Fisica Oltre Il Modello Standard
Rassegna Sperimentale

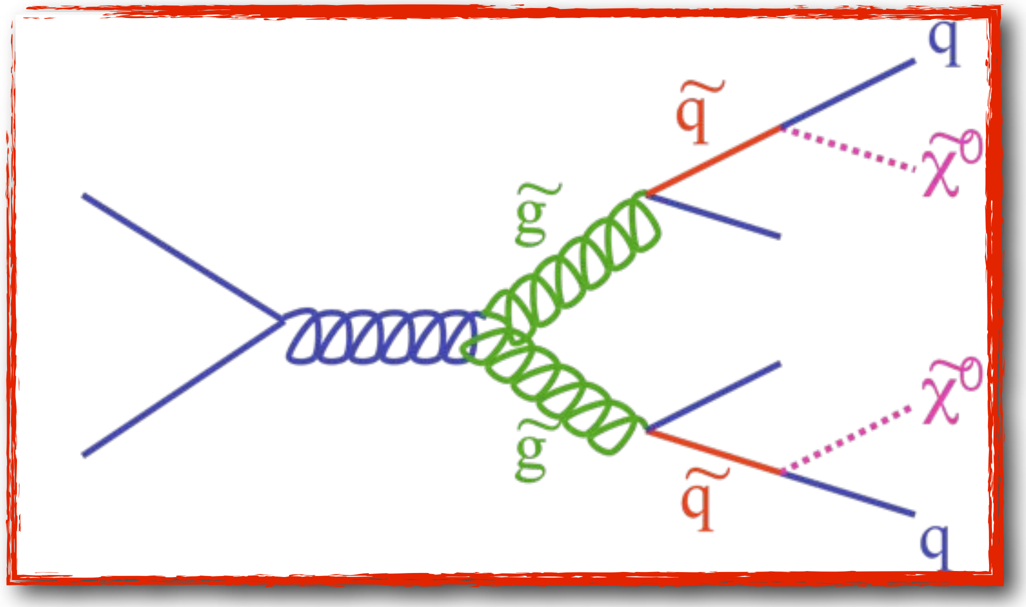
Maurizio Pierini

How to read this talk

- There are too many results to cover in 20 minutes, so I covered only the latest results (Talks at Moriond EW and QCD used as reference)
- For each subject, I tried to give both the Tevatron status and the LHC perspectives
- I tried to go beyond the SUSY option, covering also other candidates of LHC early discoveries
- I focused on early physics, so many subjects demanding high statistics (e.g. non-standard Higgs) are left for IFAE201X
- I tried to present what is done and can be done, without thinking at how “likely” things are (theoretical/personal subjective judgement).

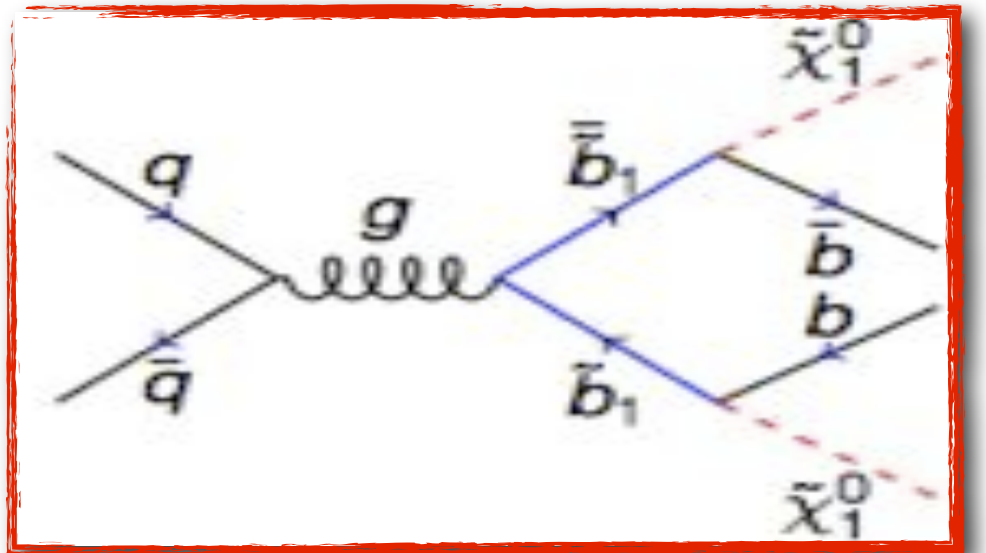
SUSY searches

Hadronic Final States



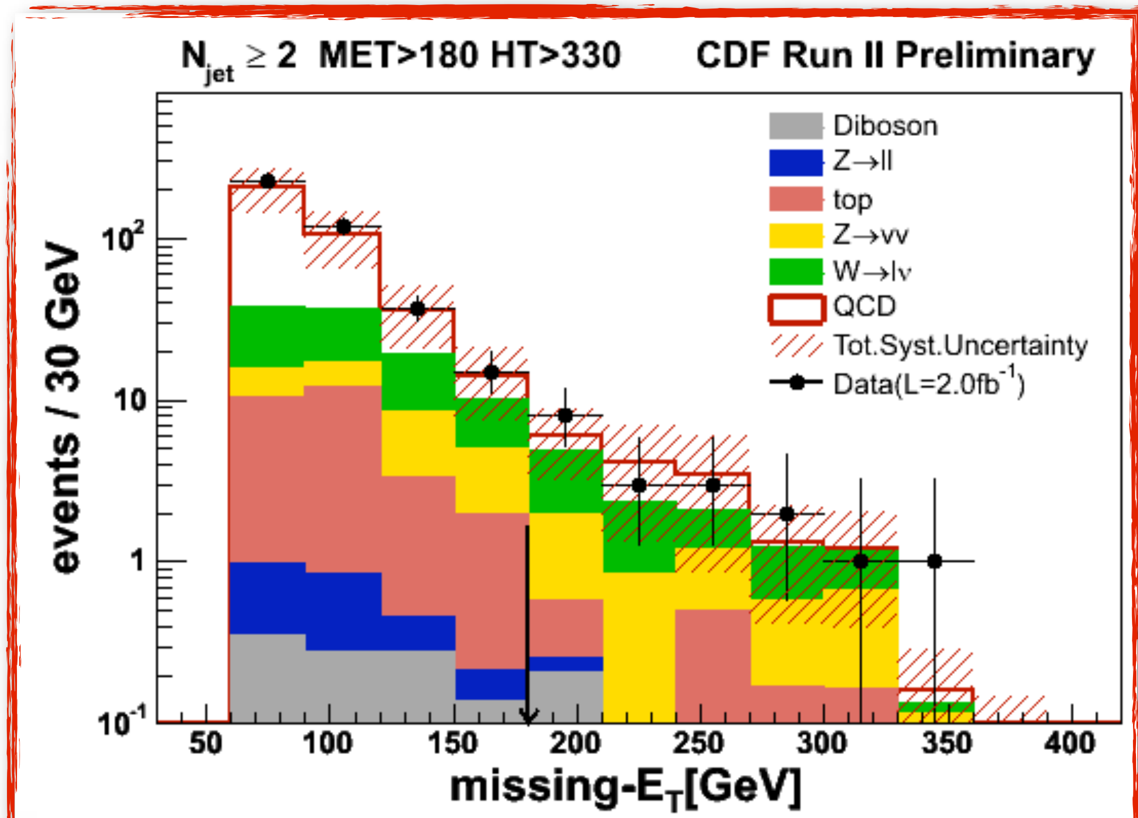
Squarks and Gluinos produced with large cross section. Final states with jets and MET. Excess searched in the MET tail. QCD background from data. Other backgrounds from Monte Carlo

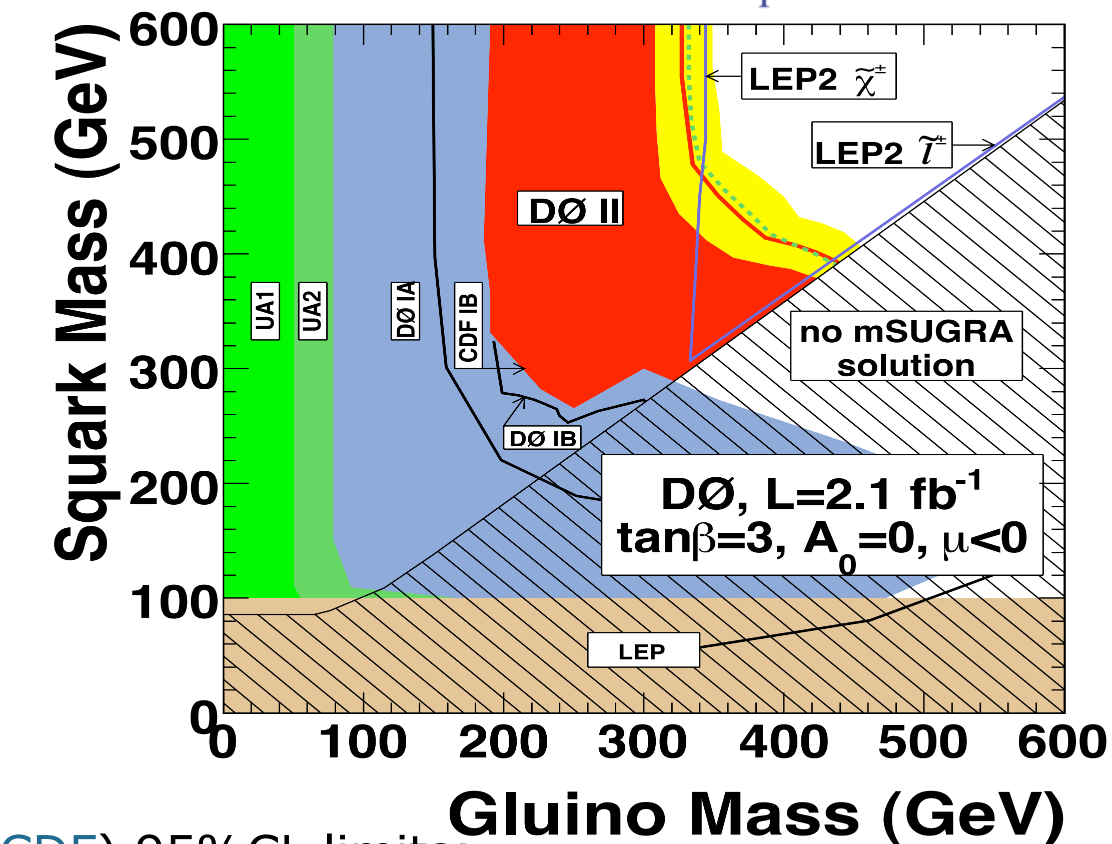
Bottom production from SUSY (e.g. through sbottom decay). Displaced vertices characterize heavy-flavor jets. Final states with jets and MET. Excess searched in the MET tail. QCD background from data. Other backgrounds from Monte Carlo. B tagging to increase S/B with respect to inclusive hadronic searches



Squarks and Gluinos

Inclusive searches of hadronic final states with large MET and/or transverse energy in the event
Event selection to improve S/B.
Looking for excess on the tails of SM distribution
QCD background templated from control samples
Understanding of detector simulation and MC generators to model the non-QCD backgrounds



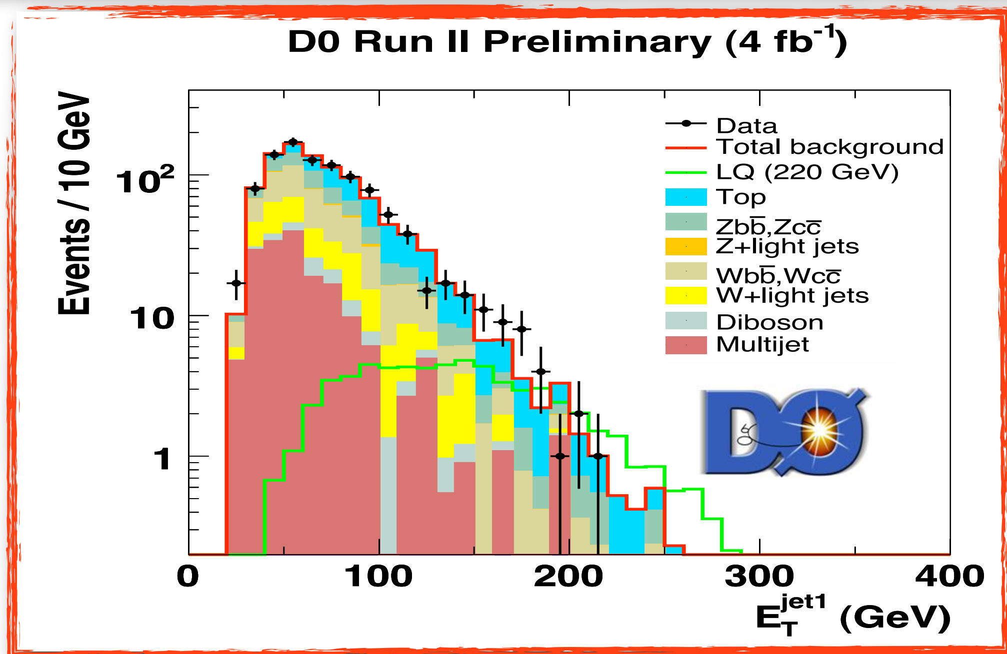


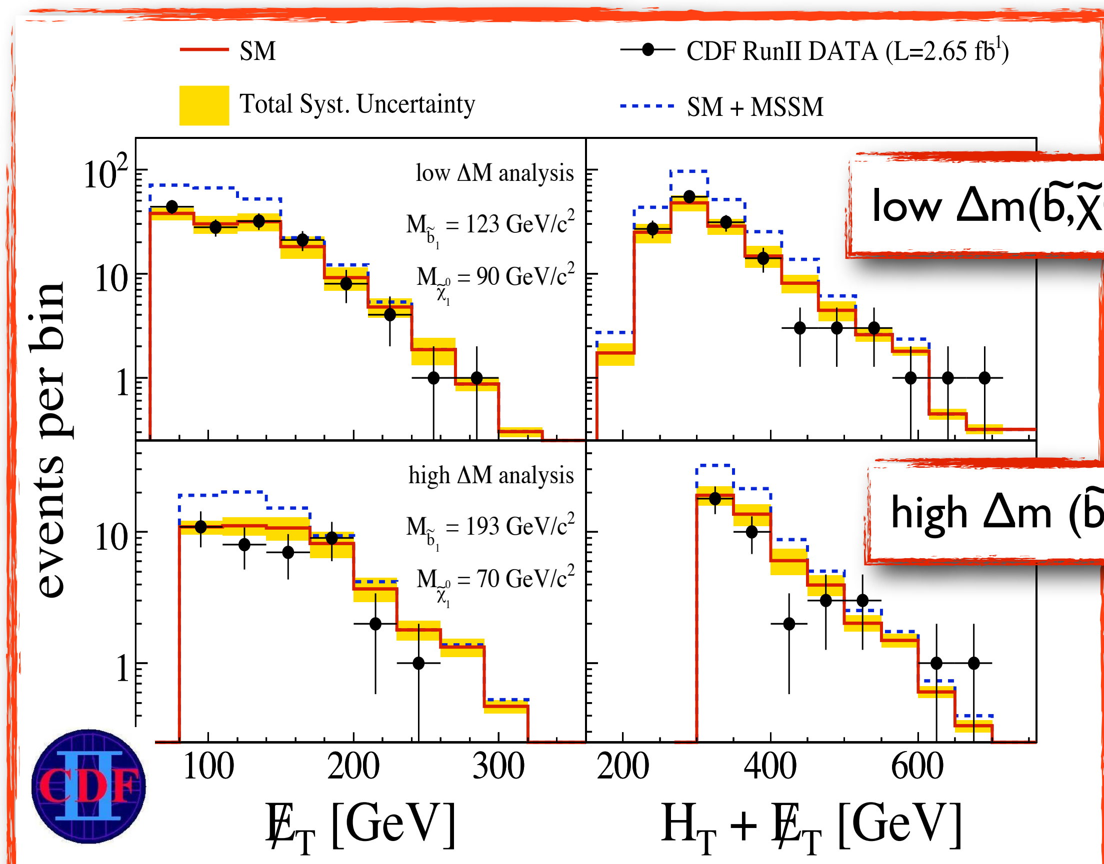
D0 (CDF) 95%CL limits:

- $M(\tilde{g},\tilde{q})$>390 (390) GeV/c² when $M(\tilde{g}) \sim M(\tilde{q})$
- $M(\tilde{g})$>308 (280) GeV/c² for any $M(\tilde{q})$
- $M(\tilde{q})$>379 (340) GeV/c² for any $M(\tilde{g})$

Analyses improved with time (started as ≥3j, moved to ≥2j (more difficult, more QCD) events after better detector understanding)
No excess seen. Result translated into a limit on masses parameter space

Sbottom Production





low $\Delta m(\tilde{b},\tilde{\chi}0)$ (<90 GeV)

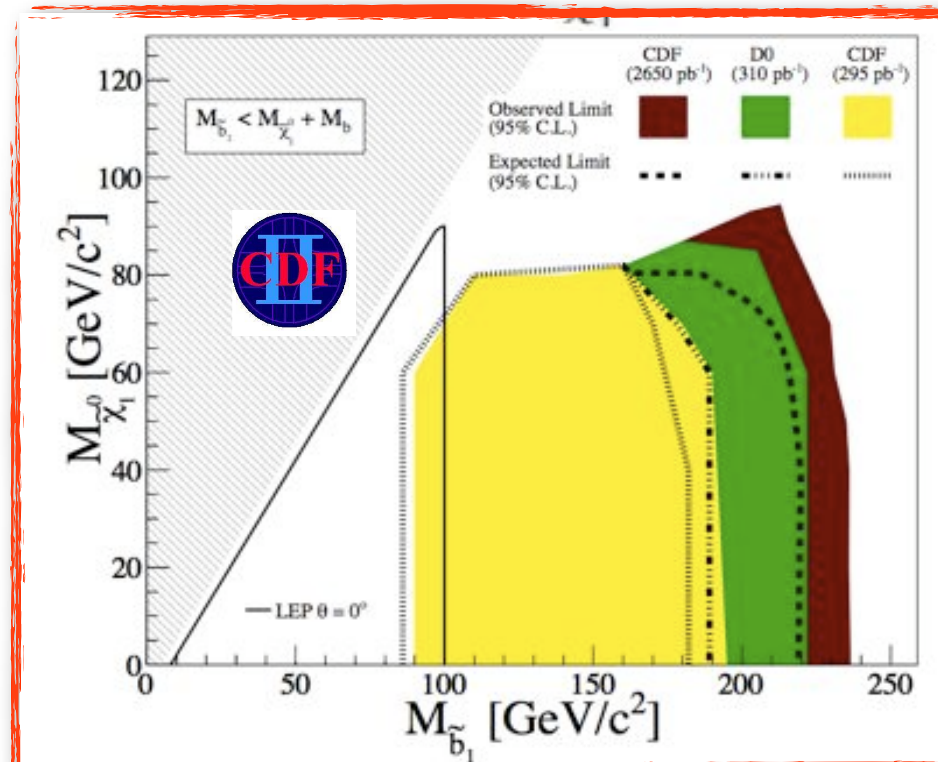
high $\Delta m(\tilde{b},\tilde{\chi}0)$ (>90 GeV)

D0 95%CL limits:

- $M(\tilde{b}) > 250$ GeV/c² when $M(\tilde{\chi}) < 70$ GeV/c²

CDF 95%CL limits:

- $M(\tilde{b}_1) > 230$ GeV/c² when $M(\tilde{\chi}) < 70$ GeV/c²

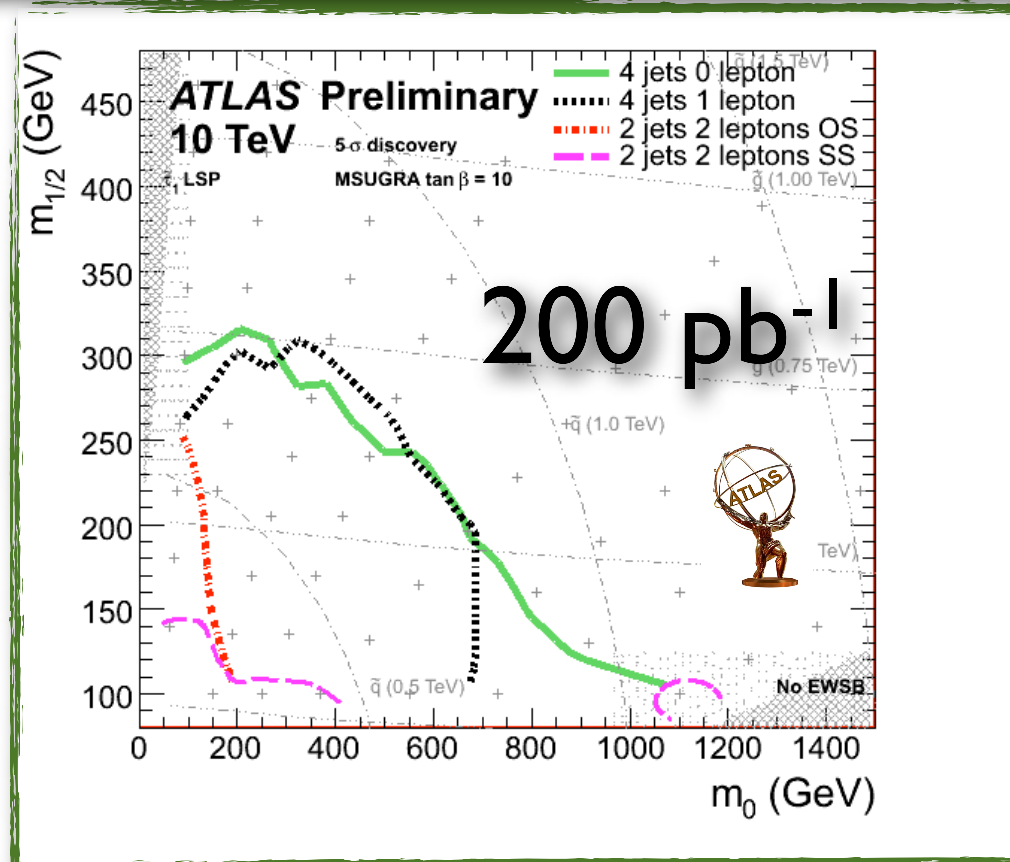


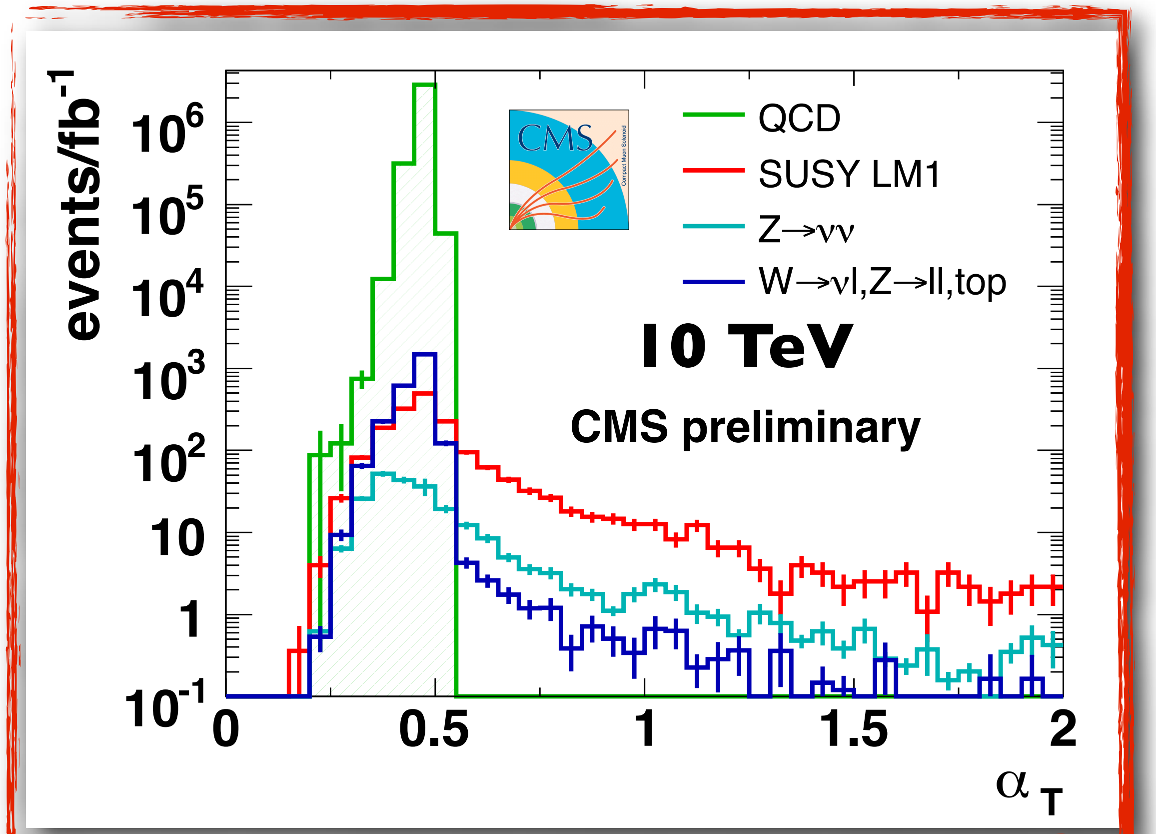
Strategy similar to inclusive hadronic searches
B-jet tagging to increase the S/B ratio
Top events understanding critical (fully hadronic events very similar to SUSY signal)
More critical for LHC (larger top x-section makes it a more problematic background)

Hadronic Searches @ LHC

high-pT searches

- Similar to the MET-based Tevatron analyses, sometimes with different variables used for search (Meff, MHT, ...).
- QCD from data (as for Tevatron)
- Focus on data-driven methods to understand the backgrounds





MET-less searches new approach based on αT variable: look for N jets, veto the N+1jet and quantify the unbalancing on transverse plane as

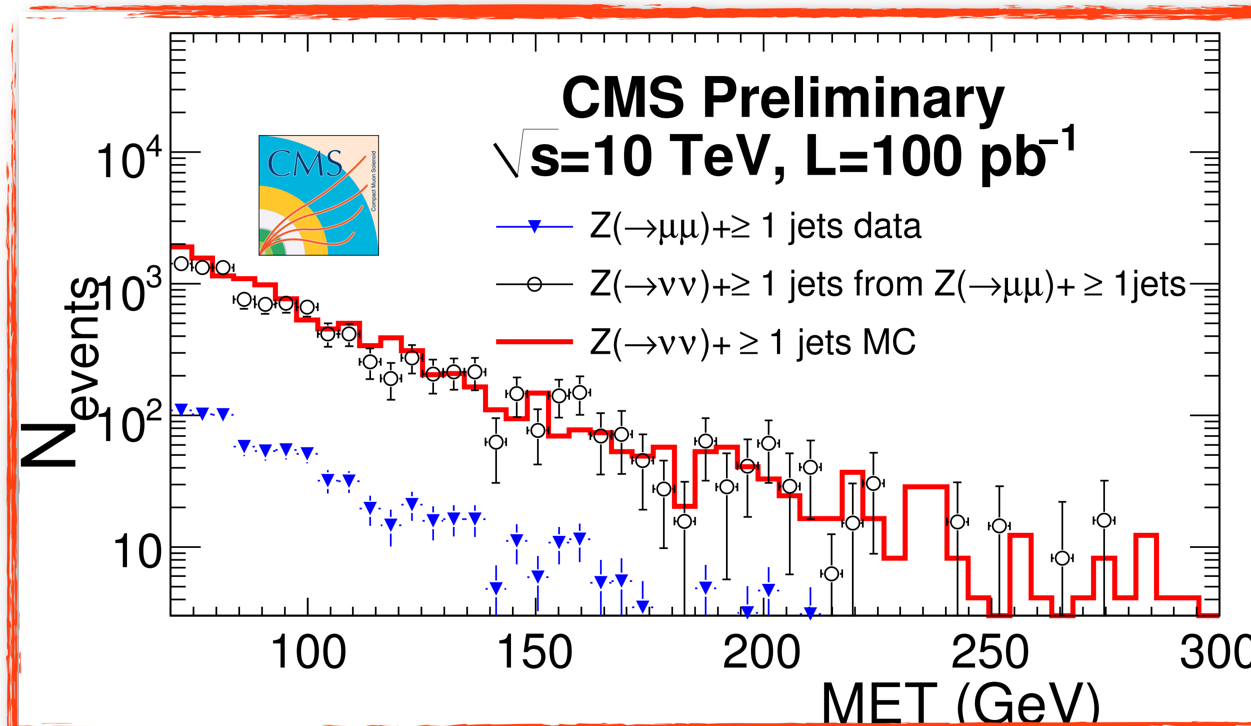
$$\alpha_T = \frac{E_T^{j2}}{\sqrt{2E_T^{j1}E_T^{j2}(1-\cos\Delta\phi)}} = \frac{\sqrt{E_T^{j2}/E_T^{j1}}}{\sqrt{2(1-\cos\Delta\phi)}}$$

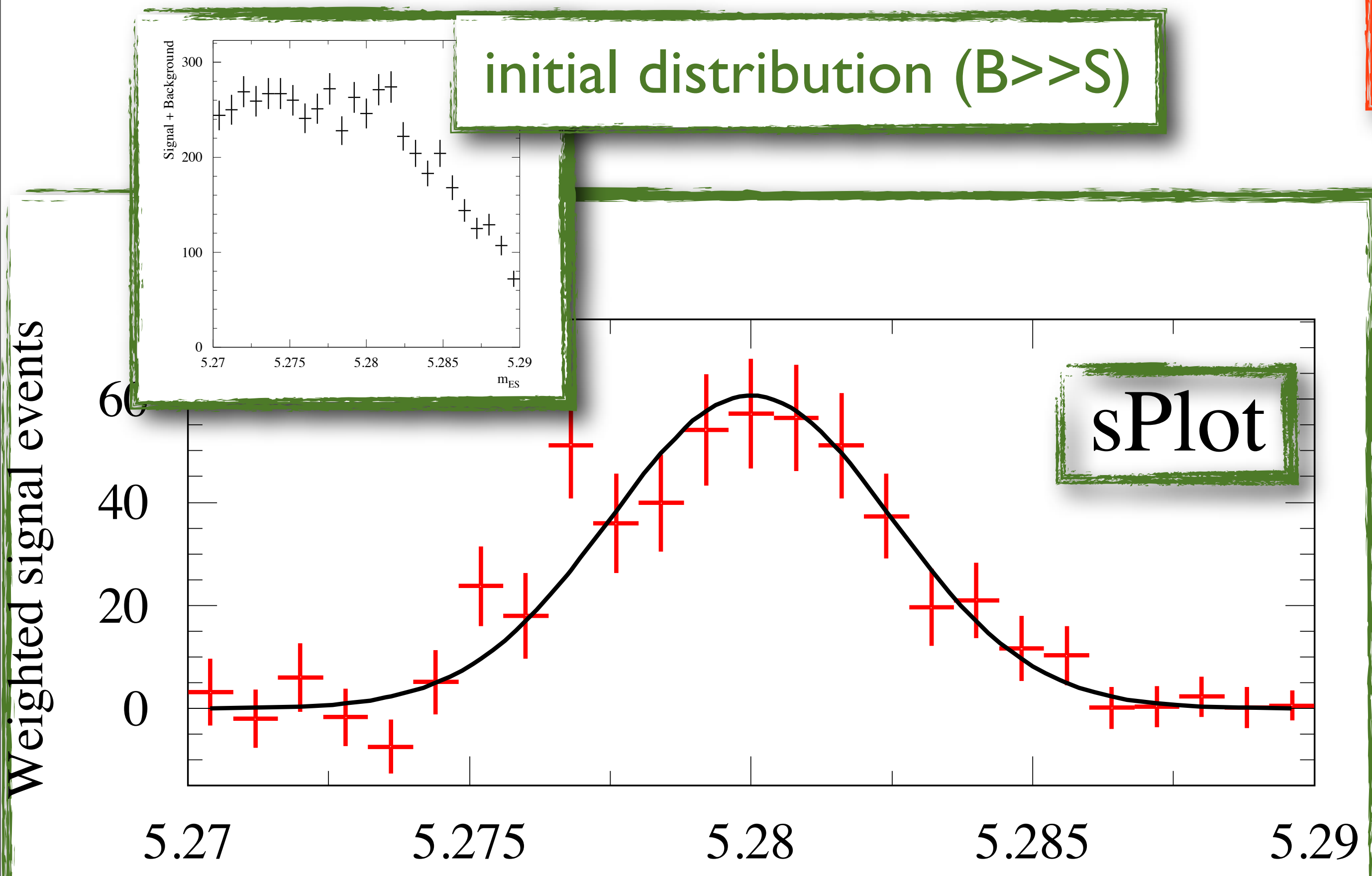
Sharp cut-off for QCD. Other backgrounds look like signal. The understanding of non-QCD backgrounds remain

Hadronic Searches @ LHC

Bkg determination from data

- methods developed to get backgrounds from data (e.g. normalizing the signal-enriched small-η region to the signal-depleted large-η region)
- Use of "candle" processes for normalization (e.g. Z(υυ)+jets from Z(μμ)+jets)





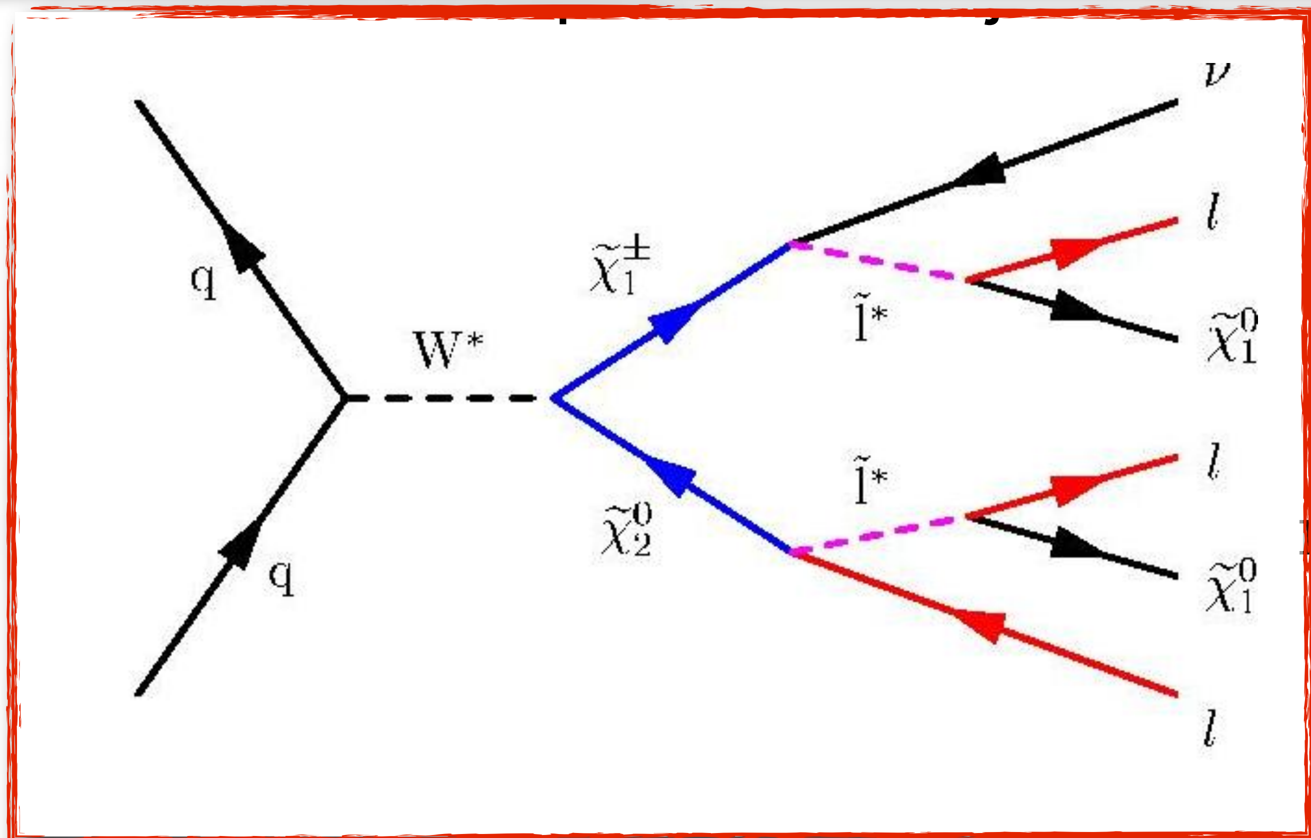
M. Pivk & F. Le Diberder arXiv:physics/0402083

Bkg characterization and MC tuning

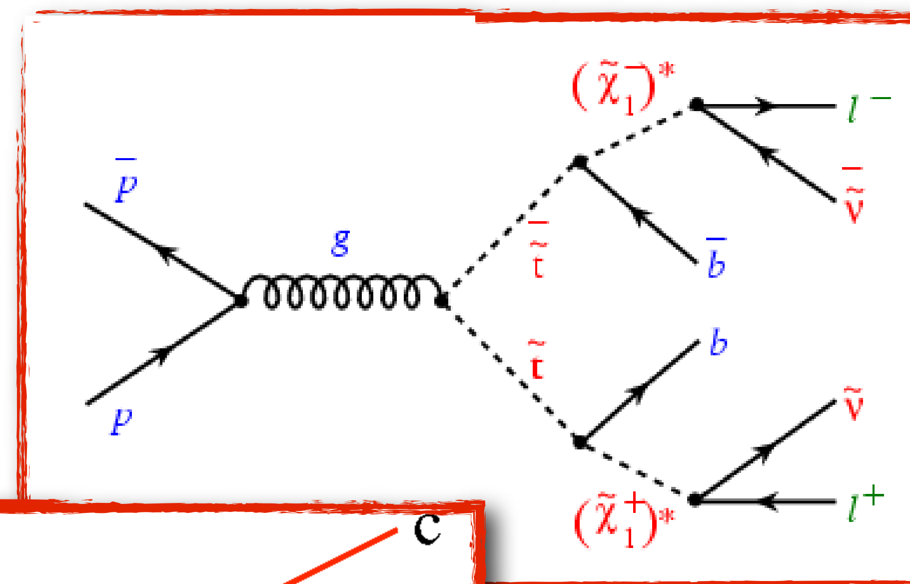
- One can characterize a given bkg sample (V +jets, ttbar, ...) in a "signal-free" region by specifying pT and η distributions (e.g. of jets)
- This study allows a tuning of the MC generators and a better understanding of the backgrounds in the signal region
- An efficient background subtraction needed.
- Better if done per event: **BaBar sPlots**

This is what we need to accomplish with the first 100 pb^{-1}

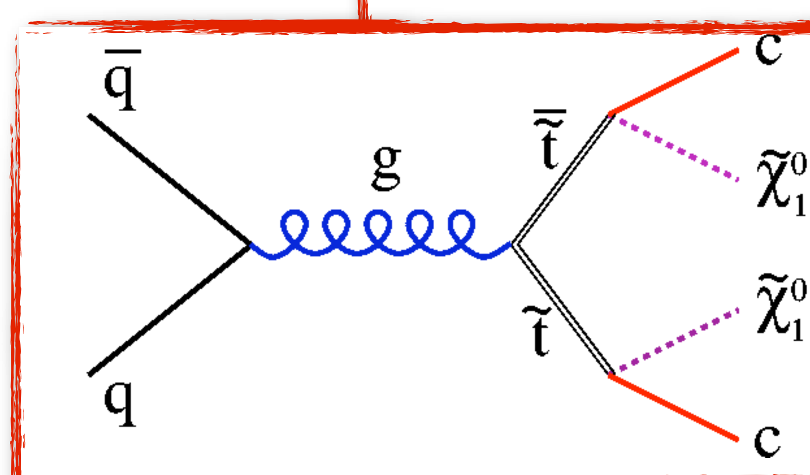
Leptonic Final States



Charginos and Neutralinos produce final states with leptons, clean signature @hadron colliders
Lower cross sections are compensated by smaller SM backgrounds (e.g. QCD)
Leptons can be soft, depending on the mass difference between SUSY particles in the decay chains



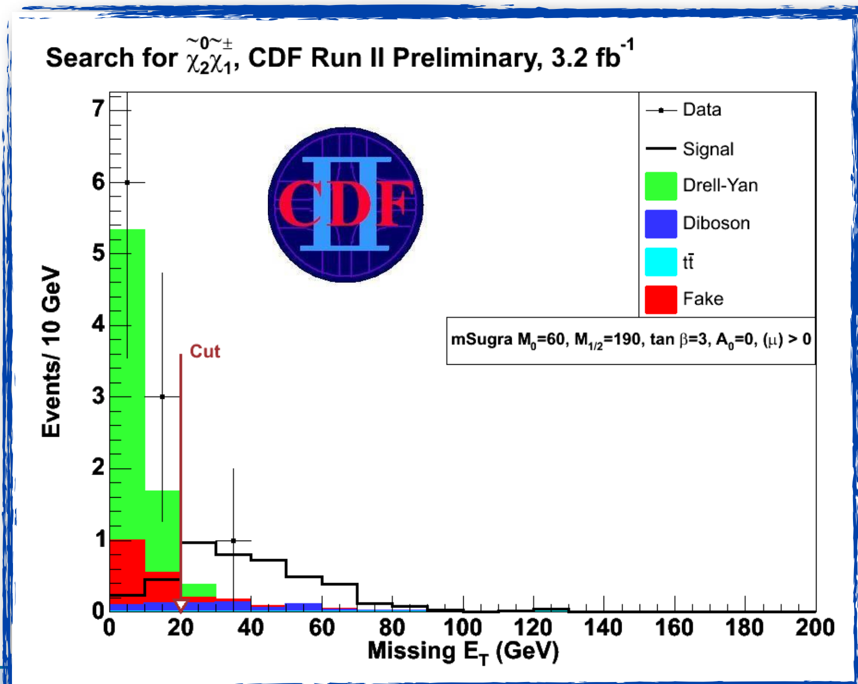
Stop quarks might be the lightest squark, maybe even lighter than the top
Dominant decay chain depends on the model (e.g. which is LSP?)
Signature not depending on decay chain (leptons + b-jets +MET).
- Dangerous background from top (heavy particles producing MET, as signal)

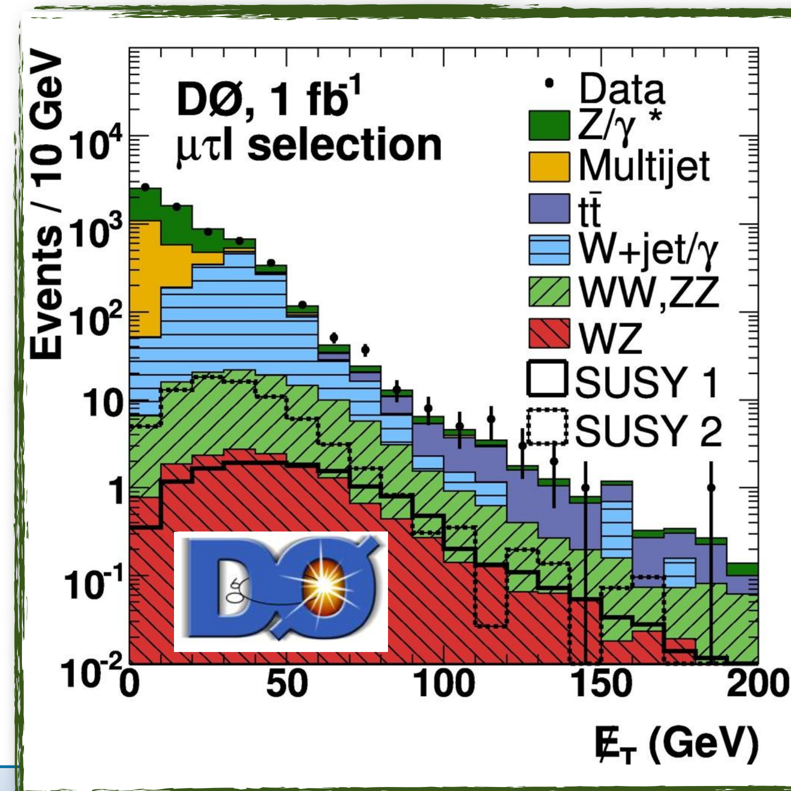


Trileptons final states @ Tevatron

Analyses look for general signatures (3l, 2l+track, l = e,μ,τ) but optimized on specific mSugra points

MET-based cut&count approach with low signal efficiency



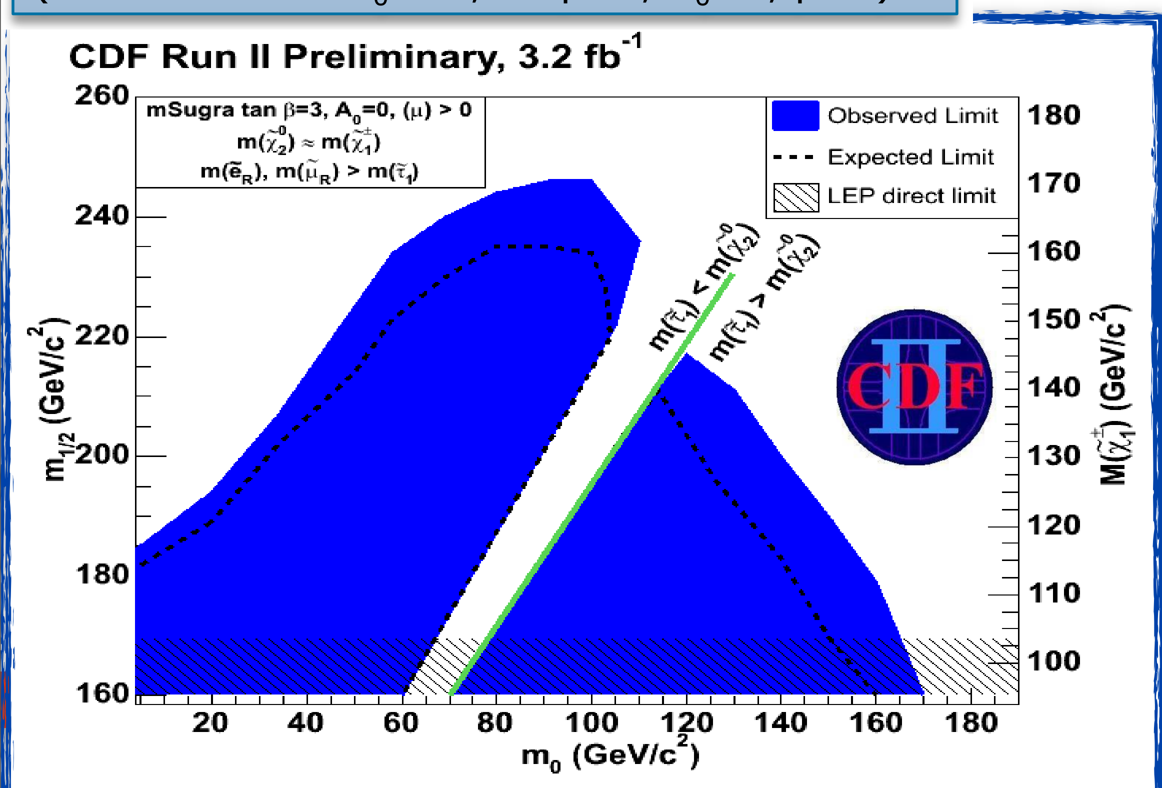


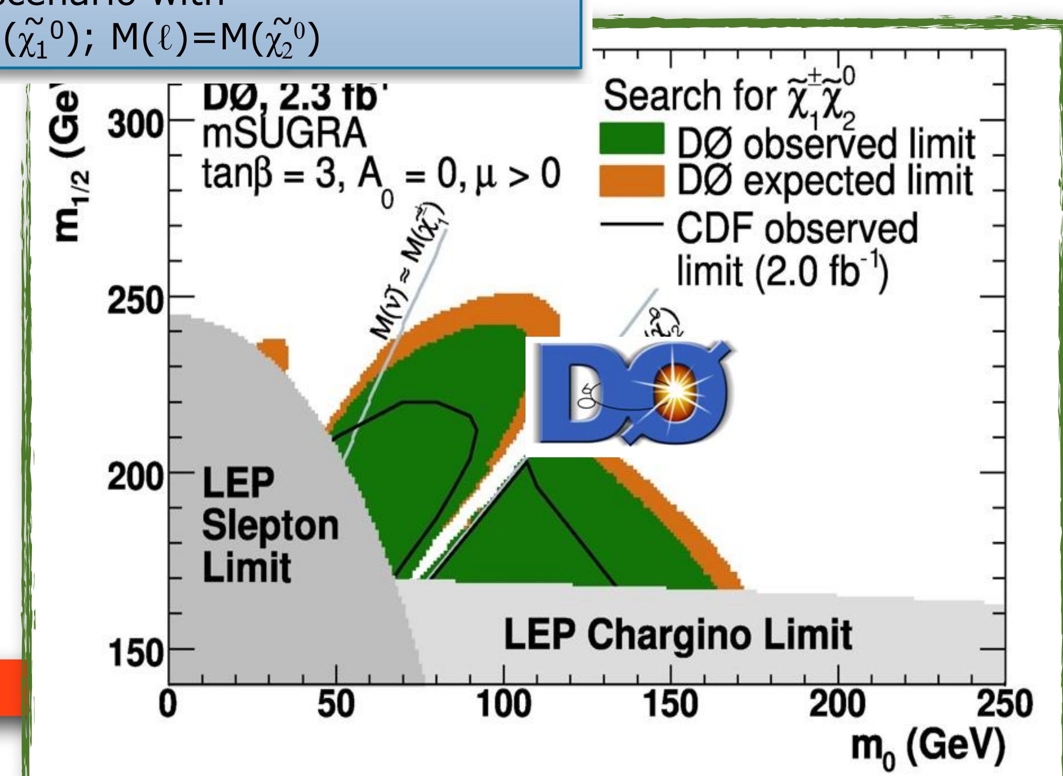
95% CL exclusion limit:

➡ $M(\tilde{\chi}^\pm) > 164$ GeV/c^2
(mSUGRA with m_0=60, tanβ=3, A_0=0, μ>0)

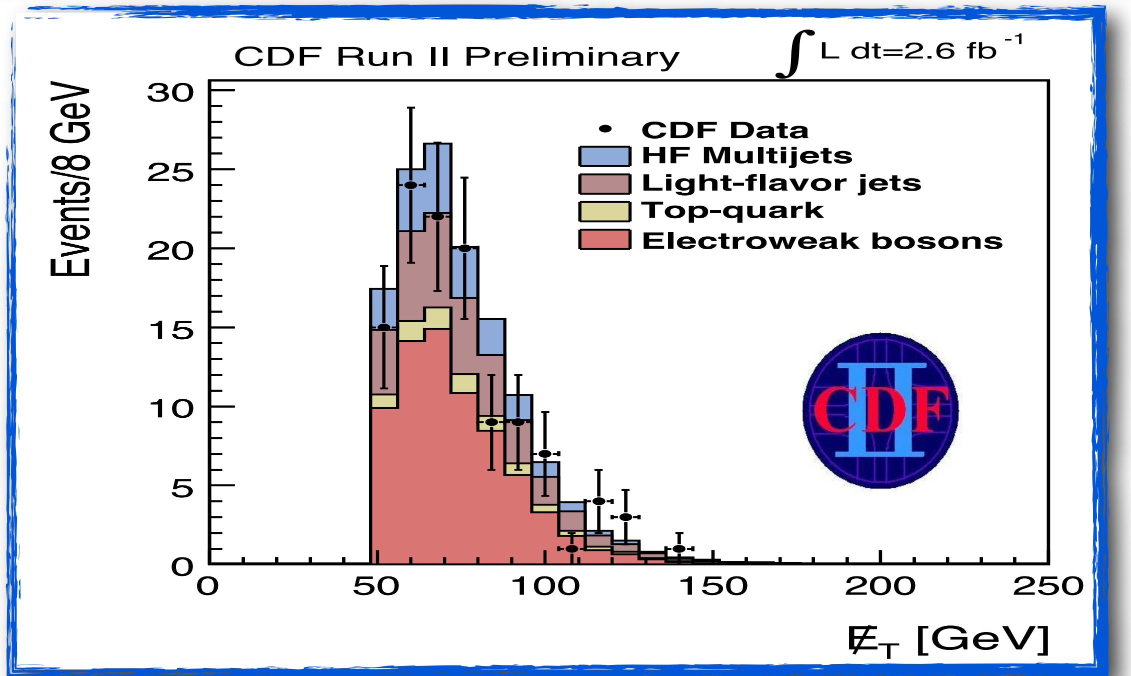
95% CL limit :

➡ $M(\tilde{\chi}^\pm) > 138$ GeV/c^2
➡ more general scenario with
$M(\tilde{\chi}_1^\pm)=M(\tilde{\chi}_2^0)=M(\tilde{\chi}_1^0)$; $M(\ell)=M(\tilde{\chi}_2^0)$

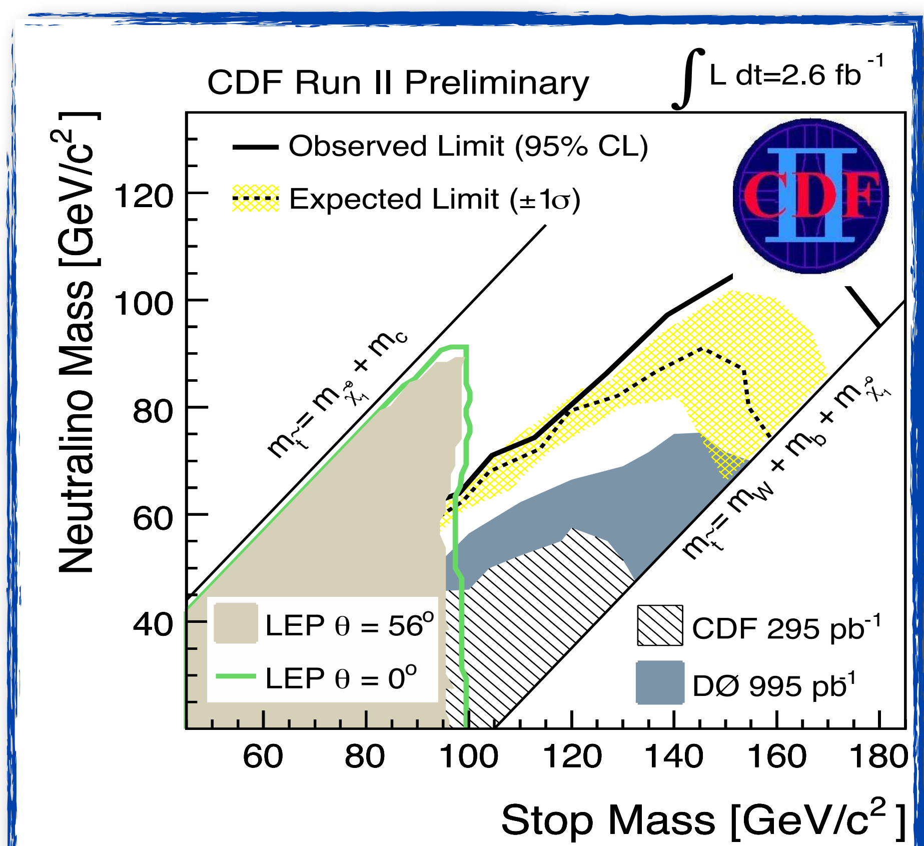




Stop searches @ Tevatron



- The requirement of leptons in final state reduces the pollution by QCD events.
- Main background from VB, top less abundant (due to xsection) but dangerous (signal-like)
- At the LHC, top will be more relevant (larger xsection)

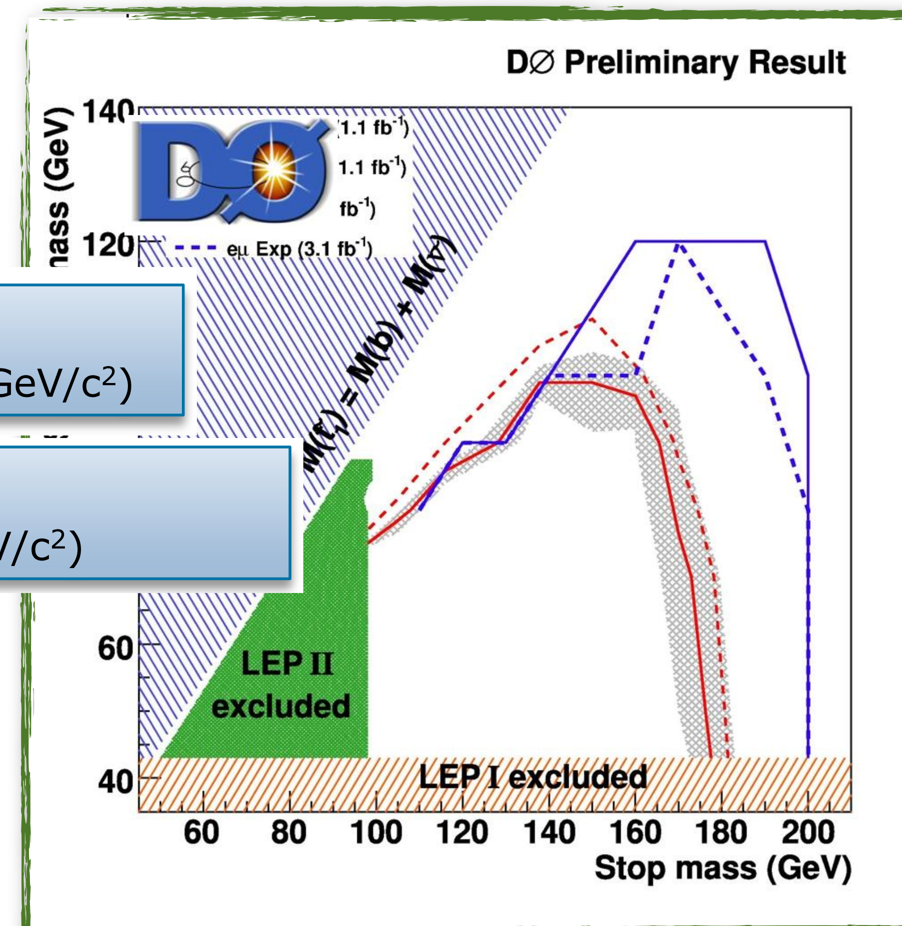


95% CL limit:

➡ $M(\tilde{t})>180$ GeV/c² (with $M_{\tilde{\chi}}\sim 90$ GeV/c²)

95% CL exclusion limit:

➡ $M(\tilde{t}_1)>200$ GeV/c² ($M_{\tilde{\nu}}<100$ GeV/c²)



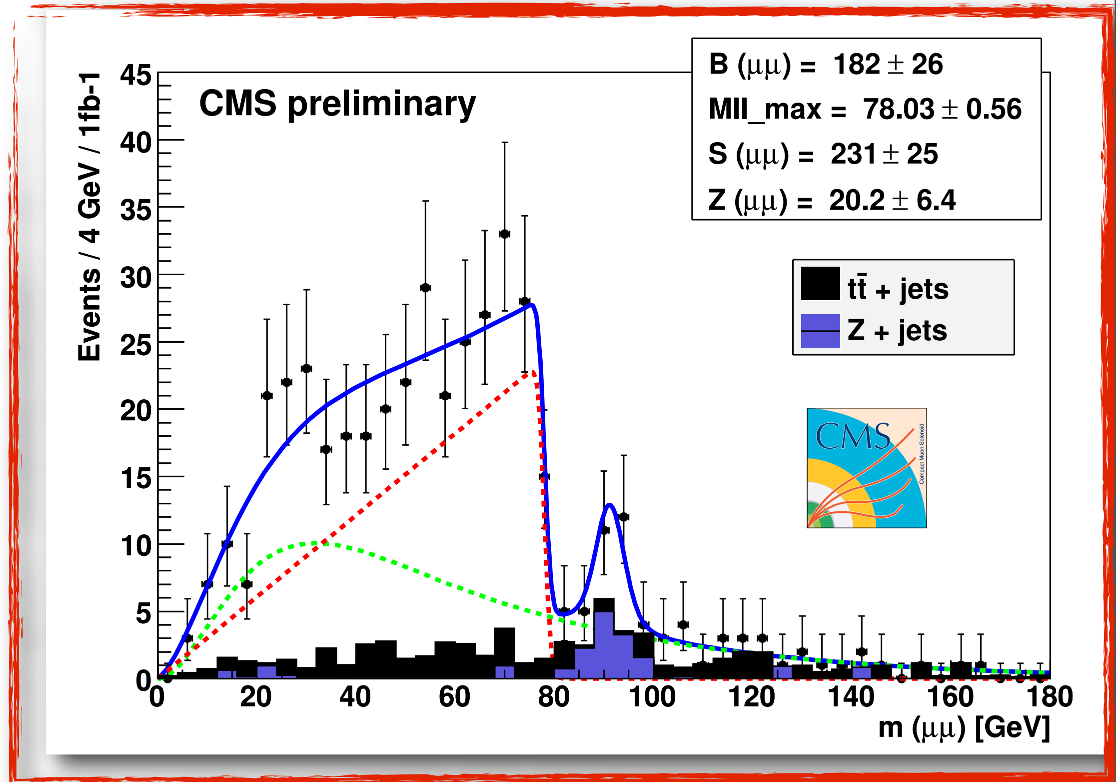
Leptonic Searches @ LHC

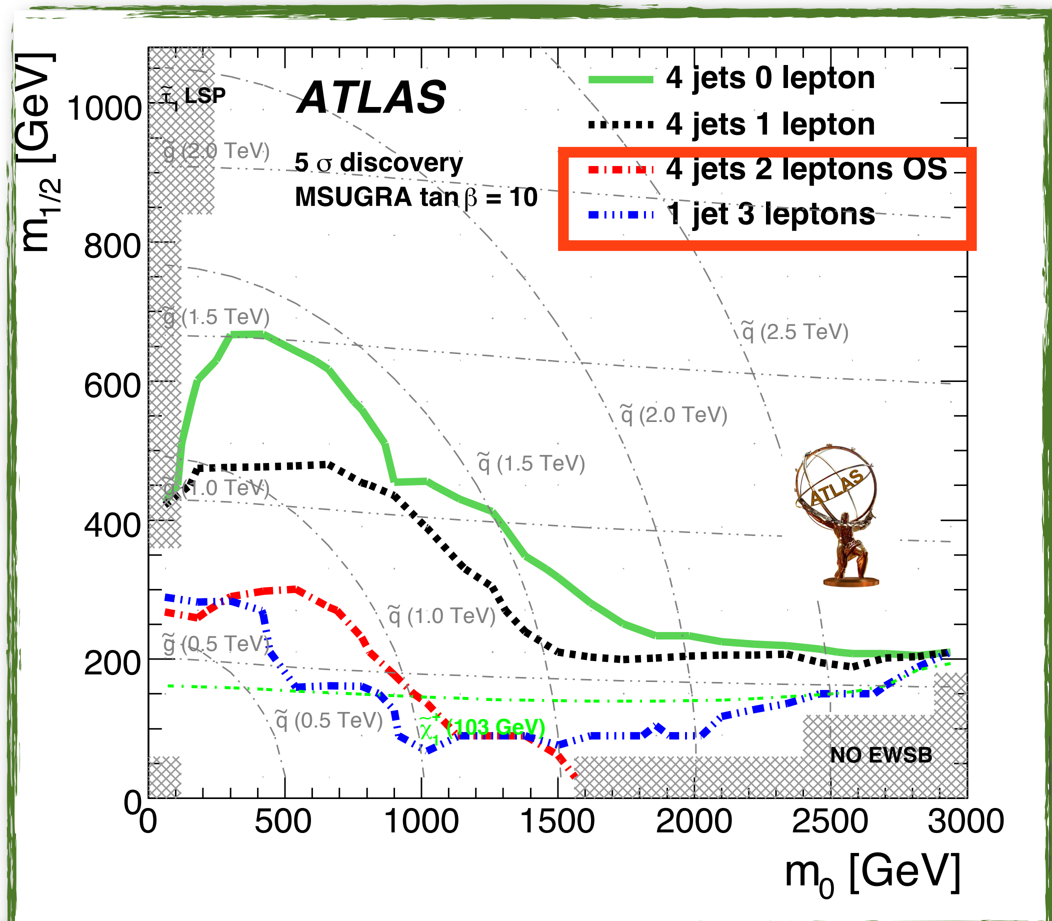
Dilepton searches:

Analyses looking for excess of events on high pT tails (as for hadronic searches) Signal vs Bkg discrimination based on the dilepton invariant mass

$$m_{\ell\ell}^{max} = m_{\tilde{\chi}_2^o}\sqrt{1-\frac{m_{\tilde{\ell}_R}^2}{m_{\tilde{\chi}_2^o}^2}}\sqrt{1-\frac{m_{\tilde{\chi}_1^o}^2}{m_{\tilde{\ell}_R}^2}}$$

Very effective for discovery as well as for phenomenology (edge measured with O(GeV) error, it measures a combination of SUSY masses)



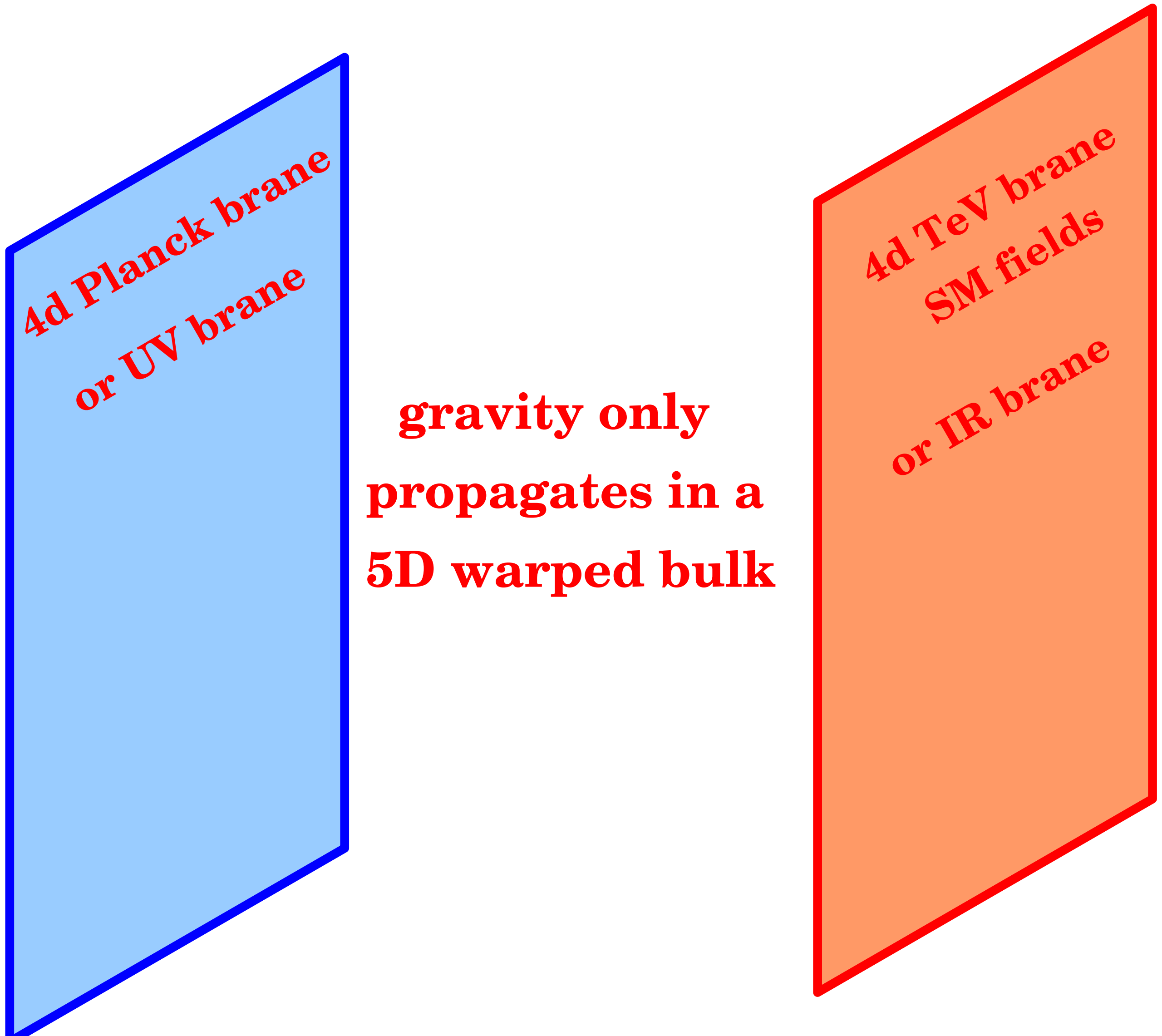


MultiLepton searches:

Less powerful for discovery, due to lower xsections
Very promising in particular scenarios (SO(10)-inspired SUSY models with multi-top production)
Very important for characterization of the underlying theory (comparison of xsection in different final states allows to perform model discrimination)

Heavy Resonances

ED & New Resonances

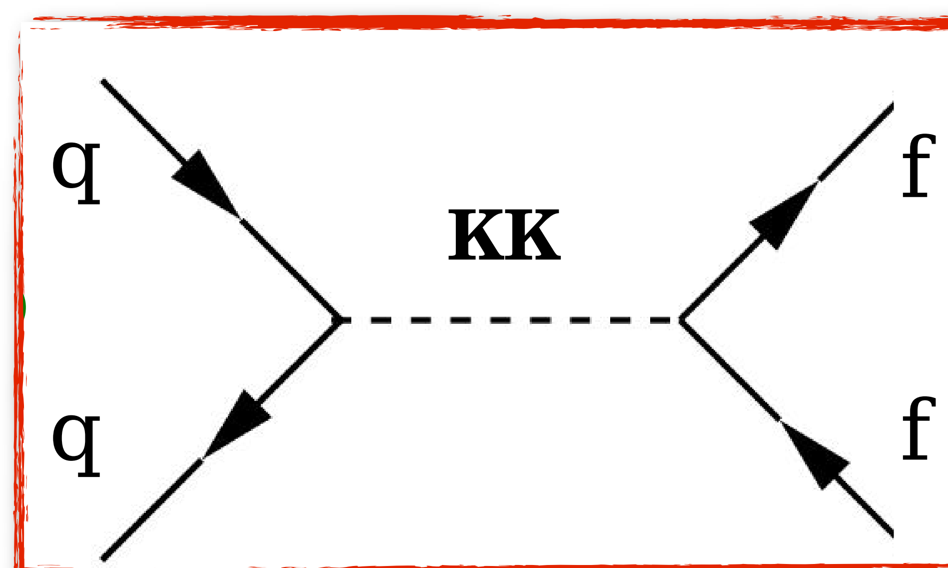


Alternative approach to EWSB.
One (or more) Extra Dimensions exist.

$$m_k^2 = m_0^2 + \frac{k^2}{R^2}$$

$$\Phi(x,y) = \sum_k \phi^{(k)}(x) e^{\frac{iky}{R}}$$

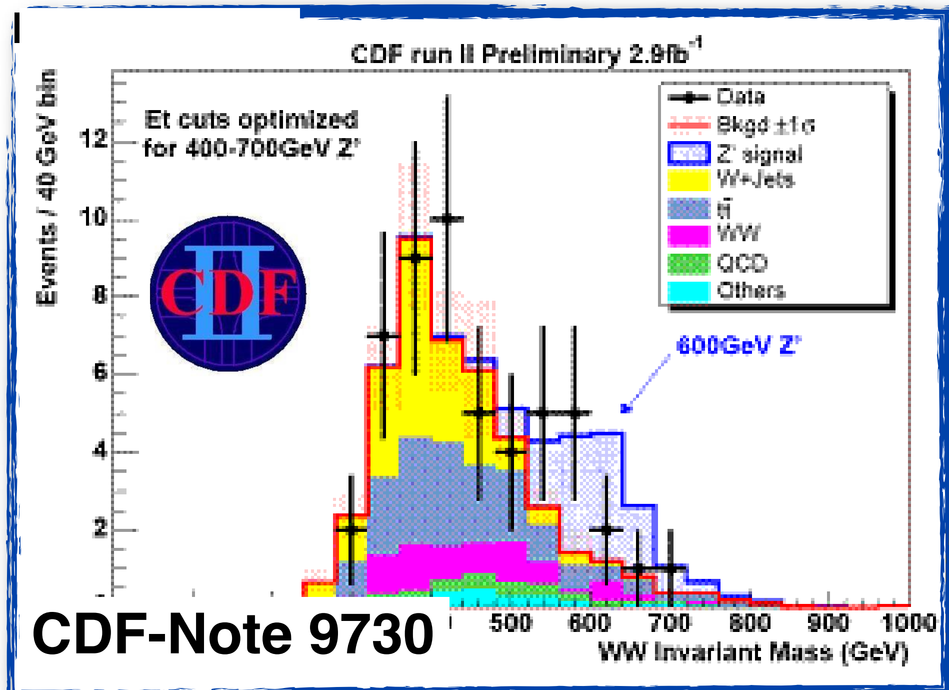
Observed particles are the "mode-0" of a KK tower, obtained by projecting a 5-D field on the 4-D space we live in



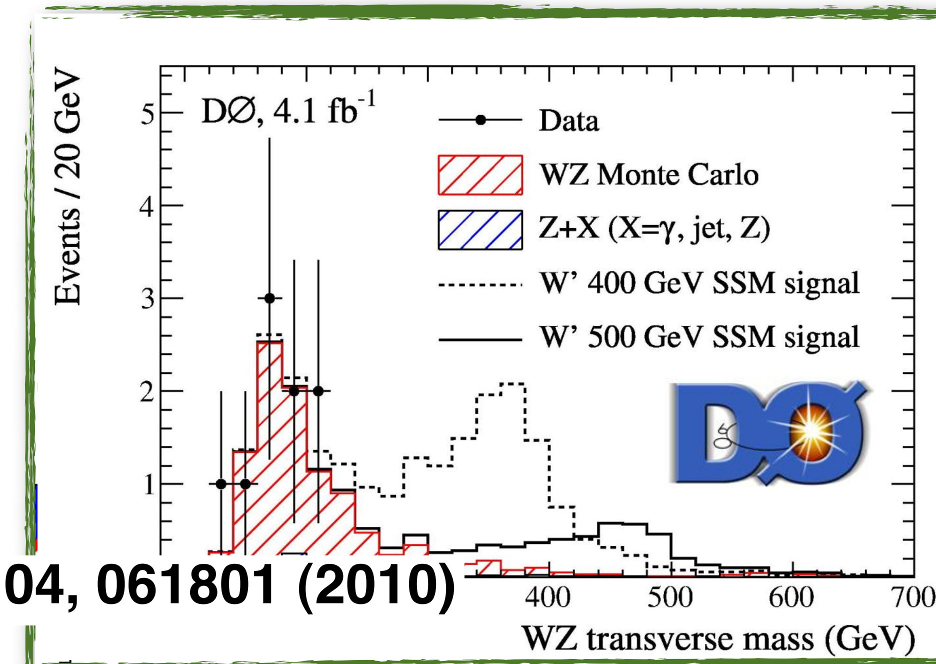
The exited modes of the KK tower can be produced at LHC, the xsection and the final state depending on the details of the model (overlap of the wave functions). This models serves as the prototype for searches of high-mass resonances at hadron colliders

Diboson Resonances

Tevatron searches fro **Z'→WW** and **W'→WZ** resonances with electrons & jets in final states

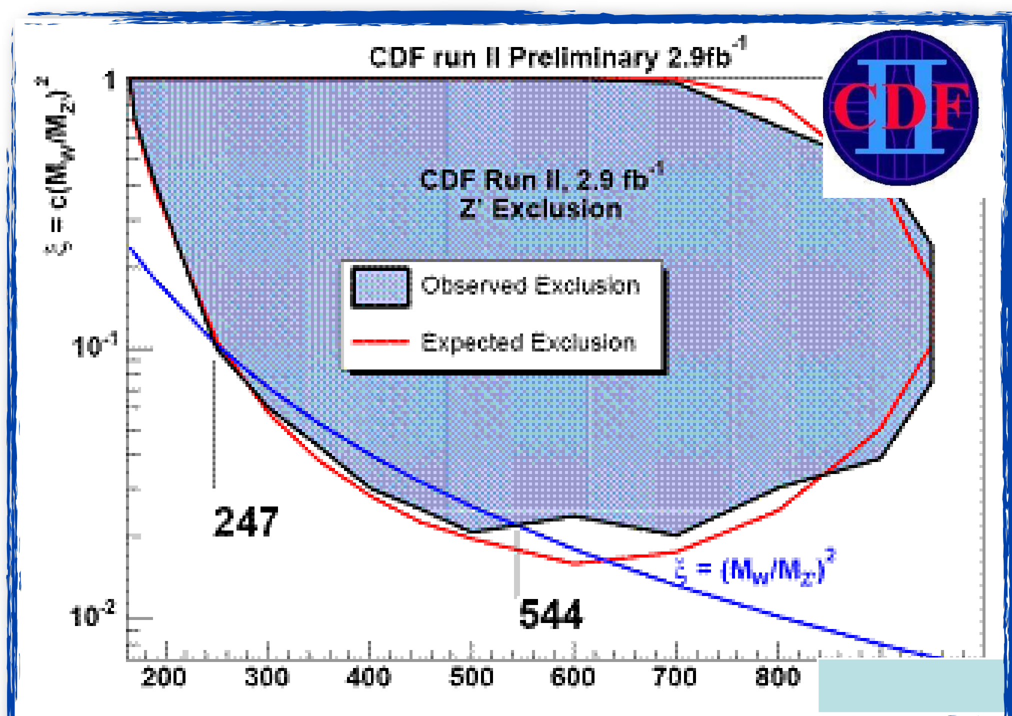


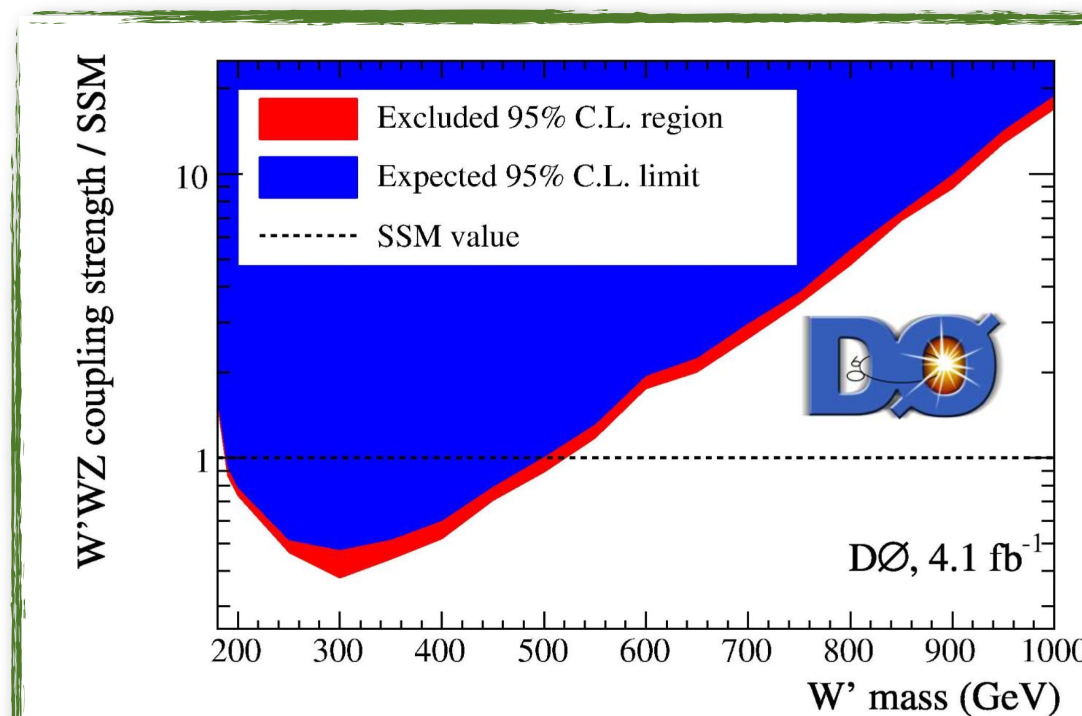
CDF-Note 9730



PRL 104, 061801 (2010)

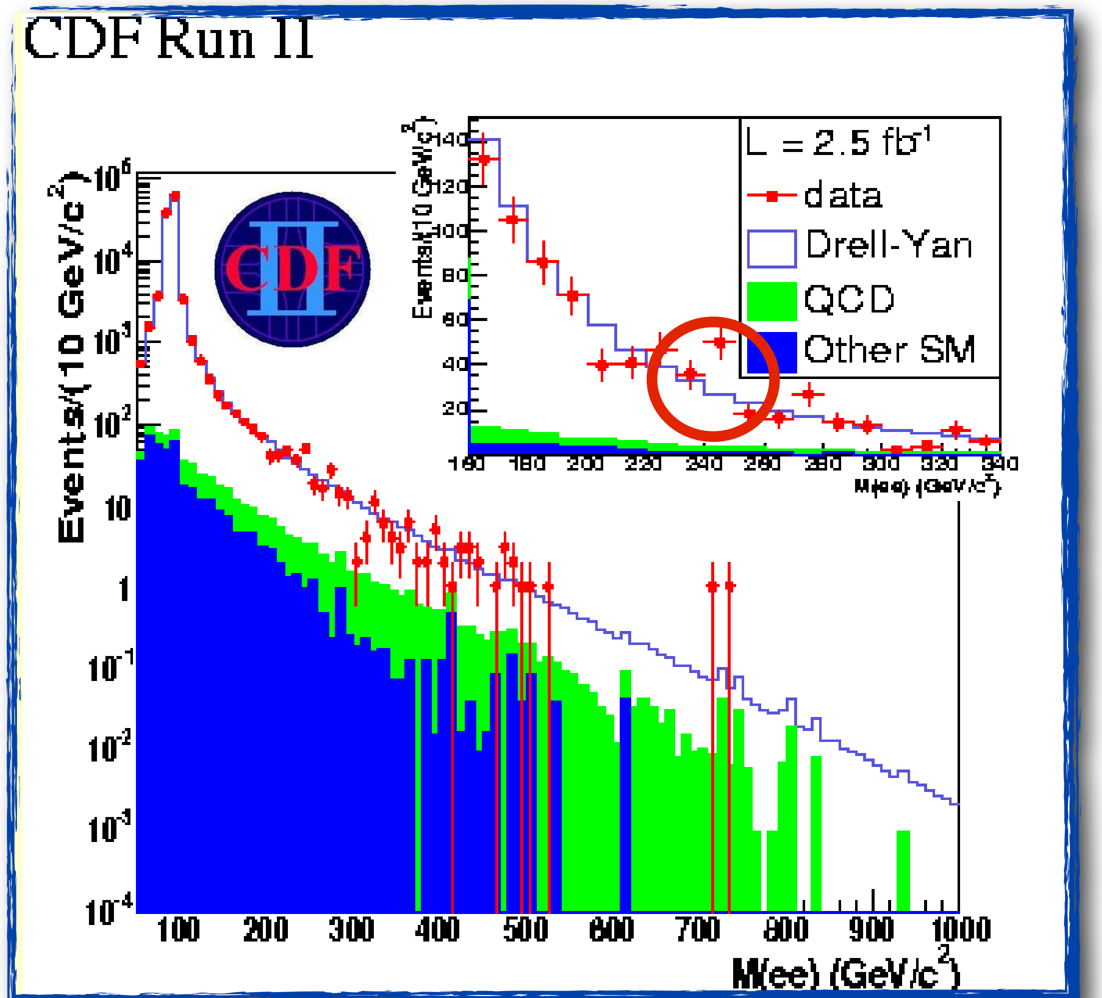
No excess is observed, which is translated in a limit on the parameter space

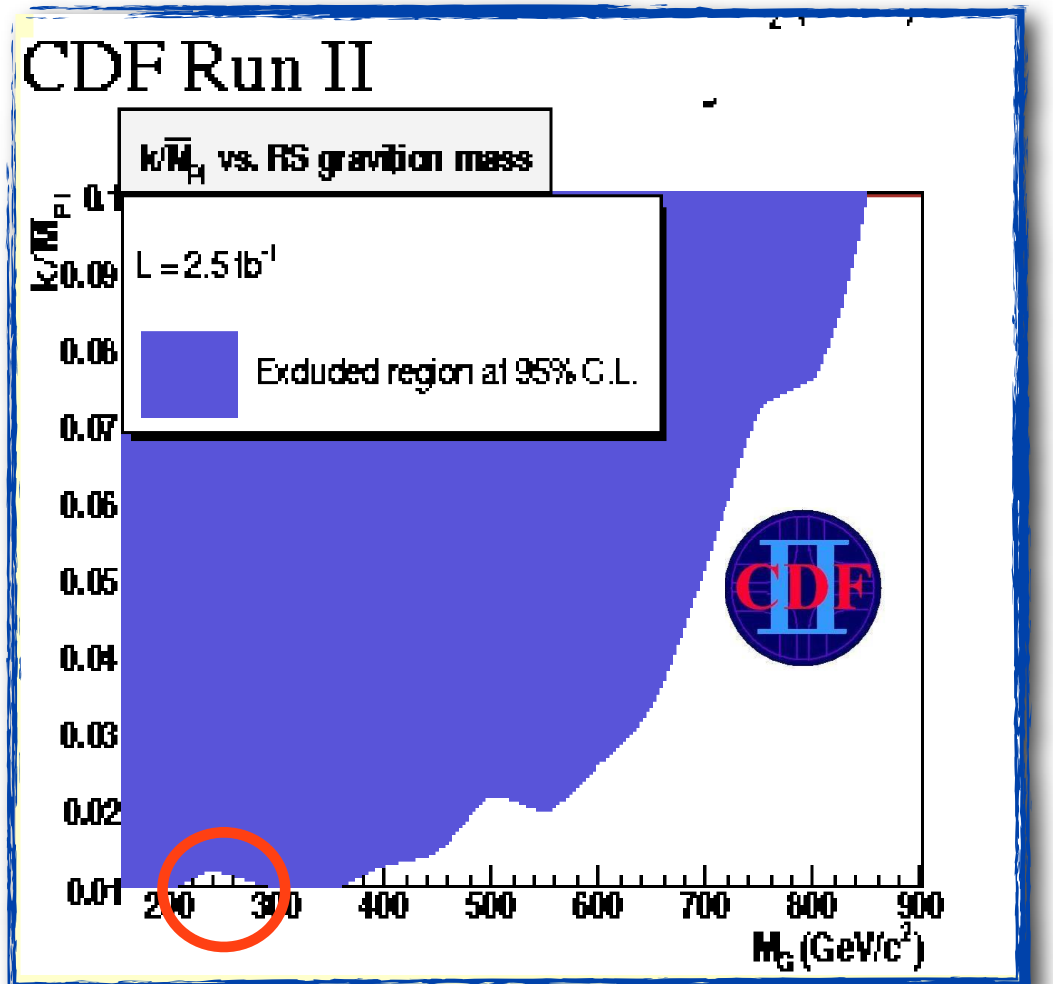




Z'→ee @ CDF

The most significant region of excess of data over background occurs for a dielectron invariant mass window of 240 GeV/c^2, and is **~3.8 standard deviations above the SM prediction** (not confirmed by the equivalent muon analysis)

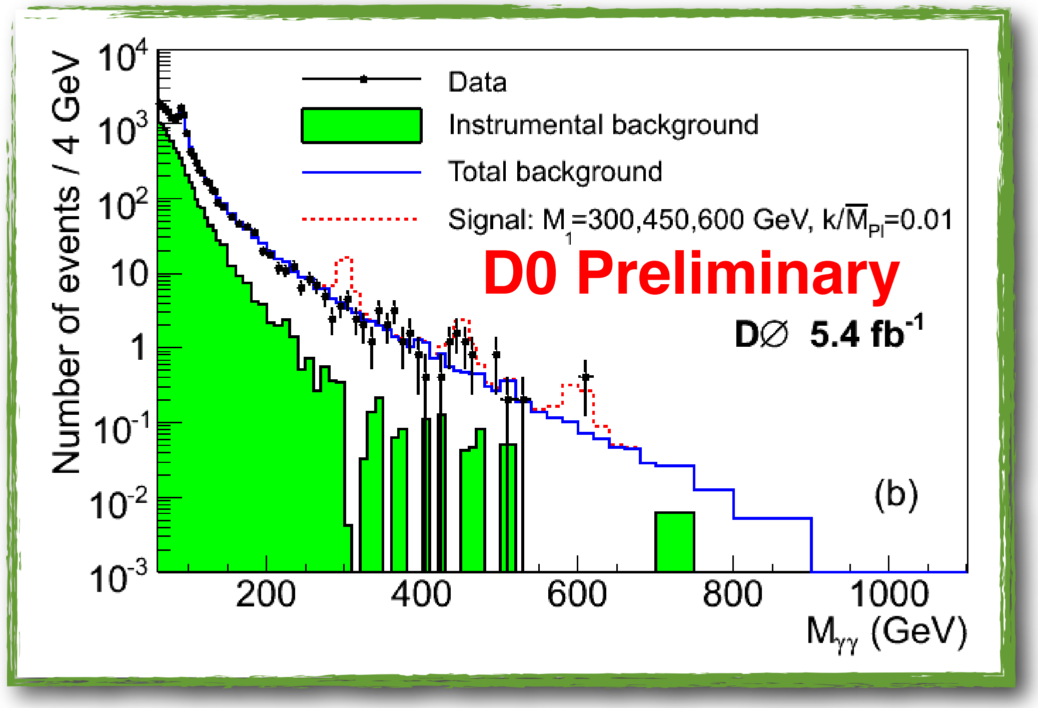


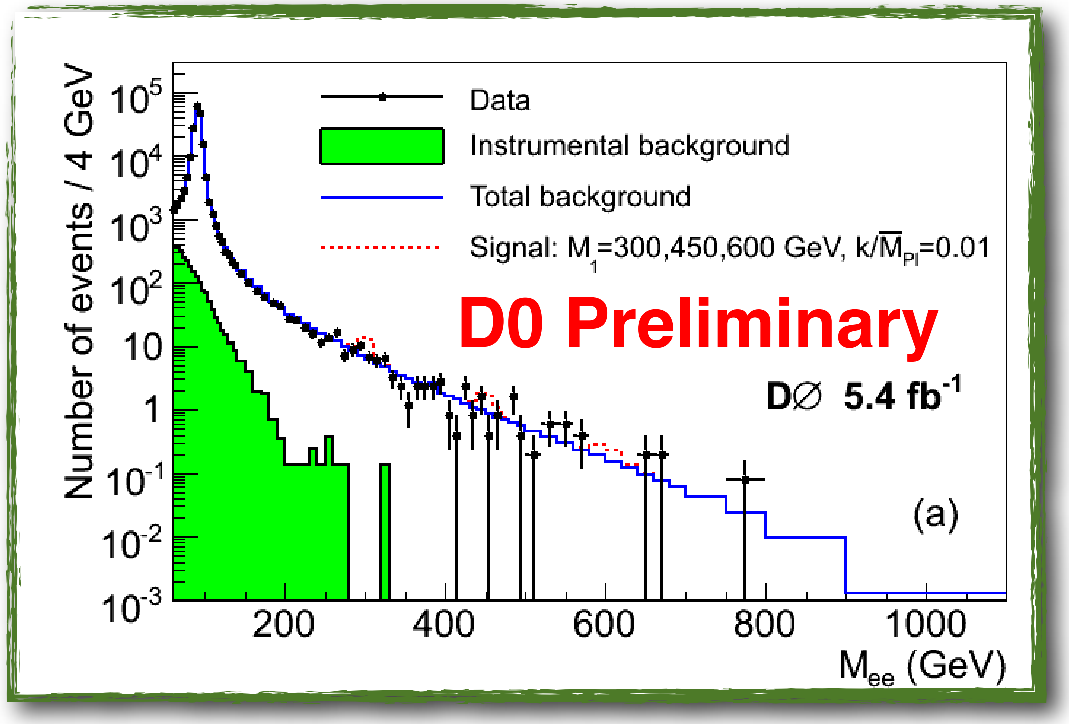


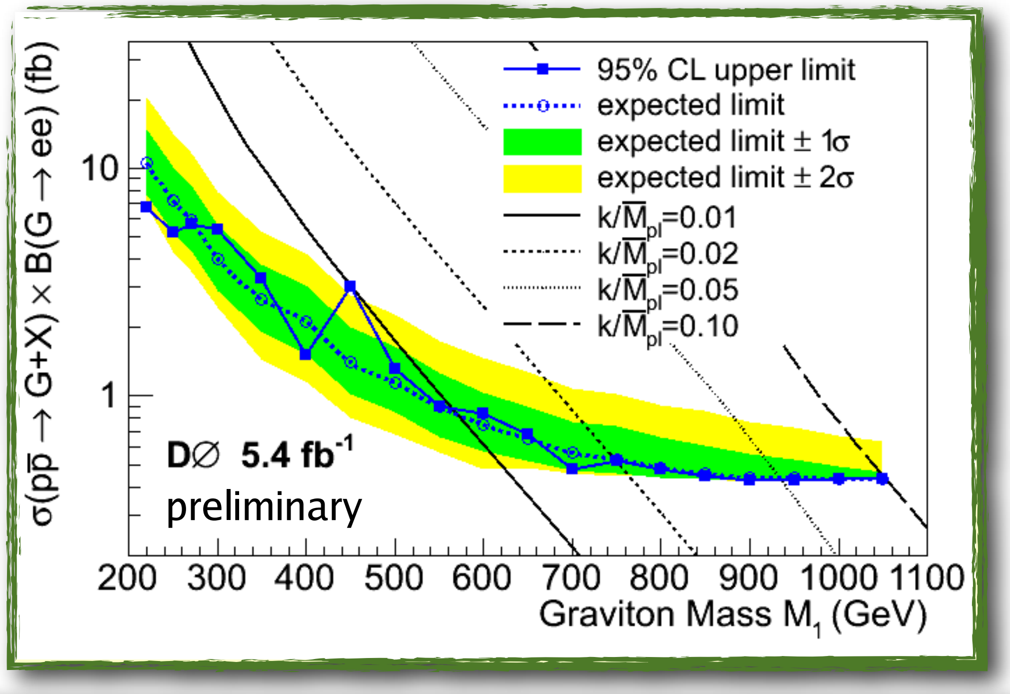
This reflect into a **worse limit around that mass region**.

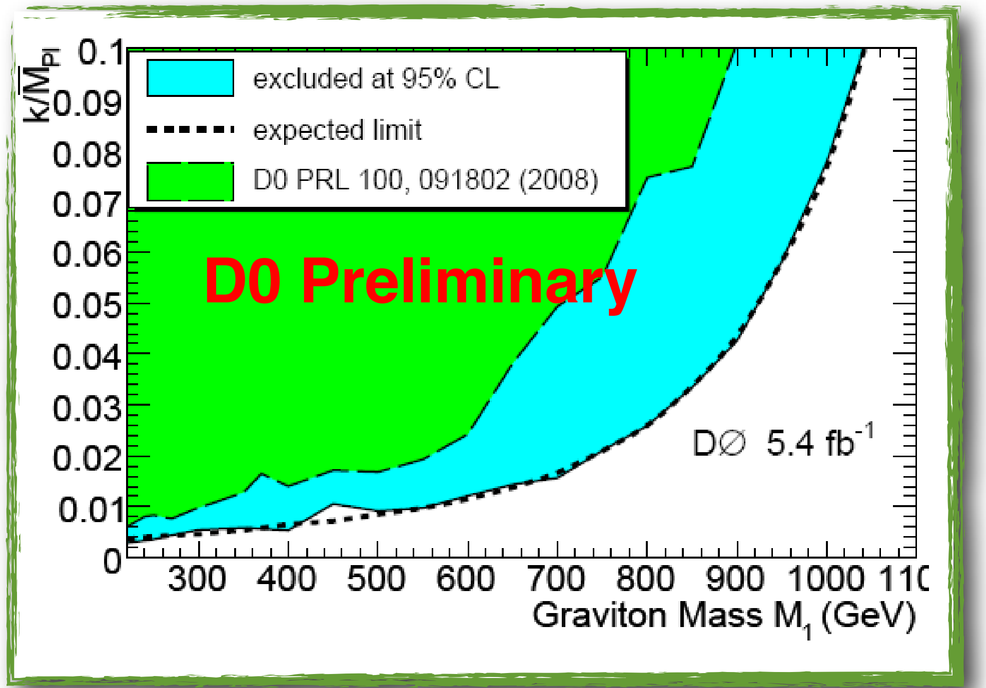
Z'→γγ & Z'→ee @ D0

D0 does not see the CDF bump, while seeing a fluctuation around 450 GeV. More data (and CDF full-statistics analysis) needed to clarify situation. A luminosity of 12 fb-1 are expected to be collected



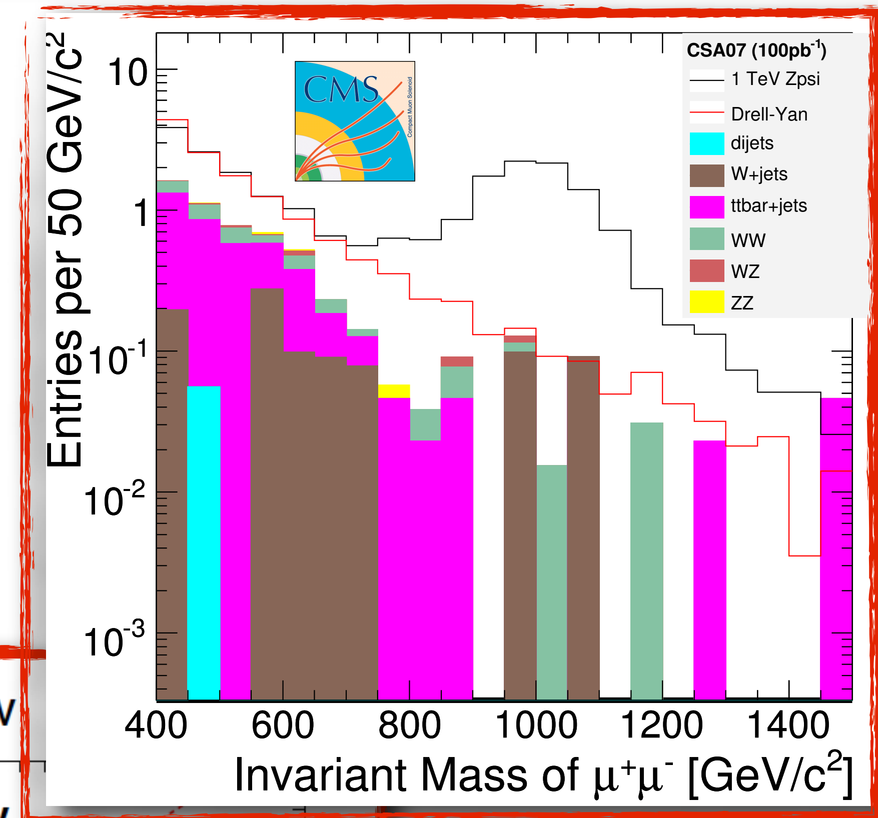


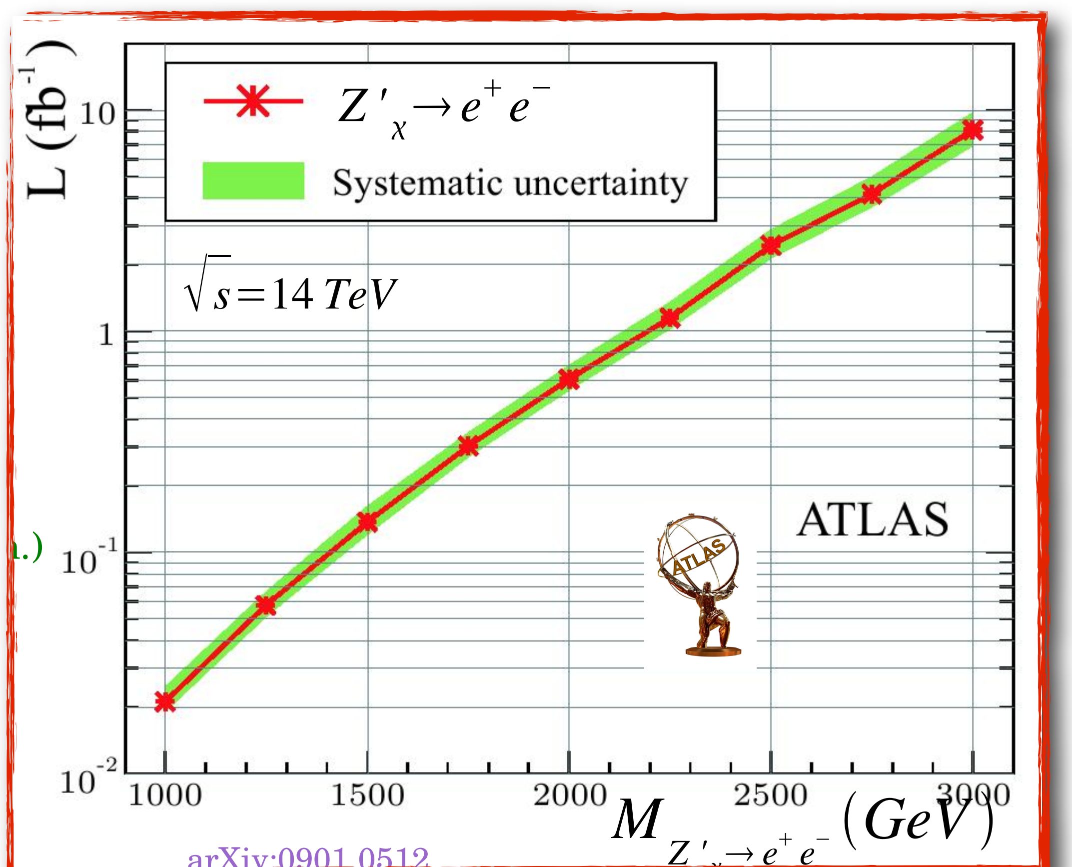


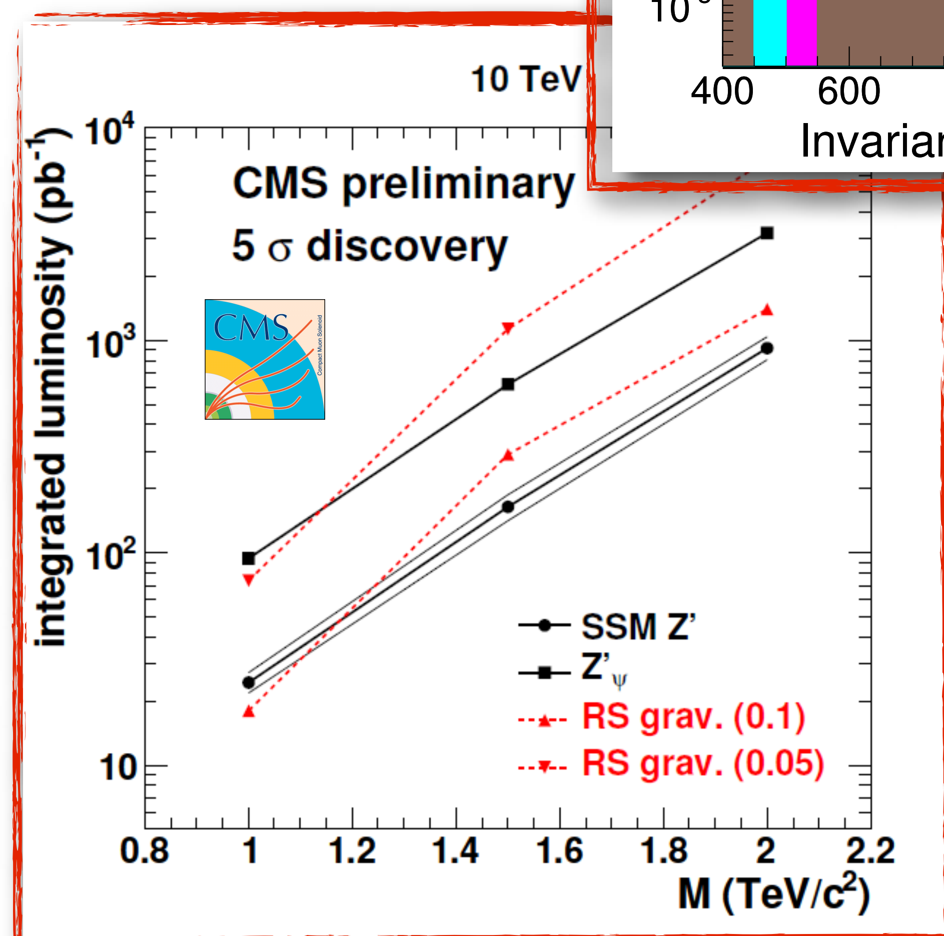


New Resonances@LHC

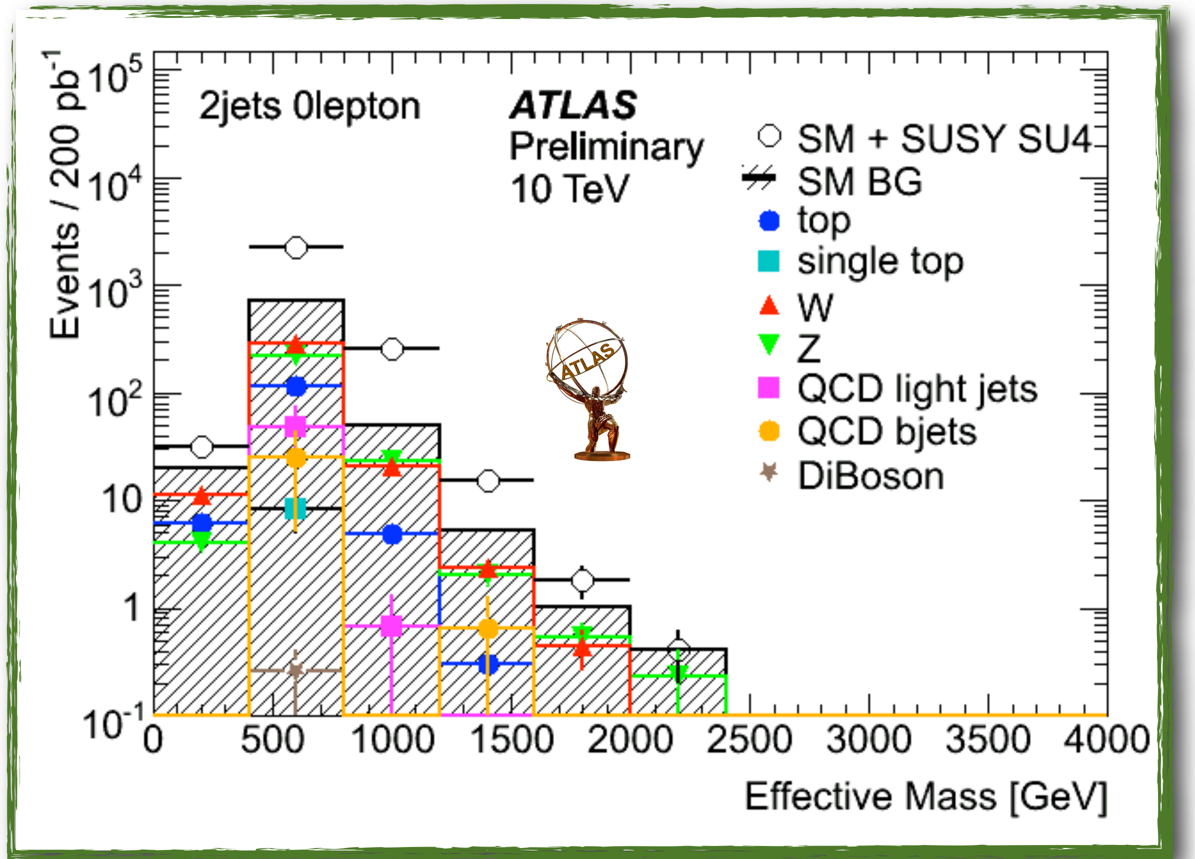
-Dilepton resonances are a smoking gun for models like ED (assuming KK towers can decay to light objects).
-With already O(100 pb-1) a m~O(TeV) resonance can be discovered or excluded (rule of thumb: xsec(7TeV)~ 1/4 xsec(10 TeV) for heavy objects)



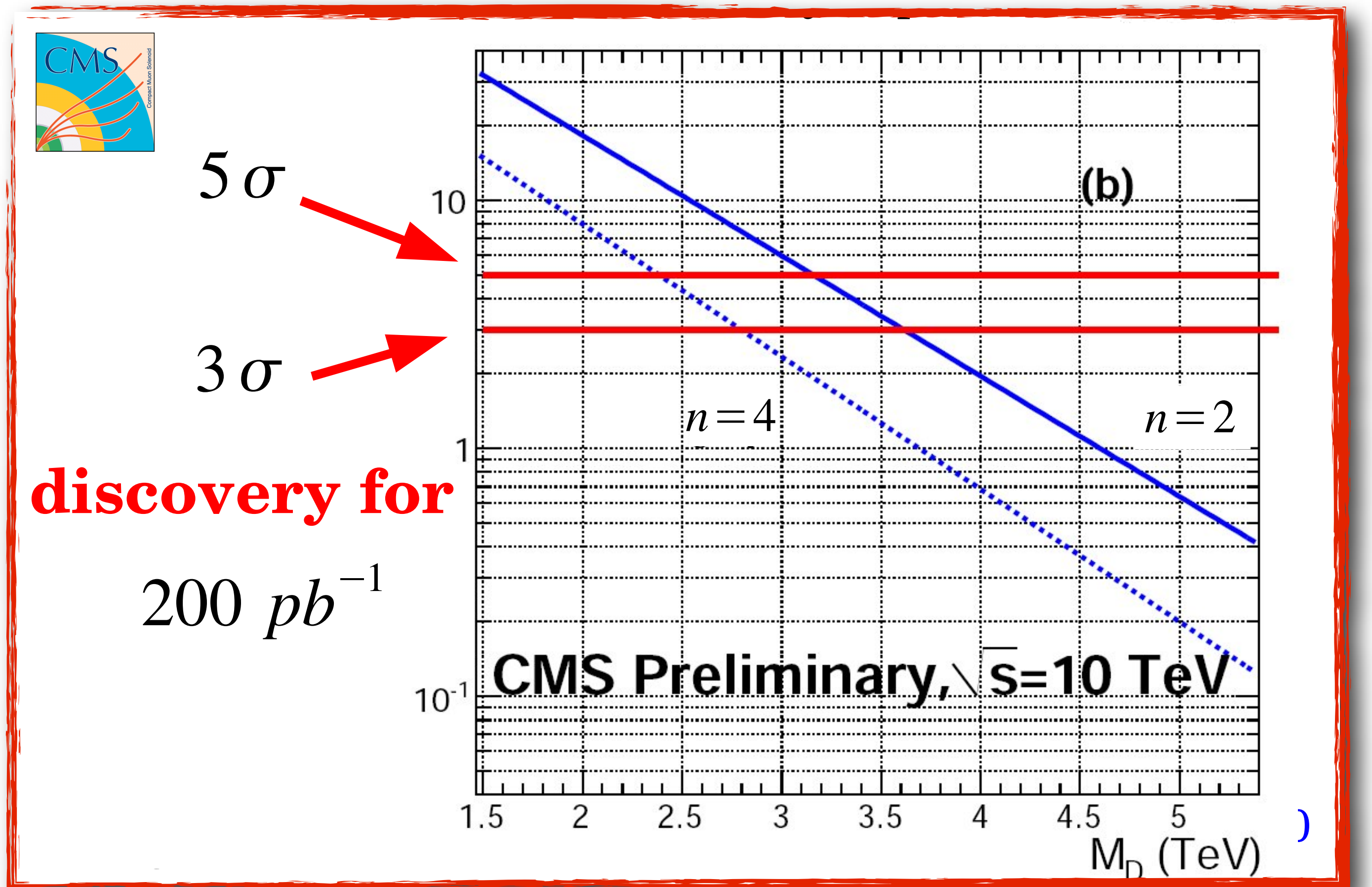




ED direct searches @LHC



- ED can also be directly searched for with inclusive hadronic analyses
- As a matter of fact, inclusive analyses look for Dark Matter production in association with jets (being the lightest stable particle coming from SUSY, ED, LittleHiggs, etc)(*)

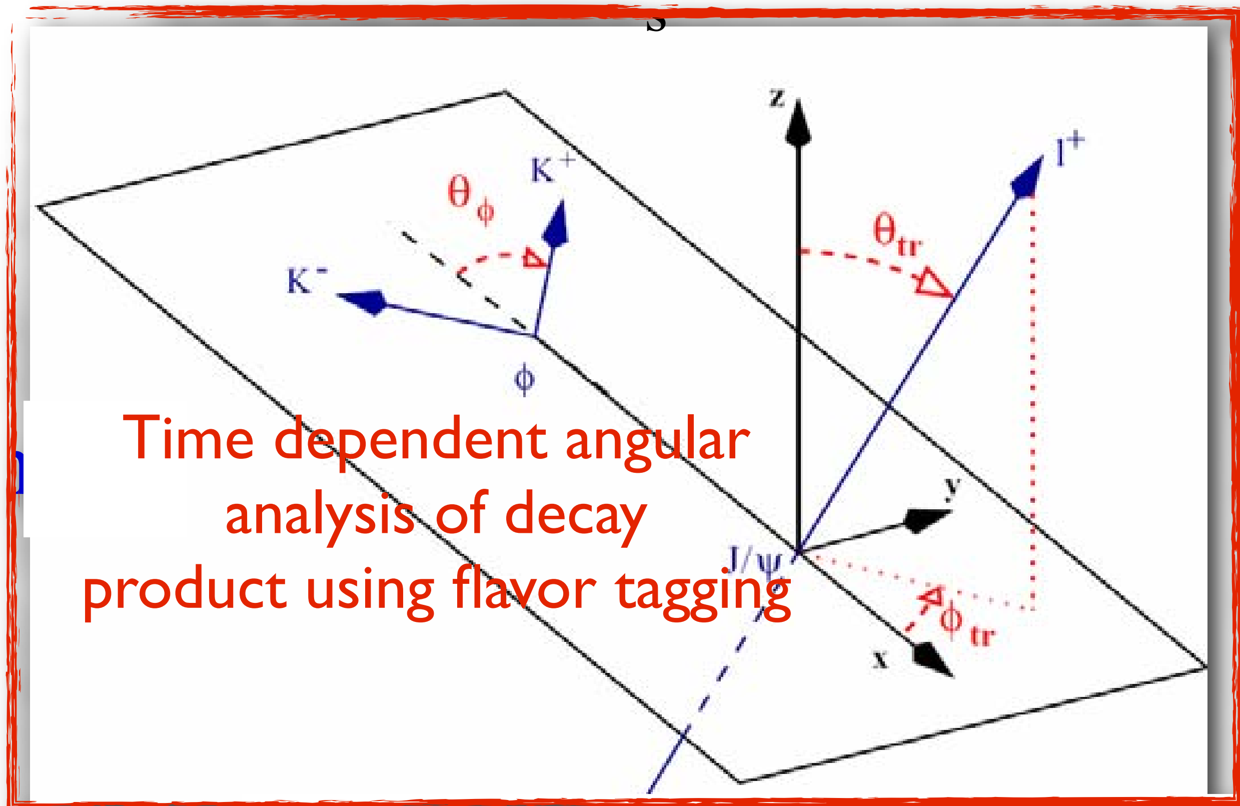


- The implication on the model comes when no excess is seen (exclusion limit on parameter space) or discovery potential (assuming an excess will be seen)
- Strategy to access the underling theory with first data are under development (see for instance J. Hubisz et al. Phys.Rev.D78:075008,2008.

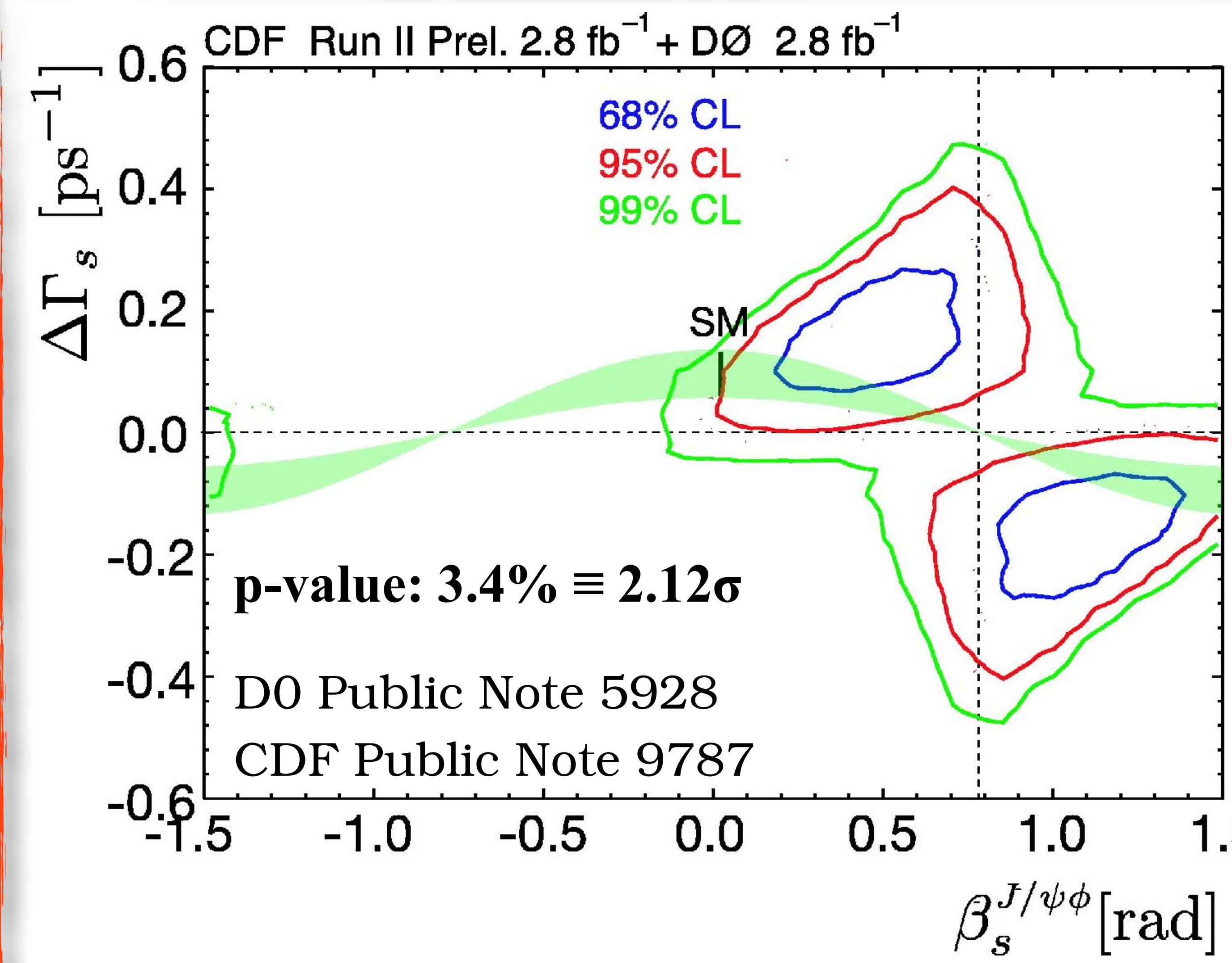
(*) strictly true as long as the event selection is not focused too much on the benchmark models. Not quite there yet

Early discovery with flavor physics?

CPV in Bs→J/Ψ ϕ



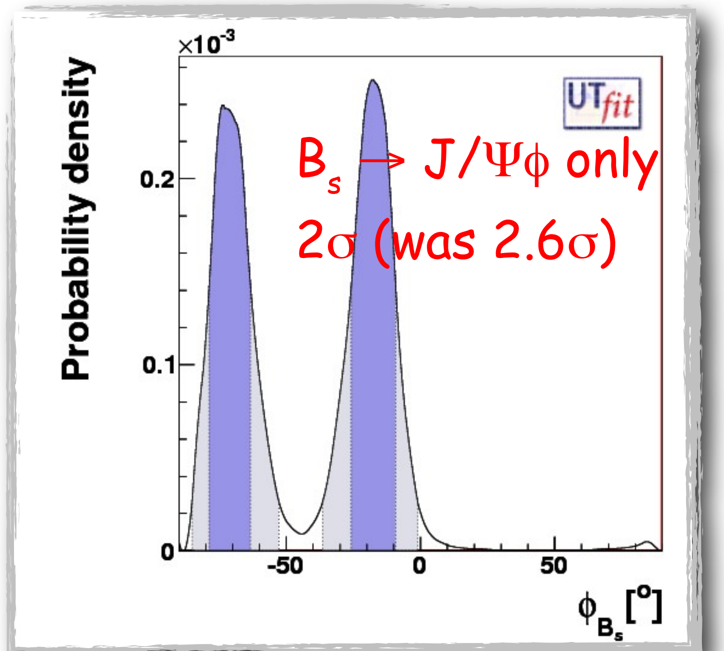
	D0	CDF	
$\Delta\Gamma_s$:	0.19 ± 0.07	0.02 ± 0.05	ps^{-1}
$\tau(B_s)$:	1.52 ± 0.06	1.53 ± 0.04	ps
φ_s:	$-0.57^{+0.25}_{-0.30}$	[-0.56, -2.58] (68%)	
ΔM_s:	Constrained to $17.77 \pm 0.12\ ps^{-1}$		



Very small CPV in the SM (βs~0)

Both experiments see a "fluctuation" to negative values with non-negligible #σ (not significant yet)

Status & Perspectives



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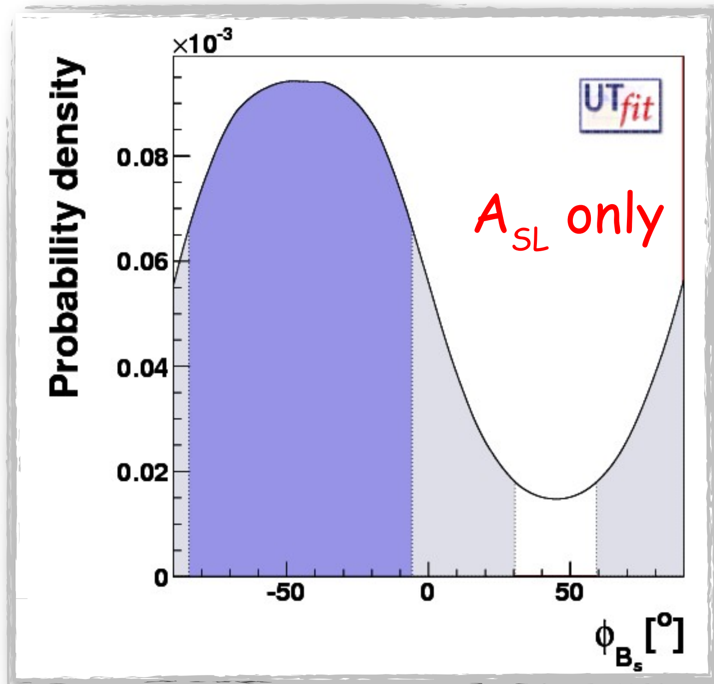

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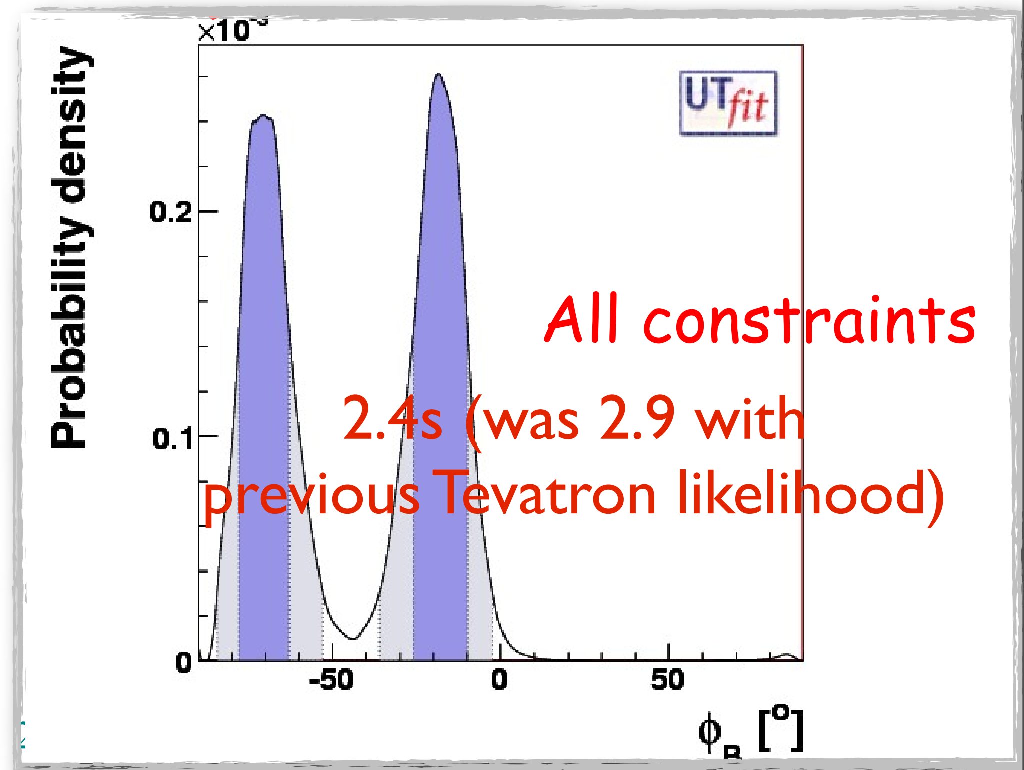


Expected sensitivity: (at Δm_s = 20 ps^{-1})

@LHC

- ✓ LHCb: 125k $Bs \to J/\psi\phi$ signal events/year
  - → $\sigma_{stat}(\sin\phi_s)$~0.031, $\sigma_{stat}(\Delta\Gamma_s/\Gamma_s)$~ 0.011 /(1year, 2fb^{-1})
  - → $\sigma_{stat}(\sin\phi_s)$~0.013 after first 5 years, adding pure CP modes like $J/\psi\eta$, $J/\psi\eta$' (small improvement)
- ✓ ATLAS: similar event rate as LHCb but less sensitive
  - → $\sigma_{stat}(\sin\phi_s)$~0.08 (1year, 10fb^{-1})
- ✓ CMS: > 50k events/year, sensitivity study ongoing

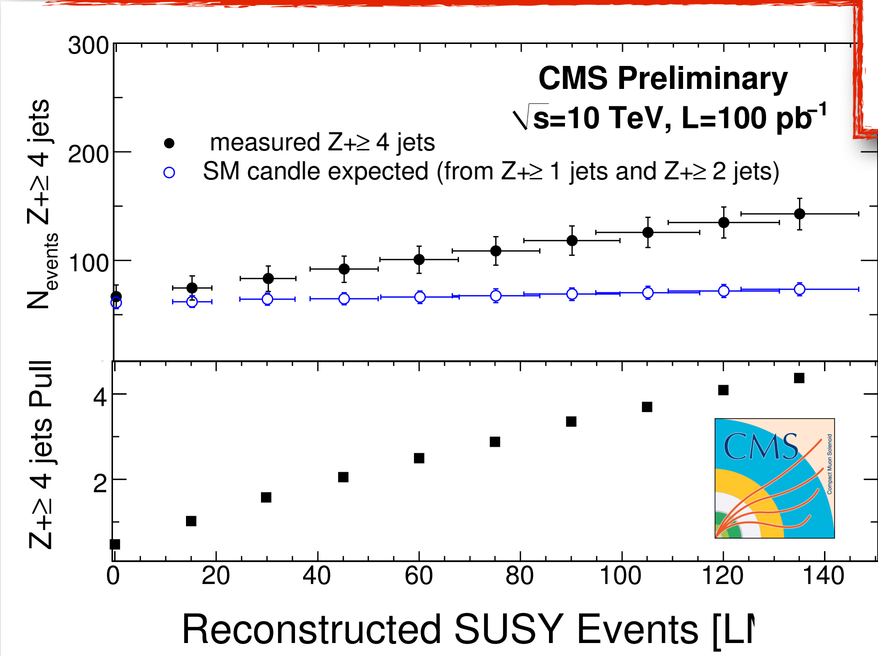
And remember: Expect the Unexpected(*)

(*) and don't expect mSugra

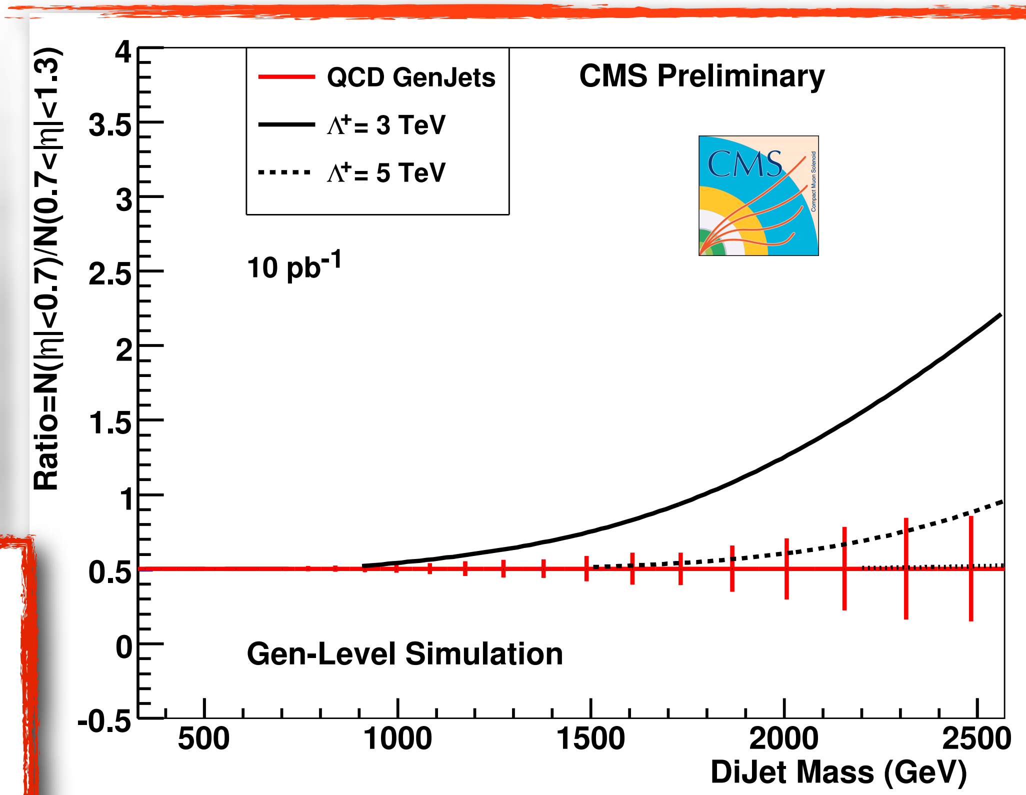
Some Example

Studying the SM processes:

Excessive production of W and Z in association with jets



Contact Interactions with dijets



Looking for spectacular signatures: many soft particles from unstable Black Holes