ETH Institute for
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same-sign dileptons at CMS

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why same-sign dileptons?

same-sign di-leptons are a very interesting signature for many analyses

-> searches for SUSY

-> also many interesting SM analyses done

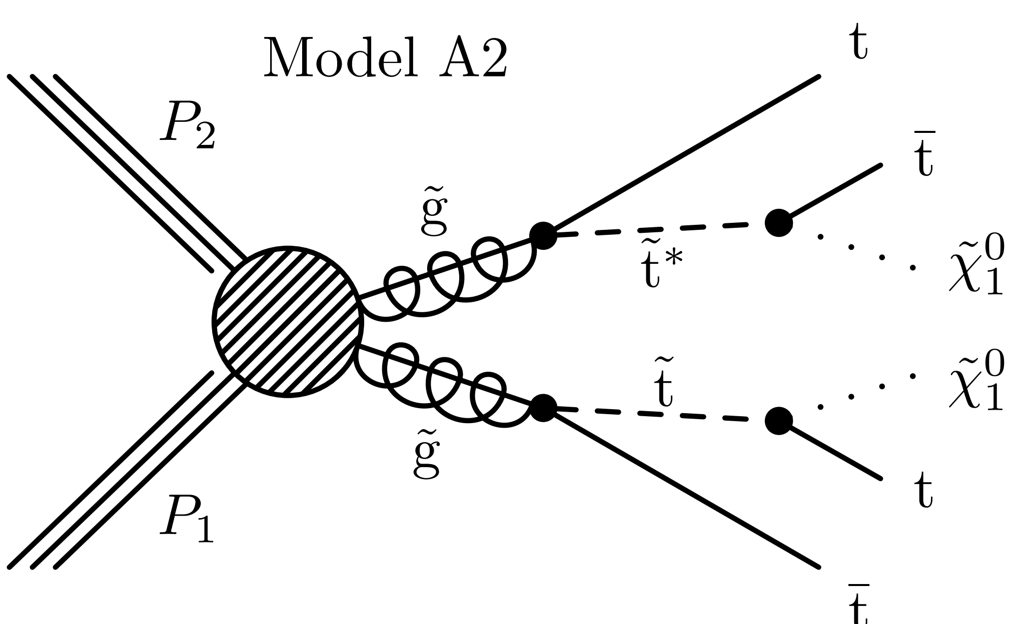
e.g. SUSY

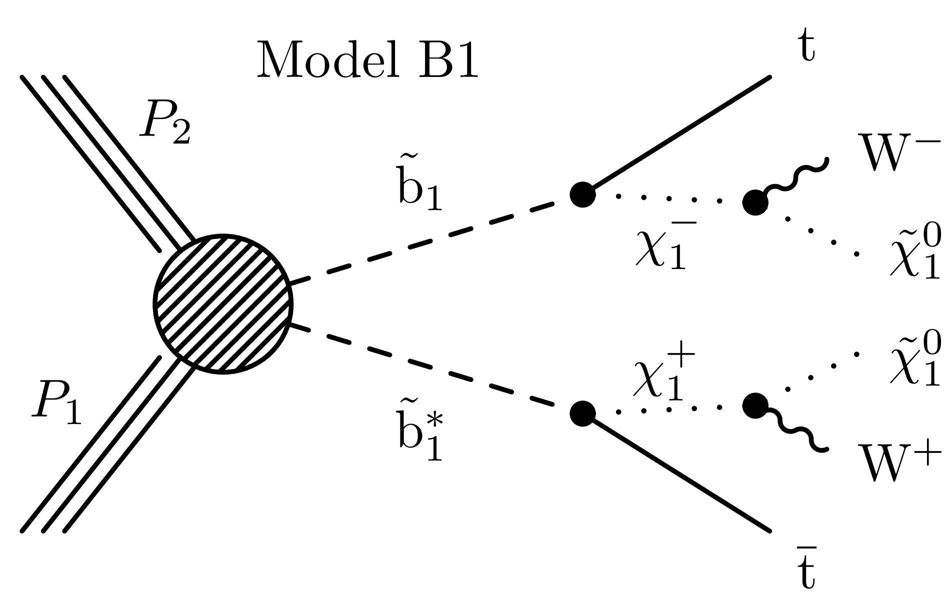
-> leptons can originate from direct decays of SUSY particles or from top/W/Z in the decay chain

-> interesting for 'natural' SUSY, where one expects light stop quarks

--> an example: gluino -> top + stop -> top + neutralino

-> other examples: direct sbottom production, EWK SUSY production





why same-sign dileptons?

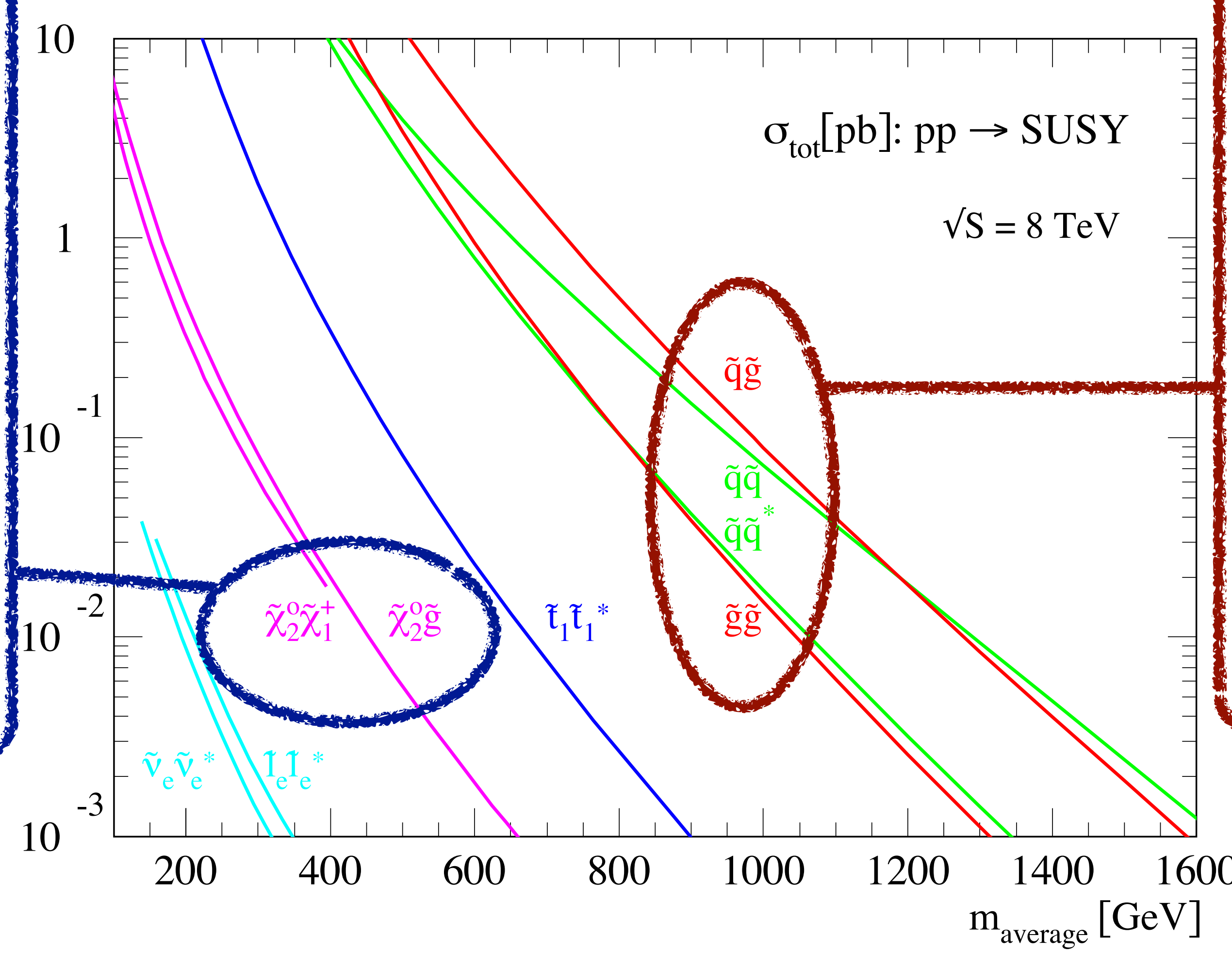
very different phase spaces for the various SUSY analyses

-> very high to very low hadronic activity

-> different spectra in missing momentum and p_T

EWK SUSY

- very low hadronic activity
- few objects in the final state
- a lot of missing momentum
- often additional leptons (WZ-like)



gluino/squarks

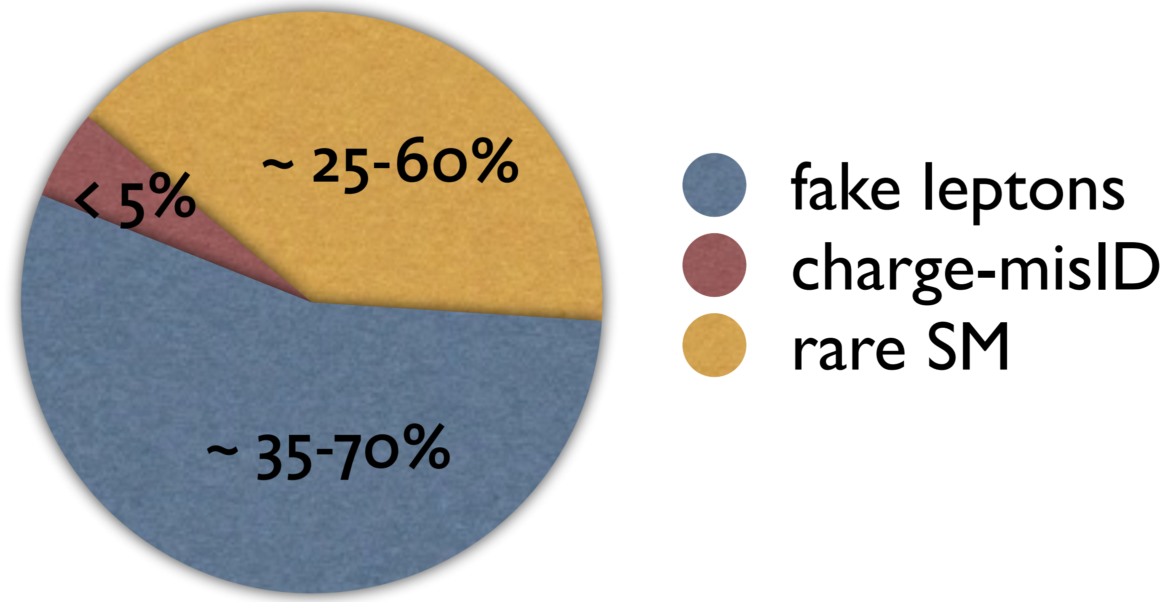
- generally high hadronic activity
- many jets, a lot of 'stuff'
- often (s)tops/(s)bottoms
  - b-tagged jets
- ttbar like signatures
  - also rare backgrounds (ttW e.g.)

the analysis - overview

select 2 same-sign leptons (e/μ) > 20/10 GeV

-> jets above 40 GeV

-> ME_T above 30 GeV



Detector related

charge mis-identification

-> electrons are affected

-> small (~5%) of total - from data

'fake' leptons

-> leptons not from W/Z/SUSY

-> largest background in many regions of phase space

-> the estimation and study of this background is an active field of research

-> fully data driven method!

Physics related

rare SM processes which produce same-sign leptons

-> can be background or signal

-> cross-sections usually in the O(100 fb) regime

-> examples: W+Z, tt+W, tt+H production

-> look very "SUSY-like"

-> taken from MC

the problem of the fakes

fakes: leptons not originating from W/Z/SUSY

-> mostly real leptons from b-jets

-> also a small fraction of mis-identified jets

we employ a fully data-driven method

-> measure a fake-ratio *f* in a data control region

-> apply this ratio *f* to a sideband of the signal regions

the problem: systematic uncertainties

-> it’s hard to fully understand the systematic uncertainties

-> e.g. background composition (W-jets vs. ttbar)

-> is this fake-ratio *f* really universal? are we measuring it in the right control region?

so far: 50% uncertainty applied on this background

-> it is a current interest of CMS to try to reduce this number

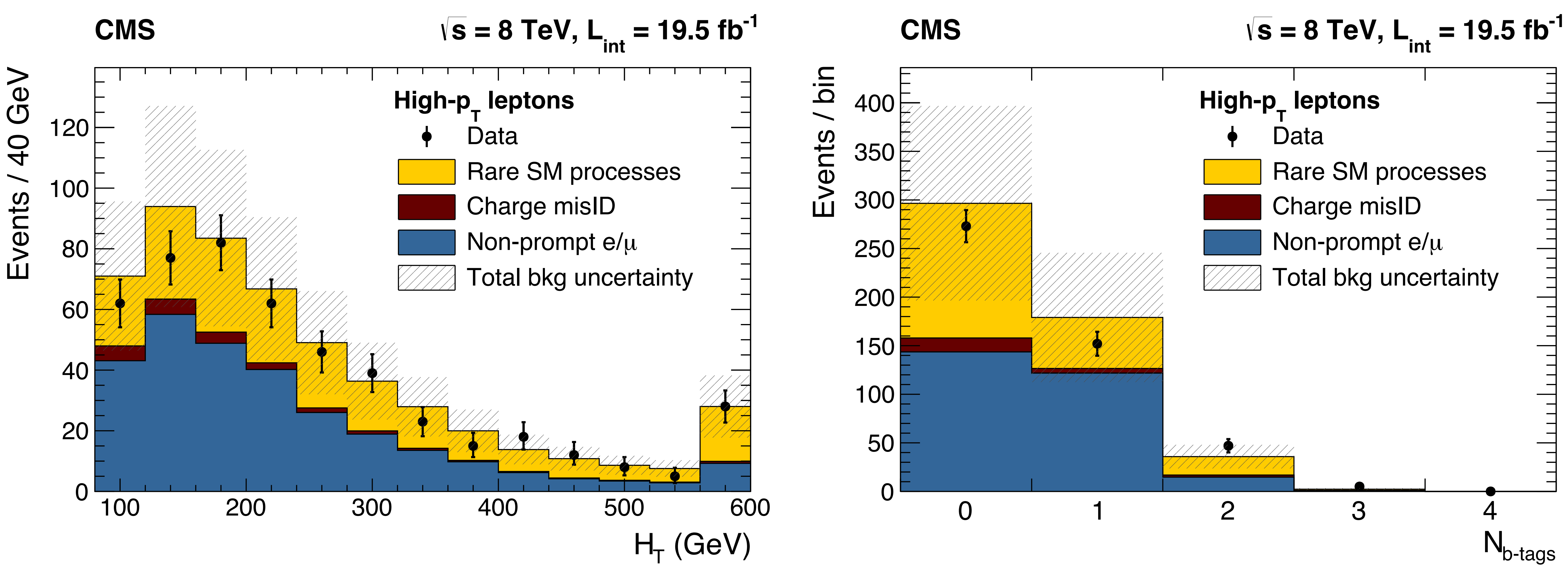
results - 'classic' SUSY

showing results of a paper on 19.5 fb^{-1} of 8 TeV pp: arXiv:1311.6736 [JHEP 01 (2014) 163]

-> a 'classical' SUSY analysis targeted at (mostly) gluino/squark production

-> 24 exclusive signal regions in kinematic variables (H_T/ME_T/N_{jets}/$N_{b\text{-}jets}$)

-> kinematic distributions look nice

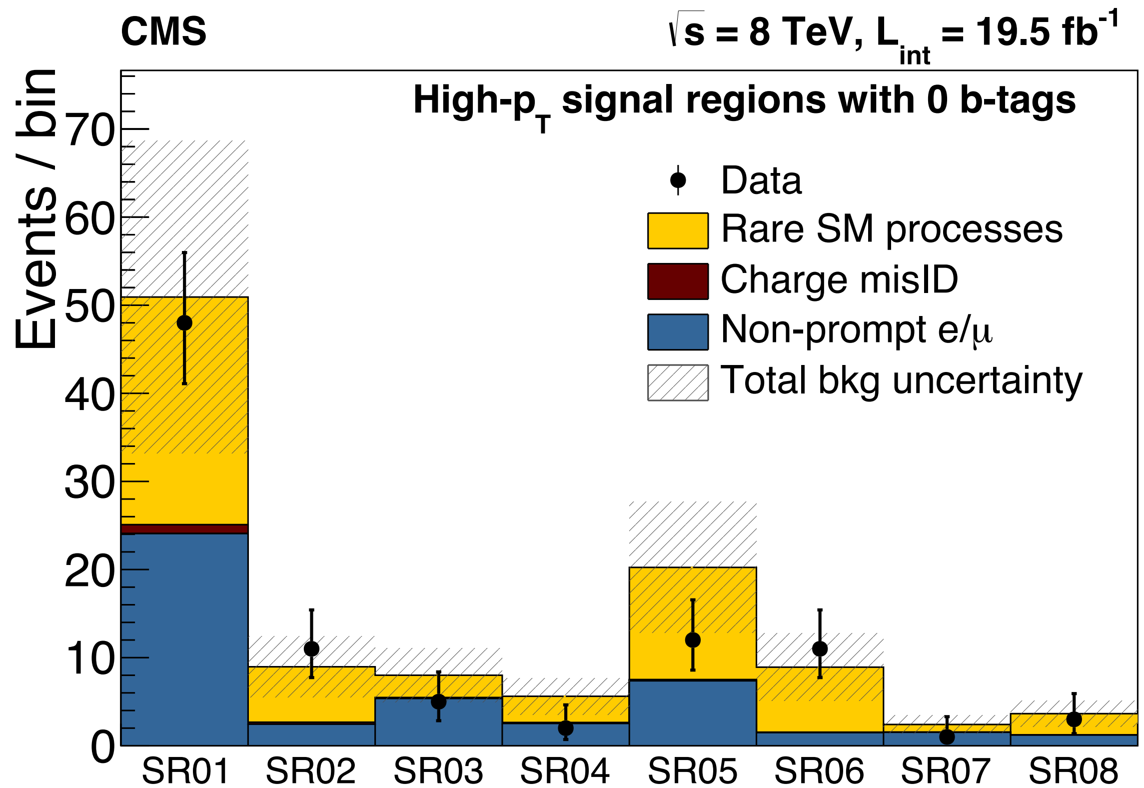


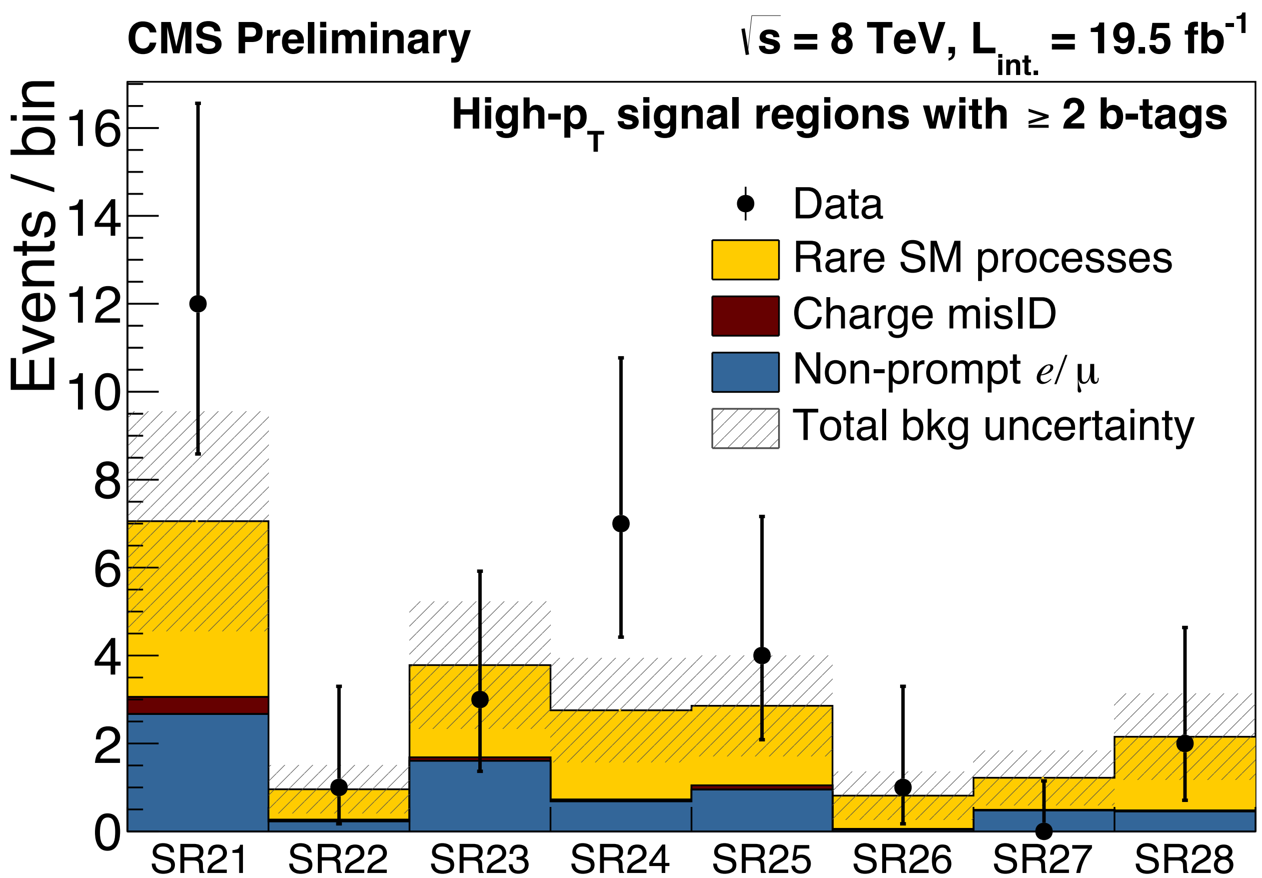
results - ‘classic’ SUSY

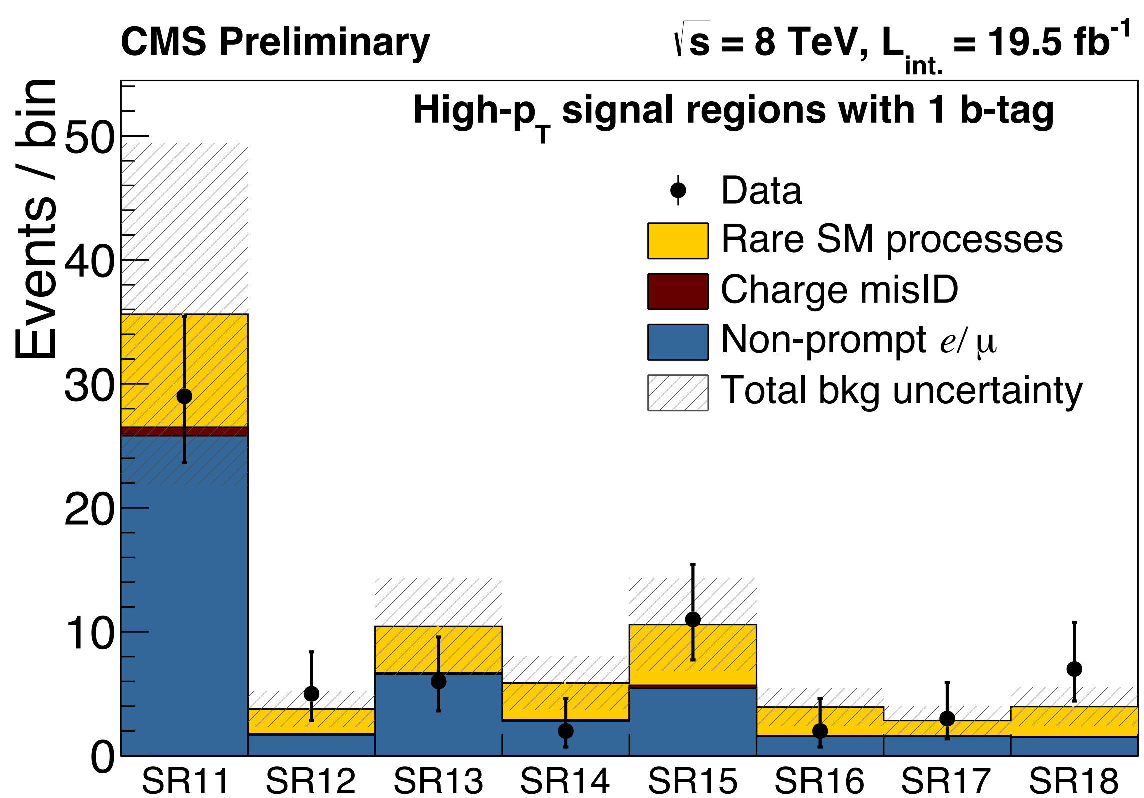
results in the 24 exclusive signal regions are in good agreement with predictions

-> no significant excess

-> can be seen how background composition varies with the number of b-tag jets







so we didn’t find anything?

unfortunately we did not observe any significant excess in data for the SUSY searches

-> so we proceeded to set limits on many different SUSY models

-> managed to publish a number of papers on different SUSY models

to set limits on signal models, it is imperative to understand a potential signal

-> what is the acceptance? which phase spaces of signal can we probe?

higher mass -> lower cross section

lower mass splitting between SUSY particles -> lower acceptance

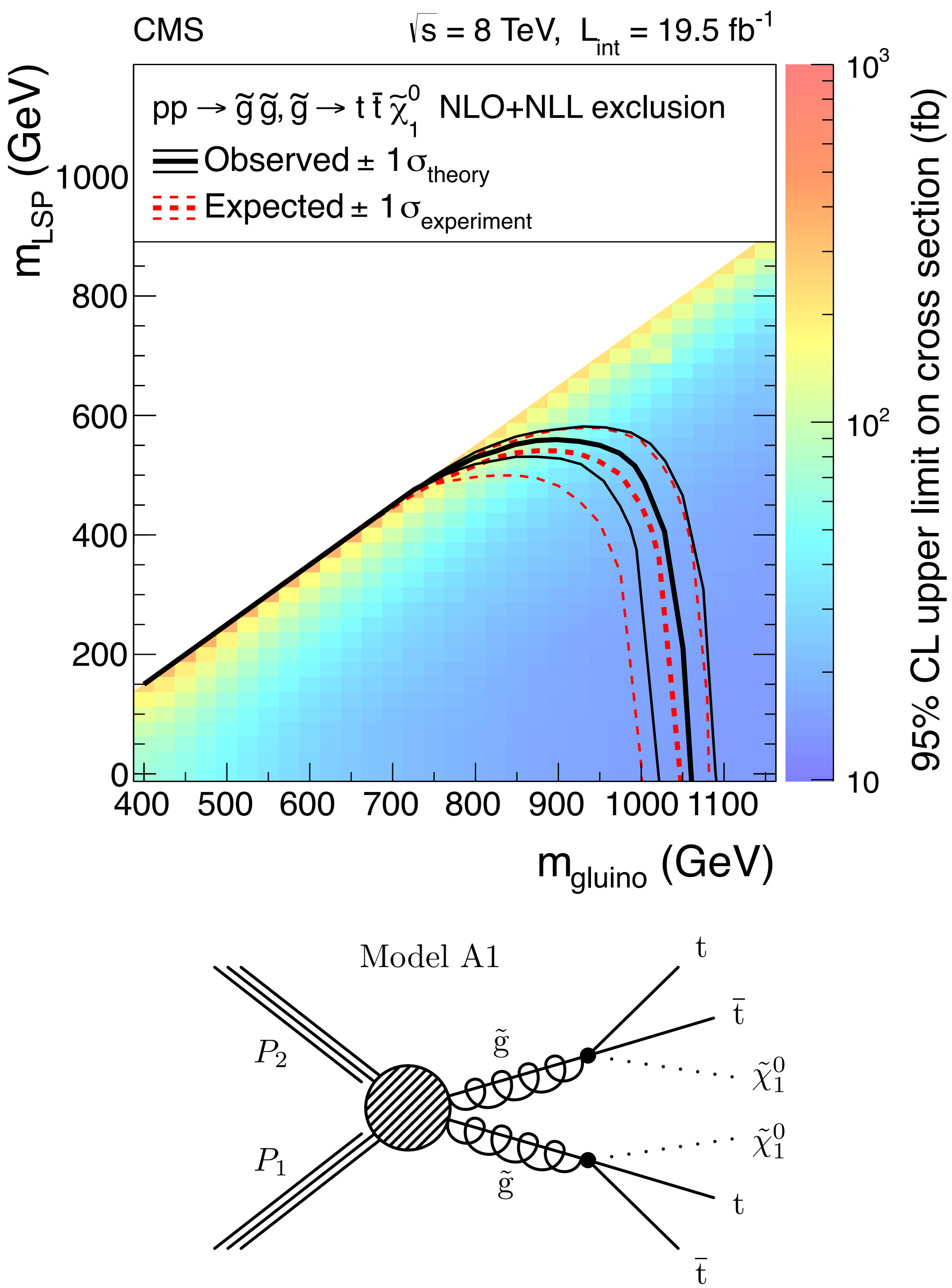
-> systematic uncertainties on the signal have to be understood

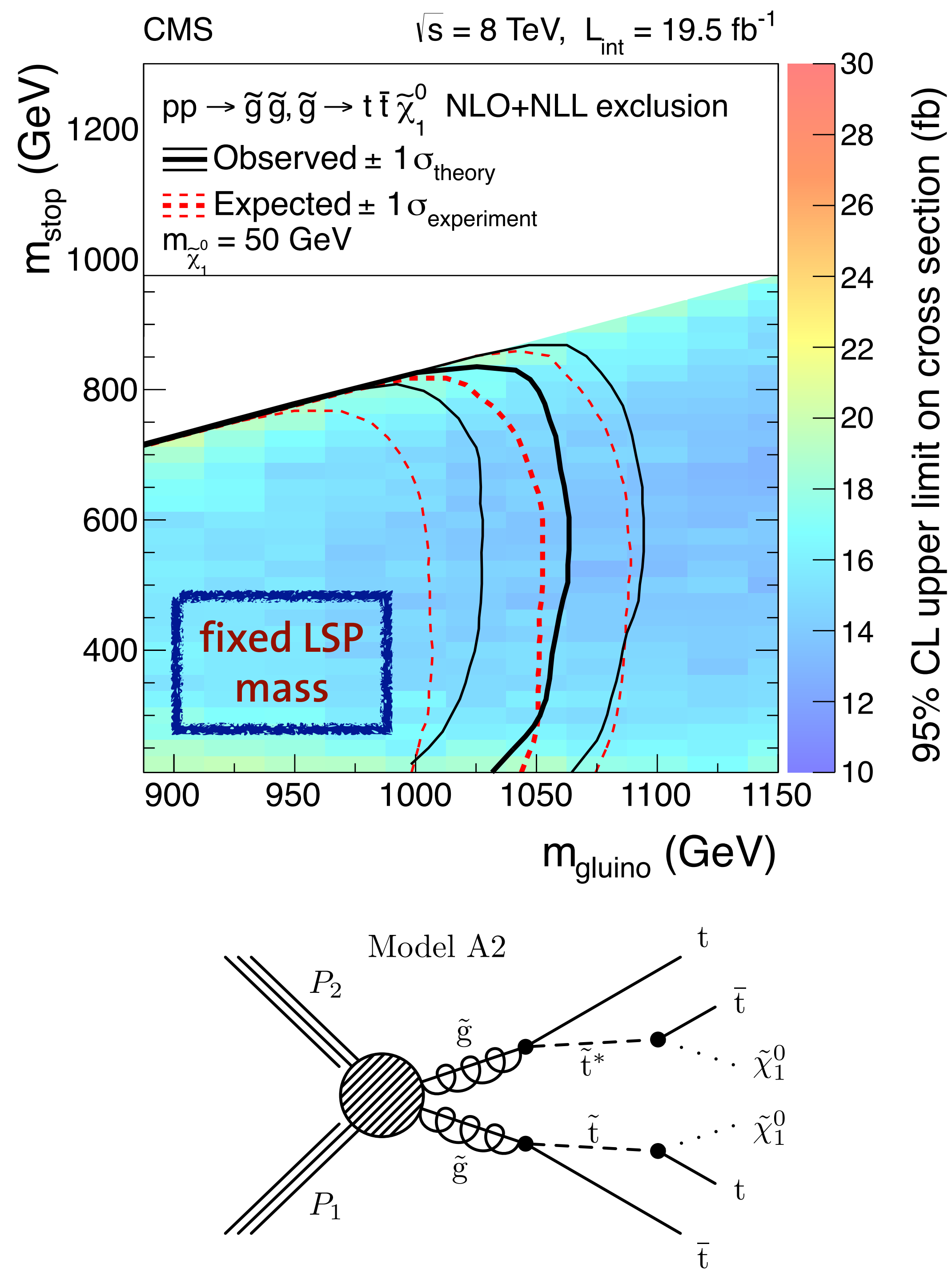
-> uncertainties from many different sources (JES, JER, PDF, etc.)

not finding an excess also tells us something about physics!

gluino - gluino production

interesting to see how limits are stable w/r/t different SUSY models





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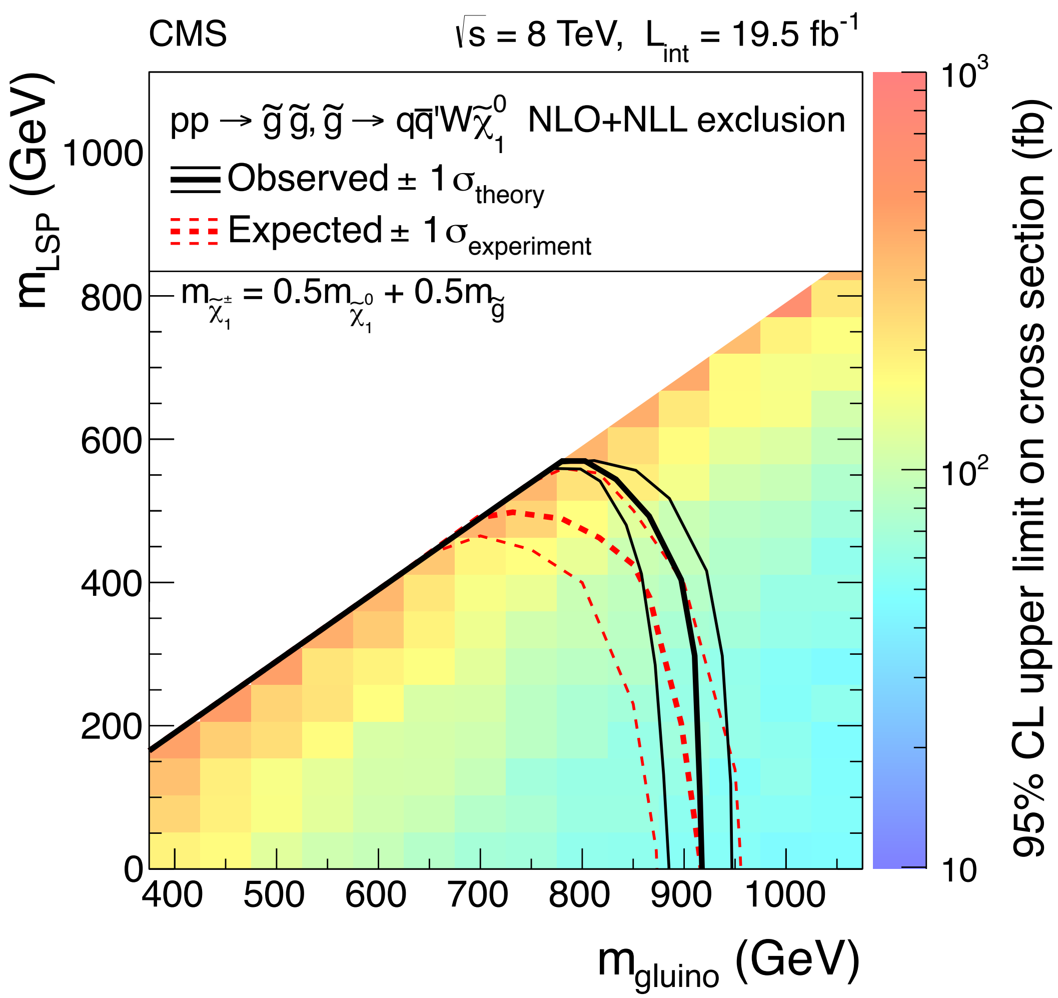
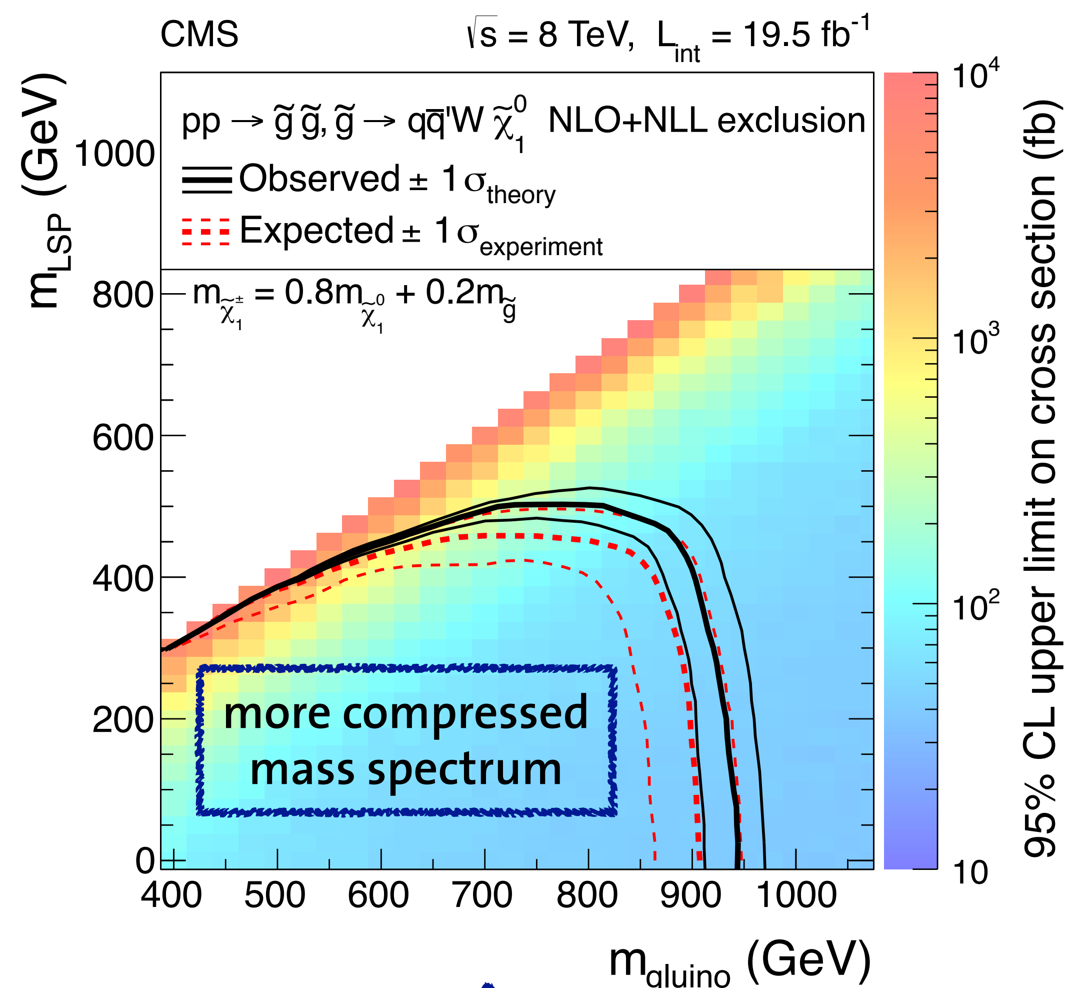
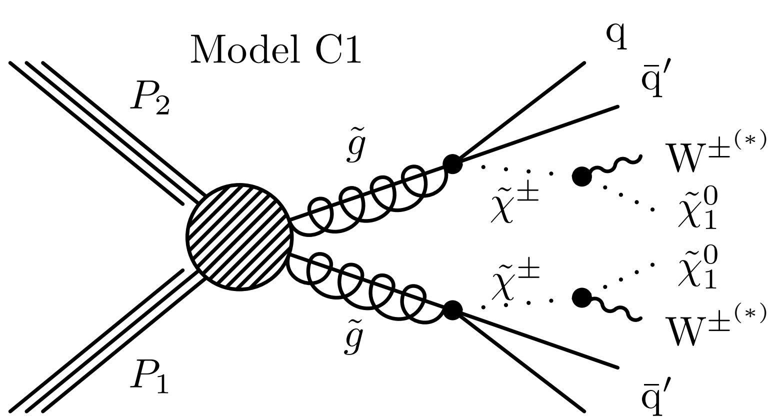


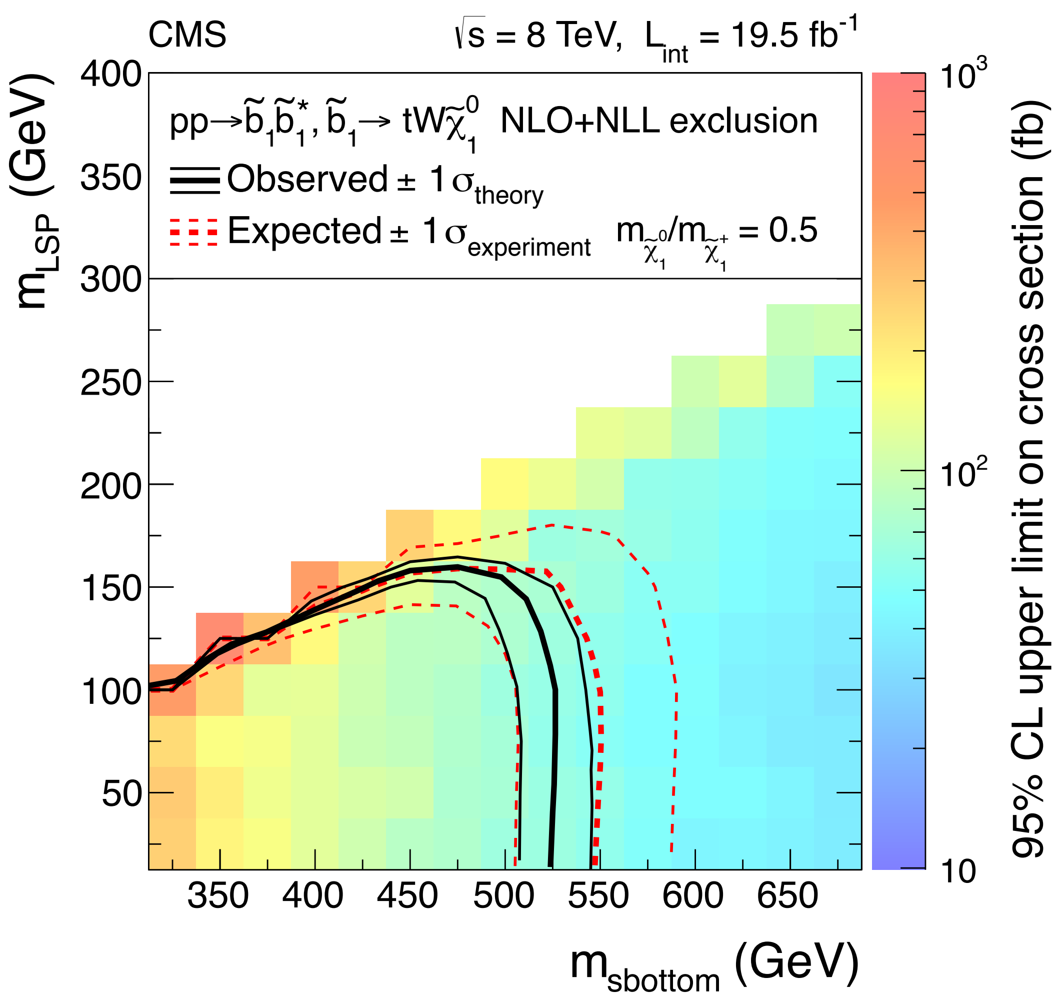


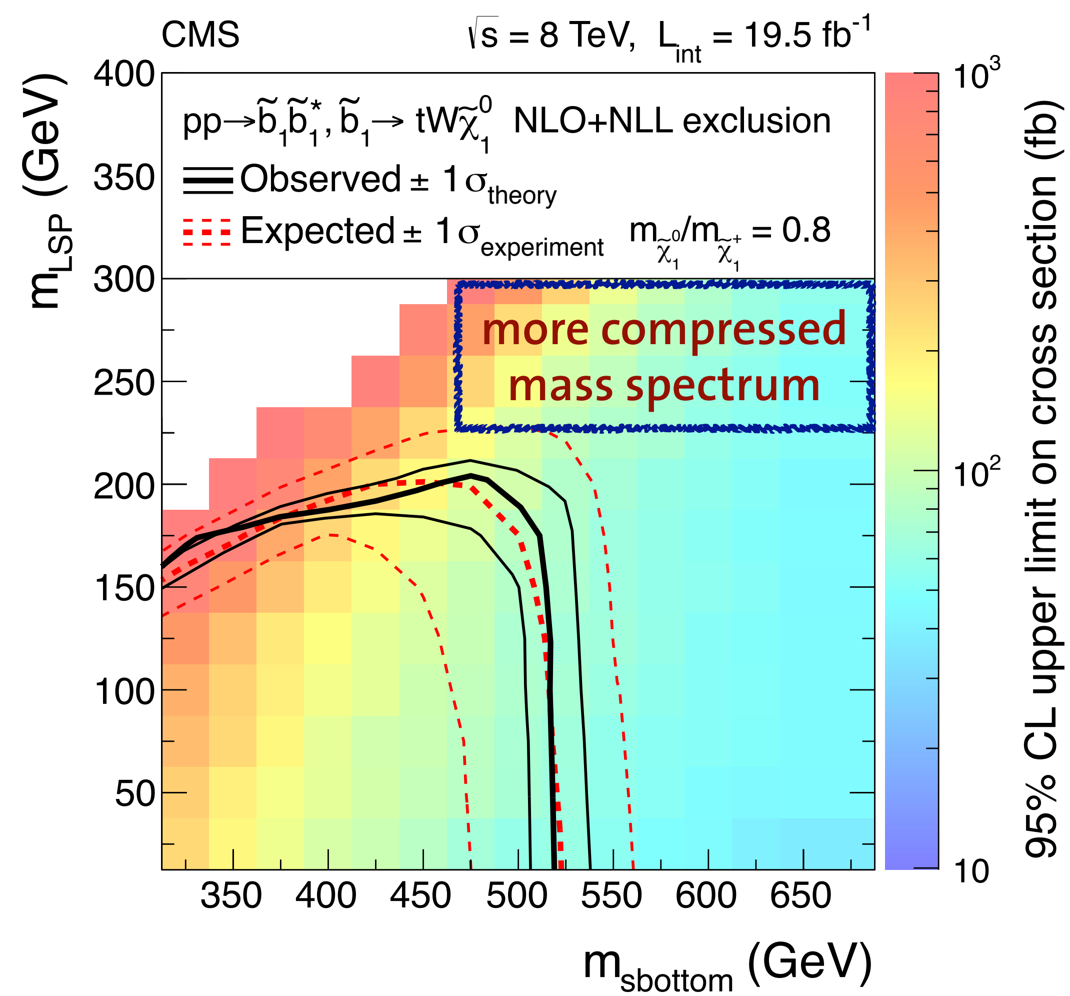


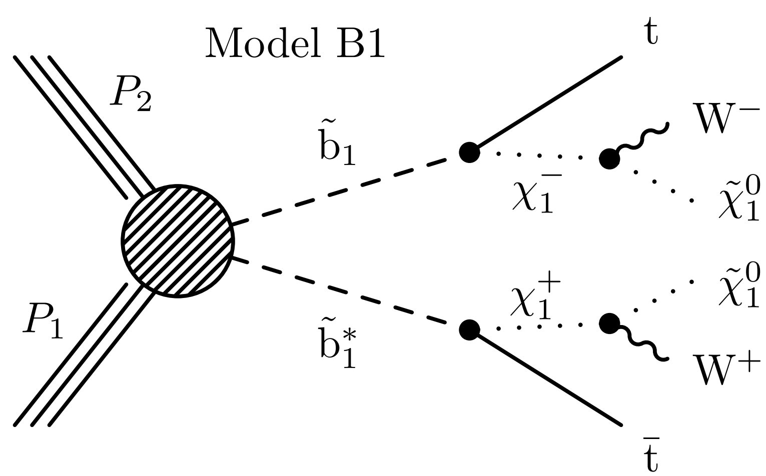
select lower-p_T leptons to maximize sensitivity

sbottom - sbottom production

interesting to see how limits are stable w/r/t different SUSY models





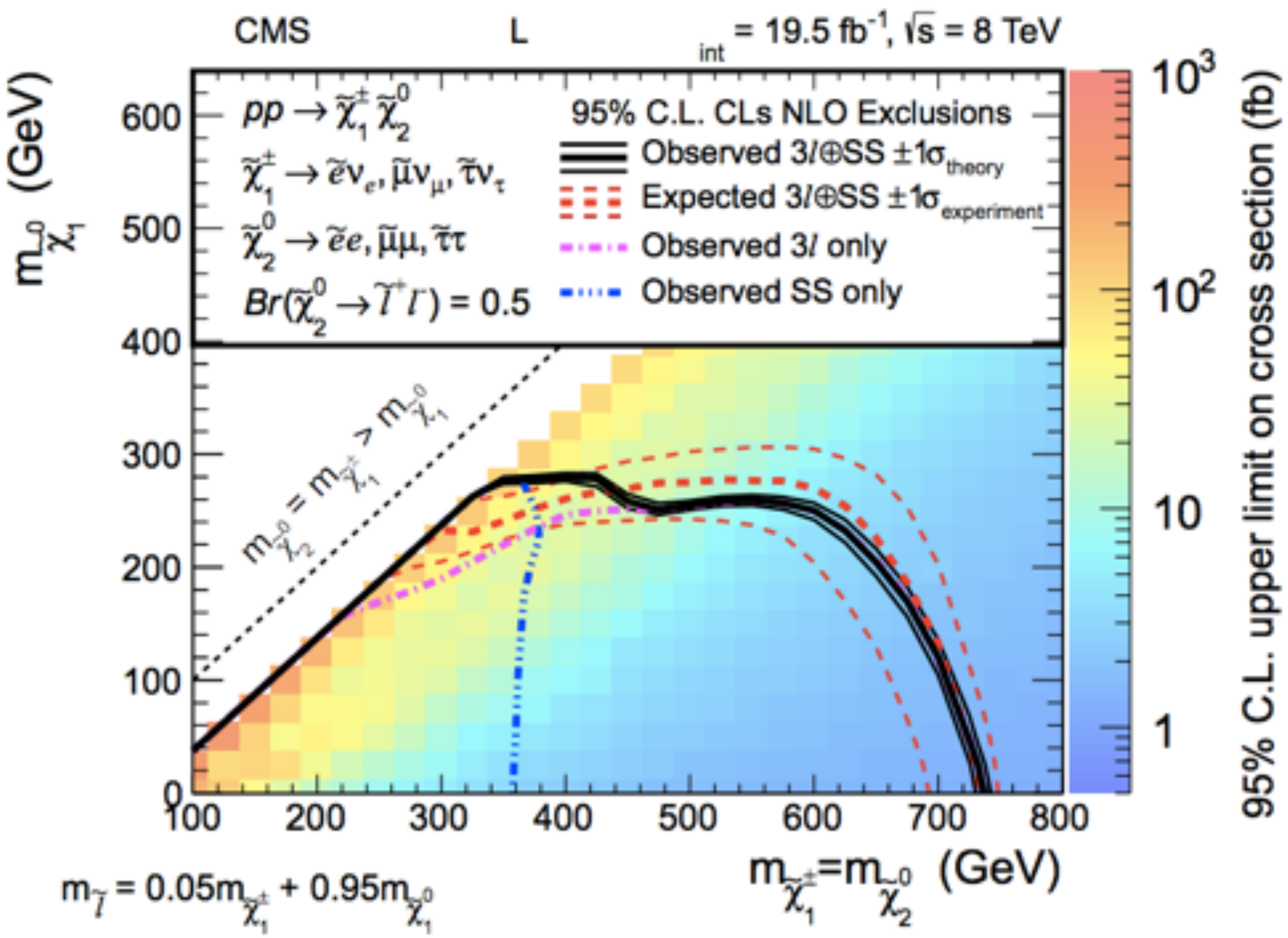


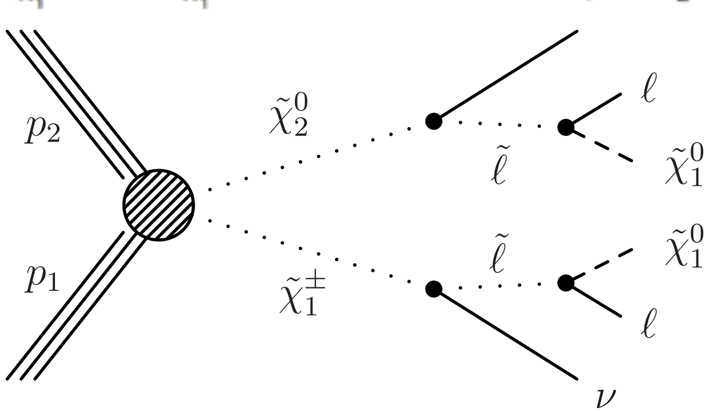
re-gaining acceptance by including lower-p_T leptons

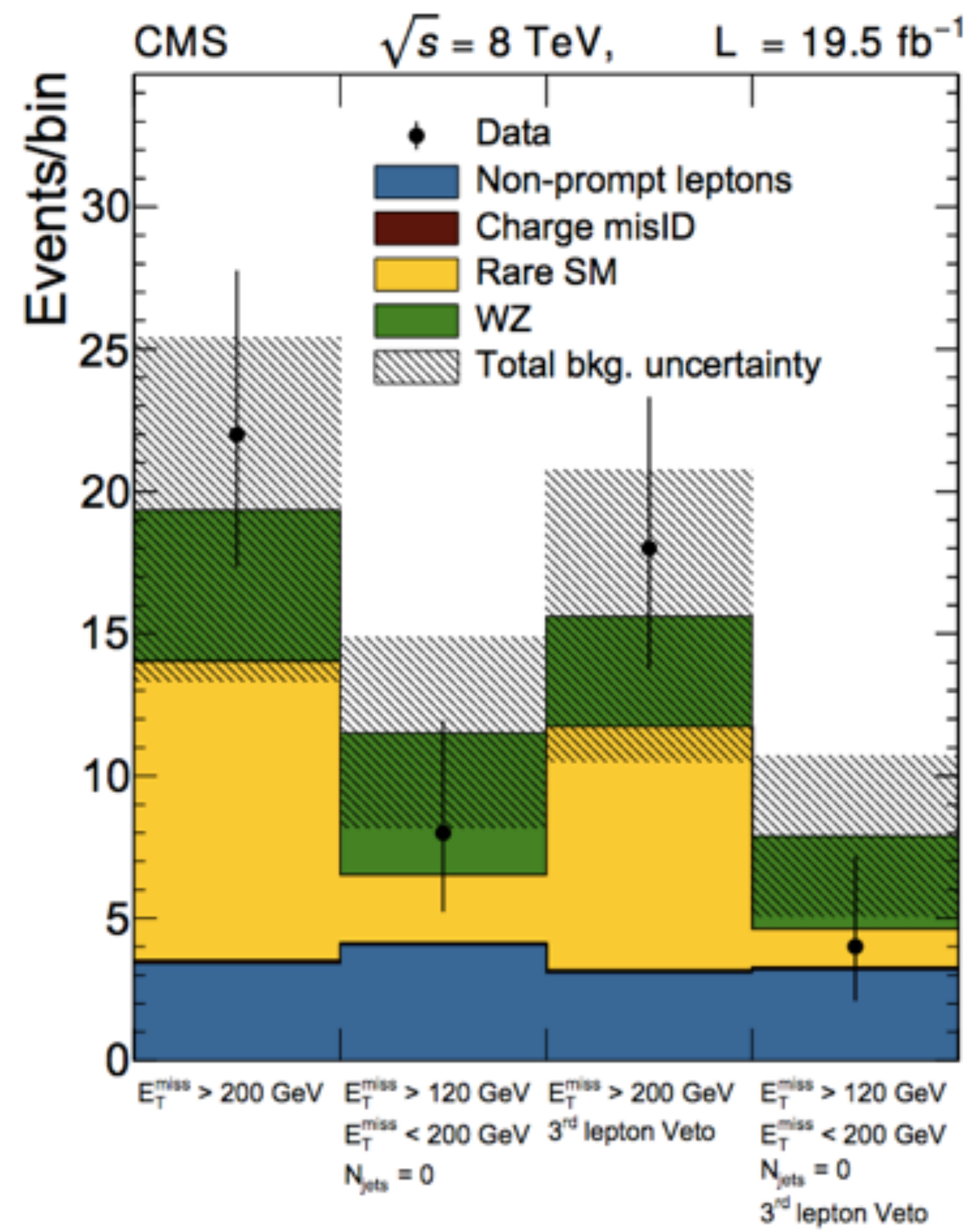
what about EWK SUSY?

4 signal regions in very different phase space (high MET, no hadronic activity)

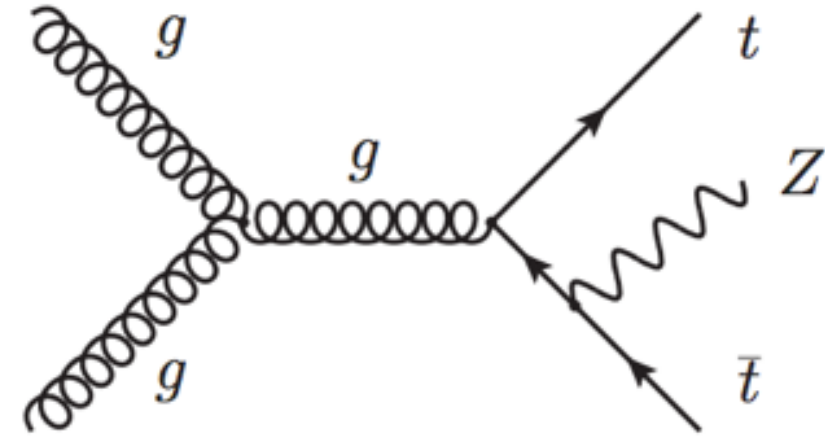
-> results published recently on [arXiv:1405.7570]

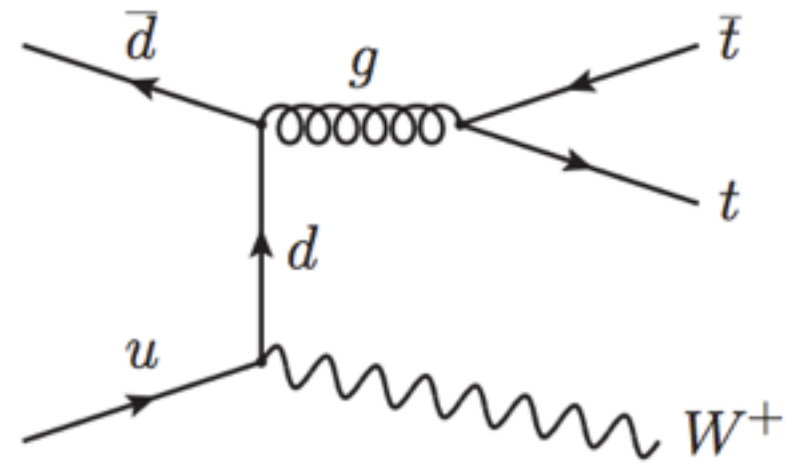






what about the SM?





interesting signatures for same-sign dileptons also in the SM

-> measured this already at 7 TeV, repeated it at 8 TeV

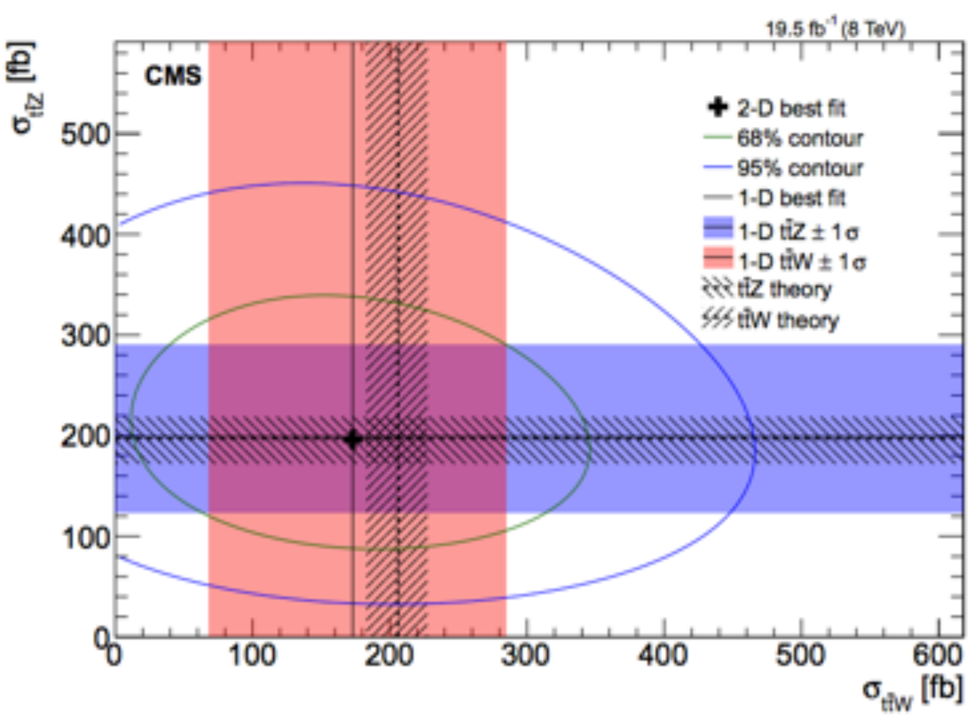
go into optimized (by expected signif.) signal region

-> $N_{jets} > 2$, $N_{b\text{-}jets} > 0$, lepton $p_T > 40$ GeV, $H_T > 155$ GeV

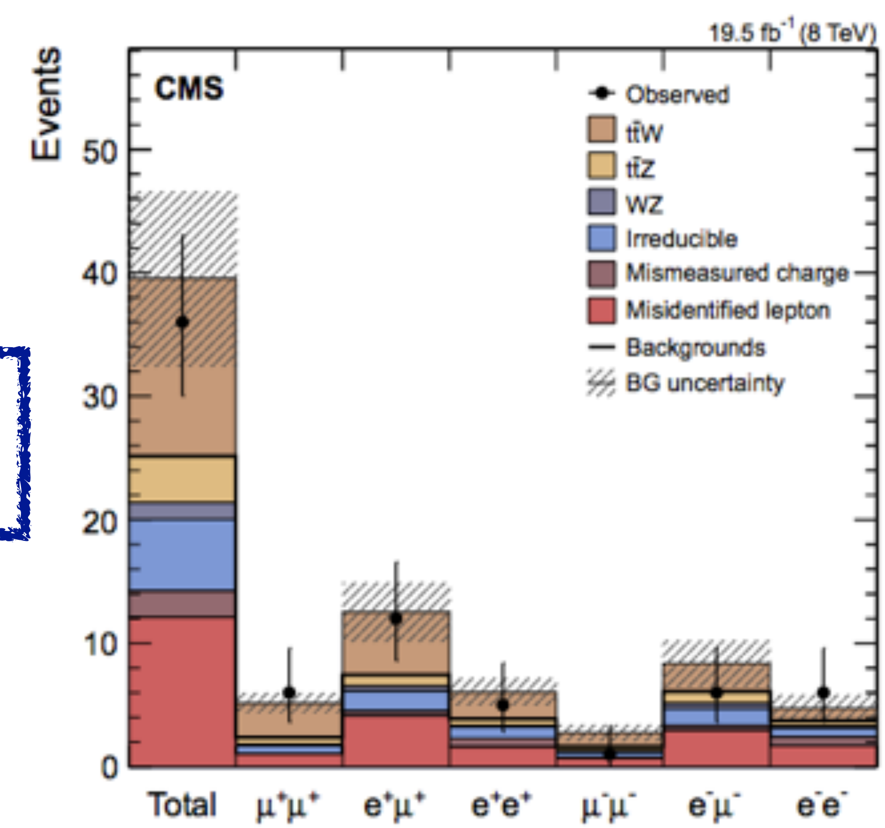
-> split by flavor and charge (signal is asymmetric)

combine the same-sign results with 3l and 4l analyses

-> simultaneous fit to all signal regions



newest of the results:
arXiv:1406.7830



is there more for same-sign?

yes, absolutely!

- -> has been used in EXO searches
- -> has been used in tt+H

same-sign leptons will play a crucial role in the early searches at 13 TeV

- -> first and foremost (I think) in SUSY

let's see what the future brings

- -> if there's no SUSY, there are other ideas floating around, e.g. double parton scattering (but this is hard) the end

SR definition

$N_{\text{b-jets}}$	E_T^{miss} (GeV)	N_{jets}	$H_T \in [200, 400]$ (GeV)	$H_T > 400$ (GeV)
$= 0$	50–120	2–3	SR01	SR02
		≥4	SR03	SR04
	>120	2–3	SR05	SR06
		≥4	SR07	SR08
$= 1$	50–120	2–3	SR11	SR12
		≥4	SR13	SR14
	>120	2–3	SR15	SR16
		≥4	SR17	SR18
≥ 2	50–120	2–3	SR21	SR22
		≥4	SR23	SR24
	>120	2–3	SR25	SR26
		≥4	SR27	SR28