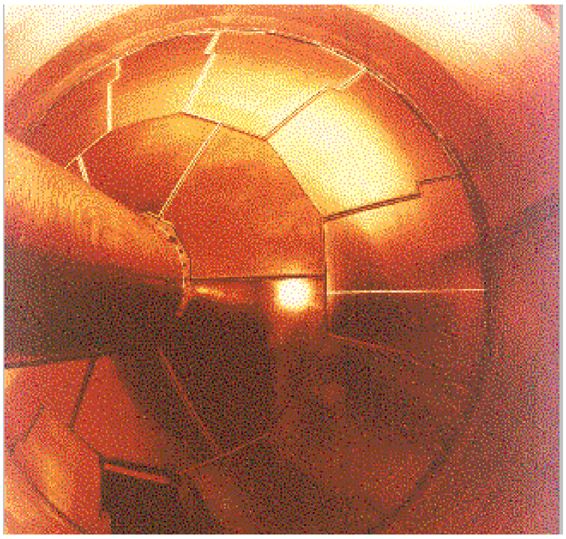
ALEPH Status Report

LEPC 31 March 1998

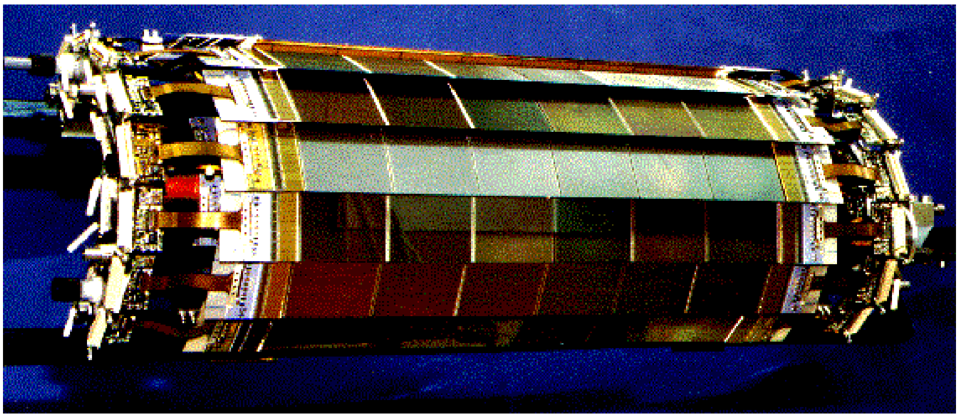
John Carr
CPP Marseille/CERN

Detector Status

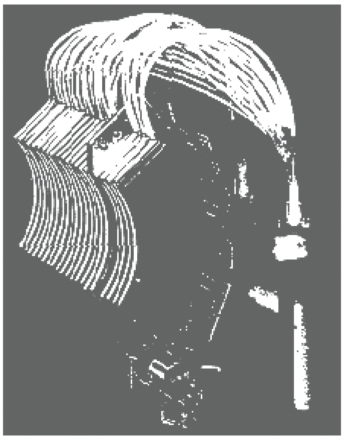
One TPC sector replaced



One VDET face replaced



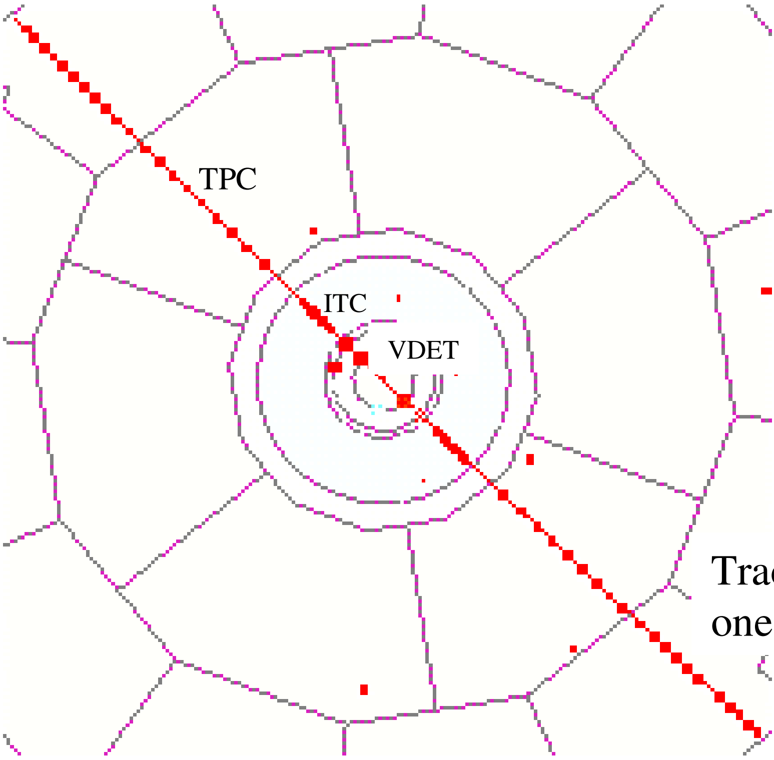
BCAL++
(Forward Beam Calorimeter)
closer to beam with new beam pipe



ALEPH ready to take data

Need for extra calibration Z run

Initial tracking alignment uses mainly $\mu^+\mu^-$ events



Track curvature fixed in fit
one helix for two tracks

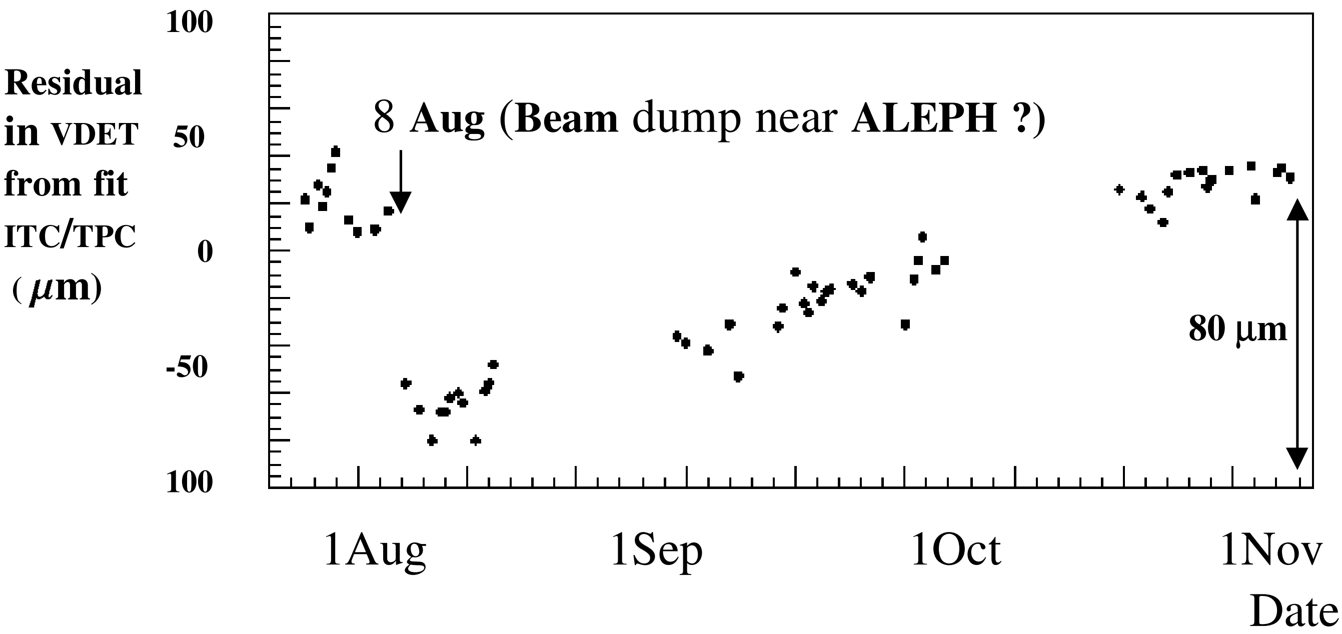
At 91 GeV ~1000 useful $\mu^+\mu^-$ per pb^{-1}
at 183 GeV ~2 per pb^{-1} and non-isotropic

During 183 GeV running hadrons used to check alignment and make adjustments. However cannot fix curvature with hadrons.

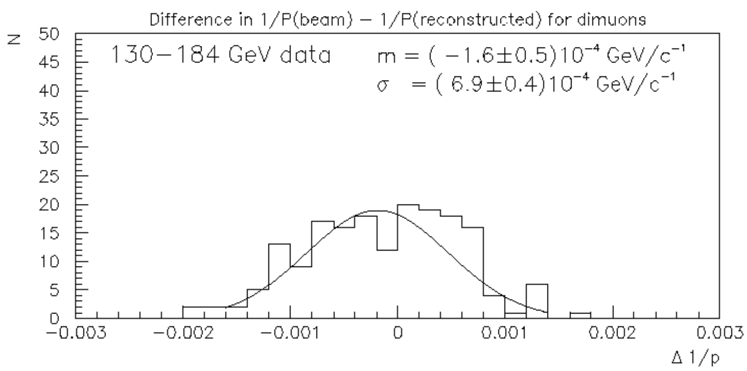
Hadrons are less safe for alignment

Initial Tracking Alignment in 1997

Tracking with constant parameters from Z peak data at start

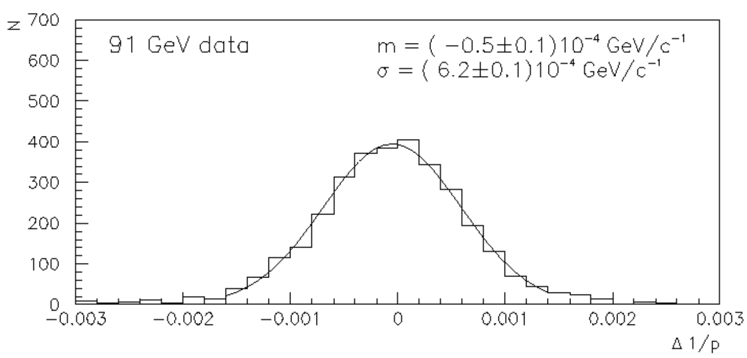


Final alignment makes corrections assuming problem in TPC



$\sigma(1/p) \sim 7\ 10^{-4}\ (\mathrm{GeV/c})^{-1}$
for high energy data

(120 events)



$\sigma(1/p) \sim 6\ 10^{-4}\ (\mathrm{GeV/c})^{-1}$
for high energy data

(2400 events)

Request for 1998

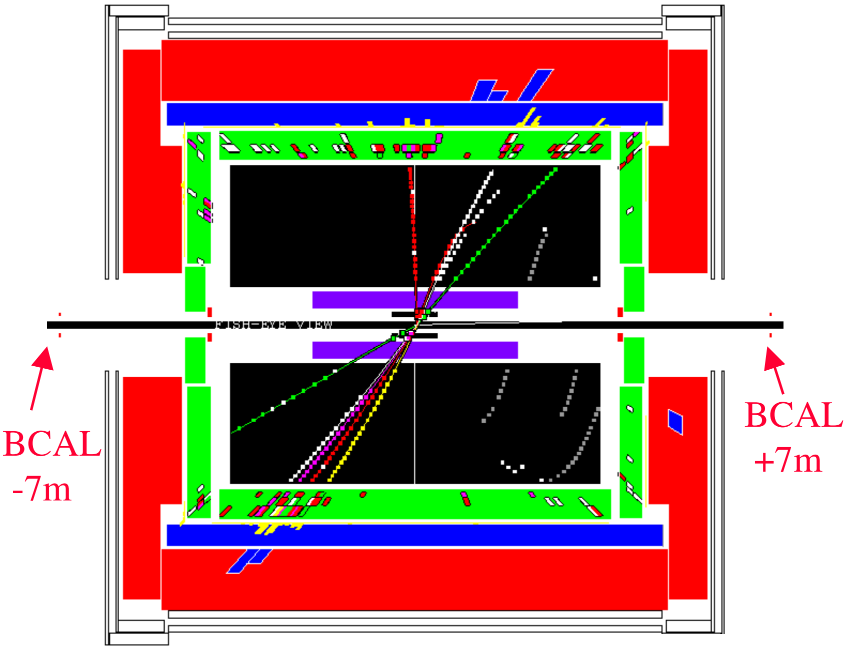
1997 Alignment corrected for using hadrons.
Impossible exactly localize cause of distortions.
Effect on physics is small.

Having seen a potential problem in 1997,
wish to have extra precautions in 1998.

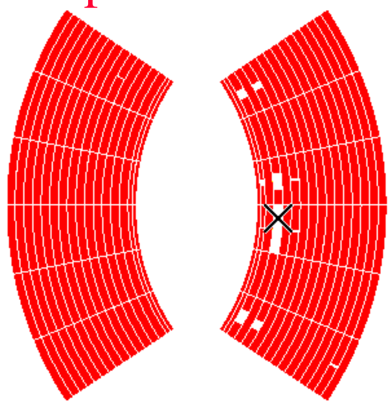
Request an extra Z calibration run at year end 0.5 pb^{-1} giving 500 $\mu^+\mu^-$.

Would appreciate option to ask for another run during run if observe shifts.
Ideal:
start 1.5 pb^{-1}, middle 0.5 pb^{-1}, end 0.5 pb^{-1}

γγ physics tagged in BCAL++

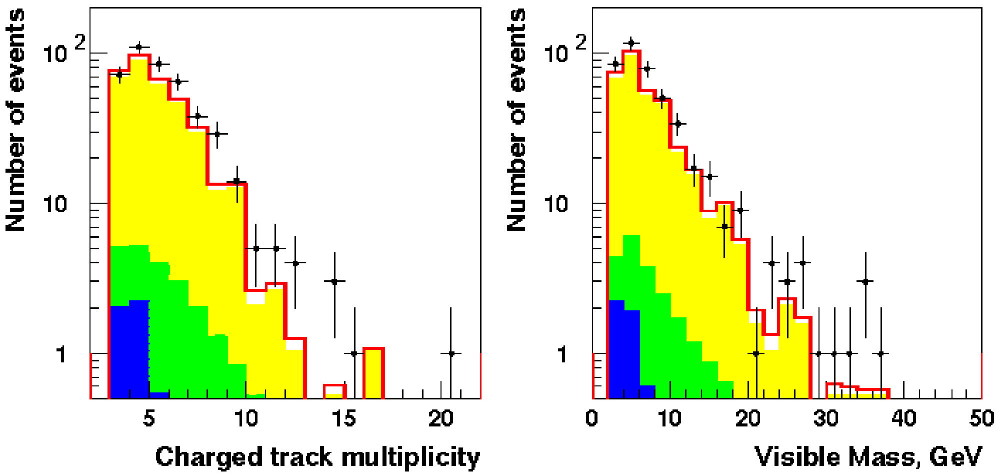


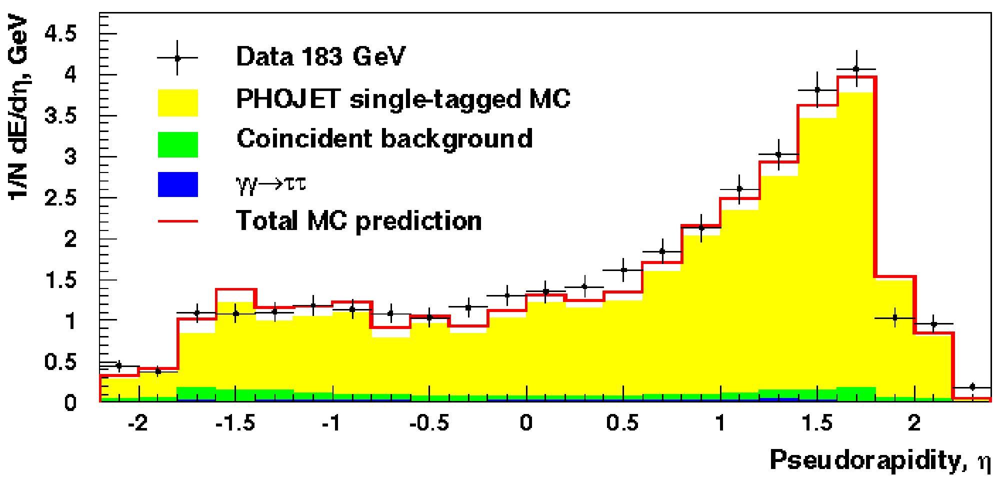
BCAL++ calorimeter
tungsten/scintillator
with plane of silicon



γγ → hadrons

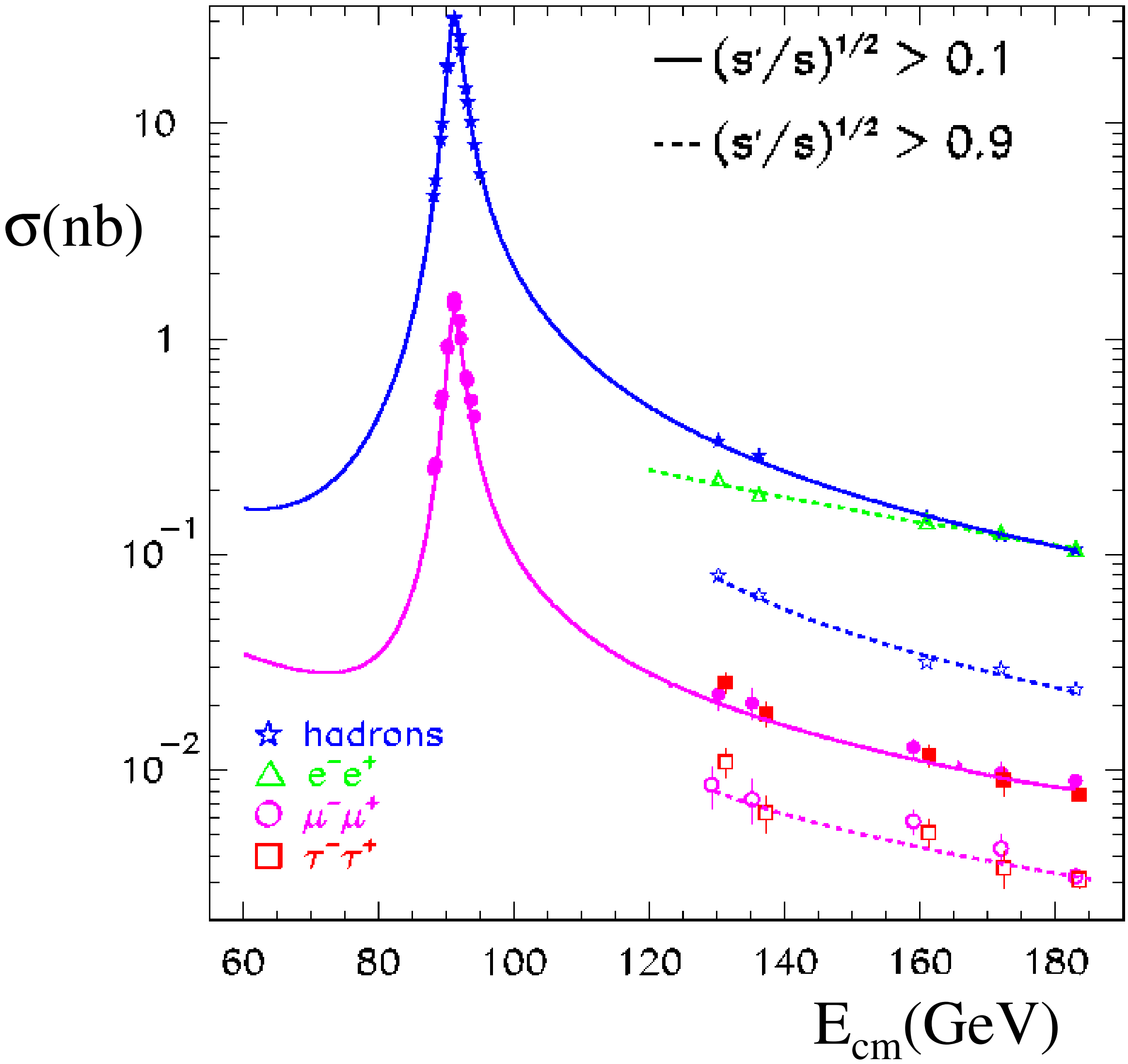
single tag
BCAL>70 GeV
≥ 3 tracks
M_{vis}> 3 GeV
E_{vis} < 50 GeV





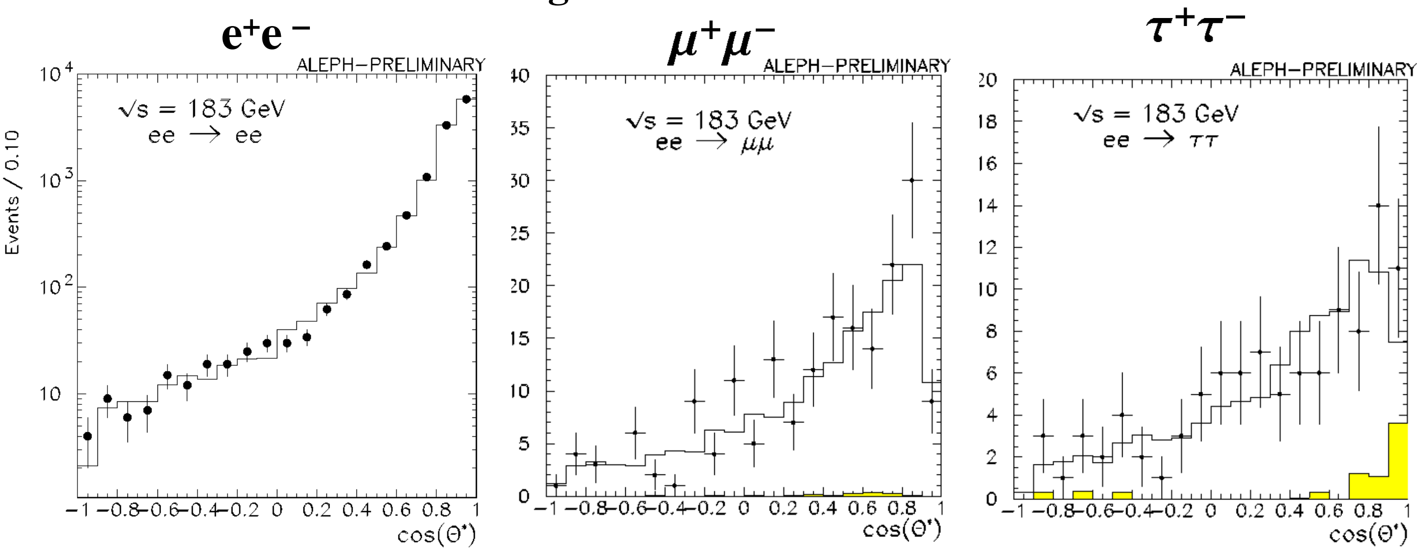
Fermion Pair Production

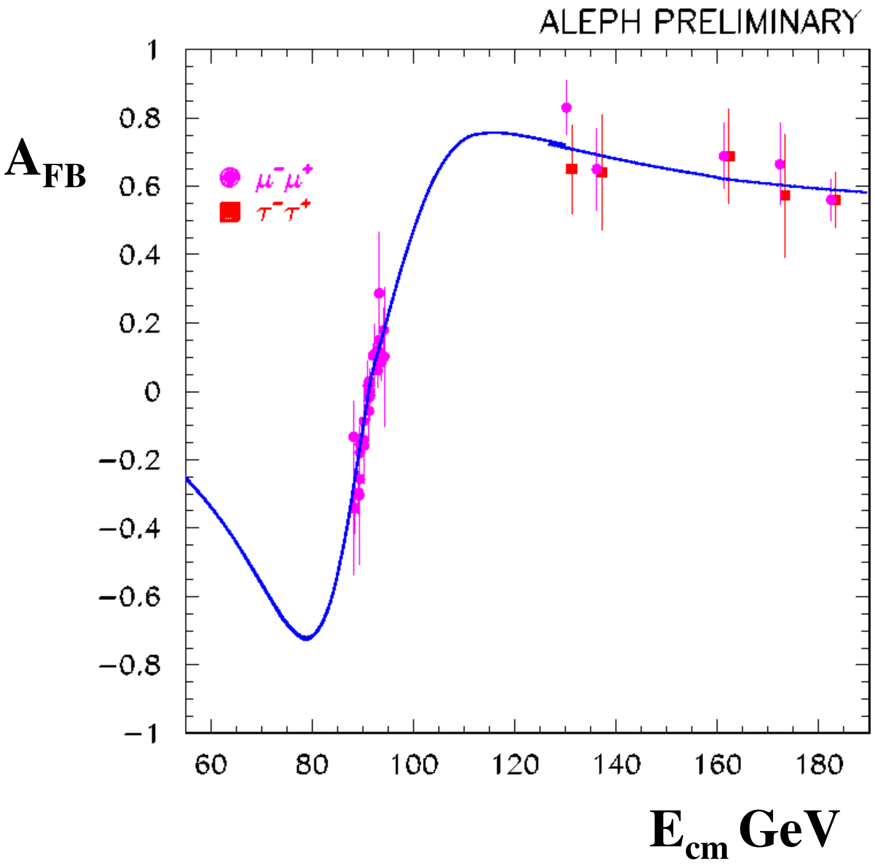
		events	σ (pb)	S.M. predictions (pb)
183 GeV	$q\bar{q}$	6072	$104.8 \pm 1.6 \pm 1.4$	104.6
$\sqrt{s'/s} > 0.1$	$\mu^+\mu^-$	406	$8.9 \pm 0.5 \pm 0.3$	8.22
	$\tau^+\tau^-$	231	$7.7 \pm 0.5 \pm 0.3$	8.22
183 GeV	$q\bar{q}$	1210	$23.6 \pm 0.7 \pm 0.2$	23.05
	$b\bar{b}$	107	$4.4 \pm 0.4 \pm 0.2$	3.80
$\sqrt{s'/s} > 0.9$	$\mu^+\mu^-$	175	$3.2 \pm 0.2 \pm 0.1$	3.13
	$\tau^+\tau^-$	126	$3.1 \pm 0.3 \pm 0.1$	3.23
	e^+e^-	5704	$106.2 \pm 1.4 \pm 2.5$	108.4



Lepton Asymmetries

Angular Distributions



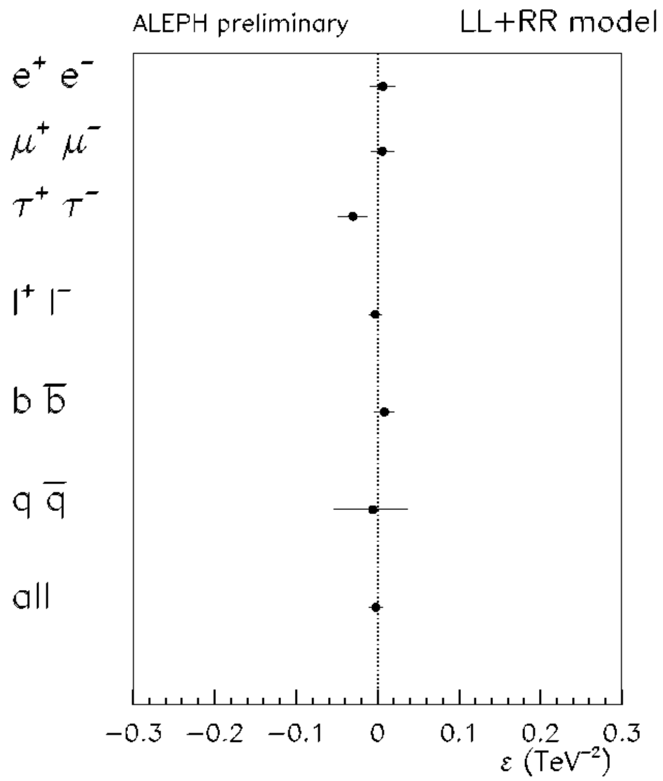


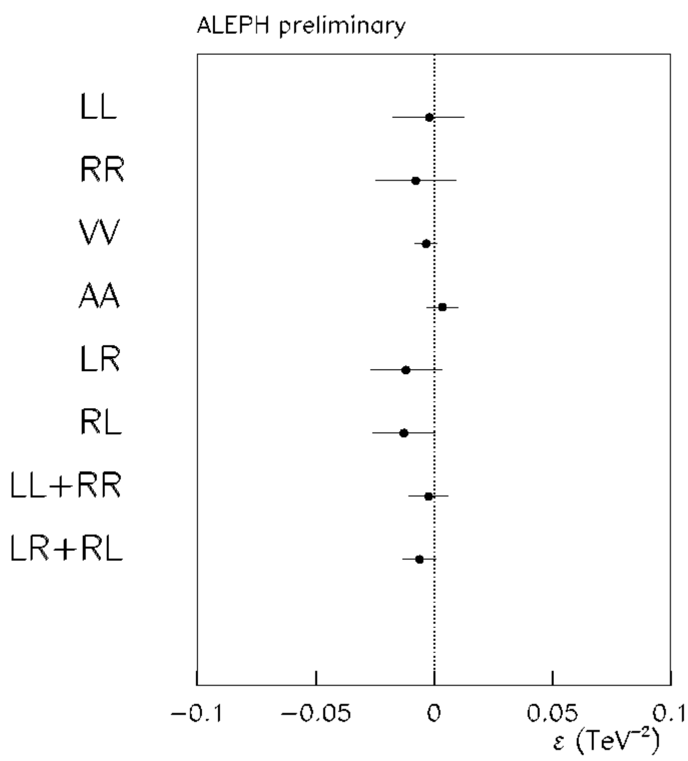
Limits on Contact Interactions

$$\frac{d\sigma}{d\cos\theta} = F_{SM}(s,t)\left[1 + C_{IF}(s,t)\,\epsilon + C_{CI}(s,t)\,\epsilon^2\right]$$

$$\epsilon = g^2\eta_{\mathrm{sign}}/(4\pi\Lambda^2)$$

Model	η_{sign}	η_{LL}	η_{RR}	η_{LR}	η_{RL}
LL$^\pm$	±1	1	0	0	0
RR$^\pm$	±1	0	1	0	0
VV$^\pm$	±1	1	1	1	1
AA$^\pm$	±1	1	1	-1	-1
LR$^\pm$	±1	0	0	1	0
RL$^\pm$	±1	0	0	0	1
LL+RR$^\pm$	±1	1	1	0	0
LR+RL$^\pm$	±1	0	0	1	1

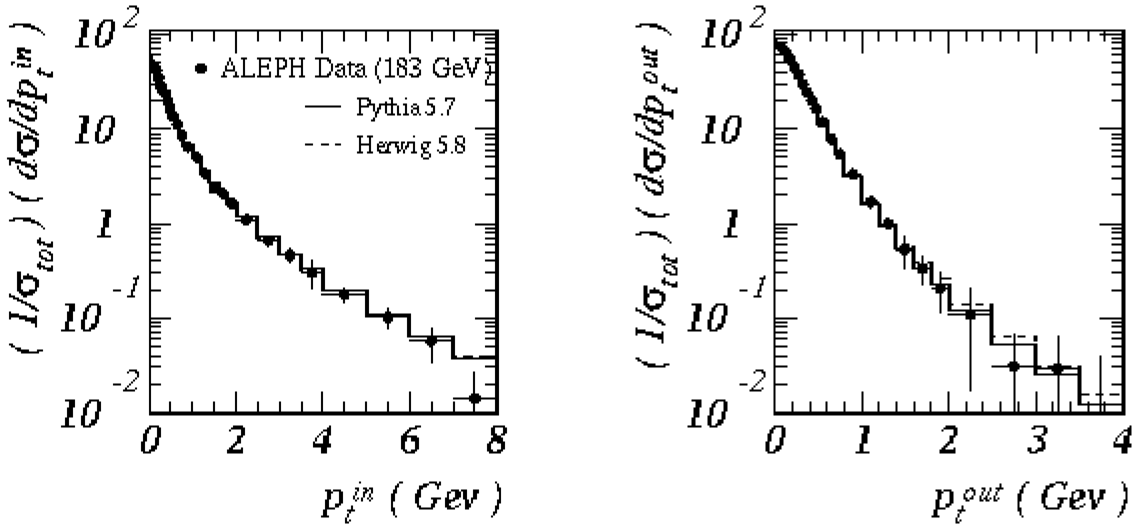




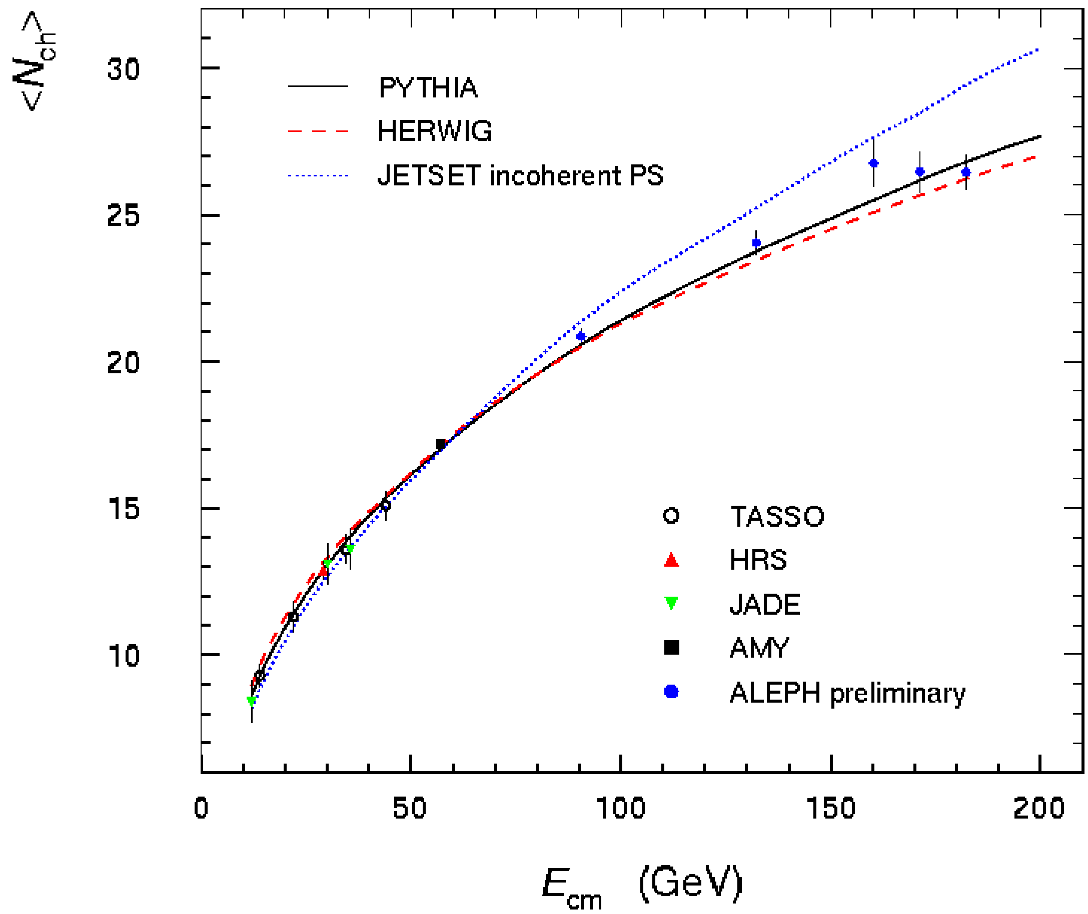
Scale $\Lambda > 5$–12 TeV depending on model

QCD Studies

p_t in and out of event plane



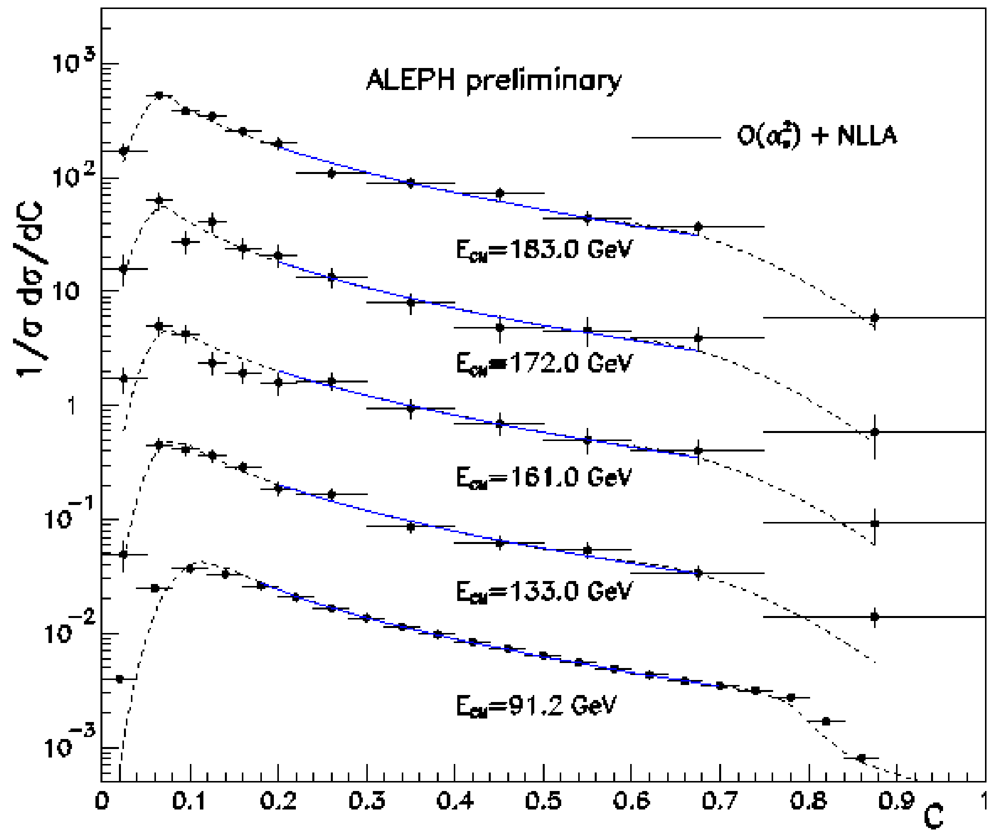
Mean charged multiplicity

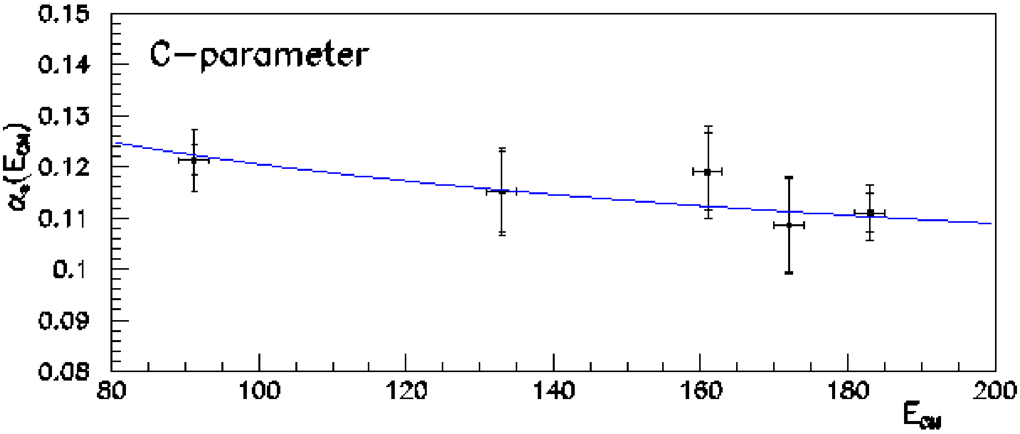


QCD: α_S measurement

Measure α_S from 5 event shape variables use C as example

$C=3(\lambda_1\lambda_2+\lambda_2\lambda_3+\lambda_3\lambda_1)$ from eigenvectors of tensor : $\dfrac{\Sigma_i(p_{i,\alpha}p_{i,\beta})/|p_i|}{\Sigma_i|p_i|}$





α_S at 183 GeV

$0.1110\pm0.0035_{\text{stat}}$

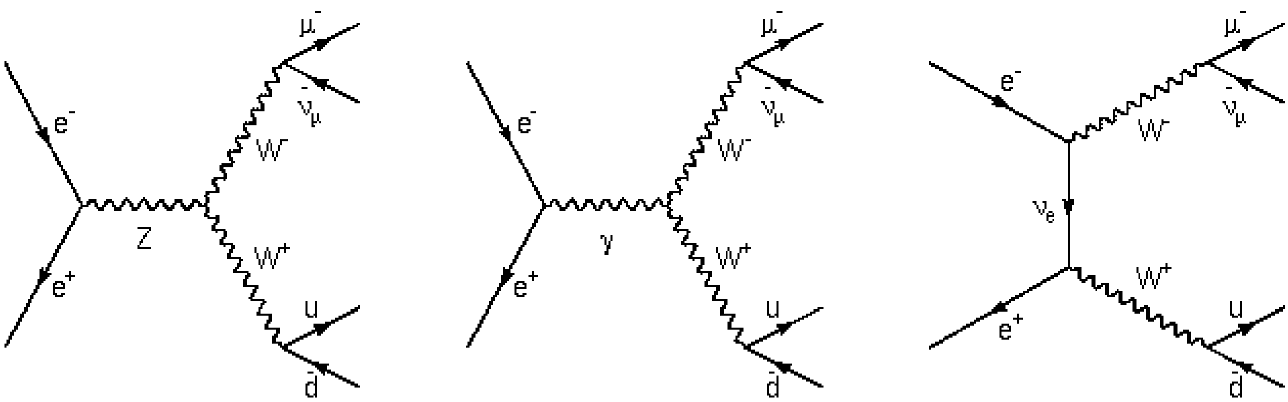
$\pm0.0010_{\text{expt syst}}$

$\pm0.0039_{\text{pert theory}}$

$\pm0.0006_{\text{hadronisation}}$

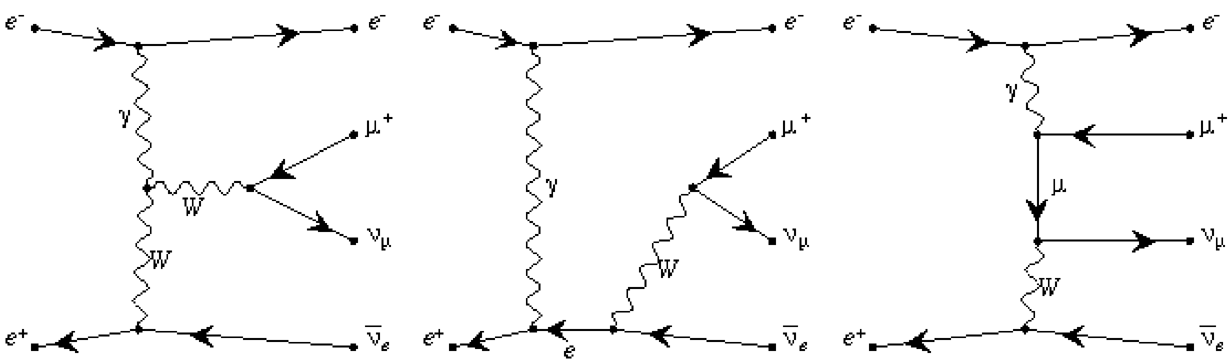
W Boson Production

W pair production



$\sigma = \mathbf{15.8}$**pb at 183 GeV**

Single W production



$\sigma = \mathbf{0.4}$ **pb at 183 GeV**

W Pair Production Cross-Section

$\sigma(WW \to l\nu l\nu) = 1.34 \pm 0.20_{stat} \pm 0.05_{syst}$ pb

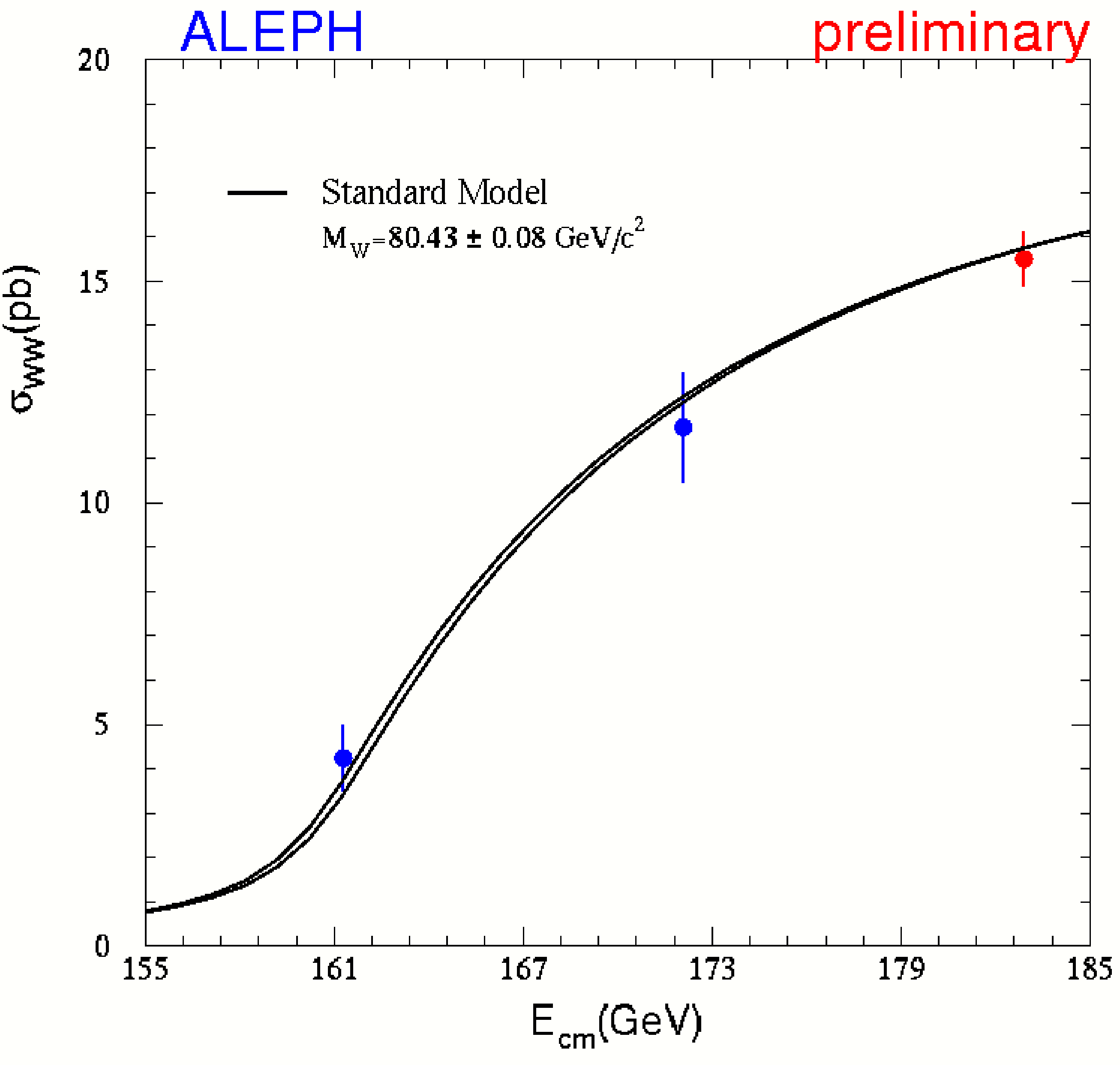
$\sigma(WW \to l\nu qq) = 6.79 \pm 0.40_{stat} \pm 0.14_{syst}$ pb

$\sigma(WW \to qqqq) = 7.33 \pm 0.41_{stat} \pm 0.30_{syst}$ pb

$\sigma(WW) = 15.51 \pm 0.61_{stat} \pm 0.36_{syst}$ pb

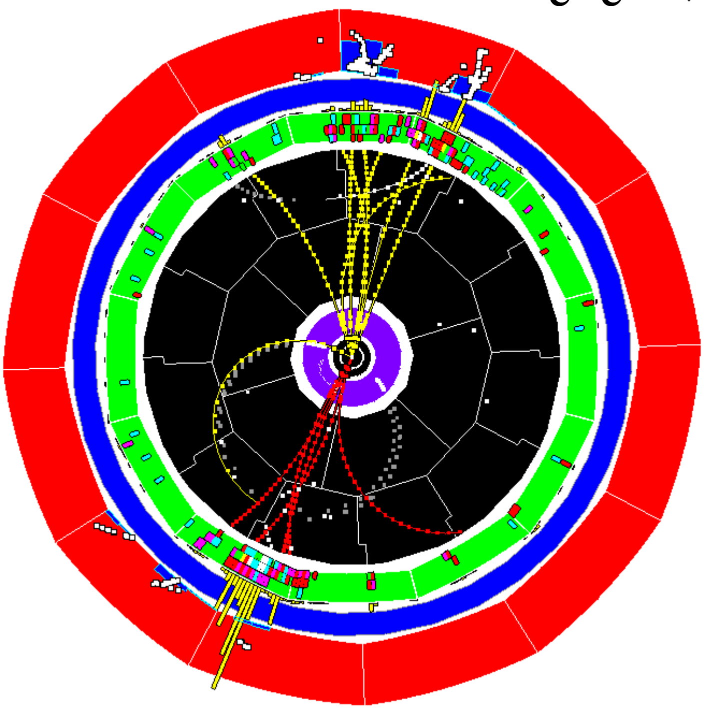
(SM 15.8 pb)

$Br(W \to qq) = 69.0 \pm 1.2_{stat} \pm 0.63_{syst}$ %

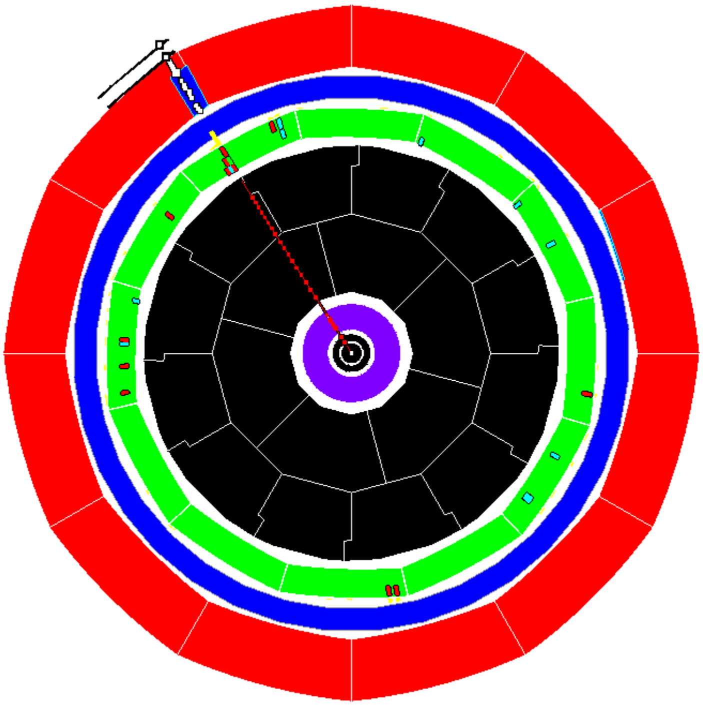


Single W Production

$e^+ e^- \rightarrow e \, \nu \, W$



$W \rightarrow q \, q$



$W \rightarrow \mu \, \nu$

$$\sigma_{qq} = 0.26 \pm 0.15_{stat} \pm 0.04_{syst} \text{ pb}$$

$$\sigma_{l\nu} = 0.14 \pm 0.07_{stat} \pm 0.01_{syst} \text{ pb}$$

$$\sigma_{W} = 0.40 \pm 0.17_{stat} \pm 0.04_{syst} \text{ pb} \quad \text{(cf. 0.41 pb SM)}$$

“Invisible” W Decays

Search for possible invisible decays: $W^+ \rightarrow X^+ Y^0$,
X and Y escape detection in detector or analysis.

For $B_{invis} = Br\ (W \rightarrow XY)$

W pair production reduced: $\sigma'_{WW} \sim \sigma_{WW}(1-B_{invis})^2$

Single W production increased: $\sigma'_W \sim \sigma_W + 2\sigma_{WW} B_{invis}$

Using measured pair W production cross-section:

$B_{invis} < 6.5\%$

Using modified single W analysis:

$B_{invis} < 1.3\%$ $\Delta M = 0$

$B_{invis} < 1.9\%$ $\Delta M < 3 GeV/c^2$

Example: $W^+ \rightarrow \chi^+ \chi^0$,

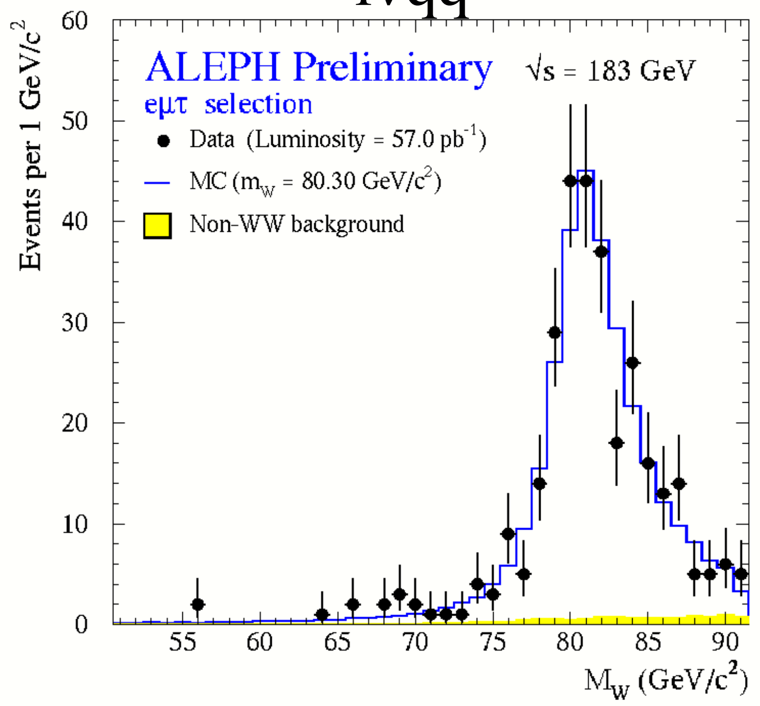
$\chi^+ \rightarrow l\, \tilde{\nu}$, $\tilde{\nu} \rightarrow \chi^0\, \nu$

invisible if $M(\chi^+) \cong M(\tilde{\nu})$

$M(\chi^+) > 51\ GeV/c^2$ **for** $M(\chi^+) - M(\tilde{\nu}) < 3 GeV/c^2$

W Mass

lνqq



M_W =

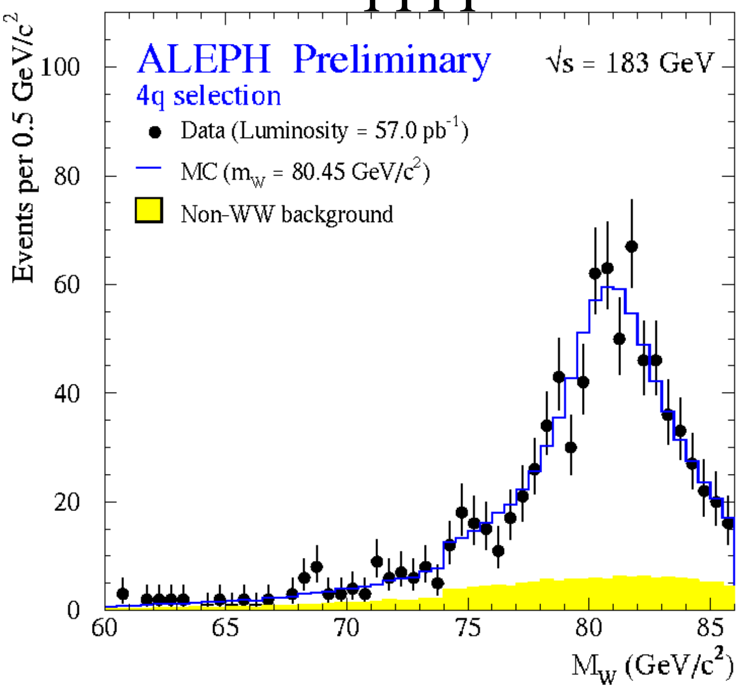
eνqq $80.19 \pm 0.28_{stat} \pm 0.06_{syst}$

μνqq $80.15 \pm 0.32_{stat} \pm 0.07_{syst}$

τνqq $80.05 \pm 0.60_{stat} \pm 0.21_{syst}$

lνqq $80.16 \pm 0.20_{stat} \pm 0.08_{syst}$ GeV/c^2

qqqq



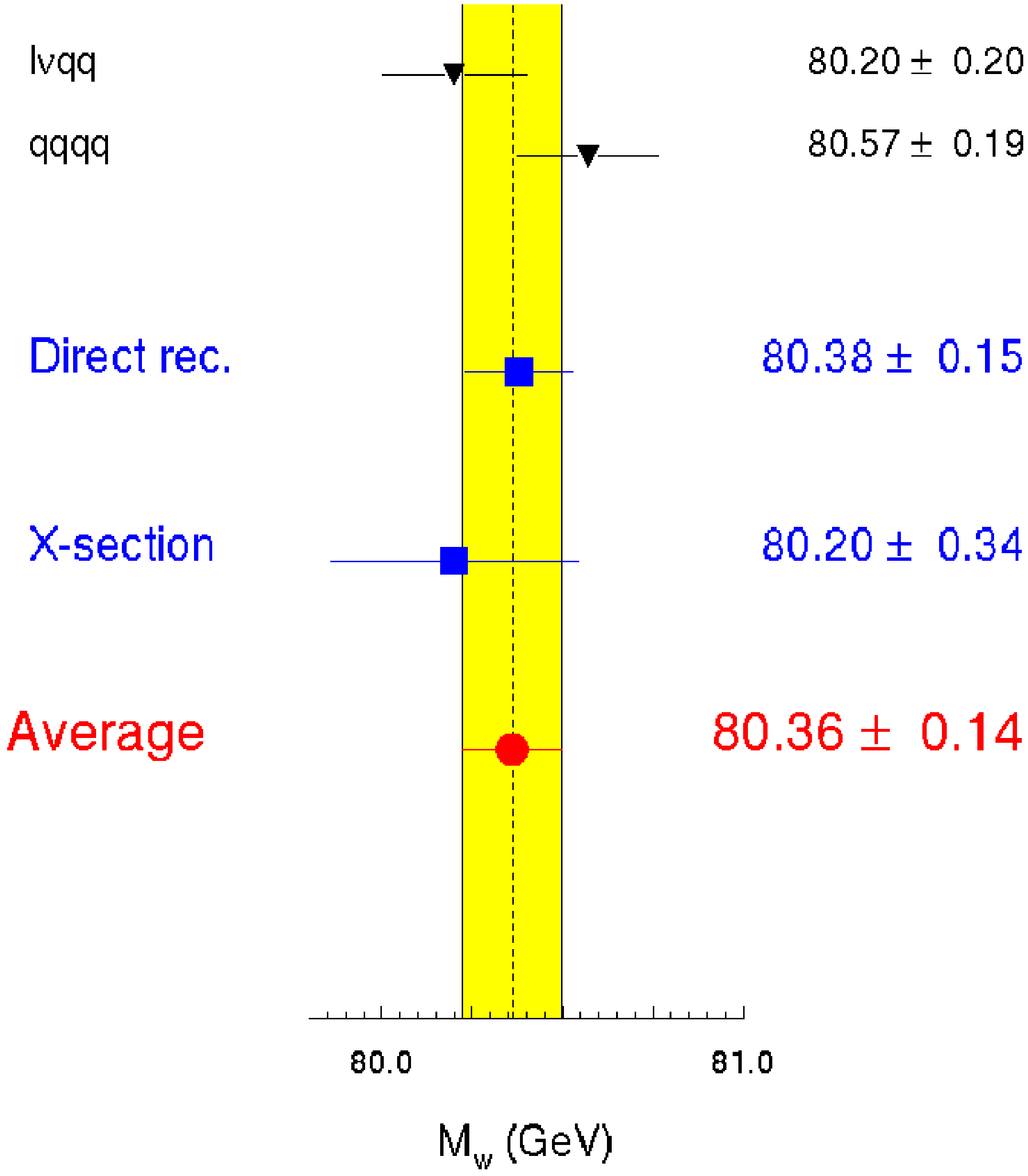
Systematic errors

	Δm_W (MeV/c^2)			
Source	4q	e	μ	τ
Correlated errors				
MC Fragmentation	35	20	20	20
CC03 MC diagrams	3	3	3	3
Detector calibration	30	52	54	176
Jet corrections	20	11	11	89
W width	10	10	10	10
Initial State Radiation	15	15	15	15
Uncorrelated errors				
Reference MC Statistics	20	20	22	64
Background contamination	10	1	4	-
Colour reconnection	50	-		-
Bose-Einstein effects	70	-		-
Total	104	63	65	209

qqqq: $M_W = 80.45 \pm 0.18_{stat} \pm 0.06_{syst} \pm 0.09_{colrec/BE}$ GeV/c^2

W Mass Combination

Direct
reconstruction
172+183 GeV

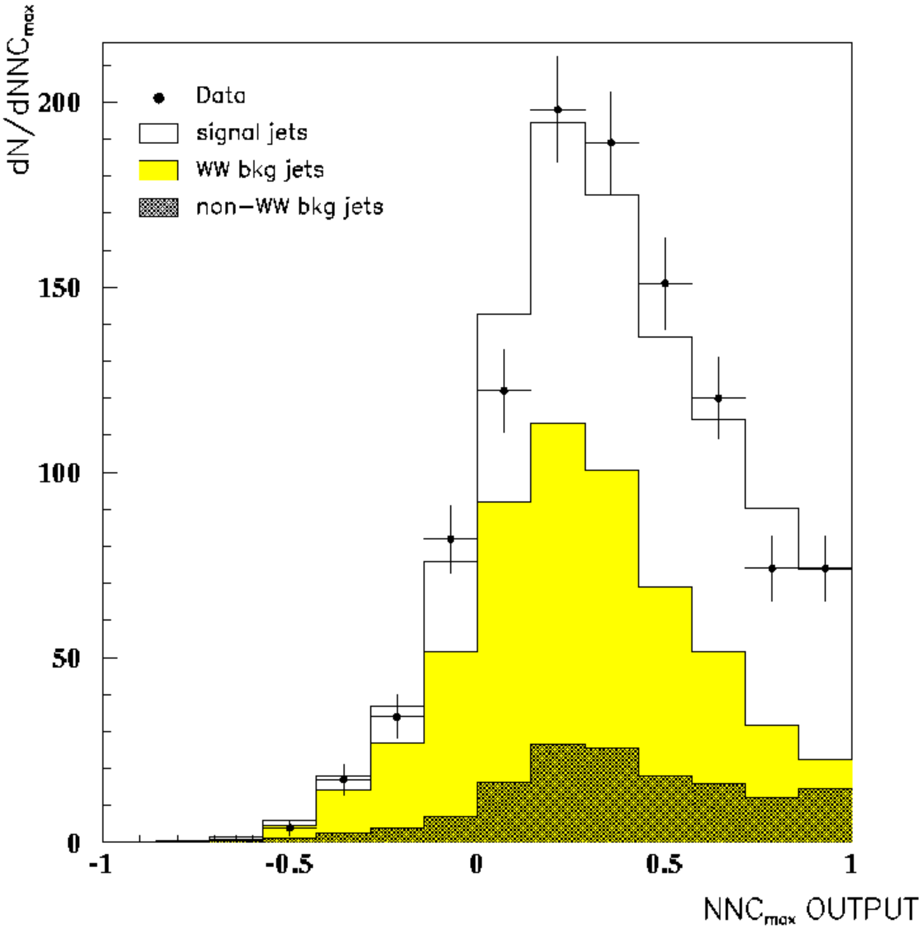


$$M_W = 80.36 \pm 0.12_{stat} \pm 0.06_{syst} \pm 0.03_{cr/BE} \pm 0.03_{LEP}\ \mathrm{GeV}/c^2$$

CKM matrix element $| V_{cs} |$

Measure fraction of W decays with charm:

$$f_c = \frac{\Gamma(W \to cX)}{\Gamma(W \to \text{hadrons})} = \frac{|V_{cd}|^2 + |V_{cs}|^2 + |V_{cb}|^2}{|V_{ud}|^2 + |V_{us}|^2 + |V_{ub}|^2 + |V_{cd}|^2 + |V_{cs}|^2 + |V_{cb}|^2}$$



$f_c = 0.51 \pm 0.05_{stat} \pm 0.03_{syst}$:

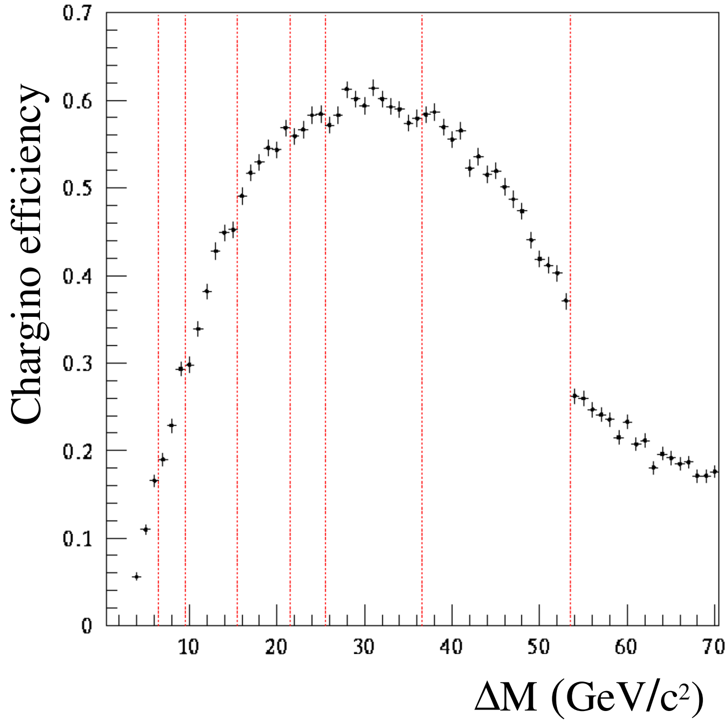
$|V_{cs}| = 1.00 \pm 0.10_{stat} \pm 0.06_{syst}$

$Br(W \to qq) = 69.0 \pm 1.2_{stat} \pm 0.63_{syst}$ % :

$|V_{cs}| = 1.05 \pm 0.06_{stat} \pm 0.03_{syst}$

$(1.01 \pm 0.18$ PDG)

Searches for Supersymmetry



Typical efficiencies

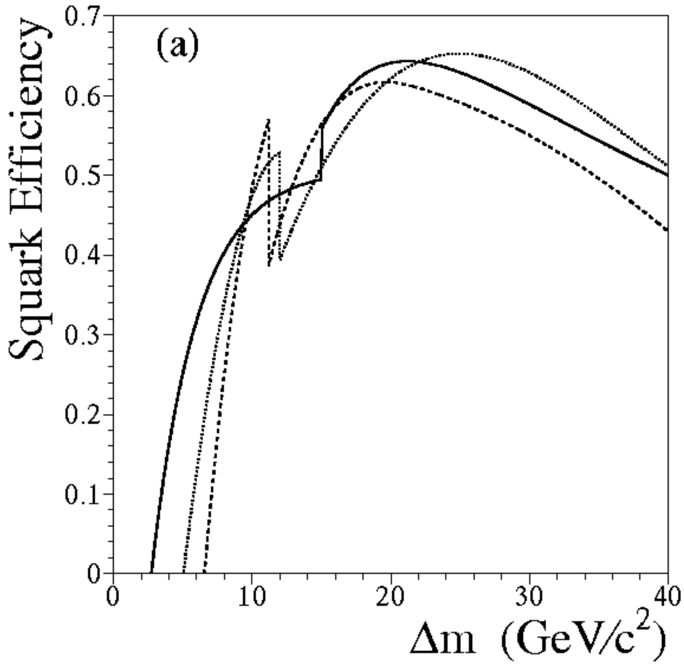
χ^+ 10-60 %

χ 10–30 %

$\tilde{l}$ 10-70 %

$\tilde{q}$ 10-60%

$\Delta M = M(\tilde{p})\text{-}M(\text{LSP})$

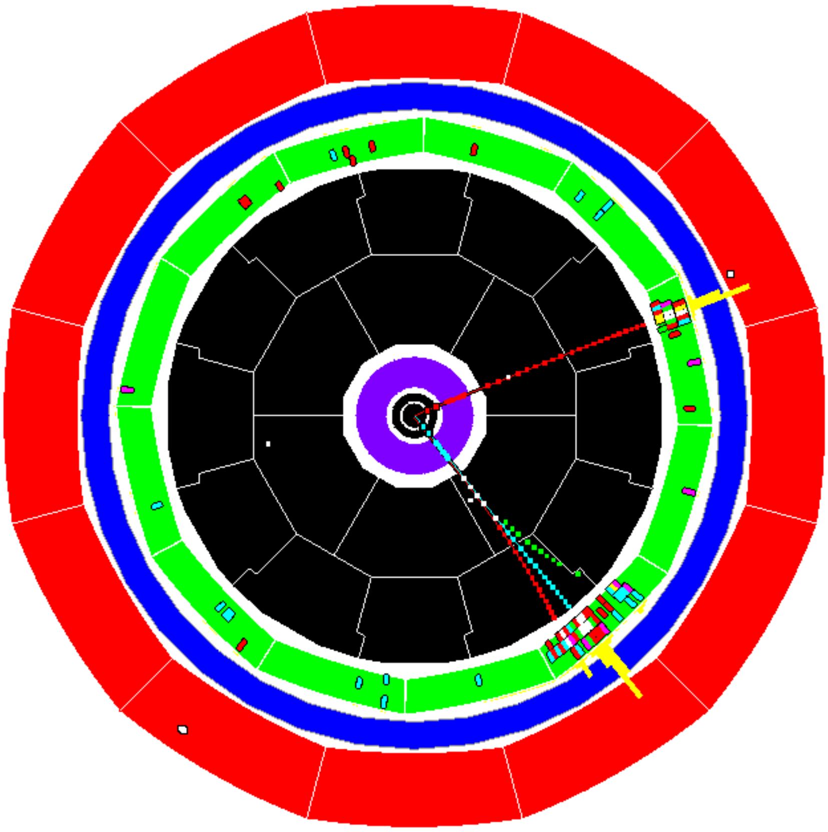


SUSY Signal	Back.	Cand.
χ^+	6.6	4
χ	3.1	1
$\tilde{e}_R$	10.2	6
$\tilde{\mu}_R$	9.2	7
$\tilde{\tau}_R$	8.9	6
$\tilde{t} \rightarrow c\chi$	5.5	5
$\tilde{t} \rightarrow bl\tilde{\nu}$	0.9	1
$\tilde{b} \rightarrow b\chi$	1.7	1

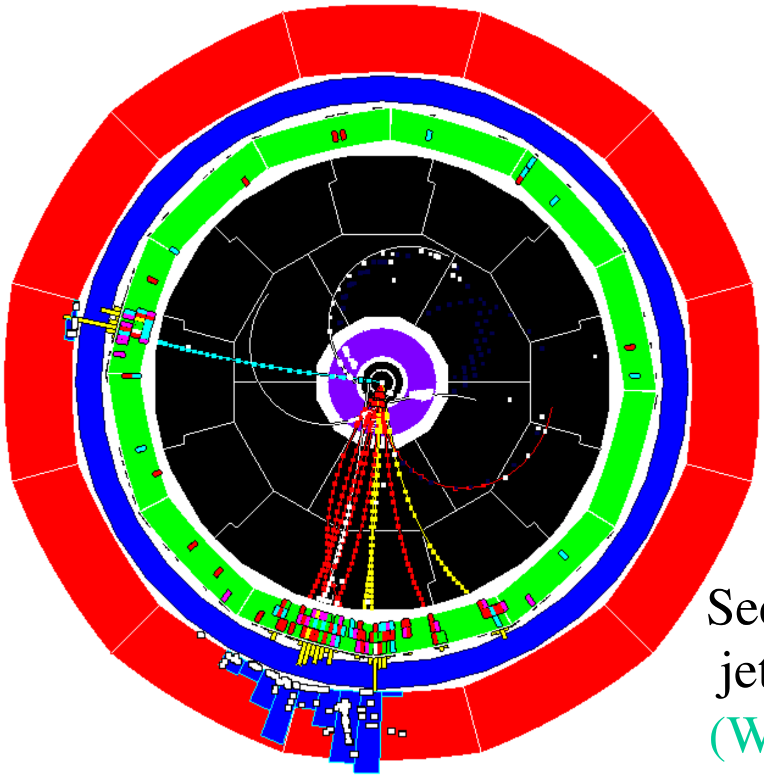
Few candidates

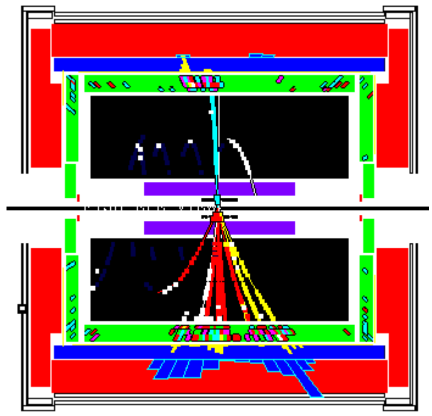
Clearly no excess

SUSY Candidates



Candidate for
$e^+e^- \to \tilde{e}\,\tilde{e} \to e\,e + \not{E}$
see 2 e + γ conversion
(Actually also selected
as $WW \to e\nu\ e\nu$)

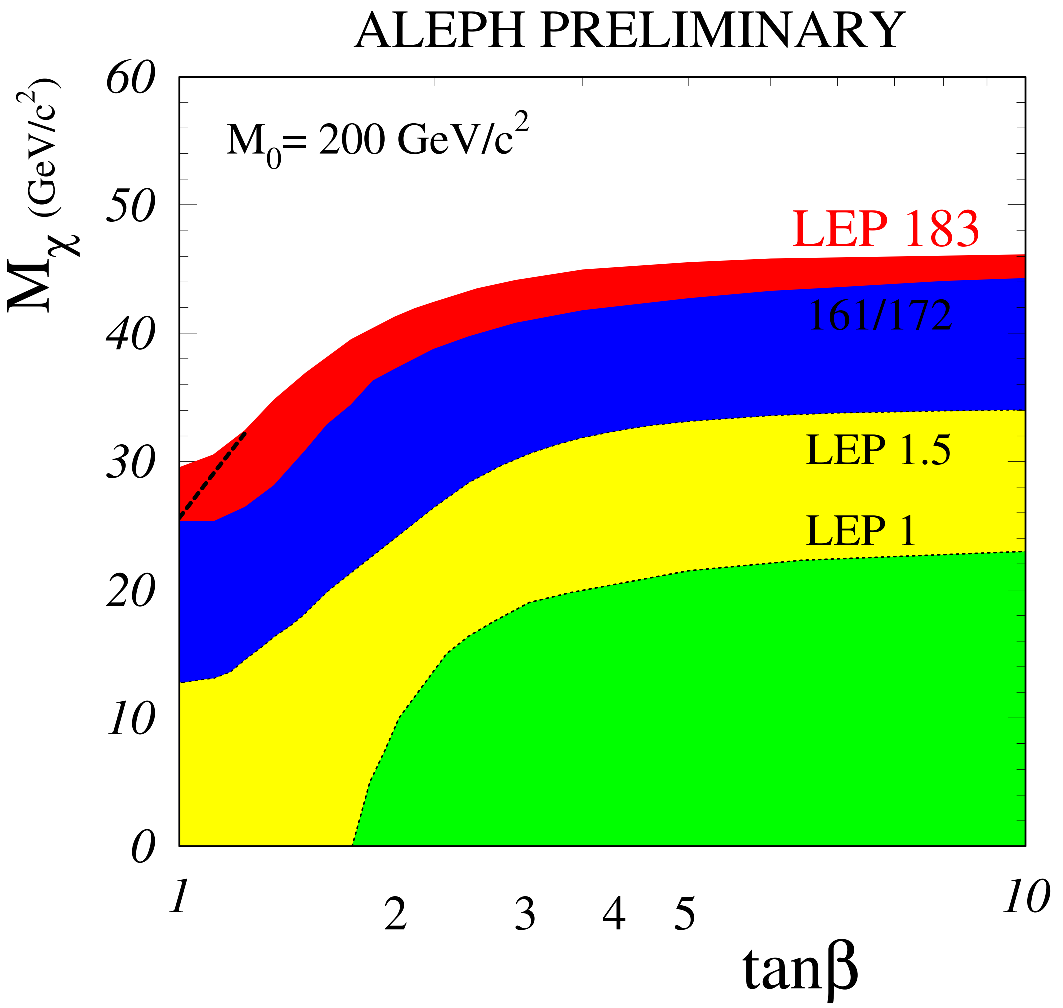




Candidate for
$e^+e^- \to \chi^+\chi^-$

See τ jet 13 GeV
jets mass 12 GeV/c^2, E 52 GeV
($WW^* \to \tau\nu$ qq or $Z\gamma^* \to \nu\nu qq$)

Lightest Neutralino Mass Limit



Slepton Mass limit

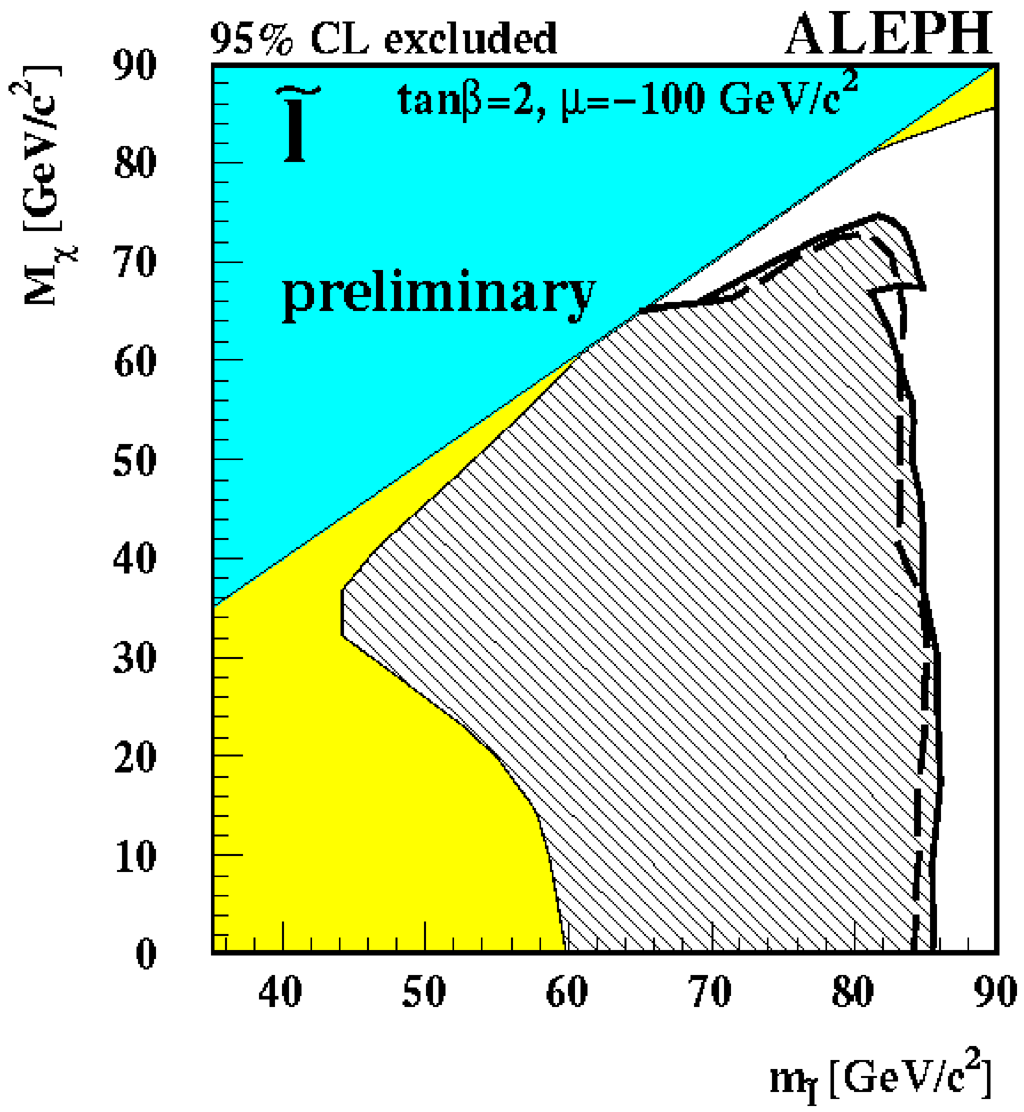
Assuming common scalar mass at GUT scale:

$$m^2_{\tilde{l}_R} = m_0^2 + 0.15 m_{1/2}^2 - \sin^2\theta_w M_z^2 \cos 2\beta$$

$$m^2_{\tilde{l}_L} = m_0^2 + 0.52 m_{1/2}^2 - 1/2(1-2\sin^2\theta_w) M_z^2 \cos 2\beta$$

$$m^2_{\tilde{\nu}} = m_0^2 + 0.52 m_{1/2}^2 + 1/2 M_Z^2 \cos 2\beta$$

Cover low $\Delta M(\tilde{e}_R-\chi)$ region
with search for $\tilde{e}_R\tilde{e}_L \rightarrow$ single e



Mass Limits in MSSM

Chargino:

$M(\chi^{\pm}) > 91$ GeV/c^2 $\Delta M(\chi^{\pm} - \mathrm{LSP}) > 4$ GeV/c^2

$M(\chi^{\pm}) > 51$ GeV/c^2 if $\Delta M(\chi^{\pm} - \tilde{\nu}) < 3$ GeV/c^2

Neutralino (LSP):

$M(\chi^{0}) > 30$ GeV/c^2 $m_0 > 200$ GeV/c^2

$M(\chi^{0}) > 14$ GeV/c^2 any m_0 (without 1997 data)

Sleptons:

$M(\tilde{e}_R) > 81$ GeV/c^2 $\Delta M > 5$ GeV/c^2

$M(\tilde{\mu}_R) > 71$ GeV/c^2 $\Delta M > 10$ GeV/c^2

$M(\tilde{\tau}_R) > 65$ GeV/c^2 $\Delta M > 15$ GeV/c^2

Assuming common scalar mass at GUT scale:

$M(\tilde{l}) > 65$ GeV/c^2 any ΔM, $\tan\beta=2$

Squarks:

$\tilde{\mathbf{t}} \rightarrow \mathbf{c}\chi$ $M(\tilde{t}) > 74$ GeV/c^2 $10 < \Delta M < 40$ GeV/c^2

$\tilde{\mathbf{t}} \rightarrow \mathbf{b}l\nu$ $M(\tilde{t}) > 82$ GeV/c^2 $\Delta M > 10$ GeV/c^2

$\tilde{\mathbf{b}} \rightarrow \mathbf{b}\chi$ $M(\tilde{b}) > 79$ GeV/c^2 $\Delta M > 10$ GeV/c^2, $\theta_{mix}=0$

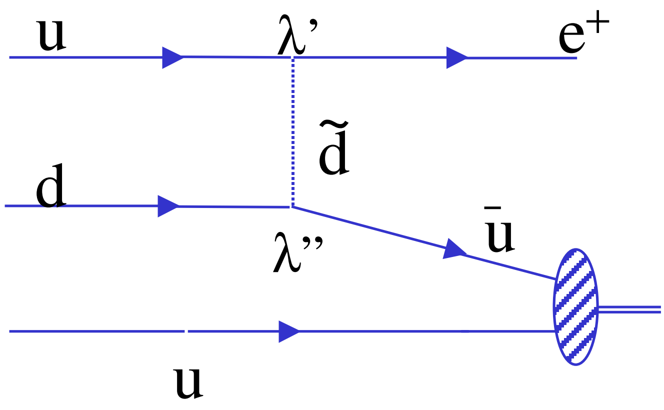
Assuming five mass degenerate squarks:

$M(\tilde{q}) > 87$ GeV/c^2 $\Delta M > 5$ GeV/c^2

R Parity Violating SUSY

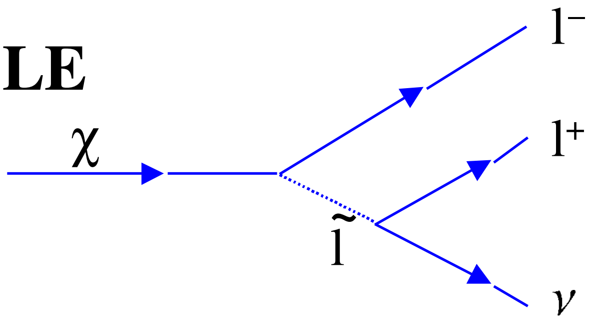
$$\lambda_{ijk} L_i L_j \bar{E}_k + \lambda'_{ijk} L_i Q_j \bar{D}_k + \lambda''_{ijk} \bar{U}_i \bar{D}_j \bar{D}_k$$

Not all terms together or fast proton decay



Typical decays:

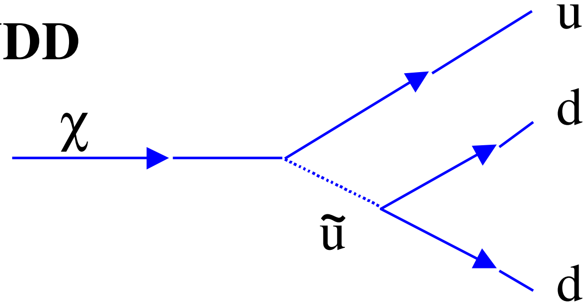
LLE



eg. $e^+e^- \rightarrow$ 4 leptons

2 leptons +2 jets

UDD



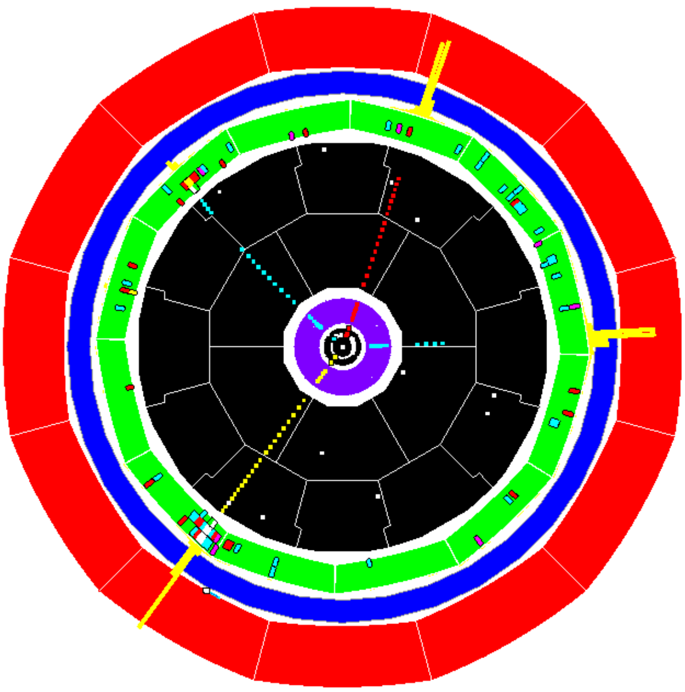
$e^+e^- \rightarrow$ 6 jets

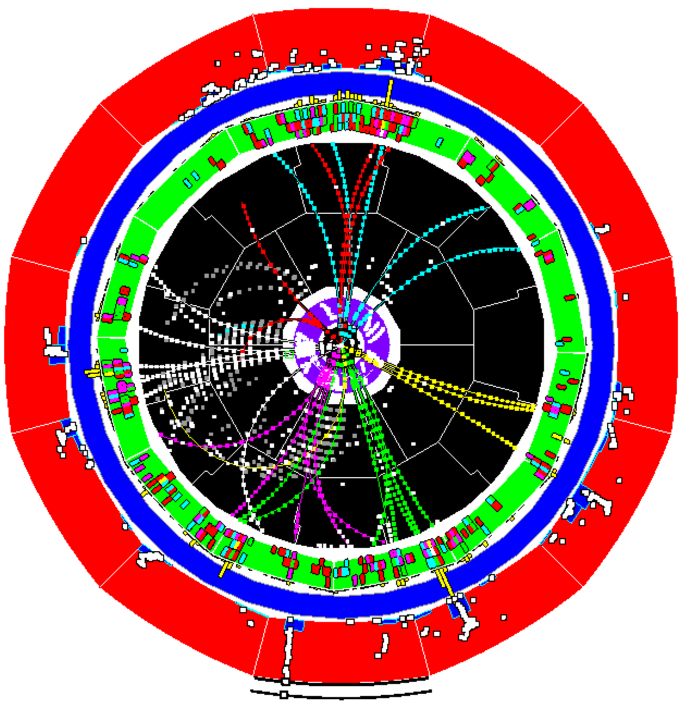
4 jets

RPV Candidates

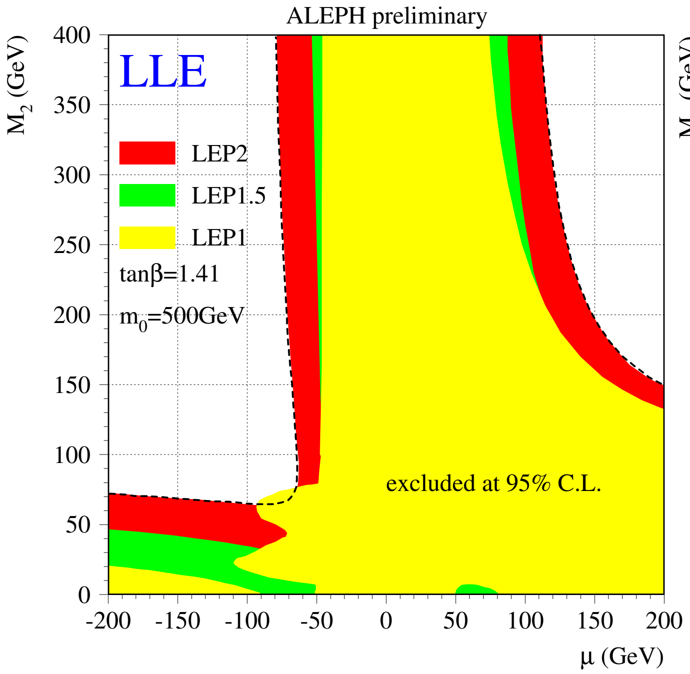
Coupling	Topology	SUSY Signal	Back.	Cand.
$LL\bar{E}$	Leptons and Hadrons	χ^+,χ	3.3	6
	6 Leptons + $\not{E}$	$\tilde{l}$, χ^+	0.2	0
	4 Leptons + $\not{E}$	$\tilde{\nu}$,$\tilde{l}$,χ	1.2	2
	Acoplanar Leptons	$\tilde{l}$,χ^+	51	44
	6 Leptons	χ^+	.02	0
	4 Leptons	$\tilde{\nu}$	1.6	2
LQD	Multijets plus Leptons	χ^+,χ	6.2	7
	4 jets	$\tilde{l}$,$\tilde{\nu}$	142	144
UDD	4 jets	χ^+,χ	127.7	128
	6 jets	χ^+,χ	3.6	1

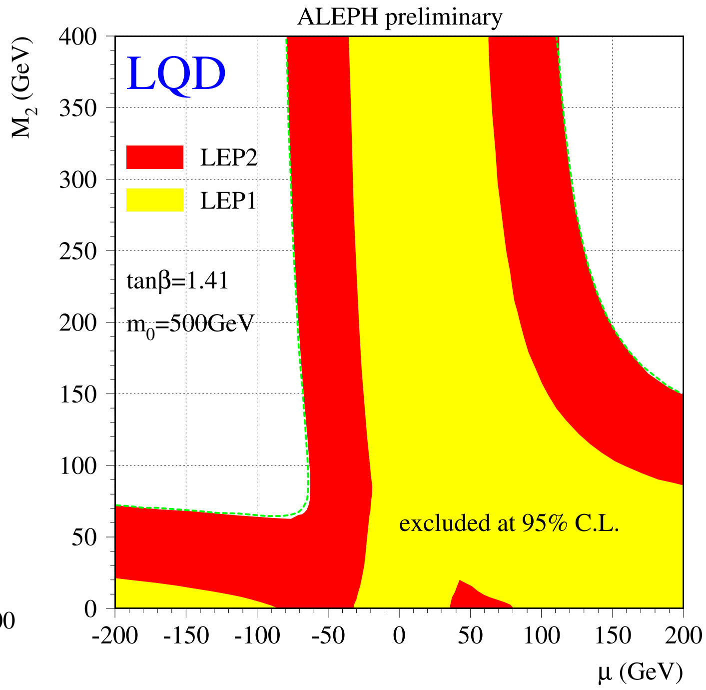
Candidates $\quad$ **$e^+e^- \rightarrow \chi\chi \rightarrow 4e$** $\qquad$ **$e^+e^- \rightarrow \chi\chi \rightarrow 6\ jets$**

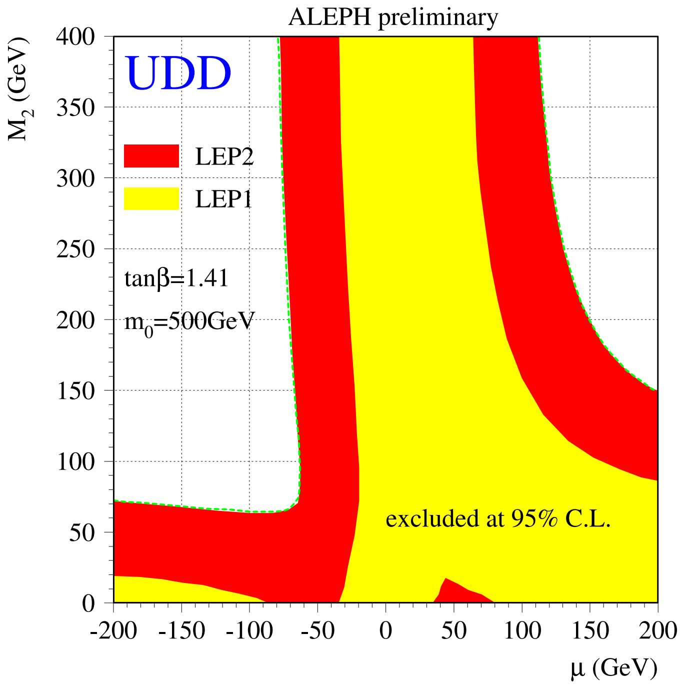




RPV SUSY Limits







Exclusion close to kinematic limit everywhere

$M(\chi^{\pm}) > 91$ GeV/c^2

any ΔM

any RPV coupling

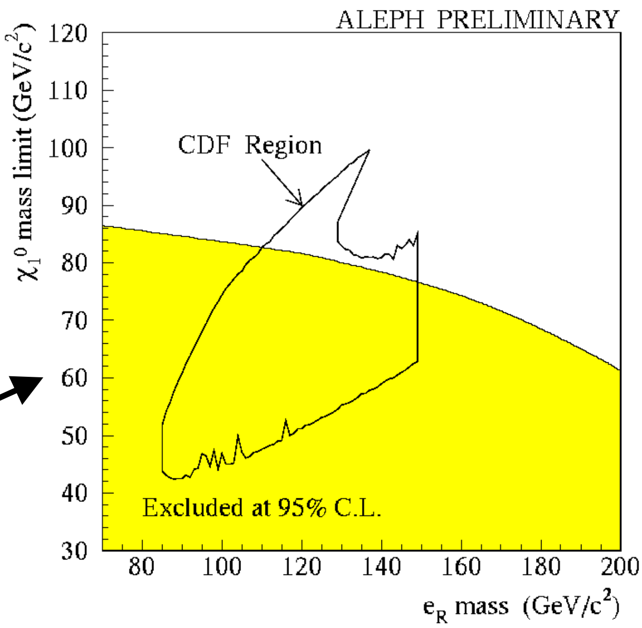
Light Gravitino Scenario
Gauge Mediated SUSY Breaking

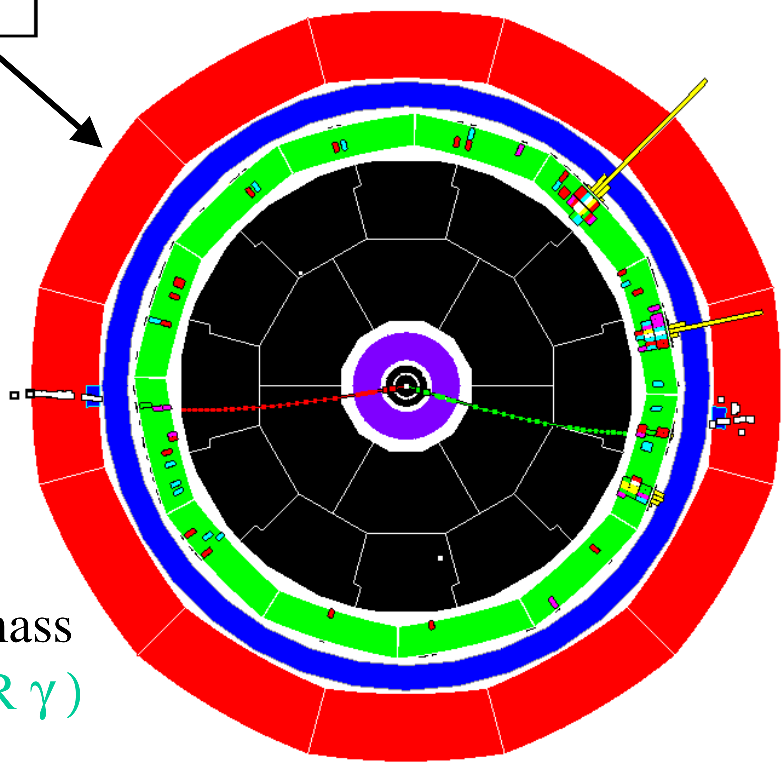
$\tilde{G}$ is LSP: $\tilde{l} \rightarrow l\, \chi^0 \rightarrow l\, \gamma\, \tilde{G}$

Motivated by CDF event with $ee\gamma\gamma$
eg. $q\, q \rightarrow \tilde{e}\, \tilde{e} \rightarrow ee\chi\chi \rightarrow ee\tilde{G}\tilde{G}\gamma\gamma$

Search for : $e^+e^- \rightarrow$
$\chi\, \chi \rightarrow \tilde{G}\tilde{G}\gamma\gamma$ (σ large)
also
$\tilde{l}\ \tilde{l} \rightarrow l\, l\, \chi\chi \rightarrow l\, l\, \tilde{G}\tilde{G}\gamma\gamma$

SUSY Signal	Back.	Cand.
$\chi\chi \rightarrow \tilde{G}\tilde{G}\gamma\gamma$	1.4	1
$\tilde{e}\tilde{e} \rightarrow ee\tilde{G}\tilde{G}\gamma\gamma$	0.6	0
$\tilde{\mu}\tilde{\mu} \rightarrow \mu\mu\tilde{G}\tilde{G}\gamma\gamma$	0.8	0
$\tilde{\tau}\tilde{\tau} \rightarrow \tau\tau\tilde{G}\tilde{G}\gamma\gamma$	1.1	1



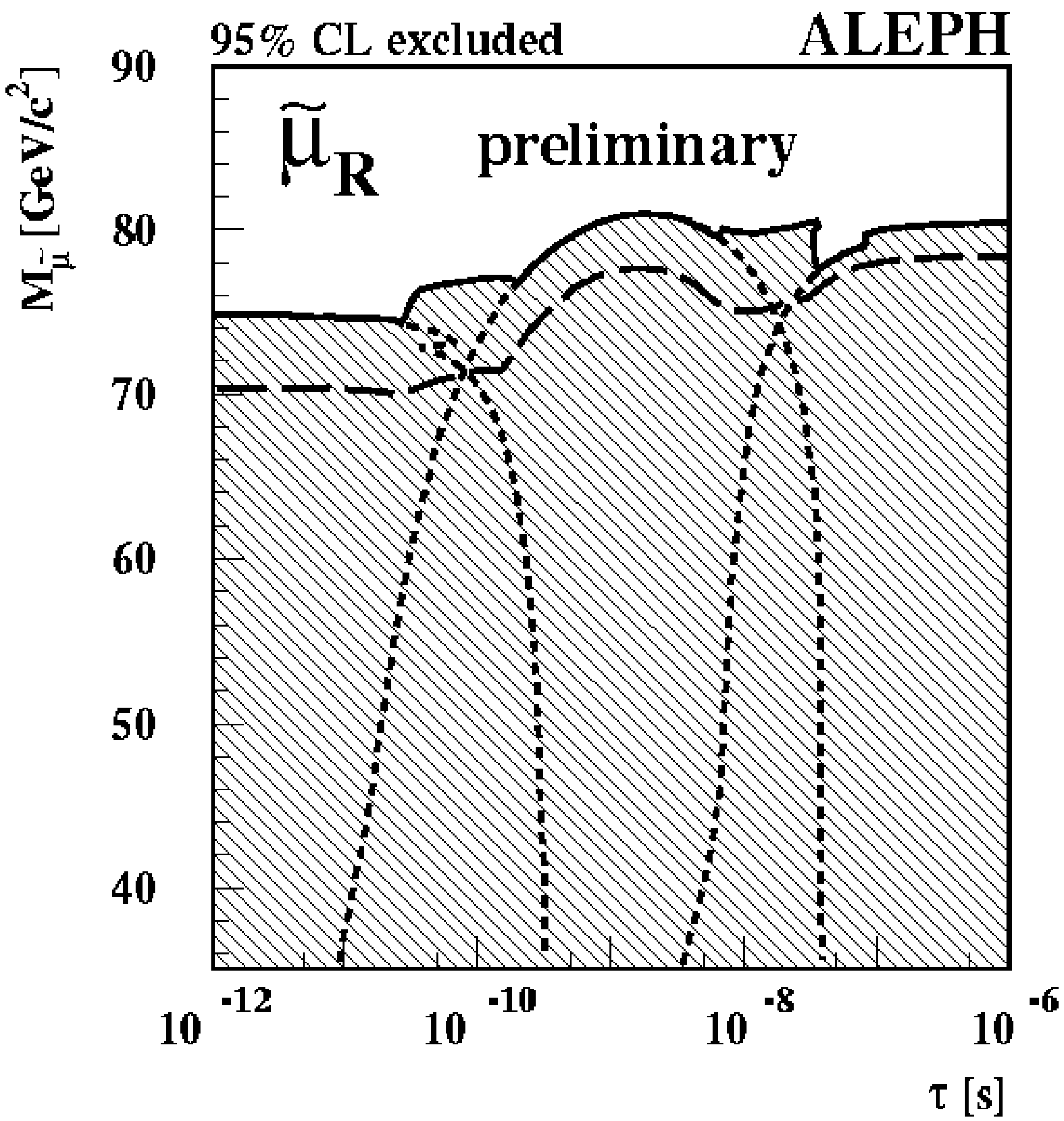


Candidate for
$e^+e^- \rightarrow \tilde{\tau}\ \tilde{\tau}$
$\rightarrow \tau\tau\tilde{G}\tilde{G}\gamma\gamma$

μ 4 GeV,
π^+ 5 GeV, π^0 8 GeV
γ 28 GeV, γ 45 GeV
plus 71 GeV/c^2 missing mass
(SM : $\tau\tau\gamma\gamma$ with ISR/FSR γ)

Search for Long Lived Sleptons

In framework of GMSB with $\tilde{l}$ next-to-lightest SP



acoplanar leptons | large impact parameter | kinks | stable particles

$M(\tilde{e}_R) > 71$ GeV/c^2 $\Delta M > 10$ GeV/c^2

$M(\tilde{\mu}_R) > 75$ GeV/c^2

$M(\tilde{\tau}_R) > 57$ GeV/c^2

Higgs Boson Search Analyses

Standard Model Higgs

$e^+e^- \rightarrow H \quad Z$

$\rightarrow bb\ qq$

$\rightarrow bb\ \nu\nu$

$\rightarrow bb\ l\,l$

$\rightarrow bb\ \tau\tau$

$\rightarrow \tau\tau\ \ qq$

SUSY Higgs h^0, A^0

$e^+e^- \rightarrow h \quad A$

$\rightarrow bb\ bb$

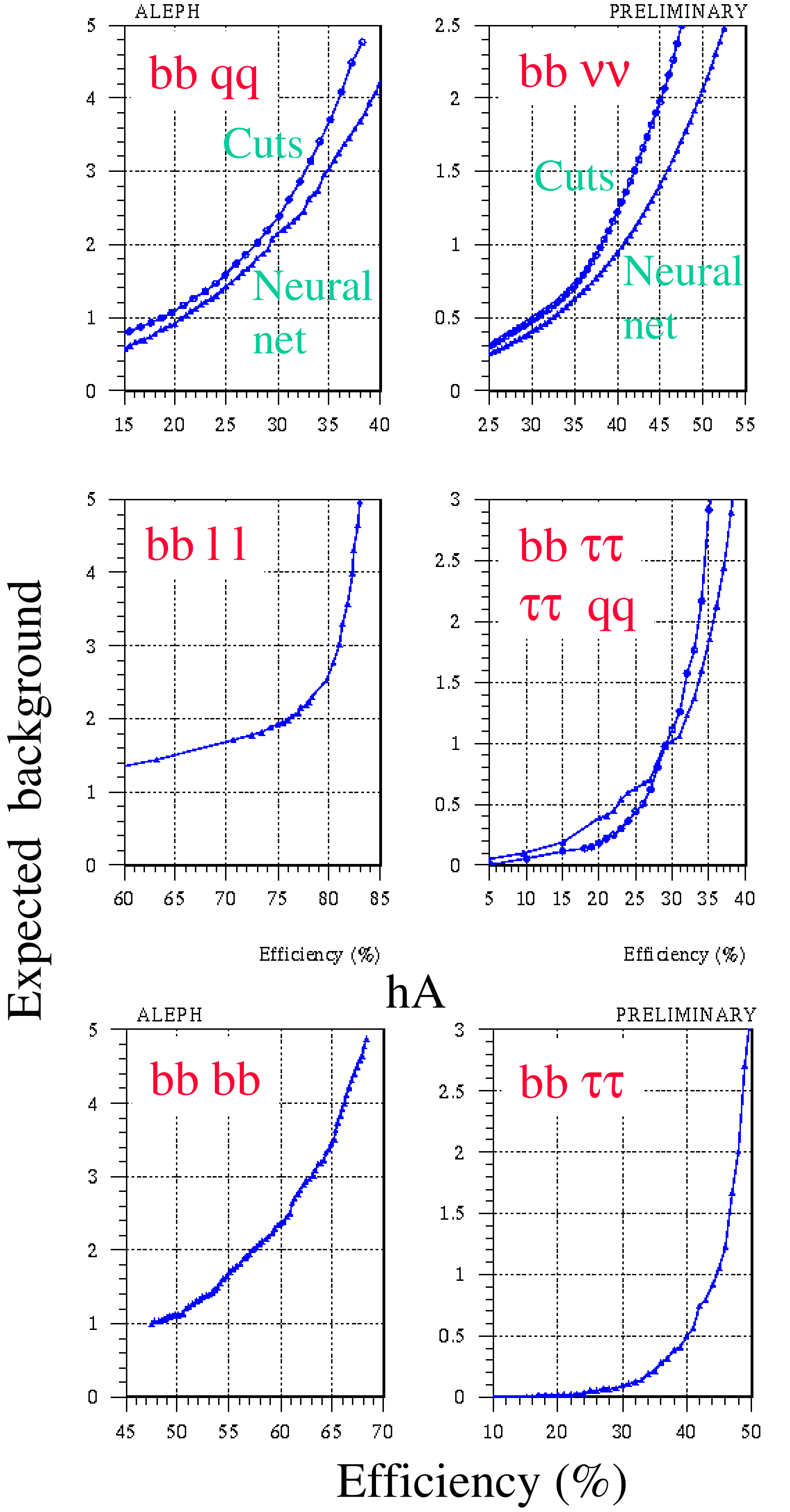
$\rightarrow bb\ \tau\tau$

$\rightarrow \tau\tau\ \ bb$

$\sigma_{ha} \propto \cos^2(\alpha-\beta)$

$\sigma_{hZ} \propto \sin^2(\alpha-\beta)$

Back. vs eff. for the various analyses



Higgs Analysis: New techniques

Using 161 and 172 GeV data:

Standard Model $M_H > 70.7$ GeV/c^2

SUSY("basic") $M_{h,A} > 62.5$ GeV/c^2

For 183 GeV analyses developed.

Extra discriminating variables eg. M+btag.

Combine Neural Net and Cuts analyses.

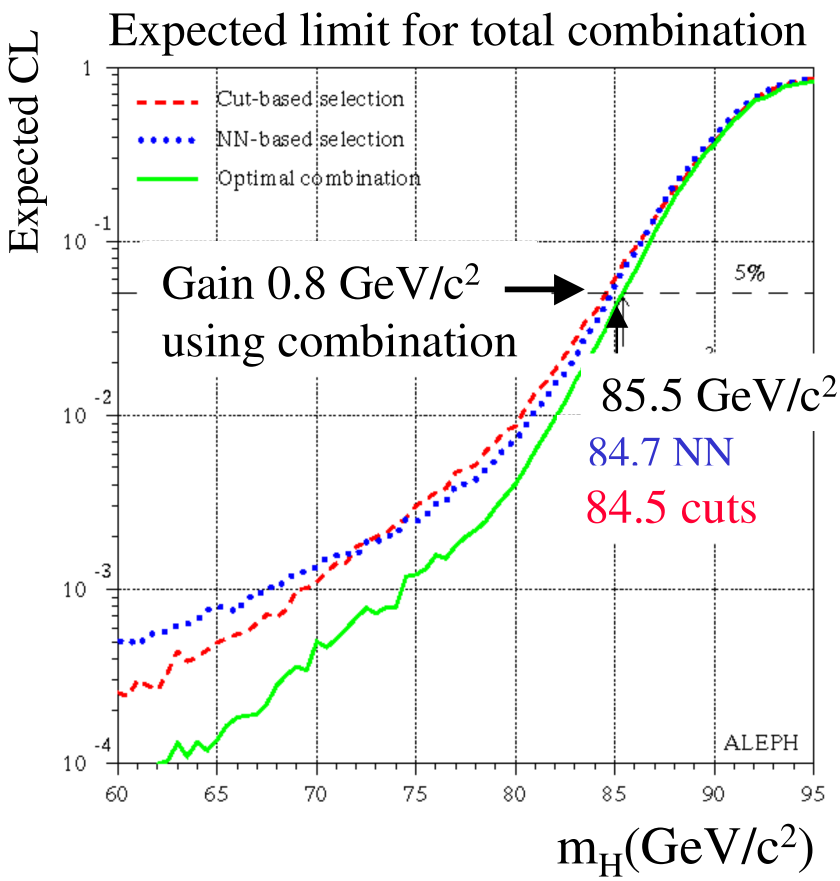
Now $ZZ^{(*)}$ background dominates.

Still make no background subtraction.

bbqq analyses

Selection	Eff(%)	Sig	Back
NN	31.4	4.3	2.4
Cuts	34.0	4.7	3.5
Cuts and NN	26.2	3.6	1.4
Cuts only	7.8	1.1	2.1
NN only	5.2	0.7	1.0
Total	39.2	5.4	4.5

AND class pure selection
but use also ONLY classes

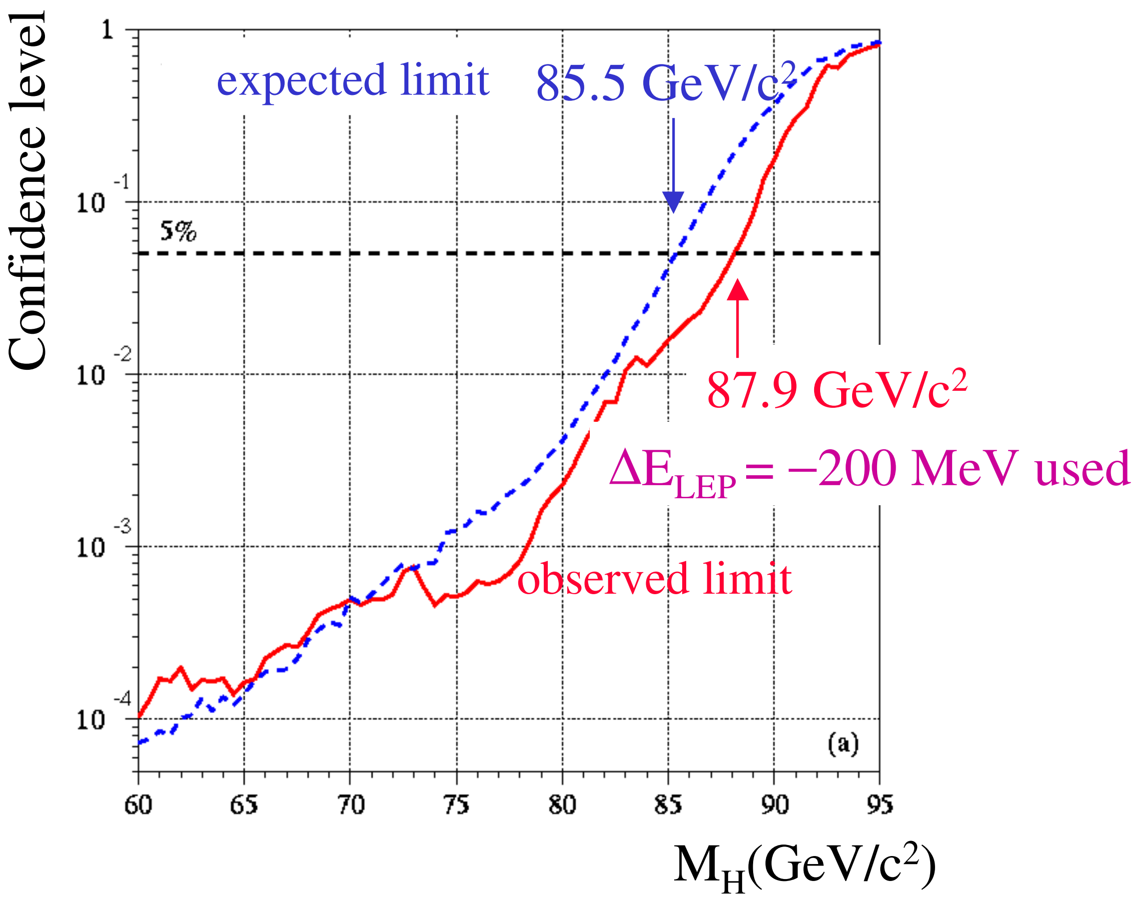


Search for Standard Model Higgs

183 GeV data results

Selection	Eff(%)	Sig	Back	Obs	Mass GeV/c^2	Weight
bbqq (total)	39.2	5.4	4.5	4		1.0
Cuts and NN	26.2	3.6	1.4	1	71	1.0
NN only	5.2	0.7	1.0	1	85	0.3
Cuts only	7.8	1.1	2.1	2	79, 84	~ 0
$bb\nu\nu$ (total)	32.3	1.6	0.4	0		2.2
Cuts and NN	17.0	0.8	0.2	0		1.0
NN only	11.6	0.6	0.2	0		1.2
Cuts only	3.7	0.2	0.1	0		2.0
bbll	76.2	1.1	2.0	3	67, 82, 97	2.5
$\tau^+\tau^- q\bar{q}$	13.7	0.2	0.2	0		8.0
$q\bar{q}\tau^+\tau^-$	19.7	0.1	0.2	0		9.7
Total	—	8.4	7.2	7		—

(efficiency and expected signal for m_H=85 GeV/c^2)



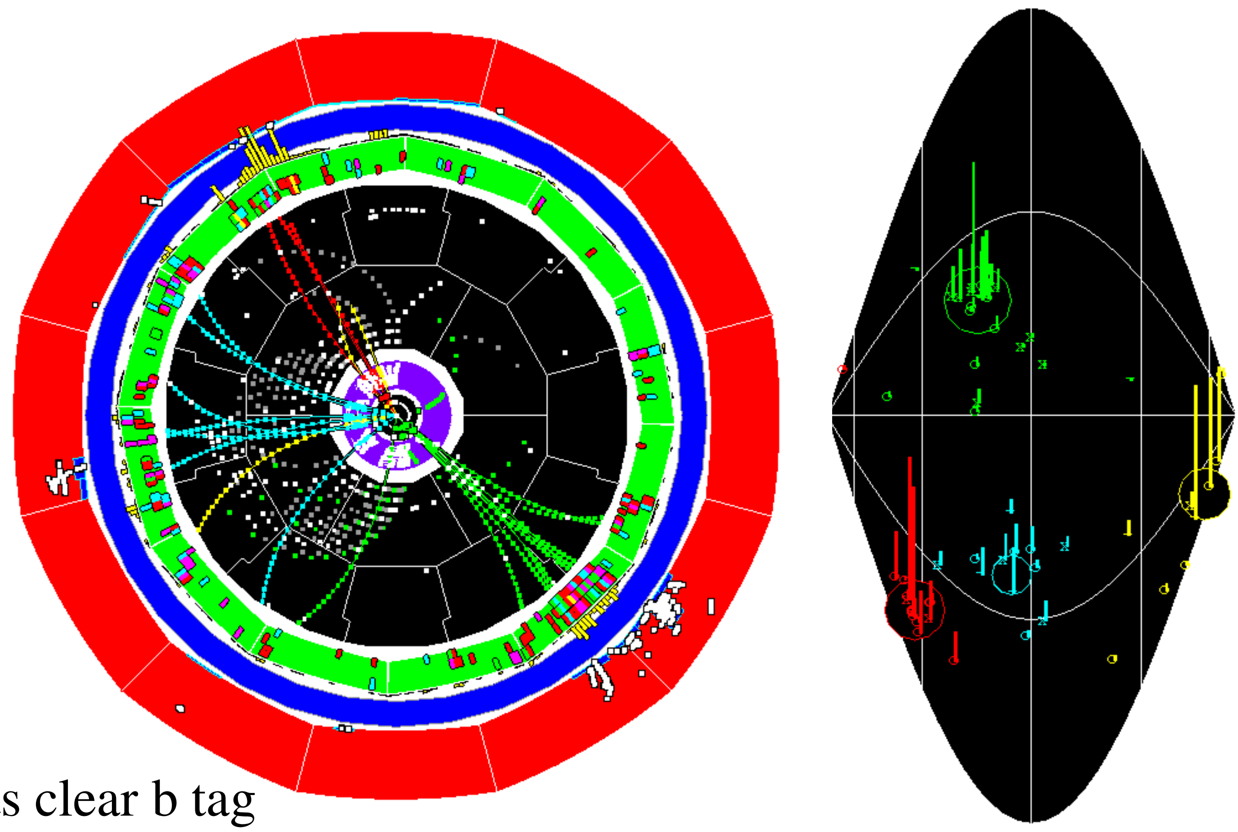
Search for SUSY Higgs hA

183 GeV data

Channel	Efficiency(%)	Signal	Backgrnd	Observed
bbbb	60.3	3.1	2.4	2
$\tau\tau$bb	28.6	0.3	0.1	0
total		3.4	2.5	2

(efficiency and expected signal for m_h = m_A= 75 GeV/c^2)

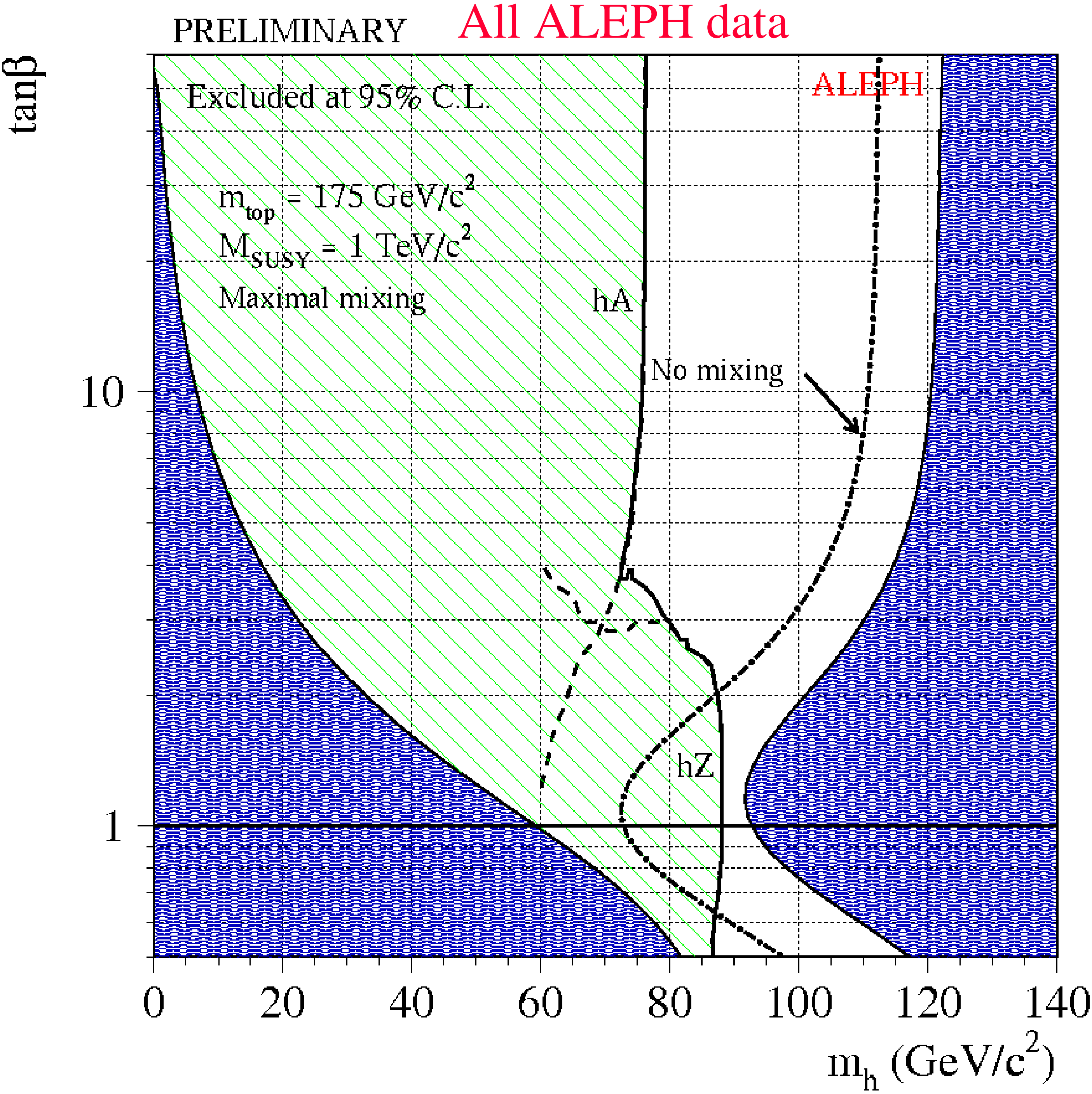
Candidate hA$\rightarrow$ bbbb, m(h)+m(A)=130 GeV/c^2



2 jets clear b tag

(likely bbgg event)

MSSM Higgs Limits



Standard Model Higgs M(H) > 87.9 GeV/c^2

MSSM ("basic" parameters) M(h) > 72.2 GeV/c^2

M(A) > 76.1 GeV/c^2

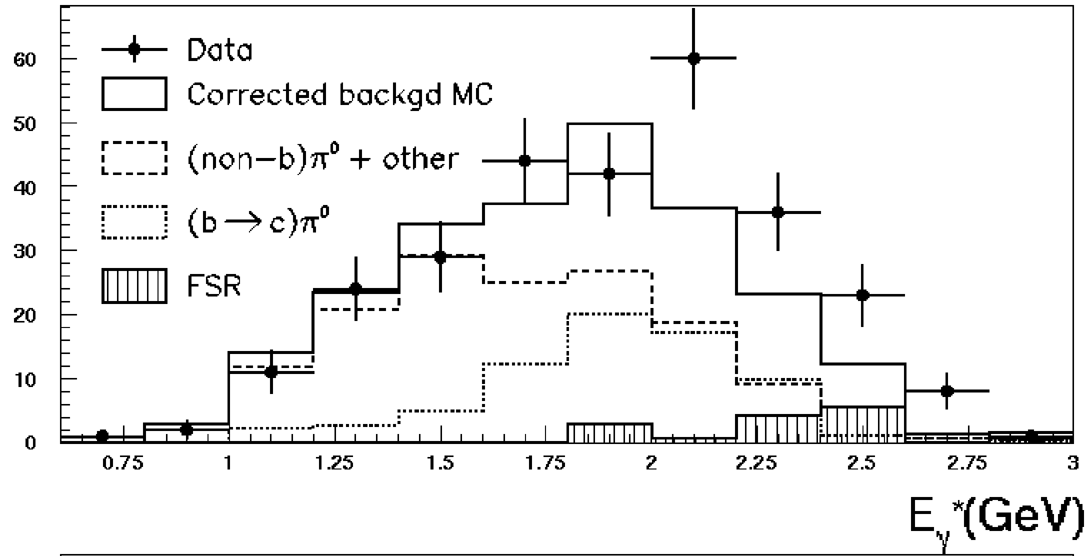
for no mixing case tanβ 0.6–2.0 excluded

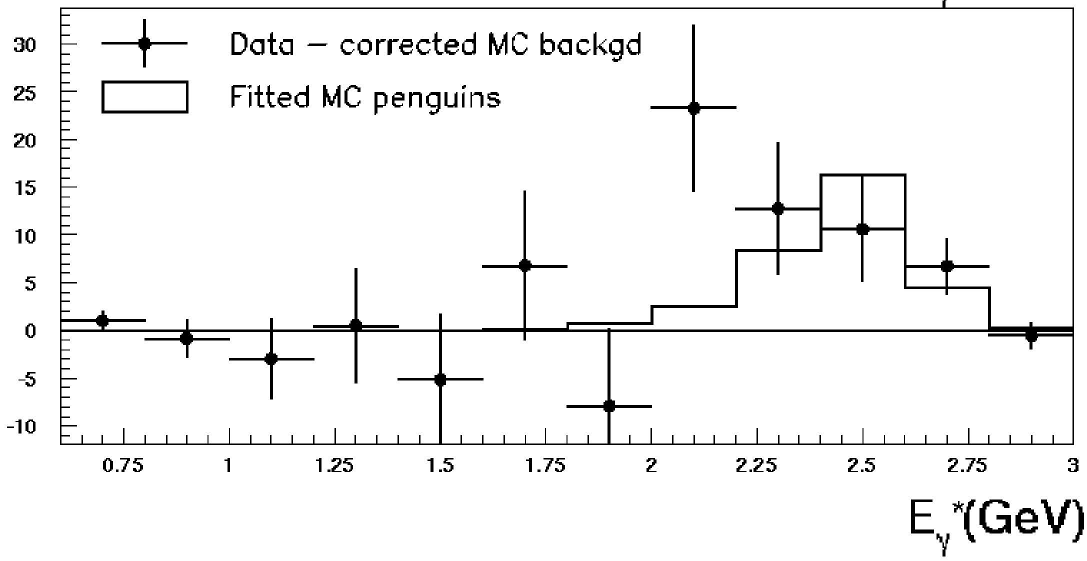
Branching ratio of $b \to s\gamma$

b tag in one event hemisphere

> 10 GeV photon in other

cuts on momentum and rapidity of track with γ





Branching ratio $(3.11 \pm 0.80_{stat} \pm 0.72_{syst}) \; 10^{-4}$

Standard Model prediction $(3.76\pm0.30) \; 10^{-4}$

CLEO $(2.32\pm0.57\pm0.35) \; 10^{-4}$

L3 $< 12 \; 10^{-4}$, DELPHI $< 5.4 \; 10^{-4}$

Conclusions

Excellent results from 1997 data

For 1998 data request extra Z calibration run(s)
2.0 (or 2.5) pb^{-1} at start, 0.5 pb^{-1} at end
or 1.5 (or 2.5) pb^{-1} start, 0.5 pb^{-1} middle, 0.5 pb^{-1} end

ALEPH ready to take data for 1998.
Look forward to an exciting year
Hope for discoveries