Simulation of Spin Effects in SUSY decay chains with pandora

Work done with M. Peskin

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What is pandora?

A self contained parton level event generator, written in C++.

Designed to:

- include full treatment of polarization and spin correlations
- efficiently handle large decay chains.
- provide the tools to implement new physics models
- produce distributions for LHC physics or ee, eγ, $\gamma\gamma$ ILC physics
- write output to lhe files for showering and hadronization

What pandora is not

Madgraph

- It is not a matrix element generator
- It is not based on Lagrangian input

pandora is toolkit designed to focus on and flesh out the details of particular processes and features of a model.

Treatment of Spin Correlations

pandora is based on helicity amplitudes for production and decay.

We keep complete quantum coherence by summing over helicity states of intermediate particles

$$\int dm_X^2 dm_Y^2 \cdots d\Pi \,|\sum_{h_X, h_Y \cdots} (pp \to X_{h_X} Y_{h_Y}) \times$$

$$\sum_{X_1, X_2} M(X_{h_X} \to X_1 X_2) \sum_{Y_1, Y_2} M(Y_{h_Y} \to Y_1 Y_2) \cdots |^2$$

More about the structure

Calculate 2->2 (and 2->3) helicity amplitudes

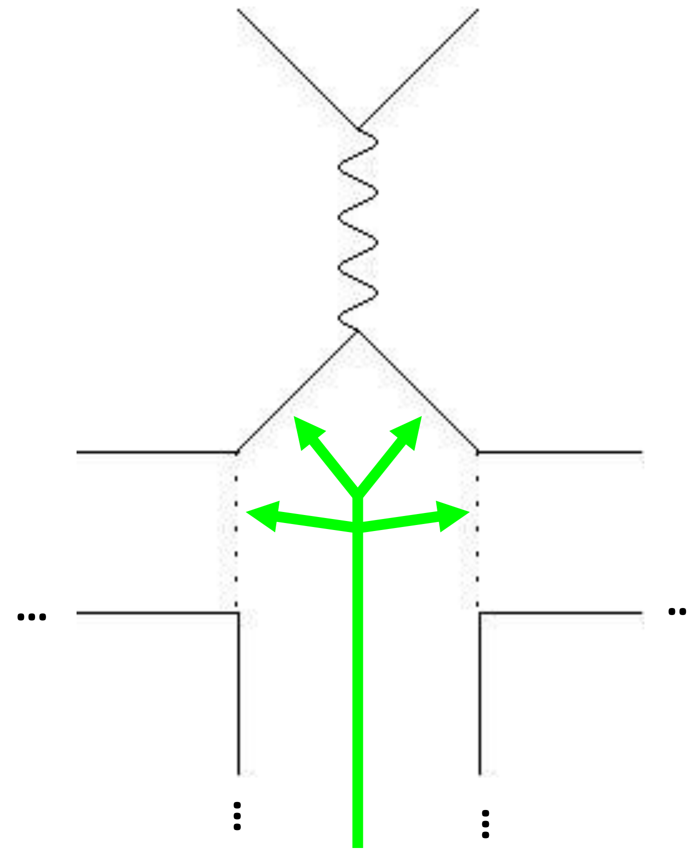
Choose decay channels and attach 1->2 (and 1->3) amplitudes

Continue down the chain until final massless or stable particles are reached (there is no fundamental limit on the decay chain length)

Use only the diagrams for narrow width approximation, but finite width effects are included, so unstable particles are created with the correct Breit-Wigner distribution

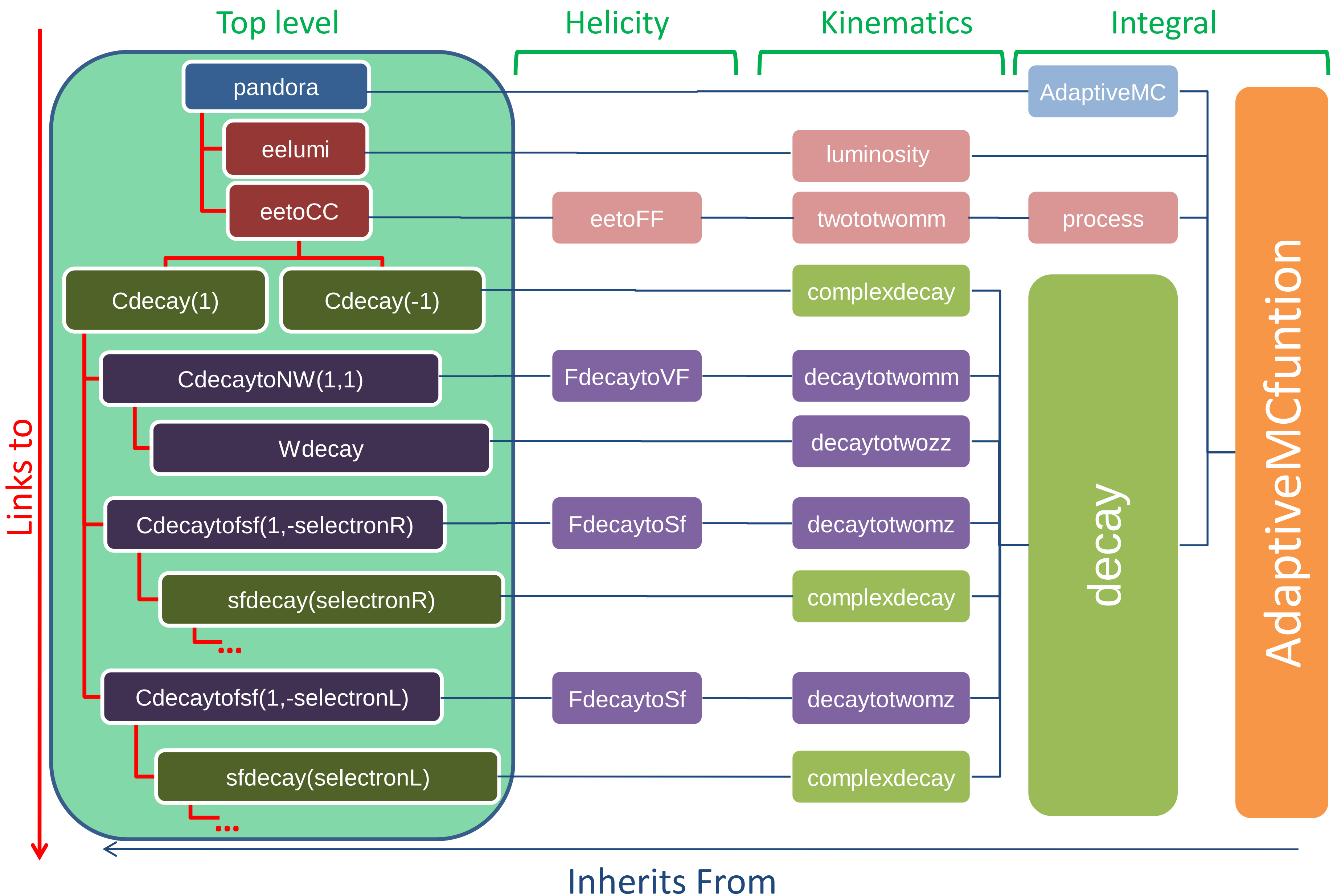
Square the constructed matrix elements and integrate to get cross section

Use the optimized grid from the integral to generate events



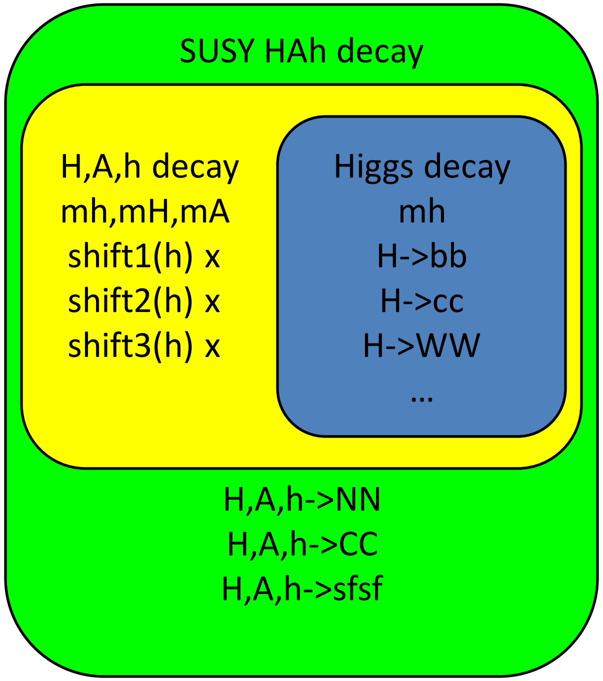
$$\frac{1}{m^2 - M_{nom}^2 + iM_{nom}\Gamma}$$

C++ class structure



Inheritance

- Using C++ class inheritance properties, the integral structure, kinematics and helicity information are each dealt with in a predefined classes and simply inherited by new process or decay.
- Additionally, a new process or decay can be built on an existing SM or other implemented class.
- For instance to implement neutral parts of doublet Higgs, declare a class that inherits all the SM Higgs decays, simply shifting the mass and couplings appropriately.
- To get the SUSY Higgs, inherit all the doublet Higgs properties, and just add the decays to SUSY particles.

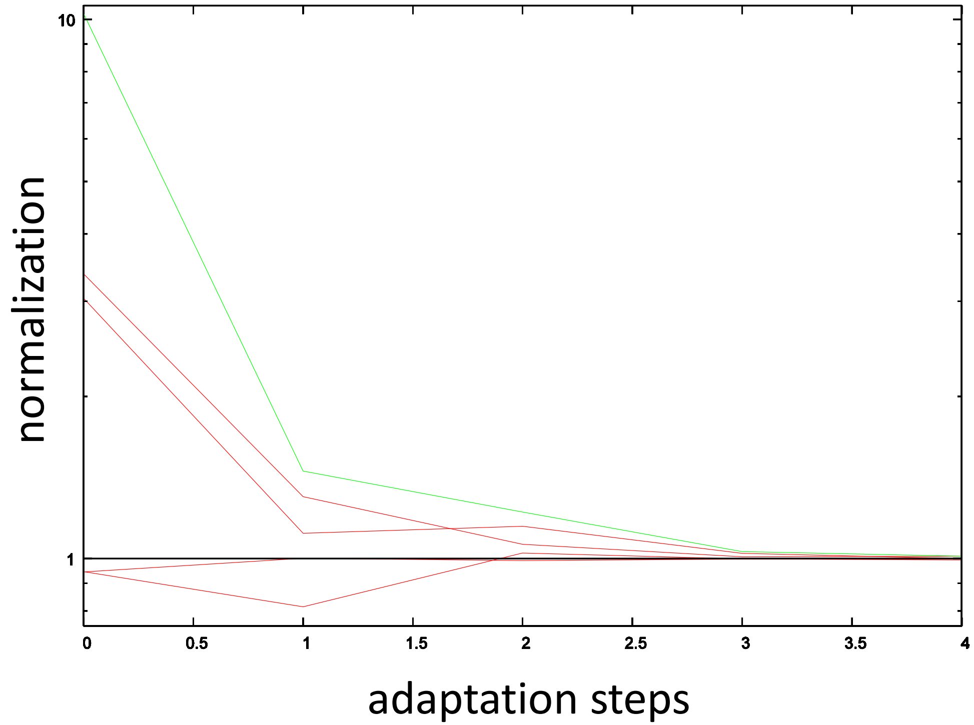


Adaptive Monte Carlo

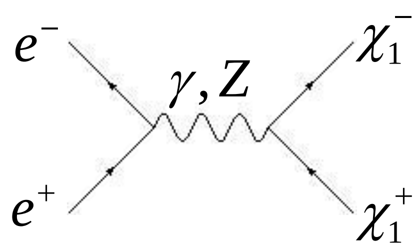
In order to get full spin correlations pandora calculates the full integral with all decays at once. Since it should return the correct cross section for the process, all decays should be normalized to 1 (by dividing by the decay width).

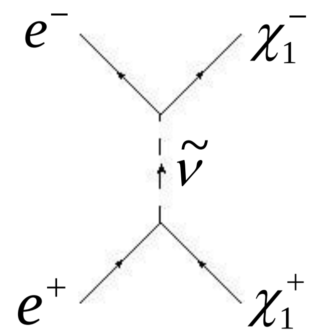
Including the Breit-Wigner widths complicates this because the normalization will not exactly match the naïve estimate of the width due to kinematic effects.

This is solved by calculating the subintegral of each decay and using this to adjust the decay normalizations. This can be accomplished using the same grid and data set used to adapt the full integral



Phenomenology of e^-e^+ to $\chi^-\chi^+$





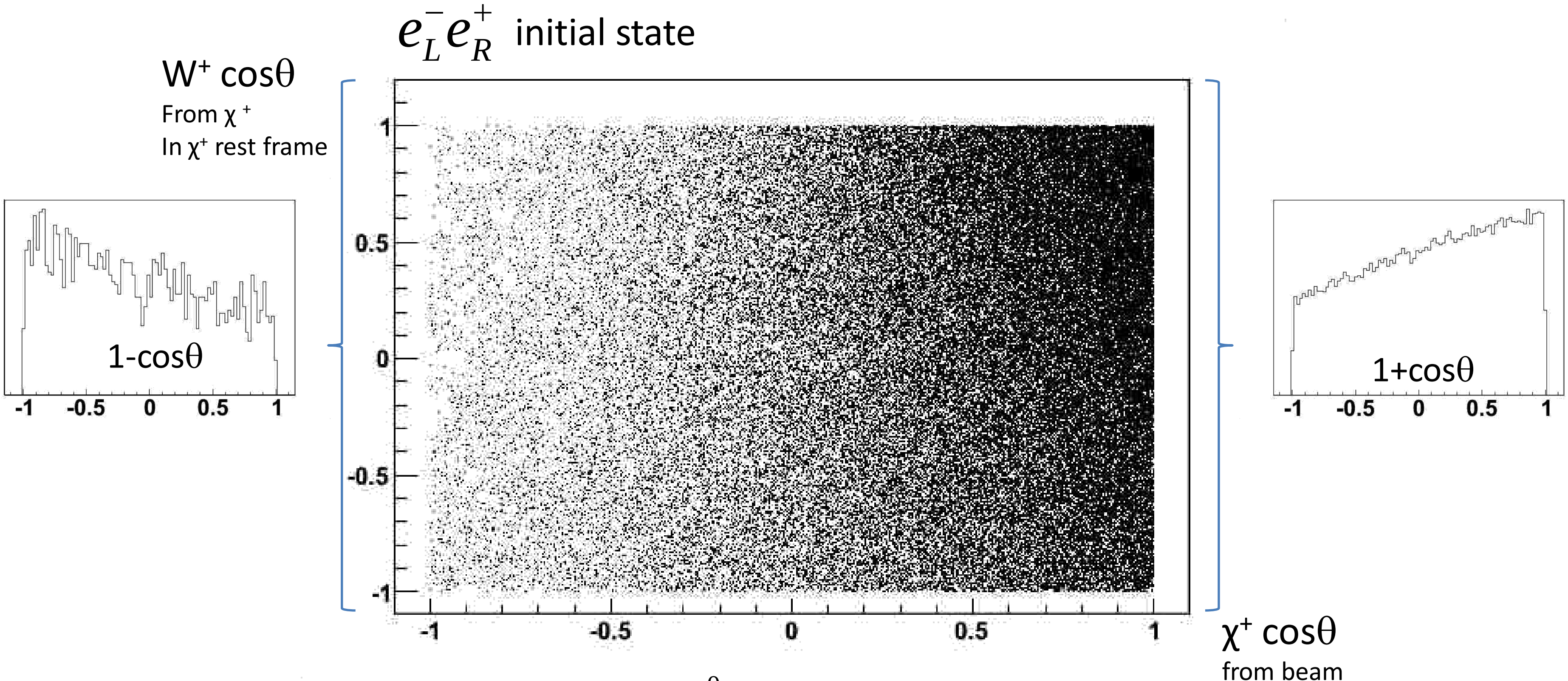
The e^- and e^+ spins forces a correlation between the $\chi_1^\pm$ angles and the helicity.

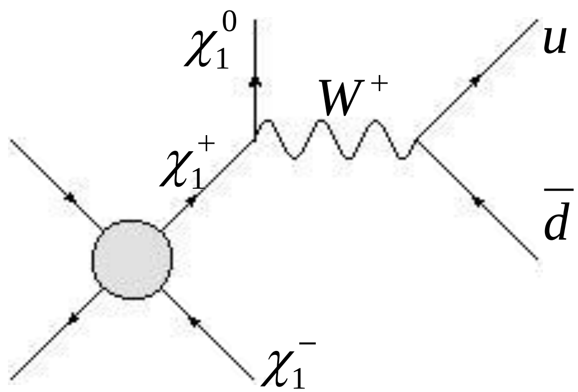
For the $e_L^- e_R^+$ initial state the $\tilde{\nu}$ t-channel diagram destructively interferes. Depending on the $\tilde{\nu}$ mass this could significantly affect both the cross section and the shape of the $\chi_1^\pm$ angular distributions

This channel is a key tool for the ILC to measure the individual Lagrangian parameters relevant to the Chargino-Neutralino system.

Some of these effects may be visible at the LHC.

Angle and helicity correlation



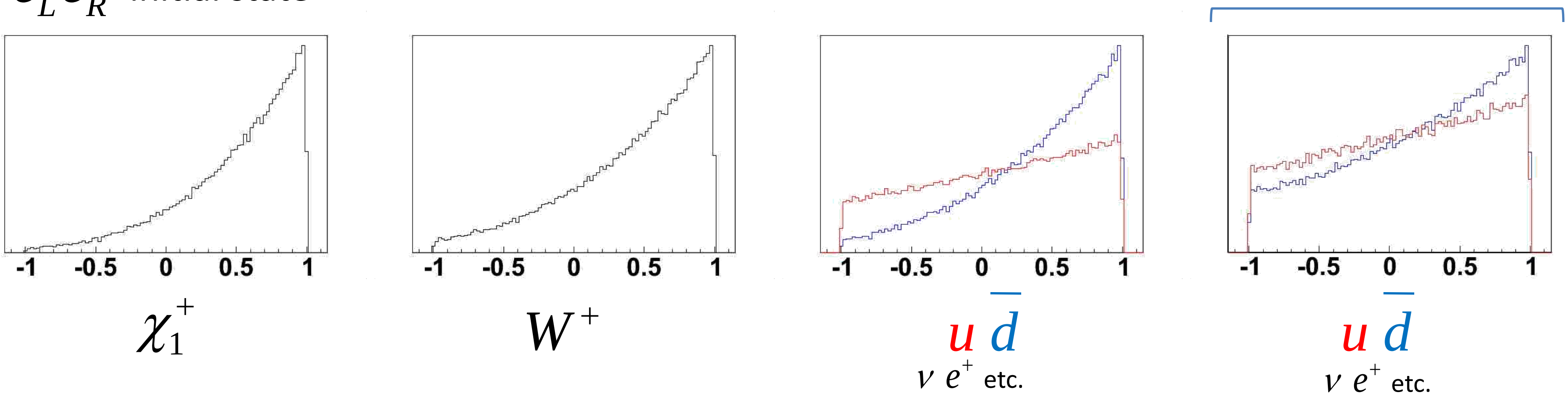


Spin correlations in e^-e^+ to $\chi^-\chi^+$

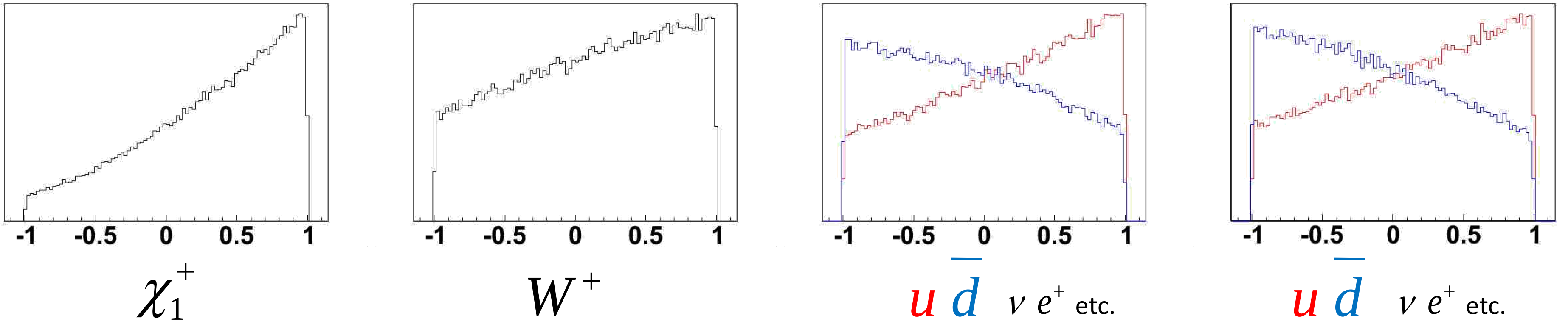
Plots of cosθ
(from e^- beam)

w/ realistic polarization
ISR and beamstrahlung

$e^-_L e^+_R$ initial state



$e^-_R e^+_L$ initial state



Conclusion

pandora is a built using an object oriented structure that allows implementation of a variety of physics models.

It can generate events in long decay chains while correctly handling the spin correlations in the decays.

Many useful features for focused study of BSM physics processes at a variety of next generation colliders.