Physics results from ALEPH
(Summer Conferences 2002)

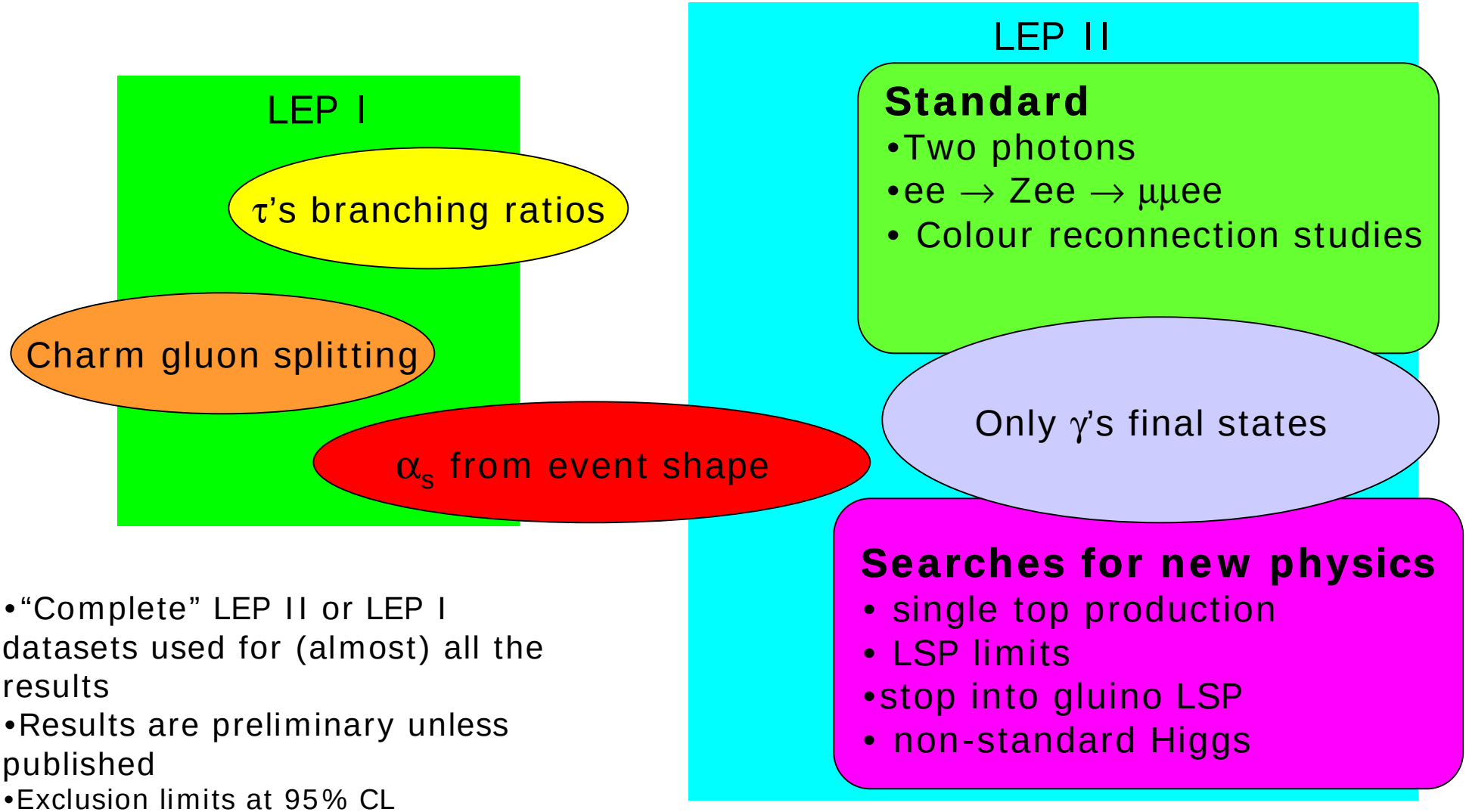
Andrea Venturi

INFN Pisa and CERN

On behalf of the ALEPH Collaboration

LEP Physics Jamboree Jul 22nd 2002

Outline



- "Complete" LEP II or LEP I datasets used for (almost) all the results
- Results are preliminary unless published
- Exclusion limits at 95% CL

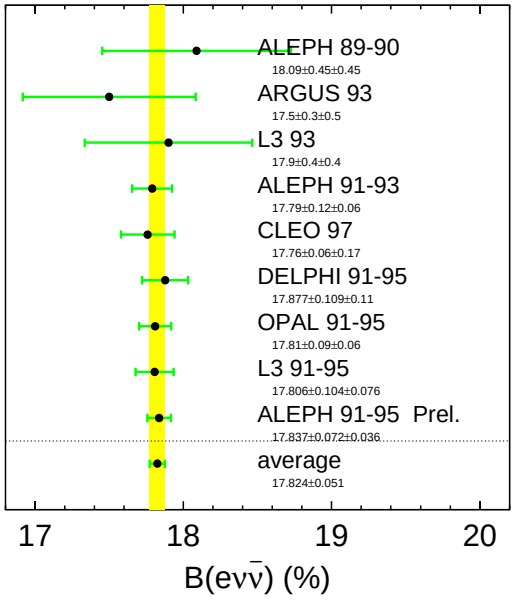
LEP I: τ Branching Ratios

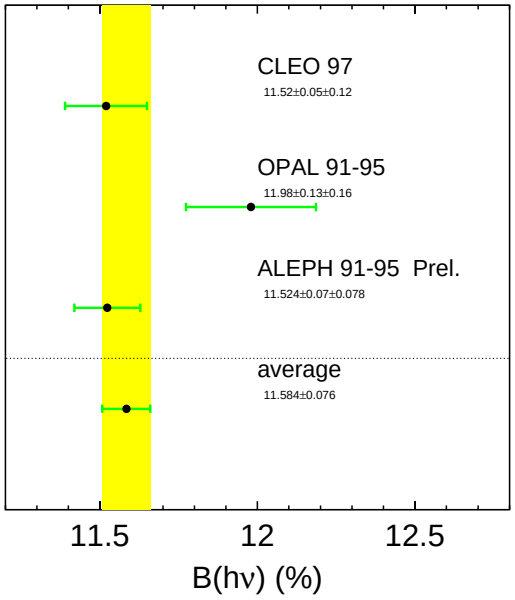
- New results with the full LEPI statistics: ~330k ττ pairs
- Classification of each τ decay according to number of tracks, π^0's and particle id: 13 classes (e,μ,h,hπ^0,h2π^0,...,3h,3hπ^0,...)
- Improved treatment of MC corrections and systematic evaluation, especially γ's and π^0's
- Results corrected for the τ decays into K's,ω's and η's using previous analyses (ALEPH and CLEO)

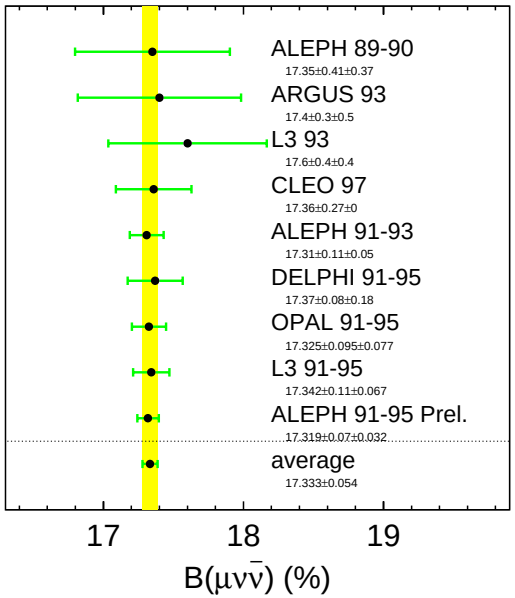
Table 1: τ Branching fractions (modes without kaons): ALEPH Preliminary

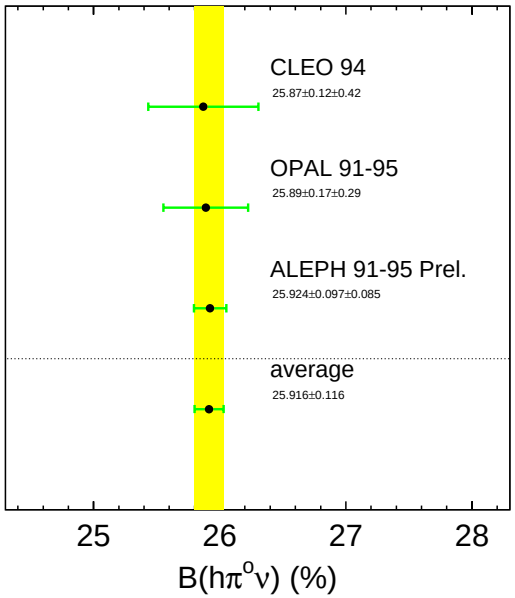
mode	B $\pm\sigma_{\rm stat} \pm \sigma_{\rm syst}$ [%]	
e	$17.837 \pm 0.072 \pm 0.036$	ALEPH
μ	$17.319 \pm 0.070 \pm 0.032$	ALEPH
π^-	$10.828 \pm 0.070 \pm 0.078$	ALEPH
$\pi^-\pi^0$	$25.471 \pm 0.097 \pm 0.085$	ALEPH
$\pi^-2\pi^0$	$9.239 \pm 0.086 \pm 0.090$	ALEPH
$\pi^-3\pi^0$	$0.977 \pm 0.069 \pm 0.058$	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
$a_1^-(\to \pi^-\gamma)$	$0.040 \pm 0.000 \pm 0.020$	estim
$\pi^-\omega(\to \pi^0\gamma, \pi^+\pi^-)$	$0.253 \pm 0.005 \pm 0.017$	ALEPH
$\pi^-\pi^0\omega(\to \pi^0\gamma, \pi^+\pi^-)$	$0.048 \pm 0.006 \pm 0.007$	ALEPH + CLEO
$\pi^-2\pi^0\omega(\to \pi^0\gamma, \pi^+\pi^-)$	$0.002 \pm 0.001 \pm 0.001$	CLEO
$\pi^-\pi^-\pi^+\omega(\to \pi^0\gamma, \pi^+\pi^-)$	$0.001 \pm 0.001 \pm 0.001$	CLEO

LEP I: τ Branching Ratios



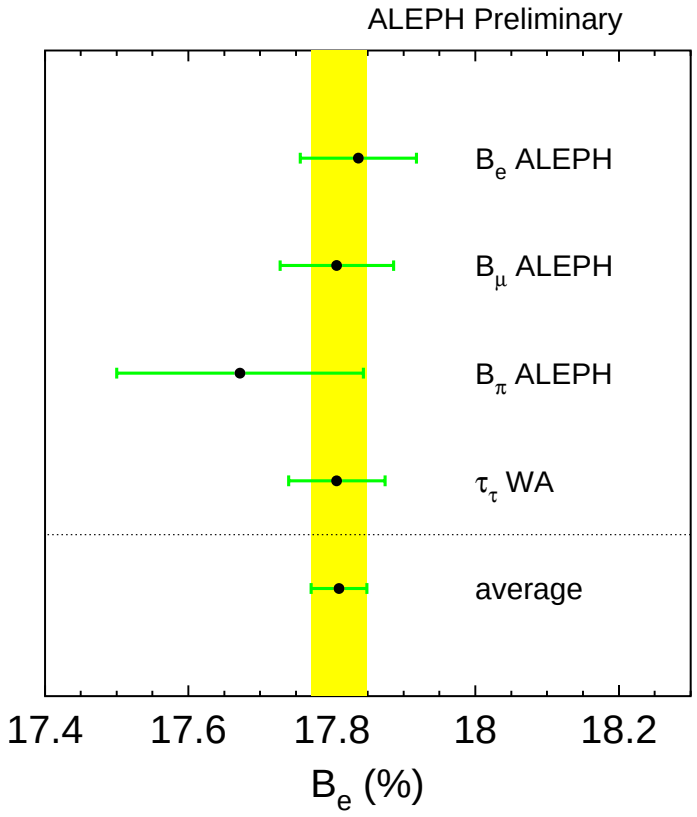






Lepton universality: B_μ and B_π translated into electron BR

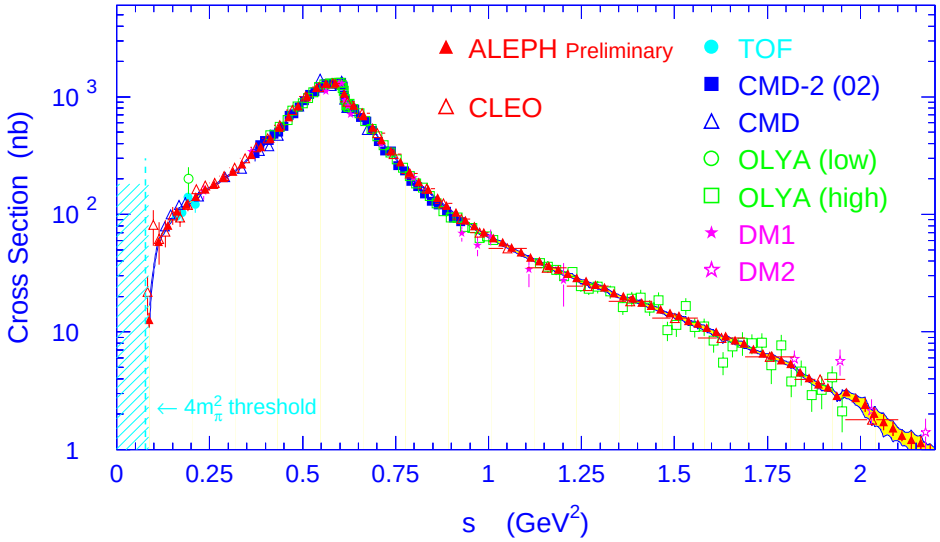
WA τ, μ and π lifetimes and τ mass used



Lepton universality tested within 2-3 per mille

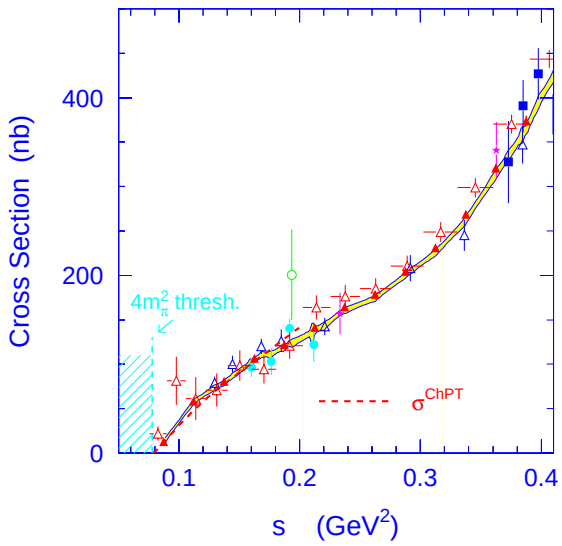
LEP I: τ Branching Ratios

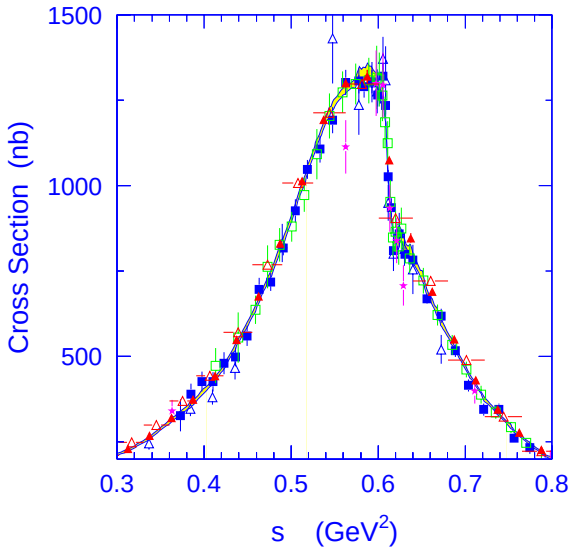
- **Vector spectral functions** from $\pi\pi^0$, $3\pi\pi^0$, $\pi 3\pi^0$ BR's and mass distributions



Hadronic contribution to g-2 radiative corrections

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





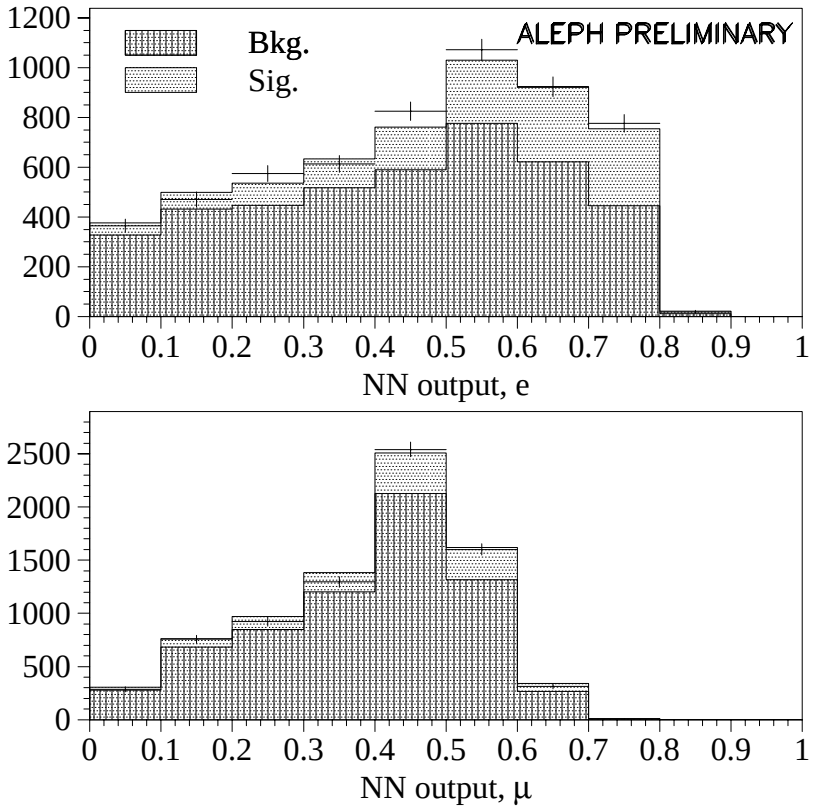
LEP I: gluon splitting into charm

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

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

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

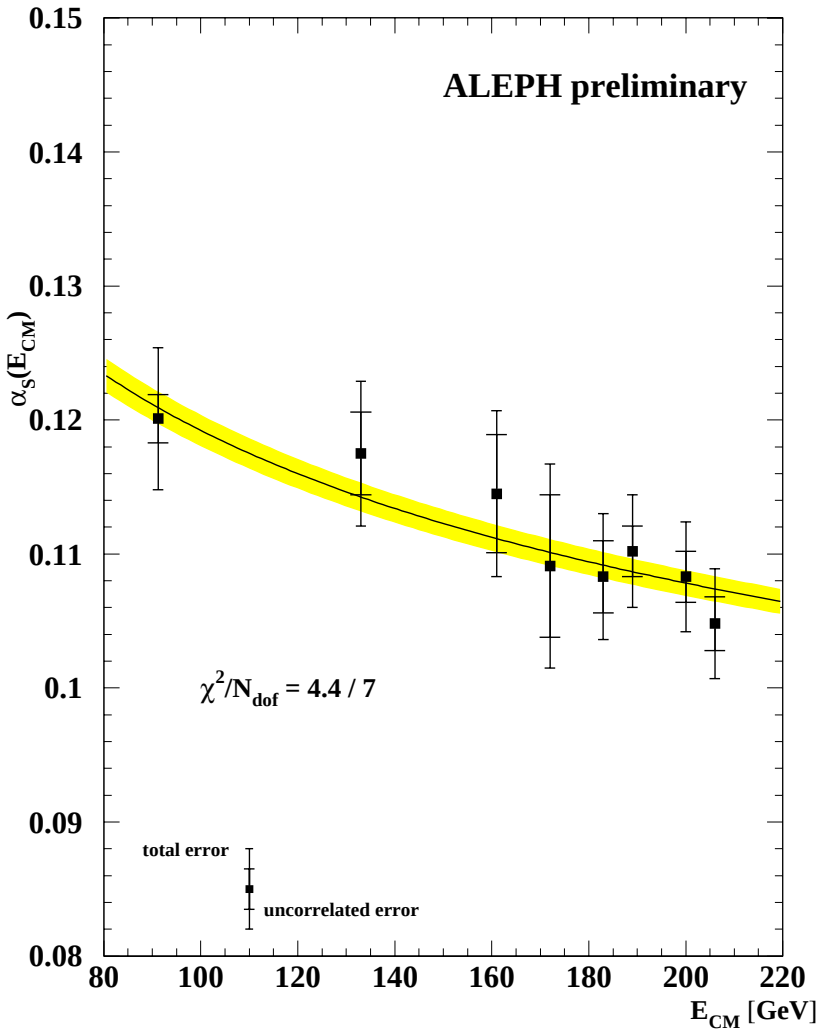
$g_{cc} = (2.98 \pm 0.48)$ %
WA: (2.96 ± 0.38)%



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

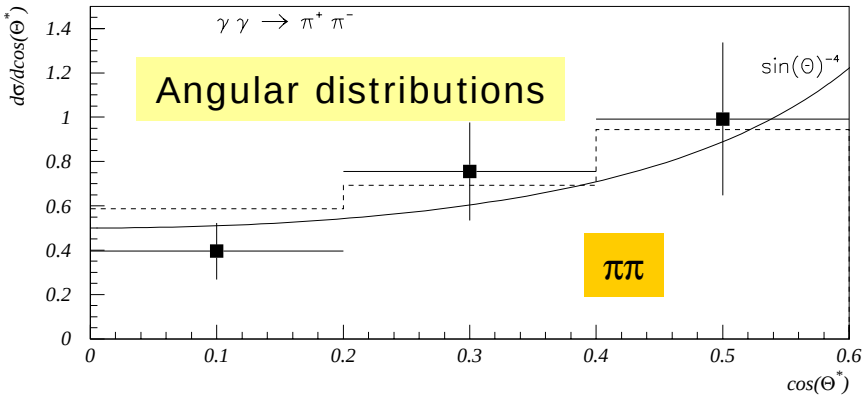
- Results from the full LEP I+LEP II ALEPH data set
- 6 event-shape variables used: T, M_H^2, B_W, B_T, C, -log y_3
- Fit with $O(\alpha_s^2)$ + NLLA
- Good agreement with α_s running

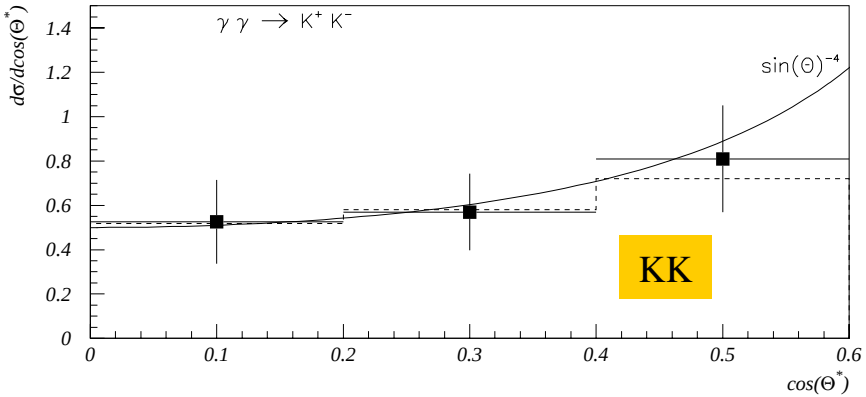
running to M_Z and combining:
$\alpha_s(M_Z) = 0.1211 \pm 0.0047$

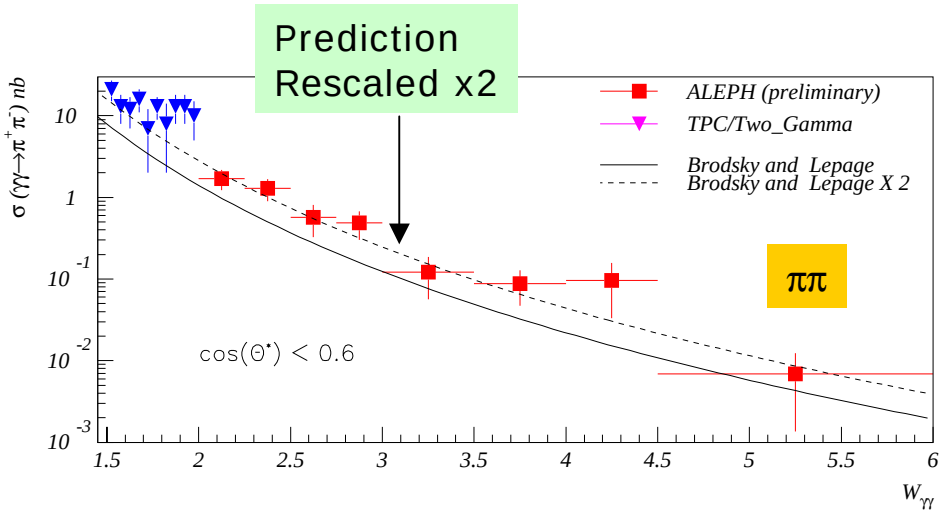


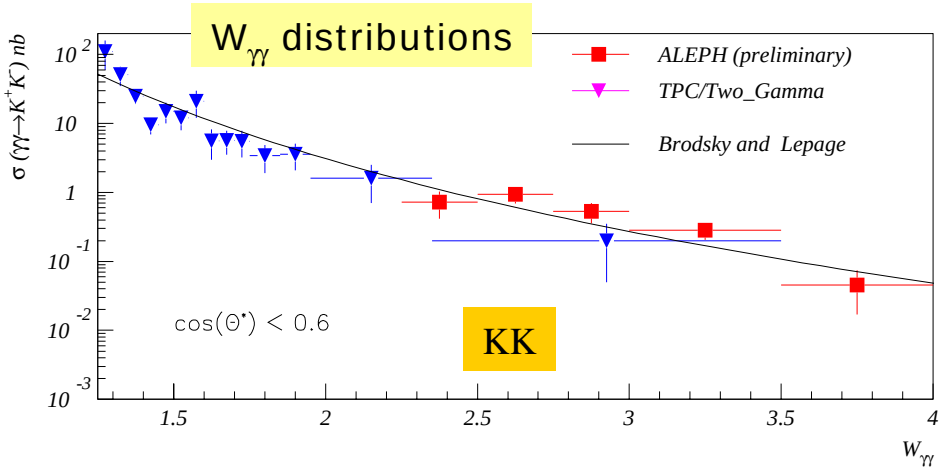
LEP II: $\gamma\gamma \to \pi^+\pi^-$ and $\gamma\gamma \to K^+K^-$

- Measurements with LEP II data



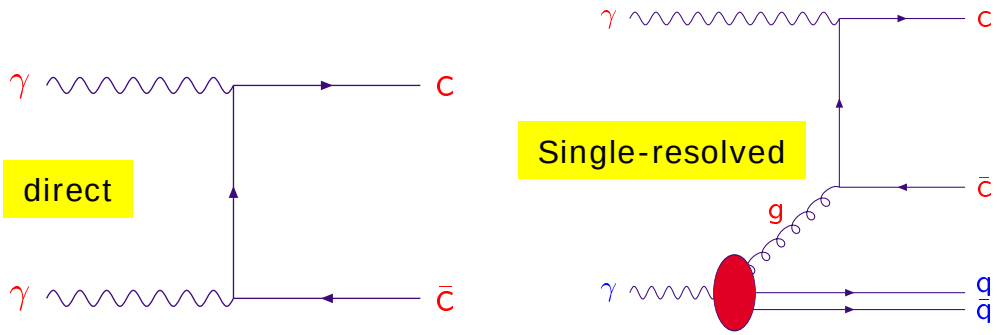


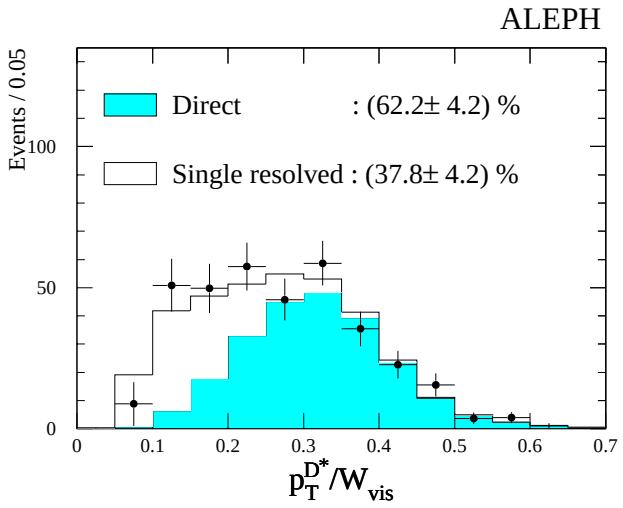


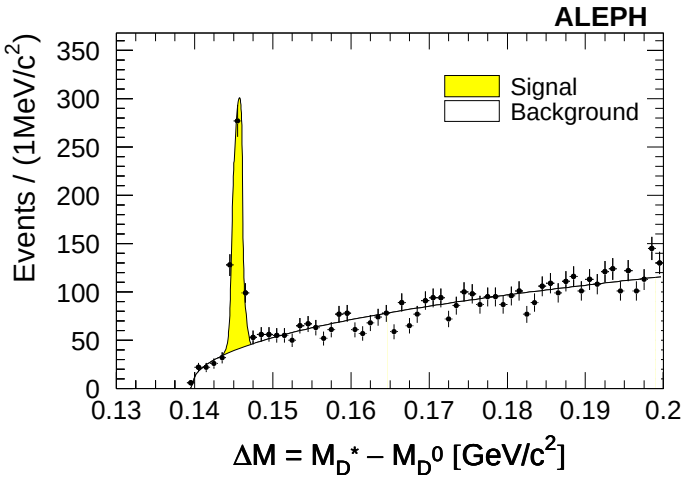


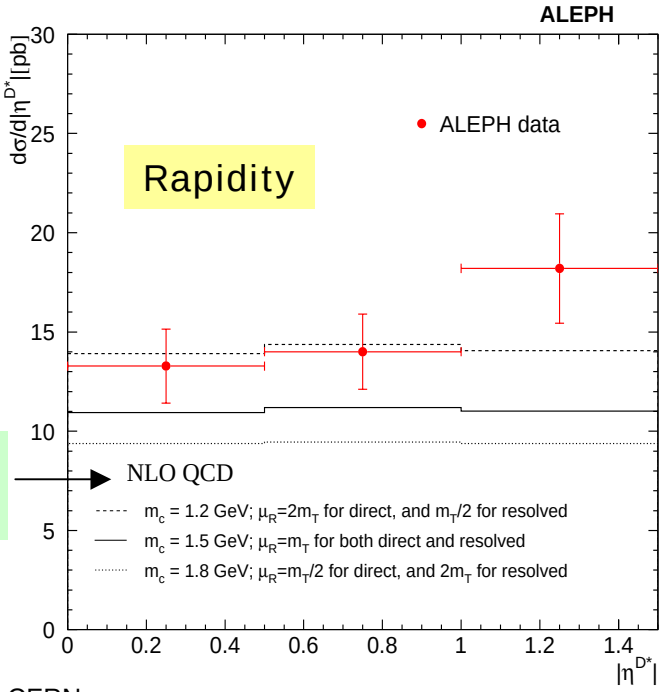
LEP II: $\gamma\gamma \rightarrow D^{*\pm} X$

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



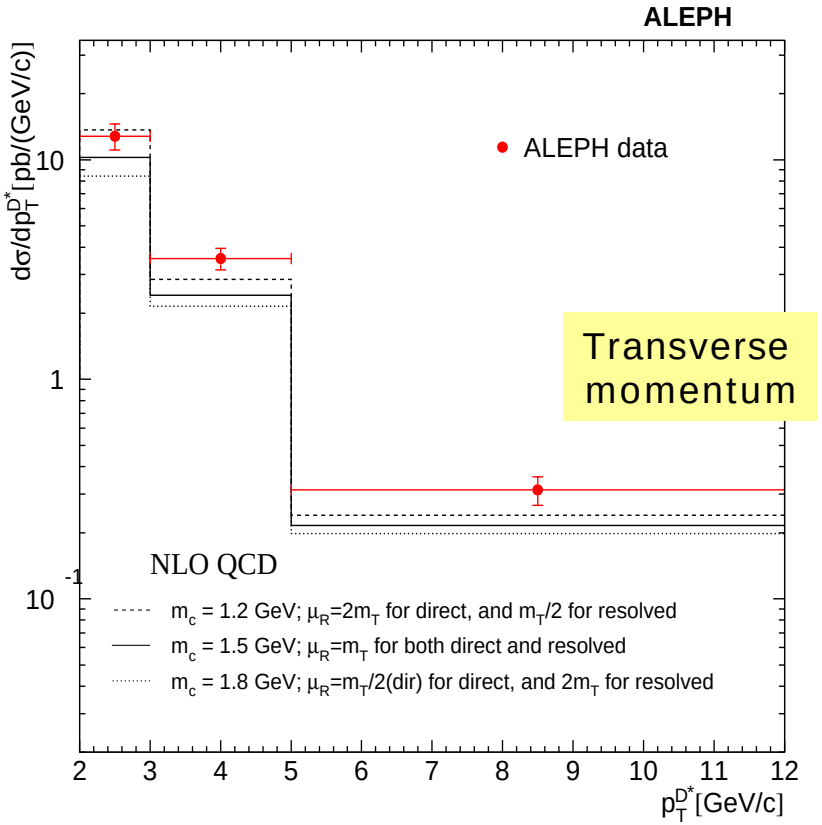


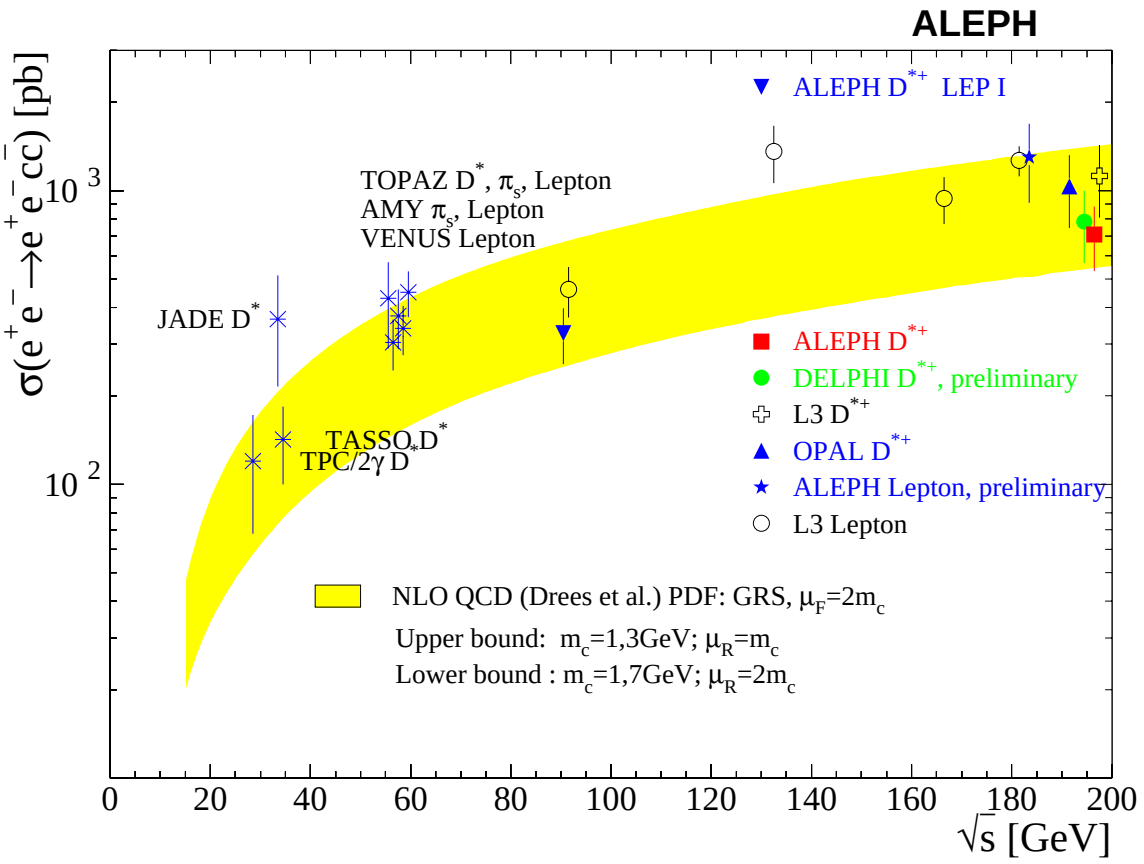




Frixione et al. (2000)

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



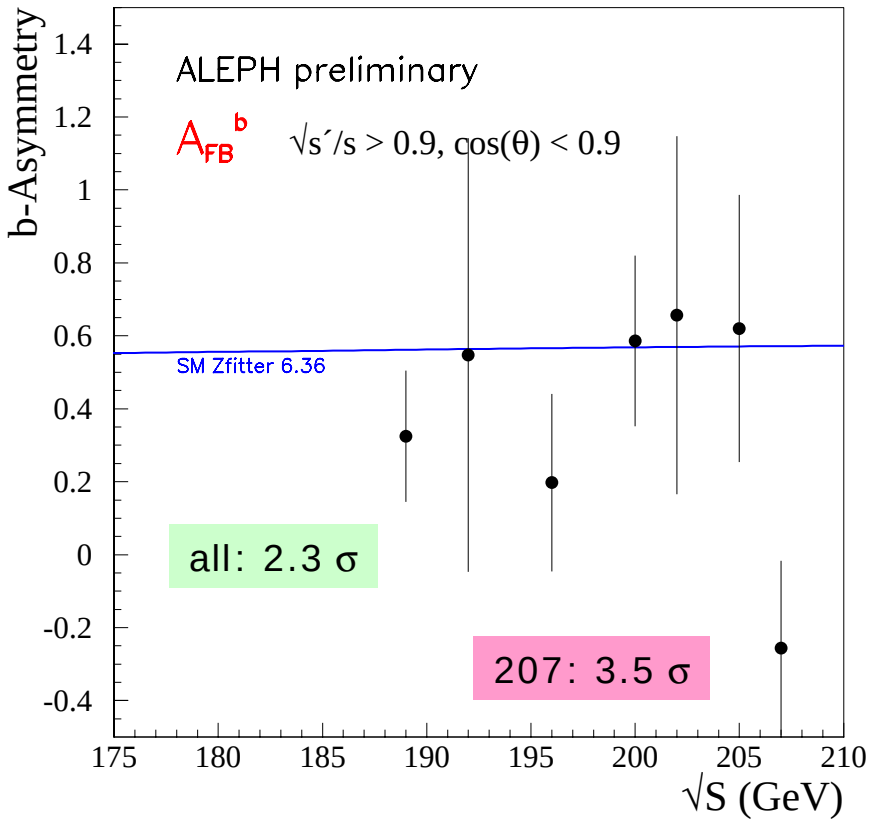


LEP II: 2 fermions production: HF results

- New results: A^b_{FB}, Q^{udsc}_{FB} and R_c

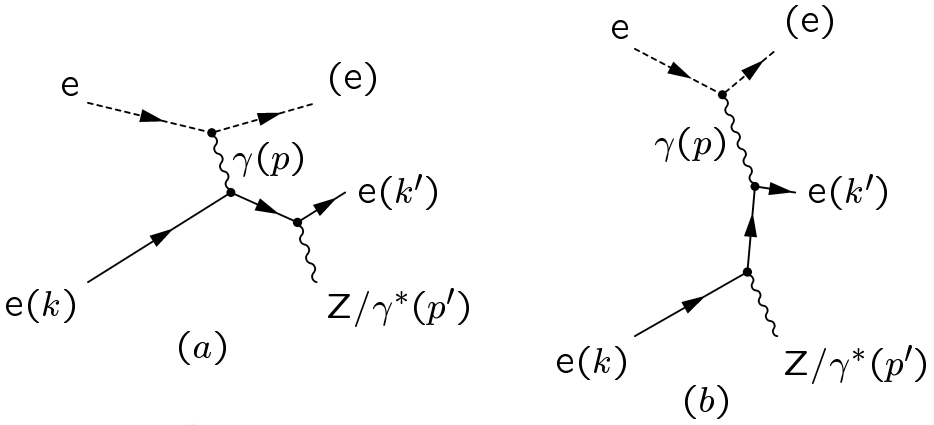
E_{CM} (GeV)			SM
205	A^b_{FB}	0.620 ± 0.338 ± 0.138	0.571
207		-0.256 ± 0.232 ± 0.057	0.572
205	Q^{udsc}_{FB}	0.0077±0.0051±0.0018	0.0070
207		0.0143±0.0039±0.0020	0.0069

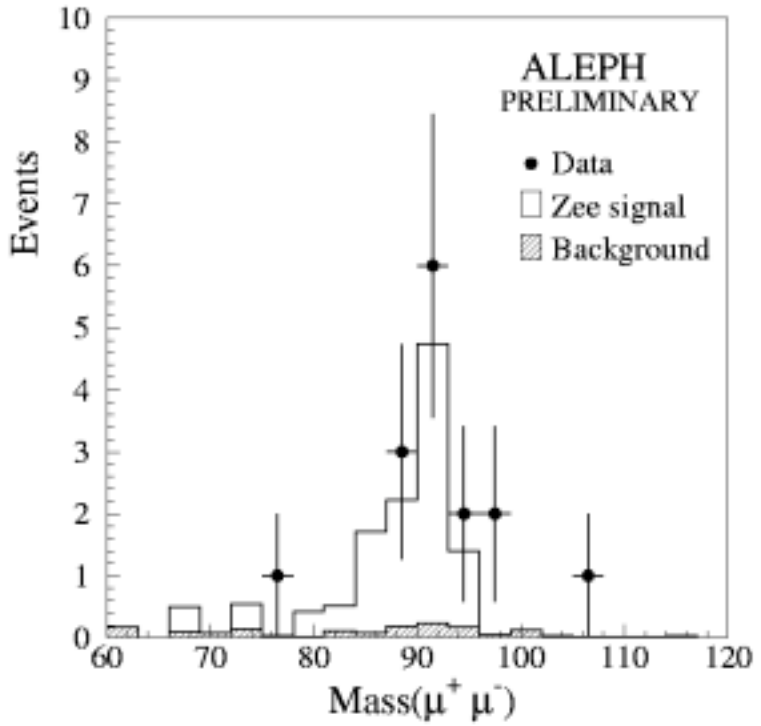
E_{CM} (GeV)	R_c	SM
196	0.287±0.033 ±0.022	0.251
200	0.262±0.035 ±0.014	0.252
205	0.296±0.037 ±0.016	0.253
207	0.287±0.029 ±0.021	0.253



LEP II (4f): ee → Zee → eeμμ cross section

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





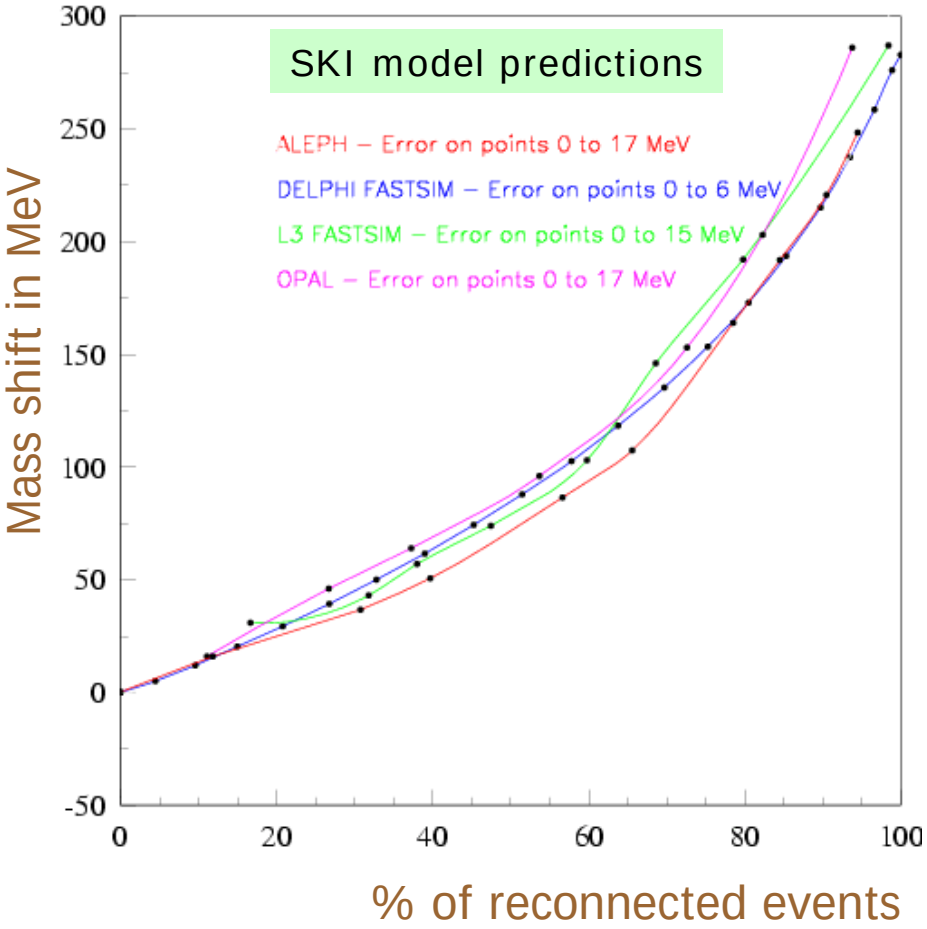
$\sigma(ee \to Zee \to ee\mu\mu) = 57 \pm 14 \pm 4$ fb
(average from 183 to 207 GeV)

Looking for Colour Reconnection in WW→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→4q and WW →lνqq events
  - Particle flow analysis in WW→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

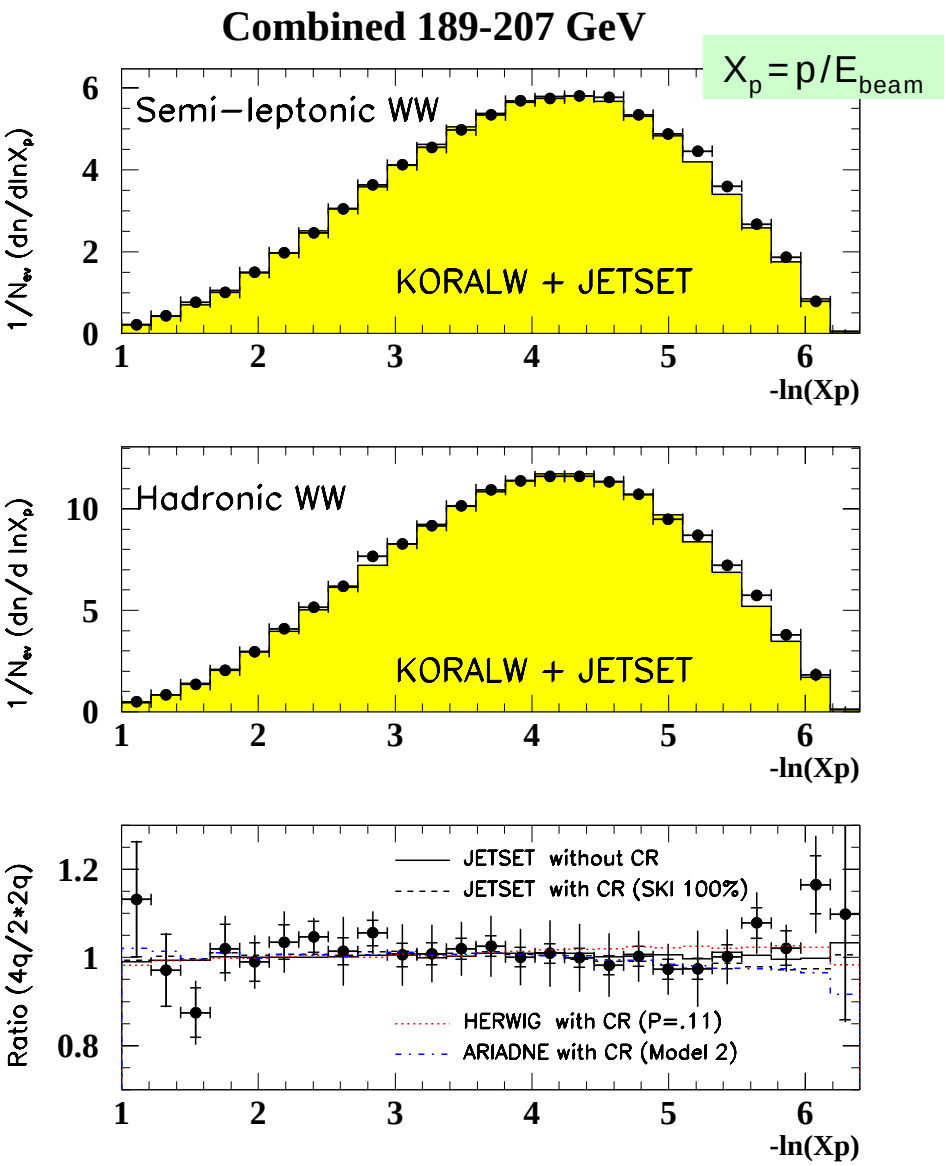
ΔM_W with CR models

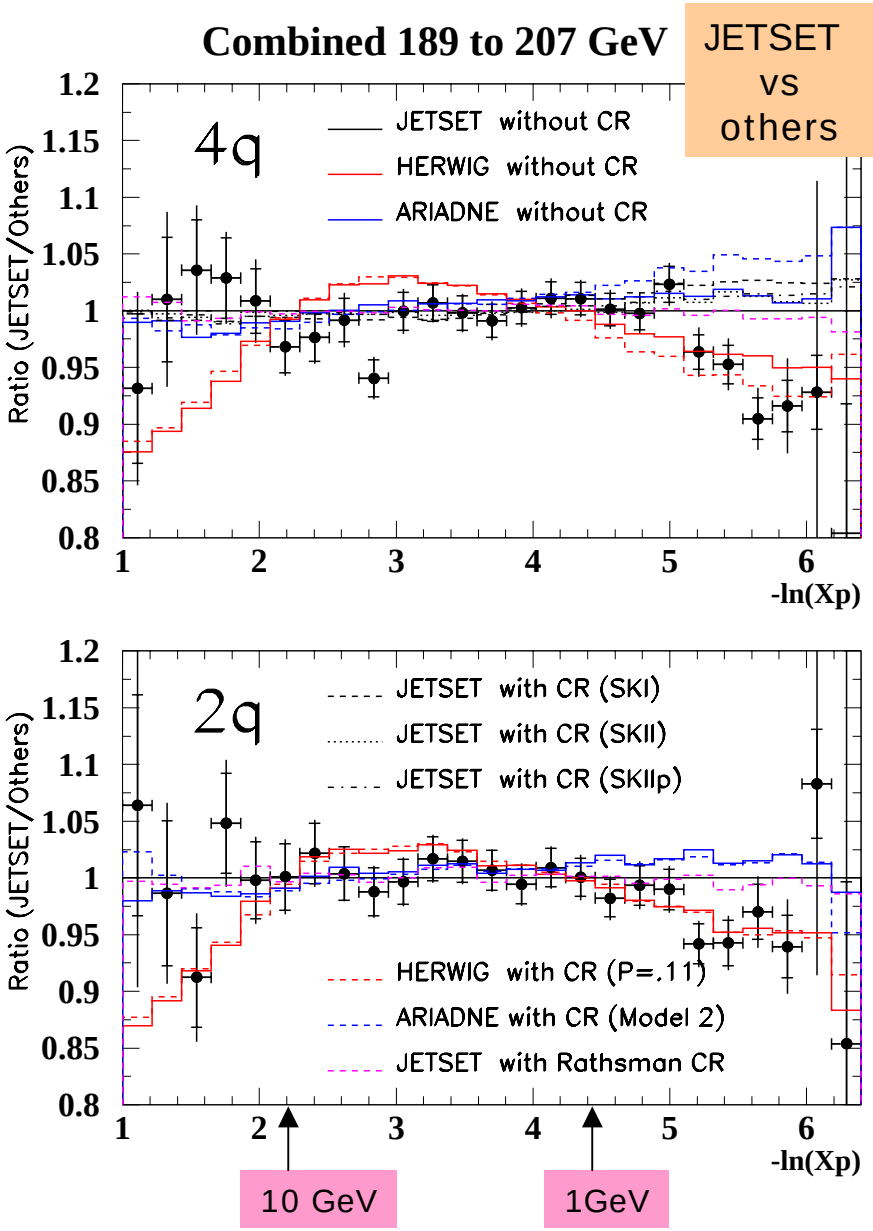


Model	ΔM (MeV)
Herwig CR	~30
Ariadne 2 CR	70-80
Rathsman (GAL)	30-40

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

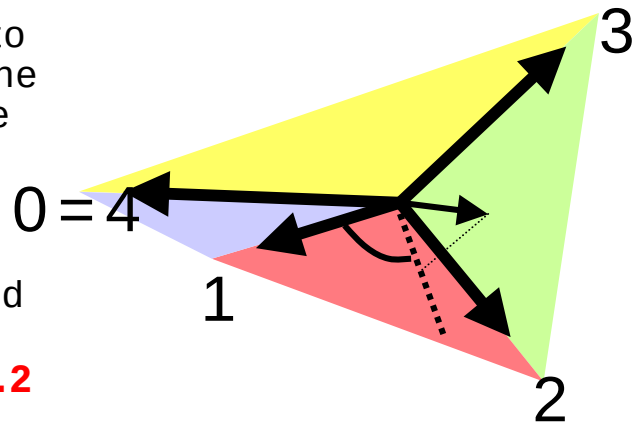
CR: Charged Particle spectra

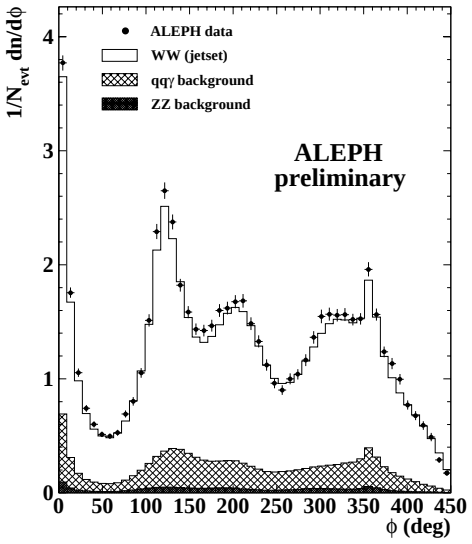


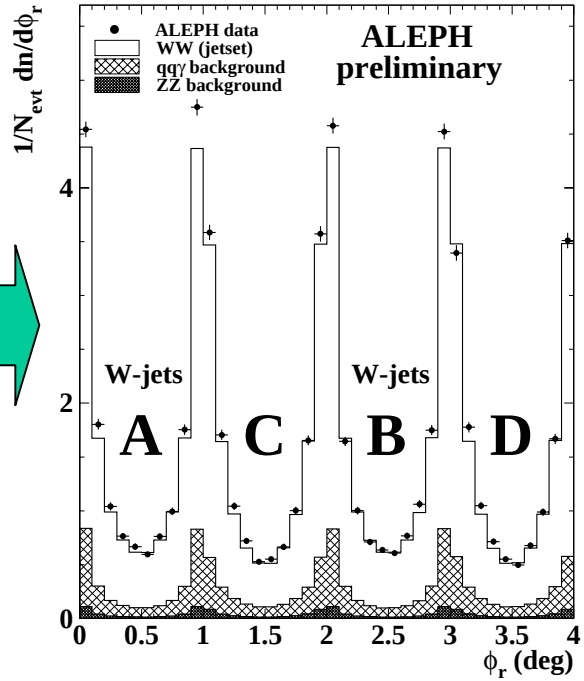


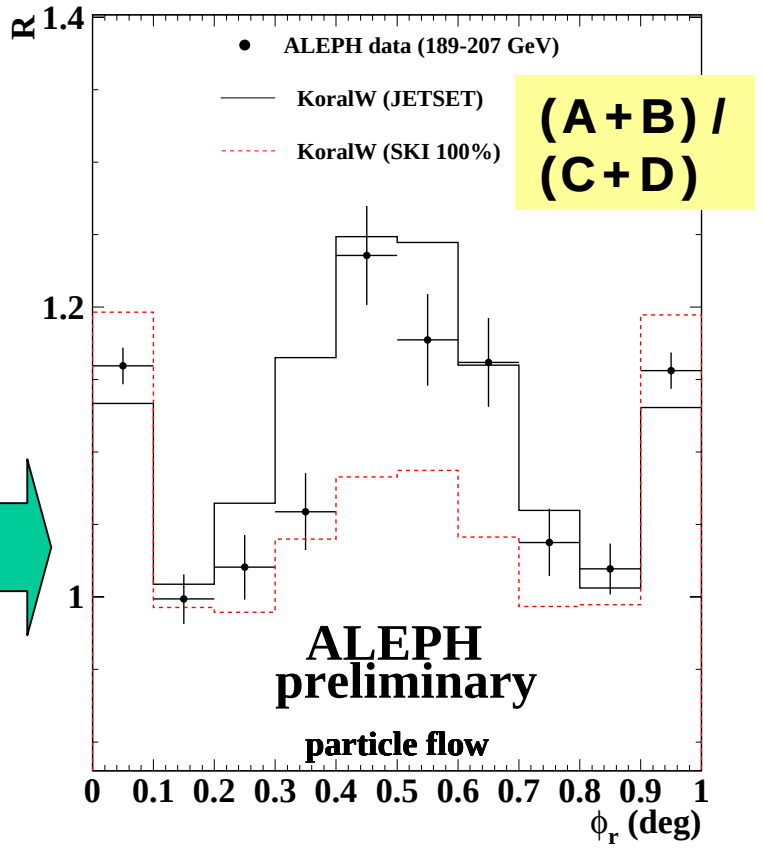
CR: Particle flow between W's

- In WW → 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 = one bin from 0.2 to 0.8









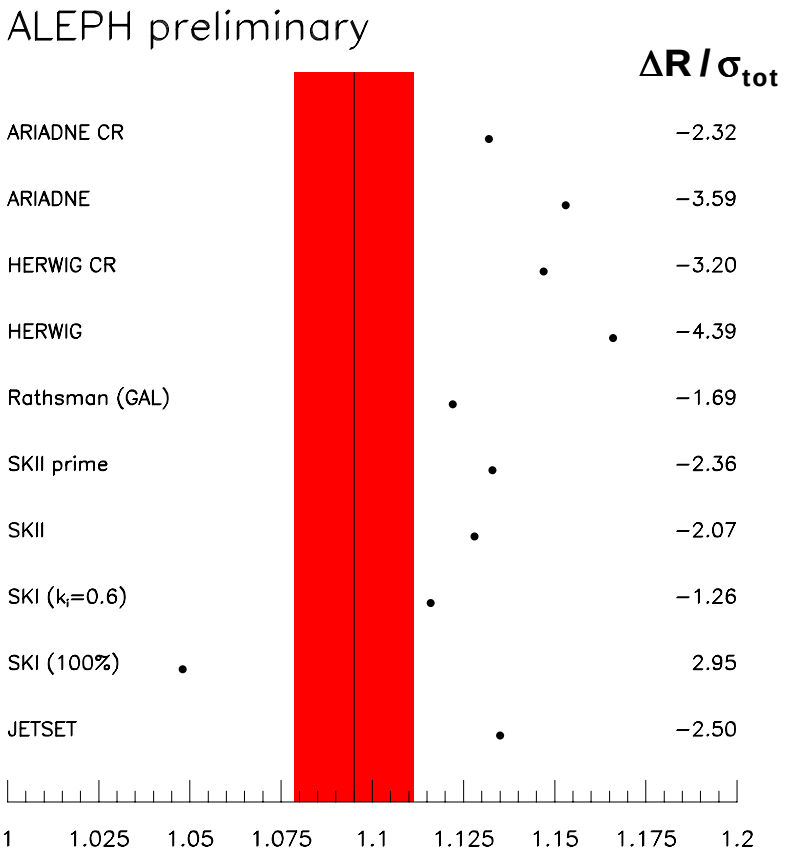
R_n = 1.095 ± 0.014 (stat) ± 0.006 (syst) ± 0.006 (extrap)

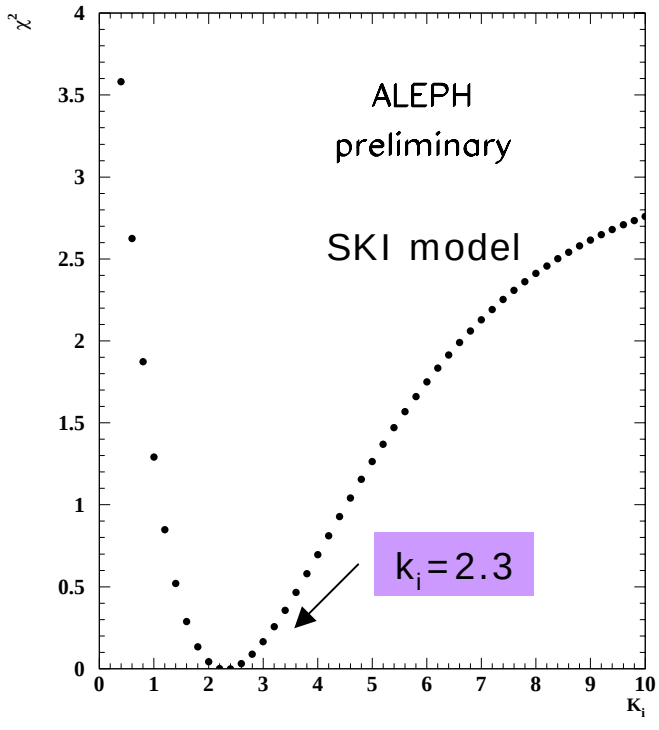
extrapolated to 189 GeV

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(data)= 1.095±0.014(stat) ±0.006(syst) ±0.006(extrap)**





Model parameter K_i

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

Bias induced by MC tuning has not been evaluated yet

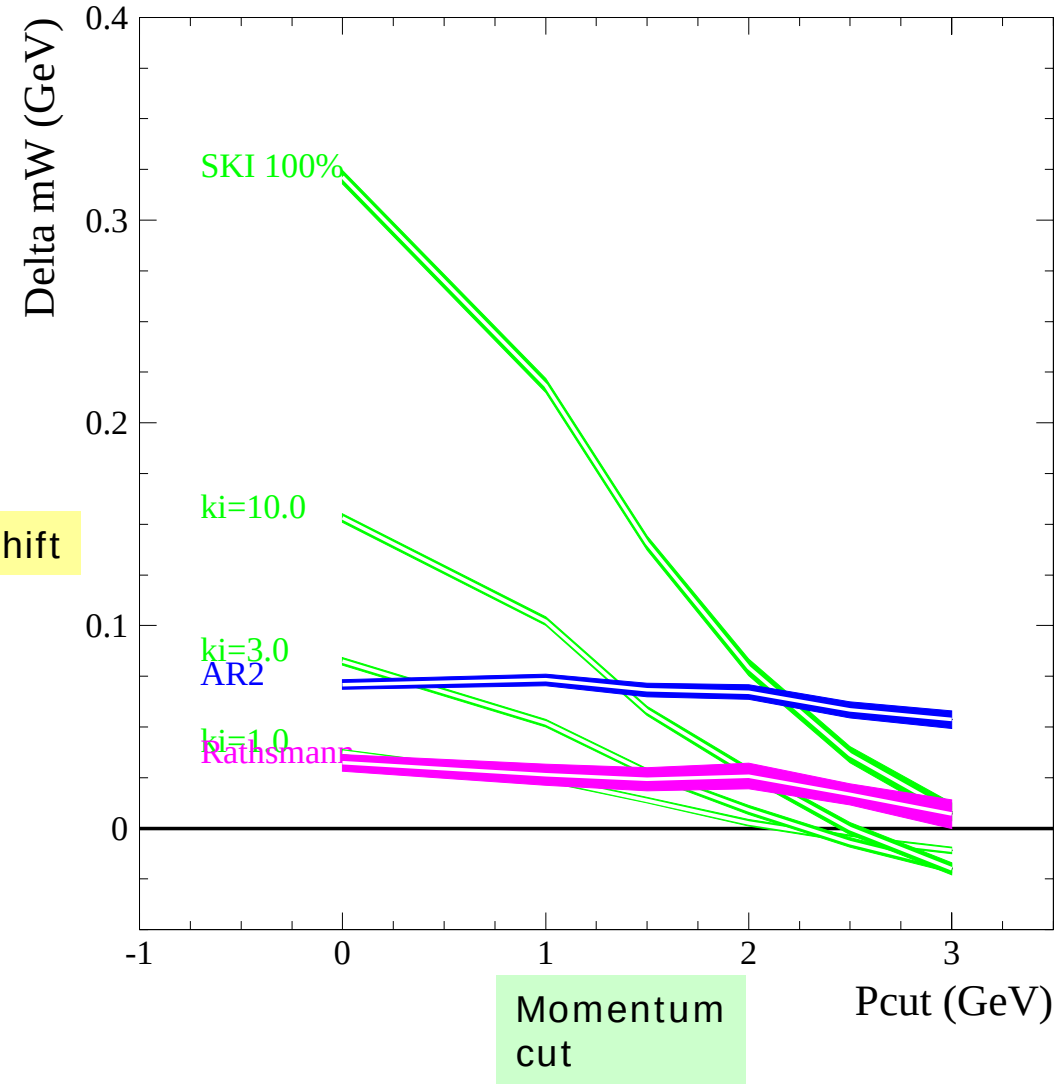
CR from the W mass

- 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)

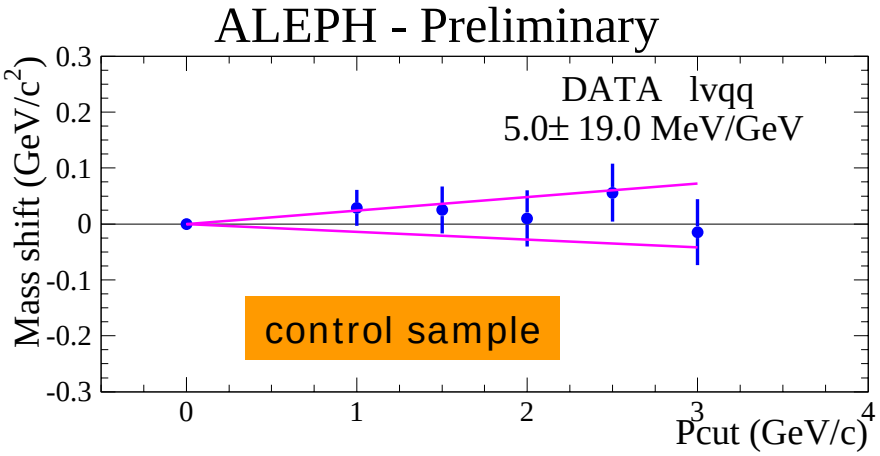
- The following results have been obtained with the **pcut analysis**

- The slope of the W mass measurement is compared to the MC predictions.

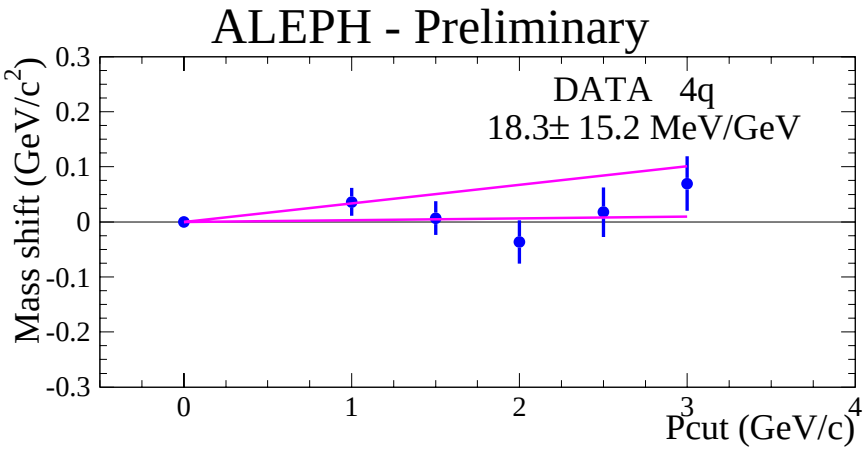


CR from the W mass

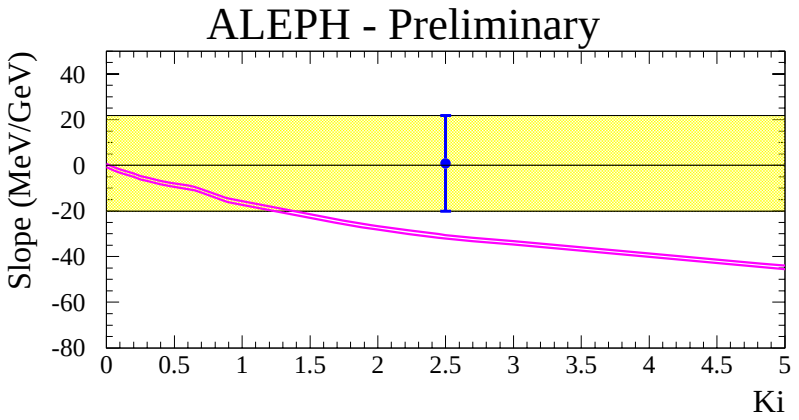
Semileptonic events

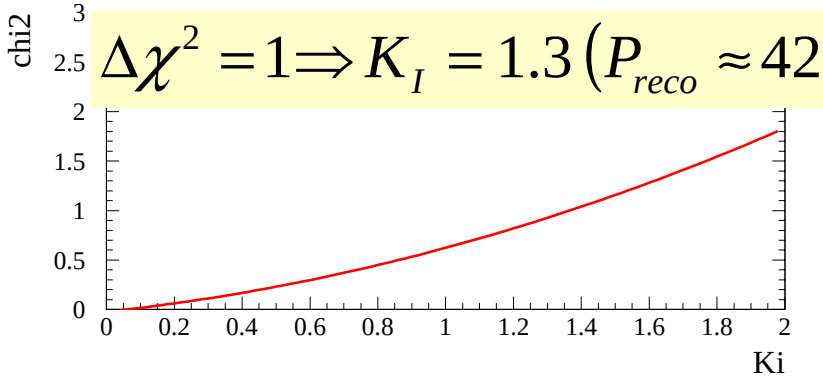


Fully hadronic events



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





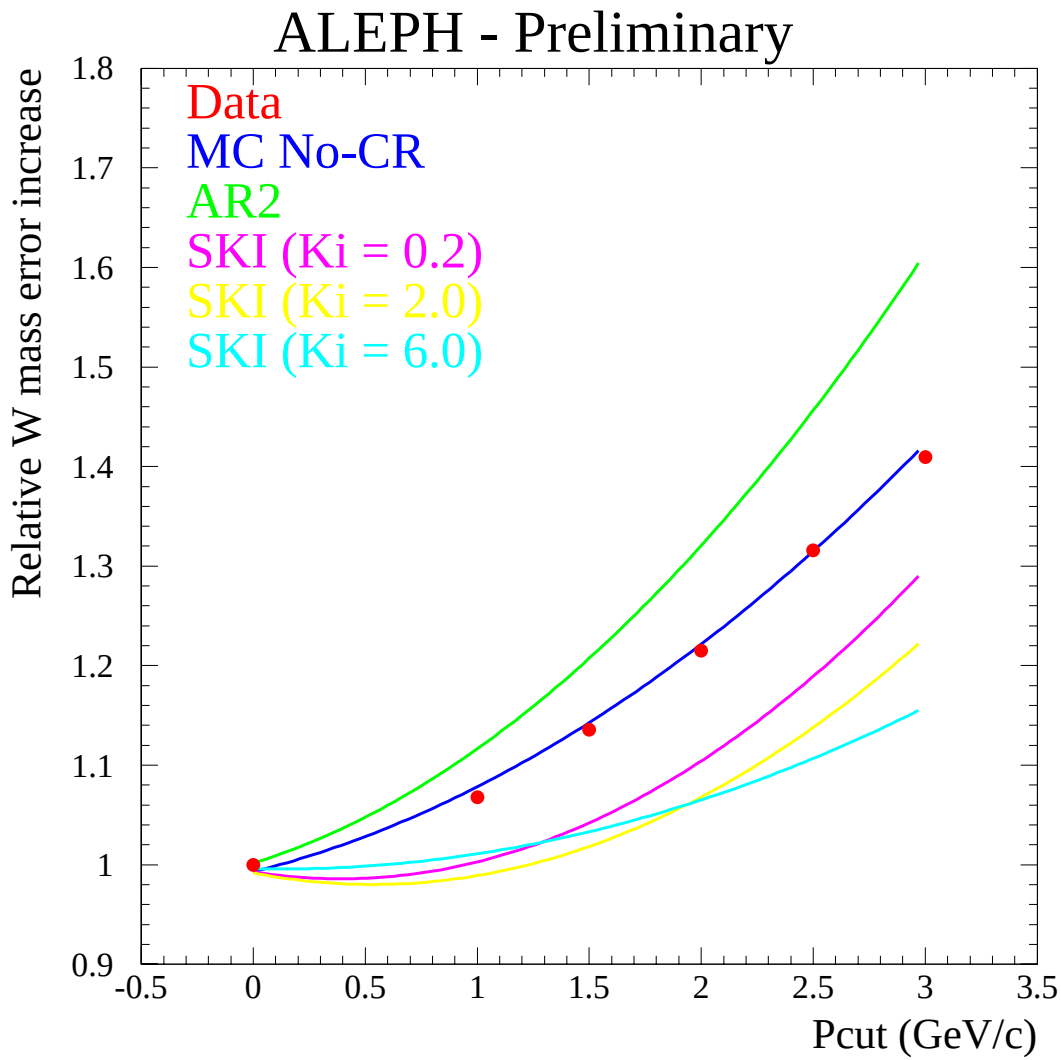
$$\Delta\chi^2 = 1 \Rightarrow K_I = 1.3 \left(P_{reco} \approx 42\%\right)$$

- **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



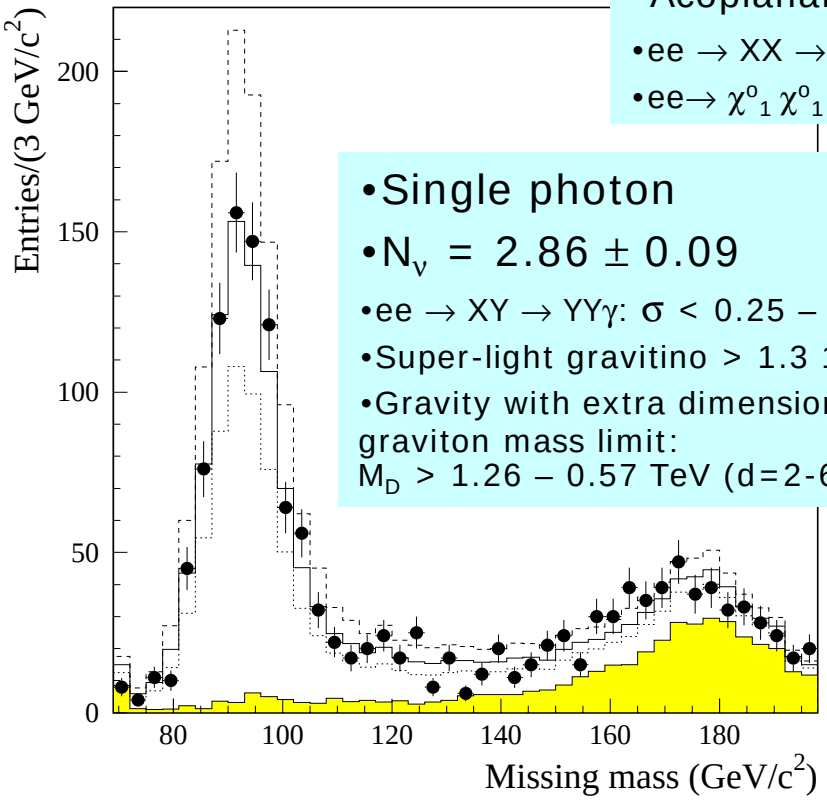
From SM to new physics: γ's final states

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

•Acoplanar photons

•ee → XX → YYγγ: σ < 0.1 – 0.04 pb

•ee→ $\chi^0_1 \chi^0_1 \rightarrow \tilde{G}\tilde{G}\gamma\gamma$: M_χ > 98.8 GeV



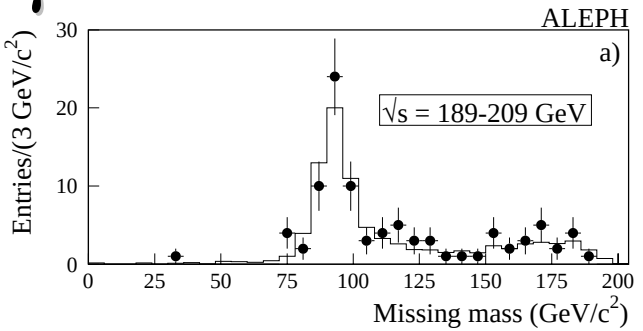
•Single photon

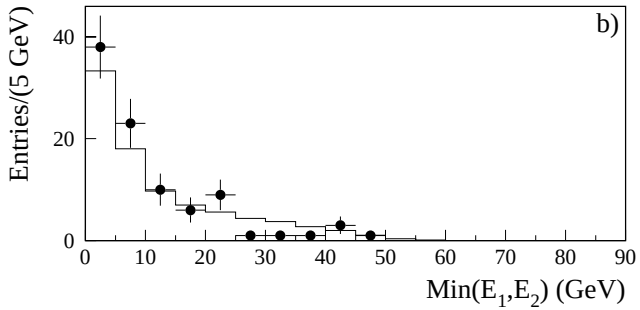
•N_ν = 2.86 ± 0.09

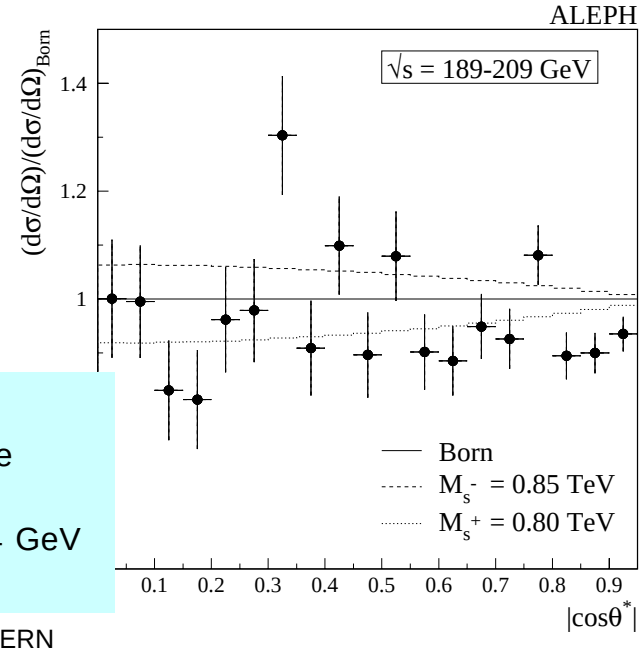
•ee → XY → YYγ: σ < 0.25 – 0.05 pb

•Super-light gravitino > 1.3 10^{-5} eV

•Gravity with extra dimension:
graviton mass limit:
M_D > 1.26 – 0.57 TeV (d=2-6)







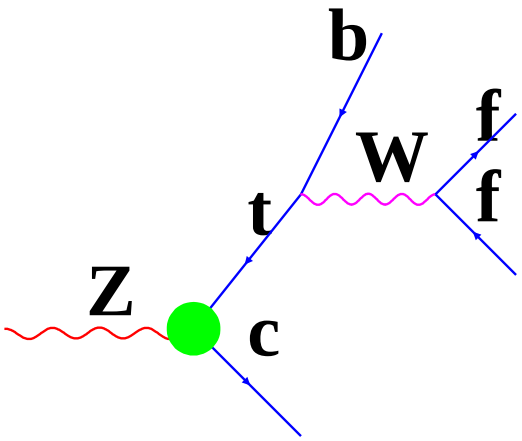
•Collinear photons

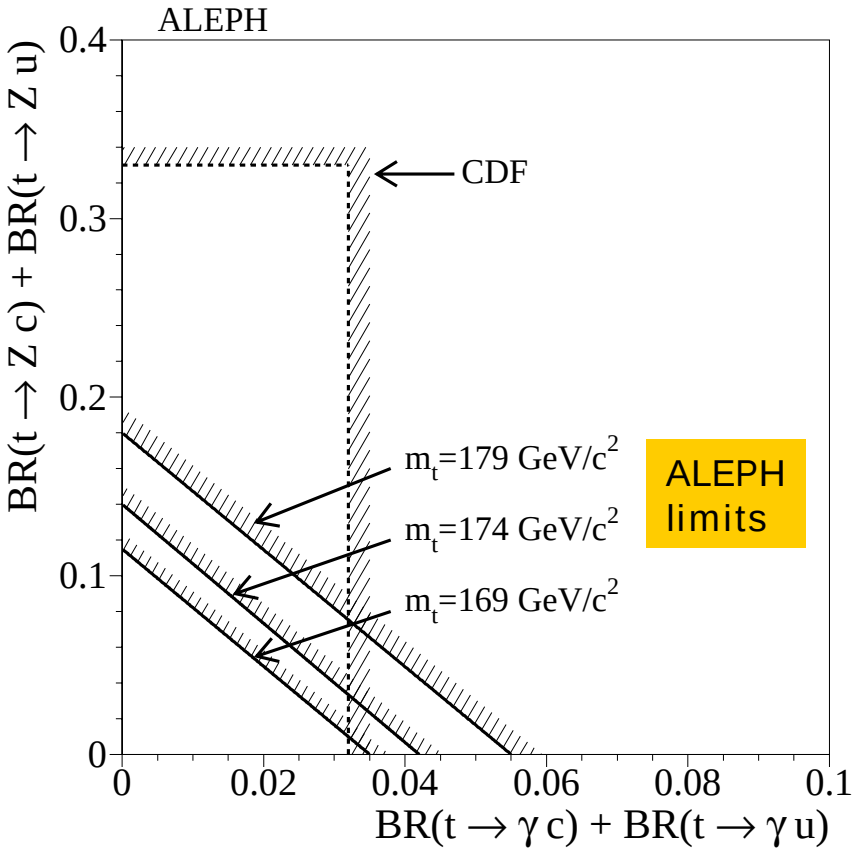
•Gravity with extra dimension: string scale

•Contact interactions:
Λ_6 > 1.35 TeV, Λ_7 > 0.74 TeV , Λ_8 > 21.4 GeV

•Excited electron: M > 213 GeV (f_γ = 1)

Single top production limits





- Final results with full LEPII data
  - CERN-EP/2002-042
- Multijet (with one b) final state (with or without leptons)
- ε ~ 3% (lepton) , ~ 13.5% (hadron) including BR's

- 24 candidates in data (20.1 expected)

- BR(t→Zc)+BR(t→Zu)<14% (95% CL) (no γ coupling, m_{top}=174 GeV)

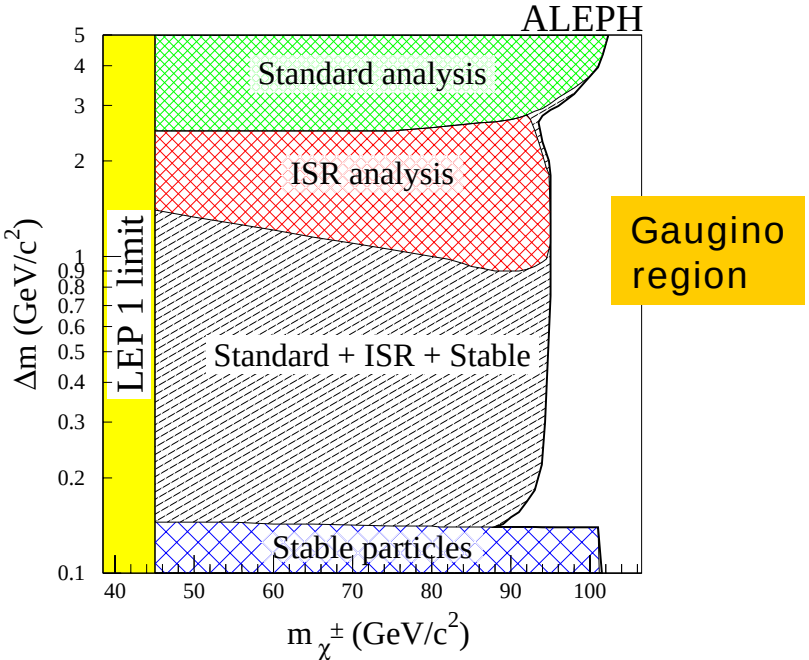
Charginos nearly degenerate with neutralino

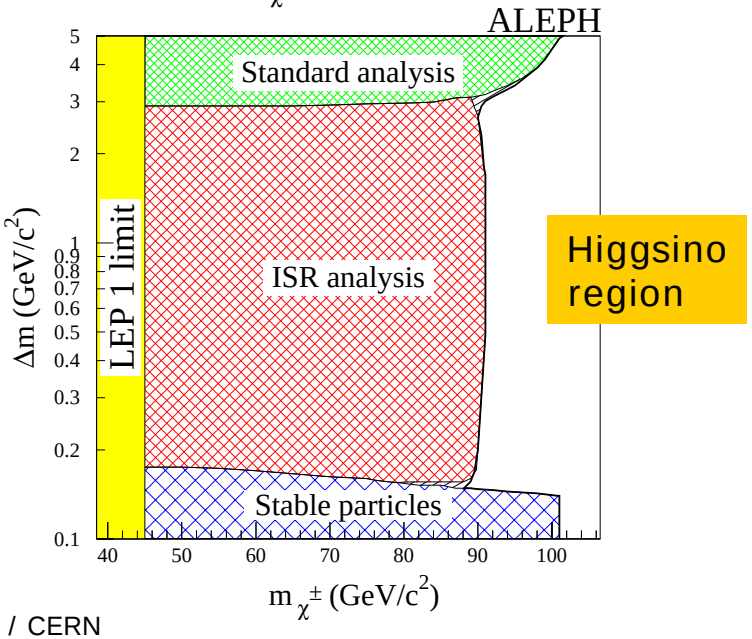
- Small mass differences with mass unification only if M_2 very large
- More “natural” with AMSB

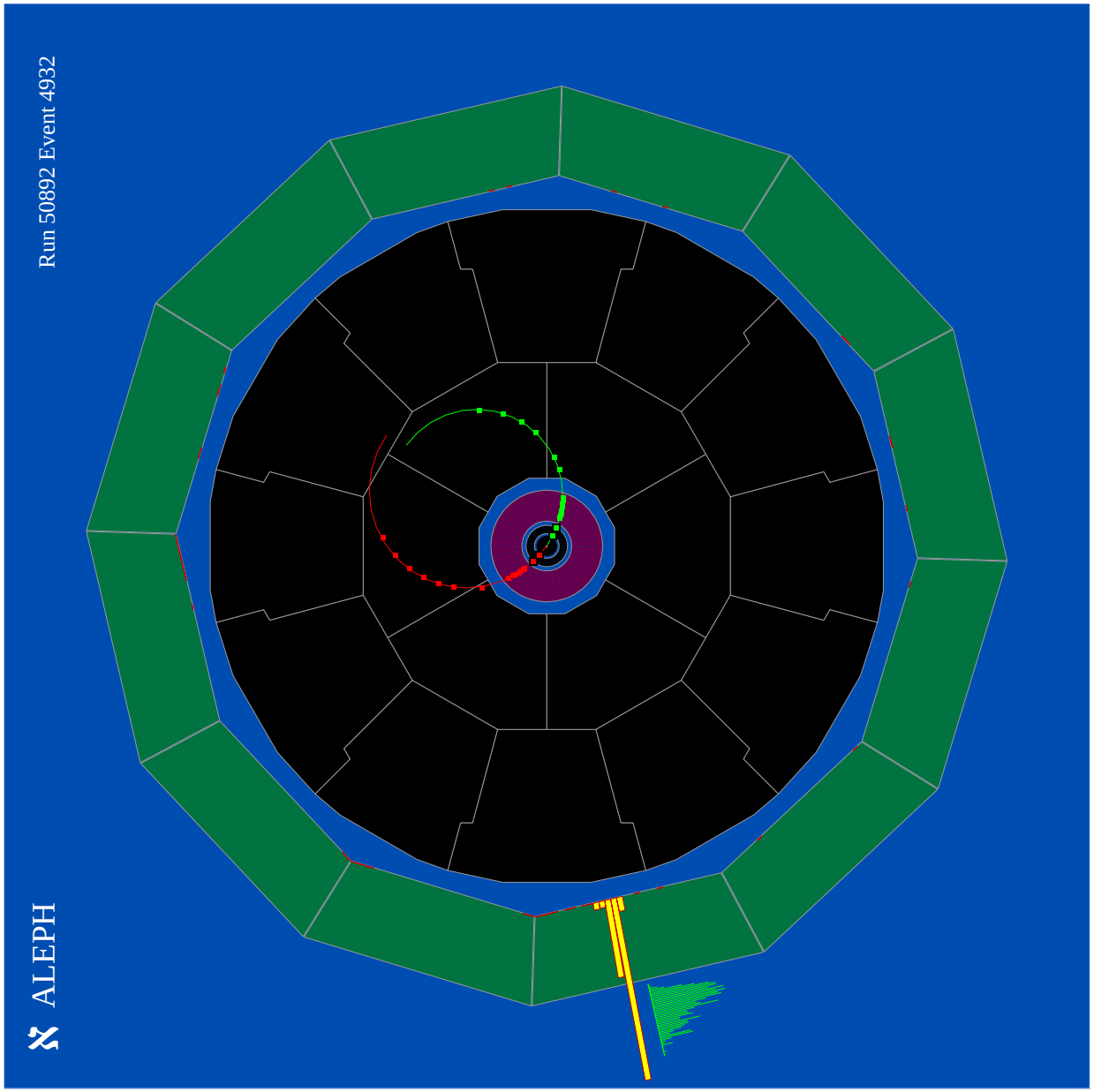
- Dedicated analysis to cover the hole between:
  - Long-lived charginos: search for heavy stable charged particles
  - Chargino’s decay products can trigger DAQ

- Search for **ISR** γ plus **soft tracks** compatible with $\gamma\chi^+\chi^-$ production and decay

M_χ > 88 GeV (heavy sfermions)
(Phys. Lett B533 (2002) 223)

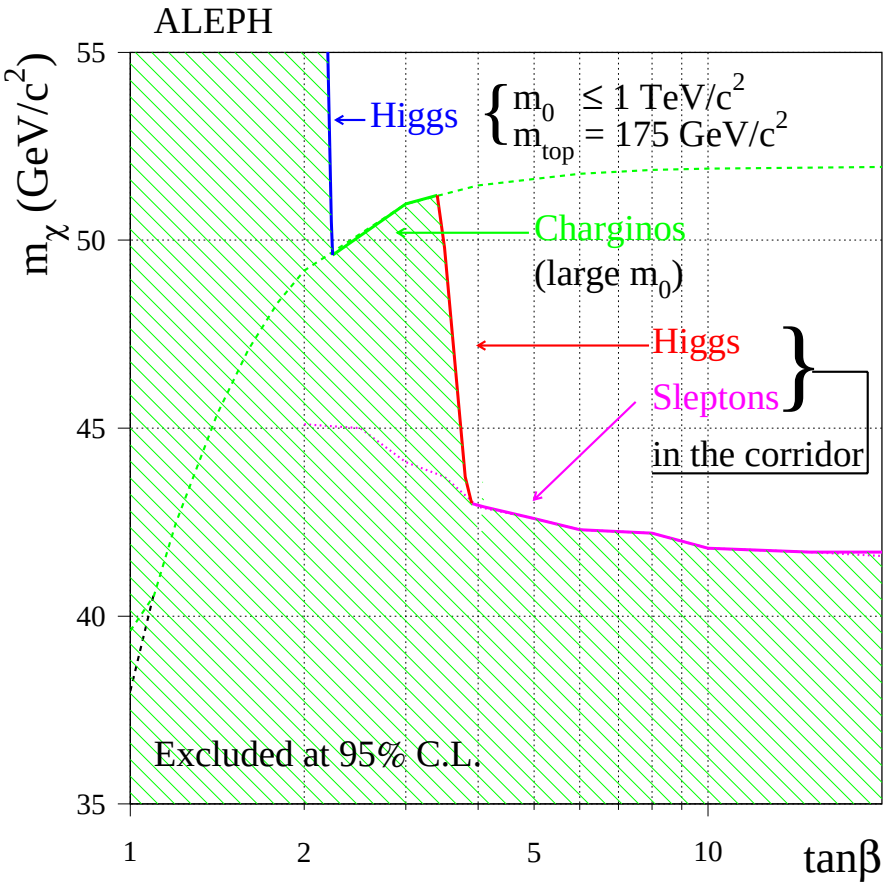





Run 50892 Event 4932
ALEPH

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**
  - $\chi^\pm \to \tilde{\tau}\nu$, $\chi^0 \to \tilde{\tau}\tau$ can be dominating
  - $\Delta m(\tilde{\tau} - \chi^0)$ can be small: **soft τ's in final state**



- **Additional searches:**

$ee \to \chi^+\chi^- \to \tilde{\tau}\nu\tilde{\tau}\nu \to \tau\nu\chi^0\tau\nu\chi^0$ acoplanar τ's pairs (large Δm), ISR γ+soft tracks (small Δm)

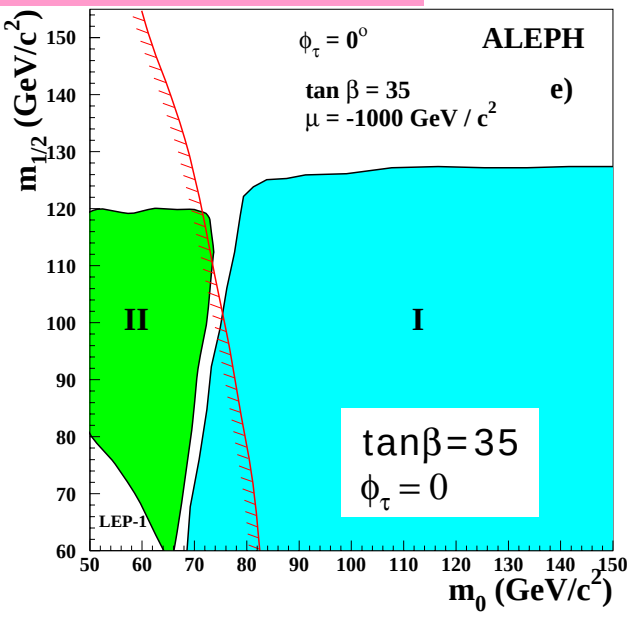
$ee \to \chi^0_1\chi^0_2 \to \tilde{\tau}\tau\chi^0 \to \tau\chi^0\tau\chi^0$ single τ (small Δm)

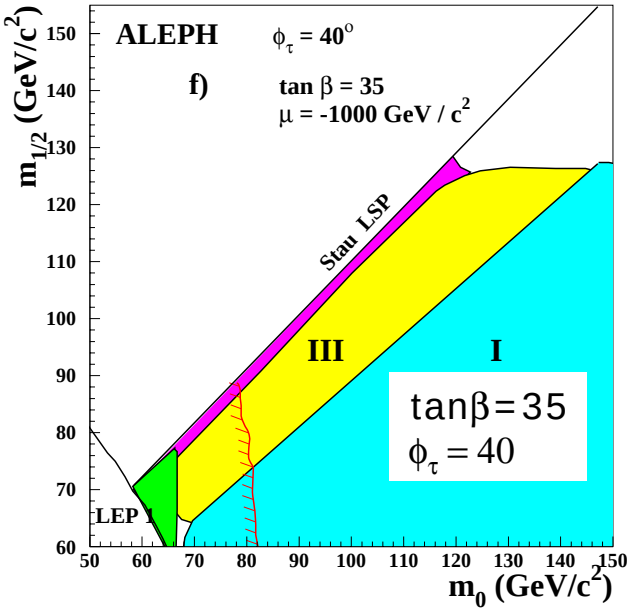
$ee \to \chi^0_2\chi^0_2 \to \tilde{\tau}\tau\tilde{\tau}\tau \to \tau\tau\chi^0\tau\tau\chi^0$ 2–4 τ's final state

LSP limit

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

$m_{1/2}$ vs m_0





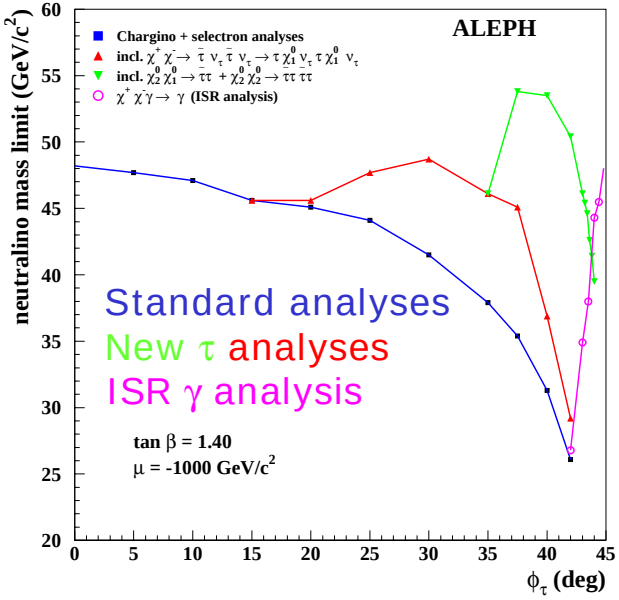
I – chargino 3-bodies

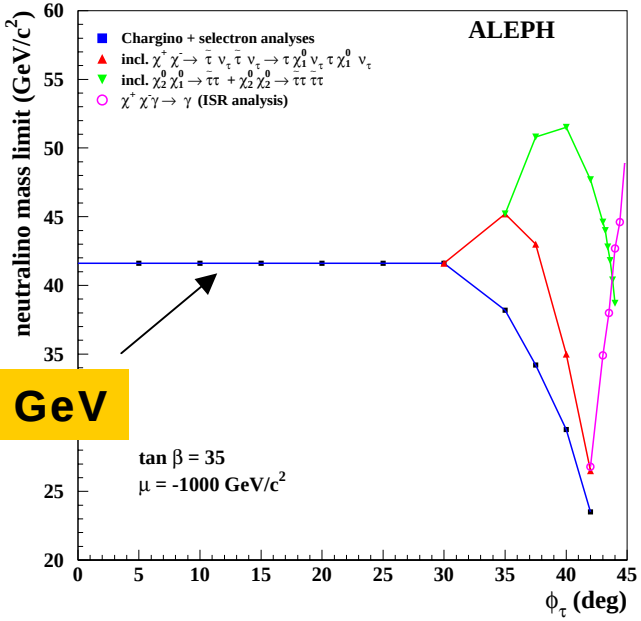
II – chargino 2 - bodies

III – τ's final states

Charginos + ISR

Selectrons





$M_{LSP} > 41.6$ GeV

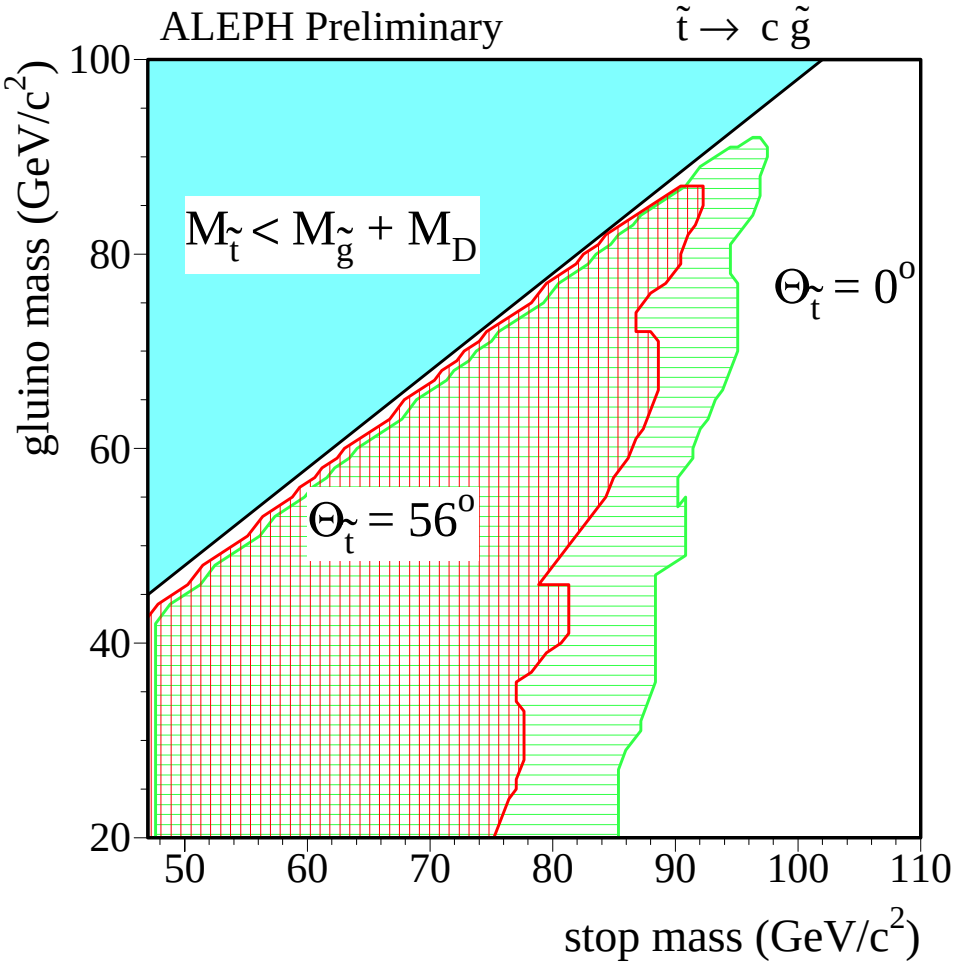
s-top decays into gluino LSP

- 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 → 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



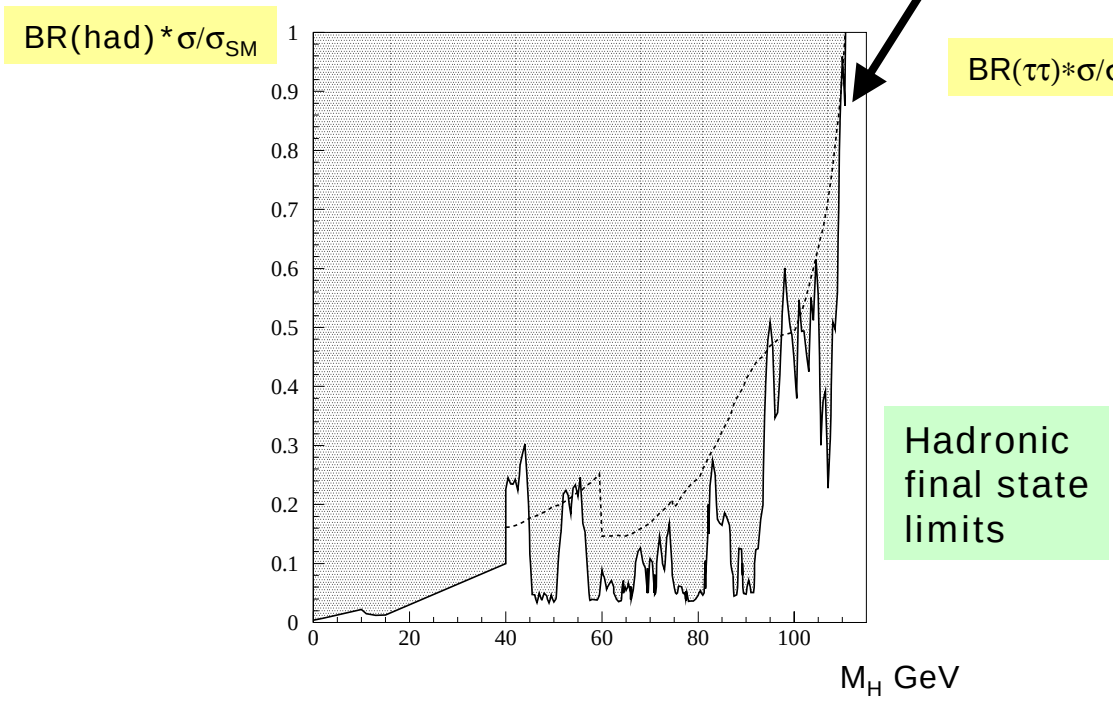
Search of Higgs boson with non-standard decays

- **Flavour-independent Higgs boson search (CERN-EP/2002-027)**
- Only HZ → qqqq analysis has been modified with respect to the standard Higgs boson search
  - No b-tagging + estimators of WW and HZ hypothesis

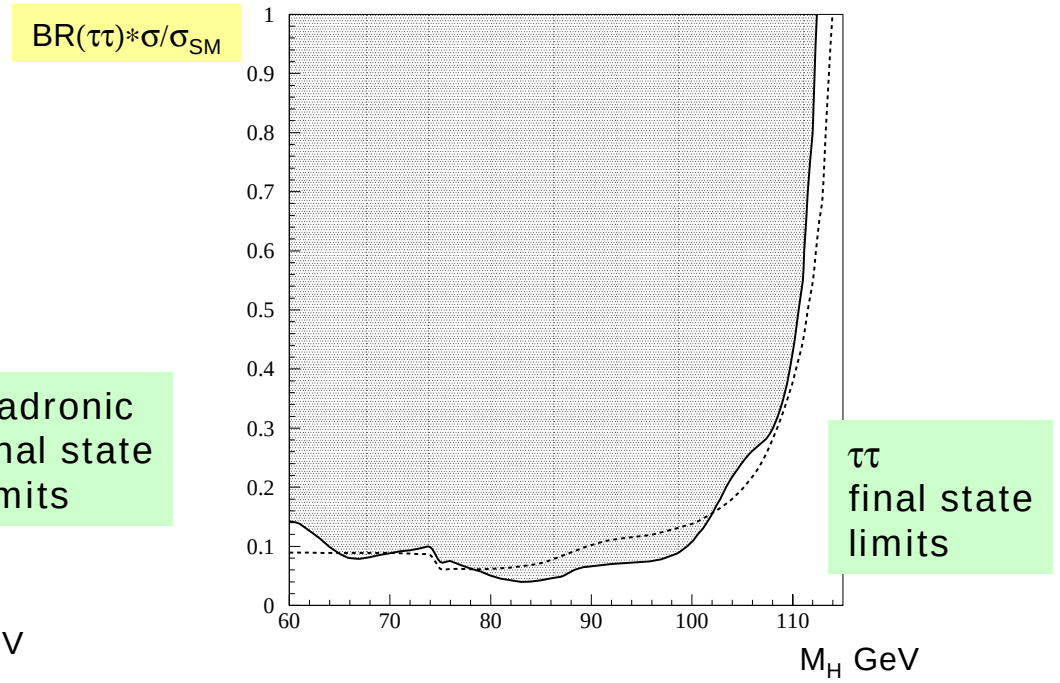
BR(had) + BR(ττ) = 1 : **M_H > 109.1 GeV**

M_H > 110.6 GeV

M_H > 112.4 GeV



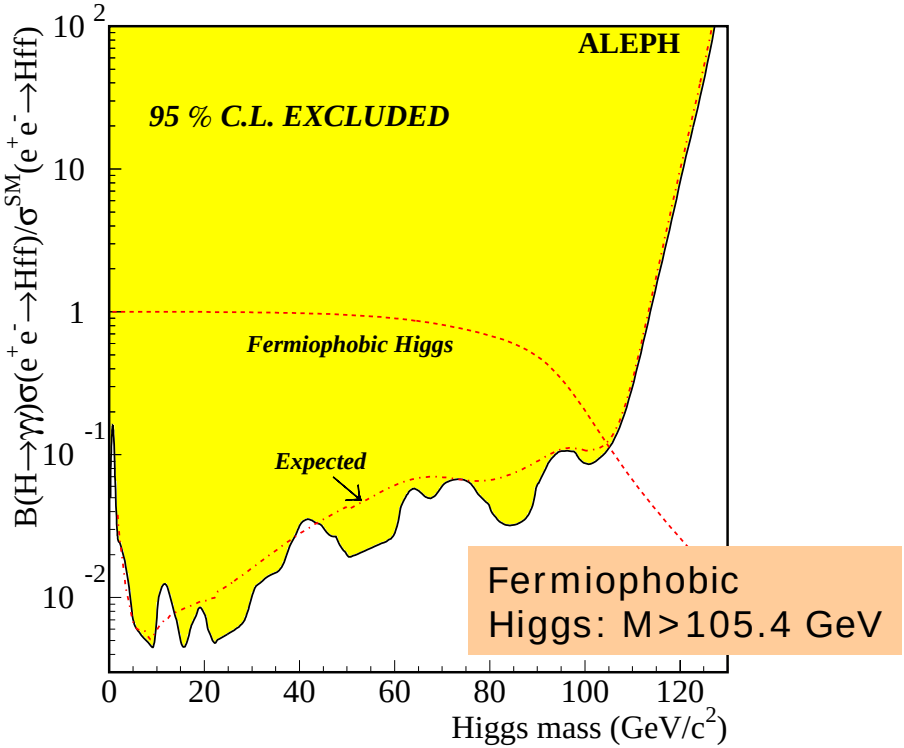
Hadronic final state limits

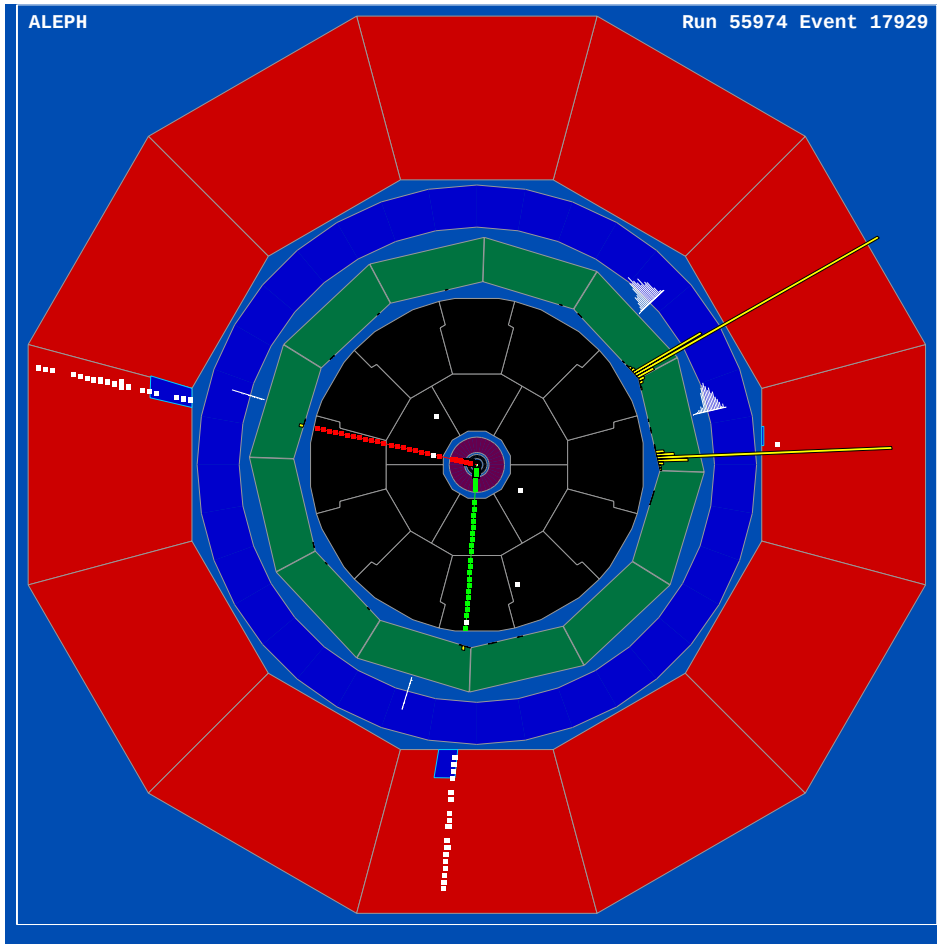


ττ final state limits

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, ...