Recent Results from LEP 1.5

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Thanks to many colleagues from all LEP experiments!

Outline:

Results from the LEP run at $130-140$ GeV in November 1995

New results from this year's run at $\sqrt{s} = 161$ GeV

- **Status of LEP**
- **Standard Model physics**
  - **Total cross sections and forward-backward asymmetries**
  - **QCD**
  - **W pairs**
- **Search for new particles**
  - **Supersymmetry**
  - **Events with hard photons**
  - **Excited & heavy leptons**

Introduction:

LEP: Large Electron Positron collider at CERN
4 experiments: ALEPH, DELPHI, L3, OPAL

Phase I: 1989–1995 $\sqrt{s} \approx m_Z$

- about 4 million Z decays per experiment
- precise determination of Z parameters
- tests of QCD
- b-quark and tau physics
- searches for new particles

Phase II: 1996–2000

- Increasing the cms energy
- First step Nov. 1995: $\sqrt{s} = 130 - 140$ GeV (LEP 1.5)
- July 1996: $\sqrt{s} = 161$ GeV
  threshold $e^+e^- \to W^+W^-$
  $\approx 11\ \mathrm{pb}^{-1}$ per experiment
- October 1996: Further increase to 175 GeV

Status of LEP

Increase of cms energy requires installation of new, superconducting RF cavities

Energy loss per turn 130 MeV at the Z
1 900 MeV for $E_{\mathrm{b}} = 90$ GeV

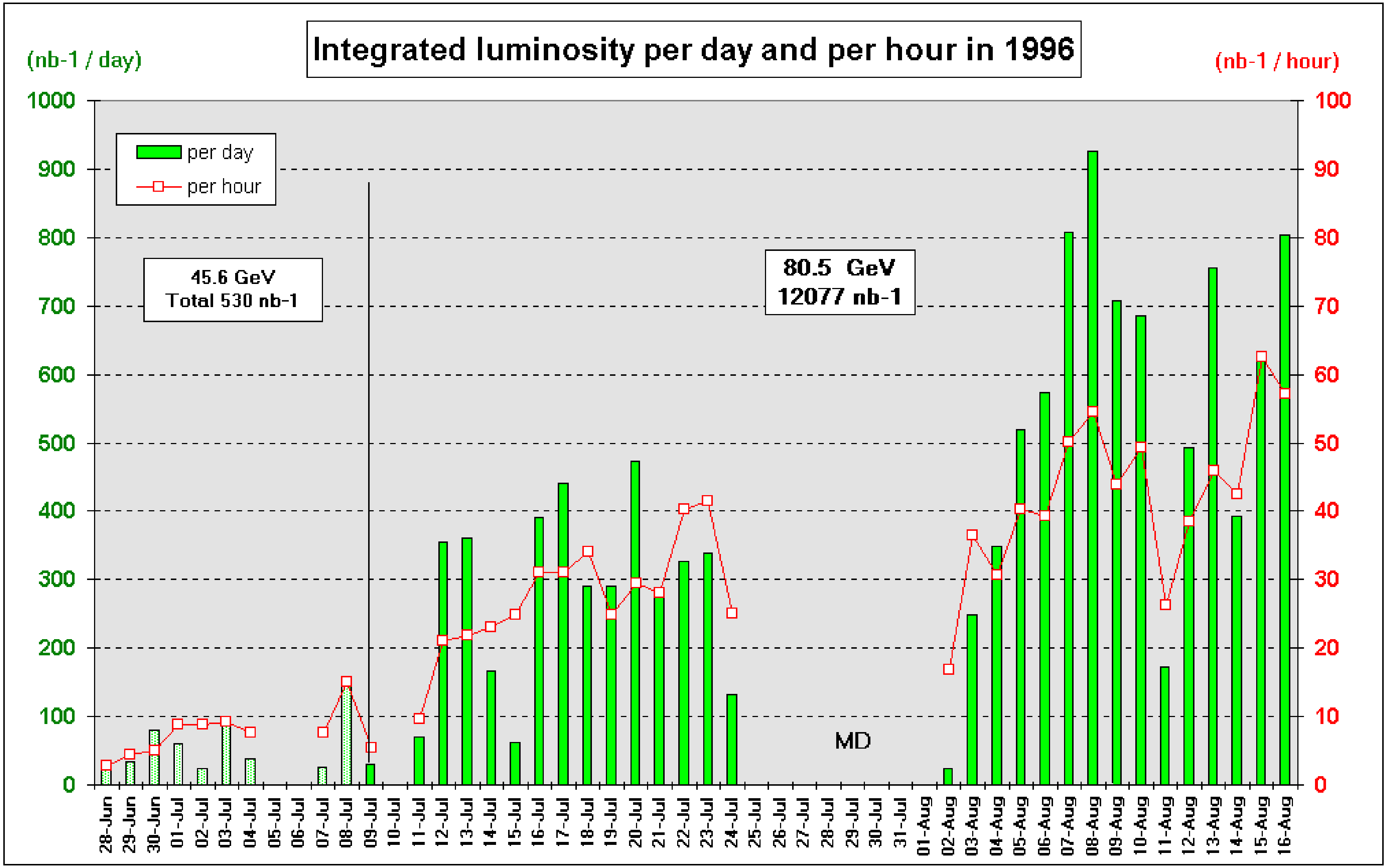
October 1995	64 SC cavities
May 1996	144 SC cavities
October 1996	172 SC cavities

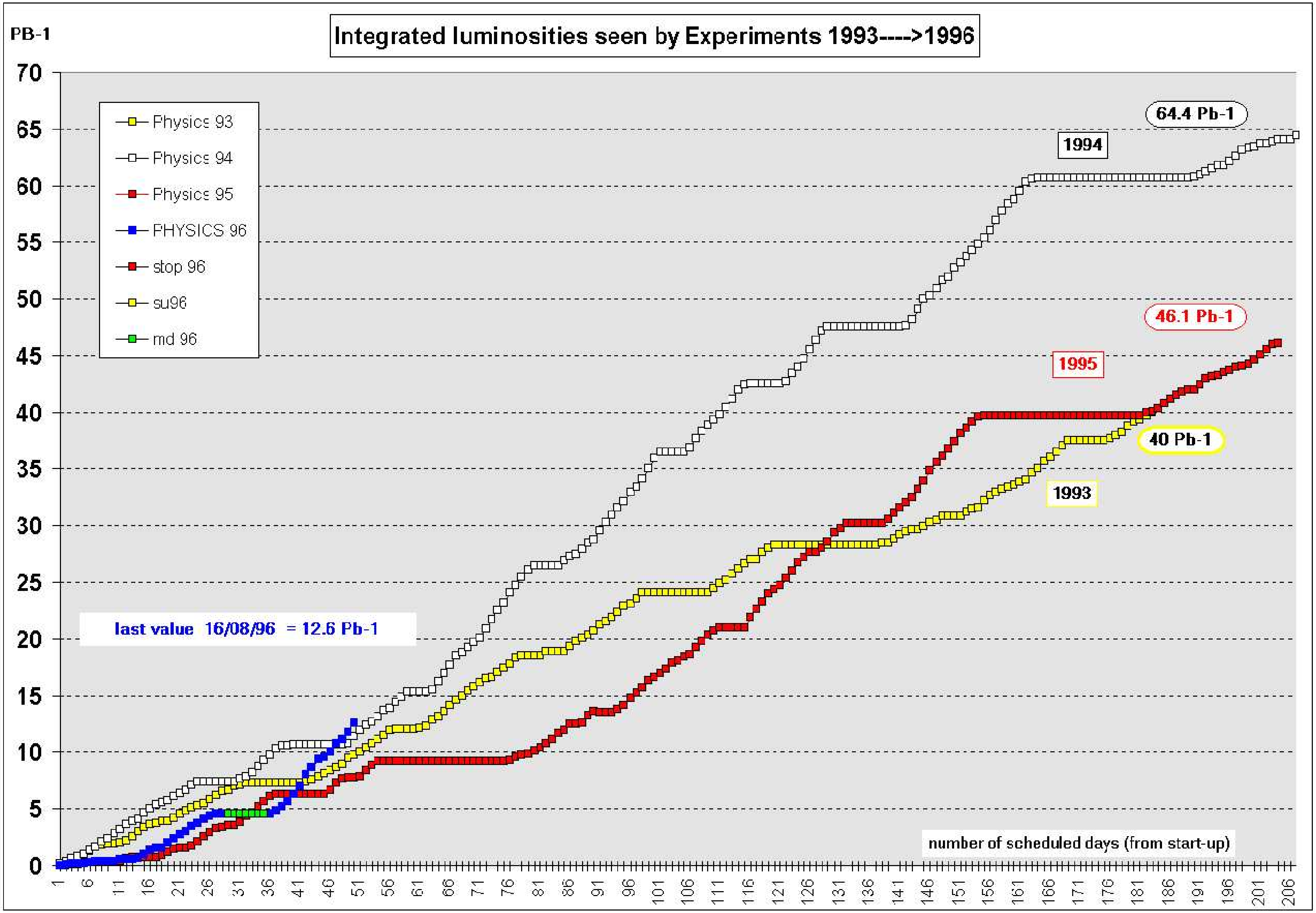
SC cavity system worked reliably at design gradient of 6 MV/m

Future plans:

1997	add 68 SC cavities	$E_{\mathrm{b}} = 94$ GeV
1998	add 32 SC cavities	$E_{\mathrm{b}} = 96$ GeV

Goal: 500 pb^{-1} per experiment by year 2000
corresponding to $\approx 8\,000$ W pairs

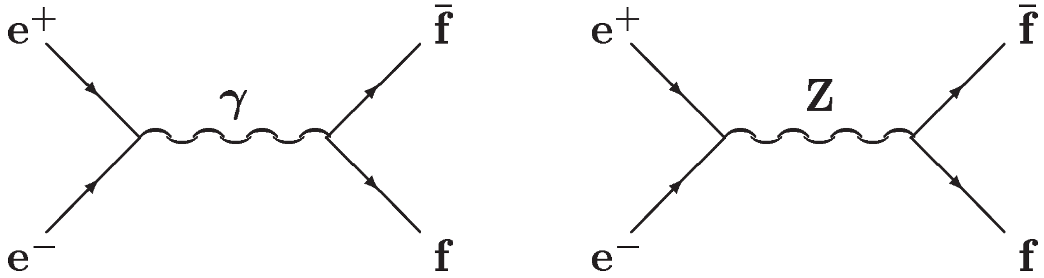

Integrated luminosity per day and per hour in 1996
(nb-1 / day)
(nb-1 / hour)
per day
per hour
45.6 GeV
Total 530 nb-1
80.5 GeV
12077 nb-1
MD



Integrated luminosities seen by Experiments 1993---->1996
PB-1
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
Physics 93
Physics 94
Physics 95
PHYSICS 96
stop 96
su96
md 96
64.4 Pb-1
1994
46.1 Pb-1
1995
40 Pb-1
1993
last value 16/08/96 = 12.6 Pb-1
number of scheduled days (from start-up)
1
6
11
16
21
26
31
36
41
46
51
56
61
66
71
76
81
86
91
96
101
106
111
116
121
126
131
136
141
146
151
156
161
166
171
176
181
186
191
196
201
206

Cross sections and FB asymmetries above the Z pole:

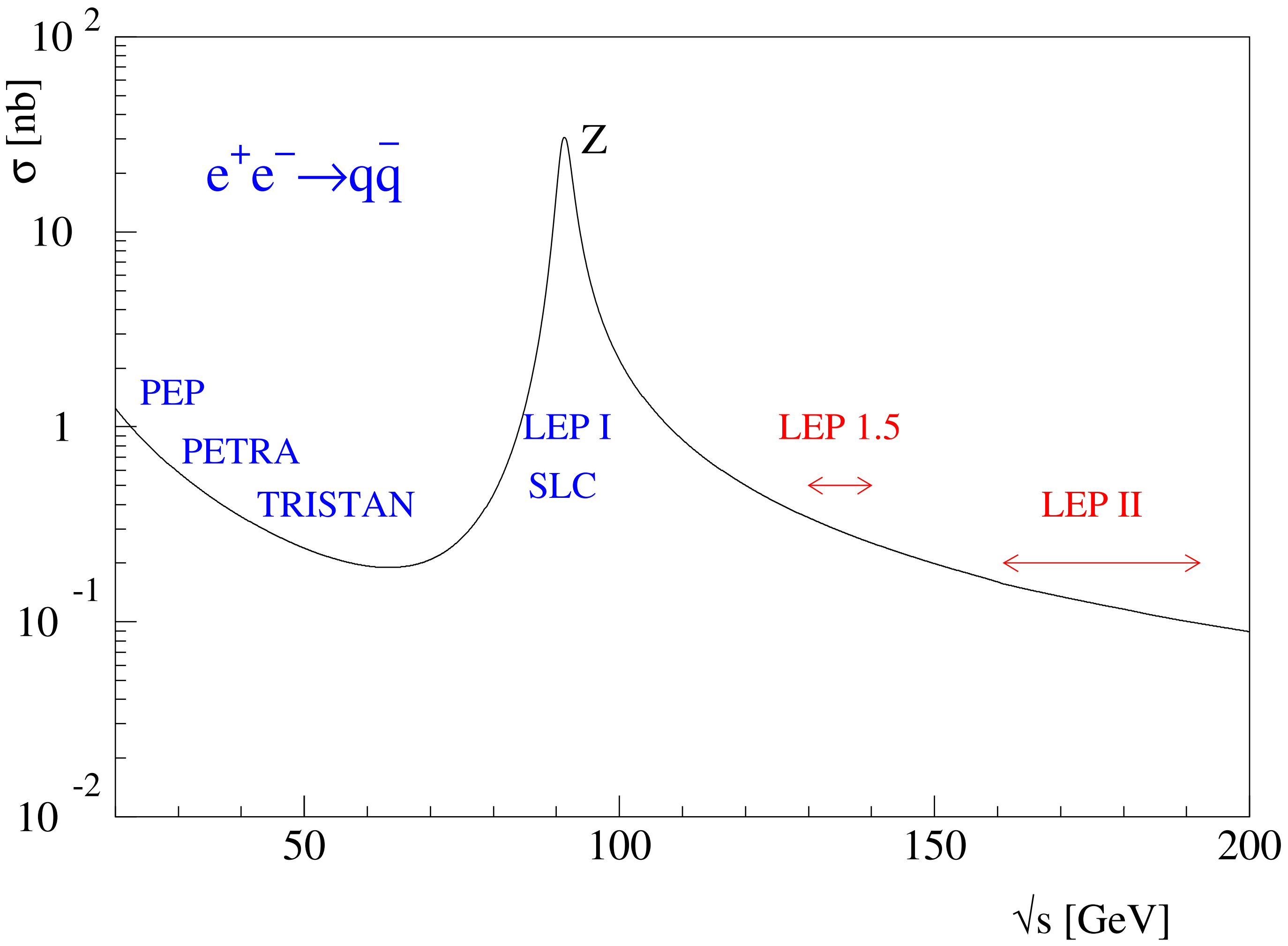
Fermion pair production:



- $e^+e^- \rightarrow$ hadrons
- $e^+e^- \rightarrow e^+e^-$
- $e^+e^- \rightarrow \mu^+\mu^-$
- $e^+e^- \rightarrow \tau^+\tau^-$

Probing the γZ interference above the Z pole

Total hadronic cross section as function of the cms energy:

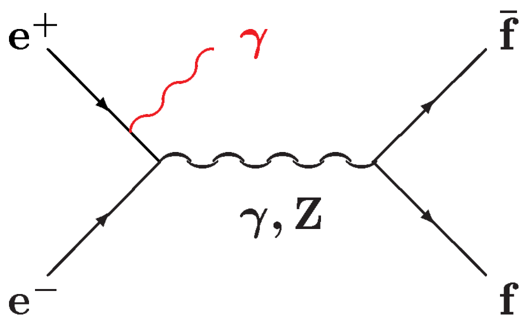


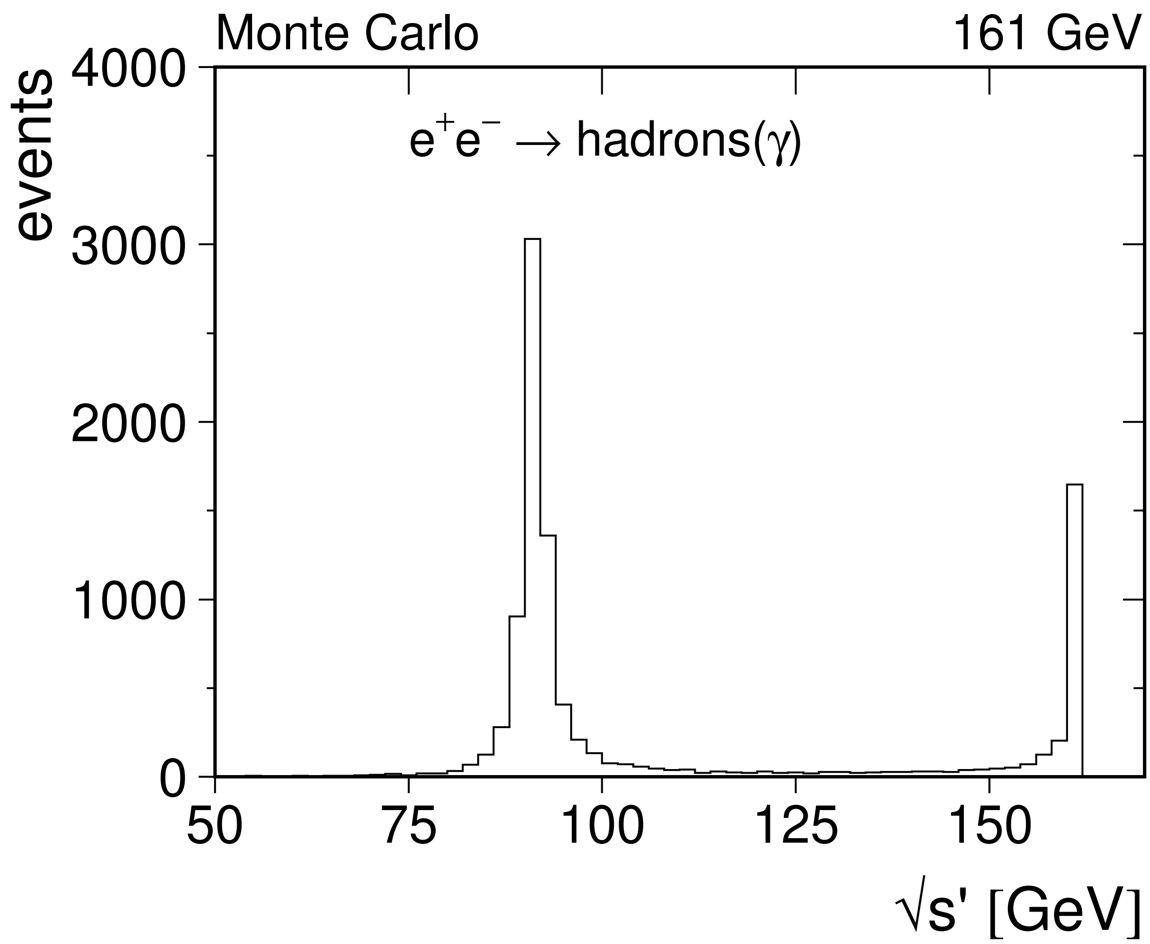
At LEP 1.5 about 100 times smaller than at the Z pole!

130 – 140 GeV 5 – 6 pb^{-1} per experiment corresponding to ≈ 1 600 hadron events

161 GeV 11 pb^{-1} ≈ 1 650 hadron events

Initial state photon radiation:





Radiative return to the Z ($\sqrt{s} < 110$ GeV):

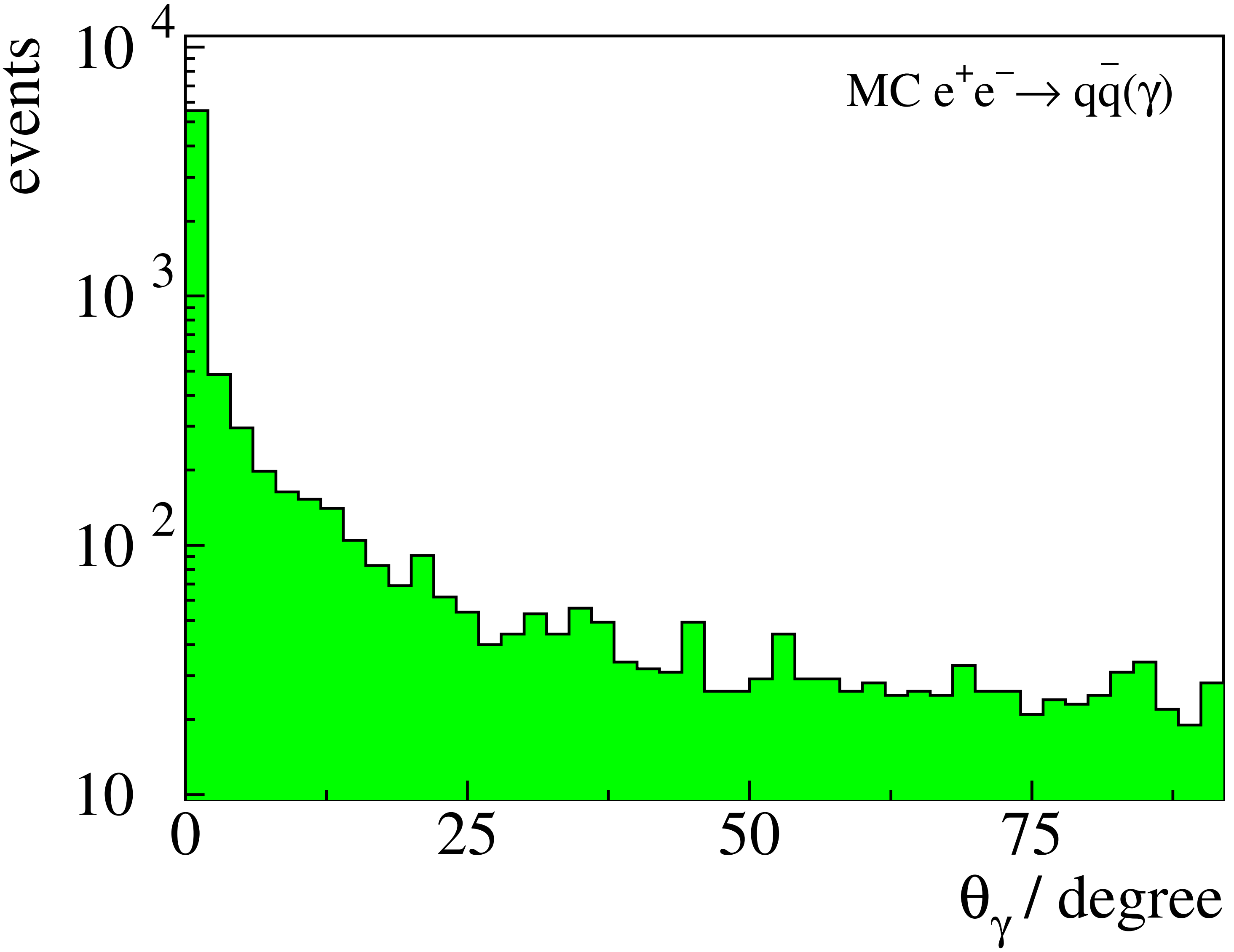
	140 GeV	161 GeV
$e^+e^- \to$ hadrons	80%	70%
$e^+e^- \to \mu^+\mu^-$	65%	50%

Determine cross section and A_{FB} for total sample and 'high energy' events

Different definitions:

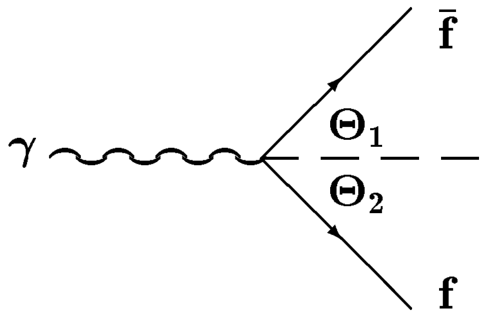
	total	high energy
ALEPH	$\sqrt{s'/s} > 0.1$	$\sqrt{s'/s} > 0.9$
DELPHI	no cut	$\sqrt{s'/s} > 0.85$
L3	no cut	$\sqrt{s'} > 110$ GeV
OPAL	$s'/s > 0.01$	$s'/s > 0.8$

Polar angle of the initial state photon:



Determination of $\sqrt{s'}$

Assume three particle final state:

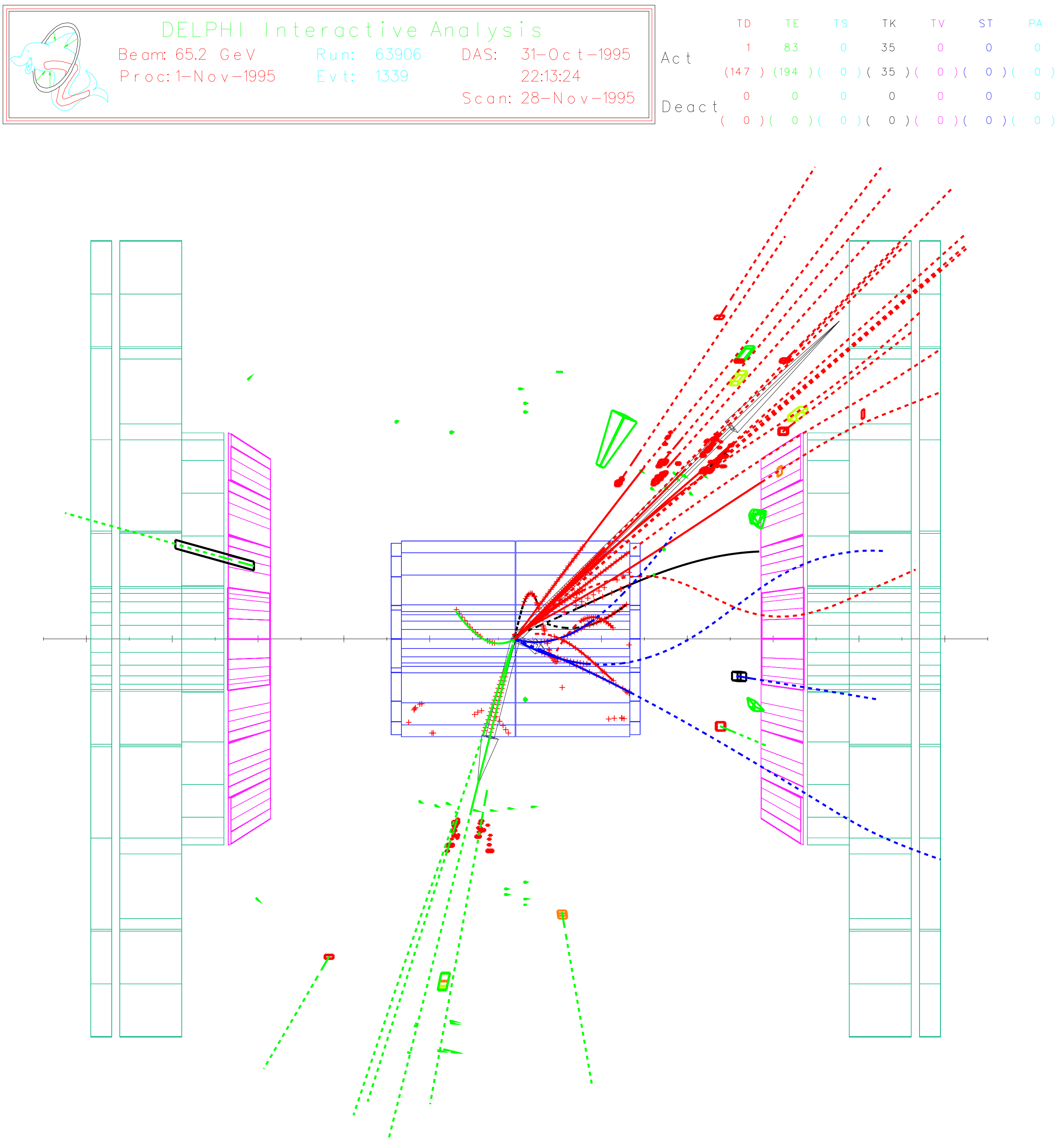


$$s' = s\left(1 - \frac{2\,E_\gamma}{\sqrt{s}}\right)$$

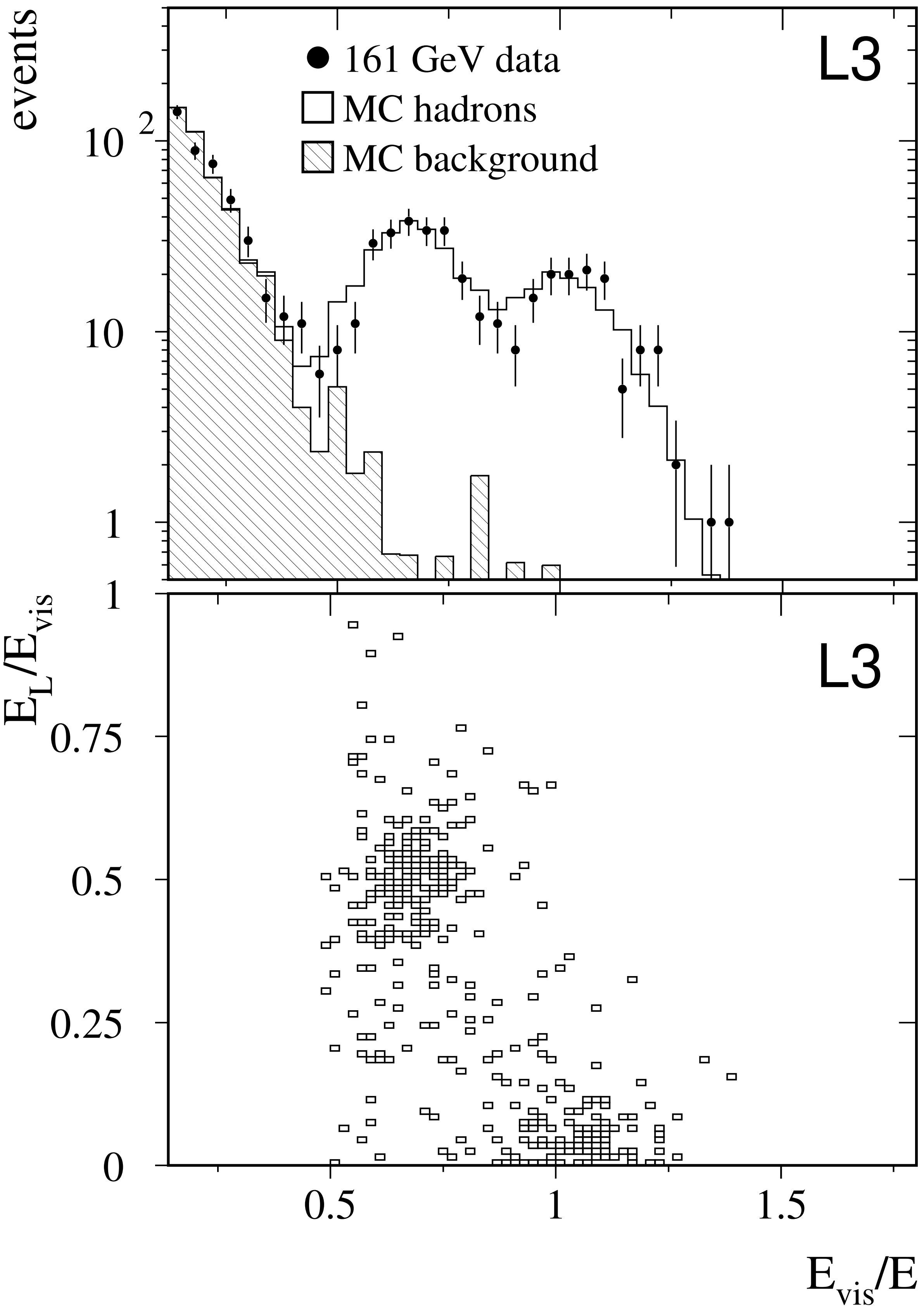
- E_γ from detected photon
- else from fermion angles:

$$E_\gamma = \sqrt{s}\,\frac{|\sin(\Theta_1 + \Theta_2)|}{\sin\Theta_1 + \sin\Theta_2 + |\sin(\Theta_1 + \Theta_2)|}$$

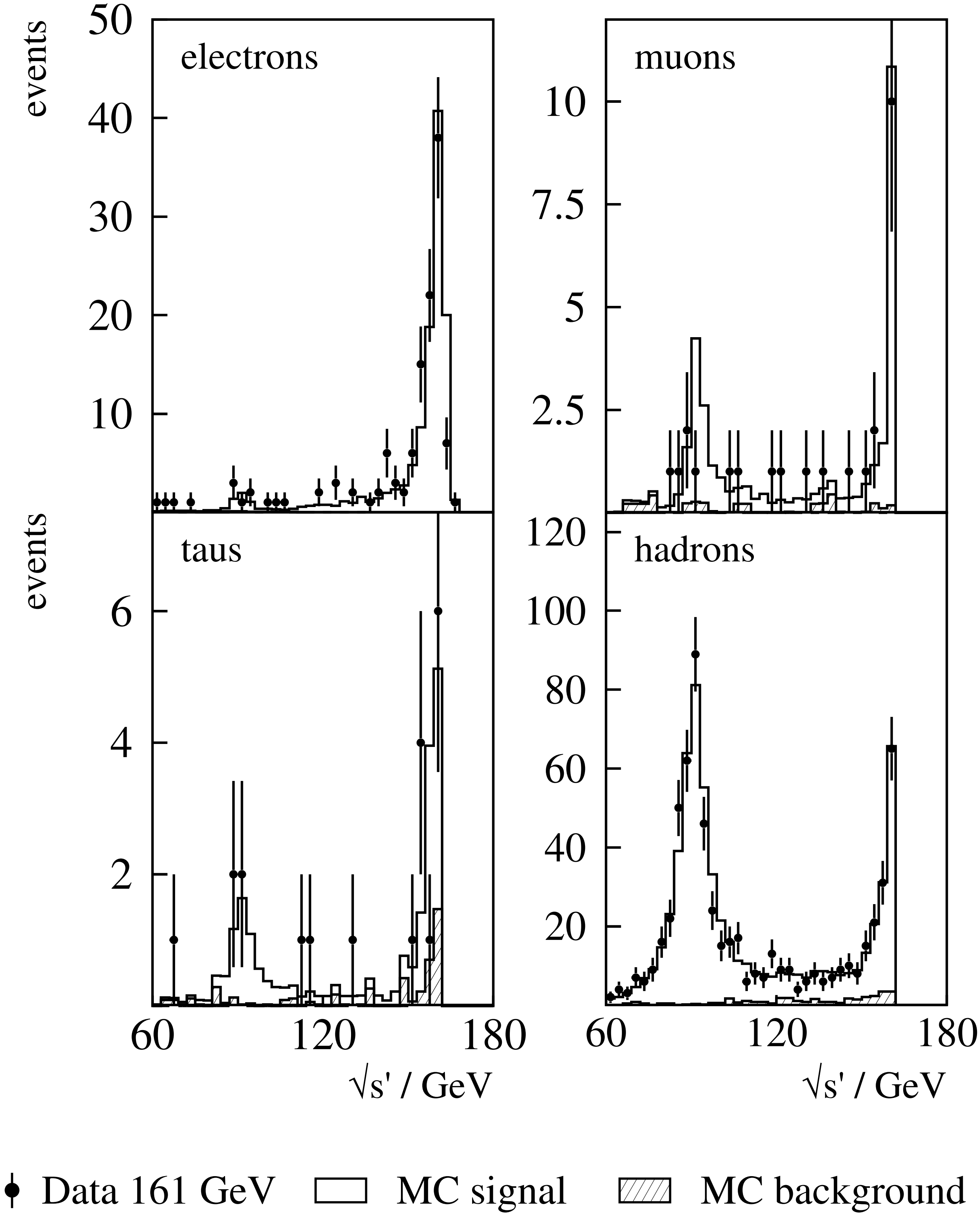
$e^+e^- \rightarrow$ hadrons $+ \gamma$ event at 130 GeV:



Visible energy and longitudinal energy imbalance in $e^+e^- \to$ hadrons

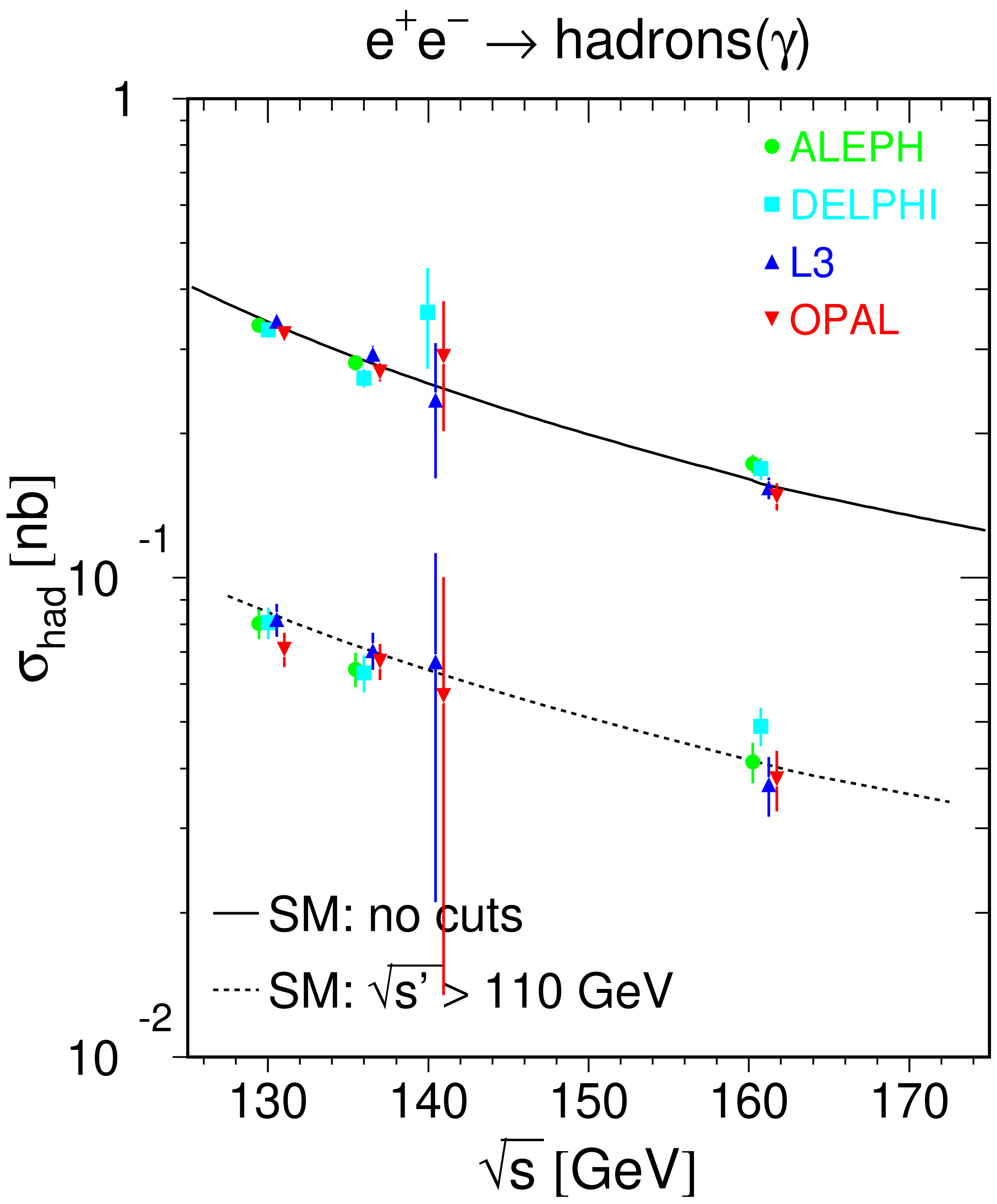


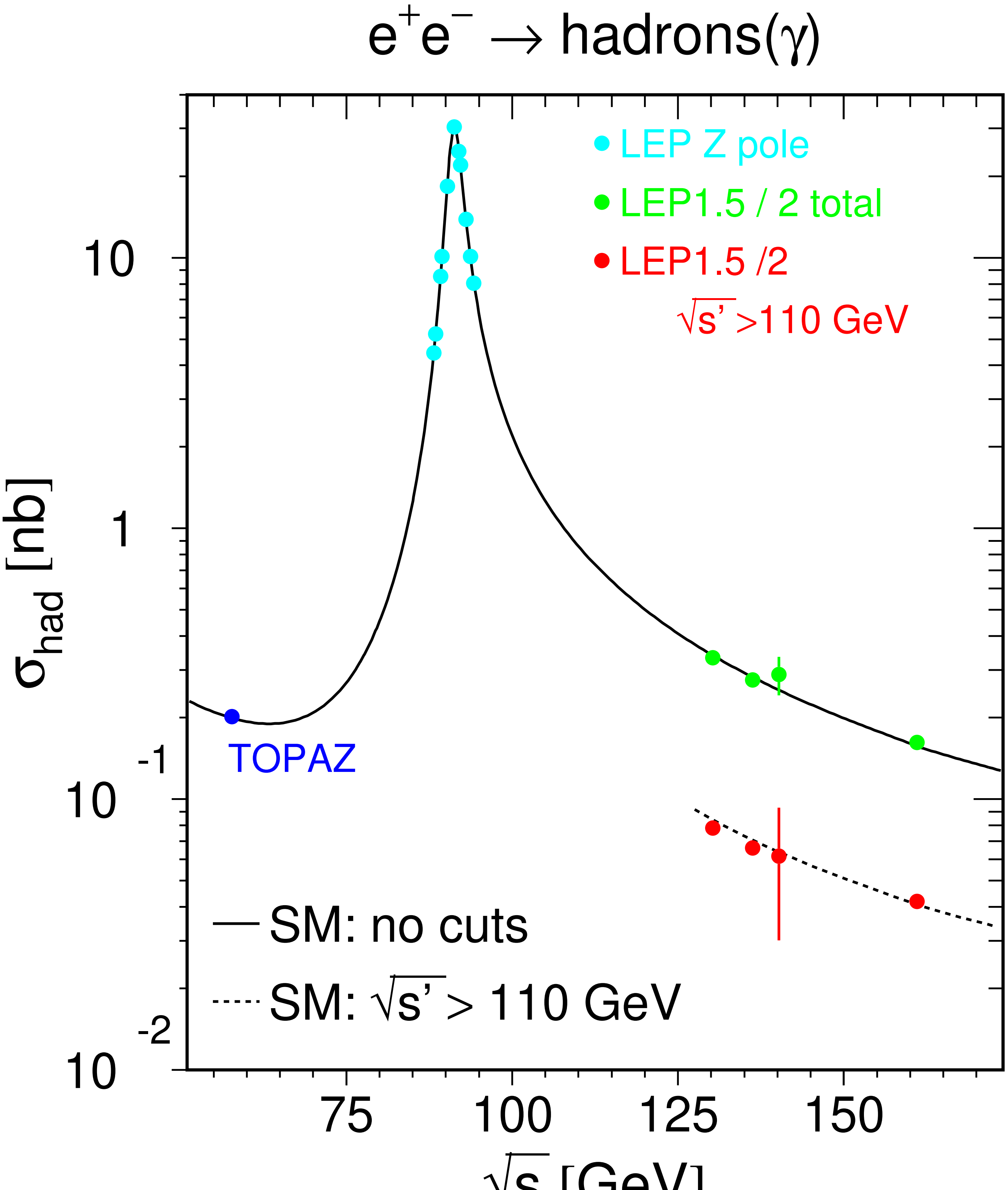
Reconstructed $\sqrt{s'}$ (L3):



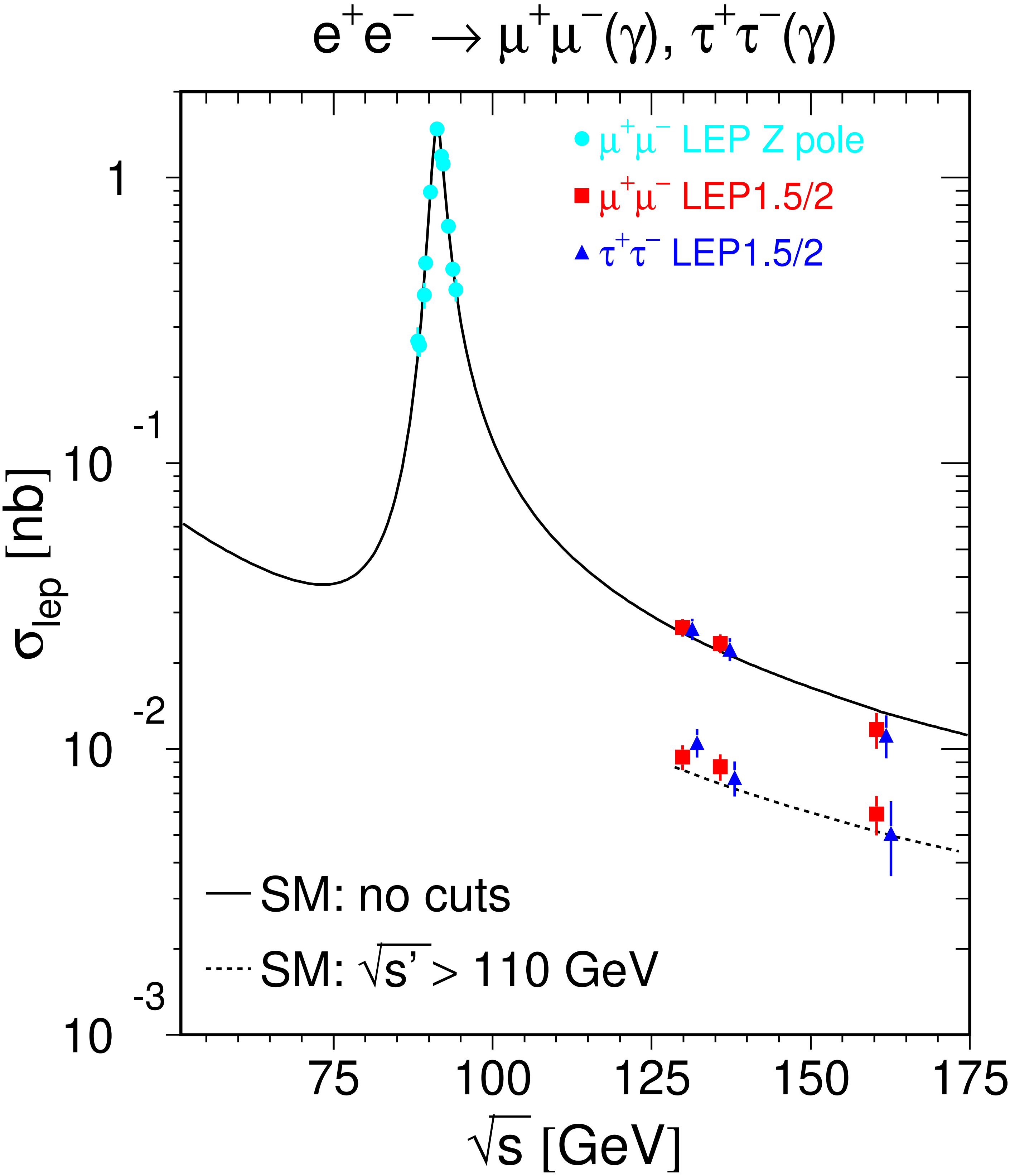
Hadronic cross section above the Z pole:

(scaled to same $\sqrt{s'}$ cut)



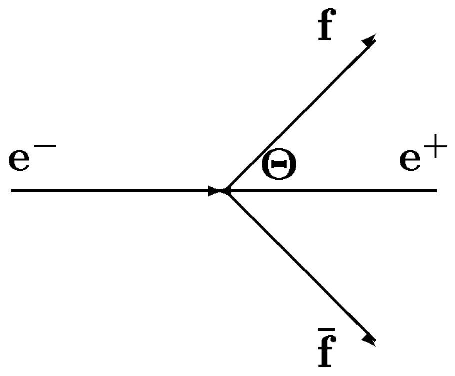


$e^+e^- \rightarrow$ hadrons(γ)
LEP Z pole
LEP1.5 / 2 total
LEP1.5 /2
$\sqrt{s'}$ >110 GeV
TOPAZ
SM: no cuts
SM: $\sqrt{s'}$ > 110 GeV
σ_{had} [nb]
$\sqrt{s}$ [GeV]
10
1
10^{-1}
10^{-2}
75
100
125
150



e+e− → μ+μ−(γ), τ+τ−(γ)
μ+μ− LEP Z pole
μ+μ− LEP1.5/2
τ+τ− LEP1.5/2
SM: no cuts
SM: √s' > 110 GeV
σlep [nb]
√s [GeV]
1
10-1
10-2
10-3
75
100
125
150
175

Leptonic forward-backward asymmetries:



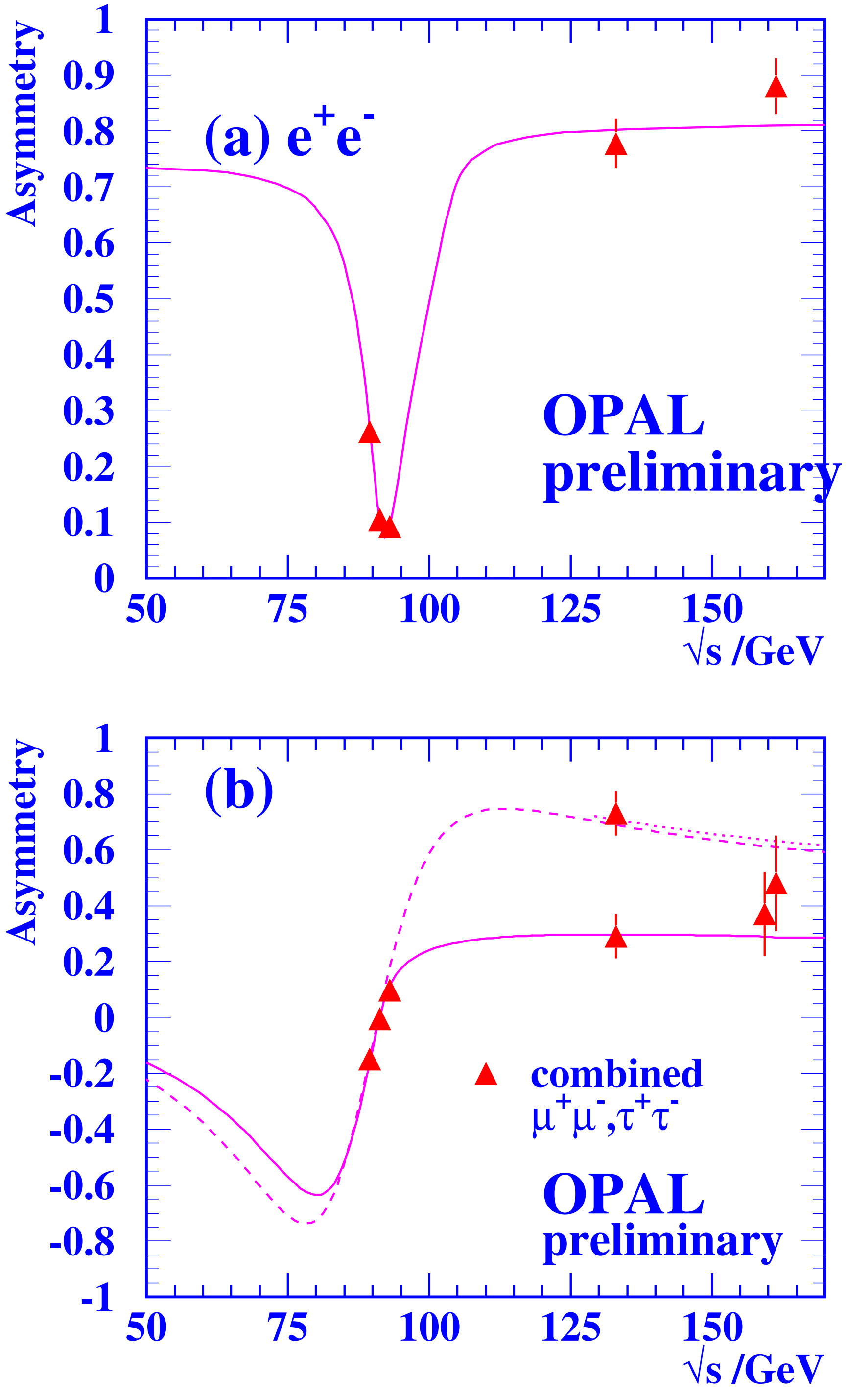
$$A_{\rm FB} = \frac{N_{\rm F} - N_{\rm B}}{N_{\rm F} + N_{\rm B}}$$

Forward event: Scattering angle of negative lepton $\Theta < 90^\circ$

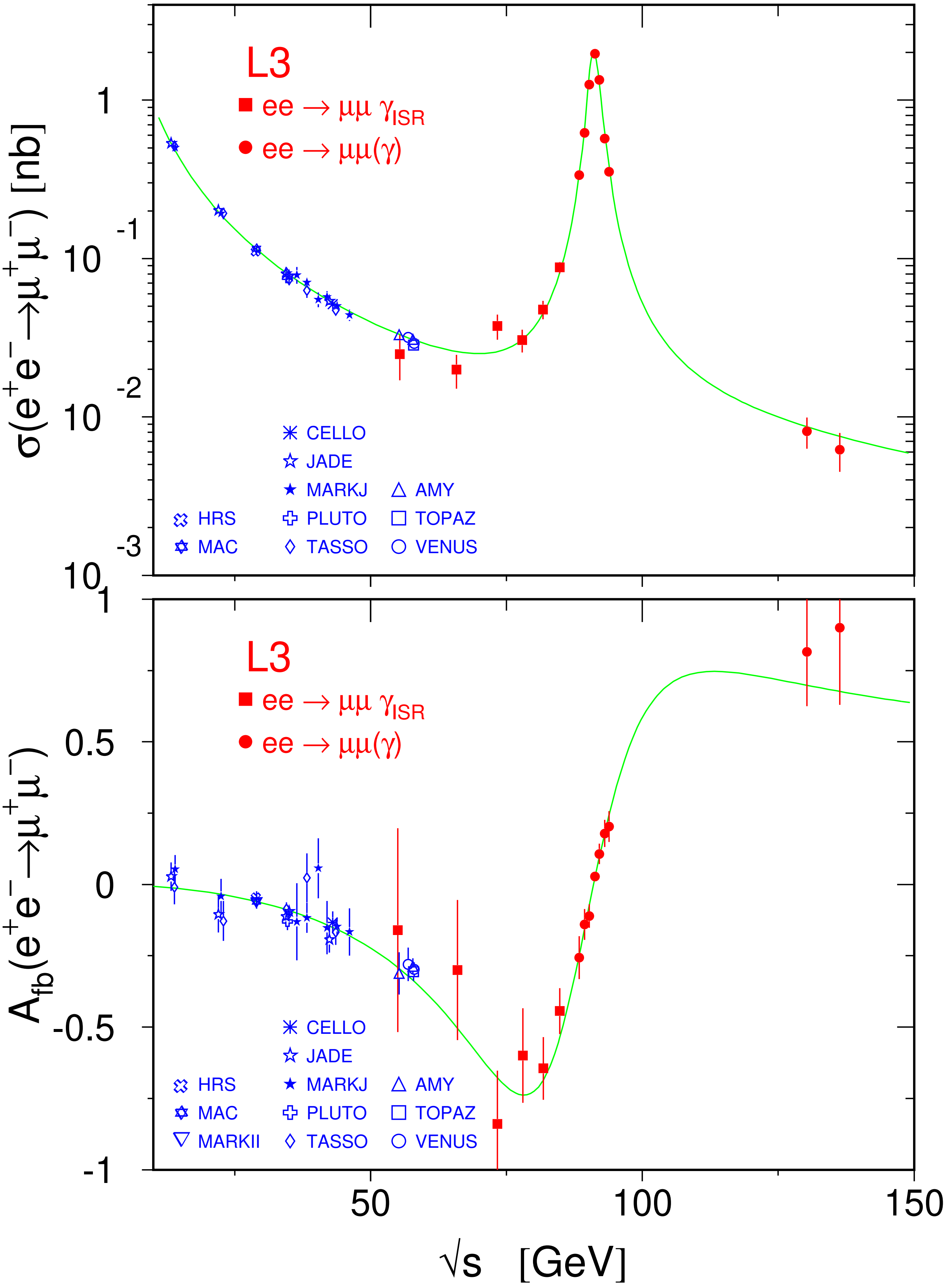
Alternatively calculate scattering angle Θ^* of lepton in $\ell^+\ell^-$ rest frame

$$\cos\Theta^* = \frac{\cos\frac{1}{2}(\Theta_- + \pi - \Theta_+)}{\cos\frac{1}{2}(\Theta_- - \pi + \Theta_+)}$$

Lepton forward-backward asymmetry and angular distributions at $\sqrt{s} = 161$ GeV (≈ 3 pb^{-1} used)



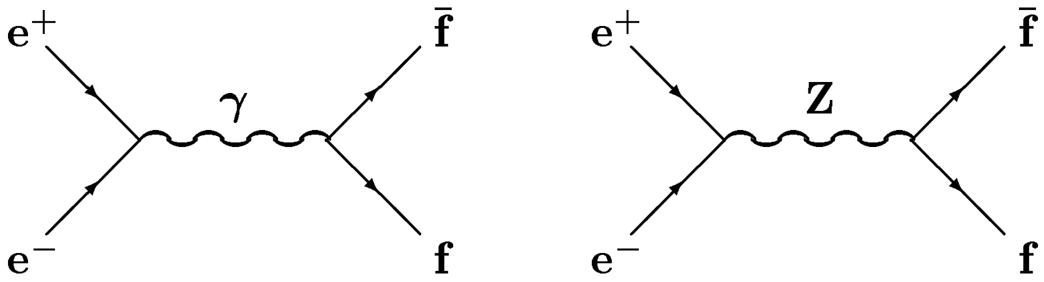
(high energy $\sqrt{s'/s} > 0.8$)


L3
ee → μμ γISR
ee → μμ(γ)
σ(e+e−→μ+μ−) [nb]
1
10-1
10-2
10-3
CELLO
JADE
MARKJ
AMY
HRS
PLUTO
TOPAZ
MAC
TASSO
VENUS
L3
ee → μμ γISR
ee → μμ(γ)
Afb(e+e−→μ+μ−)
1
0.5
0
-0.5
-1
CELLO
JADE
HRS
MARKJ
AMY
MAC
PLUTO
TOPAZ
MARKII
TASSO
VENUS
50
100
150
√s [GeV]

Conclusion:

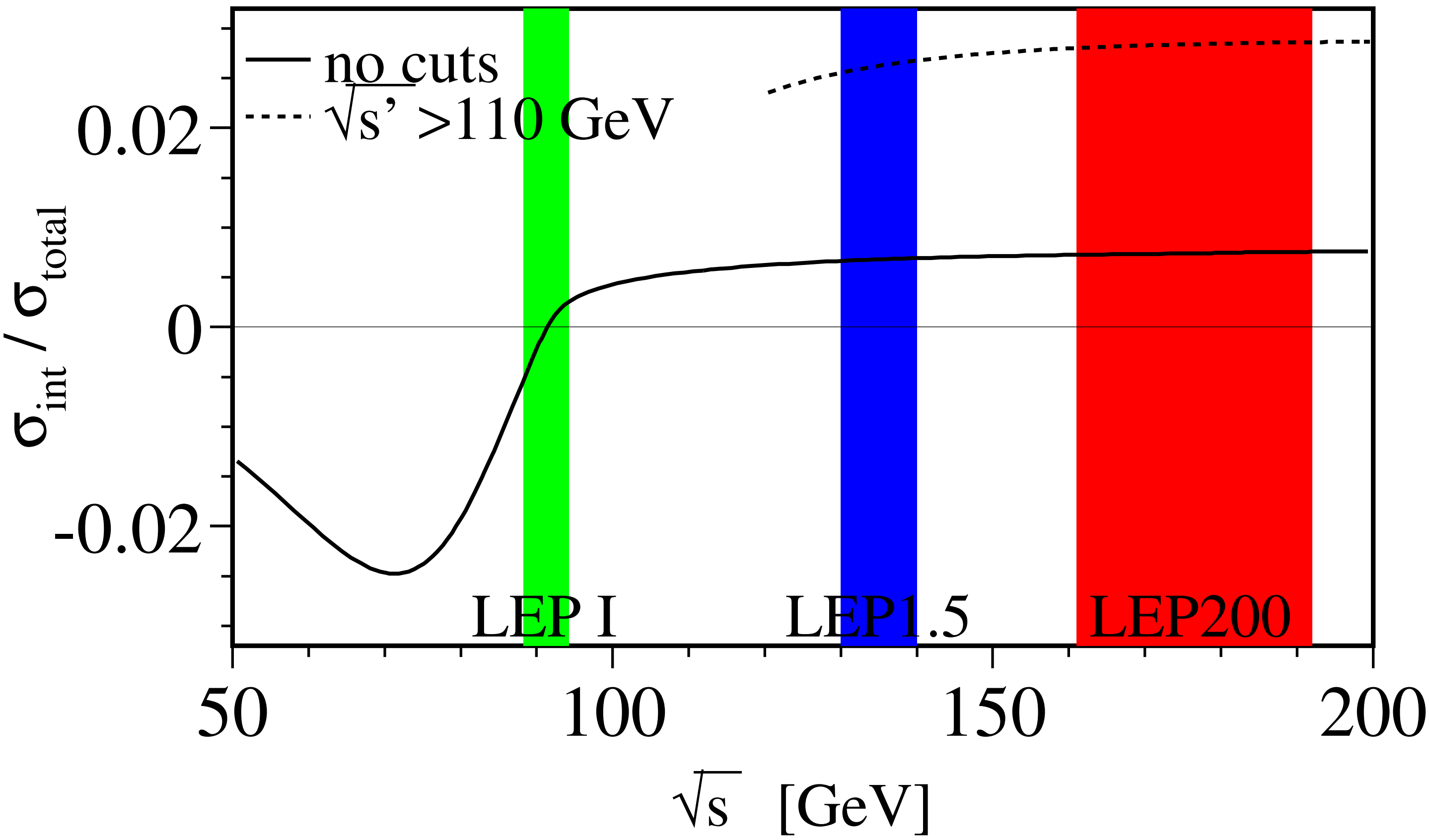
All cross sections and forward-backward asymmetries for $130 \leq \sqrt{s} \leq 161$ GeV in good agreement with Standard Model!

Measurement of γZ interference



$$\sigma_{\text{total}} = \sigma_\gamma + \sigma_Z + \sigma_{\text{int}}$$

$e^+e^- \to$ **hadrons**



Higher sensitivity to σ_{int} for $\sqrt{s} \neq m_Z$

$$\sigma_{\mathrm{int}} = \frac{4\pi\alpha^2}{3} J_{\mathrm{f}} \frac{s - m_{\mathrm{Z}}^2}{(s - m_{\mathrm{Z}}^2)^2 + s^2\Gamma_{\mathrm{Z}}^2/m_{\mathrm{Z}}^2}$$

$$J_{\mathrm{f}} = \frac{G_{\mathrm{F}}\, m_{\mathrm{Z}}^2}{\sqrt{2}\,\pi\,\alpha} q_{\mathrm{e}} q_{\mathrm{f}}\, g_{\mathrm{V}}^{\mathrm{e}} g_{\mathrm{V}}^{\mathrm{f}}$$

Hadronic interference term

$$J_{\mathrm{had}} = \sum_{\mathrm{u,d,c,s,b}} J_{\mathrm{q}}$$

usually set to $J_{\mathrm{had}} \equiv J_{\mathrm{had}}^{\mathrm{SM}}$ to obtain m_{Z}, $\Gamma_{\mathrm{Z}}\ldots$
Assumes SM couplings for quarks

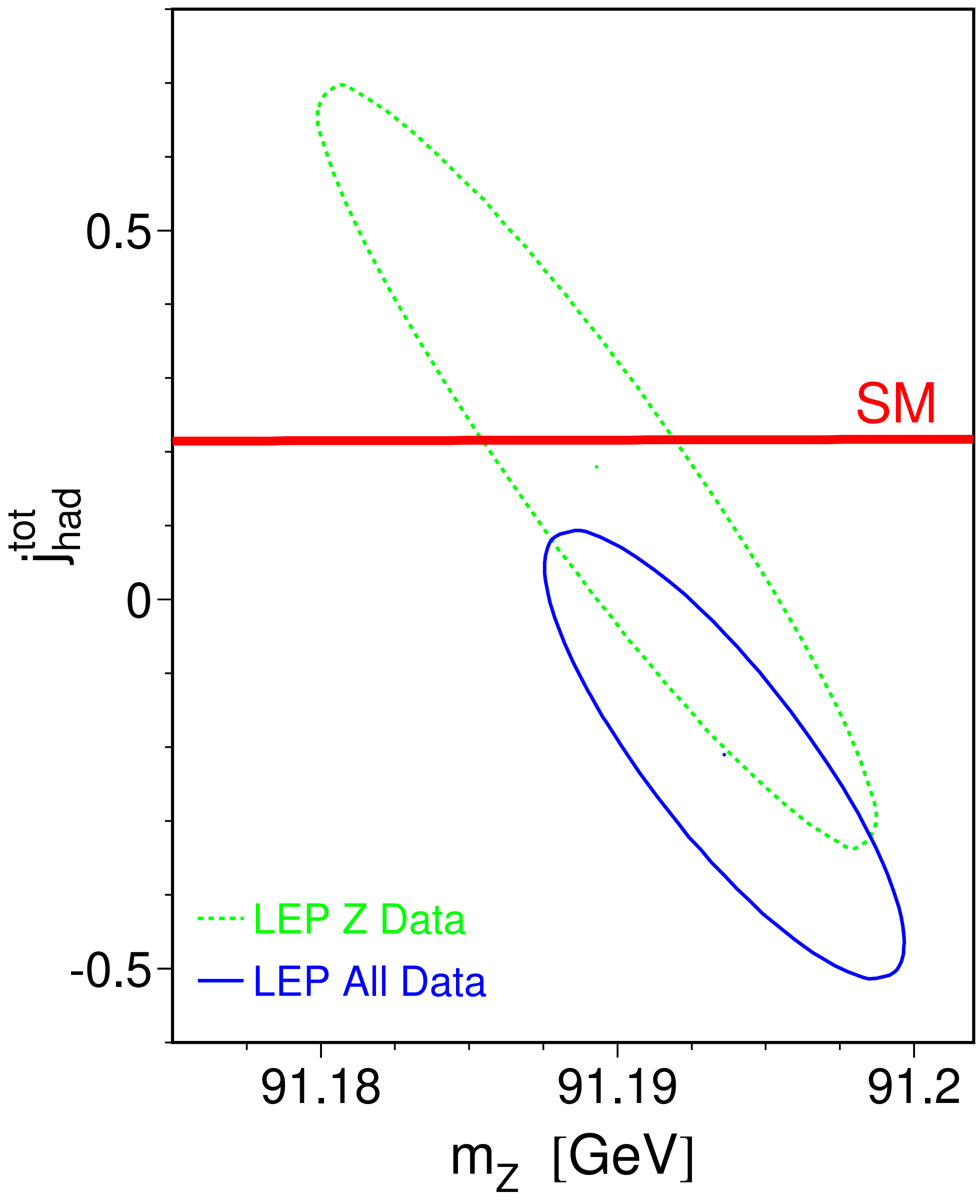
Alternatively determine J_{had} from data
e.g. with S-matrix ansatz:

LEP results (1989–95):

LEP $\sqrt{\mathrm{s}} \approx \mathrm{m_Z}$	$J_{\mathrm{had}} = +0.18 \pm 0.34$
incl. 130 – 140 GeV	$J_{\mathrm{had}} = -0.21 \pm 0.20$
	$J_{\mathrm{had}}^{\mathrm{SM}} = +0.22$

incl. TOPAZ at 58 GeV $\quad J_{\mathrm{had}} = -0.07 \pm 0.16$

Correlation of Z mass and J_{had}:



Results on m_Z [MeV]:

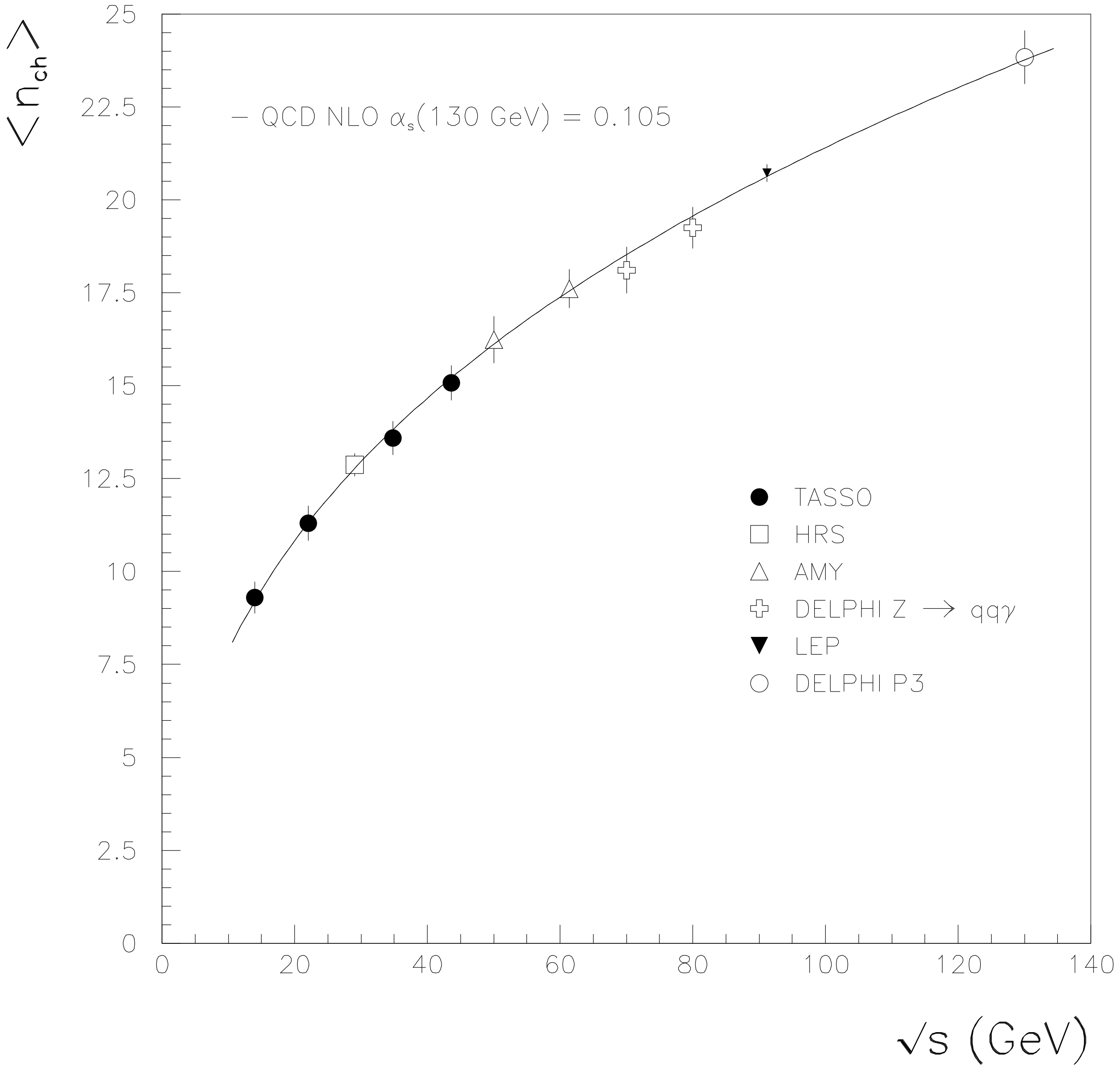
LEP $\sqrt{s} \approx m_Z$	$m_Z = 91\,189.3 \pm 6.2$
incl. 130 − 140 GeV	$m_Z = 91\,193.6 \pm 4.0$
fixed to $J_{\mathrm{had}}^{\mathrm{SM}}$	$m_Z = 91\,191.3 \pm 2.0$

Studies of QCD in $e^+e^- \rightarrow$ hadrons

Charge multiplicity:

DELPHI: hadrons with $\sqrt{s'} > 122$ GeV

$$< n_{ch} >= 23.84 \pm 0.91 \pm 0.52(\text{sys})$$

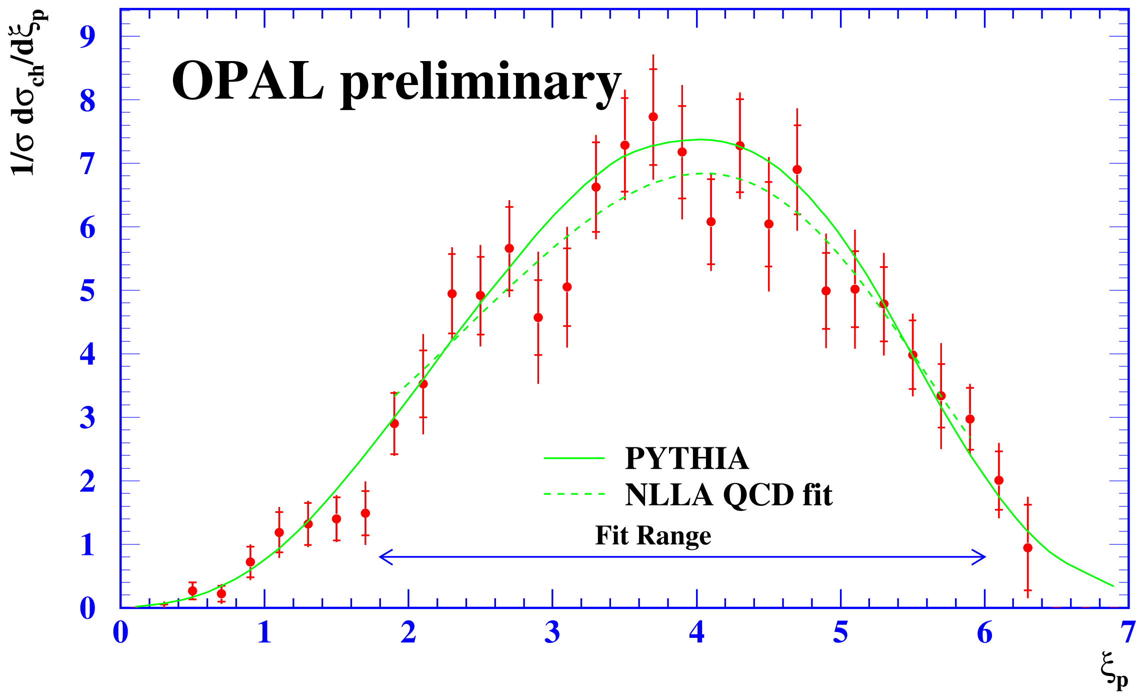


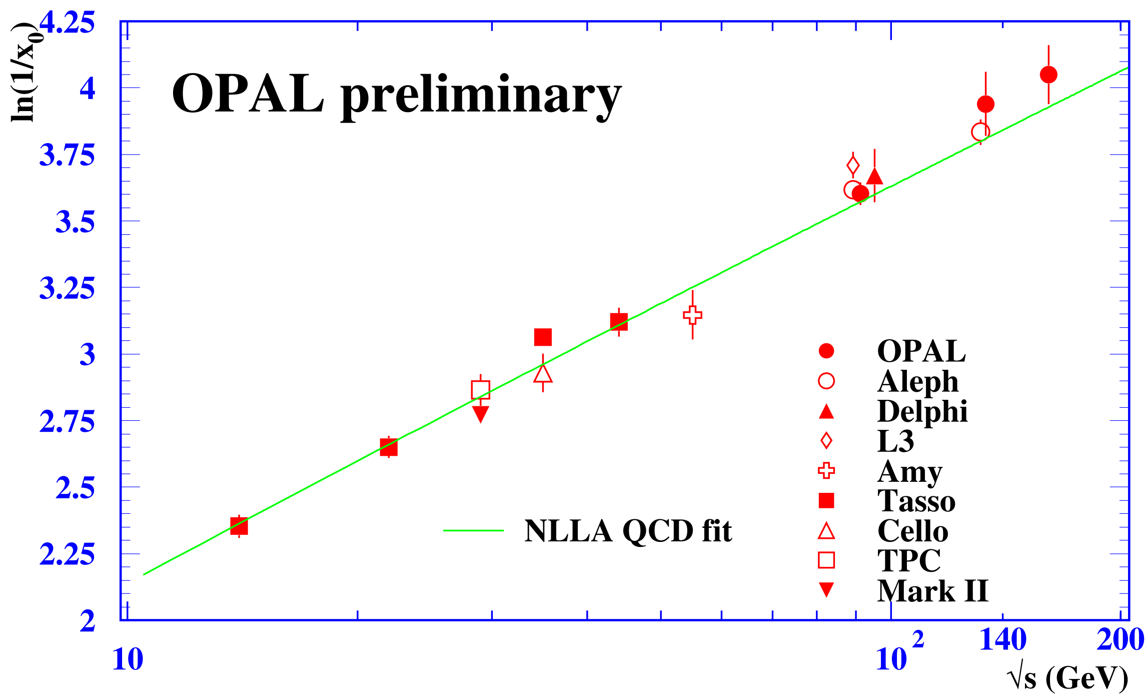
Charged particle fragmentation function

$$\xi_p = -\ln x_p \qquad \text{with } x_p = \frac{p}{E_b}$$

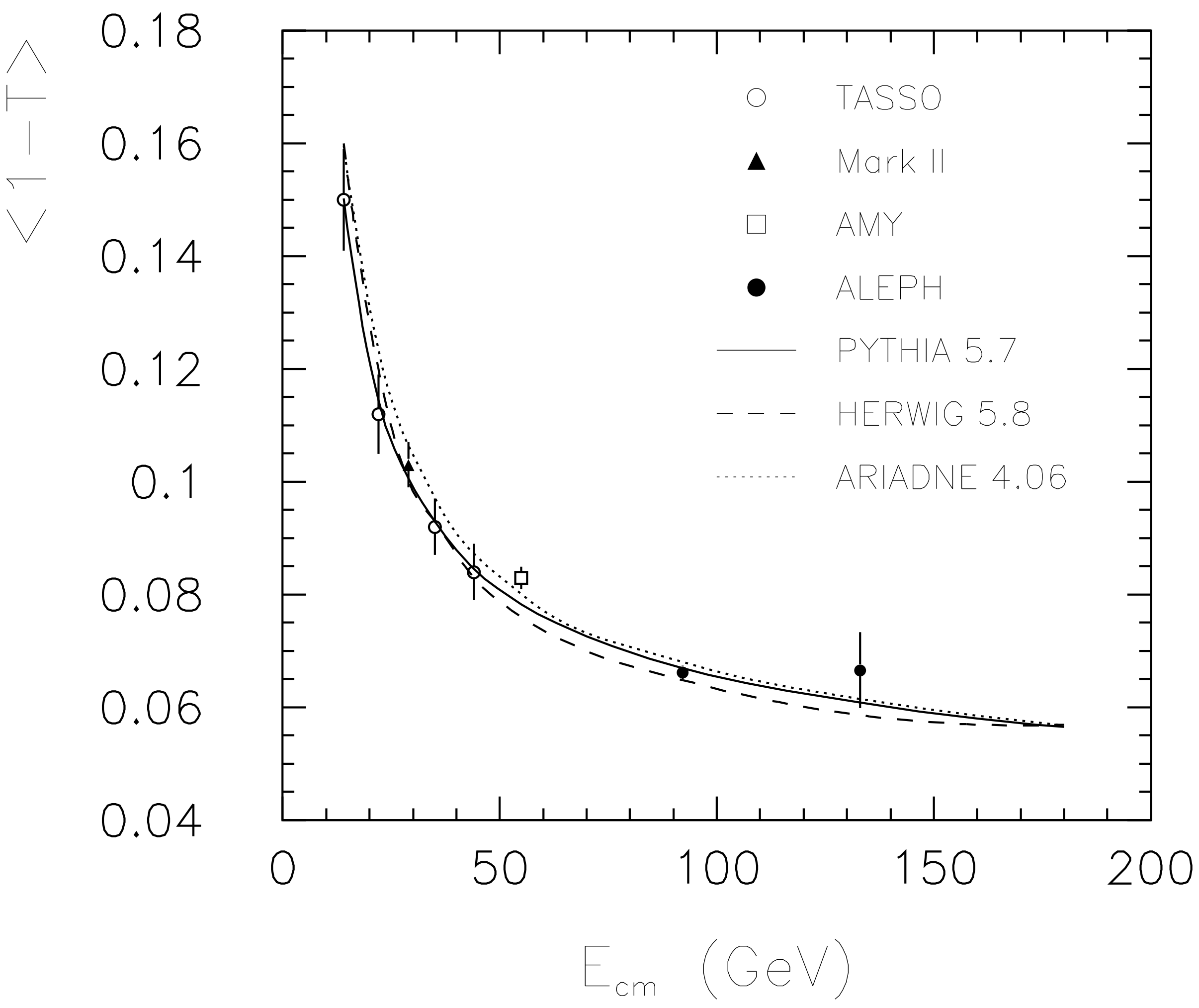
ξ_0 peak of distribution

Preliminary result from 161 GeV data:





Evolution of thrust in $e^+e^- \to$ hadrons
e.g. ALEPH:



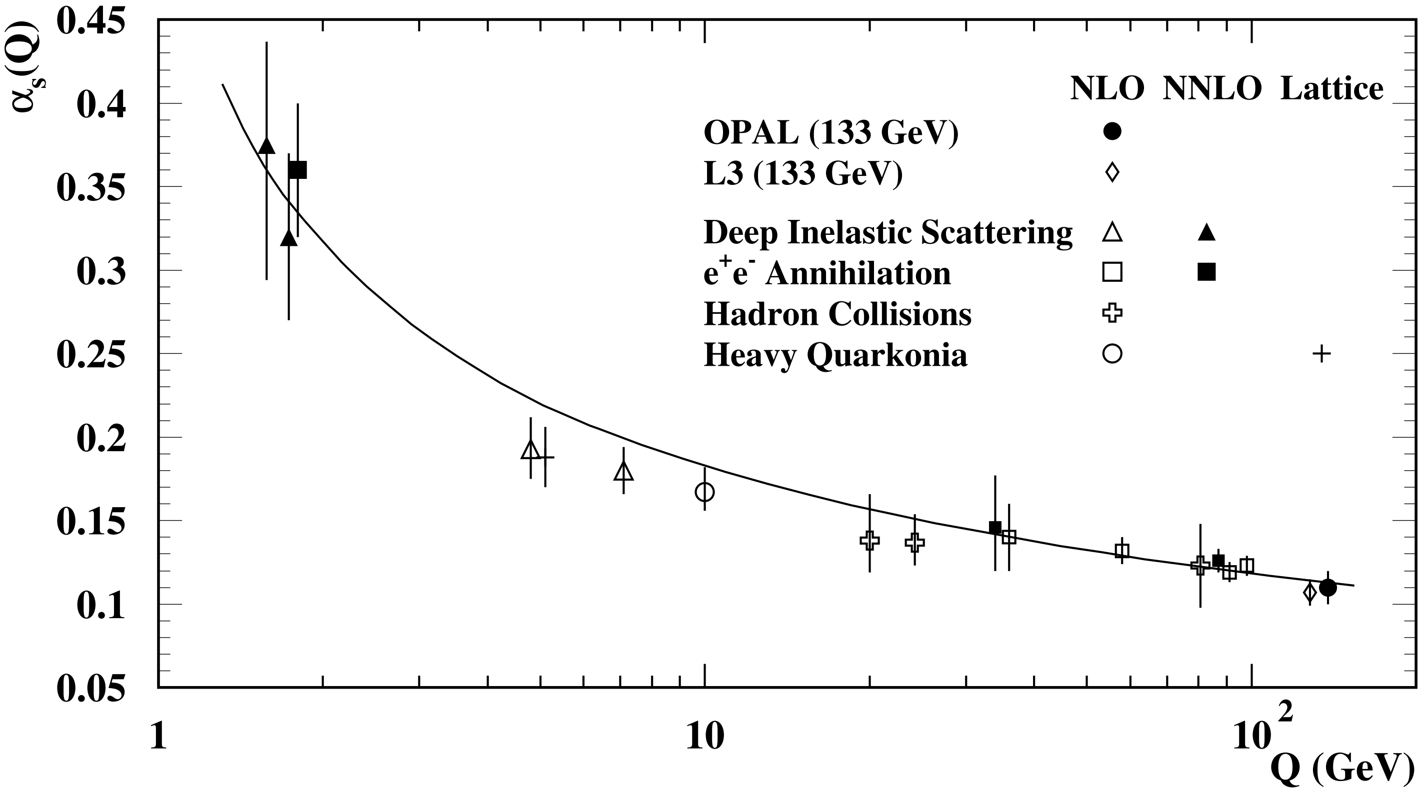
Energy evolution of all variables in $e^+e^- \to$ hadrons well decribed by QCD models

The strong coupling constant α_s

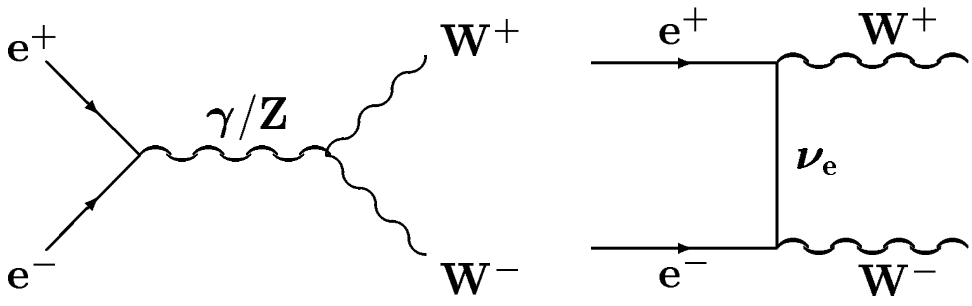
LEP: $\alpha_s(m_Z) = 0.123 \pm 0.006$

Above the Z resonance:

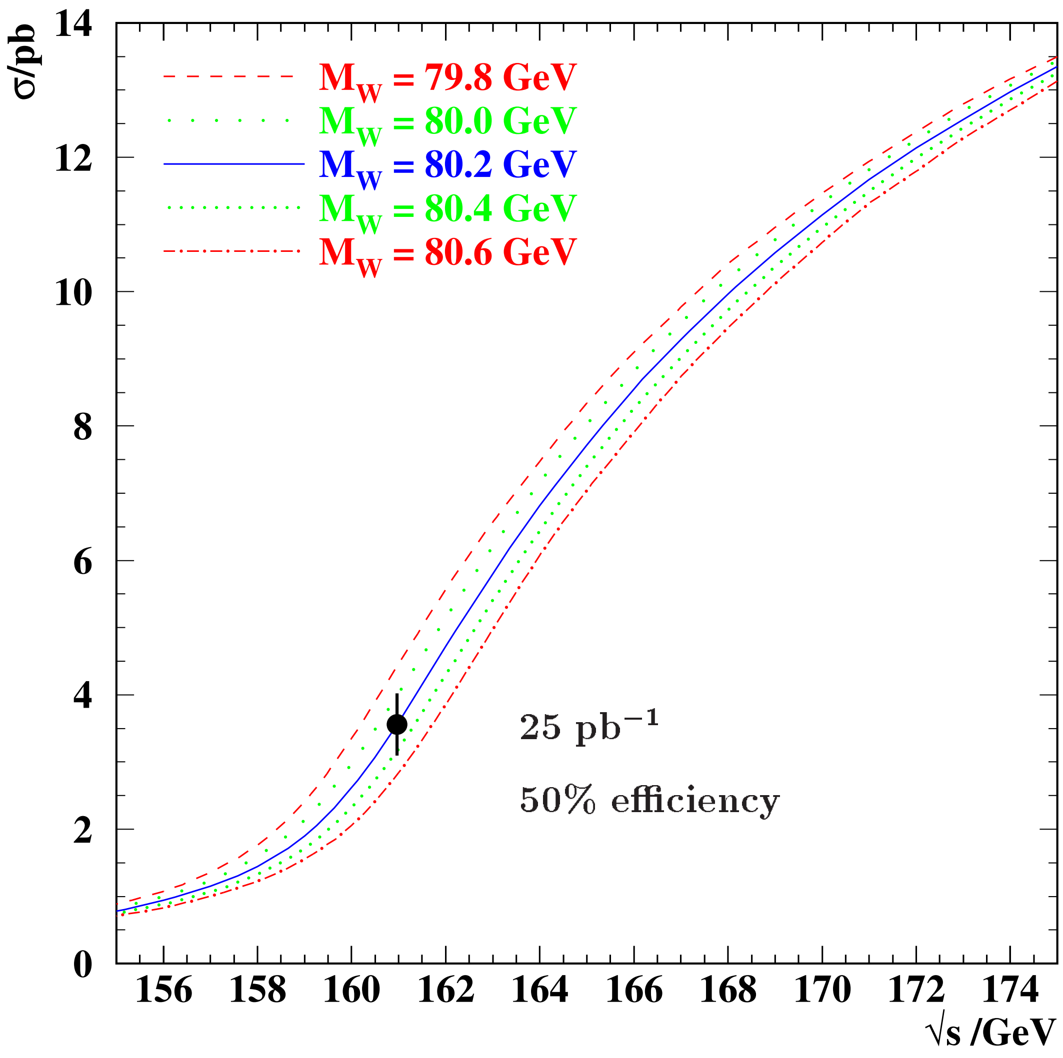
	$\alpha_s(133\ \text{GeV})$
ALEPH	0.119 ± 0.008
DELPHI	0.119 ± 0.008
L3	0.107 ± 0.008
OPAL	0.110 ± 0.010
	$\alpha_s(161\ \text{GeV})$
OPAL	0.093 ± 0.011



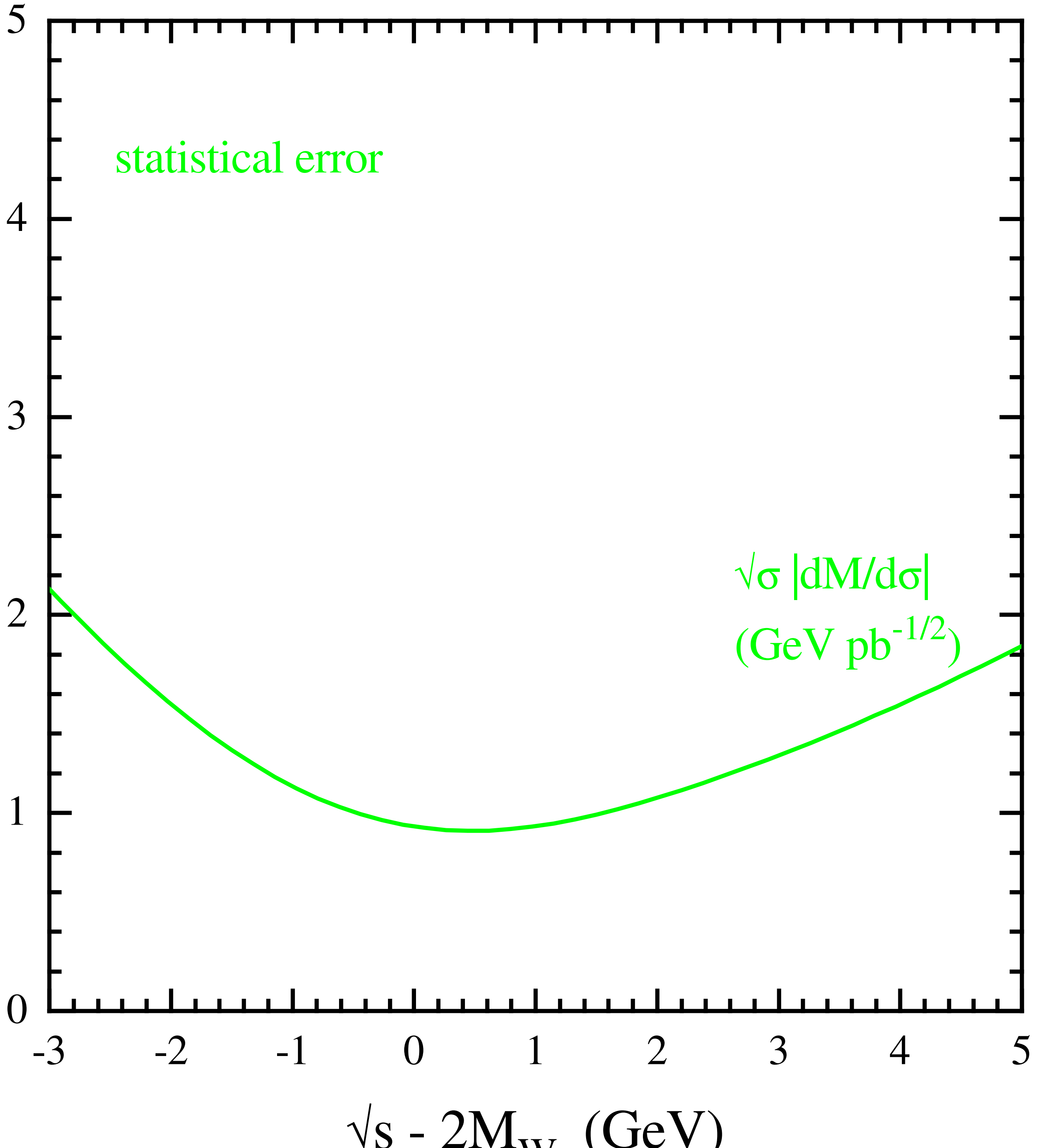
W pair production at LEP



First goal: Measurement of the W mass from the cross section at the threshold



Best energy point $\sqrt{s} = 161$ GeV


statistical error
√σ |dM/dσ|
(GeV pb^-1/2)
0
1
2
3
4
5
-3
-2
-1
0
1
2
3
4
5
√s - 2M_W (GeV)

Selection of W pairs

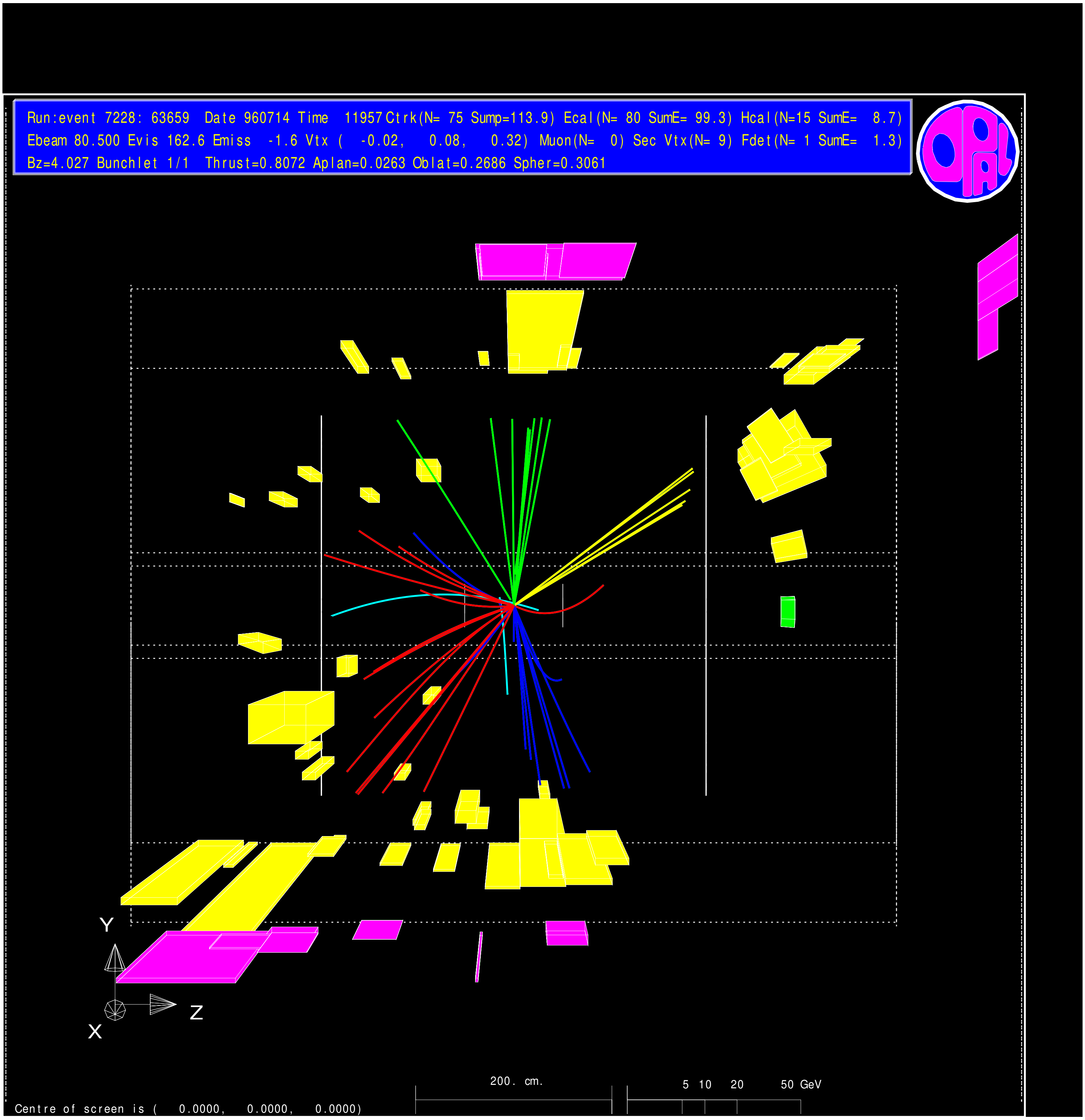
W branching fractions from $p\bar{p}$-colliders:

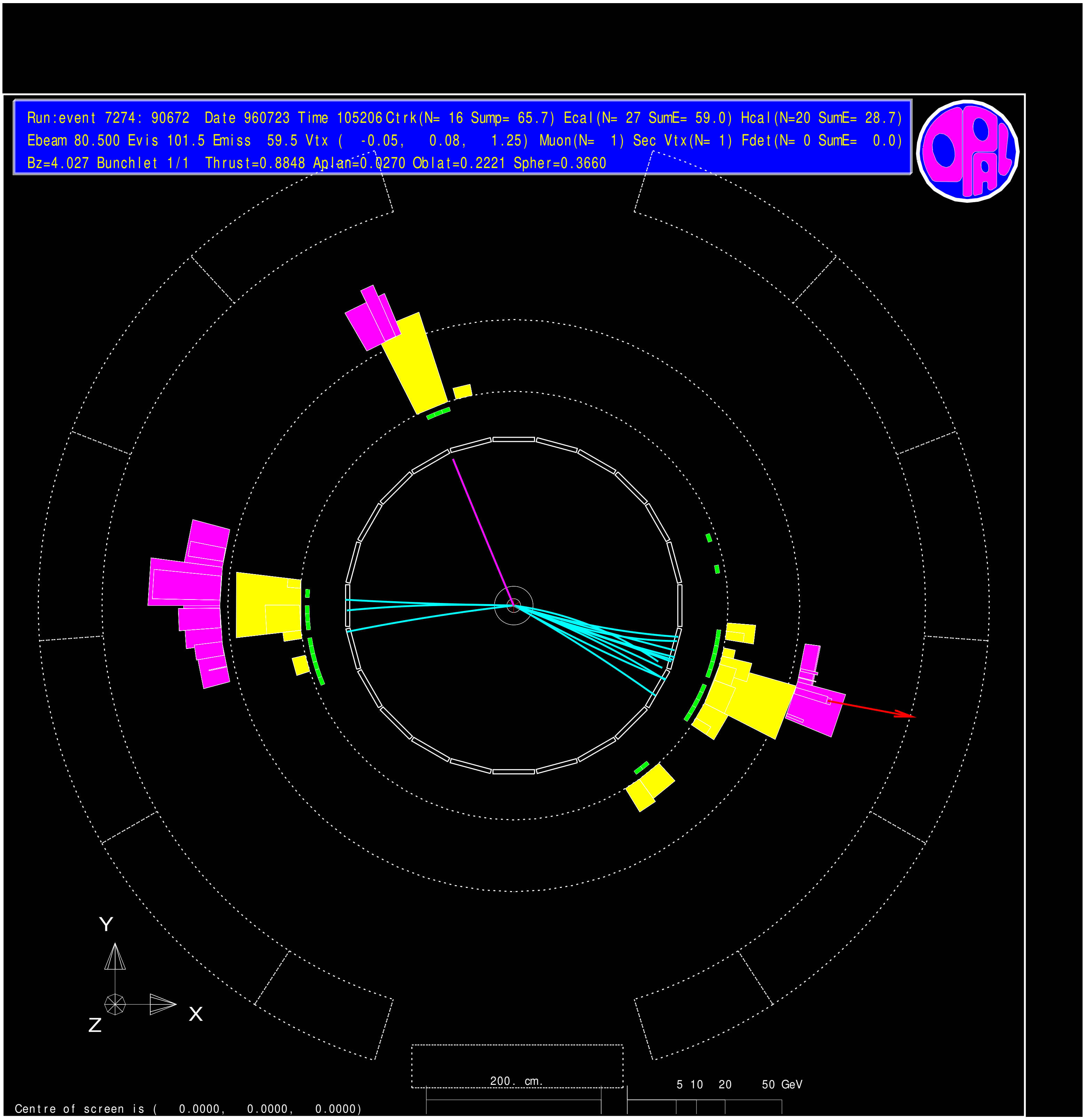
$$BR(\mathrm{W} \to \mathrm{q\bar{q}'}) = 67.9 \pm 1.5\%$$
$$BR(\mathrm{W} \to \ell\nu) = 10.8 \pm 0.4\%$$

$$\begin{array}{llll} \mathrm{e^+e^-} \to \mathrm{W^+W^-} & \to 4 \text{ jets} & & 46\% \\ & \to \ell\nu + 2 \text{ jets} & & 44\% \\ & \to \ell\nu + \ell'\nu' & & 10\% \end{array}$$

Select

- **4 jet hadronic events**
  jet pairs masses close to m_{W}
  (kinematic fit)
- **2 jet events with isolated, energetic lepton**
  (or narrow jet)
- **2 acoplanar leptons (or narrow jet)**

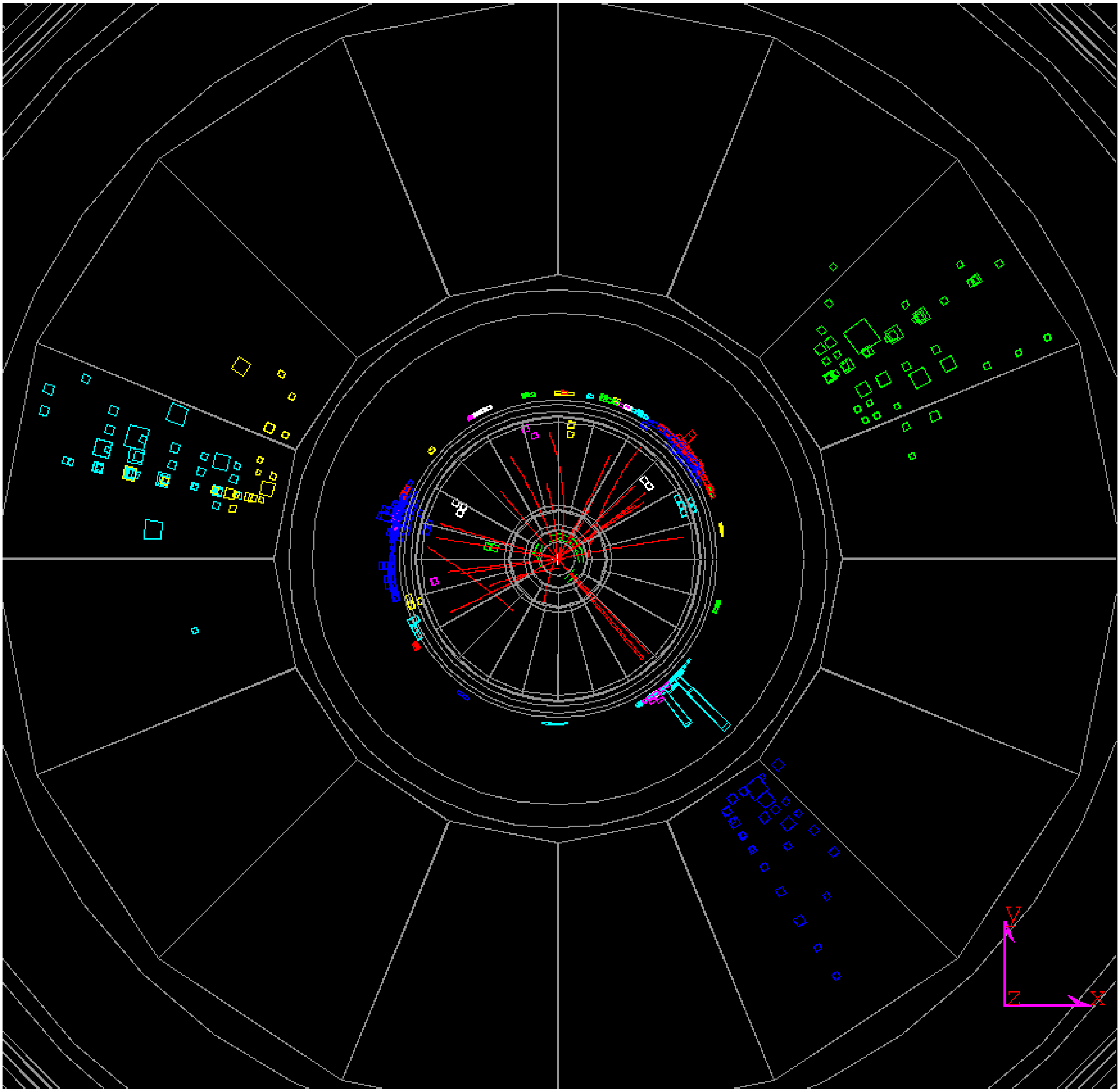

Run:event 7228: 63659 Date 960714 Time 11957 Ctrk(N= 75 Sump=113.9) Ecal(N= 80 SumE= 99.3) Hcal(N=15 SumE= 8.7)
Ebeam 80.500 Evis 162.6 Emiss -1.6 Vtx (-0.02, 0.08, 0.32) Muon(N= 0) Sec Vtx(N= 9) Fdet(N= 1 SumE= 1.3)
Bz=4.027 Bunchlet 1/1 Thrust=0.8072 Aplan=0.0263 Oblat=0.2686 Spher=0.3061
Y
Z
X
200. cm.
5 10 20 50 GeV
Centre of screen is (0.0000, 0.0000, 0.0000)

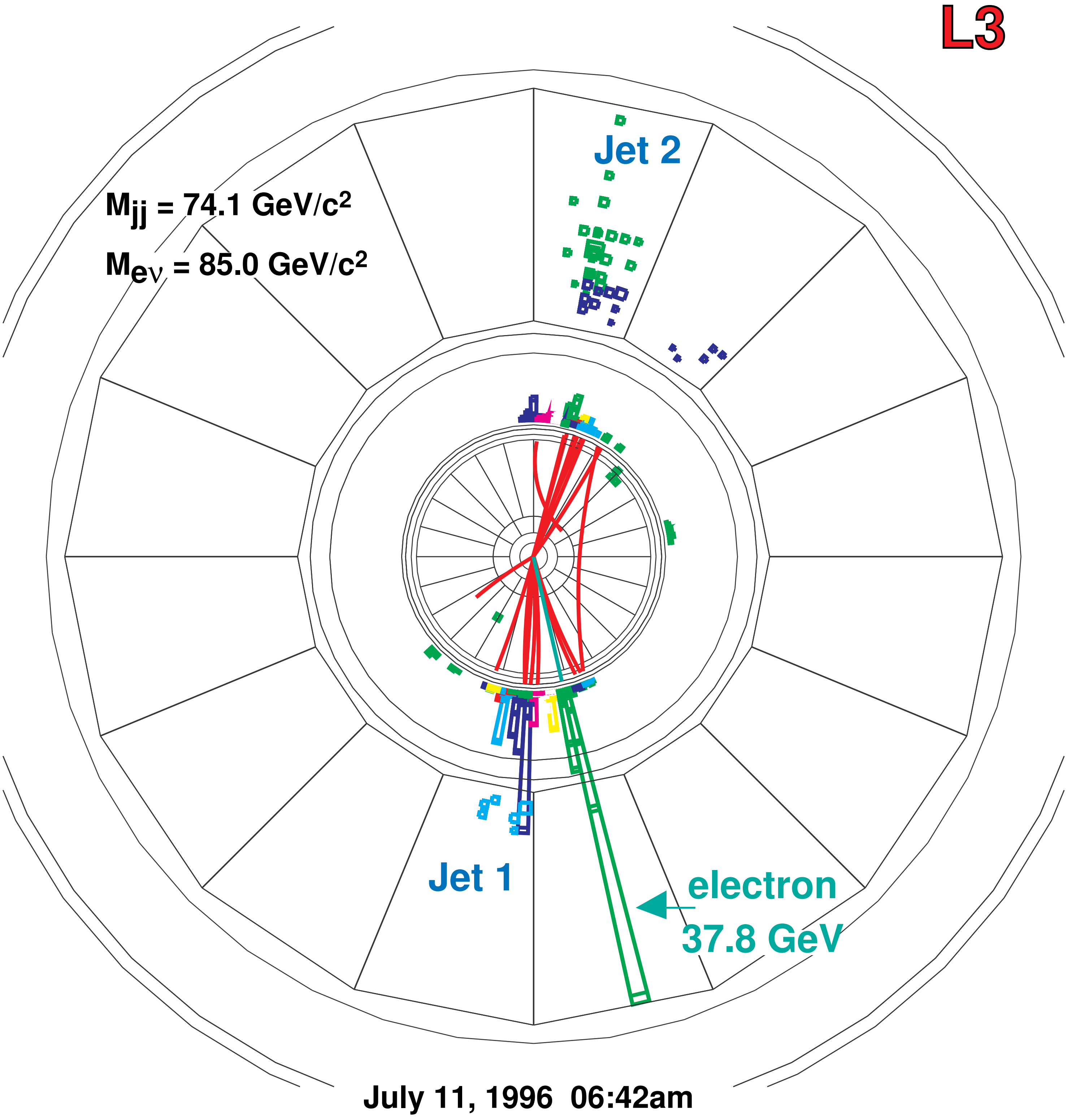


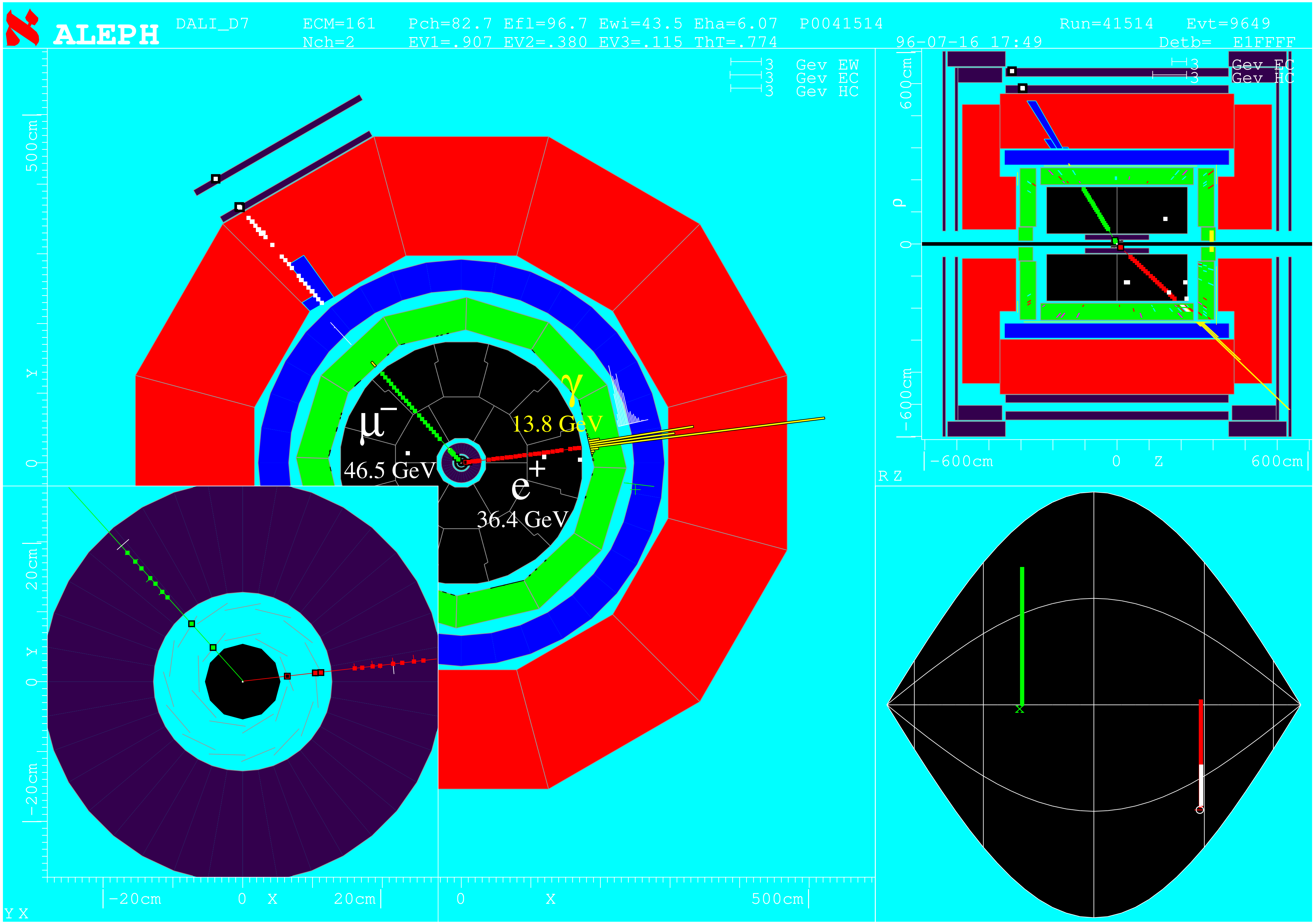
Run:event 7274: 90672 Date 960723 Time 105206 Ctrk(N= 16 Sump= 65.7) Ecal(N= 27 SumE= 59.0) Hcal(N=20 SumE= 28.7)
Ebeam 80.500 Evis 101.5 Emiss 59.5 Vtx (-0.05, 0.08, 1.25) Muon(N= 1) Sec Vtx(N= 1) Fdet(N= 0 SumE= 0.0)
Bz=4.027 Bunchlet 1/1 Thrust=0.8848 Aplan=0.0270 Oblat=0.2221 Spher=0.3660
Y
X
Z
200. cm.
5 10 20 50 GeV
Centre of screen is (0.0000, 0.0000, 0.0000)

Delphi_ww.ps

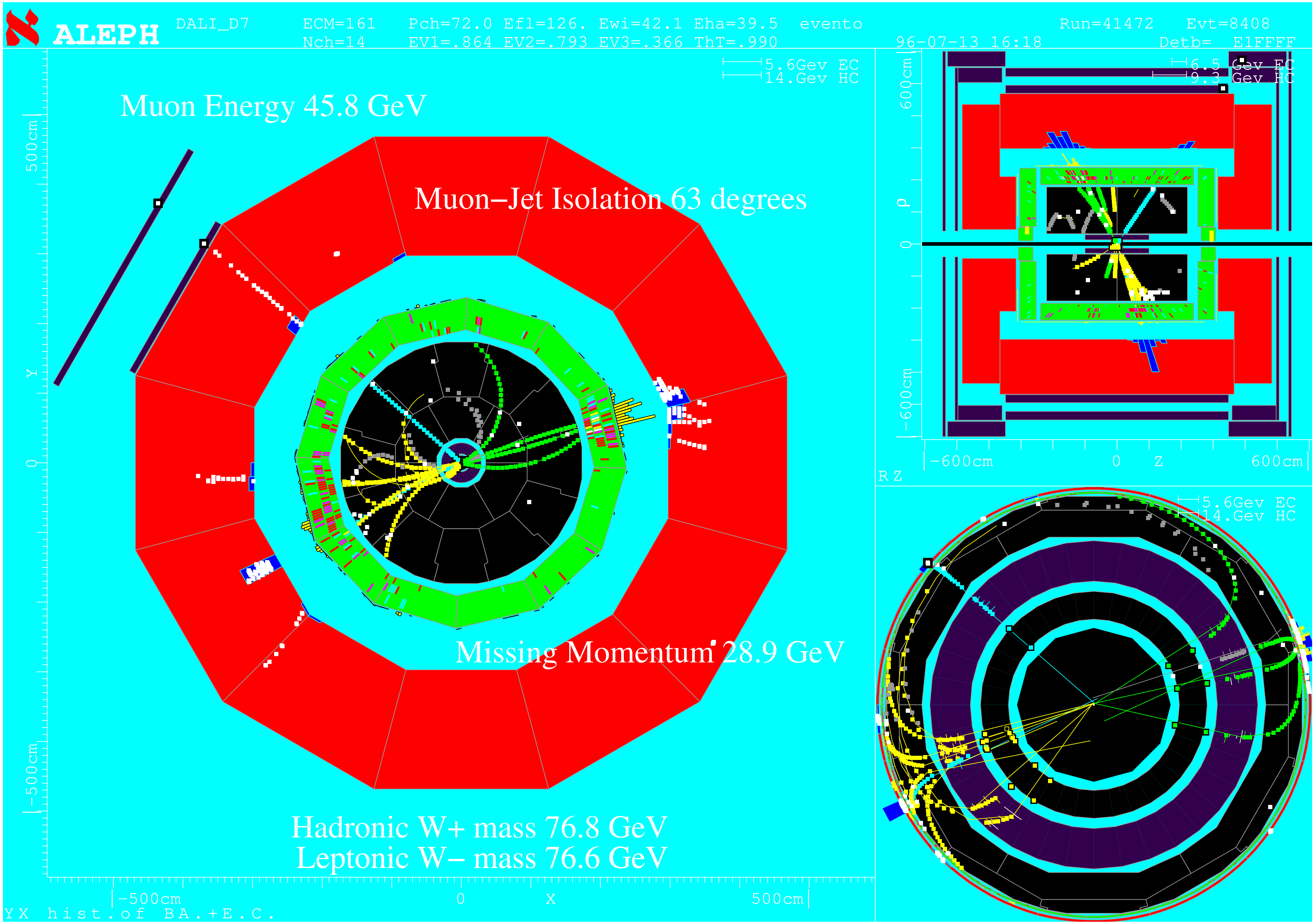
L3 candidate event $e^+e^- \to W^+W^- \to q\bar{q}'\tau\nu$




L3
Jet 2
M_{jj} = 74.1 GeV/c^2
$M_{e\nu}$ = 85.0 GeV/c^2
Jet 1
electron
37.8 GeV
July 11, 1996 06:42am



ALEPH
DALI_D7
ECM=161
Nch=2
Pch=82.7 Efl=96.7 Ewi=43.5 Eha=6.07
EV1=.907 EV2=.380 EV3=.115 ThT=.774
P0041514
96-07-16 17:49
Run=41514 Evt=9649
Detb= E1FFFF
3 Gev EW
3 Gev EC
3 Gev HC
3 Gev FC
3 Gev HC
500cm
Y
0
μ⁻
46.5 GeV
γ
13.8 GeV
e⁺
36.4 GeV
600cm
ρ
0
-600cm
-600cm
0
Z
600cm
R Z
20cm
Y
0
-20cm
-20cm
0
X
20cm
Y X
0
X
500cm


ALEPH
DALI_D7
ECM=161
Nch=14
Pch=72.0 Efl=126. Ewi=42.1 Eha=39.5 evento
EV1=.864 EV2=.793 EV3=.366 ThT=.990
Run=41472 Evt=8408
96-07-13 16:18
Detb= E1FFFF
5.6Gev EC
14.Gev HC
Muon Energy 45.8 GeV
Muon–Jet Isolation 63 degrees
Missing Momentum 28.9 GeV
Hadronic W+ mass 76.8 GeV
Leptonic W– mass 76.6 GeV
500cm
Y
0
-500cm
-500cm
0
X
500cm
YX hist.of BA.+E.C.
6.5 Gev EC
9.3 Gev HC
600cm
ρ
0
-600cm
-600cm
0
Z
600cm
RZ
5.6Gev EC
14.Gev HC

Status of $e^+e^- \to W^+W^-$ cross section measurement:

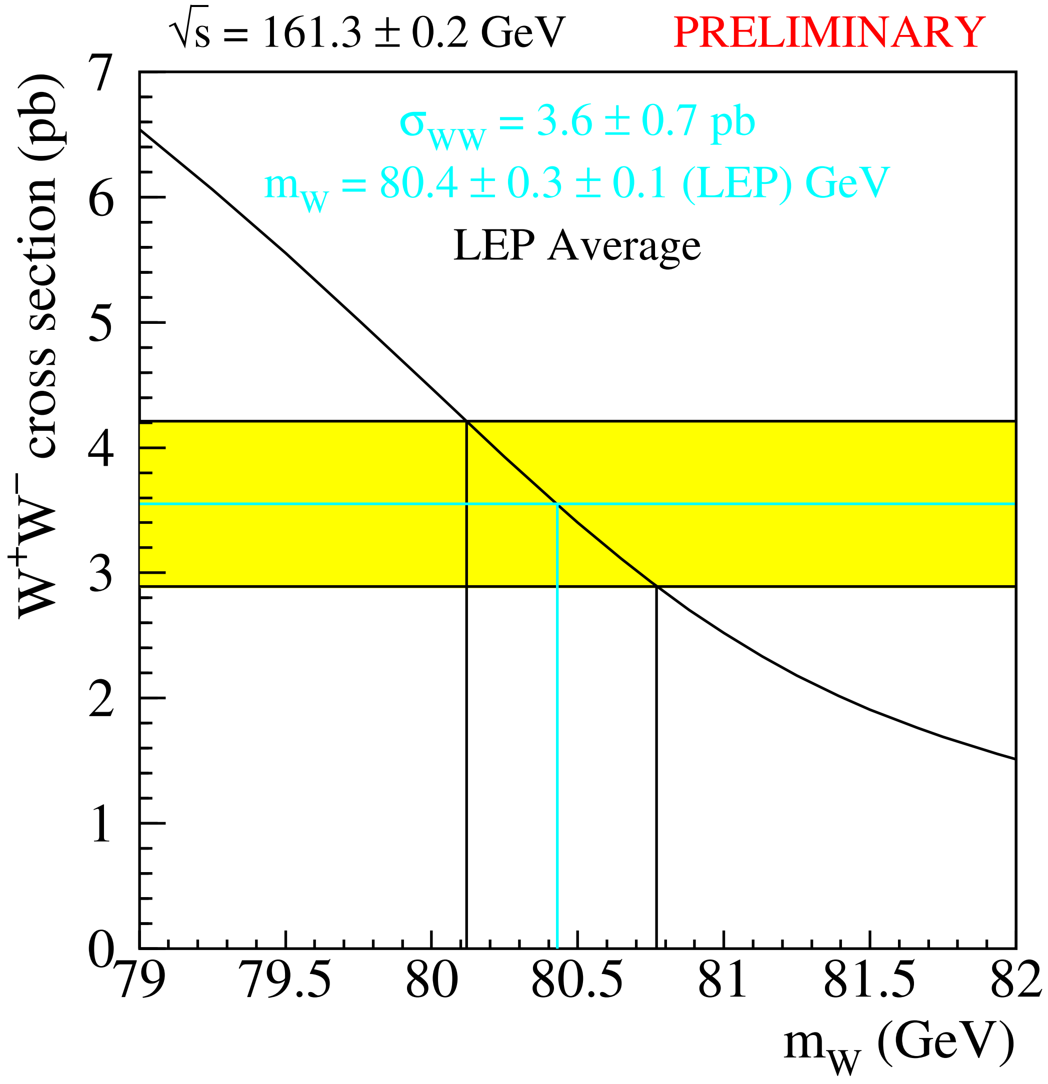
Experiment	$\int\mathcal{L}\,dt$ [pb^{-1}]	σ_{WW} [pb]
ALEPH	3	$4.9^{+1.9}_{-1.6}$
DELPHI	5	$3.5^{+1.5}_{-1.3}$
L3	6	$2.9^{+1.3}_{-1.1}$
OPAL	3	$3.9^{+1.8}_{-1.4}$
Combined	17	3.6 ± 0.7

5-10 W pairs per experiment

Total luminosity collected by LEP at 161 GeV

$$\approx 45\ \mathrm{pb}^{-1}$$

W mass determined from threshold cross section:



LEP II: $m_W = 80.4 \pm 0.3 \pm 0.1(\text{LEP})$ GeV

Good agreement with

$m_W = 80.33 \pm 0.15$ GeV   Fermilab

$m_W = 80.36 \pm 0.05$ GeV   LEP I & SLC

Search for Supersymmetry

Consider only Minimal Supersymmetric Model:

- **R parity:**
  -1 ordinary particles
  $+1$ supersymmetric partners

- **R parity is conserved**
  pair production of SUSY particles
  lightest SUSY particle is stable
  Cosmology: no charge, no colour

- **Four mass eigenstates neutralinos**
  lightest neutralino $\tilde{\chi}_1^0$, invisible

- **Two charginos $m(\tilde{\chi}_1^+) \leq m(\tilde{\chi}_2^+)$**
  superposition of fermionic W partners (winos)
  and charged Higgs (higgsinos)

- **Neutral Higgs bosons $m_h \leq m_A$**
  h CP even lightest Higgs
  A CP odd

- **Parameters:**

M_2	gaugino mass at weak scale
m_0	mass scale of scalar partners of fermions
μ	scale of Higgsino mass
$\tan\beta$	ratio of Higgs doublet vev

LEP I status:

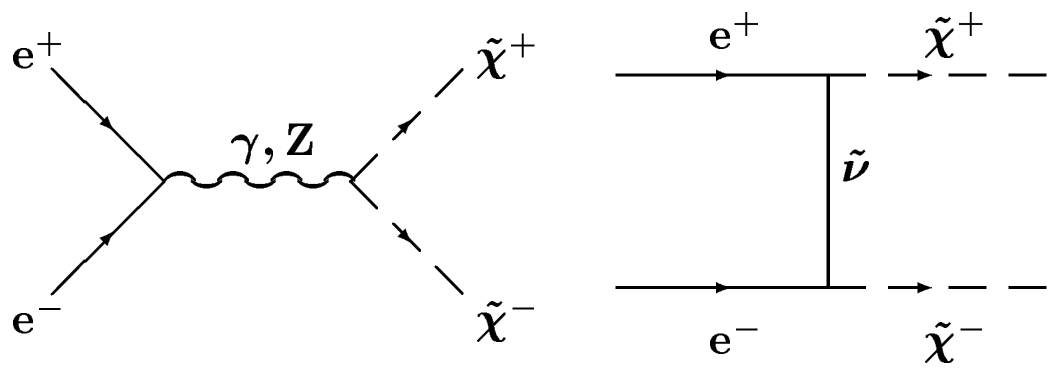
Kinematic range accessible explored for most of SUSY particles
e.g. from total width Γ_Z: $m_{\tilde{\chi}^+} > 45.2$ GeV

LEP 1.5:

high cross section $\mathcal{O}$(pb) for charginos expected
(if exist...)
depending on SUSY parameters

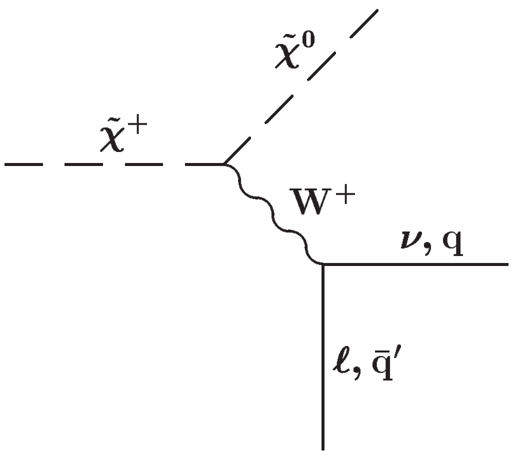
$\Longrightarrow$ discover SUSY particles
or improve LEP I limits

Chargino production:



Destructive interference!

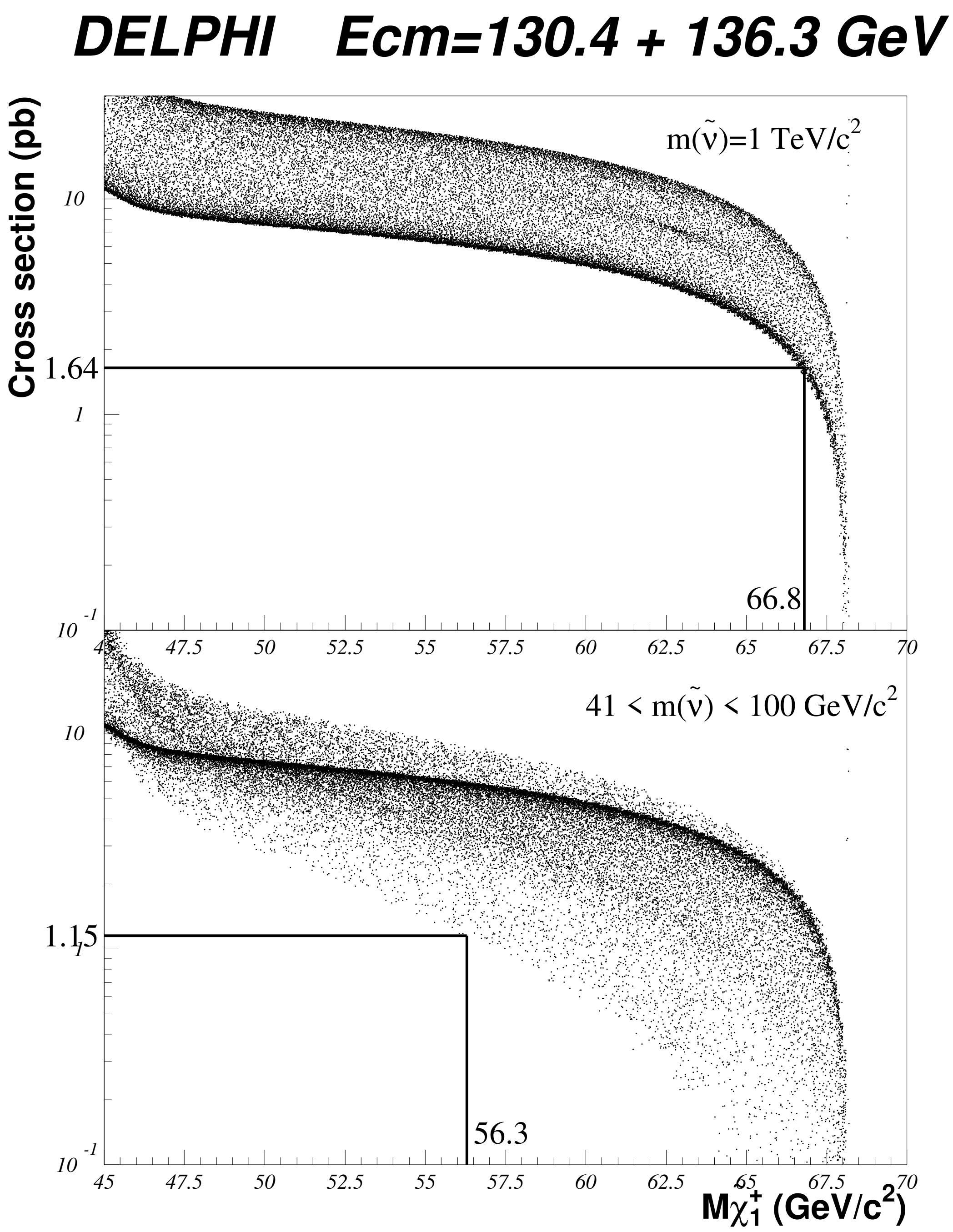
Chargino decay:



Signature:

- missing energy ($\tilde{\chi}^0$, ν)
- acoplanar lepton pair
- 2 jets + isolate lepton
- or hadrons + missing energy

Expected chargino cross section:



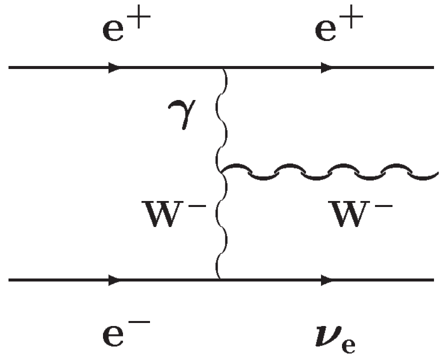
$M\tilde{\chi}_1^+ - M\tilde{\chi}_1^0 > 10\ \mathrm{GeV}/c^2$

$$0 < \ M \ < 800\ \mathrm{GeV}$$
$$-400 < \ \mu \ < 400\ \mathrm{GeV}$$
$$\tan\beta \ = \ 1,\ 1.5,\ 35$$

Search for Supersymmetry at 161 GeV:

New important background sources:

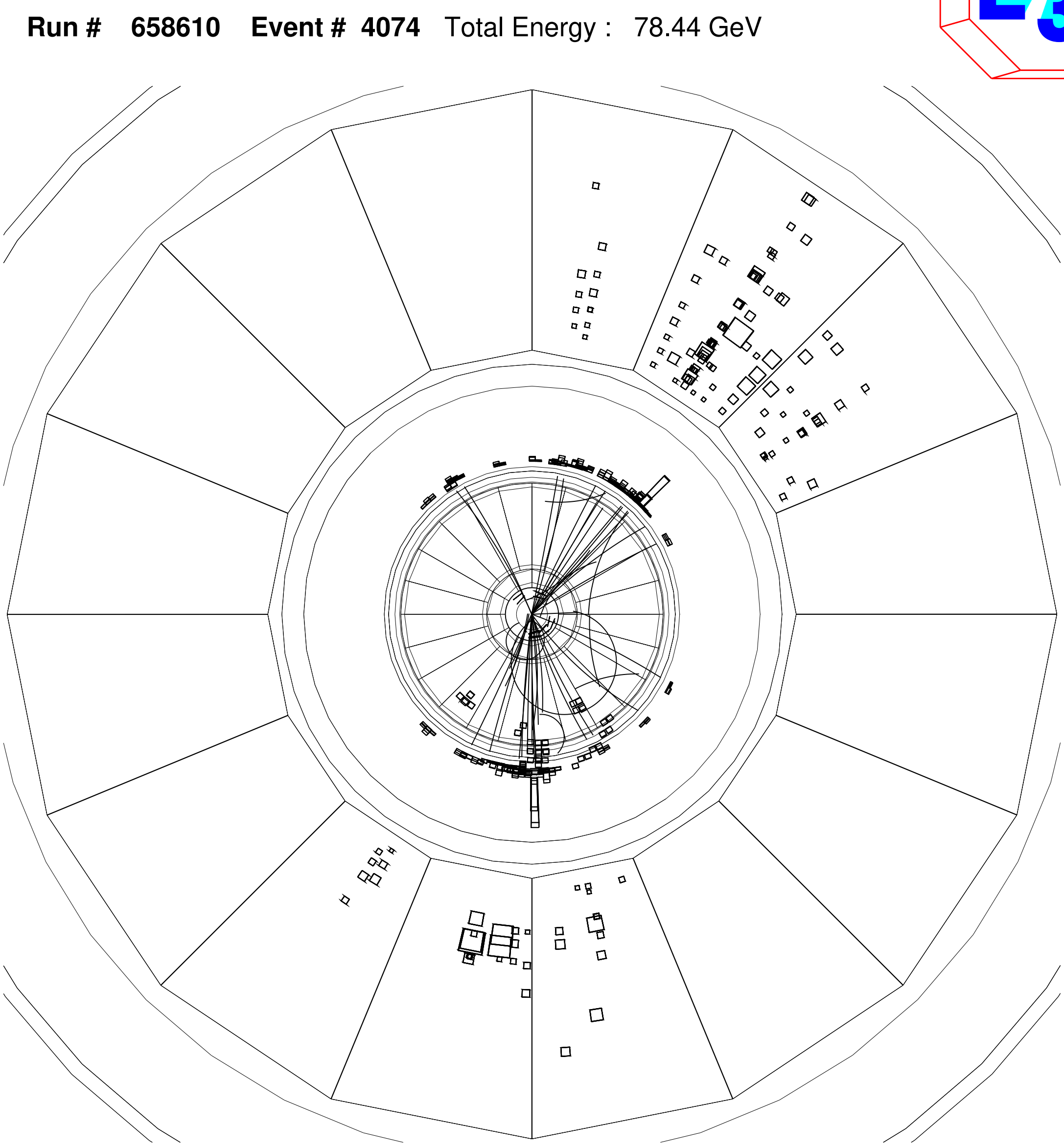
- $e^+e^- \to W^+W^-$ with $W^\pm \to \ell^\pm \nu$
- Single W production



No SUSY signal seen so far...

Final search results for 130 – 140 GeV data
Preliminary results from 161 GeV run

Candidate event

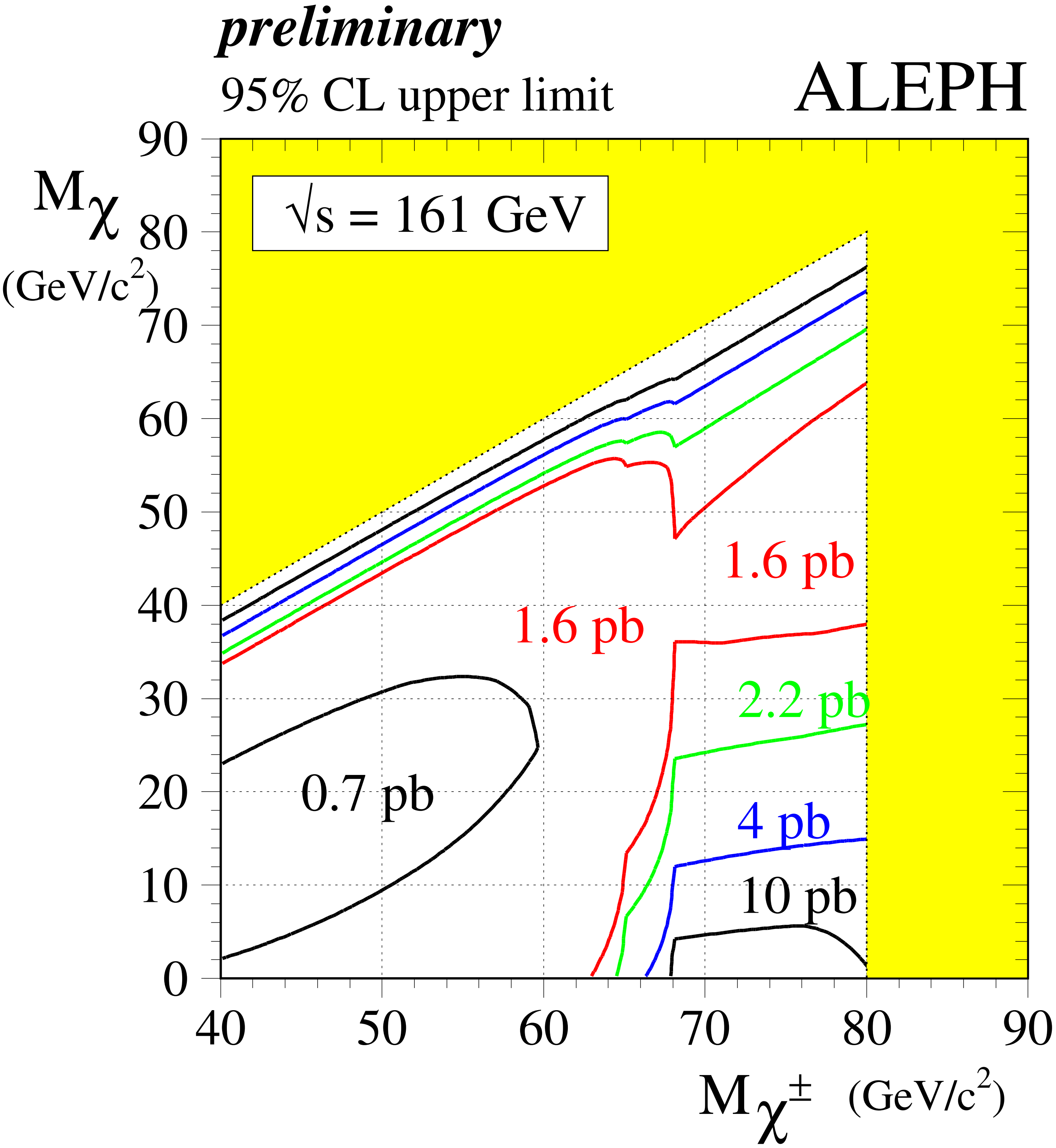


Possible explanation:

$$e^+e^- \to \quad We\nu_e$$
$$W \to \quad qq'$$

1.9 events expected

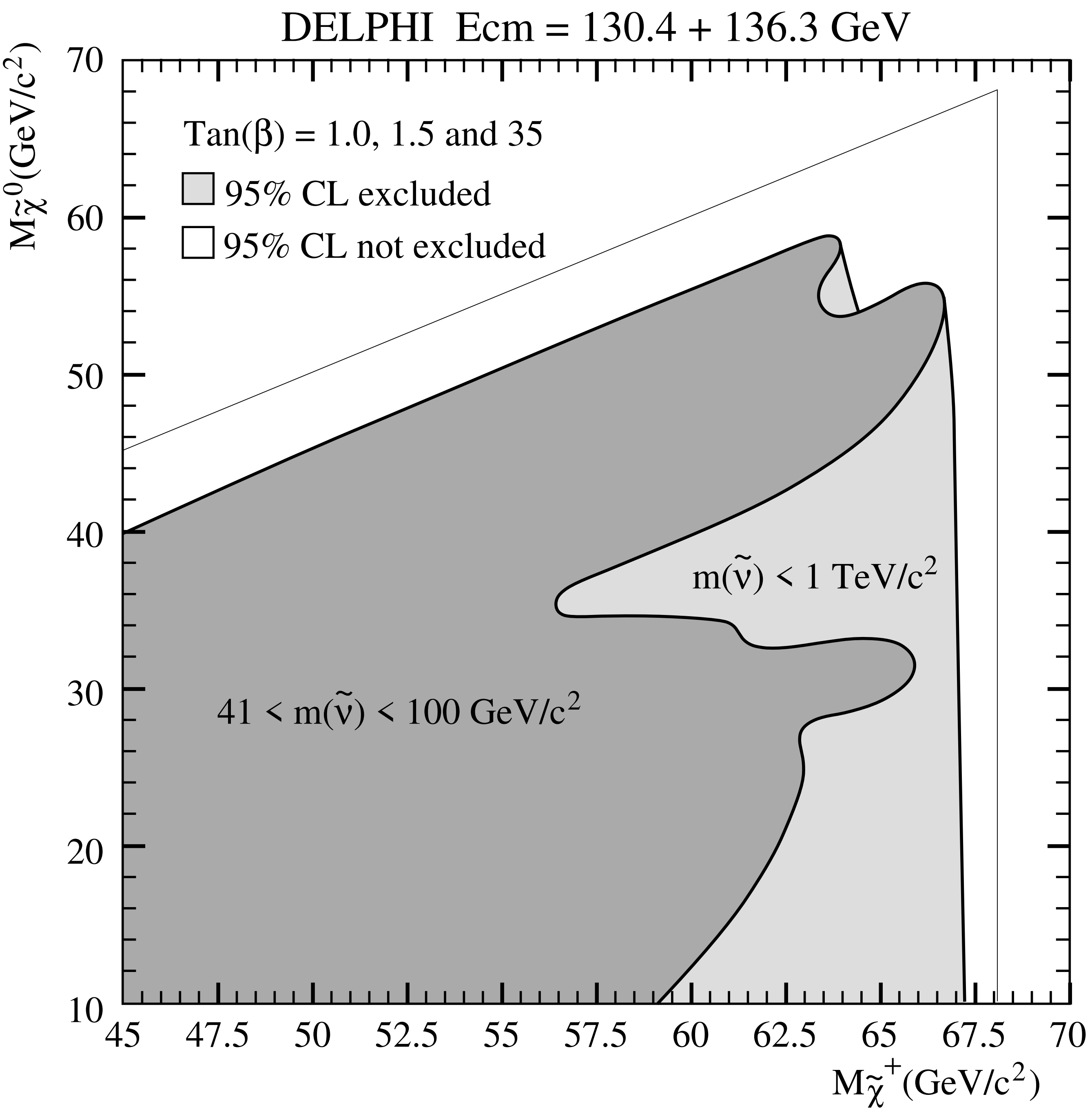
$\Longrightarrow$ **Experimental upper limit on cross section $e^+e^- \rightarrow \tilde{\chi}^+\tilde{\chi}^-$, e.g.:**



(incl. 130 – 140 GeV data)

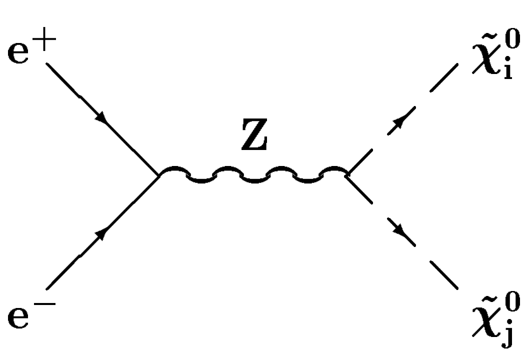
Exclusion in $m_{\tilde{\chi}^0}$–$m_{\tilde{\chi}^+}$ plane

Example from DELPHI:

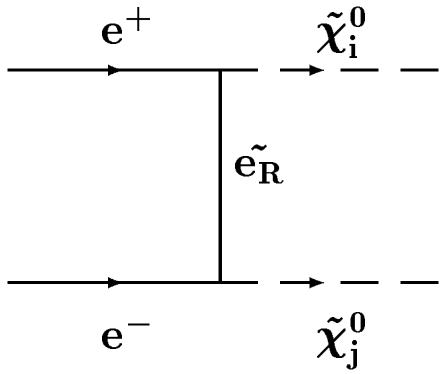


$m_{\tilde{\nu}} > 43$ **GeV from** Γ_{inv}

Neutralino production:



$i, j = 1, 2, 3, 4$

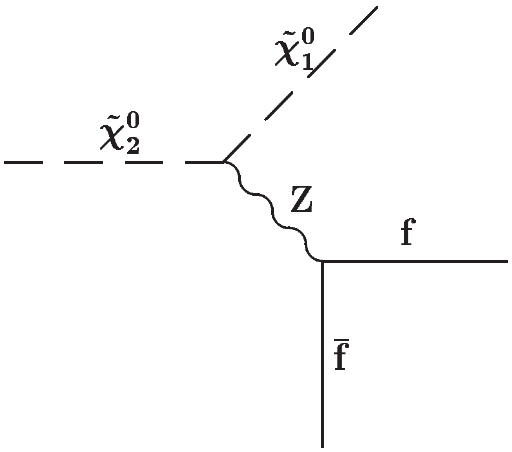


$\tilde{\chi}^0_1$ stable, invisible

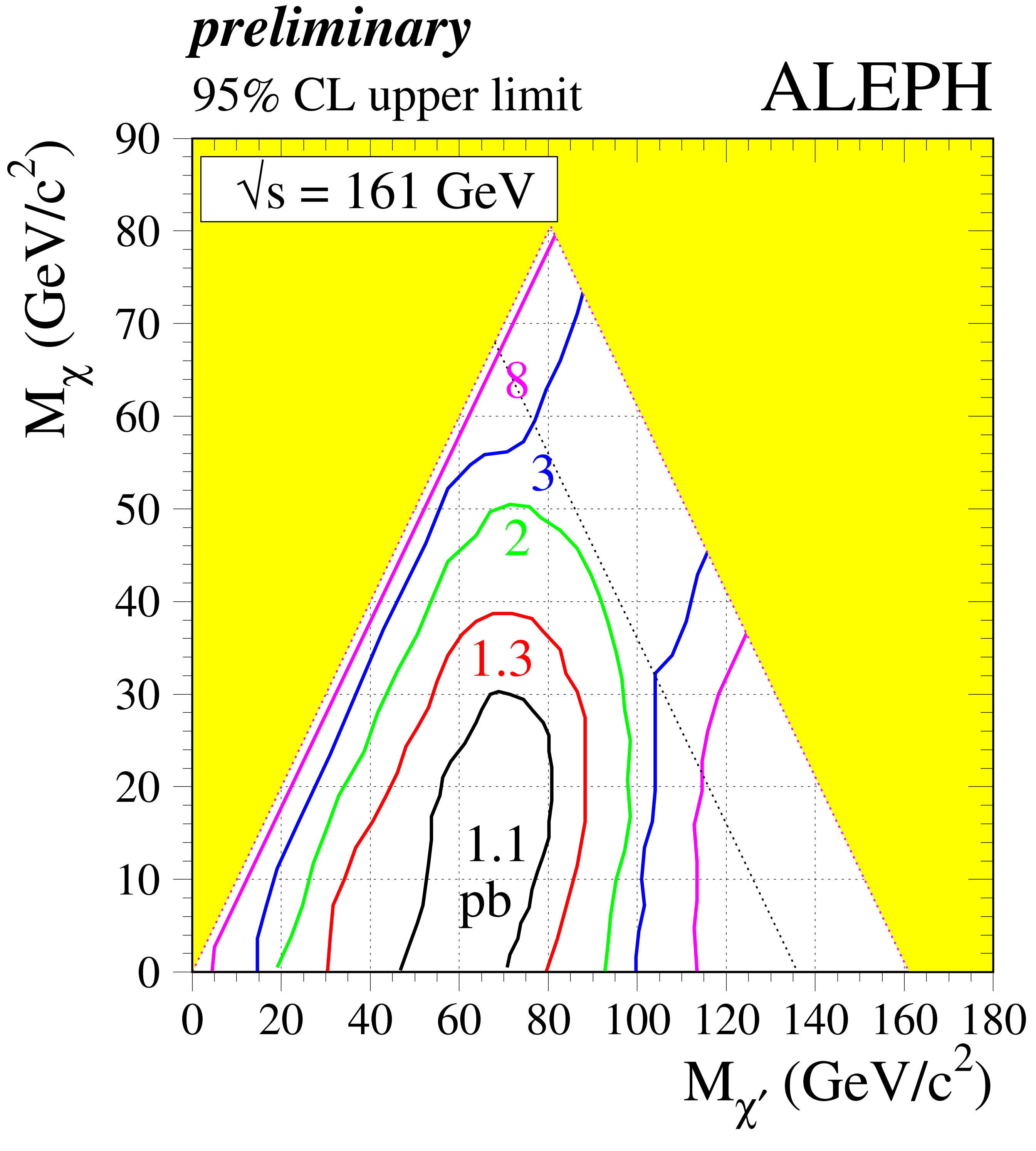
Limits on $e^+e^- \to \tilde{\chi}^0_1\tilde{\chi}^0_1$ from single photon reaction

Search for $e^+e^- \to \tilde{\chi}^0_1\tilde{\chi}^0_2$
with $\tilde{\chi}^0_2 \to \tilde{\chi}^0_1 + f\bar{f}$

Neutralino decay:



Experimental upper limits on cross section $e^+e^- \rightarrow \tilde{\chi}_1^0\tilde{\chi}_2^0$, e.g.:



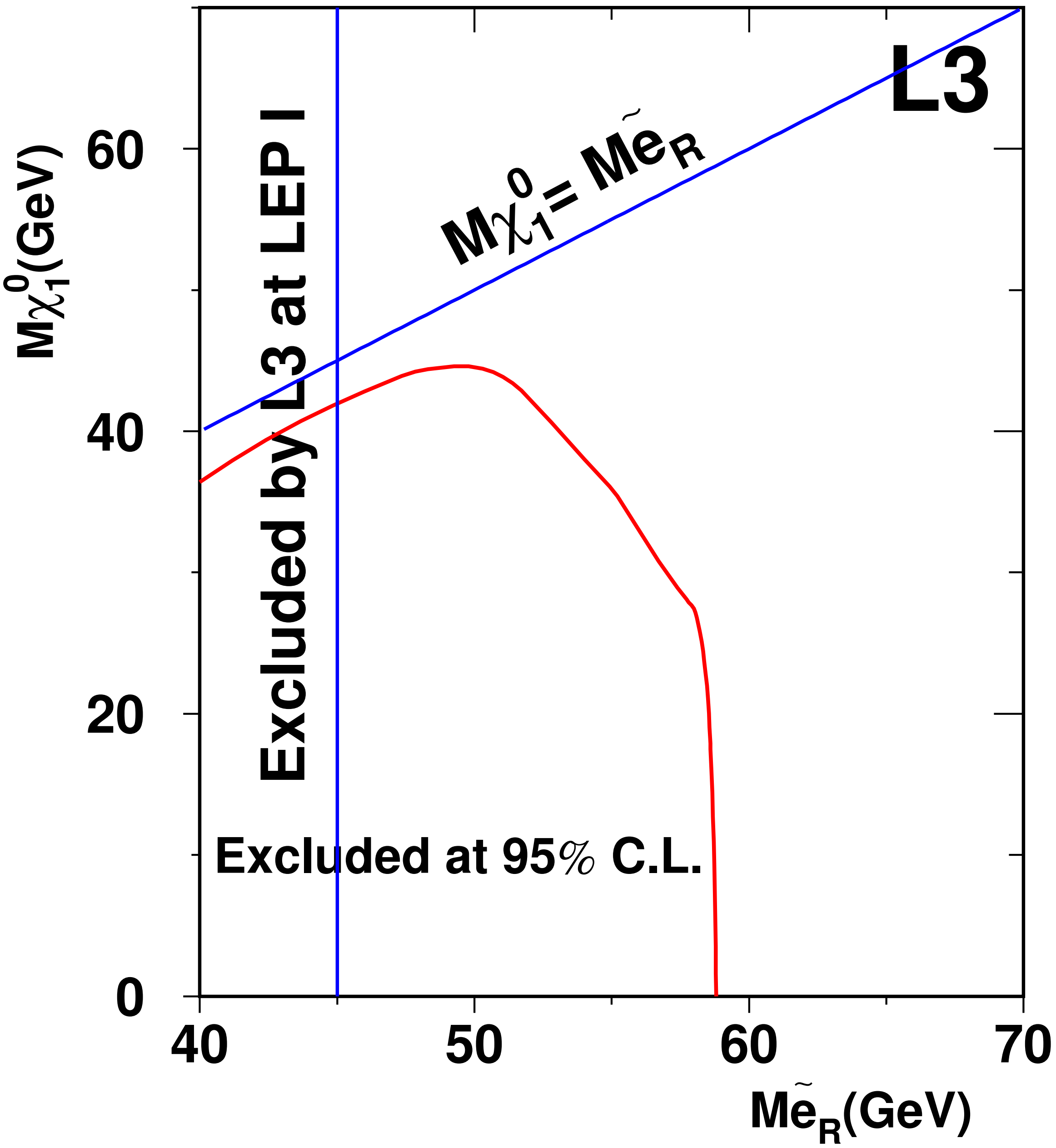
(incl. 130 − 140 GeV data)

Scalar partners of fermions:

Improvements on LEP I only for selectron

(high σ due to t-channel)

e.g. L3 from 130 – 140 GeV data:

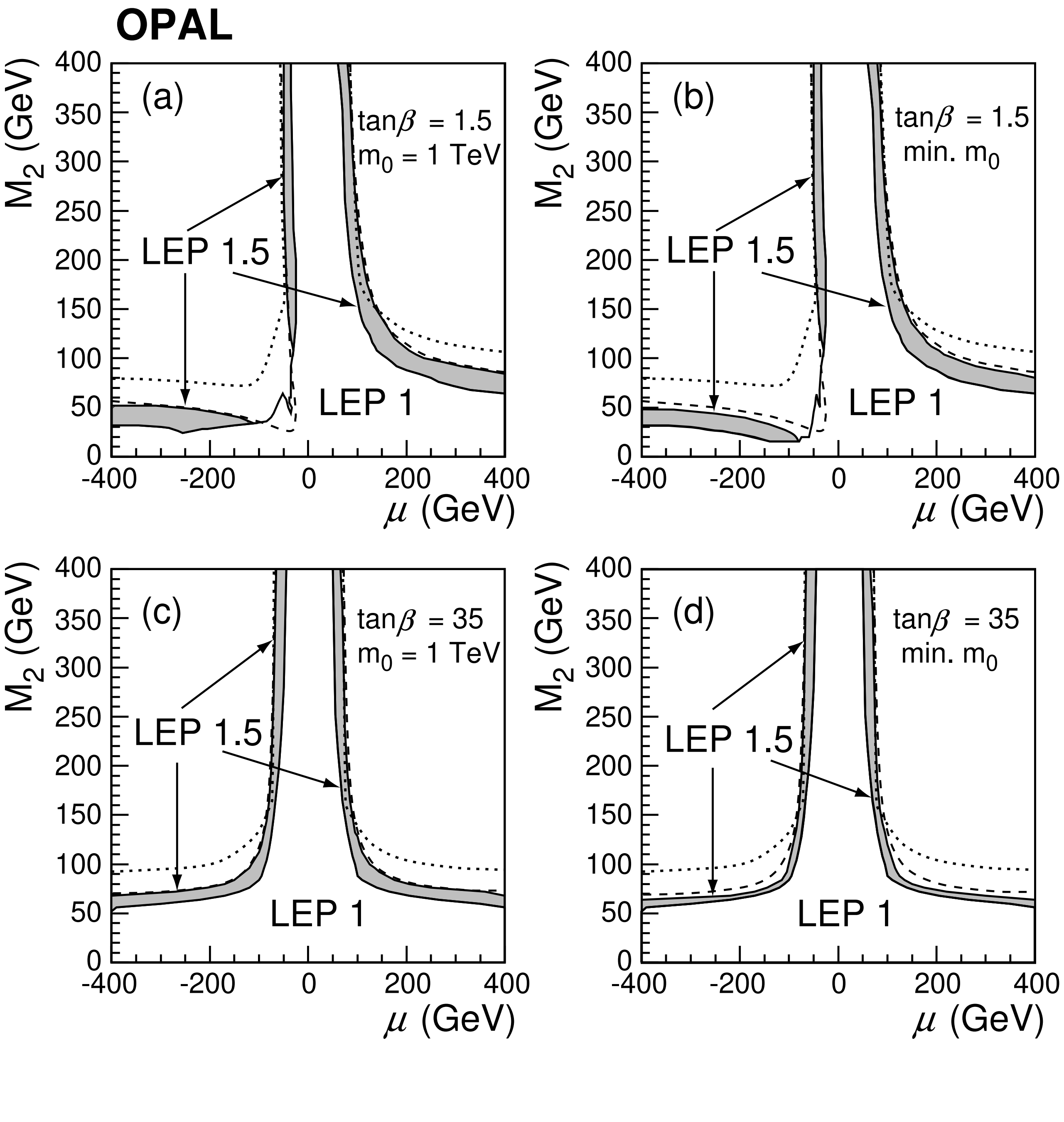


$$0 < \quad M \quad < 200 \text{ GeV}$$

$$-200 < \quad \mu \quad < 200 \text{ GeV}$$

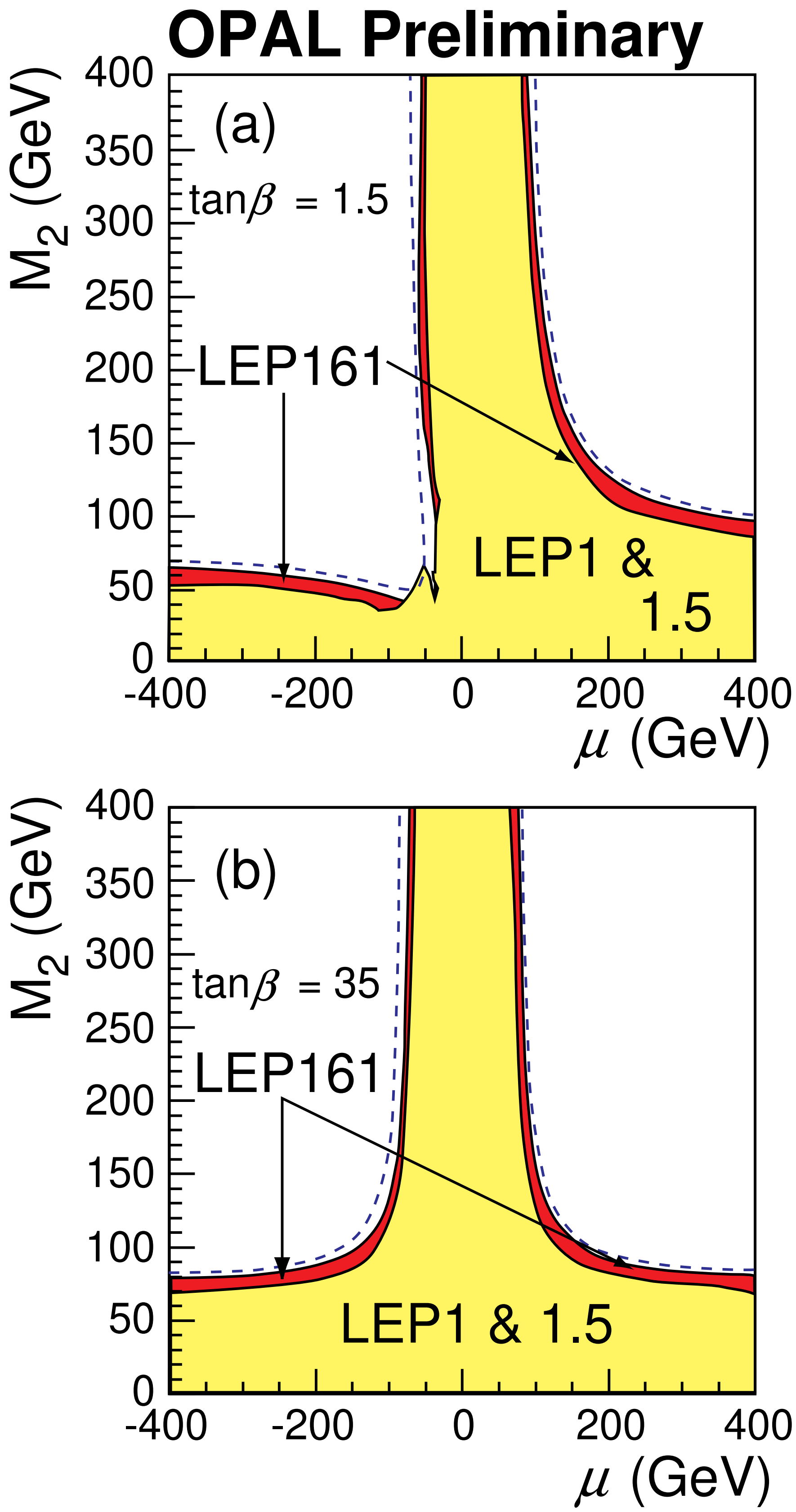
$$\tan\beta \quad = \quad 1.5$$

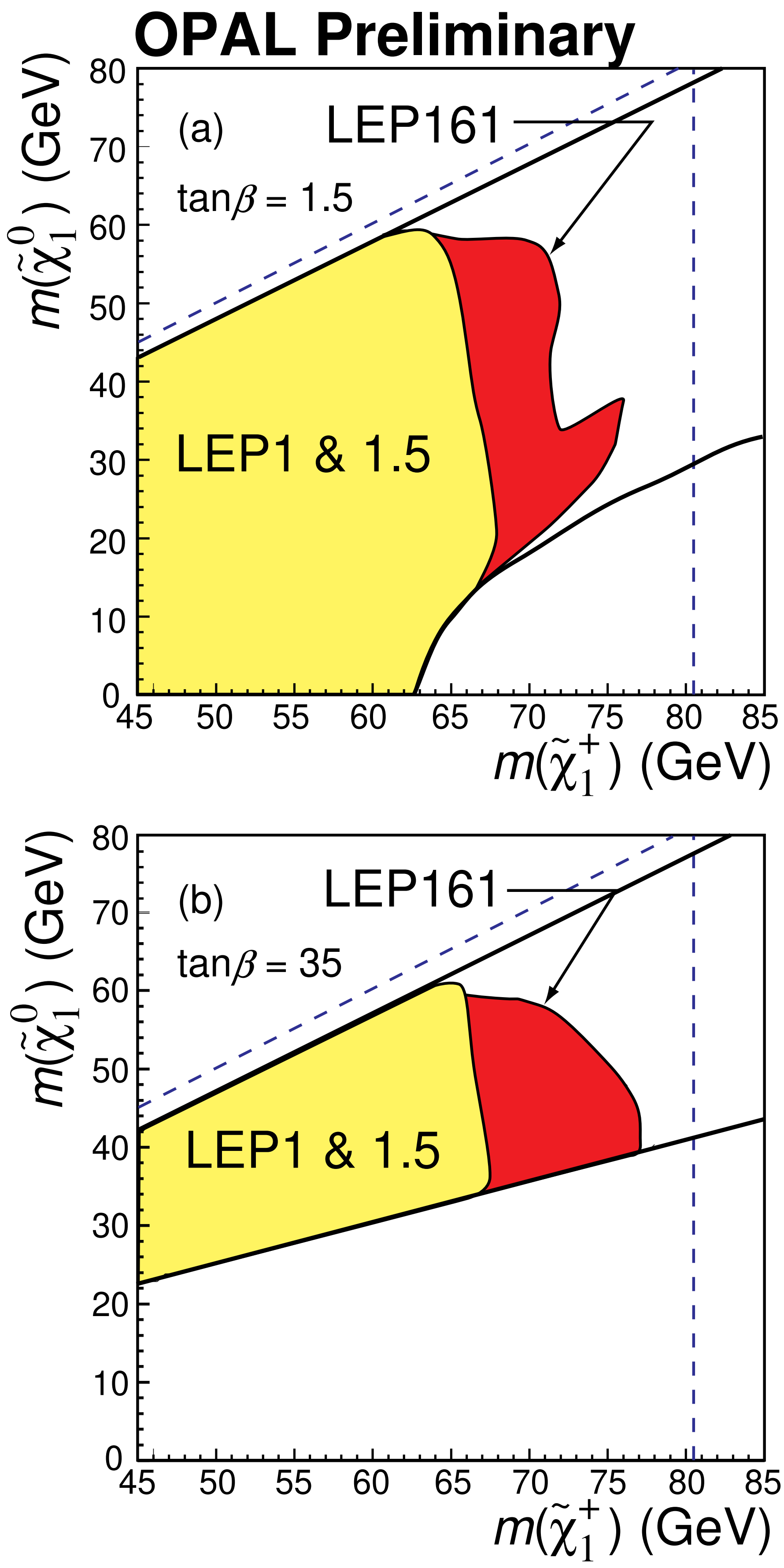
Improvements from 130−140 GeV run on SUSY parameters:



minimum m_0:
smallest m_0 complying with limits on $\tilde{\ell}$ and $\tilde{\nu}$

Improvements on SUSY parameters:




OPAL Preliminary
(a)
LEP161
tanβ = 1.5
LEP1 & 1.5
m(χ̃₁⁰) (GeV)
m(χ̃₁⁺) (GeV)
(b)
LEP161
tanβ = 35
LEP1 & 1.5
m(χ̃₁⁰) (GeV)
m(χ̃₁⁺) (GeV)

Four-jet events at $\sqrt{s} \geq 130$ GeV

Select hadronic events with four jets

- **Determine two-jet masses m_{ij}**
- **Pick pair with lowest difference $|m_{ij} - m_{kl}|$**

ALEPH result at $130 \leq \sqrt{s} \leq 140$ GeV:

$m_{ij} + m_{kl} = 105$

9 events observed

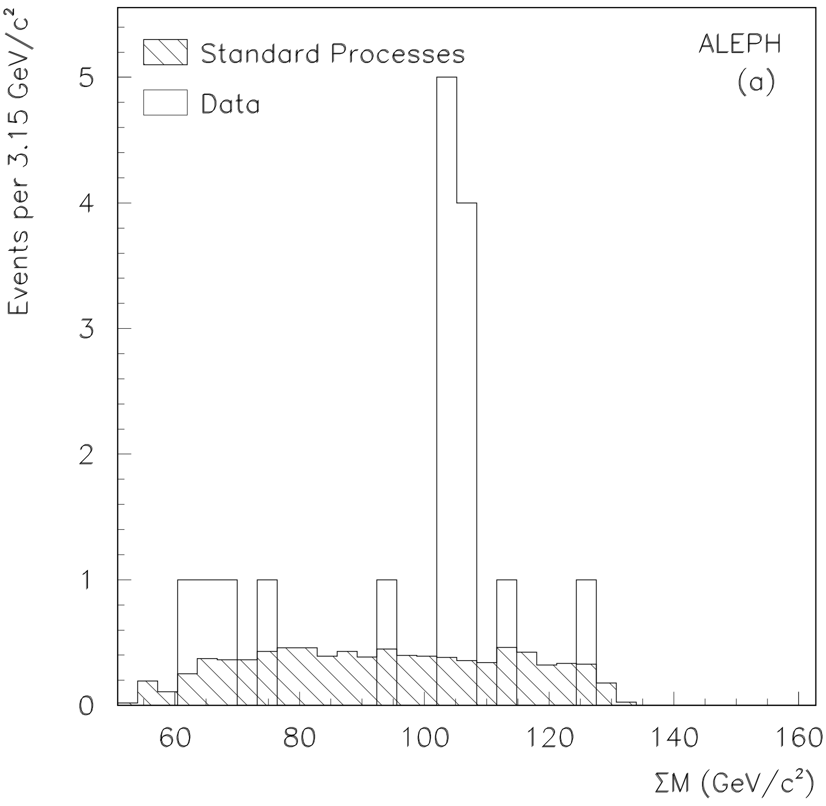
0.8 expected from QCD

$e^+e^- \to h\,A$ hypothesis:

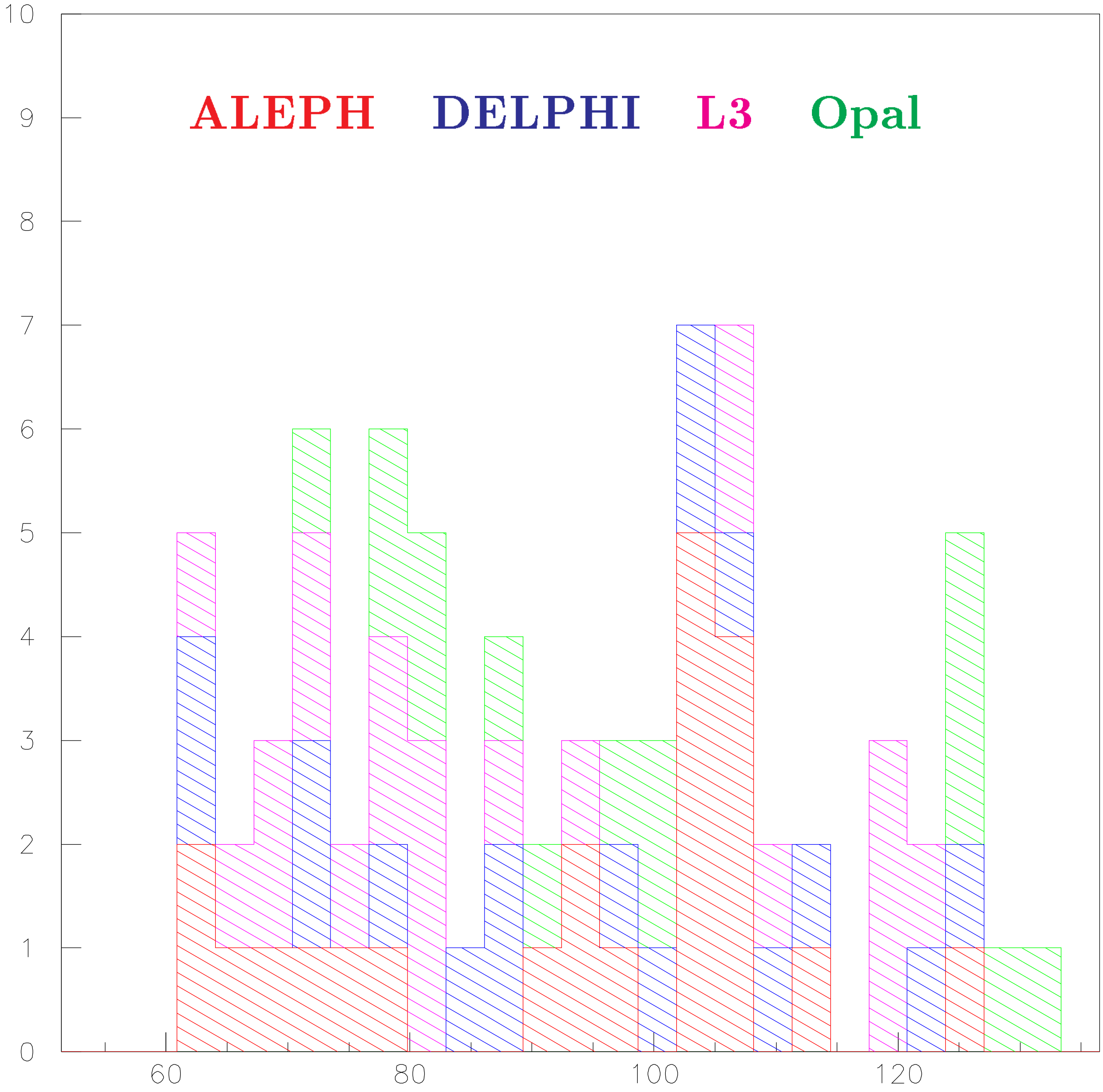
- Cross section too high

- not b-quark enriched

$e^+e^- \to H^+H^- \to c\bar{s}\,\bar{c}s$?



Identical analysis done by other experiments:



Combined LEP cross section:

$$\sigma(\sum m_{ij} = 105 \text{ GeV}) = 1.2 \pm 0.4 \text{ pb}$$

Four-jet rate at 161 GeV compatible with QCD

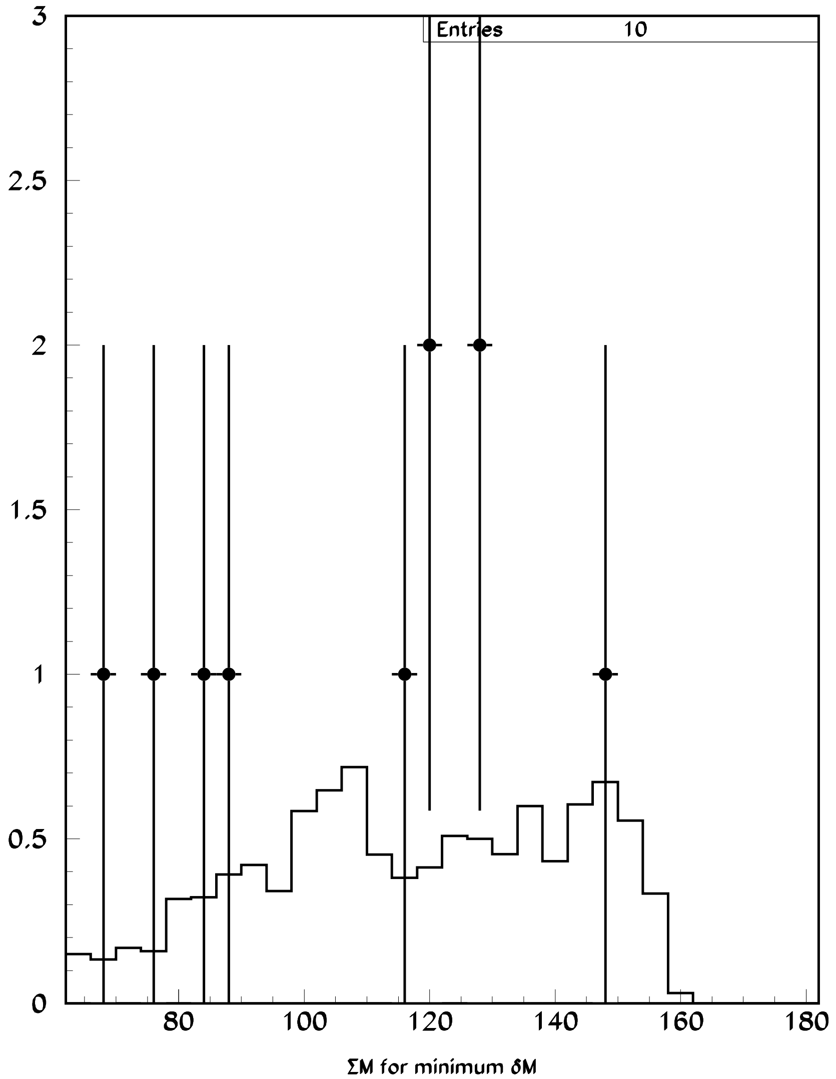
4-jet events

$\mathcal{L}_{int} = 6.5pb^{-1}$, $\epsilon = 47\%$

WW are suppressed ($\chi^2_{WW} > 10$)**:**

Expected: 10.5 events

Seen: 10 events

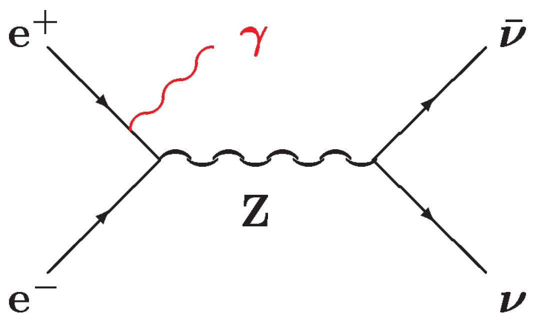


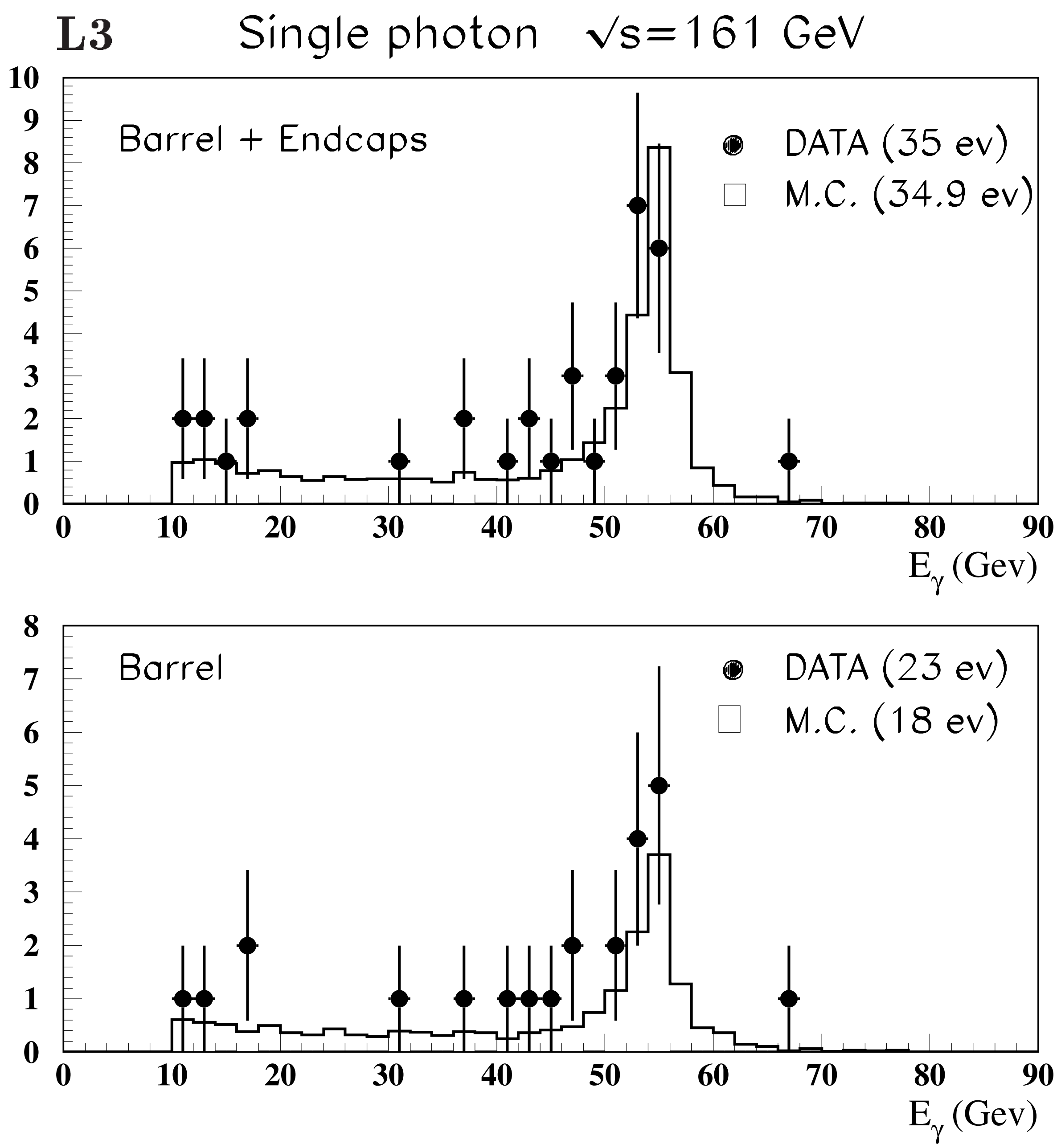
In the mass window: 105 ± 6**GeV:**

$$\sigma_{4j} < 1.44pb$$ **at 95% CL**

Events with hard photons

Single photon reaction $e^+e^- \to \nu\bar{\nu}\gamma$ above the Z pole:



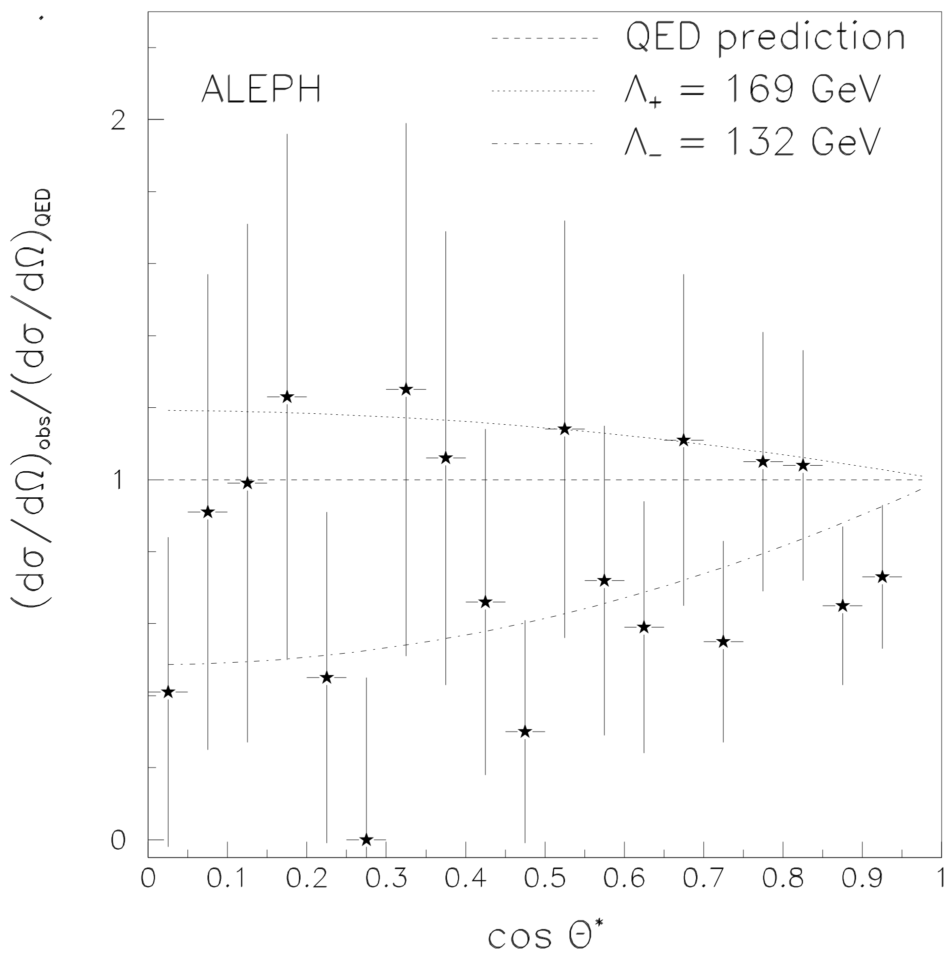


$e^+e^- \to \gamma\gamma$

Deviations from QED parametrized by cutoff parameters Λ_+ and Λ_-:

$$\frac{d\sigma}{d\Omega} = \left(\frac{d\sigma}{d\Omega}\right)_{QED} \left(1 \pm \frac{s^2}{2\,\Lambda_\pm^4}\left(1 - \cos^2\Theta^*\right)\right)$$

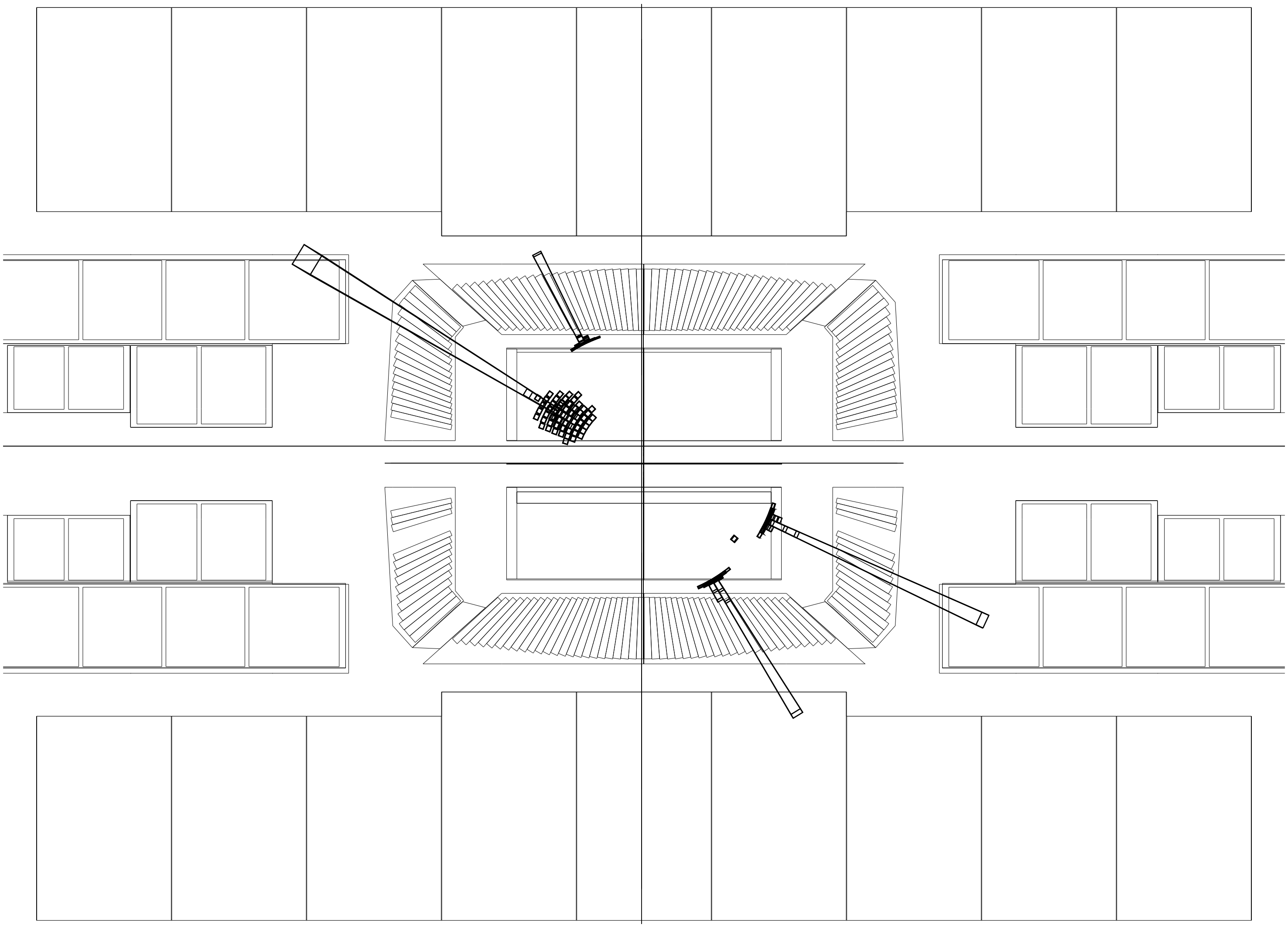
Result from $130 \leq \sqrt{s} \leq 140$ GeV:



Preliminary result from 161 GeV run (L3):

$\Lambda_+ > 190$ GeV $\qquad \Lambda_- > 162$ GeV

Run # 650701 Event # 2734 Total Energy : 90.81 GeV



Transverse Imbalance :	.0014	**Longitudinal Imbalance :**	-.4609

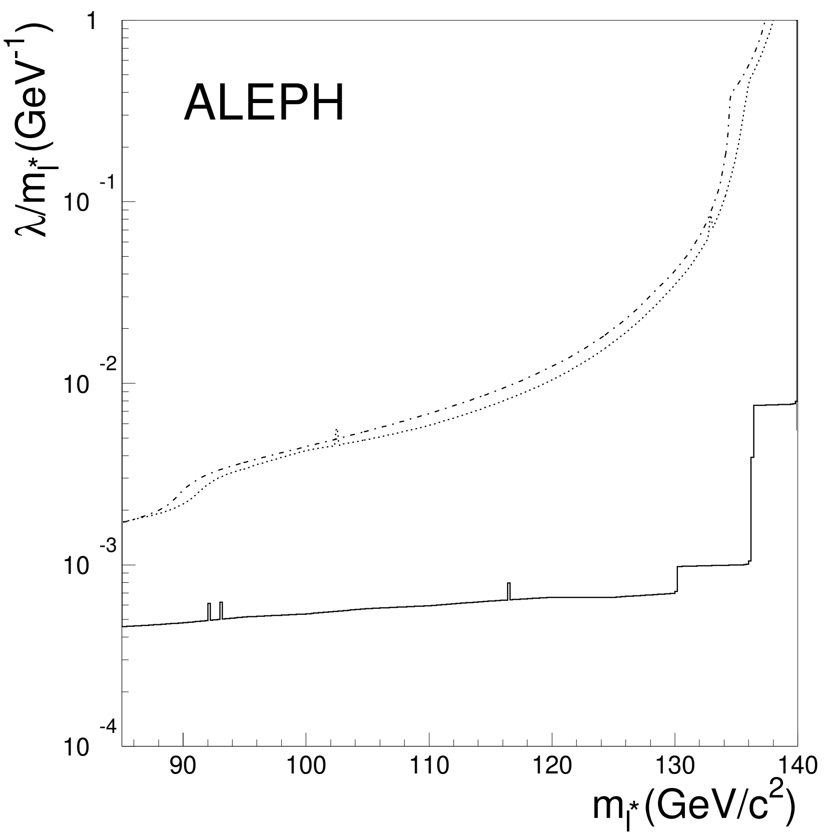
Thrust :	.8442	**Major :**	.4065	**Minor :**	.1032

Event DAQ Time :	*951104 204043*

Search for exited leptons $\ell^* \to \ell + \gamma$

- **Pair production $e^+e^- \to \ell^*\bar{\ell}^*$**
  Search for $\ell^+\ell^-\gamma\gamma$ topologies
  Assume same couplings of ℓ^* to γ/Z as ordinary leptons
  Exclusion up to $m_{\ell^*} \approx E_b$

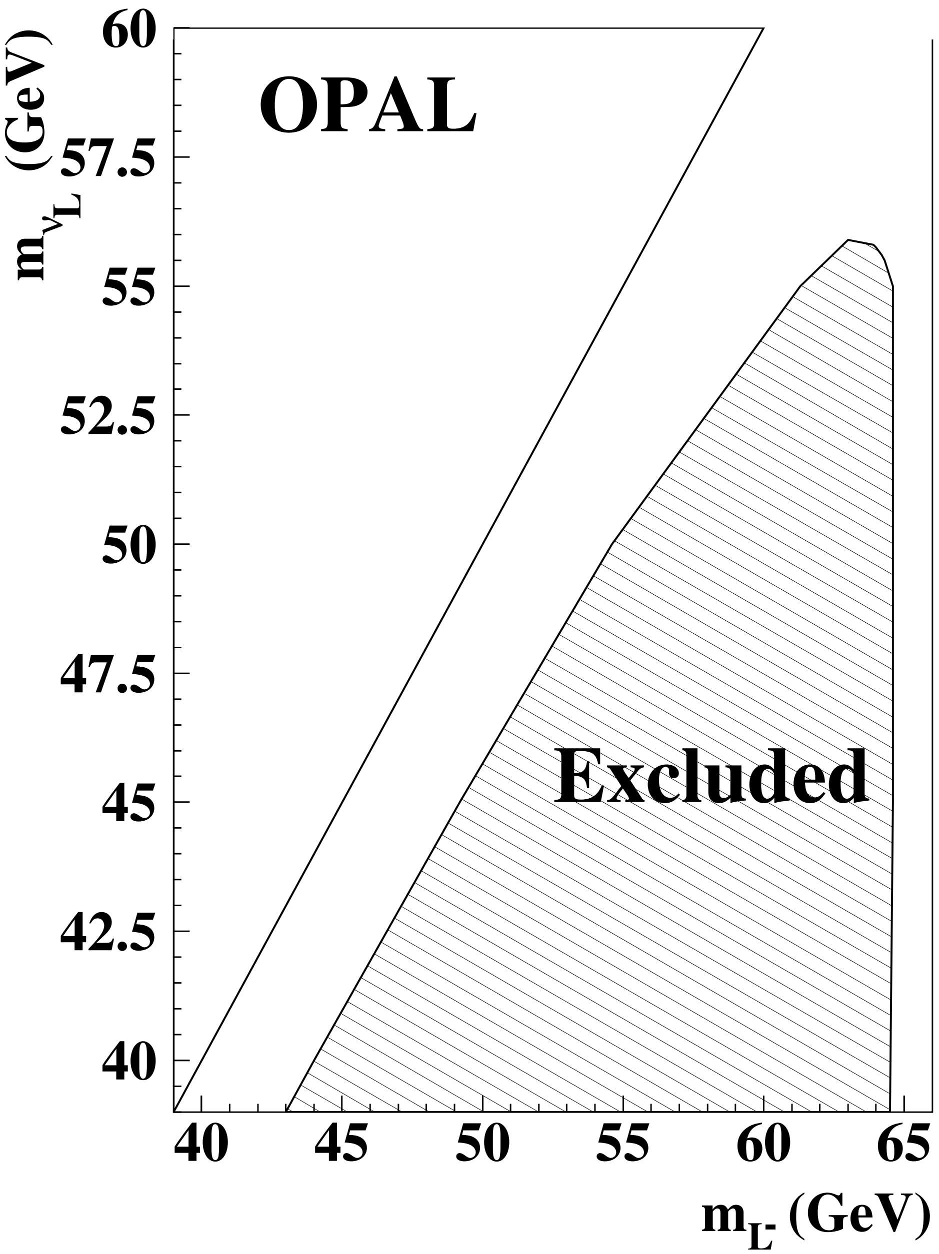
- **Single production $e^+e^- \to \ell^*\ell$**
  Search for $\ell^+\ell^-\gamma$ topologies
  Cross section depending on cutoff parameter and coupling
  Exclusion plot:



Search for heavy leptons L^0, $L^\pm$

$L^0 \to \ell^\pm W^\mp$ $L^\pm \to \nu_L^\pm W^\pm$

Mixing of ν_L with ordinary neutrinos
Different phase space factors for charged leptons, Dirac or Majorana neutrinos



Conclusions:

Successful start of LEP II

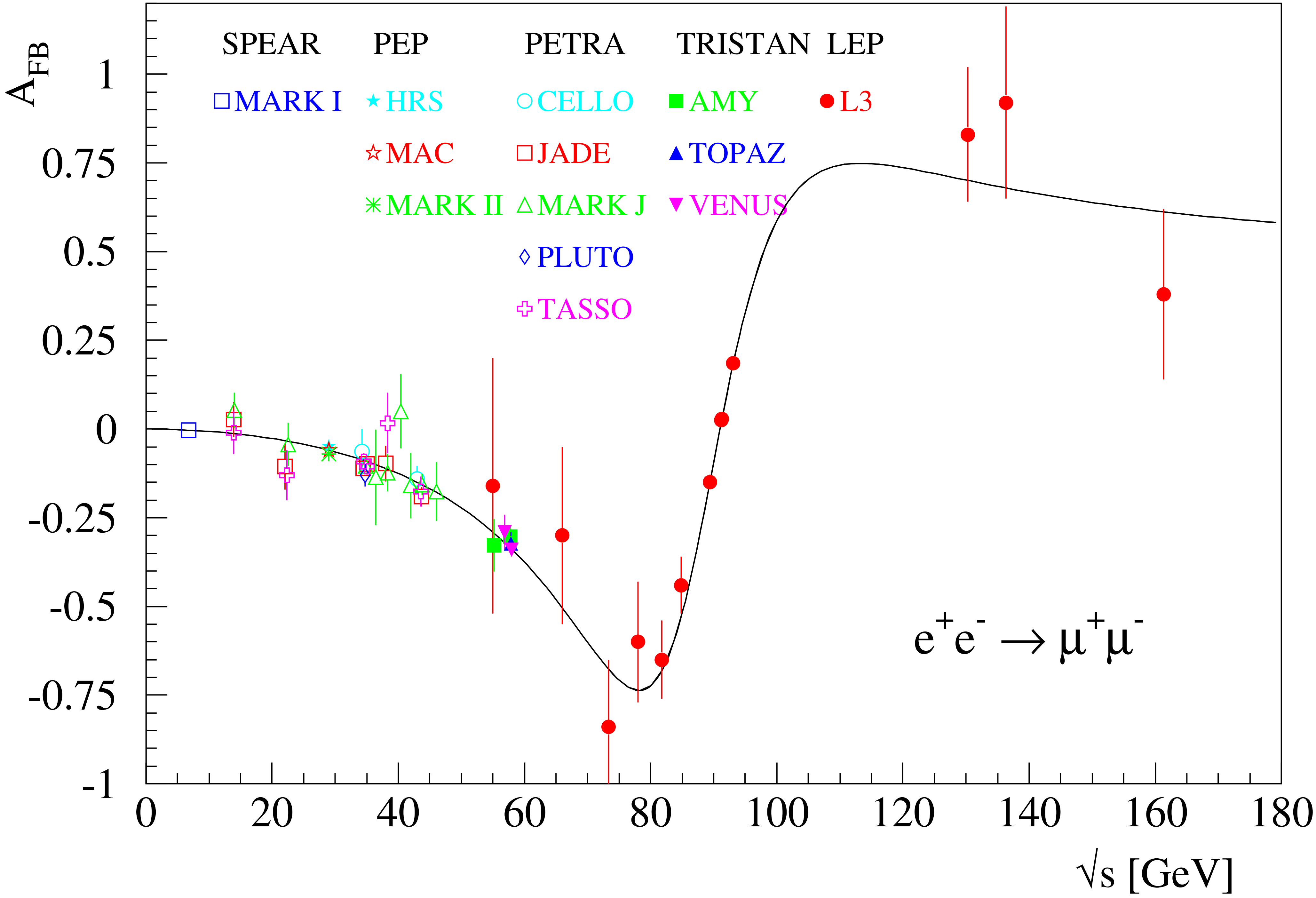
- $e^+e^- \to W^+W^-$ at threshold
  $m_W = 80.4 \pm 0.3 \pm 0.1\,(\mathrm{LEP})$ GeV
  (more data on tape)
- Measurement of fermion pair production
  γZ interference
- No sign of Supersymmetry
  improvements of limits
- No sign of new physics

$\Longrightarrow$ **Standard Model confirmed up to 161 GeV**

Future plans:

Continue LEP energy upgrade up to $\sqrt{s}$ = 192 GeV

- 500 pb^{-1} per experiment until 2000,
  i.e. $\approx$ 8 000 W pairs
- Measurement of W mass and W couplings
- Search for new particles
  Discover the Higgs up to 100 GeV



A_{FB}
1
0.75
0.5
0.25
0
-0.25
-0.5
-0.75
-1
SPEAR
PEP
PETRA
TRISTAN
LEP
MARK I
HRS
MAC
MARK II
CELLO
JADE
MARK J
PLUTO
TASSO
AMY
TOPAZ
VENUS
L3
$e^+e^- \to \mu^+\mu^-$
0
20
40
60
80
100
120
140
160
180
$\sqrt{s}$ [GeV]