What's new

- Beam energy spread
- ISR
- J/ψ production around ZH runs

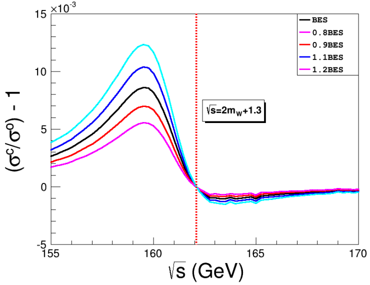
Beam energy spread

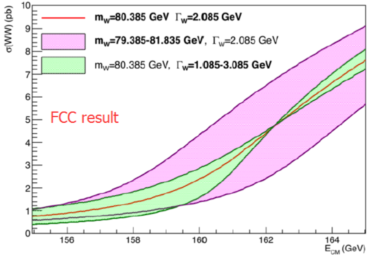
With the beam energy spread, the $\sigma_{W^+W^-}$ becomes:

$$\begin{aligned}\sigma_{W^+W^-}(E) &= \int_0^{\infty} \sigma(E^{'}) \times G(E, E^{'}) dE^{'} \\ &\approx \int_{E-6\sqrt{2}E_{BS}}^{E+6\sqrt{2}E_{BS}} \sigma(E^{'}) \times \frac{1}{\sqrt{2\pi}\sqrt{2}E_{BS}} e^{\frac{-(E-E^{'})^2}{2(\sqrt{2}E_{BS})^2}} dE^{'}\end{aligned} \tag{1}$$

For simulation, $E_{BS} = E_{BS}^0 + \Delta E_{BS}$, and $E_{BS} = E_{BS}^0$ for the fit formula. Here, the ΔE_{BS} is the shift between true value of data and the nominal one in the fit.

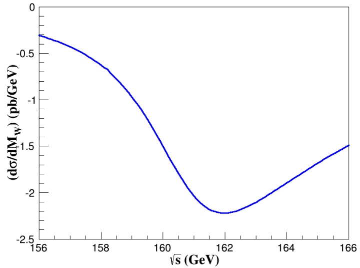
The relationship between σ^0 and σ^c is shown below, where σ^0 is the theoretical cross section (Gentle), and σ^c are the ones calculated by convoluting σ^0 with different BES:

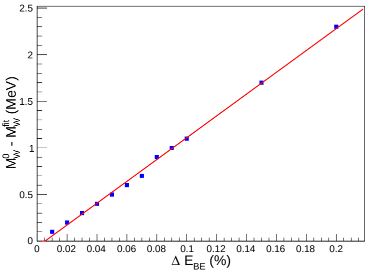




The uncertainty of BES free the m_W when taking data around $2m_W + 1.3$ GeV! (Gentle)

The left plot below shows the negative correlation between σ and m_W. The right plot and table below show the results when taking data at $E = 161.2$ GeV, with the $\Delta E_{BS}/E_{BS} \in [0.01, 0.2]$.



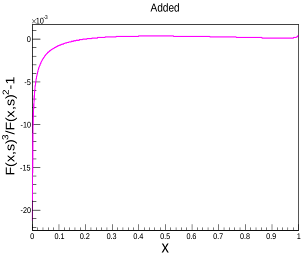


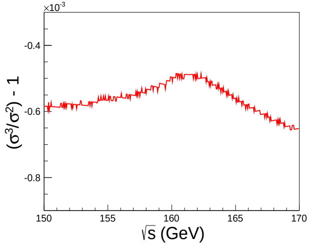
ΔE_{BE} (%)	20	15	10	9	8	7	6	5	4	3	2	1
m_W shift (-MeV)	2.3	1.7	1.1	1.0	0.9	0.7	0.6	0.5	0.4	0.3	0.2	0.1

If we taking data at $E = 162.1$ GeV, the σ^c is independent of ΔE_{BS}.

ISR

With the QED radiator to both NL O(α^2) and O(β^3), the results about ISR are updated. ▸ https://www.sciencedirect.com/science/article/pii/S0370269397007053
▸ https://arxiv.org/pdf/hep-ph/0107154.pdf





If we just conservatively take 0.6‰ as the uncertainty of ISR, the $\Delta m_W \simeq 0.4$ MeV.

$e^+e^- \to \gamma_{ISR} q\bar{q}$

The observed cross section is:

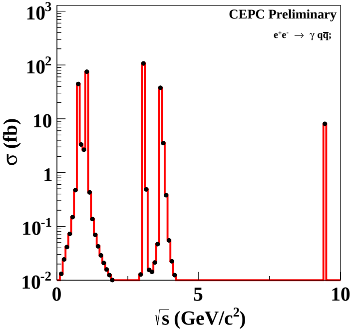
$$\sigma_{\mathrm{obs}}(s) = \int \sigma_B(s(1-x)) \cdot W(s,x) dx \tag{2}$$

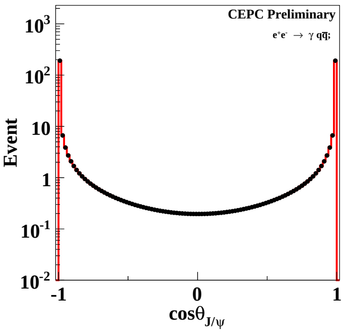
The $W(s,x)$ is the radiator, $\sigma_B(s)$ is the Born cross section. For the narrow resonance, the $\sigma_B(s)$ is given by the standard Breit-Wigner formula:

$$\sigma_B(s) = \frac{12\pi m^2 \Gamma_{ee}^2}{(s-m^2)^2 + m^2\Gamma^2}, \tag{3}$$

where m and Γ are the mass and width of resonance, Γ_{ee} is the partial width to e^+e^-.

Distributions for σ and polar angle





240 (GeV)	ω	ϕ	J/ψ	$\psi(2S)$
σ_{tot} (fb)	42.4	75.7	106.4	37.7
Accept.($\lvert cos\theta < 0.98 \rvert$)	0.14	0.14	0.14	0.14

Summary, questions and next to do

- The statistic and systematic uncertainties of m_W are studied, such as ΔE, ΔISR, $\Delta\mathcal{L}$, and ΔE_{BS}.
- The effect of above uncertainties on Γ_W should be studied.
- Optimize the data taking based on the two results above.
- Which one should be put first when optimizing the data taking? Δm_W, $\Delta\Gamma_W$, or simultaneous optimization?

Backup

Formula for polar angle of γ_{ISR}

The polar angle distribution for γ_{ISR} https://arxiv.org/abs/hep-ph/9910523v1:

$$P(\theta) = \frac{\sin^2\theta - \frac{x^2\sin^4\theta}{2(x^2-2x+2)} - \frac{m_e^2}{E^2}\frac{(1-2x)\sin^2\theta - x^2\cos^4\theta}{x^2-2x+2}}{(\sin^2\theta + \frac{m_e^2}{E^2}\cos^2\theta)^2}, \quad (4)$$

where $s = 4E^2$, E is the beam energy, m_e is the electron mass, $x = E_\gamma/E$.
The probability for the hard photon inside the opening angle θ_m

$$P(0 \le \theta \le \theta_m) = \frac{h(\theta_m)}{h(\pi)}, h(\theta_m) = \int_0^{\theta_m} P(\theta)\sin\theta d\theta, \quad (5)$$

where

$$h(\theta) = \frac{L-1}{2} + \frac{m_e^2}{2E^2}\frac{\cos\theta}{\sin^2\theta + \frac{m_e^2}{E^2}\cos^2\theta} - \frac{1}{2}\ln\frac{1+\sqrt{1-\frac{m_e^2}{E^2}}\cos\theta}{1-\sqrt{1-\frac{m_e^2}{E^2}}\cos\theta}$$

$$\frac{x^2\cos\theta}{2(x^2-2x+2)}\left(1 - \frac{m_e^2}{E^2}\frac{1}{\sin^2\theta + \frac{m_e^2}{E^2}\cos^2\theta}\right), \qquad L = 2\ln\frac{\sqrt{s}}{m_e} \quad (6)$$

$$\propto A(\theta) + B(\theta)\frac{x^2}{x^2-2x+2}$$

Cross section and cut efficiency for $\cos\theta < 0.98$

Assuming the detection region is: $\cos\theta < \cos\theta_0$, the probability for the photon:

$$\begin{aligned} P &= 2(P(\frac{\pi}{2}) - P(\theta_0)) \\ &\propto \frac{L-1}{2} - A(\theta_0) - B(\theta_0)\frac{x^2}{x^2-2x+2} \end{aligned} \tag{7}$$

Here, $B(\theta_0)$ is a positive number. We can see that the radiative photon tends to along the beam direction when its energy large.
The result is consistent with the conclusion from Eq. 7.