α_s from LEP

- α_s from 4-jet events
- α_s from radiative Z^0 decays
- α_s from fragmentation
- α_s from Z^0 lineshape and hadronic τ decays
- α_s summary

EPS HEP 2007 Manchester
Strong Interactions
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LEP Overview

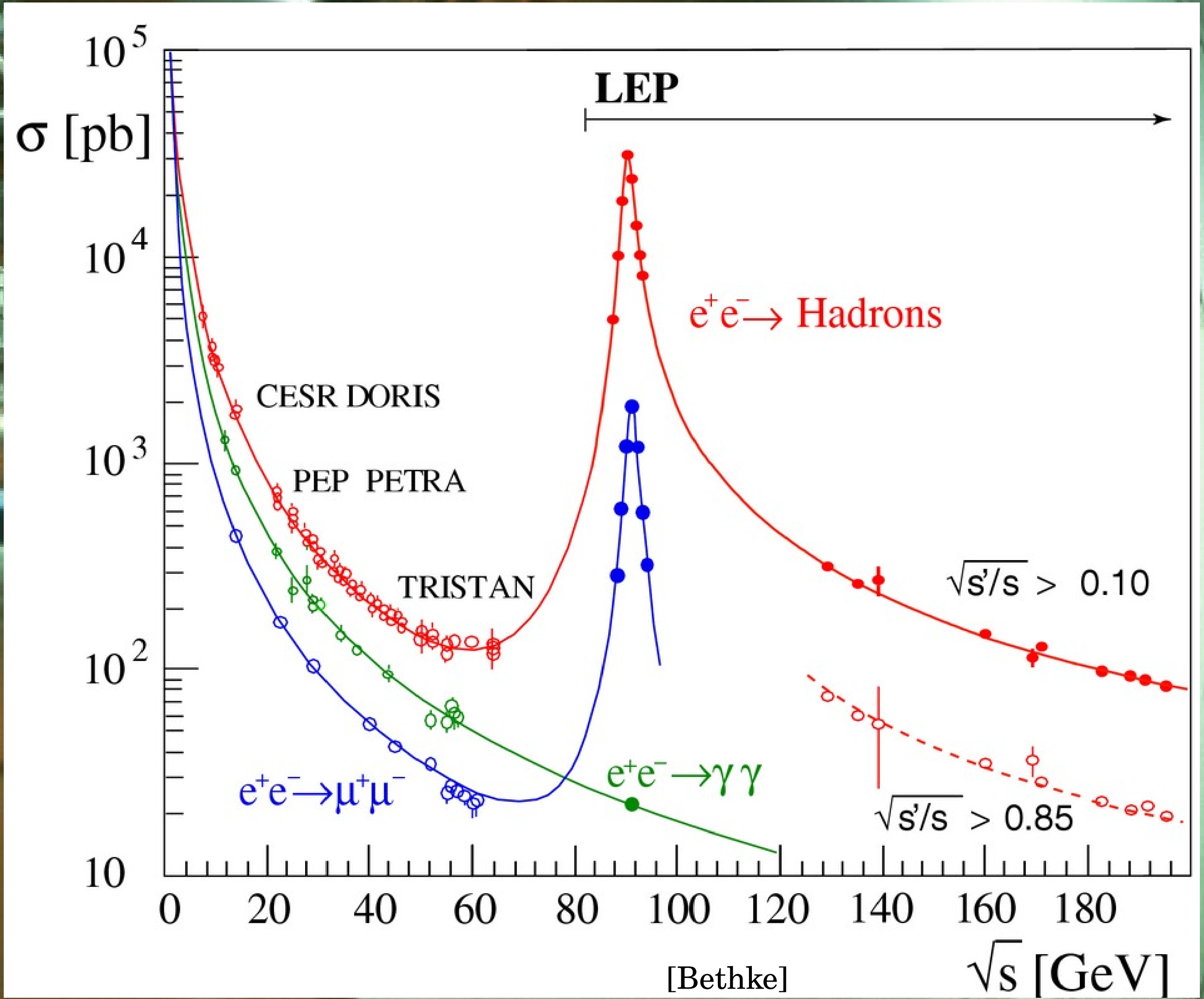
LEP: 1989-2000

ALEPH, DELPHI, L3, OPAL

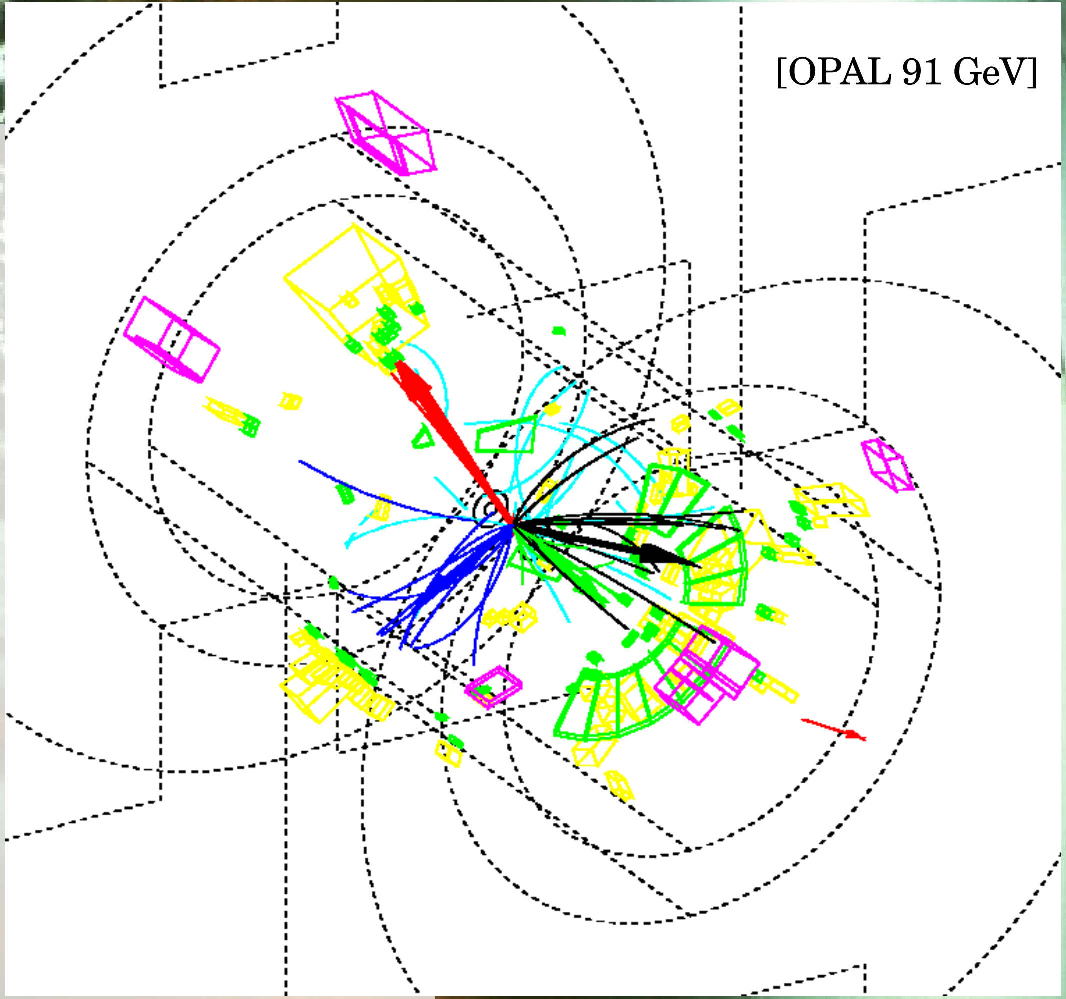
$\sqrt{s}$ = 88 to 209 GeV

LEP 1: $O(10^{5\text{-}6})$ events

LEP 2: $O(10^{2\text{-}3})$ events



α_S from 4-jet events: Intro



Durham jet clustering algorithm:

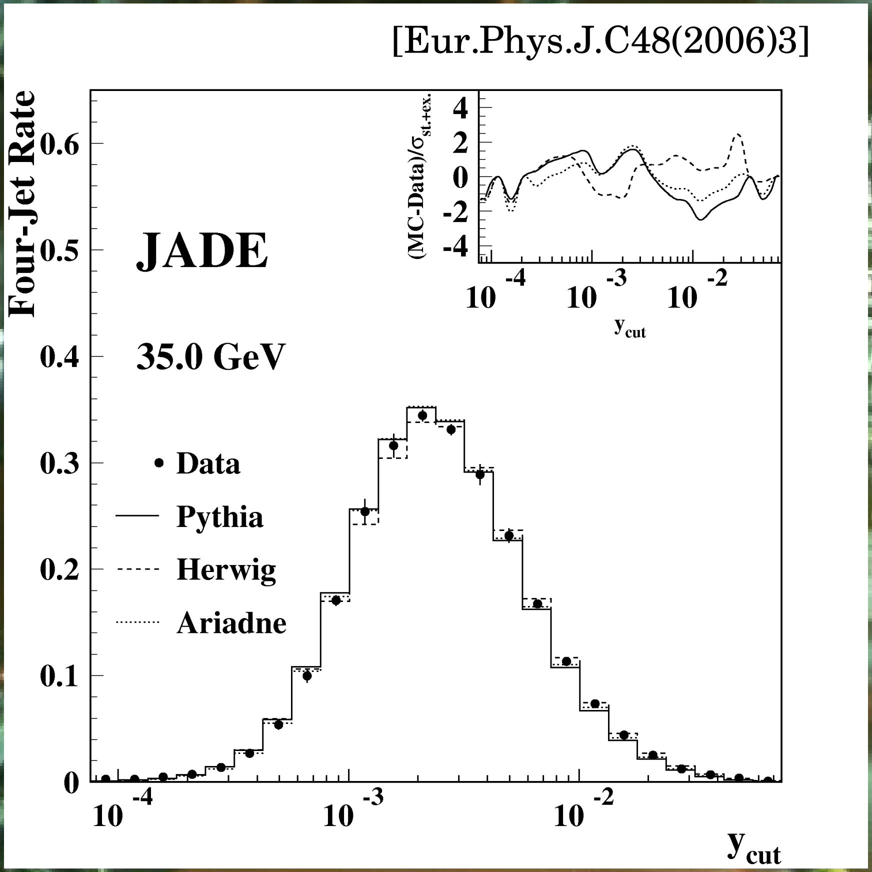
$y_{ij} = 2\min^2(E_i,E_j)(1-\cos\theta_{ij})/E_{vis}^2$

combine pair ij with smallest y_{ij}, remove i and j, repeat until one jet left

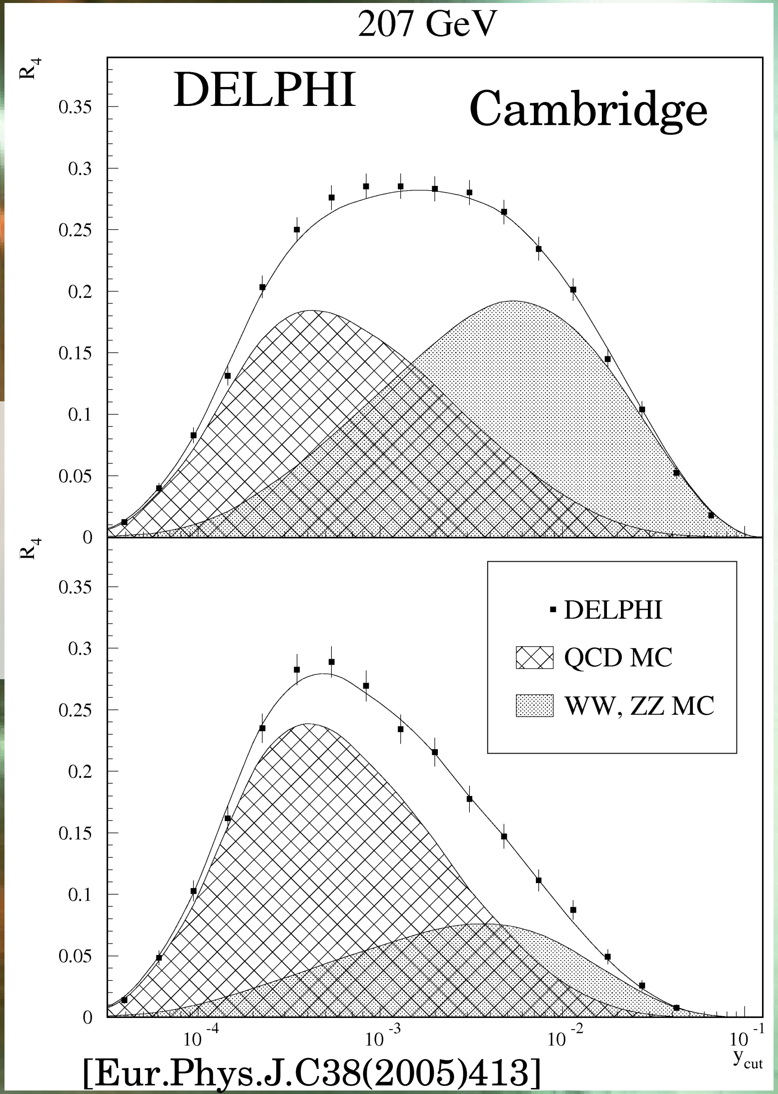
Study fraction $R_4(y_{cut})$ of 4-jet events

$e^+e^- \rightarrow$ qqqq or qqgg, $O(\alpha_S^2)$ in LO, $\Delta\alpha_S/\alpha_S = \Delta R_4/(2R_4)$

α_s from 4-jet events: Data



Before/after WW/ZZ cuts



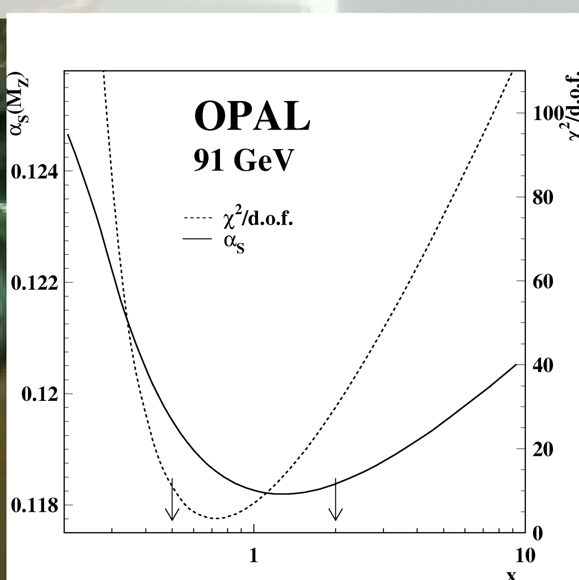
Good description of data by LEP MCs

α_S from 4-jet events: Results

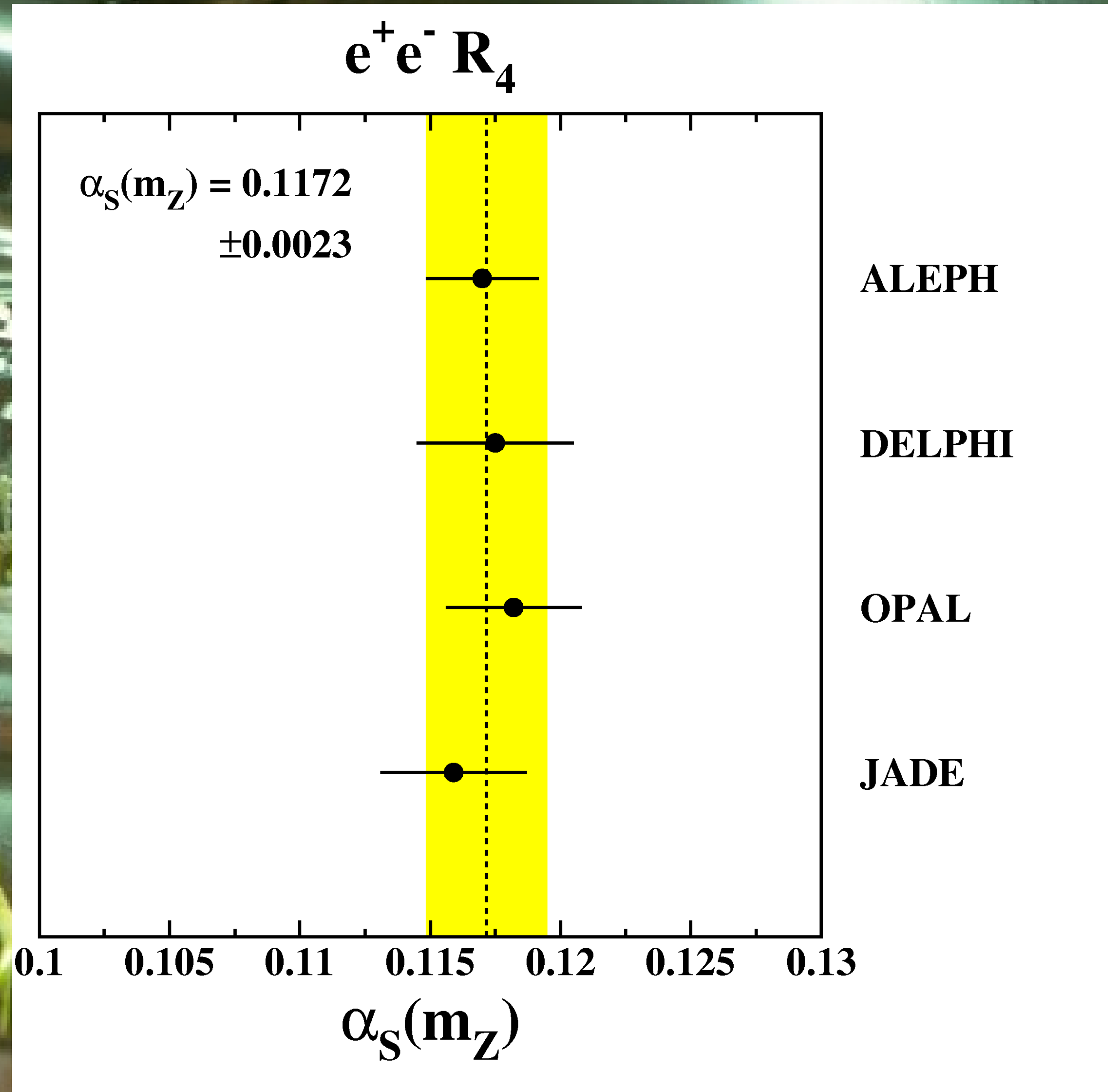
Average of NLO(+NLLA) fits:

$\alpha_S(m_Z) = 0.1172 \pm 0.0010(\text{exp.}) \pm 0.0016(\text{soft}) \pm 0.0014(\text{hard})$

But theory error might be underestimated



[Eur.Phys.J.C47(2006)295, Eur.Phys.J.C48(2006)3]

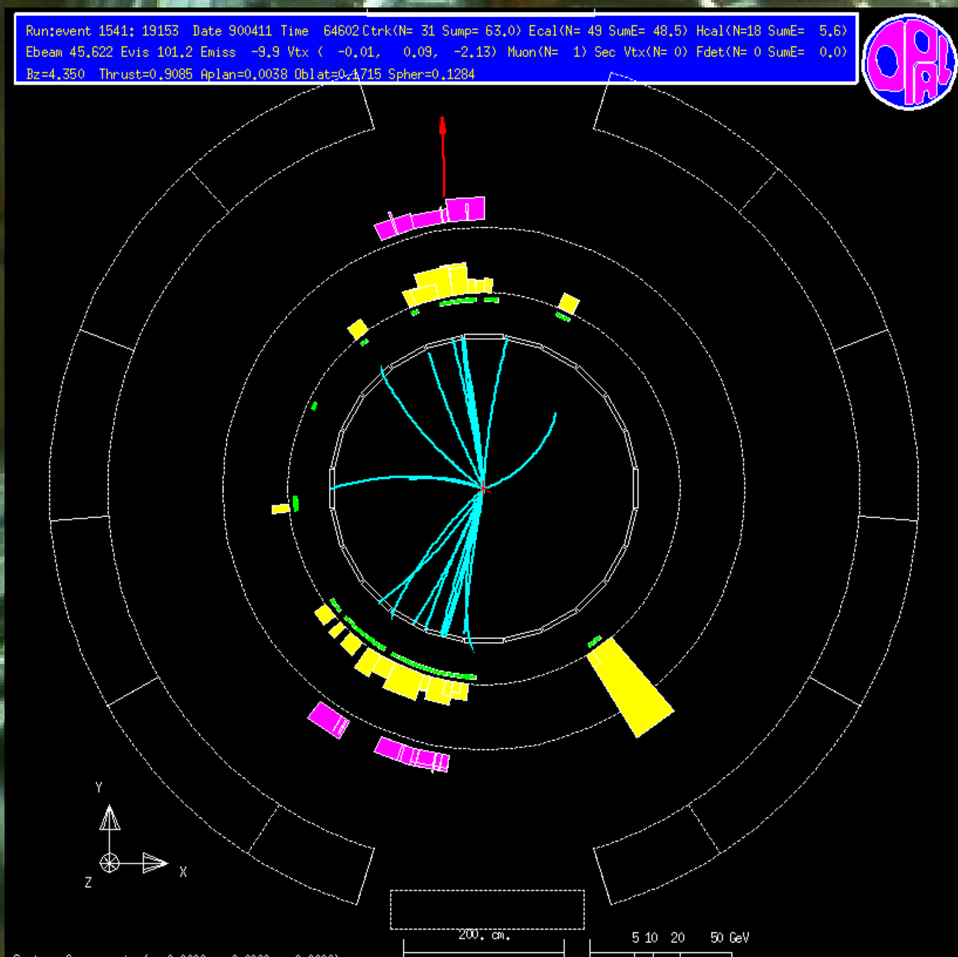


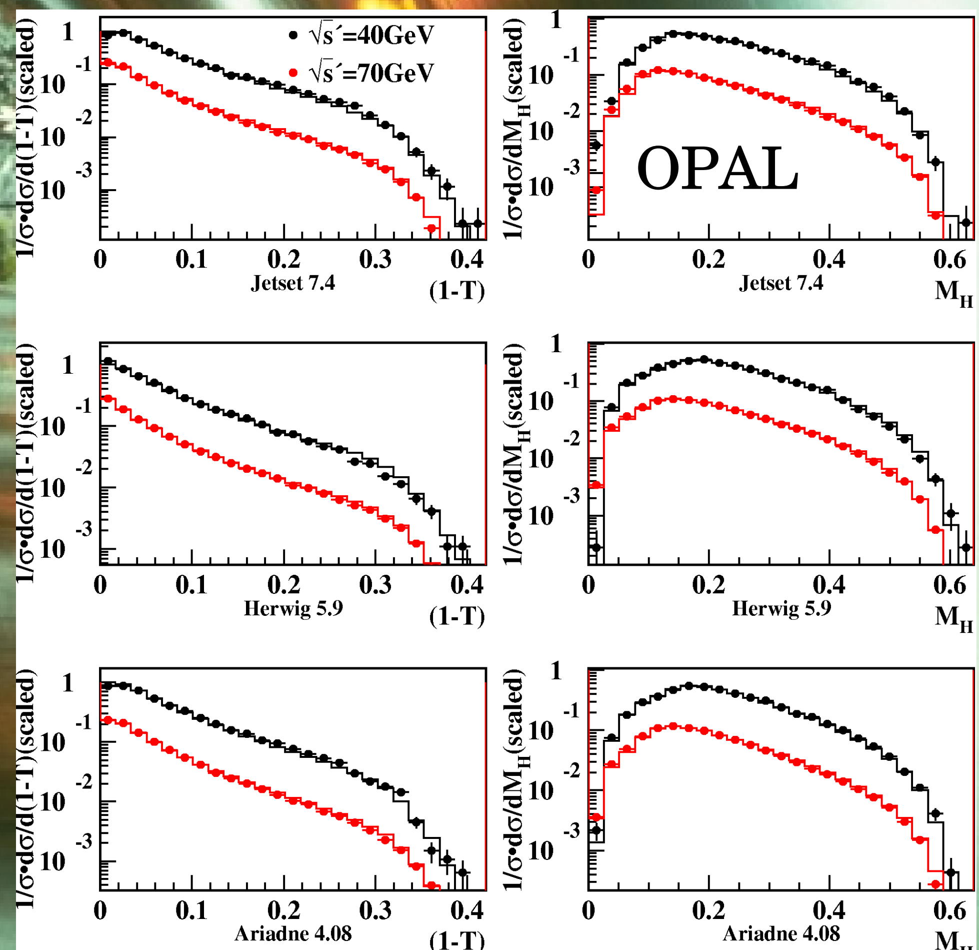
[Eur.Phys.J.C27(2003)1, Eur.Phys.J.C38(2005)413, Eur.Phys.J.C47(2006)295, Eur.Phys.J.C48(2006)3]

α_s from radiative Z^0 decays: Intro

Hadronic Z^0 decays with hard & isolated FSR (hi-FSR), study recoiling hadrons

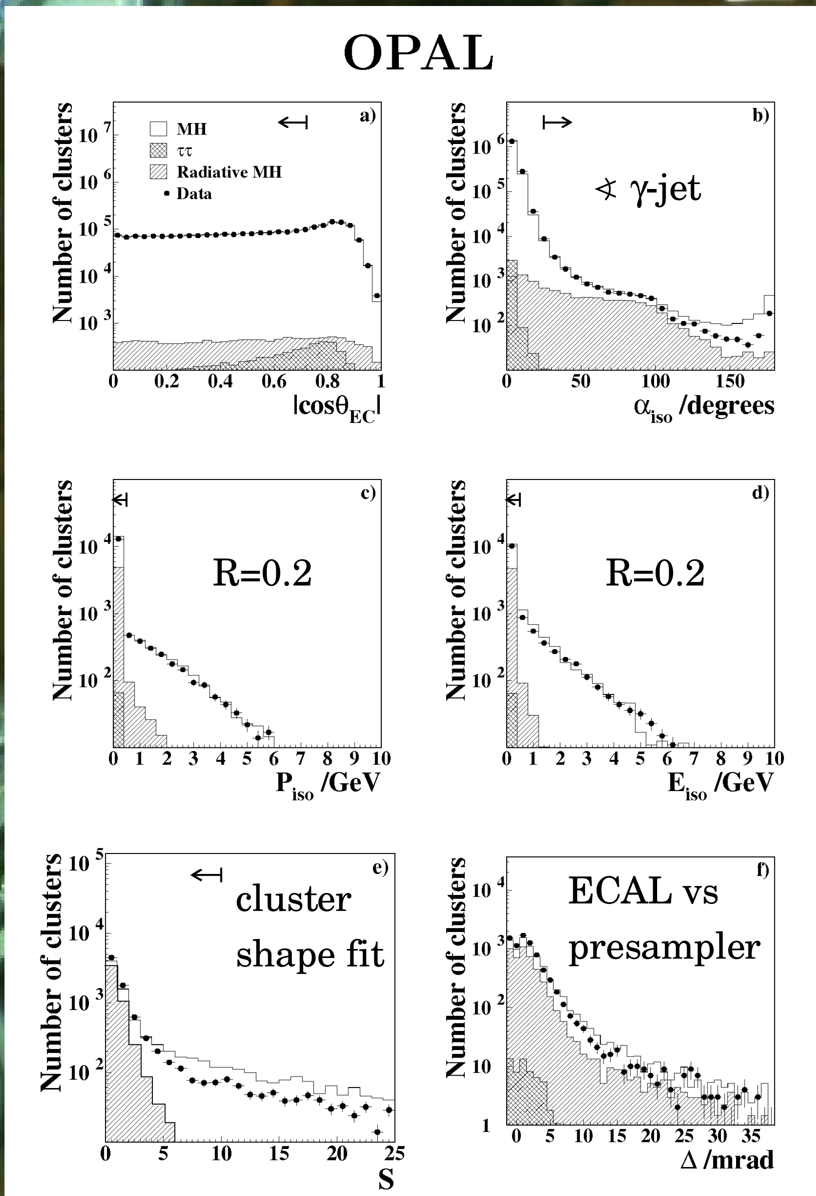
Assume “factorisation” of hi-FSR from QCD





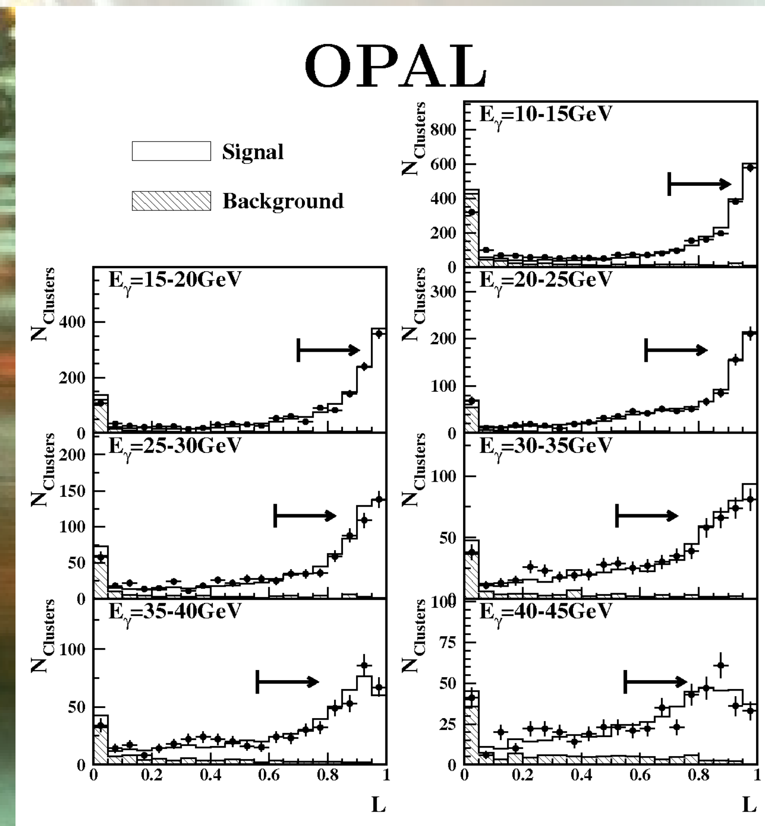
[to be sub. to Eur.Phys.J.C]

α_S from radiative Z^0 decays



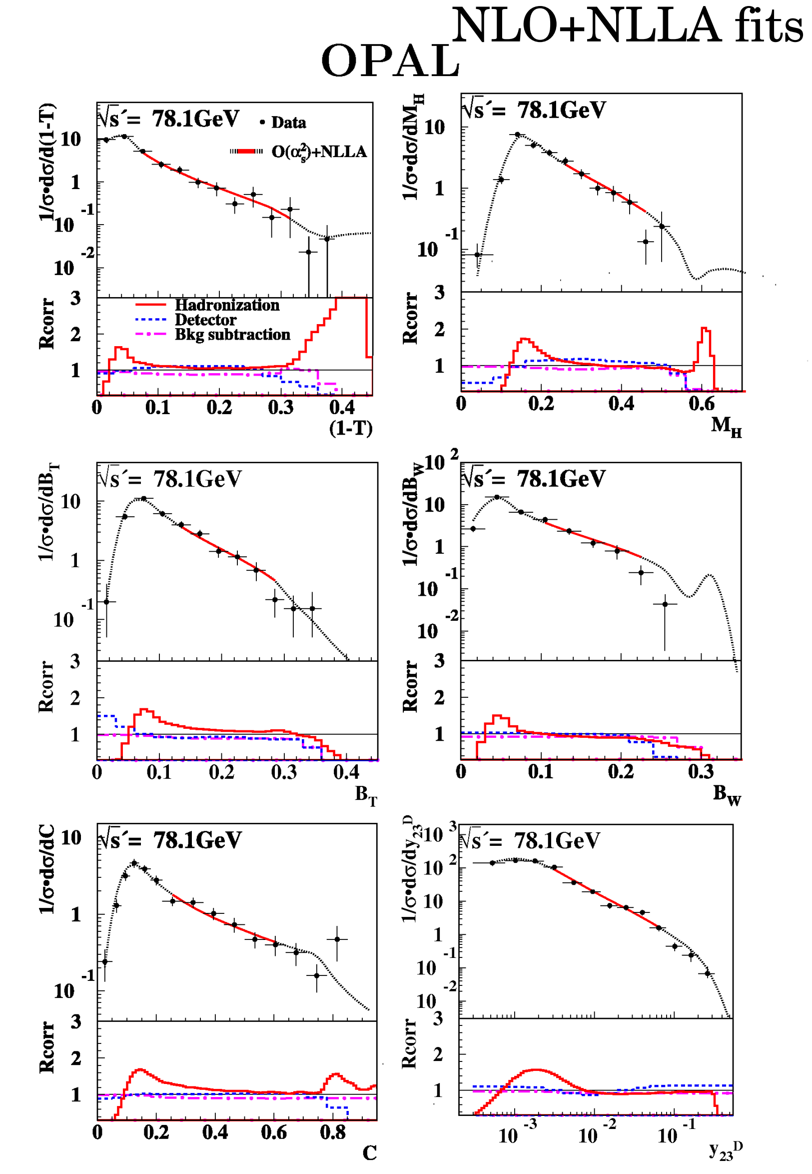
Isolated photon selection:

- isolated π^0 rate not ok in MC
- $|\cos\theta_{EC}|$, α_{iso}, S, Δ → likelihood L
- get backgrounds from data (4-11%)



[to be sub. to Eur.Phys.J.C]

α_s from radiative Z^0 decays



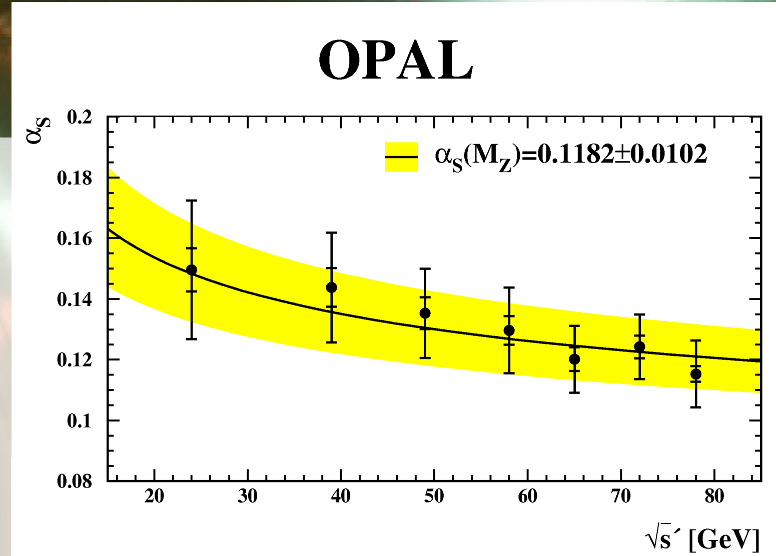
Consistent with

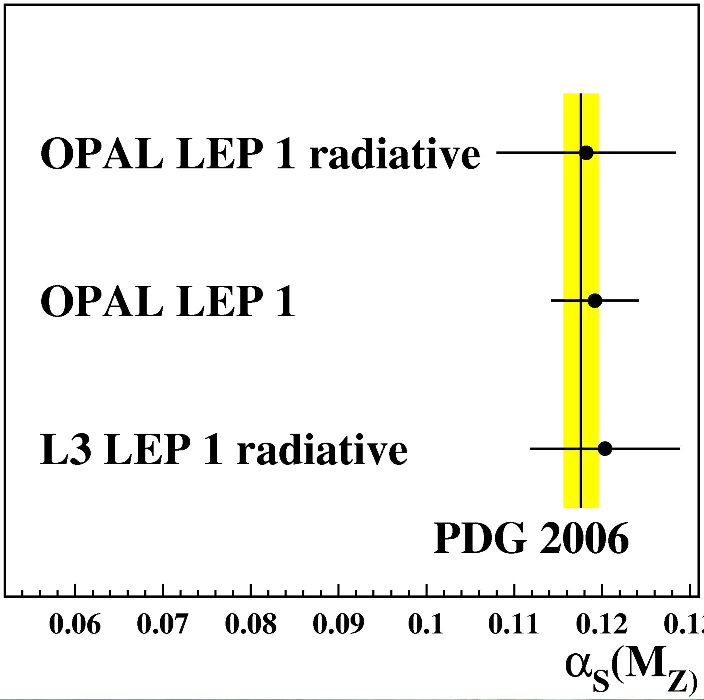
running

hi-FSR

factorisation

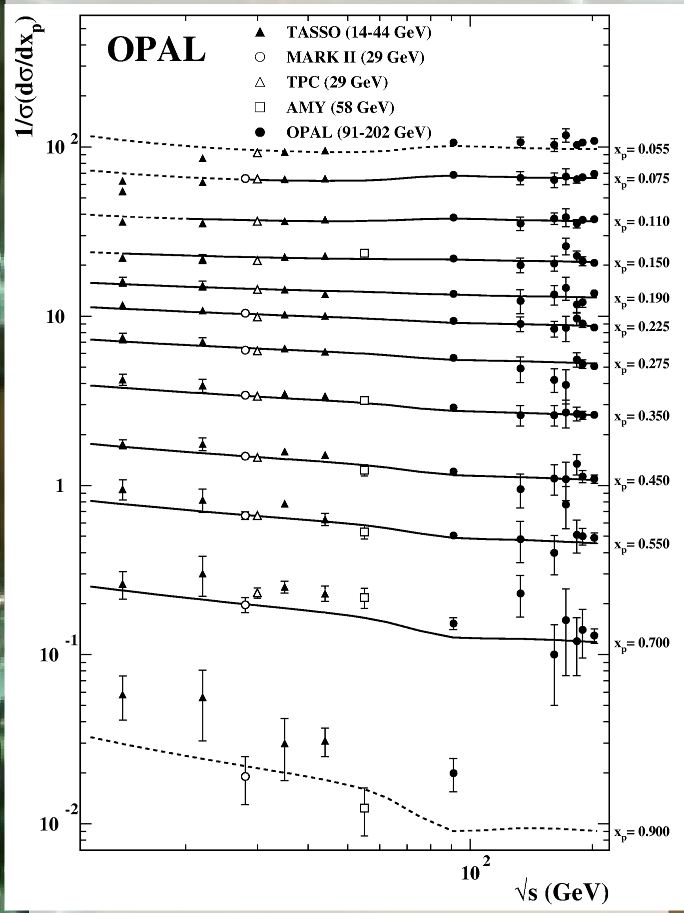
[to be sub. to Eur.Phys.J.C]





α_s from fragmentation

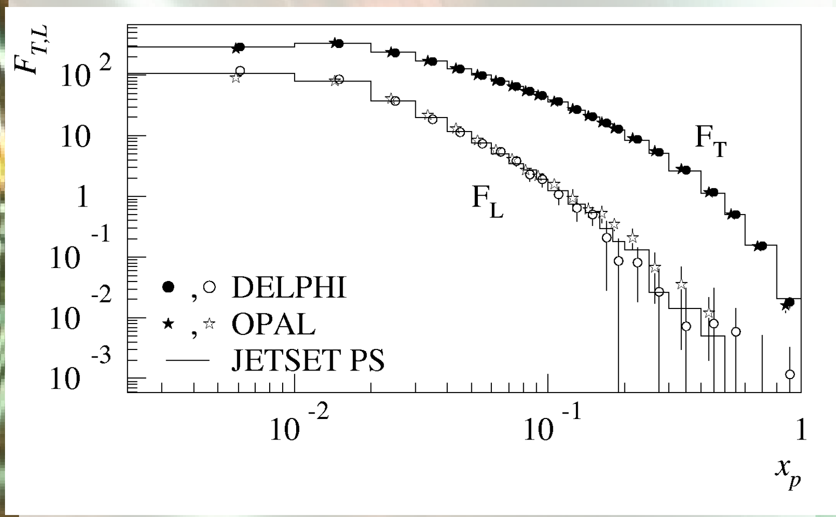
Scaling violation of e^+e^- FF (ADO)



Average:

$\alpha_s(m_z) = 0.119 \pm 0.009$

Longitudinal cross section σ_L for hadron production in e^+e^-



ADO: $\sigma_L/\sigma_{tot} = 0.056 \pm 0.002$

$\alpha_s(m_z) = 0.117 \pm 0.008$

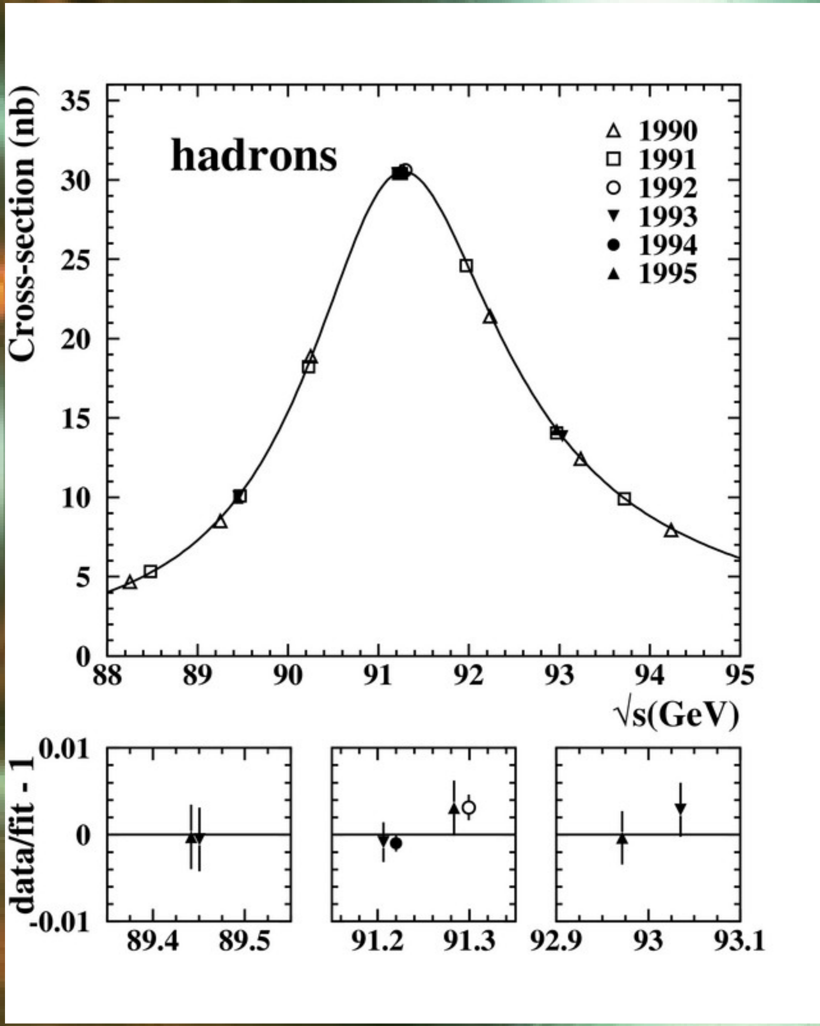
Average: $\alpha_s(m_z) = 0.118 \pm 0.004(\text{exp.}) \pm 0.001(\text{soft}) \pm 0.007(\text{hard})$

[Rep.Prog.Phys.69(2006)1771]

α_S from Z^0 lineshape

Observable	Result	correlations Γ_h	R_Z	σ_h	σ_ℓ
Γ_h[MeV]	1744.4±1.5	1.0			
R_Z	20.767±0.025	0.62	1.0		
σ_h[nb]	41.540±0.037	0.24	0.18	1.0	
σ_ℓ[nb]	2.0003±0.0027	-0.40	-0.77	0.48	1.0

Observable	$\alpha_S(m_{Z^0})\pm$	exp. $\pm$	scale $\pm$	m_H
Γ_h	0.1221	±0.0037	±0.0020	±0.0015
R_Z	0.1231	±0.0037	±0.0013	±0.0005
σ_h	0.1075	±0.0069	±0.0006	±0.0001
σ_ℓ	0.1187	±0.0030	±0.0011	±0.0004
average	**0.1189**	**±0.0027**	**±0.0013**	**±0.0007**



ZFITTER 6.41

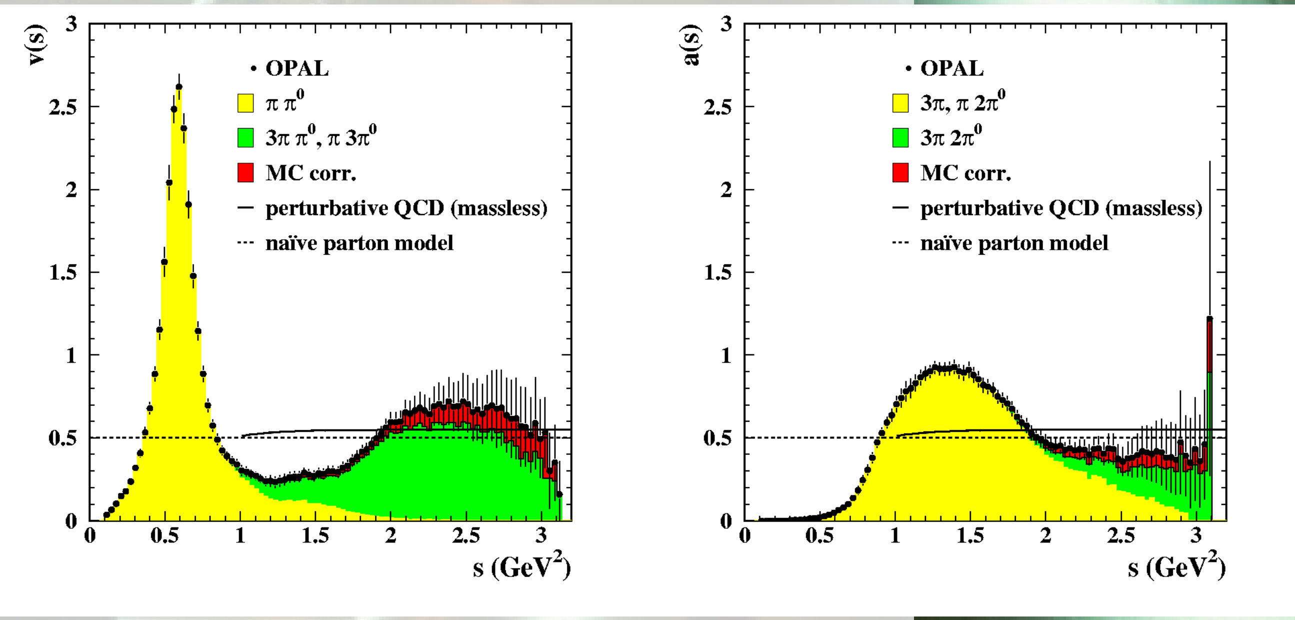
Renormalisation scale $0.5 < x_\mu < 2$

Higgs mass 69 GeV < M_H < 183 GeV

[Phys.Rept.427(2006)257, Rep.Prog.Phys.69(2006)1771]

α_S from τ decays

τ decays $\hat{=}$ virtual W decays



Hadronic branching ratio:

$R_t(s) = \Gamma(\tau \rightarrow h)/\Gamma(\tau \rightarrow l)$

$R_t(s) = 3/2\ S_{EW}\ |V_{ud}|^2 \cdot$

$(1 + \delta_{EW} + \delta_{QCD}(\alpha_S) + \delta_{np})$

NNLO QCD (CIPT): $\delta_{QCD}(\alpha_S)$

OPE with spectral moments (OPAL): $\delta_{np} = -0.0024 \pm 0.0025$

PDG04: $R_\tau = 3.468 \pm 0.011$

[Rep.Prog.Phys.69(2006)1771,
Rev.Mod.Phys.78(2006)1043]

$\alpha_S(m_\tau) = 0.347 \pm 0.005(\text{exp.}) \pm 0.003(\text{soft}) \pm 0.018(\text{hard})$

$\alpha_S(m_Z) = 0.1221 \pm 0.0006(\text{exp.}) \pm 0.0004(\text{soft}) \pm 0.0019(\text{hard})$

Summary

Average from e^+e^- NNLO incl. (Z^0, τ, R_{e+e-}):

$\alpha_S(m_Z) = 0.1211 \pm 0.0010(\text{exp.})$
$\pm 0.0018(\text{theo.})$

[Rep.Prog.Phys.69(2006)1771]

Consistent with

- all other results NLO(+NLLA)
- world aver. (Bethke, PDG, SK)

Future:

- NNLO 3-jet shape
- NNLO fragmentation