BRIDGE

A Calculator for Widths and Decays

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manual: hep-ph/0703031

http://www.lepp.cornell.edu/public/theory/BRIDGE/

Why BRIDGE?

In our experience, it has become fairly easy to generate events for arbitrary models, as long as the final-state multiplicities are not too large. Many tools exist: CompHEP/CalcHEP, MadGraph, Sherpa, etc....

However, with limited computing resources, simulating many-body final states is difficult. Need this in models with long decay chains.

Another issue is computing widths and branching ratios for a given model. CompHEP/CalcHEP can do this. MadGraph does not. This means that running processes in MadGraph requires one to compute the widths externally. One would like to automate this.

So, the idea is: we want a general code that can take a model, work out what the unstable particles and their decays are, and compute the widths.

Also, the code should be able to decay Les Houches formatted event files.

What BRIDGE Does

BRIDGE stands for Branching Ratio Inquiry / Decay Generated Events.

The "BRI" part of BRIDGE sets up amplitudes for decays of unstable particles, using the **HELAS** libraries. It integrates them over phase space using the **Vegas** algorithm, to compute partial widths.

BRI stores the Vegas grids from the integration.

The "DGE" part of BRIDGE reads in Les Houches format event files, decays the unstable particles in them, and writes the output to new files. It uses the grids generated by "BRI".

It runs in three modes:

(a) Decay a single particle (e.g., decay all tops) according to the branching ratios.

(b) Decay recursively until one reaches a specified set of final-state particles (e.g., SM particles and $\tilde{\chi}_1^0$).

(c) Decay recursively using a specified set of decay modes (e.g., decay $t \to W^+ b$, $W^+ \to e^+ \nu_e$, $W^+ \to \mu^+ \nu_\mu$).

Using "DGE", one can simulate processes with long decay chains by first simulating $2 \to 2$ (or other low-multiplicity processes), then decaying the results.

BRIDGE provides a very general tool for this. There are other options – e.g. telling Pythia a particle's quantum numbers with the QNUMBERS block and decaying with flat matrix elements. (Recall Jesse Thaler's talk.)

However, BRIDGE keeps the matrix elements, and in fact seems to do quite well at getting angular information correct.

A Simulation Pipeline

There are many simulation programs on the market, and many ways of combining them. We hope BRIDGE will be useful partnered with various programs, but there is one pipeline that is already very smooth:

$$\text{MadGraph} \rightarrow \text{BRIDGE} \rightarrow \text{Pythia} \rightarrow \text{PGS}$$

This is how the Cornell/Harvard black box you heard about yesterday was made. It is an **easy** route to go from new physics model to plots.

The structure of BRIDGE owes a great deal to the Standard Model "decay" program included in MadGraph, written by Fabio Maltoni. However: written in C++, storing the grids to disk for re-use, and allowing for **arbitrary** models.

BRIDGE interfaces smoothly with MadGraph, but in principle can be used with other event generators. (If you want BRIDGE to use some particular input or output format, feel free to implement it, or ask us for help.)

General model specification?

Now I want to show some plots to demonstrate that BRIDGE can give accurate results. The comparisons are of events with small numbers of particles generated with MadGraph and decayed with BRIDGE, versus MadGraph simulations of the full set of diagrams leading to the final state particles.

Obviously, BRIDGE will lose some interference effects. Some spin information can be lost, as at each stage a particle has a definite helicity assignment.

We find the best results by always giving particles a definite helicity in the rest frame of the *parent particle highest up the chain*.

Plots of $t\bar{t}$: BRIDGE vs full MadGraph

$$t\bar{t} \to W^+ b W^- \bar{b} \to e^+ \nu_e b e^- \bar{\nu}_e \bar{b}$$

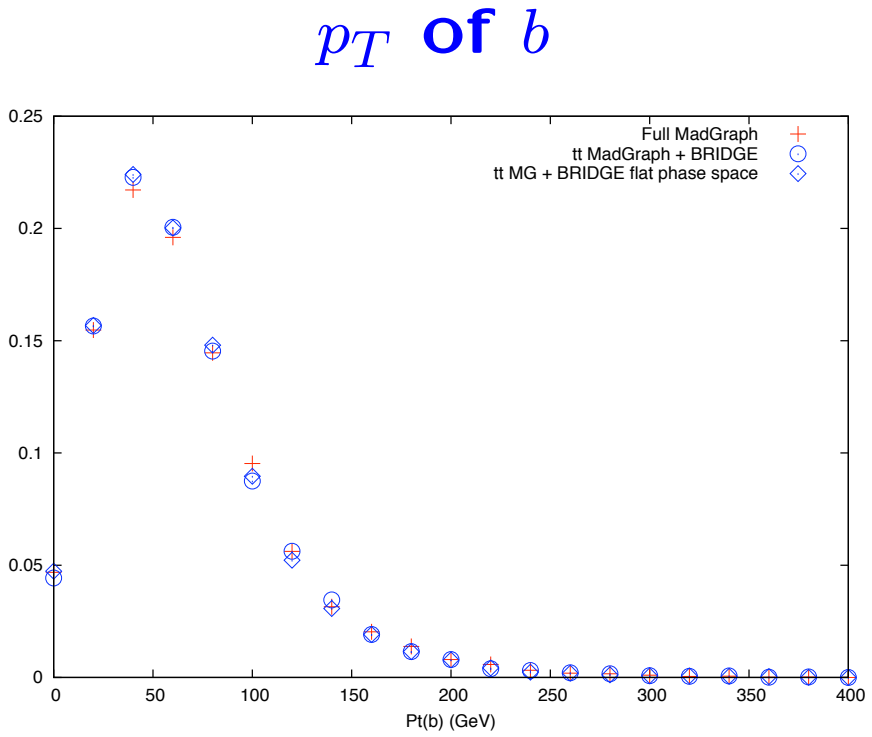
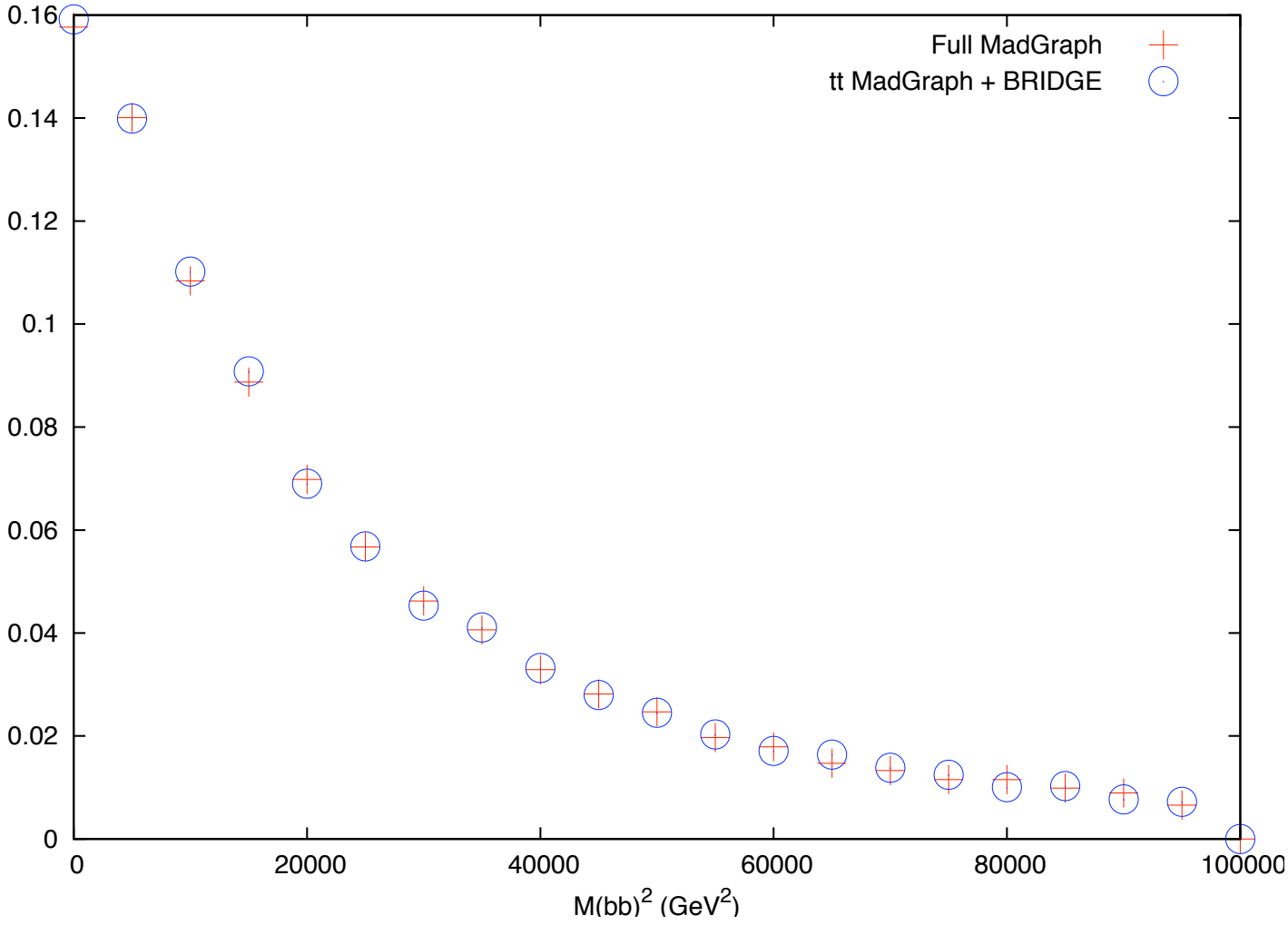
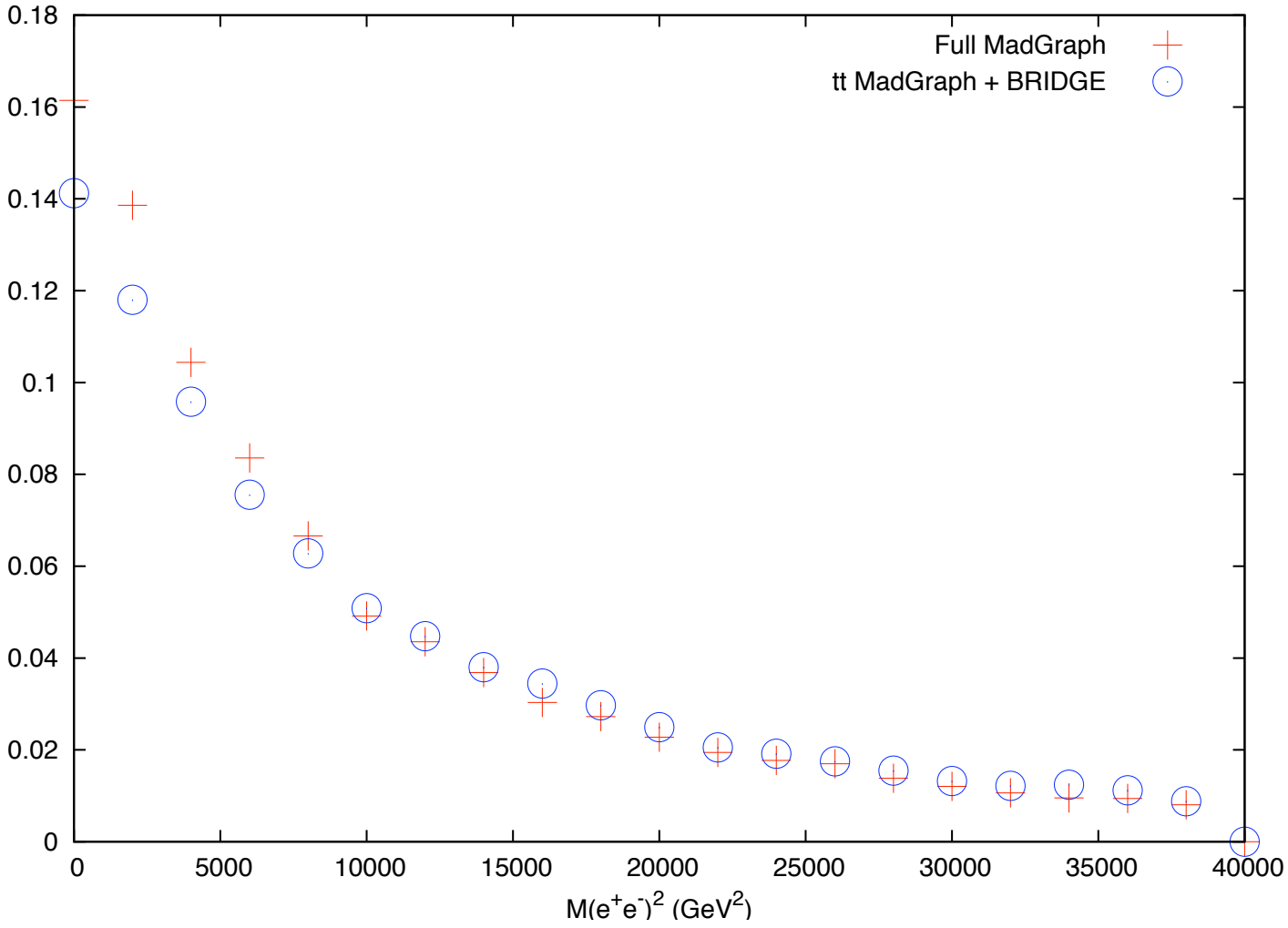


Figure 1: We have generated $t\bar{t}$ events in MadGraph and decayed them with BRIDGE, and also generated $e^+\nu_e b e^-\bar{\nu}_e\bar{b}$ events in MadGraph. Here we plot the p_T histogram for the b quark in the decayed events versus the full matrix element. In this and other figures, the histograms are normalized to have the same area. In this figure we also show $t\bar{t}$ events from MadGraph decayed with BRIDGE with the amplitude set to 1, so that the decay is governed by the phase space volume.

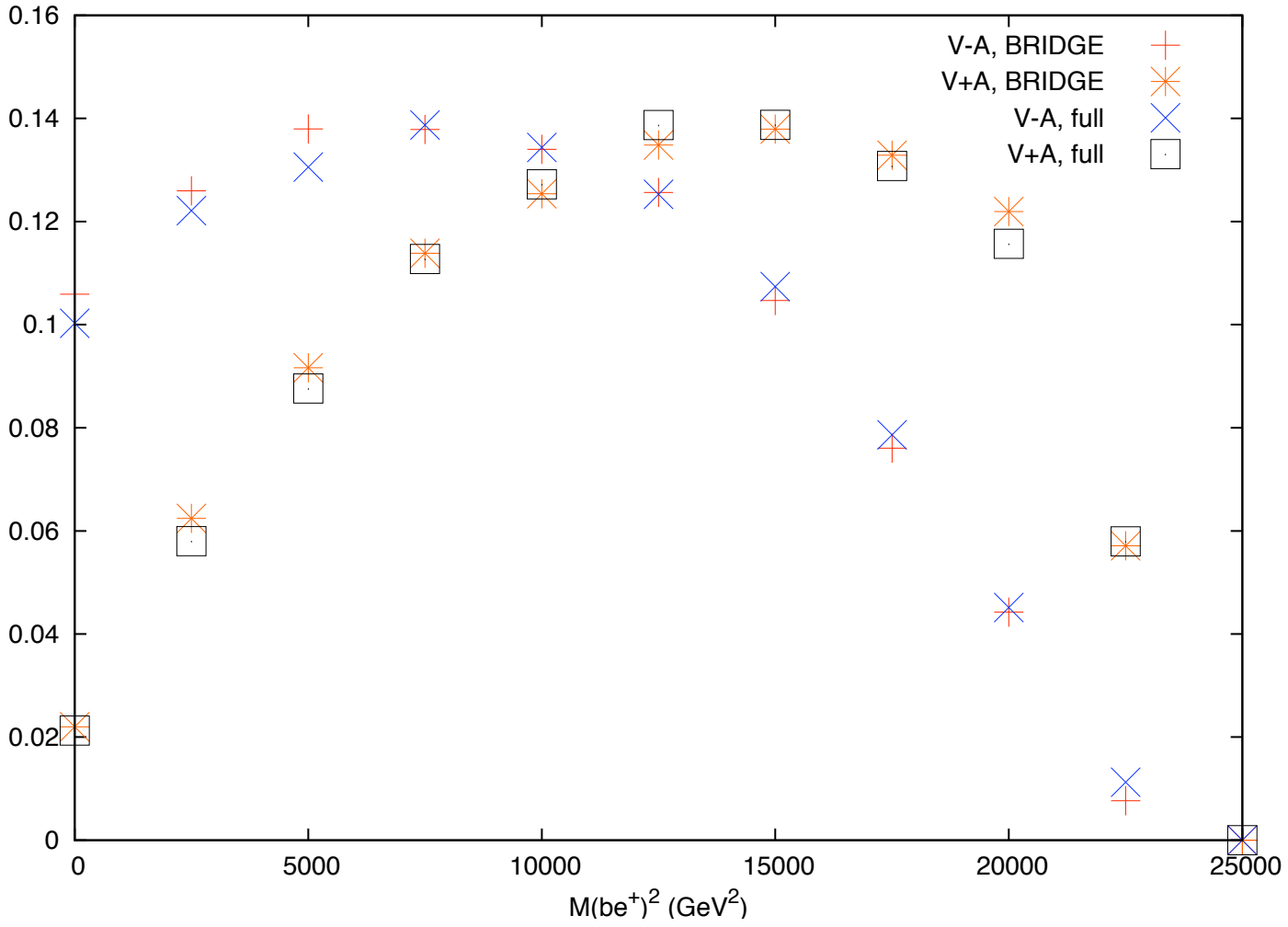
Invariant mass of $b\bar{b}$



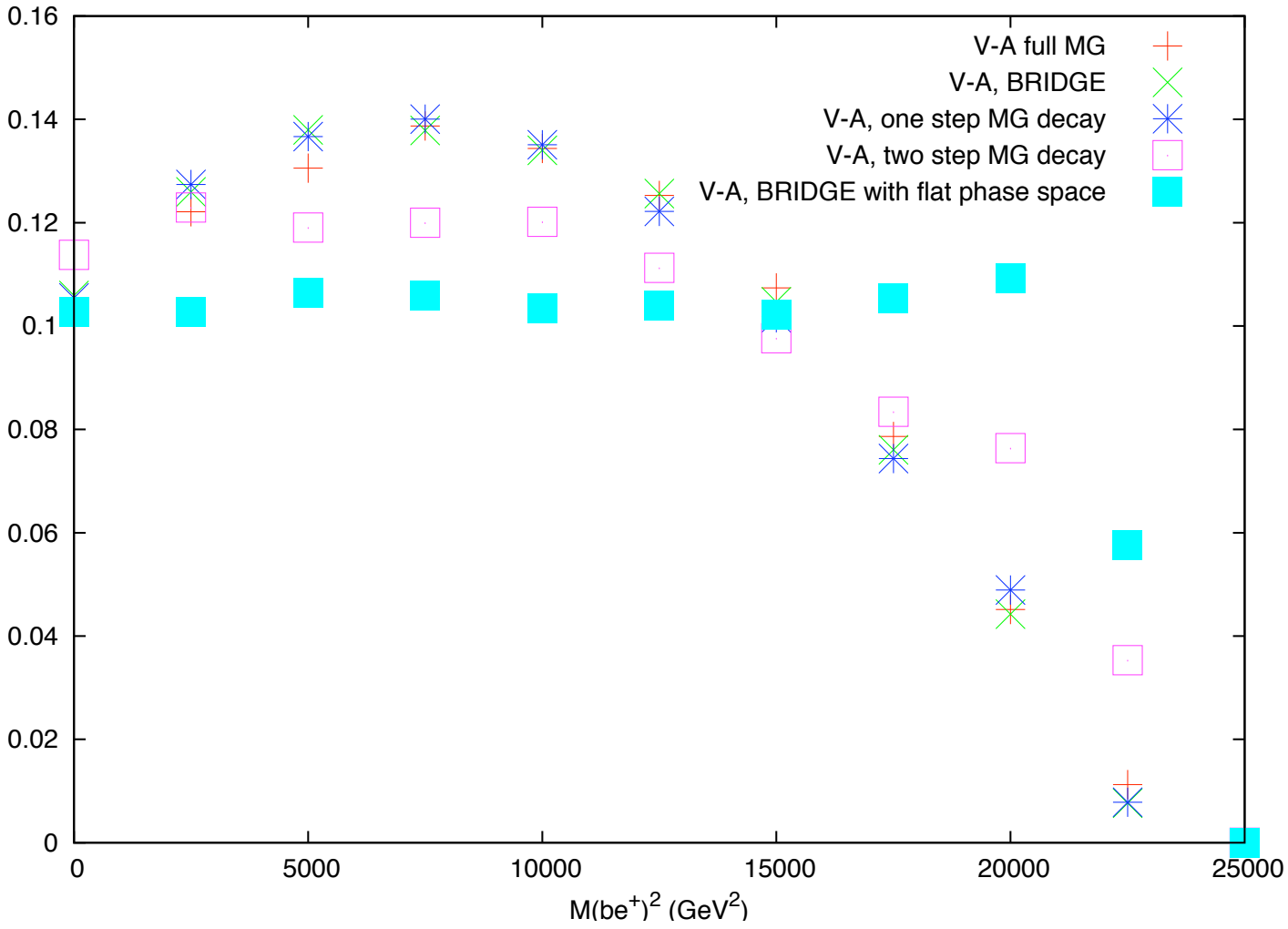
Invariant mass of e^+e^-



Invariant mass of be^+: Chirality



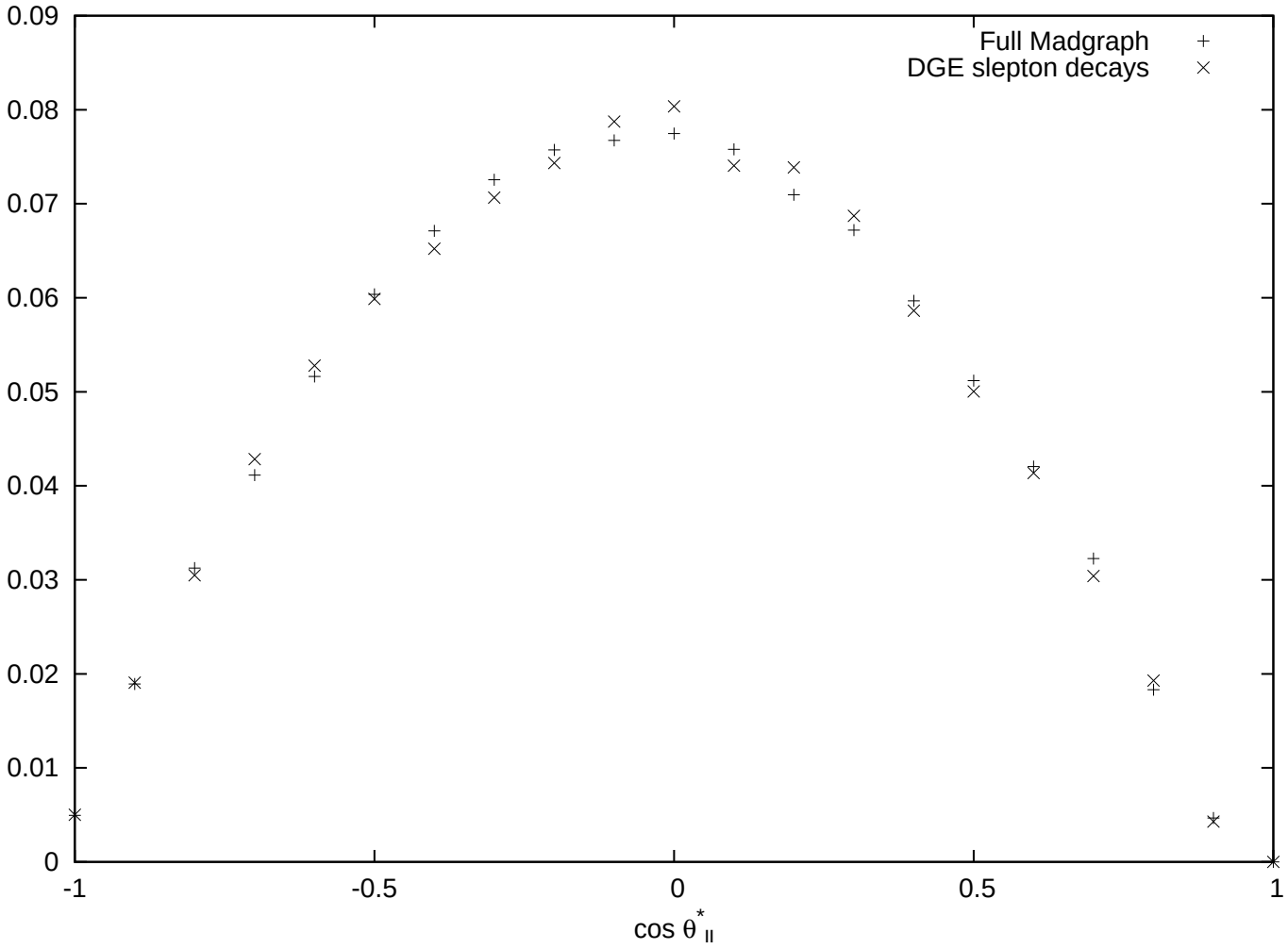
Invariant mass of be^+



MSSM

In the case of the MSSM, we've provided special executables designed to read the SUSY Les Houches Accord parameter files and set up all of the couplings BRIDGE needs. Results have been checked against SDECAY.

Barr's slepton observable



Future

We hope that you will find BRIDGE useful. We will be adding a batch mode soon (less typing!).

Work on three-body decays is (still) in progress. Treating the top decay as 3 body works in our current beta version. We will try to do some more interesting checks soon....

Everything is on-shell now. We might try to broaden the widths while still matching other distributions.

(Finally: thanks to the MadGraph team for their support!)