Predictions of QCD (background) rates from MC fits to existing data

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- Introduction and motivation.
- Data and MCs considered.
- JetWeb facility.
- Results of current best tunings. Comparison with current data.
- Predictions for a linear collider.
- Summary and outlook.

Introduction

Why study QCD? It is a fundamental part of the Standard Model.

- **Accurate measurement of quantities; α_s, F_2^{p}, F_2^{γ}, ...**
- **Tests of QCD production.**

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?

Methodology - what has been done?

Have general-purpose MC generators; HERWIG, PYTHIA,...
They have many free parameters and give varying descriptions of different data.

Want to tune to as much data as possible and find the best parameters.
E.g. structure functions, underlying event,...

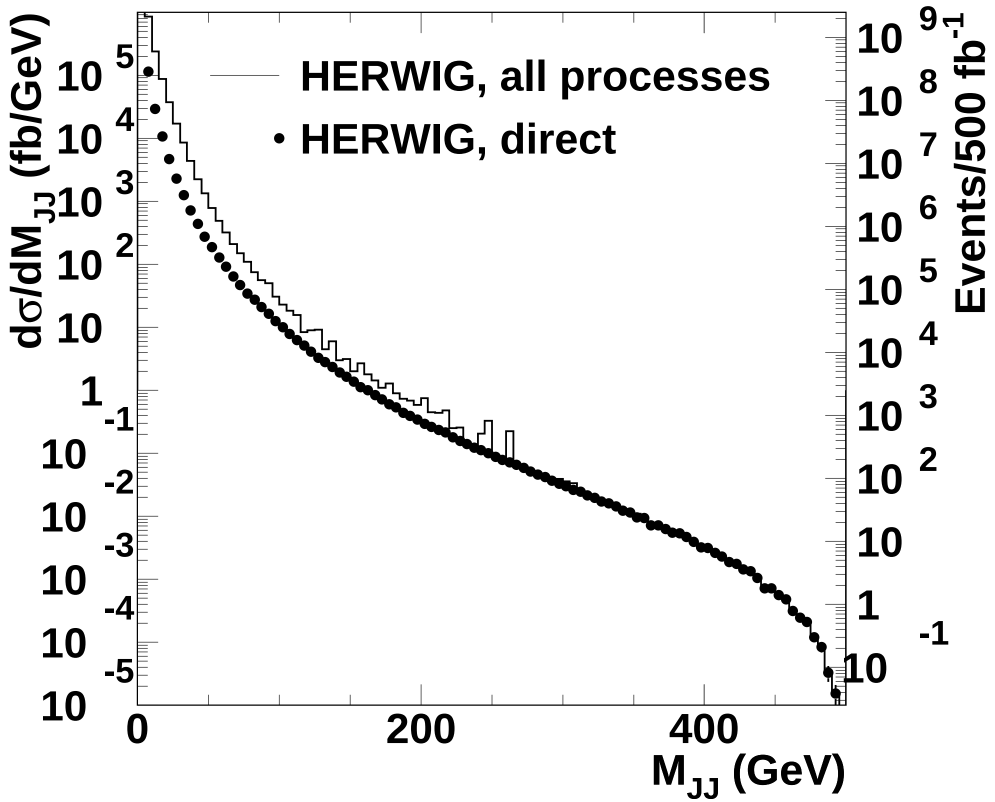
Consistency of current data sets; within an experiment, within a collider, all colliders?

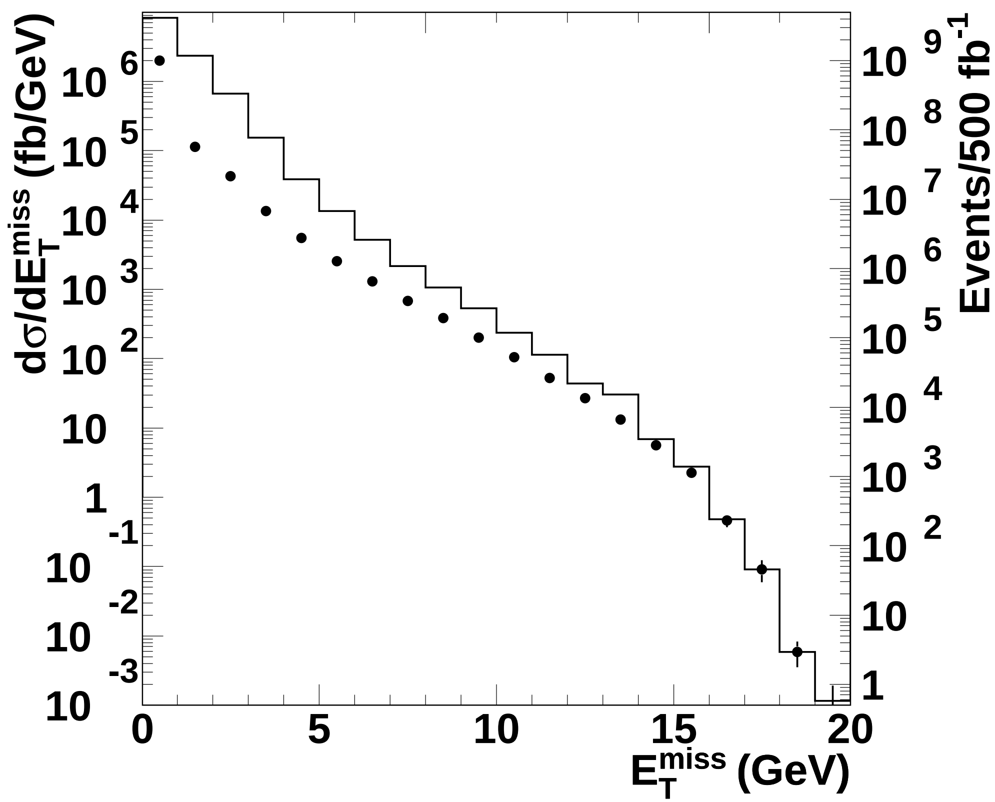
Using these parameter (with an estimation of the uncertainty) can predict rates for other colliders.

How well can QCD be measured? How precisely is the QCD background known?

How much QCD production is there at a linear collider?

Default $\gamma\gamma$ prediction from HERWIG (with beamstrahlung).





Reconstruct jets with k_T algorithm for particles passing into calorimeter (no detector simulation).

No DIS component; electrons go down the beampipe.

Significant production; at $M_{JJ} \sim$ 200 GeV, $\mathcal{O}$ (1000) events.

Quantify for different variables with estimation of uncertainty.

Spread in the predictions for a linear collider?

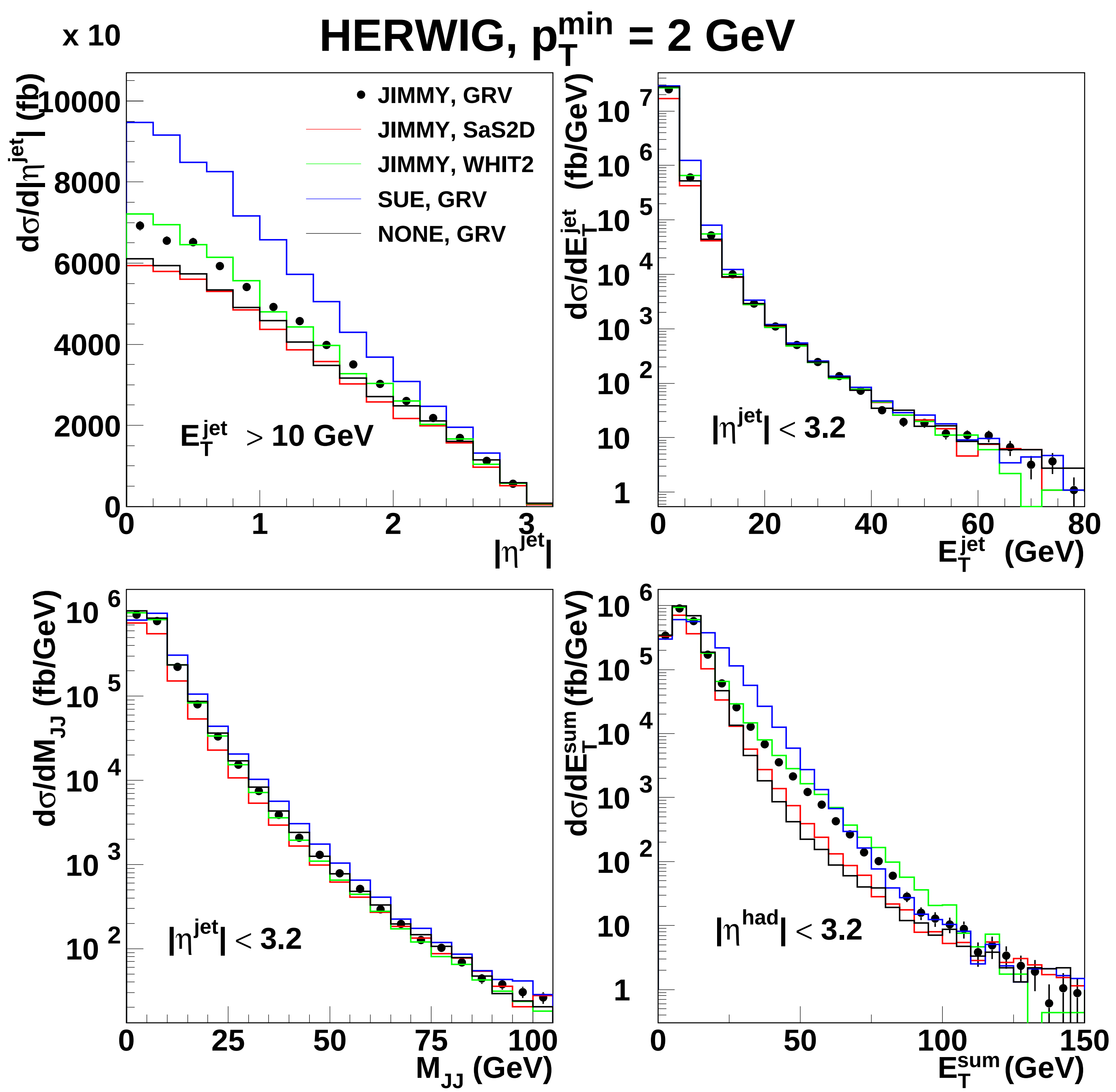
Default HERWIG prediction used with changes in underlying event and photon PDF.

All "reasonable" parameter settings.

Large spread in predictions, even at high energies.

How accurately do we know QCD production?

Not very well!



Data used for tuning

HERA jet photoproduction (γp) data (16 papers):

- **large range in scale;** $4 < E_T^{\text{jet}} < 80$ **GeV**
- **inclusive, dijet and multijet events.**

LEP $\gamma\gamma$ jet data (2 papers):

- **different centre-of-mass energies:** $130 < E_{\text{CM}} < 172$ **GeV**

Tevatron jet data (4 papers):

- **highest transverse energies**
- **strong dependency on underlying event**

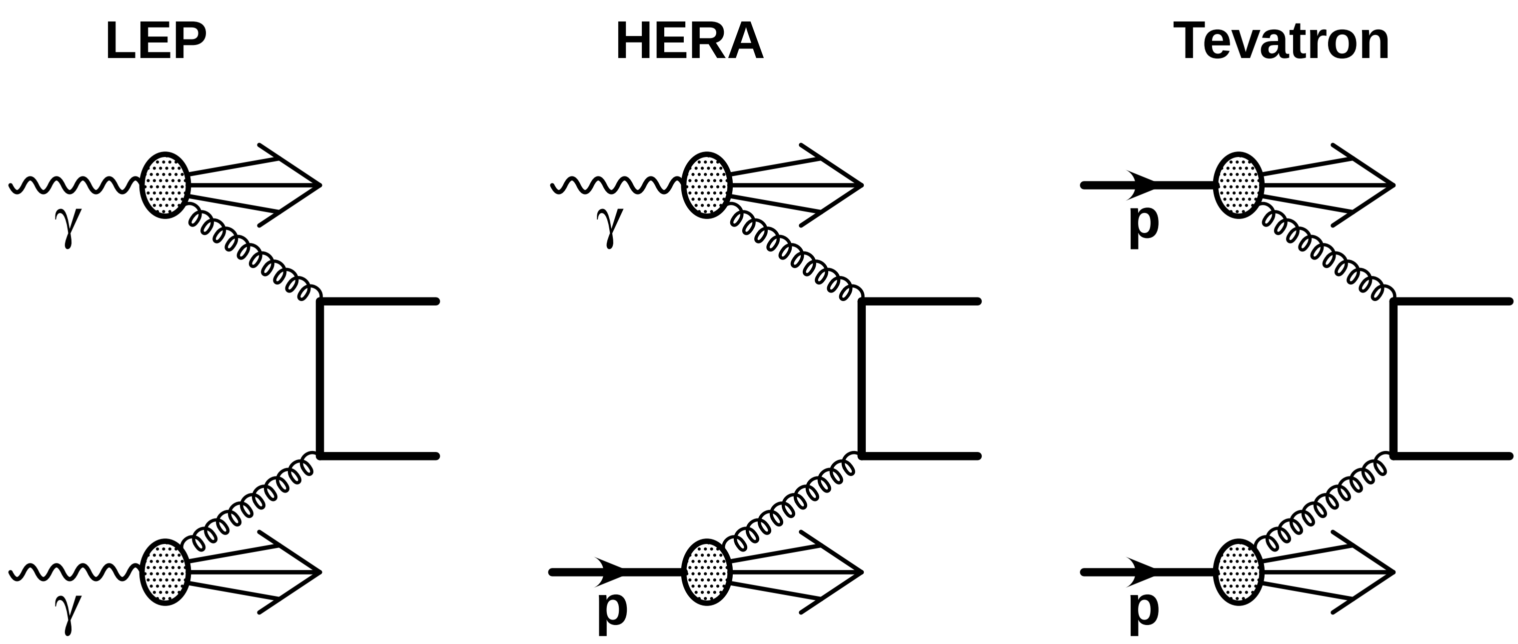
Monte Carlos used for tuning

Currently have tuned HERWIG and PYTHIA:

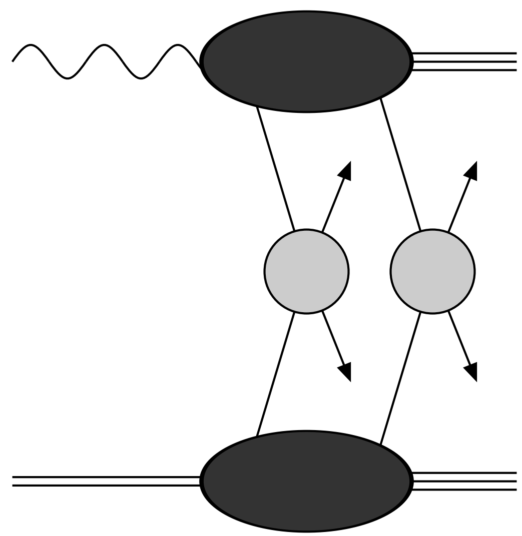
- **Minimum transverse momentum of hard scatters.**
- **Underlying event model.**
- **Proton and photon PDFs.**
- **Intrinsic transverse momenta in photon and proton.**
- **...**

Using HERWIG v6.1 $\rightarrow$ v6.4, PYTHIA v6.206, (CIRCE version 7)

Relevance of previous data



- Obvious how LEP results relate to a linear collider...
- Photon structure also being probed at HERA (higher scales).
- Remnant-remnant interactions exist at all colliders.
- HERA and LEP can turn them “on” or “off”.



JetWeb*

Based on HZTool for comparing published data and MC.

Can answer:

- **How well do my PYTHIA/HERWIG parameters agree with current data?**
- **What is the best known set of parameters describing current data?**

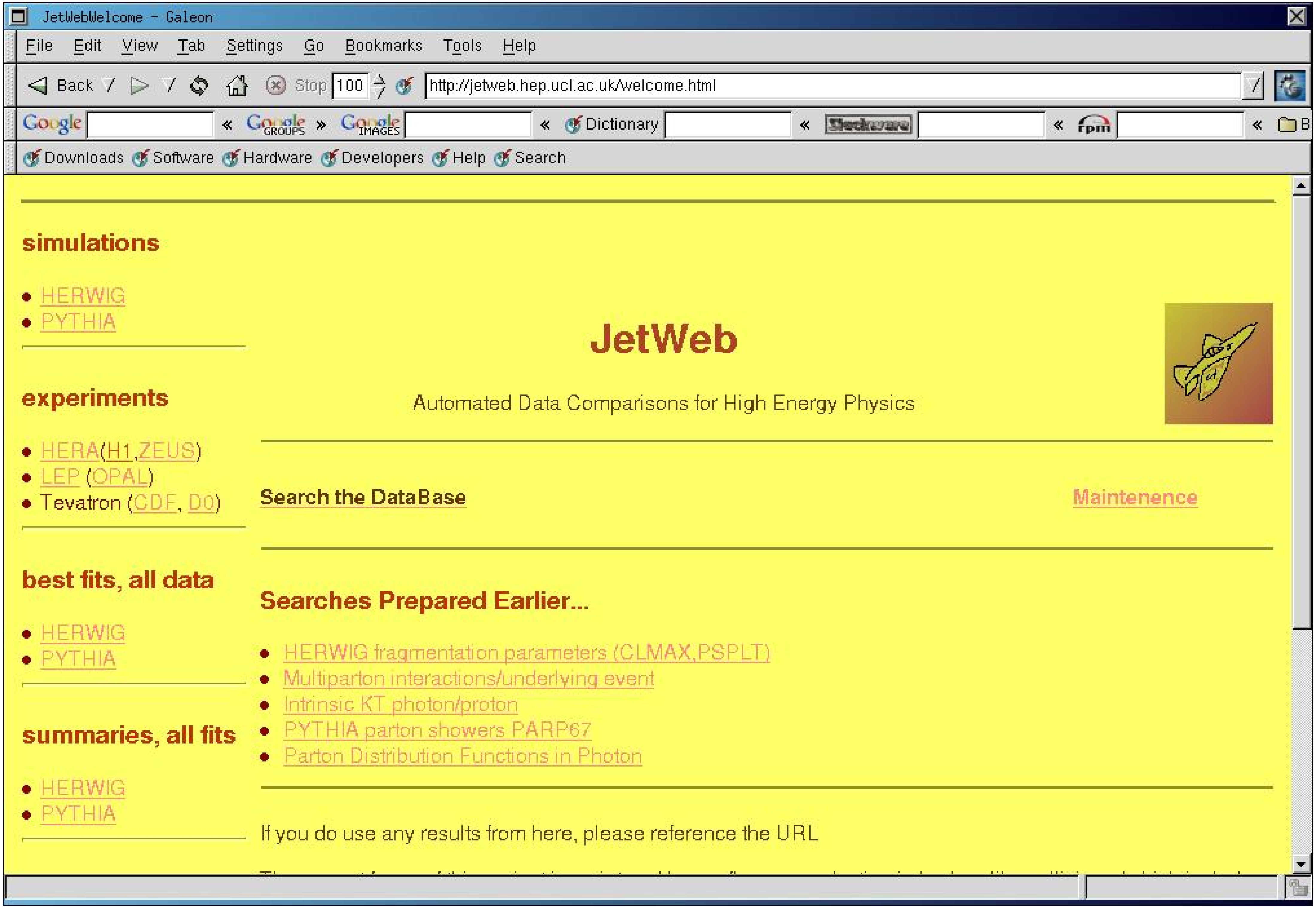
Data can be simply added (fortran,...) - help needed; Tevatron, heavy quarks.

A test version currently runs on the grid - will be available soon.

More search and analysis functionality should be added to the pages.
User feedback welcome.

Develop OO (probably C++) replacement for HZTOOL for future use (e.g. PYTHIA7 & HERWIG++)

*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/`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Searches Prepared Earlier...
HERWIG fragmentation parameters (CLMAX,PSPLT)
Multiparton interactions/underlying event
Intrinsic KT photon/proton
PYTHIA parton showers PARP67
Parton Distribution Functions in Photon
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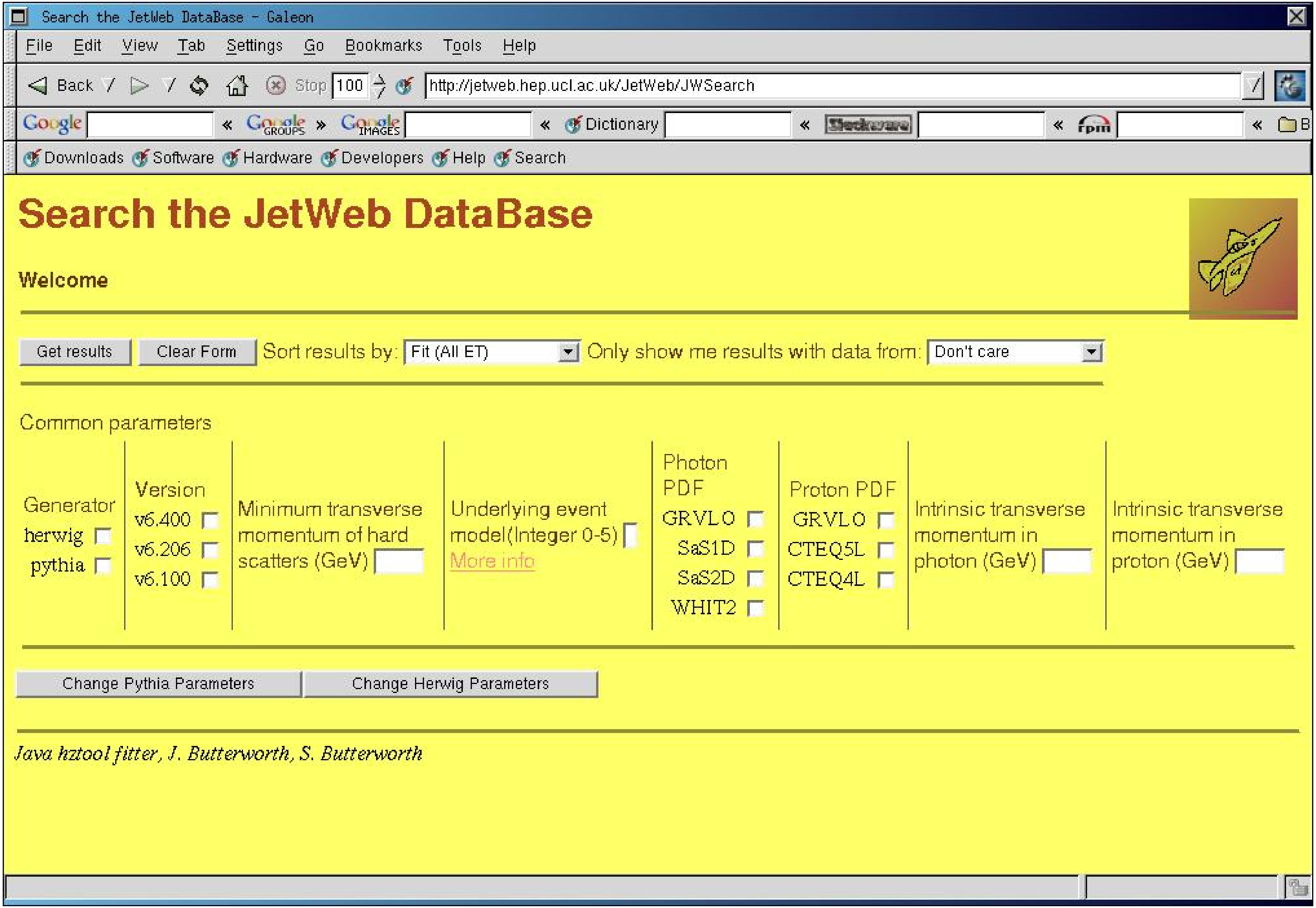
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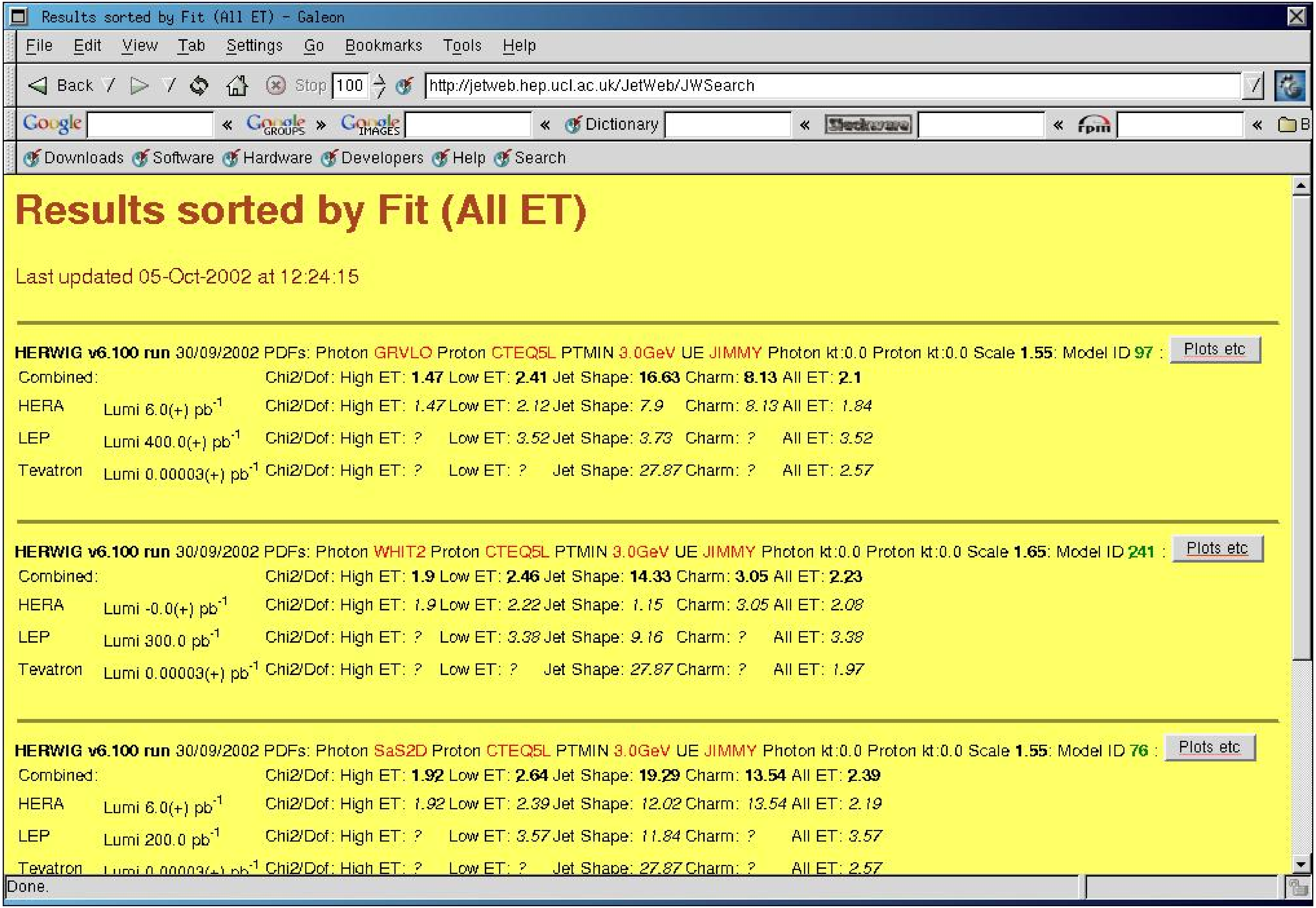
Common parameters
Generator
herwig
pythia
Version
v6.400
v6.206
v6.100
Minimum transverse momentum of hard scatters (GeV)
Underlying event model(Integer 0-5)
More info
Photon PDF
GRVLO
SaS1D
SaS2D
WHIT2
Proton PDF
GRVLO
CTEQ5L
CTEQ4L
Intrinsic transverse momentum in photon (GeV)
Intrinsic transverse momentum in proton (GeV)
Change Pythia Parameters
Change Herwig Parameters
Java hztool fitter, J. Butterworth, S. Butterworth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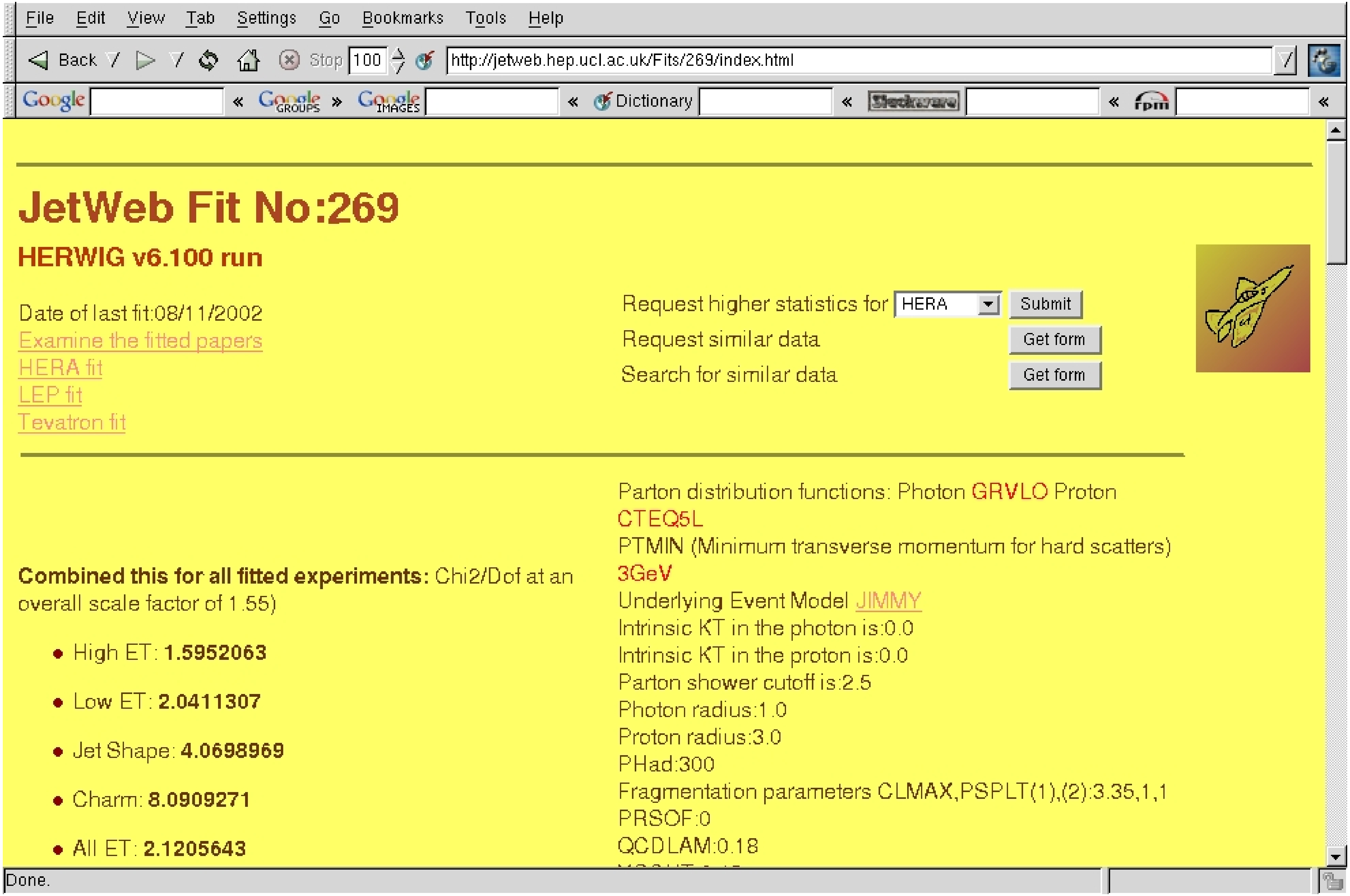
Last updated 05-Oct-2002 at 12:24:15
HERWIG v6.100 run 30/09/2002 PDFs: Photon GRVLO Proton CTEQ5L PTMIN 3.0GeV UE JIMMY Photon kt:0.0 Proton kt:0.0 Scale 1.55: Model ID 97 :
Plots etc
Combined: Chi2/Dof: High ET: 1.47 Low ET: 2.41 Jet Shape: 16.63 Charm: 8.13 All ET: 2.1
HERA Lumi 6.0(+) pb-1 Chi2/Dof: High ET: 1.47 Low ET: 2.12 Jet Shape: 7.9 Charm: 8.13 All ET: 1.84
LEP Lumi 400.0(+) pb-1 Chi2/Dof: High ET: ? Low ET: 3.52 Jet Shape: 3.73 Charm: ? All ET: 3.52
Tevatron Lumi 0.00003(+) pb-1 Chi2/Dof: High ET: ? Low ET: ? Jet Shape: 27.87 Charm: ? All ET: 2.57
HERWIG v6.100 run 30/09/2002 PDFs: Photon WHIT2 Proton CTEQ5L PTMIN 3.0GeV UE JIMMY Photon kt:0.0 Proton kt:0.0 Scale 1.65: Model ID 241 :
Plots etc
Combined: Chi2/Dof: High ET: 1.9 Low ET: 2.46 Jet Shape: 14.33 Charm: 3.05 All ET: 2.23
HERA Lumi -0.0(+) pb-1 Chi2/Dof: High ET: 1.9 Low ET: 2.22 Jet Shape: 1.15 Charm: 3.05 All ET: 2.08
LEP Lumi 300.0 pb-1 Chi2/Dof: High ET: ? Low ET: 3.38 Jet Shape: 9.16 Charm: ? All ET: 3.38
Tevatron Lumi 0.00003(+) pb-1 Chi2/Dof: High ET: ? Low ET: ? Jet Shape: 27.87 Charm: ? All ET: 1.97
HERWIG v6.100 run 30/09/2002 PDFs: Photon SaS2D Proton CTEQ5L PTMIN 3.0GeV UE JIMMY Photon kt:0.0 Proton kt:0.0 Scale 1.55: Model ID 76 :
Plots etc
Combined: Chi2/Dof: High ET: 1.92 Low ET: 2.64 Jet Shape: 19.29 Charm: 13.54 All ET: 2.39
HERA Lumi 6.0(+) pb-1 Chi2/Dof: High ET: 1.92 Low ET: 2.39 Jet Shape: 12.02 Charm: 13.54 All ET: 2.19
LEP Lumi 200.0 pb-1 Chi2/Dof: High ET: ? Low ET: 3.57 Jet Shape: 11.84 Charm: ? All ET: 3.57
Tevatron Chi2/Dof: High ET: ? Low ET: ? Jet Shape: 27.87 Charm: ? All ET: 2.57
Done.



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JetWeb Fit No:269

HERWIG v6.100 run

Date of last fit:08/11/2002

Examine the fitted papers

HERA fit

LEP fit

Tevatron fit

Request higher statistics for HERA Submit

Request similar data Get form

Search for similar data Get form

Combined this for all fitted experiments: Chi2/Dof at an overall scale factor of 1.55)

- High ET: **1.5952063**
- Low ET: **2.0411307**
- Jet Shape: **4.0698969**
- Charm: **8.0909271**
- All ET: **2.1205643**

Parton distribution functions: Photon GRVLO Proton CTEQ5L
PTMIN (Minimum transverse momentum for hard scatters) 3GeV
Underlying Event Model JIMMY
Intrinsic KT in the photon is:0.0
Intrinsic KT in the proton is:0.0
Parton shower cutoff is:2.5
Photon radius:1.0
Proton radius:3.0
PHad:300
Fragmentation parameters CLMAX,PSPLT(1),(2):3.35,1,1
PRSOF:0
QCDLAM:0.18

Done.

Dijet photoproduction at HERA and the structure of the photon - Galeon

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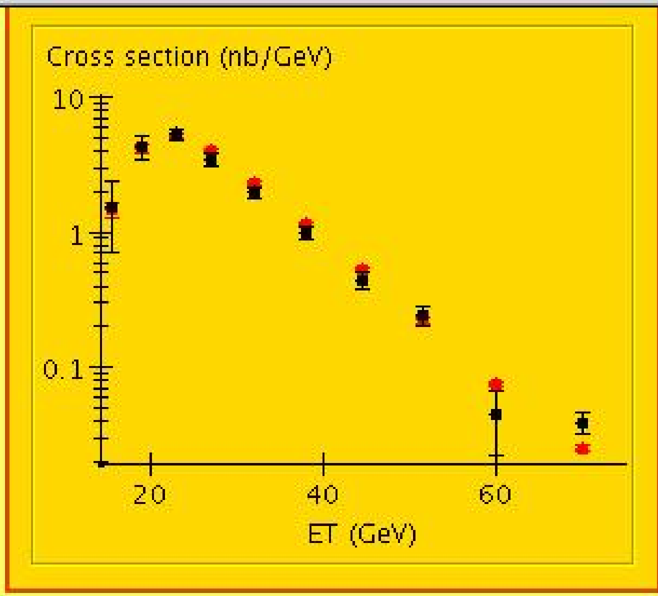
d(sigma)/d(et) high x_gamma, eta_1 (1 to 2.4), eta_2 (1 to 2.4)

Chi2 Contribution: (chi2 / DoF): 14.153 / 10

Data (black) was scaled by: 1.0
The model (red) was scaled by 1.55

This data is relevant for : All jets: High ET Jets

Pull for each point:
{0.011}{0.041}{0.043}{1.66}{3.249}{2.435}{1.412}{0.202}{1.755}{3.345}



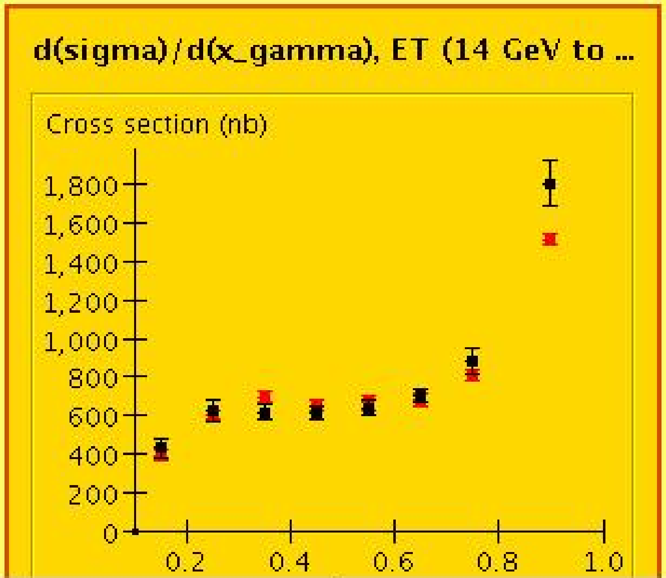
d(sigma)/d(x_gamma), ET (14 GeV to 17 GeV)

Chi2 Contribution: (chi2 / DoF): 11.498 / 8

Data (black) was scaled by: 1.0
The model (red) was scaled by 1.55

This data is relevant for : All jets: High ET Jets

Pull for each point:
{0.498}{0.146}{3.085}{0.729}{0.217}{0.224}{0.828}{5.773}



HERWIG “fit 1”

Recent high E_T measurements control the normalisation.

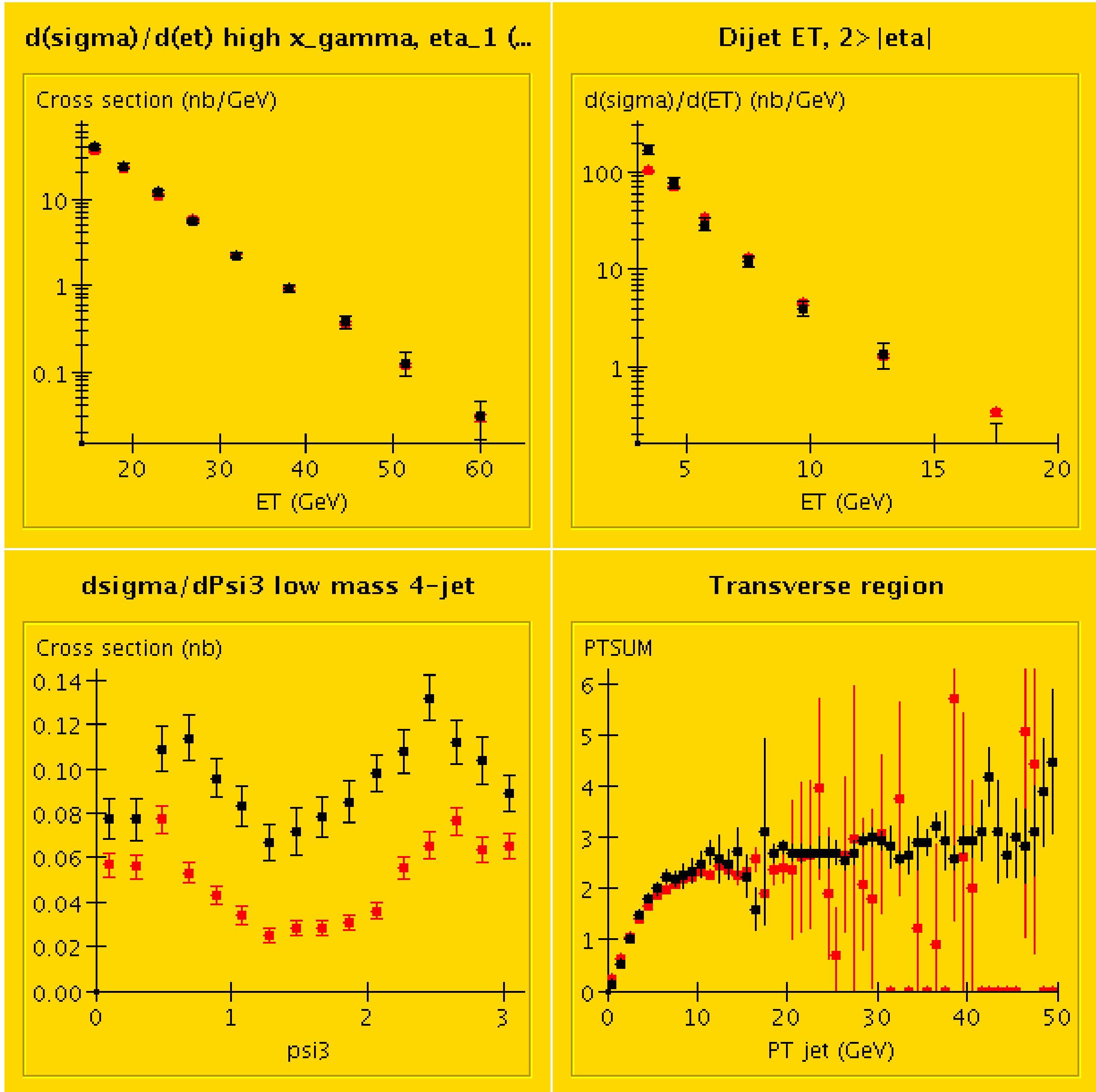
Underlying event tuned using CDF minimum bias data.

JIMMY, $p_T^{\rm min} = 3$ GeV, SaS2D
Normalisation factor: 1.6

Reasonable description of jet cross section data.

Poor description of multijet data.

$\chi^2/$dof = 1.56, 2.17 (high, all E_T)



HERWIG “fit 2”

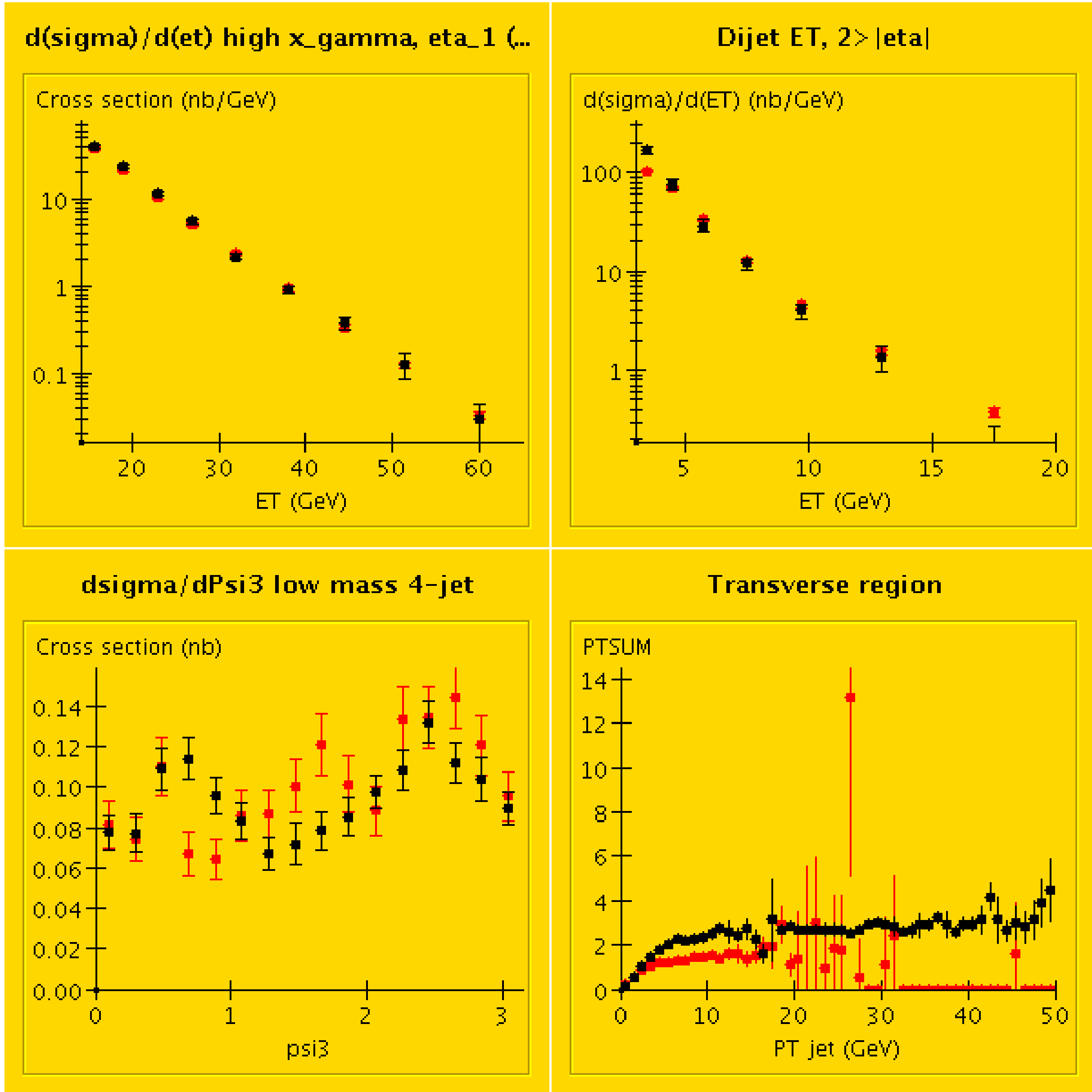
Include some soft underlying event (10%)

JIMMY, $p_T^{\rm min} = 3$ GeV, SaS2D
Normalisation factor: 1.6

Describes jet production reasonably well. N.B. 4 jet data.

Description of CDF minimum bias data is poor.

χ^2/dof = 1.60, 2.15 (high, all E_T)



HERWIG "fit 3"

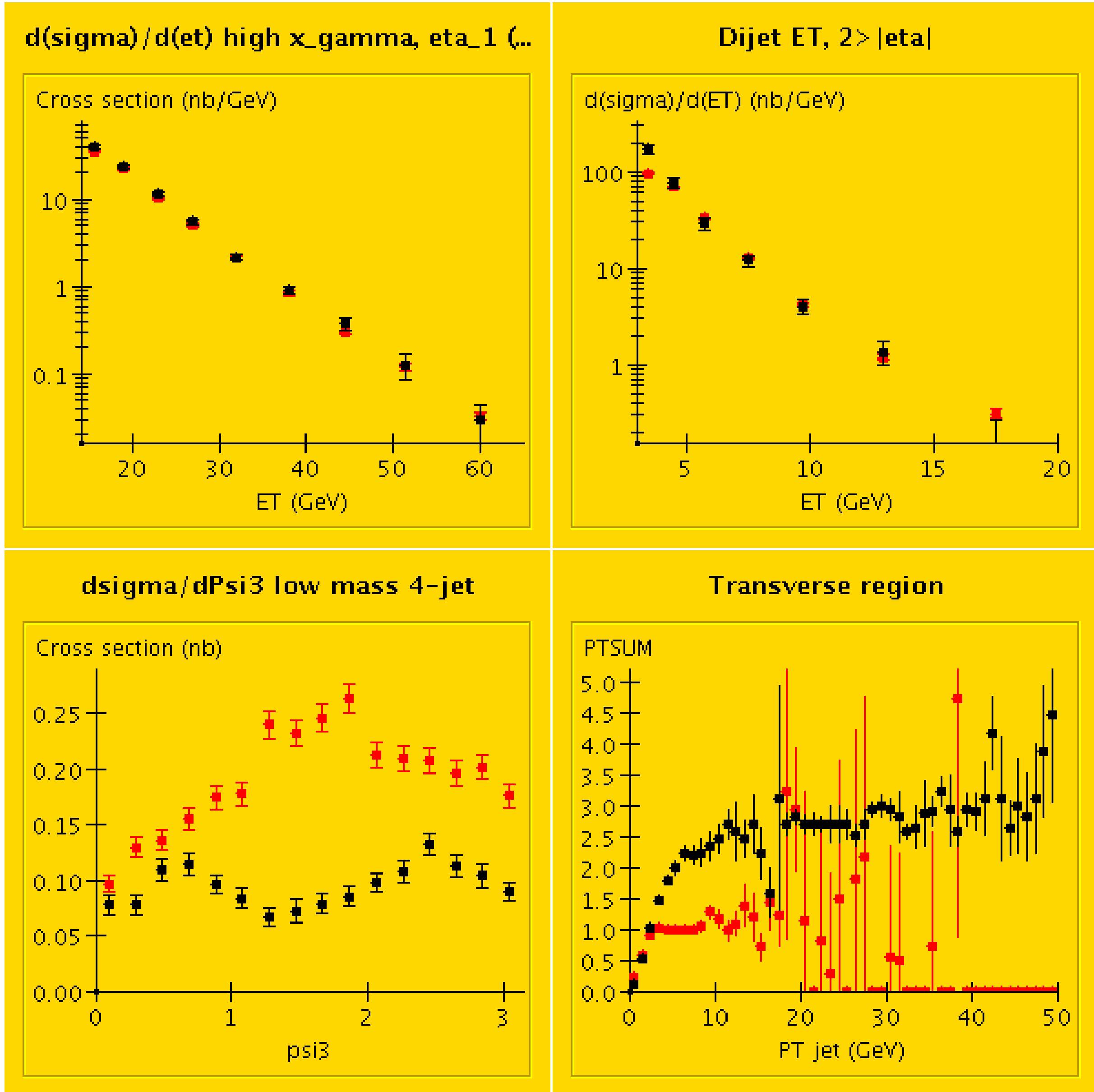
Use soft underlying event (30%) with no MPI

$p_T^{\min} = 3$ **GeV, SaS2D**
Normalisation factor: 1.55

Describes jet production reasonably well.

Description of CDF minimum bias and 4 jet data is poor.

$\chi^2/$**dof = 1.46, 2.13 (high, all ET)**



PYTHIA example fits

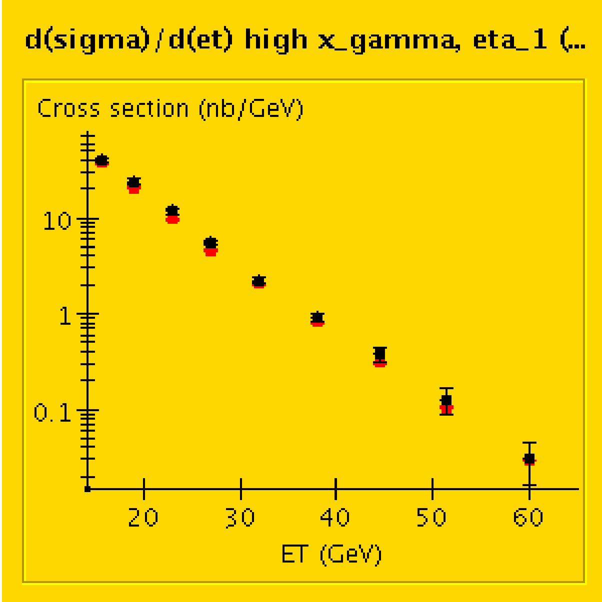
PYTHIA not as well tuned...

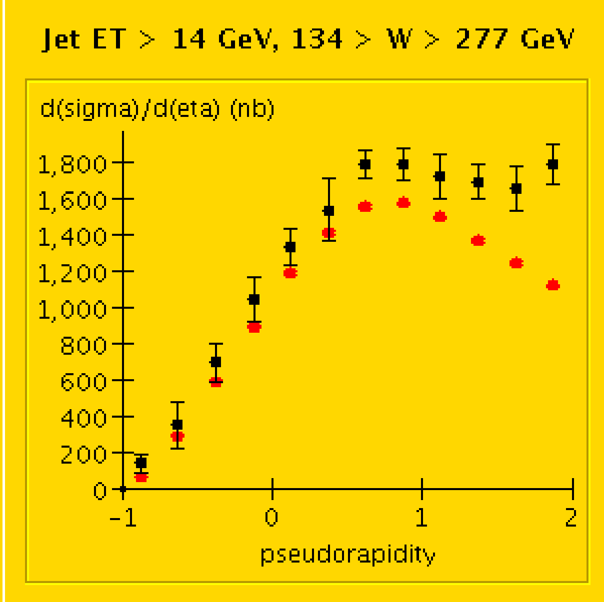
NO MPI, SaS2D

Normalisation factor: 1.35

Reasonable description of both low and high E_T

χ^2 **= 2.00, 2.35 (high, all E_T)**





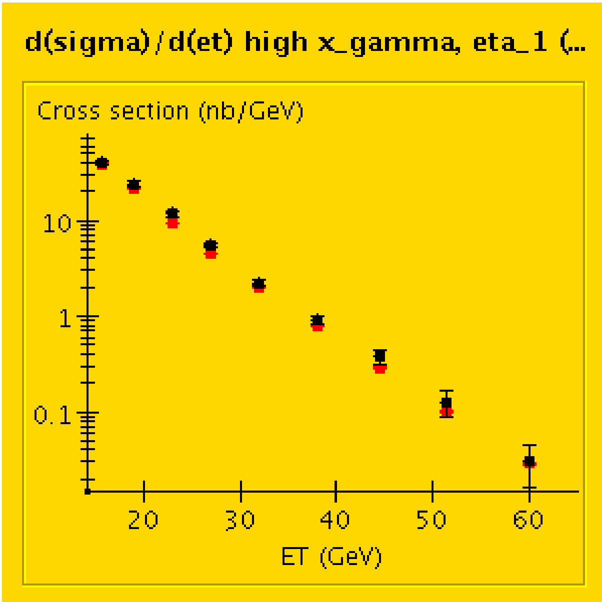
(Impact parameter dependent) MPI, SaS2D

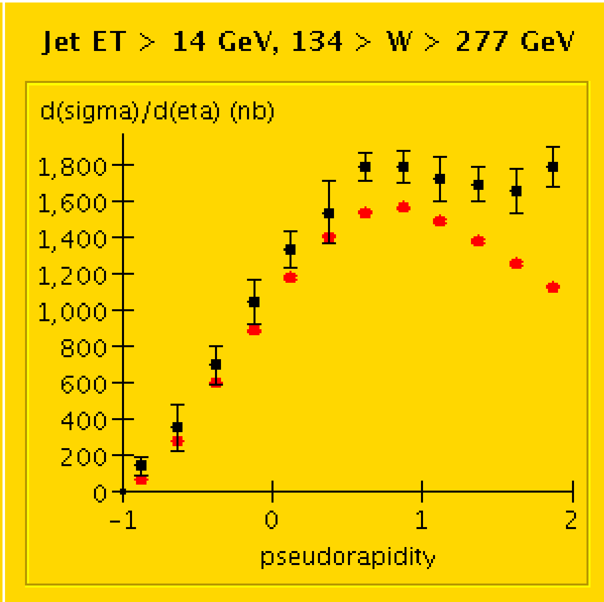
Normalisation factor: 1.3

Similar description of E_T dijets

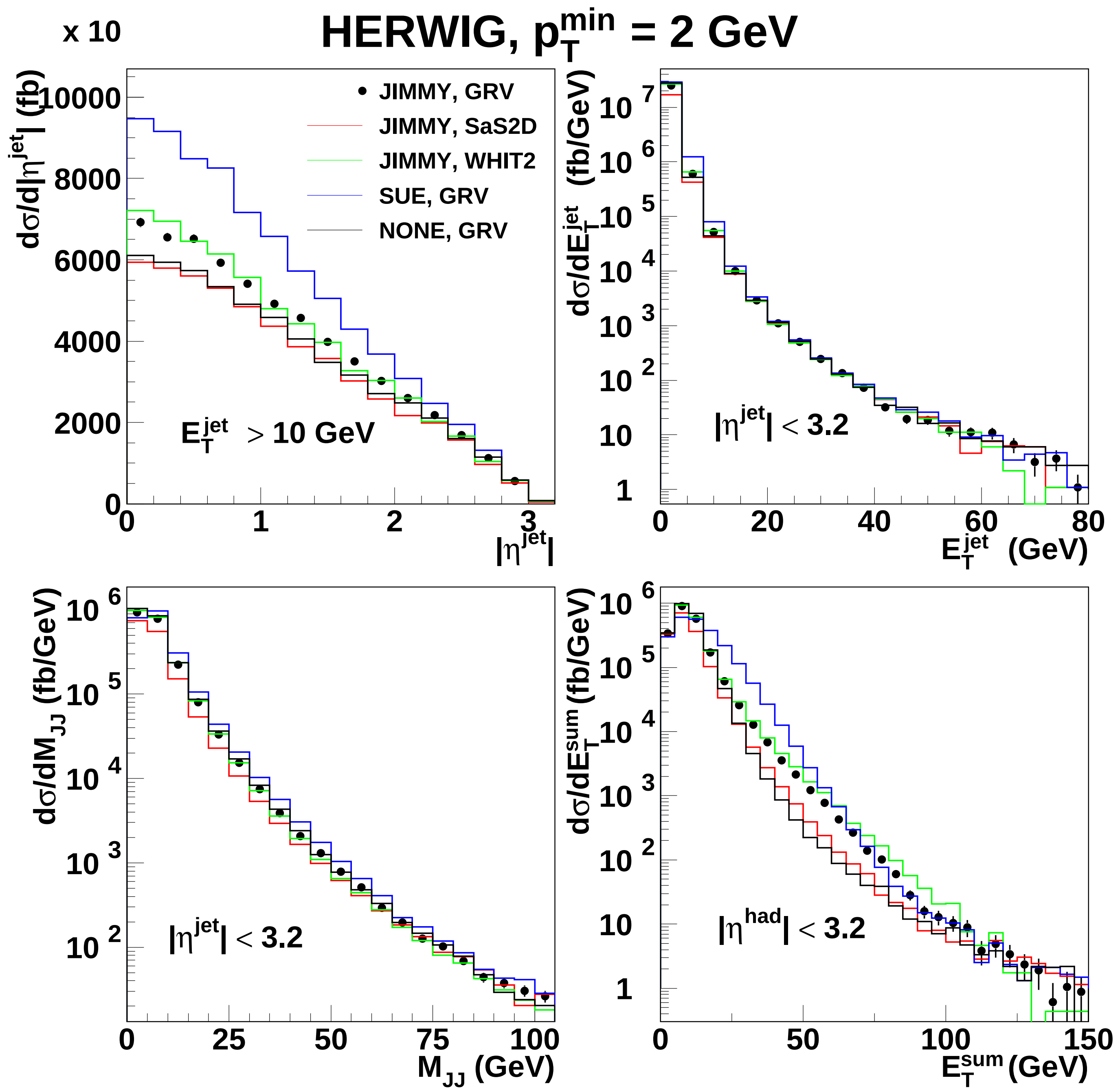
MI does not improve forward region for inclusive jets

χ^2 **= 2.38, 2.85 (high, all E_T)**





OLD predictions for the linear collider



NEW predictions for the linear collider

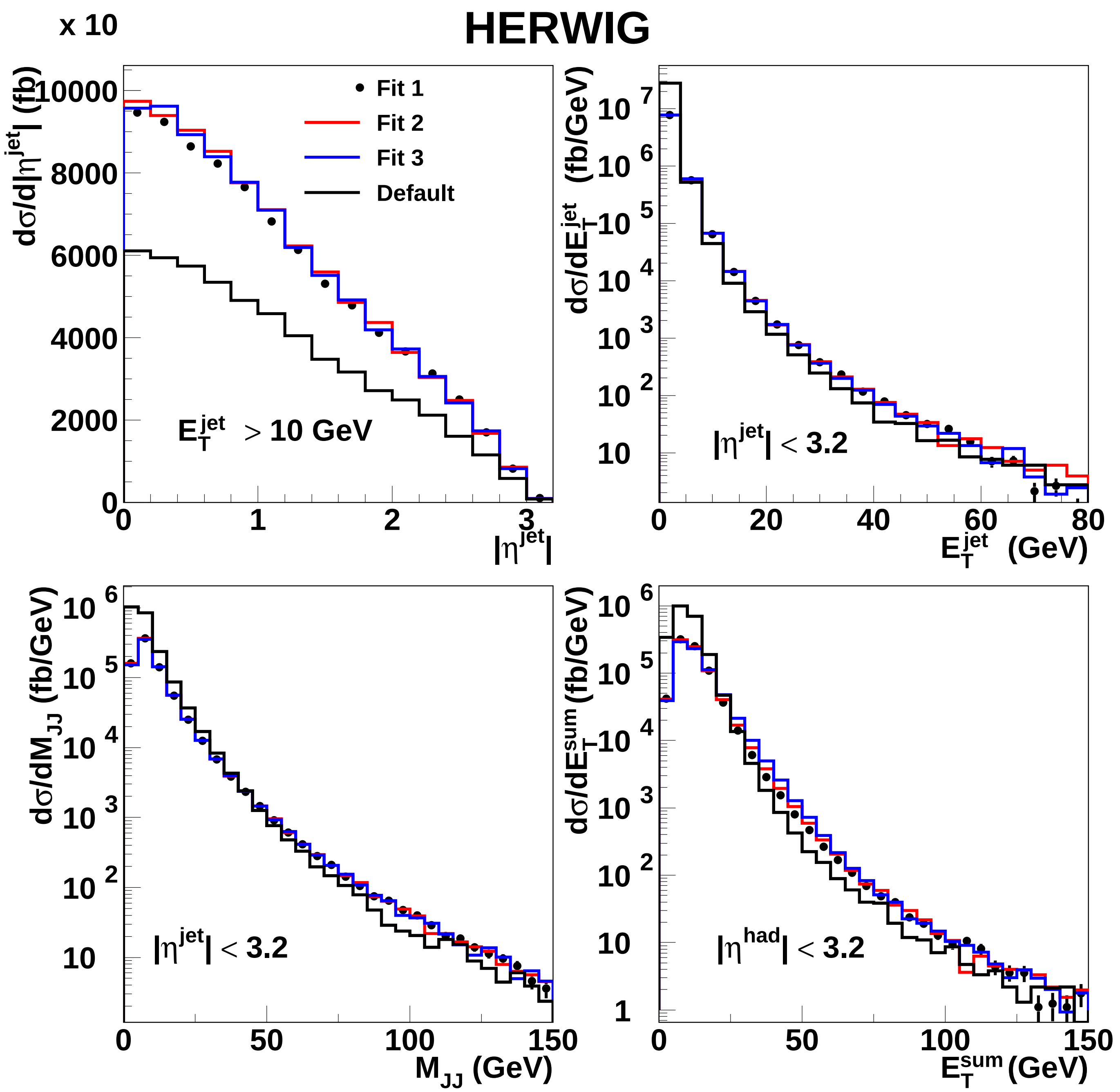
Three different fits give similar results for all variables.

Very different from default predictions.

Increased rate at high E_T and high mass.

Fitting procedure to current data giving good results for future experiments.

QCD predictions known to much better accuracy.



Future work

Improve fits for PYTHIA and obtain predictions for the linear collider.

Still more parameters to consider in HERWIG and PYTHIA.

Have found measurements which we can concentrate on.

Need to look at the heavy quark production rate - need more heavy quark data to tune to.

Still a large wealth of data to exploit.

Other interesting and relevant quantities?

Can provide estimation for other colliders; comparison e.g. LHC/FLC.

Summary

Presented MC tunes to current data which describe a wide kinematic range and different processes.

These fits yield expectations for a linear collider which have better predictive power than default MC predictions.

There is sizeable QCD production up to high energies and masses.

The predictions can be used to evaluate the physics potential for

Tests of QCD.

Many other (new) physics where QCD is a background.

What MC are you using to estimate the background to your Higgs signal?