Impact of tau polarization for study of the MSSM charged Higgses in top quark decays at ILC

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Outline

- Introduction
- Tau polarization
- Results of computations and simulations
- Preliminary analysis of prospects to measure $H^{\pm}$ mass
- Concluding Remarks

Simulations done by means of CPsuperH and FeynHiggs for parameters;
CompHEP, new CompHEP-TAUOLA-PYTHIA interface, TAUOLA and PYTHIA
for event generation with decaying polarized taus including ISR/FSR and hadronization;
SIMDET for a detector response (in progress)

In MSSM: 5 Higgs boson states

two CP–even h and H, CP-odd A (if CP is conserved) or

three nuetral Higgses without definite CP (if CP is violated)

and two charged $H^{\pm}$ bosons

In a number of scenarios charged Higgs could be rather light

$(M_{H^{\pm}} < M_{top})$

Searches at the Tevatron

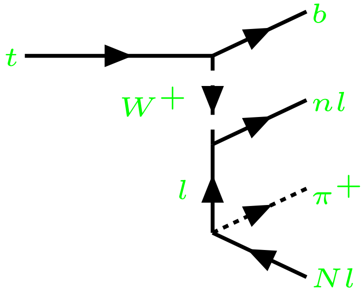
masses less 150 GeV are excluded with $BR(t \to Hb) > 0.42$ at 95% C.L.

Accuracy for charged Higgs measurements is expected to be about 5 GeV

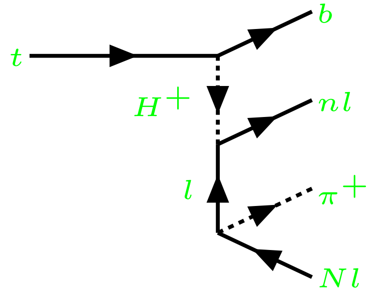
at the LHC

Importance of tau polarization in searches for charged Higgses has been stressed in many studies

(D. Roy .....)



diagr.1



diagr.2

In the rest frame of top $t \to bR \to b\tau\nu_\tau \to b\nu_\tau\bar{\nu}_\tau\pi$

where a resonance R is W boson or charged H

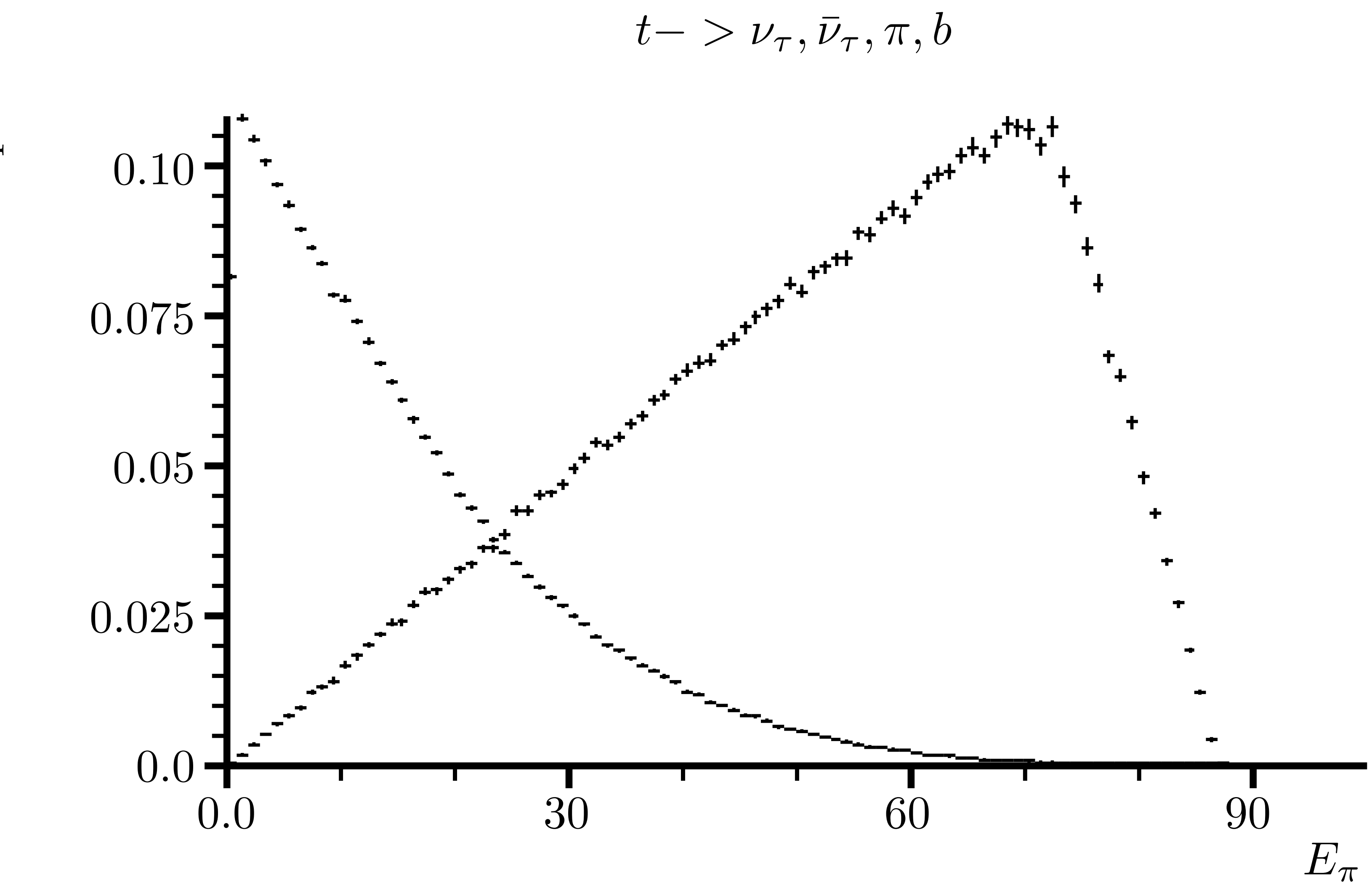
$$\frac{1}{\Gamma}\frac{d\Gamma}{dy_\pi} = \frac{1}{x_{max}-x_{min}}$$

$$\begin{cases} (1-P_\tau)log\frac{x_{max}}{x_{min}} + 2P_\tau y_\pi(\frac{1}{x_{min}} - \frac{1}{x_{max}}), & 0 < y_\pi < x_{min} \\ (1-P_\tau)log\frac{x_{max}}{y_\pi} + 2P_\tau(1 - \frac{y_\pi}{x_{max}}), & x_{min} < y_\pi \end{cases}$$

where $y_\pi = \frac{E_\pi^{top}}{M_{top}}$, $x_{min} = \frac{E_\tau^{min}}{M_{top}}$, $x_{max} = \frac{E_\tau^{max}}{M_{top}}$, $E_\tau^{min} = \frac{M_R^2}{2M_{top}}$, $E_\tau^{max} = \frac{M_{top}}{2}$

$P_\tau = -1$ for W boson and $P_\tau = 1$ for charged Higgs

(M.Nojiri; E.B.,U.Martyn, G.Moortgat-Pick, M.Sachwitz, A.Sherstnev, P.Zerwas for stau production and decay)

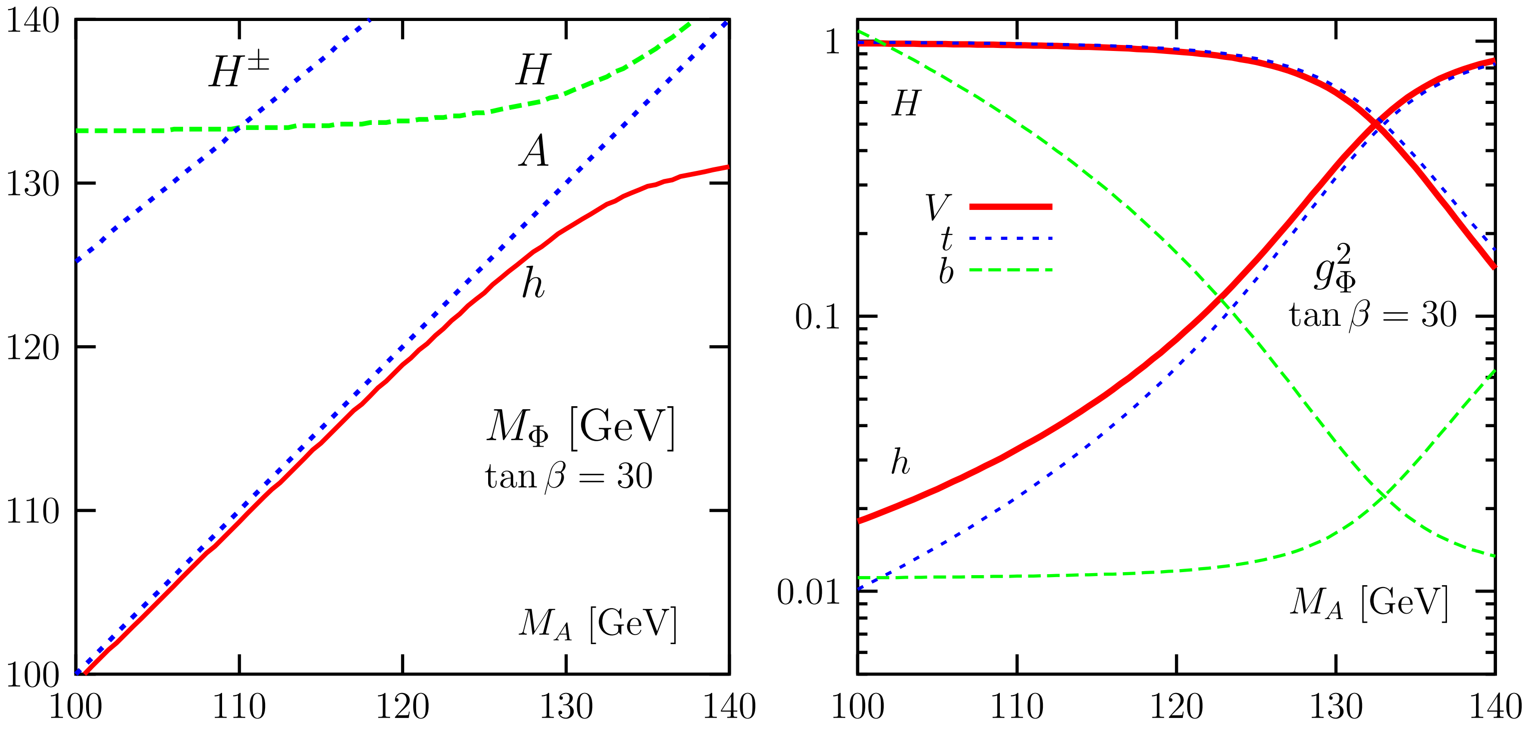


Normalized pion energy spectrum in top decays for $M_{H^\pm} = 160$ (CompHEP)

Intense coupling regime - masses of nuetral Higgs bosons are close to the critical point. (Charged Higgs lighter than Top)

The masses of the MSSM Higgs bosons (left) and the normalized couplings as a function of M_A and $tan\beta = 30$. For the b-quark couplings, the values $10 \times g_{\Phi bb}^{-2}$ are plotted.

E.B., A.Djouadi, M.Mühlleitner, A.Vologdin; E.B., A.Djouadi, A.Nikitenko;
E.B., A.Bunichev, A.Djouadi, J.Schreiber



Two scenarios with $\tan\beta = 50$, $\mu = 500$ and $\mu = -500$

The dominant SUSY corrections for large $\tan\beta$

$$\mathcal{L} \simeq \frac{g}{\sqrt{2}M_W} \frac{\bar{m_b}(Q)\tan\beta}{1+\Delta m_b} \left[V_{tb} H^+ \bar{t}_L b_R(Q) + \text{h.c.}\right]$$

$$\Longrightarrow \Gamma_{MSSM} \simeq \frac{\Gamma^{imp.}_{QCD}}{(1+\Delta mb)^2}$$

$$\Delta_b = \frac{\Delta h_b}{h_b} \tan\beta \sim \frac{2\alpha_S}{3\pi} \frac{\mu\, M_{\tilde{g}}}{\max(m^2_{\tilde{b}_1}, m^2_{\tilde{b}_2}, M^2_{\tilde{g}})} \tan\beta + \Delta_b^{\tilde{t}\tilde{\chi}^+}$$

$$\Delta_b^{\tilde{t}\tilde{\chi}^+} \sim \frac{h_t^2}{16\pi^2} \frac{\mu\, A_t}{\max(m^2_{\tilde{t}_1}, m^2_{\tilde{t}_2}, \mu^2)} \tan\beta$$

Carena, Garcia, Nierste and Wagner

Simulations are performed for e^+e^- collisions at 500 GeV cms and for 500 fb^{-1} integrated luminsity

CompHEP including ISR and beamsrahlung with polarized τ

$e^+e^- \to t\bar{t} \to \tau\nu_\tau b\bar{b} + 2jets$

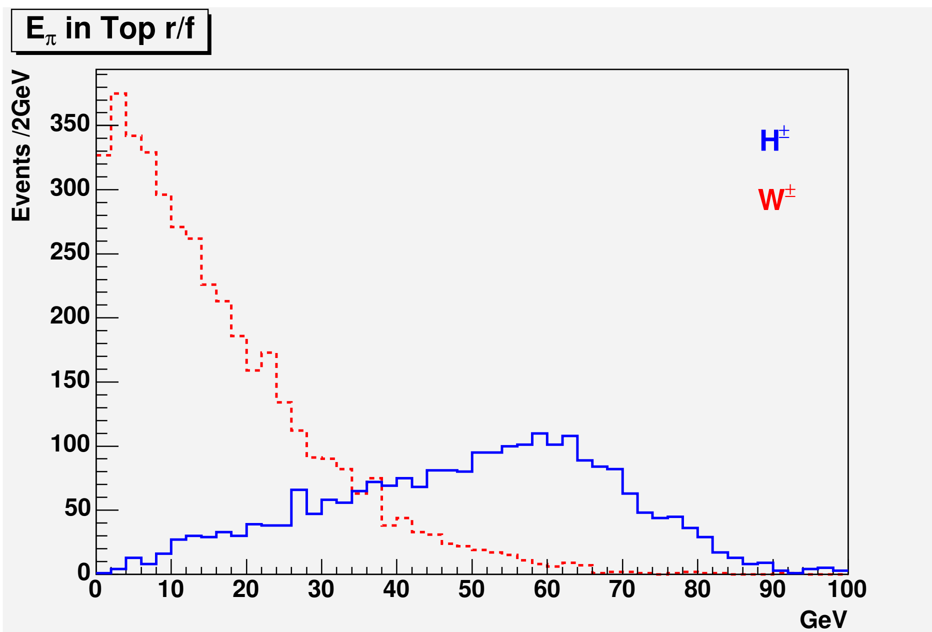
Polarized τ decays with TAUOLA using new CompHEP-TAUOLA interface

All other stages by means of PYTHIA using standard CompHEP-PYTHIA interface

Distributions are given in the reconstracted top rest frame using the recoil mass technique

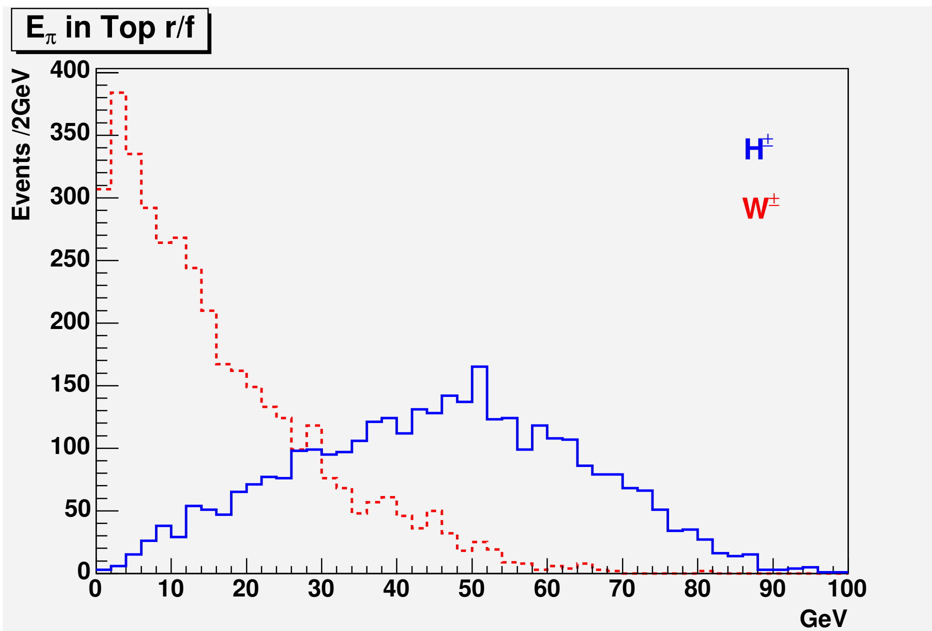
No detector effects and systematics yet

π-meson energy spectrum for the MSSM point (intense coupling regime)
$\tan\beta = 30$ ($M_A = 130\ GeV$), $M_{H^\pm} = 146\ GeV$ with $Br(t \to H^+ b) = 6.2\%$



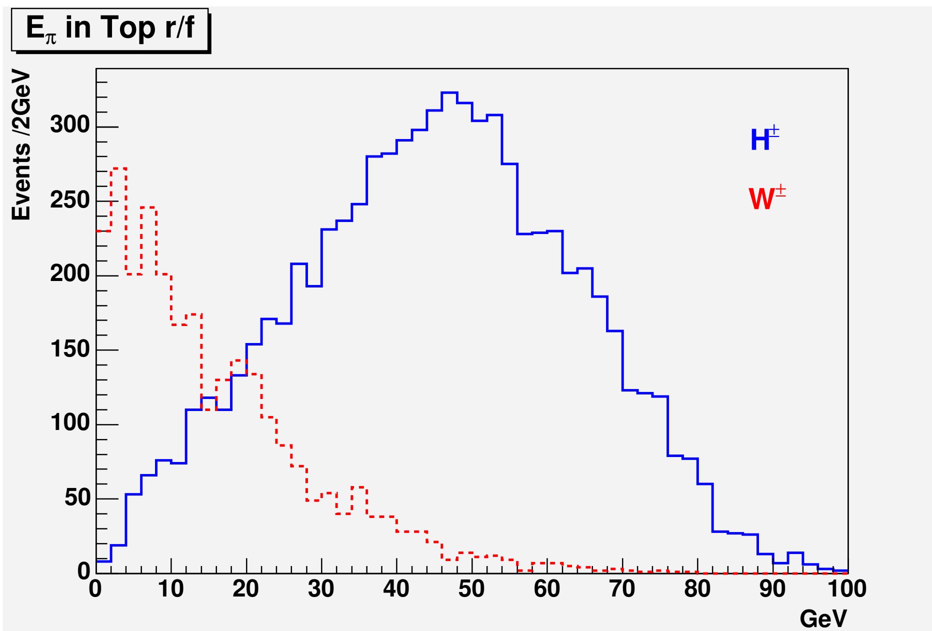
π-meson energy spectrum for the MSSM point

$\tan\beta = 50$, $\mu = 500$, $M_{H^\pm} = 130\ GeV$ with $Br(t \to H^+ b) = 9.1\%$

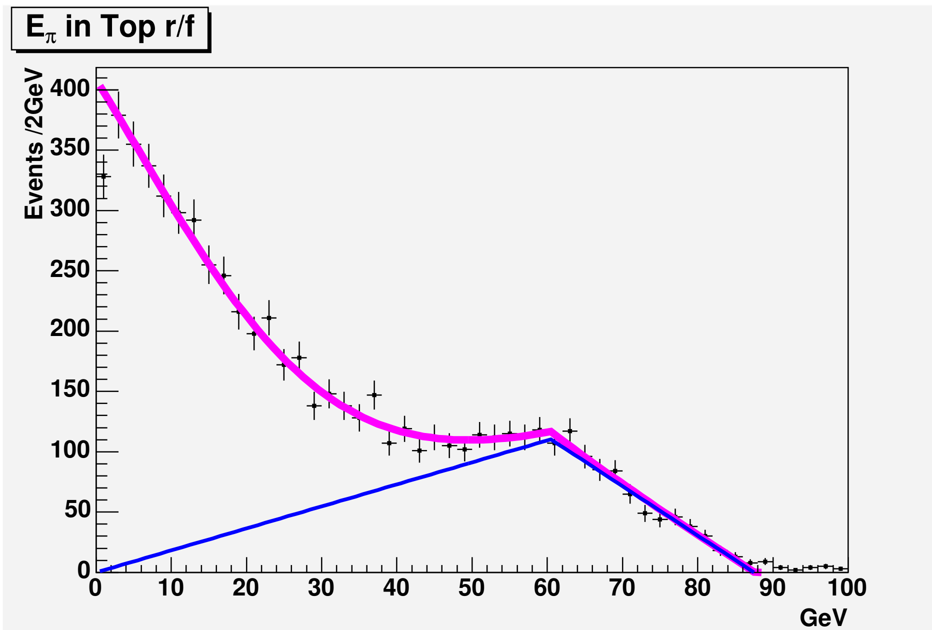


π-meson energy spectrum for the MSSM point

$\tan\beta = 50$, $\mu = -500$, $M_{H^\pm} = 130\ GeV$ with $Br(t \to H^+ b) = 24\%$



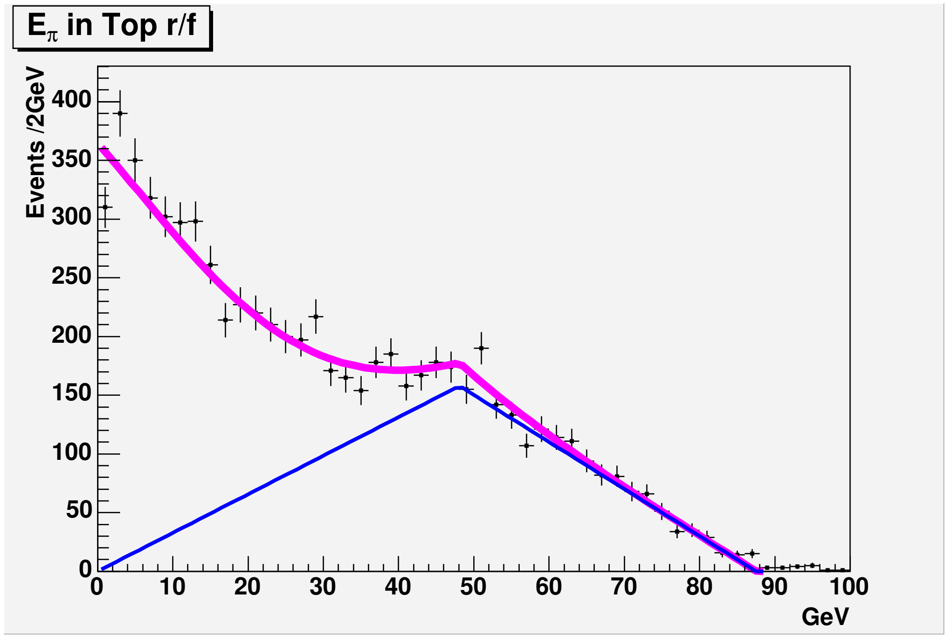
π-meson energy spectrum for MSSM intense coupling point
$\tan\beta = 30$, $M_{H^\pm} = 146\ GeV$ with $Br(t \to H^+ b) = 6.2\%$



From the signal+backgr fit $M_{H^\pm}$ = 145.5 +/- 0.9 GeV

π-meson energy spectrum for the MSSM point

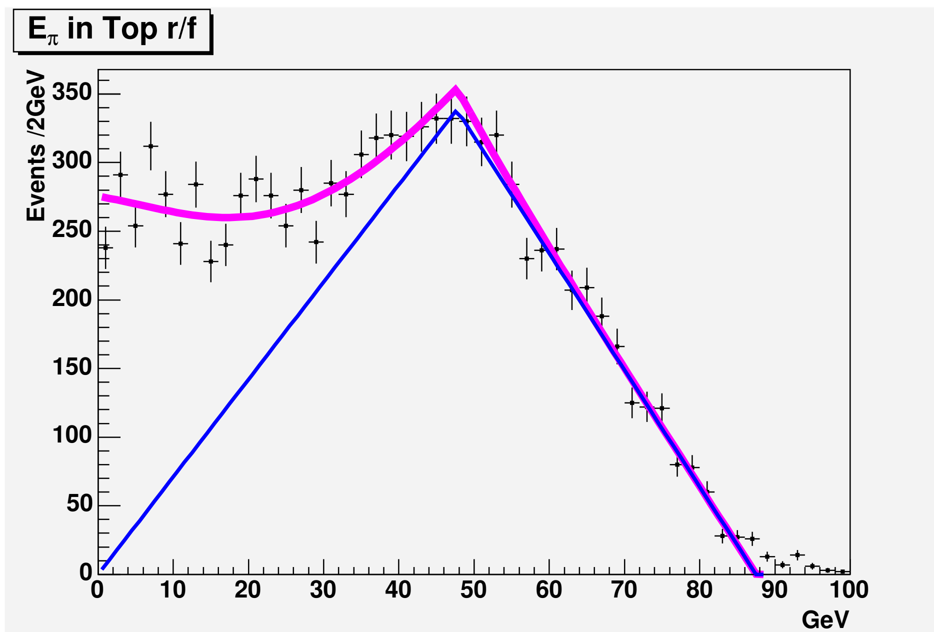
$\tan\beta = 50$, $\mu = 500$, $M_{H^\pm} = 130\ GeV$ with $Br(t \to H^+ b) = 9.1\%$



From the signal+backgr fit $M_{H^\pm}$ = 129.4 +/- 0.9 GeV

π-meson energy spectrum for the MSSM point

$\tan\beta = 50$, $\mu = -500$, $M_{H^\pm} = 130\ GeV$ with $Br(t \to H^+ b) = 24\%$



From the signal+backgr fit $M_{H^\pm}$ = 129.7 +/- 0.5 GeV

Conclusions

- Tau lepton polarization is a powerfull discriminative characteristic to separate the charged Higgs signal
- Examples are given for represantative scenarious with rather light charged Higgses
- Fit of pion energy spectra from polarized tau decay allows to extract light charged Higgs masses with an accuracy of 0.5-1 GeV (at "theoretical" level of an analysis)