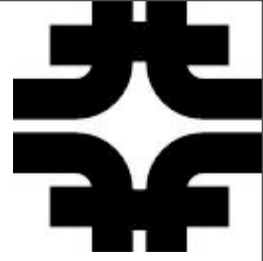


New Physics Searches at LHC

(The Energy Frontier)

Seema Sharma

(Fermilab)

On behalf of the LHC Experiments

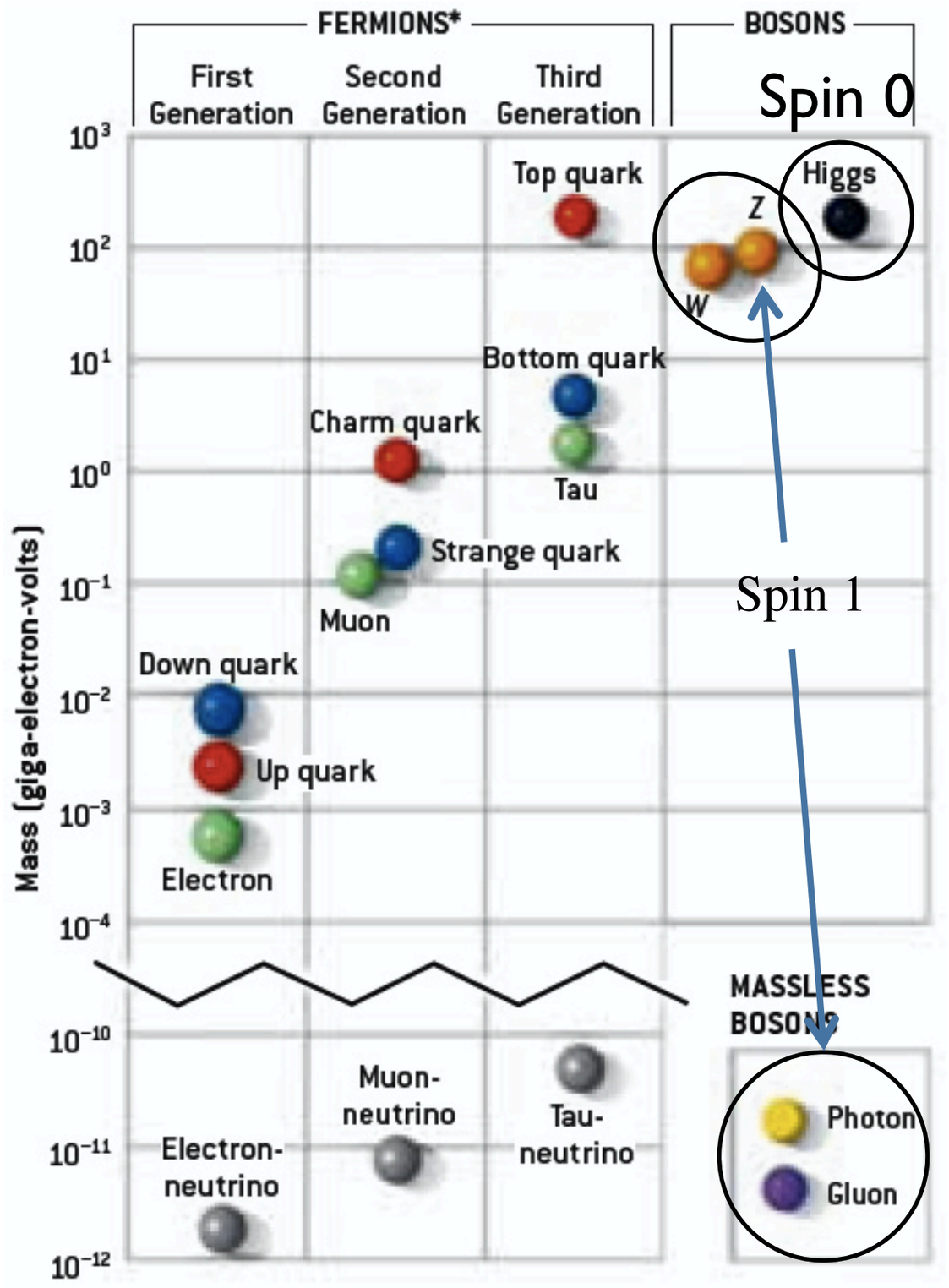
XXI International Workshop on Deep-Inelastic Scattering and Related Subjects

Marseille, France

April 22-26, 2013

Standard Model of Particles

A remarkably successful theory !!



A new boson of mass of ~125 GeV discovered at LHC : consistent with the SM Higgs boson.

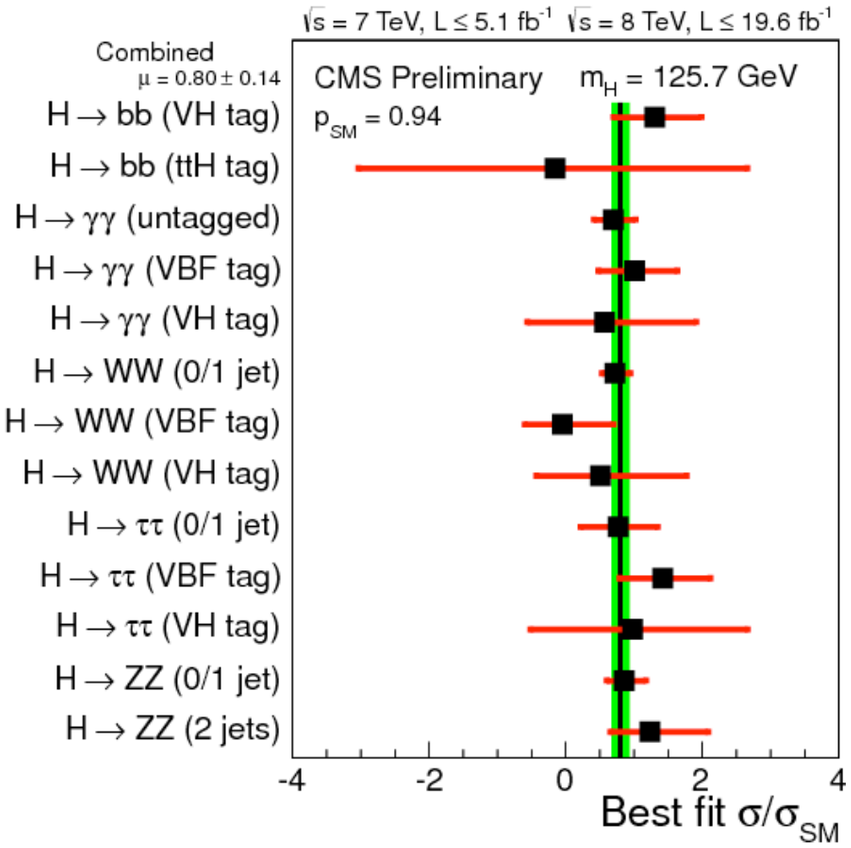
A few fundamental questions of particle physics not addressed by the Standard Model :

- Why different particles have different masses
- Is there a new symmetry ?
  - Grand unification of all the forces
- Why EWK and Plank scales are so separated ?
  - Any insight into gravity ?
- What is the nature and identity of dark matter ?
  - A new fundamental particle ?
- What is the origin of matter-antimatter asymmetry in nature ?
  - Is CP violation the answer ?
  - How do neutrino masses and mixing fits in the big picture ?

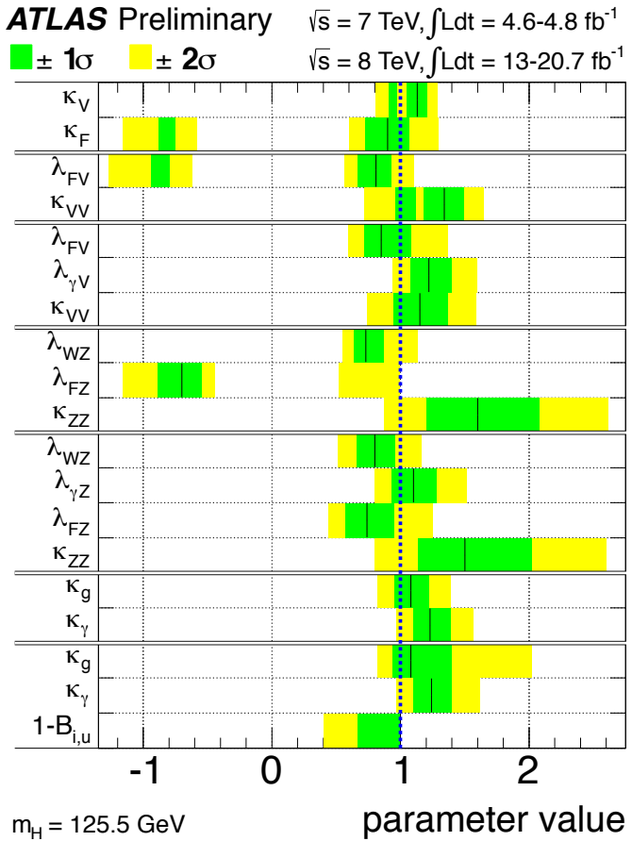
The Standard Model is an incomplete theory !

Naturalness or Hierarchy Problem (in SM)

CMS-PAS-HIG-13-005



ATLAS-CONF-13-034



Rate of different decay modes & various production mechanism cross-sections, and various couplings are consistent with SM expectations, although with large uncertainties.

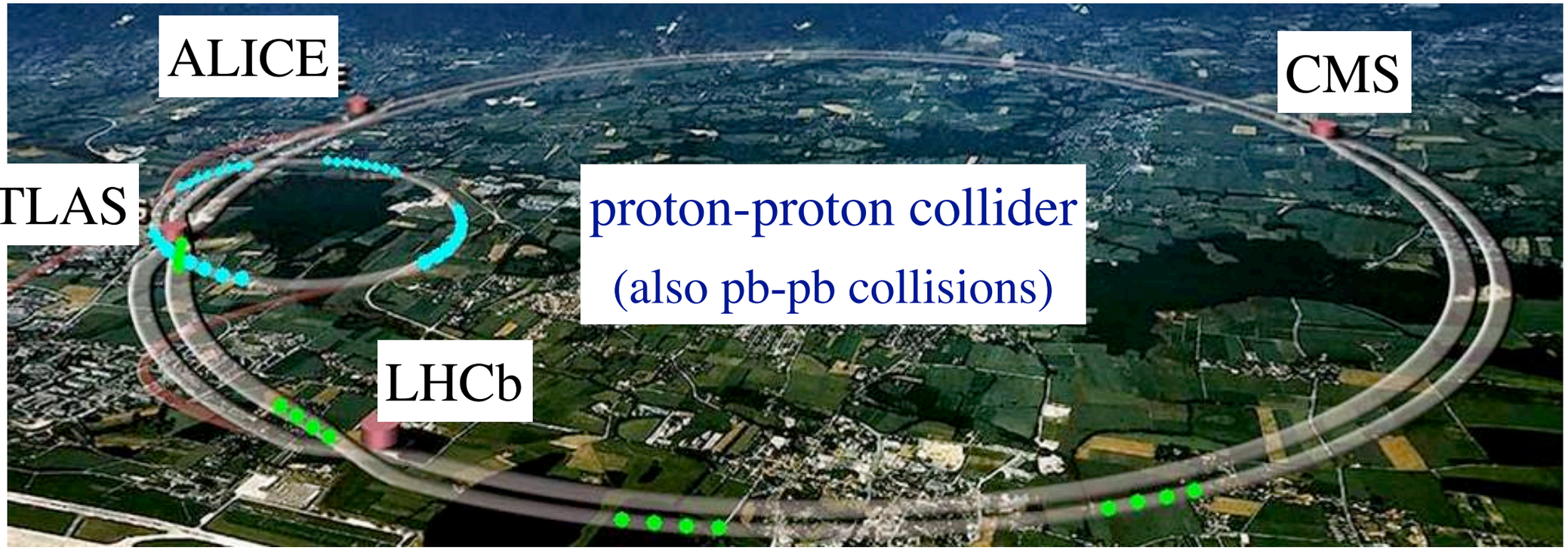
An immediate concern - Higgs boson mass get large quantum corrections (divergent fermion loop)

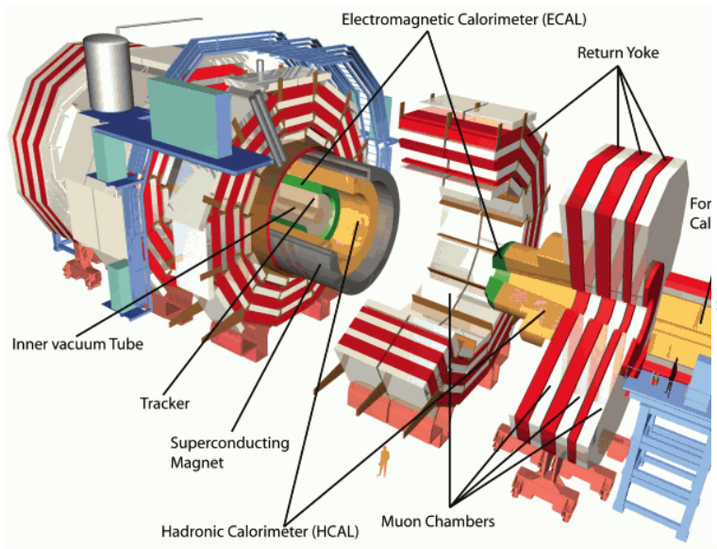
$$(\Delta m_h^2)_{SM} = \quad h \quad \lambda \quad f \quad = -\frac{N_c \lambda^2}{16\pi^2}\left[2\Lambda^2_{cutoff} + \ldots +\right]$$

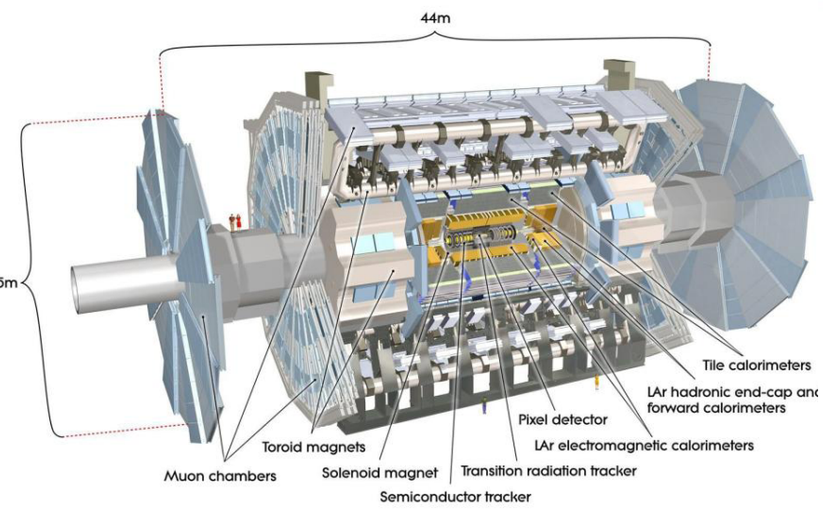
Assuming Λ extends up to highest energies, say at which gravity becomes important (Plank scale), this means we require corrections of the order of 1 in 10^{34}.

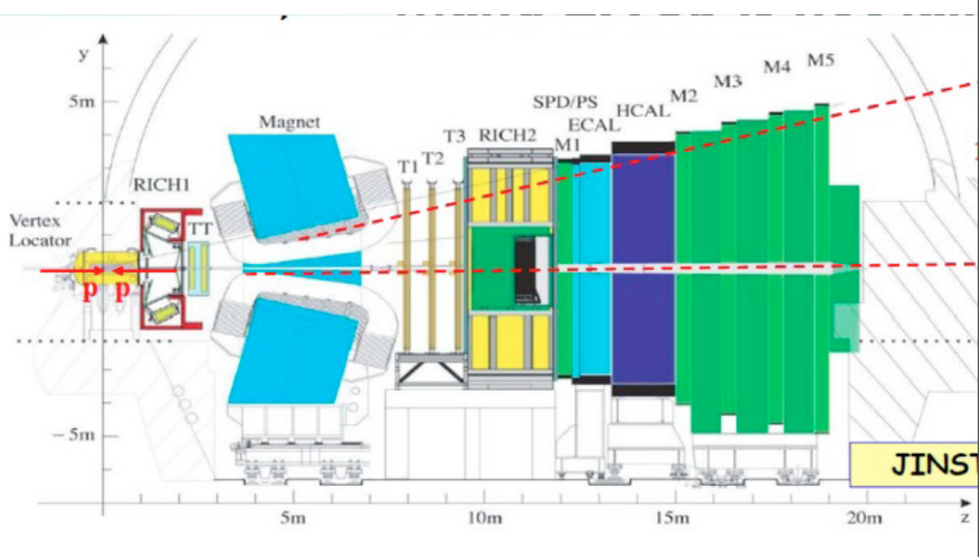
Extremely **unnatural** of this happens to be an accident.
=> Expect new physics a much lower scale (~TeV scale)

Large Hadron Collider







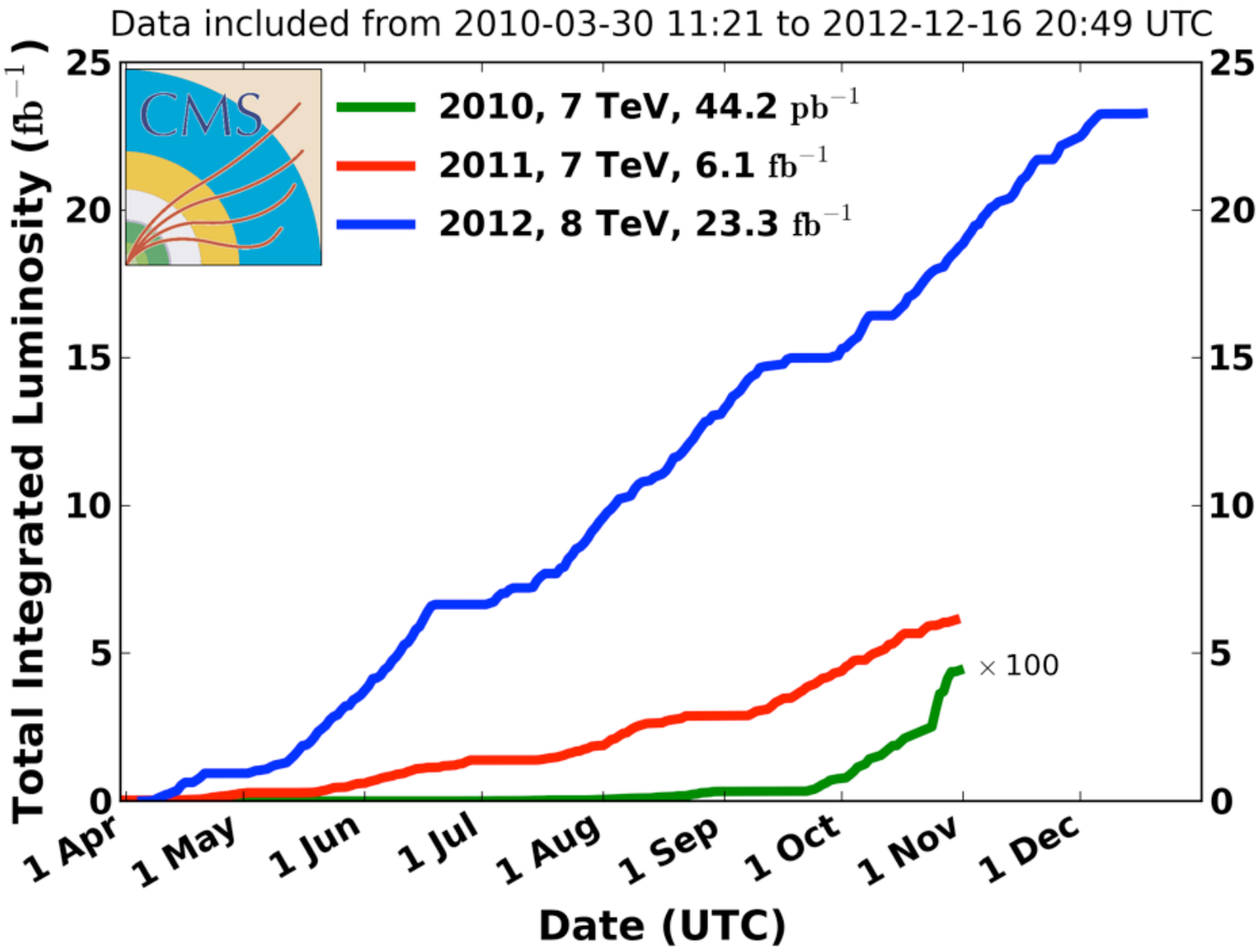


CMS ATLAS LHCb

Large Hadron Collider

A big thanks to the LHC accelerator for the excellent performance !

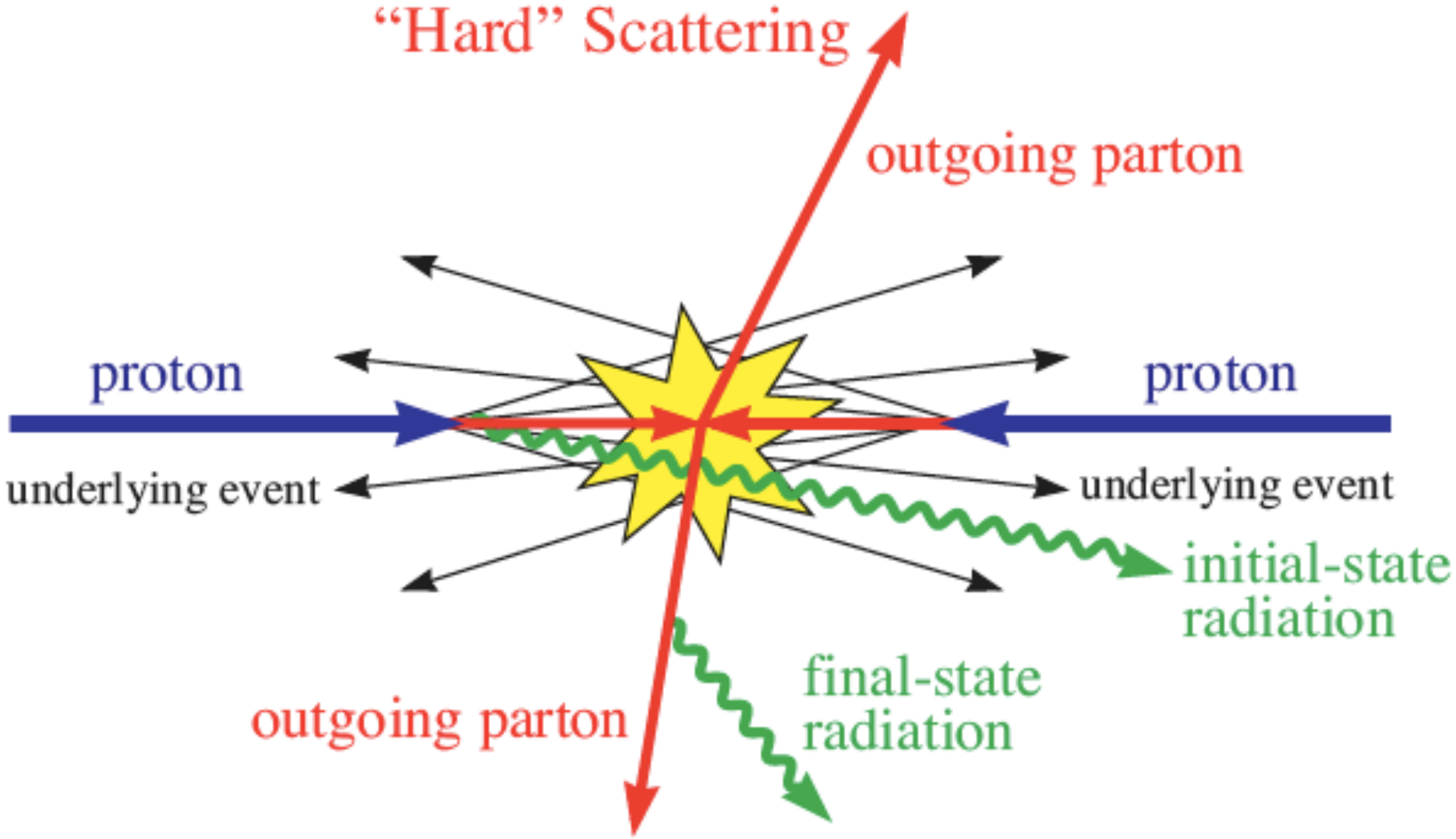
Total integrated luminosity delivered by LHC (CMS)

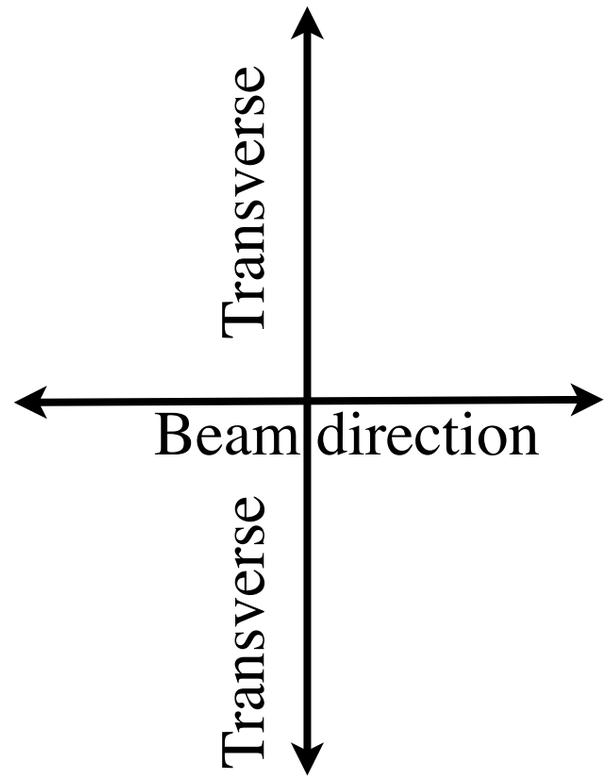


Total integrated luminosity delivered : 23 fb^{-1} @ 8 TeV or ~6 fb^{-1} @ 7 TeV for each of CMS and ATLAS experiments.

New Physics @ LHC

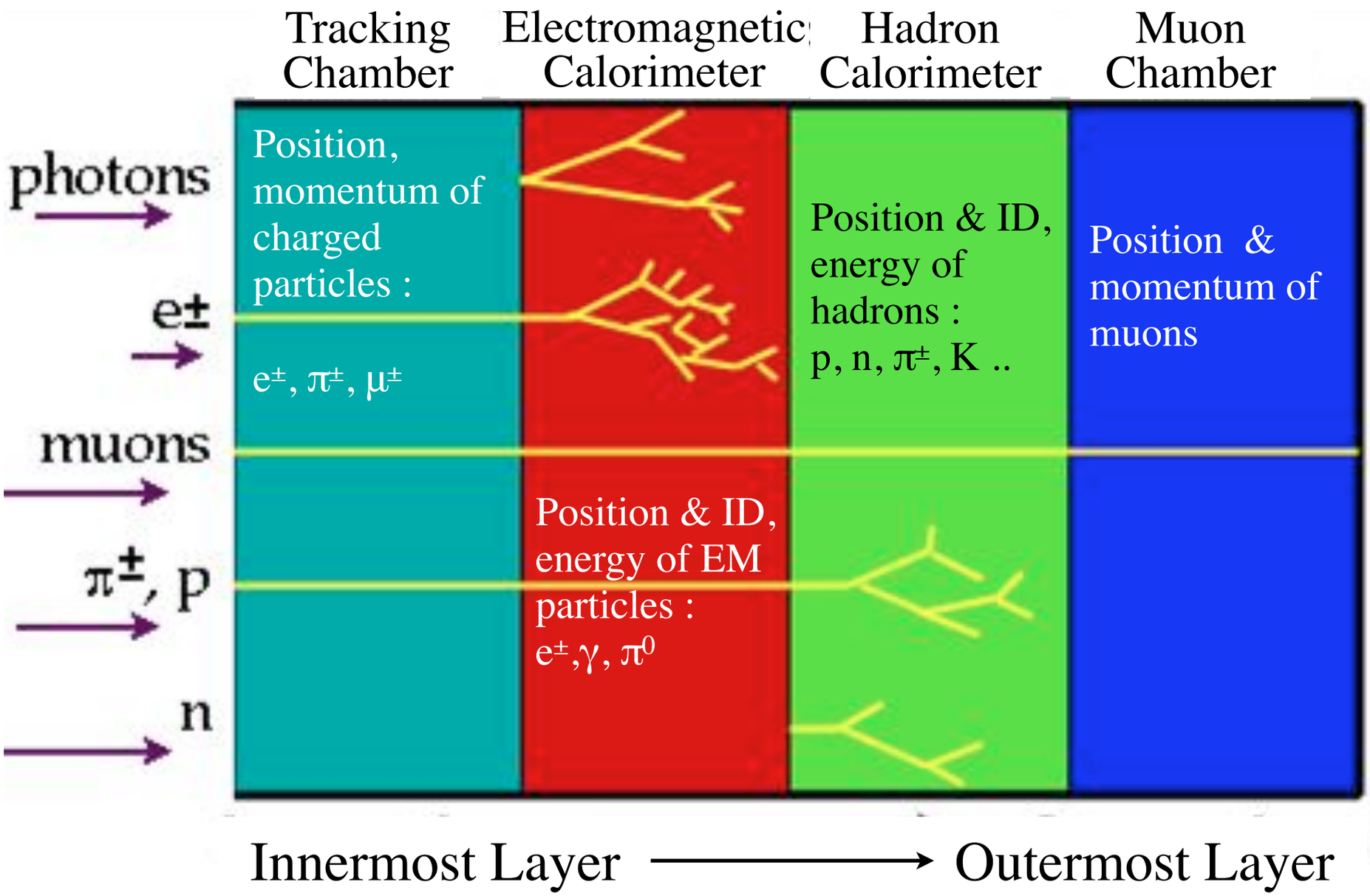
New particles can be produced in collisions of particles at high energies.





- Interactions between the constituent partons.
- As the LHC operating energy increases, massive states can be produced at higher energy thresholds : $M_{new} = \sqrt{s}$ (centre-of-mass energy)
  - 7 TeV → 8 TeV → 13 TeV
- Multiple production channels (strong, electroweak) : gg, qq', qg, WW ...

A Generic HEP Detector & Event Reconstruction

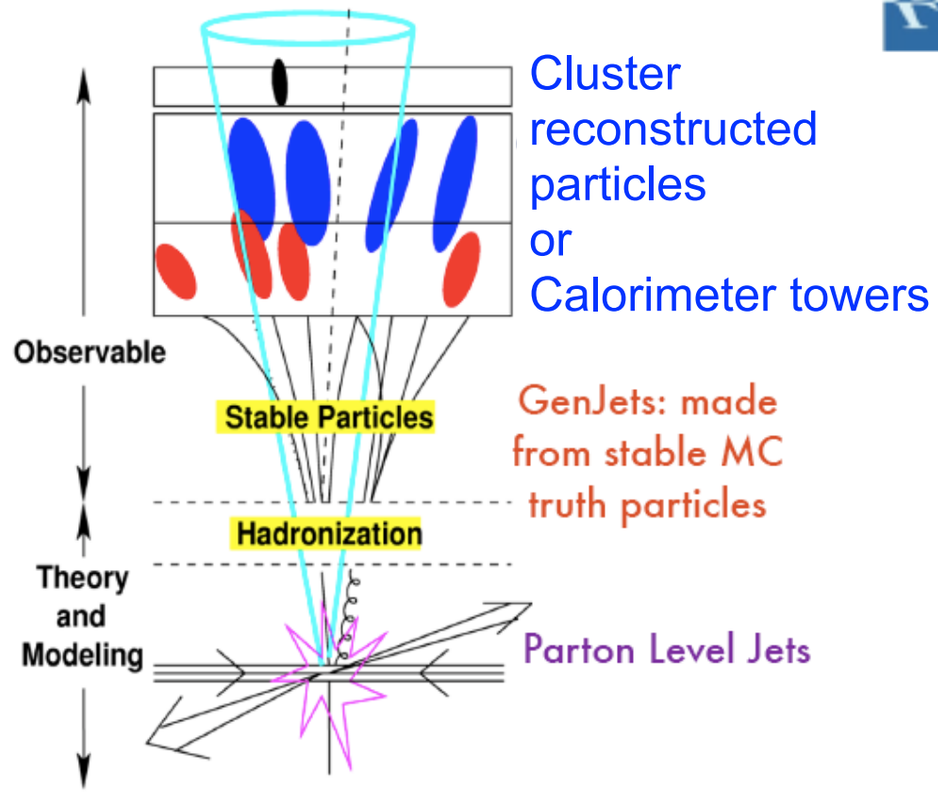


Reconstruct all the stable particles : electrons, photons, muons, charged and neutral hadrons

Jets & Missing Transverse Momentum (MET)

Jets : manifestation of quarks and gluons

- a collimated spray of "colorless" hadrons
- experimental probe to study properties of original quark or gluon

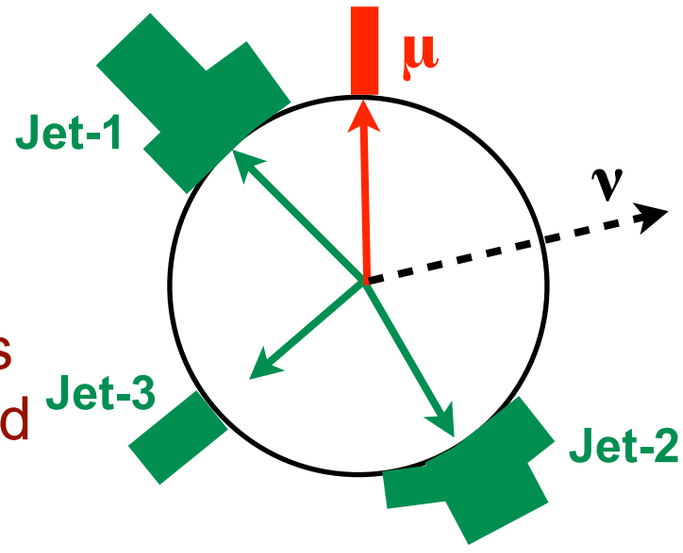


MET : vector sum of momentum of all particles transverse to the beam direction

$$\vec{P}_T^{P_1} + \vec{P}_T^{P_2} = 0 = \sum_i \vec{P}_T^{i}(measured)$$

$$\vec{P}_T^{miss} = -\sum_i \vec{P}_T^{i}(measured) \neq 0 \Rightarrow$$

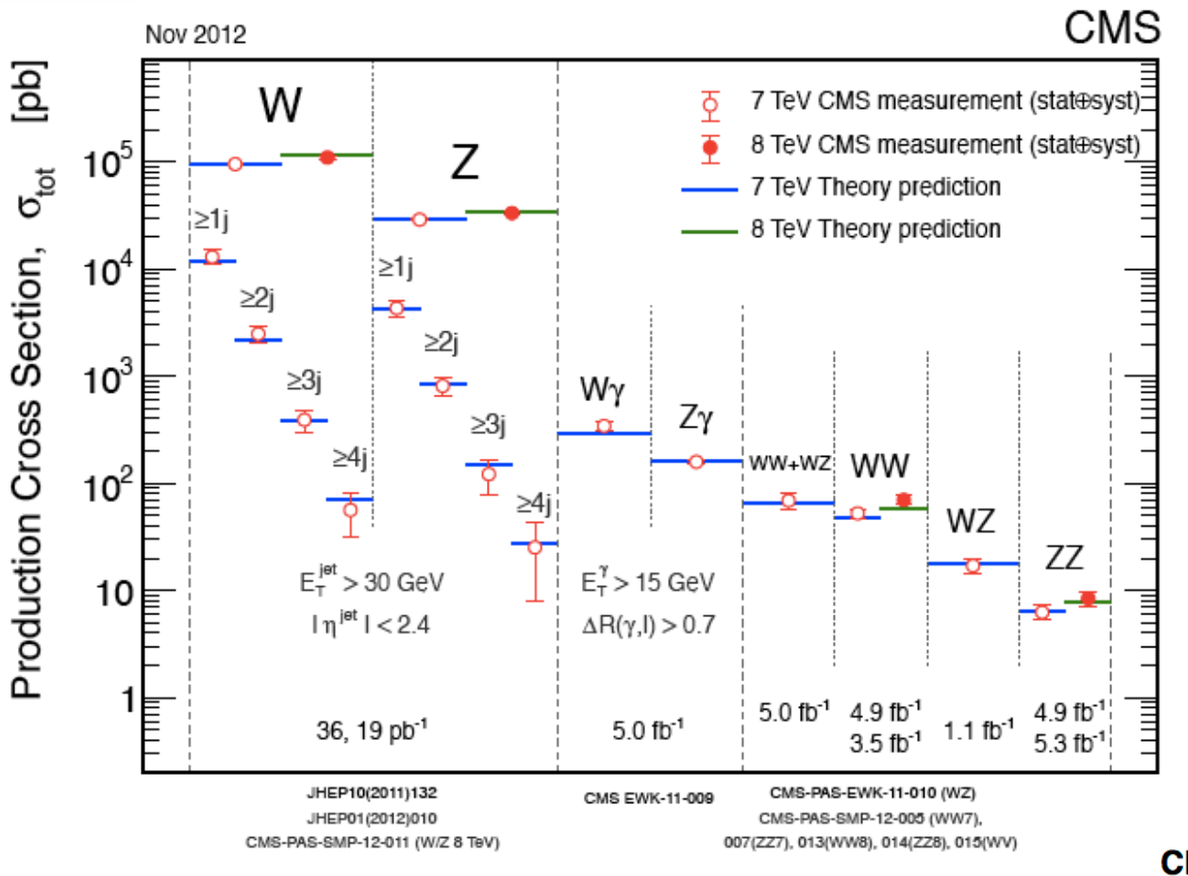
Some particles are not detected (e.g. ν)

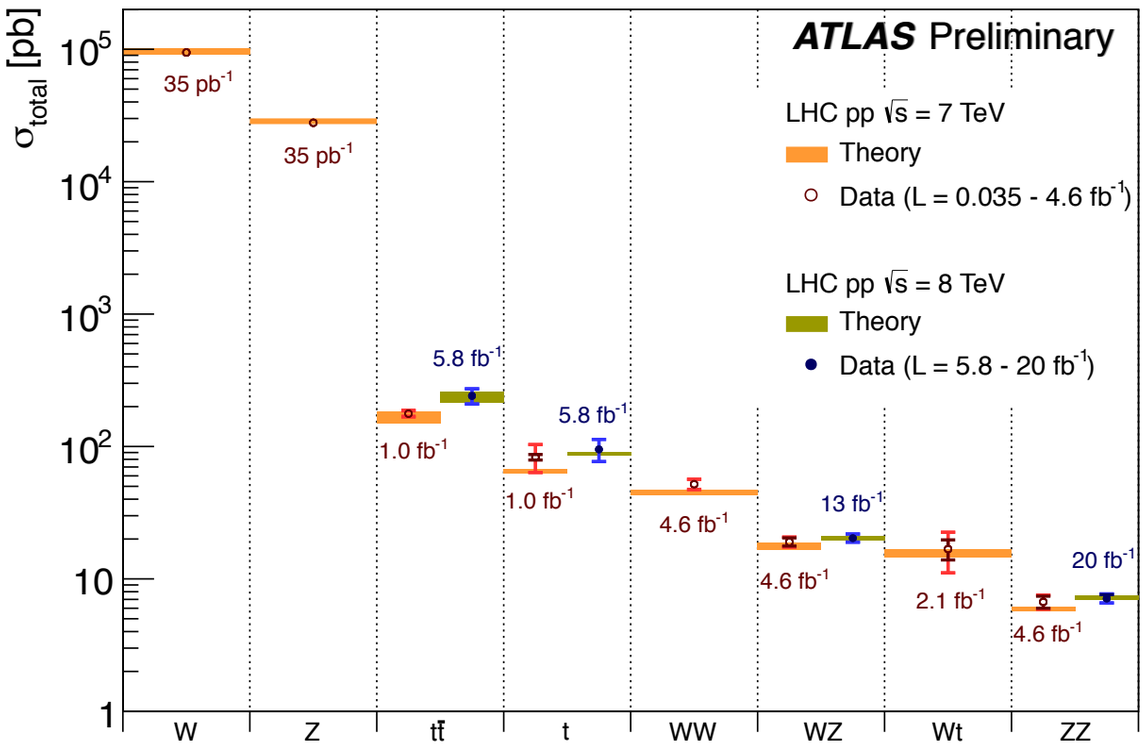


In addition, any mis-measurement may result in an imbalance in p_T

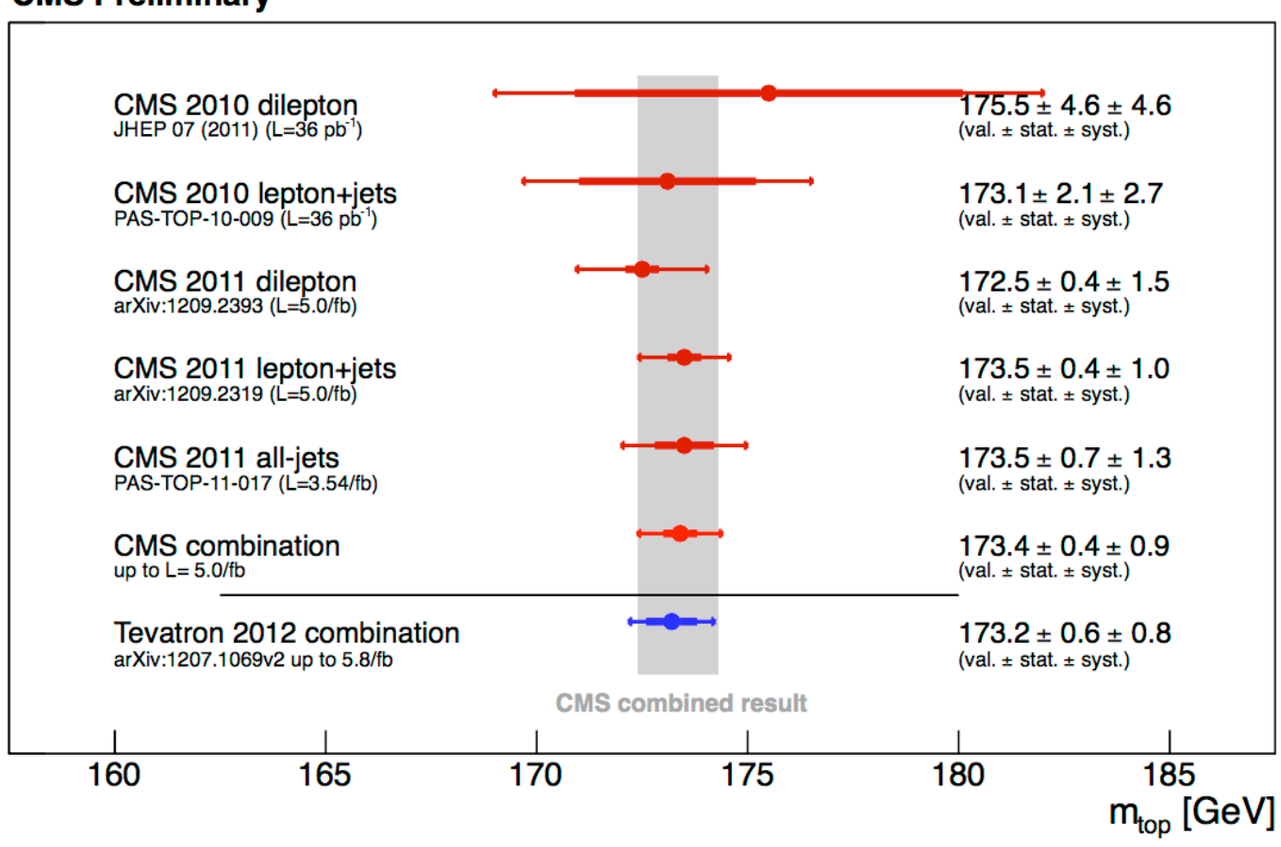
For e.g. non-functional detector channels, electronic noise, non-collision backgrounds ...

Standard Model Measurements





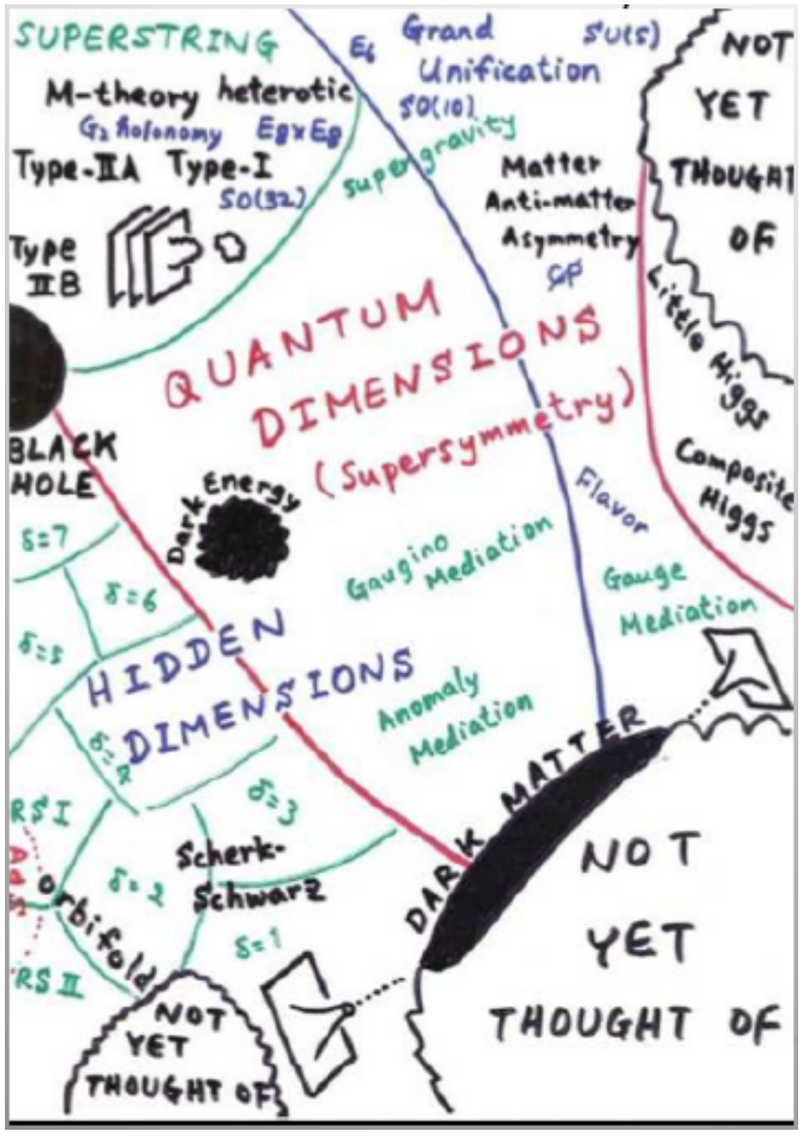
Key point for any new discovery is to understand the backgrounds due to SM processes and understanding the detector effects.



Physics Beyond Standard Model

A lot of models which predicts new physics at the TeV scale accessible at LHC :

- Supersymmetry (SUSY)
- Extra dimensions
- Grand Unified Theories (SU(5), O(10), E6 ..)
- LeptoQuarks
- TechniColor
- Compositeness
- Strong dynamics (composite Higgs)
- ...



These theories :

- Try to address hierarchy problem.
- Predicts new particles with mass scales of $\mathcal{O}$(TeV).

New Physics Searches at LHC

Outline :

- Search for Supersymmetry
  - inclusive searches for strong production
  - 3rd generation SUSY sector
  - a brief overview of EWKino production
- Search for Dark Matter & Extra-dimension
  - Monojet analysis
- Search for vector-like heavy partner of top quarks
  - t' search

Links to the results made public by collaborations at LHC :

https://twiki.cern.ch/twiki/bin/view/AtlasPublic

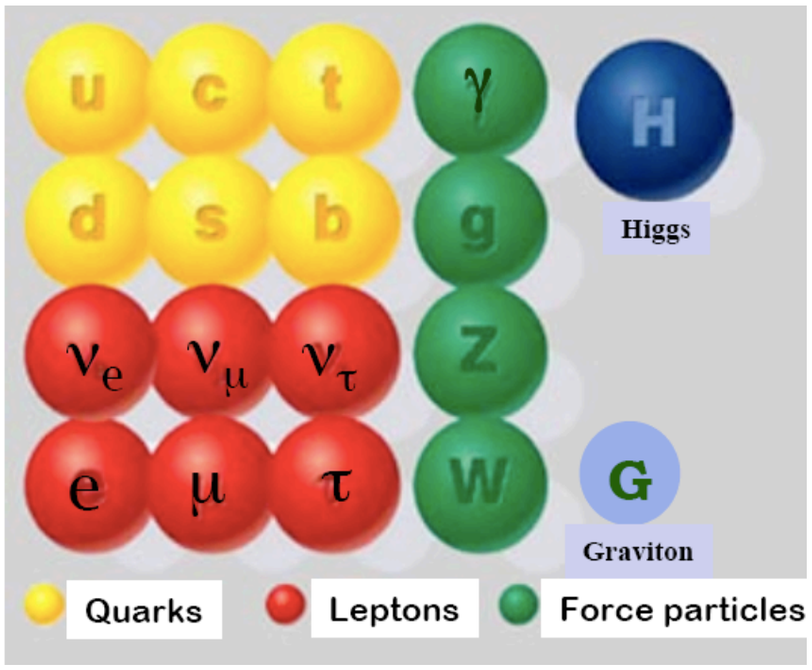
https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResults

http://lhcbproject.web.cern.ch/lhcbproject/CDS/cgi-bin/index.php

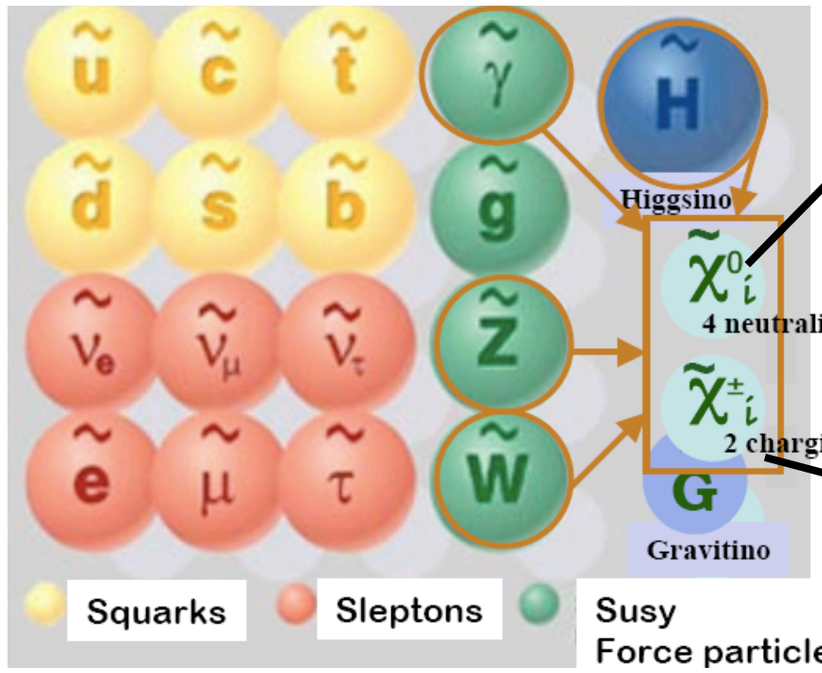
Supersymmetry : Introduction

Supersymmetry : A super-partner of every SM particle differing by spin-half

Standard Model Particles



Supersymmetry Particles



Four neutralinos

Two Charginos

SUSY is a broken symmetry : Expect new particles in ~TeV range !

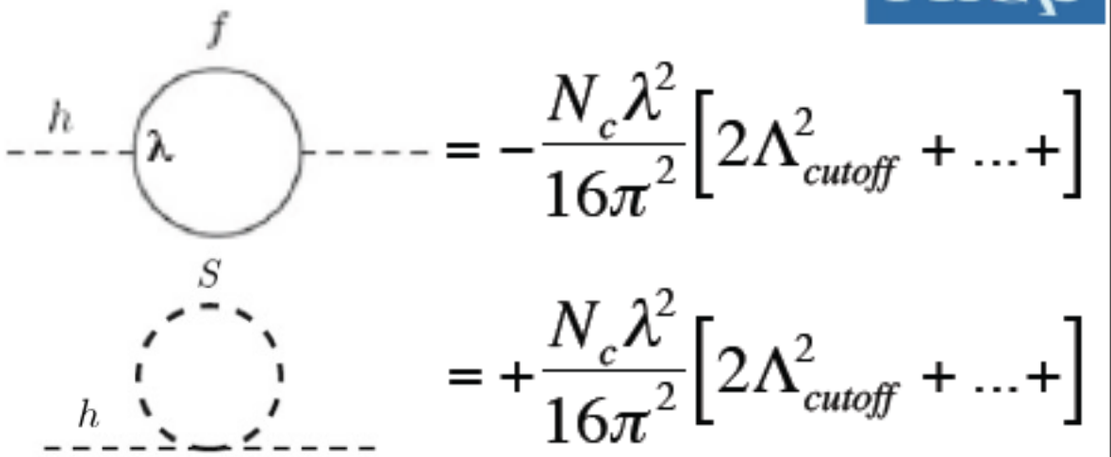
In **R-Parity conserving** models, lightest supersymmetry particle (**LSP**) is stable. Popularly lightest neutralino $\tilde{\chi}_1^0$ is an LSP.

"Natural SUSY" requires :

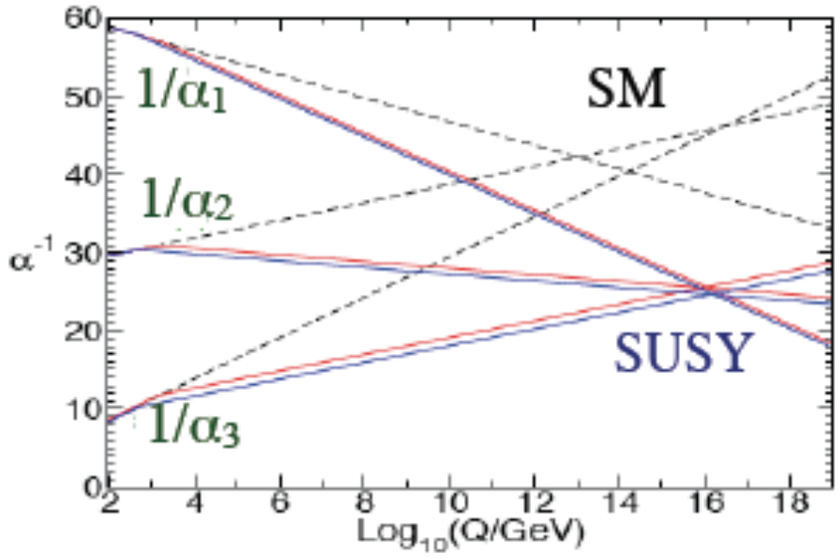
- light stops, sbottoms (<1 TeV)
- not so heavy gluinos (1.5-2 TeV)
- light $\tilde{\chi}_1^0$ $\tilde{\chi}_1^{\pm}$ (few hundred GeV)

Why is Supersymmetry Attractive ?

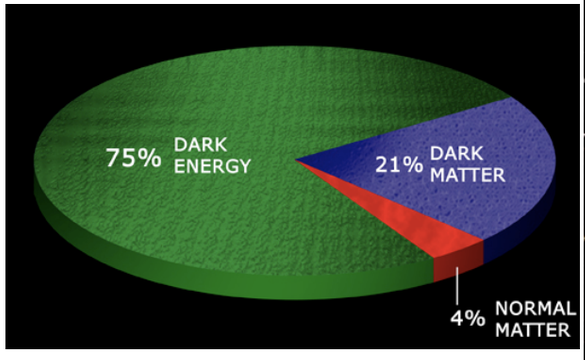
- Naturalness or Hierarchy problem :
  - fermion and boson loops contribute to higgs mass loop with opposite signs, hence avoid quadratic divergences



- Unification of couplings of three interactions
  - SM predicts "running" of coupling constants as a function of energy but without making these cross at the same energy

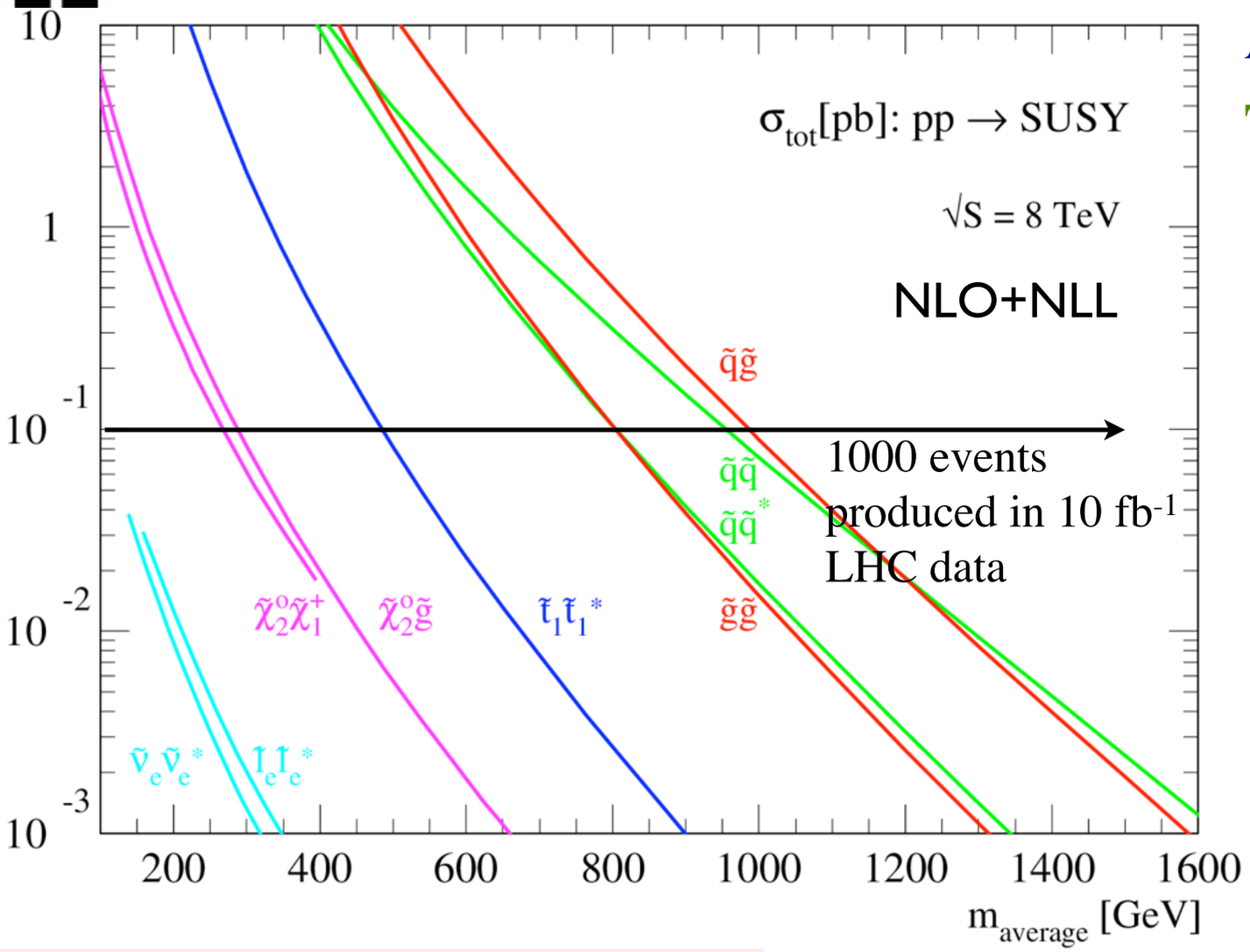


- Dark matter candidate
  - If the LSP is neutral and weakly interacting, it is a potential dark matter candidate



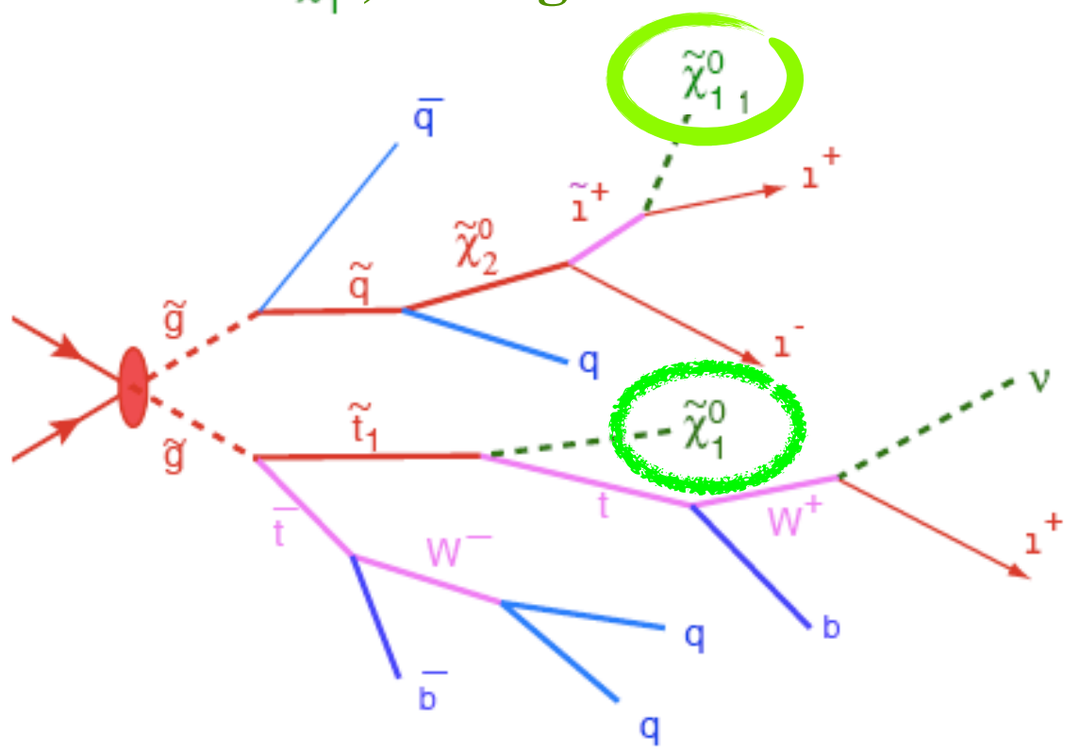
- A SUSY extension is a small perturbation consistent with the electroweak precision data

SUSY Production @ LHC



An example decay chain of a SUSY event

Two LSPs ($\tilde{\chi}_1^0$) : Large MET



- **Strong production**
- squarks and gluino pairs, large cross-section at hadron colliders
- typically Jets & MET based searches categorized in numbers of leptons (and photons)

- **Third generation squarks**
- Small cross-section as compared to light squark pair productions
- Final state may include ttbar pairs, multiple b-jets

- **Weak production**
- direct neutralino/chargino production
- searches based on multi-leptons and MET signatures

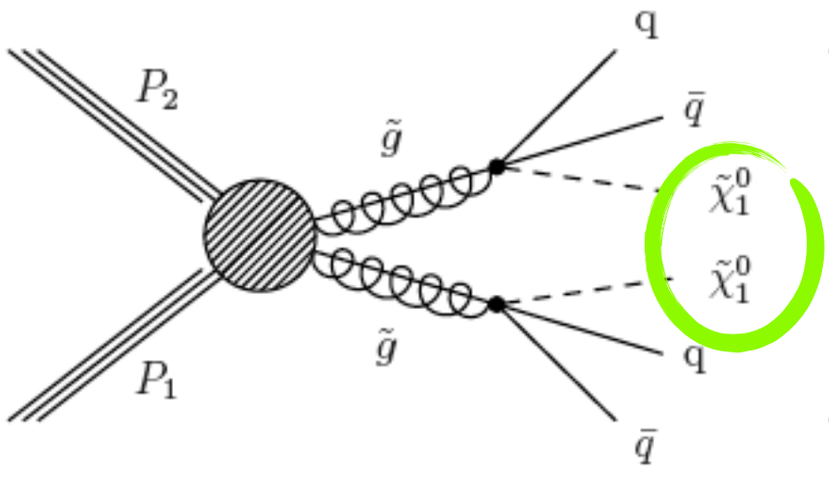
Generic Searches for Strong Production

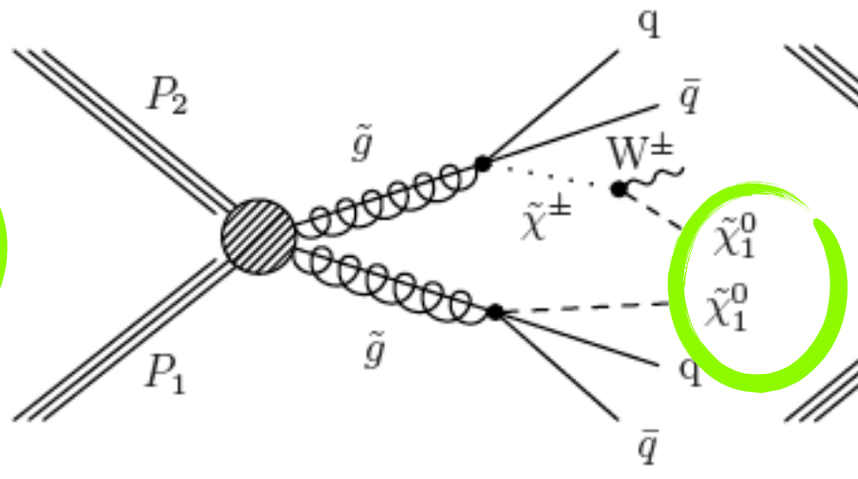
Two LSPs ($\tilde{\chi}_1^0$) : Large MET

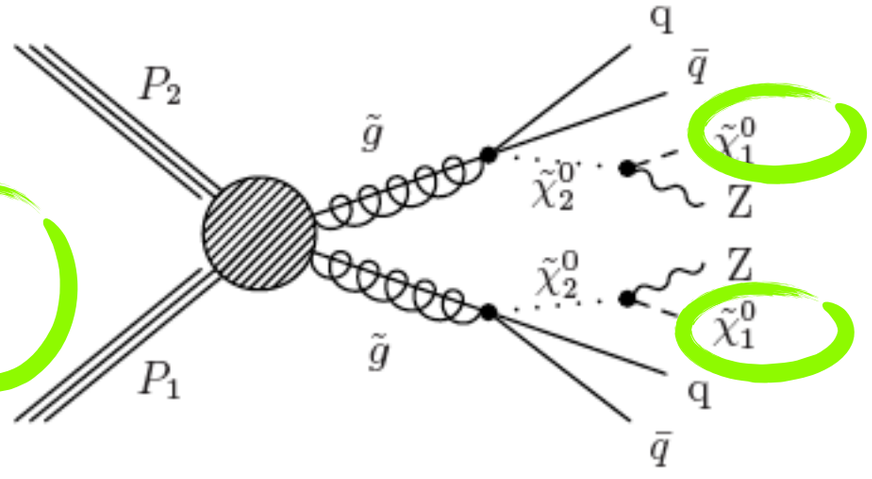
Mostly involves Jets

Categorize further in number of leptons and photons.

0-leptons	1-lepton	OSDL	SSDL	≥3 leptons	2-photons	γ+lepton
Jets + MET	Single lepton + Jets + MET	Opposite-sign di-lepton + jets + MET	Same-sign di-lepton + jets + MET	Multi-lepton	Di-photon + jet + MET	Photon + lepton + MET



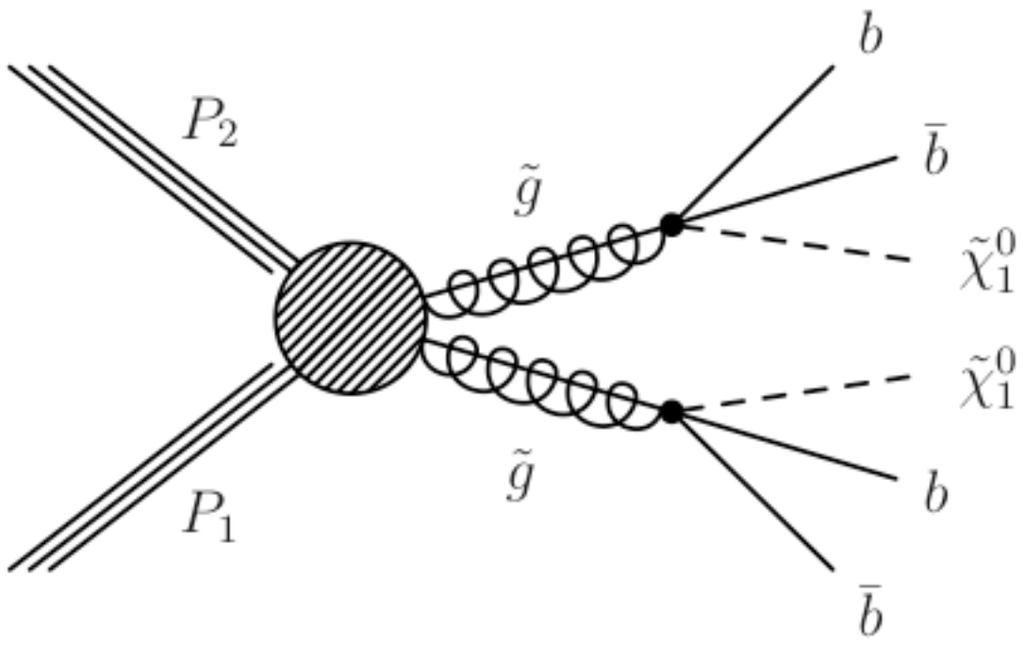




Search for Gluino Mediated Sbottom

CMS-SUS-12-024 19.4 fb^{-1}

Two LSPs ($\tilde{\chi}_1^0$) : Large MET



Signature : 4 b-jets + MET

Sensitive variables

HT (scalar sum of Pt of Jets)

& MET

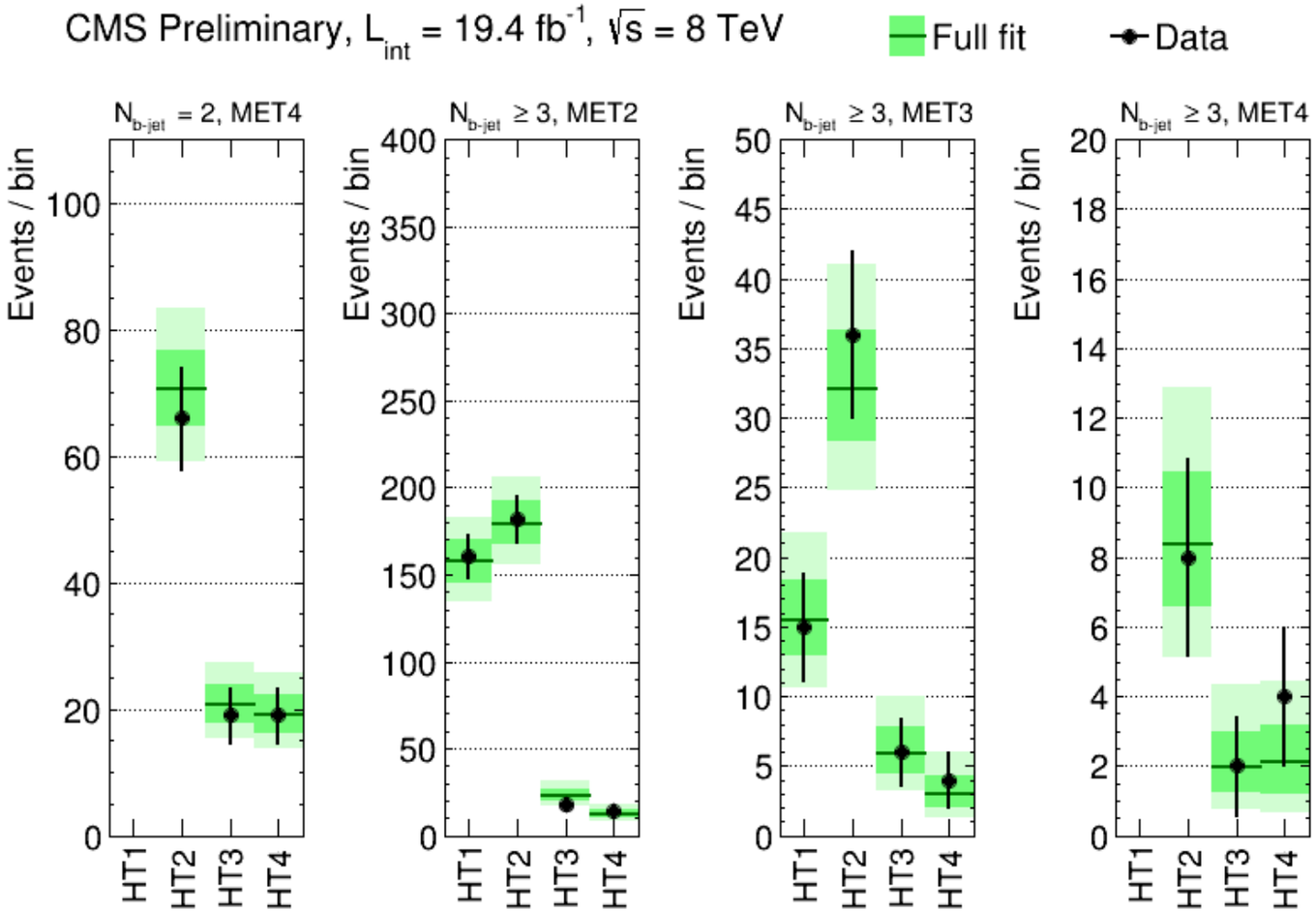
Event Selection
NJets ≥3 jets
b-jets = [1], [2], [≥3] (binned)
Search bins in HT, MET
$\Delta\Phi = \min\{\Delta\Phi(\text{MET,Jets}^{\{i\}})/\sigma^{i}_{\Delta\Phi}\} > 4.0$
Veto events with isolated leptons
Main backgrounds : tt/W+jets, Z+jets, QCD

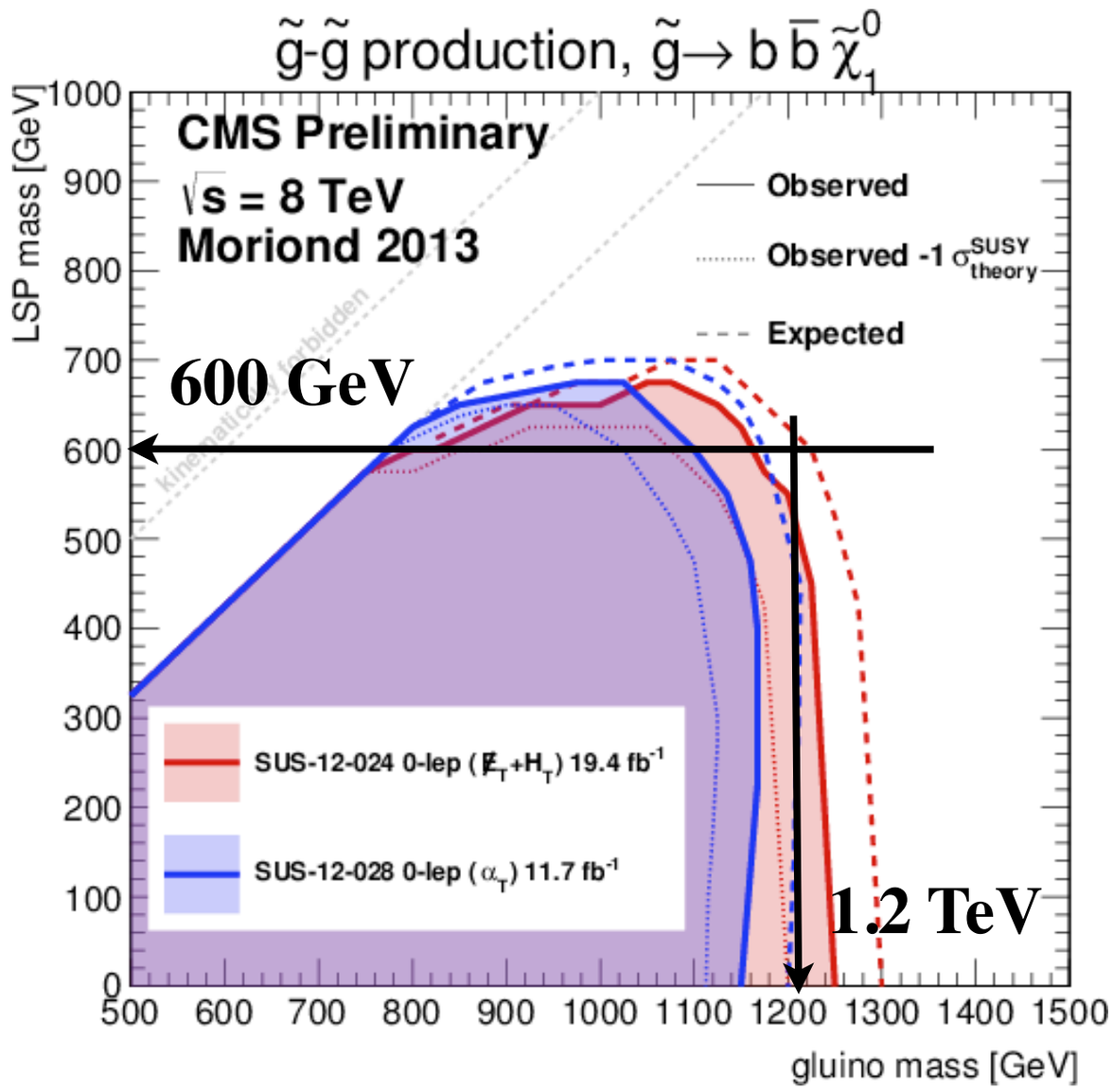
Analysis Strategy
Shape analysis in 3D (HT, MET, Nb-jets
Background estimation using single muon, dimuon/dielectron and inverted $\Delta\Phi$ control samples from data

0-lepton Search for Gluino Mediated Sbottom

Prediction and observation

CMS-SUS-12-024 19.4 fb^{-1}



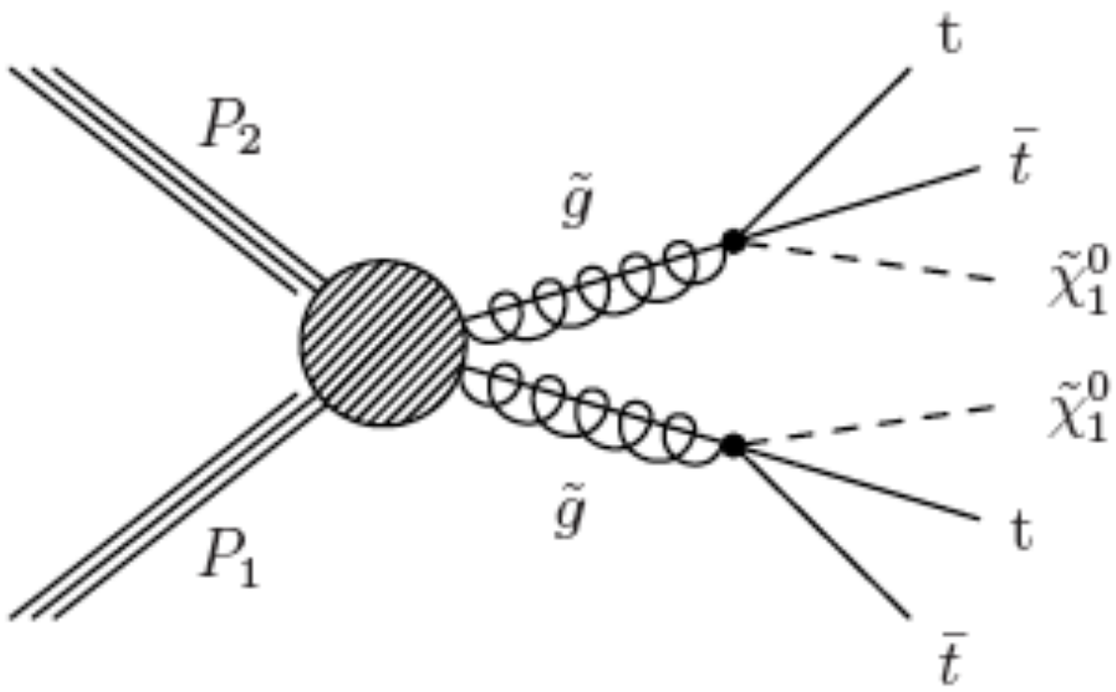


Probed Gluino masses up to 1.2 TeV for LSP masses up to 600 GeV .

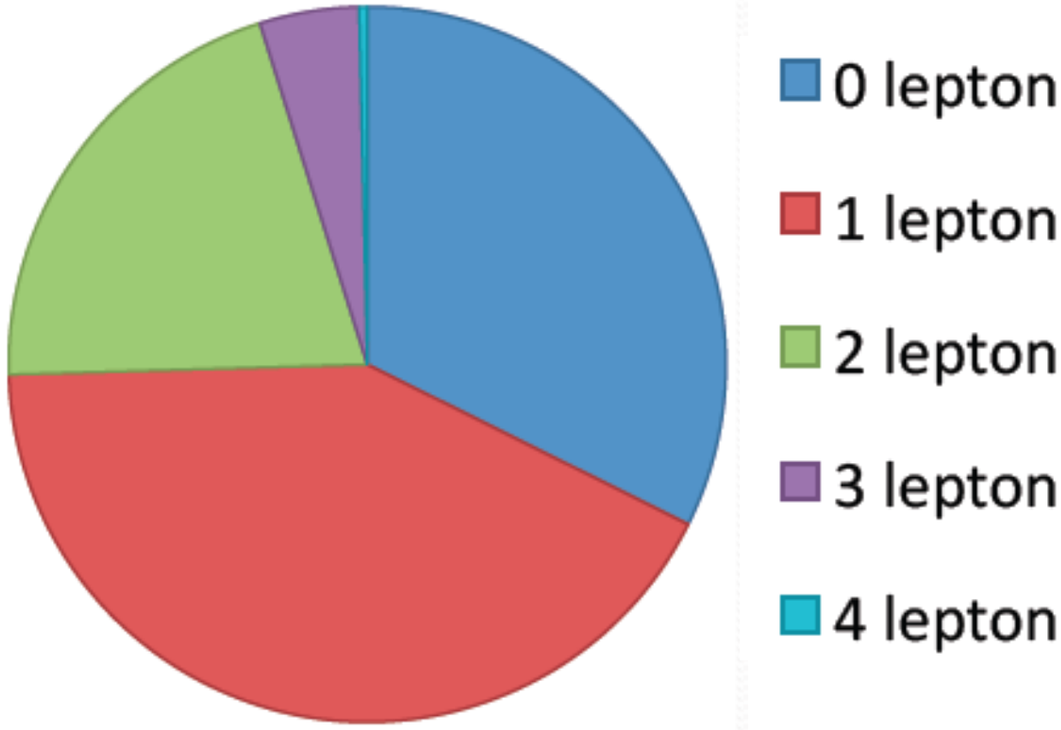
ATLAS has similar reach with 3b analysis : ATLAS-CONF-2012-145

Gluino Mediated Stop Production

Two LSPs ($\tilde{\chi}_1^0$) : Large MET



Signature : 4 Ws and 4 b-jets



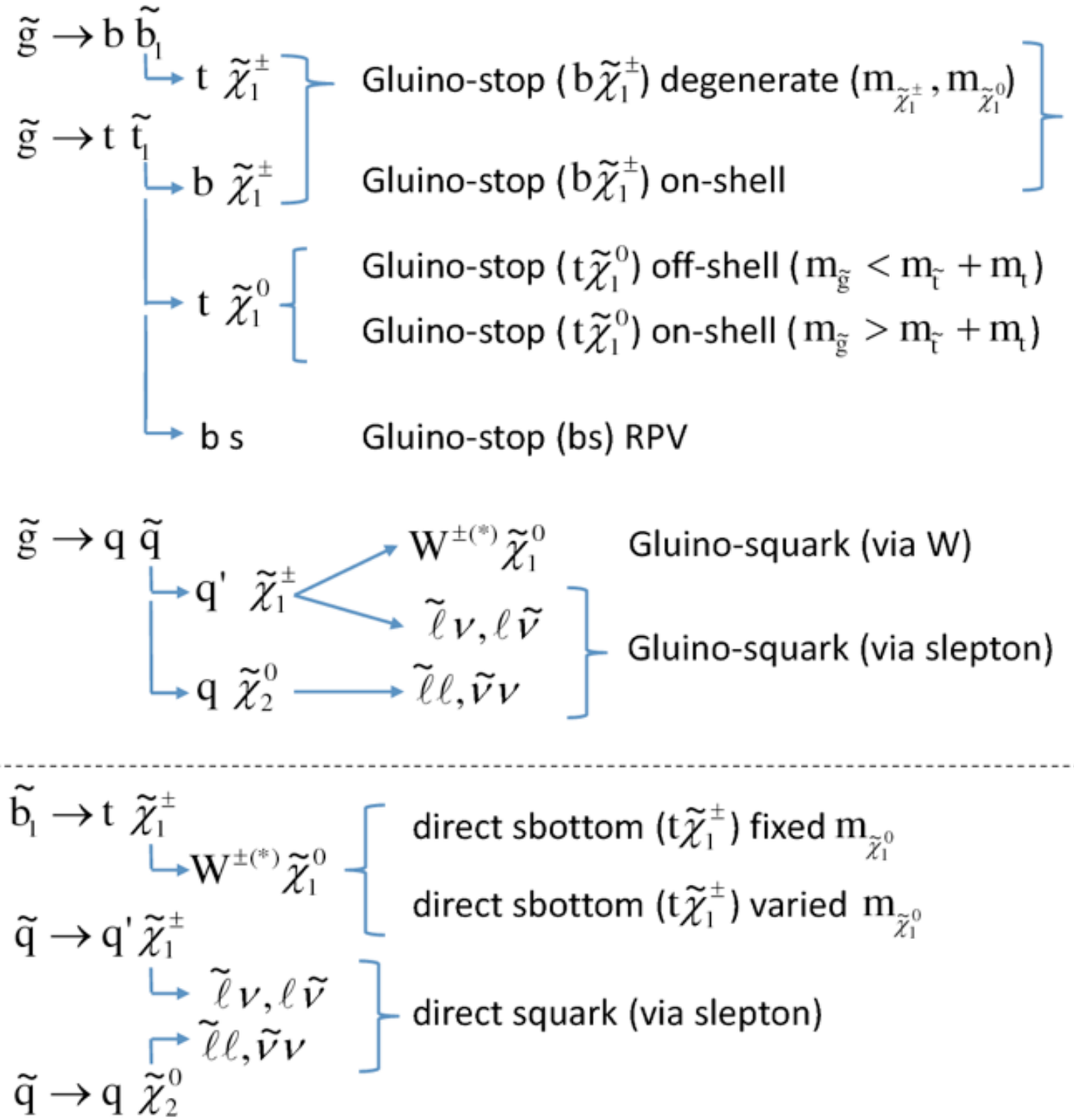
Branching fraction for 4Ws

Searches performed in the final state categorized into :

Further categorized into 0, 1, SS/OS 2-leptons, multileptons

Search with Same Sign-Dileptons + b-jets

Same sign dilepton + jets is a generic signature sensitive to many new physics.



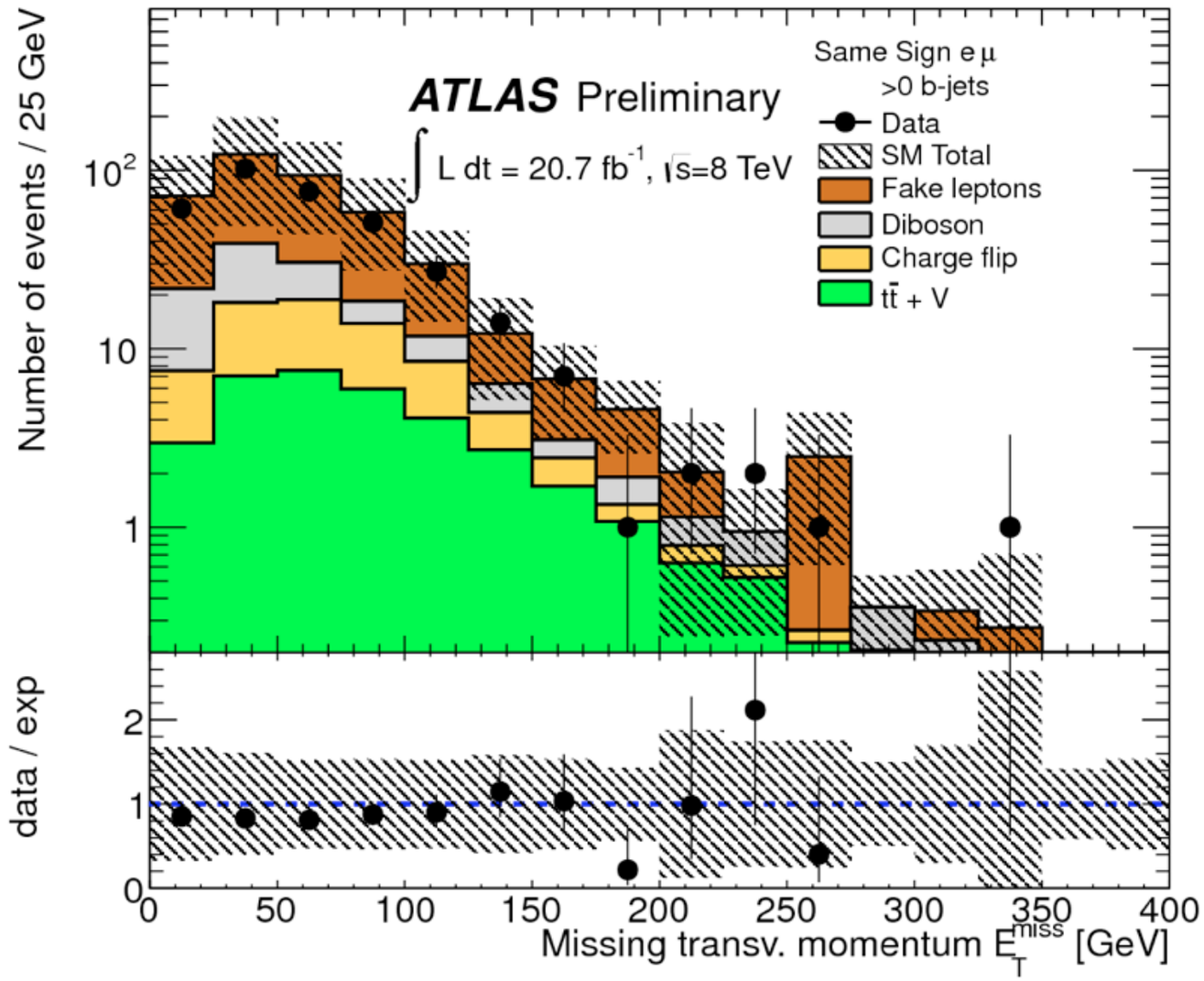
ATLAS-CONF-2013-007 20.4 fb^{-1}

Event Selection
same sign ee, μμ or eμ
b-jets = [0], [≥1], [≥3] (binned)
NJets ≥ [3], [5] jets
MT(leading Lep, MET) > 100
MEff = MET+Pt(jets)+Pt(Leptons)

Same Sign-Dileptons + b-jets Search

ATLAS-CONF-2013-007 20.4 fb^{-1}

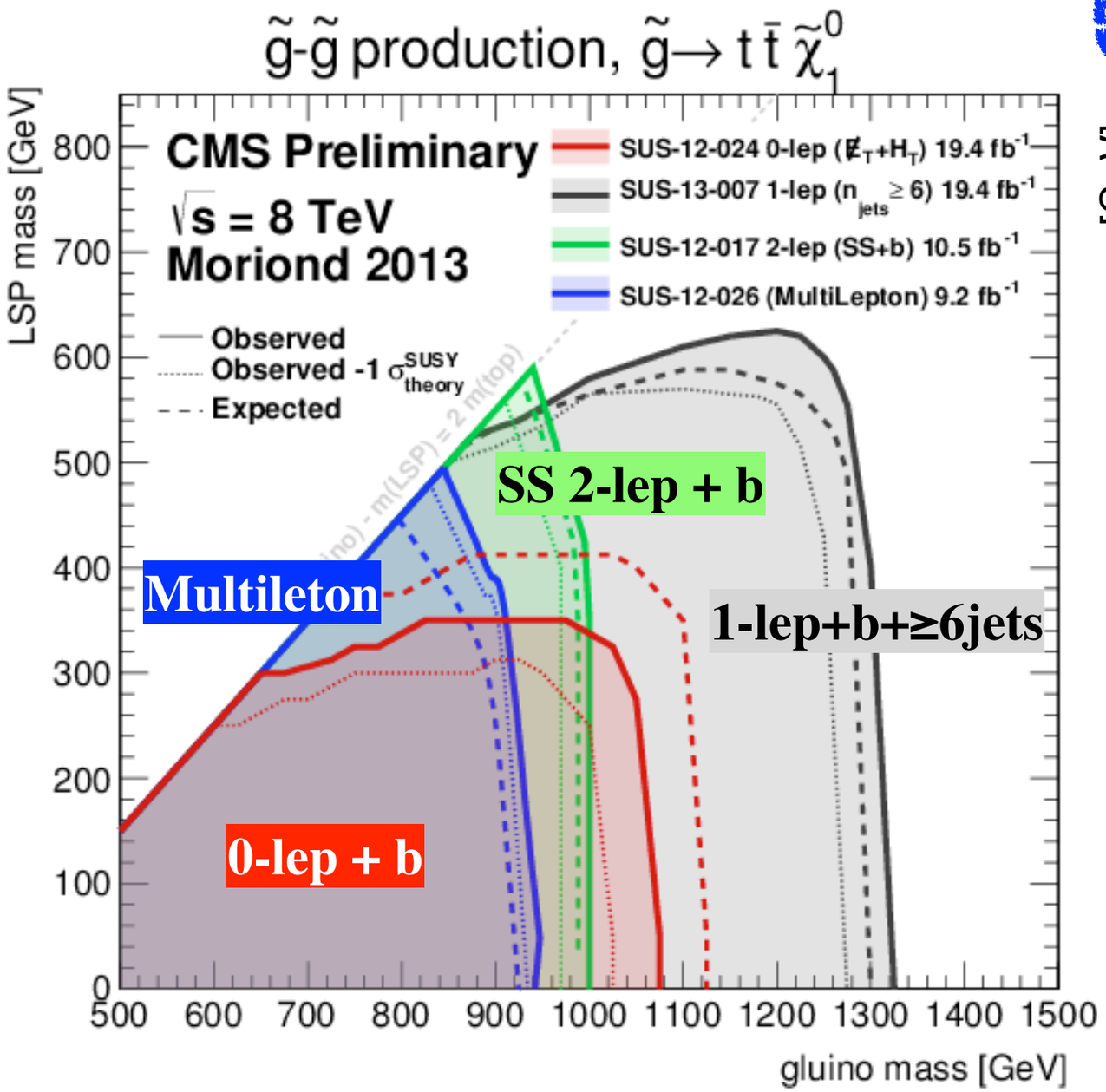
- Main Backgrounds
  - charge mis-measurement in dileptonic ttbar events : data driven by counting SS to OS ratio in Z($\ell\ell$) event under Zpeak
  - semileptonic ttbar events where one lepton comes from a b-hadron decay : data-driven using matrix method
  - ttV, diboson : using MC

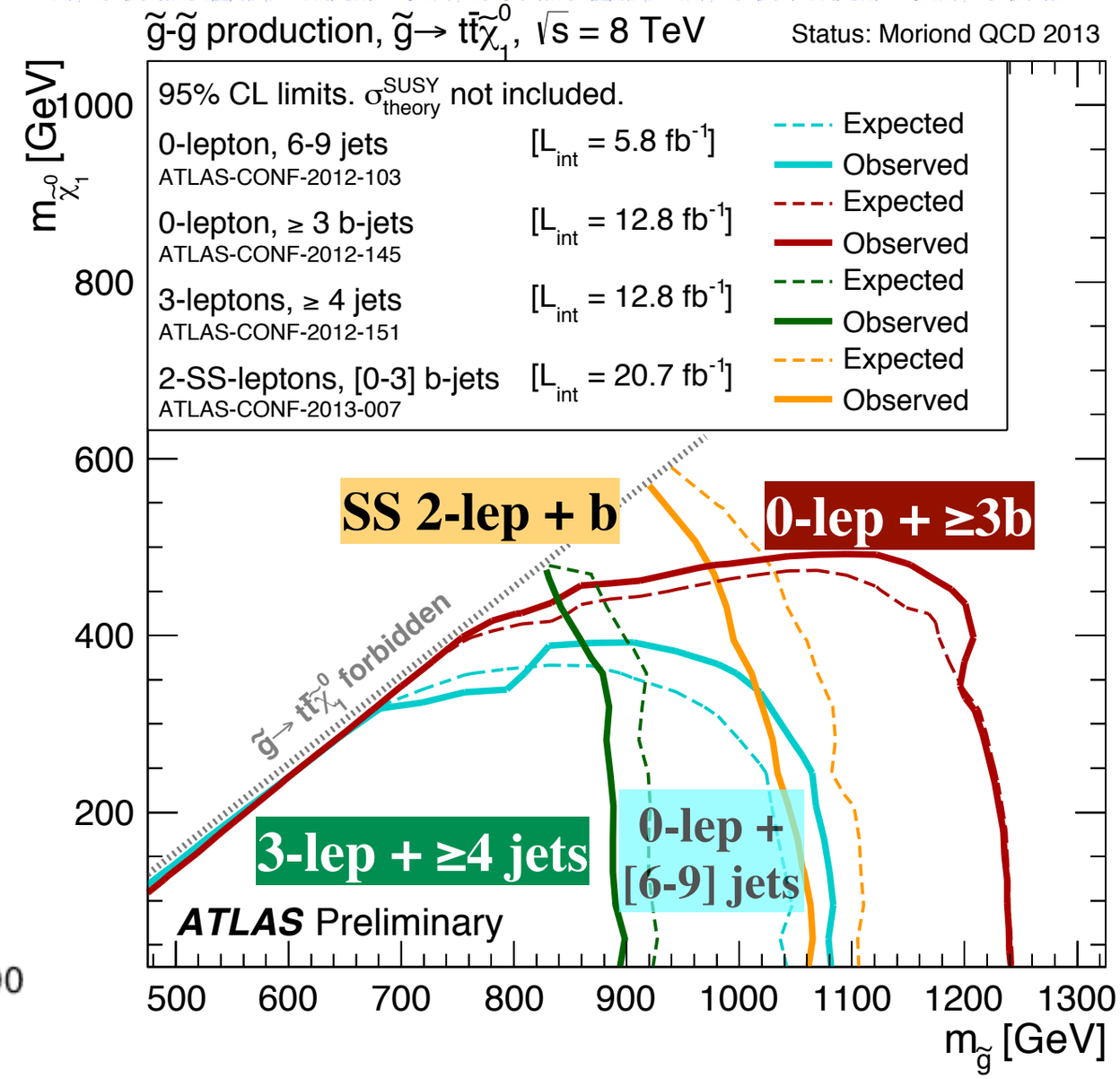


B) Exclusion case	SR0b	SR1b	SR3b
Observed events	5	11	1
Expected background events	7.5 ± 3.2	10.1 ± 3.9	1.8 ± 1.3

Summary : Gluino Mediated Stop Pairs

$\tilde{g} \rightarrow t\bar{t}\tilde{\chi}_1^0$ 100% Branching Fraction



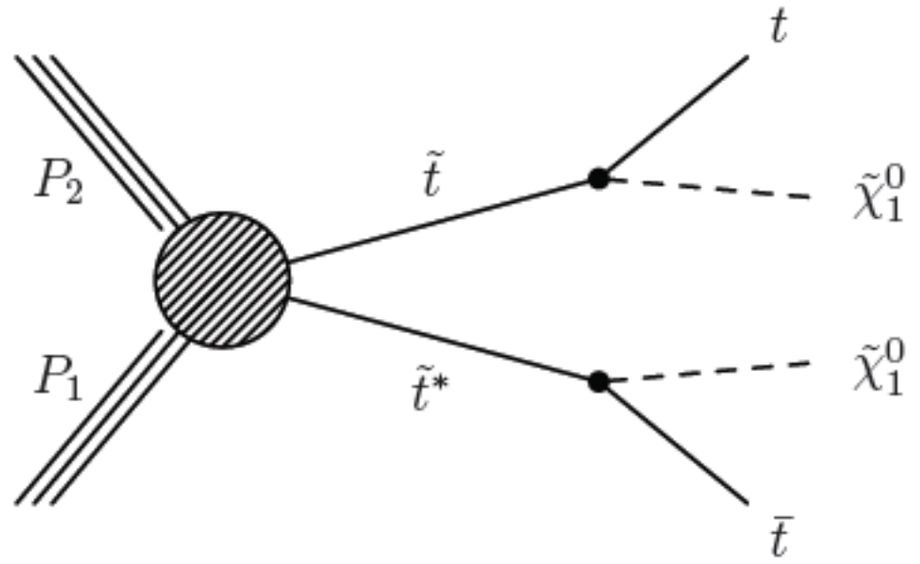


- Gluinos up to masses of 1.3 TeV are probed for LSP mass of up to 600 GeV
- Same sign dilepton + b analysis extends sensitivity to low mass splitting regions

Direct Stop Pair Production (0-lepton)

ATLAS-CONF-2013-024 20.4 fb^{-1}

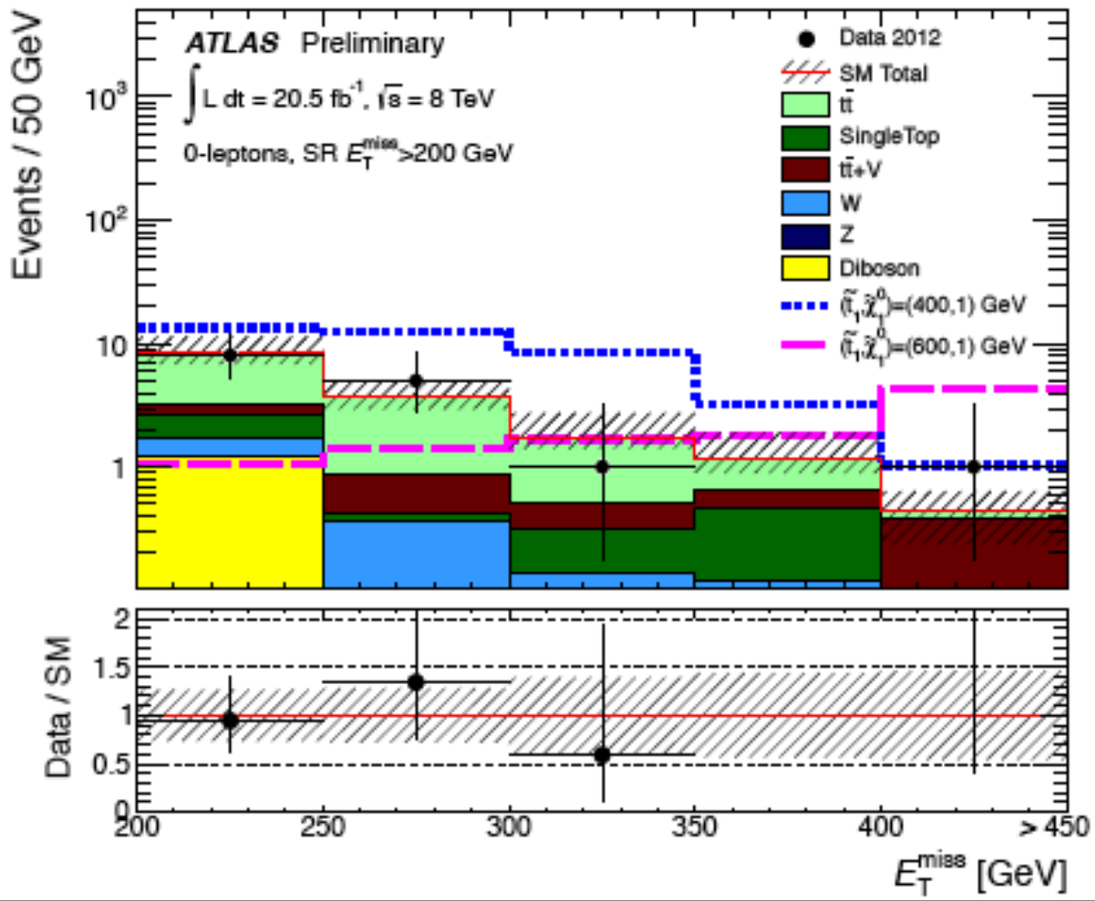
Event Selection
Veto on leptons, taus
b-jets ≥ 2 NJets ≥ 6 jets
M_T(b-jet, MET) > 175 GeV
MT(leading Lep, MET) > 100
TrackMET>30, ΔΦ(MET, TrkMET) <π/3
MET > 200, 300, 350



Fully hadronic top : Reconstruct top kinematics from top decay products 80 < m_{jjj} < 270

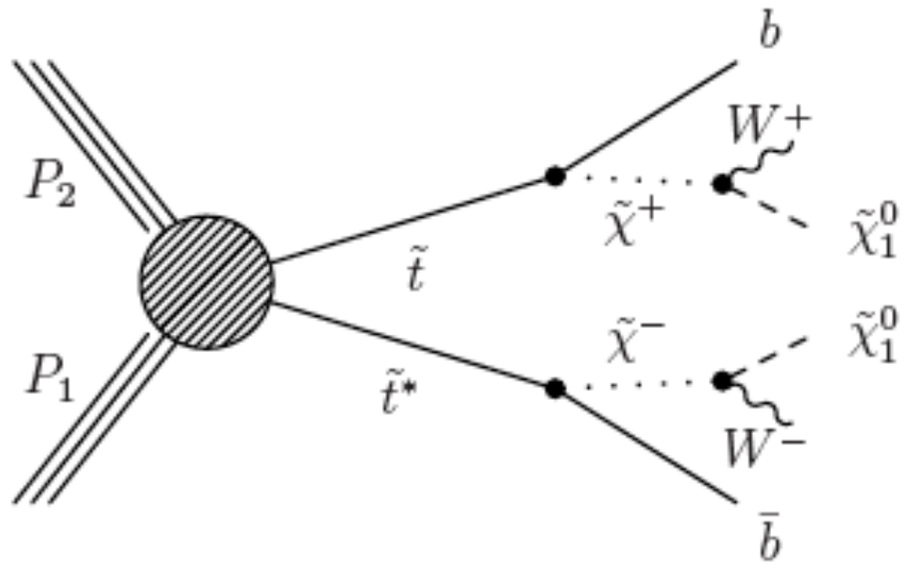
Major background due to semileptonic ttbar events.

top & Z(νν) : measured from data using single lepton and dimuon events respectively.

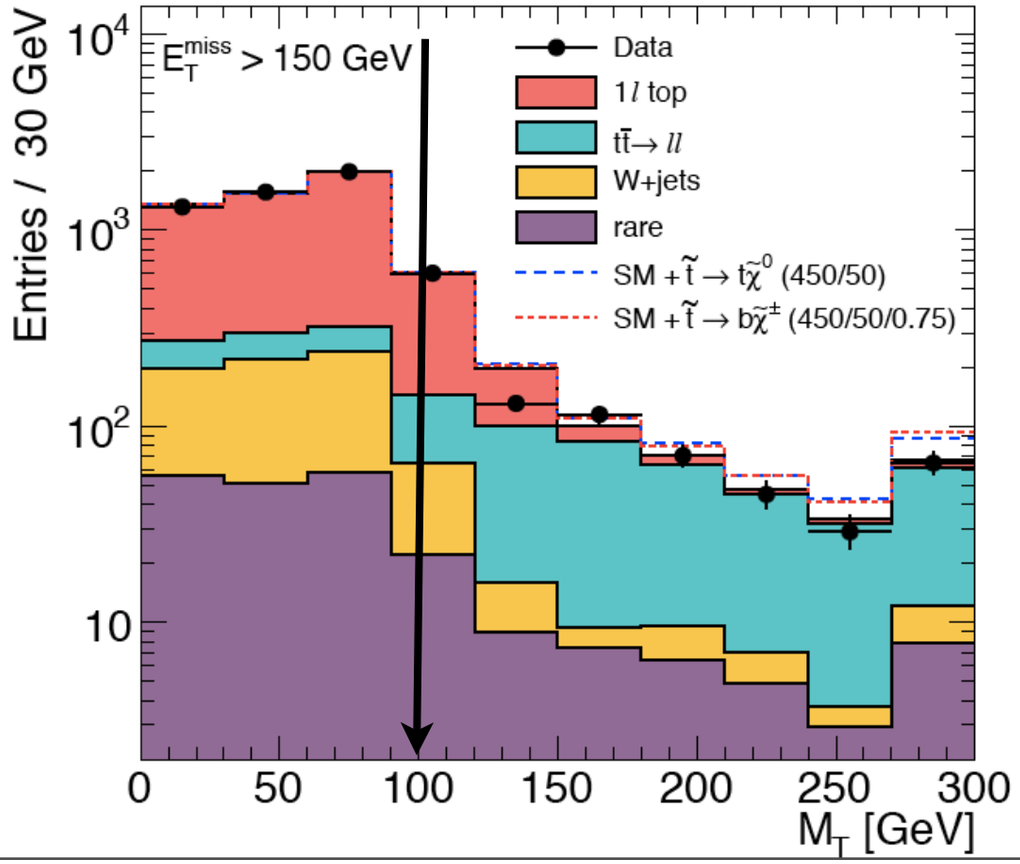


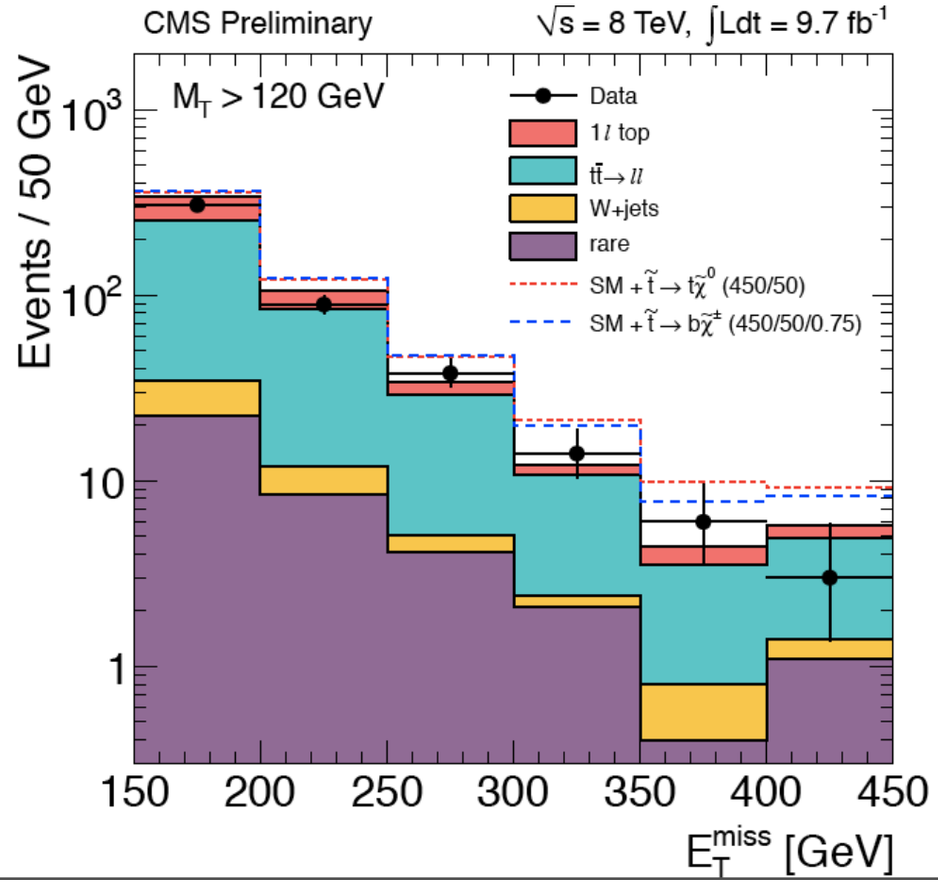
Direct Stop : Single Lepton Channel

CMS-PAS-SUS-12-023 9.7 fb^{-1}
ATLAS-CONF-1213-037 20.4 fb^{-1}



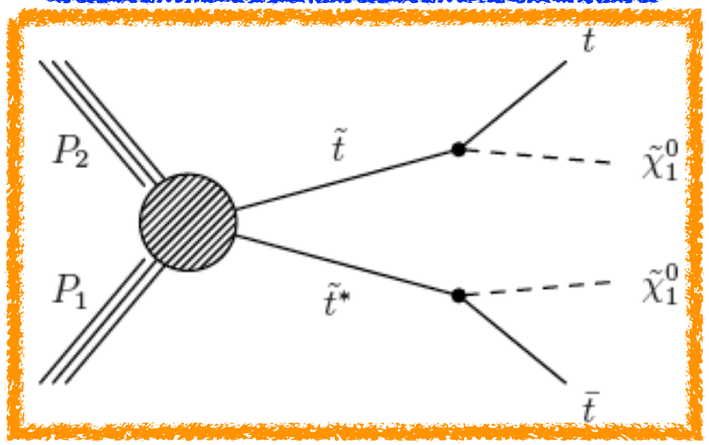
1 high p_T e or μ
No. of jets ⩾ 4, ⩾1 b-jet
Moderate MET (suppress QCD)
MT (ℓ, MET) >> M_W (suppress tt/W→ℓ+jets)
Veto additional isolated track (suppress tt→ℓℓ+jets)
Main background is due to dileptonic ttbar events

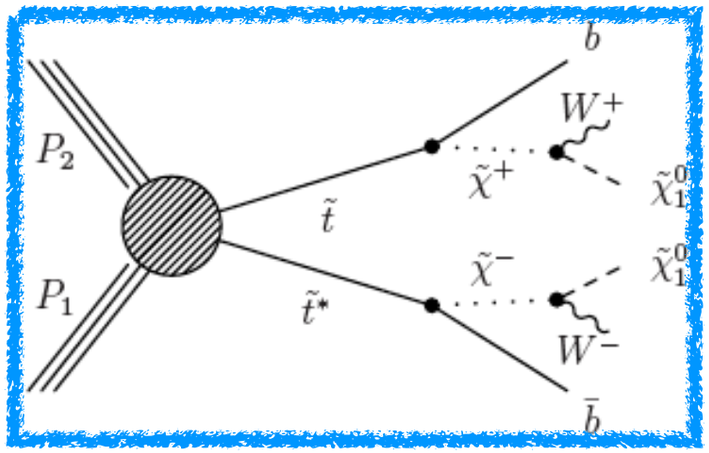


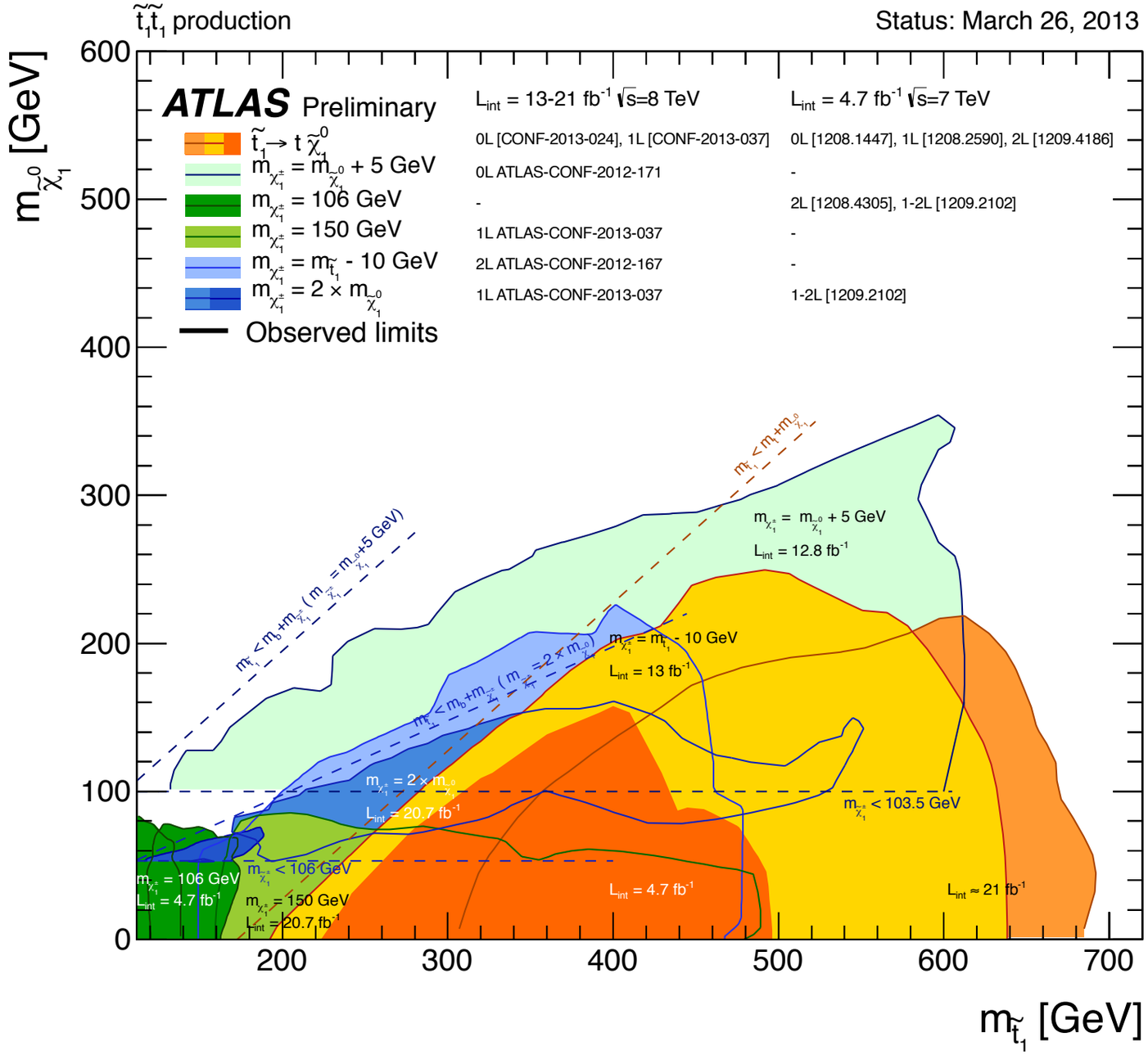


Direct Stop Searches : ATLAS

100% Branching Fraction



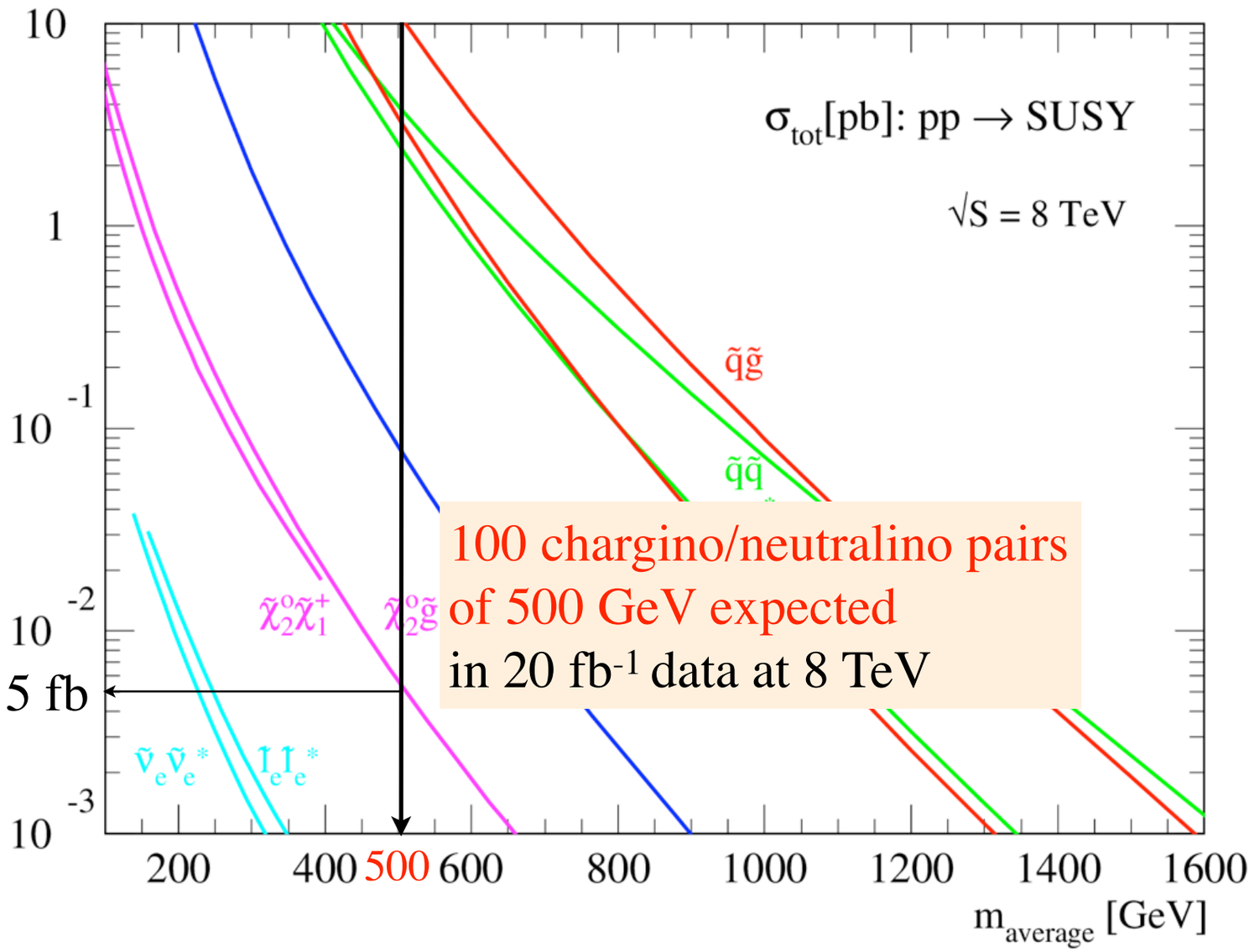


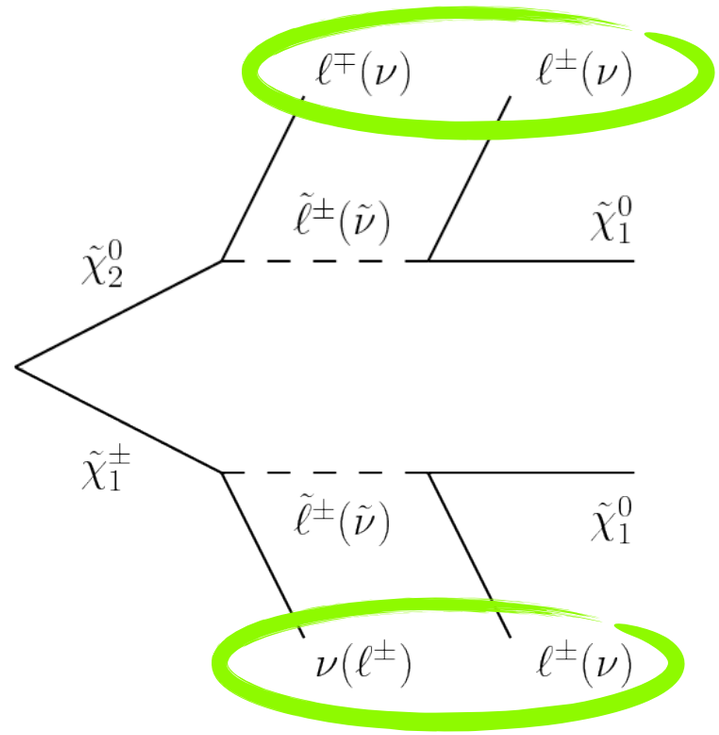


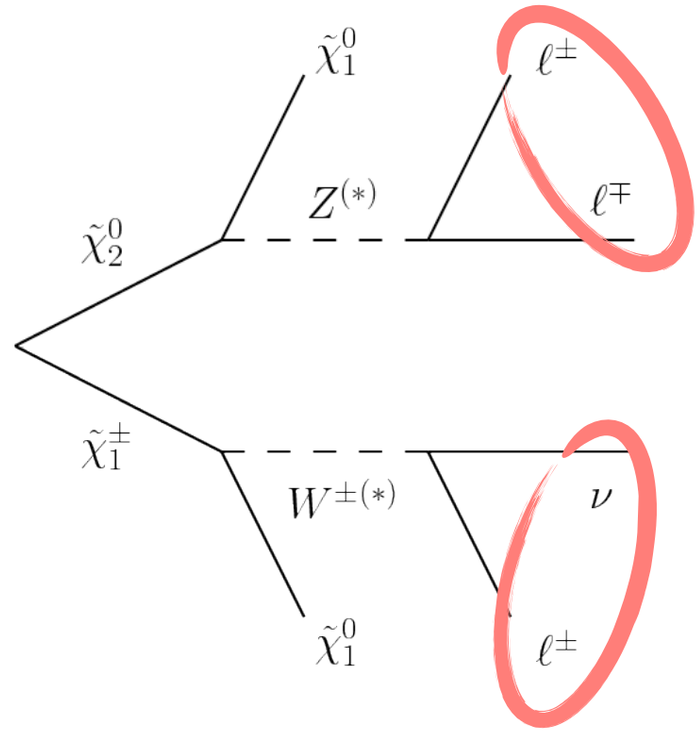
For $\tilde{t} \to t + \chi_1^0$, stop masses up to 600 GeV for zero LSP mass and up to 500 GeV for 250 GeV LSPs are probed.

For $\tilde{t} \to b + \chi^+$, the reach depends on mass scale assumed for intermediate particle. For 150 GeV chargino, stops upto 480 GeV are excluded.

Searches for Electroweakino Pairs



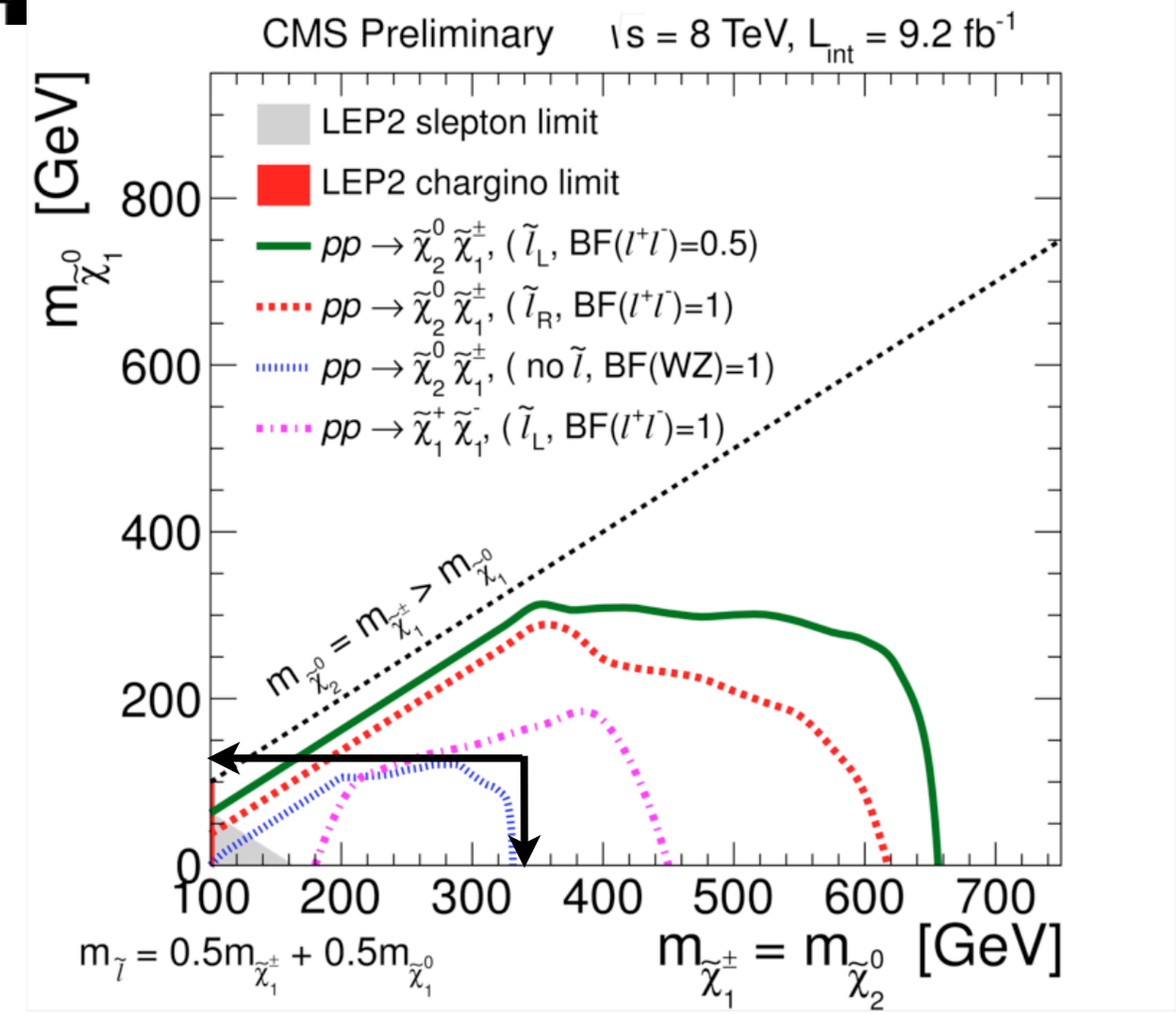


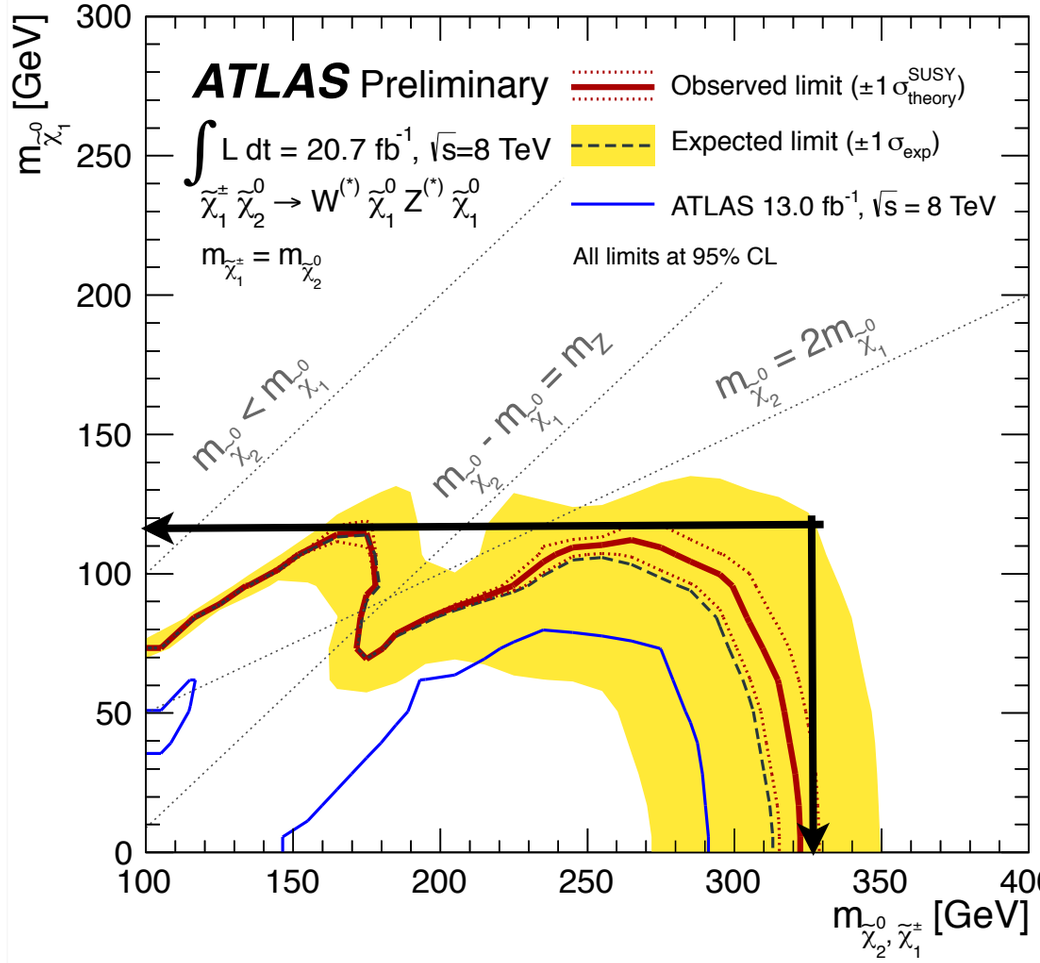


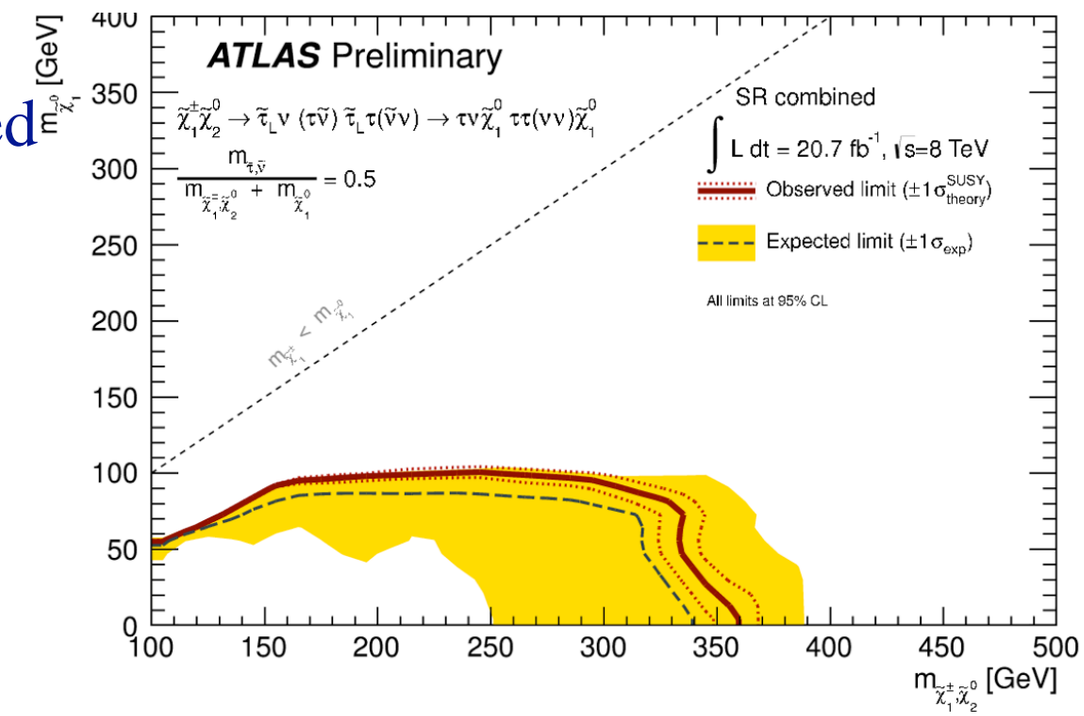
Experimental signatures : Multileptons in final state

Standard Model background mainly due to WZ, WW, ttbar production depending upon final state under study.

Results from Electroweakino searches

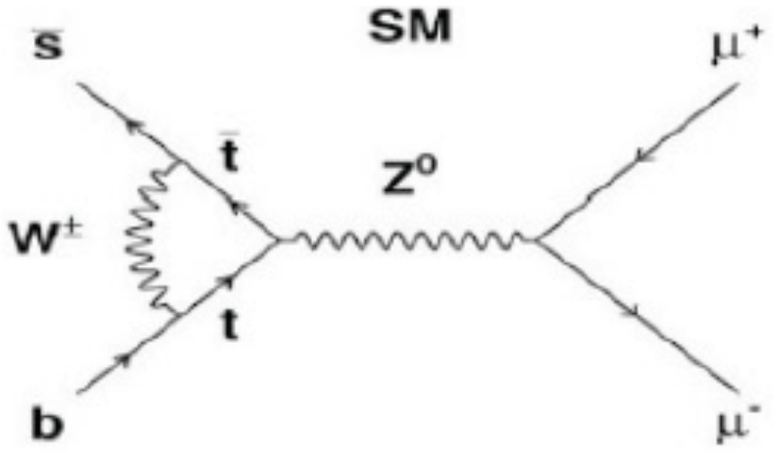






- Up to 300 GeV Charginos/Neutralinos probed with the assumption of heavy sleptons.
- The reach goes up to 600 GeV in decays via sleptons.
- Searches using taus in final state are also becoming sensitive.

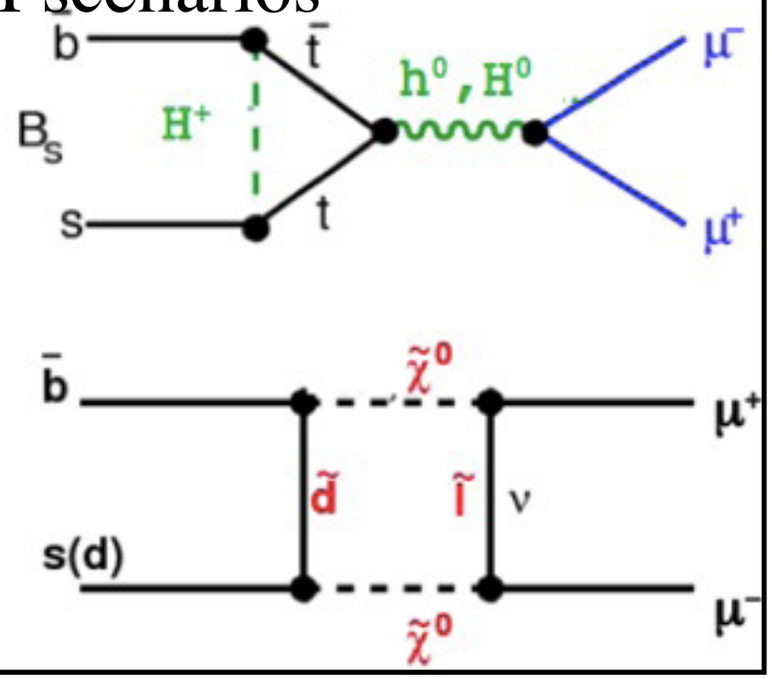
Rare Decays : $B_s \to \mu^+\mu^-$ (LHCb)

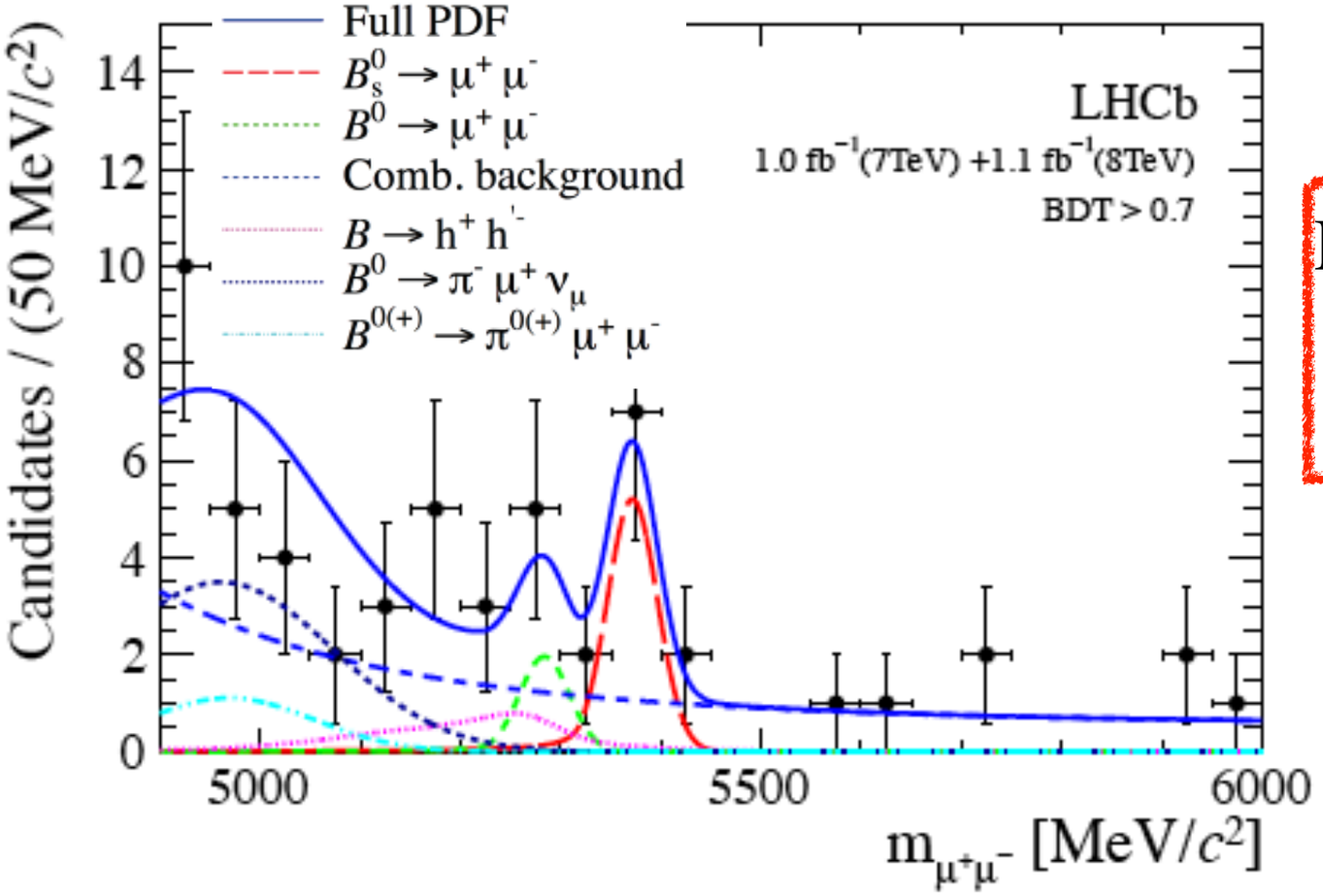


$$\mathcal{B}(B_s^0 \to \mu^+\mu^-)_{\rm SM} = (3.2 \pm 0.2) \times 10^{-9}$$
$$\mathcal{B}(B^0 \to \mu^+\mu^-)_{\rm SM} = (1.0 \pm 0.1) \times 10^{-10}$$

Enhanced in BSM scenarios

For e.g.
SUSY (CMSSM)
predicts $\tan^6\beta$
dependence





LHCB-PAPER-2012-043

First observation of $B_s \to \mu^+\mu^-$

$$(3.2^{+1.4}_{-1.2}(\text{stat})^{+0.5}_{-0.3}(\text{syst})) \times 10^{-9}$$

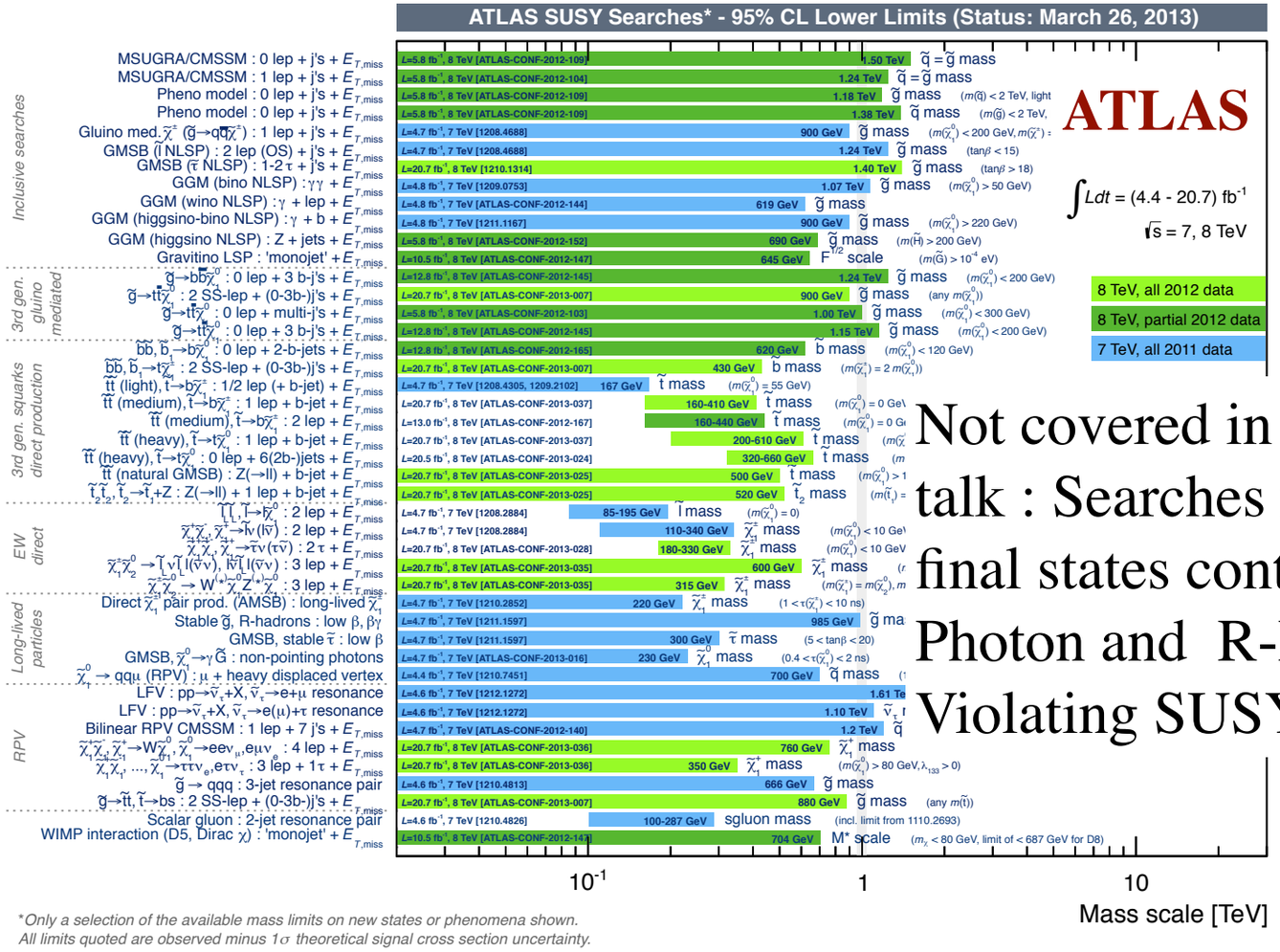
Results are consistent with the Standard Model expectations.

Summary of SUSY Searches

SUSY searches at LHC have probed particles of masses up :

- gluinos ~1.2 TeV
- stops/sbottoms ~600 GeV
- EWKinos 300-600 GeV

(using simplified models).



Not covered in this talk : Searches for final states containing Photon and R-Parity Violating SUSY.

Many interesting talks in parallel session (WG3) on Tuesday

Direct production of stop/squarks
L. Gouskos, P. Pani

Gluino mediated stop/squarks
C. Deluca

Searches for squarks/gluinos
E. Adam, R. Schoefbeck

Electroweak production
M. Agustoni

Multilepton final state
P. Thomasses

R Parity & long lived particles
M. King

Sorry if I missed any entry.

Large Extra-Dimensions Searches

Electroweak scale (EWSB)

$$m_{EW} = \frac{1}{(G_F \cdot \sqrt{2})^{\frac{1}{2}}} = 246\,\text{GeV}$$

Plank scale (Gravity)

$$M_{Pl} = \frac{1}{\sqrt{G_N}} = 1.2 \cdot 10^{19}\,\text{GeV}$$

Motivates extra dimensions in space where gravity can propagate.

Experimental signatures depends on model :

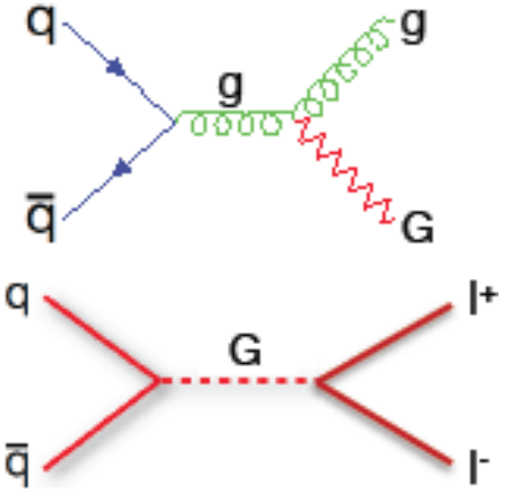
ADD Models (postulate n extra-dimenstions) **:**

Direct graviton emission :

large MET + mono jet/mono photon

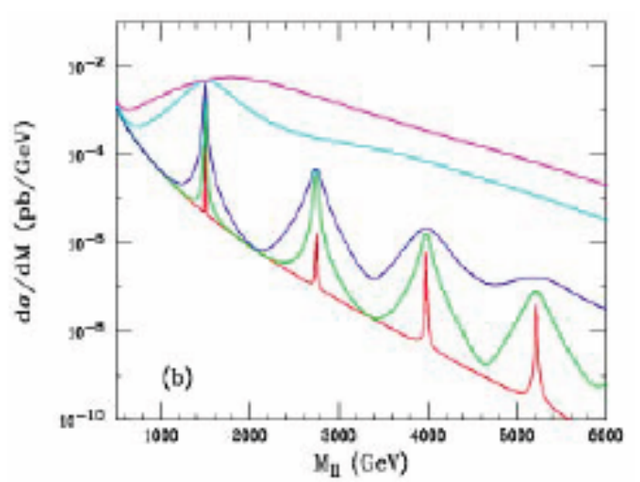
Virtual KK graviton exchange :

continuous spectrum resulting in a excess of dilepton, diphotons .. over SM



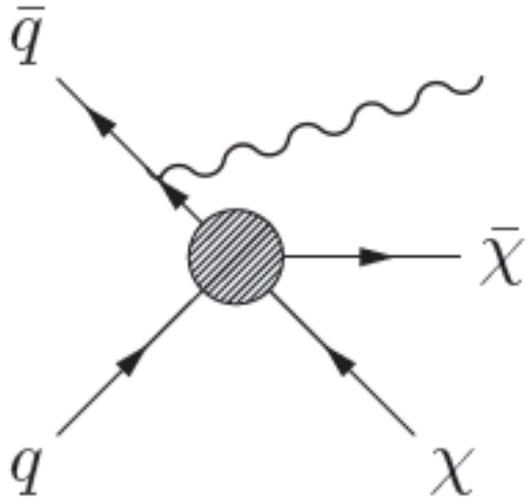
RS Models (one extra warped dimension) **:**

Virtual KK graviton exchange, narrow separate states : resonant excess over SM prediction

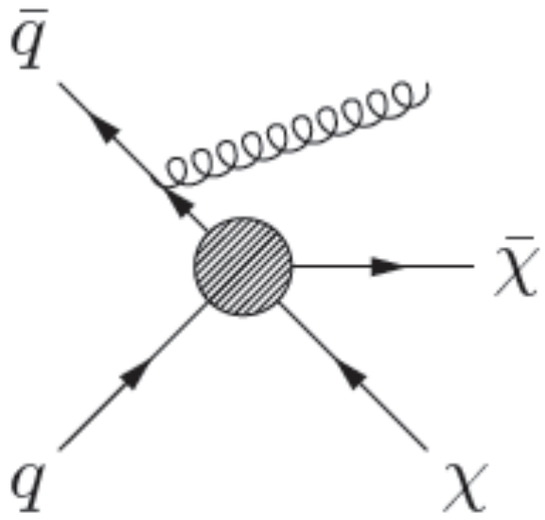


Dark Matter Using MonoJet(Photon)

Direct pair production of **Dark Matter** at colliders can be studied using ISR/FSR tagging : radiated jet or photon



MonoPhoton + MET

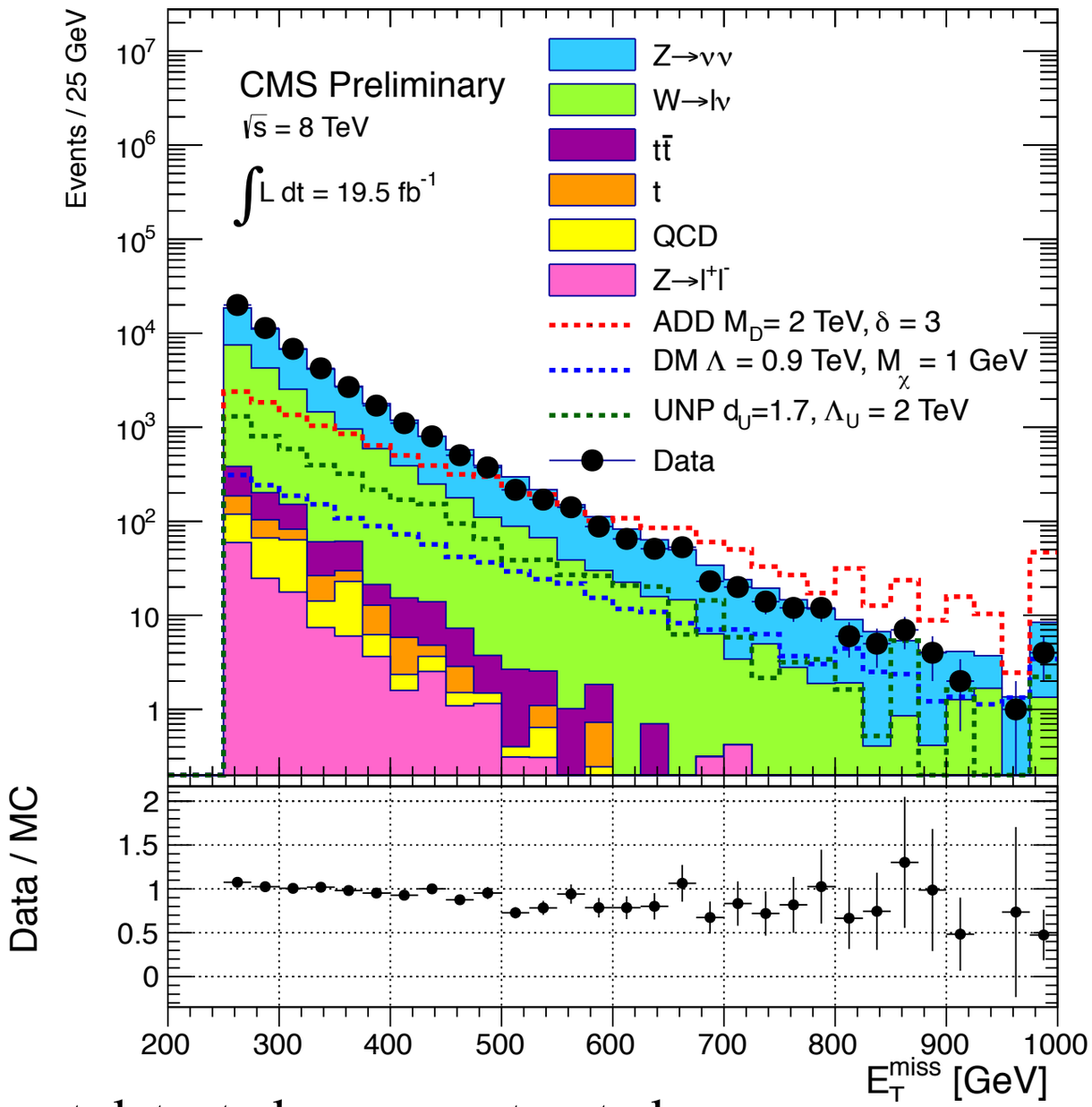


MonoJet + MET

Mono Jet + MET Search

Event Selection
central jet with Pt > 110 GeV
Veto leptons (e, μ, τ)
Pt of 2nd jet<30 GeV, ΔΦ(j1,j2)<2.5
Veto events with third jet with Pt>30
MET > 250 (multiple search bins in MET)

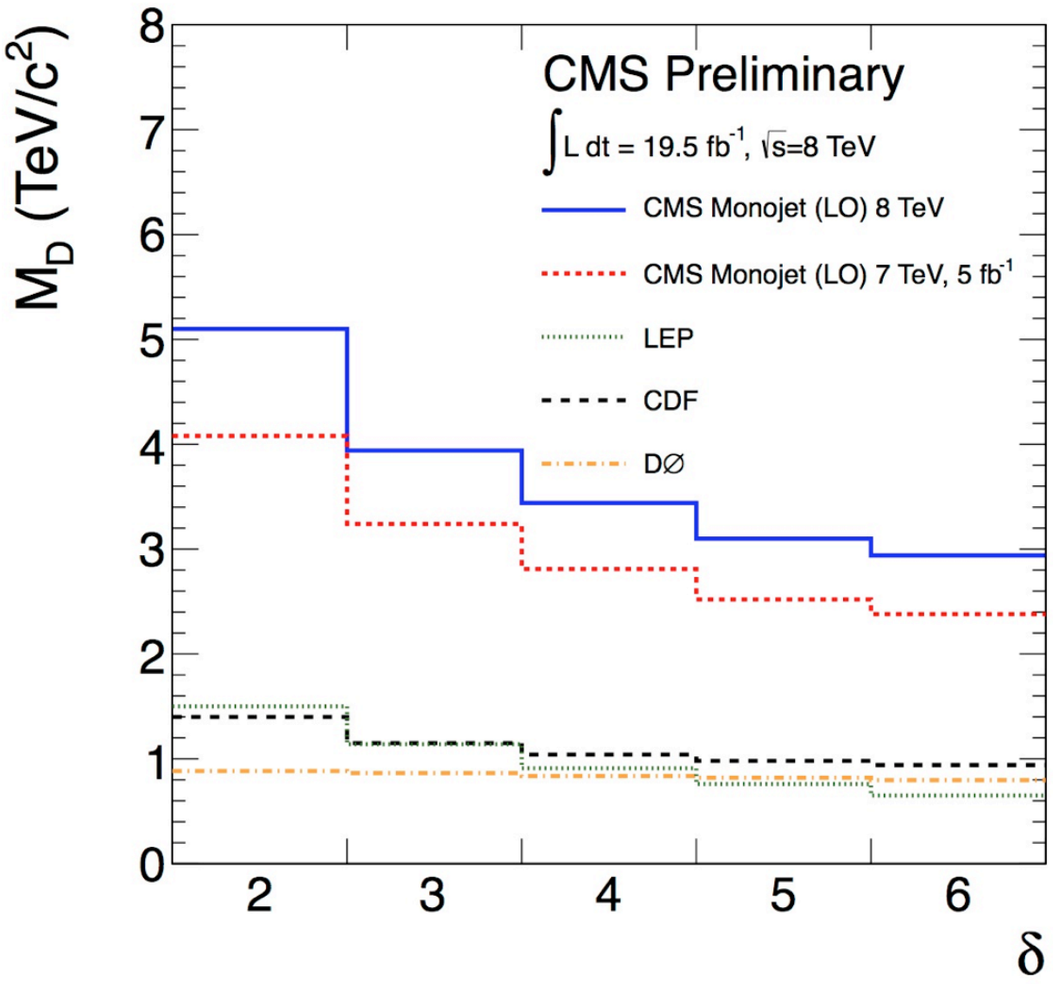
CMS-EXO-13-048 20 fb^{-1}



- Z + Jets
  - with Z decaying to neutrinos
- W/top + Jets
  - t → W (→ lost lepton + ν) + Jets :
    - W decays leptonically and e/μ is not detected or reconstructed
  - t → W (→ hadronic τ + ν)+ Jets :
    - W decays to τ+ν and τ decays hadronically

Mono Jet + MET Search : Results

E_T^{miss} (GeV) →	> 250	> 300	> 350	> 400	> 450	> 500	> 550
Z($\nu\nu$)+jets	30600 ± 1493	12119 ± 640	5286 ± 323	2569 ± 188	1394 ± 127	671 ± 81	370 ± 58
W+jets	17625 ± 681	6042 ± 236	2457 ± 102	1044 ± 51	516 ± 31	269 ± 20	128 ± 13
$t\bar{t}$	470 ± 235	175 ± 87.5	72 ± 36	32 ± 16	13 ± 6.5	6 ± 3.0	3 ± 1.5
Z($\ell\ell$)+jets	127 ± 63.5	43 ± 21.5	18 ± 9.0	8 ± 4.0	4 ± 2.0	2 ± 1.0	1 ± 0.5
Single t	156 ± 78.0	52 ± 26.0	20 ± 10.0	7 ± 3.5	2 ± 1.0	1 ± 0.5	0 ± 0
QCD Multijets	177 ±88.5	76 ±38.0	23 ±11.5	3 ±1.5	2 ±1.0	1 ± 0.5	0 ± 0
Total SM	49154 ± 1663	18506 ± 690	7875 ± 341	3663 ± 196	1931 ± 131	949 ± 83	501 ± 59
Data	50419	19108	8056	3677	1772	894	508

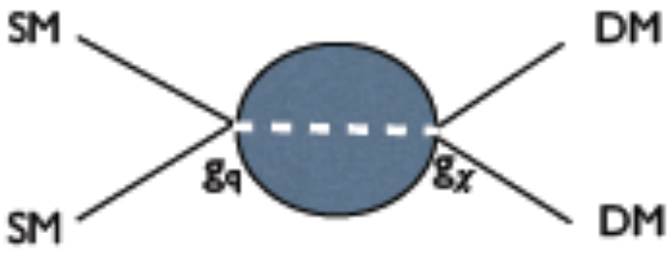


ADD Model of extra-dimensions

$M_D < 5$ TeV excluded for ADD n=2

$M_D < 2.9$ TeV excluded for ADD n=6

Mono Jet + MET Search : Results

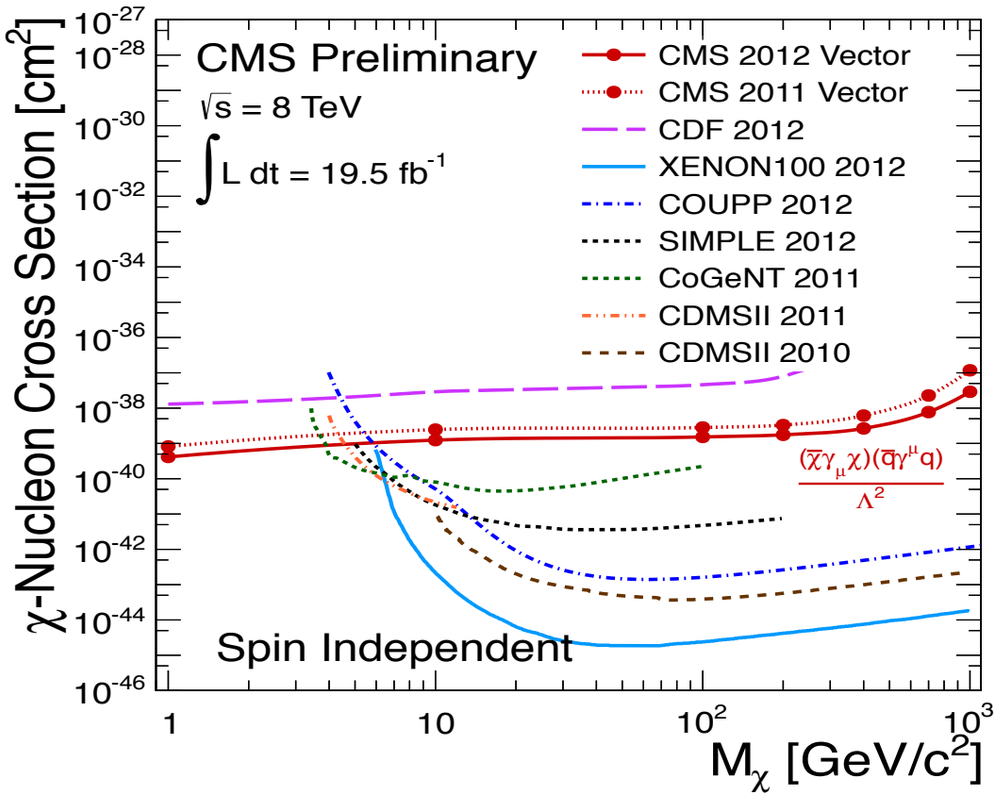


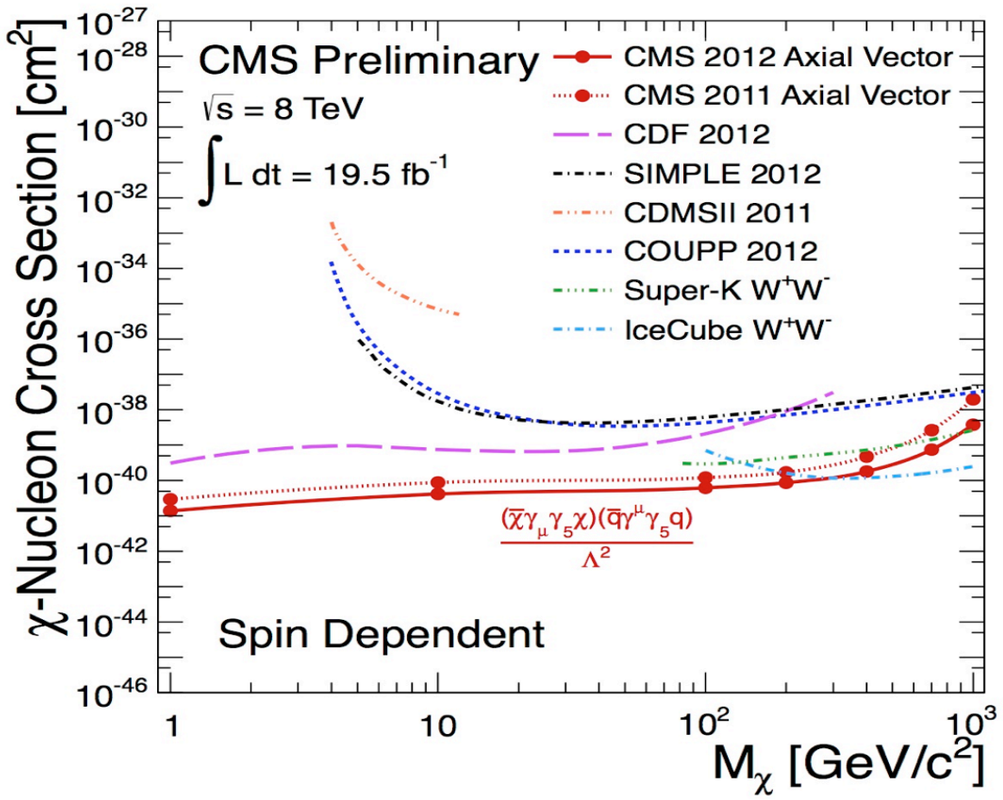
$$\Lambda = M/\sqrt{g_\chi g_q}$$

where,
M : mediator mass,
g_χ : coupling with DM particle
g_q: coupling with SM quark

Interaction between DM & quarks can be vector, axial-vector, scalar interactions.

vector & scalar : spin independent DM-nucleon interactions
axial-vector : spin dependent DM-nucleon interactions





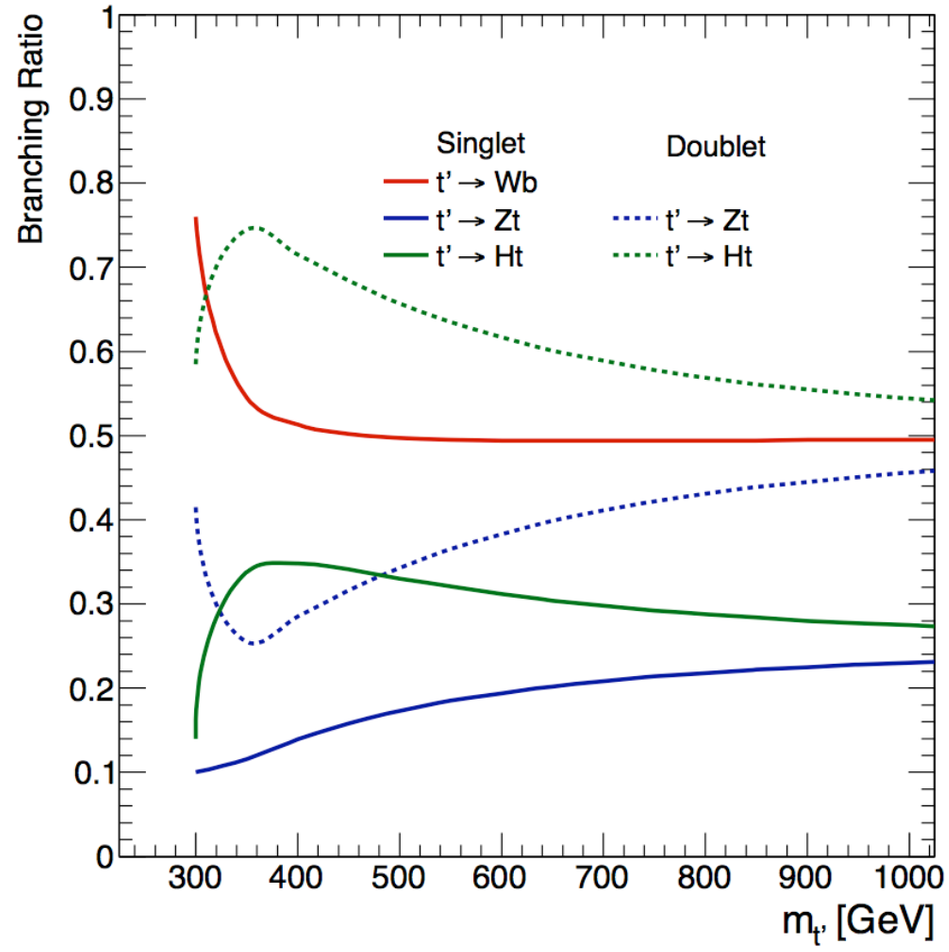
Search for Vector-like top quark (t')

ATLAS-CONF-2013-018

- Vector like quarks are postulated by many extension of Standard Model, for e.g. in Little Higgs models & Extra dimensions
  - top counterpart **t'** plays a key role in canceling quadratic corrections to Higgs boson mass
  - More generically one can add weak-isospin singlets, doublets or triplets of vector-like quarks
- Vector like quarks can couple preferentially to third generation quarks

In particular for t', possible decay modes are t'→Wb, Zt, Ht.

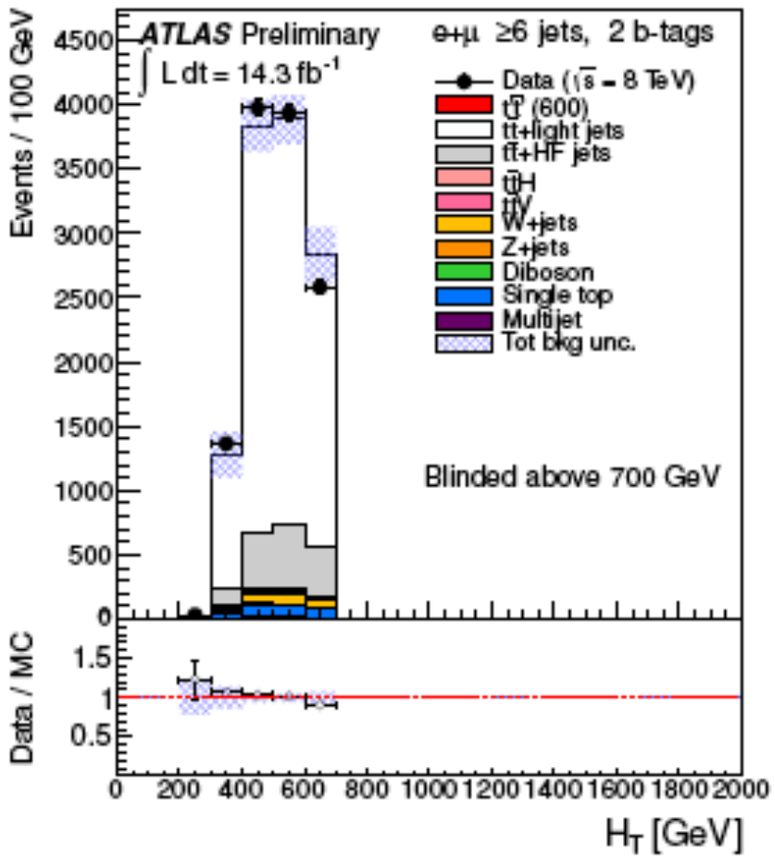
- BR will depend on t' being a single or doublet
- t'→Wb, Zt, Ht with BRs dependent on mass of t'

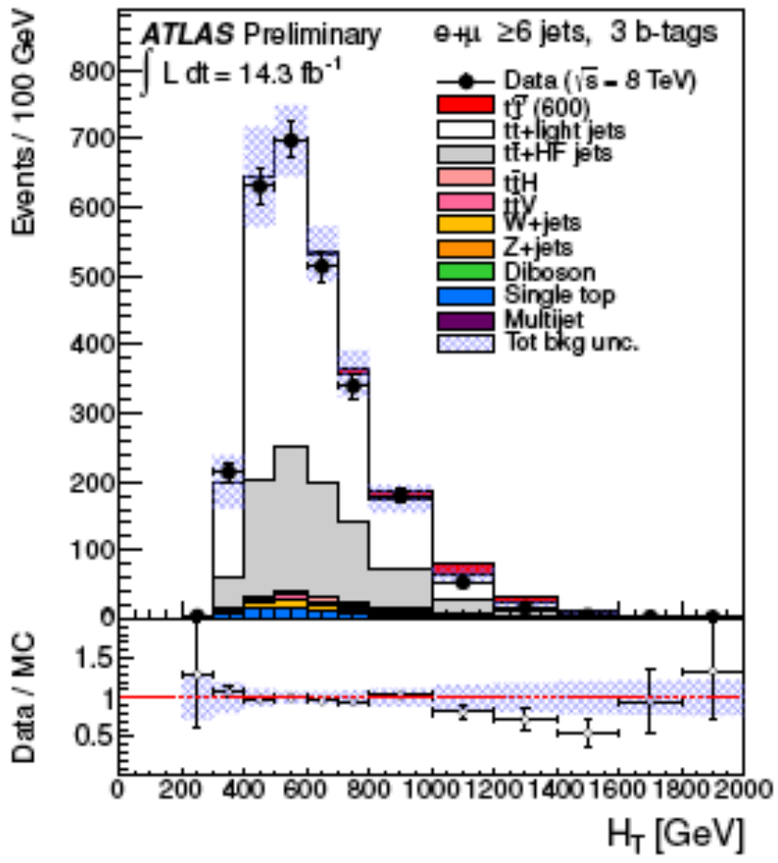


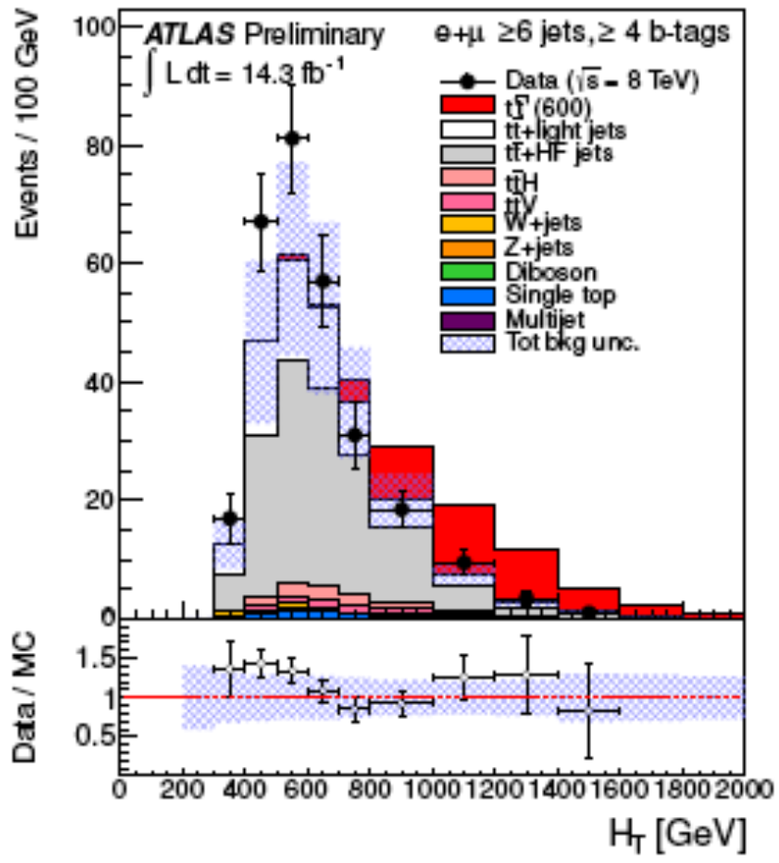
Search for Vector-like t'

ATLAS-CONF-2013-018

- Inclusive search for pair production of t'
  - consider decay to Wb, Zt, Ht
- 1 lepton + ≥6 jets + MET + MT
  - bin in number of b-tags (2, 3 and ≥4)
- Use control (HT<700 GeV) regions to fit for ttbar+LF and ttbar+HF



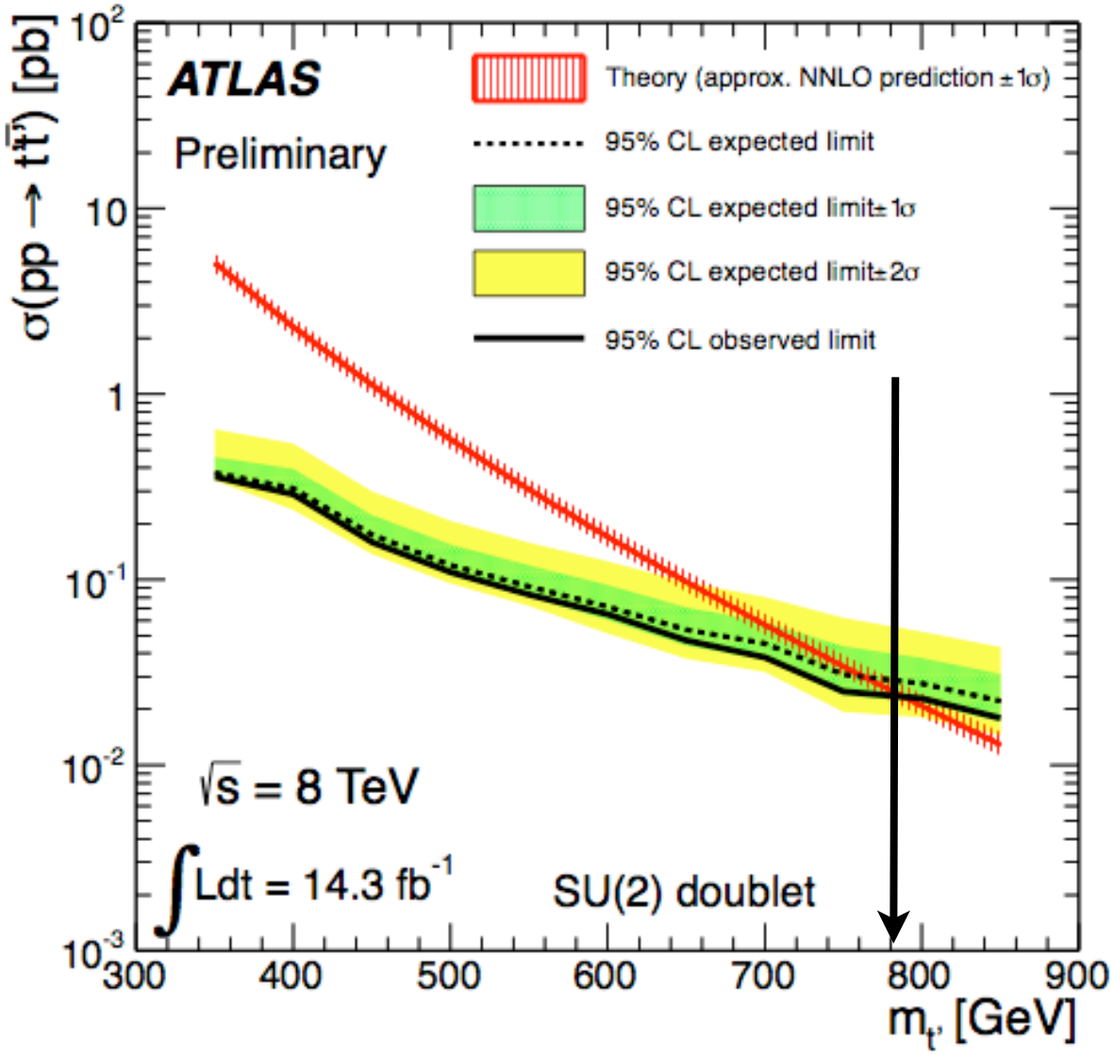


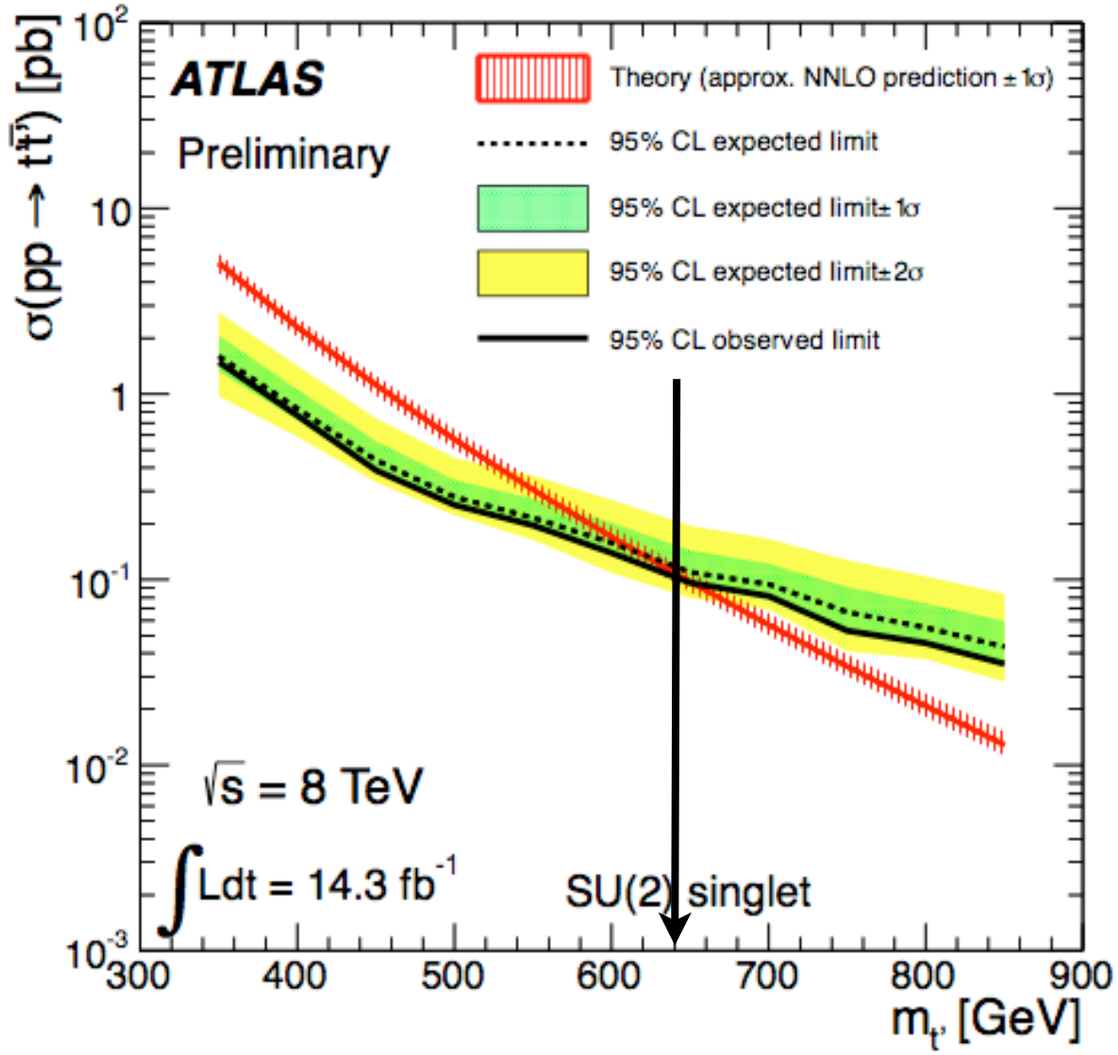


Search for Vector-like t' : Results

ATLAS-CONF-2013-018

Set limits on weak-isospin double and singlet models





- Vector-like t' is probed up to a mass of ~800 GeV for a weak-isospin doublet and ~650 GeV for weak isospin singlet.
- CMS also has a recent search for a heavy partner of top with charge 5e/3 excluding masses below ~750 GeV. (**CMS-B2G-12-012**)

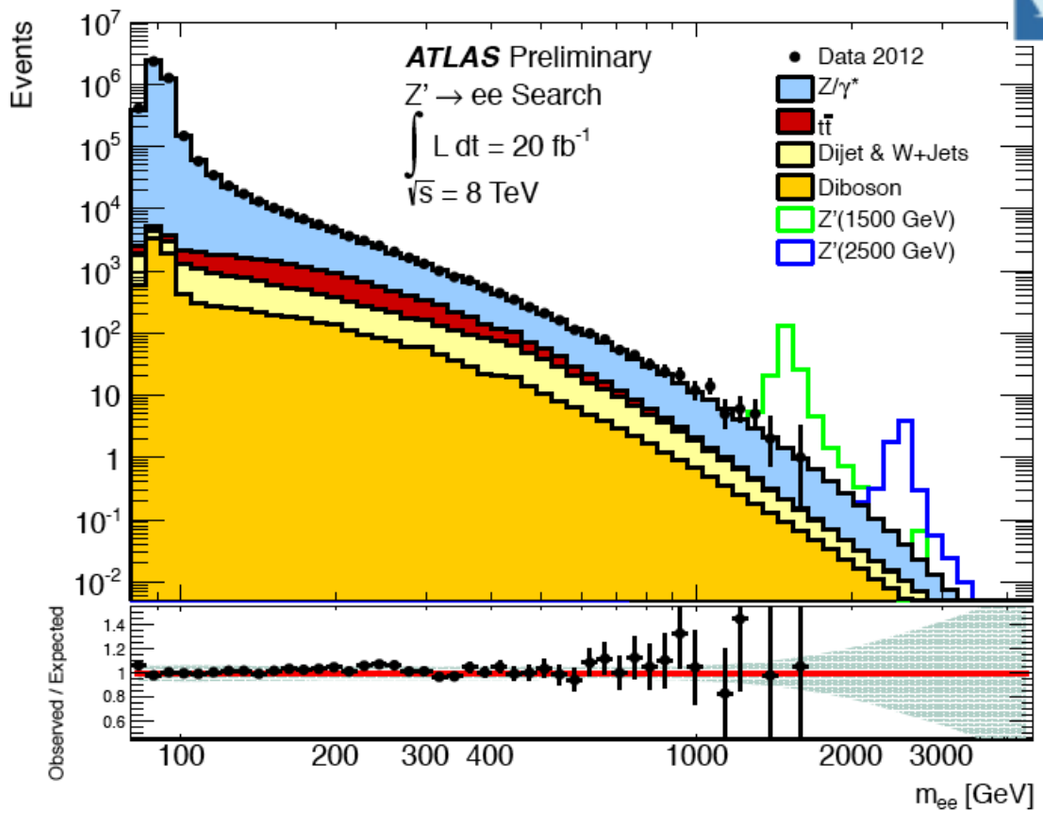
Search for Z'

CMS-PAS-EXO-12-061
ATLAS-CONF-2013-017

Narrow resonances at a TeV scale :
Sequential Standard Model or
in Grand Unified Theories.

Search for an excess in dilepton mass spectra using a shape analysis.

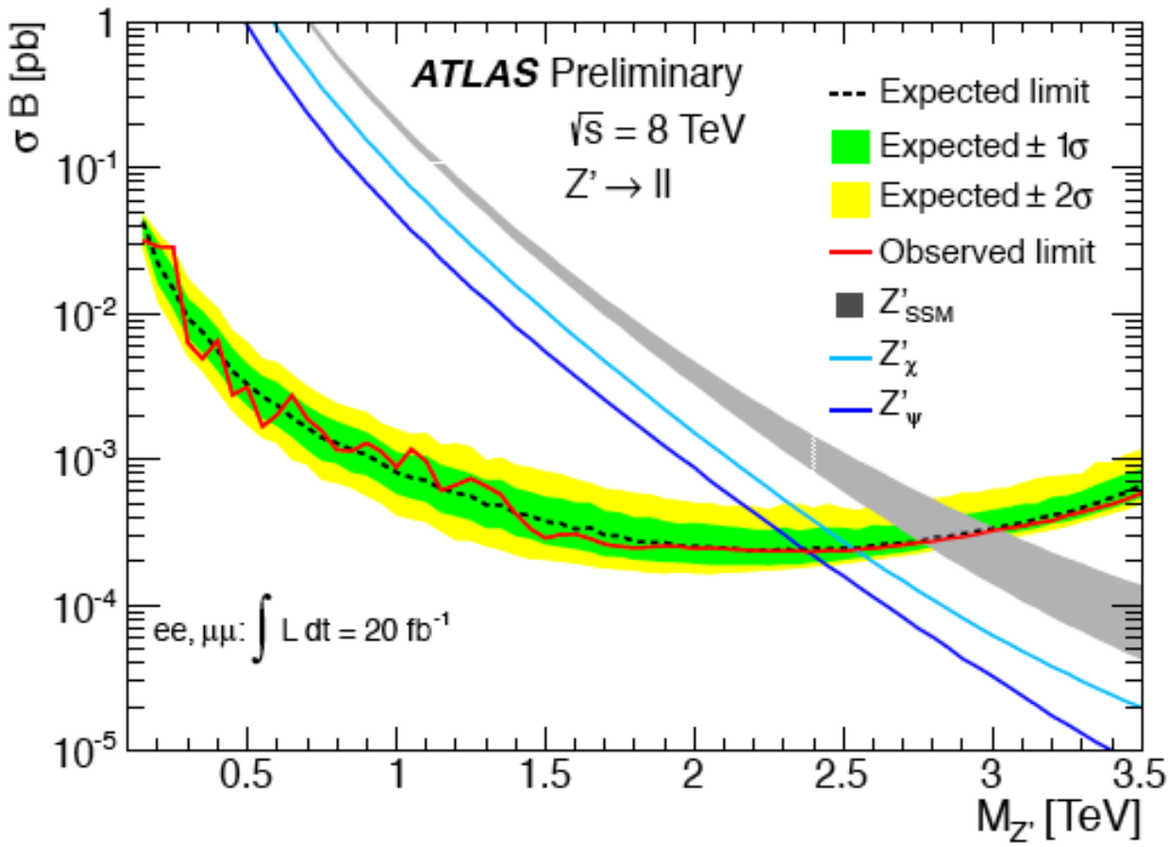
Main bkg : Drell-Yan process



CMS : Exclude a Z' with SM like couplings below ~2.9 TeV and superstring inspired Z' below ~2.6 TeV

ATLAS limits on Graviton

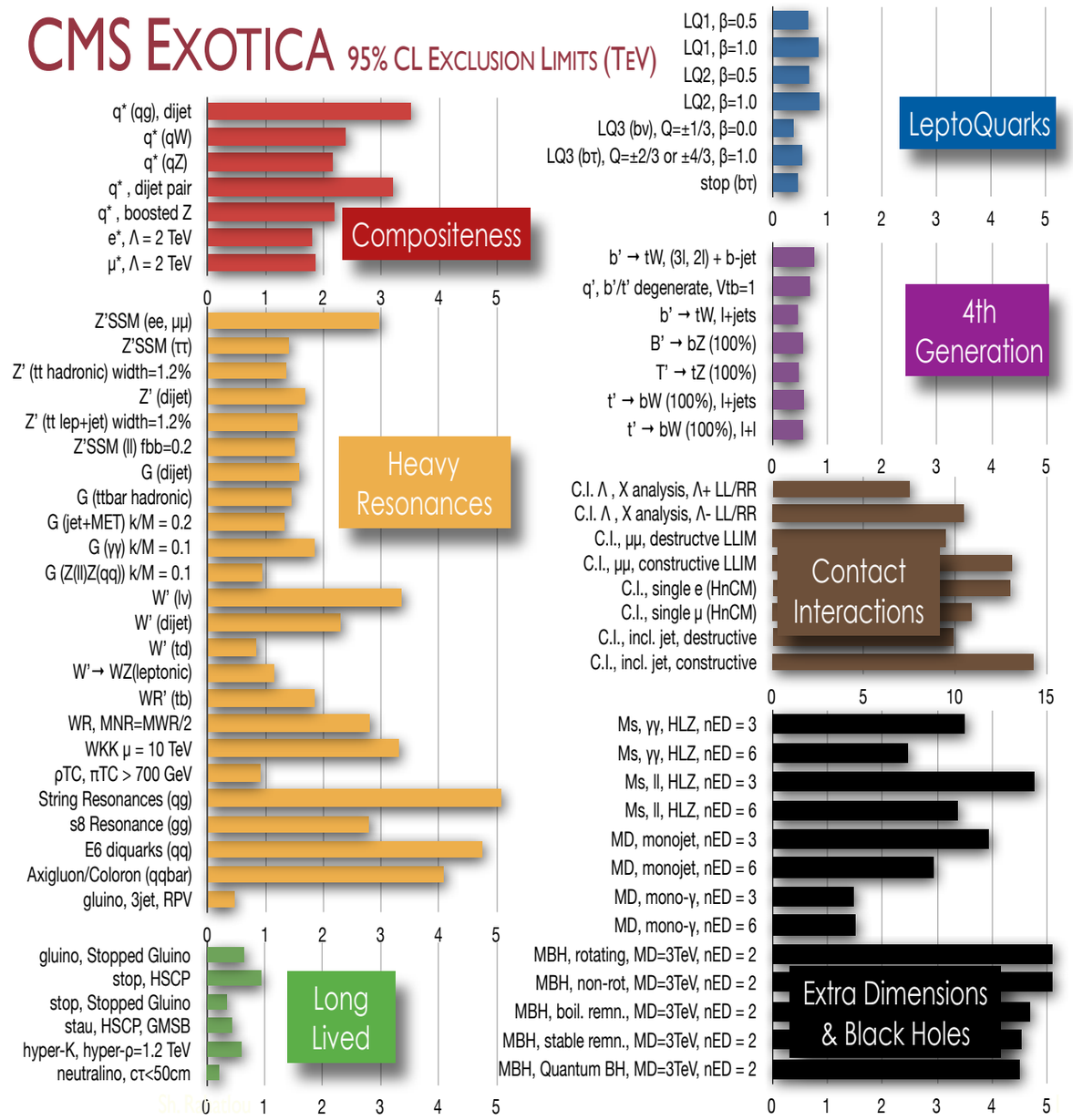
	$G^* \to e^+e^-$	$G^* \to \mu^+\mu^-$	$G^* \to \ell^+\ell^-$
Observed mass limit [TeV]	2.40	2.10	2.47
Expected mass limit [TeV]	2.40	2.17	2.47



Summary of Exotica Searches

Exotica searches from CMS & ATLAS in parallel sessions (WG3) on Wed. & Thu. :

- Search for heavy resonances
  - S. Zimmerman, S. Schmitz
- Search for resonant diboson production
  - Peter V. Loscutoff
- Searches for W', Z'
  - E. Accomando
- Long lived particles, lepton+jets
  - P. Pais, C. Vuosalo
- Monojet/MonoPhoton
  - R. Armadans
- Forth generation vector-like quarks & ttbar resonances
  - J. Webster
- Multileptons
  - D. Yu
- Sorry if I missed any entry



Summary

- Experiments at LHC have an extensive & robust program searching for physics beyond standard model.
  - ATLAS and CMS focus on searches for direct production of massive particles.
  - LHCb corners the new physics via rare decays.

- So far, data is consistent with the Standard Model expectations.
- Many analyses using ~20 fb^{-1} data collected at 8 TeV are in progress !

- The LHC will resume operation after 2014 and plans to operate at ~13 TeV which will extend the new physics searches to multiTeV scale.
- The collaborations are working to upgrade detector and reconstruction to meet the requirements of expected new running conditions.

Exciting times ahead at LHC !!

Stay tuned !!

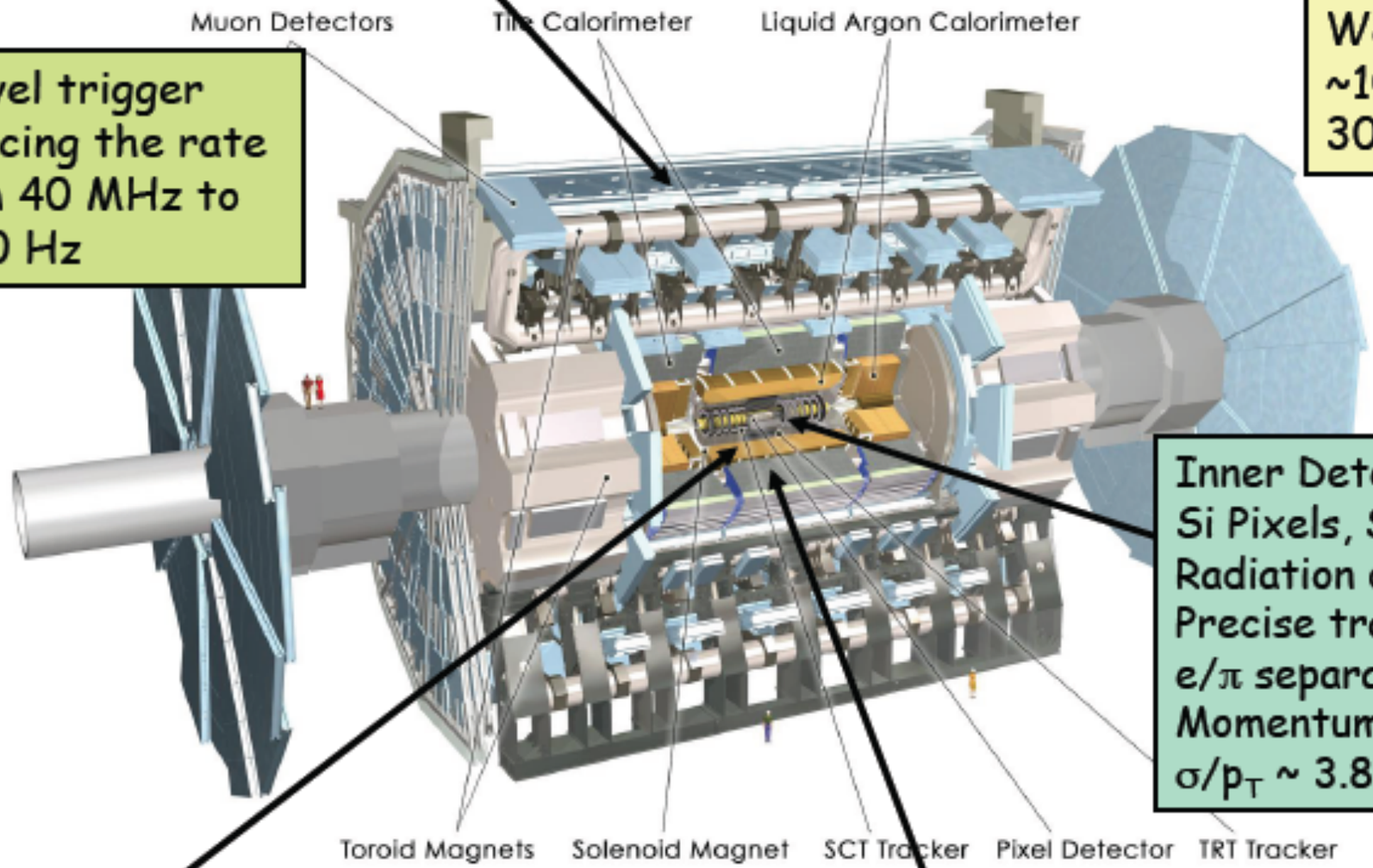
Backup

ATLAS Detector

Muon Spectrometer ($|\eta|<2.7$) : air-core toroids with gas-based muon chambers
Muon trigger and measurement with momentum resolution < 10% up to E_μ ~ 1 TeV

Length : ~ 46 m
Radius : ~ 12 m
Weight : ~ 7000 tons
~10^8 electronic channels
3000 km of cables

3-level trigger reducing the rate from 40 MHz to ~200 Hz

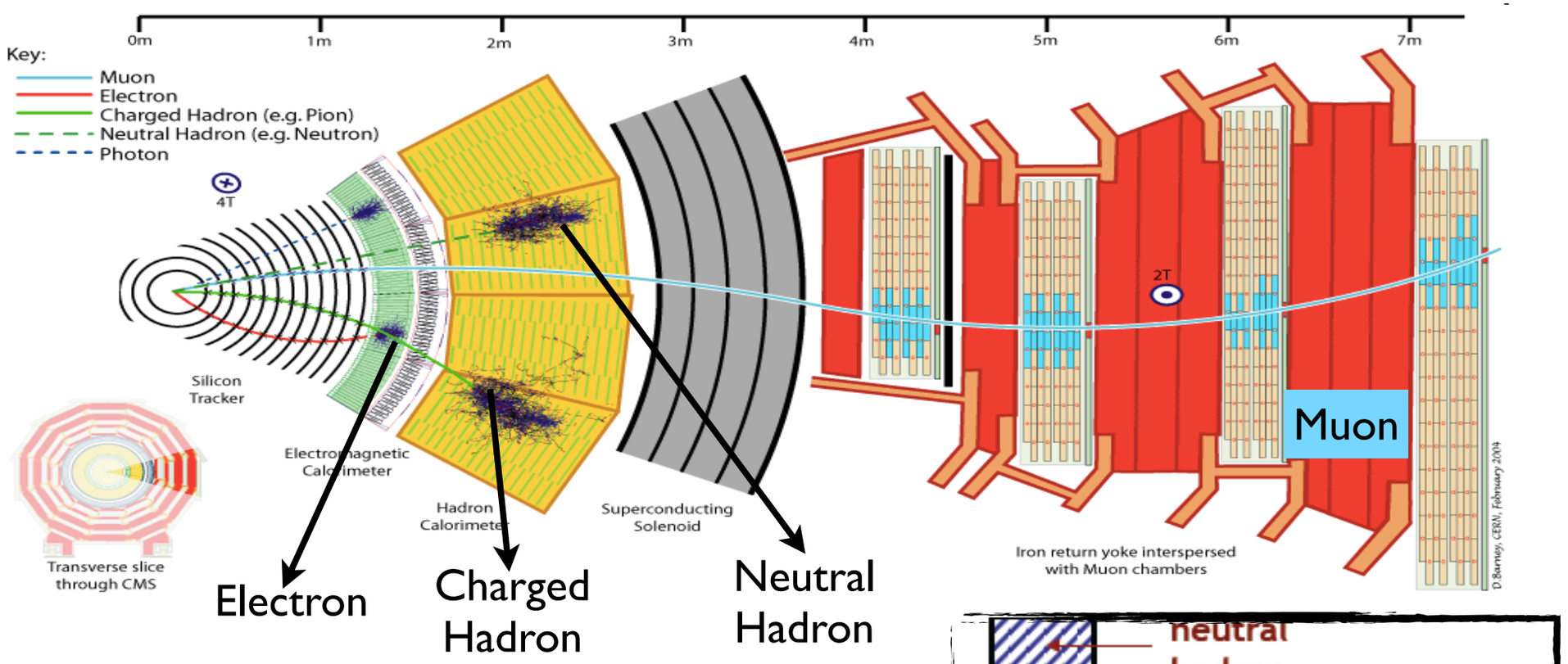


Inner Detector ($|\eta|<2.5$, B=2T):
Si Pixels, Si strips, Transition Radiation detector (straws)
Precise tracking and vertexing, e/π separation
Momentum resolution:
$\sigma/p_T \sim 3.8\times10^{-4}\ p_T\,(GeV) \oplus 0.015$

EM calorimeter: Pb-LAr Accordion
e/γ trigger, identification and measurement
E-resolution: $\sigma/E \sim 10\%/\sqrt{E}$

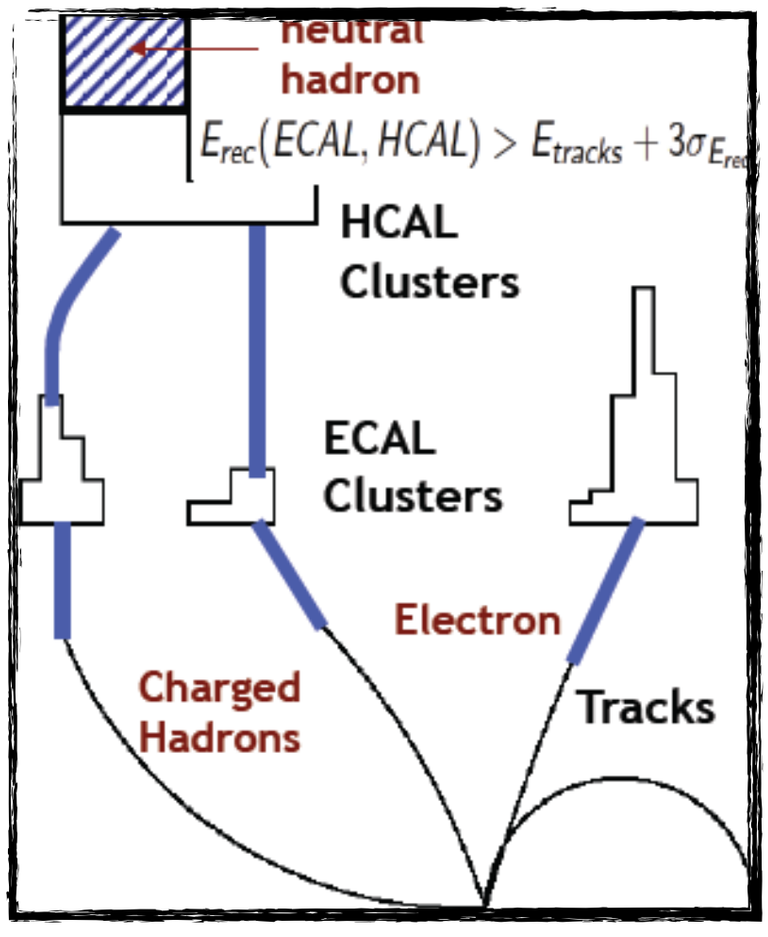
HAD calorimetry ($|\eta|<5$): segmentation, hermeticity
Fe/scintillator Tiles (central), Cu/W-LAr (fwd)
Trigger and measurement of jets and missing E_T
E-resolution: $\sigma/E \sim 50\%/\sqrt{E} \oplus 0.03$

CMS Detector & Event Reconstruction

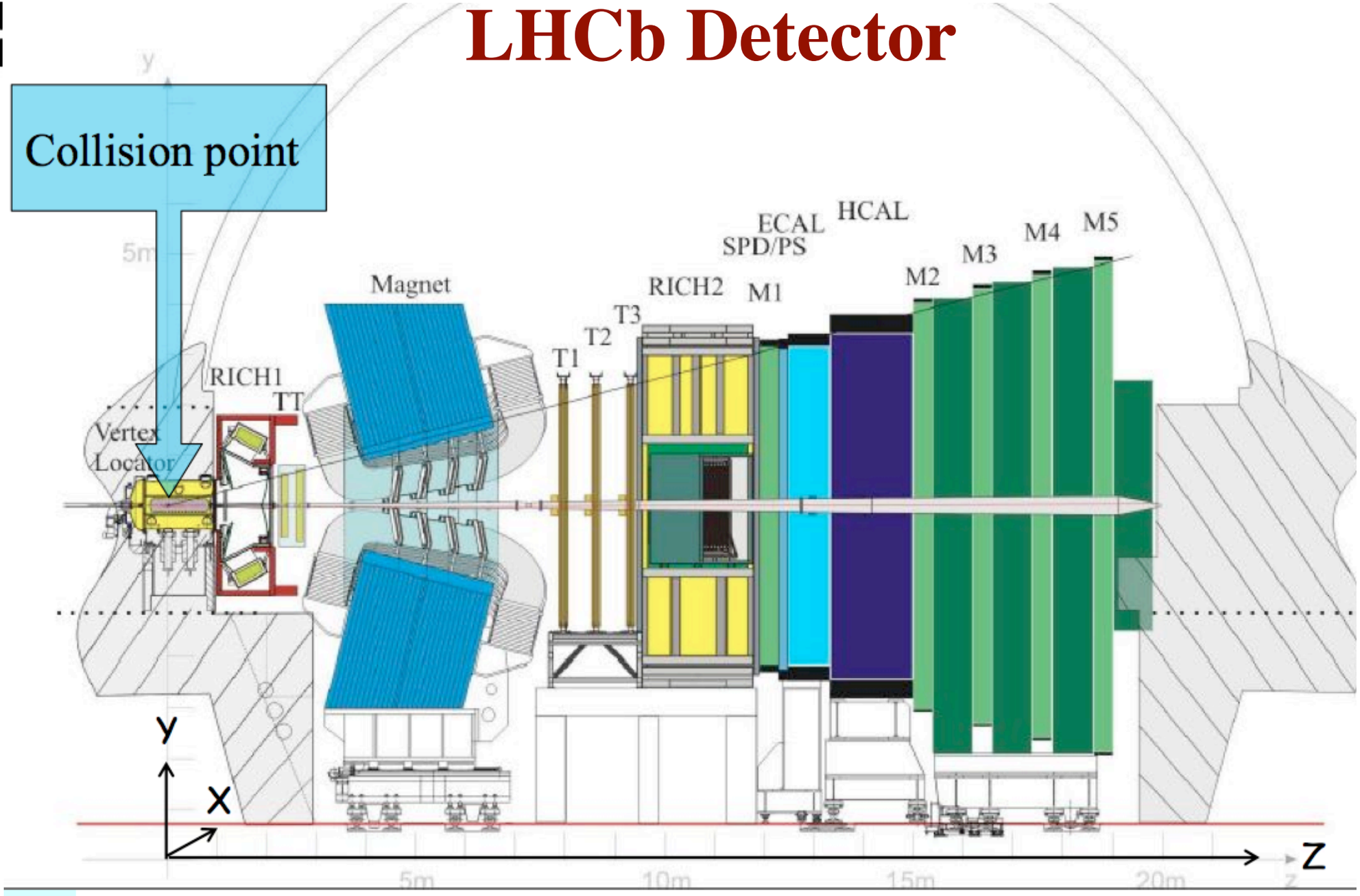


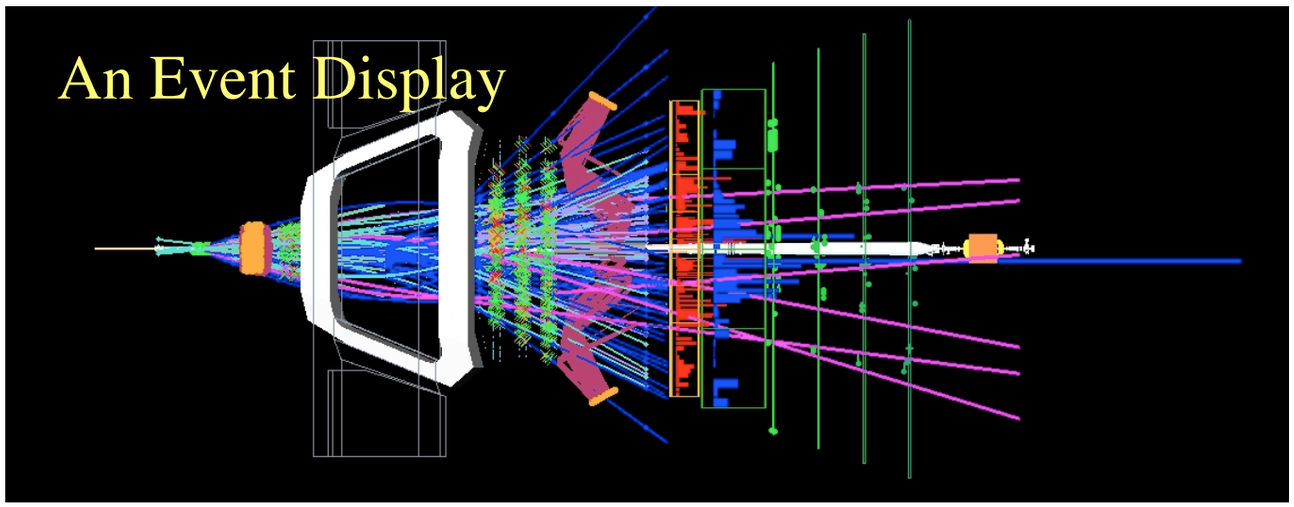
Events are reconstructed using Particle Flow algorithm which combines information from the tracker, EM calorimeter, Hadron Calorimeter and Muon detectors in an optimized way to get the best estimate of energy, direction and identity of particles.

The various physics objects used in this analysis are jets (antiKT 0.5), photons, electrons & muons.



LHCb Detector





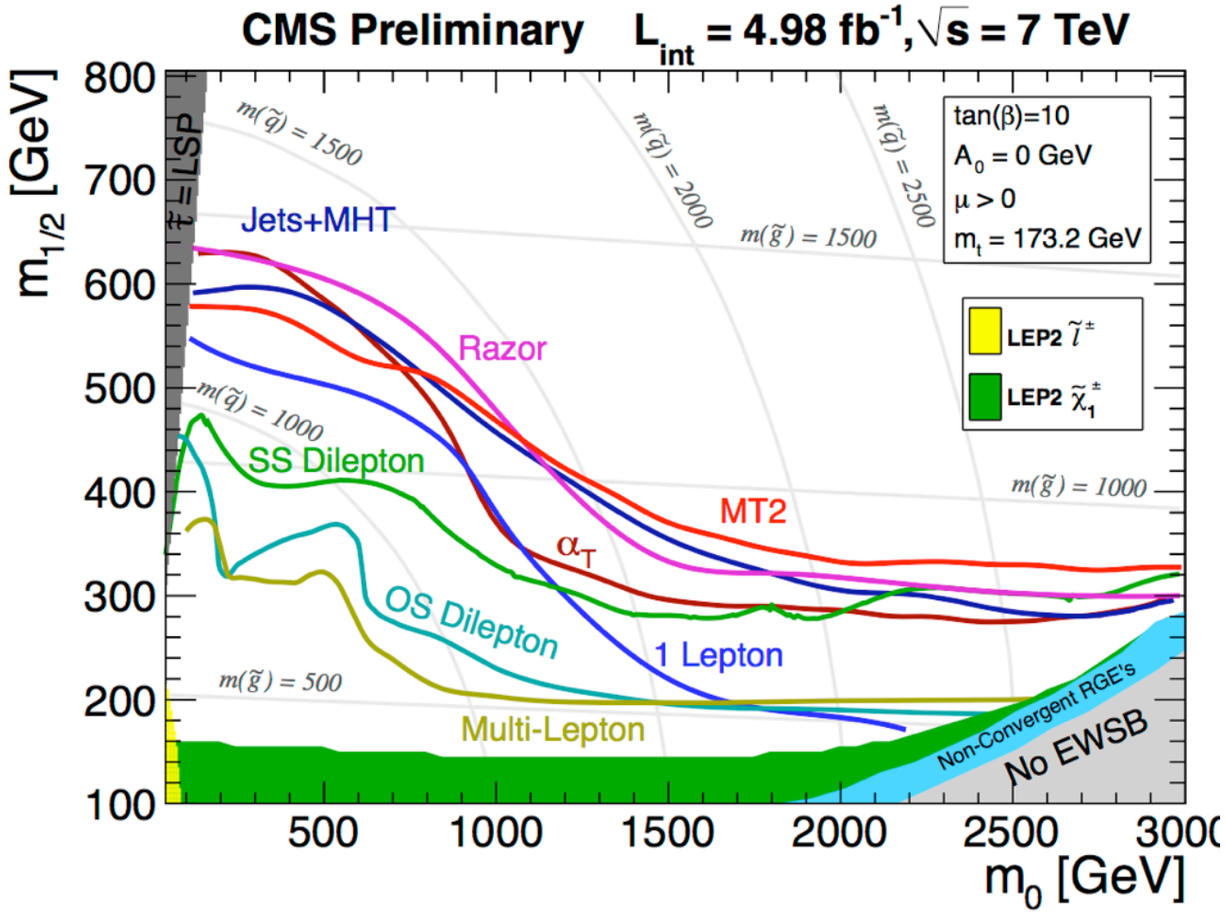
- Vertex Locator $\sigma_{PV}(x,y) \sim 10\mu m$, $\sigma_{PV}(z) \sim 60\mu$m
- Tracking $\Delta p/p = (0.4 - 0.6)\%$ in the range $5 - 100$GeV/c
- RICH Detectors $\epsilon(K) \sim 95\%$, mis-ID$(\pi \to K) \sim 5\%$
- Muon system $\epsilon(\mu) \sim 97\%$, mis-ID$(\pi \to \mu) 1 - 3\%$
- ECAL $\frac{\sigma_E}{E} \sim \frac{10\%}{\sqrt{E}} \bigoplus 1\%$ (E in GeV)
- HCAL $\frac{\sigma_E}{E} \sim \frac{70\%}{\sqrt{E}} \bigoplus 10\%$ (E in GeV)

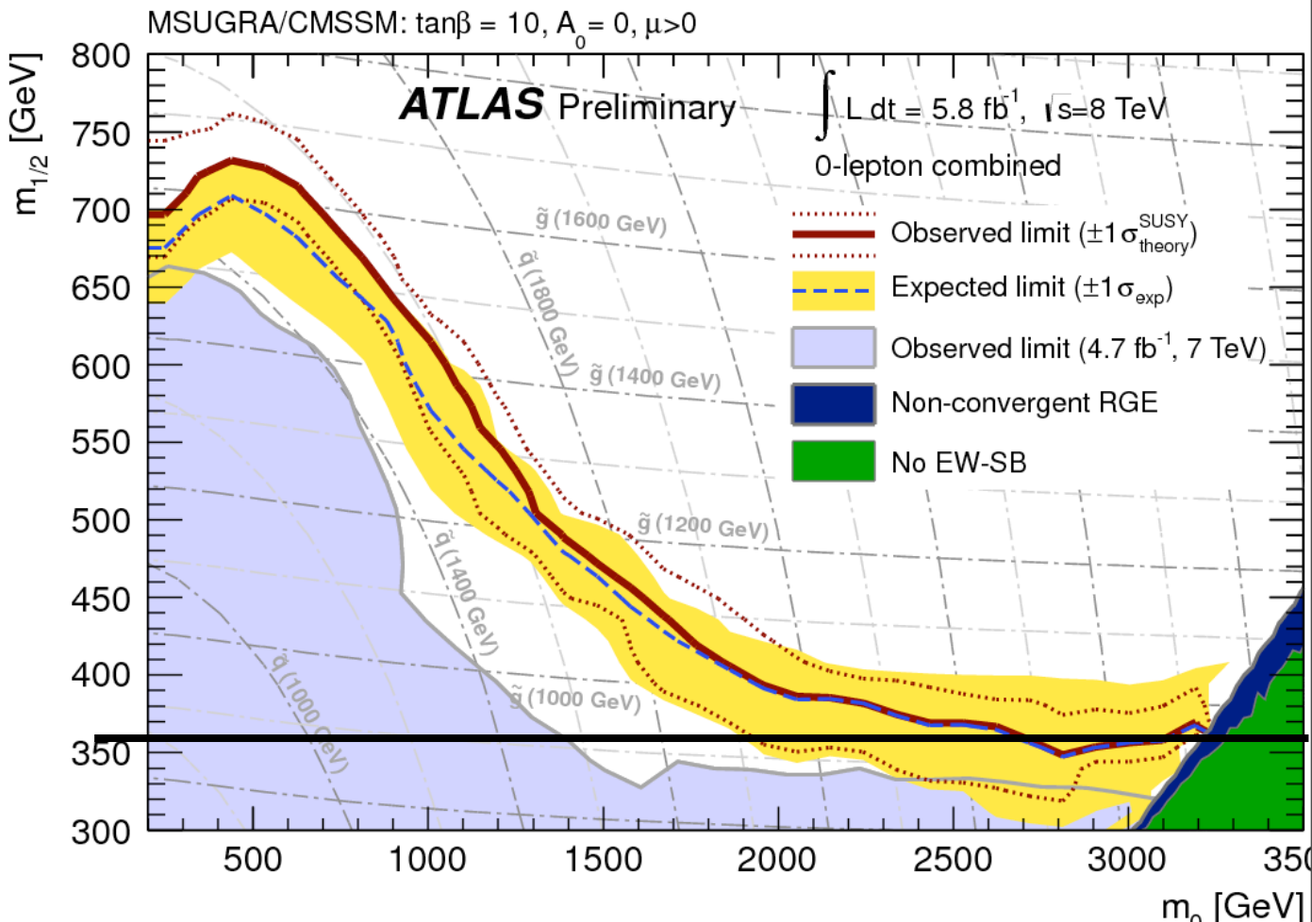
cMSSM : ATLAS & CMS

- Constrained MSSM in mSUGRA framework : parameter space can be explored in terms of 5 quantities defined at GUT scale.

  m_0 (common scalar mass) **$m_{1/2}$** (common gaugino mass)

  tan β **Trilinear coupling A** **sign (μ)**



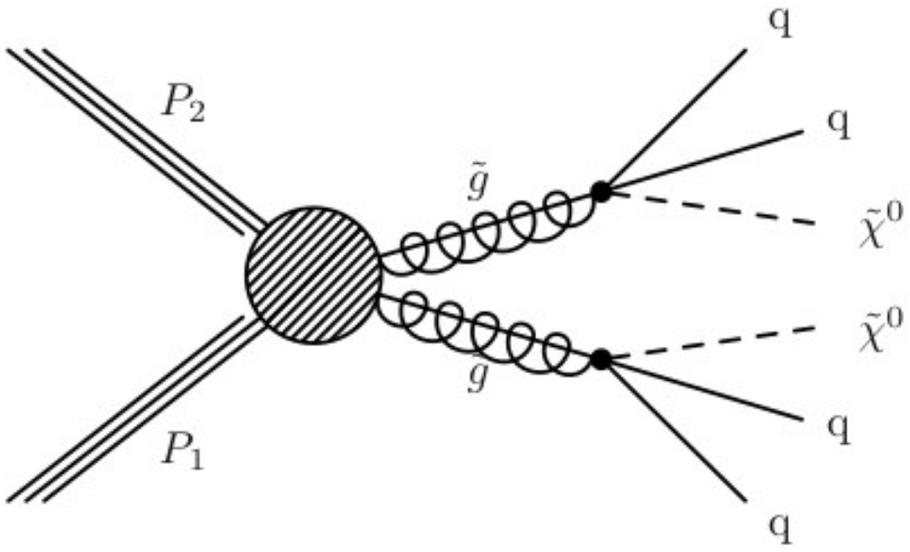


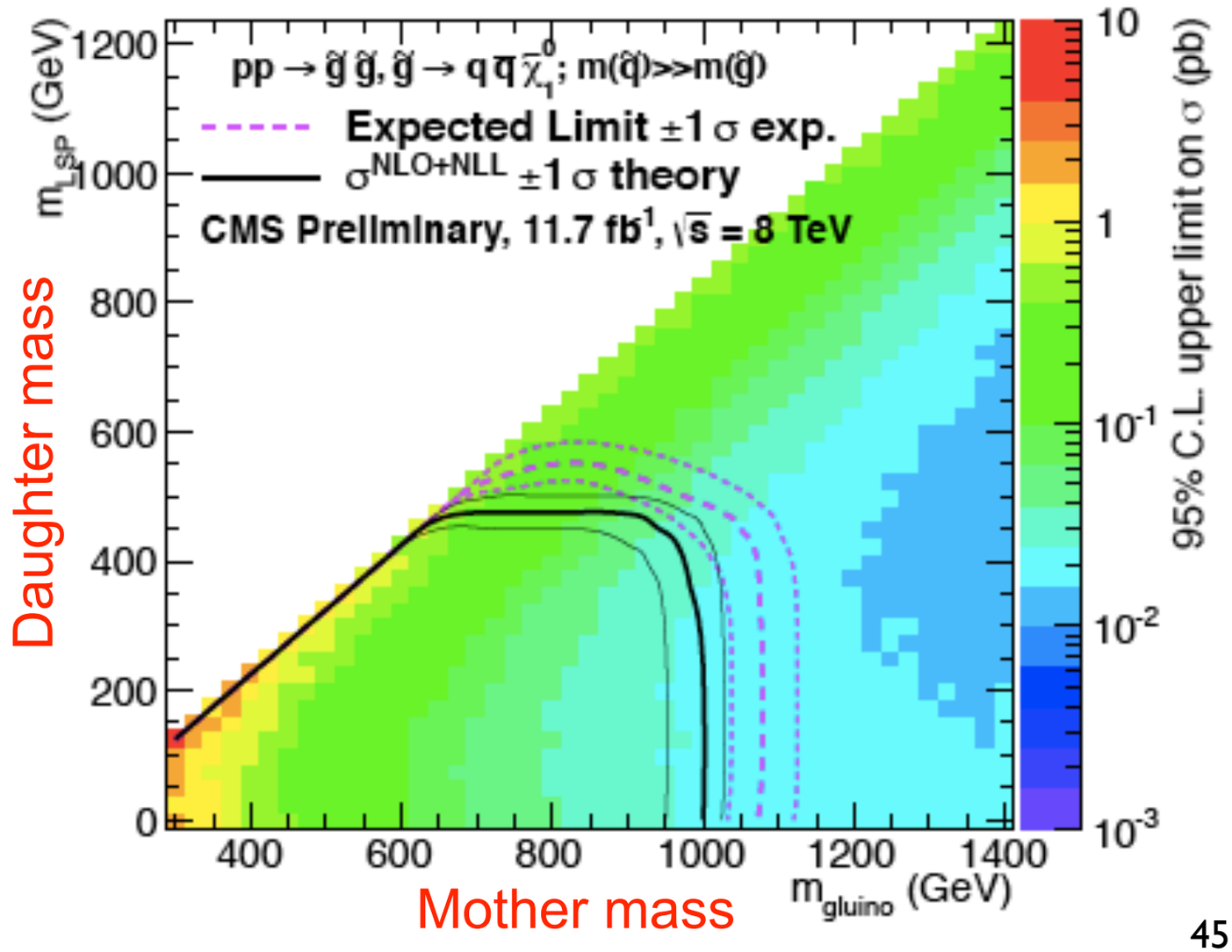
Inclusive searches rapidly constrained the allowed parameter space in cMSSM.

Upto 1.5 TeV squarks & gluinos excluded when these have equal masses.

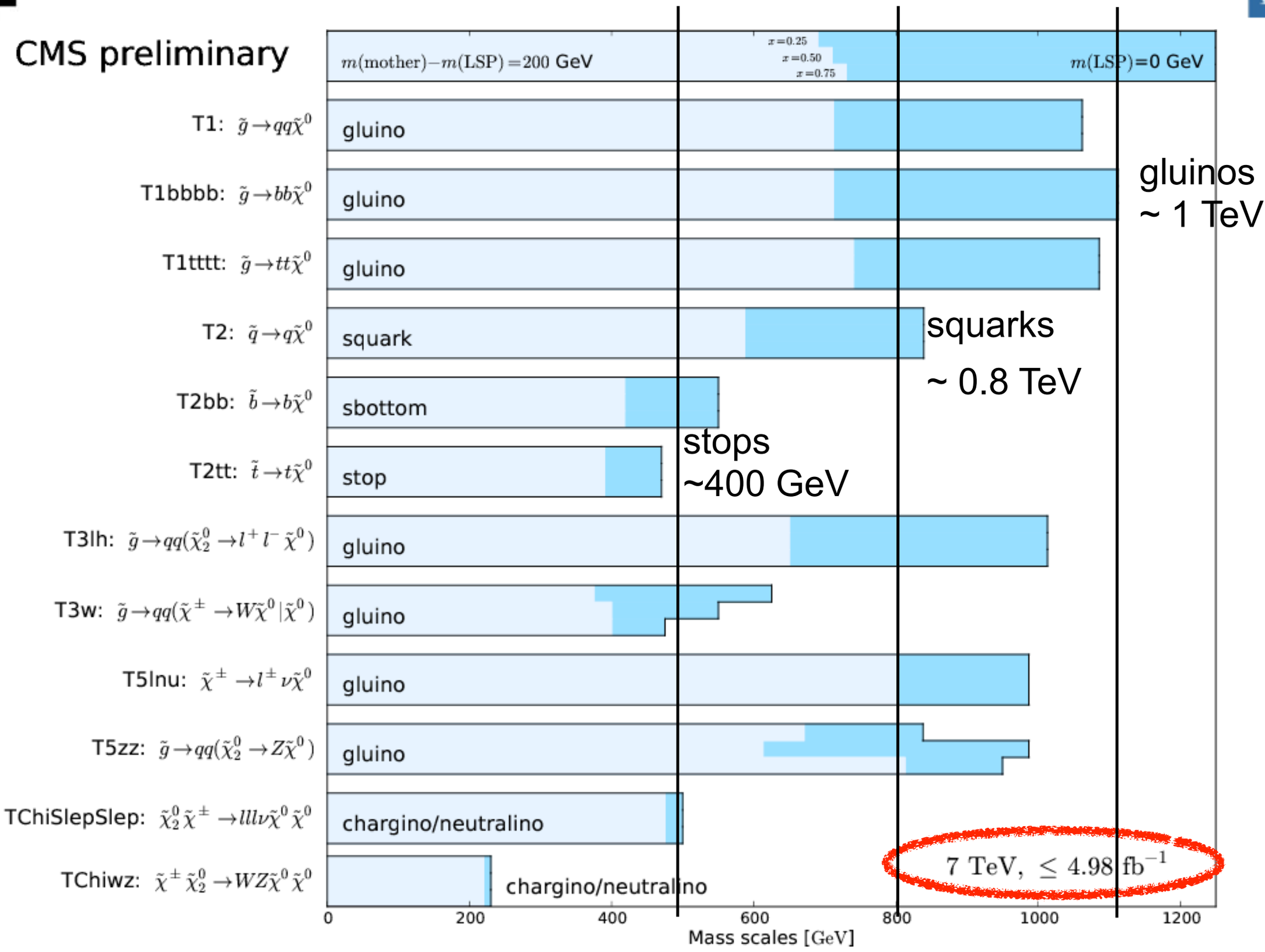
Simplified Topologies

- Constrained models allows to explore well framed theoretical and experimental ideas. However, specific mass patterns and signatures may not be indicative of general MSSM or extensions.
- Simplified models
  - Defined for a limited set of hypothetical particles with simple decay chains
  - Exploring a wide range of mass splitting between mother (eg. a colored particle) and daughter masses (e.g. an LSP).



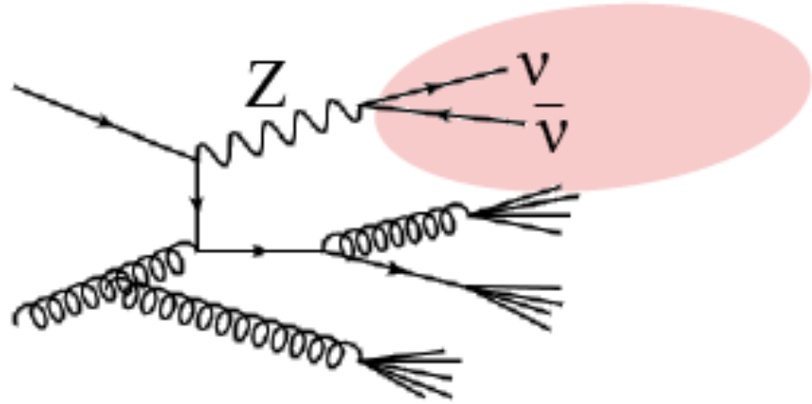


(Incomplete) Summary of SUSY Searches @ CMS

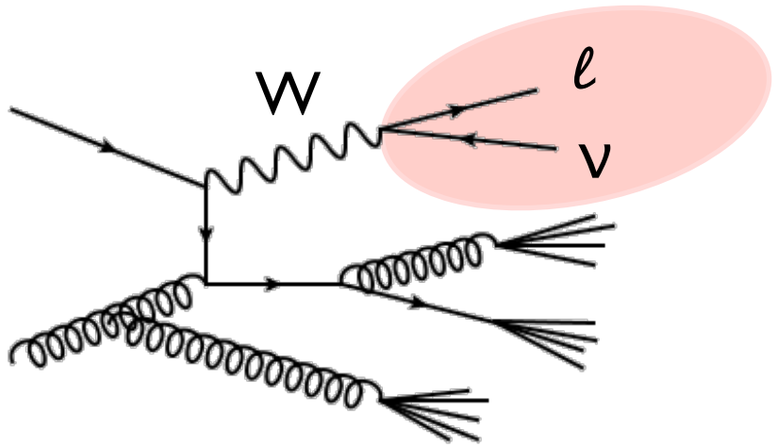


Physics Backgrounds : Jets+MET Search

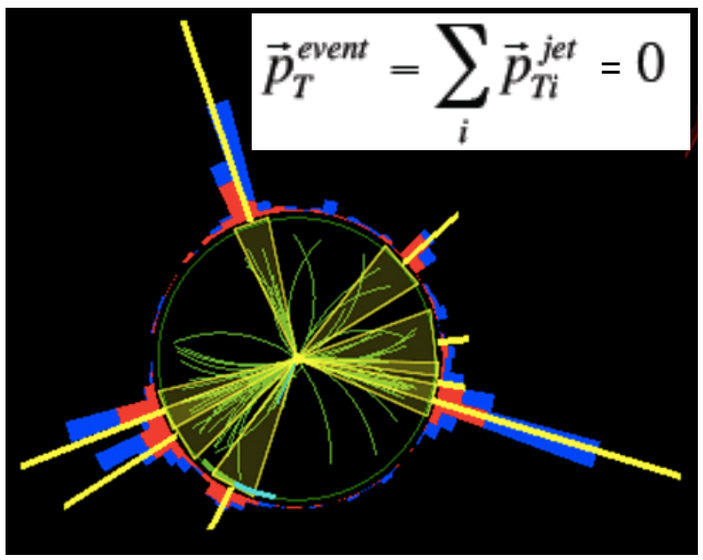
- Z + Jets
  - with Z decaying to neutrinos

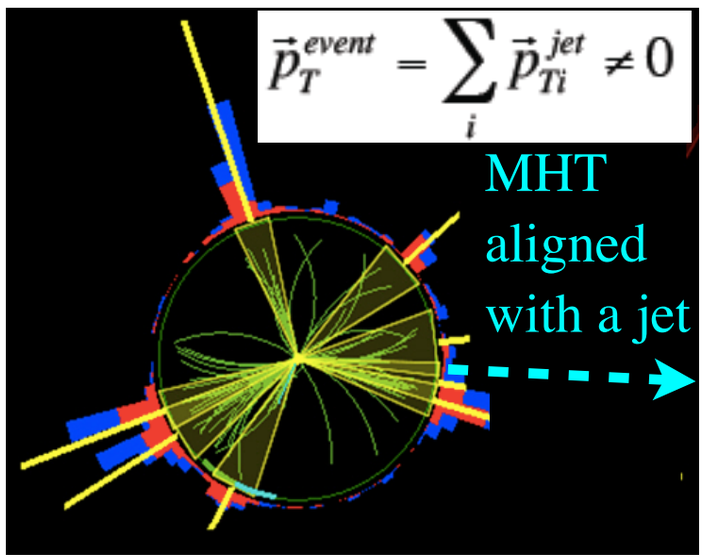


- W/top + Jets
  - t → W (→ lost lepton + ν) + Jets :
    - W decays leptonically and e/μ is not detected or reconstructed
  - t → W (→ hadronic τ + ν)+ Jets :
    - W decays to τ+ν and τ decays hadronically



- QCD MultiJets
  - jet mis-measurements
  - semi leptonic decays of b or c quarks

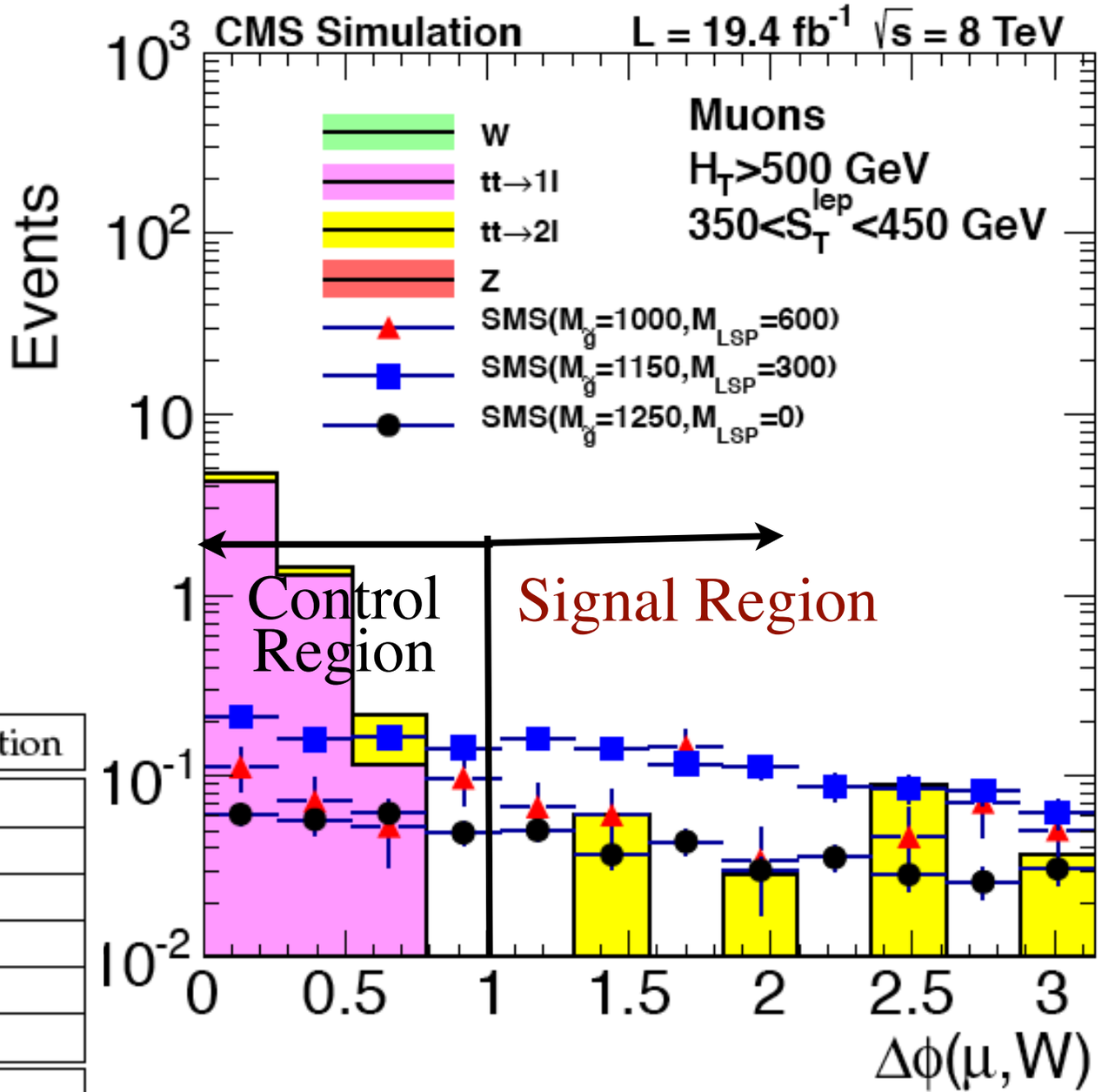




1-Lepton Search for Gluino Mediated Stops

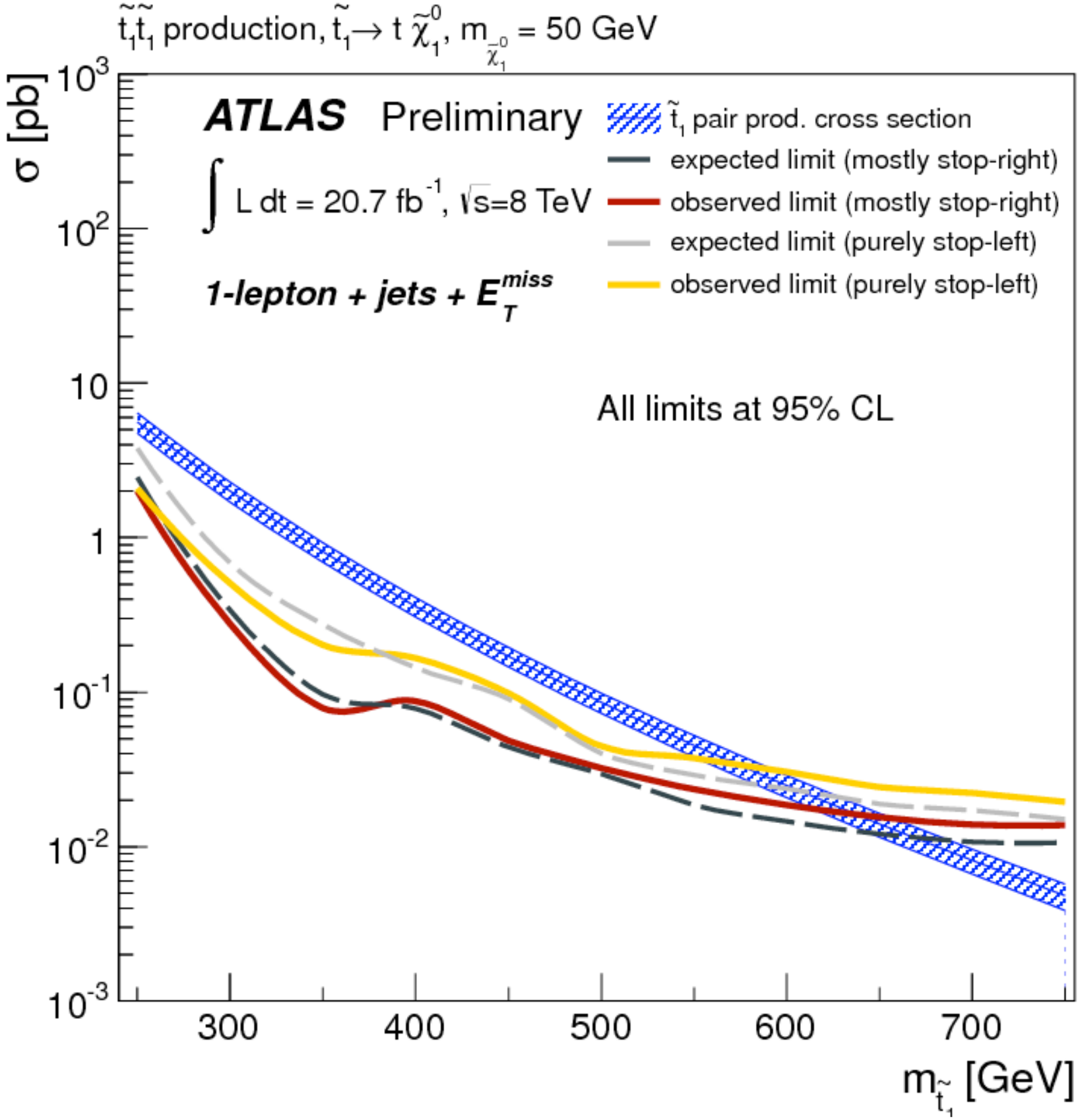
Event Selection
Exactly one isolated e or μ
b-jets = [2], [≥3] (binned)
NJets ≥ 6 jets
$\Delta\Phi(\mu, W) > 1.0$
Search bins in ST (MET+Pt(l), MET
Main backgrounds : dileptonic ttbar

CMS-SUS-13-007 19.4 fb^{-1}

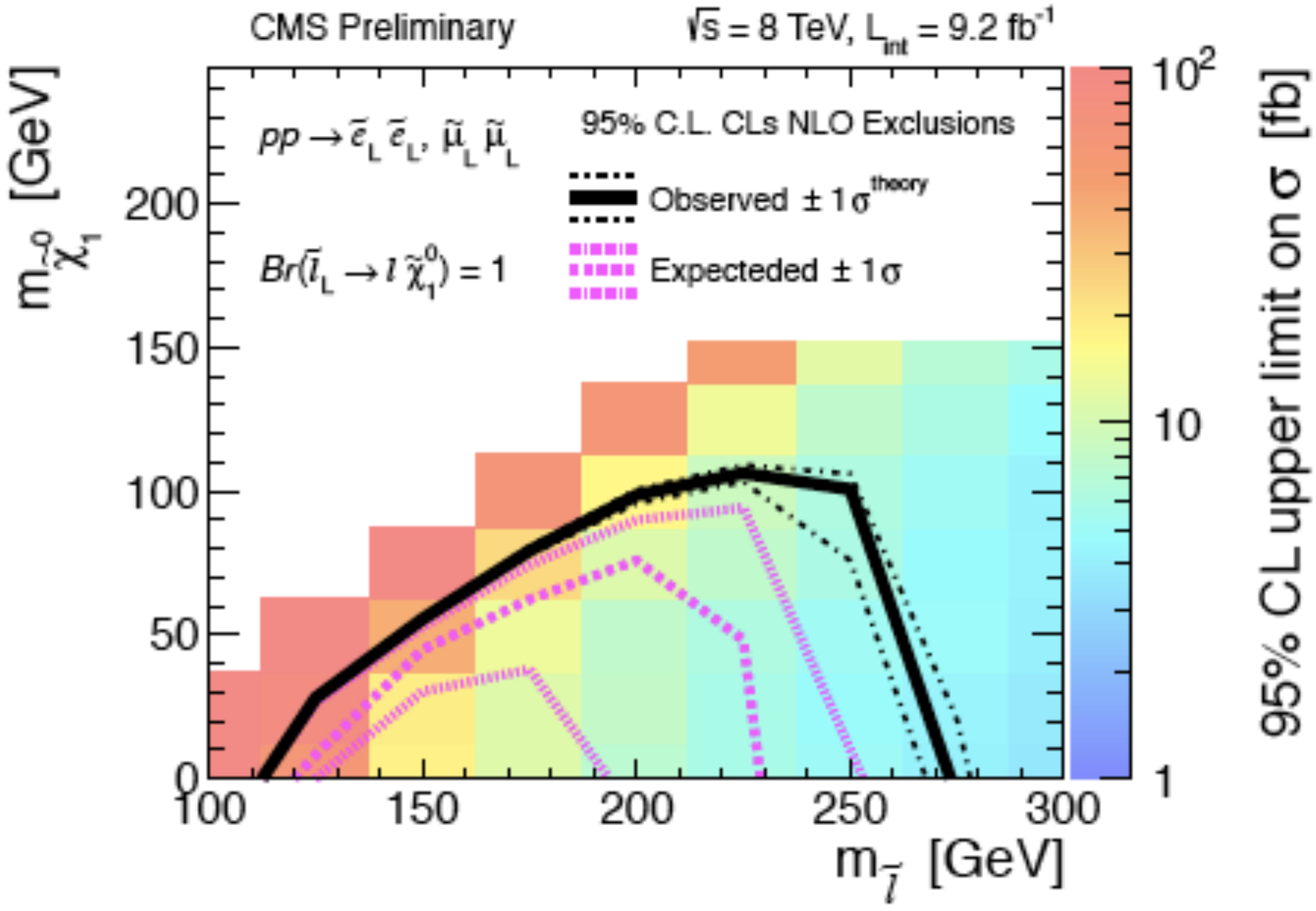


		S_T^{lep} [GeV]	control reg. data	prediction	observation
N_b=2	Muons	[250,350]	632	41.94± 5.63	59
		[350,450]	188	8.51± 2.39	11
		> 450	71	2.46± 1.32	1
	Electr.	[250,350]	548	34.23±5.37	30
		[350,450]	174	5.11±1.85	8
		>450	61	5.57±2.14	1
$N_b \geq 3$	Muons	[250,350]	59	3.88±0.81	5
		[350,450]	25	1.09±0.44	0
		> 450	7	0.26±0.21	0
	Electr.	[250,350]	70	3.91±0.92	2
		[350,450]	12	0.32±0.16	2
		>450	4	0.32±0.24	0

Dependence of limits on Chirality of Stop

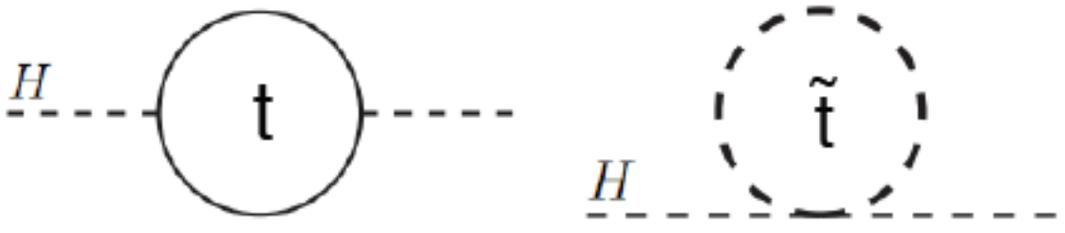


Search for Pairs of Sleptons : Summary

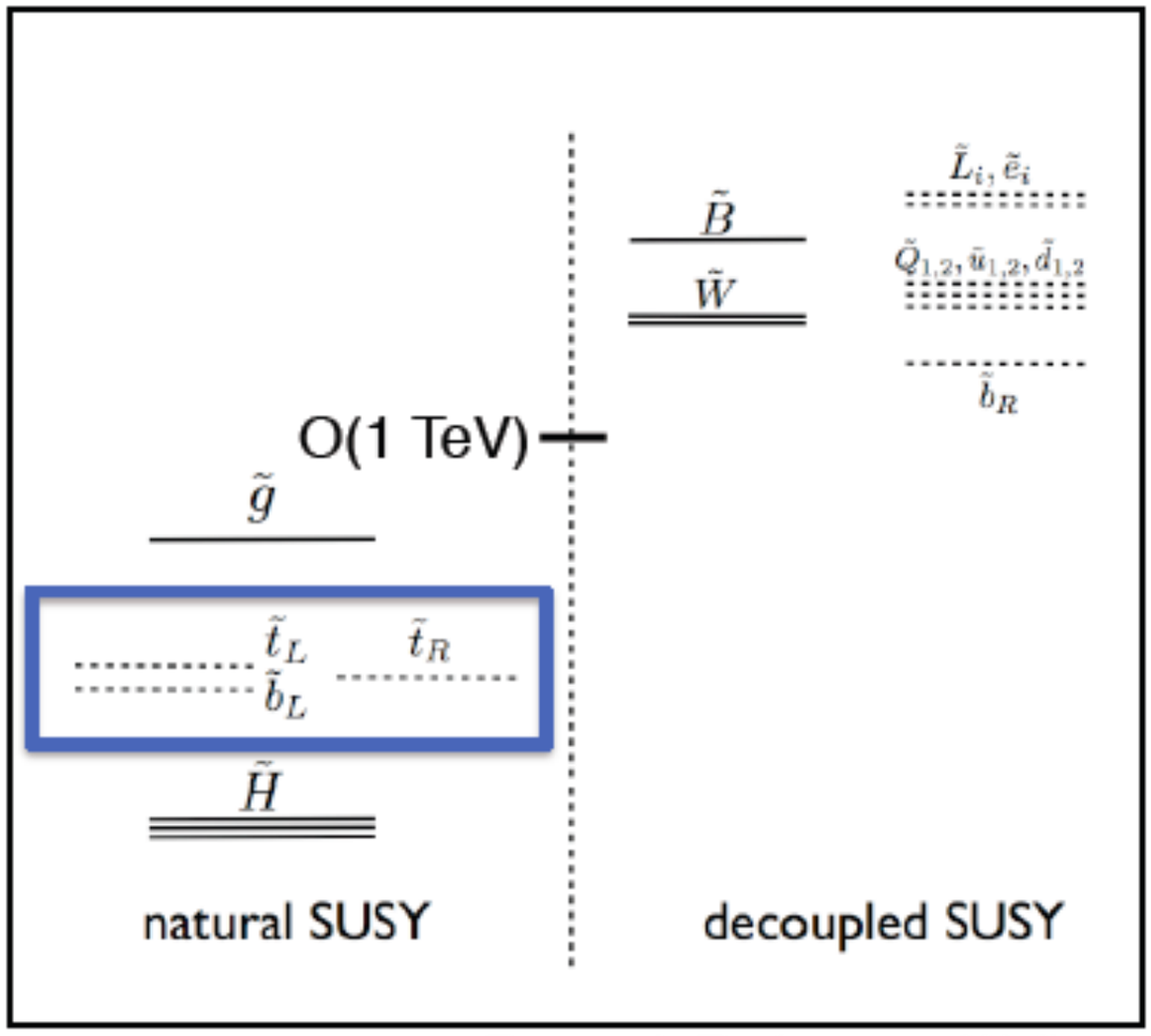


Naturalness & SUSY searches

- "Naturalness" says there is no fine tuning of parameters.



- Expect top-squarks < 1 TeV
- Left-handed bottom-squark must also be light due to weak isospin symmetry.
- Gluinos required to be $\mathcal{O}$(1 TeV) to keep corrections to stop mass small.

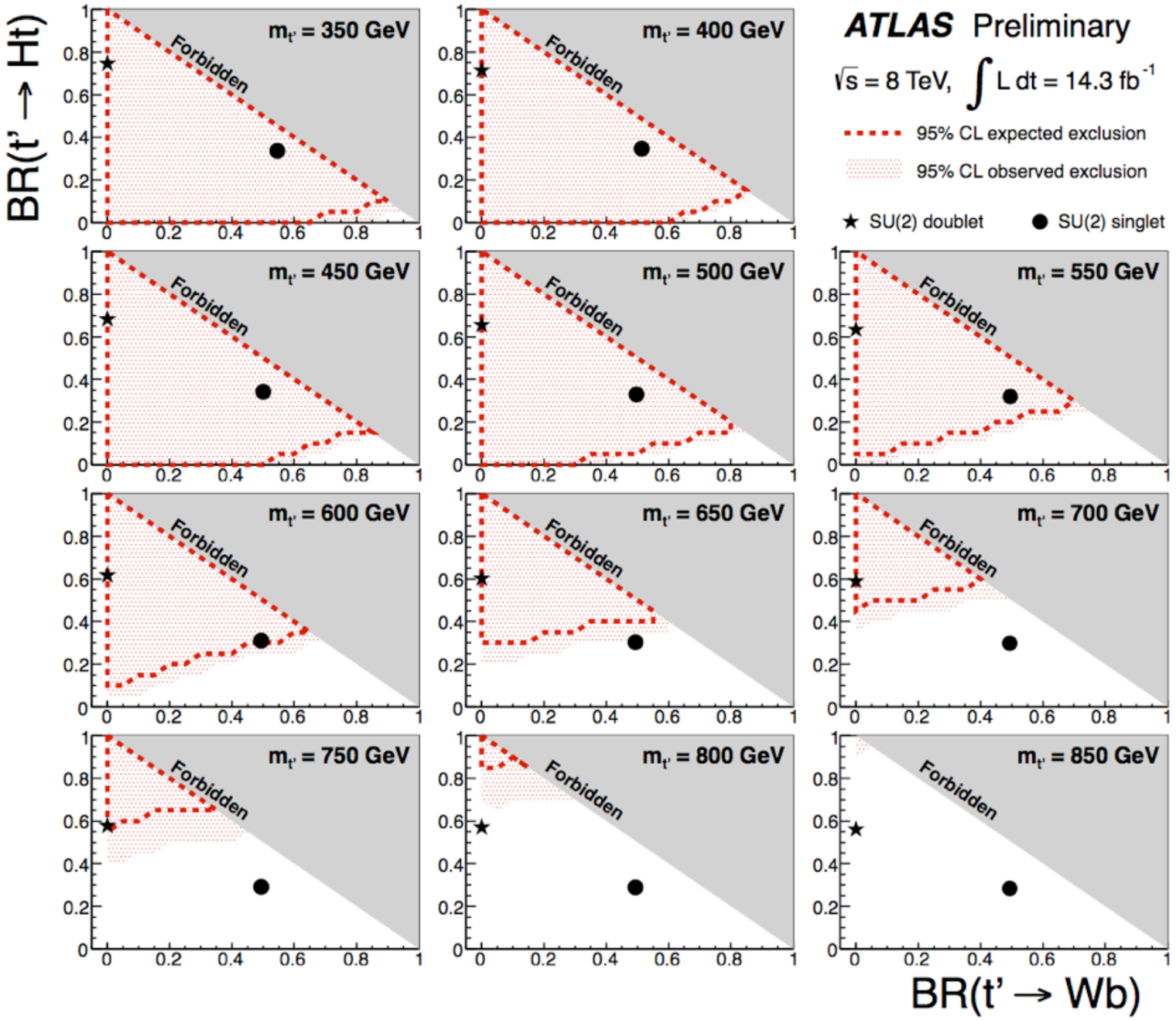


Papucci, Ruderman, Weiler
CERN-PH-TH/265

Focus more on 3rd generation squark searches both for dedicated searches and interpretation on inclusive searches.

Search for Vector-like t' : Results

Limits are also set for different t' mass as a function of two branching ratios BR(t' -> Wb) and BR(t'->Ht).



$$BR(t' \rightarrow Zt) = 1 - BR(t' \rightarrow Wb) - BR(t' \rightarrow Ht).$$