

READYGEN Monte Carlo generator for the simulation of radiative effects in Drell-Yan process

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Motivation

Question: Why, having READY we need in READYGEN?

Answer:

READY is fast for events without real hard photons, but

READY is slow for real hard photon events (due to 6-dimension integral and the complex detector geometry)

and, at last,

READYGEN will be fast for all events: with and without hard photons.

Born (or non-radiative) kinematics

Let $p_{q1} = x_1^b P_A$, $p_{q2} = x_1^b P_B$. In centre mass system

$$P_A = \frac{1}{2}\sqrt{S}(1, 0, 0, 1), \quad P_B = \frac{1}{2}\sqrt{S}(1, 0, 0, -1).$$

Naturally that

$$p_{1q} + p_{2q} = k_1 + k_2 = k = \frac{1}{2}\sqrt{S}(x_1^b + x_2^b, 0, 0, x_1^b - x_2^b)$$

Taking into account that $S = 2P_A P_B$,

$t_b = (k_1 - p_{q1})^2$, $s_b = x_1^b x_2^b S$ and ϕ is polar angle

Born (or non-radiative) kinematics

$$k_{10} = \frac{x_1^b s_b + (x_1^b - x_2^b) t_b}{2\sqrt{x_1^b x_2^b s_b}}, \quad k_{20} = \frac{x_2^b s_b + (x_2^b - x_1^b) t_b}{2\sqrt{x_1^b x_2^b s_b}},$$

$$k_{11} = -k_{21} = \sqrt{-\frac{t_b(s_b + t_b)}{s_b}} \cos(\phi),$$

$$k_{12} = -k_{22} = \sqrt{-\frac{t_b(s_b + t_b)}{s_b}} \sin(\phi),$$

$$k_{13} = \frac{x_1^b s_b + (x_1^b + x_2^b) t_b}{2\sqrt{x_1^b x_2^b s_b}}, \quad k_{23} = -\frac{x_2^b s_b + (x_1^b + x_2^b) t_b}{2\sqrt{x_1^b x_2^b s_b}},$$

Radiative kinematics

Real photon emission $p_{1q}^r + p_{2q}^r = k_1 + k_2 + p = k + p$
described by $v = 2p \cdot k_2$, $z_1 = 2p \cdot p_{1q}^r$ and $u_1 = 2p \cdot p_{2q}^r$
In centre mass system:

$$p_0 = \frac{1}{2\sqrt{S}} \left(\frac{z_1}{x_1^r} + \frac{u_1}{x_2^r} \right), \quad p_3 = \frac{1}{2\sqrt{S}} \left(\frac{u_1}{x_2^r} - \frac{z_1}{x_1^r} \right)$$

From

$$k_0 = \frac{1}{2} \sqrt{S} (x_1^b + x_2^b) = \frac{1}{2} \sqrt{S} (x_1^r + x_2^r) - p_0,$$

$$k_3 = \frac{1}{2} \sqrt{S} (x_1^b - x_2^b) = \frac{1}{2} \sqrt{S} (x_1^r - x_2^r) - p_3$$

Radiative kinematics

one can find that ($S = 2P_A \cdot P_B$, $s_b = x_1^b x_2^b S$):

$$x_1^r = \frac{x_1^b}{2s_b} (s_b + u_1 - z_1 + \sqrt{(s_b - u_1 + z_1)^2 + 4s_b u_1}),$$

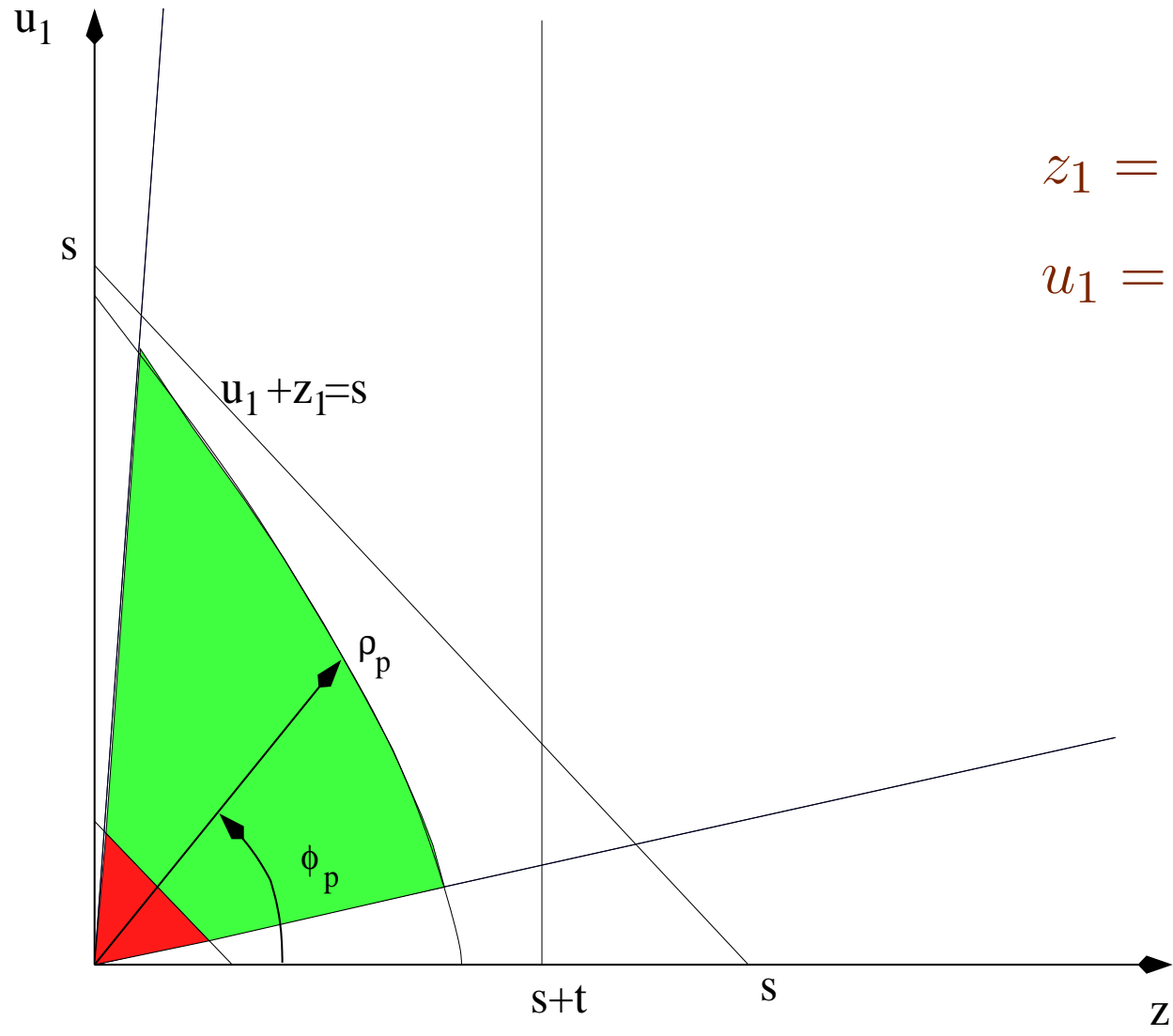
$$x_2^r = \frac{x_2^b}{2s_b} (s_b - u_1 + z_1 + \sqrt{(s_b - u_1 + z_1)^2 + 4s_b u_1}),$$

Radiative and Born $x_{1,2}$ variables connected through radiative invariants z_1 and u_1 !!!

$$\frac{d\sigma}{dx_1^b dx_2^b dt^b d\phi} \sim \int du_1 dz_1 dv \sum_{q=u,d,s,\dots} f_q(x_1^r, Q^2) f_{\bar{q}}(x_2^r, Q^2) \mathcal{K}^{q\bar{q}}$$

During real photon generation it is possible to integrate ANALYTICALLY over v

Region of integration over u_1 and z_1



$$z_1 = \rho_p \cos \phi_p$$

$$u_1 = \rho_p \sin \phi_p$$

Radiatively corrected cross section

$$\sigma^{obs} = \sigma^b + \sigma^V + \sigma^R \quad \left(\sigma \equiv \frac{d\sigma}{dx_1^b dx_2^b dt^b d\phi} \right)$$

σ^b — Born contribution

σ^V — contribution of additional virtual particles

σ^R — contribution of real photon emission.

The separation of photon emission:

$$\sigma^R = \sigma_{soft}^R(\omega) + \sigma_{hard}^R(\omega),$$

ω — separator between soft and hard real photons.

$$\sigma^{obs} = \sigma^N(\omega) + \sigma_{hard}^R(\omega)$$

$\sigma^N(\omega)$ — non-radiative part of cross section,

$\sigma^R(\omega)$ — radiative part of cross section.

Method of generation

- For the fixed initial energy, x_1^b , x_2^b and t^b the non-radiative and radiative parts of the radiatively corrected cross section are calculated.
- The channel of scattering is simulated for this event in accordance with partial contributions of these two positive parts into the radiatively corrected cross section.
- For any process ϕ is simulated uniformly from 0 to 2π .
- For the radiative event the kinematic variables ρ_p , ϕ_p , v are simulated in accordance with their calculated distribution.

Method of generation

- The 4-momenta of all final particles in the required system are calculated.
- If the initial x_1^b , x_2^b and t^b has not a fixed value but is instead simulated according to some probability distribution then the cross sections have to be stored for reweighting. The distribution of x_1^b , x_2^b and t^b is simulated over the Born cross section, and realistic observed t distribution is calculated as sum of weights, they are ratios of the radiatively corrected and Born cross sections.

Conclusion

- The method of the real photon simulation for Drell-Yan process has been proposed.
- Base on this method the Monte Carlo generator READYGEN will be ready very soon.