

Physics results from ALEPH (Summer Conferences 2002)

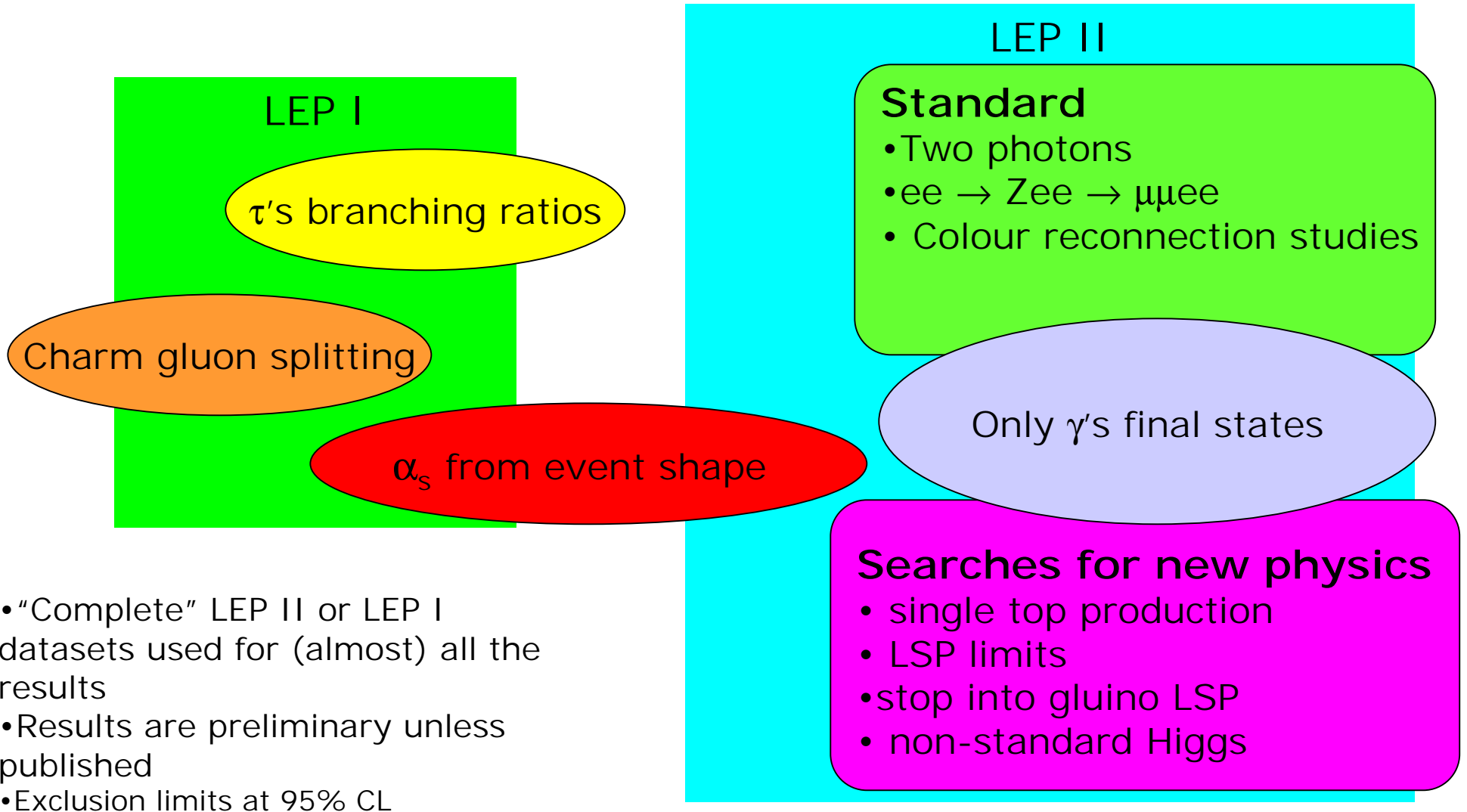
Andrea Venturi

INFN Pisa and CERN

On behalf of the ALEPH Collaboration

LEP Physics Jamboree Jul 22nd 2002

Outline



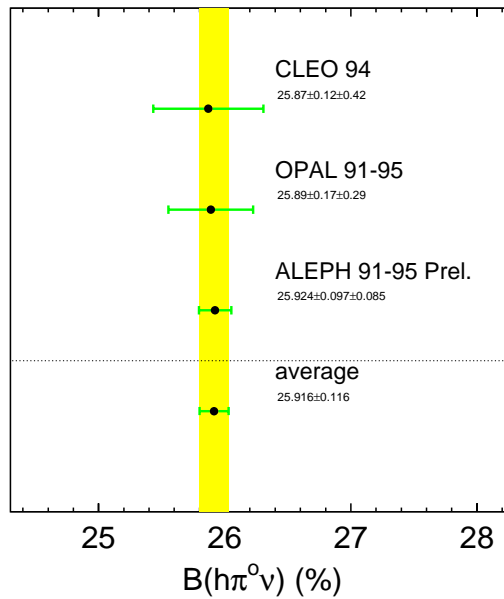
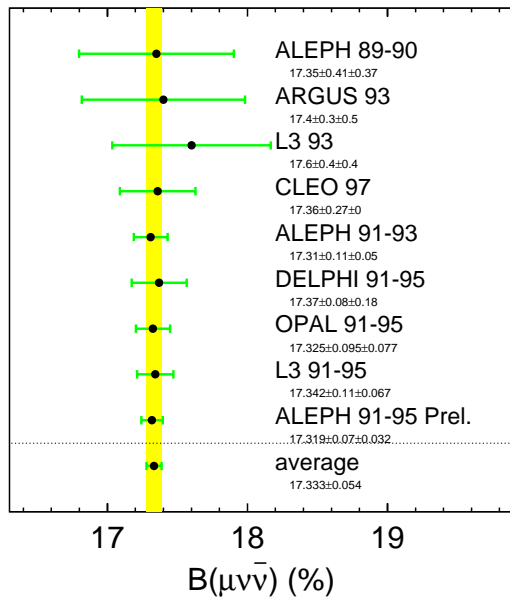
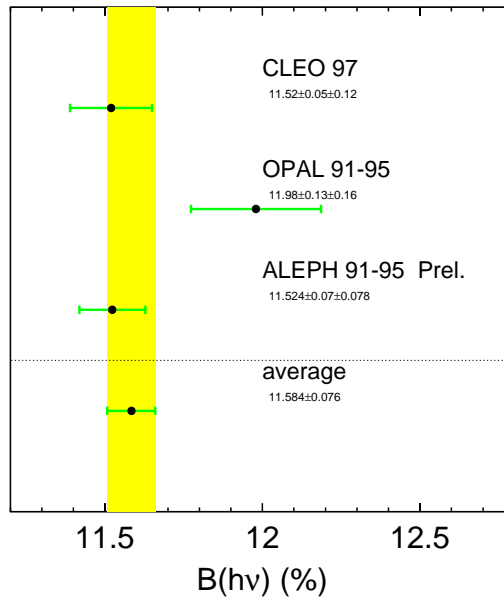
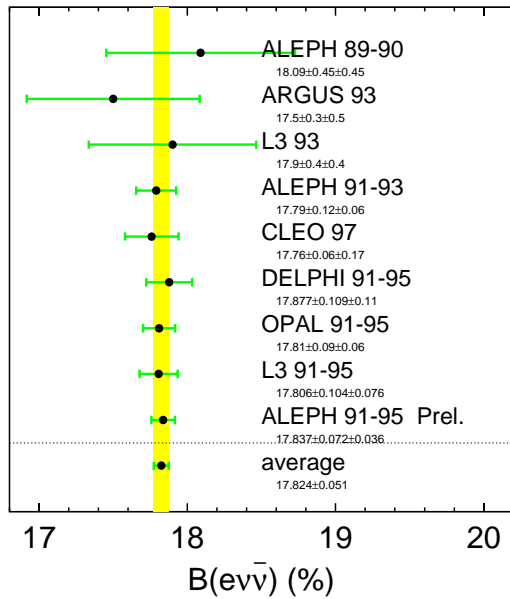
LEP I: τ Branching Ratios

Table 1: τ Branching fractions (modes without kaons): ALEPH Preliminary

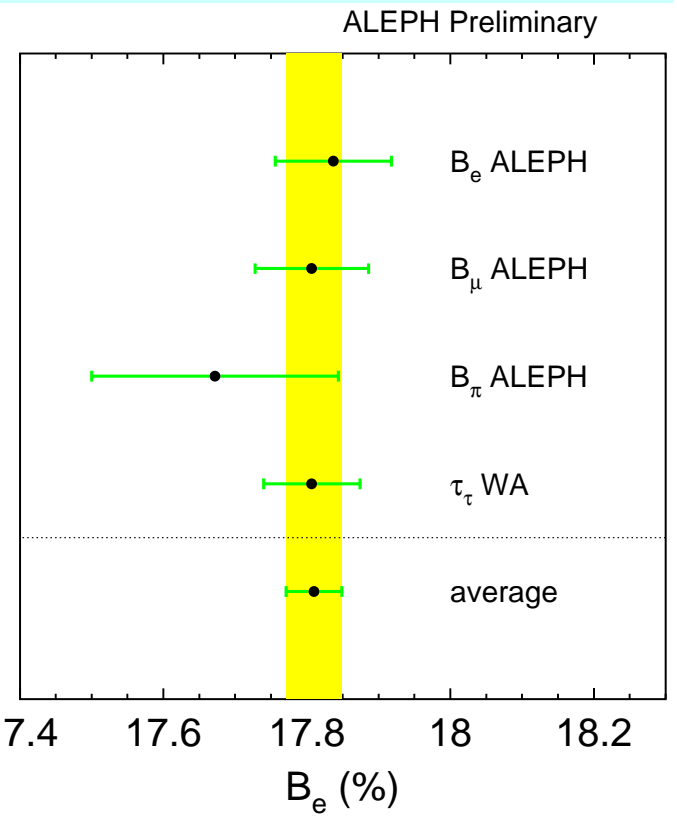
- New results with the full LEPI statistics: $\sim 330\text{k}$ $\tau\tau$ pairs
- Classification of each τ decay according to number of tracks, π^0 's and particle id: 13 classes ($e, \mu, h, h\pi^0, h2\pi^0, \dots, 3h, 3h\pi^0, \dots$)
- Improved treatment of MC corrections and systematic evaluation, especially γ 's and π^0 's
- Results corrected for the τ decays into K's, ω 's and η 's using previous analyses (ALEPH and CLEO)

mode	$B \pm \sigma_{\text{stat}} \pm \sigma_{\text{syst}} [\%]$	
e	$17.837 \pm 0.072 \pm 0.036$	ALEPH
μ	$17.319 \pm 0.070 \pm 0.032$	ALEPH
π^-	$10.828 \pm 0.070 \pm 0.078$	ALEPH
$\pi^-\pi^0$	$25.471 \pm 0.097 \pm 0.085$	ALEPH
$\pi^-2\pi^0$	$9.239 \pm 0.086 \pm 0.090$	ALEPH
$\pi^-3\pi^0$	$0.977 \pm 0.069 \pm 0.058$	ALEPH
$\pi^-4\pi^0$	$0.112 \pm 0.037 \pm 0.035$	ALEPH
$\pi^-\pi^-\pi^+$	$9.041 \pm 0.060 \pm 0.076$	ALEPH
$\pi^-\pi^-\pi^+\pi^0$	$4.590 \pm 0.057 \pm 0.064$	ALEPH
$\pi^-\pi^-\pi^+2\pi^0$	$0.392 \pm 0.030 \pm 0.035$	ALEPH
$\pi^-\pi^-\pi^+3\pi^0$	$0.013 \pm 0.000 \pm 0.010$	estim
$3\pi^-2\pi^+$	$0.072 \pm 0.009 \pm 0.012$	ALEPH
$3\pi^-2\pi^+\pi^0$	$0.014 \pm 0.007 \pm 0.006$	ALEPH
$\pi^-\pi^0\eta$	$0.180 \pm 0.040 \pm 0.020$	ALEPH
$\pi^-2\pi^0\eta$	$0.015 \pm 0.004 \pm 0.003$	CLEO
$\pi^-\pi^-\pi^+\eta$	$0.024 \pm 0.003 \pm 0.004$	CLEO
$a_1^-(\rightarrow \pi^-\gamma)$	$0.040 \pm 0.000 \pm 0.020$	estim
$\pi^-\omega(\rightarrow \pi^0\gamma, \pi^+\pi^-)$	$0.253 \pm 0.005 \pm 0.017$	ALEPH
$\pi^-\pi^0\omega(\rightarrow \pi^0\gamma, \pi^+\pi^-)$	$0.048 \pm 0.006 \pm 0.007$	ALEPH + CLEO
$\pi^-2\pi^0\omega(\rightarrow \pi^0\gamma, \pi^+\pi^-)$	$0.002 \pm 0.001 \pm 0.001$	CLEO
$\pi^-\pi^-\pi^+\omega(\rightarrow \pi^0\gamma, \pi^+\pi^-)$	$0.001 \pm 0.001 \pm 0.001$	CLEO

LEP I: τ Branching Ratios



Lepton universality: B_μ and B_π translated into electron BR
 WA τ , μ and π lifetimes and τ mass used



Lepton universality tested within 2-3 per mille

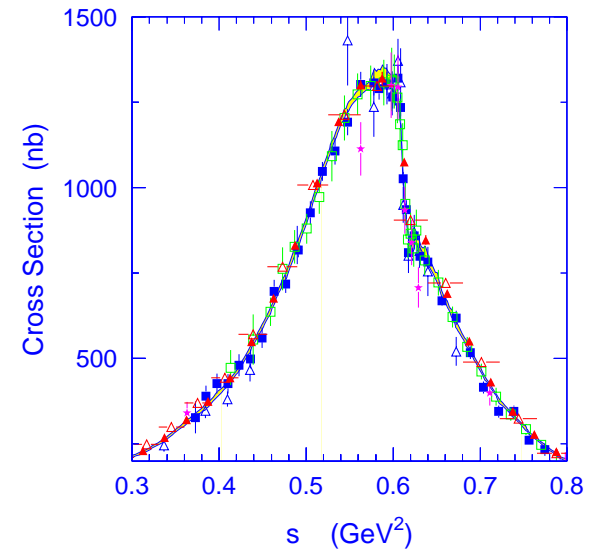
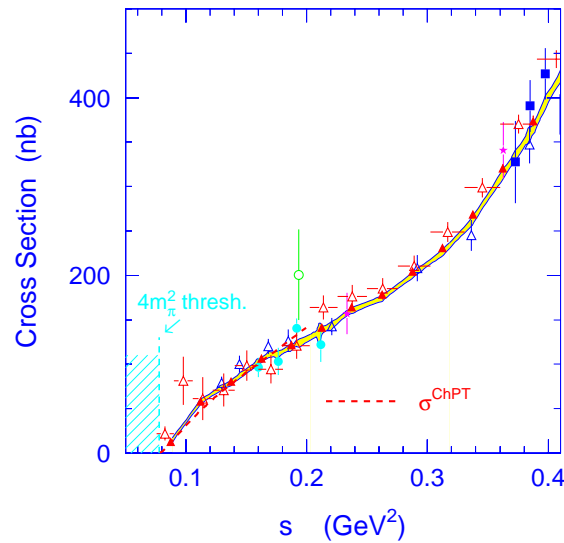
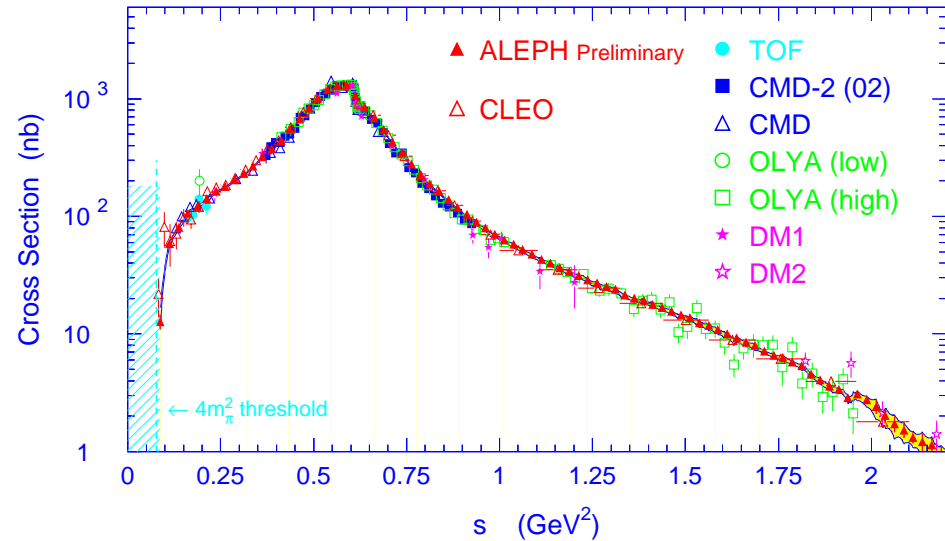
LEP I: τ Branching Ratios

- Vector spectral functions from $\pi\pi^0$, $3\pi\pi^0$, $\pi3\pi^0$ BR's and mass distributions



Hadronic contribution to $g-2$ radiative corrections

An example:
 $ee \rightarrow \pi^+\pi^-$ cross section from
 $BR(\pi^\pm\pi^0)$



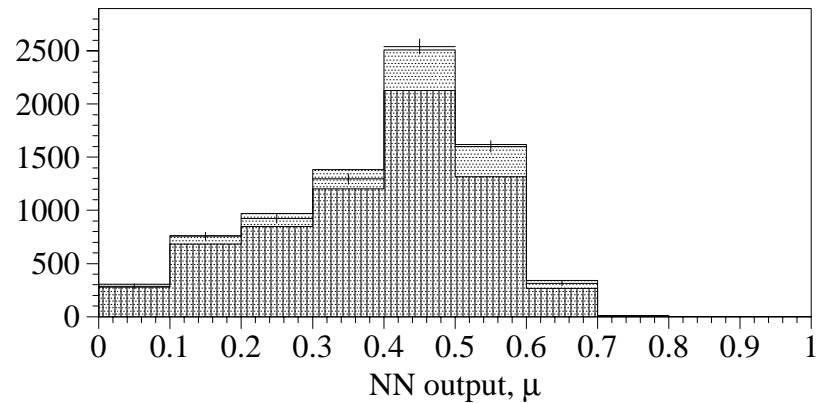
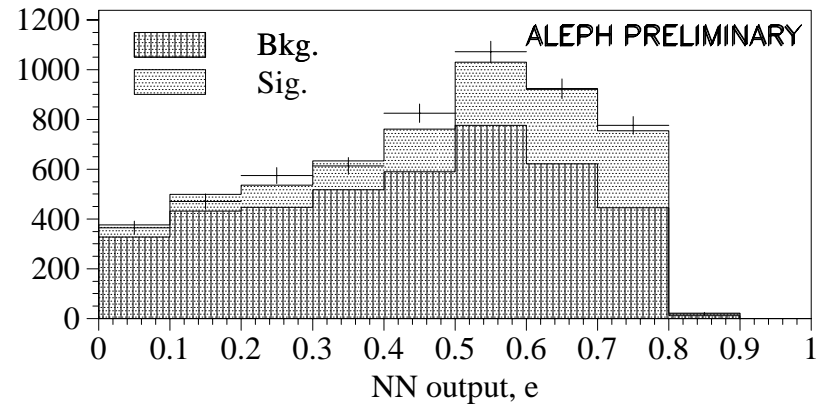
LEP I: gluon splitting into charm

$$g_{c\bar{c}} = \frac{N(Z \rightarrow \bar{q}qg, g \rightarrow \bar{c}c)}{N(Z \rightarrow \text{hadrons})}$$

- 3 jets events with a lepton in the least energetic jet
- NN with 6 variables to increase signal purity: $\sim 25\%$ e, $\sim 18\%$ μ
- Main systematics:
 - Lepton id
 - Charm jet simulation
 - $\text{BR}(c \rightarrow l)$

- $g_{cc}(e) = (2.99 \pm 0.28 \pm 0.41) \%$
 $g_{cc}(\mu) = (2.90 \pm 0.38 \pm 0.74) \%$

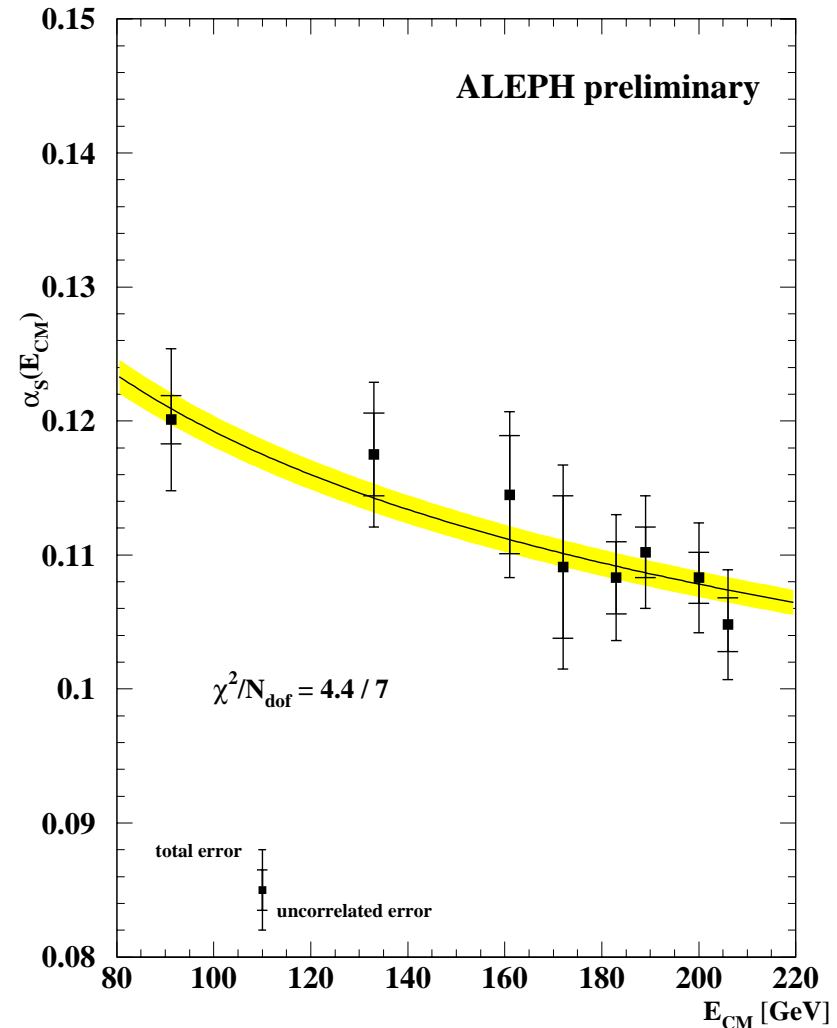
$g_{cc} = (2.98 \pm 0.48) \%$
 WA: $(2.96 \pm 0.38) \%$



LEP I + LEP II: α_s from event-shape variables

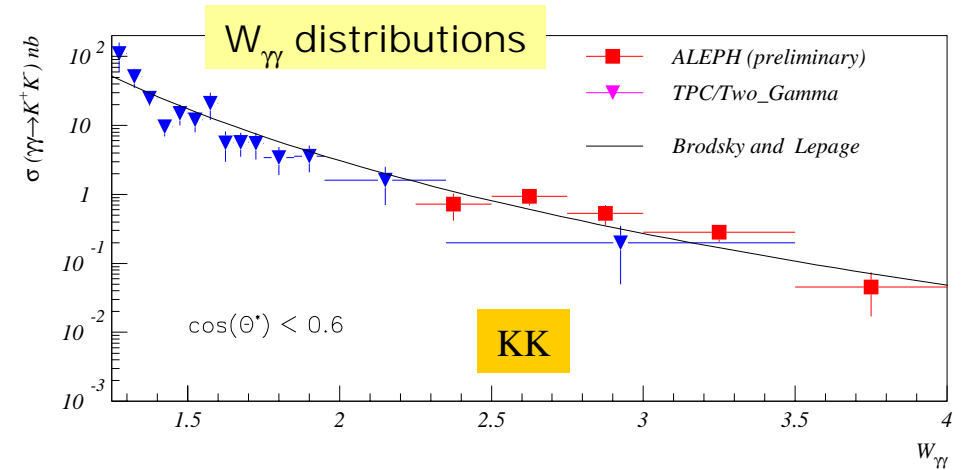
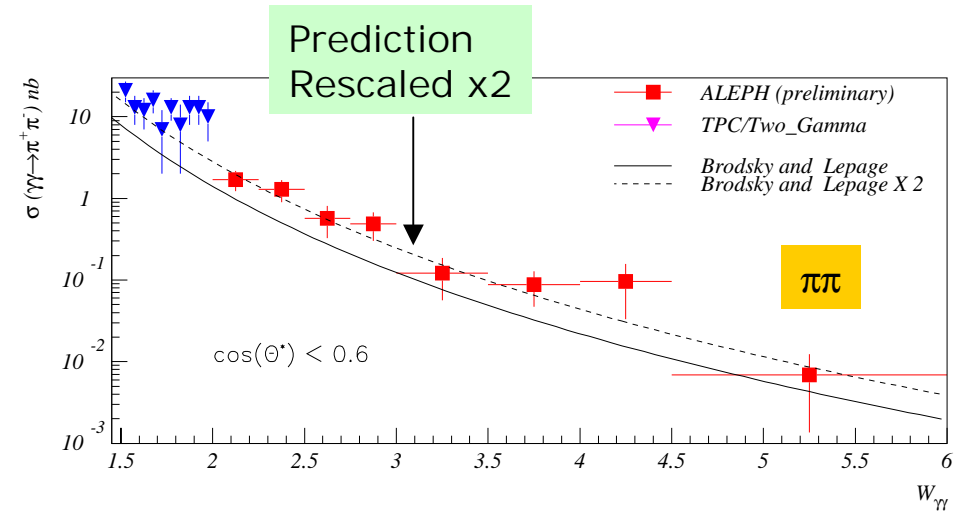
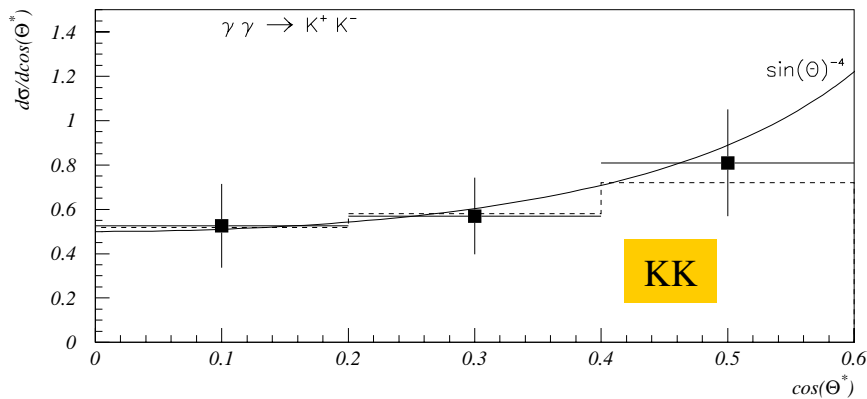
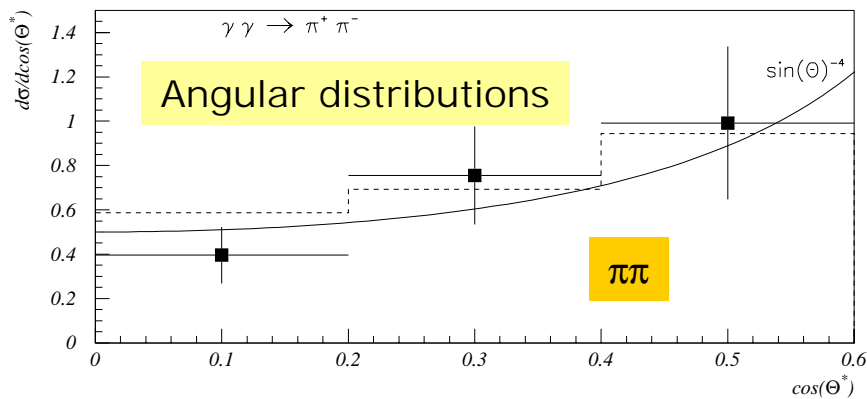
- Results from the full LEP I+LEP II ALEPH data set
- 6 event-shape variables used: $T, M_H^2, B_W, B_T, C, -\log y_3$
- Fit with $O(\alpha_s^2) + \text{NLLA}$
- Good agreement with α_s running

running to M_Z and combining:
 $\alpha_s(M_Z) = 0.1211 \pm 0.0047$



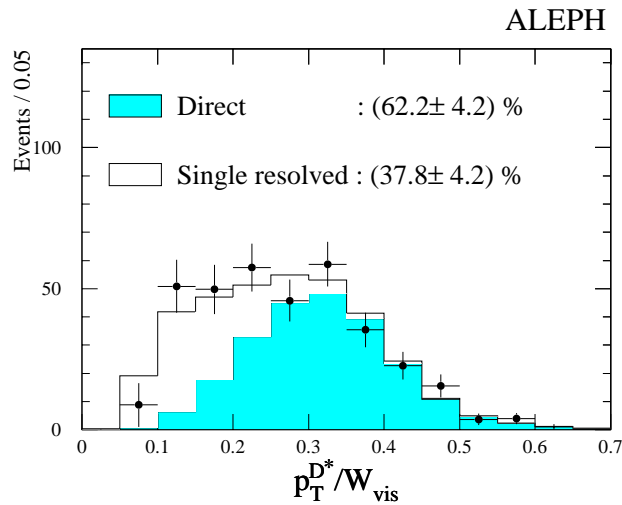
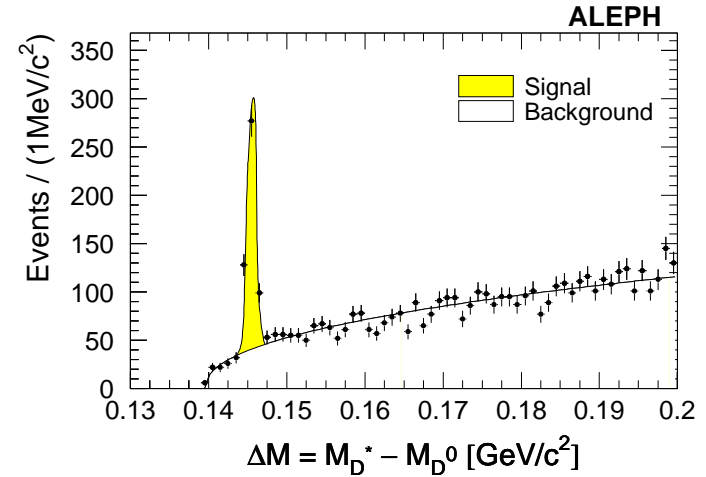
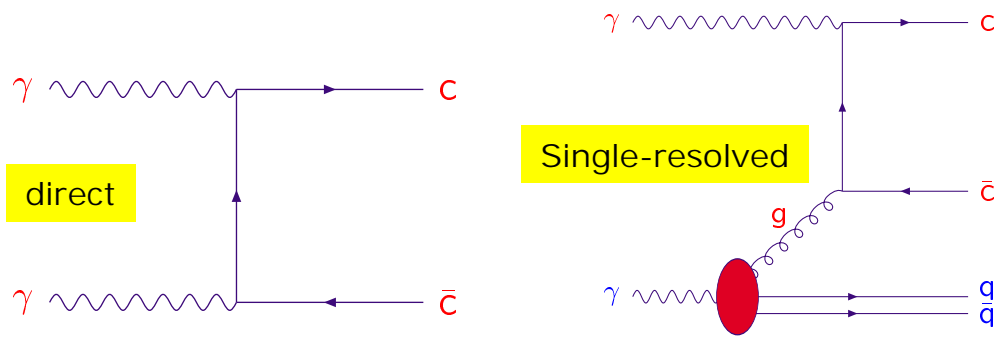
LEP II: $\gamma\gamma \rightarrow \pi^+\pi^-$ and $\gamma\gamma \rightarrow K^+K^-$

- Measurements with LEP II data

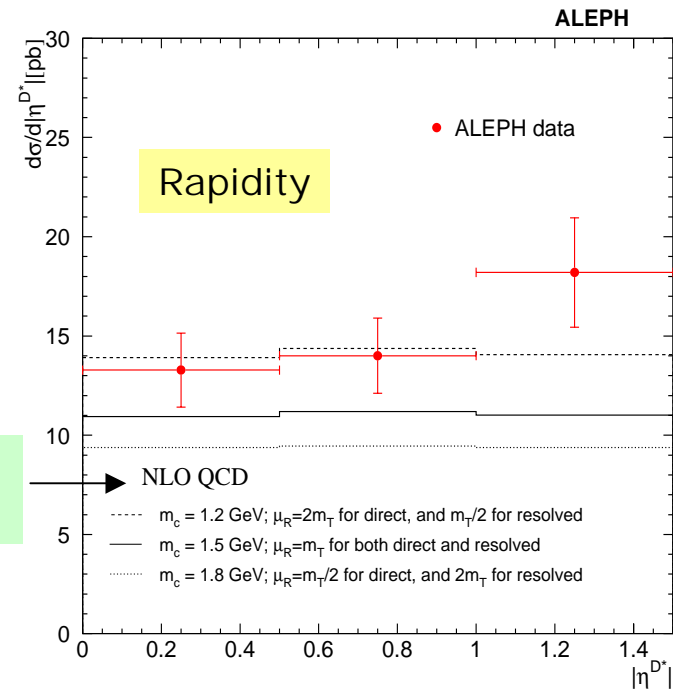


LEP II: $\gamma\gamma \rightarrow D^{*\pm} X$

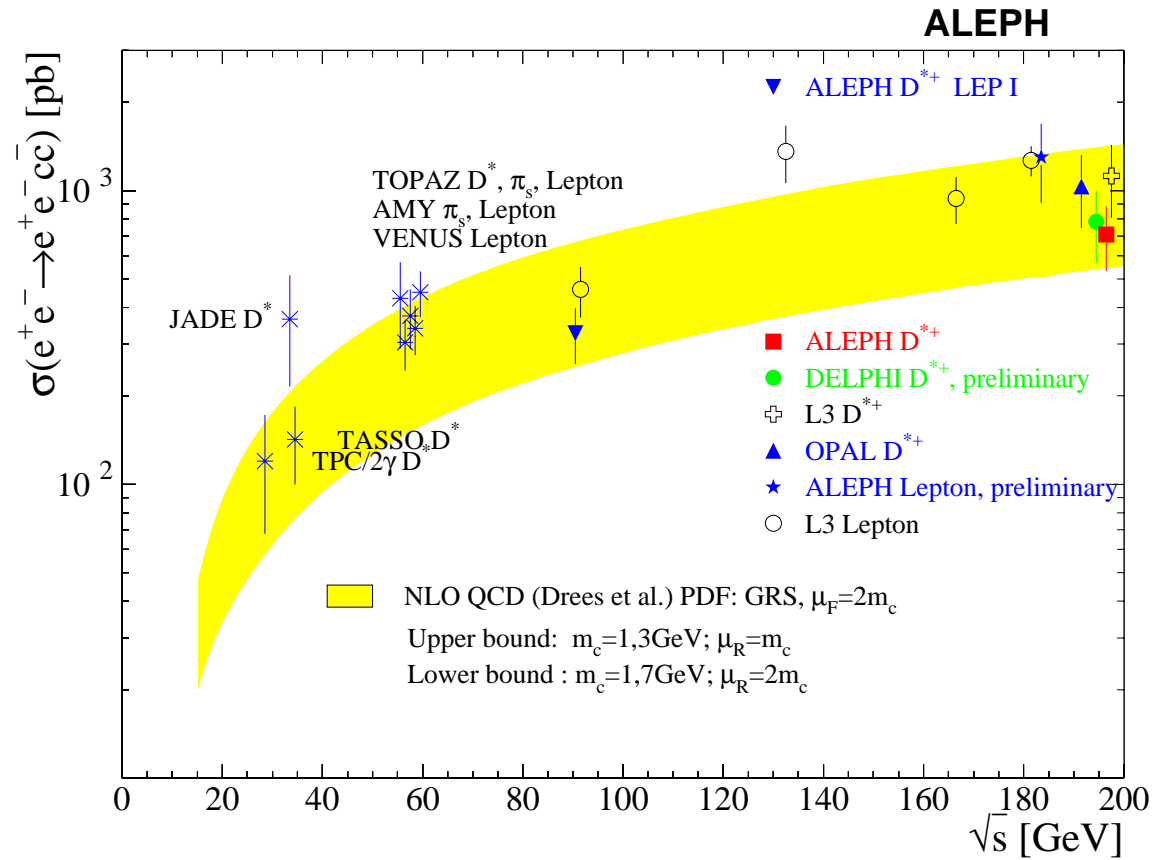
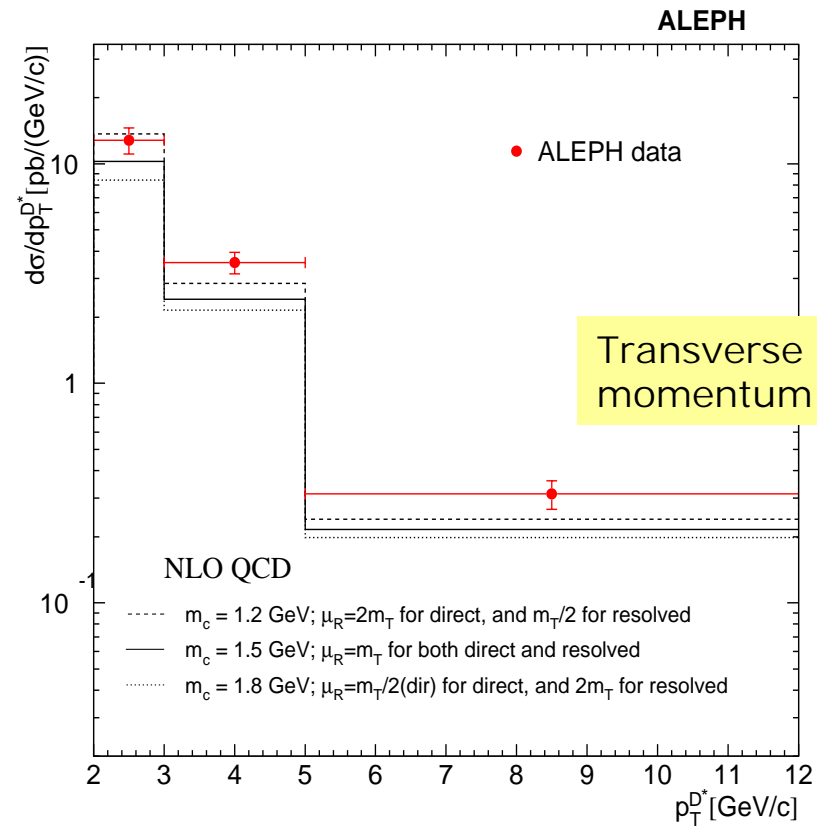
- $D^{*\pm}$ from $D^0 + \text{soft pion}$
- Measurement "direct" and "single-resolved" contributions
- $D^{*\pm}$ cross sections vs p_t and η
- $\sigma(ee \rightarrow ee cc)$



Frixione et al. (2000)



$\gamma\gamma \rightarrow D^{*\pm} X$ and $\sigma(ee \rightarrow eec\bar{c})$

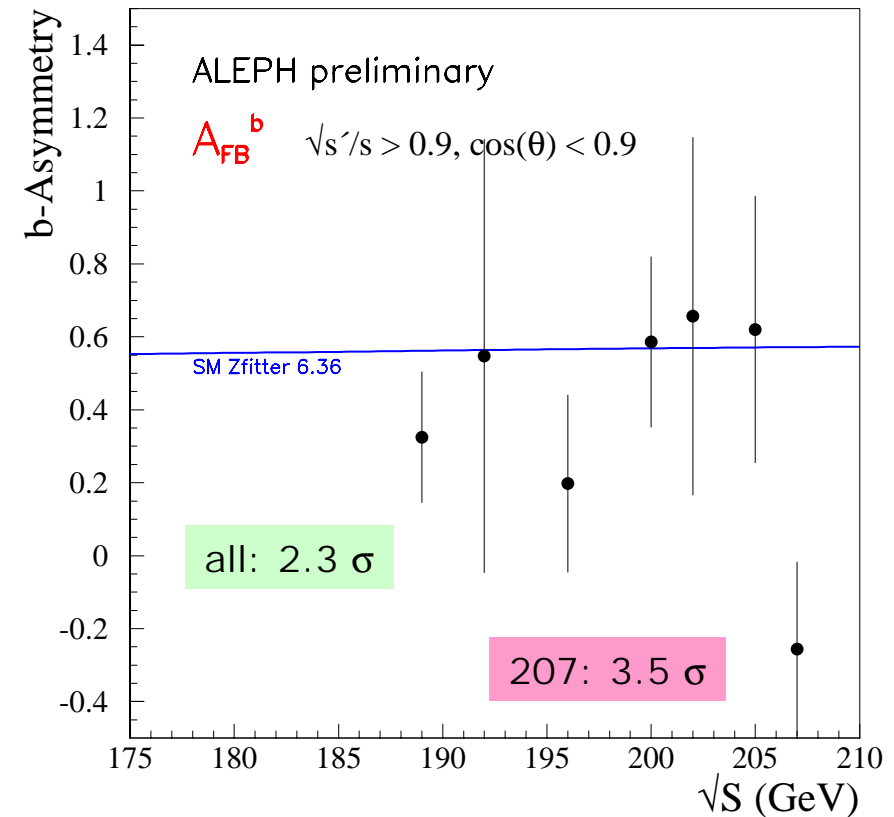


LEP II: 2 fermions production: HF results

- New results: A_{FB}^b , Q_{udsc}^{FB} and R_c

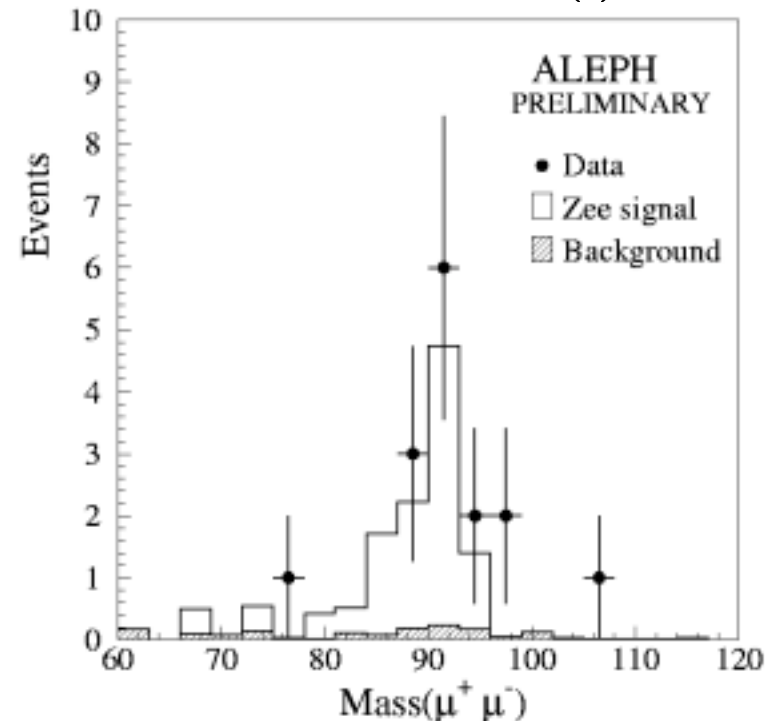
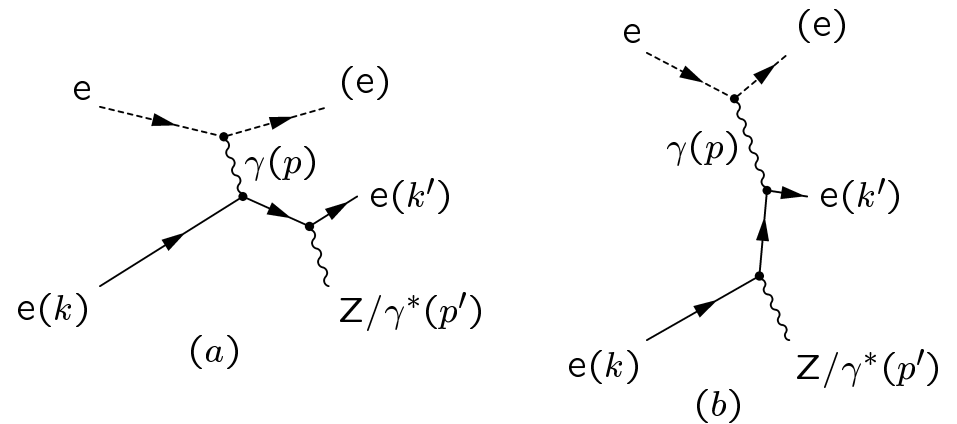
E_{CM} (GeV)			SM
205	A_{FB}^b	$0.620 \pm 0.338 \pm 0.138$	0.571
207		$-0.256 \pm 0.232 \pm 0.057$	0.572
205	Q_{udsc}^{FB}	$0.0077 \pm 0.0051 \pm 0.0018$	0.0070
207		$0.0143 \pm 0.0039 \pm 0.0020$	0.0069

E_{CM} (GeV)	R_c	SM
196	$0.287 \pm 0.033 \pm 0.022$	0.251
200	$0.262 \pm 0.035 \pm 0.014$	0.252
205	$0.296 \pm 0.037 \pm 0.016$	0.253
207	$0.287 \pm 0.029 \pm 0.021$	0.253



LEP II (4f): $ee \rightarrow Zee \rightarrow ee\mu\mu$ cross section

- New analysis
- Signal definition according to LEP WG (phase space cuts):
 - $M_{\mu\mu} > 60$ GeV
 - Forw electron $\theta < 12^\circ$
 - bckw elect: $E > 3$ GeV, $12^\circ < \theta < 168^\circ$
- Selection efficiency: $(36 \pm 2)\%$
- 16 events selected (183-207 GeV) (1.9 expected bkg)



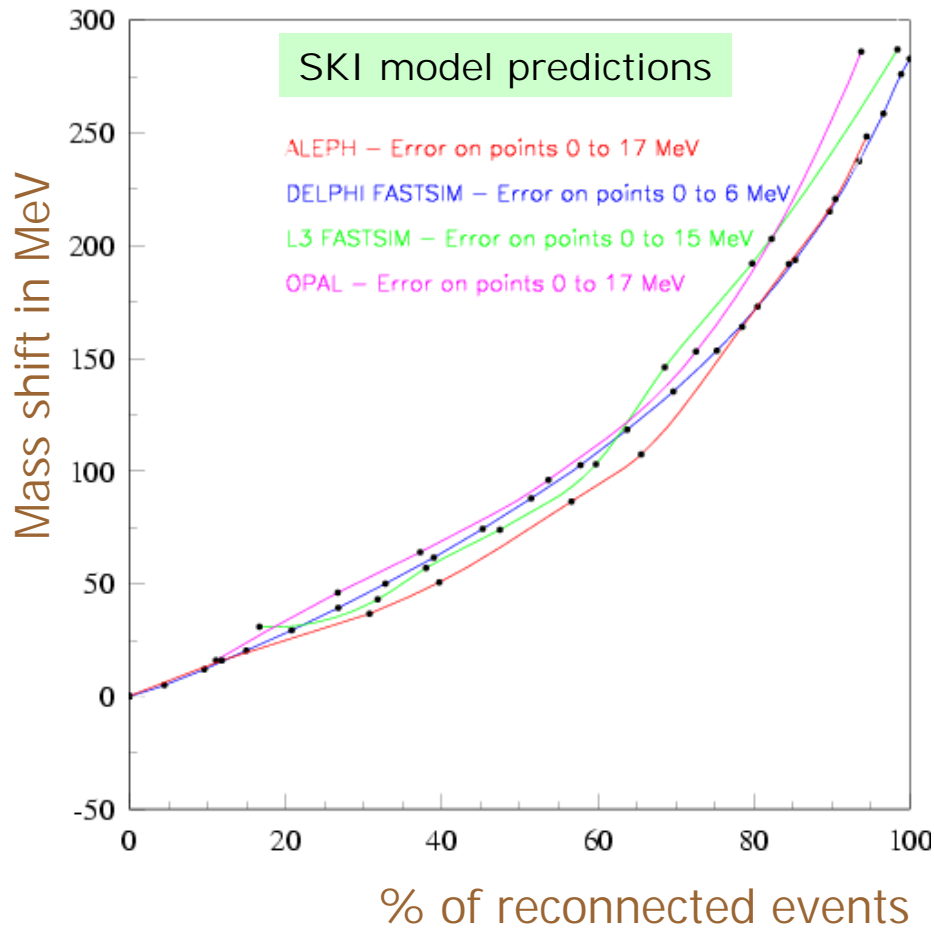
$\sigma(ee \rightarrow Zee \rightarrow ee\mu\mu) = 57 \pm 14 \pm 4$ fb
 (average from 183 to 207 GeV)

Looking for Colour Reconnection in $WW \rightarrow 4q$ events: preliminary results

- Colour singlets can be created across decay products of different W's: **we cannot ask ourselves which W a particle comes from.**
- Interesting to better understand non-perturbative QCD, **worrying for the W mass measurement**
- Larger effects at the end of the parton shower and in the non-perturbative part → **MC models**

- **ALEPH preliminary** results from:
 - Charged particle multiplicity and momentum spectrum analysis
 - Real data are compared to different MC models using $WW \rightarrow 4q$ and $WW \rightarrow l\nu qq$ events
 - Particle flow analysis in $WW \rightarrow 4q$ (started by L3)
 - Particle multiplicity between jets from the same and different W's are compared to MC models with and without Colour Reconnection
 - Variation of the W mass measurement when soft particle (momentum cut) are discarded from jet reconstruction

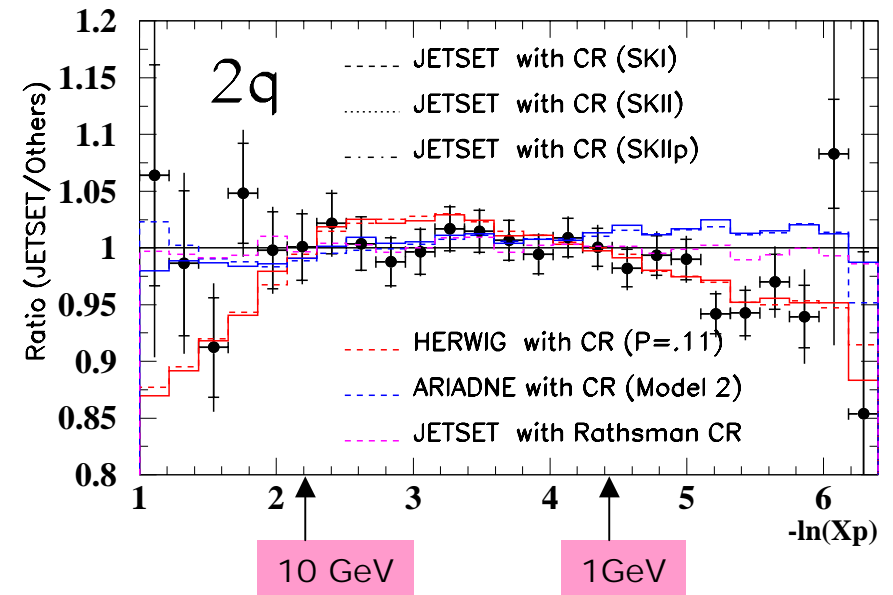
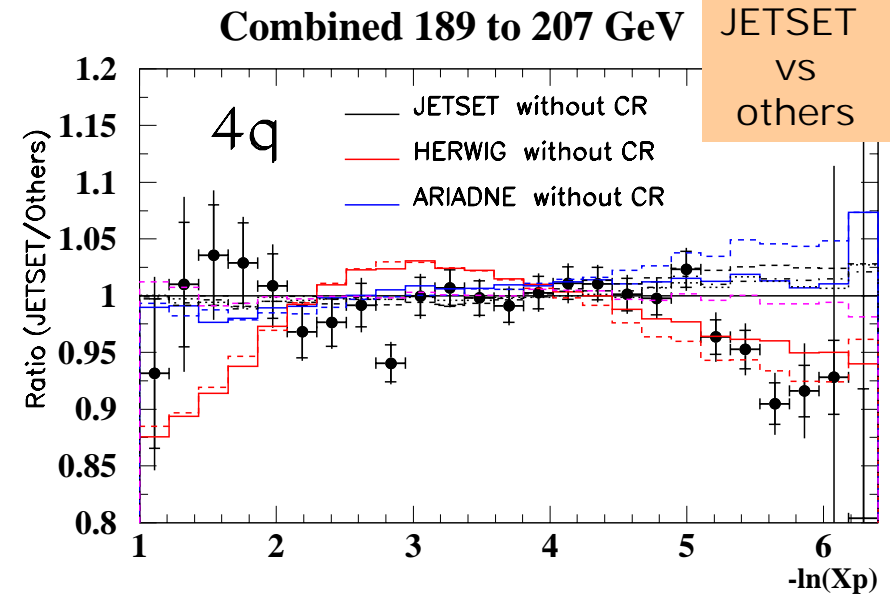
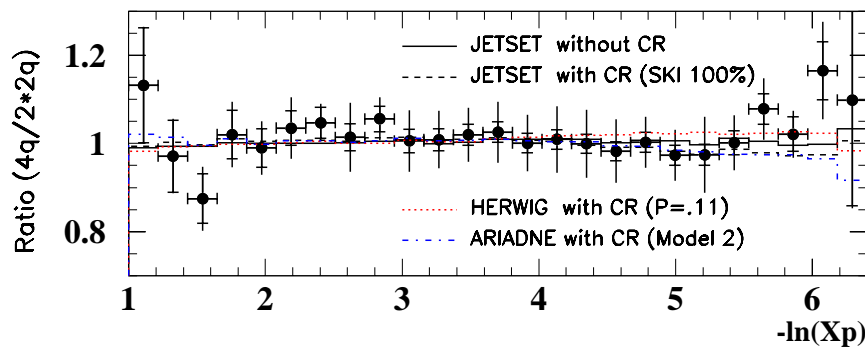
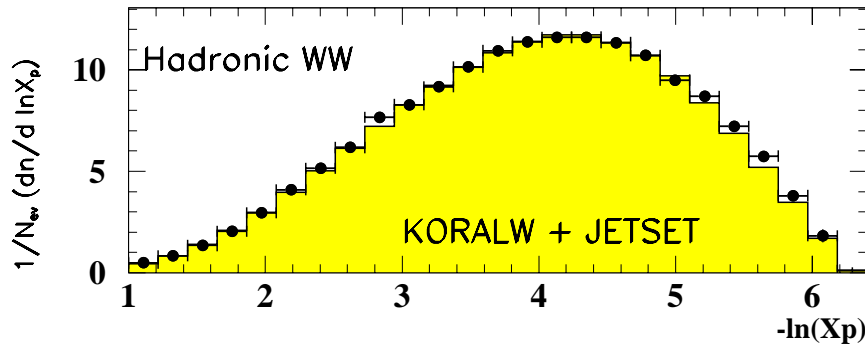
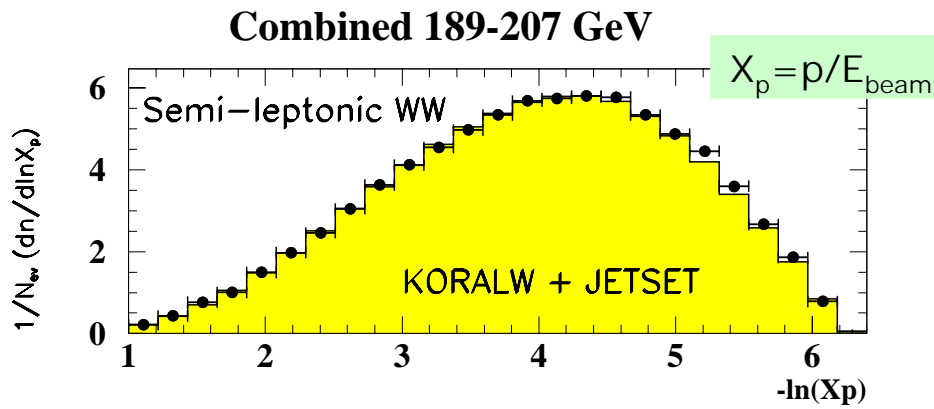
ΔM_W with CR models



In SKI model P_{reco} is controlled by the parameter K_i

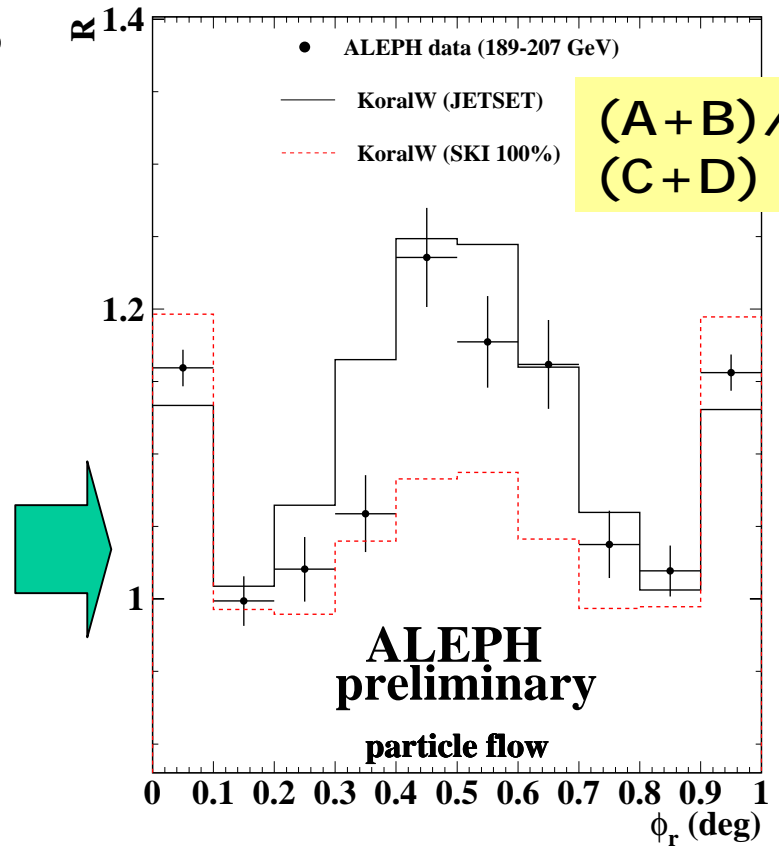
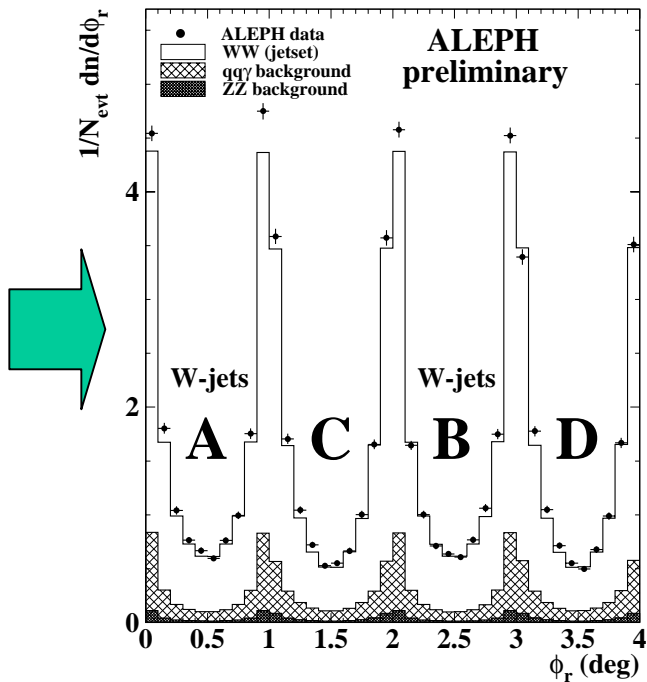
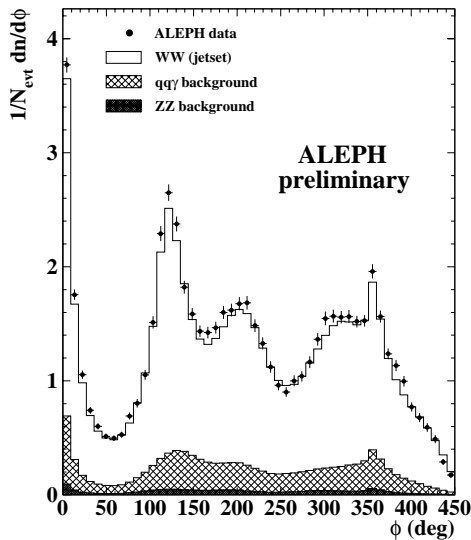
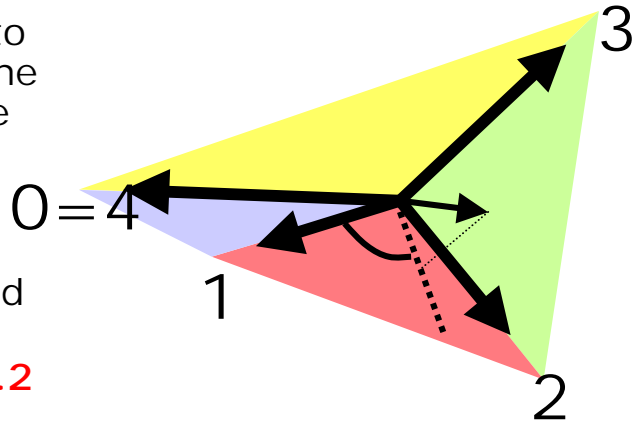
Model	ΔM (MeV)
Herwig CR	~30
Ariadne 2 CR	70-80
Rathsman (GAL)	30-40

CR: Charged Particle spectra



CR: Particle flow between W's

- In $WW \rightarrow 4q$ events particles are projected to the closest inter-jet plane and angles w.r.t. jet are measured
- Inter-jet angles are normalized to 1
- Distribution is folded and binned ratio is done:
 $R_n = \text{one bin from 0.2 to 0.8}$



$$R_n = 1.095 \pm 0.014 (\text{stat}) \pm 0.006 (\text{syst}) \pm 0.006 (\text{extrap})$$

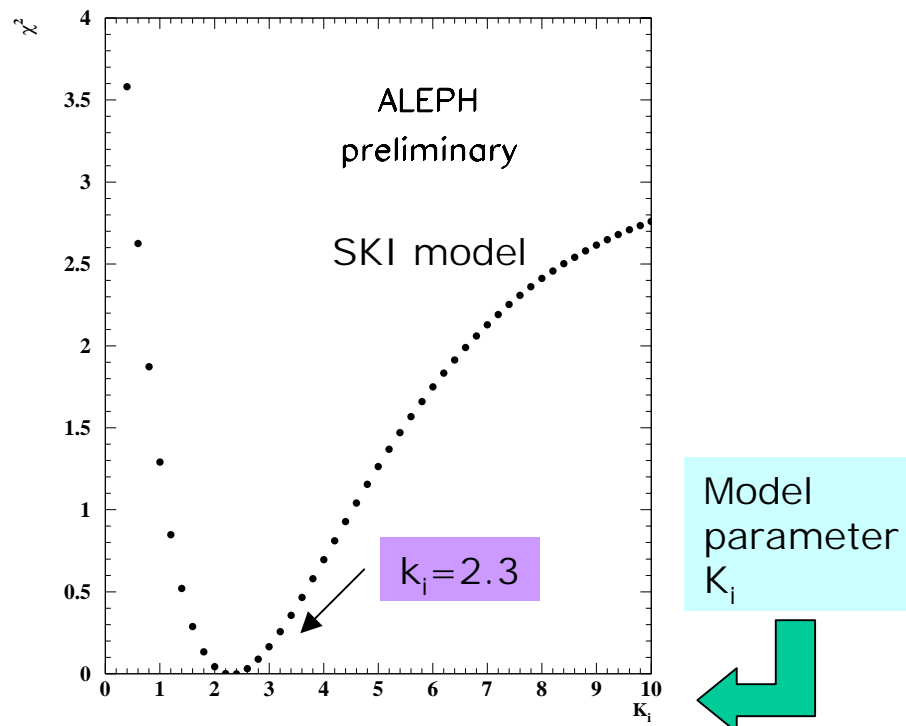
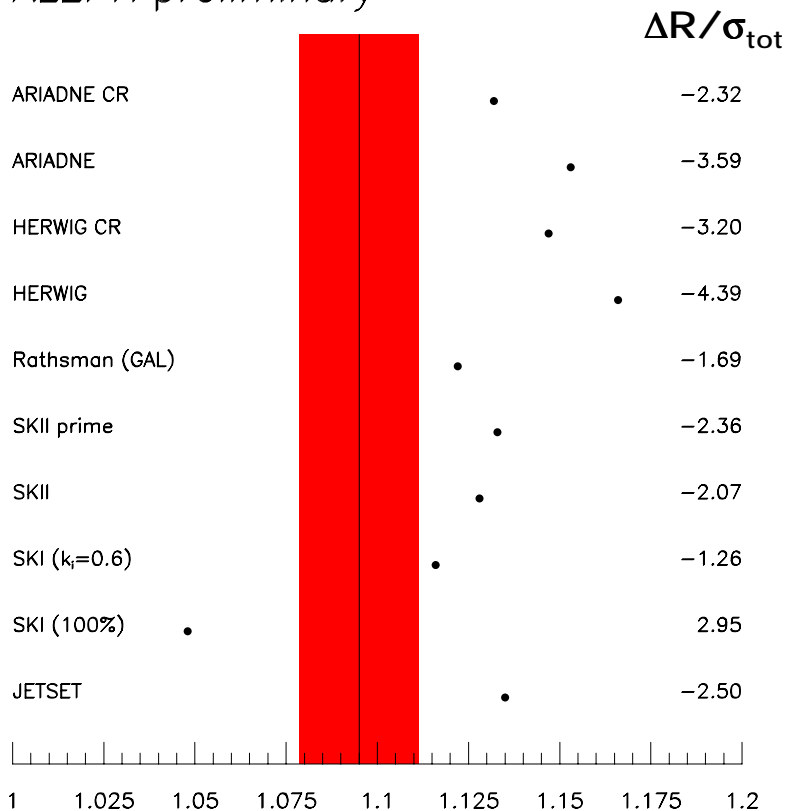
extrapolated to 189 GeV

CR: Particle flow between W's

- R_n measured in data is compared with MC predictions from different models with and without CR

- $R_n(\text{data}) = 1.095 \pm 0.014(\text{stat}) \pm 0.006(\text{syst}) \pm 0.006(\text{extrap})$

ALEPH preliminary

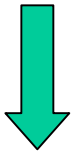


- Background, BE and detector systematics are included. Fragmentation is **not** included

Bias induced by MC tuning has not been evaluated yet

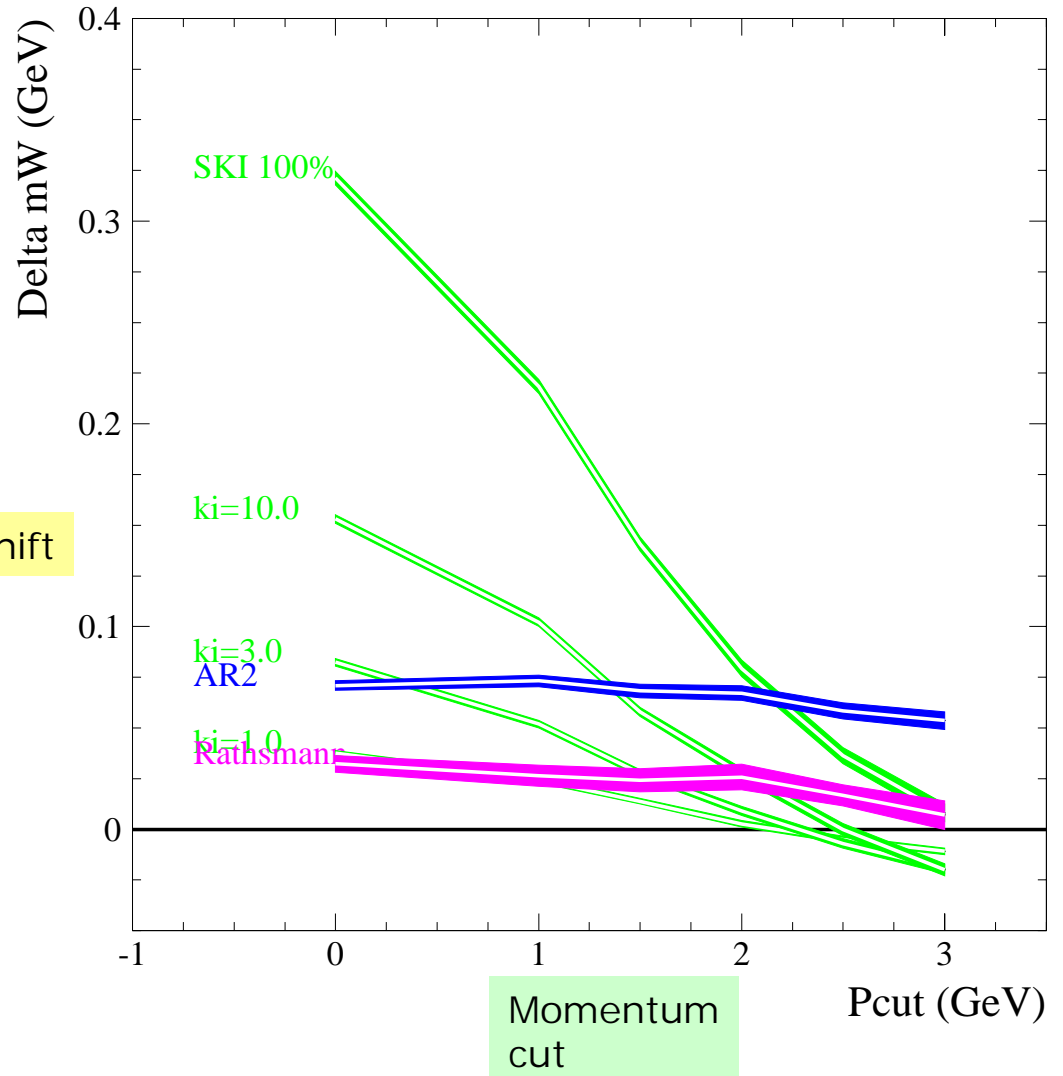
CR from the W mass

- CR is expected to affect mainly low momentum particles and particles away from the jet core



- Measure the **variation of the W mass** obtained removing progressively **low momentum particles (pcut analysis)** or "far away" particles (cone analysis)
- The following results have been obtained with the **pcut analysis**
- The slope of the W mass measurement is compared to the MC predictions.

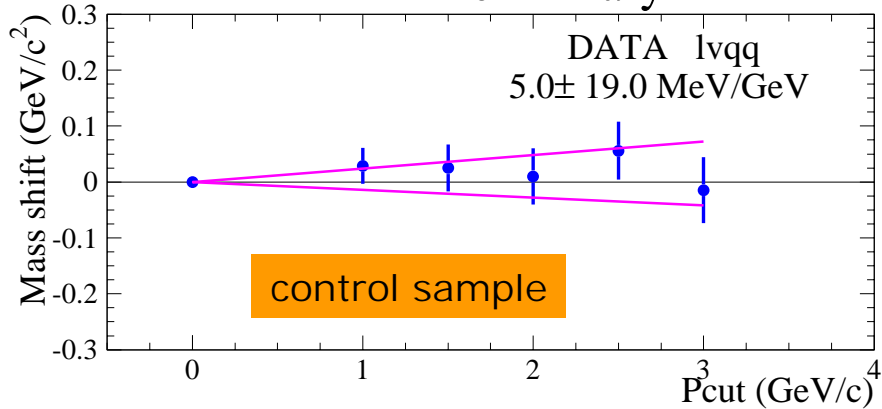
Mass shift



CR from the W mass

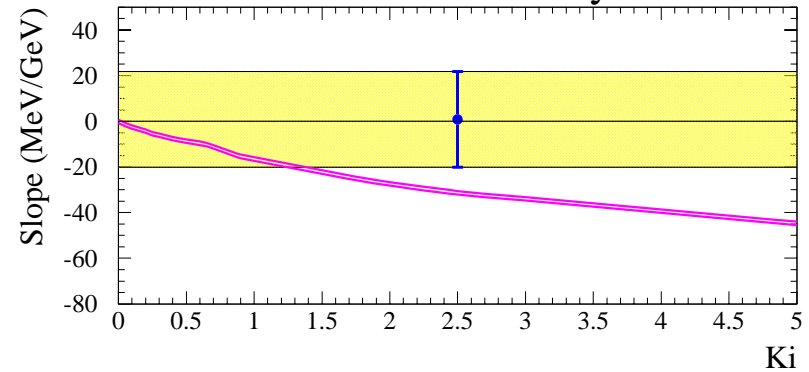
Semileptonic events

ALEPH - Preliminary



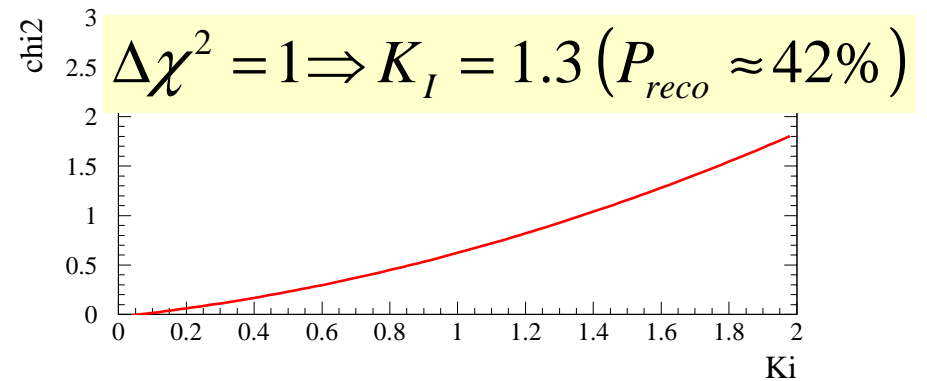
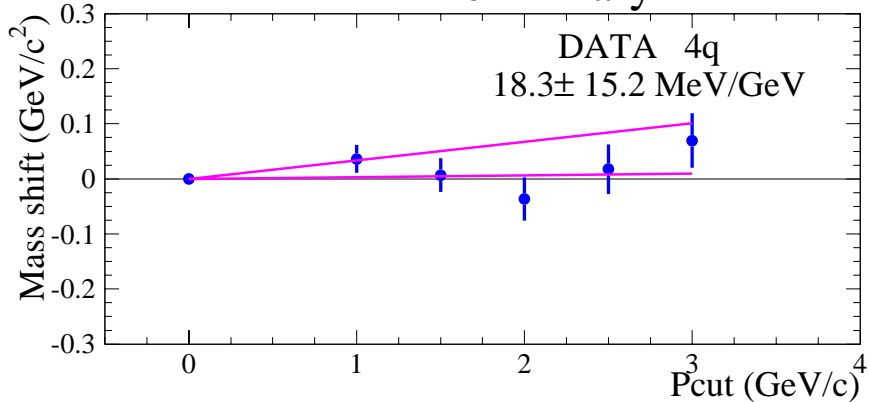
- Very preliminary results:
- conservative systematics and **bias**
- improved “calibration” studies to be done

ALEPH - Preliminary



Fully hadronic events

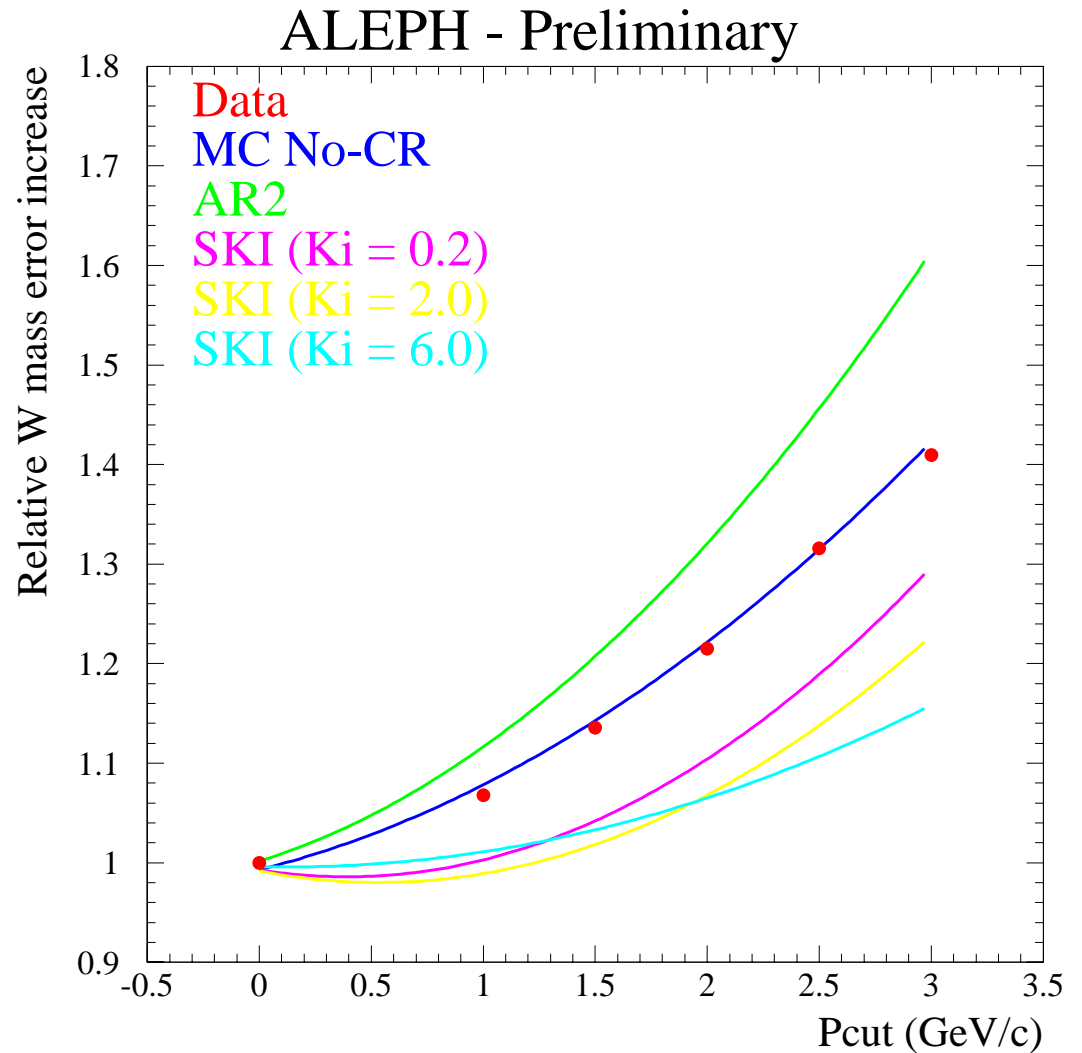
ALEPH - Preliminary



- **Ariadne2 (CR)** model predicts a fairly large mass shift (~70-80 MeV) but quite insensitive to momentum and cone cuts

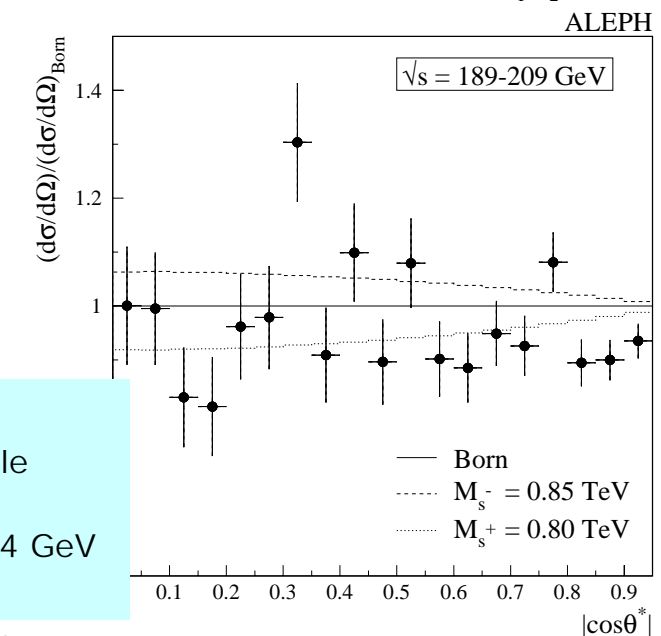
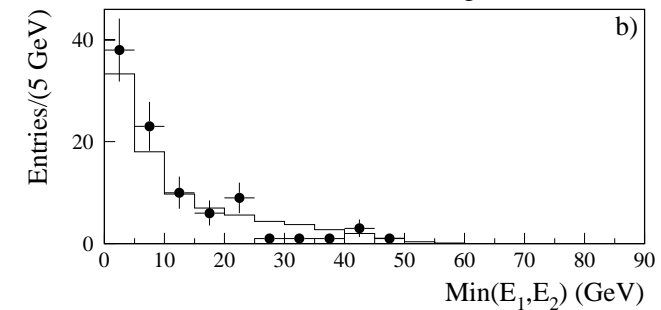
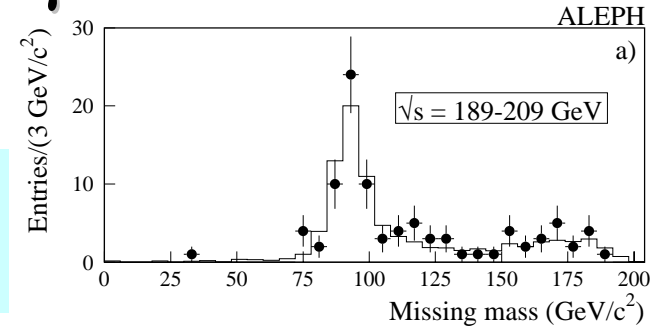
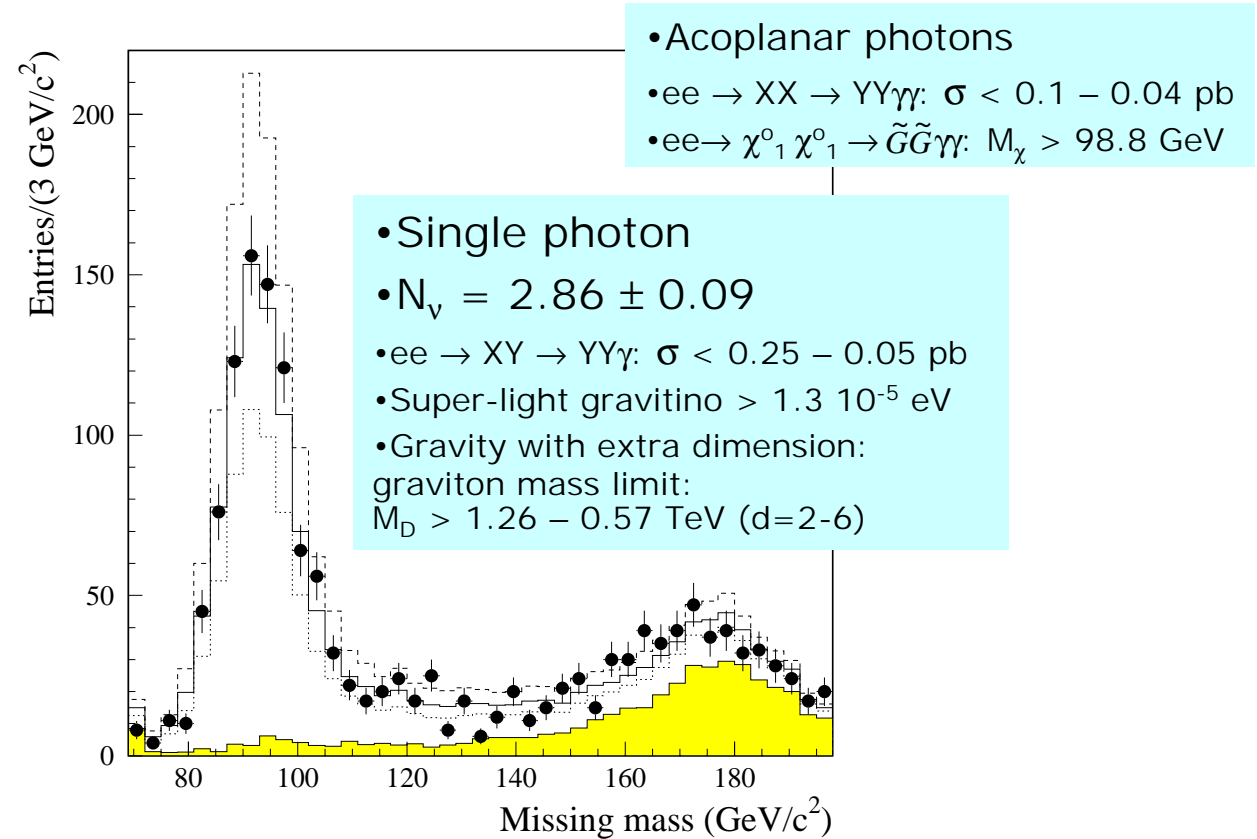
CR from the W mass statistical error

- **VERY** preliminary study
- Relative error variation wrt no P_{cut} analysis
- It is sensitive to CR
- It can differentiate models
 - In particular AR2



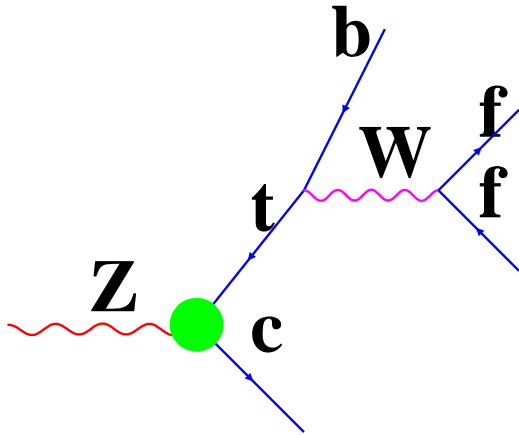
From SM to new physics: γ 's final states

- Final results (CERN-EP/2002-033):

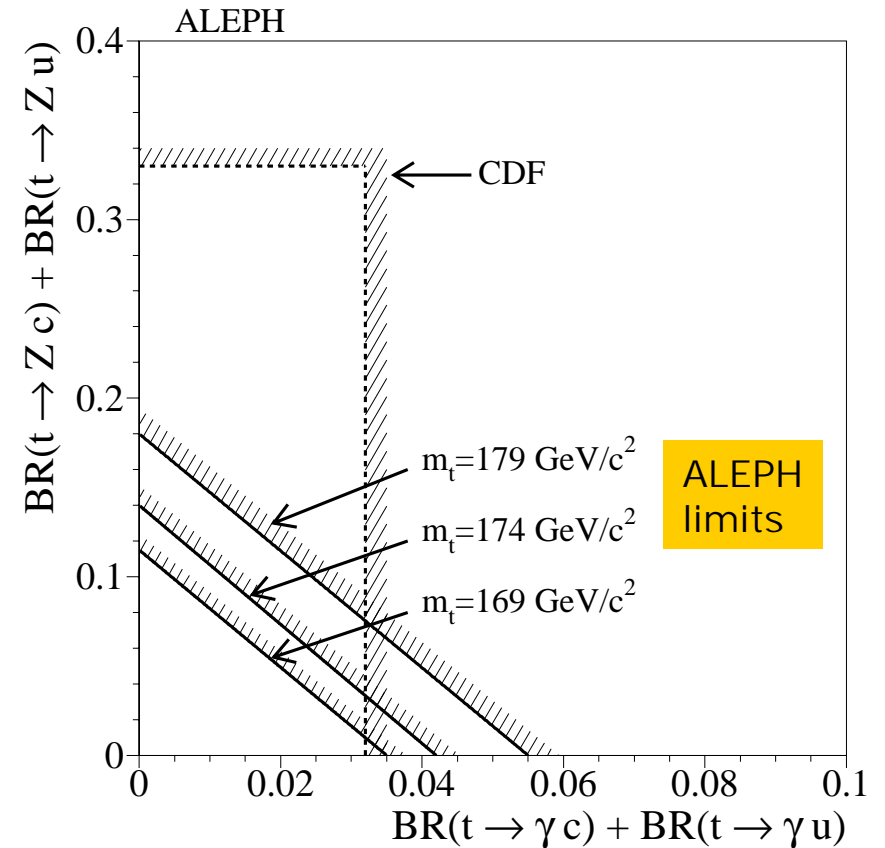


- Collinear photons
- Gravity with extra dimension: string scale
- Contact interactions: $\Lambda_6 > 1.35$ TeV, $\Lambda_7 > 0.74$ TeV, $\Lambda_8 > 21.4$ GeV
- Excited electron: $M > 213$ GeV ($f_\gamma = 1$)

Single top production limits



- Final results with full LEP II data
 - CERN-EP/2002-042
- Multijet (with one b) final state (with or without leptons)
- $\epsilon \sim 3\%$ (lepton) , $\sim 13.5\%$ (hadron) including BR's



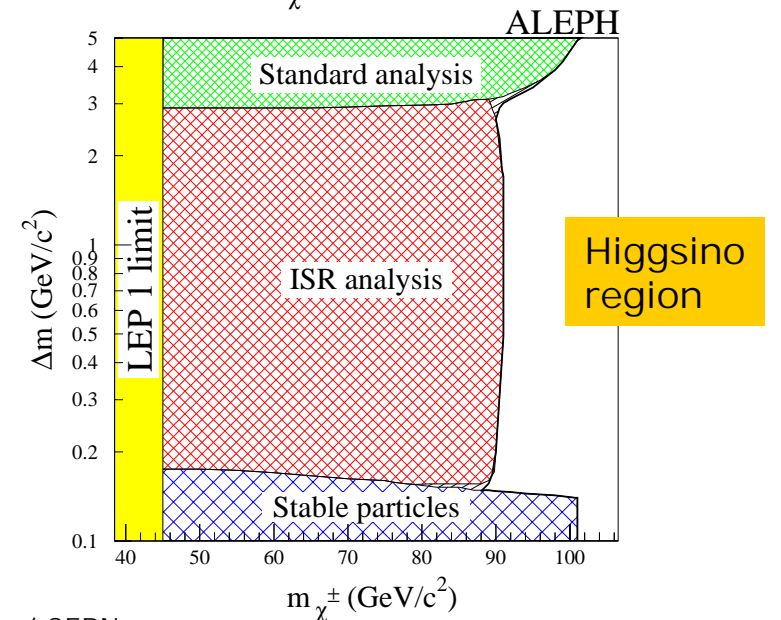
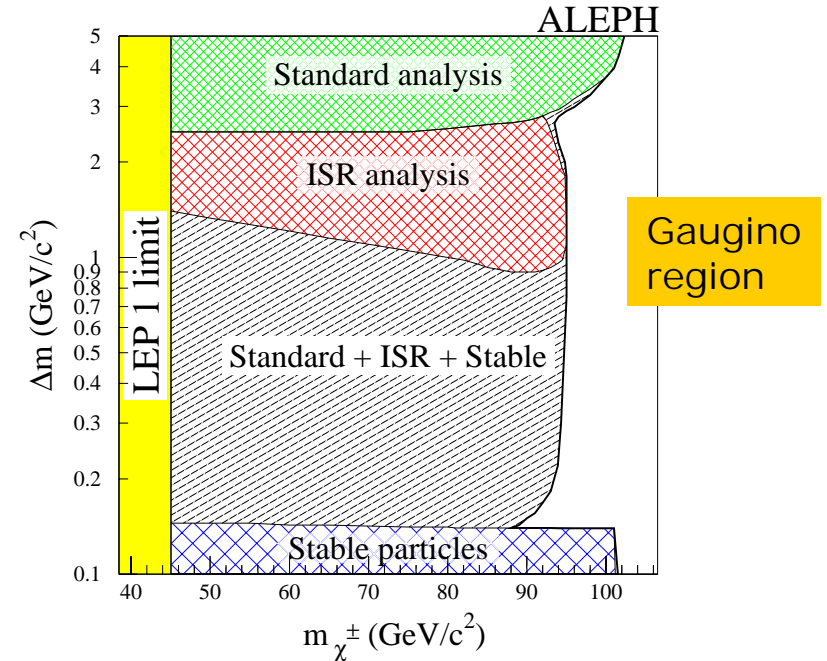
- 24 candidates in data (20.1 expected)

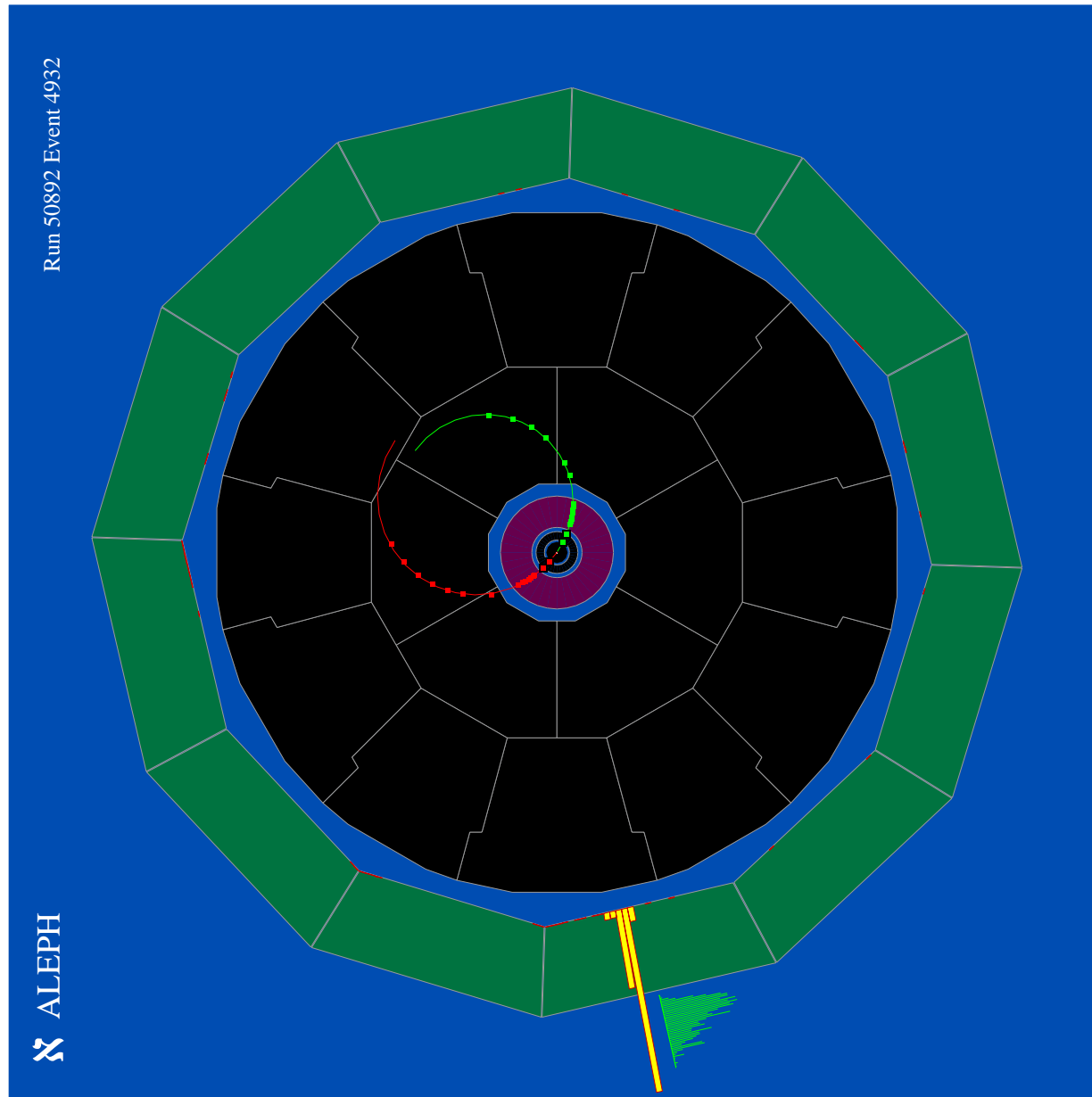
• $BR(t \rightarrow Zc) + BR(t \rightarrow Zu) < 14\%$ (95% CL)
(no γ coupling, $m_{\text{top}} = 174 \text{ GeV}$)

Charginos nearly degenerate with neutralino

- Small mass differences with mass unification only if M_2 very large
- More “natural” with AMSB
- Dedicated analysis to cover the hole between:
 - Long-lived charginos: search for heavy stable charged particles
 - Chargino’s decay products can trigger DAQ
- Search for **ISR γ plus soft tracks** compatible with $\gamma\chi^+\chi^-$ production and decay

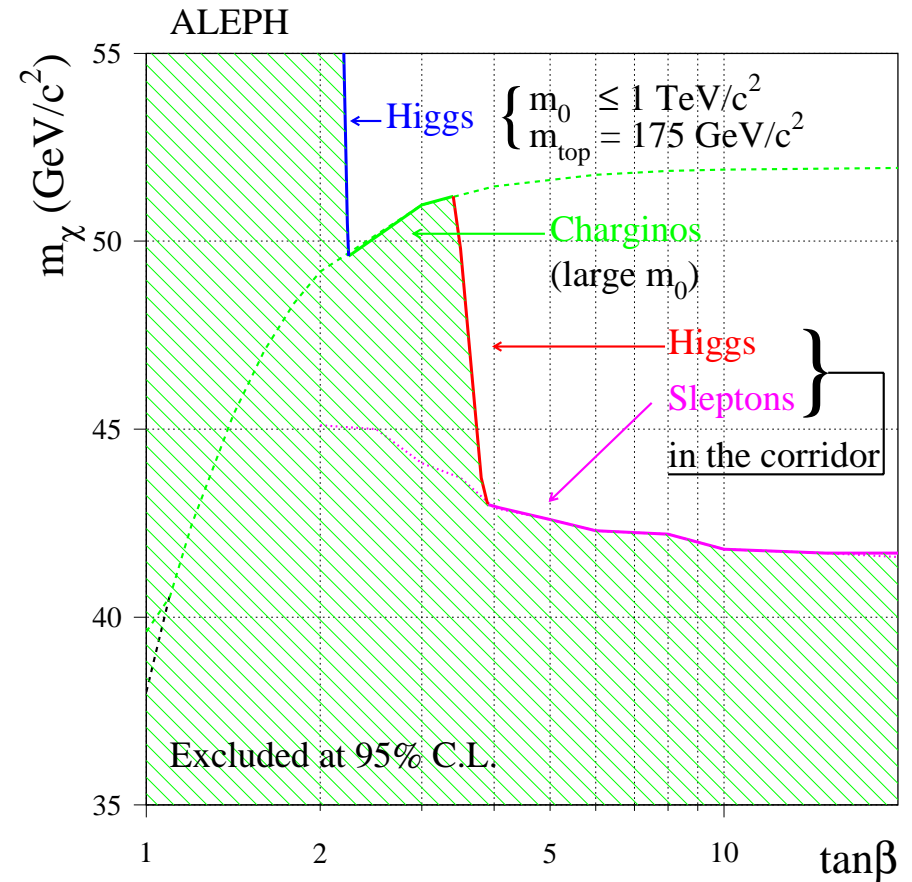
$M_\chi > 88 \text{ GeV}$ (heavy sfermions)
(Phys. Lett B533 (2002) 223)





LSP mass: toward an absolute limit

- Framework : MSSM
 - LSP = χ^0_1
 - Mass unification
- “Standard” analyses:
 - Chargino and Neutralino searches
 - Squarks and sleptons
 - Higgs Boson
- If stau mixing ϕ_τ is let free
 - $\chi^\pm \rightarrow \tilde{\tau} \nu$, $\chi^0 \rightarrow \tilde{\tau} \tau$ can be dominating
 - $\Delta m(\tilde{\tau} - \chi^0)$ can be small: **soft τ 's in final state**



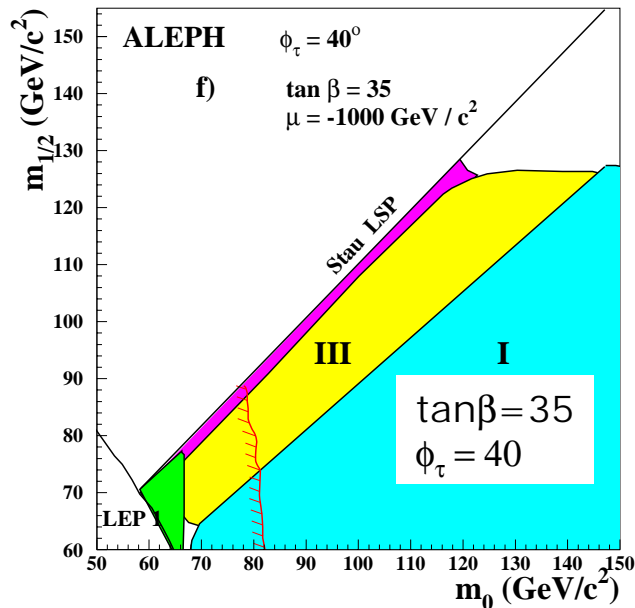
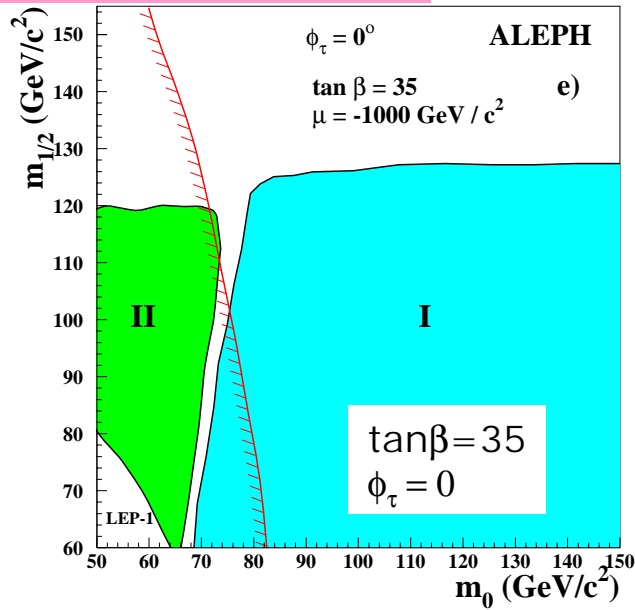
• Additional searches:

- $ee \rightarrow \chi^+ \chi^- \rightarrow \tilde{\tau} \nu \tilde{\tau} \nu \rightarrow \tau \nu \chi^0 \tau \nu \chi^0$ acoplanar τ 's pairs (large Δm), ISR γ +soft tracks (small Δm)
- $ee \rightarrow \chi^0_1 \chi^0_2 \rightarrow \tilde{\tau} \tau \chi^0 \rightarrow \tau \chi^0 \tau \chi^0$ single τ (small Δm)
- $ee \rightarrow \chi^0_2 \chi^0_2 \rightarrow \tilde{\tau} \tau \tilde{\tau} \tau \rightarrow \tau \tau \chi^0 \tau \tau \chi^0$ 2–4 τ 's final state

An example: $\mu = -1000$ GeV
 $\tan\beta = 35$: $\phi_\tau = 0 - 40$

$m_{1/2}$ vs m_0

LSP limit



I – chargino
3-bodies

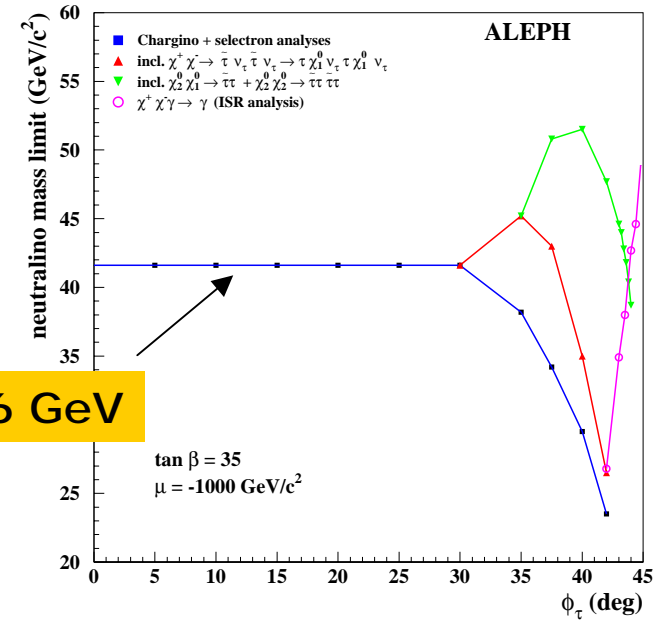
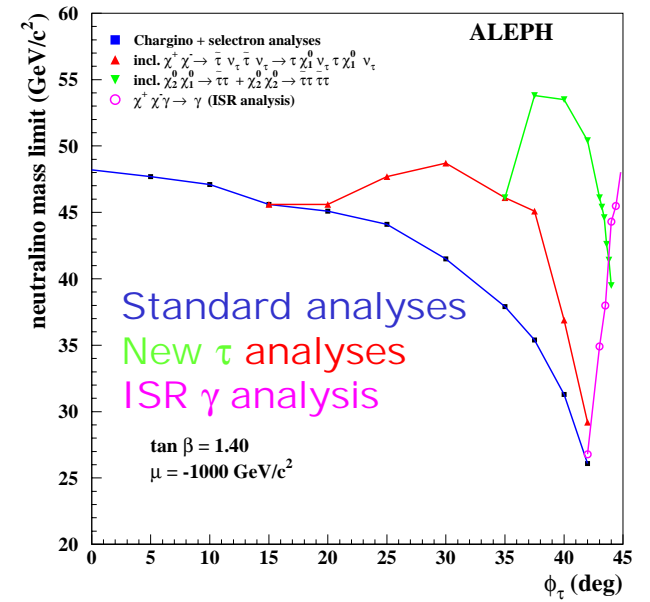
II – chargino
2 - bodies

III – τ 's final
states

Charginos +
ISR

Selectrons

$M_{LSP} > 41.6 \text{ GeV}$



s-top decays into gluino LSP

- Very preliminary Y2K data only
- Gluino is LSP
- $\tilde{t}\tilde{t}$ can be produced at LEP II
- $e^+e^- \rightarrow \tilde{t}\tilde{t} \rightarrow c\tilde{g}c\tilde{g}$

- R-parity conserved \rightarrow R-hadrons

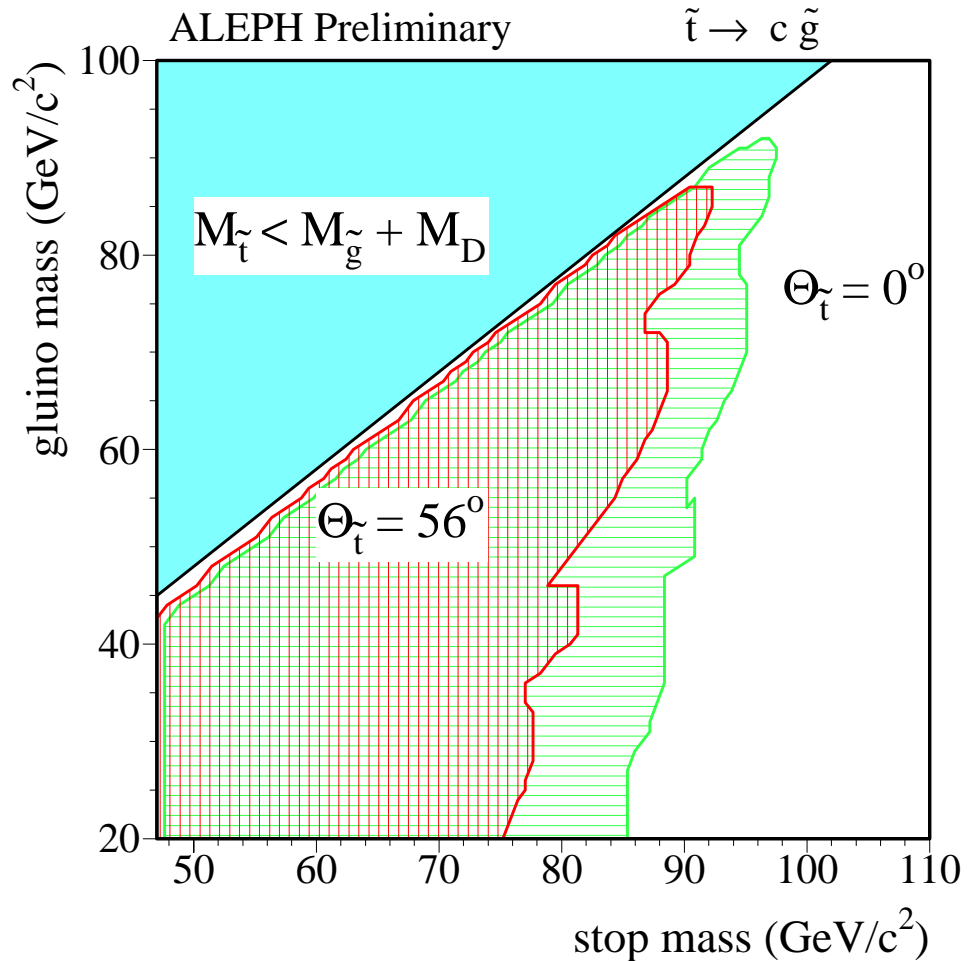


MC simulation

- gluino parton shower in PYTHIA
- R-hadrons interact as heavy pions



- **Missing energy is not always present**
- Selection of acoplanar jets
 - depends on ΔM
 - efficiencies: 10-22 %
 - 4f background is subtracted



Search of Higgs boson with non-standard decays

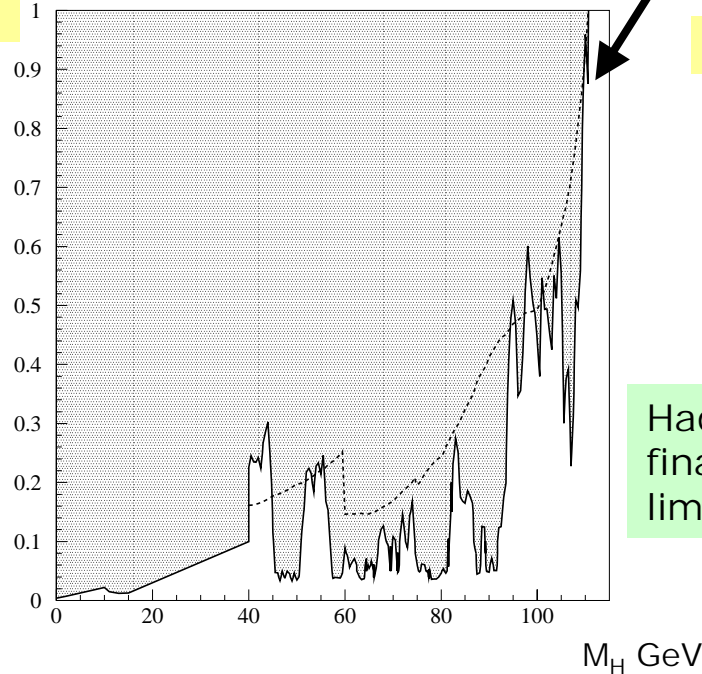
- Flavour-independent Higgs boson search (CERN-EP/2002-027)
- Only $HZ \rightarrow q\bar{q}q\bar{q}$ analysis has been modified with respect to the standard Higgs boson search
 - No b-tagging + estimators of WW and HZ hypothesis

$BR(\text{had}) + BR(\tau\tau) = 1 : M_H > 109.1 \text{ GeV}$

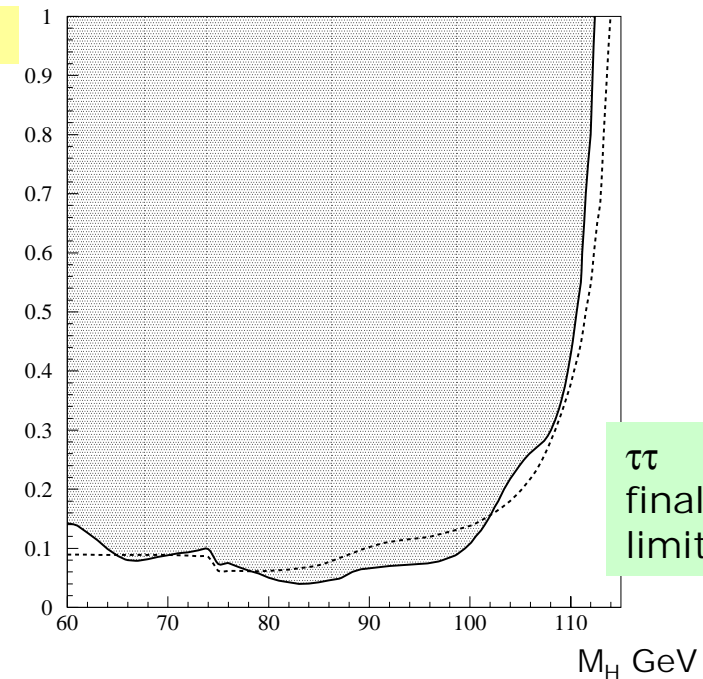
$M_H > 110.6 \text{ GeV}$

$M_H > 112.4 \text{ GeV}$

$BR(\text{had}) * \sigma / \sigma_{SM}$

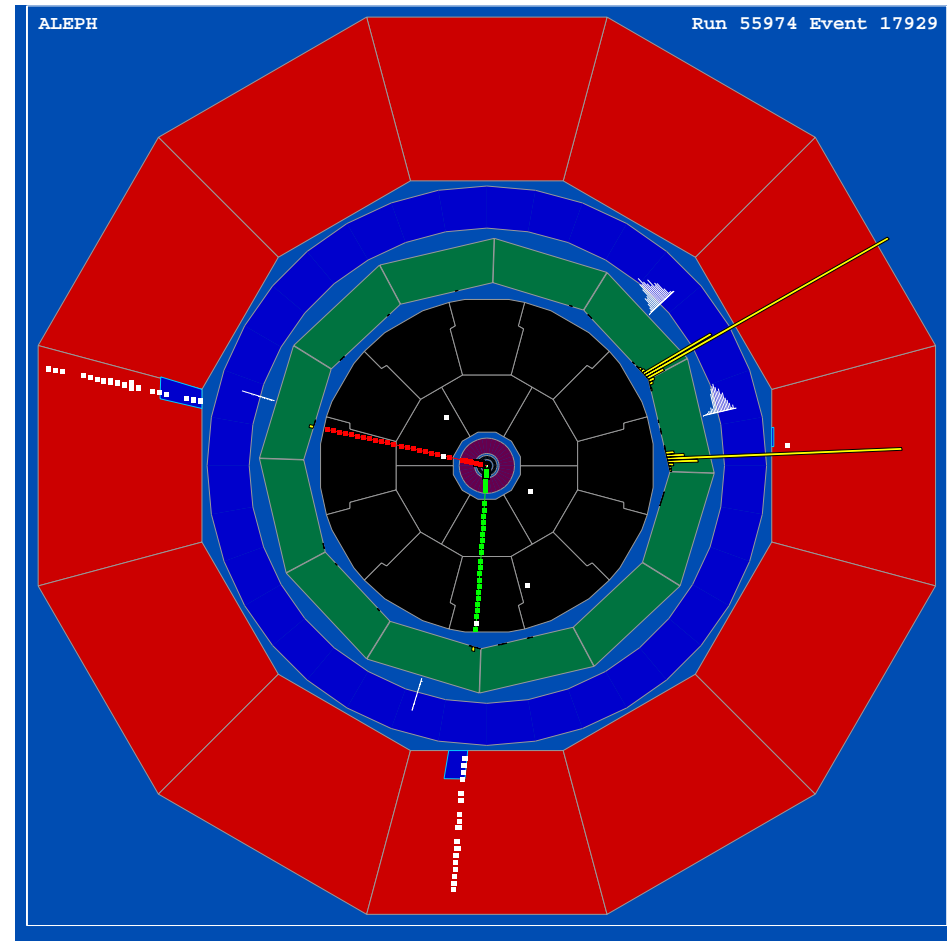
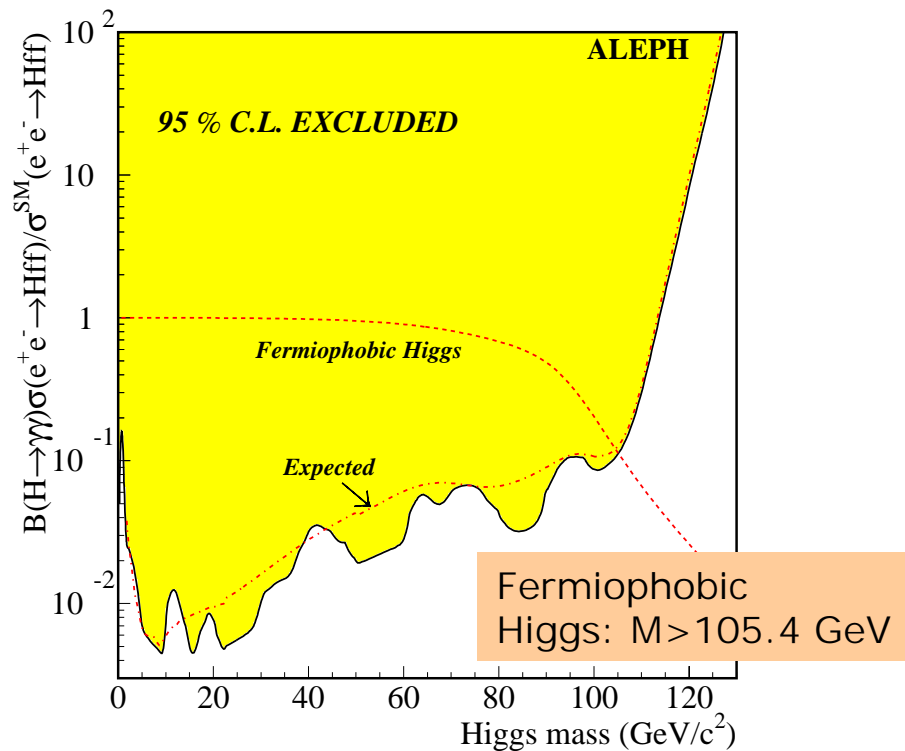


$BR(\tau\tau) * \sigma / \sigma_{SM}$



Search of Higgs boson with non-standard decays

- Search for $\gamma\gamma$ decays of a Higgs boson (CERN-EP/2002-044):
 - LEP I + LEP II
- Looking for events with two γ 's +:
 - Missing energy ($H\nu\nu$)
 - 2-4 charged tracks (Hll)
 - > 5 tracks (Hqq)



Summary and conclusions

- ALEPH is still obtaining interesting results from LEP I data
- Exclusion limits from searches are becoming more and more general
- More exotic models have been explored
- Progress in understanding the main systematics of the W mass measurement (LEP-wide joint effort)
- See you in Winter 2003 with other (final) results: 4f cross sections, searches, W mass, ...