European Organization for Nuclear Research

Physics at CLIC and Cosmology

New Physics Scenarios and Experimental Challenges

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CERN, Geneva and LBNL, Berkeley

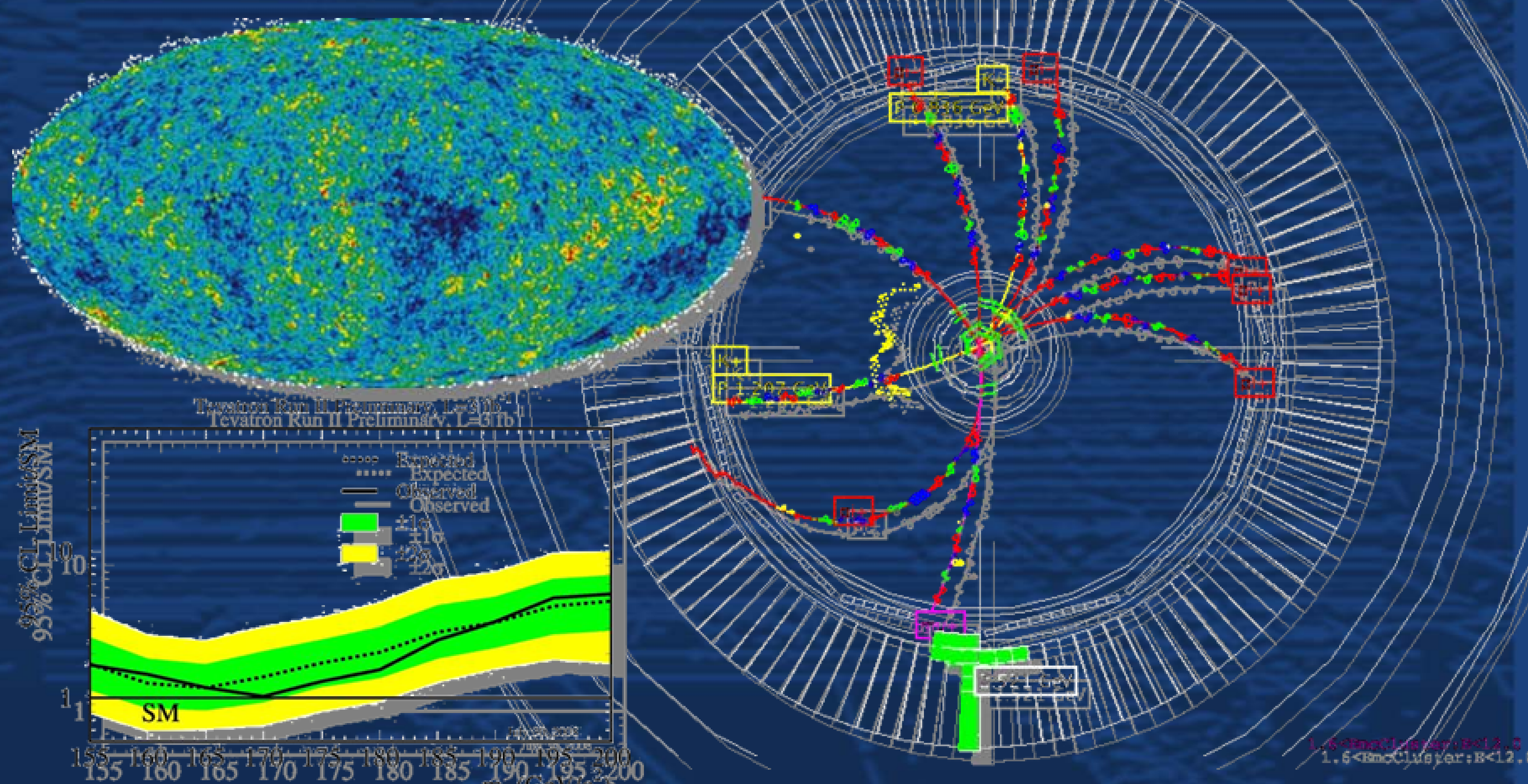
LC09

Perugia, 24 September, 2009

Which is the scale of New Physics ?

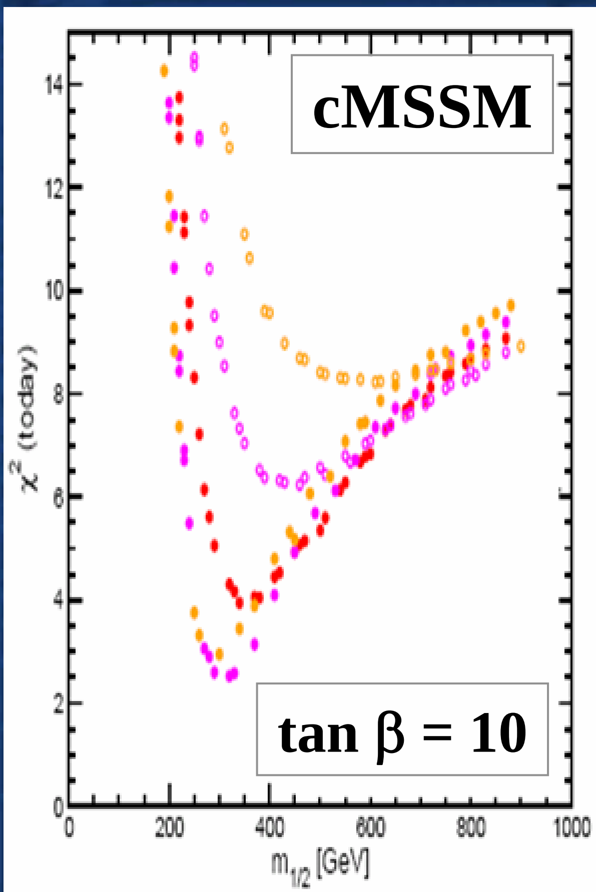
BERKELEY LAB

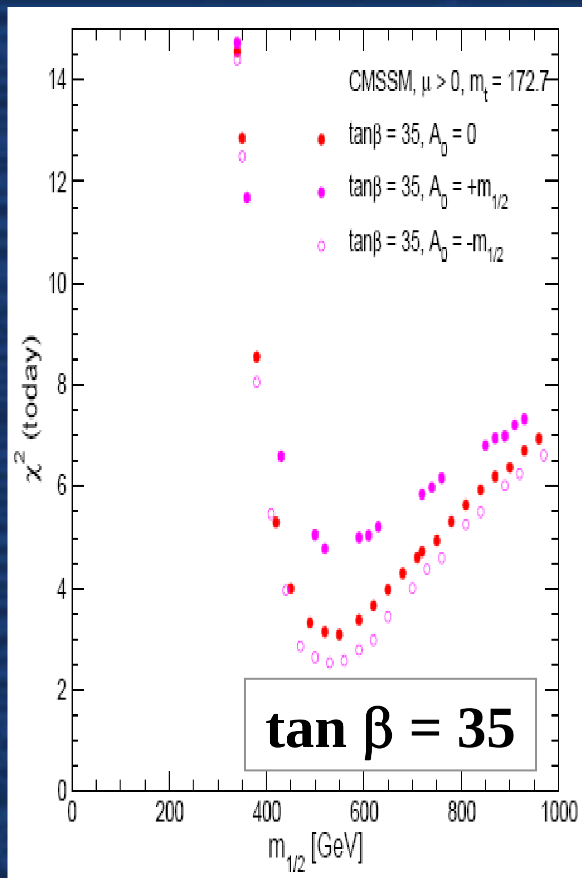
Waiting for LHC results, many attempts to define "most likely" region(s) of parameters based on LEP+Tevatron, low energy data and Cosmology (DM and BBN):

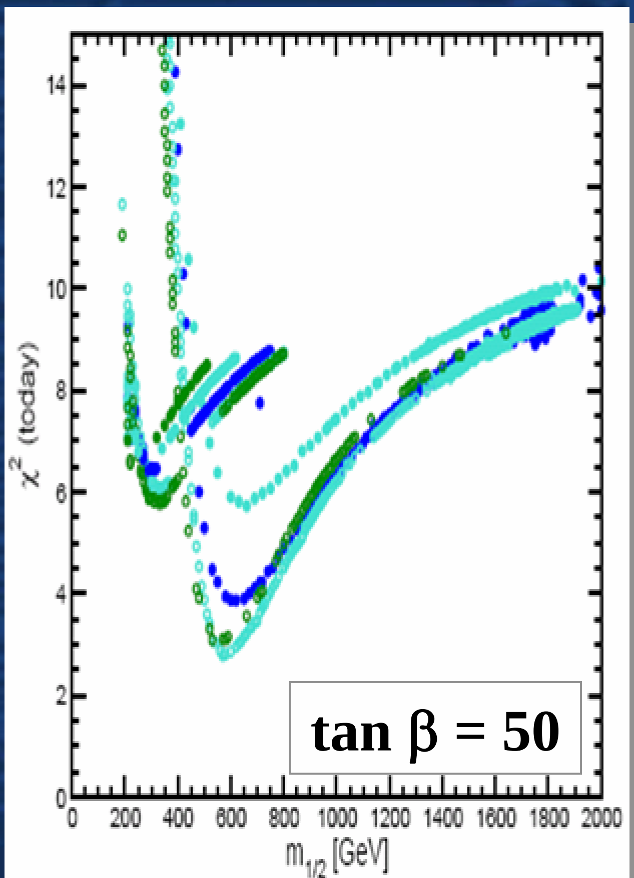


Which is the scale of New Physics ?

1) cMSSM with $M_W, \sin^2 \vartheta_{eff}, M_h, (g-2)_\mu, \mathrm{BR}(b \to s\gamma)$ constraints and m_0 tuned to match $\Omega_{CDM}h^2$ at various tan β values



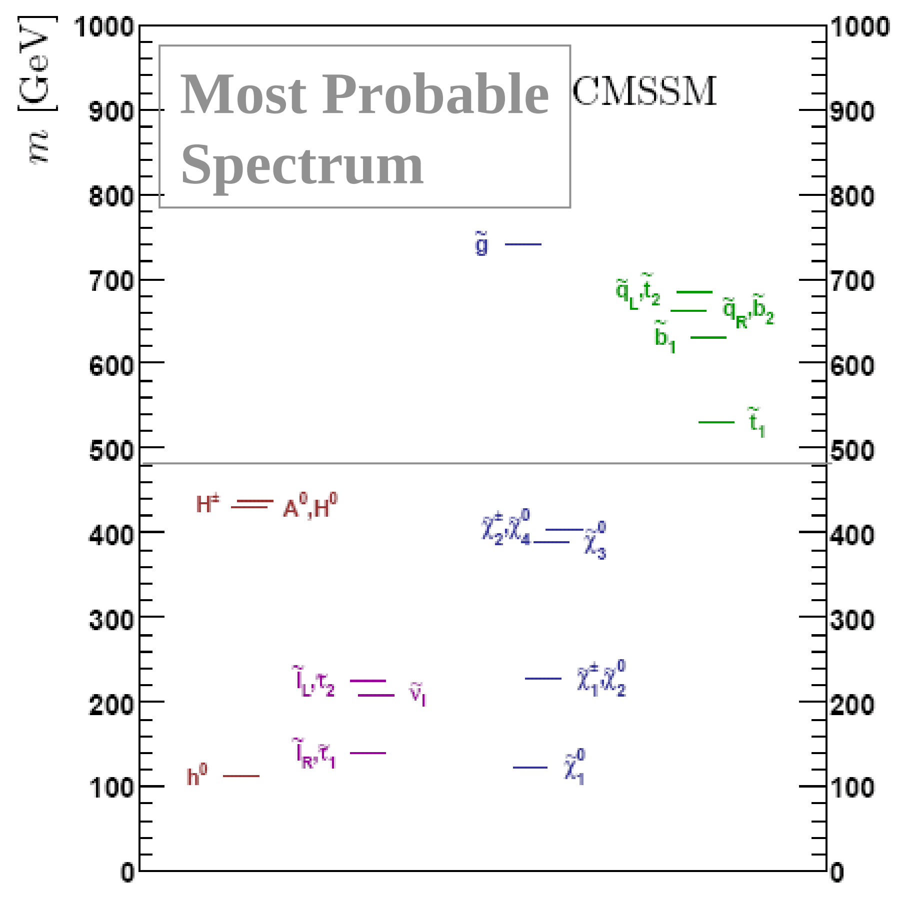




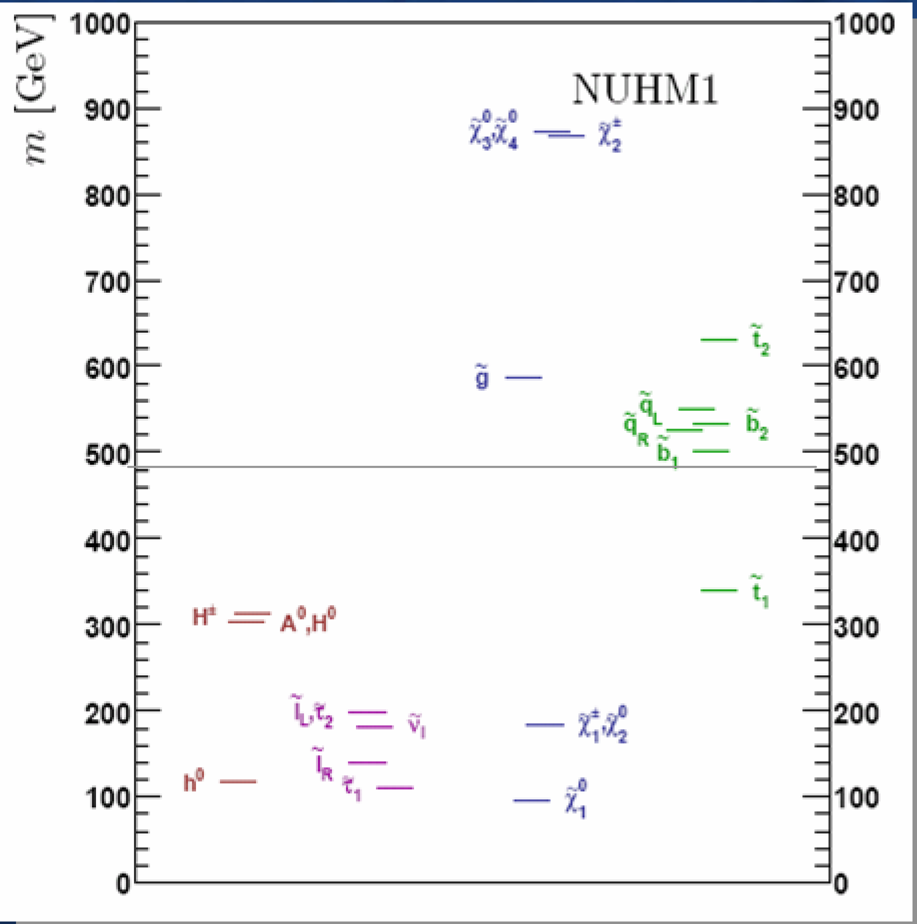
Ellis et al., JHEP 0605 (2006)

Which is the scale of New Physics ?

2) cMSSM with 15 constraints (EW, B physics, $(g-2)_\mu$ and $\Omega_{CDM}h^2$)



3) NUHM SUSY with 15 constraints (EW, B physics, $(g-2)_\mu$ and $\Omega_{CDM}h^2$)

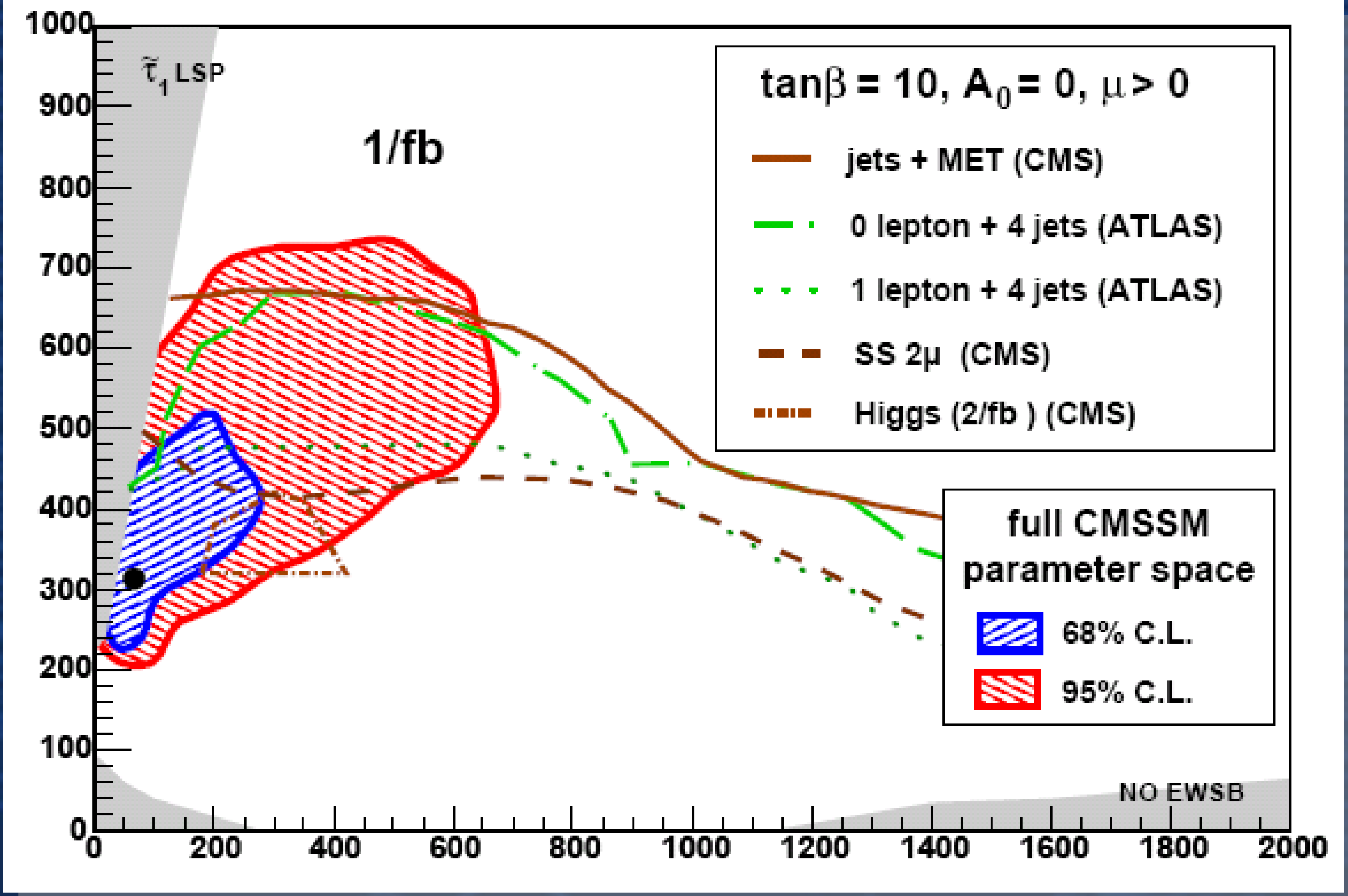


Buchmuller et al., JHEP 0809 (2008)

Which is the scale of New Physics ?

2) cMSSM with 15 constraints (EW, B physics, $(g-2)_\mu$ and $\Omega_{CDM}h^2$)

allowed region largely extends towards high mass solutions



Buchmuller et al., JHEP 0809 (2008)

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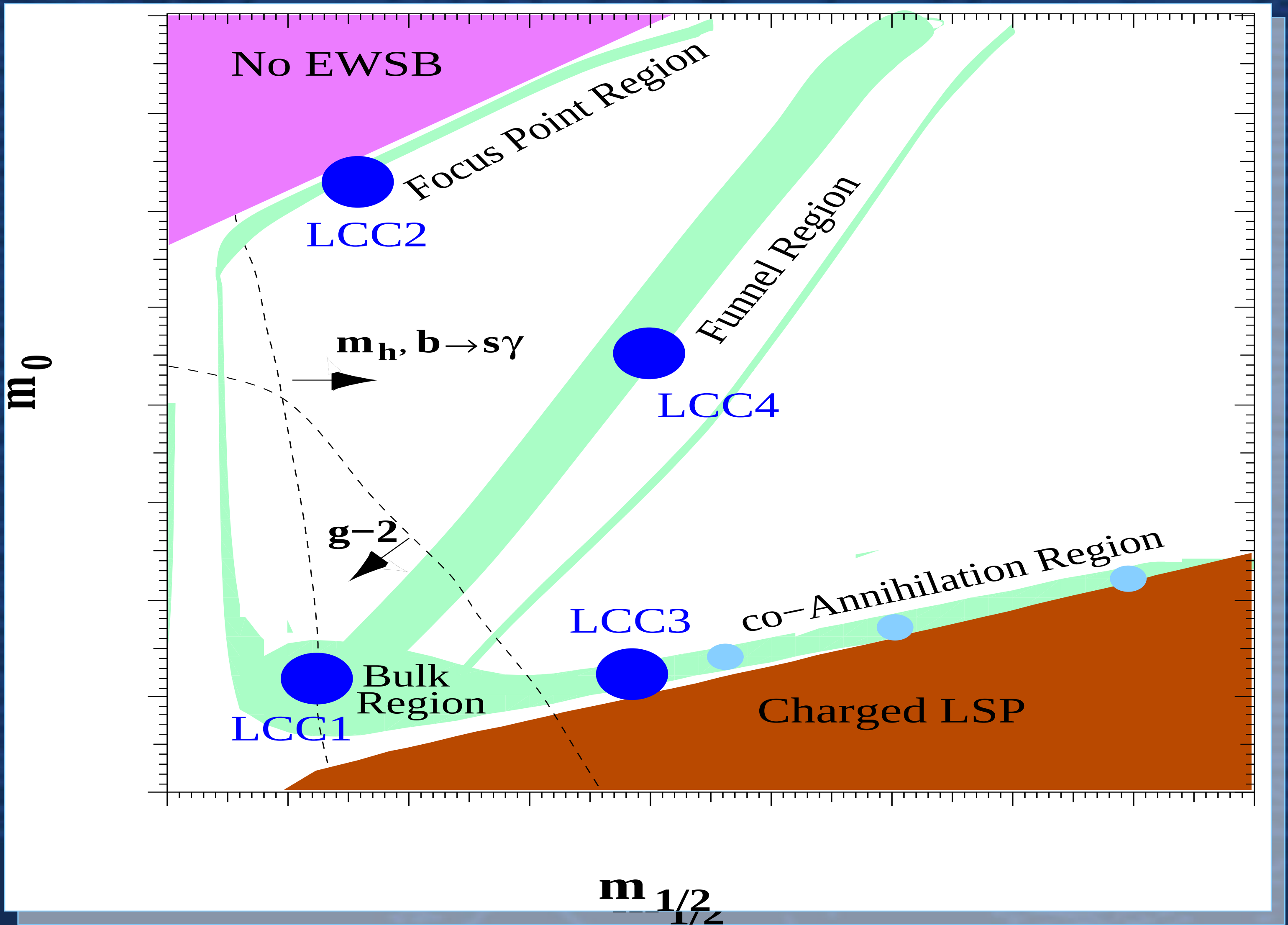
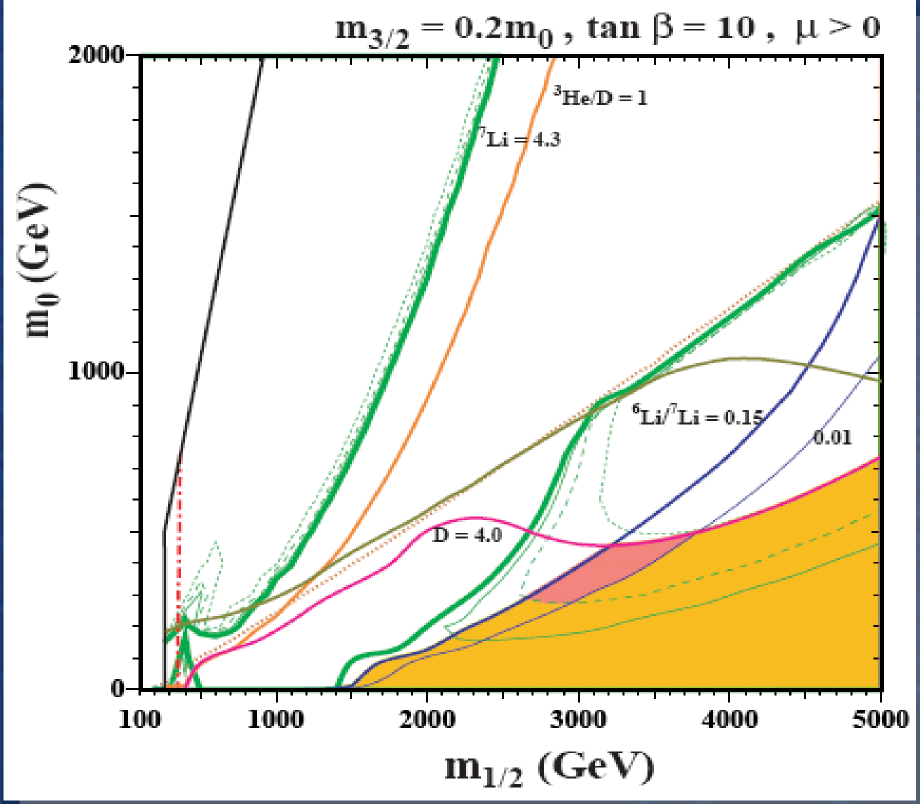
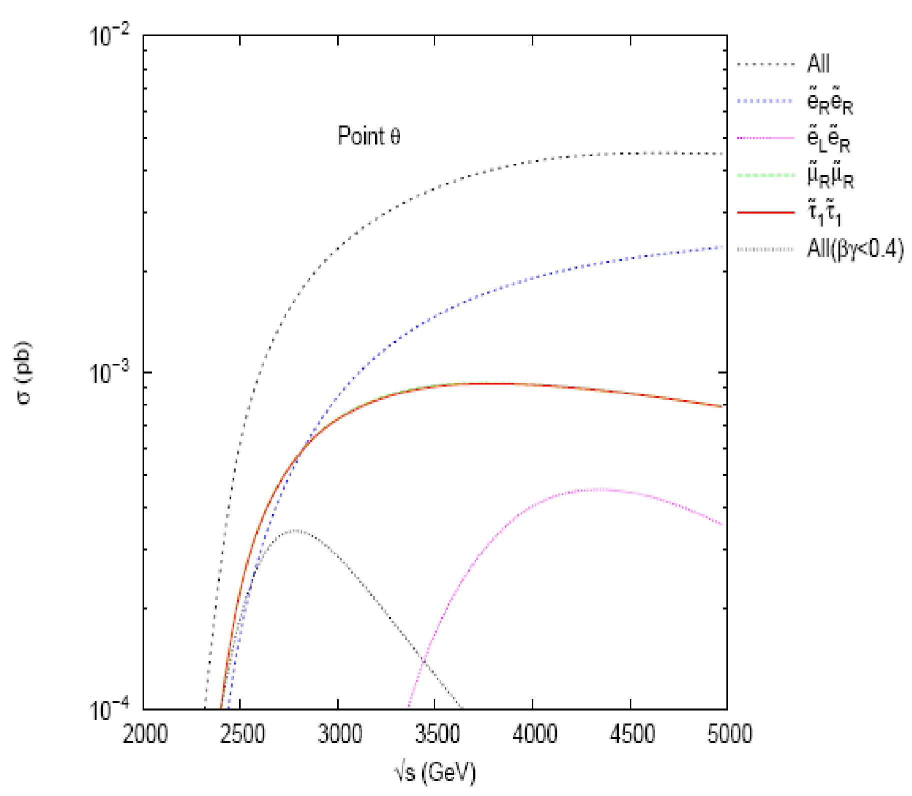


Which is the scale of New Physics ?

4) In scenarios with gravitino LSP, long-lived staus may form metastables states with nuclei affecting Big Bang Nucleosynthesis;

These scenarios indicate very large sparticle masses, even too large for detection at LHC but well suited for CLIC:

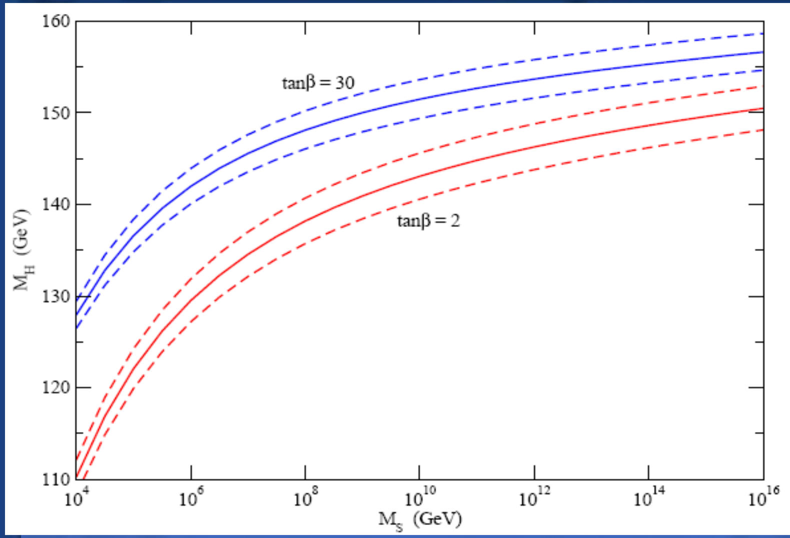


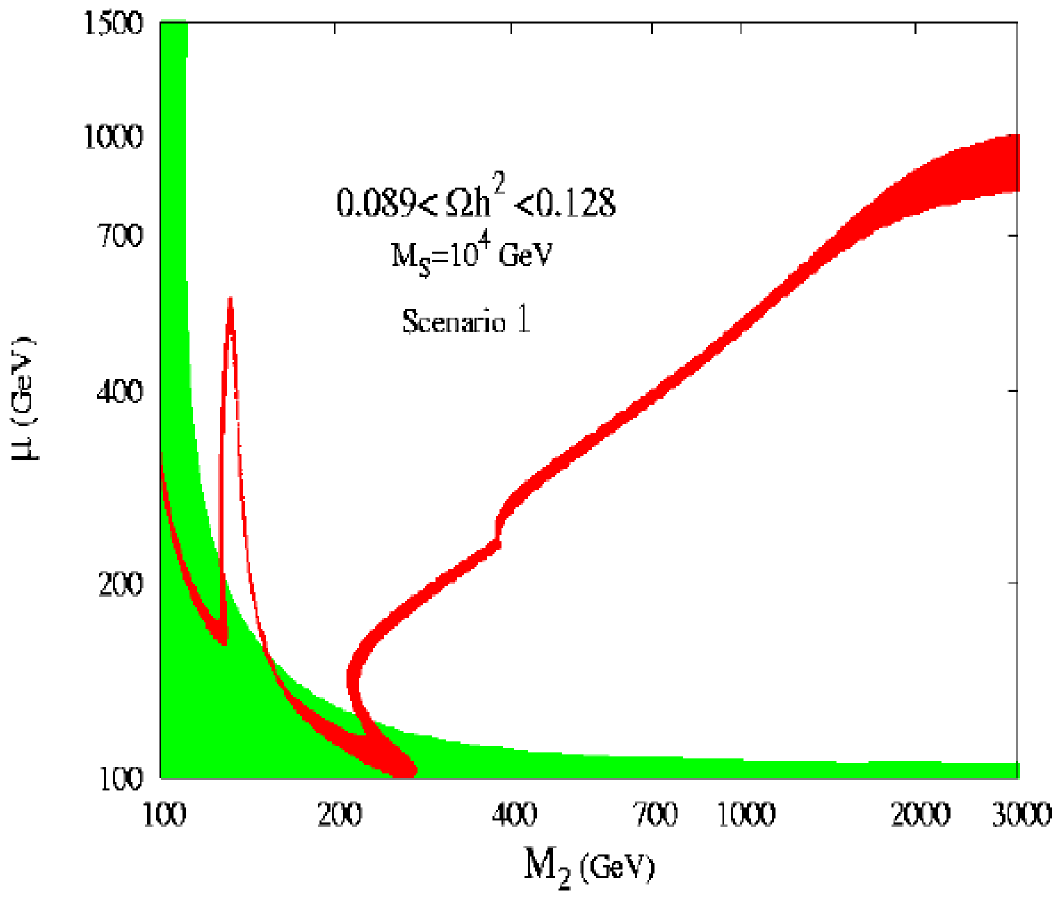


Cakir et al, hep-ph/0203121

Split-SUSY and Dark Matter

As only gauginos and higgsinos need to be relatively light to achieve unification and provide a DM candidate upper limit on M_{SUSY} may be >> 1 TeV;

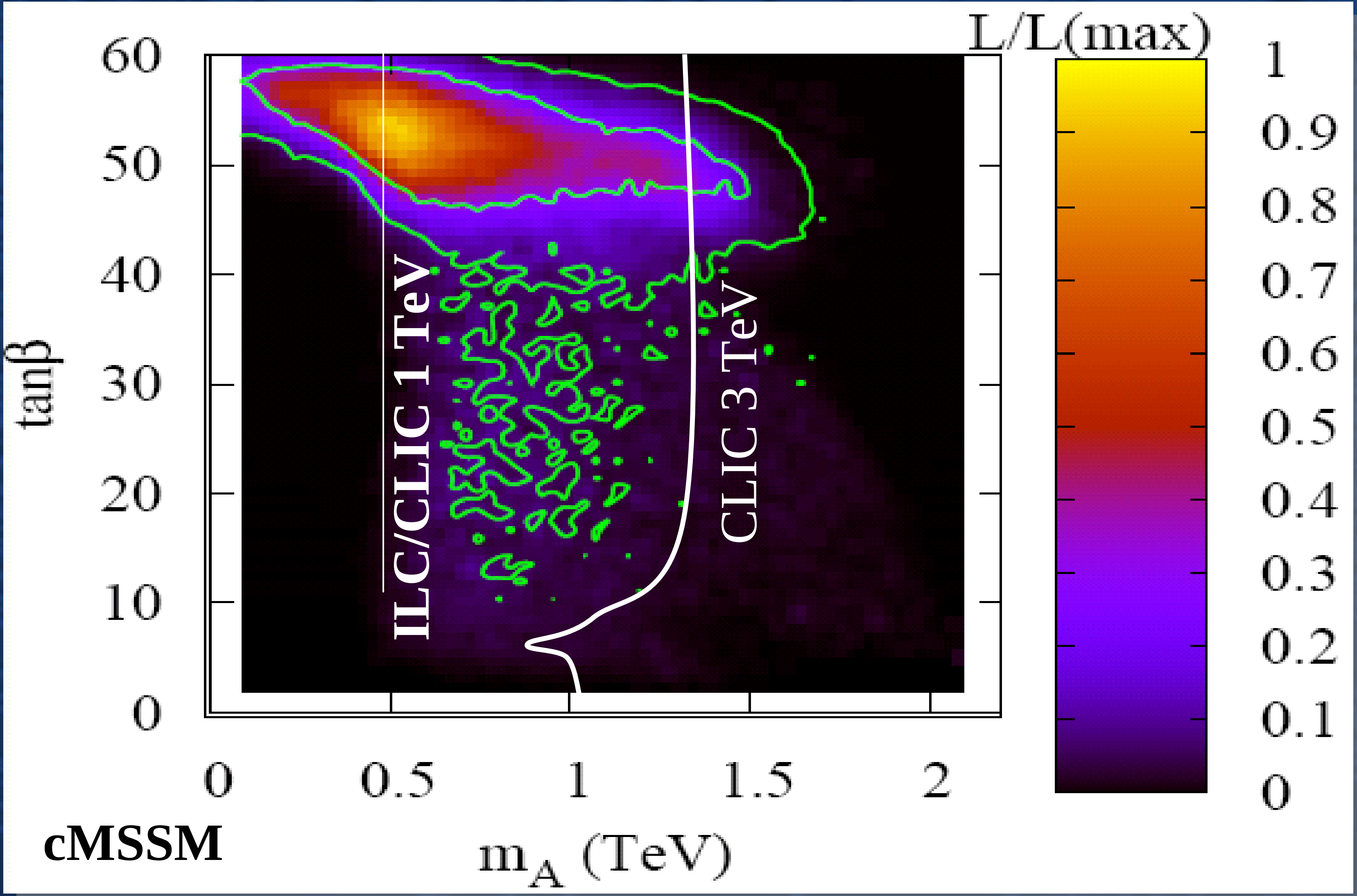




Because sfermions decouple $\chi \to \chi$ +W, Z and h^0 making this a challenging benchmark for reconstruction at an high energy collider.

Djouadi et al., JHEP 0707 (2007)

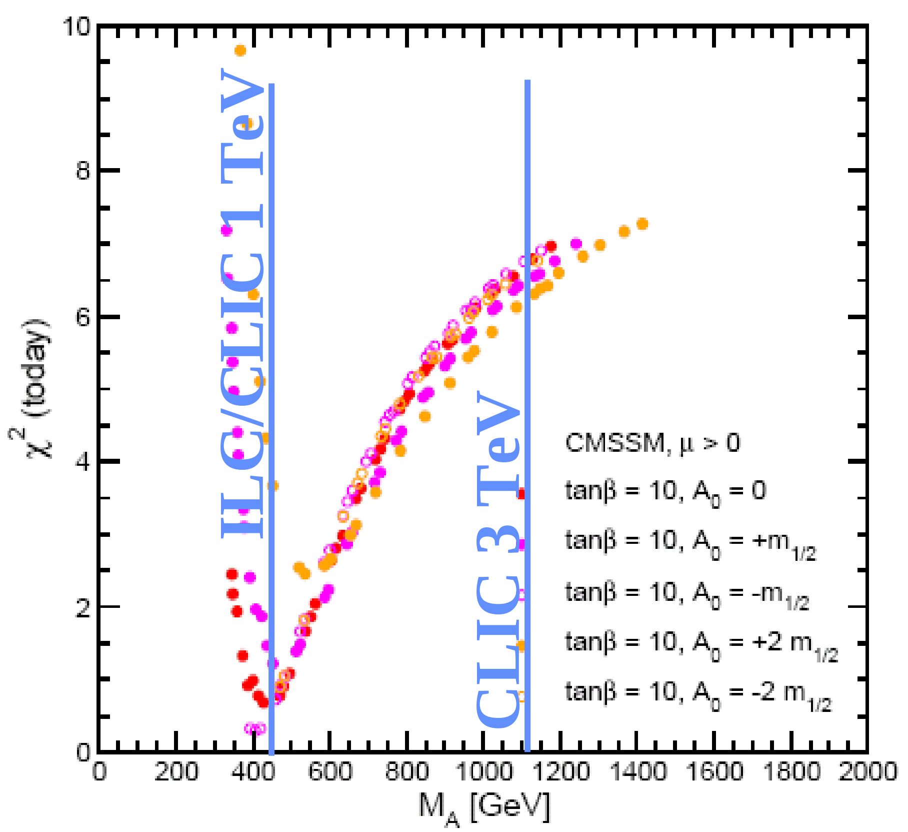
SUSY Heavy Higgs Bosons: M_A – tan β

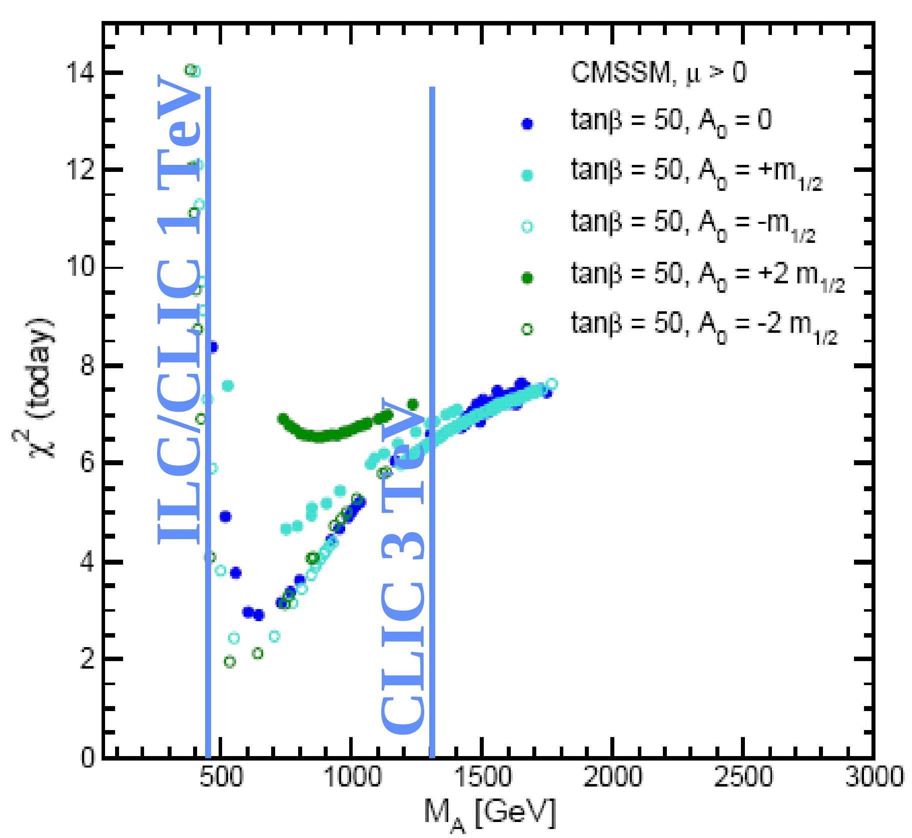


Allanach et al., PRD 73 (2006)

SUSY Heavy Higgs Bosons: M_A

1) cMSSM with $M_W, \sin^2\vartheta_{eff}, M_h, (g-2)_\mu, \mathrm{BR}(b \to s\gamma)$ constraints and m_0 tuned to match $\Omega_{CDM}h^2$

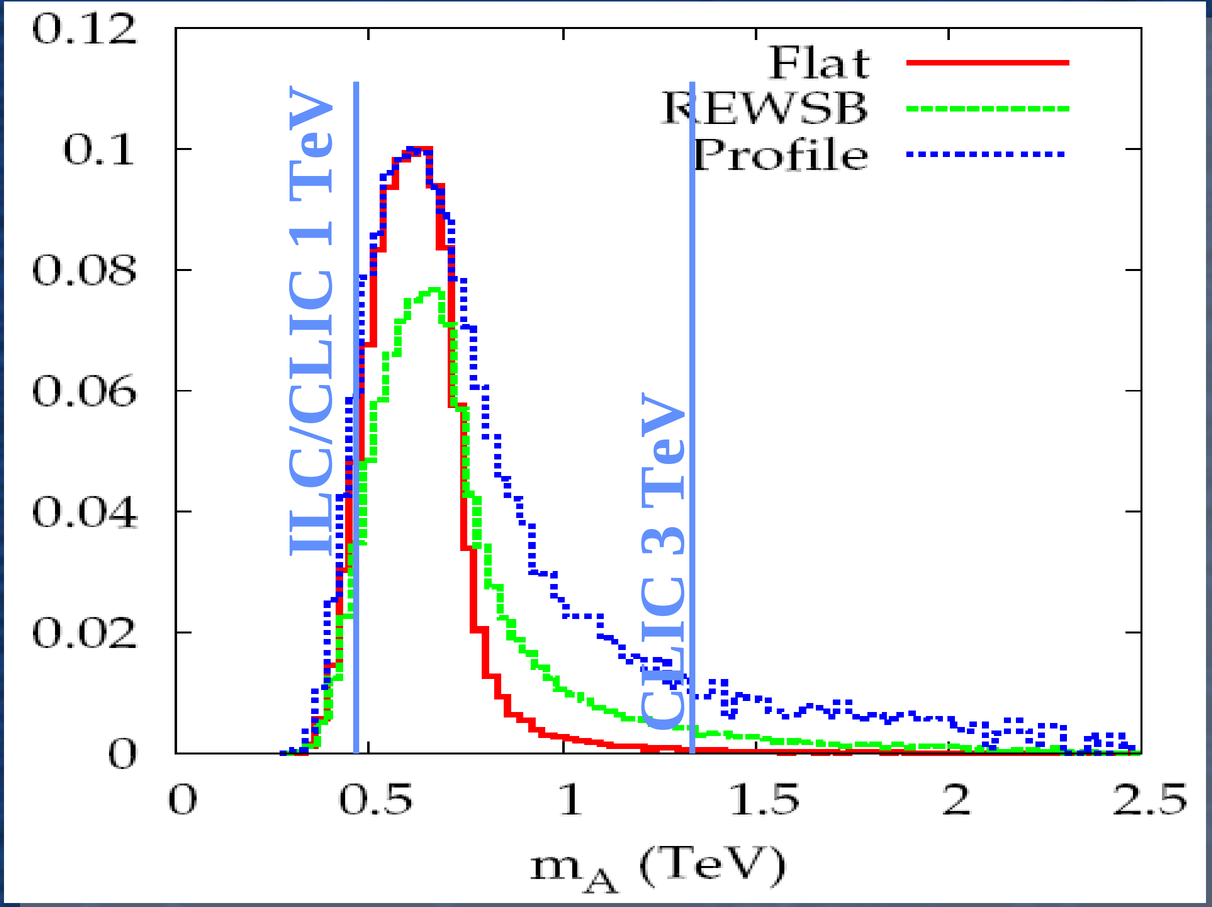




Ellis et al., JHEP 0502 (2005)

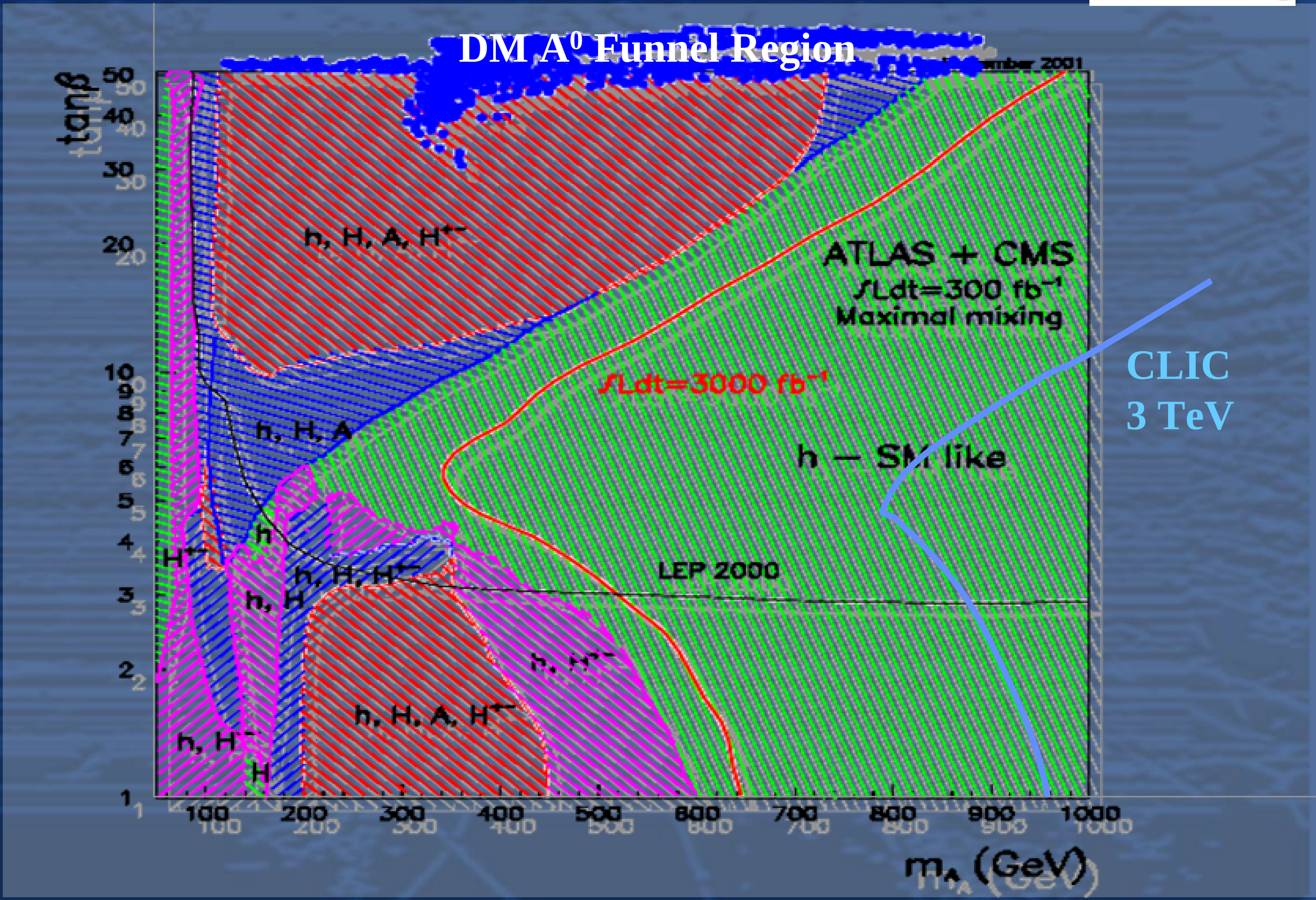
SUSY Heavy Higgs Bosons: M_A

5) String-inspired Large Volume Scenario SUSY with MCMC in Bayesian statistics formalism

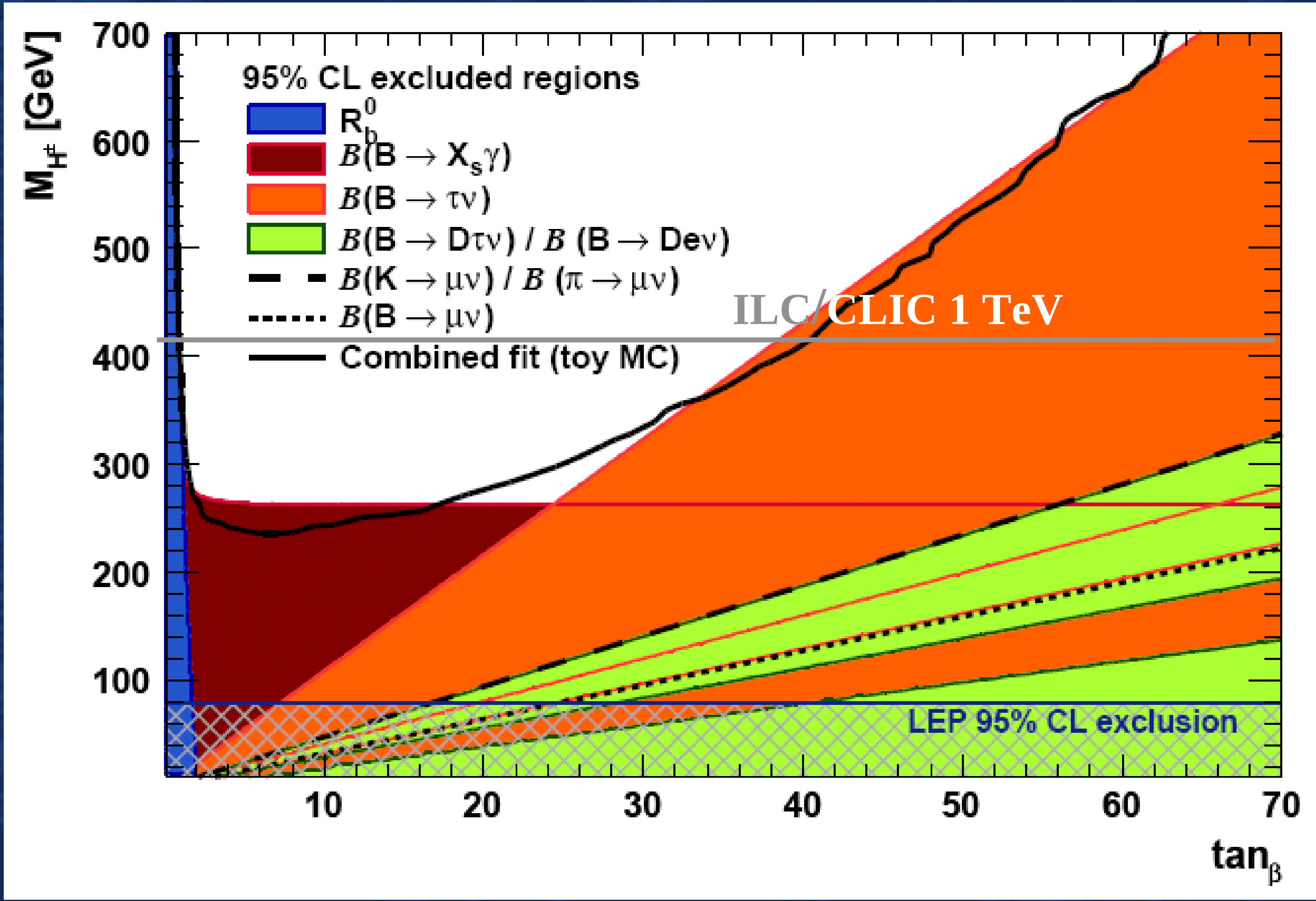


Allanach et al., JHEP 0808 (2008)

LHC/ILC/CLIC Reach in M_A – tan β

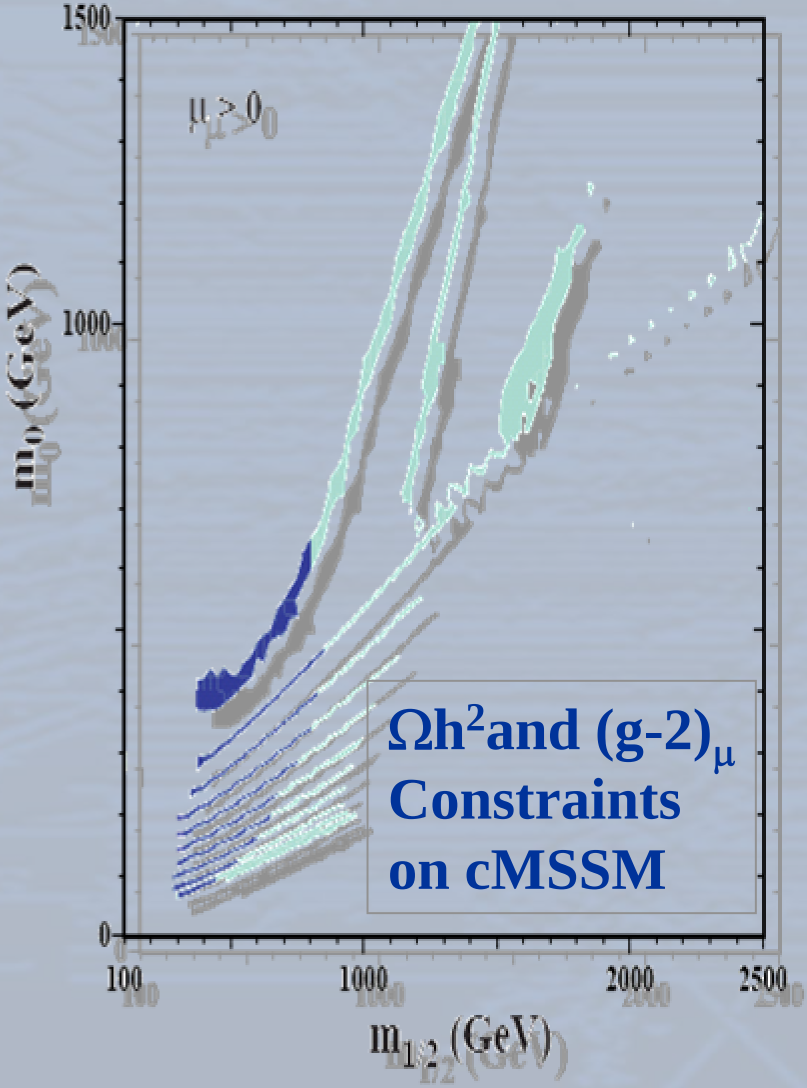


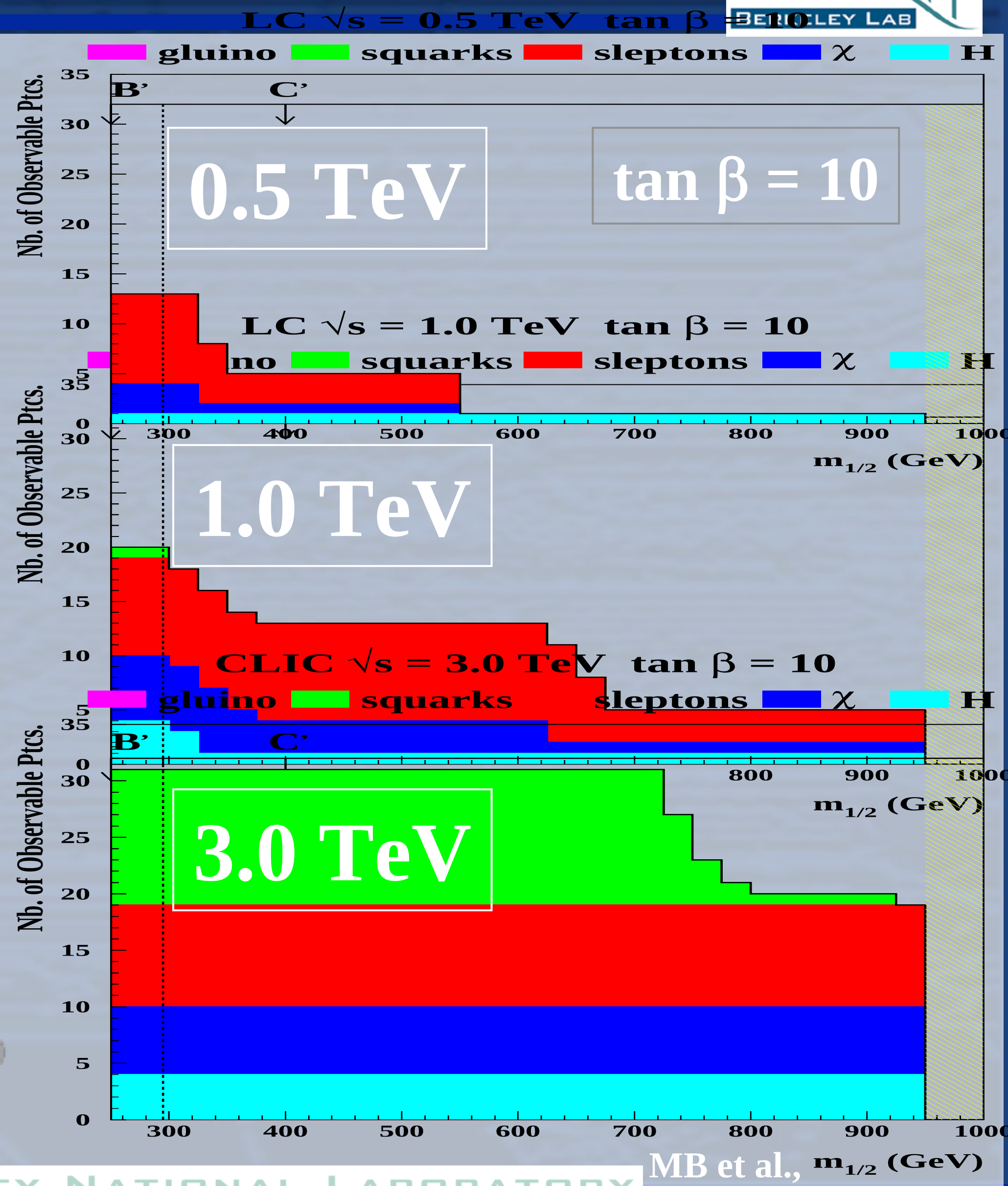
2HDM Model: M_H - tan β



Flaecher et al.
arXiv:0811:0009v2

How Many Observable Particle ?

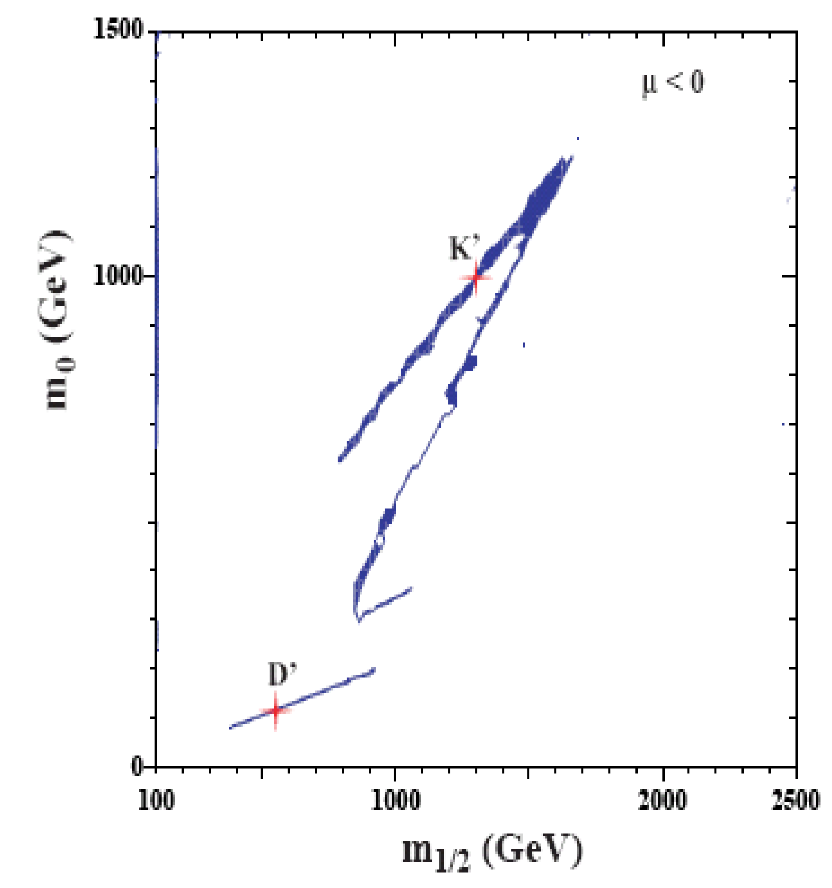


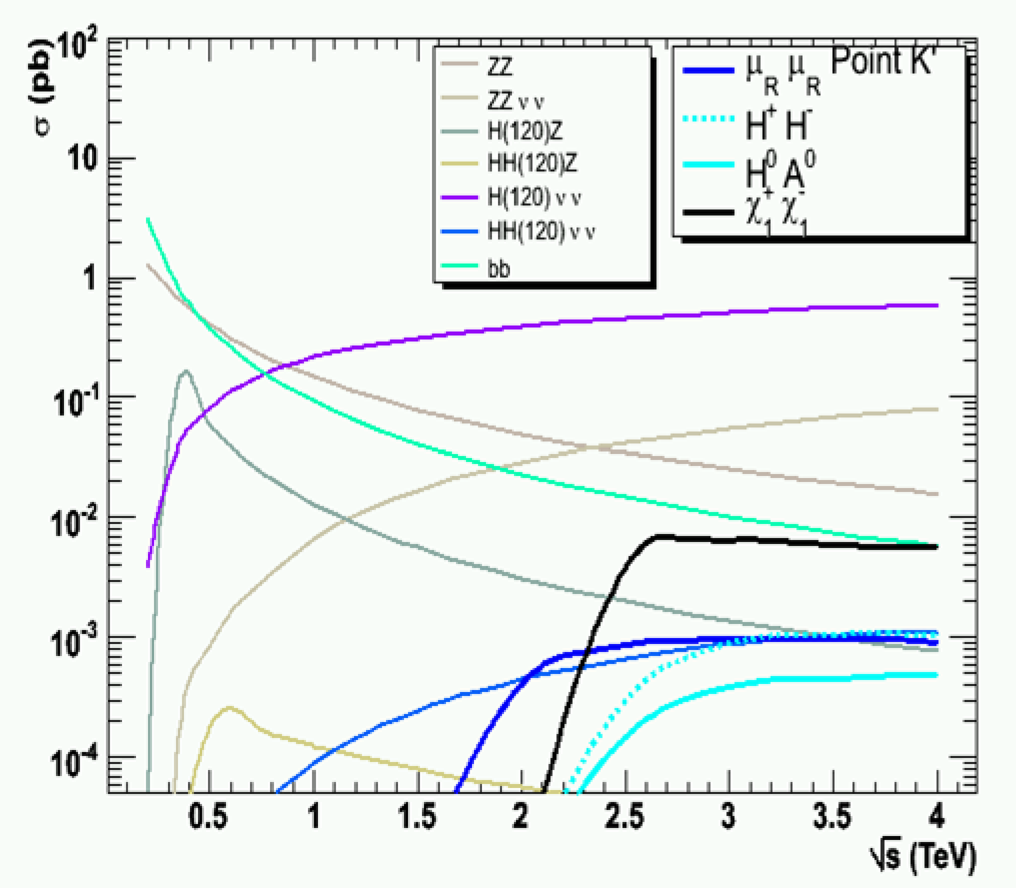


Ellis et al.,
PLB565 (2003)

MB et al.,
Eur Phys J C33 (2004)

How Many Observable Particle ?





MB et al.,
Eur Phys J C33 (2004)

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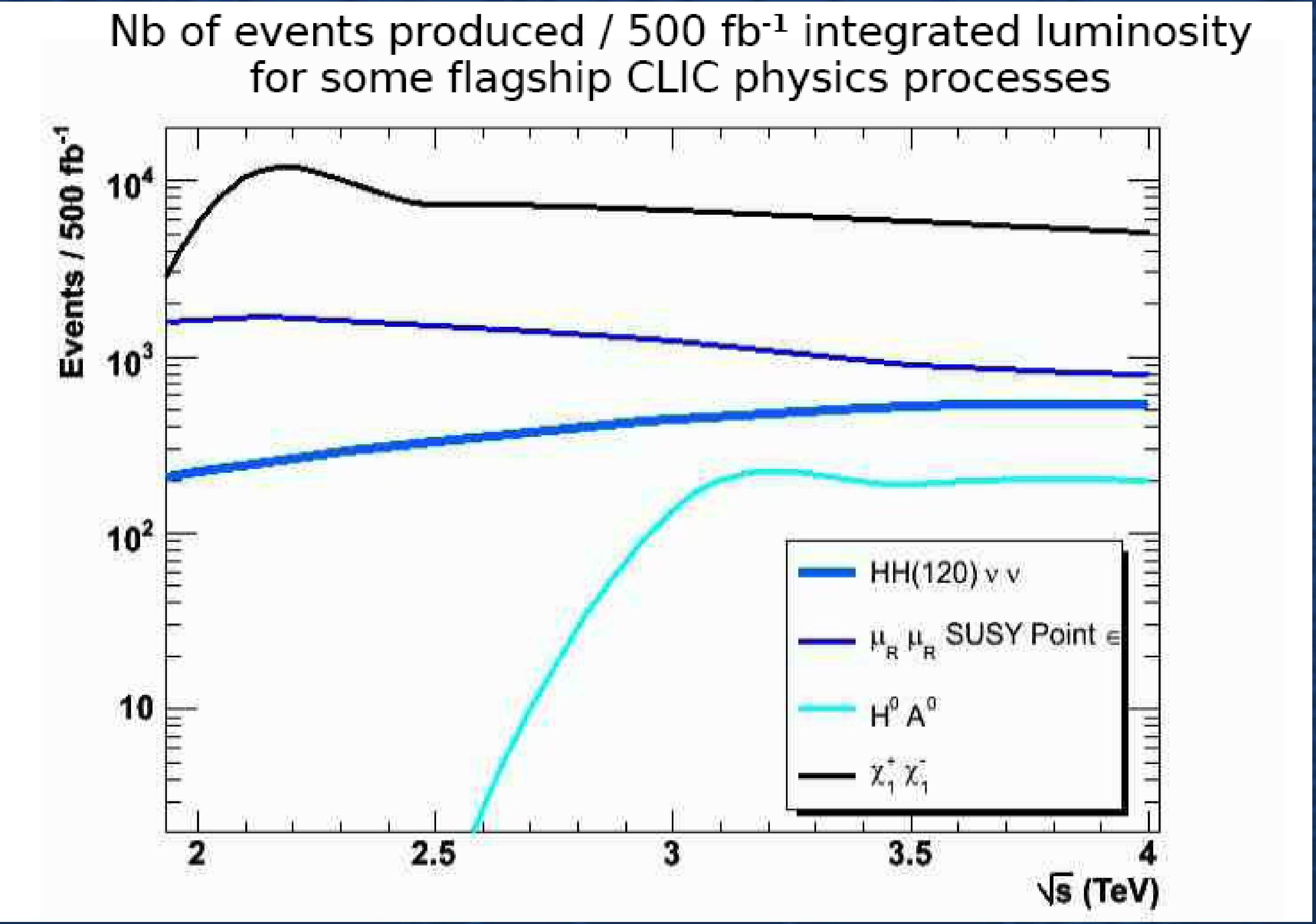
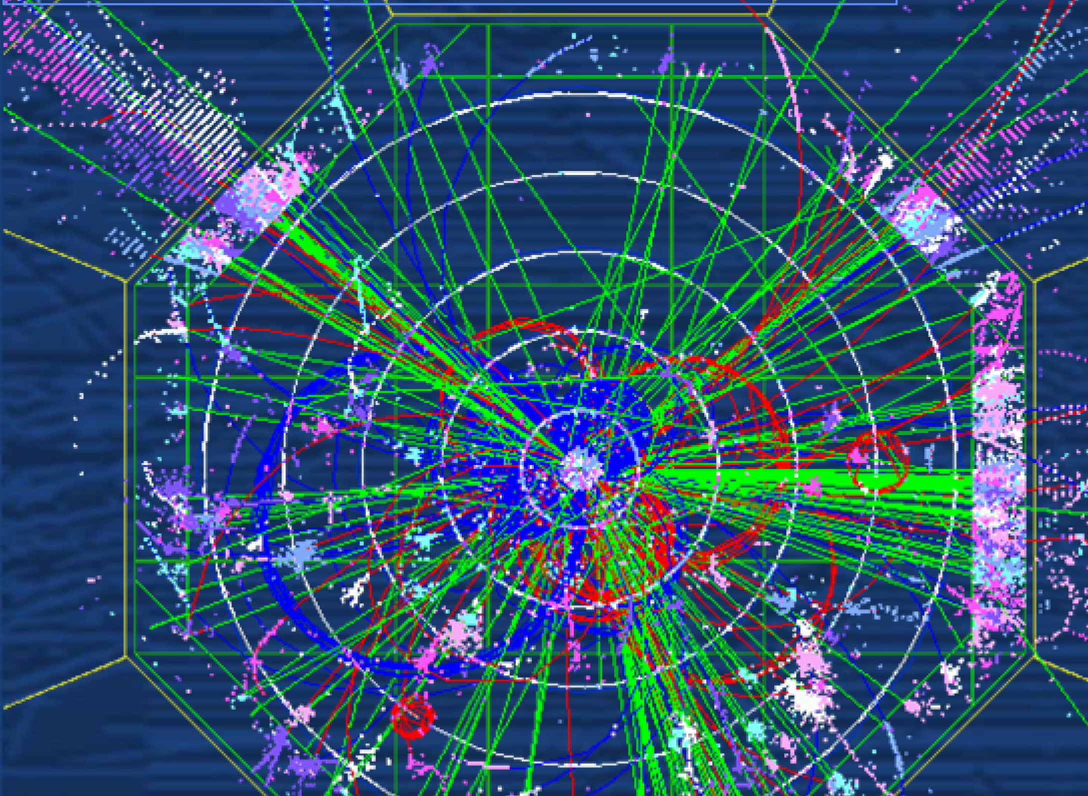
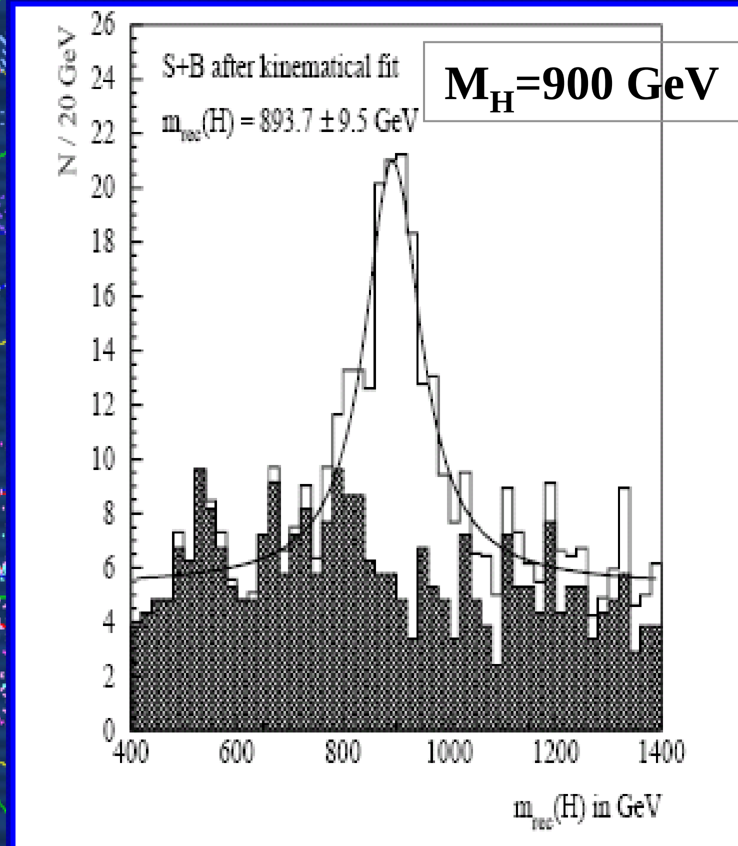


Heavy Higgs Bosons: $H^{\pm}$ at 3 TeV

$e^+e^- \rightarrow H^+H^- \rightarrow tbtb$ at 3 TeV





$$\frac{\delta M_H}{M_H} = 0.01$$

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

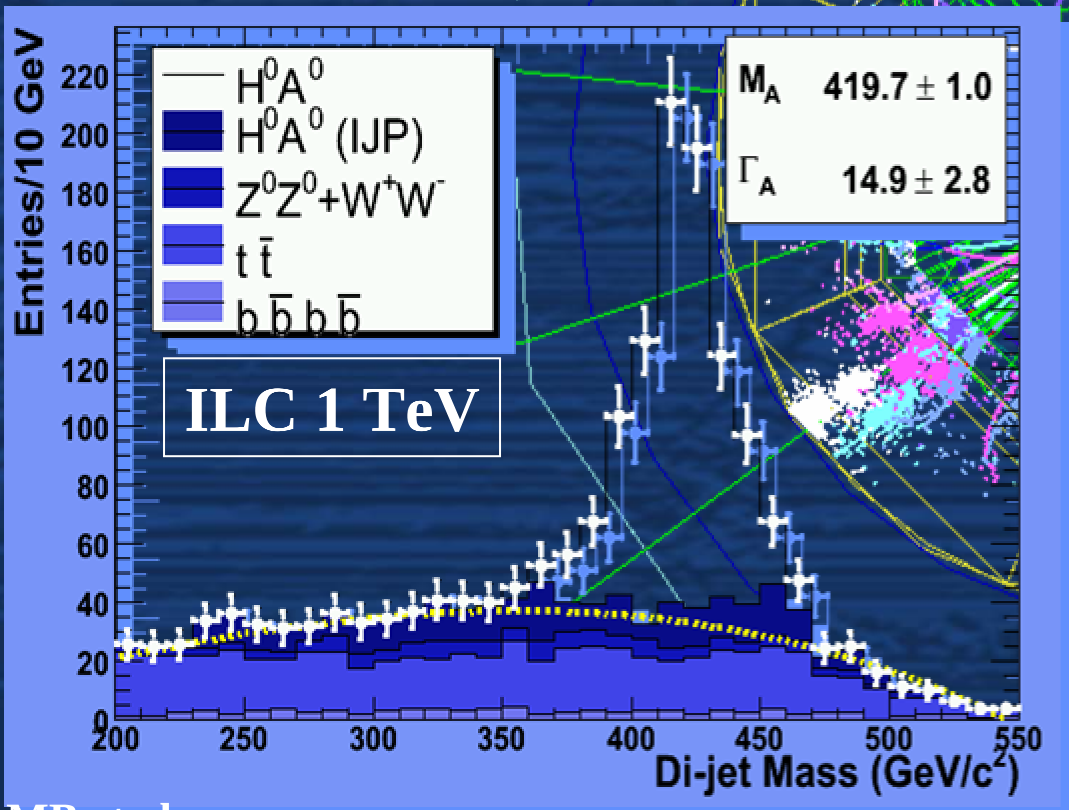
Ferrari,
in CERN-2004-005

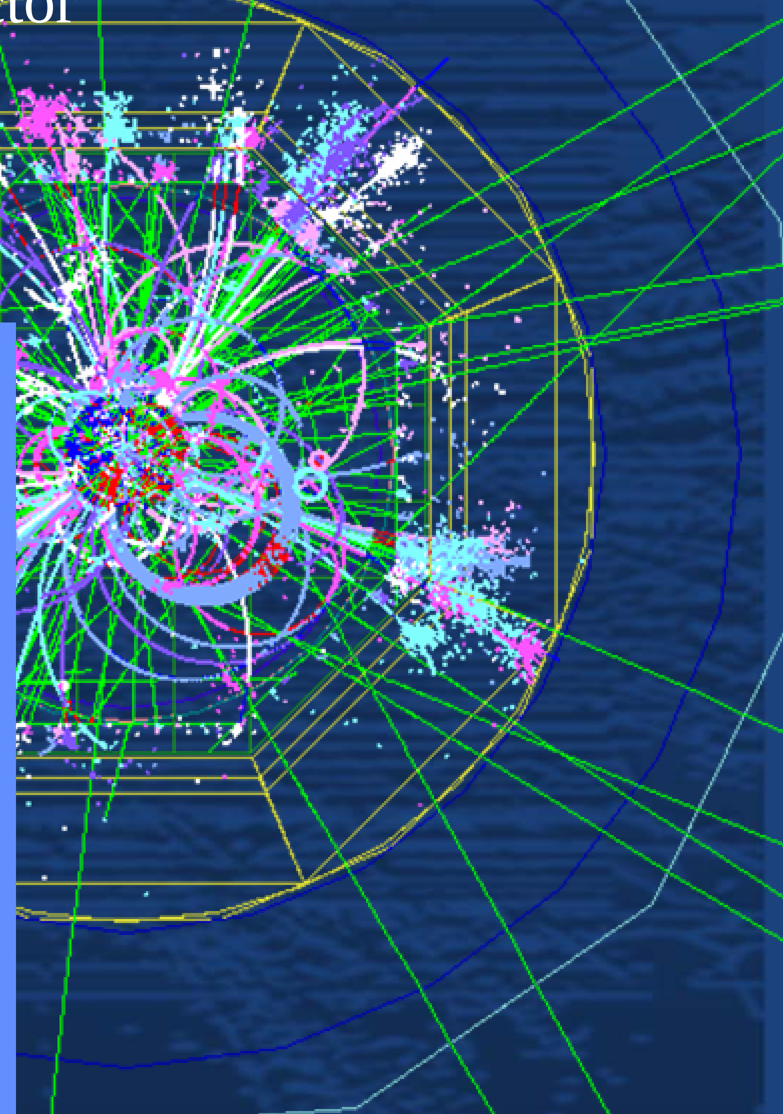
Heavy Higgs Bosons: H^0A^0 at 1 TeV

Analysis of 1 TeV Events with ILC Detector

Study $e^+e^- \rightarrow HA \rightarrow bbbb$ with LDC

$\Omega_{CDM}h^2$ gives tight requirement of $M_A \pm 1\,\mathrm{GeV}$





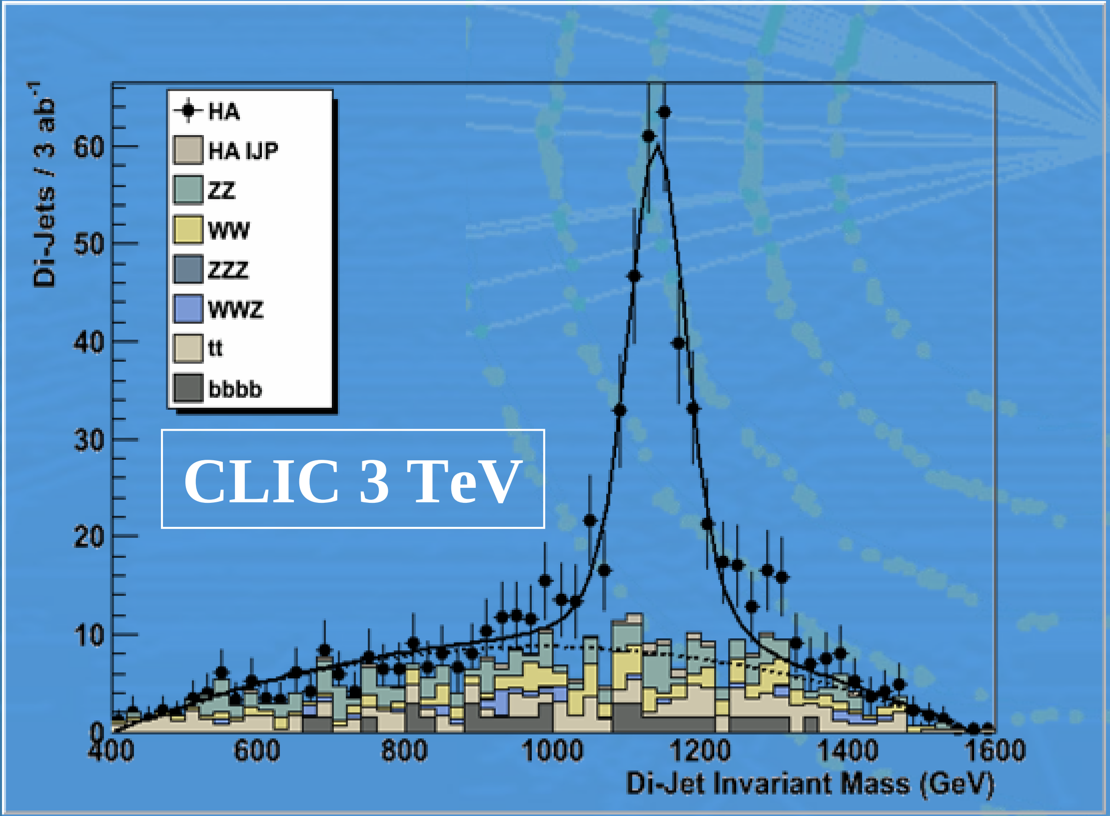
MB et al
PRD 78 (2008)

Heavy Higgs Bosons: H^0A^0 at 3 TeV

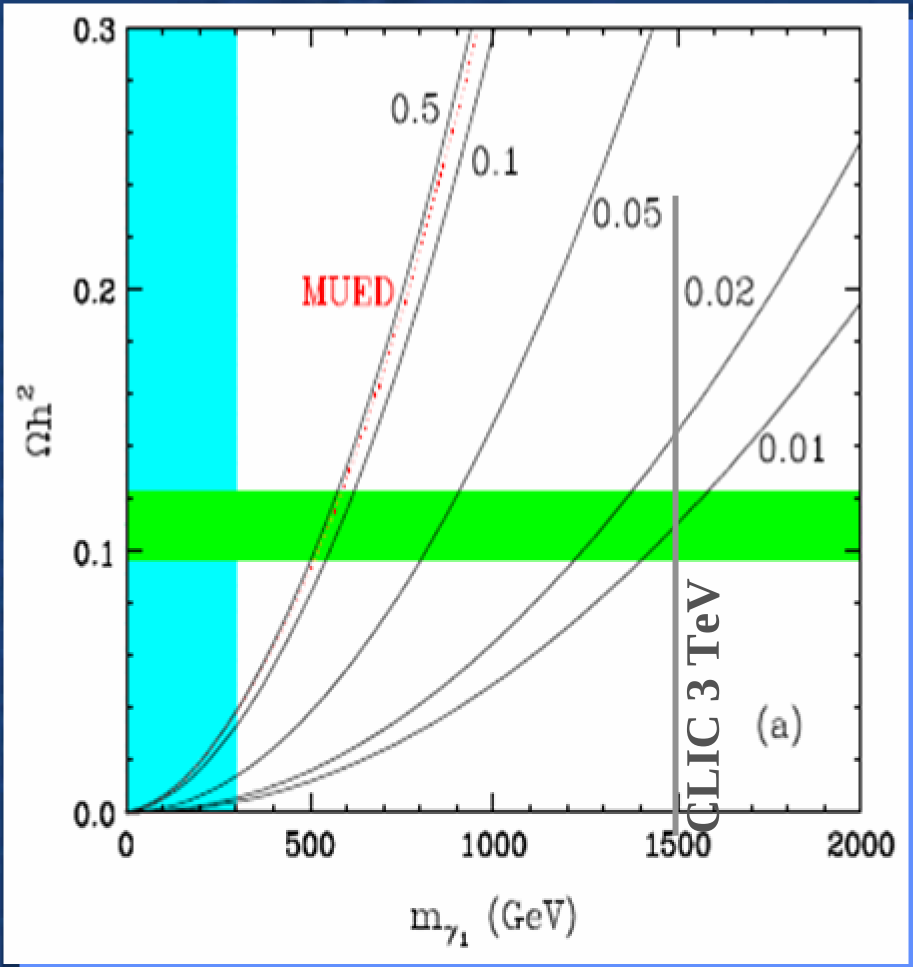
Analysis of 3 TeV Events with CLIC Detector

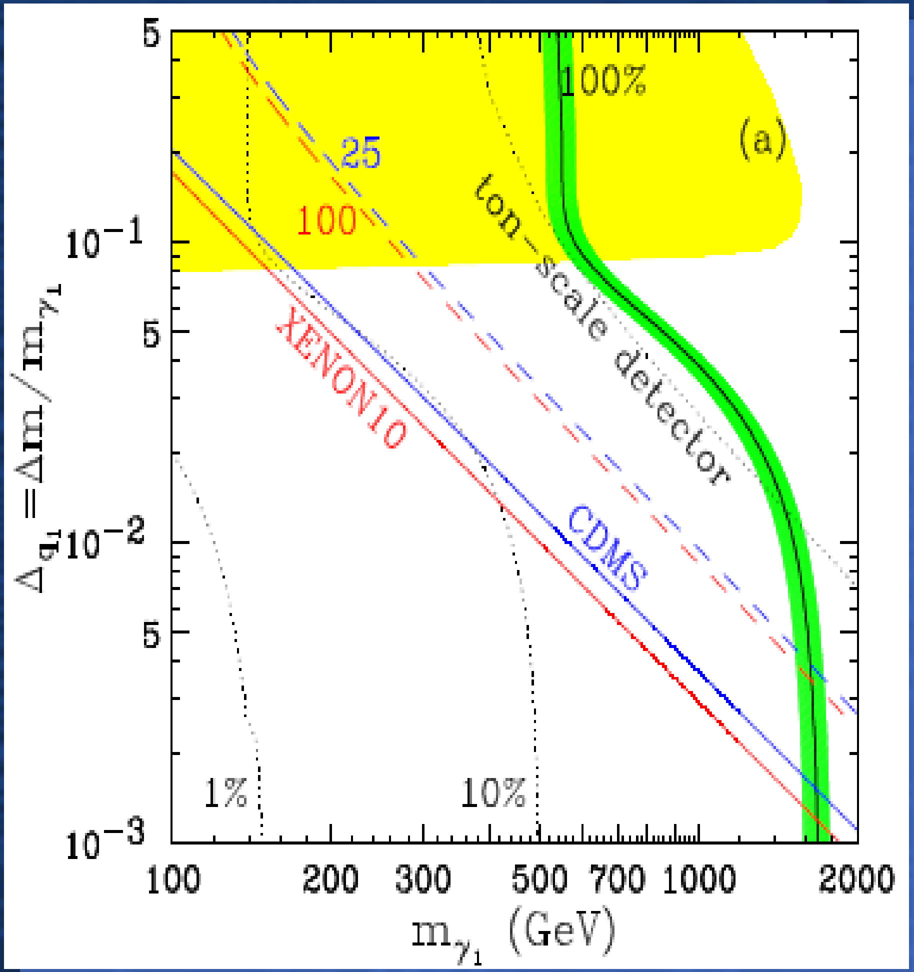
Study $e^+e^- \rightarrow HA \rightarrow bbbb$ with modified ILD

$M_A = (1140 \pm 4.5)\text{GeV}$



Kaluza-Klein Dark Matter





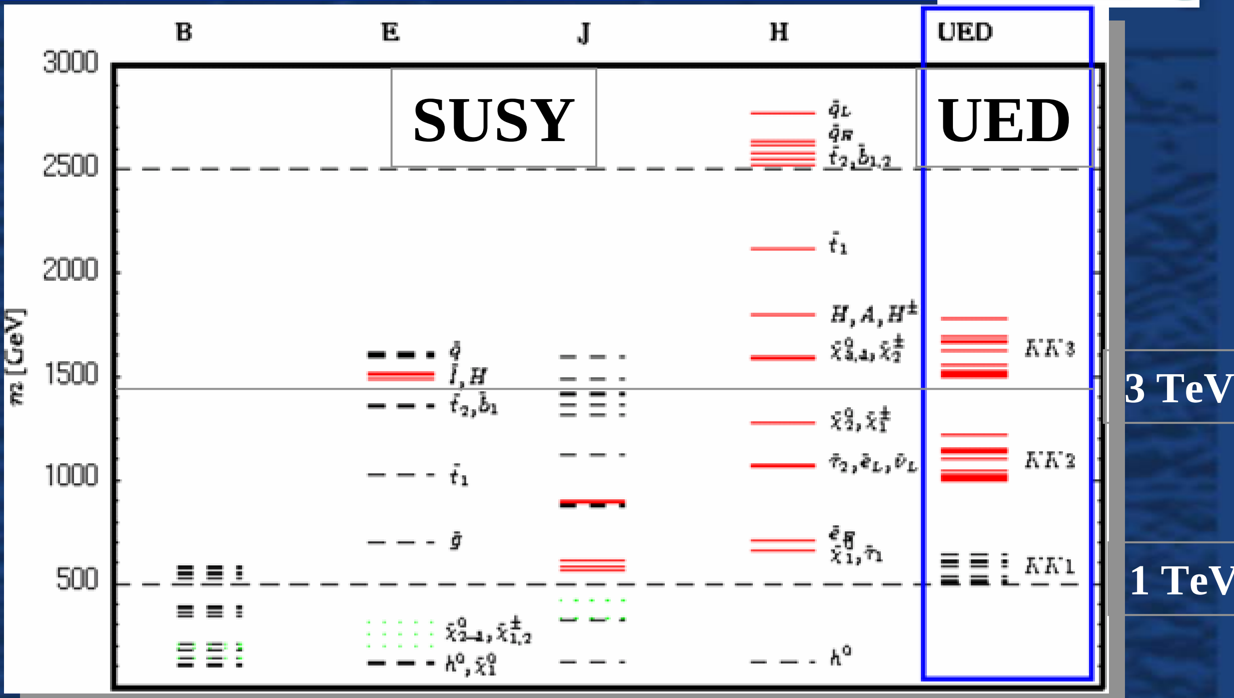
Tait, Servant
NP B650 (2003)

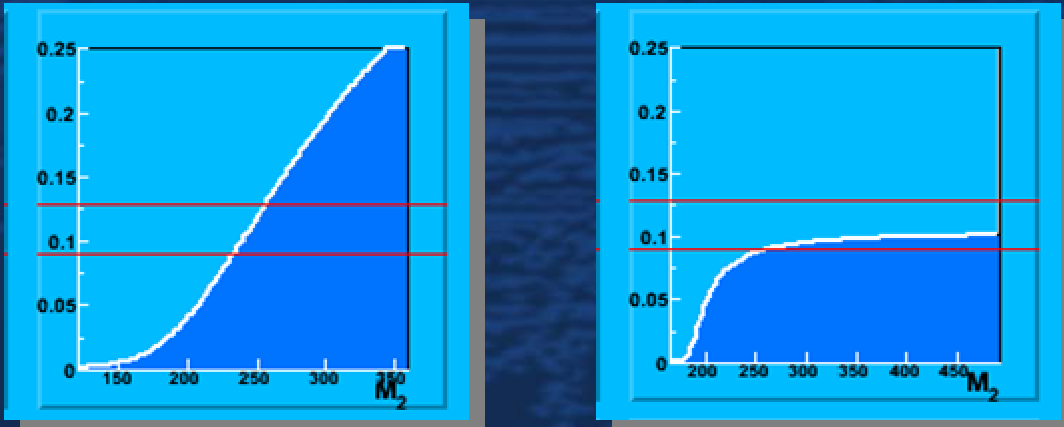
Arrenberg et al.,
PRD78 (2008)

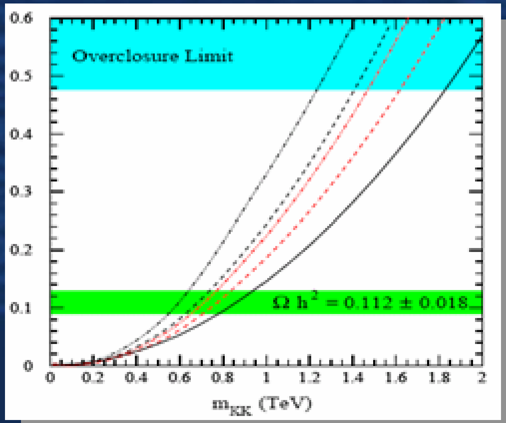
Establishing the Nature of New Physics

Given limited nb. of observable particles determine the nature of new physics:

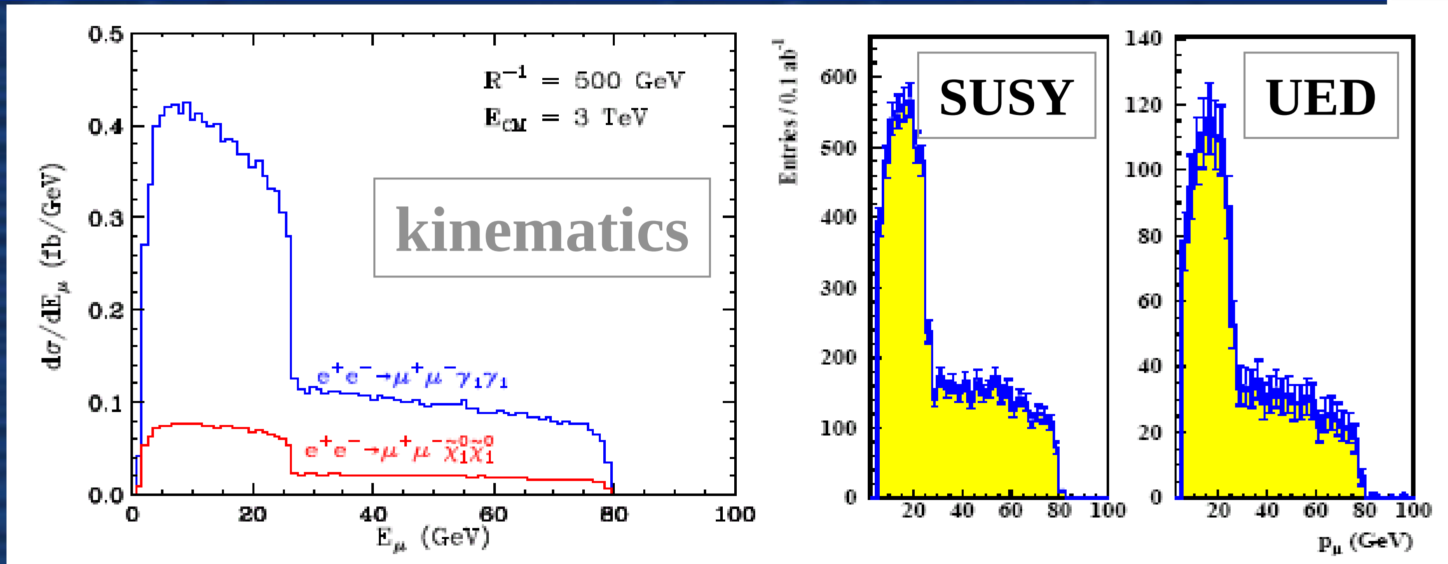
Example:
tell UED from SUSY

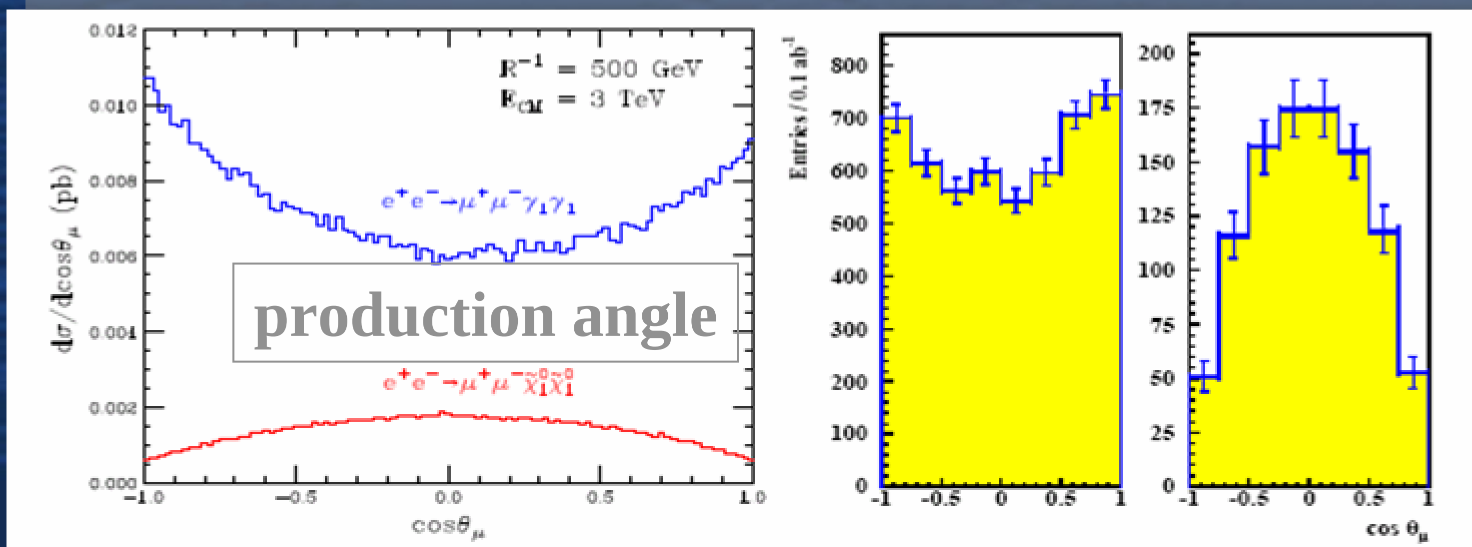






Establishing the Nature of New Physics

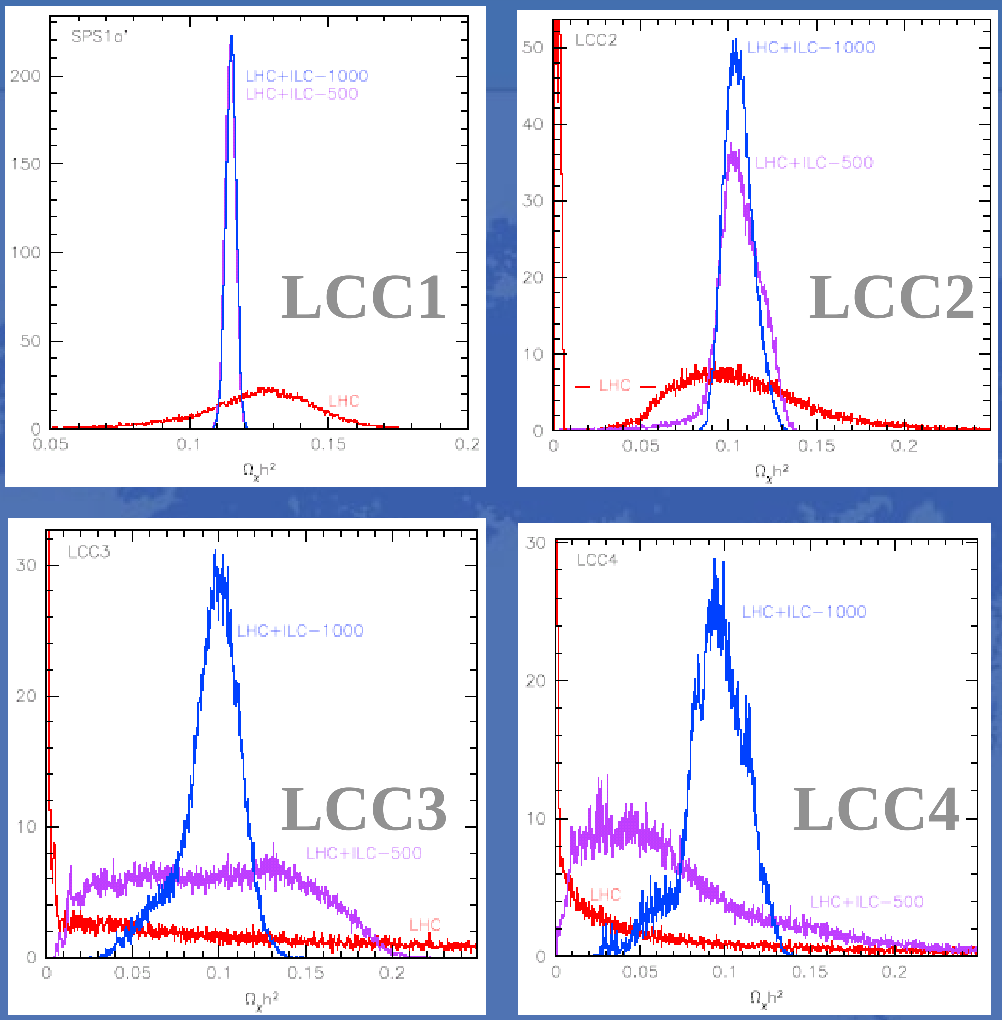




MB et al,
JHEP 0507 (2005)

Understand SUSY-Cosmology Connection

Dark Matter Density



Baltz, MB, Peskin, Wiszanski, PRD74 (2006)

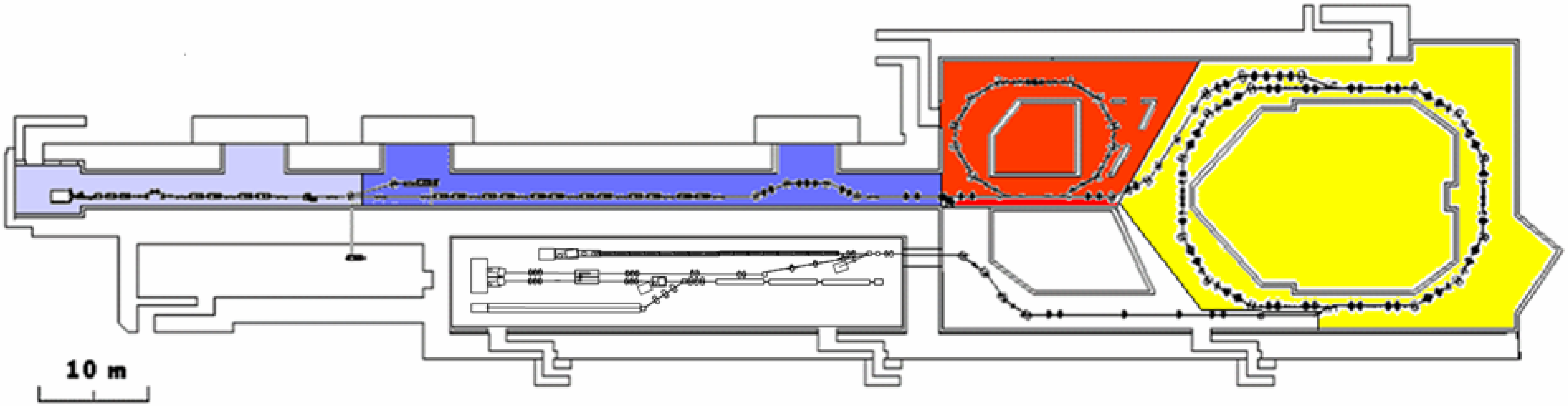
LC precision motivated by need to match Ωh^2 accuracy from CMB data (± 3%):

	Ωh^2	LHC	ILC-500	ILC-1000
LCC1	0.192	7.2%	1.8%	0.24%
LCC2	0.109	82.%	14.%	7.6%
LCC3	0.101	167%	50.%	18.%
LCC4	0.114	405%	85.%	8%
	σv			
LCC1	0.0121	165.%	54.%	11.%
LCC2	0.547	143.%	32.%	8.7%
LCC3	0.109	154.%	178.%	10.%
LCC4	0.475	557.%	228.%	20.%
	$\sigma(\chi p)$			
LCC1	0.418	44.%	45.%	5.7%
LCC2	1.866	62.%	63.%	22.%
LCC3	0.925	184.%	146.%	8.6%
LCC4	1.046	150.%	190.%	7.5%

European Organization for Nuclear Research

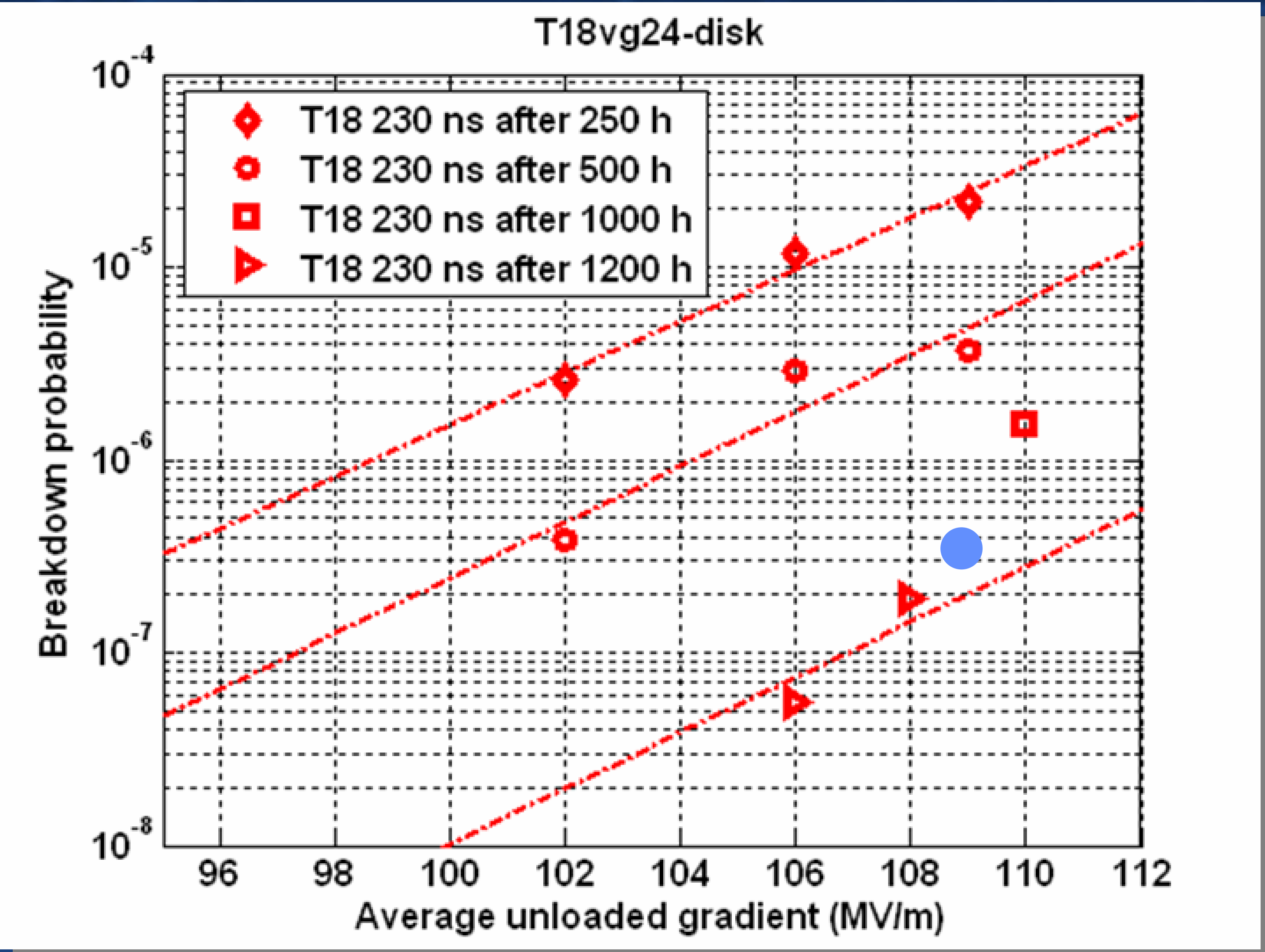
CLIC Test Facility (CTF3) to demonstrate:

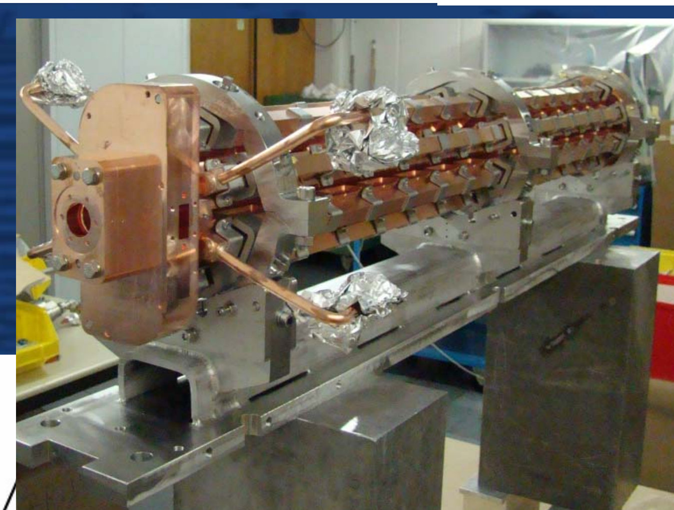
- drive beam generation
- RF power production
- two-beam acceleration and reliability of structures:

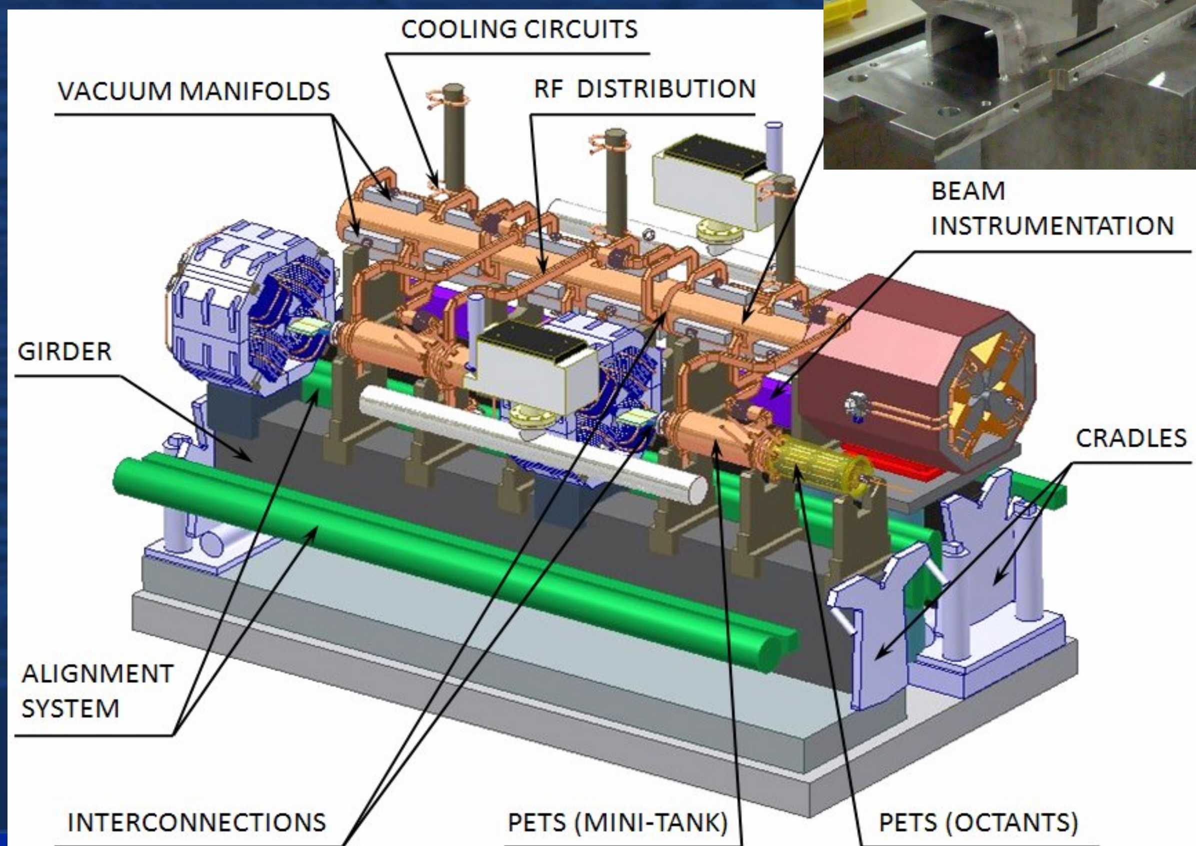


European Organization for Nuclear Research

Nominal Structure Performance Demonstrated

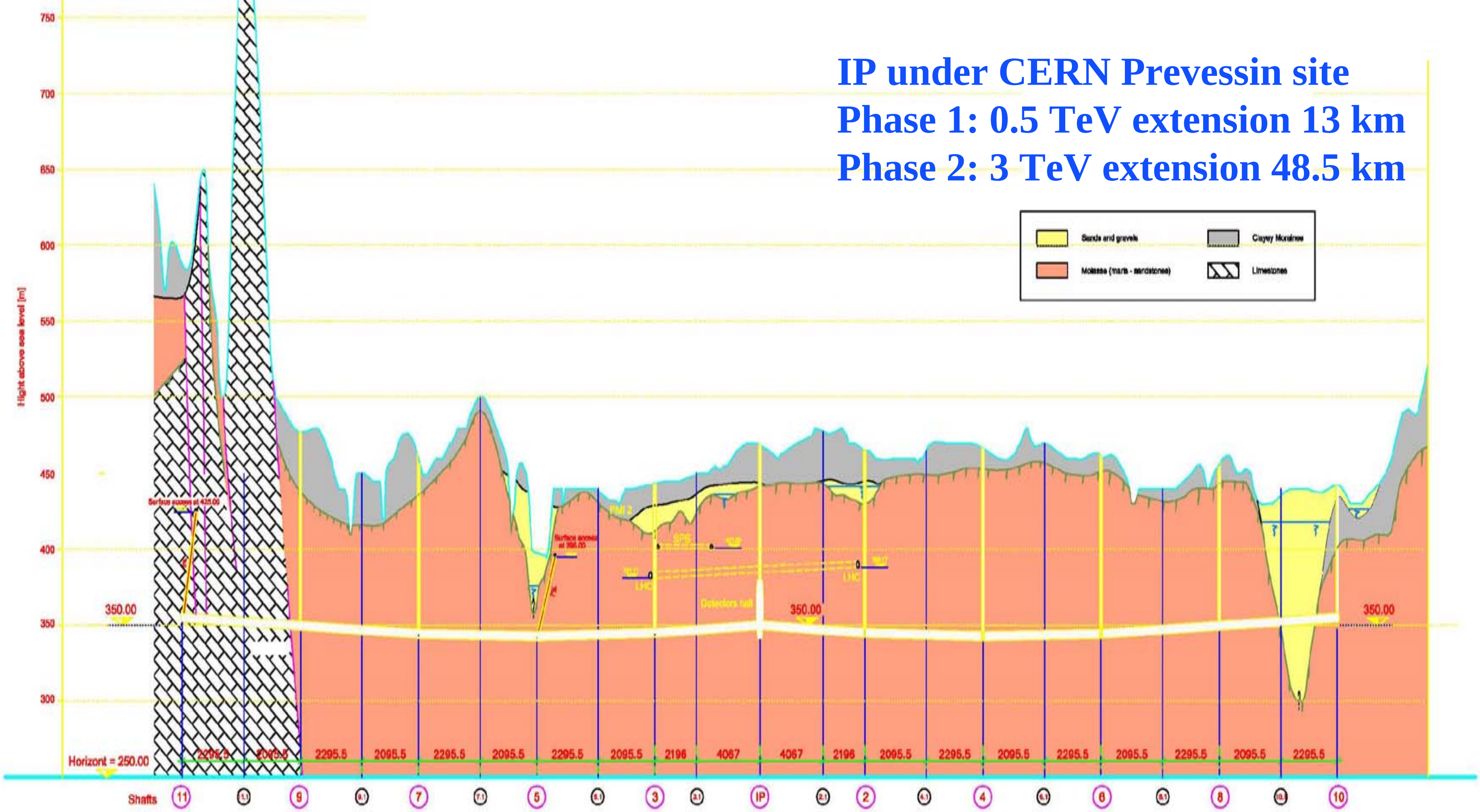





COOLING CIRCUITS
VACUUM MANIFOLDS
RF DISTRIBUTION
BEAM INSTRUMENTATION
GIRDER
CRADLES
ALIGNMENT SYSTEM
INTERCONNECTIONS
PETS (MINI-TANK)
PETS (OCTANTS)

Longitudinal section of a laser straight Linear Collider on CERN site

IP under CERN Prevessin site
Phase 1: 0.5 TeV extension 13 km
Phase 2: 3 TeV extension 48.5 km



Physics and Experimentation at (and beyond) 1 TeV

BERKELEY LAB

Physics Signatures

Independent of Physics Scenarios can we identify Physics Signatures most relevant to e^+e^- physics at 1 TeV and beyond ?

Is the study of these Physics Signatures enabled by the Accelerator Parameters ?

Reach and Accuracy

Is the Physics Reach complementary and supplemental to the LHC capabilities ?

Is the signature e^+e^- Accuracy preserved at 1 TeV and beyond ?

Experimental Issues

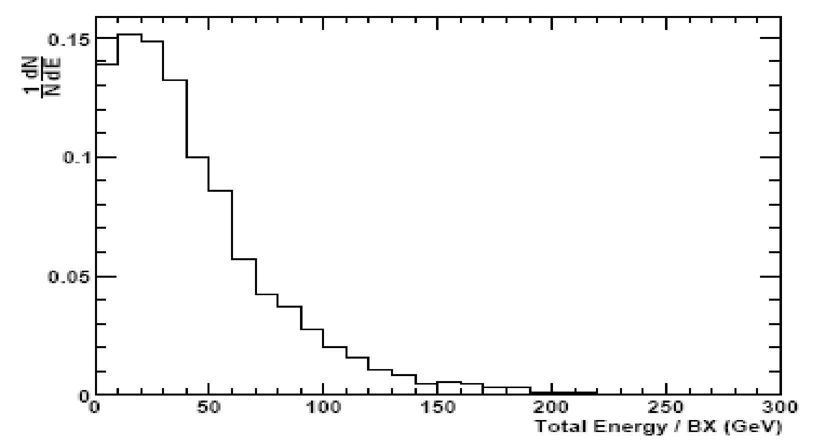
Is Particle Flow applicable to multi-TeV collisions ?

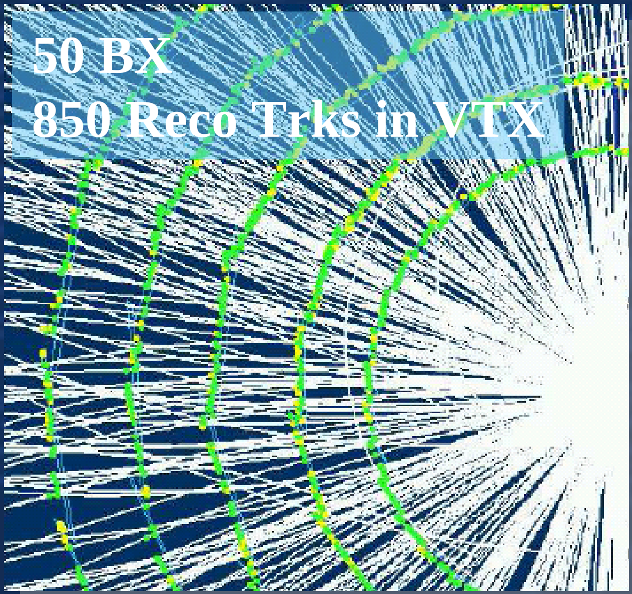
Are the Forward Regions exploitable ?

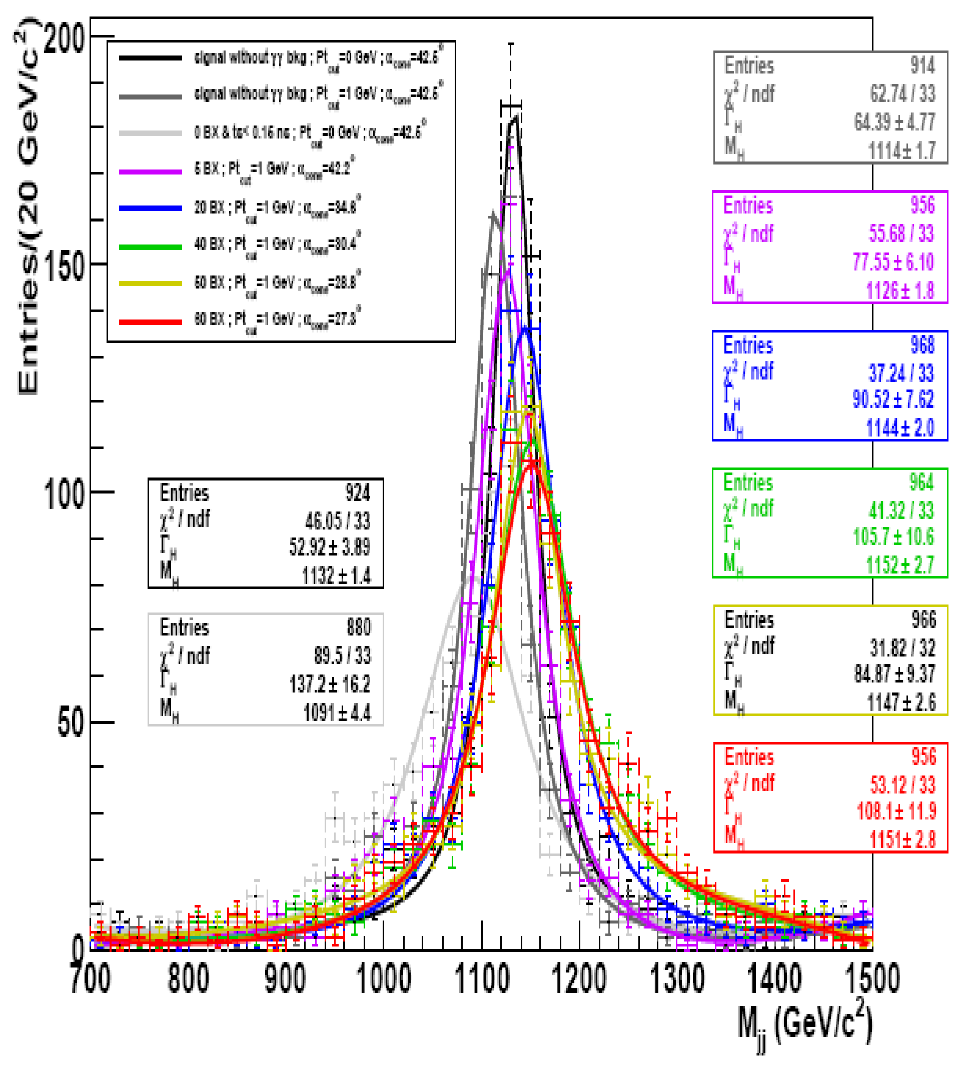
Is accurate Jet Flavour Tagging possible ?

$\gamma\gamma \rightarrow$ hadrons background

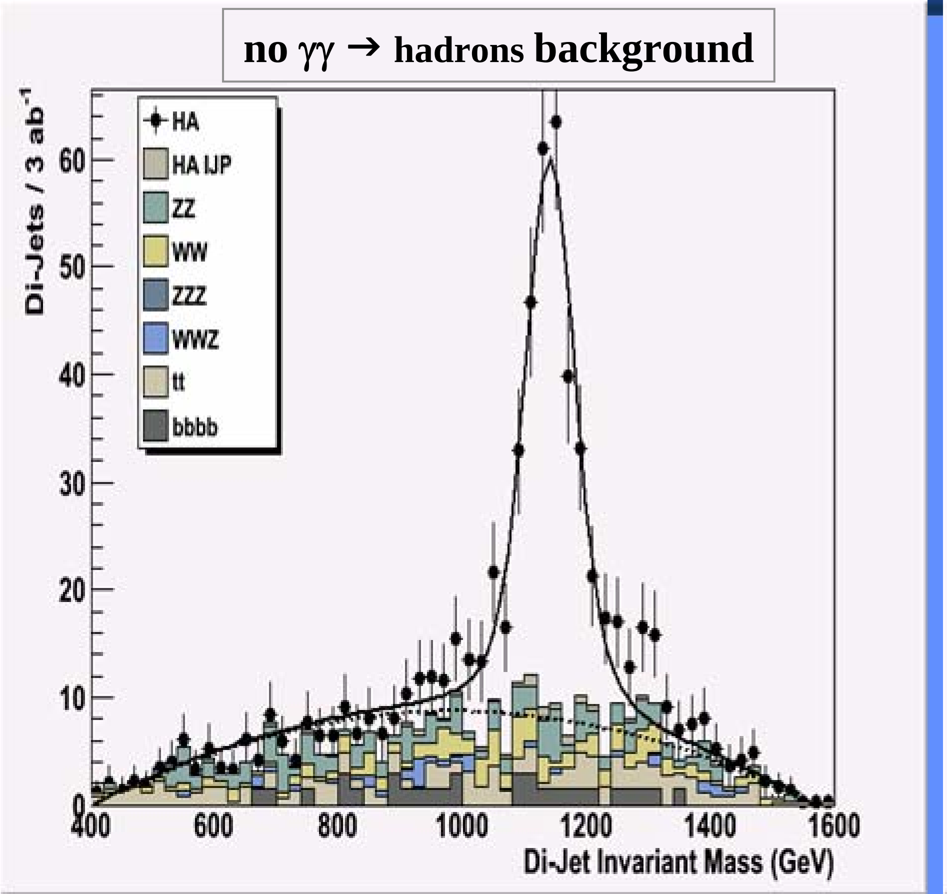
Additional energy dumped in event: 30 GeV / BX = 9.4 TeV / train

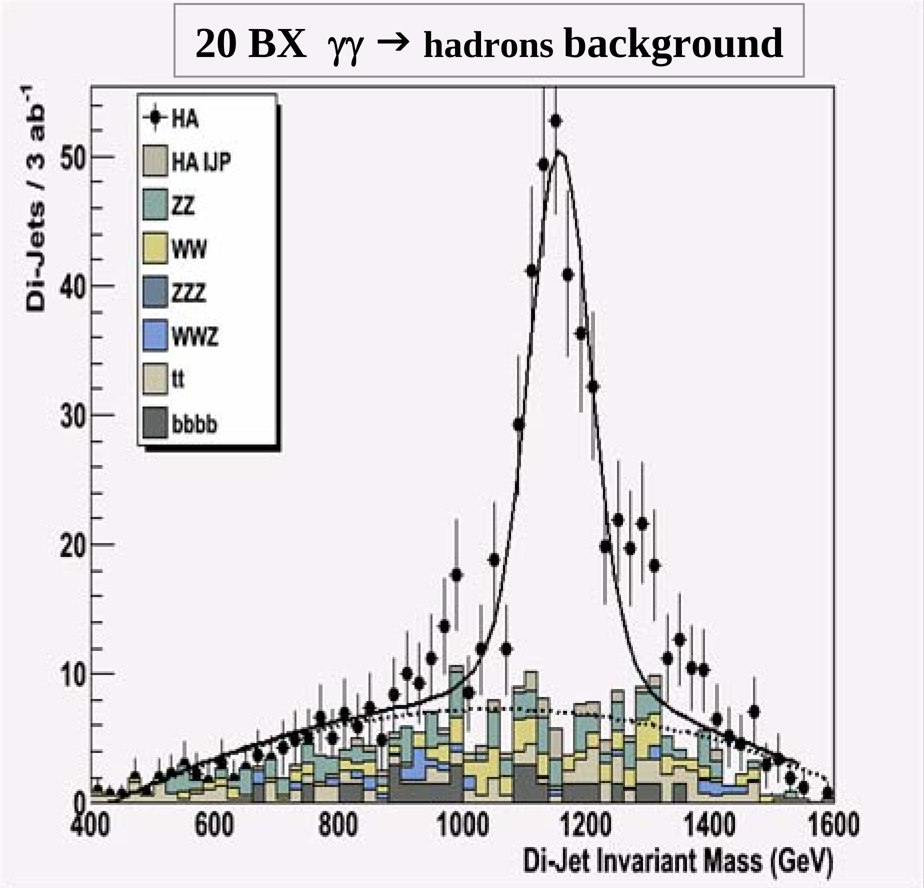




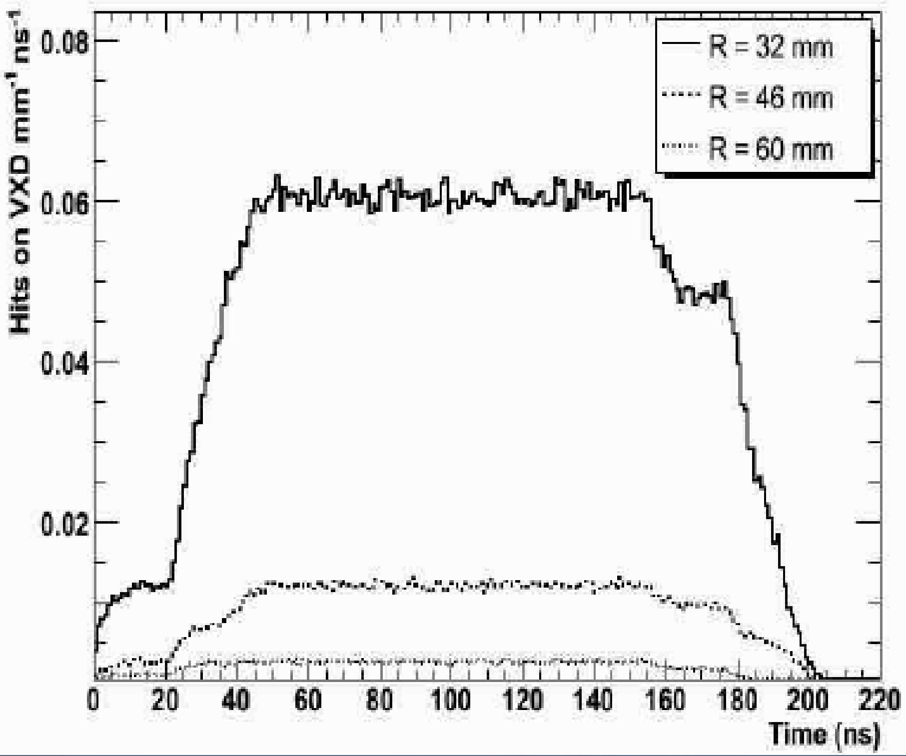


γγ → hadrons background

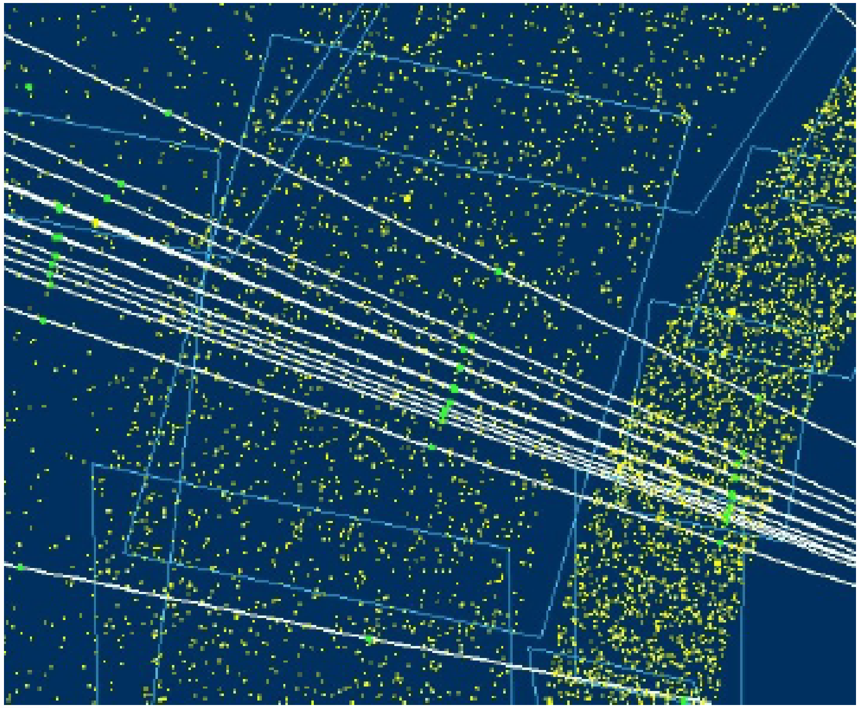




Hit Density on VTX vs. time
from GuineaPig+Mokka Simulation



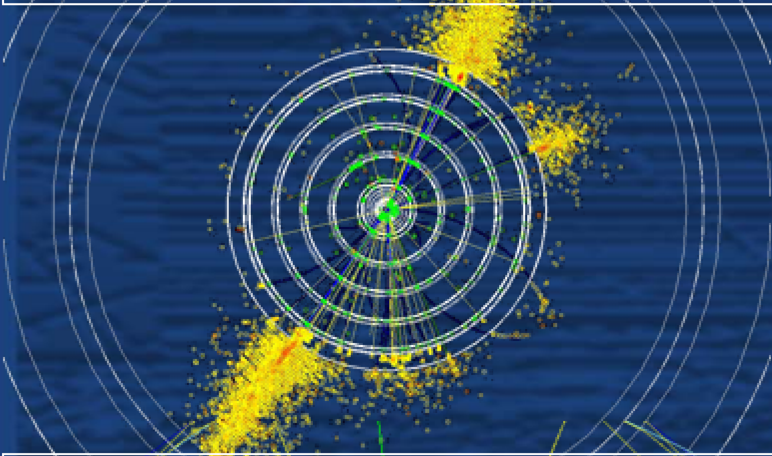
Physics and Pair Hits on VTX
Mokka simulation + Marlin reconstruction



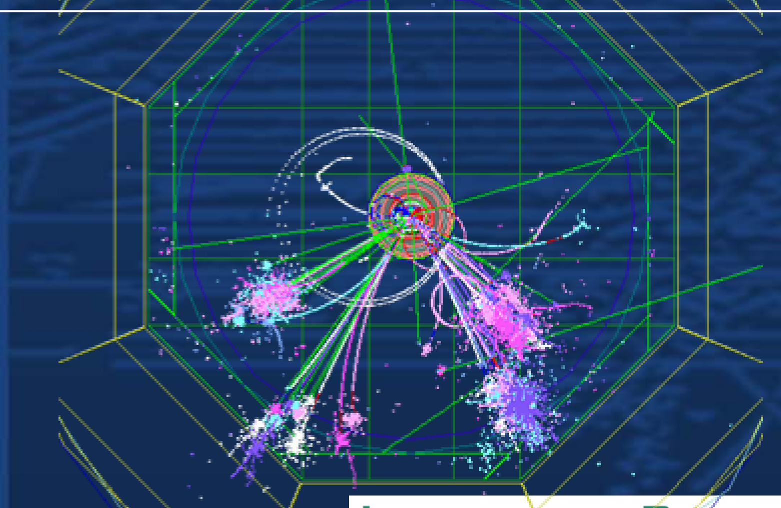
Calorimetry

Charged-Neutral Particle Distance in Calorimeters

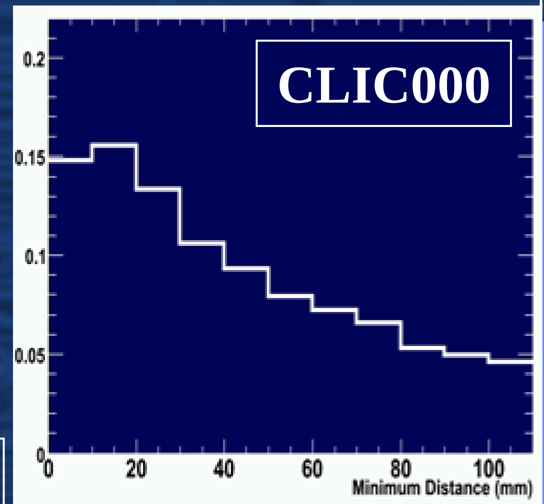
$e^+e^- \rightarrow$ WW/ZZ at 3 TeV

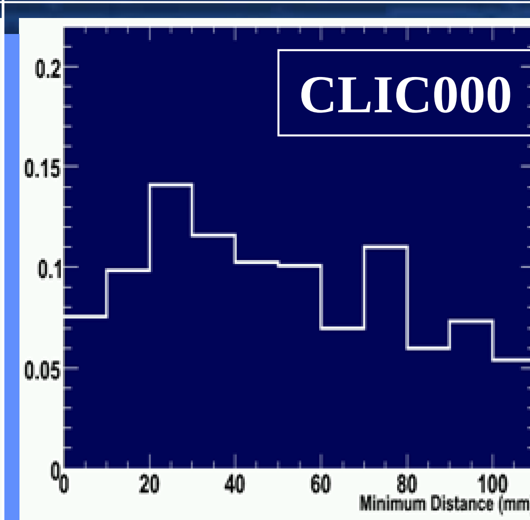


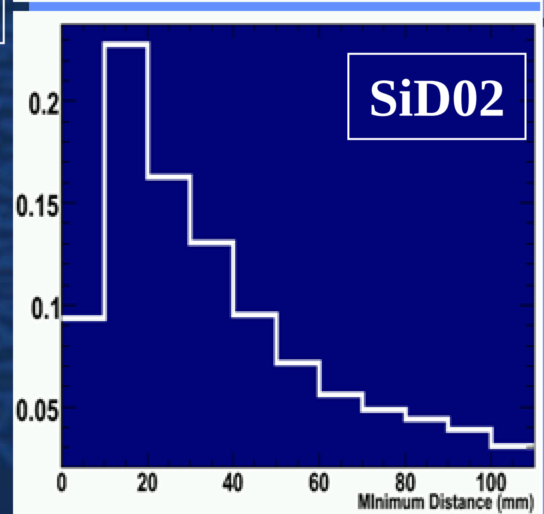
$e^+e^- \rightarrow ZZ\nu\nu$ at 3 TeV

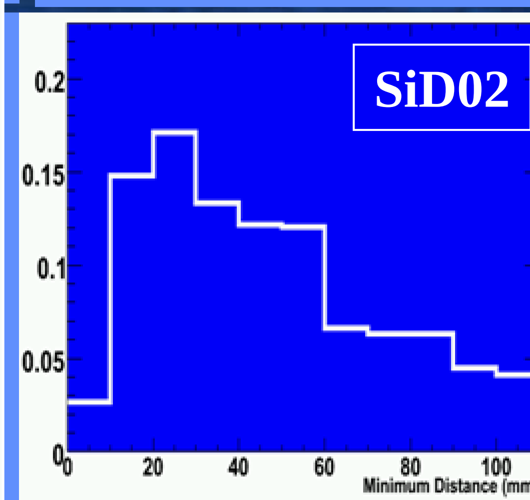


ECal	HCal



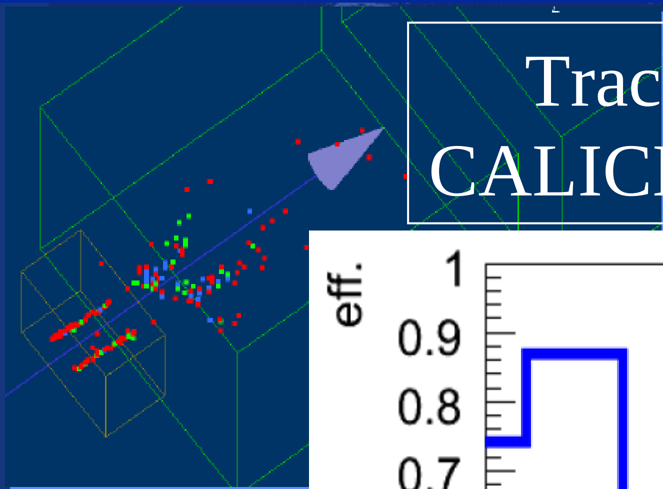


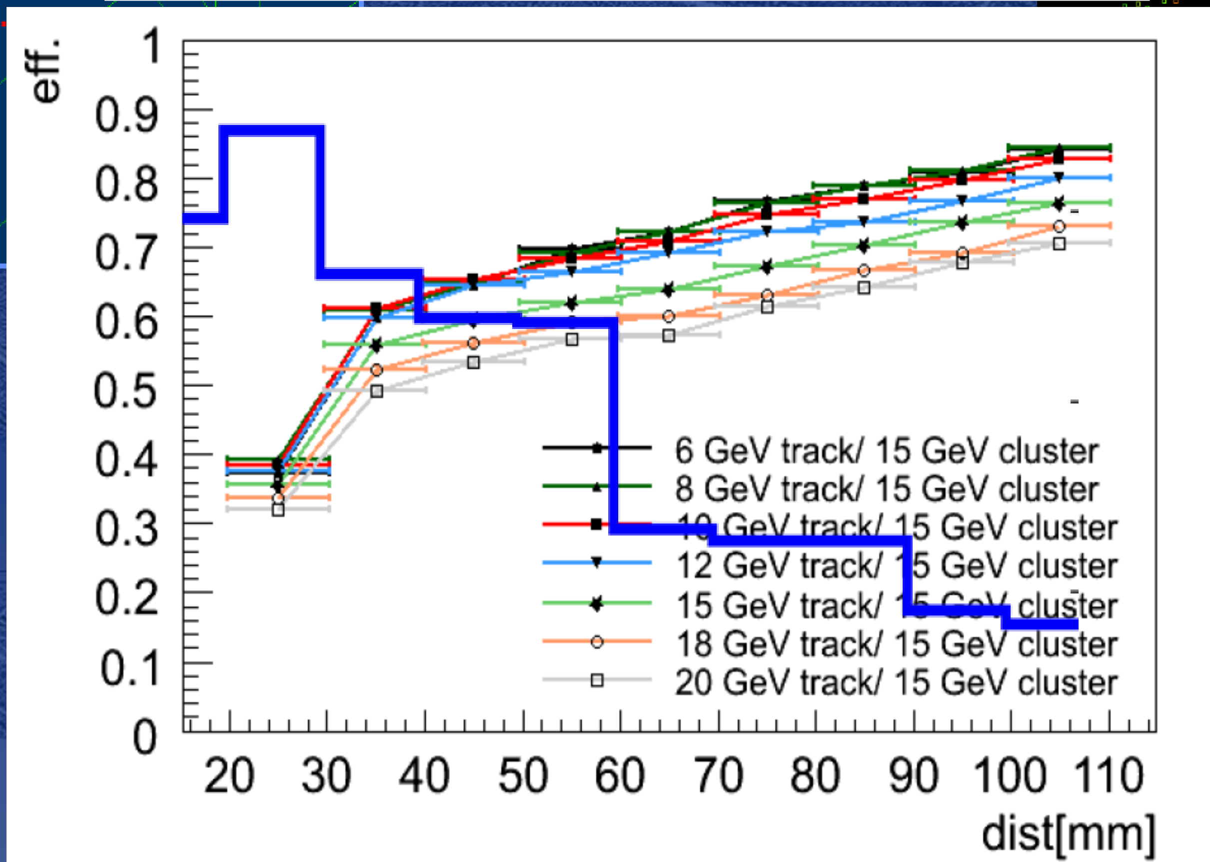


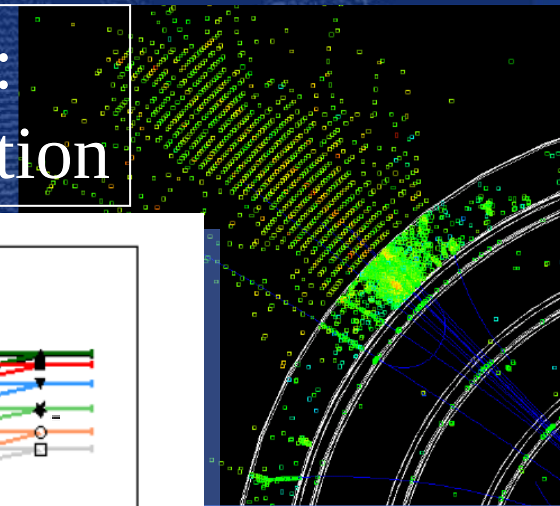


Calorimetry

Track - Shower separation: CALICE data – CLIC Simulation

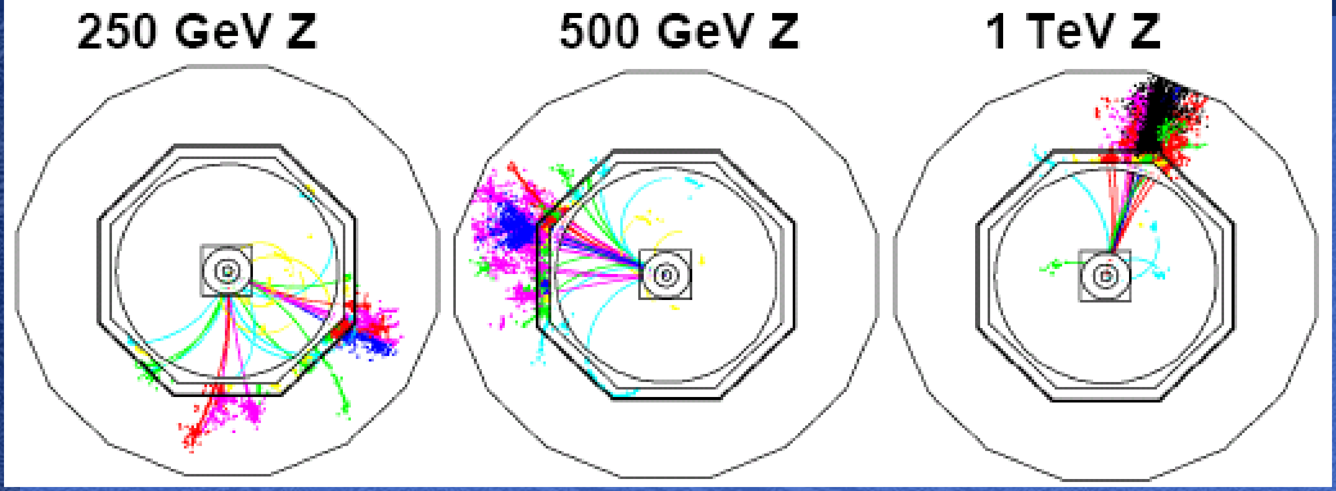


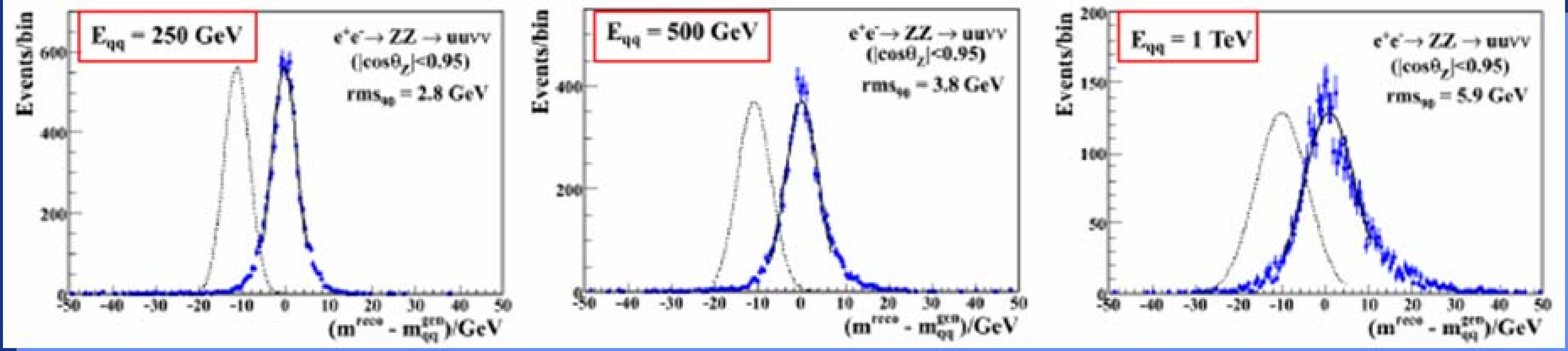




CALICE Data
D Ward
CLIC G4 ZZνν
MB

Calorimetry





Waiting for first LHC data, there is a compelling case for vigorously pursuing a technology able to offer e^+e^- collisions at, and beyond, 1 TeV with high luminosity;

CLIC offers unmatched energy range from 0.5 TeV up to 3 TeV making it an extremely appealing option for accessing the energy scale of LHC and beyond with e^+e^- collisions;

Physics potential at 1 – 3 TeV appears very rich, preserving the signature e^+e^- features of cleanliness and accuracy represents a challenge, which needs a combined effort from physics benchmarking, detector R&D, machine parameter optimisation;

Optimal balance between very high precision at high energy and high precision at very high energy can be assessed only with first LHC results at hand. For now enough to do tackling the issues above.

European Organization for Nuclear Research

CLIC09 Workshop, CERN, October 12-16, 2009

Discuss physics signatures, experimental issues and detector R&D specific to multi-TeV collisions;

Launch study for the CLIC Conceptual Design Report (to be finalised by end 2010);

Expect to engage a broad community bridging from ILC expertise to LHC preparation;

Compelling case to study physics and experimentation issues unexplored by ILC and LHC studies (time stamping, fwd detection, paradigms for optimal event reconstruction, ...);

Three days of Physics and Detector parallel sessions + interaction with machine groups.