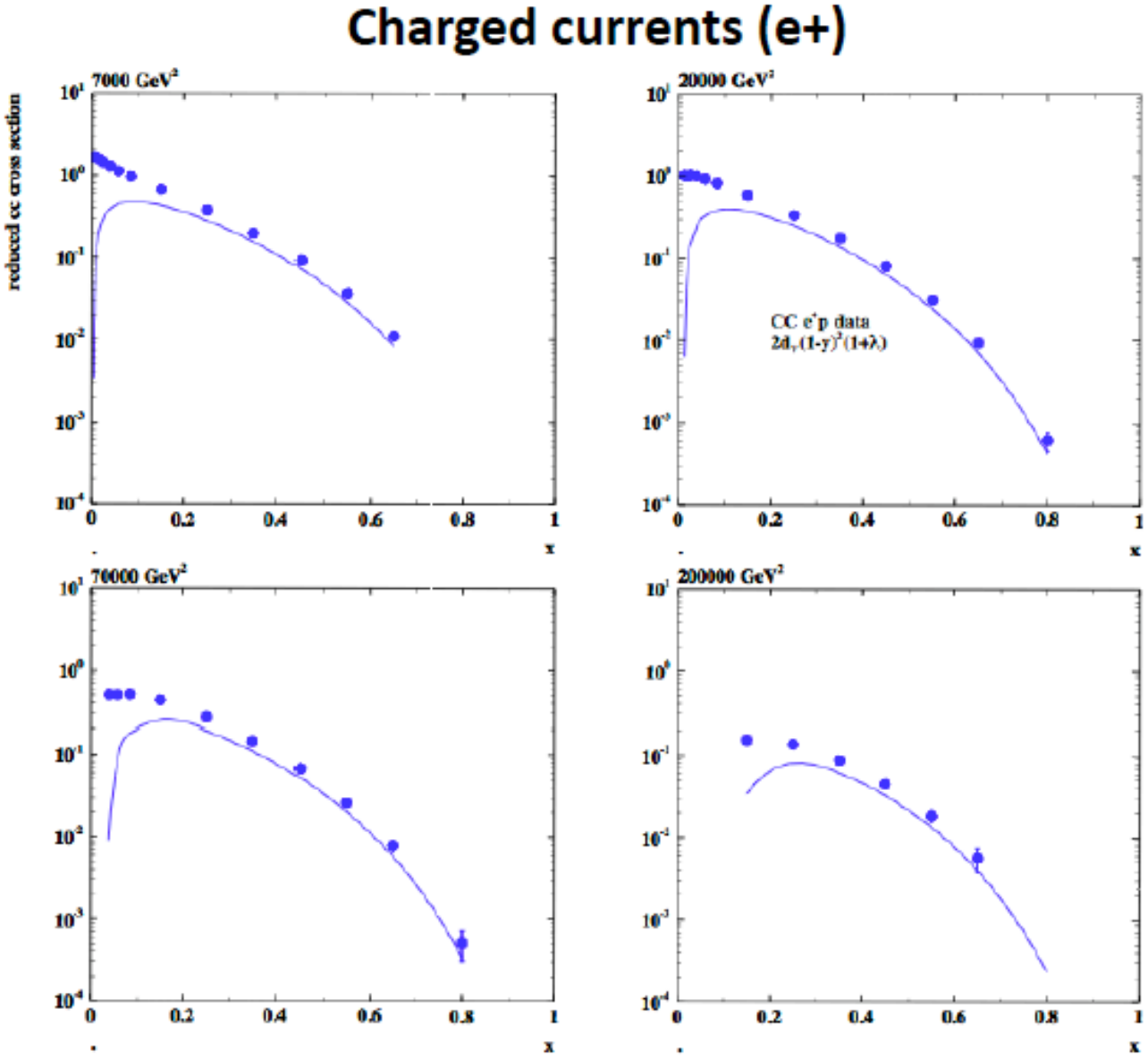
Charged Current Event Rates



LHeC: expect ~ two orders of magnitude **more events** + better coverage for x>0.5

Direct measurement of valence quarks

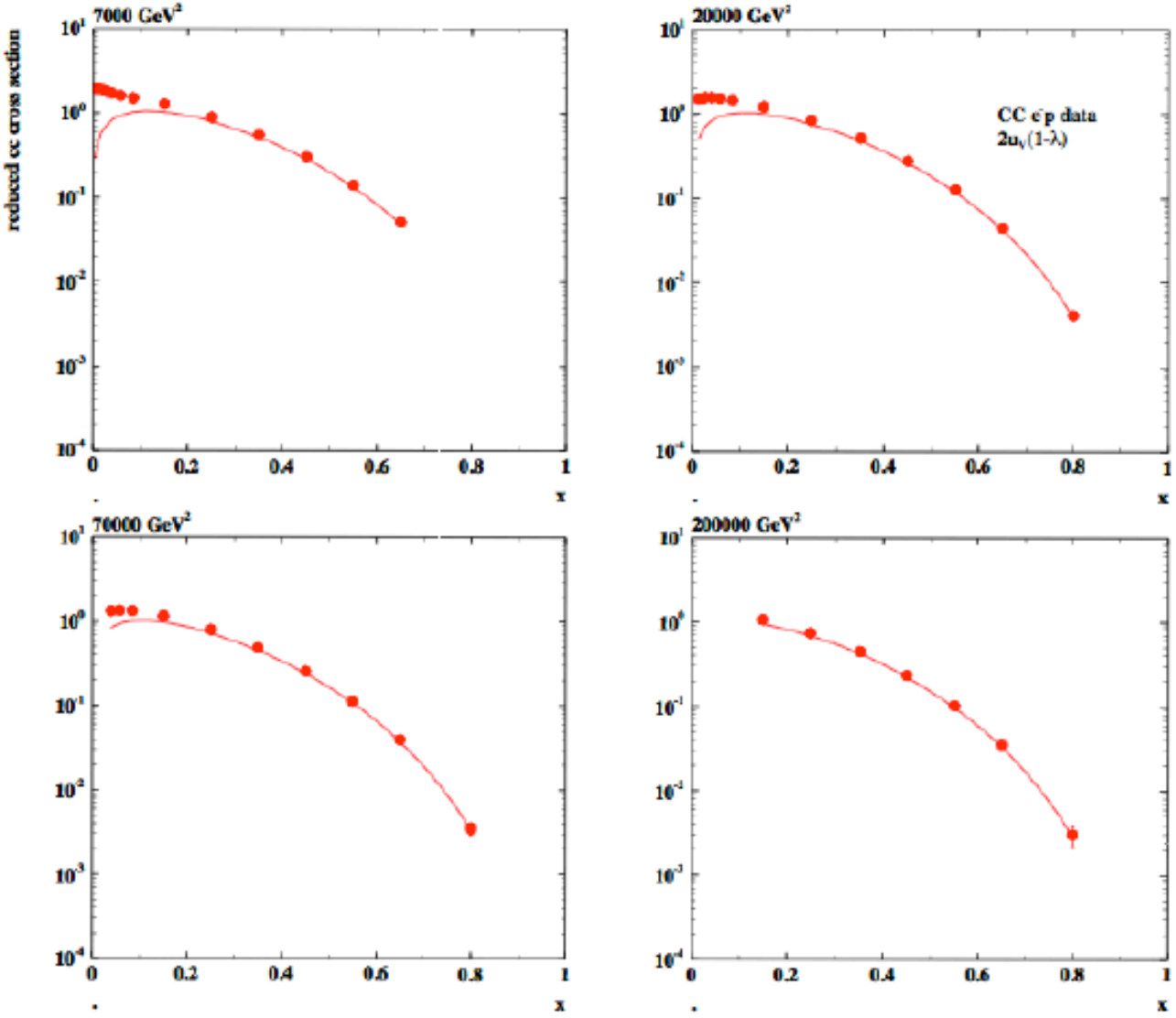
Max Klein



Direct measurement of valence quarks

Max Klein

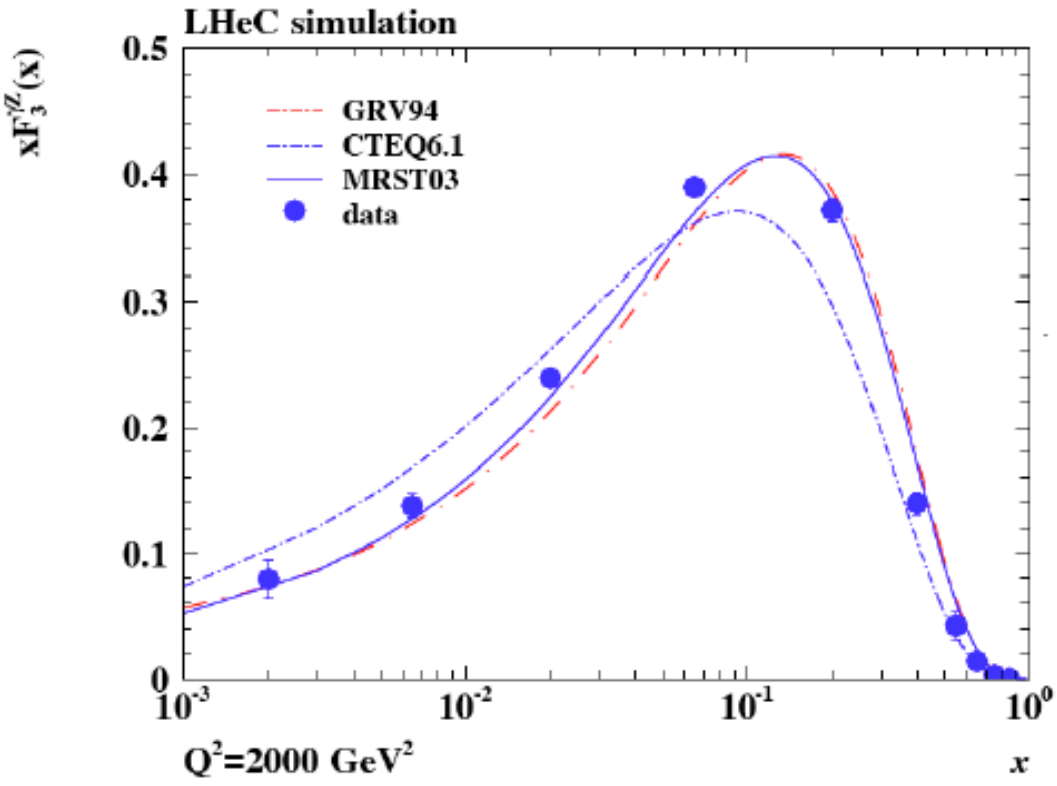
Charged currents (e-)



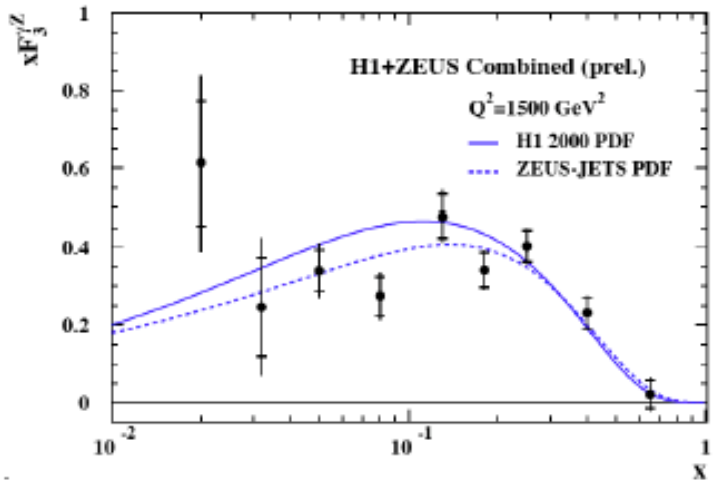
Back to Neutral currents...

Max Klein

$xF_3^{\gamma Z}$



HERA I



$$xF_3^{\gamma Z} = 2x[e_u a_u (u_v + \Delta_u) + e_d a_d (d_v + \Delta_d)]$$

Valence quarks at low x

or/and unexpected sea

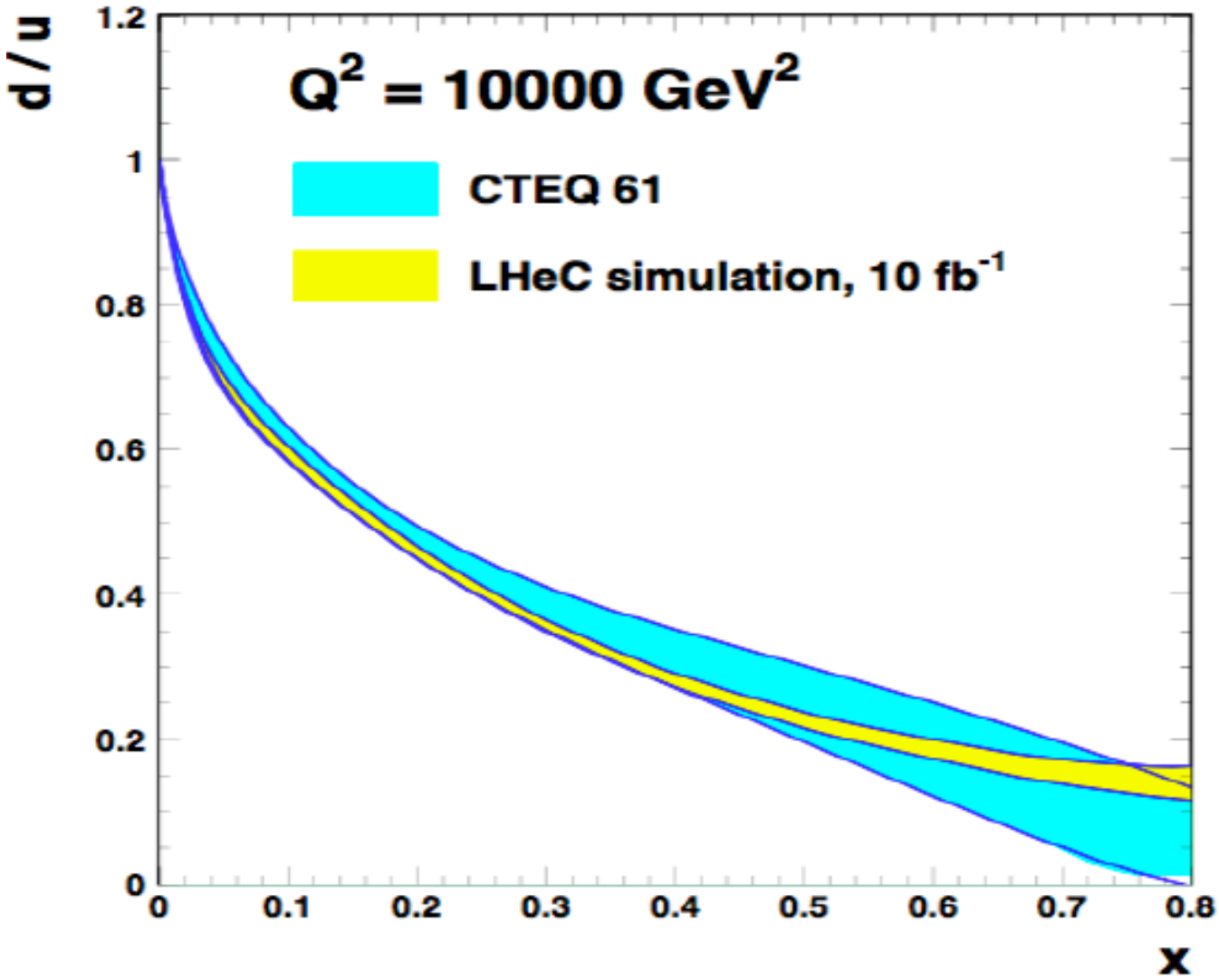
asymmetries

$$\Delta_u = (u_{sea} - \overline{u} + c - \overline{c})$$
$$\Delta_d = (d_{sea} - \overline{d} + s - \overline{s})$$

from vZ interference

Combined fit to NC and CC

d/u at large x



E.Perez

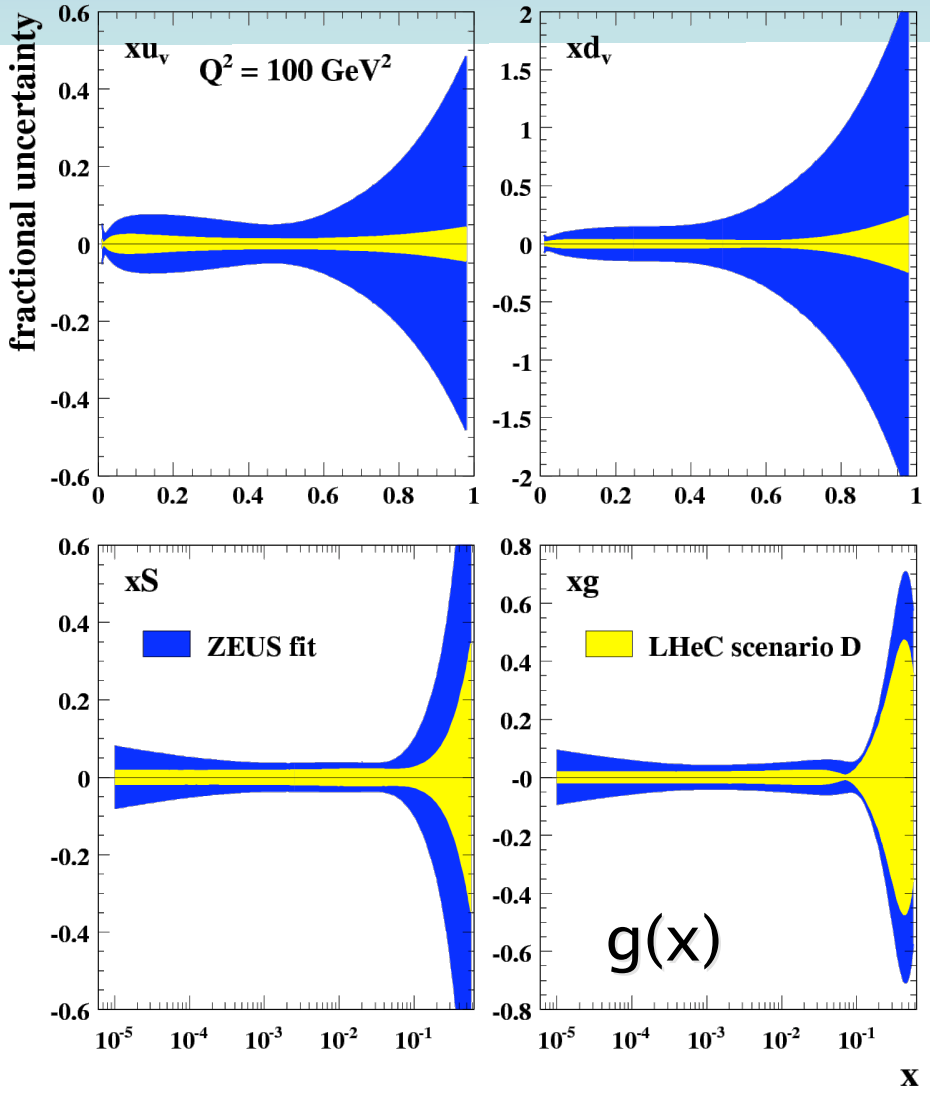
Proton PDFs

Claire Gwenlan

$Q^2 = 100\ GeV^2$

scenario D

» only PDF parameters free (LHeC **NC** and **CC** $e^{\pm}p$ included)



Looks very promising, model and parameterisation uncertainties to be studied

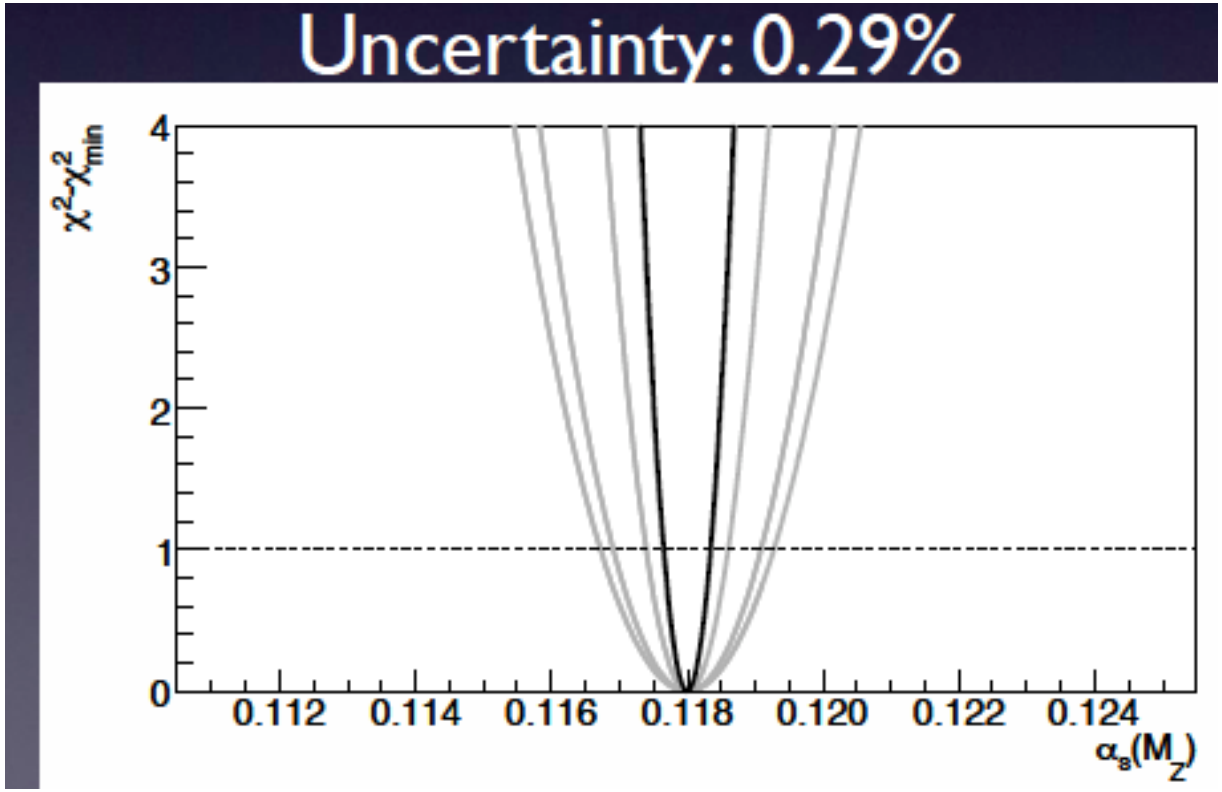
α_s from inclusive NC+CC

Thomas Kluge

Sensitivity mainly from scaling violations of F2

config.	E(e)	E(N)	N	|L(e⁺)|	|L(e⁻)|	|Pol|	L/10³² P/MW years			type
A	20	7	p	1	1	-	1	10	1	SPL
B	50	7	p	50	50	0.4	25	30	2	RR hiQ^2
C	50	7	p	1	1	0.4	1	30	1	RR lo x
D	100	7	p	5	10	0.9	2.5	40	2	LR
E	150	7	p	3	6	0.9	1.8	40	2	LR
F	50	3.5	D	1	1	--	0.5	30	1	eD
G	50	2.7	Pb	0.1	0.1	0.4	0.1	30	1	ePb
H	50	1	p	--	1	--	25	30	1	lowEp

Fitting to Pseudodata B+C+F+H ->

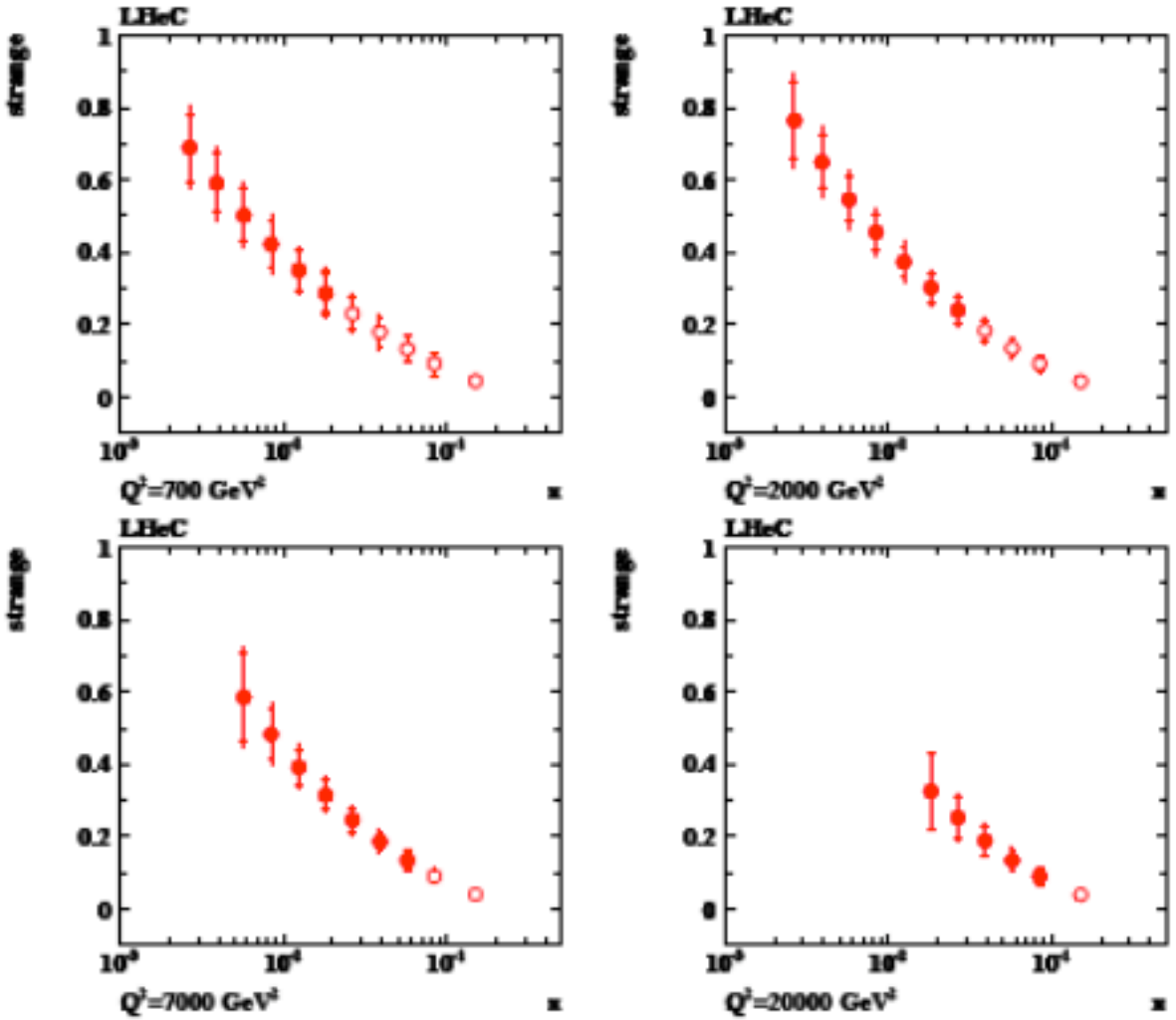


Plan to add also simulated inclusive jet data, shown on page 30

2. Physics using charm and/or beauty tagging in the final state

Strange Quark

Max Klein



$W^+ s \to c$

$1 fb^{-1}$

$\varepsilon_c = 0.1$

$\varepsilon_q = 0.01$

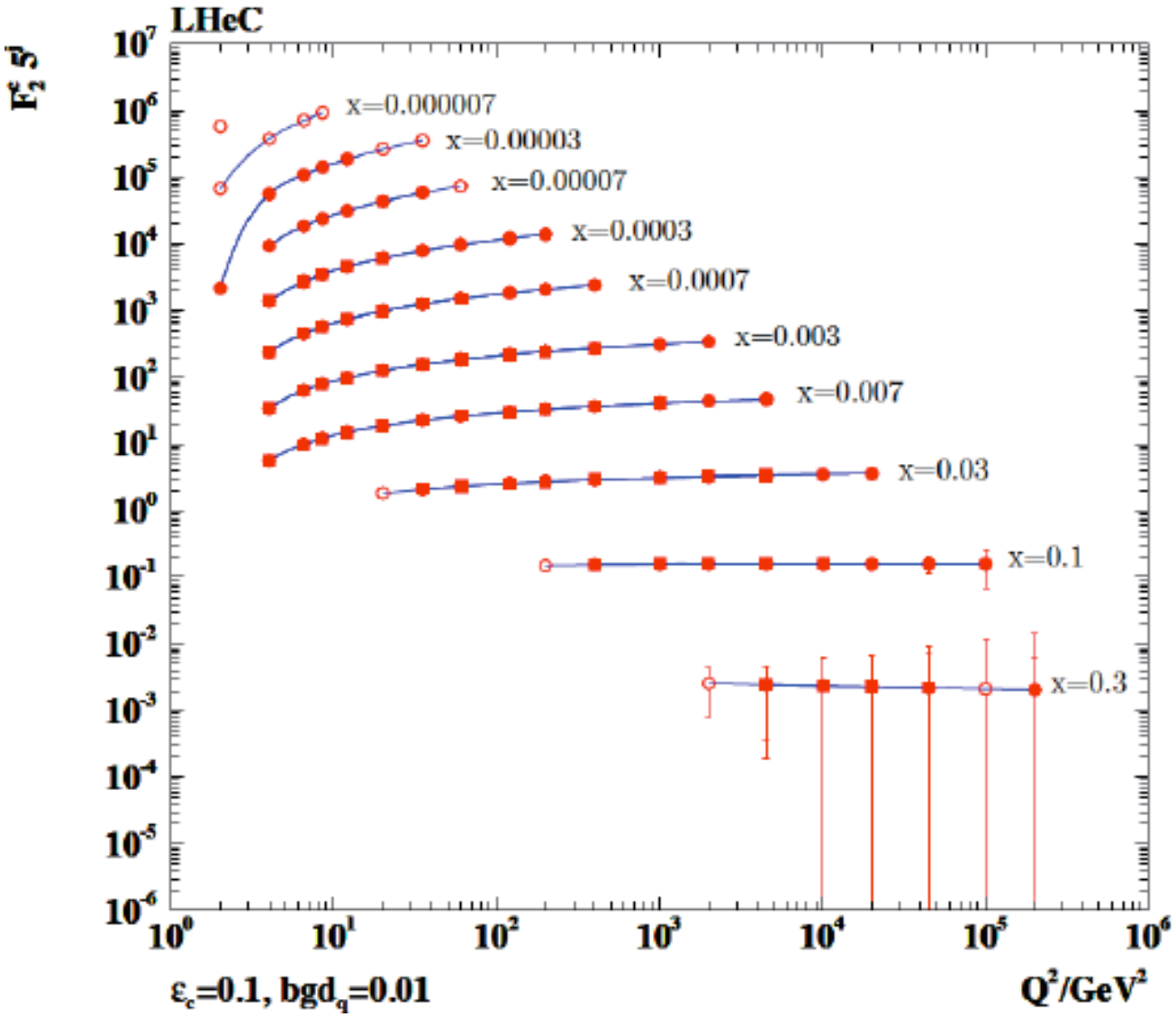
$\delta_{syst} = 0.1$

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

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

F_2^{cc} projected LHeC results (only QPM like part):

Max Klein



Systematic error dominates (so far 3%)

Precise measurement near threshold and up to 10^5 GeV^2

F_2^{cc} will become precision testing ground for QCD and proton structure

open: 1^o

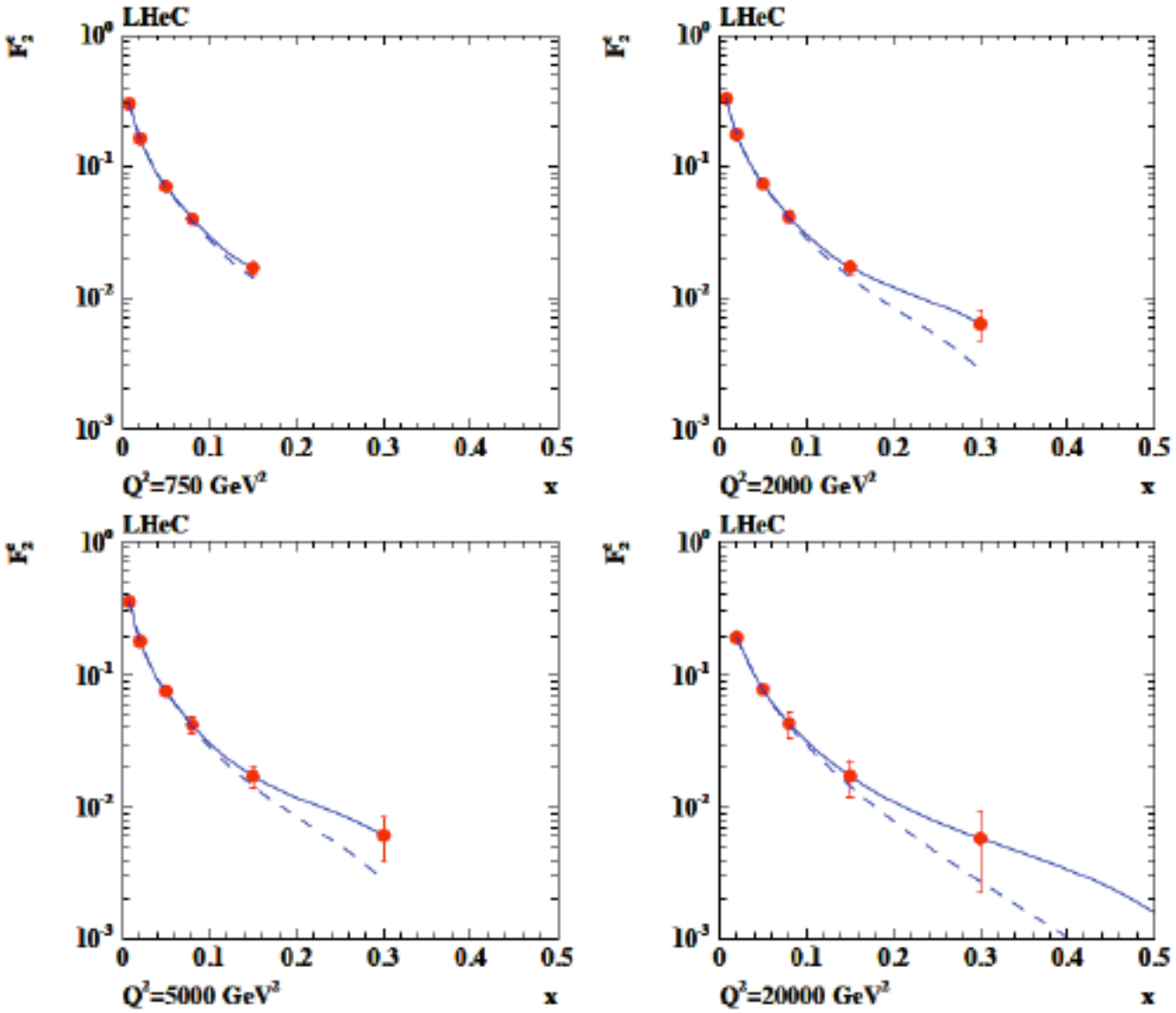
closed: 10^o

box: 1 TeV

xF_3, $F_2^{cc,\gamma Z}$? → charm NC couplings

Intrinsic Charm ??

Max Klein

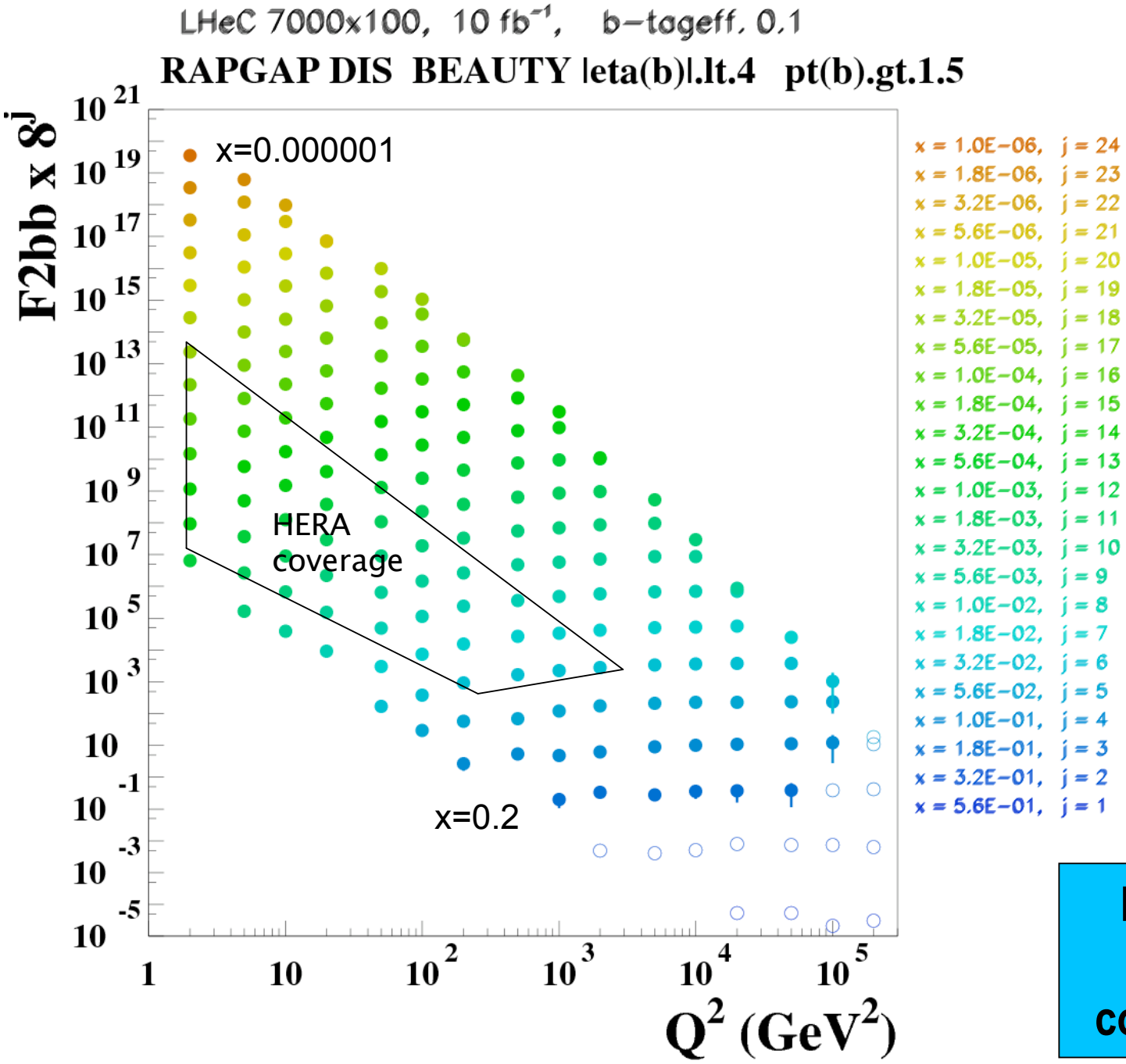


CTEQ6 with (solid) and w/o (dashed) intrinsic charm

To access the high x region one needs to tag charm in fwd direction and lower the proton beam energy and get high luminosity.

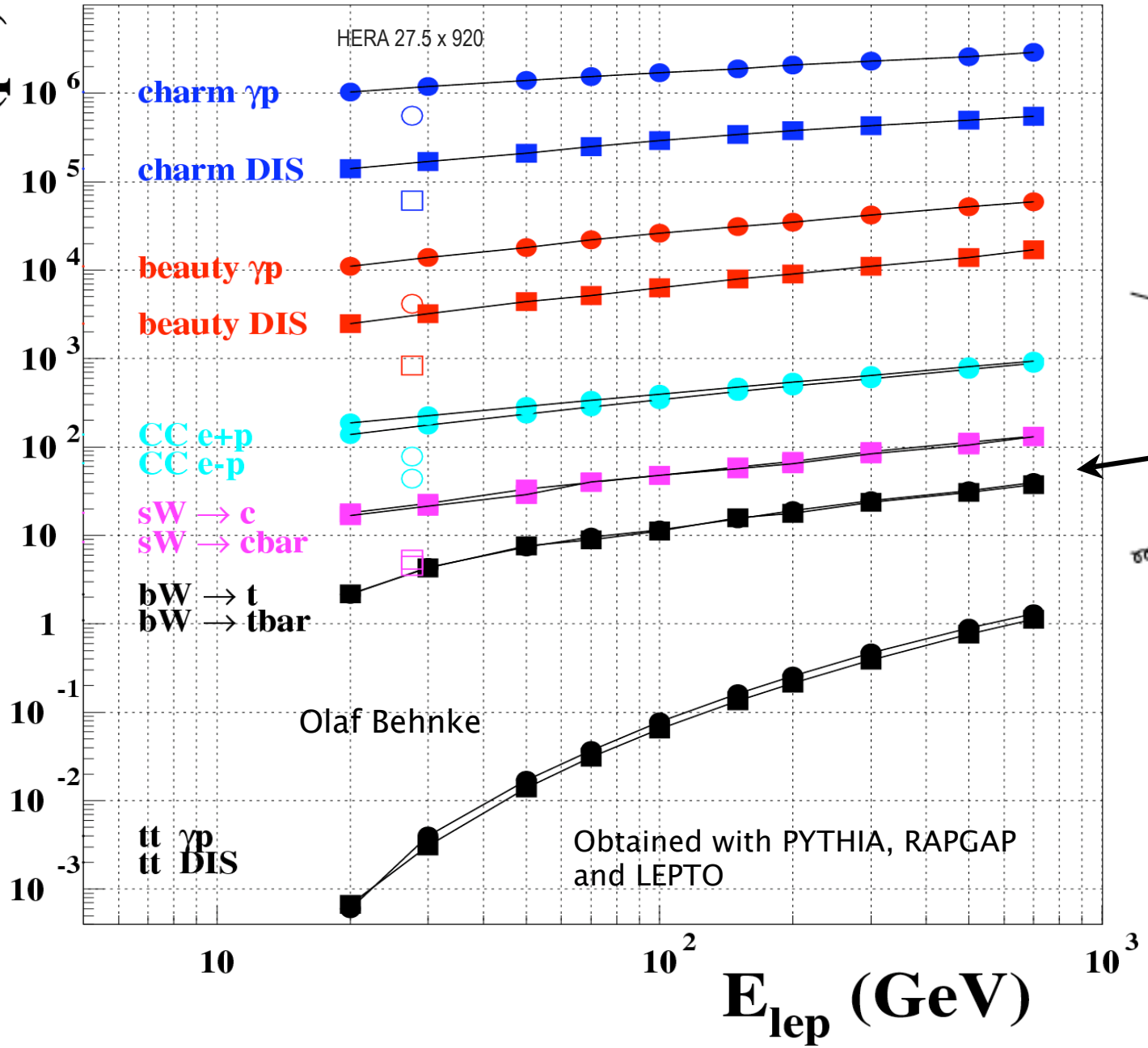
Beauty in DIS

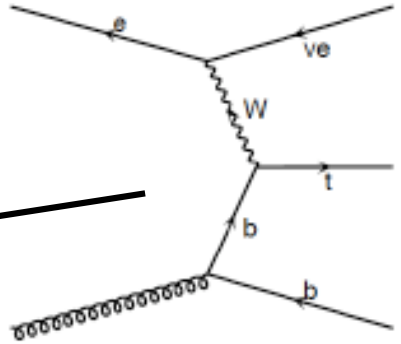
O.B.



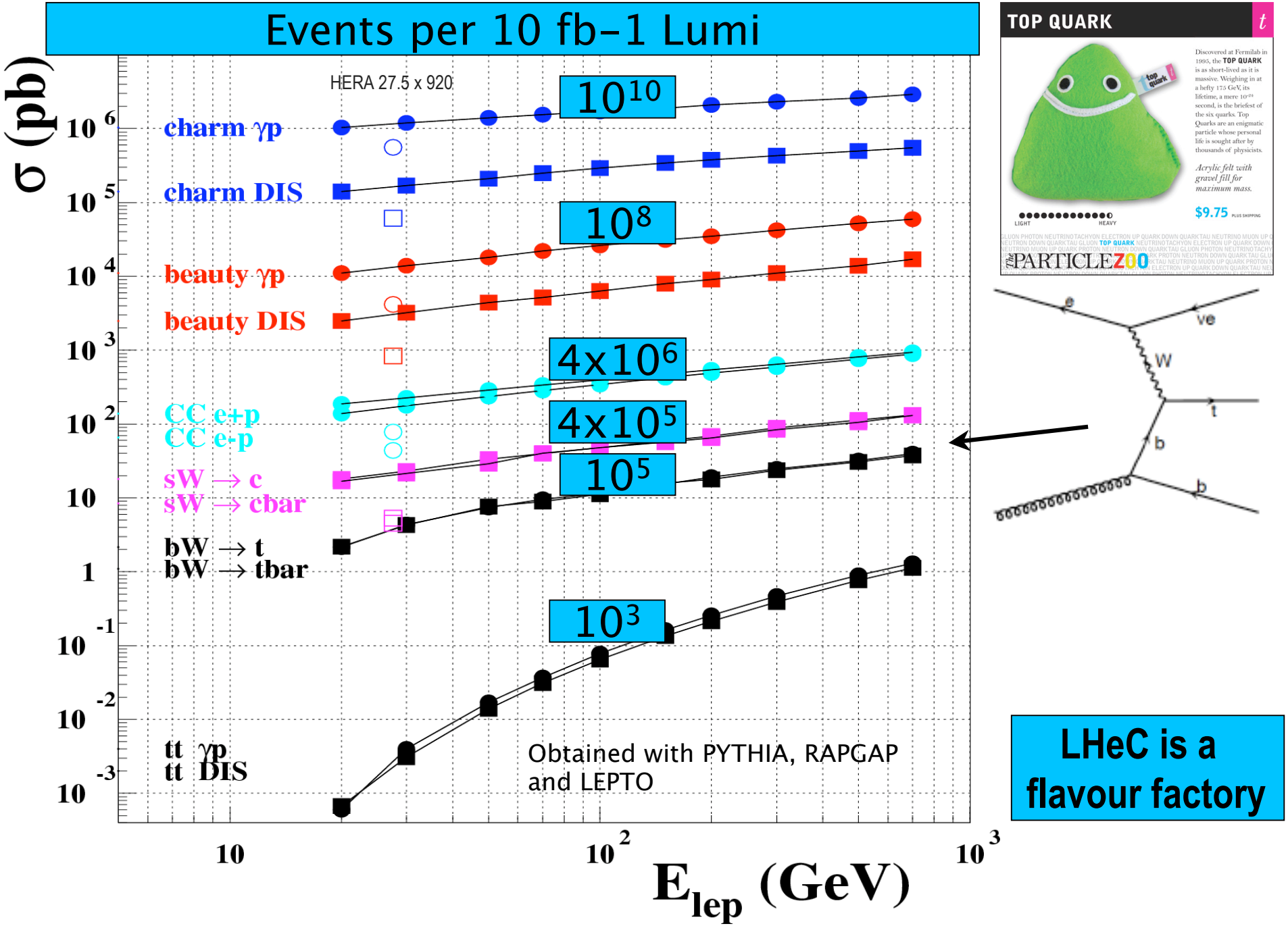
Largely extended phasespace compared to HERA

LHeC total cross sections (MC simulated)



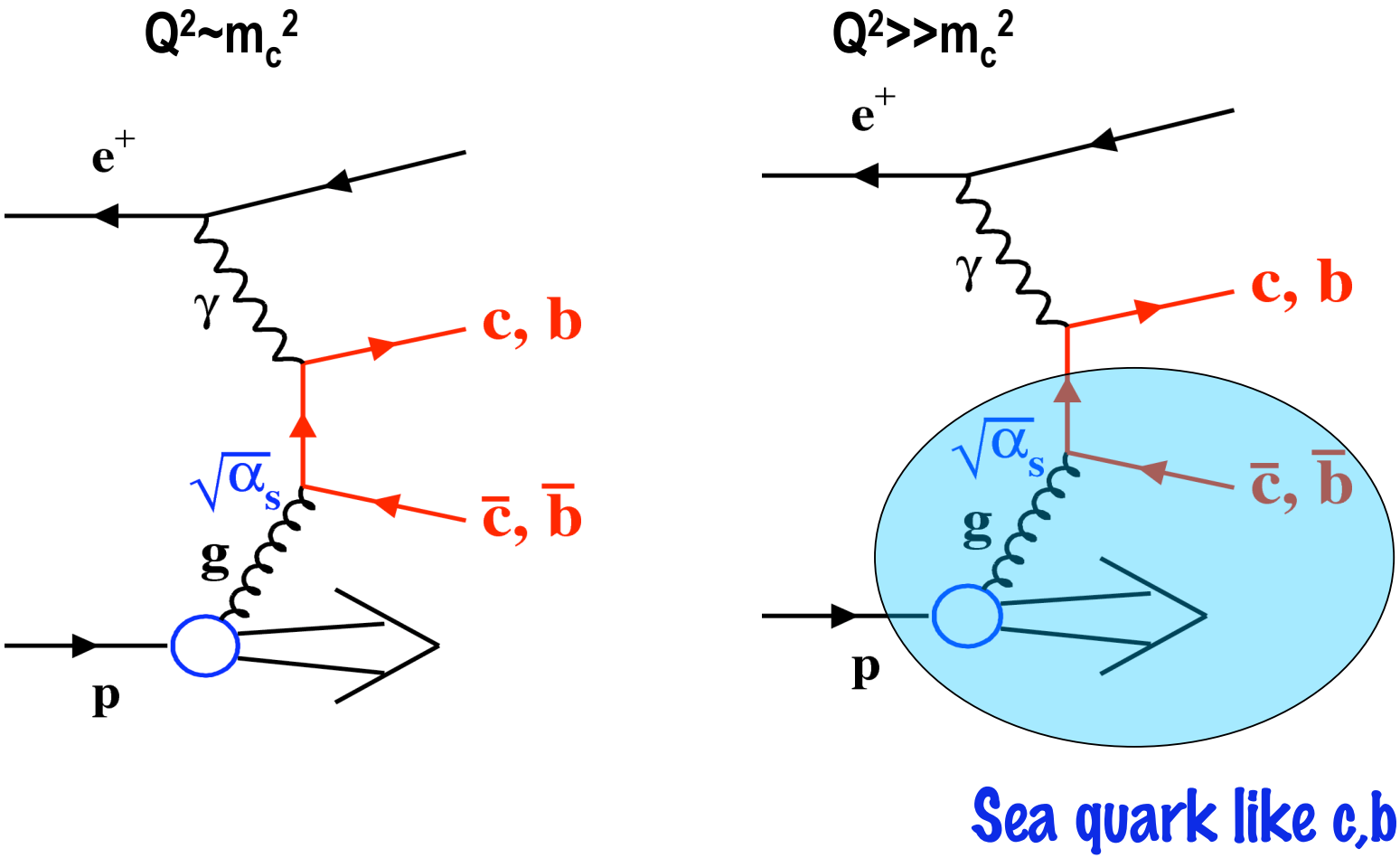


LHeC is a flavour factory



LHeC is a flavour factory

Subtle topic: correct treatment of heavy flavour masses in pQCD

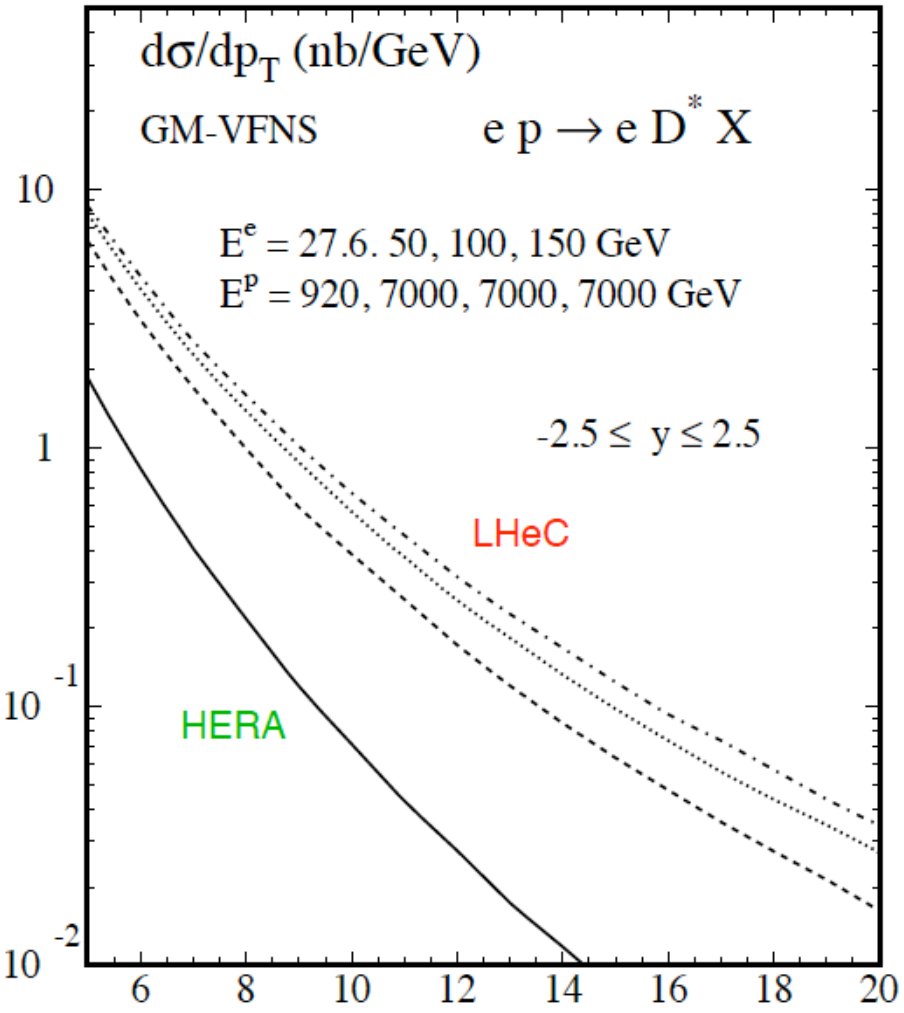


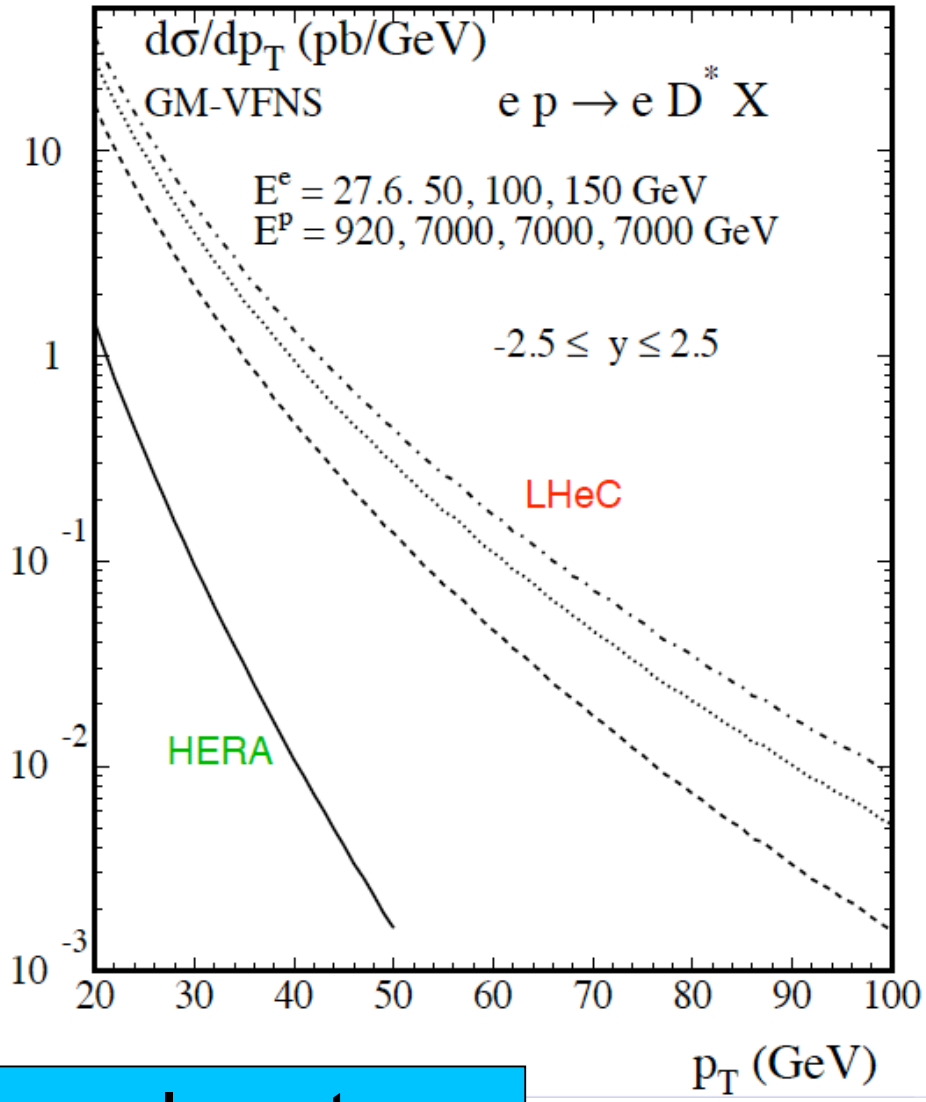
Sea quark like c,b

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

Inclusive photoproduction of D* mesons at LHeC

Gustav Kramer,
Hubert Spiesberger





→ **Can be studied at LHeC over very large pt range**

Charm production at an γp collider

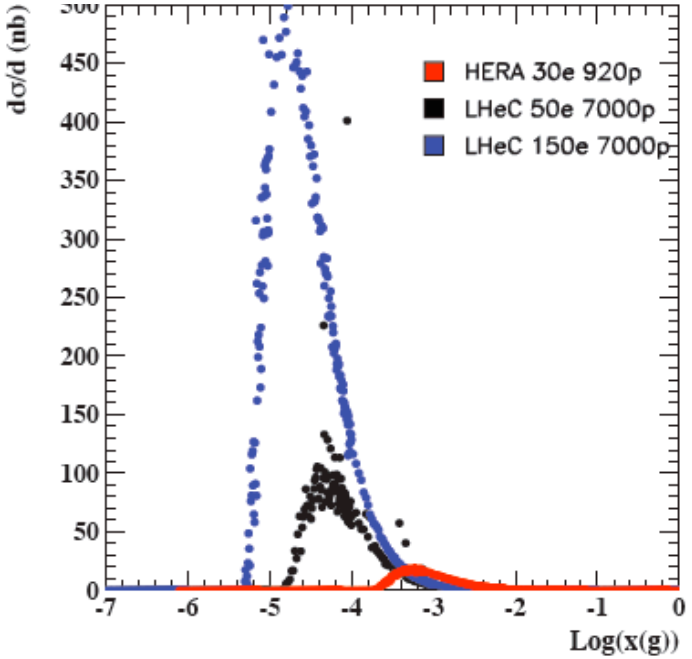
- Comphep 4.5.1/ Calchep 2.5.4

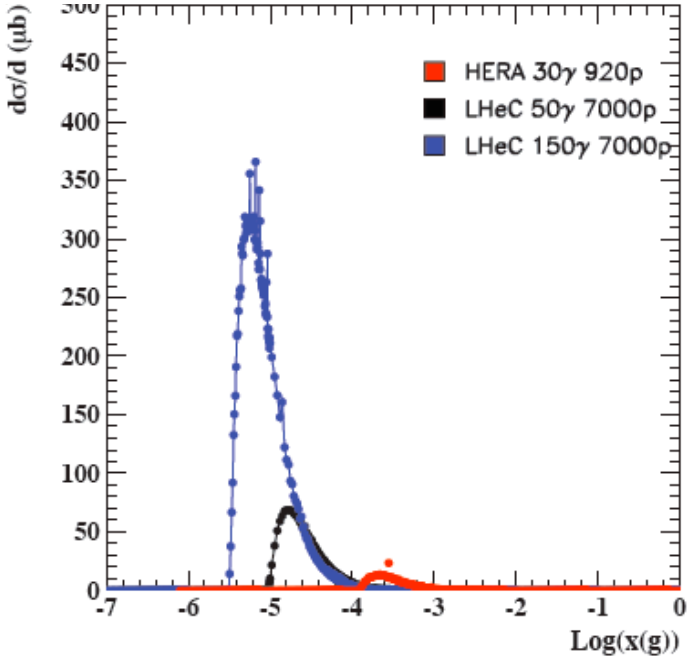
x(g) with Heavy Flavours in ep & γp collisions at LHeC

Gökhan Ünel

4

Compare charm production cross sections in DIS (left) vs cross sections at an Photon proton collider (right)



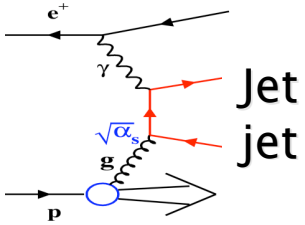


Cross sections much higher for photon proton collider

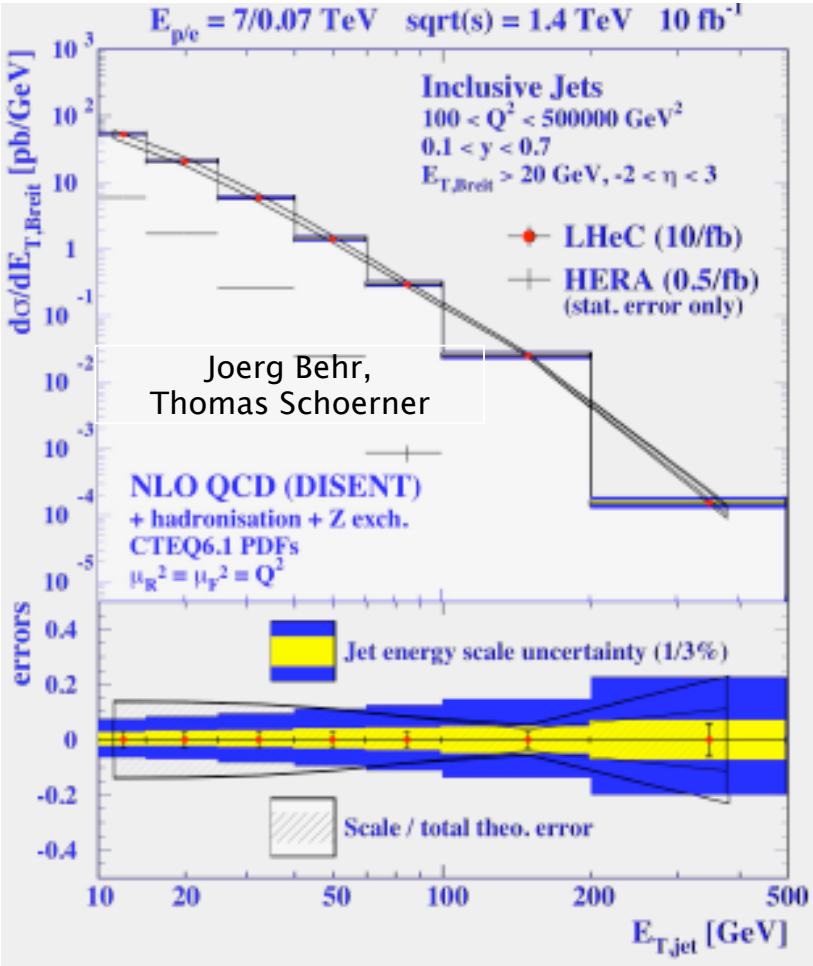
3. Physics using hard jets

(subject to hadronic corrections but unaffected by volcanic ash)

Jet production

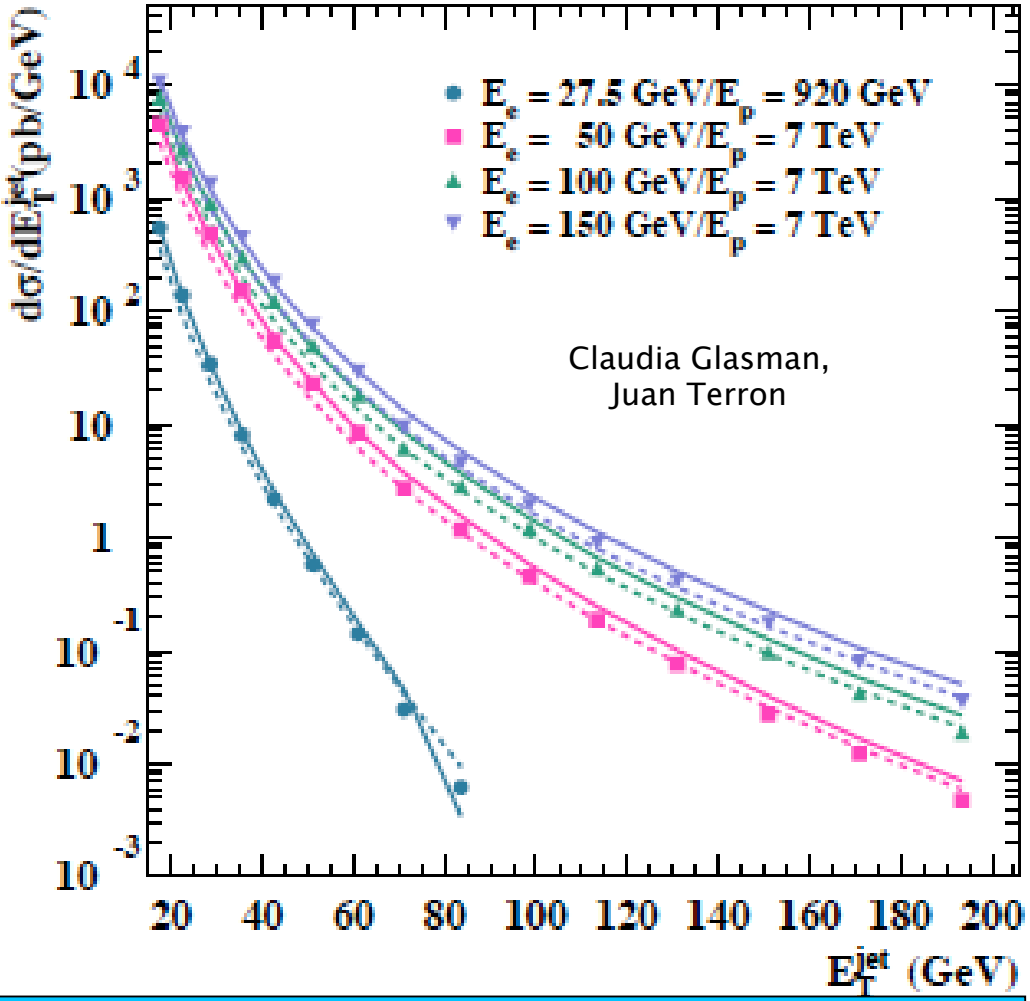


DIS



Joerg Behr,
Thomas Schoerner

Photoproduction



Claudia Glasman,
Juan Terron

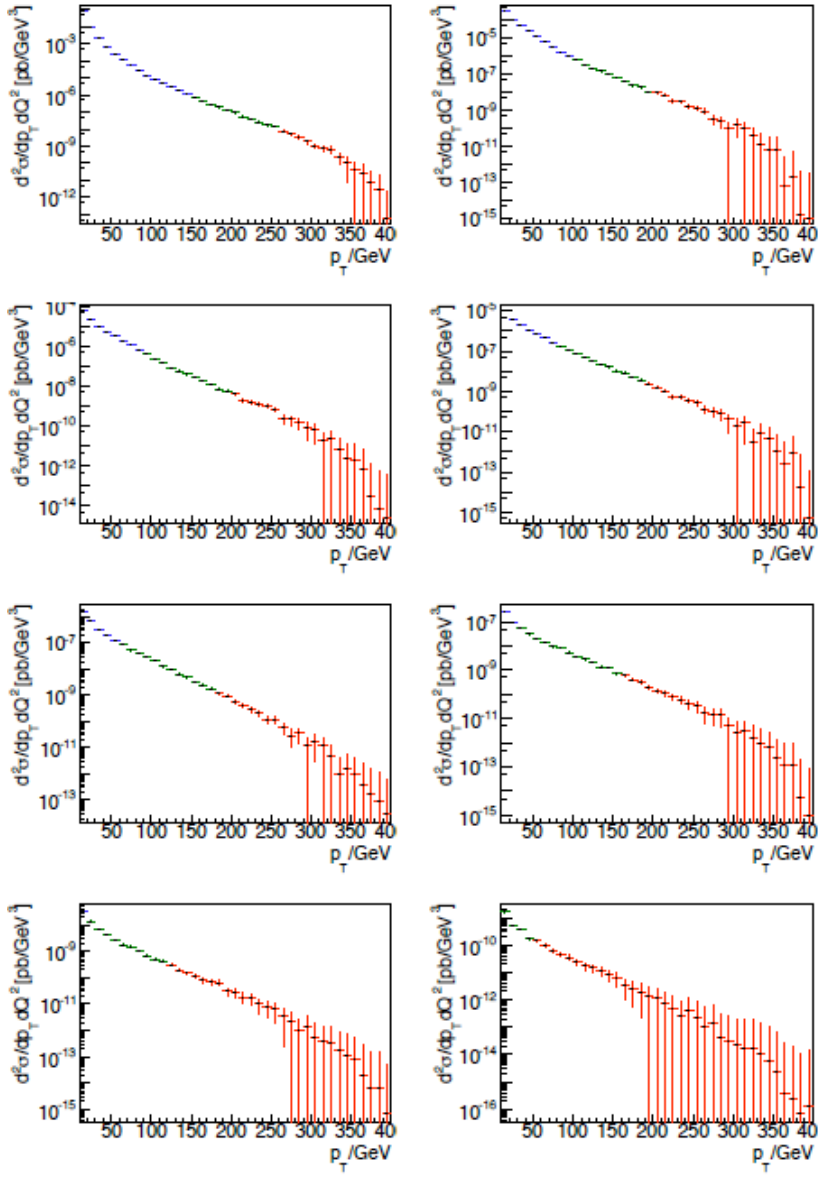
Reach scales up to $2m_{top}$ where change of $1/\alpha_s$ slope is expected

Inclusive Jets in DIS (with NLOJET++4.0.1

Thomas Kluge

- $s=4\cdot7000\cdot50$, $y=0.1\ldots0.9$, $170°<\Theta_{lab}<10°$
- $L=200fb^{-1}$

Q^2 Regions	
5-5000 Gev^2	5000-10000 Gev^2
10000-20000 Gev^2	20000-40000 Gev^2
40000-80000 Gev^2	80000-160000 Gev^2
16000-320000 Gev^2	320000-640000 Gev^2



Summary

The LHeC has the potential to completely unfold the partonic content of the proton: u,d, c,s, t,b and the gluon in an unprecedent kinematic range. This is based on inclusive NC, CC cross sections complemented by heavy quark identification. The (almost) whole p structure which the LHC assumes/needs to know will become accuralely determined.

Electroweak high precision SM tests in the t-channel, especially for u and d quarks

Single Top production: sensitive test of the standard model (Wtb couplings)

The LHeC is the ultimate clean precision tool for hard QCD physics:
- **α_s measurements at the permille level from inclusive and jet data**
- **charm and beauty: understand/control the treatment of mass in pQCD calculations**
- **High pt jets: also sensitive to proton and photon structure**

Demanding detector requirements:
- **Large x>0.1 programme necessiates excellent forward hadronic calorimetry and control of hadronic energy scale to <= 1 %,**
- **s,c,b,t programme needs efficient charm and beauty tagging over wide rapidity range**

Next plans of working group: complete studies and write QCD & electroweak chapter of the LHeC conceptional design report (until summer)

Backup slides

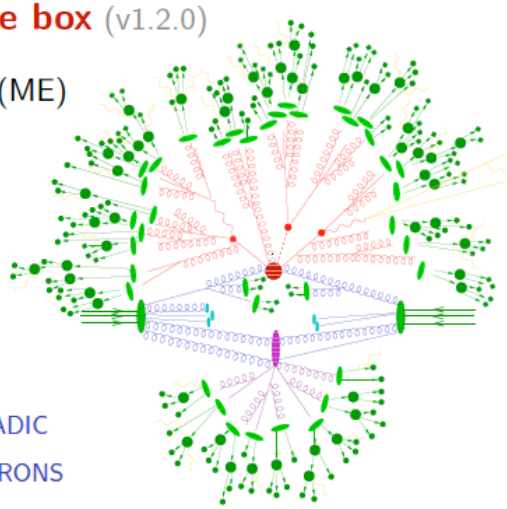
SHERPA

Stefan Hoeche

Sherpa's event generation framework JHEP02(2009)007

Things that are currently in the box (v1.2.0)

- Two multi-purpose Matrix Element (ME) generators AMEGIC++ JHEP02(2002)044 and Comix JHEP12(2008)039
- A standard Parton Shower (PS) APACIC++ CPC174(2006)876 and the dipole-like PS CSS JHEP03(2008)038
- A multiple interaction simulation à la Pythia AMISIC++ hep-ph/0601012
- A cluster fragmentation module AHADIC
- A hadron and τ decay package HADRONS
- A photon radiation generator à la YFS PHOTONS JHEP12(2008)018



Sherpa's traditional strength is the perturbative part of the event
NLO real ME's consistently combined with PS à la JHEP05(2009)053

Summary

Things already done ...

- SHERPA including ME⊗PS set up for DIS framework stable, promising first results
- HZTool steering included in SHERPA
  → "any" existing HZTool analysis can be done

Things to be done ...

- More tests and validations
  forward jets, 4-jets, ...
- Resolved photons
- Multiparton events

Looking forward to meet the challenge !

Could be a nice tool for further specific LHeC predictions