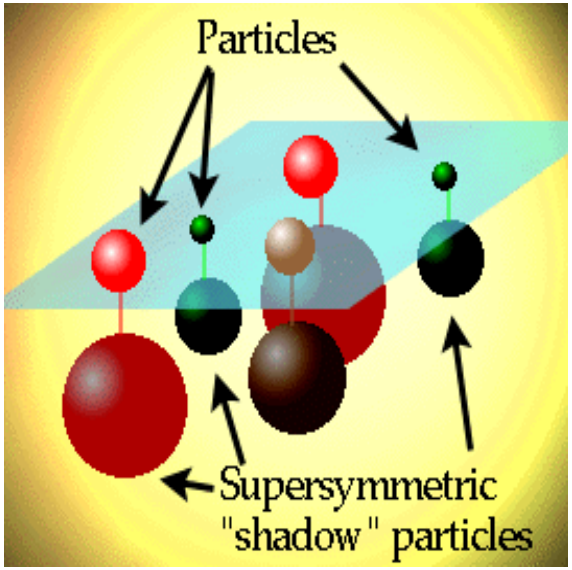


SUSY SEARCHES IN ATLAS

Xuai Zhuang (庄胥爱)

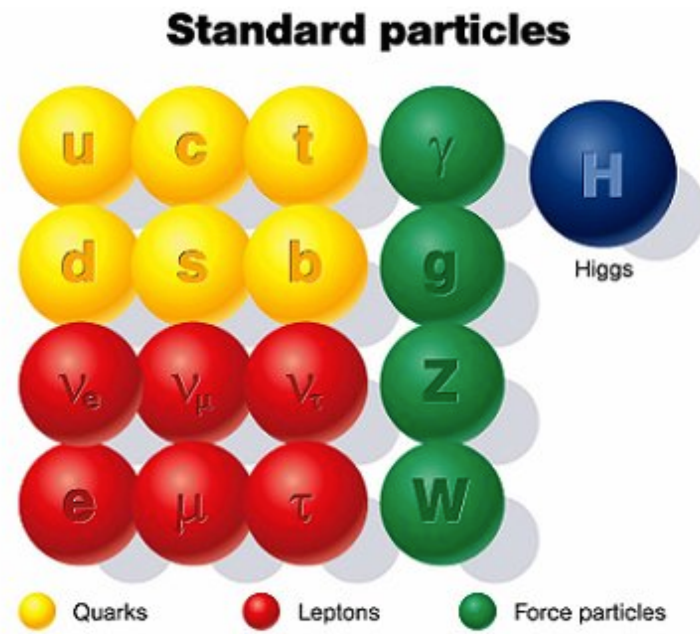
xuai.zhuang@cern.ch

IHEP, Beijing, China

15-19 Aug. 2016, Weihai

中国科学院高能物理研究所
Institute of High Energy Physics Chinese Academy of Sciences

Standard Model

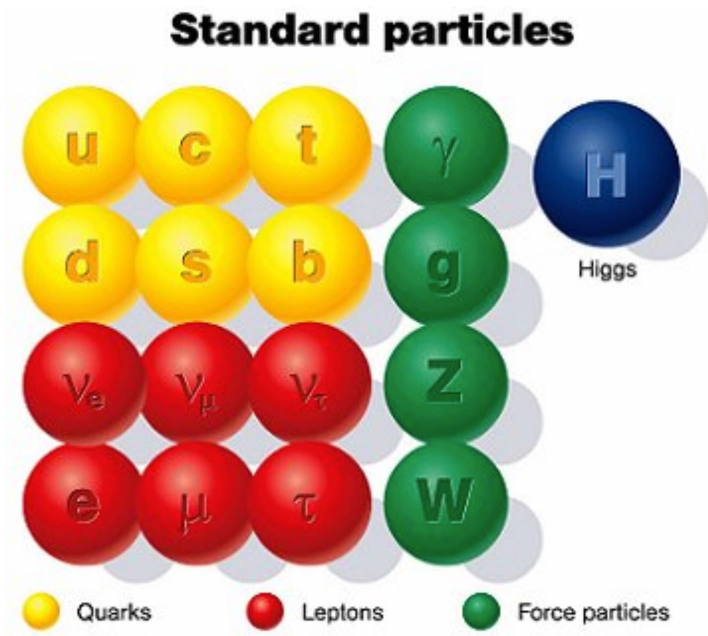


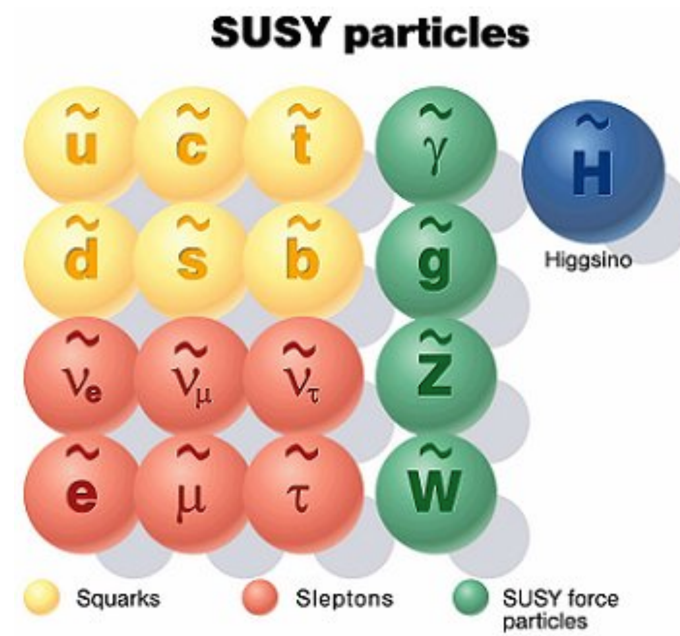
- **Standard Model (SM)**

  Very successful description of phenomena at TeV scale, but some shortcomings:

  - Hierarchy problem
  - Can not unify gauge couplings
  - No dark matter (DM)
  - …

Standard Model and Supersymmetry





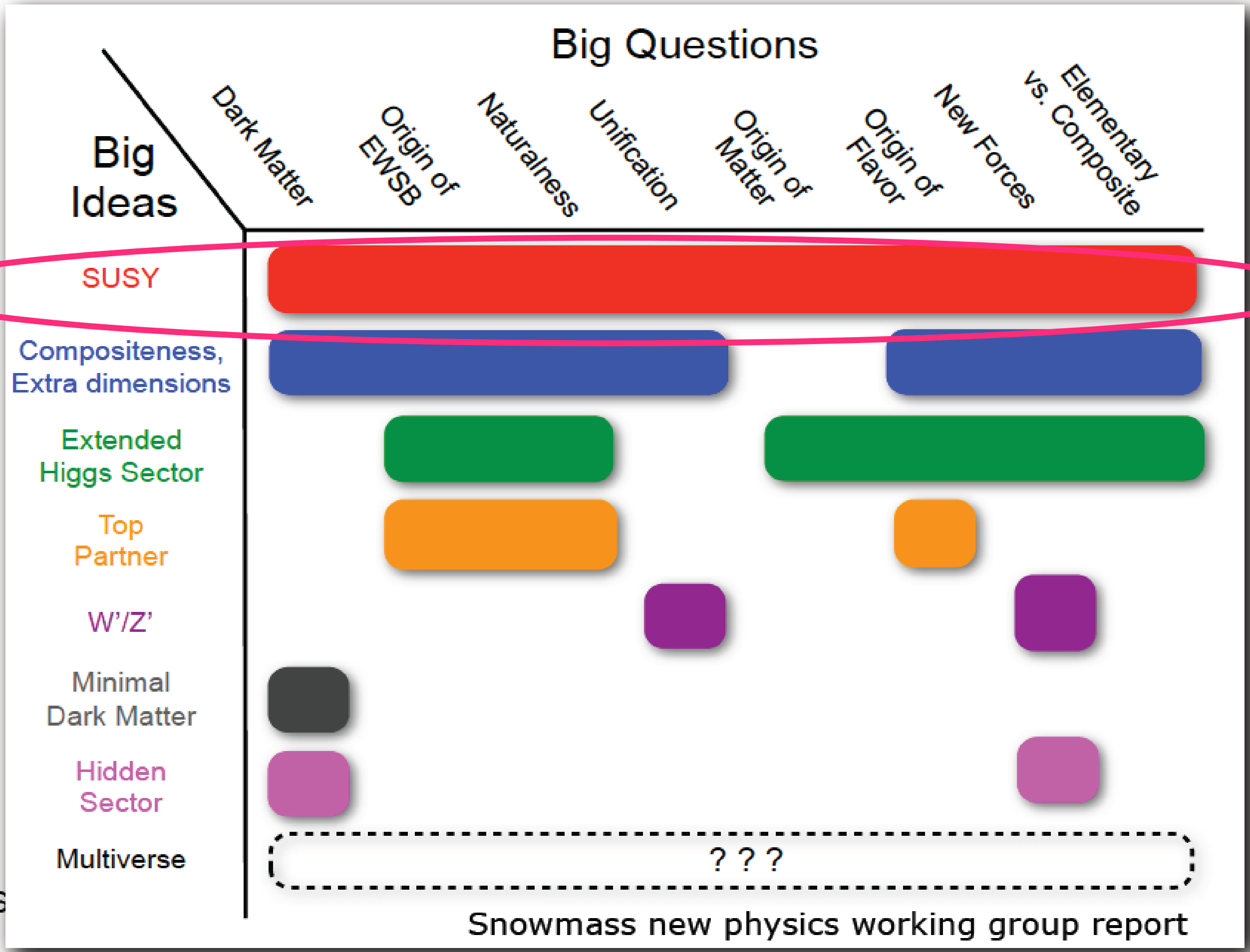
- **Standard Model (SM)**

  Very successful description of phenomena at TeV scale, but some shortcomings:
  - ❑ Hierarchy problem
  - ❑ Can not unify gauge couplings
  - ❑ No dark matter (DM)
  - ❑ …

- **Supersymmetry (SUSY)**

  Unique extension of Poincare spacetime symmetry
  - ❑ Moderate the hierarchy problem
  - ❑ Grand unification of gauge couplings
  - ❑ Provide excellent DM candidate
  - ❑ …

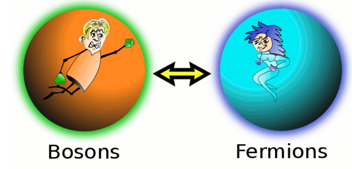
New Physics beyond the SM



S. S

- **If SUSY is at TeV scale, it will be produced copiously at LHC**
- **SUSY search is one of the most hot topic at LHC and beyond**

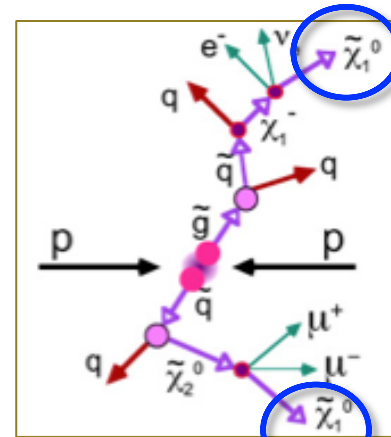
SUSY Introduction



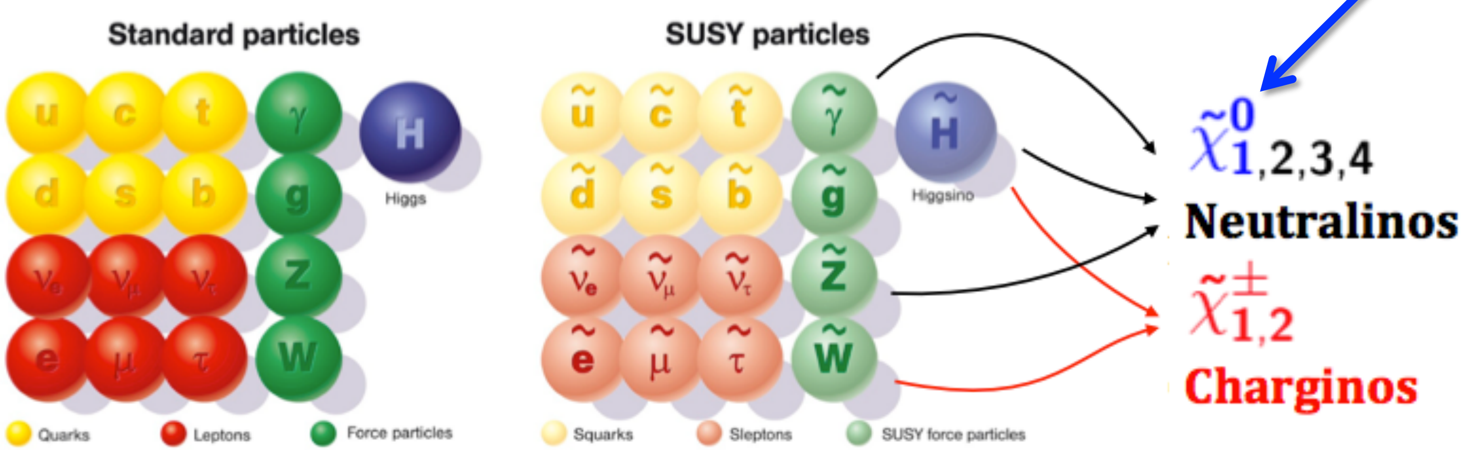
- **A symmetry which unified fermions (matter) and bosons (forces)** -> A fundamental theory
- **Conserved R parity (RPC):** (originally introduced for stability of proton) $\boxed{R=(-1)^{3(B-L)+2S}}$

  R=+1 (SM)
  R=-1 (SUSY)

  - SUSY particles produced/annihilated in pairs
  - Lightest SUSY particle (LSP) stable (DM candidate)
  - Typical signature: <u>jets/leptons/photons + **MET**</u>

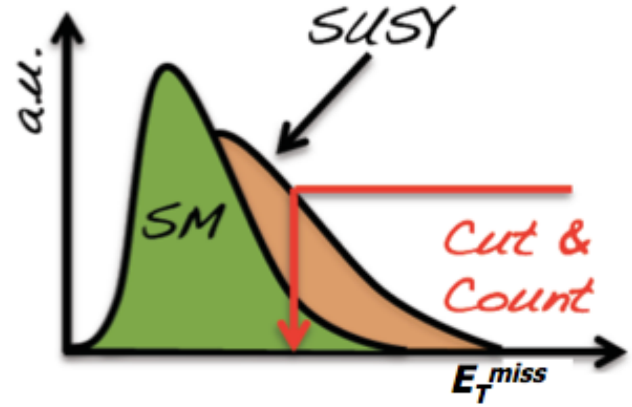


- **Violated R parity (RPV):** no Dark Matter candidate



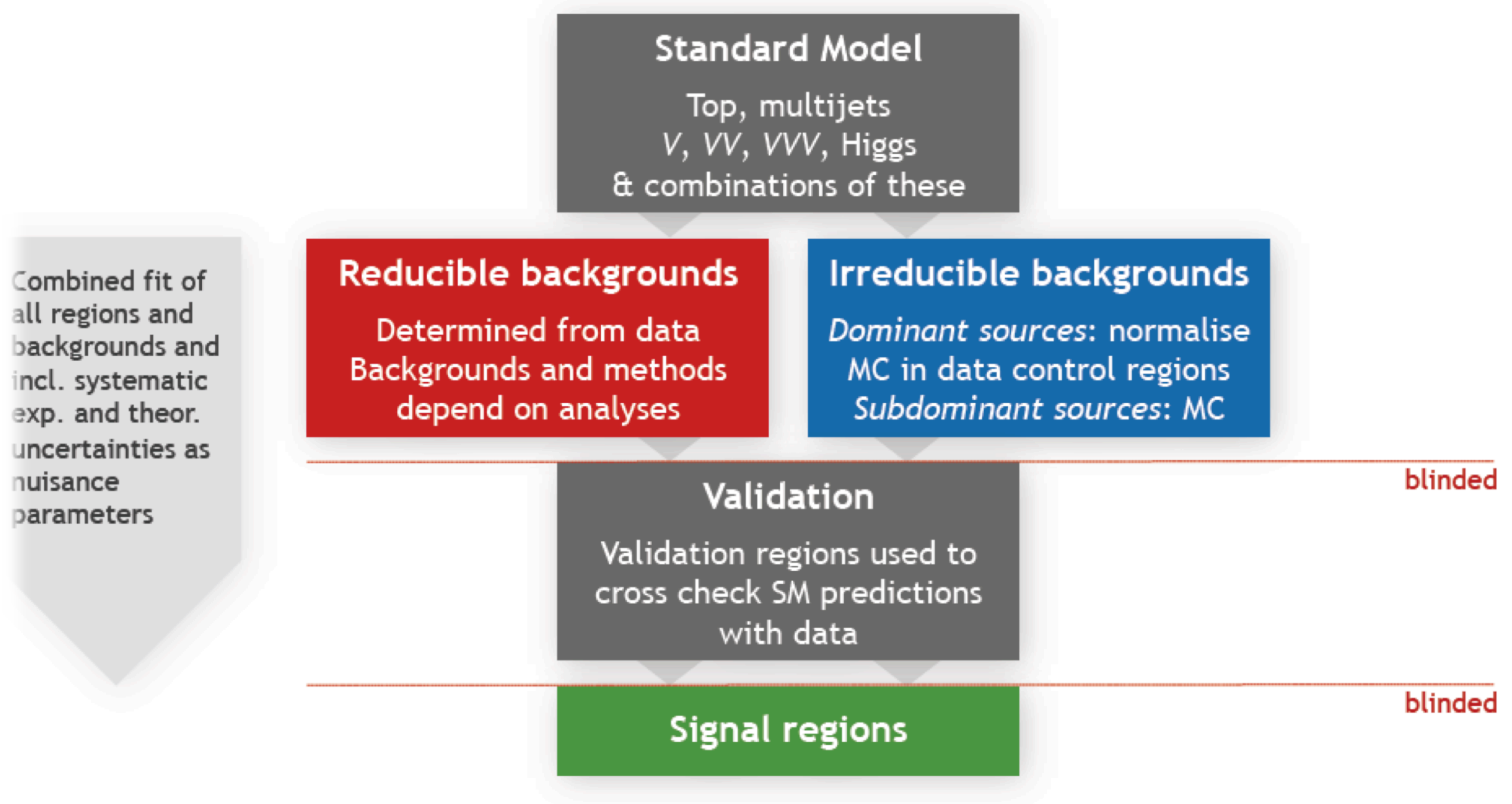
SUSY Search Strategy

- **SUSY search strategy:** search for deviation from SM
- **SUSY sensitive variables:** Try to establish excess of events in some sensitive kinematic distribution (E_T^{miss}, Meff, mT …)
- **SM background:** SUSY searches rely on accurate modeling of the Standard Model backgrounds

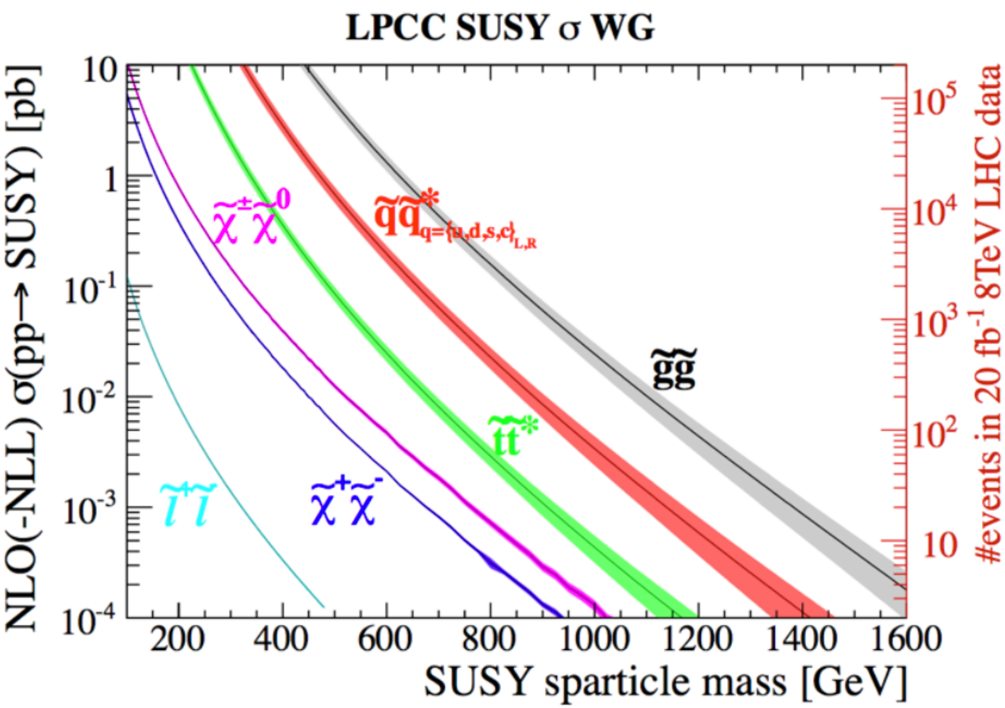


SM Background Modeling

- **SUSY searches rely on accurate modeling of the Standard Model backgrounds**



SUSY Search @ LHC



- **Most results are based on 13-15 fb^{-1} @ 13 TeV from 2015+2016**
- **Few of them from 8 TeV (EWK)**

Strong production:

- targeting gluinos and 1st and 2nd generation squarks
- by far largest cross-sections

3rd generation:

- targeting stop and sbottoms
- Should be lowest mass squarks for naturalness reasons

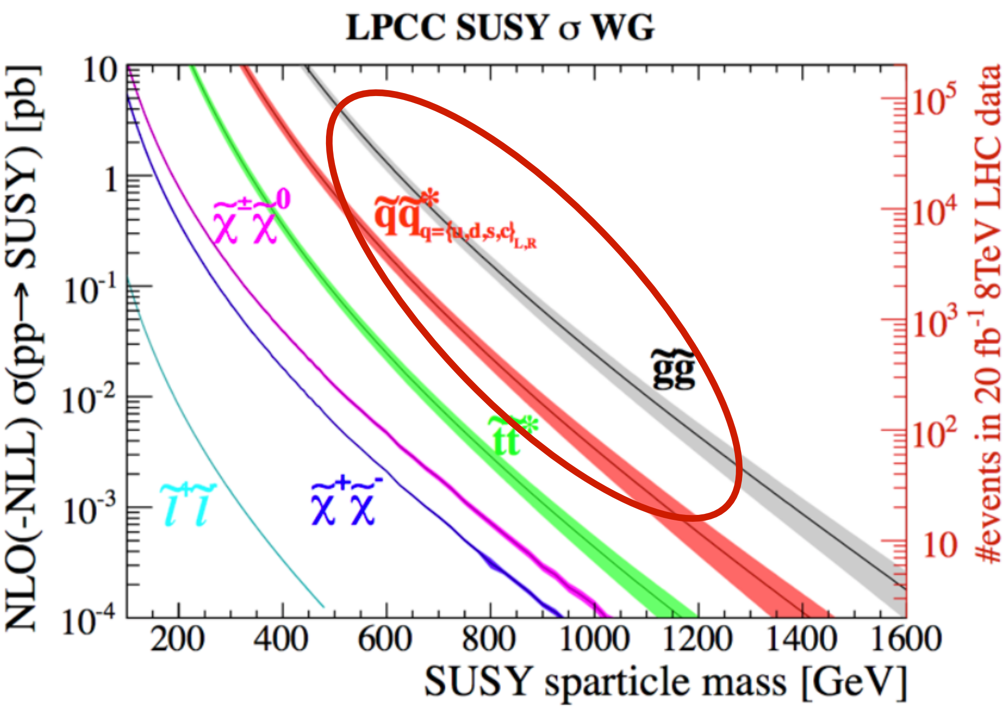
Electroweak production:

- targeting Electroweakinos, sleptons
- Lowest mass sparticles, clean signature

RPV/LL:

- targeting R-parity violating models and long lived sparticles
- More exotic models

SUSY Search @ LHC



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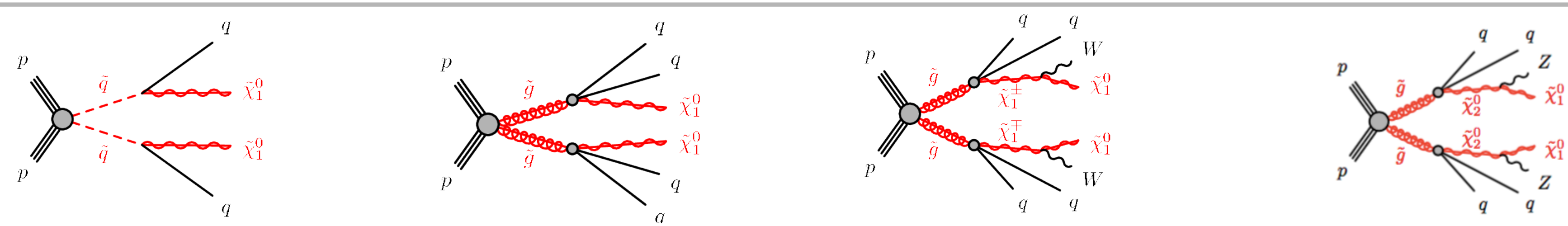
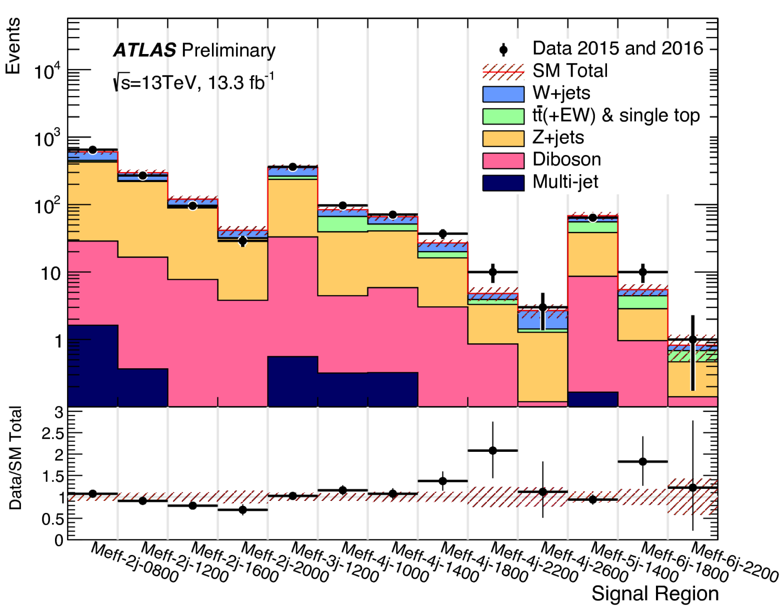
RPV/LL:
- ❑ targeting R-parity violating models and long lived sparticles
- ❑ More exotic models

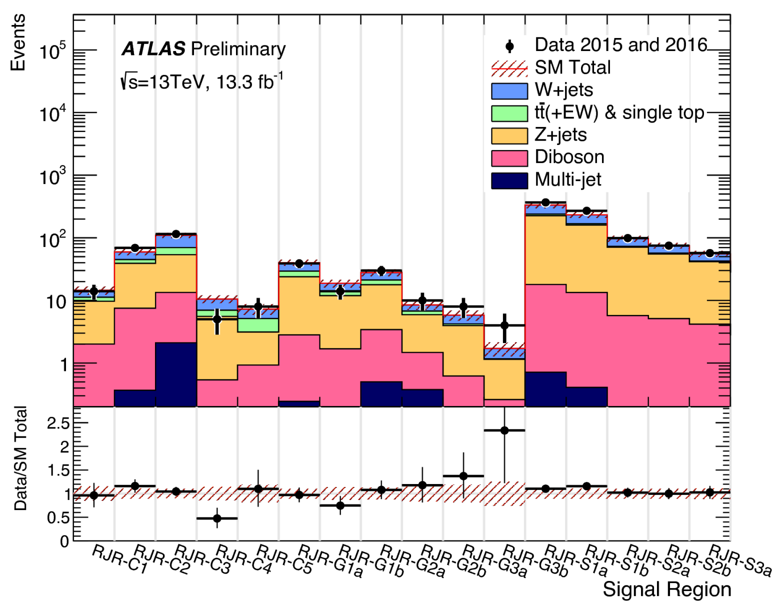
ATLAS-CONF-2016-078

Strong Production: 0L+jets+MET

- **Search for gluinos and 1st and 2nd generation squarks**
- **Final states with jets, MET and no isolated lepton (e/μ)**
- **Signal to BG discrimination based on: Meff, MET, RJigsaw**
- **30 signal regions (SRs) defined targeting different search scenarios and phase space → No significant excess observed**



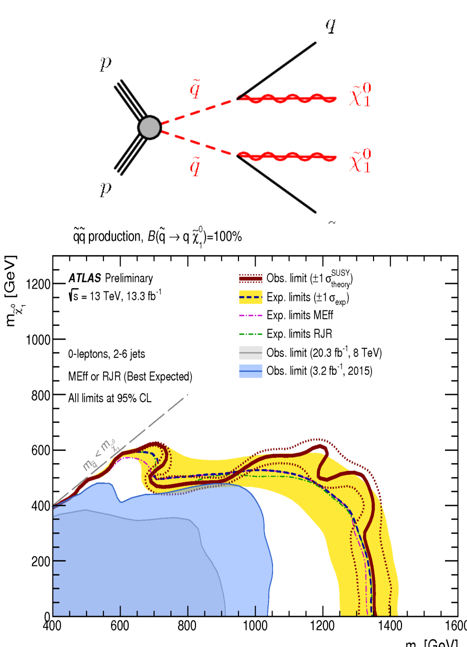


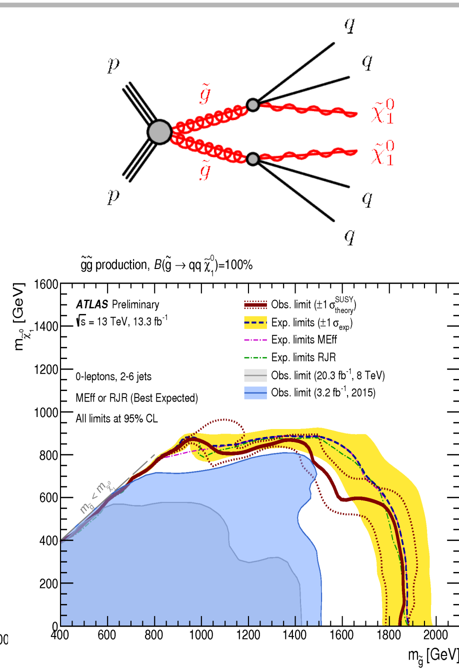


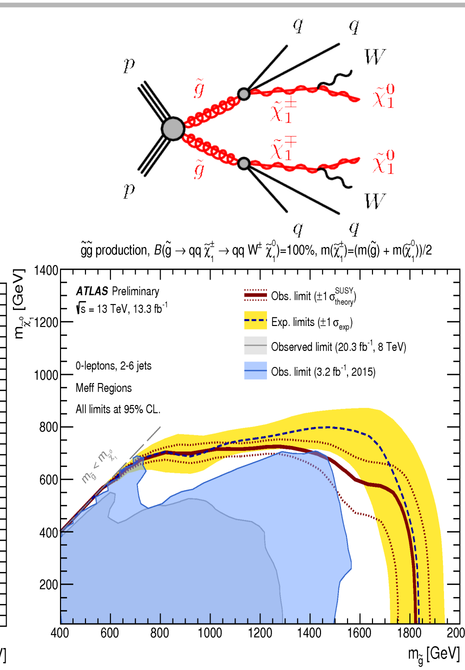
[ATLAS-CONF-2016-078]

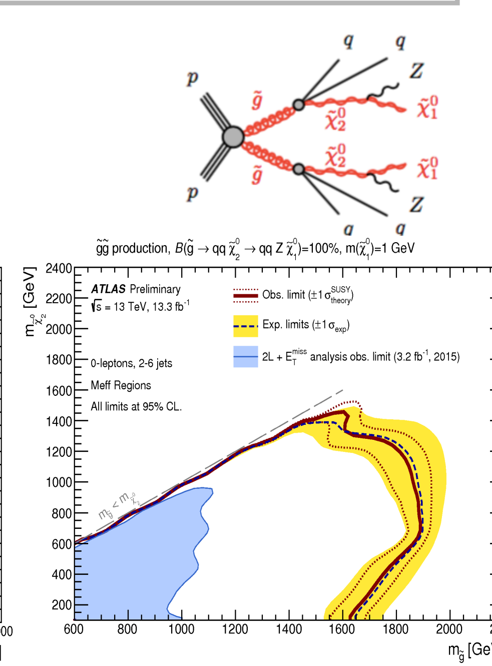
Strong Production: 0L+jets+MET

- Search for **gluinos and 1st and 2nd generation squarks**
- Final states with jets, MET and **no isolated lepton (e/μ)**
- Signal to BG discrimination based on: **Meff, MET, RJigsaw**
- 30 signal regions (SRs) defined targeting different search scenarios and phase space → No significant excess observed
- Excludes gluino (squark) masses up to 1.86 (1.35) TeV for massless LSP. For gluino decay via N2 model, gluino masses below 1.9 TeV are excluded for N2 masses of ~ 600 GeV







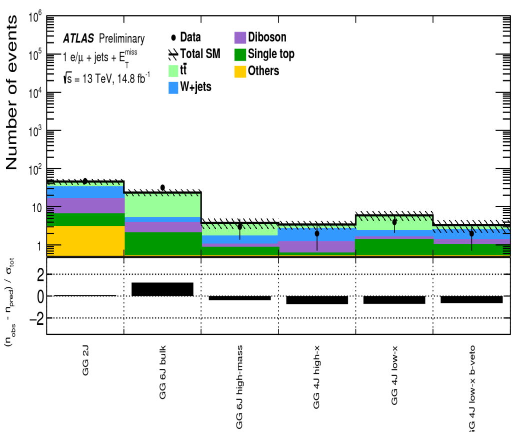


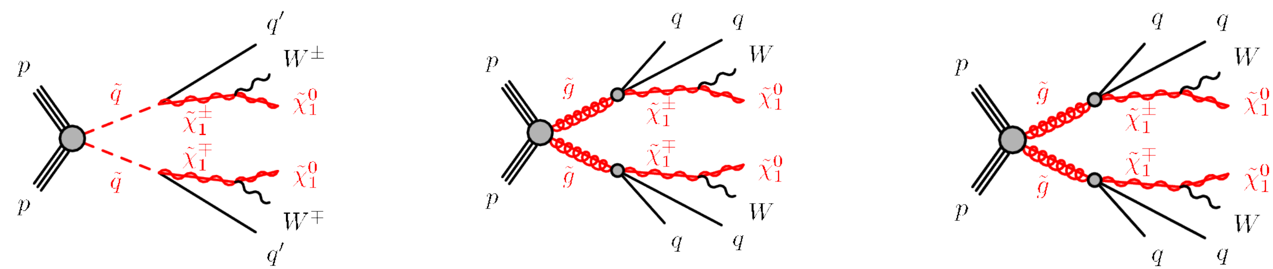
ATLAS-CONF-2016-054

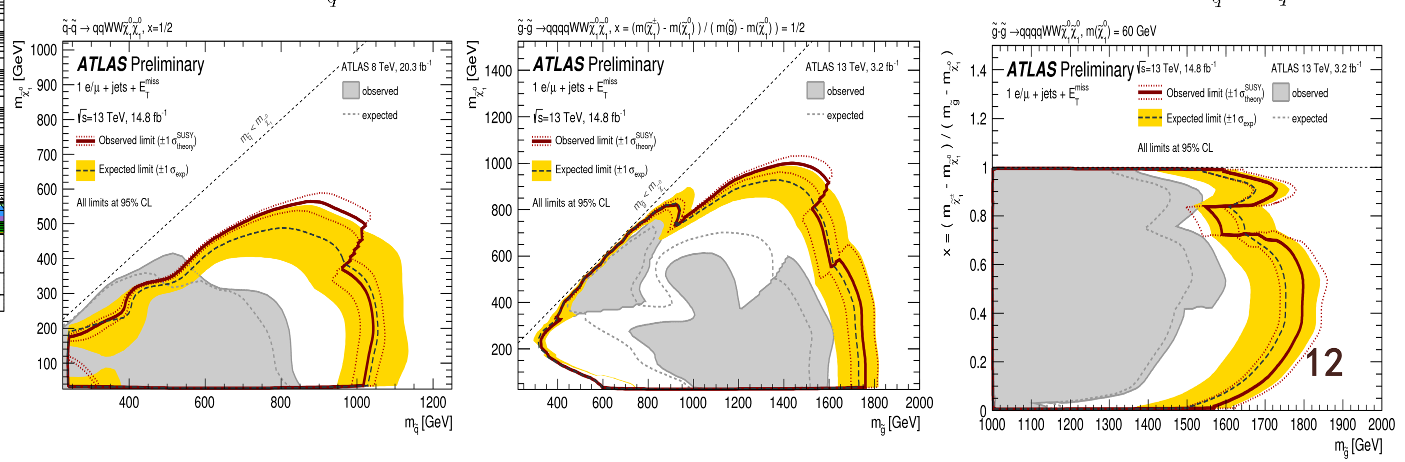
Strong Production: 1L+jets+MET

- Search for **gluinos and 1st and 2nd generation squarks**
- Final states with jets, missing transverse momentum and **one isolated lepton (e/μ)**
- Signal to BG discrimination based on: **Meff, MET, mT**
- 10 SRs defined targeting different search scenarios
- **Gluino (squark) masses up to 1.7 TeV (1.0 TeV) are excluded for low neutralino masses (≤ 400 GeV or ≤ 300 GeV)**

No significant excess observed



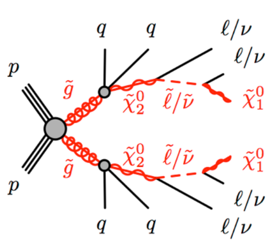
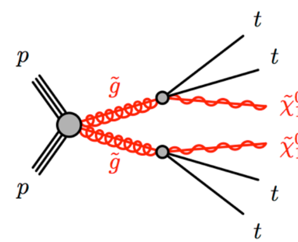
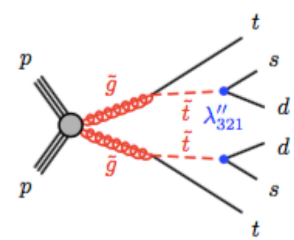
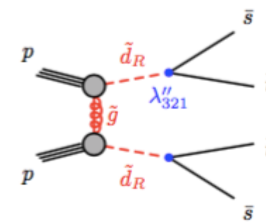


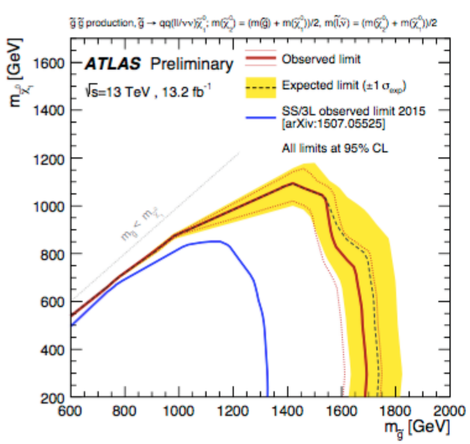


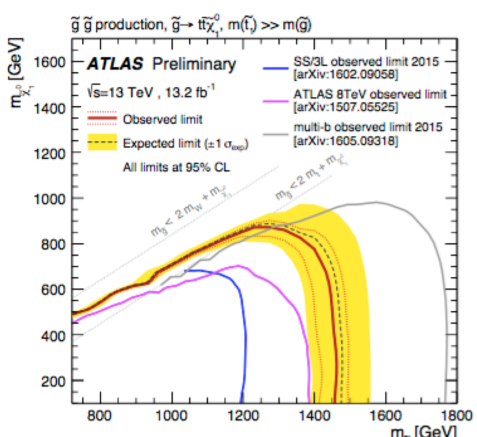
ATLAS-CONF-2016-037

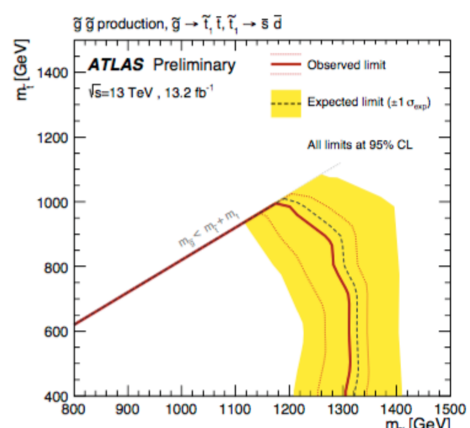
Strong Production: SS/3L+jets+MET

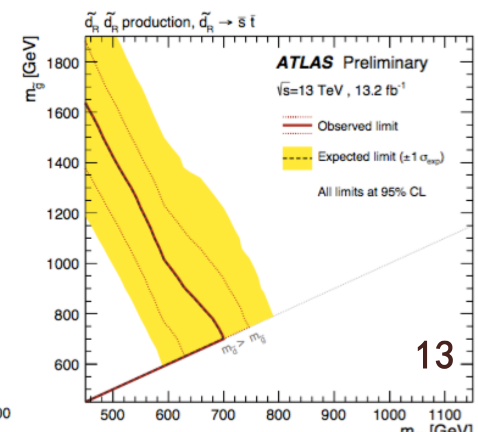
- Search for squarks/gluinos via long decay chain in SS/3L
  - Sensitive for a wide range of models (4 RPC+4 RPV)
  - Very clean channels with only tiny SM bg (mainly top+V, diboson, triboson) → A good probe for new physics
- 4 RPC+3 PRV SRs defined, targeting specific scenarios → no excess
- **Gluino mass <1.3-1.7 TeV and LSP mass < 850-1100 GeV are excluded for gluino pair production. Right-handed down squark masses are probed up to $m_{\tilde{d}_R} \approx 700$ GeV in RPV scenarios**



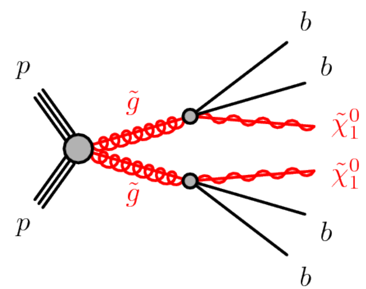


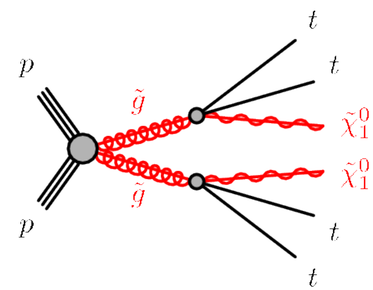




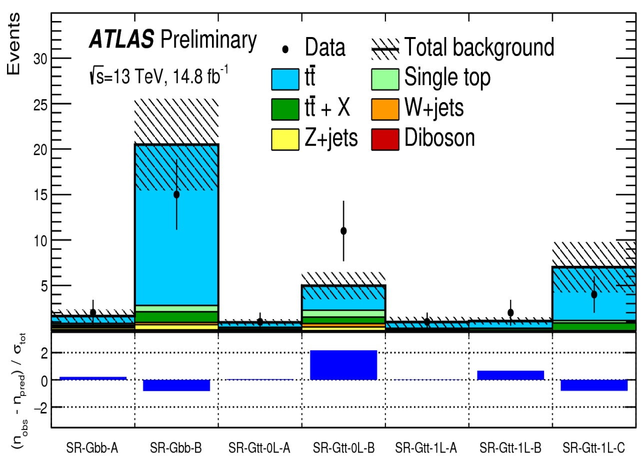
Strong Production: bjets +MET

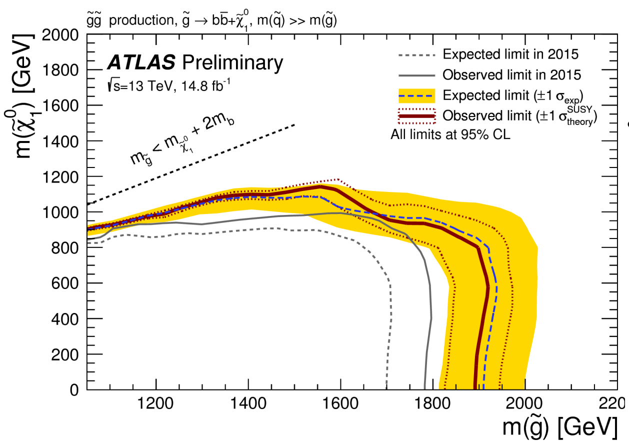
- Search for gluinos via stop or sbottom decay
- Final states with ≥3b-jets, MET, no or one lepton (e/μ)
- Signal to BG discrimination based on: Meff, MET, mT
- 7 SRs defined targeting different search scenarios
- Excludes gluino masses up to 1.89 TeV for massless LSP

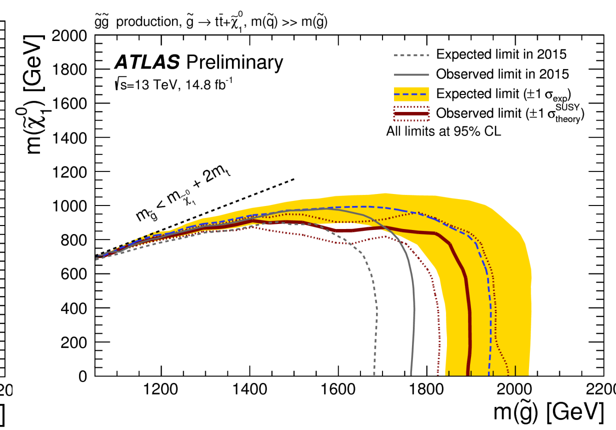




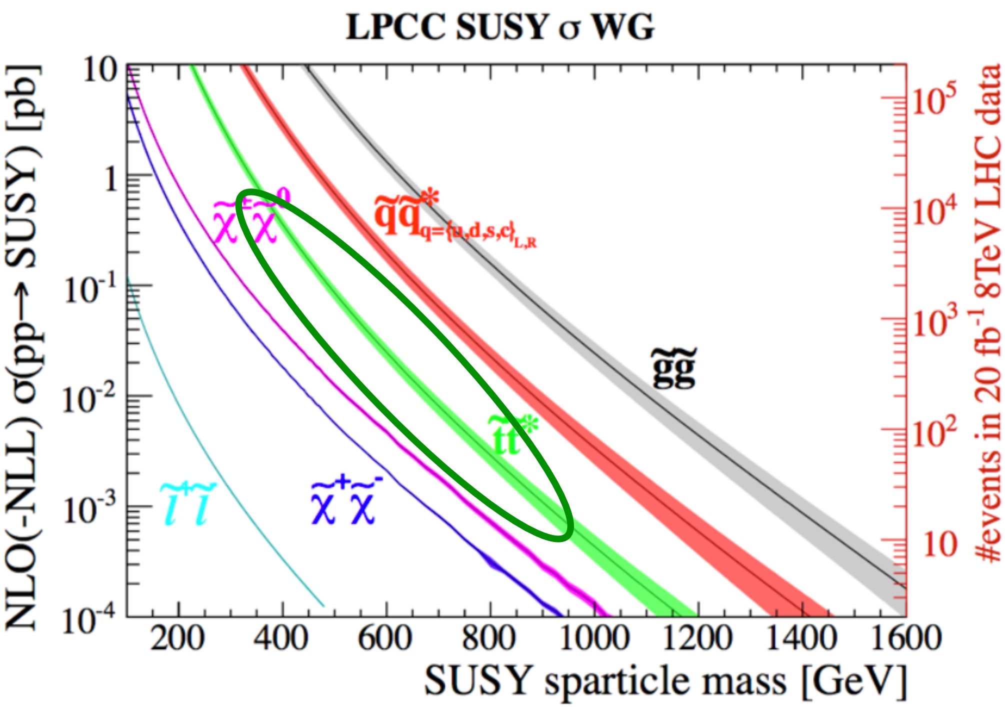
No significant excess observed







SUSY Search @ LHC



The results are based on 13-15 fb^{-1}@ 13 TeV (Run2)

Strong production:

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- by far largest cross-sections

3rd generation:

- targeting stop and sbottoms
- Should be lowest mass squarks for naturalness reasons

Electroweak production:

- targeting Electrowe ...s, sleptons
- Lowest mass ...icles, clean signature

RPV/L...

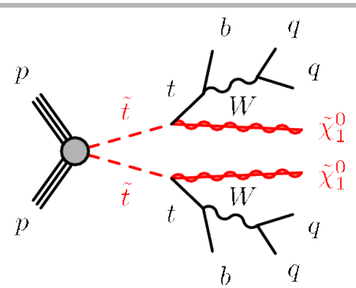
- ...geting R-parity violating models and long lived sparticles
- More exotic models

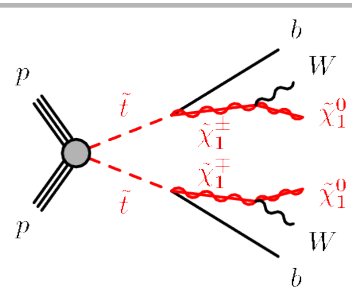
Only focus stop in this talk

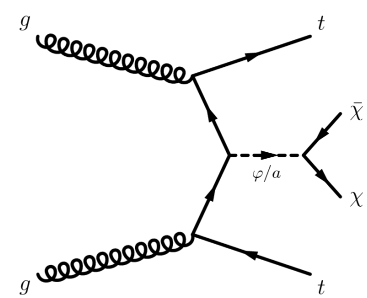
ATLAS-CONF-2016-077

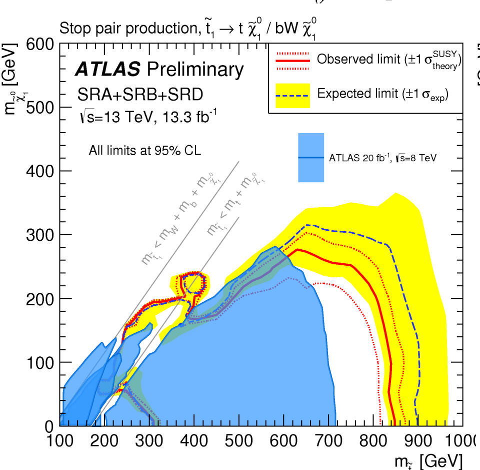
3^{rd} Generation: stop 0L

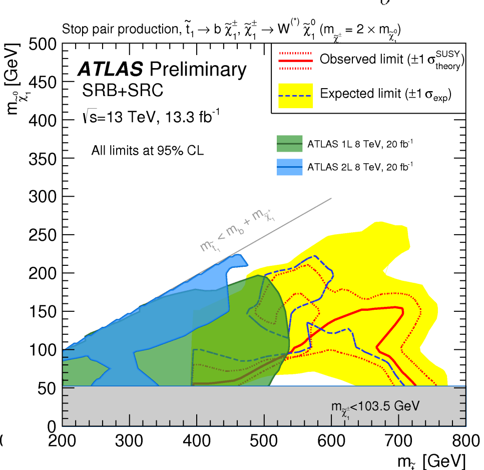
- Search for **stop** with **0L+(b)jets+MET** (hadronic decay)
- Signal to BG discrimination based on: **MET, mT(b), HT**
- ~19 SRs defined, targeting specific scenarios and phase space
- Exclusion for m(~t1) < ~820GeV for massless LSP
- For the models of the associated production of DM(χ) with top pairs, with a global coupling of 3.5, mediator masses up to 300 GeV, and χ masses below 40 GeV are excluded

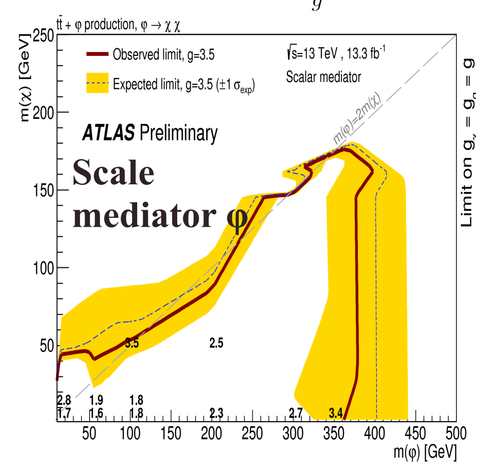


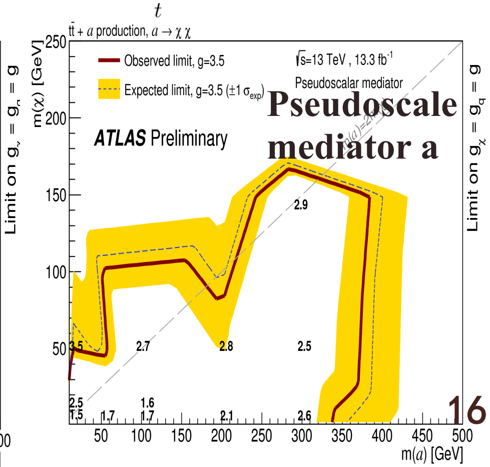








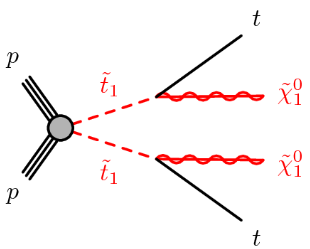


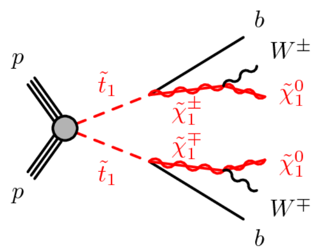


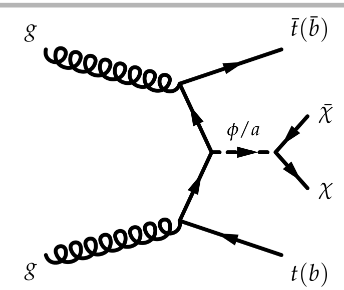
[ATLAS-CONF-2016-050]

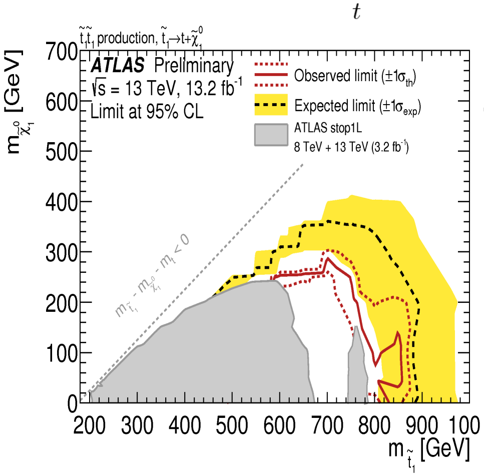
3rd Generation: stop 1L

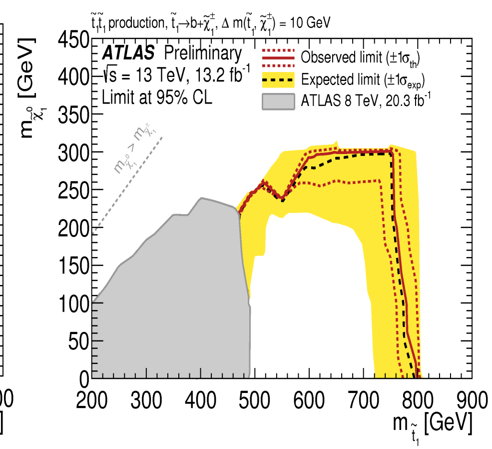
- Search for **stop** with **1L+(b)jets+MET**
- Signal to BG discrimination based on: **MET, mT(b), HT**
- ~7 SRs defined, targeting specific scenarios and phase space (~3.3σ excess in DM_low SR)
- **Exclusion for m(~t1) < ~830GeV for massless LSP**
- **The maximal coupling of g = 3.5 is excluded @95% CL for a (pseudo-) scalar mediator mass up to (350) 320 GeV assuming a 1 GeV DM mass.**

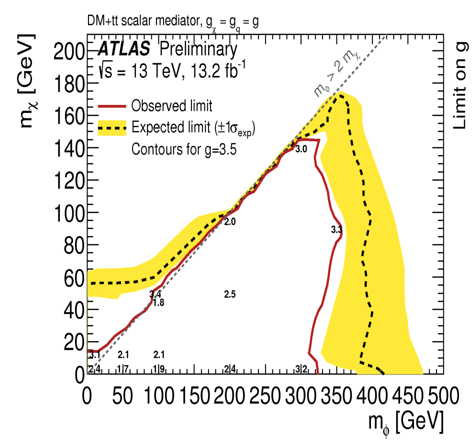


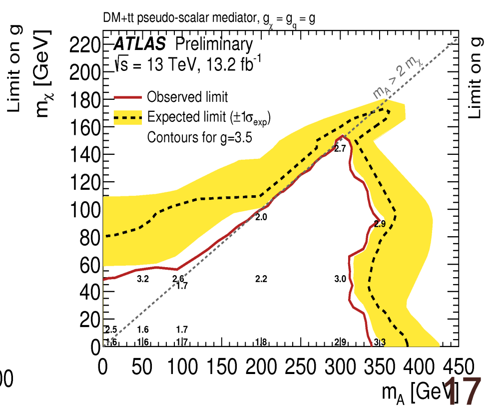








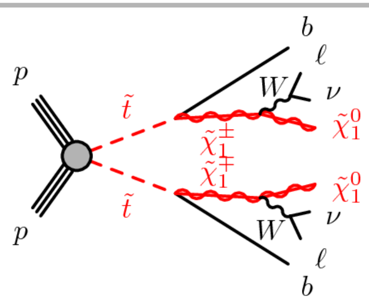


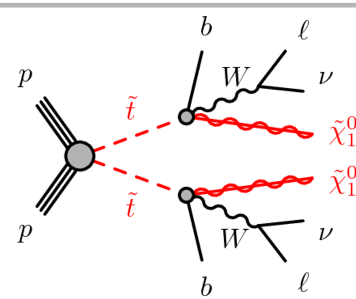


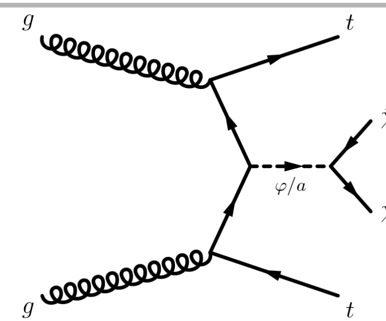
ATLAS-CONF-2016-076

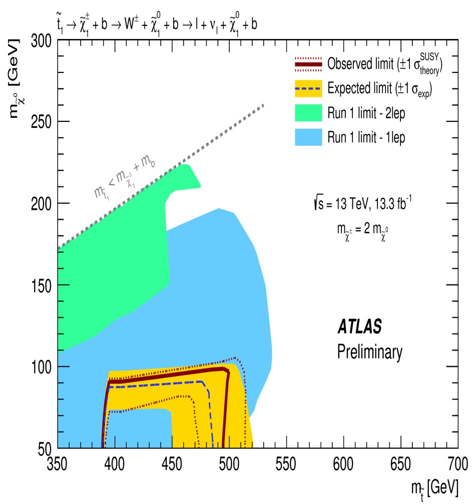
3rd Generation: stop 2L

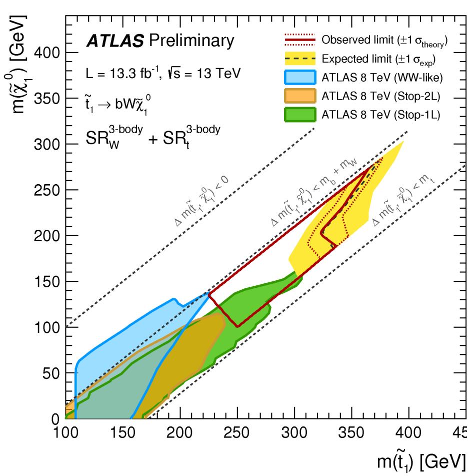
- Search for stop with 2L+(b)jets+MET
- Signal to BG discrimination based on: MET, mT2
- ~7 SRs defined, targeting specific scenarios and phase space
- Exclusion for m(~t1) < ~480GeV for massless LSP
- For the models of the associated production of DM with top pairs, mediator mass < 330 GeV and DM particle mass < 20 GeV excluded

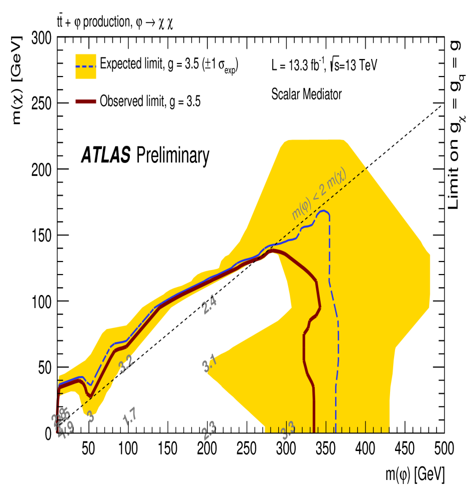


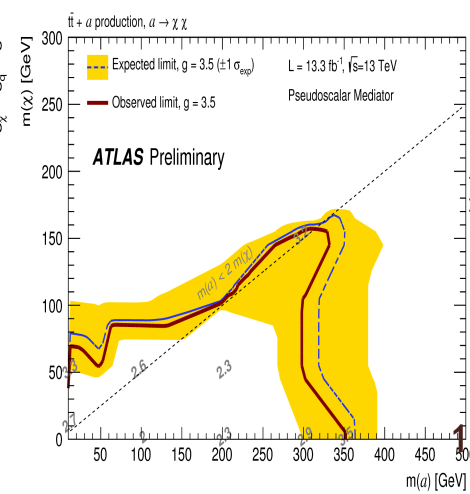








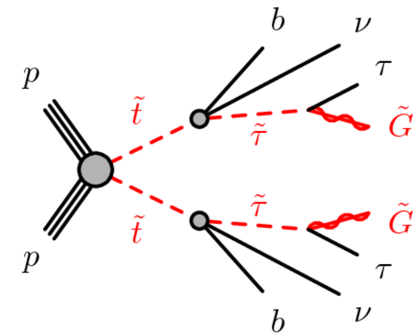


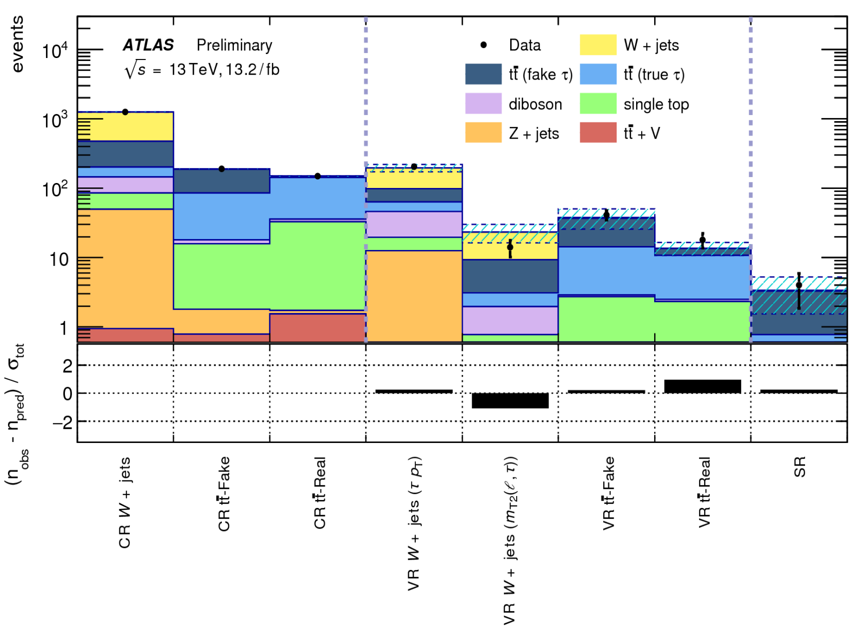


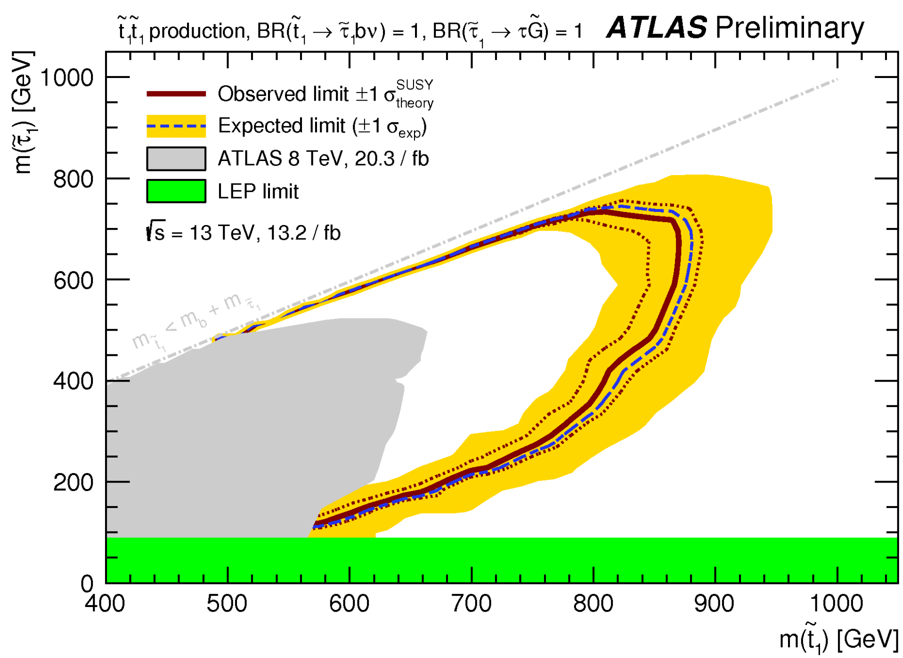
ATLAS-CONF-2016-048

3rd Generation: stop via stau

- Search for stop with 2τ +(b)jets +MET (GMSB, nGM)
- Signal to BG discrimination based on: MET, mT2
- 1 SR defined targeting high stop mass region
- Masses of the top squark up to 870 GeV and stau up to 730 GeV are excluded.



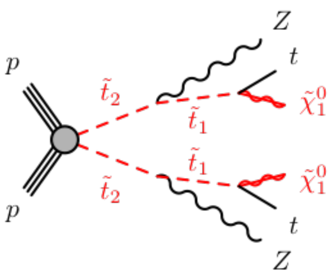


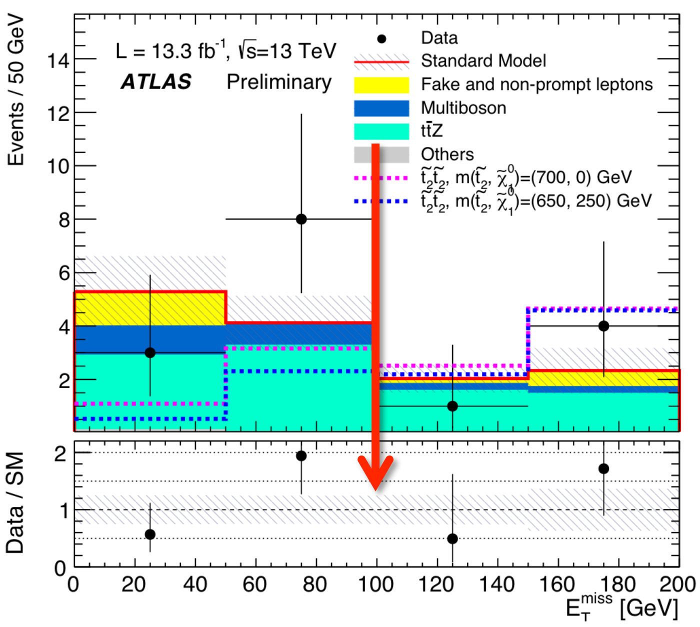


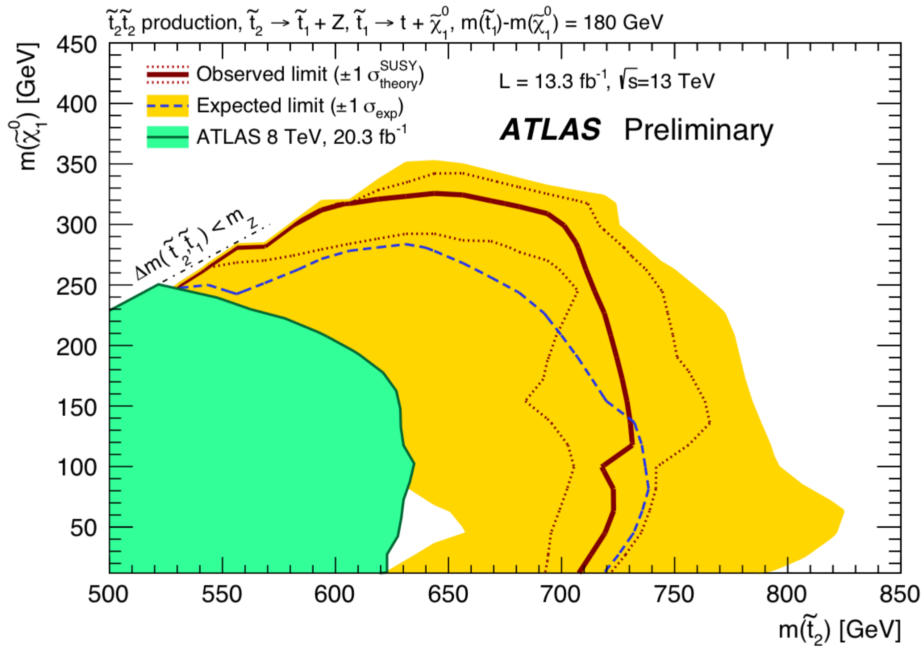
ATLAS-CONF-2016-038

3rd Generation: stop with Z

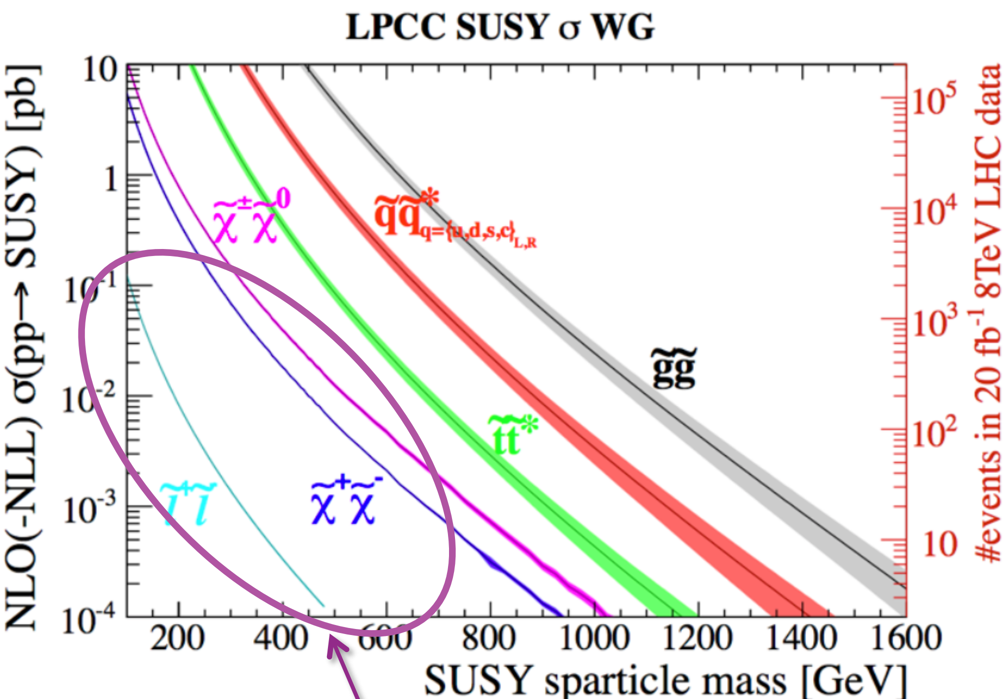
- Search for **stop** with **Z +(b)jets +MET**
- Signal to BG discrimination based on: **MET, p_T^{ll}**
- 3 SRs defined targeting from low to high mass splitting
- **Parameter space regions up to $m_{\tilde{t}_2}$ < 730 GeV and *LSP* < 325 GeV are excluded**

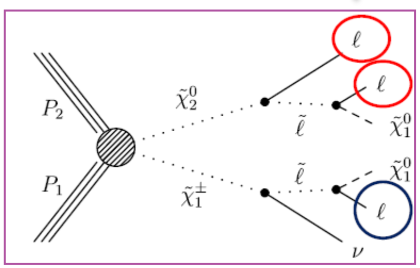






SUSY Search @ LHC





Generic signatures: low–jet multiplicity + ≥ 2leptons + MET(2/3/4L, >=2tau)

Electroweak process benefit less from the energy increase, while as luminosity increase they actually become more and more competitive and are actually the most interesting channels for the LHC upgrade phase → only 4L updated to 13 TeV, 2-3L and 2taus aiming for SEARCH CONF

for naturalness reasons

Electroweak production:

- targeting Electroweakinos, sleptons
- Lowest mass sparticles, clean signature

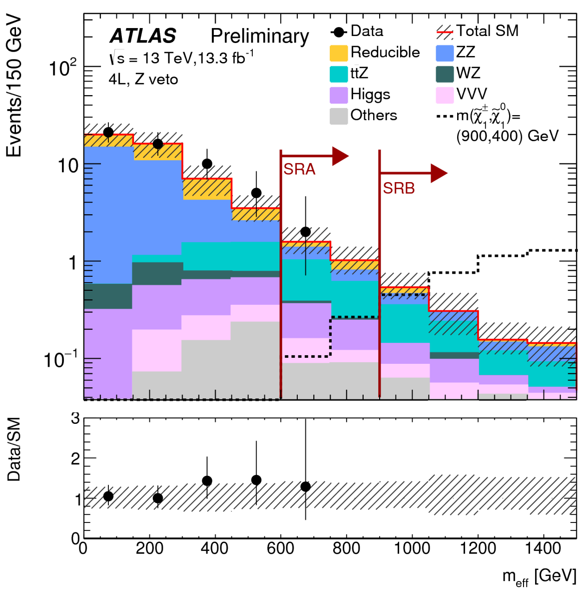
RPV/LL:

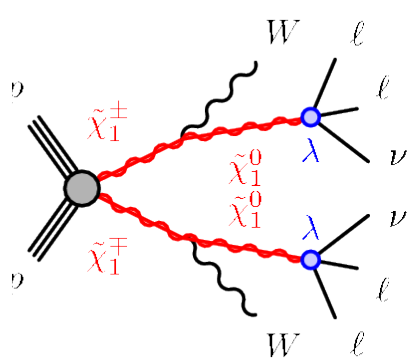
- targeting R-parity violating models and long lived sparticles
- More exotic models

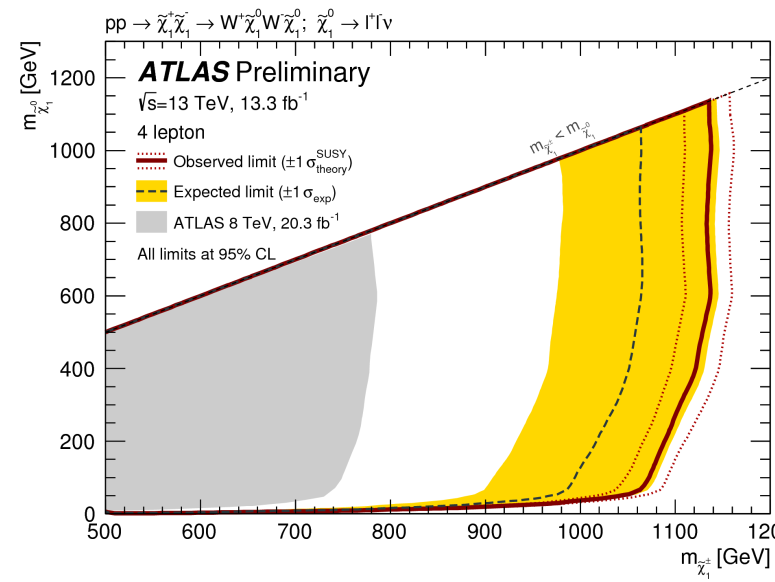
ATLAS-CONF-2016-075

EWK Production: 4L+MET

- Search for **charginos** for chargino production with indirect RPV decays
- RPV SUSY scenarios can therefore result in signatures with **high lepton multiplicities and substantial MET → 4L (e/μ) + MET** FS
- Signal to BG discrimination based on: **Meff**
- 2 SRs defined targeting different chargino mass region
- chargino masses up to 1.14 TeV are excluded for large LSP masses

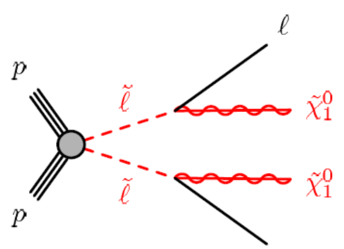


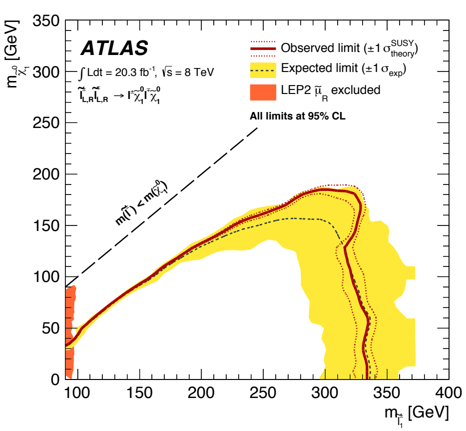


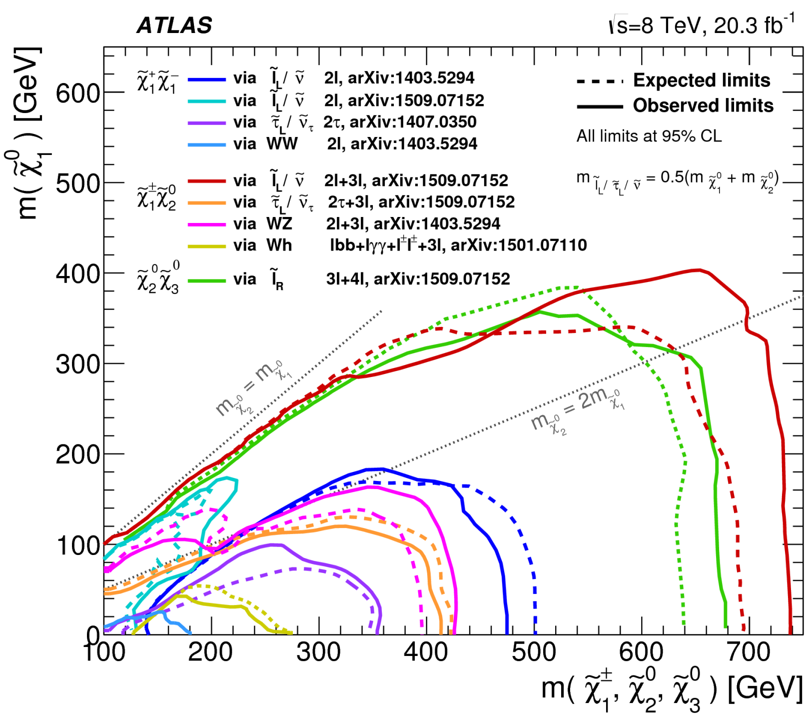


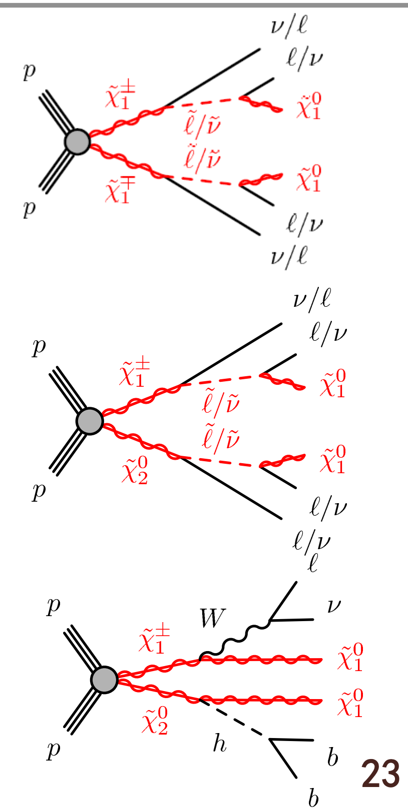
EWK Production: 1-4L(e,μ,τ) +MET *(8 TeV)*

- Search for **sleptons** with **2L (e/μ) + MET** FS → ~l > 330 GeV
- Search for **charginos and neutralinos** with **2-3L (e/μ/τ) + MET** FS
  → Excludes electroweakino masses up to 350-700 GeV
- Search for **charginos and neutralinos via higgs decay (Wh→1l +bb, γγ, ll, ττ)** → Excludes electroweakino masses up to 250 GeV



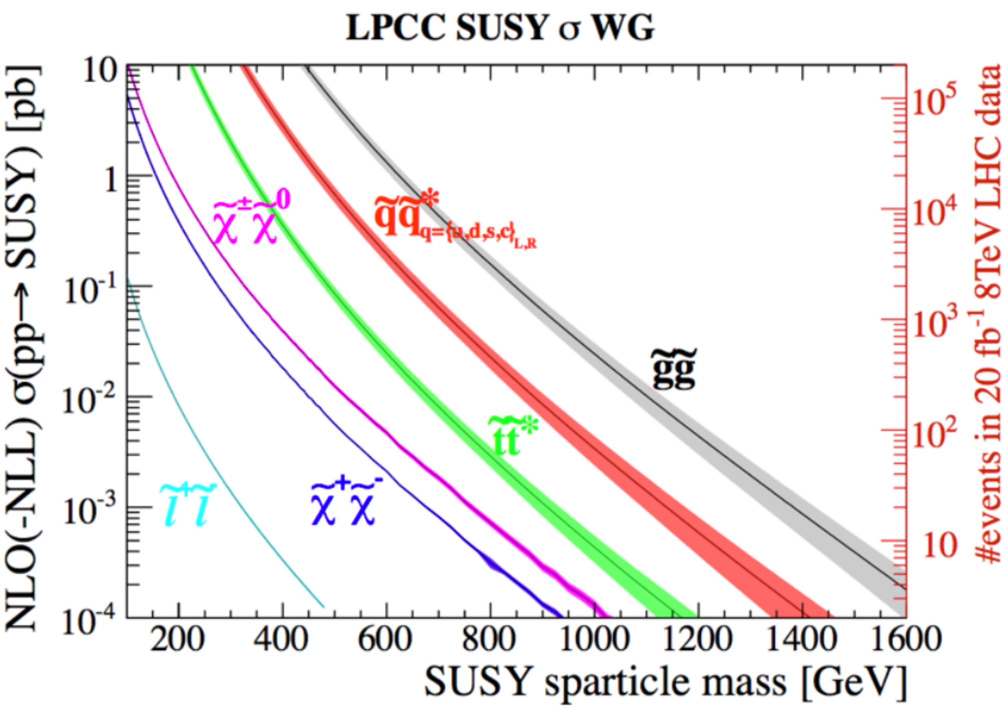






[Phys. Rev. D 93, 052002 (2016)]

SUSY Search @ LHC



Some are already covered at previous slides

Strong production:

- targeting gluinos and 1st and 2nd generation squarks
- by far largest cross-sections

3rd generation:

- targeting stop and sbottoms
- Should be lowest mass squarks for naturalness reasons

Electroweak production:

- targeting Electroweakinos, sleptons
- Lowest mass sparticles, clean signature

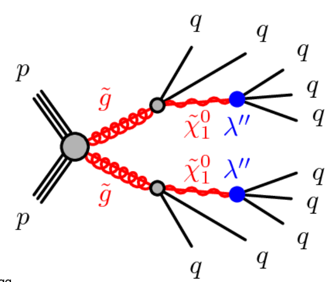
RPV/LL:

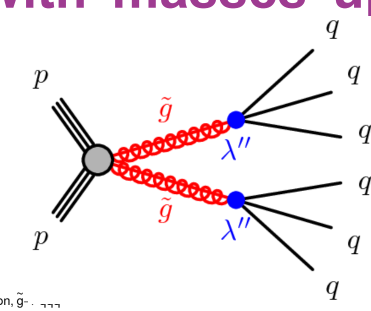
- targeting R-parity violating models and long lived sparticles
- More exotic models

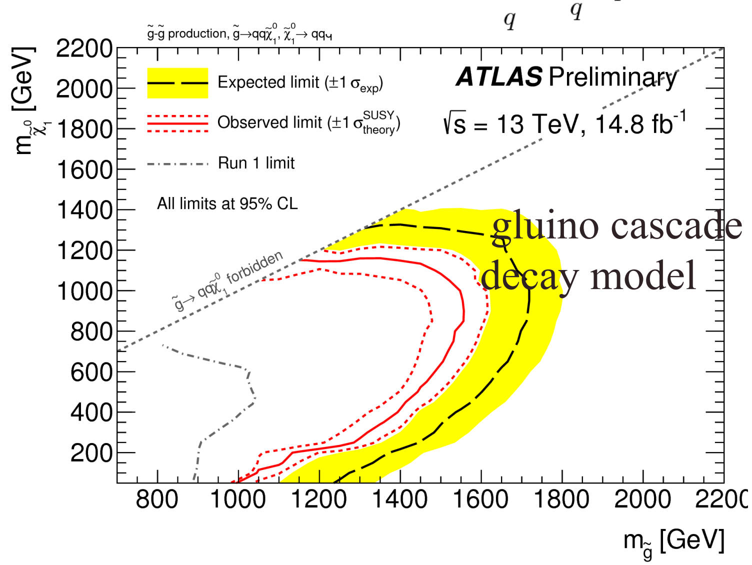
ATLAS-CONF-2016-057

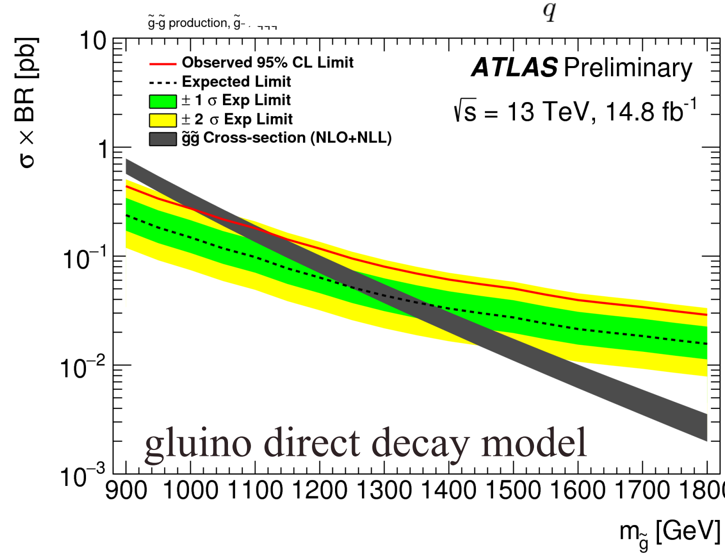
RPV: multi-jets

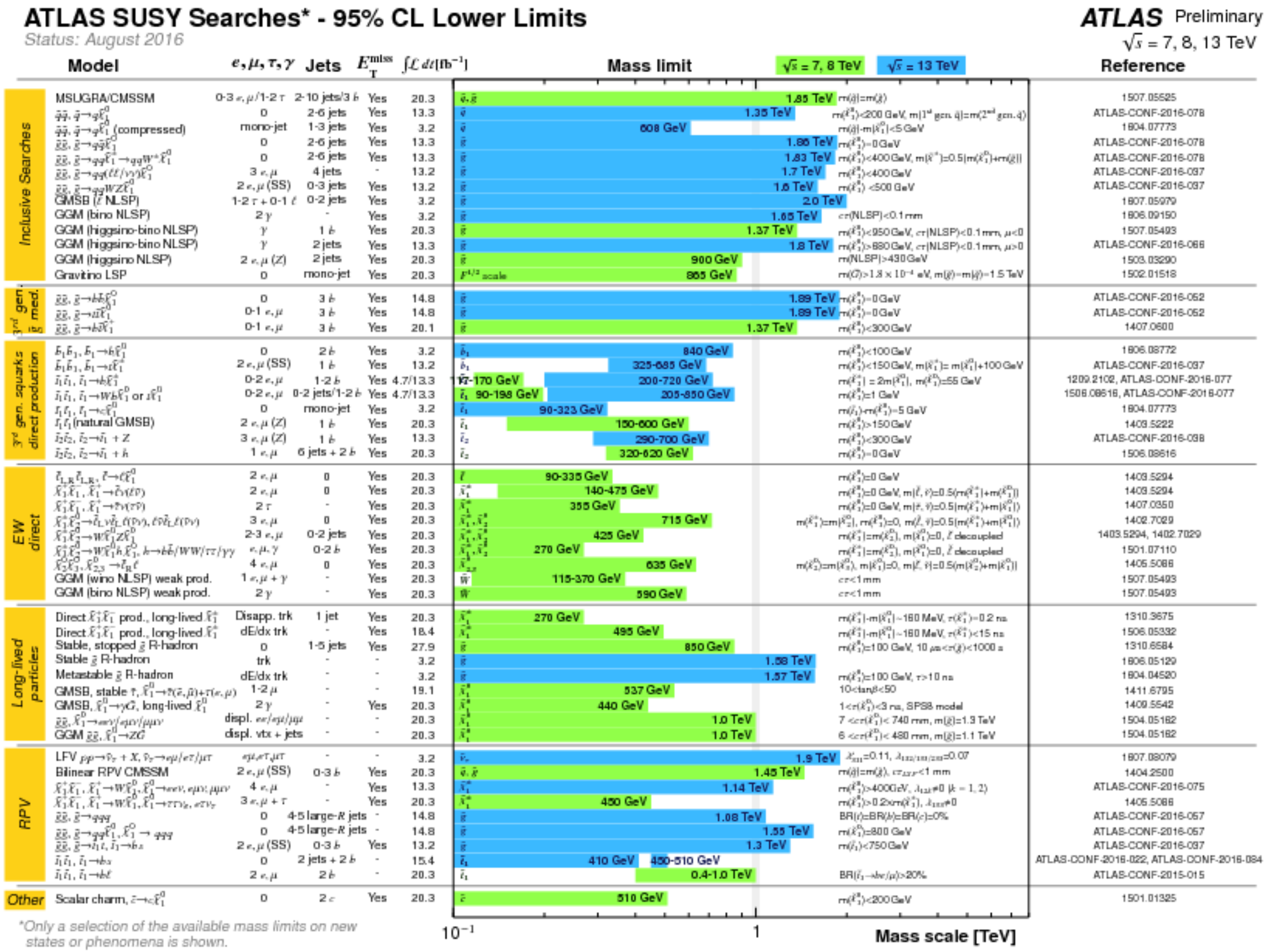
- **Search for gluinos with RPV decays to quarks**
- **Signal to BG discrimination based on: sum mass of jets**
- **4 SRs defined targeting different search scenarios**
- **In the gluino cascade decay model, gluinos with masses up to 1000-1550 GeV are excluded, depending on the neutralino mass**
- **In the gluino direct decay model, gluinos with masses up to 1080 GeV are excluded.**










ATLAS SUSY Searches* - 95% CL Lower Limits
Status: August 2016
ATLAS Preliminary
$\sqrt{s}$ = 7, 8, 13 TeV
Model
e, μ, τ, γ
Jets
E_T^{miss}
$\int \mathcal{L}\, dt [fb^{-1}]$
Mass limit
$\sqrt{s}$ = 7, 8 TeV
$\sqrt{s}$ = 13 TeV
Reference
Inclusive Searches
3rd gen. $\tilde{g}$ med.
3rd gen. squarks direct production
EW direct
Long-lived particles
RPV
Other
MSUGRA/CMSSM
GMSB ($\tilde{\ell}$ NLSP)
GGM (bino NLSP)
GGM (higgsino-bino NLSP)
GGM (higgsino NLSP)
Gravitino LSP
GGM (wino NLSP) weak prod.
GGM (bino NLSP) weak prod.
Stable, stopped $\tilde{g}$ R-hadron
Stable $\tilde{g}$ R-hadron
Metastable $\tilde{g}$ R-hadron
Bilinear RPV CMSSM
Scalar charm, $\tilde{c} \to c\tilde{\chi}_1^0$
10^{-1}
1
Mass scale [TeV]
*Only a selection of the available mass limits on new states or phenomena is shown.

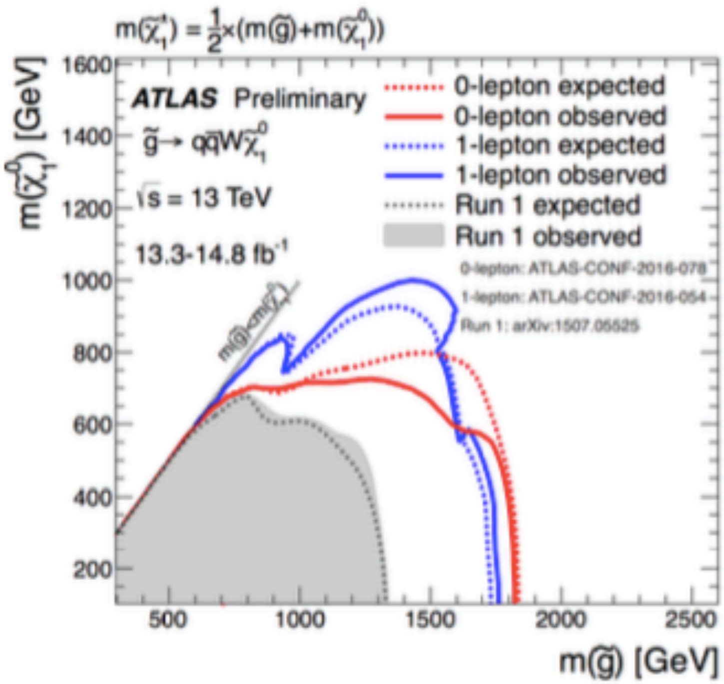
Summary

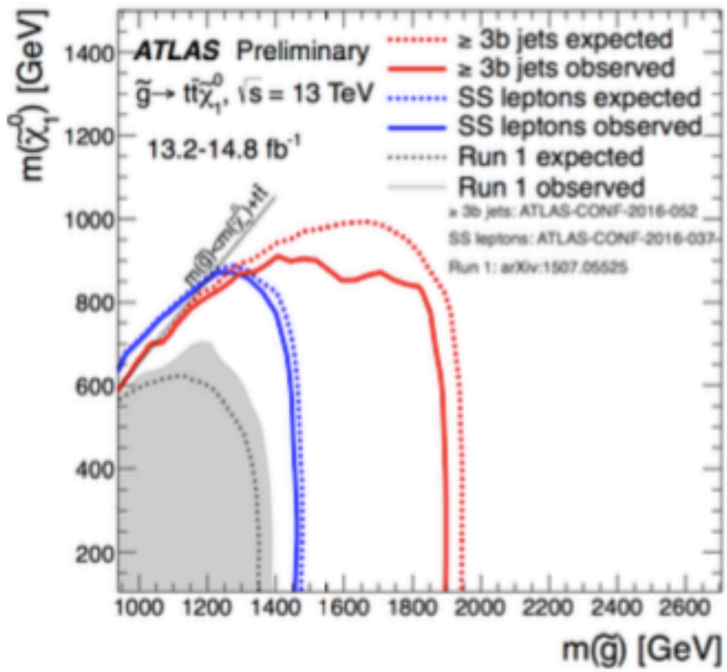
- **ATLAS developed a vast program to search for SUSY**
  - **No significant excess seen so far**
  - **More PUB results @here**

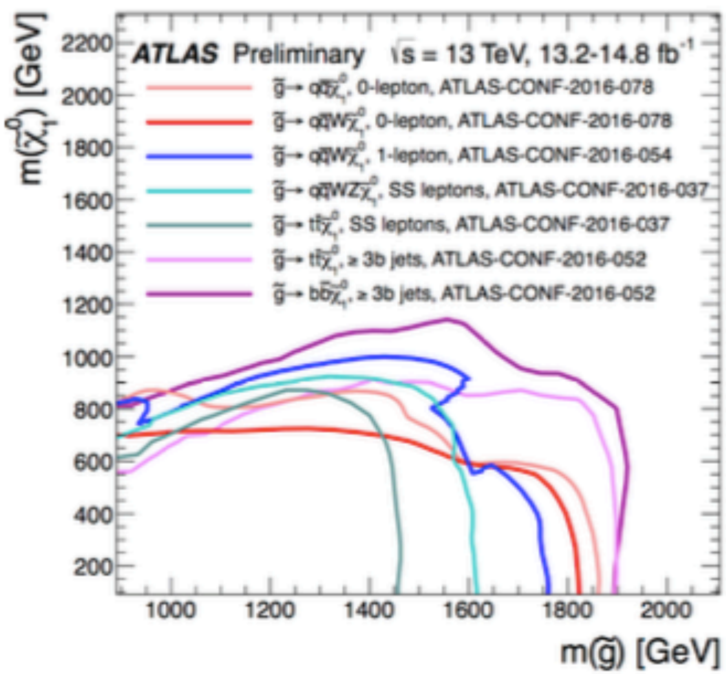
- **In canonical scenarios, sensitivity is achieved to ~1.9 TeV gluinos, ~900 GeV stops**
  - **More (EWK) results will be ready for SEARCH CONF**

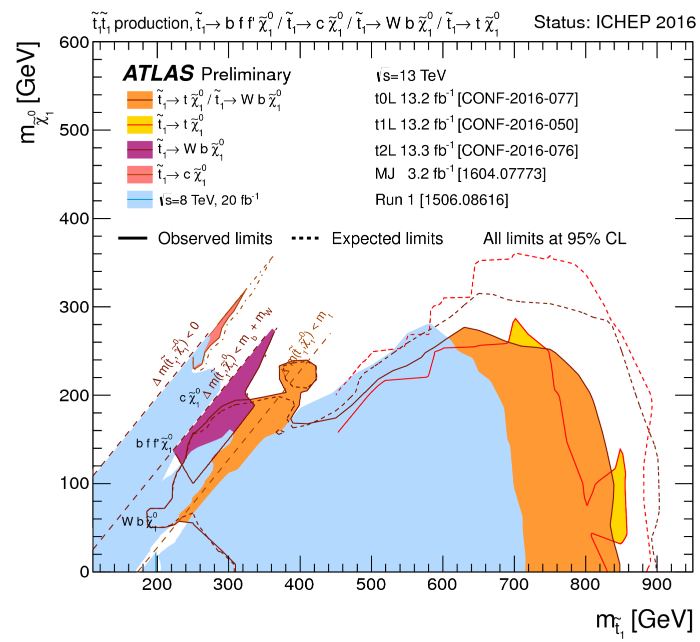
- **~30 (100) fb-1 data at this year (end of run2), which is very challenging years for SUSY in front of us!**

Thanks for your attention!


$m(\tilde{\chi}_1^\pm) = \frac{1}{2}\times(m(\tilde{g})+m(\tilde{\chi}_1^0))$
ATLAS Preliminary
$\tilde{g}\to q\bar{q}W\tilde{\chi}_1^0$
$\sqrt{s}$ = 13 TeV
13.3-14.8 fb^{-1}
0-lepton expected
0-lepton observed
1-lepton expected
1-lepton observed
Run 1 expected
Run 1 observed
0-lepton: ATLAS-CONF-2016-078
1-lepton: ATLAS-CONF-2016-054
Run 1: arXiv:1507.05525
$m(\tilde{g})<m(\tilde{\chi}_1^0)$
$m(\tilde{\chi}_1^0)$ [GeV]
$m(\tilde{g})$ [GeV]


ATLAS Preliminary
$\tilde{g}\to t\bar{t}\tilde{\chi}_1^0$, $\sqrt{s}$ = 13 TeV
13.2-14.8 fb^{-1}
≥ 3b jets expected
≥ 3b jets observed
SS leptons expected
SS leptons observed
Run 1 expected
Run 1 observed
≥ 3b jets: ATLAS-CONF-2016-052
SS leptons: ATLAS-CONF-2016-037
Run 1: arXiv:1507.05525
$m(\tilde{g})<m(\tilde{\chi}_1^0)+t\bar{t}$
$m(\tilde{\chi}_1^0)$ [GeV]
$m(\tilde{g})$ [GeV]

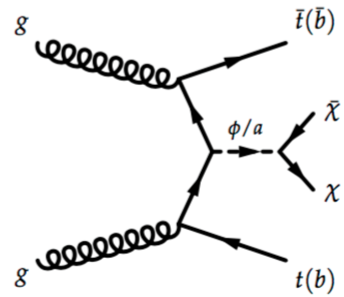

ATLAS Preliminary $\sqrt{s}$ = 13 TeV, 13.2-14.8 fb^{-1}
$\tilde{g}\to q\bar{q}\tilde{\chi}_1^0$, 0-lepton, ATLAS-CONF-2016-078
$\tilde{g}\to q\bar{q}W\tilde{\chi}_1^0$, 0-lepton, ATLAS-CONF-2016-078
$\tilde{g}\to q\bar{q}W\tilde{\chi}_1^0$, 1-lepton, ATLAS-CONF-2016-054
$\tilde{g}\to q\bar{q}WZ\tilde{\chi}_1^0$, SS leptons, ATLAS-CONF-2016-037
$\tilde{g}\to t\bar{t}\tilde{\chi}_1^0$, SS leptons, ATLAS-CONF-2016-037
$\tilde{g}\to t\bar{t}\tilde{\chi}_1^0$, ≥ 3b jets, ATLAS-CONF-2016-052
$\tilde{g}\to b\bar{b}\tilde{\chi}_1^0$, ≥ 3b jets, ATLAS-CONF-2016-052
$m(\tilde{\chi}_1^0)$ [GeV]
$m(\tilde{g})$ [GeV]


$\tilde{t}_1\tilde{t}_1$ production, $\tilde{t}_1\to b f f' \tilde{\chi}_1^0$ / $\tilde{t}_1\to c\tilde{\chi}_1^0$ / $\tilde{t}_1\to W b\tilde{\chi}_1^0$ / $\tilde{t}_1\to t\tilde{\chi}_1^0$
Status: ICHEP 2016
ATLAS Preliminary
$\sqrt{s}$=13 TeV
$\tilde{t}_1\to t\tilde{\chi}_1^0$ / $\tilde{t}_1\to W b\tilde{\chi}_1^0$
t0L 13.2 fb^{-1} [CONF-2016-077]
$\tilde{t}_1\to t\tilde{\chi}_1^0$
t1L 13.2 fb^{-1} [CONF-2016-050]
$\tilde{t}_1\to W b\tilde{\chi}_1^0$
t2L 13.3 fb^{-1} [CONF-2016-076]
$\tilde{t}_1\to c\tilde{\chi}_1^0$
MJ 3.2 fb^{-1} [1604.07773]
$\sqrt{s}$=8 TeV, 20 fb^{-1}
Run 1 [1506.08616]
Observed limits
Expected limits
All limits at 95% CL
$m_{\tilde{\chi}_1^0}$ [GeV]
$m_{\tilde{t}_1}$ [GeV]

summaries

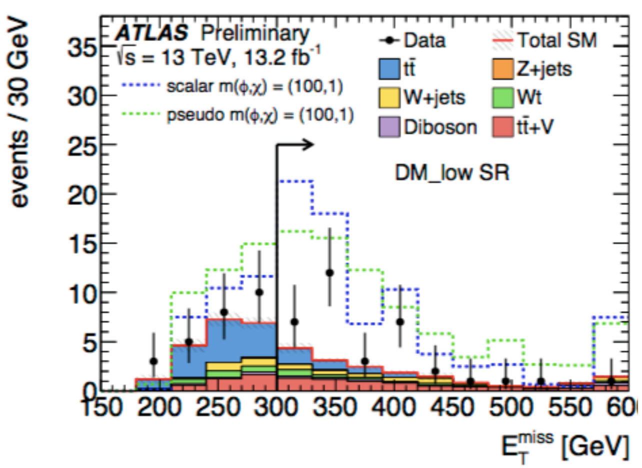
3rd Generation: stop 1L

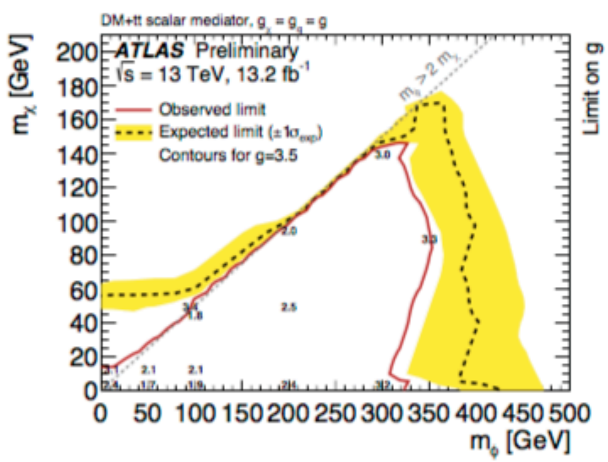
Signal region	DM_low
Observed	35
Total background	17.26 ± 2.18
$t\bar{t}$	4.18 ± 1.32
W+jets	3.09 ± 1.50
Single top	1.91 ± 0.90
$t\bar{t}+V$	6.44 ± 1.37
Diboson	1.49 ± 0.58
zjets	0.16 ± 0.14
$t\bar{t}$ NF	0.90 ± 0.17
W+jets NF	0.94 ± 0.13
Single top NF	1.36 ± 0.36
$t\bar{t}+W/Z$ NF	1.47 ± 0.22
$p_0\ (\sigma)$	0.0004493 (3.32)
$N^{\rm limit}_{\rm non-SM}$ exp. (95% CL)	$11.48^{+5.01}_{-3.43}$
$N^{\rm limit}_{\rm non-SM}$ obs. (95% CL)	28.28



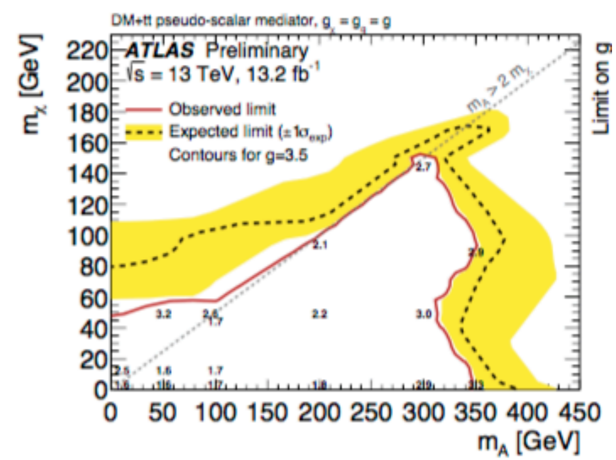
Variable	DM_low
≥4 jets with $p_{\rm T} >$ [GeV]	(60 60 40 25)
$E_{\rm T}^{\rm miss}$ [GeV]	> 300
$H^{\rm miss}_{\rm T,sig}$	> 14
$m_{\rm T}$ [GeV]	> 120
$am_{\rm T2}$ [GeV]	> 140
$\min(\Delta\phi(\vec{p}_{\rm T}^{\rm miss}, {\rm jet}_i))$	> 1.4
$\Delta\phi(\vec{p}_{\rm T}^{\rm miss}, \ell)$	> 0.8
$\Delta R(b_1, b_2)$	–
Number of b-tags	≥ 1

The observed upper limit on the couplings in the plane of $m_{\rm Med}$ versus m_χ, Numbers on the plot show the value of the excluded coupling for the corresponding points on the signal grid





scalar mediator



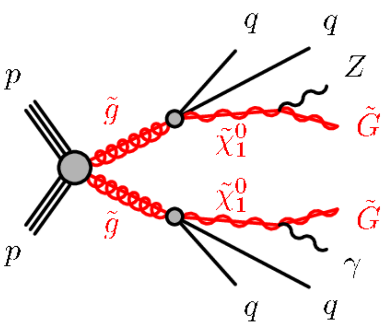
pseudo-scalar mediator

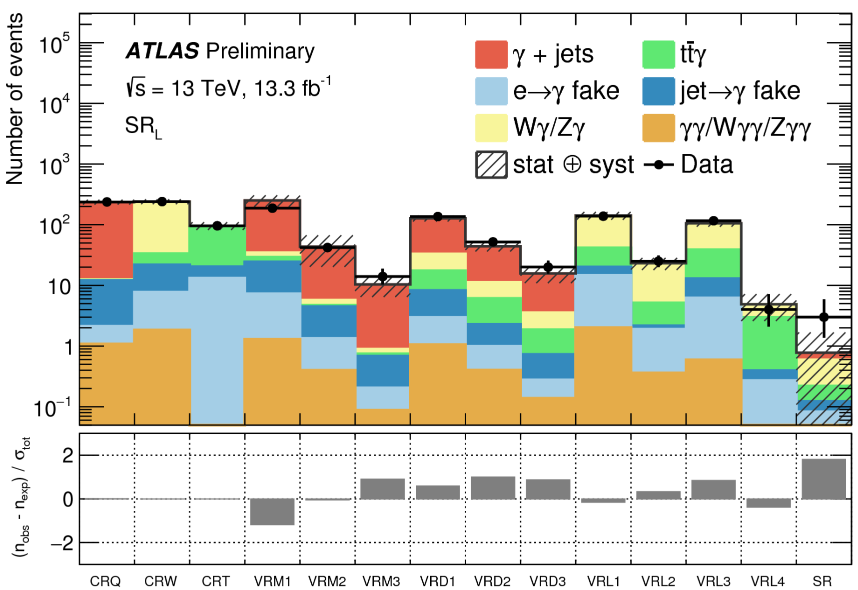
CONF-SUSY-2016-15

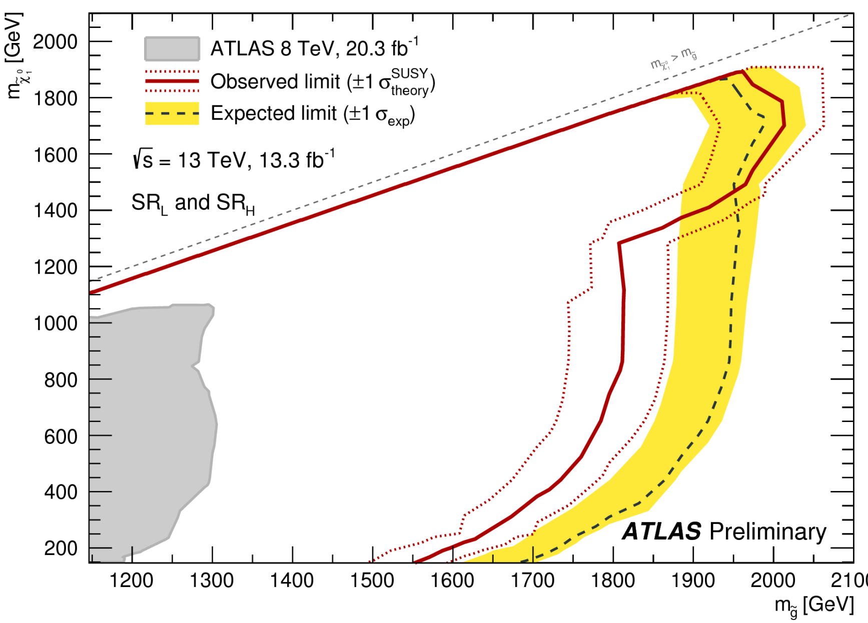
ATLAS-CONF-2016-066

Strong Production: photon +jets +MET

- Search for **gluinos with photon +jets +MET** FS (GGM)
- Signal to BG discrimination based on: **Meff, MET**
- 2 SRs defined targeting different search scenarios
- **Excludes gluino masses up to 1.8 TeV for for a large range of neutralino masses, increasing to 2 TeV in the case of a high mass neutralino**

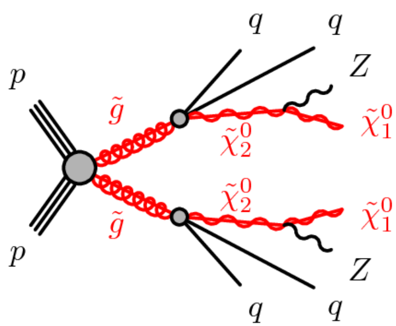


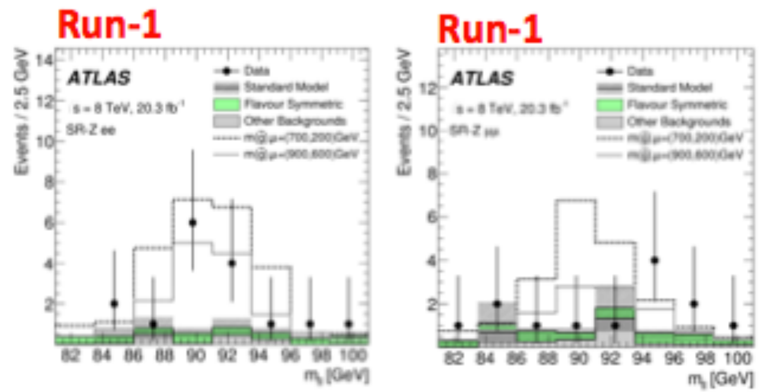




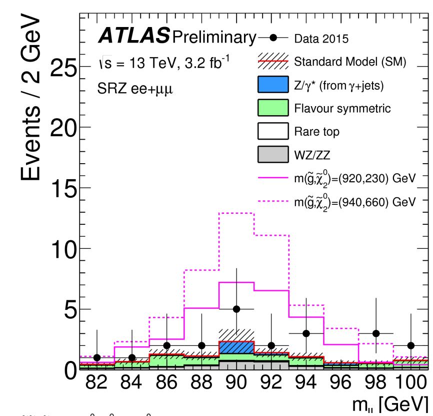
Strong Production: Z(ll)+MET

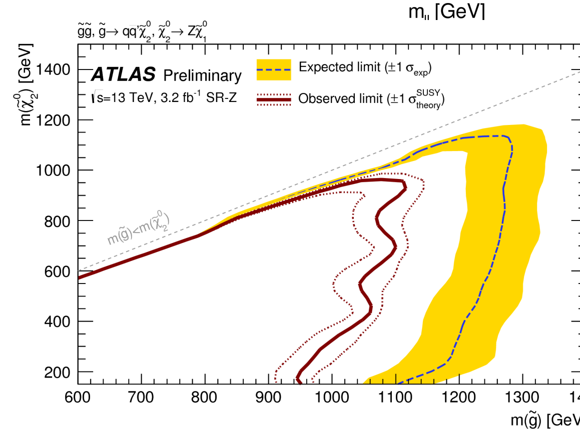
- Search for gluinos with a Z + jets + MET signature





- There is an excess (3σ) at ATLAS Run1 (not at CMS): obs. 29, exp. 10.8+-2.2
- Check it with Run2 using run1-like SR: Z (ll), 2jets, MET>225 GeV, HT>600 GeV
- a mild excess seen in Run2: obs. 21, exp. 10.4+-2.4 (2.2σ in intermediate MET)
- Excludes gluino masses up to 1.1 TeV





ATLAS-CONF-2015-082

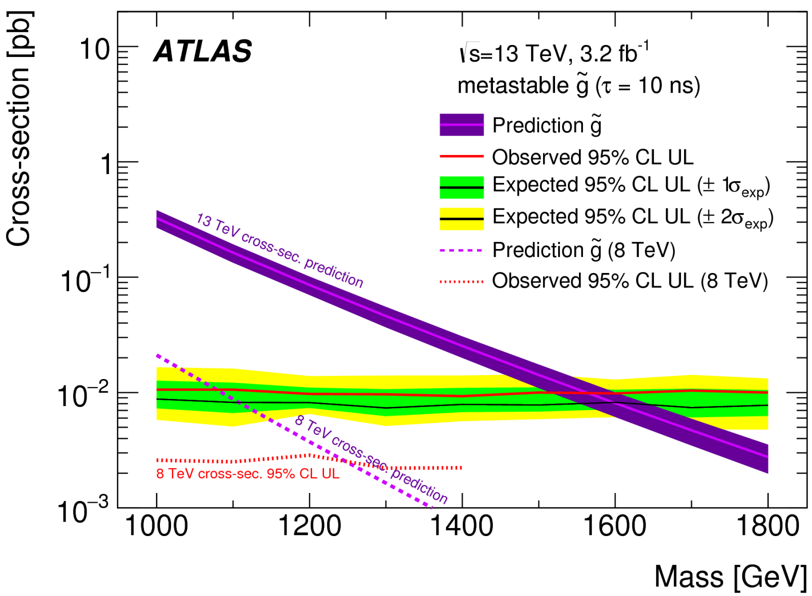
Long-lived highly ionizing particles

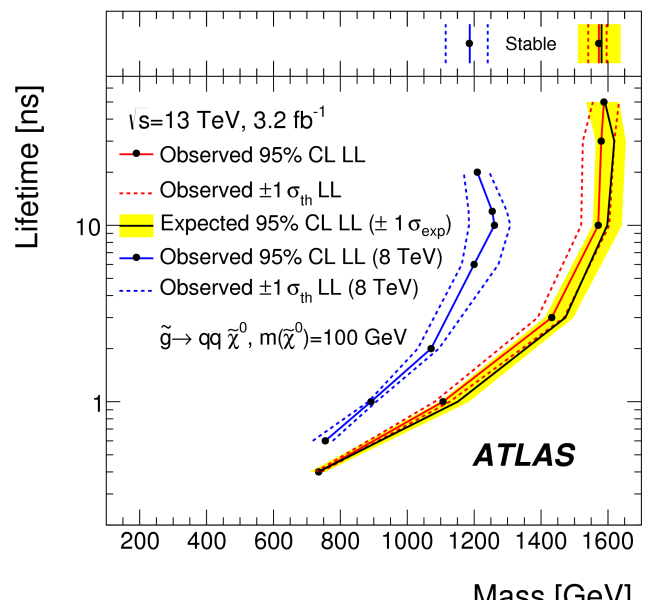
[Phys. Rev. D 93, 112015 (2016)]

- **Gluino (charged) R-hadrons:**
  - stable (lifetime>50ns， escape detectors)
  - metastable (lifetime ~ns, detection in Pixels with dE/dx)
- **Two SRs for stable/metastable long lived particles**

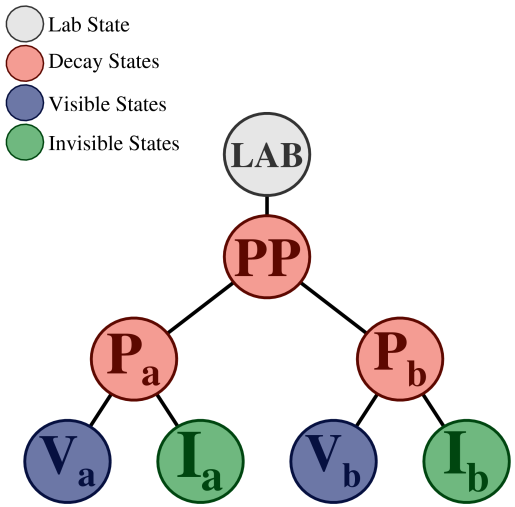
→ **Stable gluino R-hadrons excluded below 1570 GeV**

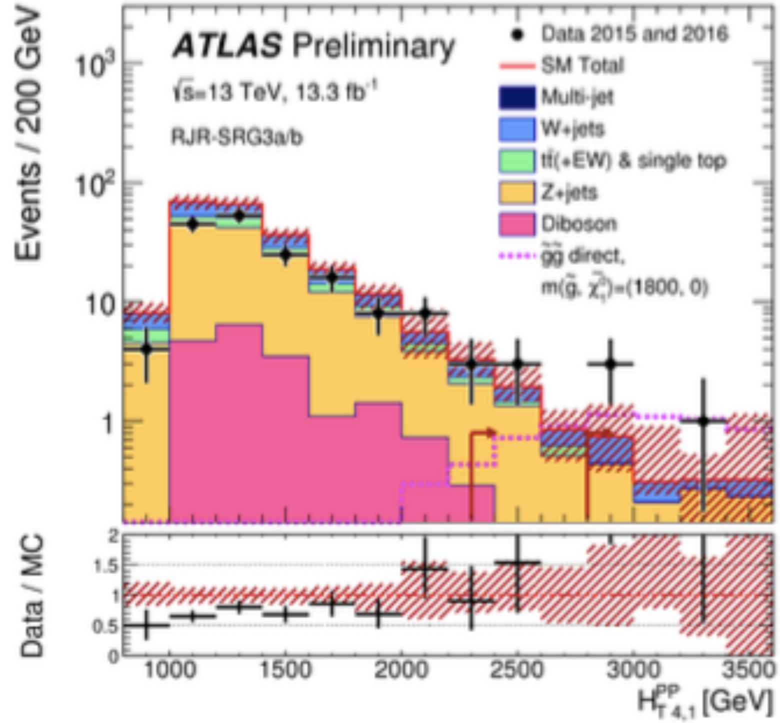
→ **Gluino R-hadrons with lifetime > 0.4 ns exclusions given for 100 GeV LSP, lower mass limits 740-1590 GeV**





RJigsaw





the complementary search using the **Recursive Jigsaw Reconstruction (RJR) techniques** in the construction of a discriminating variable set ('RJR-based search'). By using a dedicated set of selection criteria, the RJR-search improve the sensitivity to supersymmetric models with small mass splittings between the sparticles (models with compressed spectra).

Recursive jigsaw reconstruction

- based on assumption of decay tree
- fix set of rules to resolve combinatorics and unknowns in invisible system
- can form set of variables in the rest frame of each level in the decay tree

For the 13 TeV ATLAS searches, we utilize each of these classes:

- **Missing energy-type:**
  - **Missing transverse momentum:** $E_{\mathrm{T}}^{\mathrm{miss}}$ and $\vec{p}_{\mathrm{T}}^{\,\mathrm{miss}}$
  - **Missing transverse momentum significance:** $E_{\mathrm{T}}^{\mathrm{miss}}/\sqrt{H_{\mathrm{T}}}$
  - **RJigsaw H-scale for 1 visible, 1 invisible state:** $H_{1,1}^{\mathrm{PP}}$ (Similar to $E_{\mathrm{T}}^{\mathrm{miss}}$)
- **Energy scale-type:**
  - **Effective mass:** $M_{\mathrm{eff}} = \sum_{\mathrm{jets}} p_{\mathrm{T}} + \sum_{\mathrm{leptons}} + E_{\mathrm{T}}^{\mathrm{miss}}$ (also considering only first 4 jets)
  - **Scalar sum of visible momenta:** H_{T},
  - **Transverse mass:** $m_{\mathrm{T}} = \sqrt{2p_{\mathrm{T}}^{\ell}E_{\mathrm{T}}^{\mathrm{miss}}(1-\cos(\Delta\phi(\vec{p}_{\mathrm{T}}^{\,\mathrm{miss}},\ell))}$ (b-quarks can also replace the lepton)
  - **RJigsaw H-scale:** $H_{2,1}^{\mathrm{PP}}$, $H_{4,1}^{\mathrm{PP}}$ (Similar to M_{eff})
  - **RJigsaw ISR p_{T} scale:** $|p_{TS}^{\mathrm{ISR}}|$ (sum p_{T} of ISR jets
- **Energy structure-type:**
  - **Jet multiplicity:** N_{jet}, $N_{b-\mathrm{jet}}$
  - **Total jet mass:** $M_{\mathrm{J}}^{\Sigma} = \sum m^{\mathrm{jet}}$ (also considering only first 4 large-radius jets)
  - **Angular distributions:** $\Delta\phi_{\mathrm{min}}^{4j} = \min(|\phi_{\mathrm{any-jet}} - \vec{p}_{\mathrm{T}}^{\,\mathrm{miss}}|) > 0.4$ (for all 0ℓ selections)
  - **Aplanarity:** $A = (3/2)\lambda_3$
  - **QCD $E_{\mathrm{T}}^{\mathrm{miss}}$ alignment:** Δ_{QCD} (signed asymmetry between $E_{\mathrm{T}}^{\mathrm{miss}}$ and jet azimuthal directions)

Long term prospects

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- ATLAS studied long term prospects for the (HL-)LHC with 300, 3000 fb^{-1}@14 TeV
- Discovery potential up **to 2.5 TeV gluinos, 1.3 TeV squarks/sbottom and 800 GeV Electroweakinos**