Aspects of W mass measurements at e^+e^- Colliders

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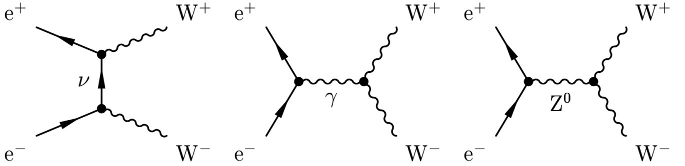
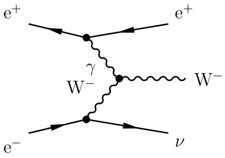




Single W

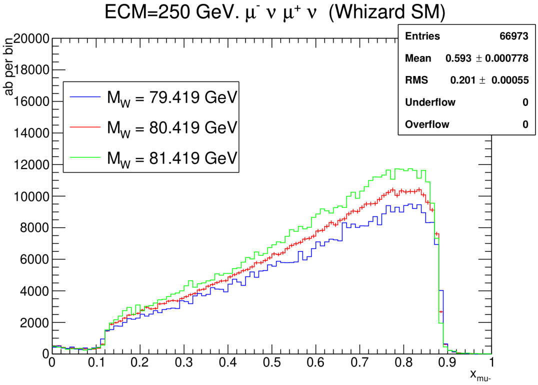
W^+W^- production

I focused on work for my second talk today - so have little to report on this topic. For a general intro. see Paolo's talk this morning and also a relatively recent talk.

Introduction

Several years ago I had looked into the potential m_W sensitivity of leptonic end-points and di-leptonic pseudo-mass observables at center-of-mass energies above 200 GeV, and "discovered" some strange dependence of the WW cross-section calculated with Whizard.

Leptonic $\mathrm{M_W}$: $x_{\mu^-} = E_{\mu^-}/E_{\mathrm{b}}$



Sensitivity to $\mathrm{M_W}$ from edges and from normalization (NB σ increases with $\mathrm{M_W}$!)

Effect seems real

Effect seems real. WW has rich SM physics

Mod. Phys. Lett. A 1986.01:203-210

T. Muta et al. see same cross-over behaviour.

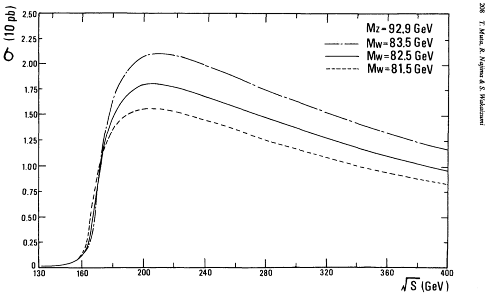
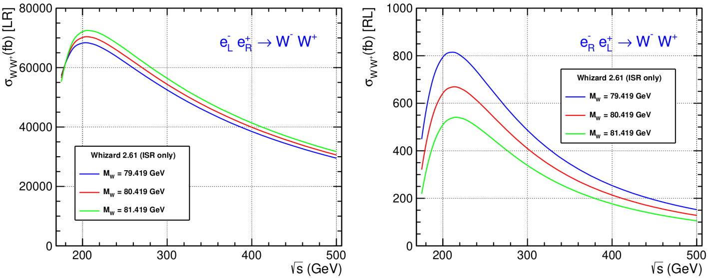


Fig. 3(b) The W-boson-mass dependence of the total cross section with finite W-boson width.

Striking dependence on initial-state polarization

Initial State Polarization Dependence

LR has contributions from ν_e, γ and Z channels and their interferences.
RL has only contributions from the γ and Z channels and their interference.



$\mathrm{M_W}$ sensitivity remarkably different both in size and sign

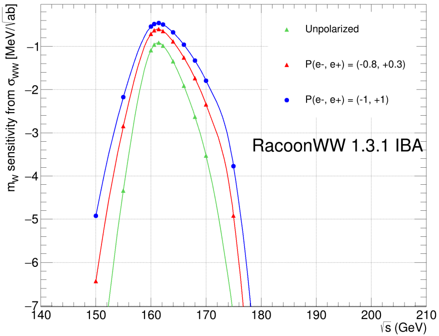
What next

- Was not sure the results should be believed and was unable to do cross-checks recommended at the time by Whizard authors.
- What I have done now, both with the perspective of precision luminosity for WW at 240 GeV and above, and the renewed interest in m_{W}, is to revisit these predictions using more of a state of the art LEP2 program following Stefan Dittmaier's suggestions. Obviously not the final word given approximations but should get at the approximate sensitivity.
- Found and "digested" some of the older (too old?) theory papers including some like Aoki, Hioki, Hagiwara-Zeppenfeld that addressed such issues.
- What follows are the plots of apparent m_{W} sensitivity calculated using RacoonWW. Signed deviations are plotted. The uncertainty should be the absolute value of the signed deviation.

W Mass Sensitivity from Cross-Section

As is well known, σ_{WW} near threshold depends directly on m_{W}. For 100% efficiency, zero background, at known $\sqrt{s}$,

$$\Delta m_{\mathrm{W}} = \sqrt{\sigma_{WW}} \left(\frac{d\sigma_{WW}}{dm_{\mathrm{W}}} \right)^{-1} \frac{1}{\sqrt{\mathcal{L}}} .$$

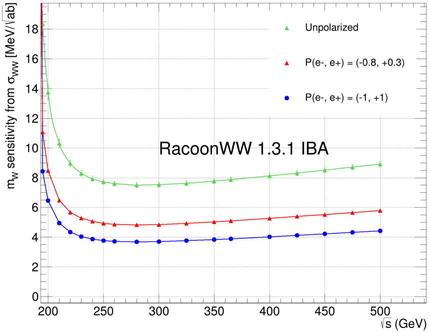


- Calculate σ_{WW} with RacoonWW in G_μ scheme with IBA for various m_{W}.
- Estimate the above blue sensitivity factor.
- Negative so derivative is negative. Higher σ_{WW} implies lower m_{W}.

W Mass Sensitivity from Cross-Section

This can also be done at other values of $\sqrt{s}$. For 100% efficiency, zero background, at known $\sqrt{s}$,

$$\Delta m_{\mathrm{W}} = \sqrt{\sigma_{WW}} \left(\frac{d\sigma_{WW}}{dm_{\mathrm{W}}} \right)^{-1} \frac{1}{\sqrt{\mathcal{L}}} .$$



- Calculate σ_{WW} with RacoonWW in G_μ scheme with IBA for various m_{W}.
- Estimate the above blue sensitivity factor.
- Positive so derivative is positive. Higher σ_{WW} implies higher m_{W}.

Shallow Higgs-factory optimum at around $\sqrt{s} = 280$ GeV

What is going on?

The G_μ-scheme chooses $(G_\mu, m_{\rm Z}, m_{\rm W})$ as the 3 SM input parameters to describe EW interactions. This contrasts with the conventional one of the best measured values $(\alpha, G_\mu, m_{\rm Z})$ used in Z physics studies.

In addition to some kinematic dependences associated with $m_{\rm W}$ that are more observable in differential distributions, the coupling associated with the t-channel neutrino exchange, namely,

$$g^2 = e^2/\sin^2\theta_W = 4\sqrt{2}G_\mu m_{\rm W}^2$$

is directly determined by G_μ and $m_{\rm W}$ at tree level, and so the cross-sections are directly affected in the sense that the weak charge depends directly on $m_{\rm W}$.

- I understand that this is not seemingly the best way to "measure $m_{\rm W}$ unambiguously" as a kinematic mass parameter. Also see (too old) literature.
- But it is a very well motivated direction to directly test the SM and its consistency in the W sector. What new physics a deviation may/may not be able to point to, may be a topic for EFT advocates but does not diminish the utility of a powerful test with falsifiability.
- For our purposes, I think the essence is to figure out whether there are new constraints on detectors / physics program / accelerator options.
- One immediate one. More focus on absolute lumi. at high $\sqrt{s}$. See later talk!
- END OF TALK ONE