The EvtGen-based Model for the Monte-Carlo Generation of the Rare Radiative Leptonic *B*-decays

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Introduction

The main goal of this talk is to present the new Monte-Carlo model for the simulation of the **rare radiative leptonic *B*-mesons decays** in the framework of the program package EvtGen. This model is based on the thorough theoretical calculations of these decays in the SM with *CP*-violation effects. In addition, in this model it is possible to easily change all the input parameters (including CKM-matrix elements in the Wolfenstein parametrization).

Program package EvtGen

- The EvtGen package has been created for the simulation of the *b*-hadrons decays at *B*-factories. Now this package is used by LHC Collaborations (LHCb, ATLAS, CMS).

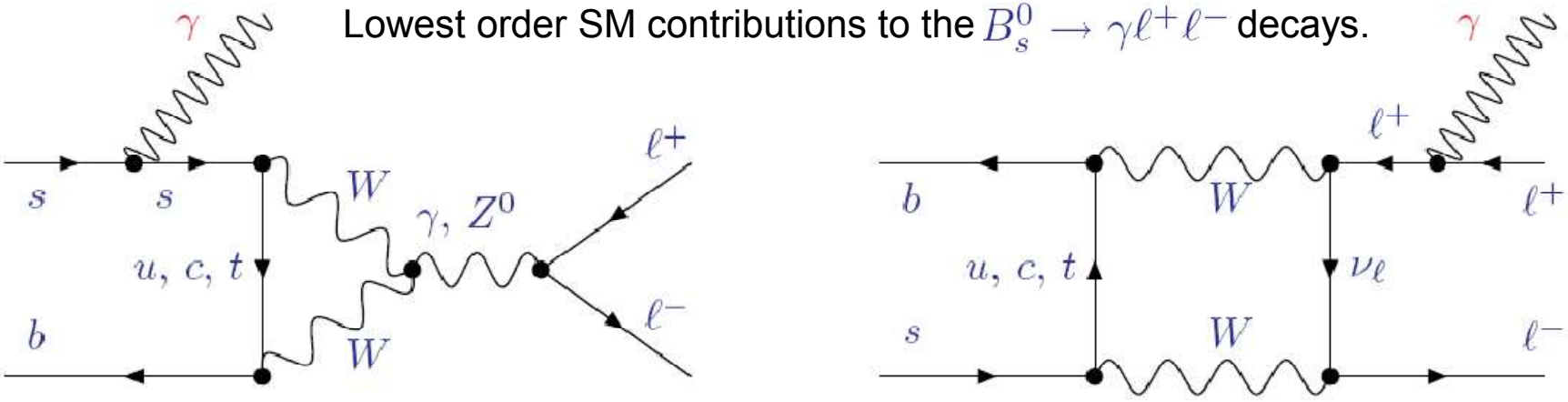
- The basic idea of EvtGen is that each decay is described in terms of helicity amplitudes which are forming a density matrix. So EvtGen makes it possible to correctly simulate the angular and spin correlations in the entire decay chain.

- The EvtGen package provides a service in which new decays can be simply added as new modules. These modules, which perform the simulation of decays, are called **models** in EvtGen.

Rare radiative leptonic *B*-decays

Rare radiative leptonic $B^0_{d,s}(\bar{B}^0_{d,s}) \to \gamma\,\ell^+\ell^-$ decays are induced by flavor changing neutral currents (FCNC) *b→d, s*, which are forbidden at the tree level in the framework of the SM and occur starting from the lowest order only through the one-loop "penguin" and "box" diagrams.

Lowest order SM contributions to the $B^0_s \to \gamma\ell^+\ell^-$ decays.



Channel	Branching
$\mathbf{B^0_d} \to \gamma\mu^+\mu^-$	4.0×10^{-10}
$\mathbf{B^0_s} \to \gamma\mu^+\mu^-$	1.9×10^{-8}

- I.Balakireva, D.Melikhov, N.Nikitin, D.Tlisov, Phys.Rev. D81, 054024 (2010).
- D.Melikhov, N.Nikitin, K.Toms, Phys.Rev. D70, 114028 (2004).
- F.Kruger, D.Melikhov, Phys.Rev. D67, 034002 (2003).

Theoretical review

The $b \to q$ transitions $q=\{d,s\}$ are described using the effective Hamiltonian in the Wilson expansion form with CP-violation effects:

$$H_{\text{eff}}^{b\to q} - \frac{G_F}{\sqrt{2}} V_{tb}V_{tq}^* \left[\left(1+\lambda_u^{(q)}\right) \left(C_1(\mu) O_1^{(c)}(\mu) + C_2(\mu) O_2^{(c)}(\mu) \right) - \right.$$

$$\left. - \lambda_u^{(q)} \left(C_1(\mu) O_1^{(u)}(\mu) + C_2(\mu) O_2^{(u)}(\mu) \right) + \sum_{i=3}^{\dots} C_i(\mu) O_i(\mu) \right] + (\bar{b} \to \bar{q})$$

where G_F is the Fermi constant, V_{tq} and V_{tb} are the CKM matrix elements, $\lambda_u^{(q)}=V_{ub}V^*_{uq}/V_{tb}V^*_{tq}$. The set of Wilson coefficients $C_i(\mu)$ depends on the chosen model. The scale parameter μ (approximately equal to the *b*-quark mass ~5 GeV) separates the perturbative and nonperturbative contributions of the strong interactions. $O_i(\mu)$ is the set of basic operators. The nonperturbative contributions of the strong interactions are contained in the matrix elements of this operators:

$$\langle \text{final states} \,|O_i(\mu)|\, \text{initial states} \rangle$$

It can be described in terms of Lorentz-invariant form factors and structures composed of 4-momenta of the initial and final particles, metrical tensor $g^{\mu\nu}$ and Levi-Civita symbol $\varepsilon^{\alpha\beta\mu\nu}$.

EvtGen model for rare radiative leptonic *B*-decays

We prepare the new EvtGen model BSTOGLLMNT for rare radiative leptonic B-mesons decays. In this model:

- decay channels of B_d- and B_s-mesons are included:

  ⇨ $B_{d(s)} \to \gamma l^+ l^-$ where $l=\{e,\mu,\tau\}$;

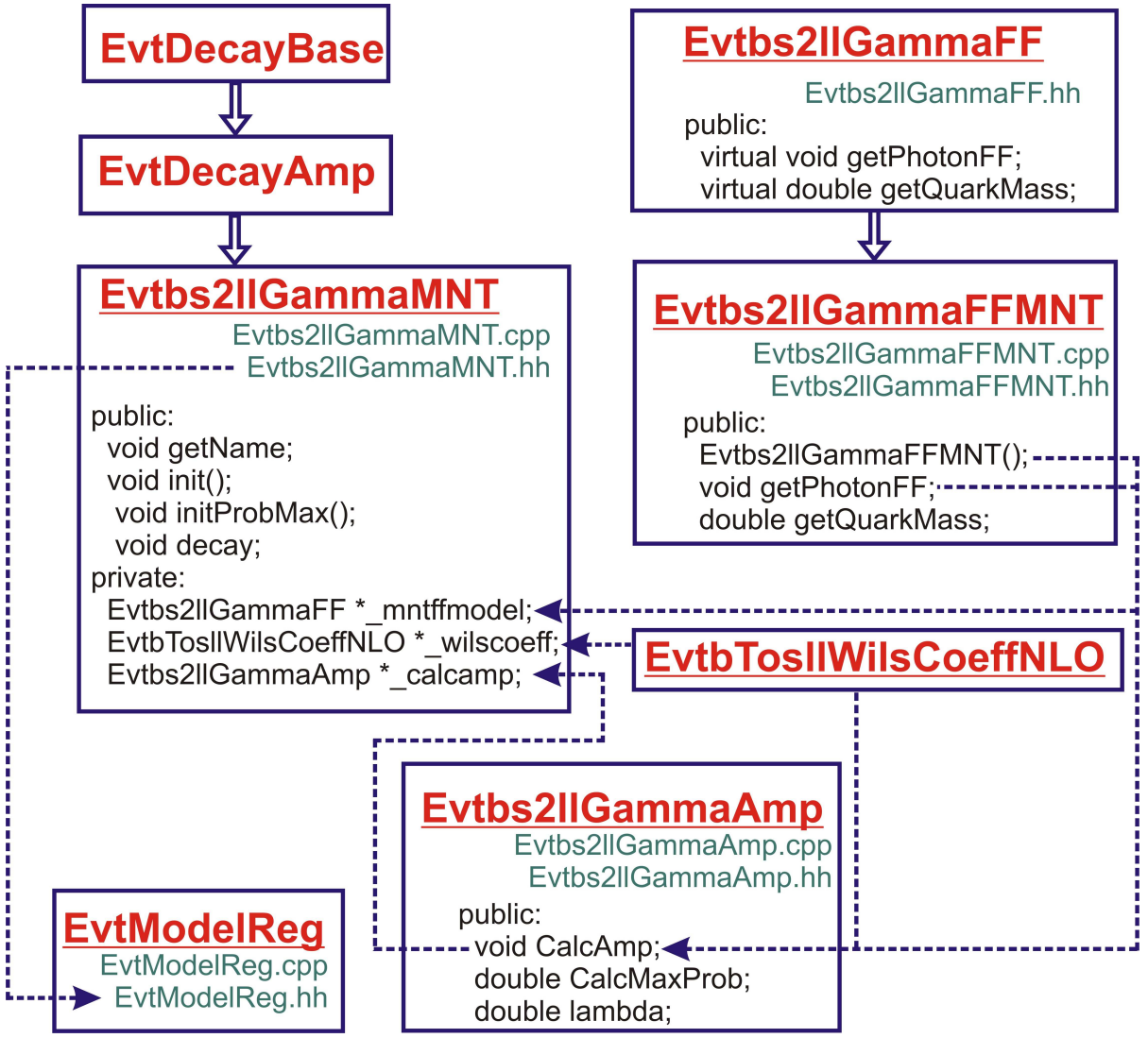
- the form factors are calculated using the dispersion relation of the QM and the vector-meson dominance approach;
- the μ-dependence of the Wilson coefficients C_i and the contribution from ρ, ω, ψ`` etc. vector resonances in the SM are included;
- the *CP*-violation effects are included.

Input parameters for BSTOGLLMNT

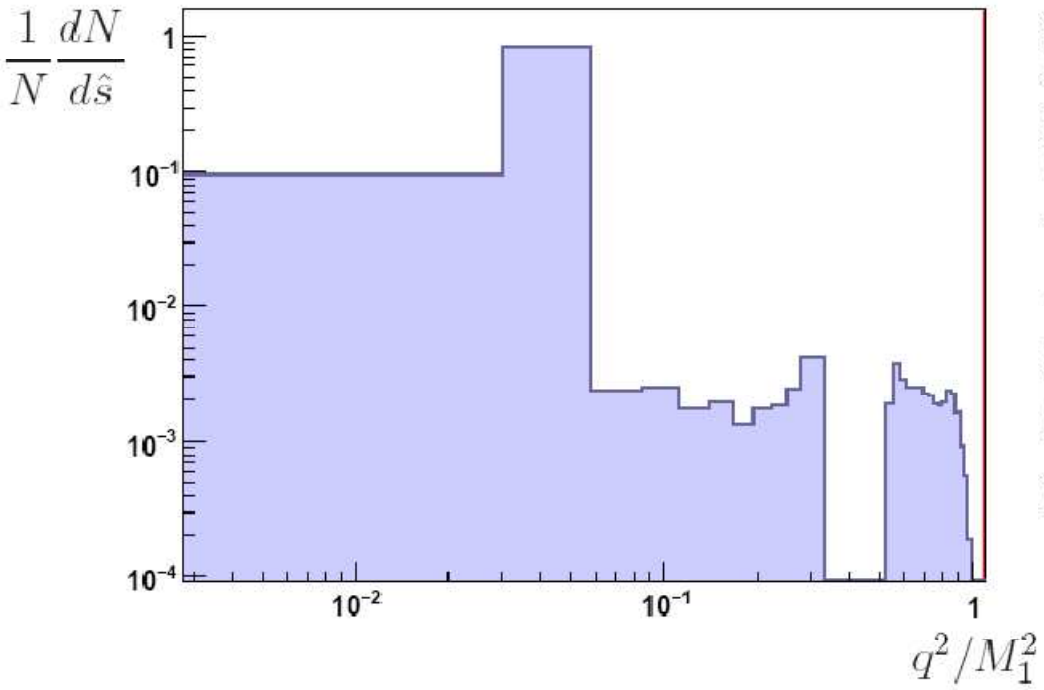
There are 9 input parameters specified in BSTOGLLMNT model:

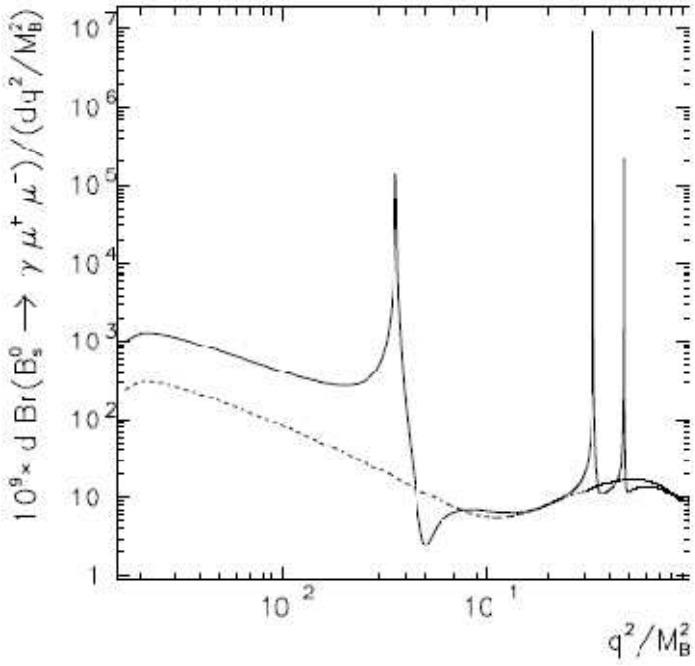
- mu is the scale parameter μ ~5 GeV;
- Nf is the number of "effective" quark flavours, used for calculation of the strong interaction running constant $\alpha_S(M_Z)$ (Nf=5 by default);
- Res_swch is the parameter of switching on/off the resonant contribution (with resonances by default). The area of J/ψ and ψ'-resonances is excluded in the matrix element;
- ias defines a choice of the strong interaction running constant $\alpha_S(M_Z)$ value.
- Egamma is the photon energy cut (20 MeV by default) in the *B*-meson rest frame.
- A, lambda, barrho and bareta are the CKM matrix parameters corresponding the Wolfenstein parametrisation: A, λ, ρ, and η.

Classes structure of BSTOGLLMNT



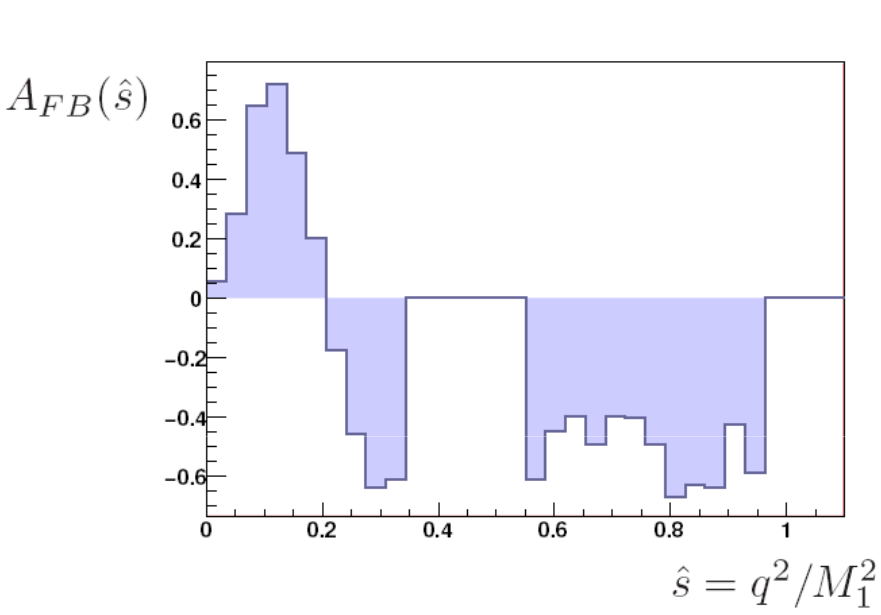
Example of the q^2-distribution

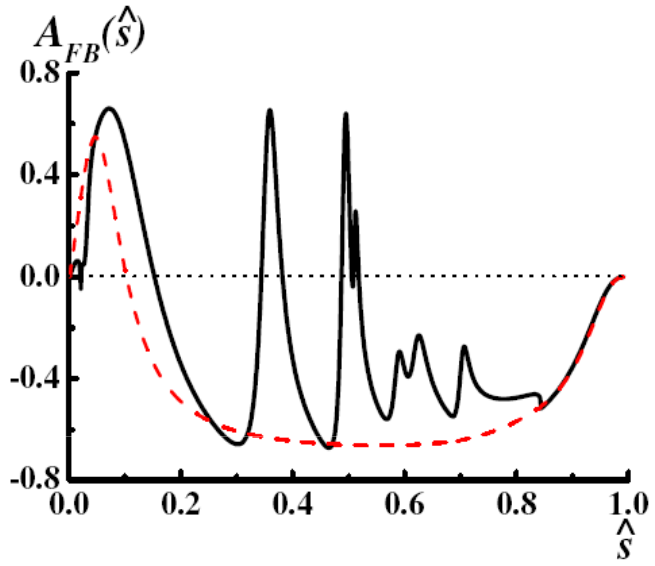




The normalized $\hat{s} = q^2/M_1^2$ distribution for the BSTOGLLMNT (left) and the theoretical prediction from Phys.Rev. D70, 114028 (2004) (right) for the decays $B_s^0(B_s^0) \to \gamma\mu^+\mu^-$.

Example of the A_{FB}-distribution





The A_{FB}-distributions for the BSTOGLLMNT (left) and the theoretical prediction from Phys.Rev. D81, 054024 (2010) (right) for the decay $\bar{B}_d^0 \to \gamma\mu^+\mu^-$.

Conclusion

We have prepared the EvtGen-based Monte-Carlo generator model for the description of the rare radiative leptonic decays $B_{d,s} \to \gamma \ell^+ \ell^-$, which includes the resonant contribution and the CP-violation effects.

We have found a good agreement between the theoretical predictions and the MC results.