Predictions of QCD (background) rates for an e^+e^- collider from MC fits to existing data

Jon Butterworth (University College London)

Matthew Wing (Bristol University)

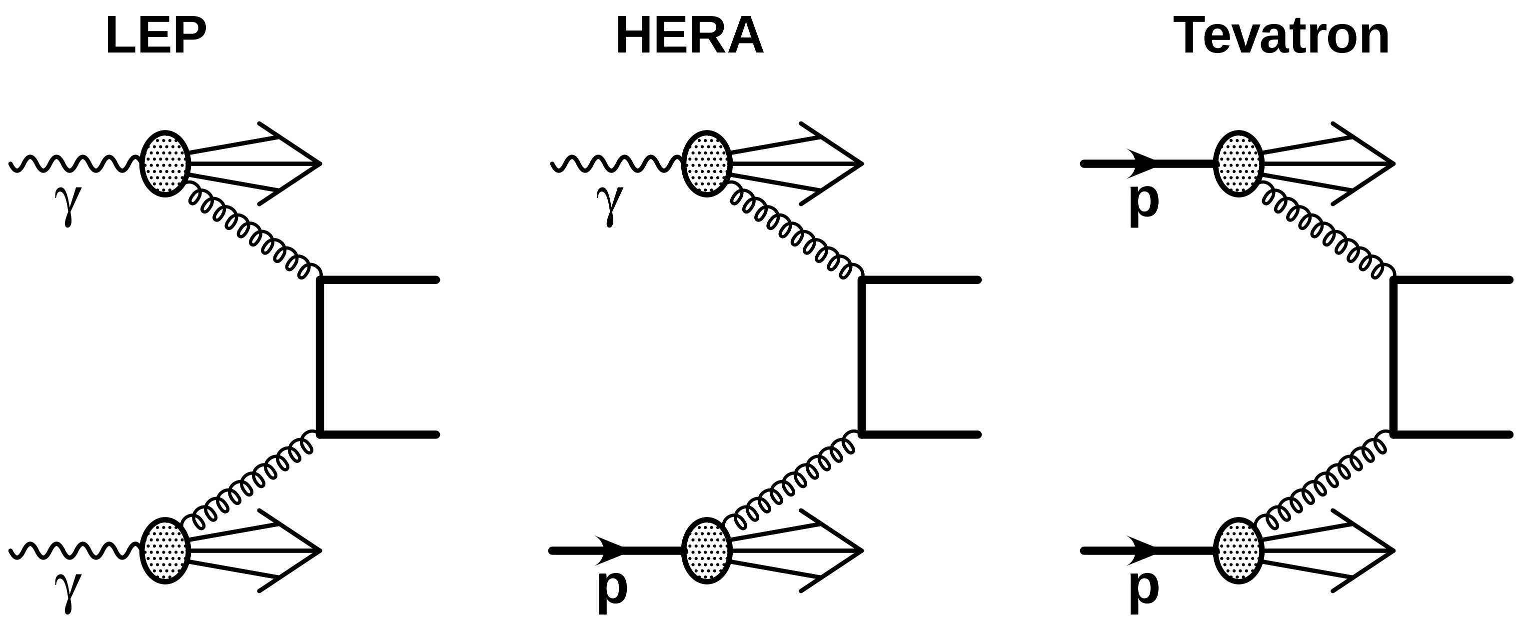
- Introduction and strategy.
- Recent changes and improvements - fitting and predictions.
- Current best tunings - HERWIG and PYTHIA
- Predictions for a linear collider.
- Summary and outlook.

Introduction

Why study QCD? It is a background.

- **Colliding beams are QCD objects.**
- **New physics often sits on a large QCD production background.**

Have a lot of data on QCD from HERA, LEP and Tevatron. What have we learnt from the current data? How will this help us for future experiments?



In particular, measure variables sensitive to γ structure, underlying events, etc..

Strategy

Have compared HERWIG 6.4, PYTHIA 6.206 with (fit to) current data sets.

This checks the consistency of current data and provides reliable MC for future colliders.

Using over 20 papers (mainly from HERA) to test the MC.

Varied many parameters not already constrained by LEP tunes (by eye rather than complete tune.)

Using JetWeb facility which is a WWW interface database for MC tuning.

J. M. Butterworth, S. Butterworth, "JetWeb: A WWW Interface and Database for Monte Carlo Tuning and Validation" `hep-ph/0210404`, `http://jetweb.hep.ucl.ac.uk/`

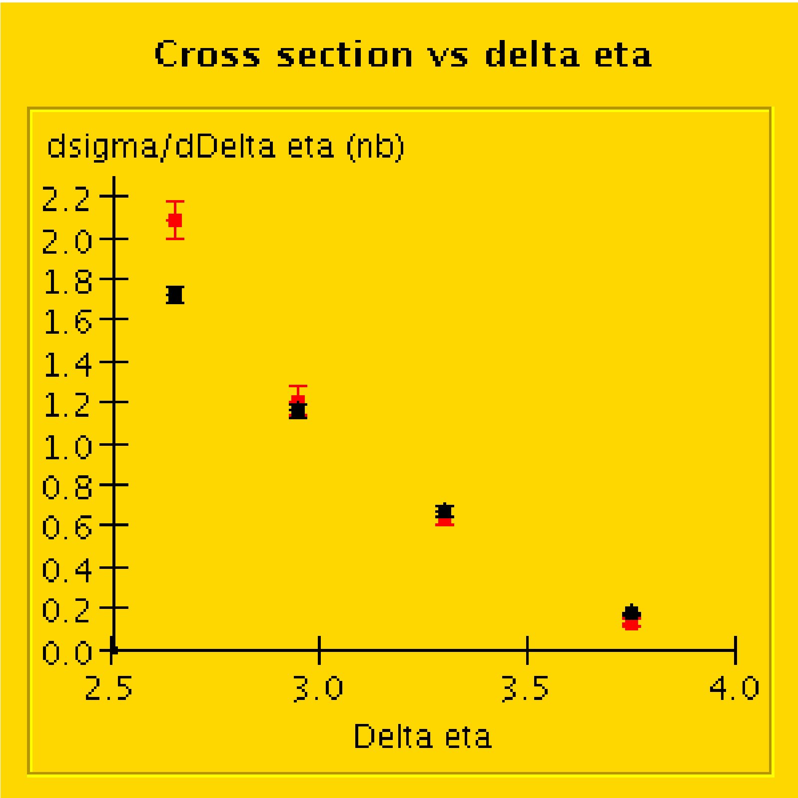
Recent additions for fits

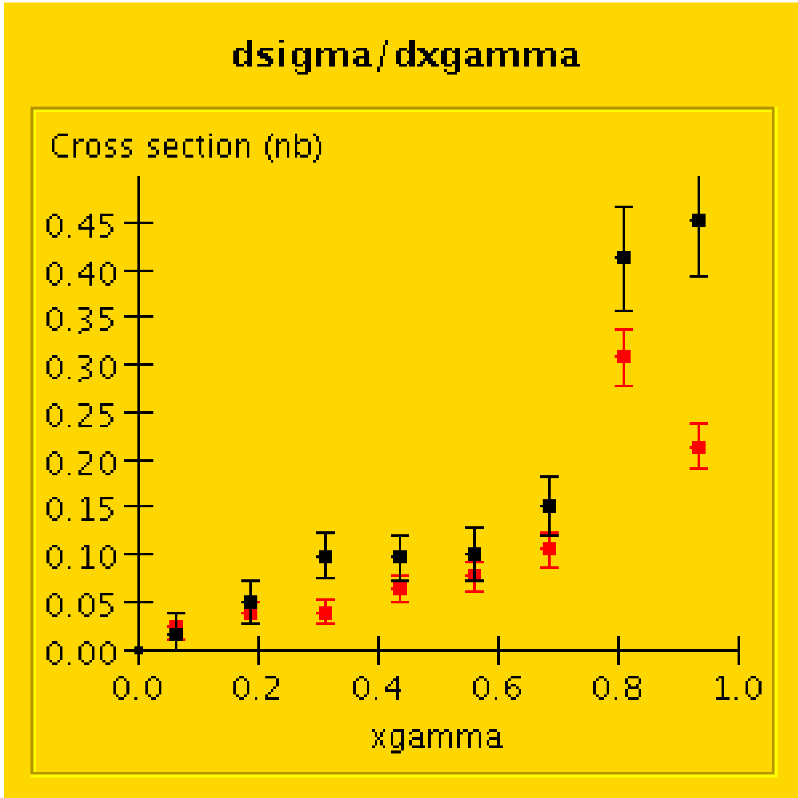
Generation of more and much larger HERWIG and PYTHIA MC samples (although still more needed).

Finding and fixing bugs to give better fits.

(Ongoing) addition of new data from HERA, Tevatron, LEP, minimum bias SPS data

Rapidity gaps, H1 DESY 02-023. **Charm and beauty, ZEUS DESY 00-166.**





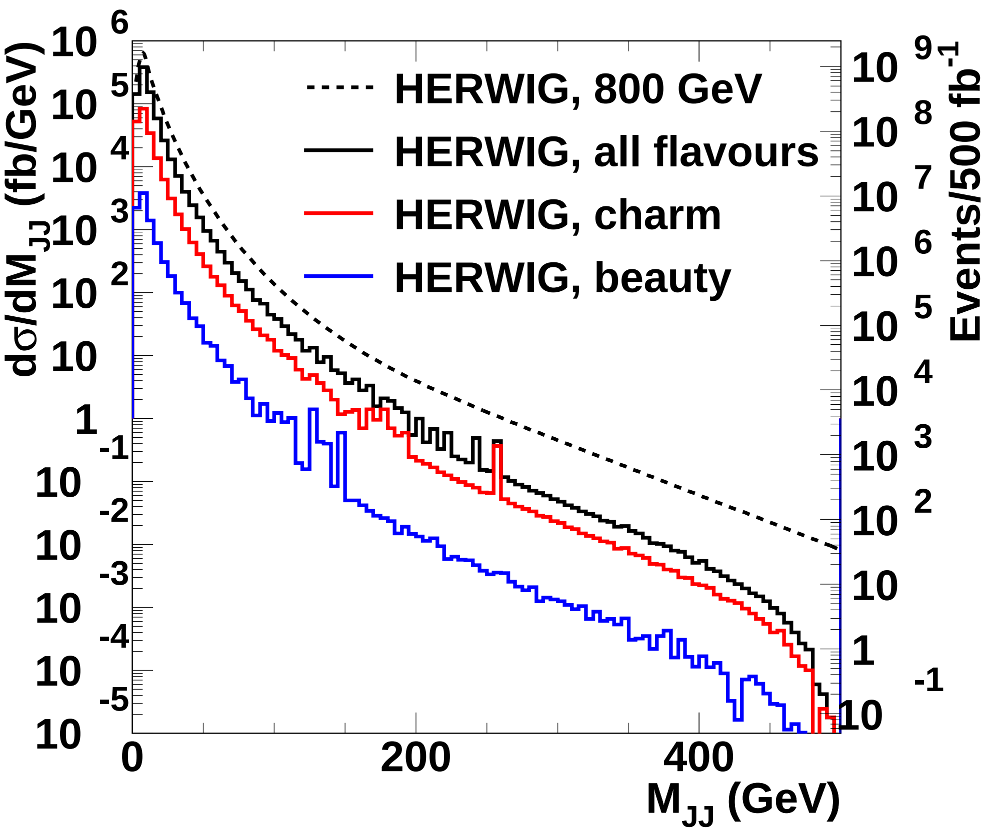
Recent additions for predictions

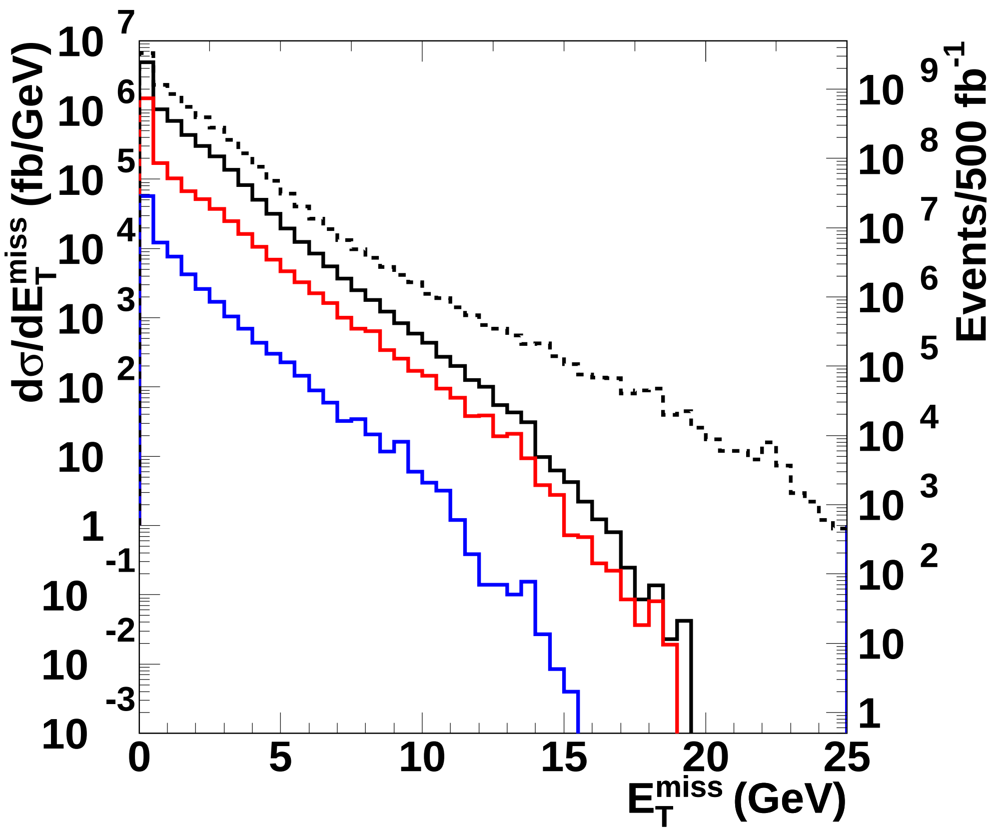
Predictions now obtained for PYTHIA - beamstrahlung taken from HERWIG and event-by-event weight applied to PYTHIA.

Predictions for 800 GeV as well as 500 GeV - much larger background at higher (more interesting) masses and energies.

Looked at charm and beauty production - charm particularly relevant.

Looked at detector relevant aspects, e.g. events/particles per bunch crossing (for a given p_T^{min}).





Implementation of Beamstrahlung in PYTHIA

Beamstrahlung not available in PYTHIA for $\gamma\gamma \rightarrow$ QCD processes.

Could implement into PYTHIA as done in HERWIG.

Easier to extract weights from HERWIG by considering a cross section with beamstrahlung on and off.

A 2D grid in the energy fractions ($\log_{10}(E_\gamma/E_e)$) of the two virtual photons was formed.

A weight was then found as the ratio of cross sections in each bin in the grid.

Direct, single-resolved and double-resolved events used to span all phase space.

Performed separately for 500 and 800 GeV.

Testing of Beamstrahlung weights

Found for a given set of HERWIG parameters.

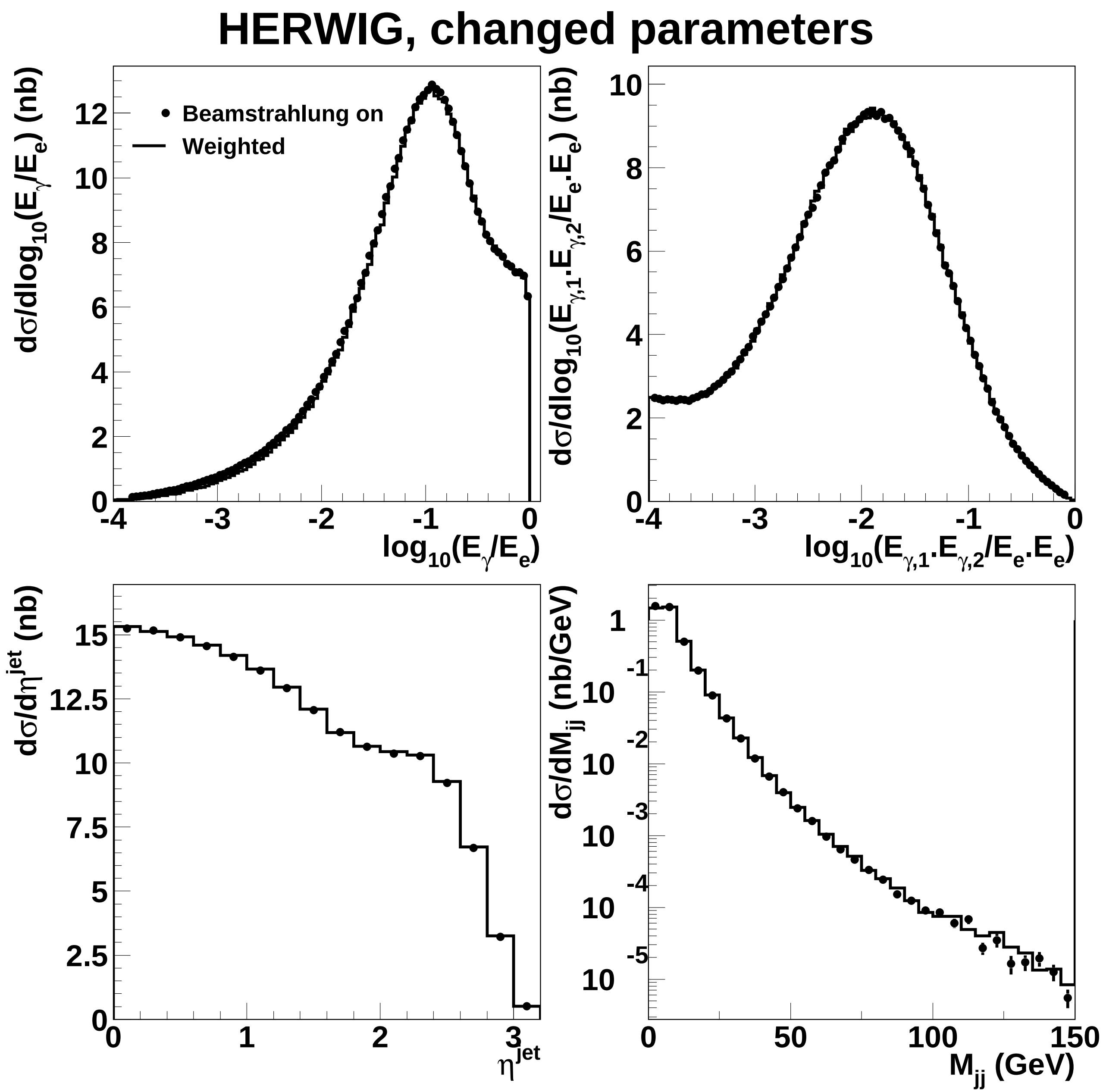
(Trivial) retest on HERWIG sample with same settings.

Apply to a sample of direct photon-photon collisions.

Parameters changed (p_T^{min}, PDF) and weight applied $\rightarrow$

Energy fractions and other complicated distributions reproduced exactly.

Confidence in weighting procedure $\Rightarrow$ use in PYTHIA.



Current good fits

HERWIG (Fit 707): PDF$_\gamma$ - SaS2D, $p_T^{\rm min} = 3$ GeV, JIMMY + SUE (PRSOF = 0.05), Normalisation $= 1.7$. High E_T, $\chi^2/$dof $= 2.0$, Low E_T, $\chi^2/$dof $= 3.6$.

HERWIG (Fit 464): PDF$_\gamma$ - SaS2D, $p_T^{\rm min} = 3$ GeV, SUE (PRSOF = 0.3), Normalisation $= 1.6$. High E_T, $\chi^2/$dof $= 1.8$, Low E_T, $\chi^2/$dof $= 3.5$.

HERWIG (Fit 236): PDF$_\gamma$ - GRV LO, $p_T^{\rm min} = 3$ GeV, JIMMY, Normalisation $= 1.65$. High E_T, $\chi^2/$dof $= 1.9$, Low E_T, $\chi^2/$dof $= 3.4$,

PYTHIA (Fit 3): PDF$_\gamma$ - SaS2D, $p_T^{\rm min} = 2.4$ GeV, UE model 3 Normalisation $= 1.3$. High E_T, $\chi^2/$dof $= 2.4$, Low E_T, $\chi^2/$dof $= 3.1$.

PYTHIA (Fit 235): PDF$_\gamma$ - SaS2D, $p_T^{\rm min} = 3$ GeV, UE model 1 Normalisation $= 1.3$. High E_T, $\chi^2/$dof $= 2.5$, Low E_T, $\chi^2/$dof $= 2.7$.

Trend for $p_T^{\rm min} = 3$ GeV to be favoured for high E_T measurements.

Example: Fits at high E_T

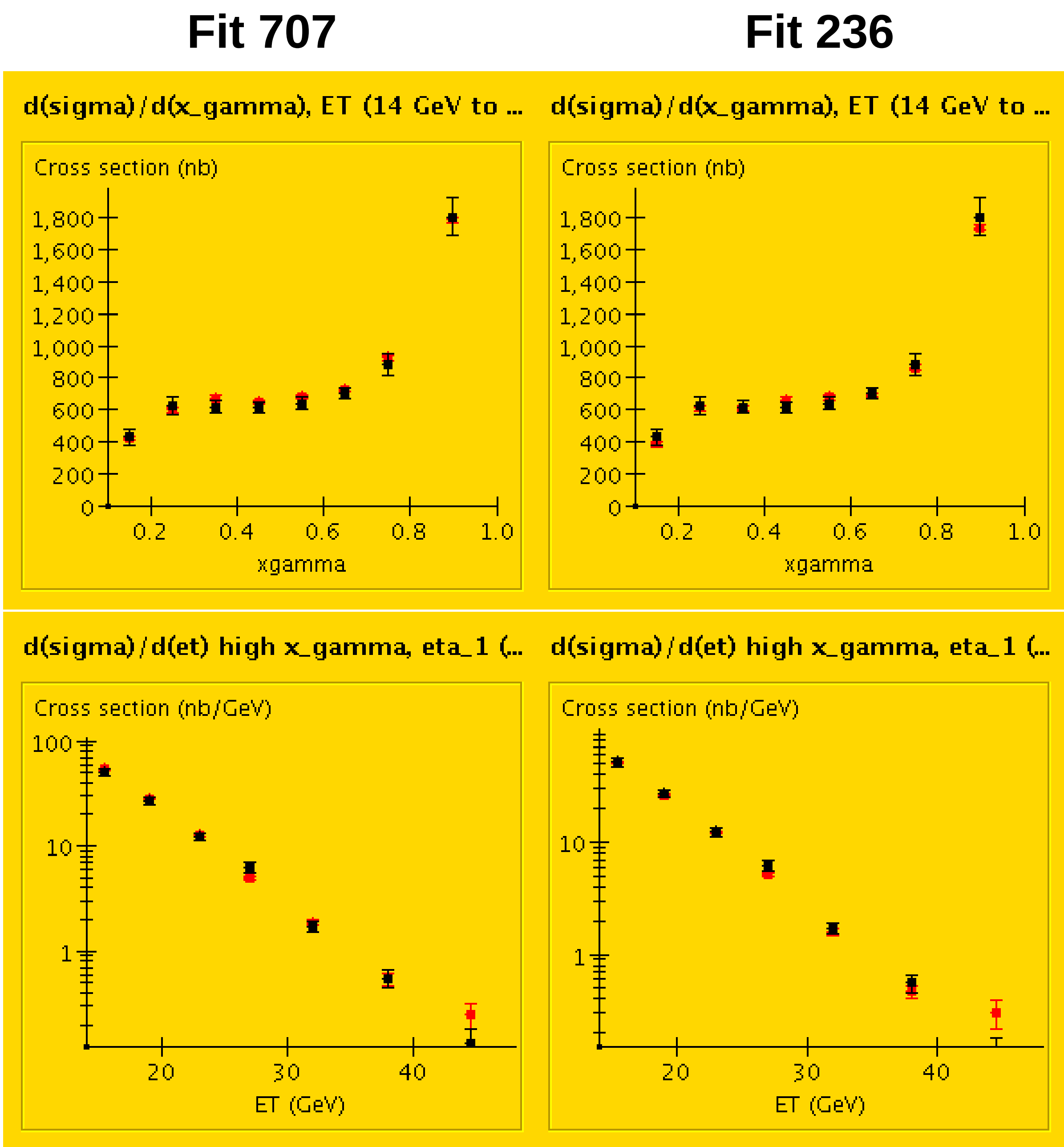
Fits 707 and 236 for HERWIG (see before) compared to dijet data.

Good description of direct to resolved ratio - persists up to higher E_T.

Good description of leading jet in forward region.

Poorest description for η^{jet} cross sections.

Generally similar descriptions of high E_T data.



Example: Fits for more exclusive final states

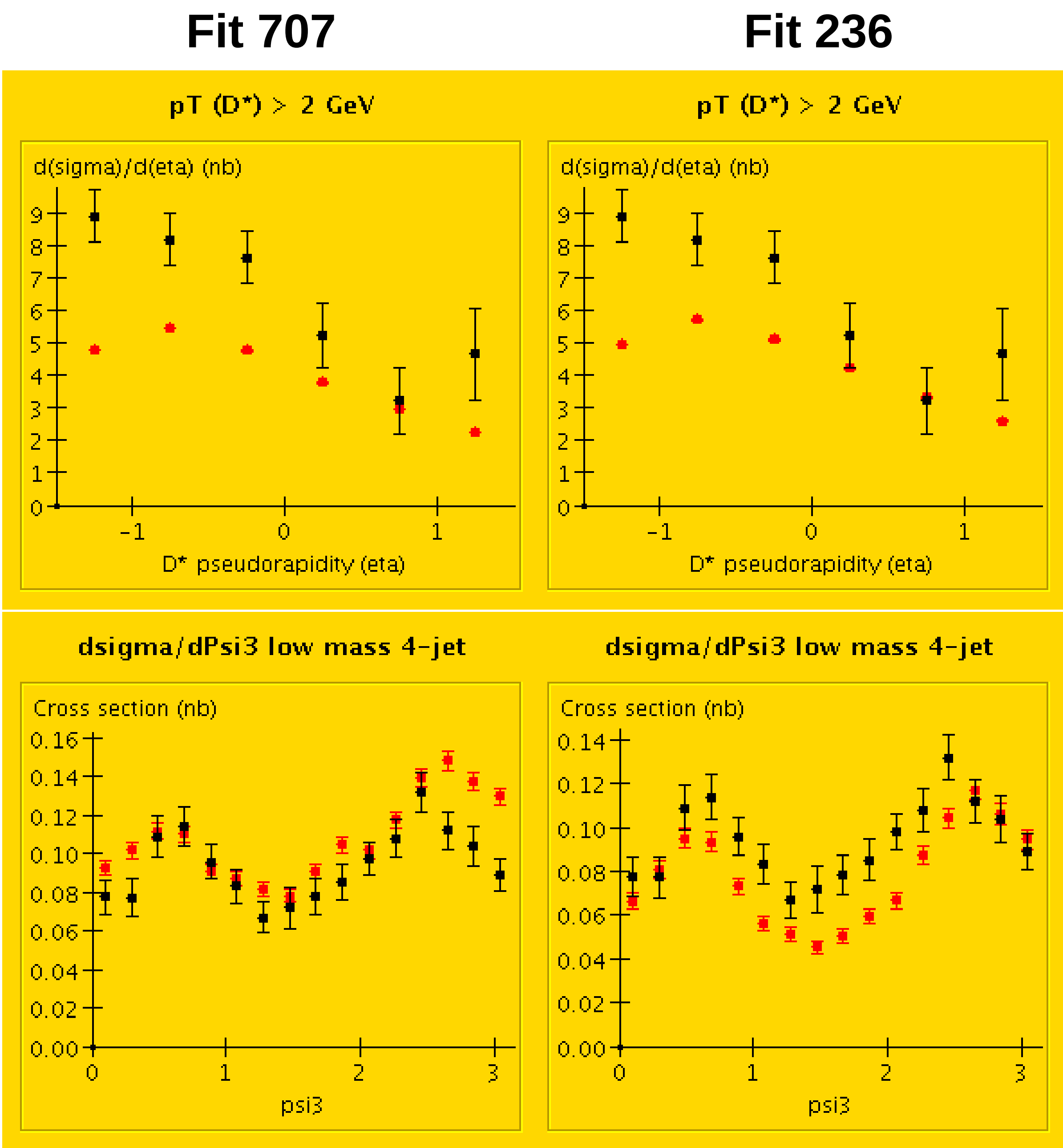
Poor description of low p_T D^* data from both fits. Improves with increasing p_T.

Additional charm data will help, but more needed.

Description of multijet angle is poor although trend is not far off.

Differences in predictions show up in the multijet cross sections.

Low E_T physics (of course) more challenging.



Example: Fits from PYTHIA

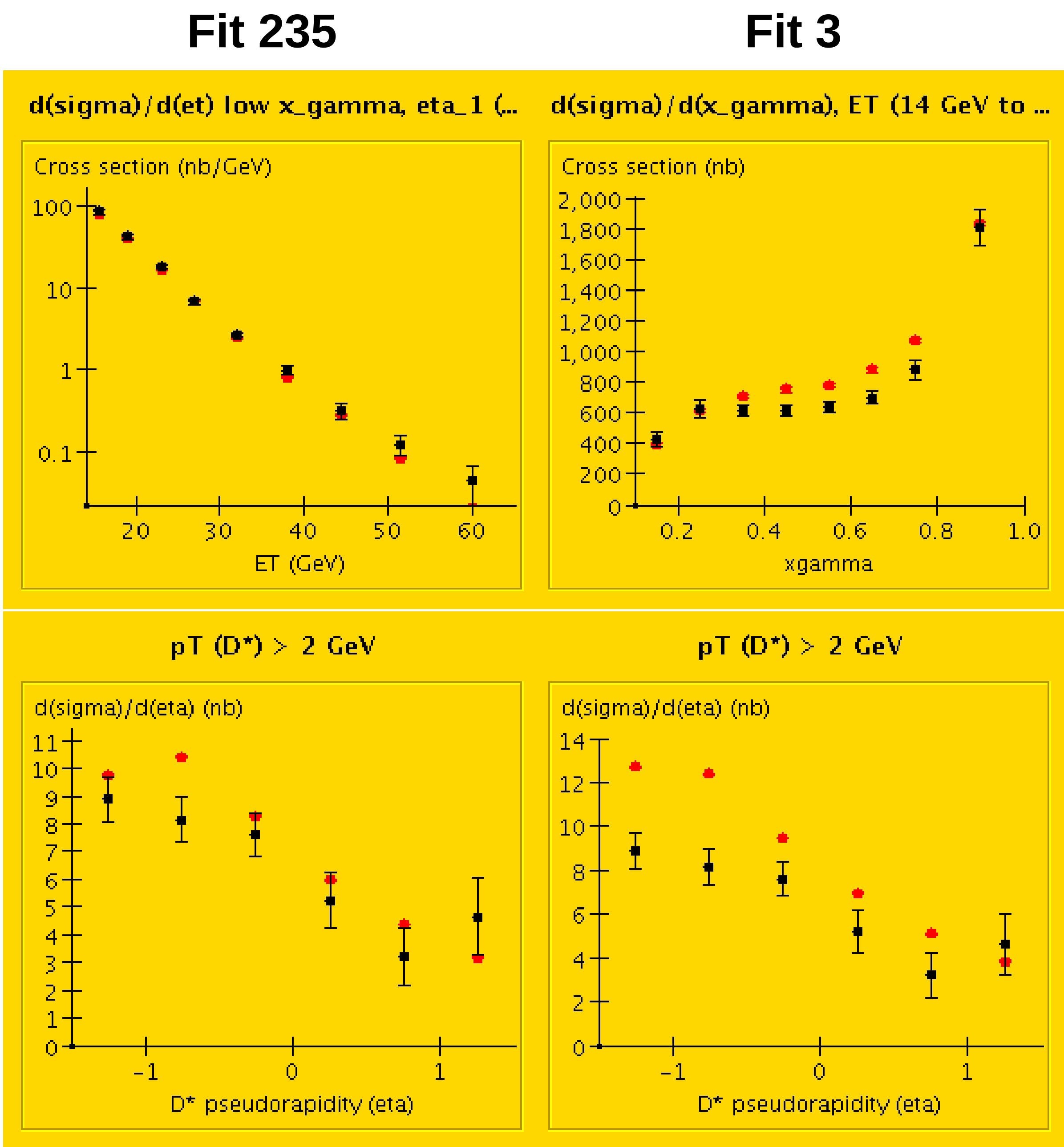
Less uniformly good description of high E_T data from PYTHIA.

E_T spectrum looks good but direct to resolved ratio is poor.

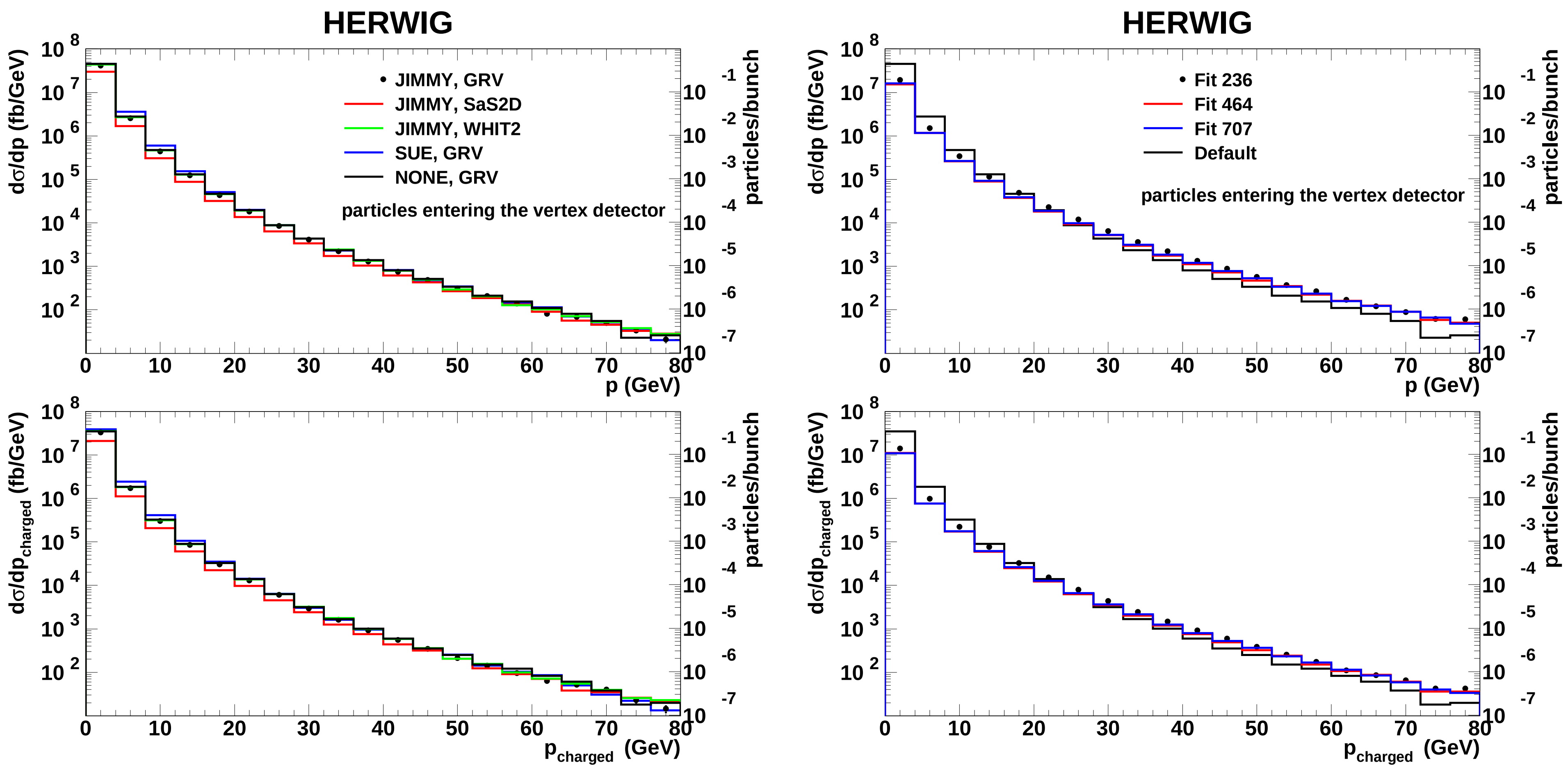
Low E_T data can be described well(ish).

Note the good description of the charm distribution (Fit 235 has higher p_T^{min}).

Still more trials with PYTHIA needed. Will still use these fits for predictions.



Rates of $\gamma\gamma$ events per bunch crossing



Total $\gamma\gamma$ events/bunch crossing ($p_T^{\rm min} = 3$ GeV) = 0.01 at 500 GeV and = 0.02 at 800 GeV.

Rate should not be a problem for detectors - not "all" events counted.

However, the parameter settings I have detailed are a good input for any detector studies you might want to do.

(Default) predictions at 500 GeV

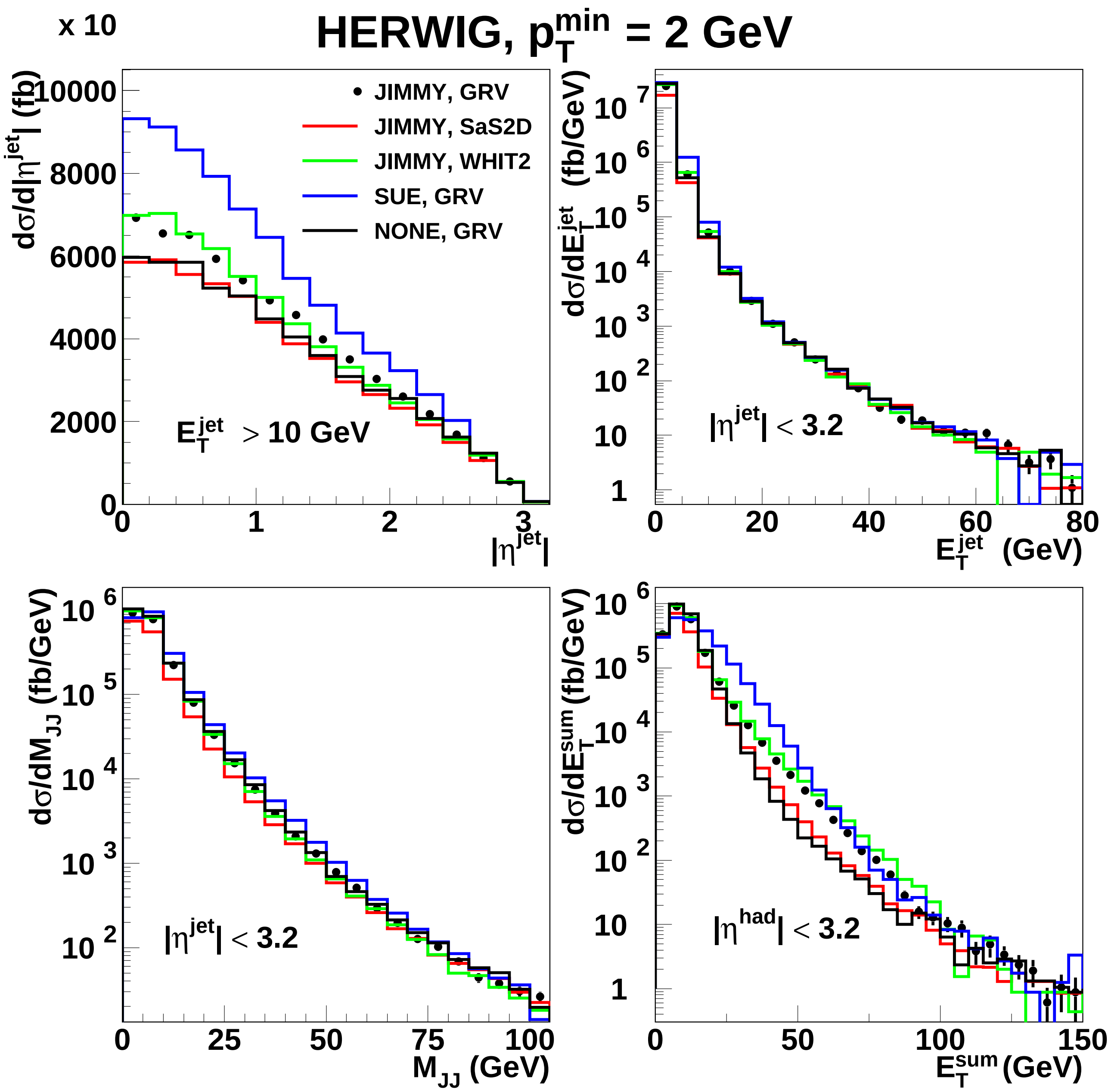
Default HERWIG prediction used with changes in underlying event and photon PDF.

All “reasonable” parameter settings.

Large spread in predictions, even at high energies.

How accurately do we know QCD production?

Not very well!



(Fitted) predictions at 500 GeV

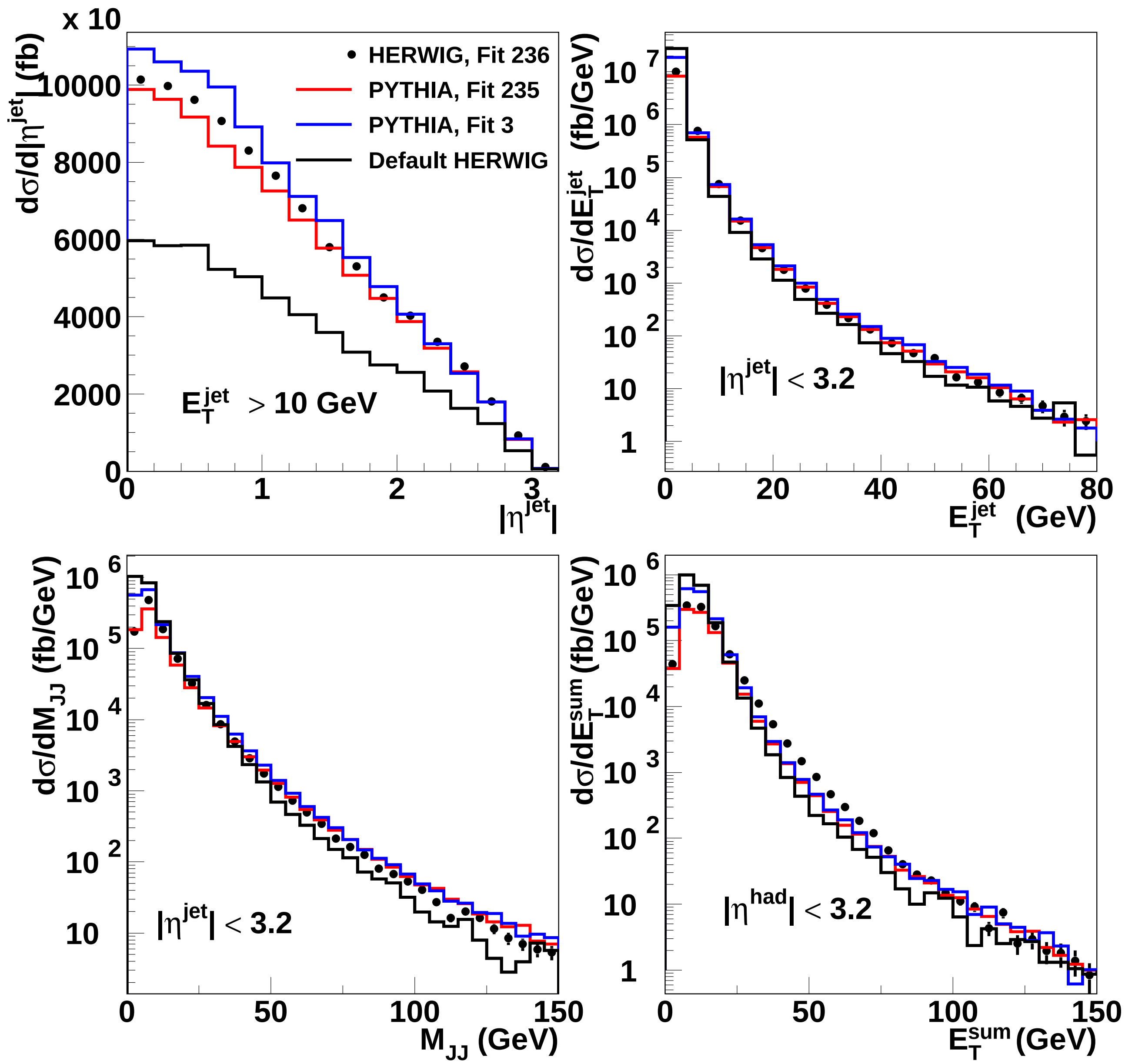
Again fits give similar results.

Spread is also reduced,
NB. predictions from two MCs

Significant differences to "default" prediction.

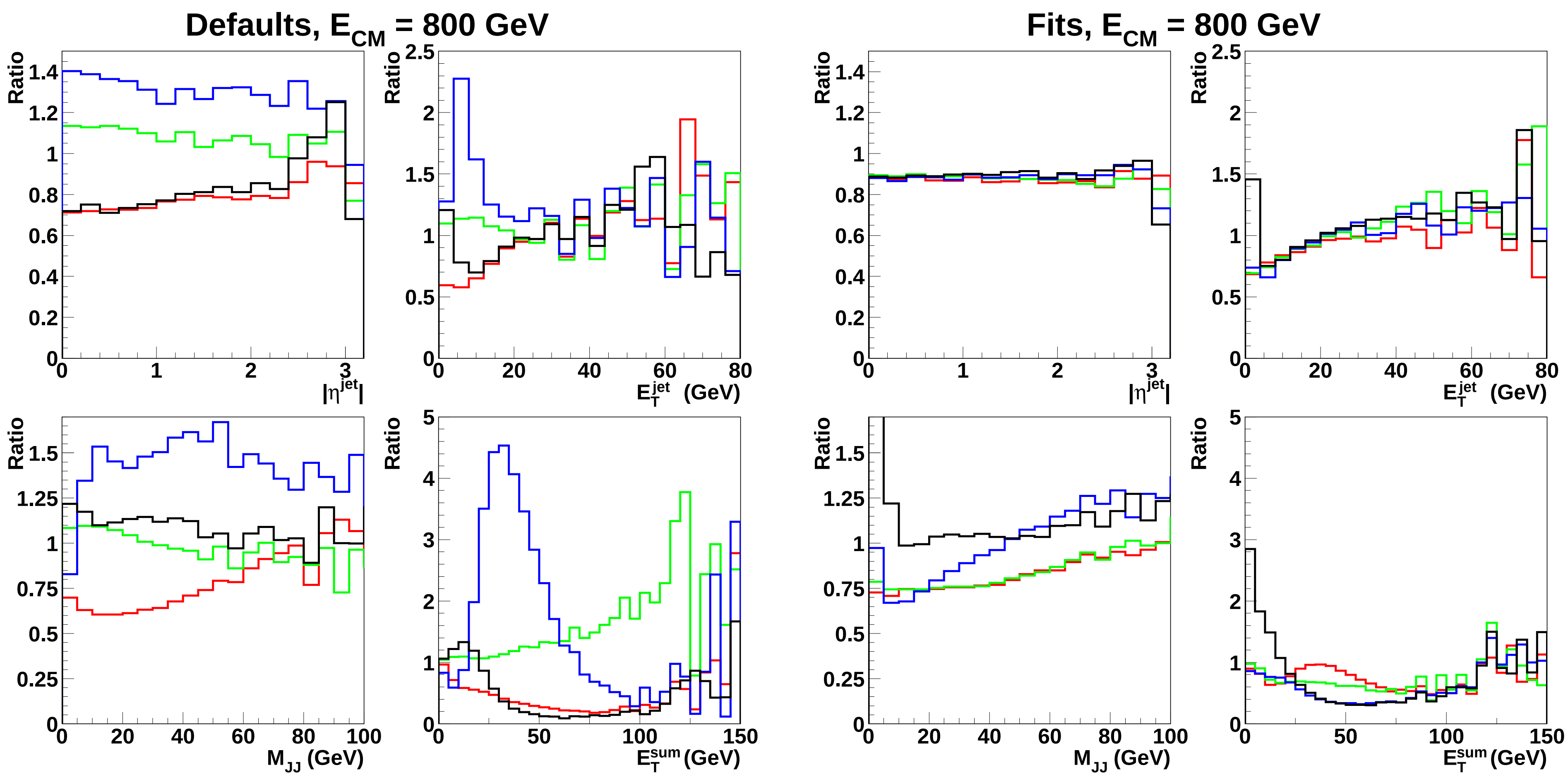
Predictions of QCD background known to much better accuracy.

These MC settings should be used in QCD background estimates for ee and $\gamma\gamma$ colliders.



(Fitted) predictions at 800 GeV

Choose "central" MC prediction and calculate how much other predictions differ.

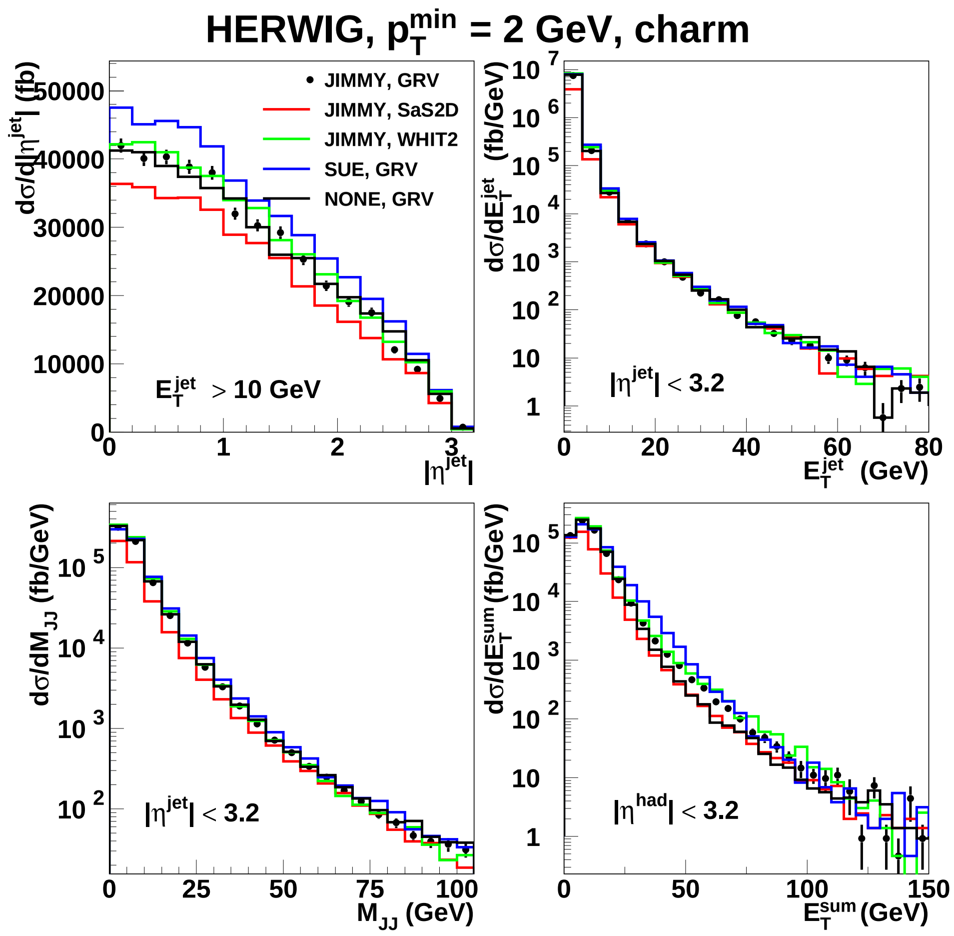


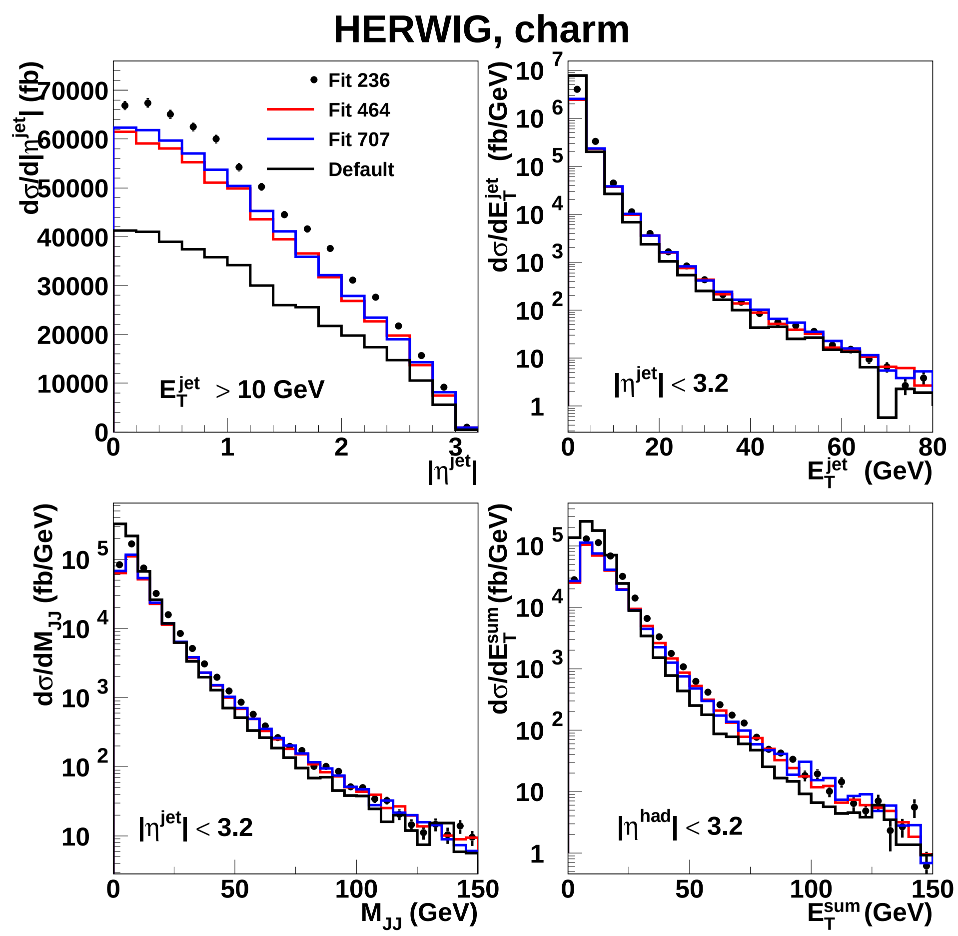
Five HERWIG predictions $\leftrightarrow$ three HERWIG, two PYTHIA predictions.

Same $p_T^{\min}$ $\leftrightarrow$ different $p_T^{\min}$.

Significant reduction in spread in predictions.

Charm production cross sections





Default predictions give reasonably consistent picture, but these are very different from fitted predictions.

Fits to charm data are not yet good if anything too low.

Summary

Have detailed MC parameter settings which describe a number of processes over a large kinematic range.

The QCD production rates have been calculated for a future linear collider with accurate predictive power.

These MCs and the parameter settings detailed should be used to calculate QCD production for future colliders.

Beamstrahlung has been implemented into PYTHIA. Code available.

Will improve fits but general proof of principle has been achieved and will write up a note detailing these results and making recommendations of what to use.

As a quick solution, details will be give at: `http://jetweb.hep.ucl.ac.uk/flc/`