Prospect of BSM/SUSY in CMS

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On behalf of the CMS Collaboration

Outline

- Motivations
- Planning for the LHC Upgrade
- How projections are made
- Some results on Supersymmetry and vector like quark searches
- Conclusions

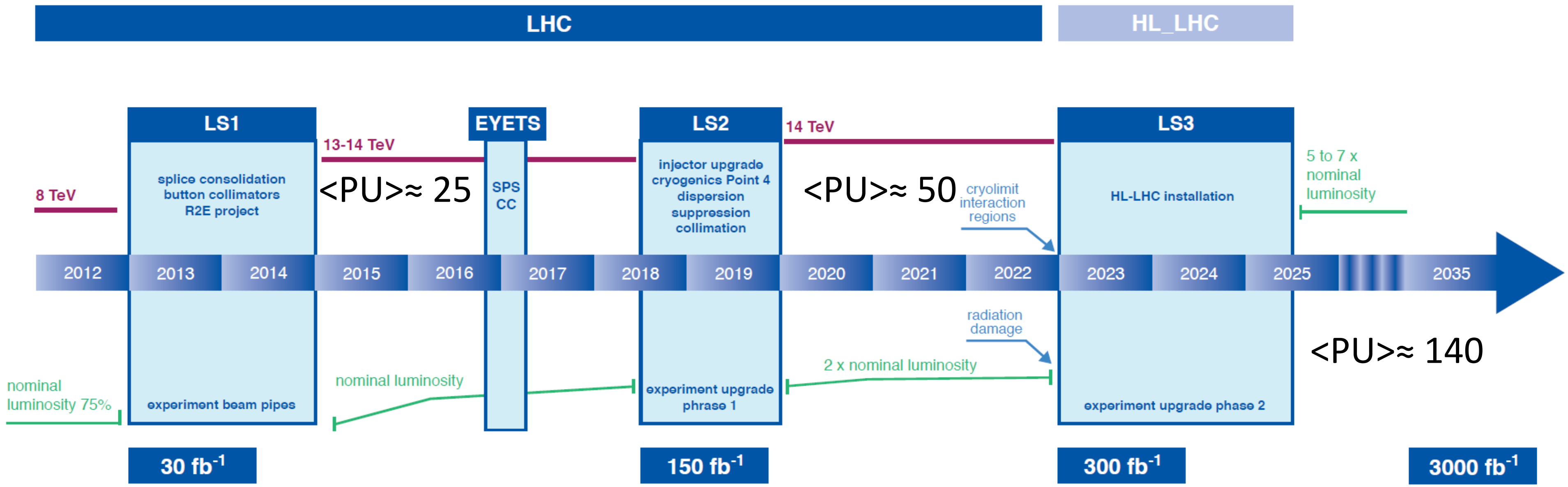
Motivations

- Conclusions from Run1:
  - Discovery of the Higgs Boson
  - No evidence of new physics so far
- There should be something more
  - in order to cancel divergences appearing in the Higgs mass computation
  - also to explain the Dark Matter
- How to find this "something"?
  - increase the energy in the center of mass → look for higher mass particles
  - increase the luminosity → look for lower cross-section processes

This is precisely what we can get with LHC upgrades!

Planning of the LHC Upgrade

New LHC / HL-LHC Plan



CMS: Detector Consolidation

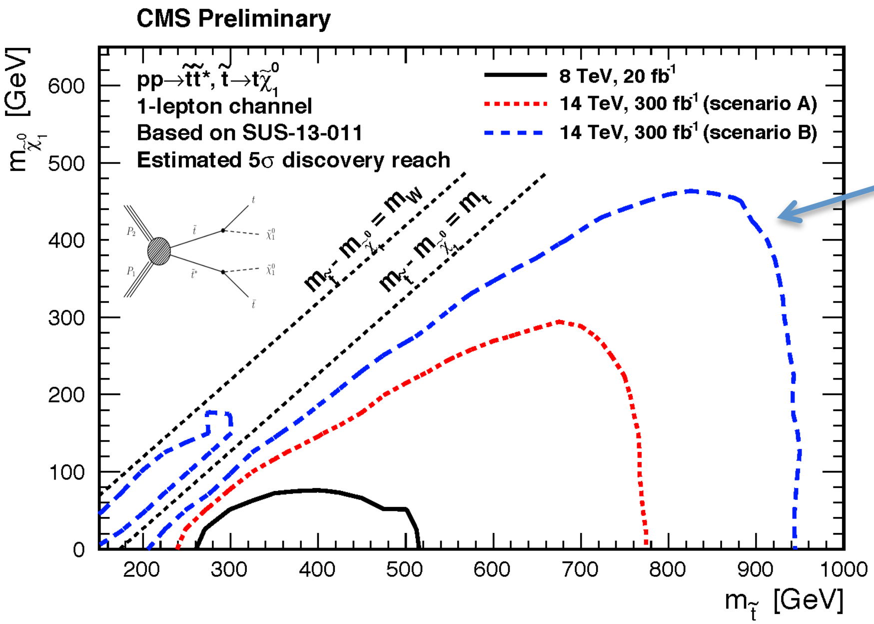
Phase 1:
Pixel
Hcal
L1 trigger

Phase 2:
Tracker replacement, |η|<4
Forward calorimetry
Muon |η|< 2.4 to 3
Trigger upgrade

→See talk of Yves Sirois

How projections for physics are made?

- First studies: extrapolation based on 8 TeV data with a scaling of the luminosity and the cross-sections
  - no re-optimization, assume no performance degradation
  - 2 different scenarios are considered for the systematics:
    - "A" : Conservative = same uncertainties as now
    - "B" : More optimistic = relative background uncertainty is reduced



Examples of 5σ discovery w/ $300 fb^{-1}$:

- Stop in t+LSP:

M_{stop} of 750-950 GeV,

M_{LSP} of 300-450 GeV

- Heavy gauge bosons in dileptons:

$M_{z'}$ of 4.5-5 TeV depending of the models

(8 TeV : $M_{z'}$ > 2.5 TeV)

http://arxiv.org/pdf/1307.7135v2.pdf
(CMS-PAS-FTR-13-013)

How projections for physics are made?

- First studies: extrapolation based on 8 TeV data with a scaling of the luminosity and the cross-sections

- Detailed studies: Prospects using the Delphes simulation, up to 3000 fb^{-1},

<PU>~140

Pile-up included in Delphes3

- If $\Delta z(PV - V_{PU})<0.1$: PU incorporate for the object reco
- Else: charged particle suppression inside tracker,

& FastJet area method for neutral particles or charged outside tracker

The impact of the PU is studied on the discovery potential

How projections for physics are made?

- First studies: extrapolation based on 8 TeV data with a scaling of the luminosity and the cross-sections

- Detailed studies: Prospects using the Delphes simulation, up to 3000 fb^{-1}, using 2 configurations for the Phase 2 detector:
  - "Conf3": new tracker with $|\eta| < 2.5$, muon system up to $|\eta| = 2.4$, EM endcap calo à la "shashlik", Had endcap calo with ϕ segmentation x4
  - "Conf4": new tracker with $|\eta| < 4$, muon system up to $|\eta| = 4$, EM endcap calo à la "shashlik", new Had endcap calo

Impact of the $|\eta| < 4$ tracker

- Better background identification (Susy produced centrally , background also populating the forward direction) → gain in S/B
- Reconstruction of vertices and charged particle association to forward jets → PU suppression (particularly important for VBF)

How projections for physics are made?

- First studies: extrapolation based on 8 TeV data with a scaling of the luminosity and the cross-sections

- Detailed studies: Prospects using the Delphes simulation, up to 3000 fb^{-1}, using 2 configurations for the Phase 2 detector:
  - "Conf3": new tracker with $|\eta| < 2.5$, muon system up to $|\eta| = 2.4$, EM endcap calo à la "shashlik", Had endcap calo with ϕ segmentation x4
  - "Conf4": new tracker with $|\eta| < 4$, muon system up to $|\eta| = 4$, EM endcap calo à la "shashlik", new Had endcap calo

  Remark: Full trigger is not available → assume triggers similar to 8 TeV data taking: not realistic but as most of the signal regions are in the tails, they should be triggered without problems.

  → **Main topics of this talk**

  CMS-PAS-FTR-13-014
  CMS-PAS-FTR-13-06

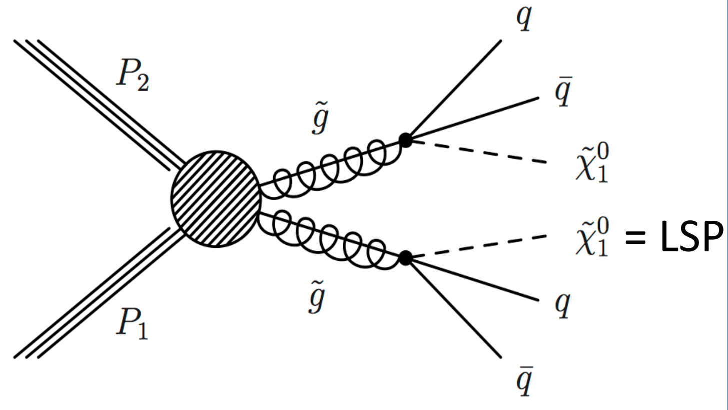
- Ongoing studies with latest performance estimates for the Upgrade detector

Search for SUSY with jets & missing hadronic energy

CMS-PAS-FTR-13-014

- Based on CMS-PAS-SUS-13-012 @ 8 TeV
- Topology: many jets, no leptons,

  Use of $H_T = \sum_{\text{jets}} p_T$ and $\not{H}_T = |-\sum_{\text{jets}} \vec{p}_T|$



- Event selection: 0 e/μ, ≥ 3 jets, H_T > 500 GeV, $\not{H}_T$ > 200 GeV, |Δϕ(J, $\vec{\not{H}}_T$))|
- SM backgrounds: Z(νν)+jets, W(lν)+jets, (QCD multijets negligible at high $\not{H}_T$)

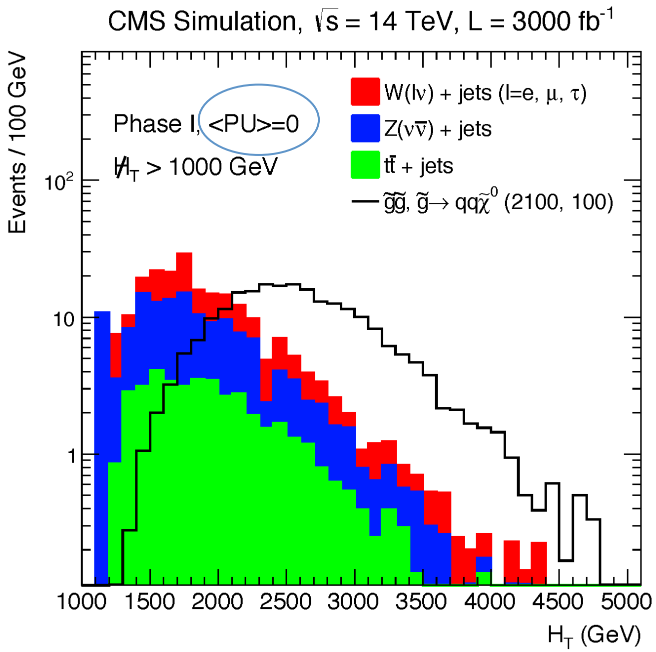
- Search regions for 3000 fb^{-1}: tighter cuts than for the 8 TeV analysis

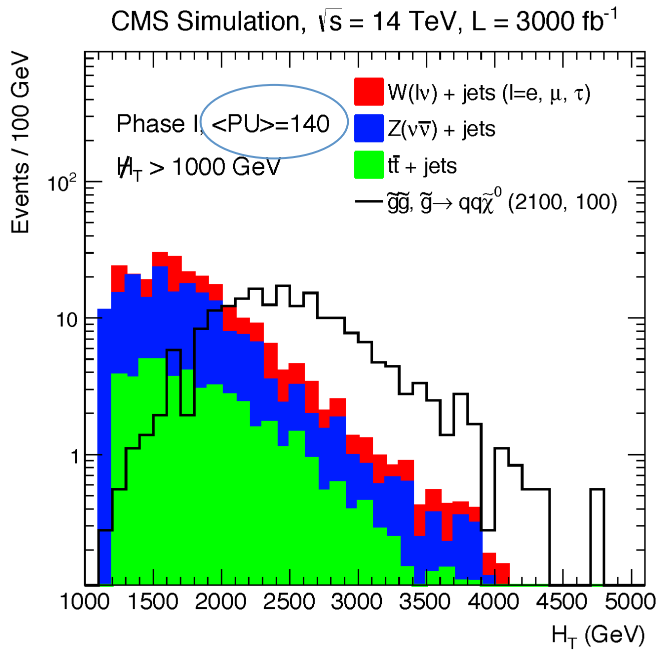
	High M_{gluino}	High M_{LSP}	Medium M_{gluino} & medium M_{LSP}	Low M_{gluino} & low M_{LSP}	Low M_{gluino} & high M_{LSP}
nJets	≥6	≥6	≥6	≥6	≥6
H_T	>2500	>1600	>2000	>800	>1100
$\not{H}_T$	>1000	>700	>1000	>400	>600

Search for SUSY with jets & missing hadronic energy

CMS-PAS-FTR-13-014

- Study of the PU effect on H_T and $\not{H}_T$: no major impact in the search regions





- 30 % uncertainty on the background prediction.

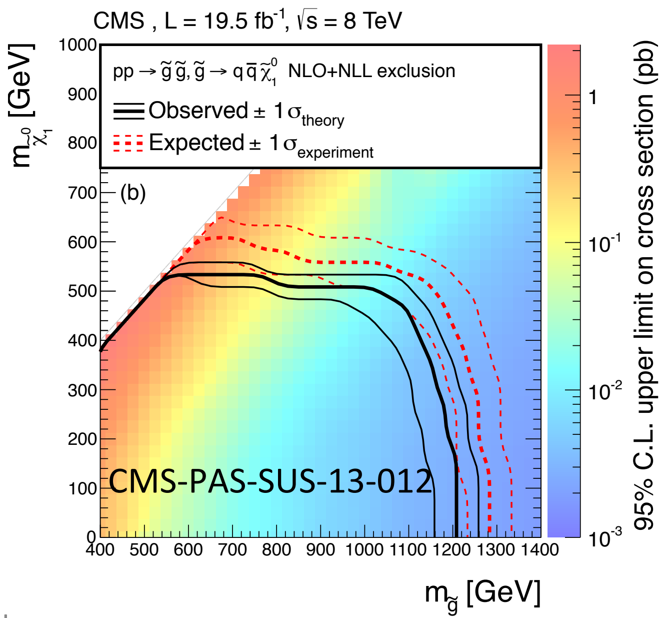
Search for SUSY with jets & missing hadronic energy

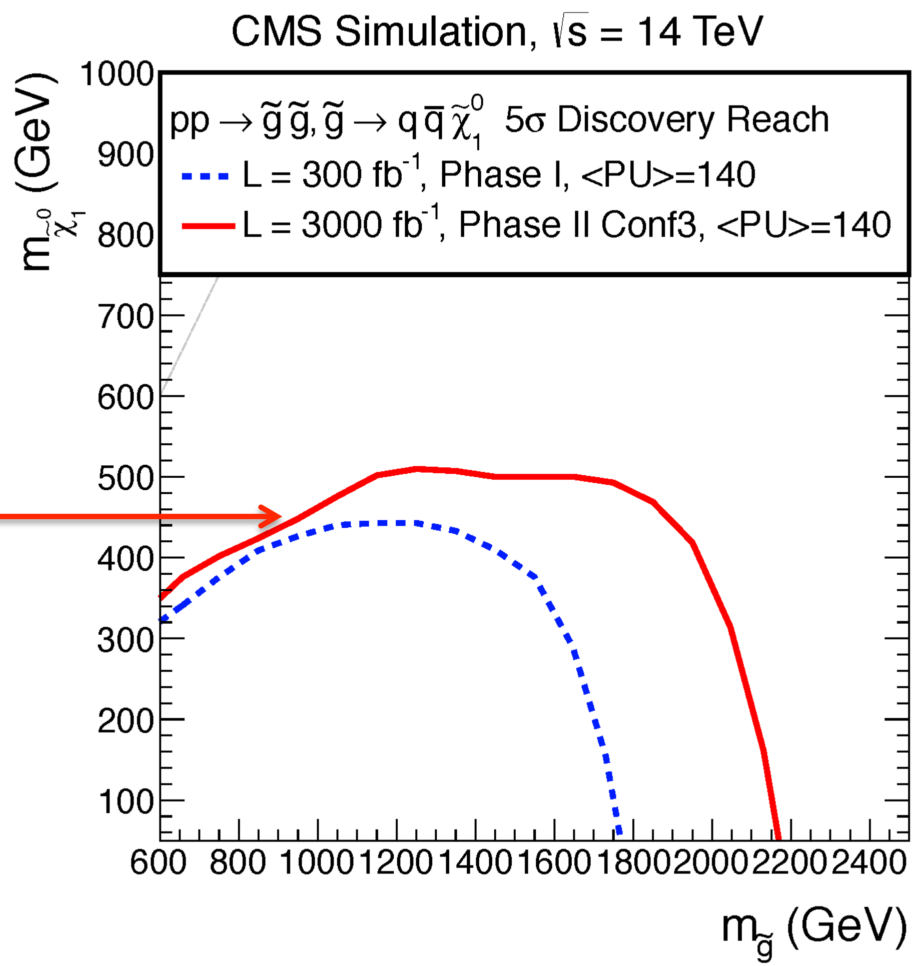
CMS-PAS-FTR-13-014

- **5σ discovery reach@3000 fb^{-1}:**

Gluino masses up to ~ 2.2 TeV and LSP masses up to ~ 500 GeV.

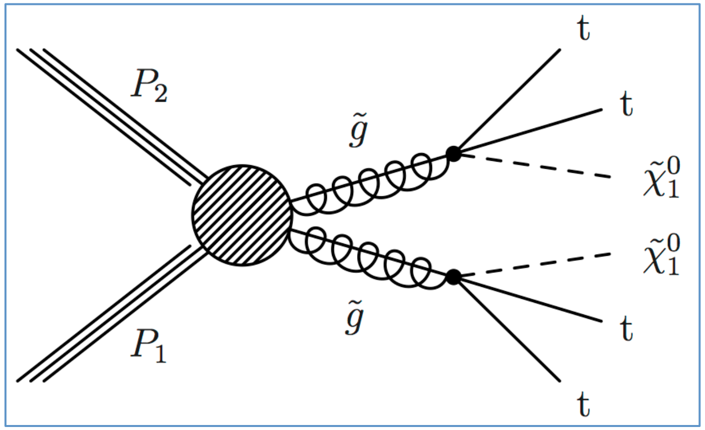
For comparison: 95% exclusion limit with 8 TeV data: M_{gluino} up to 1.16 TeV are excluded for M_{LSP}< 100GeV)





Search for gluinos into tops & LSP

CMS-PAS-FTR-13-014



- Based on CMS-PAS-SUS-13-007 @ 8 TeV
- Topology: 1 lepton, MET, jets (some being b-tagged)

- Event selection: 1 e/μ, ≥ 6 jets (≥ 1 b-tagged), H_T > 500 GeV, S_T^{lep} > 250 GeV , Δϕ(W,l)>1
  with S_T^{lep} = scalar Σ of [MET + pT(l)]

- SM backgrounds: ttbar+jets, V+jets, ttbar +V, single top.
- "Data-driven" background estimate with $N_{SM}^{pred}(\Delta\phi(W,\ell) > 1) = R_{CS} \cdot N_{data}(\Delta\phi(W,\ell) < 1)$

$$R_{CS} = \frac{N_{signal}}{N_{control}} = \frac{\text{Number of events with } \Delta\phi(W,\ell) > 1}{\text{Number of events with } \Delta\phi(W,\ell) < 1}$$

- Search regions:

S_T^{lep}	[450,550], [550,650], [650,750], ≥750
N_b	=3, ≥4

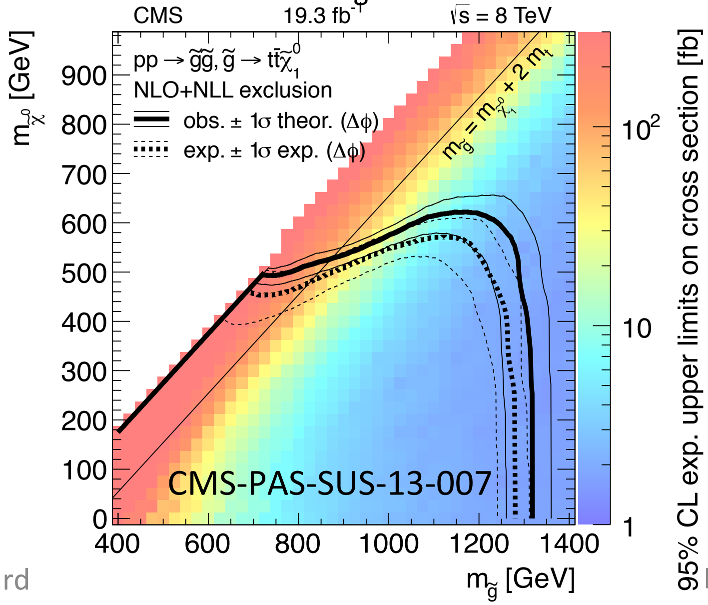
Search for gluinos into tops & LSP

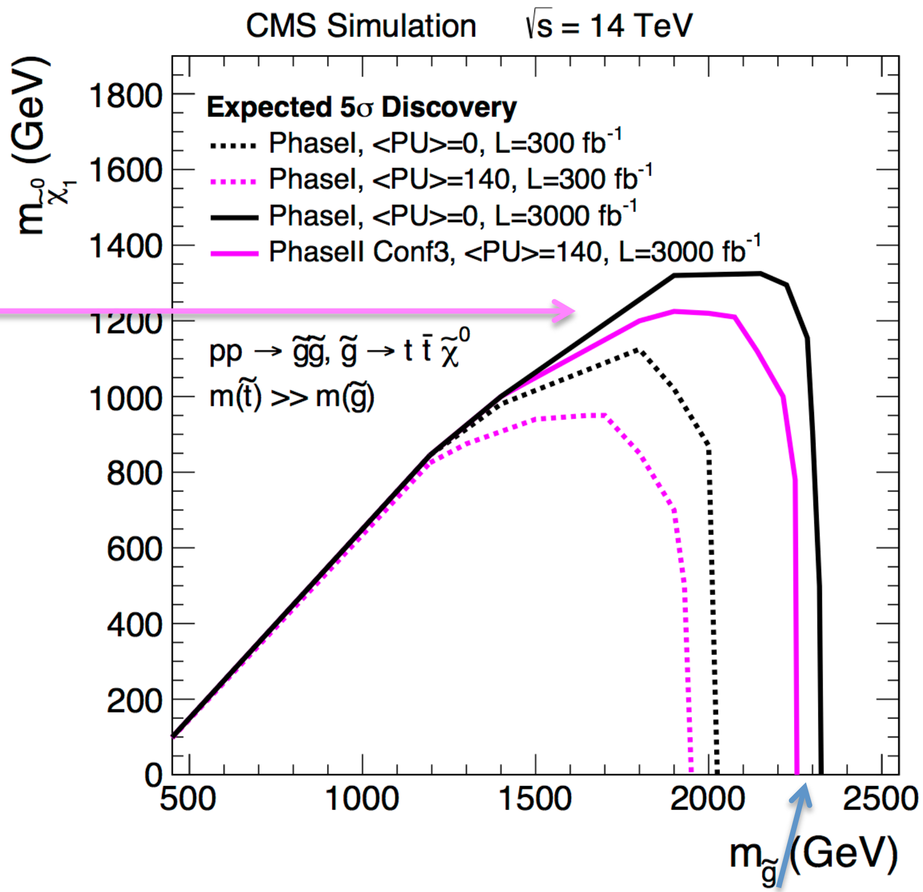
CMS-PAS-FTR-13-014

- **5σ discovery reach@3000 fb^{-1}:**

Gluino masses up to ~ 2.2 TeV and LSP masses up to ~ 1.2 TeV.

For comparison: 95% exclusion limit with 8 TeV data: M_{gluino} up to 1.26 TeV are excluded for light M_{LSP}, and M_{LSP} up to 580 GeV for M_{gluino} = 1.1 TeV.



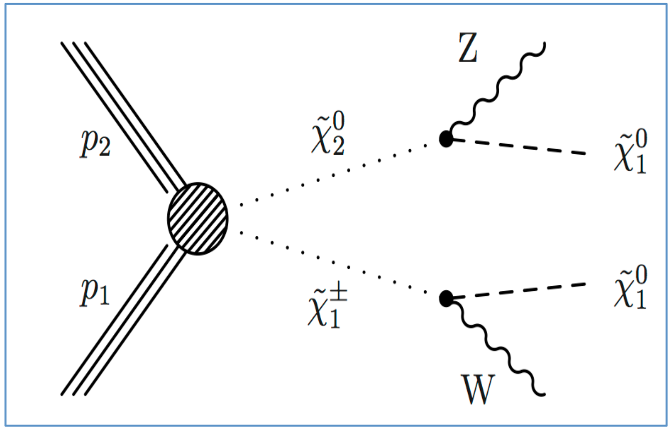


The mass reach is mitigated due to pileup by about 100 GeV

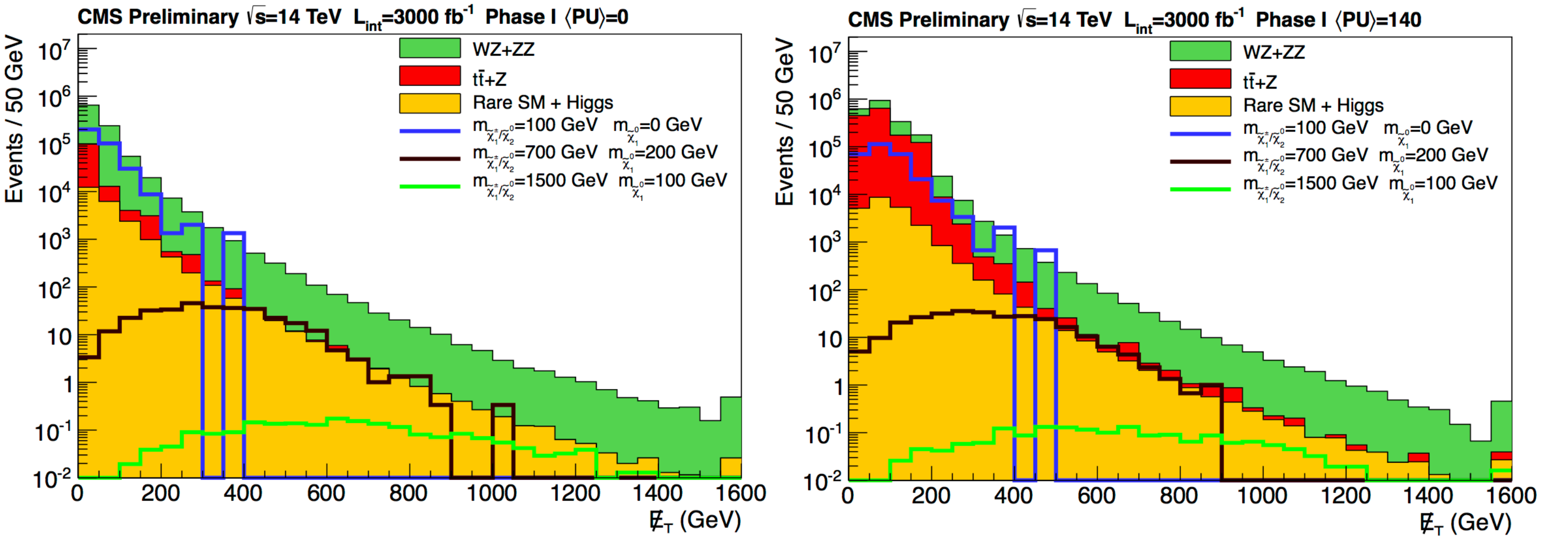
EWKino search with 3 leptons and MET

CMS-PAS-FTR-13-014

- Based on CMS-PAS-SUS-13-006 @ 8 TeV
- Topology: 3 leptons, MET, low hadronic activity



- Event selection: 3 e/μ (with 1 OSSF pair → Z) , no b-tagged jet
- SM backgrounds: WZ, ttbar, rare, single V
- Search regions: 15 SR with asymmetric binning in M_T and MET
- Remark at large PU: worse MET resolution, higher fake rate → need optimization!

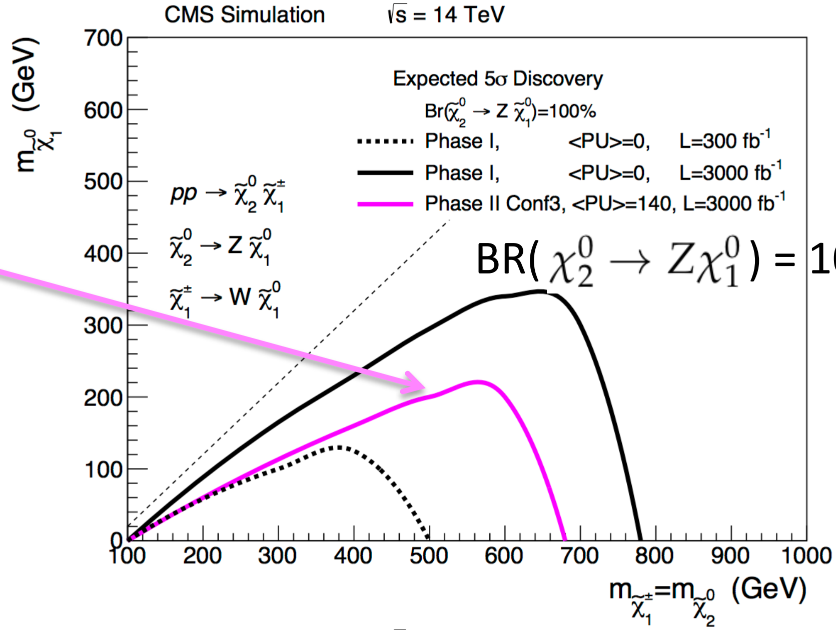


EWKino search with 3 leptons and MET

CMS-PAS-FTR-13-014

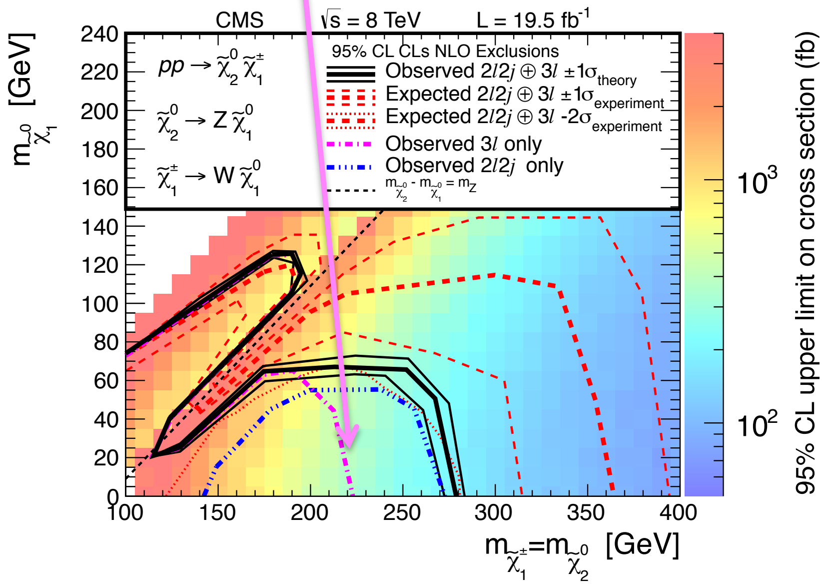
- **5σ discovery reach@3000 fb^{-1}:**

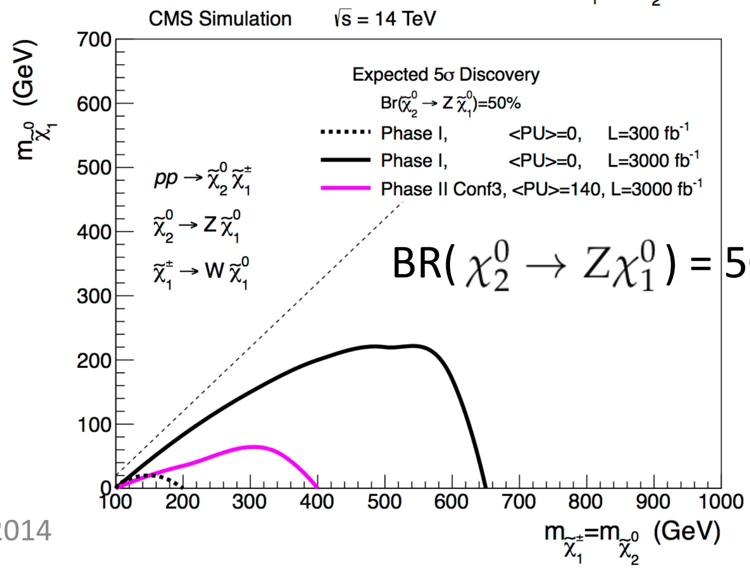
$\chi_1^{\pm}$ and χ_2^0 masses up to ~ 700 GeV and LSP masses up to ~ 200 GeV.



BR($\chi_2^0 \rightarrow Z\chi_1^0$) = 100%

For comparison: 95% exclusion limit with 8 TeV data:



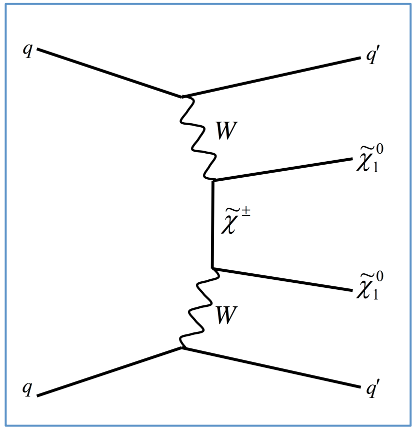


BR($\chi_2^0 \rightarrow Z\chi_1^0$) = 50%

Dark matter in VBF

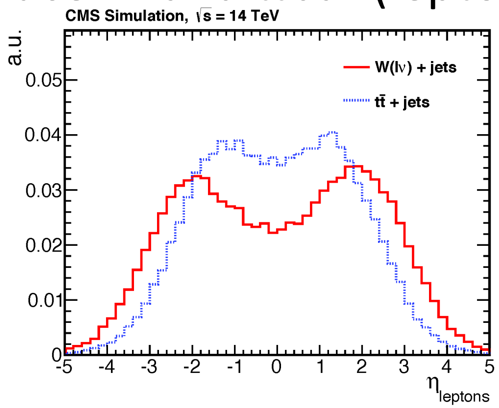
CMS-PAS-FTR-13-014

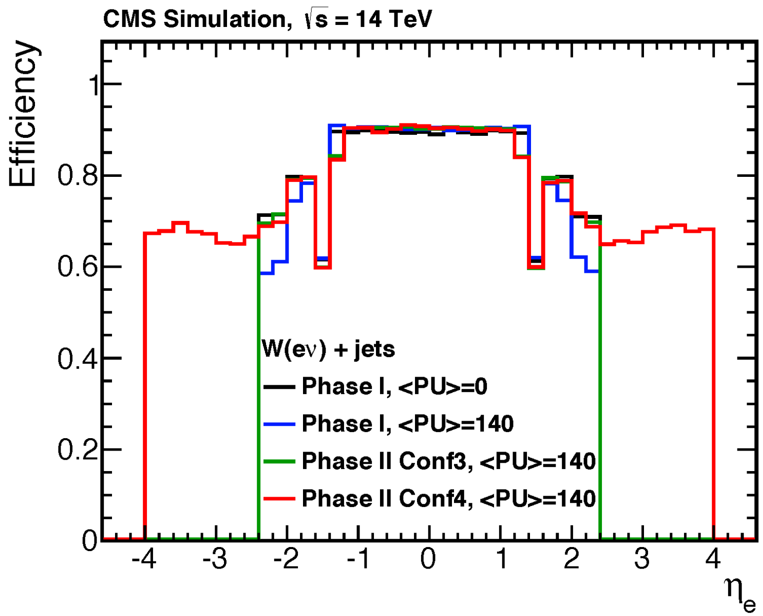
- $\chi_1^{\pm}$ and LSP: nearly mass-degenerate → both invisible
- Topology: 2 forward jets (large M_{jj}, opposite hemi), MET



- Event selection: 2 jets (η_1-η_2>4.2, η_1*η_2<0, M_{jj}>1500 GeV) no 3rd jet in between, 0 b-tagged jets, 0 lepton, $\not{H}_T$ >200 GeV
- SM backgrounds: V+jets, QCD, VBF production of V, ttbar

- Impact of the tracker η extension:
  - Improve the lepton acceptance
  - → reduce W and ttbar (lepton veto)

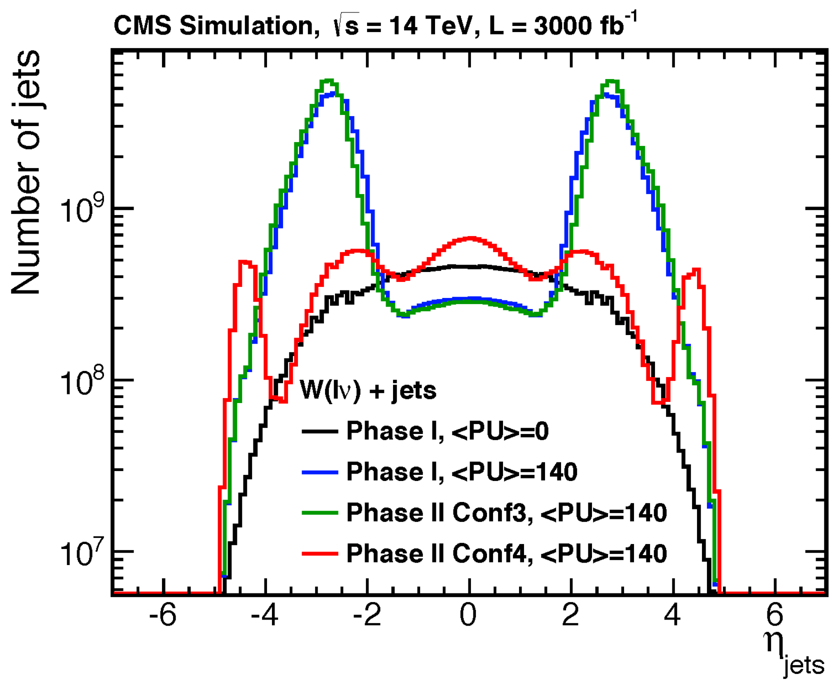


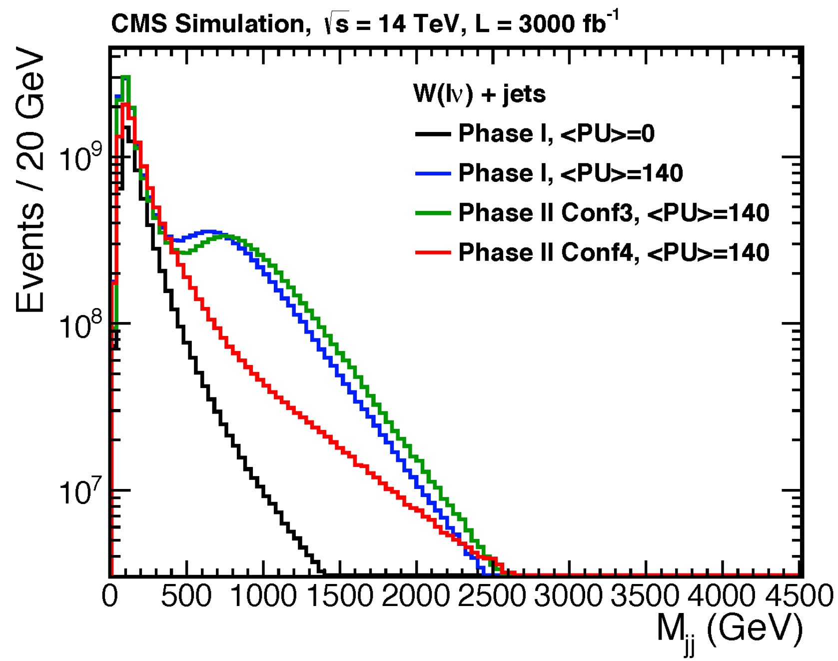


Dark matter in VBF

CMS-PAS-FTR-13-014

- Impact of the tracker η extension:
  - Improve PU mitigation in forward region → improve the VBF tagging and MET resolution



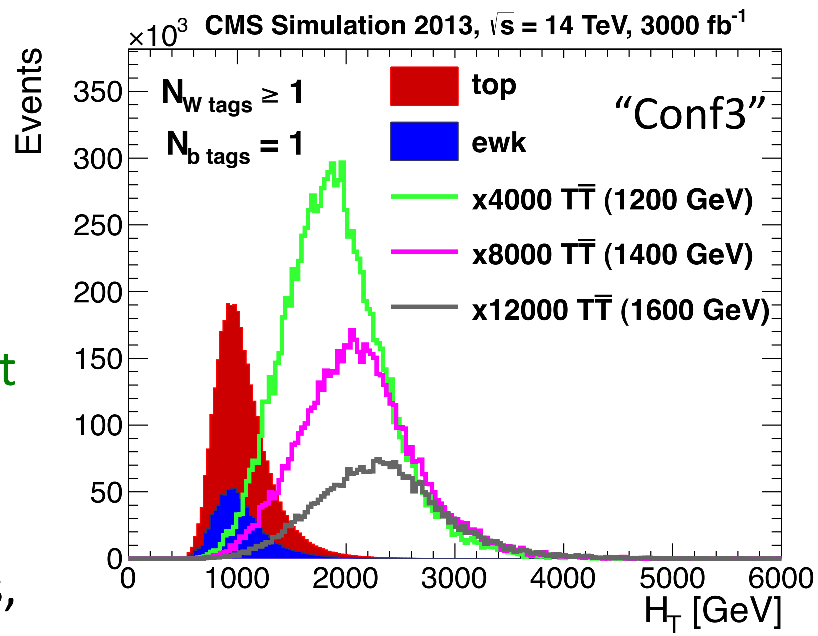


Heavy vector-like charge 2/3 quarks

CMS-PAS-FTR-13-026

- Based on CMS-PAS-B2G-12-015 @ 8 TeV
- Vector-like quarks are non-SM 4th generation quarks, with only vector-coupling to W → mass term without the need of a Yukawa coupling to H. They can cancel divergences due to top loops in H mass.
- Explore tH, tZ, bW decay modes (in limit of large mass: BR= 25/25/50%)

  → topology: 2 to 4 V and ≥ 2 b-quarks.
- Event selection:
  - Single-lepton+jets: 1 e/μ, ≥ 3 jets (leading b pT>150 GeV), MET>20 GeV
  - Multi-leptons: ≥ 2 leptons
  - \+ Reconstruction of boosted hadronic W/t
- SM backgrounds: ttbar, V+jets, single top, DY, WW, WWW, ttbar+V
- Search regions: # & flavour of leptons, nJets, if boosted hadronic W/top



Heavy vector-like charge 2/3 quarks

CMS-PAS-FTR-13-026

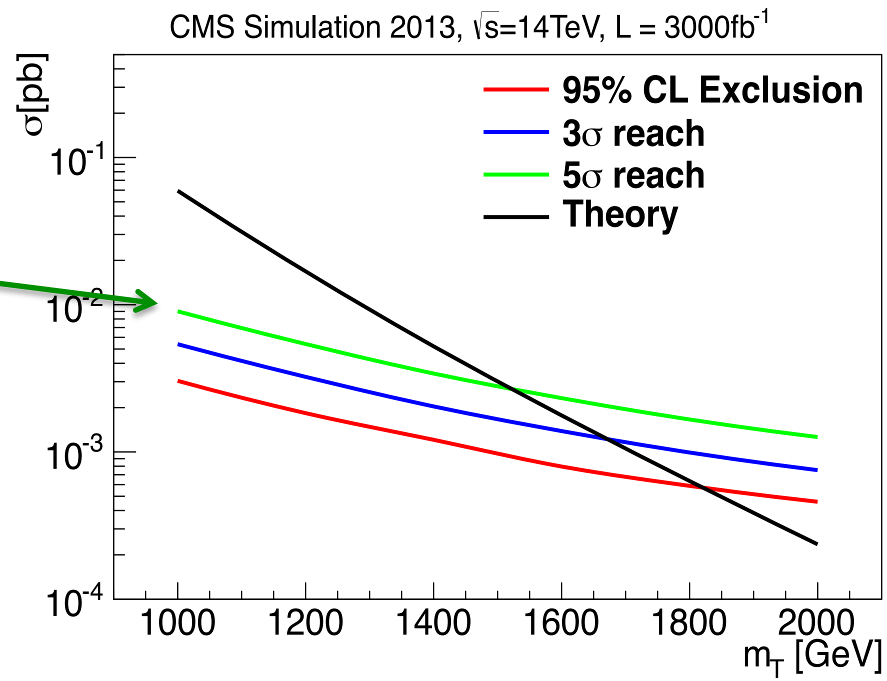
- Systematics: 20 % uncertainty on the background prediction, 5% for the signal selection efficiencies.

- **5σ discovery reach@3000 fb^{-1}:**

mass up to 1.48 TeV for the combined multi-lepton & single-lepton+jets channels.

For comparison: 95% exclusion limit with 8 TeV data: $M_T > 696$ GeV

→ Exclusion with HL-LHC : x2.6 larger



Conclusions

- CMS investigates the projection at $\sqrt{s}$ = 14 TeV with up to 3000 fb^{-1} (HL-LHC) for several SUSY searches, interpreted within simplified models, and one benchmark of BSM scenario (VLQ).
- A huge improvement in term of sensitivity is expected, especially for low cross-section processes. A significant part of the interesting range of phase space will be accessible with HL-LHC. When searching for heavy particles, it becomes very interesting to use boosted reconstruction techniques.
- The big difficulty will come from a huge pile-up rate (~140 in average). But the extension of the tracker up to $|\eta|=4$ will help a lot to cope with that. This extension is also important for the SM background reduction (reduce $W \rightarrow \mu\nu$ by a factor 3).

Backup Slides

Expected increase of the different signals