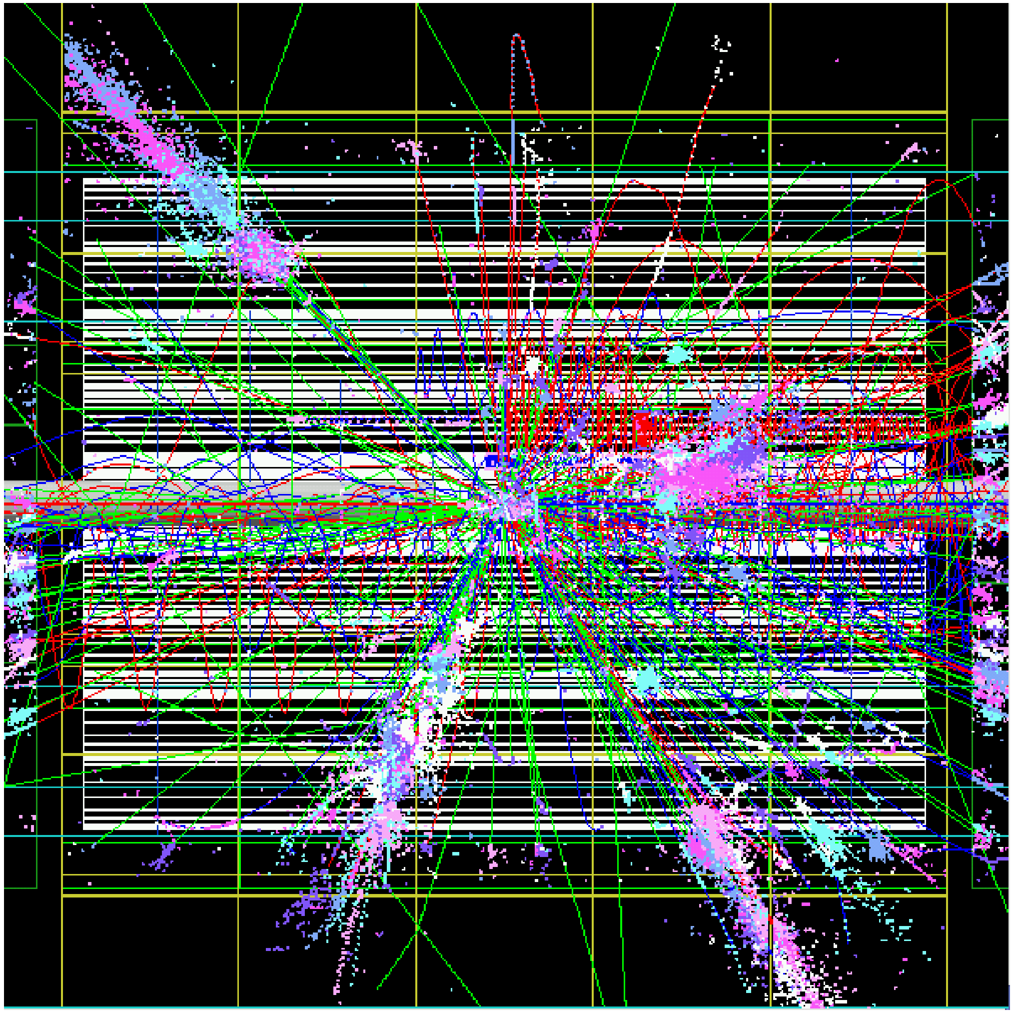
Highlights of Charged Higgs Boson Physics at a Future e^+e^- Linear Collider

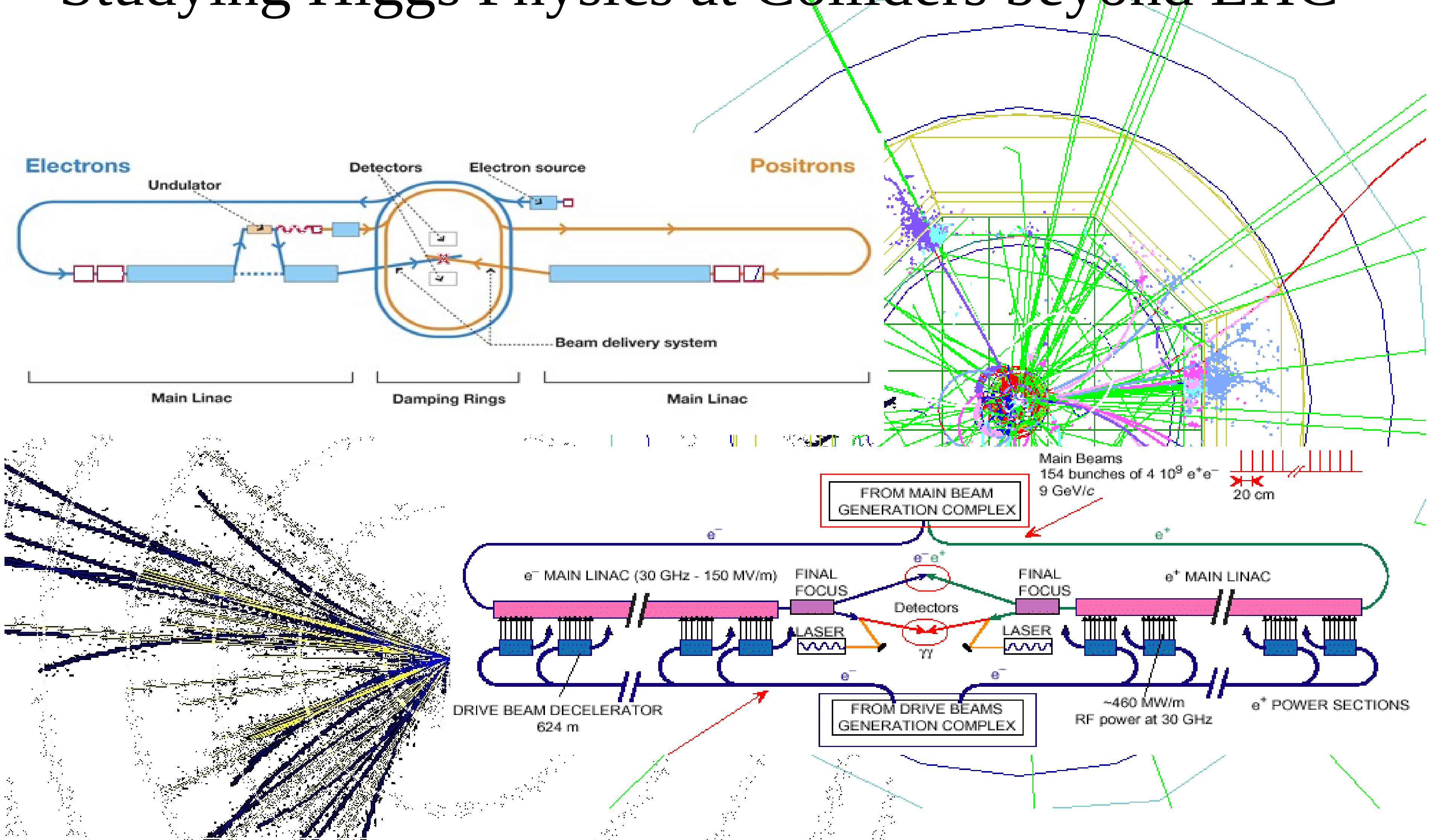


Marco Battaglia

University of California,
Lawrence Berkeley National Laboratory
and CERN

Charged Higgs Workshop,
Uppsala, 30 September 2010

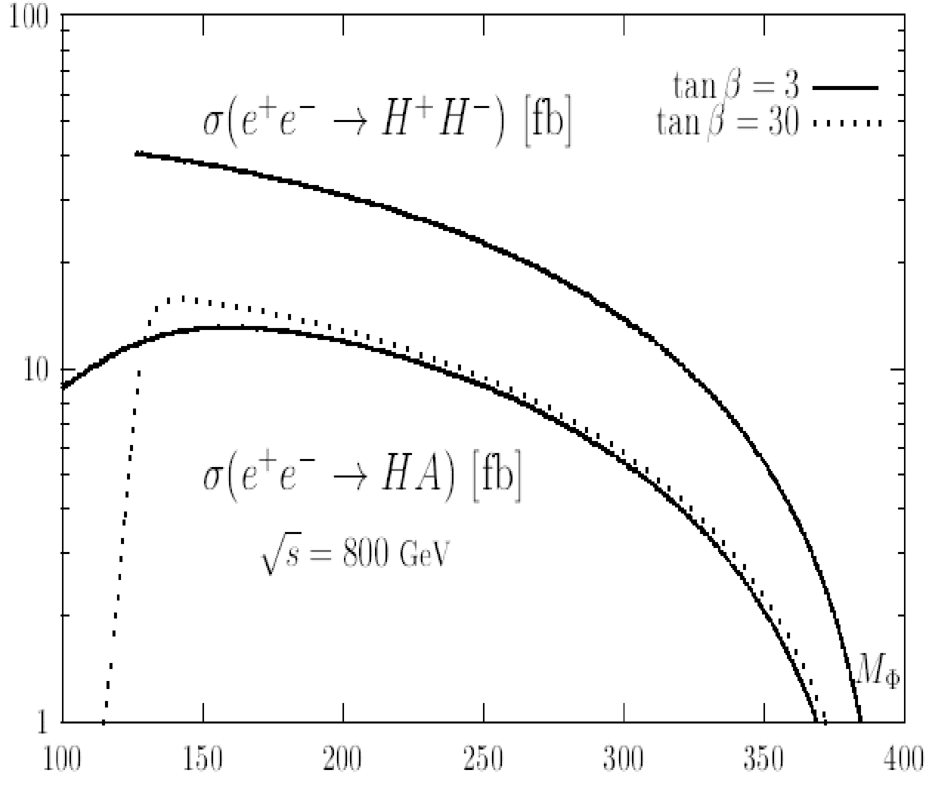
Studying Higgs Physics at Colliders beyond LHC

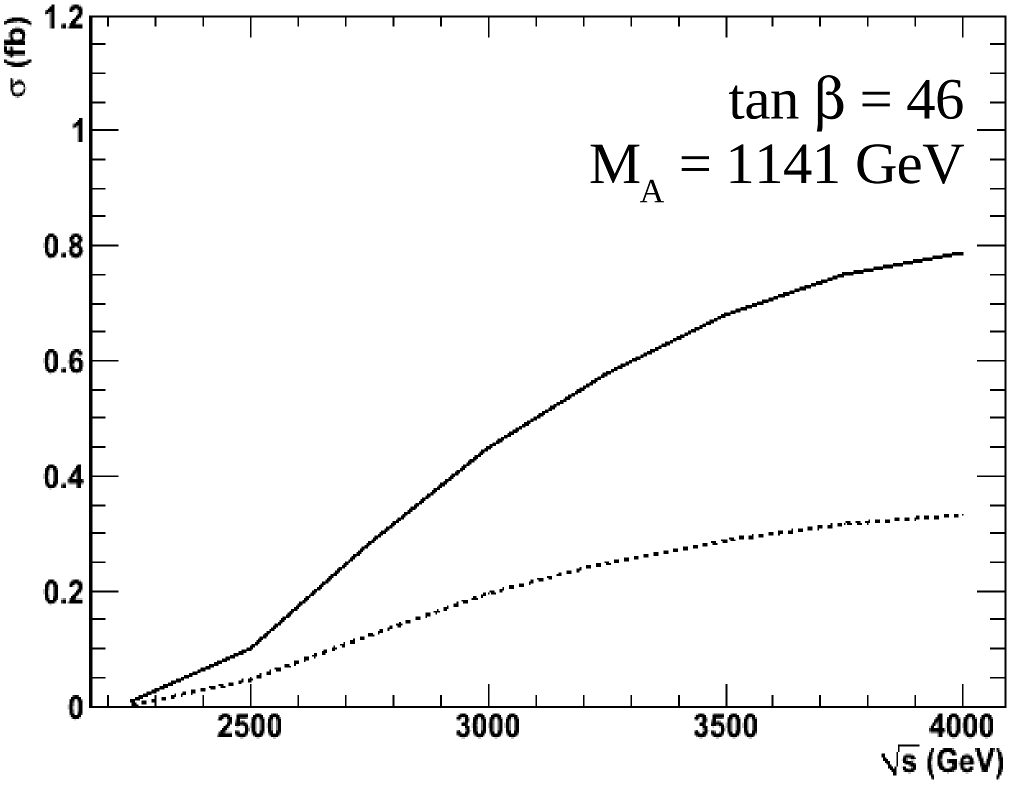


ILC to provide point-like particle collisions from 0.3 TeV up to ~ 1 TeV with tunable centre-of-mass energies, particle species and polarization states;

CLIC multi-TeV e^+e^- collider further pushes energy frontier up to 3 TeV.

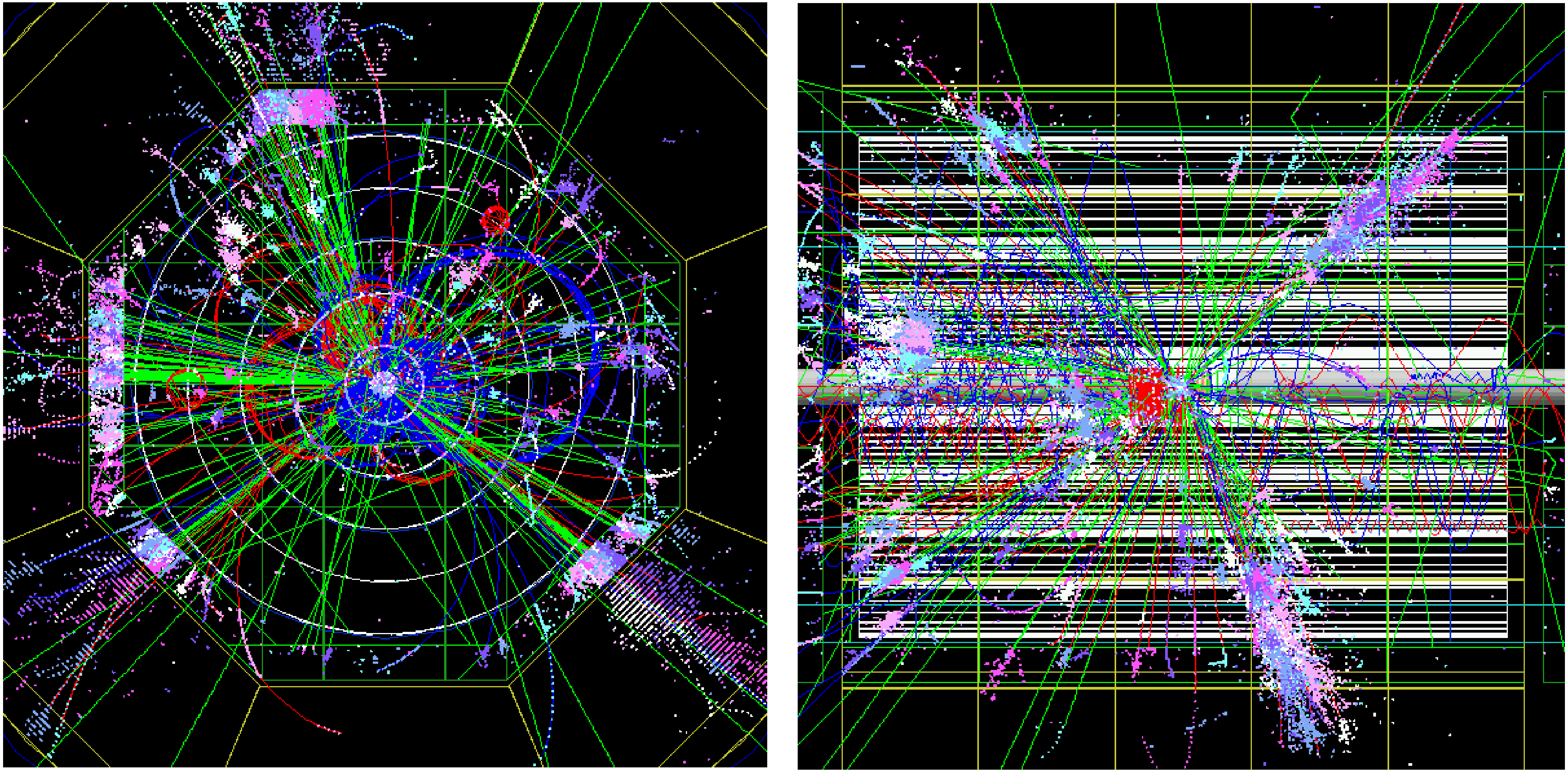
Charged Higgs at the Linear Collider: Pair Production





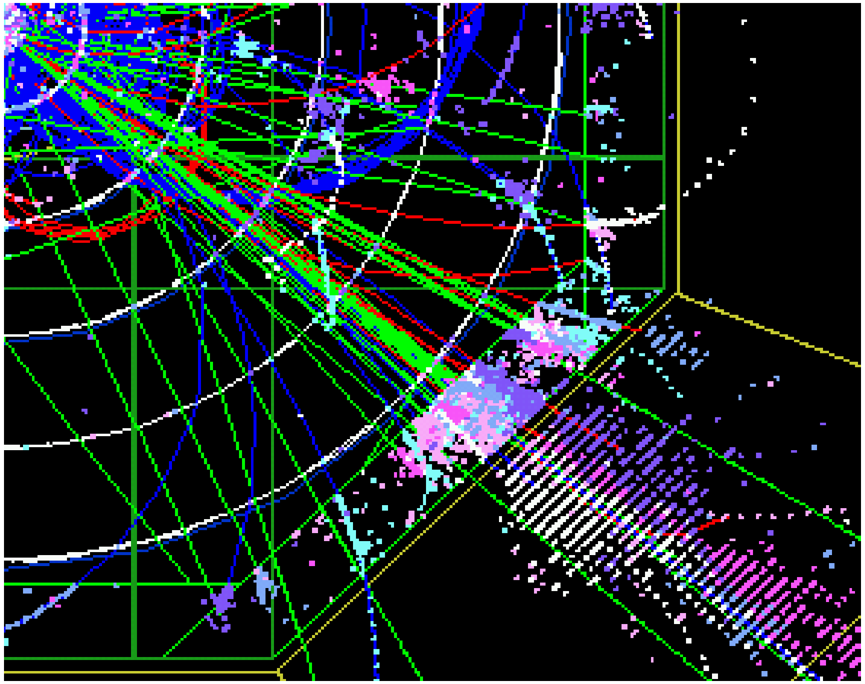
Simulation studies so far have focused on $H^+H^- \to tbtb$, $W^+h^0W^-h^0$ and $tb\tau\nu$ irreducible tbtb background cross section is 3.2 fb at 0.8 TeV and 1.2 fb at 3 TeV.

Charged Higgs Reconstruction

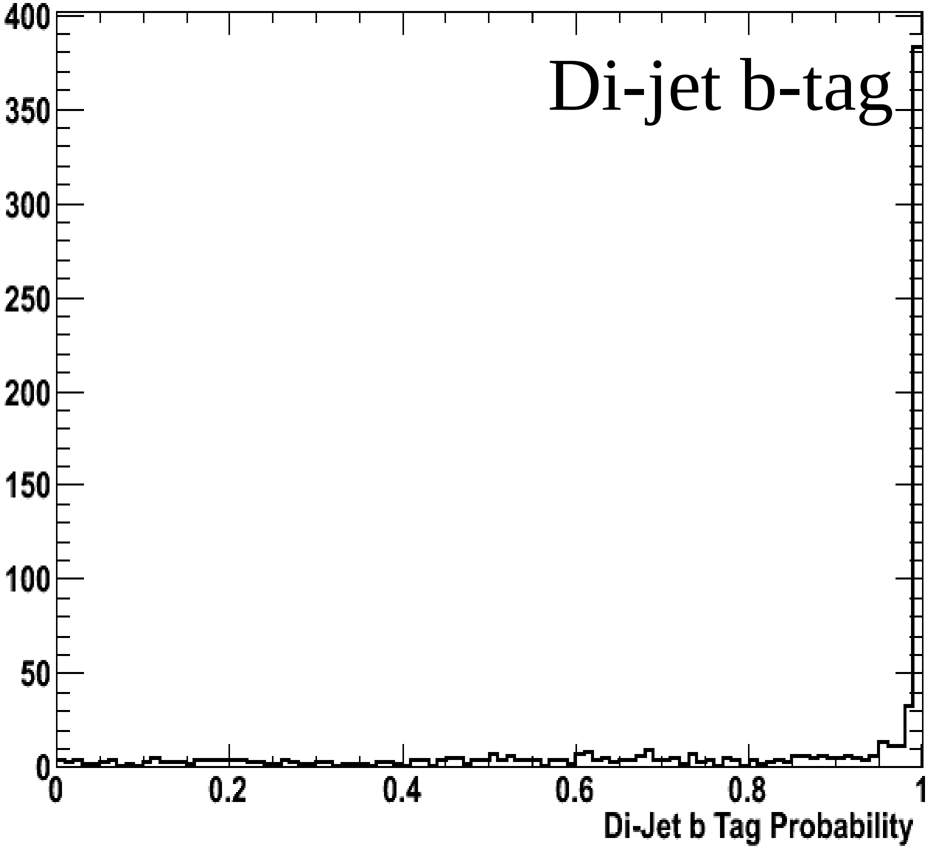


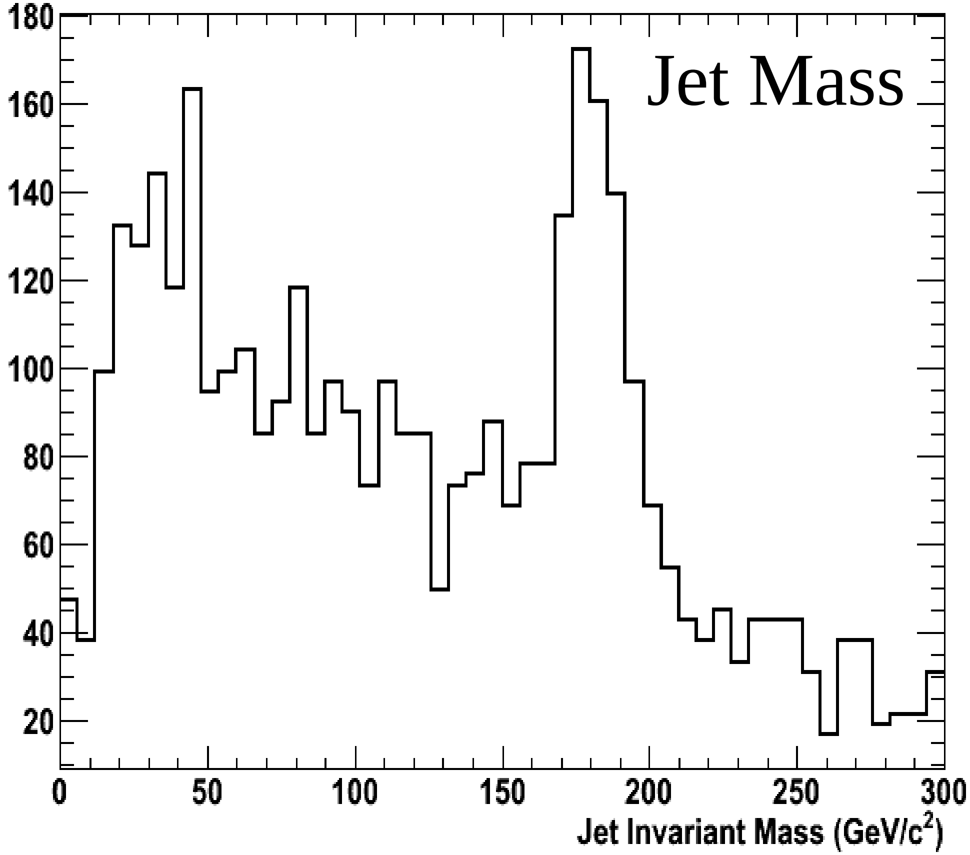
Large jet multiplicity in $H^+H^- \rightarrow tbtb$, $W^+h^0W^-h^0$ benchmarks detector granularity and ability to perform accurate reconstruction of kinematics and flavour tagging in high multiplicity environment.

Charged Higgs Reconstruction: b and top tagging

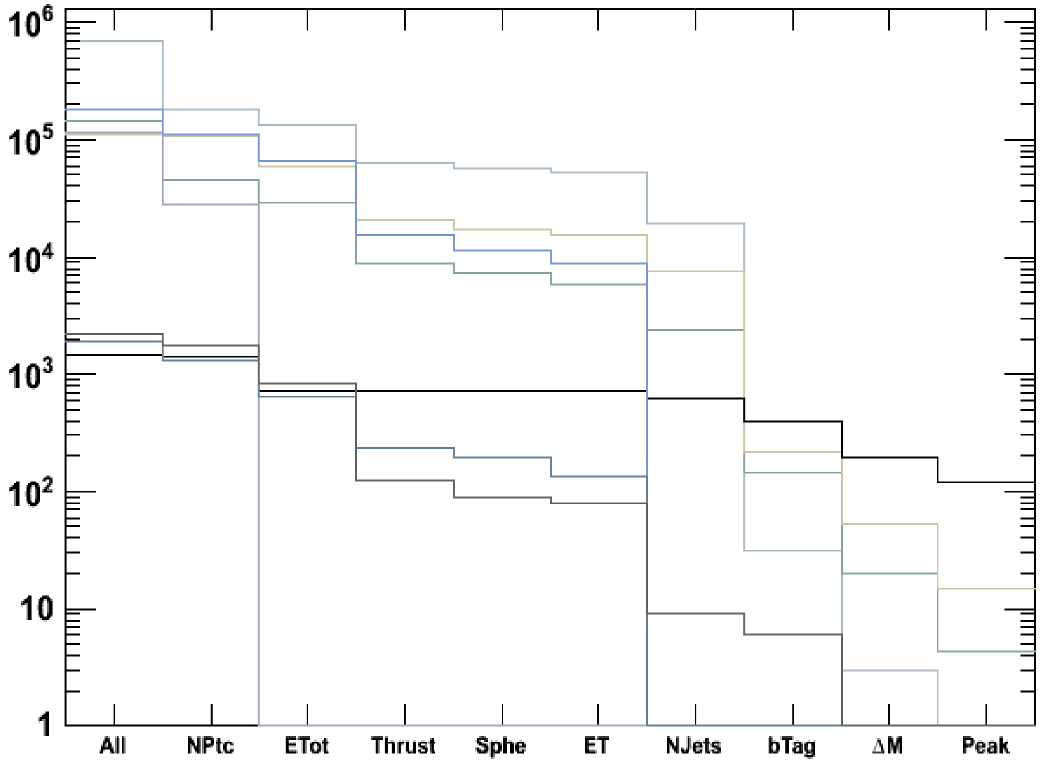


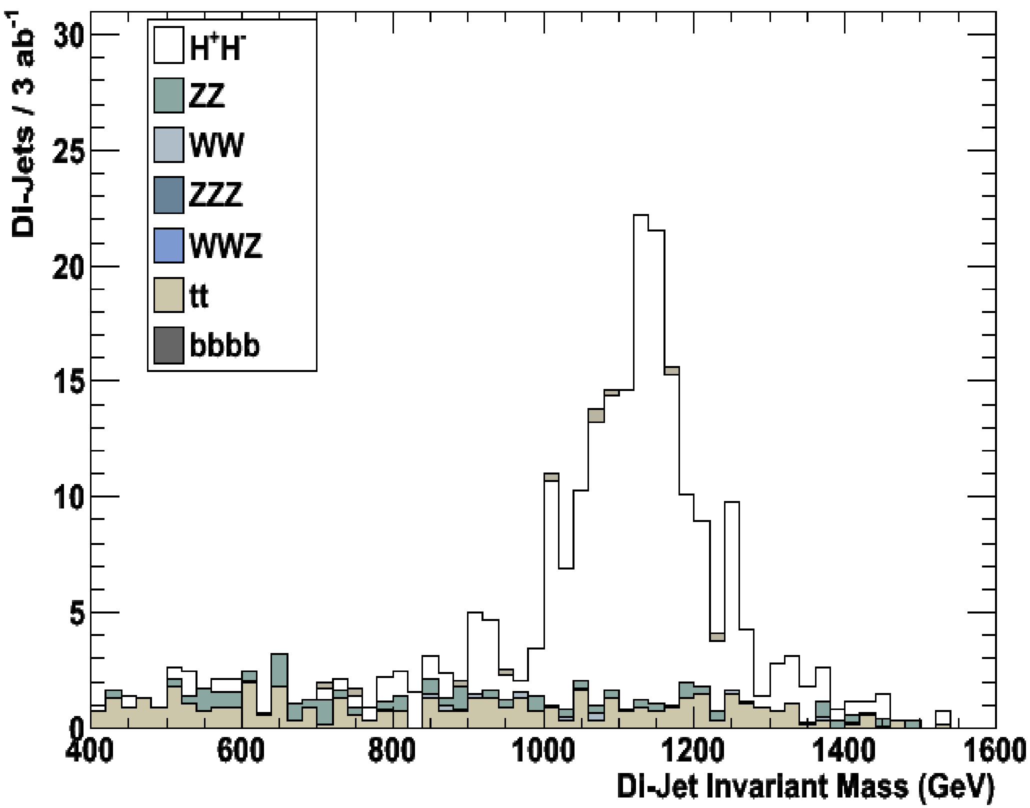
Large mass H+ produced in multi-TeV characterised by dominant H+ → tb decay; by clustering event into 4 jets the reconstruction is based on di-jet pairing of b-tagged jets with one top condidate per pair, reducing both background and combinatorial.



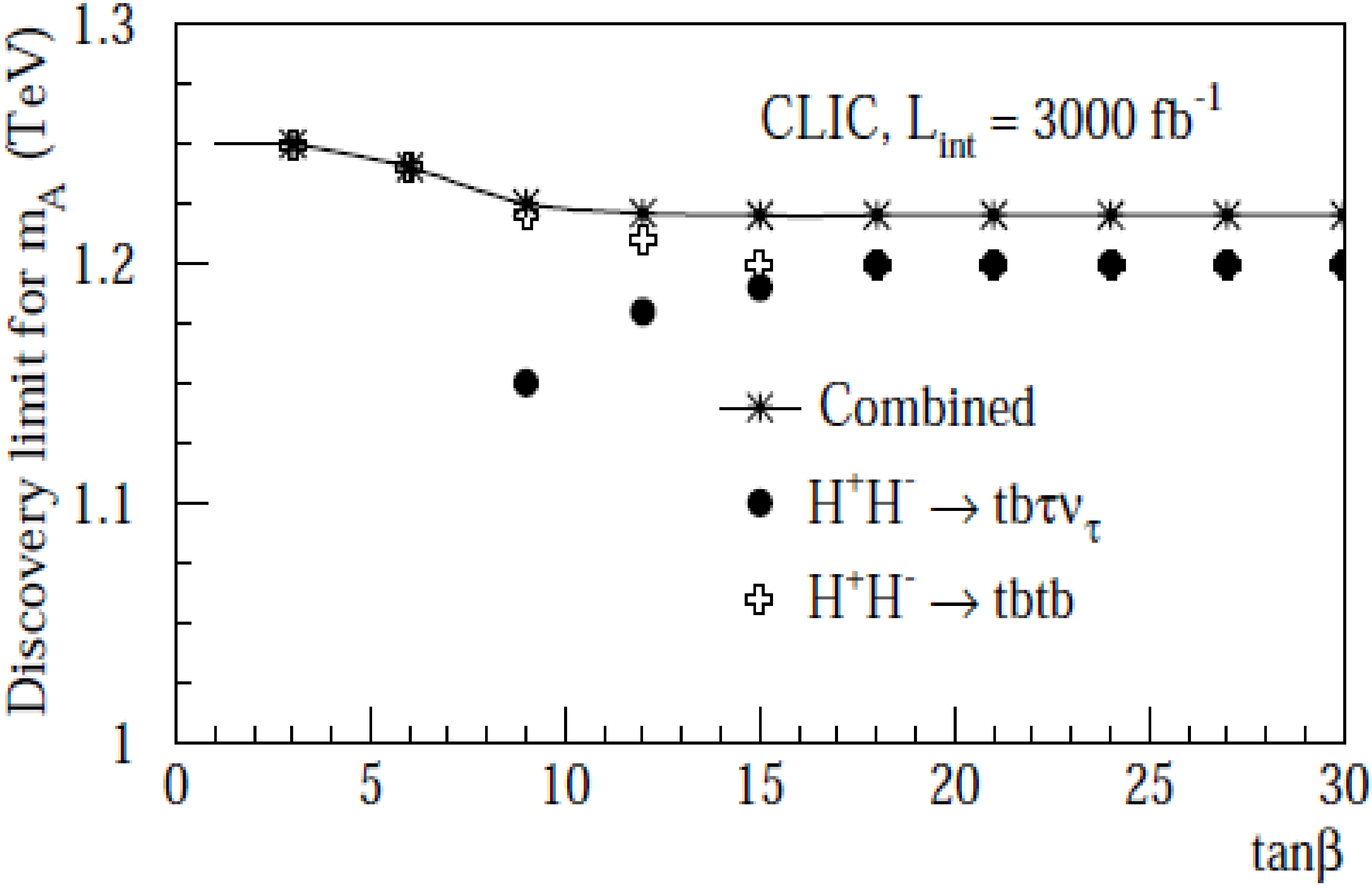


Charged Higgs Reconstruction: Event Selection





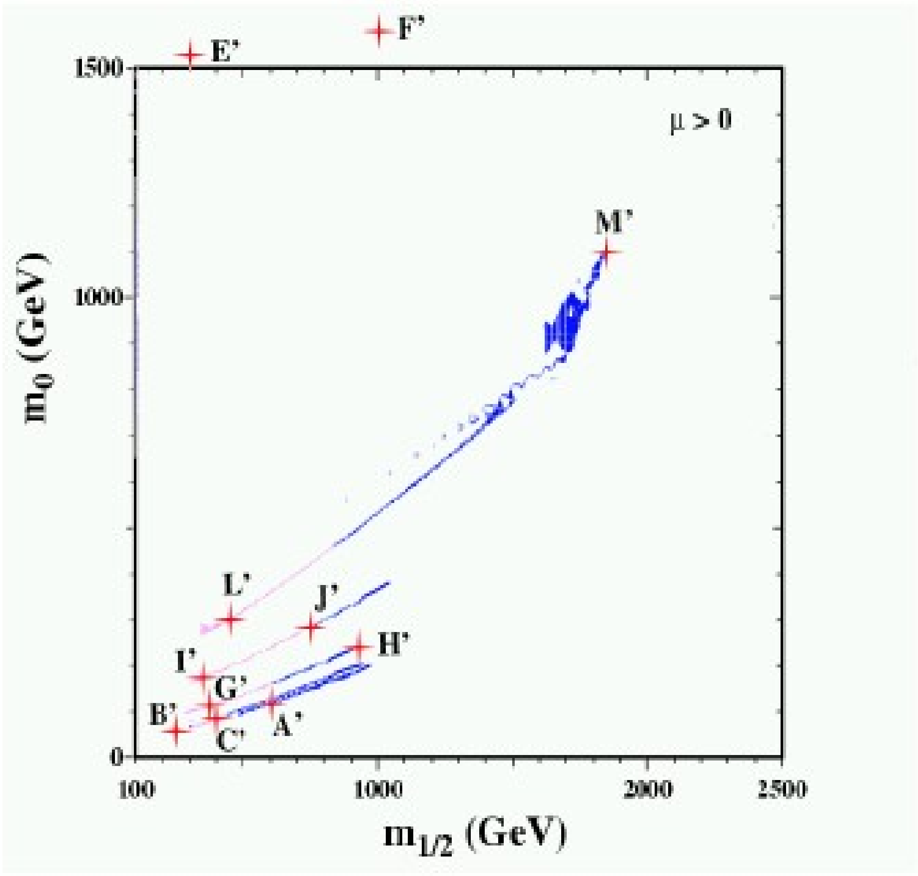
Discovery Reach:
CLIC at 3 TeV

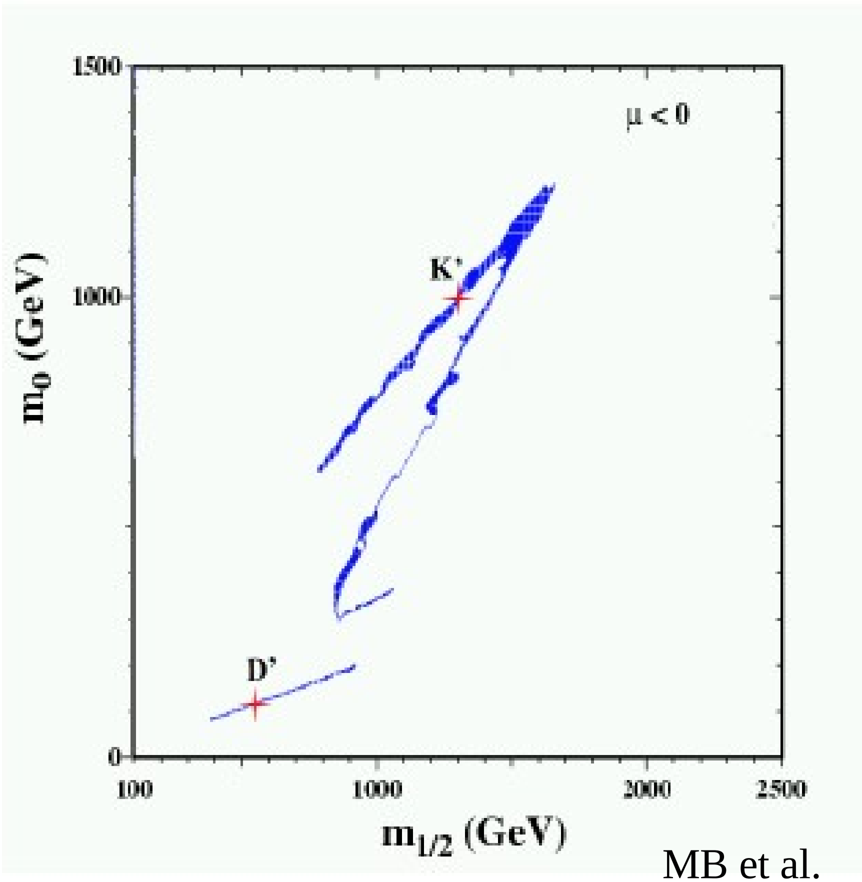


Coniavitis, Ferrari
PRD 75 (2007)

Discovery Reach

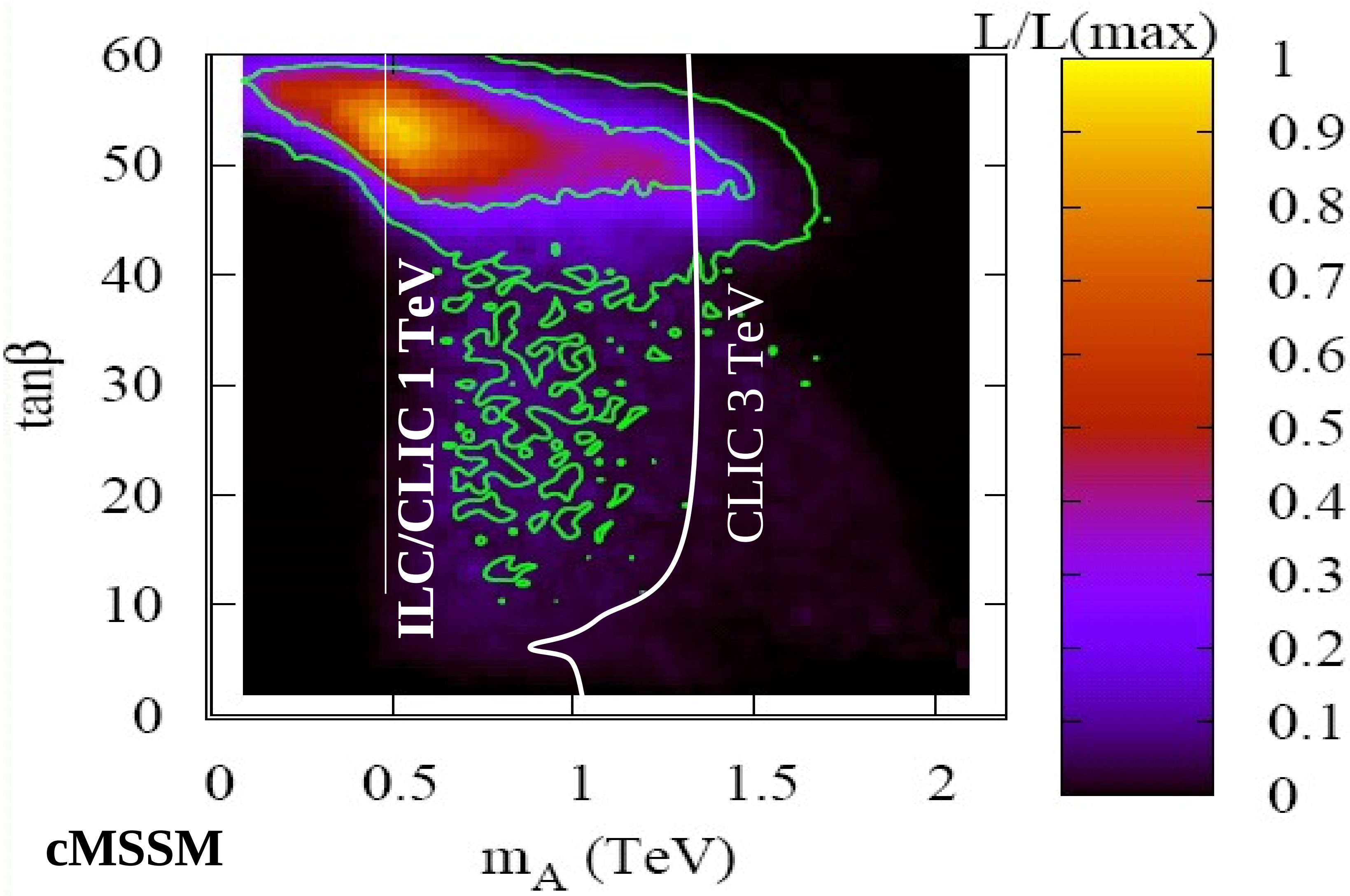
Heavy Higgs sector acquires special importance in dark matter motivated SUSY where the A^0 boson plays a special role in the χ annihilation cross section and in the χ scattering cross section on nuclei which is the fundamental parameter for direct detection experiments. Conversely within DM-compatible MSSM scenarios predictions are possible on mass scale of the heavy Higgs sector:





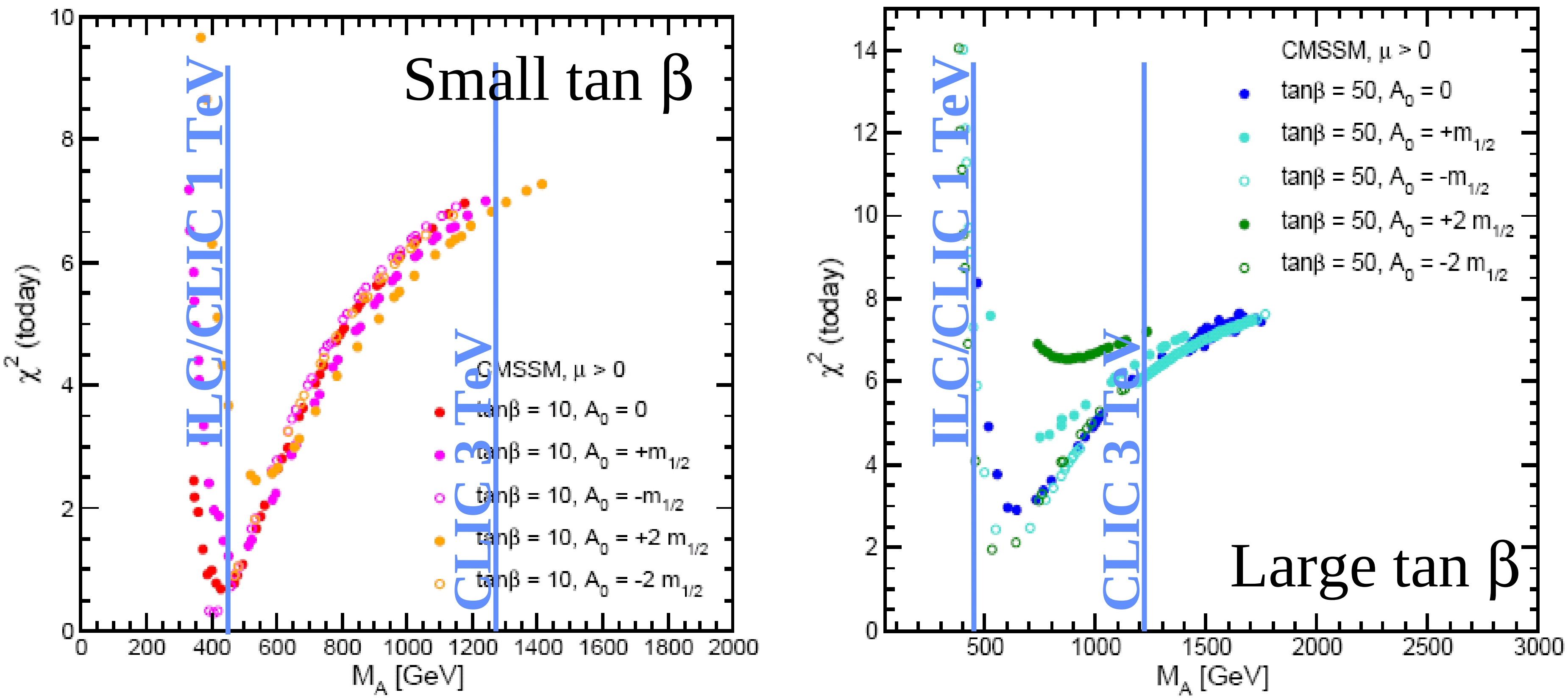
MB et al.
EPJ C33 (2004)

Discovery Reach: cMSSM



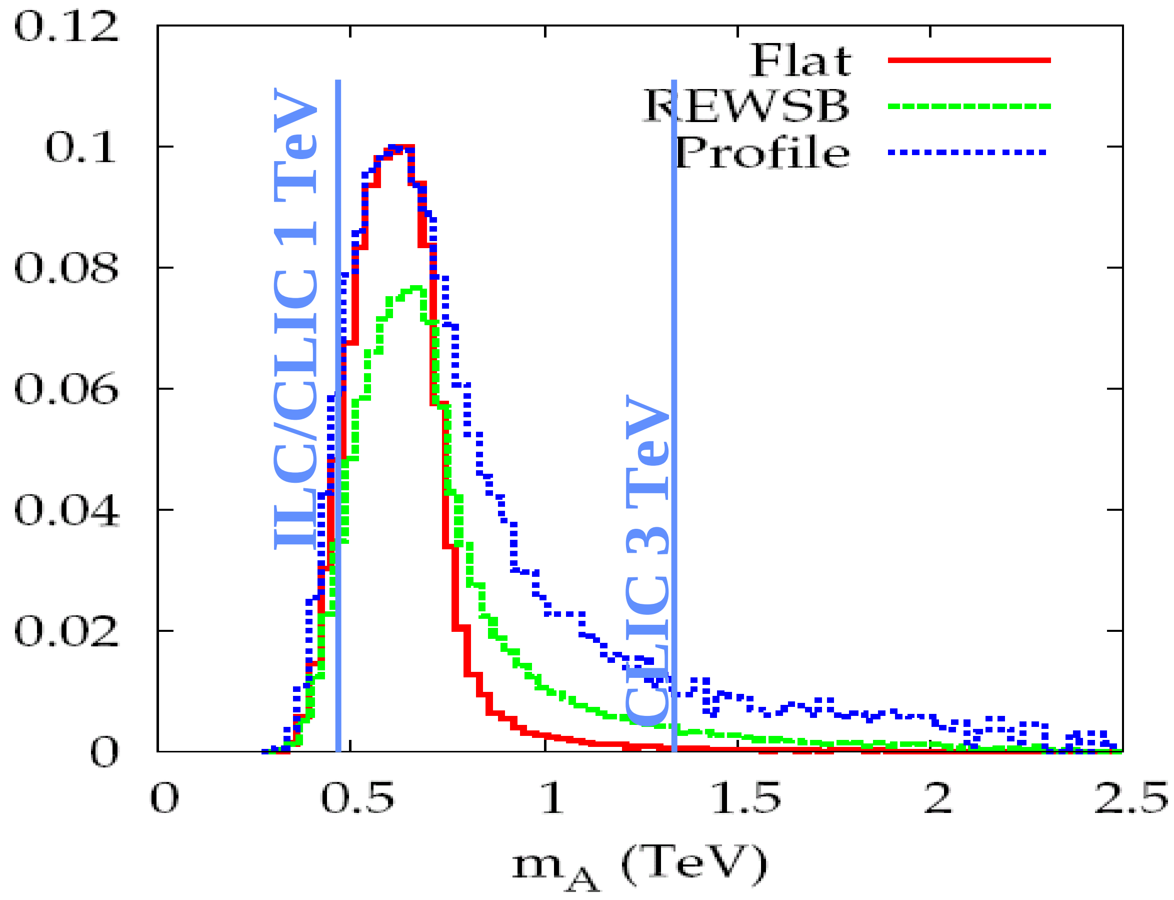
Allanach et al
PRD 73 (2006)

Discovery Reach: cMSSM



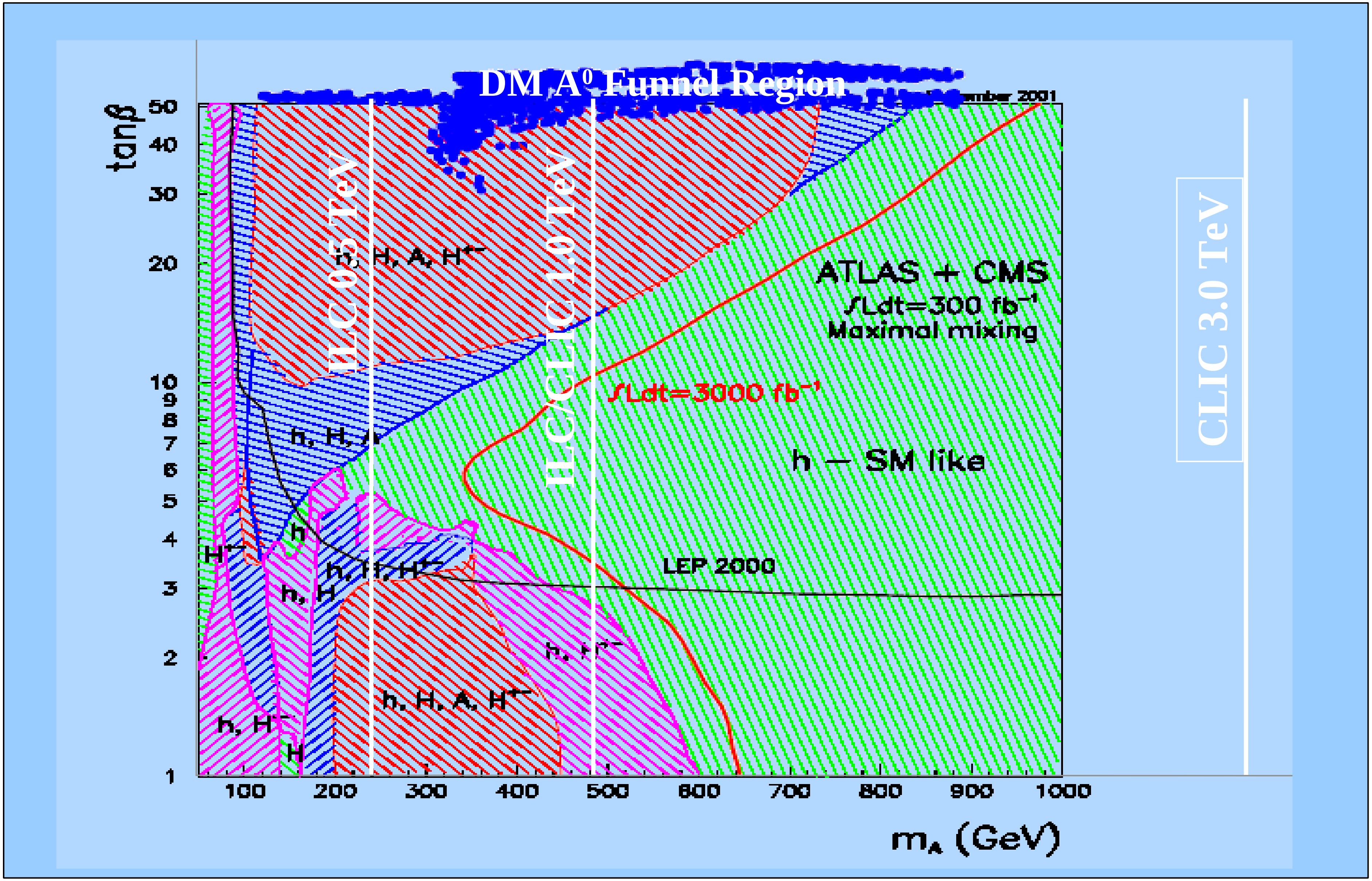
Ellis et al
JHEP 0502 (2005)

Discovery Reach: “Large Volume” SUSY



Allanach et al
JHEP 0808 (2008)

Discovery Reach: LHC and LC

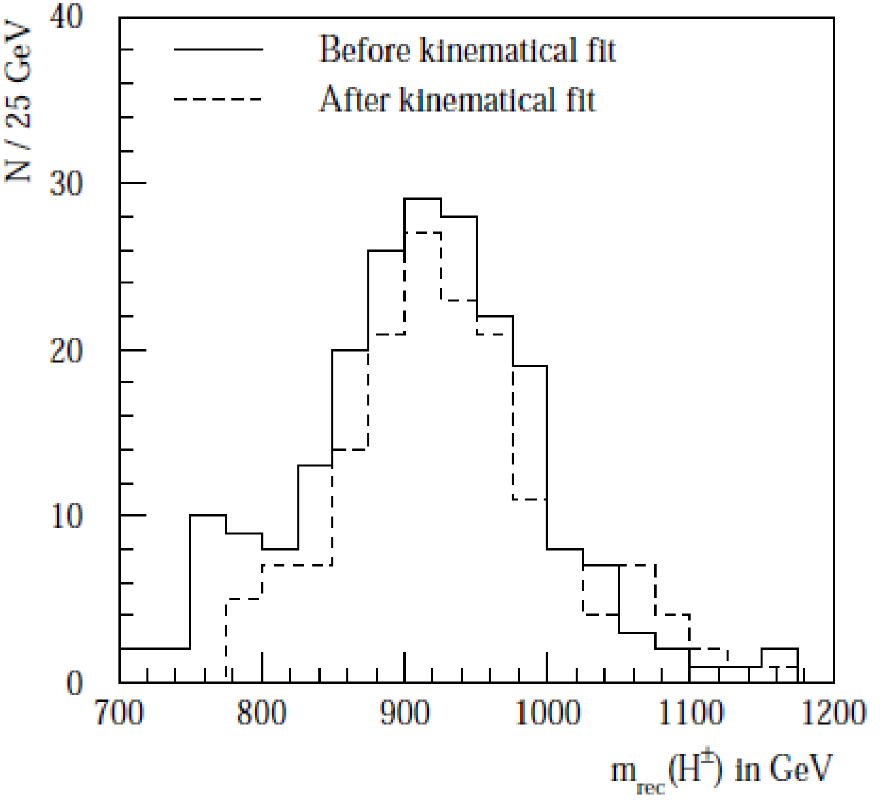


Charged Higgs Reconstruction
Mass Determination

Mass resolution can be improved by applying kinematic fit to jet final states;

Because beamstrahlung energy loss is significant at LC, beam energy constrained must be replaced by p_t=0 of escaping photons;

Still kinematic fit improves mass resolution by typically 50% down to $\sigma M/M \sim 0.02\text{-}0.05$.

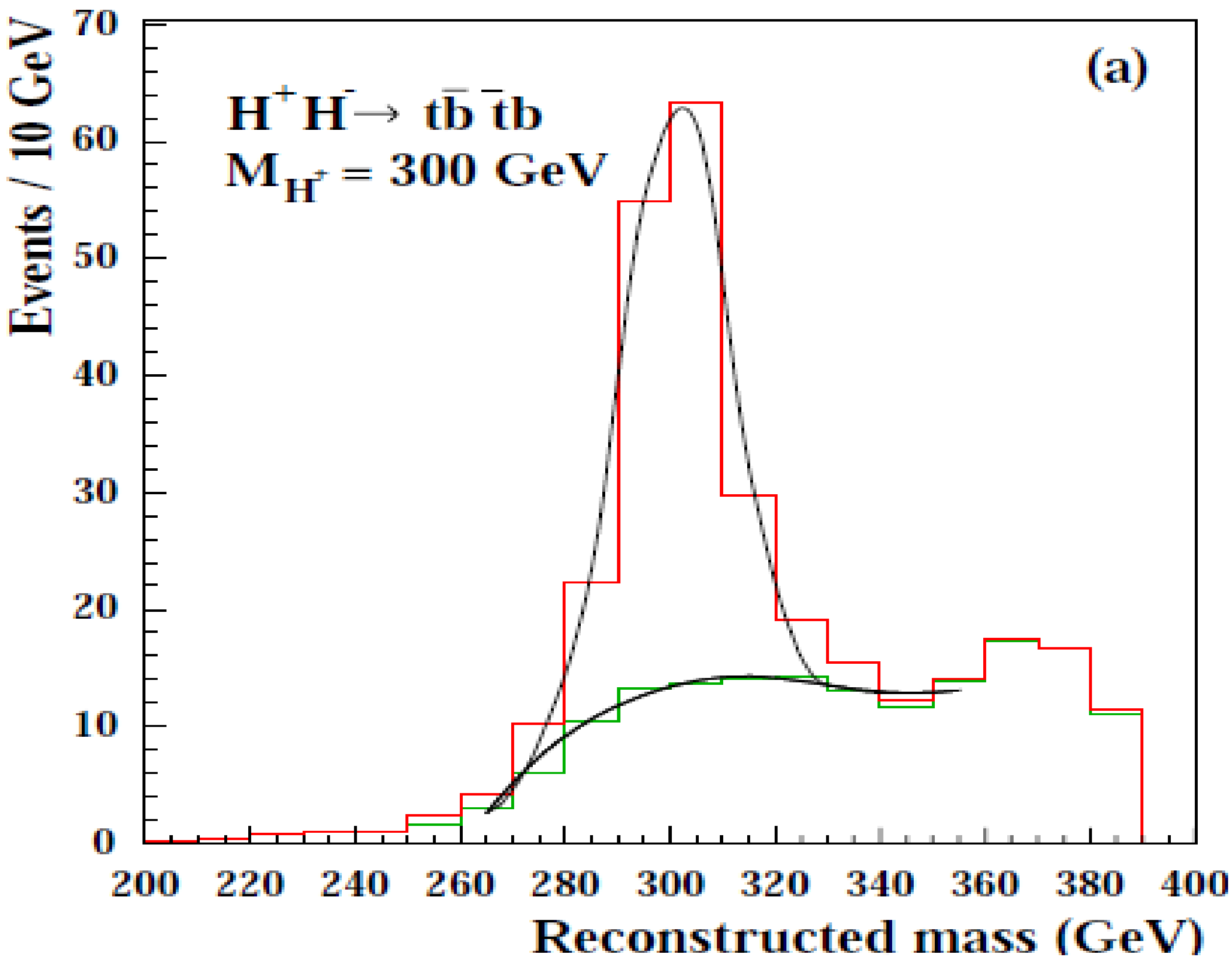


CERN-2004-005

Charged Higgs Reconstruction
Mass Determination: 300 GeV

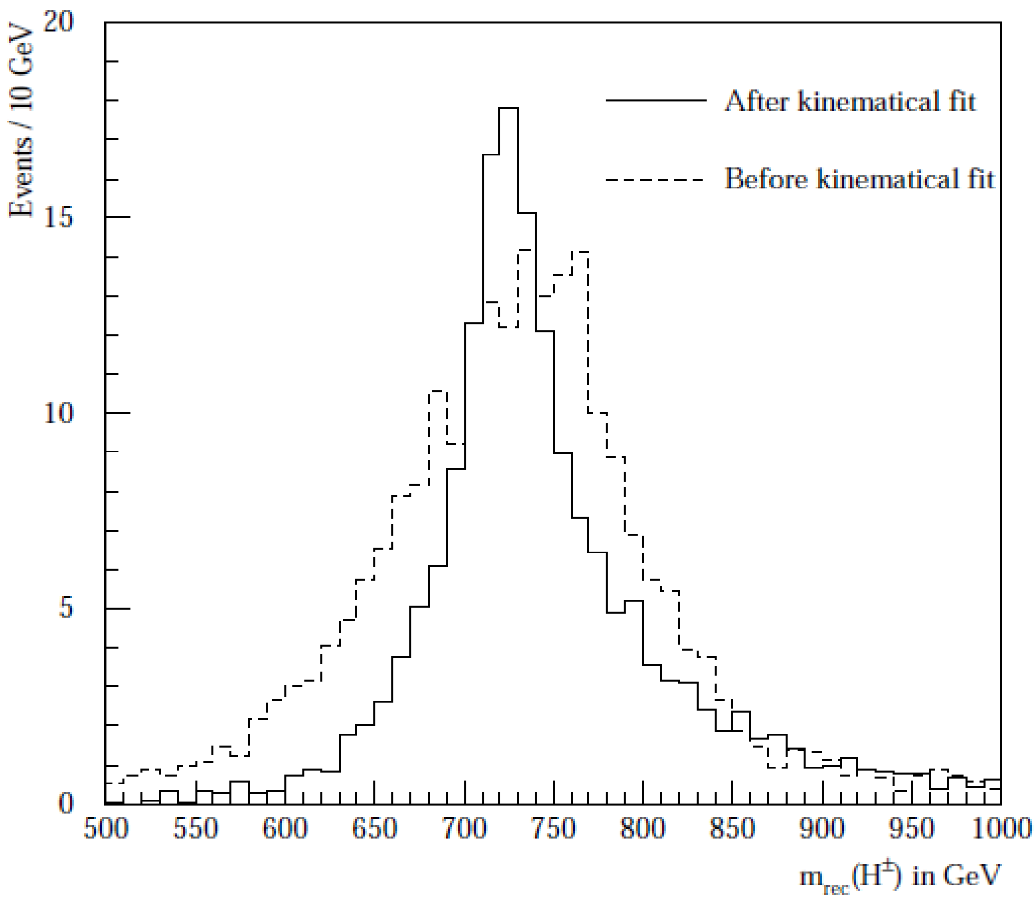
M_{H+} = 300 GeV
E_{cm} = 800 GeV
Final states:
tbtb and WhWh → Wwbbbb

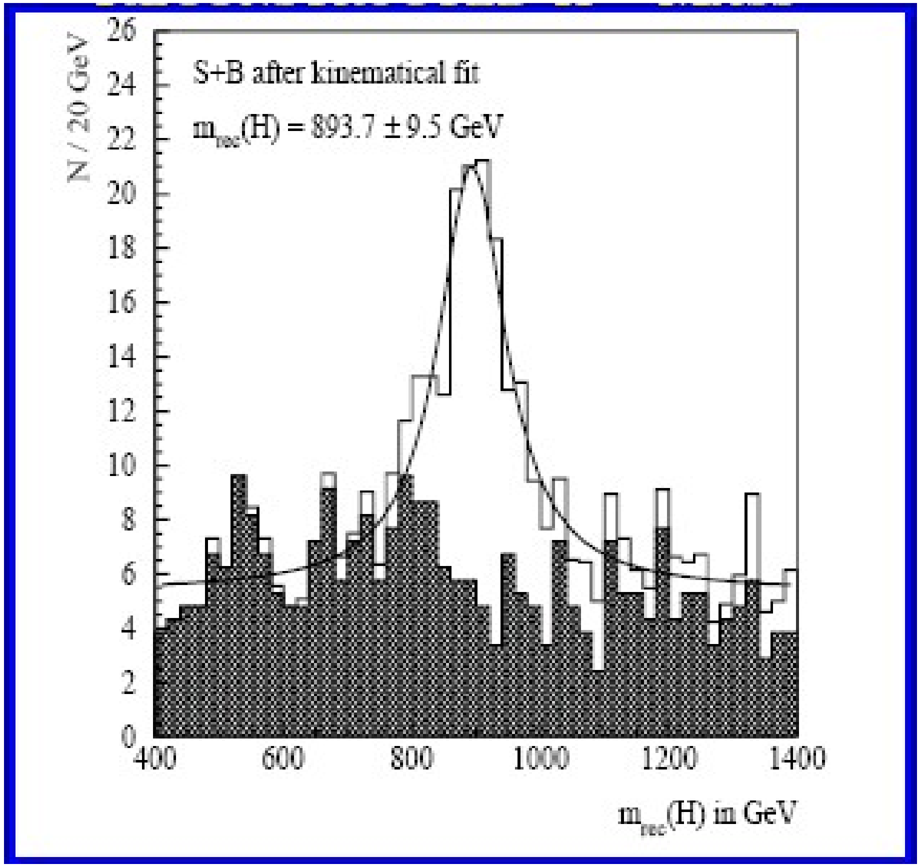
σM = 10 GeV
δM = 1 GeV
δσ x BR/σ x BR= 0.15



MB, Kiiskinen, Poyhonen,
LC-PHSM-2001-041

Charged Higgs Reconstruction
Mass Determination: 700-900 GeV





Coniavitis, Ferrari
PRD75 (2007)

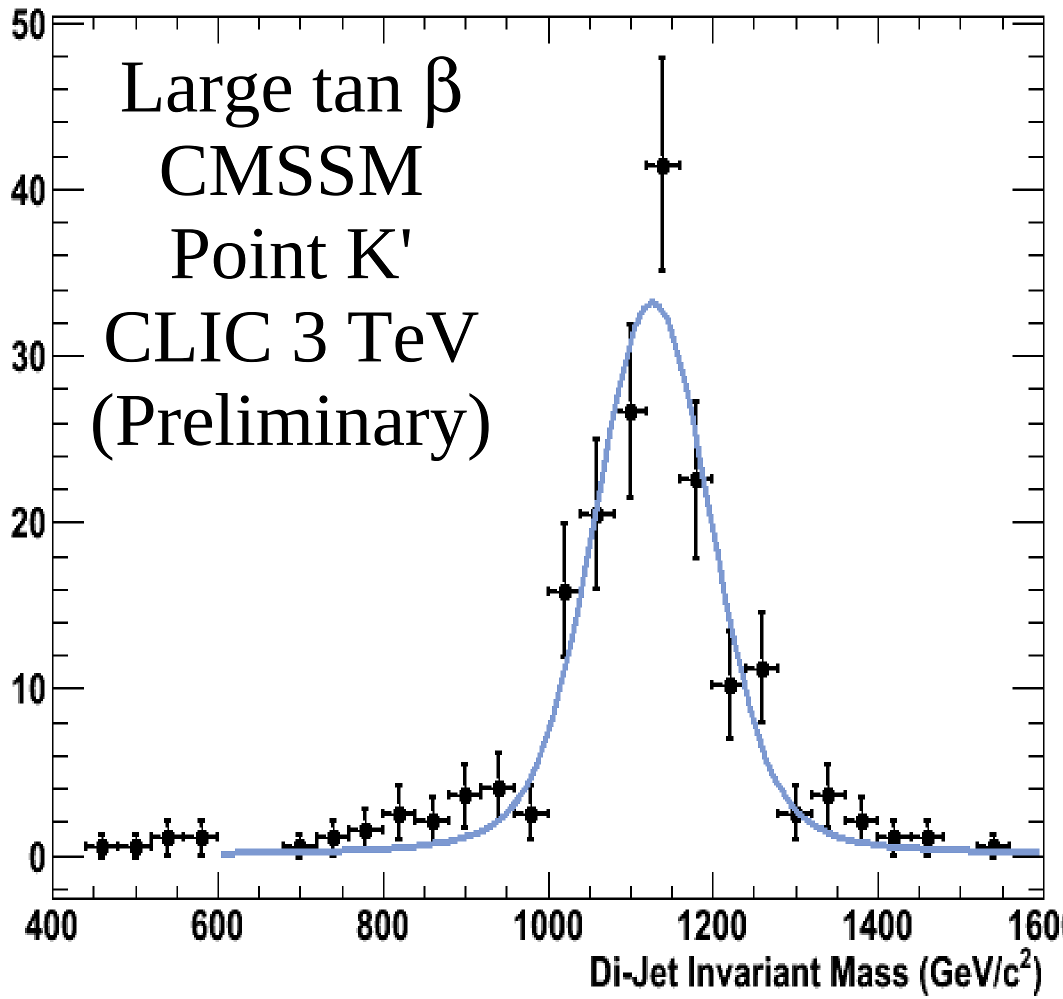
Ferrari, CERN2004-005

Charged Higgs Reconstruction Mass Determination: 1140 GeV

First full simulation and reconstruction analysis taking into account SM and machine induced backgrounds with explicit topological b-tagging of high-energy jets performed for 3 TeV CLIC parameters..

M_{H+} = 1136 GeV
E_{cm} = 3000 GeV
Final states:
tbtb

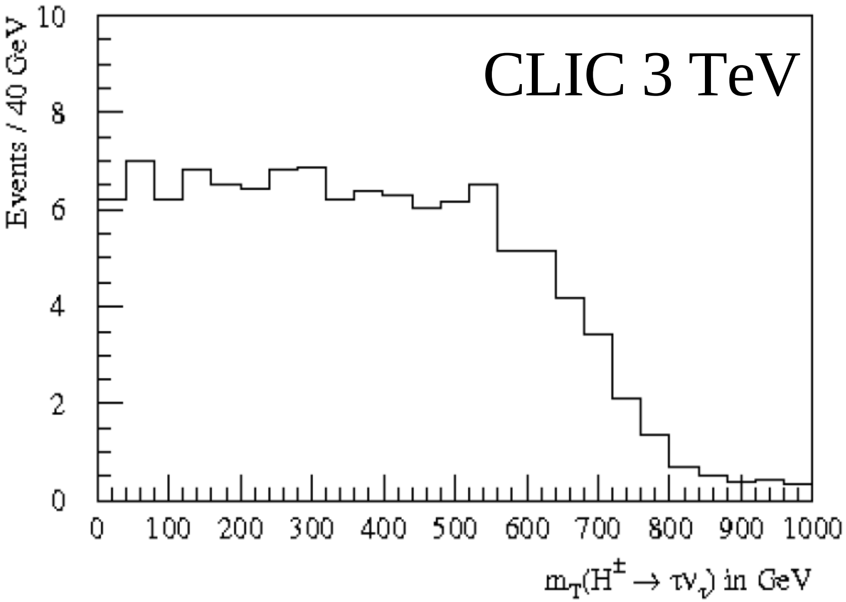
σM ~ 50 GeV
δM = 5.5 GeV
$\delta\sigma$ x BR/σ x BR ~ 0.10



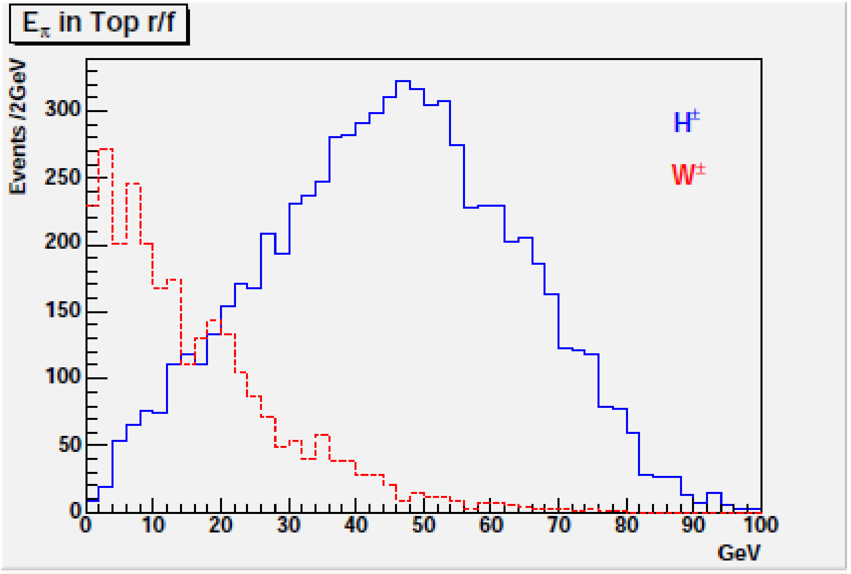
Charged Higgs Reconstruction
Mass Determination: the τν channel

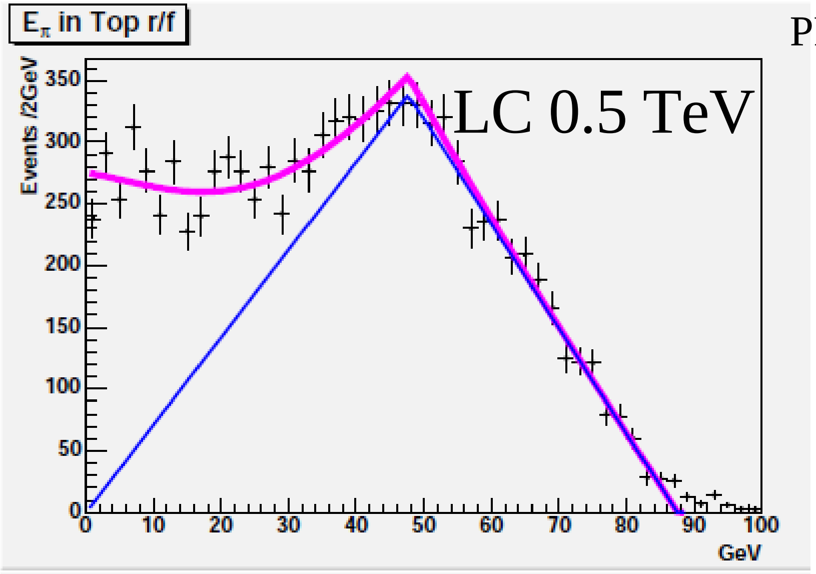
M_{H+} = 130-146 GeV
E_{cm} = 500 GeV
Final states: τν

δM = 0.5-0.9 GeV



Coniavitis, Ferrari
PRD75 (2007)





Boos et al.,
arXiv:hep-ph/0507100

Charged Higgs Reconstruction
Summary of Mass Determinations

Mass (GeV)	Ecm (TeV)	L (ab^{-1})	Selection Efficiency	$\delta M/M$
145	0.5	0.5	-	0.006
200	0.8	0.5	0.02	0.002
300	0.8	0.5	0.04	0.004
702	3.0	3.0	0.02	0.007
1136	3.0	3.0	0.05	0.005

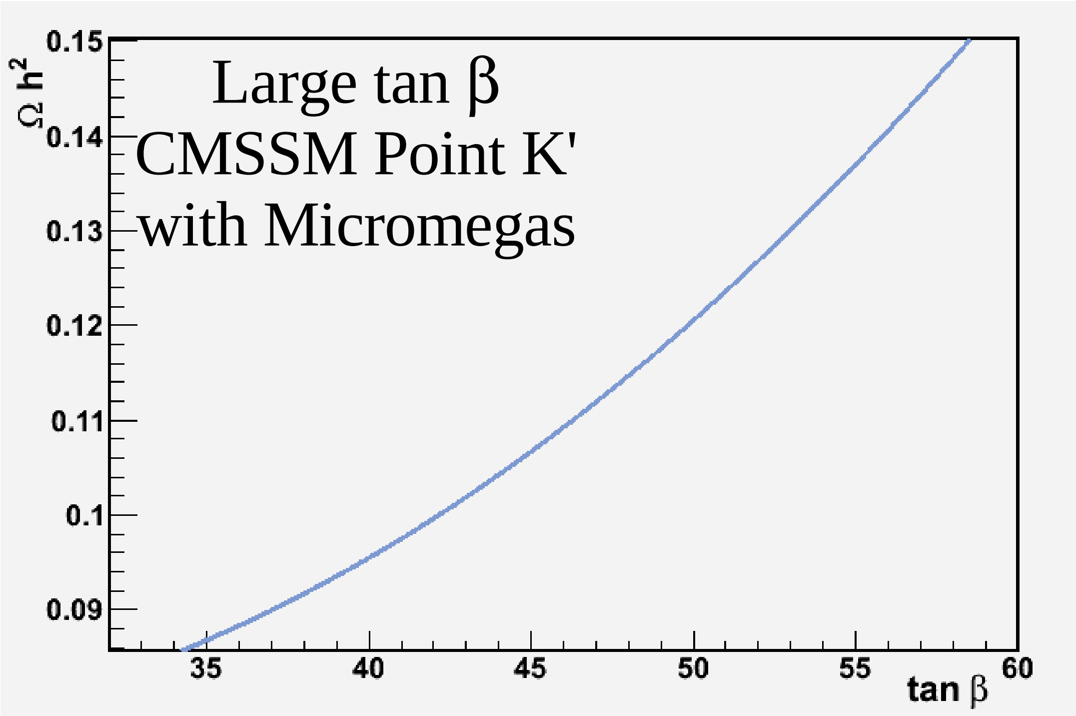
Charged Higgs Properties:

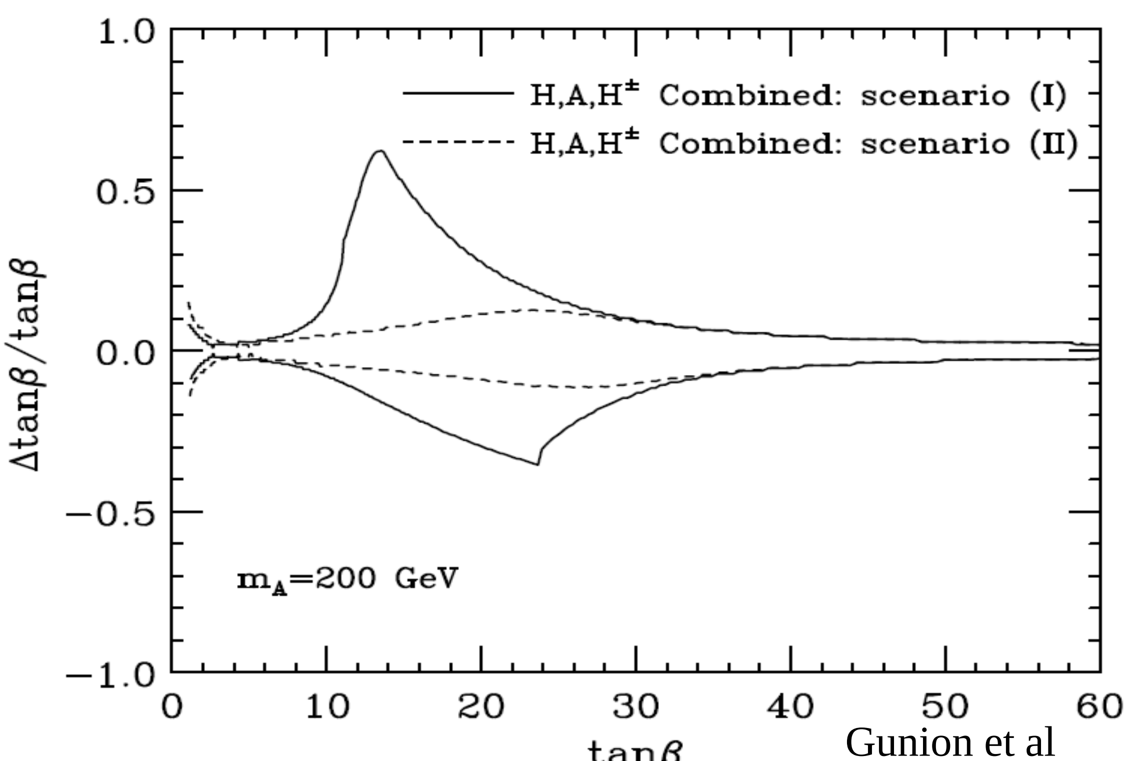
Decay Branching Fractions and tan β

Determination of tan b will be essential to constrain phenomenology and relate the extended Higgs sector to cosmology through dark matter;

Possible to constrain tan β by determining H^0, A^0, H^+ widths and decay branching ratios $H^0A^0 \rightarrow bb, \tau^+\tau^-, H^+ \rightarrow tb, \tau\nu$

Precision of a LC expected to provide essential input.

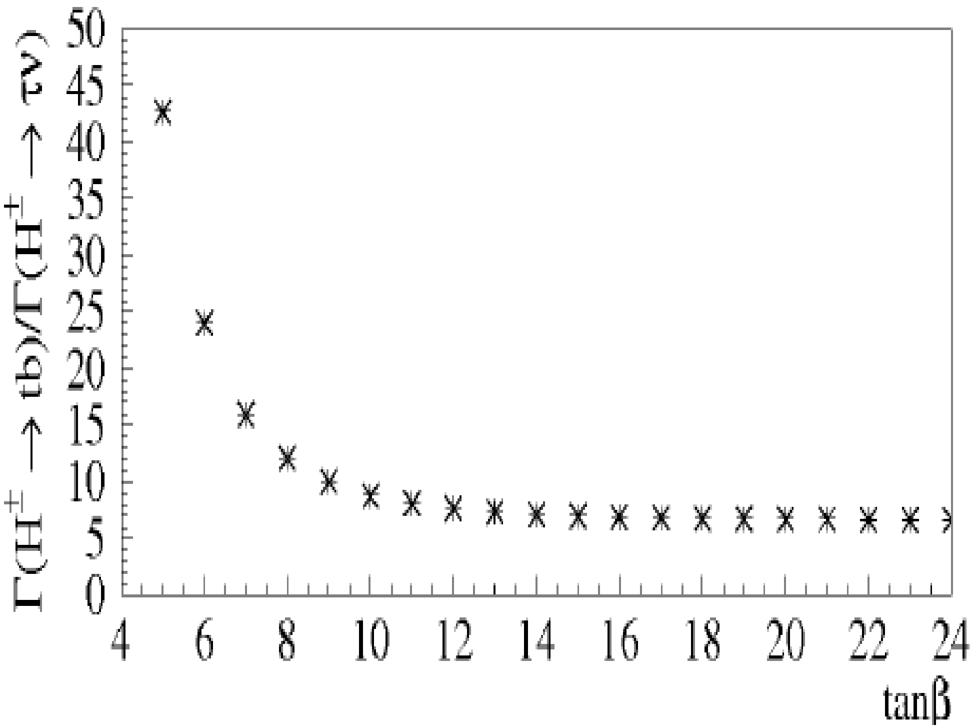


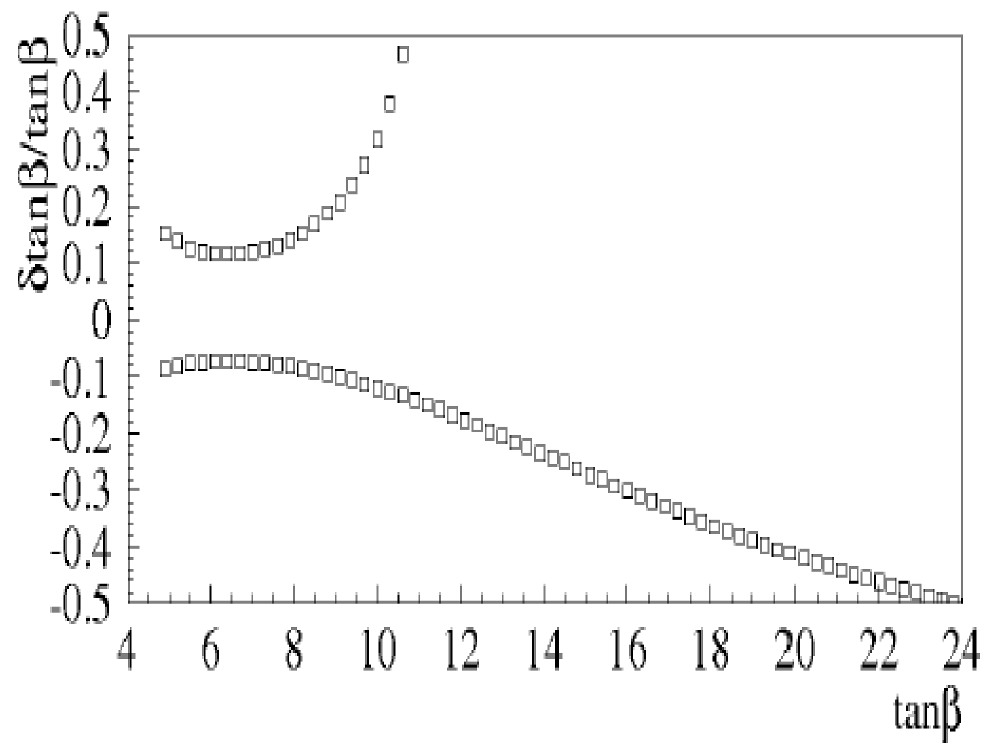


Gunion et al
PLB 565 (2003)

Charged Higgs Properties:
Decay Branching Fractions and tan β

$$\frac{\delta(\sigma \times BR)}{\sigma(e^+e^- \to H^+H^-) \times BR(H^+ \to t\bar{b})} = 0.05$$



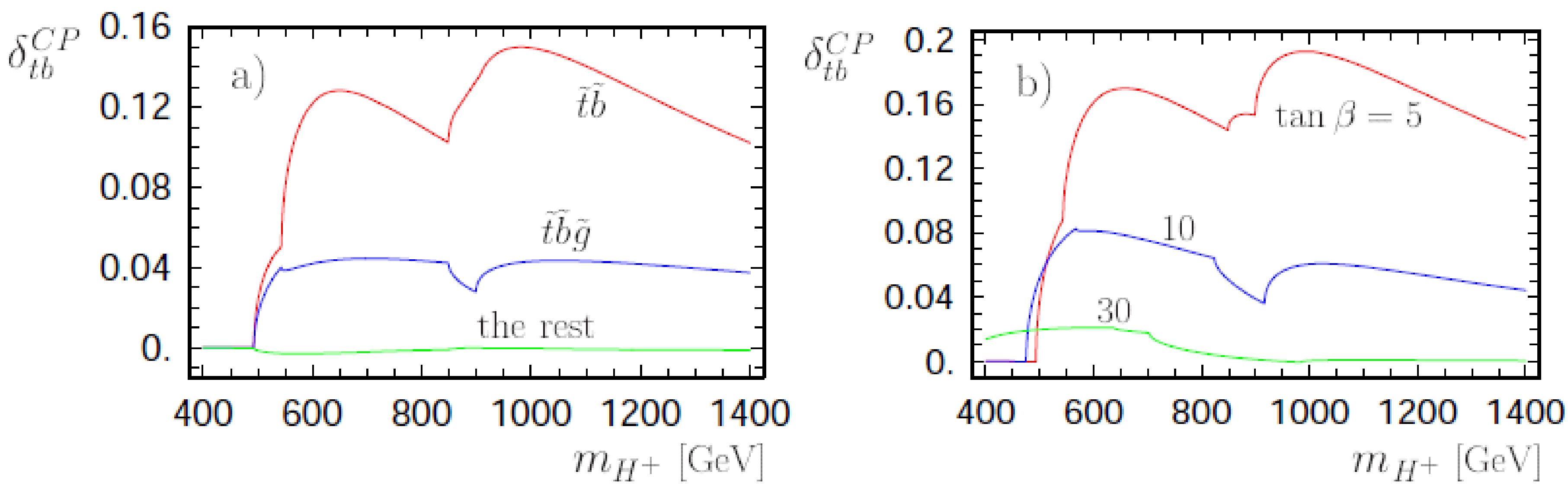


Coniavitis, Ferrari
PRD75 (2007)

Charged Higgs Properties: CP Violation in H Decays

CP violation in the New Physics sector can manifest in decay rate asymmetries for H^+ in MSSM mostly due to squark loops in $H+ \rightarrow tb$ decays:

$$\delta_f^{CP} = \frac{\Gamma(H^+ \rightarrow f) - \Gamma(H^- \rightarrow \bar{f})}{\Gamma(H^+ \rightarrow f) + \Gamma(H^- \rightarrow \bar{f})}$$



Asymmetry can be measured with quark-antiquark tagging, need to use hadronic top decays and adopt vertex charge algorithm for b and c jets.

With typical cross sections ~ 1fb and few ab^{-1} of integrated luminosity, sensitivity to < 10% should be feasibile.

Christova et al, NP B639 (2002), JHEP 0702 (2007)

Conclusions

A linear collider of sufficiently high energy and luminosity can provide good accuracy in the determination of mass, production cross section and decay branching fractions for charged Higgs pair production virtually up to the kinematic limit;

Accuracy will be essential for interpretation of the role of extended Higgs sector in relation to relic dark matter;

Study of heavy Higgs sector one of the important drivers towards high energy and high luminosity performance, essential LHC input to define machine requirements.

Significant activity in simulation studies for ILC at 1 TeV and CLIC at 3 TeV will help clarifying soon requirements and physics potential based on realistic simulation and reconstruction including accelerator effects.