H^+ Iterative Discriminant Analysis of Spin Effects at the Tevatron and LHC

André Sopczak[1]
Collaborators: Stefan Hesselbach[2], Stefano Moretti[3], Johan Rathsman[4]
[1]Lancaster University

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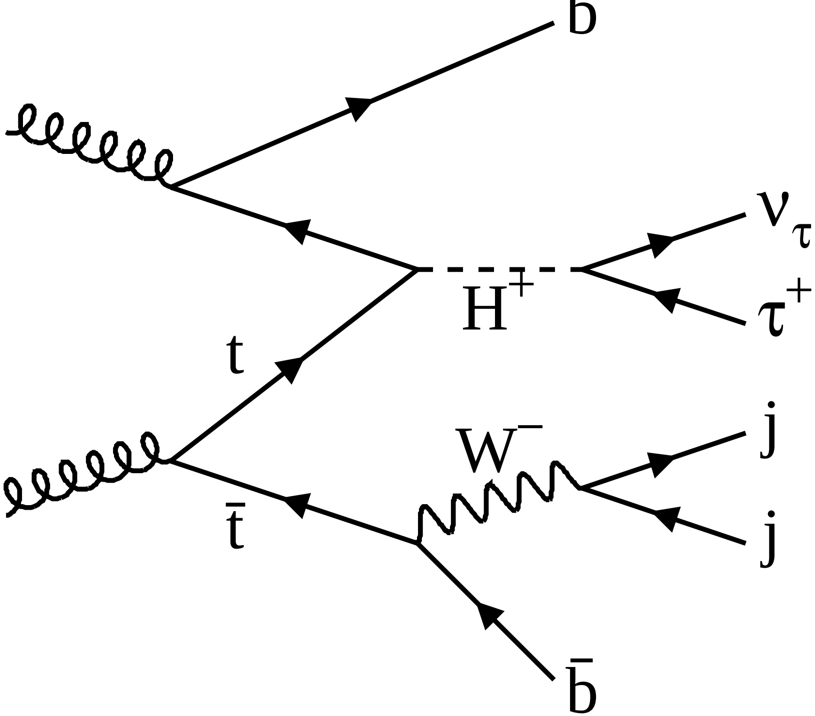
[2]Durham IPPP, [3]Southampton, [4]Uppsala

Outline

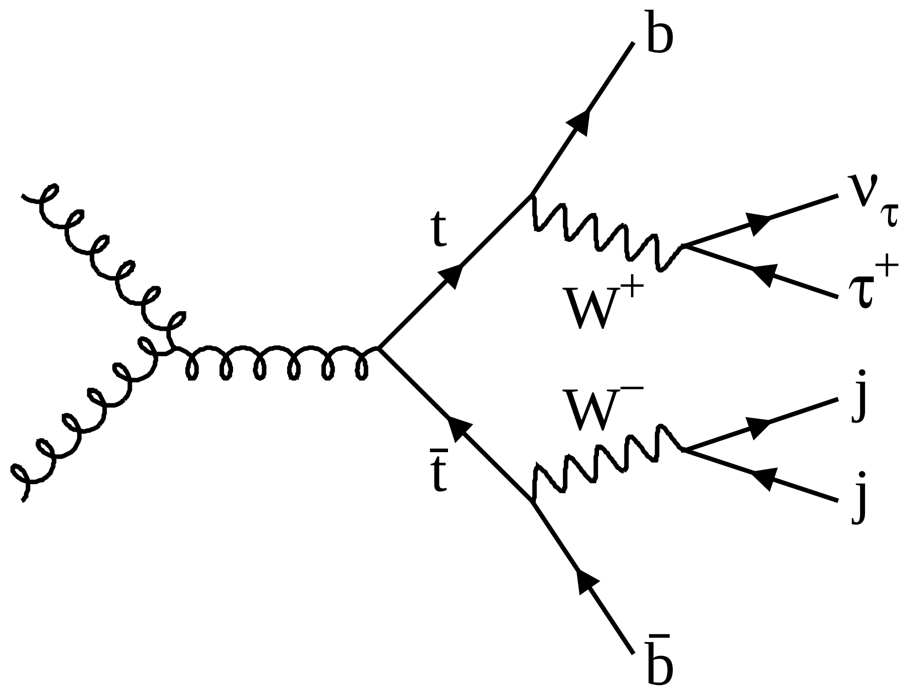
- Introduction
- Production Cross-section at the Tevatron
- Event selection
- Example distributions of selection variables
- IDA method
- Tevatron signal efficiency versus purity
- Analogous study for the LHC energy
- Conclusions

Signal Process



Background Process

(Example of one decay mode, all W decay modes generated)



Introduction

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- Signal: $q\bar{q}, gg \rightarrow tbH^{\pm}$
  $(t \rightarrow bW) \quad (H^{\pm} \rightarrow \tau^{\pm}\nu_{\tau})$
- 500k signal and 500k $t\bar{t}$ background events simulated
- Parametrized detector response included

Production Cross-Sections

Signal: $tbH^{\pm}$

Background: SM $t\bar{t}$

Tevatron at 2 TeV

tanβ=35

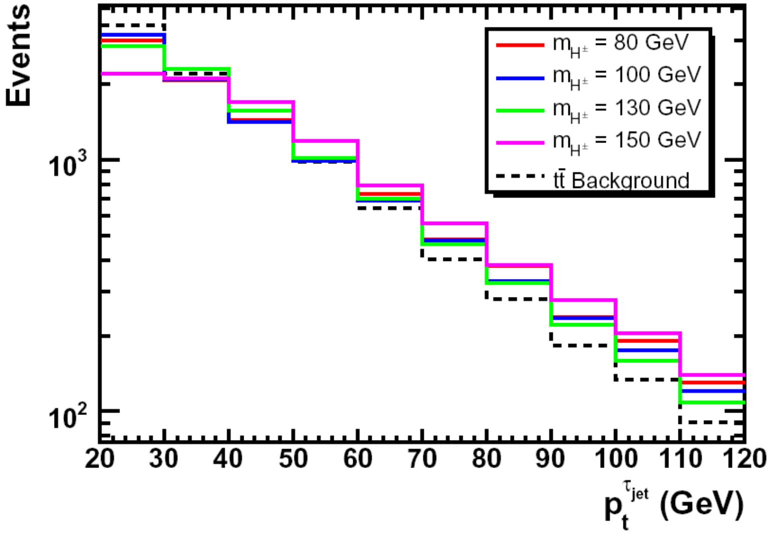
$m_{H^\pm}$ (GeV)	$q\bar{q}, gg \to t\bar{t}$	$q\bar{q}, gg \to tbH^\pm$ 80	100	130	150
$\sigma^{\rm th}$ (fb)	350	535	415	213	85
σ (fb) for $p_t^{\rm jets} > 20$ GeV	125	244	202	105	32
σ (fb) for $(p_t^{\rm jets}, p_t^{\rm miss}) > (20, 100)$ GeV	21	30	25	18	7

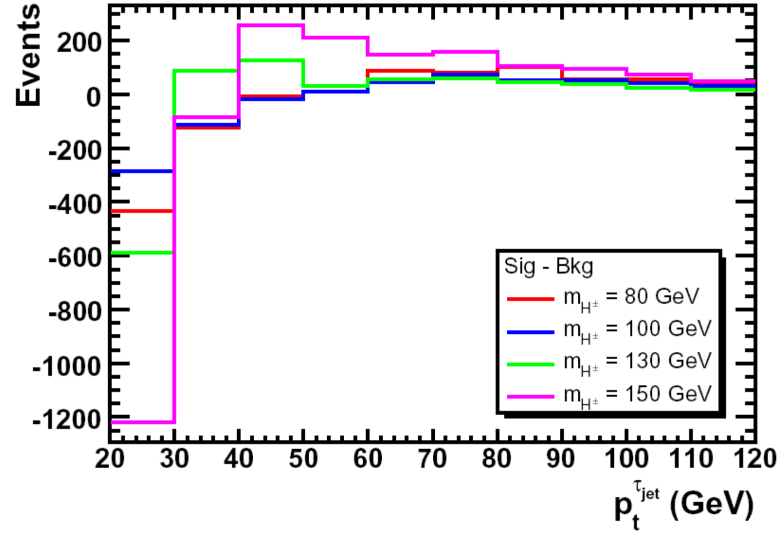
$$2b + 2j + \tau_{\rm jet} + p_t^{\rm miss}$$

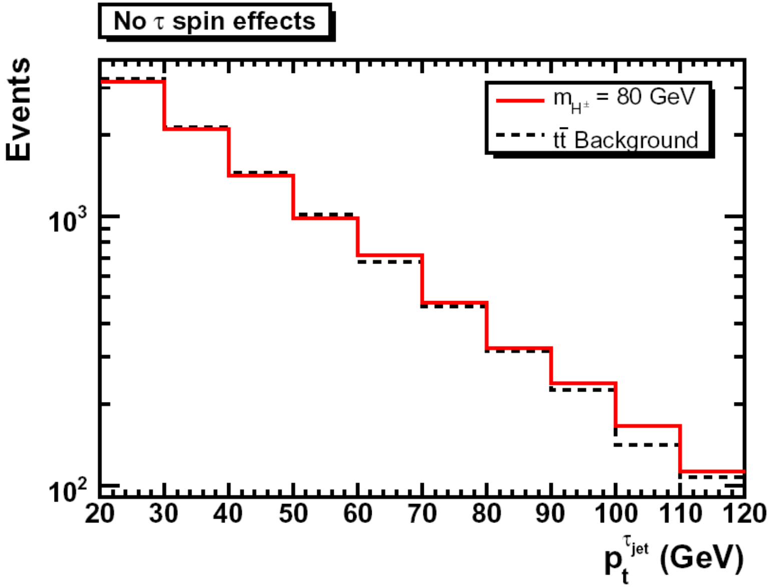
Selection of Events

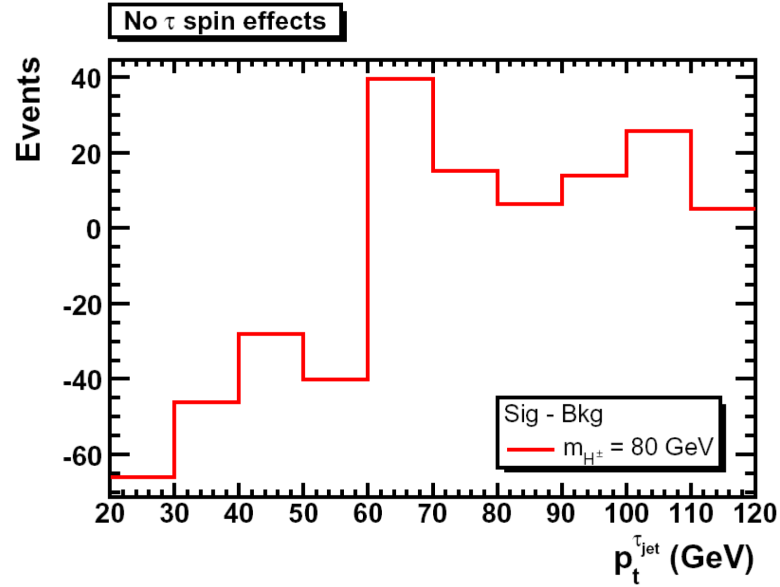
- the transverse momentum of the τ jet, $p_t^{'\mathrm{jet}}$ (Fig. 1),
- the transverse momentum of the leading $\pi^\pm$ in the τ jet, $p_t^{\pi^\pm}$ (Fig. 2)
- the ratio $p_t^{\pi^\pm}/p_t^{\tau_{\mathrm{jet}}}$ (Fig. 3),
- the transverse momentum of the second (least energetic) b quark jet, $p_t^{b_2}$ (Fig. 4),
- the transverse mass in the $\tau_{\mathrm{jet}} + p_t^{\mathrm{miss}}$ system, $m_t = \sqrt{2p_t^{\tau_{\mathrm{jet}}} p_t^{\mathrm{miss}}[1 - \cos(\Delta\phi)]}$, where $\Delta\phi$ is the azimuthal angle between $p_t^{\tau_{\mathrm{jet}}}$ and p_t^{miss} (Fig. 5),
- the invariant mass distribution of the two light quark jets and the second b quark jet, m_{jjb_2} (Fig. 6),
- the spatial distance between the τ jet and the second b quark jet, $\Delta R(\tau, b_2) = \sqrt{(\Delta\phi)^2 + (\Delta\eta)^2}$, where $\Delta\phi$ is the azimuthal angle between the τ and b jet (Fig. 7) and
- the total transverse momentum of all quark jets, $H_{\mathrm{jets}} = p_t^{j_1} + p_t^{j_2} + p_t^{b_1} + p_t^{b_2}$ (Fig. 8).

Transverse Momentum Tau(jet)

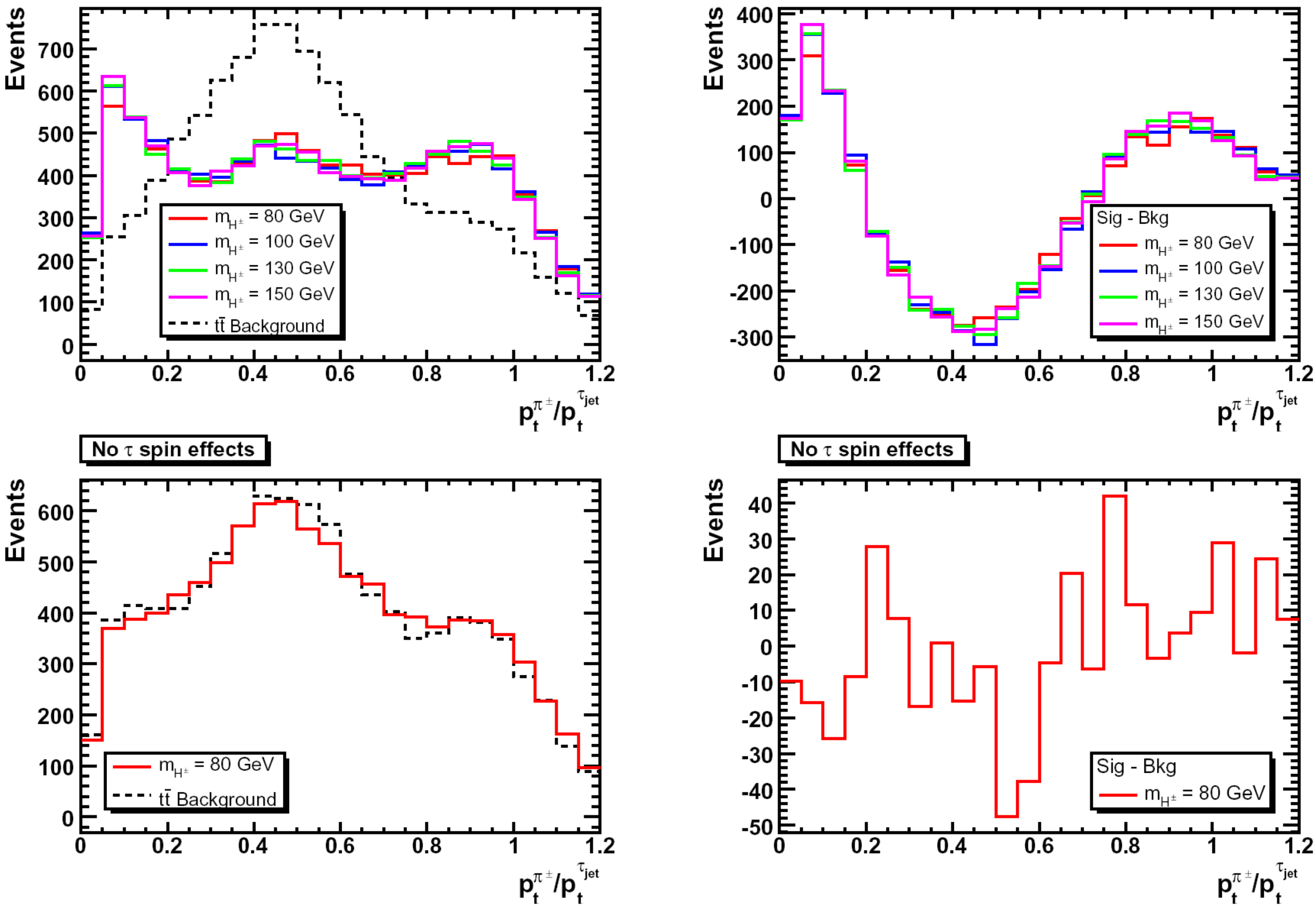








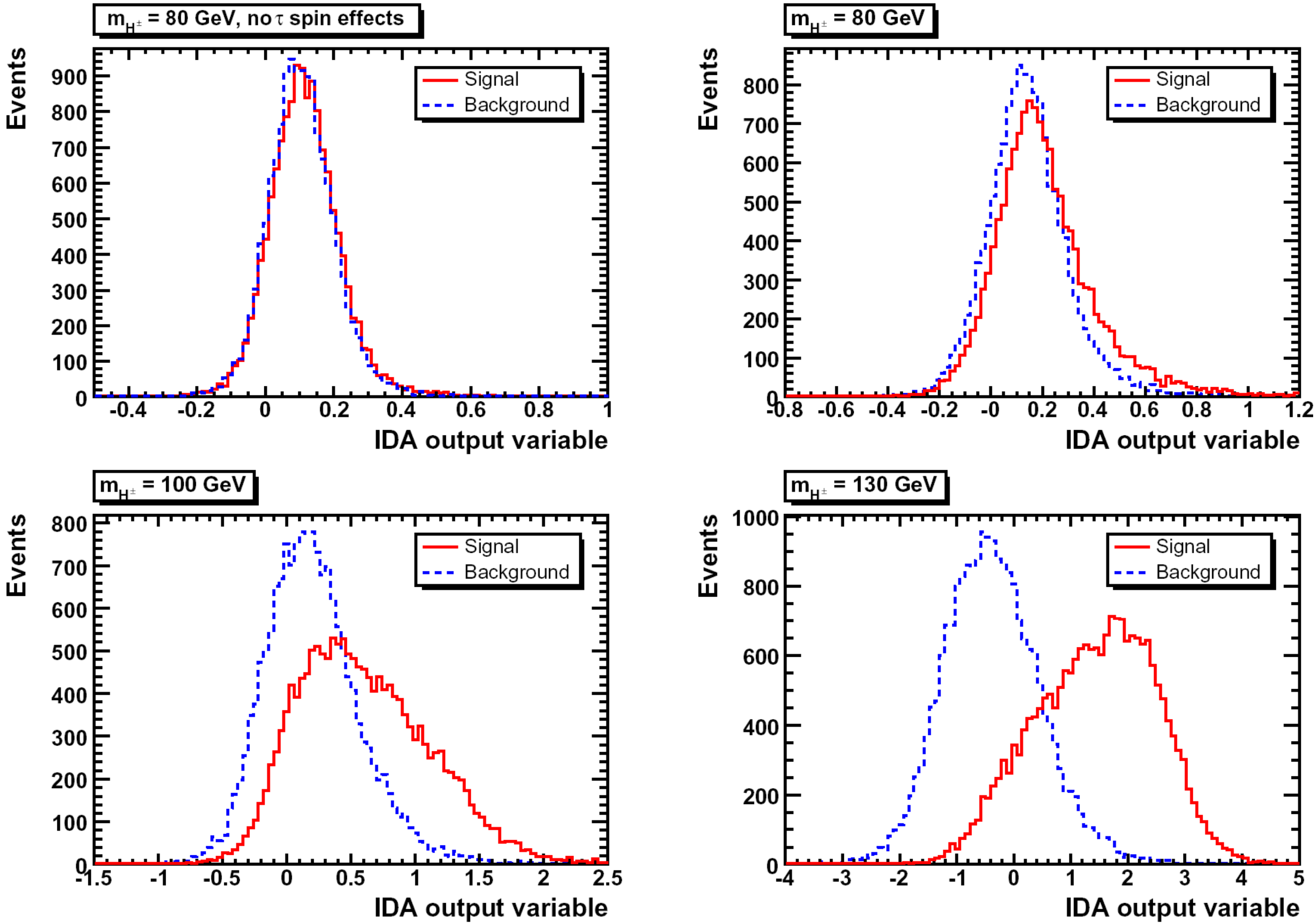
Transverse Momentum pi/tau(jet)



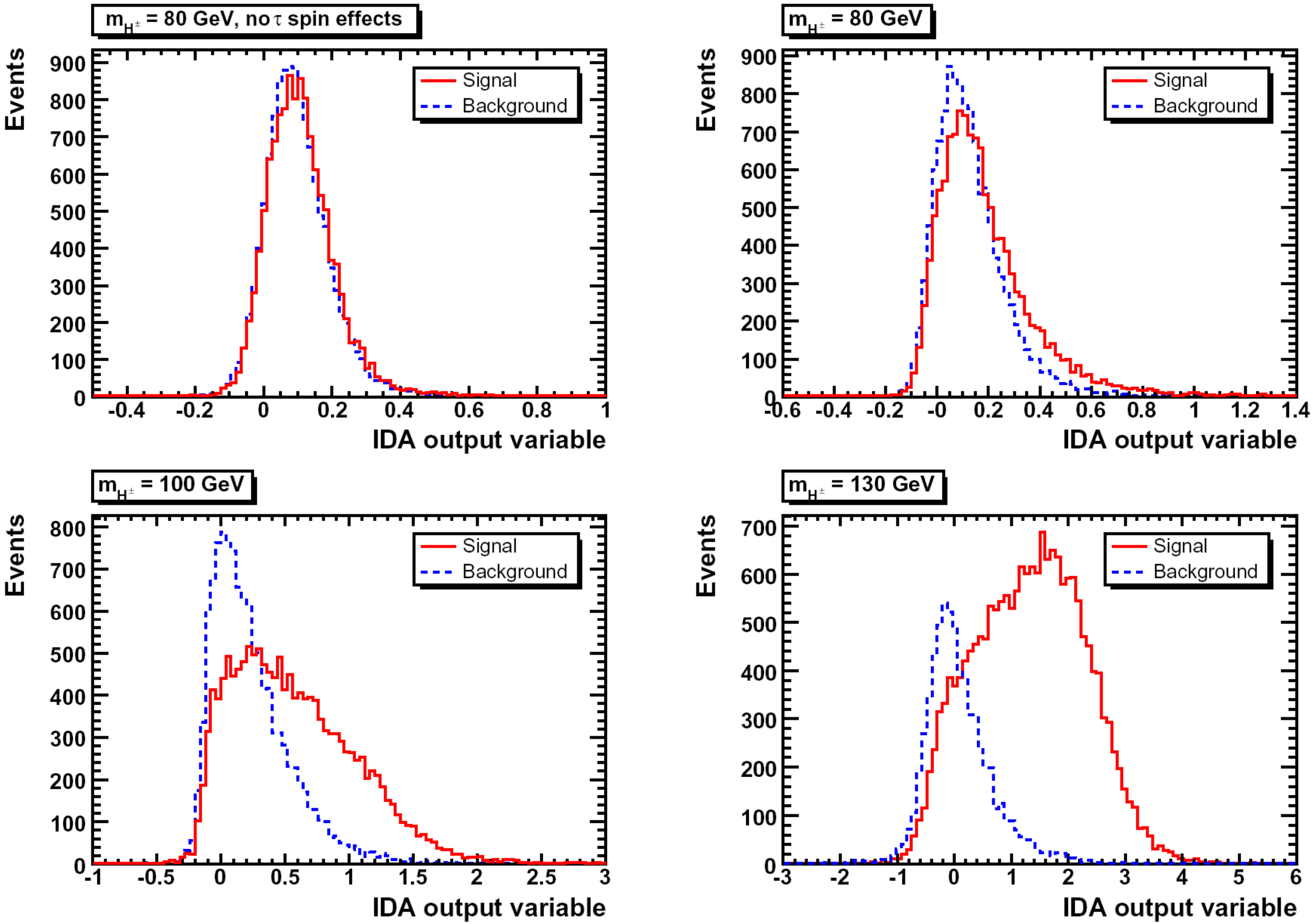
IDA Method

- The IDA method is a modified Fisher Discriminant Analysis.
- This IDA method is characterized by:
  1. the use of a quadratic instead of a linear discriminant function.
  2. and iterations in order to enhance the separation of signal and background.
- Two IDA iterations have been performed, with a cut after the first IDA iteration keeping 90% of the preselected events, and deriving the efficiency versus purity from the second IDA iteration.

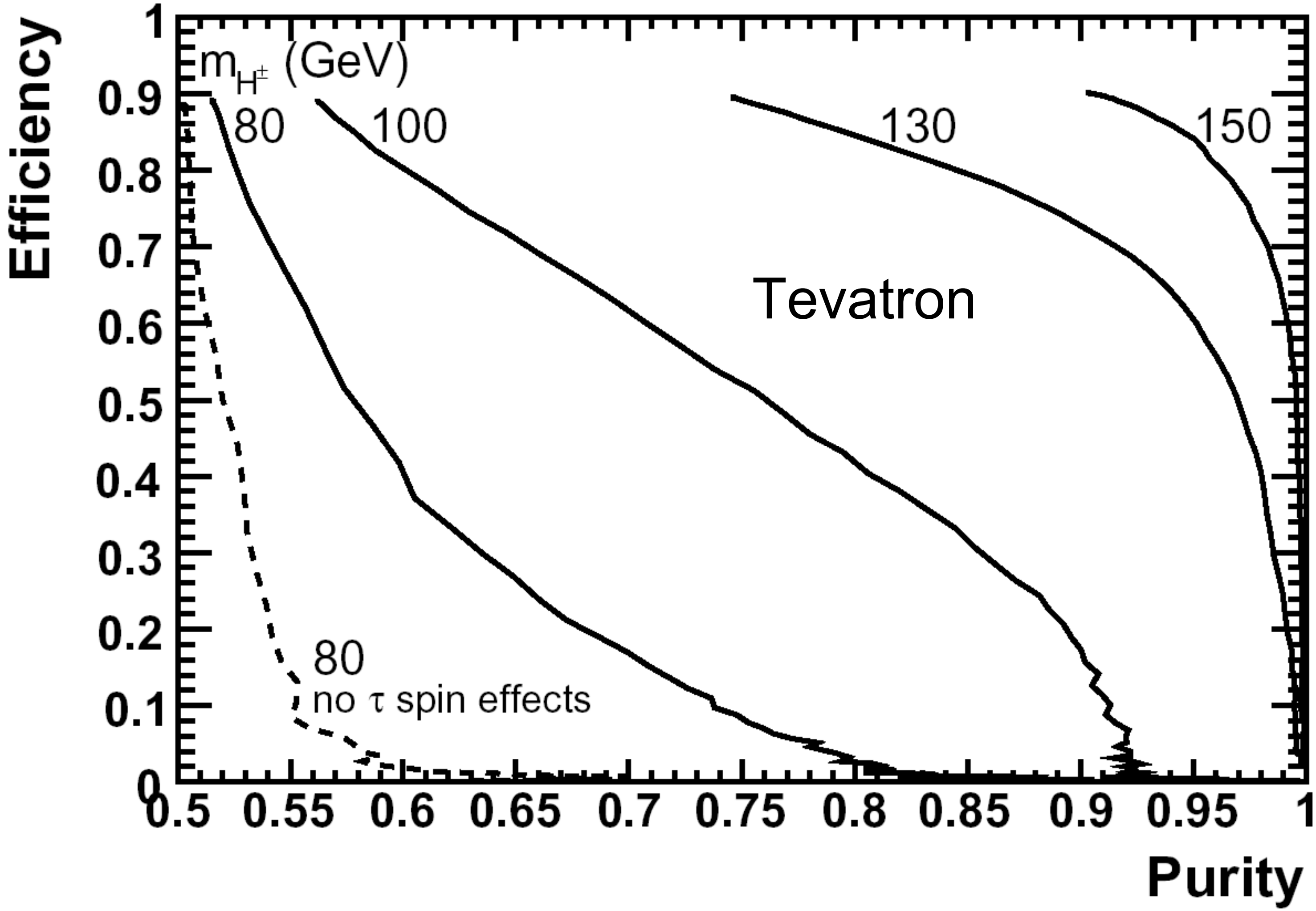
Tevatron: IDA Output Step-1



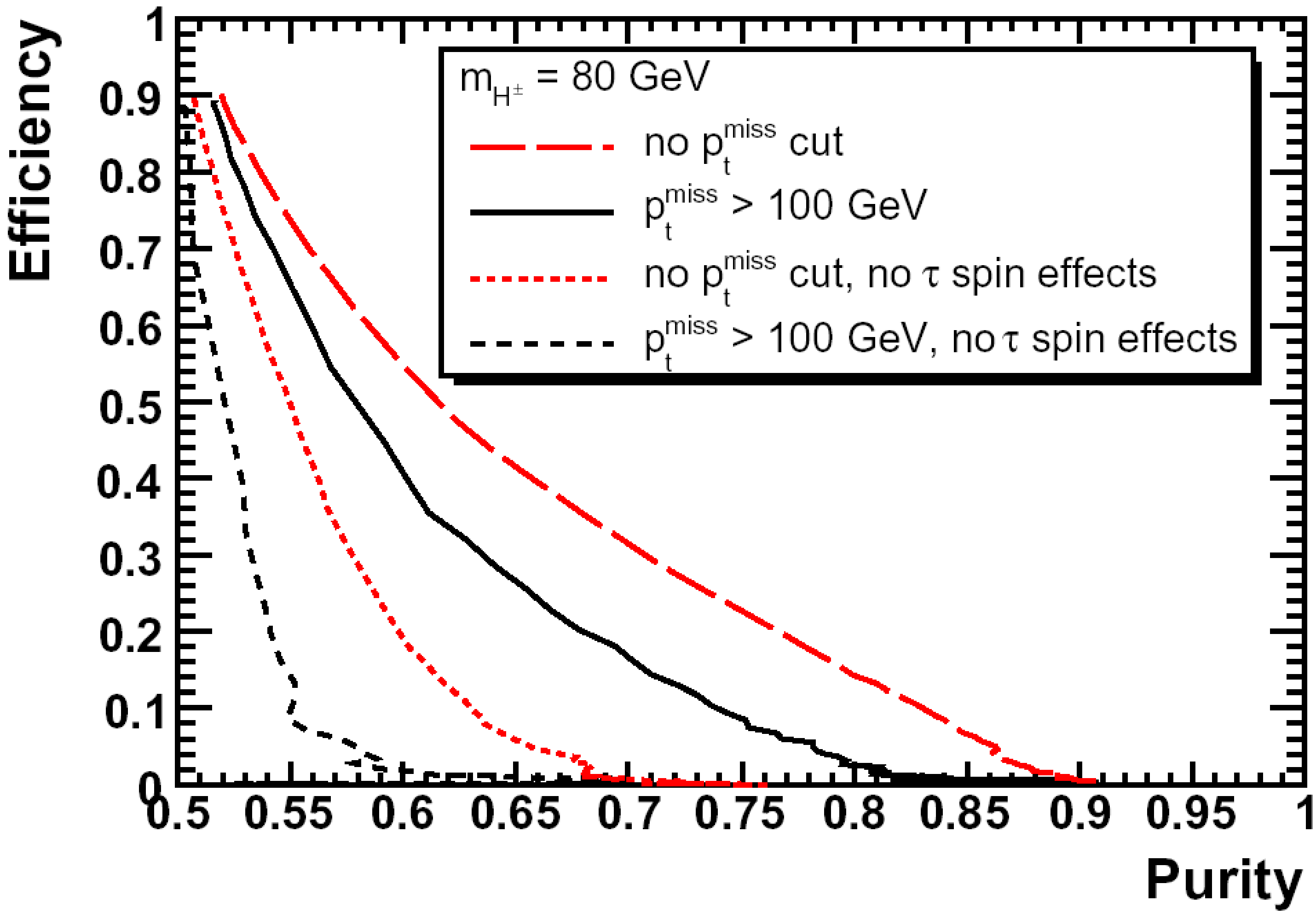
Tevatron: IDA Output Step-2



Efficiency vs. Purity: Spin Importance



Results Including Anti-QCD Cut



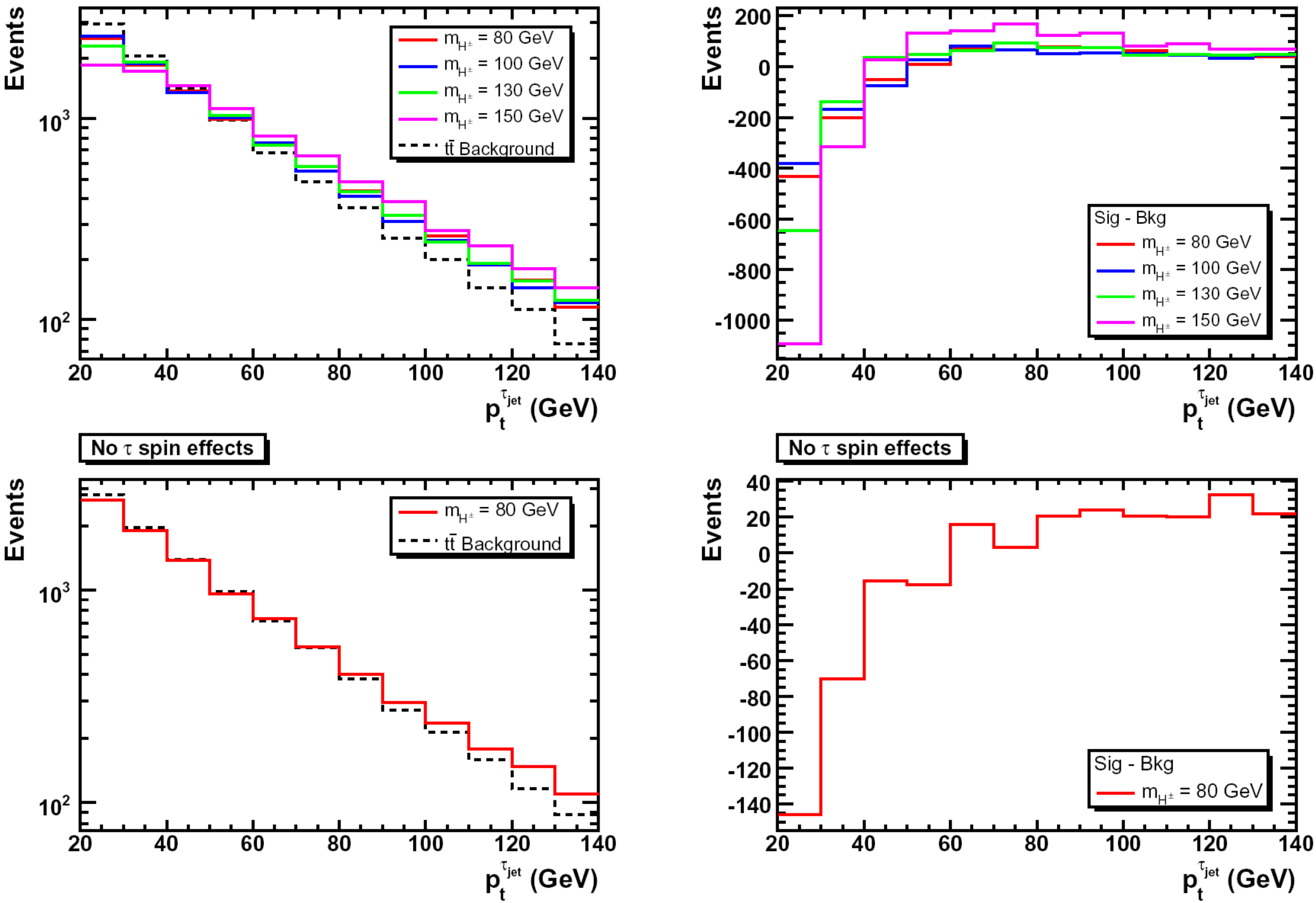
LHC Production Cross-Sections

$m_{H^\pm}$ (GeV)	$q\bar{q}, gg \to t\bar{t}$	$q\bar{q}, gg \to tbH^\pm$ 80	100	130	150
$\sigma^{\rm th}$ (pb)	45.5	72.6	52.0	24.5	9.8
σ (pb) for $p_t^{\rm jets} > 20$ GeV	17.3	33.9	25.7	12.2	3.8
σ (pb) for $(p_t^{\rm jets}, p_t^{\rm miss}) > (20, 100)$ GeV	4.6	6.0	4.8	2.9	1.2

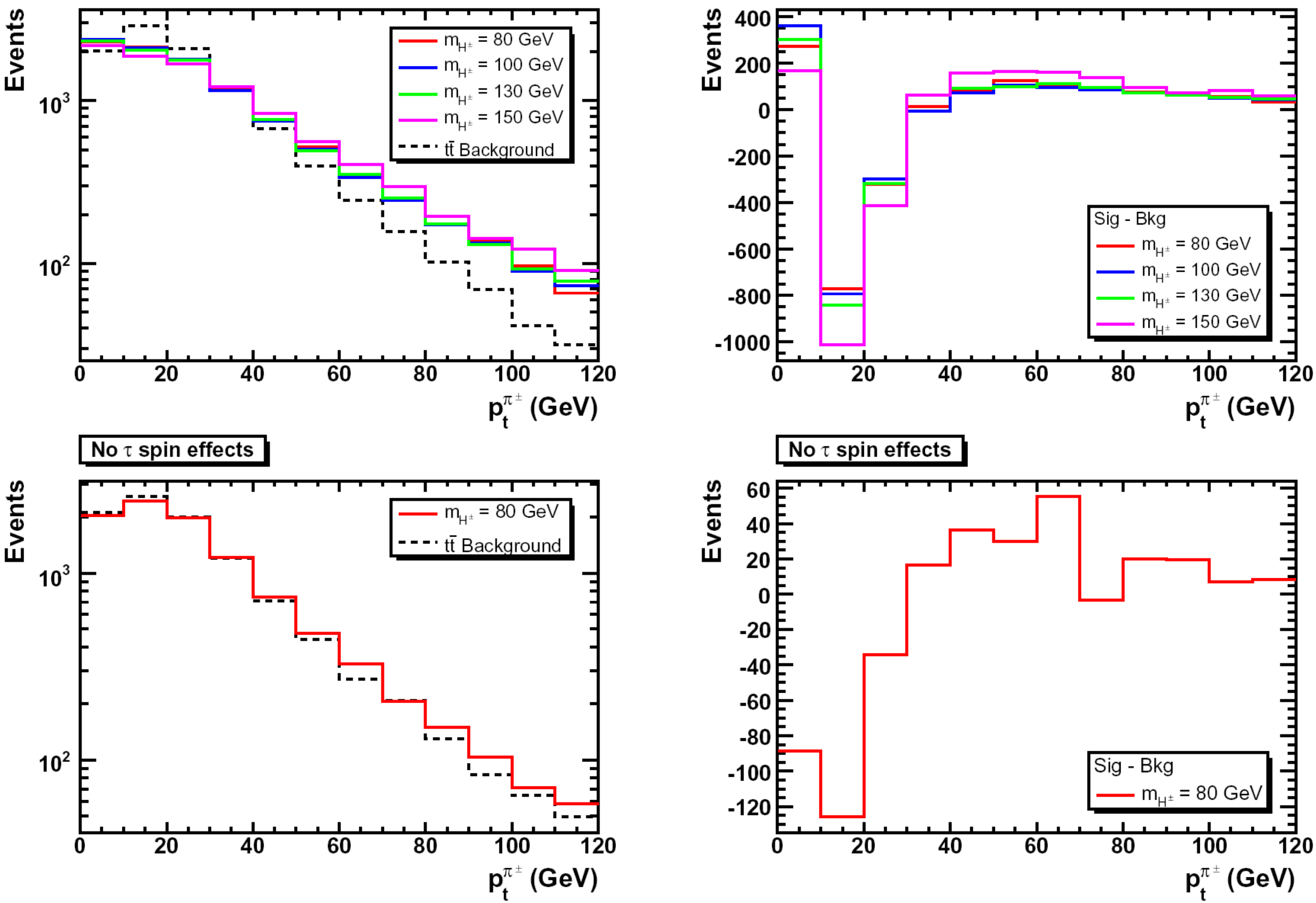
$$2b + 2j + \tau_{\rm jet} + p_t^{\rm miss}$$

- 14 TeV center-of-mass energy
- tanβ=35

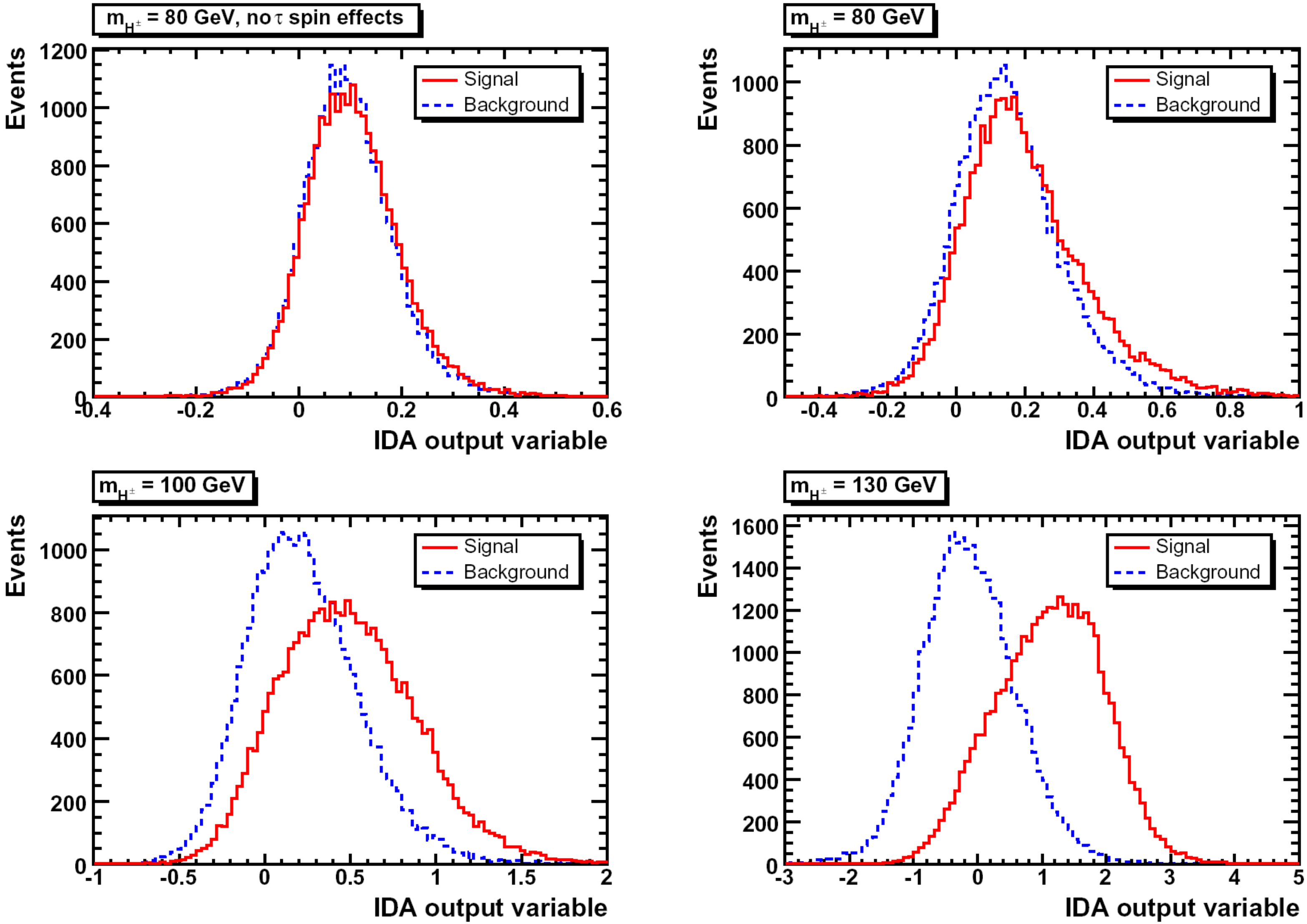
Transverse Momentum tau(jet)



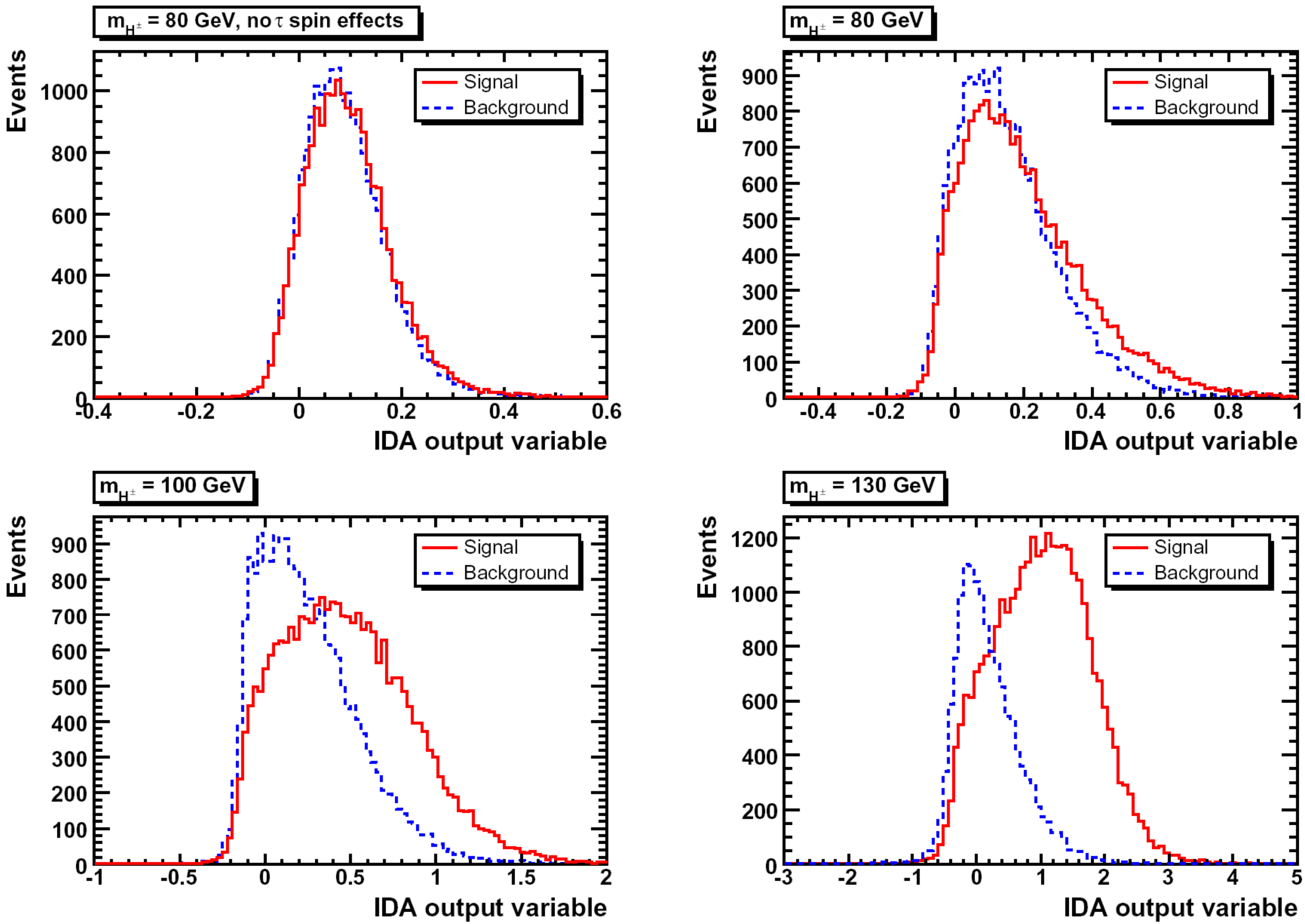
Transverse Momentum pi/tau(jet)



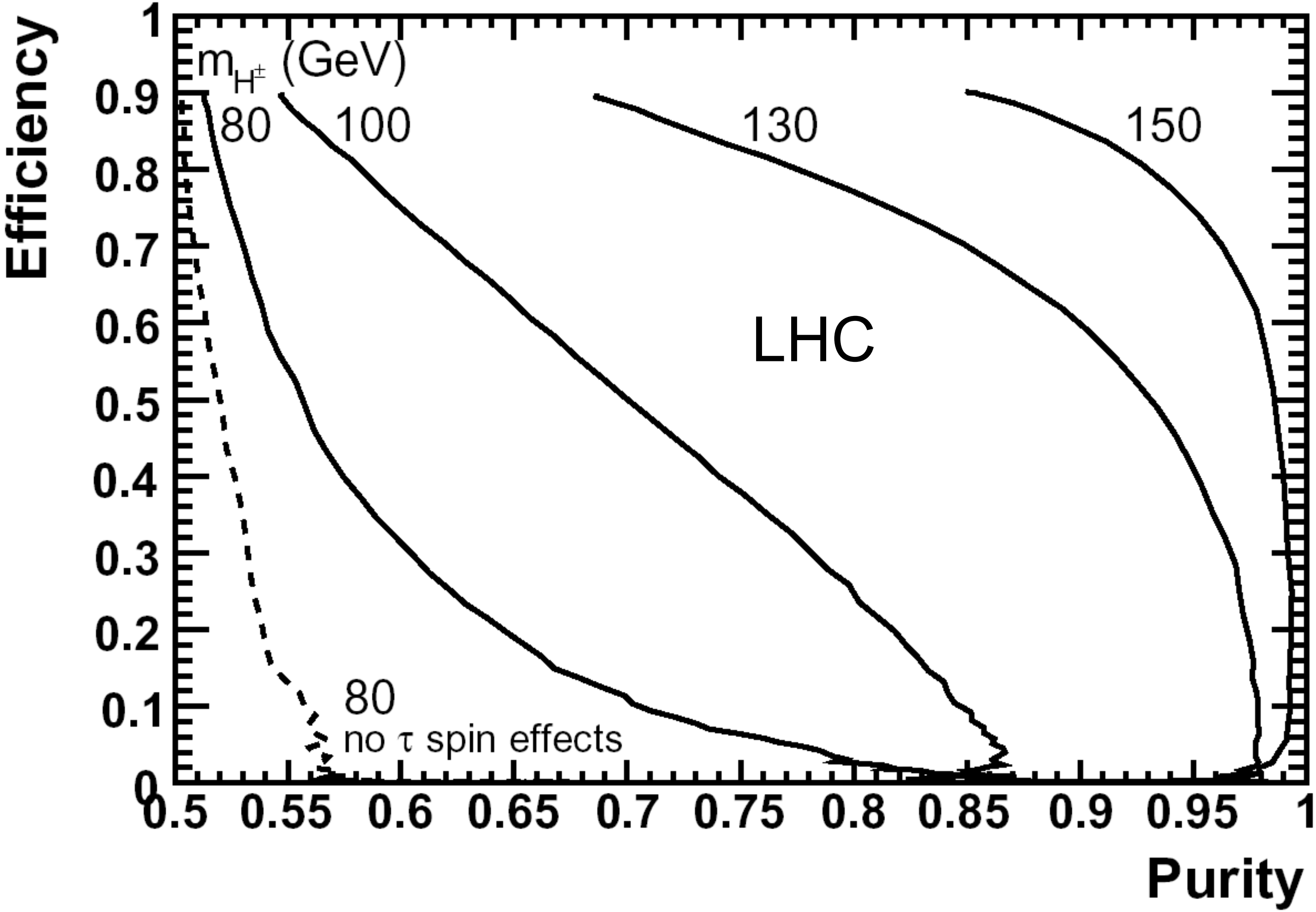
LHC: IDA Output Step-1



LHC: IDA Output Step-2



Efficiency vs Purity: Spin Importance



Conclusions (1)

- Investigated charged Higgs boson topologies at Tevatron and LHC energies and compared against irreducible SM background due to tt production.
- While sizable differences between signal and background are expected whenever $m(H^+) \neq m(W)$, near the current mass limit of about $m(H^+) \approx 80$GeV the kinematic spectra are very similar between SM decays and those involving charged Higgs bosons.
- Spin information will significantly distinguish between signal and irreducible SM background. In fact, we have considered hadronic $\tau\nu$ decays of charged Higgs bosons, wherein the τ polarization is significantly different from those emerging in the vector W decays in the SM tt case.

Conclusions (2)

- For a realistic analysis which is not specific for a particular detector, a dedicated Monte Carlo event generation and a simplified multipurpose detector response approximation have been applied.
- The identification of a hadronic tau-lepton will be an experimental challenge in an environment with typically four jets being present.
- We have demonstrated how IDA-type methods can be an important complement to cut based analyses in cases where the differences between the signal and background are small. Our results show that the IDA method will be equally effective at both the Tevatron and LHC.

Conclusions (3)

- While only the dominant irreducible tt background has been dealt with in detail, we have also specifically addressed the QCD background.
- A suitably hard missing transverse momentum cut has been applied to reject such jet activity and we have demonstrated that although the discriminative power is reduced by such a cut, the reduction is small compared to the gain from including the τ polarization effects.
- Using the differences in τ polarization between the signal and the dominant SM irreducible background is crucial for disentangling signal and background.