SEARCHES FOR SUPERSYMMETRY WITH THE ATLAS DETECTOR

ALPS 2019

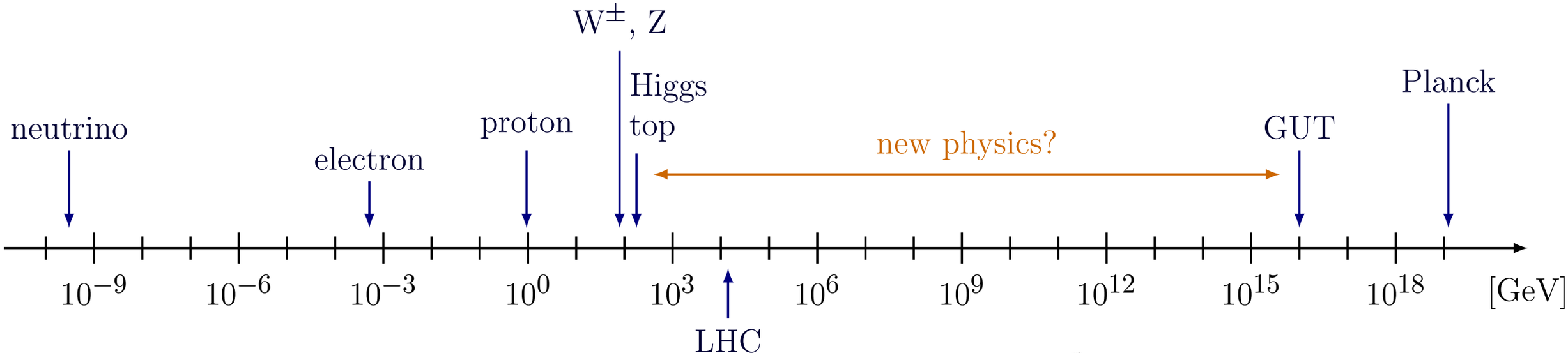
JOAKIM OLSSON (UC IRVINE)

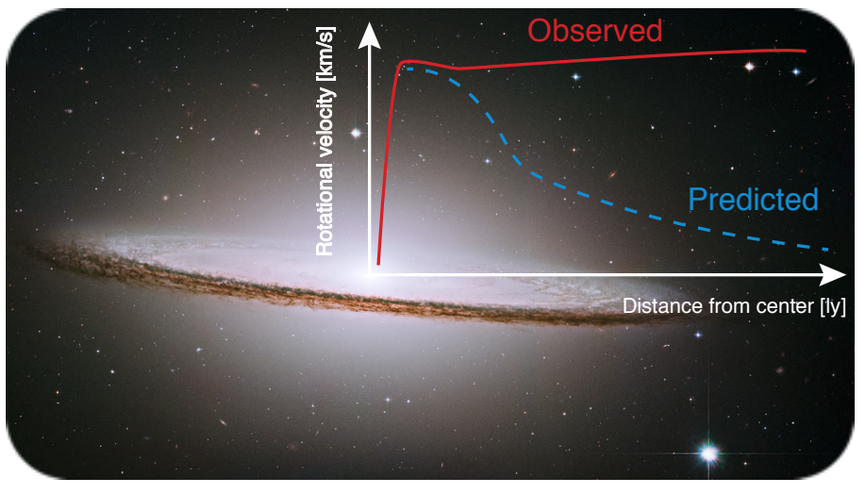
— ON BEHALF OF THE ATLAS COLLABORATION

APRIL 26, 2019

New Physics?
SUSY?

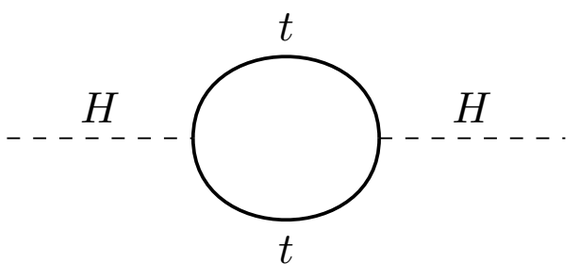
New Physics? SUSY?

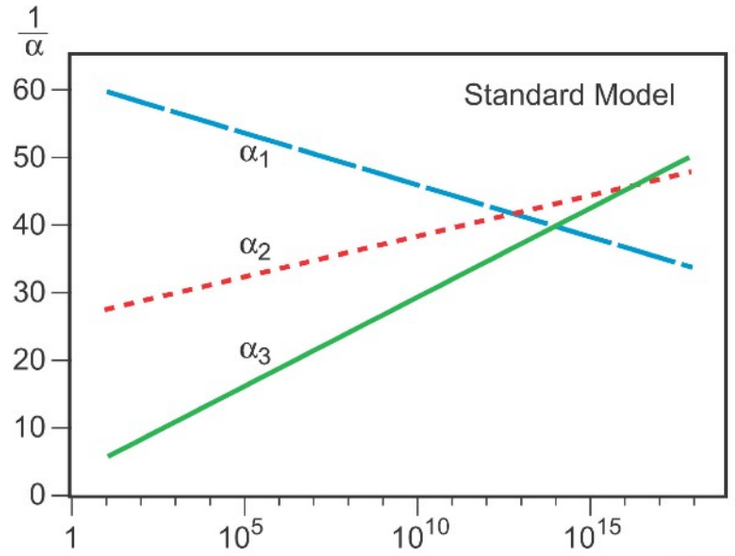




Dark matter

Hierarchy problem

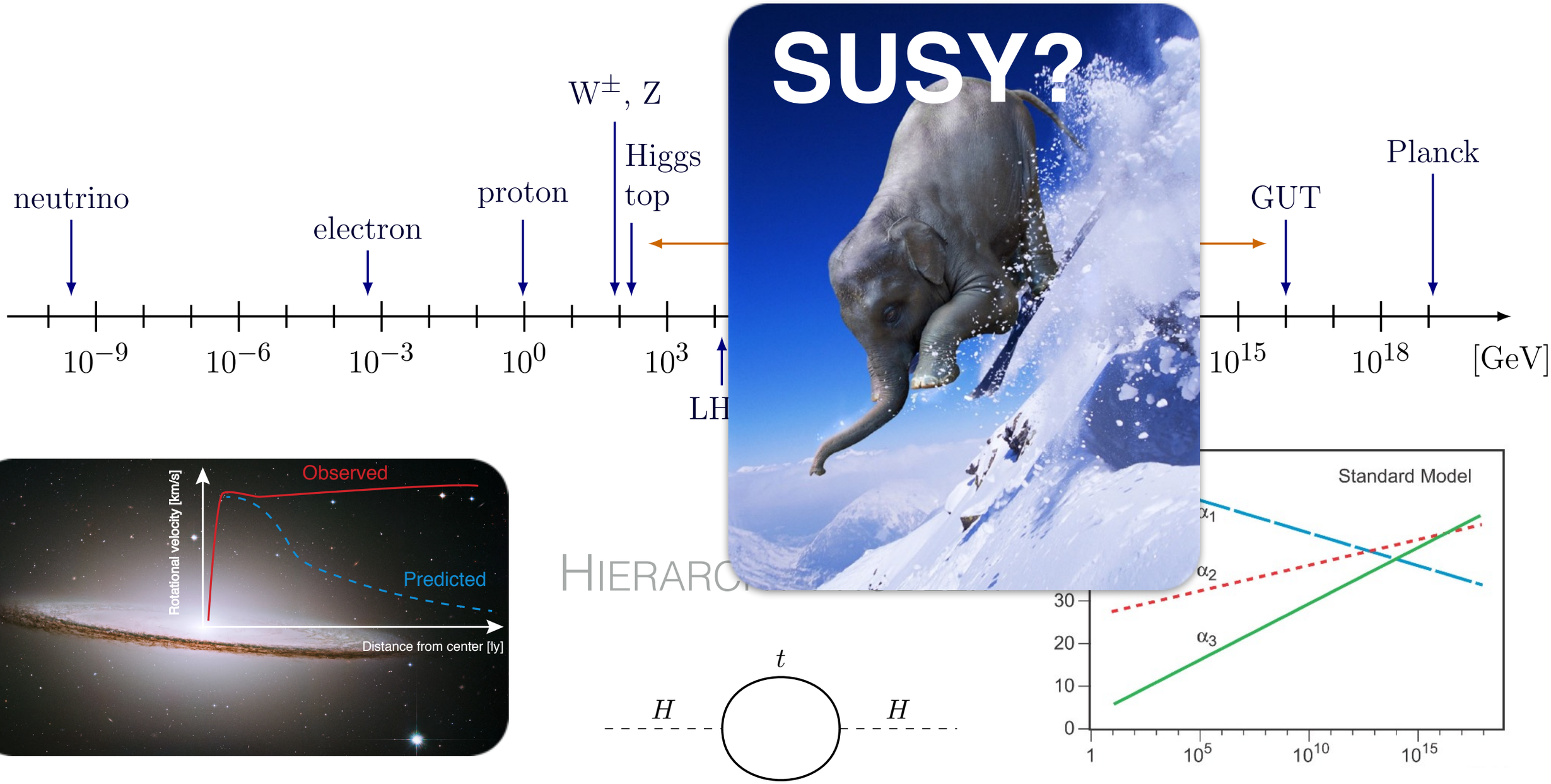




Grand Unified Theory

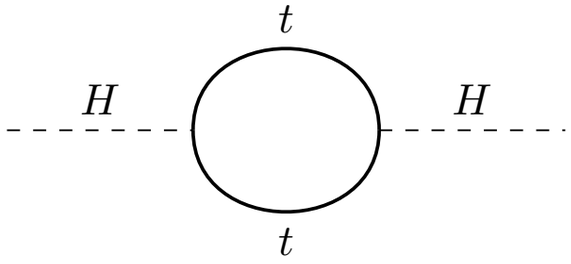
Baryogenesis, Inflation, Neutrino mass, etc…

New Physics? SUSY?



Dark matter

Hierarc



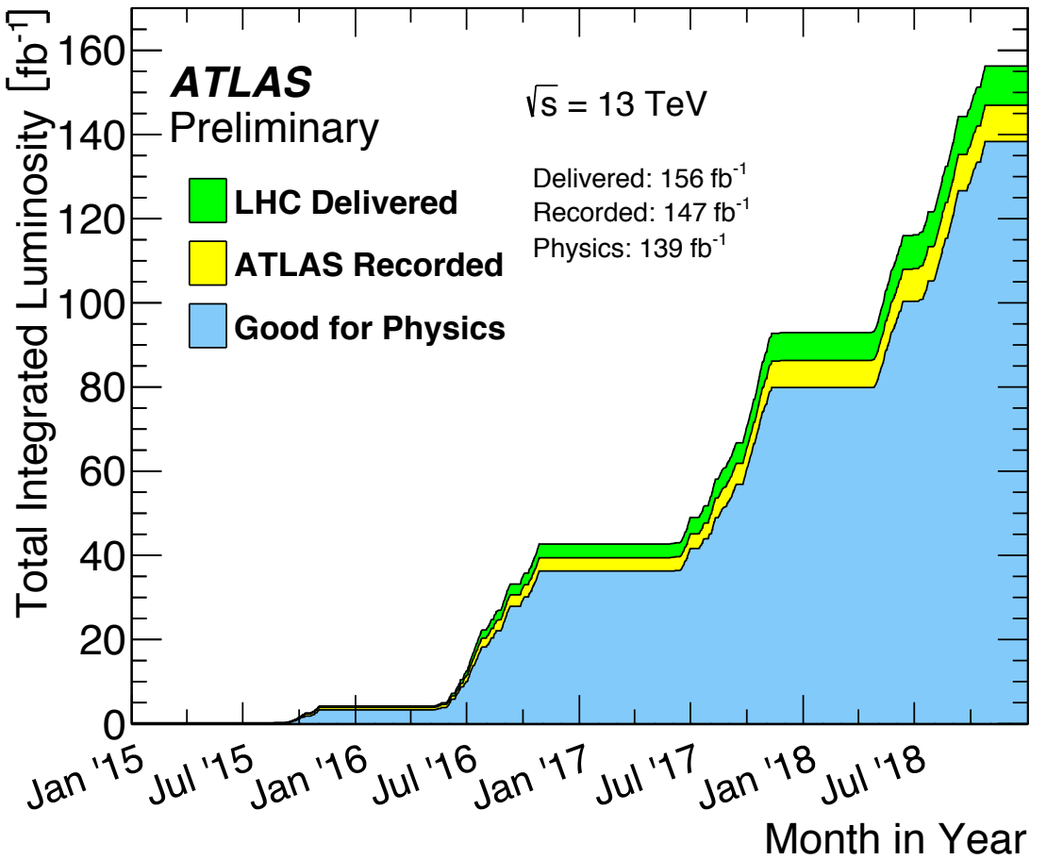
Grand Unified Theory

Baryogenesis, Inflation, Neutrino mass, etc…

SEARCHES FOR SUSY @ ATLAS

- SUSY FOR **THEORISTS**: WELL-MOTIVATED FRAMEWORK FOR BSM PHYSICS
- SUSY FOR **EXPERIMENTALISTS**: A SET OF (SIMPLIFIED) BENCHMARK MODELS
  - MSSM has over 100 free parameters… simplify and focus on models with few decoupled particles with distinct signatures (MET, leptons, jets, mT2,…)
  - Production: Inclusive q/g, direct 3rd gen., direct electroweak (EW)
  - Cover both R-parity conserving (RPC) and violating (RPV) scenarios
  - Long-lived (LL) particle scenarios

- EXCELLENT PERFORMANCE OF THE LHC AND ATLAS DURING THE PAST 4 YEARS
- **139 FB^{-1}** OF 13 TEV PP COLLISIONS READY FOR ANALYSIS (**FULL RUN 2 DATASET**)
- NOW SENSITIVE TO CHALLENGING SCENARIOS, E.G. **DIRECT ELECTROWEAK PRODUCTION**
- **IMPOSSIBLE TO COVER ALL ATLAS SUSY RESULTS**
- **TODAY**: FOCUS ON DIRECT EW PRODUCTION AND LATEST 139 FB^{-1} RESULTS—**EW, 3RD GEN. AND LLP**



Exploring new regions of phase space

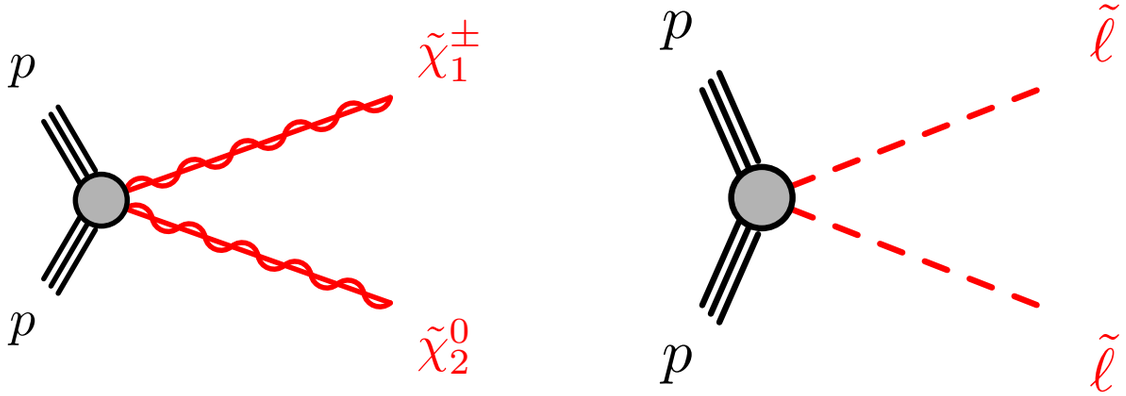
$\tilde{\chi}^{\pm}$

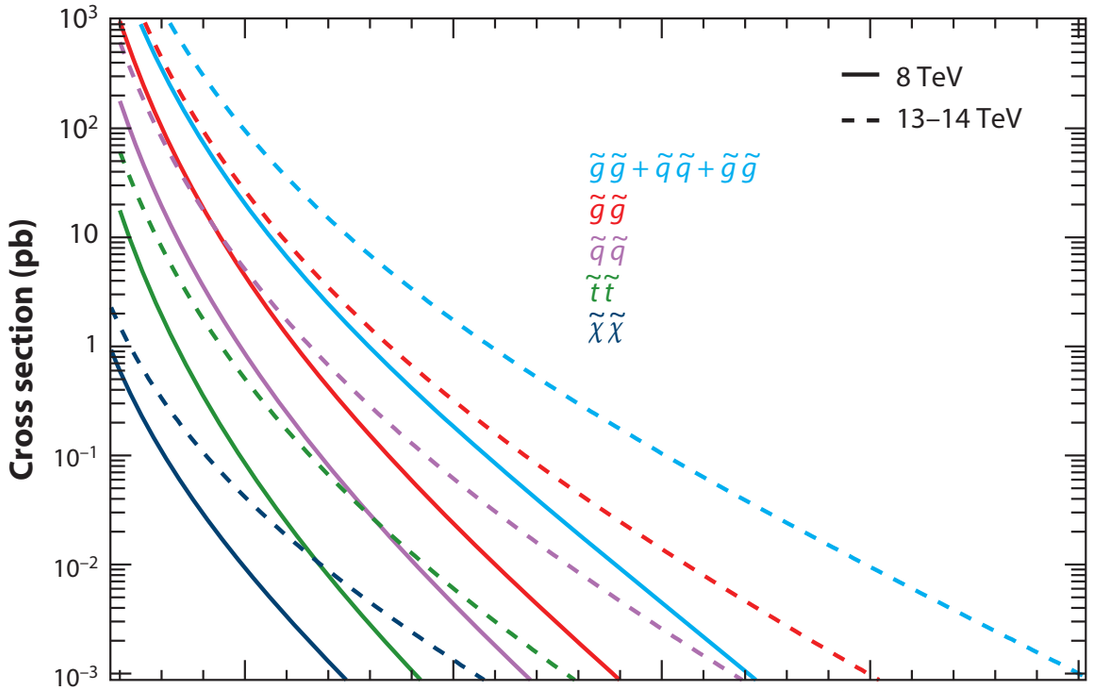
$\tilde{t}$

$\tilde{\chi}^{0}$

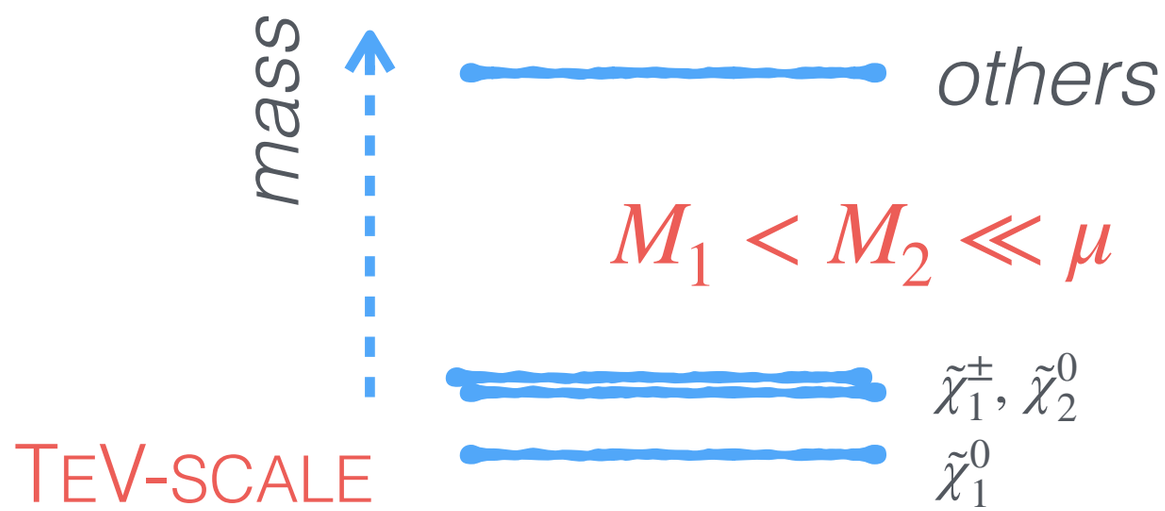
Electroweak Production

- No SUSY so far…
  WHERE MIGHT IT BE HIDING?
- **EW PRODUCTION** has **LOWER CROSS SECTION** than strong production
  - If strongly produced sparticles are heavier, EW could be discovered first
- Simplified Models (e.g. Wino-bino)
  - Assumptions: Only few particles,100% BR
- Direct chargino and neutralino
  - Mixing of gauge bosons and Higgs sector superpartners determine cross section, mass, branching ratio, etc.
- Direct Sleptons





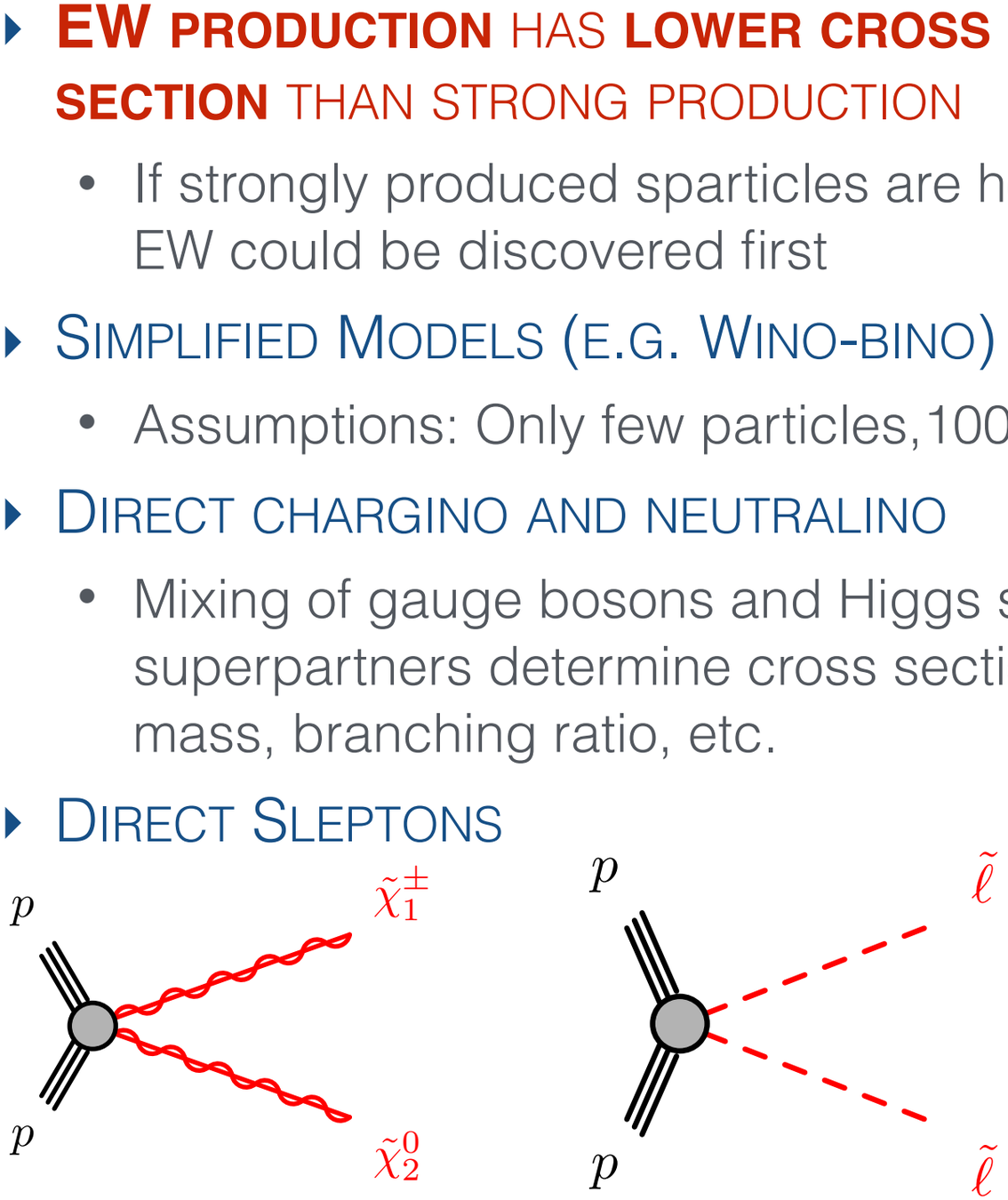
Production cross section

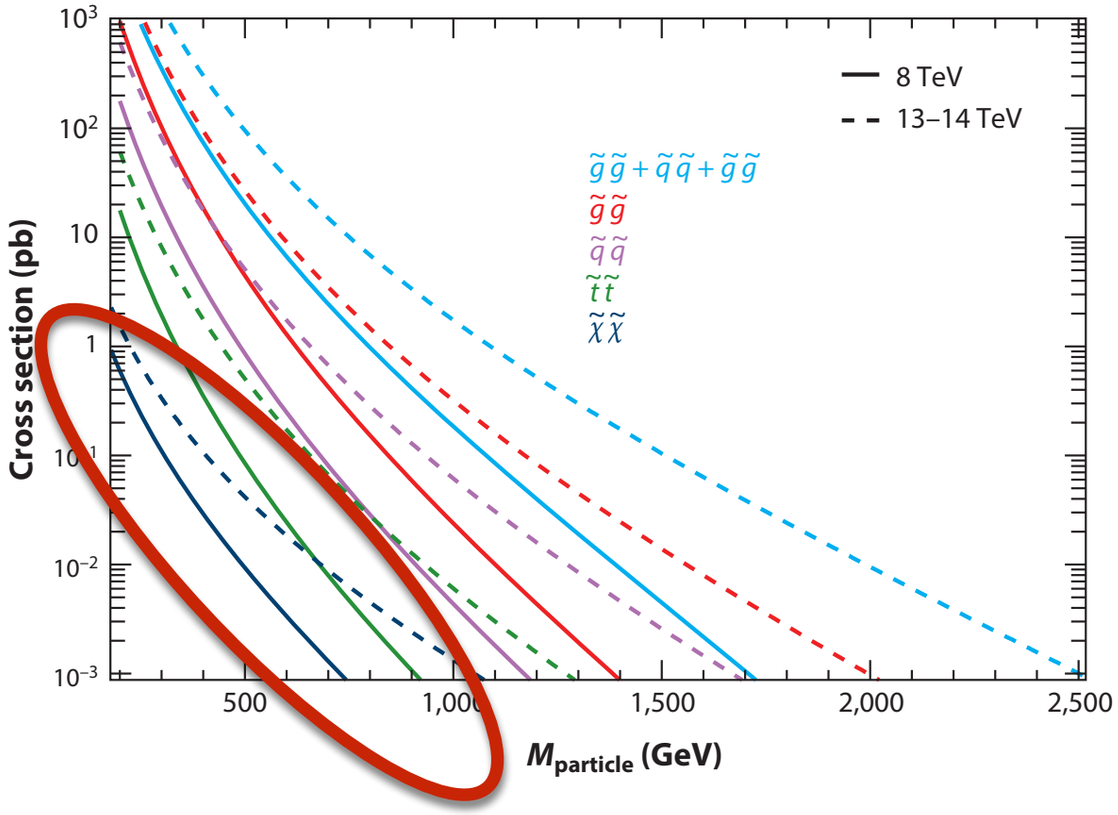


Simplified models

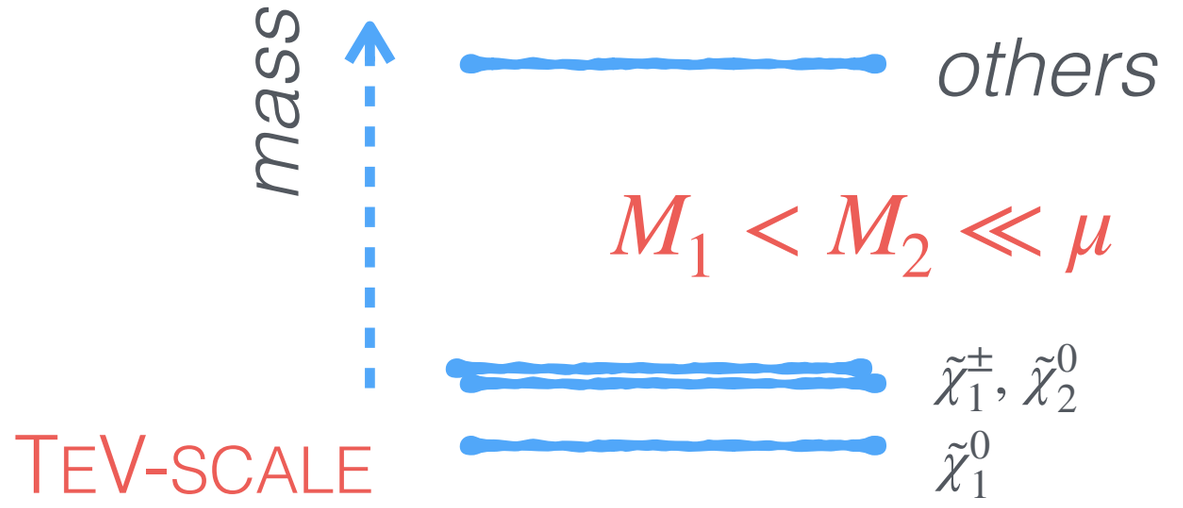
ELECTROWEAK PRODUCTION

- NO SUSY SO FAR…
  WHERE MIGHT IT BE HIDING?
- **EW PRODUCTION** HAS **LOWER CROSS SECTION** THAN STRONG PRODUCTION
  - If strongly produced sparticles are heavier, EW could be discovered first
- SIMPLIFIED MODELS (E.G. WINO-BINO)
  - Assumptions: Only few particles,100% BR
- DIRECT CHARGINO AND NEUTRALINO
  - Mixing of gauge bosons and Higgs sector superpartners determine cross section, mass, branching ratio, etc.
- DIRECT SLEPTONS





PRODUCTION CROSS SECTION



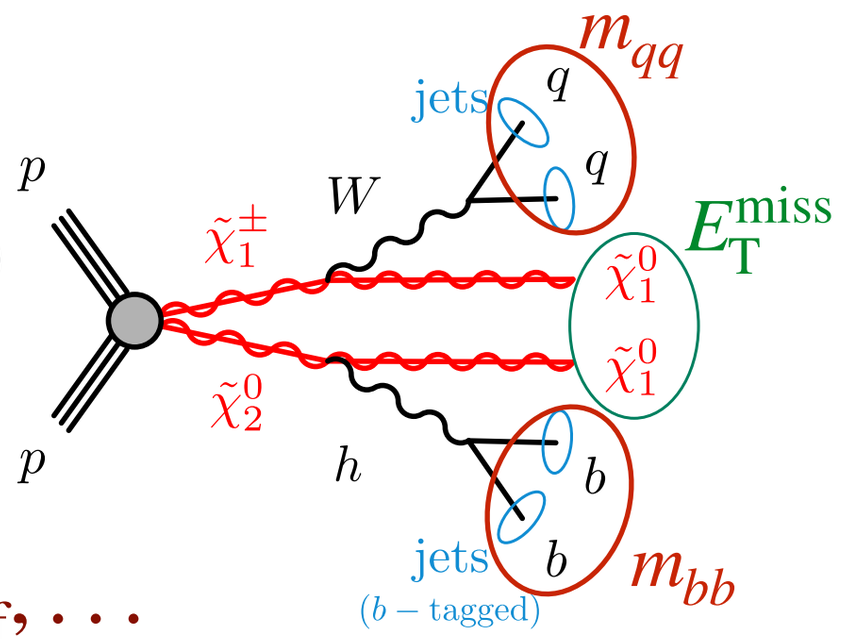
SIMPLIFIED MODELS

WH, FULLY HADRONIC

arXiv:1812.09432

- RECENT ATLAS PAPER INCLUDED $0lbb, 1lbb, 1l\gamma\gamma, l^{\pm}l^{\pm}$
- HADRONIC CHANNEL IMPORTANT AT HIGH MASS
  - Benefits from high W -> hadrons branching ratio (~67%)
- CHALLENGING BACKGROUNDS: TOP PAIRS, WT, Z+JETS
  - Semi-data driven BG estimate (Control Regions + MC)
- **MET TRIGGER + B-TAGGING + KINEMATIC VARIABLES:**

$$m_{bb},\ m_{qq},\ m_{\mathrm{T}},\ m_{\mathrm{CT}},\ m_{\mathrm{T2}},\ m_{\mathrm{eff}},\ \ldots$$



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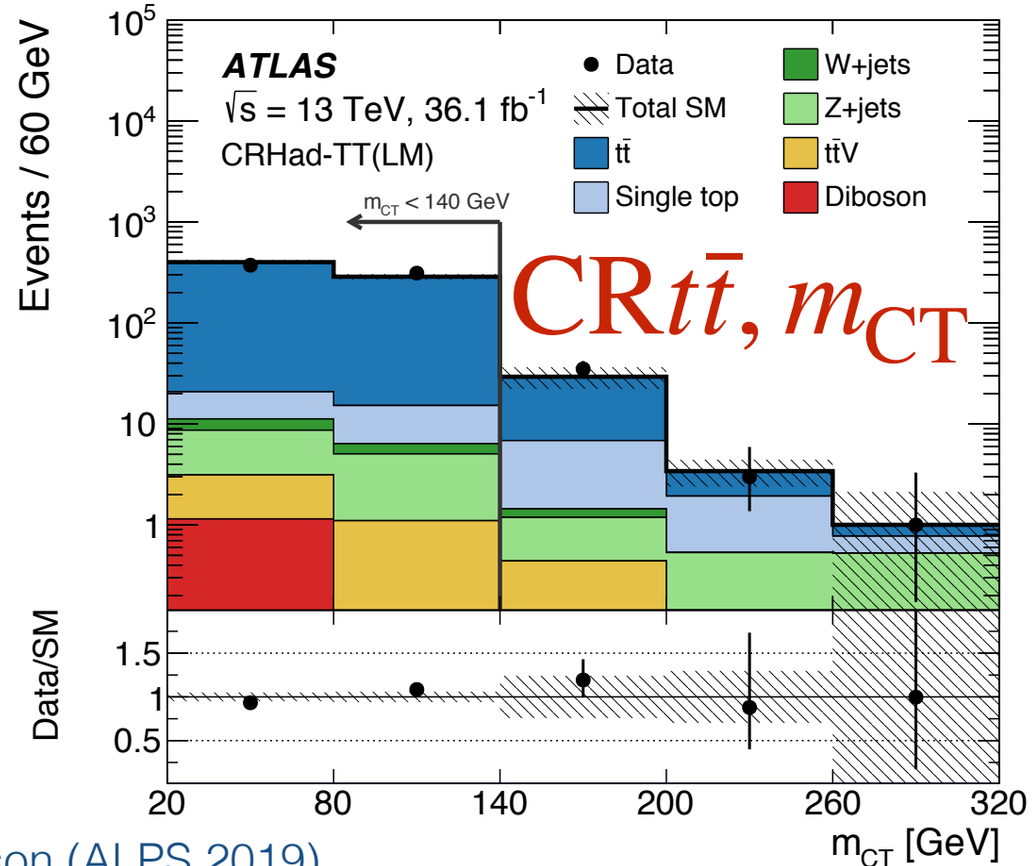

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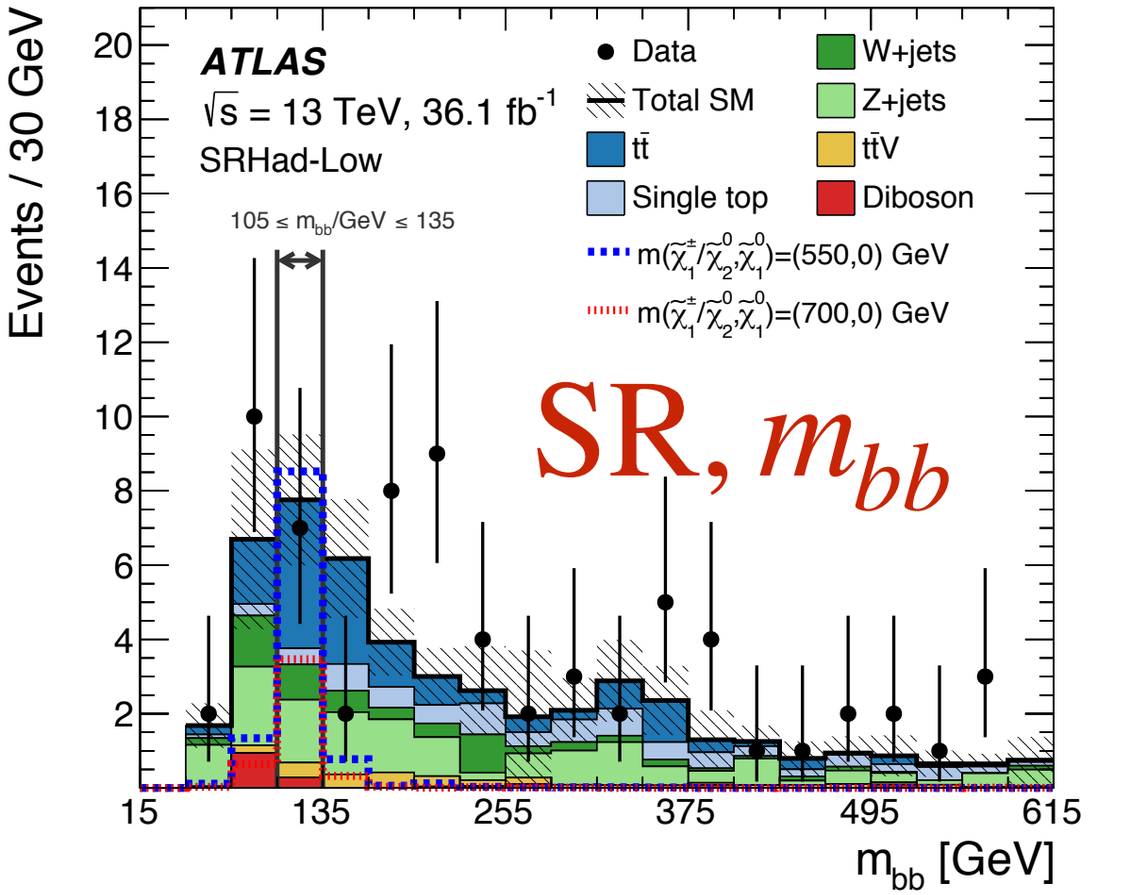
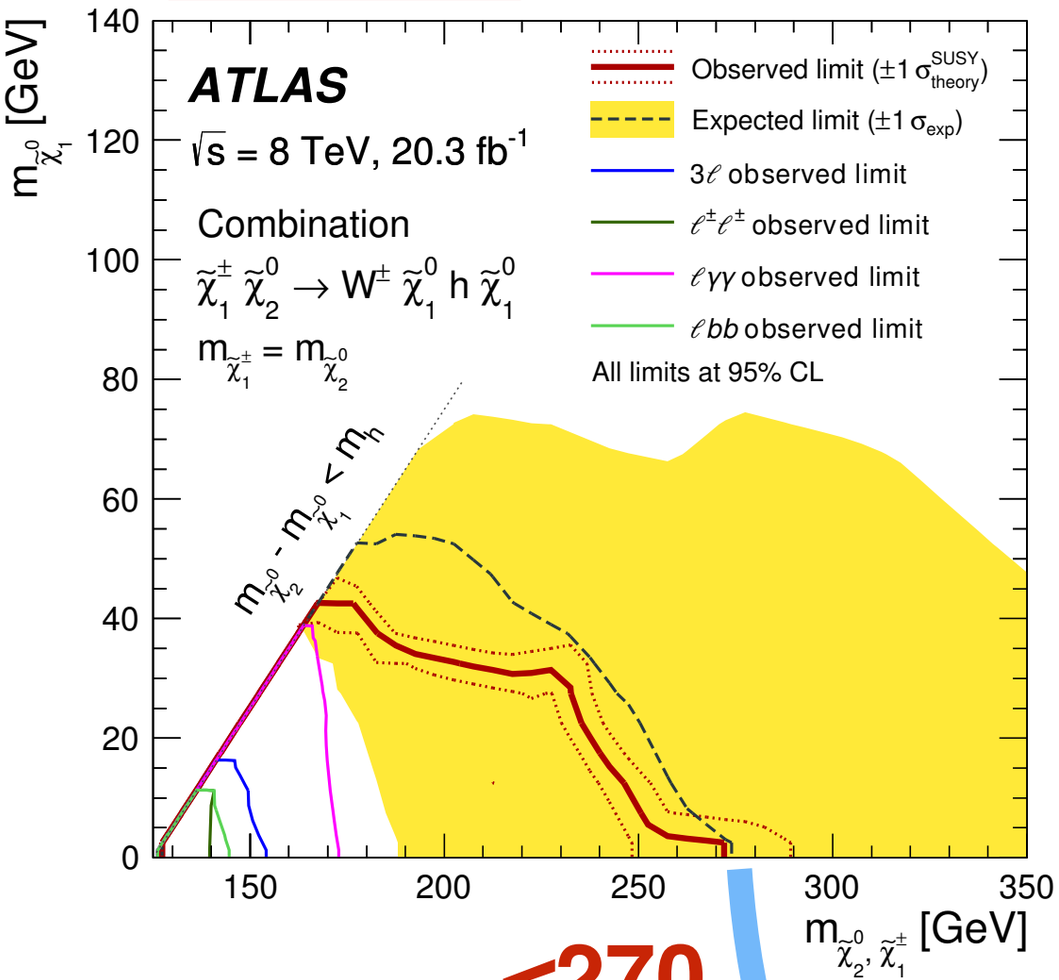


WH, Fully Hadronic

arXiv:1812.09432

arXiv:1501.07110



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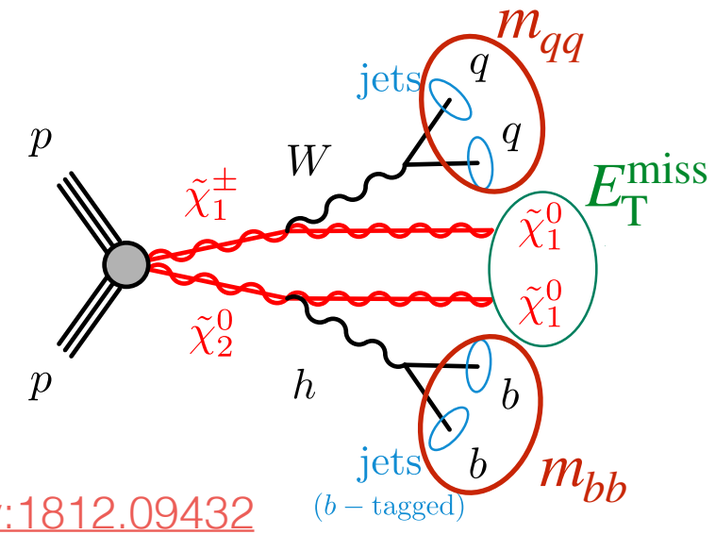

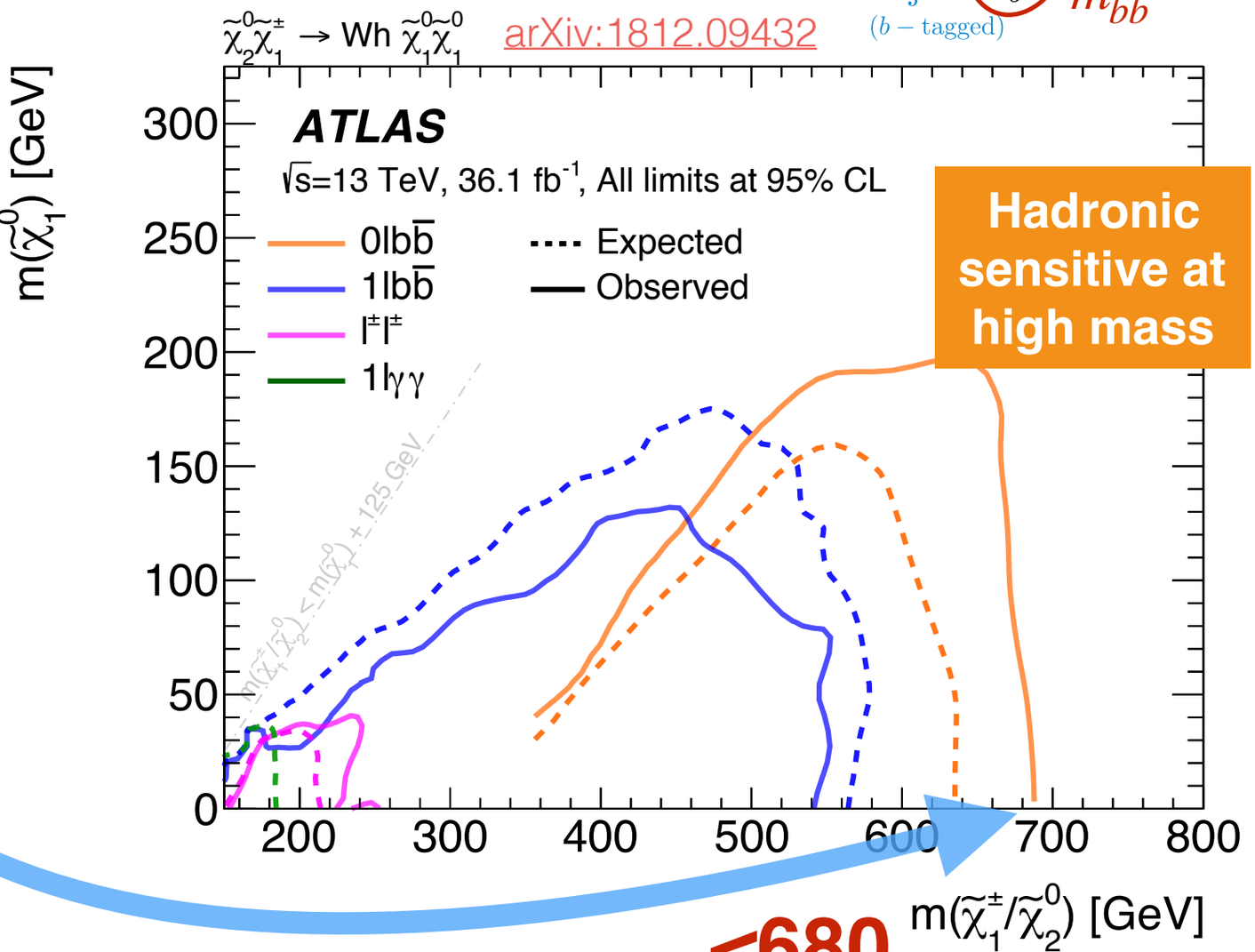

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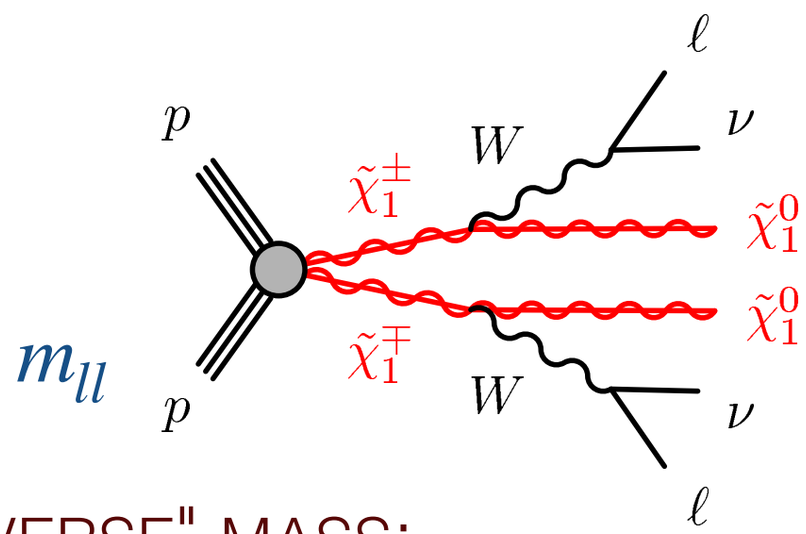
Huge improvement wrt Run 1

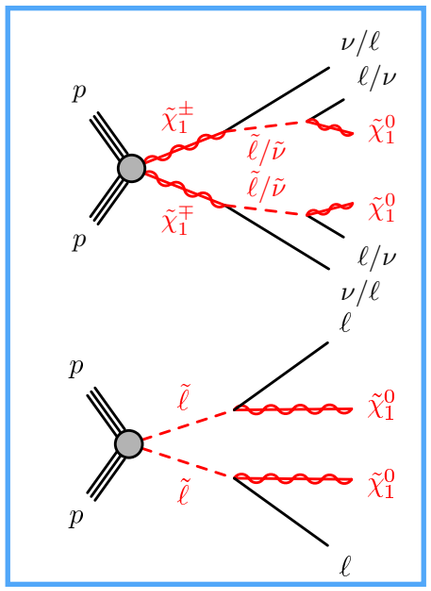
WW, 2L+MET

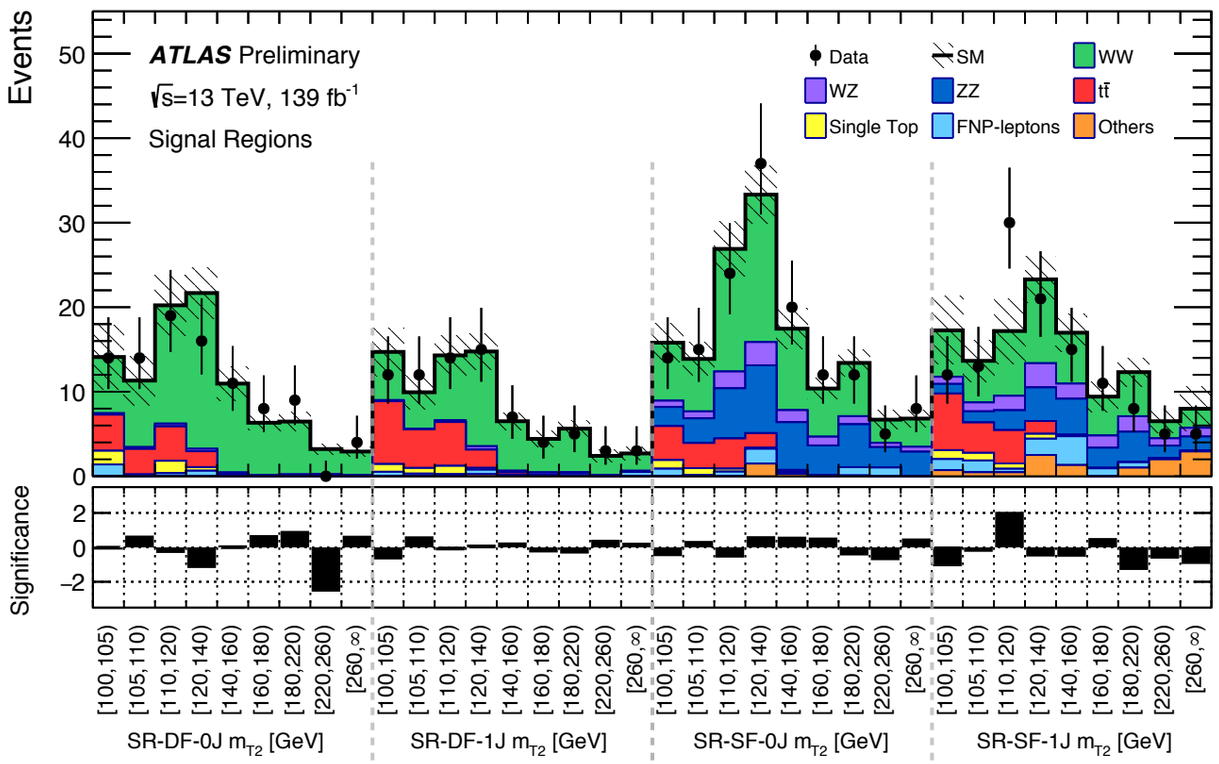
FULL RUN 2 RESULTS ATLAS-CONF-2019-008

- MAIN BACKGROUNDS: WW, TOP
- DILEPTON TRIGGER, 2 OS LEPTONS
- SELECTIONS ON E_T^{miss}
- SEPARATE 0J AND 1J, SF AND DF
- DISCRIMINATION BASED ON "STRANSVERSE" MASS:

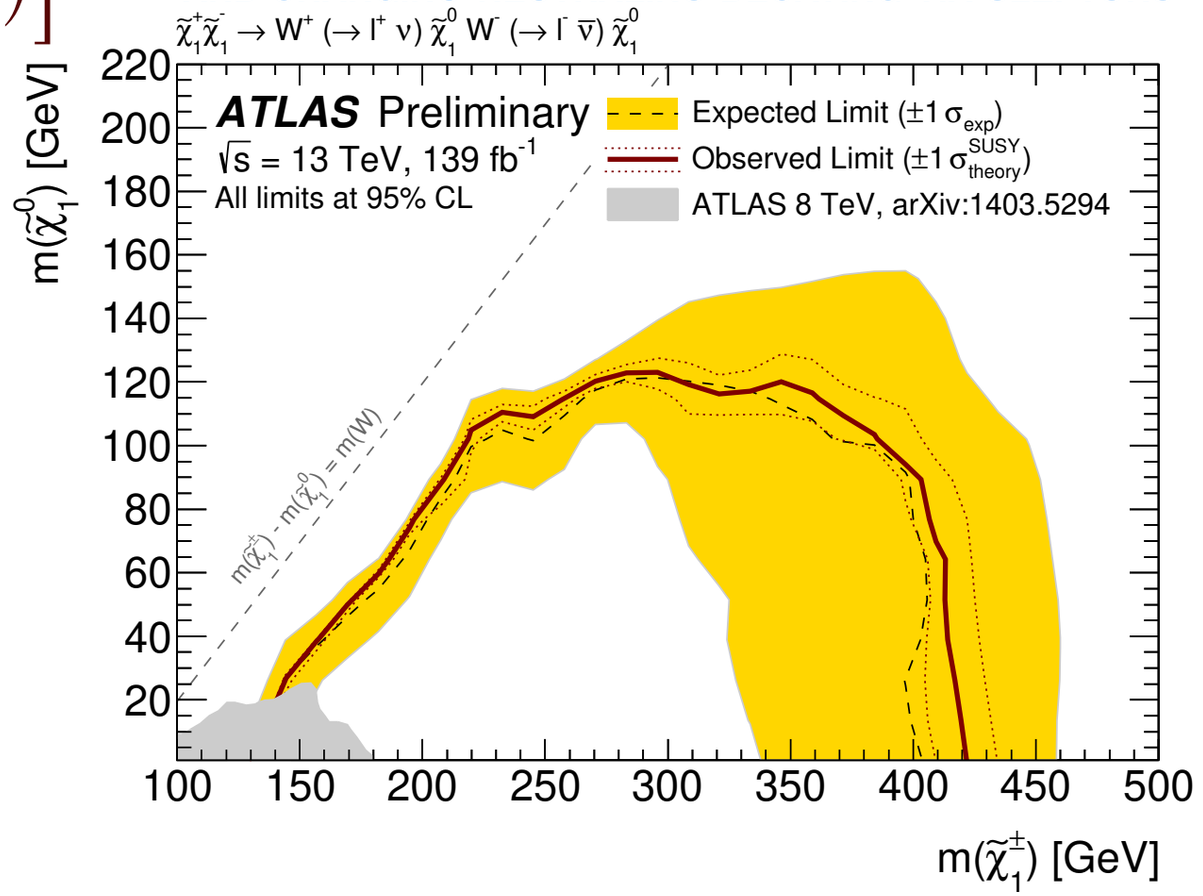
$$m_{\text{T2}} = \min_{q_{\text{T}}} \left[\max \left(m_{\text{T}}(\vec{p}_{\text{T}}^{\,l,1}, \vec{q}_{\text{T}}),\, m_{\text{T}}(\vec{p}_{\text{T}}^{\,l,2}, \vec{p}_{\text{T}}^{\,\text{miss}} - \vec{q}_{\text{T}}) \right) \right]$$





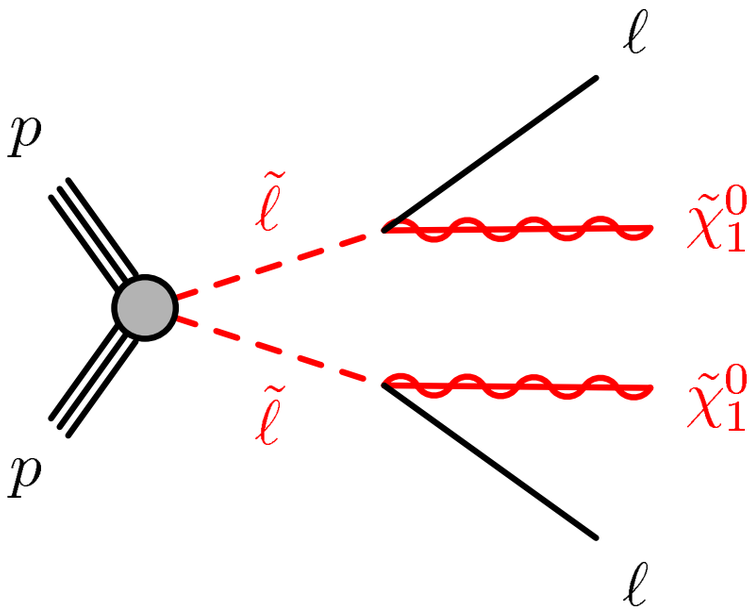


REINTERPRETATIONS FOR: SLEPTON PRODUCTION AND CHARGINO-NEUTRALINO DECAYING VIA SLEPTONS



FULL RUN 2 RESULTS | ATLAS-CONF-2019-008

DIRECT SLEPTON PRODUCTION

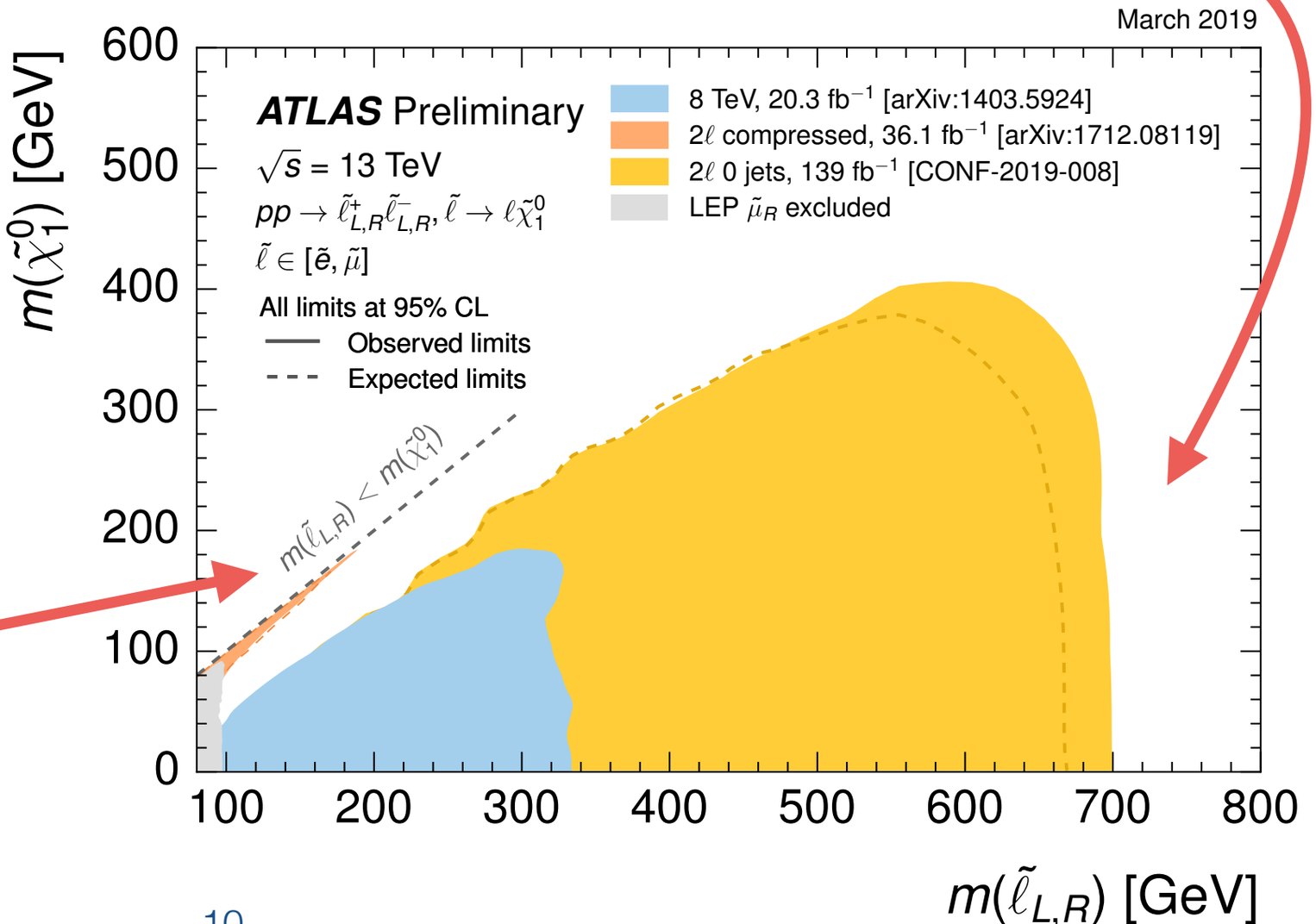


2L COMPRESSED

arXiv:1712.08119

REINTERPRETATION OF WW, 2L+MET

ATLAS-CONF-2019-008



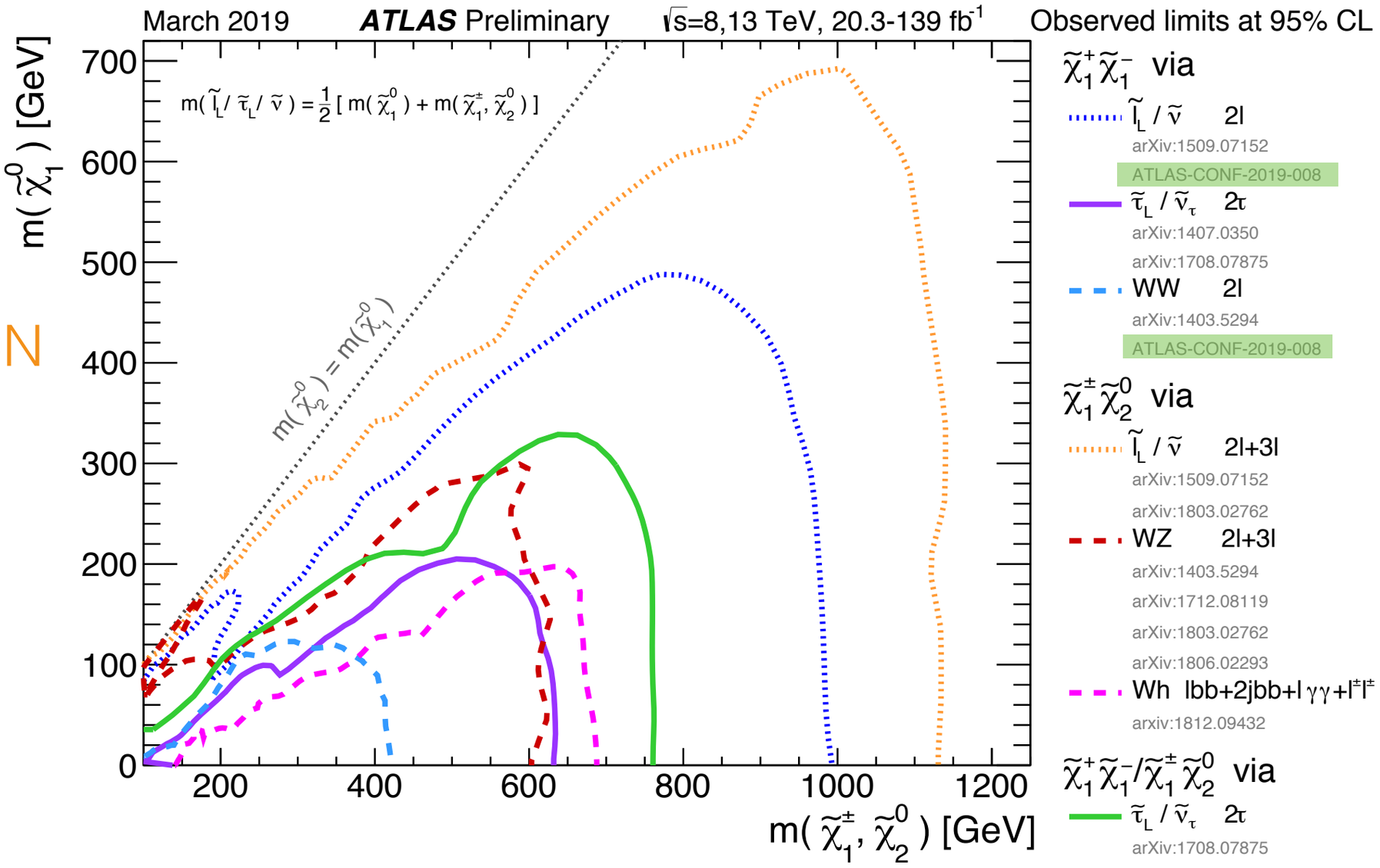
Link: Summary plots

UPDATED EW SUMMARY PLOT

- **WH** NOW (SLIGHTLY) STRONGER THAN **WZ** IN THE $\tilde{\chi}^{\pm}\tilde{\chi}^{0}_{2}$ MASS
- **WW 2L** $\tilde{\chi}^{+}_{1}/\tilde{\chi}^{-}_{1}$ EXCLUSIONS UP TO 400 GEV **NEW**
- **REINTERPRETED** $\tilde{\chi}^{+}_{1}\tilde{\chi}^{-}_{1}$ VIA SLEPTONS EXCLUDED <1 TEV **NEW**

ALSO SHOWN:

- $\tilde{\chi}^{\pm}\tilde{\chi}^{0}_{2}$ VIA SLEPTON [ARXIV:1803.02762]
- $\tilde{\chi}^{+}_{1}\tilde{\chi}^{-}_{1}/\tilde{\chi}^{\pm}\tilde{\chi}^{0}_{2}$ VIA HADRONIC TAU [ARXIV:1708.07875]

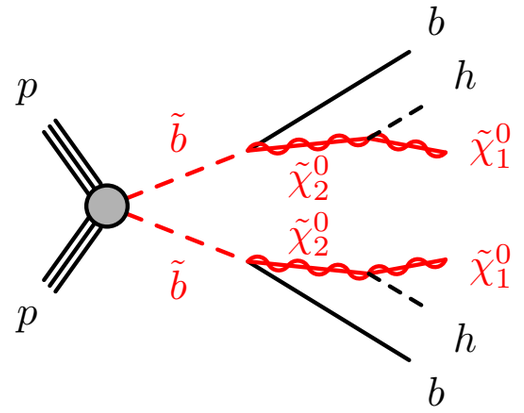


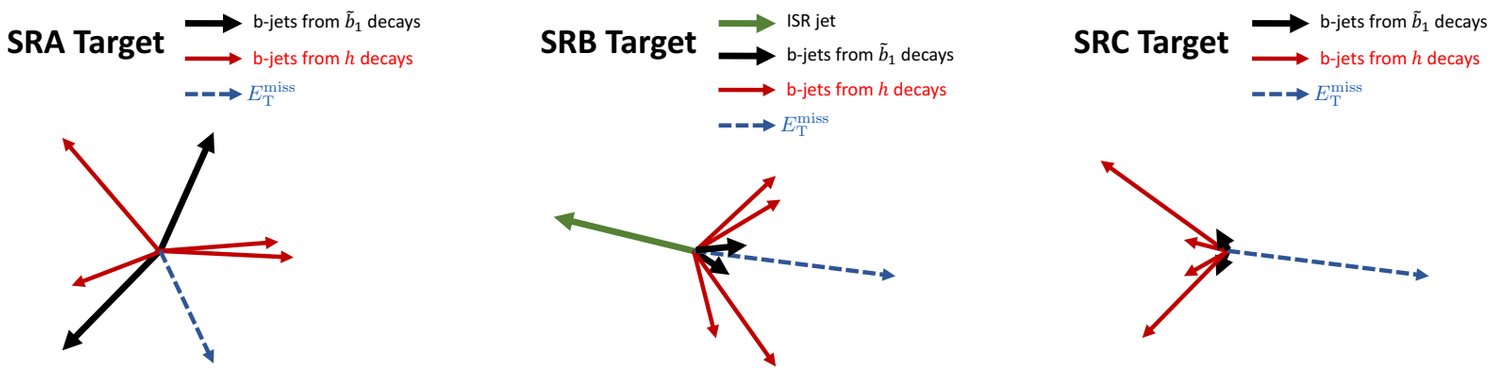
J. Olsson (ALPS 2019)

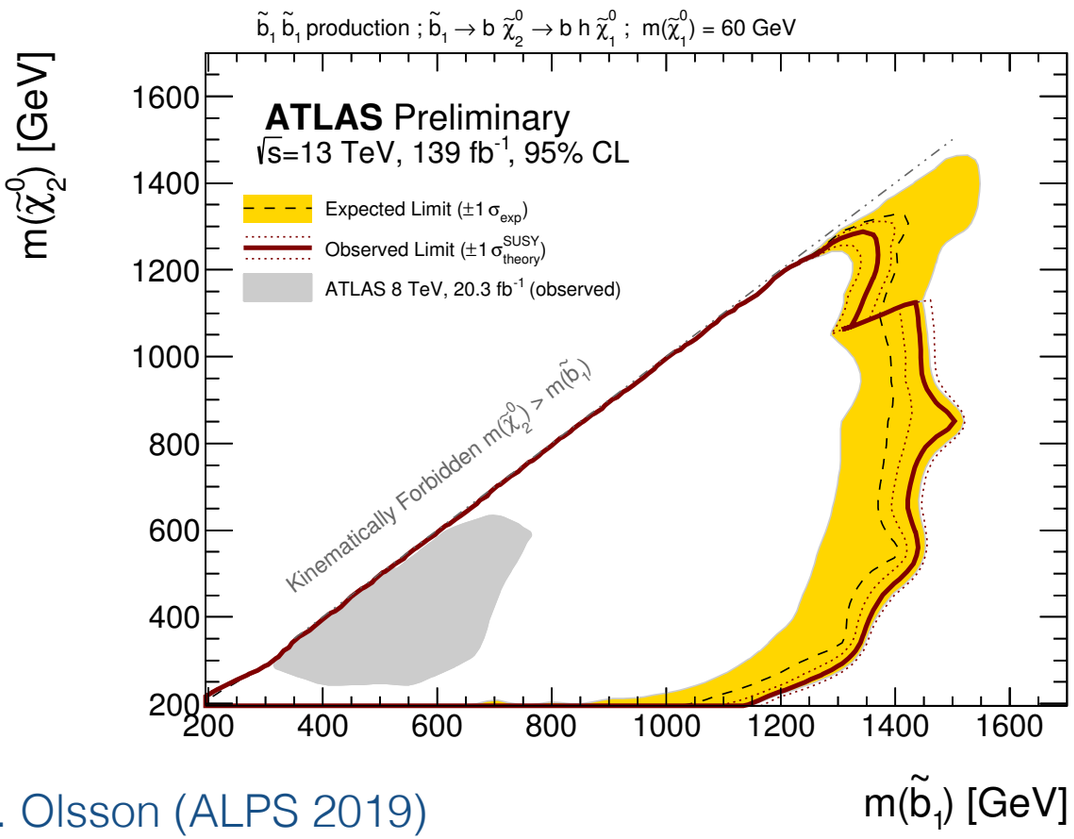
3RD GEN. SQUARKS

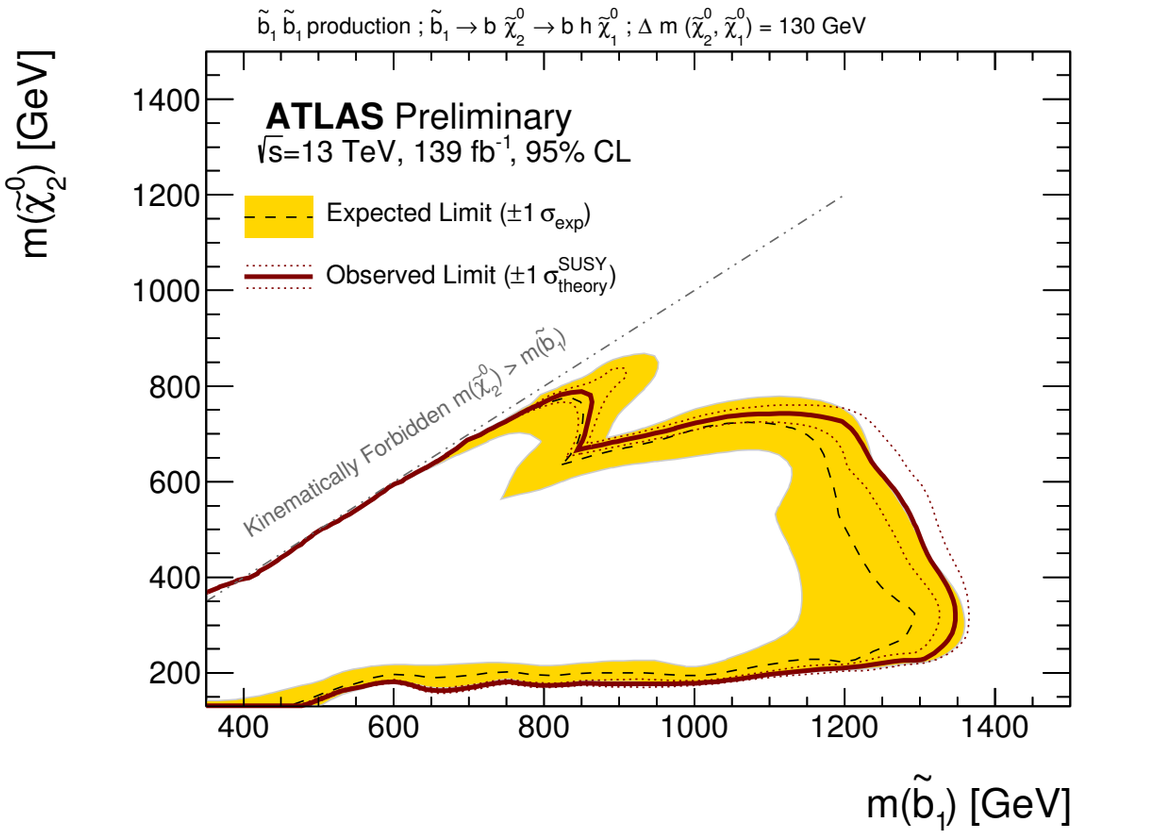
FULL RUN 2 RESULTS | ATLAS-CONF-2019-011

- SBOTTOMS IN DECAYS WITH HIGGS BOSONS
- 3 DIFFERENT SIGNAL CATEGORIES TARGETING DIFFERENT MASS HIERARCHIES
- NO EXCESS OVER SM
  - Two different signal mass scenarios





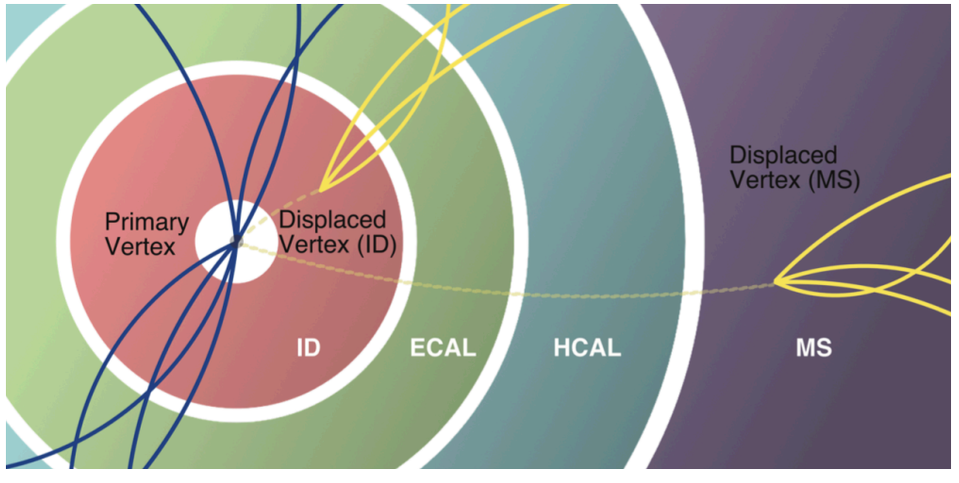




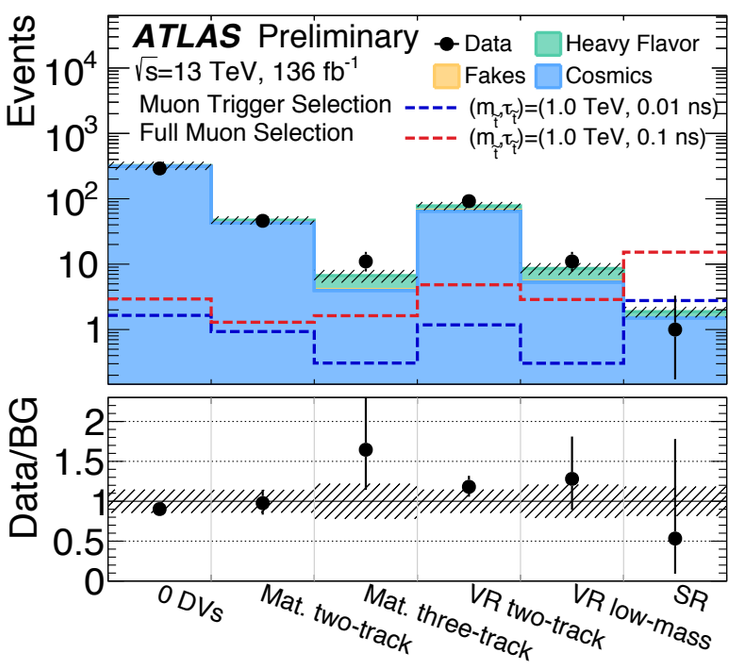
FULL RUN 2 RESULTS | ATLAS-CONF-2019-006

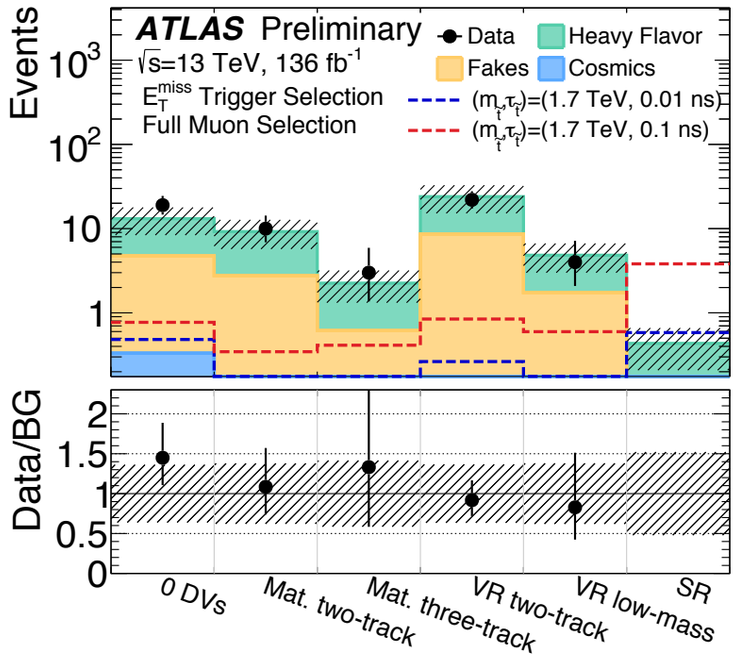
LONG-LIVED PARTICLES

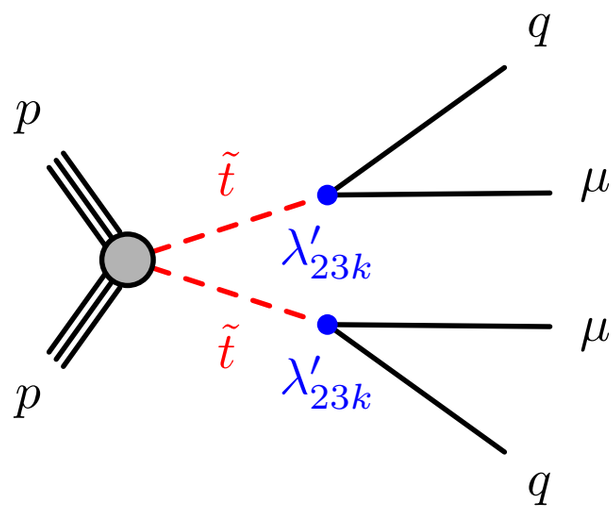
- SEARCH FOR LL PARTICLES DECAYING INTO AT LEAST ONE MUON AND HADRONS
- DISPLACED VERTEX AND DISPLACED MUON
- TWO SIGNAL REGIONS BASED ON EITHER MUON OR E_T^{miss} TRIGGER
- NO IRREDUCIBLE SM BACKGROUNDS



- MAIN BACKGROUNDS: COSMICS, FAKES AND IN-FLIGHT HADRON DECAYS



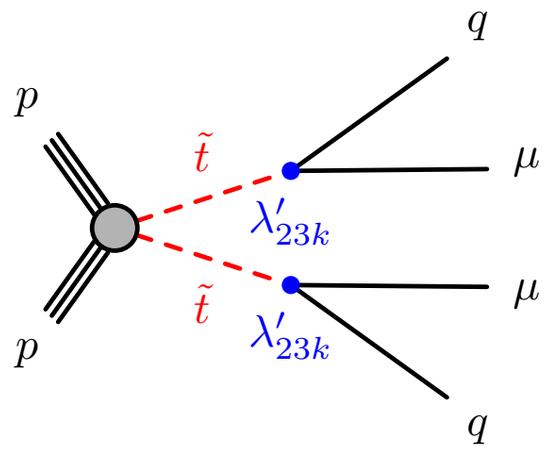




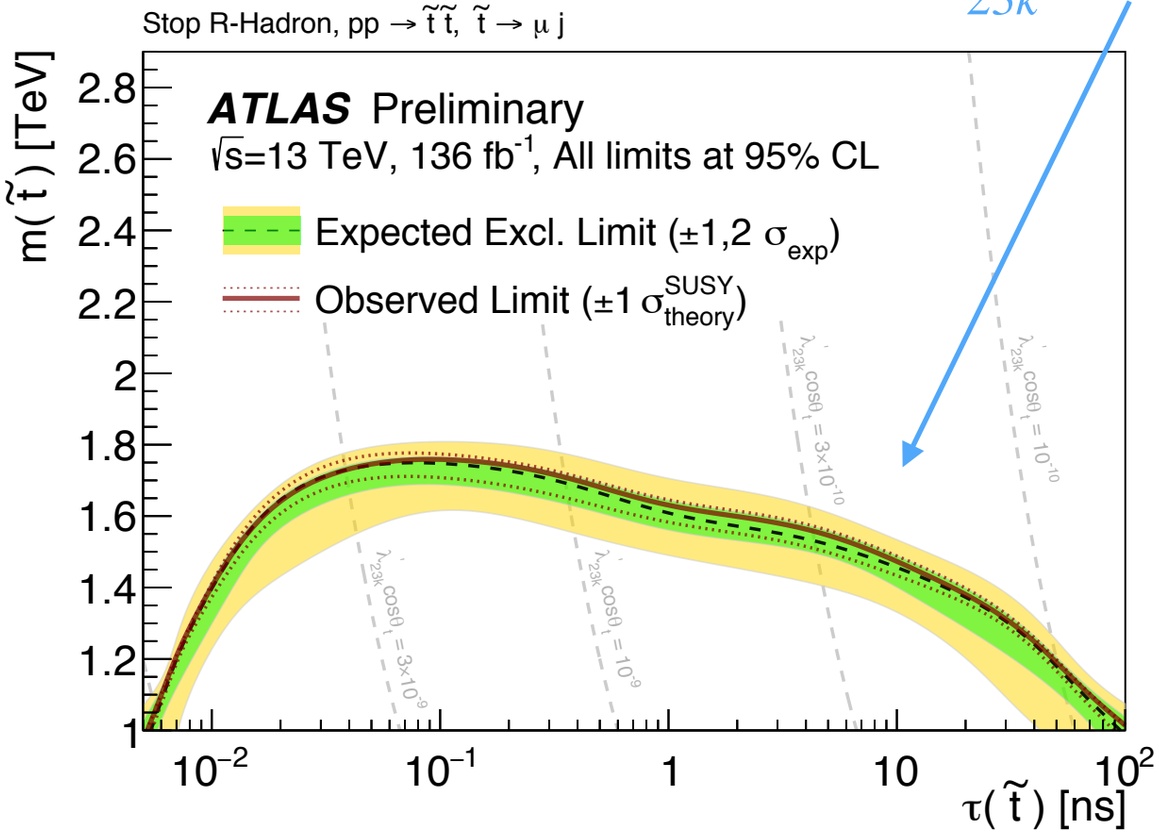
FULL RUN 2 RESULTS | ATLAS-CONF-2019-006

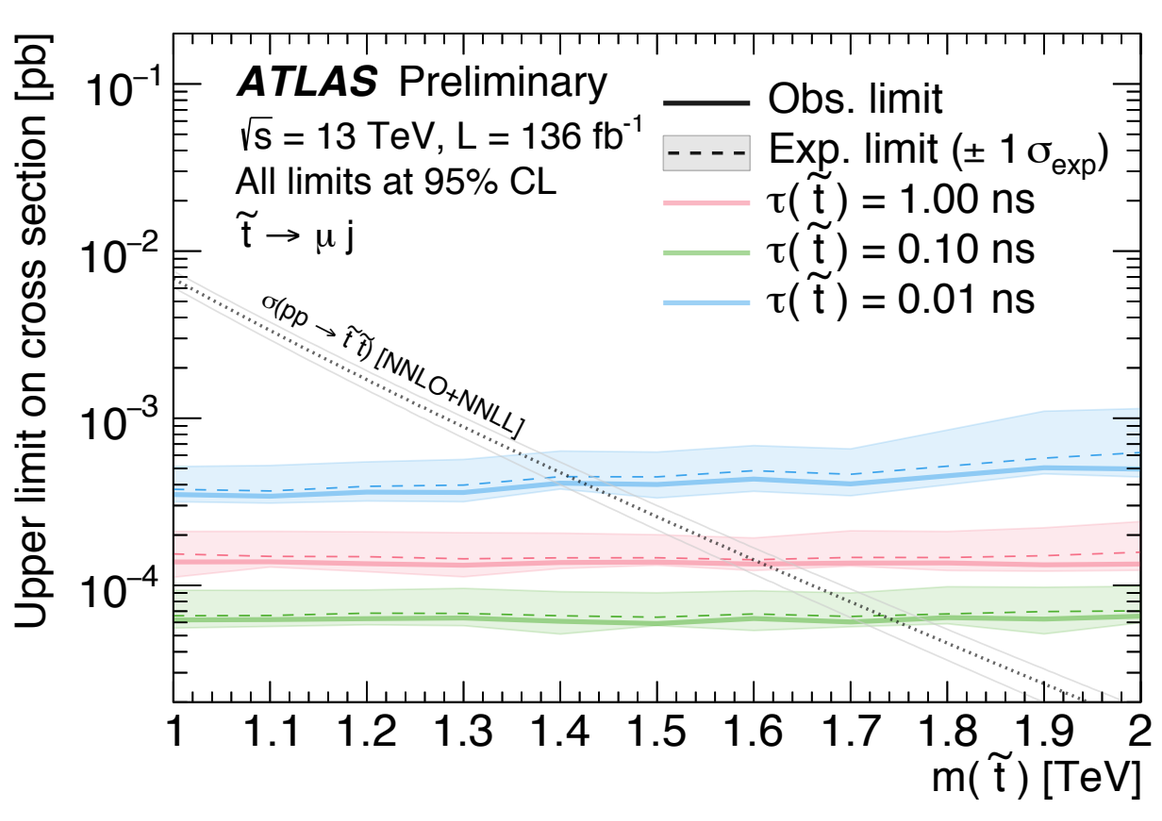
LONG-LIVED PARTICLES

- RESULTS COMPATIBLE WITH SM
- EXCLUDE <1.7 TEV FOR A LIFETIME OF 0.1 NS
- AND <1.3 TEV FOR ALL LIFETIMES BETWEEN 0.01 NS AND 30 NS



CONTOURS: DIFFERENT VALUES OF λ'_{23k}

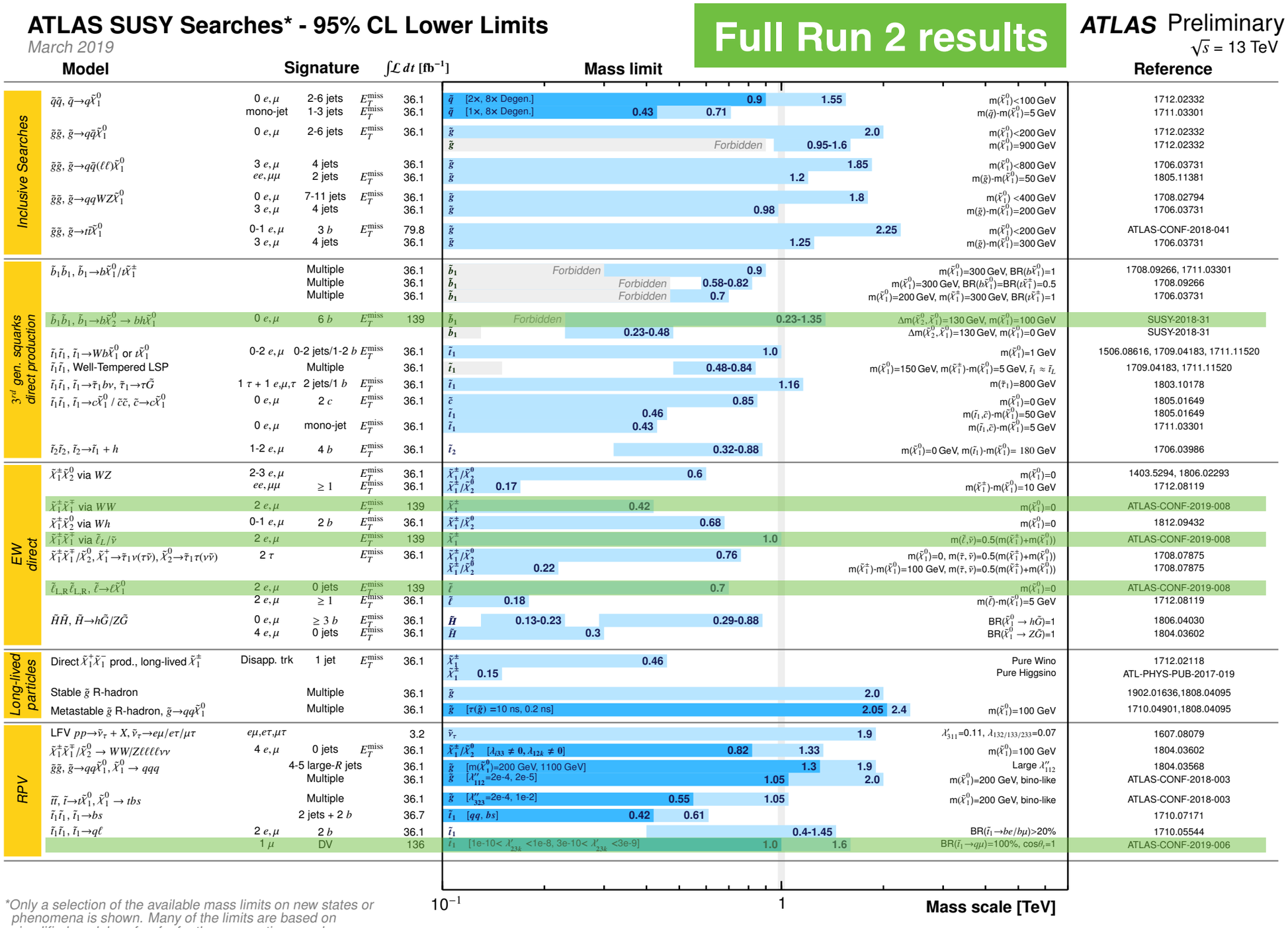




SUMMARY OF SUSY SEARCHES

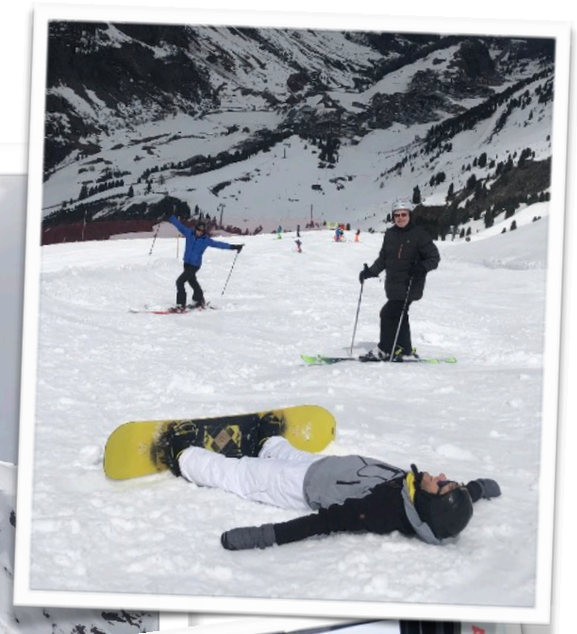
Link: Summary plots

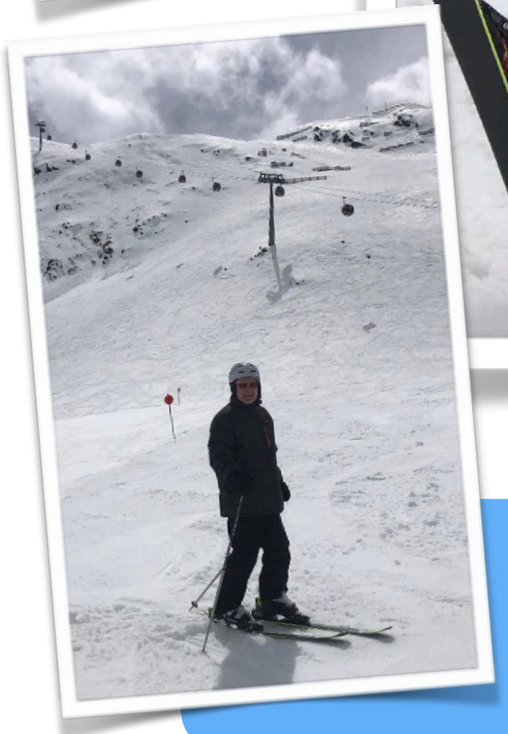
Lots of full Run 2 results in the pipeline…

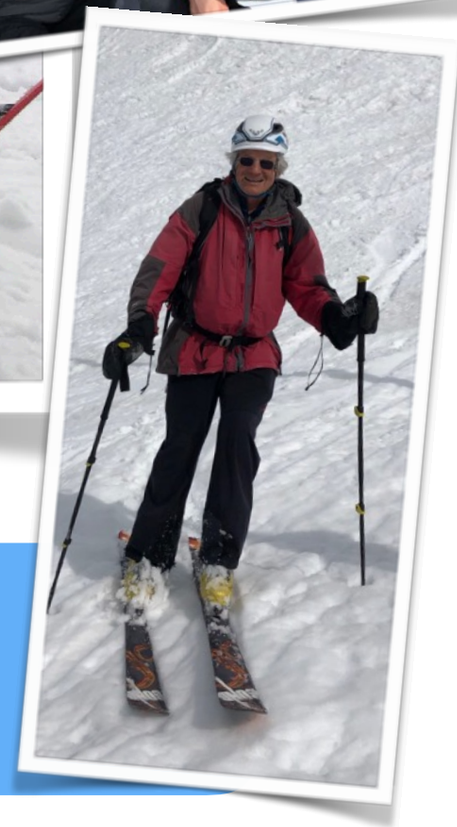


Conclusion

- Excellent performance of the LHC and ATLAS
- Lots of new results… but no sign of new physics
- Most standard signatures are well covered
- Where might SUSY still be hiding?
  - Experimentally challenging signatures
  - Difficult backgrounds
- Lots of results in the pipeline with full Run 2 dataset! Stay tuned!







THANKS