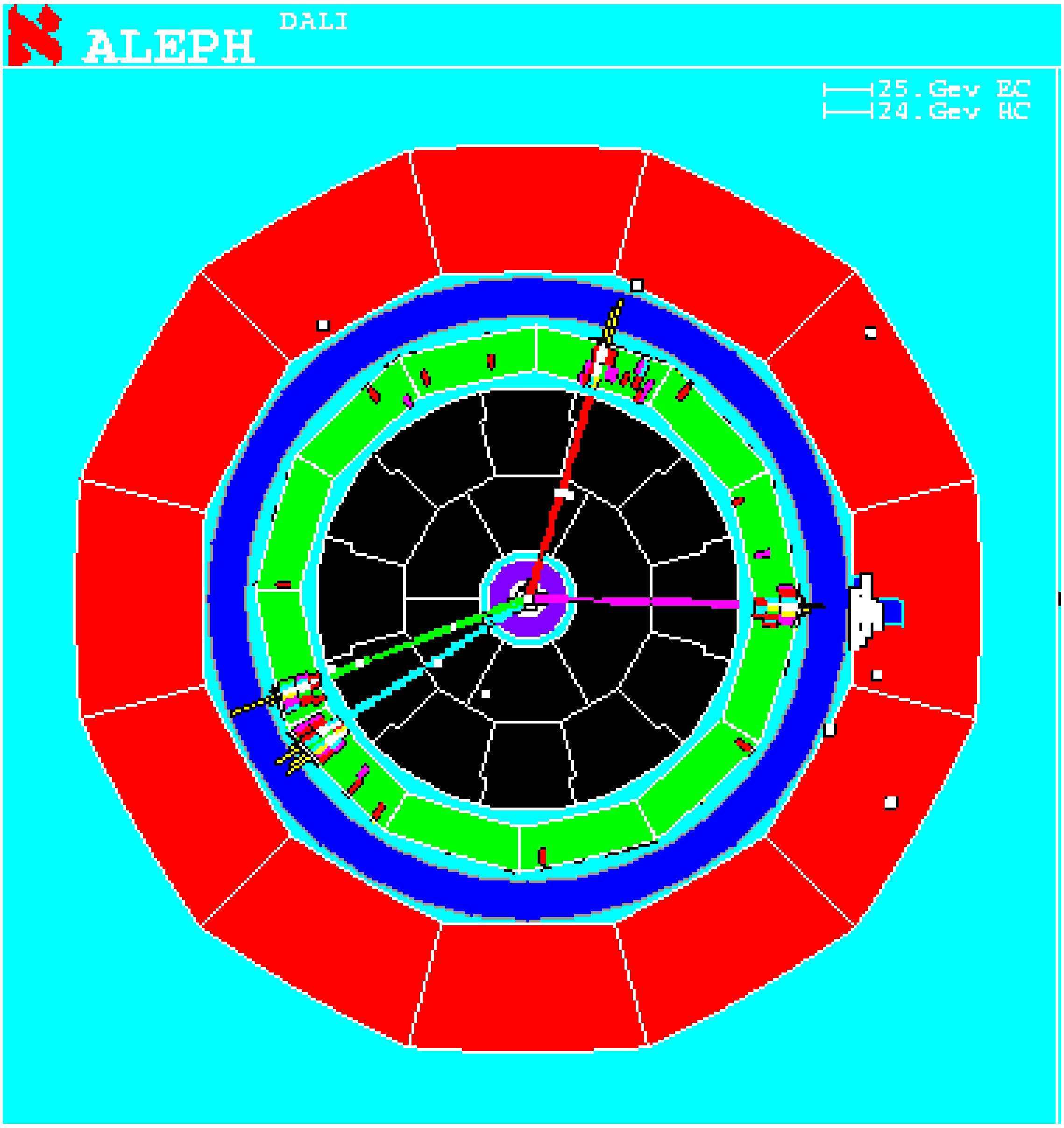
ALEPH Status Report

LEPC March 24th ‘99



Fabiola Gianotti (CERN)

- Physics results based on '98 data:

$\sqrt{s} \approx 188.6$ GeV $\qquad$ $L \approx 174$ pb^{-1}

- Covered here:
  - Higgs searches
  - SUSY searches
  - 2-fermion production
  - QCD
  - W W

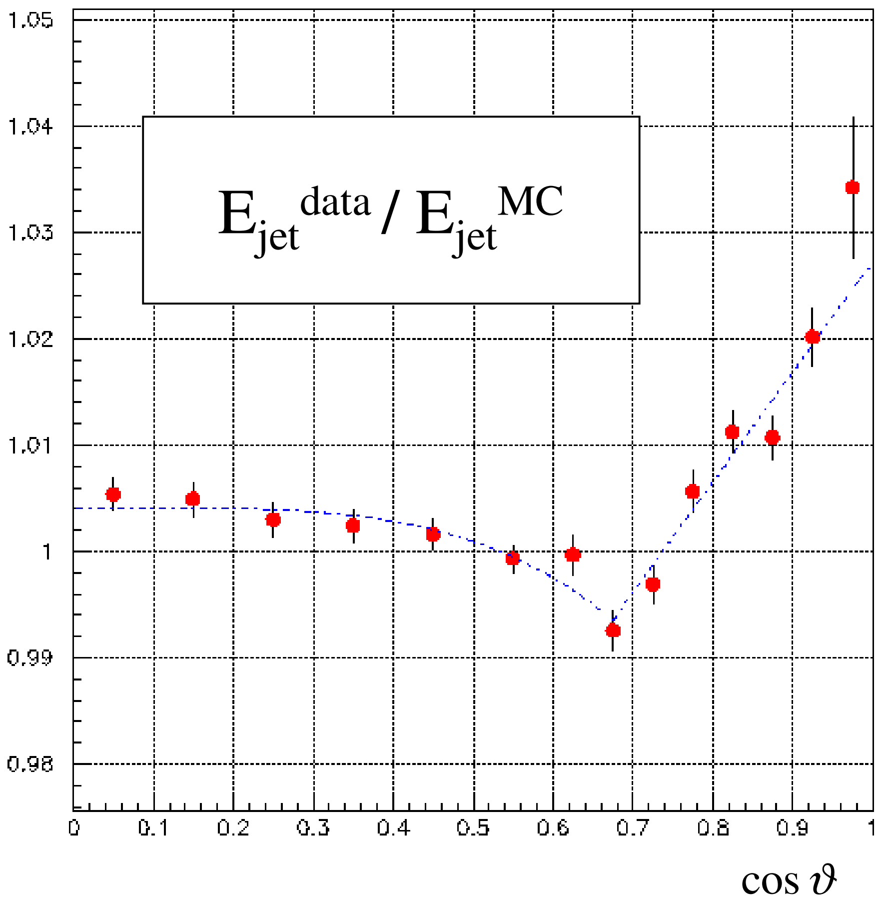
- Results shown here are: - preliminary …
  - non exhaustive …

All limits are at 95% C.L.
All errors are ± stat. ± syst.

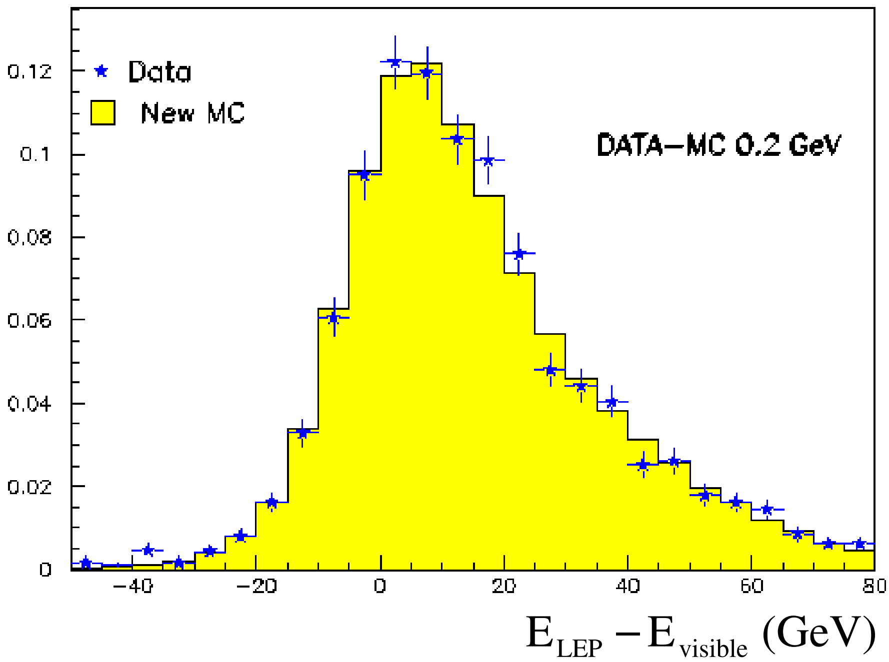
- Data reprocessing
(alignment, calibration, detector fixes)
and
MC production (~ 10 million events)

} completed in January

Data / MC comparison for energy flow

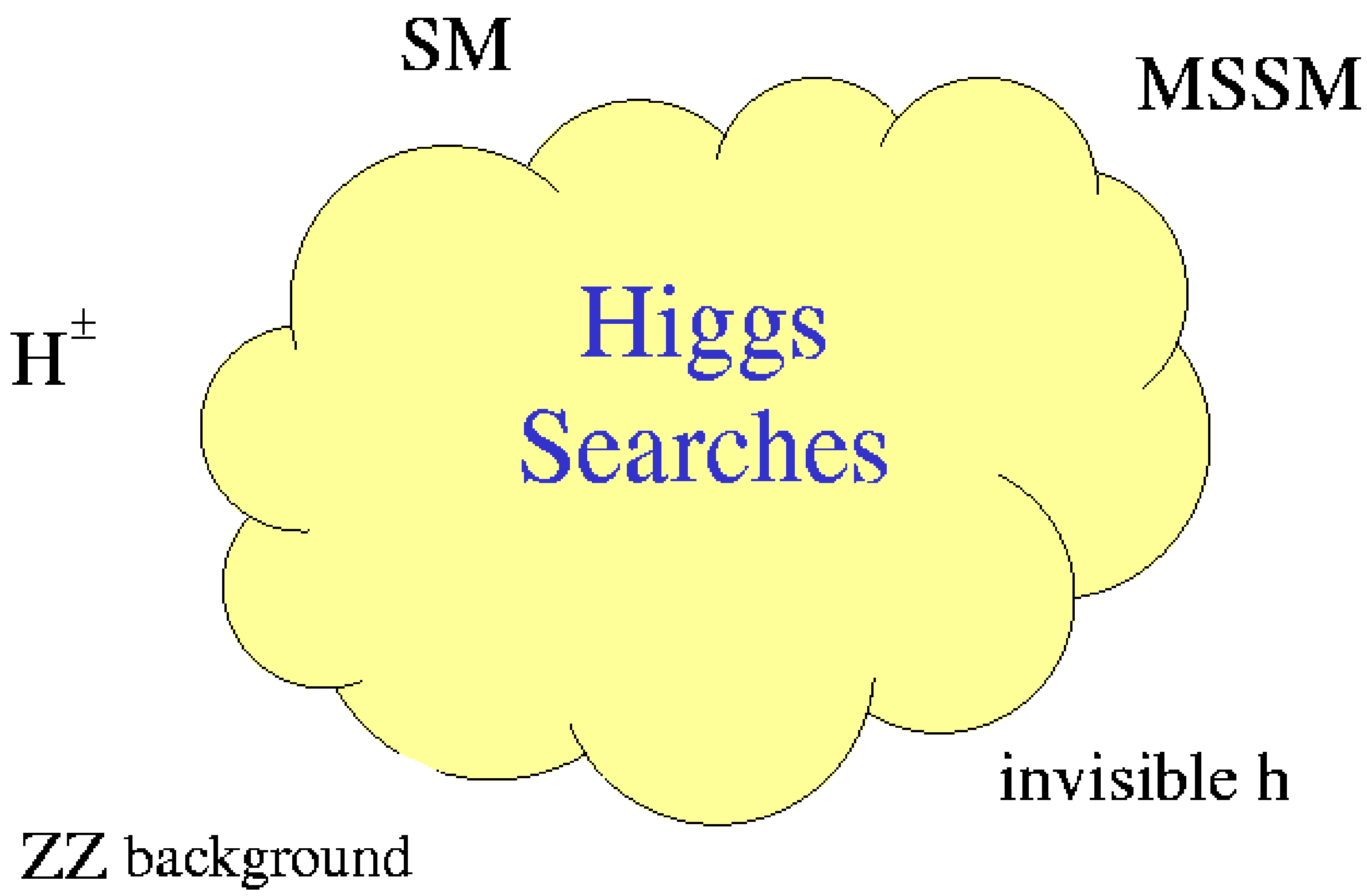


$Z \rightarrow qq$ events:
data from Z-peak
run (~ 3 pb^{-1})



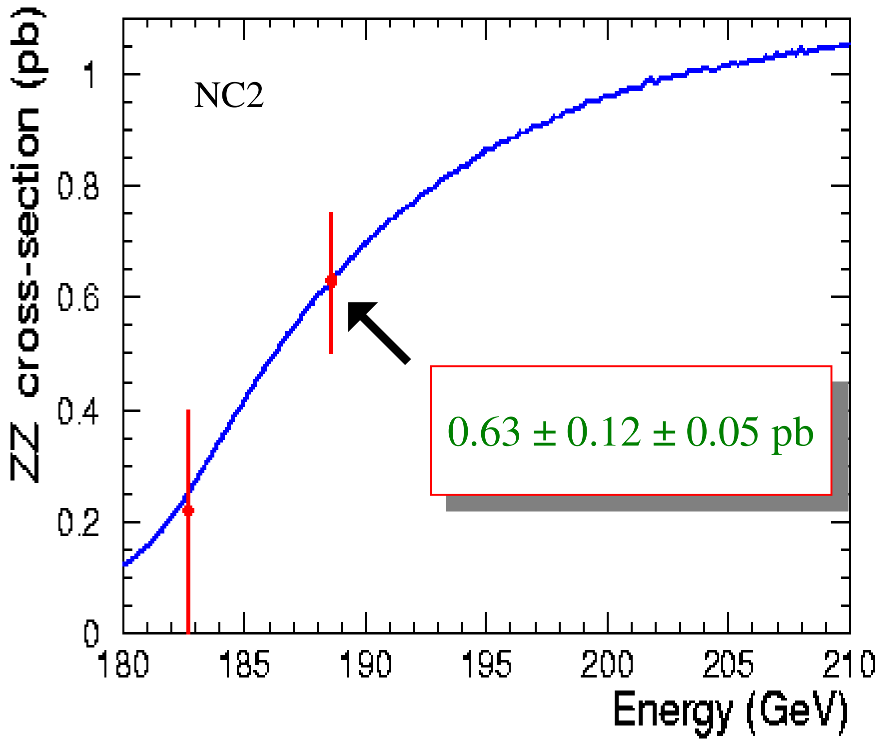
$\sqrt{s}$ = 189 GeV

Hadronic WW
preselection


SM
MSSM
$H^{\pm}$
Higgs
Searches
invisible h
ZZ background

ZZ cross-section

Aleph preliminary



All visible channels studied

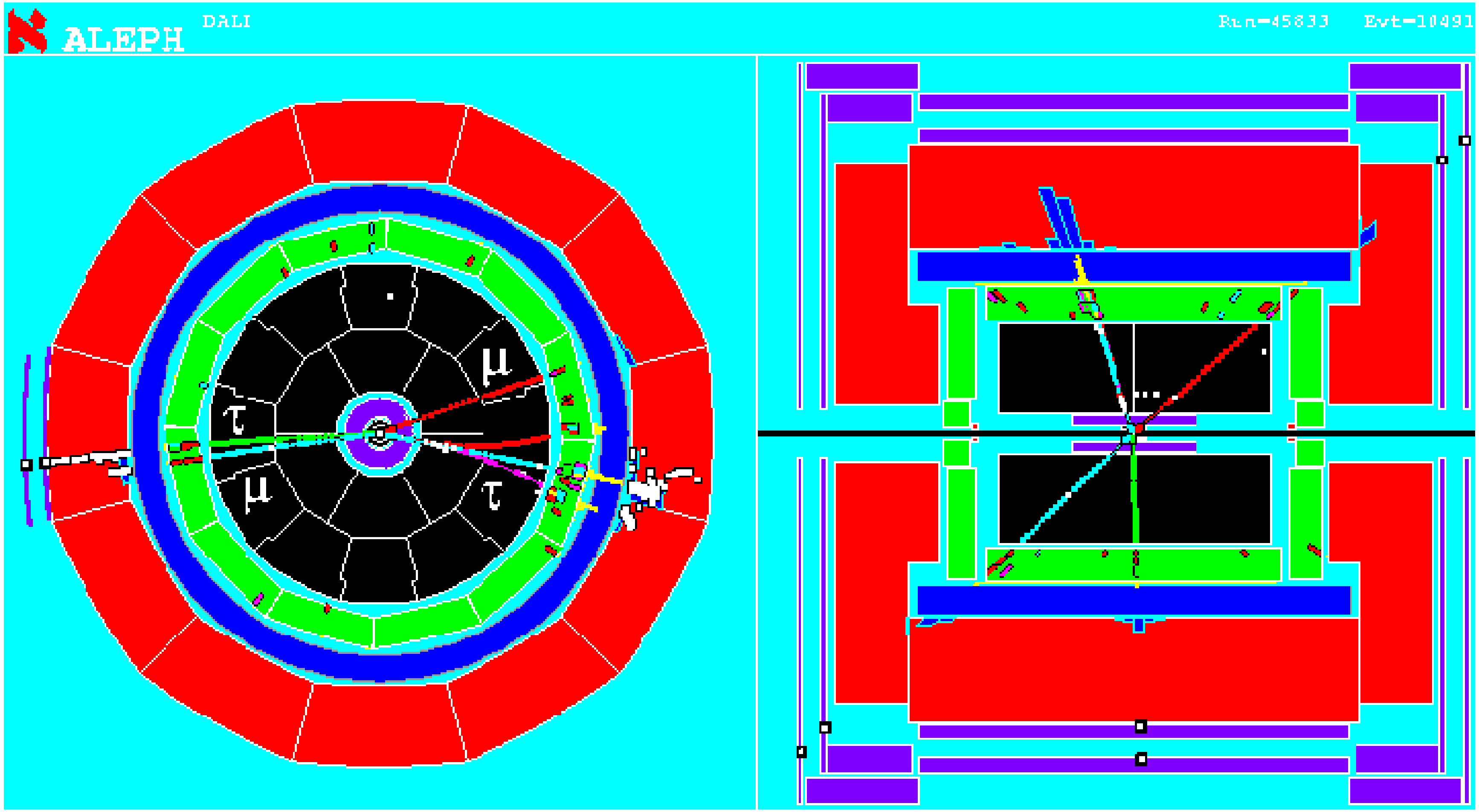
189 GeV

Channel	N_{exp} ZZ	N_{exp} backg	N_{exp} total	N_{obs}
llXX	8.7	1.1 ± 0.3	9.8	11
ll$\nu\nu$	1.3	1.4 ± 0.2	2.7	1
qq$\nu\nu$	14.4	13.8 ± 0.6	28.2	29
4q (b)	8.1	3.8 ± 0.4	11.9	13
4q(non-b)	15.7	59.9 ± 1.4	75.6	67

Analyses similar to hZ searches except mass constraints on both Z and relaxed b-tagging.

$ZZ \rightarrow \mu^+\mu^-\tau^+\tau^-$

$\sqrt{s} = 189$ GeV



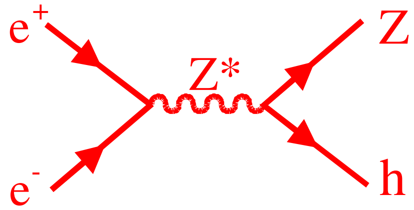
$m_{\mu^+\mu^-} = 96.0$ GeV

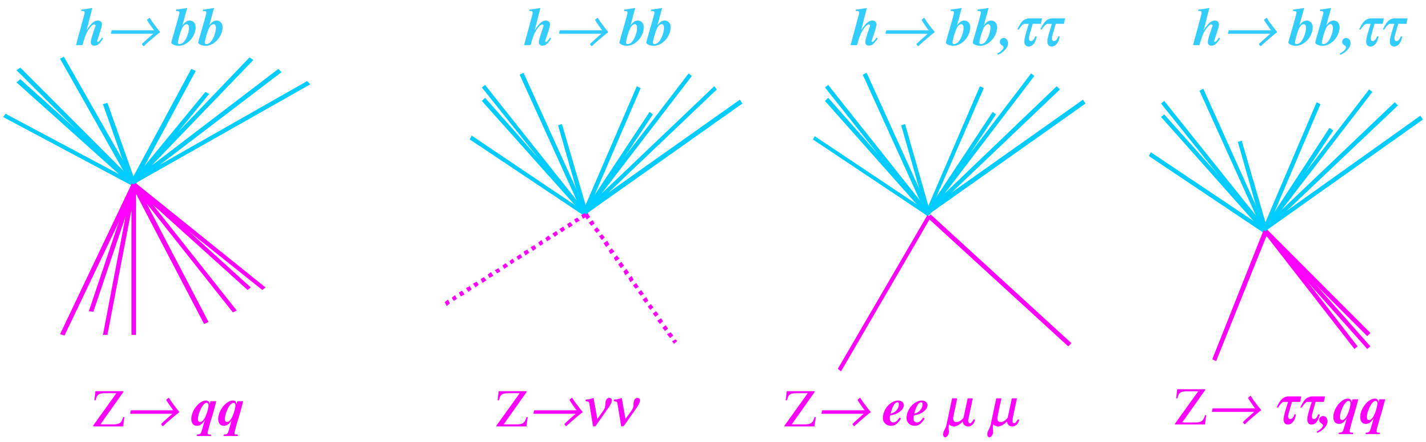
$m^{\mathrm{recoil}}_{\tau^+\tau^-} = 89.9$ GeV

ALEPH - Fabiola Gianotti

LEPC 24/3/99

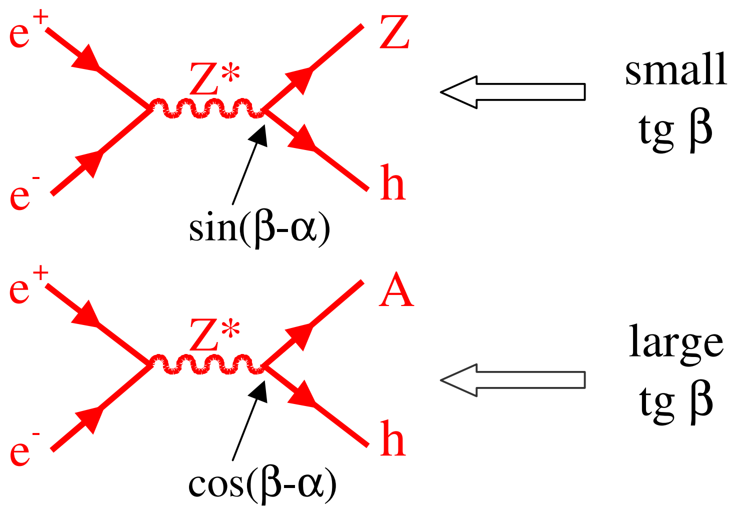
SM Higgs:





b-tag	b-tag	lepton ID	τ-ID
4j topology	$m_{miss} = m_Z$	$m_{\ell\ell} = m_Z$	b-tag

MSSM Higgs:



$$\left.\begin{array}{ll} \text{hZ :} & \text{SM topologies} \\ \text{hA :} & b\bar{b}b\bar{b},\ b\bar{b}\tau^+\tau^- \end{array}\right\} \text{combined vs tg } \beta$$

Note: SM Higgs limit obtained for $\sin^2(\beta-\alpha)=1$

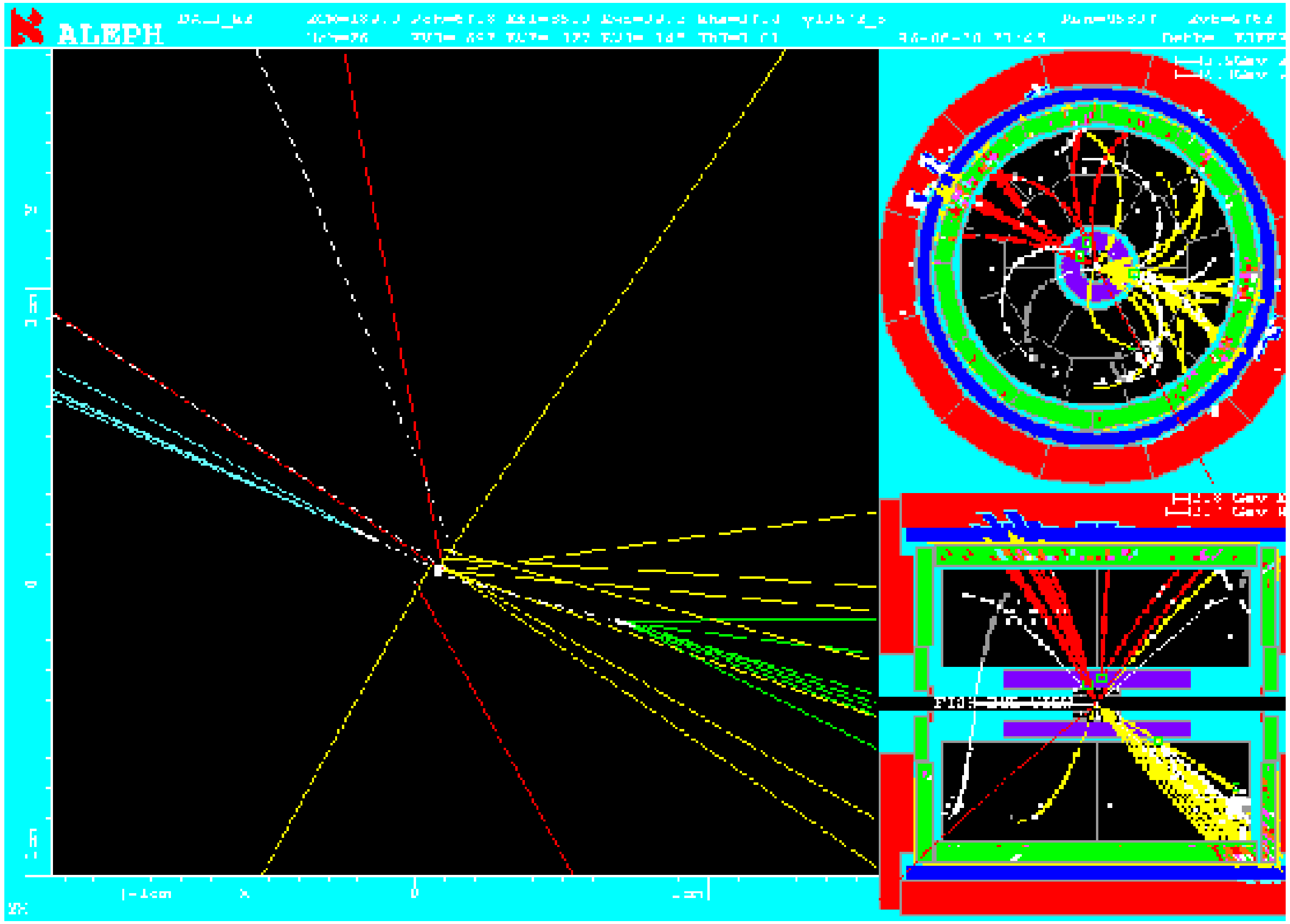
Searches in various channels similar to $\sqrt{s}$=183 GeV :

Channel	Cut-based	Neural Network
hqq	✖	✖
h$\nu\nu$	✖	✖
hll	✖	
$\tau\tau$qq		✖
bbbb	✖	
bb$\tau\tau$		✖

Main differences at $\sqrt{s}$=189 GeV :

- full background subtraction: ZZ background (~irreducible) is ~ 3 times larger
- handle overlap of hZ / hA analyses in 4j and bb$\tau\tau$ topologies (common background)

$b\bar{b}\nu\bar{\nu}$ event $\sqrt{s}$ = 189 GeV



$m_{b\bar{b}} = 88.1\,\mathrm{GeV}$ $m_{miss} = 100.0\,\mathrm{GeV}$

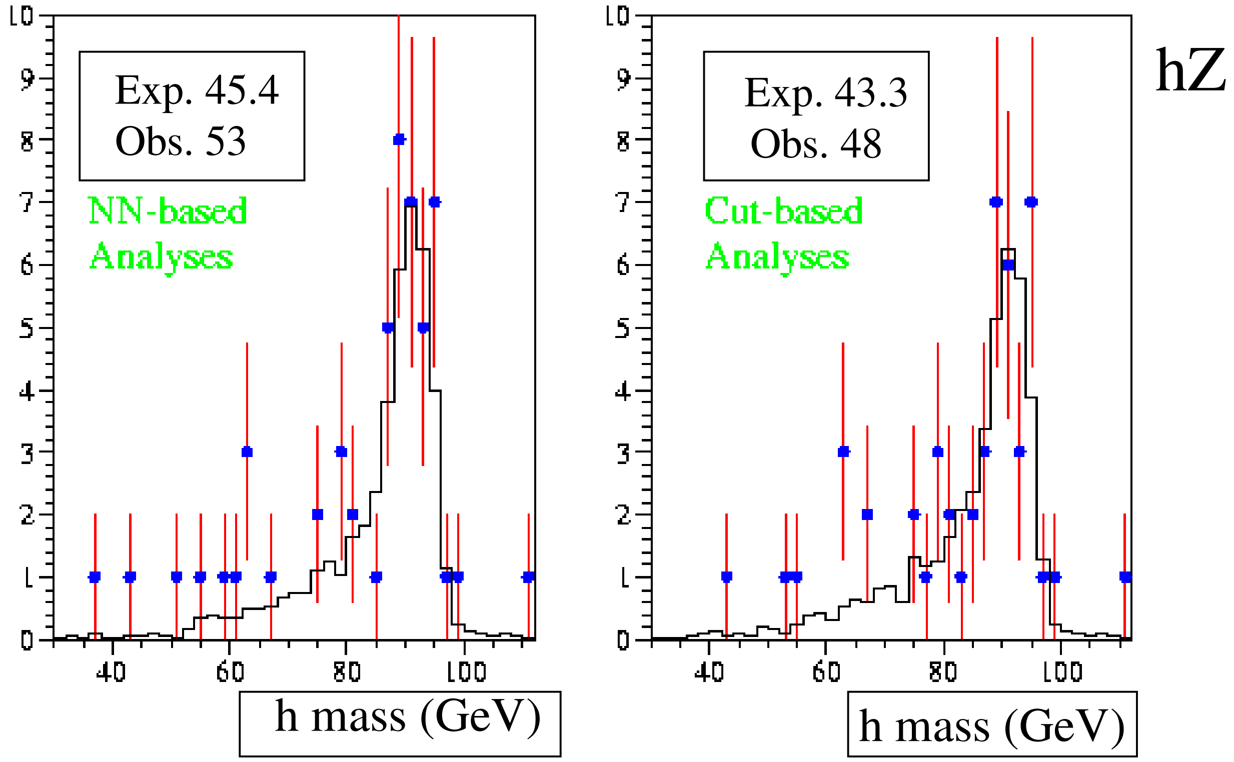
Topology	N_{backg}	N_{obs}	Exp. N_{signal}
hqq	21.4	28	8.5
$h\nu\nu$	7.1	9	3.1
hll	14.4	14	1.5
$\tau\tau$qq	2.5	2	0.7
Total (hZ)	45.4 ± 3.7	53	13.8
bbbb	5.0	7	3.2
bb$\tau\tau$	2.5	3	0.5
Total (hA)	7.5 ± 1.0	10	3.7

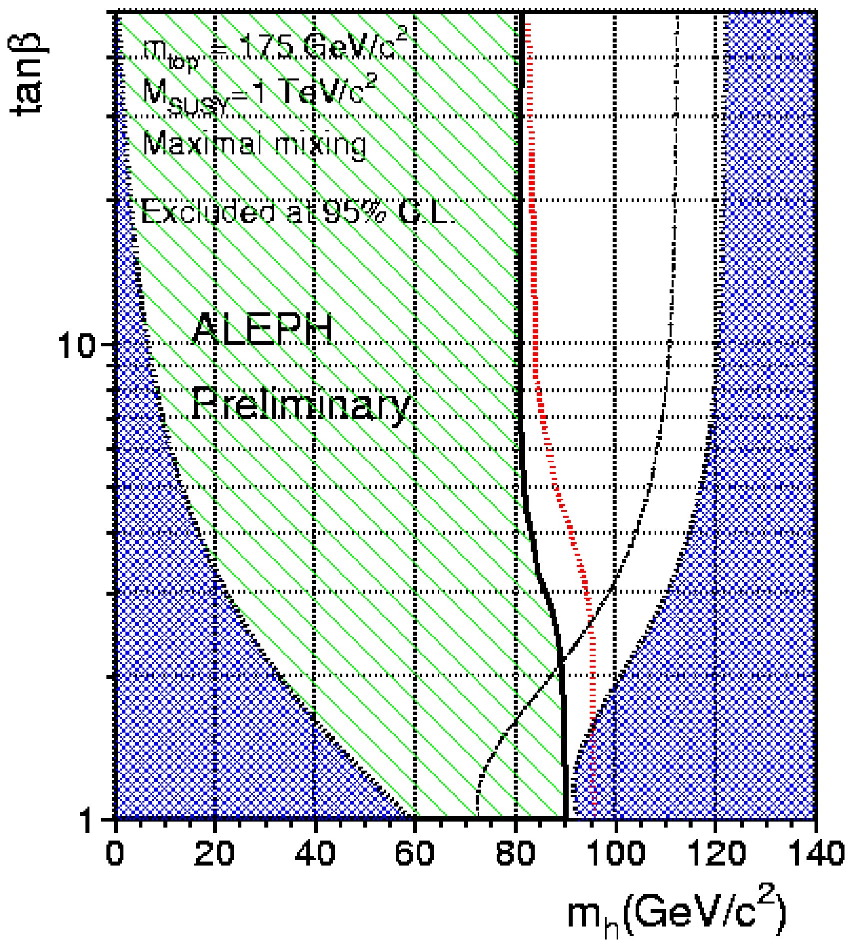
NN analysis

← hZ
m= 95 GeV

← hA/hZ
m = 85 GeV
$\cos^2(\beta-\alpha)=1$

Aleph preliminary





√s ≤ 189 GeV

expected limit

observed limit

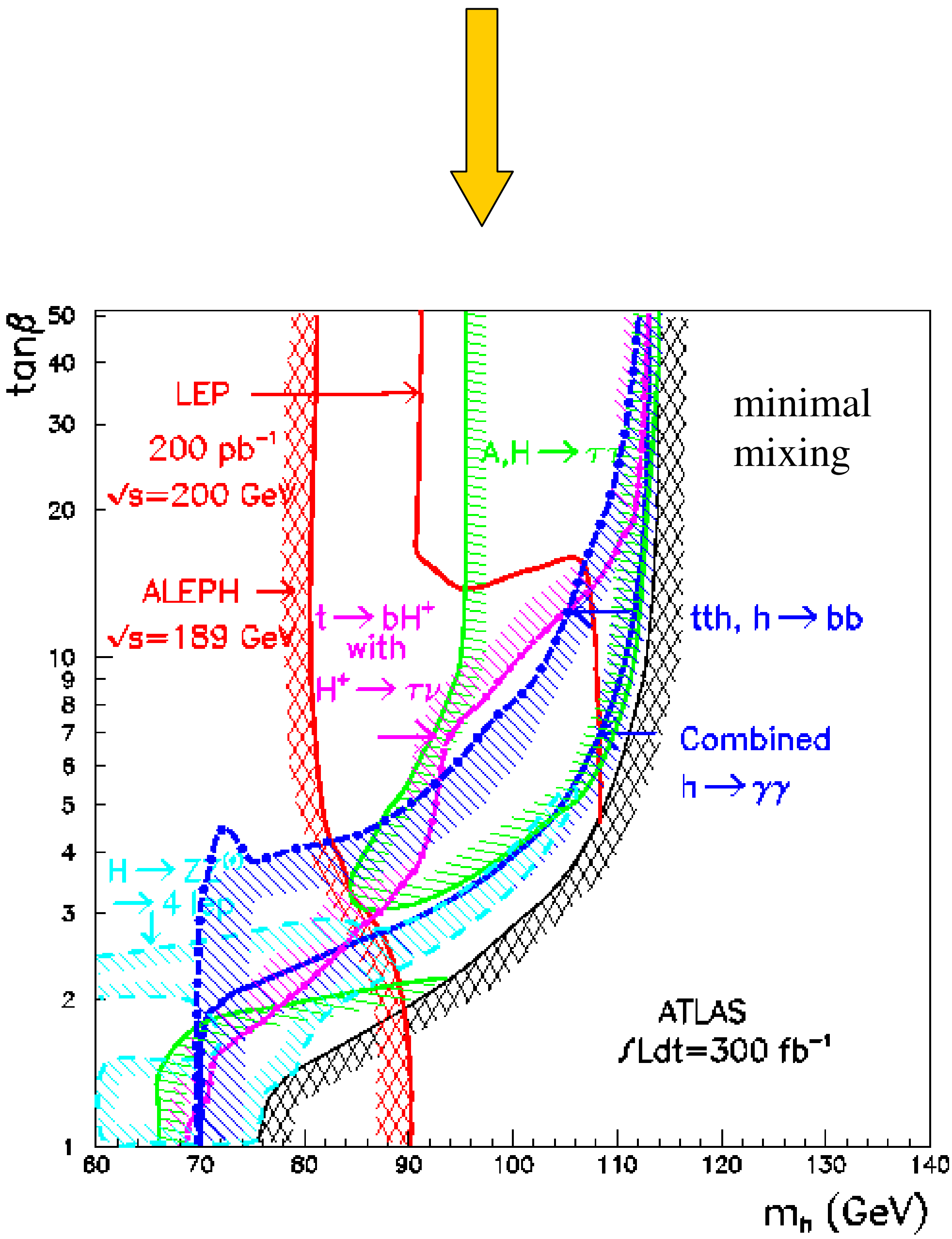
	Expected limit (GeV)	Observed limit (GeV)
SM h	95.7	90.2
MSSM h (any tgβ)	82.7	80.8
A (tgβ ≥ 1)	82.7	81.2
hZ (cut analysis)	95.4	93.8

← probability 1%

Fine scan of MSSM parameter space: ~ 0.1% of unexcluded points with m_h smaller than benchmark limit. These cases are beyond LEP2 sensitivity.

m_h - tanβ plane in year ~ 2015

here direct production of
h not observable at LHC

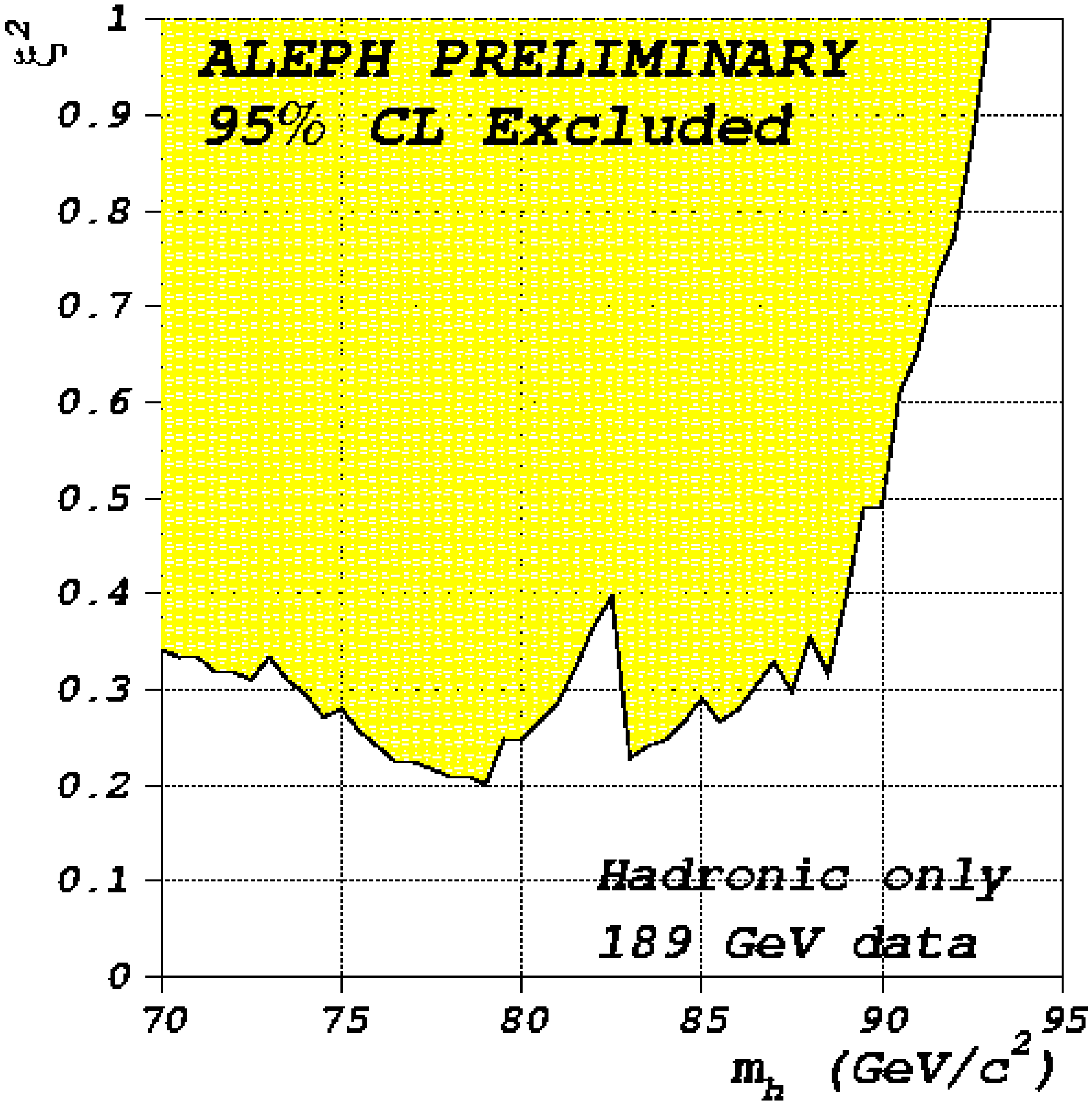


thanks to
P. Janot
E. Richter-Was

Need luminosity to cover large tanβ region

INVISIBLE HIGGS

$m_h > 92.8$ GeV $\xi^2=1$



$\chi^{\pm}$ χ'

$\tilde{q}$

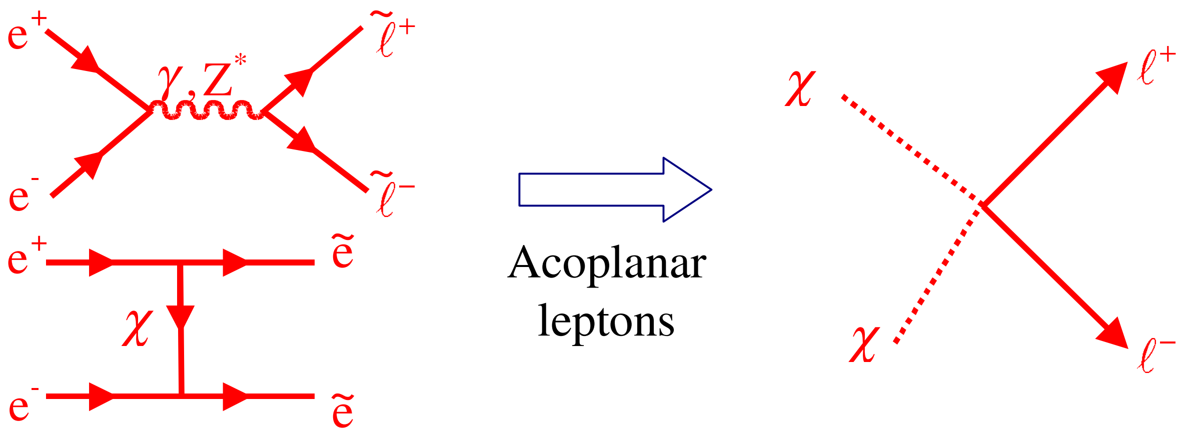
LSP

$\tilde{l}$

$R\!\!\!/_P$

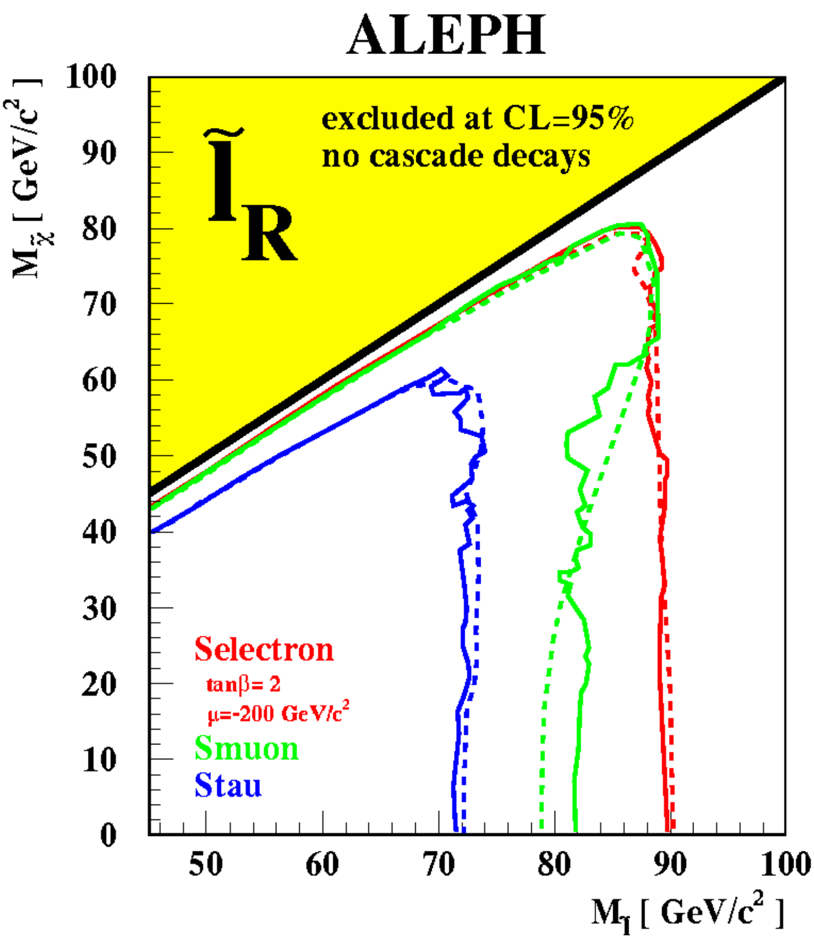
GMSB

SLEPTONS



Channel	N_{back}	N_{obs}
ee	32.8	33
μμ	29.6	28
ττ	15.5	21

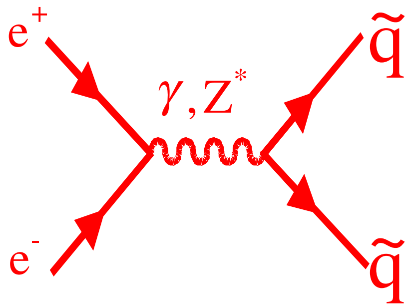
← mainly WW



$\sigma \sim \beta^3/s$

$\rightarrow$ need L

SQUARKS



$\boxed{\tilde{t}_1, \tilde{b}_1}$ can be light:

$$\tilde{t}_L, \; \tilde{t}_R \longrightarrow \tilde{t}_1, \; \tilde{t}_2$$

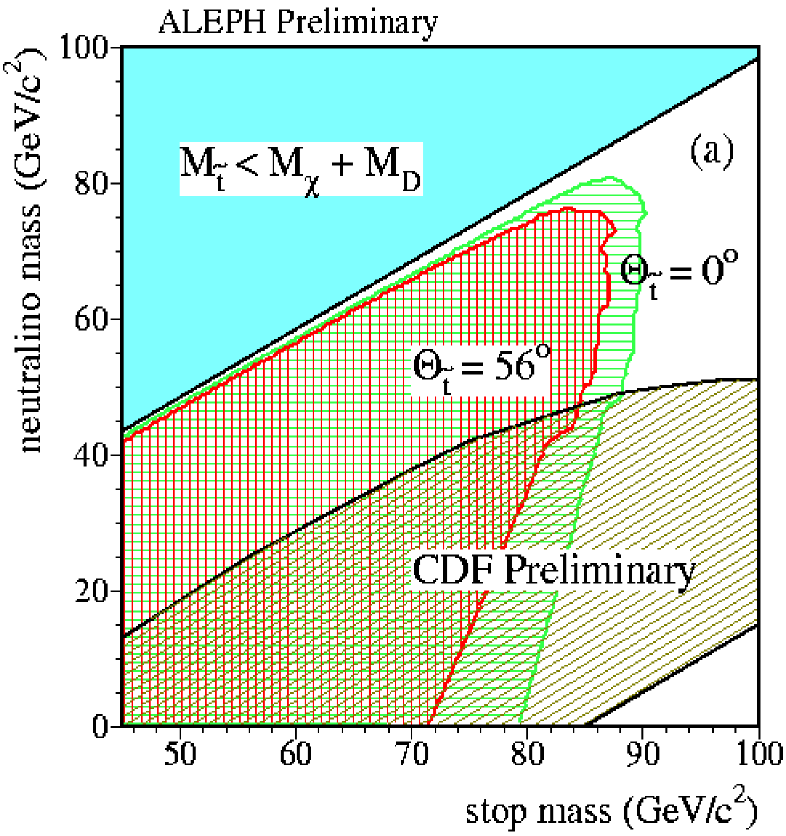
mixing (θ_{mix}) ~ m_t

$$\left.\begin{array}{l} \tilde{t} \rightarrow c\,\chi \\ \tilde{b} \rightarrow b\,\chi \end{array}\right\} \rightarrow \text{Acoplanar jets}$$

$\tilde{t} \rightarrow b\,l\,\tilde{\nu}$

Channel	N_{back}	N_{obs}
$c\chi\; c\chi$	9.5	8
$b\chi\; b\chi$	4.2	3
$bl\nu bl\nu$	2.3	2

← $\gamma\gamma$, 4f, $qq(\gamma)$

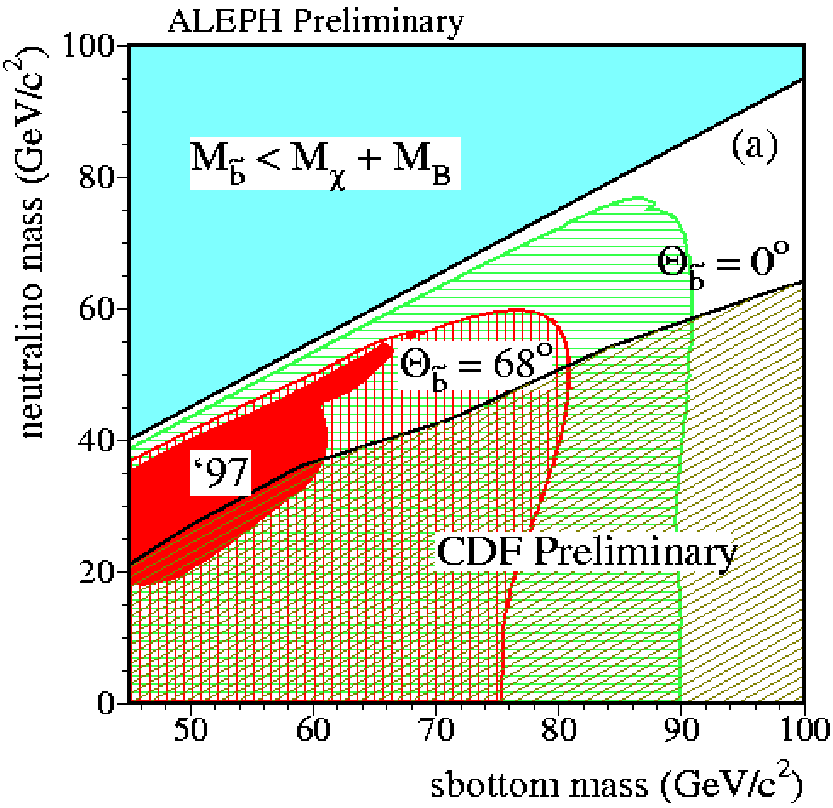


$$\tilde{t}\,\tilde{t} \rightarrow c\chi\, c\,\chi$$

$\theta_{mix} = 0^0$: largest cross-section

$\theta_{mix} = 56^0$: smallest cross-section

$$\tilde{b}\,\tilde{b} \rightarrow b\,\chi\, b\chi$$

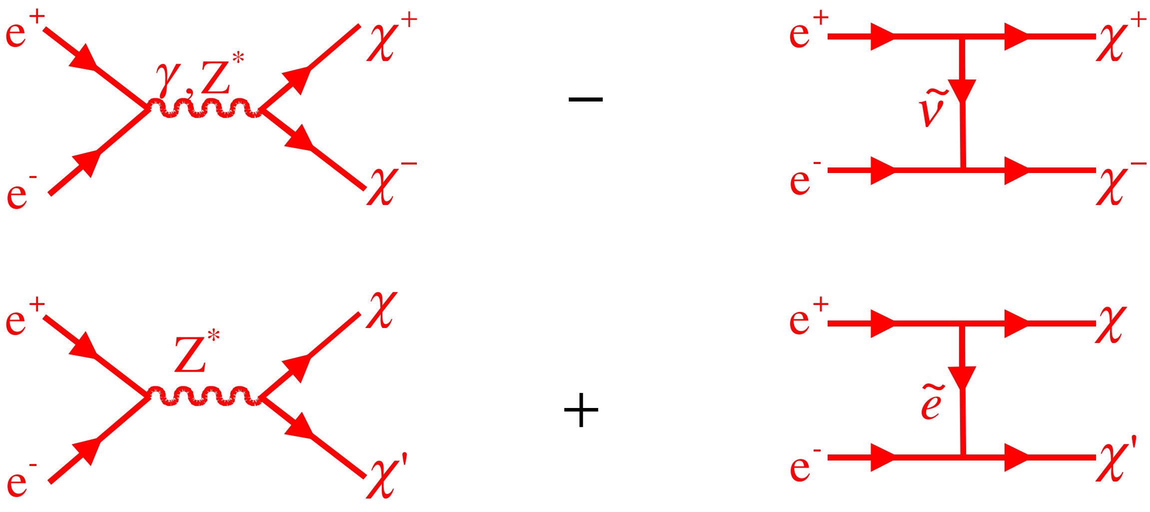


$\theta_{mix} = 0^0$: largest cross-section

$\theta_{mix} = 68^0$: smallest cross-section

Similar results for $\tilde{t} \rightarrow bl\tilde{\nu}$

Charginos, neutralinos, LSP



Assume gaugino mass unification ($m_{1/2}$) and sfermion mass unification (m_0) at the GUT scale.

Large m_0: - $\chi+\ \chi-$ cross-section large (no t-channel)

- $\chi^{\pm} \rightarrow W^{*}\ \chi$ ⇨ qql $\not{E}$, qqqq $\not{E}$
- $\chi' \rightarrow Z^{*}\ \chi$ ⇨ qq $\not{E}$

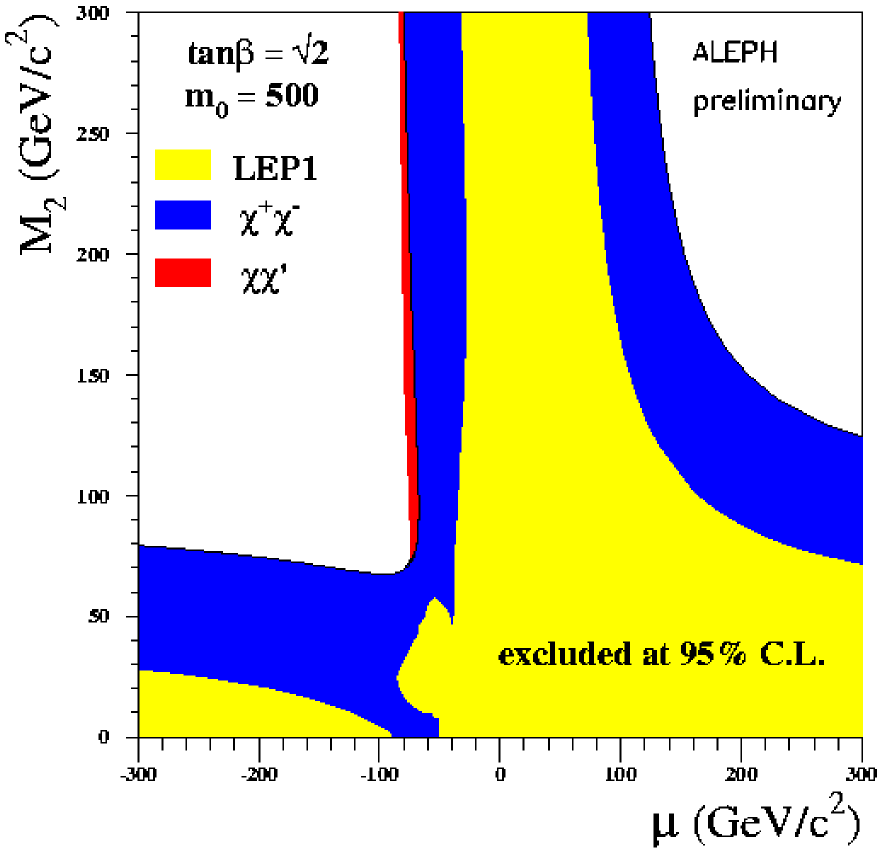
Small m_0: - $\chi+\ \chi-$ cross-section suppressed } by t-channel
$\chi\ \chi'$ cross-section enhanced

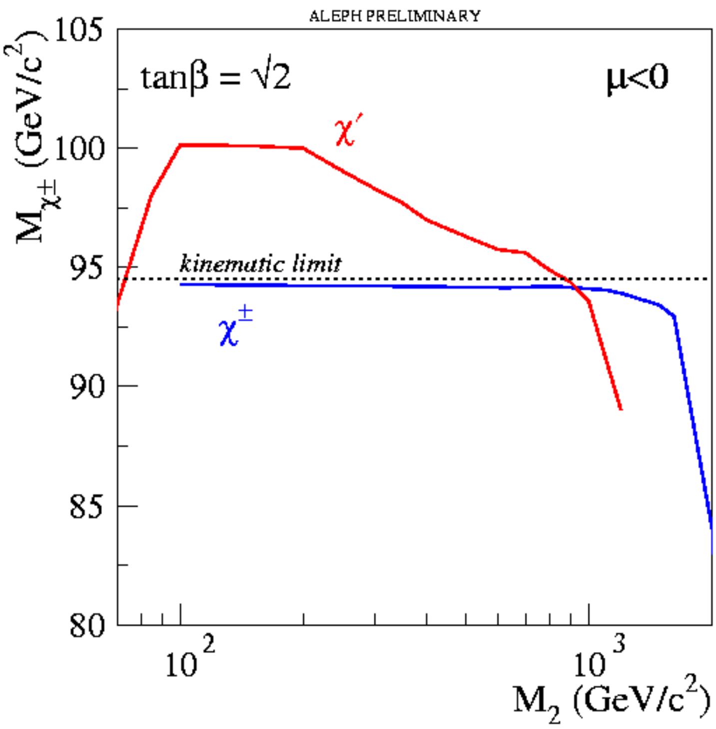
- $\chi^{\pm} \rightarrow l\nu$ ⇨ ll $\not{E}$
- $\chi' \rightarrow ll$ ⇨ ll $\not{E}$

Channel	N_{back}	N_{obs}
$\chi+\ \chi-$	23.0	25
$\chi^{i}\ \chi^{j}$	49.6	45

Leptonic WW subtracted

Large m_0



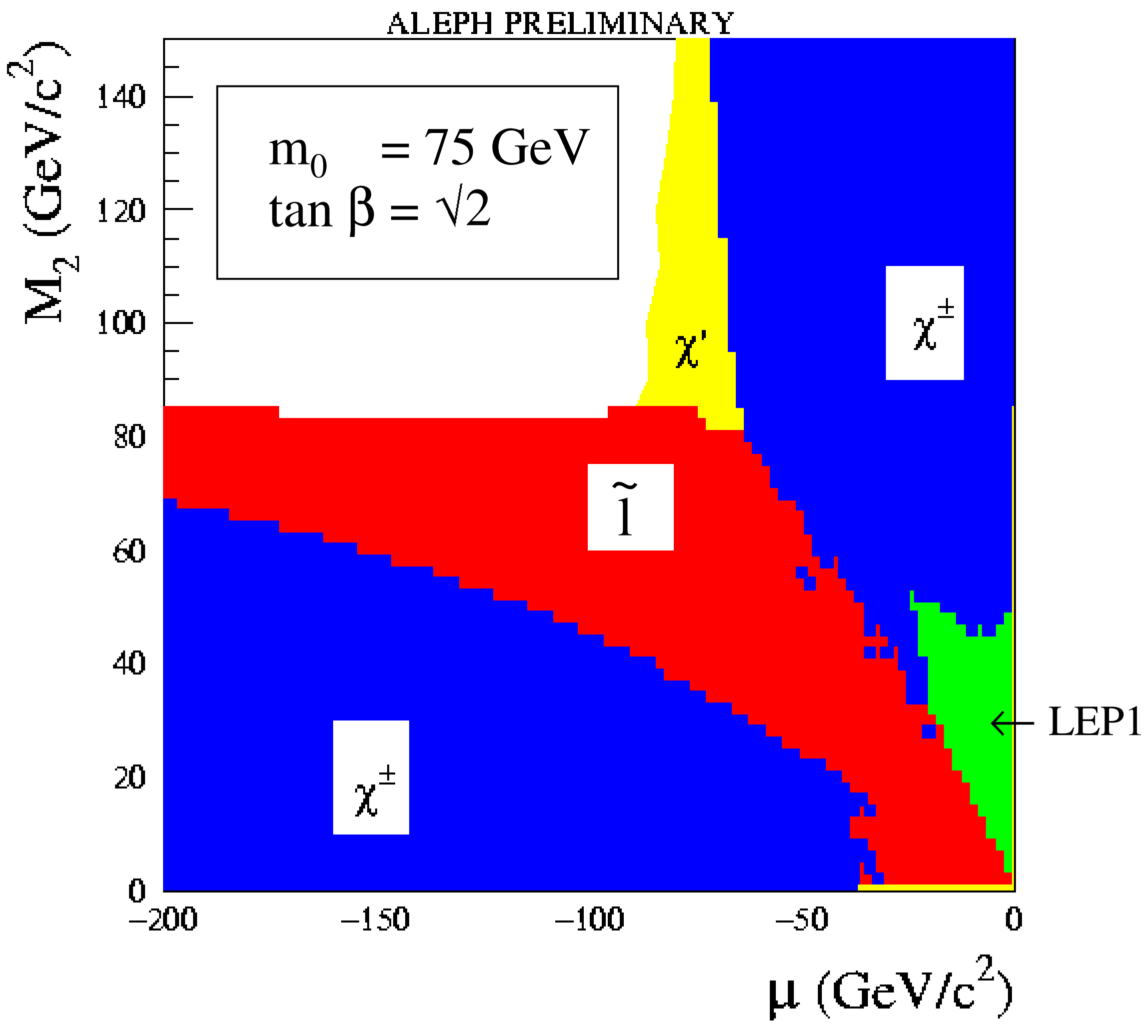


← 94.3 GeV

$\chi^{\pm}$ excluded (at least) up to kinematic limit for any tanβ

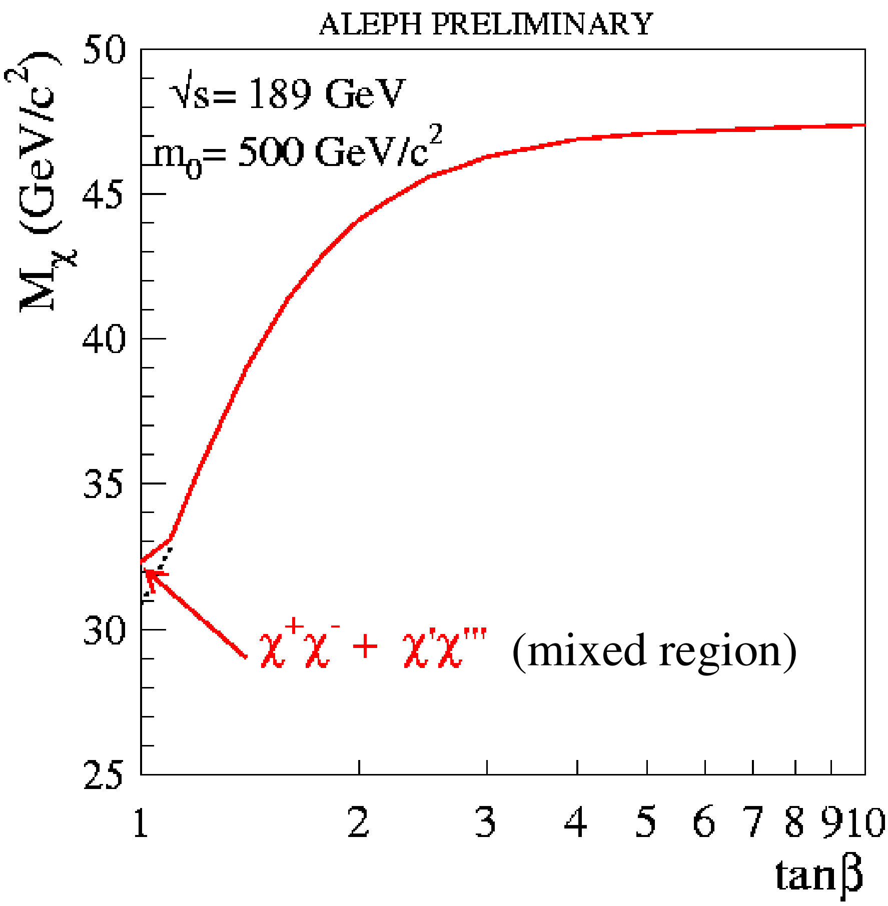
Small m_0

$\chi^+\chi^-$ sensitivity decreases (t-channel, large WW $\rightarrow$ lνlν background)
Slepton searches (small m_0) and neutralino searches (t-channel) compensate



Absolute limit on the LSP

Indirect limit from interplay of exclusion domains in parameter space obtained from $\chi^+\chi^-$, $\chi^i\chi^j$, $\tilde{l}\,\tilde{l}$ (small m_0) searches.



From full scan of parameter space

Limit is better for smaller m_0, equal for larger m_0.

➡ $m_\chi > 32.3$ GeV

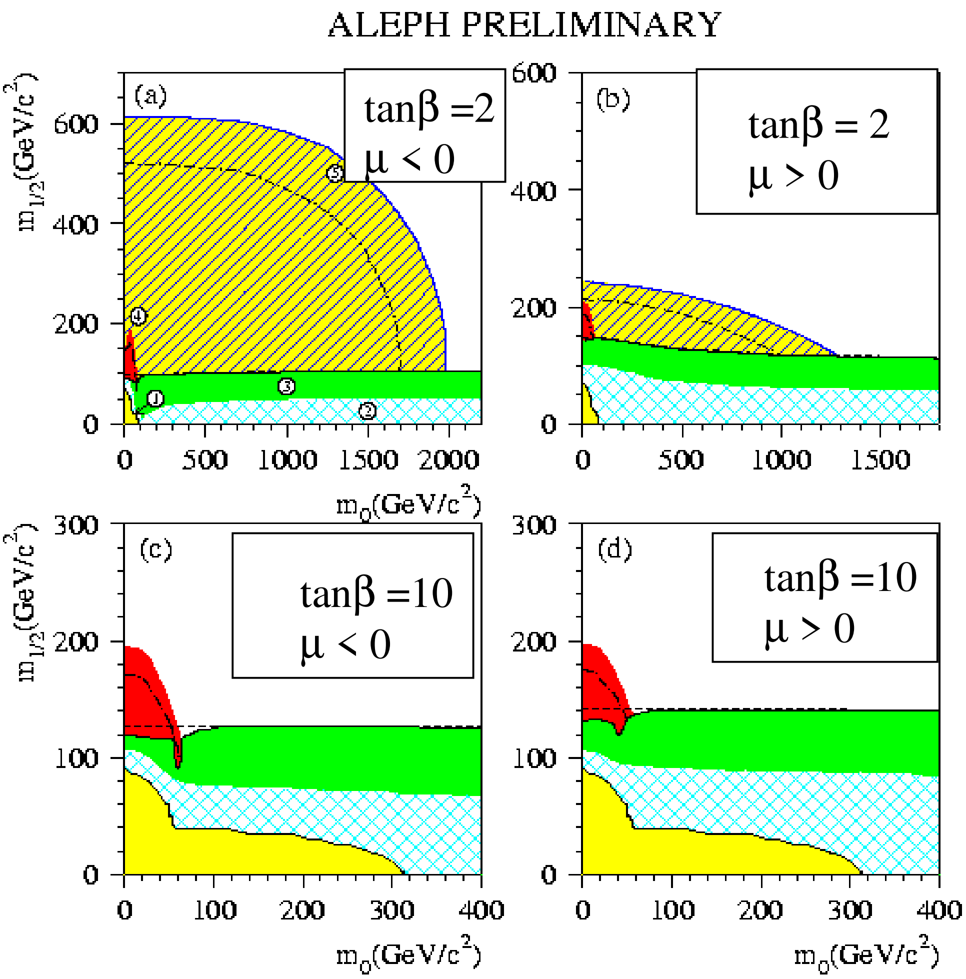
any tanβ, m_0

($\sqrt{s}$= 183 GeV: $m_\chi > 27$ GeV)

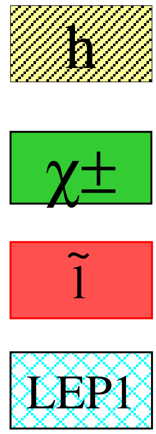
Note: h limits do not help ($m_h > 96$ GeV at the minimum for large m_A /mixing)

Interpretation in mSUGRA

Only 5 parameters : m_0, $m_{1/2}$, $\tan\beta$, sign (μ), A_0



$\sqrt{s} \leq 189$ GeV



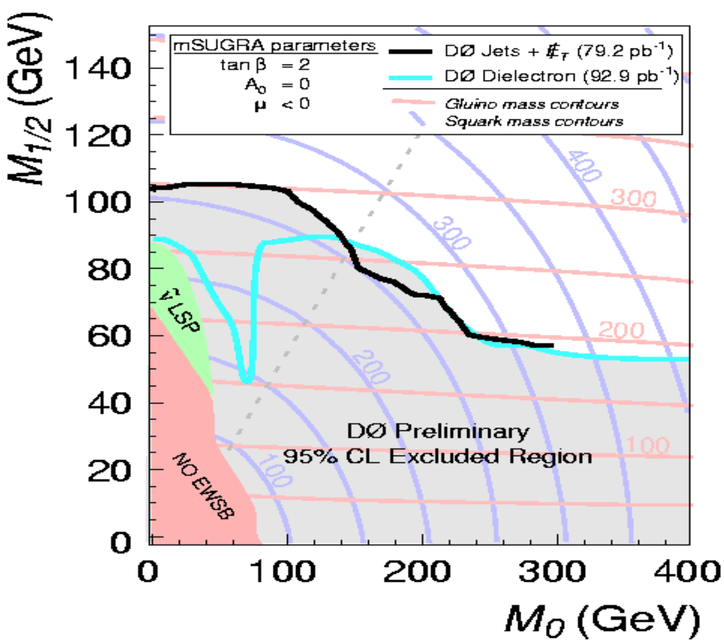
$A_0 = 0$

D0: Run 1

$\tan\beta = 2$

$\mu < 0$

$A_0 = 0$



Gauge-Mediated Susy-Breaking searches

LSP = $\tilde{G}$ (~ massless)

NLSP ≡ χ : $\chi\chi \to \gamma\tilde{G}\,\gamma\tilde{G}$

$c\tau \ll L_{det}$ acoplanar photons

$c\tau \approx L_{det}$ non pointing photons

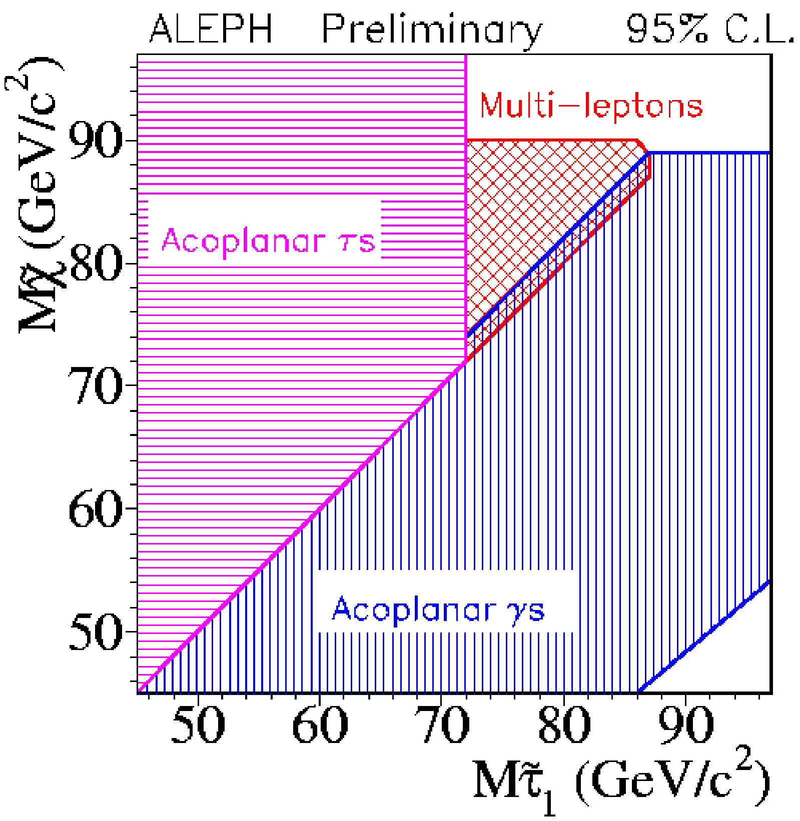
NLSP ≡ l : $l\,l \to l\,\tilde{G}\,l\,\tilde{G}$

$c\tau \ll L_{det}$ acoplanar leptons

$c\tau \approx L_{det}$ kinks

$c\tau \gg L_{det}$ heavy stable charged particles

$\chi\chi \to \tilde{l}\,l\,\tilde{l}\,l \to l\,l\,\tilde{G}\,l\,l\,\tilde{G}$



From scan of parameter space:

n =1- 4

Λ = 1- 100 TeV

$Q_{mess} = \Lambda - 10^3\,\Lambda$

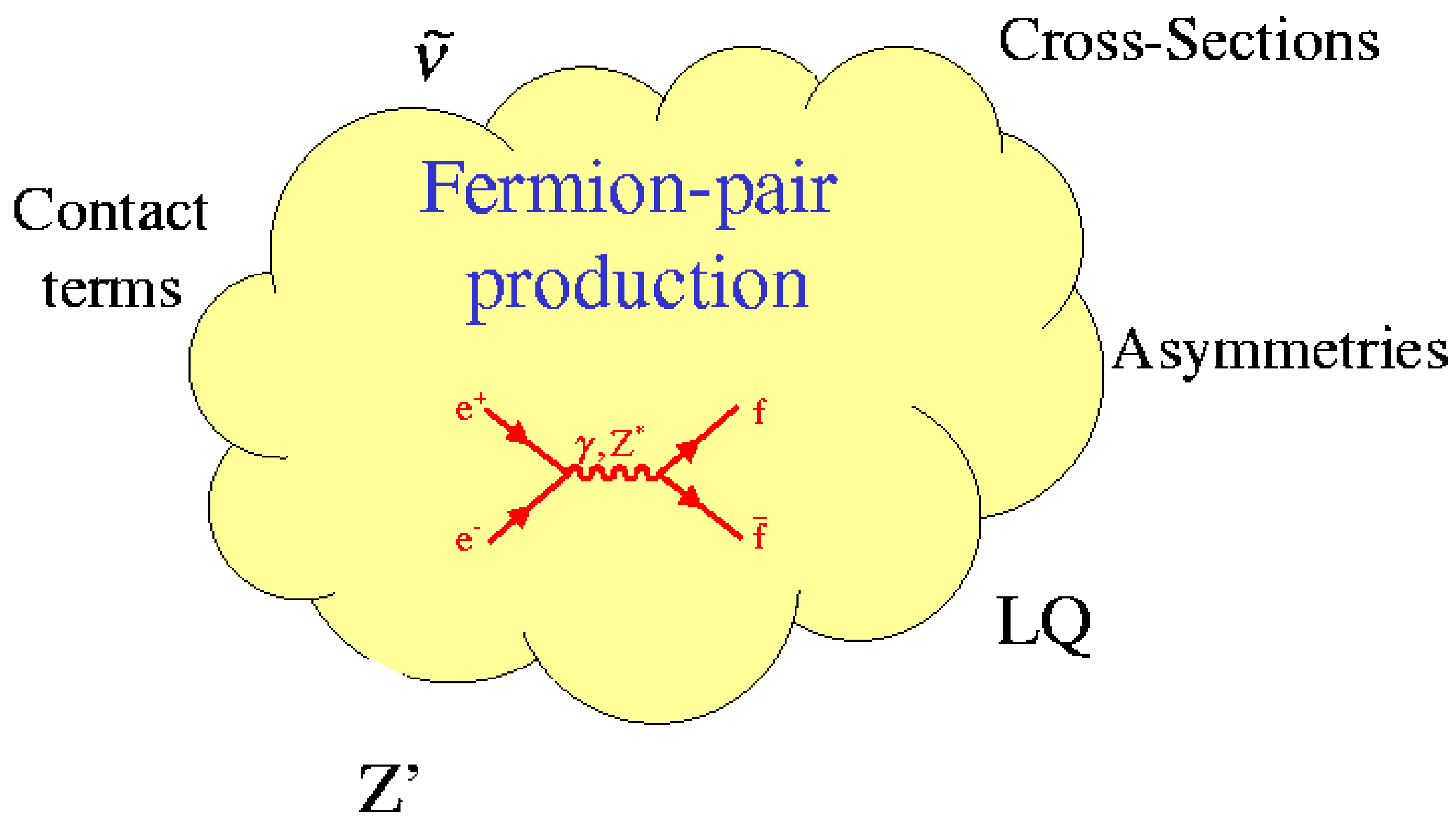
tan β = 1- 32

$\mu = \pm$

$c\tau \ll L_{det}$

More results from searches

Particle	Mass limit (95% C.L.)	Comments
$H^{\pm}$	62.5 GeV	
h invisible	92.8 GeV	$\xi^2 = 1$
$\chi^{\pm}$	94 GeV	RPV(LLE,LQD,UDD) large m_0
μ_R	83/77/80 GeV	RPV(LLE,LQD,UDD) indirect decays
μ_R	60 GeV	RPV(LLE) direct decays
u_L	67 GeV	RPV(UDD) direct decays
$\tilde{G}$	1.1×10^{-5} eV	Super-light $\tilde{G}$ scenario

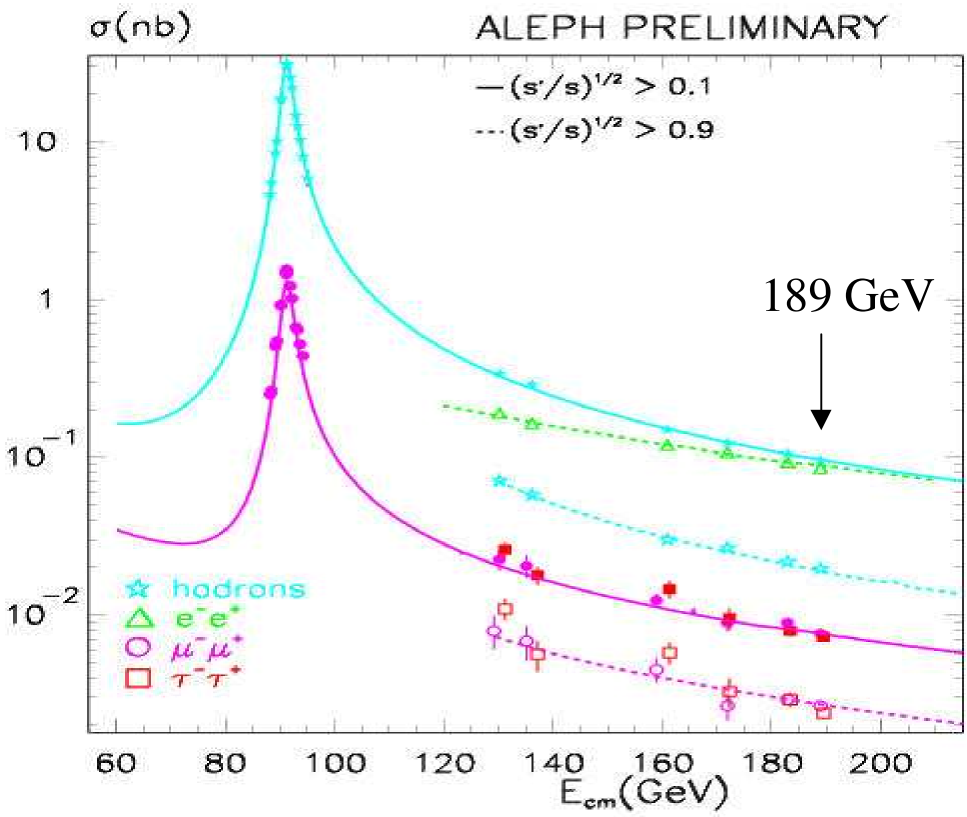


Cross-Sections
$\tilde{\nu}$
Contact terms
Fermion-pair production
e^+
e^-
γ, Z^*
f
$\bar{f}$
Asymmetries
LQ
Z'

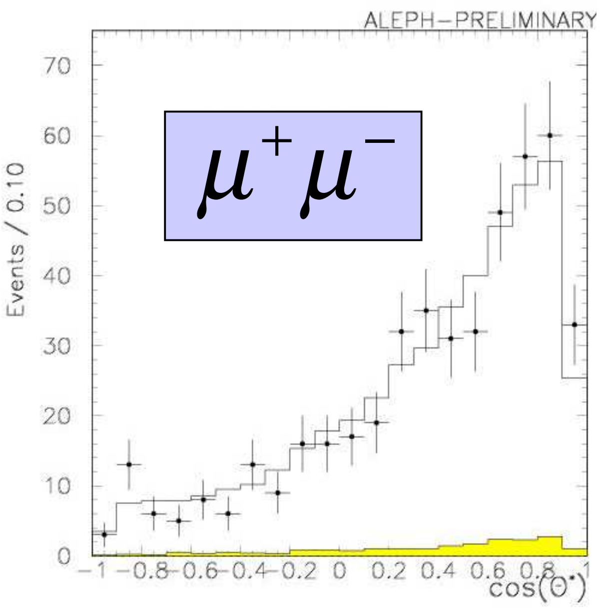
$f\bar{f}$ cross - section

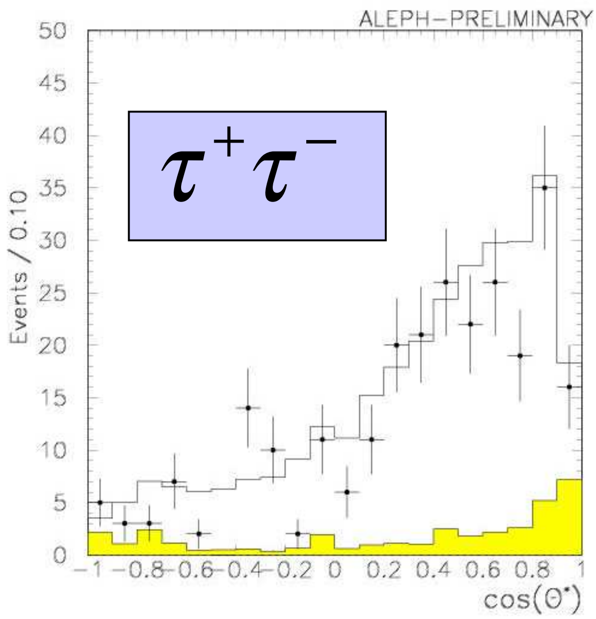
	Channel	σ (pb)	SM
Inclusive $\sqrt{s'/s} > 0.1$	$q\bar{q}$ $\mu^+\mu^-$ $\tau^+\tau^-$	97.20 ± 0.67 ± 0.77 7.62 ± 0.24 ± 0.19 7.33 ± 0.31 ± 0.12	96.26 7.64 7.64
Exclusive $\sqrt{s'/s} > 0.9$	$q\bar{q}$ $\mu^+\mu^-$ $\tau^+\tau^-$ e^+e^-	19.59 ± 0.44 ± 0.15 2.66 ± 0.13 ± 0.06 2.39 ± 0.15 ± 0.05 84.08 ± 0.74 ± 0.72	19.30 2.69 2.78 87.25

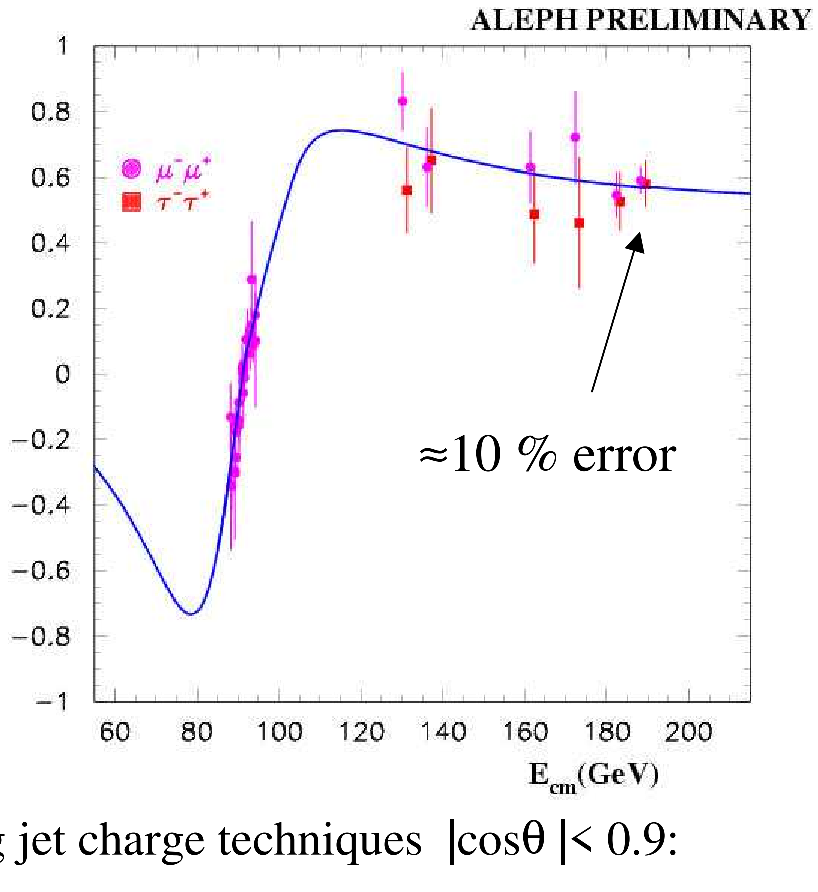
- systematic ≈ statistical error e^+e^-, $q\bar{q}$ inclusive
- e^+e^- dominated by theoretical uncertainty (BHWIDE MC)



Asymmetries $\sqrt{s'/s} > 0.9$







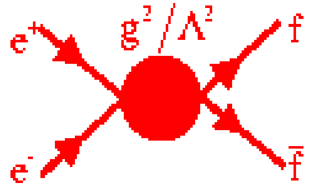
Using jet charge techniques $|\cos\theta| < 0.9$:

$$< Q_{FB}(udcs) > = 0.015 \pm 0.005 \quad SM: 0.018$$

$$A_{FB}(b\bar{b}) = 0.34 \pm 0.19 \quad SM: 0.56$$

Limits on New Physics: two examples …

Contact interactions:

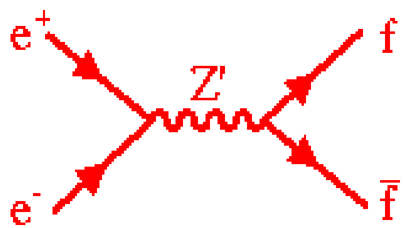


$$L^{\mathrm{Contact}} \approx \pm \frac{g^2}{\Lambda^2} \sum_{i,j=L,R} \eta_{ij} \left[\bar{e}_i \gamma^\mu e_i\right]\left[\bar{f}_j \gamma^\mu f_j\right]$$

$$g^2 = 4\pi$$

Model	Lower limit (TeV)	
	Λ^-	Λ^+
VV	14.9	12.0
AA	15.2	10.1
LL+RR	14.2	9.7
LR+RL	9.0	10.4

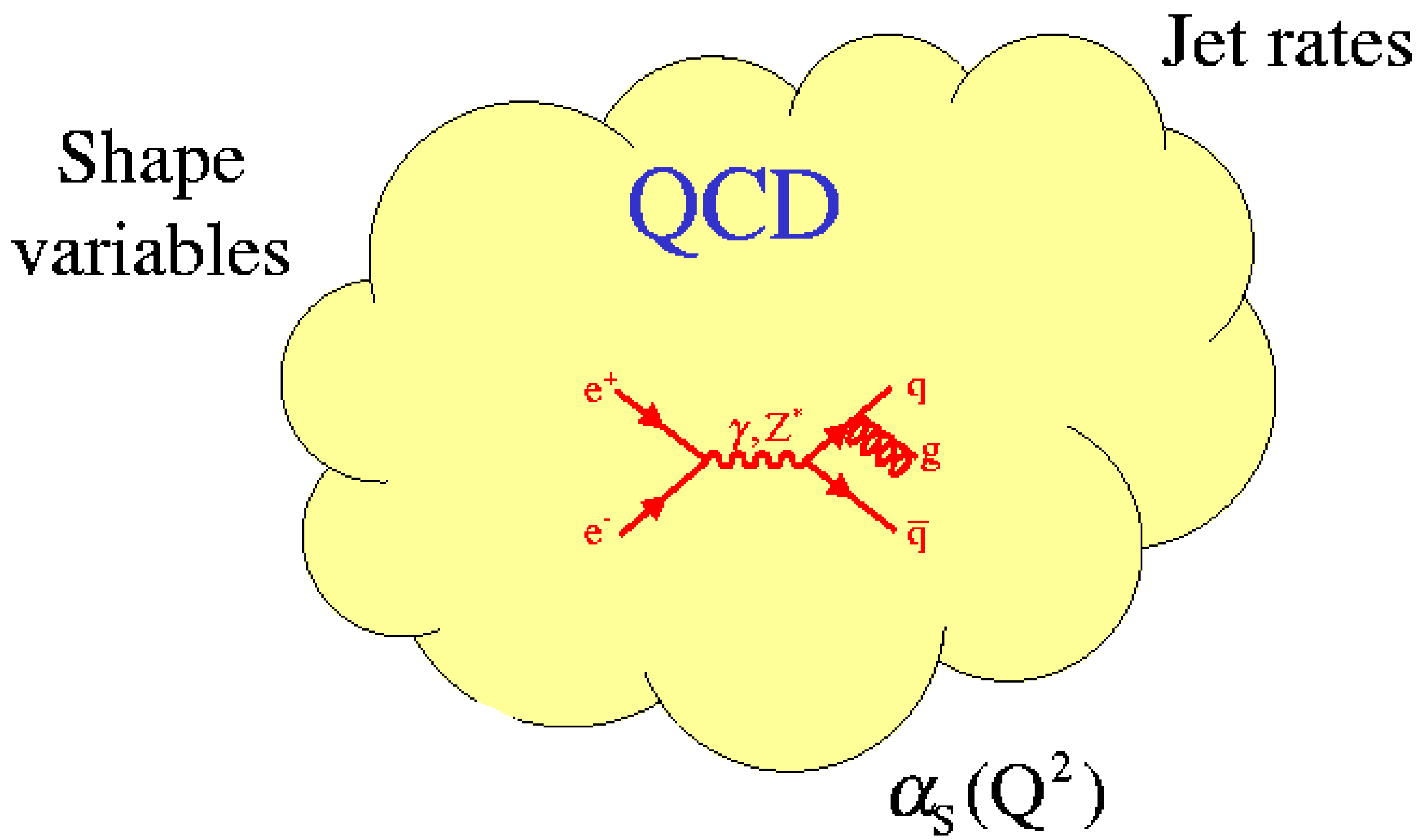
New Z' boson:



No Z'/Z mixing (from LEP1)

Model	Lower limit on $m_{Z'}$ (GeV)
E_6 (χ)	460
E_6 (ψ)	285
E_6 (η)	295
E_6 (I)	385
LR symmetric	470
Sequential SM	1050 (CDF: 690)

Note: $e^+e^-\ell^+\ell^-$, $e^+e^-b\bar{b}$ contact terms unaccessible to HERA / Tevatron / LHC



Jet rates
Shape variables
QCD
e^+
e^-
γ, Z^*
q
g
$\bar{q}$
$\alpha_s(Q^2)$

Study observables for which evolution with $\sqrt{s}$ well predicted by QCD

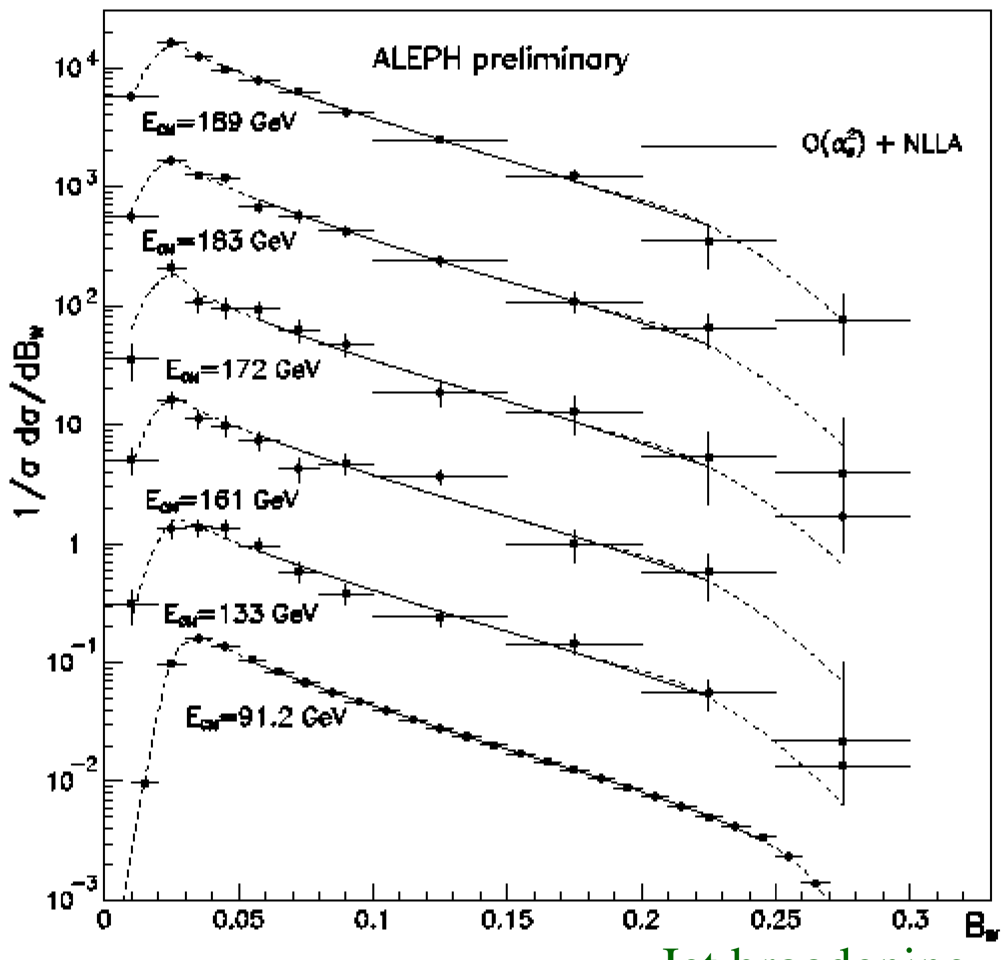
$\rightarrow$ test theory

$\rightarrow$ measure running of $\alpha_S(Q^2)$

Shape variables (thrust, C, jet broadening, ...) :

– sensitive to "three-jetness" $\rightarrow$ α_S

– infrared / collinear safe $\rightarrow$ computed in perturbative QCD

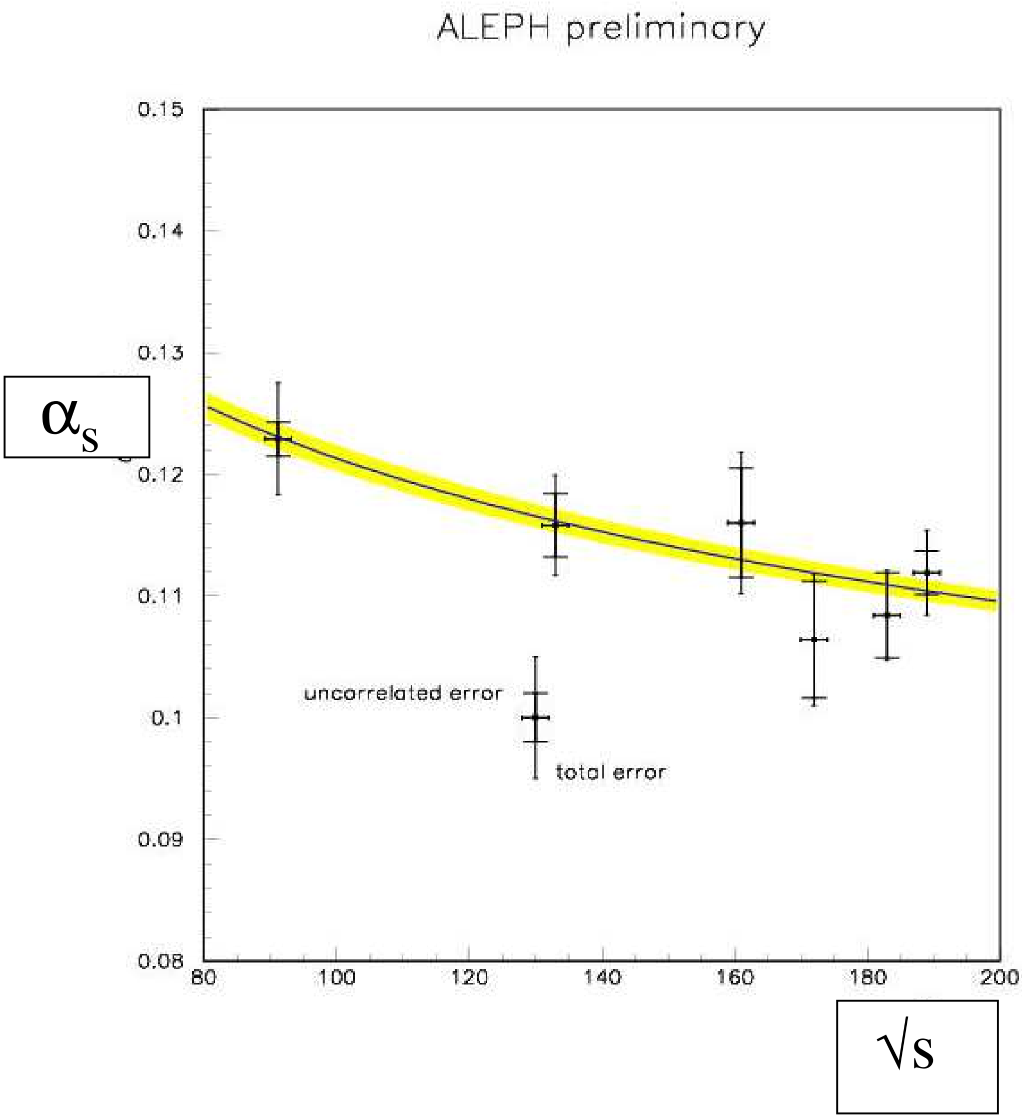


Jet broadening

Fit C, y_3, thrust, B_W, M_j^2/s with QCD (α_S^2 + NLLA) prediction

$\rightarrow$ measure $\alpha_S(Q^2)$

Measurement of running α_S



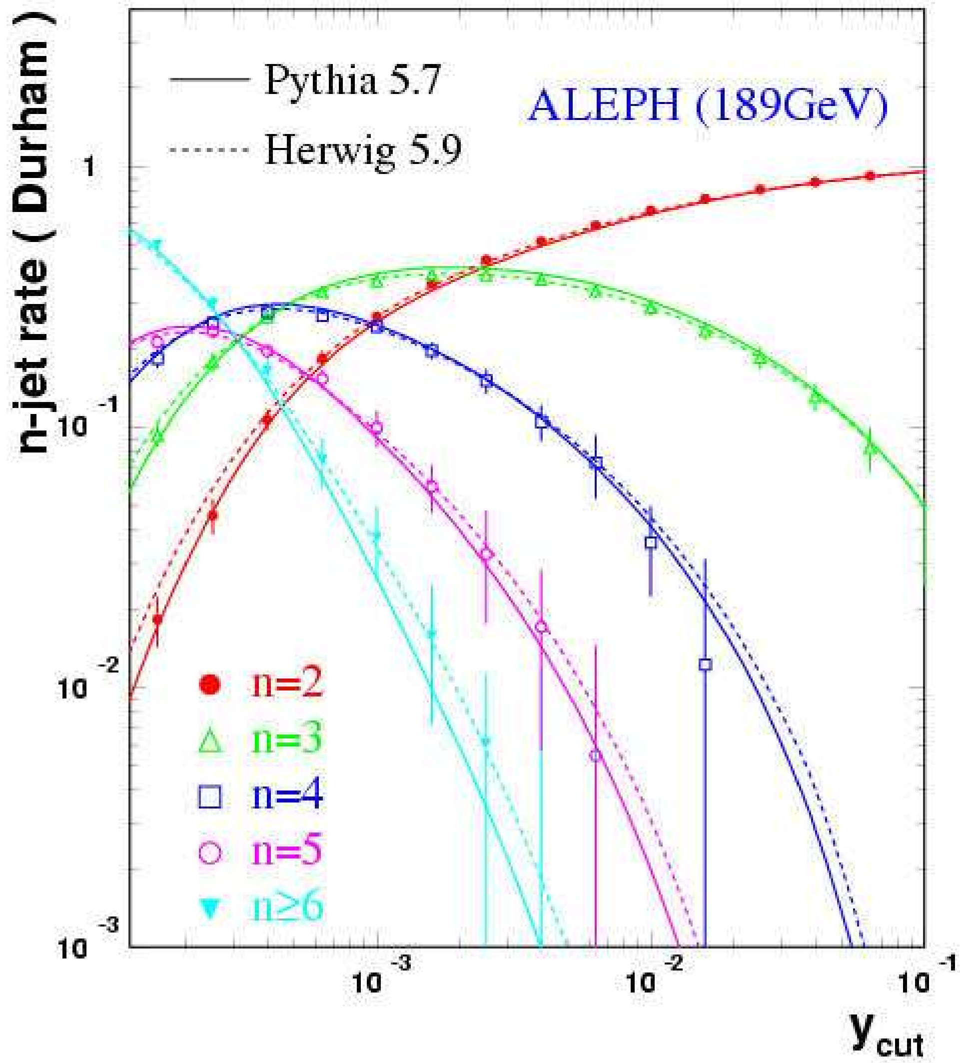
Fit: QCD 3-loop prediction

$$\alpha_S(\sqrt{s} = 189\,\text{GeV}) = 0.1119 \pm 0.0015\,(\text{stat.}) \pm 0.0011(\text{exp.}) \pm 0.003(\text{th.})$$
$$\alpha_S(\sqrt{s} = m_z) = 0.1216 \pm 0.0039 \quad \text{from LEP2 data}$$

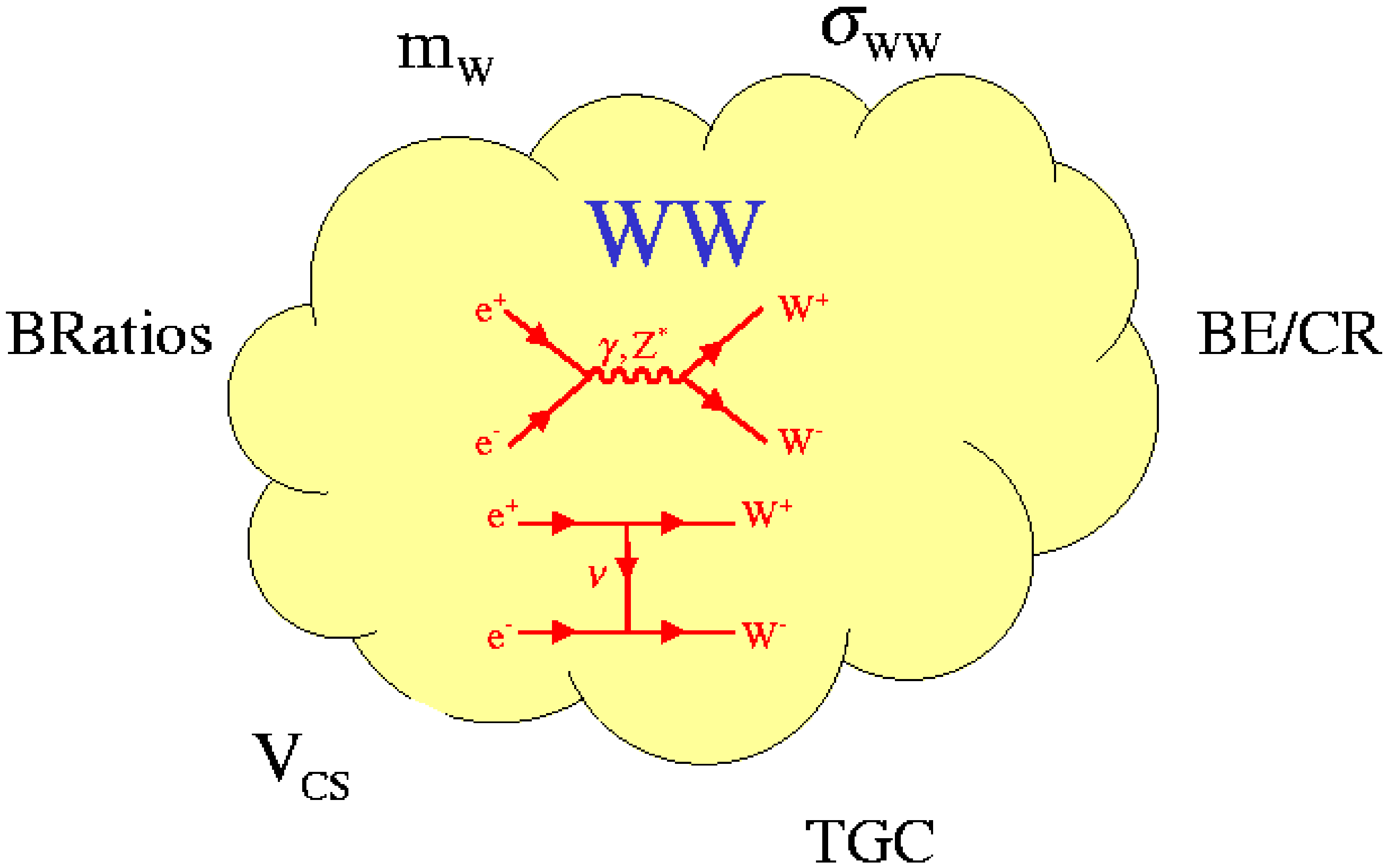
LEP2: statistical error larger than LEP1
theoretical error (missing higher orders, hadronization) smaller

Note: benefits from large energy/luminosity

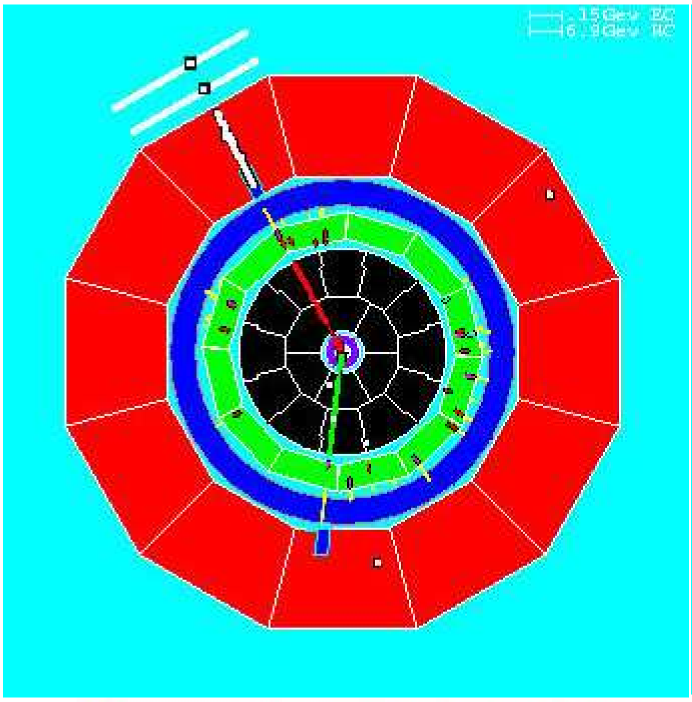
Test reliability of Monte Carlo (Pythia, Herwig, …) used to estimate background, efficiency, systematics for WW, Higgs, …...

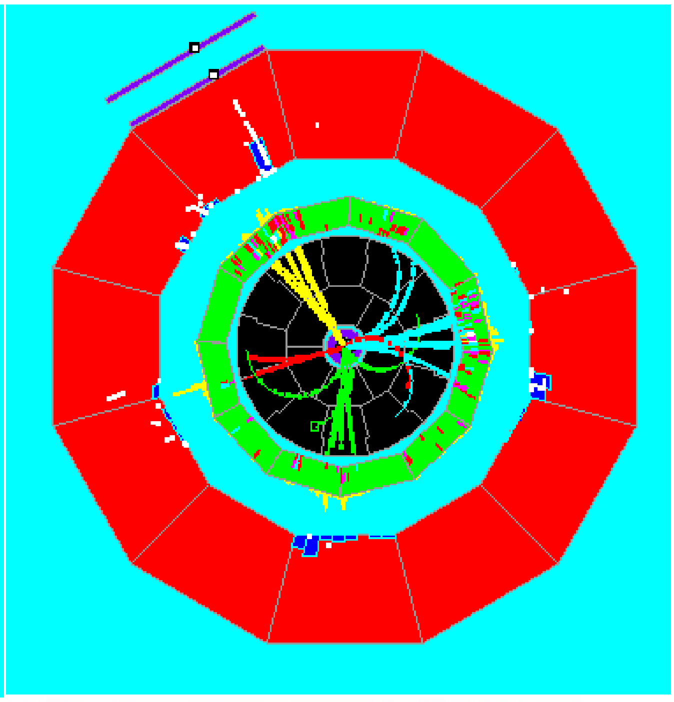


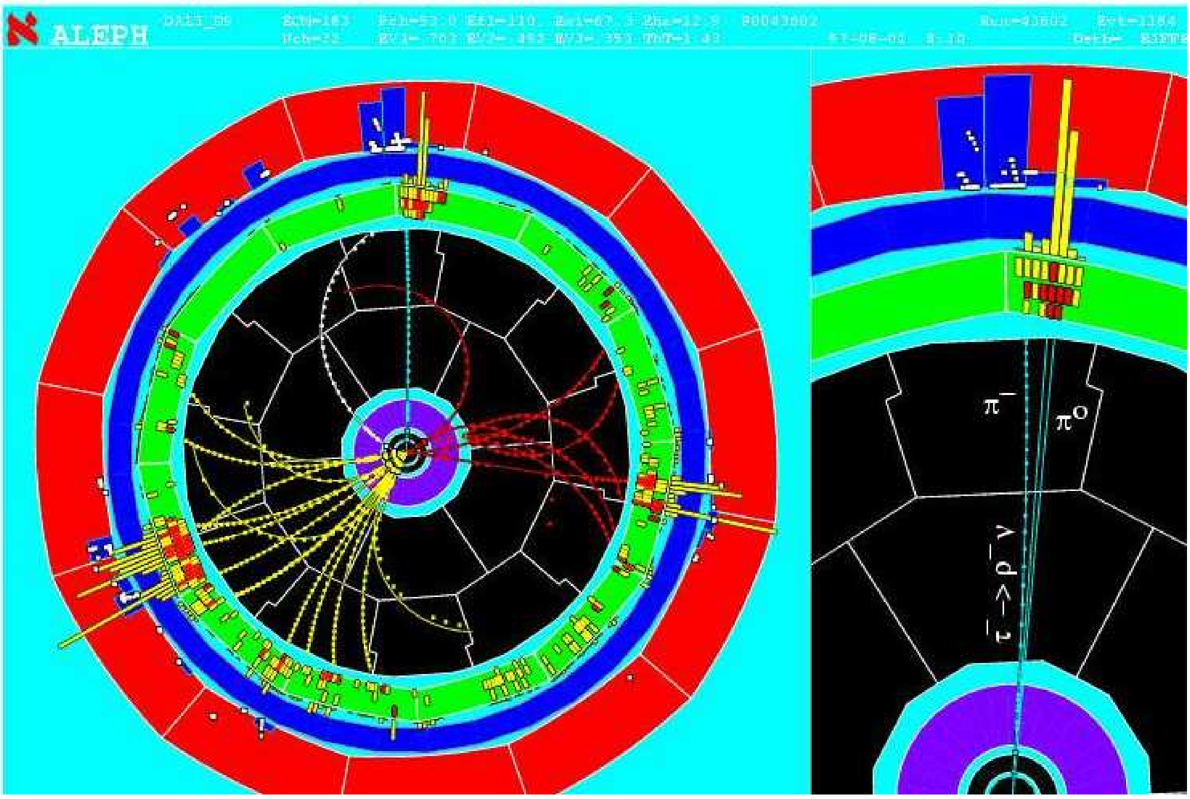
4-jet rate is OK


m_W
σ_{WW}
WW
BRatios
BE/CR
e^+
e^-
γ, Z^*
W^+
W^-
e^+
e^-
ν
W^+
W^-
V_{cs}
TGC

WW events at 189 GeV



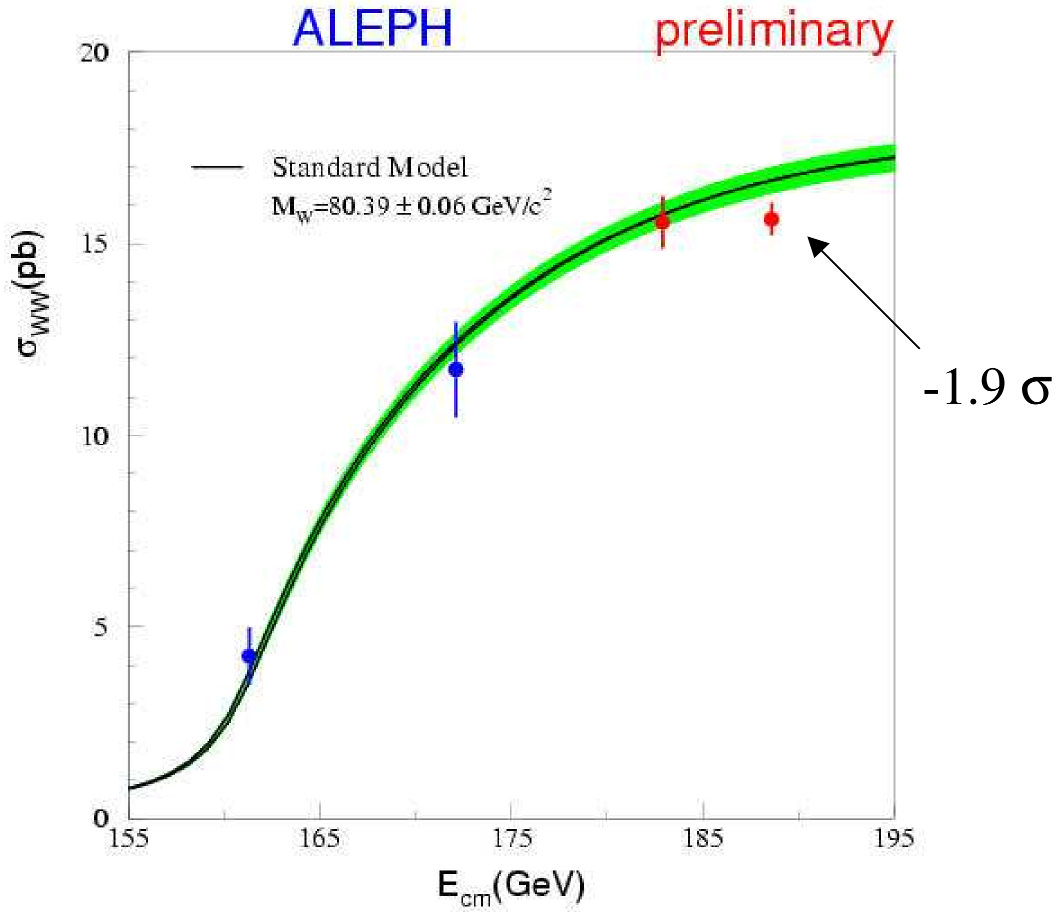




~2500 WW $\sqrt{s}$=189 GeV

~3500 WW ALEPH total

WW cross-section



Channel	σ (pb)	SM CC03	N_σ no th. error
$\ell\nu\ell\nu$	$1.77 \pm 0.13 \pm 0.05$	1.76	+0.1
$\ell\nu q\bar{q}$	$7.14 \pm 0.23 \pm 0.14$	7.30	-0.6
4q	$6.83 \pm 0.23 \pm 0.21$	7.59	-2.4
Total	$15.64 \pm 0.34 \pm 0.26$	16.65 ± 0.33	-2.4

-1.9 σ including theoretical error

Checks of WW$\rightarrow$ 4q cross-section

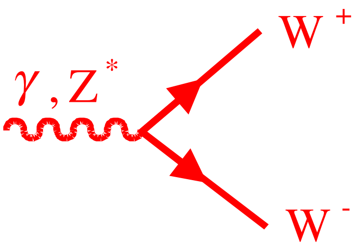
- Monte Carlo :
  - KORALW/EXCALIBUR compared for cross-section and selection efficiency
  - QCD 4-jet rate well understood
  - detector simulation: good agreement data / MC for $q\bar{q}$

- Detector :
  - data / MC comparison vs $E_{jet}, \vartheta_{jet}, \varphi_{jet}$
  - analysis redone with tracks only

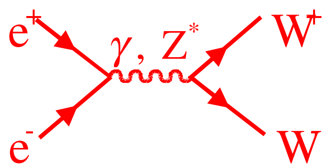
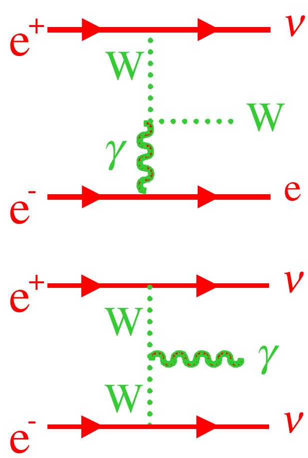
- Analysis :
  - data / MC comparison for all selection variables
  - preselection and NN cuts varied
  - three different analyses performed

$\rightarrow$ No bias found

Triple Gauge Couplings



- Probe non-abelian structure of $SU(2)\otimes U(1)$. Sensitive to new physics
- Parametrized by $g_1^Z, k_\gamma, \lambda_\gamma$ (SM≡1,1,0)
- Anomalous contributions grow with energy and affect cross-section and angular distributions
- 3 processes at LEP2:

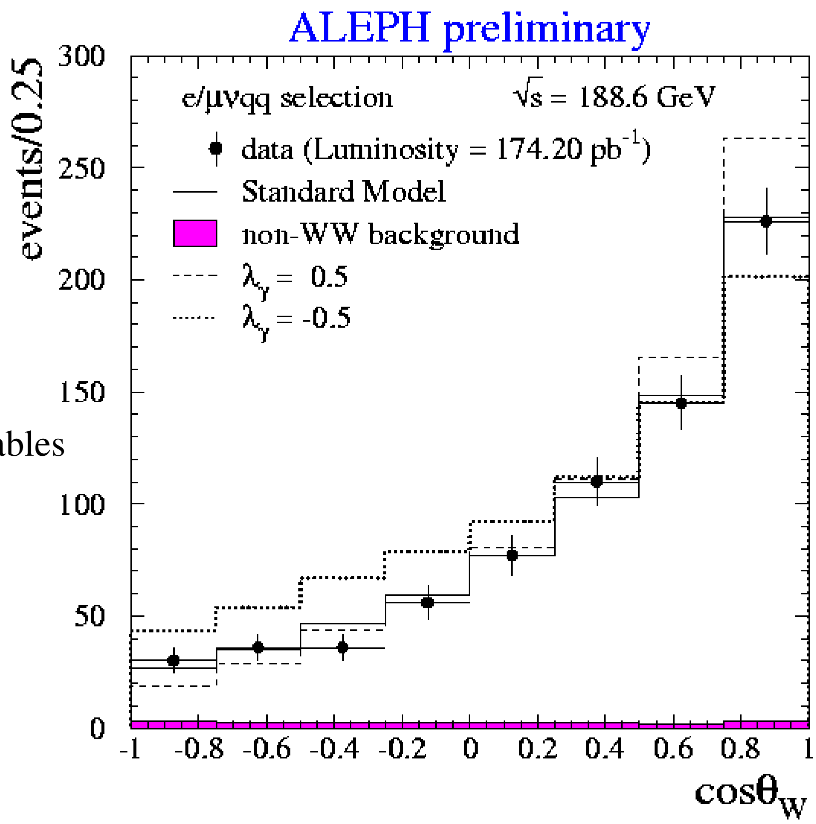
	• clean, large statistics • sensitive to all couplings • γWW, ZWW not separated
	• probe γWW • insensitive to g_1^Z • little sensitive to λ_γ (small Q^2) • small statistics • large $\gamma Z \rightarrow \nu\nu$ background to single γ

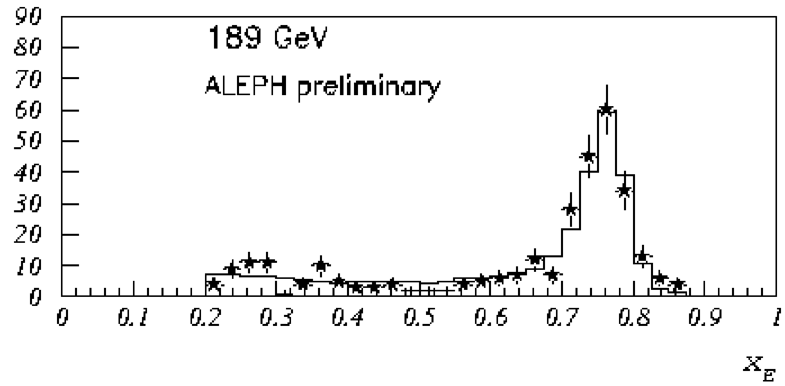
All three channels studied

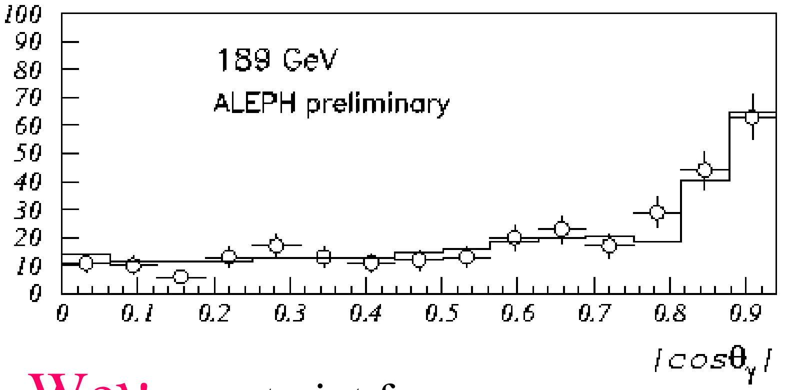
WW: all channels used
($l\nu l\nu$, $l\nu qq$, 4q)

constraints from σ_{WW}

$\cos\theta_{W^-}$
$\theta^-, \varphi^-, \bar{\theta}^+, \bar{\varphi}^+$ } combined in Optimal Observables







$\gamma\nu\nu$:
constraints from
$\sigma(\gamma\nu\nu)$, E_γ, θ_γ

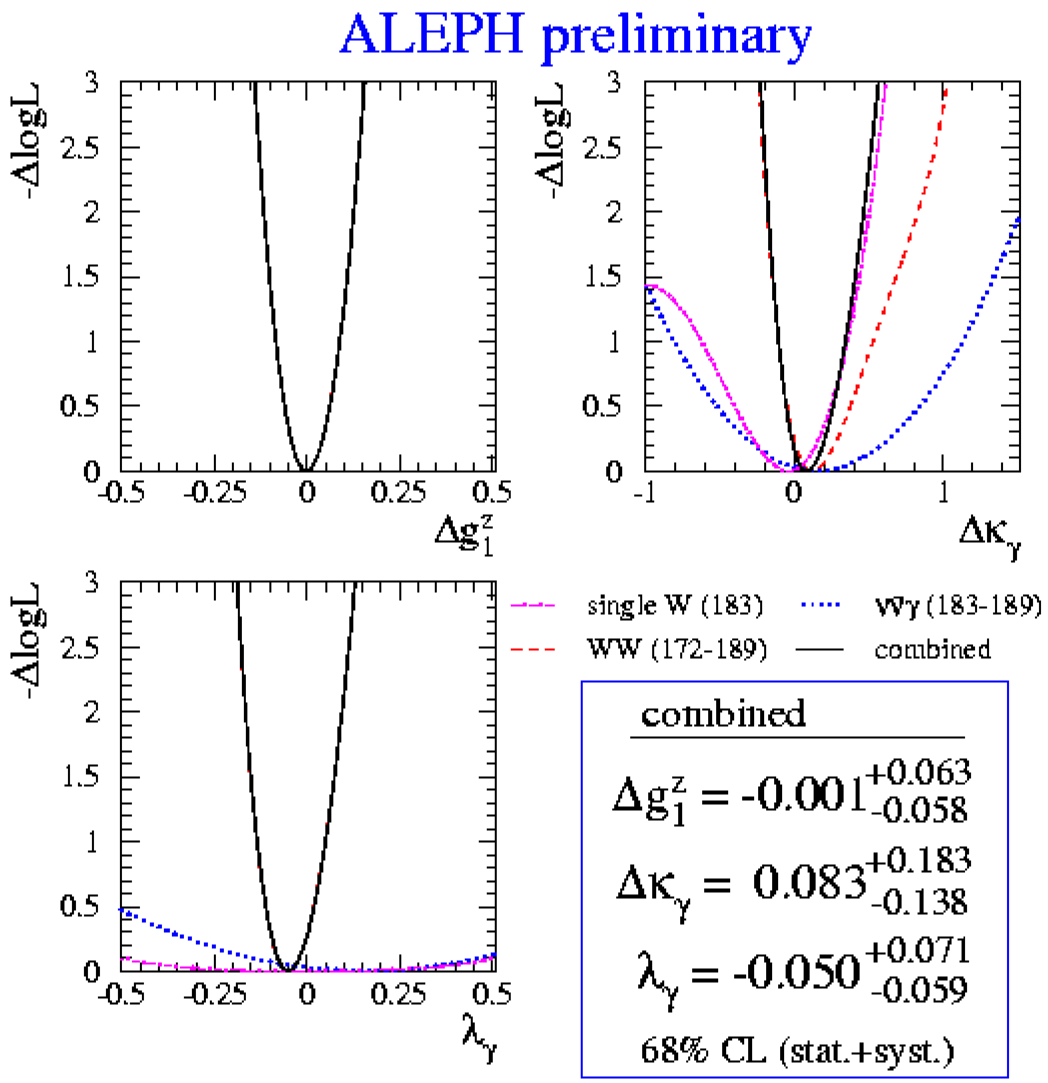
298.9 events expected
300 events observed

$We\nu$: constraint from
$\sigma(We\nu)$ = 0.41±0.17 (stat.) ±0.04 (syst.)

$\sqrt{s}$=183 GeV
SM : 0.41 pb

Combining WW, $\gamma\nu\nu$ (161-189 GeV)

Wеν (161-183 GeV)

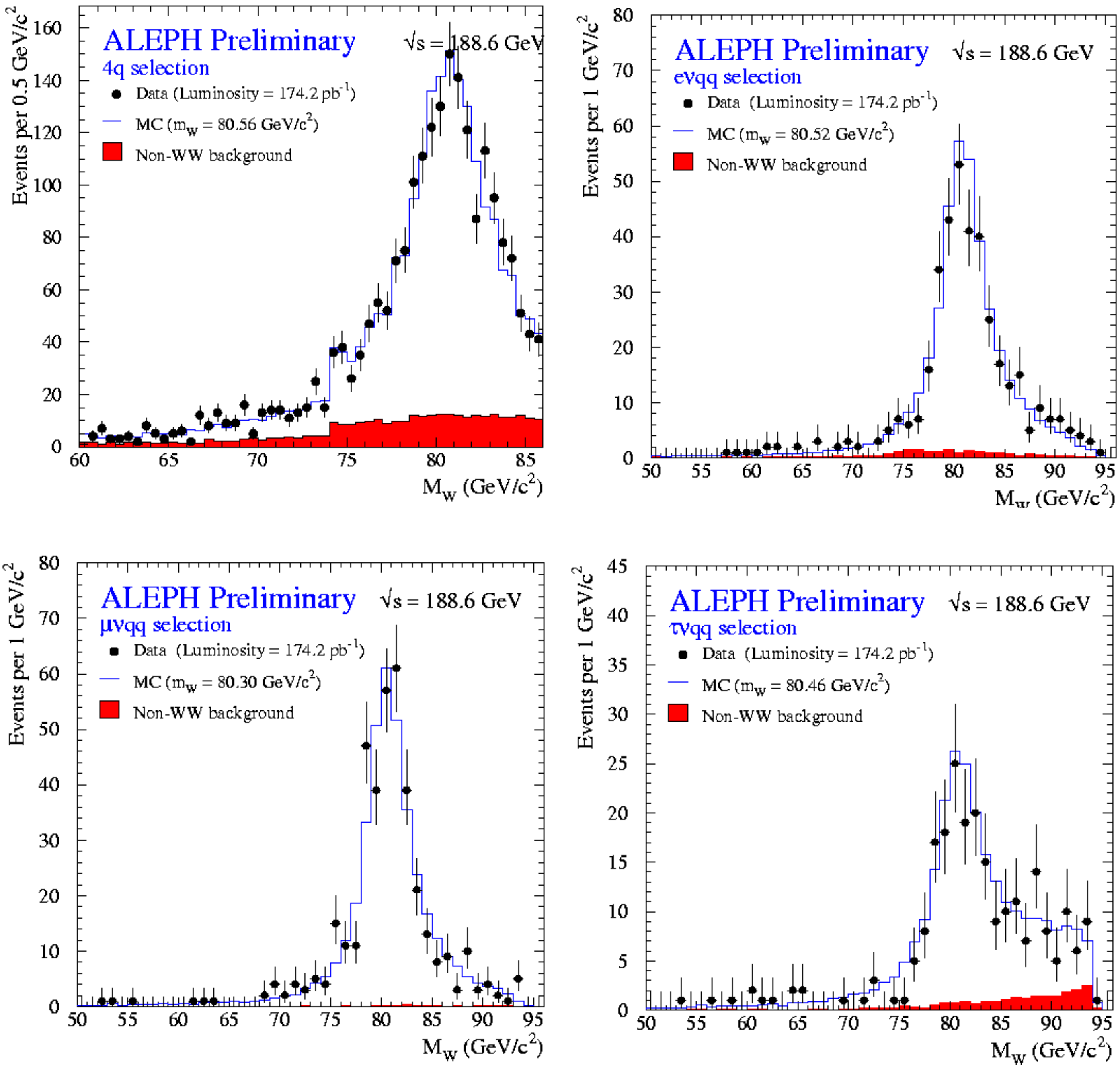


1D fit

- 2D and 3D fits: similar results
- error dominated by statistics
- benefit from high energy/luminosity

Measurement of W mass

- 4q channel: 4C fit (E/ $\vec{p}$ conservation) + mass rescaling $\rightarrow$ 2 m_W per event $\rightarrow$ 2D reweighting
- $l\nu qq$ channel: 2C fit (E/$\vec{p}$ conservation + mass equality - $\vec{p}_\nu$) $\rightarrow$ 1 m_W per event $\rightarrow$ 1D reweighting



Uncertainties on m_W (MeV)

Source	4q	$e\nu q\bar{q}$	$\mu\nu q\bar{q}$	$\tau\nu q\bar{q}$
Statistics	116	180	164	332
Calorimeter calibration	30	27	14	19
Jet corrections	8	14	4	7
Tracking	-	7	3	3
Background	10	8	1	25
ISR	10	5	5	5
Fragmentation	35	25	25	30
Colour reconnection	25	-	-	-
Bose-Einstein	50	-	-	-
MC statistics	10	16	15	23
LEP energy	17	17	17	17
Total systematics	77	47	37	53

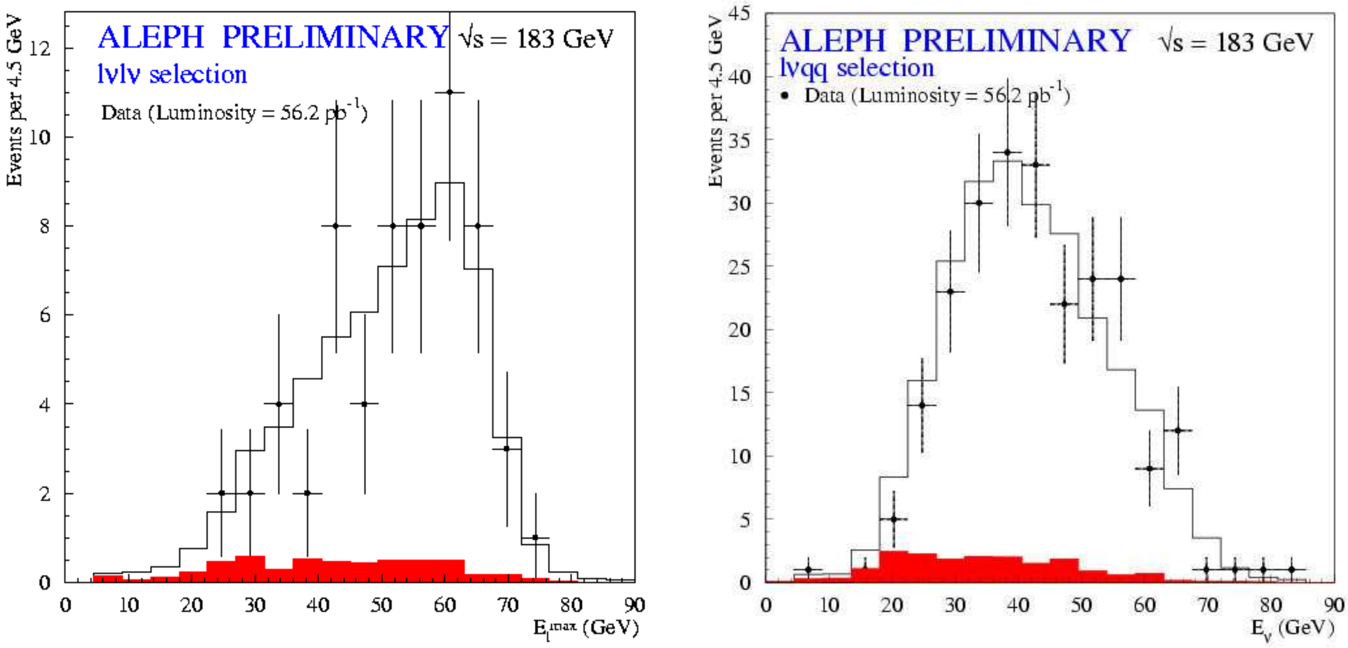
from 183 GeV data
correlated errors

Detector systematics relatively small thanks also to Z-peak run

Leptonic W mass (new)

Extract m_W from kinematic properties of l,ν in the final state:

$$\boxed{\begin{array}{l} -\, l\nu l\nu: \text{ fit } E_l^{max}, E_l^{min}, \not{E} \text{ spectra} \\ -\, l\nu q\bar{q}: \text{ fit } E_l, E_\nu, \text{ rescaled } m_{l\nu} \text{ (no kin. fit)} \end{array}}$$



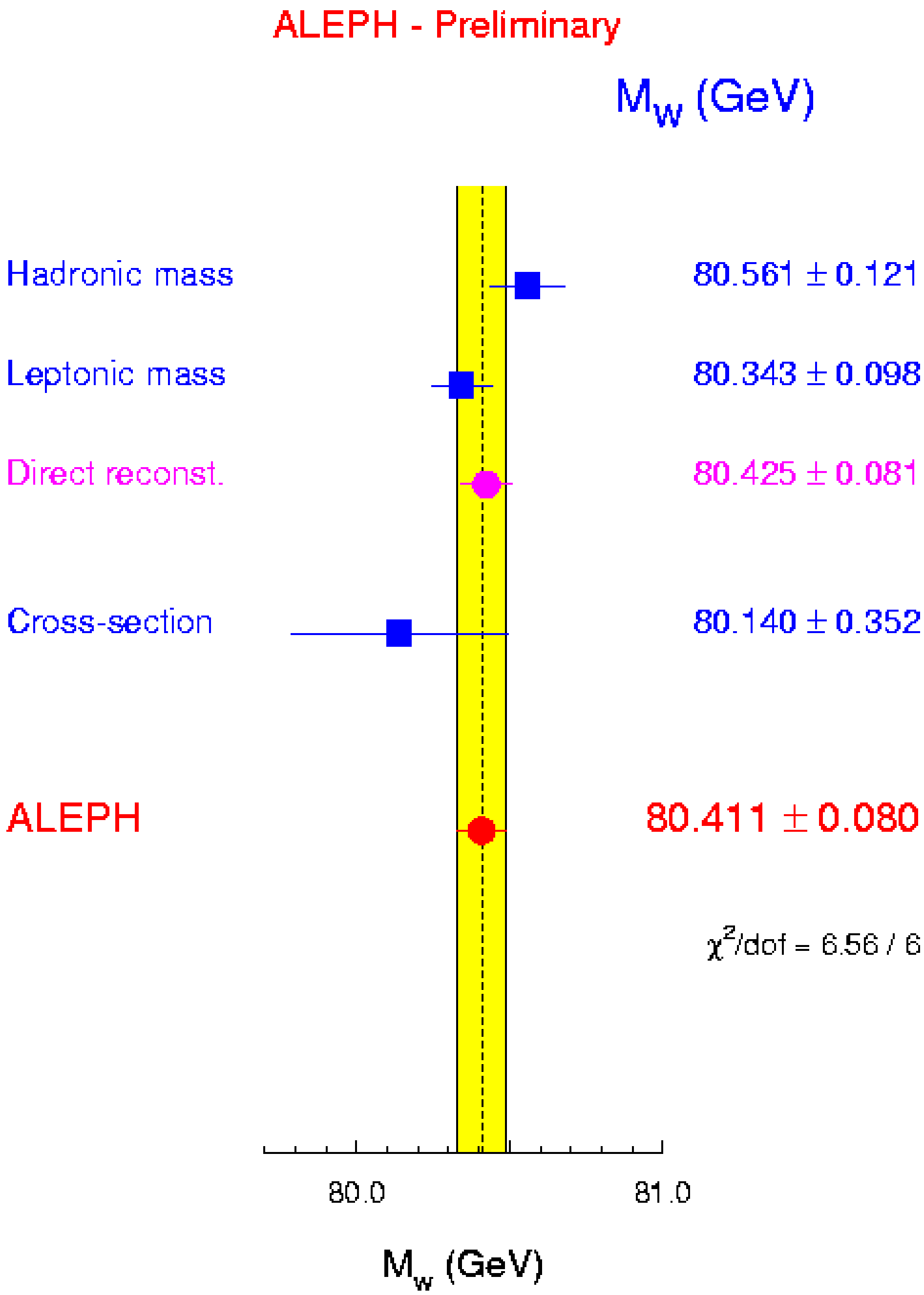
Measurement done at $\sqrt{s}$ = 183 GeV:

$$\boxed{m_W\,(l\nu\, l\nu) = 80.291 \pm 0.526\,(\text{stat.}) \pm 0.090\,(\text{syst.})\ \text{GeV}}$$

$$\boxed{m_W\,(l\nu\, qq) = 80.151 \pm 0.210\,(\text{stat.}) \pm 0.089\,(\text{syst.})\ \text{GeV}}$$

$\rightarrow$ Δm_W improves from 139 MeV to 129 MeV at 183 GeV

Results



$\Delta m = 0.219 \pm 0.132$ GeV

$\sqrt{s} = 172\text{-}189$ GeV

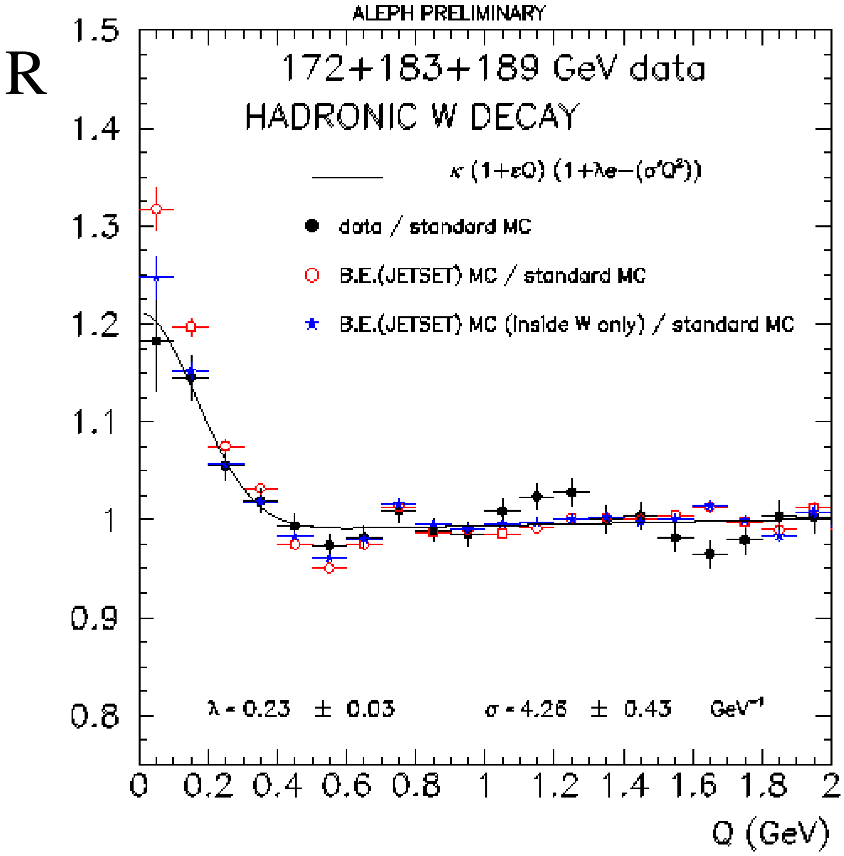
$\sqrt{s} = 161\text{-}189$ GeV

$$m_W = 80.411 \pm 0.064 \text{ (stat)} \pm 0.037 \text{ (syst.)}$$
$$\pm 0.018 \text{ (LEP)} \pm 0.022 \text{ (BE/CR) GeV}$$

Bose-Einstein correlations

$W \to 4q$: correlations also between identical pions from different W's ? Use Z/W data to constrain

$$R = (N_\pi^{++,--} / N_\pi^{+-})_{data} / (N_\pi^{++,--} / N_\pi^{+-})_{MC}$$



Jetset MC:

- tuned and corrected at Z-peak (udsc sample)
- checked with WW $\to l\nu$ qq decays

	σ	χ^2 (DATA - MC)
BE inside W only	0.6	2.2 / 5
BE also between W	2.7	15.4 / 5

Conclusions

- Plenty of (preliminary) physics results from '98 ALEPH data: limits from searches and precision measurements improved significantly thanks to high energy/luminosity.

- For many measurements systematic error is comparable to statistical error:
  - theoretical inputs needed in many cases
  - more statistics → understand detector/physics better
  - Z- peak data necessary at beginning/end of run

- Note : status of detector
  - no major problem during last run
  - VDET (2% of dead region in Z) repaired
  - shutdown operations going on (extensive maintenance of magnet control system)

↓

READY TO TAKE DATA

ALEPH WEB page for conference notes:

http://alephwww.cern.ch/ALPUB/oldconf/oldconf_99.html