

# Radiative Corrections in polarized SiDIS

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February 4, 2020

## RC without exclusive radiative tail

- RC to unpolarized three-fold cross section  $\frac{d\sigma}{dx dy dz}$   
A.V. Soroko, N.M. Shumeiko. Sov.J.Nucl.Phys. 49 (1989) 838-844,  
Yad.Fiz. 49 (1989) 1348-1358
- RC to polarized three-fold cross section  $\frac{d\sigma}{dx dy dz}$   
A.V. Soroko, N.M. Shumeiko. Sov.J.Nucl.Phys. 53 (1991) 628-631  
Yad.Fiz. 53 (1991) 1015-1020  
as an option SIRAD of FORTRAN code POLRAD 2.0  
I.Akushevich, et al. Comp.Phys.Comm. 104 (1997) 201-244
- RC to unpolarized five-fold cross section  $\frac{d\sigma}{dx dy dz d\phi_h dp_T}$   
I.Akushevich, N.Shumeiko, A.Soroko. Eur.Phys.J. C10 (1999) 681-687  
Basing on this calculation FORTRAN code HAPRAD has been developed.

## RC with exclusive radiative tail

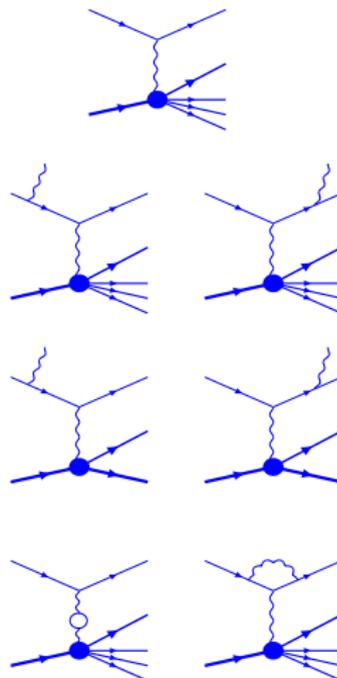
- Exclusive radiative tail contribution to unpolarized five-fold cross section  $\frac{d\sigma}{dx dy dz d\phi_h dp_T}$

I.Akushevich, A.Ilyichev, M.Osipenko. *Eur.Phys.J. C10 (1999) 681-687*

has been included in FORTRAN code HAPRAD. As it will be shown later, in some kinematical region this contribution is rather important.

# Contribution to the lowest-order RC in SiDIS $ep \rightarrow ehX$

- The lowest order contribution.
- Real photon emission from lepton line with the inelastic final hadronic state. Contains the infrared divergence.
- Real photon emission from lepton line with the exclusive final hadronic state. Infrared free.
- Additional virtual particle contribution. Last graph contains the infrared divergence.



# Advantages of Model-Independent RC

- The task can be solved exactly.
- Model-Independent RC is rather large because of including so-called leading-order term  $\log(Q^2/m^2)$ .
- Uncertainties of the model-independent RC come only from fits and models used for structure functions.
- The calculation of model-dependent correction (box-type graphs, real photon emission from hadronic line) requires additional assumptions about hadron interaction, so it has additional pure theoretical uncertainties, which are hard to control.

One of the important thing for the numerical estimation of model-independent RC consists in the knowledge of the hadronic tensor structure as well as the structure function parameterization in the rather wide kinematical region both for SiDIS and exclusive final hadronic states.

According to [Aram Kotzinian, Nucl.Phys. B441 \(1995\) 234-248](#) the hadronic tensor for SiDIS with the initial polarized nucleon reads

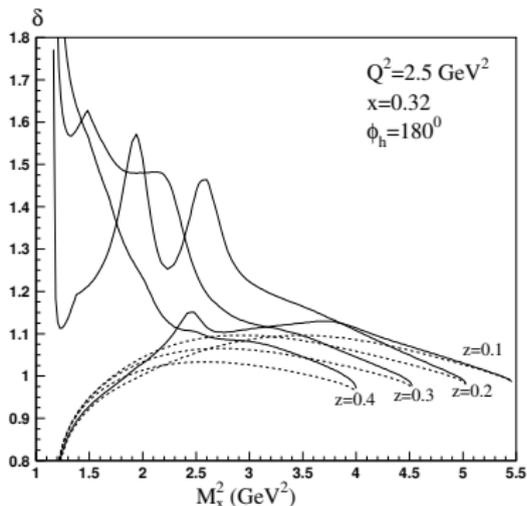
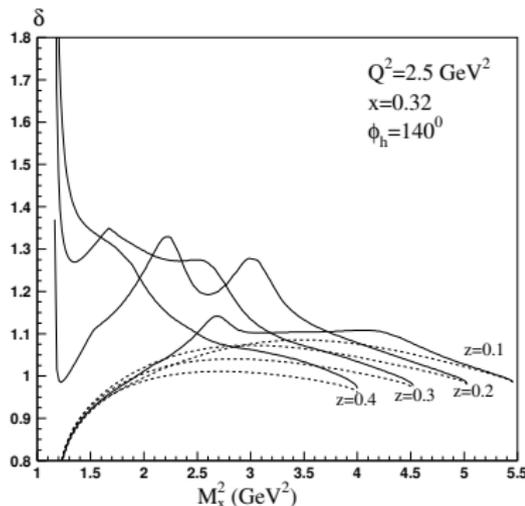
$$W_{\mu\nu} = \sum_{a,b=0}^3 e_{\mu}^{\gamma(a)} e_{\nu}^{\gamma(b)} (H_{ab}^{(0)} + \sum_{\rho,i=0}^3 s^{\rho} e_{\rho}^{h(i)} H_{abi}^{(S)}).$$

$e^{\gamma(a,b)}$  ( $e^{h(i)}$ ) are the complete set of the basis vectors for the polarization 4-vectors of the virtual photon (nucleon) in the target rest frame.

Due to the parity and current conservation, hermiticity as well as  $p_S \equiv 0$ , only 5 spin-independent  $H_{ab}^{(0)}$  and 13 spin-dependent  $H_{abi}^{(S)}$  SF are survived. All the rest of the SF have to be set to zero.

Another set of SF can be found in [A. Bacchetta et al. JHEP 0702 \(2007\) 093](#)

## Importance of exclusive radiative tail



$$M_X^2 = (p + q - p_h)^2 = M^2 + (q - p_h)^2 + 2(1 - z)pq$$

$M_X^2$ -dependence of the RC factor for the semi-inclusive  $\pi^+$  electroproduction at fixed proton for lepton beam energy 6 GeV: solid lines show the total correction, dashed lines represent the correction excluding the exclusive radiative tail (I.Akushevich, A.Ilyichev, M.Osipenko, Phys.Lett. B672(2009)35)

- Basing on Aram's expression we construct the hadronic tensor in the covariant form

$$\begin{aligned}
 W_{\mu\nu} = & -g_{\mu\nu}^{\perp} \mathcal{H}_1 + p_{\mu}^{\perp} p_{\nu}^{\perp} \mathcal{H}_2 + p_{h\mu}^{\perp} p_{h\nu}^{\perp} \mathcal{H}_3 + (p_{\mu}^{\perp} p_{h\nu}^{\perp} + p_{h\mu}^{\perp} p_{\nu}^{\perp}) \mathcal{H}_4 \\
 & + i(p_{\mu}^{\perp} p_{h\nu}^{\perp} - p_{h\mu}^{\perp} p_{\nu}^{\perp}) \mathcal{H}_5 + (p_{\mu}^{\perp} n_{\nu} + n_{\mu} p_{\nu}^{\perp}) \mathcal{H}_6 + i(p_{\mu}^{\perp} n_{\nu} - n_{\mu} p_{\nu}^{\perp}) \mathcal{H}_7 \\
 & + (p_{h\mu}^{\perp} n_{\nu} + n_{\mu} p_{h\nu}^{\perp}) \mathcal{H}_8 + i(p_{h\mu}^{\perp} n_{\nu} - n_{\mu} p_{h\nu}^{\perp}) \mathcal{H}_9.
 \end{aligned}$$

$$g_{\mu\nu}^{\perp} = g_{\mu\nu} - q_{\mu} q_{\nu} / q^2 \quad p_{\mu}^{\perp} = p_{\mu} - q_{\mu} p q / q^2 \quad \text{and} \quad n^{\mu} = \varepsilon^{\mu\nu\rho\sigma} q_{\nu} p_{\rho} p_{h\sigma}$$

with 9 generalized SF  $\mathcal{H}_{1-9}$  and found that the born cross section exactly reproduced the cross section obtained by Alessandro Bacchetta.

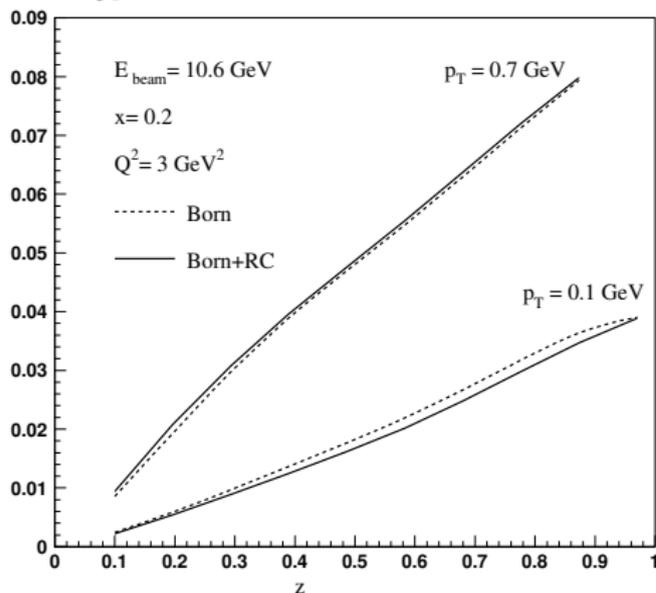
- Using Bardin-Shumeiko approach we obtained the analytical expressions for the lowest order model-independent RC to polarized SiDIS. These expressions are written in the most compact, covariant form convenient for the numerical analysis.
- The analytical expressions for the exclusive radiative tail is reproduced within a rather general assumption: the hadronic tensor for the exclusive process has the same structure as for SiDIS one.

- The obtained above results have been published in  
*I.Akushevich, A.Ilyichev. Phys.Rev. D100 (2019) no.3, 033005*
- Recently using WW-SIDIS model for the structure functions  
*S. Bastami et al., JHEP 1906, 007 (2019)*  
we start to develop the new version of FORTRAN code  
HAPRAD that allows to calculate RC to polarized SiDIS  
coming from the inelastic final hadronic state.

It is expected that in some kinematical region the exclusive radiative tail gives dominant contribution into the total lowest order model-independent RC. That is why it is a rather important to find out a correct models for the description of the polarized exclusive process in a wide kinematical region and incorporate them into the new version of HAPRAD.

# RC to polarized SIDIS. Preliminary result.

$$A_{UT}^{\sin(\phi_h - \phi_S)}, \quad e \bar{p} \rightarrow e \pi^+ X$$



$$A_{UT}^{\sin(\phi_h - \phi_S)} = 2 \frac{\int_0^{2\pi} d\phi_S \int_0^{2\pi} d\phi_h \sin(\phi_h - \phi_S) \sigma^{UT}}{\int_0^{2\pi} d\phi_S \int_0^{2\pi} d\phi_h \sigma^{UT}}$$

- Basing on the expressions of the article  
[I.Akushevich, A.Ilyichev. Phys.Rev. D100 \(2019\) no.3, 033005](#)  
and WW-SIDIS model for the structure functions  
[S. Bastami \*et al.\*, JHEP 1906, 007 \(2019\)](#)  
the new version of the FORTRAN code HAPRAD for calculation of the  
model-independent lowest order RC in polarized SiDIS is developing
- The next important step consists in the correct estimation of the  
exclusive radiative tail, that can give rather important contribution in  
some kinematical region.

Many thanks for fruitful discussion

- Igor Akushevich
- Harut Avakyan
- Andrei Afanasev