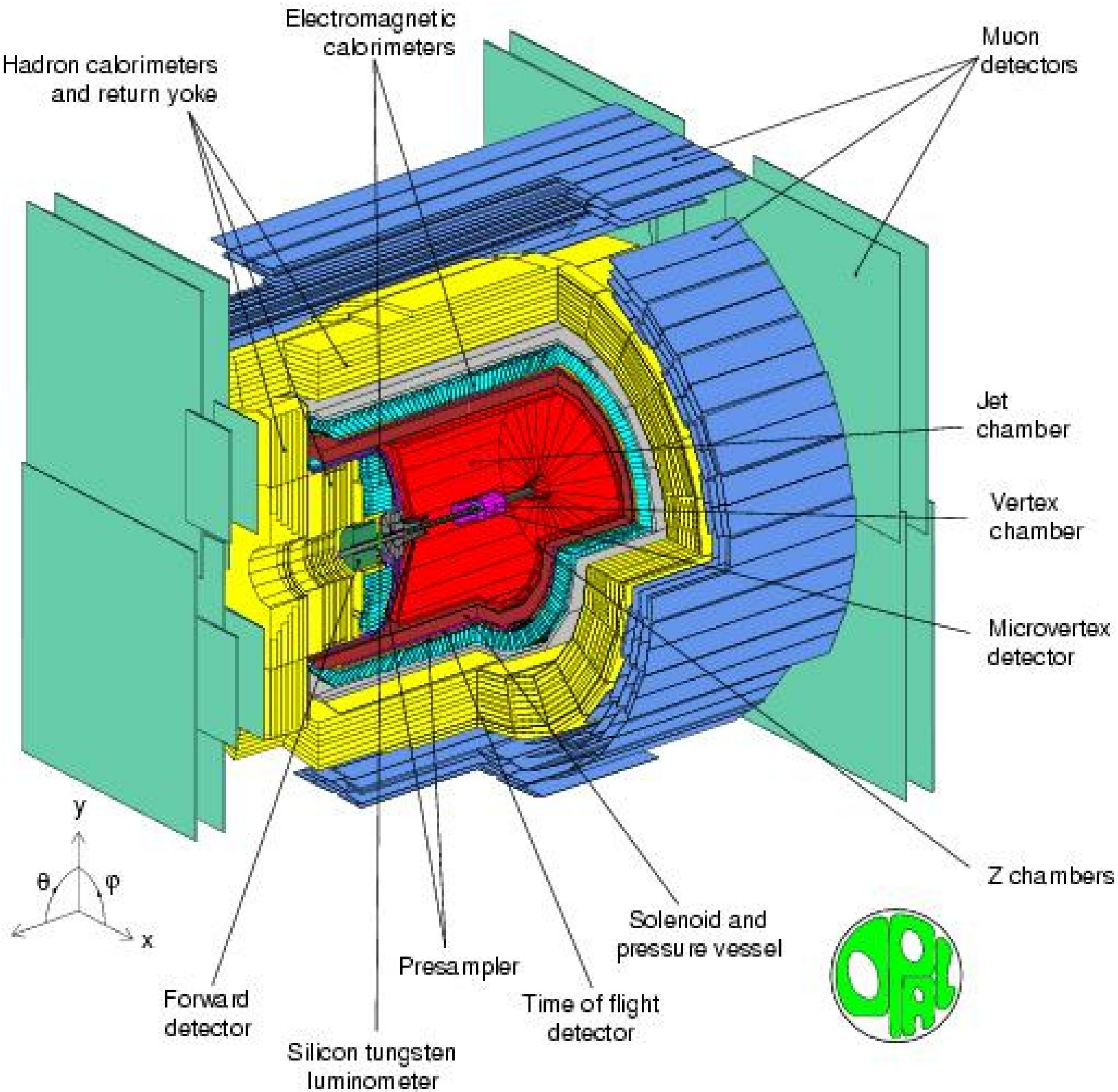
New results from old data
-JADE and OPAL-

- OPAL experiment
- Event shape distributions
- Measurement of α_S from JADE- and OPAL distributions using NNLO calculations
  - **EPJ C64:351, S. Bethke, S. Kluth, C. Pahl, J. Schieck and the JADE Collaboration**
  - **CERN-PH-EP-2010-089, submitted to EPJ C, the OPAL Collaboration**
- Outlook: Contemporary and planned experiments
- Conclusion

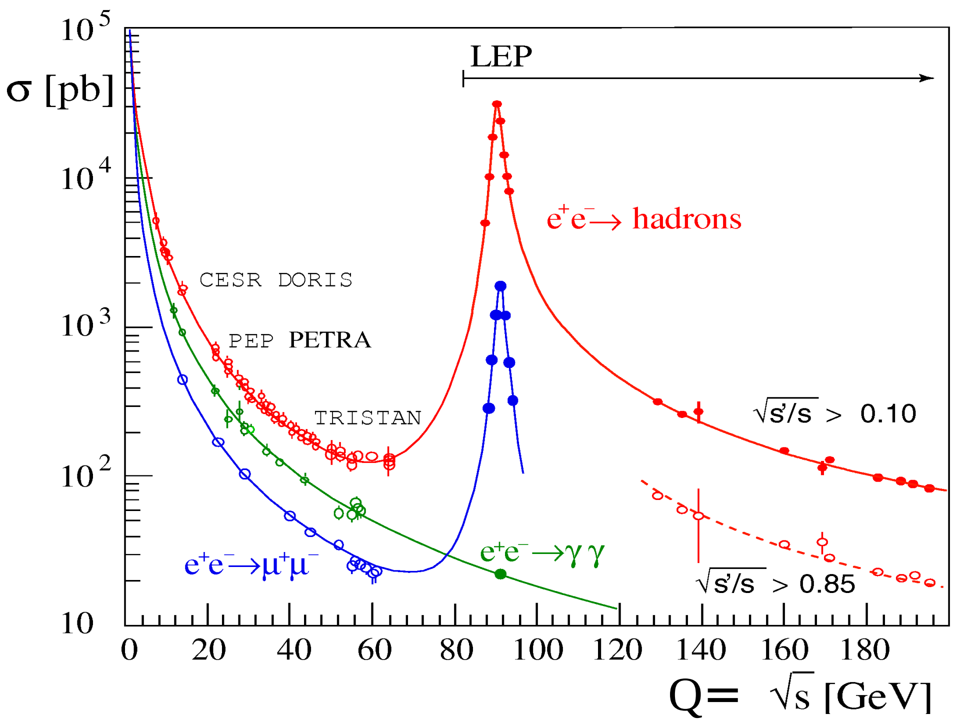
OPAL Experiment



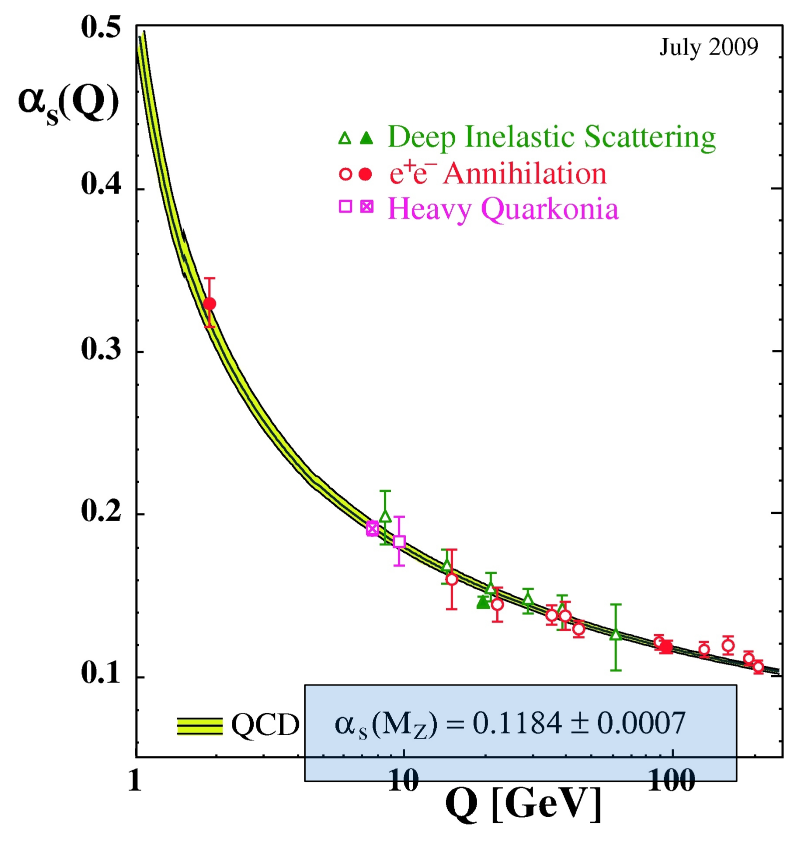
OPAL: 1989-2000 at LEP
Q=91-209 GeV

QCD up to 200 GeV

Hadronic cross section



Running strong coupling
(Eur. Phys. J. C 64:689)

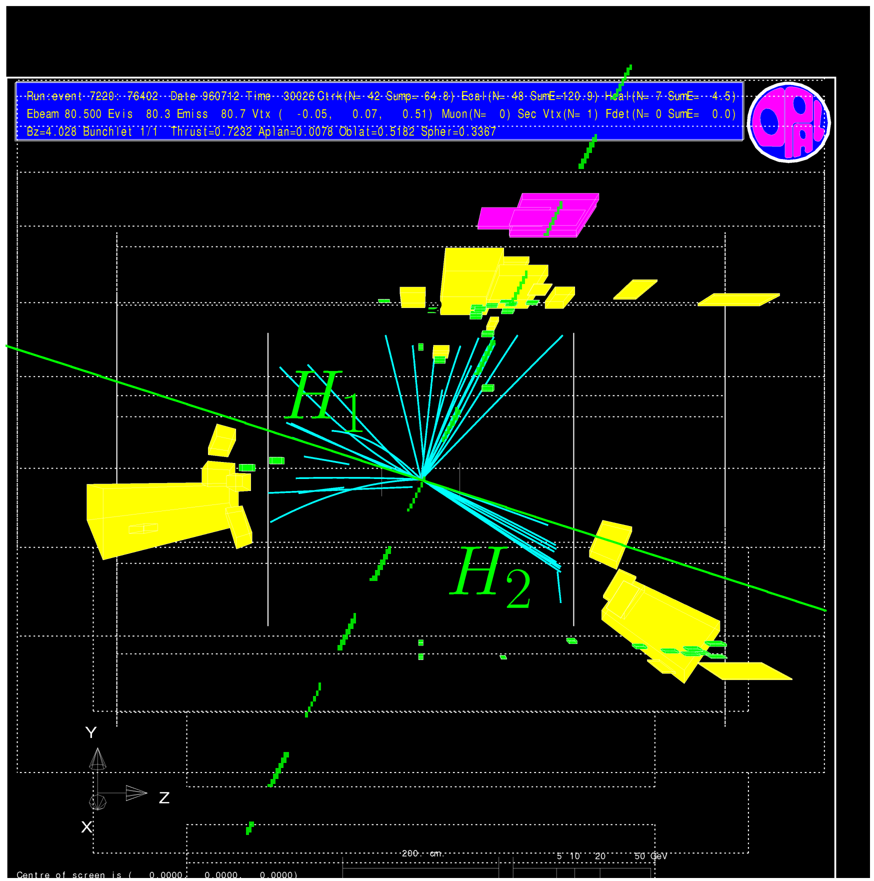


Event shape variables y

Two-hemisphere variables:

One-hemisphere variables:

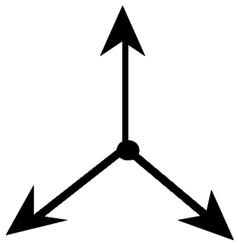
- Thrust 1-T
- C parameter
- Total Jet Broadening B_T



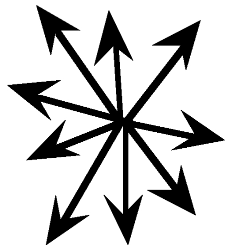
- Wide Jet Broadening B_W
- Durham two-jet flip parameter y^D_{23}
- Heavy Jet Mass M_H

Event shape distributions

qq: 2 Jets, y≈0

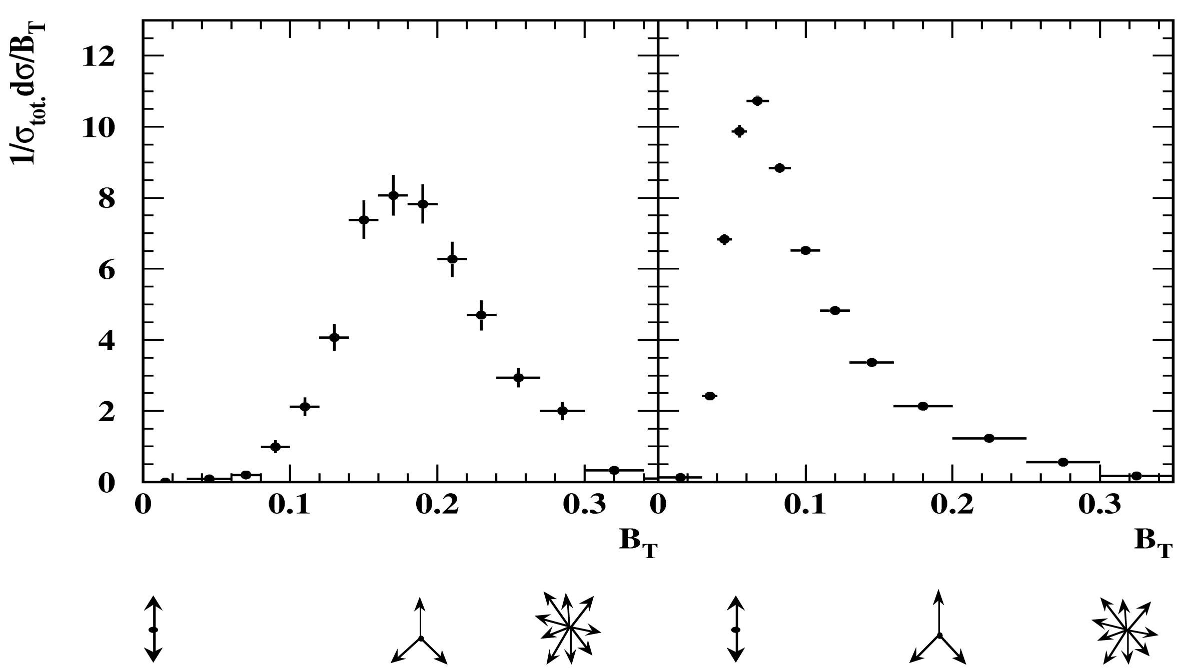


qqg: 3 Jets, e.g. 1-T ≈ ⅓



Many gluons, e.g. 1-T ≈ ½

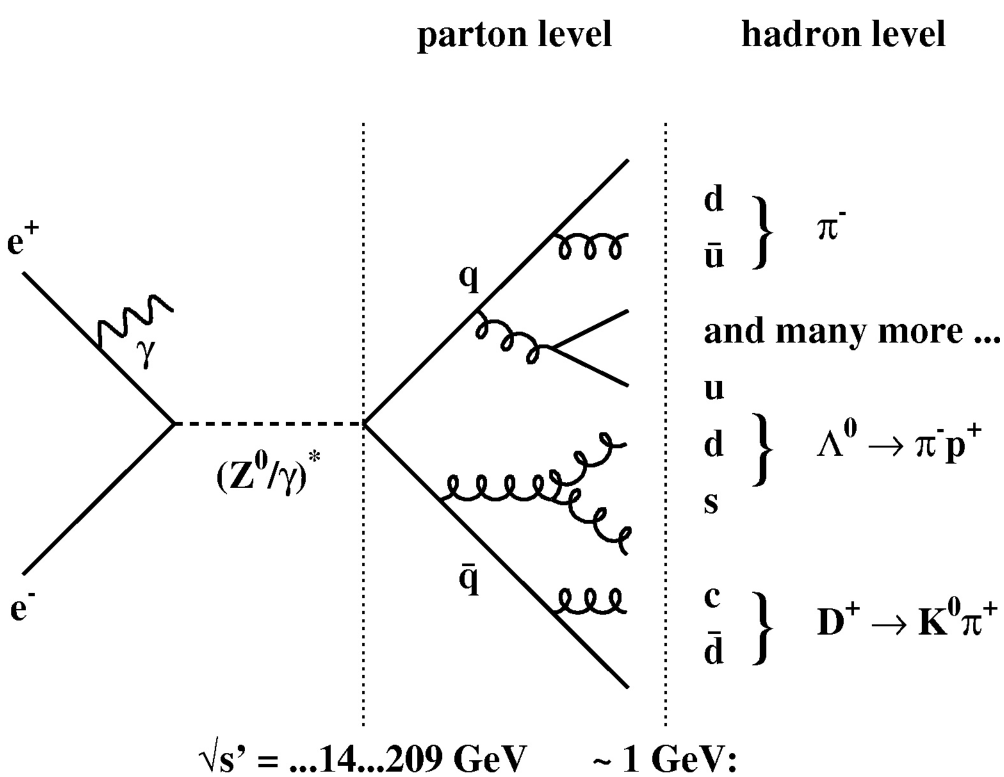
B_T at 14 GeV: α_s large



B_T at 91 GeV: α_s small

Fits of distributions

Hadronisation: Monte Carlo models



Hadronic event in $e^+ e^-$ annihilation

Predictions: **N**ext to **N**ext to **L**eading **O**rder $O(\alpha_s^3)$

(finished 2008 after 25 years of work)

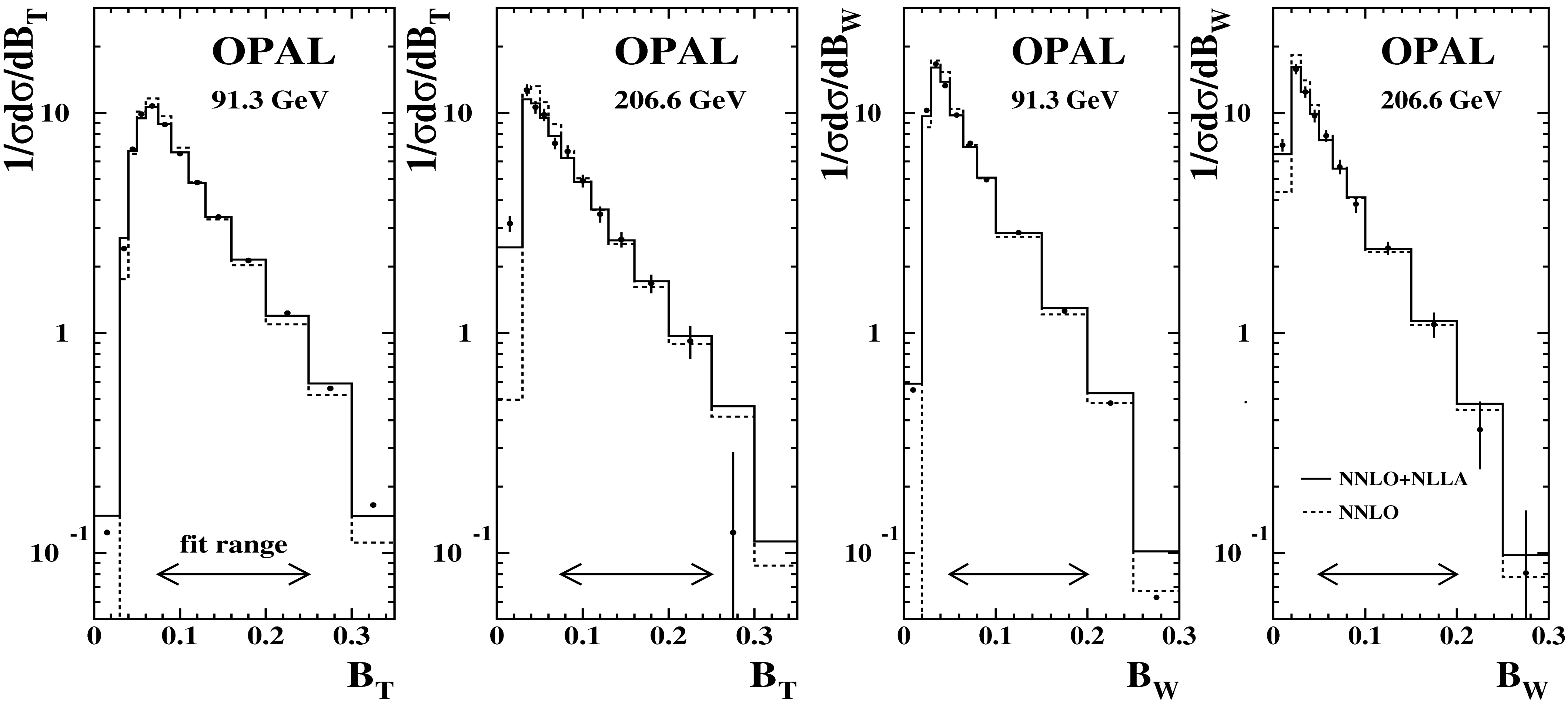
$$\frac{1}{\sigma}\frac{d\sigma}{dy}=\frac{dA}{dy}\frac{\alpha_S}{2\pi}+\frac{dB}{dy}\left(\frac{\alpha_S}{2\pi}\right)^2+\frac{dC}{dy}\left(\frac{\alpha_S}{2\pi}\right)^3$$

+normalization
+scale dependence (compensation in 2 loops)

optionally:
+**N**ext to **L**eading **L**ogarithmic **A**pproximation (scale compensation in 1 loop)

Fits of distributions

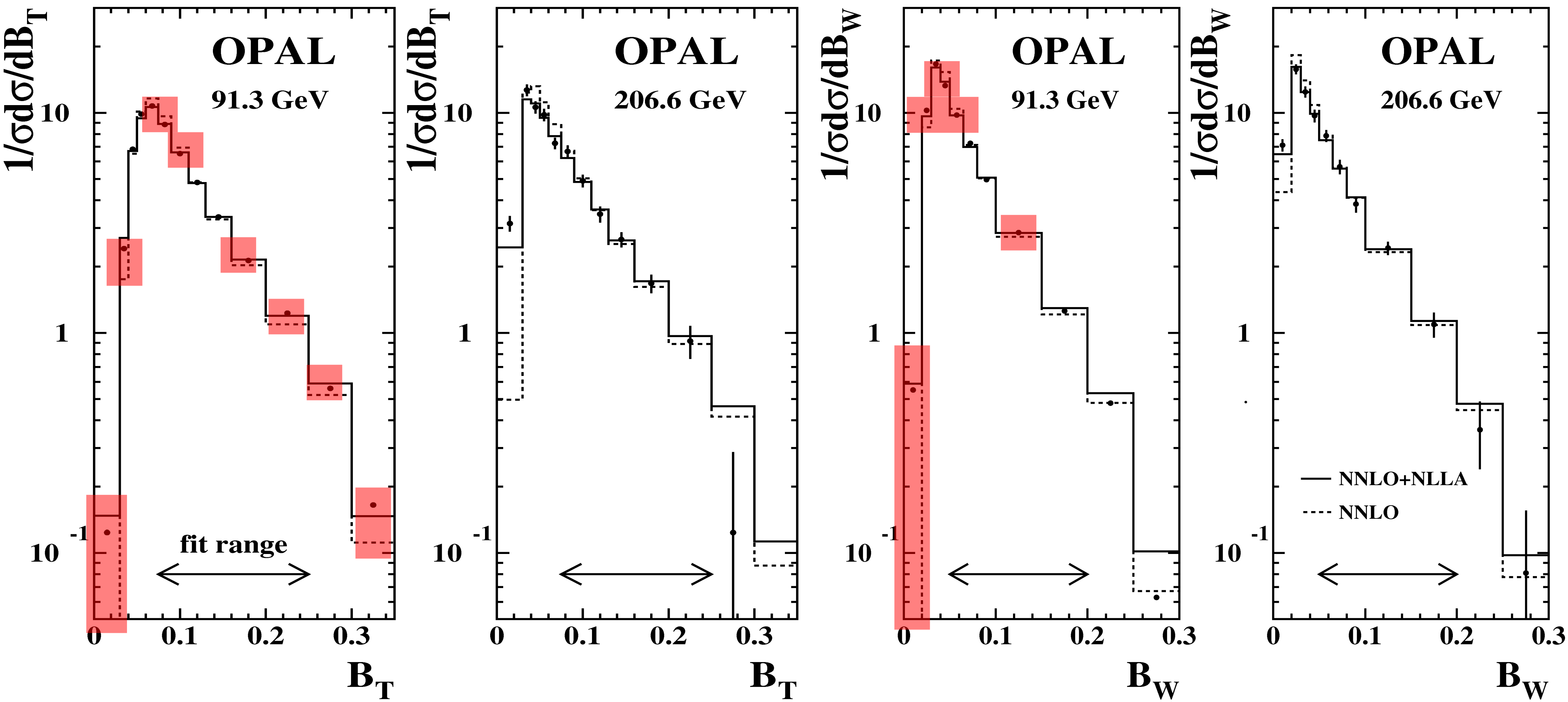
Event shapes total, wide jet broadening (hadron level with stat. errors)



More complete than NLO analyses:
Data described well over virtually all phase space

Fits of distributions

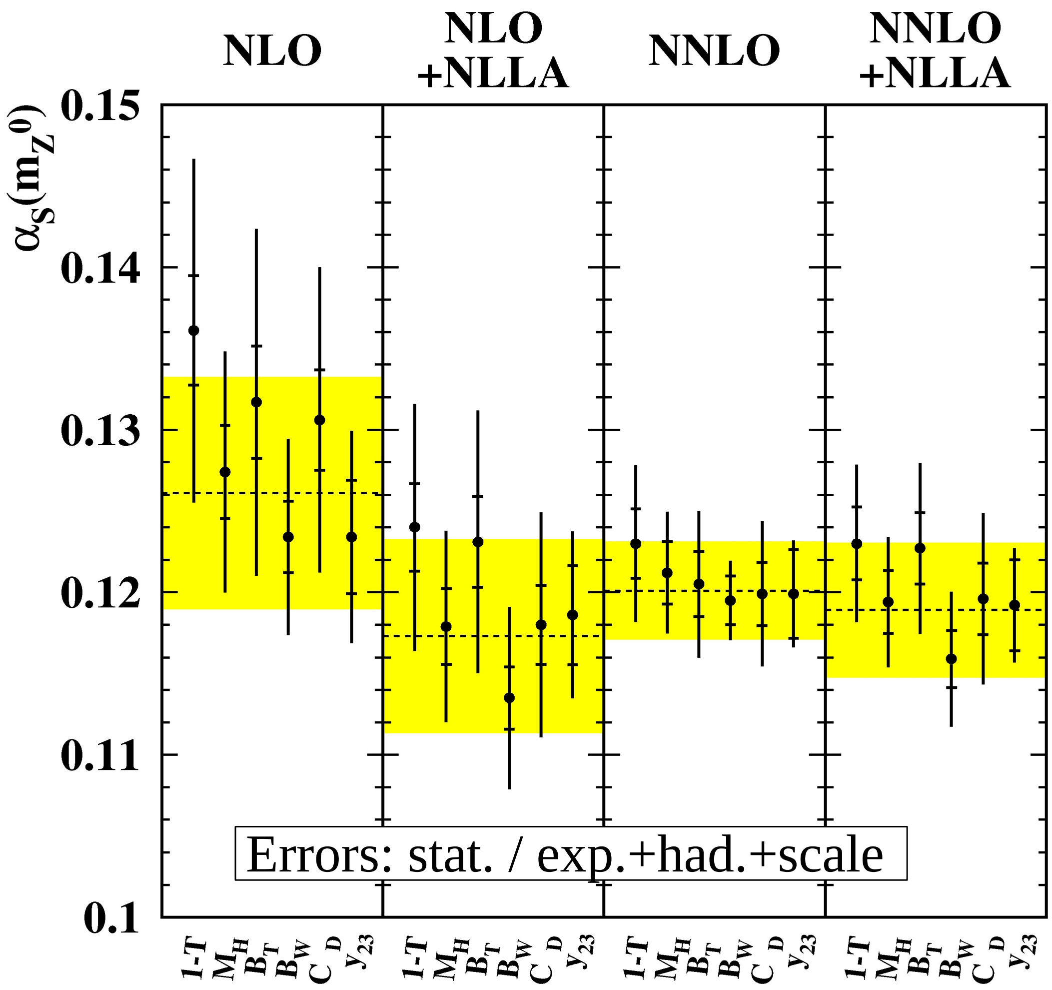
Event shapes total, wide jet broadening (hadron level with stat. errors)



More complete than NLO analyses:
Data described well over virtually all phase space - in particular including NLLA

Measuring α_s

$\alpha_s(m_{Z^\circ})$ results, OPAL



- More complete than NLO+NLLA analyses:
  - renormalisation scale uncertainty reduced
  - scatter from different variables reduced
  - in particular **w\o** NLLA

$\alpha_s(m_{Z^\circ})$ results:

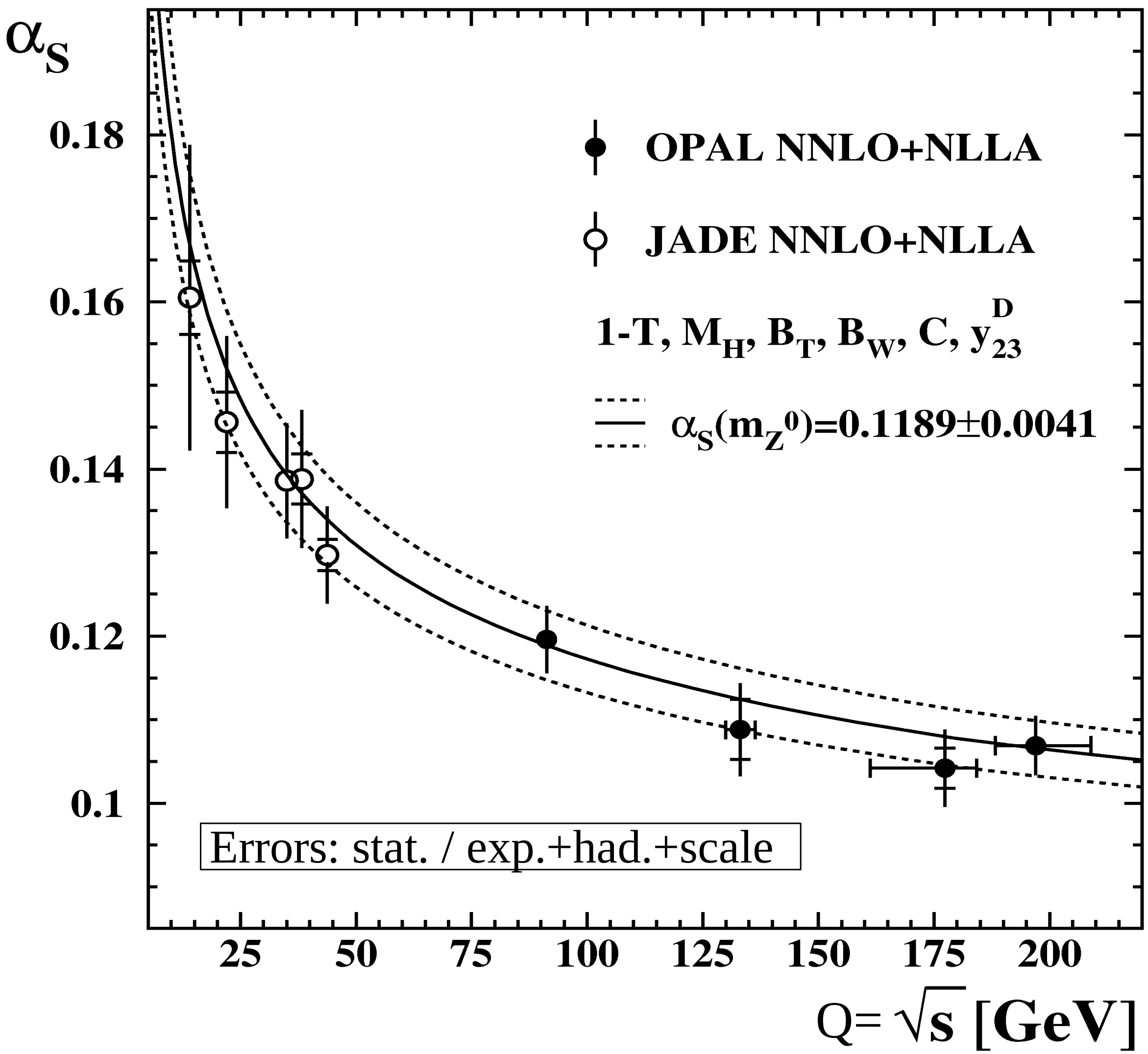
	JADE	OPAL
NNLO	0.1210 ± 0.0061	0.1201 ± 0.0030
NNLO+NLLA	0.1172 ± 0.0051	0.1189 ± 0.0041

- 2.5-5.0% precision, among the best measurements

Running coupling

Running $\alpha_S(Q)$ result

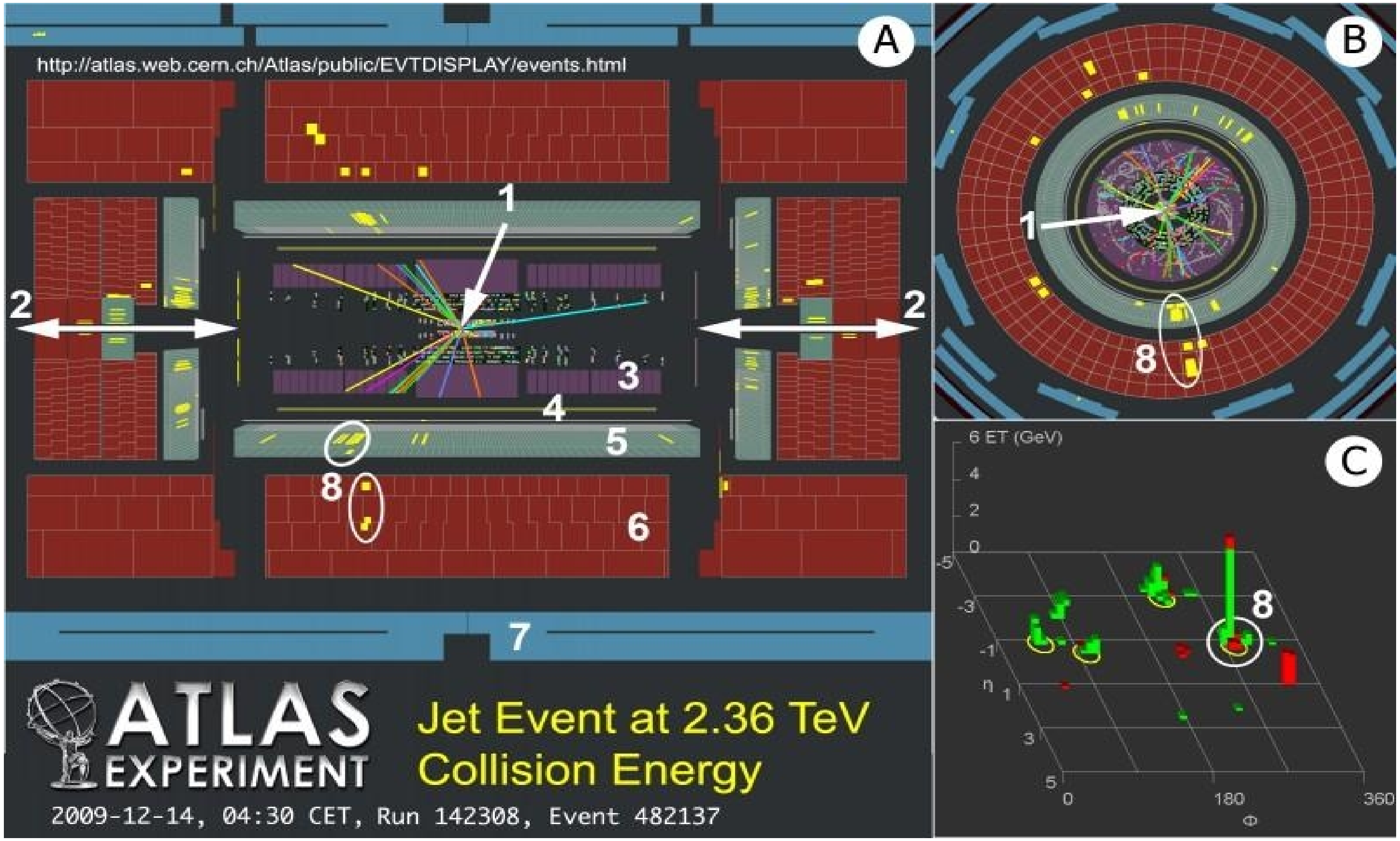
from event shape combination, OPAL



- JADE energy range 14-44 GeV: running confirmed strongly
- OPAL range 91-209 GeV: better precision

Connection to contemporary physics?

Connection to contemporary physics? Running: LHC

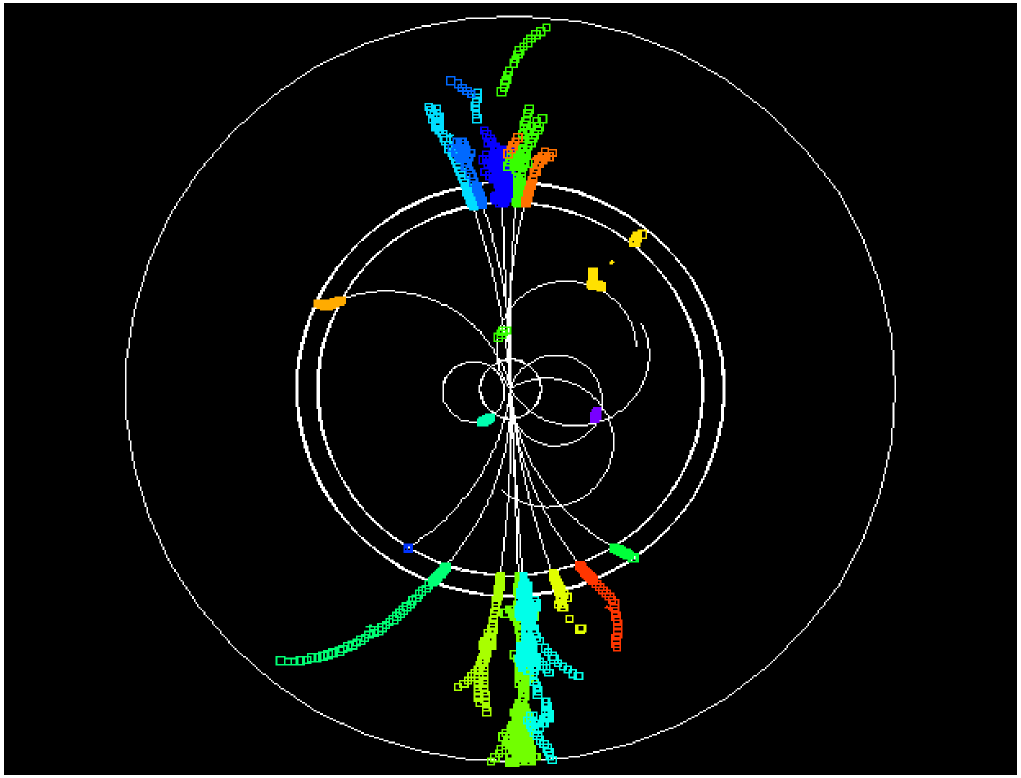


New jet algorithms have been defined (anti-k_T, SIS cone, invariant k_T algorithm, ...). Measurement and interpretation using OPAL planned.

Connection to contemporary physics?
Planned: e^+e^- collider >> 200GeV

Proposals:

- International Linear Collider **ILC**: 500...1000 GeV
- Compact Linear Collider **CLIC**: 500...3000...5000 GeV
- Much higher c.m. energy?



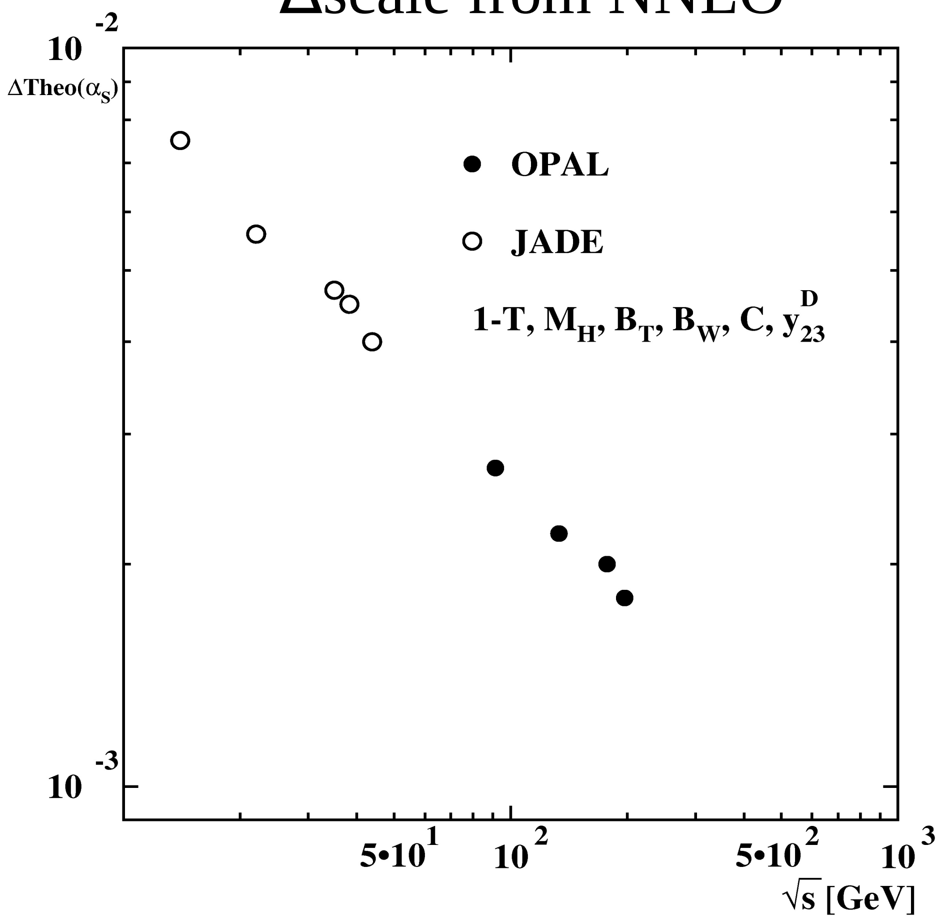
qq event (no gluons) at 500 GeV in the SID detector at the ILC

ILC: α_s uncertainties at 500 GeV

Uncertainty due to uncalculated higher orders

- Estimated conventionally by varying the renormalisation scale $\mu_R=0.5\sqrt{s} \ldots 2.0\sqrt{s}$

Δscale from NNLO



Compare scale uncertainties 500 GeV vs. 91 GeV:

	α_S measurement at LEP1	α_S(500GeV) estimate	$\alpha_S(m_{Z^\circ})$ evolved from α_S(500GeV)
NLO missing: α_S^3	0.1192 ±0.0047 (OPAL PR404)	0.0959 ±0.0024	0.1192 ±0.0038
NNLO missing: α_S^4	0.1205 ±0.0027	0.0967 ±0.0011	0.1205 ±0.0017

NLO: Scale uncertainty reduced to 80%,
NNLO: To 60%.

ILC: α_s uncertainties at 500 GeV

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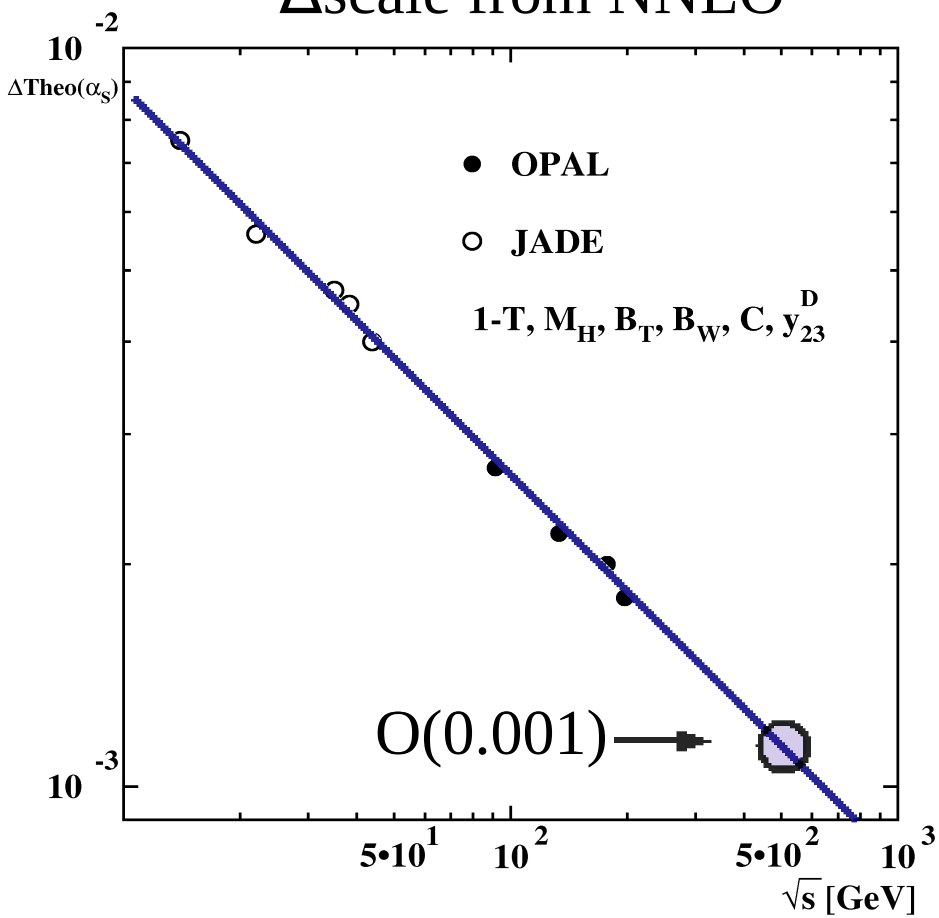

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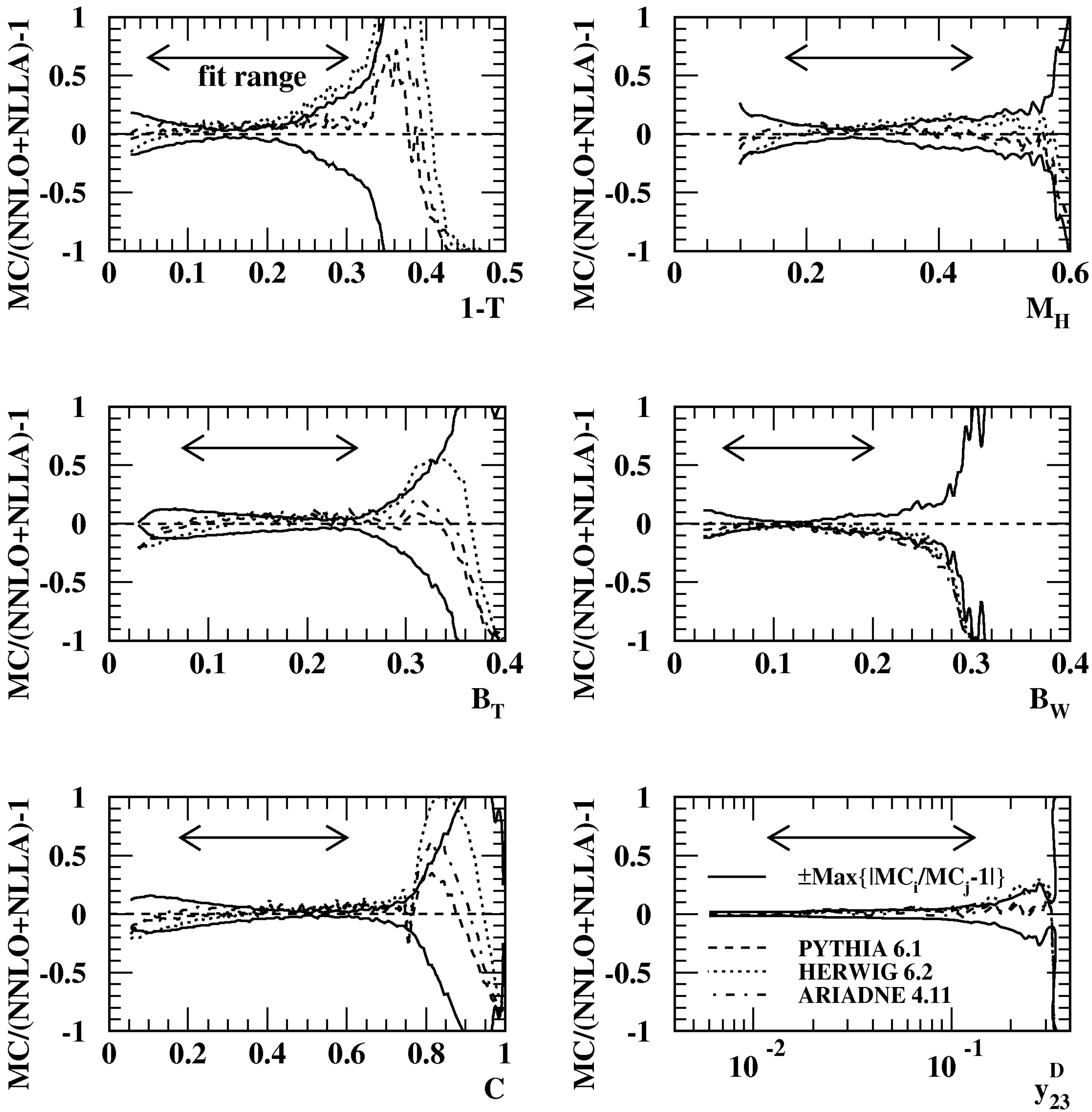
Summary

- Analyses of data taken at the JADE and OPAL experiment are still ongoing
- Measurements not limited by statistical and experimental precision: New models and calculations allow improved determination of α_S
- Running of $\alpha_S(Q)$ confirmed strongly in the JADE energy range
- $\alpha_s(m_{Z^\circ})$ measured precisely by OPAL using NNLO
- QCD precisely studied in e^+e^- important for LHC and linear collider
- LHC triggers new LEP analyses

Backups

Monte Carlo vs. calculation



ILC: α_s uncertainties at 500 GeV

Hadronisation uncertainties

- JADE & OPAL: Estimated by larger difference between PYTHIA and HERWIG, ARIADNE

Δhad from NNLO+NLLA