JADE, H1, OPAL and ZEUS status

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Annual project review, MPP, München,
December 14, 2015

H1 and ZEUS at HERA (1992-2007)

Allen Caldwell, Iris Abt, Vladimir Chekelian, Günter Grindhammer, Christian Kiesling, Andrii Verbytskyi. In collaboration with:

Daniel Britzger, Halina Abramowicz, Aharon Levy.

- No funding in DESY, but still active: 5 papers in 2015! See list in the backup.
- **23 years of dedicated efforts with decisive input from MPP resulted in 2015 in a state of art paper EPJ C75 (2015) 580**
  - H1 and ZEUS completed the inclusive DIS program at HERA by combining all inclusive unpolarised cross-section measurements at HERA into one coherent data set.
  - The combined inclusive HERA data set is used as a sole input to the QCD analysis resulting in the set of parton distribution functions HERAPDF2.0.
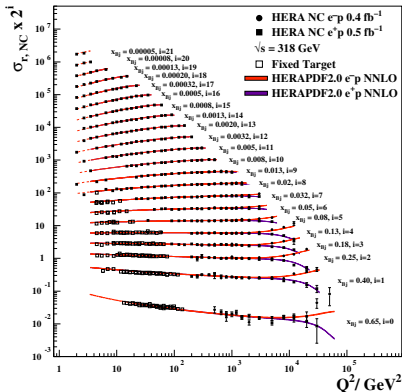
Combination of all NC and CC data at HERA
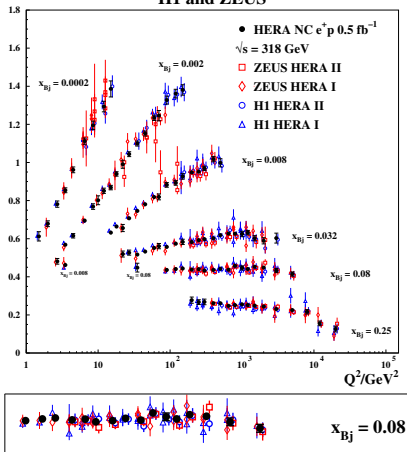
- 2927 measurements from
  - $e^{\pm}p$ NC/CC $\sqrt{s} = 318\,\text{GeV}$
  - e^+p NC $\sqrt{s} = 300, 251, 225\,\text{GeV}$,

  combined into 1307 points (up to 6 points merged).

- $\chi^2/ndof = 1685/1620$.

- 169 correlated systematic uncertainties considered.

- correlated shifts propogated to all points.

- $0.045 \leq Q^2 \leq 50\,\text{GeV}^2$, $6 \times 10^{-7} \leq x_{Bj} \leq 0.65$.

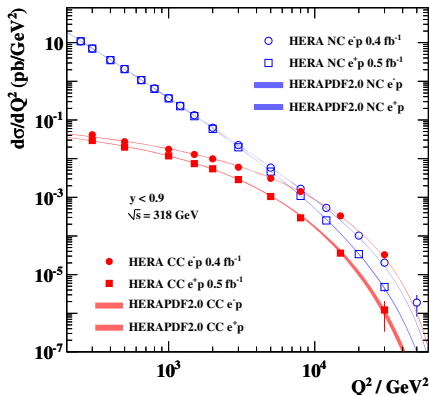- Total uncertainties $\leq 1.5\%$ for $Q^2 \leq 5 \times 10^3\,\text{GeV}^2$.

Combined data: the legacy of HERA

Inclusive NC e^+p and e^-p reduced cross sections+BCDMS&NMC fixed-target data.


NC and CC e^-p and e^+p cross sections.

Parton distribution functions HERAPDF2.0

- The combined HERA NC/CC data set is the sole input.
- The HERAPDF2.0 sets in NLO and NNLO are available at
  `http://www.desy.de/h1zeus/herapdf20`.
- Also with $\alpha_s(M^2(Z)) = [0.110, 0.111 \ldots 0.130]$.
- Featured HERAPDF2.0 sets: AG$\rightarrow xg(x) \geq 0$;
  HiQ2$\rightarrow Q^2_{min} = 10\,\text{GeV}^2$; FF3A and FF3B$\rightarrow$FFNS@NLO.
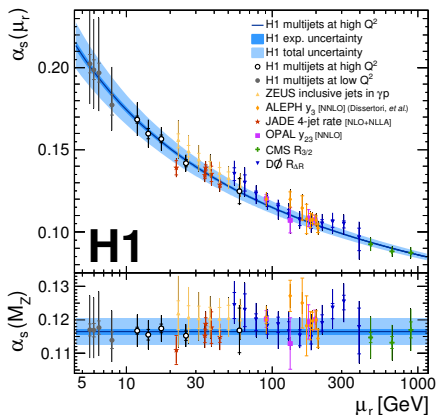- See details in the backup slides.

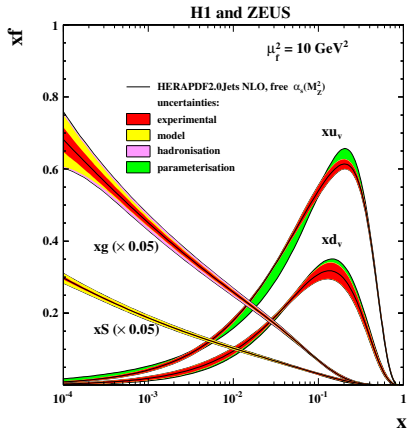# HERAPDF2.0 vs. global modern PDFs
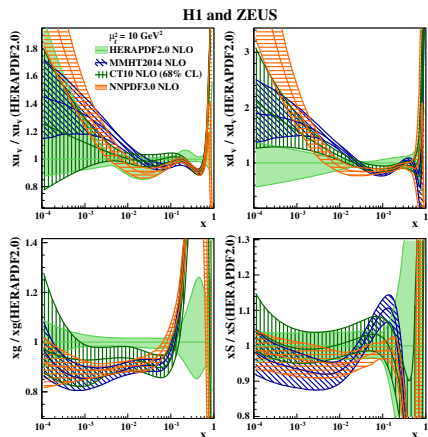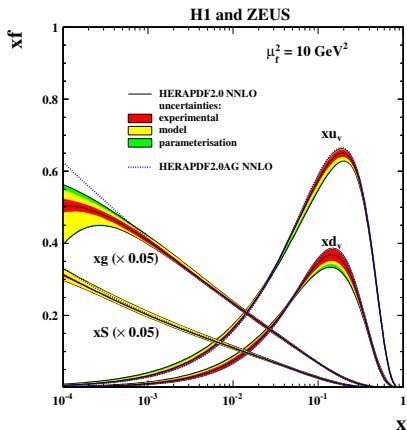
HERAPDF2.0 NNLO (left) and comparison to MMHT2014, CT10 and NNPDF3.0 (right).
Highly compatible, largest deviation is 2.5 st.d. for $xu_v(x)$ at $x = 0.4$.

V. Andreev *et al.*, EPJ C**75** (2015) 2, 65 α_s from HERA,LEP,Petra,Tevatron and LHC.

α_s from HERAPDFs:
$\alpha_s(M^2(Z)) = 0.1183 \pm 0.0009(exp.) \pm 0.0005(mod.) \pm 0.0012(had.)^{+0.0037}_{-0.0030}(sc.)$.

Some of ongoing H1&ZEUS analyses

Analyses with strong MPP involment progressed in 2015:

- With preliminary results:
    - ZEUS: "Prompt photon production in diffractive photoproduction"
    - H1+ZEUS: "Limit on the Effective Quark Charge Radius from Inclusive ep Scattering at HERA"
    - H1: "Search for QCD Instanton-Induced Processes in DIS at HERA"
- More to come!

OPAL@LEP and JADE@PETRA

Siegfried Bethke, Stefan Kluth, Hans von der Schmidt, Andrii Verbytskyi. In collaboration with: Matthias Schröder, Nadine Fischer, Jan Olsson.

- OPAL and JADE data sets will remain unique in the next 20+ years.
- Ultimate data set for any test of a new models in QCD.
- Oportunities for analyses and re-analyses:
  - QCD analysis: N. Fischer *et al.* [OPAL Coll.], "Measurement of observables sensitive to coherence effects in hadronic Z decays with the OPAL detector at LEP," EPJ C **75** (2015) 12, 571

OPAL QCD analysis

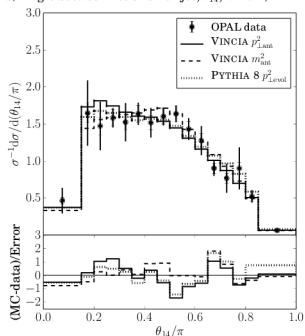Explore color coherence and the models that implement it.
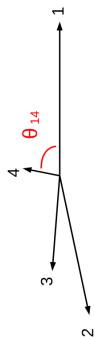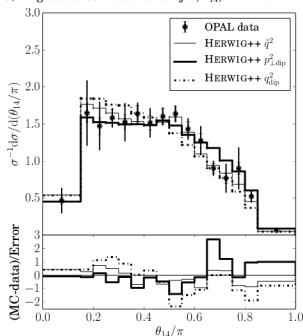
- Special 4-jet event configuration: $y^{4\to3} > 0.0045$, $\theta_{12} > 2\pi/3$, $\theta_{13} > 2\pi/3$, $\theta_{23} < \pi/6$.
- Comparison to six models for the parton shower (HERWIG++, PYTHIA8, and VINCIA).

OPAL/JADE jet rates with new algorithms
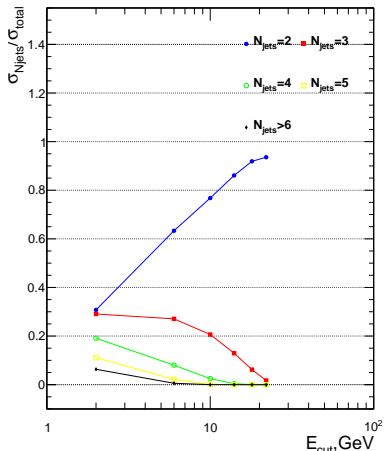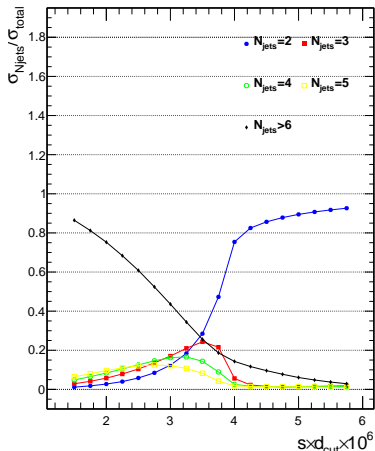
Anti-k_T, $\sqrt{s} = 91$ GeV.   SISCone $R = 0.7$, $\sqrt{s} = 91$ GeV.
+Re-analysis of event shapes(+moments) with modern methods.

Conclusions

- HERA combination! Outcome of more than 2 decades of work.
- H1&ZEUS&OPAL remain active and produce new results.
- Data preservation efforts for JADE, H1, OPAL and ZEUS are in progress.
- Preserved data will remain unique for a long time and will serve for a valuable physics results. The technical aspects are covered in "Scientific computing" talk.

Backup slides

H1&ZEUS 2015 papers

- H. Abramowicz *et al.* [ZEUS Coll.], "Production of exclusive dijets in diffractive deep inelastic scattering at HERA," arXiv:1505.05783.
- H. Abramowicz *et al.* [H1 and ZEUS Colls.], "Combination of differential $D^{*\pm}$ cross-subsection measurements in deep-inelastic *ep* scattering at HERA," JHEP **1509** (2015) 149.
- H. Abramowicz *et al.* [H1 and ZEUS Colls.], "Combination of Measurements of Inclusive Deep Inelastic $e^{\pm}p$ Scattering Cross Sections and QCD Analysis of HERA Data," EPJ C75 (2015) 580.
- V. Andreev *et al.* [H1 Coll.], "Exclusive ρ^0 Meson Photoproduction with a Leading Neutron at HERA," arXiv:1508.03176.
- V. Andreev *et al.* [H1 Coll.], "Diffractive Dijet Production with a Leading Proton in *ep* Collisions at HERA," JHEP **1505** (2015) 056.

HERAPDF2.0 details

- GVFNS, m_c and m_b from HERA charm and beauty production.
- PDFs evolution with DGLAP at NLO and NNLO.
- PDFs parametrisation at starting scale $Q_0^2 = 1.9\,\text{GeV}^2$

$$xg(x) = A_g x^{B_g} (1-x)^{C_g} - A'_g x^{B'_g} (1-x)^{C'_g} \qquad x\bar{U}(x) = A_{\bar{U}} x^{B_{\bar{U}}} (1-x)^{C_{\bar{U}}} \left(1 + D_{\bar{U}} x\right)$$

$$xu_v(x) = A_{u_v} x^{B_{u_v}} (1-x)^{C_{u_v}} \left(1 + E_{u_v} x^2\right) \qquad x\bar{D}(x) = A_{\bar{D}} x^{B_{\bar{D}}} (1-x)^{C_{\bar{D}}}$$

$$xd_v(x) = A_{d_v} x^{B_{d_v}} (1-x)^{C_{d_v}} \qquad xs(x) = f_s(x) xD, f_s = 0.4 \text{ at } Q_0^2 \rightarrow \text{Total 14 parameters}$$

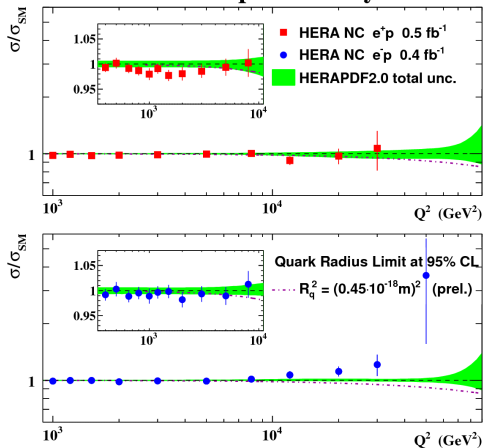"Prompt photon production in diffractive photoproduction"
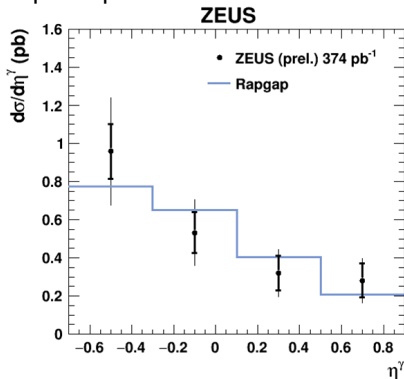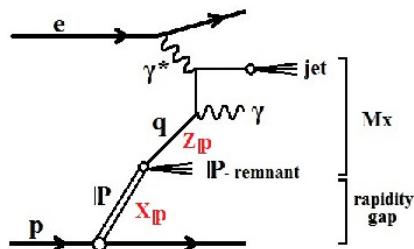
- Prompt photons emerge the hard scattering process and give a particular view of this.
- Probing the partonic structure of pomeron and virtual photon.
- Presented at Low-x 2015.

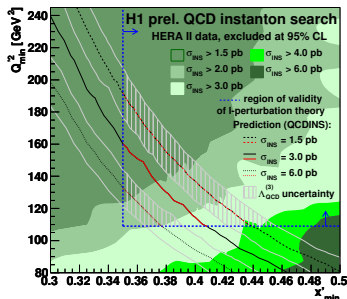"Limit on the Effective Quark Charge Radius from Inclusive ep Scattering at HERA"

- Extension of HERAPDF2.0 analysis to take into account possible signals from physics beyond SM. Tests quark substructure or finite spatial distribution of the quark charge.
- Presented at EPS 2015.

"Search for QCD Instanton-Induced Processes in DIS at HERA "
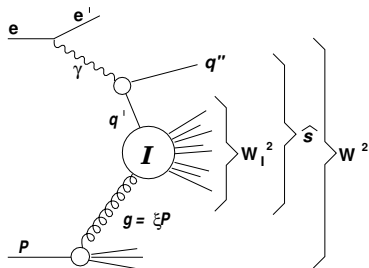
- Instantons can be viewed as tunneling transitions between different vacua states.
- The discovery would have an importance on itself + would imply certain quantum numbers violation.
- Presented at ISMD 2015 and Low-x 2015.

OPAL/JADE event shapes
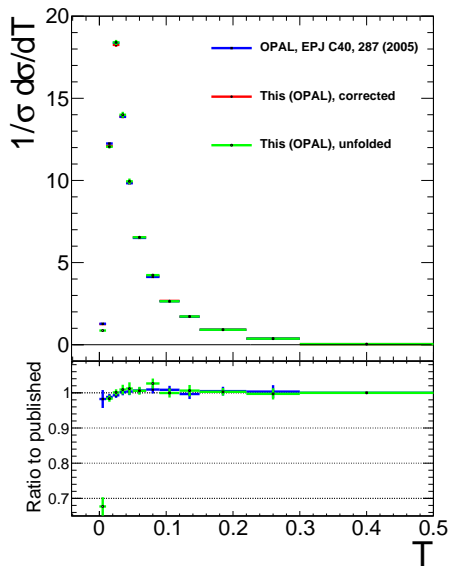
Example for thrust distribution.

- Repeated previous results.
- Use new advanced methods to get smaller systematics.
- Same for new MC and predictions + ultimate tuning of new MC.

HERA, LEP and PETRA data preservation

H1, JADE, OPAL and ZEUS experiments are concerned:

- more than 40 years of data taking.
- thousands of FTE for hardware/software development and analysis.
- more than 600 papers.
- 1Pb of data in 3.5 millions of files.
- 100Gb of software and auxiliary files.

The main intention is to provide facilities for the physics analysis and to do physics analysis for in house experiments.
See details on the implementation in the "Scientific computing" talk.

ZEUS event display@MPP connected to MPCDF

HW independant: VirtualBox on 64-bit CentOS7 runs 64-bit CentOS6.
Outside of DESY: ZEVIS in MPP reads via dCap ZEUS data from MPCDF.

Current status of H1&ZEUS DP

Data/MC	ZEUS	H1
DESY archive	Processed data/MC ntuples	Raw data/MC, processed data/MC
DESY available online	Everything	up to 80%
DESY access	NFS, from 2 machines in DESY+BIRD	NFS, from 2 machines in DESY+BIRD
MPCDF/MPP online+archive	As in DESY+raw data	As in DESY (online)
MPCDF/MPP access	Multiprotocol,	Multiprotocol,
	worldwide with ZEUS VO cert.	worldwide with H1 VO cert.

Software		
DESY reconstruction	No	Yes
DESY MC generation	No	Yes
DESY analysis	Yes	Yes(up to 5y)
DESY user storage	Yes, limited, on 2 machines in DESY	Yes, limited, on 2 machines in DESY
DESY environment	2 machines in DESY+BIRD(up to 5y)	2 machines in DESY+BIRD(up to 5y)
MPCDF/MPP reconstruction	Yes	Planned
MPCDF/MPP MC generation	Yes	Planned
MPCDF/MPP analysis capability	Yes	Planned
MPCDF/MPP user storage	Yes, unlimited, MPCDF SE+CephFS	Yes, unlimited, MPCDF SE+CephFS
MPCDF/MPP environment	CentOS7 virtual machine available	CentOS7 virtual machine planned

Documentation		
DESY analysis primer/manual	Archived web-server	Archived web-server
DESY legacy notes, drafts etc.	InSpire+DESY library	InSpire+DESY library
DESY preservation paper/note	No	No
MPCDF/MPP analysis primer/manual	Relies on DESY	Relies on DESY
MPCDF/MPP legacy notes, drafts etc.	InSpire+DESY library	InSpire+DESY library
MPCDF/MPP preservation paper/note	First draft is available	Planned
	(+A.G.)	

DESY	Finished	Finished, but not optimal	Significant advance	Moderate advance	Will not be done
MPCDF/MPP	Finished	Finished, but not optimal	Significant advance	Moderate advance	Will not be done

Current status of OPAL&JADE DP

Data/MC	OPAL, Host=CERN	JADE, Host=DESY
Host data	Raw/processed, data/MC on CASTOR/EOS	Probably
Host access	Multiprotocol, CERN	No
MPCDF/MPP available online	Raw/processed, data/MC	Raw/Processed Data/MC
MPCDF/MPP archive	Raw/processed, data/MC	Raw/Processed Data/MC
MPCDF/MPP access	Multiprotocol,	Multiprotocol,
	worldwide with OPAL VO cert.	worldwide with ZEUS VO cert.
Software		
Host reconstruction	Yes	No
Host MC generation	Yes	No
Host analysis	Yes	No
Host user storage	CERN users only	No
Host environment	Default CERN	No
MPCDF/MPP reconstruction	Yes (M.S.)	Planned
MPCDF/MPP MC generation	Yes (M.S.)	Update/Planned
MPCDF/MPP analysis	Yes	Planned
MPCDF/MPP user storage	Yes, unlimited, MPCDF SE+CephFS	Not needed
MPCDF/MPP environment	CentOS7 VM available	AIX → Fedora17 PPC
		or CentOS7 x86_64 VM planned
Documentation		
Host analysis primer/manual	CERN web-server	No
Host legacy notes, drafts etc.	InSpire+CERN library	InSpire+DESY+J.O.
Host preservation paper/note	No	No
MPCDF/MPP analysis primer/manual	Relies on CERN	Yes (Update!)
MPCDF/MPP legacy notes, drafts etc.	InSpire+CERN library	InSpire+DESY library+
MPCDF/MPP preservation paper/note	Yes, early stage update	Yes (Update!)

Host	Finished	Finished, but not optimal	Significant advance	Moderate advance	Will not be done
MPCDF/MPP	Finished	Finished, but not optimal	Significant advance	Moderate advance	Will not be done