Ian Tomalin
C.E.R.N.

Limits on New Physics from $e^+e^- \rightarrow f\bar{f}$ with the ALEPH Detector at LEP2

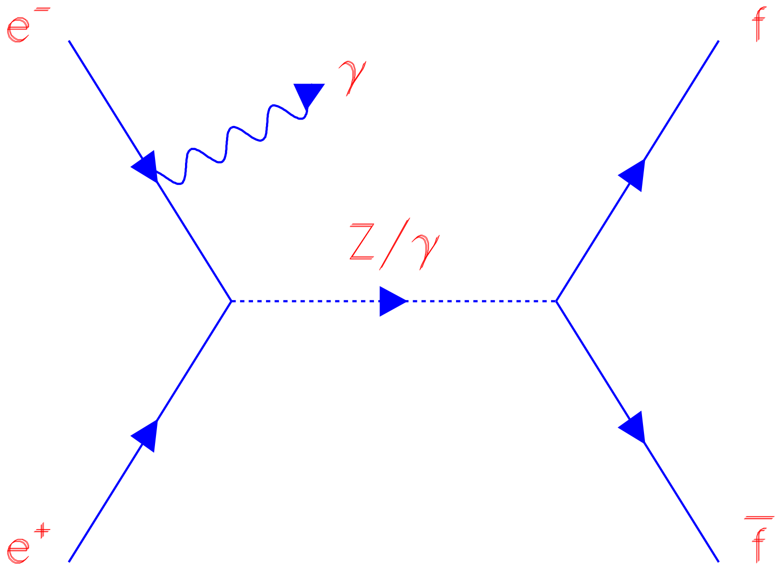
- Measurements of $f\bar{f}$ production
- Contact interactions
- R-parity violating sneutrinos
- Leptoquarks
- Z' bosons

Measurements of $\mathrm{f\bar{f}}$ Production

Data Sample -

Year	$\sqrt{s}$ (GeV)	Luminosity (pb^{-1})
1995 & 1997	130	6
1995 & 1997	136	6
1996	161	11
1996	172	11
1997	183	57
1998	189	174

Measurements of $\mathrm{f\bar{f}}$ Production



Cross section and forward-backward asymmetries presented for

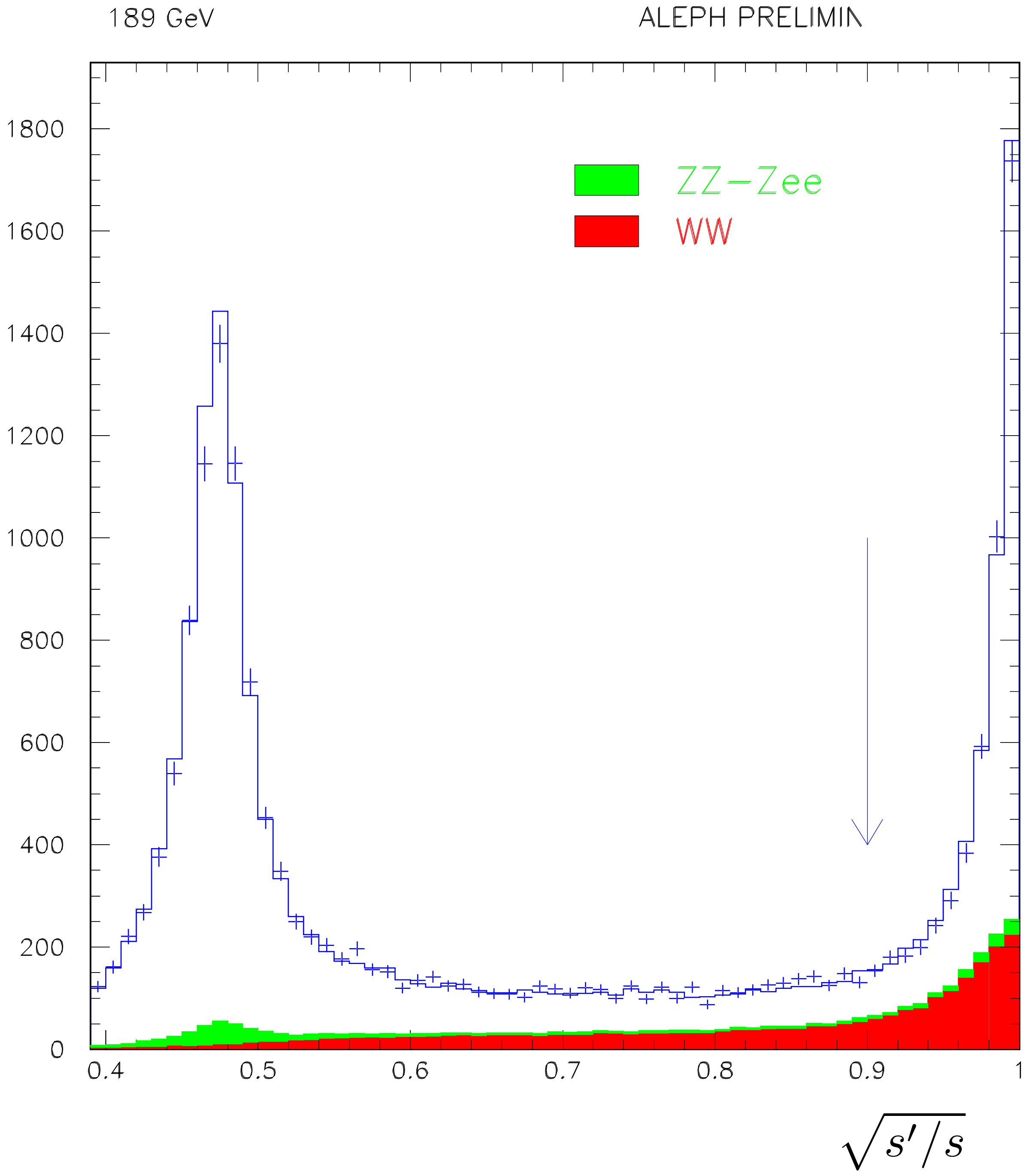
- $\sqrt{s'/s} > 0.1$ (inclusive)
- $\sqrt{s'/s} > 0.9$ & $|\cos\theta| < 0.95$ (exclusive)

where $\sqrt{s'}$ is $\mathrm{l^+l^-}$ mass (leptons)

propagator mass (hadrons)

Polar angle cut reduces theoretical uncertainties from ISR/FSR interference.

Measurements of $f\bar{f}$ Production



$q\bar{q}$ events at 189 GeV.

Measurements of $f\bar{f}$ Production

$e^+e^- \to q\bar{q}$ at $\sqrt{s} = 189$ GeV

For $|\cos\theta| < 0.95$

	$\sqrt{s'/s} > 0.9$	$\sqrt{s'/s} > 0.1$
Efficiency	84%	84%
Background	11%	21%
σ (pb)	$19.6 \pm 0.4 \pm 0.2$	$97.2 \pm 0.7 \pm 0.8$
SM (pb)	19.3 ± 0.3	96.3

Systematics:

- ECAL/HCAL energy scale
- Radiative events
- Luminosity
- Theory Error: ZFITTER

Measurements of $\mathrm{f\bar{f}}$ Production

b physics

Tag $\mathrm{b\bar{b}}$ events using long b hadron lifetime.

$$\epsilon = 41\% \text{ and } p = 83\%$$

Calibrate using Z^0 data.

$\Rightarrow \quad R_b = 0.15 \pm 0.01 \quad$ (SM=0.17).

Also using jet charge techniques for $|\cos\theta| < 0.9$ -

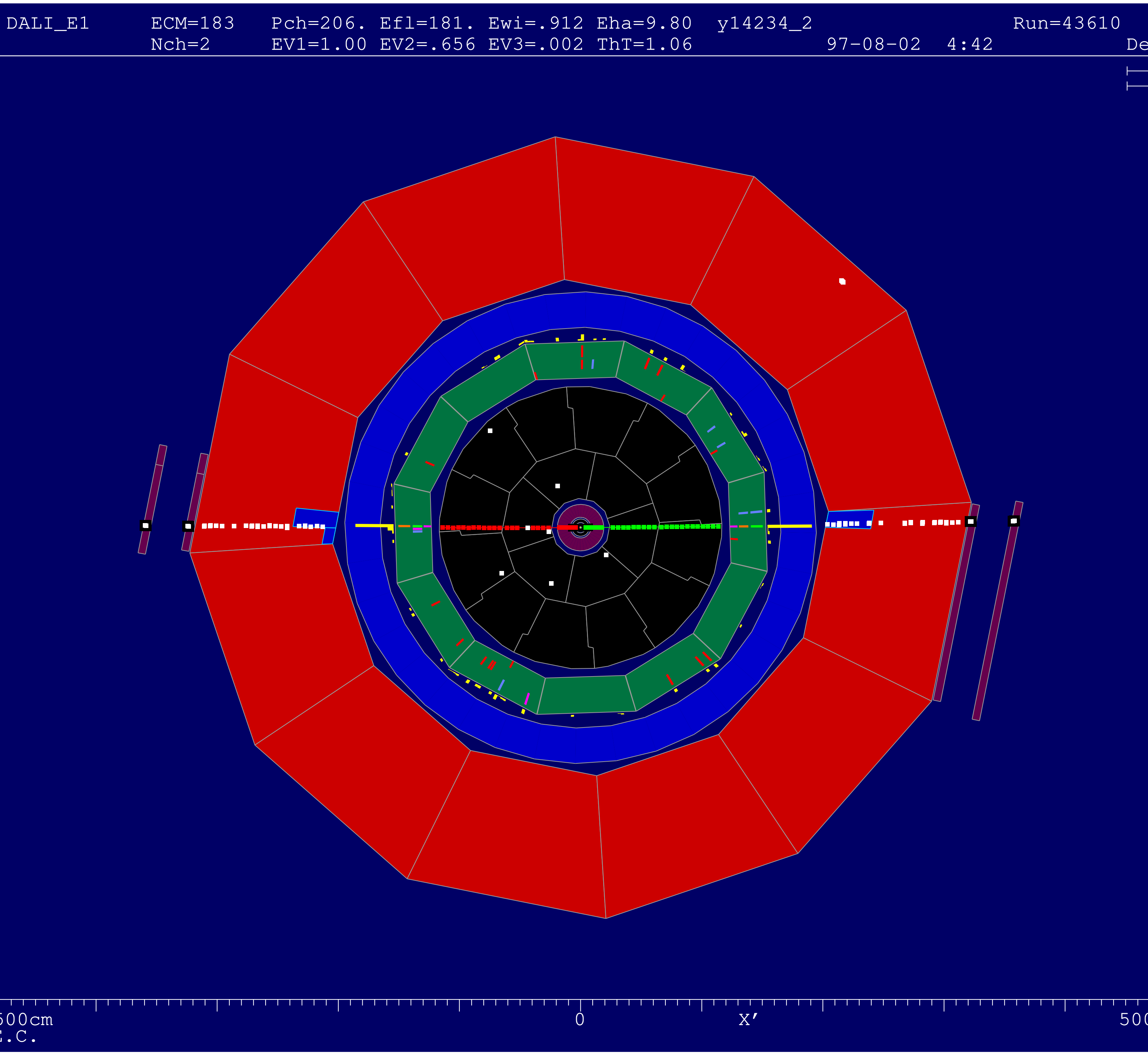
$\Rightarrow \quad A_{FB}(\mathrm{b\bar{b}}) = 0.34 \pm 0.19 \quad$ (SM=0.58).

$\Rightarrow \quad A_{FB}(\mathrm{c\bar{c}}) = 0.95 \pm 0.29 \quad$ (SM=0.60).

$\Rightarrow \quad Q_{FB}(\mathrm{udsc}) = 0.015 \pm 0.005 \quad$ (SM=0.018).

$Q_{FB}(\mathrm{udsc})$ constrains $A_{FB}(\mathrm{udsc})$ and σ_u/σ_d.

Measurements of $f\bar{f}$ Production



$\mu^+\mu^-$ event at 189 GeV.

Measurements of $\mathrm{f\bar{f}}$ Production

$\mathrm{e^+e^-} \rightarrow \mu^+\mu^-$ at $\sqrt{s} = 189$ GeV

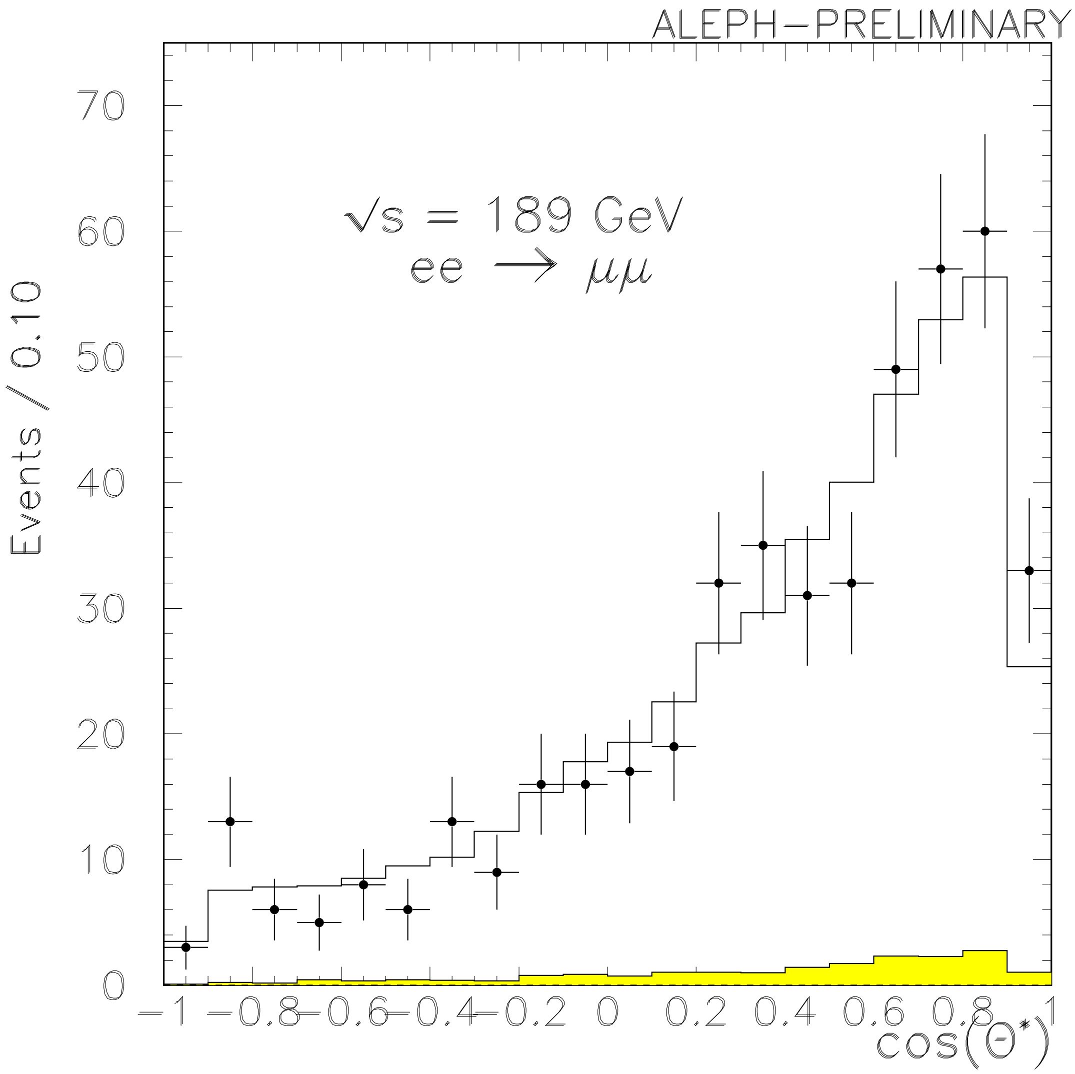
For $|\cos\theta| < 0.95$

	$\sqrt{s'/s} > 0.9$	$\sqrt{s'/s} > 0.1$
Efficiency	96%	74%
Background	4%	9%
σ (pb)	$2.66 \pm 0.13 \pm 0.06$	$7.6 \pm 0.2 \pm 0.2$
SM (pb)	2.69	7.6

Systematics:

- Muon acceptance/identification

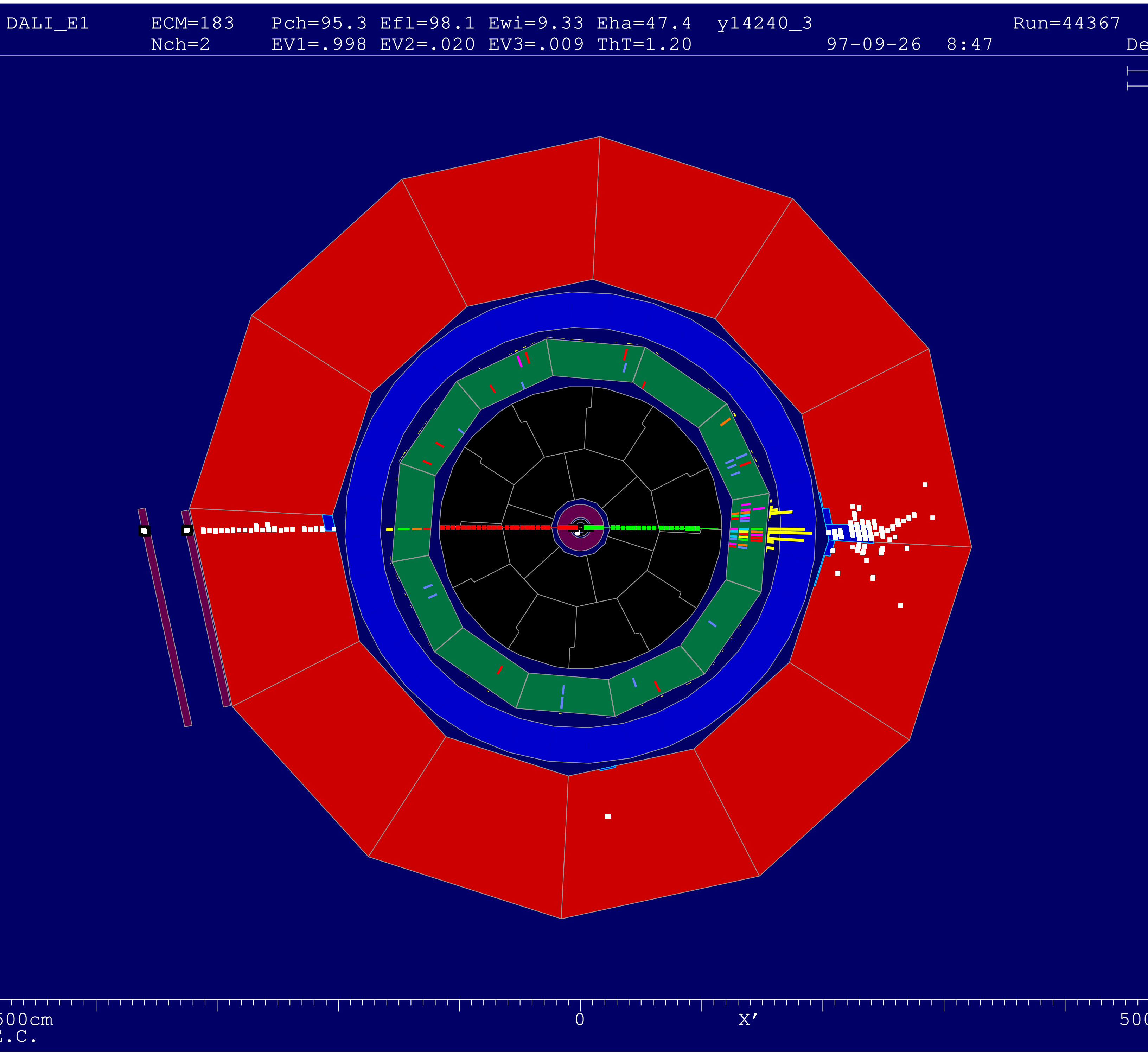
Measurements of $\mathrm{f\bar{f}}$ Production



$$A_{FB}(\mu^+\mu^-) = 0.58 \pm 0.04 \pm 0.01 \text{ at } 189 \text{ GeV}$$

(SM=0.57).

Measurements of $f\bar{f}$ Production



$\tau^+\tau^-$ event at 189 GeV.

Measurements of $f\bar{f}$ Production

$e^+e^- \to \tau^+\tau^-$ at $\sqrt{s} = 189$ GeV

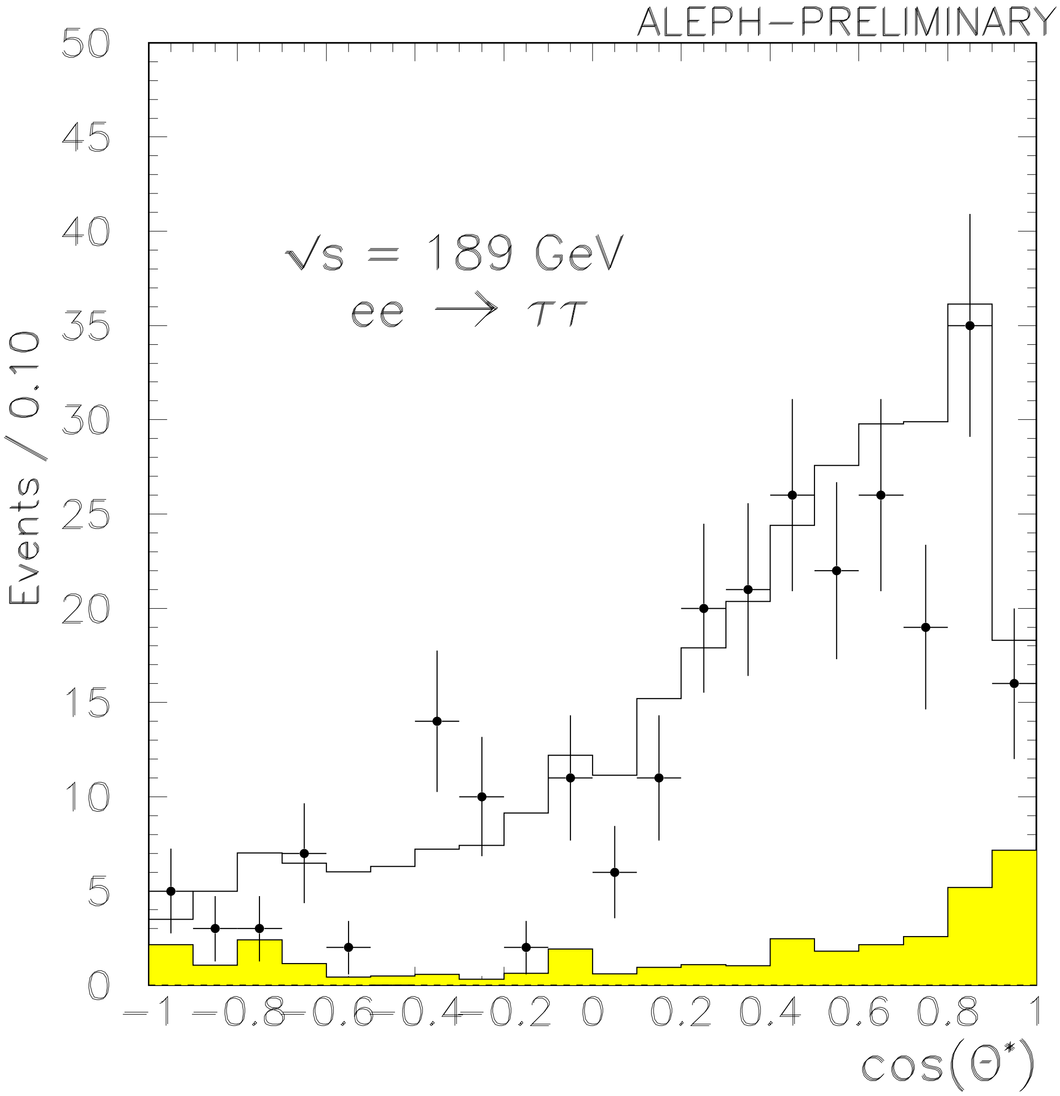
For $|\cos\theta| < 0.95$

	$\sqrt{s'/s} > 0.9$	$\sqrt{s'/s} > 0.1$
Efficiency	64%	44%
Background	15%	14%
σ (pb)	$2.39 \pm 0.15 \pm 0.05$	$7.3 \pm 0.3 \pm 0.1$
SM (pb)	2.78	7.6

Systematics:

- ECAL/HCAL energy scale
- e^+e^- background

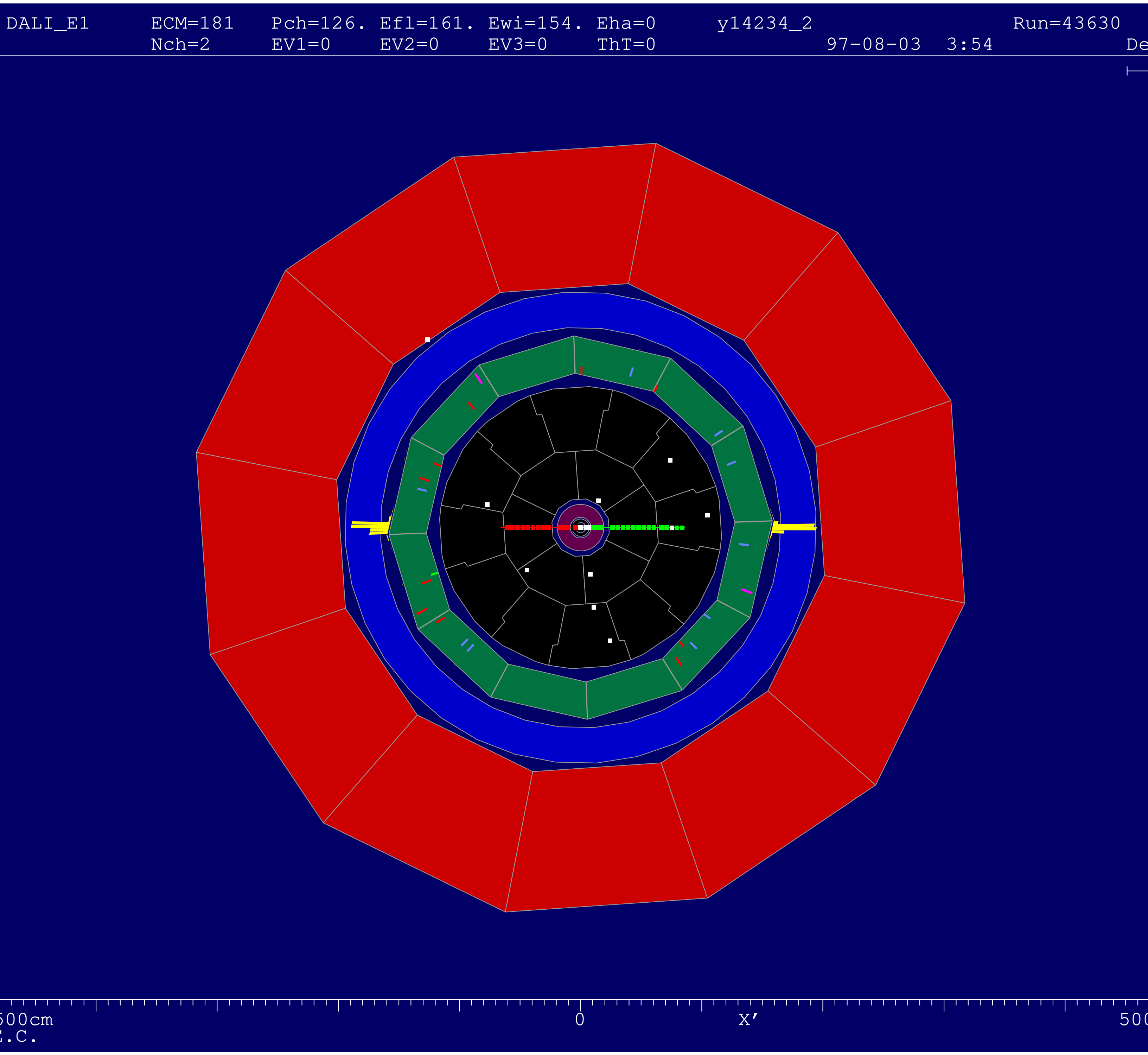
Measurements of $f\bar{f}$ Production



$$A_{FB}(\tau^+\tau^-) = 0.57 \pm 0.05 \pm 0.05 \text{ at } 189 \text{ GeV}$$

(SM=0.57).

Measurements of $f\bar{f}$ Production



e^+e^- event at 189 GeV.

Measurements of $\mathrm{f\bar{f}}$ Production

$\mathrm{e^+e^-} \rightarrow \mathrm{e^+e^-}$ at $\sqrt{s} = 189$ GeV

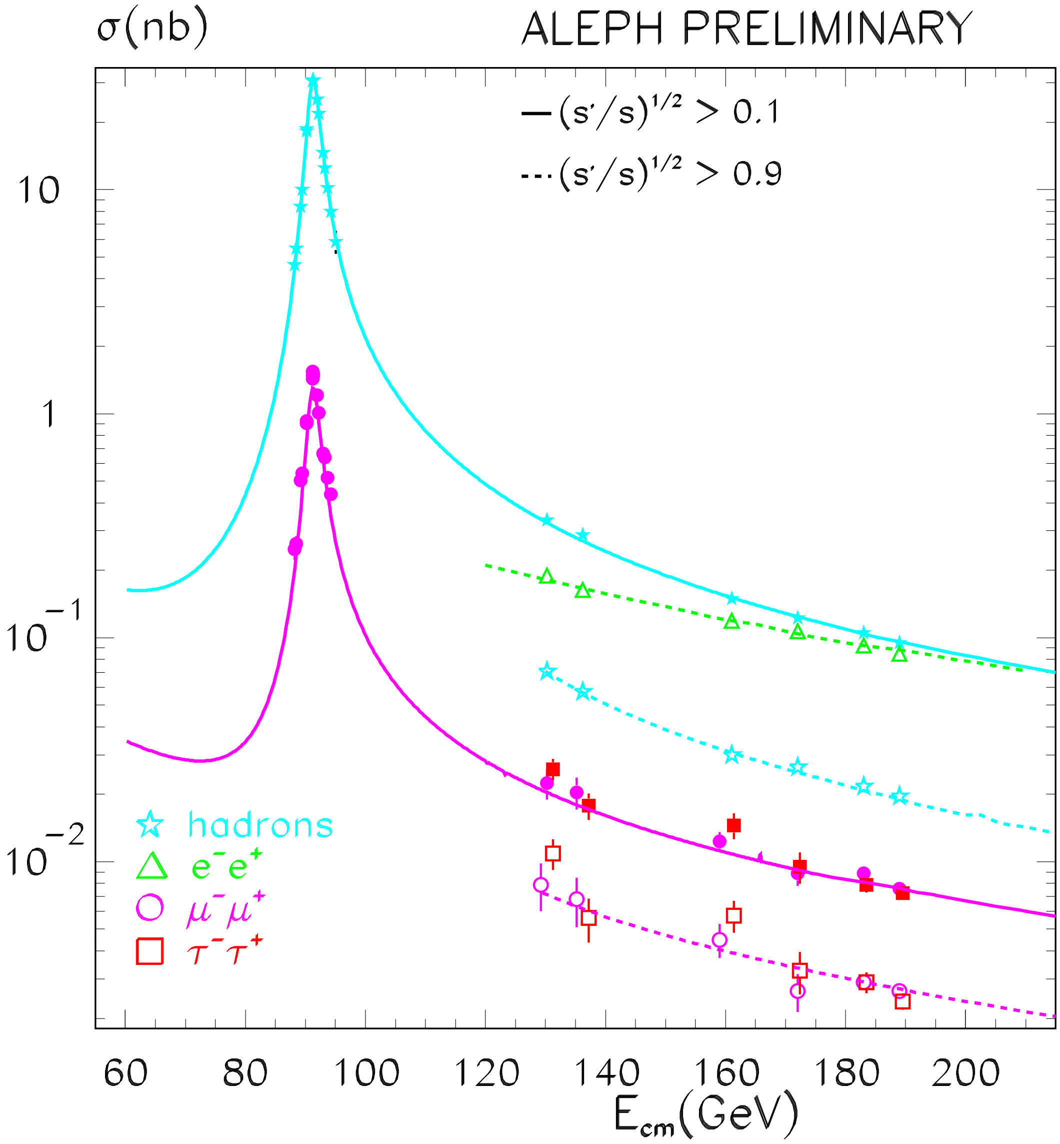
For $\sqrt{s'/s} > 0.9$

	$-0.9 < \cos\theta^* < 0.9$	$-0.9 < \cos\theta^* < 0.7$
Efficiency	88%	95%
Background	12%	14%
σ (pb)	$84.1 \pm 0.7 \pm 0.7$	$17.0 \pm 0.3 \pm 0.2$
SM (pb)	87.3 ± 2.6	17.8 ± 0.5

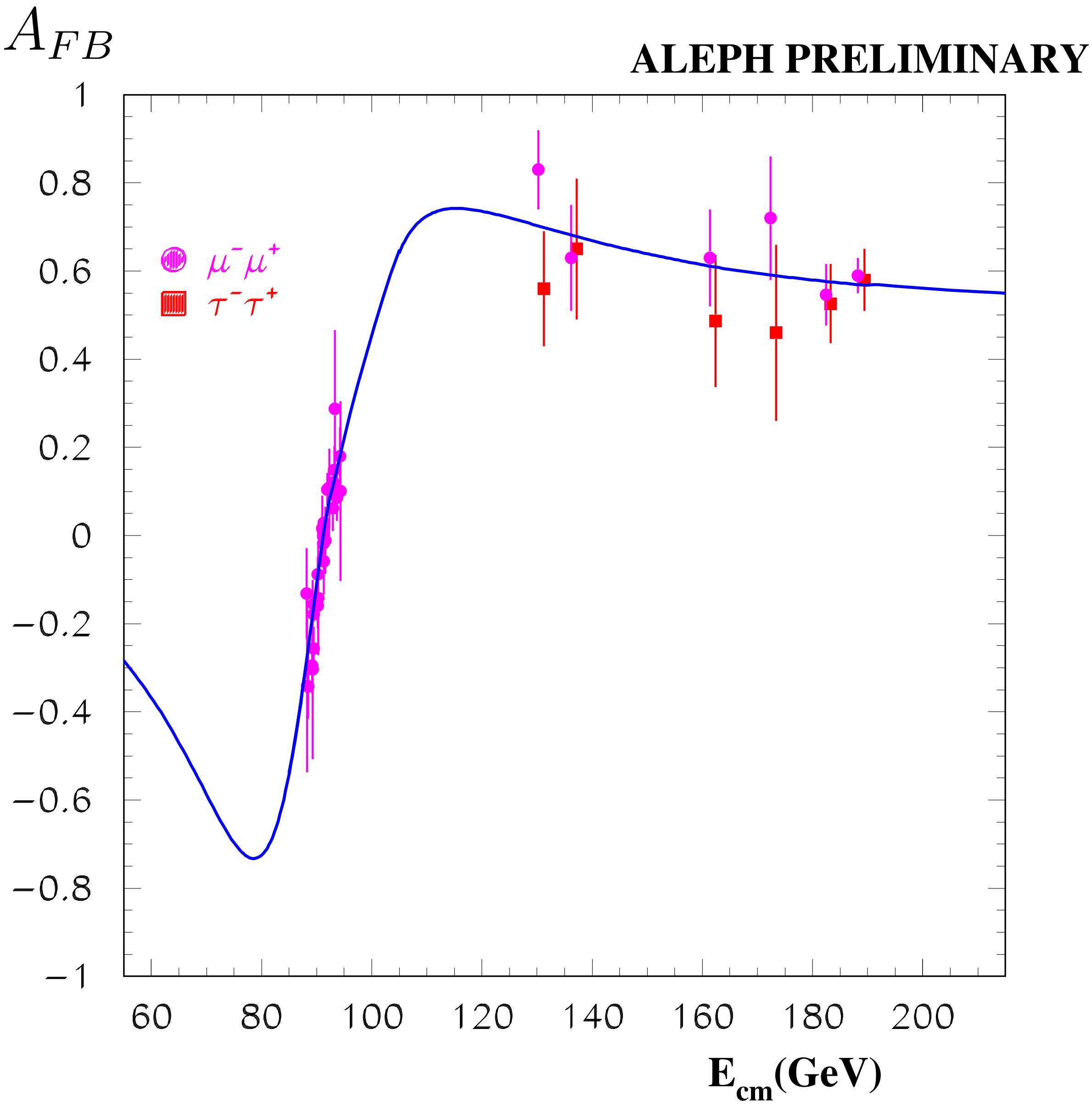
Systematics:

- ECAL energy scale
- Radiative background
- Luminosity
- Theory Error: BHWIDE

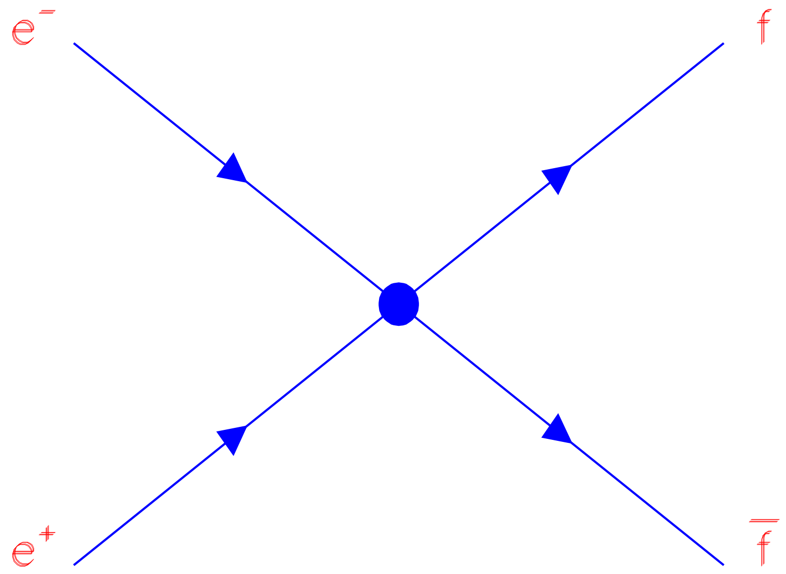
Measurements of $f\bar{f}$ Production



Measurements of $f\bar{f}$ Production



Contact Interactions

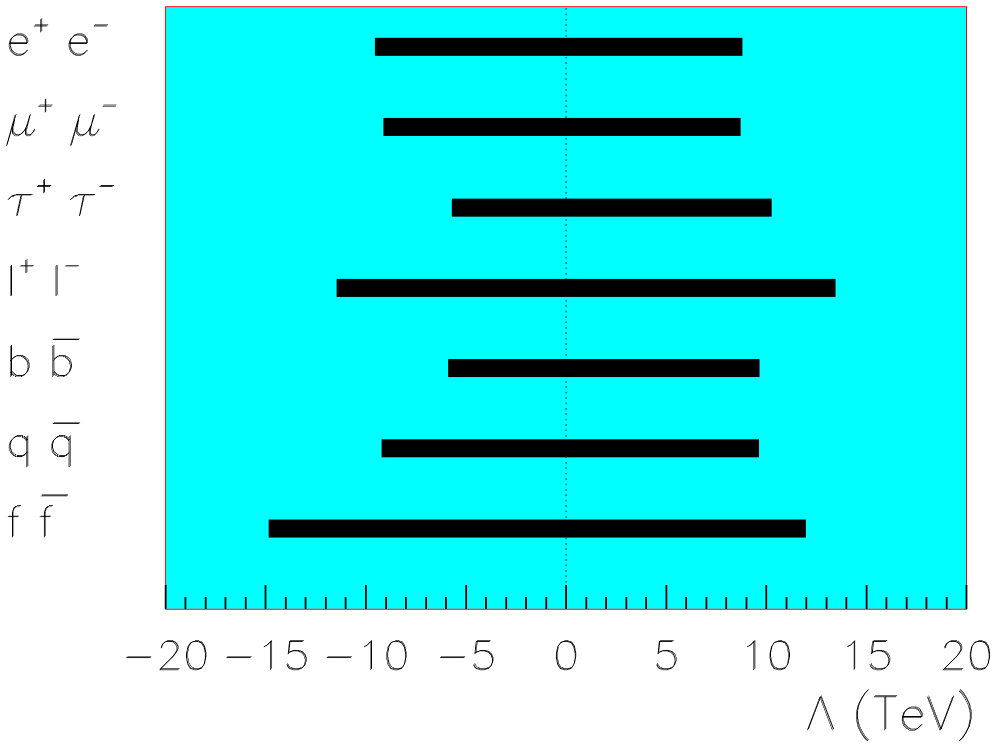


$$L = \frac{g^2}{(1+\delta_{\mathrm{ef}})\Lambda^2} \sum_{i,j=L,R} \eta_{ij} [\bar{\mathrm{e}}_i \gamma^\mu \mathrm{e}_j][\bar{\mathrm{f}}_i \gamma_\mu \mathrm{f}_j]$$

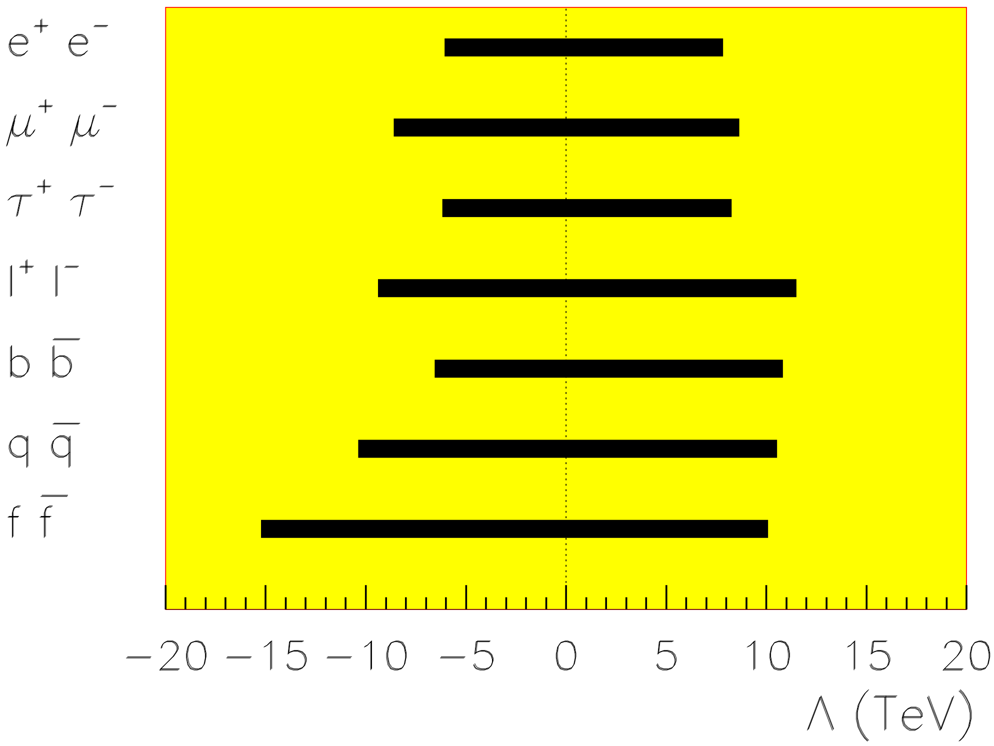
g	Coupling, convention $= \sqrt{4\pi}$.
Λ	Mass scale.
η_{ij}	Helicity amplitudes.

Contact Interactions

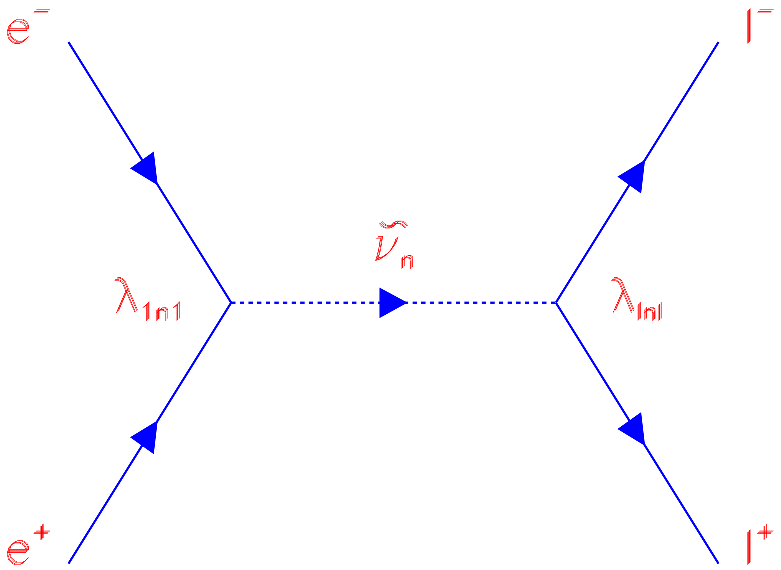
Model VV: $\eta_{LL} = \eta_{RR} = \eta_{LR} = \eta_{RL} = 1$



Model AA: $\eta_{LL} = \eta_{RR} = -\eta_{LR} = -\eta_{RL} = 1$



R-parity Violating Sneutrinos



$$L = \lambda_{ijk} \mathrm{L}_i \mathrm{L}_j \bar{\mathrm{E}}_k$$

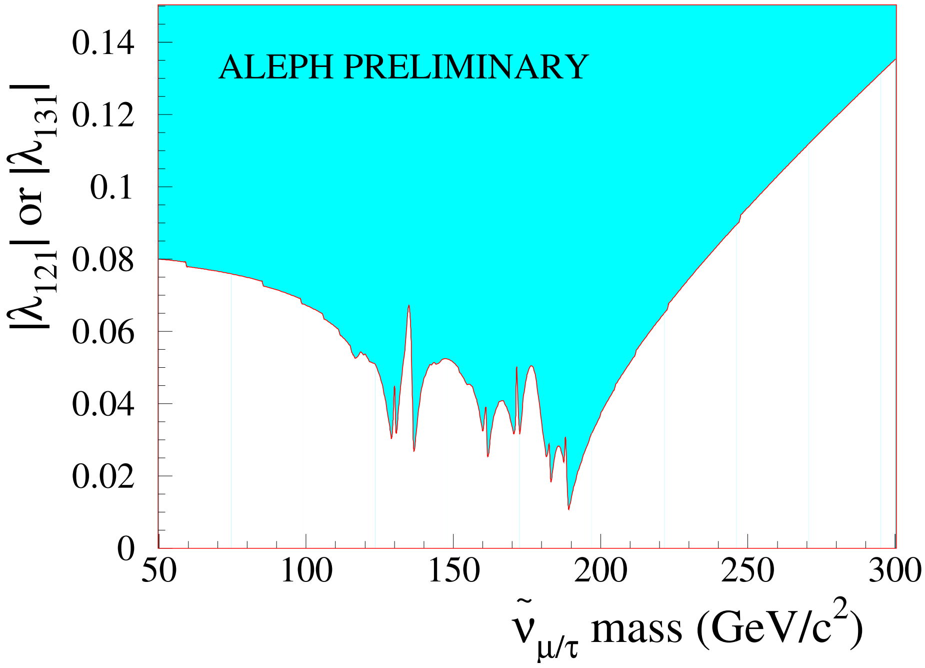
L_i Left-handed lepton doublet superfield.

E_i Right-handed lepton singlet superfield.

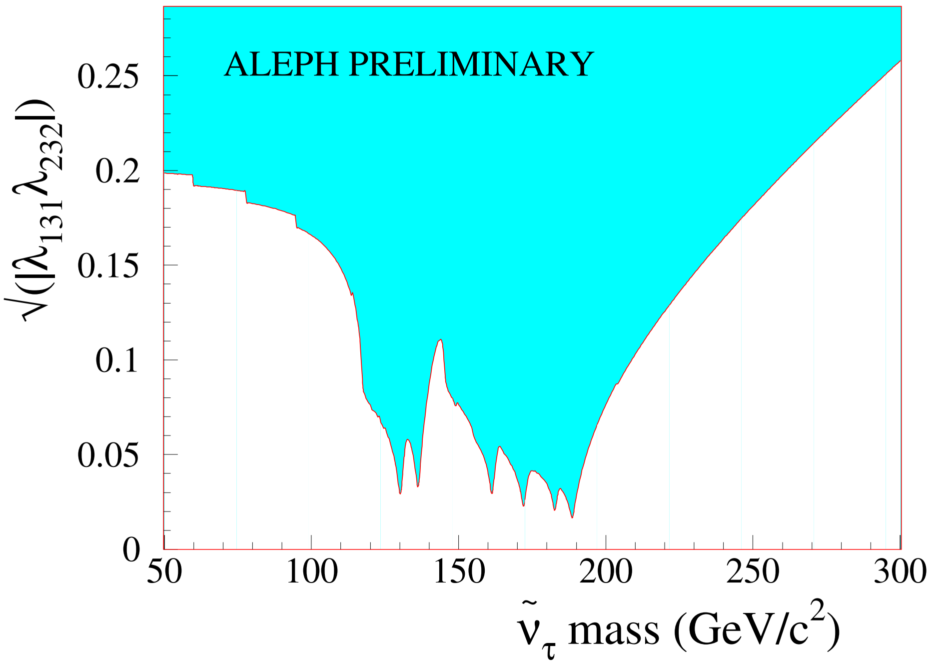
(Complementary ALEPH analysis looks for $\tilde{\nu} \to l\chi$)

R-parity Violating Sneutrinos

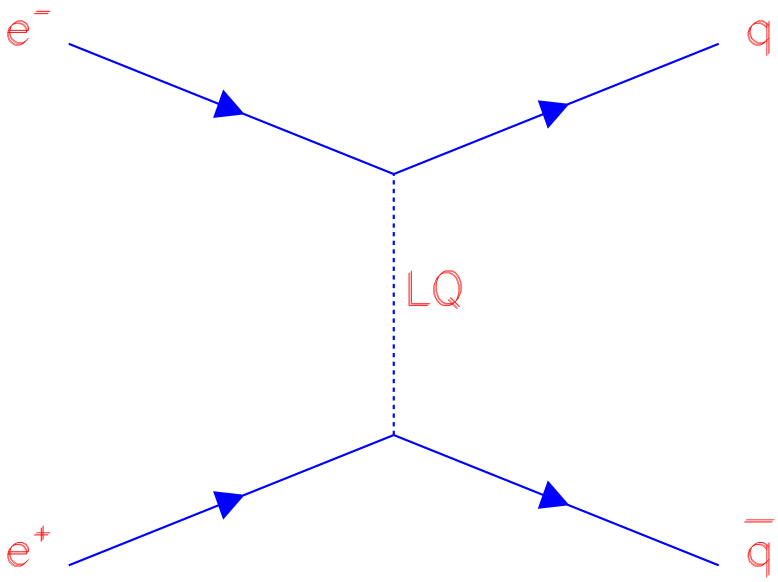
$e^+e^- \longrightarrow e^+e^-$



$e^+e^- \longrightarrow \mu^+\mu^-$



Leptoquarks



LQ with interactions respecting SM gauge symmetries

$$S_I(L/R) \qquad \text{and} \qquad V_I(L/R)$$

I Weak isospin.

L/R Helicity of coupled lepton.

Leptoquarks

95% C.L. limits on LQ mass for $g = e$

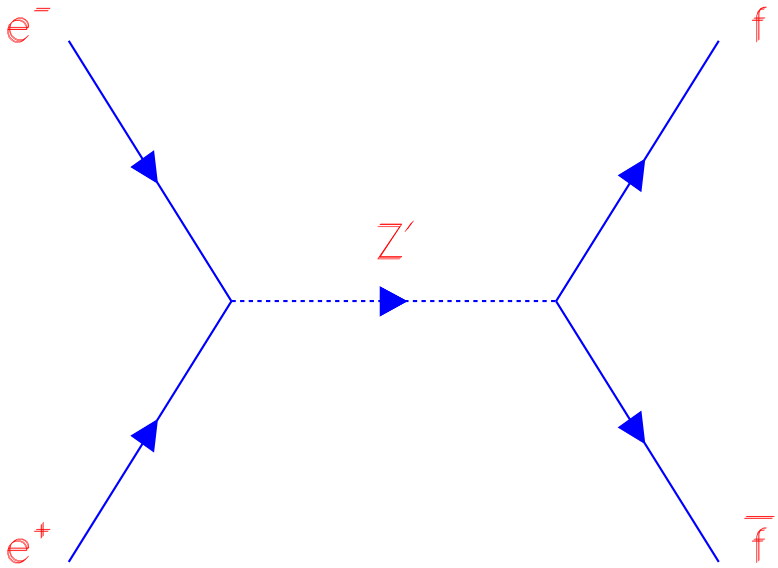
	Quark Generation	
	1^{st} or 2^{nd}	3^{rd}
S_0 (L) $(\tilde{d})$	310	—
$\tilde{S}_0$ (R)	130	310
S_1 (L)	370	710
$V_{1/2}$ (R)	250	430
$V_{1/2}$ (L)	140	220
V_0 (L)	420	450
$\tilde{V}_0$ (R)	350	—
V_1 (L)	590	450

c.f. TEVATRON ≈ 225 GeV$/c^2$.

and for 1st generation LQ -

c.f. Atomic Physics > 500 GeV$/c^2$,
HERA ≈ 250 GeV$/c^2$.

Z' Bosons



LR $\quad \mathrm{SO(10)} \rightarrow \mathrm{SU_c(3)} \otimes \mathrm{SU_L(2)} \otimes \mathrm{SU_R(2)} \otimes \mathrm{U_{B-L}(1)}$

E_6 $\quad \mathrm{E_6} \rightarrow \mathrm{SU(5)} \otimes \mathrm{U(1)}_\psi \otimes \mathrm{U(1)}_\chi$

For θ_{mix} $(\mathrm{Z} - \mathrm{Z}') = 0$ (from LEP1)

	ALEPH (GeV/c^2)	CDF (GeV/c^2)
Sequential SM	1050	690
LR-symmetric	470	630
$E_6(\chi)$	460	595
$E_6(\psi)$	285	590
$E_6(\eta)$	295	620
$E_6(I)$	385	565

Conclusions

From 265 pb^{-1} of data at 130-189 GeV

- $\mathrm{q\bar{q}}$, $\mathrm{b\bar{b}}$, $\mathrm{e^+e^-}$, $\mu^+\mu^-$, $\tau^+\tau^-$ cross sections and asymmetries compatible with SM.

- Contact Interactions explored to $\Lambda \approx 10$ TeV.
- R-parity violating sneutrino limits to 300 GeV/c^2.
- LQ limits of up to 700 GeV.
- Z' limits up to 1 TeV.