NEAR-THRESHOLD BOSON-PAIR PRODUCTION IN THE MODEL OF UNSTABLE PARTICLES

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I. FINITE-WIDTH EFFECTS IN THE PRODUCTION OF UP'S

Near-threshold productions of the unstable particles (UP's) are the most suitable process to observe the finite-width effects (FWE). The main feature of the FWE is the "smearing" (fuzzing) of the threshold. In the standard treatment, this effect is described by an account of the virtual states of UP's. There are another approaches:

1.Time-asymmetric QFT of UP's (Bohm et al);

2.Effective theory of UP (Beneke, Chapovsky et al);

3.Modified perturbation theory approach (Necrasov)

4.Phenomenological QF model of UP's with smeared mass (Mathews, Salam; Kuksa).

We describe FWE's in the frame-work of the model of UP's with a smeared mass. The conception of mass smearing follows from time-energy UR.

II. MODEL OF UP'S WITH SMEARED MASS

Now, we consider the main elements of the model of UP with a smeared mass (Kuksa, 2003). The model field function of the UP is superposition of the standard ones:

$$\Phi_a(x) = \int \Phi_a(x,\mu)\,\omega(\mu)\,d\mu, \tag{2.1}$$

where $\omega(\mu)$ is some weight function and spectral component $\Phi_a(x,\mu)$ has standard form for the case of fixed mass, $m^2 = \mu$:

$$\Phi_a(x,\mu) = \frac{1}{(2\pi)^{3/2}} \int \Phi_a(k)\delta(k^2-\mu)e^{ikx}\,dk. \tag{2.2}$$

Using the representation (2.2), we suppose that for an arbitrary mass parameter μ the spectral component of field function, $\Phi_a(x,\mu)$, satisfies to the Klein-Gordon equation:

$$(\Box - \mu)\Phi_a(x,\mu) = 0, \;\; k^0 = \pm\sqrt{k^2+\mu}. \tag{2.3}$$

In another words, within the framework of the model, UP is on a smeared mass shell.

The third element of the model is the commutation relations:

$$[\dot{\Phi}_a^-(\bar{k},\mu),\ \Phi_b^+(\bar{q},\mu')]_\pm = \delta(\mu-\mu')\delta(\bar{k}-\bar{q})\delta_{ab}, \tag{2.4}$$

The amplitude of the process with UP in a final or initial state has the form:

$$A(k,\mu) = \omega(\mu)A^{st}(k,\mu), \tag{2.5}$$

where $A^{st}(k,\mu)$ is amplitude at fixed μ, which is defined in a standard way. In the frame of the model UP's in initial or final states are described by the following polarization matrixes:

$$\sum_{a=1}^{3} e_m^a(\bar{k})\dot{e}_n^a(\bar{k}) = -g_{mn} + \frac{k_m k_n}{k^2} \quad \text{(vector UP)};$$
$$\sum_{a=1}^{2} u_i^{a,\mp}(\bar{k})\bar{u}_k^{a,\pm}(\bar{k}) = \frac{1}{2k^0}(\hat{k}+k)_{ik} \quad \text{(spinor UP)}. \tag{2.6}$$

The coincidence of the expressions for the numerators of propagators and polarization matrixes leads to the effects of exact factorization.

Now, we consider the model expressions for the cross-section at the tree level. In the case $e^+e^- \to Z\gamma$, when there is one UP in a final state, the model cross-section at the tree level has a convolution form:

$$\sigma^{tr}(s) = \int \sigma^{tr}(s, m_Z)\rho(m_Z)\, dm_Z^2, \tag{2.7}$$

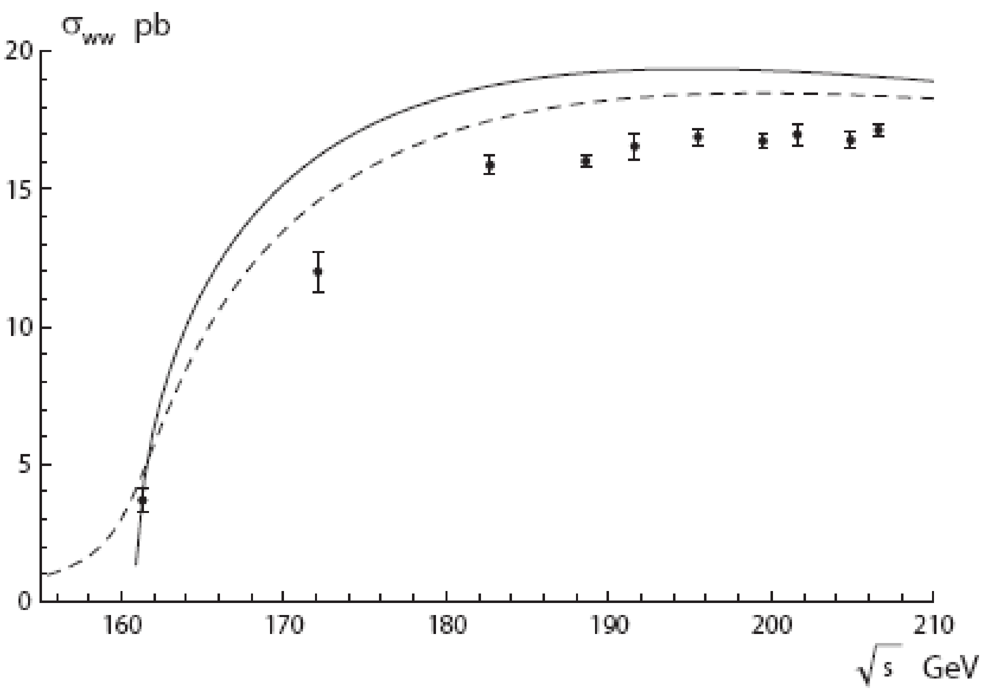
where $\sigma^{tr}(s, m_Z)$ is defined in a standard way, m_Z is variable mass of Z-boson and $\rho(m_Z)$ is the model probability density of UP's mass. In the case of the boson-pair production $e^+e^- \to ZZ,\, W^+W^-,\, ZH$ the model cross-section has double-convolution form:

$$\sigma^{tr}(s) = \int\int \sigma^{tr}(s, m_1)\sigma^{tr}(s, m_2)\rho(m_1)\rho(m_2)\, dm_1^2\, dm_2^2, \tag{2.8}$$

where m_1 and m_2 are the variable masses of bosons. The limits of integrations are defined by the kinematics of process.

III. FWE AND THE SMEARING OF THRESHOLD

Effect of threshold smearing is illustrated by Fig.1, where we present Born cross-section $\sigma(e^+e^- \to WW)$ in the standard approach with fixed mass M_W (solid line) and with a smeared mass (dashed line). We give, also, LEP2 experimental data on cross-section to show the role of FWE and radiative corrections.



IV. RADIATIVE CORRECTIONS

The model description of UP includes the self-energy type RC's in all orders of perturbation theory. So, the traditional program of RC's calculation is not valid in the framework of the model. Here, we restrict ourselves by an accounting of the main part of RC's which is common for all processes under consideration. Such a correction is ISR which includes hard, soft real and virtual γ-radiation. We use the effective couplings $g(M_Z)$ and $\alpha(M_W)$ in the vertex and $\alpha = 1/137$ in the RC's. So, the principal part of the vertex corrections is effectively included into the coupling, and the low-energy behavior of the bremsstrahlung and radiative corrections is taken into consideration. Summary set of corrections:

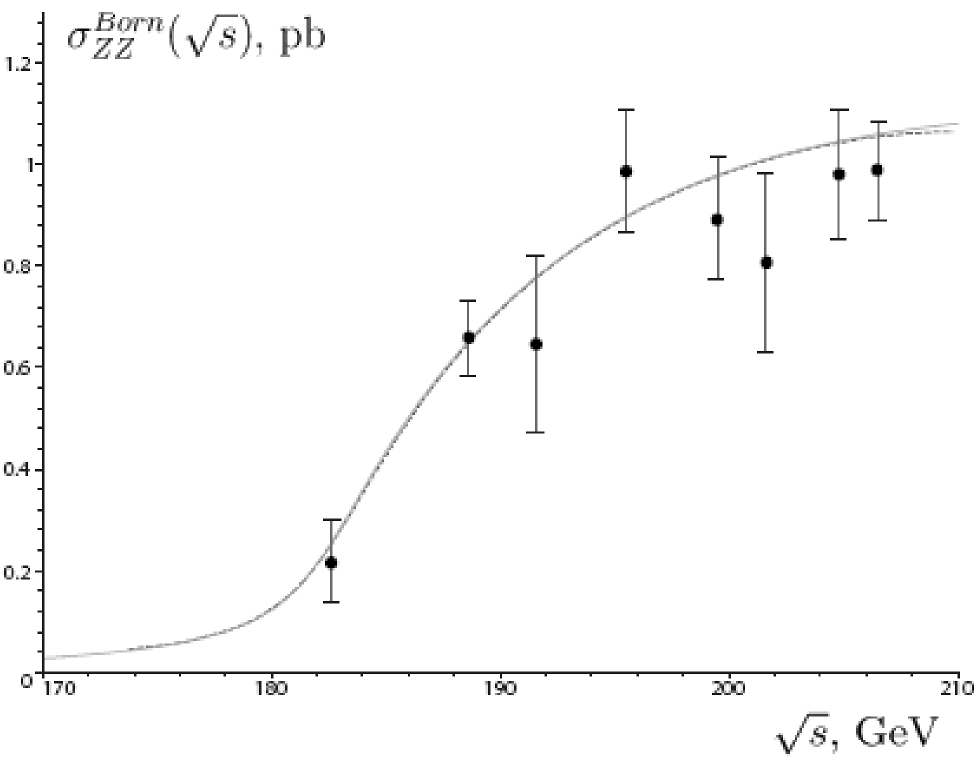
1.Hard, soft and virtual initial state radiation.

2.Principal part of vertex corrections.

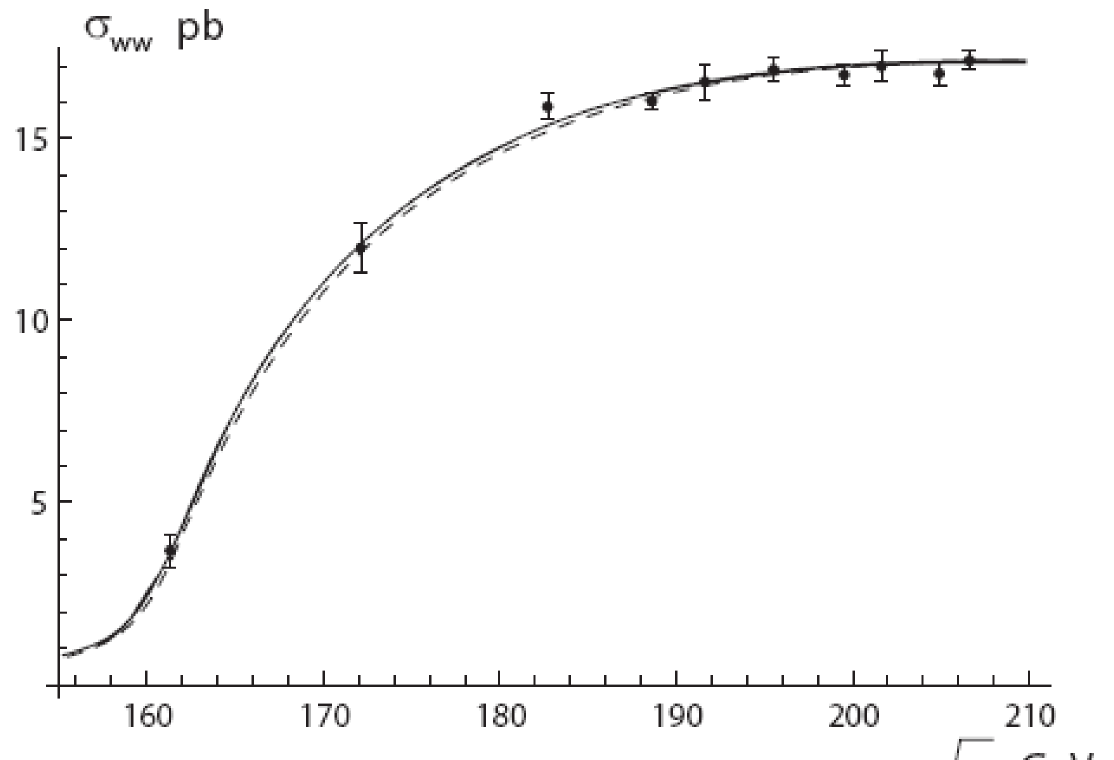
3.Self-energy type corrections to the final states.

V. THE MODEL CROSS-SECTION OF TWO-BOSON PRODUCTION

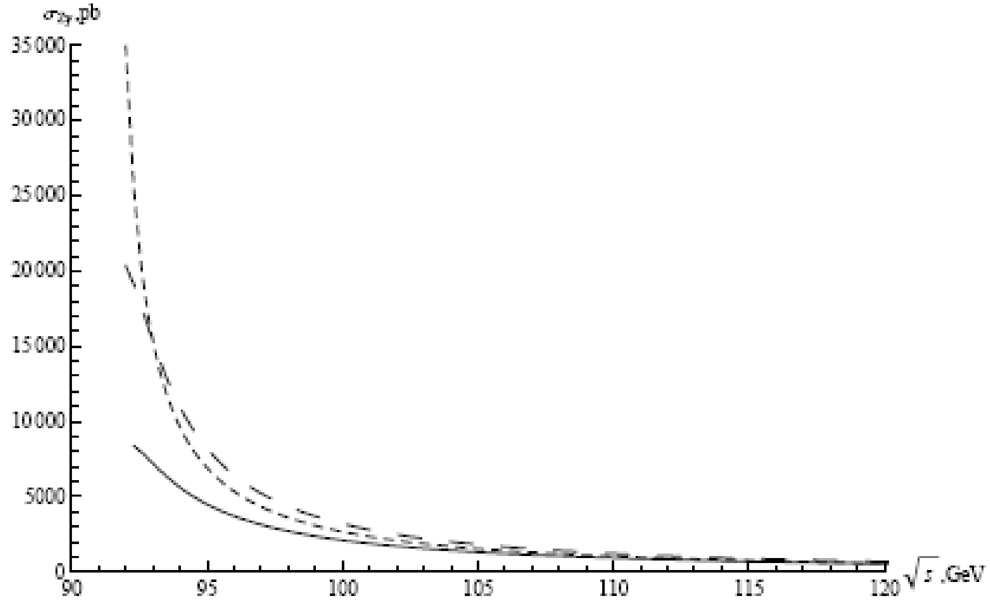
The model cross-section $\sigma(e^+e^- \to ZZ)$ with above mentioned corrections is represented in Fig.2 (the solid line) together with the result of Monte-Carlo simulation (the dashed line) and LEP data (points). Both results are consistent with the data within the error bars and coincide one with another with very high precision.



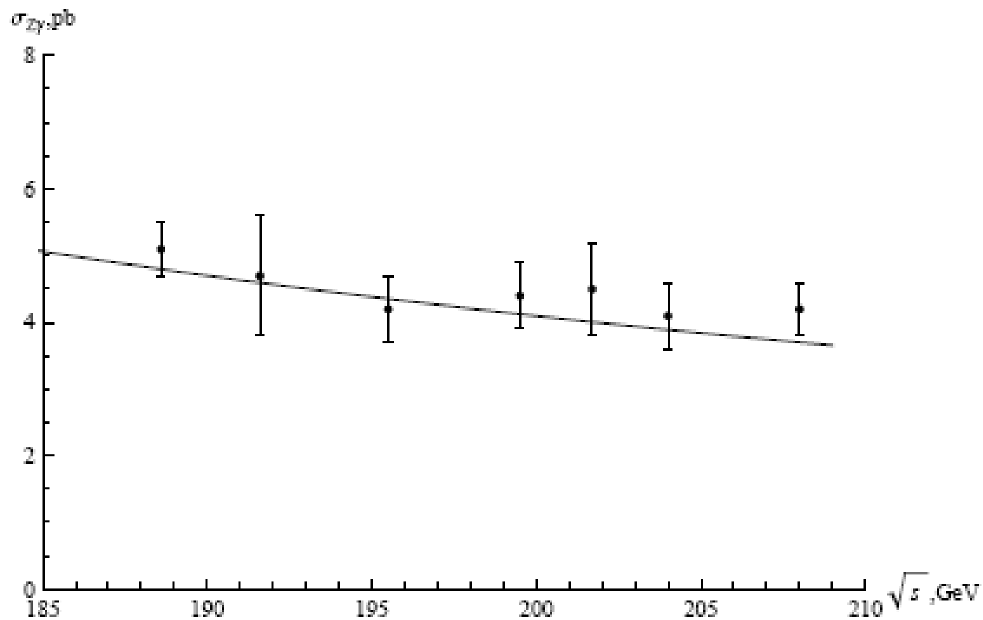
Now, we consider the corrected cross-section of the W-pair production. The model cross-section $\sigma_{WW}(s)$ is represented in Fig. 3 as a function of s by dashed line. The results of MC simulations, RacconWW and YFSWW , are represented for comparison by two corresponding error bars. From Fig. 3, one can see that the model cross-section with RC's is in good agreement with the experimental data. Moreover, the deviation of the model from MC curves is significantly less then the experimental errors ($\lesssim 1\%$).



The cross-section of the process $e^+e^- \to Z\gamma$ is given in Fig.4 at the tree level for fixed (M_Z, dotted curve) and smeared boson mass (account of FWE, dashed curve). The corrected cross-section (ISR, effective couplings etc.) is represented in this figure by the solid curve. From the results of calculation it follows that the contribution of the FWE and RC's is significant at threshold energy region $\sqrt{s} \gtrsim M_Z$.



The comparison of the model cross-section with the experimental data was fulfilled for exclusive process $e^+e^- \to Z\gamma \to \nu\bar{\nu}\gamma$. In Fig.5 we represent the model cross-section as function of $\sqrt{s}$ by solid line and experimental data by points. One can see that that the model description of the process under consideration is in agreement with the experimental data.



VI. CONCLUSION

1. The conception of mass smearing is physical basis for QF model of UP,s.
2. Model description of the near-threshold boson-pair production is in good agreement with the experimental data and the results of Monte-Carlo simulations.
3. The model formalism is simple, transparent and convenient tool for the description of the processes with UP participation.