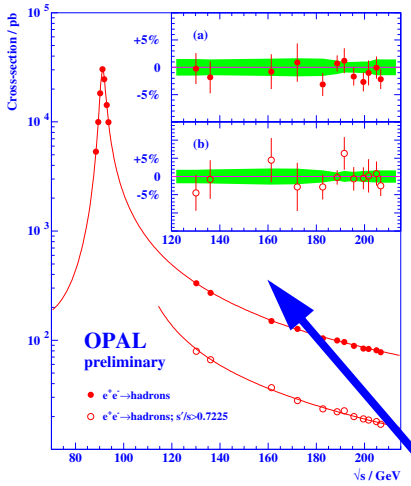
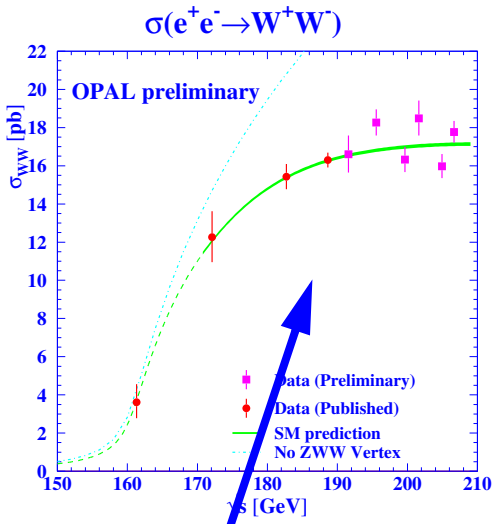
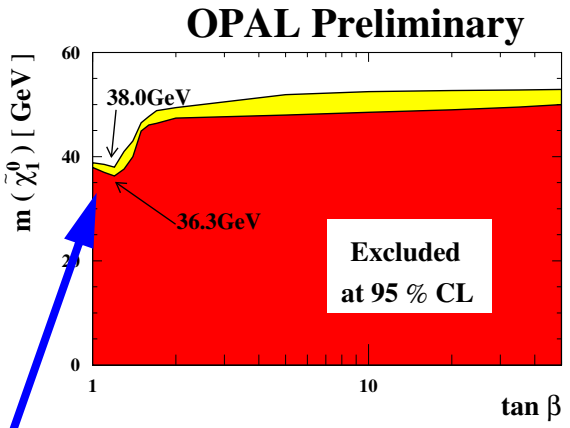
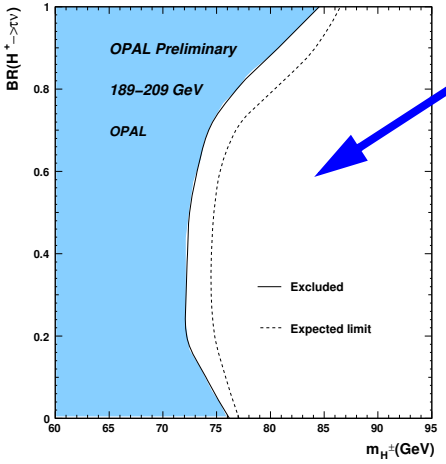
HIGHLIGHTS FROM THE OPAL EXPERIMENT

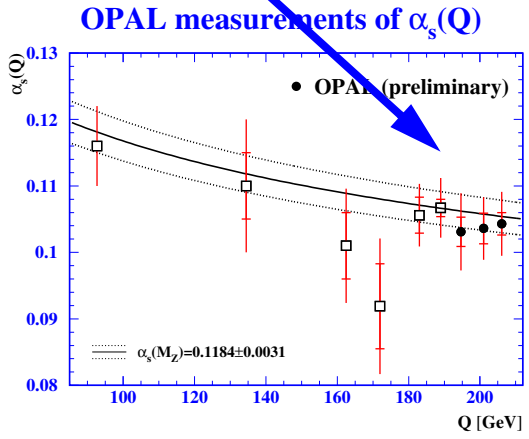


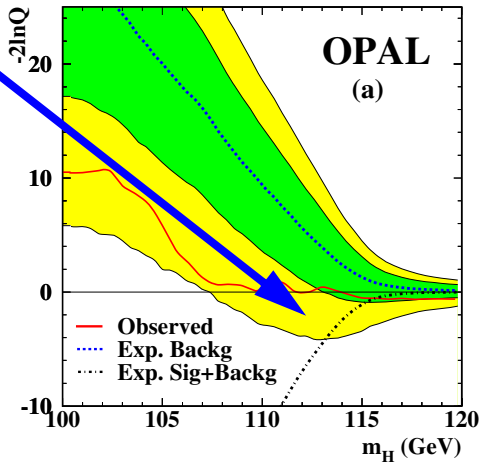




working on final papers



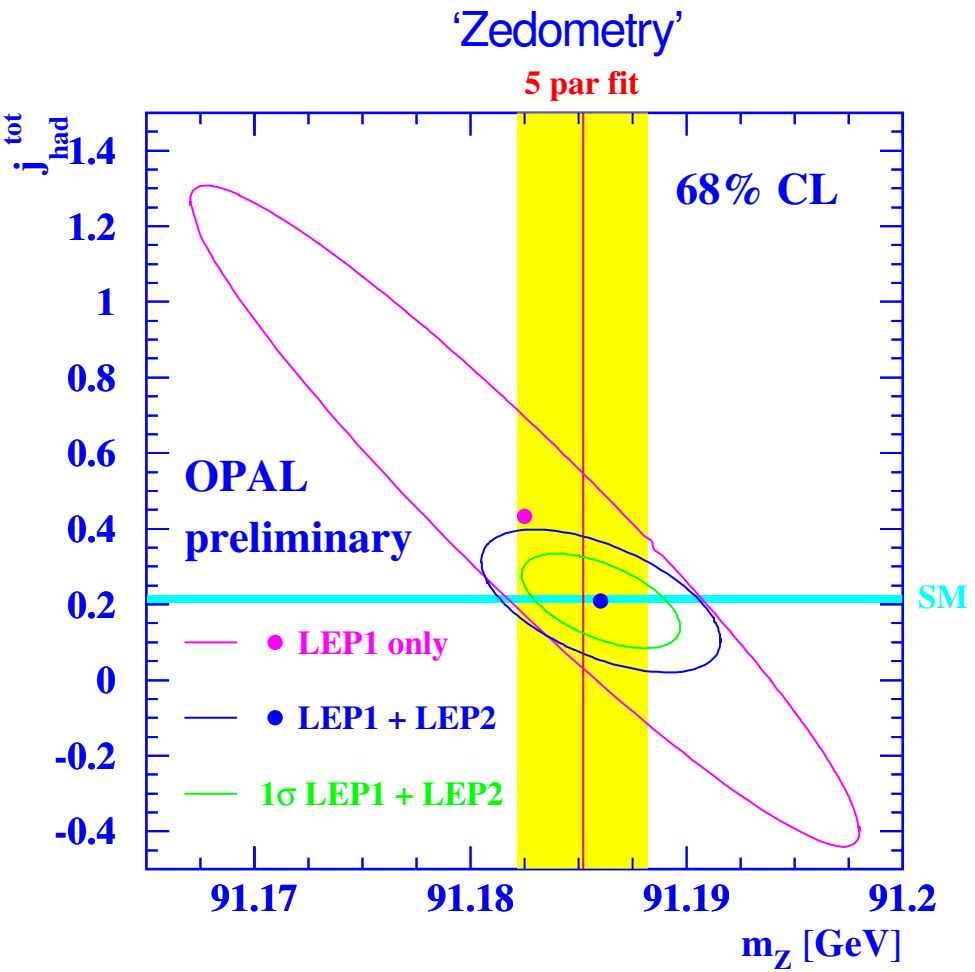




- Standard Model Measurements
  - S- Matrix parameters from 2-fermion cross-sections
  - ZZ production and anomalous neutral current gauge couplings
  - LEP beam energy from radiative return events
- Heavy Quark Physics
  - BR(b -> l u X) and $|V_{ub}|$
  - BR(b -> $\tau\,\nu$ X) and limits on $\tan\beta/m_{H^+}$
  - BR(D_s -> $\tau\,\nu$) and f_{Ds}
- QCD and Hadron Production
  - The running b quark mass
  - Bose-Einstein correlations
  - Fermi-Dirac correlations
  - Scattering of virtual photons
- Searches for New Particles
  - Lifetime dependent GMSB searches
  - Search for Technicolour
- Searches for Higgs Bosons Beyond the SM
  - 2HDM interpretation of neutral Higgs boson searches
  - Search for Yukawa production of light Higgs bosons

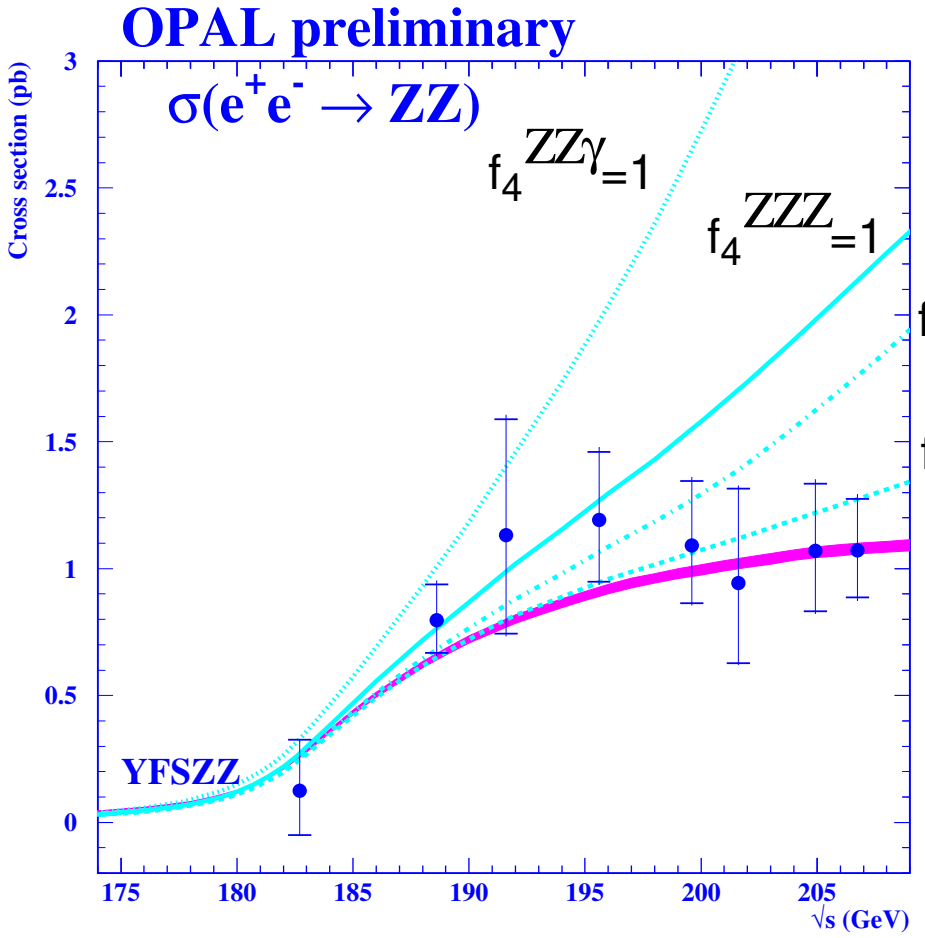
S-Matrix parameters from 2-fermion cross-sections

- LEP1 5 parameter fit assumes SM value for hadronic interference j^{tot}_{had}
- S-matrix fit (nearly) model independent, assumes exchanges of two spin-1 bosons in $e^+e^- \to f\bar{f}$
- 266 hadronic and leptonic cross-sections and asymmetries from LEP1 and LEP2 used (excluding Bhabha data at LEP2)
- LEP2 data strongly constrains the interference term j^{tot}_{had}



m_Z=(91186.0 +- 3.7) MeV

ZZ production



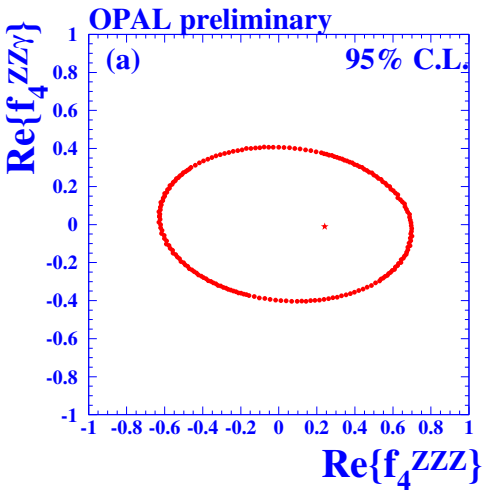
Anomalous NC gauge couplings

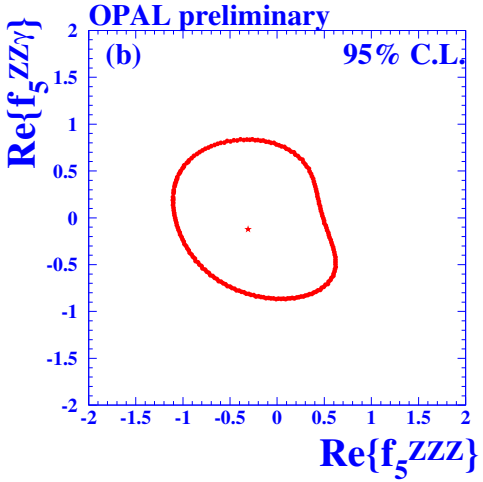
New:

cross-section information

and

optimal observables (angular information of the four leptons)

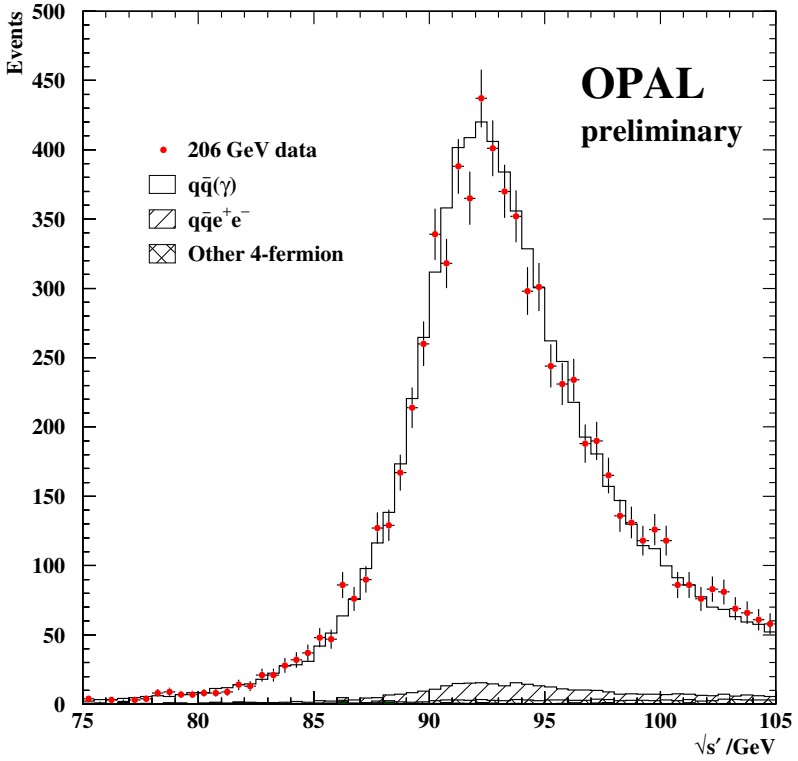


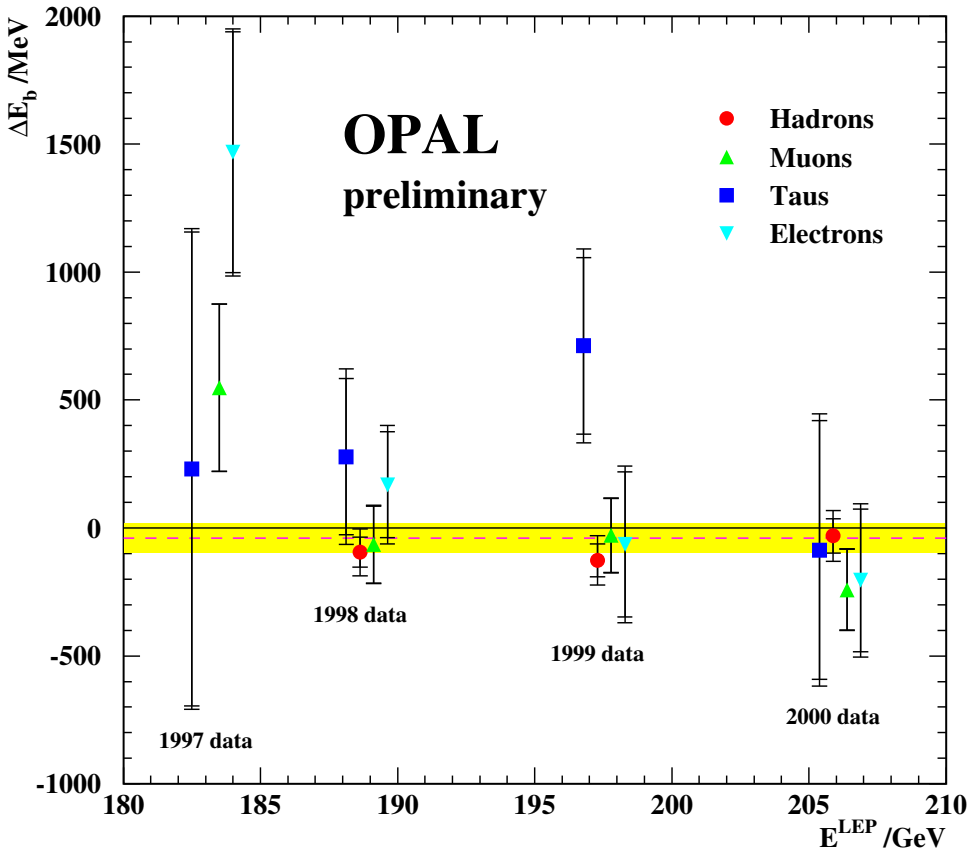


LEP beam energy from radiative return events ($f\bar{f}\gamma$)

m_Z measured very well

shift in peak position indicates shift in beam energy





$$\Delta E_b = -40 \pm 40(\text{stat}) \pm 35(\text{syst}) \text{ MeV}$$

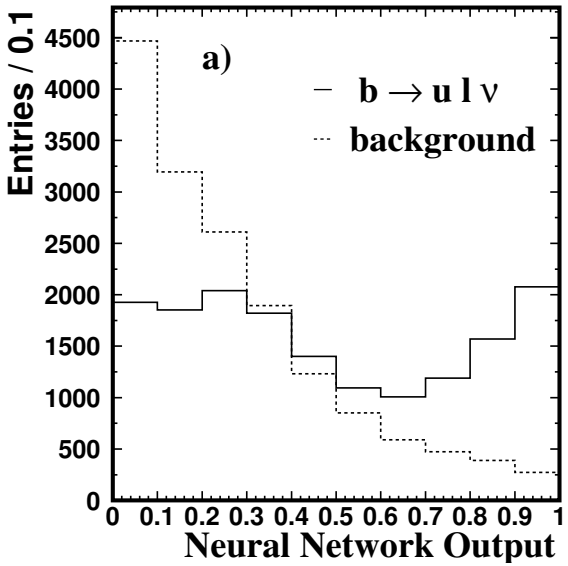
i.e. consistent with E_b of LEP energy group

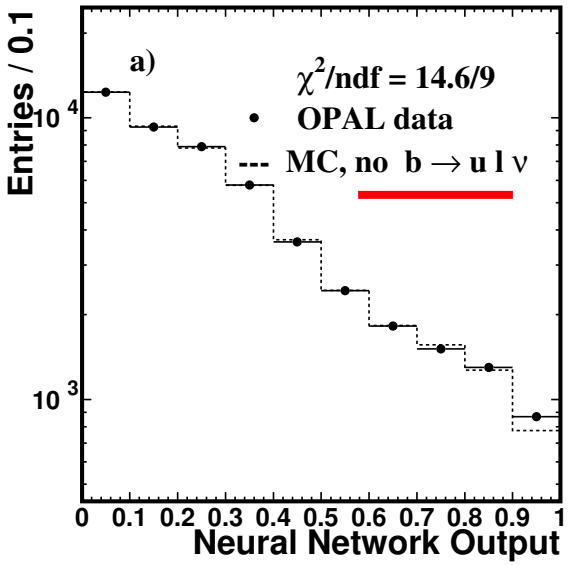
Measurement of $|V_{ub}|$

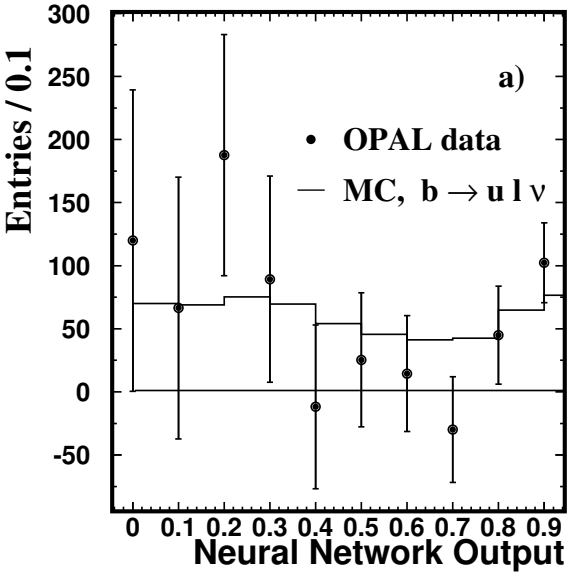
signal b->ulν

largest background b->clν

7 variable ANN







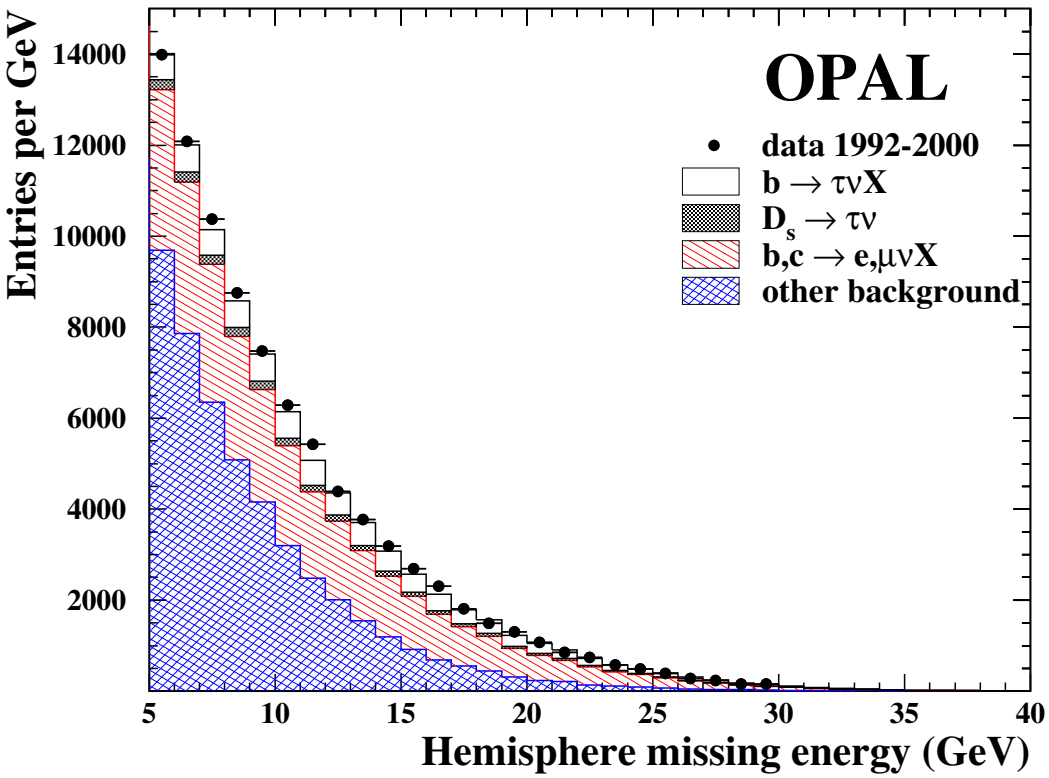
depends critically on b->u and b->c decay modelling

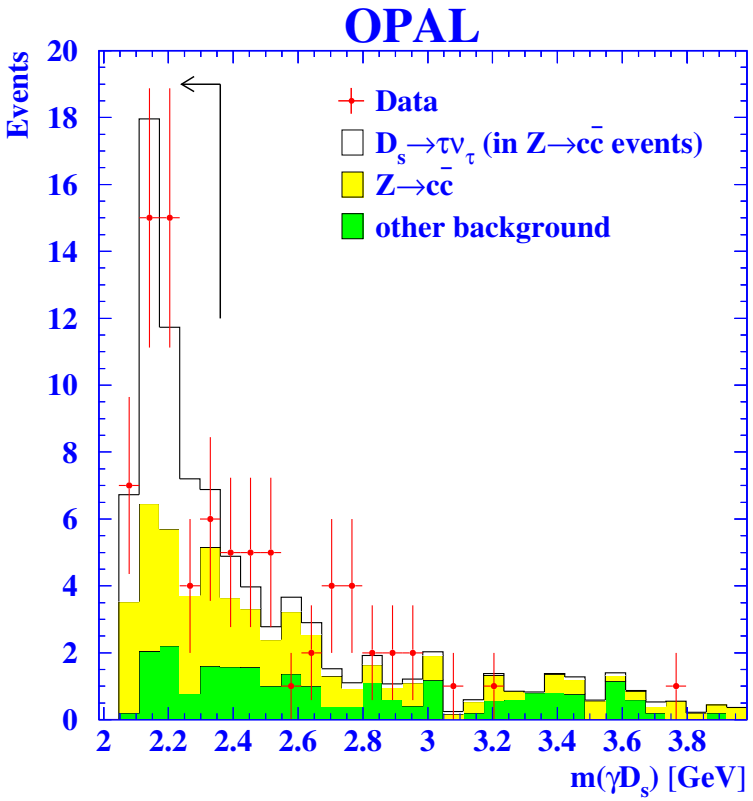
$$\mathrm{Br}(\mathrm{b} \to \mathrm{X_u}\ell\nu) = (1.63 \pm 0.53\ (\mathrm{stat})\ ^{+0.55}_{-0.62}\ (\mathrm{sys})) \times 10^{-3}$$

$$|V_{\mathrm{ub}}| = (4.00 \pm 0.65\ (\mathrm{stat})\ ^{+0.67}_{-0.76}(\mathrm{sys}) \pm 0.19\ (\mathrm{HQE})) \times 10^{-3}$$

B->τ ν X

$$D_s^{\star -} \rightarrow \gamma\, D_s^-$$
$$\hookrightarrow \tau\bar{\nu}_\tau$$
$$\hookrightarrow \ell^-\bar{\nu}_\ell\nu_\tau \quad (\ell = e, \mu)$$





$$\mathrm{BR}(b \rightarrow \tau^-\bar{\nu}_\tau X) = (2.78 \pm 0.18 \pm 0.51)\%$$

$$\mathrm{BR}(D_s^- \rightarrow \tau^-\bar{\nu}_\tau) = (7.0 \pm 2.1(\mathrm{stat}) \pm 2.0(\mathrm{syst}))\ \%$$

$$\frac{\tan\beta}{M_{H^\pm}} < 0.53\ \mathrm{GeV}^{-1} \text{ at } 95\%\ \mathrm{CL} \text{ in } 2\mathrm{HDM(II)} \text{ models}$$

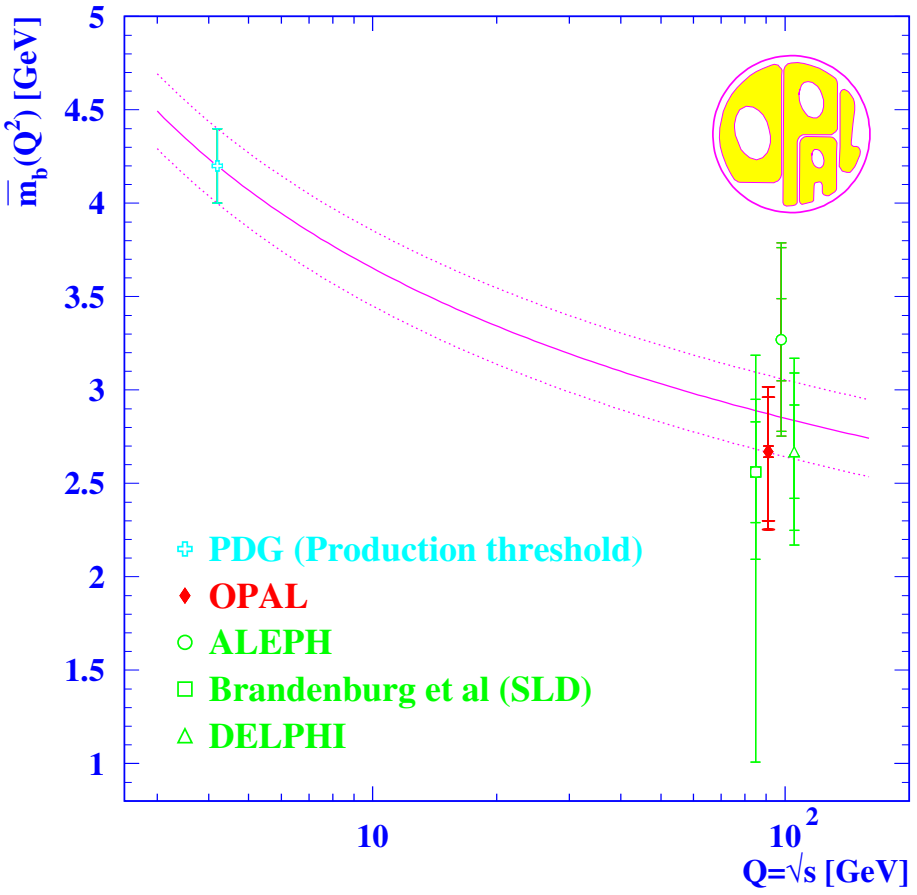
$$f_{D_s} = (286 \pm 44(\mathrm{stat}) \pm 41(\mathrm{syst}))\ \mathrm{MeV}$$

The running b quark mass

$\overline{\text{MS}}$ mass to 4-loop accuracy:

$$\overline{m}_{\mathrm{b}}(Q^2) = \hat{m}_{\mathrm{b}} \cdot \left(\frac{\alpha_{\mathrm{S}}(Q^2)}{\pi}\right)^{12/23} \cdot \left[1 + 1.175 \cdot \left(\frac{\alpha_{\mathrm{S}}(Q^2)}{\pi}\right) + 1.500 \cdot \left(\frac{\alpha_{\mathrm{S}}(Q^2)}{\pi}\right)^2 + 0.172 \cdot \left(\frac{\alpha_{\mathrm{S}}(Q^2)}{\pi}\right)^3 + \mathcal{O}\left(\alpha_{\mathrm{S}}(Q^2)^4\right)\right]$$

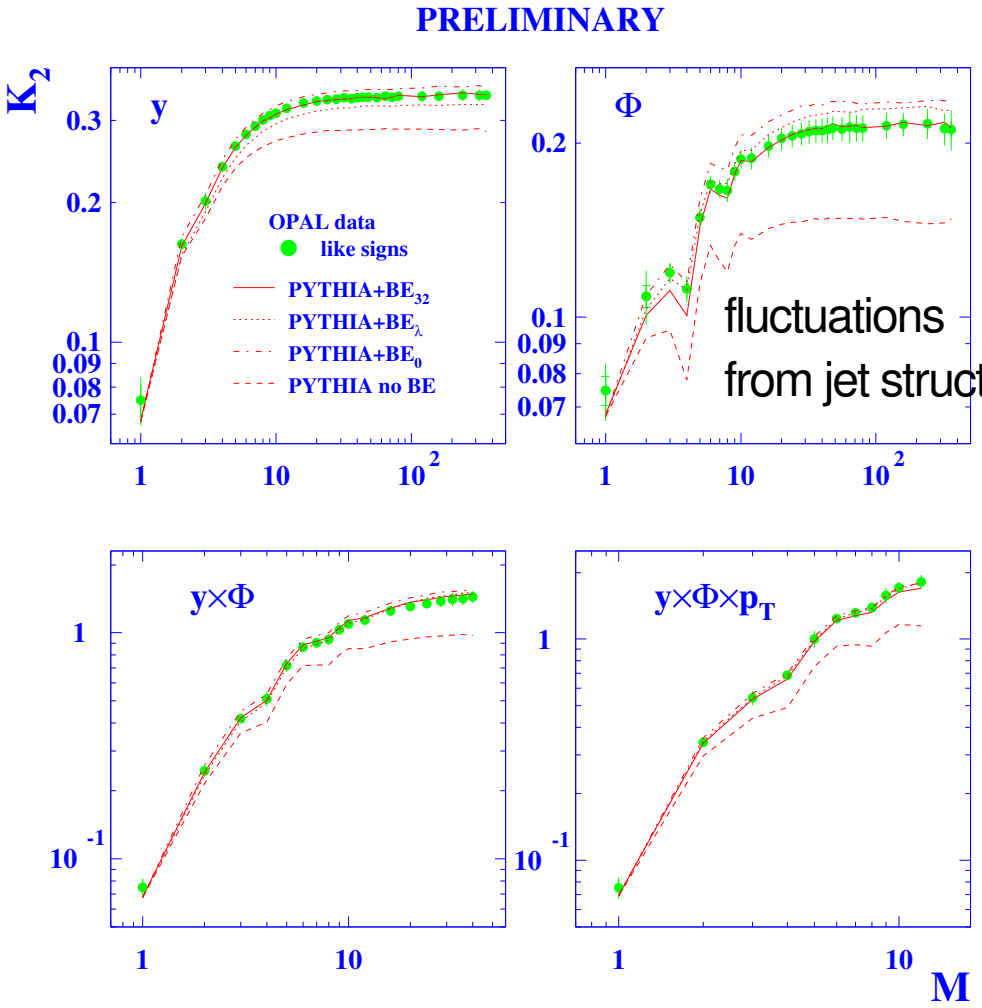
$$B_3 = \frac{R_3^{\mathrm{b}}}{R_3^{\mathrm{dusc}}} = a_0 + a_2 \cdot \overline{m}_{\mathrm{b}}^2$$



seven different jet finders used

$$\overline{m}_{\mathrm{b}}(m_{\mathrm{Z}}) = (2.67 \pm 0.03\ (\mathrm{stat.})^{+0.29}_{-0.37}\ (\mathrm{syst.}) \pm 0.19\ (\mathrm{theo.}))\ \mathrm{GeV}$$

Bose-Einstein correlations between like-sign hadrons



with BE

no BE

fluctuations from jet structure

$$K_2 = \frac{\langle n(n-1)\rangle}{\langle n\rangle^2} - 1$$

n: number of particles/cell

rapidity y, azimuth ϕ, ln p_T

complementary to Q distribution

PYTHIA with various BE models describes data well

Important for W mass studies

long range -> short range

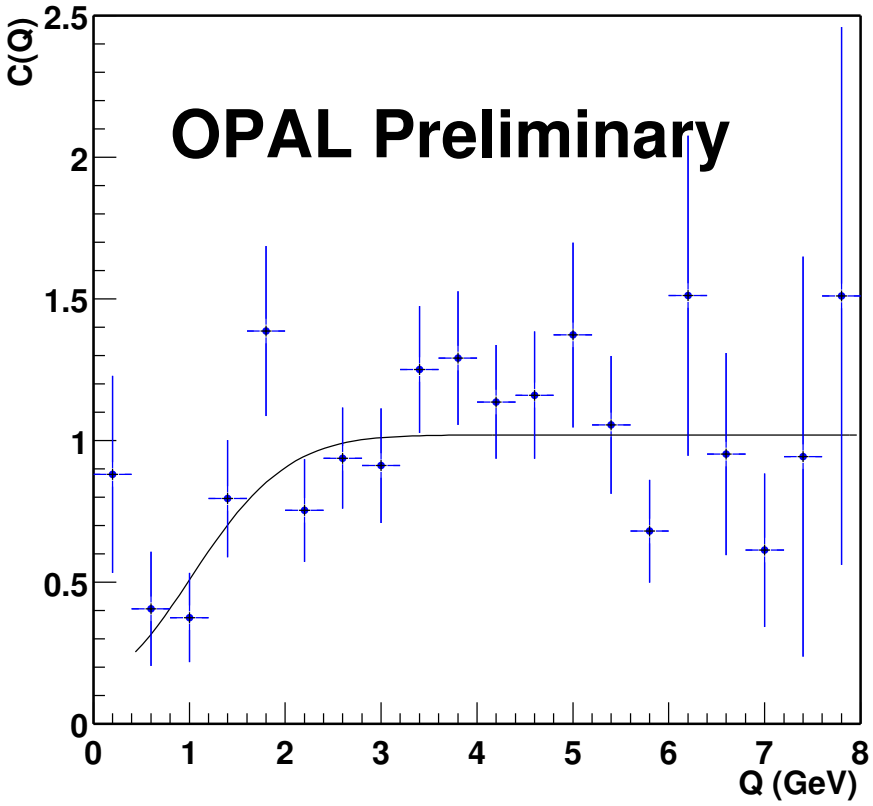
M: number of cells

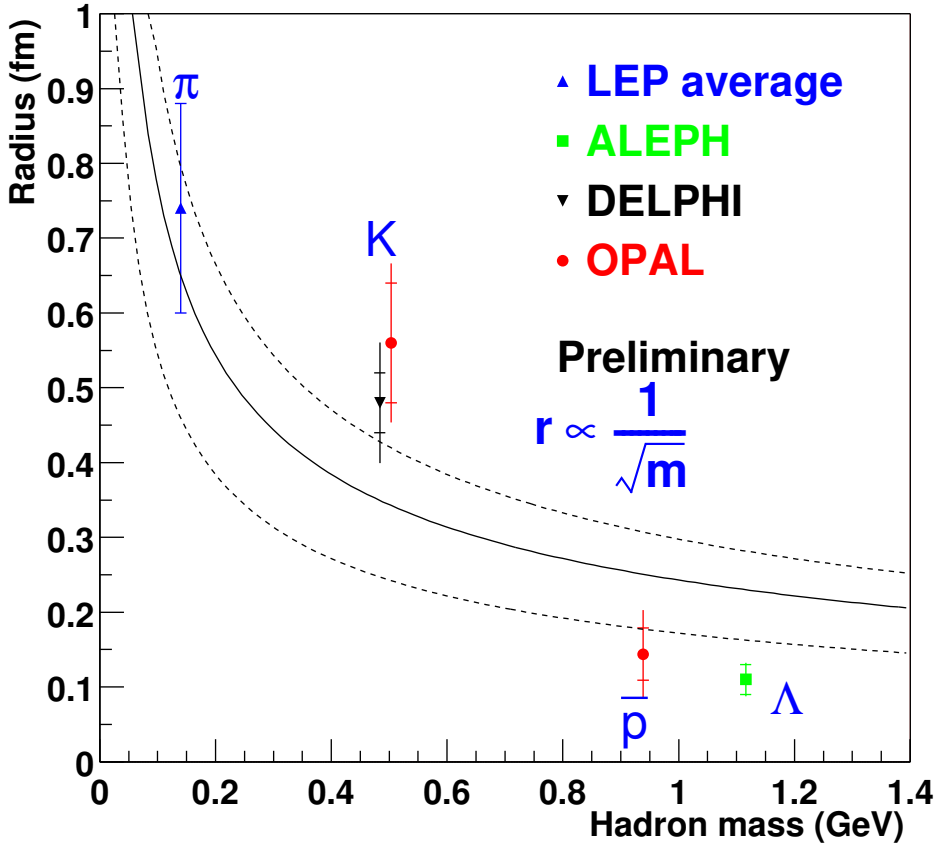
Fermi-Dirac correlation between antiprotons

$$C(Q) \propto 1 \pm \lambda \exp(-r^2 Q^2)$$

+ for Bose-Einstein

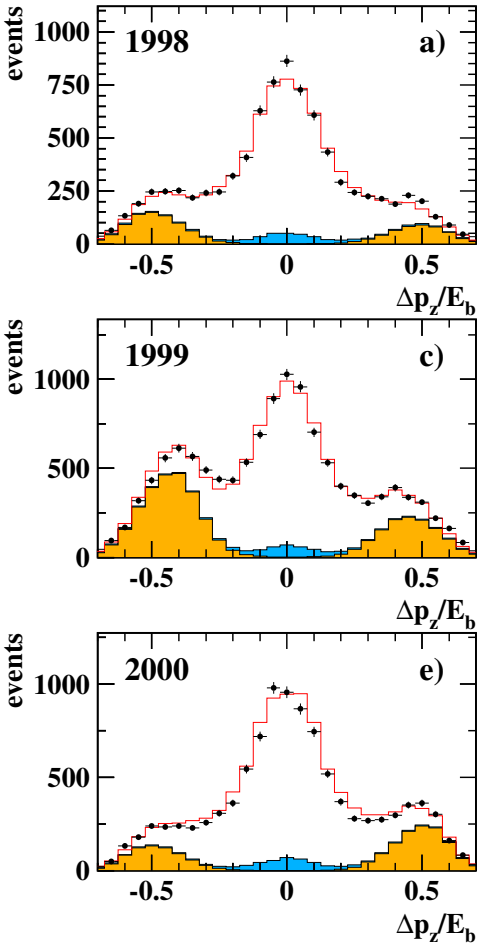
- for Fermi-Dirac



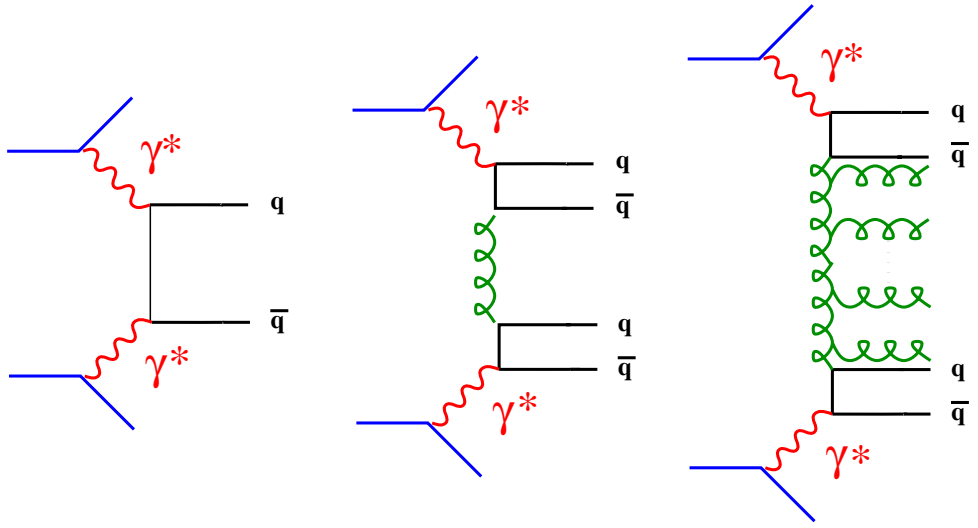


mixed event reference sample

Scattering of virtual photons:



absolute prediction!



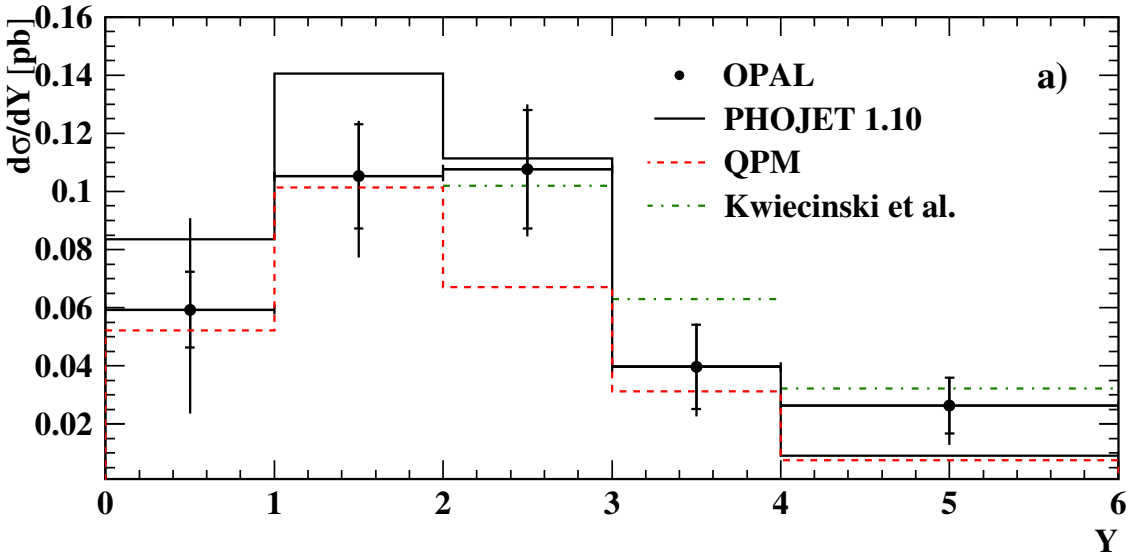
$Q^2_1 \sim Q^2_2$ no DGLAP evolution
no non-perturbative input
'golden' test of BFKL

electrons tagged in SW detectors
(accepting $34<\theta<59$ mrad)

large background from beam-gas
studied using Bhabha & single-tag $e\gamma$ events

132.6 events after background subtraction

ee cross-section



$$\langle Q^2 \rangle = 17.9\,\mathrm{GeV}^2$$

$$\sigma_{\gamma^*\gamma^*} \propto e^{(\alpha_P - 1)Y}$$

$$Y \approx \ln \frac{s_{\gamma\gamma}}{\sqrt{Q_1^2 Q_2^2}} >> 1$$

LO: α_p-1~0.5

LO about one order of magnitude to high at large Y....

GMSB Searches

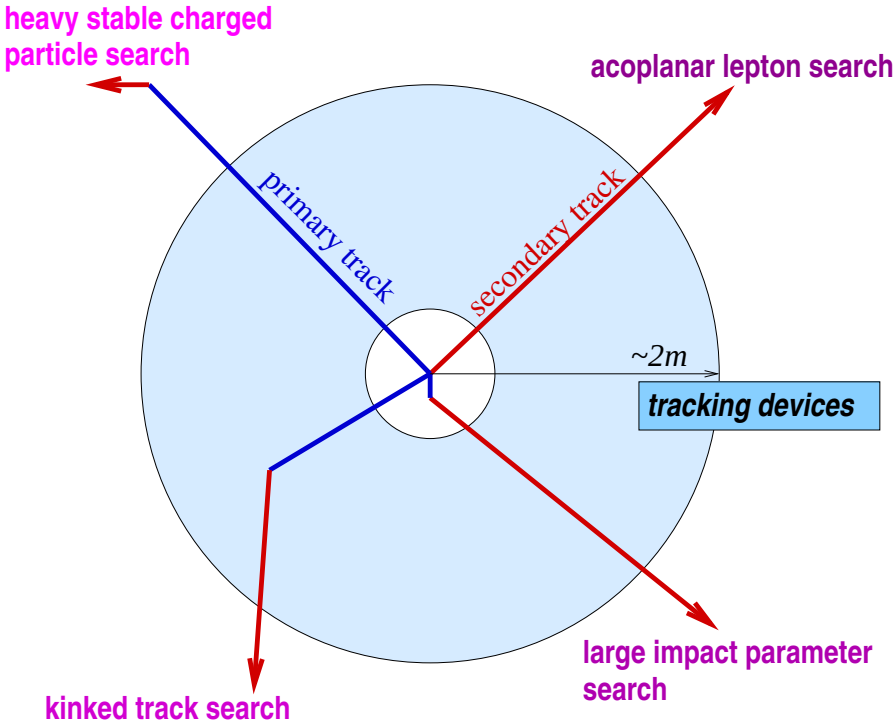
- Gravitino almost massless (LSP)
- Lightest slepton assumed to be NLSP

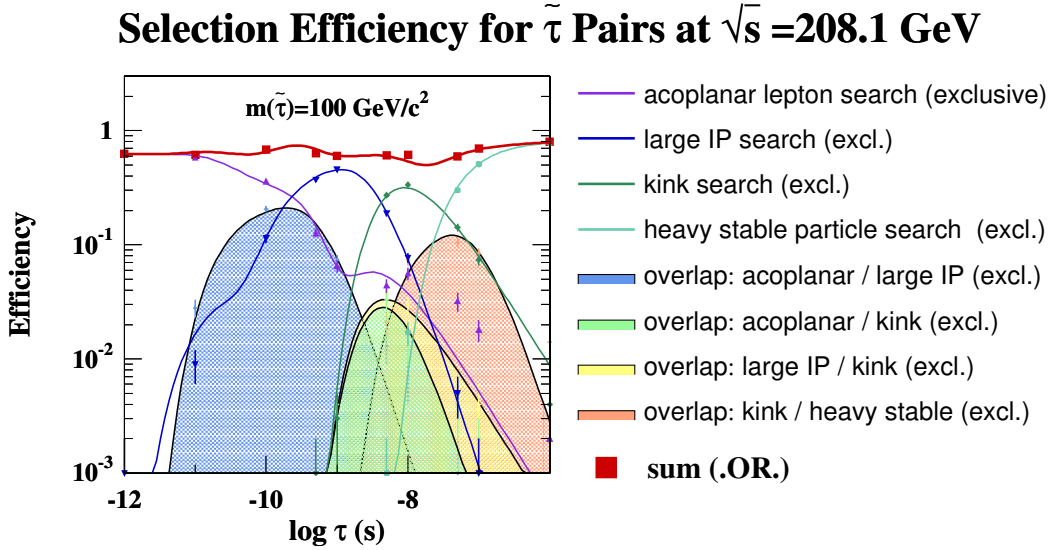
Lifetime of the NLSP given by

$$\beta\gamma c\tau = 0.01 \left(\frac{100\ \mathrm{GeV}}{m_{\tilde{\ell}}}\right)^5 \left(\frac{\sqrt{F}}{100\ \mathrm{TeV}}\right)^4 \left(\frac{E^2_{\tilde{\ell}}}{m^2_{\tilde{\ell}}} - 1\right)^{\frac{1}{2}}$$

SUSY breaking scale $\sqrt{F}$

$$e^+e^- \longrightarrow \tilde{\tau}^+_R \tilde{\tau}^-_R$$
$$\hookrightarrow \tau^- \tilde{G}$$
$$\hookrightarrow \tau^+ \tilde{G}$$

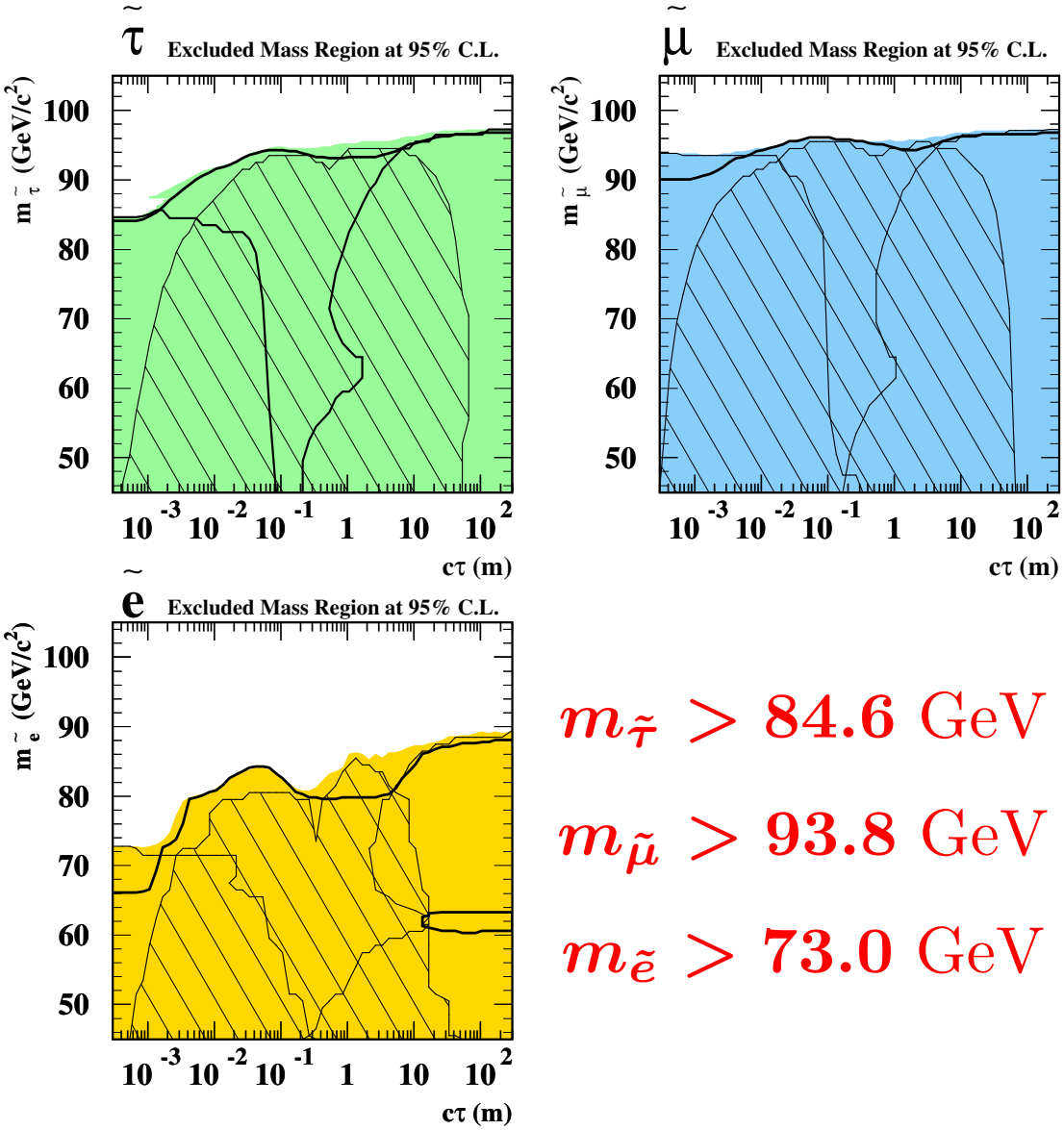




GMSB parameter space scanned

For each slepton flavour the minimal cross-section x BR^2 in the slepton co-NLSP scenario (all sleptons degenerate in mass) is used

lowest mass excluded by the data for all lifetimes

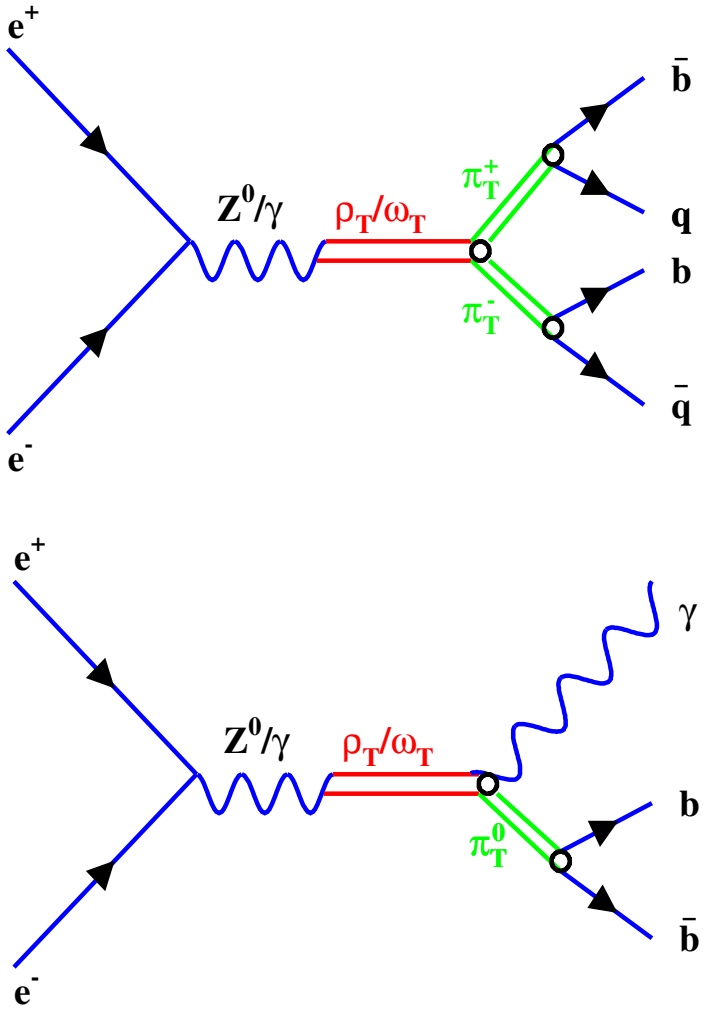


$m_{\tilde{\tau}} > 84.6$ GeV

$m_{\tilde{\mu}} > 93.8$ GeV

$m_{\tilde{e}} > 73.0$ GeV

Search for Technicolour



- Alternative mechanism for electroweak symmetry breaking
- Technicolour Straw Man Model (TCSM)
- $N_{TC}=4$, $N_D=9$,$M_V=200$ GeV,$Q=5/3$

- year 2000 data (L=209 pb^{-1})
- likelihood selection

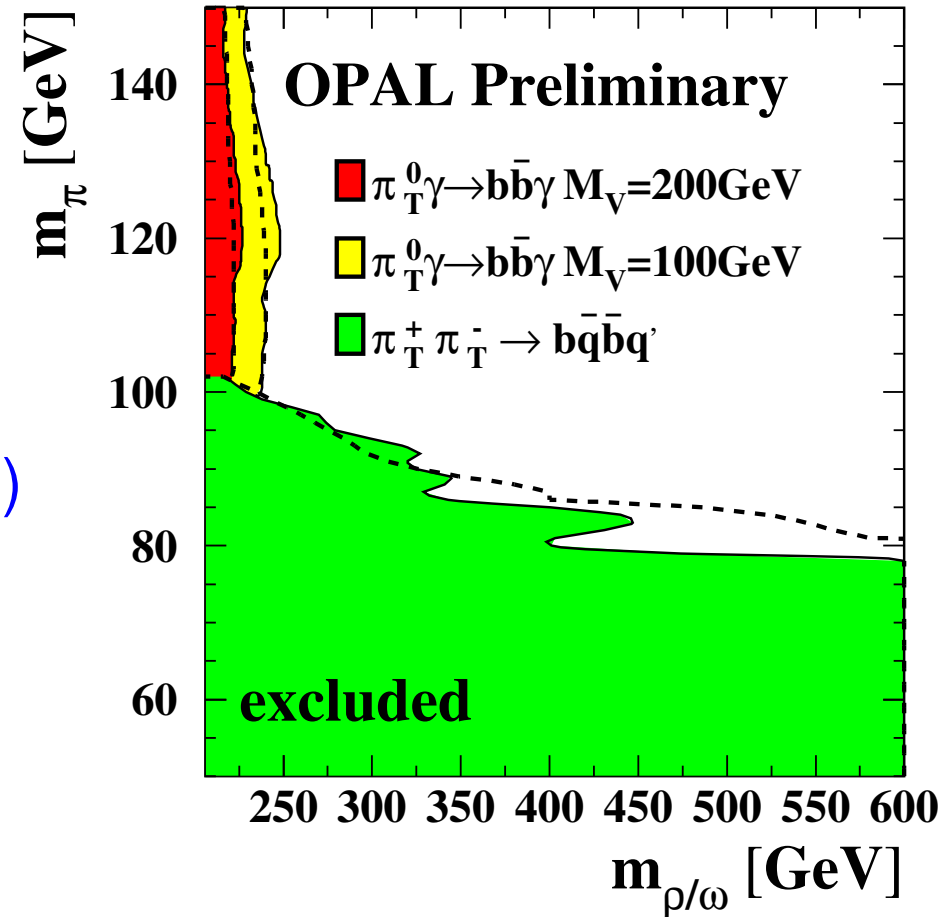
$m_{\rho/\omega} > \sqrt{s}$

accessible due to large Techni-rho decay width

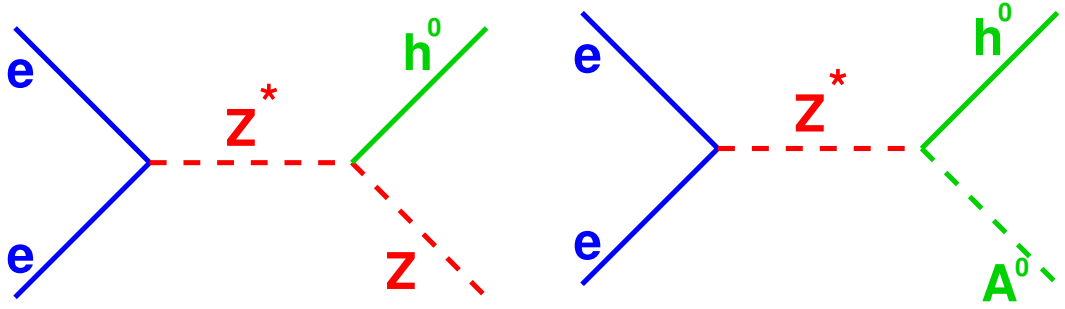
(m_ρ=400 GeV, m_π=50 GeV,Γ_ρ=68 GeV)

$m_{\rho/\omega} < \sqrt{s}$

cross-section dominated by radiative return to ρ/ω, currently not simulated



2HDM (II) interpretation of neutral Higgs boson searches

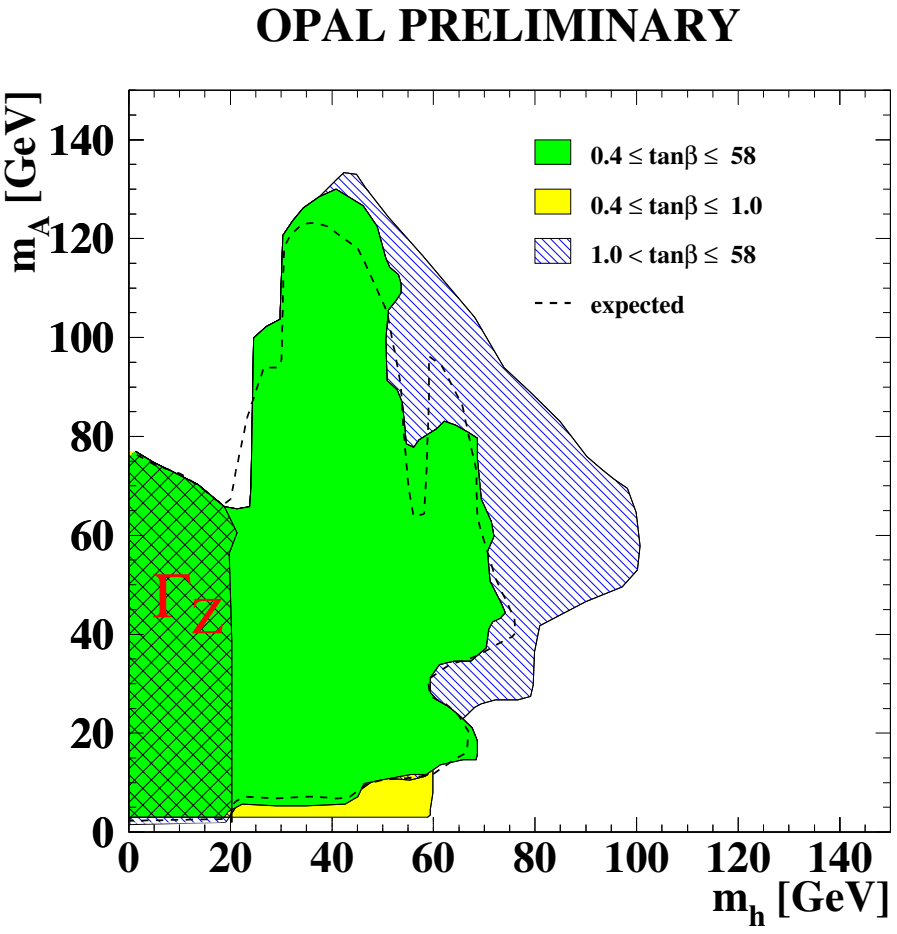


$1\,\mathrm{GeV} \le m_h \le 120\,\mathrm{GeV}$

$3\,\mathrm{GeV} \le m_A \le 2\,\mathrm{TeV}$

$0.4 \le \tan\beta \le 58$

$-\frac{\pi}{2} \le \alpha \le \frac{\pi}{2}$



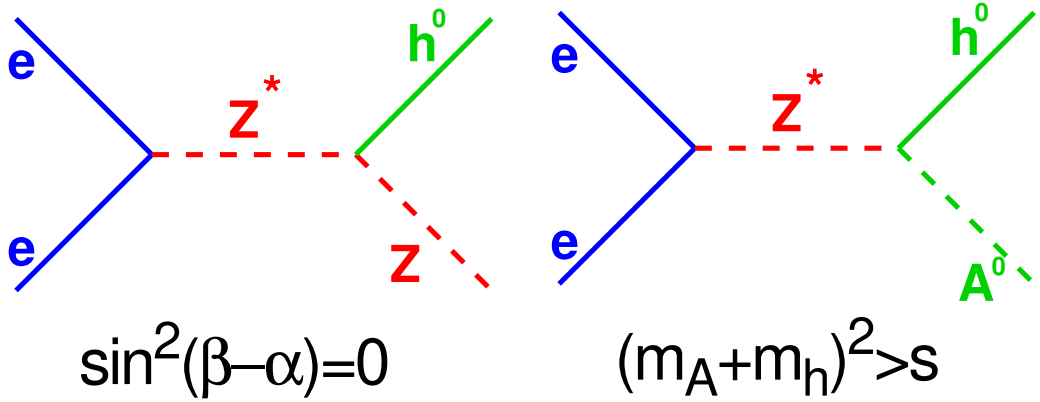
All LEP1 and LEP2 data used

many final states

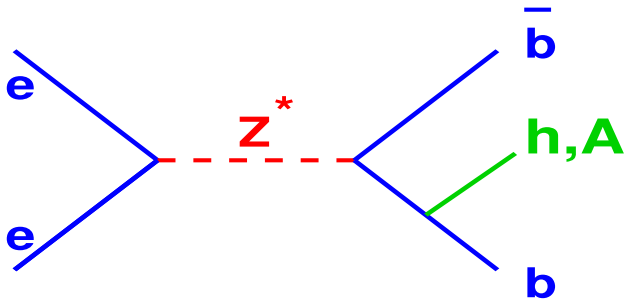
minimal limit for all mixing angles α

Yukawa production of light Higgs bosons

Scenario (2HDM Type II):

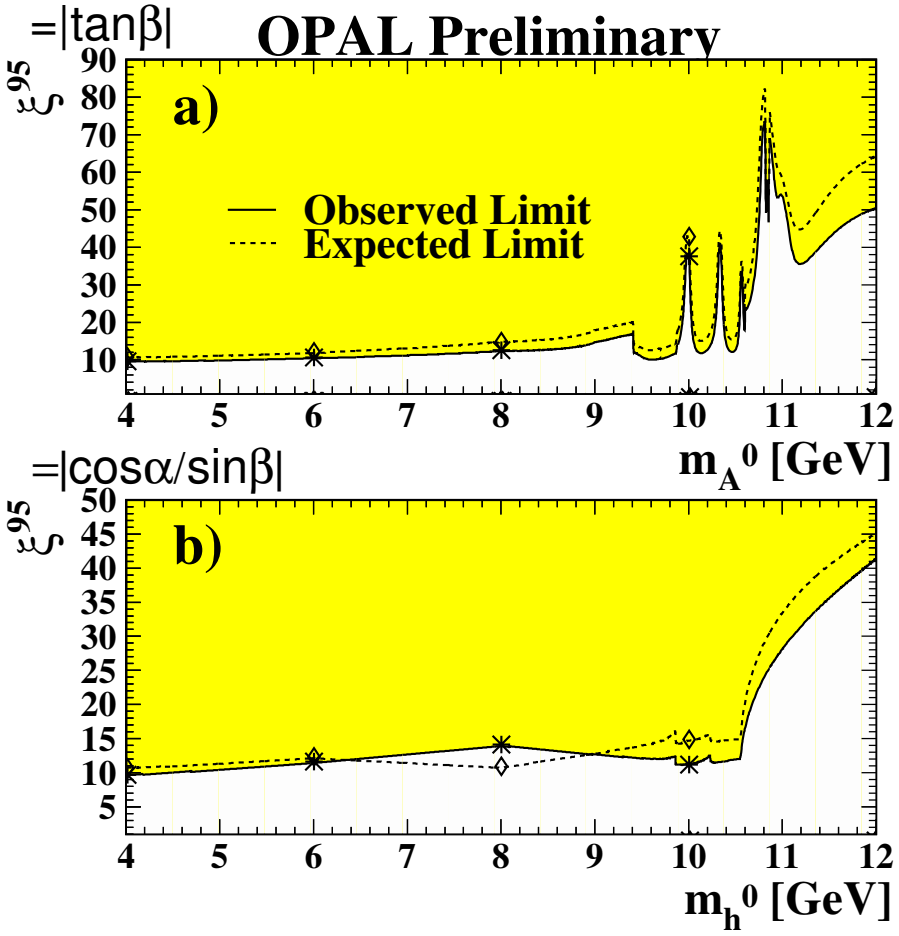


$\sin^2(\beta-\alpha)=0$ $(m_A+m_h)^2>s$



Likelihood selection for three-jet bb$\tau\tau$ final states

$\sigma_{\mathrm{Yukawa}} \propto m_f^2 N_c \xi^2_{A,h}$



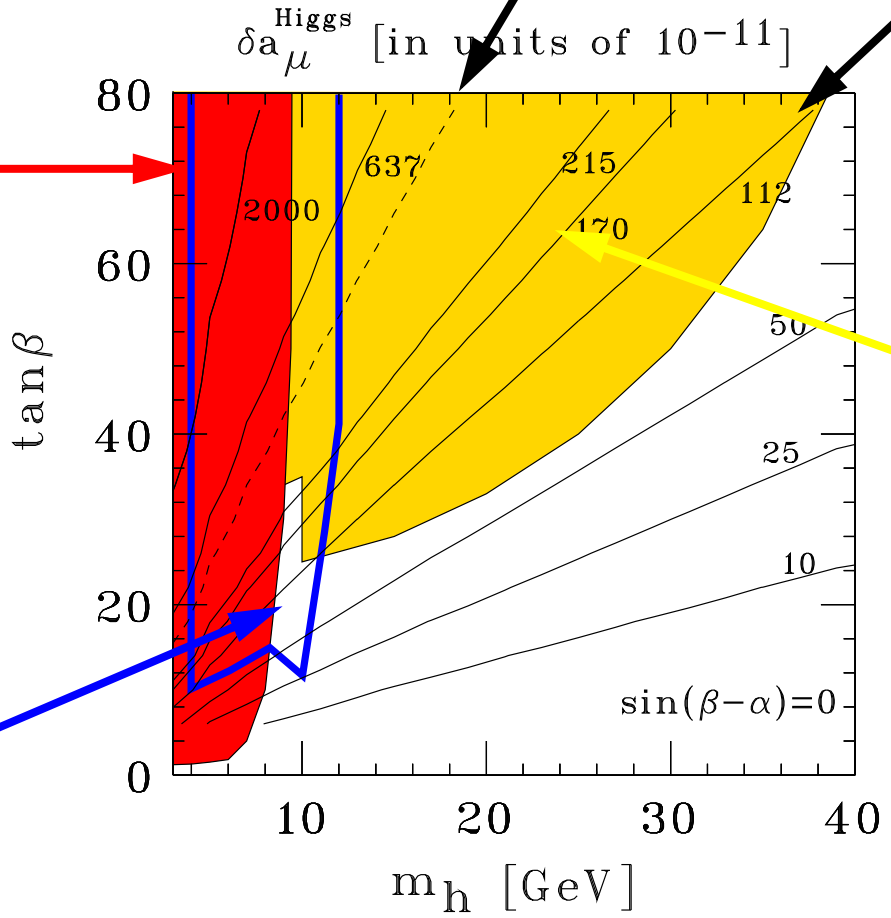
BR model of M.Drees and K.I. Hikasa

A. Dedes and H.E. Haber

central value

90 % CL lower limit consistent with $(g-2)_\mu$

$\Upsilon \to h\gamma$



$\delta a_\mu^{\rm Higgs}$ one loop Higgs sector contribution to (g-2)/2

ALEPH, DELPHI Yukawa search

95 % CL excluded by OPAL

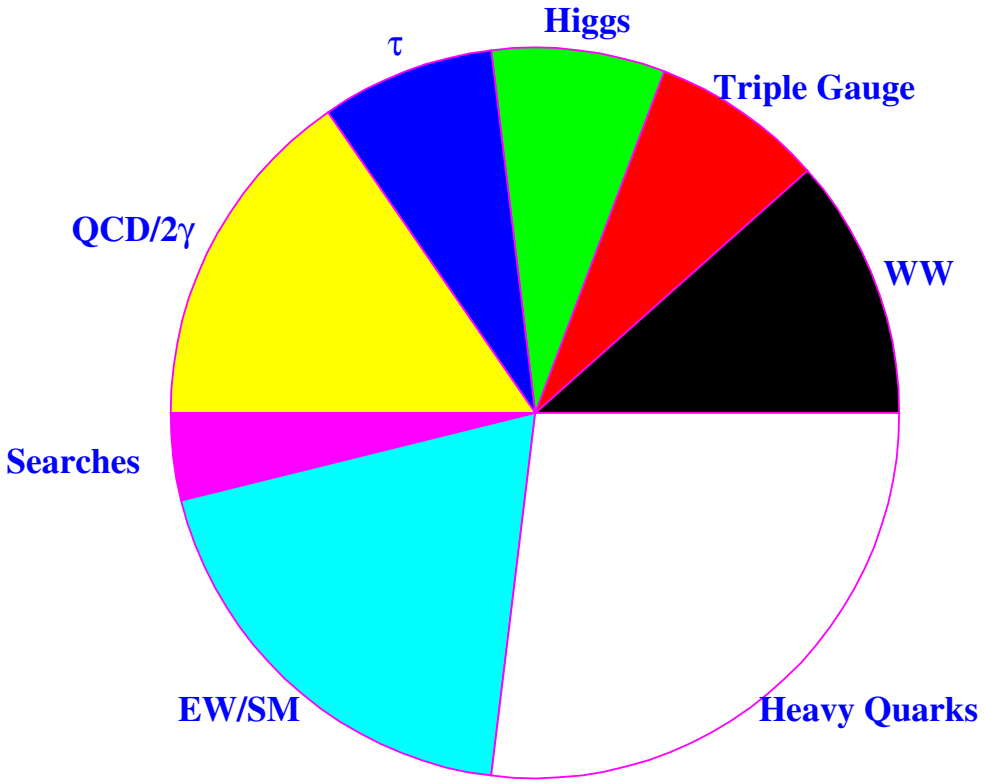
$m_A=m_H=m_{H^+}=200$ GeV

Summary

- We are working hard to turn preliminary results into papers
- My apologies that only a small fraction of the current work could be shown
- More than 80 new journal papers expected until the end of 2003
- Still many interesting analysis topics available for newcomers!

16 LEP1 and 10 LEP2

26 journal papers since July 2000



see http://opal.web.cern.ch/Opal/pubs/eps2001/abstr.html