Reconstructing SUSY Point K' at CLIC

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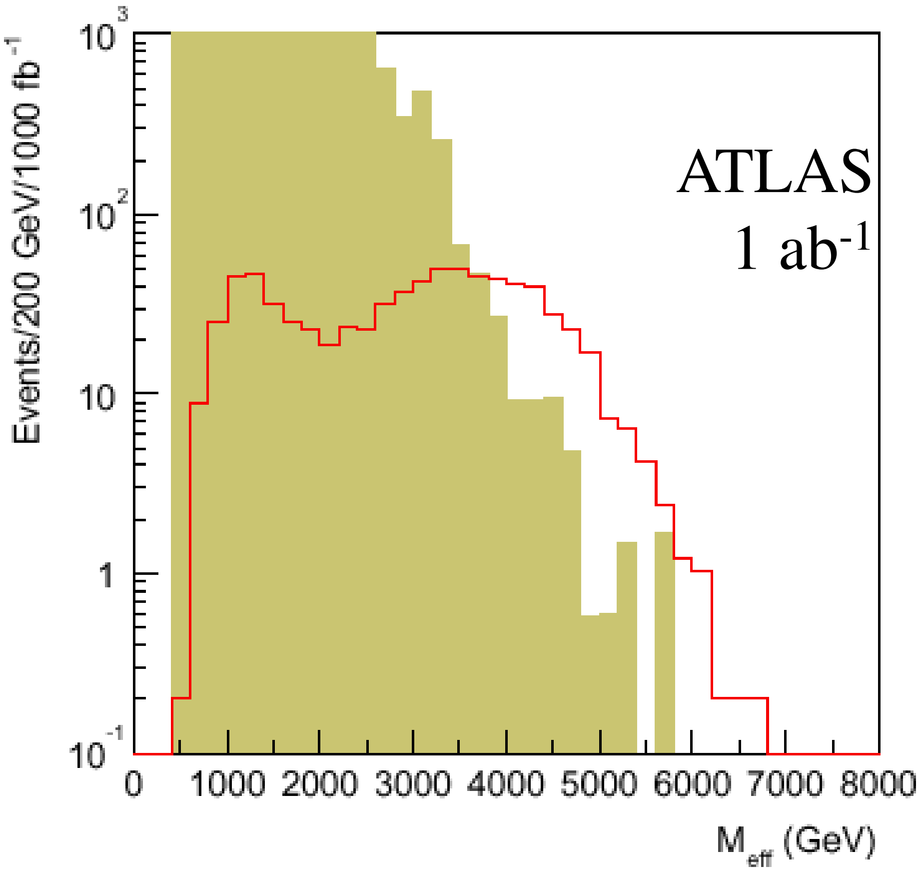
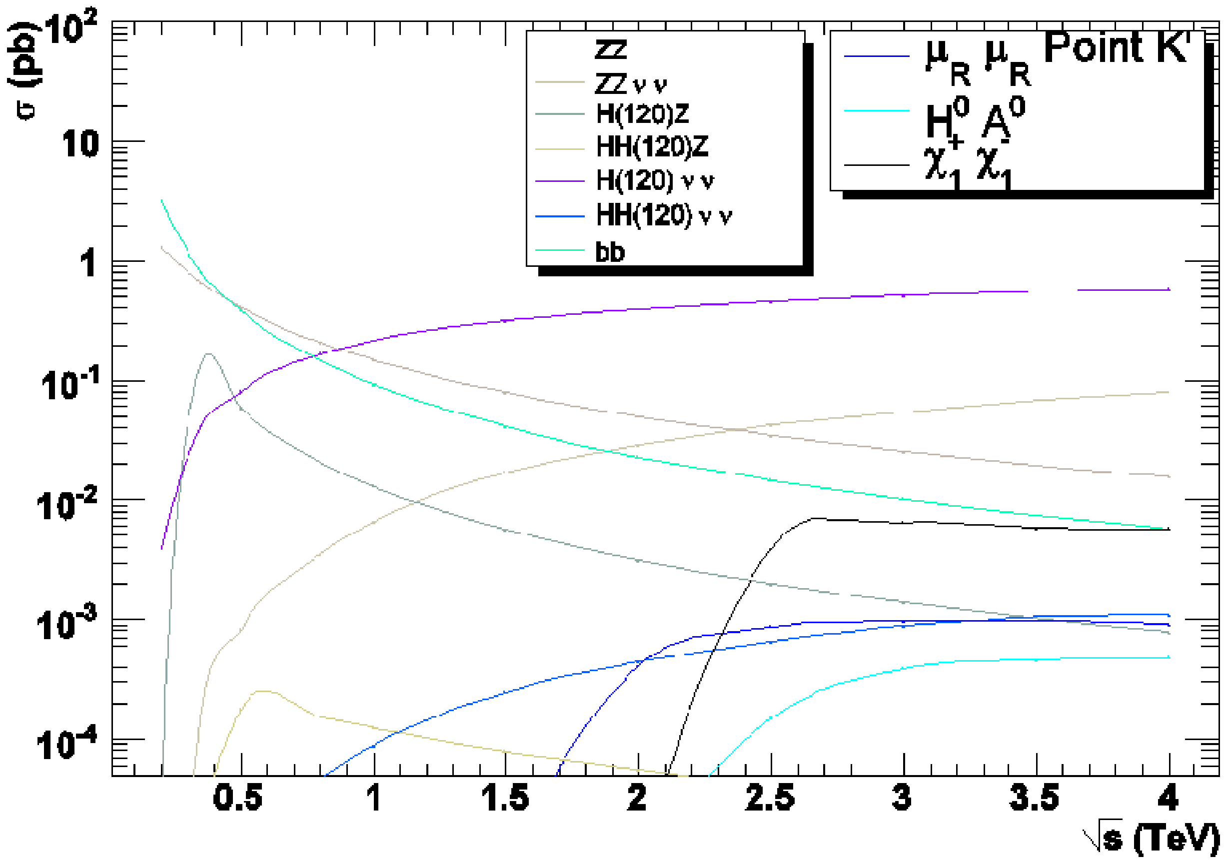
Point K' representative of a class of SUSY scenarios, compatible with current constraints (including CDM), characterised by high sparticle masses which are barely observable at the LHC while might be studied in enough details in multi-TeV e^+e^- collisions to connect them to DM.



Here first attempt to study processes accessible at 3 TeV to map CLIC potential, benchmark detector response but also also understand and overcome possible limitations and issues in event reconstruction algorithms.

Adopt CLIC-modified ILD detector in MOKKA+Marlin, assume CLIC08 Parameters, analyses include beamstralung (CALYPSO) and $\gamma\gamma \rightarrow$ hadrons background (HADES) (D Schulte)

Mass Spectrum and
e^+e^- Pair-Production Cross Sections

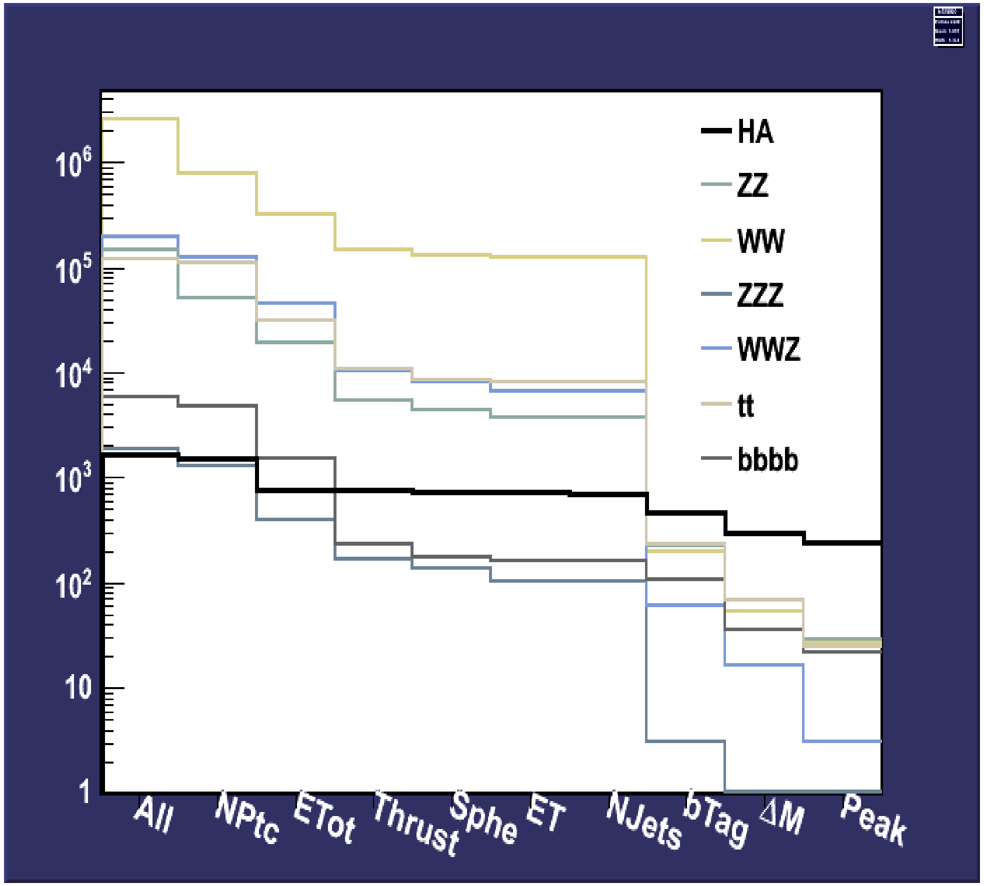


Model	K'
$m_{1/2}$	1300
m_0	1001
$\tan\beta$	46
sign(μ)	−
m_t	175
Masses	
$\|\mu(m_Z)\|$	1420
h	123
H	1161
A	1153
$H^\pm$	1164
χ	554
χ_2	1064
χ_3	1430
χ_4	1437
$\chi_1^\pm$	1064
$\chi_2^\pm$	1435
$\tilde{g}$	2820
e_L, μ_L	1324
e_R, μ_R	1109
ν_e, ν_μ	1315
τ_1	896
τ_2	1251
ν_τ	1239
u_L, c_L	2722
u_R, c_R	2627
d_L, s_L	2723
d_R, s_R	2615
t_1	2095
t_2	2366
b_1	2297
b_2	2349

$e^+e^- \rightarrow H^0A^0 \rightarrow bbbb$
Samples and Event Selection

Process	Generator	xSec (fb)	Events generated
H^0A^0	ISASUGRA +PYTHIA	0.3	2900
W^+W^-	PYTHIA	464.9	7600
Z^0Z^0	PYTHIA	26.9	7000
tt	PYTHIA	19.9	8200
WWZ	PYTHIA	32.8	1750
ZZZ	PYTHIA	0.32	1000
bbbb	CompHep +PYTHIA	0.41	2200
H^+H^-	ISASUGRA +PYTHIA		2000
Inclusive SUSY	ISASUGRA +PYTHIA		5000
$\gamma\gamma \rightarrow$had	HADES +PYTHIA	3.2 evts / BX	Ssgnal only

Simple Cut Analysis:
suppress SM bkg through event shape variables
b-tagging and ΔM, SUSY through missing E.



$e^+e^- \rightarrow H^0A^0 \rightarrow bbbb$

Di-Jet Mass Resolution

Parton energy resolution: w/o $\gamma\gamma$ bkg $Rms_{90}/E = 0.11$:
contribution from b s.l. decays (=0.07 for HA → qqqq) and jet clustering;
degrades to 0.15 for 20 BX and 0.18 for 40 BX.

<u>Constrained Kinematic Fit</u>

Adjust measured jet momenta p_M

$$\vec{p}_F = e^a \vec{p}_M + b\vec{p}_B + c\vec{p}_C$$

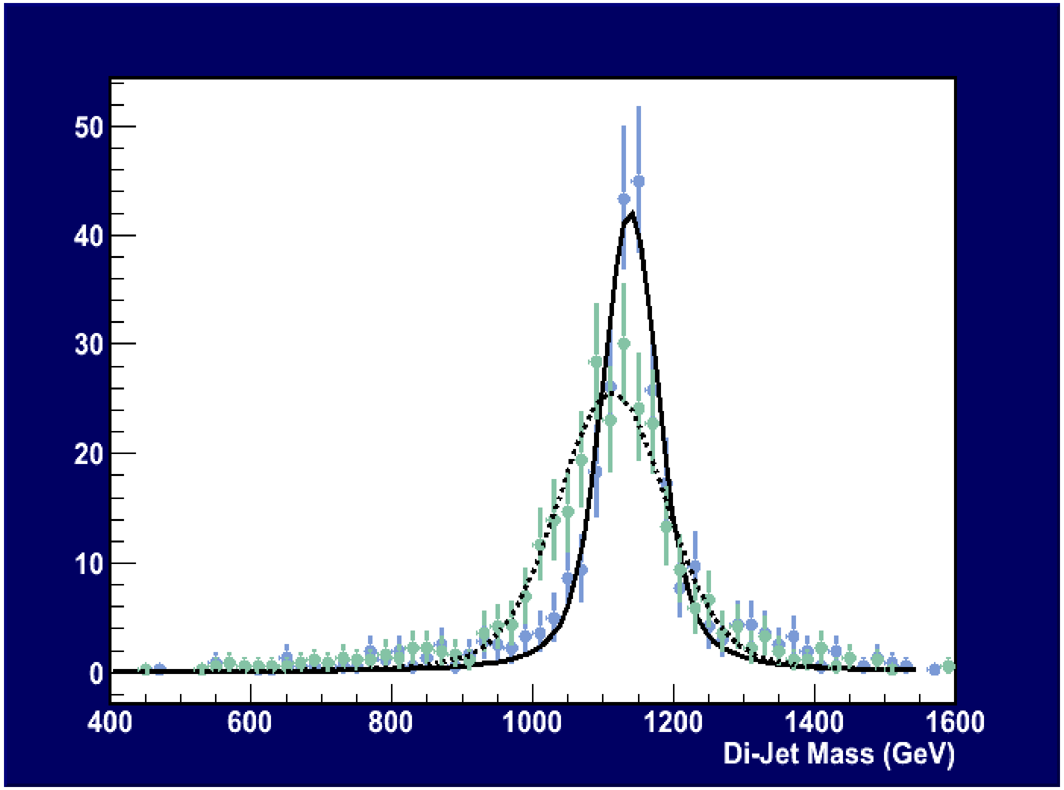
minimising the χ^2 given by

$$\Sigma_i \ (a_i - a_0)^2/\sigma_a^2 + b_i^2/\sigma_b^2 + c_i^2/\sigma_c^2$$

imposing the constraints

$$p_x = p_y = 0$$

$$E \pm |p_z| = \sqrt{s}$$



Improvement of di-jet inv. mass:
Gaussian resolution 68 GeV → 30 GeV

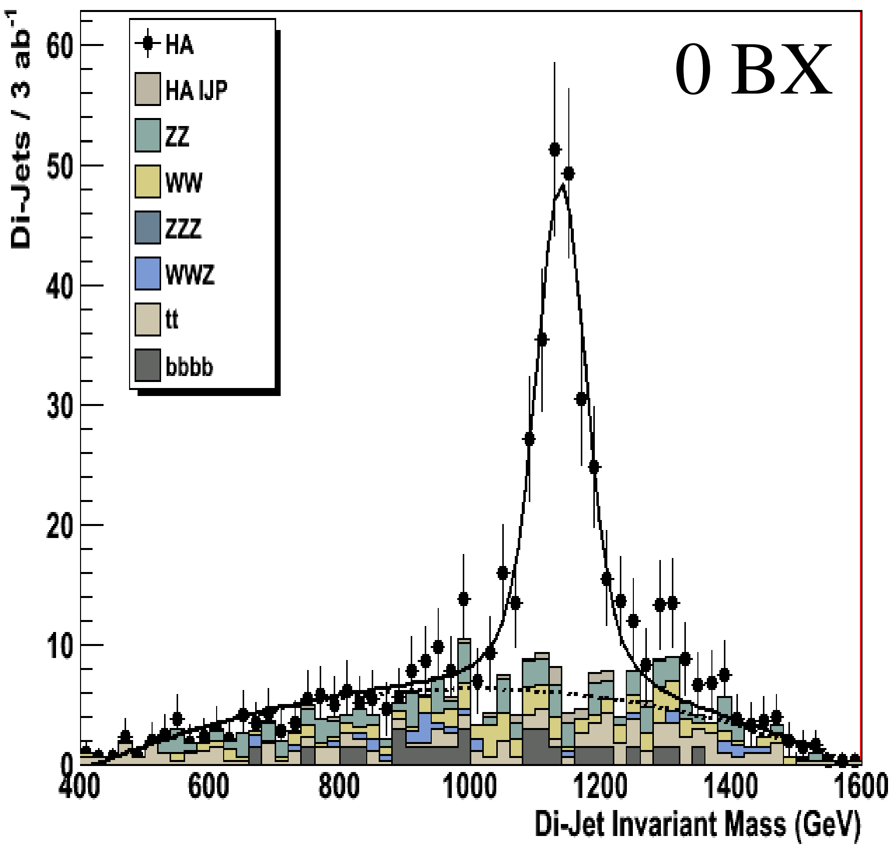
Raw Di-Jet Mass Fit

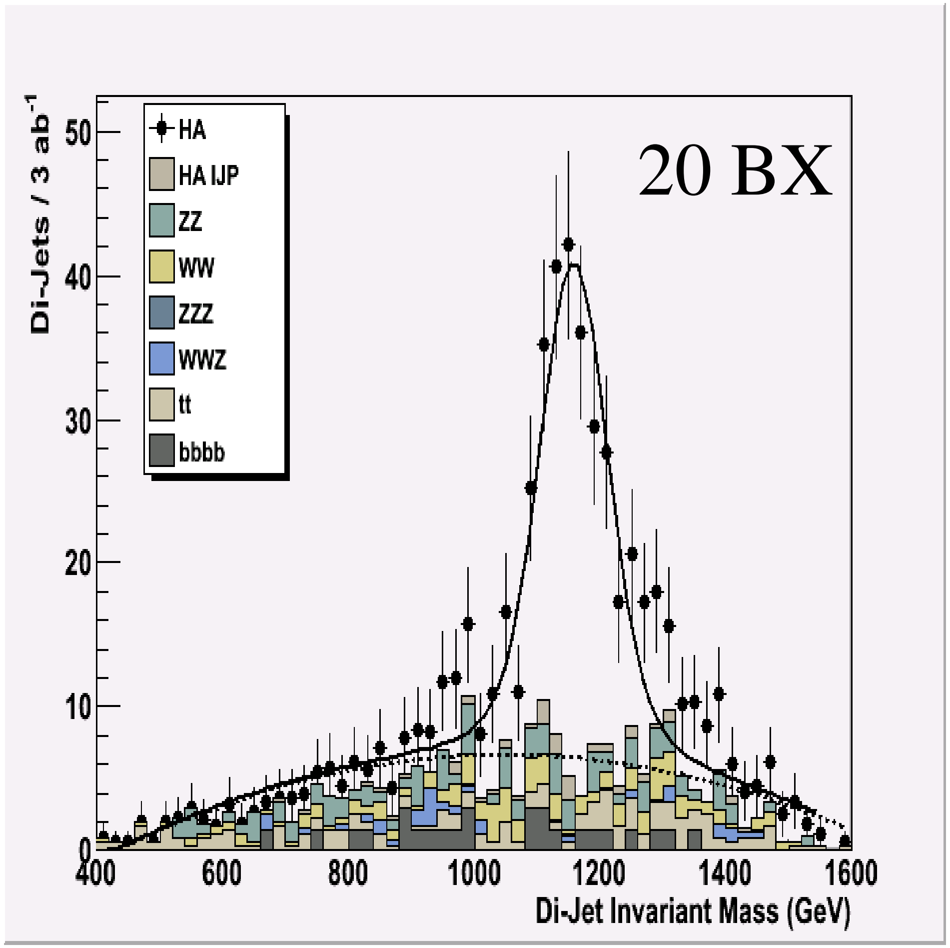
Nb. of BX	Signal Events	Resolution (GeV)	Mass (GeV)
0	257 18	68.5 5.7	1112.2 5.3
5	283 18	78.7 6.5	1120.0 5.7
20	320 19	92.0 6.5	1168.3 6.9
40	248 17	118.2 8.3	1190.2 9.2
60	234 16	121.1 8.5	1209.0 9.5

Constrained Kinematic Fit

Nb. of BX	Signal Events	Resolution (GeV)	Mass (GeV)
0	319 21	30.2 4.6	1139.5 3.1
5	270 23	40.1 7.1	1146.9 4.7
20	259 22	46.3 8.4	1158.3 5.6
40	230 21	57.3 8.7	1169.0 8.1
60	270.8 34	107.8 14.8	1176.3 10.1

$e^+e^- \rightarrow H^0A^0 \rightarrow bbbb$
Preliminary Results





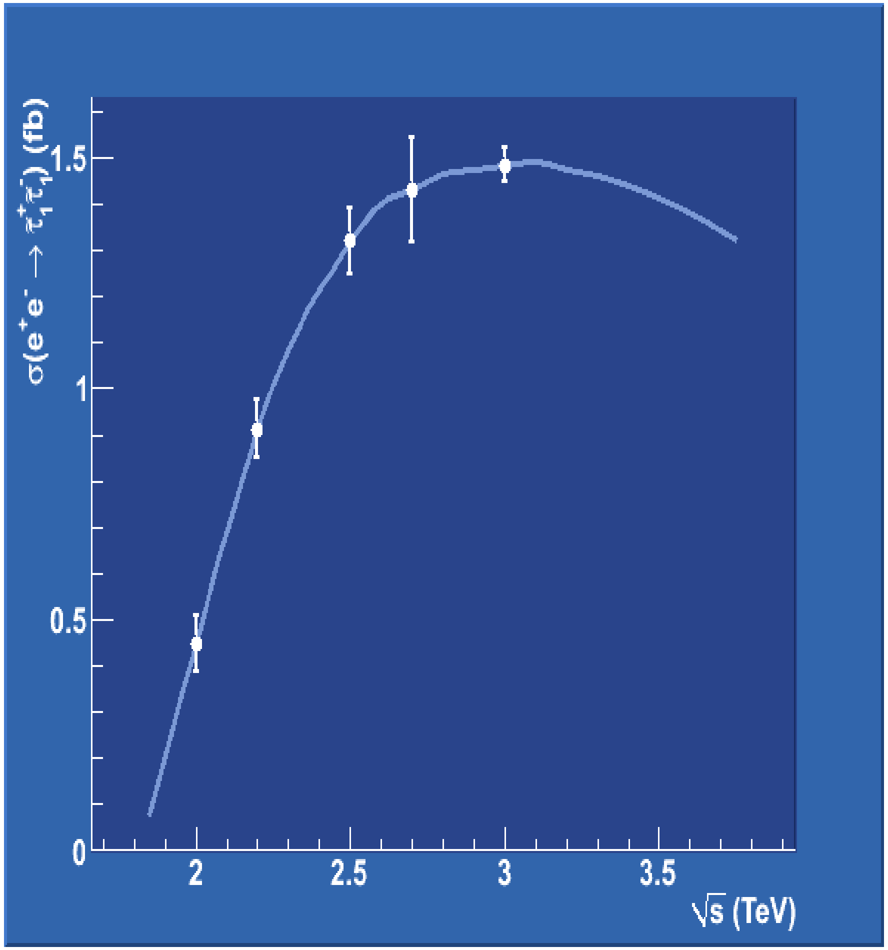
$M_A = (1139.5 \pm 3.1)$ GeV

$M_A = (1158.6 \pm 5.6)$ GeV

CLIC

$e^+e^- \rightarrow \chi^+_1\chi^-_1$, $\mu_R\ \mu_R$, $\tau_1\ \tau_1$
Threshold Scan Preliminary Results

Threshold scans with 2 ab^{-1} at maximum energy and 2 ab^{-1} at 2.0-2.7 GeV



Particle	Mass Accuracy (GeV)
$\chi^{\pm}_1$	± 4.3
$\mu^{\pm}_R$	± 6.2
$\tau^{\pm}_1$	± 6.7

$e^+e^- \rightarrow \chi^+_1\chi^-_1 \rightarrow W^\pm\chi^0_1X$
Preliminary Results

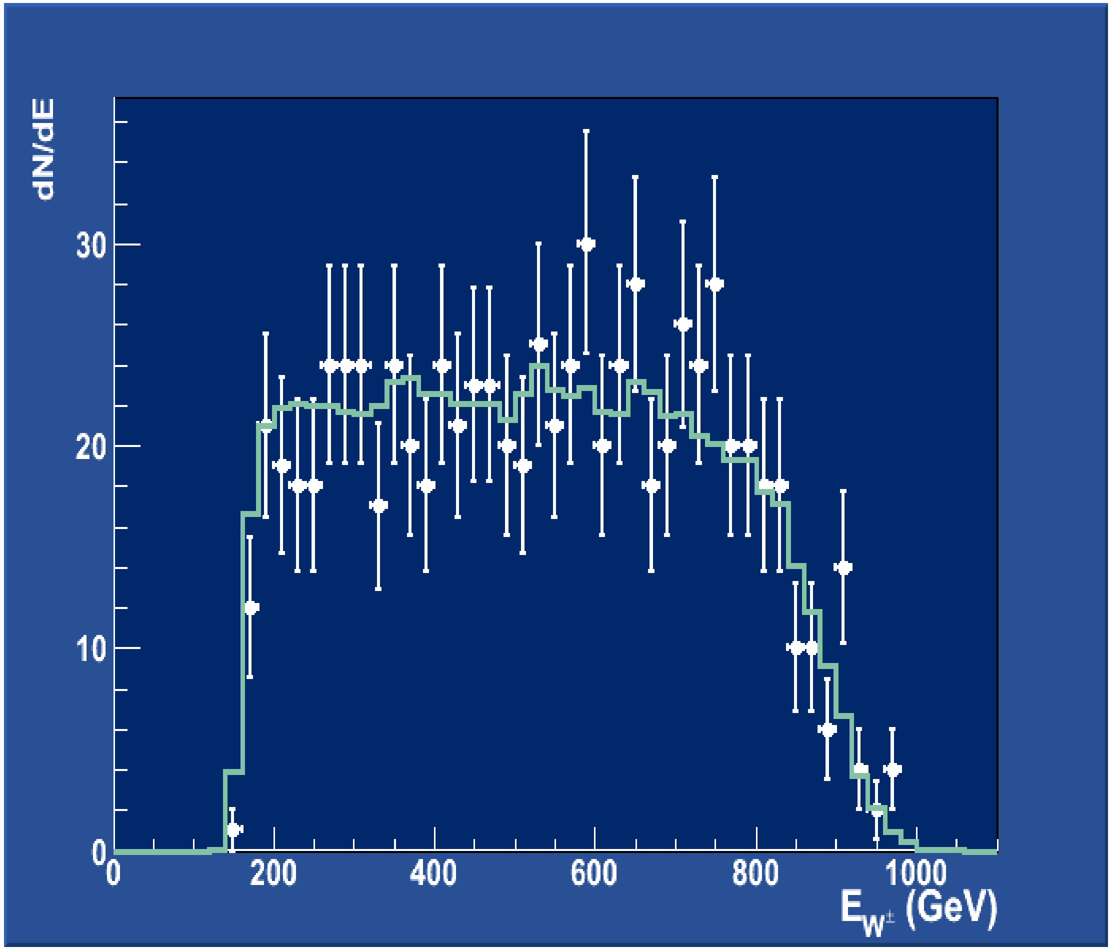
Two useful topologies:
LJJ, 4J

3 TeV 2 ab^{-1}

Select $W \rightarrow qq'$ and measure W energy

Fit kinematic endpoints of E_W for $M(\chi^0_1)$ assuming $M(\chi^\pm_1)$ from threshold scan:

$$\delta M(\chi^0_1) = \pm 8.0 \text{ GeV}$$



Need to improve $\delta Ej/Ej$ to ensure W/Z/h separation in chargino and neutralino decays

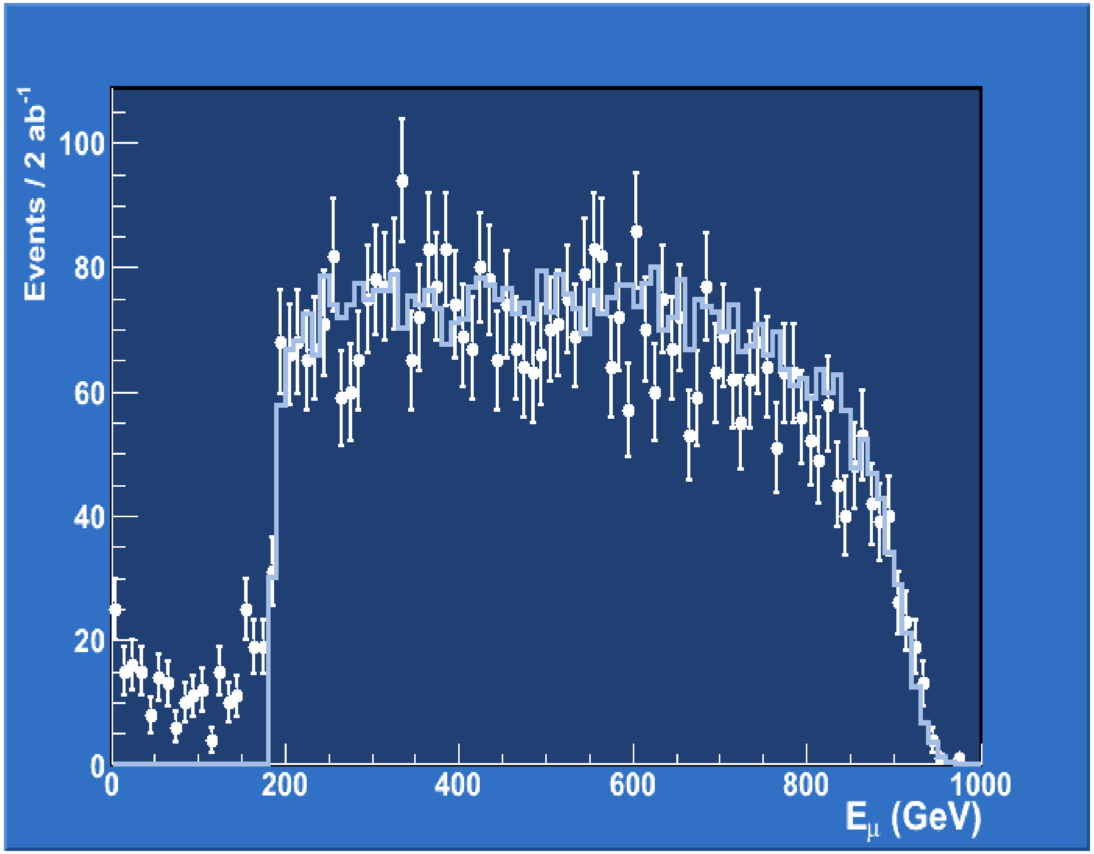
$e^+e^- \rightarrow \mu^+_R\mu^-_R \rightarrow \mu+\chi^0_1\mu^- \chi^0_1$
Preliminary Results

2 ab^{-1} at 3 TeV

reject SM $\mu\mu\nu\nu$ and $ee\mu\mu$ backgrounds with p_t and $M_{\mu\mu}$ cuts

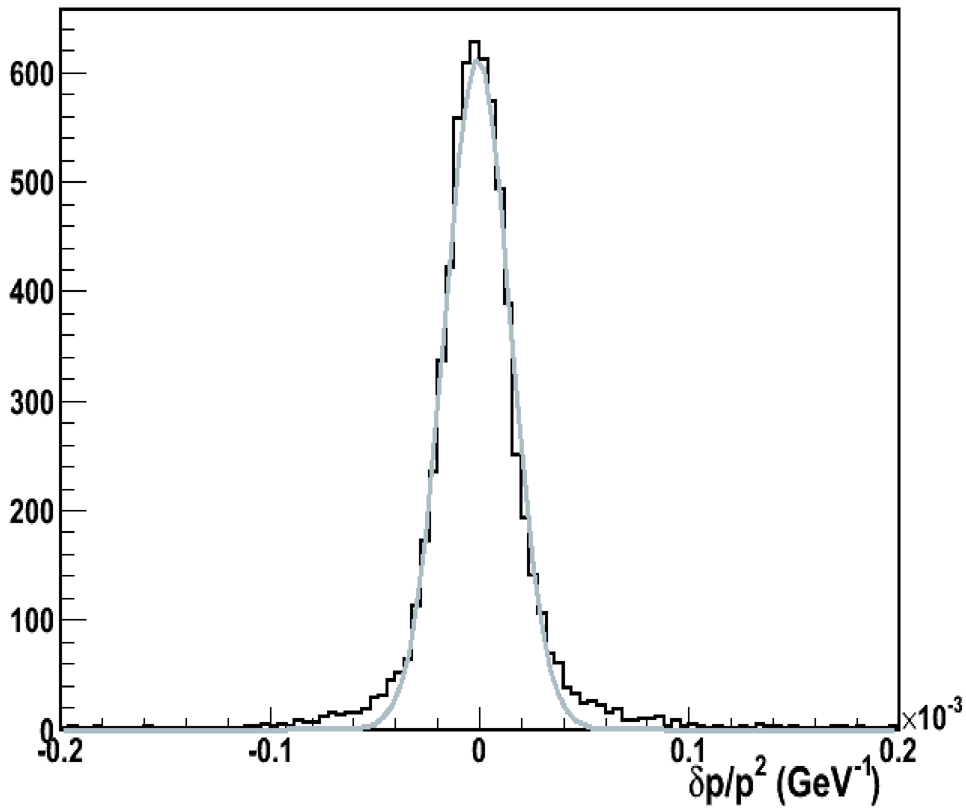
Fit kinematic endpoints of E_μ for $M(\chi^0_1)$ assuming $M(\mu_R)$ from threshold scan:

$$\delta\, M(\chi^0_1) = \pm\, 5.0 \text{ GeV}$$

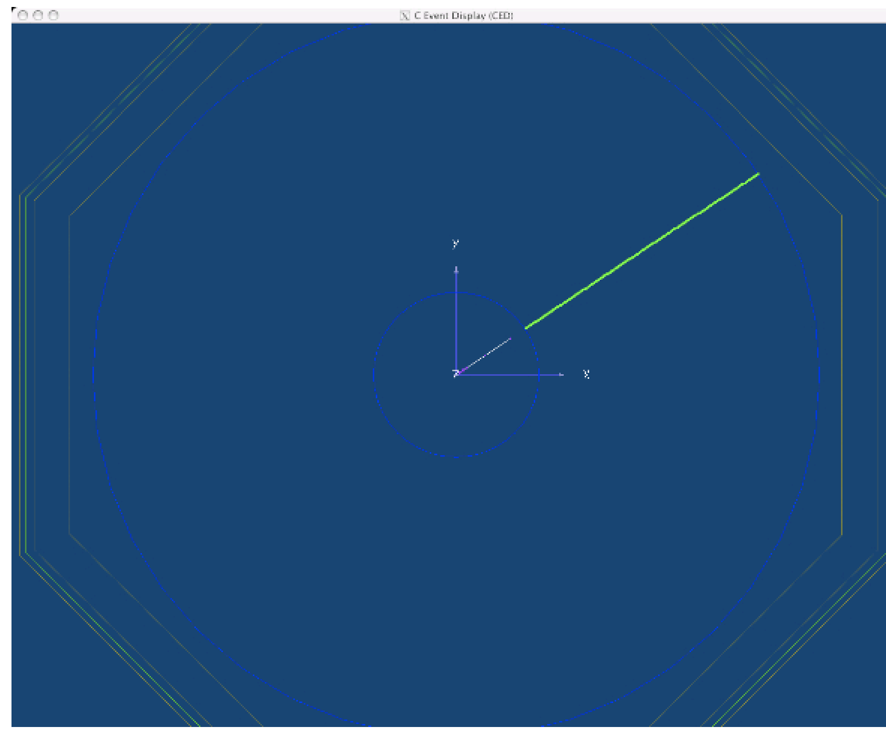


$e^+e^- \rightarrow \mu^+_R\mu^-_R \rightarrow \mu+\chi^0_1\mu^-\chi^0_1$ Tracking

Track momentum resolution adequate to analysis, resolution dominated by beamstrahlung



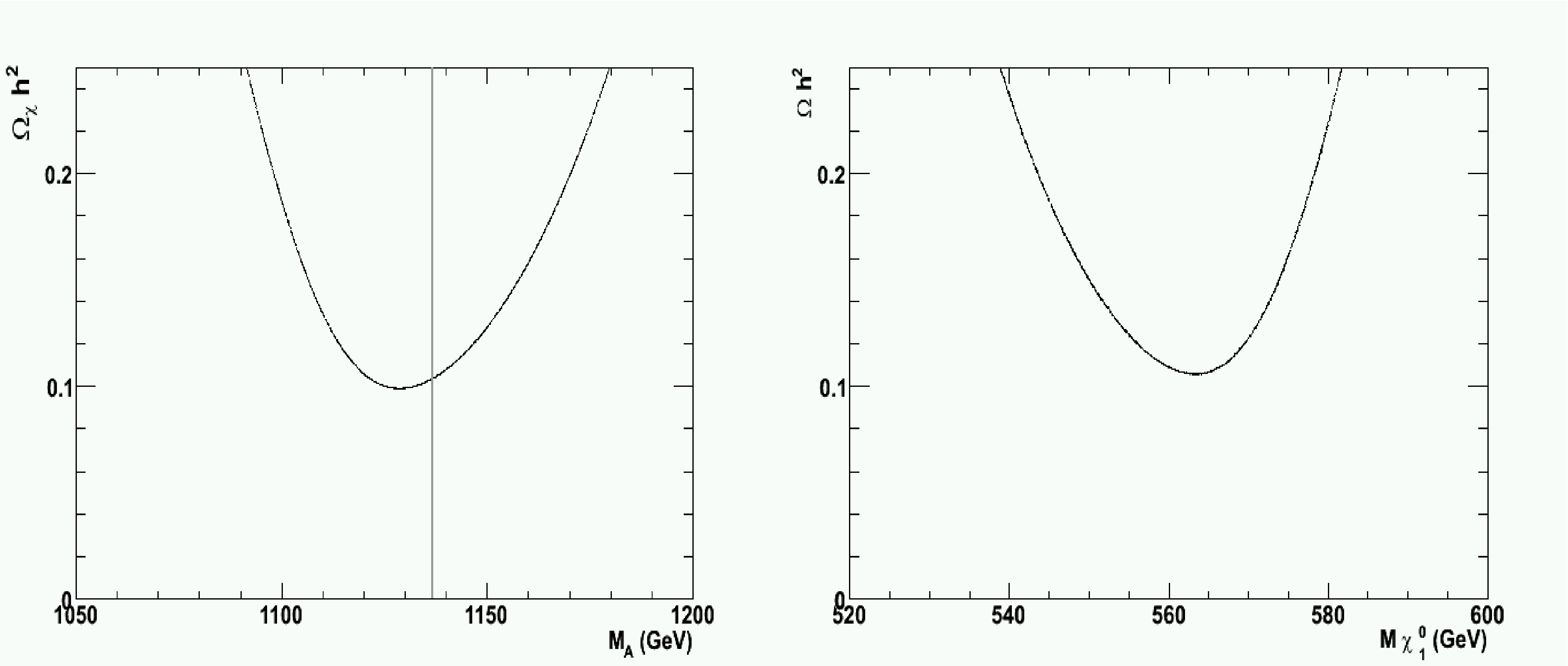
Observe broken tracks for p > 600 GeV resulting in drop in efficiency after quality cuts.



S Aplin

Implications of the CLIC Accuracies: Neutralino Relic Density Ωh^2 in MSSM

First determine dependence of Ωh^2 on sparticle masses by varying only parameter under study:

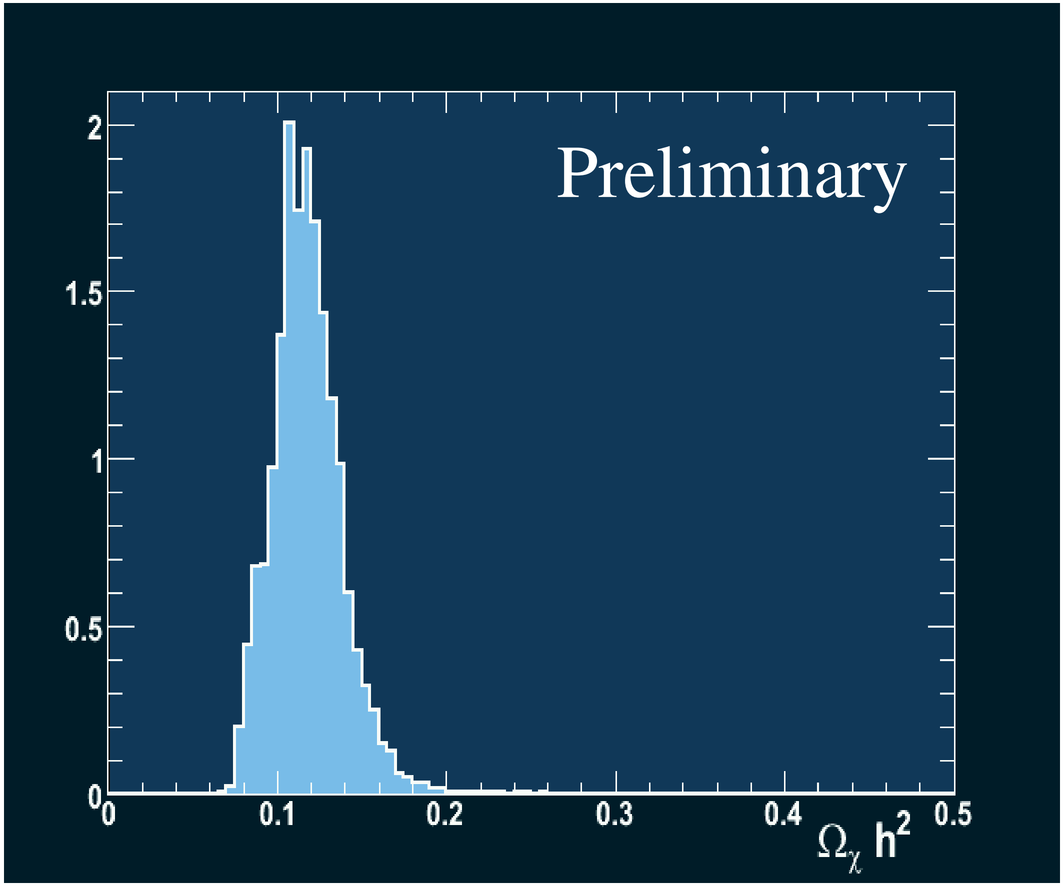


Implications of the CLIC Accuracies: Neutralino Relic Density Ωh^2 in MSSM

Perform scan to full MSSM imposing constraints on sparticle masses as obtained from preliminary CLIC analyses;

Particle	Mass Accuracy (GeV)
$\chi^{\pm}_1$	± 4.3
$\mu^{\pm}_R$	± 6.2
$\tau^{\pm}_1$	± 6.7
χ^0_1	± 4.0
H^0/A^0	±5.6

Result Set	$\delta\Omega h^2/\Omega h^2$
H^0/A^0, χ^0_1, $\chi^{\pm}_1$, τ_1, μ_R	**±0.167**
+ $\chi^{\pm}_2$, τ_2, χ^0_3 and χ^0_4	**±0.110**



Encouraging preliminary results on reconstruction of heavy SUSY particle pairs production at 3 TeV with events full simulation and reconstruction, full SM backgrounds and overlay of $\gamma\gamma \rightarrow$ hadrons background, shows CLIC potential;

Current corpus of analyses may represent a basis for first round of detector optimisation and benchmarking and establishing a repository of CLIC events for detector and physics studies (stdhep, slcio, tuples);

Significant effort is required to address crucial issues raised by this first exercise:

- parton energy resolution and degradation in presence of b-jets and $\gamma\gamma$ bkg (need to separate W/Z/h with high efficiency purity);
- jet clustering in presence of $\gamma\gamma$ bkg;
- highly efficient b-tagging in presence of heavy hadrons decaying in the detector;
- mitigation of machine-induced background by detector space-time granularity and optimised event reconstruction algorithms.