HERA / JADE / OPAL

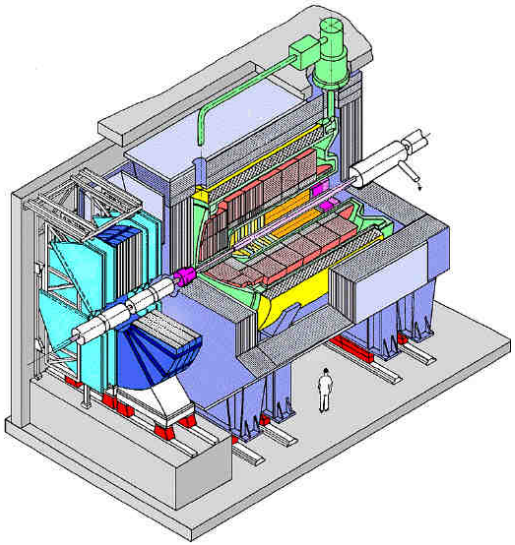
Vladimir Chekelian

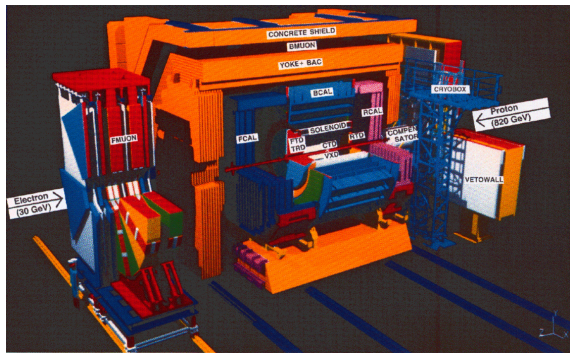
Completed experiments with strong MPP contributions and still on-going analyses

H1 and ZEUS at HERA (1992-2007)	$e^{\pm}p$	$\sqrt{s}$=225-319 GeV
OPAL at LEP (1989-2000)	$e^{+}e^{-}$	$\sqrt{s}$=88-209 GeV
JADE at PETRA (1979-1986)	$e^{+}e^{-}$	$\sqrt{s}$=11-46 GeV

H1 & ZEUS at HERA (1992-2007)

2014: the last year of full financial support at DESY
H1 and ZEUS have published 10 papers



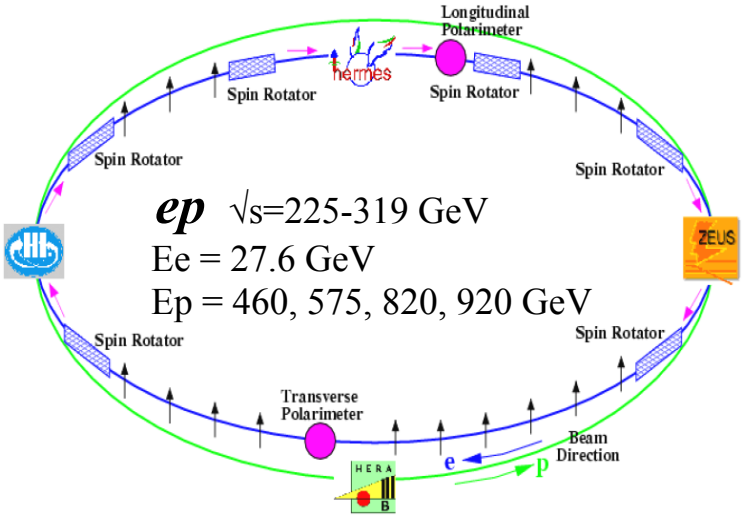


People :

Allen Caldwell,
Iris Abt,
Vladimir Chekelian,
Guenter Grindhammer,
Christian Kiesling

in close collaboration with

Stas Shushkevich, Daniel Britzger,
Halina Abramowicz, Aharon Levy



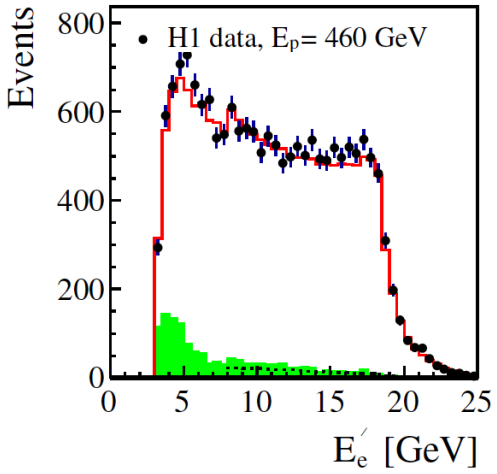
Completion of the HERA DIS cross section measurements:

1. *NC at E_p=460, 575 GeV and model independent F_L measurements*
2. *NC measurements at highest x→1*
3. *Multijets at high Q^2 and determination of α_s*
4. *Combination of all HERA NC&CC inclusive measurements and HERAPDF2.0 fits*

H1: Eur. Phys. J. C 74 (2014) 2814 ZEUS: Phys. Rev. D90 (2014) 072002

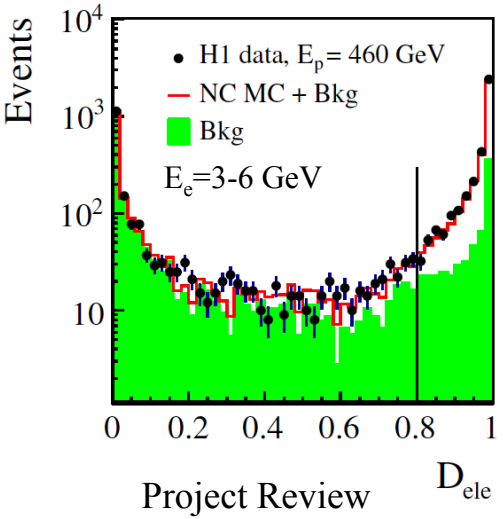
1. NC at high y for E_p= 460, 575 (and 920) GeV

Experimental challenge: large γp background at high y (low scattered electron energy)

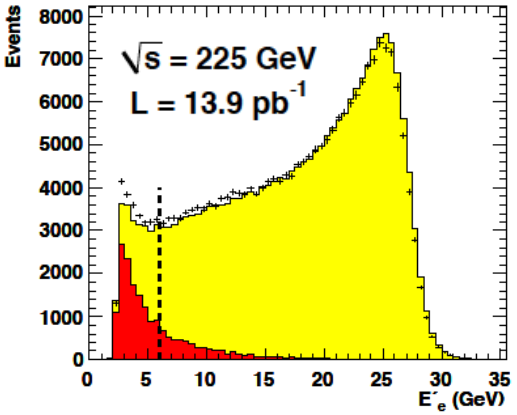


H1:
E_e down to 3 GeV

→ ***"soft electron identification"***:
optimal use of information on shower shape in LAr calorimeter, momentum matching with the track, dE/dx

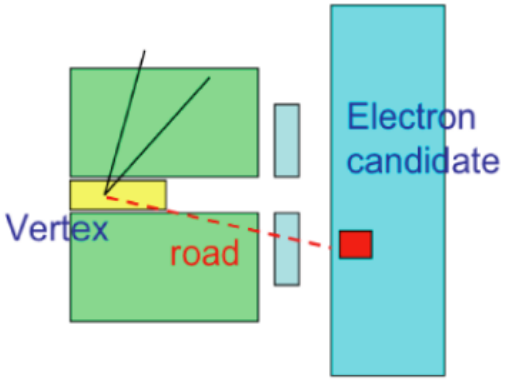


→ accept only electron candidates with the *"right electric charge"* and use the *"wrong charge"* events for estimation of remaining background.



ZEUS:
E_e down to 6 GeV

→ ***"backward tracking"***: use hits in the tracking detectors

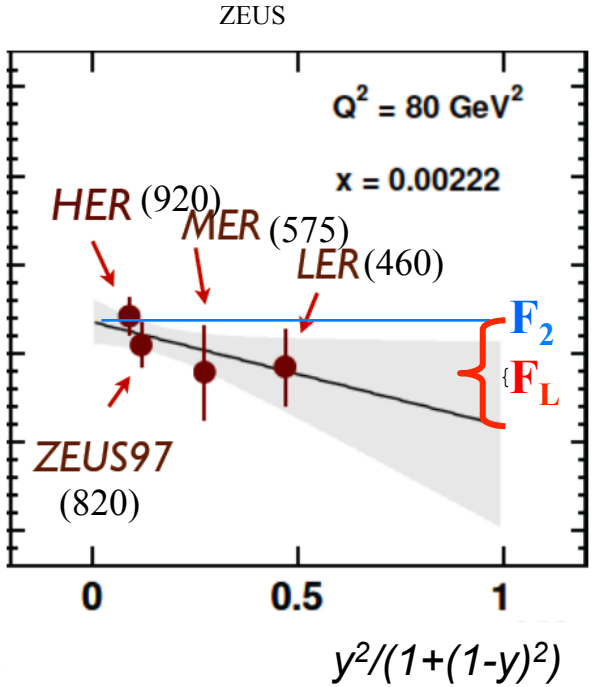


→ remaining bkg is subtracted using MC predictions verified from 6m–tagger and γp enriched sample (agreement within 10%)

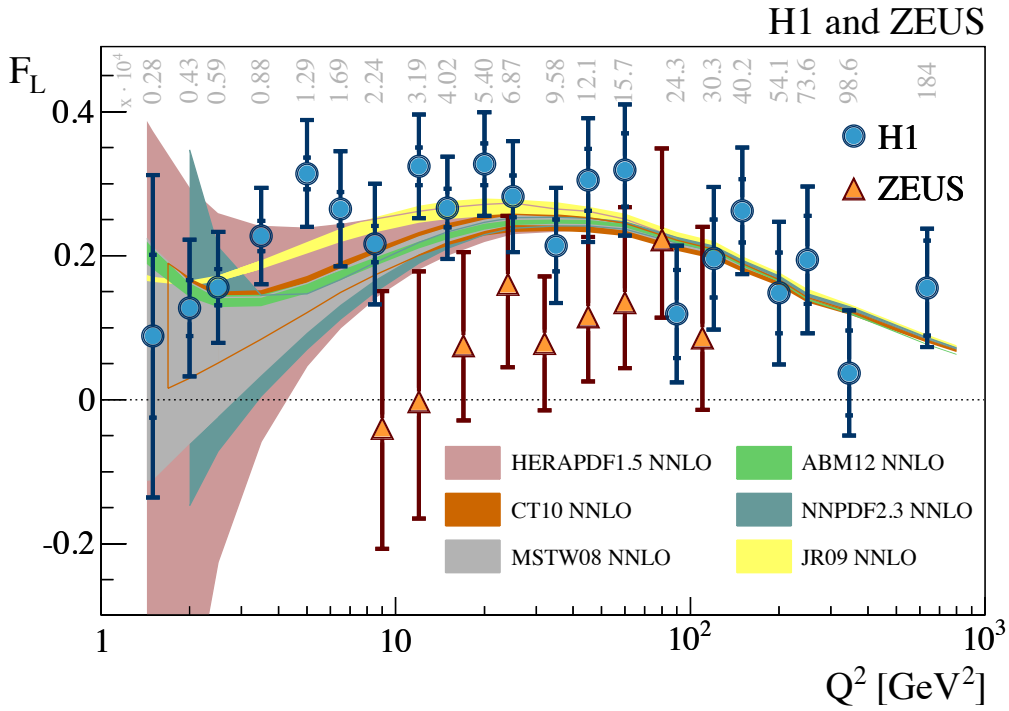
A model independent measurement of F_L using data at E_p=460, 575 and 920 (820) GeV

→ F_L and F_2 can be determined in a model independent way at each x and Q^2

$$\sigma_{NC}(x,Q^2,y) = F_2(x,Q^2) - f(y)\, F_L(x,Q^2), \quad f(y)=y^2/(1+(1-y)^2)$$



Measurements at E_p=820 GeV (ZEUS97) are included in fits

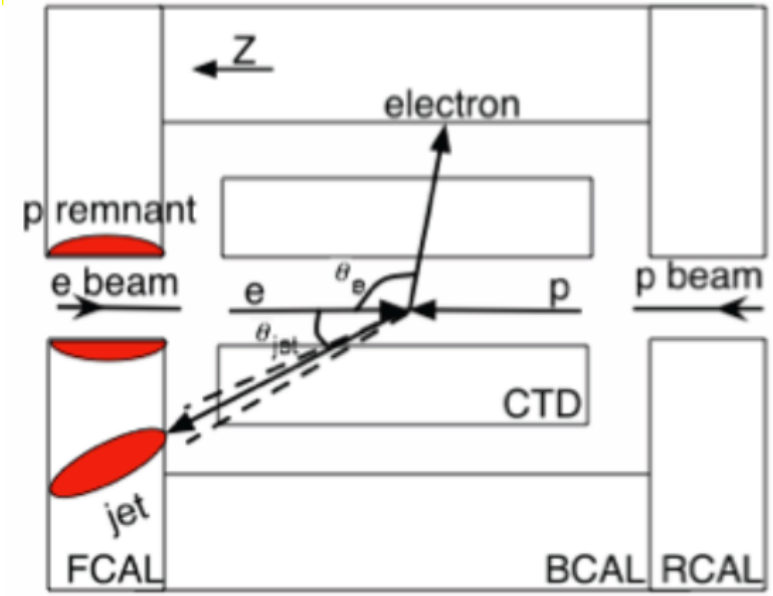


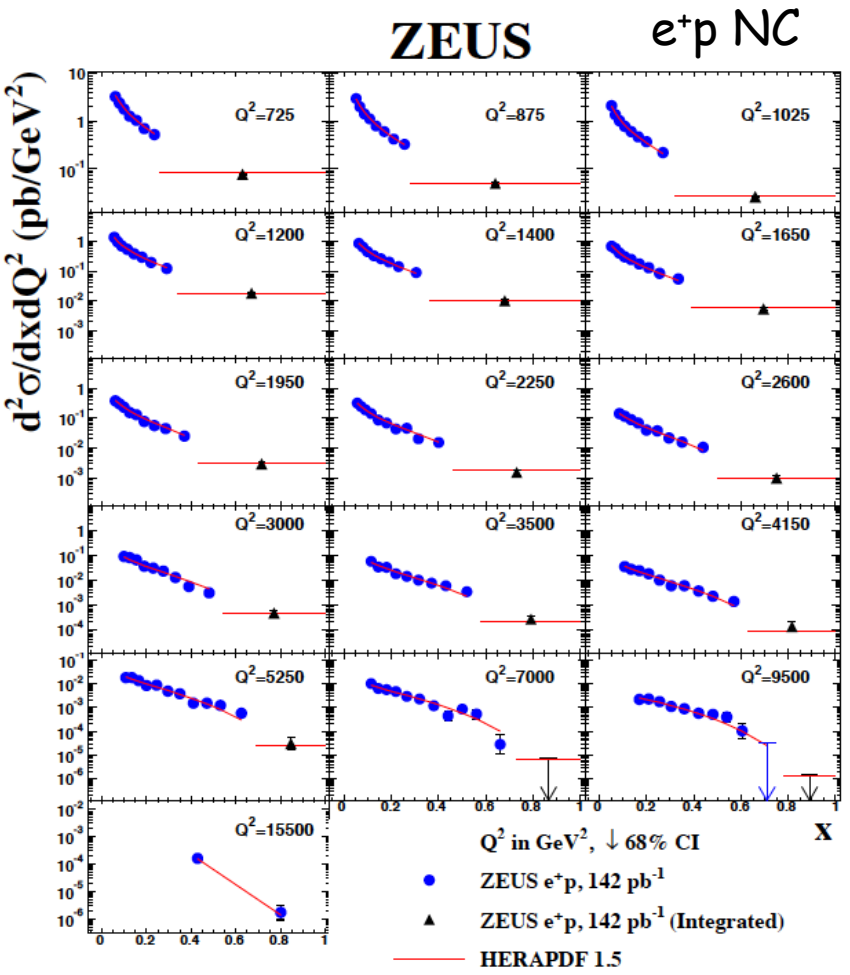
Consistency of the H1 and ZEUS FL data was checked accounting for corr. errors: χ^2/ndf=11/8 (p-value=20%).

Phys. Rev. D 89 (2014) 072007

2. Integrated $e^{\pm}p$ NC cross section at high x→1

NC events at high Q^2 have about 100% acceptance and efficiency for the scattered electron but at highest x the hadronic final state disappears in the beam pipe and there are no means to measure x

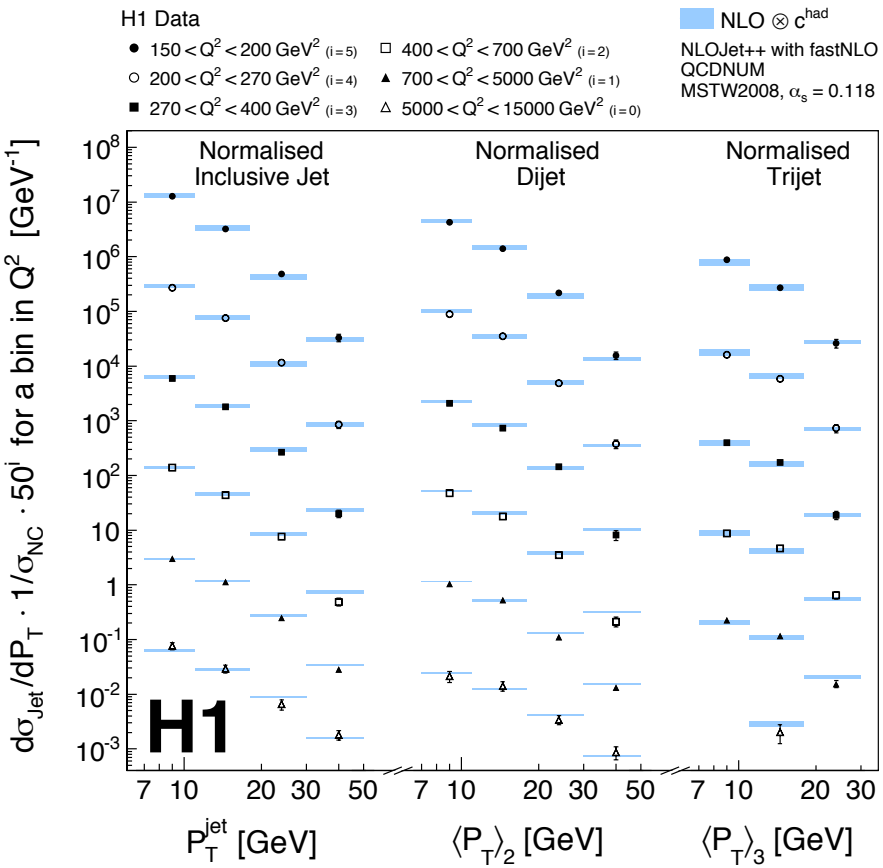


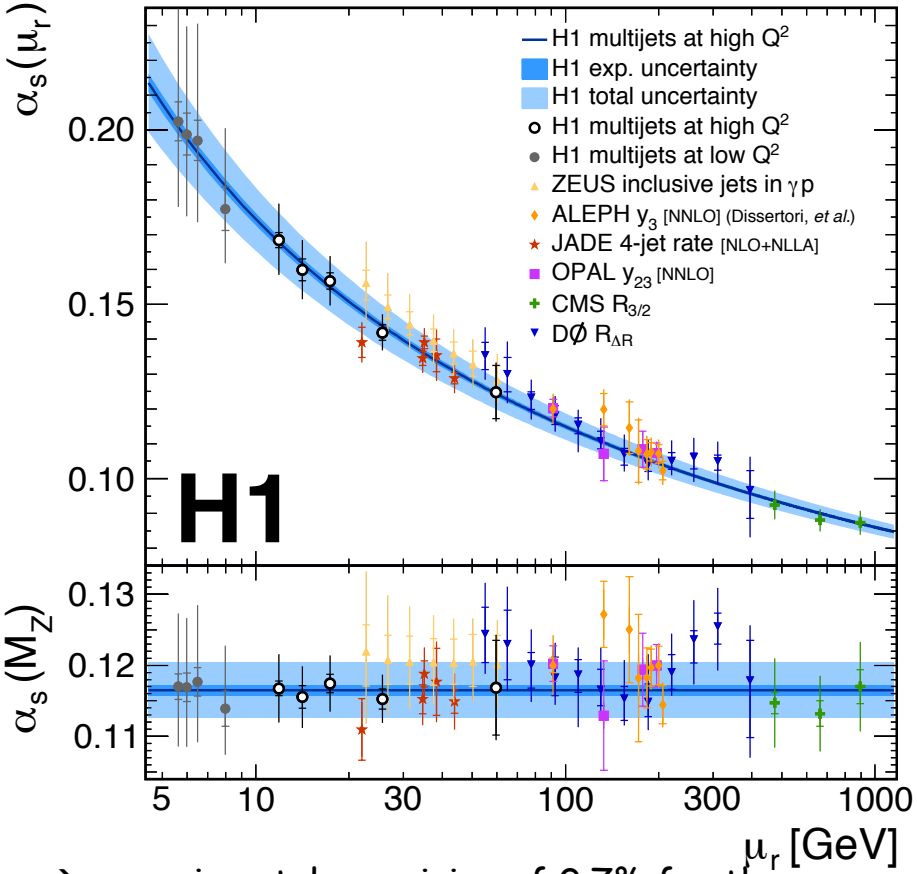


→ there is sensitivity to PDFs at high x→1

3. Multijets Production at High Q^2 and Determination of α_s

Absolute and normalised (to inclusive NC DIS) inclusive jets, dijets and trijets cross sections are measured using regularised unfolding procedure for detector effects with determination of correlations of multijet statistical errors



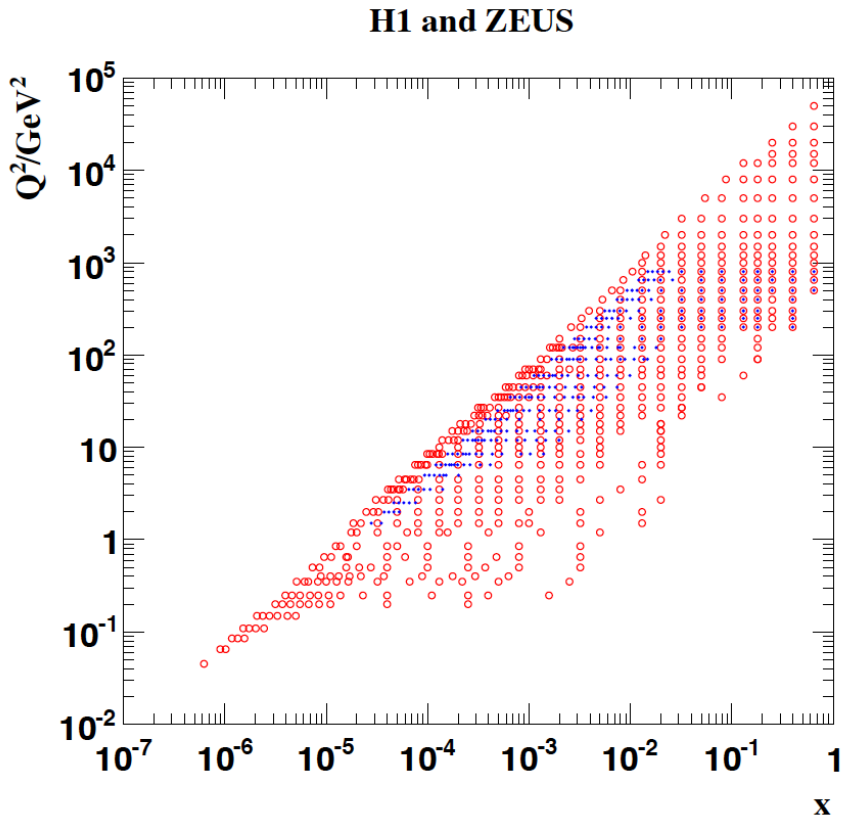


→ experimental precision of 0.7% for the α_s determination in NLO using normalised jets

$\alpha_s(m^2_Z)=0.1165\pm(8)_{exp}(38)_{pdf,theo}$

4. Combined Measurement of Inclusive $e^{\pm}p$ Scattering Cross Sections and QCD Analysis of HERA Data

last Friday (12.12.2014): presentation of the draft of the paper to H1&ZEUS for review



Combination of the H1 & ZEUS incl. unpolarized NC and CC data include expert knowledge in the treatment of the correlations between individual data sets.

→ precise, complete and easy in use

→ reduction of stat. and syst. uncertainties

41 data sets from H1 and ZEUS (1 fb^{-1}): $0.045 \le Q^2 \le 50000$ GeV^2, $6\ 10^{-7} \le x \le 0.65$

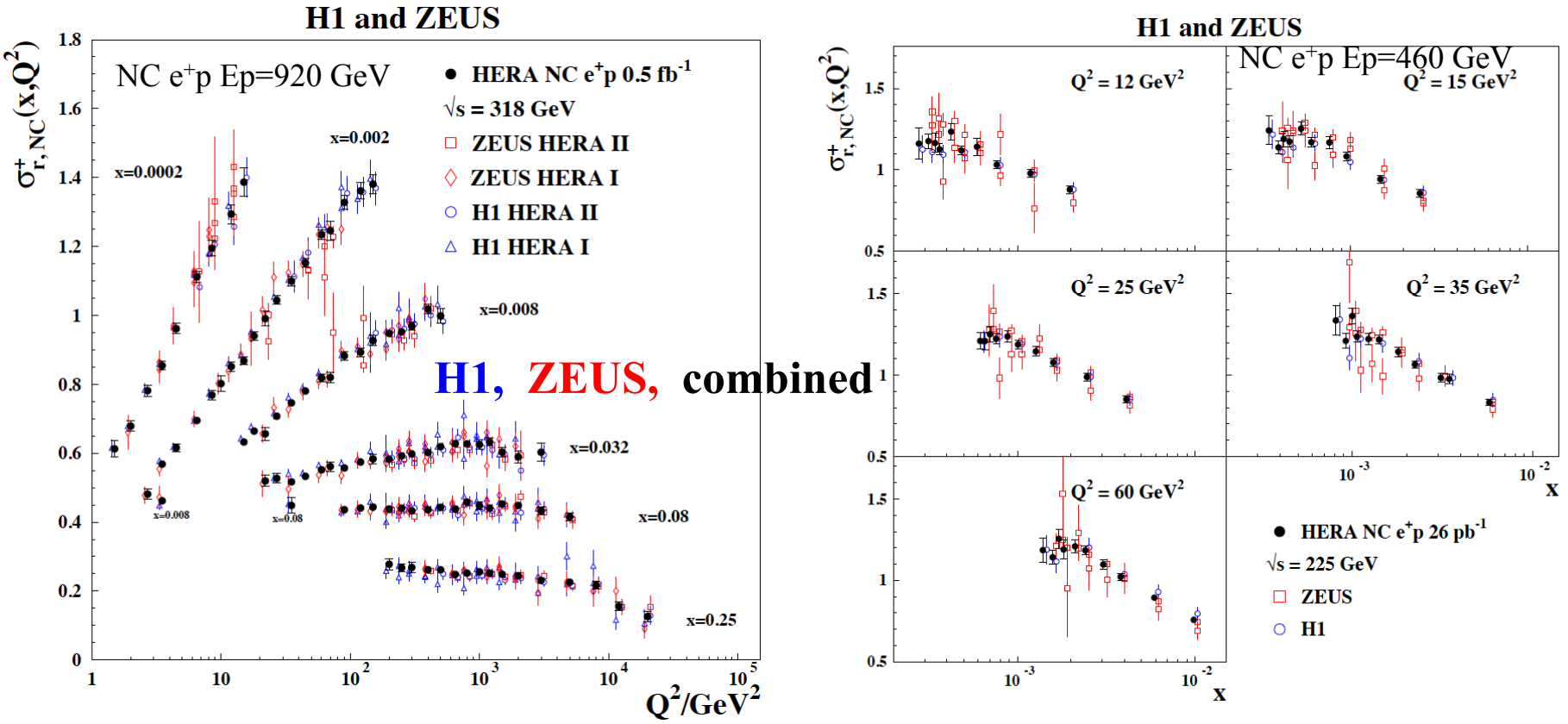
21 data sets from HERA I (E_p=920 and 820 GeV) and
20 data sets from HERA II (12/4/4 sets for E_p= 920/575/460 GeV)

averaging similar to:
1. HERA I data: JHEP 1001:109,2010 HERAPDF 1.0
2. HERA I and preliminary HERA II data HERAPDF 1.5

162 corr. syst. sources plus
7 additional procedural errors

Averaging of all NC and CC HERA I+II data

2927 cross sections are combined to 1307 points with 169 correlated systematic errors

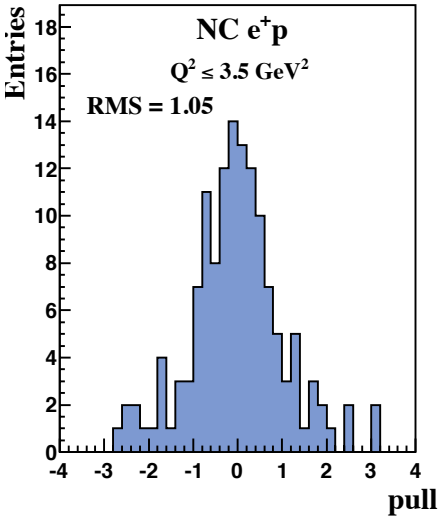


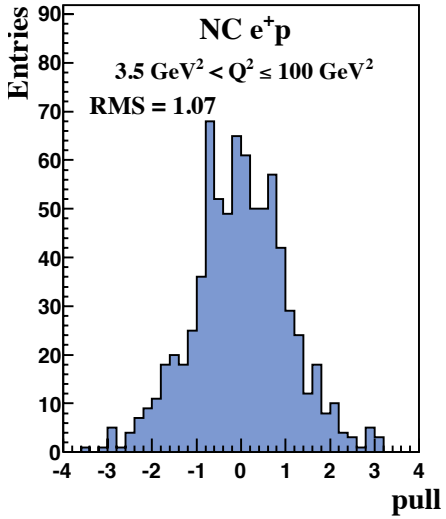
→ up to 6 measurements are combined into one averaged point
→ good consistency of the input data sets ($\chi^2/ndf = 1685/1620$)

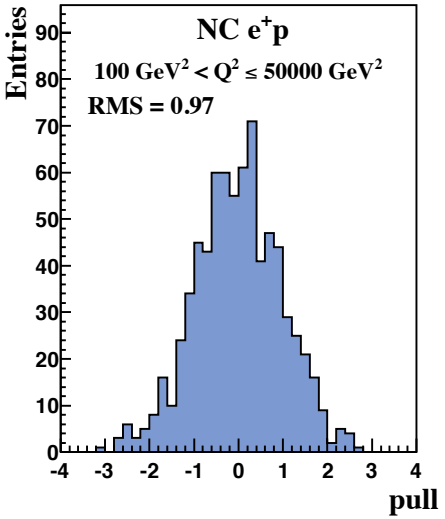
Pulls for different samples

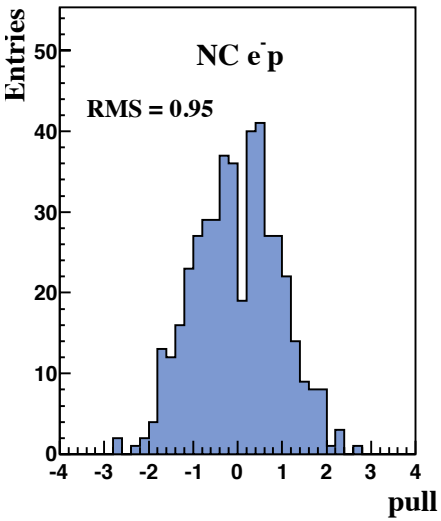
$$p^{i,k} = \frac{\mu^{i,k} - \mu^{i,\text{ave}}\left(1 - \sum_j \gamma_j^{i,k} b_{j,\text{ave}}\right)}{\sqrt{\Delta_{i,k}^2 - \Delta_{i,\text{ave}}^2}}$$

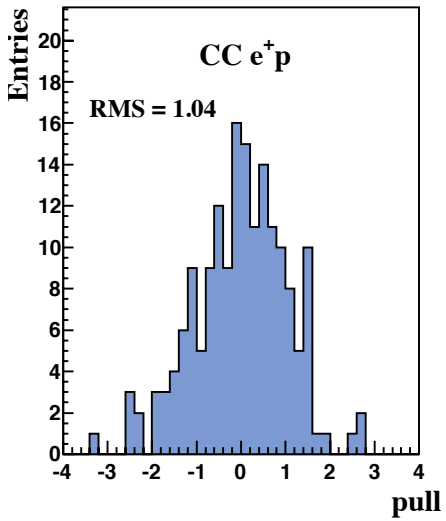
H1 and ZEUS preliminary

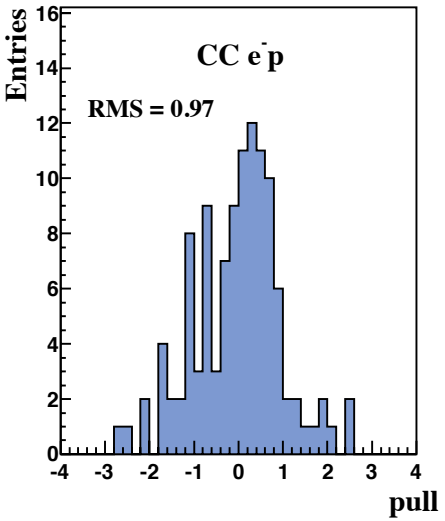










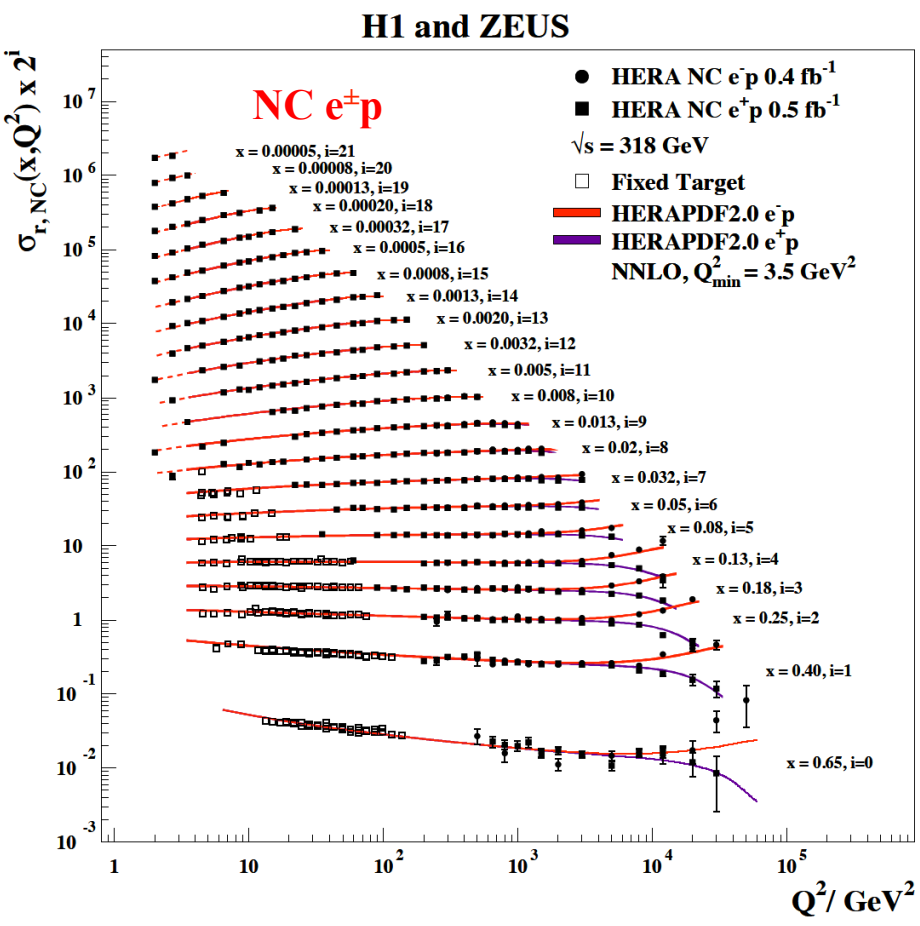


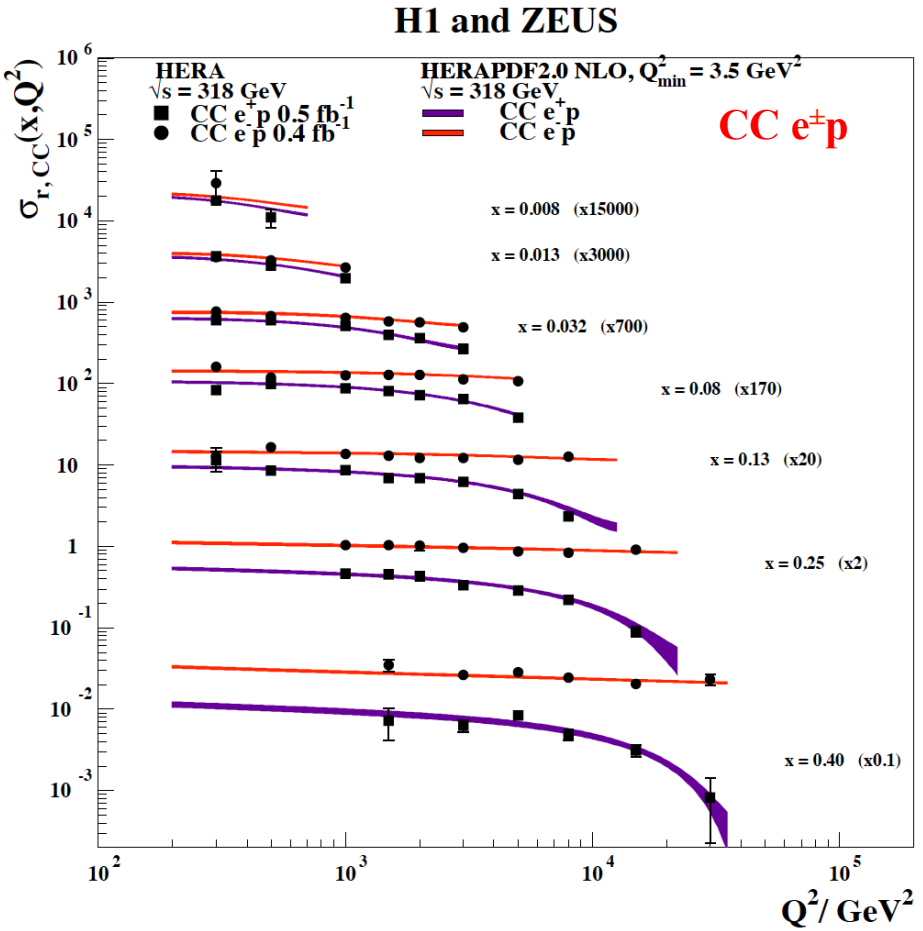
→ everywhere consistent with expected one sigma gaussian

Combined NC and CC data set from HERA

$e^{\pm}p$ NC&CC (E_p=920 GeV), $e^{+}p$ NC (E_p = 820, 575, 460 GeV), corresponding to 1 fb^{-1}

→ 169 correlated syst. err.; $0.045 \le Q^2 \le 50000$ GeV^2, $6\ 10^{-7} \le x \le 0.65$

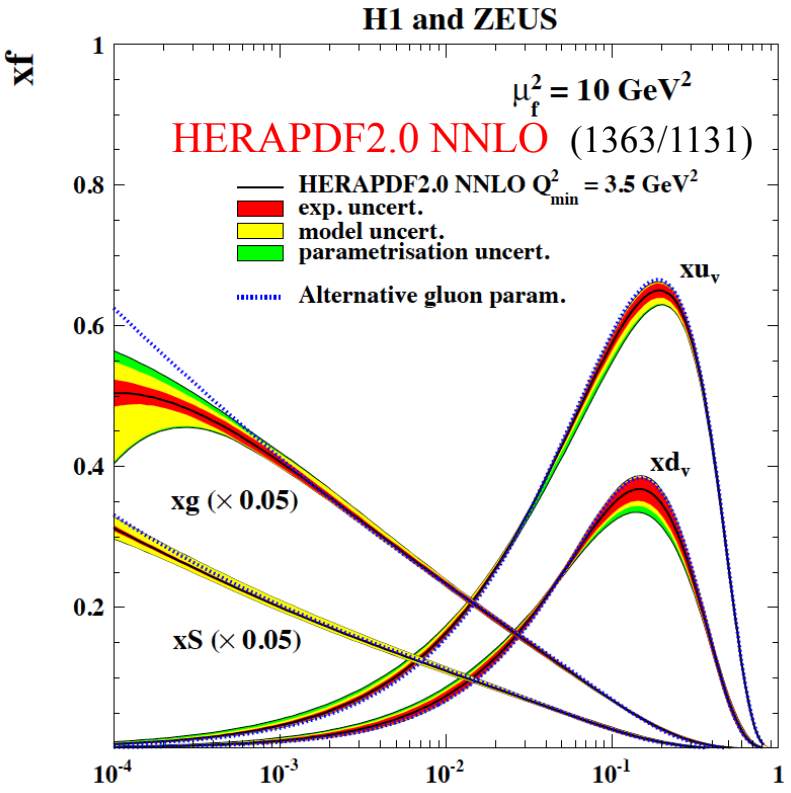




HERAPDF2.0

PDF QCD fits using combined HERA data only ($e^{\pm}p$ NC/CC, Ep=460,575,820,920 GeV)

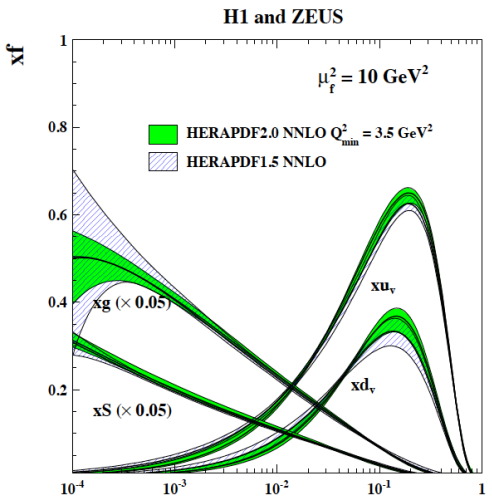
- no nuclear or heavy target corrections, $\Delta\chi^2 = 1$ criterion for exp. errors
- parametrise $xg(x), xu_v, xd_v, xUbar, Dbar$ at starting scale $Q_o^2 = 1.9\ GeV^2$ using 14 parameters
- using the RTOPT variable flavor scheme
- $Q^2_{min} = 3.5\ GeV2$, $f_s = 0.40$, m_c and m_b are optimised using HERA data, $\alpha_s(m^2_Z) = 0.118$
- three uncertainty bands: experimental, exp. + model (variations of Q^2_{min}, f_s, m_c, m_b) and exp. + model + parameterisation (variation of param.assumptions and Q_o^2)

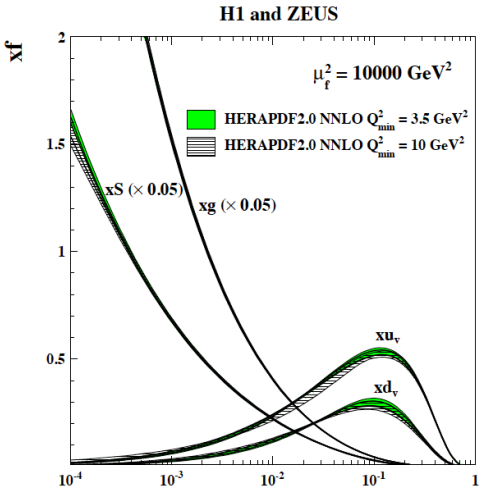


HERAPDF2.0 will be provided at LO / NLO / NNLO

additional PDF sets :

- fixed flavor number schemes at NLO
- alternative (positive) parametrisation of xg(x)
- $\alpha_s(m^2_Z)$ scan from 0.114 to 0.122 in steps of 0.001

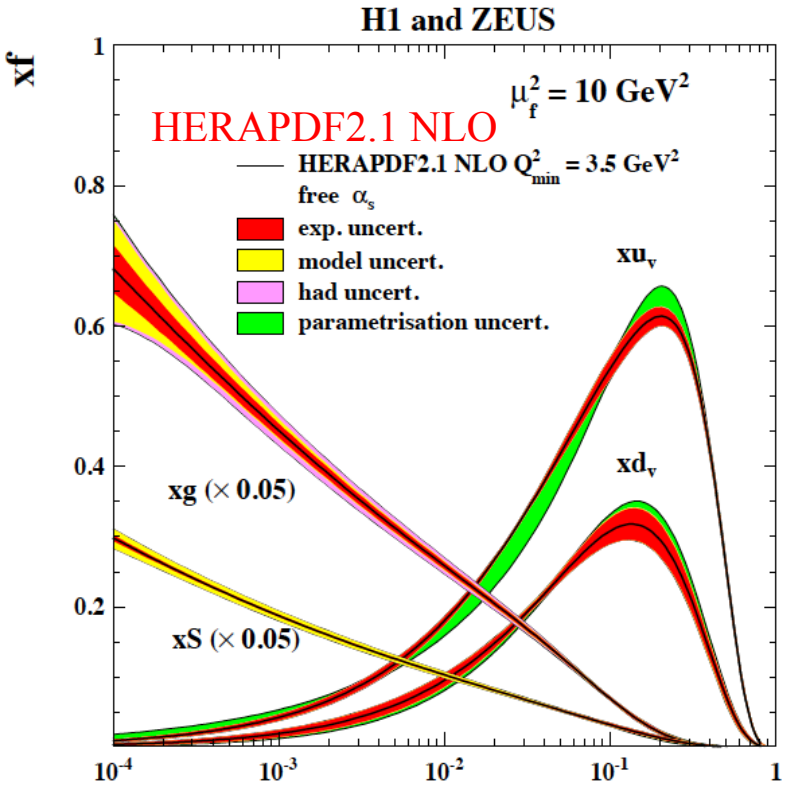




HERAPDF2.1
(inclusive + charm + jets)

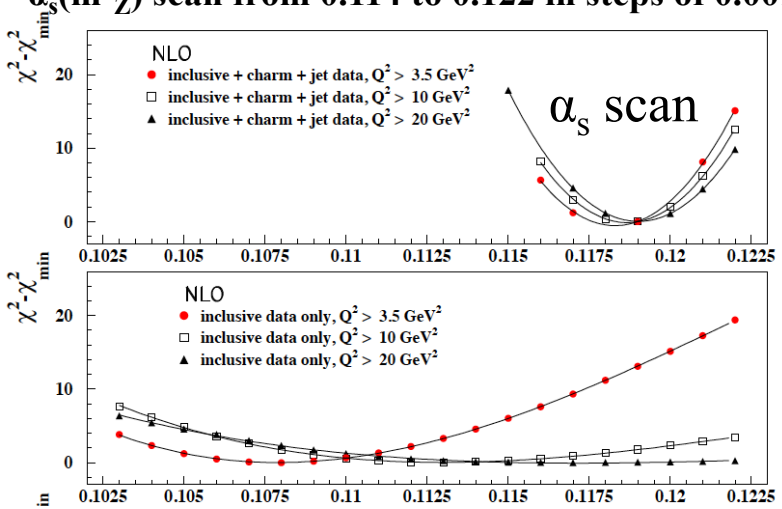
add combined charm production HERA data (Eur.Phys.J. C73 (2013) 2311) and selected jet production HERA cross sections including recent multijets from H1

- NLO; with additional error band related to hadronisation of jets
- free α_s: it is determined in a simultaneous fit with PDFs $\alpha_s(m^2_Z)=0.1182\pm(9)(5)(12)(+37,-30)$



additional PDF sets :

- $\alpha_s(m^2_Z)$ scan from 0.114 to 0.122 in steps of 0.001



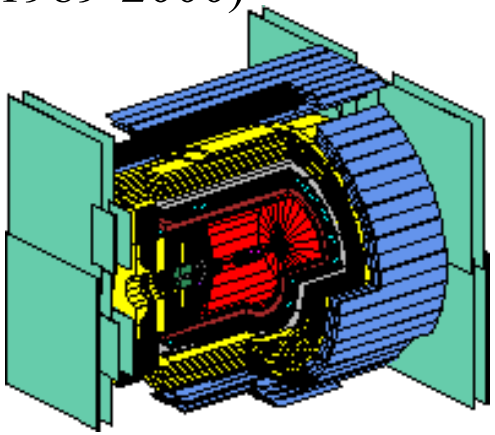
PDFs and error bands of HERAPDF2.1 with charm and jet data and free α_s are very close to HERAPDF2.0 obtained using inclusive data, optimized charm and bottom masses and fixed α_s (slightly increased err. band due to hadronisation).

OPAL and JADE

→ *clean e^+e^- environment for jet studies*

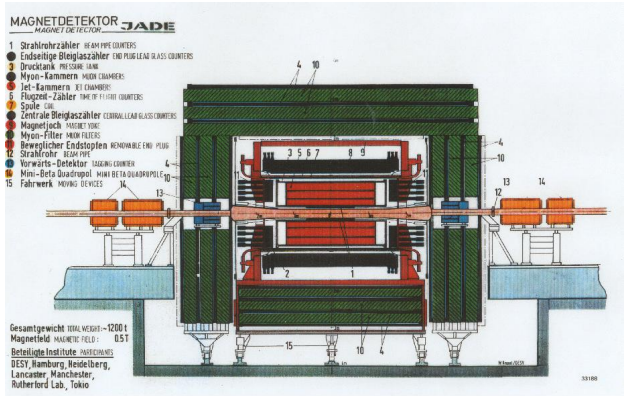
OPAL at LEP (1989-2000)

√s=88-209 GeV



JADE at PETRA (1979-1986)

√s=11-46 GeV



People:

Siegfried Bethke (director)
Stefan Kluth, Andrii Verbytskyi
Nadine Fischer (KIT)

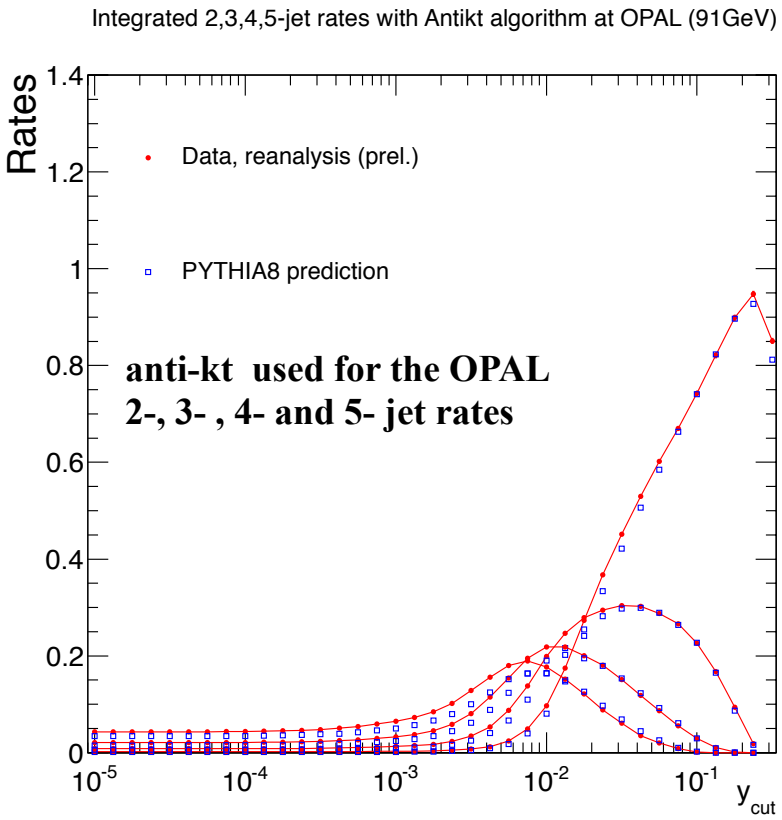
Analyses:

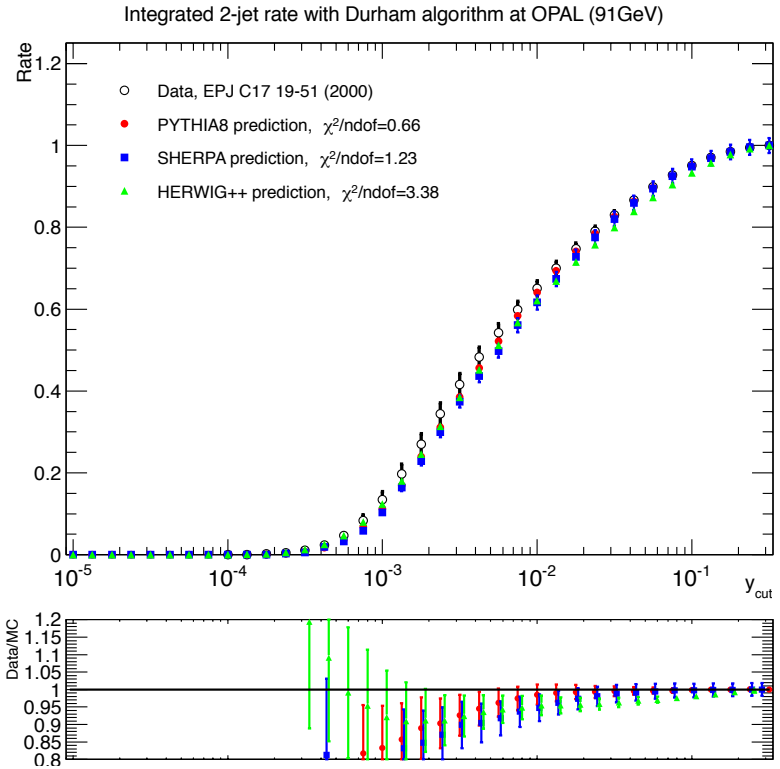
- tests of the jet algorithms
- tuning of the modern MC generators
- investigation of properties of QCD shower

Jets algorithms, jet rates and tuning of MC

- study of new jet algorithms (anti-kt, siscone) using the OPAL and JADE data
- study and tuning of modern generators SHERPA, Pythia8, Herwig++
(create a plugin to the Rivet toolkit for analysis and comparison with OPAL and JADE data)

→ *the analysis is taken over by Andrii Verbytskyi from Christoph Pahl*





Measurement of observables sensitive to coherence effects in hadronic Z decays with the OPAL detector at LEP

Various angular jet variables / topologies for 4-jet events, sensitive to higher order QCD effects modeled by parton shower (PS), are investigated using the OPAL data

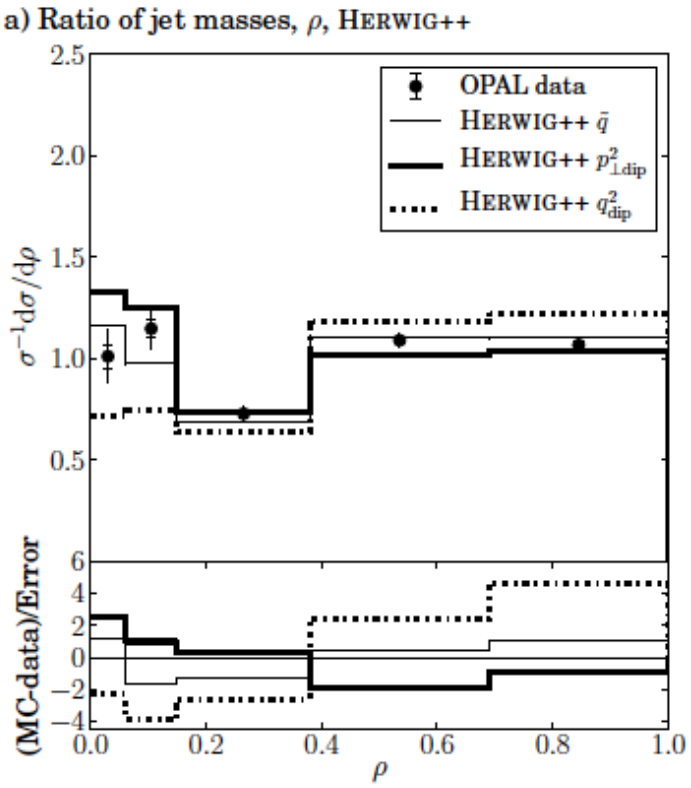
→ **the paper is in the EB review in OPAL for publication**

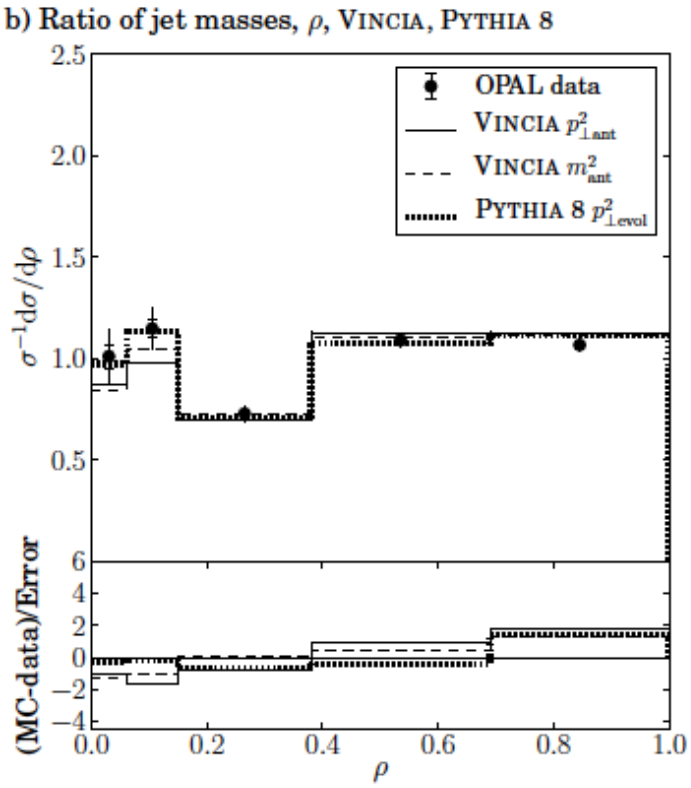
example:

the ratio of hemi-sphere masses

$$\rho = M_L^2/M_H^2$$

comparisons with different implemen-tations of PS show that some PS variants in Herwig++ are not optimal





Preservation of the HERA/OPAL/JADE data at MPP

People: Andrii Verbitskyi
Siegfried Bethke, Allen Caldwell (directors)
Stefan Kluth, Iris Abt, V. Chekelian (OPAL/JADE, ZEUS, H1)

in close cooperation with DESY:

- since few months dedicated DESY position at IT for data preservation (Dirk Krücker)
- permanent storage of ~620 TB is foreseen on disk with two safe copies on tapes
- about 90% of ZEUS and H1 data (& MC) are already copied to permanent DESY storage

→ 100% of ZEUS and about 80% of H1 data available at the DESY permanent storage
plus OPAL&JADE data are stored at Garching RZ (finally foreseen ~ 500 TB)

→ well defined strategy for ZEUS using data/MC ntuples, possibility for analysis with frozen environment, limited possibility for MC production
corresponding software is already running on virtual machine including MC production

→ the H1 preservation strategy is more involved aiming to keep complete software environment with full functionality

Conclusions

In 2014 the H1 and ZEUS published 10 concluding papers on different subjects.

H1 and ZEUS completed high Q^2 DIS cross section measurements at HERA:
- *e^+p NC cross sections measurements at low E_p=460 and 575 GeV and a model independent determination of F_L.*
- *ZEUS $e^\pm p$ NC measurements at high $x \rightarrow 1$*
- *multijet production at high Q^2 and determination of a_s*

All inclusive $e^\pm p$ NC and CC cross sections at E_p=920, 820, 575 and 460 GeV are combined in one coherent HERA data set which is used as a sole input to the HERAPDF 2.0 QCD fits

OPAL / JADE data stay a clean testing ground for new developments related to jets.

Good progress in preservation of the HERA / OPAL /JADE data at MPP.