

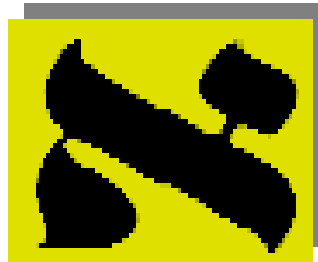
# Status of Physics Analyses in ALEPH

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CERN , EP-Division

on behalf of the ALEPH Collaboration

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LEP Physics Jamboree, July 10 2001,

# Status of the Detector



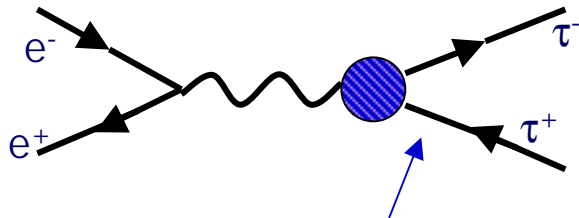
# Outlook LEP1:

- Tau Physics
- Heavy Flavour Physics
- QCD



LEP 1

# Weak Dipole Moments of the $\tau$ Lepton



- Aim** : Study the Lorentz structure of this coupling

$$ie \left( v_\tau \gamma^\mu - a_\tau \gamma_5 \gamma^\mu + i \frac{\mu_\tau}{2m_\tau} \sigma^{\mu\nu} q_\nu + \frac{d_\tau}{2m_\tau} \gamma_5 \sigma^{\mu\nu} q_\nu \right)$$

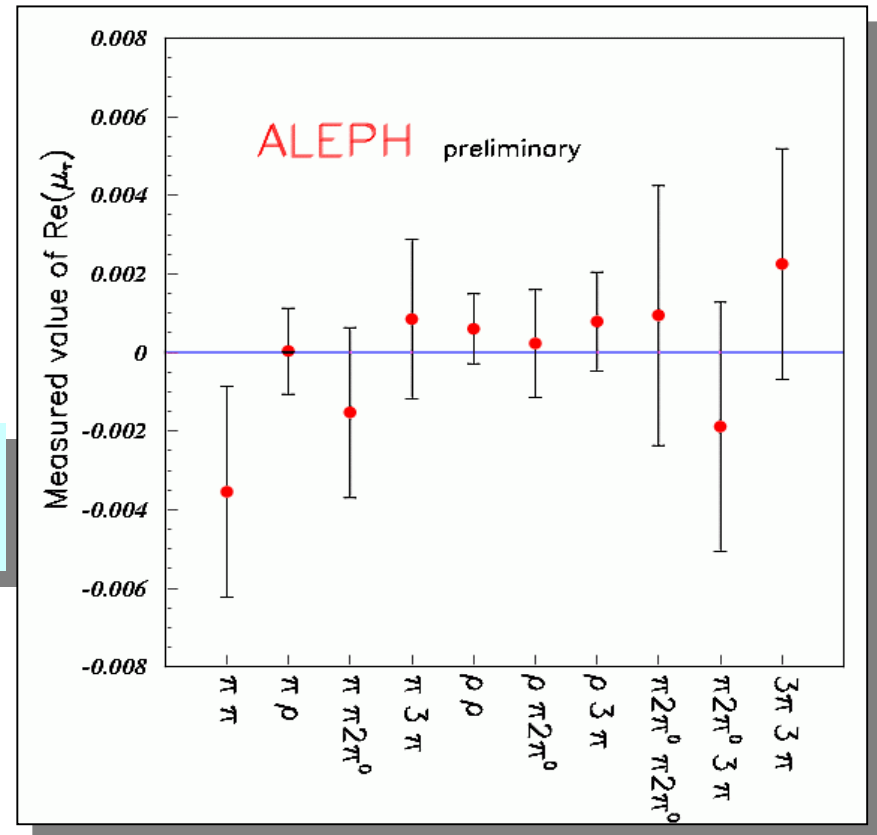
- Method** : Likelihood fit (simultaneous for all couplings) to fully differential cross section for

$$\frac{d\sigma}{d \cos \theta d^n X} (e^+ e^- \rightarrow \tau^+ \tau^- \rightarrow X)$$

Production

decay :  $\pi, \rho, a_1 \rightarrow \pi 2\pi^0 (3\pi)$

- Data** : 155 pb<sup>-1</sup> (1990-1995)  $\Rightarrow$  39k events



95% CL upper limits	$ \text{Re}(O) $	$ \text{Im}(O) $
$\mu_\tau$	$1.05 \times 10^{-3}$	$2.22 \times 10^{-3}$
$d_\tau$ [e cm]	$5.42 \times 10^{-18}$	$11.93 \times 10^{-18}$



# $A_{FB}^b$ using Jet Charge

## Aim : Measure

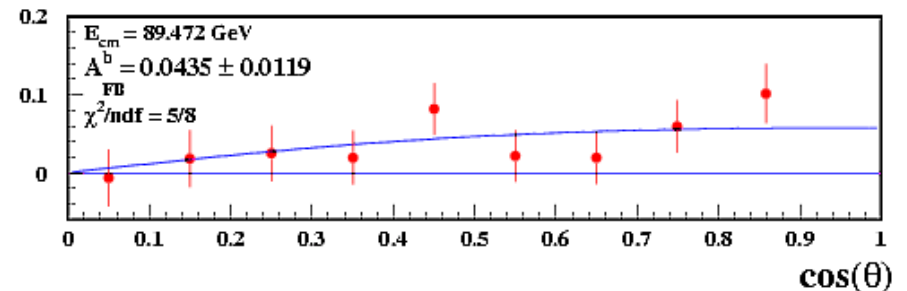
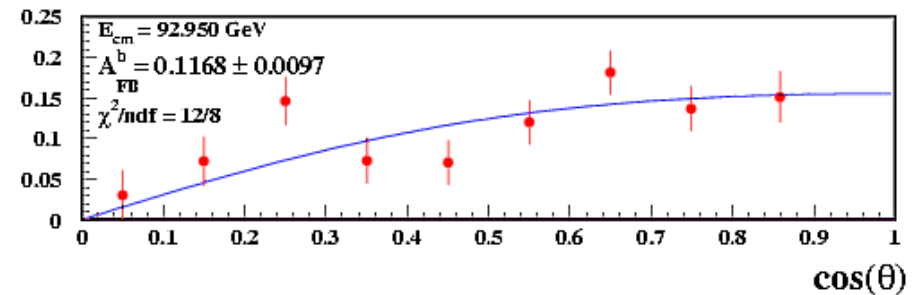
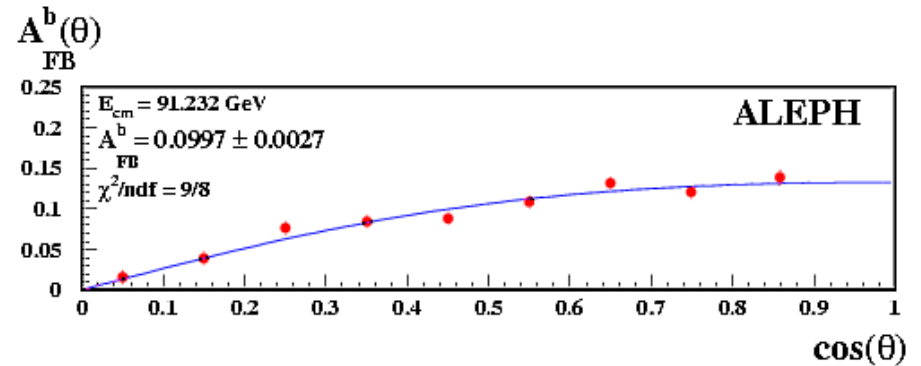
$$\sigma_{\text{tot}}^b A_{FB}^b = \left[ \begin{array}{c} b \\ \swarrow \\ \rightarrow \\ \searrow \\ \bar{b} \end{array} \right] - \left[ \begin{array}{c} \bar{b} \\ \swarrow \\ \rightarrow \\ \searrow \\ b \end{array} \right] \Rightarrow \sin^2 \theta_W$$

## Method : inclusive measurement

- b-tag via NN (30% more stat)
- Improved jet charge tag includes
  - fast Kaon tagging
  - primary+secondary vertex charge
- lower systematics because
  - lower mistag rate
  - purities from double tag method

## Data : 1991-1995

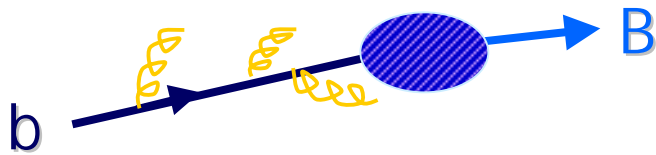
- 4 million evts, 670k b-tagged evts



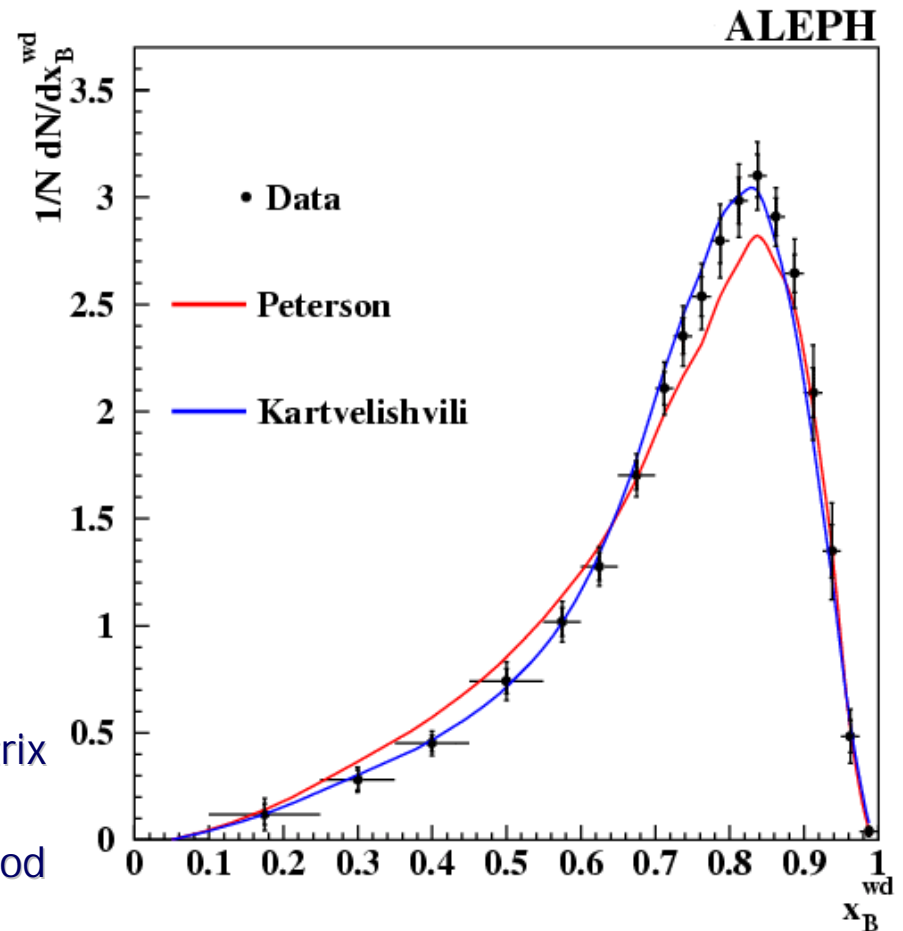
$$A_{FB}^{0,b} = 0.1009 \pm 0.0027 \pm 0.0012$$

$$\sin^2 \theta_W = 0.23193 \pm 0.00056$$

# b Quark Fragmentation Function



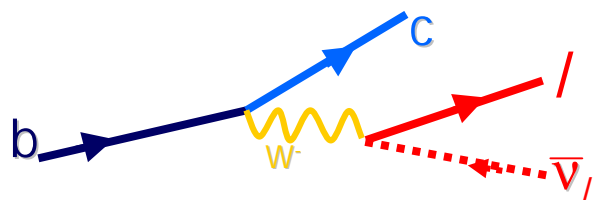
- **Aim** : measure the spectrum of
 
$$x_E = E_B / E_{\text{beam}}$$
- **Method** : semi-exclusive reconstruction
  - $B \rightarrow D^{(*)} / \nu$
  - 5 channels for  $D^{(*)}$  decays
  - $E_\nu$  from missing energy in hemisphere
  - Unfold raw distribution with resolution matrix from MC
  - avoid model dependence by iterative method
- **Data** : 1991 - 1995
  - $\approx 4$  million hadr. Z decays
  - $\approx 3400$   $B^0$  and  $B^\pm$  candidates
- **Accepted** by Phys.Lett.B



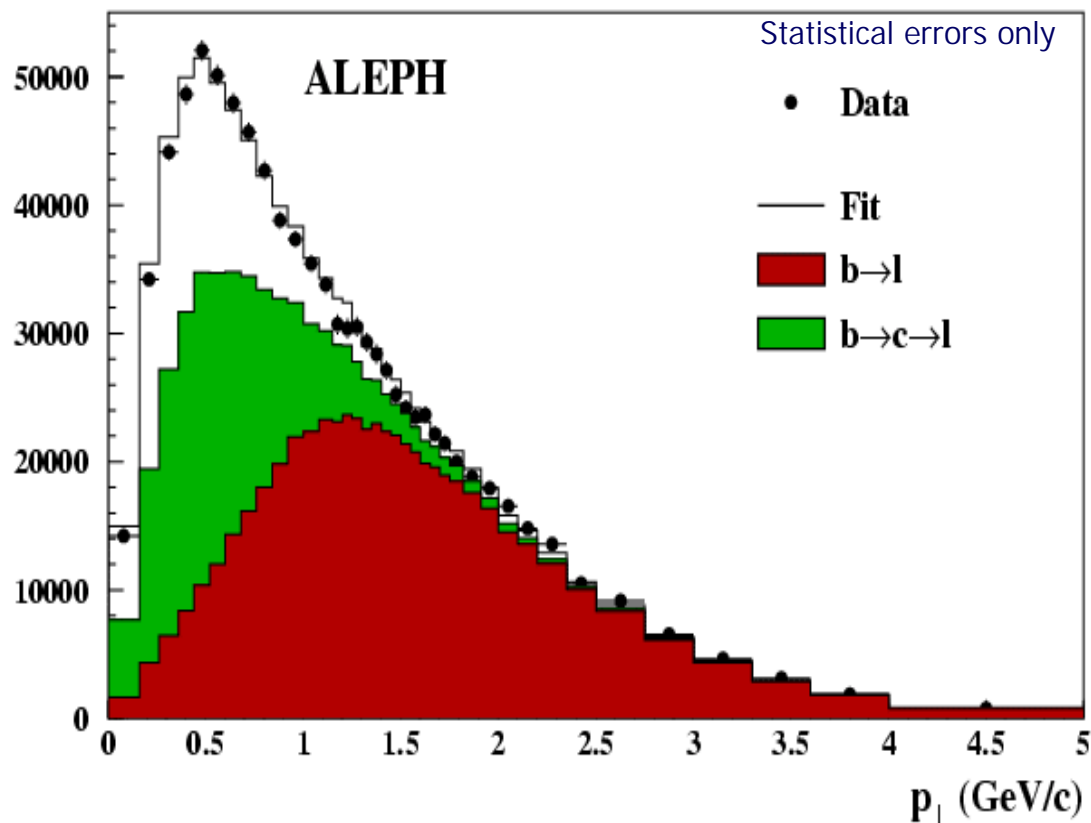
$$\langle x_B^{\text{wd}} \rangle = 0.716 \pm 0.006 \pm 0.006$$

$$\text{SLD} : \langle x_B^{\text{wd}} \rangle = 0.710 \pm 0.003 \pm 0.005 \pm 0.004$$

# Inclusive b semileptonic BR



- **Aim** : measure the BRs
  - $BR(b \rightarrow X / \nu)$
  - $BR(b \rightarrow c \rightarrow X / \nu)$
- **Method** : 2 analyses
  - b-tag OR high  $p_{\perp}$  lepton OR charge+impact parameter tag
  - search for lepton ( $e, \mu$ ) in opposite hemisphere
    - improved  $dE/dx$  (TPC pads)
  - A) fit  $p_{\perp}$  spectrum
  - B) measure charge correlation
- **Data** : 1991 - 1995
  - combine results a) and b)



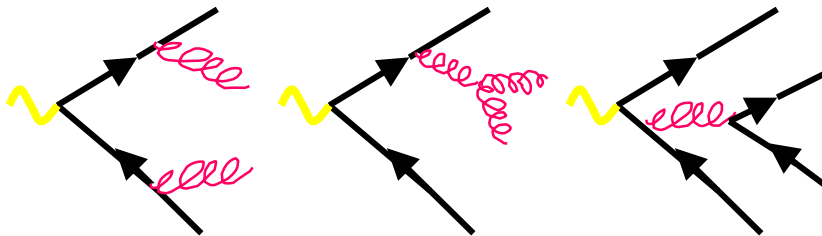
$$BR(b \rightarrow X / \nu) = 0.1070 \pm 0.0010 \pm 0.0024 \pm 0.0025_{\text{model}}$$

$$BR(b \rightarrow c \rightarrow X / \nu) = 0.0818 \pm 0.0015 \pm 0.0023^{+0.0008}_{-0.0012_{\text{model}}}$$

Sending to journal

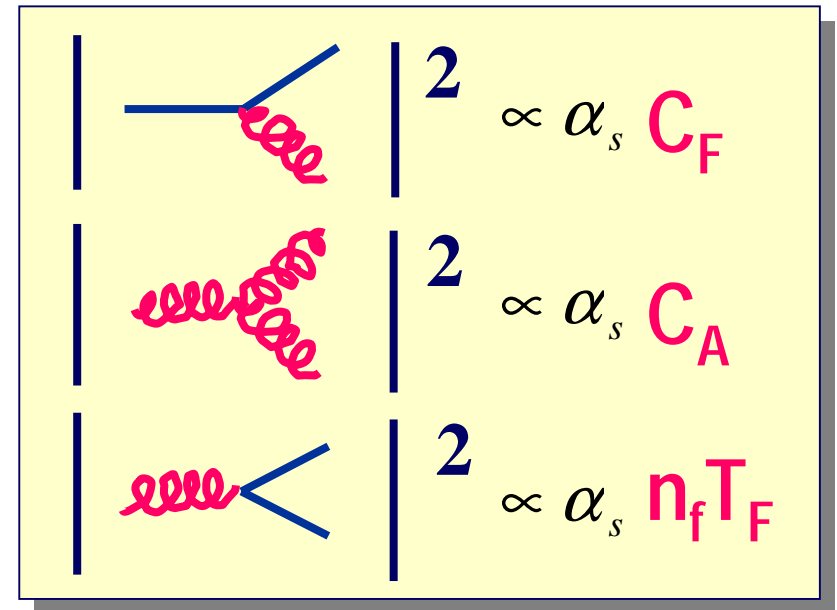
# $\alpha_s$ and QCD Colour factors

- **Aim** : measure simultaneously the strong coupling and the QCD colour factors using **4-jet evts**



- **Method** : Fit **NLO** predictions to 4-jet observables
  - $R_4(y_{\text{cut}})$
  - four angular correlations in 4-jet events
    - Bengtsson-Zerwas angle, ...

- **Data** : 1994 - 1995
  - $\approx 2.5$  million hadr. Z decays
  - $\approx 163\text{k}$  4-jet evts ( $y_{\text{cut}} = 0.008$ )



QCD : SU(3)  
 $C_F=4/3, C_A=3, T_F=1/2$

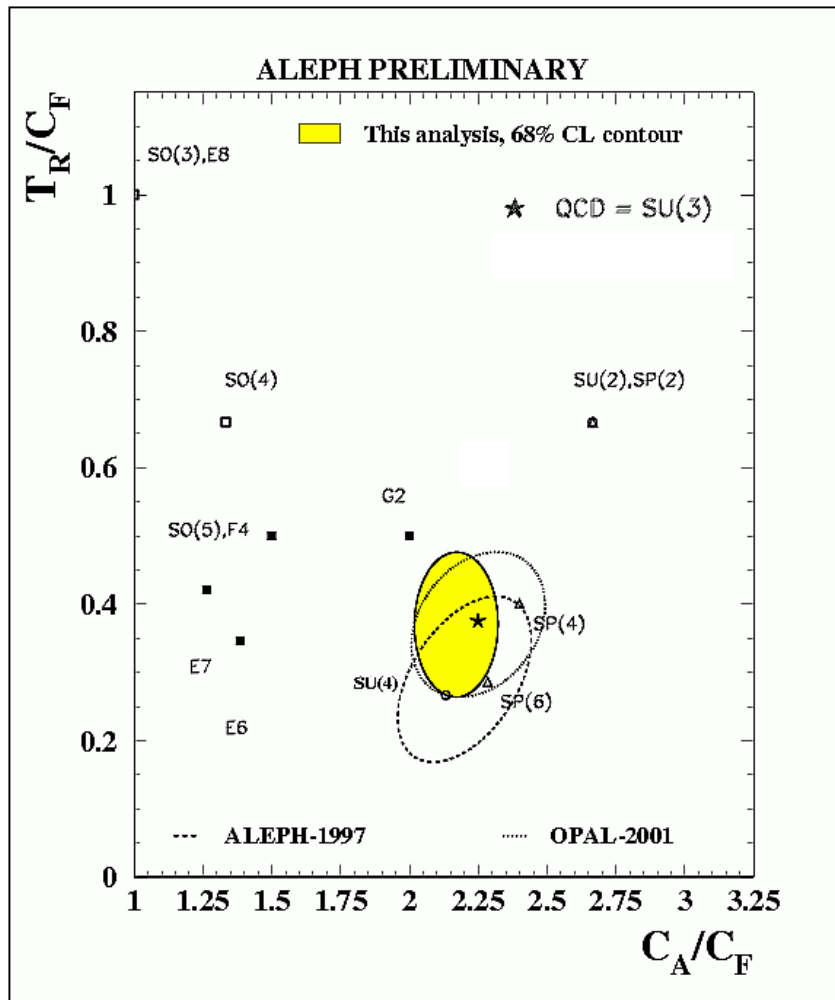
$$\alpha_s(M_Z) = 0.119 \pm 0.006 \pm 0.022$$

$$C_A = 2.93 \pm 0.14 \pm 0.49$$

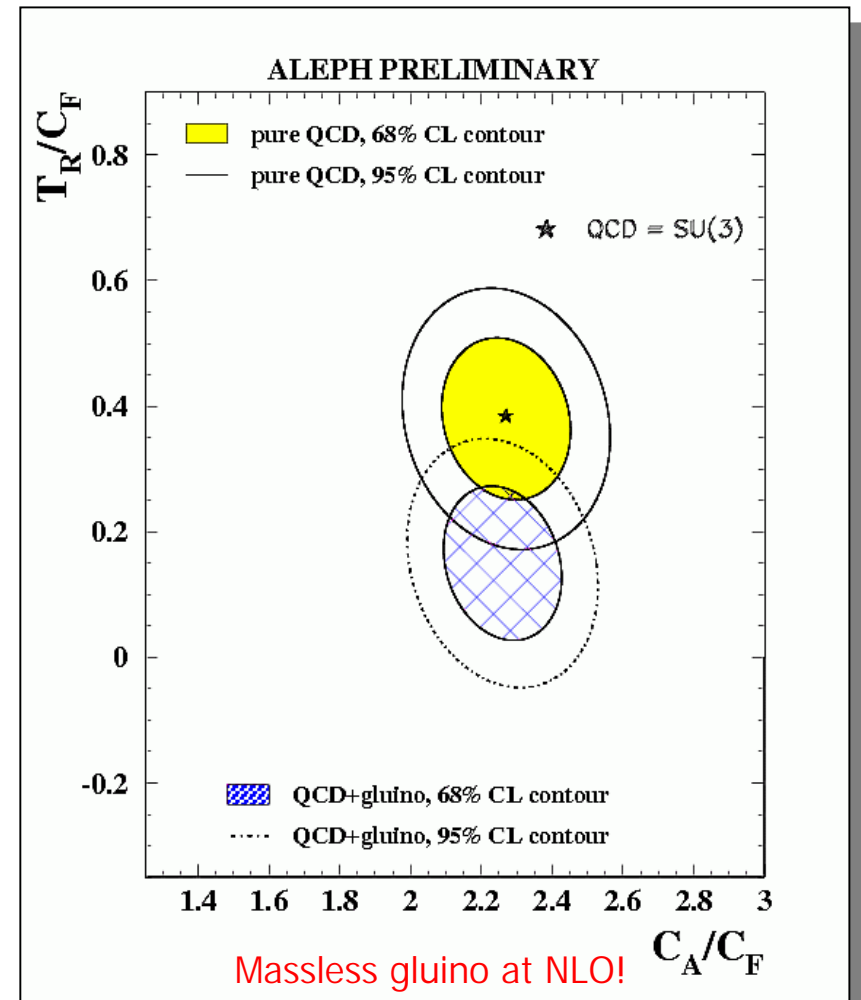
$$C_F = 1.35 \pm 0.07 \pm 0.22$$



# $\alpha_s$ and QCD Colour factors...



Using all variables

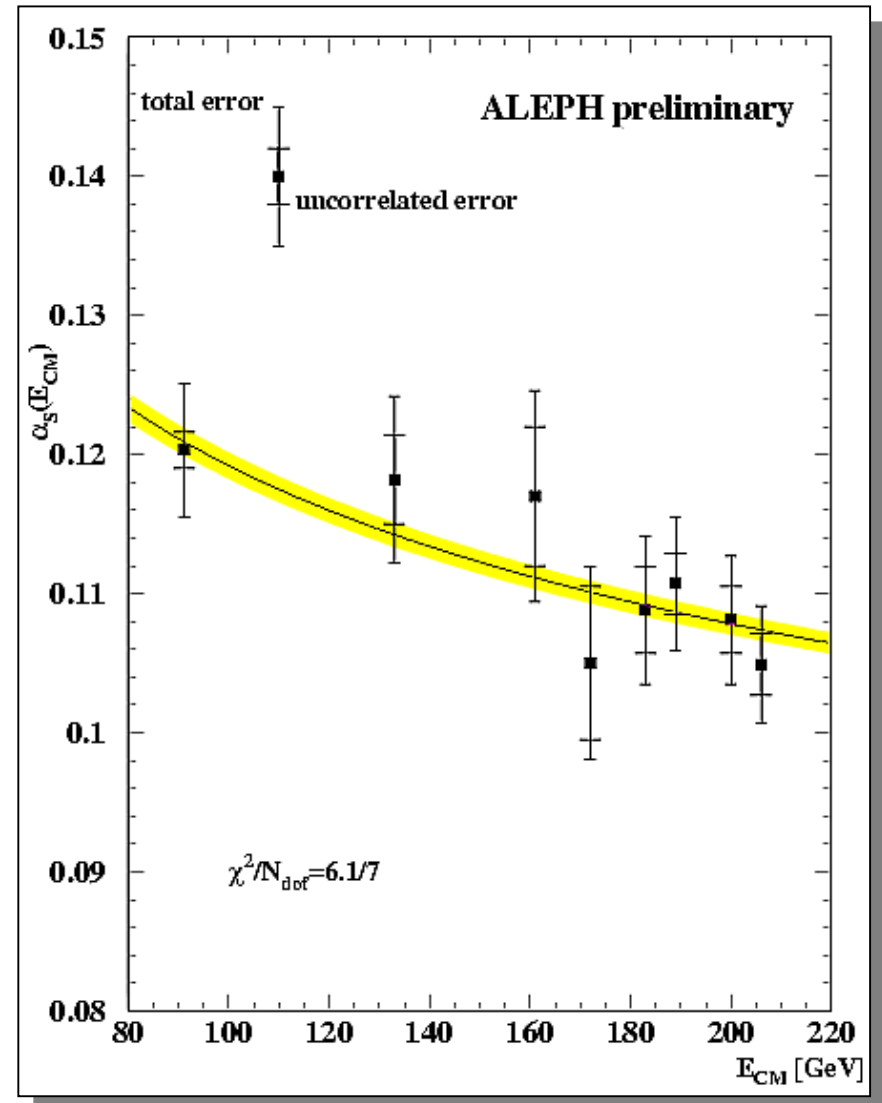


Using only angular correlations +  
assuming standard hadronization corrections!

# $\alpha_s$ from Event Shapes

$$\frac{1}{\sigma_{had}} \frac{d\sigma}{dy} = \alpha_s A(y) + \alpha_s^2 B(y) + f(\alpha_s^n \ln^m y)$$

- **Aim** : measure  $\alpha_s$  from fit of NLO+resummed QCD predictions to event shape distributions
- **Method** : from hadronic Z decays
  - Thrust,  $-\ln y_3$ ,  $M_h$ ,  $C_{par}$ ,  $B_{tot}$ ,  $B_w$
  - at LEP1 and LEP2
  - hadronization corrections from MC
  - consistent treatment of systematic errors at all energies
- **Data** : combined fit to 91 - 207 GeV



$$\alpha_s(M_Z) = 0.1203 \pm 0.001 \pm 0.0013 \pm 0.0046_{theo}$$



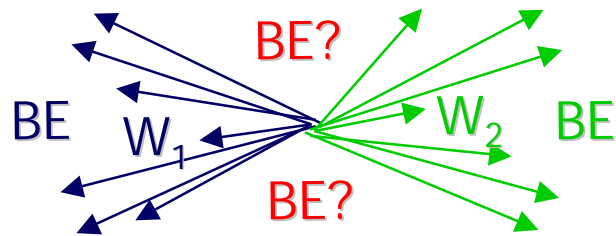
# Outlook LEP2:

- WW (FSI)
- Exotics :
  - anomalous couplings
  - single top
- “Standard exotics”:
  - SUSY
  - Higgs



LEP 2

# Bose-Einstein Correlations in WW events



- **Aim** : look for BE correlations between pions from different Ws

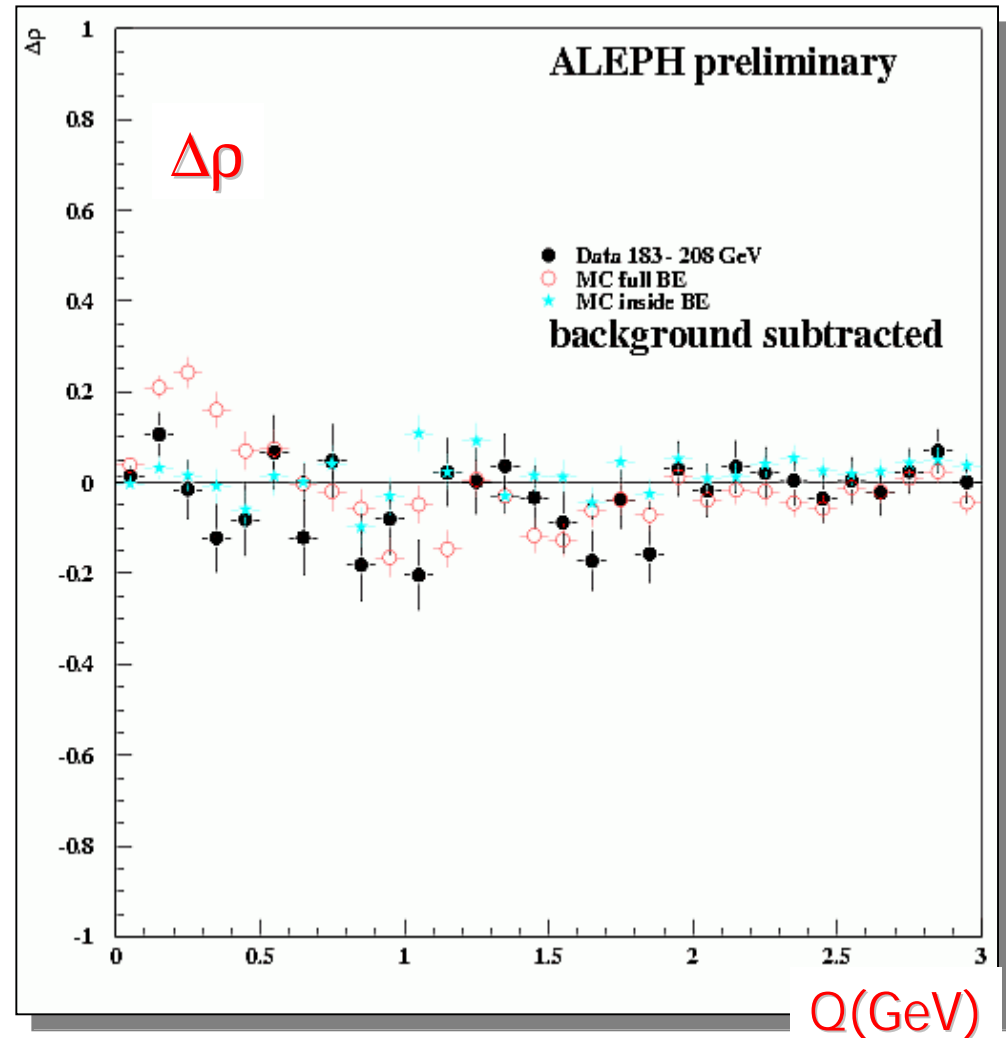
- **Method** : measure the observable

$$\Delta\rho = \left( Q^{\text{hadr}} - Q^{\text{mixed}} \right)_{\text{DATA - Bkgr}} - \left( Q^{\text{hadr}} - Q^{\text{mixed}} \right)_{\text{MC, no BE}}$$

$$Q = \sqrt{\Delta p^2 - \Delta E^2}$$

- **mixed** hadronic parts of different semi-leptonic evts

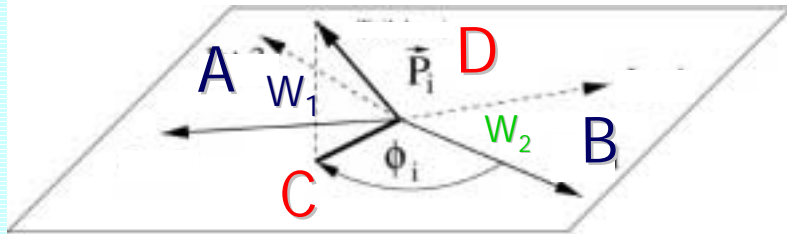
- **Data** : 183 - 208 GeV



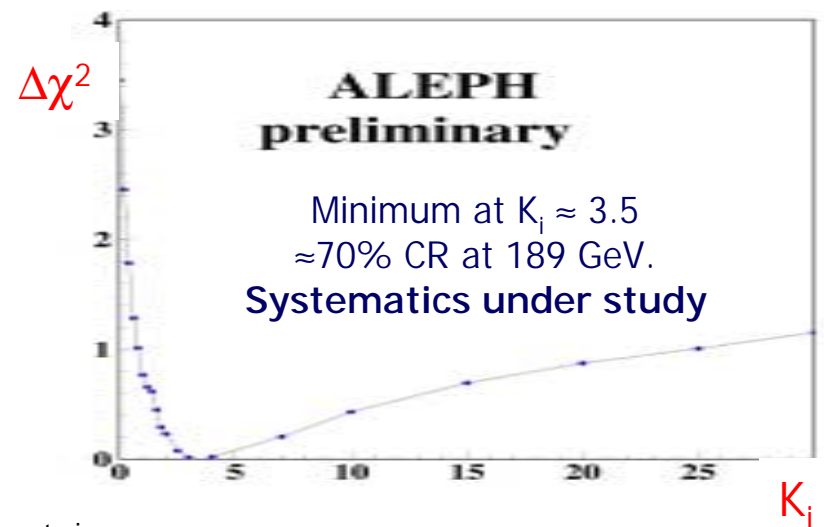
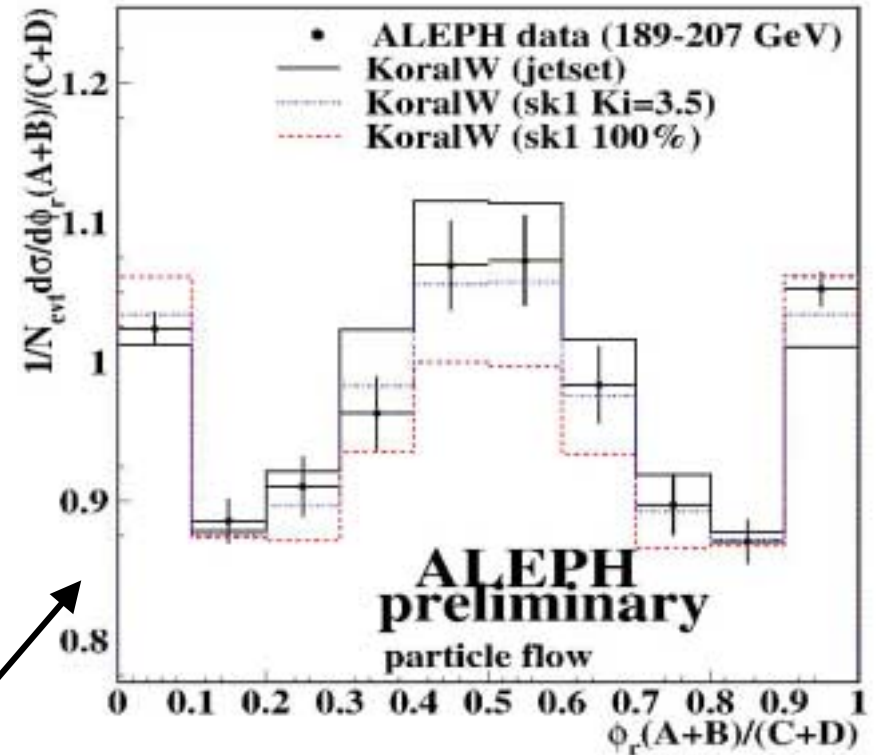
Confirms our previous results:

**BE correlations between pions from different Ws are disfavoured**

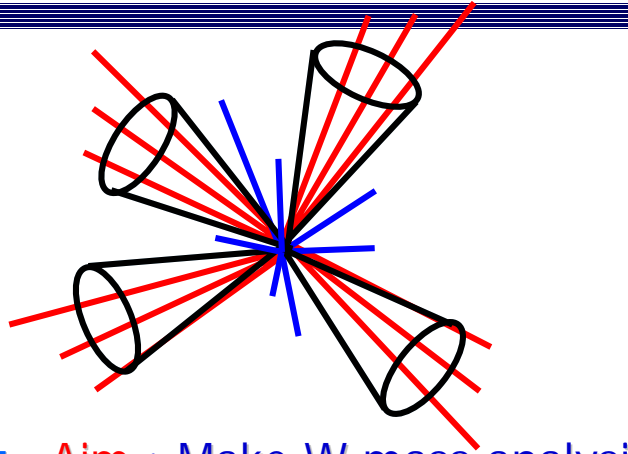
# Particle Flow in WW events



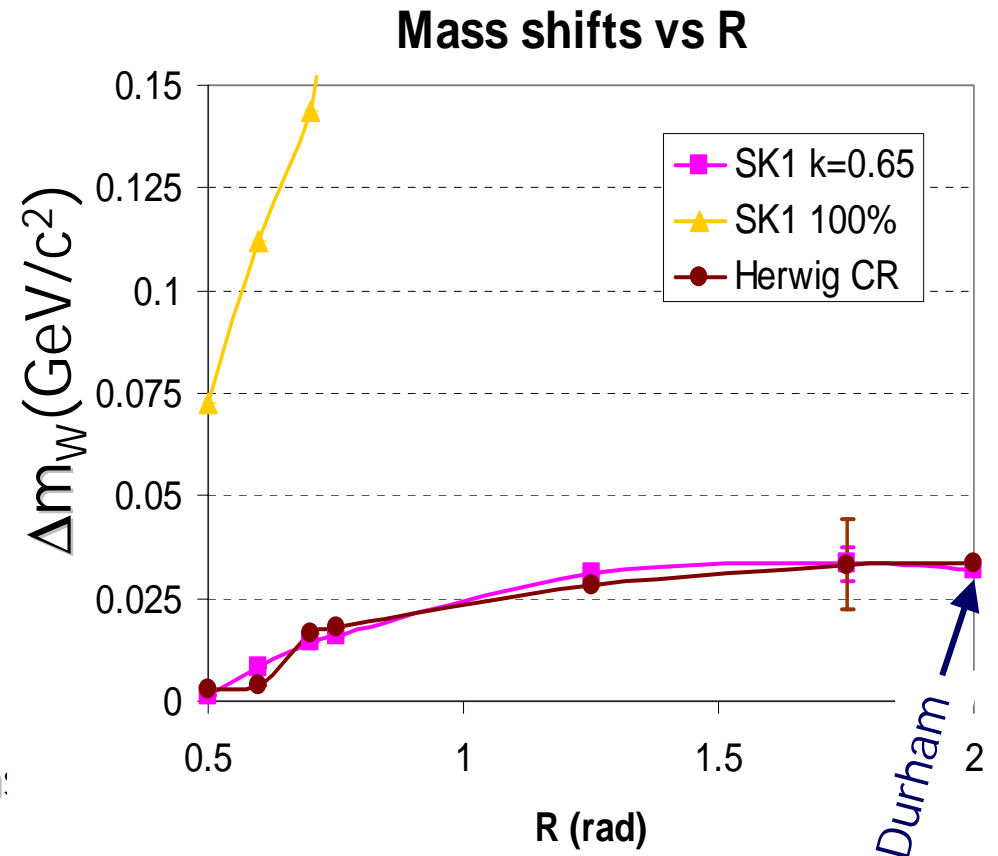
- **Aim** : look for colour reconnection effects in fully hadronic WW evts
- **Method** : apply the same selection as for W mass analysis
  - project chg+neutral particles into planes between jets from Ws
  - compute the ratio of particle flow in different interjet regions
  - compare to predictions of different MC models
  - check SKI for different  $K_i$  values
- **Data** : 189 - 207 GeV



# Reduction in FSI uncertainty on $M_W$ ?

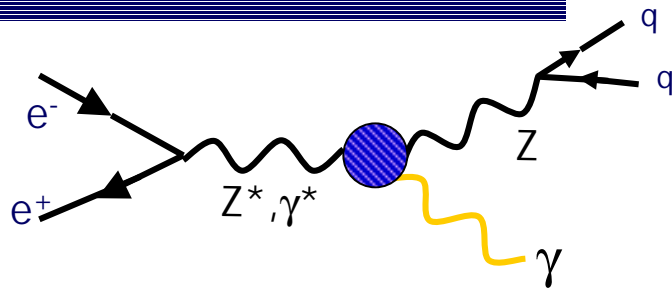


- **Aim** : Make  $W$  mass analysis in fully hadronic channel more robust w.r.t. colour reconnection effects
- **Method** :
  - a) apply **cone jet algorithm** in order to recompute jet direction:
    - study dependence on **cone size**
  - b) **cut out** particles which
    - lie in interjet region
    - are soft

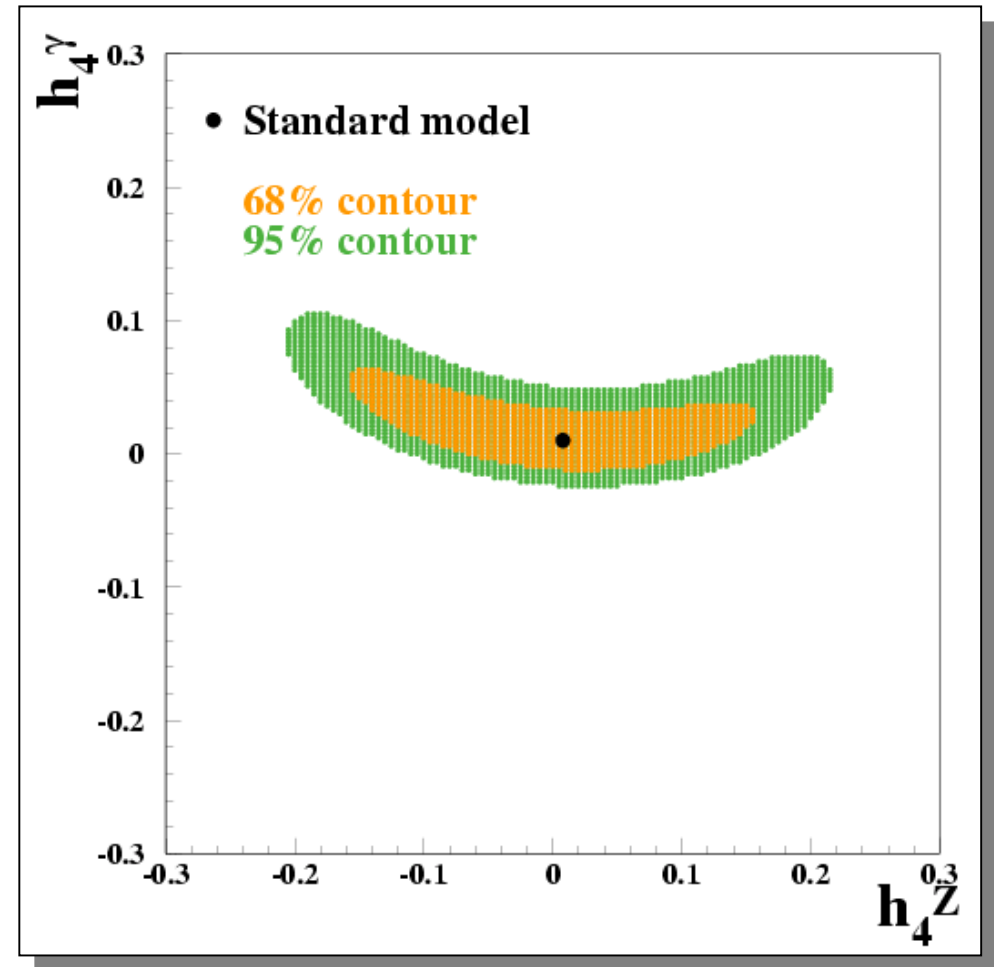


e.g. expected for  $R=0.75$  **reduction by a factor of 2** in  $\Delta m_W$ , with 13% increase in statistical uncertainty

# Anomalous Neutral Couplings

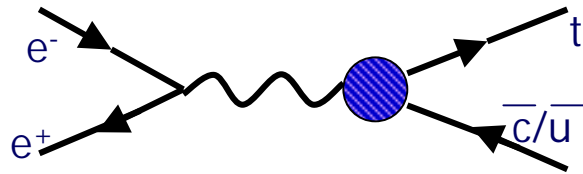


- **Aim** : look for anomalous contr.
  - in SM forbidden at tree level
  - model them by anomalous vertex contributions  $h_{1,\dots,4}^{\gamma,Z}$
  
- **Method** : same topology as radiative returns
  - 2 jets + isolated photon
  - measure cross section,  $\cos(\theta_\gamma)$ , angle( $\gamma$ -jets)
  - likelihood including anomalous couplings
  
- **Data** : 189-207 GeV ,  $>600 \text{ pb}^{-1}$

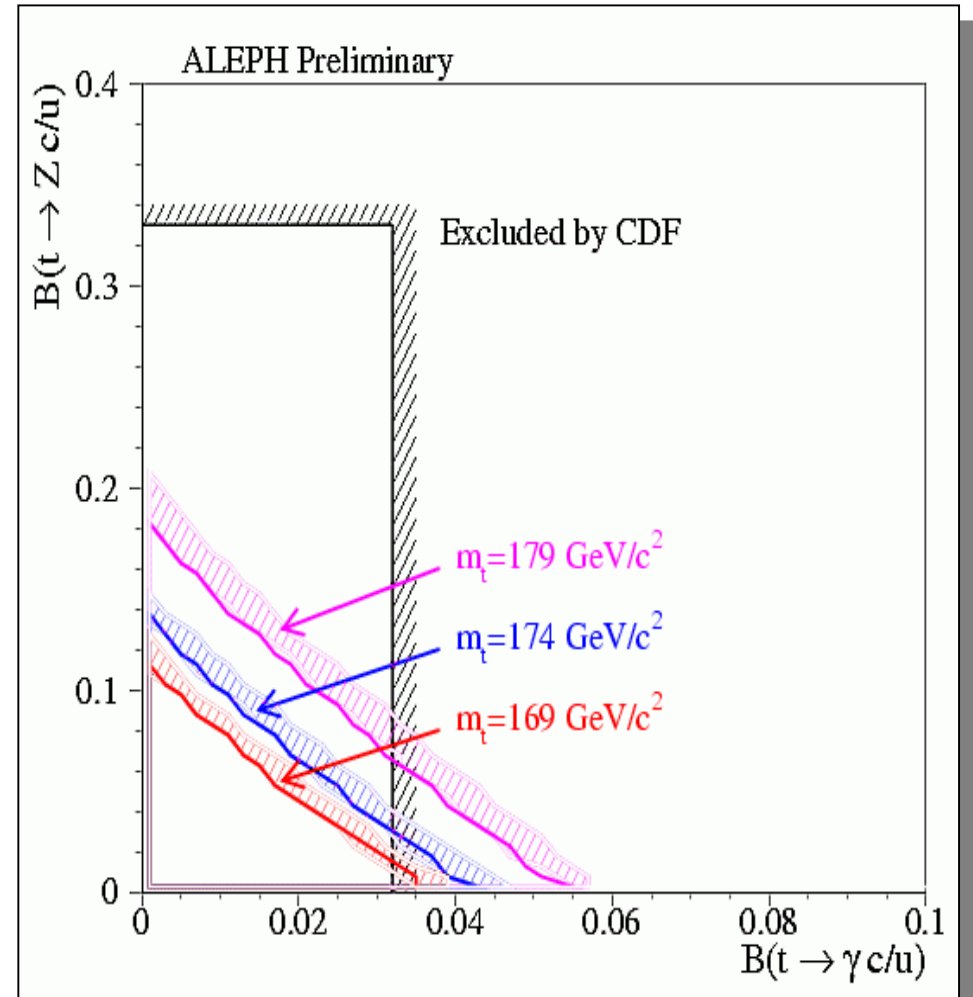


no deviation from SM observed

# Single Top Production



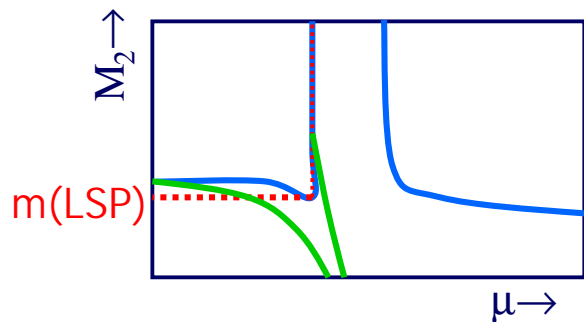
- **Aim** : look for FCNC
  - in SM only via loops  $\sigma < 10^{-9}$  fb
  - model FCNC by anomalous vertex contributions
  
- **Method** : depending on W decay from  $t \rightarrow bW$ , search for
  - $W \rightarrow qq'$  : 4 jet topology
  - $W \rightarrow l\nu$  : 2 jets + isolated lepton
  - tag the b-jet
  - $m_{\text{top}}$  dependence reduced by re-optimization
  
- **Data** : 189-207 GeV , 625 pb<sup>-1</sup>



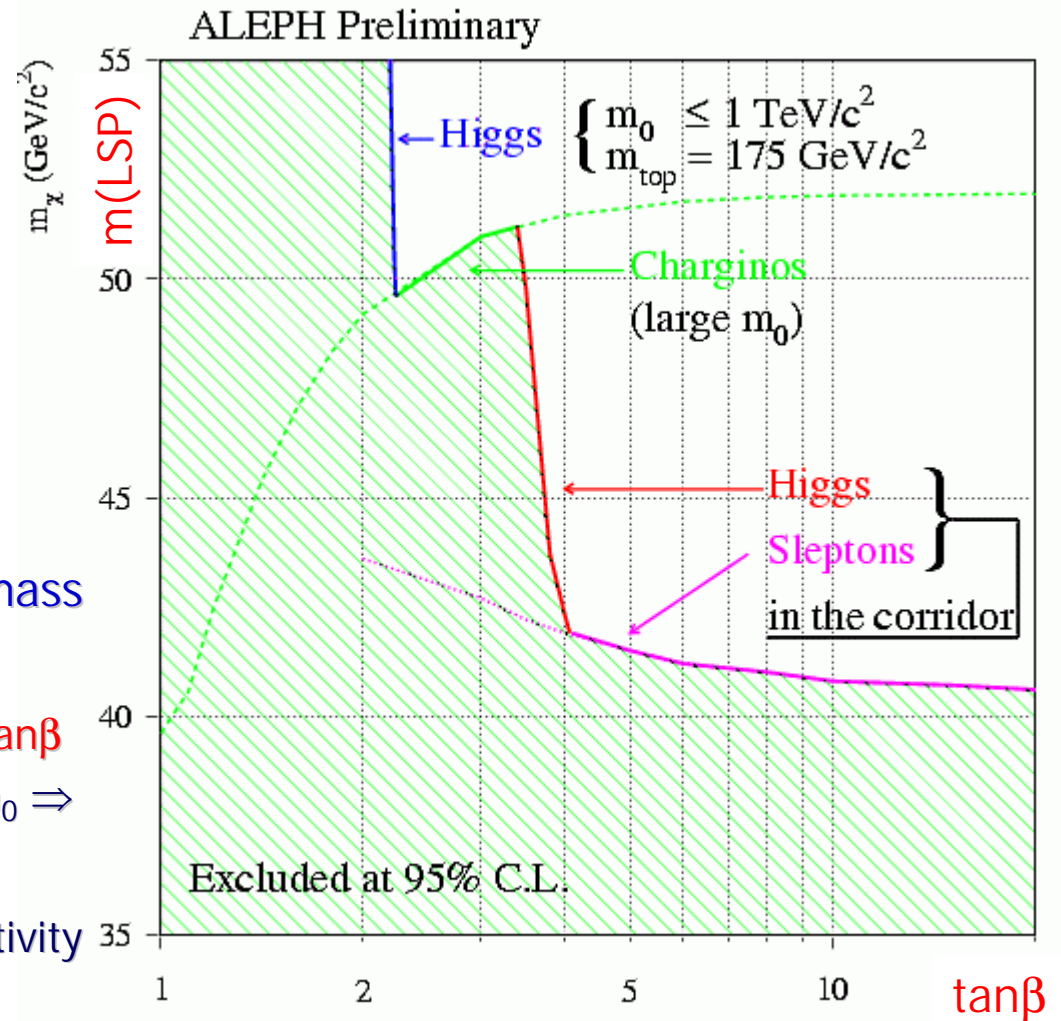
no significant excess observed



# Impact of Higgs searches on LSP limit



- **Aim** : study impact of Higgs searches on  $m(\text{LSP})$  limit
- **Method** : radiative corr. to Higgs mass  
 $= f(\log(m_{\text{stop}}/m_{\text{top}}), \tan\beta)$ 
  - limit on  $m_h \Rightarrow$  limit on  $m_{\text{stop}}$  vs  $\tan\beta$   
 $\Rightarrow$  limit on  $M_2$  vs  $\tan\beta$  for fixed  $m_0 \Rightarrow$   
improve limit  $m(\text{LSP})$  vs  $\tan\beta$
  - small  $m_0 \Rightarrow m_{\tilde{\chi}^{\pm}} = m_{\tilde{\nu}}$   $\Rightarrow$  no sensitivity  
(corridor)
    - but small  $m_0 \Rightarrow$  small slepton masses



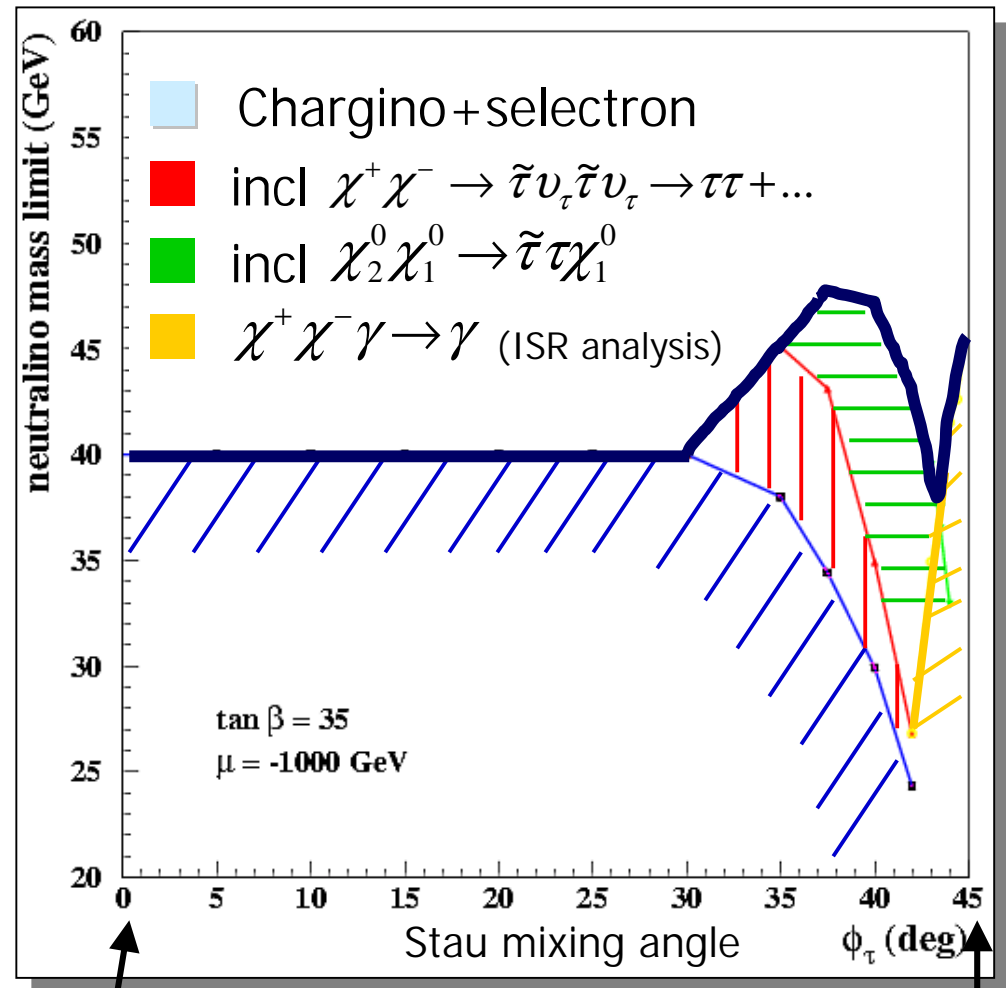
- **Data** : take limits on  $m_h < 113.5 \text{ GeV}/c^2$  as well as MSSM scan

# Impact of stau mixing on LSP limit

$$M_{\tilde{\tau}} = \begin{pmatrix} m_{\tilde{\tau},L}^2 & m_{\tau}(A_{\tau} - \mu \tan \beta) \\ & m_{\tilde{\tau},R}^2 \end{pmatrix}$$

large mixing  $\Rightarrow m_{\tilde{\tau},1}$  small

- **Aim** : avoid drop in  $m(\text{LSP})$  limit for large stau mixing
- **Method** : design dedicated searches for
  - tau final states
  - "invisible" final states
  - for **large  $\tan\beta$** , deep gaugino region
- **Data** : 189 - 208 GeV



No mixing

maximal mixing

# Status of the SM Higgs Search

- Results published in **PLB 495 (2000) 1 :  $3\sigma$  excess**
  - 2 independent analysis streams. Analyses frozen before data taking!
- During last months following developments
  - Additional MC → more precise shapes and efficiencies
  - all Y2K data reprocessed in December 2000 (gained  $\approx 1\text{pb}^{-1}$ )
    - **NOTE** : 3 most significant candidates were already reprocessed before the publication, showing that they are stable
  - New LEP  $E_{\text{CM}}$  (about 140 MeV lower)
  - improved treatment of beam-induced background
    - studied on random triggers, “dirty MC” generated, cleaning procedure implemented
  - further systematic studies
    - evaluated **impact of uncertainties** from b-tagging, correlations in discriminating variables, jet smearing, gluon splitting,  $\alpha_s$ , MC description of selection variables **on  $(1-CL_b)$**



# Status of the SM Higgs Search...

- Outcome :

The effects of recent changes and of systematic uncertainties  
are within  $0.2 \sigma$   
**as estimated in our publication**

- We are very close to publishing our final paper on this topic...



# Summary

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- Plenty of (preliminary and final) physics results using data collected by ALEPH at LEP1 and LEP2.
- Extensive work put into the studies of systematic uncertainties of the SM Higgs search
  - result is stable. Final publication to come soon.
- For more details, have a look at <http://alephwww.cern.ch/ALPUB/oldconf/summer01/summer.html>