LEP Trieste
27 Aprile
Monica Pepe Altarelli
INFN Frascati

Search for single top production with the ALEPH detector

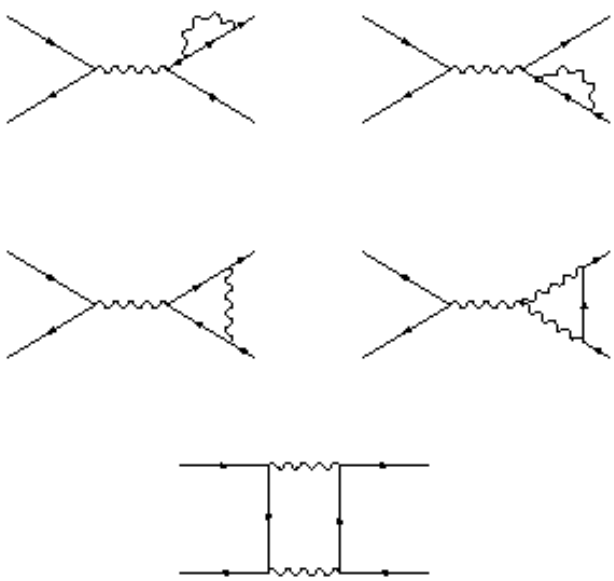
- Motivation
- Analysis
- Systematics
- Results
- Comparison with CDF and DELPHI

Search for single top production via FCNC

$$e^+e^- \to t\bar{q} \quad (\bar{q} = \bar{c}, \bar{u})$$

At tree level SM, there are no vertices for these FCNC processes.

FCNC appear at loop level



⇒ Very small cross section (10^{-9} fb)
(Huang,Wu,Zhu)

Suppressed by loop + GIM
Extensions of SM could lead to enhancement of such transitions

The FCNC vertices tcV (V = γ,Z) probed in

- top-charm associated production
- rare decays of t-quark

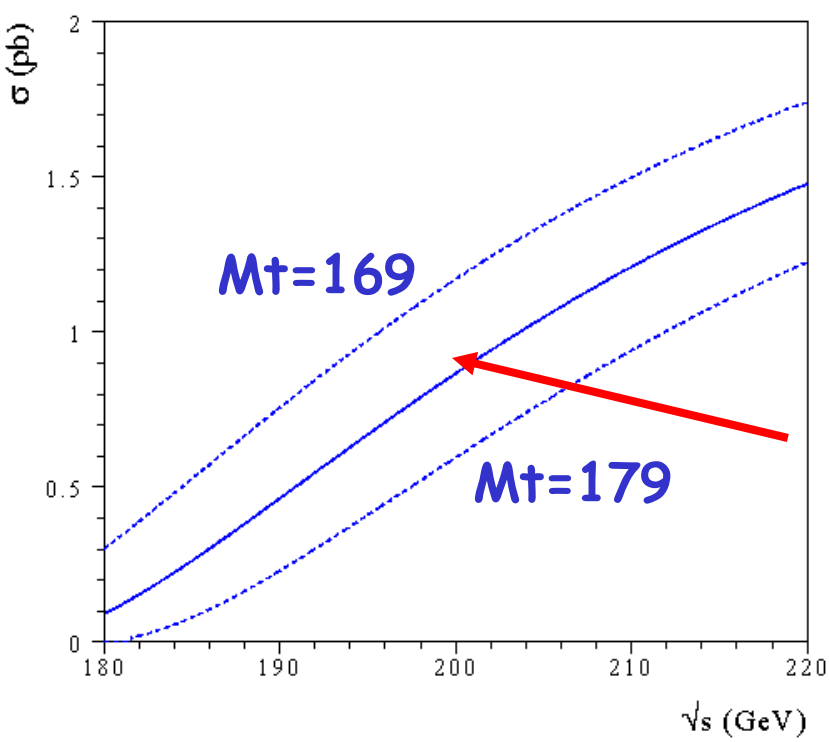
Existing limits

CDF: $p\bar{p} \to t\bar{t}X$

$$BR(t \to c\gamma) + BR(t \to u\gamma) < 3.2\% \quad 95\% \text{ CL}$$
$$BR(t \to cZ) + BR(t \to uZ) < 33\% \quad 95\% \text{ CL}$$

SM: $BR(t \to c\gamma, cZ) = 5.2\ 10^{-13}, 1.5\ 10^{-13}$

very weak constraint: $N_{tt} \sim 10^2$



σ corresponding to CDF limits

$\sigma^{95}_{CDF} < 0.85$ pb

$\sqrt{s} \sim 200$ GeV

Mt=174 GeV

MODELLING

Top decays rapidly via $t \rightarrow W + b$
(10^{-24} sec) $\Longrightarrow$ no top hadrons formed

$$e^+e^- \rightarrow \bar{c}\, t$$
$$\hookrightarrow bW$$
$$\hookrightarrow f\bar{f}'$$

- b & c quarks joined by string to form a colour singlet
- b allowed to develop parton shower to take into account hard gluon emission

Kinematics

top produced close to threshold

→ characteristic kinematic properties of final states

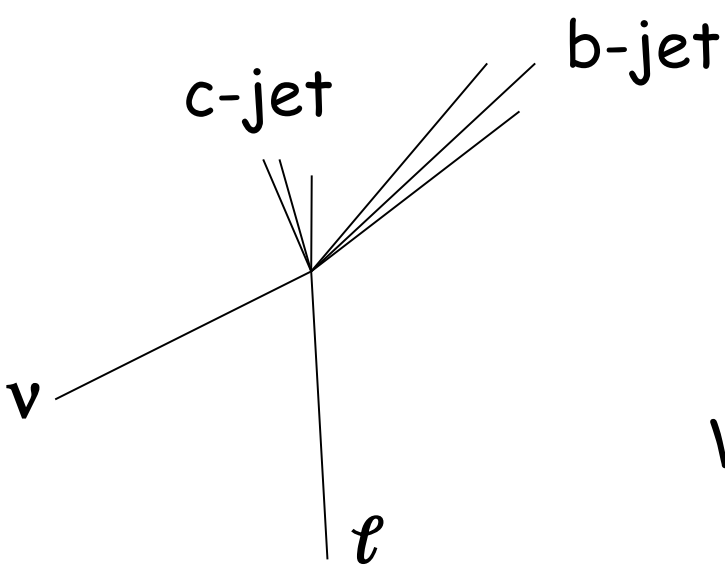
$$E_t \cong m_t \qquad E_{c(u)} \cong \sqrt{s} - m_t$$

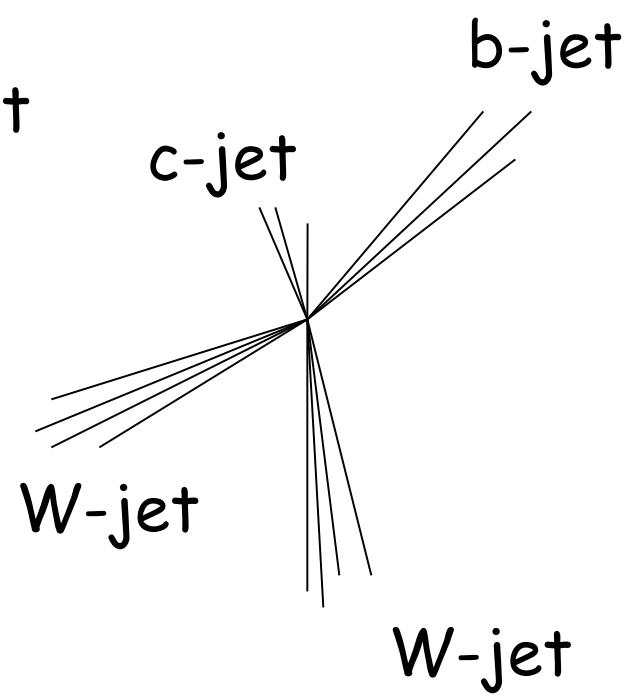
$$E_b \cong \frac{m_t^2 - m_w^2 + m_b^2}{2m_t} \qquad E_w \cong \frac{m_t^2 + m_w^2 - m_b^2}{2m_t}$$

Topologies

$W \longrightarrow qq'$

$\hookrightarrow \ell\nu$





Data sample

WW selection at 189-> 200 GeV

189 GeV 174 pb^{-1}	
192 GeV 29 pb^{-1}	196 GeV 86 pb^{-1}
200 GeV 80 pb^{-1}	202 GeV 42 pb^{-1}

MC samples

Background: L> 1500 pb^{-1}:

WW, ZZ, Zee, Wev, Zvv, qq(γ)

fully simulated at 189-196-200-202

Signal: 2000 events

M_{top}=174 (169, 179) GeV

fully simulated at all energies

Preselection

Rejects $\gamma\gamma$, dileptons and radiative Z-returns:

$N_{charged} > 8$

$E_{tot} > 100$ GeV

$|P_z| < 55$ GeV

$N_{charged}(Jet) > 0$

$M_{tot} > 50$ GeV

$E_{\gamma,MAX} < 38$ GeV

Elep	MC	DT
189	6742	6687
192	1123	1167
196	2901	2957
200	3045	2980
202	1457	1458
Tot	15268	15249

- Good agreement between Monte Carlo and Data for the most relevant variables at all energies

Selection

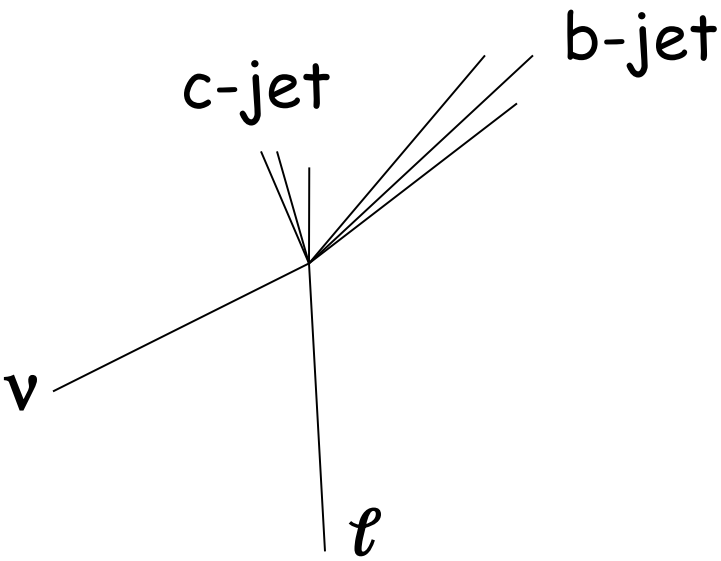
- Cuts optimized by minimizing expected 95% CL cross section upper limit in absence of signal at 200 GeV for a L=200 pb^{-1}
  (at $\sqrt{s}$~200 GeV largest sensitivity to the single top production cross-section)

- Same selection used for all energies:
  most important cuts based on invariant quantities

- Loose cuts for non invariant quantities

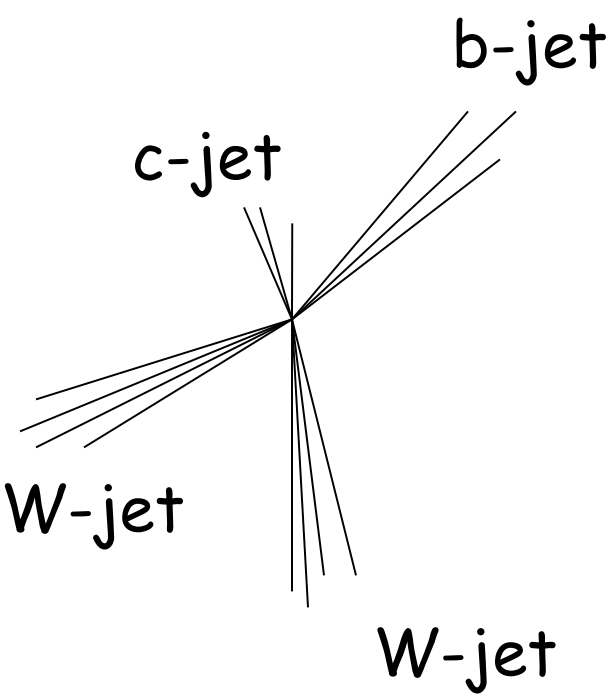
Selection

- Identify one isolated e or μ



Force to 3 jets
1C kinematic fit

- No isolated e or μ



Force to 4 jets
4C kinematic fit

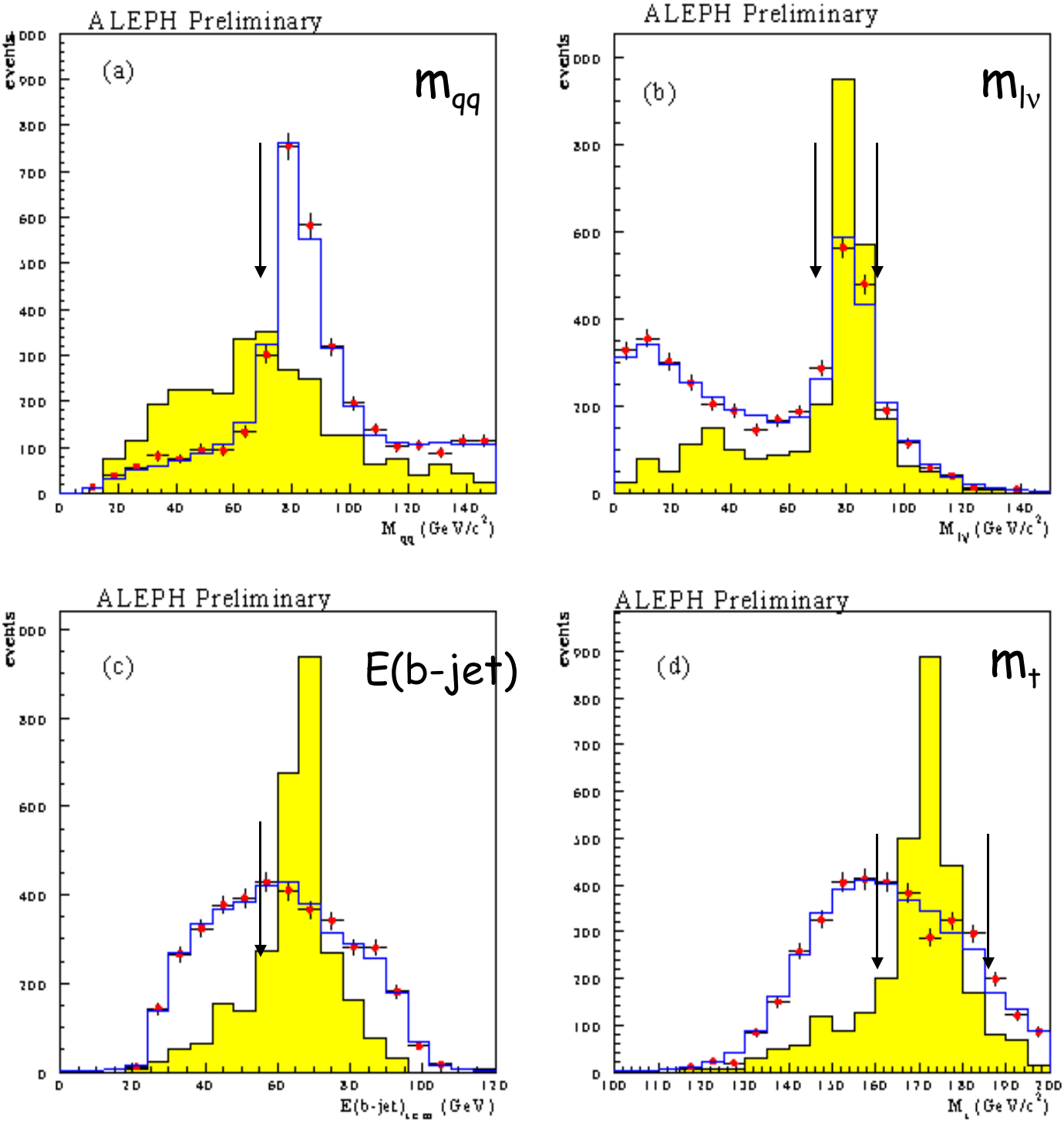
Selection cuts:

Inclusive combination of two separate analyses: 3-jets and 4-jets

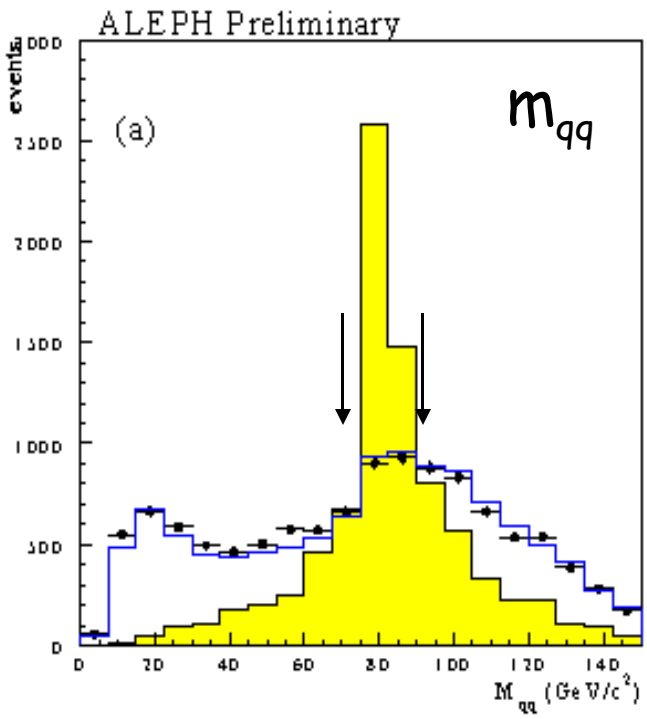
- 3-jets
  - isolated and energetic e or μ (E > 10 GeV)
  - b-tag for b-jet > 2
  - 55 GeV< $E(\text{b-jet})_{tcm}$
  - 70 GeV < $m_{\ell\nu}$ < 90 GeV
  - 160 GeV < m_t < 187 GeV
  - m_{qq} < 70 GeV ($m_{qq}=m_{bc}$)

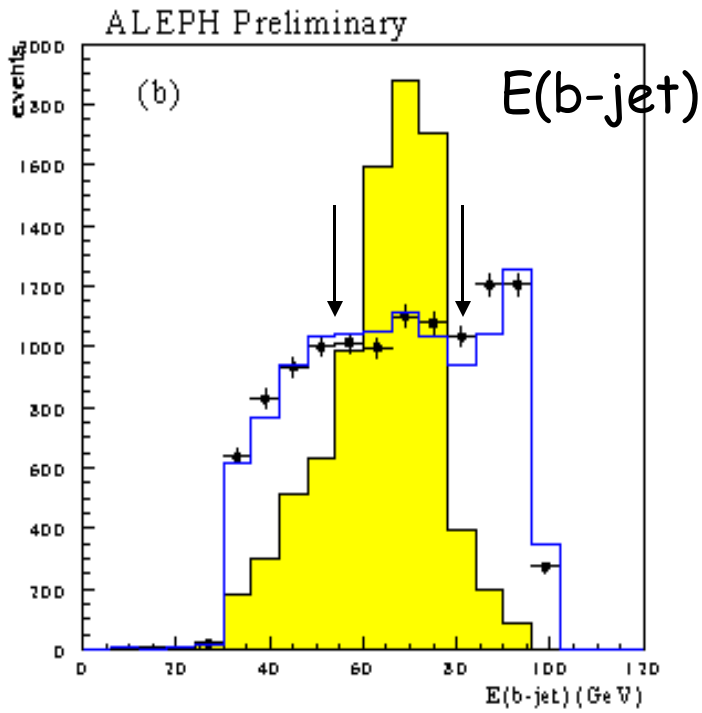
- 4-jets
  - b-tag for b-jet > 5.8
  - b-tag for second more energetic jet < 6
  - 55 GeV< E(b-jet) < 80 GeV
  - 72 GeV < m_{qq} < 91 GeV ($m_{qq}=m_W$)
  - 0.57 < p_{qq}/E_{qq} < 0.73
  - Thrust < 0.90
  - E_{qq} > 145 GeV

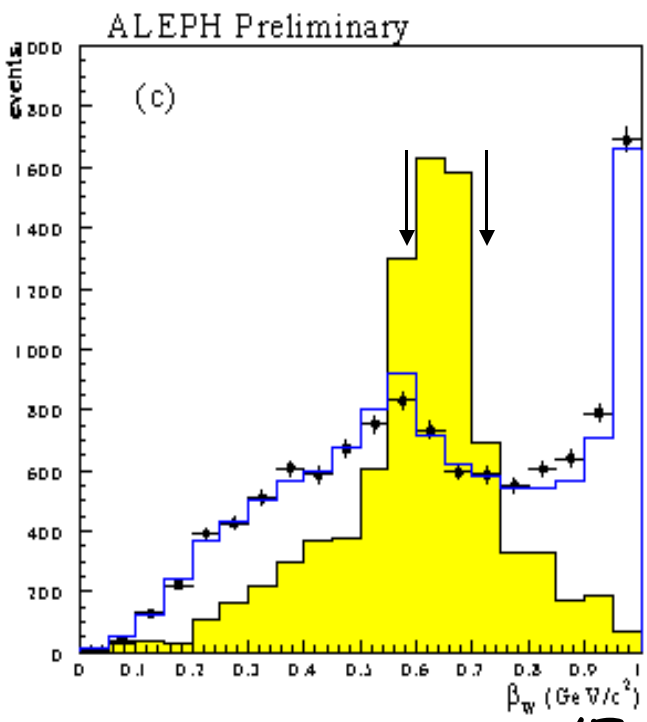
3-jet variables



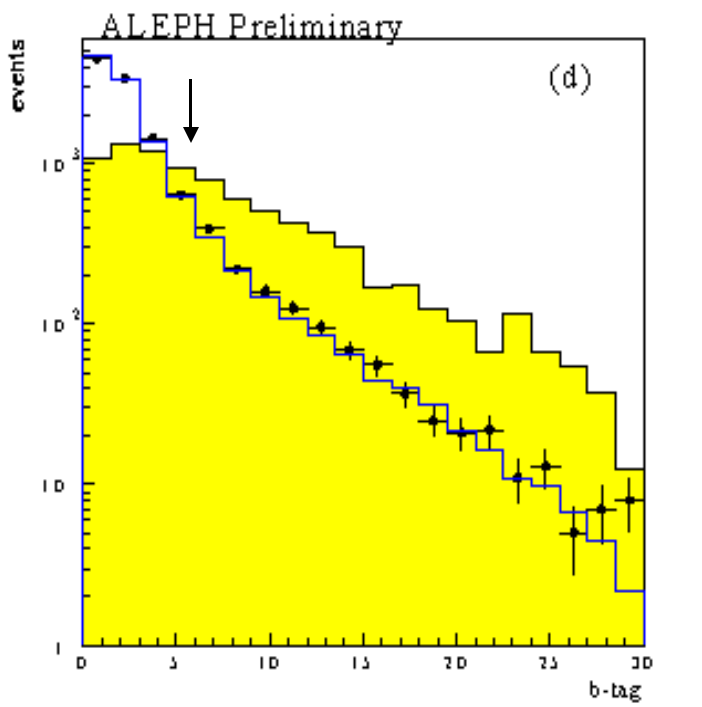
4-jet variables







p_{qq}/E_{qq}



b-tag

Results

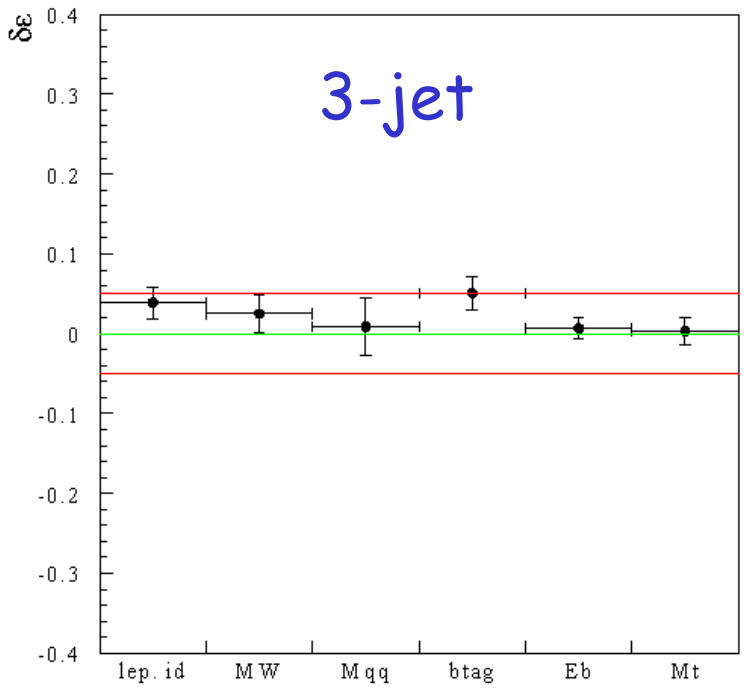
$\sqrt{s}(GeV)$	189		192		196		200		202	
$L(pb^{-1})$	174		29		80		86		42	
	lept	had	lept	had	lept	had	lept	had	lept	had
N^{Bck}_{WW}	2.1	4.5	0.3	0.7	1.3	3.9	0.9	5.8	0.7	2.6
N^{Bck}_{4f}	0.1	1.2	0.0	0.2	0.0	0.8	0.1	0.8	0.0	0.4
N^{Bck}_{qq}	0.1	10.6	0.0	1.8	0.1	5.5	0.1	3.7	0.1	2.0
N^{Bck}_{tot}	2.2	16.3	0.3	2.7	1.4	10.2	1.0	10.3	0.8	5.0
N^{Obs}	4	21	0	5	1	13	1	9	0	4
$\varepsilon(\%)$	7.0	17	6.2	16	5.5	15	4.9	13	3.5	14
σ^{exp}_{95}(pb)	0.4	0.3	2.1	1.2	1.0	0.8	1.0	0.8	2.7	1.1
σ^{m}_{95}(pb)	0.6	0.5	1.7	1.7	0.9	1.0	1.0	0.7	2.0	0.9

6 candidates selected by lept. selection (5.7 expected)
52 by hadronic selection (44.5 exp)

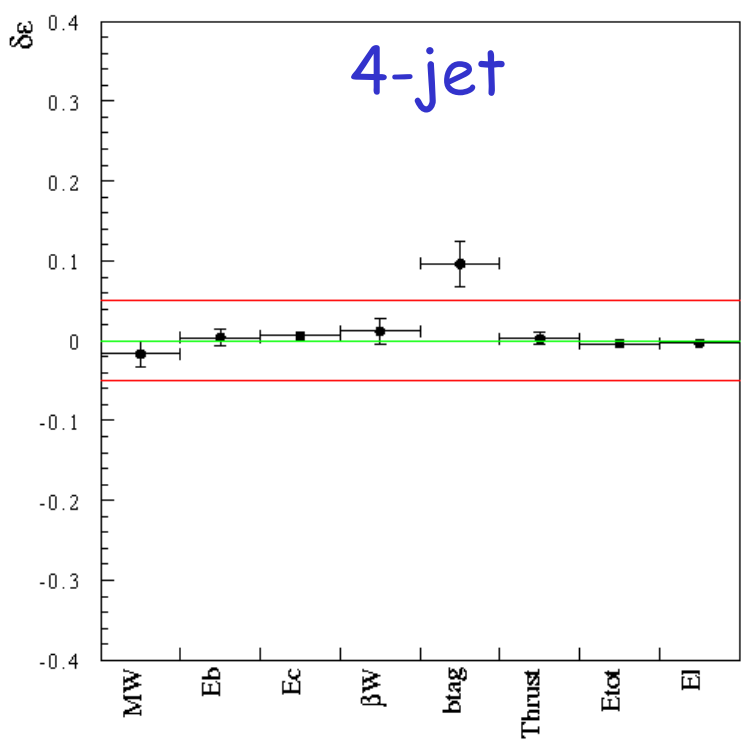
Background Systematics

One cut at a time applied after preselection

$$\delta\varepsilon_{BKG} = (\varepsilon_{Data} - \varepsilon_{MC}) / \varepsilon_{MC}$$

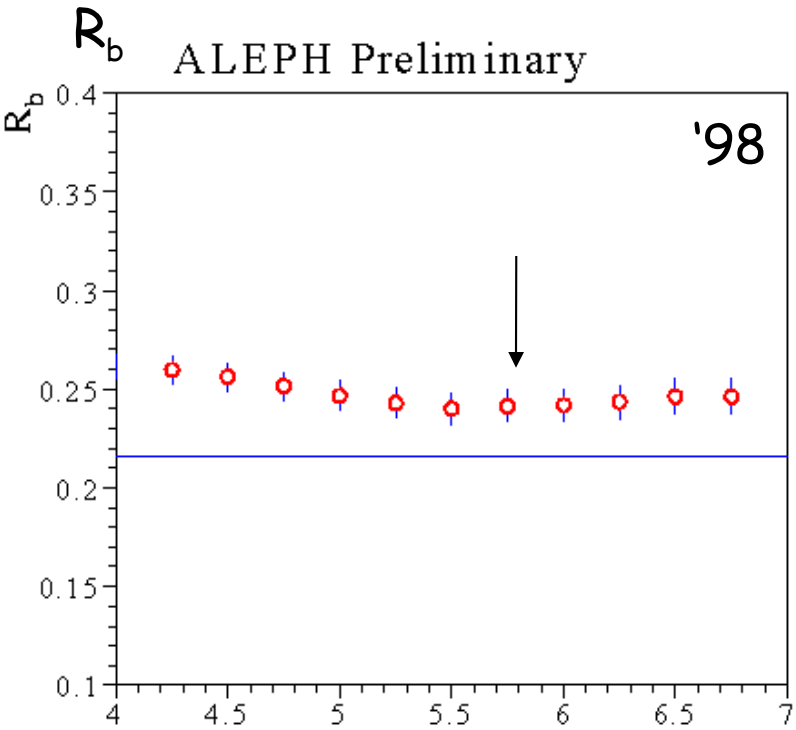


5% effect



10% effect

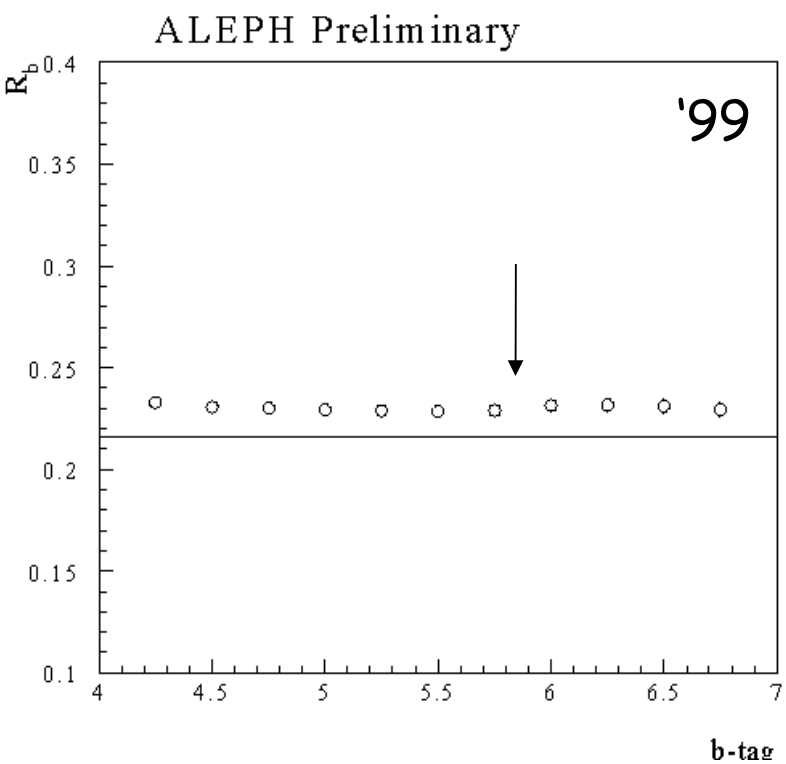
R_b from Z calibration data (single tag)



R_b=0.241 ± 0.008$_{stat}$

+12%

b-tag



R_b=0.228 ± 0.003$_{stat}$

+6%

$R_{b(LEP1)}$=0.2167± 0.0017

Systematic uncertainties

- All $\delta\varepsilon_{BKG}$ within $\approx$ 3%

  except b-tag $\delta\varepsilon_{BKG} \approx$10%

- R_b with '99 ('98) Z data 6% (12%)

  larger than LEP1 value (for ε_b ~30%)

- Uncertainty on ε_{signal} dominated by δm_{top}

  (~10-30% effect)

- Limit setting approach:
  - Expected background reduced by 10%
  - ε_{signal}: 5% effect (b-tag) for each m_{top}
  - Limits evaluated for $m_{top}\pm5$ GeV

Combination of results

- Results at 189 -> 202 GeV combined in

  $K\gamma$ -K_Z plane (M_{top}=174±5 GeV)

  using σ ($K\gamma$,K_Z,m_{top},s) BR(t->bW)

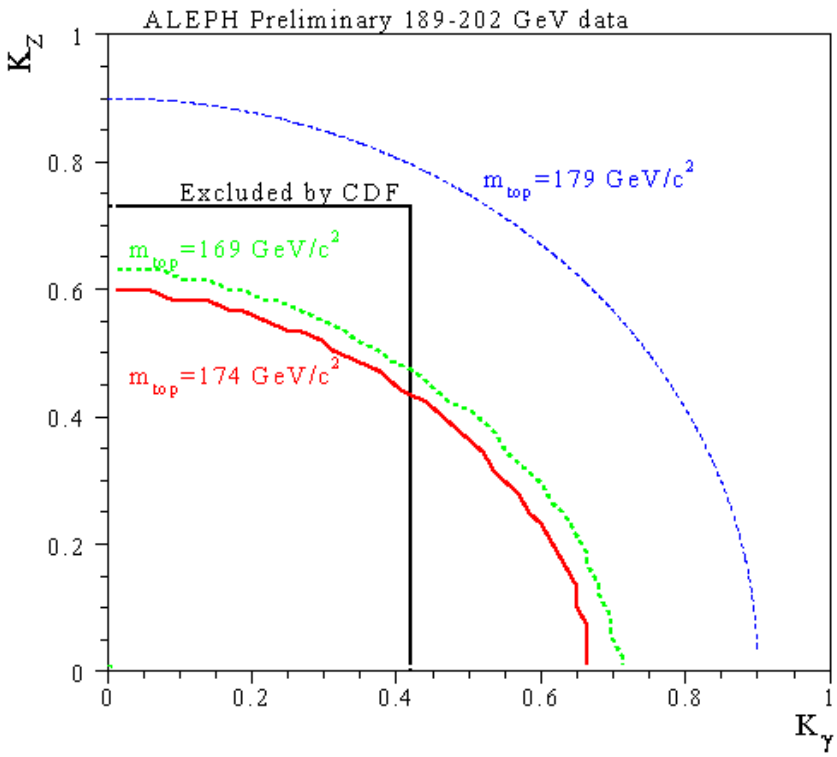
  BR(t->Z(γ)c) subtracted from efficiency

- Likelihood-ratio method used:
  - Combined (2 channels + 5 E_{CM})

- Combined exclusions compared with

  CDF limits

Limits on K_γ-K_Z



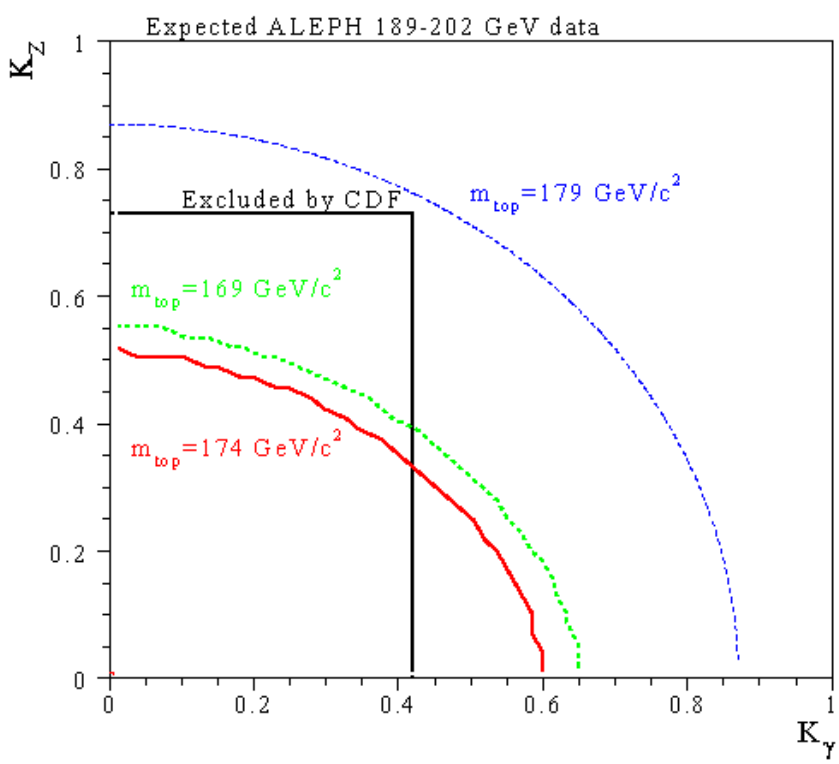
Limits

189 -> 202 GeV

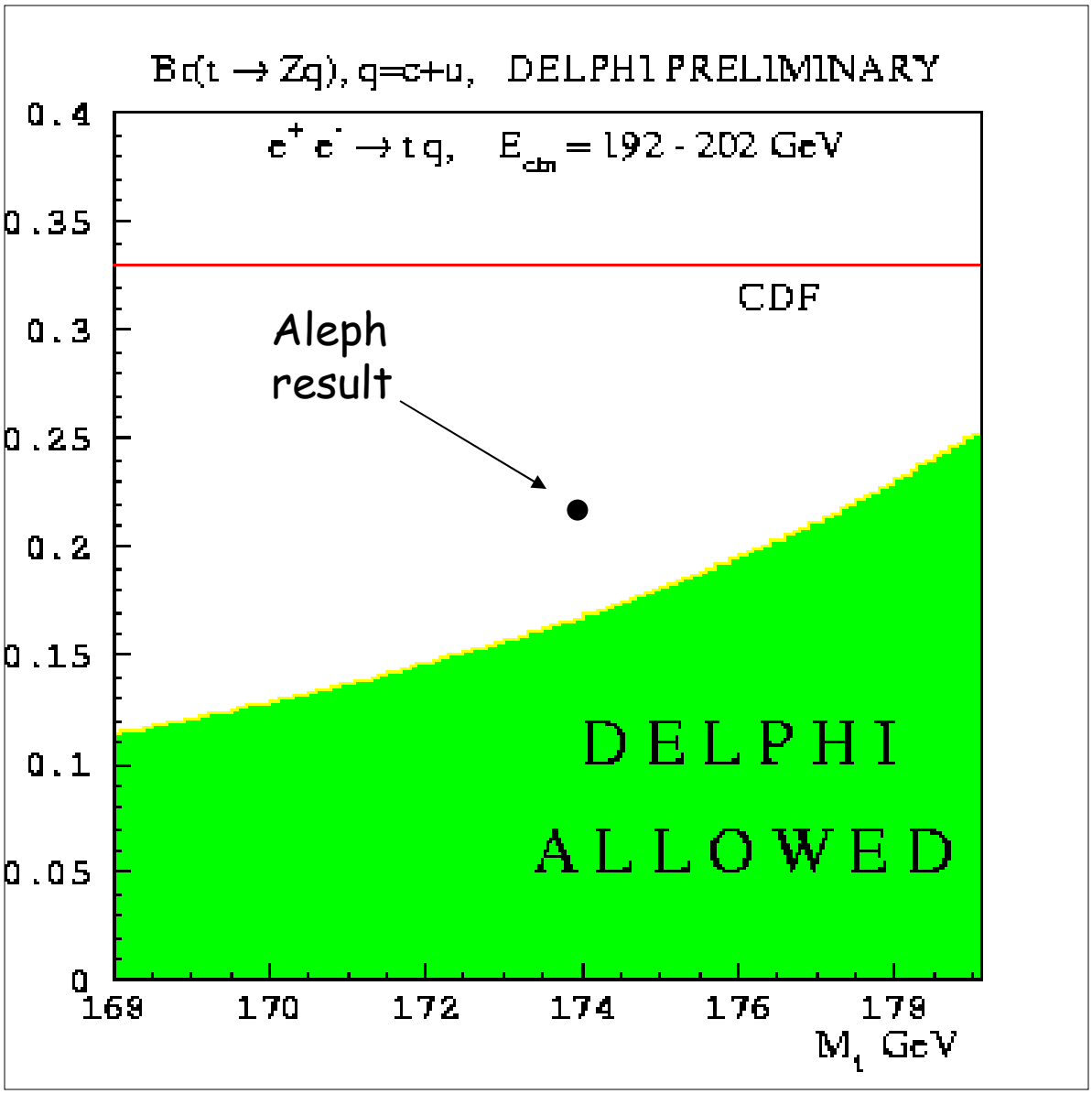
For m_t=169,174 GeV
K_Z limits improved

Expected

189->202 GeV



New analysis by DELPHI
(DELPHI 2000-032 CONF 351, March '00)

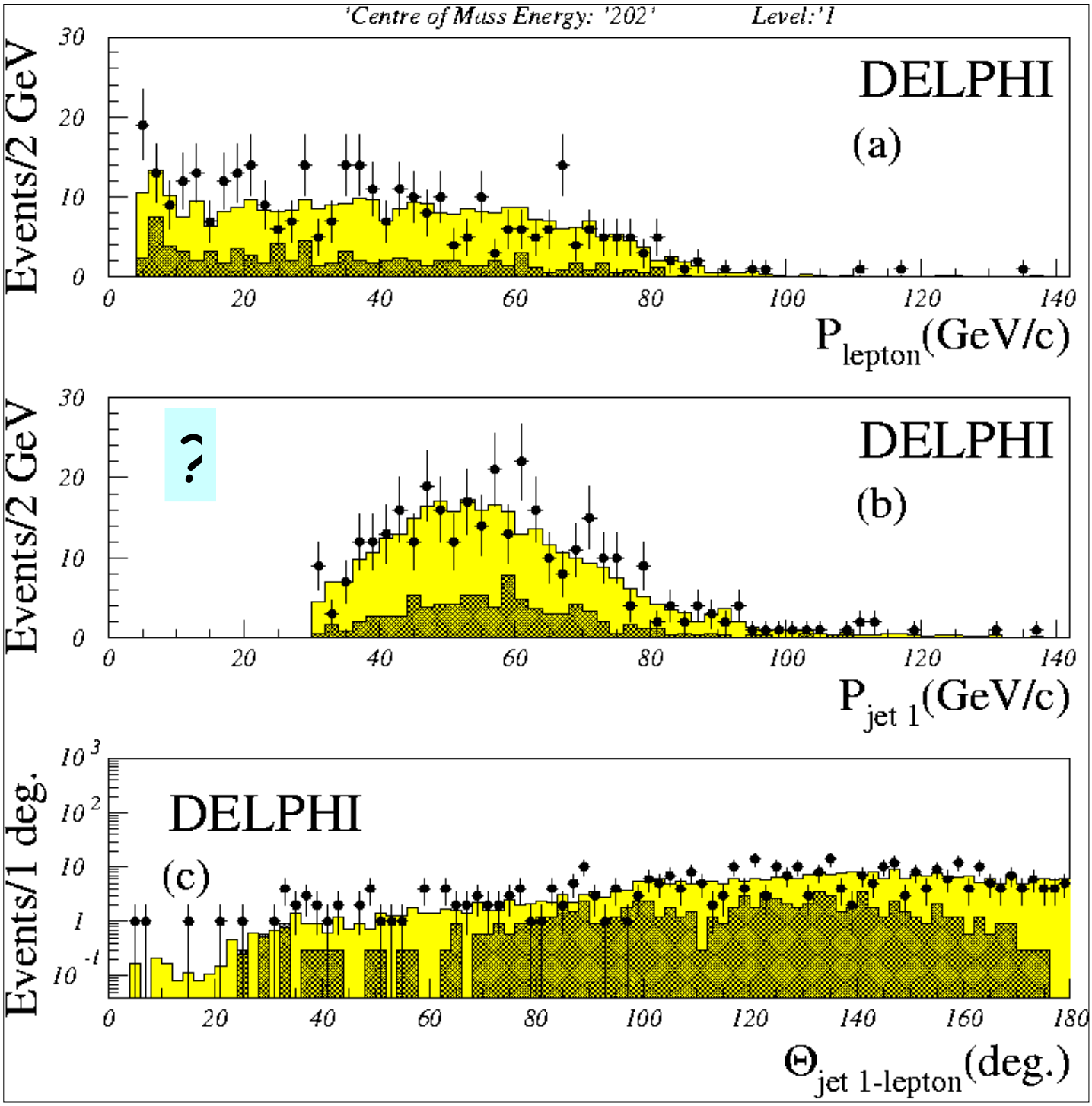


New analysis by DELPHI
(DELPHI 2000-032 CONF 351, March '00)

$\sqrt{s}$ (GeV)	192	196	200	202
$L(pb^{-1})$	30	78	84	41
$\varepsilon_{3j}(\%)$	8 6	7 6	5 5	5 4
N_{exp}	0.6 0.3	1.7 1.4	1.9 1.0	0.9 0.8
N_{obs}	1 0	0 1	2 1	0 0
$\sigma_{exp}(pb)$	1.6 2.1	0.9 1.0	1.2 1.0	2.0 2.7
$\varepsilon_{4j}(\%)$	8.4 16	7.3 15	7.9 13	8.1 14
N_{exp}	1.5 2.7	4.0 10.2	5.0 10.3	2.5 5.0
N_{obs}	1 5	4 13	2 9	5 4
$\sigma_{exp}(pb)$	1.8	1.1	1.0	1.6

DELPHI 2000-032 CONF 351
INTRODUCTION

The energy of the last LEP run ($\sqrt{s} = 192 - 202$ GeV) is well above tc production threshold and gives the possibility to perform a search for FCNC in the specific process $e^+e^- \to \bar{t}q + t\bar{q}$ where q can stand either for u- or c-quark. The advantage of this specific FCNC consists in the fact that the t-quark can decay into Wb only. This can produce some distinct signatures both in leptonic and hadronic W decay modes. The numerical estimations for the expected number of events taking into account the limits on anomalous vertices recently set by the CDF collaboration [5] can be found in [6].


'Centre of Muss Energy: '202'
Level:'1
DELPHI
(a)
Events/2 GeV
P lepton (GeV/c)
DELPHI
(b)
Events/2 GeV
P jet 1 (GeV/c)
DELPHI
(c)
Events/1 deg.
Θ jet 1-lepton (deg.)

Conclusions

~411 pb^{-1} at E_{CM} 189-202 GeV analyzed

- No signal of single-top FCNC
- Results used to set limits in Kz-Kγ plane
- Kz CDF exclusion improved
- ALEPH 95% CL exclusion on K_z implies

  BR(t -> Zc) < 22% (Kγ = 0, m_t=174 GeV)

(CDF: BR(t -> Zc) < 33%)

- No improvement for m_t=179 GeV

(σ too low!)