Automation of the leading order calculations for $e^+e^- \to$ hadrons

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Radio Monte Carlo Working Group meeting

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Motivation

The knowledge of $\sigma_{e^+e^-\to\mathrm{hadrons}}(s)$ allows, through dispersion relations, for determination of hadronic contributions to the vacuum polarization.

$\Rightarrow$ Better precision of theoretical predictions for the muon anomalous magnetic moment and evolution of the fine structure constant from the Thomson limit to high energy scales.

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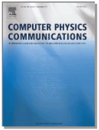

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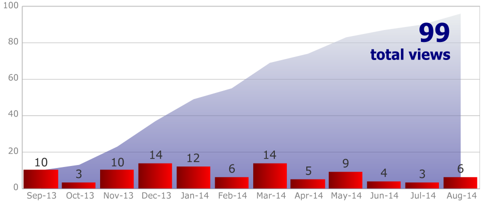

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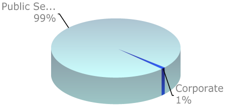

 Terms and conditions Support

Anomalous *Wtb* coupling

The effective Lagrangian of the *Wtb* interaction containing operators of dimension four and five has the following form:

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L_{Wtb} &= \frac{g}{\sqrt{2}} V_{tb} \Big[W_\mu^- \bar{b} \gamma^\mu \left(f_1^L P_L + f_1^R P_R \right) t \\
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$$L_{\gamma NN} = e A_\mu \bar{N}(p') \left[\gamma^\mu F_1(Q^2) + \frac{i}{2m_N} \sigma^{\mu\nu} q_\nu F_2(Q^2) \right] N(p).$$

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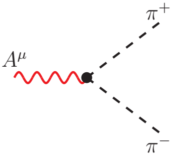
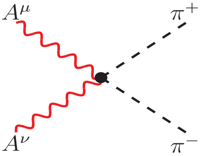


$\equiv \; ie(p_{+} - p_{-})^{\mu}$



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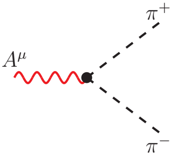

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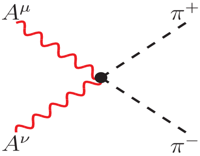

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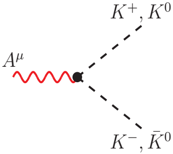

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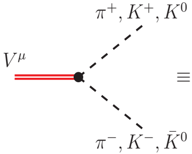

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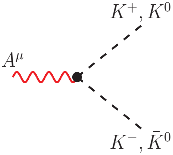

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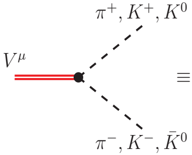

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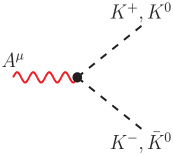

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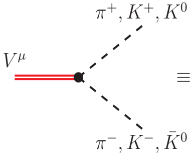

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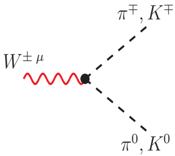

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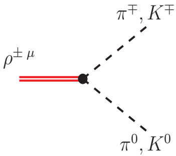

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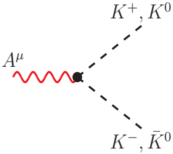

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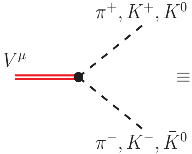

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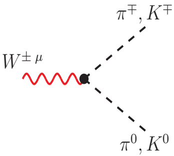

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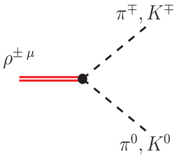

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Vertices of sQED and particle mixing

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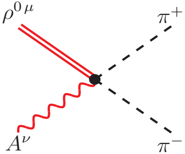

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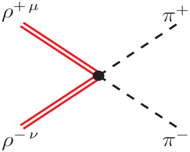

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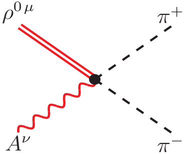
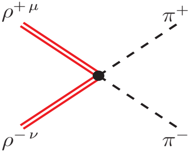


$\equiv\ 2ieg_{\rho\pi\pi}g^{\mu\nu}$



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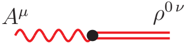
can also be implemented in a straightforward manner.

Implementation of the particle mixing such as, e.g.



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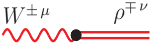

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is more challenging.

Vertices of sQED and particle mixing

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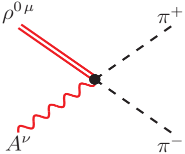

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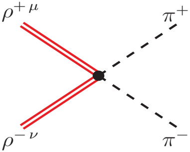

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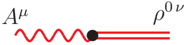

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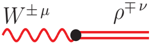

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Substantial changes in the code generating part of the program are required.

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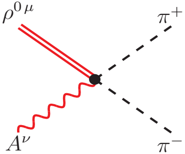

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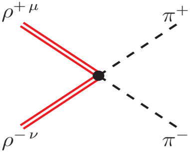

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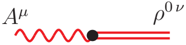

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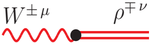

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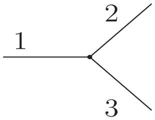
Topologies are generated for models with triple and quartic couplings, starting with 1 topology of a 3 particle process.



Line 4 is attached to each line and to the vertex $\Rightarrow$ 4 topologies of a 4 particle process.

Topology generation in `carlomat`

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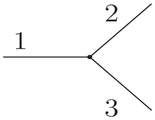

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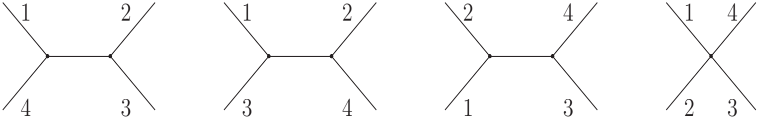

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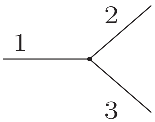

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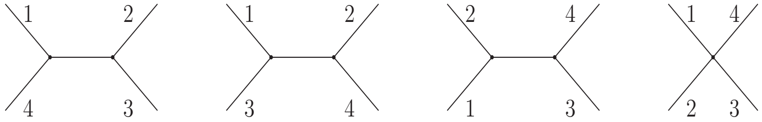

Line 5 is attached to each line, including the internal ones, and to each triple vertex ⇒ 25 topologies of a 5 particle process.

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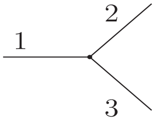

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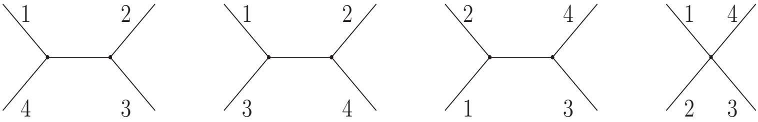

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$\#$ of topologies grows dramatically with $\#$ of external particles.

$\#$ of particles	$\#$ of topologies
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8	34 300
9	559 405
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Topology generation in carlomat

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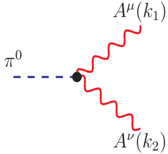
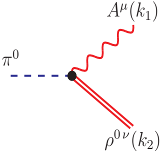
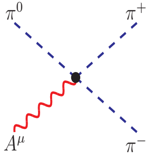
Vertices of the Resonance Chiral Perturbation Theory (RChPT):



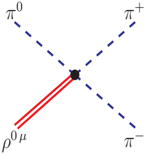
$\equiv \; e^2 g_{\pi\gamma\gamma}\varepsilon^{\mu\nu\alpha\beta}k_{1\,\alpha}k_{2\,\beta}$



$\equiv \; ieg_{\pi^0\gamma\rho^0}\varepsilon^{\mu\nu\alpha\beta}k_{1\,\alpha}k_{2\,\beta}$



$\equiv \; -eg_{\gamma\pi\pi\pi}\varepsilon^{\mu\nu\alpha\beta}k_{0\,\nu}k_{+\,\alpha}k_{-\,\beta}$



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Their implementation in the program required just a few new subroutines for computation of the corresponding helicity amplitudes.

At the moment, all the form factors are set to 1 or e.

They should be implemented soon in collaboration with Fred Jegerlehner, who provided me with the Feynman rules of the RChPT.

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