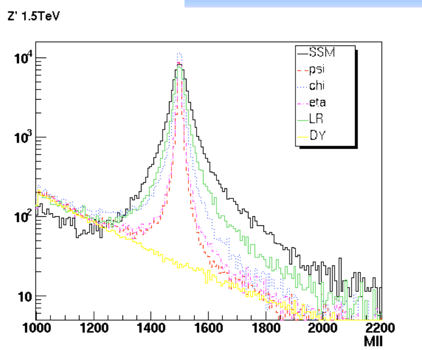
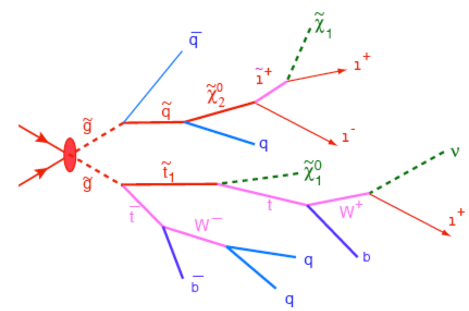
Search for New Physics at the LHC
Focus: First Physics Run 2009/2010



Oliver Buchmüller
Imperial College London



- *Expectations for 2009/2010*
- *A few illustrative examples*
- *Making sense out what we will see ..*

UK HEP Forum: „Tevatron2LHC" 7/8 May 2009

Timeline of LHC Discoveries?

Many people now ask:

Will the LHC discover the Higgs boson?

A (provocative) answer could be …

Timeline of LHC Discoveries?

Many people now ask:

Will the LHC discover the Higgs boson?

A (provocative) answer could be …

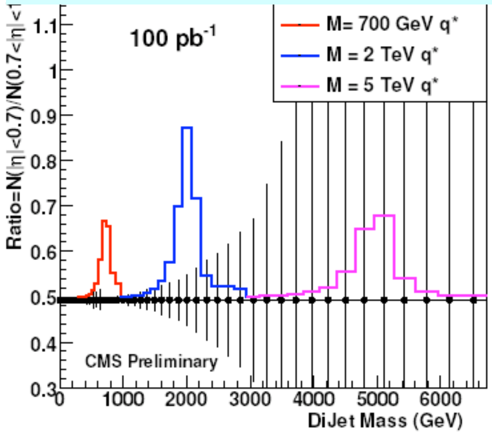
By the time the LHC discovers the Higgs boson, that discovery will no longer be considered interesting.

M.E. Peskin - Tools 2008

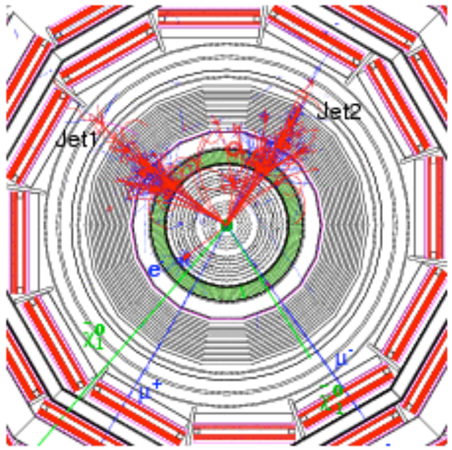
SM + X: New Physics Potential of the LHC

What could make a Higgs discovery "uninteresting"?

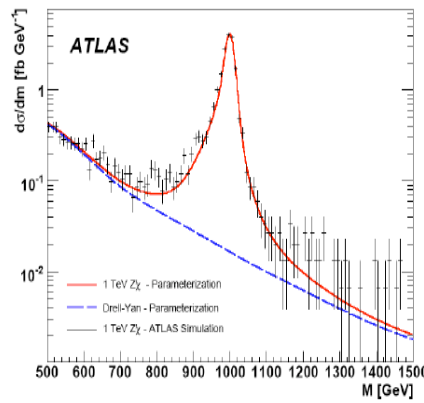
Contact Interaction /Excited Quarks?



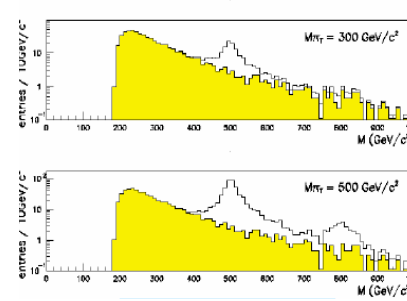
Supersymmetry?



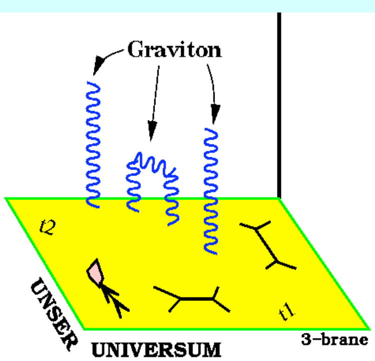
New Gauge Bosons?



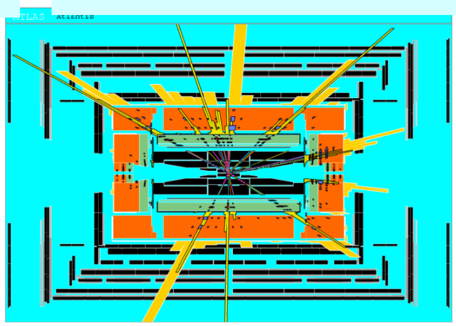
Technicolor?



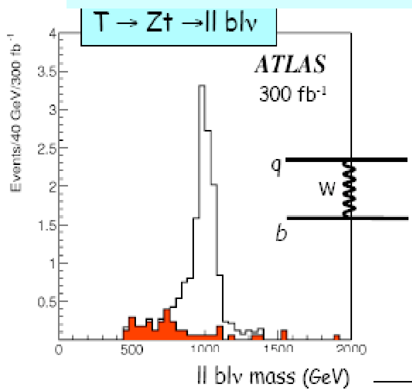
Extra Dimensions?



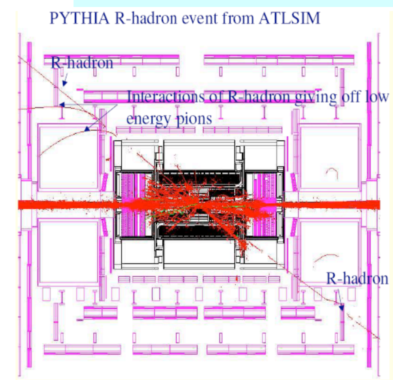
Black Holes???



Little Higgs?



Split Susy?



First LHC Physics Run: Expectations

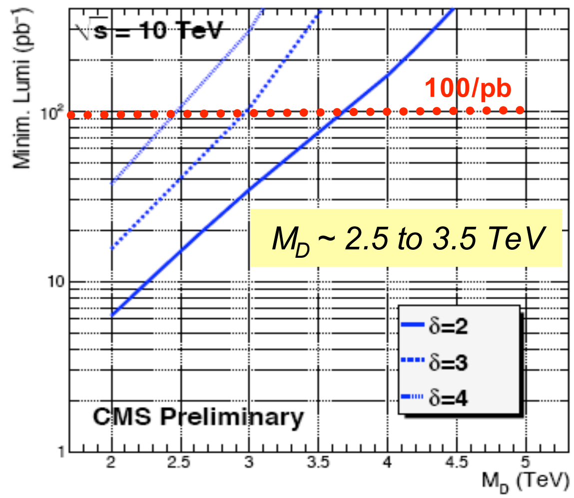
Few Examples of important BSM searches in 2009/2010 (Benchmark 10 TeV 100/pb)

Significant discovery potential in 2009/2010.

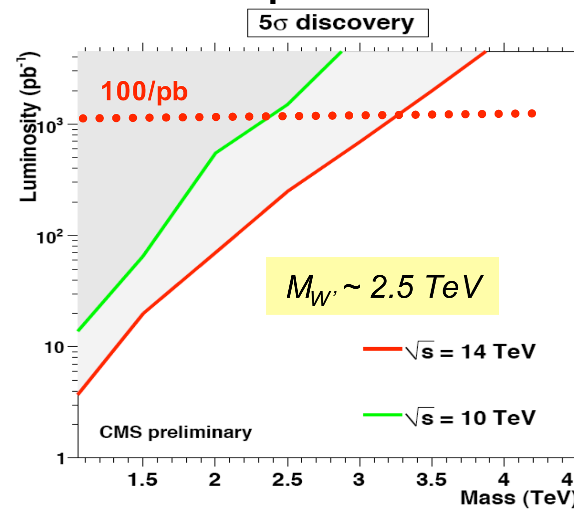
Will explore new territory with several BSM searches!

(Plots all CMS but ATLAS similar!)

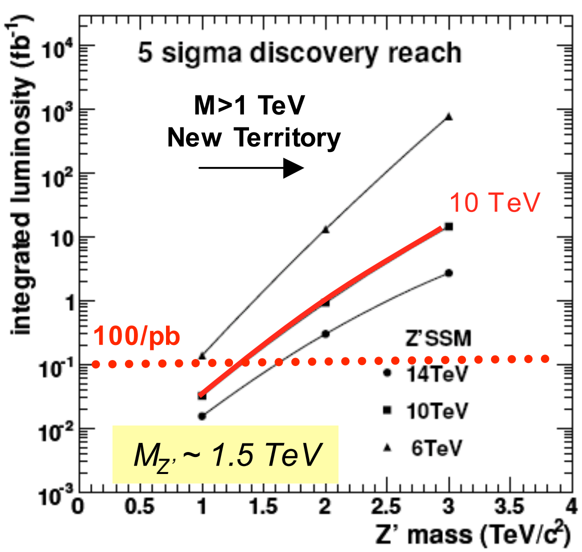
ADD: Monojet (+Etmis) search



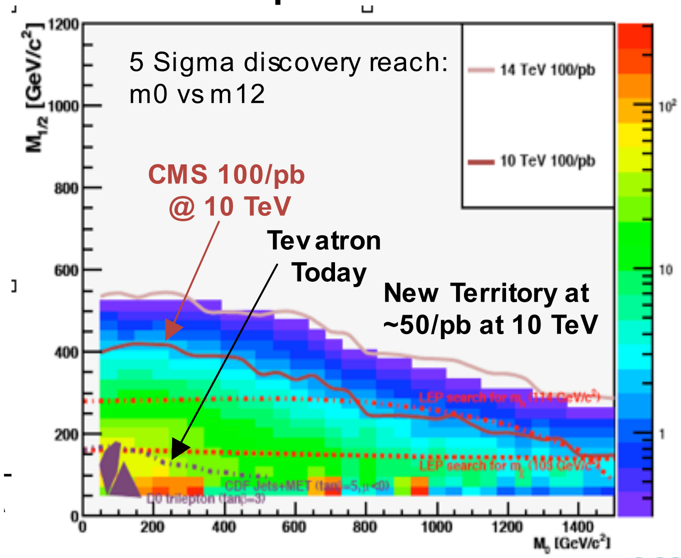
Heavy Resonances Example: W'→ eν



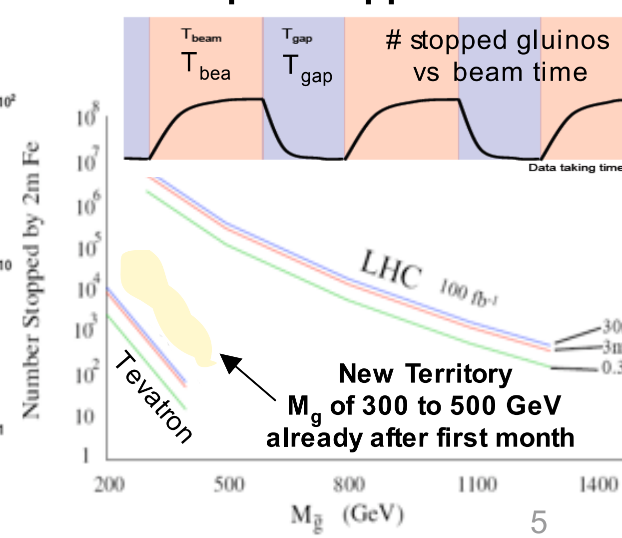
Heavy Resonances Example: Z'→ ee



Inclusive SUSY Searches Example: Jets+Etmis



Long lived Particles Example: Stopped Gluinos



14 TeV plots and numbers

BSM Searches

Model	Mass reach	Luminosity (fb^{-1})	Early Systematic Challenges
Contact Interaction	Λ < 3 TeV	0.01	Jet Eff., Energy Scale
Z' W'	M ~ 1 TeV M ~ 1 TeV	0.01-0.1 0.01	Alignment Alignment/MET
Black Holes	M_D~ 2.0 TeV	0.01	MET/ Jet Energy Scale
Excited Quark	M ~0.7 – 3.6 TeV	0.1	Jet Energy Scale
Axigluon or Colouron	M ~0.7 – 3.5 TeV	0.1	Jet Energy Scale
E6 diquarks	M ~0.7 – 4.0 TeV	0.1	Jet Energy Scale
Technirho	M ~0.7 – 2.4 TeV	0.1	Jet Energy Scale
ADD Virtual G_{KK}	M_D~ 4.3 - 3 TeV, n = 3-6 M_D~ 5 - 4 TeV, n = 3-6	0.1 1	Alignment
ADD Direct G_{KK}	M_D~ 1.5-1.0 TeV, n = 3-6	0.1	MET, Jet/photon Scale
SUSY Jet+MET+0 lepton Jet+MET+1 lepton	M ~1.5 – 1.8 TeV M ~0.5 TeV M ~0.5 TeV	1 0.01 0.1	MET, Jet Energy Scale, Multi-Jet backgrounds, Standard Model backg.
mUED	M ~0.3 TeV M ~ 0.6 TeV	0.01 1	Lepton ID
HSCP	M ~ 0.3 TeV M ~ 1.0 TeV	0.1 1	TOF, dE/Dx
RS1 di-jets di-muons	 M_{G1}~0.7- 0.8 TeV, c=0.1 M_{G1}~0.8- 2.3 TeV, c=0.01-0.1	 0.1 1	 Jet Energy Scale Alignment

Not an exhaustive list!!

Understood data - of course!

14 TeV plots and numbers

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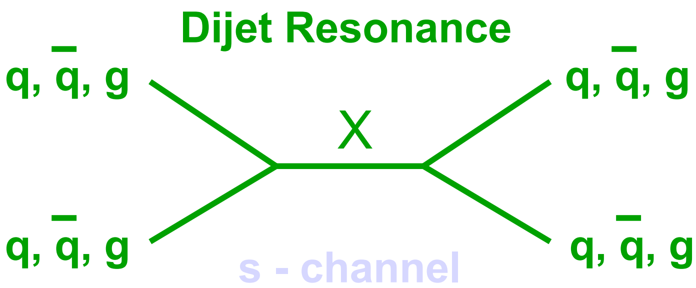
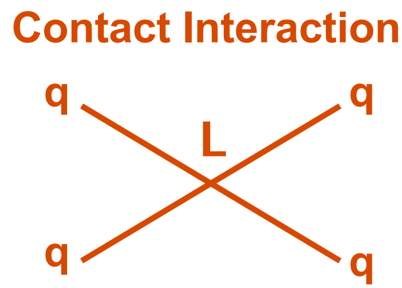
mUED	M ~0.3 TeV M ~ 0.6 TeV	0.01 1	Lepton ID

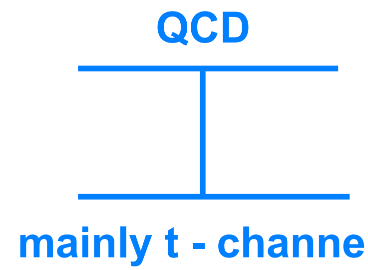
Not an exhaustive list!!

Rather than presenting the generic reach plots for each scenario (we have seen them so many times already), I will discuss a few illustrative examples in more detail.

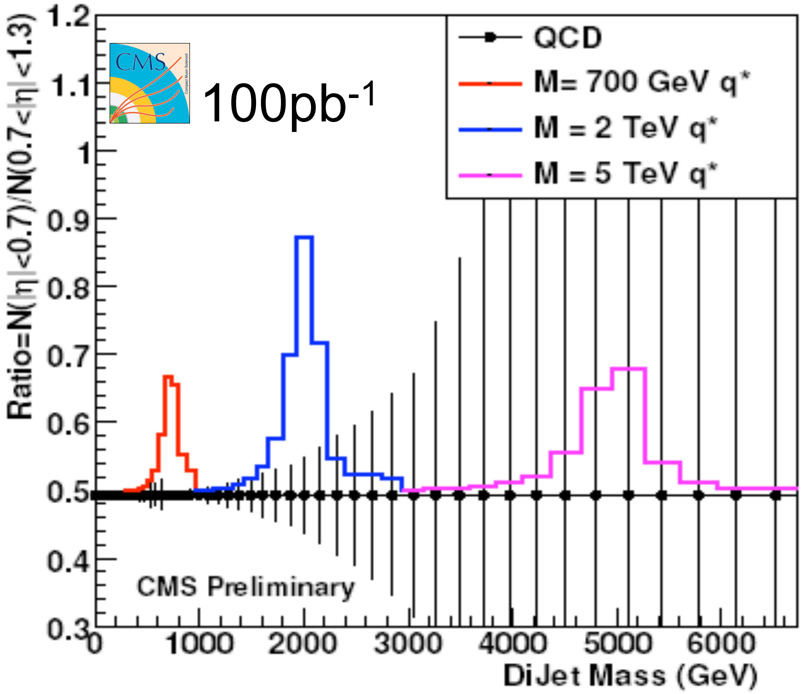
New Physics Search with Di-jets



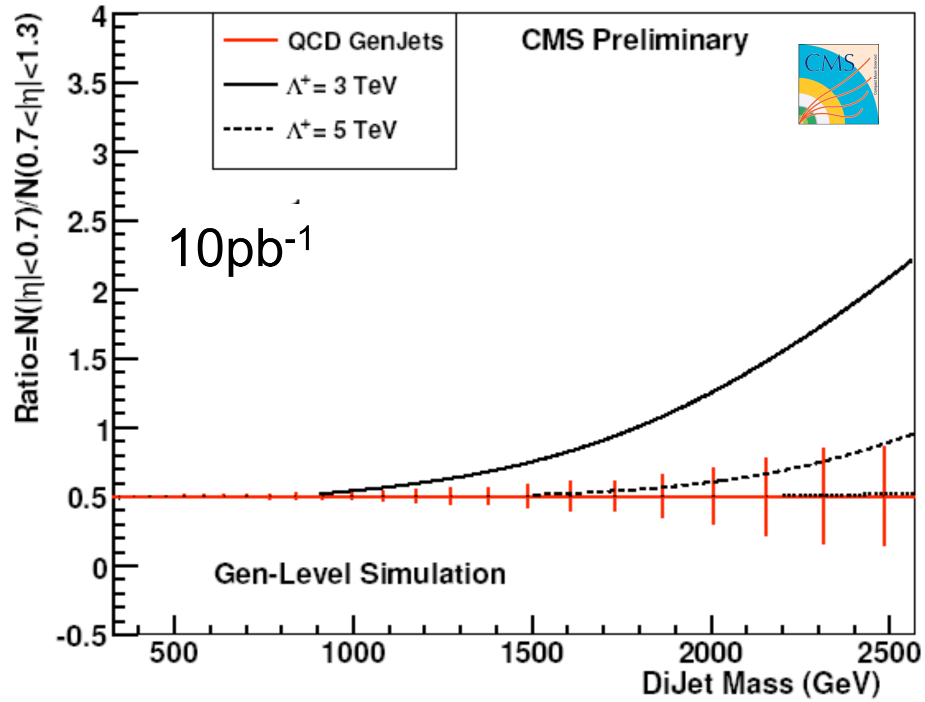




Exited Quarks



Contact Interaction



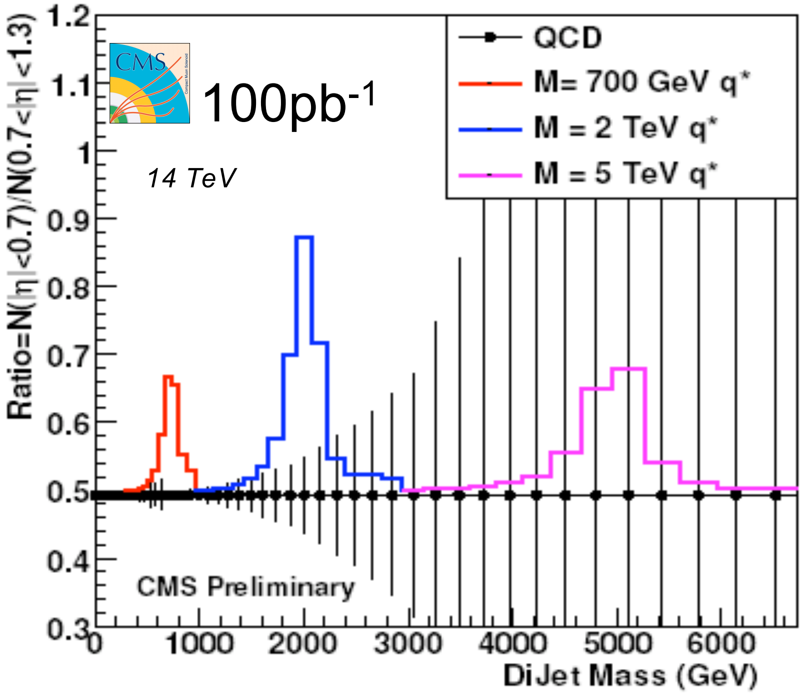
New Physics Search with Di-jets

Exited Quarks

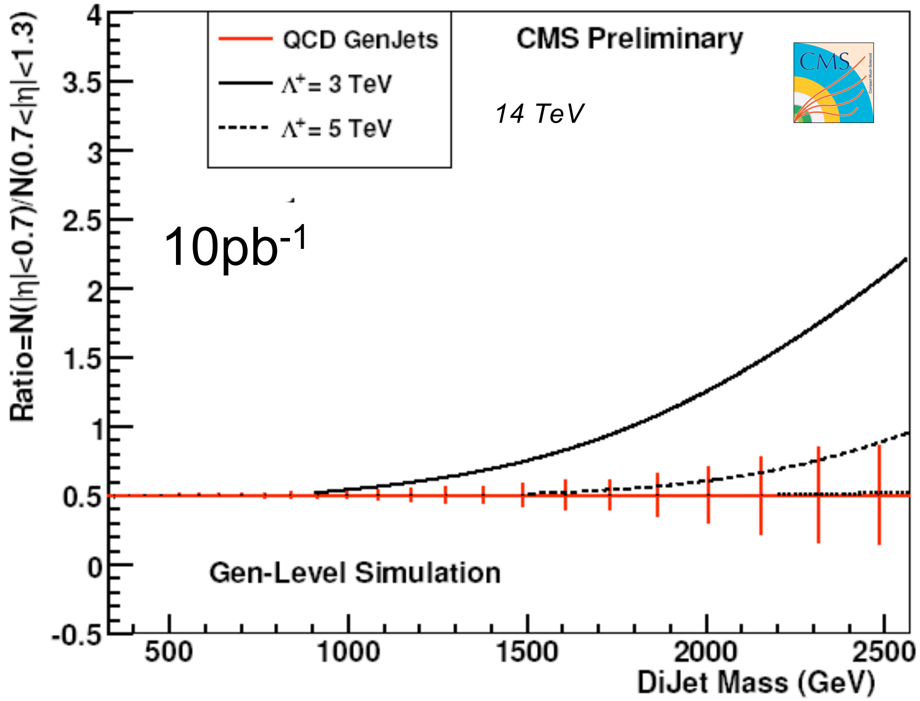
Integrated Lumi (pb^{-1})	Mass reach (TeV) LHC @ 10 TeV	Mass reach (TeV) LHC @ 14 TeV
10	1.80	2.20
100	2.50	3.25
1000	3.30	4.25

Significant discovery potential: e.g. up to Λ~8 TeV in 2009/2010

Exited Quarks



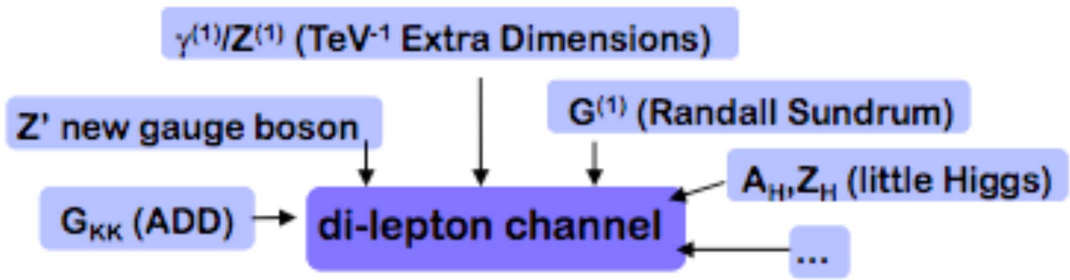
Contact Interaction



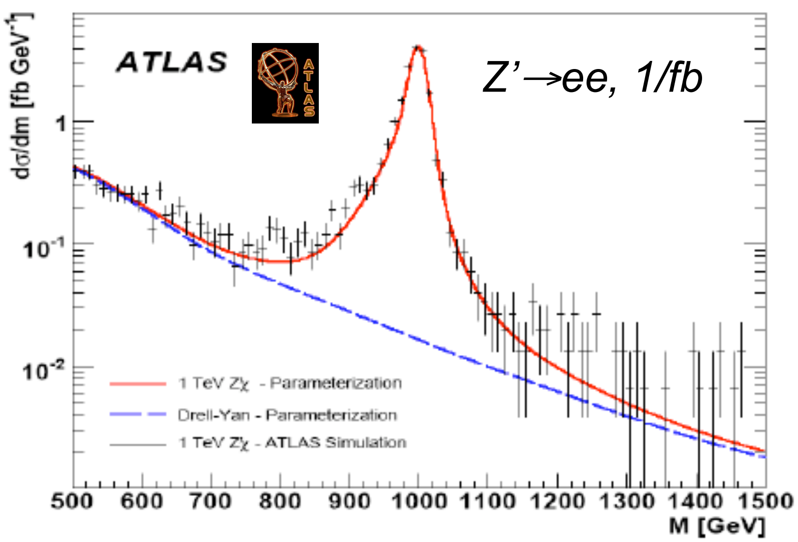
Di-lepton Resonances

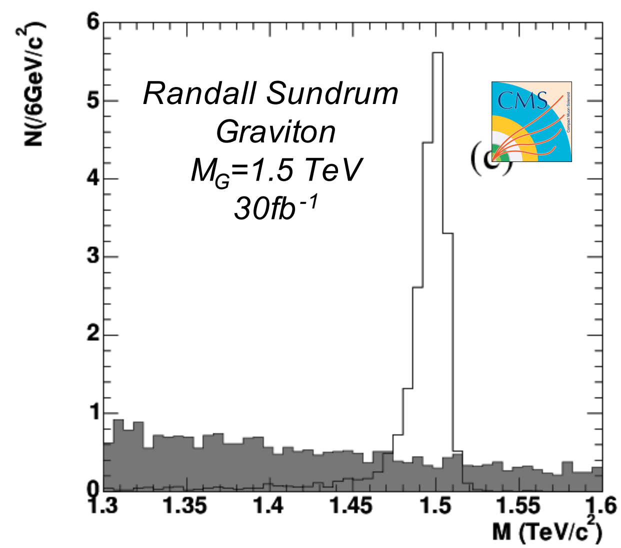
Because of their clear signature di-lepton resonances have always been the subject of new physics searches.

At the LHC they are predicted to arise in many BSM models:

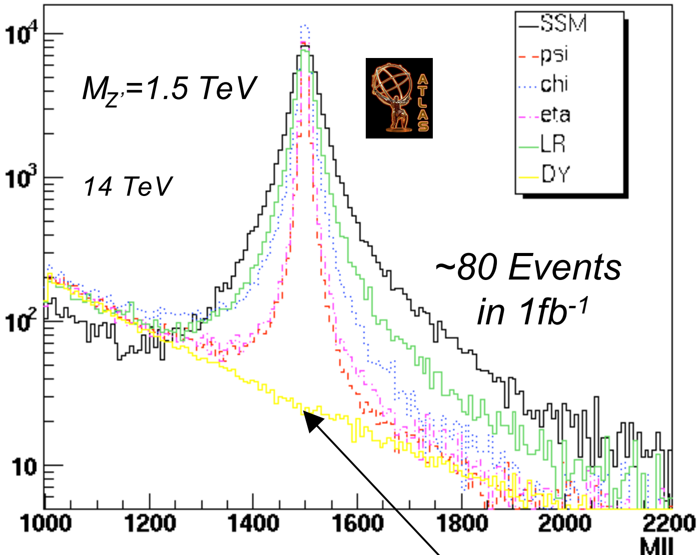


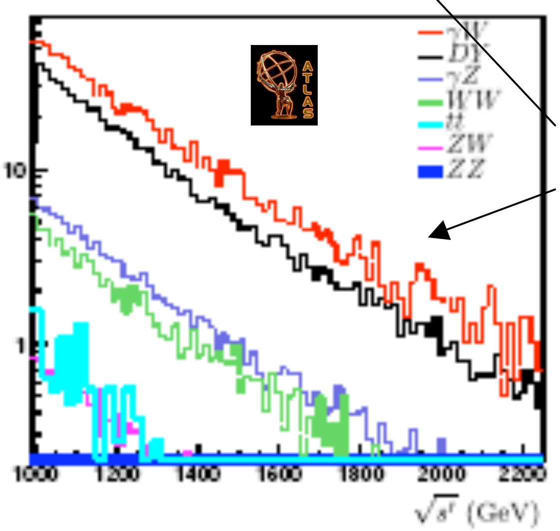
Clear signatures: $\mu^+\mu^-$ and e^+e^- final state





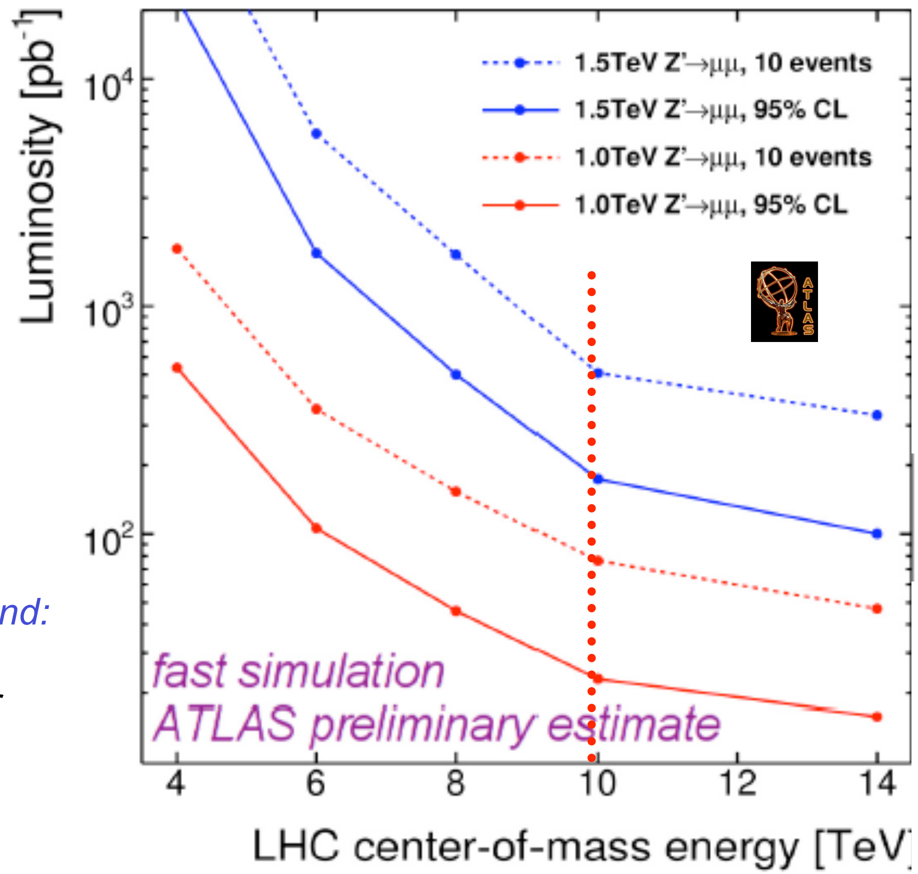
Di-lepton Resonances (Example Z')





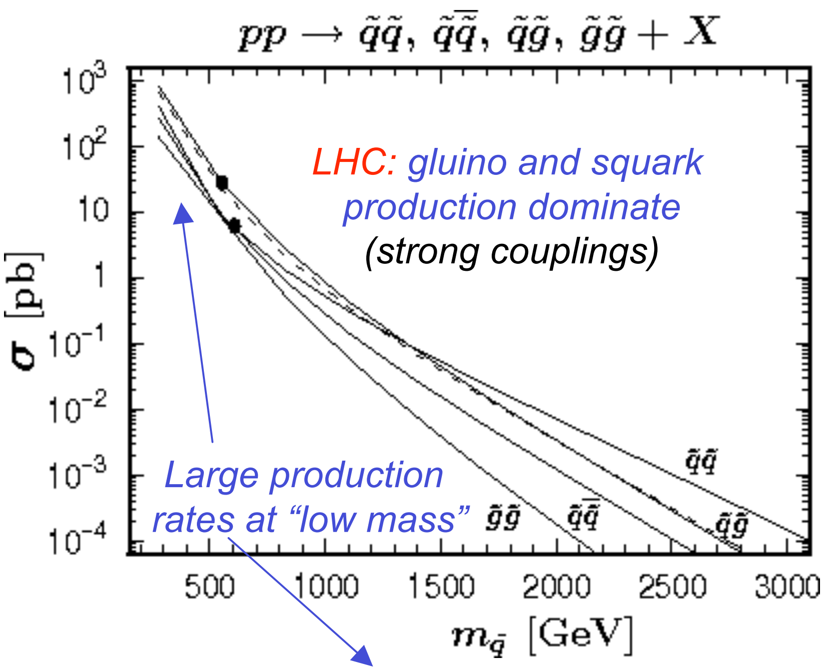
Main background:
Drell-Yan:
<1 event for
M>1.5 TeV
in $1fb^{-1}$

$Z' \to mu^+mu^-$ Discovery Potential



Very early discovery potential with clean signatures!

SUSY Searches @ LHC

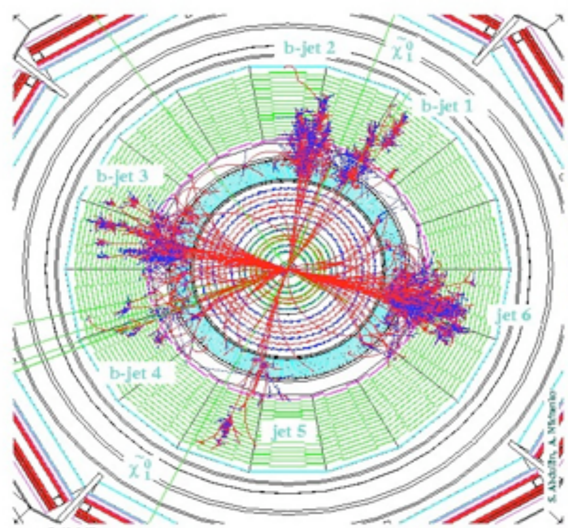


M_{sp}(GeV)	σ (pb)	Evts/yr
500	100	10^6-10^7
1000	1	10^4-10^5
2000	0.01	10^2-10^3

For low masses the LHC becomes a real ***SUSY factory***

Huge number of theoretical models

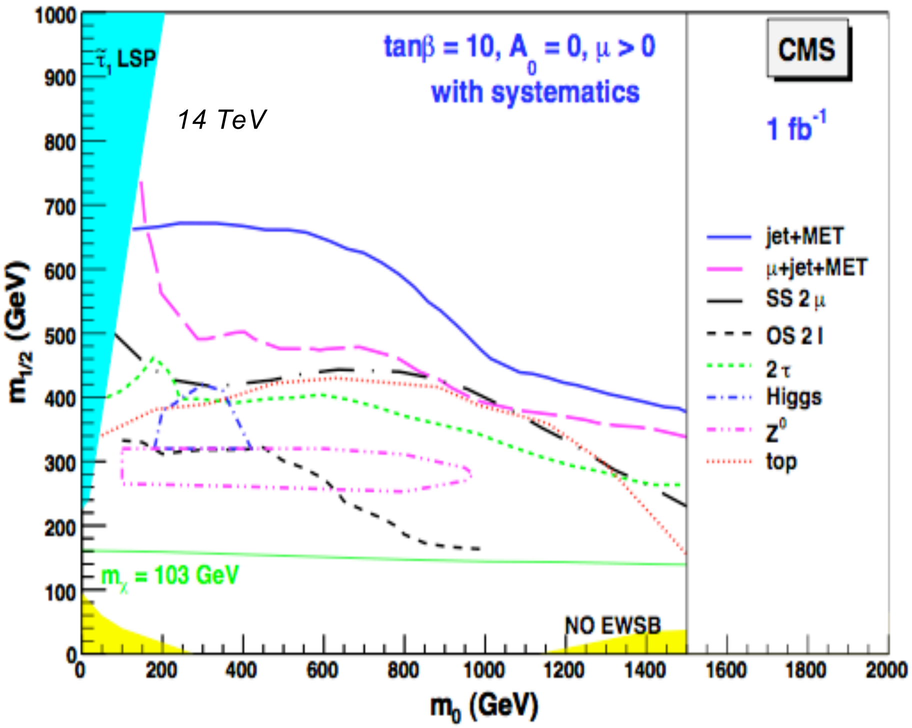
- Very complex analysis; MSSM >100 parameter
- To reduce complexity we have to choose some "reasonable", "typical" models; use a theory of dynamical SUSY breaking
  - mSUGRA (main model)
  - GMSB (studied in less detail)
  - AMSB (studied in less detail)
- Use models to study different SUSY signatures in the detector.

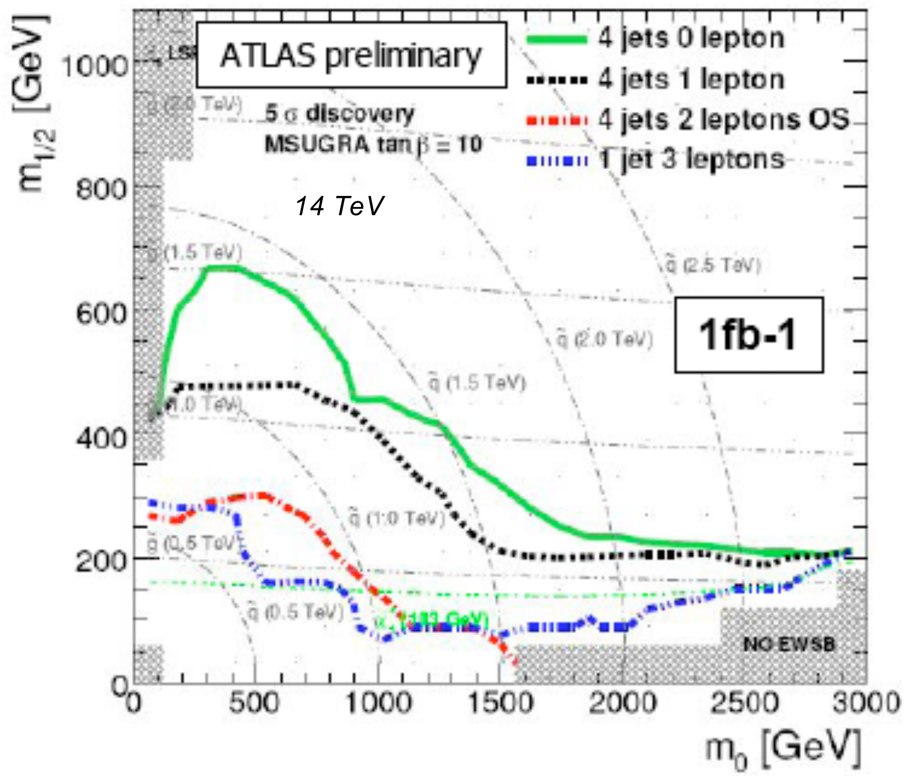


Clear signatures of large missing energy, hard jets and many leptons!
(assume R-Parity)

Could be very spectacular!

SUSY Discovery Potential - CMSSM





Discover Potential for "muli-jet, multi-lepton and missing energy search" is described in the CMSSM.

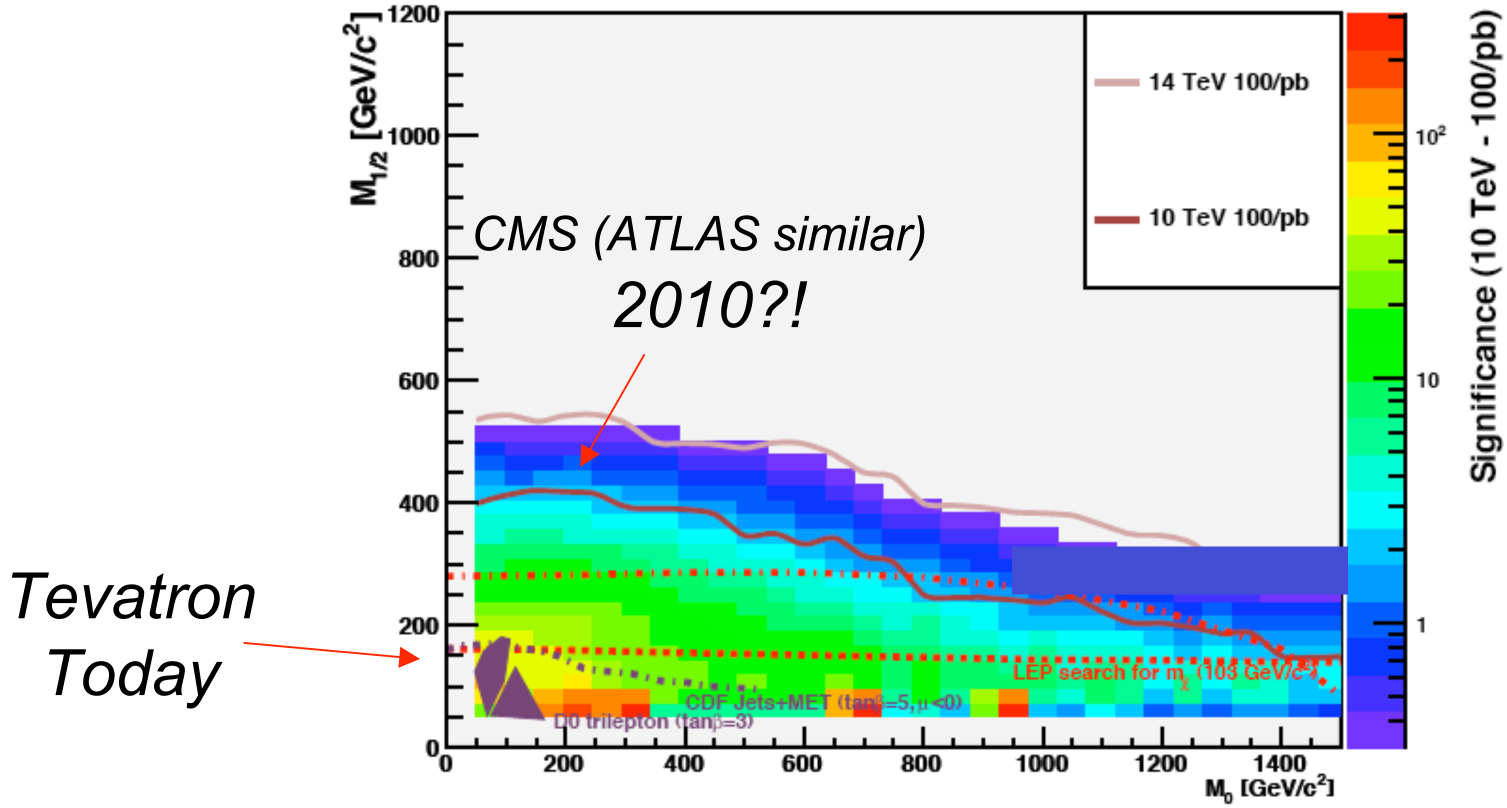
Both ATLAS and CMS have very similar performance (as expected).

First LHC Running 2009/2010 - Expectations

Expectations are high!

With as little as ~50/pb @ 10 TeV of (understood!) data we should be able to go significantly beyond the reach of the Tevatron!

All-hadronic Reach project to 10 TeV

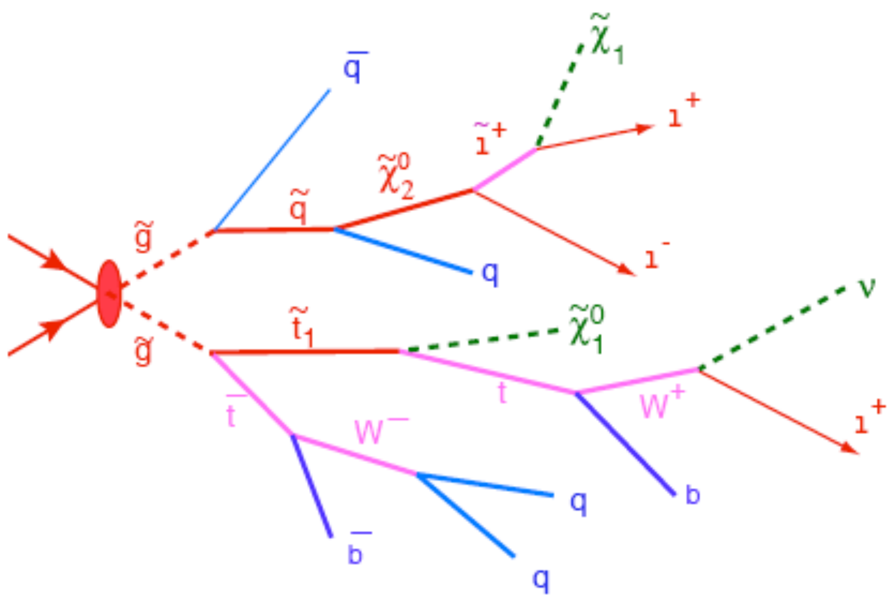


What do we call a "SUSY search"?

The definition is purely derived from the experimental signature.

Therefore, a "SUSY search signature" is characterized by

Lots of missing energy, many jets, and possibly leptons in the final state



Missing Energy:
- *from LSP*

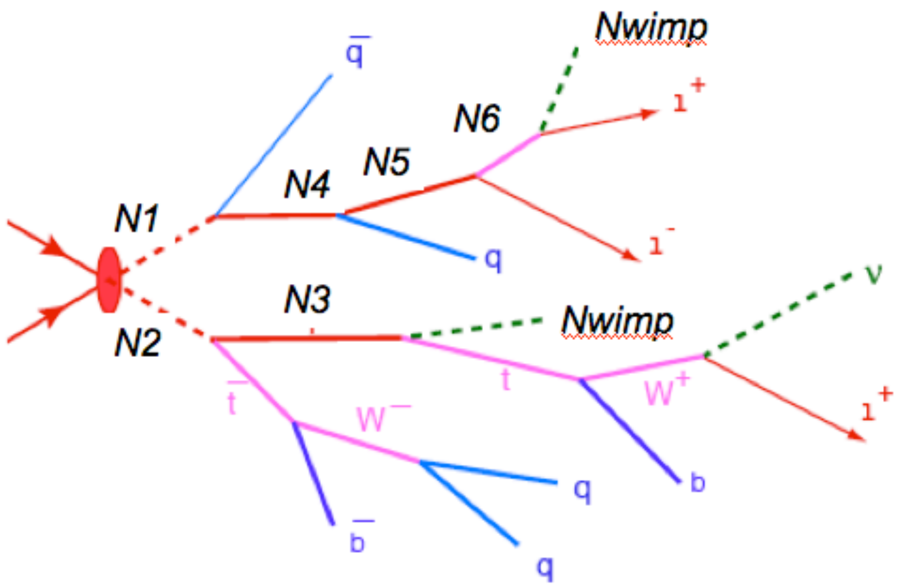
Multi-Jet:
- *from cascade decay (gaugino)*

Multi-Leptons:
- *from decay of charginos/neutralios*

RP-Conserving SUSY is a very prominent example predicting this famous signature but …

What is its experimental signature?

… by no means is it the only New Physics model predicting this experimental pattern. Many other NP models predict this genuine signature



Missing Energy:
- *Nwimp - end of the cascade*

Multi-Jet:
- *from decay of the Ns (possibly via heavy SM particles like top, W/Z)*

Multi-Leptons:
- *from decay of the N's*

Model examples are Extra dimensions, Little Higgs, Technicolour, etc but a more generic definition for this signature is as follows.

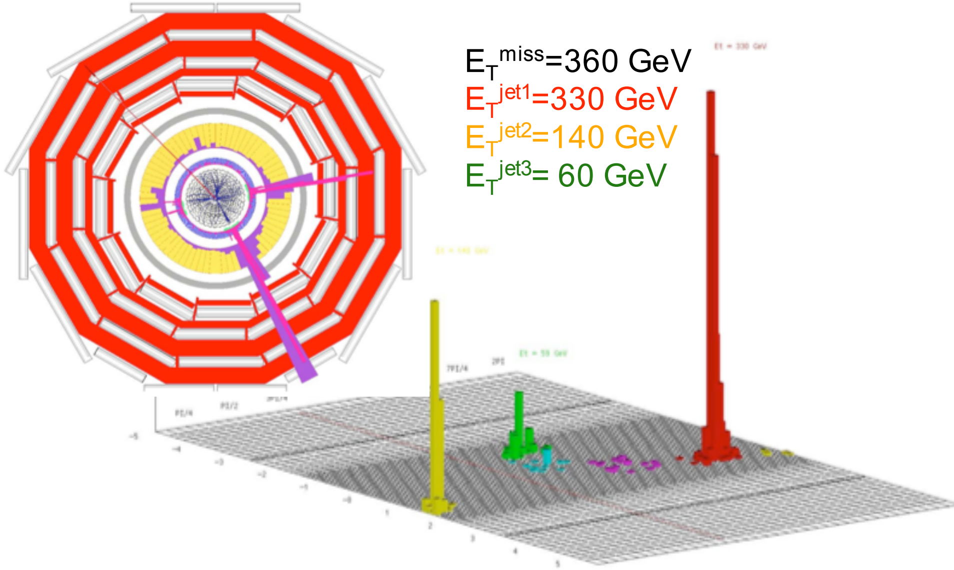
"SUSY Searches" - What are we searching for?

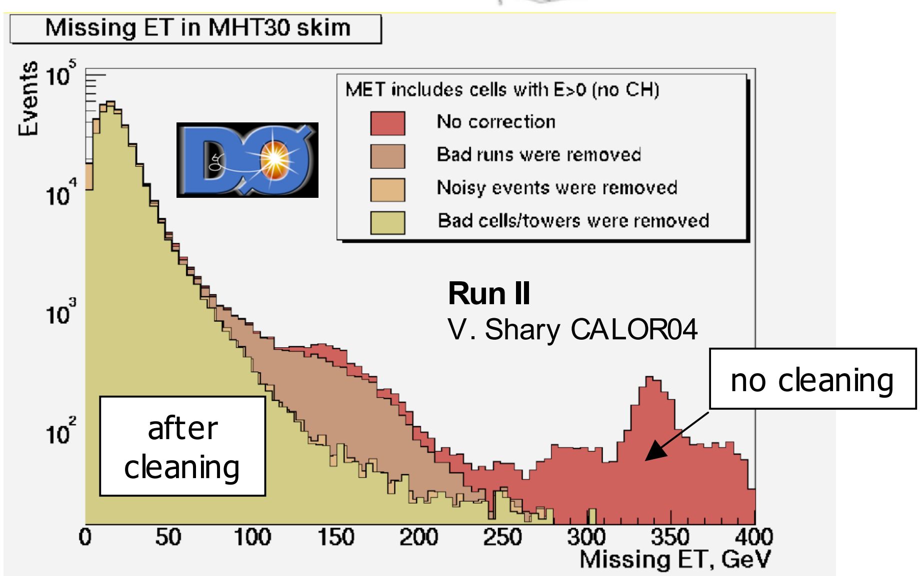
- Pair-produced new particles N with a colour charge and a mass of O(TeV/2)
- N decays via a cascade into other new particles as well as SM particles like bosons, leptons and quarks
- At the end of the cascade decay is a weakly interacting new particle - i.e. a dark matter candidate

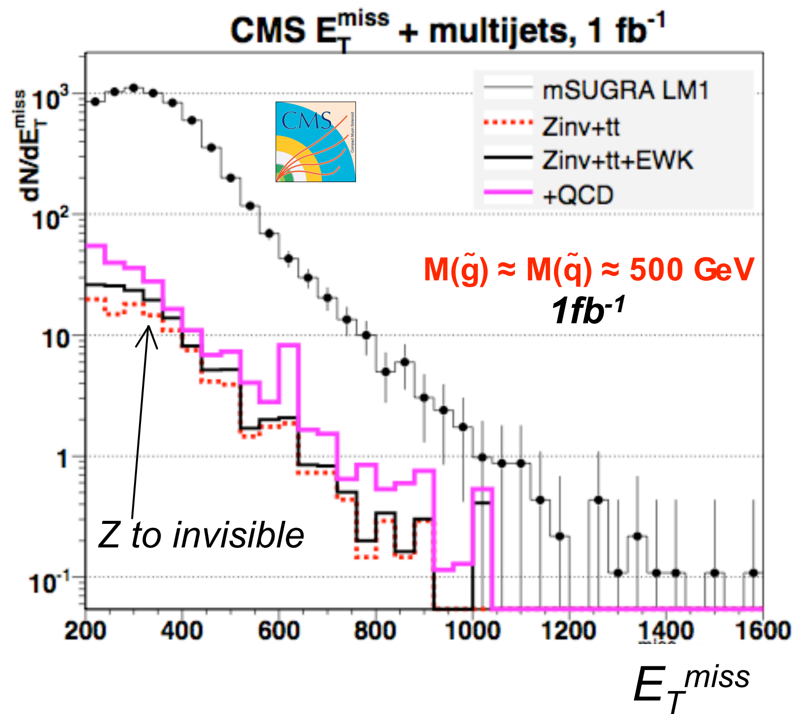
In other words, a "SUSY search" is a search for a weakly interacting (stable) particle that was produced in the cascade decay of a heavy new particle.

Use "SUSY" as a convenient tool to characterize this search!

Jets + E_T^{miss} - Inclusive Search







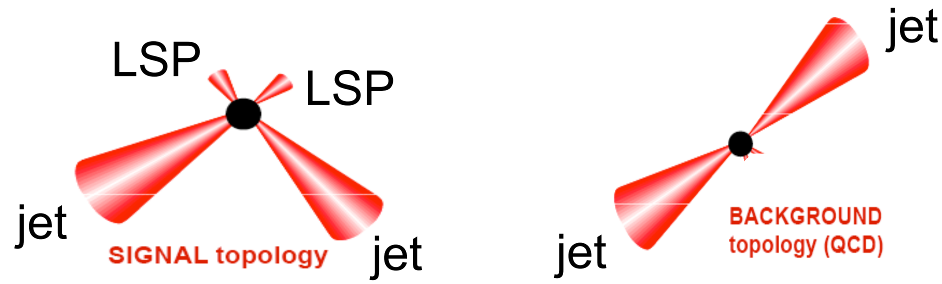
Big discovery potential

But requires a very good detector understanding and background control:

Analysis Strategy:

- Be brave
- Fight background and noise
- Use data control samples
- Estimate background from data

SUSY search with dijet events



Idea:

Search for squark-squark production with squark decay directly to quark + LSP

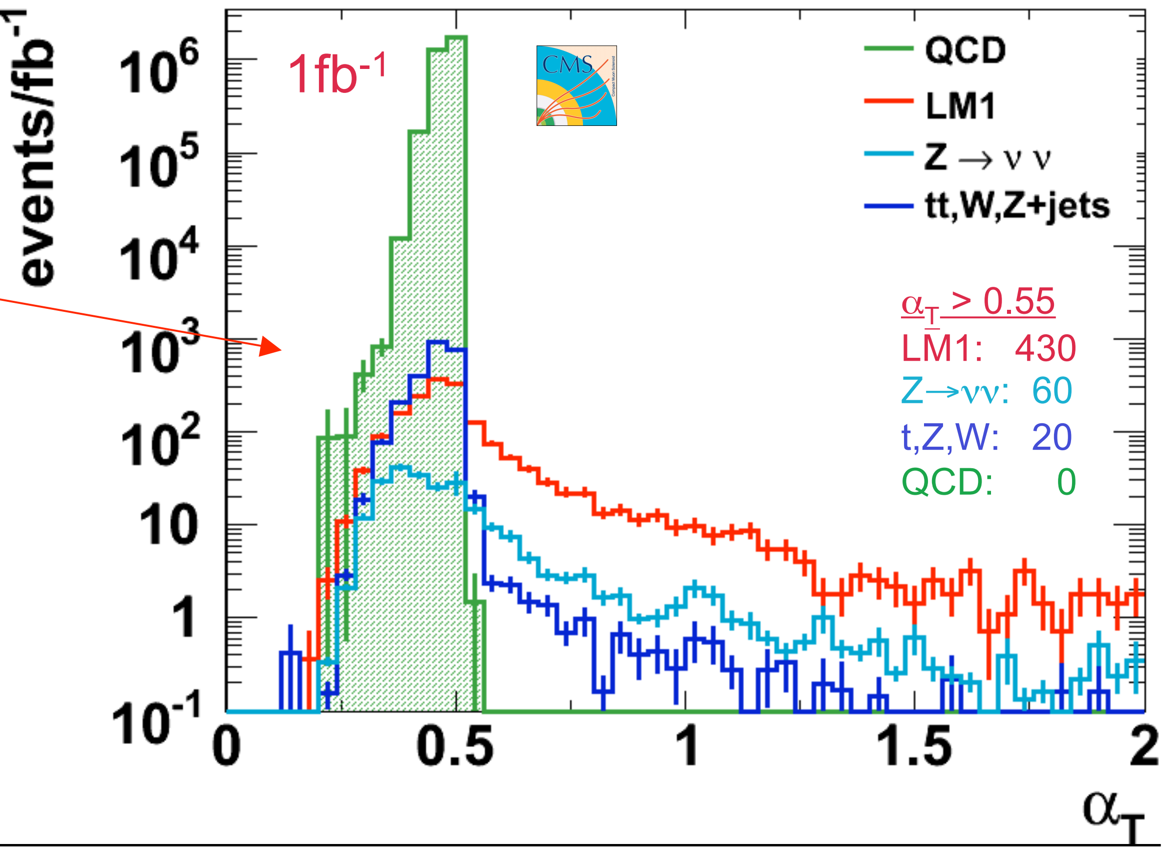
Exp. signature: 2 jets + missing ET

Important analysis properties:

- Trigger: HLT2jet
- $\Delta\Phi < 2/3\pi$
- $\alpha_T = E_{Tj2}/M_{Tj1,j2} > 0.55$ (inspired by arXiv0806.1049)

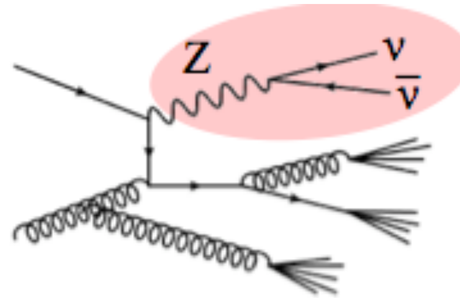
Analysis only relies on kinemtaic of dijet system:

- no direct calorimetric missing Energy dependence
- idea can be extended to generic n-jet system



Irreducible Background Z to invisible + Jets

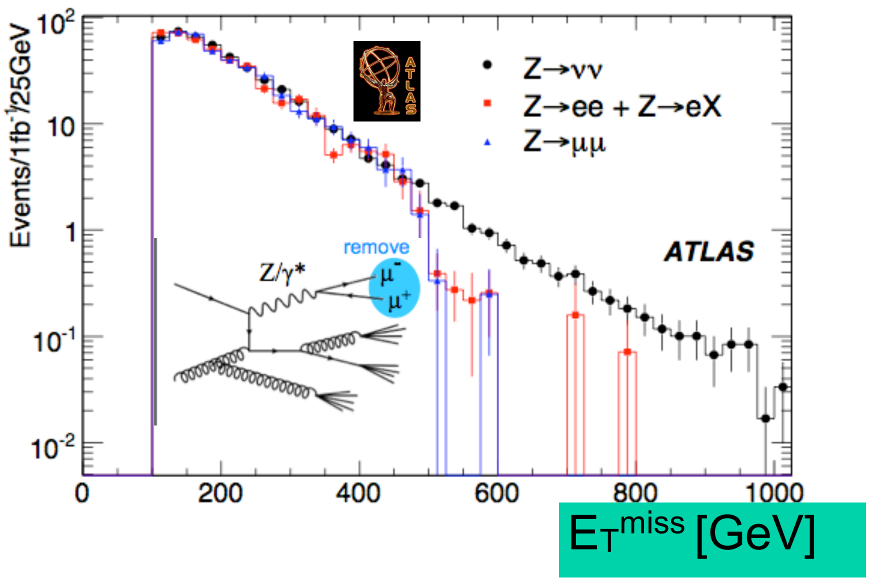
Method:
- select clean sample of kinematic similar control background
- define **“pseudo E_T^{miss}”** in control sample
- correct for differences

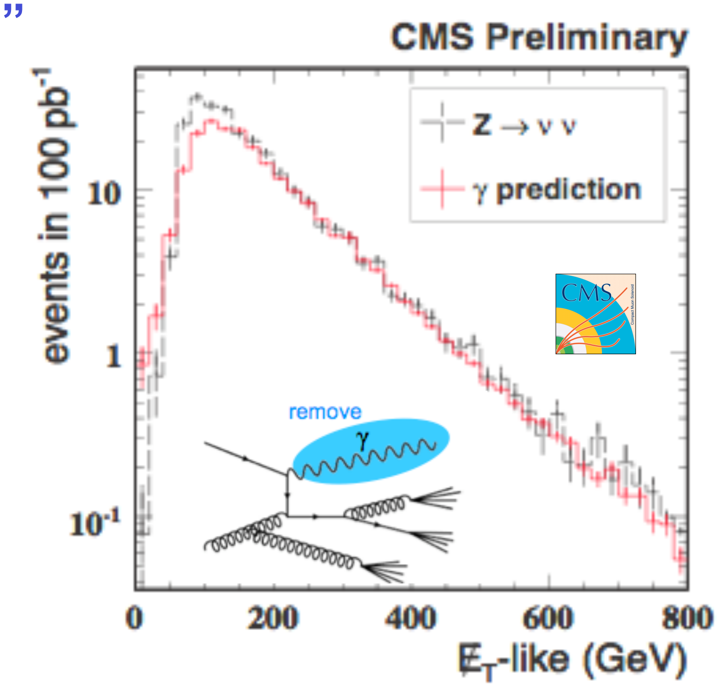


Z->ll + jets: di-lepton $\mathbf{p_T} \equiv$ **“pseudo E_T^{miss}”**;

photon + jets: photon $\mathbf{p_T} \equiv$ **“pseudo E_T^{miss}”**;

W->lν+jets: lepton $\mathbf{p_T}$ + $\mathbf{E_T^{miss}} \equiv$ **“pseudo E_T^{miss}”**

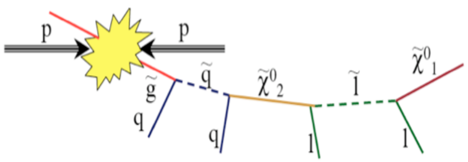




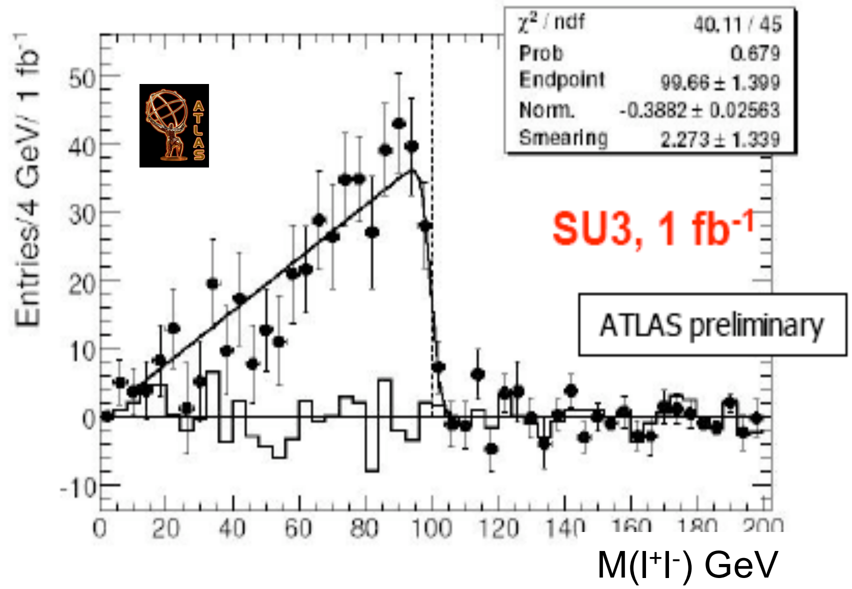
First Kinematic Measurements

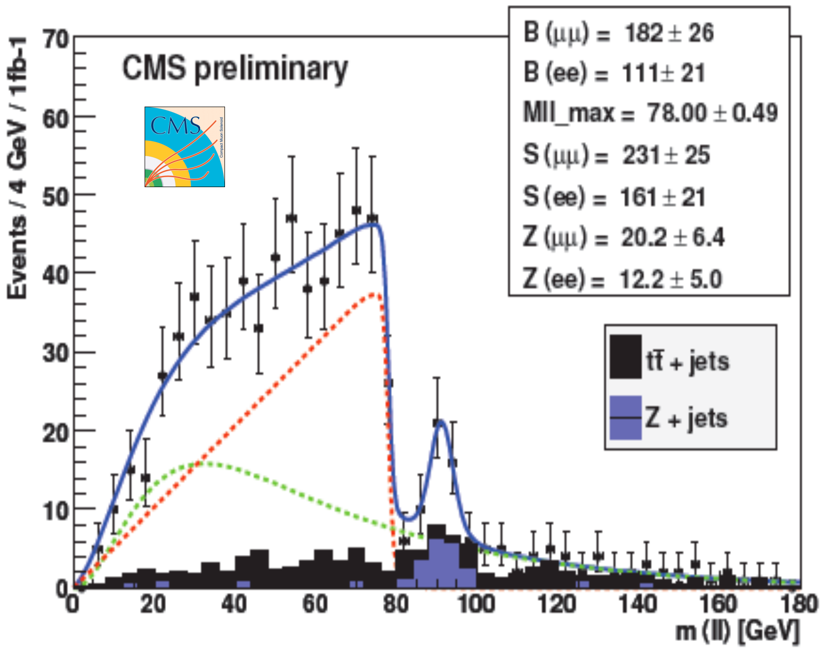
...and if we are a bit lucky we might see such spectacular signals already in the early days!

Look for generic signatures of cascade decays:



Jets + E_t^{miss}
+SFOS di-leptons





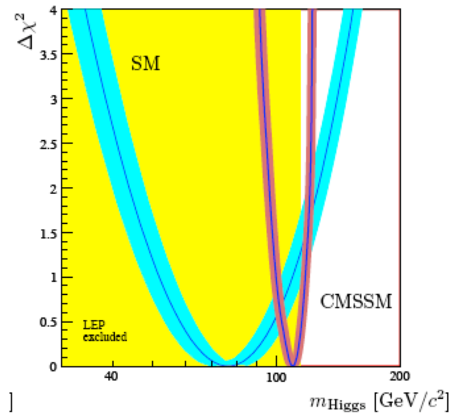
Extract: $M_{\ell\ell}^{max} = M(\tilde{\chi}_2^0)\sqrt{1 - \frac{M^2(\tilde{\ell}_R)}{M^2(\tilde{\chi}_2^0)}}\sqrt{1 - \frac{M^2(\tilde{\chi}_1^0)}{M^2(\tilde{\ell}_R)}}$

from a fit to the "edge distribution".

- *ΔM_{ee}^{max}=1.07$_{stat}$±0.36$_{sys}$ GeV for 1/fb (CMS)*
- *$\Delta M_{\mu\mu}^{max}$=0.75$_{stat}$±0.18$_{sys}$ GeV for 1/fb (CMS)*
- *Estimate same flavour top and di-boson bkg directly from eμ data*
- *Relatively precise extraction of M_{ll}^{max} in the first few hundred pb^{-1} is still possible.*

Making sense out of what we will see

- What observables can be used to constrain the model?
  - Low energy (precision) data
    - Flavour physics (many constraints from B physics)
    - Other low energy observables, e.g. g-2
  - High energy (precision) data
    - Precision electroweak observables, e.g. M_W, m_{top}, asymmetries
  - Cosmology and Astroparticle data
    - e.g. relic density



See O. B et al.,
PLB 657/1-3 pp.87-94

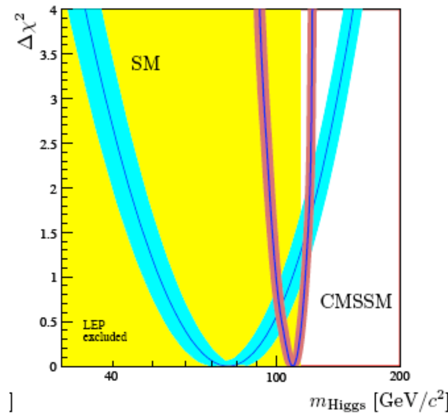
- How to exploit this information?
  - State of the art theoretical predictions (tools)
  - Development of a framework for combination of these tools

- Collaboration between experiment and theory

Buchmüller, Oliver (CERN) – Exp.
Cavanaugh, Richard (Uni. of Florida) – Exp.
De Roeck, Albert (CERN & Uni. Antwerpen) – Exp.
Ellis, John (CERN) – Theo.
Flächer, Henning (CERN) – Exp.
Heinemeyer, Sven (Santander) – Theo.
Isidori, Gino (INFN Frascati) – Theo.
Olive, Keith (Uni. of Minnesota) – Theo.
Paradisi, Paride (Tech. Uni. München) – Theo.
Ronga, Frédéric (CERN) – Exp.
Weiglein, Georg (Durham) – Theo.

Making sense out of what we will see

- What observables can be used to constrain the model?
  - Low energy (precision) data
    - Flavour physics (many constraints from B physics)
    - Other low energy observables, e.g. g-2
  - High energy (precision) data
    - Precision electroweak observables, e.g. M_W, m_{top}, asymmetries
  - Cosmology and Astroparticle data
    - e.g. relic density



See O. B et al.,
PLB 657/1-3 pp.87-94

- How to exploit this information?
  - State of the art theoretical predictions (tools)
  - Development of a framework for combination of these tools

- *There are several similar other efforts;*
  Latest Examples:
  arXiv:0904.2548:
  S.S. AbdusSalam, B.C. Allanach, F. Quevedo, F. Feroz, M. Hobson
  arXiv:0903.2487:
  F. Feroz, M.P. Hobson, L. Roszkowski, R.Ruiz de Austri, R. Trotta

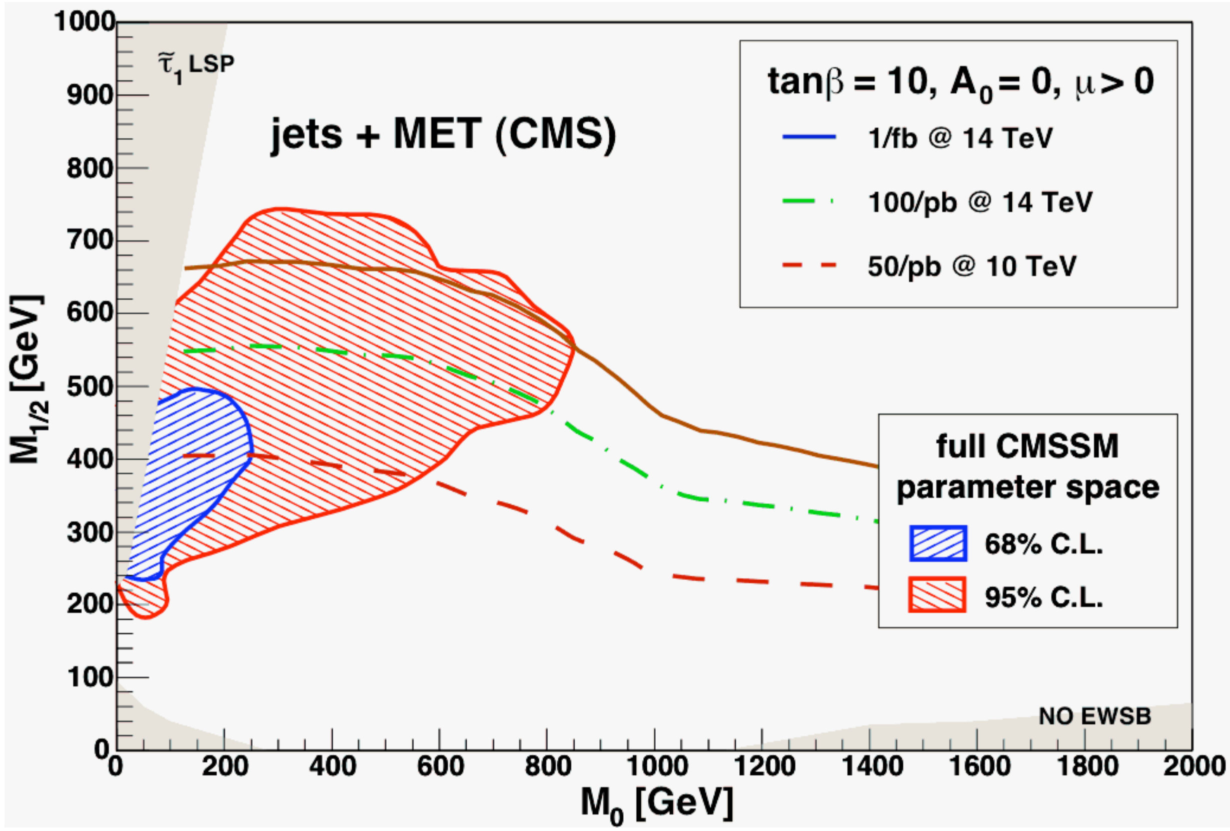
LHC Weather Forecast - CMSSM

JHEP 0809:117,2008

O.B, R.Cavanaugh, A.De Roeck, J.R.Ellis, H.Flaecher, S.Heinemeyer, G.Isidori, K.A.Olive, P.Paradisi, F.J.Ronga, G.Weiglein

Simultaneous fit of CMSSM parameters m_0, $m_{1/2}$, A_0, $\tan\beta$ (μ>0) to more than 30 collider and cosmology data (e.g. M_W, M_{top}, g-2, BR(B→X γ), relic density)

"LHC Weather Forecast"



"CMSSM fit clearly favors low-mass SUSY - Evidence that a signal might show up very early?!"

2010? - Example CMSSM

JHEP 0809:117,2008

O.B, R.Cavanaugh,
A.De Roeck,J.R.Ellis, H.Flaecher,
S.Heinemeyer,G.Isidori, K.A.Olive,
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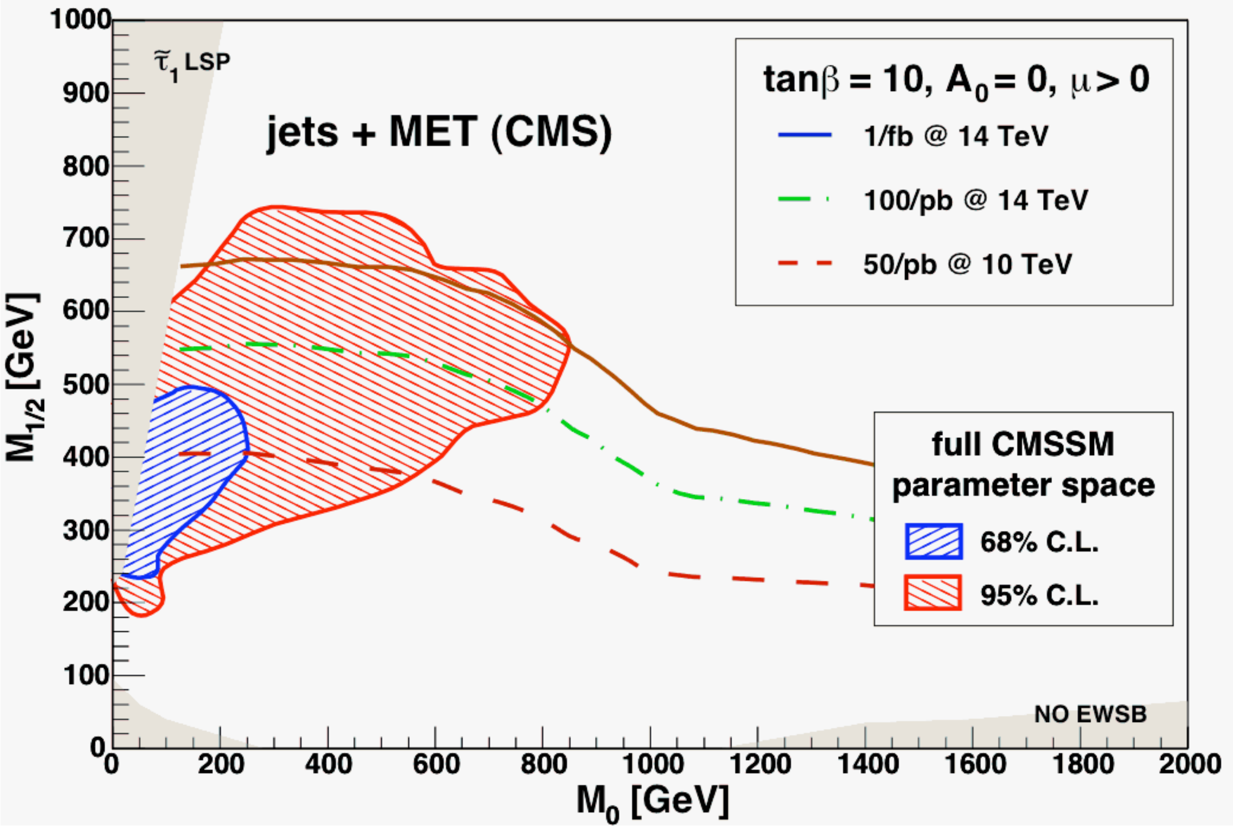

2010? - Example CMSSM

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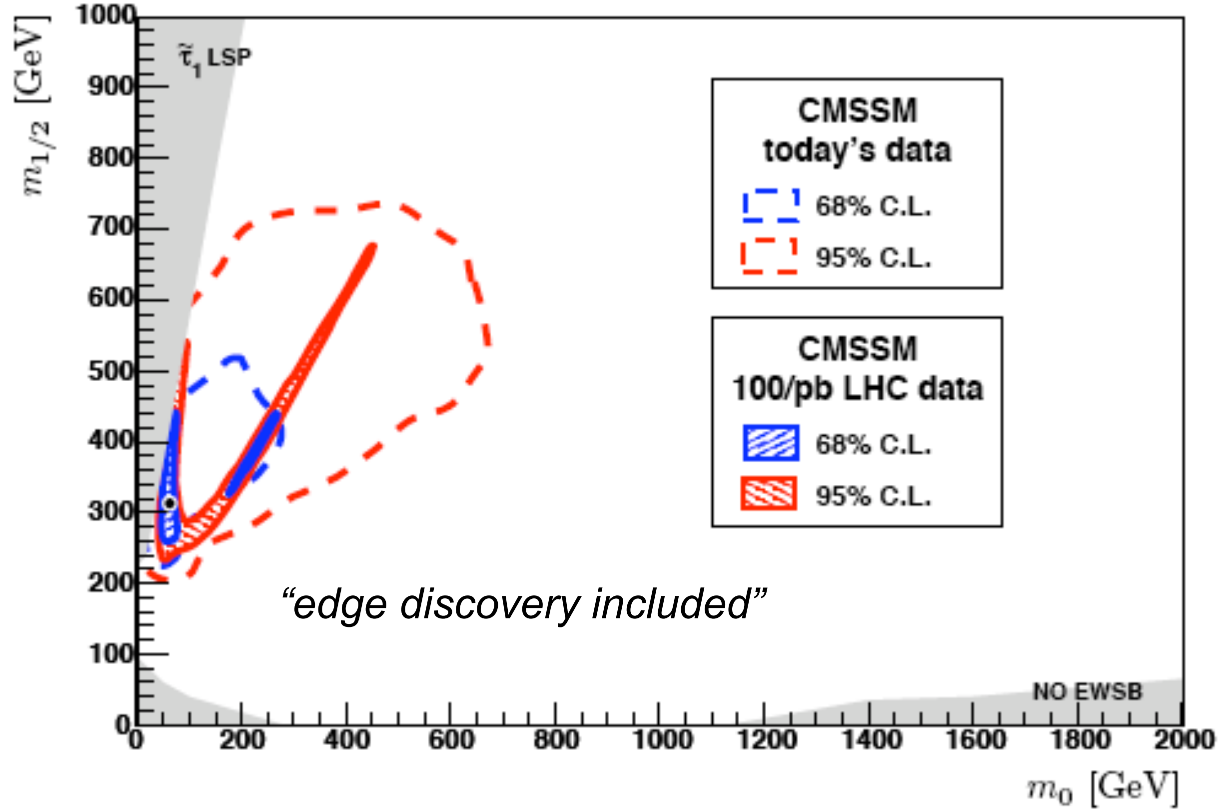
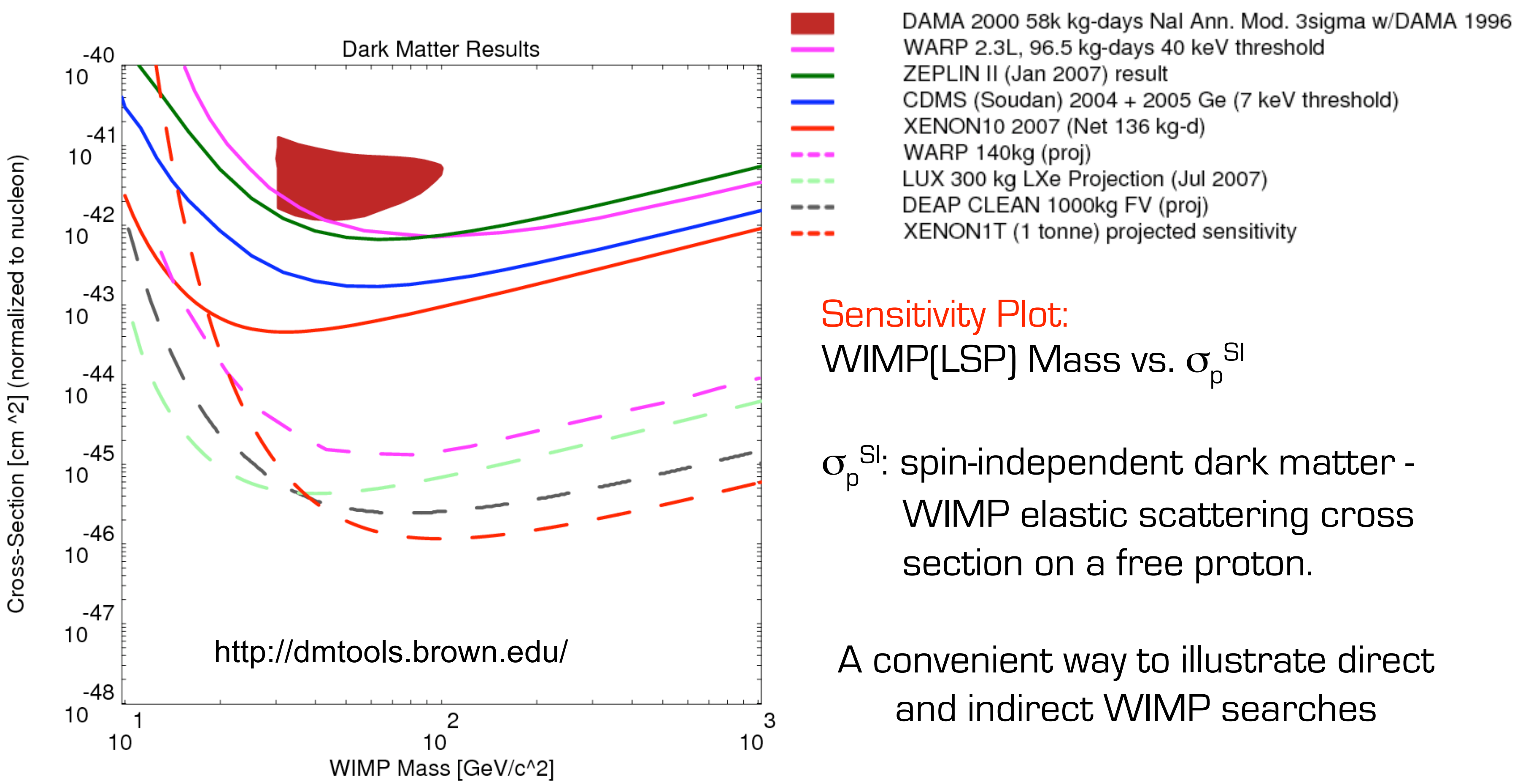


Including a "edge discovery" in the CMSSM fit constraints significantly the parameter space …

Connection to Direct WIMP Searches

Direct detection of WIMP (LSP) Dark Matter



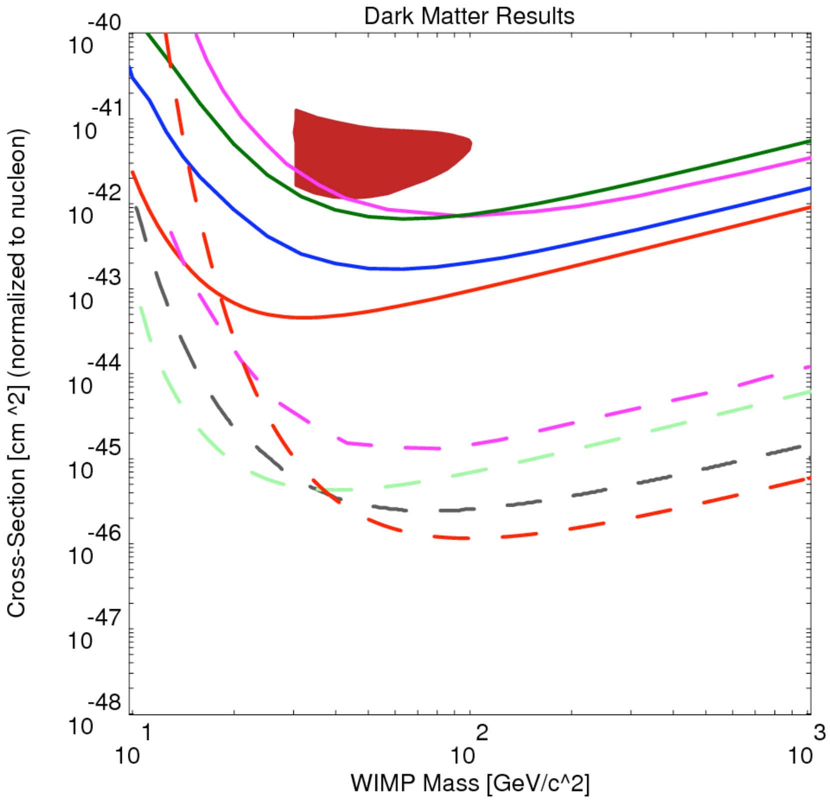
Sensitivity Plot:

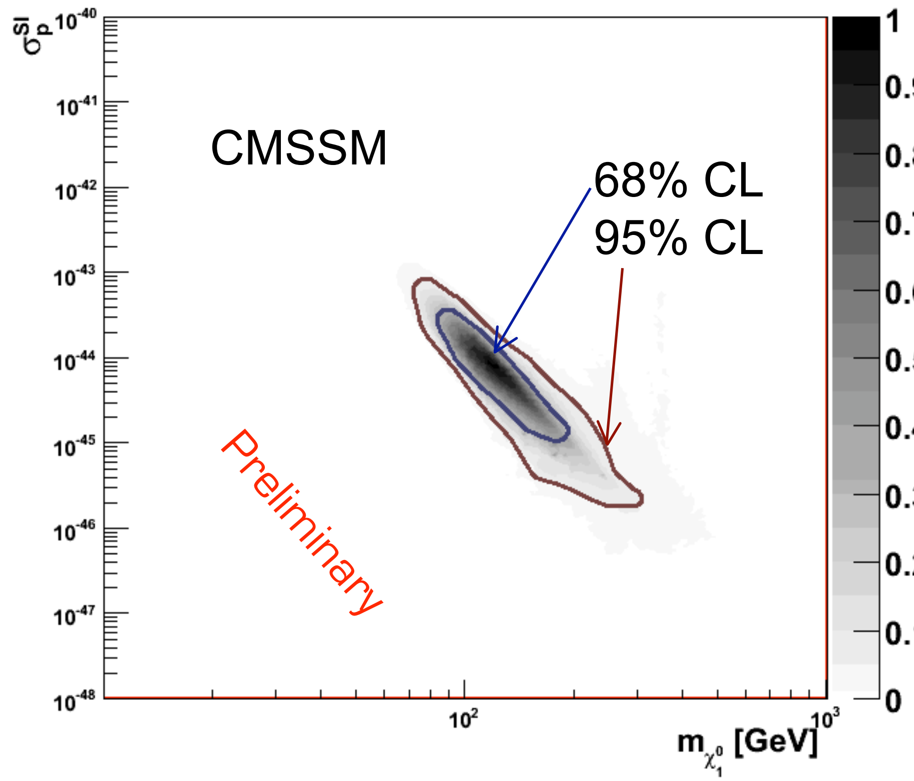
WIMP(LSP) Mass vs. σ_p^{SI}

σ_p^{SI}: spin-independent dark matter - WIMP elastic scattering cross section on a free proton.

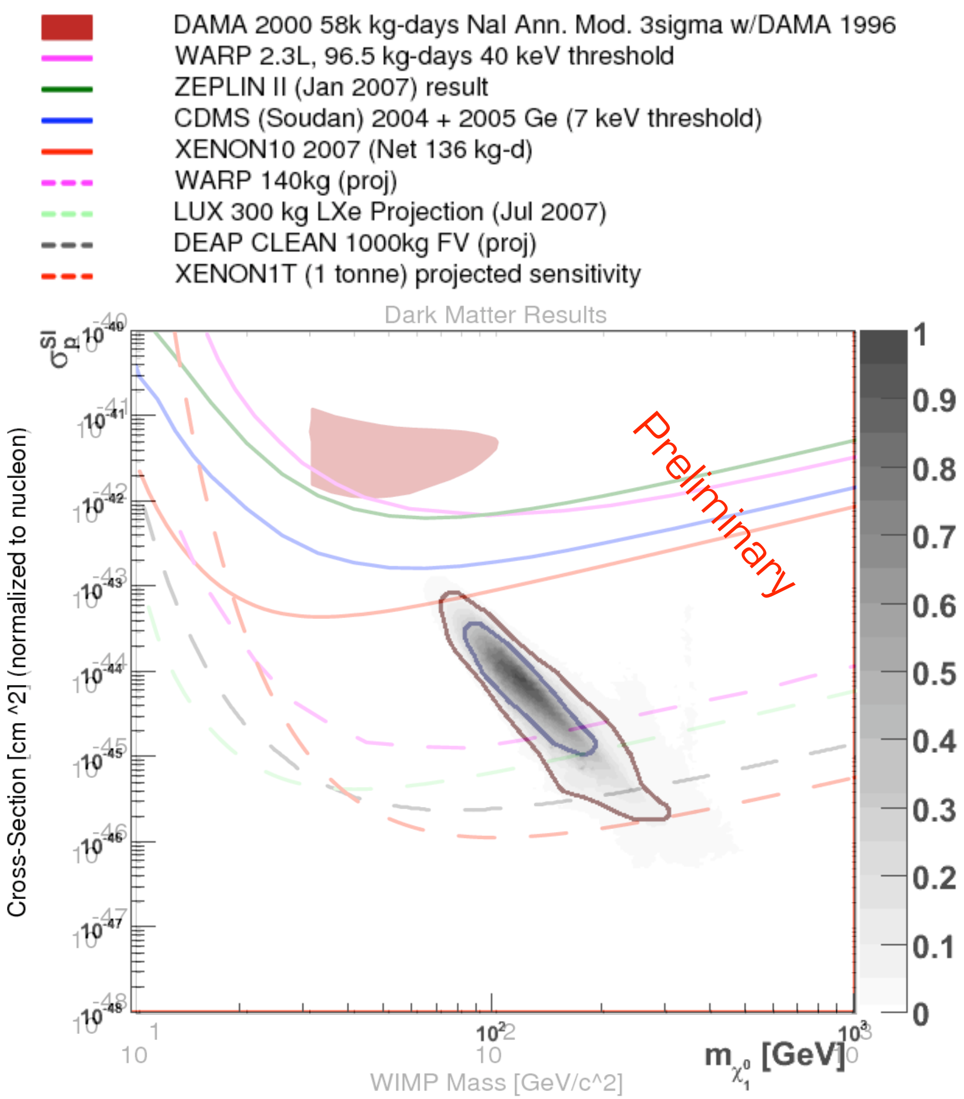
A convenient way to illustrate direct and indirect WIMP searches

Connection to Direct WIMP Searches





Connection to Direct WIMP Searches



Sensitivity will further increase once auxiliary measurement are made, e.g. lepton edges, m_{Higgs}, etc.

Interesting possibility to connect collider results (in particular discoveries) with direct dark matter searches. Theoretical limitations in e.g. the calculation of σ_p^{SI} still need to be addressed though.

Summary

- 2010 will be the year of machine, detector, and physics analysis commissioning but with ~100/pb @ 10 TeV there are also very interesting BSM discovery possibilities!
  - Challenge: commissioning of machine and detectors of unprecedented complexity, technology, and performance
  - Re-discover the Standard Model at 10 TeV, understand the "LHC environment"
  - Significant discovery sensitivity for several BSM scenarios like Z',W, etc' but also SUSY.
- The LHC will discover low energy SUSY (if it exists).
  - Already 2010 could become the year of "SUSY" but it could also take more time and ingenuity before we can claim a discovery
  - First signals might emerge already in the first data but do we understand them?!
- Eventually the LHC will cover a new physics scale of 1-3 TeV.
  - Many new physics models; Black hole, Extra Dimensions,Little Higgs, Split Susy, New Bosons, Technicolour, etc …
- 'Making sense' of what we will see should be an integral part of the program of work
  - Develop methodology and tools able to consitently interepret the results, in particular discoveries, in the context of Particle (Astro)Physics and Cosmology.

More on Global Fits

Used Constraints

Low energy observables

R($b \to s\gamma$)	Isidori & Paradisi	micrOMEGAs
R($B \to \tau\nu$)	Isidori & Paradisi	
BR($K \to \mu\nu$)	Isidori & Paradisi	
R($B \to X_s \ell\ell$)	Isidori & Paradisi	
R($K \to \pi\nu\bar{\nu}$)	Isidori & Paradisi	
BR($B_s \to \ell\ell$)	Isidori & Paradisi	micrOMEGAs
BR($B_d \to \ell\ell$)	Isidori & Paradisi	
R(Δm_s)	Isidori & Paradisi	
R(Δm_s)/R(Δm_d)	Isidori & Paradisi	
R(Δm_K)	Isidori & Paradisi	
R($\Delta_0(K^*\gamma)$)	SuperIso	
$\Delta(g-2)$	FeynHiggs	

Higgs sector observables

m_h^{light}	FeynHiggs

Cosmology observables

Ωh^2	micrOMEGAs	DarkSUSY
σ_p^{SI}	DarkSUSY	

Electroweak observables

$\Delta\alpha_{\text{had}}^{(5)}(m_Z^2)$	SUSY-Pope
m_Z	SUSY-Pope
Γ_Z	SUSY-Pope
σ_{had}^0	SUSY-Pope
R_l	SUSY-Pope
$A_{\text{fb}}(\ell)$	SUSY-Pope
$A_\ell(P_\tau)$	SUSY-Pope
R_b	SUSY-Pope
R_c	SUSY-Pope
$A_{\text{fb}}(b)$	SUSY-Pope
$A_{\text{fb}}(c)$	SUSY-Pope
A_b	SUSY-Pope
A_c	SUSY-Pope
$A_\ell(\text{SLD})$	SUSY-Pope
$\sin^2\theta_w^\ell(Q_{\text{fb}})$	SUSY-Pope
m_W	SUSY-Pope
m_t	SUSY-Pope

LHC Weather Forecast - NUHM1

JHEP 0809:117,2008

O.B., R.Cavanaugh,
A.De Roeck,J.R.Ellis, H. Flaecher
S.Heinemeyer,G.Isidori, K.A.Olive,
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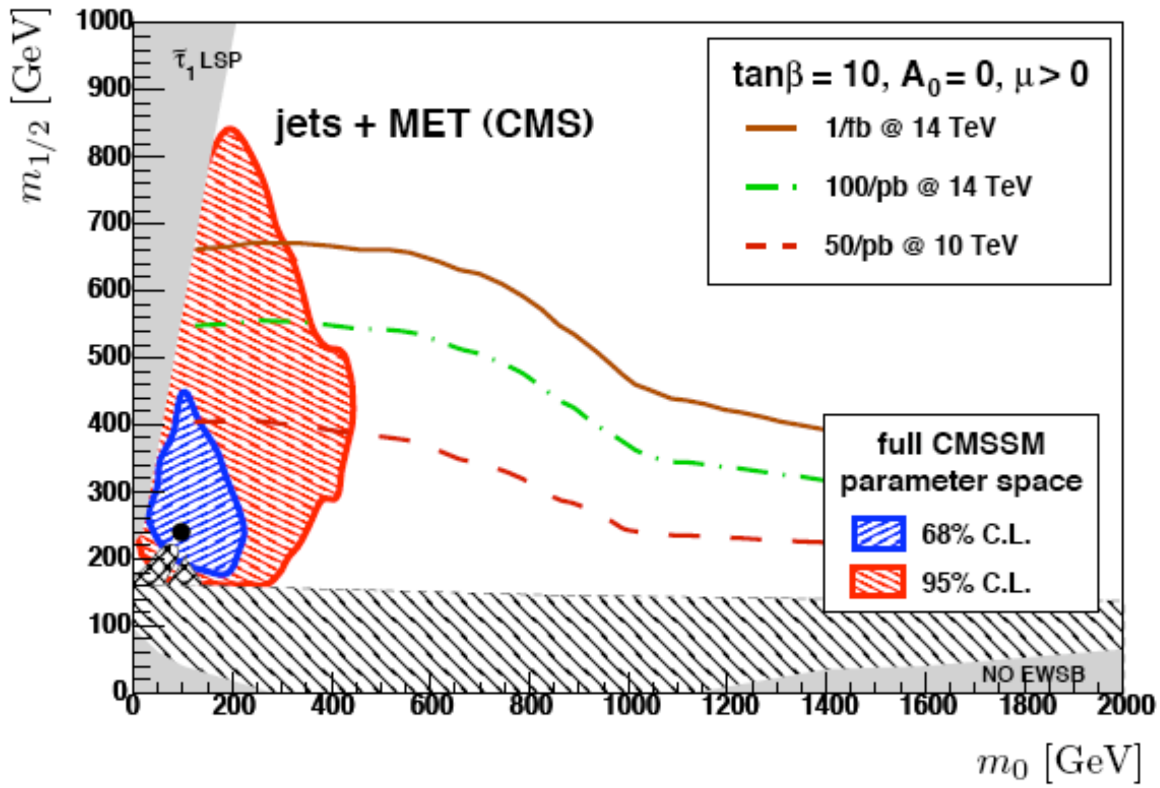
Non Universal Higgs Model1:
- one extra free parameter

scalar contributions to Higgs masses at GUT scale allowed to differ from those to squark and slepton masses

Simultaneous fit of NUHM1 parameters m_0, $m_{1/2}$, A_0, $\tan\beta$, m_H^2 and μ to more than 30 collider and cosmology data (e.g. M_W, M_{top}, g-2, BR($B \rightarrow X\gamma$), relic density)

"LHC Weather Forecast"



NUHM1 fit also favours low-mass SUSY

Global χ^2 Fit

- Constraining the parameter space of the CMSSM
  - multi-parameter χ^2 "fit"

$$\chi^2 = \sum_i^N \frac{(C_i - P_i)^2}{\sigma(C_i)^2 + \sigma(P_i)^2} + \sum_j^M \frac{(f^{\mathrm{obs}}_{\mathrm{SM}_j} - f^{\mathrm{fit}}_{\mathrm{SM}_j})^2}{\sigma(f_{\mathrm{SM}_j})^2}$$

C_i: experimental constraint
P_i: predicted value for a given CMSSM parameter set

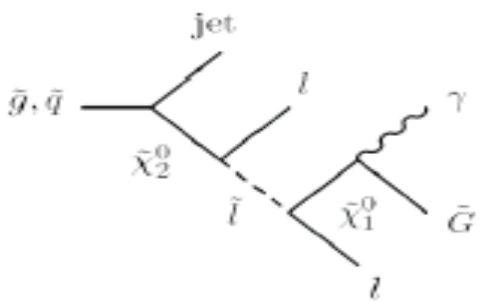
- fitting for all CMSSM (aka mSUGRA) parameters:
  - M_0 – common scalar mass (at GUT scale)
  - $M_{1/2}$ – common gaugino mass (at GUT scale)
  - A_0 – tri-linear mass parameter (at GUT scale)
  - $\tan\beta$ – ratio of Higgs vacuum expectation values
  - sign(μ) – sign of Higgs mixing parameter (fixed)
- including relevant SM uncertainties (m_{top}, m_Z, $\Delta\alpha^{(5)}_{\mathrm{had}}$)

- Sampling of parameter space with Markov-Chain Monte Carlo type technique

More BSM Reach Studies

SUSY: GMSB

SUSY breaking mediated via gauge interactions:

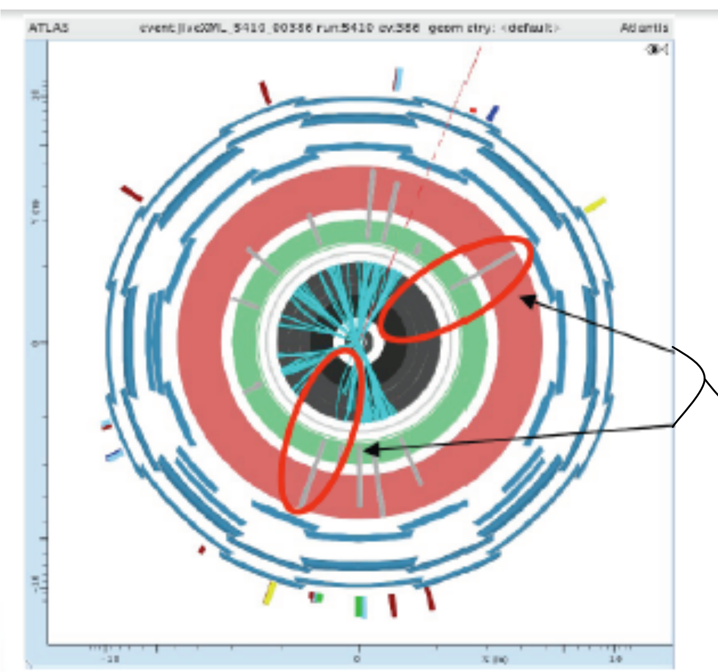


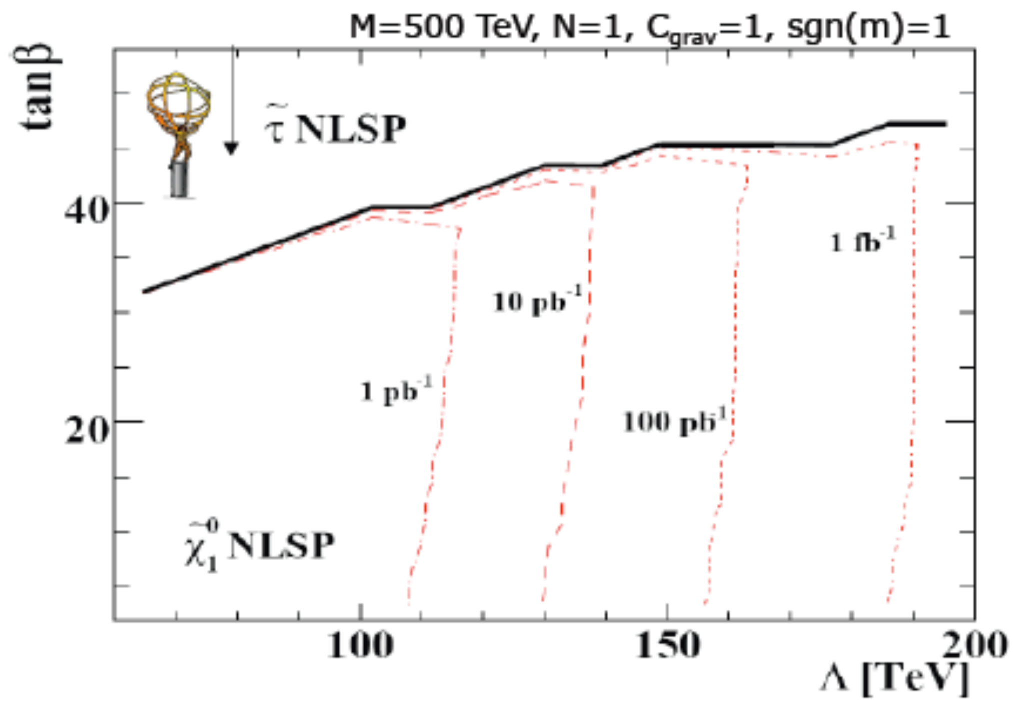
Experimental Signature:

- *lepton and jets*
- *missing energy from gravition*
- *hard photons pointing or non-pointing or long lived staus*

Example:

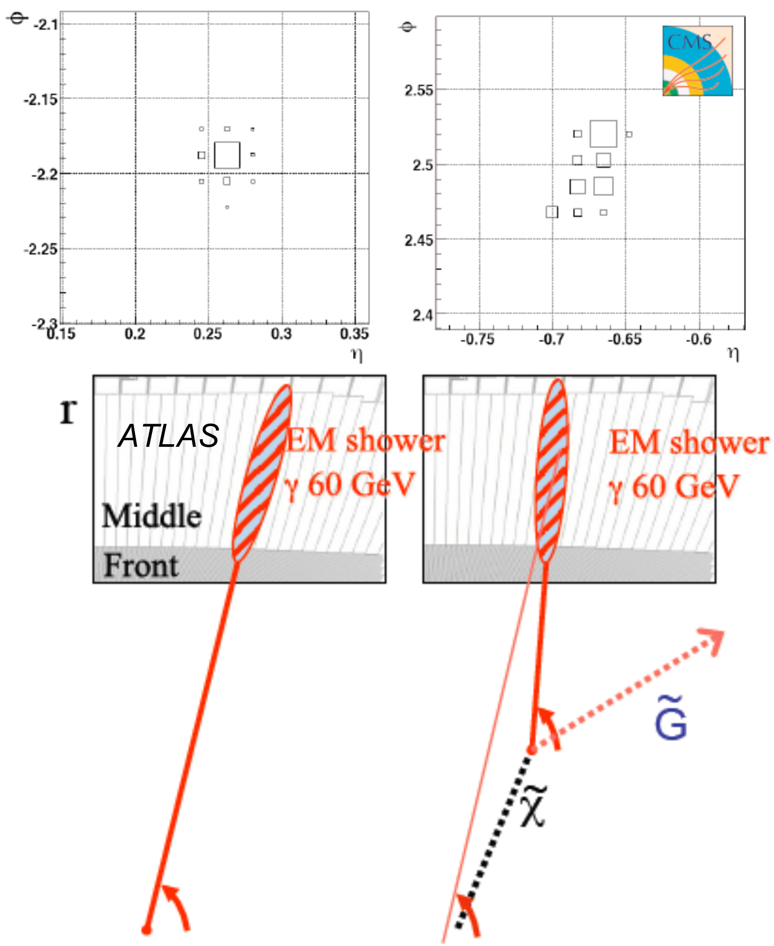
2 Photons & "Standard" SUSY cuts



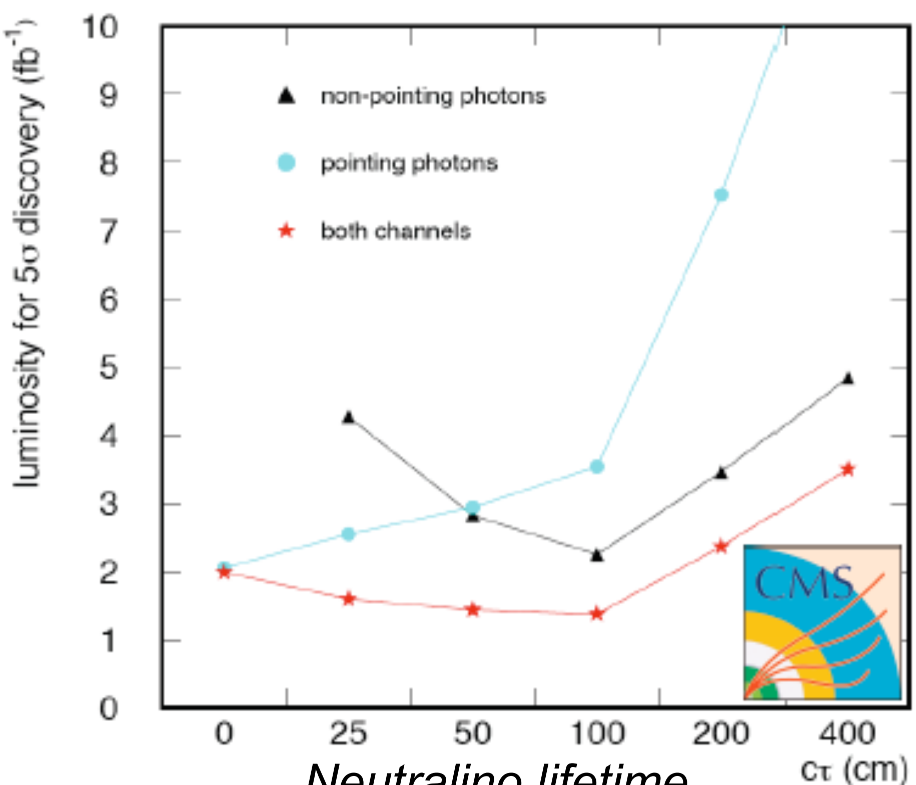


SUSY: GMSB

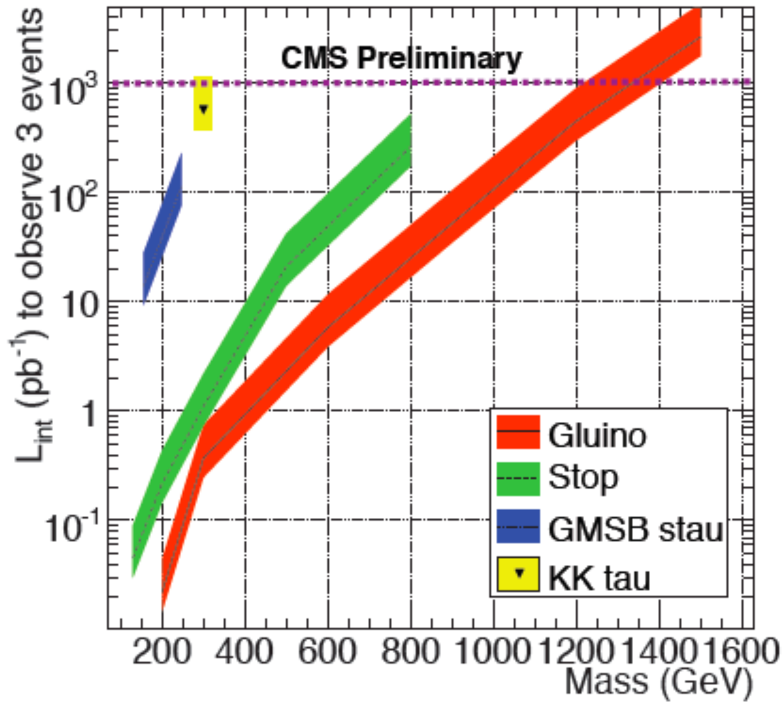
Separate pointing from non-pointing photons by looking at the ECAL cluster shape



Discovery potential already with 1/fb



Heavy Stable Charged Particles



Predicted by several models:

- lepton like
  - •GMSB staus
  - •Kaluza-Klein tau's in UED
- R-Hadrons
  - •long lived stop in SUSY
  - •long lived gluino in split-susy

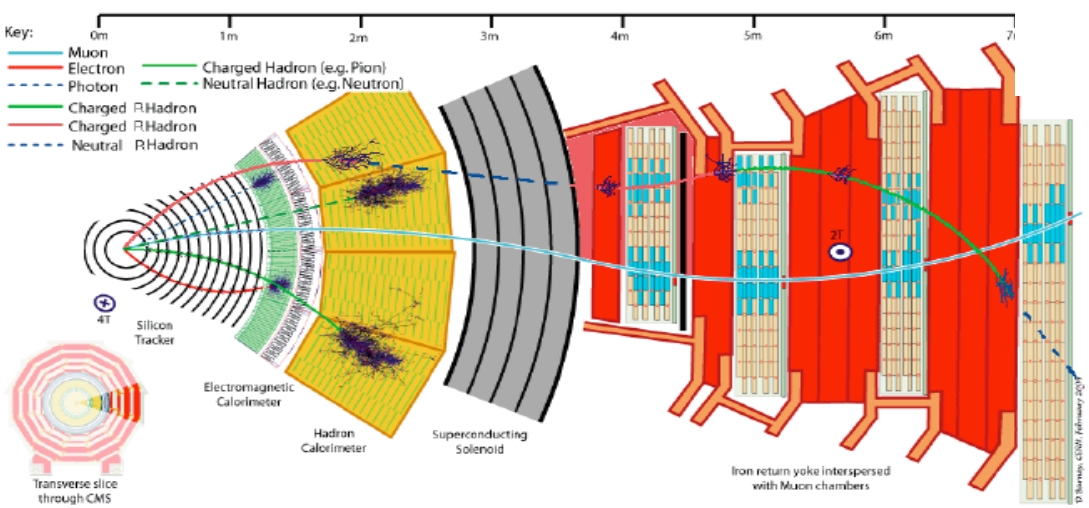
Properties:

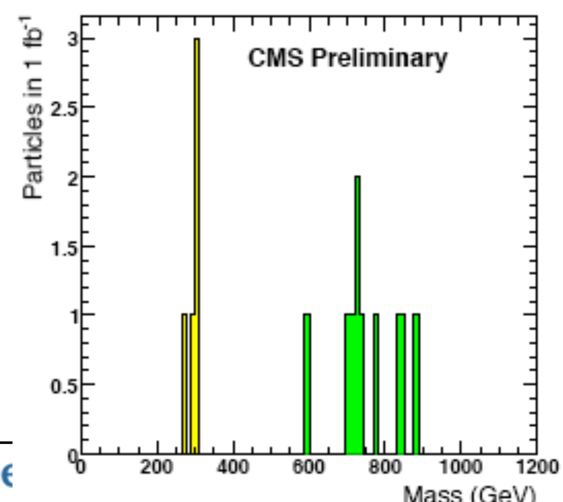
•O(100 GeV), β<1
•$c\tau$ few meters
•electrical or colour charge

Measurement

• momentum in Tracker&Muon
•β TOF in Muon DT & dE/dx in Tracker

ATLAS similar





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Measurement

- *momentum in Tracker&Muon*
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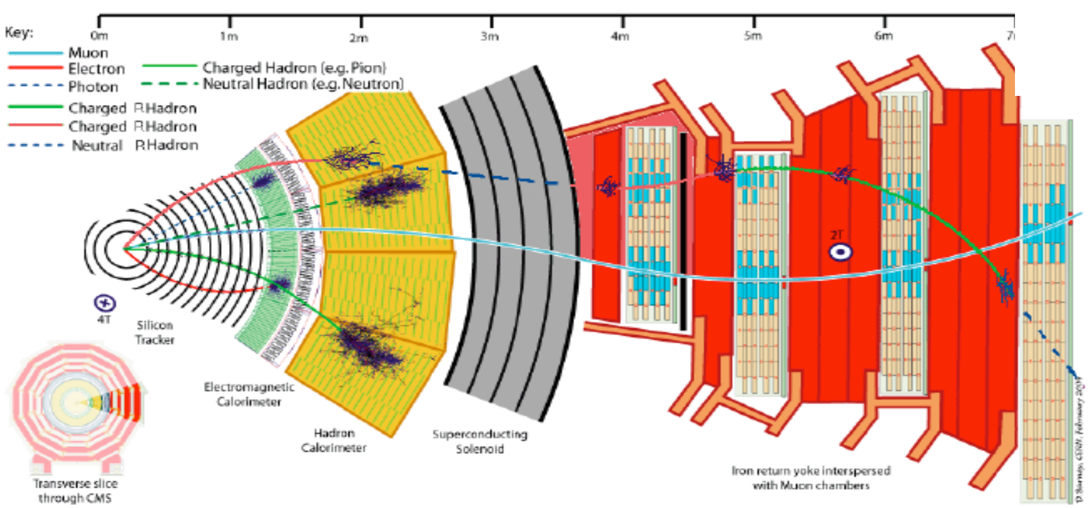
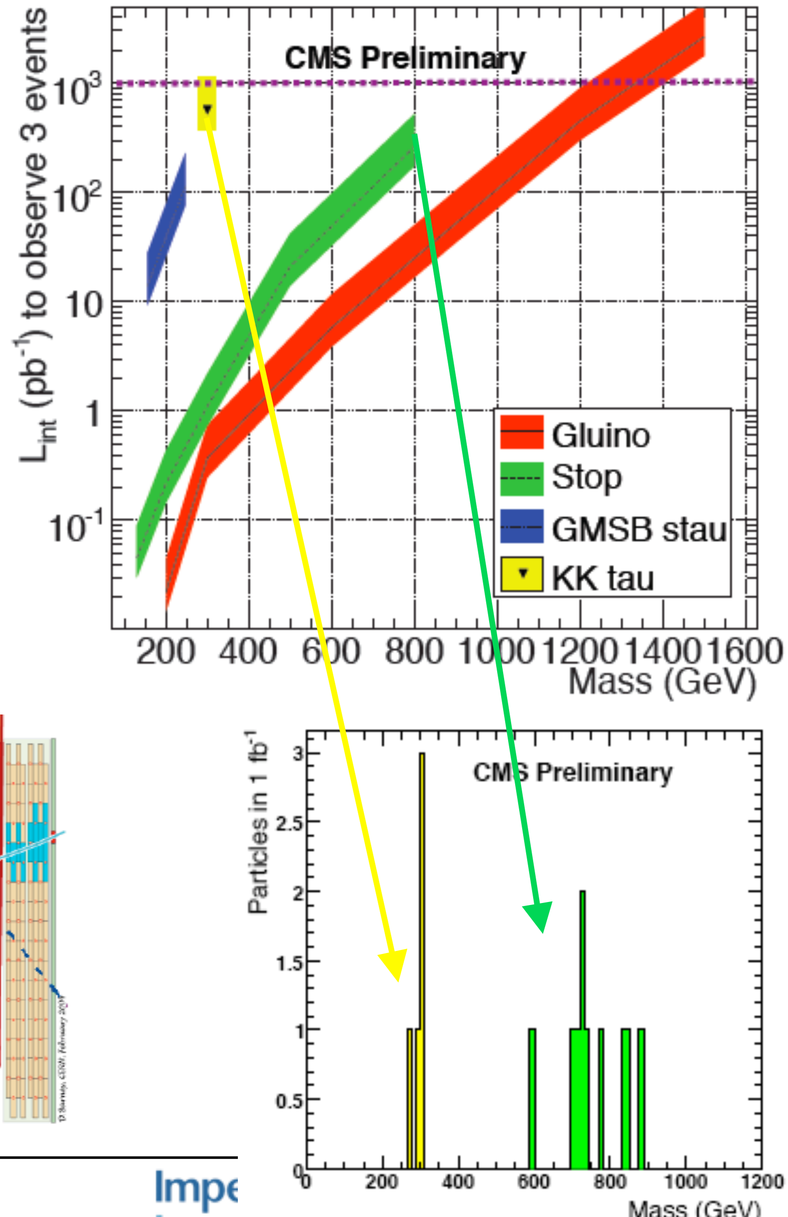
ATLAS similar

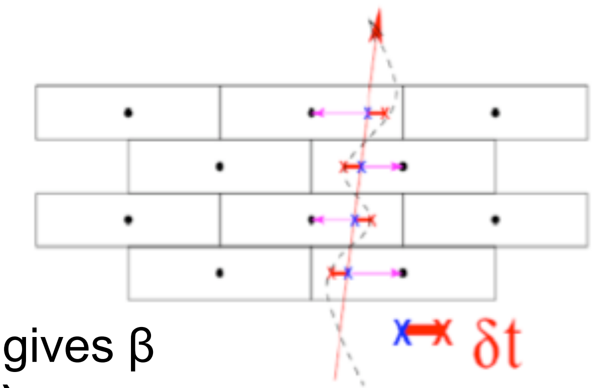




Heavy Stable Charged Particles (HSCP)

similar Analysis done by ATLAS

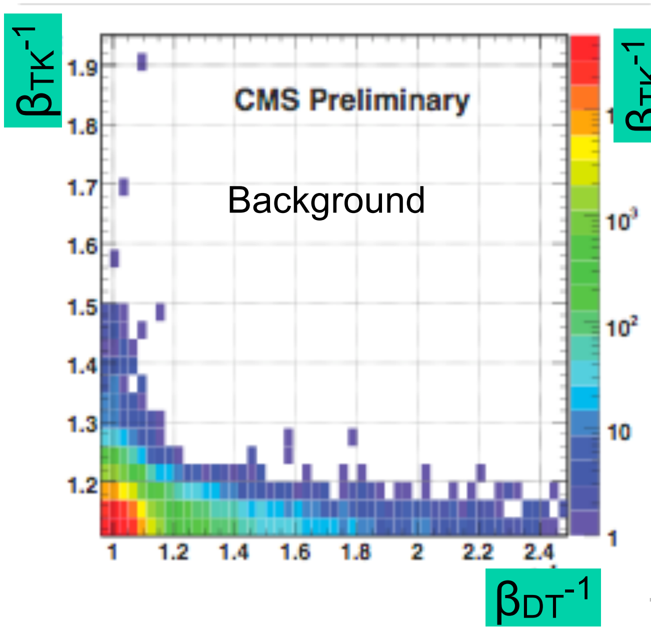
HSCP predicted by many models SUSY (GMSB, split SUSY..) + non-SUSY (UED..)
- could see sleptons or R-hadrons (metastable stops and gluinos build R-Hadrons)

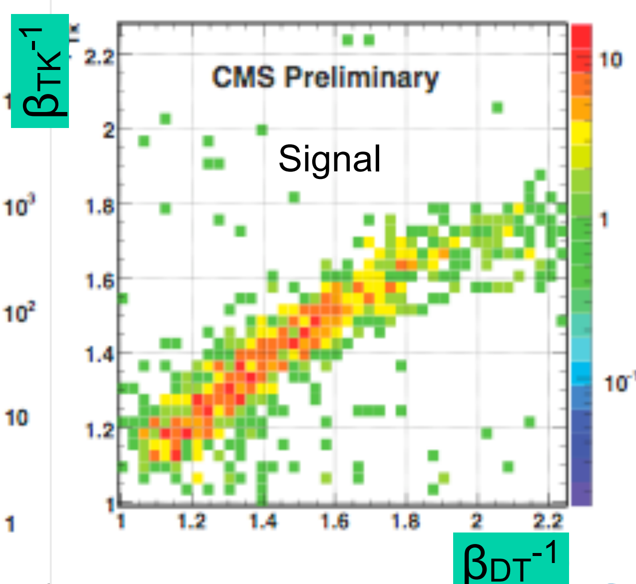


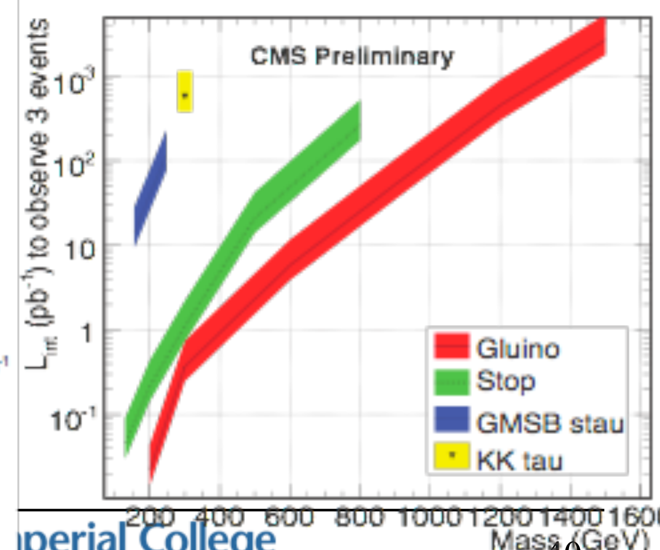
Challenging channel:
- trigger: slow particles might arrive late in muon system
⇒ wrong bunch crossing associated
- muon reconstruction: R-Hadrons could change charge

β_{DT} from drift tubes: looks like muon with wrong timing; δt gives β
dE/dx from silicon tracker ⇒ β_{TK} (Bethe-Bloch equation)
Requiring $\beta_{DT} < 0.8$ & $\beta_{TK} < 0.8$

CMS PAS EXO-08-003



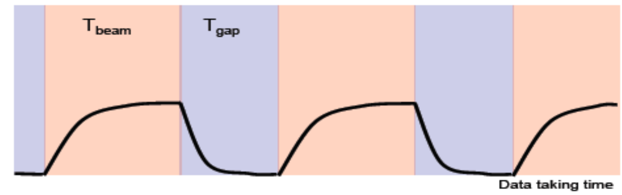




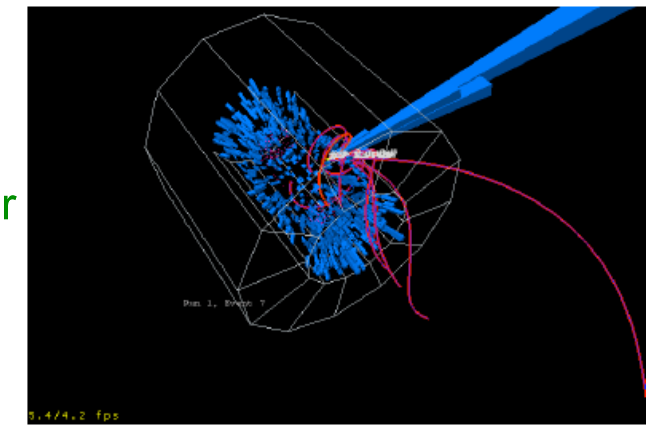
Long Lived Particles: Stopped Gluinos

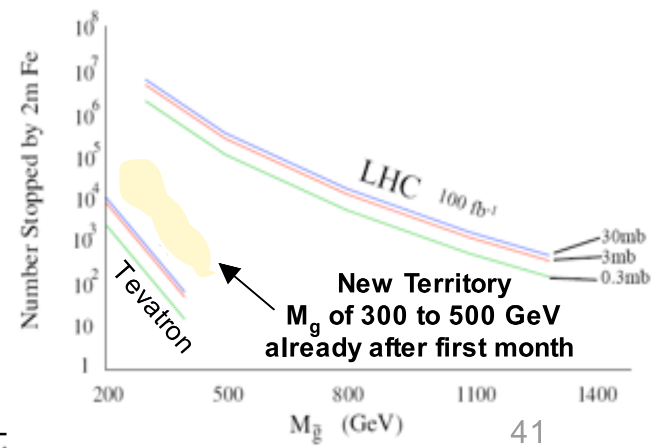
Interesting discovery potential for stopped gluinos

- Long lived gluinos are predicted in a number of models e.g. split SUSY
- Strongly produced they hadronize and eventually stop in the dense detector material.
- Decay in energy splash micoseconds or even days later
- Needs special beam-gap trigger to capture the decay
- Crucial cosmic background already measured during dedicated CMS cosmic runs (CRAFT)
- Already sensitive to gluino masses of ~300 GeV after only days of data taking



stopped gluinos vs beam time

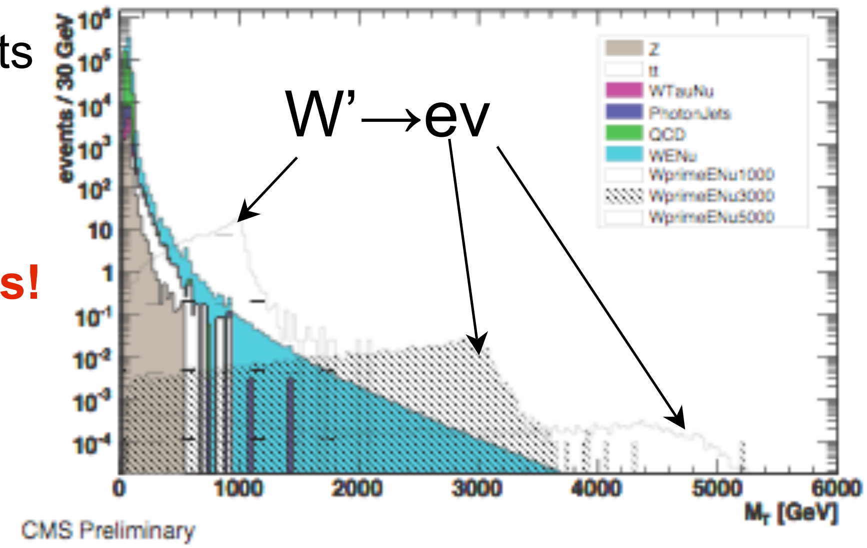




di-object signature search

CMS PAS EXO-08-004

Search for final states with just two physics objects like leptons, jets, E_T^{miss},
predicted by various models



definition of signature allows generic searches!

- di-lepton (see next slide):
models: GUT, extra dimensions,...

- di-jets: **contact interactions** ⇒ large rate at high pT
q*, Z' ⇒ heavy mass resonances

-di-photons: Important cross-check to **rule out spin-1 hypothesis**
(i.e. **RS graviton** instead of a Z')

- lepton+ E_T^{miss} : signature of new **heavy W-like bosons** (LR model)

- jet+ E_T^{miss}: **signature: 1 high p_T central jet + E_T^{miss} ~back to back**
mono-jet final states proposed by extra dimension models ADD

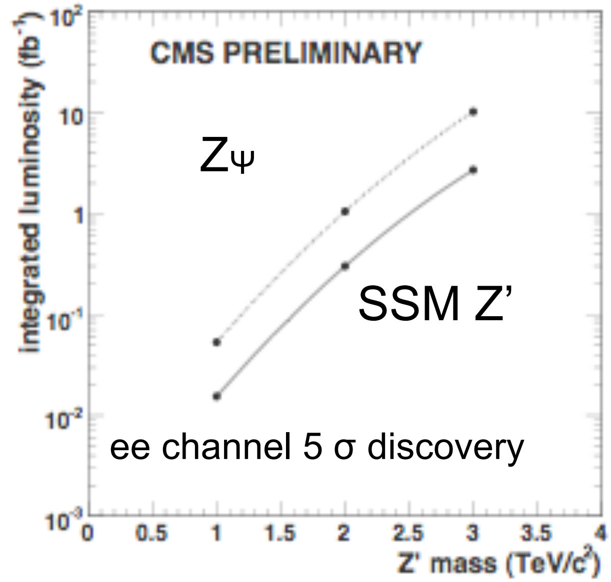
Di-lepton resonance (Z')

SSM Z' (carbon copy of Z)
Z_ψ: arises in E_6 and SO(10) GUT theories

Z' → ee/μμ: (CMS , ATLAS) CMS PAS EXO-08-004

- very clean signature
- various methods developed to evaluate: efficiencies, background, uncertainties

search strategies are in good shape



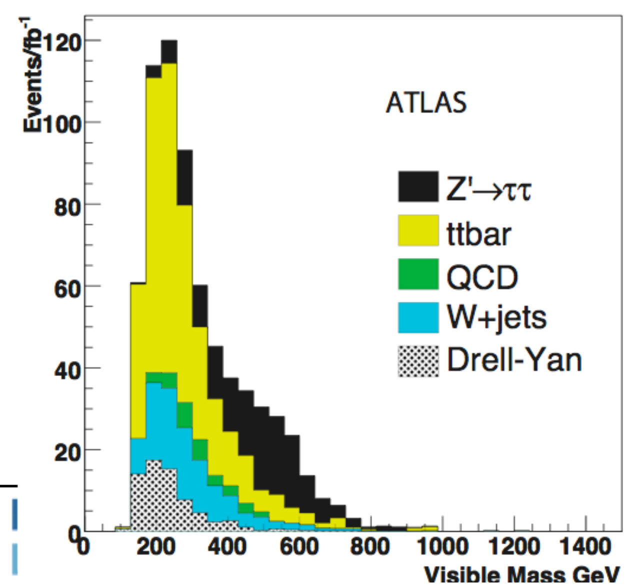
Z' → ττ: (ATLAS): ATLAS: CERN-Open-2008-020

- studied: hadron-lepton final state for m(Z')=600 GeV
- event selection: hadronic tau + charged l + E_T^{miss}
- **direct mass reconstruction not possible**
- use m_{vis} instead

$$m_{vis} = \sqrt{\vec{p}_l + \vec{p}_h + \vec{E}_T^{miss}}$$

significance : $\frac{S}{\sqrt{B+\delta B^2}}$ = 3.4 at 1 fb^{-1}

δB: background uncertainties



More exotic searches ...

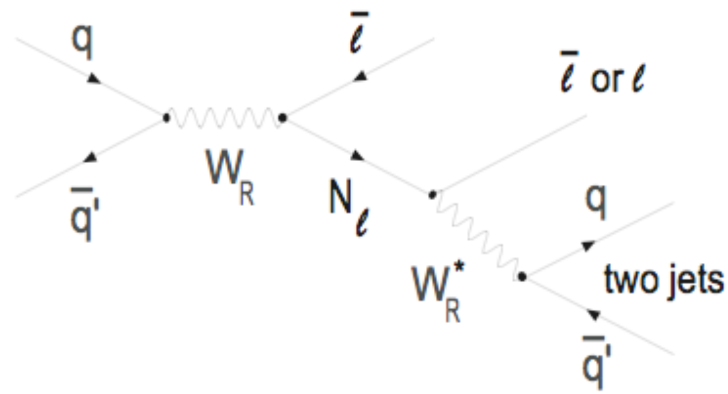
3-object searches:

2 leptons + jets: W_R, lepto-quarks (LQ)

studied decay modes: LQ → e\μ q

W_R → e\μ N

N: heavy majorana neutrino



something even more spectacular:

Vector boson resonances (high luminosity search):

signature: - 2 high rapidity high pT "tag" jets

- 2 highly boosted bosons in the center
- no jets between the two "tag" jets

b'b'->WWWWbb: a fourth generation quark

signature: lots of leptons(1-4) +2 b-jets

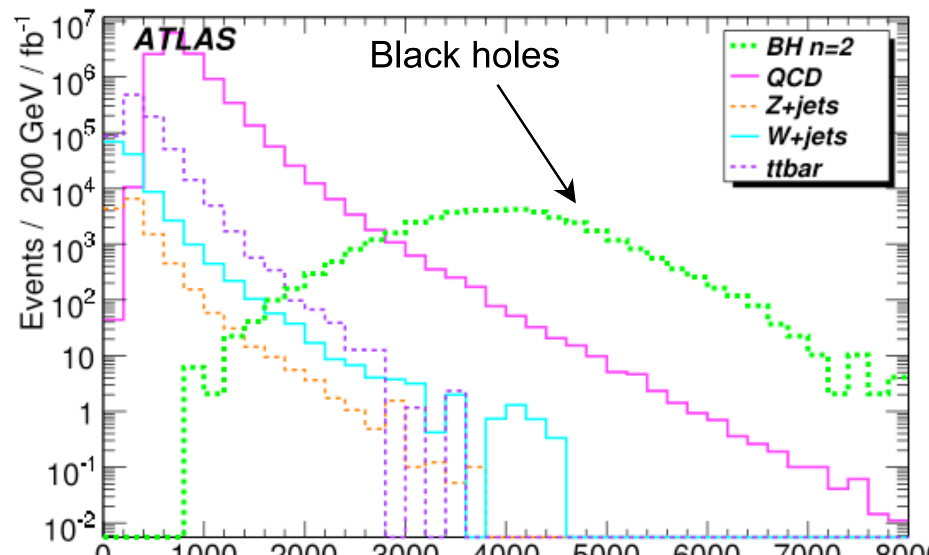
Black holes: decay via Hawking radiation

signature: large number of decay products

⇒ large transverse momentum sum

or stay unspecific:

MUSIC model unspecific search in CMS



ATLAS: CERN-Open-2008-020

More on data-driven Bkg. extraction

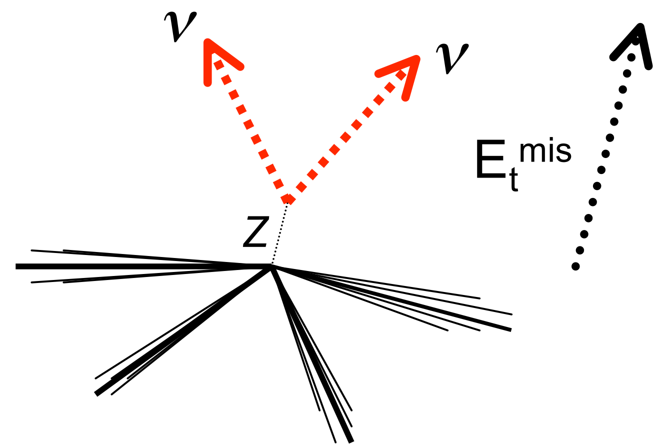
Data Driven Background Estimations

An illustrative example: $Z \rightarrow \nu\nu$+jets

Irreducible background for Jets+E_t^{mis} search

Data-driven strategy:

- *define control samples and understand their strength and weaknesses:*



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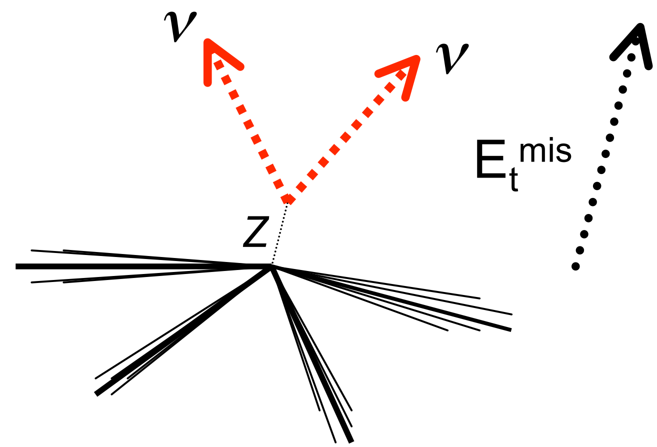

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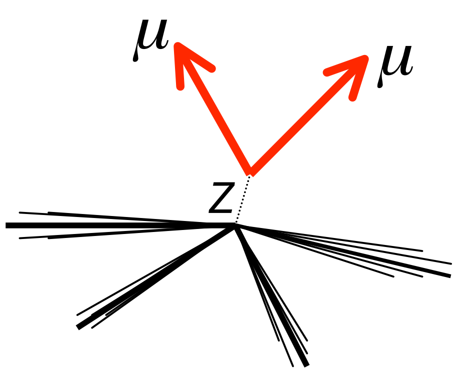


$Z \to \mu\mu$+jets

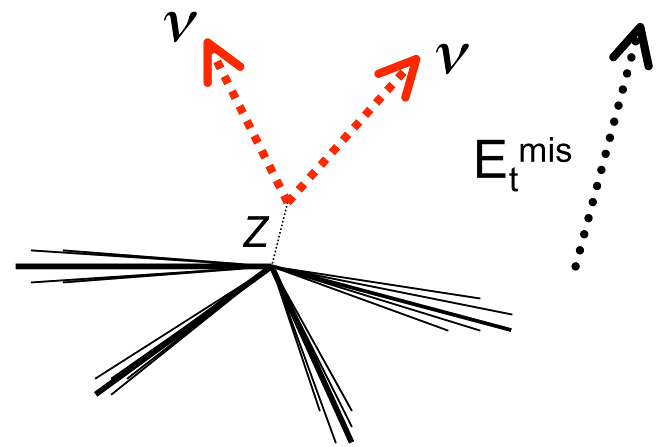
Strength:

- *very clean, easy to select*

Weakness:

- *low statistic: factor 6 suppressed w.r.t. to $Z \to \nu\nu$*

Data Driven Background Estimations



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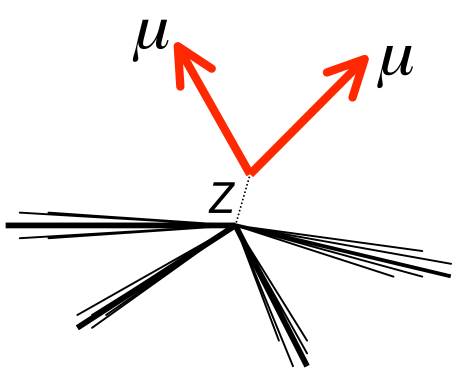

Z→μμ+jets

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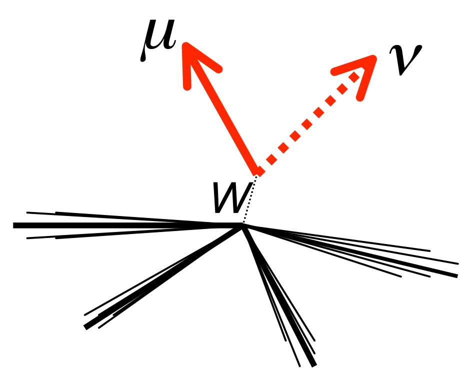


W→μν+jets

Strength:

- *larger statistic*

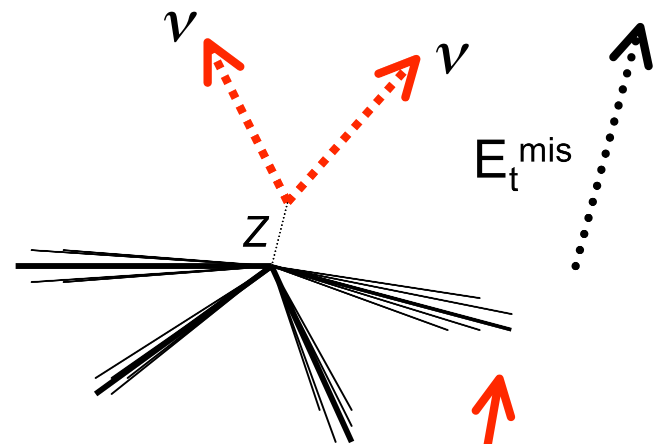
Weakness:

- *not so clean, SM and signal contamination*

Data Driven Background Estimations

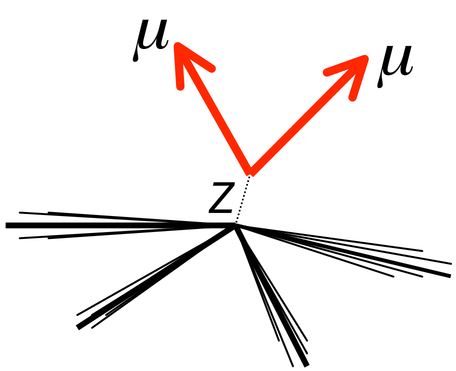
An illustrative example: $Z \rightarrow \nu\nu$+jets

Irreducible background for Jets+E_t^{mis} search



Data driven strategy:

- *define control samples and understand their strength and weaknesses:*



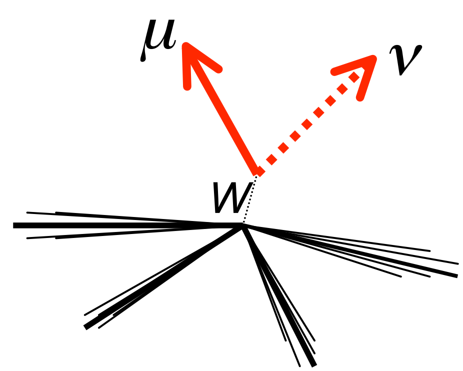
Z→ll+jets

Strength:

- *very clean, easy to select*

Weakness:

- *low statistic: factor 6 suppressed wrt. to $Z \rightarrow \nu\nu$*



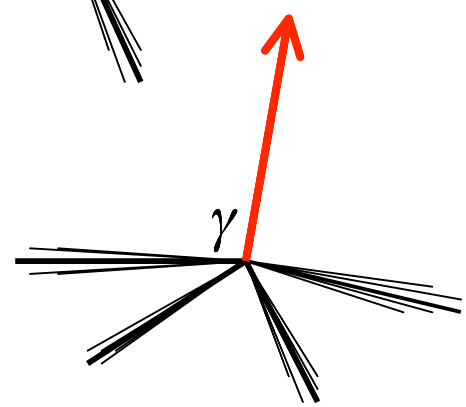
W→lν+jets

Strength:

- *larger statistic*

Weakness:

- *not so clean, SM and signal contamination*



γ+jets

Strength:

- *large stat, clean for high E_γ*

Weakness:

- *not clean for E_γ<100 GeV, possible theo. issues for normalization (u. investigation)*

γ+jets: Estimate Z to invisible

γ+jets selection & properties:

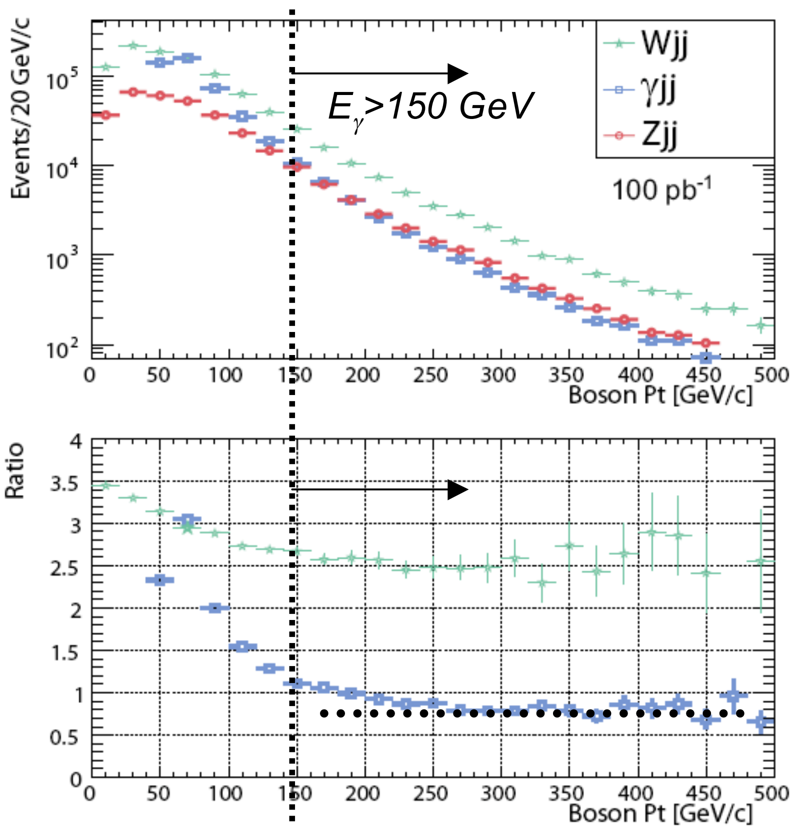
- E_γ>150 GeV

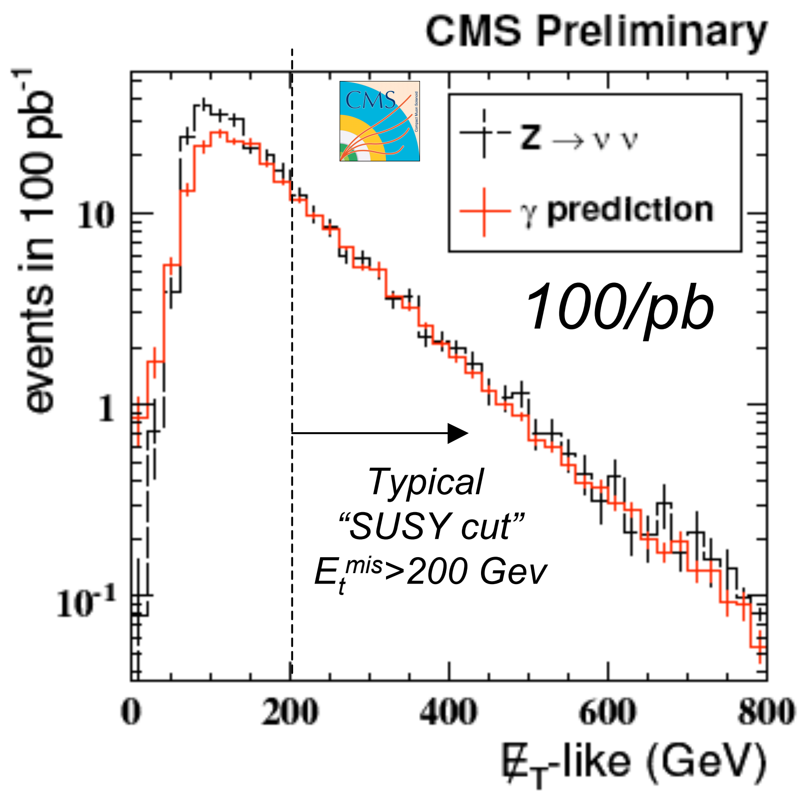
→ clean sample: S/B>20

→ ratio σ(Z+jet)/σ(γ+jet) constant

γ+jets: Strategy:

- remove γ from the event:
  → γ becomes E_T^{mis}
- take σ(Z+jet)/σ(γ+jet) for E_γ>200 GeV from MC or measure in data



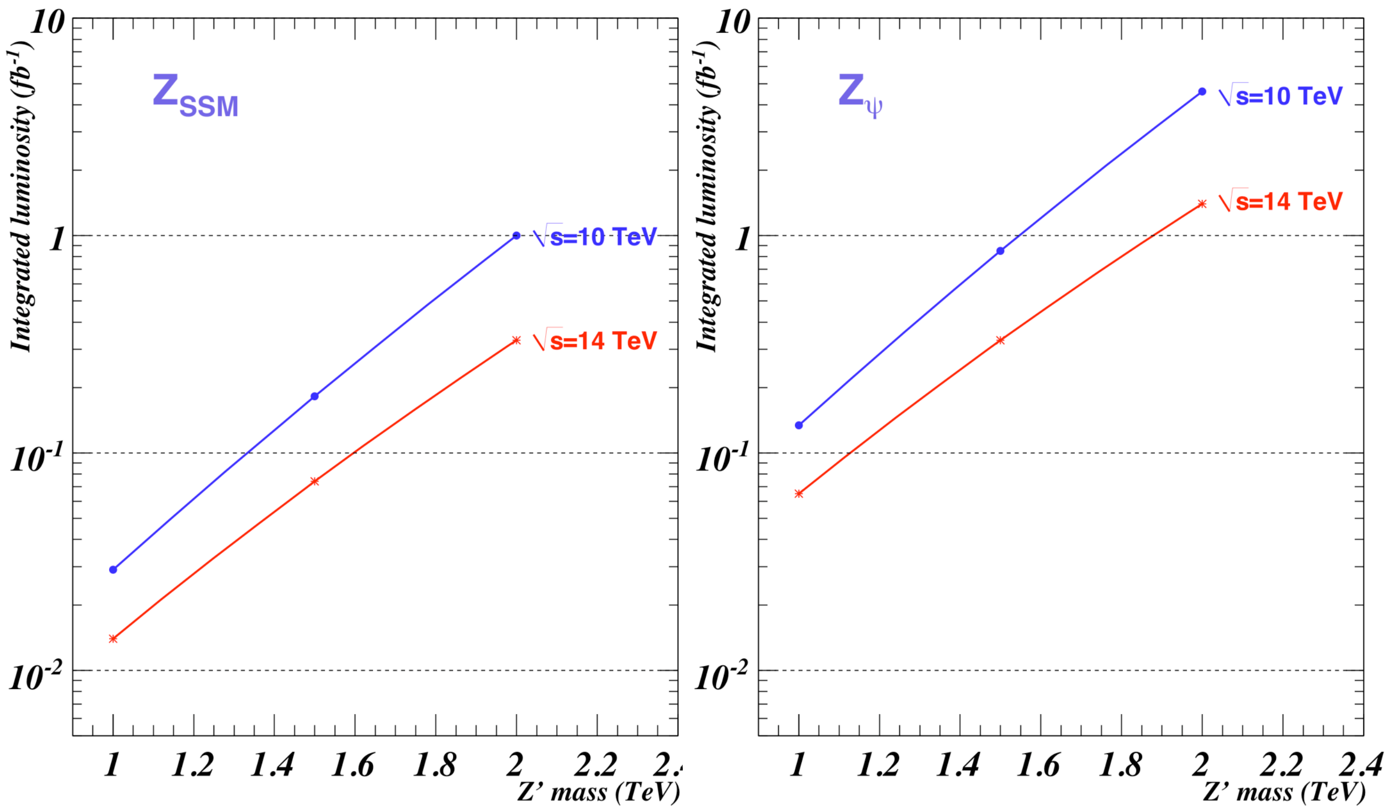


More on (CMS) Reach @ 10 TeV

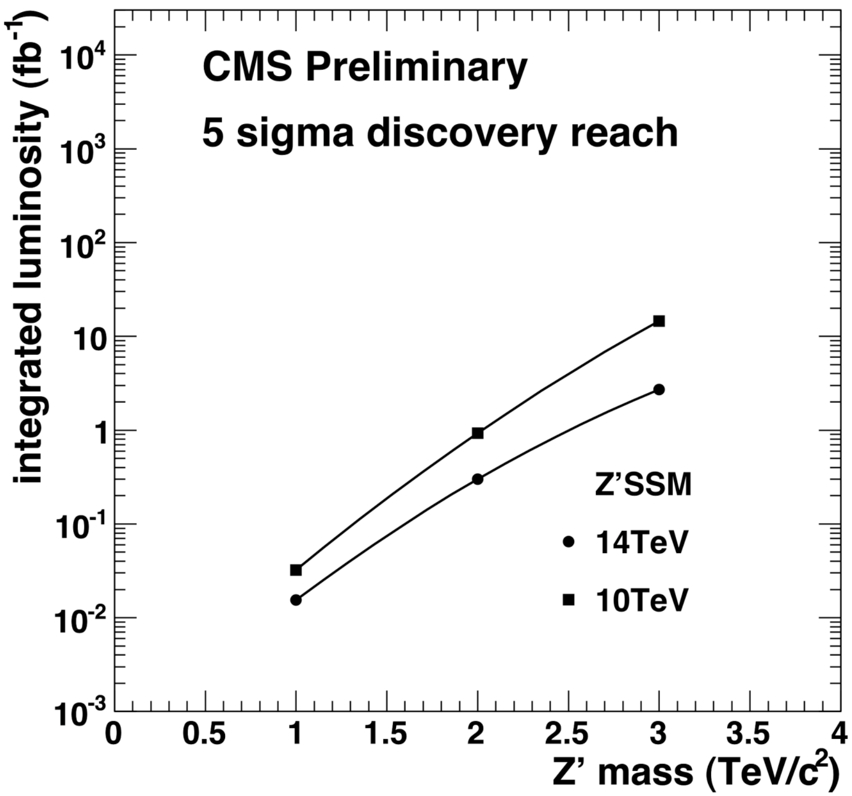
Z' to mumu

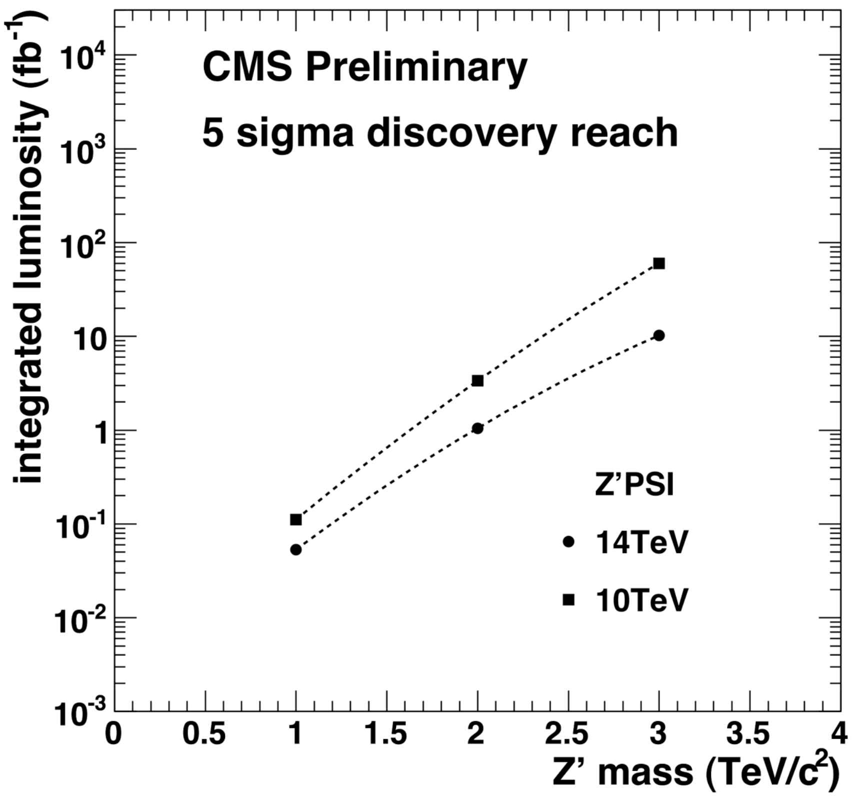
- 14 TeV curves: from PAS SBM-07-002
  - Rescale 14 TeV curves by corresponding cross section ratios for Signal and Drell-Yan bkg → 10 TeV curves
  - Z_y and Z_{SSM}: the two extremes in "reach":

Z' mass (TeV)	s(14 TeV)/s(10TeV)
1	2
2	3

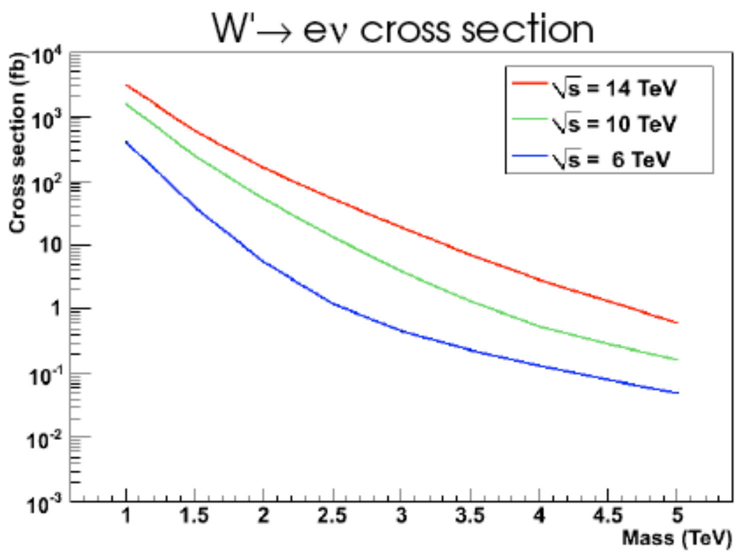


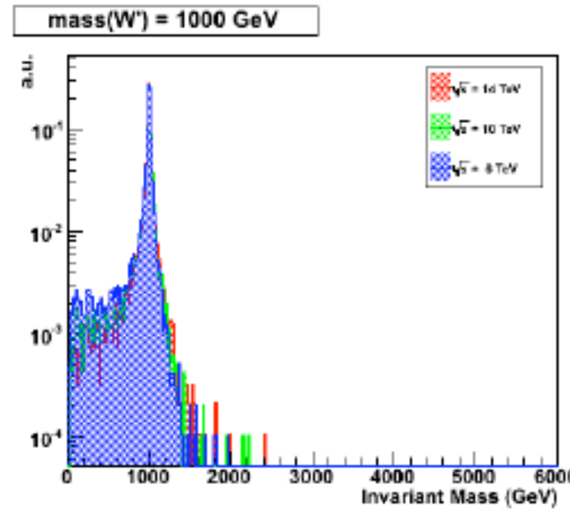
Z' to ee


CMS Preliminary
5 sigma discovery reach
Z'SSM
14TeV
10TeV
integrated luminosity (fb^{-1})
Z' mass (TeV/c^2)

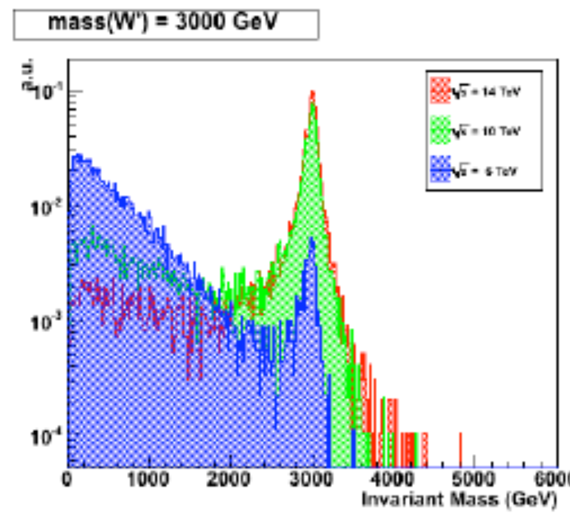

CMS Preliminary
5 sigma discovery reach
Z'PSI
14TeV
10TeV
integrated luminosity (fb^{-1})
Z' mass (TeV/c^2)

W' to eν

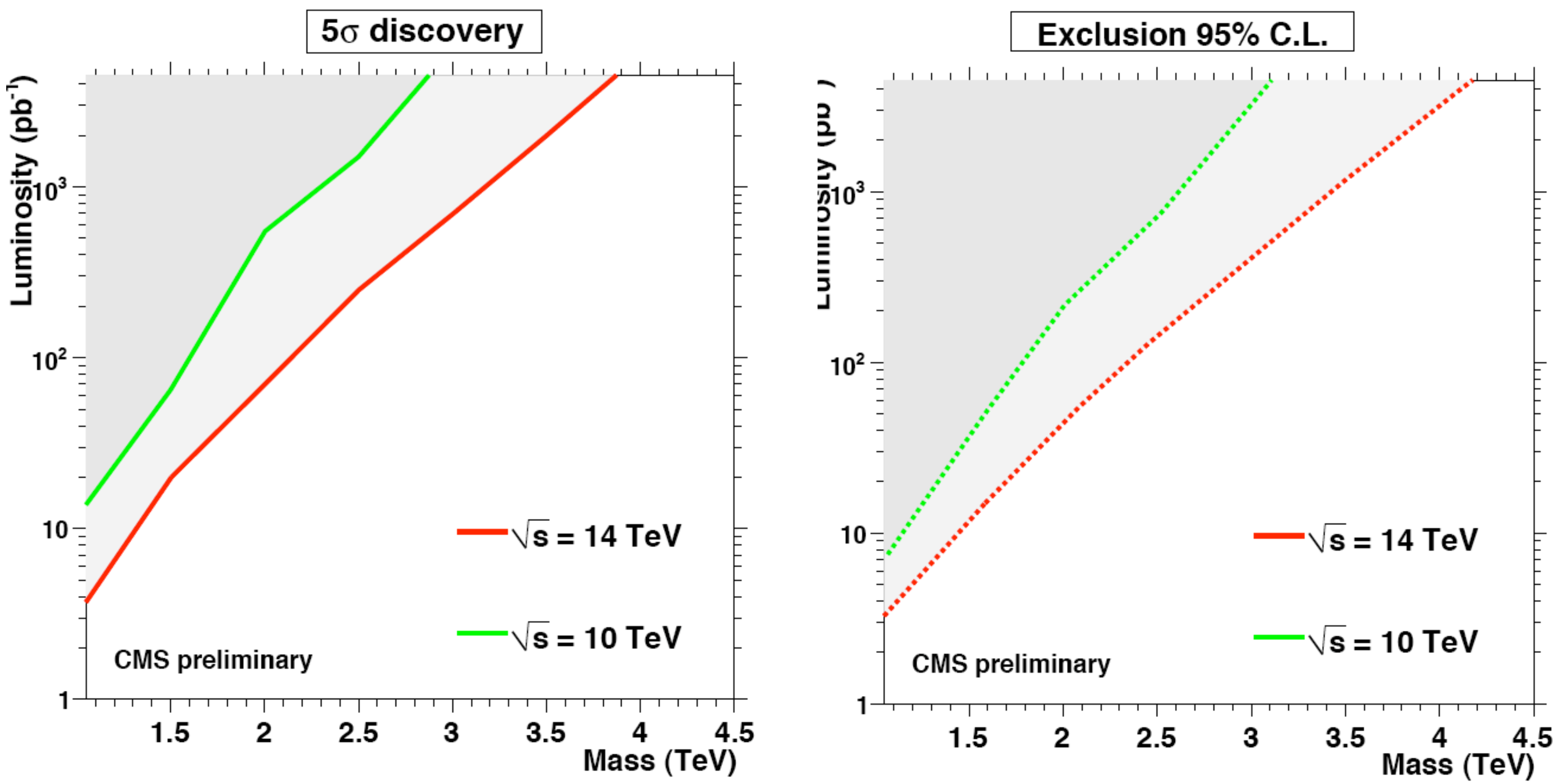




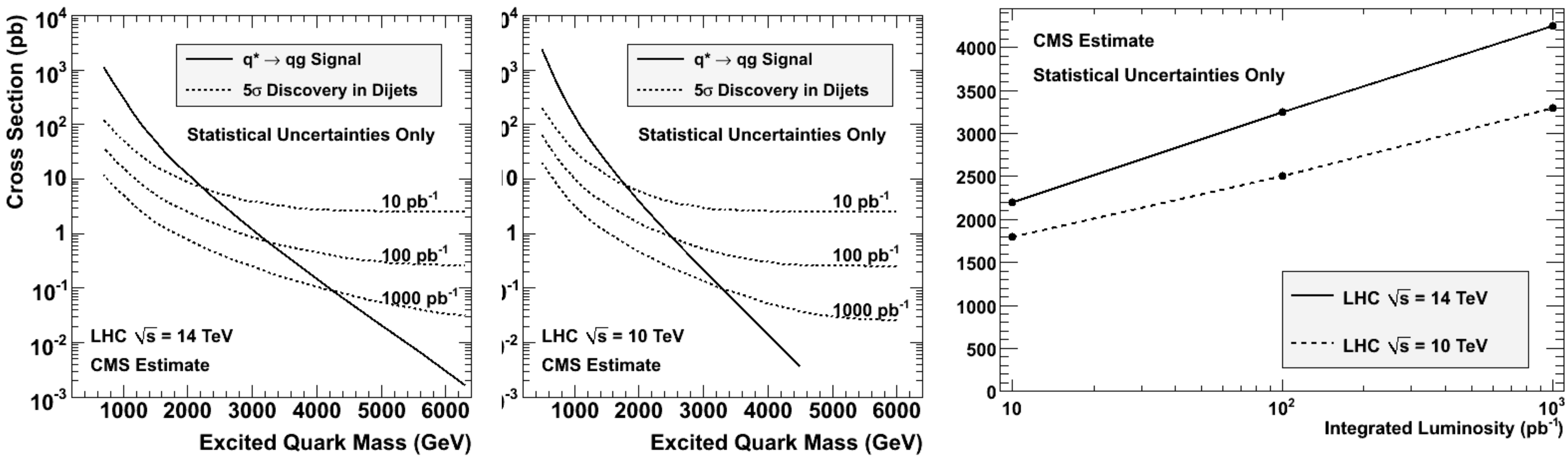
Process	X-sec. @ 14 TeV	X-sec @ 10 TeV	X-sec @ 6 TeV
W→eν (M>200GeV)	6.8 nb	4.35 nb (0.640)	2 nb (0.294)
DY ee	1.79 nb	1.23 nb (0.687)	0.67 nb (0.374)
Ttbar	480 pb	241 pb (0.502)	58 pb (0.121)
QCD	54.7 mb	51.5 mb (0.941)	47.2 mb (0.863)



W' to eν


5σ discovery
Luminosity (pb^{-1})
10^3
10^2
10
1
1.5
2
2.5
3
3.5
4
4.5
Mass (TeV)
$\sqrt{s}$ = 14 TeV
$\sqrt{s}$ = 10 TeV
CMS preliminary
Exclusion 95% C.L.
10^3
10^2
10
1
1.5
2
2.5
3
3.5
4
4.5
Mass (TeV)
$\sqrt{s}$ = 14 TeV
$\sqrt{s}$ = 10 TeV
CMS preliminary

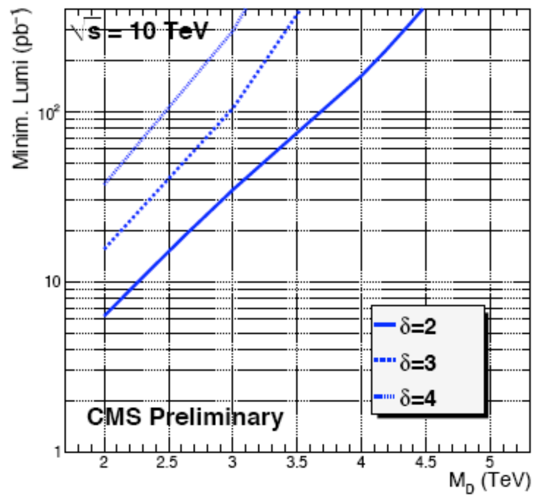
Exotica: excited quark

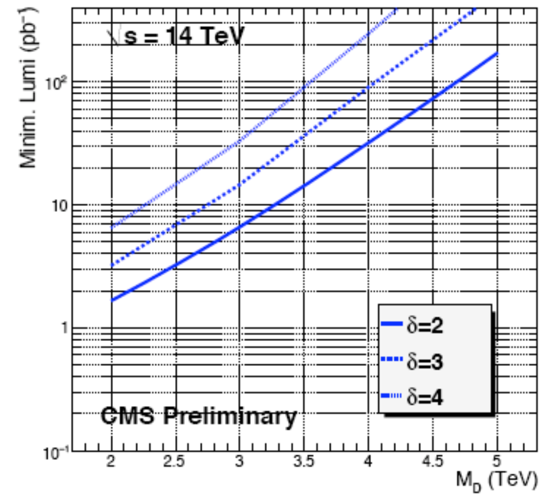


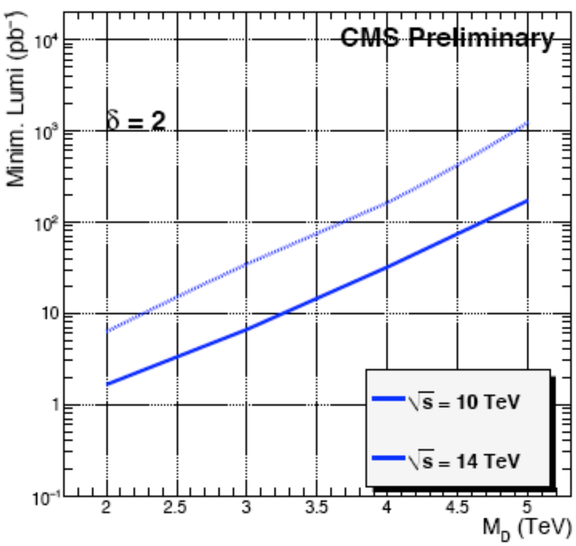
Integrated Lumi (pb^{-1})	Mass reach (TeV) LHC @ 10 TeV	Mass reach (TeV) LHC @ 14 TeV
10	1.80	2.20
100	2.50	3.25
1000	3.30	4.25

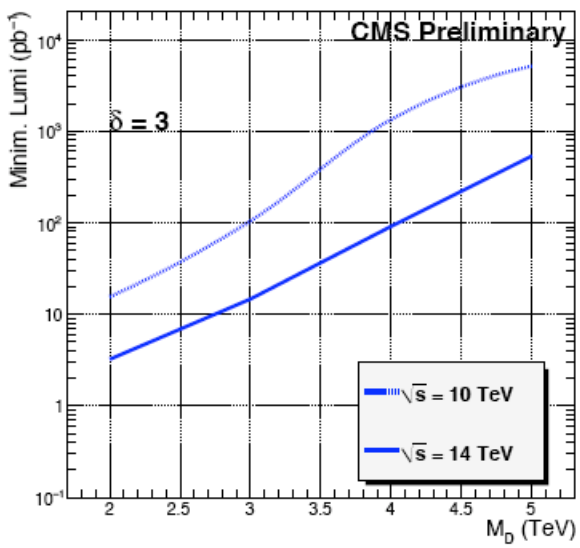
Extra dimensions

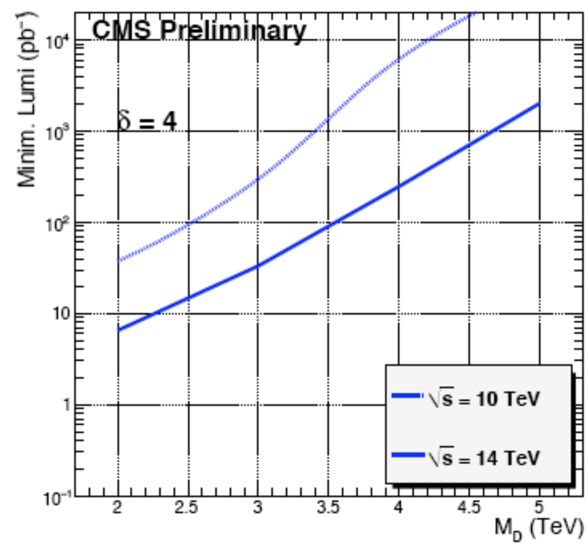
ADD monojets









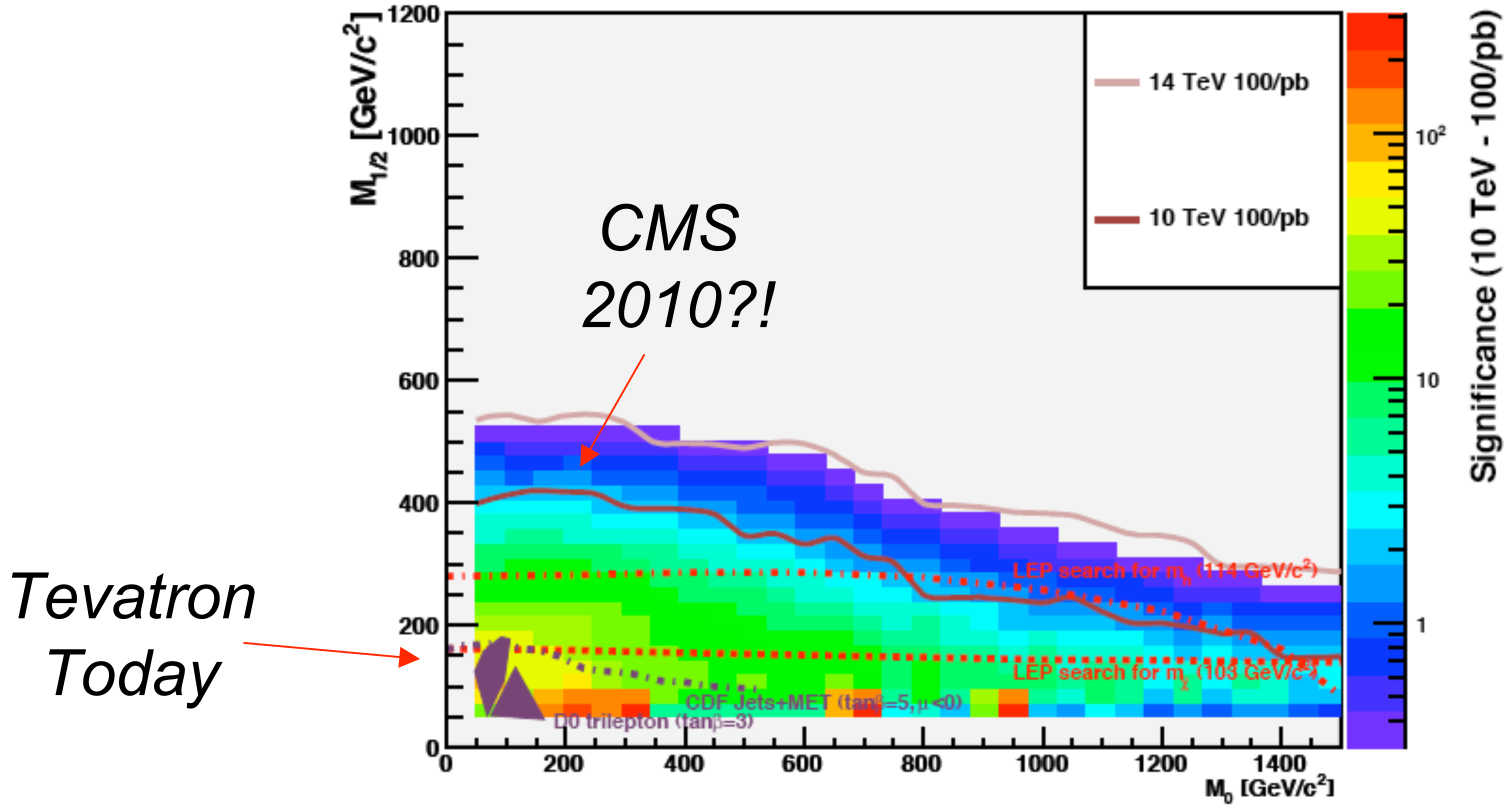


First LHC Running 2009/2010 - Expectations

Expectations are high!

With as little as ~50/pb @ 10 TeV of (understood!) data we should be able to go significantly beyond the reach of the Tevatron!

All-hadronic Reach project to 10 TeV

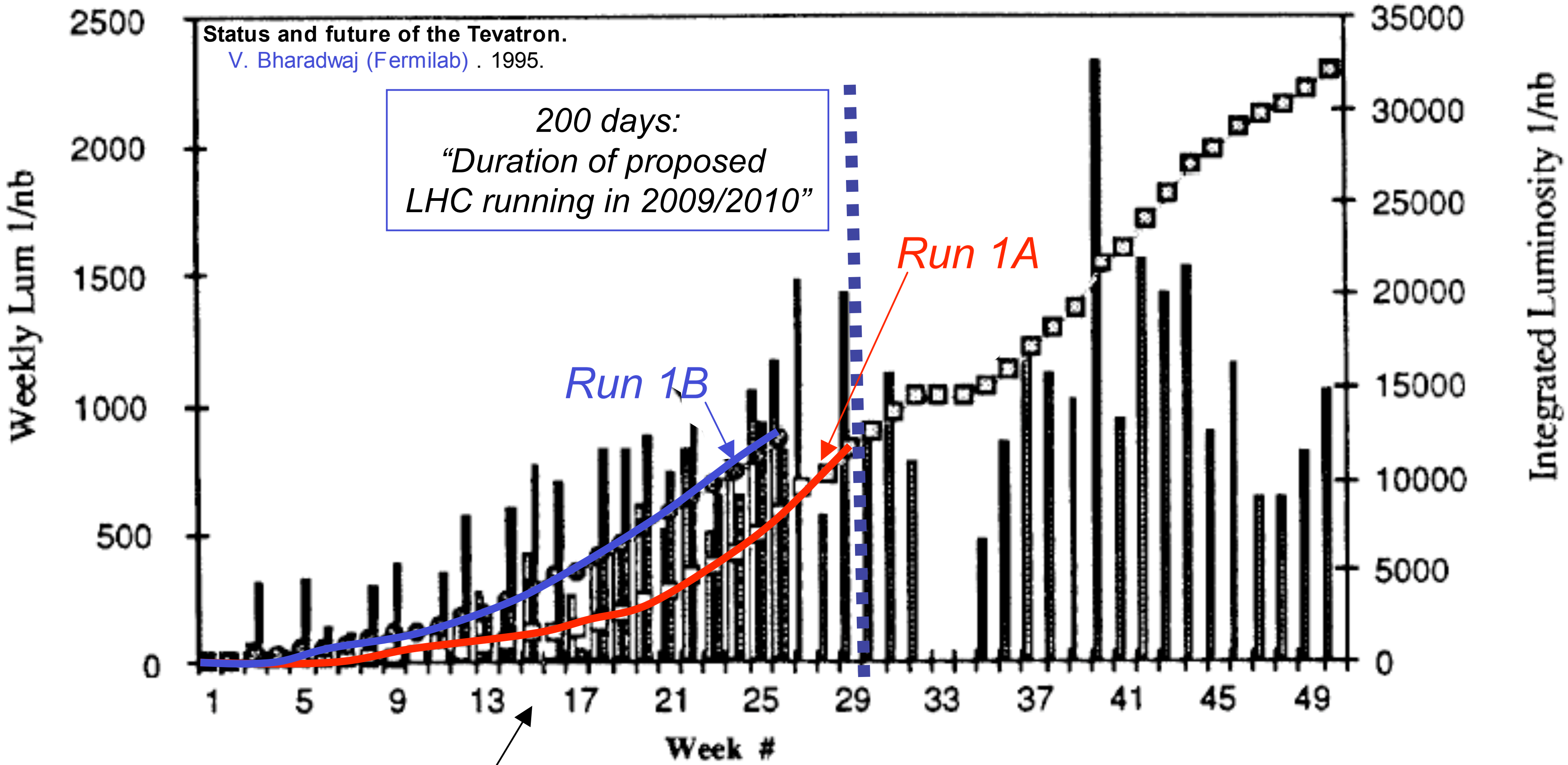


Ronga/Lungu AN 2009/016

Timeline: First SUSY Analyses

Use Run 1A of the Tevatron to illustrate a possible(!)

Luminosity profile for the first LHC physics run



Luminosity profile of Run 1A - first 200 days:

At "half-time" only ~20% of the total integral Luminosity was recorded.
The remaining 80% were taken in the second half of run period.