SUSY @ the Large Hadron Collider

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Outline

Brief SUSY Introduction

- A 36 years old theory
- On SUSY

Search, Discovery & Characterization

- Canonical SUSY program as a function of luminosity
- Interplay of inclusive and exclusive measurements
- Results from inclusive measurements
- Reconstruction
- Prospects for Dark Matter

Preparation For First Data

- From Detector Projects and Pieces to Physics Data
- History

Outline

Initial Conception

Problem

Introduce fermions in string theory

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Introduce fermions in string theory

Solution

1971, P. Ramond:Dual Theory for free fermions, DOI: 10.1103/PhysRevD.3.2415

Superspace

Particles in space

- Bosons: commuting fields, integer spin, bose-statistics
- Fermions: anticommuting fields, half-integer spin, fermi-statistics

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Superspace contains extra anticommuting coordinates θ

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Example

An electron field is written as a Taylor expansion in the extra coordinates:

$$\Phi(\chi, \theta) = s(\chi) + \theta\phi(\chi)$$

electron field in superspace =selectron(boson)+electron(fermion)

Superspace

Particles in space

- Bosons: commuting fields, integer spin, bose-statistics
- Fermions: anticommuting fields, half-integer spin, fermi-statistics

$\longrightarrow$ For each boson of spin J there is a fermion of spin $J \pm 1/2$ of equal mass

On SUSY

Not a gauge symmetry

The only and last extension of spacetime symmetry

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The only and last extension of spacetime symmetry

Broken symmetry

No mass predictions, only couplings

On SUSY

Not a gauge symmetry

The only and last extension of spacetime symmetry

with R-parity conservation

Provides a natural candidate for CDM

On SUSY

Not a gauge symmetry

The only and last extension of spacetime symmetry

predicted top mass in 1983

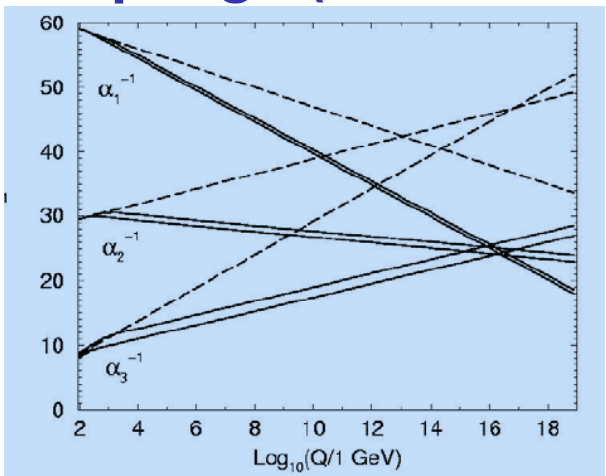
L. Alvarez-Gaume, J. Polchinski, M. Wise NPB221:495 (1983) also L. Ibanez, and J. Ellis, D. Nanopoulos, K. Tamvakis the same year
”We discuss the motivation for considering models of particle physics based on N=1 supergravity...renormalization effects drive spontaneous symmetry breaking of SU(2)xU(1) to U(1) for a top quark mass between 55-200 GeV.”

On SUSY

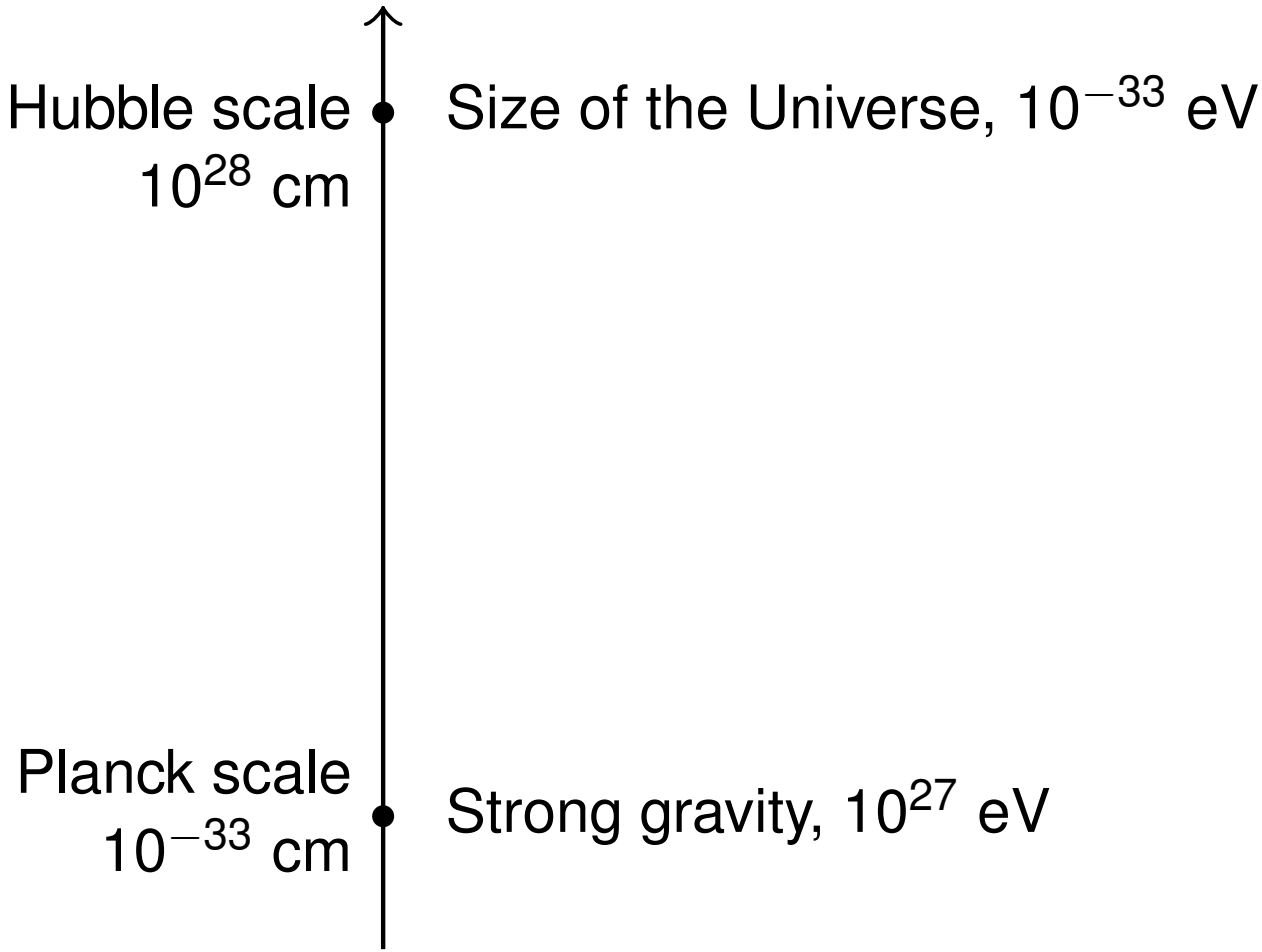
Not a gauge symmetry

The only and last extension of spacetime symmetry

couplings (better than SM) unification



Scales & Hierarchies



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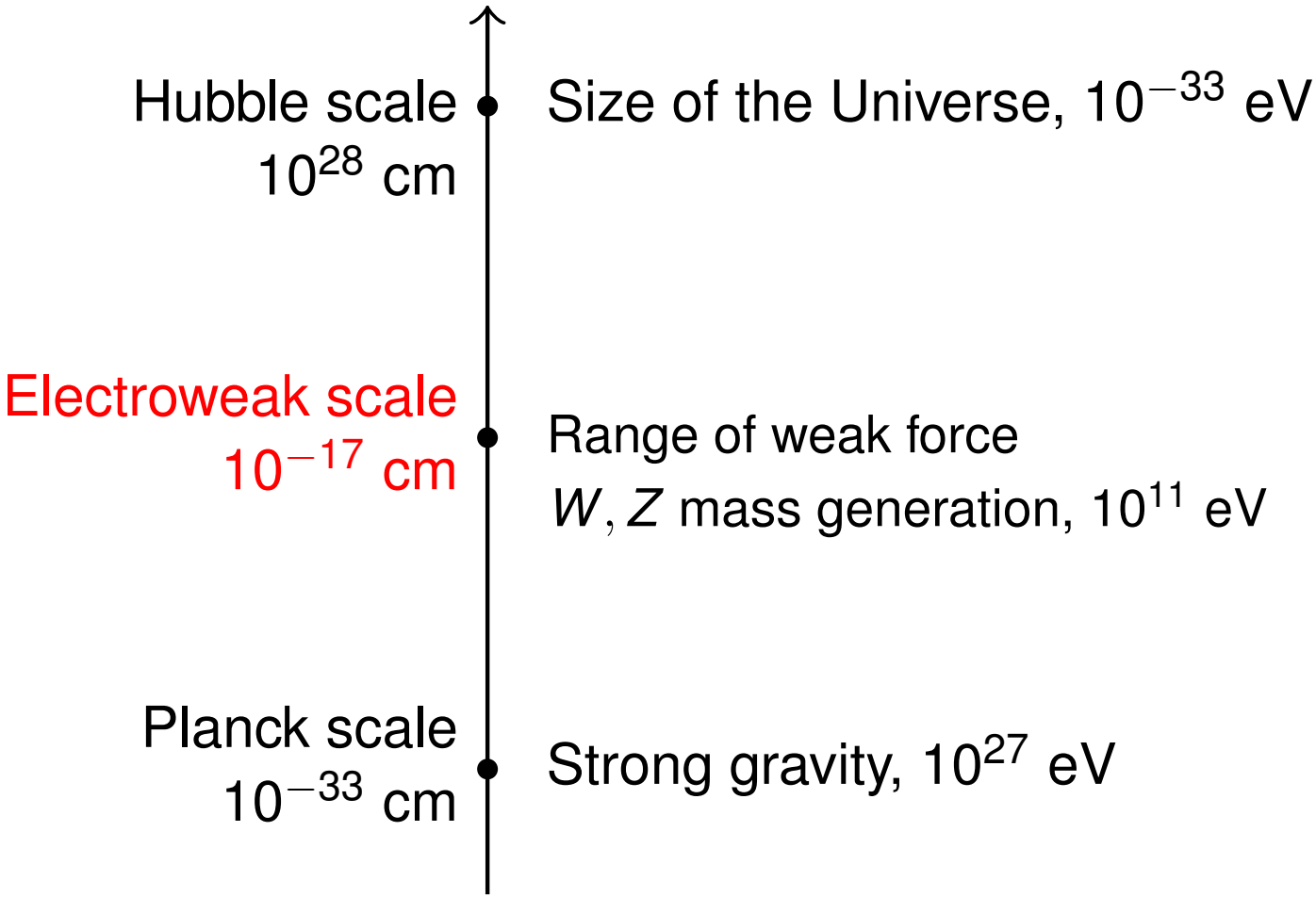

Outline

The SUSY Search Path

Discovery

Inclusive canonical searches

Characterization

Which other channels show excesses? multileptons? photons (GMSB perhaps) ? third generation particles ? spin analysis?

Reconstruction

(some) masses and decays: two LSP's in the final state $\rightarrow$ no mass peak. But kinematic endpoints (e.g. di-lepton edges) can provide masses of the particles involved.

"Measurement" of the underlying theory

We take more mass combinations, more decay chains, mass peaks once the LSP mass is known, determine the mass hierarchies, spins, &tc model parameters. How many simple measurements do we need to "nail" the theory?

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The SUSY Search Path

Inclusive

Inclusive canonical searches : large jet multiplicity, isolated leptons, large missing energy $\longrightarrow$ counting, identifying an excess.

Exclusive

specific decay processes $\longrightarrow$ [modulo reasonable assumptions] measure object combination of invariant masses and determine susy masses and parameters.

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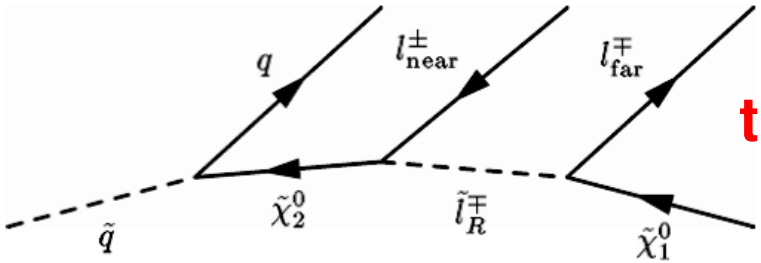

traps and pitfalls?

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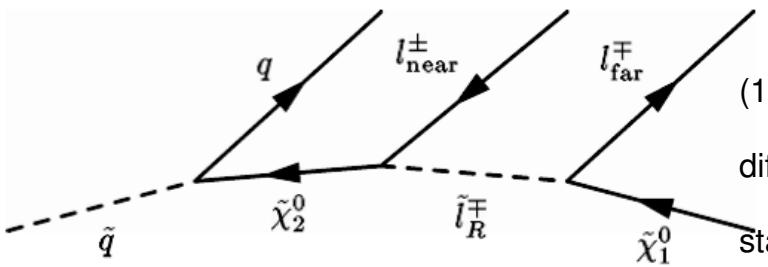

(1) is decay open? (2) kinematic edges are sensitive to mass differences (3) what other decay chains have the same final state [as the data analysis selection is designed for]? could be higher mass neutralinos or left-hand sleptons involved...

Attempts to Map Measurements to the Parameter Space

Inclusive+Exclusive

Inclusive [counting/cross section] and exclusive [end-point type] of measurements $\longrightarrow$ a-posteriori probabilities of mapping back to the parameter space (*cf* references last slide and “Olympics” series)

Attempts to Map Measurements to the Parameter Space

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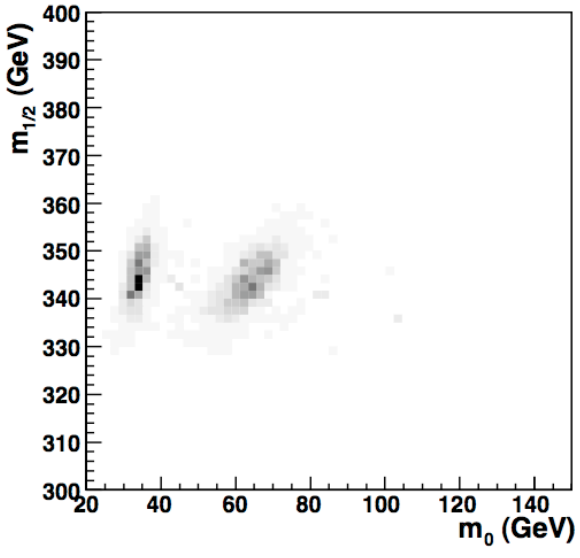
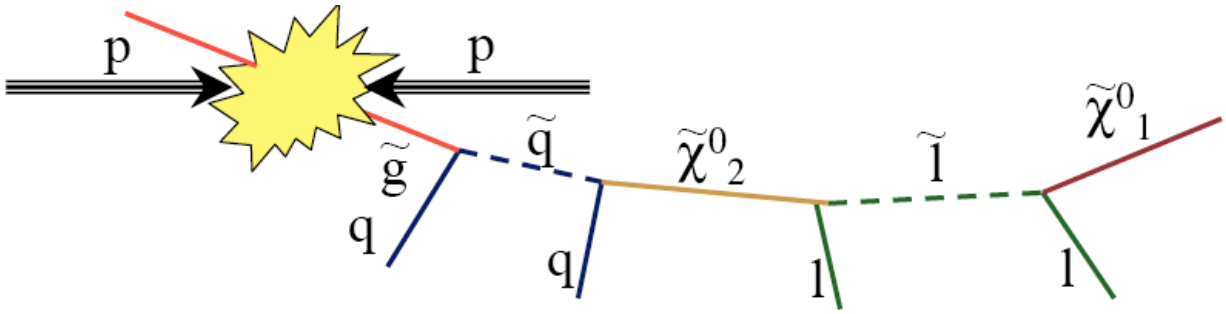
Example



[3] a-posteriori probability distribution of mSUGRA parameters using cross-section + end-point measurements in a Markov Chain Monte Carlo sampling of the parameter space. The two regions reflect the lack of knowledge of which slepton is involved in the decay chain.

Discovery: Inclusive Signatures



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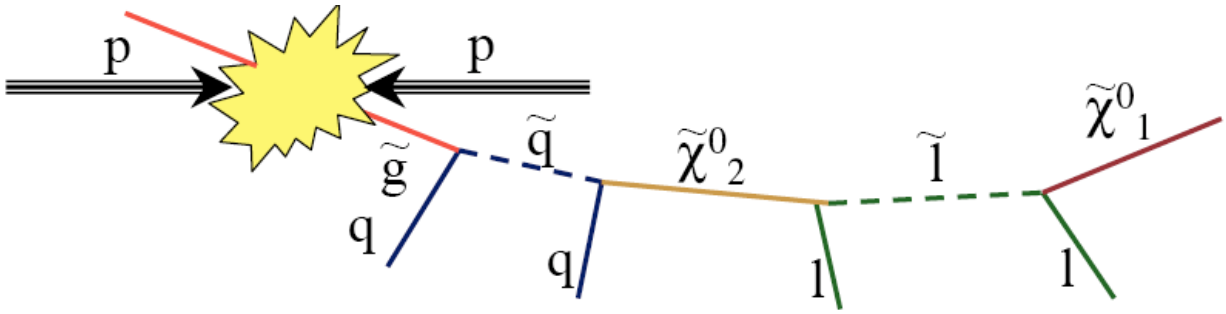
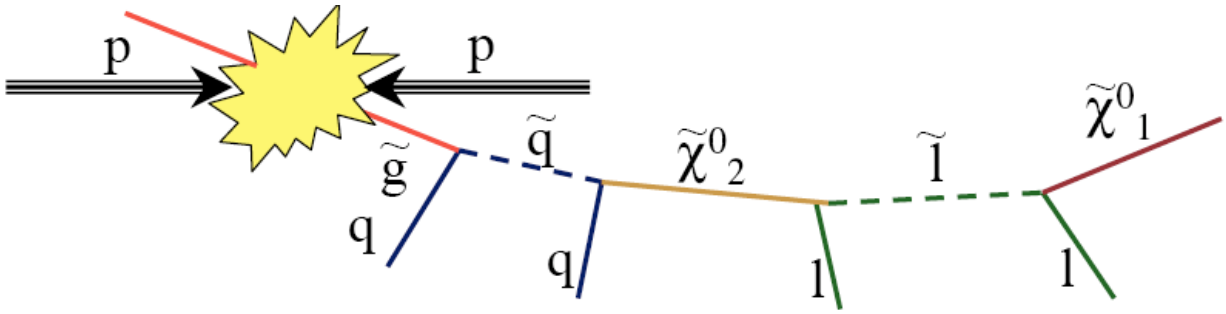


squarks and gluinos dominate production

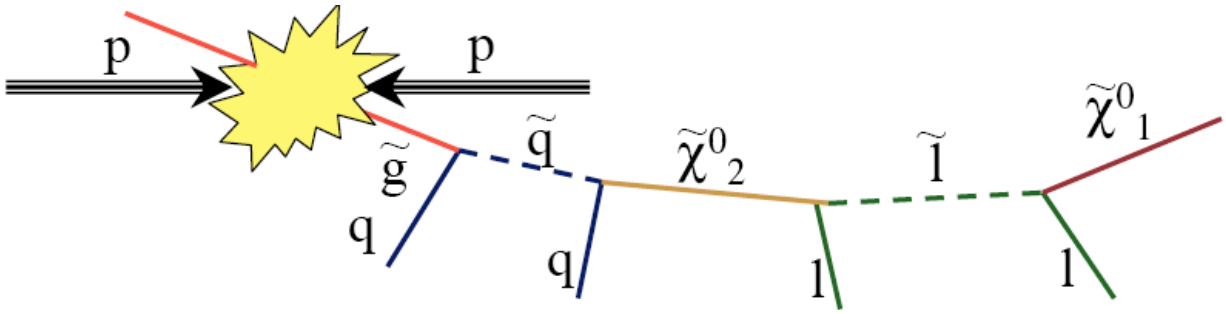
Discovery: Inclusive Signatures



Example

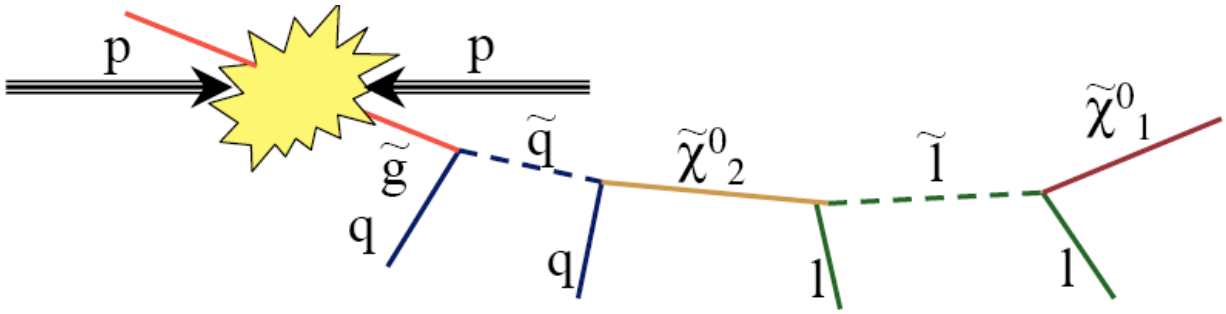
- long decay chains possible
- many high P_T objects: leptons, jets, b-jets ...
- $R-$parity conservation $\longrightarrow$ LSP stable and weakly interacting $\longrightarrow$ large missing energy

Discovery: Inclusive Signatures



The closest SM process is $t \rightarrow Wb$

Discovery: Inclusive Signatures



Example

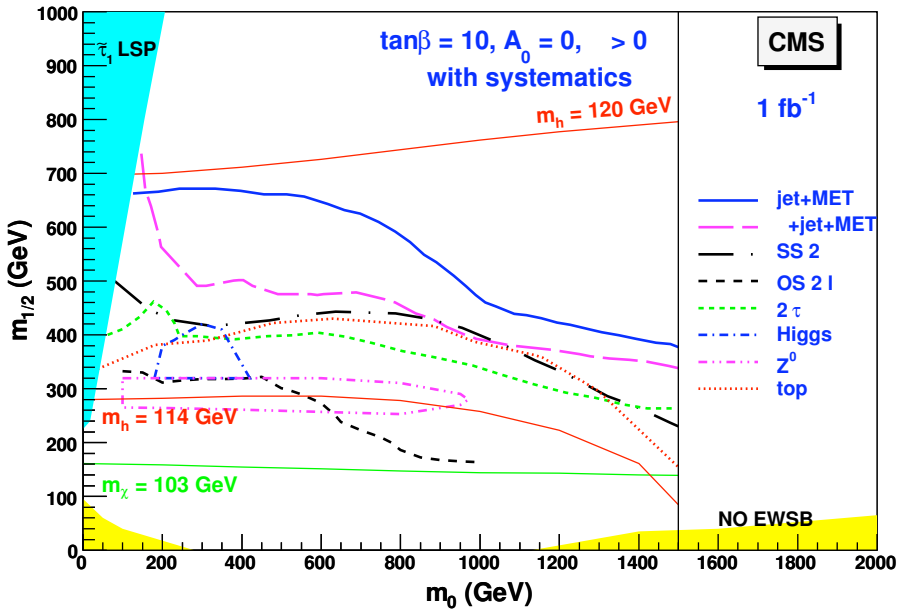
- assuming 600 GeV gluino and MSSM-like SUSY:
- large cross-section [QCD couplings] and coloured particles in the final state (jets)
- Majorana new particles $\longrightarrow$ excess of same-sign lepton pairs
- decay of neutral particle into two particles with lepton quantum numbers $\longrightarrow$ excess of opposite-sign same-flavor lepton pairs

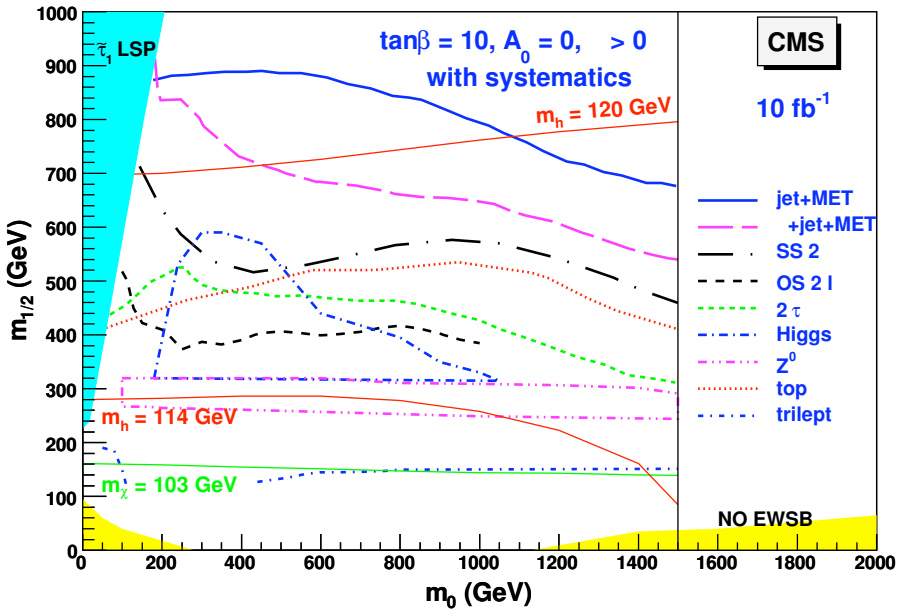
Inclusive Signatures CMS PTDR2:LCHCC-2006/021

- canonical inclusive
  - jets+ E_T^{miss} (*)includes strategies for beam halo/noise, first data Yetkin, Jinnouchi, this afternoon
  - jets+ μ+ E_T^{miss} Pakhotin, this afternoon
  - same-sign dimuon Pakhotin, this afternoon
  - opposite-sign same flavor dielectron and dimuon
  - opposite-sign same flavor hadronic ditau
  - trileptons at high m_0
- higher reco object inclusive
  - Z + E_T^{miss}
  - t hadronic + E_T^{miss}
  - $h^0(b\bar{b})$ + E_T^{miss} (*) includes strategies for decay chain separation aka “hemispheres”
- flavor violating
  - opposite-sign different flavor $e\mu$ for FV neutralino decays

Inclusive Signatures CMS PTDR2:LCHCC-2006/021

Discovery map including background systematics





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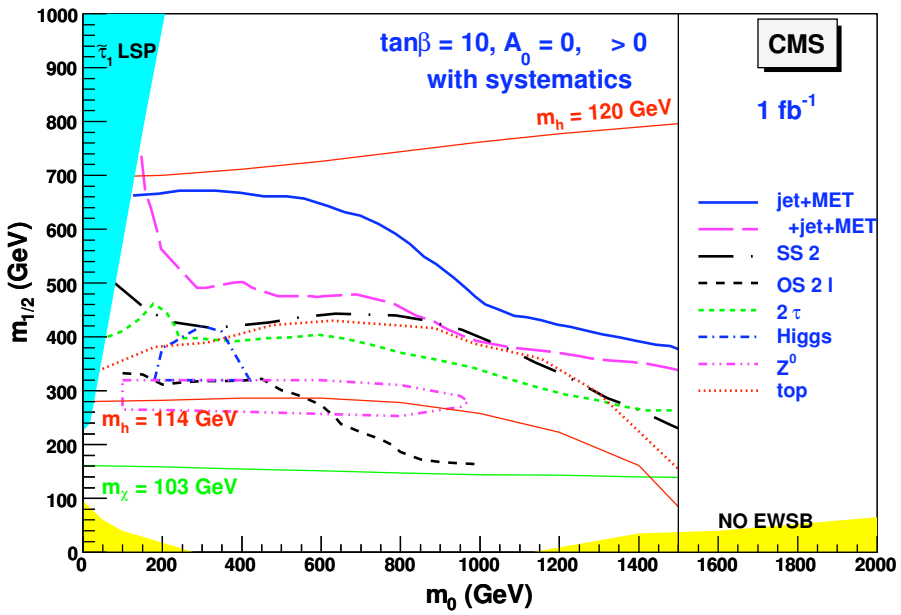
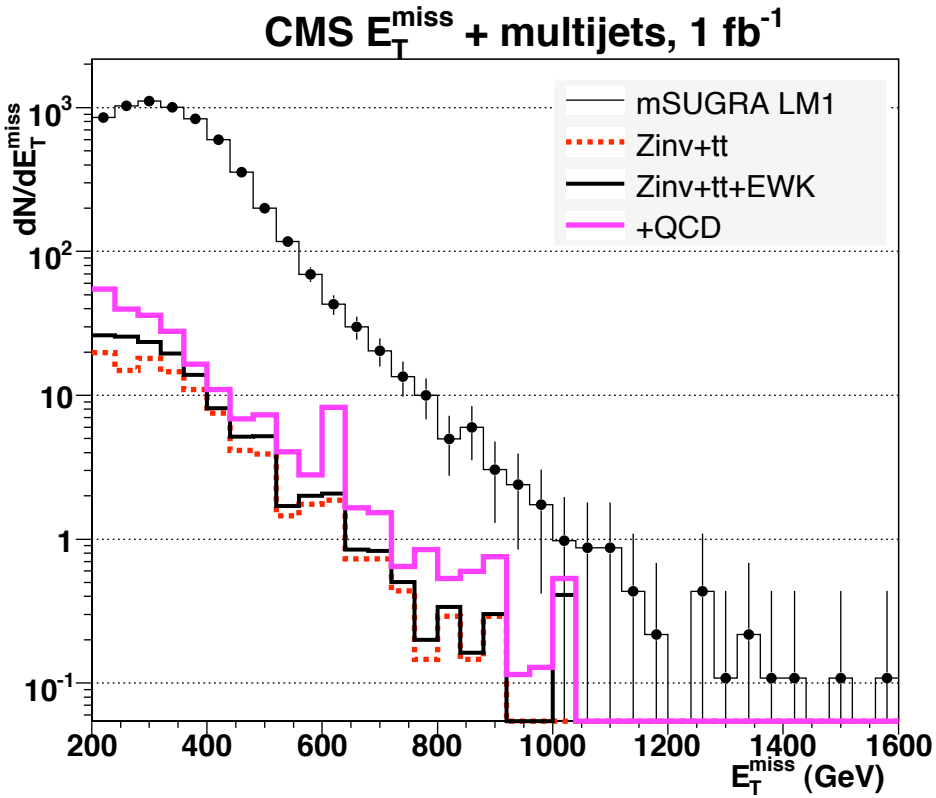


- interplay of signatures in the parameter space
- including excess of *t*'s, τ's, *b*'s, *Z*'s and *W*'s
- for fast orientation need to understand very fast and very well lepton efficiencies and E_T^{miss} tails

Inclusive Signatures CMS PTDR2:LCHCC-2006/021

E_T^{miss} +jets, $m_0 = 60$, $m_{1/2}$ = 250, A_0 = 0, $\tan(\beta)$ = 10, $sgn(\mu)$ = +1 [CMS LM1 test-point]

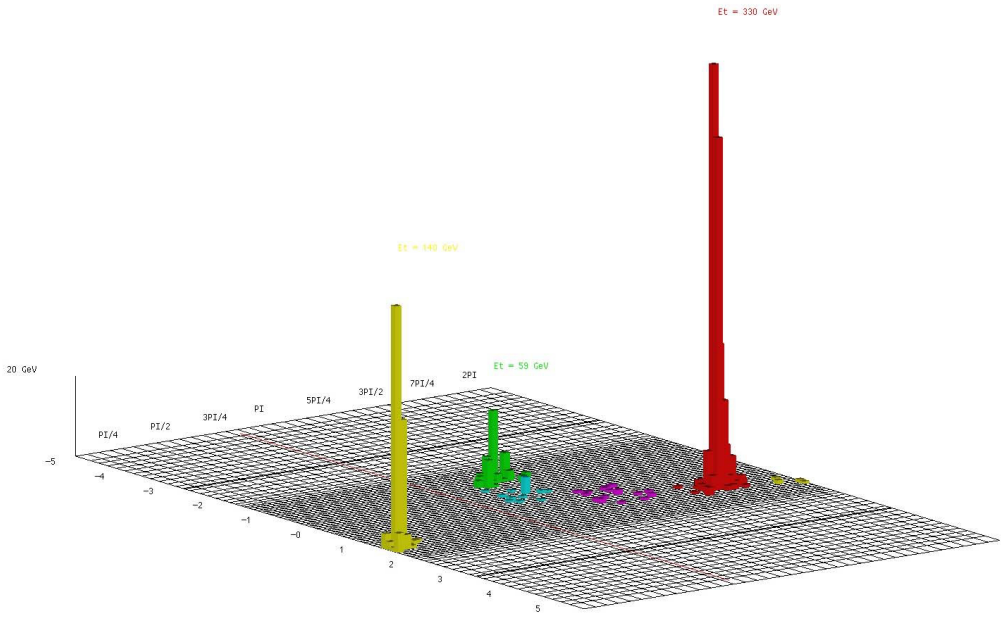


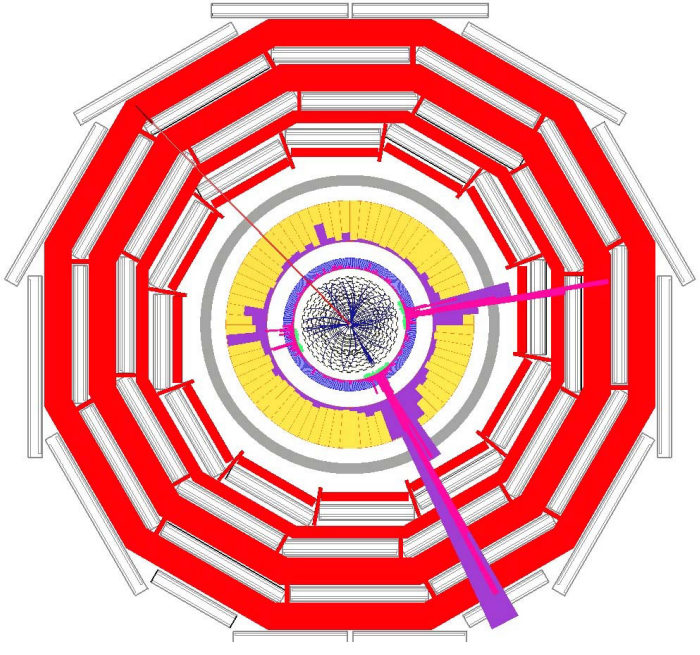
- fast-track to discovery of low mass SUSY $\mathcal{O}(10)$ pb^{-1} b/c of signal cross section – control of systematics using SM processes (e.g. Z+jets, top)
- BUT $\sim$ fb^{-1} needed to reliably do this: the time between $\mathcal{O}(10)$ and $\mathcal{O}(100)$ pb^{-1} of well understood data will be critical for the discovery and characterization of SUSY

Inclusive Signatures CMS PTDR2:LCHCC-2006/021

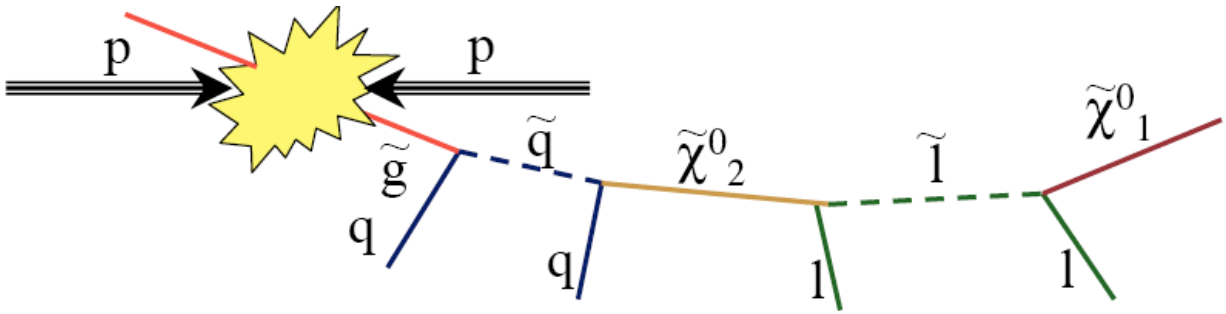
E_T^{miss} +jets candidate event display

E_T^{miss}=360 GeV, E_T(1)=330 GeV, E_T(2)=140 GeV, E_T(3)=60 GeV





First Mass Clues (dileptons)



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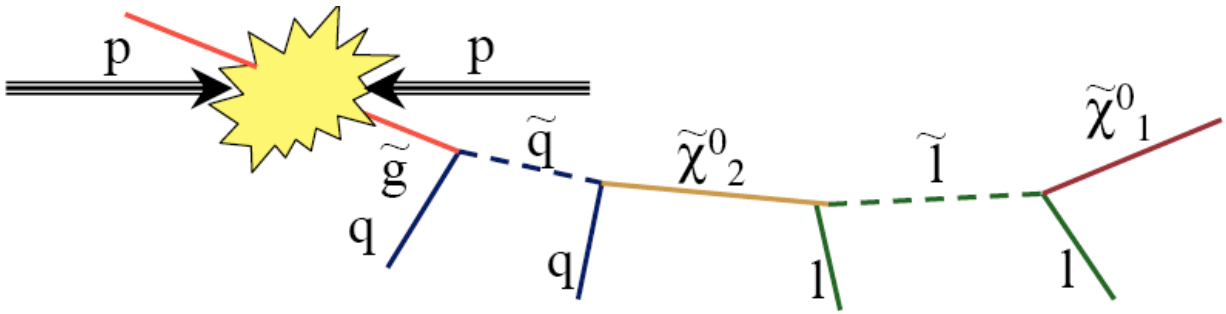
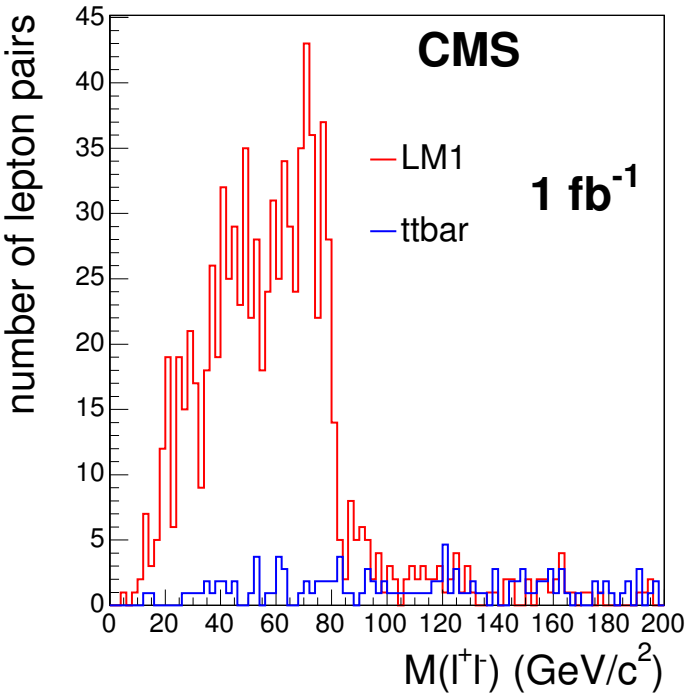
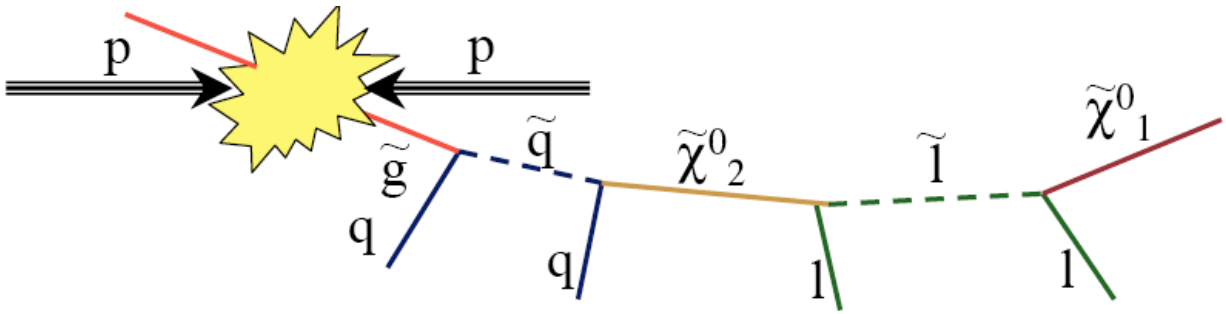


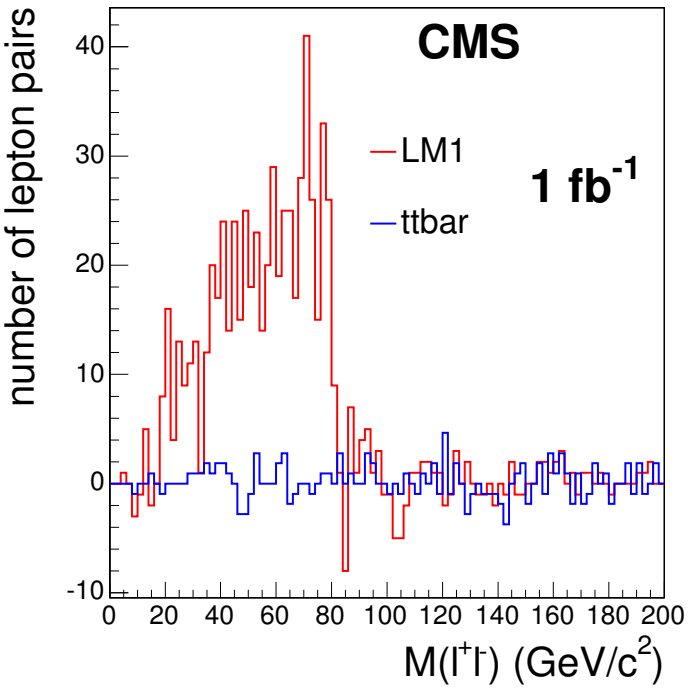
poster 3: Chiorboli *et al.*



- SFOS dilepton+jets+E_T^{miss}
- $t\bar{t}$:WW+j:Z+j:other$\sim$ 6:1:1:1
- flavor subtraction ($e^-\mu^+ + e^+\mu^-$) to supress chargino, W, $t\bar{t}$, WW, "other"
- L1+HLT trigger path required
- overall systematic on the background 20% (JES dominated)
- 5σ discovery with $\sim$ 20 pb^{-1} (of data understood as expected with 1 fb^{-1}).

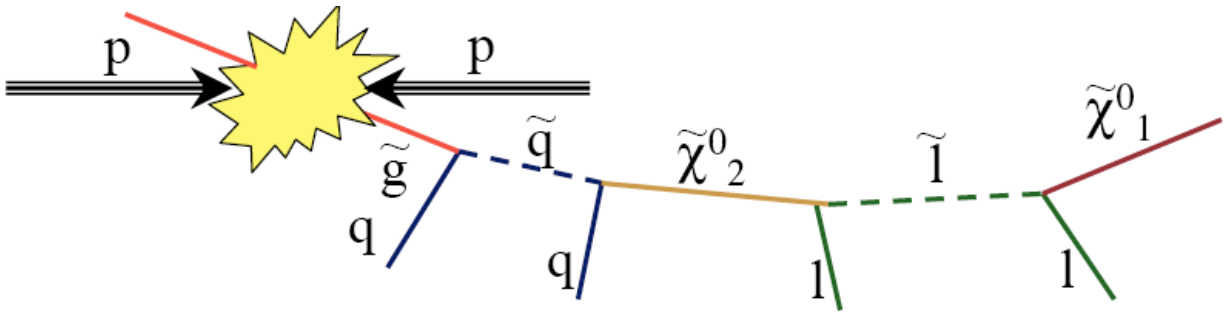
First Mass Clues (dileptons)

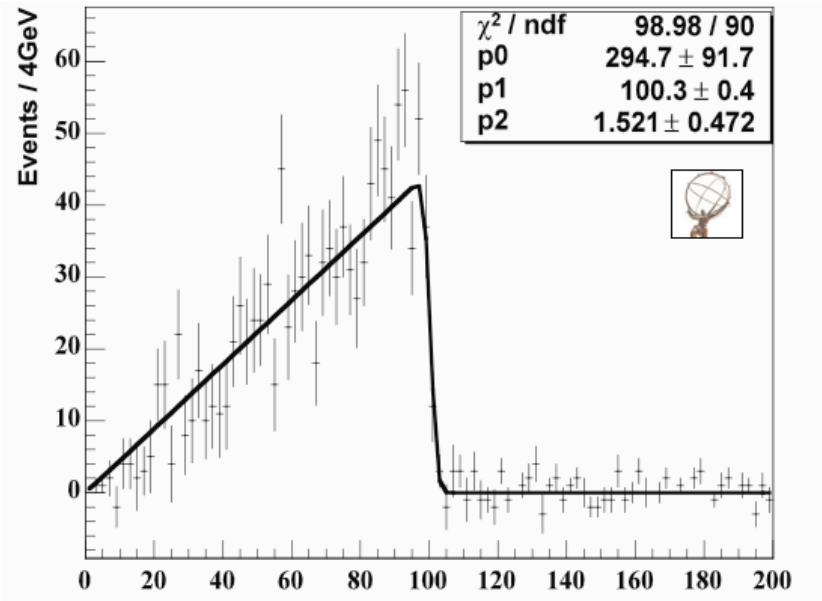




- $M_{\ell\ell}^{max} = M(\tilde{\chi}_2^0)\sqrt{1 - \frac{M^2(\tilde{\ell}_R)}{M^2(\tilde{\chi}_2^0)}}\sqrt{1 - \frac{M^2(\tilde{\chi}_1^0)}{M^2(\tilde{\ell}_R)}}$
- $M_{\ell\ell}^{max}$(meas)= 80.42 $\pm$ 0.48 GeV/c^2, *cfr* with
- expected $M_{\ell\ell}^{max}$= 81 GeV/c^2 [given $M(\tilde{\chi}_1^0)$ = 95, $M(\tilde{\chi}_2^0)$= 180 and $M(\tilde{\ell}_R)$ = 119 GeV/c^2]

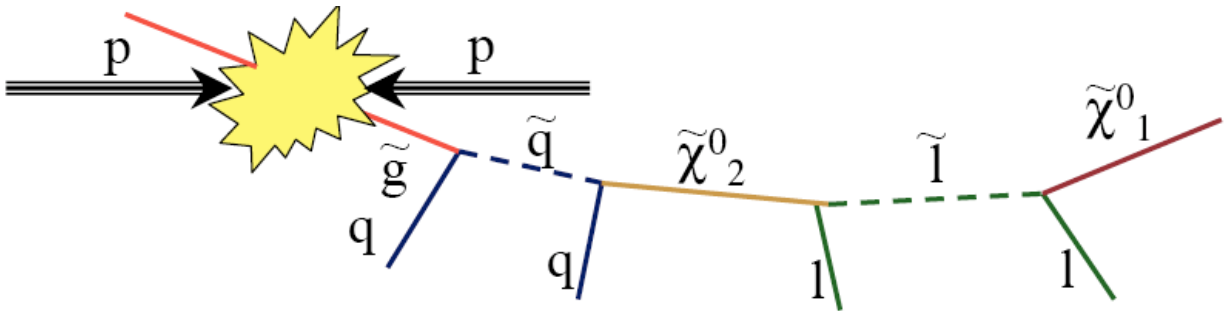
First Mass Clues (dileptons)

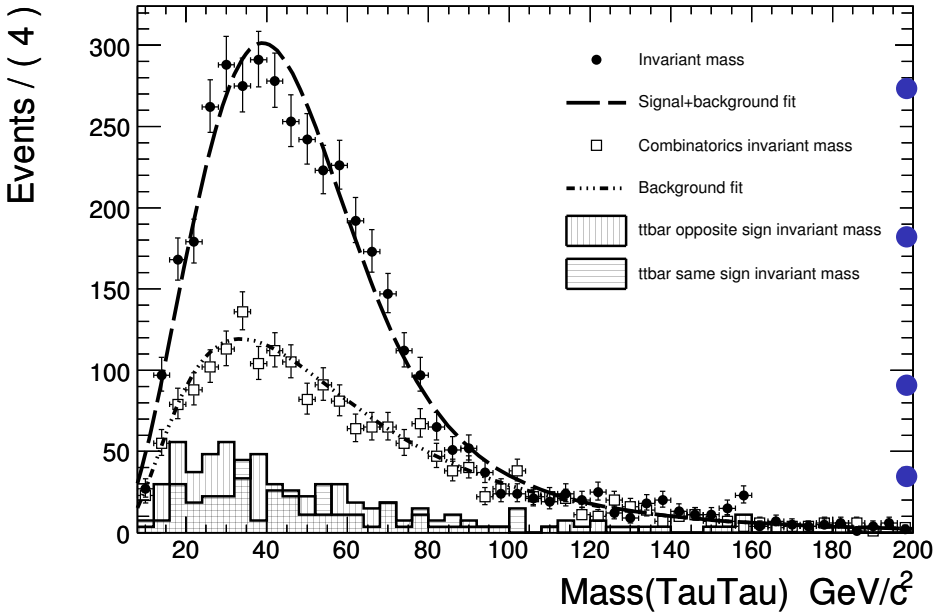




- $m_0 = 100$ GeV, $m_{1/2} = 300$ GeV , $A_0 = -300$ GeV, $\tan\beta = 6$ $\mathrm{sgn}(\mu) = +1$ [ATLAS SU3 test-point]
- $M_{\ell\ell}^{max}$(meas)= 100.3 $\pm$ 0.4 GeV/c^2 with 4.20 fb^{-1} (Geant-4 based simulation, no systematics)
- ATLAS-preliminary

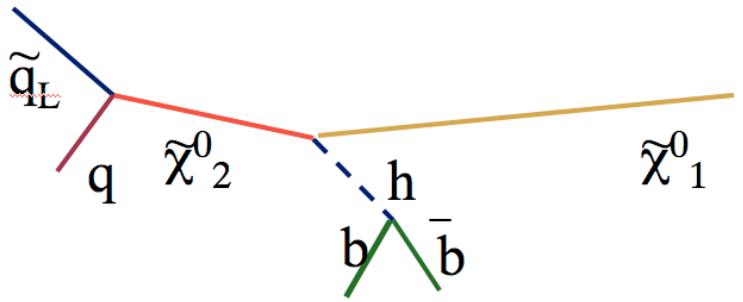
First Mass Clues (dileptons)





- $m_0 = 185$, $m_{1/2} = 350$, $A_0 = 0$, $\tan(\beta) = 35$ $sgn(\mu) = +1$ [CMS LM2 test-point]
- selection uses 1-prong/3-prong OS hadronic τ, two jets, E_T^{miss}
- $M_{\tau\tau}^{max}$(meas) 95$\pm$5 with 40 fb^{-1}
- difficult due to (soft) τ decays and energy scale

First Mass Clues ($b\bar{b}$)



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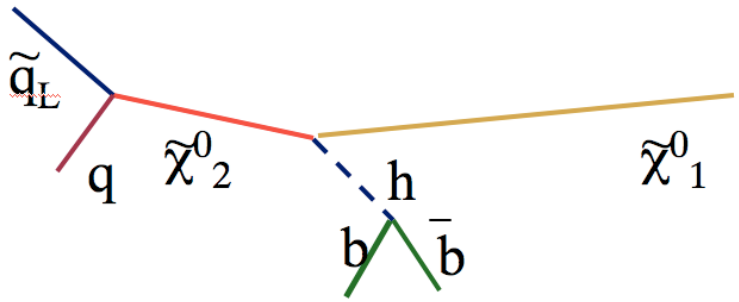

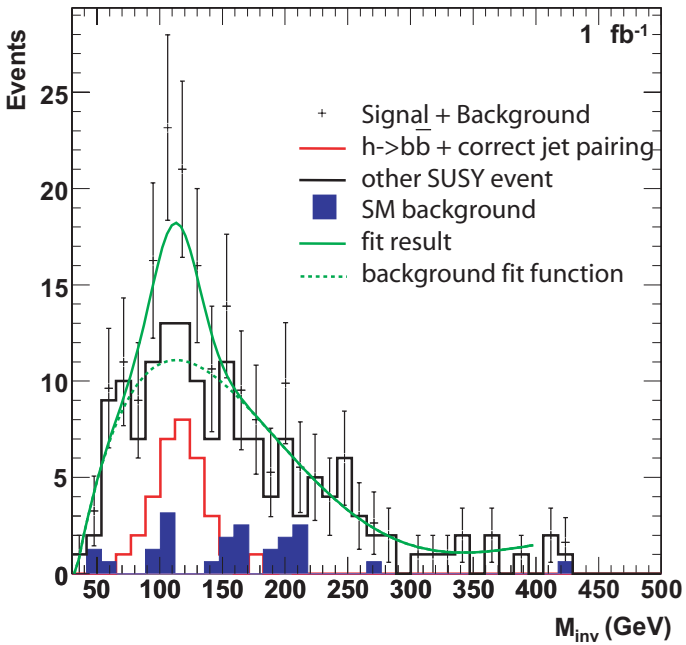

- $b\bar{b}$ width to be extracted from SM control processes
- 5σ excess with 1.5 fb^{-1}
- background here 5th order polynomial, signal Gaussian of fixed width
- cascade chain separation using 2 axis (aka “hemisphere”)
- 2 b’s required in the same hemisphere and closest in ΔR

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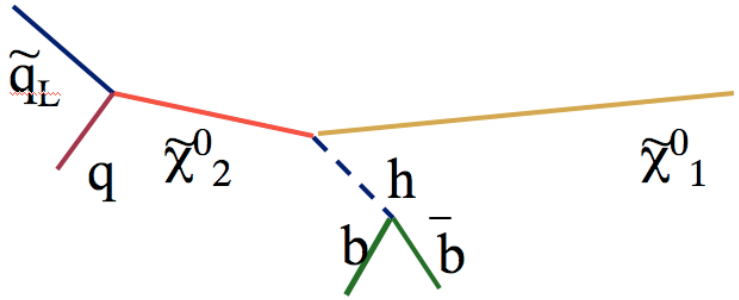

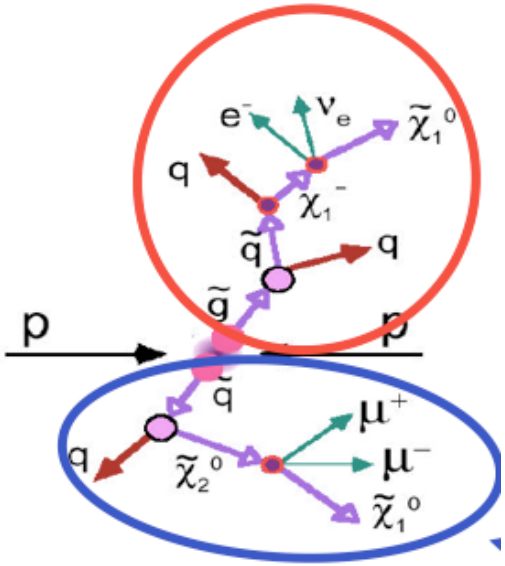

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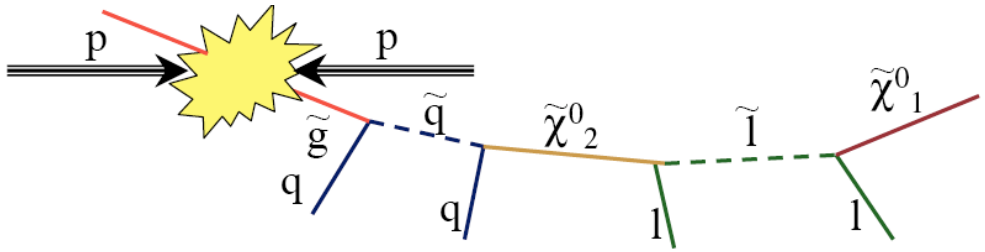
First Mass Clues (adding the jets)



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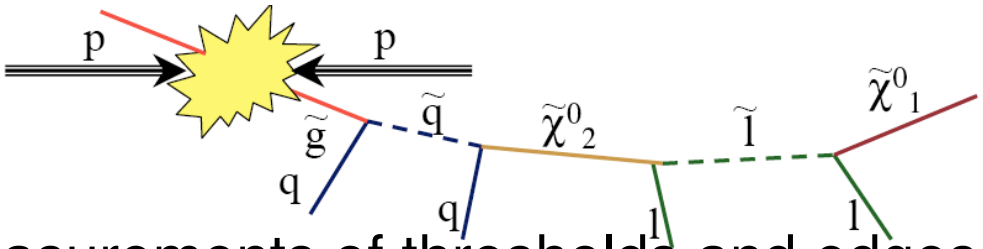
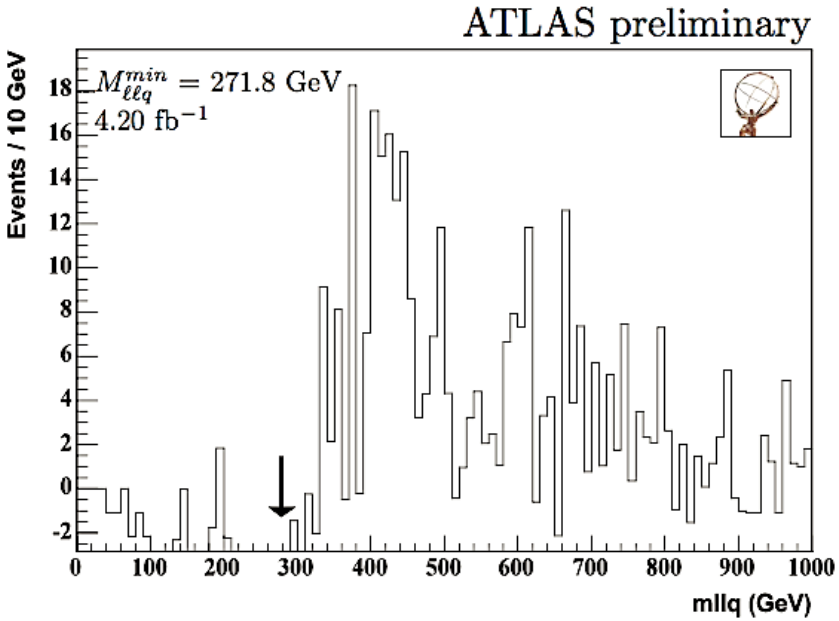
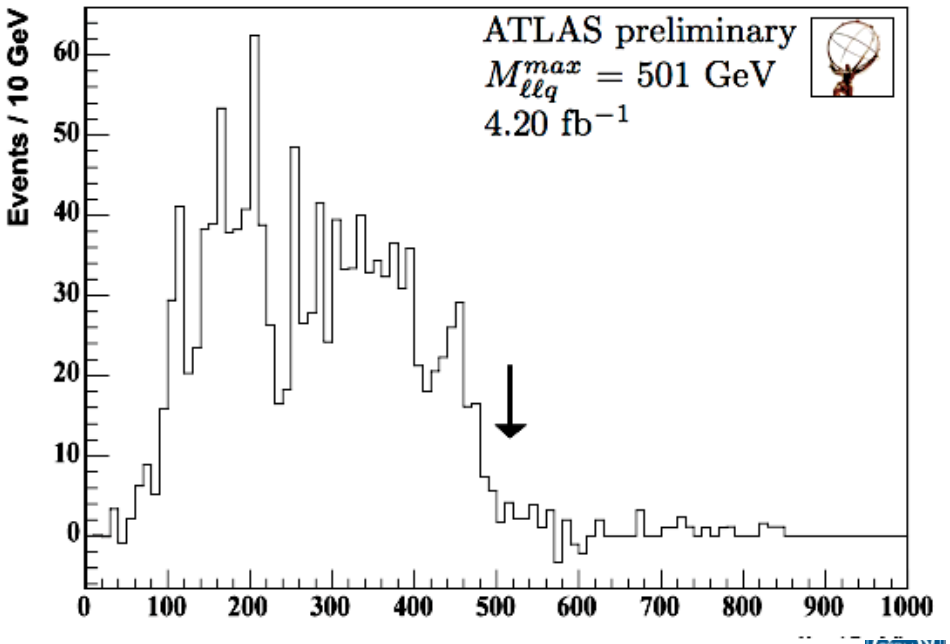
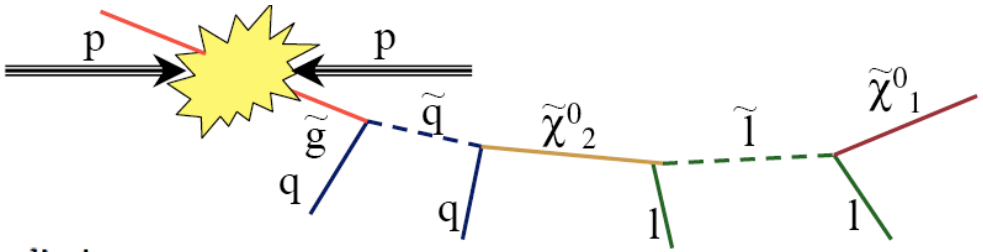


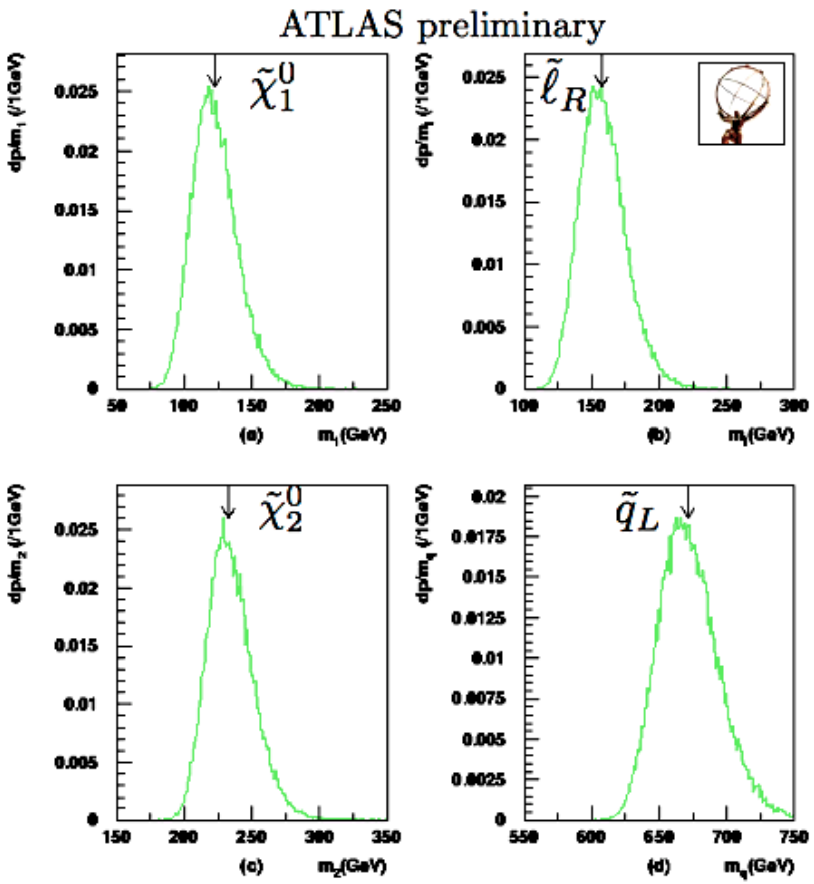
Combine measurements of thresholds and edges from different jet/lepton mass combinations to obtain mass measurements:





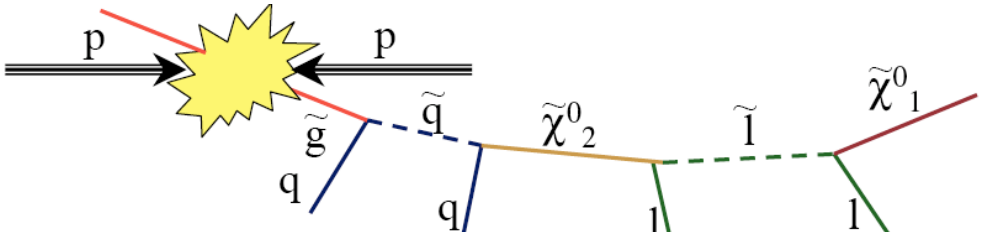
First Mass Clues (adding the jets)

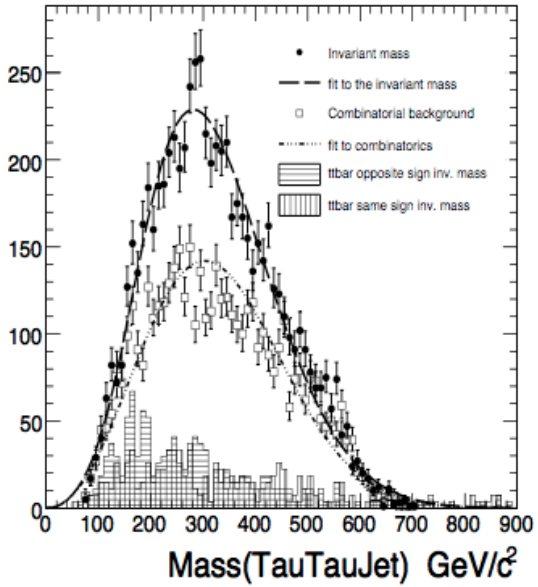


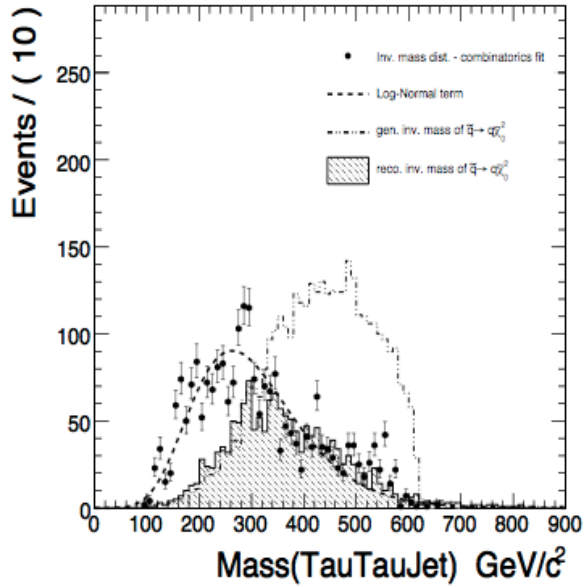


- LHCC Point 5 [ATLAS]
- expected precision on mass measurement with 100 fb^{-1}
- $\tilde{\chi}_1^0$ 12%, $\tilde{\ell}_R$ 9%
- $\tilde{\chi}_2^0$ 6%, $\tilde{q}_L$ 3%
- (no systematics)

First Mass Clues (adding the jets)

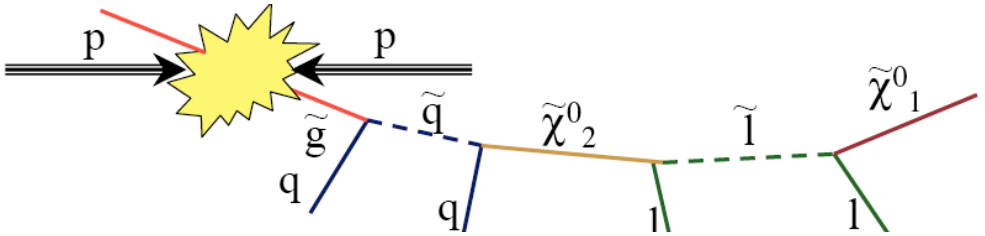


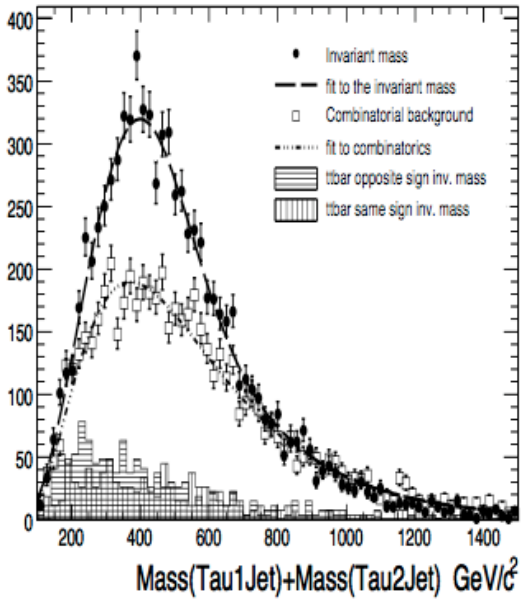


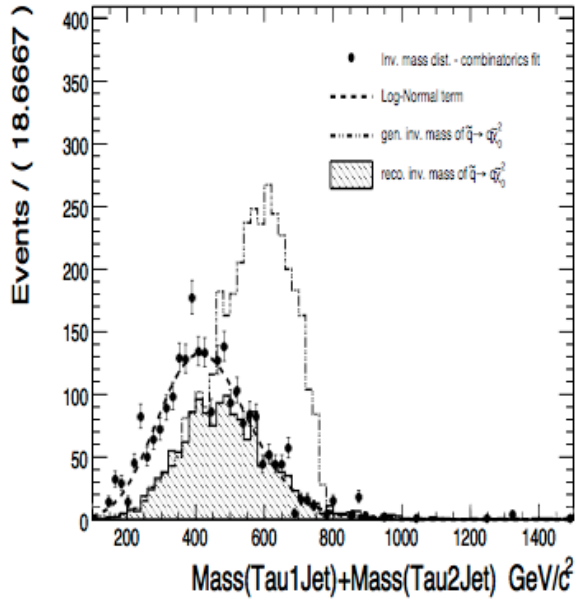


CMS PTDR [1]

First Mass Clues (adding the jets)

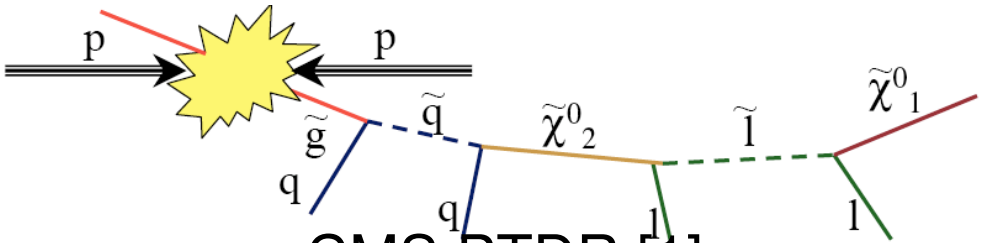






CMS PTDR [1]

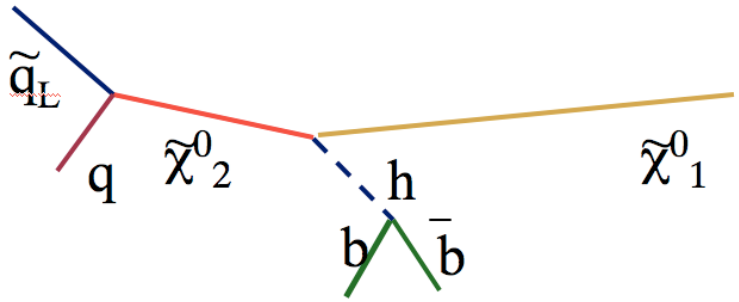
First Mass Clues (adding the jets)



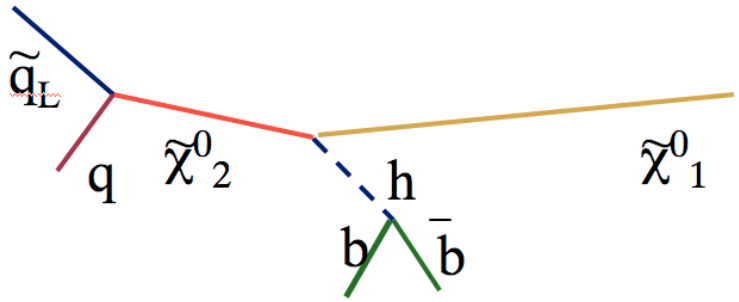
CMS PTDR [1]

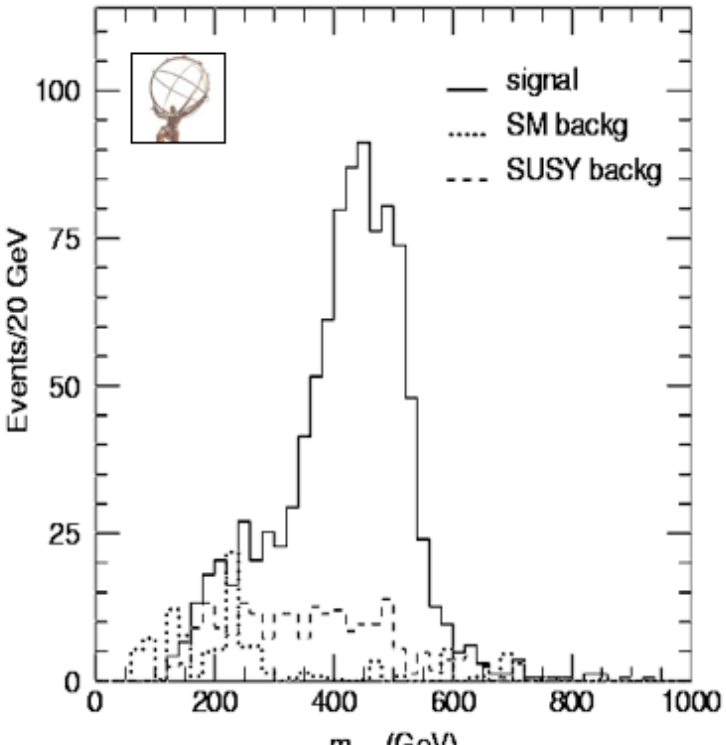
	LM2 test point	
	measured	theory
$M(\tilde{\chi}^0_1)$ (GeV)	$147 \pm 23(\text{stat}) \pm 19(\text{sys})$	138.2
$M(\tilde{\chi}^0_2)$ (GeV)	$265 \pm 10(\text{stat}) \pm 25(\text{sys})$	265.5
$M(\tilde{\tau})$ (GeV)	$165 \pm 10(\text{stat}) \pm 20(\text{sys})$	153.9
$M(\tilde{q})$ (GeV)	$763 \pm 33(\text{stat}) \pm 58(\text{sys})$	753-783 (light $\tilde{q}$)

Mass Clues (adding the jets)



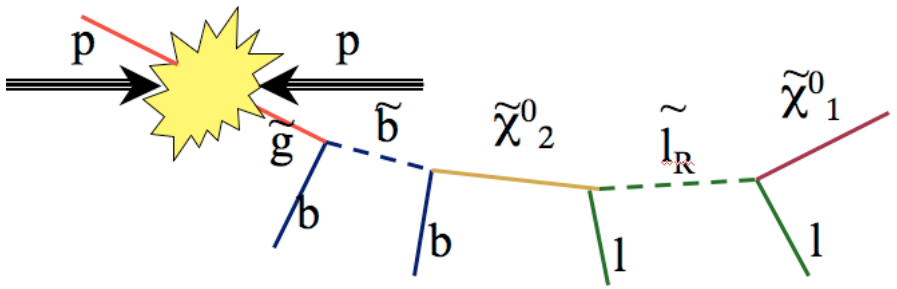
Mass Clues (adding the jets)



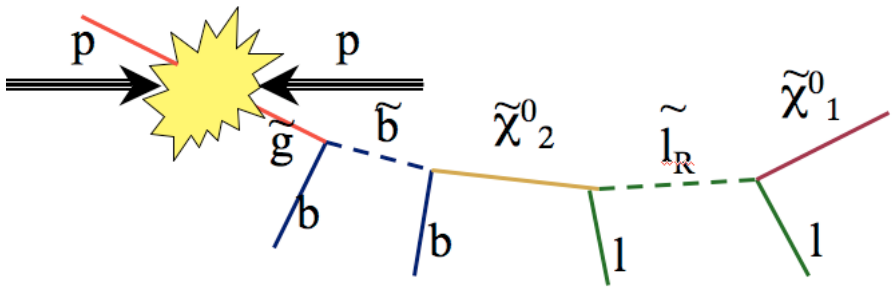


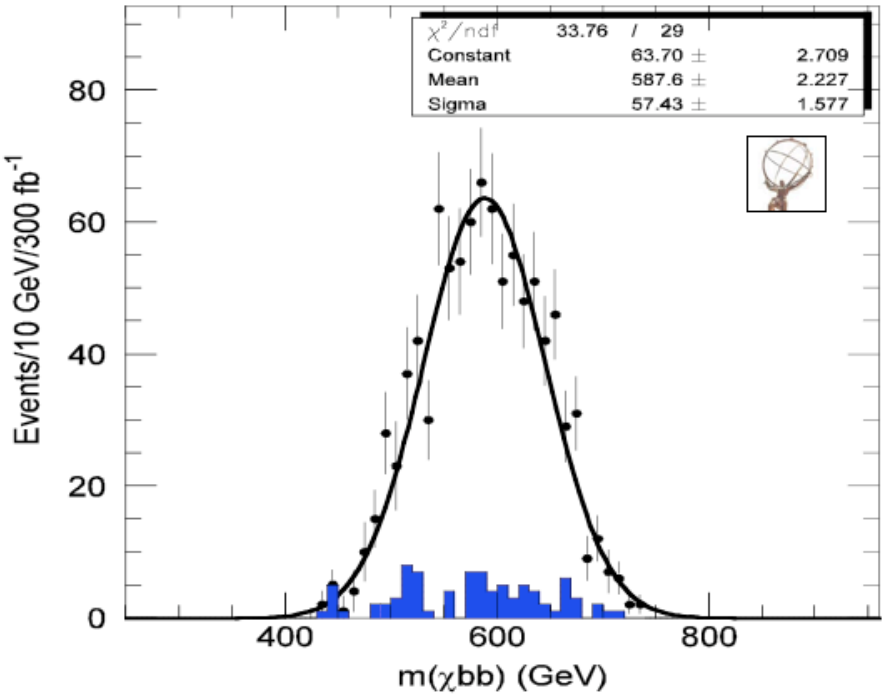
- LHCC Point 5- [ATLAS TDR[2]]
- M^{max}_{bbq} 1% precision with 100 fb^{-1}
- (fast simulation, no systematics)

300 fb^{-1} Mass Clues



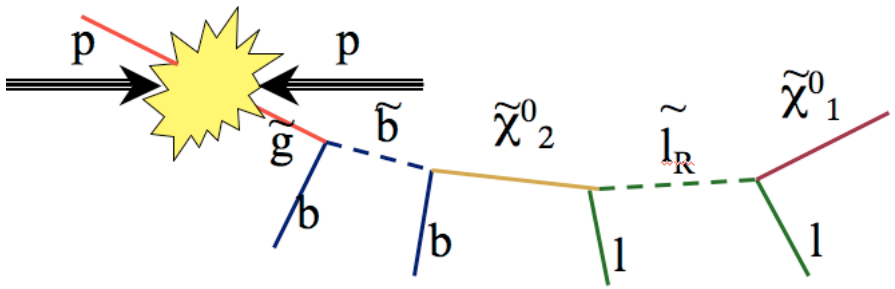
300 fb^{-1} Mass Clues

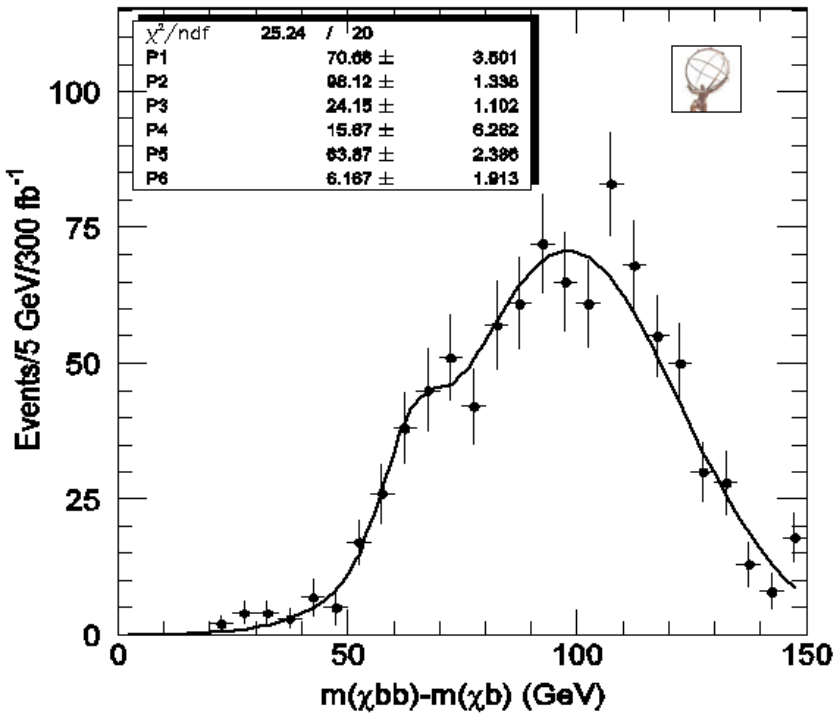




- already extracted $\tilde{\chi}^0_{1,2}$, $\tilde{q}$, $\tilde{\ell}$ with 100 fb^{-1}
- move to alternate chains: e.g. with $\tilde{g} \rightarrow \tilde{b}b$
- require dileptons and *b*-tag
- measure mass differences: $m(\tilde{g}) - m(\tilde{\chi}^0_1) = 500 \pm 6.4$.
- not statistics limited - effort beating down the systematic

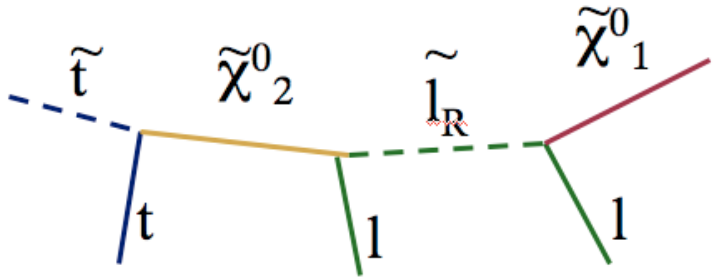
300 fb^{-1} Mass Clues



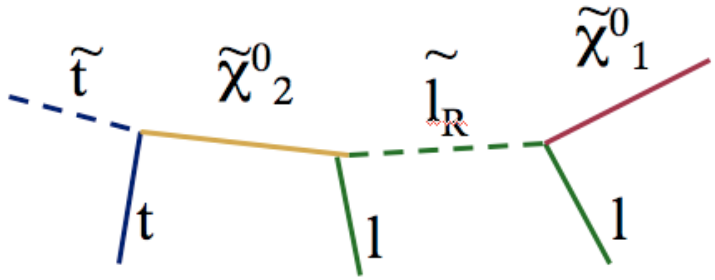


- sensitivity to $\tilde{b}$ mass
- two peaks :$\tilde{b}_{1,2}$ mass separation with 300 fb^{-1}
- $m(\tilde{g}) - m(\tilde{b}_1)$= 103$\pm$ 1.8, $m(\tilde{g}) - m(\tilde{b}_2)$=70.6$\pm$2.6
- N.B. large uncertainty on $\tilde{\chi}^0_1$ propagates to the rest of the mass measurements

stop: inclusive top excess



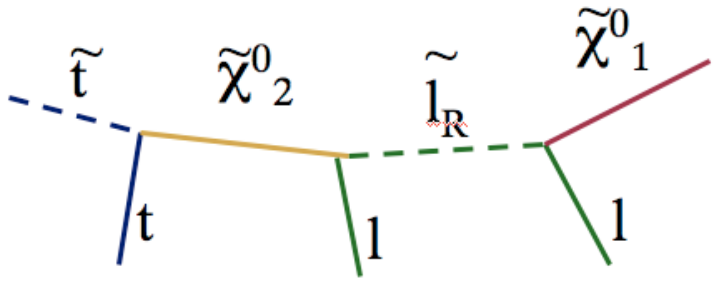
stop: inclusive top excess

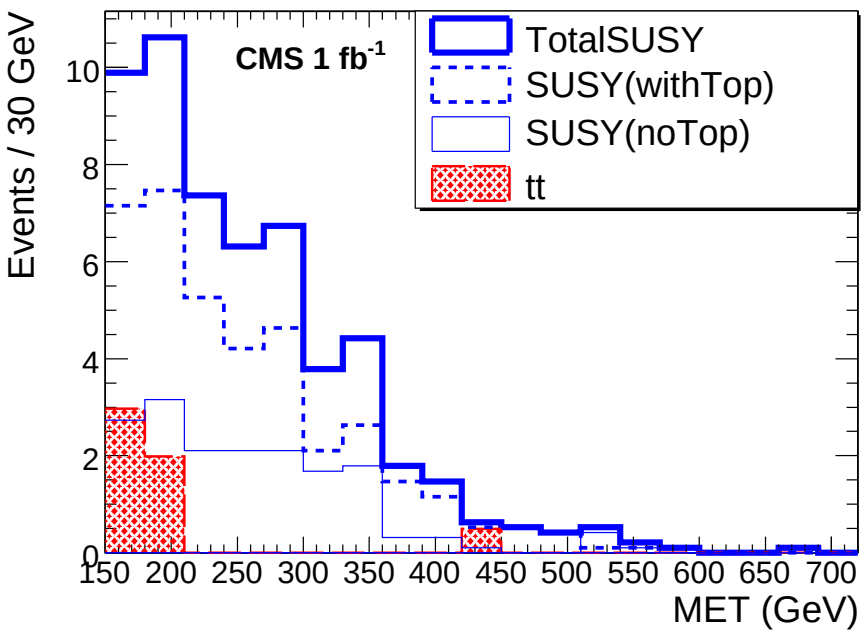


$\tilde{t}$ sources (LM1)

$Mother \rightarrow Daughters$	B.R(%)	$Mother \rightarrow Daughters$	B.R(%)
$\tilde{g} \rightarrow \bar{t} + \tilde{t_1}$	6.16	$\tilde{g} \rightarrow \bar{b} + \tilde{b_1}$	18.09
$\tilde{g} \rightarrow \bar{b} + \tilde{b_2}$	12.67	$\tilde{t_2} \rightarrow Z^0 + \tilde{t_1}$	12.17
$\tilde{t_2} \rightarrow h_0 + \tilde{t_1}$	2.62	$\tilde{b_2} \rightarrow W^- + \tilde{t_1}$	16.33
$\tilde{b_1} \rightarrow W^- + \tilde{t_1}$	6.64	$\tilde{t_1} \rightarrow \chi^0_2 + t$	12.53
$\tilde{t_1} \rightarrow \chi^0_1 + t$	17.70	$\tilde{t_2} \rightarrow \chi^0_{all} + t$	40.58
$\tilde{b_1} \rightarrow \chi^+_1 + t$	48.36	$\tilde{b_2} \rightarrow \chi^+_1 + t$	23.85

stop: inclusive top excess





- excess of reconstructed hadronic top
- $m(jj)$ consistent with W mass and $m(jjb)$ consistent with top mass
- 2C kinematic fit
- additional b's can be used to start reconstruction
- excess of t's in LM1 used inclusively

stop: reconstruction methods

Edges in *tb* invariant mass distribution

Contributions come *e.g.* from

- $\tilde{g} \longrightarrow tt_1 \longrightarrow tb\chi_1^+$
- $\tilde{g} \longrightarrow bb_1 \longrightarrow bt\chi_1^+$

poster 15: Milosavljevic *et al.* with G4 simulation

stop: reconstruction methods

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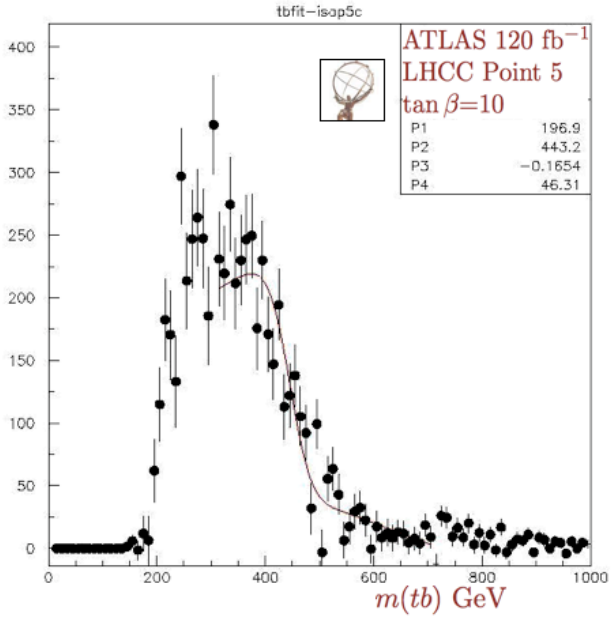

- $m(jj)$ consistent with W mass and $m(jjb)$ consistent with top mass
- index of weighted mean of end-points
- sideband subtraction form $m(jj)$
- $m(tb)^{max} = 443.2 \pm 7.4$ GeV
- expected = 459 GeV

stop: reconstruction methods

Edges in *tb* invariant mass distribution

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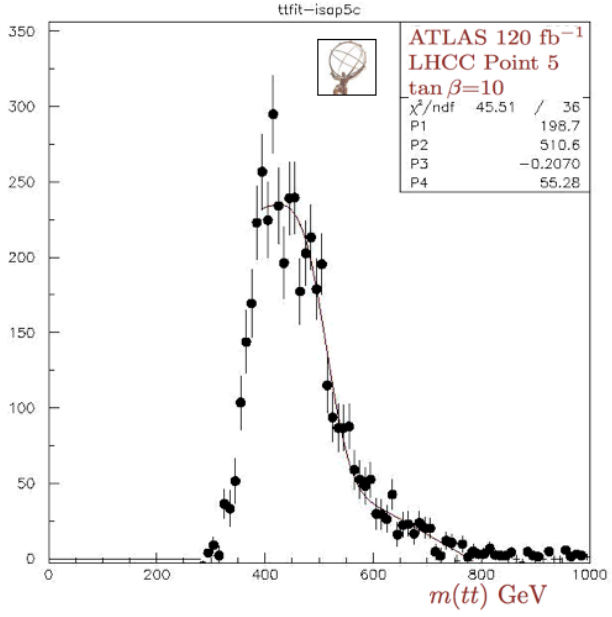

- di-top selection with sideband subtraction
- probes $\tilde{g} \longrightarrow tt_1 \longrightarrow tt\chi_1^0$
- + can go back to the *bbll* analysis
- N.B. note that $W \longrightarrow jj$ is a jet calibration candle
- N.B. careful with biases from the mass constraints

more reconstruction

right-handed squarks

- $q_R \rightarrow q\chi_1^0$
- 2-jets and large E_T^{miss}
- MT ("stransverse mass" [6]), poster 15: Milosavljevic *et al.* with G4 simulation

heavy gaugino measurements

- disentangling contributions in dilepton edges
- high statistics required
- input for MSSM neutralino mass matrix reconstruction
- chargino mass reconstruction, usually with W's and opposite side χ_1^0 dilepton tag

$\longrightarrow$ model parameters

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$\longrightarrow$ **model parameters**

Onto Model Parameters

$\longrightarrow$ **model parameters**

- as per global EW fitters
- SFITTER, FITINO &tc used with input all the measurements and output the model parameters....

voilá

SPS1a m_0=100,$m_{1/2}$=250,A_0=-100, $\tan\beta = 10$, sign(μ)=+1 and 300 fb^{-1}

Variable	Value (GeV)	Errors Stat. (GeV)	Errors Scale (GeV)	Errors Total
$m_{\ell\ell}^{max}$	77.07	0.03	0.08	0.08
$m_{\ell\ell q}^{max}$	428.5	1.4	4.3	4.5
$m_{\ell q}^{low}$	300.3	0.9	3.0	3.1
$m_{\ell q}^{high}$	378.0	1.0	3.8	3.9
$m_{\ell\ell q}^{min}$	201.9	1.6	2.0	2.6
$m_{\ell\ell b}^{min}$	183.1	3.6	1.8	4.1
$m(\ell_L) - m(\tilde{\chi}_1^0)$	106.1	1.6	0.1	1.6
$m_{\ell\ell}^{max}(\tilde{\chi}_4^0)$	280.9	2.3	0.3	2.3
$m_{\tau\tau}^{max}$	80.6	5.0	0.8	5.1
$m(\tilde{g}) - 0.99 \times m(\tilde{\chi}_1^0)$	500.0	2.3	6.0	6.4
$m(\tilde{g}_R) - m(\tilde{\chi}_1^0)$	424.2	10.0	4.2	10.9
$m(\tilde{g}) - m(\tilde{b}_1)$	103.3	1.5	1.0	1.8
$m(\tilde{g}) - m(\tilde{b}_2)$	70.6	2.5	0.7	2.6

[FITTING GIVEN MEASUREMENTS ABOVE]

$\longrightarrow$ m_0 to $\pm 2\%$, $m_{1/2}$ to $\pm 0.6\%$, $\tan\beta$ to $\pm 9\%$ and A_0 to $\pm 16\%$

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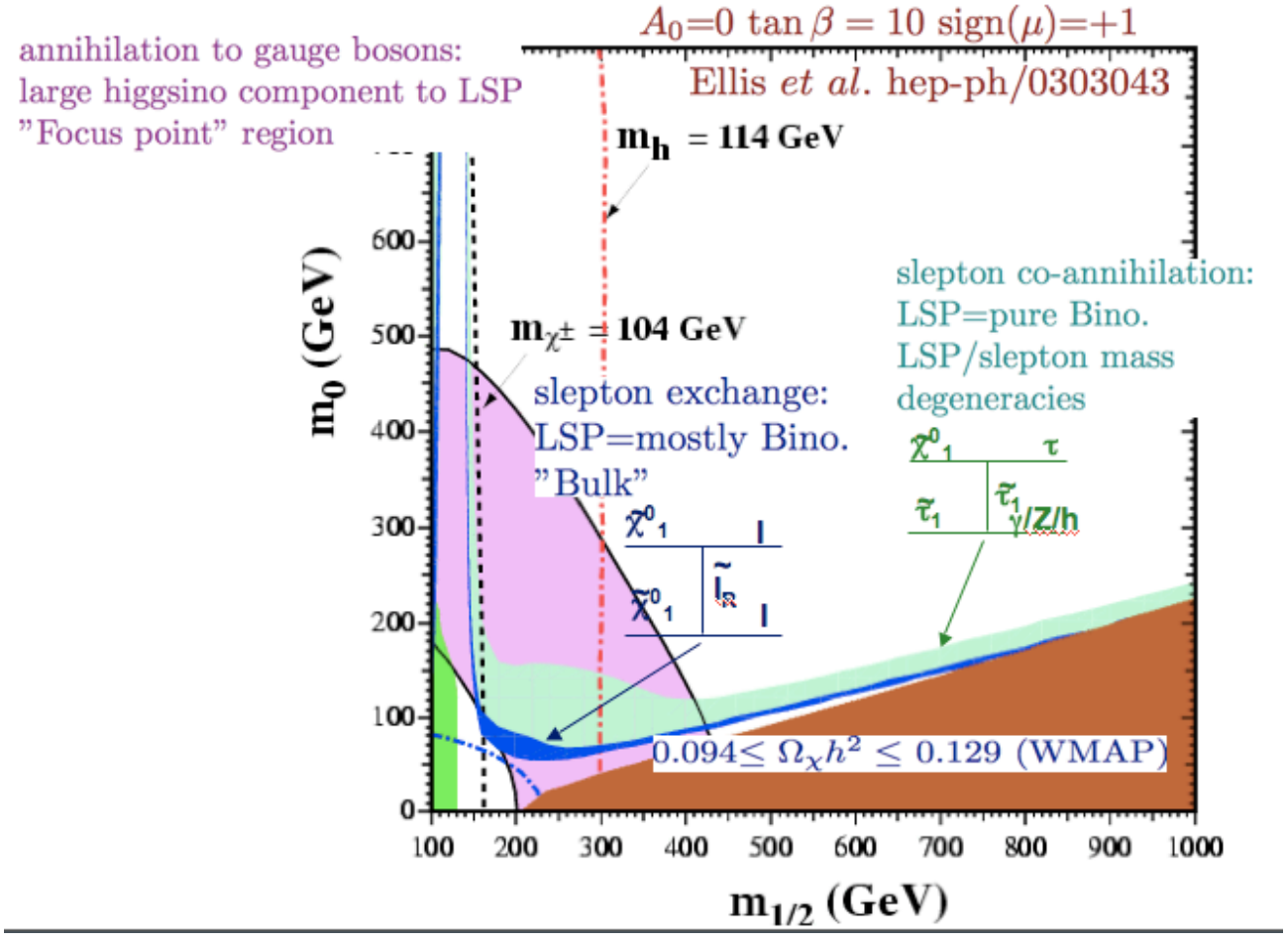
$\longrightarrow$ m_0 to $\pm 2\%$, $m_{1/2}$ to $\pm 0.6\%$, $\tan\beta$ to $\pm 9\%$ and A_0 to $\pm 16\%$

Dark Matter

use extracted model parameters to estimate LSP DM properties (using Micromegas [8], DarkSUSY[9])



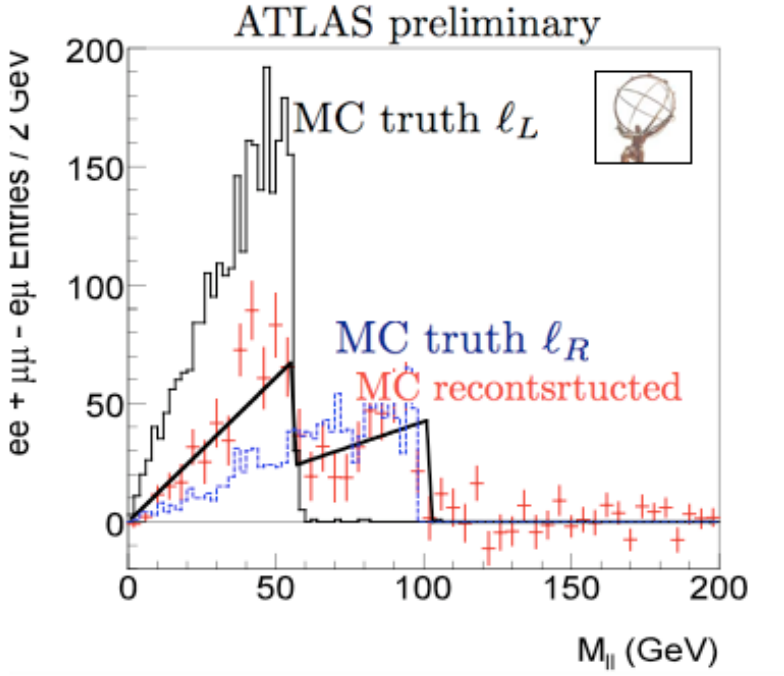
Case study

co-annihilation signatures

- m_0=70 $m_{1/2}$=350 A_0=0 tan β=10, sgn(μ)=+1
- $\chi_2^0 \longrightarrow \ell\tilde{\ell}_{L,R} \longrightarrow \ell\ell\chi_1^0 \longrightarrow$ double dilepton invariant mass edge
- small slepton-neutralino mass difference $\rightarrow$ one soft lepton
- large E_T^{miss}, 1 hard jet, dileptons (with flavor subtraction OSSF-OSOF)
- measure edges/thresholds in $q\ell\ell$, $q\ell$

Case study

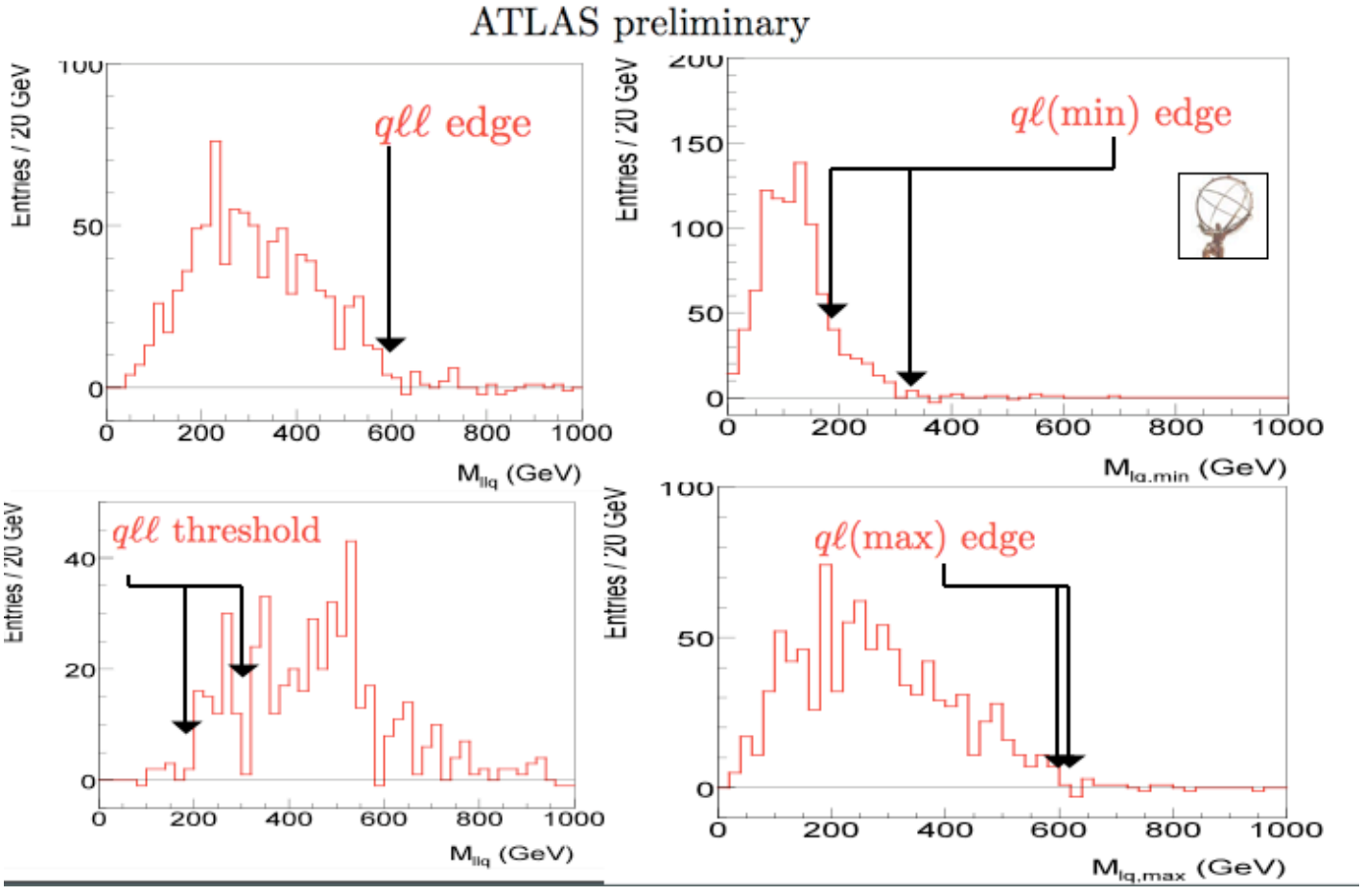
co-annihilation signatures



- full G4 simulation
- 20.6 fb^{-1}
- + $q\ell$ distributions

Case study

co-annihilation signatures



Case Study

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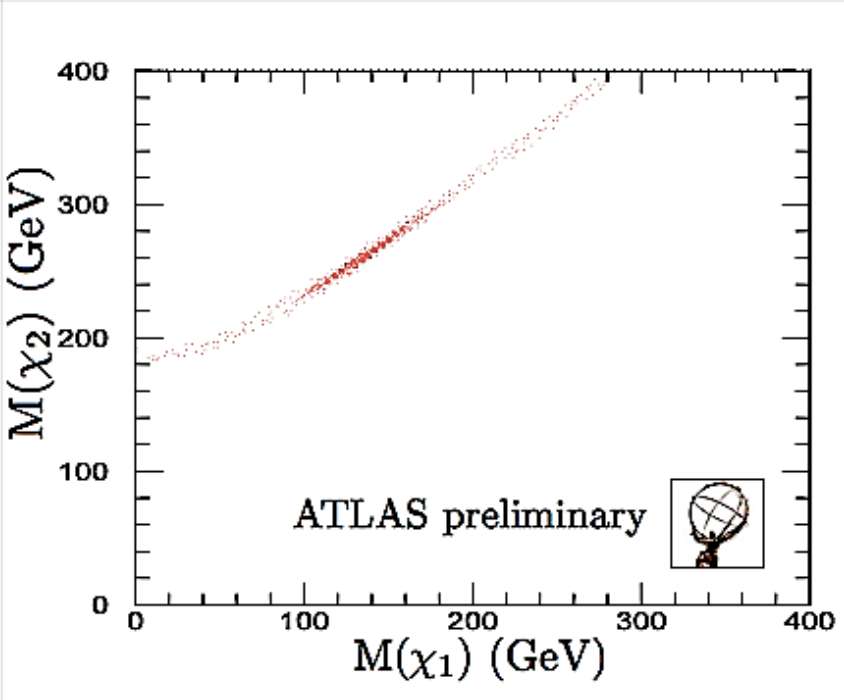
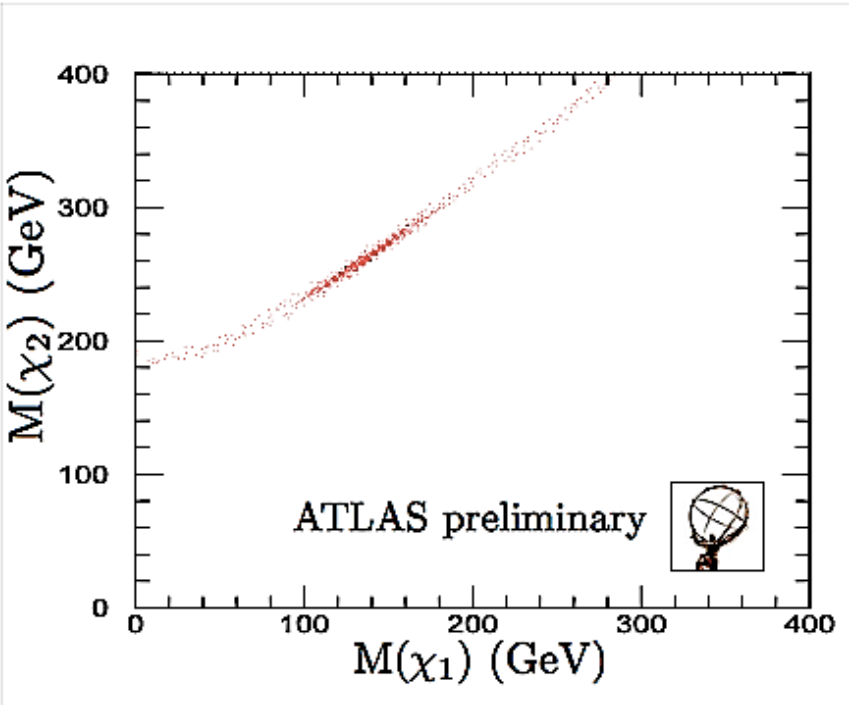


- analysis to be optimized for SM rejection
- assumption: 1% error on lepton-jet endpoints measurement
- fit all distributions
- 20.6 fb^{-1}

Case Study

co-annihilation signatures



- analysis to be optimized for SM rejection
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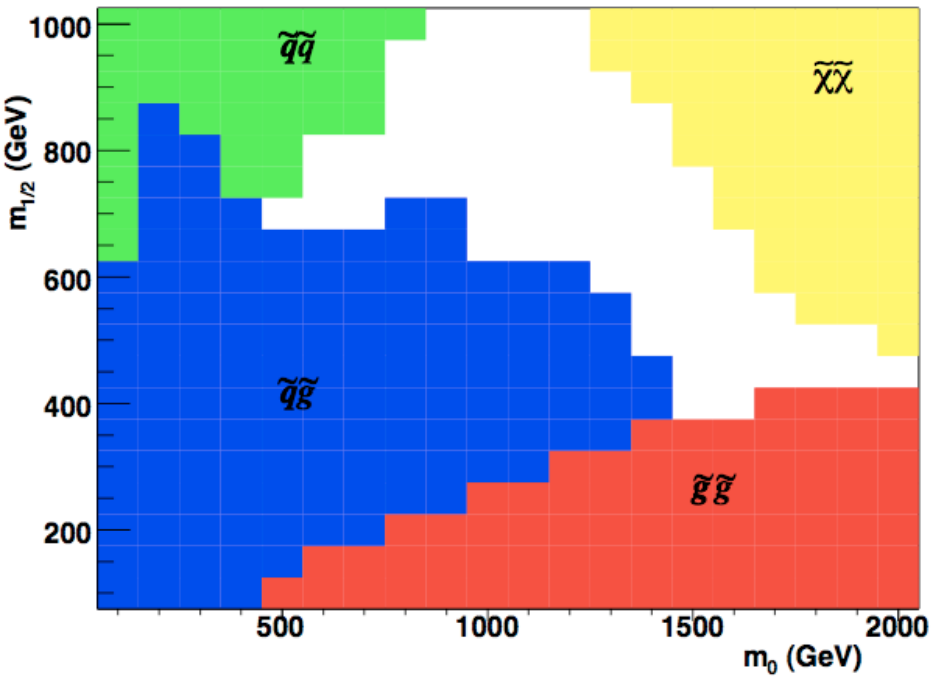
- 20.6 fb^{-1}

other signatures from “focus” points (heavy sfermion) direct 3-body decays $\chi_i^0 \to \chi_1^0 \ell\ell \to M(\ell\ell)$ edges analysis with flavour subtraction and detailed “bulk” studies and extraction of DM parameters in references [5], [7]

SUSY maps

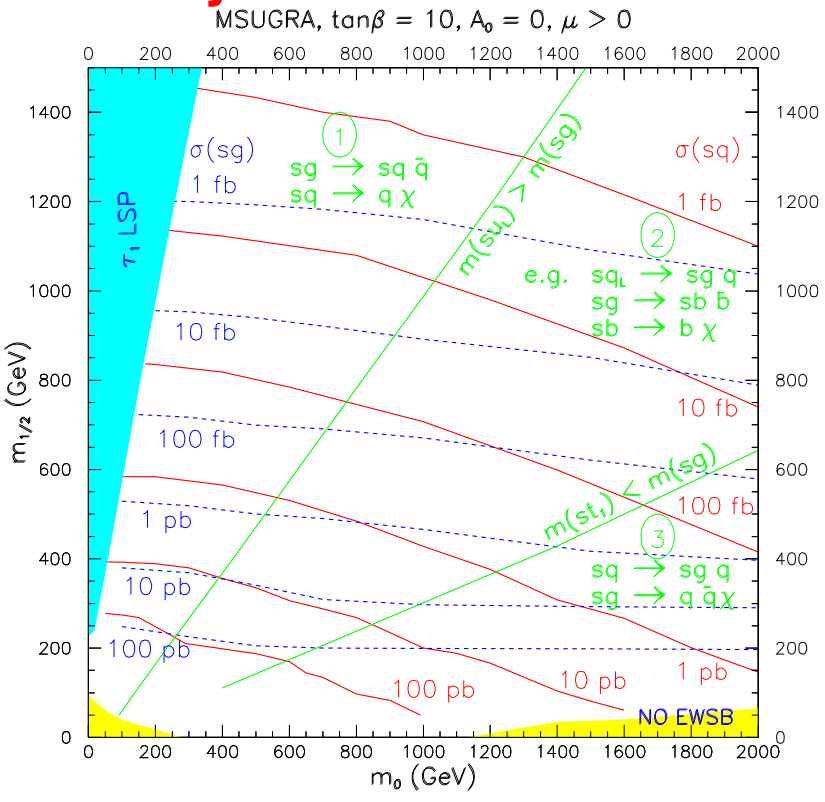
production



- major production mechanisms in parameter space

SUSY maps

decays



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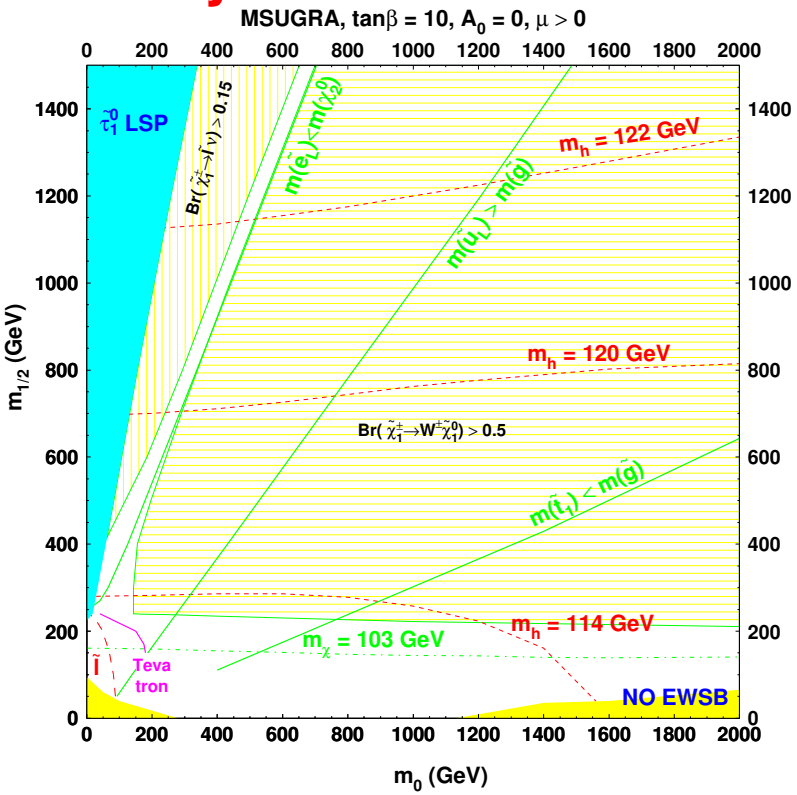

- major decays in parameter space

SUSY maps

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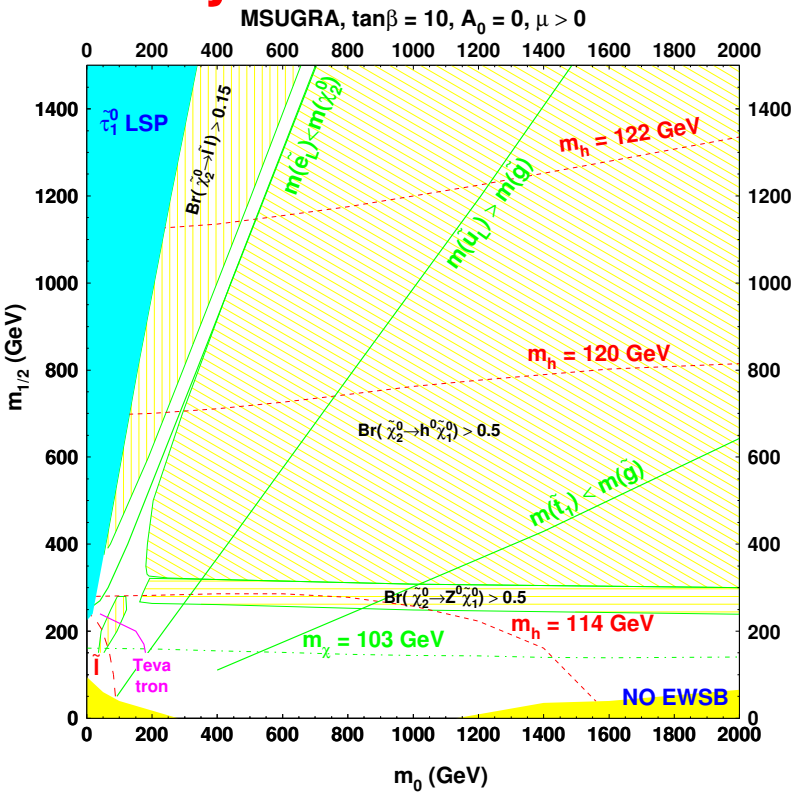

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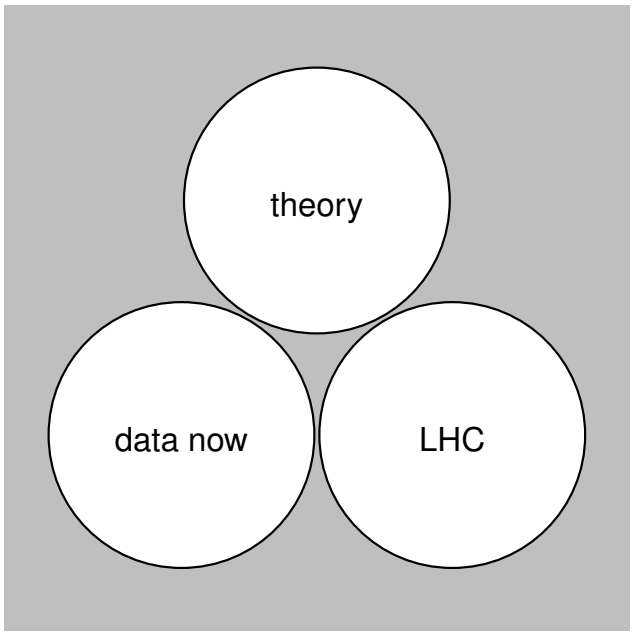
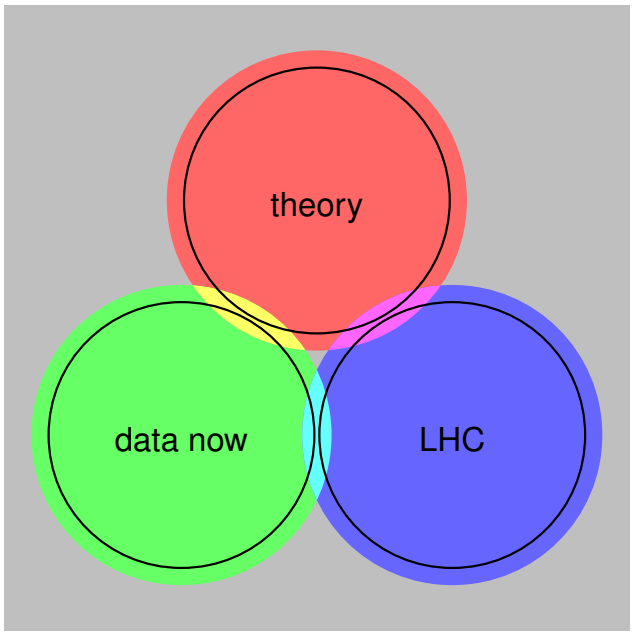


knowledge,ignorance,enlightenment and temptation

- we know something about dark matter
- we think we know something about SUSY
- we think we will measure it at the LHC

Note

Efforts to put all what we know, what we think we know and what we know we don't know, into one coherent picture: tough without the LHC data in hand but preparative value is huge.



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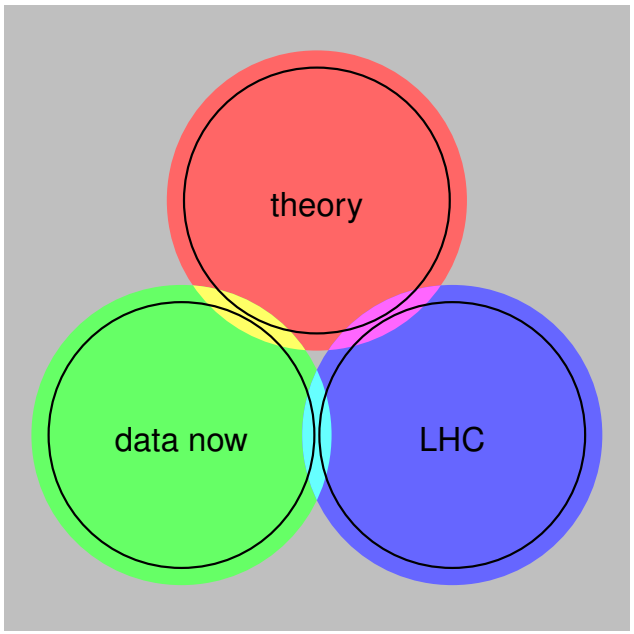
Note

Efforts to put all what we know, what we think we know and what we know we don't know, into one coherent picture: tough without the LHC data in hand but preparative value is huge.



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Outline

Integration-Commissioning-Start-up Physics

test beams/cosmics/single beam/collisions

Definition (commissioning & physics)

test beams-cosmics-one beam-collisions:

1. commissioning data (alignment/calibration/synchronization)
2. commissioning data (trigger)
3. physics data
4. first analyses

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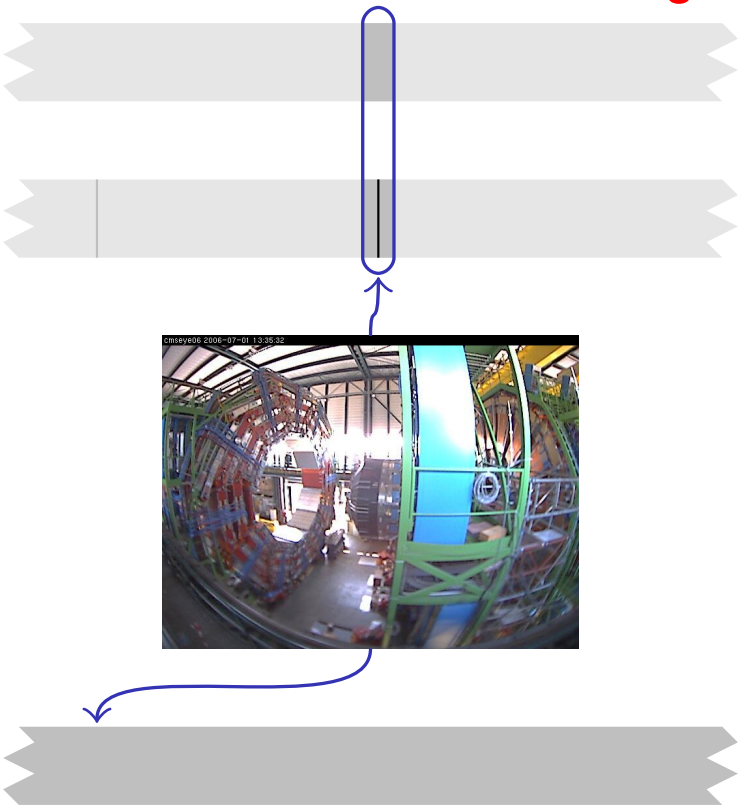

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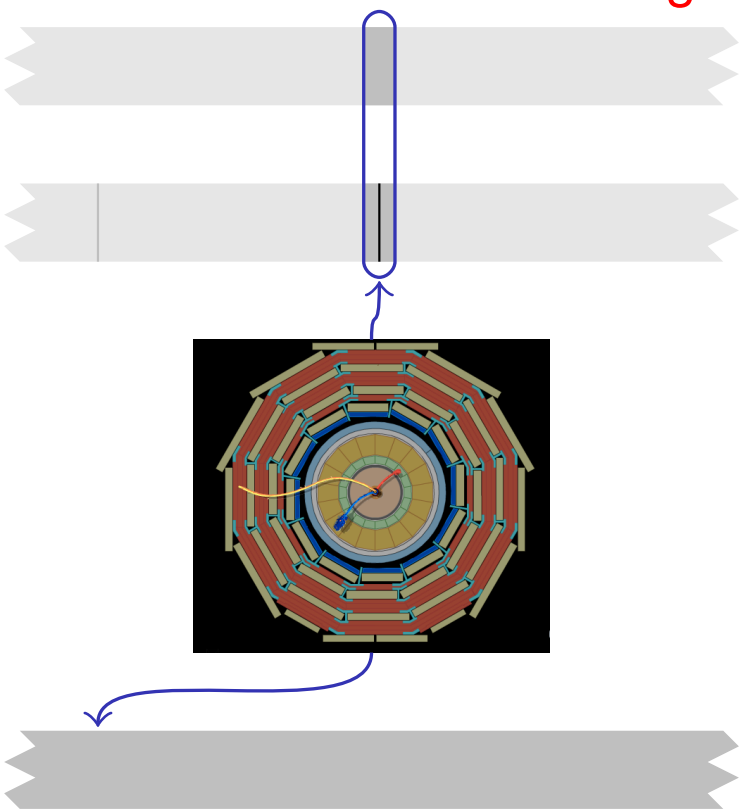

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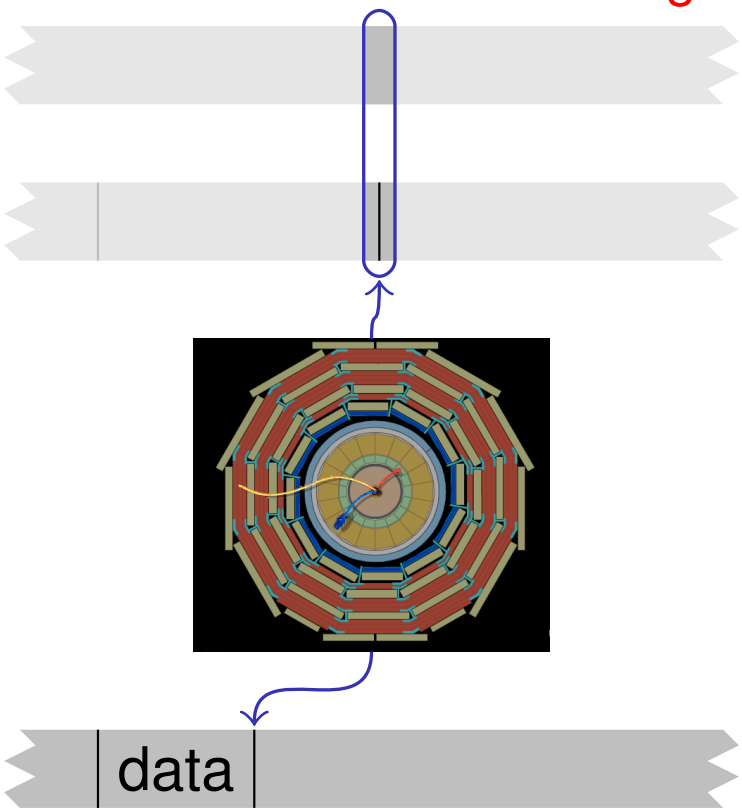

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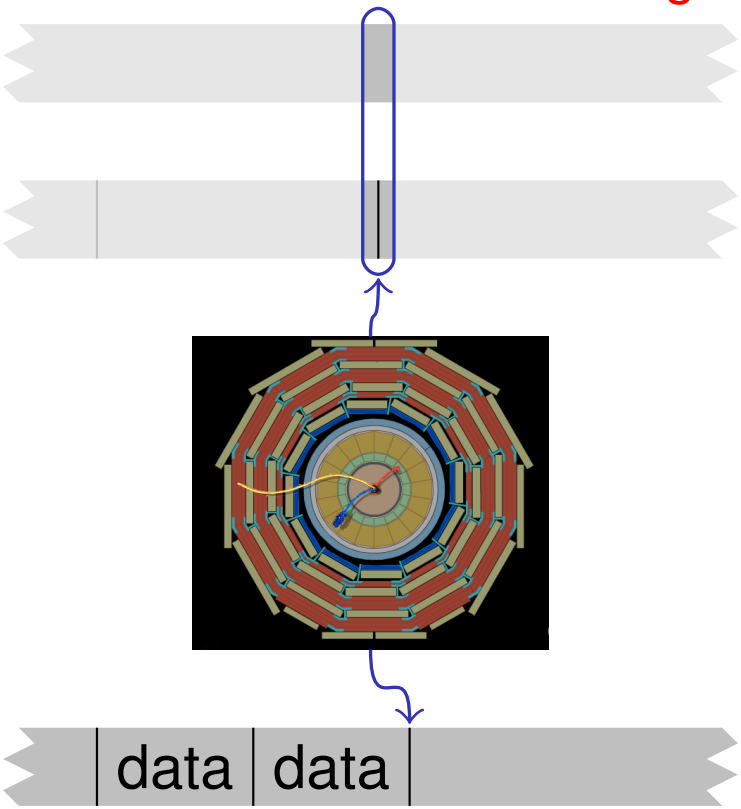

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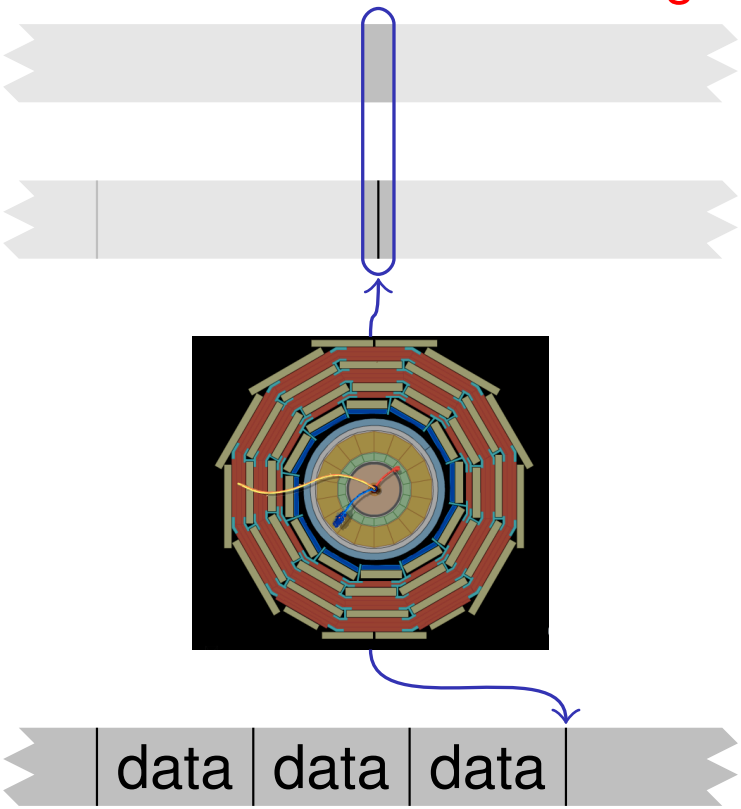

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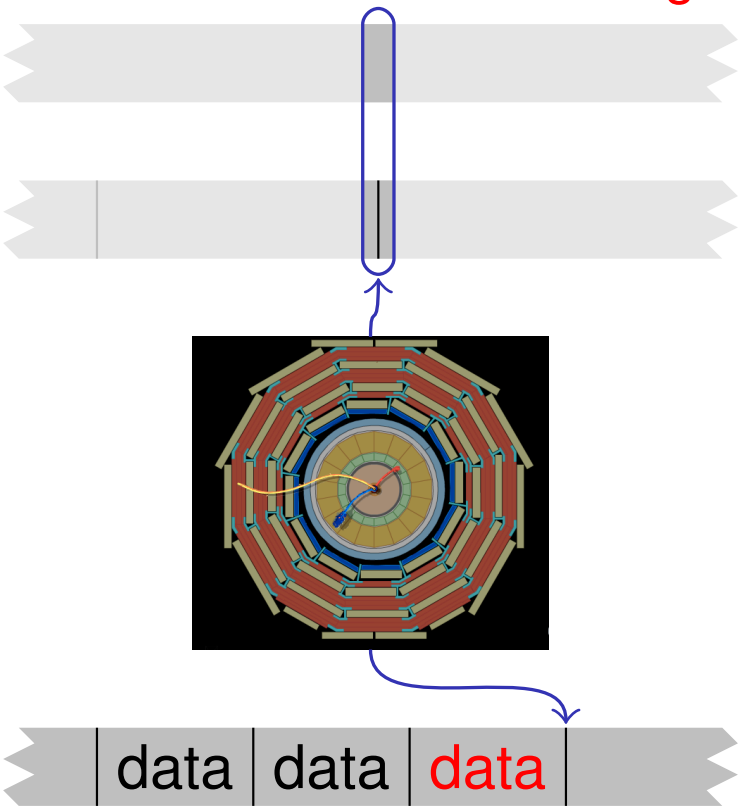

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Comparative History:First Papers from CDF

Minimum Bias

- P_T of charged particles 1988
- η distribution of charged particles 1990
- K_s production 1990

Jets

- Dijet angular distribution 1989
- Inclusive jet cross section 1989
- Two-jet inv-mass distributions 1990
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First Data and SUSY

At start-up

- understand detectors and SM backgrounds
- control/understand: trigger, initial calibrations, scales, resolutions, efficiencies...
- minimize poorly estimated standard model backgrounds
- use SM “candle”/control samples (W/Z/top) to estimate backgrounds as possible (this afternoon)
- adapt methods for background extraction as a function of luminosity
- have in place MC tools

First Data and SUSY

General Stategy

- Choose signatures identifying well defined decay chains
- Extract constraints on masses, couplings, spin from decay kinematics/rates (especially for spin, need clever ideas!)
- try to match emerging pattern to tentative template models
- having adjusted template models to measurements, try to find additional signatures to discriminate different options

CMS PTDR, LHCC-2006-021

ATLAS PTDR, LHCC-1999-015

Lester *et al.* hep-ph/0508143 JHEP01,080 (2006)

A.J.Barr, JHEP02, 042 (2006),hep-ph/0511115

M.M. Nojiri, G. Polesello, D.R. Tovey JHEP03,063 (2006) hep-ph/0512204

Allanach et al hep-ph/0507283

Baltz et al hep-ph/0602187

Belanger *et. al* hep-ph/0405253

Gondolo *et. al* astro-ph/0406204

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