View on recent results of ATLAS and CMS

Paris Sphicas
CERN & University of Athens
Amsterdam Particle Physics Symposium
Nov 30, 2011

- **Prelude – reasons for this talk**
  - **(High) expectations from the LHC**
- **A quick tour of pp collisions at 7 TeV**
  - **Strong interaction physics (jets, QCD); Electroweak signals (W/Z production & properties); The top quark (still there)**
- **Searching for New Physics**
  - **Closing in on the Higgs; evidence for new physics!**
  - **Where is SUSY? Searches for exotica**
- **So what next? More data (lumi?); higher energy?**
- **Summary**

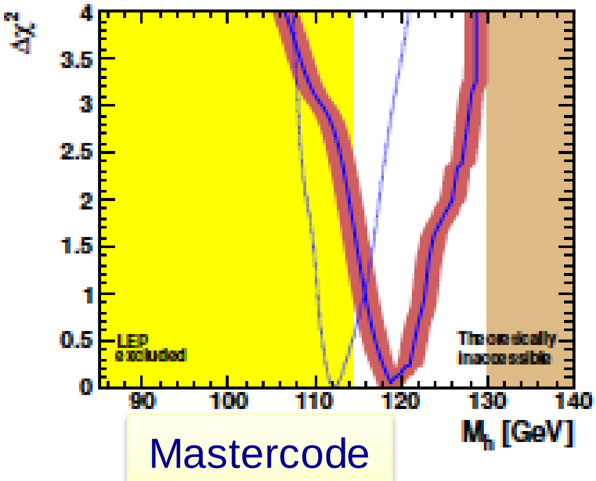
Summary of the talk (I)

- **At 95% CL:**
  - APPS participants are aware of the fact that the LHC has had a spectacular year, breaking luminosity records and all expectations
  - Most people are aware of the incredibly successful operation of ATLAS and CMS
  - Standard model (SM) of particle physics reigns supreme in pp collisions at 7 TeV
  - The mass of the SM Higgs boson is not in the ranges M_H<114 or M_H>141 GeV
  - R_P-conserv: gluinos, $1^{st}/2^{nd}$-gen squarks, not lighter than ~0.5TeV
  - There exist no new resonances with mass <~2 TeV
  - There are no spectacular signatures from objects of mass ~few TeV decaying "democratically" to lots of jets, MET, leptons....
  - Most of the information in this talk is already well known
  - Standard model of human behavior reigns supreme in pp collisions at 7 TeV (some level of worry has set in; still in control)

Summary of the talk (II)

- **At 100% CL, all the reasons for building the LHC are still there, intact:**
  - **The WW cross section regulator is still missing. (S)he must be there before we explore fully the 1 TeV.**
    - **Old name: "LHC no-lose theorem"; new name: "not finding the Higgs is a major discovery"**
  - **Any (reasonable) M_H unnatural; Higgs needs its own regulator**
    - **Old name: SUSY; New name: SUSY; its main prediction is (so far) vindicated ☺**
    - **Old CW: SUSY around the corner; New CW: she's in the third generation (stop, sbottom)**
  - **Other stuff:**
    - **Extra-dimension physics, new gauge bosons, leptoquarks, fourth fermion Generation, quark substructure…**

      Still huge space of unexplored physics
- **The best has yet to come – read on.**

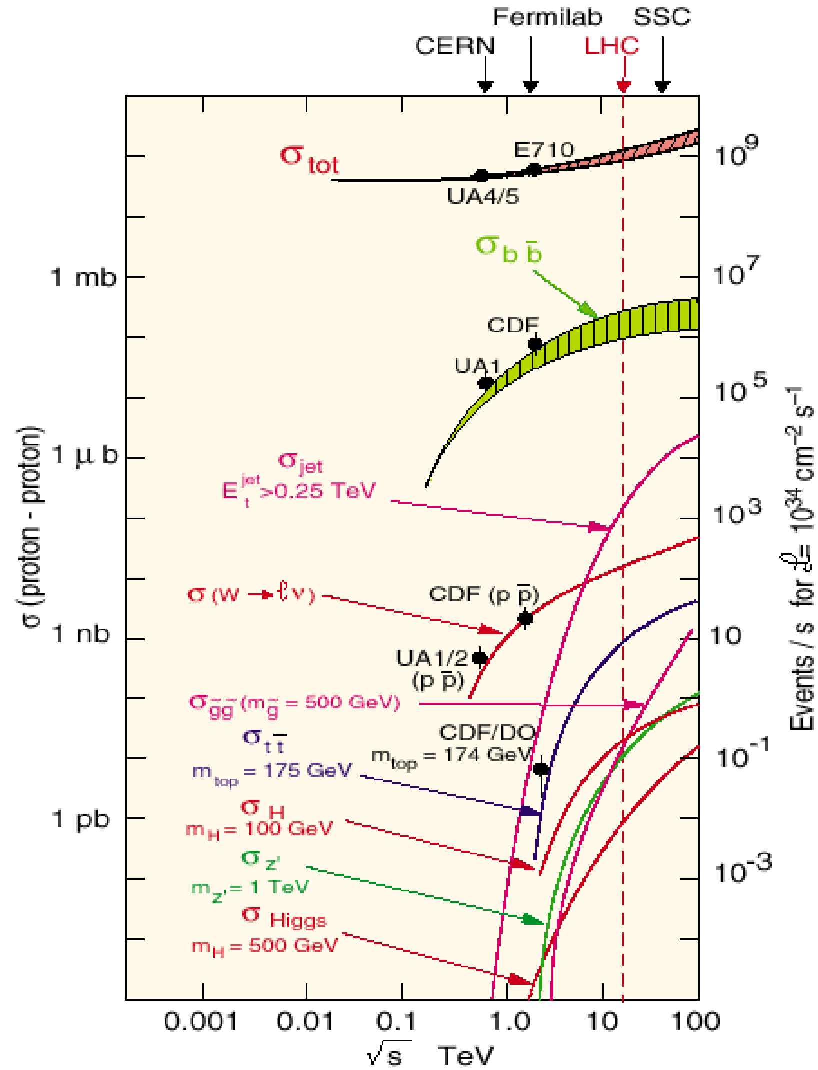


What was (and still is) expected from the LHC?

The question: why where the “expectations from the LHC” so, so very high?

What (new elements) the LHC experiments bring in

- **All that has been developed and learned up to “now” is “in” CMS and ATLAS**
  - **With the exception of track and vertex triggering [UPGRADES!]**
  - **The precision of all devices and their coverage represents major steps forward with respect to the previous generation**
- **There are two major new elements brought in:**
  - **Tough: rad-hardness; can withstand huge luminosities**
  - **Quick: can process 100 kHz of Lvl-1, can store 500-1000 Hz**
- **Both summarized in “extreme selectivity”**



30 years (1980-2010) spent in looking for the "completion or the breakdown of the Standard Model"

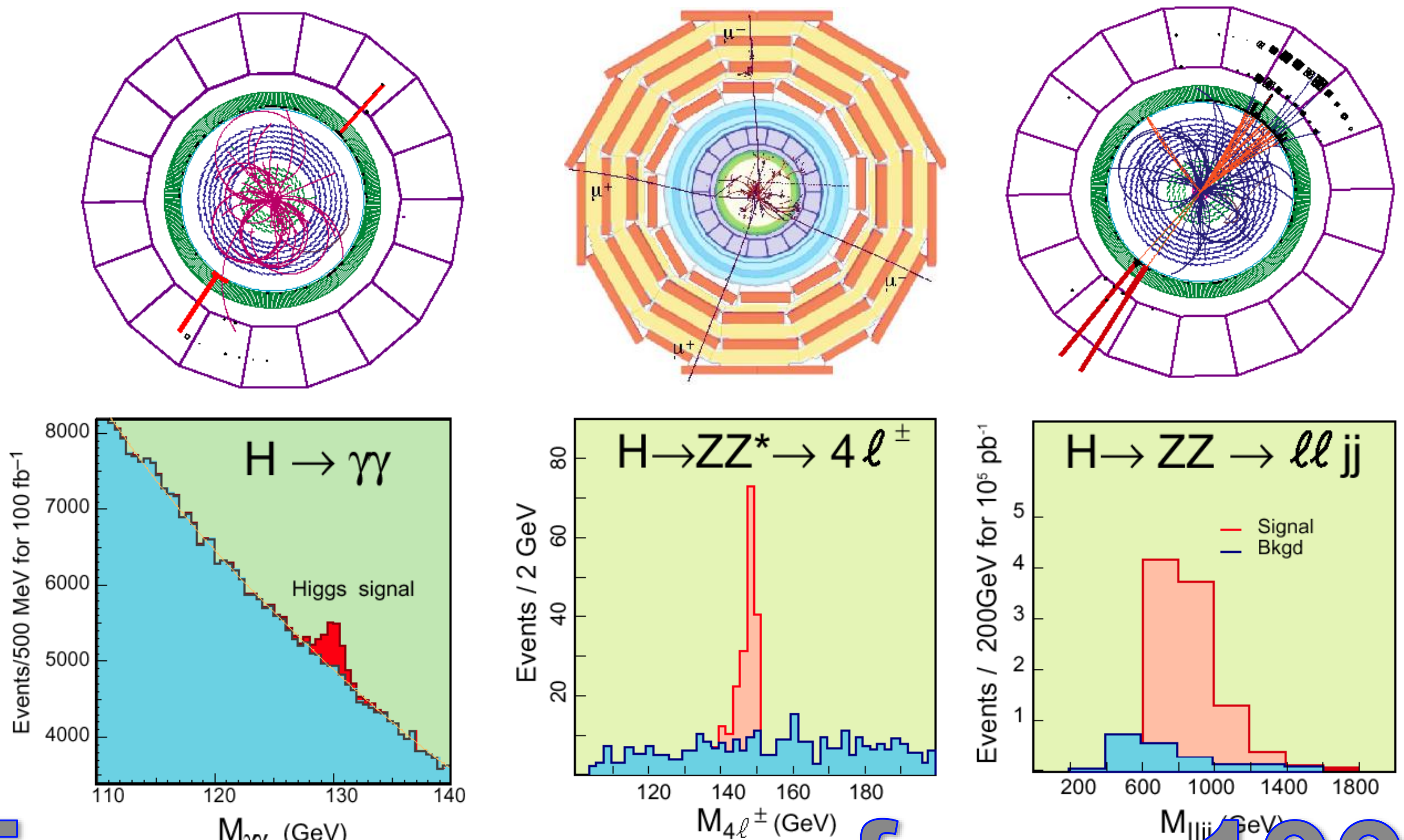
One machine that-was-not-to-be (SSC)
One machine-that-was-to-be (LHC)

And in between, we were told to "excite the public"
(and excite we did: outreach information is up by two orders of magnitude)

Conventional Wisdom (pre-LHC startup):
"Turn on the LHC and find Higgs & SUSY"

"Turn on the LHC and find Higgs & SUSY"

- **ATLAS and CMS were designed to do this; they were (are) "guaranteed" to find the Higgs – . ; "easily".**

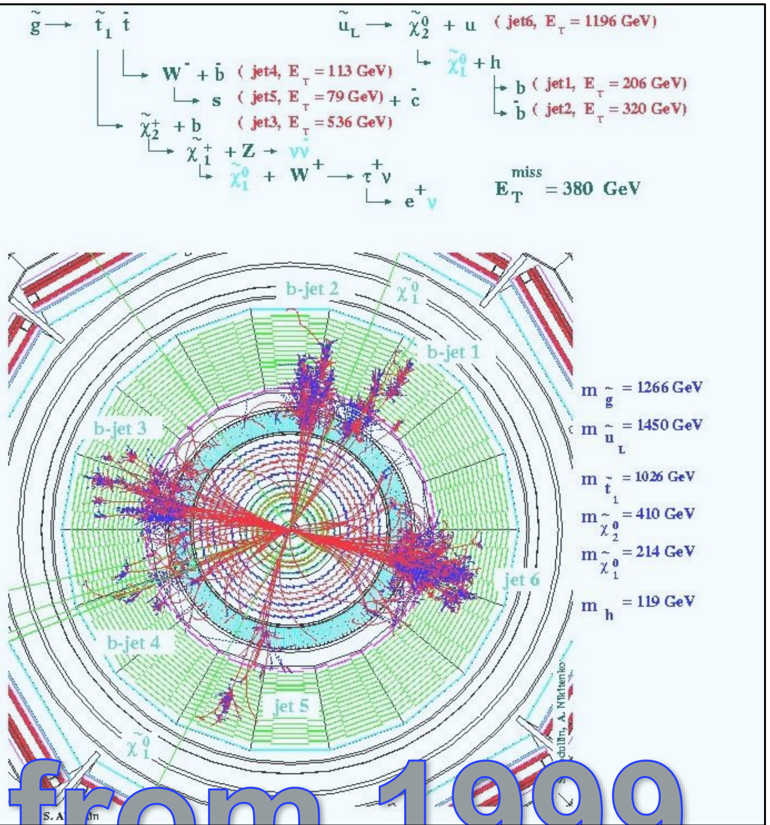


Transparency from 1997

"Turn on the LHC and find Higgs & SUSY"

- **ATLAS and CMS were designed to do this; they were "guaranteed" to find the Higgs – period; right away**
  - **In fact: SUSY is strongly produced, so will be observed first**
    - **For the "impatient": join SUSY physics group**

- **Many hard Jets**
- **Large missing energy**
  - **2 LSPs**
  - **Many neutrinos**
- **Many leptons**
- **In a word Spectacular!**

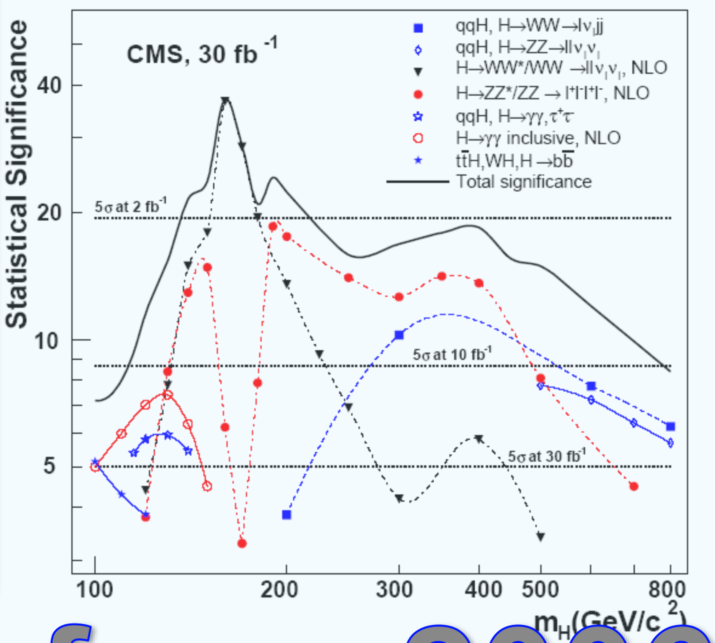


Text & simu from 1999

"Turn on the LHC and find Higgs & SUSY"

- **ATLAS and CMS were designed to do this; they were "guaranteed" to find the Higgs – period; right away**
  - **In fact: SUSY is strongly produced, so will be observed first**
    - **For the "impatient": join SUSY physics group**
    - **For the "patient" ones: join the Higgs group**

- **The LHC can probe the entire set of "allowed" Higgs mass values;**
  - **in most cases a few months at $10^{33} cm^{-2} s^{-1}$ are adequate for a 5σ observation**



Text & simu from 2006

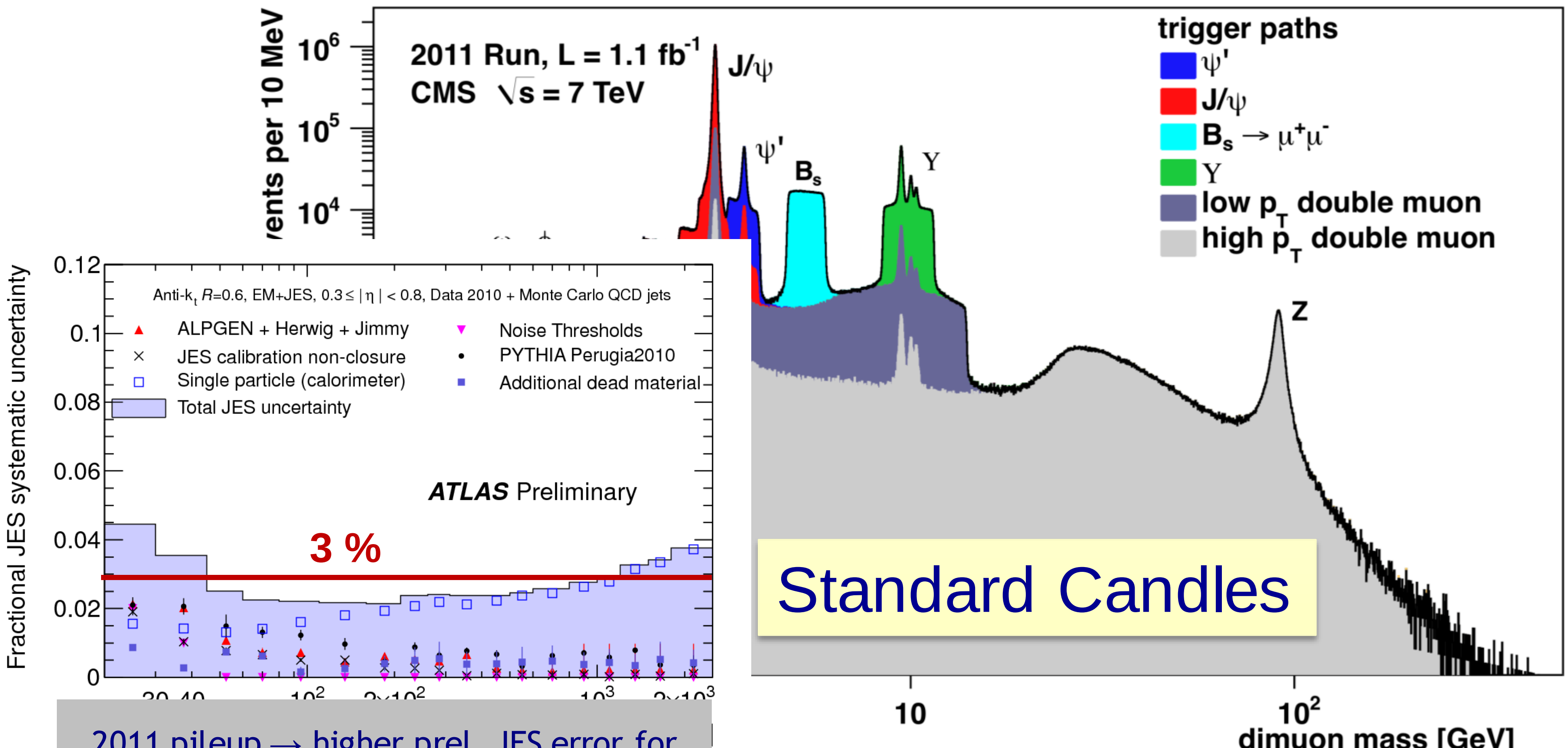
Turn on the LHC and find Higgs & SUSY

- **ATLAS and CMS were designed to do this; they were "guaranteed" to find the Higgs – period; right away**
  - **In fact: SUSY is strongly produced, so will be observed first**
    - **For the "impatient": join SUSY physics group**
    - **For the "patient" ones: join the Higgs group**
  - **For all others:**
    - **For those who like smaller analyses: join the Exotica group**
    - **For those who like finding something:**
      - **➔ QCD, EWK, B physics, …**

Surprise #1

Really fast turn-on: detector performance

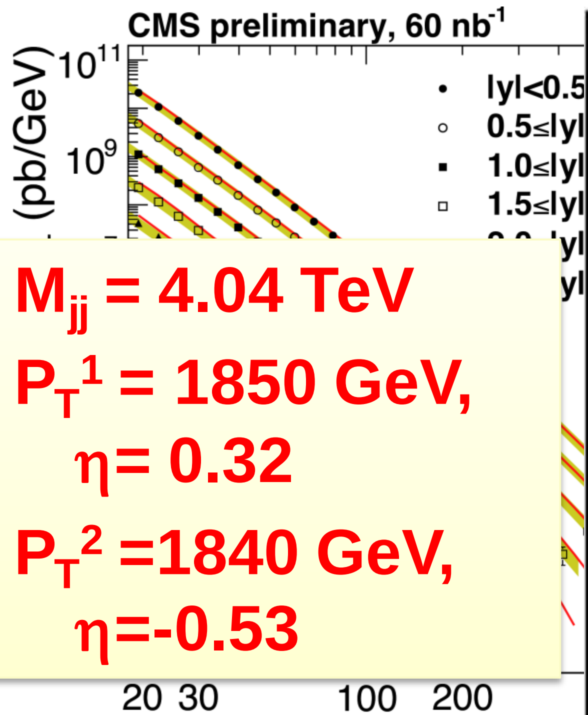
- **The startup of the experiments was the biggest discontinuity with the past: it was fast and efficient.**



2011 pileup → higher prel. JES error for E_T<100 GeV jets (±2-5% for |η|<2.1)

So what followed?
The LHC Tour de Force

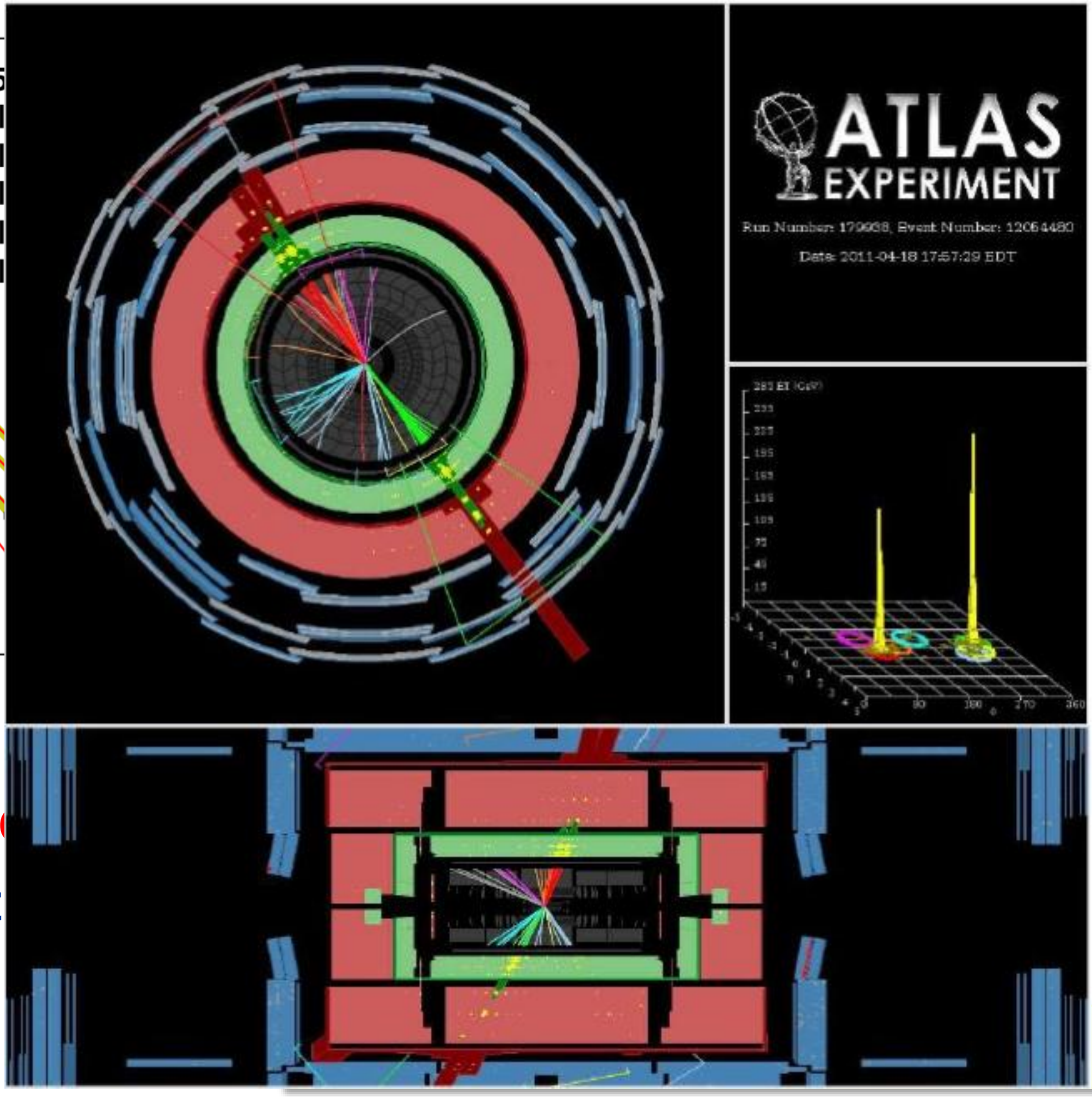
Jets



M_{jj} = 4.04 TeV

P_T^1 = 1850 GeV, η= 0.32

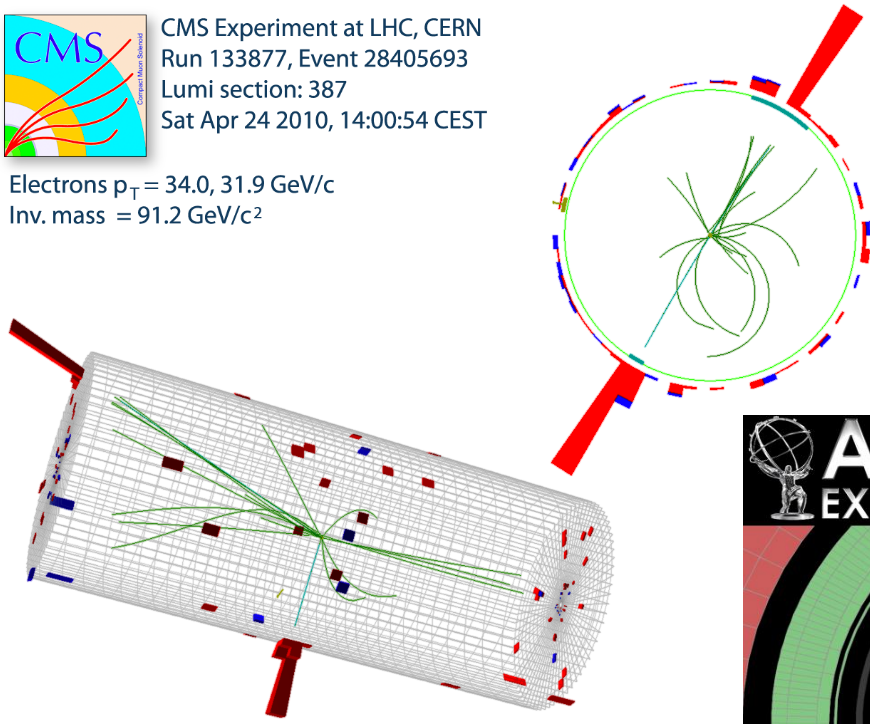
P_T^2 =1840 GeV, η=-0.53



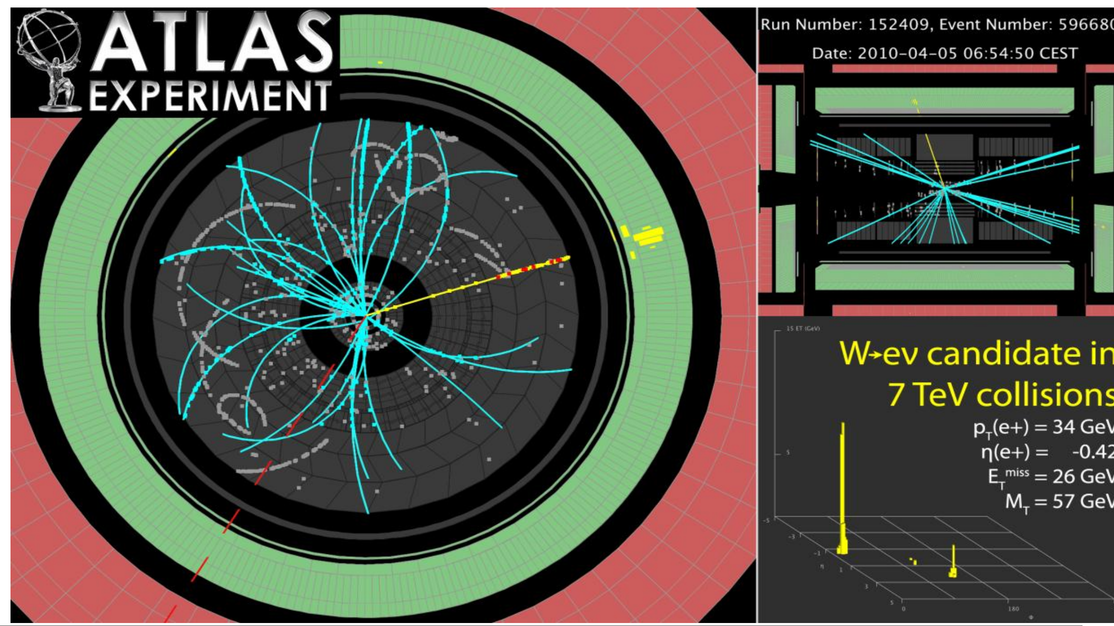
- **To probe the hard sc**
  - **The hard scatter: jet**

W/Z at 7 TeV: (still) clean & beautiful

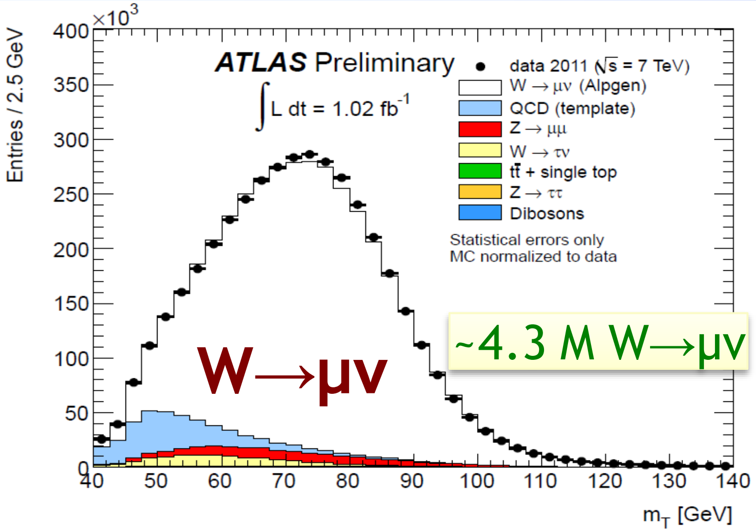
Z → electron + positron

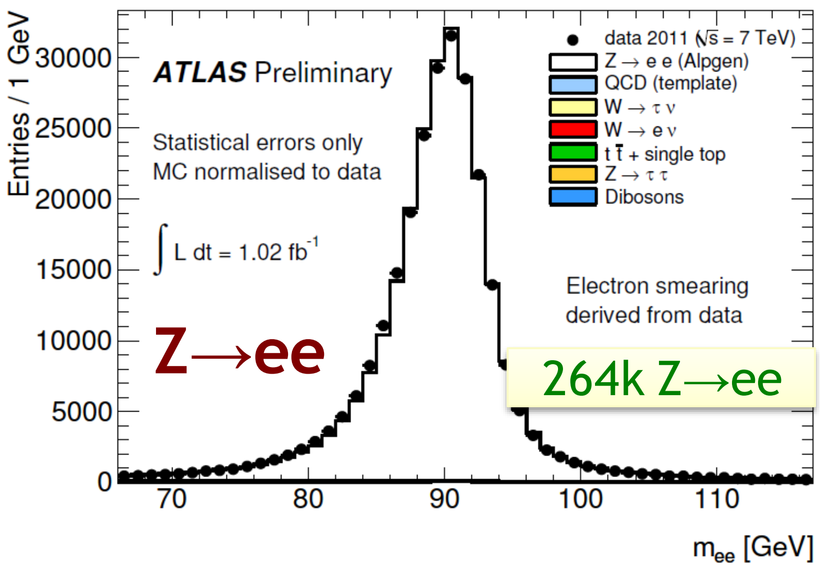


W → electron + neutrino

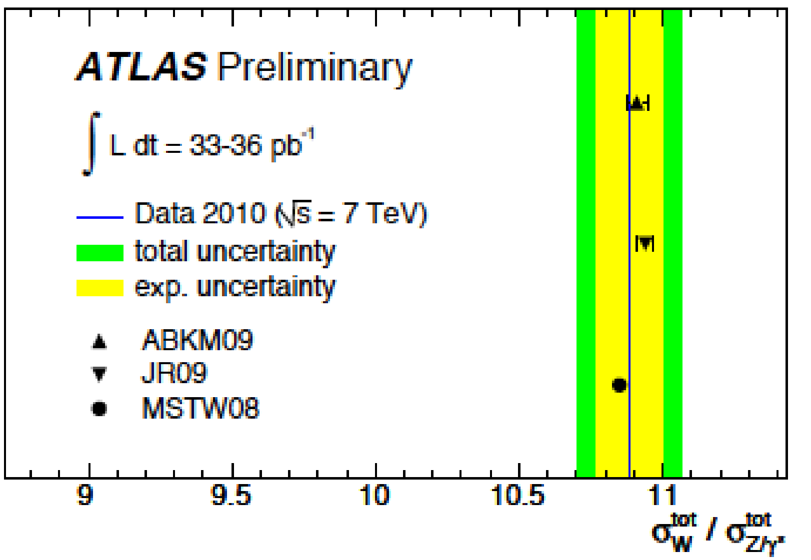


W/Z production (+LHC-specific obs)





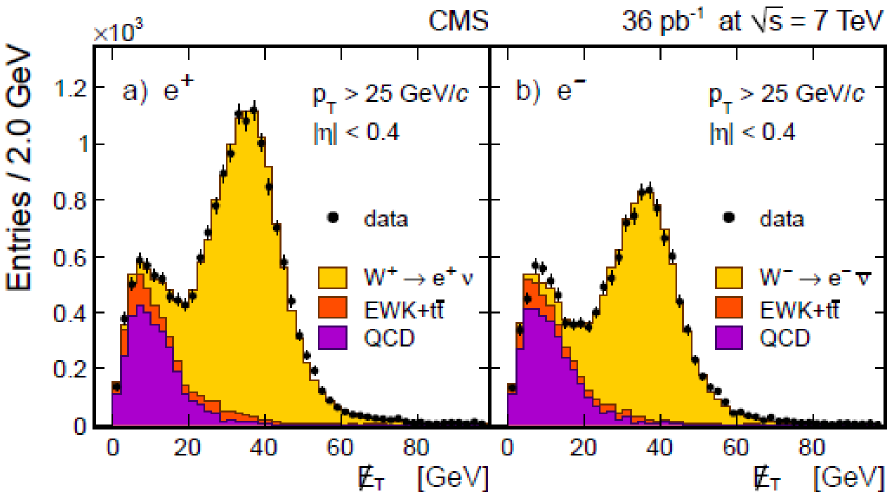
- **Excellent agreement between data and simulation**
- **Good agreement with NNLO+PDF theory predictions**



- **Move to "new environment":**
  - **$\sigma(W^+) \neq \sigma(W^-)$ (~1.4)**
  - **W polarization**

W production: charge asymmetry

- **Split samples in η; fit W⁺, W⁻.**



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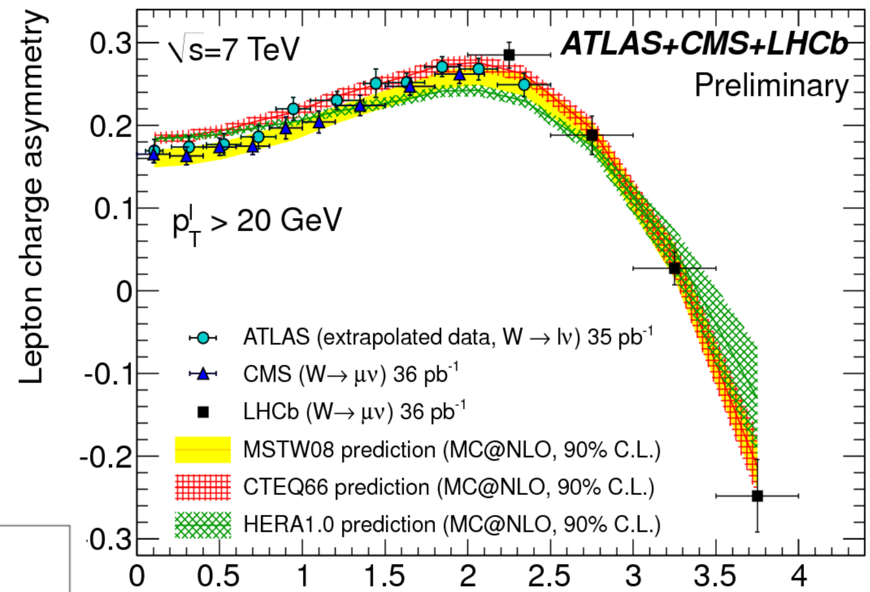
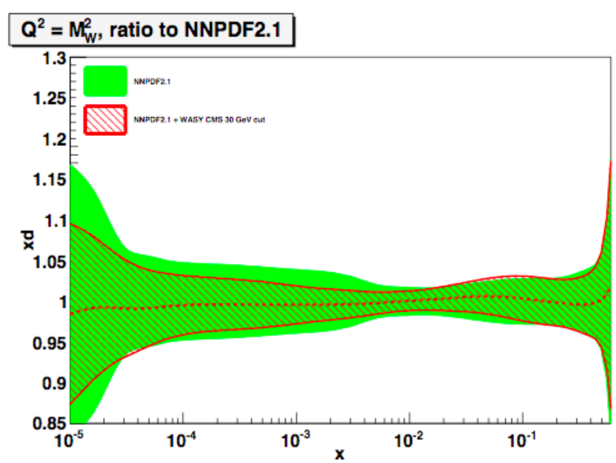


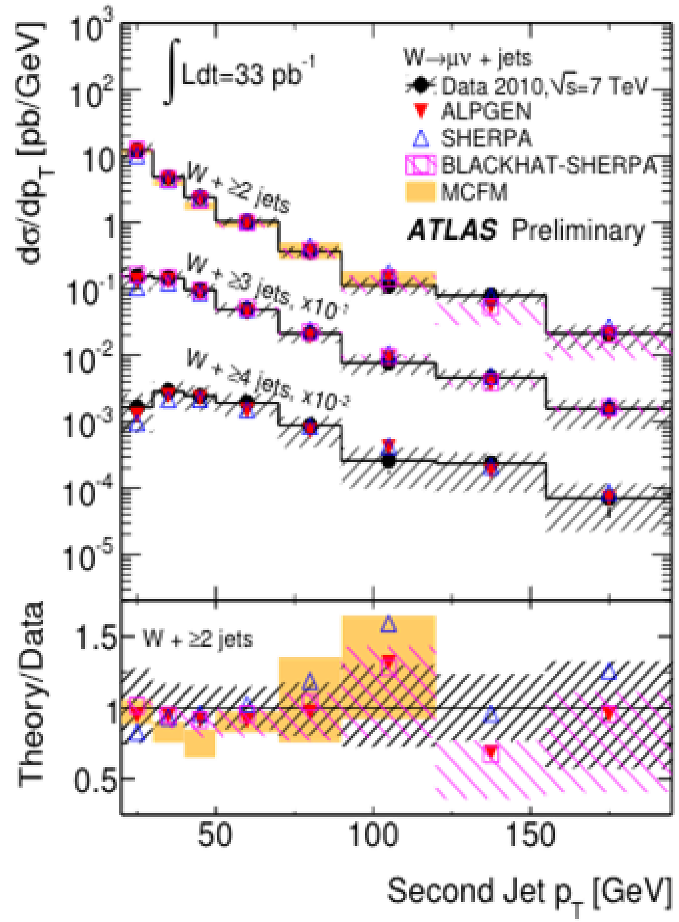
ATLAS-CONF-2011-129
LHCb-CONF-2011-039
CMS-EWK-10-006 (aXiv:1103.3407)

In $10^{-3} < x < 10^{-2}$: measurement already improves d,u,q-bar PDFs by >40%

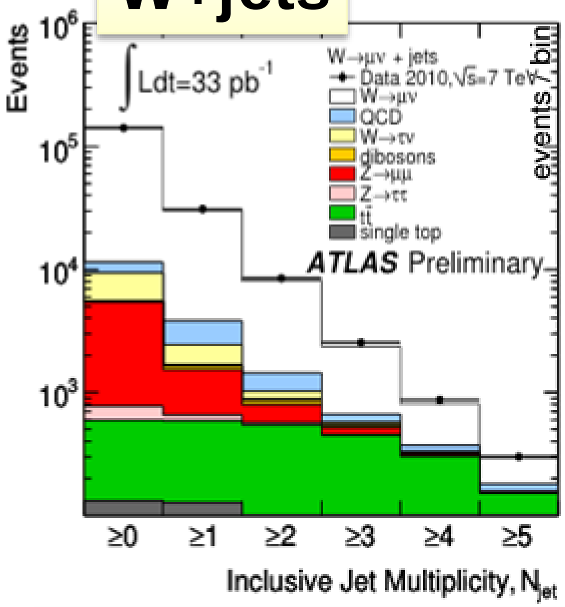


W/Z + jets

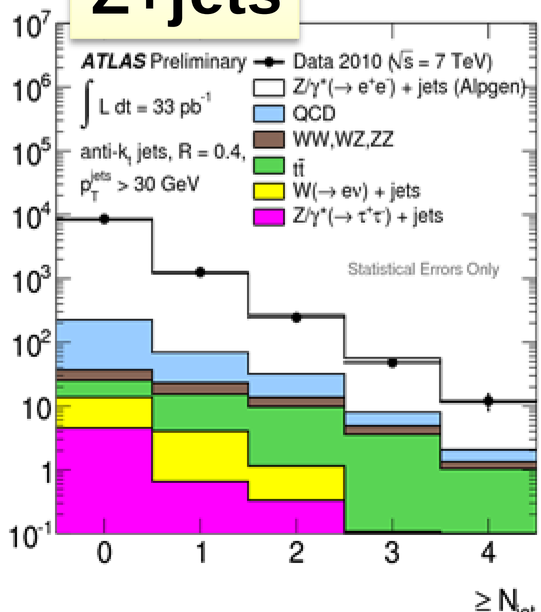
- **Background for top and new physics; especially at high p_T(W/Z); each jet "costs" ~α_s**
- **Jet multiplicity and p_T distributions**
  - **Good description by state-of-the art QCD NLO calculations and LO multi-parton generators**



W+jets

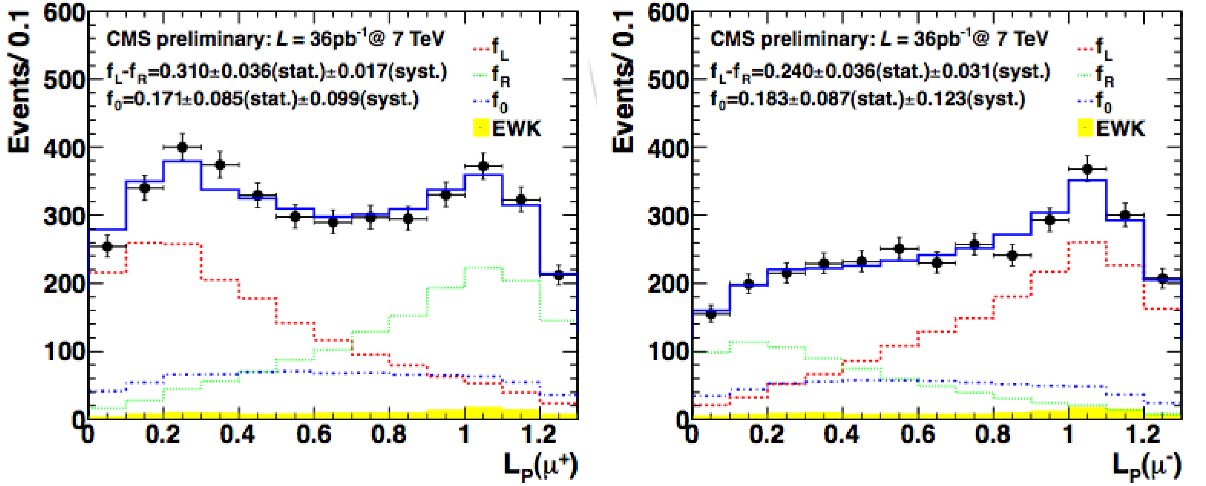


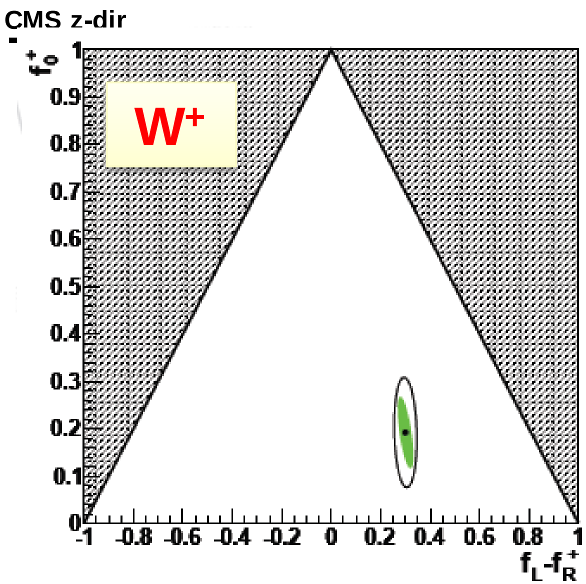
Z+jets

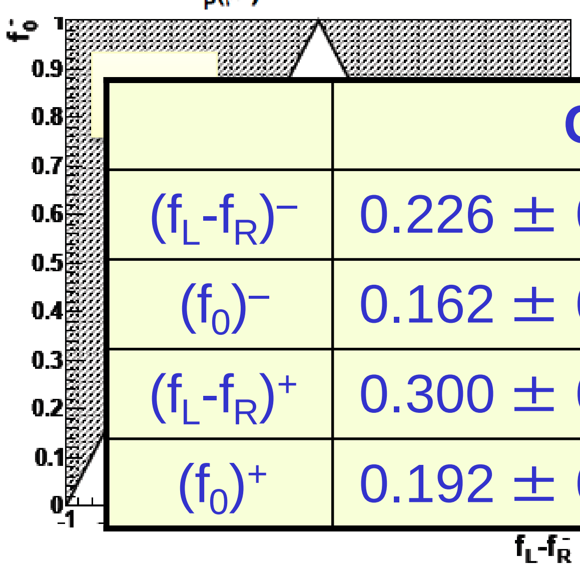


LHC-specific: W polarisation in pp

- Prod
  - Va … arisation
    eff
  - Ini … ual amounts
    at
  - ➔ W





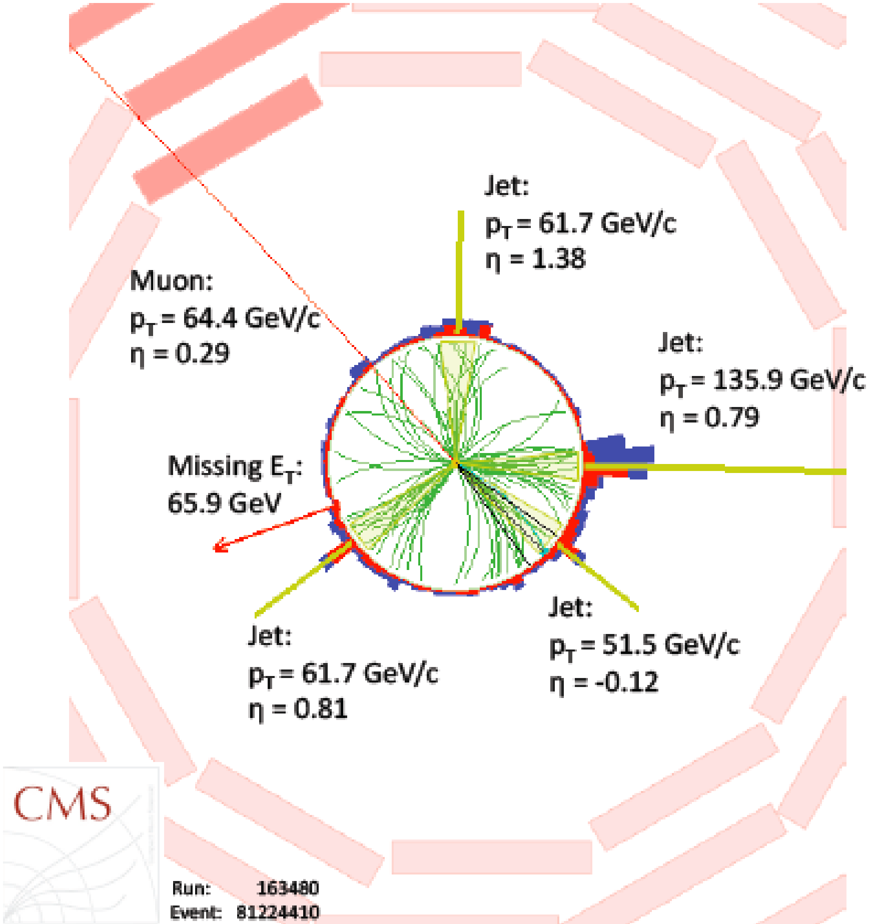


	Combined Result
$(f_L\text{-}f_R)^-$	0.226 ± 0.031 (stat) ± 0.050 (syst)
$(f_0)^-$	0.162 ± 0.078 (stat) ± 0.136 (syst)
$(f_L\text{-}f_R)^+$	0.300 ± 0.031 (stat) ± 0.034 (syst)
$(f_0)^+$	0.192 ± 0.075 (stat) ± 0.089 (syst)

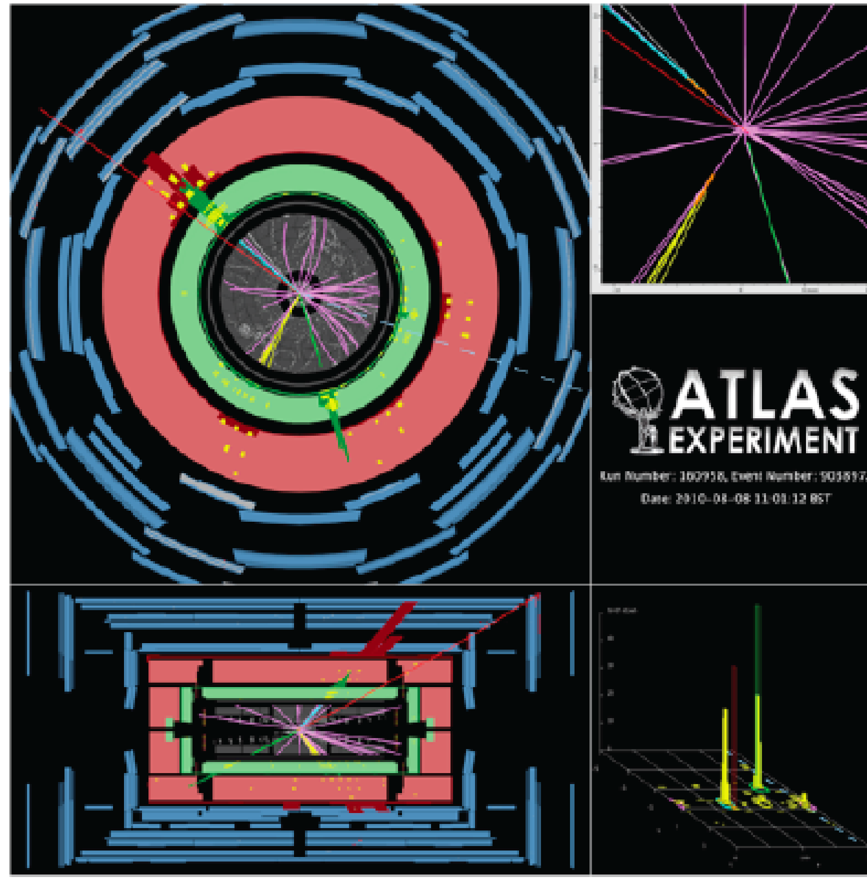
at LHC (not a Feynman diagram)

…cosθ* (missing neutrino)

The most complex SM signal: the top



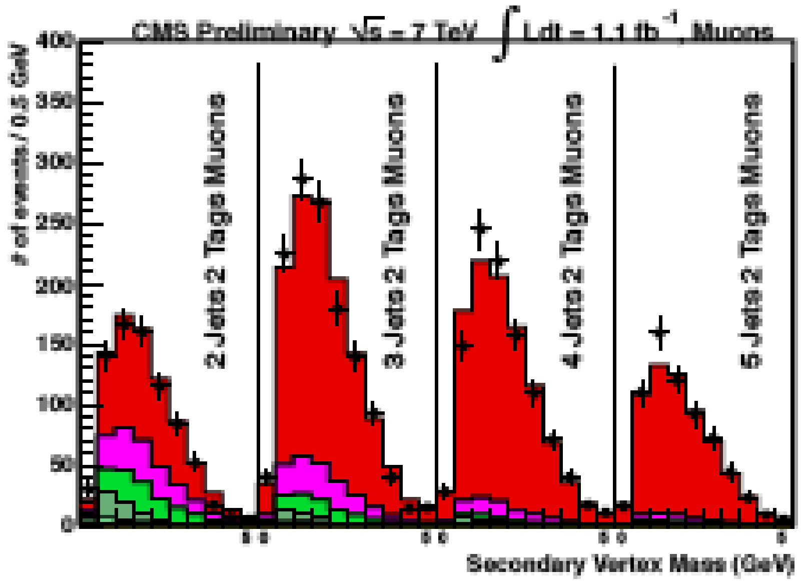
muon+jets event

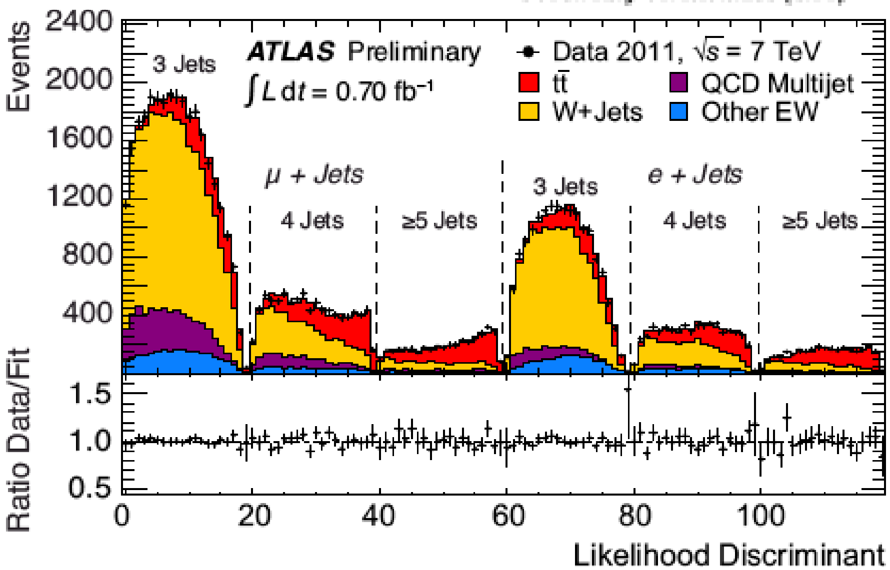


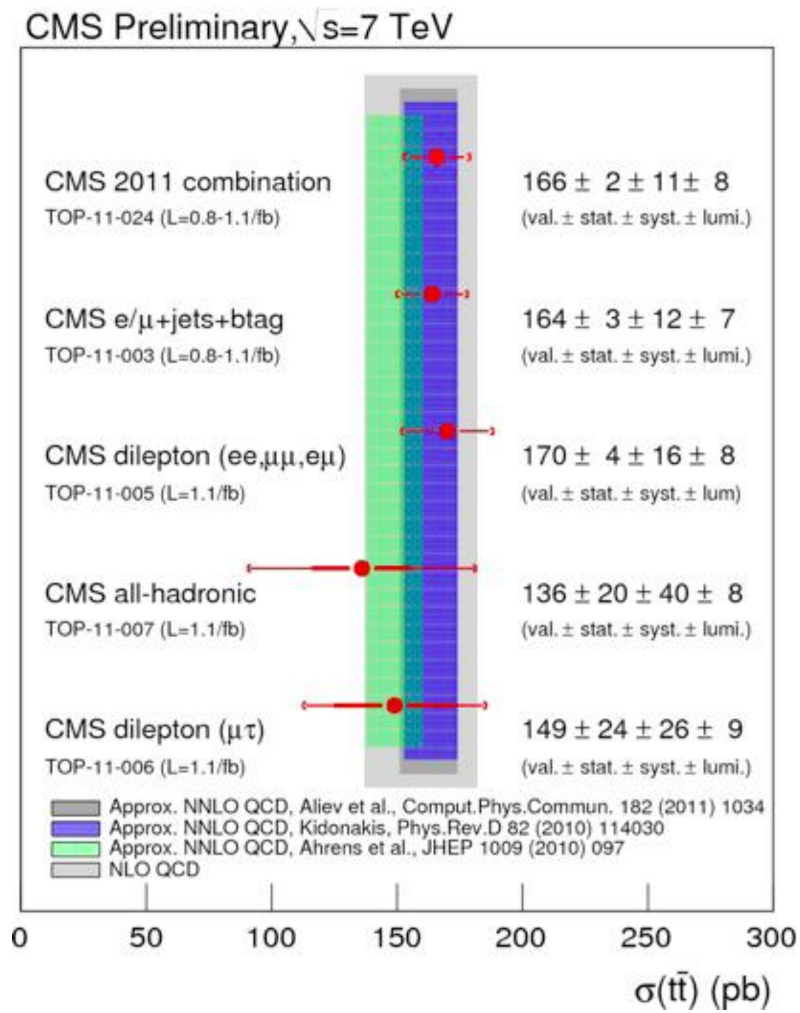
electron+muon event

HCP at Paris, 14/11/2011 3 Tae Jeong Kim

Top physics @ 7 TeV

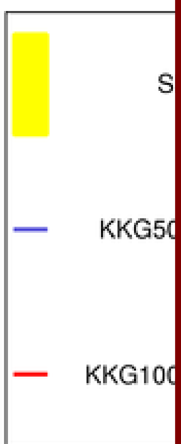


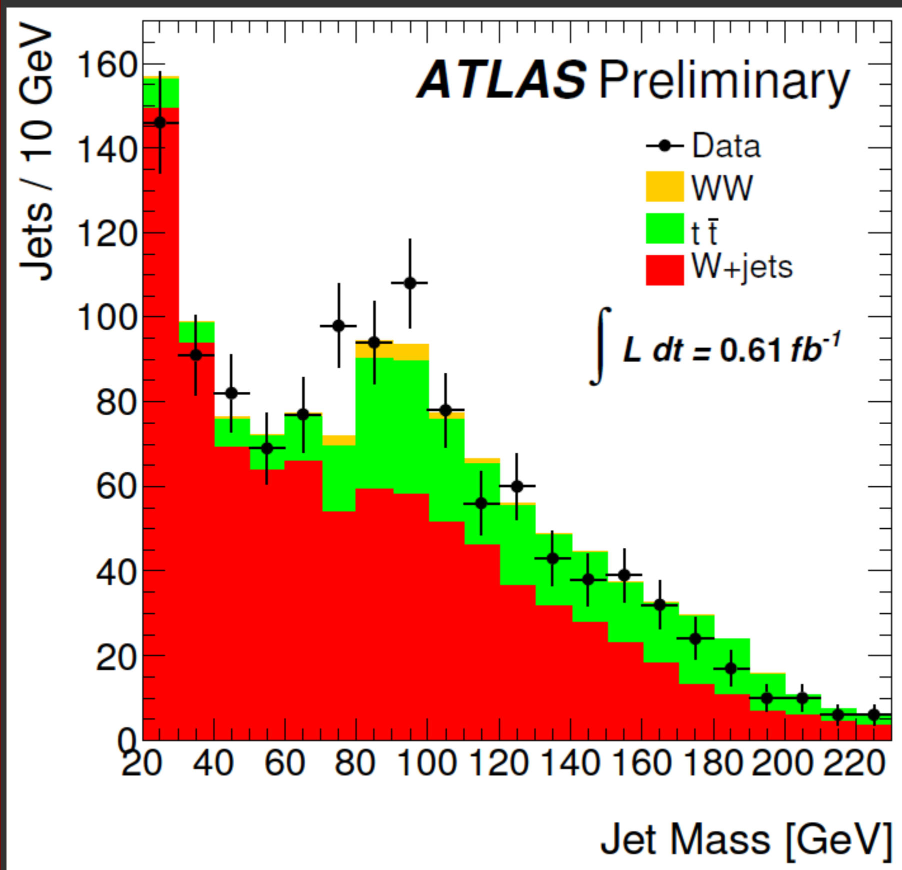




The biggest new tool: jet substructure

- R
  d





Events with $W \to \ell\nu$ with $p_T(W)>200$ GeV

Mass distribution of split & filtered subjets with $p_T>180$ GeV

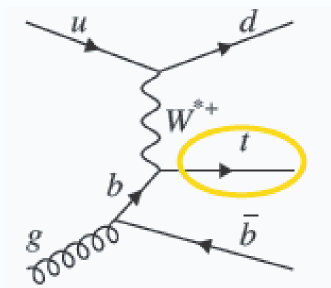
Evident hadronic W peak from boosted tt

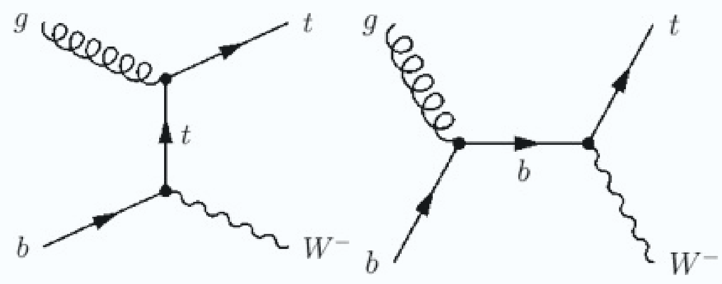
Promising for the future

Next stop: High-P_T VH!

Small, tricky signals as well

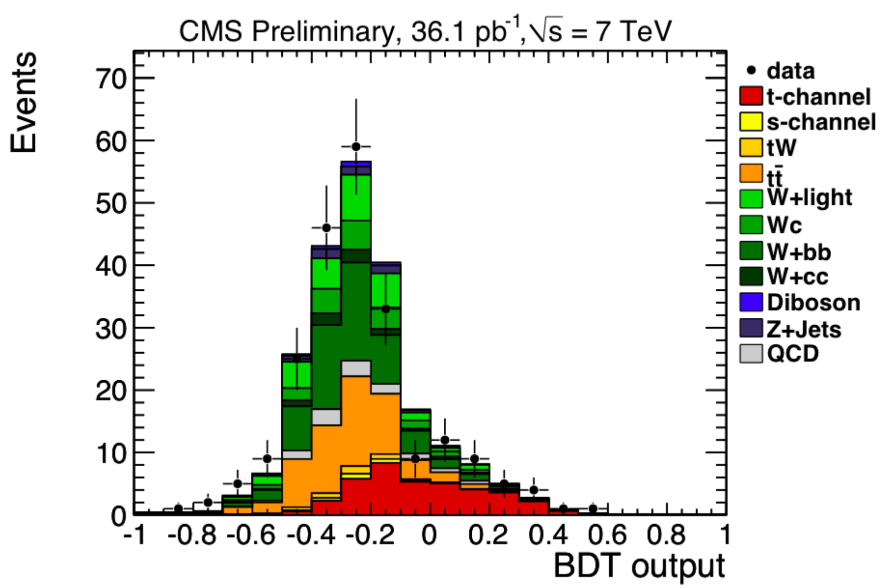
- **Single-top production**

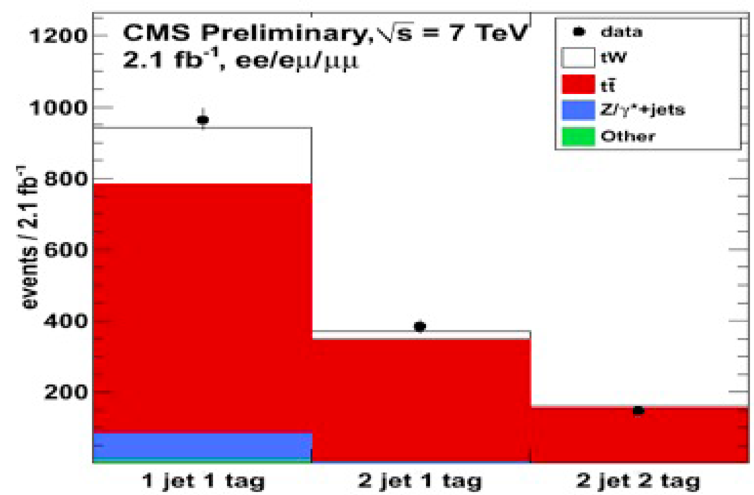




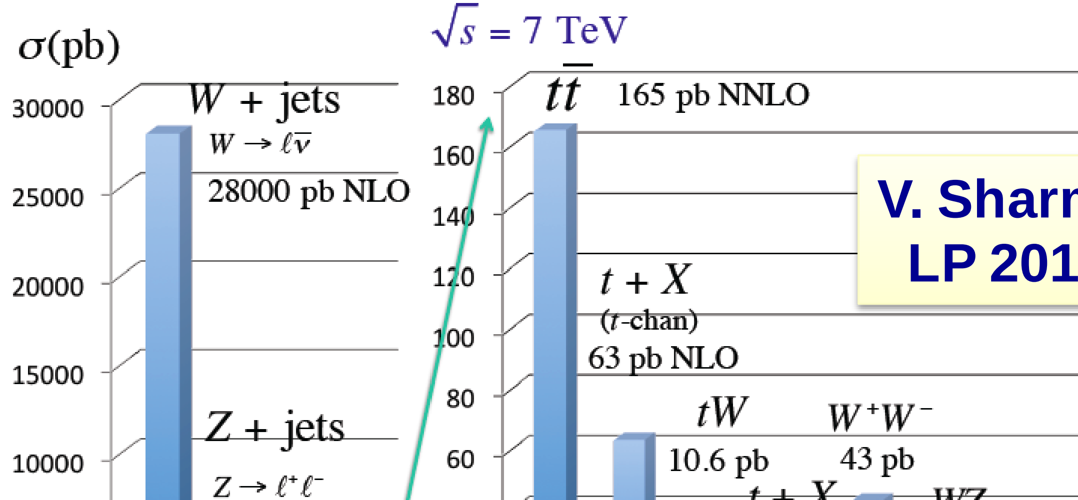
t channel: 63 pb

Wt channel: 10 pb



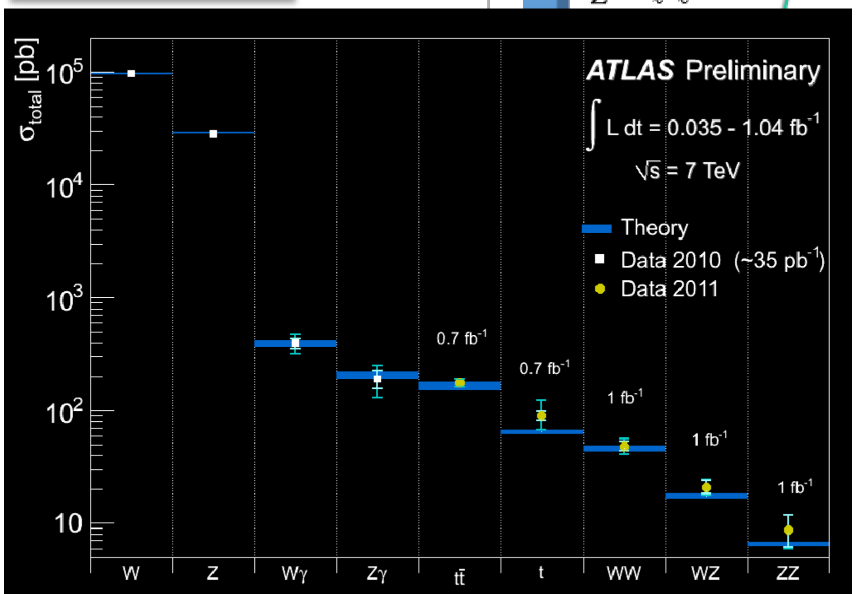


Standard model in pp collisions @ 7 TeV

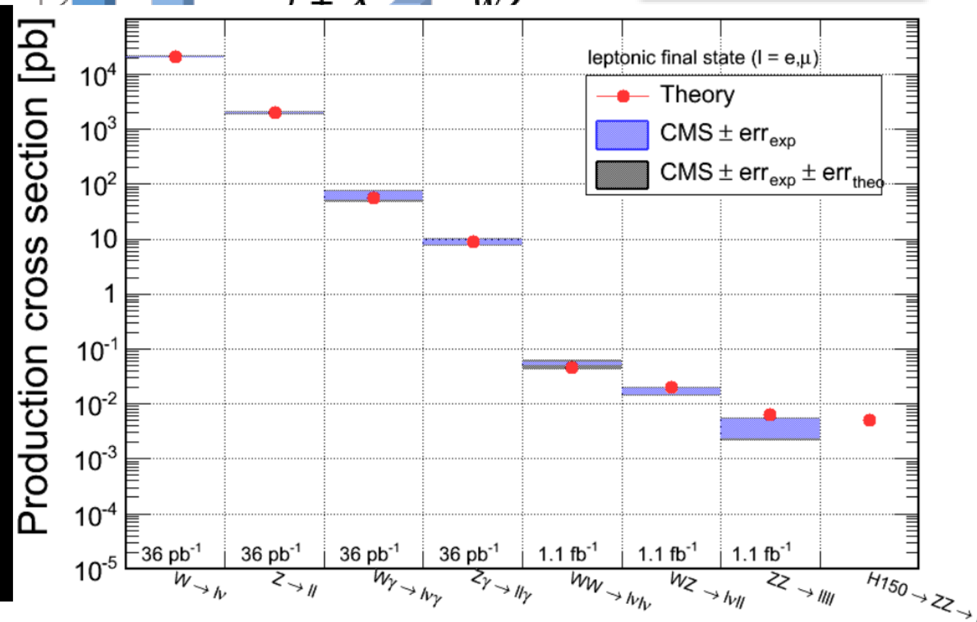


V. Sharma LP 2011

ATLAS @ EPS 2011



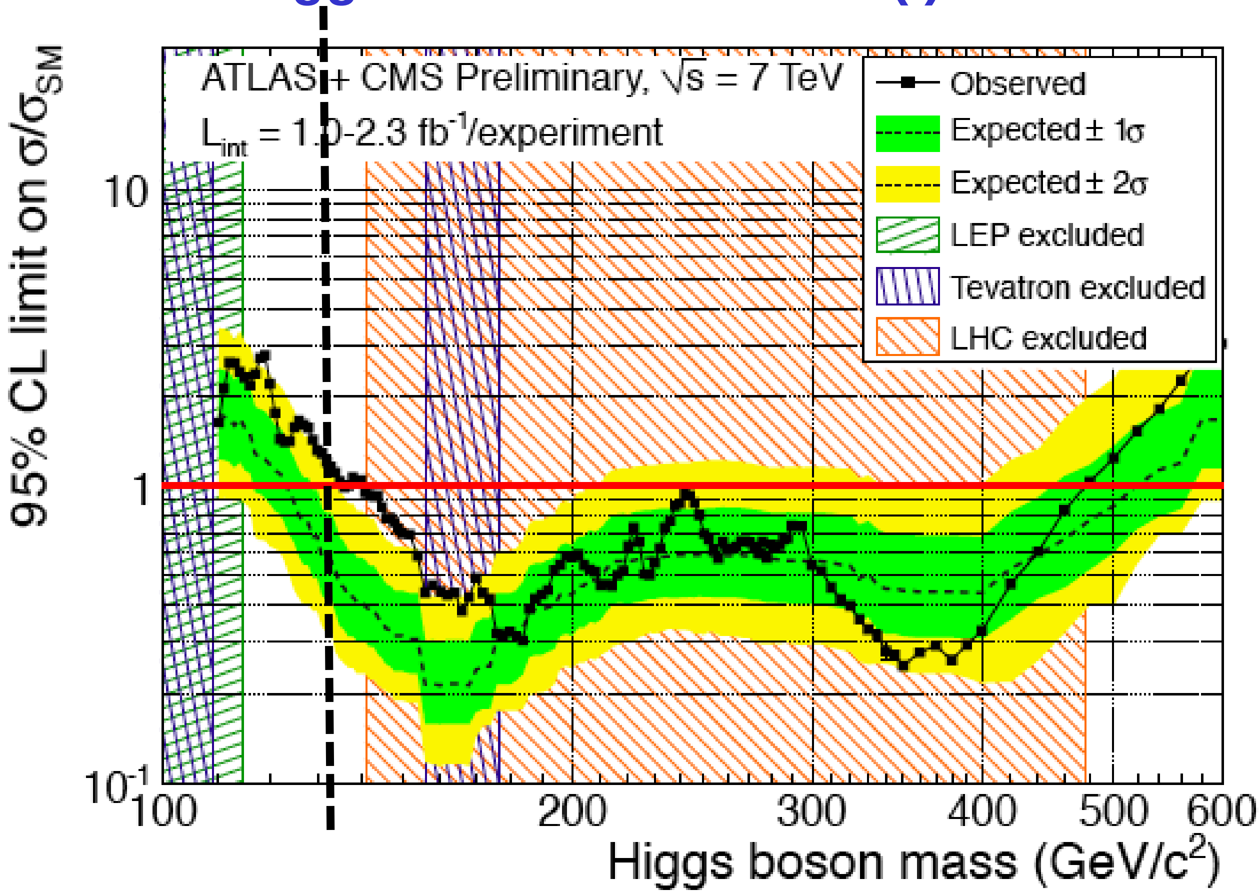
CMS @ EPS 2011



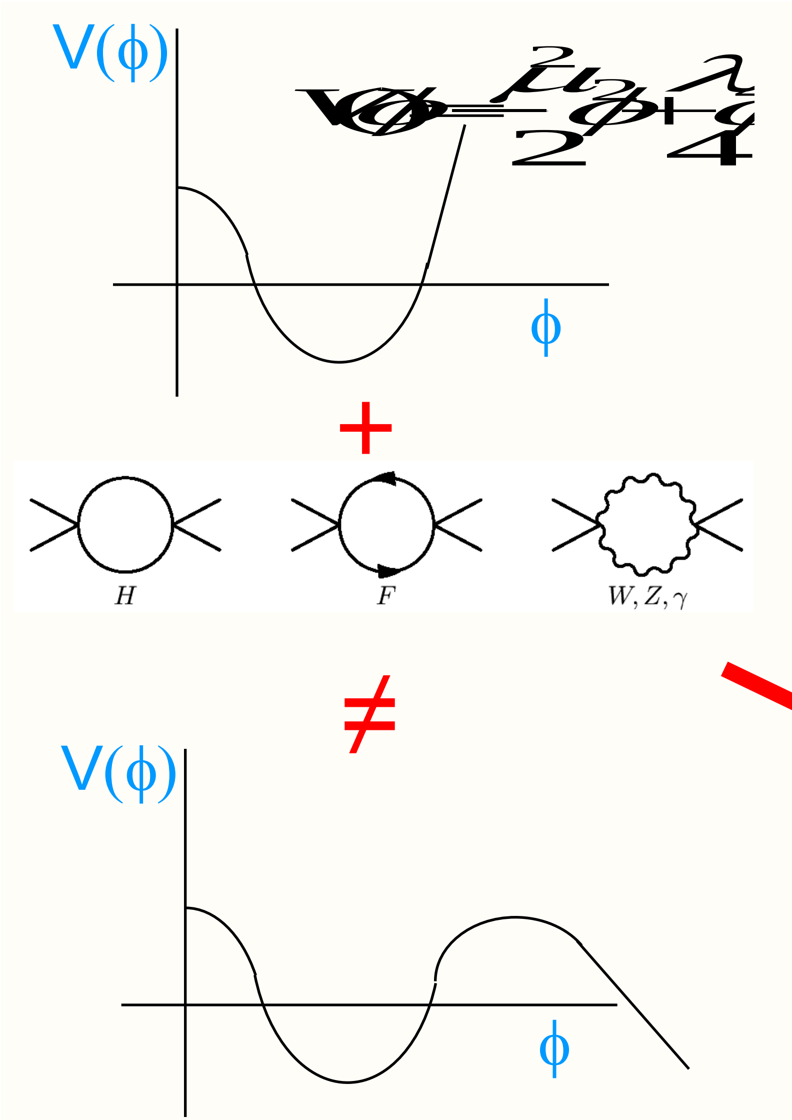
Closing in on the Higgs

A big hint that new physics is "there"

- **HCP 2011: combination of ATLAS + CMS**
  - **At 95% CL: Higgs not in 141-476 GeV**
  - **At 90% CL: Higgs not above 132 GeV (!)**



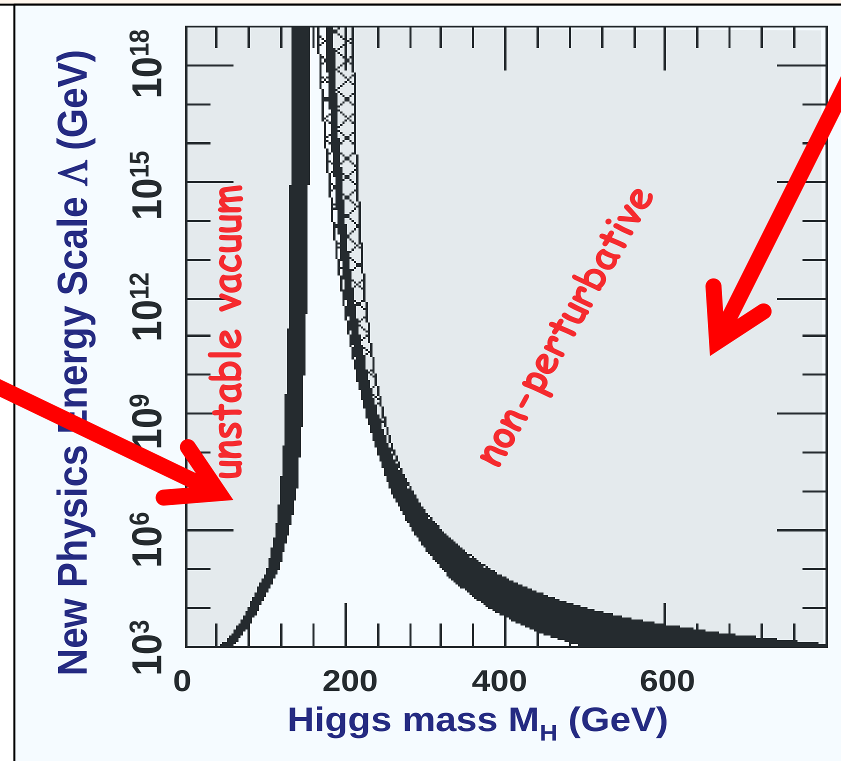
Scale of New Physics = F(M_H)



$$\lambda(Q^2) = \frac{\lambda(Q_0^2)}{1 - \lambda(Q_0^2)/16\pi^2 \log(Q^2/Q_0^2)}$$

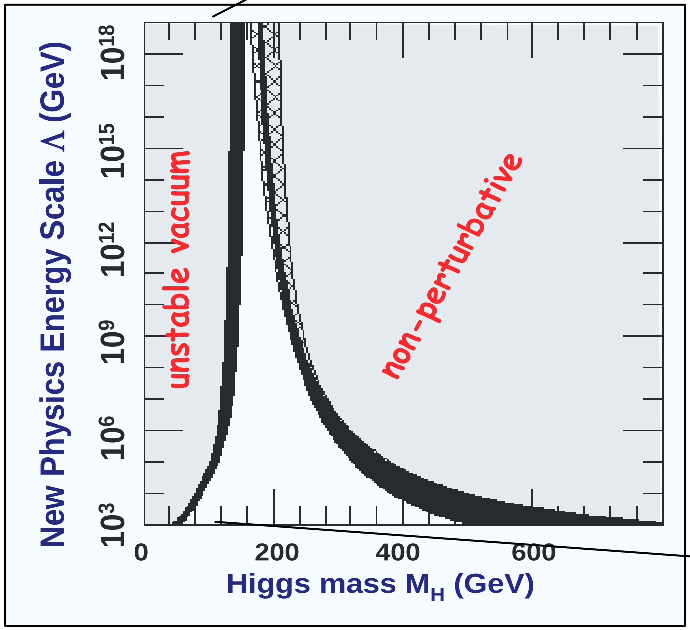
$Q^2 \to \infty$, $\lambda \to \infty$!

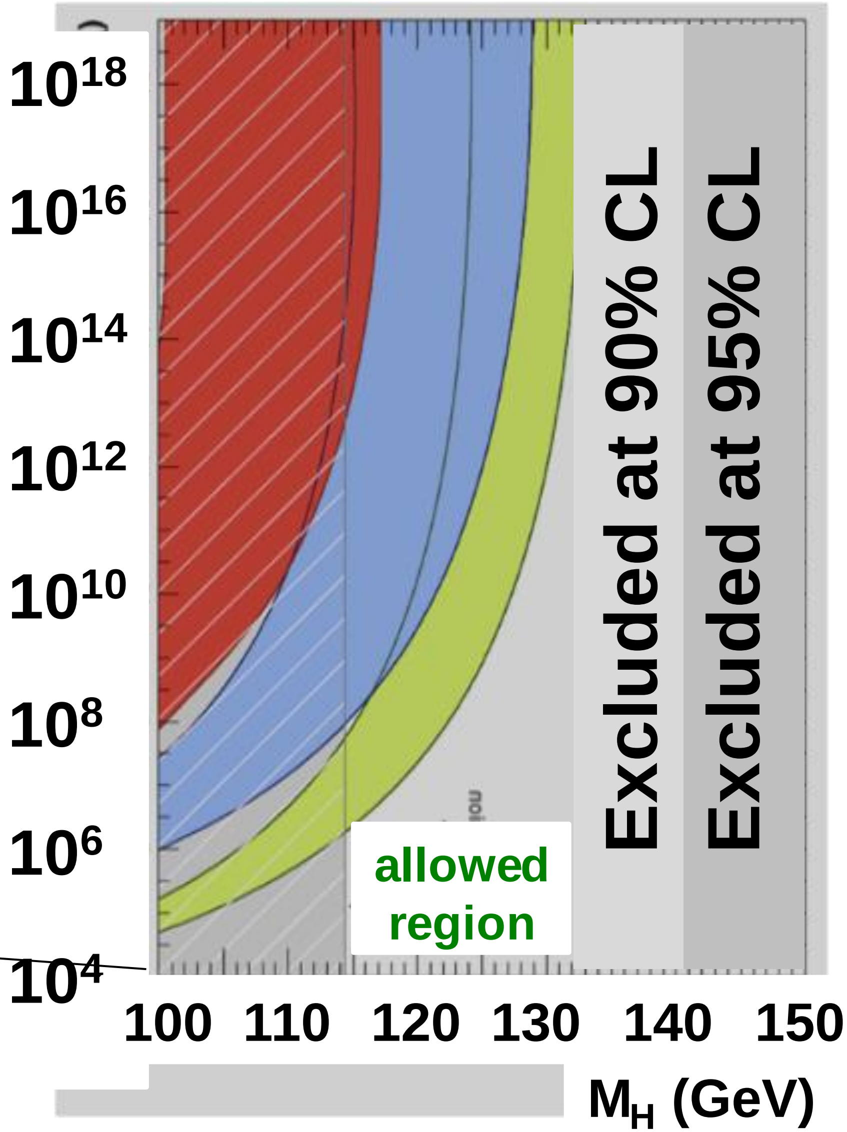
$$\Lambda \approx M_H \exp\left(\frac{4\pi^2 v^2}{3 M_H^2}\right)$$



Zooming in: some good news

- **At 90% CL: there Is new physics at a scale below the GUT scale ☺**





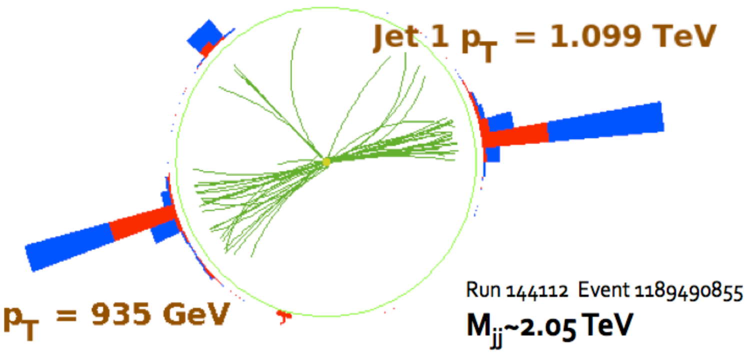
Where is the new physics?

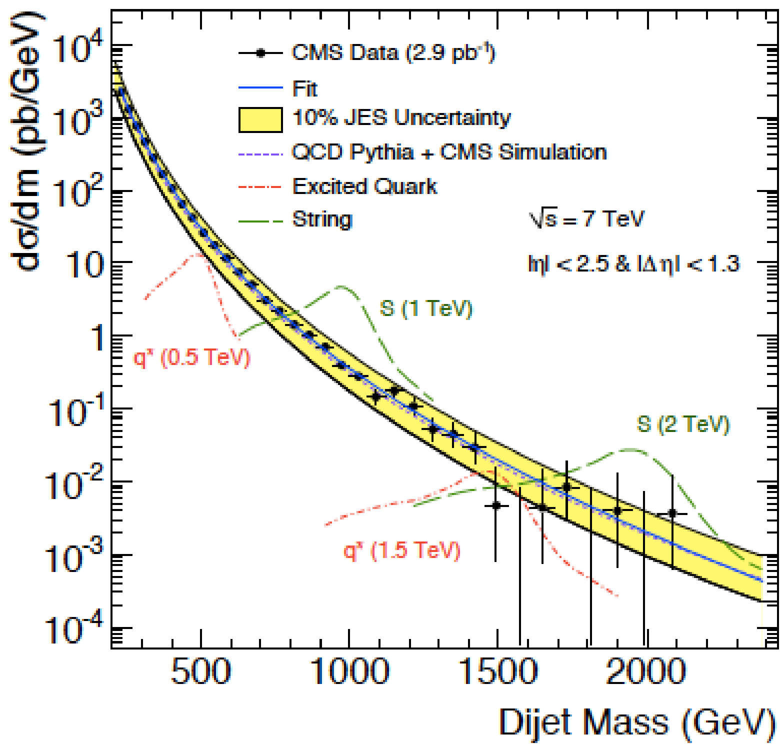
Searches for signs of exotic New Physics

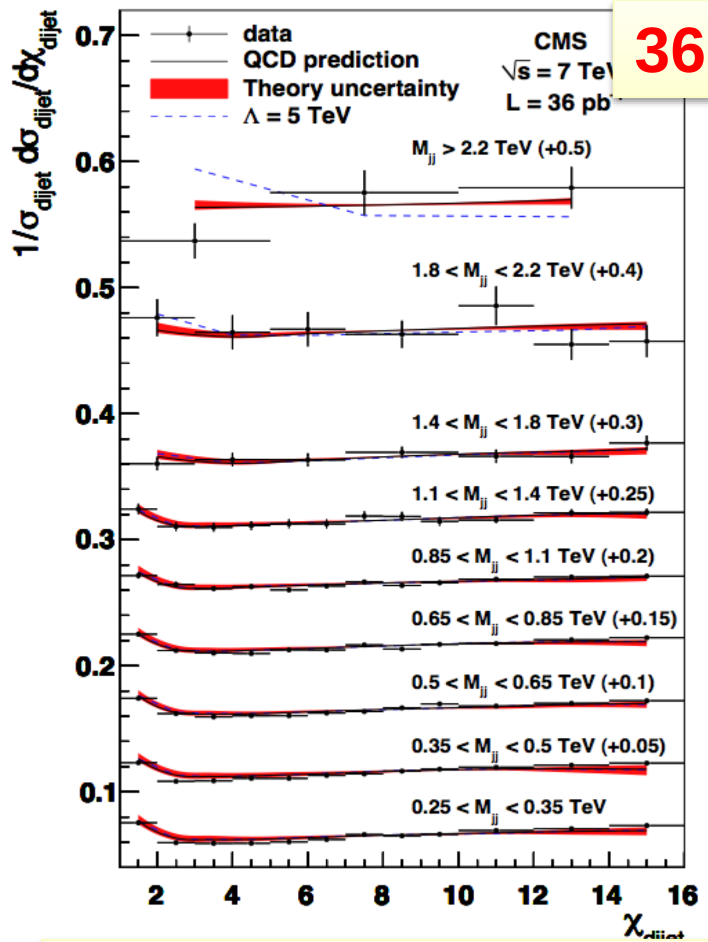
Many (many) possibilities

- Compositeness; new contact interaction(s)
- Exotica:
  - Leptoquarks
  - New gauge bosons (W', Z') – or resonances
  - Fourth generation (b')
  - TeV-scale gravity: Black Holes; mono-jets; mono-photons; UED
    - Universal Extra dimensions (diphotons)
- Supersymmetry
  - Squarks and gluinos
    - Decays into jets and MET plus 0, 1 or 2 leptons
    - Decays into photons (GMSB)
- SUSY-based exotica
  - Long-lived particles
- The totally unexpected

Searches…







36pb^{-1}

Scale of contact interaction Λ>5.6 TeV (95% CL)

(Null) search for W'

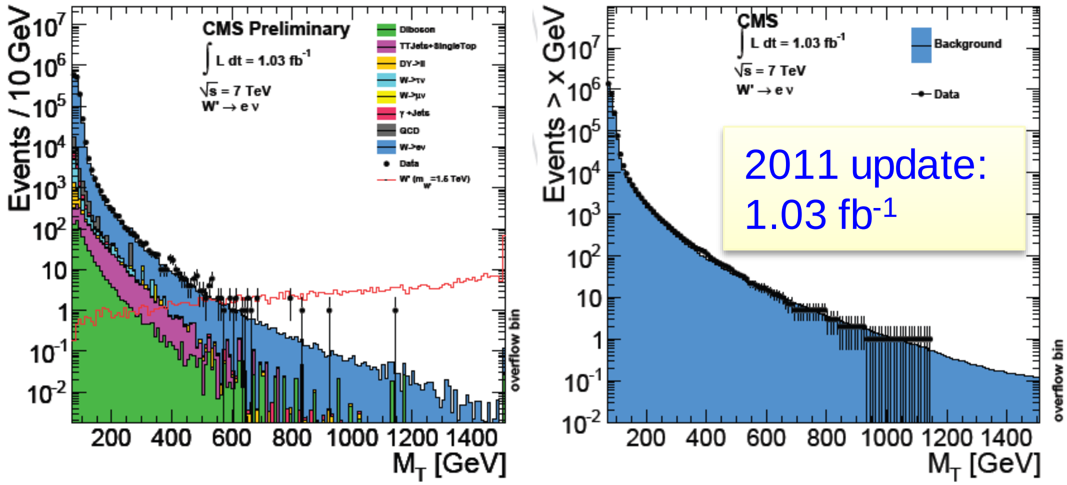
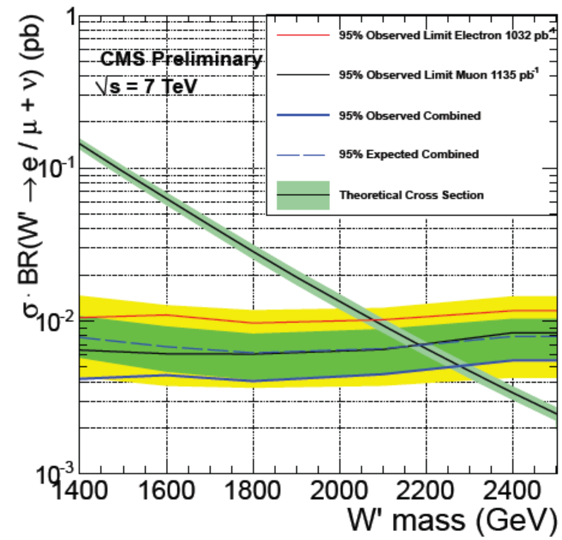


Figure 2: Transverse mass distribution (left) and cumulative distribution (right) for the electron channel.



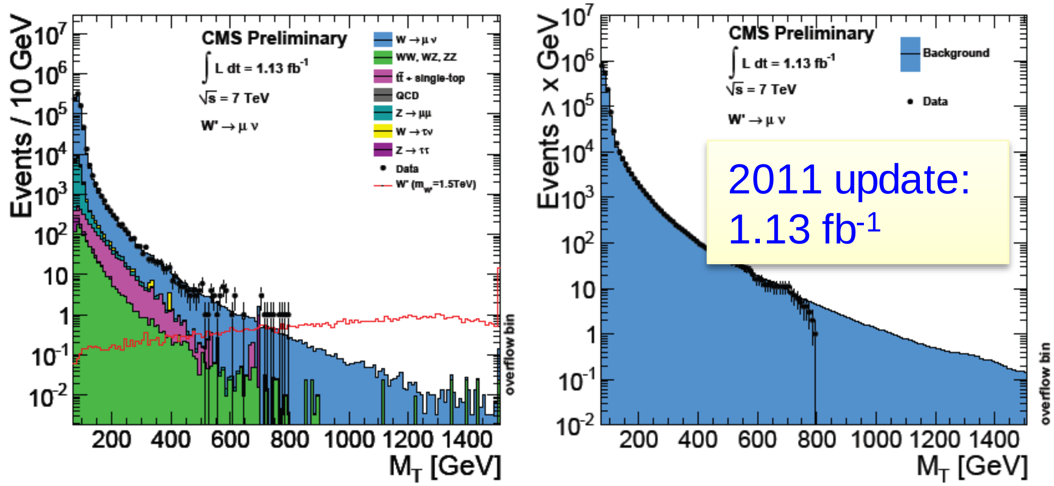


Figure 3: Transverse mass distribution (left) and cumulative distribution (right) for the muon channel.

Combined (SSM) limit:
M(W')>2.20 TeV obs
M(W')>2.27 TeV exp

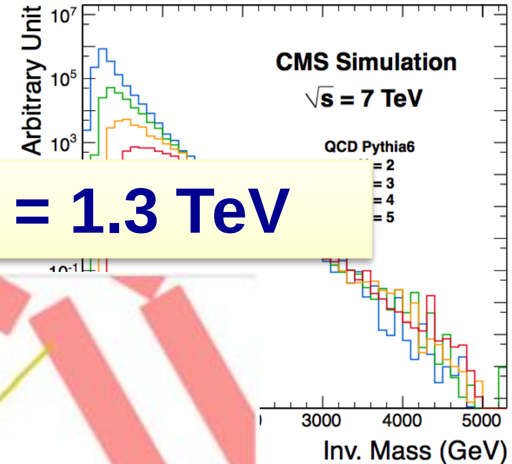
(Null) search for BHs

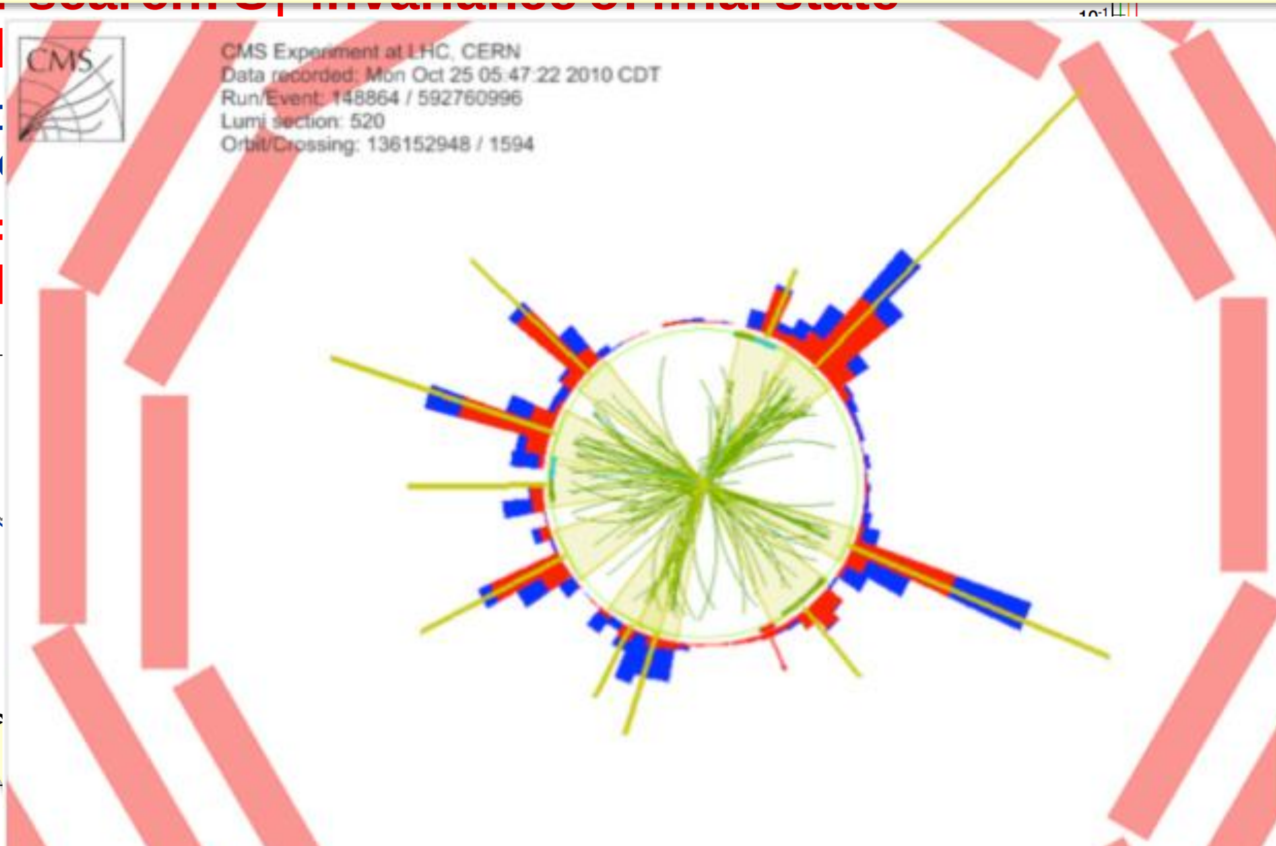
arXiv:1012.3375

- Expect lots of activity in the event, so
  - Use S_T = Sum E_T of all objects (including ME_T) with E_T>50 GeV.

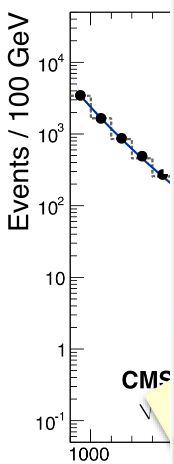
A candidate event with 10 jets and S_T = 1.3 TeV

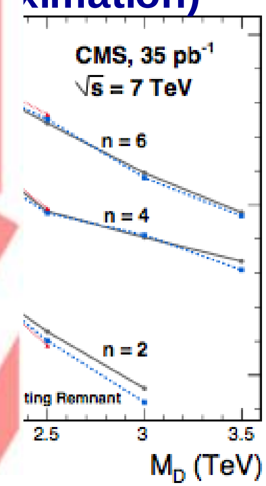
- Ke
  multipl
  - A po
    affe
- Use N=
  multipl





.5-4.5 TeV
classical
ximation)

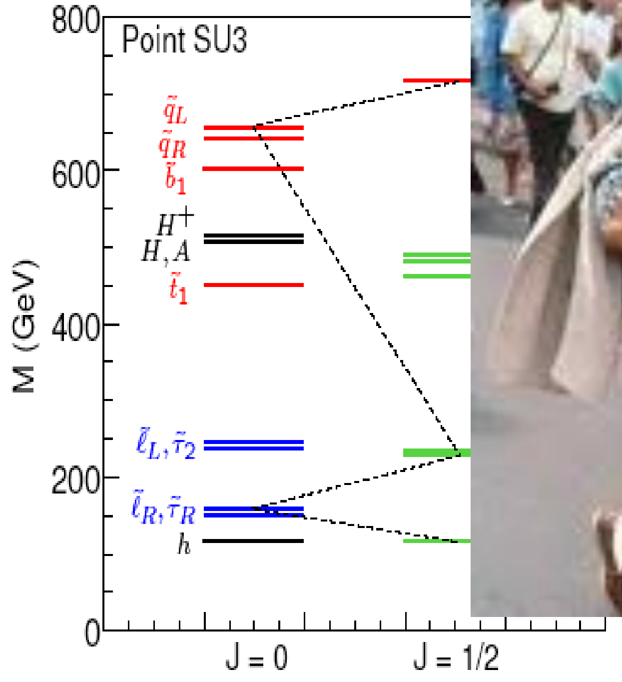


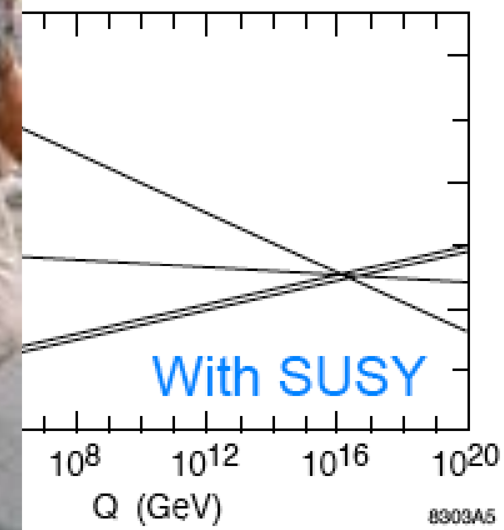


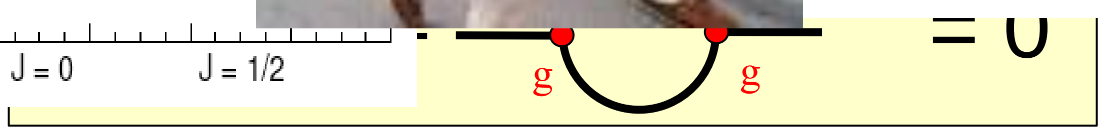
Supersymmetry

Supersymmetry: TO"E" at the Weak Scale

- For a small price increase (one principle plus an unknown SB mechanism → 500% increase in number of parameters), achieves quite a lot:
  - No fine-tuning (lar … s cancel)
  - If Lightest SUSY P … natural" dark-matter
  - Equality of Strong … gs at ~10^{16} GeV
- D … s actually quite p … rs
- H

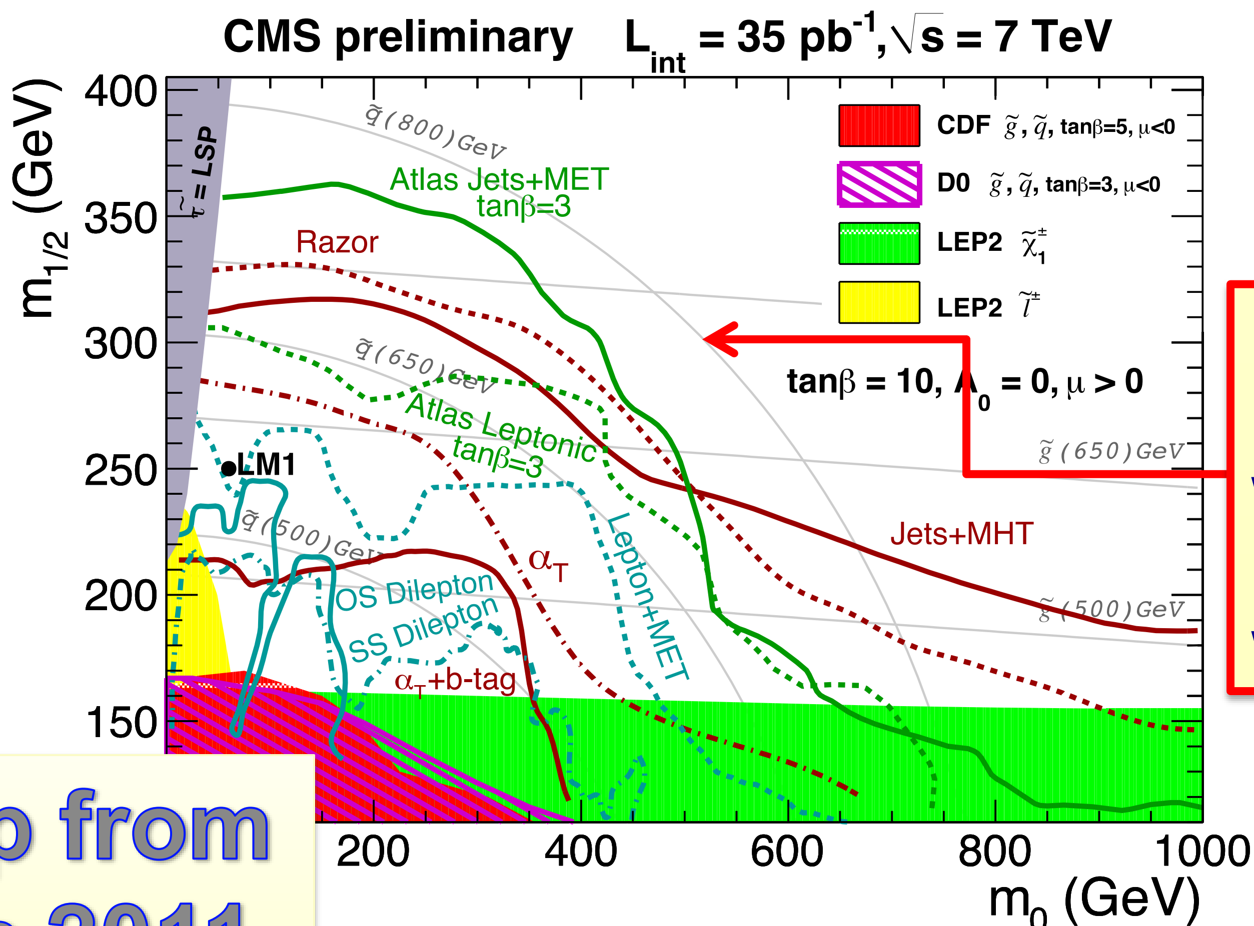






SUSY search with ME_T: summary of 2010

- **No signs yet. But all analysis methods in place; now need more data (2011!)**



Corner around which SUSY would lie

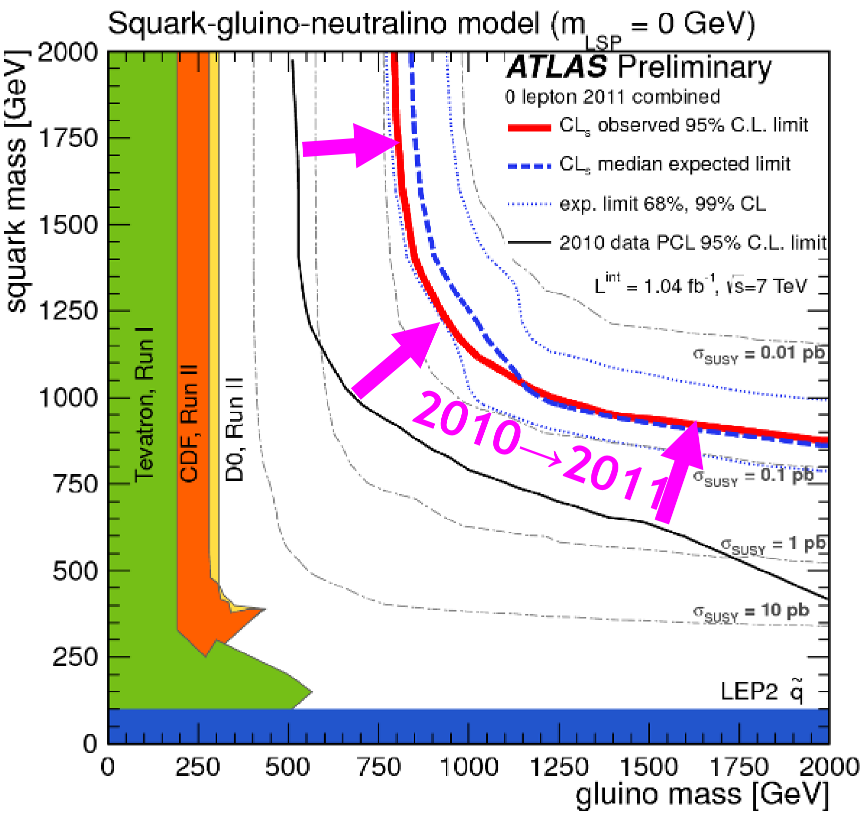
Transp from March 2011

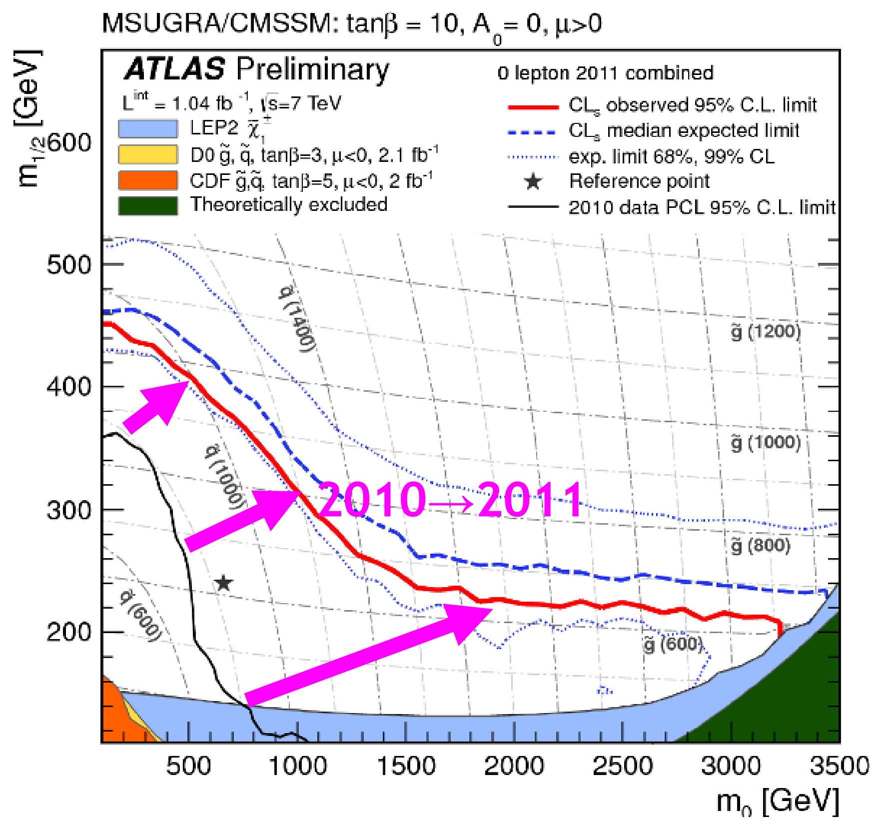
Surprise #2

In brief: SUSY moving further out

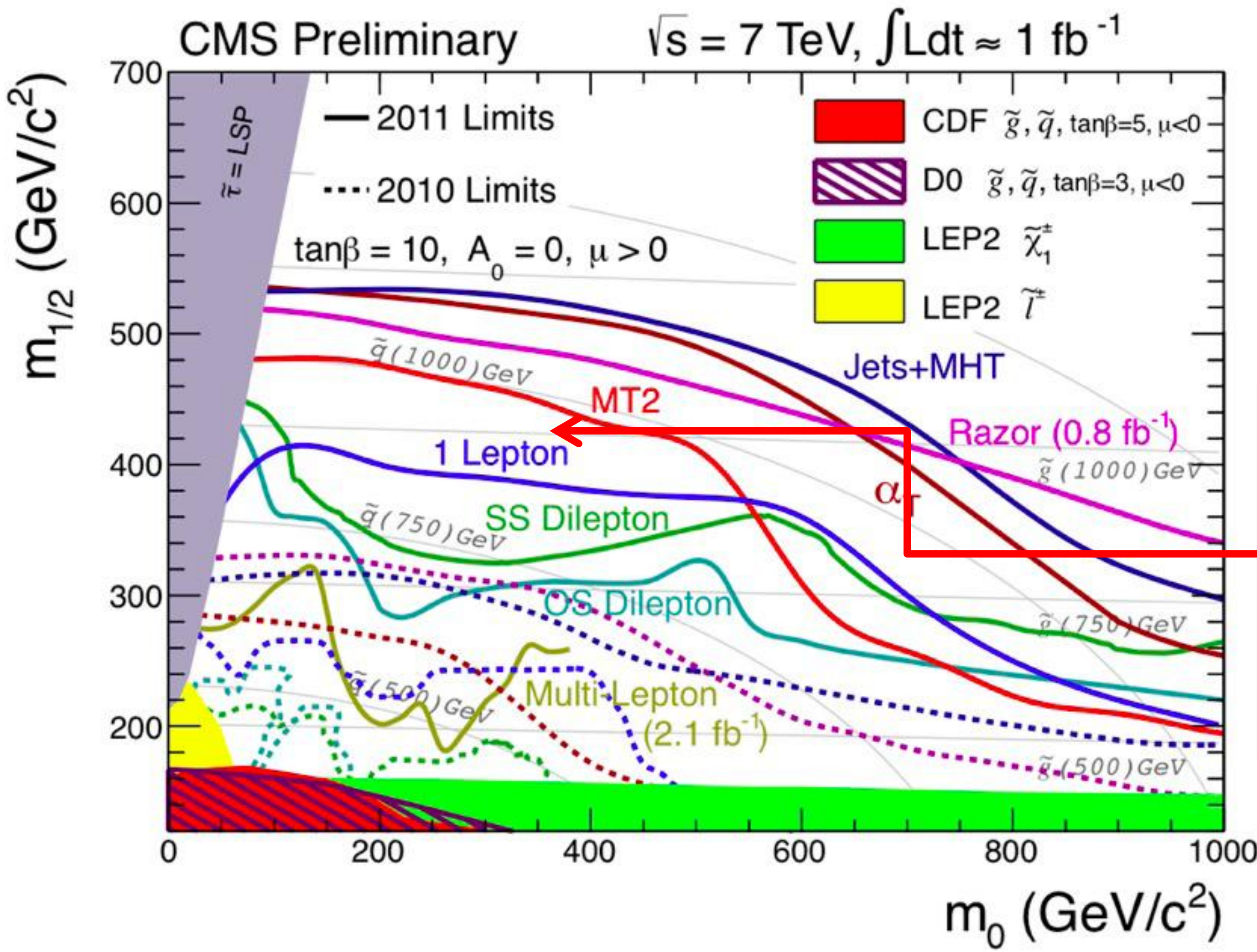
Simplified model: two squark (q) generations, $m(/_1^0)\sim 0$
m_g>800 GeV m_q>850 GeV
Equal mass case: $m_g=m_q$>1.075 TeV

MSUGRA/CMSSM:
tanβ=10, A_0=0, μ>0
Equal mass case:
$m_q=m_g$ > 980 GeV





Constrained MSSM



Corner around which SUSY used to lie

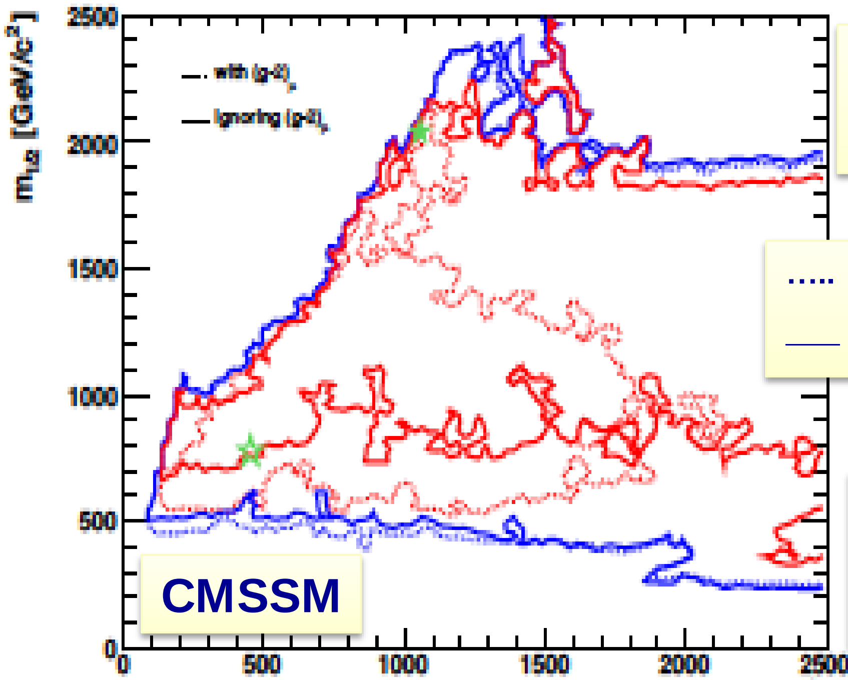
Then again…

- **A bit of a self-fulfilling prophecy; early searches were guided by combination of "probability of success" and "obeying the rules":**
  - **Go after high cross section processes (i.e. accessible at low luminosity ~10-50 pb^{-1})**
  - **Do not rely on a perfectly working detector: seek robust signatures with good experimental control of "things"**
  - **Do not rely on Monte Carlo; "thou shall use the data" (well, ok, and some Monte Carlo)**
  - **Beat the competition: go after the simplest signatures**

- **We have followed these four guidelines extremely well**
  - **(another reason to rejoice – when we set to do stnhg, we do)**
  - **(another reason to think that there is much, much more)**

What the LHC has done to/for the CMSSM

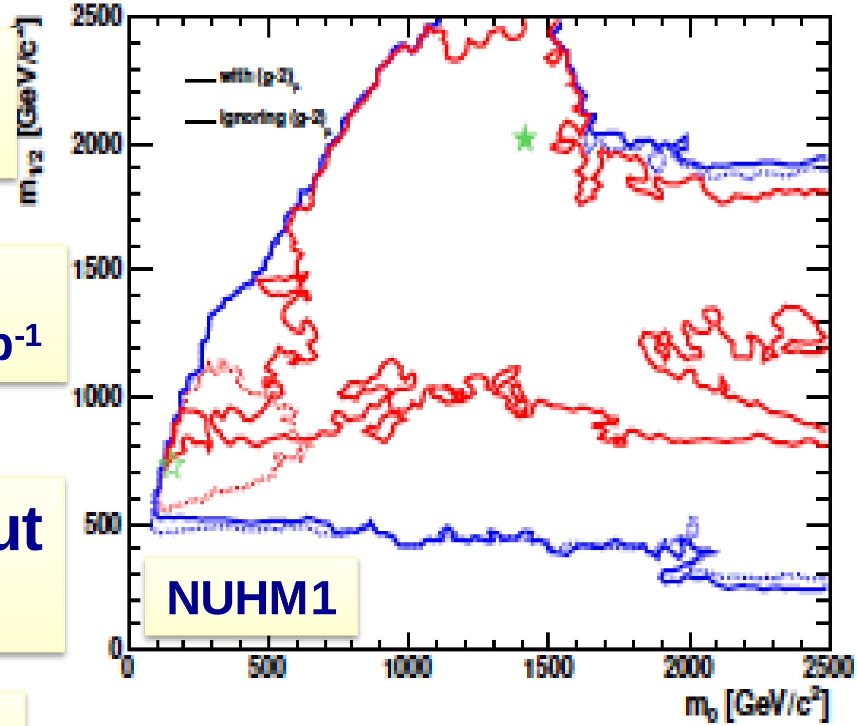
- With $1fb^{-1}$ of data the amount of naturalness need has diminished to "unnaturally" small values [?!?!]
  - CMSSM being cornered. Not excluded [yet] but looking unlikely [e.g. "high fine-tuning price of the LHC" hep.ph/1101.2195]
- But: (a) effect of g-2 ?! (b) SUSY >> CMSSM



68% CL
95% CL

····· pre-LHC
— LHC@$1fb^{-1}$

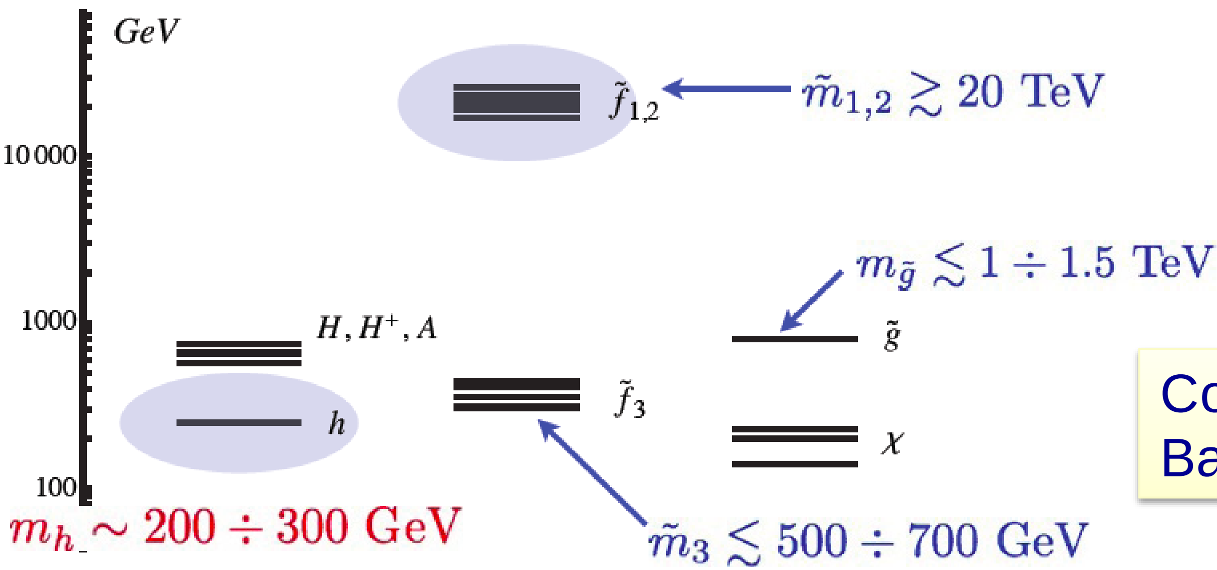
without g-2



MasterCode Project (Oliver Buchmüller et al)

SUSY is far from excluded (let alone dead)

- Simple models (e.g. universal soft masses) being squeezed
- Numerous other scenarii still very much unprobed [thus very unconstrained]. Two examples:
  - Large flavor splitting: very heavy squarks [1st, 2nd gen], light 3rd gen (plus gluino at ~1-1.5 TeV)
  - Low ME_T: not only within R_p-violation; small mass splittings (would be equally lethal to ME_T signature)
    - Could even have all sparticles with mass < ~0.5 TeV…



Cohen et al (96)
Barbieri et al (07)

SUSY: we will always have the stop

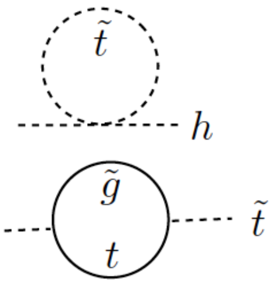
- **Only the stop (+sb) need be light** **[e.g. Barbieri @ HCP 2011]**

The key equations:

$$\frac{m_h^2}{2} \approx -|\mu|^2 + m_u^2 \qquad (m_{\tilde{h}})$$

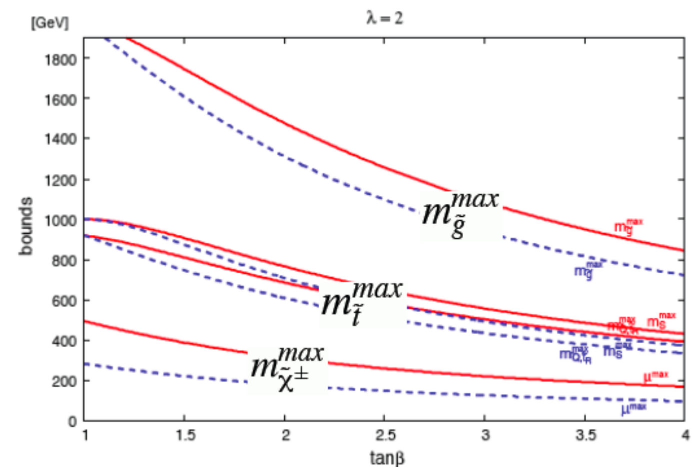
$$\delta m_u^2 \approx -\frac{3y_t^2}{8\pi^2}(m_{\tilde{t}_L}^2 + m_{\tilde{t}_R}^2 + A_t^2)\log M/m_{\tilde{t}} \qquad (m_{\tilde{b}_L})$$

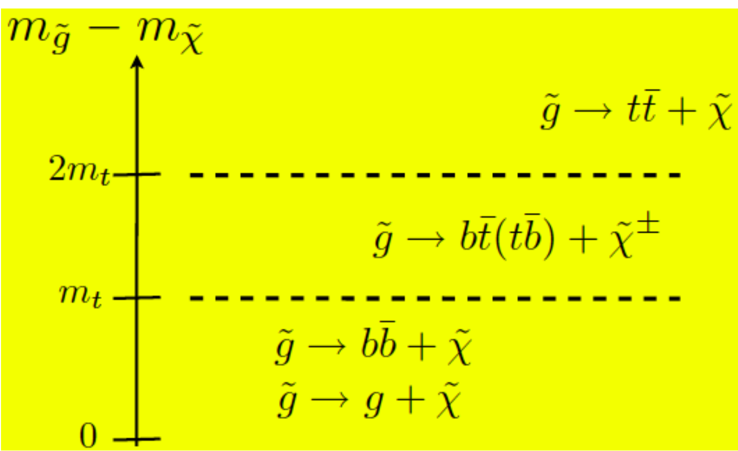
$$\delta m_{\tilde{t}}^2 \approx \frac{8\alpha_s}{3\pi} m_{\tilde{g}}^2 \log M/m_{\tilde{t}}$$



(to be made more precise in any given SB-mediation scheme)

see, e.g., Dimopoulos, Giudice for SUGRA-mediation, 1995



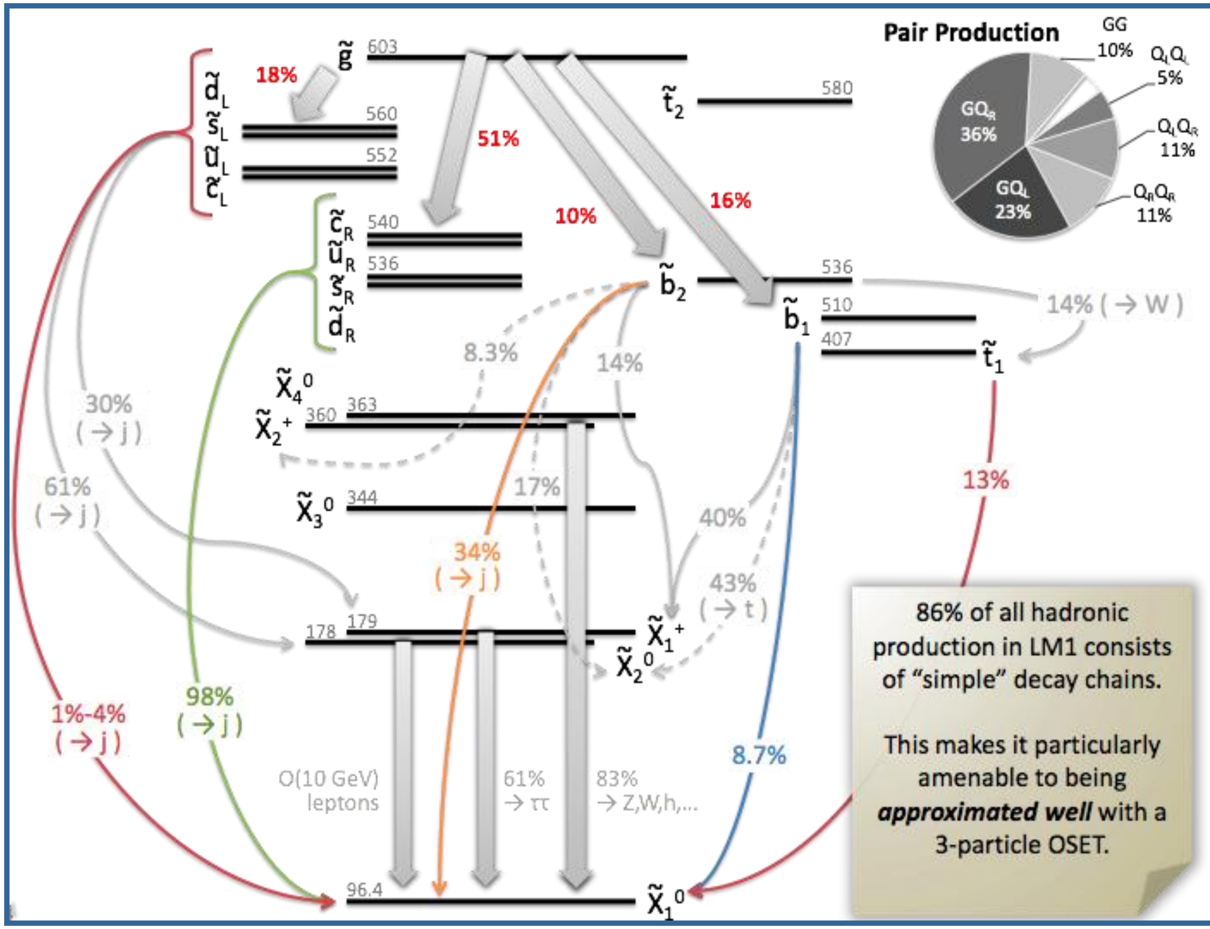


Some incredible signatures…

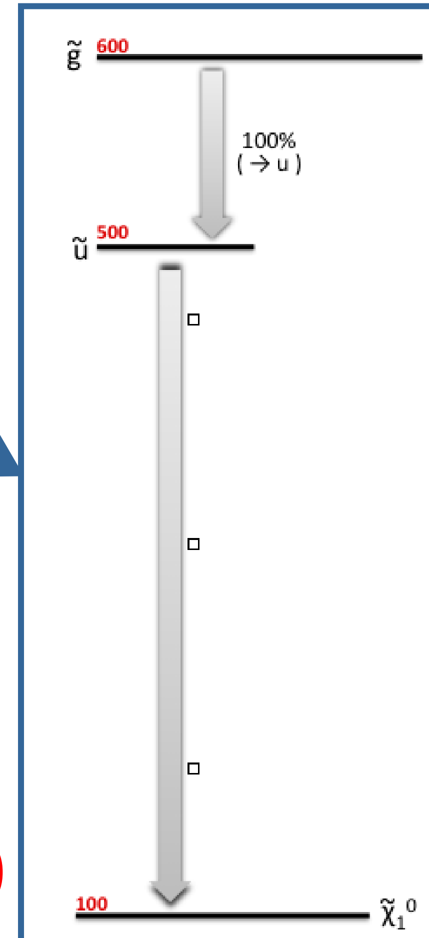
$$pp \to \tilde{g}\tilde{g} \to tttt + \chi\chi$$
$$pp \to \tilde{g}\tilde{g} \to tt\bar{t}b(\bar{t}\bar{t}tb) + \chi\chi$$
$$pp \to \tilde{g}\tilde{g} \to tt\bar{b}\bar{b}(\bar{t}\bar{t}bb) + \chi\chi$$
$$pp \to \tilde{g}\tilde{g} \to t\bar{t}b\bar{b} + \chi\chi$$
$$\chi = \chi^{\pm}, \chi_1, \chi_2$$

Recently: use of simplified models

CMSSM



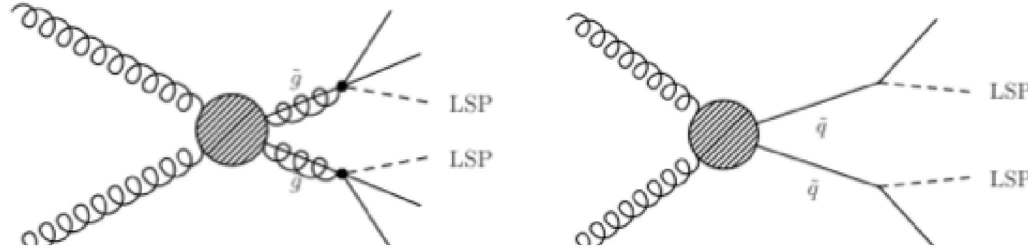
What we see: much simpler…



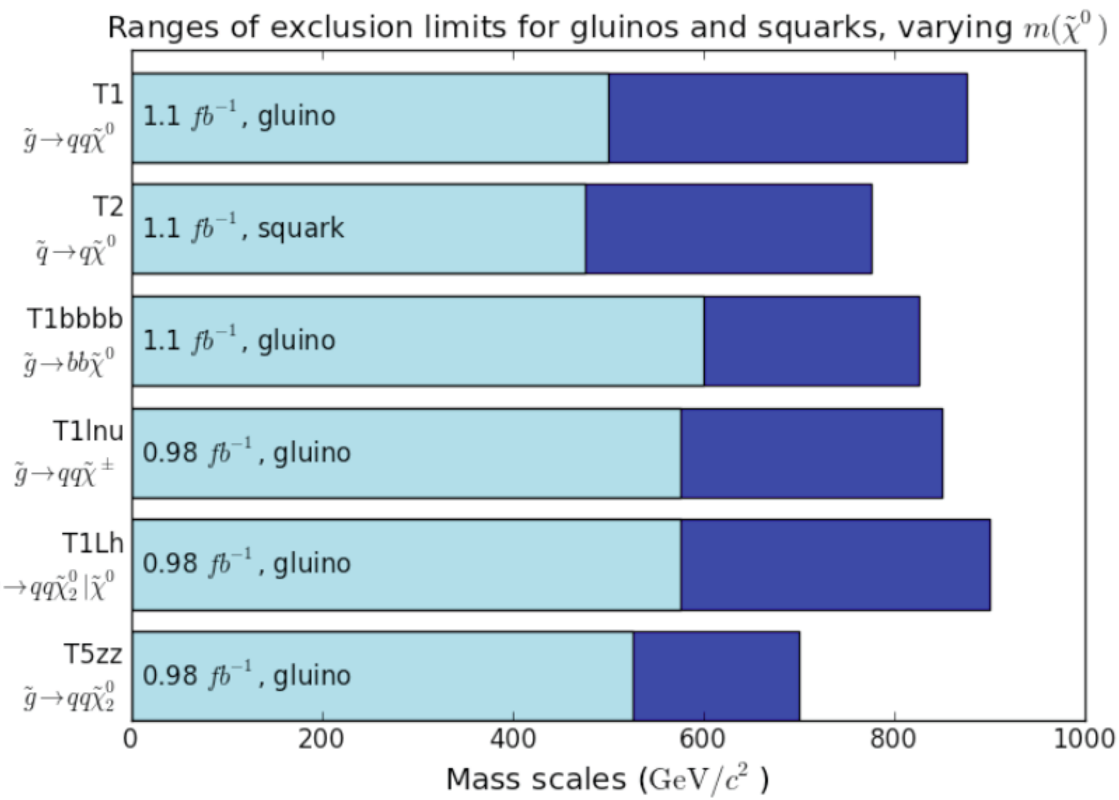
Simplified Model Spectrum (SMS) with 3 particles, 2 decay modes

Simplified Model Spectra

- **Started with squark and gluino pair-production topologies**
- **Limits are “best of N” searches (usually not a combination)**
- **Black lines are QCD-like cross sections**
- **Theoretical uncertainties like ISR simulation important (under study)**



CMS preliminary



M(gluino)>0.4-0.5 TeV

SUSY: what we do not know

$\tilde{u}_L, \tilde{d}_L$	$\tilde{u}_R$	$\tilde{d}_R$	$\tilde{e}_L, \tilde{\nu}_L$	$\tilde{e}_R$	$\tilde{h}^{\pm}, \tilde{h}_u^0, \tilde{h}_d^0$	$\tilde{b}^0$	$\tilde{w}^{\pm}, \tilde{w}^0$	$\tilde{g}$
Q	U	D	L	E	H	B	W	G
M_Q	M_U	M_D	M_L	M_E	M_H	M_B	M_W	M_G

- **Agnostic approach: consider all possible mass hierarchies: there are 9! = 362880 of them**
  - **ME_T: 4x8! (161,280) cases, LSP=weakly-interacting, neutral particle; phenomenology depends crucially on mass hierarchy**
  - **CHAMPs: 8! (40,320) cases, LSP=e_R (charged, color-neutral); signature: CHAMP (independently of hierarchy)**
  - **R-hadrons: 4x8! (161,280) cases, LSP=colored object; again, independent of hierarchy**

arXiv:1008.2483: “How to look for supersymmetry under the lamppost at the LHC”; P.Konar, K.Matchev, M.Park, G.Sarangi

Heavy Stable Charged Particles

- **Both in SUSY and other SM extensions:**
  - SUSY (split SUSY: M(gluino)<<M(squark) → long lifetime; GMSB models: stau NLSP, decaying via gravitational coupling only…)
  - Other: hidden valleys; GUTs; …
- **Two types of signatures: MIP & strongly-interacting**

MIP: HSCP passes through tracker & muon chambers

R-hadrons traversing material can flip Q or become neutral

dE/dx: Massive, charged particles traversing detector: highly ionizing tracks (tracker, possibly muon dets)

(Out-of-time) Jet: particles stopping in the detector and decaying – possibly out-of-time with the collisions

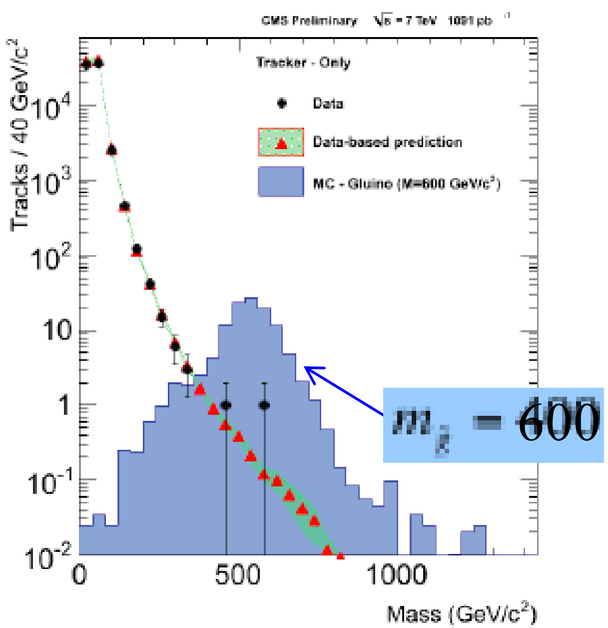
Heavily ionizing tracks

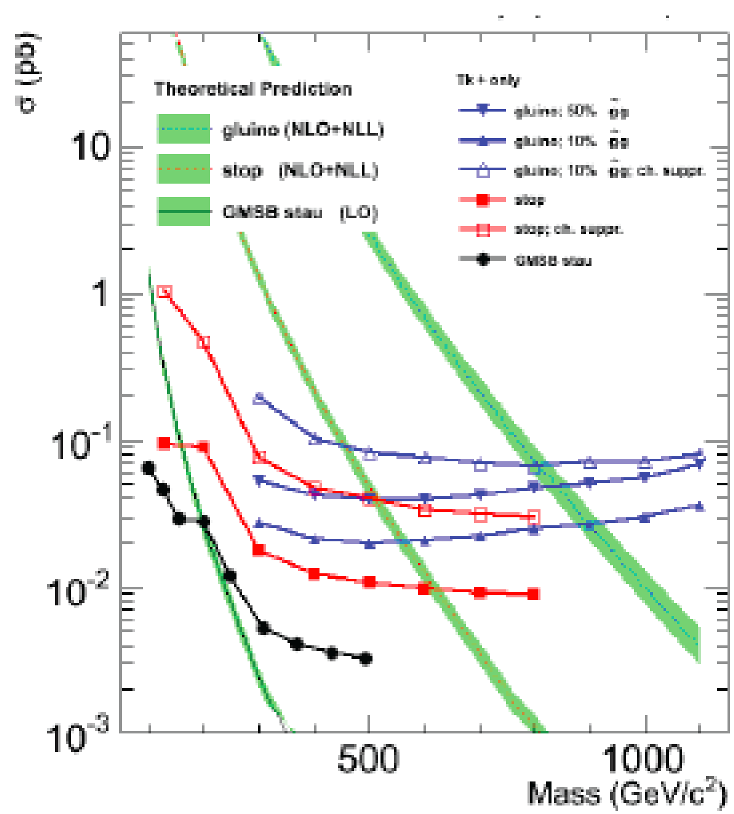
- **Mass estimate from approximate Bethe-Bloch:** $I_h = K\frac{m^2}{p^2} + C$
  - K and C determined from proton data
    - Mass resolution: 12% at 300 GeV

K=2.58 MeV c²/cm
C=2.56 MeV/cm

- **Cut on I_{AS} (MIP compatibility) & p_T (I_{AS}, p_T: uncorrelated)**

Bkg $= \frac{(\#\text{pass } I_{AS} \text{ only})(\#\text{pass } p_T \text{ only})}{\#\text{Fail } I_{AS} \cap p_T}$

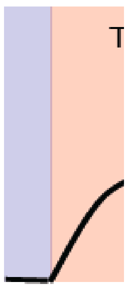


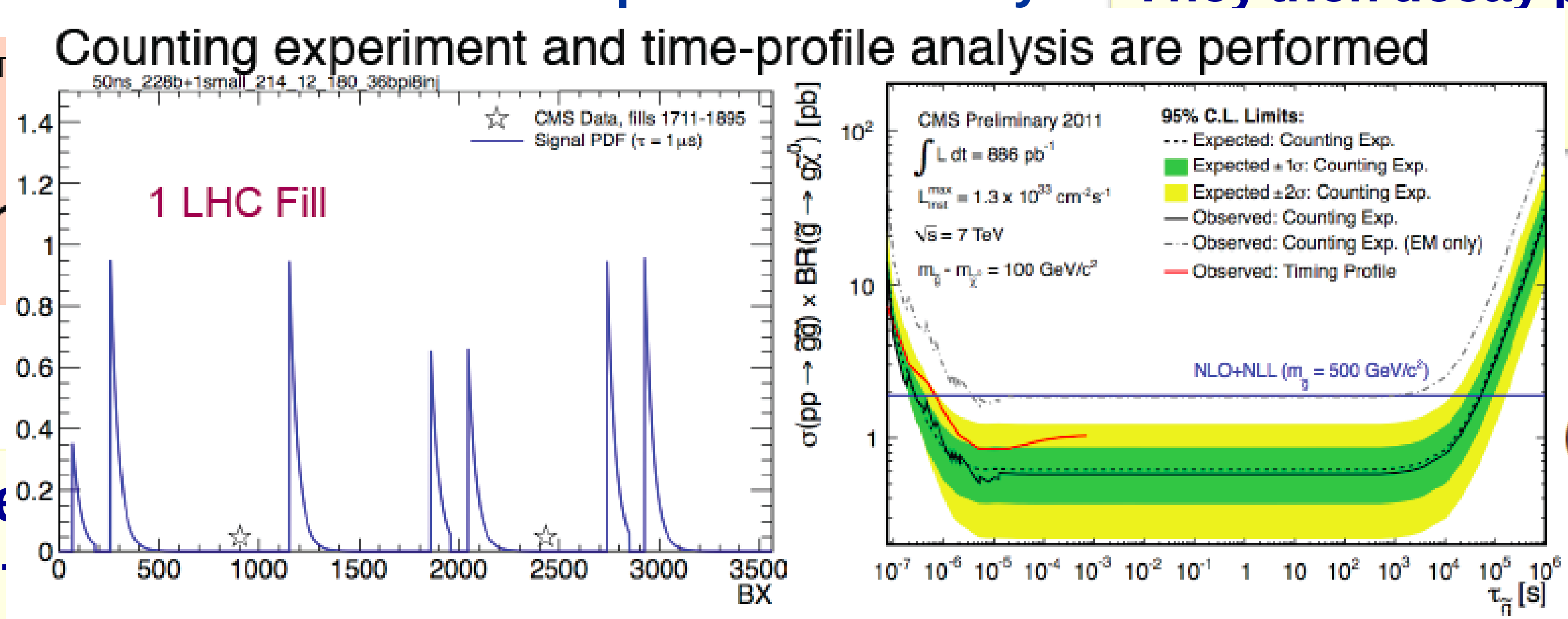


Stopped gluinos

- **Slow (β < 0.4) long-lived gluinos hadronize into and then stop in the dense material of the CMS detector**
  - **Their number builds up with luminosity:**

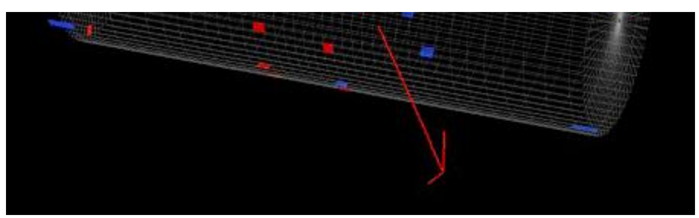
They then decay μs,

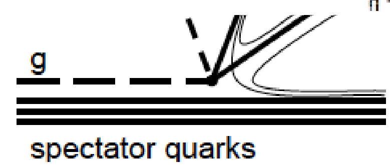




(uu)

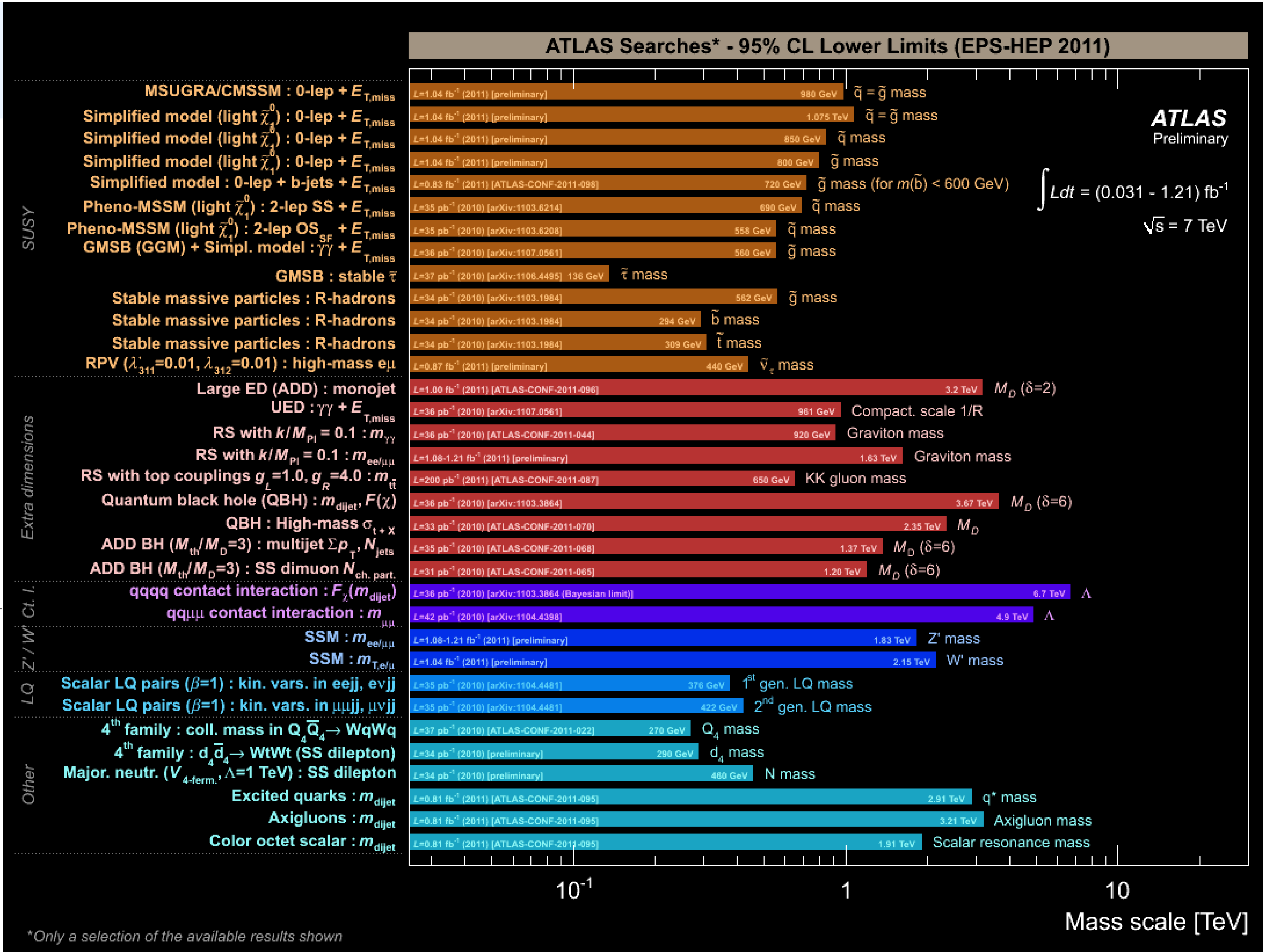
Sp... je... absence of beam





$$\Delta_{\tilde g}^{++} \to \tilde g\, u(uu) \to q\bar q\, \chi_1^0\, u(uu)$$

Mt


ATLAS Searches* - 95% CL Lower Limits (EPS-HEP 2011)
ATLAS
Preliminary
$\int Ldt = (0.031 - 1.21)\ \mathrm{fb}^{-1}$
$\sqrt{s}$ = 7 TeV
SUSY
MSUGRA/CMSSM : 0-lep + $E_{T,miss}$ — 980 GeV — q̃ = g̃ mass
Simplified model (light $\tilde{\chi}_1^0$) : 0-lep + $E_{T,miss}$ — 1.075 TeV — q̃ = g̃ mass
Simplified model (light $\tilde{\chi}_1^0$) : 0-lep + $E_{T,miss}$ — 850 GeV — q̃ mass
Simplified model (light $\tilde{\chi}_1^0$) : 0-lep + $E_{T,miss}$ — 800 GeV — g̃ mass
Simplified model : 0-lep + b-jets + $E_{T,miss}$ — 720 GeV — g̃ mass (for m(b̃) < 600 GeV)
Pheno-MSSM (light $\tilde{\chi}_1^0$) : 2-lep SS + $E_{T,miss}$ — 690 GeV — q̃ mass
Pheno-MSSM (light $\tilde{\chi}_1^0$) : 2-lep OS_{SF} + $E_{T,miss}$ — 558 GeV — q̃ mass
GMSB (GGM) + Simpl. model : γγ + $E_{T,miss}$ — 560 GeV — g̃ mass
GMSB : stable τ̃ — 136 GeV — τ̃ mass
Stable massive particles : R-hadrons — 562 GeV — g̃ mass
Stable massive particles : R-hadrons — 294 GeV — b̃ mass
Stable massive particles : R-hadrons — 309 GeV — t̃ mass
RPV (λ'_{311}=0.01, λ_{312}=0.01) : high-mass eμ — 440 GeV — $\tilde{\nu}_\tau$ mass
Extra dimensions
Large ED (ADD) : monojet — 3.2 TeV — M_D (δ=2)
UED : γγ + $E_{T,miss}$ — 961 GeV — Compact. scale 1/R
RS with k/M_{Pl} = 0.1 : $m_{\gamma\gamma}$ — 920 GeV — Graviton mass
RS with k/M_{Pl} = 0.1 : $m_{ee/\mu\mu}$ — 1.63 TeV — Graviton mass
RS with top couplings g_L=1.0, g_R=4.0 : $m_{t\bar{t}}$ — 650 GeV — KK gluon mass
Quantum black hole (QBH) : m_{dijet}, F(χ) — 3.67 TeV — M_D (δ=6)
QBH : High-mass σ_{t+X} — 2.35 TeV — M_D
ADD BH (M_{th}/M_D=3) : multijet Σp_T, N_{jets} — 1.37 TeV — M_D (δ=6)
ADD BH (M_{th}/M_D=3) : SS dimuon $N_{ch. part.}$ — 1.20 TeV — M_D (δ=6)
Ct. I.
qqqq contact interaction : $F_\chi(m_{dijet})$ — 6.7 TeV — Λ
qqμμ contact interaction : $m_{\mu\mu}$ — 4.9 TeV — Λ
Z' / W'
SSM : $m_{ee/\mu\mu}$ — 1.83 TeV — Z' mass
SSM : $m_{T,e/\mu}$ — 2.15 TeV — W' mass
LQ
Scalar LQ pairs (β=1) : kin. vars. in eejj, eνjj — 376 GeV — 1st gen. LQ mass
Scalar LQ pairs (β=1) : kin. vars. in μμjj, μνjj — 422 GeV — 2nd gen. LQ mass
Other
4th family : coll. mass in $Q_4\bar{Q}_4$ → WqWq — 270 GeV — Q_4 mass
4th family : $d_4\bar{d}_4$ → WtWt (SS dilepton) — 290 GeV — d_4 mass
Major. neutr. ($V_{4\text{-ferm.}}$, Λ=1 TeV) : SS dilepton — 460 GeV — N mass
Excited quarks : m_{dijet} — 2.91 TeV — q* mass
Axigluons : m_{dijet} — 3.21 TeV — Axigluon mass
Color octet scalar : m_{dijet} — 1.91 TeV — Scalar resonance mass
10^{-1}
1
10
Mass scale [TeV]
*Only a selection of the available results shown

SES (Simplified Exp/ntalist's Summary)

- **Effective Theories work extremely well**
  - **They can explain things very, very well: Newton's Law for the solar system, the point proton for the atom, the standard model for physics at ~10-100 GeV ☺**
- **[As is well known] most important characteristic of Effective Theories: they explain things within a range of energy scales – *no pretense of explaining "everything"***
  - **Perhaps our notion of SUSY should give up on solving all three problems (naturalness, grand unification, dark matter) in one shot**
    - **Two out of three would not be a bad scoring average! [Even one!]**
  - **How about resurrecting R_P-violating SUSY and leaving dark matter to axions? Or… ? Beyond the loss of "minimality" – would nature [still] be well described [?]**
    - **Free dictionary: "The verb *minimize* … undergone … extension of meaning. In its strict sense it means "to reduce to the smallest possible level," but quite often the context requires us to interpret what the smallest possible level might be."**

Some near-term prospects

LHC running in 2012: 8 TeV [?]

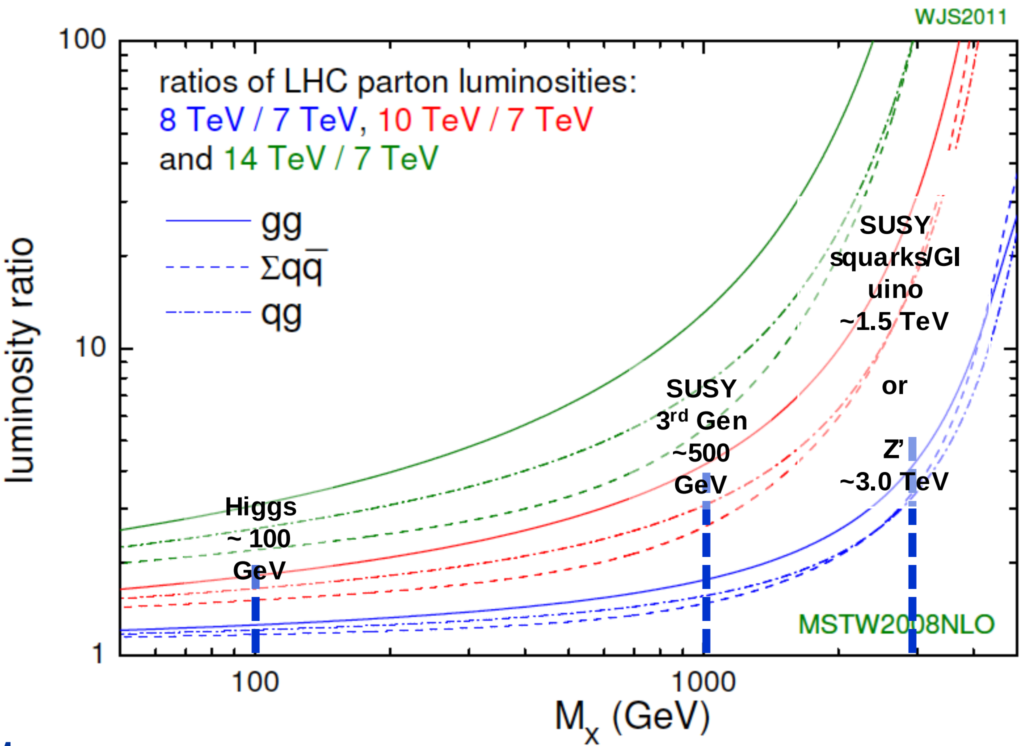
- **Enhances physics reach in two ways:**
  - Higher cross sections for new physics over full mass range

Higgs: pp → H, H→ WW, ZZ & γγ
mainly gg: Factor ~1.2

SUSY: 3rd Gen Mass ~ 0.5 TeV
qq and gg: Factor ~1.5

SUSY: Squarks/Gluino M~1.5TeV
qq,gg,qg: Factor ~4.0

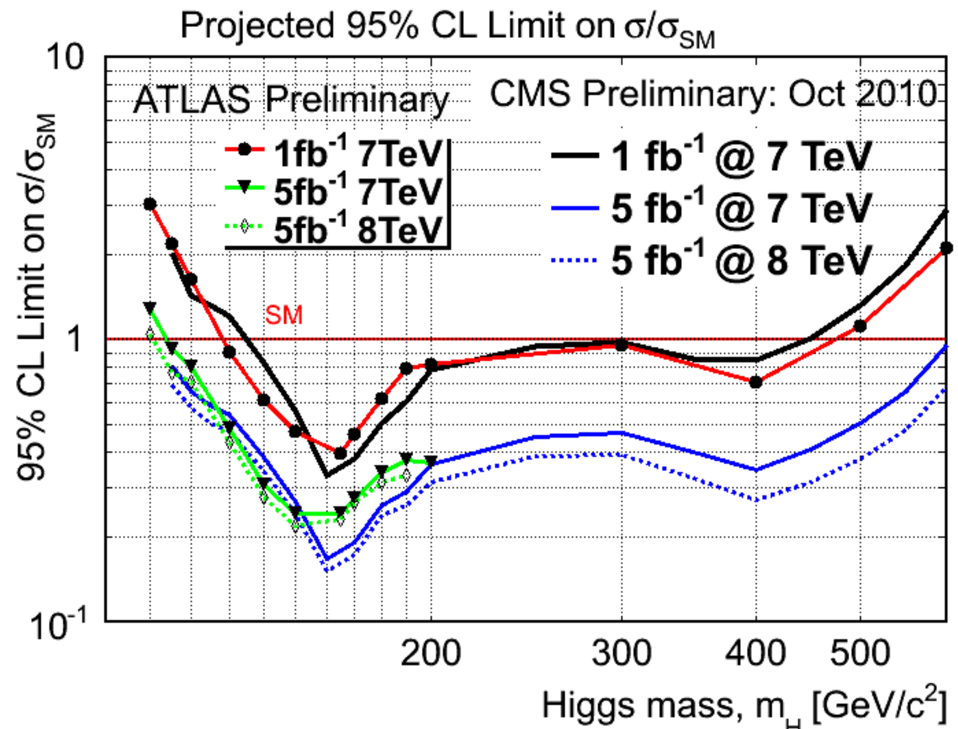
Z' : Mass ~ 3.0 TeV
qq: Factor ~3.5



- More integrated luminosity
  - @ 8 TeV: 10-16 fb^{-1} expected (25/50 ns bunch-crossing)

CMS+ATLAS Projections

Old transp: March 2011



2xCMS≈ATLAS+CMS	Limit @ 95% CL	3σ sensitivity	5σ sensitivity
1 fb^{-1}	120 - 530	135 - 475	152 - 175
2 fb^{-1}	114 - 585	120 - 545	140 - 200
5 fb^{-1}	114 - 600	114 - 600	128 - 482
10 fb^{-1}	114 - 600	114 - 600	117 - 535

Summary

Summary

- **LHC and experiments' run at 7 TeV truly impressive**
  - **By now the detectors are fully functioning scientific instruments: physics-producing engines**
- **With ~40pb^{-1} the LHC has observed all particles of the standard model (indirectly, even neutrinos)**
  - **Solid basis for understanding the "background" to searches at higher mass and transverse energy scales**
- **With 1 fb^{-1} we entered the true Higgs discovery era. With 5 fb^{-1}: discovery [no matter what]**
  - **"SUSY" explorable over very large area with 1fb^{-1}; possible new resonances. Very large reach for other new physics.**
  - **But nobody said it would be easy. May soon have to start looking hard for the more complicated scenarios.**
  - **Perhaps unification should start in the physics [search] groups**
- **Thankfully, there is also always the anthropic principle.**
  - **Anthropically, history repeats itself $\rightarrow$ we will find the unexpected!**
- **The journey has only just started!**