LEP II $f\overline{f}$ averaging group

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The LEP II $f\overline{f}$ averaging group

A subgroup of the LEP EWWG

Representatives from each of the 4 LEP experiments:

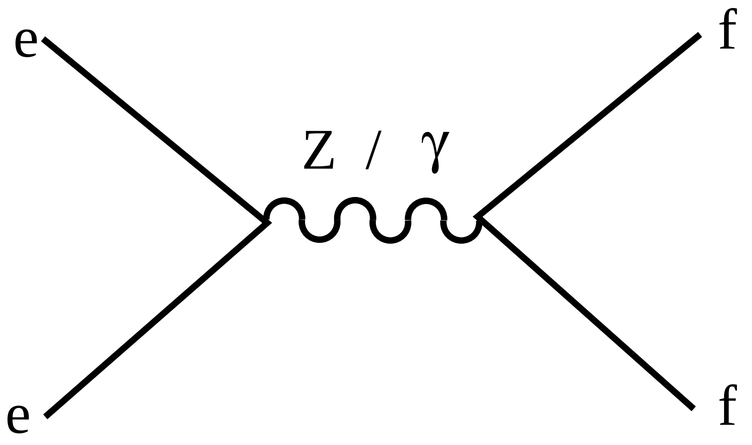
D. Bourilkov, F. Filthaut, J. Holt,
T. Kawamoto, M. Kobel, M-N. Minard,
A. Olshevski, P. Renton, I. Tomalin, P. Ward

Useful discussions with many theorists

in particular:

D. Bardin, S. Jadach, G. Passarino, Z. Was

Outline



- Averages for Summer Conferences in 1999
  - Channels and measurements considered
  - Issues encountered while trying to average data: definition of $\sqrt{s'}$; ISR $\otimes$ FSR ; PP
  - Handling of systematic errors
  - Results obtained - precision
- Ultimate aims
  - Ultimate statistical precision of combined measurements

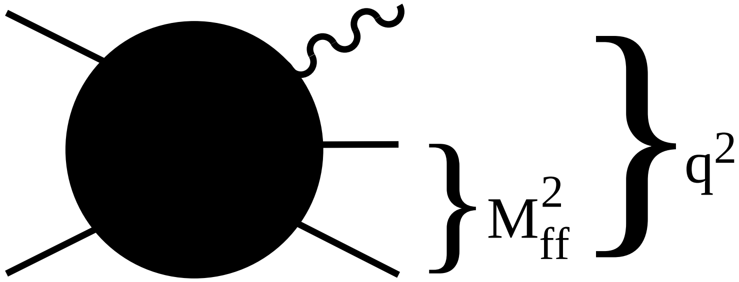
See `http://www.cern.ch/LEPEWWG/lep2` for our note

Averages for 1999 Summer Conferences

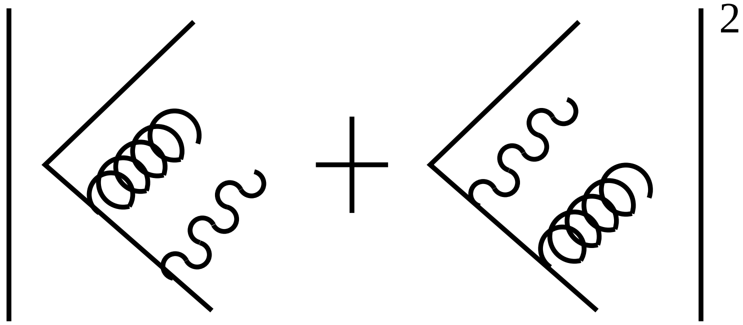
- The first attempt to average LEP results on $f\overline{f}$ production at LEP II
- The aim was to make available a set of numbers which can be used to investigate models of new physics
- Combinations made by EWWG of LEP I results were based on pseudo-observables
- For LEP II directly combine observables: cross-sections, asymmetries
- Started with restricted list of the easiest quantities to average: $\sigma_{\mu\mu}$, $\sigma_{\tau\tau}$, σ_{had}, $A_{fb}^{\mu\mu}$, $A_{fb}^{\tau\tau}$
- Originally took two energy points $\sqrt{s} \sim 183, 189$ GeV, updated with preliminary results from data collected this year at $\sqrt{s} \sim 192, 196$ GeV.
- Only averaged the measurements from events with high $\sqrt{s'/s}$
- Measurements corrected from experimental signal definition to a common definition
- Results shown are preliminary - based in part on preliminary data

Definition of s'

- Different ideas as to what is meant by the s', either:
  - The invariant mass of the difermion system, M^2_{ff}
  - The invariant mass of the exchanged boson, q^2

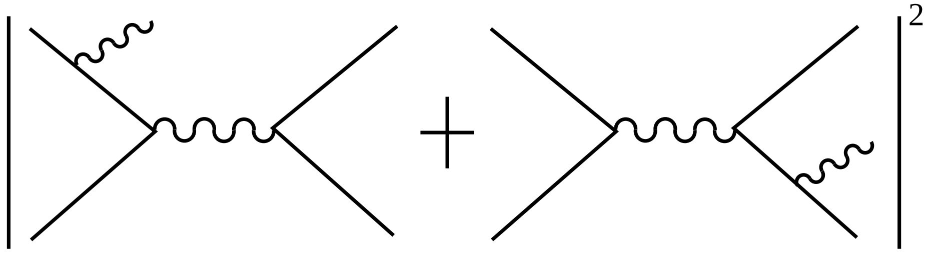


- $s' = M^2_{ff}$ or q^2 is always an approximation
- Best approximation can vary from channel to channel
  - depends on how s' is estimated
    - from the angles/4-momenta of fermions/jets
    - visible photon energy is/isn't summed
  - For hadronic final states photon and gluon radiation can interfere $\longrightarrow$ M^2_{ff} ambiguous



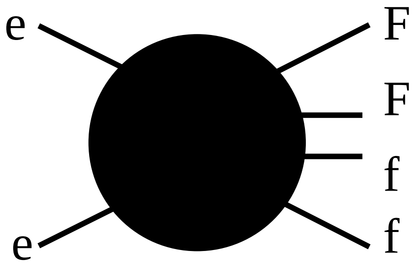
- Produced results for two different definitions
  - $s' = q^2$ with $\sqrt{s'/s} > 0.85$
  - for l^+l^-: $s' = M^2_{ff}$ with $\sqrt{s'/s} > 0.85$ for hadrons: $s' = q^2$ with $\sqrt{s'/s} > 0.85$
- With suitable MC can always change from one definition to another

ISR $\otimes$ FSR Interference



- Analytic calculations of ISR $\otimes$ FSR only performed to $\mathcal{O}(\alpha)$
- Existing generators could be used with/without $\mathcal{O}(\alpha)$ ISR $\otimes$ FSR
- Known that higher orders important at LEP II
- Usual that fully simulated events, used for efficiency calculations, had no ISR $\otimes$ FSR
- In future will use KK2f with exponentiation of ISR $\otimes$ FSR
- My personal suggestion
  - Include ISR $\otimes$ FSR for efficiency calculations
  - Compare generator with/without ISR $\otimes$ FSR
  - Correct measurements to no ISR $\otimes$ FSR
  - Easy to compare to analytic calculations excluding ISR $\otimes$ FSR
- Should not be a problem in future

Pair Production



- What is signal, what is background ?
  - $\gamma\gamma$ collisions - background ?
  - IS $\gamma \rightarrow e^+e^-$ in beampipe - signal ?
- Made approximation that signal corresponded to integration over ISPP radiator function with $s' > 0.85\sqrt{s}$ in ZFITTER.
- Personal opinion: need cut on energy/mass and angles
- Need to carefully study the interface between 2f and 4f MC and analytic calculations

Signal definitions

- **Definition 1**
  - **all $f\overline{f}$:** $s' = q^2$; ISR $\otimes$ FSR subtracted; $\sqrt{s'/s} > 0.85$; Pairs $\sqrt{s'_{pair}} > 0.85\sqrt{s}$; 4π
- **Definition 2**
  - l^+l^-: $s' = M^2_{ff}$; ISR $\otimes$ FSR included; $\sqrt{s'/s} > 0.85$; Pairs $\sqrt{s'_{pair}} > 0.85\sqrt{s}$; 4π
  - **hadrons:** $s' = q^2$; ISR $\otimes$ FSR included but computed for $s' = M^2_{ff}$; $\sqrt{s'/s} > 0.85$; Pairs $\sqrt{s'_{pair}} > 0.85\sqrt{s}$; 4π
- Correct from experimental definition of signal to common definition by scaling measurements by the ratio of the SM predictions for the common definition to the predictions for the experimental definition
- Differences in definition corresponds to changes in SM predictions of:

$\Delta\sigma_{had} \sim -0.45\%$; $\Delta\sigma_{\mu\mu} \sim -4.08\%$; $\Delta\sigma_{\tau\tau} \sim -1.50\%$; $\Delta A^{\mu\mu}_{fb} \sim 0.019$; $\Delta A^{\tau\tau}_{fb} \sim 0.018$

Where $(\Delta X = X_2 - X_1/X_1)$

Systematic Errors

- Treatment of experimental errors
  - Split Systematics into 5 categories:
    1) The statistical uncertainty plus uncorrelated systematic uncertainties, added in quadrature.
    2) The systematic uncertainty for the final state X which is fully correlated between energy points for that experiment.
    3) The systematic uncertainty for experiment Y which is fully correlated between different final states for this energy point.
    4) The systematic uncertainty for the final state X which is fully correlated between energy points and between different experiments.
    5) The systematic uncertainty which is fully correlated between energy points and between different experiments for all final states.
- Additional Theoretical Uncertainty
  - Comparison of codes in factors to correct predictions to a common signal definition $\Delta\sigma_{had} \sim 0.2\%$ $\Delta\sigma_{ll} \sim 0.7\%$ $\Delta A_{fb}^{ll} \sim 0.003$
  - Need a more realistic evaluation - options in codes

Results: Definition 1

Averages: Correlation Matrix:

183	XSEC-QQ	24.575±0.434	1.000	0.011	0.020	0.000	0.000	0.189	0.011	0.010	0.000	0.000
183	XSEC-MUMU	3.498±0.146	0.011	1.000	0.005	0.000	0.000	0.010	0.100	0.004	0.000	0.000
183	XSEC-TAUTAU	3.438±0.177	0.020	0.005	1.000	0.000	0.000	0.009	0.004	0.095	0.000	0.000
183	AFB-MUMU	0.547±0.033	0.000	0.000	0.000	1.000	0.010	0.000	0.000	0.000	0.040	0.000
183	AFB-TAUTAU	0.615±0.045	0.000	0.000	0.000	0.010	1.000	0.000	0.000	0.000	-0.002	0.031
189	XSEC-QQ	22.410±0.249	0.189	0.010	0.009	0.000	0.000	1.000	0.019	0.017	0.000	0.000
189	XSEC-MUMU	3.194±0.083	0.011	0.100	0.004	0.000	0.000	0.019	1.000	0.008	0.000	0.000
189	XSEC-TAUTAU	3.138±0.102	0.010	0.004	0.095	0.000	0.000	0.017	0.008	1.000	0.000	0.000
189	AFB-MUMU	0.563±0.022	0.000	0.000	0.000	0.040	-0.002	0.000	0.000	0.000	1.000	0.036
189	AFB-TAUTAU	0.597±0.028	0.000	0.000	0.000	0.000	0.031	0.000	0.000	0.000	0.036	1.000

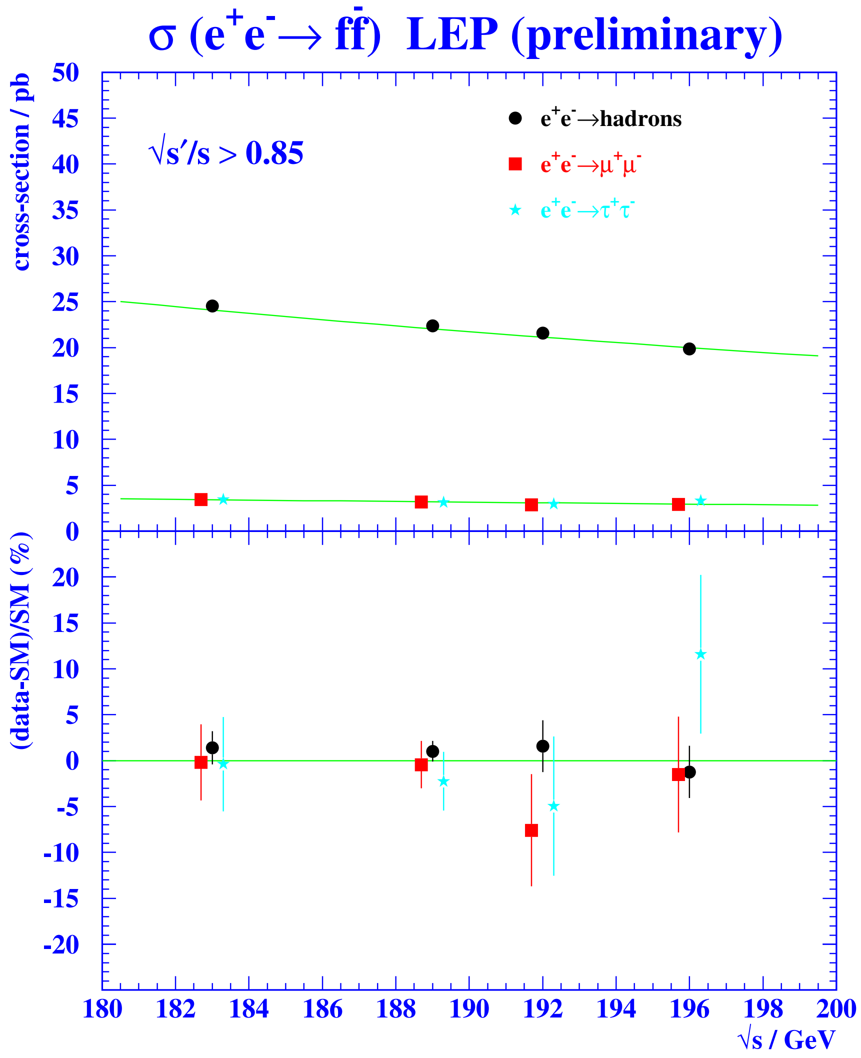
Chi-squared / d.o.f 25.404 / 30

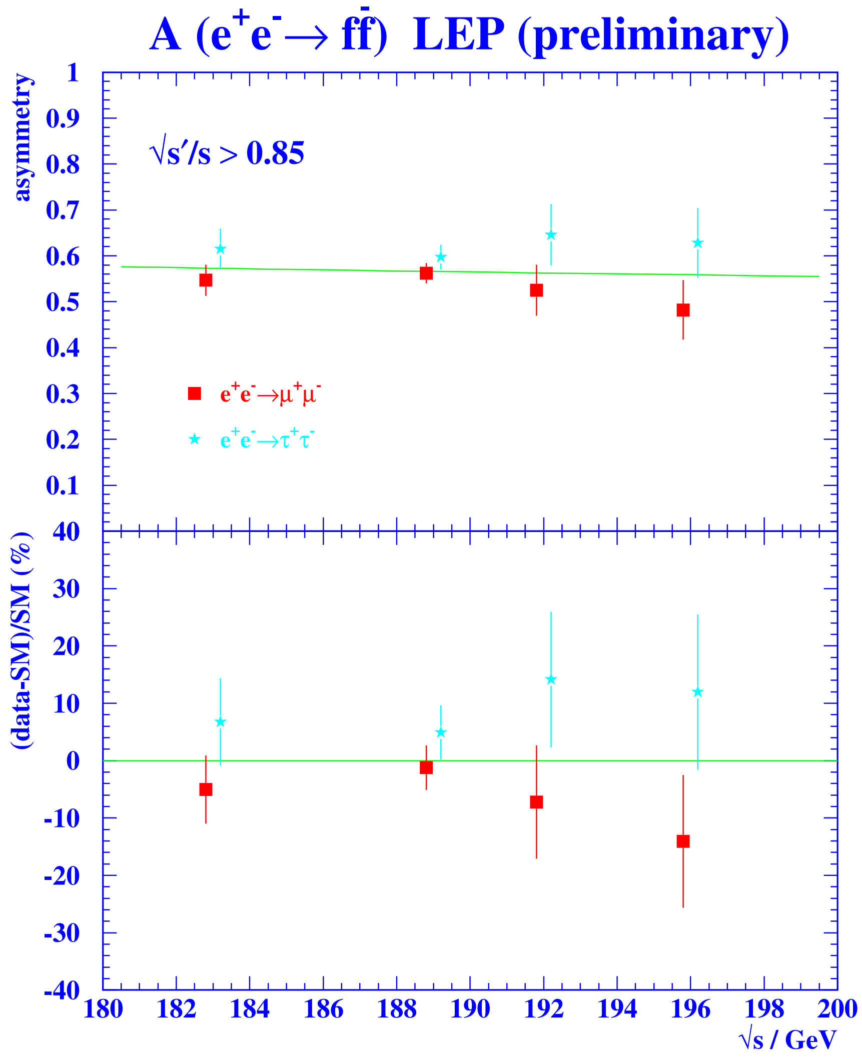
Precision of combined $\sqrt{s} \sim 189$ data

$\sigma_{had} \sim 1.0\%$, $\sigma_{\mu\mu} \sim 2.5\%$, $\sigma_{\tau\tau} \sim 3.0\%$, $A_{fb}^{\mu\mu} \sim 0.02$, $A_{fb}^{\tau\tau} \sim 0.03$

Correlations small; largest between $\sigma_{had}(183)$ and $\sigma_{had}(189) \sim 20\%$

Results


σ (e+e- → ff̄) LEP (preliminary)
cross-section / pb
√s′/s > 0.85
e+e-→hadrons
e+e-→μ+μ-
e+e-→τ+τ-
(data-SM)/SM (%)
√s / GeV


A (e+e- → ff̄) LEP (preliminary)
asymmetry
√s′/s > 0.85
e+e-→μ+μ-
e+e-→τ+τ-
(data-SM)/SM (%)
√s / GeV

Future Aims

- Include all LEP II energy points
- Include electrons
- Revisit signal definition in light of improvements in MC/calculations
- Probably try to combine angular distributions $d\sigma/d\cos\theta$
- Include results on flavour tagged hadronic final states

Final Precision

- Estimate of final statistical precision with all LEP2 data :
  - just high $\sqrt{s'/s}$
  - assume 4 experiments $\times \int \mathcal{L} dt = 600$ pb^{-1}
  - assume all data at $\sqrt{s} = 200$ GeV
  - this sets scale for theoretical uncertainties which tend to be correlated between experiments and energy points
  - $\sigma_{had} \sim 0.5\%$, $\sigma_{\mu\mu} \sim 1.2\%$, $\sigma_{\tau\tau} \sim 1.5\%$, $A_{fb}^{\mu\mu} \sim 0.010$, $A_{fb}^{\tau\tau} \sim 0.015$

Conclusions

- A preliminary combination of results on $f\overline{f}$ production at LEP II has been made
- Precision obtained: $\sigma_{had} \sim 1.0\%$, $\sigma_{\mu\mu} \sim 2.5\%$, $\sigma_{\tau\tau} \sim 3.0\%$, $A_{fb}^{\mu\mu} \sim 0.02$, $A_{fb}^{\tau\tau} \sim 0.03$
- Correlations small except for σ_{had}; may grow when extra data included
- Number of problems encountered in defining a common signal definition
  - definition of $\sqrt{s'}$; ISR $\otimes$ FSR ; PP
- These problems need further study to be resolved
- Would benefit from:
  - Improved MC
  - Improved analytic calculations
- Combination would also benefit from:
  - Better ways of evaluating theoretical uncertainties
  - Smaller theoretical uncertainties