Prospects of CMS

plans for early data and long-terms analyses

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Outline

- Searching for New Physics: Direct vs Indirect strategy
- CMS detector

- **Search For SUSY in early data:**
  - discovery (as early as possible)
  - SUSY characterization

- **Non-SUSY searches**
  - What we can search from the beginning (e.g. Z')
  - Things for which we will have to wait (e.g. Higgs sector)
  - indirect probe of NP scale with QCD

Search for New Physics Today

Indirect Search

virtual effects in flavor (but also EW & QCD physics)

shake the box

& listen

Not limited by collider energy

effective-hamiltonian approaches: less parameters than the underlying models

Limited by luminosity (effects are small)

CRUCIAL: knowledge of SM expectation is the limiting factor (e.g. $\sin 2\beta_{eff}$ in $b \to s$ penguins)

for CMS see talk by J.Olsen

Direct Search@hadron colliders

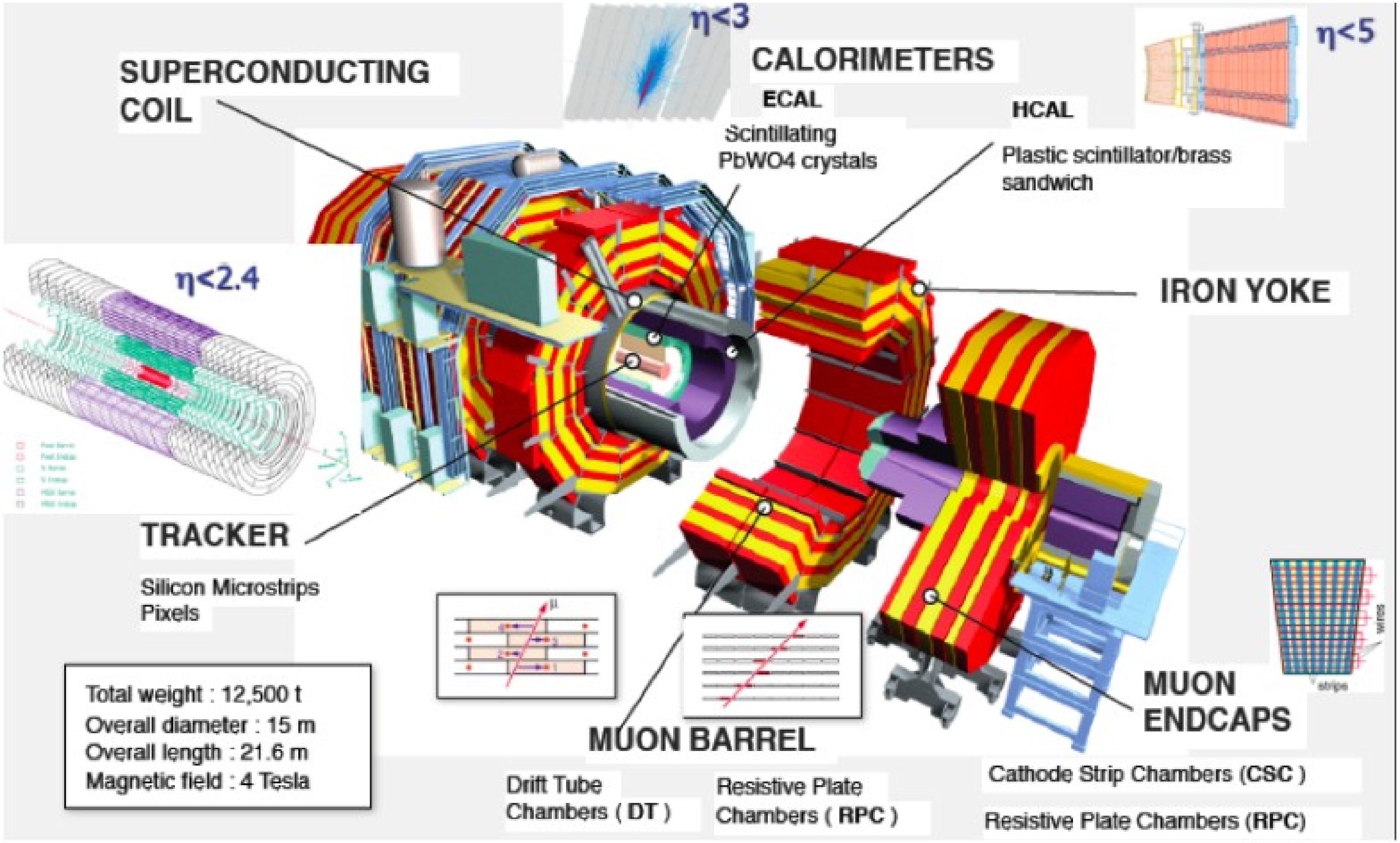
Open the LHC box

Sensitivity should not be limited by the initial kinematic conditions (we think we are at the right energy) and by luminosity

but it might not be enough

this talk

the CMS detector



General purpose detector

- good **resolution** in a large range of particle spectrum
- high performances for **direct search of new particles**
- good potentiality in a set of **golden channels for $B_{(s)}$ physics**

First Data and SUSY

General Stategy:

analysis on early data: understand detector response and backgrounds with low statistics

- Focus at startup on general (i.e. LSP, inclusive searches) analyses with a discovery potential at low luminosity
- Choose signatures identifying well defined decay chains

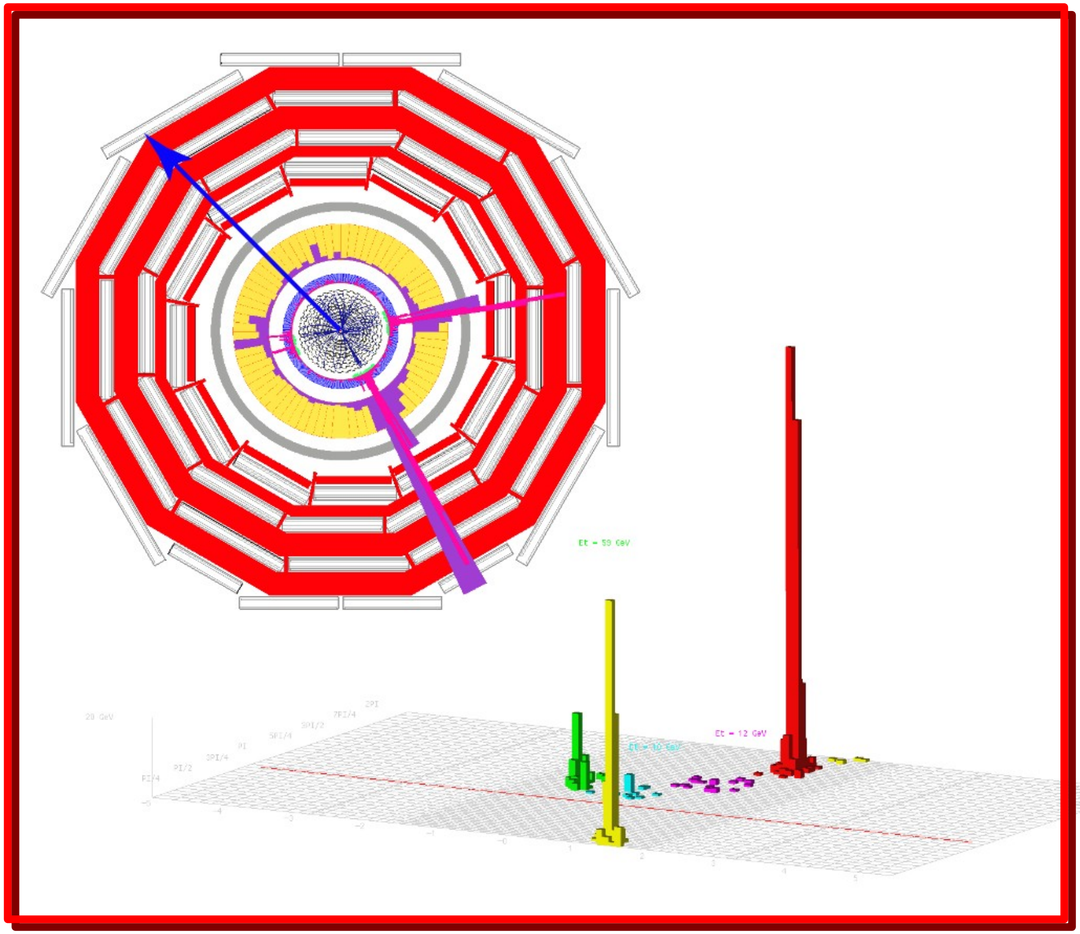
- Extract constraints on masses, couplings, ... from decay kinematics/rates

to perform with larger statistics but also suitable for discovery

- Try to match emerging pattern to tentative template models
- Having adjusted template models to measurements, try to find additional signatures to discriminate different options

interplay with theory community and with other experiments

Missing Energy is the crucial handle to discover stable neutral particles crossing the detector w/o interacting



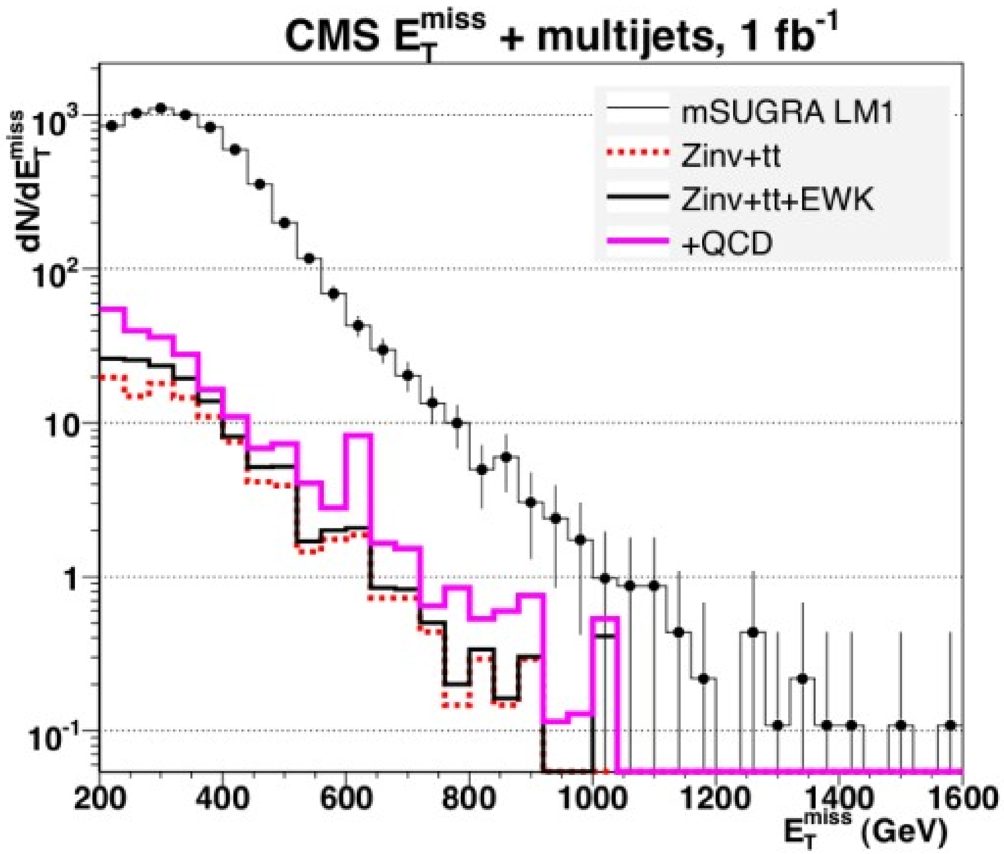
Example: 3jets + missing E_T

E_T =360 GeV, $E_T(1)$=330 GeV, $E_T(2)$=140 GeV, $E_T(3)$=60 GeV

LHC can **discover** such events **fast**: Typical cross section values imply >10K events per year with machine at regime

Inclusive Signatures with Missing Energy

Example:
gluino=600 GeV
neutralino=100 GeV



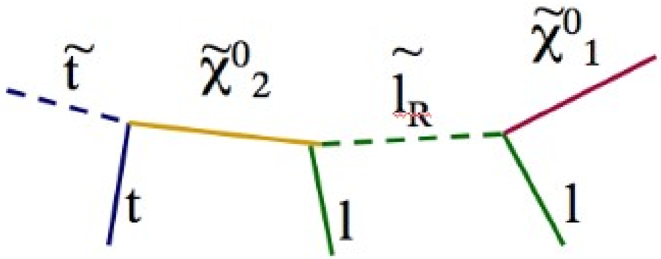
fast-track to discovery of "low mass" SUSY

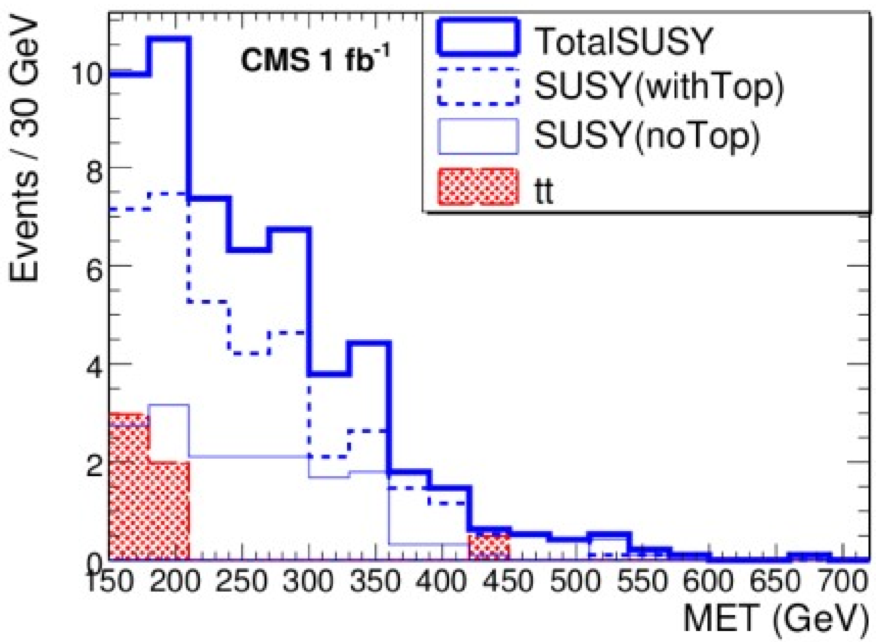
Case for early (i.e. O(100 pb^{-1})) discovery: large cross section allowed by current direct and indirect constraints

control of QCD and EW backgrounds: systematics using SM processes (e.g. Z +jets, top) to be studied in parallel on the same data

the time between O(10 pb^{-1}) and O(100 pb^{-1})of well understood data will be critical for the discovery and characterization of SUSY

Stop from inclusive top excess





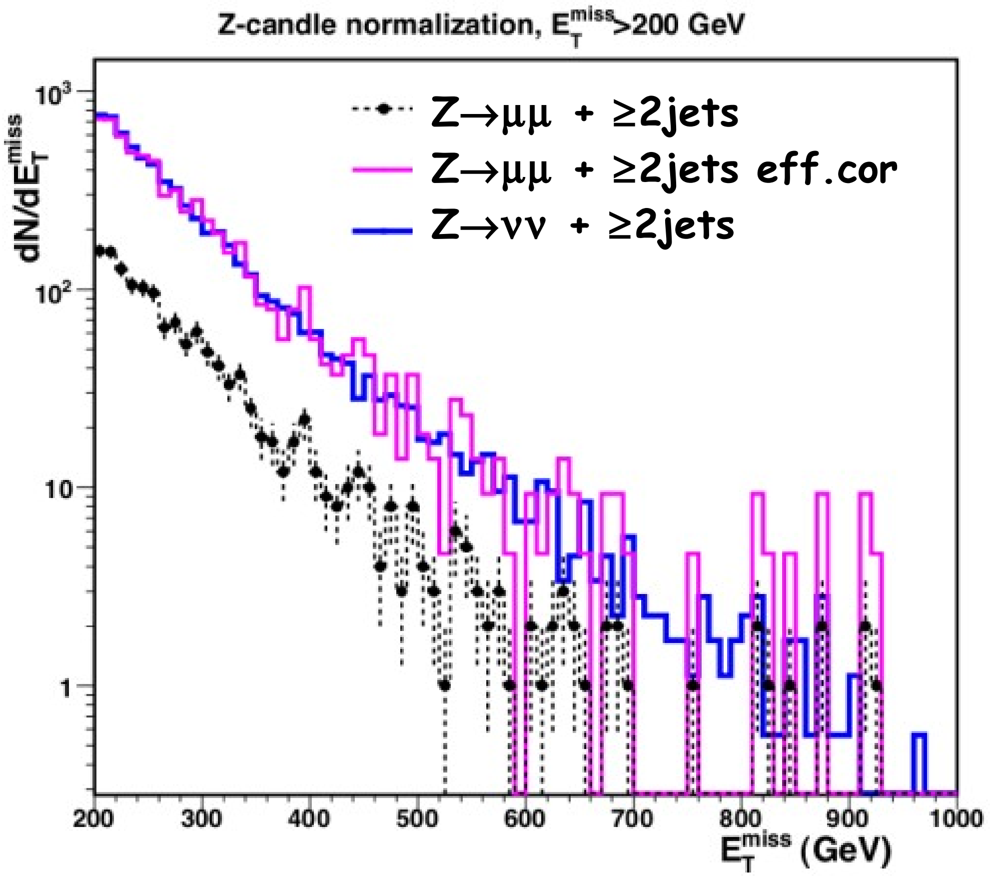
Several production mechanisms merged in an inclusive search (example from our LM1 benchmark point)

$Mother \rightarrow Daughters$	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	$\tilde{t}_1 \rightarrow \chi_2^0 + t$	12.53
$\tilde{t}_1 \rightarrow \chi_1^0 + t$	17.70	$\tilde{t}_2 \rightarrow \chi_{all}^0 + t$	40.58
$\tilde{b}_1 \rightarrow \chi_1^+ + t$	48.36	$\tilde{b}_2 \rightarrow \chi_1^+ + t$	23.85

- Missing E_T as discriminating variable
- Excess of reconstructed hadronic top
- m(jj) consistent with mW and m(jjb) consistent with mtop (imposed in a kinematic fit)

Example: The Z candle

use Zll+jets after efficiency correction to predict Zνν+jets (irreducible bkg to jets + missing ET)



If we want to have early discovery WHILE we are understanding the backgrounds, standard model MC samples cannot be used for bkg predictions

data-driven strategies and MC to data normalization avoids systematics due to QCD scale, PDF's, ISR/FSR, jet energy scale, ...
Systematic effects dominated by luminosity
5% precision expected with ~ 1.5 fb^{-1}

CMS plan for SUSY/BSM search (I)

- Search for SUSY (Evidence for excess) in ≥1 lepton+E_T +jets at 14 TeV in the electron and muon channels (100 pb^{-1}).
- Search for SUSY (Evidence for excess) in opposite sign dilepton pairs+ missing E_T +jets at 14 TeV in the electron and muon channels (20 pb^{-1})
- Search for SUSY (Evidence for excess) in same-sign dilepton pairs + E_T +jets at 14 TeV in the electron and muon channels (200 pb^{-1})
- Search for SUSY (Evidence for excess) in Z^0 leptonic decays+ E_T +jets at 14 TeV in the electron and muon channels (100 pb^{-1})
- Search for LFV SUSY (Evidence for excess) in e + μ final state at 14 TeV (500 pb^{-1})
- Search for SUSY (Evidence for excess) in trileptons + jets at 14 TeV. (~ fb^{-1})

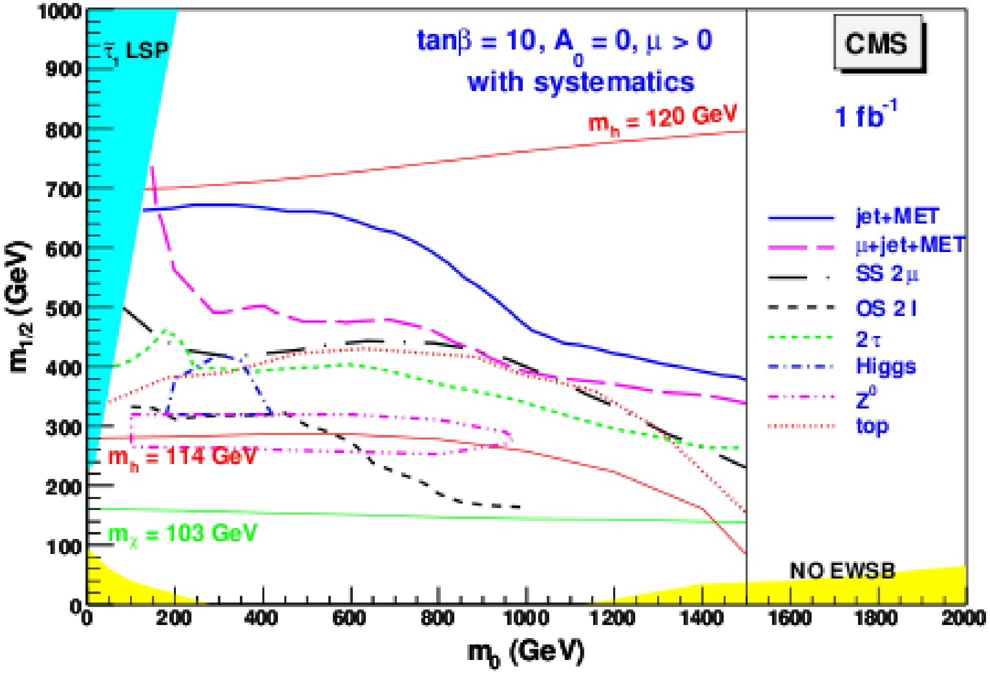
CMS plan for SUSY/BSM search (II)

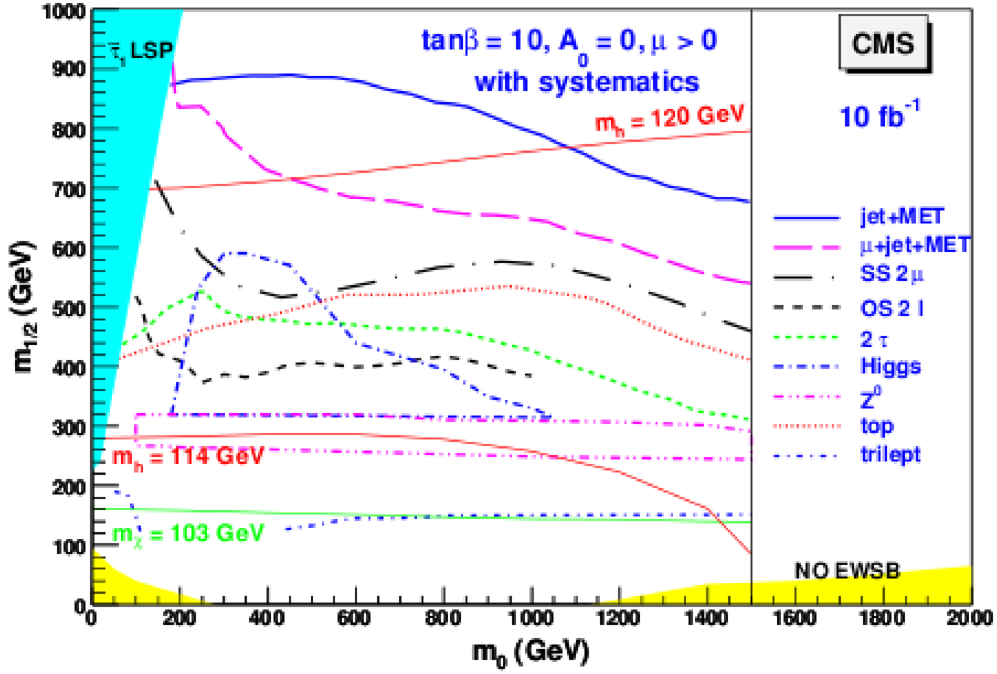
- Search for SUSY (Evidence for excess) in bb + 1 lepton at 14 TeV.
- Search for SUSY (Evidence for excess) in 0 lepton + E_T + jets at 14 TeV (10 pb^{-1})
- Search for SUSY (Evidence for excess) in bb + E_T + jets at 14 TeV (100 pb^{-1})
- Search for SUSY (Evidence for excess)in top hadronic decays+ E_T at 14 TeV (200 pb^{-1})
- Serach for SUSY (Evidence for excess) in opposite-sign ditau + E_T at 14 TeV (200 pb^{-1})
- Search for GMSB (Evidence for excess) in prompt γ final states at 14 TeV (500 pb^{-1})
- Search for GMSB (Evidence for excess) in non-pointing γ at 14 TeV (1 fb^{-1})
- Search and reconstruction of heavy stable charged particles at 14 TeV using TOF and dE/dx (500 pb^{-1})
- ...

New with respect to physics TDR

SUSY discovery potential@CMS

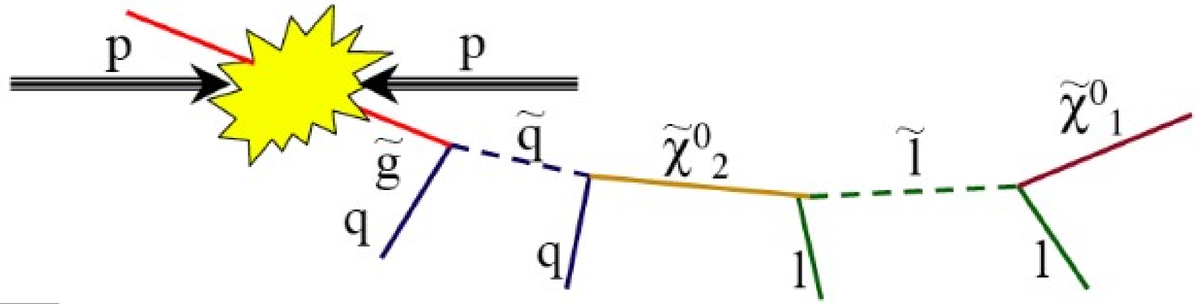
quantified discovery potential using mSugra as a benchmark





Characterization of new particles

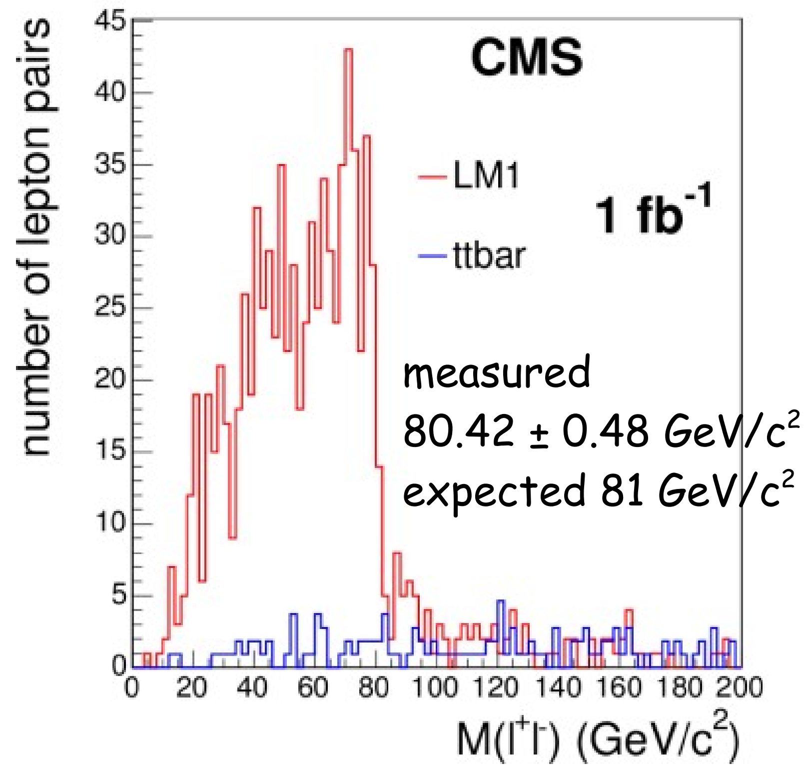
Measuring the Masses (I)



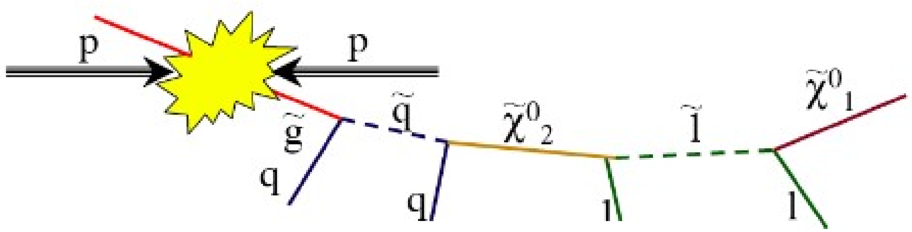
SameFlavorOppositeSign
dileptons+jets+ET

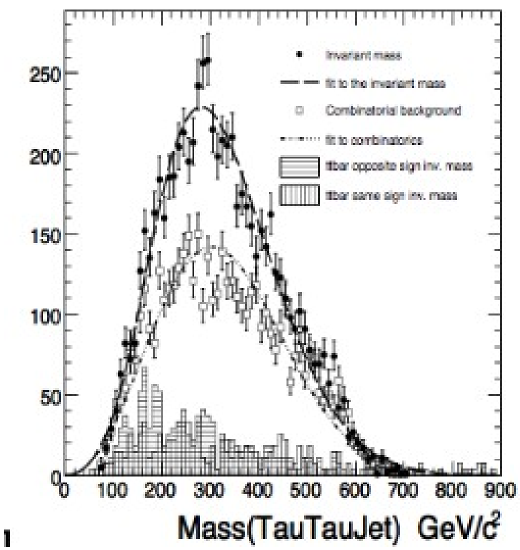
$$M_{\ell\ell}^{max} = M(\tilde{\chi}^0_2)\sqrt{1-\frac{M^2(\tilde{\ell}_R)}{M^2(\tilde{\chi}^0_2)}}\sqrt{1-\frac{M^2(\tilde{\chi}^0_1)}{M^2(\tilde{\ell}_R)}}$$

- main bkg from tt production:
  tt : WW+j : Z+j : other~ 6:1:1:1
- flavor subtraction ($e^- \mu^+ + e^+ \mu^-$) to suppress other contributions (chargino,W , t WW , ...)
- overall systematic on the background 20%
- 5σ discovery with ~ 20 pb^{-1}
- M(ll) measured with O(1 GeV) uncertainty for O(1 fb^{-1}) samples

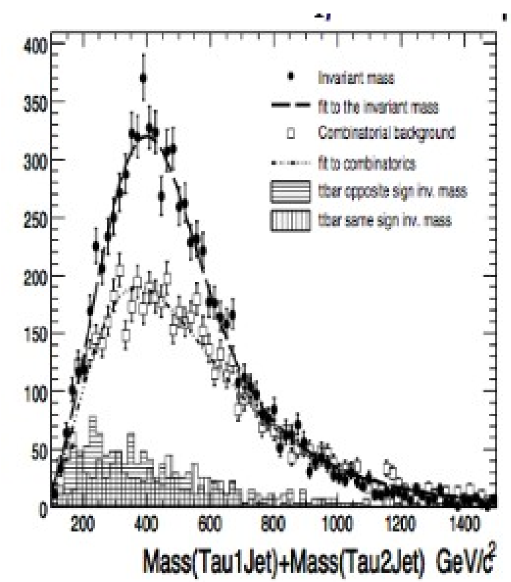


Combine measurements of thresholds and edges from different jet/lepton mass combinations to obtain mass measurements



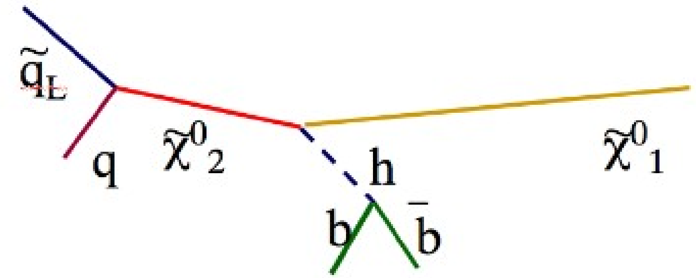


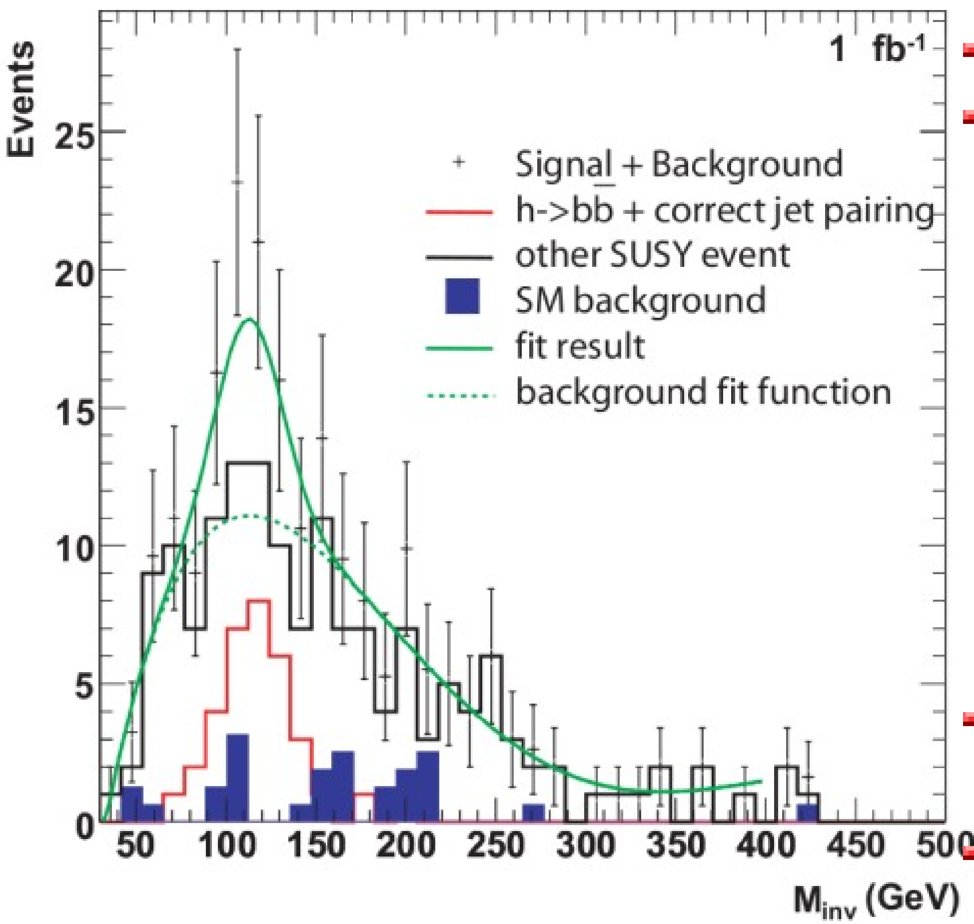
	LM2 test point	
	measured	theory
$M(\tilde{\chi}^0_1)$ (GeV)	$147 \pm 23(\text{stat}) \pm 19(\text{sys})$	138.2
$M(\tilde{\chi}^0_2)$ (GeV)	$265 \pm 10(\text{stat}) \pm 25(\text{sys})$	265.5
$M(\tilde{\tau})$ (GeV)	$165 \pm 10(\text{stat}) \pm 20(\text{sys})$	153.9
$M(\tilde{q})$ (GeV)	$763 \pm 33(\text{stat})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



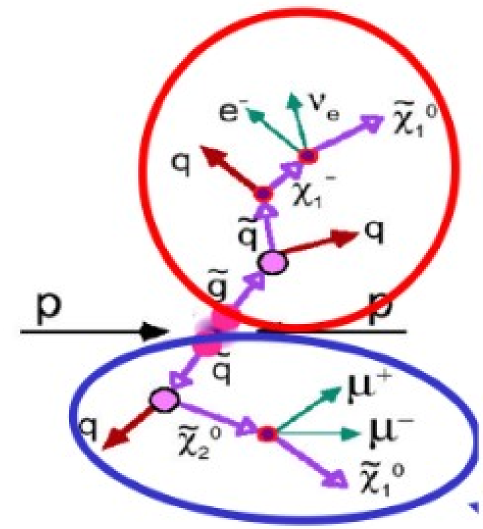
Measuring the Masses (III)

Search of $\bar{b}b$ pairs in decay chains





- $\bar{b}b$ to be extracted from SM control processes
- 5σ excess with 1.5 fb^{-1}



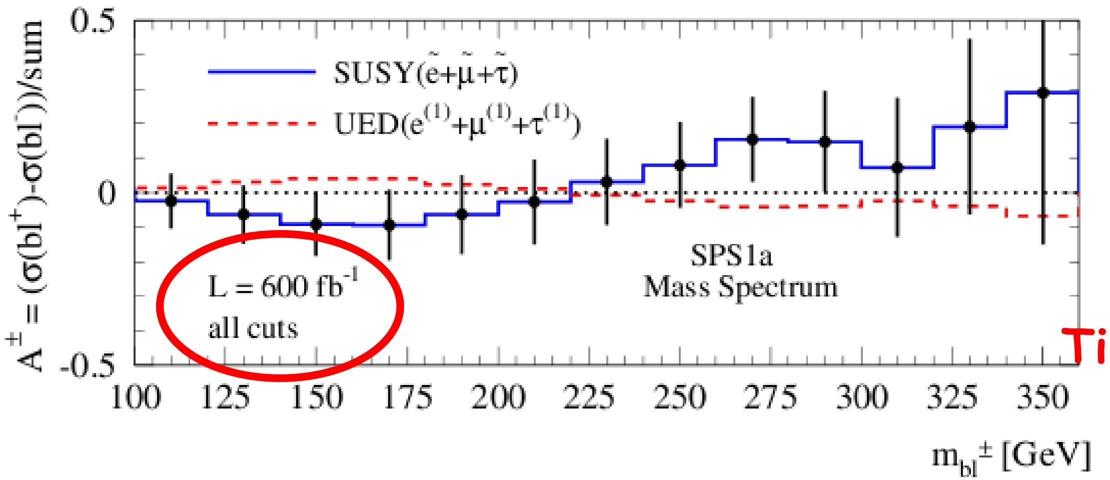
- cascade chain separated in 2 hemisphere
- 2 b's required in the same hemisphere and close in dR

Spin Measurement

The measurement of the spin of SUSY particles is more challenging but very useful to distinguish among models

Example: SUSY vs UED with bl asymmetry

$A = [\sigma(bl+) - \sigma(bl-)]/[\sigma(bl+) + \sigma(bl-)]$



from Tilman Plehn

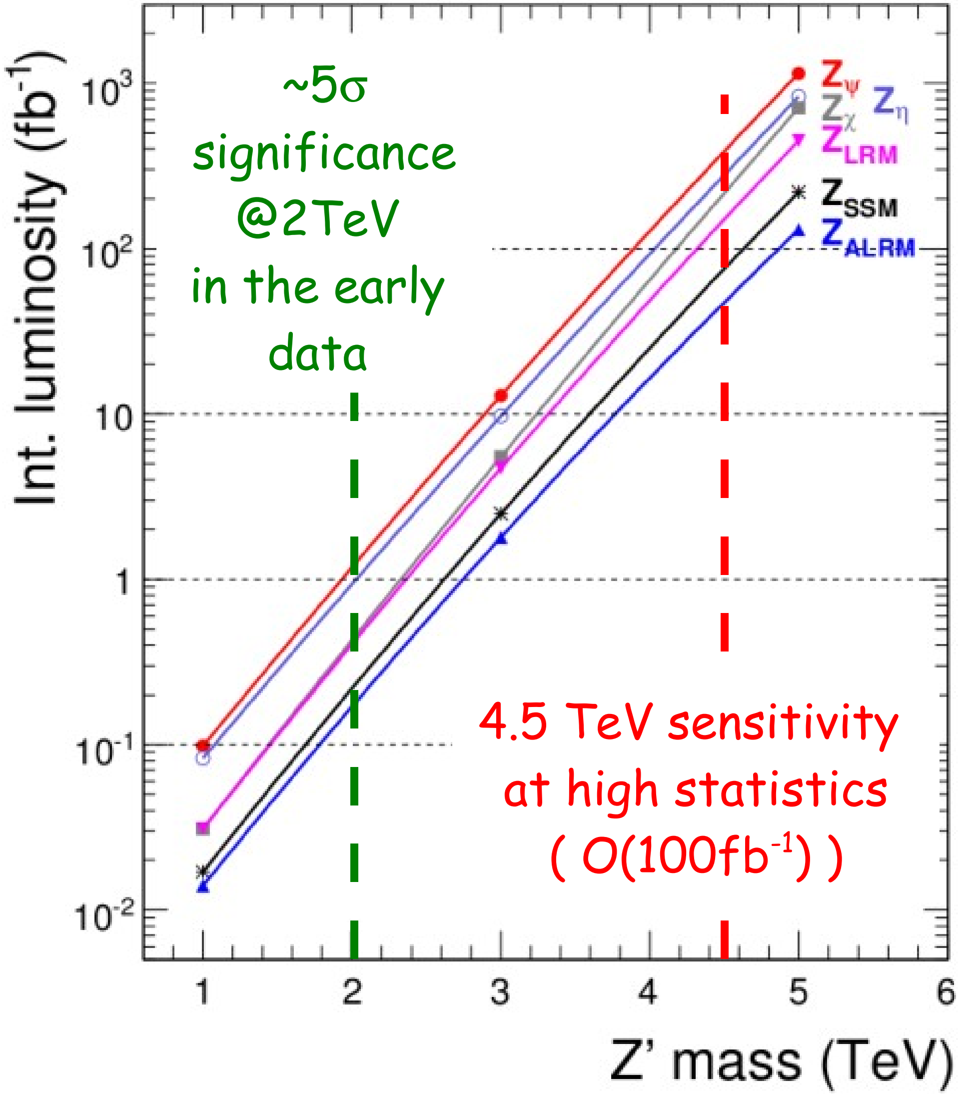
Other methods needs smaller but still large statistics in order to get any meaningful conclusion

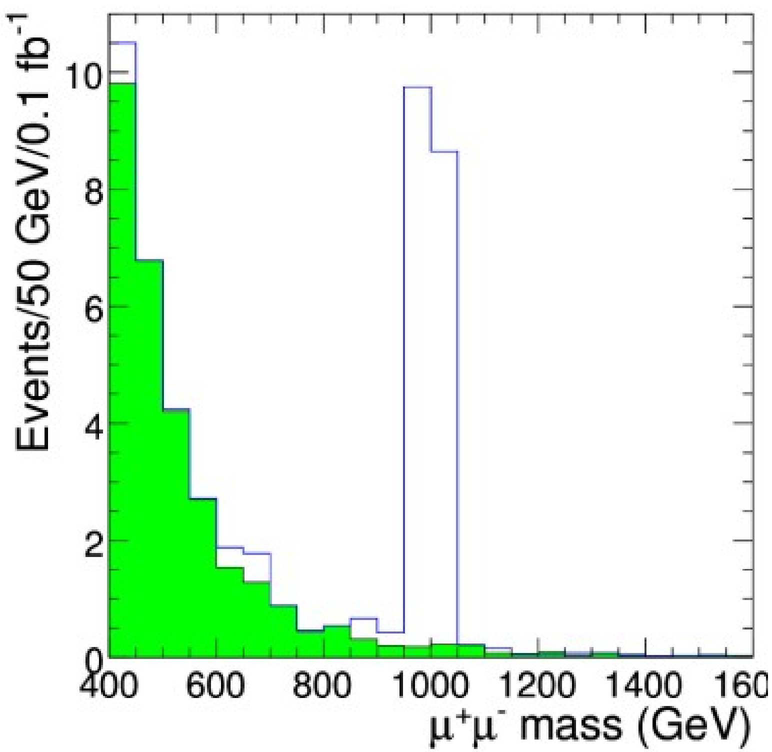
This is where more thinking is ongoing from both experiments and phenomenology point of view

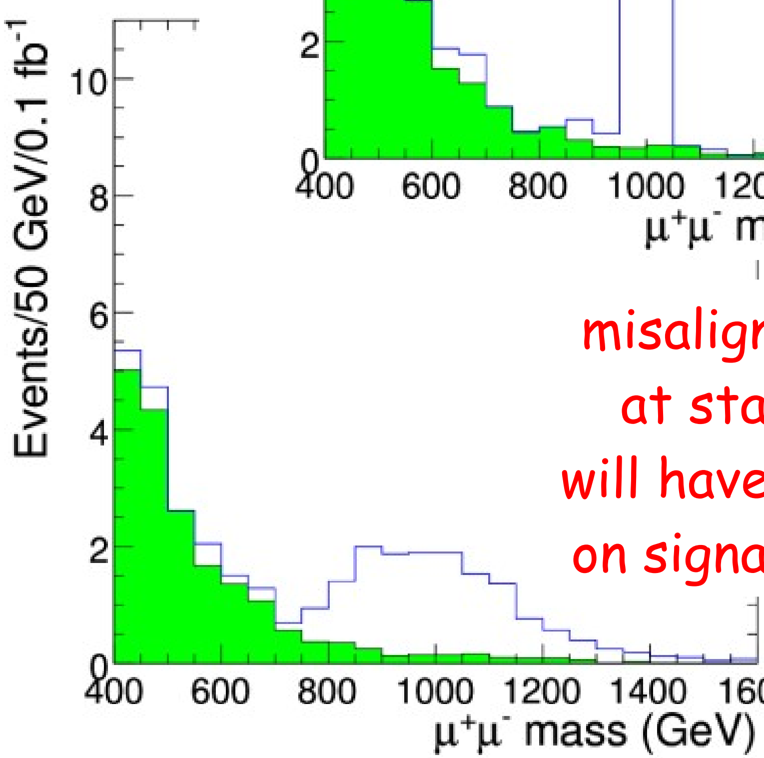
Non-SUSY searches early searches and long-term plans

Di-lepton Resonances (Example Z')

Two high-momentum leptons are a clean signature in the detector





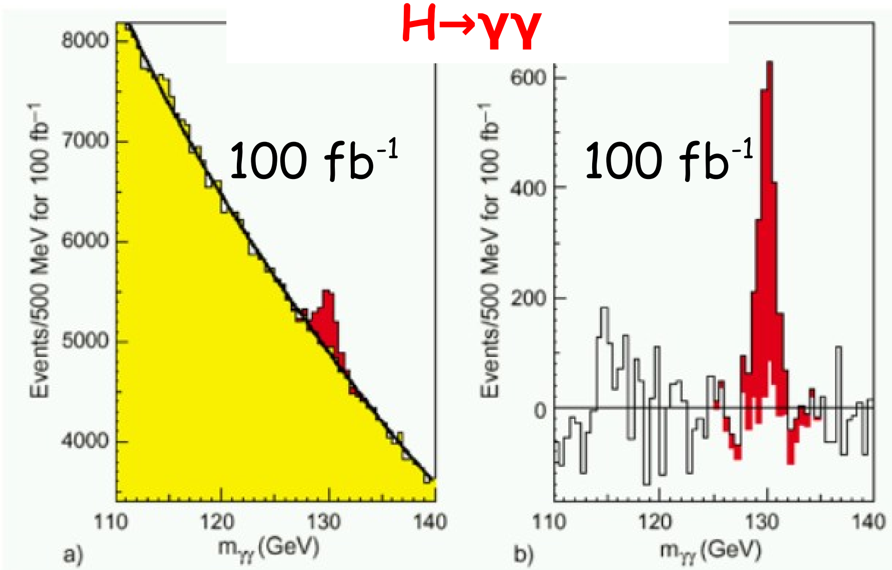


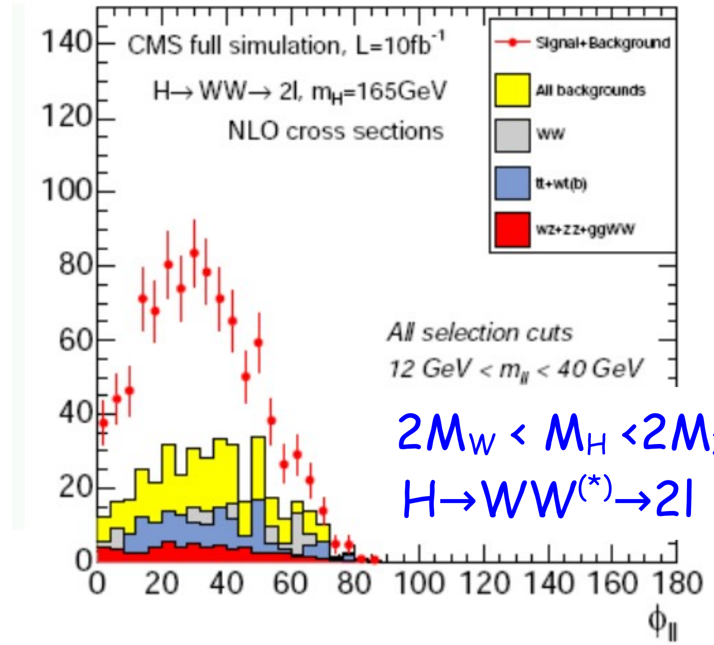
misalignement at startup will have impact on signal shape

Neutral Higgs Search: where to look for

Low M_H < 140 GeV

$H \to \gamma\gamma$



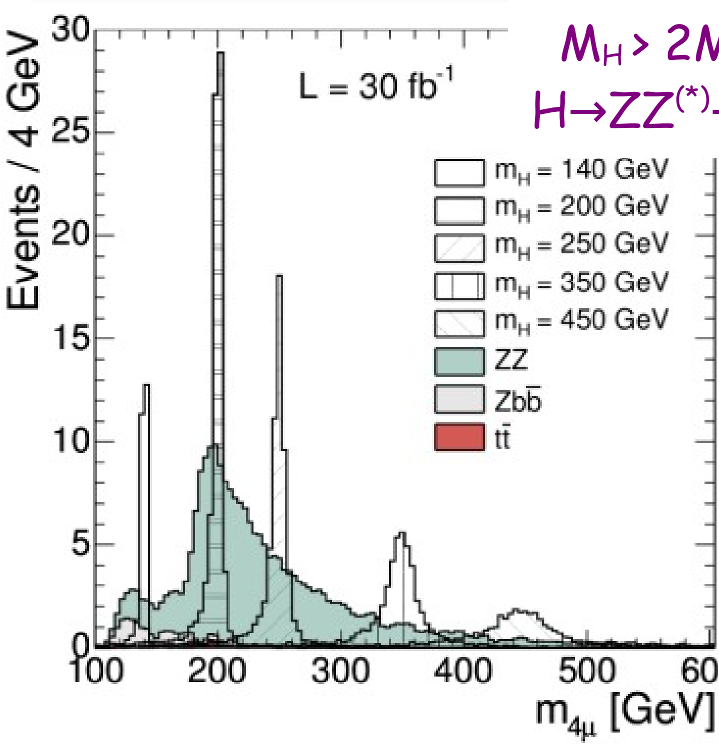


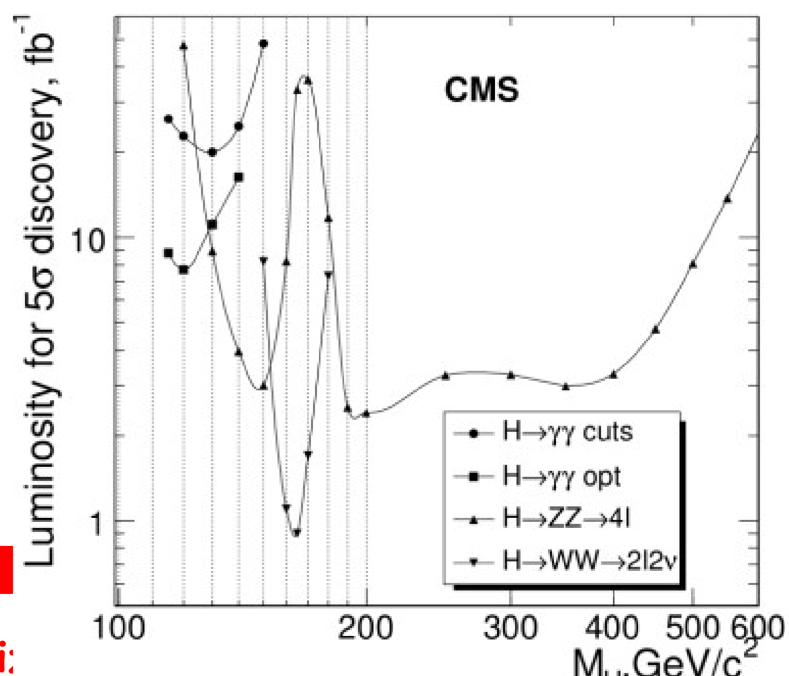
$2M_W < M_H < 2M_Z$

$H \to WW^{(*)} \to 2l$

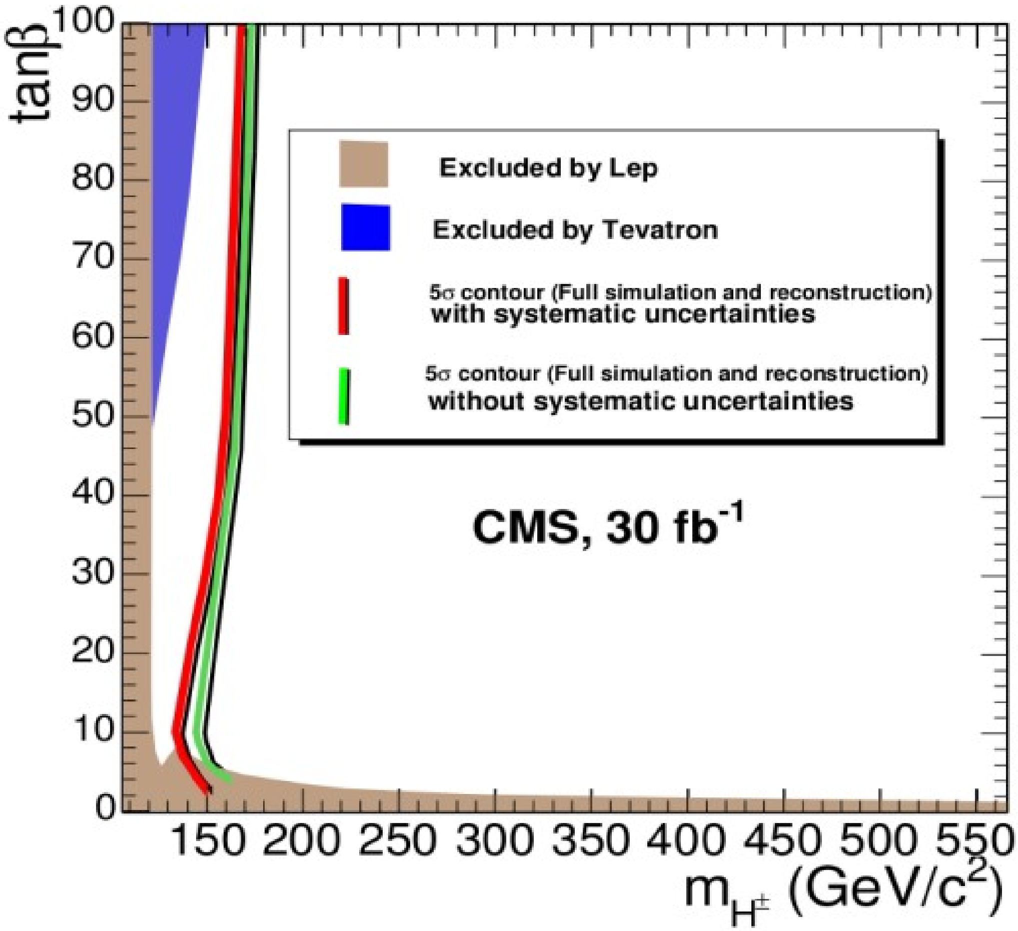
$M_H > 2M_W$

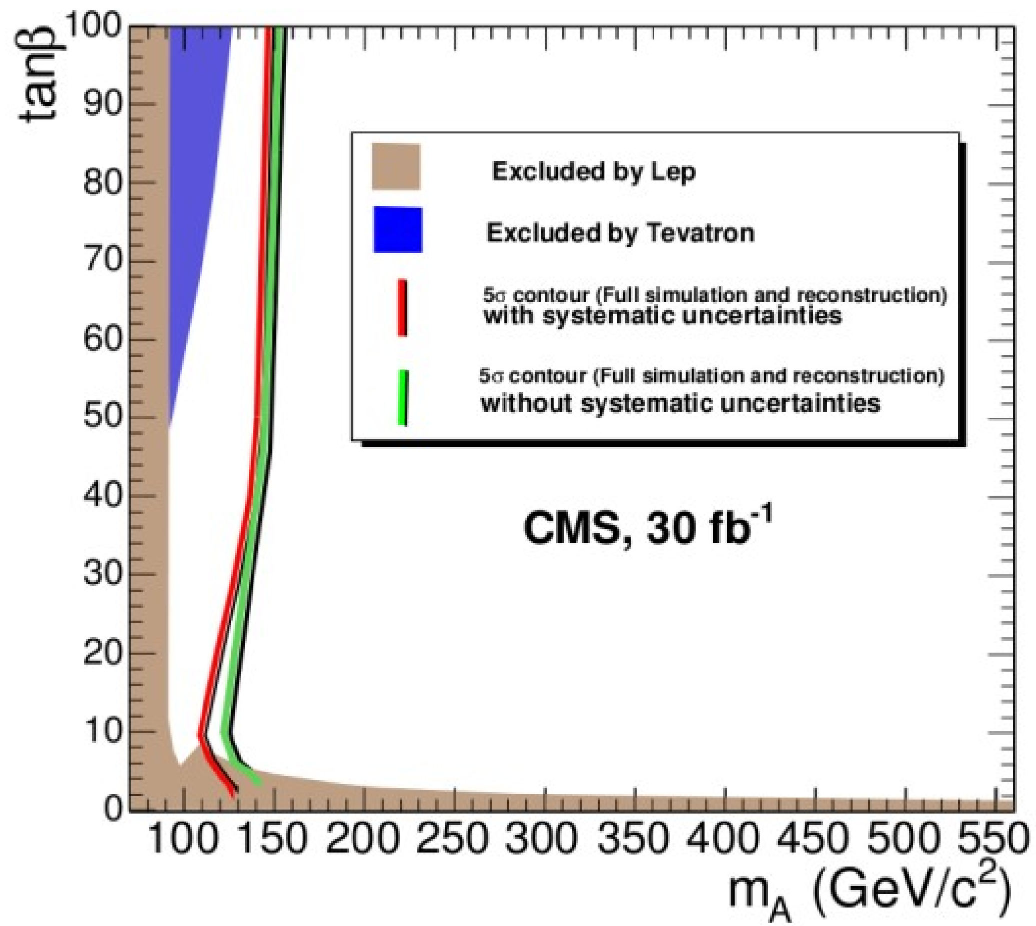
$H \to ZZ^{(*)} \to 4l$





MSSM Higgs & Model disentangle



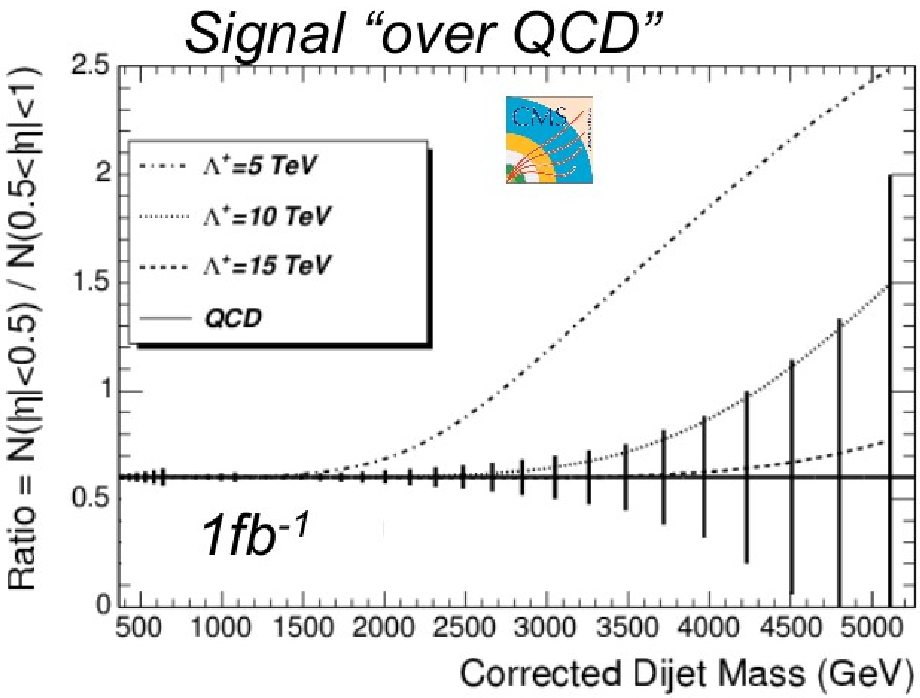


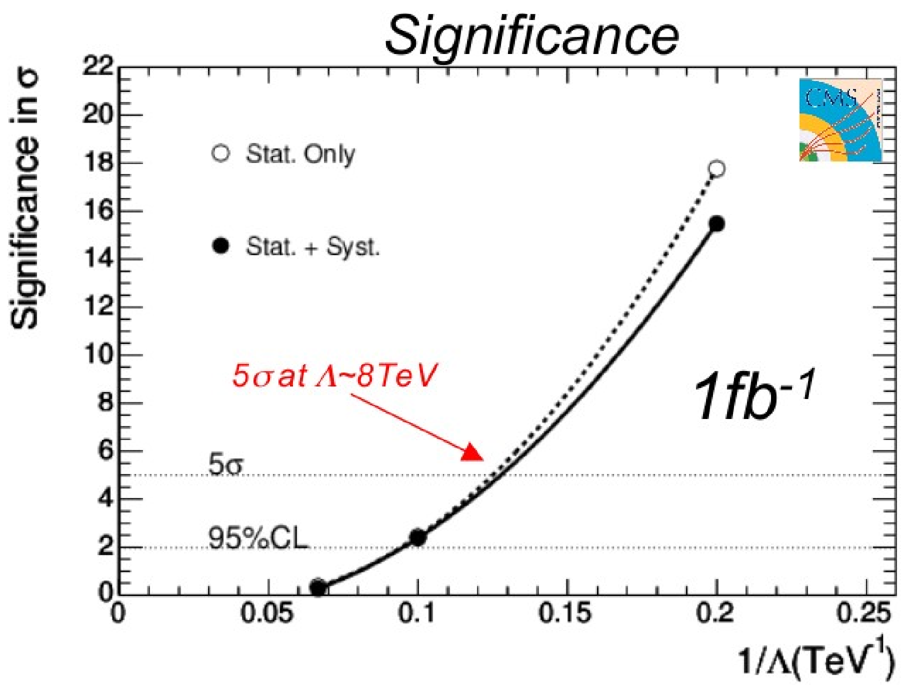
- Good sensitivity to the masses
- Interplay with other measurements
  (e.g. flavor) to extract information on tanβ

Contact Interactions with Di-jets

Small systematic due to use of ratio:

Di-jet Ratio = N(|η|<0.5) / N(0.5<|η|<1)





Discovery Sensitivity (CMS)

100pb^{-1} → Λ~ 5 TeV

1fb^{-1} → Λ~ 8 TeV

10fb^{-1} → Λ~ 12 TeV

Conclusions

With LHC approaching, CMS is defining the strategy for search and characterization of new physics

- At startup, inclusive analyses will play the major role
- Missing E_T is crucial to search for Dark Matter candidates
- Multichannel signal searches assist the missing Et search in particular at startup
- SM background will be normalized on data using control samples

- With ~1fb^{-1} statistics, SUSY masses will be accessible (using leptons and heavy quarks)

- Other possible BSM scenarios provide clean signatures in the detector
  Example: Z' (sensitivity vs luminosity strongly dependent on mass scale)

- Higgs (charged and neutral) search: 10fb^{-1}-30fb^{-1} for evidence of signal
- Search strategy depends on the true mass value (i.e. on favorite final state)

- Contact interactions as an indirect probe: it allows to extend the search range well above the LHC energy (similarly to EW and flavor indirect constraints)

Backup

Neutral Higgs Discovery Potential