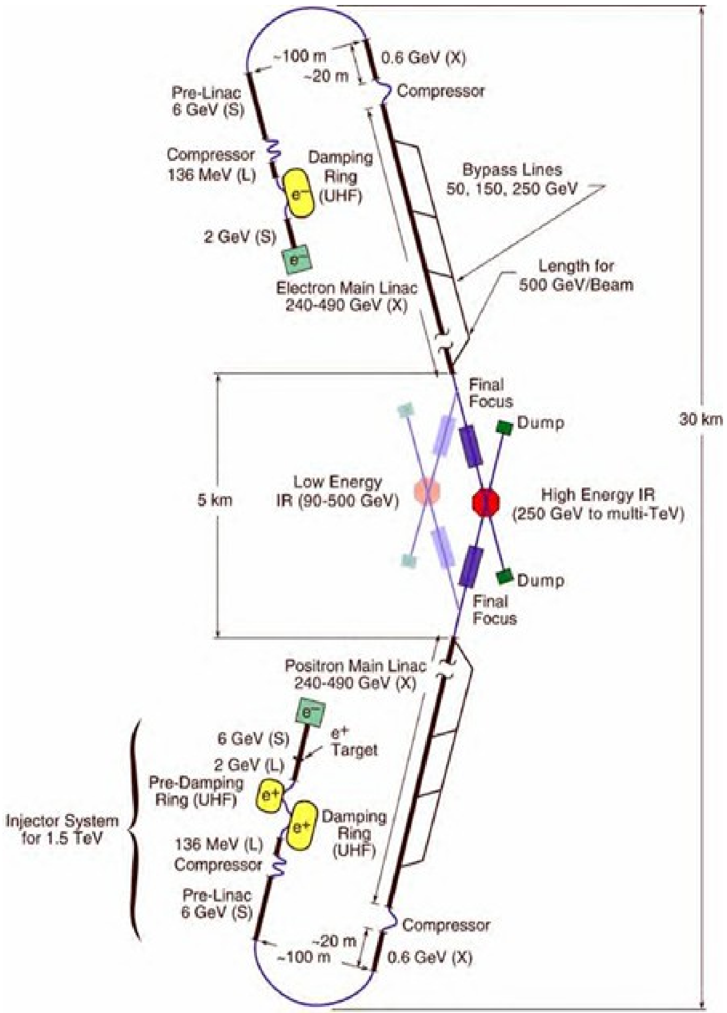
α_s at the ILC

- The **I**nternational **L**inear **C**ollider
- Why do we need it?
  - Measurement of α_s from JADE- and OPAL distributions using NNLO calculations
    EPJC 64:351, S. Bethke, S. Kluth, C. Pahl, J. Schieck and the JADE Collaboration
    Submitted to EPJC, the OPAL Collaboration
  - Outlook for the ILC: α_s-error budget
- The **Si**licon **D**etector at ILC: Measuring thrust

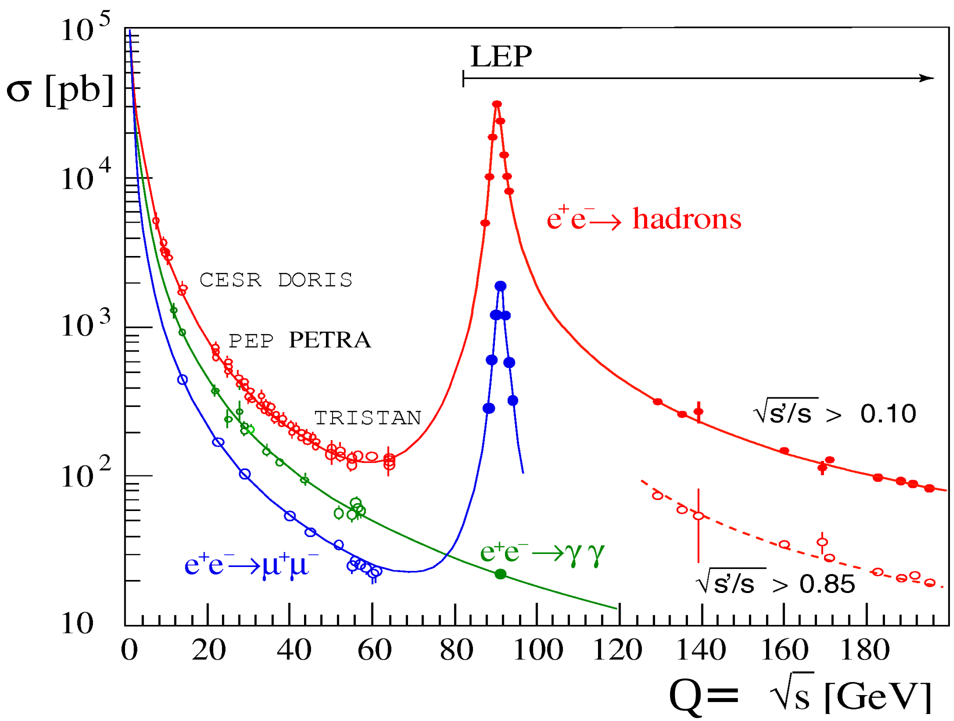
The International Linear Collider



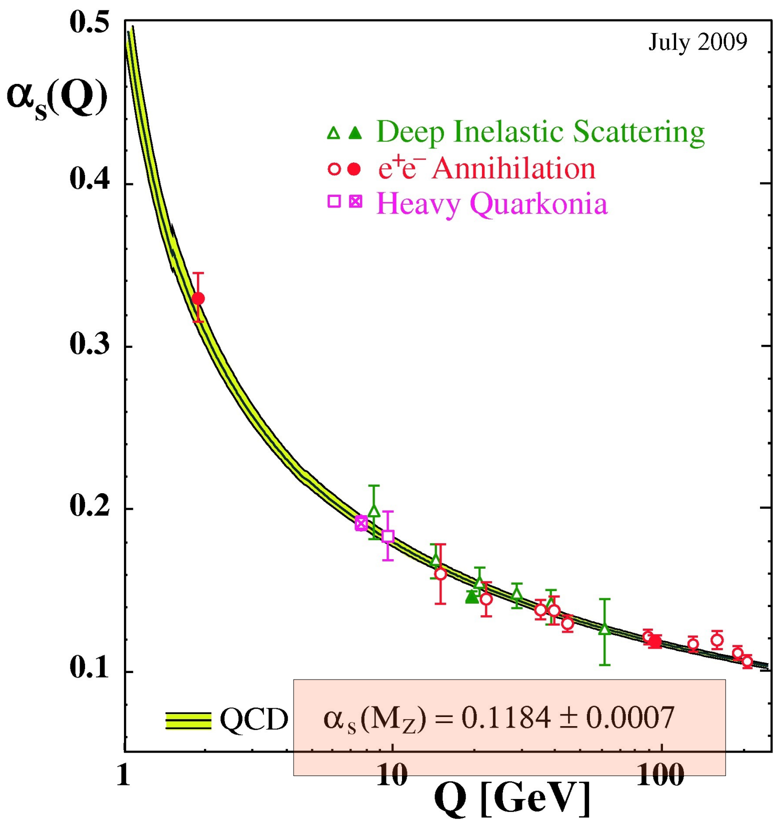
- Q=500 GeV, upgrade: 1 TeV
- $L=2 \cdot 10^{34}/cm^2 s$

QCD up to 200... GeV

Hadronic cross section



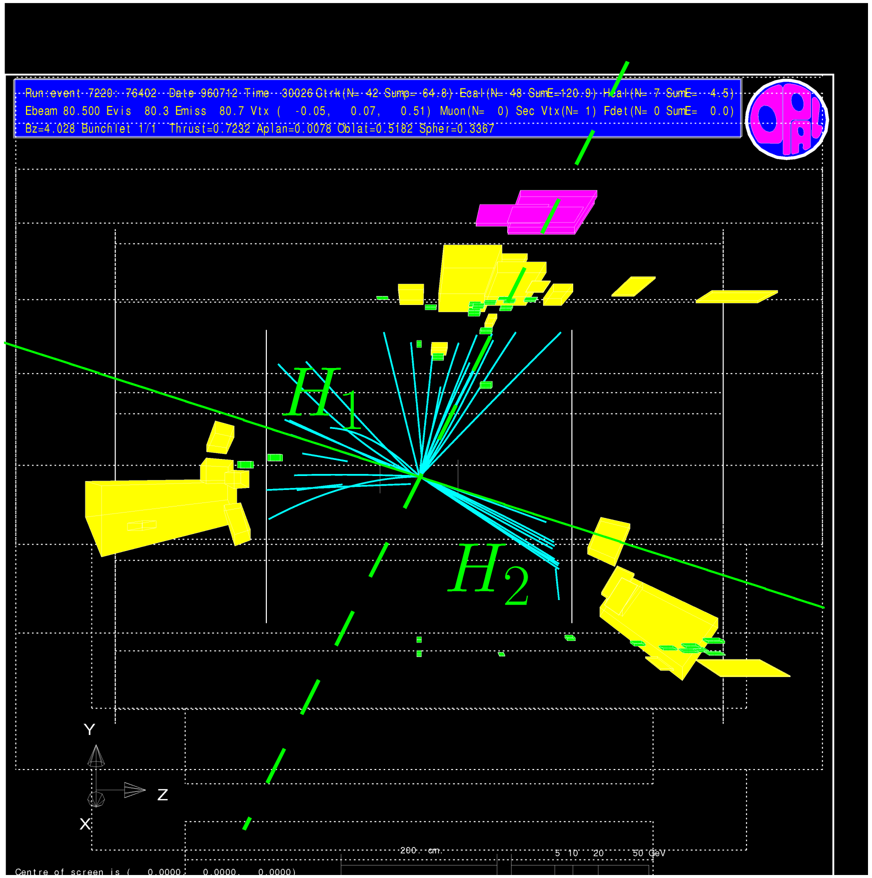
Running strong coupling
(Eur. Phys. J. C 64, 689)



Event shape variables y

Two-hemisphere variables:

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

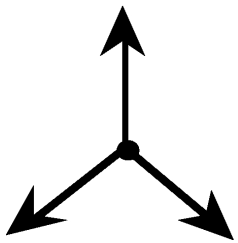


One-hemisphere variables:

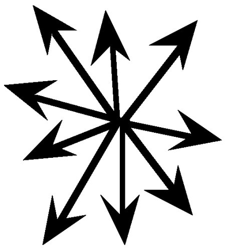
- Wide Jet Broadening B_W
- Durham two-jet flip parameter y^D_{23}
- Heavy Jet Mass M_H

Event shape variables y

qq: 2 Jets, y≈0

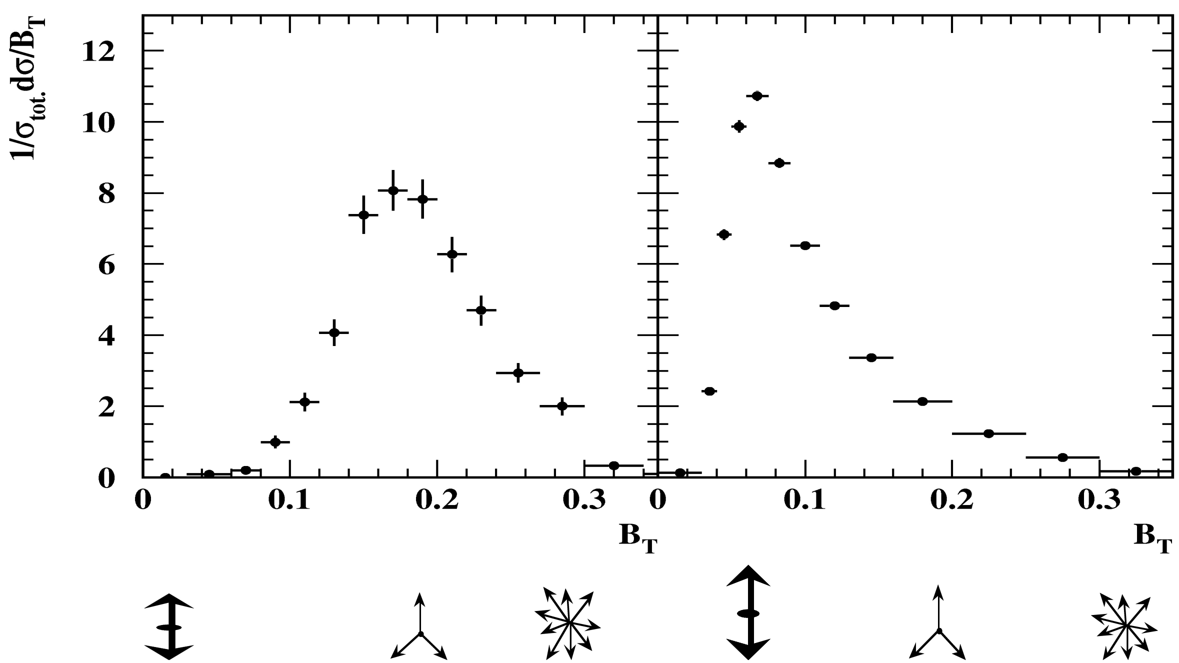


qqg: 3 Jets, e.g. 1-T ≈ ⅓



Many gluons, e.g. 1-T ≈ ½

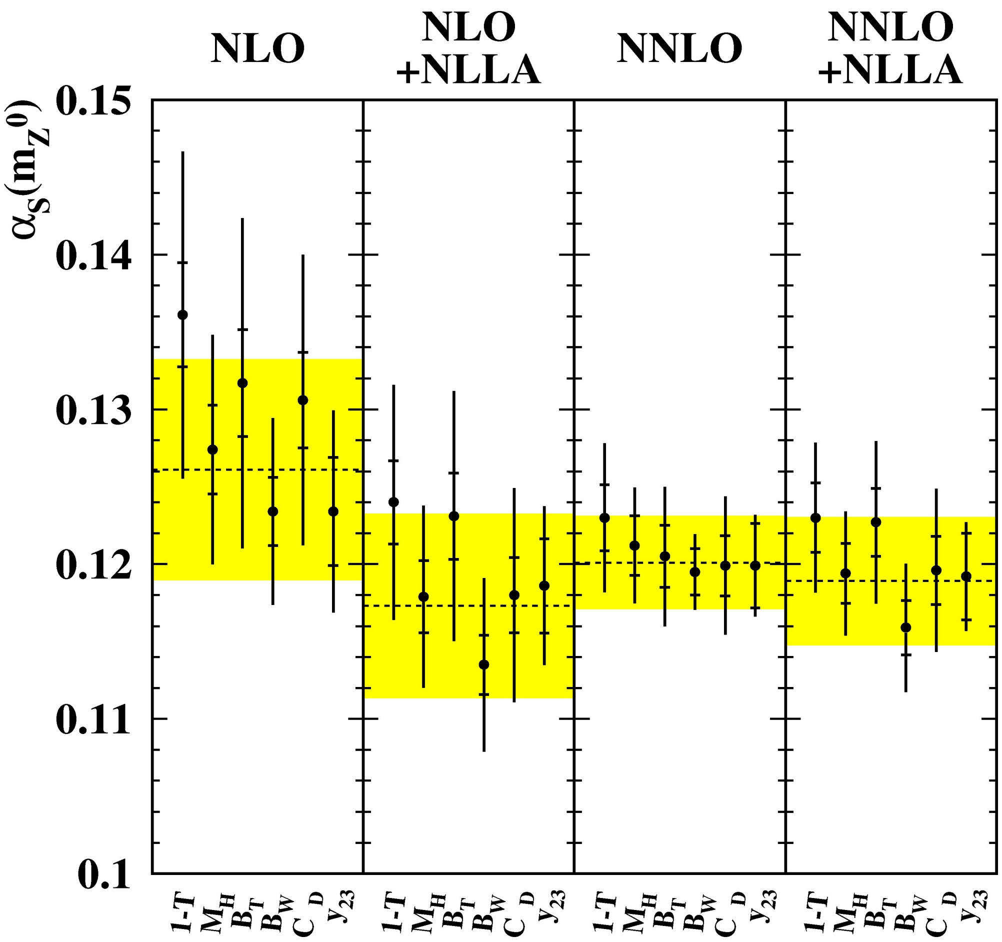
B_T at 14 GeV: α_s large



B_T at 91 GeV: α_s small

α_s to NNLO by JADE and OPAL

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



Errors: stat. / exp.+had.+scale

- More complete than NLO+NLLA analyses:
  - renormalisation scale uncertainty reduced
  - scatter from different variables reduced

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

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

- 2.6-5.0% precision, among the best measurements

α_s to NNLO by JADE and OPAL

- 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

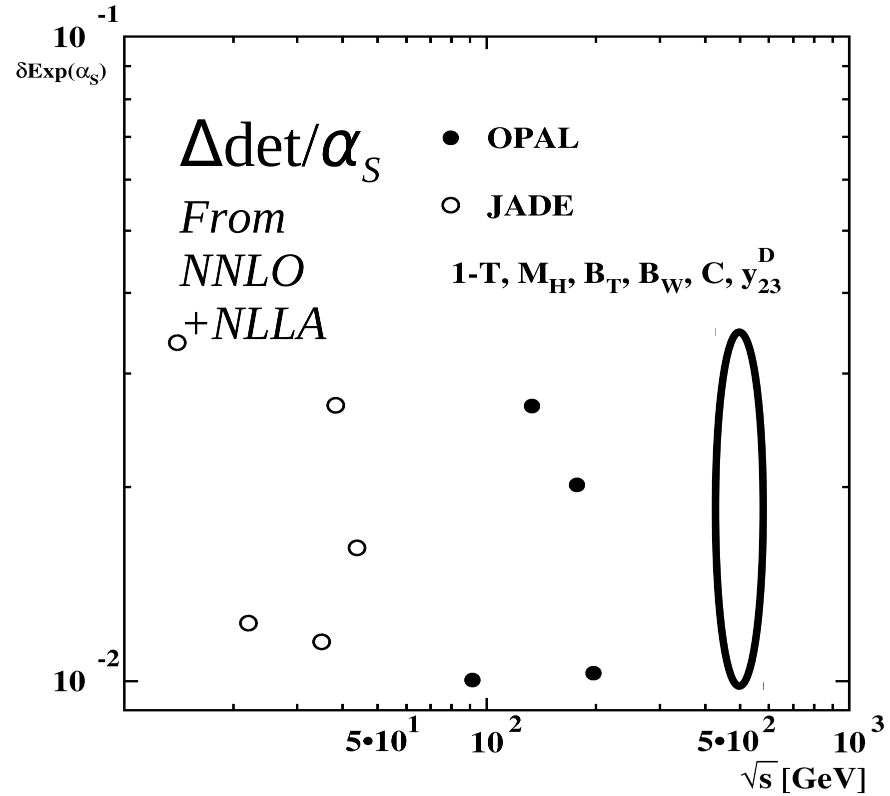
ILC: α_s uncertainties at 500 GeV

Statistical

- $L = 2 \cdot 10^{34}/cm^2 s \sim 10^3 \cdot$ LEP1
- $\sigma_{had} \sim 10^{-3} \cdot$ LEP1
- Selection efficiency slightly worse than LEP2 hep-ex/9912051
- Precision of 0.0001 in few years

Detector uncertainties

- OPAL
  - acceptance cut
  - tracks+cluster
  - MC model
- JADE, additionally:
  - data version



ILC detector very hermetic, good tracking & calorimetry: Detector uncertainty $\alpha_S(m_{Z^\circ}) \sim 0.001$ expected

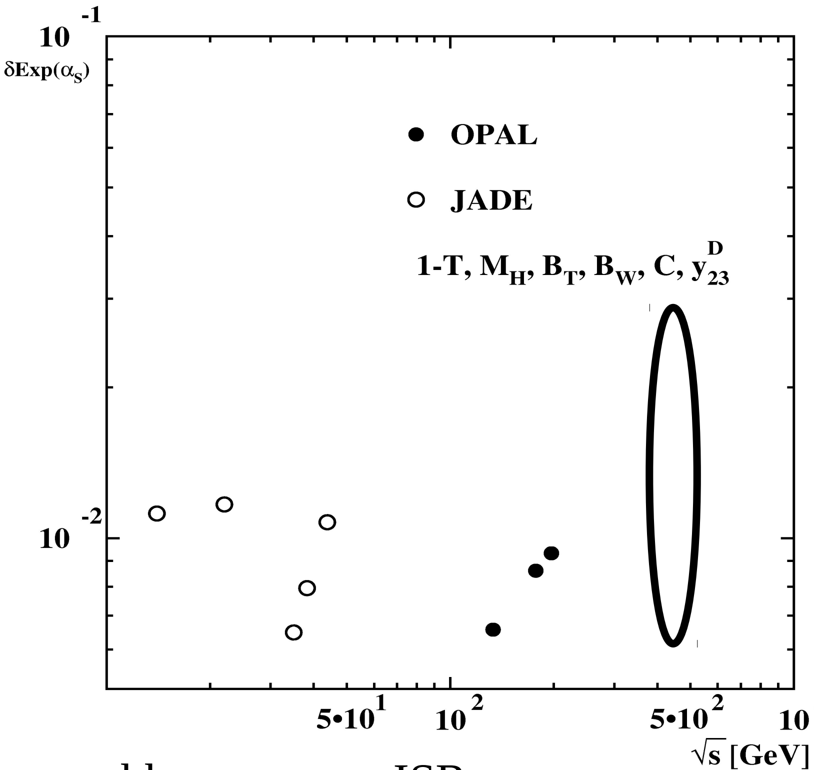
http://tesla.desy.de/new_pages/TDR_CD/PartIII/partIII.pdf

ILC: α_s uncertainties at 500 GeV

Residual Background

- Selection cuts varied
- JADE, additionally:
  - bb cross section ± 5%
- OPAL, additionally:
  - 4f cross section ± 5%
  - ISR algorithm varied

Δbkg/α_s from NNLO+NLLA



bb ISR

WW,ZZ,tt,beamstrahlung

500 GeV: uncertainty of $\alpha_s(m_{Z^\circ})$ ~ 0.001 expected

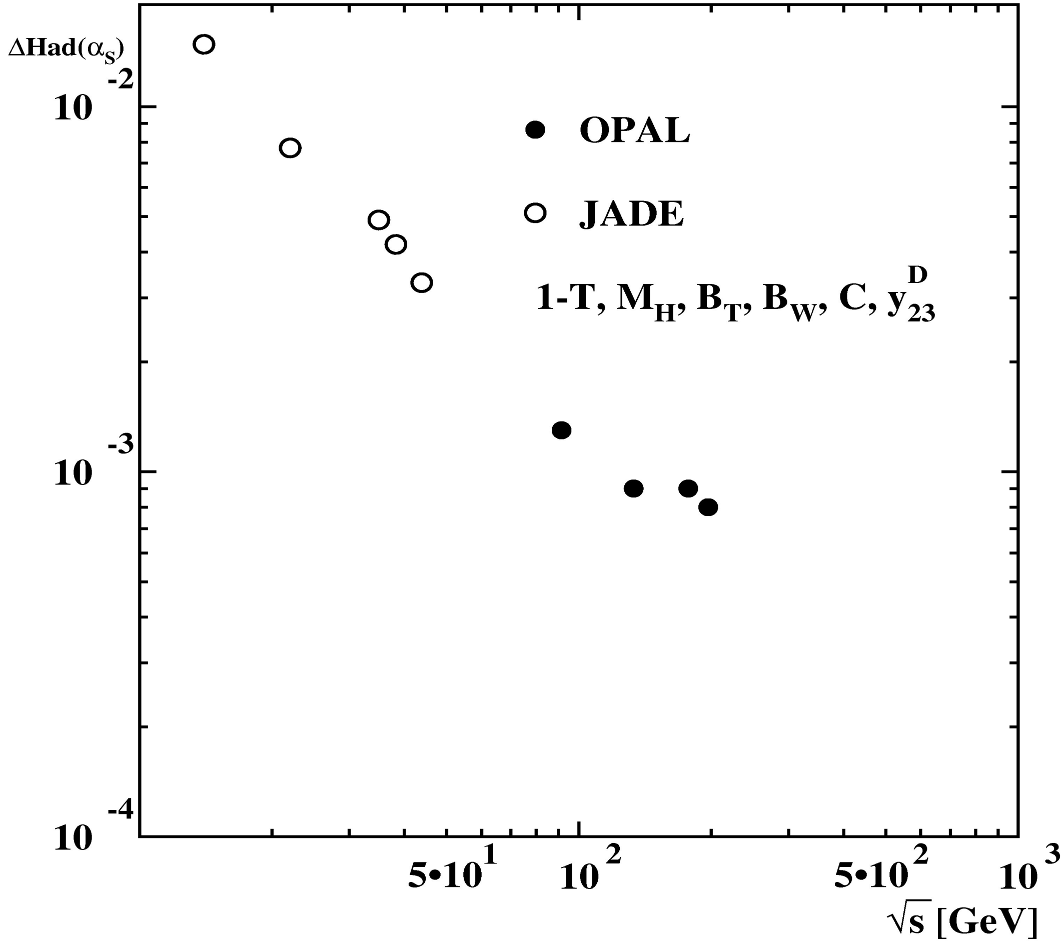
http://tesla.desy.de/new_pages/TDR_CD/PartIII/partIII.pdf

ILC: α_s uncertainties at 500 GeV

Hadronisation uncertainties

Δhad from NNLO+NLLA

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



ILC: α_s uncertainties at 500 GeV

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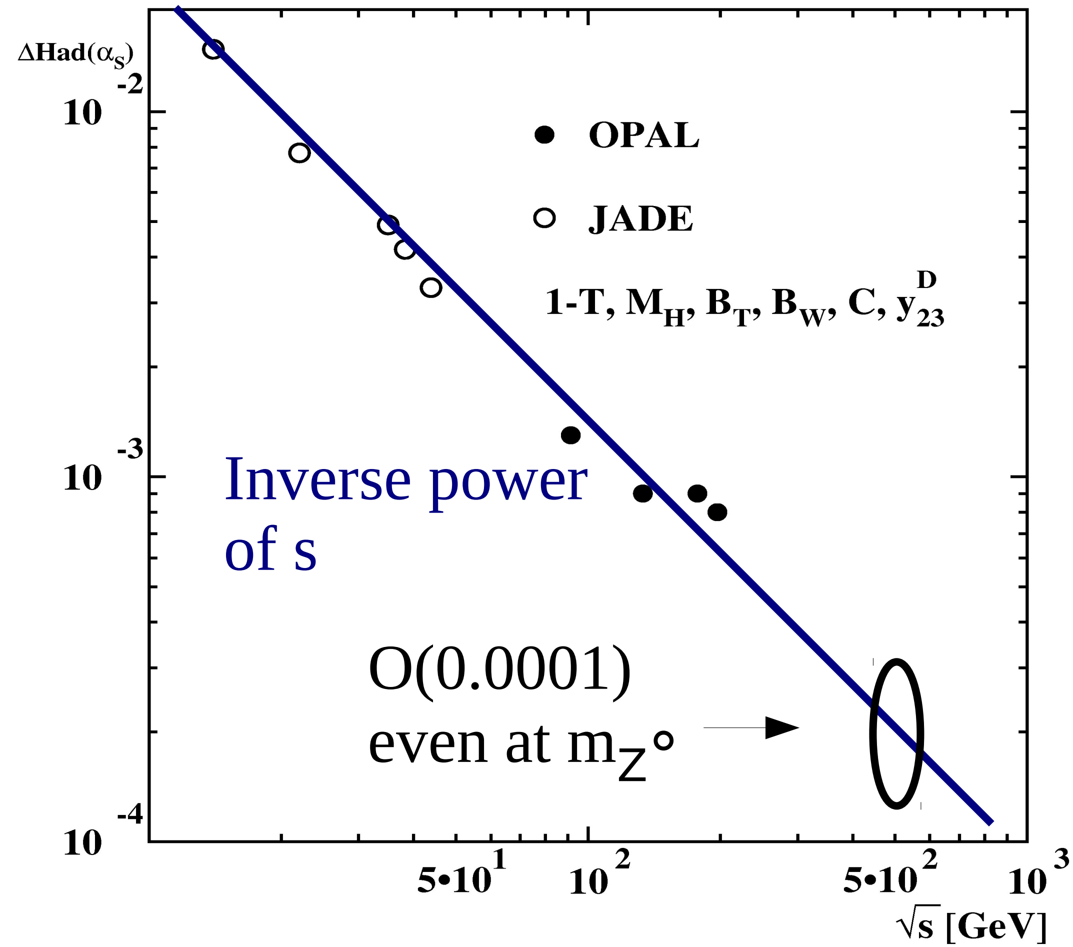
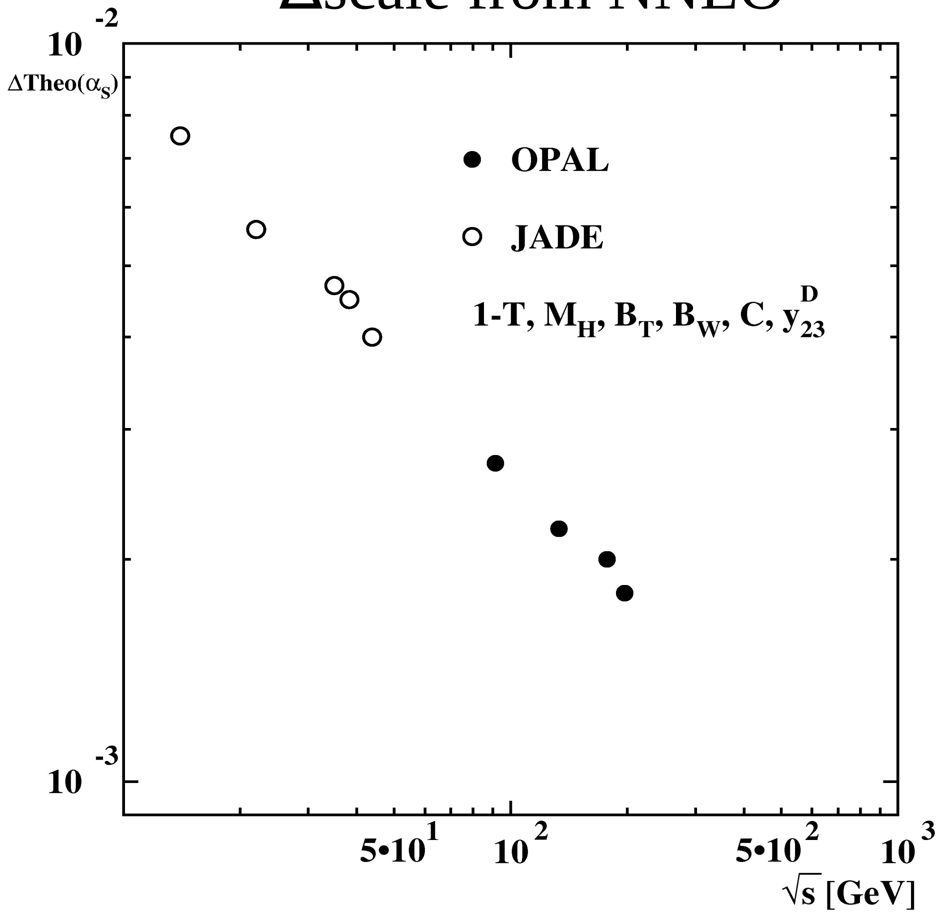


ILC: α_s uncertainties at 500 GeV

Uncertainty due to uncalculated higher orders

- Estimated conventionally by varying the renormalisation scale μ_R=0.5 √s ... 2.0 √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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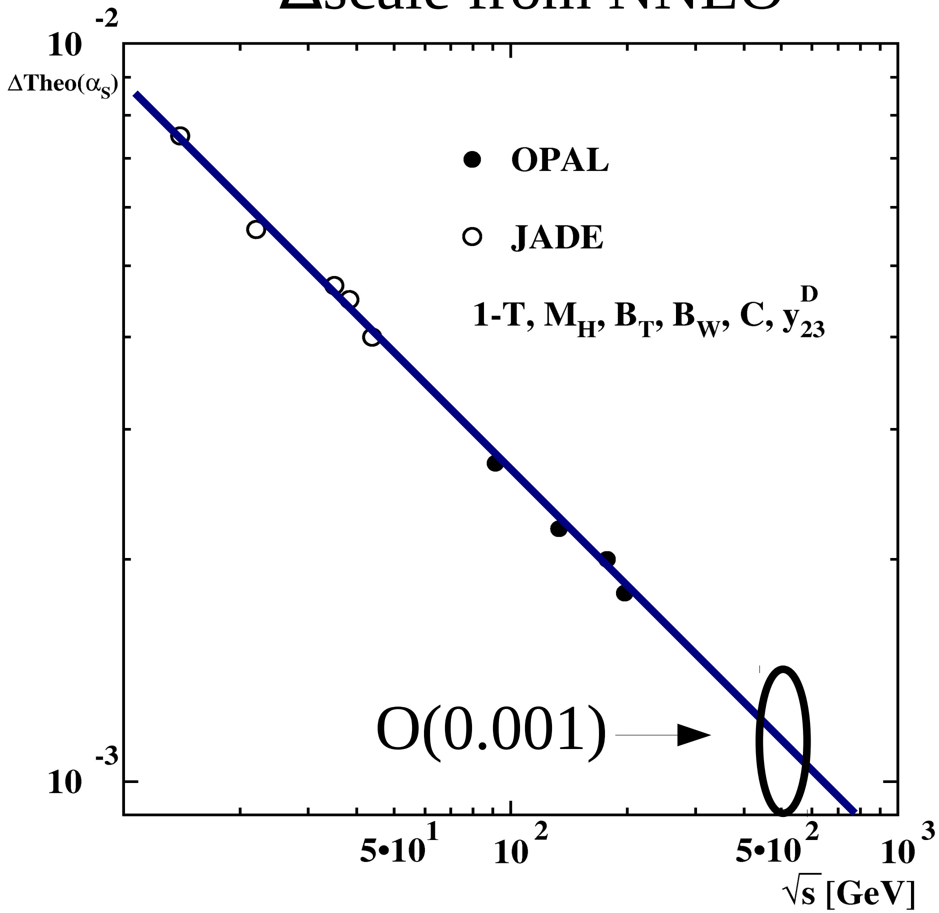

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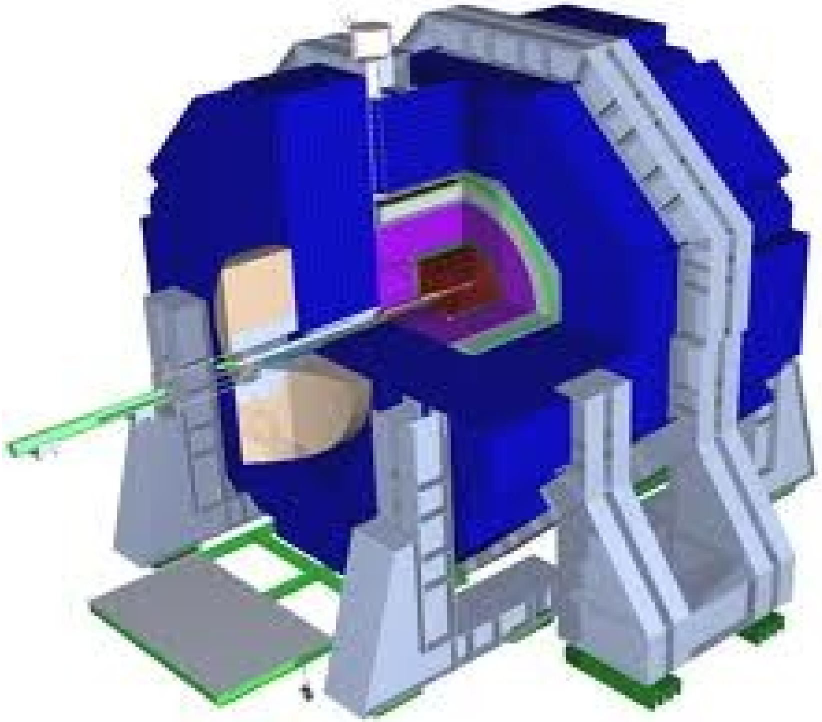
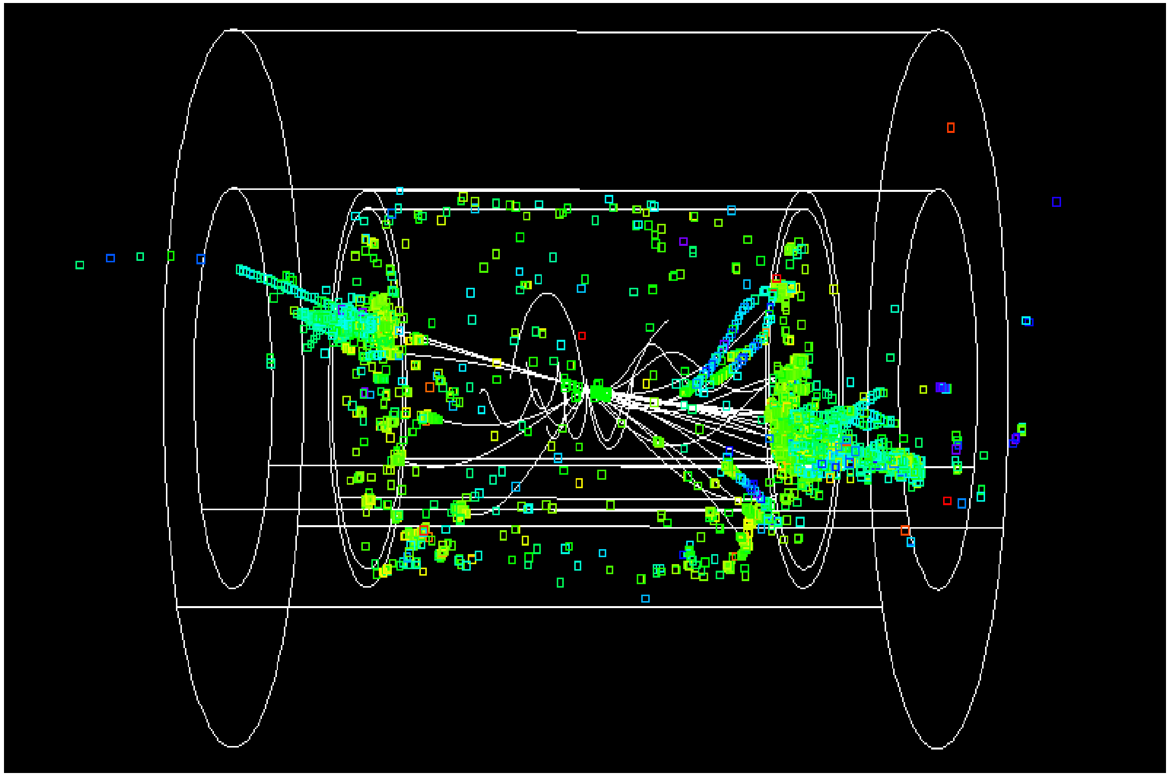
The SiD detector at the ILC

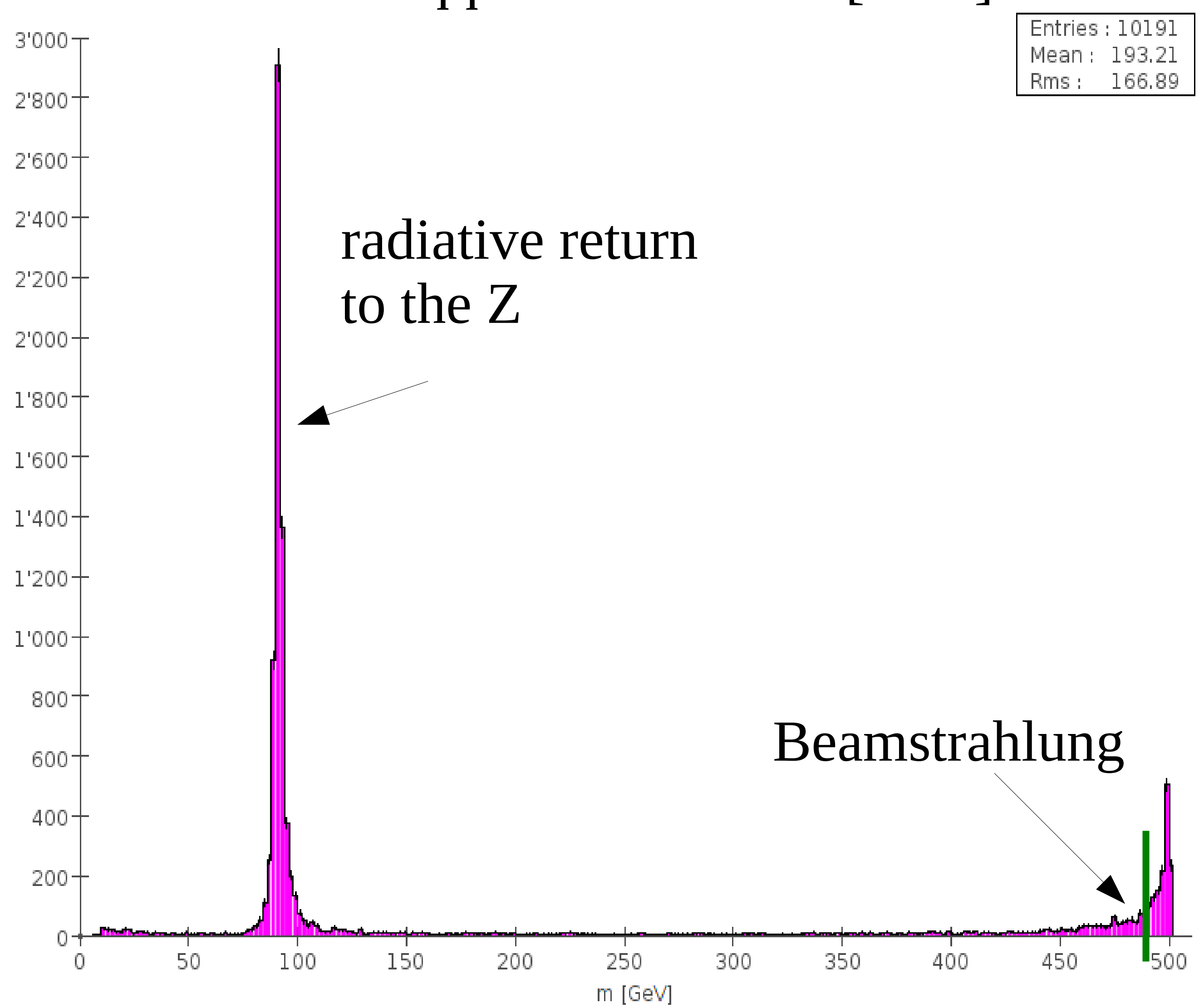




cc event at 500 GeV (tracks and calorimeter hits).

Radiation effects at 500 GeV

qq invariant mass [GeV]



u, d, s, c, b -quark pairs: whizard with PYTHIA-parton-shower and hadronization

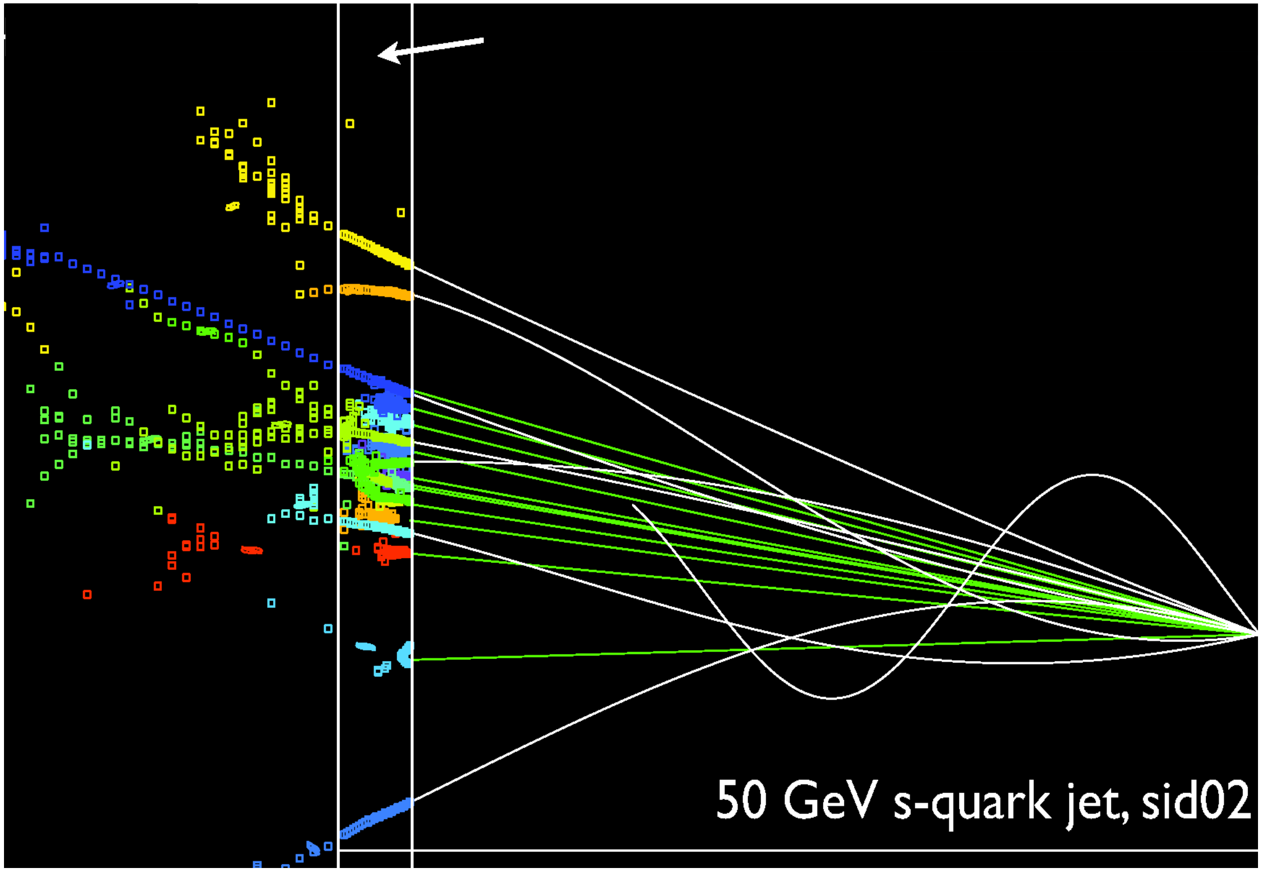
Detector sample:
m > 475 GeV

91 GeV

500 GeV

Particle **F**low **A**lgorithm

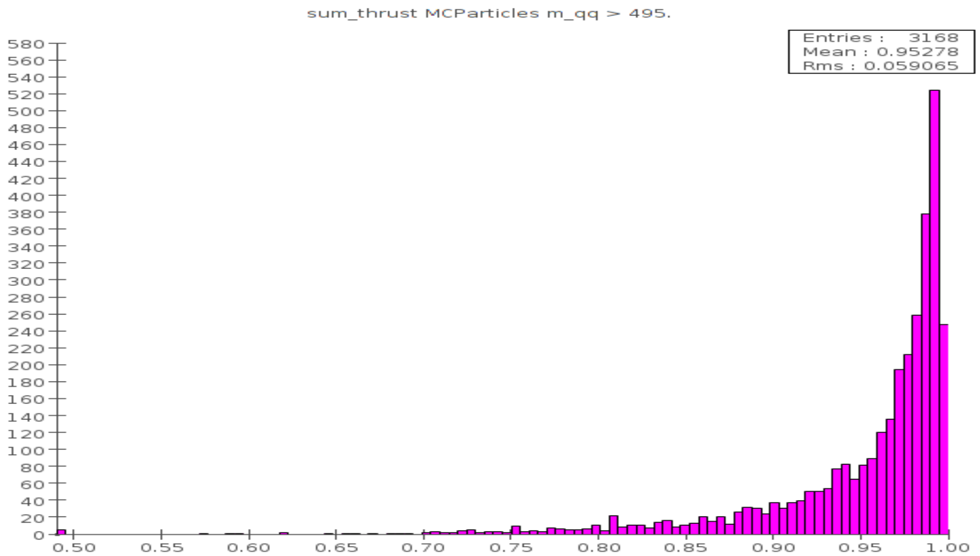
HCAL ECAL



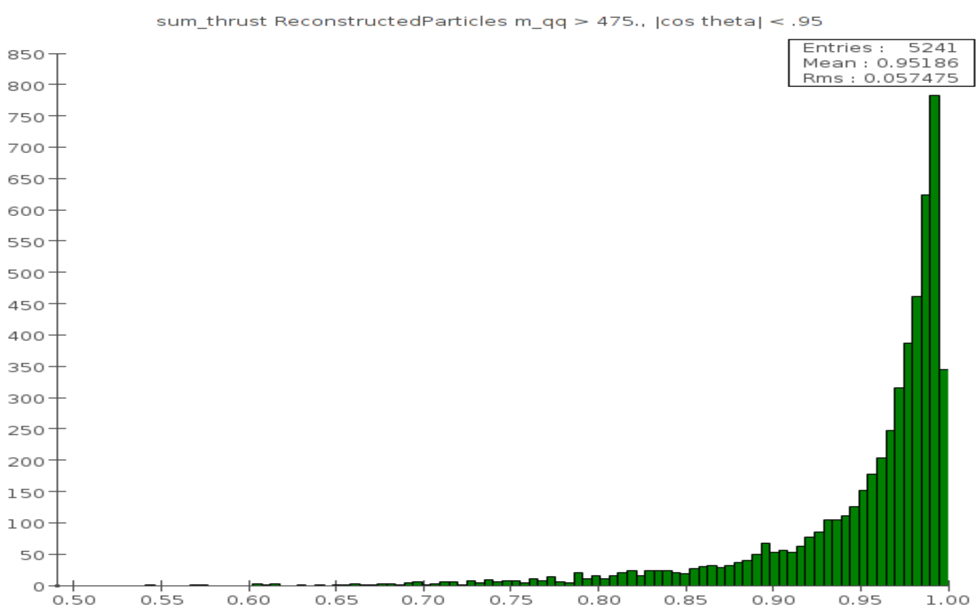
Showing PFA output

- White: reconstructed tracks.
- Calorimeter hits colour grouped by reconstructed particle
- Green lines: reconstructed neutrals

The SiD: Thrust Reconstruction



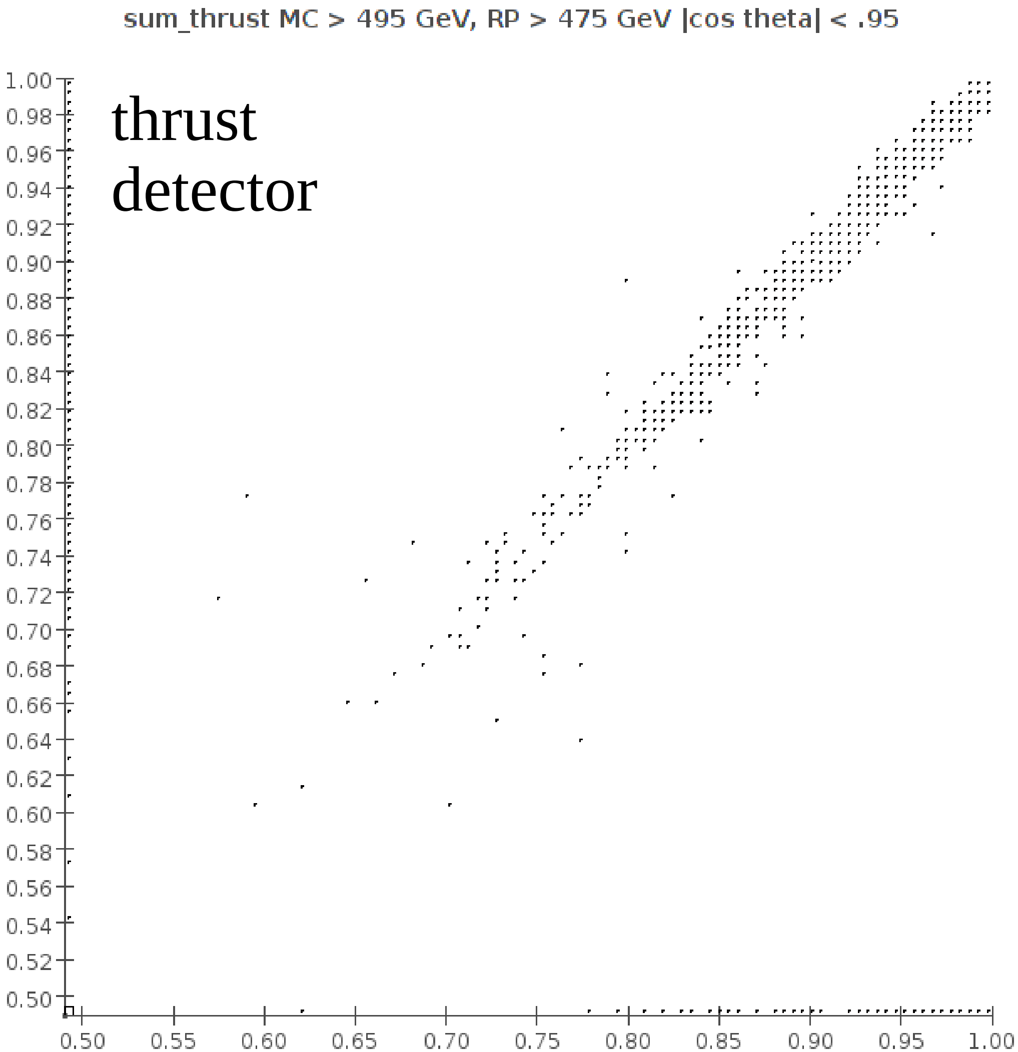
hadron level



detector level

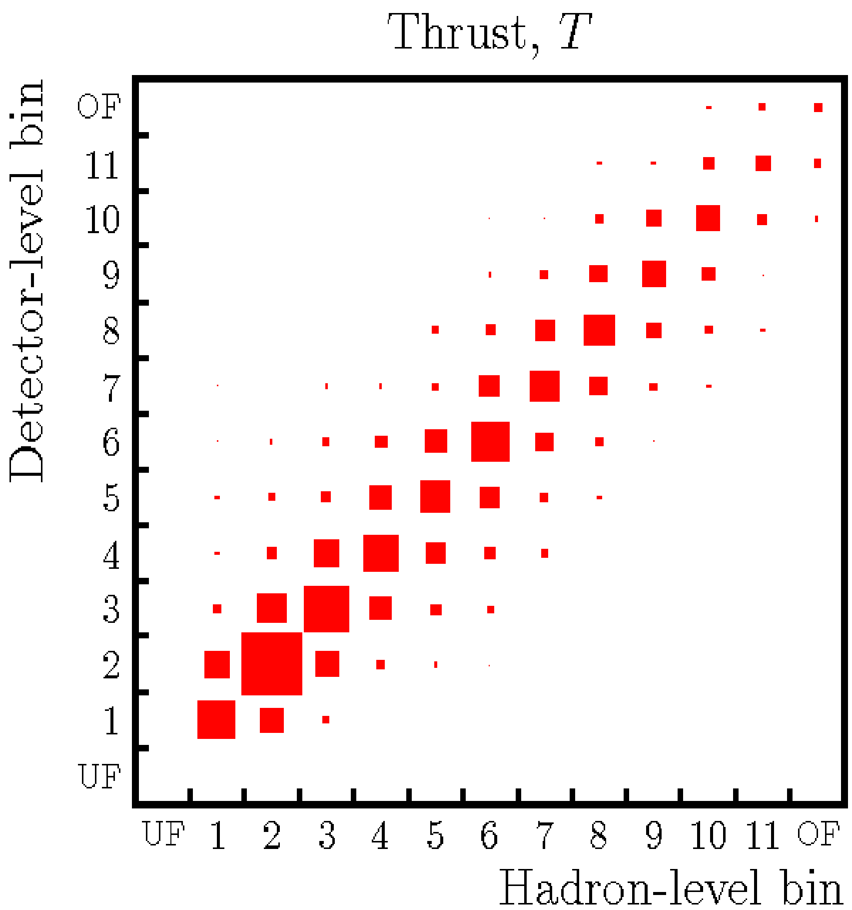
u, d, s, c, b – quark pairs at 500 GeV. whizard with PYTHIA parton shower and hadronisation

The SiD: Thrust Reconstruction



thrust
detector

thrust hadron



Comparison: 1-T by OPAL at 189 GeV (M.T.Ford)

Summary, ILC

- Uncertainties of $\alpha_s(m_{Z^\circ})$ measurement at 500 GeV:
  - Statistical ~ 0.0001
  - Detector ~ 0.001
  - Background ~ 0.001
  - Hadronisation ~ 0.0001 ... *partons* are almost seen!
  - Scale ~ 0.001 ... NNLO very important
- ILC+NNLO = precision
- Test of the running of $\alpha_s(\sqrt{s})$: Extended lever arm
- High resolving detectors with elaborate reconstruction algorithms promise good event shape measurement