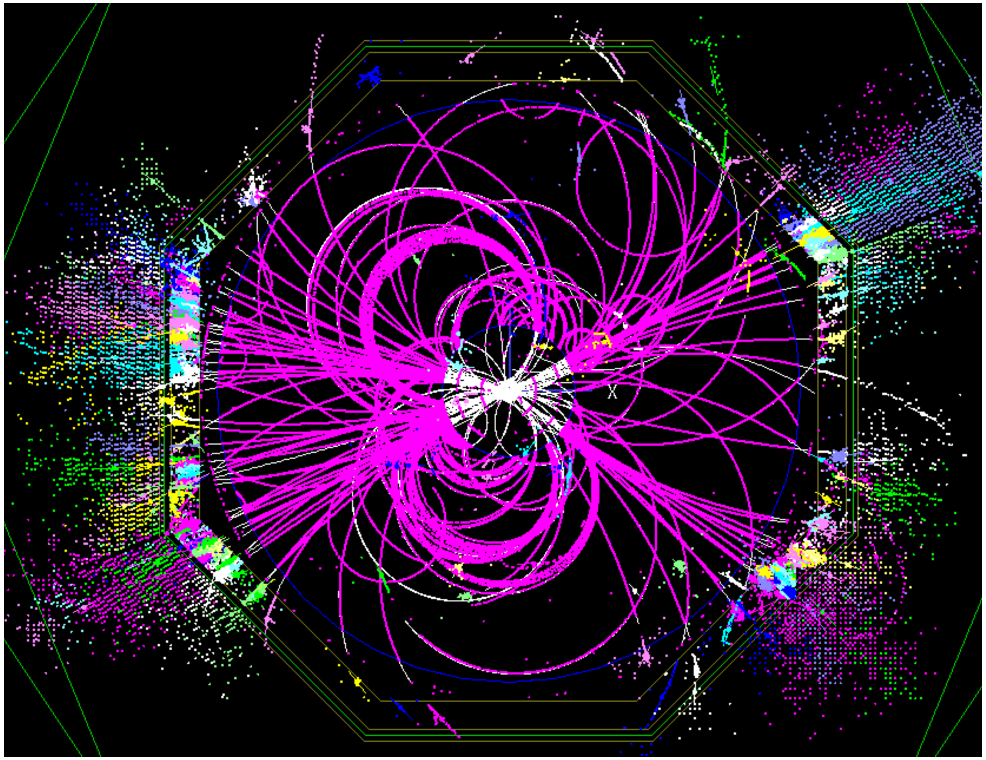
A Study of $e^+e^- \to H^0A^0 \to bbbb$ at 3 TeV at CLIC

Marco Battaglia

UCSC,
Lawrence Berkeley National Laboratory
and CERN

(with contributions by P. Ferrari)



IWLC2010
Geneva, 18-22 October 2010

Heavy Neutral Higgs Bosons in DM-motivated SUSY

Consider two benchmark scenarios with $M_A \sim 1$ TeV to study H and A mass reconstruction at 3 TeV CLIC:

Scenario 1) (S Martin, CLIC Study Group)

MSSM model
with non-unified gaugino masses

M_1=780 GeV, M_2=940 GeV, M_3=540 GeV
m_0 = 303 GeV, A_0 = -750 GeV, tan β = 24, $\mu>0$

M_A = 902.6 GeV M_H = 902.4 GeV

Scenario 2) (Point K' of MB et al, Eur. Phys. J. C33 (2004))

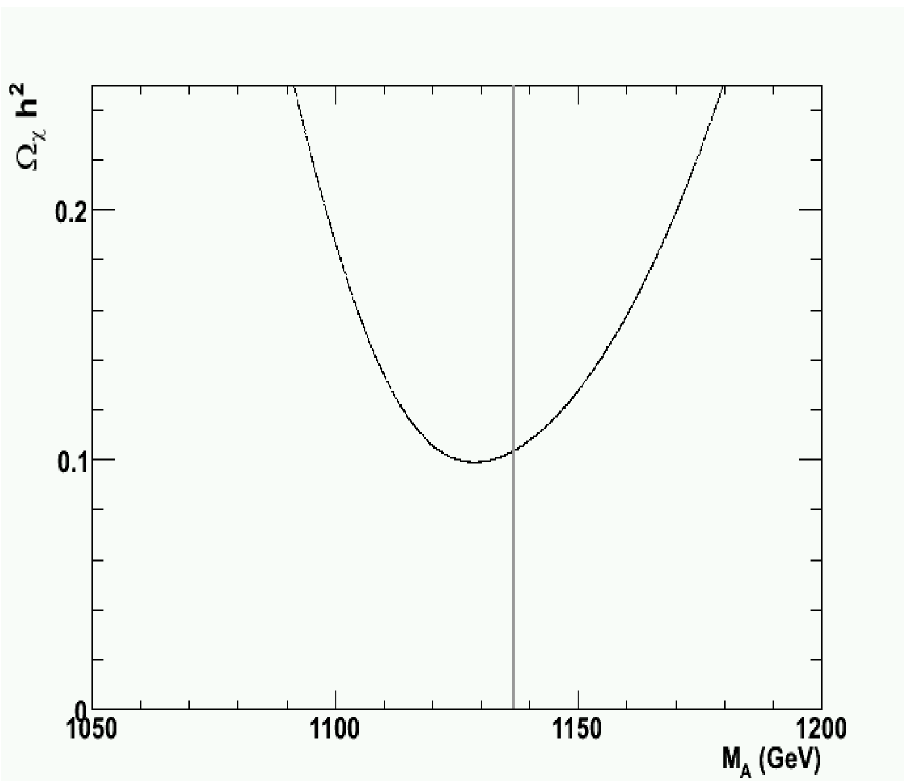
cMSSM model

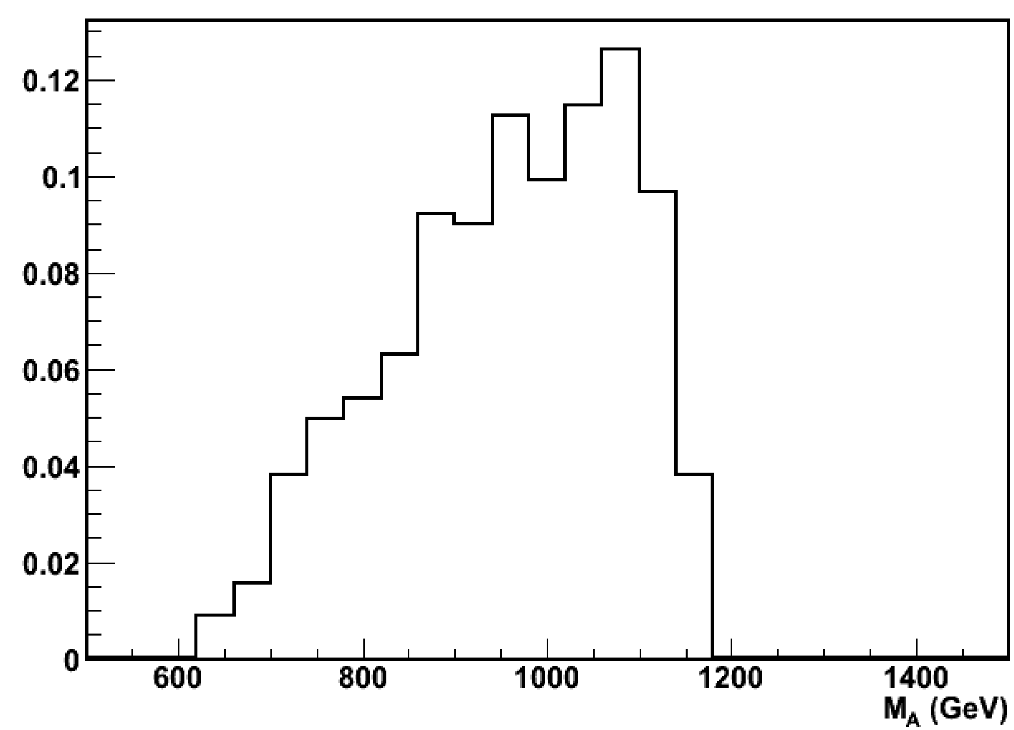
m1/2=1300 GeV, m_0 = 1001 GeV,
A_0 = 0, tan β = 46, $\mu<0$

M_A = 1139.2 GeV M_H = 1143.8 GeV

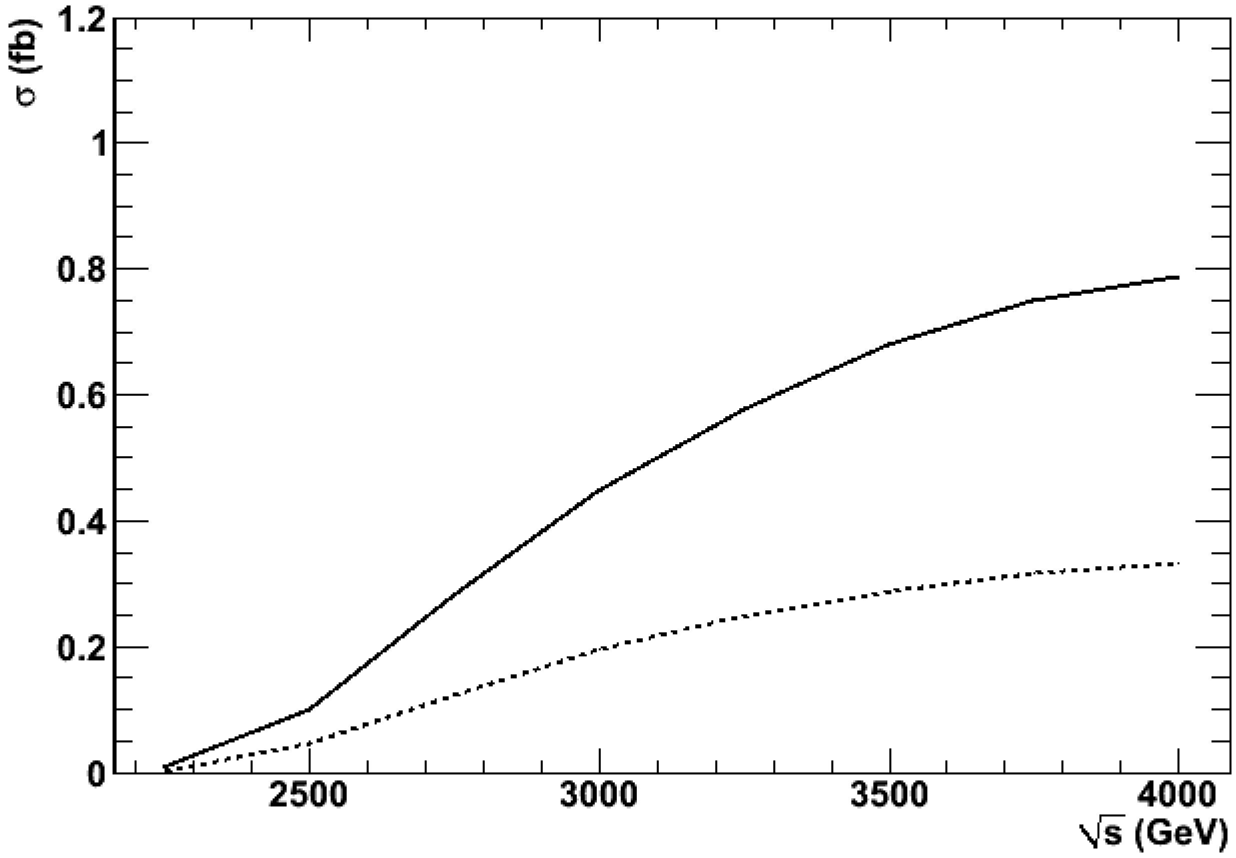
Heavy Neutral Higgs Bosons in DM-motivated SUSY

Study M_A performing scans in M_1, M_2, M_3, ($m_{1/2}$), m_0, A_0, tan β, sign μ around the parameters of the two benchmark scenarios and retaining solutions compatible with WMAP 7-years $\Omega_{CDM}h^2$, BR($b \rightarrow s\gamma$) with MicroMEGAS 2.2 + SuSPECT 2:





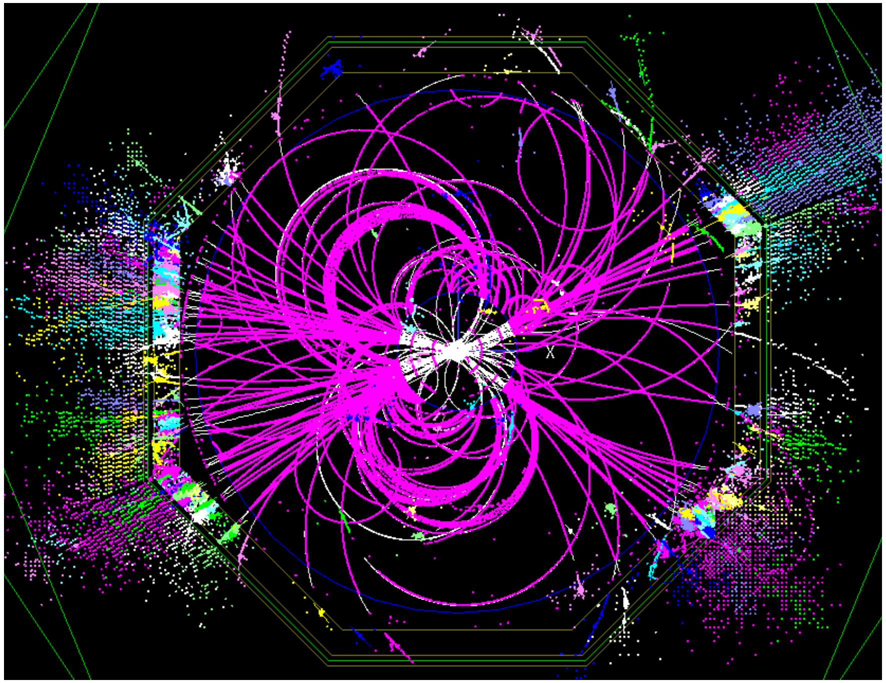
Production Cross Section

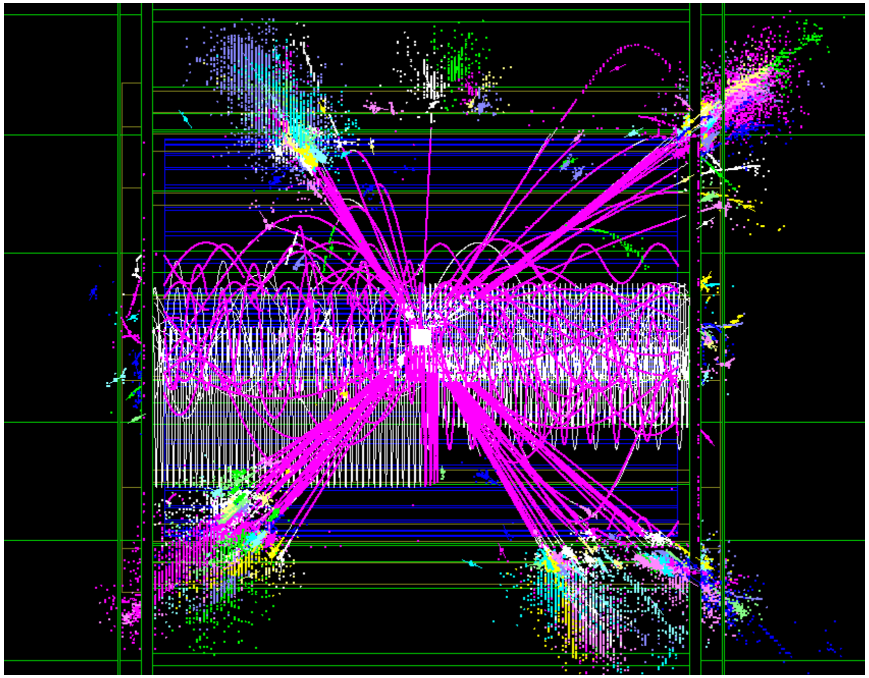


Event Generation,
Simulation and Reconstruction

Signal generation with PYTHIA 6.215+ISASUGRA 7.67,
Backgrounds with PYTHIA+ISASUGRA and CompHEP+PYTHIA;

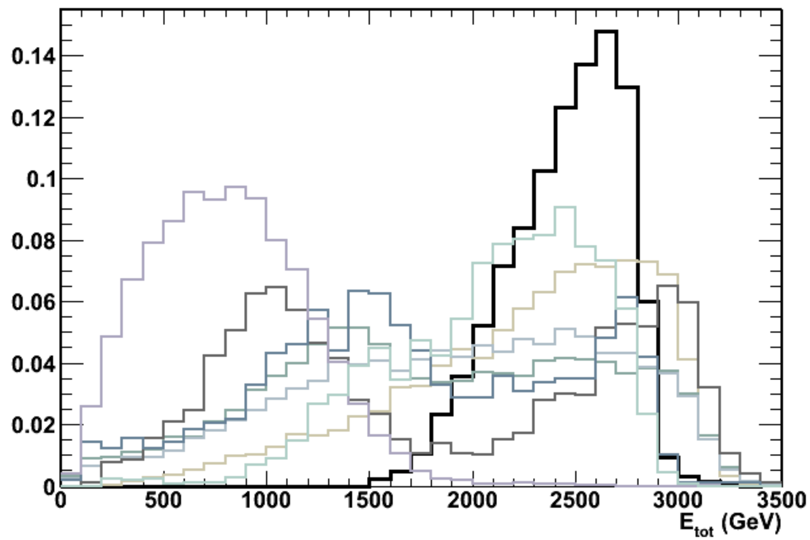
Full simulation with MOKKA using CLIC_ILD detector model;
reconstruction using Marlin v01-09 + port to Marlin of DELPHI PUFITC kinematic fitter, FASTJet jet clustering and b-tagging based on ZVTOP vars;

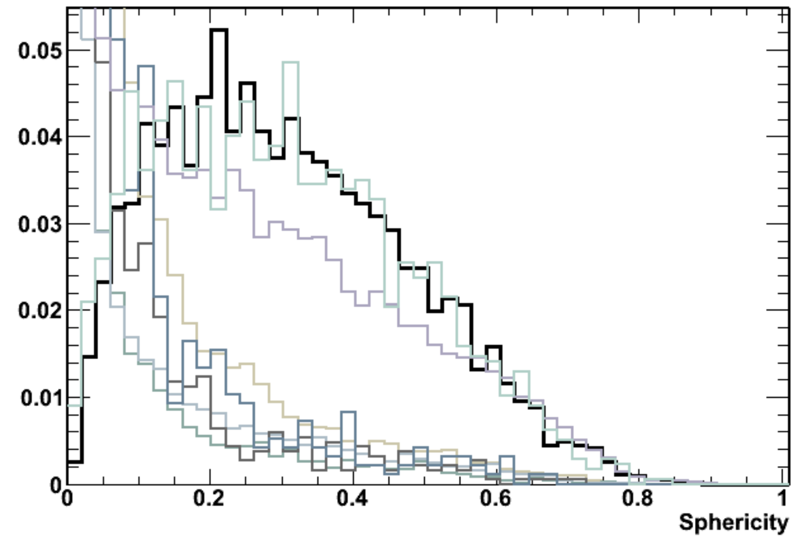


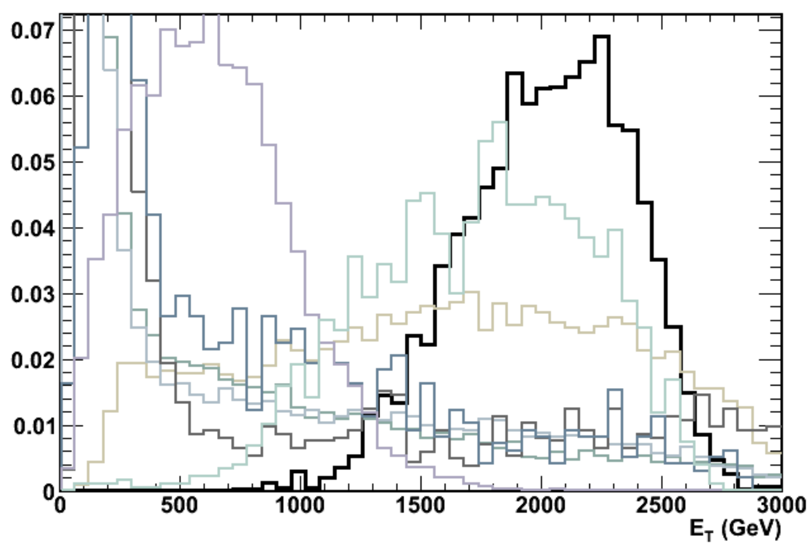


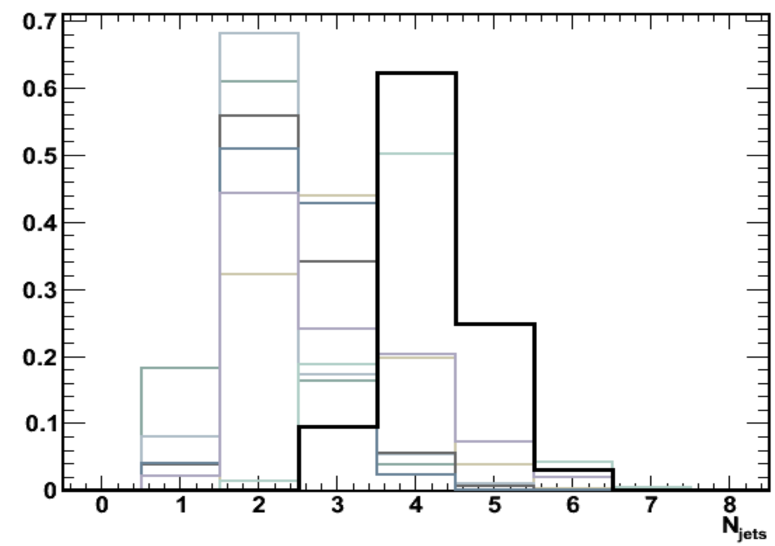
Signal Event Selection

Pair production of heavy objects decaying into 4 b jets gives signal very distinctive signature ensuring good S/B after selection with moderate efficiency







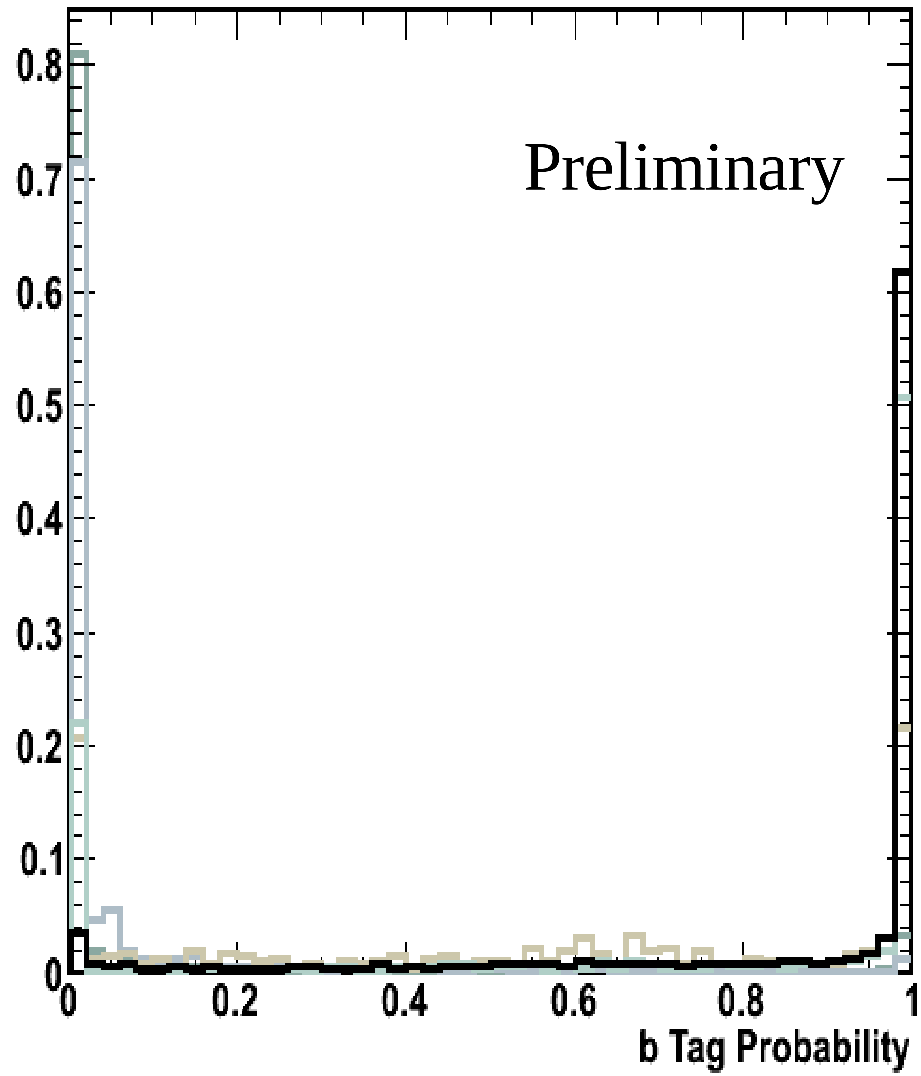


Signal Event Selection:
b Tagging

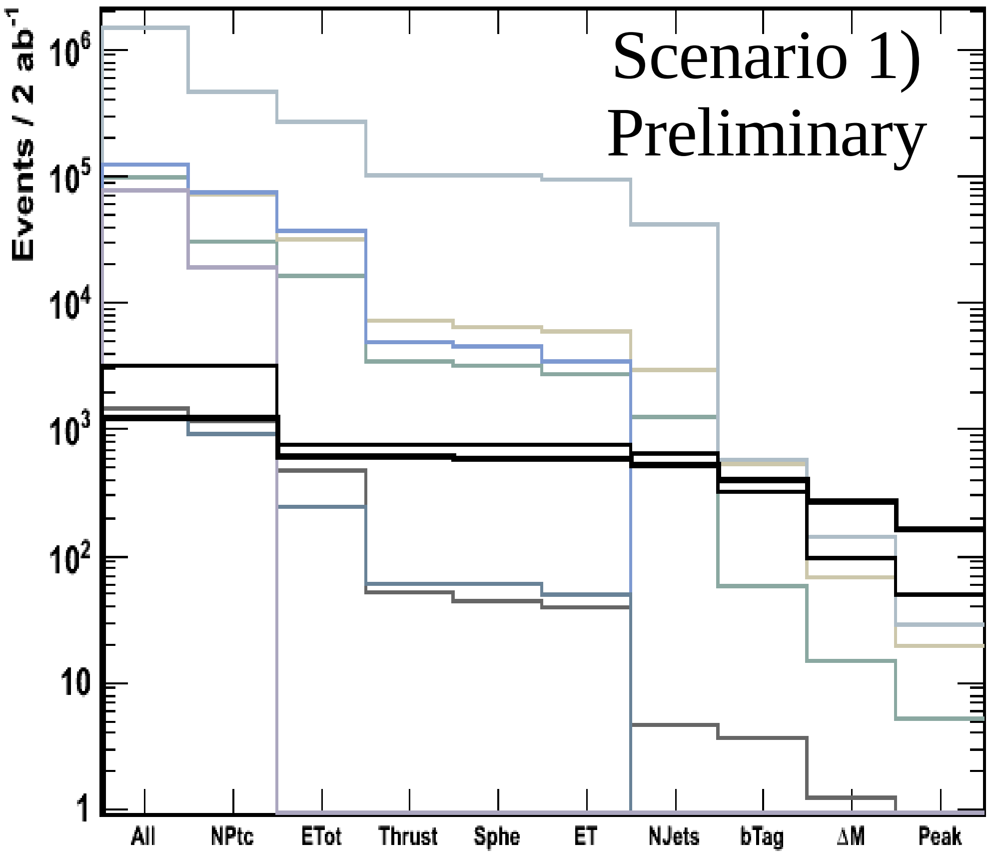
b-tagging based on topological vertex reconstruction with ZVTOP-ZVRES in LCFI package;

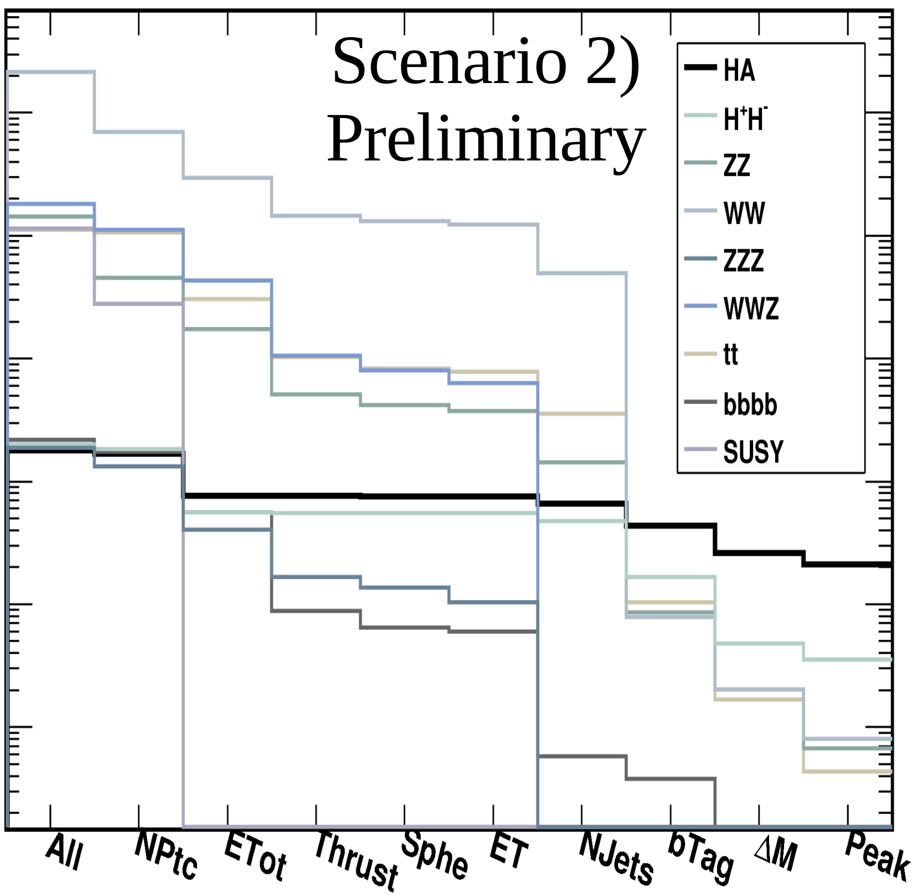
TeV b-jets requires some special care due to long decay length of B hadrons (30% flying past first VXD layer), optimise for high efficiency by performing secondary particle search in jets with no reco secondary vertices;

B-tag probability computed per jet using boosted decision tree strategy in TMVA package and then combined for di-jets and event.



Signal Event Selection

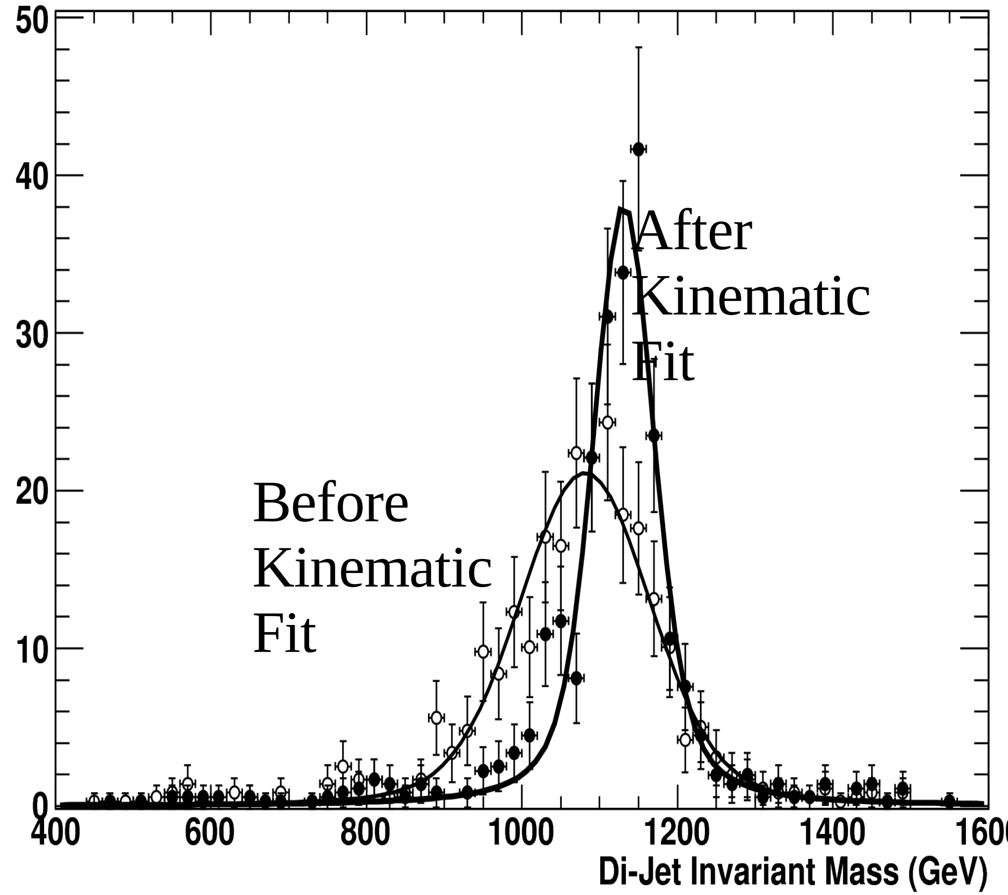




Higgs Mass Reconstruction: Kinematic Fit

Apply kinematic fit, accomodating beamstrahlung, to improve di-jet mass resolution (finite detector resolution, particle flow confusion, jet clustering confusion and s.l. B decays (+17% $\delta E_{jet}/E_{jet}$)) ;

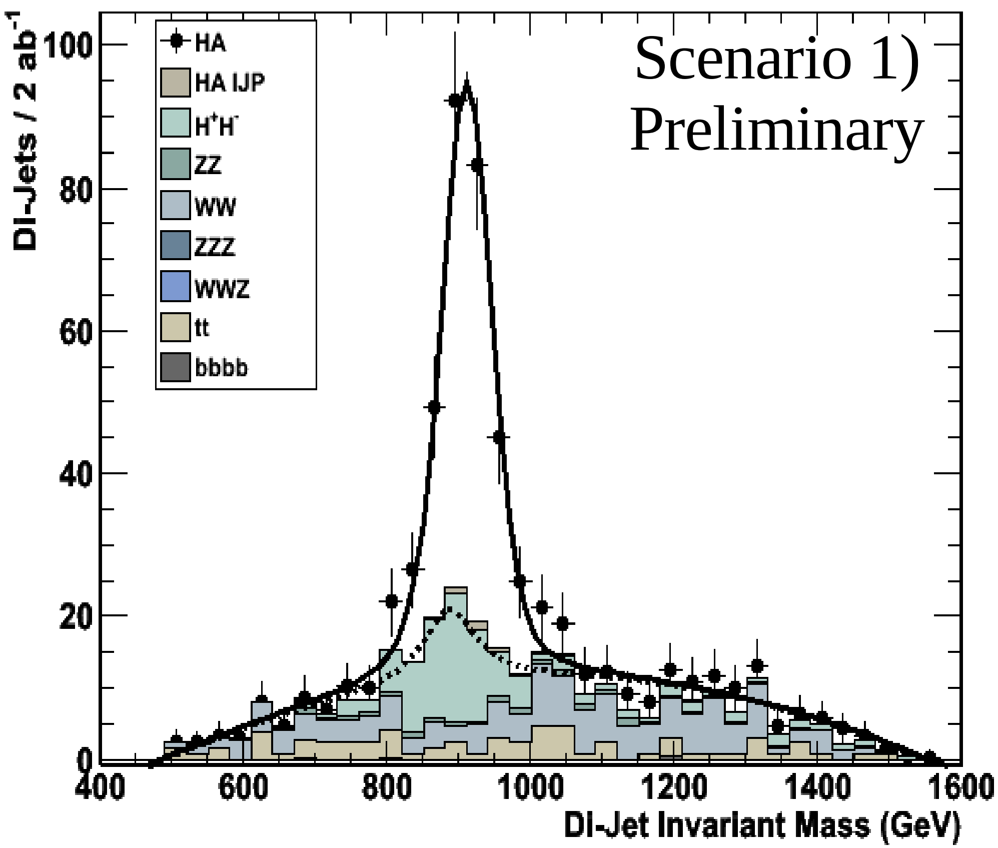
Model mass as convolution of BW (natural width) and Gaussian (detector resolution), after kinematic fit Gaussian resolution improves by ~35% and accuracy on fitted mass by ~30%.



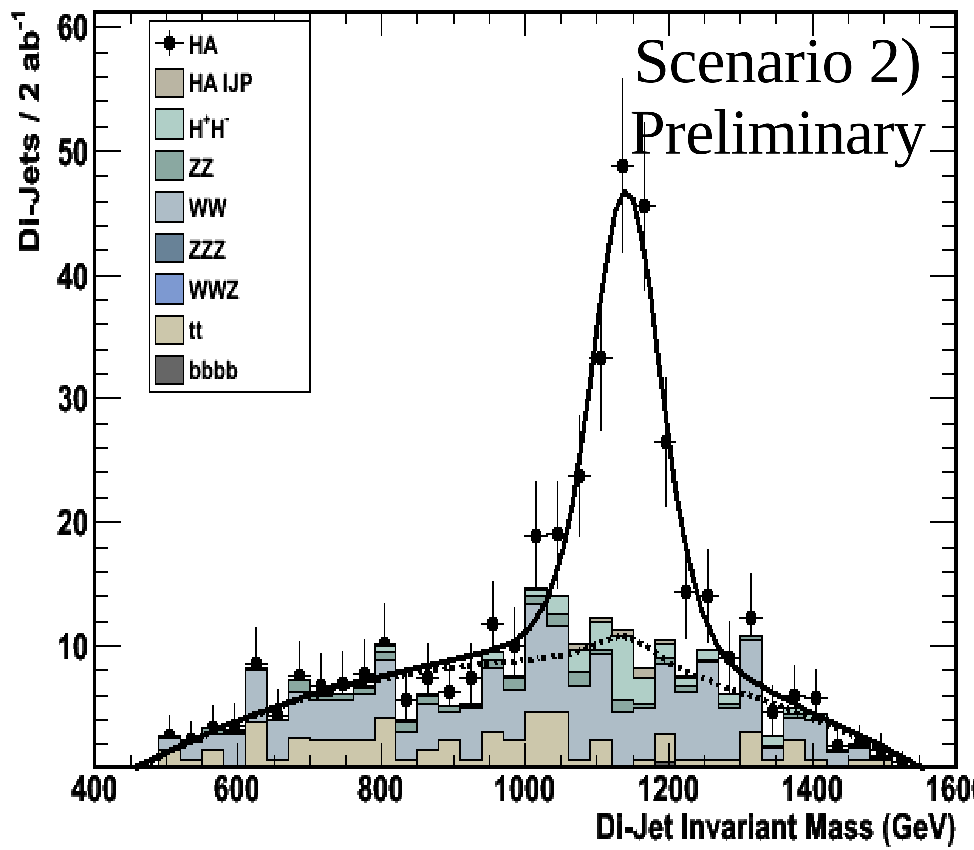
Scenario 1)
2-par Fit to Signal Only
M_A = (909.2+/-2.9 (stat)) GeV

Scenario 2)
2-par Fit to Signal Only
M_A = (1142.1+/-4.3 (stat)) GeV

Higgs Mass Reconstruction
(3 TeV, 2 ab^{-1})



7-par Fit (M_A, Γ, N_{sig}, Bkg shape)
M_A = (906.2+/-3.3 (stat)) GeV



7-par Fit
M_A = (1141.0+/-6.0 (stat)) GeV

Higgs Mass Reconstruction
$\gamma\gamma \rightarrow$ hadron Background

Standard approach to force event into 4 jets fails in presence of gg → hadron background since background particles are added to b jet particles degarding the energy and angular resolution;

More appropriate to use a cone-like algorithm selecting only four most energetic jets for Higgs reconstruction;

Adopted anti-kt algorithm in cylindrical coordinates in FastJet package, now implemented as Marlin processor;

Find R values for which event has 4 jets each with energy exceeding 150 GeV, use these jet for Higgs reconstruction and disregard lower energy jets mostly Containing background particles;

Higgs Mass Reconstruction
$\gamma\gamma \rightarrow$ hadron Background

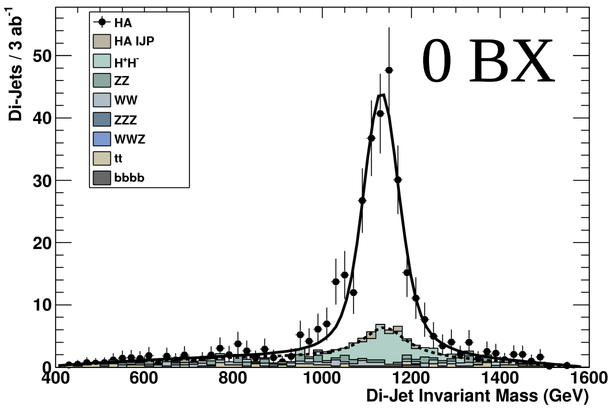
CLIC beams and bunch structure make impact of $\gamma\gamma \rightarrow$ hadron background on physics reconstruction non negligeable;

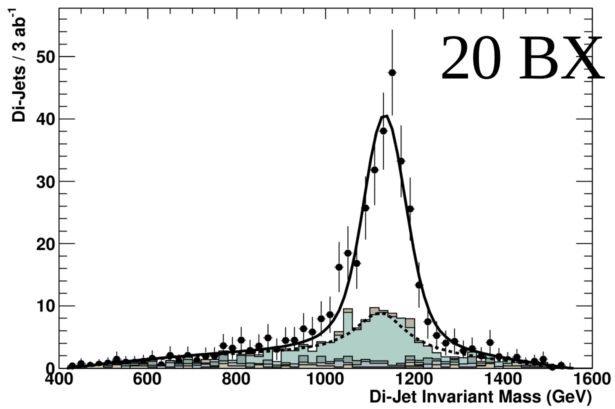
Use of a semi-inclusive jet clustering allows us to mitigate the impact of this background on the width of the di-jet invariant mass.

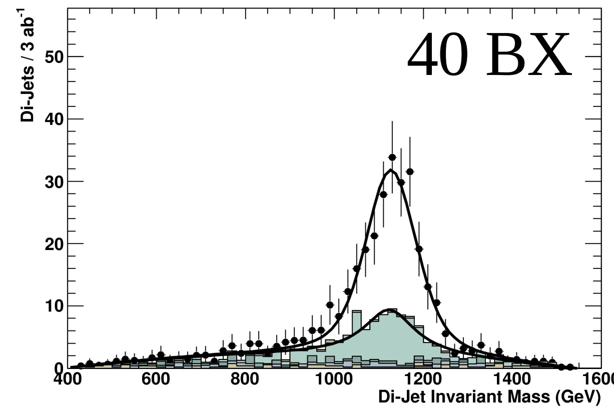
Kinematic fit also helps in reducing the contribution of these hadrons to the jet energy.

Nb of BX of overlayed $\gamma\gamma$	Kinematic Fit $\sigma_{M_{jj}}$ (GeV)	
	4-jet	semi-incl.
0	27.7$\pm$ 4.8	29.8$\pm$4.7
5	32.0$\pm$ 5.0	30.1$\pm$5.0
20	54.0$\pm$ 8.3	34.5$\pm$6.7
40	72.2$\pm$ 7.4	45.4$\pm$5.6
60	78.6$\pm$10.9	52.5$\pm$8.2

Higgs Mass Reconstruction
$\gamma\gamma \rightarrow$ hadron Background







Nb of overlayed BXs	4-jet $\Delta\sigma_{stat}/\sigma_{sta}$	semi-incl $\Delta\sigma_{stat}/\sigma_{stat}$
0	0	0
5	+0.15	+0.10
20	+1.10	+0.60
40	+1.49	+1.10
60	+1.93	+1.53

Conclusions

Mass (and width) determination of SUSY heavy Higgs bosons an important part of the possible physics program of a multi-TeV collider;

H0A0 → bbbb represent a compelling benchmark for detector studies with energetic jets, highly efficient b tagging, possibility of constraints to mitigate beamstrahlung effects and jet clustering robust against $\gamma\gamma \rightarrow$ hadron accelerator induced background.