Max-Planck-Institut für Physik
(Werner-Heisenberg-Institut)

Data preservation

(JADE, H1, OPAL and ZEUS status)

Andrii Verbytskyi

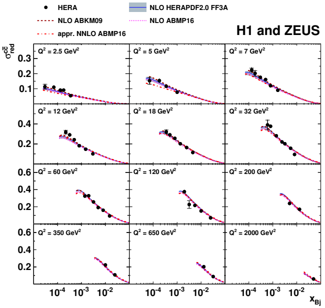
Annual project review, MPP, München,
December 17, 2018

OPAL, JADE, ZEUS and H1

- People: I. Abt[ZEUS], S. Bethke[OPAL,JADE], D. Britzger[H1] , A. Caldwell[ZEUS], V. Chekelian[H1], G. Grindhammer[H1], Ch. Kiesling[H1], S. Kluth[OPAL,JADE], A. Verbytskyi[ZEUS,OPAL,JADE], (H. von der Schmidt[OPAL,JADE], H. Abramowicz[ZEUS], A. Levy[ZEUS]).
- Data: All data of OPAL, JADE, H1 and ZEUS.
- Services: storage for user analysis for all experiments + MC generation for ZEUS + software for JADE and OPAL.

H1+ZEUS: Combination and QCD analysis of charm and beauty production cross-section measurements in deep inelastic *ep* scattering at HERA

Published: EPJC 78 (2018) no.6, 473 [1]



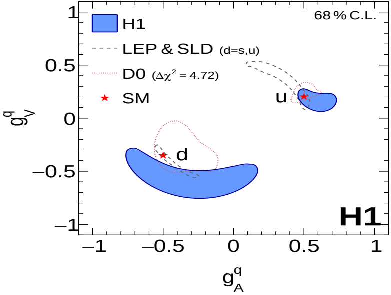
- $\sigma_{\mathrm{red}}^{c\bar{c}}$ and $\sigma_{\mathrm{red}}^{b\bar{b}}$ obtained for $2.5\ \mathrm{GeV}^2 \leq Q^2 \leq 2000\ \mathrm{GeV}^2$, $3 \cdot 10^{-5} \leq x_{\mathrm{Bj}} \leq 5 \cdot 10^{-2}$ from combination of multiple measurements. The combination accounts for all the correlations → **precision**.
- NLO QCD analysis to extract charm- and beauty-quark masses.

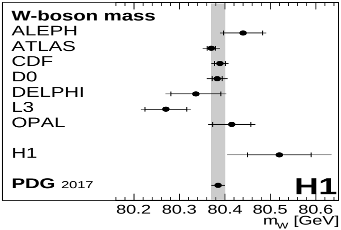
$$m_c(m_c) = 1.290^{+0.046}_{-0.041}(\mathrm{exp/fit})\ ^{+0.062}_{-0.014}(\mathrm{model})\ ^{+0.003}_{-0.031}(\mathrm{par})\ \mathrm{GeV}.$$
$$m_b(m_b) = 4.049^{+0.104}_{-0.109}(\mathrm{exp/fit})\ ^{+0.090}_{-0.032}(\mathrm{model})\ ^{+0.001}_{-0.031}(\mathrm{par})\ \mathrm{GeV}.$$

Combined cross-sections – another big milestone in HERA program!

H1: Determination of EW in polarised deep-inelastic scattering at HERA

Published: EPJC 78 (2018) no.9, 777 (H1+H. Spiesberger) [2].

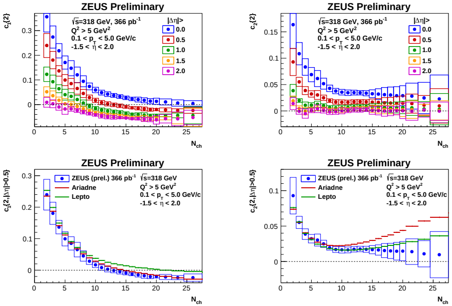




- Electroweak parameters are extracted from QCD+QED analysis from H1 data.
- $m_W = 80.520 \pm 0.115\, GeV$ – indirect measurement.
- **Republished full set of HERA inclusive NC and CC cross-sections.**

ZEUS: Azimuthal particle correlations as a probe of collectivity in deep inelastic electron-proton collisions at HERA

Preliminary, Quark Matter 2018, ICHEP2018, LOWX2018



2-particle correlations

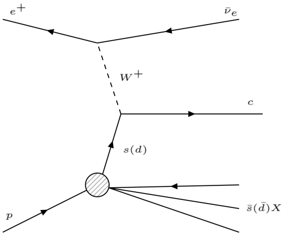
$$c_n\{2\} =< \cos(n(\phi_\alpha - \phi_\alpha)) >$$

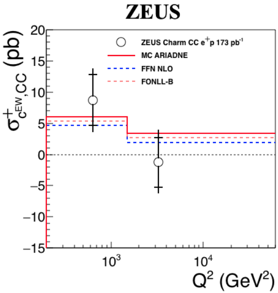
compared to QCD predictions.

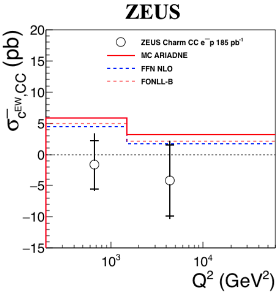
- Collectivity? Seen in HFS of $A+A$, $p+A$ and $p+p$.
- HFS in *ep* is even smaller than *pp*. **First analysis of this kind in *ep*!**
- Expertise from external group (Heidelberg/GSI).
- A limit is put on the possible collective effects in high multiplicity *ep* collisions.

ZEUS: Charm production in charged current deep inelastic scattering at HERA

Preliminary.



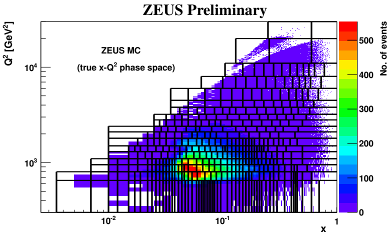


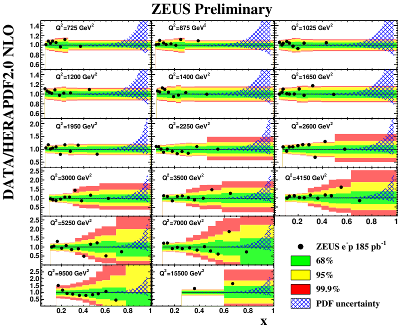


- $ep \rightarrow c + \nu_e + X$
- Charm tagging from secondary vertices $\rightarrow$ attempt to do inclusive analysis.
- $200\,GeV^2 < Q^2 < 60000\,GeV^2$, $y < 0.9$, $E_T(jet) > 5\,GeV$ and $-2.5 < \eta(jet) < 2.0$.
- Constrain on strange content of proton $\rightarrow$ extremely important for all PDFs.

Study of transfer matrix for high-x ZEUS data

Preliminary, ICHEP2018.



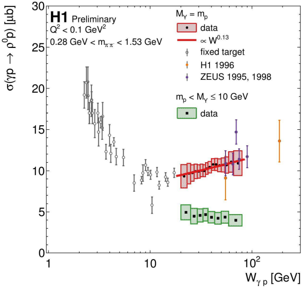


- Motivation: develop a reliable technique to check predictions by different PDFS in high-x region.
- How: publish data and a transfer matrix *true events*$(x, Q^2) \rightarrow$ *observed events*(x, Q^2).
- Predictions obtained with such transverse matrix can be used to validate "any" PDFs in high-x region.

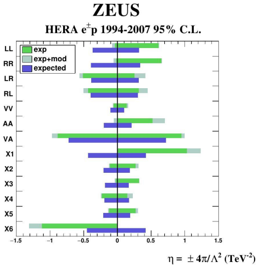
	e^-p		e^+p	
PDF	$x < 0.6$	$x \geq 0.6$	$x < 0.6$	$x \geq 0.6$
HERAPDF2.0	0.06	0.2	0.6	0.1
CT14	0.0008	0.2	0.7	0.6
MMHT2014	0.00003	0.1	0.6	0.6
NNPDF2.3	0.00007	0.2	0.6	0.6
NNPDF3.0	0.00003	0.2	0.6	0.6
ABMP16	0.01	0.2	0.8	0.5
ABM11	0.03	0.3	0.7	0.4

TABLE 2. The p-values from comparisons of predictions (at NLO) using different PDF sets to the observed numbers of events are shown. The p-values are given for two different x ranges for the e^+p and e^-p data sets.

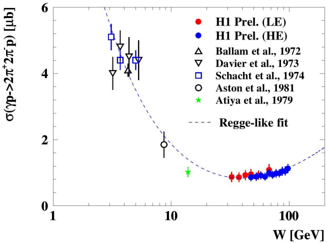
Other preliminaries



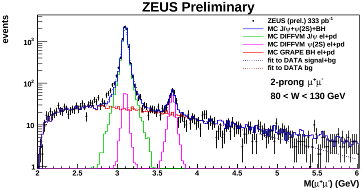
- Measurement of Exclusive ρ^0 Meson Photoproduction at HERA



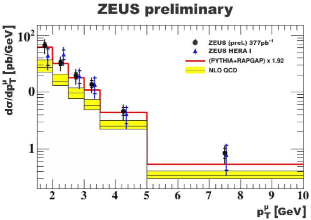
- Limits on contact interactions at HERA, DIS2017 (redone)



- Exclusive Photoproduction of $2\pi^+ 2\pi^-$ Final State at HERA, DIS2018

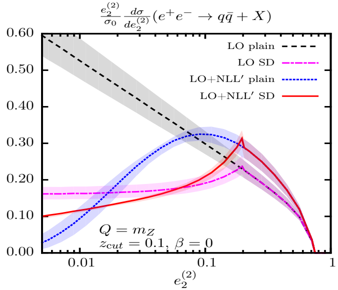


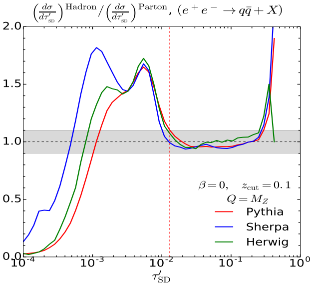
- Measurement of the $\psi(2S)$ and J/ψ cross section ratio in photoproduction with the ZEUS detector at HERA, ICHEP2018



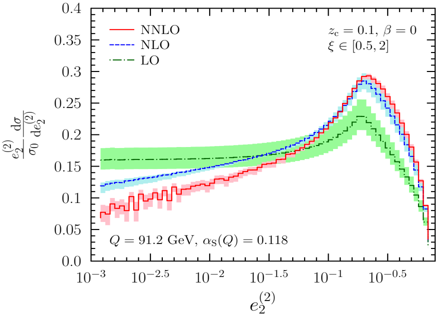
- Measurement of beauty from dimuon at HERA

New OPAL analysis: Soft drop event shapes

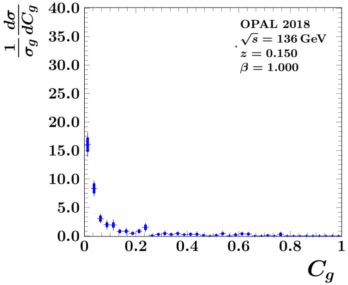


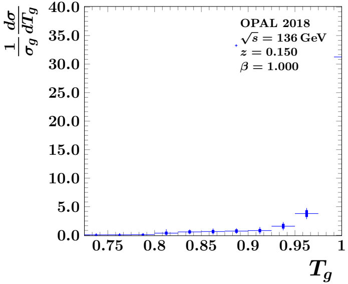


- Soft drop (SD) technique is aimed to remove soft objects from consideration.
- Originally developed for LHC, considered for e^+e^- in JHEP 1808 (2018) 105[3].
- Small and well-understood hadronisation corrections for event shapes with SD.
- NNLO[4] and NLL[3] predictions are available



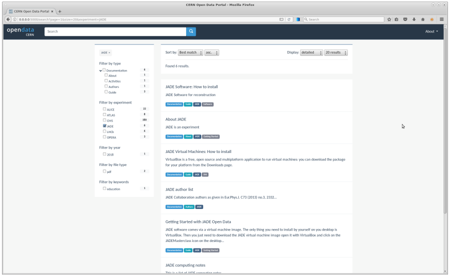
New OPAL analysis: Soft drop event shapes

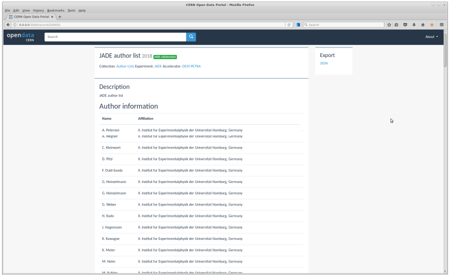




- Does it work? Are SD observables better that these w/o SD?
- Does "less soft component" means better precision of measurements and QCD analyses?
- Should one expect much from SD also at LHC?
- Work in progress. **S. Kluth**, **A. Verbytskyi**, J. Schieck, A. Hoang, S. Plätzer, A. Pathak, S. Kulkarni.

JADE @ opendata.cern.ch





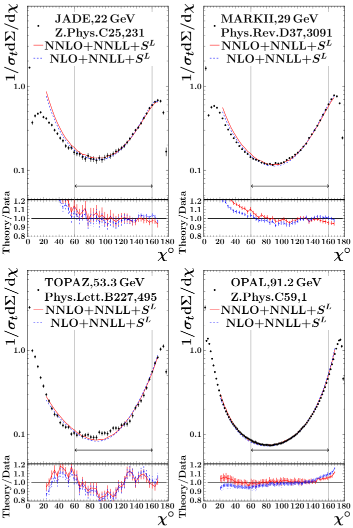
- JADE data, software, virtual machines and documentation is copied to CERN.
- A non-public version of JADE CERN OpenData portal is in development.
- Not public so far because of formal issues (formal agreement to publish the data, etc.).
- **S. Kluth**, **A. Verbytskyi** , **S. Bethke**, (**H. von der Schmidt**)

JADE/JADE data

- JADE@OpenData could serve as a model for other experiments e.g. efforts to bring ZEUS data to opendata.cern.ch.
  - Test of non-CERN experiments at opendata.cern.ch.
  - Test of experiments with "sub petabyte" data.
- As any OPAL analysis can be extended to JADE data without much efforts $\rightarrow$ Soft Drop analysis is under discussion.

The energy-energy correlations in $e^+e^- \rightarrow hadrons$ (EEC)

Fits:



EEC is:

$$\frac{\mathbf{dEEC}(\chi)}{\mathbf{d}\chi} = \frac{\sum_{\mathbf{i}}^{\mathbf{N}}\sum_{\mathbf{j}}^{\mathbf{N}} \mathbf{E_i E_j}\delta(\cos\chi - \cos\chi_{\mathbf{ij}})}{(\sum_{\mathbf{k}}^{\mathbf{N}} \mathbf{E_k})^2},$$

E_i = energy of particle i,

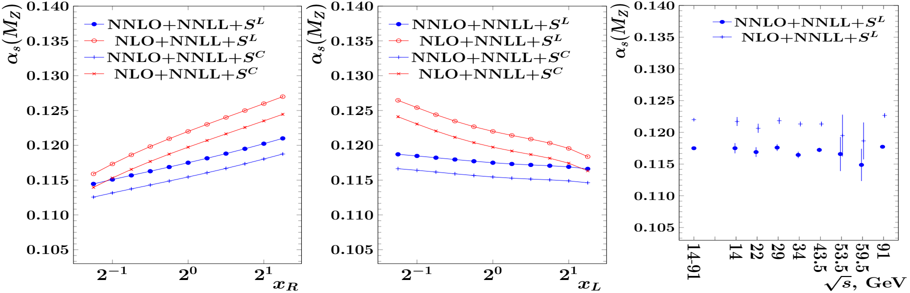
χ_{ij} = angle between particles i and j.

Analysis includes

- TRISTAN, LEP, PETRA, PEP data
- Resumed NNLL from EPJC**77** (2017) no.11, 749 [6].
- Precise NNLO from EPJC**77** (2017) no.11, 749 [6].
- b mass corrections at NLO, PLB **407** (1997) 57 [7].
- Multiple NLO MC (S^L,S^C,H^C) &analytic hadronisation corrections.

The energy-energy correlations in $e^+e^- \rightarrow hadrons$ (EEC)

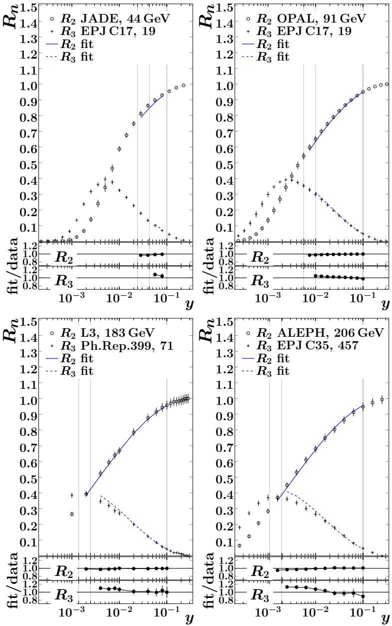
Dependence on renormalisation(left) and resummation(center) scale, data $\sqrt{s}$(right).



- $\alpha_S(M_Z) = 0.11750 \pm 0.00018(exp.) \pm 0.00102(hadr.) \pm 0.00257(ren.) \pm 0.00078(res.)$.
- First precise fits with EEC.
- Competitive result with impact on world average.

Precise determination of $\alpha_S(MZ)$ from a global fit of energy-energy correlation to NNLO+NNLL predictions, EPJC **78** (2018) no.6, 498

The n-jet rates in $e^+e^- \to hadrons$ (R_n)



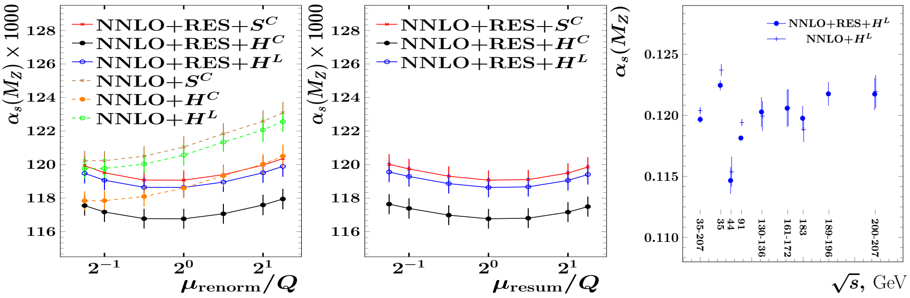
$$\mathbf{R_n} = \frac{\sigma(\mathbf{e^+e^-\to n\ jets})(\mathbf{y_{cut}})}{\sigma_{\mathbf{tot}}(\mathbf{e^+e^-\to hadrons})}$$

y_{cut} is a cut on Durham jet resolution parameter $y = \dfrac{2min(E_i^2, E_j^2)(1-\cos\chi_{ij})}{(\sum_k^N E_k)^2}$

Analysis includes

- LEP and PETRA data.
- Resumed R_2 NNLL from PRL **117** (2016) no.17, 172001 [8].
- Precise NNLO from PRD **94** (2016) no.7, 074019 [9].
- b mass corrections at NLO, PLB **407** (1997) 57 [7].
- Multiple NLO MC hadronisation corrections.

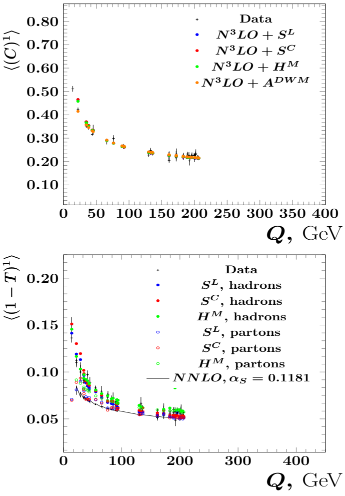
The n-jet rates in $e^+e^- \to hadrons$ (R_n)



- $\alpha_S(M_Z) = 0.11789 \pm 0.00027(exp.) \pm 0.00097(hadr.) \pm 0.00035(ren.) \pm 0.00038(res.) \to 0.11789 \pm 0.00113(comb.)$
- First precise fits of R_2 data.
- Highest precision ($< 1\%$), strong impact on world average.
- First simultaneous fit of multiple jet rates (test).

Precise determination of $\alpha_S(M_Z)$ from a global fit of jet rates to high order matched predictions, prepared for submission, QCD2018. A. Banfi, A. Kardos, P.F. Monni, **S. Kluth**, G. Somogyi, Z. Szőr, Z. Trocsányi, Z. Tulipánt, **A. Verbytskyi**, **G. Zanderighi** .

Event shape moments in $e^+e^- \to hadrons$ ($\langle V^n \rangle$)



$$\langle \mathbf{V^n} \rangle = \frac{1}{\sigma_{\mathbf{tot}}(\mathbf{e^+e^- \to hadrons})} \int_{\mathbf{V_{min}}}^{\mathbf{V_{max}}} \mathbf{V^n d\sigma(V)}$$

where V is event shape observable.

- LEP and PETRA data on C and T event shapes.
- Precise NNLO (A. Kardos, G. Somogyi).
- b mass corrections at NLO, PLB **407** (1997) 57 [7].
- Multiple NLO MC hadronisation corrections.
- Analytic hadronisation model.

Analysis is an attempt to perform first $\alpha_S^4(M_Z)$ analysis with precise NNLO predictions. Work in progress. A. Kardos, G. Somogyi, **A. Verbytskyi**.

Other (daughter) projects

Usage of Monte Carlo simulations for modelling of hadronisation requires advanced Monte Carlo event generators and related tools. SHERPA-MC, Herwig7, OpenLoops, GoSam, MadGraph.

- Implementation of Lund hadronisation model in Herwig7.
  - Useful for ATLAS for estimation of multiple systematics uncertainties related to MC modelling within one generator framework (Herwig7).
  - ATLAS internal, **L. Scyboz**, **A. Verbytskyi**, +(S. Plätzer).
- New cluster hadronisation model for SHERPA MC.
  - Improvements in description of data.
  - First usage of *ep* data in systematic MC generator tunes.
  - A new cluster hadronisation model for Sherpa, in preparation, POETIC8. F. Krauss, **F. Klimpel**, H. Schultz, **A. Verbytskyi**.
- HepMC3: Next generation of event record for Monte Carlo generators.
  - Version 3.1 to be released soon.
  - Focus on simplicity, flexibility and easy usage for experimental physicists.
  - Work in progress, submitted to ACAT2019. A. Buckley, D. Grellscheid, D. Konstantinov, L.Lönnblad, J. Monk, W. Pokorski, T. Przedzinski, **A. Verbytskyi**.

Conclusions

- Data preservation efforts for JADE, H1, OPAL and ZEUS are in progress.
- H1&ZEUS&OPAL remain active and produce new results.
- Many new analyses were started in ZEUS as a result of collaboration with external groups. External groups are interested in OPAL data, work in progress.
- Modern theory predictions and MC can help to obtain precise results, e.g. $> 1\%$ precision on α_S.

Backup slides

Bibliography I

[1] H. Abramowicz *et al.* [H1 and ZEUS Collaborations], "Combination and QCD analysis of charm and beauty production cross-section measurements in deep inelastic *ep* scattering at HERA," Eur. Phys. J. C **78** (2018) no.6, 473 doi:10.1140/epjc/s10052-018-5848-3 [arXiv:1804.01019 [hep-ex]].

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[4] A. Kardos, G. Somogyi and Z. Trócsányi, "Soft-drop event shapes in electron–positron annihilation at next-to-next-to-leading order accuracy," Phys. Lett. B **786** (2018) 313 doi:10.1016/j.physletb.2018.10.014 [arXiv:1807.11472 [hep-ph]].

[5] A. Kardos, S. Kluth, G. Somogyi, Z. Tulipánt and A. Verbytskyi, "Precise determination of $\alpha_S(M_Z)$ from a global fit of energy-energy correlation to NNLO+NNLL predictions," Eur. Phys. J. C **78** (2018) no.6, 498 doi:10.1140/epjc/s10052-018-5963-1 [arXiv:1804.09146 [hep-ph]].

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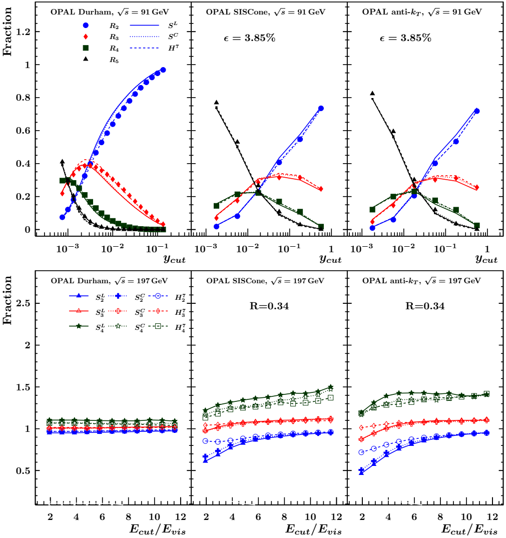
[7] P. Nason and C. Oleari, "Next-to-leading order corrections to momentum correlations in $Z^0 \to b\bar{b}$," Phys. Lett. B **407** (1997) 57 doi:10.1016/S0370-2693(97)00721-1 [hep-ph/9705295].

[8] A. Banfi, H. McAslan, P. F. Monni and G. Zanderighi, "The two-jet rate in e^+e^- at next-to-next-to-leading-logarithmic order," Phys. Rev. Lett. **117** (2016) no.17, 172001 doi:10.1103/PhysRevLett.117.172001 [arXiv:1607.03111 [hep-ph]].

[9] V. Del Duca, C. Duhr, A. Kardos, G. Somogyi, Z. Szőr, Z. Trócsányi and Z. Tulipánt, "Jet production in the CoLoRFulNNLO method: event shapes in electron-positron collisions," Phys. Rev. D **94** (2016) no.7, 074019 doi:10.1103/PhysRevD.94.074019 [arXiv:1606.03453 [hep-ph]].

n-jet rates in $e^+e^- \rightarrow hadrons$ (R_n) with new jet algorithms



$$\mathbf{R_n} = \frac{\sigma(\mathrm{e^+e^-} \rightarrow \mathbf{n\ jets})(\mathbf{y_{cut}})}{\sigma_{\mathbf{tot}}(\mathrm{e^+e^-} \rightarrow \mathbf{hadrons})}$$

with new jet algorithms anti-k_t and SISCone, Durham (for comparison)

+ y defined via cut on jet energy. Analysis includes

- OPAL data.
- Multiple NLO MC predictions, hadronisation corrections, etc.
- Analysis in Editorial board, preliminary results used as a cross-check in α_S extraction.