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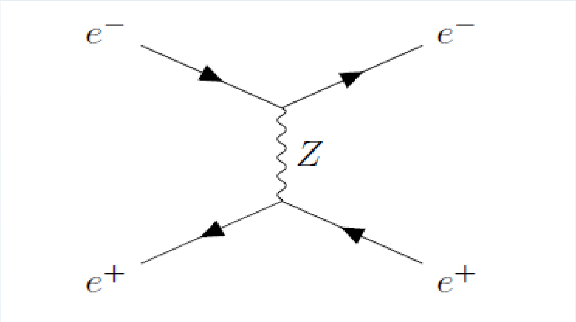
Theoretical calculation on production cross section of Z-boson and experimental measurement of production cross section of Z-boson in e-e+ channel with Monte Carlo simulated data

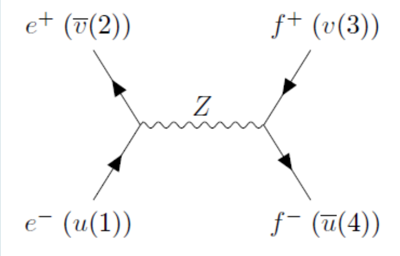


Abstract

The main topic of this research is measurements of ***Z*- bosons** produced through by the ***e*-*e*+ channel** both theoretically and experimentally. This process is well known for studying partonic structure of hadrons. Moreover, the measurement of its total cross section provides a unique opportunity to test the **Standard Model** (SM) at a very high energy scale (13TeV), with merits of small background, large cross sections and clear experimental signature.

Theoretical calculation

By adopting QFT, we start from Feynman diagram



For electron-positron pair scattering via Z boson at high energy, from Golden Rule we can derive the cross section. We first find out the matrix element for such Feynman diagram ,the vertex factor for the neutral weak interaction is:

$$(-ig_Z/2)\gamma^\mu(c_V - c_A\gamma^5) = (-ig_Z/2)\gamma^\mu\Gamma$$

Therefore, the matrix element of quantum

$$\mathcal{M} = \int \frac{d^4q}{(2\pi)^4}(2\pi)^8\delta(q-p_1-p_2)\delta(q-p_3-p_4)\overline{u}(4)(\frac{-ig}{2}\gamma^\mu\Gamma)v(3)(\frac{-i(g_{\mu\nu}-q_\mu q_\nu/M^2)}{q^2-M^2})\overline{v}(2)(\frac{-ig}{2}\gamma^\mu\Gamma)u(1) \tag{5.2}$$

$$= \frac{g^2}{4}(\overline{u}(4)\gamma^\mu\Gamma v(3))\frac{g_{\mu\nu}-q_\mu q_\nu/M^2}{q^2-M^2}(\overline{v}(2)\gamma^\nu\Gamma u(1)) \tag{5.3}$$

We would … as follows:

$$\frac{d\sigma}{d\Omega} = (\frac{1}{8\pi})^2\frac{|p_f|}{|p_i|}\frac{|\mathcal{M}|^2}{(2E)^2}$$

$$\sigma = \frac{1}{(16\pi E)^2}\int d\Omega|\mathcal{M}|^2$$

The square of quantum amplitude is calculated by Feynman rules with certain propagators, initial states and final states of particles:

$$|\mathcal{M}|^2 = (\frac{g^2E^2}{(2E)^2-M^2})^2((c_V^2+c_A^2)^2(1+\cos^2\theta) - 8c_V^2c_A^2\cos\theta)$$
$$\approx (\frac{g^2E^2}{(2E)^2-M^2})^2((1+\cos^2\theta)/16 - 8c_V^2c_A^2\cos\theta)$$

Main Results

We give the cross section for $e^+e^- \rightarrow \mu^+\mu^-$. Suppose **CM frame** (centre of mass frame) energy $2E = 500GeV$, neglect electron and muon mass and the running constant problem. Take $g_Z = 0.718$, $c_A = -1/2$, $c_V = -\frac{1}{2} + 2sin^2\theta_W = -0.037$ so $c_A^2 + c_V^2 \approx 1/4$.

$$\sigma = (\frac{g^2E}{(16\pi((2E)^2-M^2)})^2 2\pi\int_0^\pi \frac{1+\cos^2\theta}{16} - 8c_V^2c_A^2\cos\theta$$
$$= (\frac{g^2E}{(16\pi((2E)^2-M^2)})^2\frac{\pi}{8}(\frac{3}{2}\pi)$$
$$= \frac{3g^4E^2}{16^3(4E^2-M^2)^2}$$
$$\approx 8.33\times10^{-10}GeV^{-2}$$

Experimental Calculation

Now we are interested in the experimental measurement in order to testify the results by theoretical calculation using **QFT(Quantum Field Theory)** and **Standard Model**. The experimental test is carried by a event-generating programme named **PYTHIA8** which is widely used in high-energy event generating by using **Monte Carlo** algorithms which generates effective events signal from background.

PYTHIA Event and Cross Section Statistics

Subprocess	Code	Number of events Tried	Selected	Accepted
f fbar -> gamma*/Z0	221	4474	500	500
sum		4474	500	500

The results of cross section calculated by Pythia8, would be acceptable if it is within 20% deviation range and therefore it is deemed as a sensible testification of theoretical calculation of cross section of Z Bosons by e^+e^- channel.

sigma +- delta (estimated) (mb)	
4.030e-10	9.692e-12
4.030e-10	9.692e-12