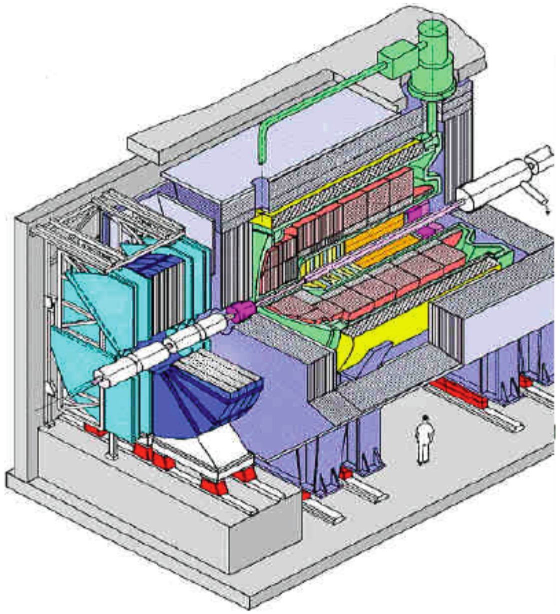
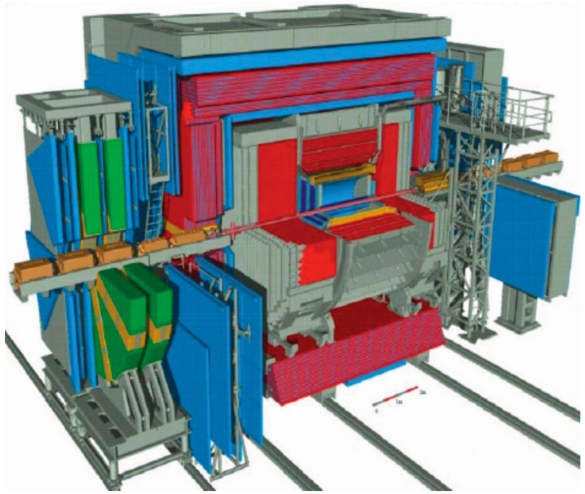
Physics at HERA

and what it means for the Large Hadron Collider



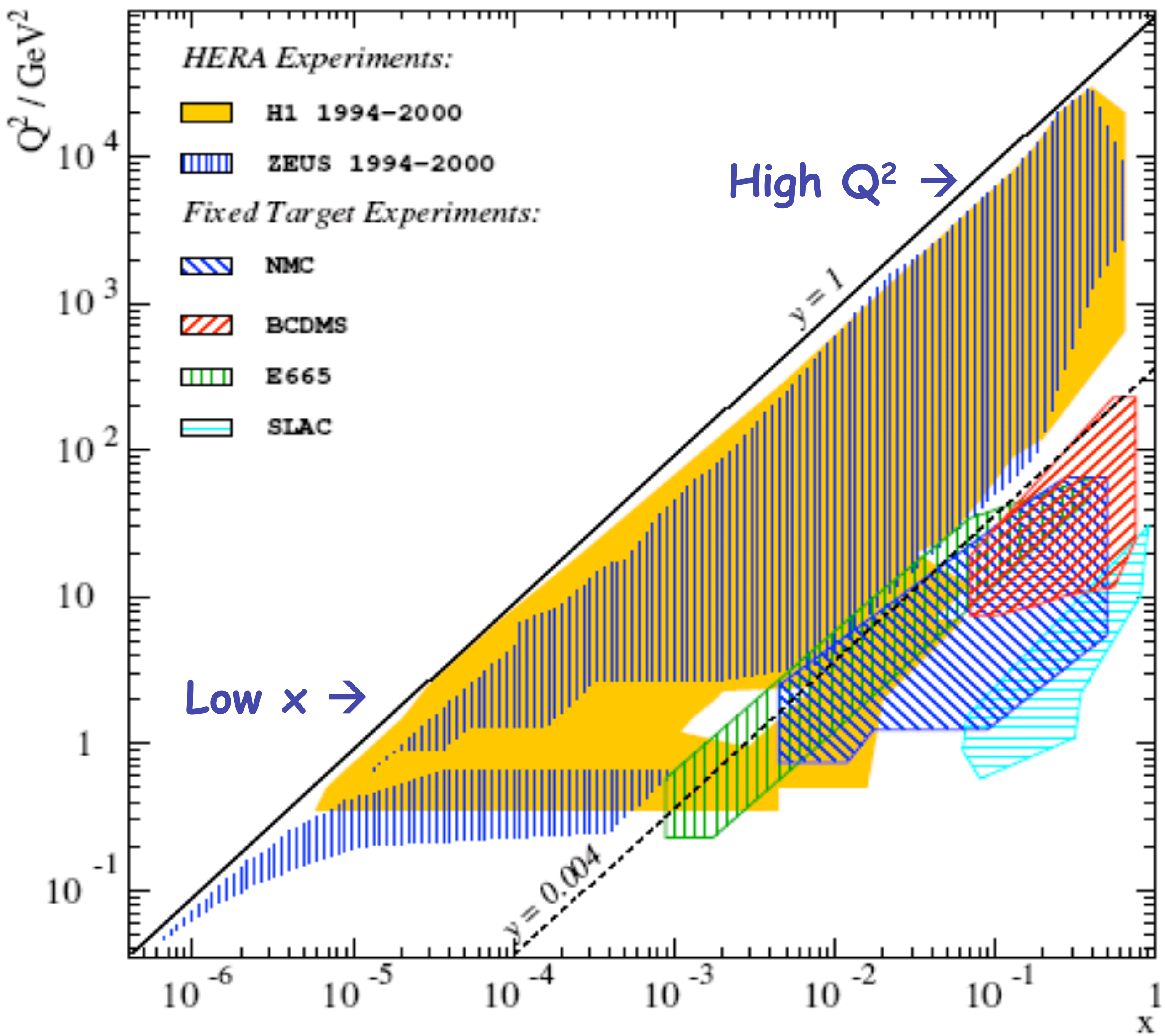
Introduction
Low x
Plateau
Developments

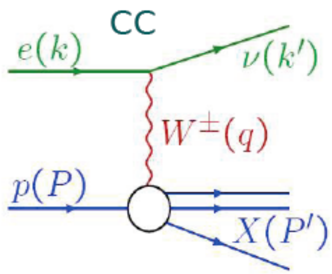


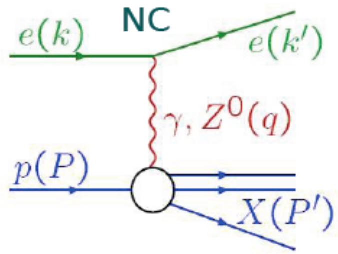
Max Klein (DESY)

Workshop on HERA and the LHC
Proceedings being written. Continues with annual meetings (January 06)

Deep inelastic ep scattering, photoproduction (γp) and searches at energy frontier







$$E_e = 27.6 GeV, E_p = 920 GeV$$

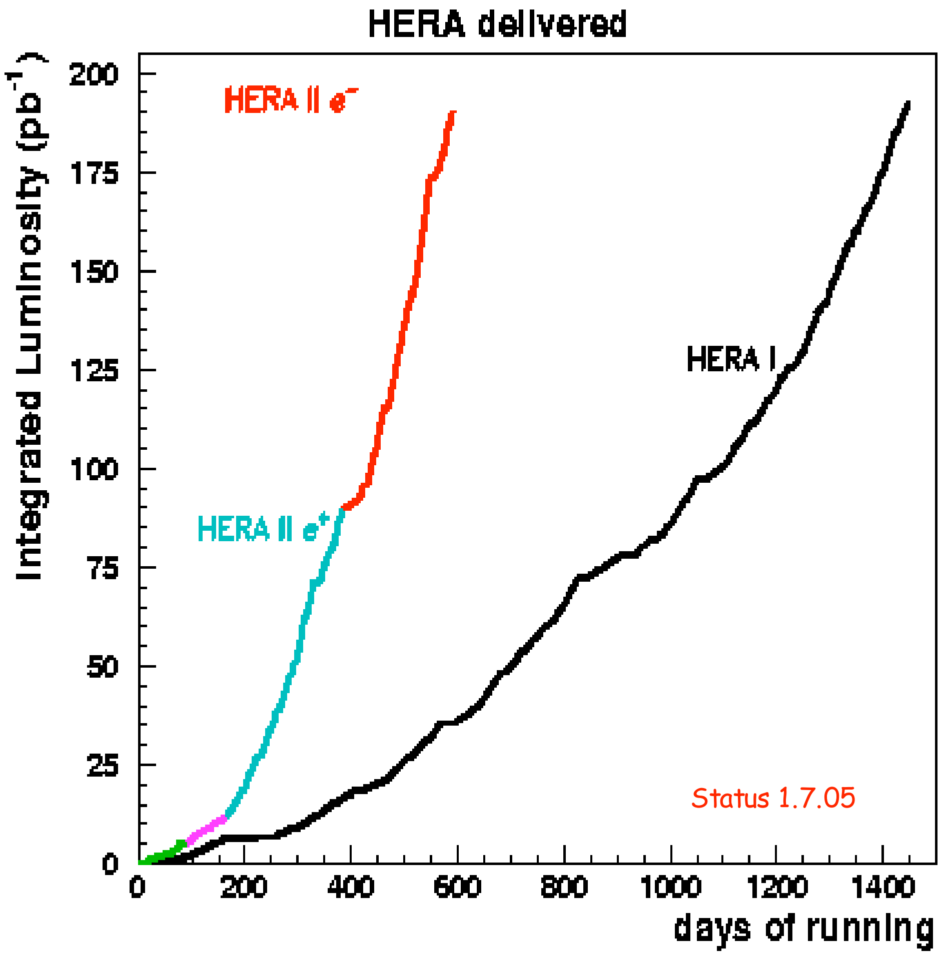
$$\sqrt{s} = 2\sqrt{E_e E_p} = 319 GeV$$

$$\Leftrightarrow E_e^{ft} = 54.1 TeV$$

$$Q^2 = sxy - high$$

$$x = Q^2 / sy - low$$

Luminosity development at HERA (I: 92-00, II: 03-07)

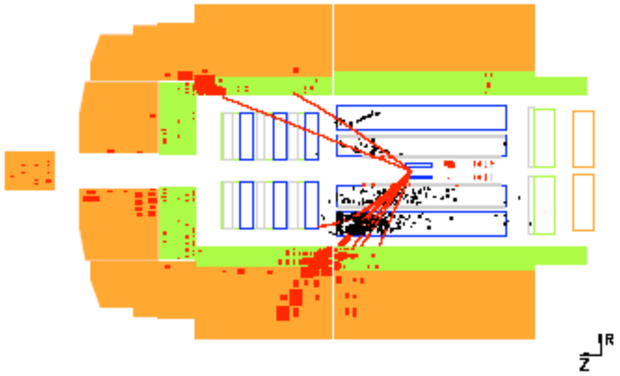


HERA delivering 1pb^{-1} /day and HV on feasible

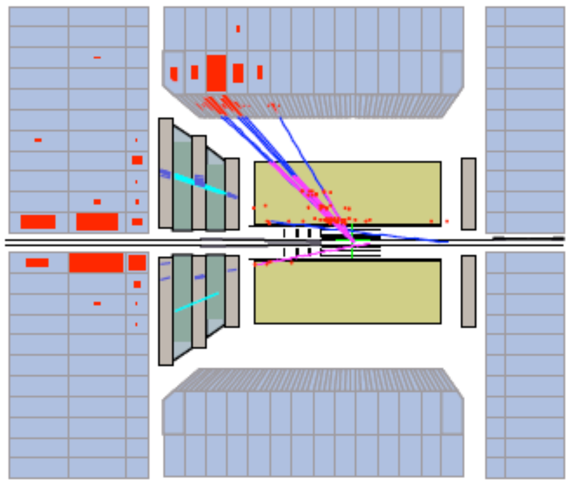
- HERAI: H1 and ZEUS took about 130pb^{-1} with HV on (1992-2000)
- 2001 "luminosity upgrade"
- 2002/03 background problems
- 2004: positrons (50 pb^{-1})
- 2005: electrons: so far 55 (H1) 75 (ZEUS)
- One further shutdown Nov05/Jan06
- 2007: scheduled end of HERA: PETRA III

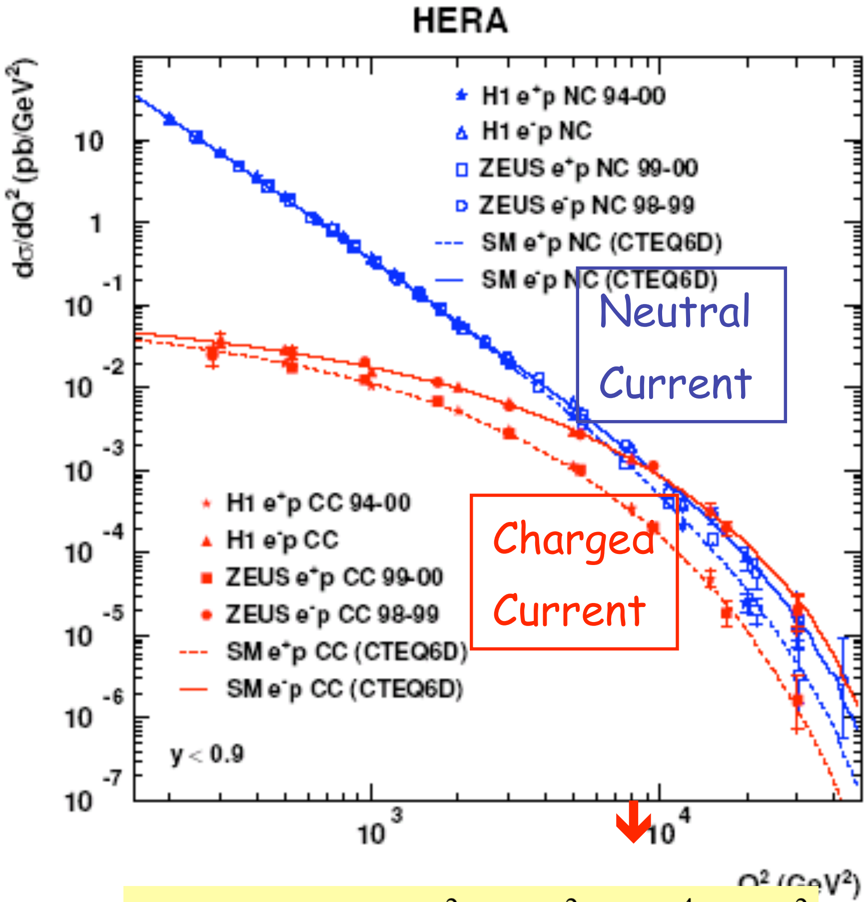
quarks are pointlike down to proton radius/1000

Neutral current $e^+ p \rightarrow e^+ X$



Charged current $e^+ p \rightarrow \bar{\nu} X$

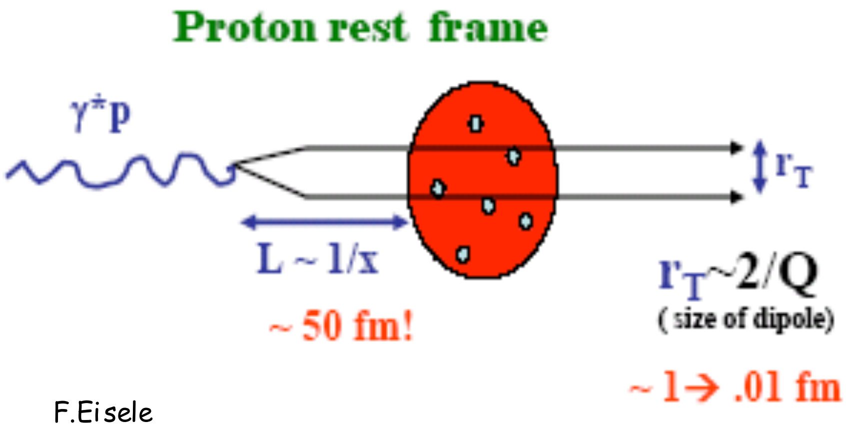




$$\sigma^{\pm}_{NC} \approx \sigma^{\pm}_{CC} \leftrightarrow Q^2 \approx M_Z^2 \approx 10^4 GeV^2$$

ZEUS r < 0.85 H1 r < 1.0 10^{-18}m

Low x Physics is HEP



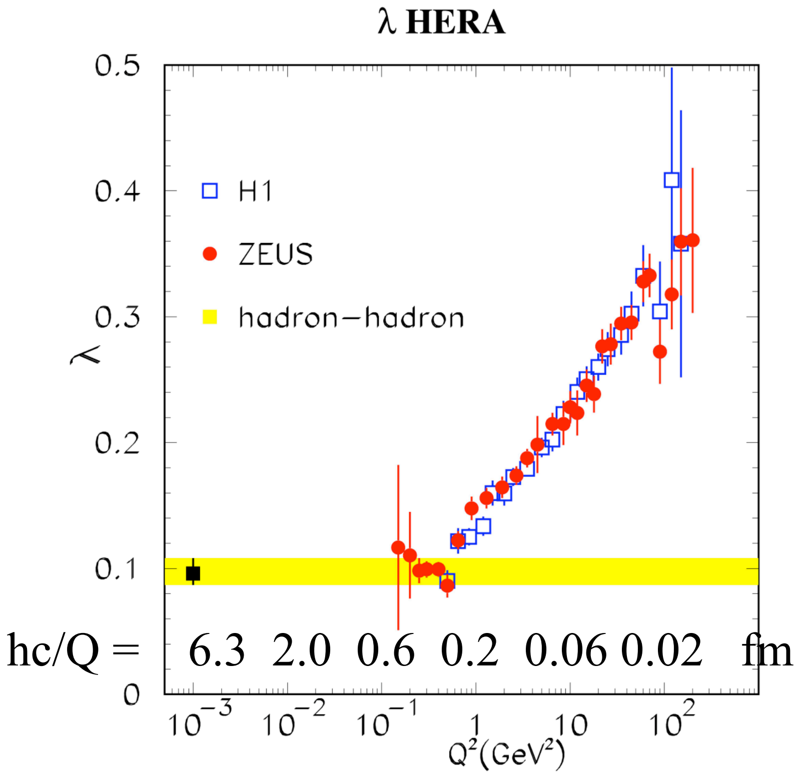
F.Eisele

At low x<0.01 a color dipole of variable size 2/Q interacts with the proton at high CM energy $s^{\gamma p} = W^2 \approx Q^2/x \approx 1000 \div 90000\ \mathrm{GeV}^2$

Low x = high energy scattering!

Q^2 steers the transition from hard collisions (perturbative QCD) to soft hadron physics.

Precision measurements of structure functions, final state, vector mesons, diffraction, heavy flavours



$F_2 \propto x^{-\lambda}$ at small x

rise of the parton densities

HERA collider experiments are precision experiments because

- Measure E'_e, θ_e, E_h, θ_h → Reconstruct x, Q^2: Kinematics is overconstrained
  [0.3 -1%; 0.2-1mrad; 1-2%, 1-2mrad]

- Highly efficient, 4π Detectors (Calorimeters, Chambers in solenoidal field)

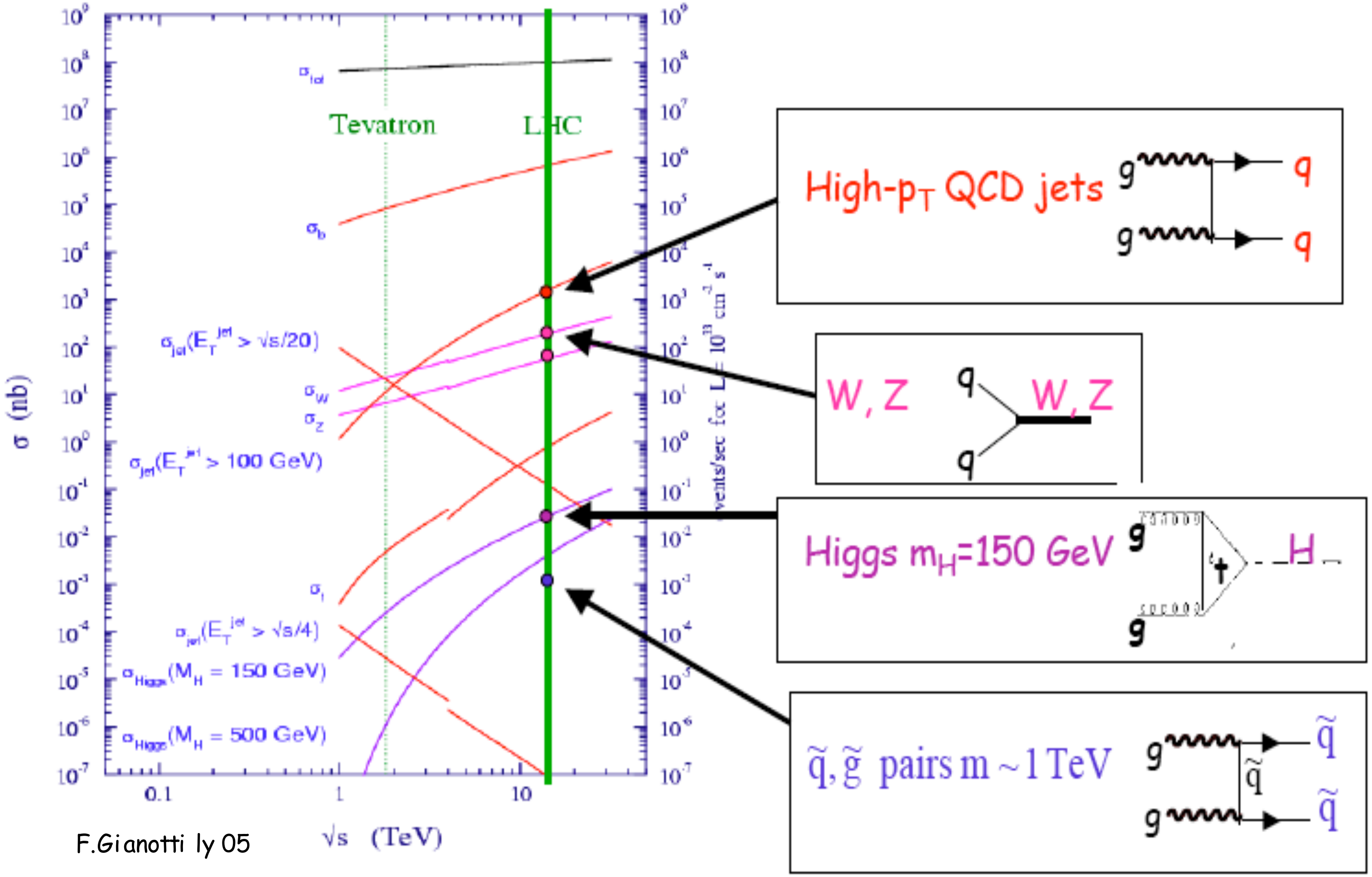
- Energy calibration: double angle method and kinematic peak constraint
  [high resolution calorimeters: 10%...35%/$\sqrt{E'_e}$ and 30-50%/$\sqrt{E_h}$]

- Energy momentum conservation ($E-p_z$): reduces radiative (QED) corrections

- Polar angle measurement using redundant trackers. Run vertex accurate
  [drift chambers: 200μm and Si trackers: 20μm resolution]

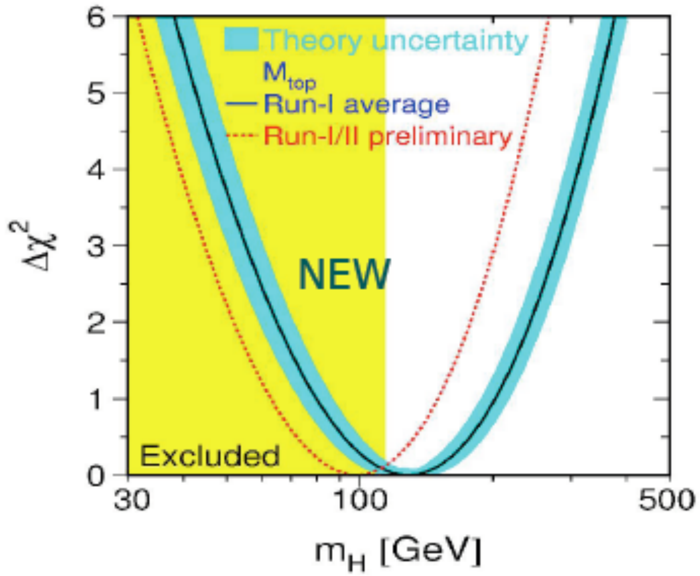
- Luminosity from Bethe-Heitler scattering [$ep \rightarrow ep\gamma$] to 1%.

The LHC is a discovery machine based on developping QCD



F.Gianotti ly 05

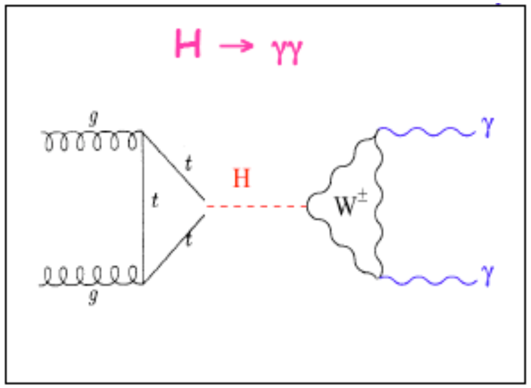
The Higgs gets lighter

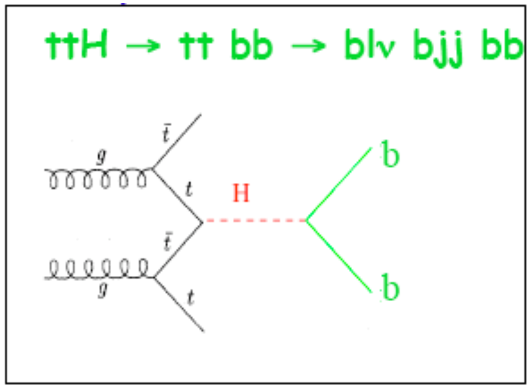


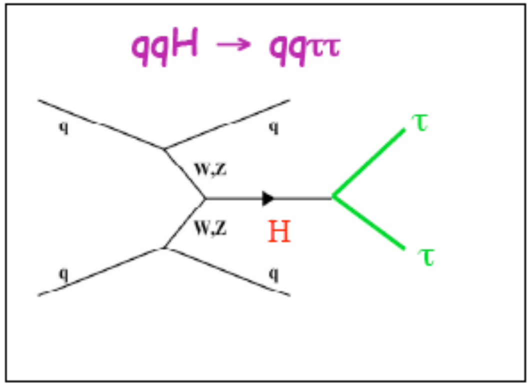
$M_{Higgs} = 98^{+52}_{-26}$ GeV

M_{higgs} <208 GeV @95% C.L.

C. Diaconu ly 05



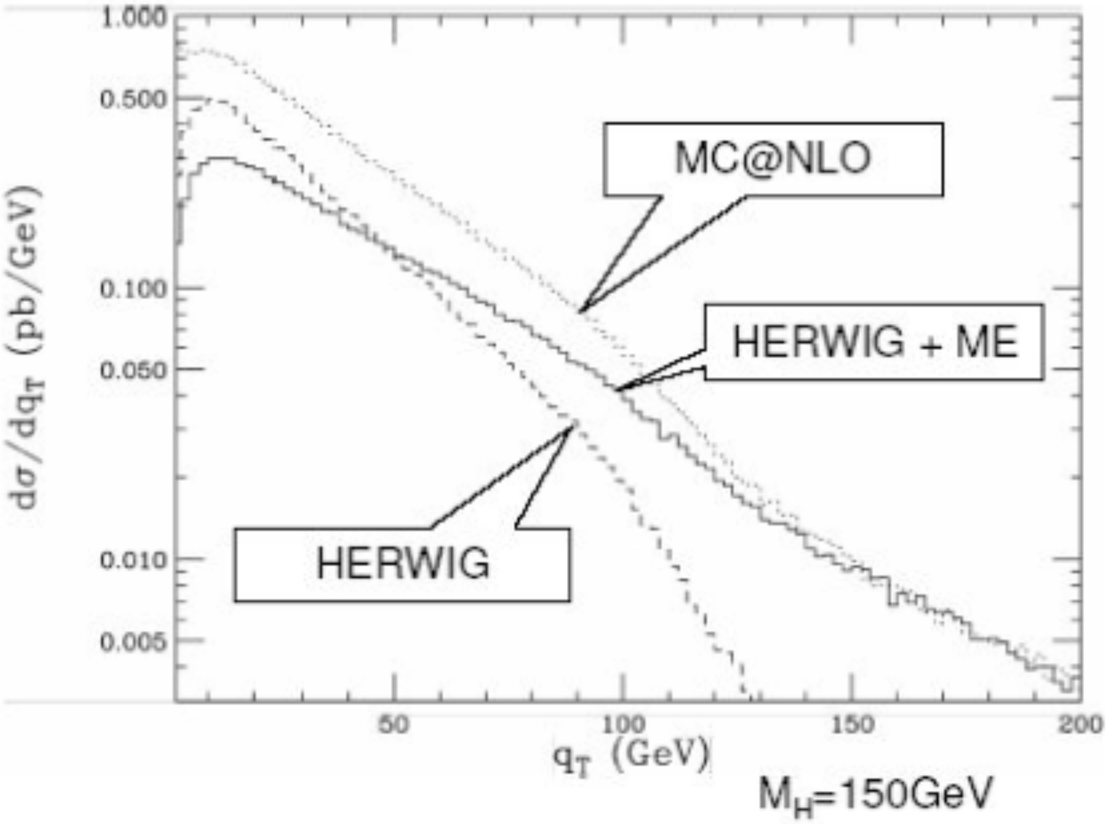




gg → Higgs (matrix element corrections)

Hadronisation and simulations very important

G.Corcella, S.Moretti, in progress



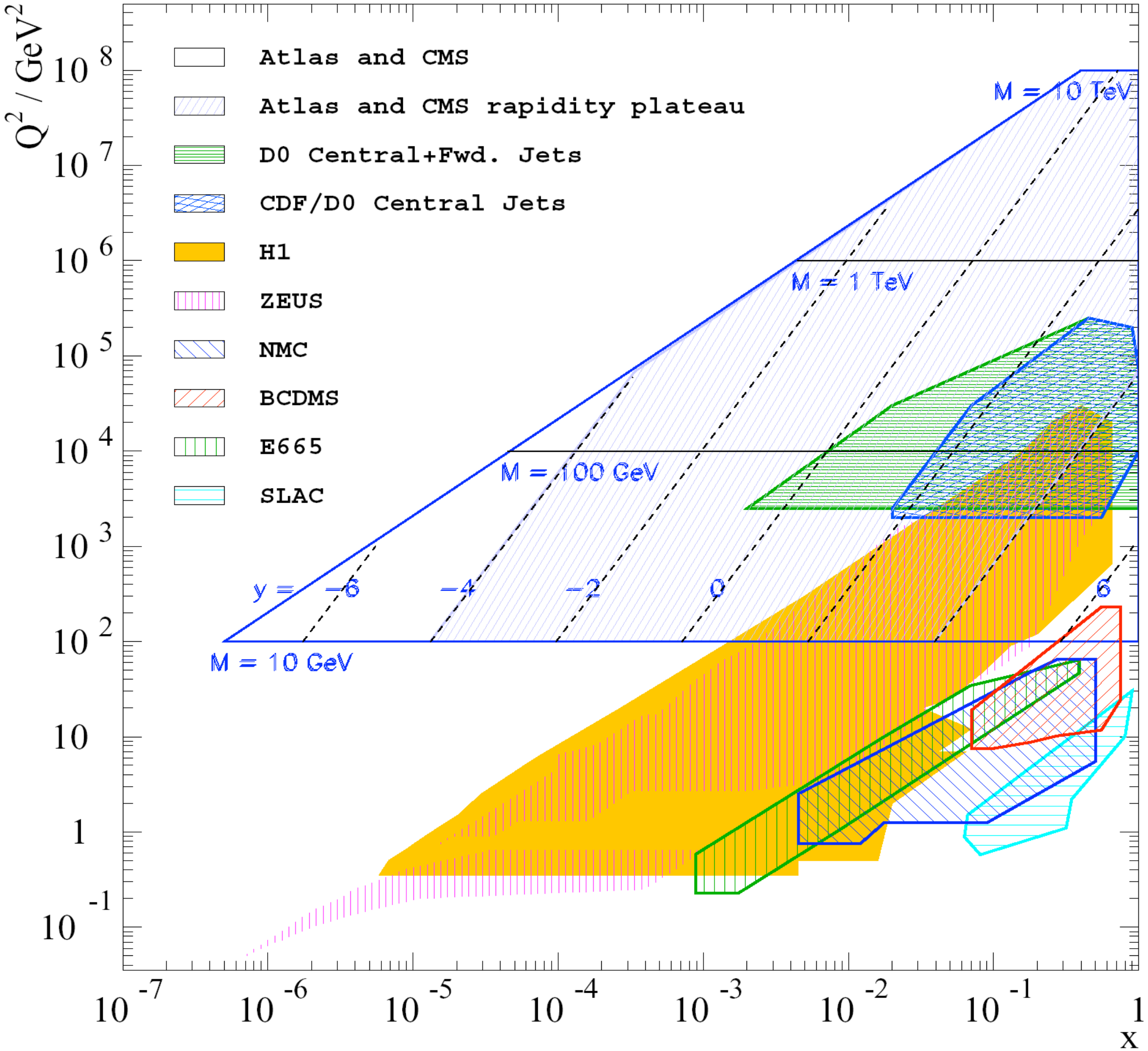
HERA-LHC workshop

Most Physics at HERA (the expected and the unexpected) is related to Tevatron & LHC

- classic DIS
  - Inclusive ep measurements (NC, CC-inverse neutrino i.a.) → pdf's, gluon,
- QCD
  - Low x physics: small coupling and high density of partons → "CGC, BFKL.."
  - Heavy flavour physics (c and b: production and fragmentation dynamics)
  - Final state physics (parton emission,,jets, multiparticles, dijet correlations)
  - Diffraction [all related: e.g. "the structure of charm jets in diffraction"]
  - Parton amplitudes (DVCS)
- Searches
  - Searches for exotic states (pentaquarks) and less? exotic ones (instantons)
  - Searches: substructure, leptoquarks, SUSY, isolated lepton events
- elweak
  - Electroweak physics (spacelike region)

for HERA physics see also:

- Talks at DIS05, April 2005, Madison
- Ringberg Workshop (2003) Proceedings ed by G.Grindhammer, B.Kniehl, G.Kramer



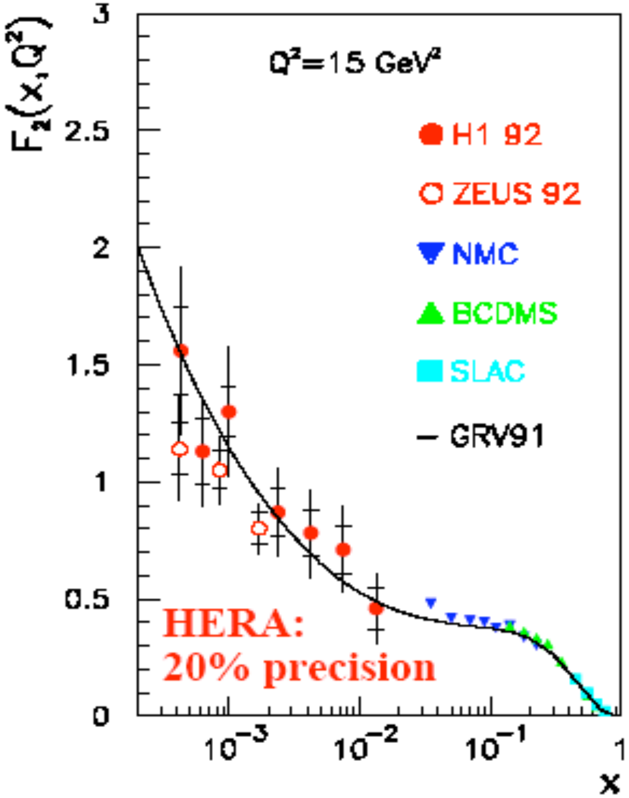
Low x physics at HERA: high parton density: forward at LHC
Plateau region at the LHC: medium x at HERA (two subjects)

2. Physics at Low Bjorken x ("forward physics")

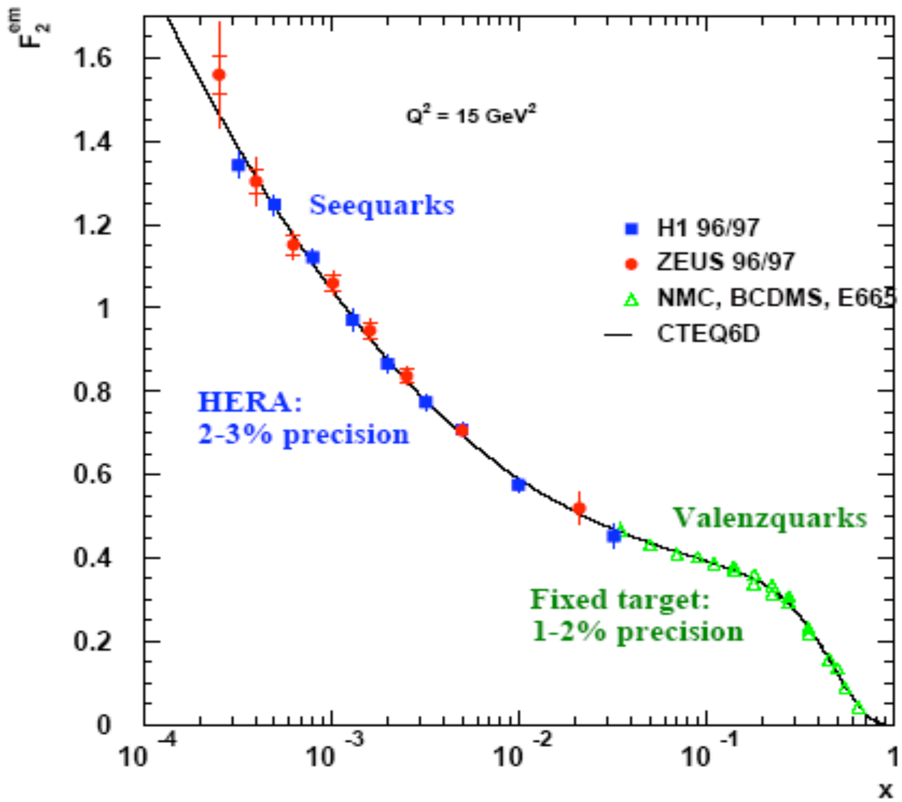
The rise towards low x
DGLAP or not? Final state and F_L
Diffraction (Higgs production)

Gluon and pdf's, see below
Sum rules relate low x to higher x

1992 data ~30nb-1



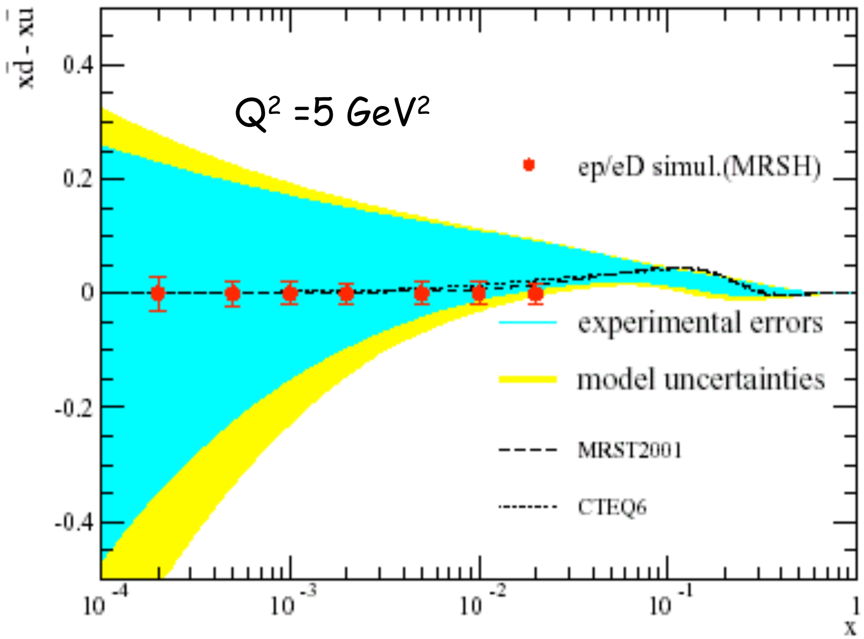
1997 data ~30pb-1



consequences, regarding the pointwise evolution of structure functions, were derived. The most dramatic of these, that protons viewed at ever higher resolution would appear more and more as field energy (soft glue), was only clearly verified at HERA twenty years later.

F. Wilczek

Is the proton sea flavour symmetyric at low x?

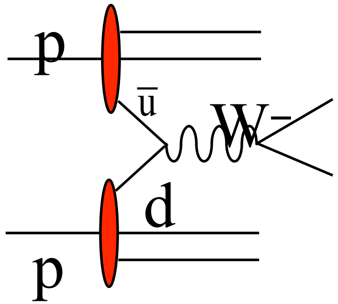


LoI: Electron-Deuteron Scattering with HERA: DESY 03-194
also: A New Experiment for the HERA Collider: MPI-2003-06

tag spectator proton: en scattering 'free' of Fermi motion
control/relate shadowing to diffraction

basic interest in eD at HERA

sea (a)symmetry important for ν
astrophysics at UHE <--> small x



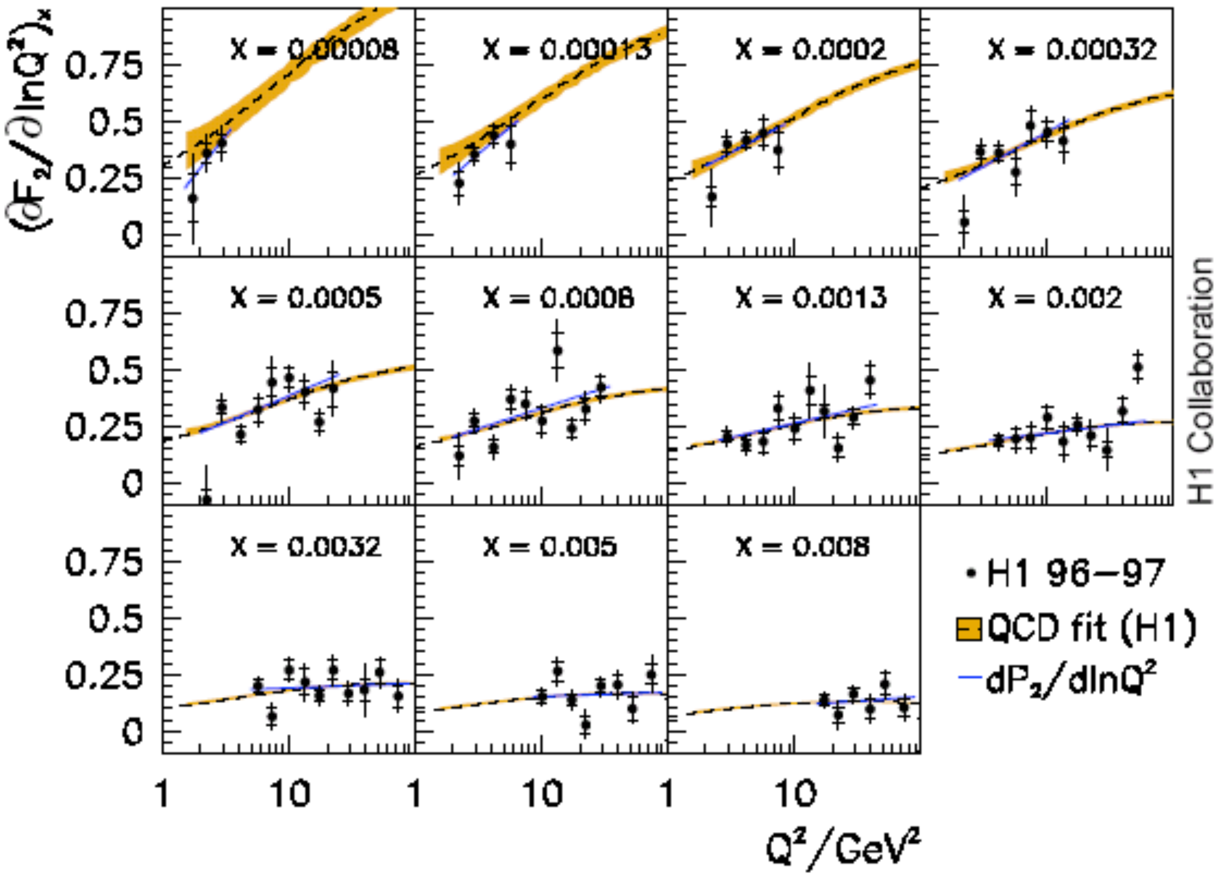
$$A_l(\eta) = \frac{d\sigma(e^+)/d\eta - d\sigma(e^-)/d\eta}{d\sigma(e^+)/d\eta + d\sigma(e^-)/d\eta} \simeq \frac{d(x)}{u(x)}$$

parton luminosity at the LHC

singlet- NS evolution - low x thy

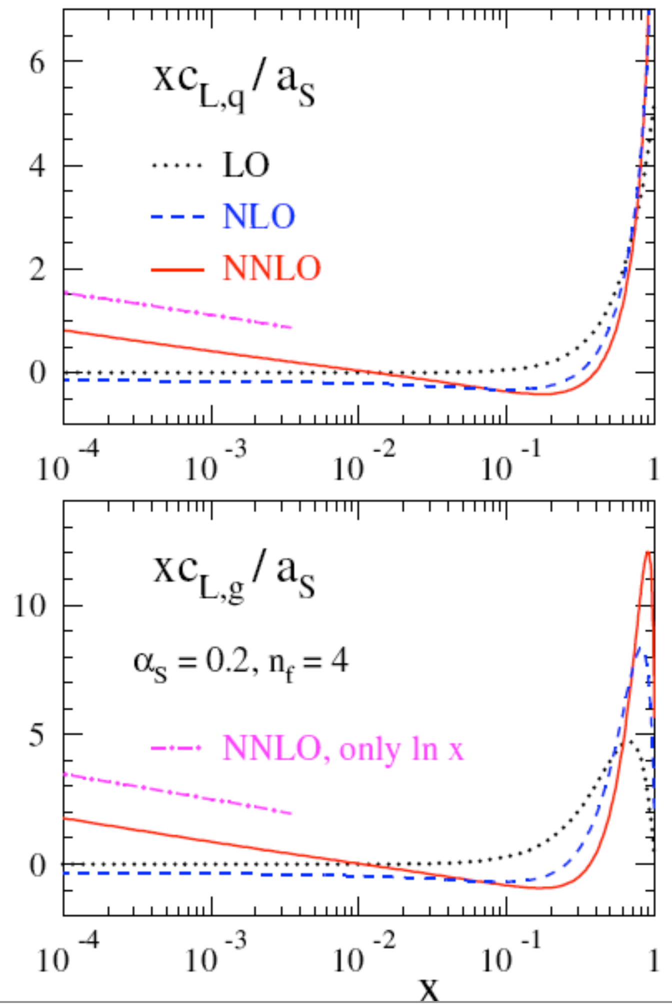
…eA for nuclear parton densities,
bb limit, saturation etc.

deuterons@HERA lack 1-2 years, injector + source



At low x gluon is determined by $\ln Q^2$ derivative of F_2

This has been measured to rise with Q^2 which is not in conflict with DGLAP NLO analyses. More precision!



NNLO F_L IMPORTANT!

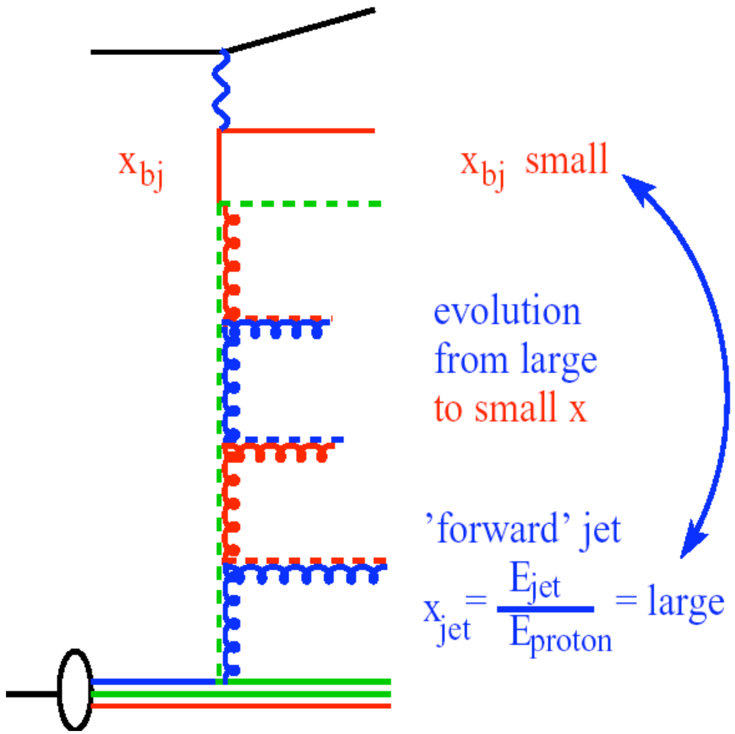
- Perturbative expansion of singlet-quark and gluon coefficient functions $c_{L,\mathrm{q}}$ and $c_{L,\mathrm{g}}$ for F_L with $n_f = 4$ and $\alpha_s(\mu^2) = 0.2$ (results divided by $a_\mathrm{s} = \alpha_\mathrm{s}/(4\pi)$)
- LO and NLO contributions remarkably small
- At small-x $c_{L,\mathrm{q}}$ and $c_{L,\mathrm{g}}$ dominated by NNLO term
- Leading small-x term at NNLO results $xc^{(3)}_{L,a} \sim \ln x$

S. Moch

Much more information (cf Forte) on low x theory and F_L presented to Workshop.

Not much time left to measure F_L at HERA in low E_p run(s).

Low x parton radiation: forward particle production (in p direction).



How are partons (gluons) emitted?

kt ordered

- DGLAP(Dokshitzer-Gribov-Lipatov-Altarelli-Parisi)
  DISENT/NLOJET

angular ordered

- CCFM(Ciafaloni-Catani-Fiorani-Marchesini)
  CASCADE

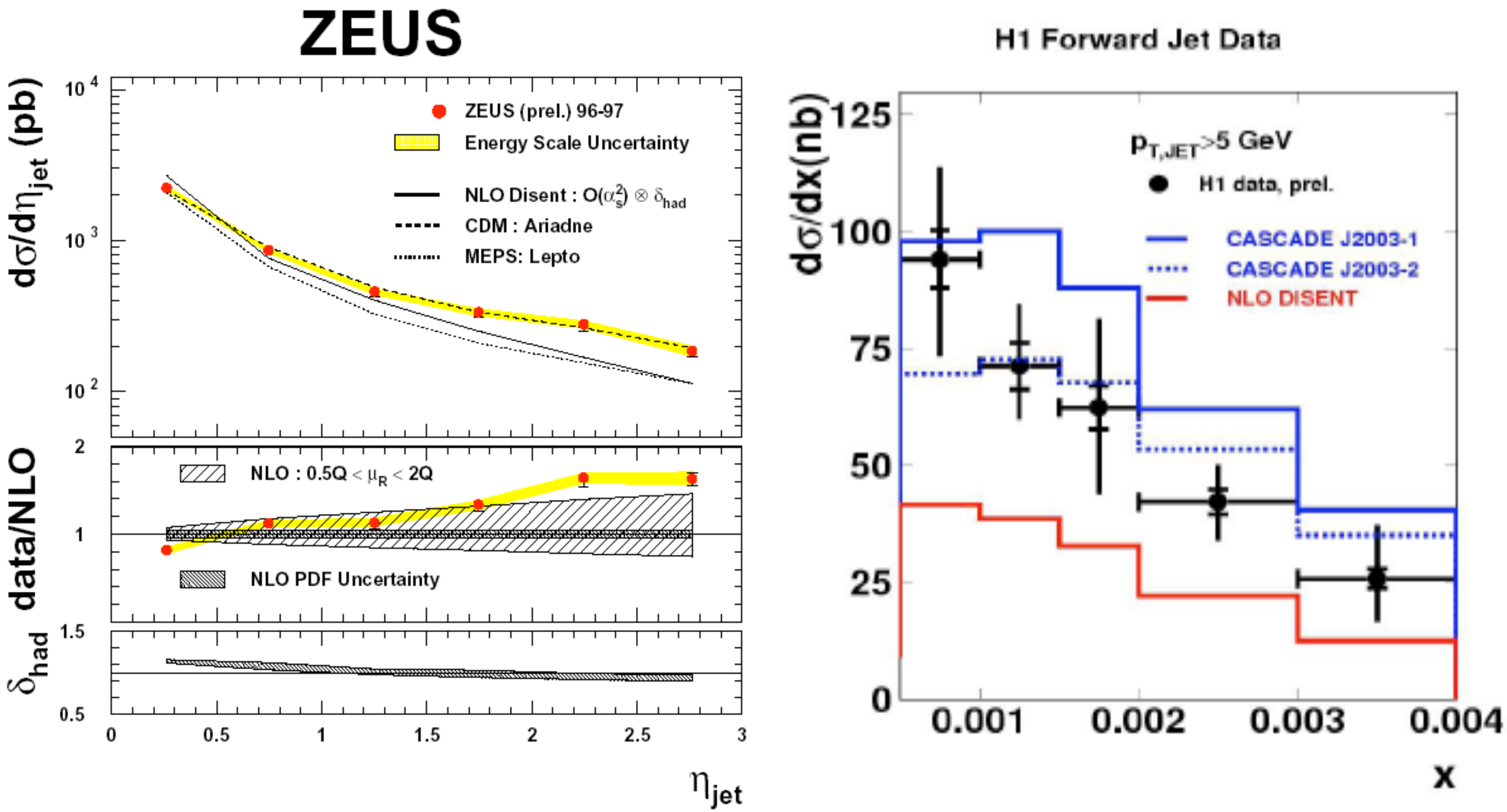
x ordered

- BFKL(Balitsky-Fadin-Kuraev-Lipatov)
  ARIADNE (colour dipole. random in kt)

$x_{jet} = E_{jet}/E_{proton} \gg x_{Bj}$ enhances BFKL effect

$E^2_{T,jet} \sim Q^2$ suppress DGLAP evolution

Forward jet production in deep inelastic scattering



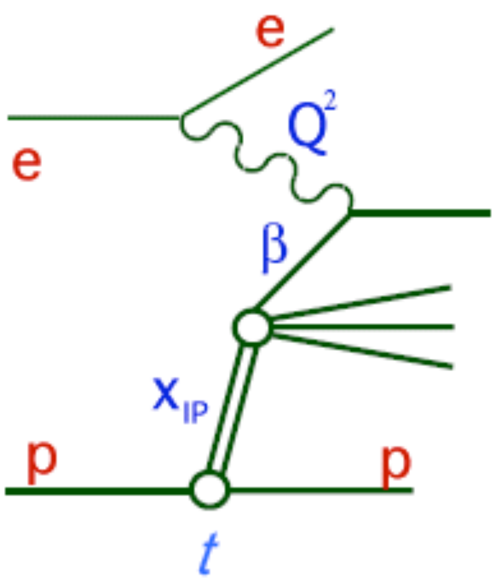
• Standard NLO pQCD prescription poor at lowest x for jets in forward direction where scale uncertainty is largest (higher orders? different radiation mechanism? best described by Ariadne – CDM – "BFKL like"). Cf also azimuthal decorrelation data

[note success of kt dependent ("unintegrated") parton distributions (CASCADE)]

Diffraction and Forward Physics

~10% of NC DIS events have gap between forward proton and central activity.

Measure gap or detect p with LPS/VFPS



- Why does the p sometimes remain intact?
- Understand nature of diffractive exchange
- Does diffraction affect proton PDF's?
- Is diffractive exchange universal, ep – pp?
- 2 g exchange → high gluon density – unitarity?
- Study an old phenomenon at hard scales!

•Could one use this to observe the Higgs @ LHC?
[cf M. Deile, next talk]

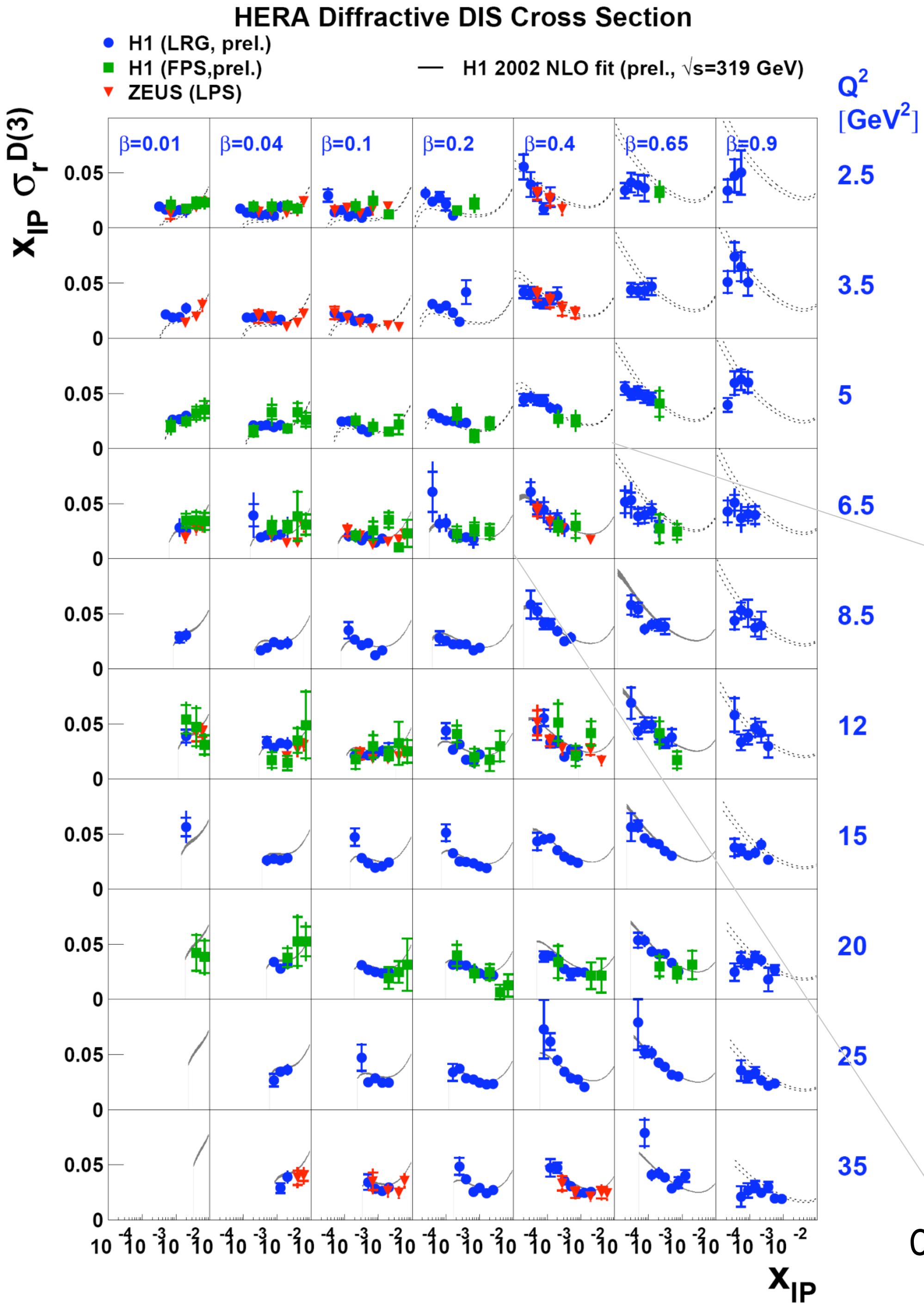
$$\frac{d\sigma_{diff}^{NC}}{dx_{IP}dtd\beta dQ^2} \propto \frac{1}{Q^4} F_2^{D(4)}(x_{IP},t,\beta,Q^2) \sim f(x_{IP},t)\cdot F_2^{IP}(\beta,Q^2)$$

Pomeron exchange,

2gluon exchange, dipols,

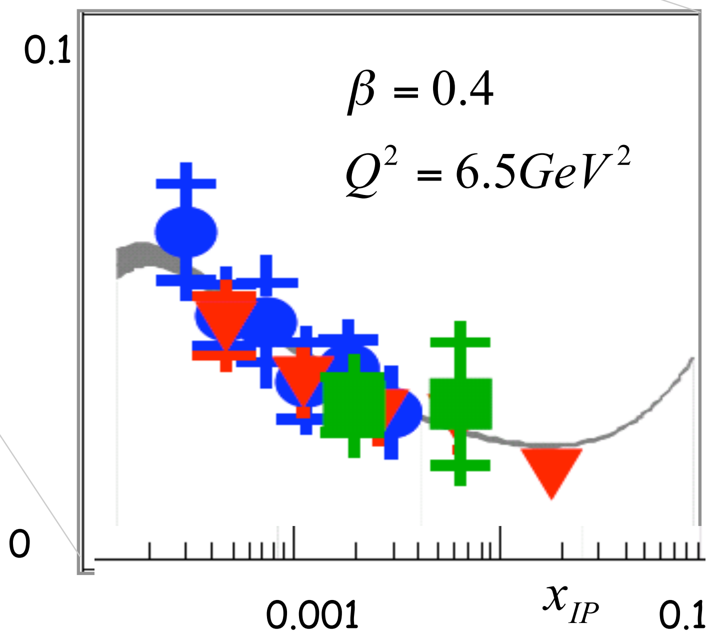
Soft colour ia's, rescattering

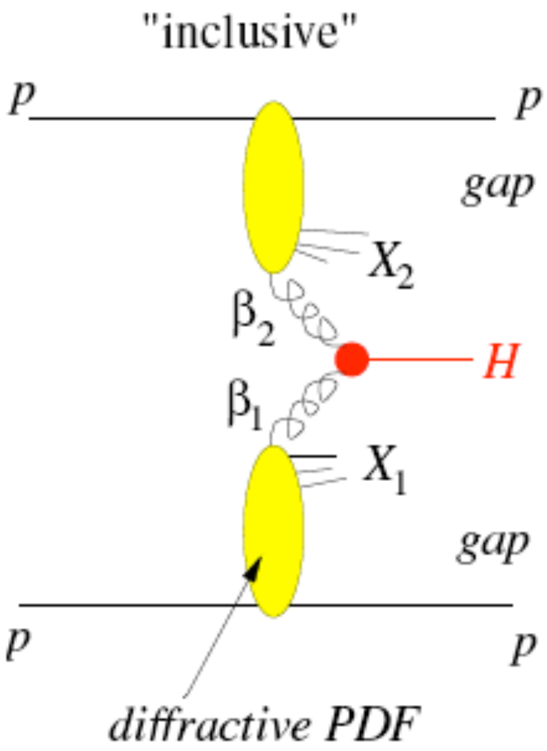
cf G. Ingelman ly 05

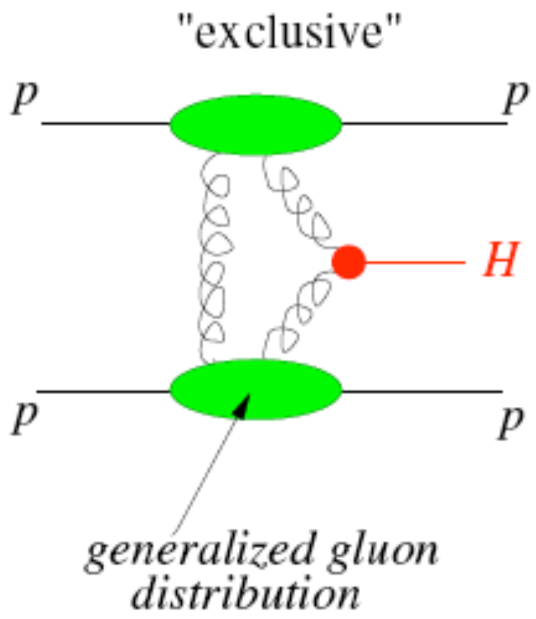


- New diffractive DIS data tagged with:
  - Large rapidity gap i.e. forward detector veto.
  - Tagged proton using Forward p Spectrometer FPS (H1) Leading p Spectrometer LPS (ZEUS)
- Good agreement between all data [M_X vs rapidity gap selection??]

$$x_{IP}\sigma_r^{D(3)} = x_{IP}[F_2^{D(3)} - f(y)F_L^{D(3)}]$$

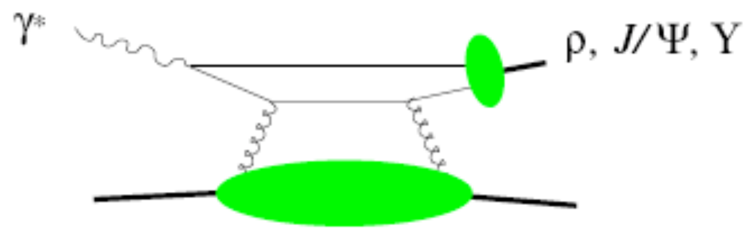






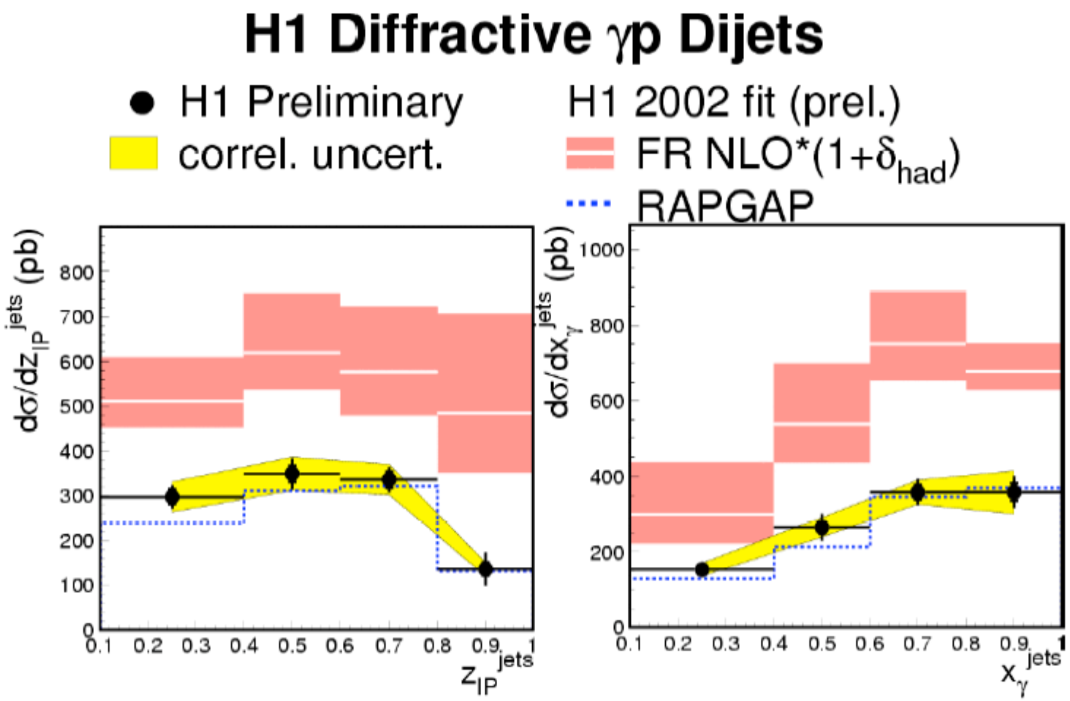
Diffractive Higgs at the LHC is more challenging (exp and thy) than the naïve diagram suggests. HERA: diffraction, factorisation (gap survival), GPD's, DVCS and vector meson production

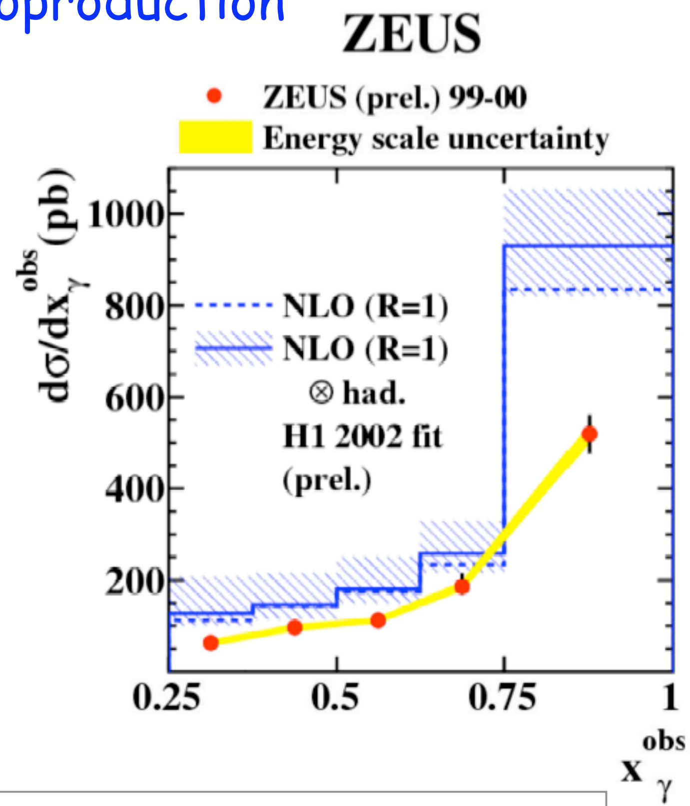
--> for more on pp see next talk

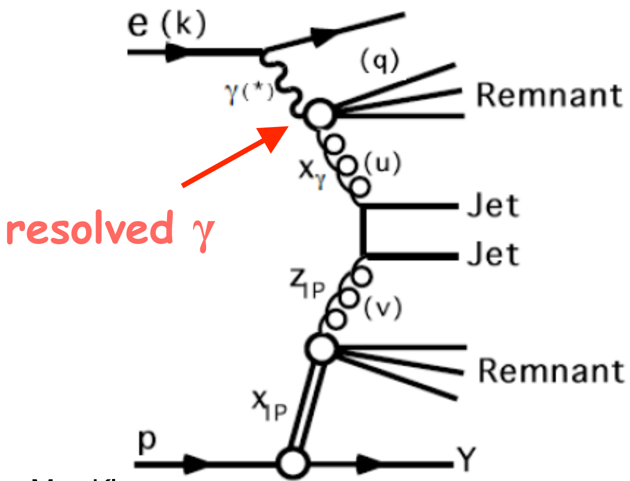


M. Diehl HERA LHC 3/05

Final states in diffractive photoproduction



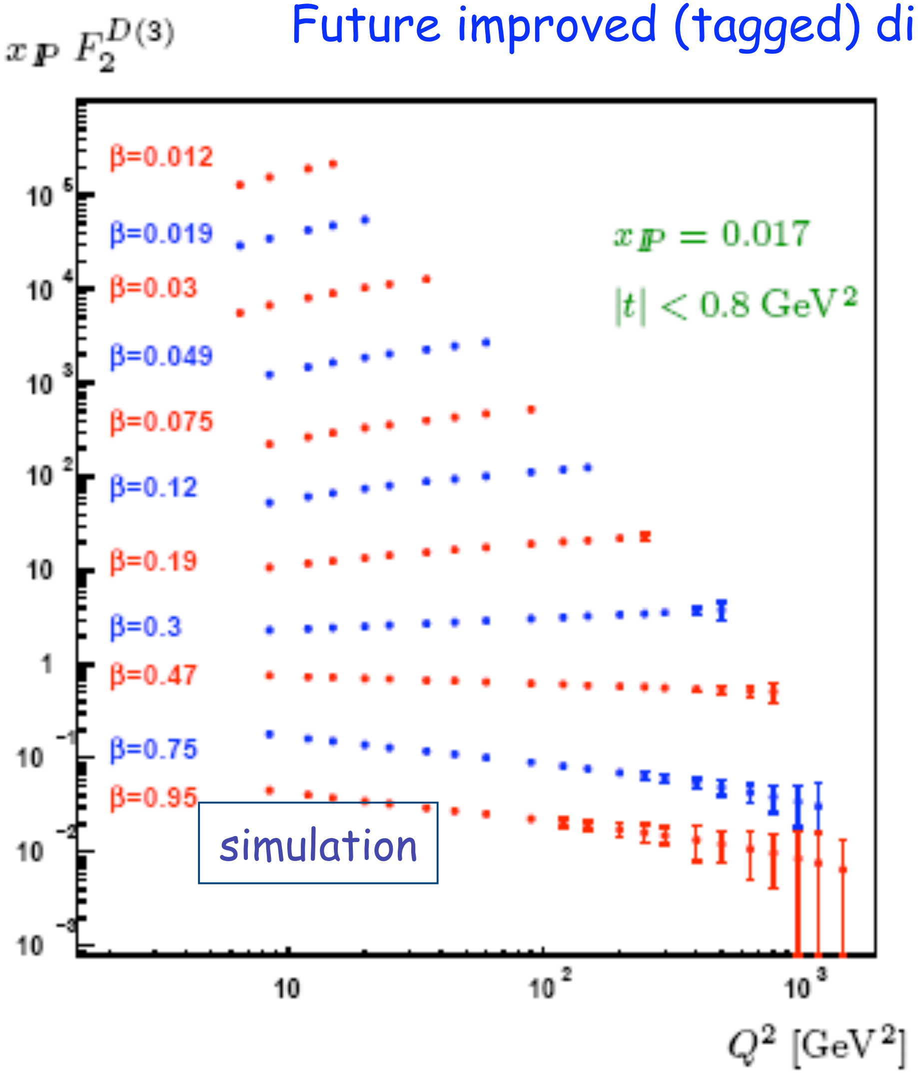




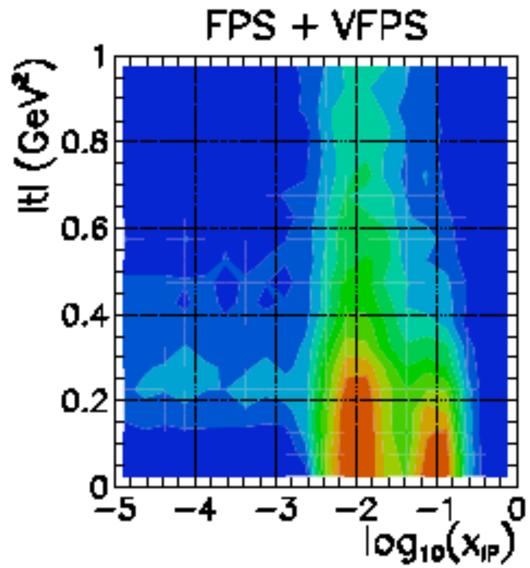
In photoproduction need factor of ~2 (prelim.) suppression of NLO theory to describe the data, both in the resolved region, which is similar to pp where a factor of ~10 is needed, and in the direct region which resembles DIS

Theory predicted suppression of only the resolved part

Future improved (tagged) diffractive measurements



$F_2^{D(4)}$ (Q^2, β, x_{IP}, t) ->
~5% stat error,



10^6 Events for $Q^2 > 5$ GeV^2

⟶ Study t dependence

⟶ $F_2^{D(4)}(Q^2, \beta, x_{I\!P}, t)$

Uncorrelated systematic errors can reach 2-3 %
(similar to F_2 precision)

⟶ Extract diffractive pdf's at fixed $x_{I\!P}$ and t and predict final states at same $x_{I\!P}$ and t to test factorization theorem

3. Medium x - Plateau: Precision pdf Determinations

Parton distribution functions
Strong coupling constant
Heavy Quark (c,b) measurements

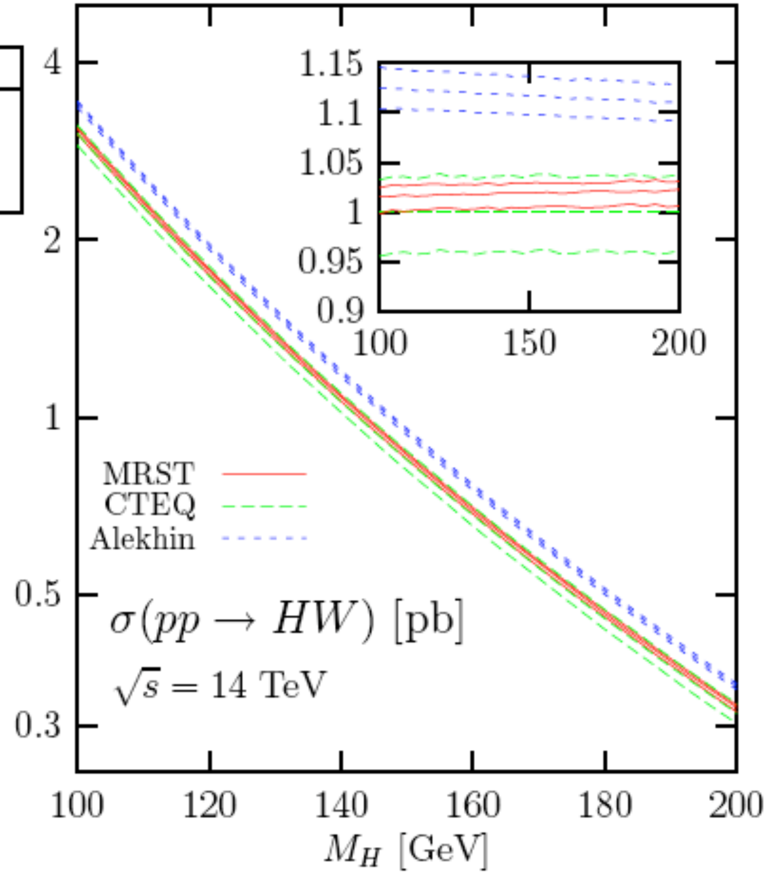
W PRODUCTION CROSS-SECTION TEVATRON

PDF SET	XSEC [NB]	PDF UNCERTAINTY
ALEKHIN	2.73	± 0.05 (TOT)
MRST2002	2.59	± 0.03 (EXPT)
CTEQ6	2.54	± 0.10 (EXPT)

THORNE

- ALEKHIN VS. MRST/CTEQ → W PRODUCTION XSECT AT TEVATRON DO NOT AGREE WITHIN RESPECTIVE ERRORS
- ALEKHIN VS. MRST/CTEQ → PREDICTIONS FOR ASSOCIATE HIGGS W PRODUCTION LHC DO NOT AGREE WITHIN RESPECTIVE ERRORS

HIGGS PRODUCTION AT LHC



DJOUADI AND FERRAG

S. Forte: HERA-LHC March 05

NC

$$\frac{d^2\sigma^{\pm}_{NC}}{dx\, dQ^2} = \frac{2\pi\alpha^2}{xQ^4}\, \phi^{\pm}_{NC}\, (1+\Delta^{\pm,weak}_{NC}),$$

with $$\phi^{\pm}_{NC} = Y_+\tilde{F}_2 \mp Y_- x\tilde{F}_3 - y^2\tilde{F}_L,$$

$$[F_2, F_2^{\gamma Z}, F_2^Z] = x\sum_q [e_q^2, 2e_q v_q, v_q^2 + a_q^2]\{q+\bar{q}\}$$

$$[xF_3^{\gamma Z}, xF_3^Z] = 2x\sum_q [e_q a_q, v_q a_q]\{q-\bar{q}\} \overset{?}{=} 2x\sum_{q=u,d}[e_q a_q, v_q a_q] q_v$$

below bottom threshold

$$xU = x(u+c)$$
$$x\overline{U} = x(\overline{u}+\overline{c})$$
$$xD = x(d+s)$$
$$x\overline{D} = x(\overline{d}+\overline{s})$$

$$xu_v = x\,(U-\overline{U}), \quad xd_v = x\,(D-\overline{D})$$

at HERA determine complete set of pdf's in single experiment(s) including c, b (s??) free of Ht and free of nuclear corrections

CC

$$\frac{d^2\sigma^{\pm}_{CC}}{dx\, dQ^2} = \frac{G_F^2}{2\pi x}\left[\frac{M_W^2}{Q^2+M_W^2}\right]^2 \phi^{\pm}_{CC}\,(1+\Delta^{\pm,weak}_{CC})$$

with $$\phi^{\pm}_{CC} = \frac{1}{2}(Y_+W_2^{\pm} \mp Y_- xW_3^{\pm} - y^2W_L^{\pm}),$$

$$W_2^+ = x(\overline{U}+D), \quad xW_3^+ = x(D-\overline{U})$$

$$W_2^- = x(U+\overline{D}), \quad xW_3^- = x(U-\overline{D})$$

$$\phi^+_{CC} = x\overline{U} + (1-y)^2 xD, \quad \phi^-_{CC} = xU + (1-y)^2 x\overline{D}$$

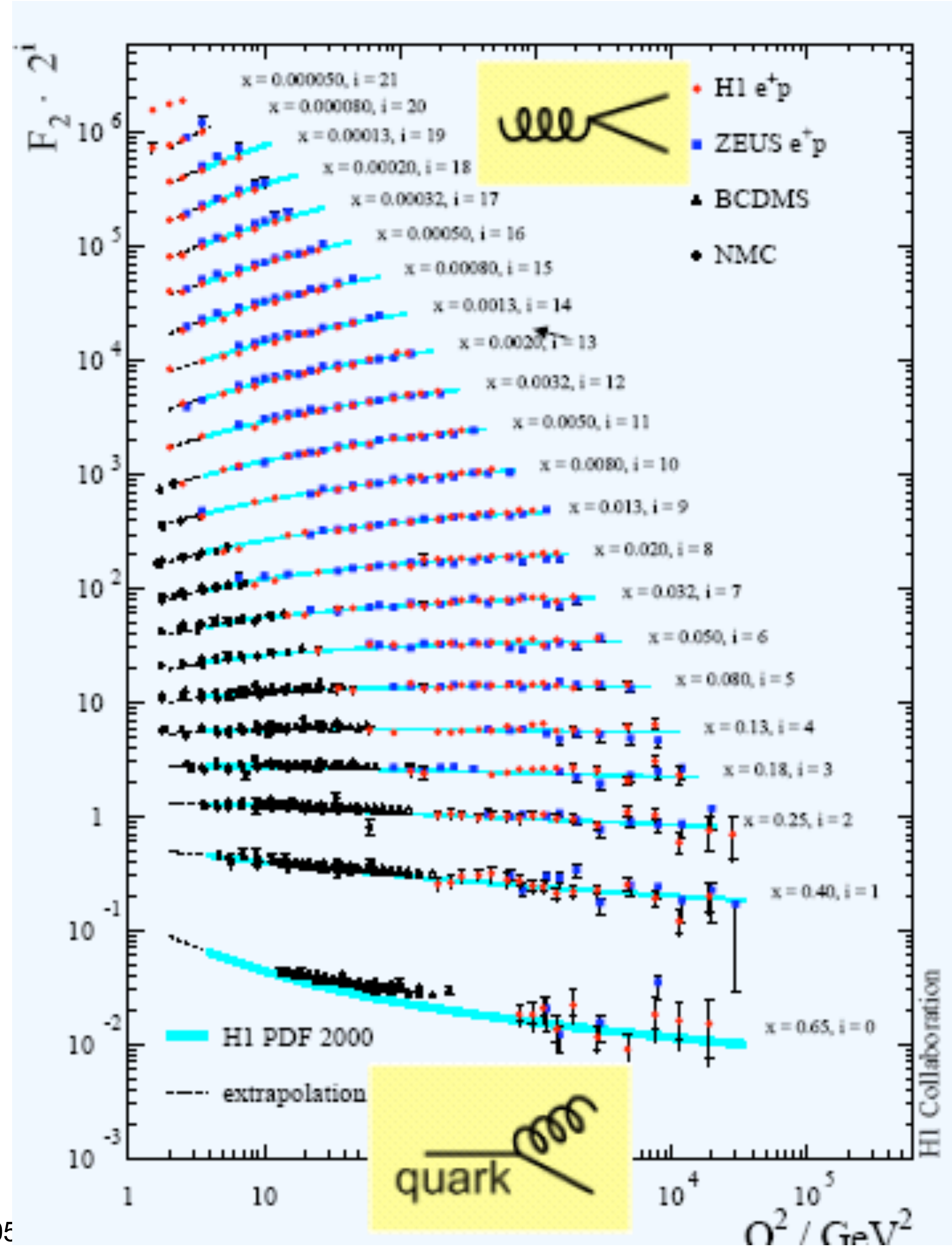
HERA data generally well described by NLO QCD

$$\frac{\partial F_2}{\partial \ln Q^2} \propto \alpha_s(Q^2) xg(x,Q^2)$$

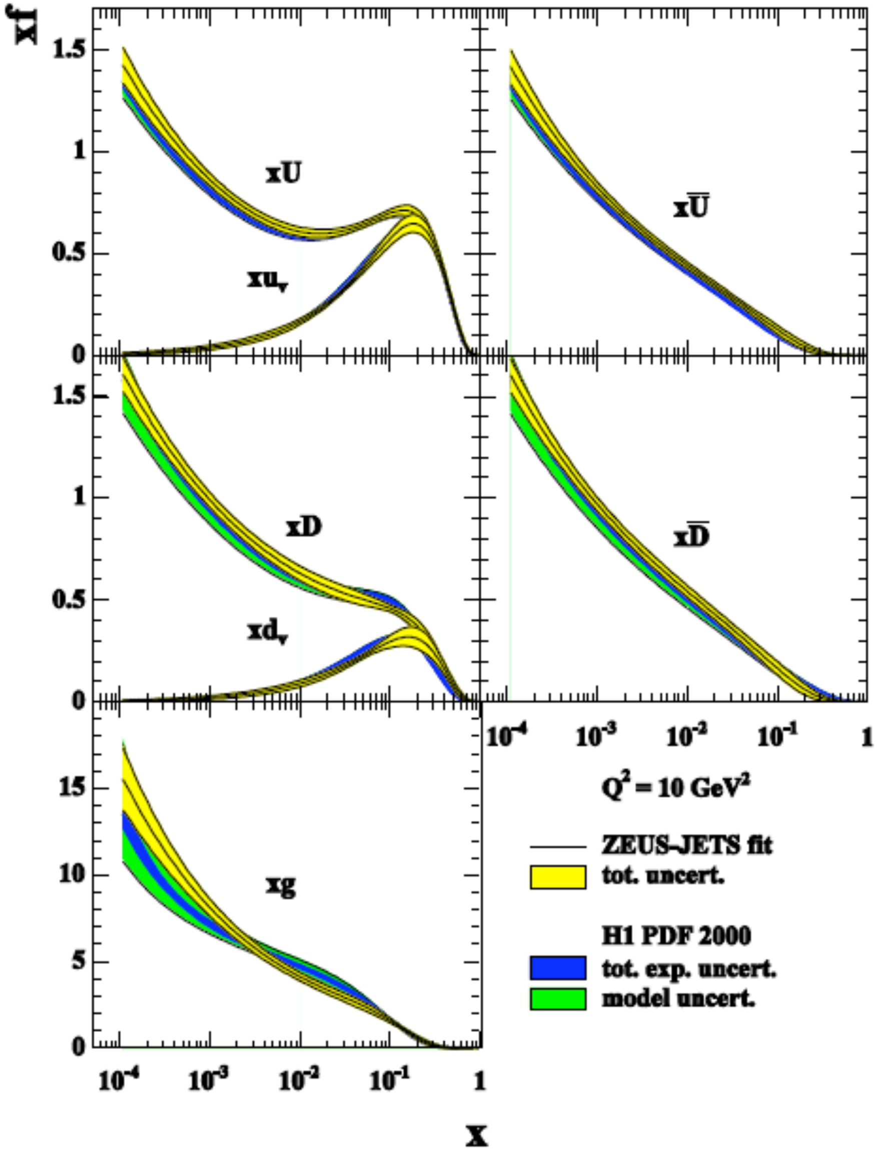
resolve correlation
of coupling and gluon
by accessing wide
range of x and Q^2

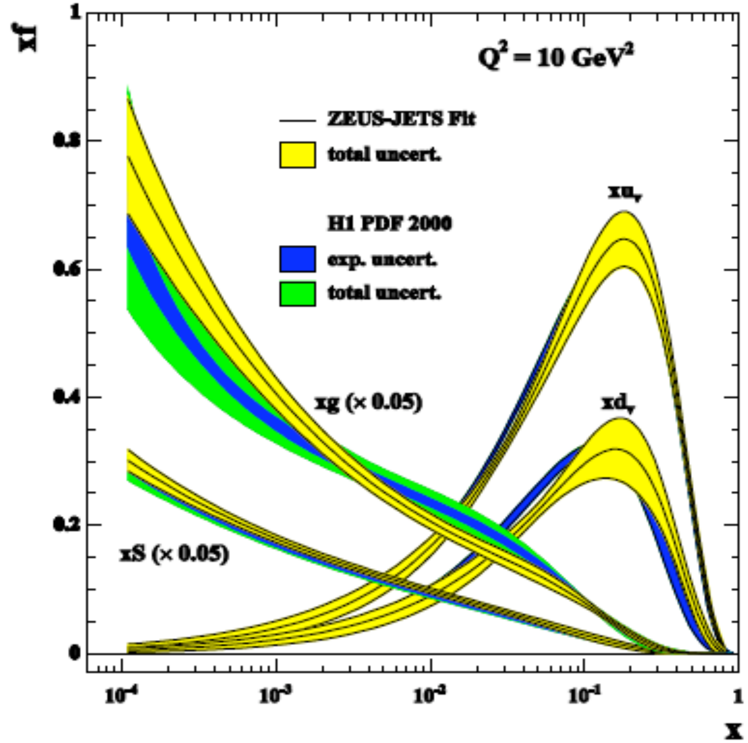
mostly assume DGLAP evolution
although that neglects ln(1/x)

$$\frac{\partial F_2}{\partial \ln Q^2} \propto \alpha_s(Q^2) q(x,Q^2)$$



Status of NLO pdf's from HERA

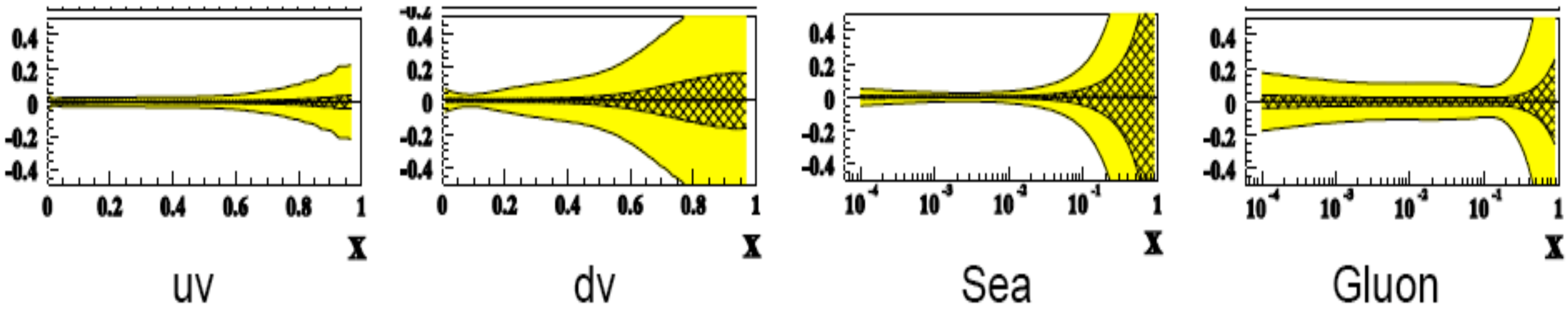




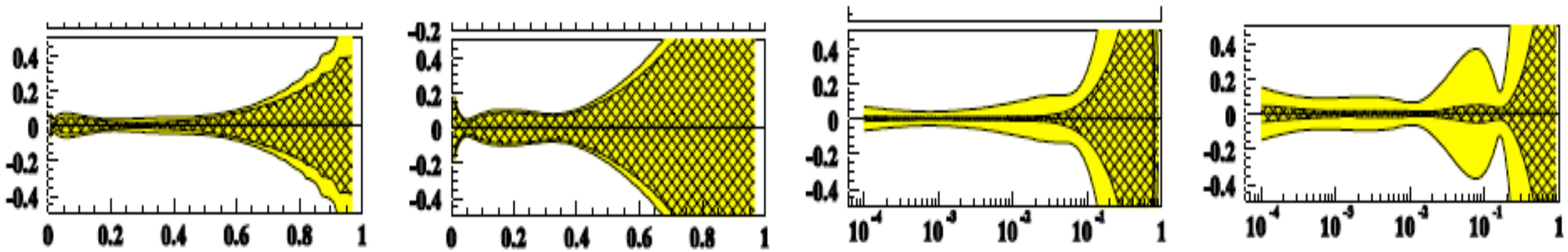
exp uncertainties of H1 pdfs based on HERA I data using Lagrange method for fit:

x	0.01	0.4	0.65
xU	1%	3%	7%
xD	2%	10%	30%

Compare the uncertainties for uv, dv, Sea and glue in a global fit to DIS data



Compare the uncertainties for uv, dv, Sea and glue in a fit to ZEUS data alone

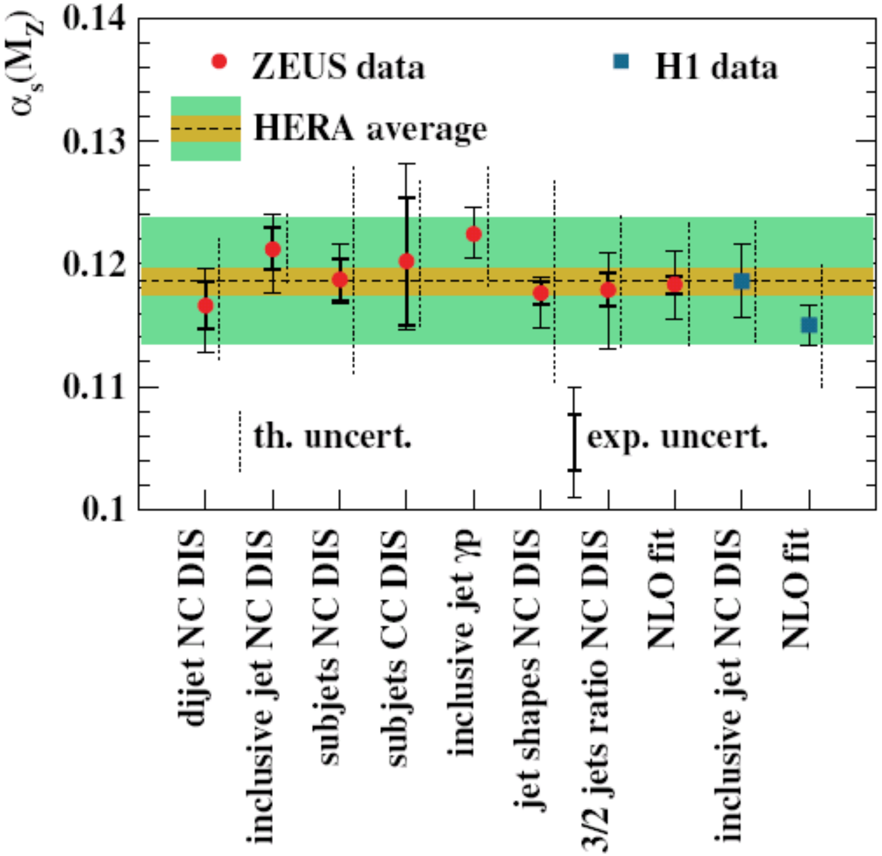


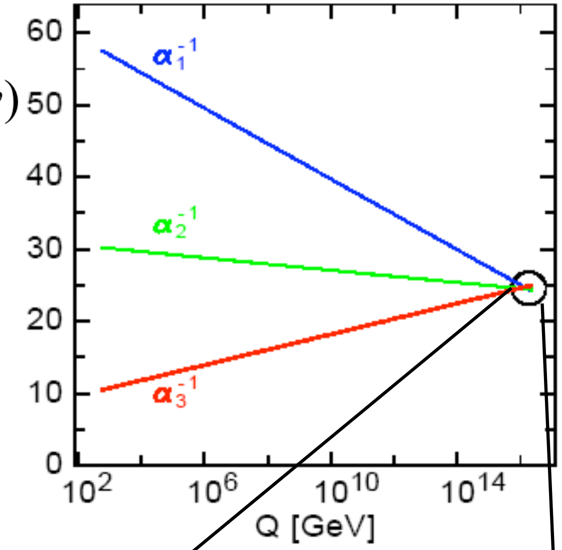
M. Cooper Sarkar HERA LHC 3/05

HERA can determine full pdf set with controlled systematics.
Great potential but serious challenge (data, analysis, NNLO…)

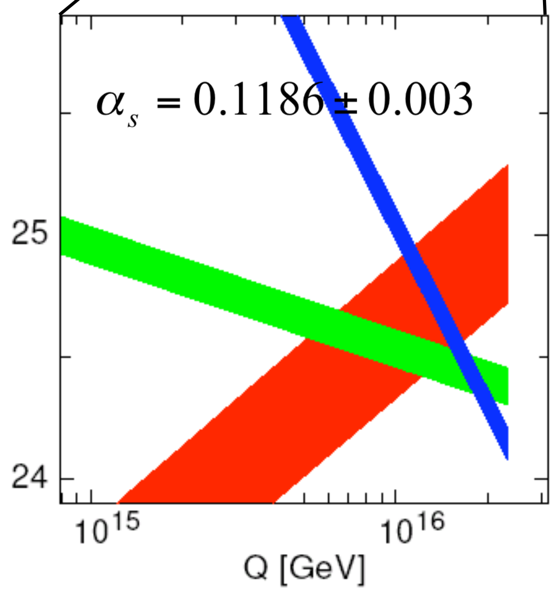
HERA may determine strong coupling best

$$HERA(prel.) - \alpha_s(M_Z^2) = 0.1186 \pm 0.0011(\exp) \pm 0.005(thy)$$





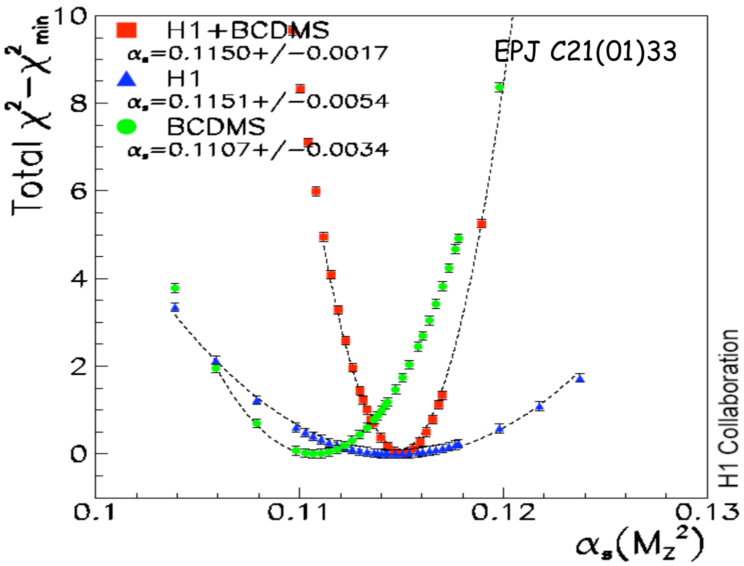
Unification??

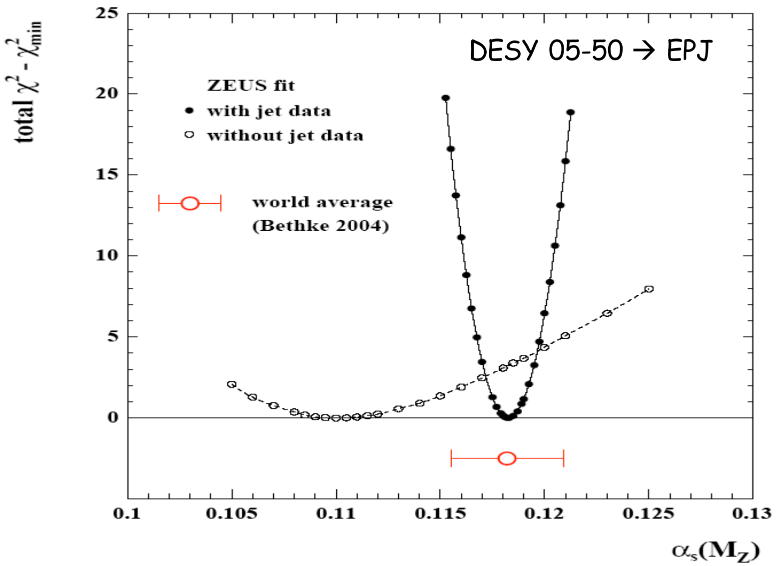


The theory 'error' is ad hoc and calls for NNLO

hep-ph/0407067 B.Allanach ... P.Zerwas

Is the strong coupling constant smaller in inclusive DIS than in jets?





- Strong improvement observed from using ep jet data [dijets in direct photoproduction]

- More and more accurate data (luminosity, instrumentation, analyses of data and of all uncertainties (HQ, low x, ..)

- Will take years to answer and also determine pdf's better.

- Deuterons would disentangle nonsinglet – singlet evolution and halve alpha_s error

The bottom quark can enter, in the form of a PDF, a number of interesting processes:

Process	Interest	Accuracy
single-top t-channel	SM, top EW couplings and polarization, Vtb. Anomalous couplings.	NLO
single-top + W		NLO
Wbj	SM, bkg to single top	(NLO)
gamma+b	SM, SUSY bkg, b-pdf	NLO
Z+b		NLO
inclusive h,A	SUSY discovery/ measurements at large tan(beta)	NNLO
h,A+b		NLO
H^+ + t	SUSY discovery, couplings	NLO

A. Tonazzo Study in ATLAS. (← Z+b)

Standard processes

Searches (discoveries?)

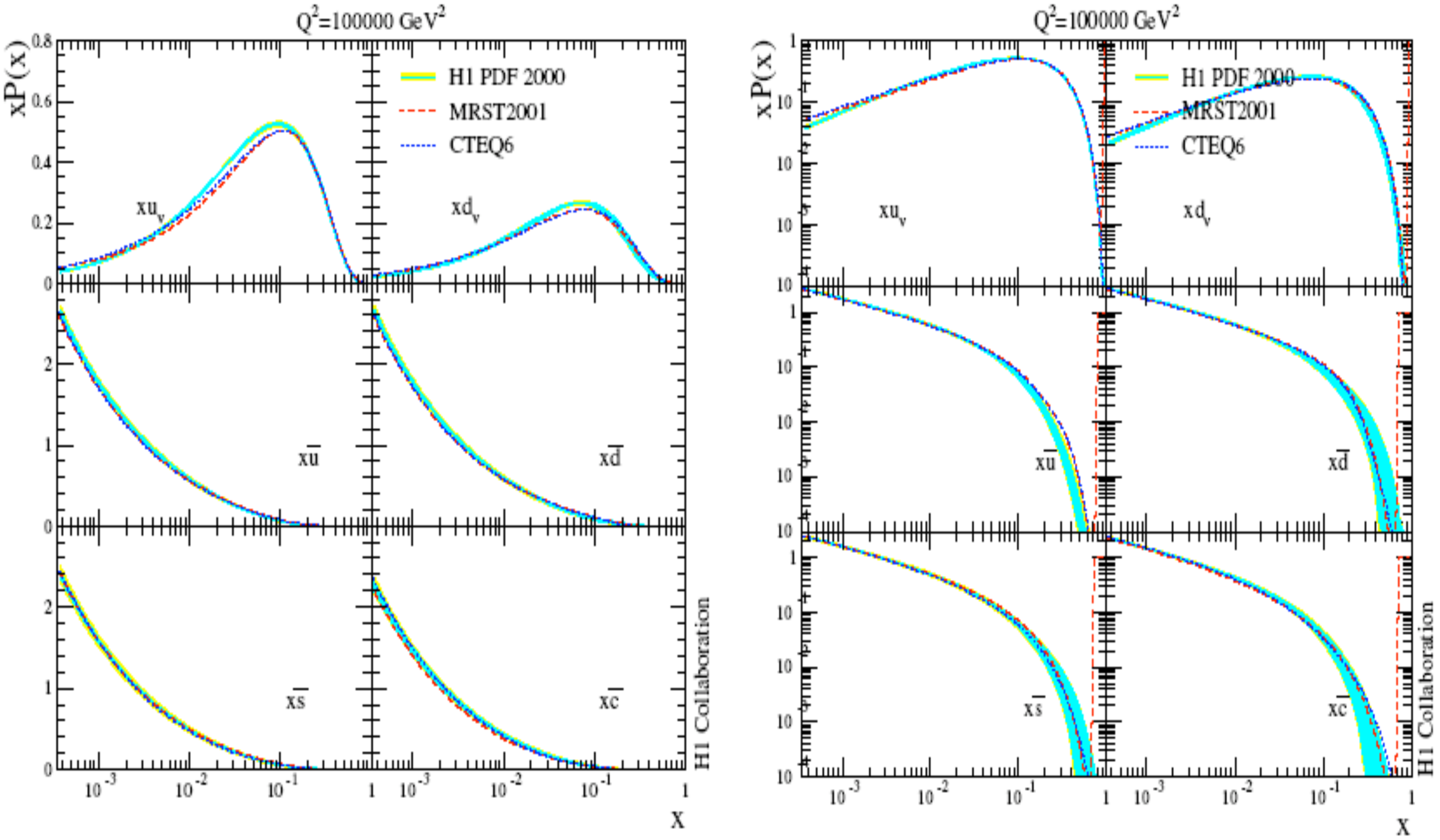
F. Maltoni

b is 5% of pp to Z

thus <20% accuracy required for 1% accurate cross section

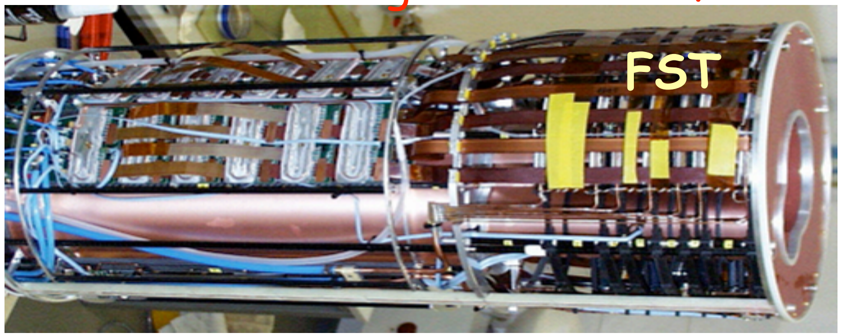
M. Cacciari HERA LHC March 05

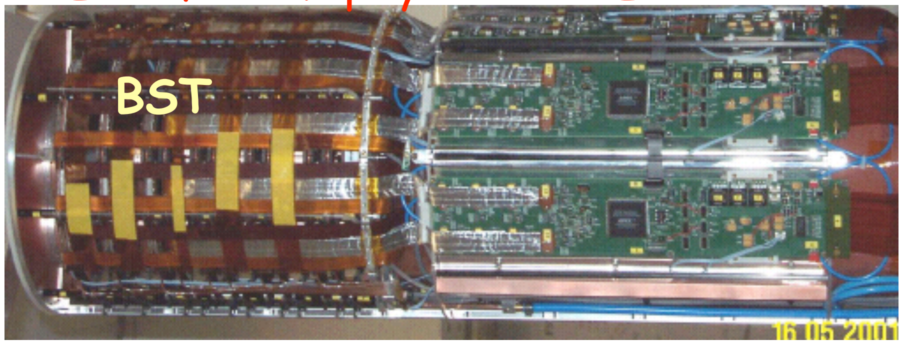
pdfs extrapolated to LHC



at very high Q^2 heavy quark distributions are of size comparable to light sea quarks

New tracking detectors of H1 and ZEUS for HF physics in HERA II



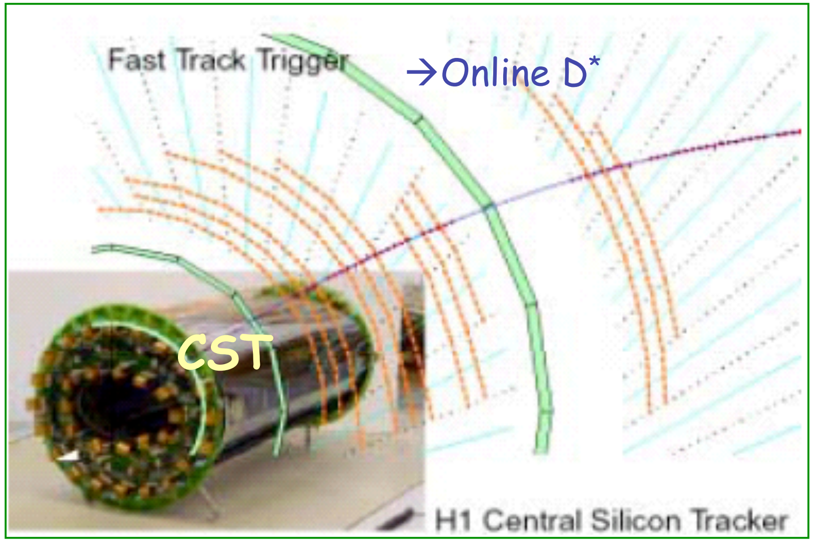


charm and beauty

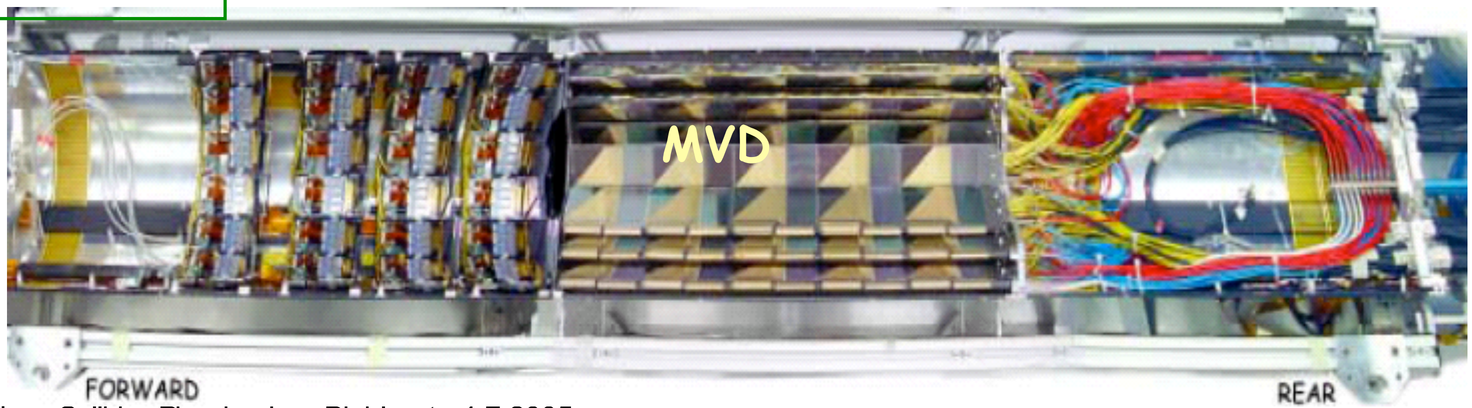
evt vtx (lo and hi y)

eID (DVCS, J/Ψ,
searches)

F_L

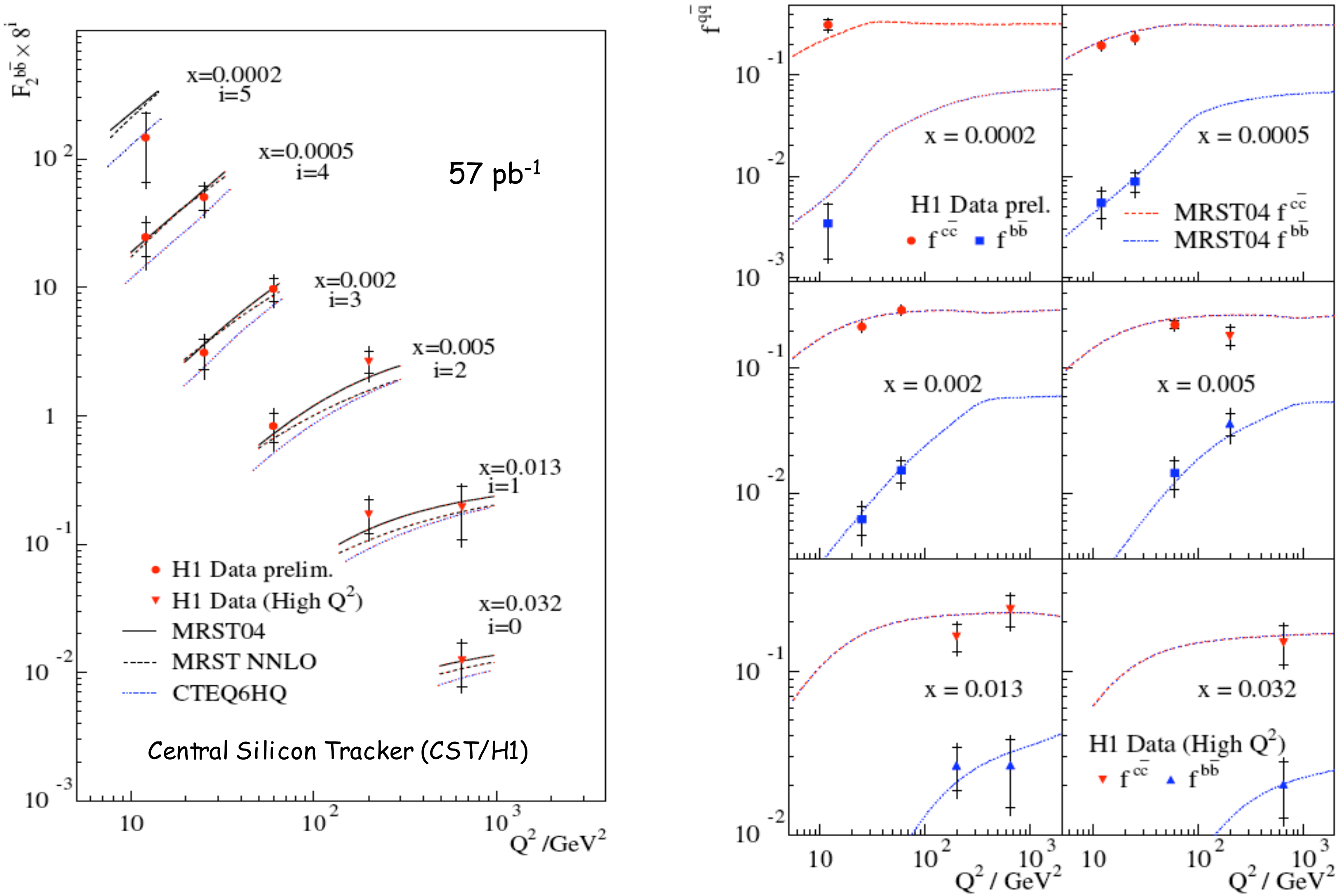


Huge investments for high lumi phase by H1 and ZEUS & fwd chambers

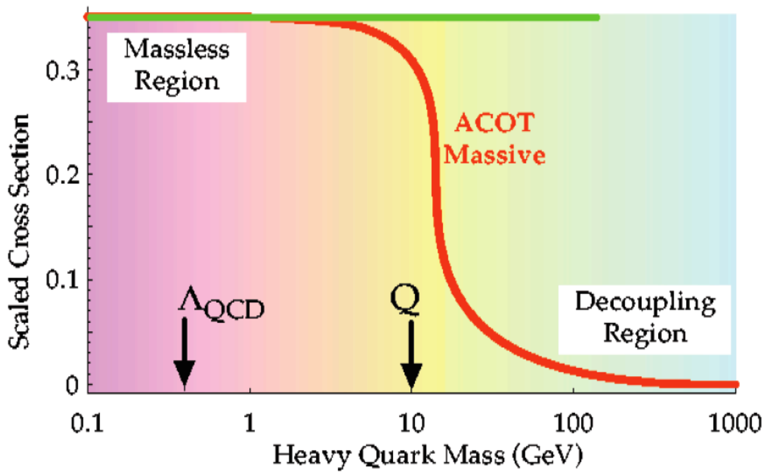


The first measurements of F_2^b using lifetime information.

Small fraction of cross section. Beauty in pt(rel) and μ still above NLO QCD (HVQDIS).

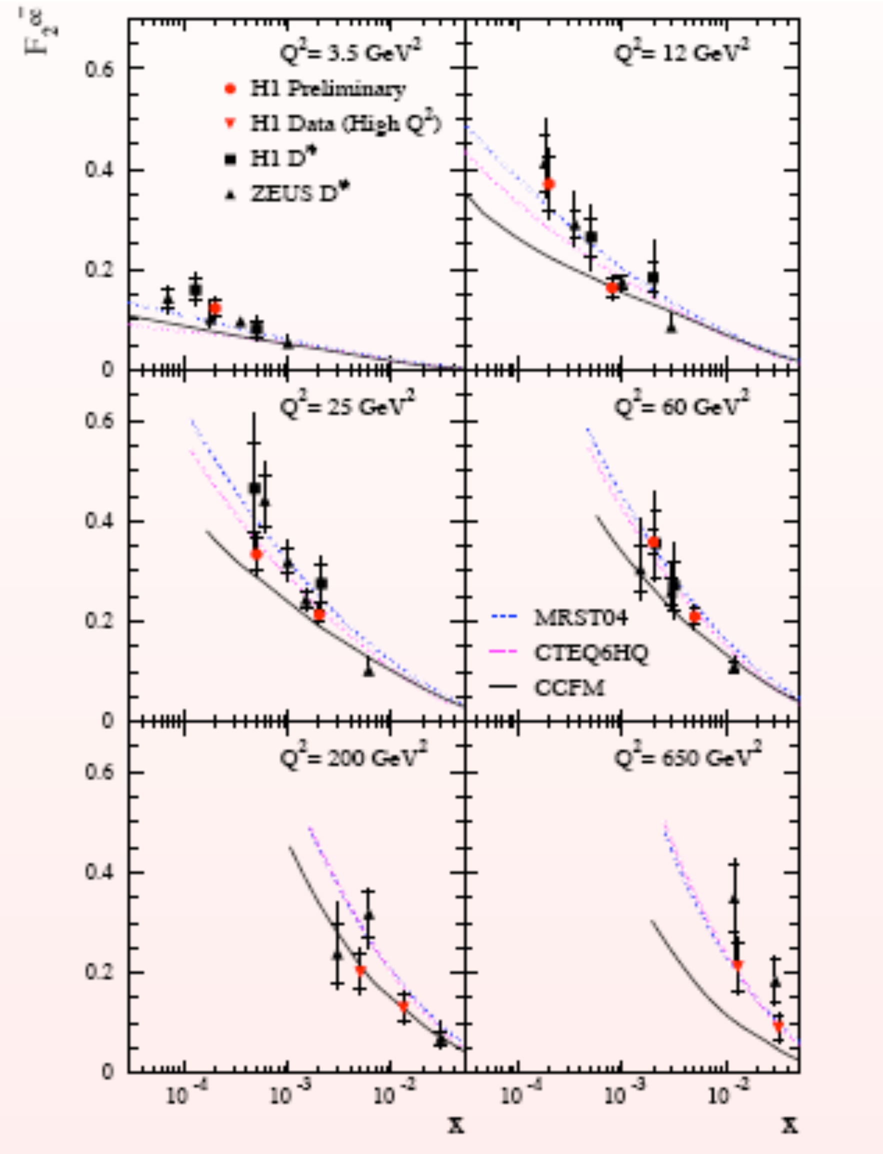


Charm lifetime measurement data consistent with D* (ZEUS and H1).



Fred Olness DIS05 Madison

Need too measure c and b over wide range of Q^2 to study theory of HQ at high orders and provide reliable prediction for LHC kinematic range.



100 MeV sensitivity to charm mass in charm reactions and inclusive DIS

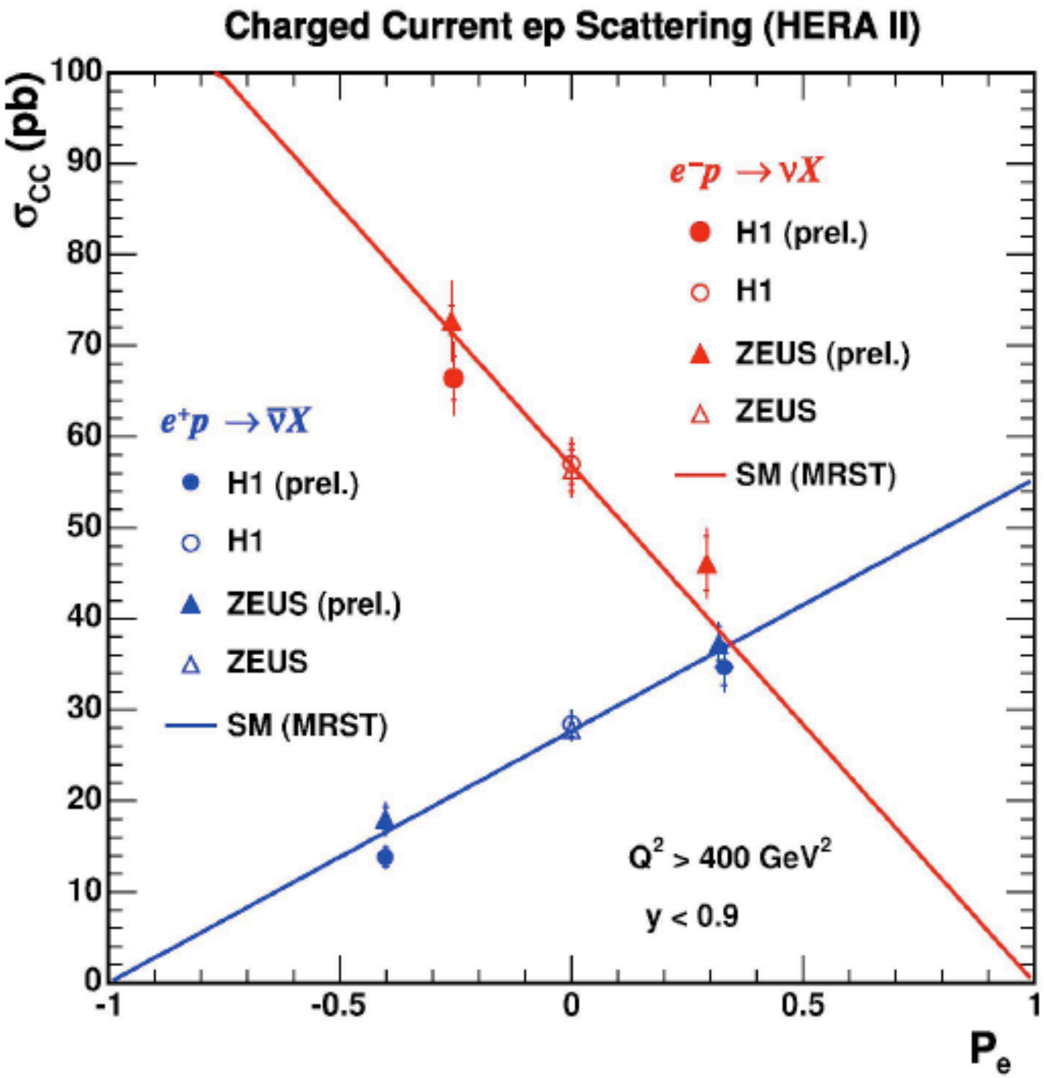
4. Ongoing Developments

There are many more than I can mention next:

Simulations, MC@NLO for ep, diffractive pdf's,
Jet physics, HQ fragmentation, vector mesons,...
H1 and ZEUS submitted 90 papers to EPS05

Left out searches, generic and dedicated
for LQ, Rp violating SUSY, light gluino, monopoles

No time for pentaquarks or peculiar events
(multileptons and events with isolated leptons
and missing transverse momentum)

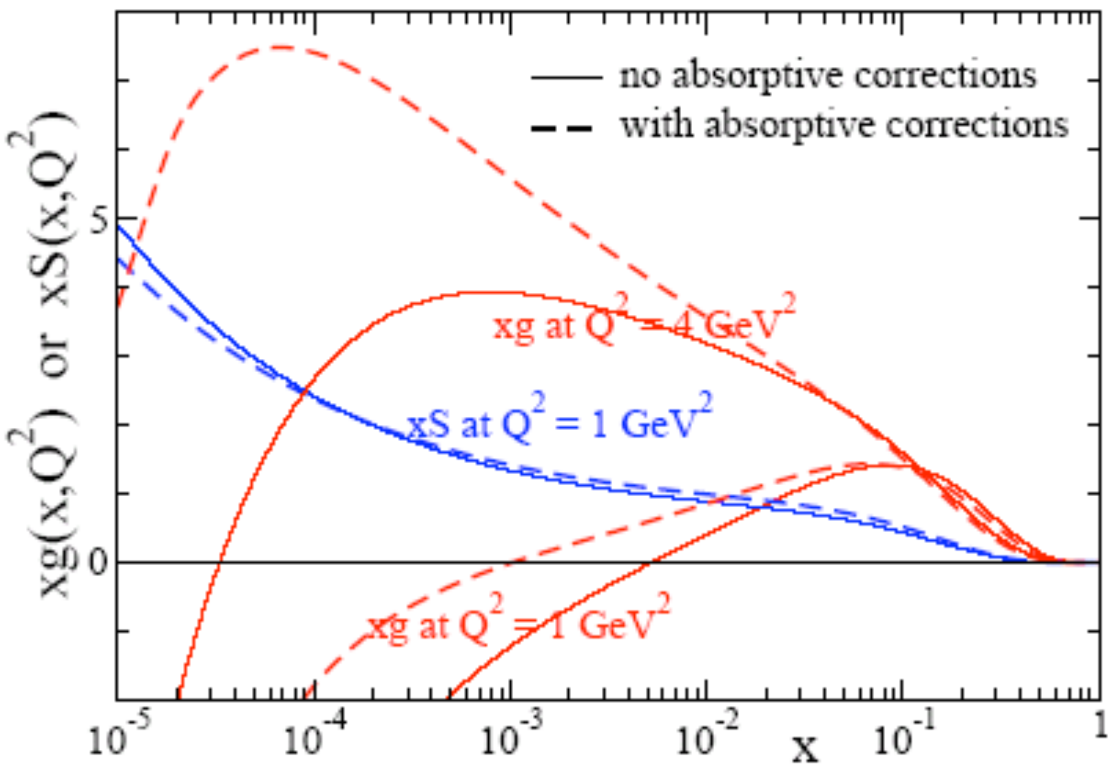


First cross section measurements (polarised CC) including 2005 data: HERA runs

How diffraction has to be treated is not really clarified yet

Ignored (inclusive scattering)? As an absorptive correction?

→ gluon distribution depends on theory, is not observed directly



?

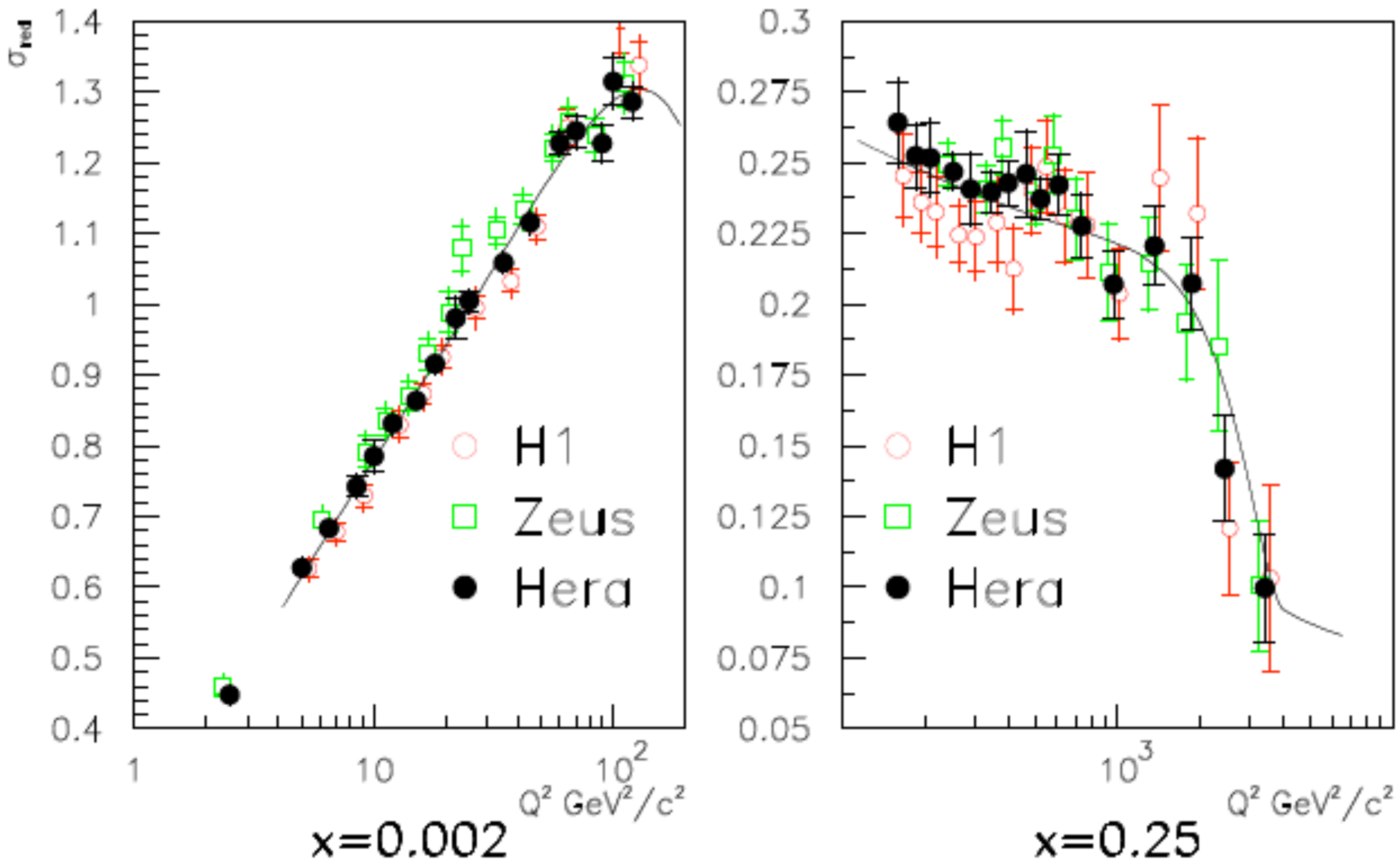
more accurate diffractive data from HERA II.

extra info on gluon, charm, F_L

• Martin, Ryskin, Watt: absorptive corrections to F_2. analysis of F_2 and F_2^D → xg ??

note that without absorptive correction xg also differs from H1/ZEUS gluons!

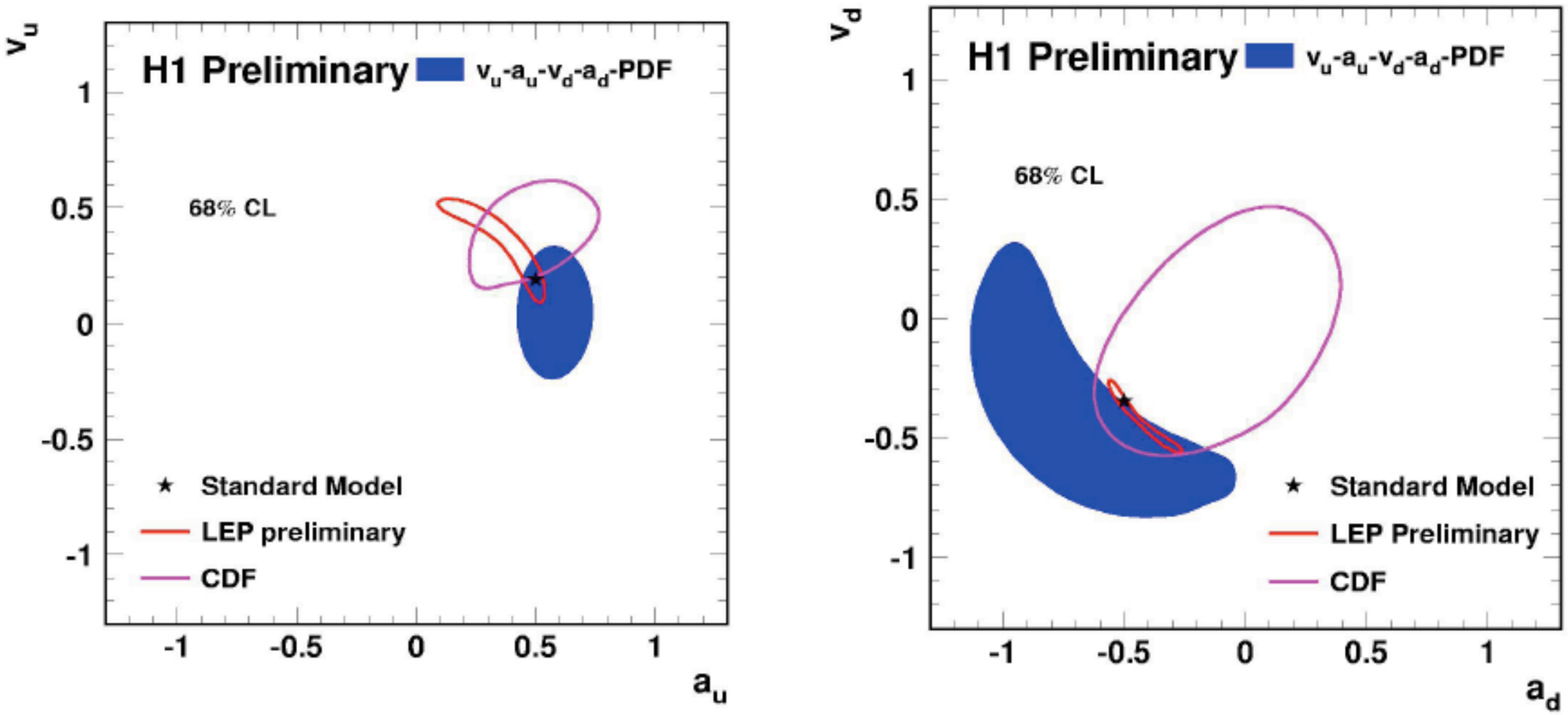
New approach to obtain average NC and CC data from H1 and ZEUS with improved precision (~2 times) by considering systematics.



Cross calibration of H1 - ZEUS
Lar - Spacal - U/Sc, trackers ..
A. Glazov HERA LHC workshop

Determination of light quark couplings to Z boson from LEP, CDF, H1

HERA has entered "new", electroweak, territory in QCD&electroweak analysis (HERA I so far)



Second solution for LEP data not shown

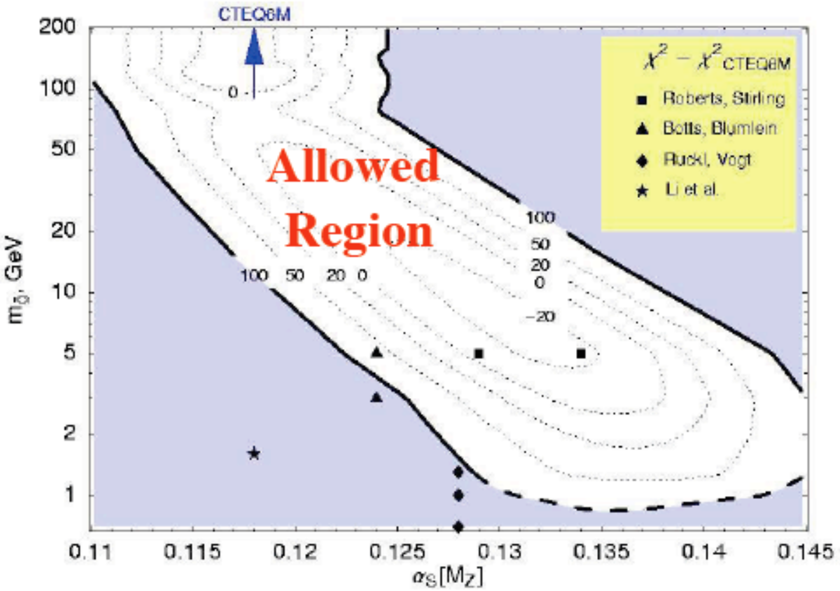
Inclusion of new strongly interacting particles *(e.g., gluino)* affect PDF's at higher scales.

Bulk of PDF constraints are at low Q scales

Strong correlation between α_s gluino (and gluon)

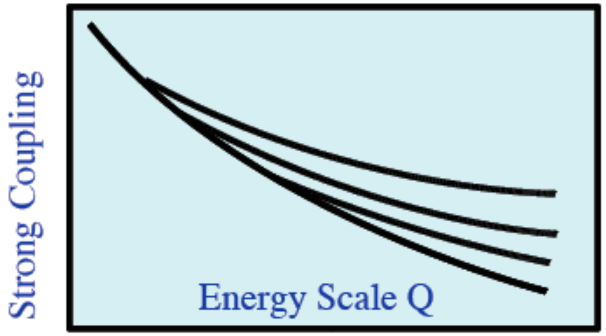
Will affect gluon production of Higgs

SUSY Gluino Mass Parameter



Strong Coupling Constant

Running of $\alpha_s(Q)$ with thresholds

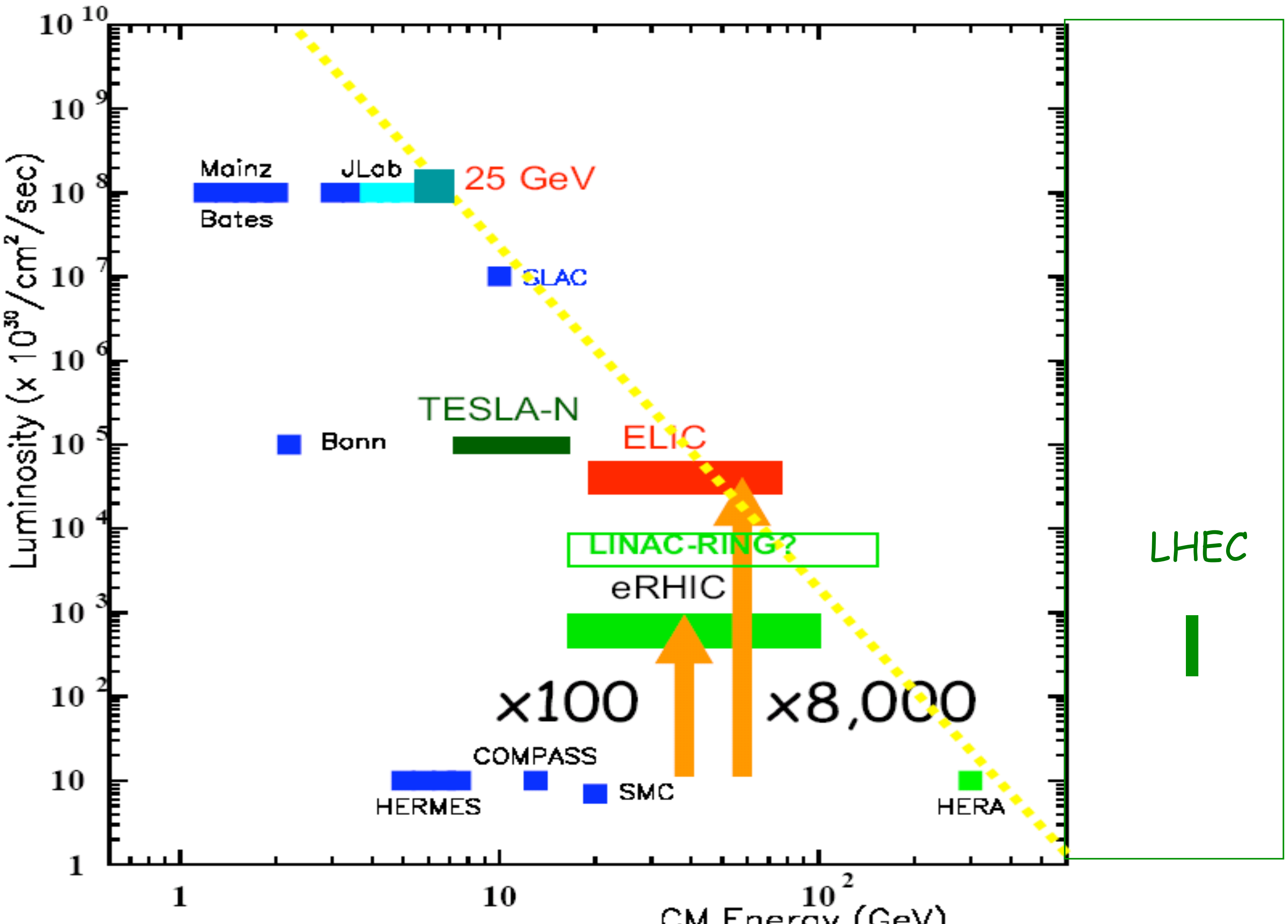


New thresholds can significantly alter PDF's at large Q

E. L. Berger, P. M. Nadolsky, F. I. Olness and J. Pumplin. Phys.Rev.D71:014007,2005

F. Olness DIS05 Madison

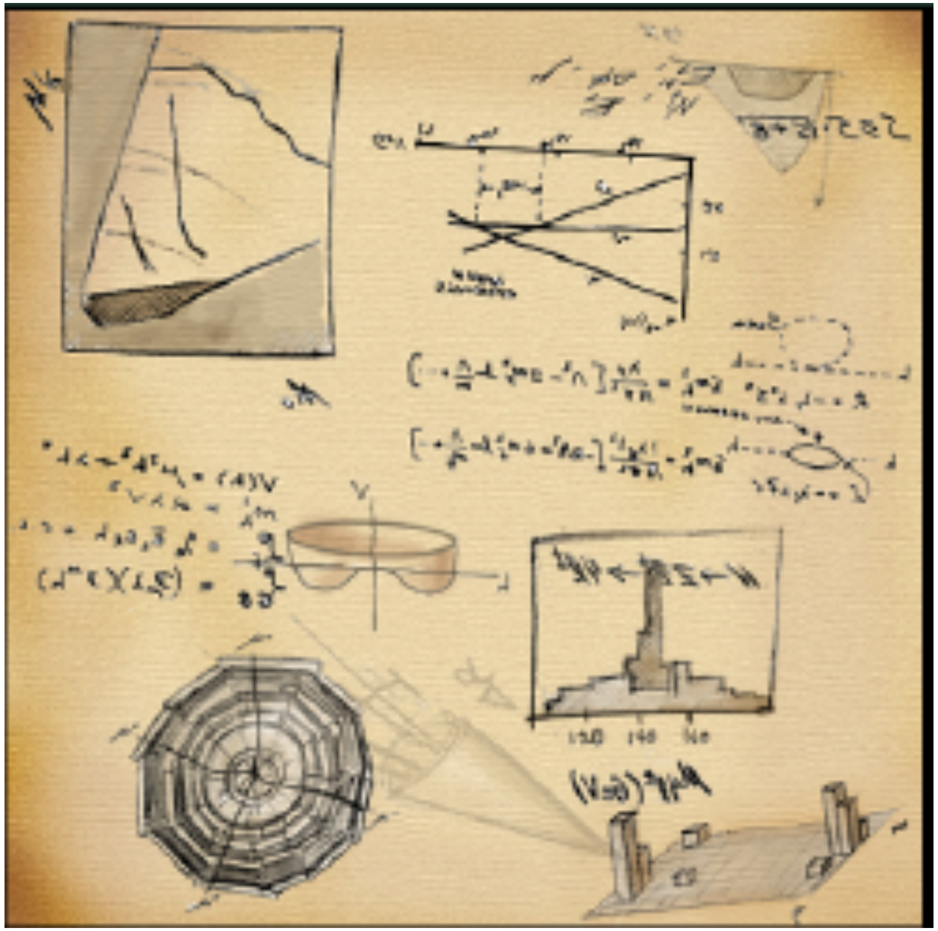
Lepton nucleon scattering - machines and visions



C. Keppel DIS 05

cf M.K. DIS05
F.Willeke, JBD

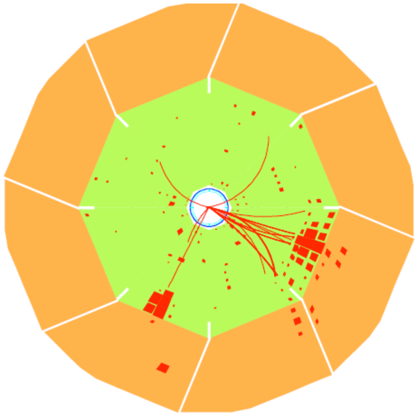
Physics with HERA will be of much use

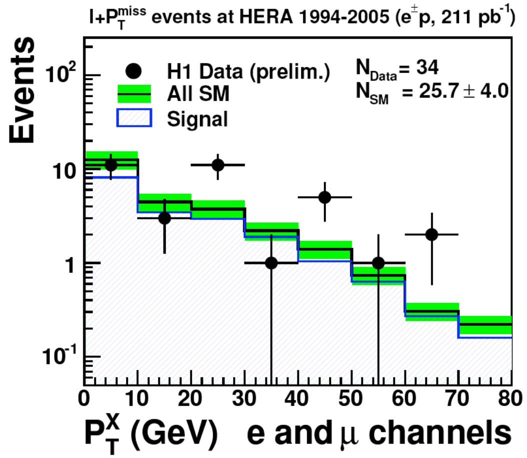


when the physics at the LHC becomes real.

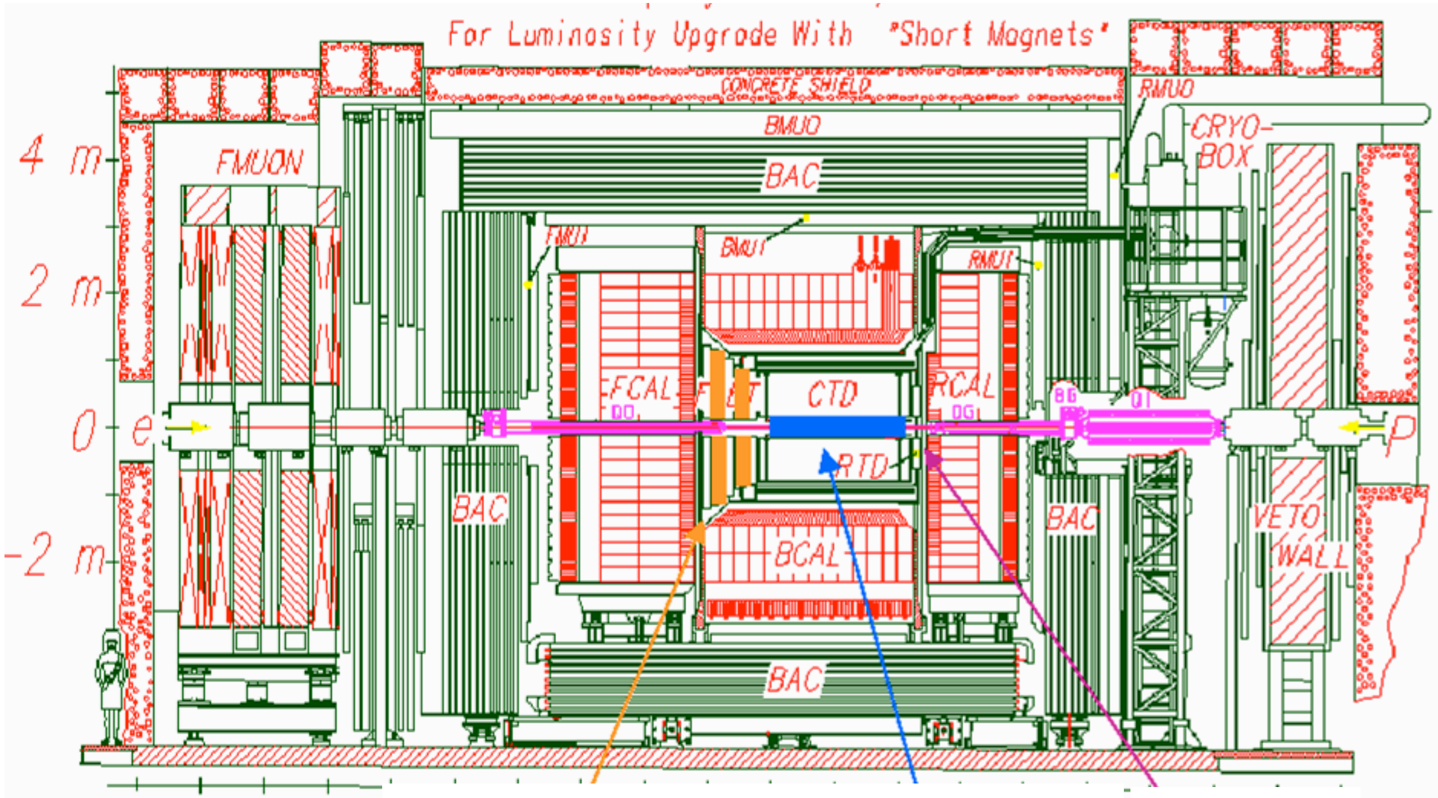
Backup slides

Events with isolated leptons and missing transverse momentum





	electron		muon		tau new	
	all	p_T^X>25GeV	all	p_T^X>25GeV	all	p_T^X>25GeV
H1 HERA I 118 pb^{-1}	11 11.54±1.50	5 1.76±0.30	8 2.94±0.50	6 1.68±0.30	5 5.8±1.36	0 0.53±0.10
H1 e$^+$p 53 pb^{-1} new	9 4.75±0.76	5 0.84±0.19	1 1.33±0.19	0 0.85±0.13		
H1 e$^-$p 39 pb^{-1} new	5 4.09±0.61	1 0.62±0.11	0 1.10±0.17	0 0.67±0.11		
ZEUS HERA I 130 pb^{-1}	24 $20.6^{+1.7}_{-4.6}$	2 $2.90^{+0.59}_{-0.32}$	12 $11.9^{+0.6}_{-0.7}$	5 2.75±0.21	3 $0.40^{+0.12}_{-0.13}$	2 0.20±0.05
ZEUS e$^+$p 40 pb^{-1} new	0 0.46±0.10	0 $0.58^{+0.08}_{-0.09}$				

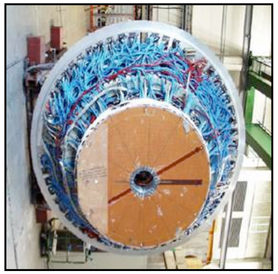


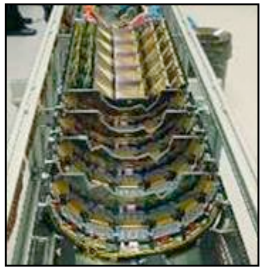
Straw Tube Forward Tracker

Micro Vertex Detector

Beam Pipe Magnets

Luminosity spectrometer





ZEUS

350 authors

~35 institutes

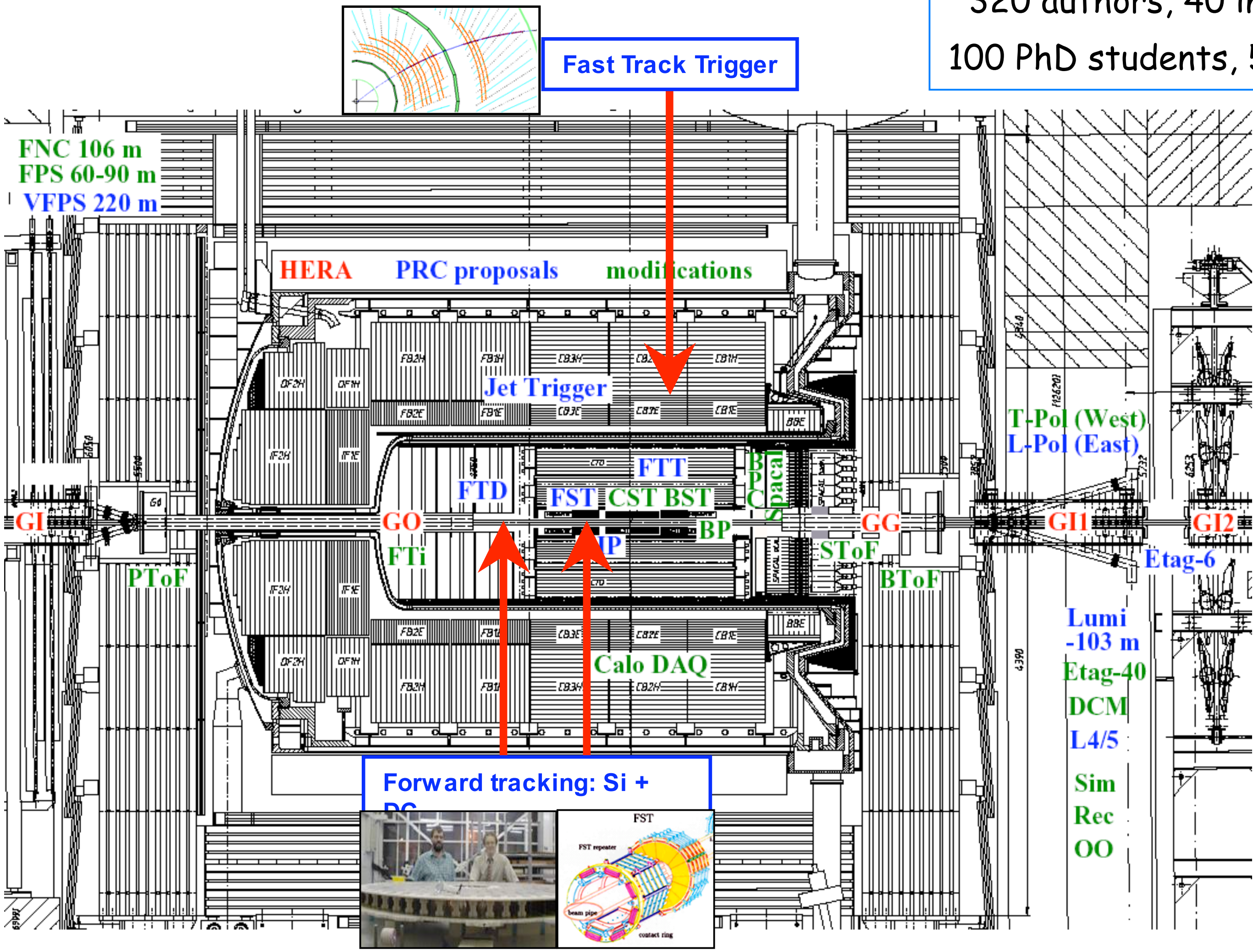
320 authors, 40 institutes

100 PhD students, 50 engineers

Forward Proton and Neutron Spectro-meters

e

27.5 GeV



Luminosity spectrometer

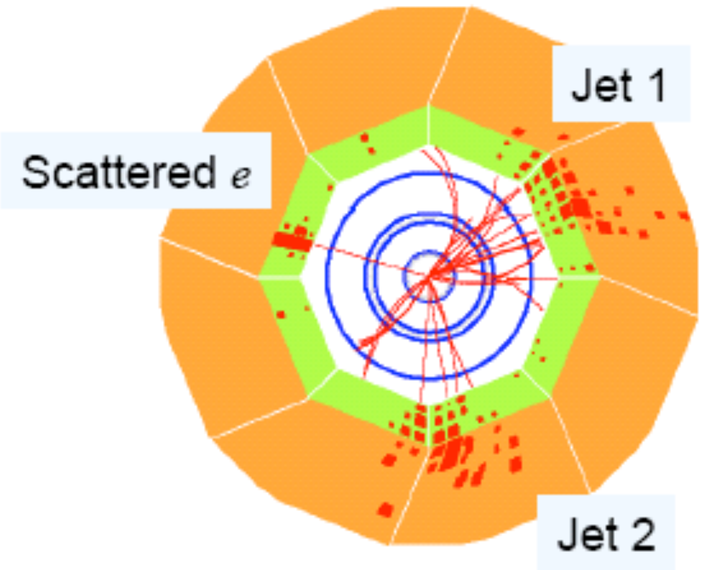
p

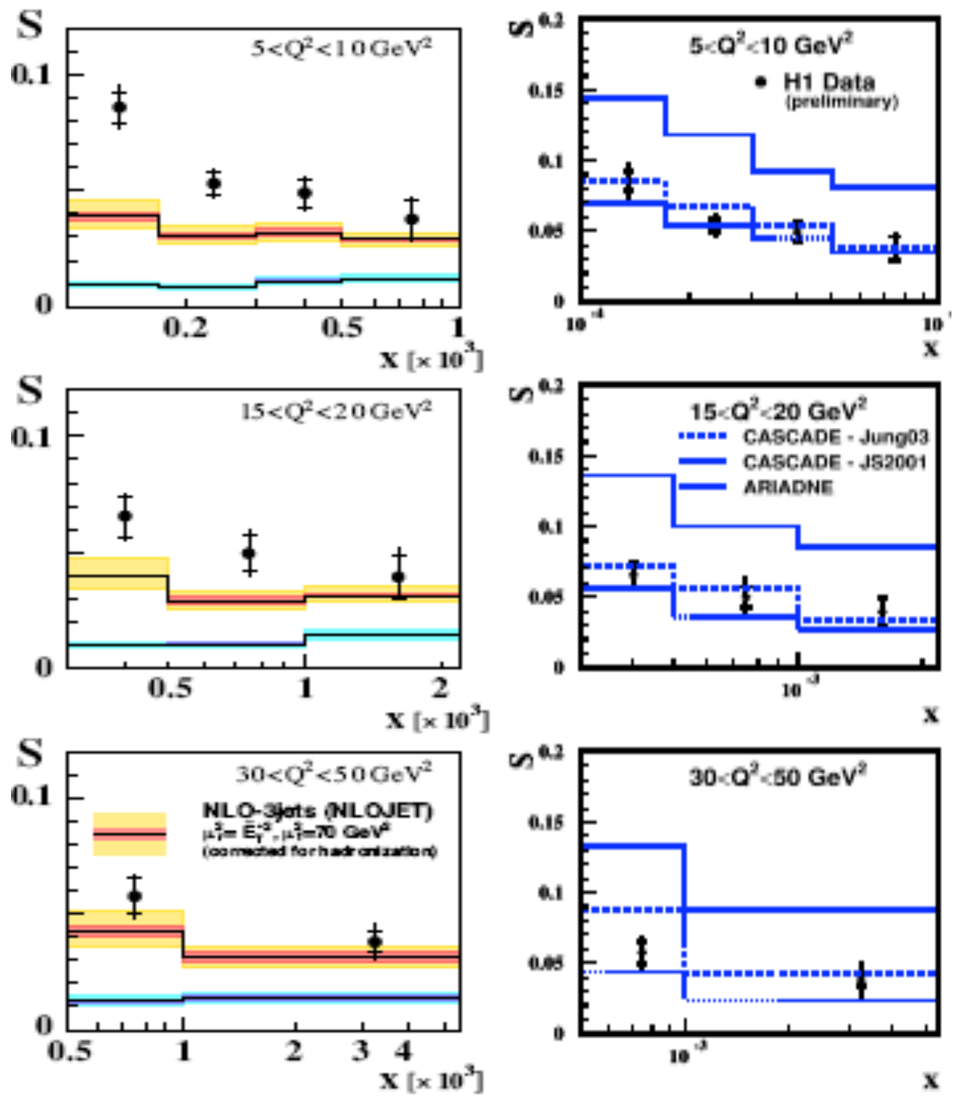
920 GeV

Jet azimuthal correlations to study parton radiation - DGLAP or not at low x?

$$S(\alpha) = \frac{\int_0^{\alpha} N_{dijet}(\Delta\Phi^*, x, Q^2)\, d\Delta\Phi^*}{\int_0^{\pi} N_{dijet}(\Delta\Phi^*, x, Q^2)\, d\Delta\Phi^*}$$

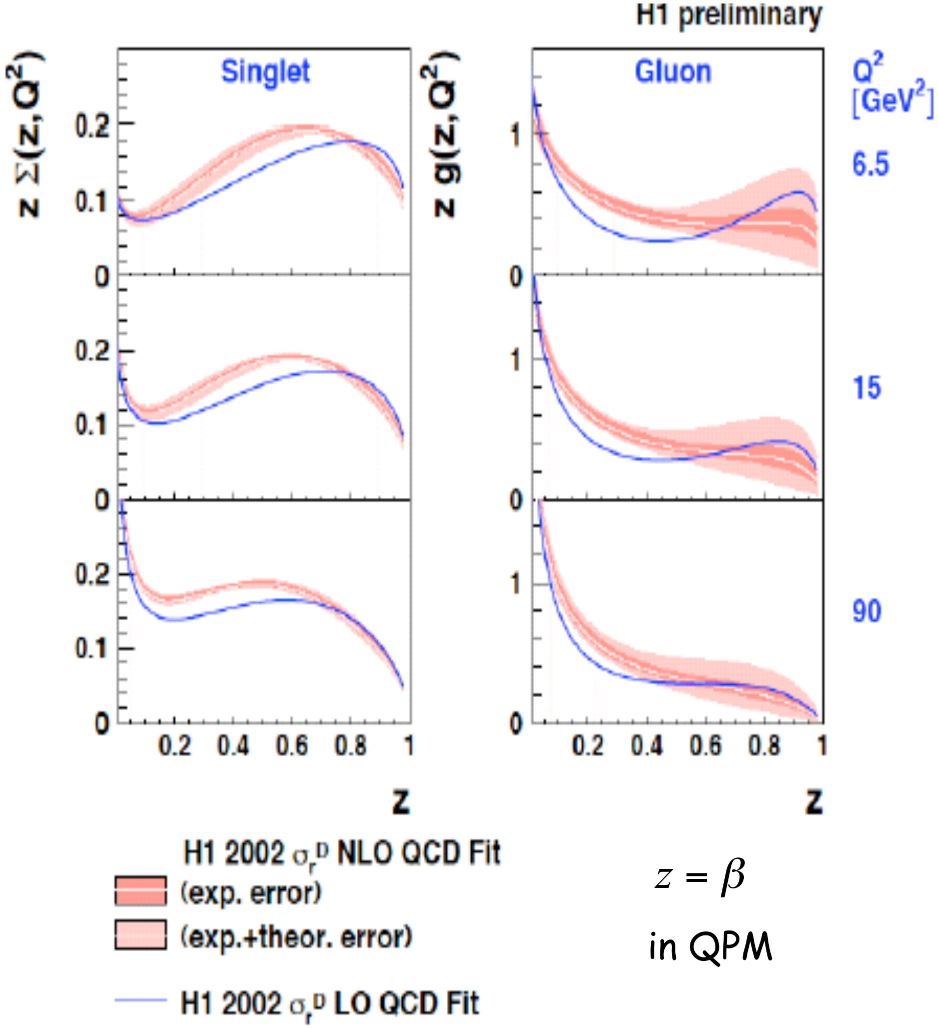
$\alpha = 120^0$





NLO 3-jets in trouble at lowest x   CCFM (unintegrated g) and CDM ok

Diffractive parton distributions

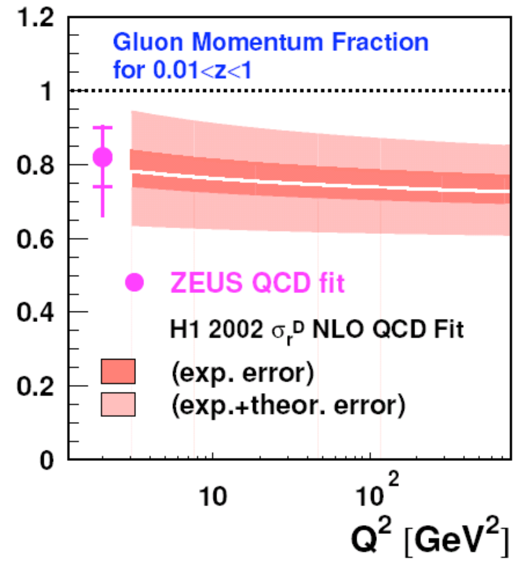


$z = \beta$

in QPM

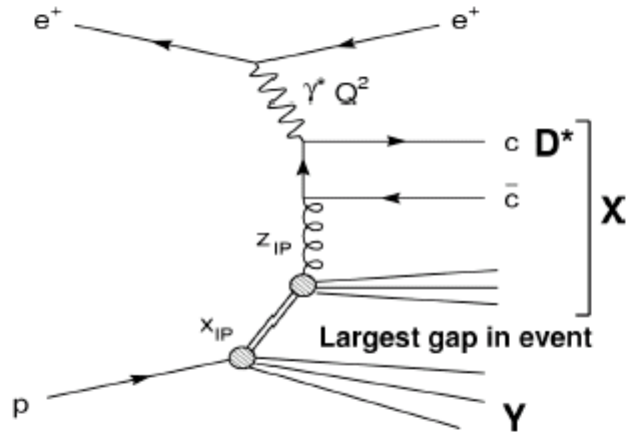
uses Regge flux ('resolved Pomeron model')

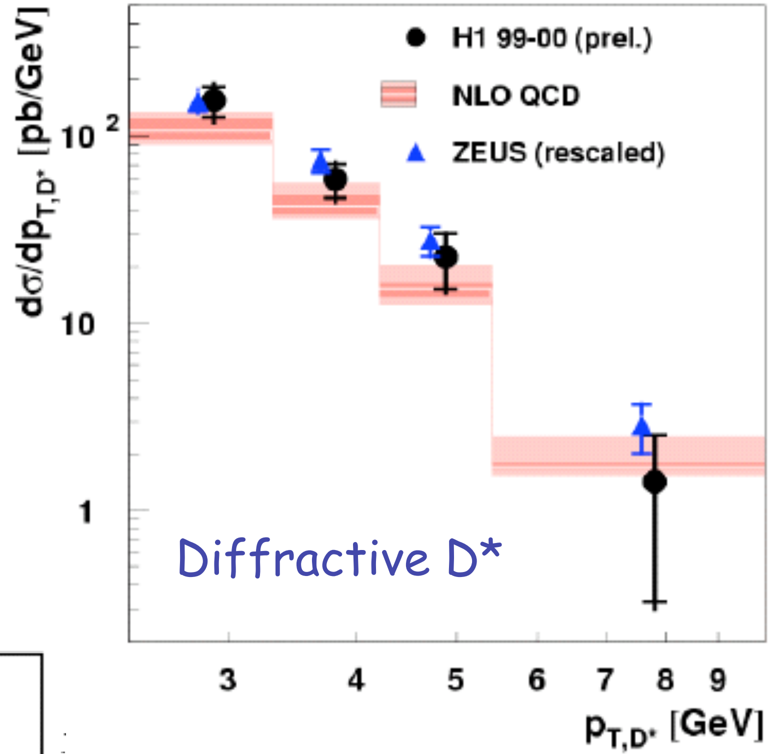
$$\frac{\int zg(z,Q^2)dz}{\int z[g+\sum]dz}$$

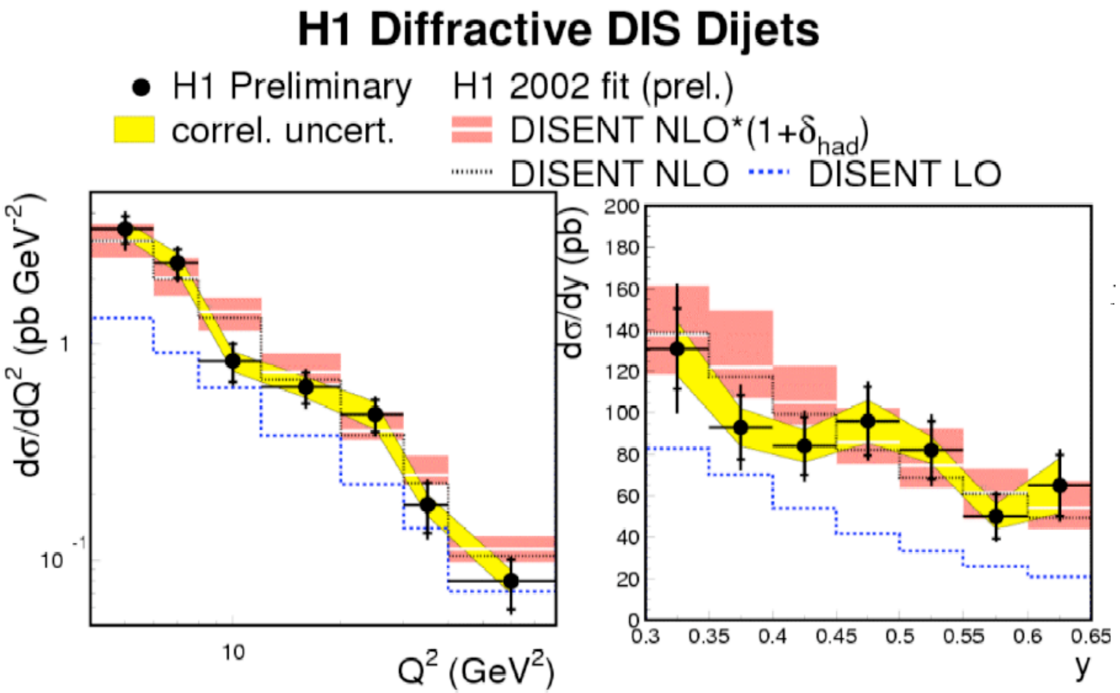


- Extract diffractive PDFs from NLO fit to inclusive diffractive structure functions
- Momentum distribution of quarks and gluons in the 'Pomeron': gluons dominate at large z > 0.01 unlike the non diffractive xg.
- QCD evolution (DGLAP) fits recent F_2^D data up to Q^2=2000 GeV^2.
- If factorisation holds, these PDFs are universal and NLO QCD should describe diffractive final states and Tevatron data

Final states in diffractive deep inelastic scattering

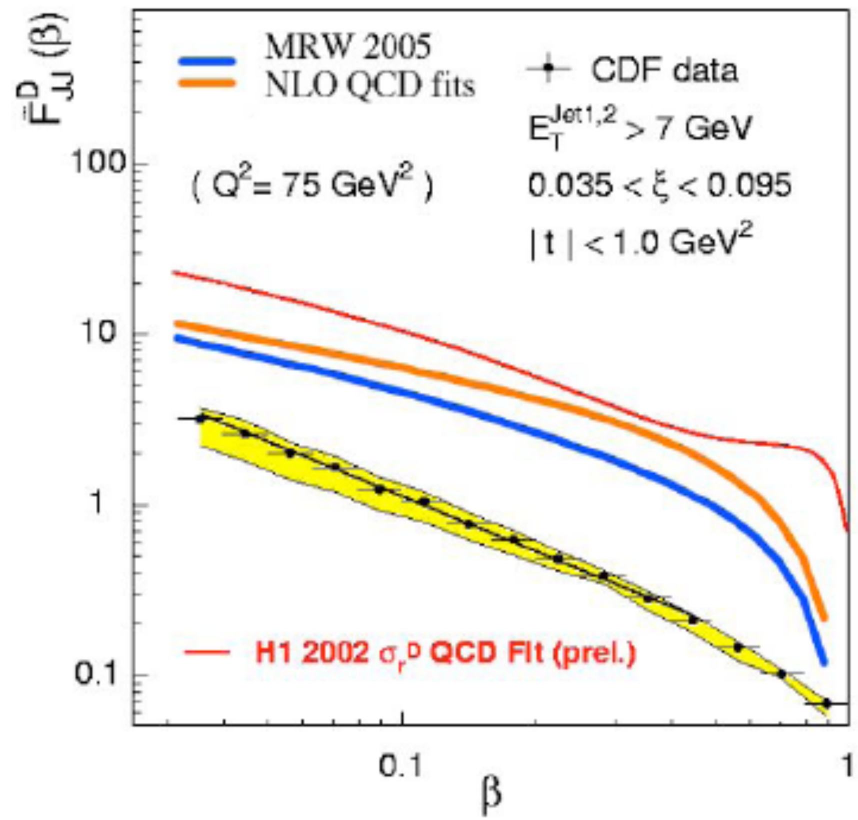






➔ factorisation holds

in DIS – jets, D*


$\bar{F}^D_{JJ}(\beta)$
MRW 2005
NLO QCD fits
CDF data
$E_T^{Jet1,2} > 7$ GeV
(Q^2= 75 GeV^2)
$0.035 < \xi < 0.095$
$|t| < 1.0$ GeV^2
100
10
1
0.1
H1 2002 σ_r^D QCD Fit (prel.)
0.1
1
β

It is vital to consider theoretical corrections, and to look at data which determines the small differences in parton distributions. These include ....

- Data determining quark decomposition, e.g. W-asymmetry, dimuon data and Drell-Yan asymmetry.

- possibility of isospin violation, $s(x) \neq \bar{s}(x)$, etc.

- higher orders (NNLO)

- QED (comparable to NNLO ? ($\alpha_s^3 \sim \alpha$)

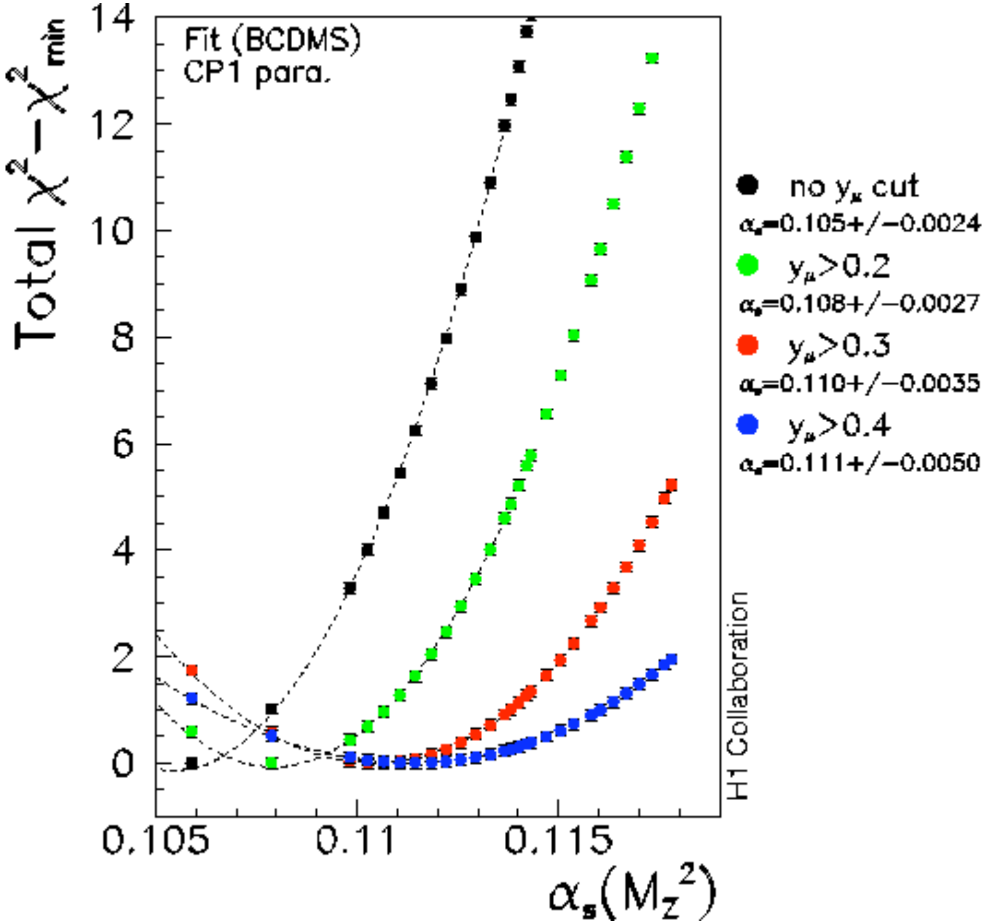
- large x ($\alpha_s^n \ln^{2n-1}(1-x)$)

- low Q^2 (higher twist)

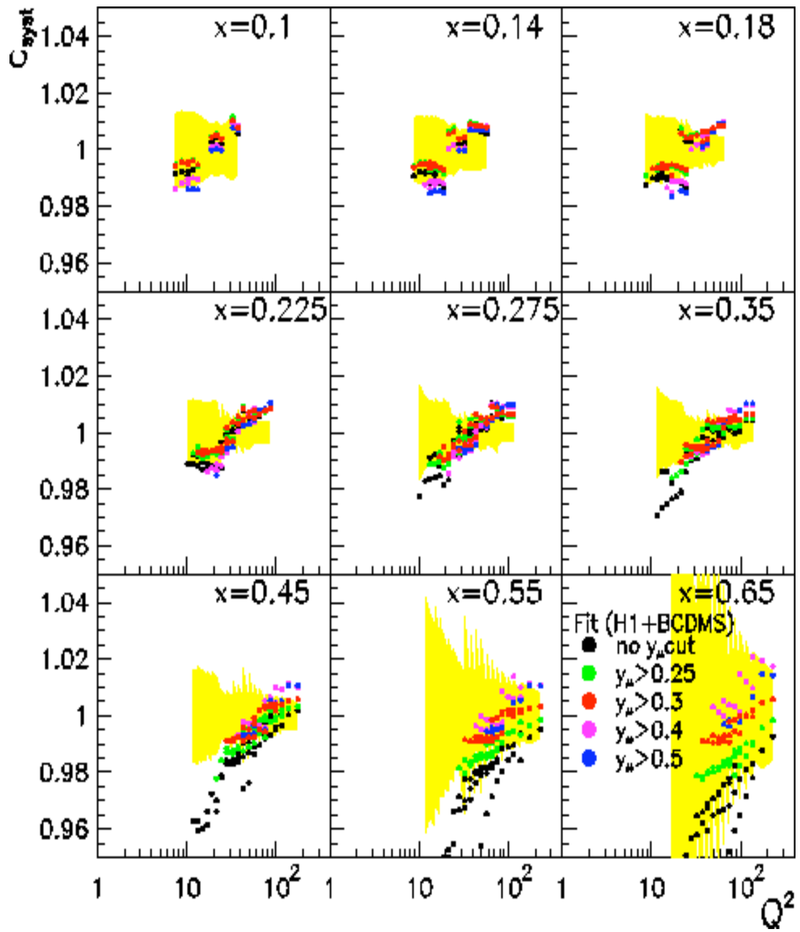
- small x ($\alpha_s^n \ln^{n-1}(1/x)$)

R. Thorne HERA LHC March03

The BCDMS data determines all DIS determinations of the strong coupling, **BUT**



shifts imposed by QCD fit to BCDMS data



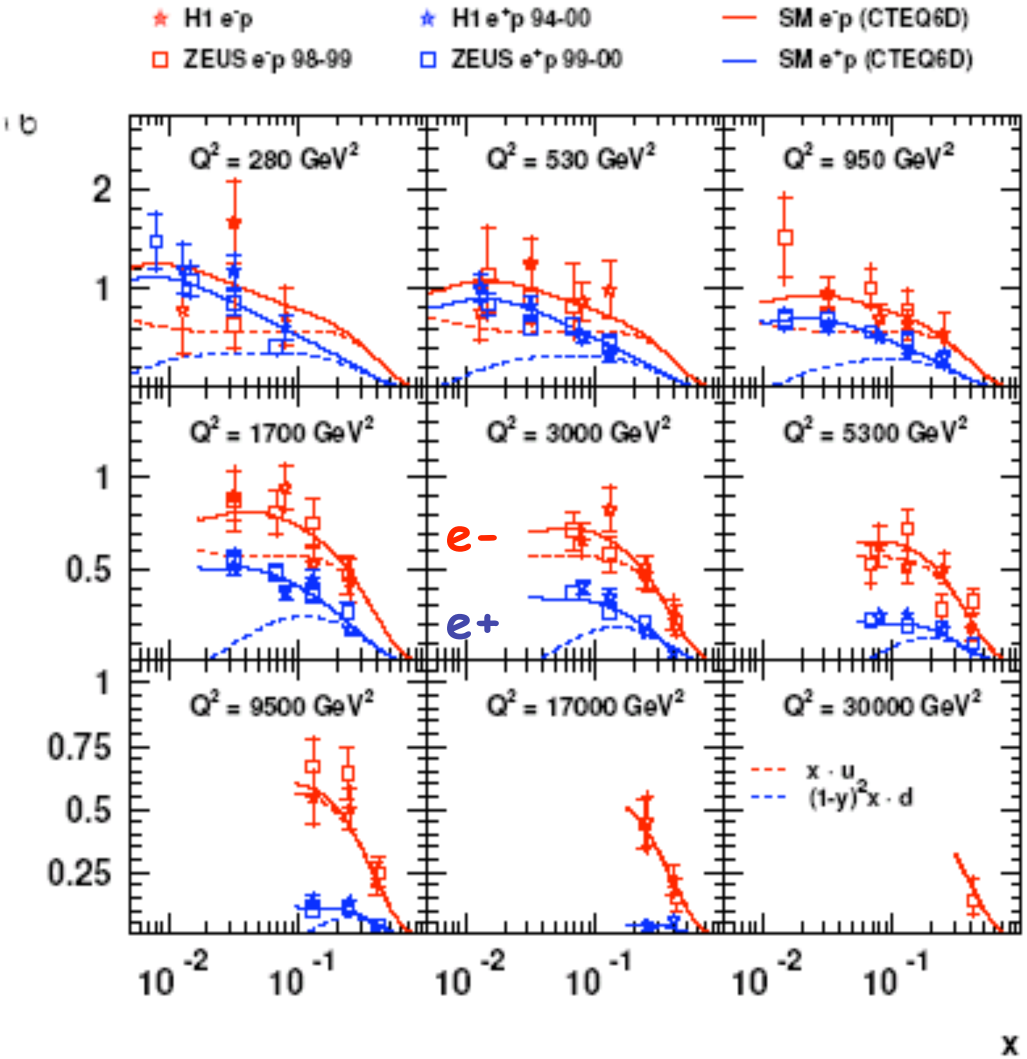
alphas (BCDMS) very low and strongly y dependent („electron method")

low y – large x region in conflict with SLAC F2

systematic errors of BCDMS data

H1 EPJ C21(01)33 R.Wallny Thesis 01-058

Reduced charged current scattering cross section



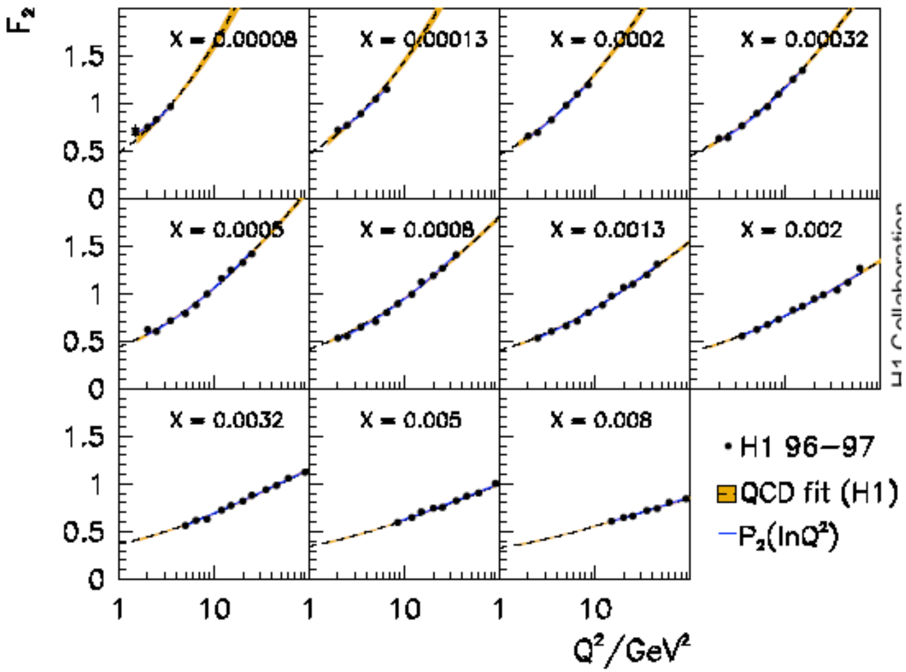
$$\sigma_{CC}^{-} \sim xU + (1-y)^2 x\overline{D} \rightarrow xu_v$$

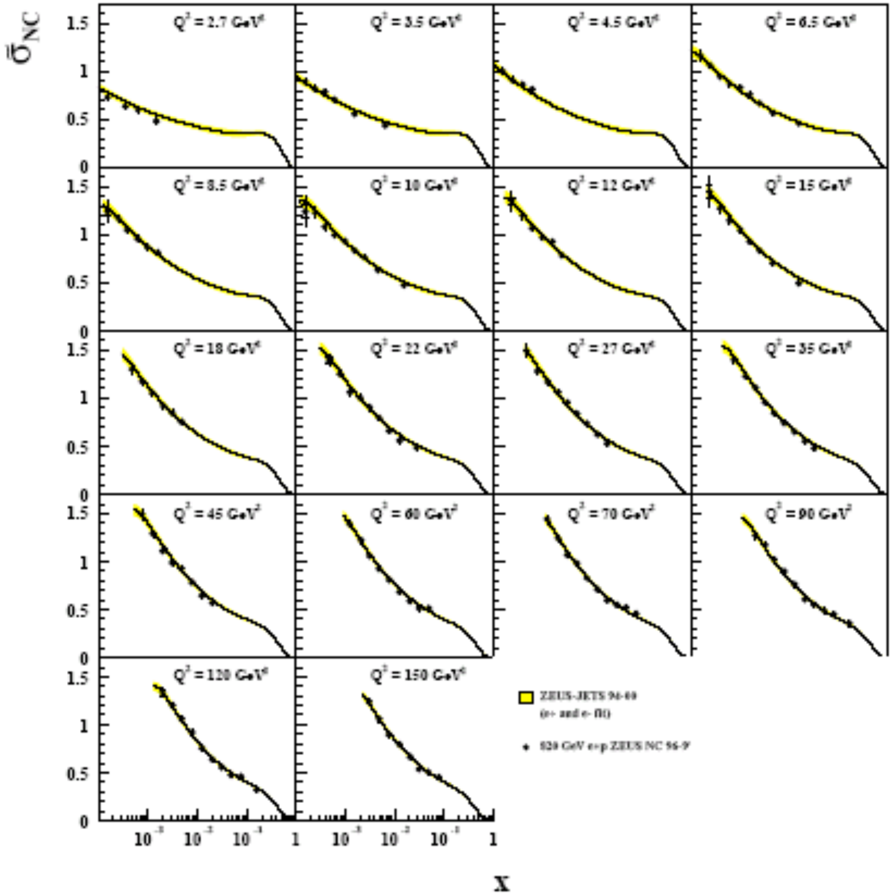
$$\sigma_{CC}^{+} \sim x\overline{U} + (1-y)^2 xD \rightarrow (1-y)^2 xd_v$$

HERA can disentangle parton distributions at large Q^2 and large x > 0.01 within single experiments, independently of nuclear corrections and free of higher twists

ZEUS

H1

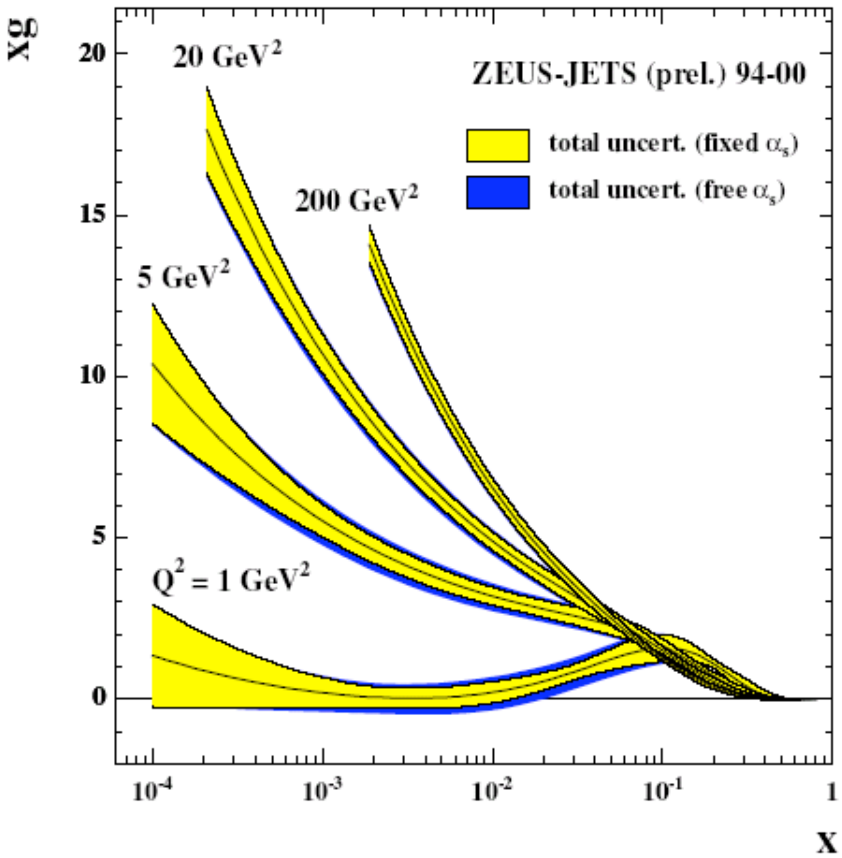


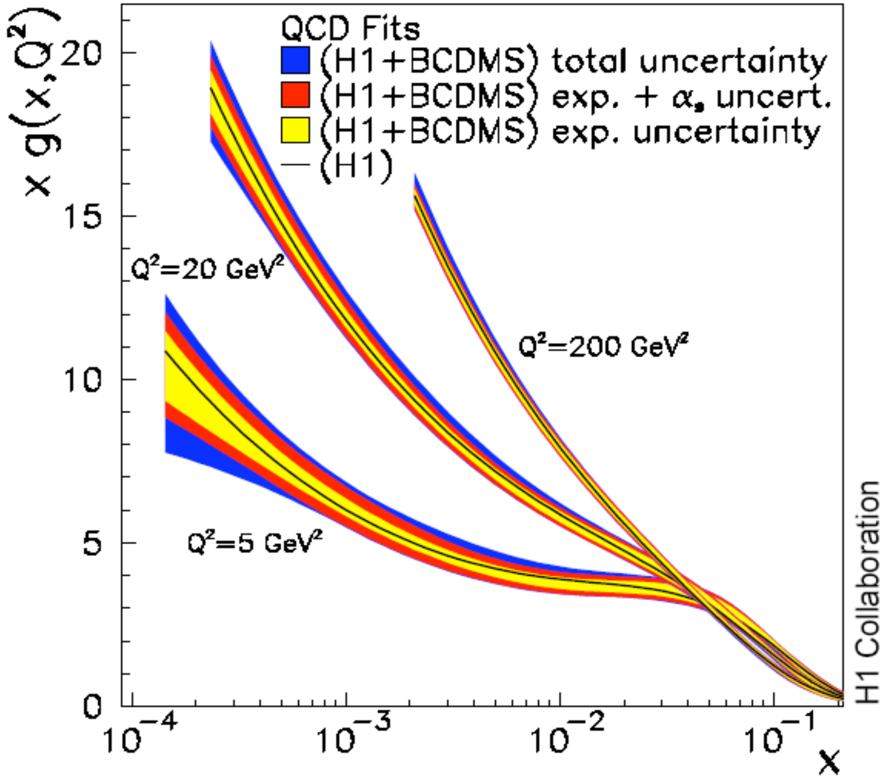


is DGLAP evolution valid at low x? measurement of F_L

ZEUS inclusive NC+CC & jets

H1 inclusive NC+CC





xg is NOT an observable. Charm treatment important (ZEUS: VFNS RT, H1: FFNS)

In the region of low x and $Q^2 \sim 1\ GeV^2$ the gluon distribution becomes very small

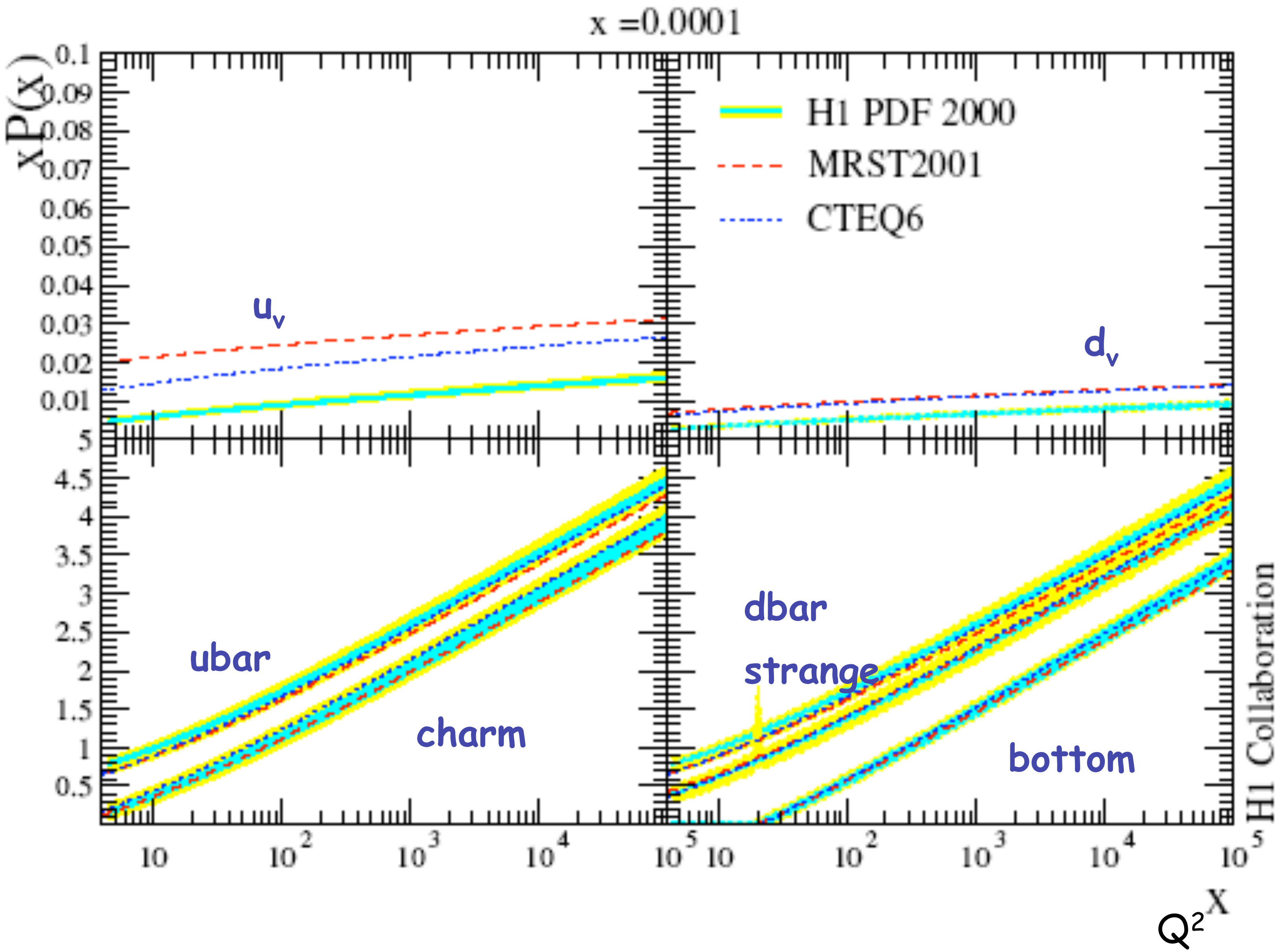
→ transition from hadronic to partonic behaviour at about 0.3 fm

Parton interaction discoveries at the energy frontier*)

1970	→	2000	→	2015
DIS: Bjorken scaling – QPM, PV neutral currents scaling violations – QCD		high parton densities diffraction		?
e+e-: J/Ψ gluons – 3jet events		three neutrinos electroweak theory		… ILC
hh: open charm, W,Z,bottom quark		top quark		LHC …

the standard model emerged as a result of decades of joint research in e+e-, ep, hh accelerator experiments including quark and neutrino mixing

*) incomplete



Differences between the quark distributions are maintained at higher Q^2