Exerimental Issues Associated with a Precise Measurement of α_S at a Linear Collider

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With higher order calculations, theoretical limitations → 1-2%.

Will the experimental situation justify this effort?

<u>Major concern</u>: $q\bar{q}$ event selection

BORN LEVEL PRODUCTION

Table I: e^+e^- Annihilation at E_{cm} = 500 GeV.

Final State	Cross Section ($R^{(a)}$)	Events/($10\ fb^{-1}$)
QCD ($udscb$)	9	31,000
W^+W^-	20	70,000
Z^0Z^0	1.2	4,200
$t\bar{t}$ (m_t = 150 GeV)	1	3,400

(a) R ≡ 87 fb/E^2_{cm}, where E_{cm} is the e^+e^- center-of-mass energy in TeV.

Diboson, $t\bar{t}$ events have substantially different event shape + jet rate behavior

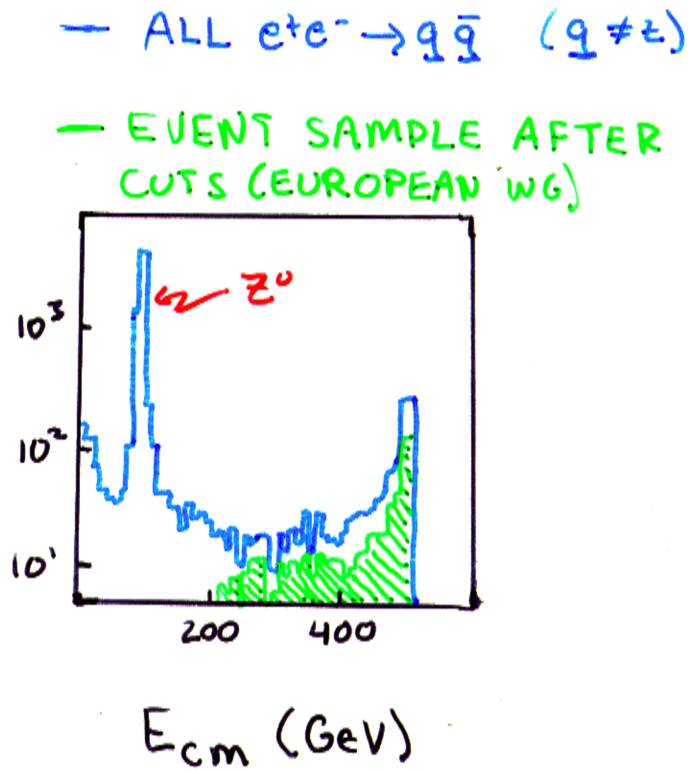
European Working Group

$q\bar{q}$ Selection Cuts (pre-Snowmass)

Cut	Value	Vetoes
particle multiplicity	$N_{part} \geq 8$	2-γ events beam-gas events leptonic final states
Polar angle of thrust axis	$\lvert\cos\theta_T\rvert < 0.8$	W^+W^- events highly radiative events losses around beampipe
visible hadronic energy and longitudinal momentum balance	$\frac{E_{vis}}{E_{cm}} > 0.5$ $\frac{\lvert\sum \vec{p}_z\rvert}{E_{vis}} < 0.4$	2-γ events highly radiative events poorly measured events
hemisphere masses	$M_1, M_2 > 3$ GeV	τ pair events
hemisphere multiplicities	$N^{1,2}_{charged} \geq 4$	lept. decays of boson pairs
hemisphere masses *	$\left[\frac{M_1}{E_{vis}}.\mathrm{or}.\frac{M_2}{E_{vis}}\right] < 0.13$	$t\bar{t}$ and boson pair events

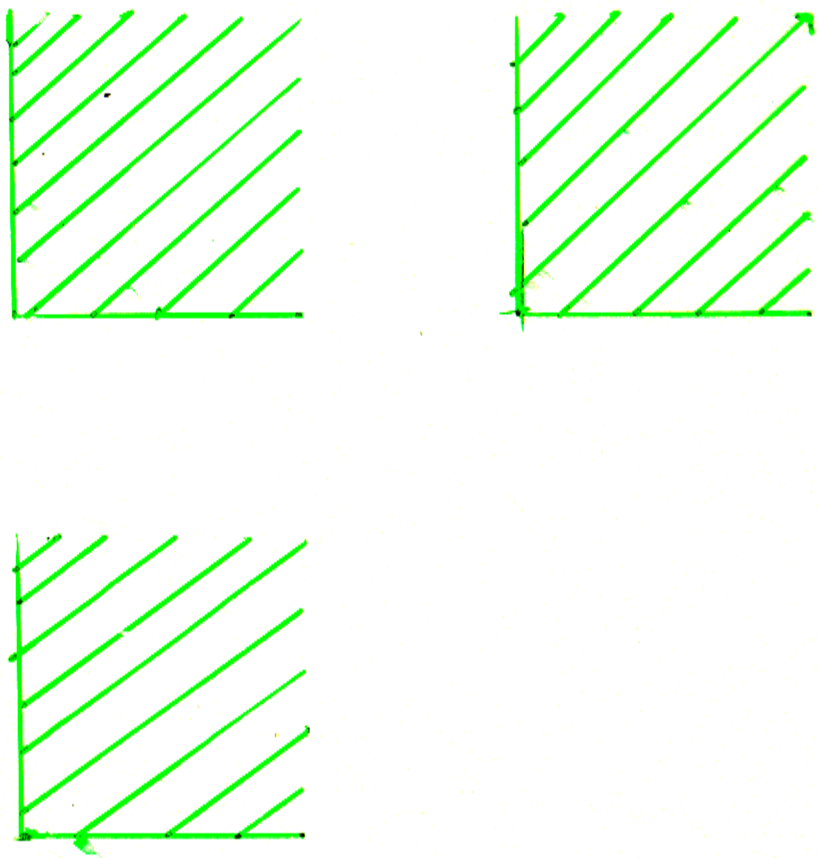
But introduces substantial bias (especially *)
to 3-jet rates

$\Rightarrow$ 20-25% correction to α_s!



Sample Composition After Cuts

$q\bar{q}$ $(q \neq t)$	83 %
W^+W^-	11 %
Z^0Z^0	0 %
$t\bar{t}$	6 %



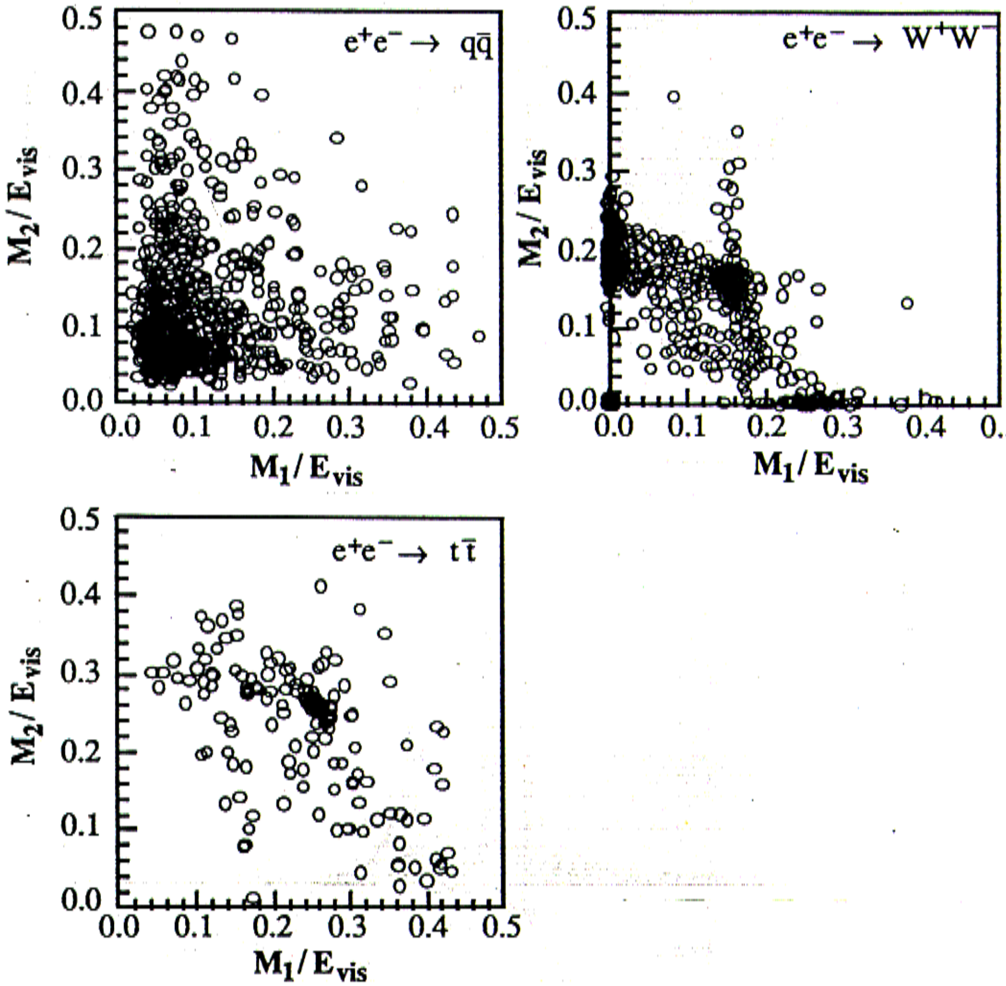
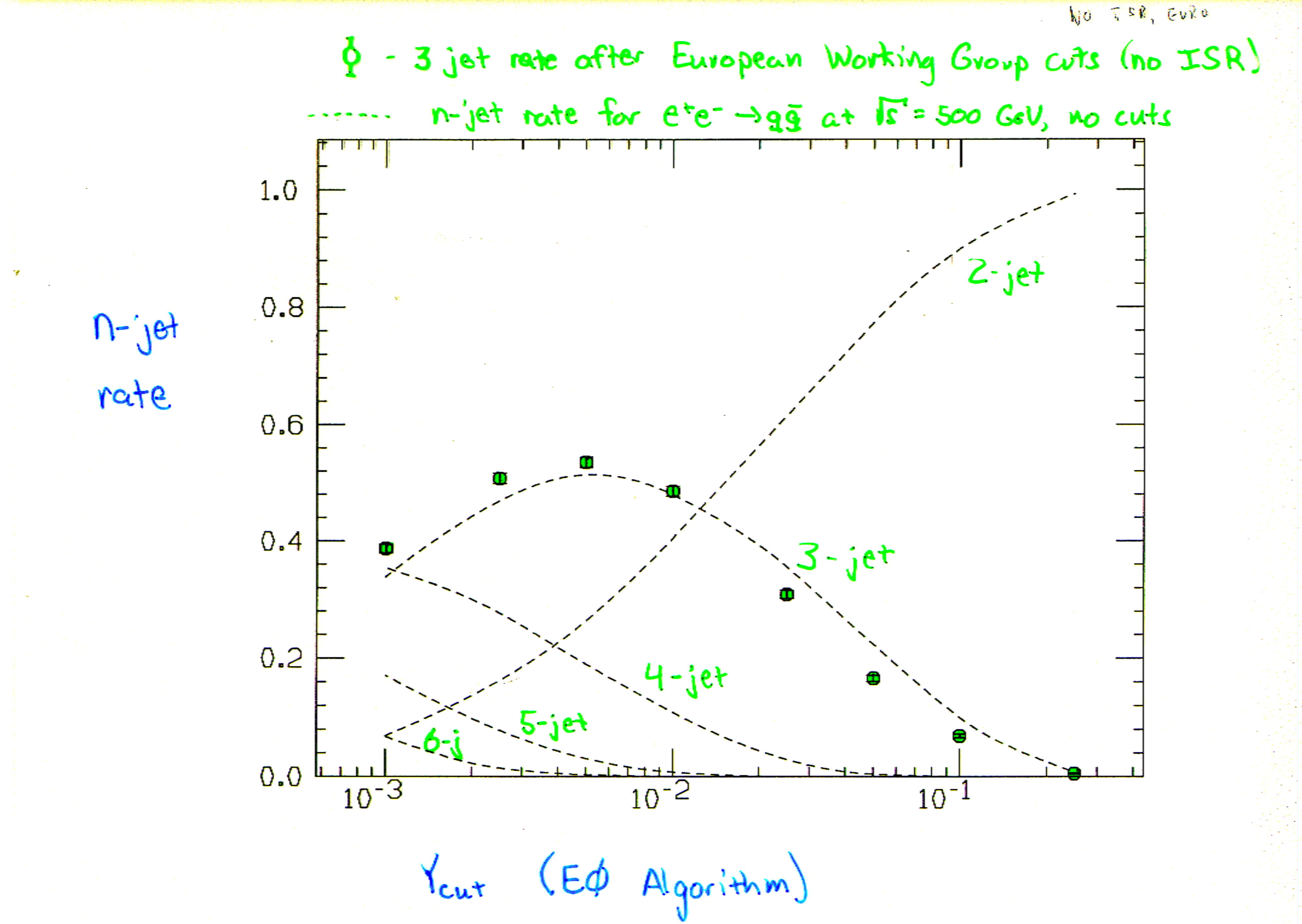


Fig.7. Two-dimensional correlation plots of reduced hemisphere masses of light quark hadronic events, of W^+W^- and of $t\bar{t}$ events, without photon radiation and detector acceptance effects.


No ISR, EURO
- 3 jet rate after European Working Group cuts (no ISR)
n-jet rate for e⁺e⁻ → qq̄ at √s = 500 GeV, no cuts
n-jet rate
1.0
0.8
0.6
0.4
0.2
0.0
10⁻³
10⁻²
10⁻¹
2-jet
3-jet
4-jet
5-jet
6-j
Ycut (E0 Algorithm)

NLCQCD EVENT SAMPLE STUDY (hep-ex/9612013)

IDEA: Relax most biasing of the European working group cuts. Make up for it via

1. Precision vertexing (anti-b tag) $t\bar{t}$
2. Electron beam polarization W^+W^-

Example:

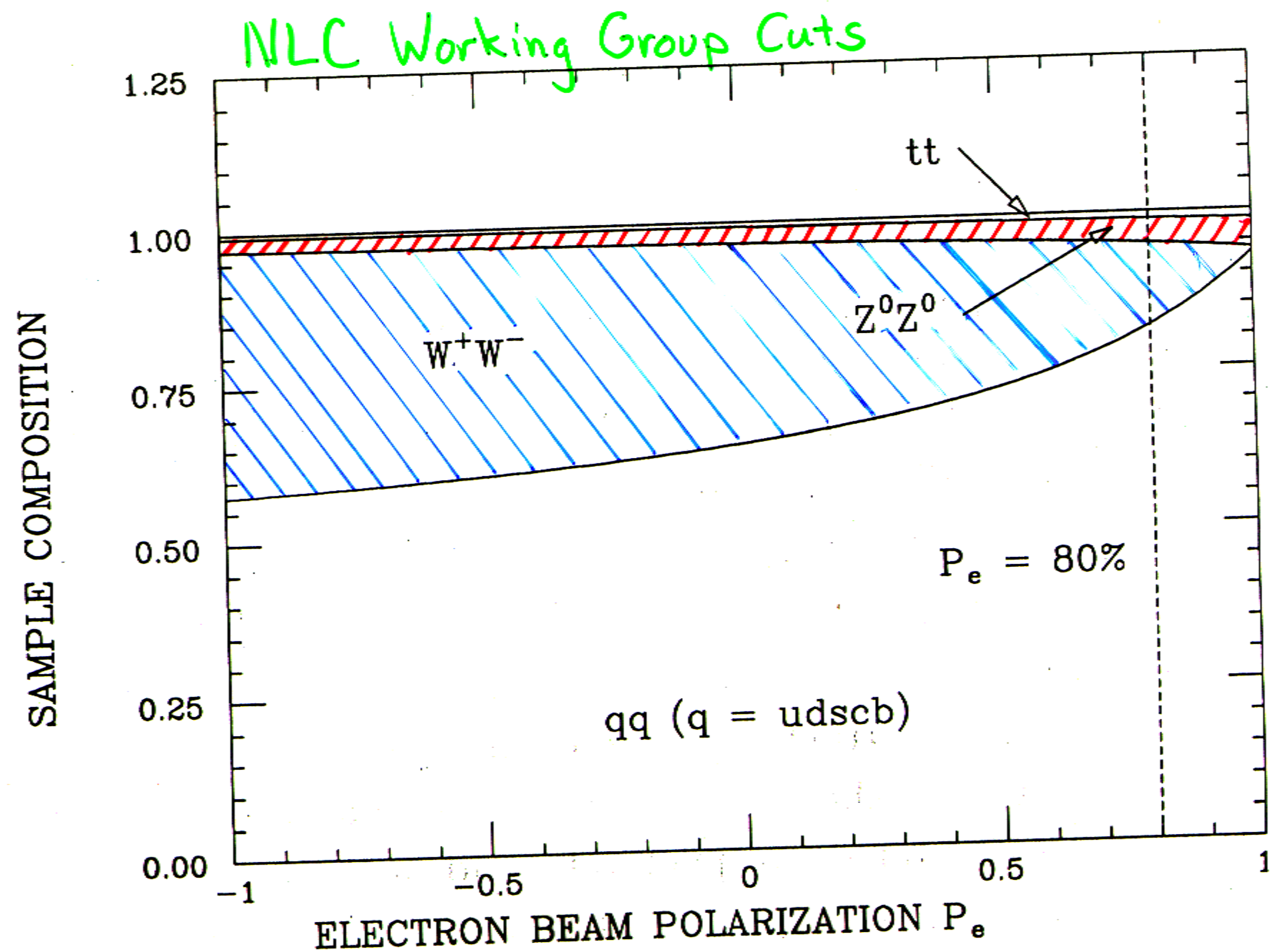
Remove hemisphere mass cut ($M/E_{vis} < 0.13$) and require that no more than 3 tracks miss the IP by more than 3σ ...

$\Rightarrow$ small (20%) loss of ε, and $t\bar{t}$ eliminated (~1%)

... and then add in beam polarization

$\Rightarrow$ resulting efficiency for e.g. $P_e = 80\%$ is 28% of EWG, but clean, unbiased sample.

$\hookrightarrow$ $\delta\alpha_s/\alpha_s \simeq 1/2\%$ per year @ design $\mathcal{L}$. for 'NLC' sample.


NLC Working Group Cuts
1.25
1.00
0.75
0.50
0.25
0.00
SAMPLE COMPOSITION
tt
W⁺W⁻
Z⁰Z⁰
Pₑ = 80%
qq (q = udscb)
−1
−0.5
0
0.5
1
ELECTRON BEAM POLARIZATION Pₑ

With $P_e = -0.8$, and NLC Working Group Cuts

Event Sample Fractions (ISR included)

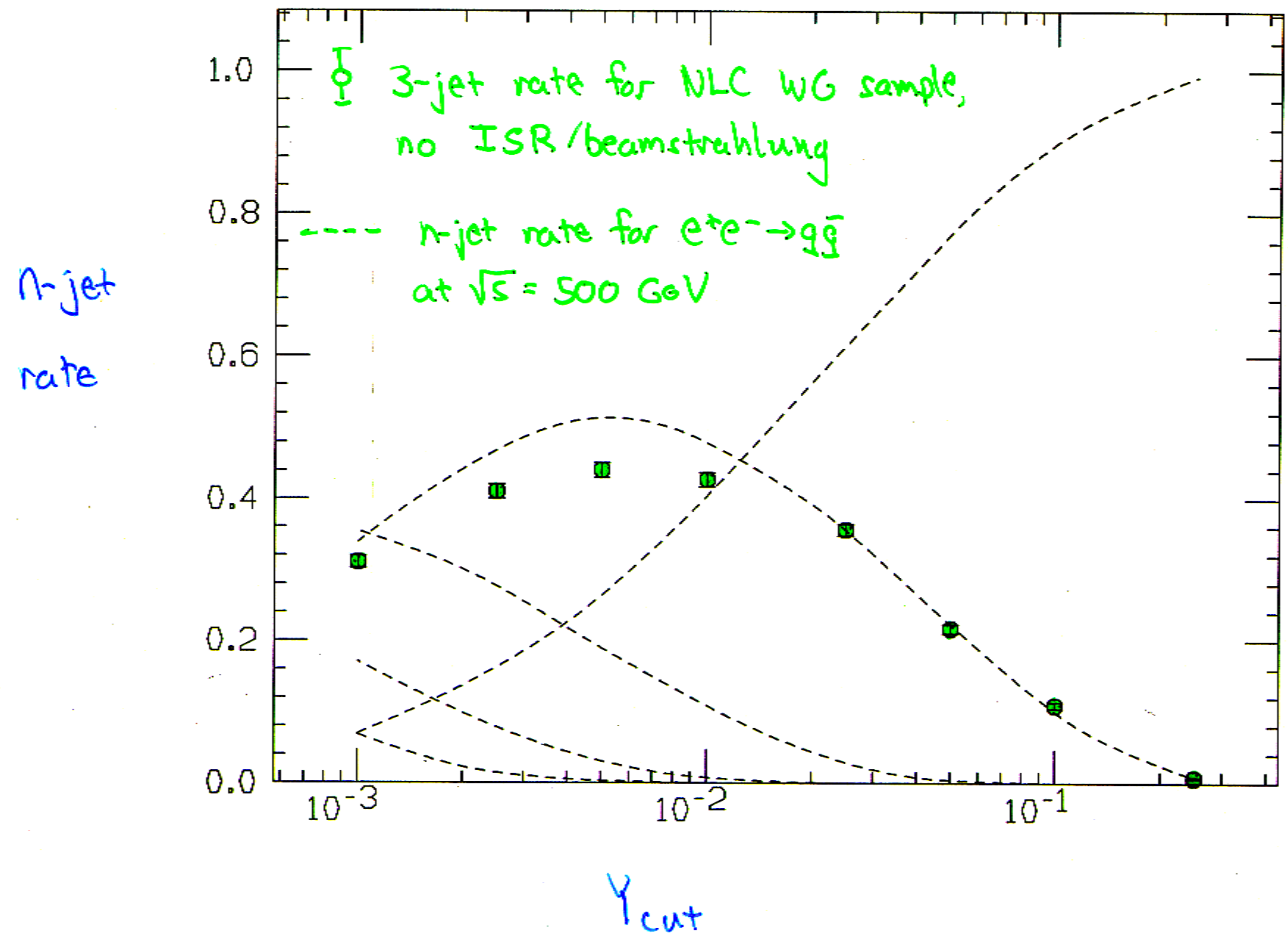
		($P_e = 90\%$)
$q\bar{q}$	81.7%	(86.6%)
W^+W^-	13.2%	(7.8%)
Z^0Z^0	3.9%	(4.3%)
⇒ $t\bar{t}$	1.2%	(1.3%)

Event Sample Efficiency

Assuming 50/50 running between $P_e = \pm 80\%$, about 28% of EWG sample, or 5,000 $q\bar{q}$ events per $10\,fb^{-1}$ (1 NLC "Snowmass" year = $50\,fb^{-1}$)

What do jet fractions look like including event selection biases, sample contamination, ISR... ?

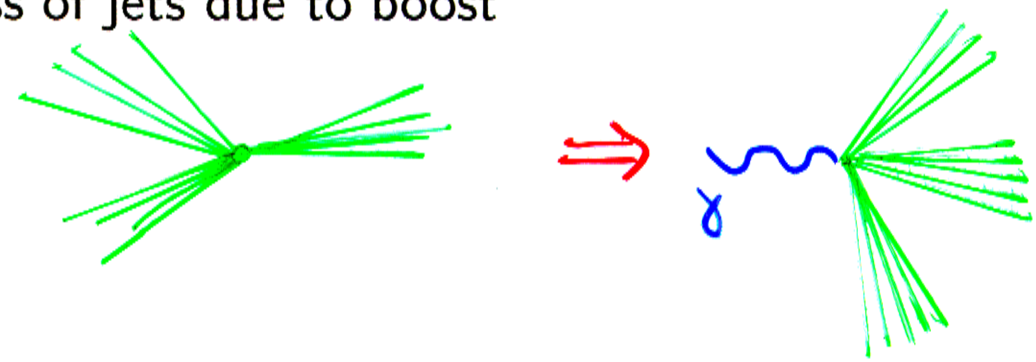
No ISR, $t\bar{t}$, WW, ZZ



Systematics Associated with S^* Distribution

The distribution of effective cms energies introduces systematics in two ways:

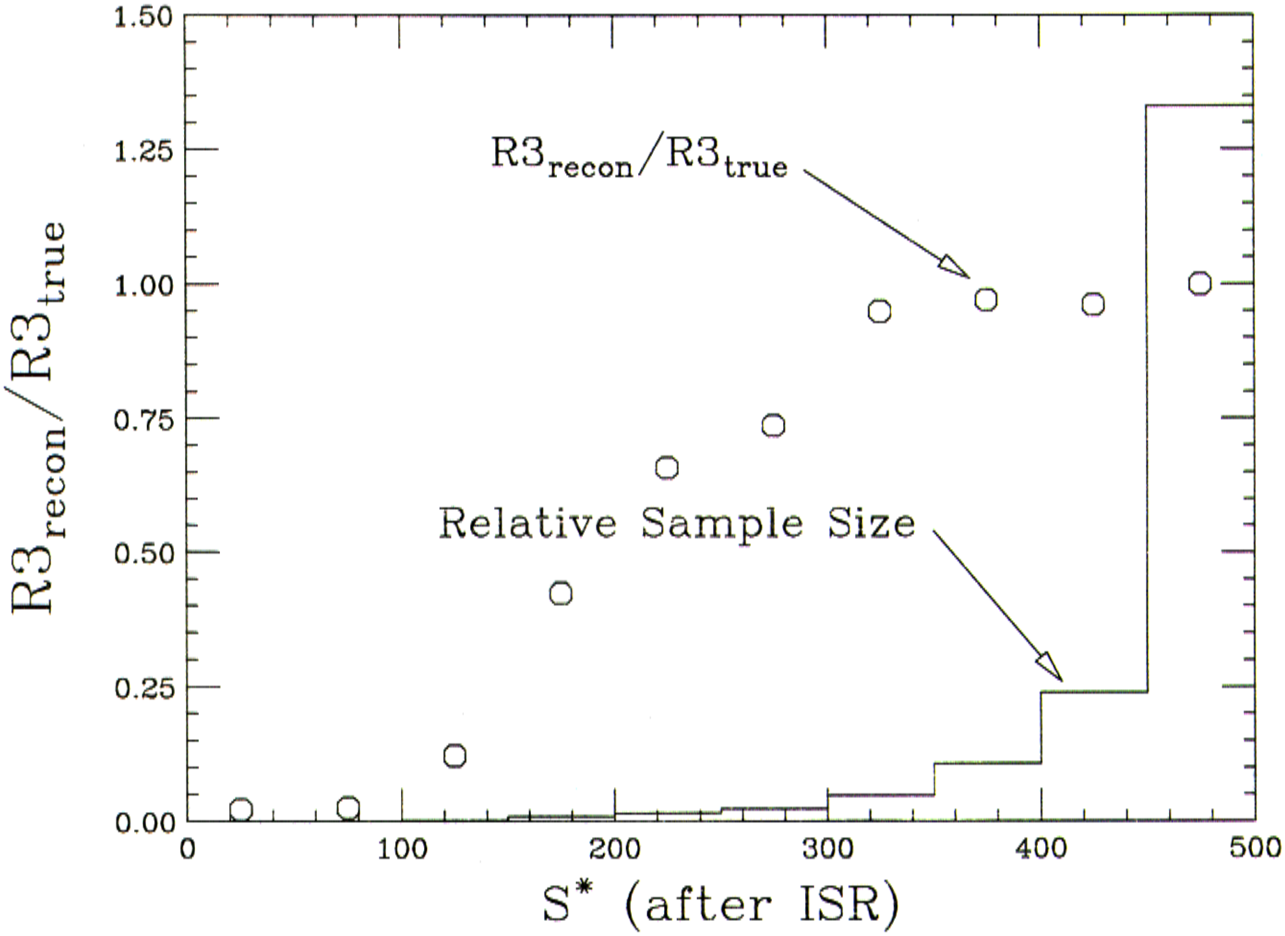
- Loss of jets due to boost



- The running of α_S itself

How well does one have to know the differential luminosty spectrum in order to measure α_S to $\pm 1\%$?

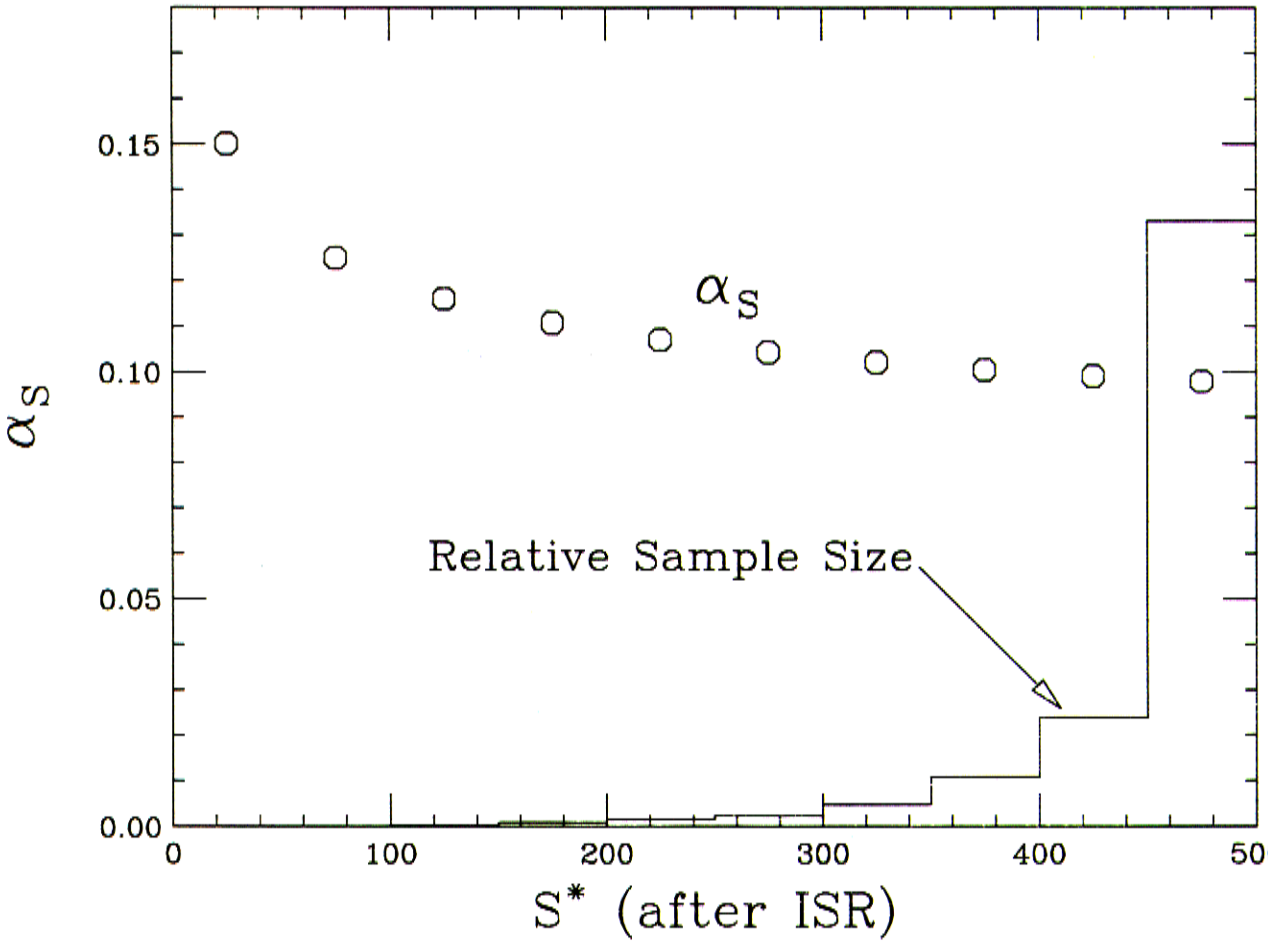
EFFECT DUE TO LOSS OF JETS (YCUT = 0.03)



Assume all clusters with $|\cos\theta| < 0.99$ measured

$$\frac{< R3 >}{< R3_{true} >} = 0.982$$

EFFECT DUE TO RUNNING OF α_S (YCUT = 0.03)



$$\frac{\alpha_{meas}}{\alpha_{500}} = 1.012$$

Conclusions

Experimental effects under control at $\pm 1\%$ level.

Energy spread appears not to be a problem (differential luminosity will have to be understood much better for top threshold)

Possible caveat: crude simulation assumed perfect segmentation

Limiting factor still seems to be next-to-leading calculation