BSM @ HL/HE LHC

Nicola De Filippis

Politecnico & INFN, Bari and LPC-FNAL, Batavia

on behalf of

ATLAS, CMS and LHCb collaboration

Working Group 3

HL/HE LHC Meeting,
4-6 Apr 2018, FNAL, Batavia

Physics landscape by 2018

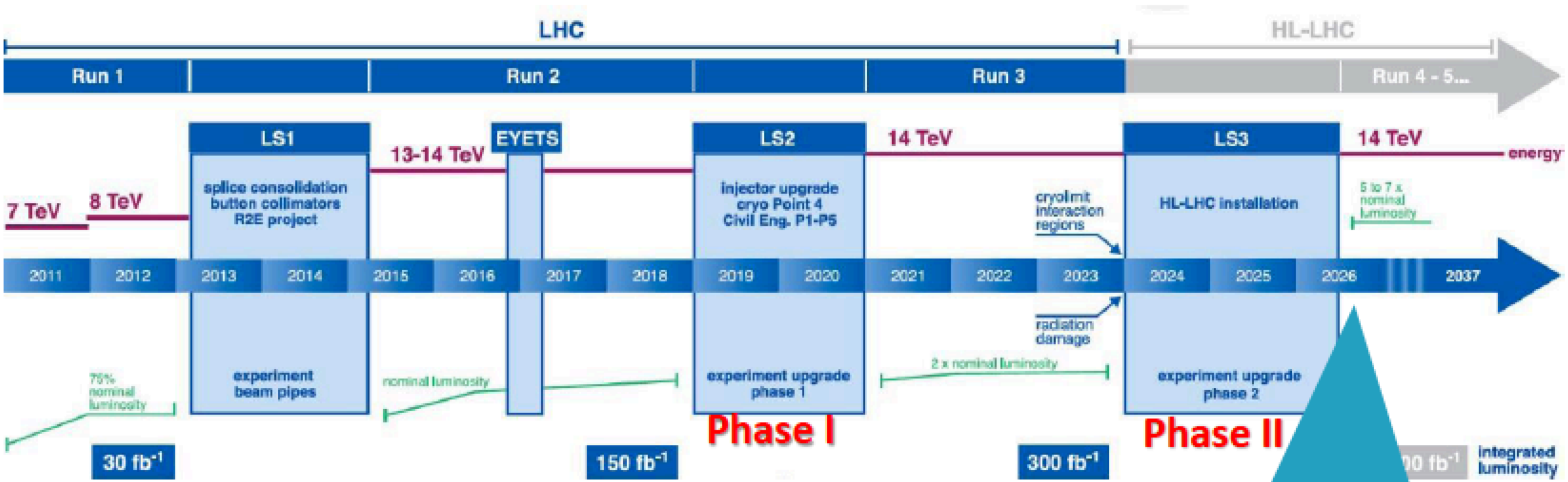
LHC experiments confirm that the SM is robust but it should not be the ultimate theory of particle physics, because of many questions:

- *why is the Higgs boson so light ("naturalness"/fine-tuning/hierarchy problem) ?*
- *what is the the nature of the dark part (96% !) of the universe ?*
- *what is the origin of the matter-antimatter asymmetry ?*
- *why is gravity so weak ?*
- *Is supersymmetry realized in Nature?*
- *Inflation*

→ HL/HE-LHC era after Phase II upgrade of LHC detectors:

- searching for direct signs of new physics:
  - Supersymmetry
  - Long-lived particles
  - New heavy resonances
  - Dark Matter and its nature
- doing Precision measurements (Couplings, Cross Sections, Width, Differential Distributions,…) which might be an indirect sign of it

LHC and HL-LHC schedule



Luminosity

Nominal scenario: $\mathcal{L} = 5\times10^{34}\ \mathrm{cm^{-1}s^{-1}}$
for 3000/fb; Pile-up = 140

Ultimate Scenario: $\mathcal{L} = 7.5\times10^{34}\ \mathrm{cm^{-1}s^{-1}}$
for 4000/fb; Pile-up = 200
$\Rightarrow$25% increase in integrated lum.

CMS Phase 2 upgrade

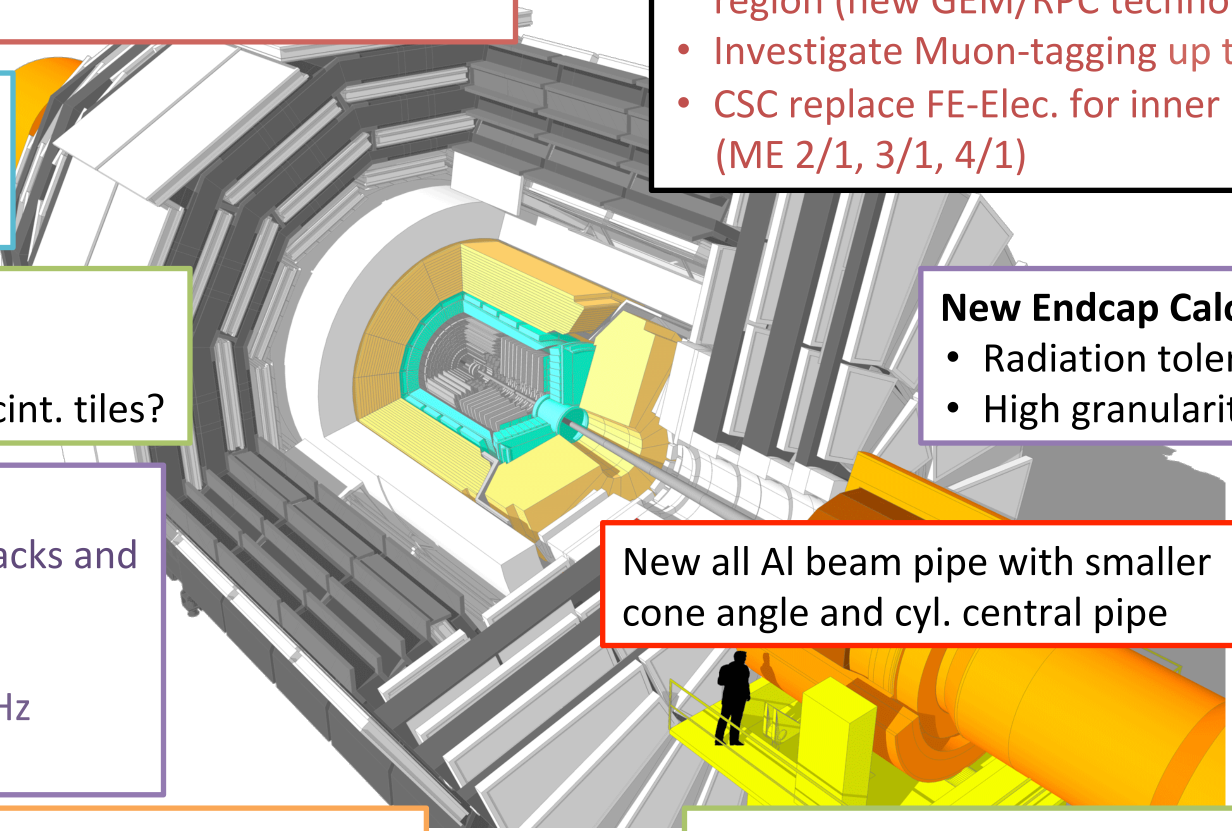
New Tracker
- Radiation tolerant - high granularity - less material
- Tracks in hardware trigger (L1)
- Coverage up to η ~ 4

Muons
- Replace DT FE electronics
- Complete RPC coverage in forward region (new GEM/RPC technology)
- Investigate Muon-tagging up to η ~ 3
- CSC replace FE-Elec. for inner rings (ME 2/1, 3/1, 4/1)

Barrel ECAL
- Replace FE electronics
- Cool detector/APDs

Barrel HCAL
- Replace HPD by SiPM
- Replace inner layers scint. tiles?

New Endcap Calorimeters
- Radiation tolerant
- High granularity (**HGCAL**)



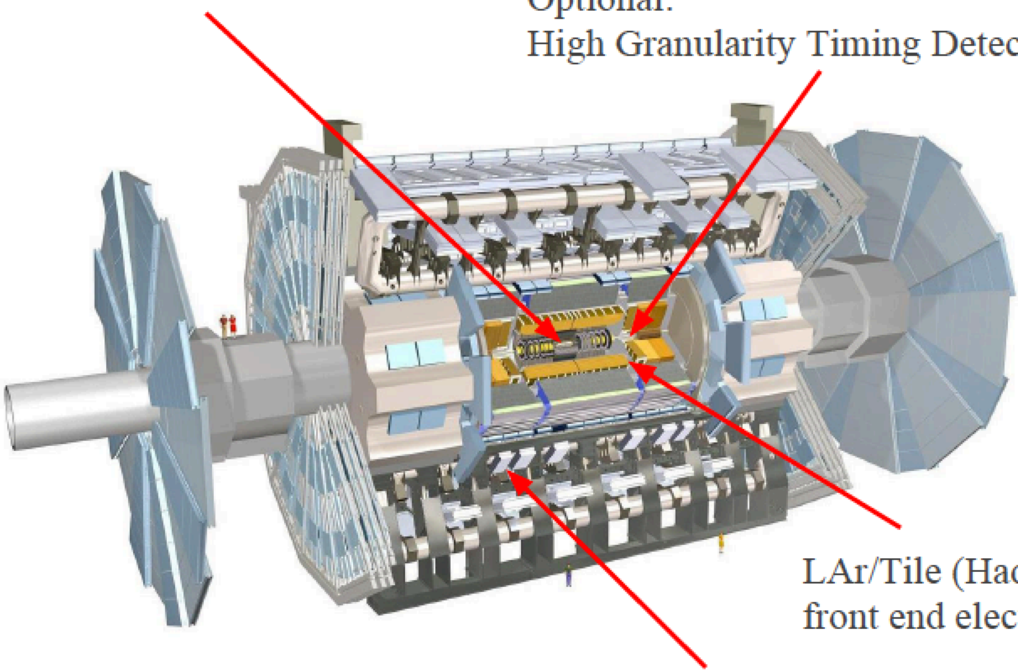
Trigger/DAQ
- L1 (hardware) with tracks and rate up ~ 750 kHz
- L1 Latency 12.5 μs
- HLT output rate 7.5 kHz
- New DAQ hardware

New all Al beam pipe with smaller cone angle and cyl. central pipe

Other R&D
- Fast-timing for in-time pileup suppression

Proposal for a Timing layer
- Timing resolution ~ 10 ps
- Space resolution ~ 10's of μm

ATLAS Phase 2 upgrade



DAQ off detector electronics:

- L0 hardware triggers will provide trigger decisions within a latency of 10 μs.
  - Based on muon and calorimeter data + their combinations in the topological processors.
- The L1Track trigger processes L0 RoIs to search for ITk tracks with high transverse momentum.
- The L1Global uses full-granularity calorimeter information and improved granularity for the entire detector.

Itk: All-silicon tracker which provides **coverage for tracking for up to $|\eta| < 4.0$.**
Optional: A new High Granularity Timing Detector (HGTD) instrumenting the gap region between the two LAr cryostats
Muon: new RPCs and sTGCs which are able to cope with the high rate trigger

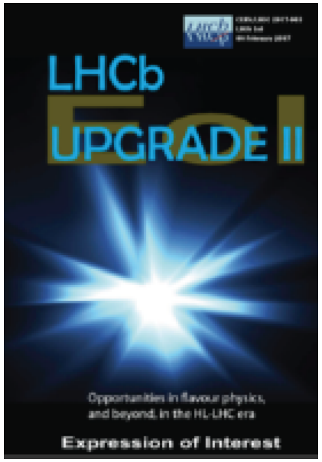
LHCb Phase 2 upgrade

CERN-LHCC-2017-003

	LHC era			HL-LHC era	
	Run 1 (2010-12)	Run 2 (2015-18)	Run 3 (2021-24)	Run 4 (2027-30)	Run 5+ (2031+)
ATLAS, CMS	25 fb^{-1}	150 fb^{-1}	300 fb^{-1}	⟶	3000 fb^{-1}
LHCb	3 fb^{-1}	9 fb^{-1}	30 fb^{-1}	50 fb^{-1}	*300 fb^{-1}

* assumes a future LHCb upgrade to raise the instantaneous luminosity to 2×10^{34} $cm^{-2}s^{-1}$

- A first upgrade (Phase I) will be operational in Run-3
  – Will raise the instantaneous luminosity to 2×10^{33} $cm^{-2}s^{-1}$ (x5)
  – Improved tracking and new "trigger-less" scheme
- LHCb has submitted at the beginning of 2017 an Expression of Interest for a further upgrade (Phase II) to reach 2×10^{34} $cm^{-2}s^{-1}$ (x50 wrt now)



→ New physics searches in the flavour sector

Strategy for physics at HL-LHC

- HL-LHC is a great opportunity to address some of the questions mentioned
- Focus on relatively broad scenarios with rather generic expectations
- Make use of either consistent EFT approach when possible or simplified models
- Perform specific “signature based” analyses with minimum theoretical bias → model independent studies
- Think about new strategies optimized for HL-LHC and maybe not been overlooked because not optimal at LHC (different triggers)
- In case of a deviation from the SM prediction focus on more specific BSM assumptions to identify the origin of new physics
- In case of no deviation the constraint should be set in the most model independent way possible.

Analysis approaches for HL-LHC

- **Method 1 – Full simulation (CMS)**: use of the most advanced geometry, algorithms and tuning, PU simulation

- **Method 2 - Full analysis with parameterized detector performance (CMS)**: use DELPHES with up-to-date phase-2 detector performance (tracking, vertexing, timing, dedicated PUPPI jet algorithms, increased acceptance, performance of new detectors)

- **Method 3 - truth + smearing (ATLAS):** truth-level events overlaid with jets (full sim) from pileup library, reconstruct particles (electrons, muons, jets, MET) from truth+overlay and smear their energy and p_T using appropriate smearing functions
  - Cross checked with some of the 'real' data analyses

- **Method 4: projections (mostly CMS and LHCb)**
  - Existing signal and background samples (simulated at 13 TeV) scaled to higher lumi and √s luminosity and 14 TeV. Analysis steps (cuts) from present analyses
  - 2 scenarios for uncertainties:
    - Scenario 1: all systematic uncertainties are kept unchanged with respect to those in current data analyses + PU/detector upgrades (S1+)
    - Scenario 2: the theoretical uncertainties are scaled by a factor of 1/2, while other systematical uncertainties are scaled by $1/\sqrt{L}$ + PU/detector upgrades (S2+)

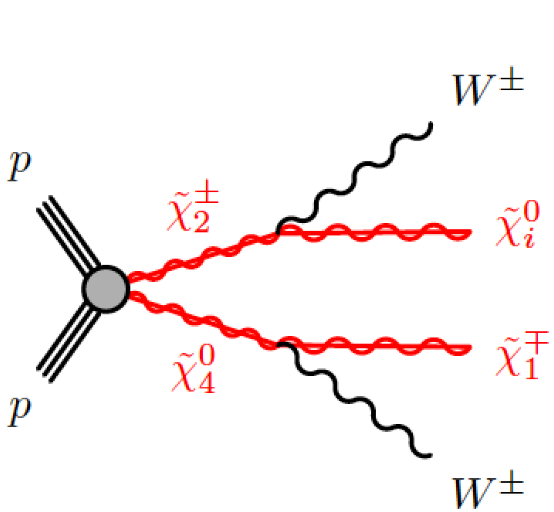
SUSY particles

SUSY: signatures with multi-leptons (1)

SUSY in a natural scenario with higgsino, bino, and wino at a few hundred GeV scale or below, and almost mass degenerate higgsino-like → low p_T particle and in the forward region

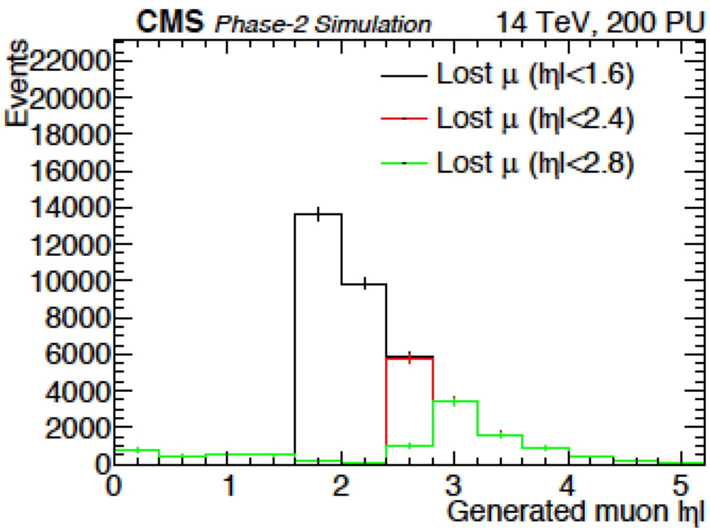
CMS TDR-17-003

Example: $\tilde{\chi}_2^{\pm}, \tilde{\chi}_4^0$ signal process which yields two **same-sign leptons** and large MET in the final state (BR in Ws = 25%)



Analysis is performed using DELPHES and a scenario with an average of 200 pileup events

WZ background events



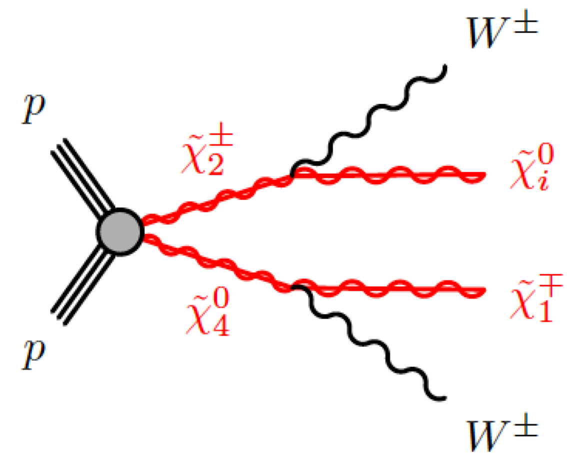
Muon detector coverage extended from |η| < 1.6 to |η| < 2.8

→ WZ background in the selected mode decreases by a factor four.

The improved **muon** detector acceptance will lead to reduced backgrounds and improved sensitivity in this analysis and for a whole class of similar searches for new physics.

SUSY: signatures with multi-leptons (2)

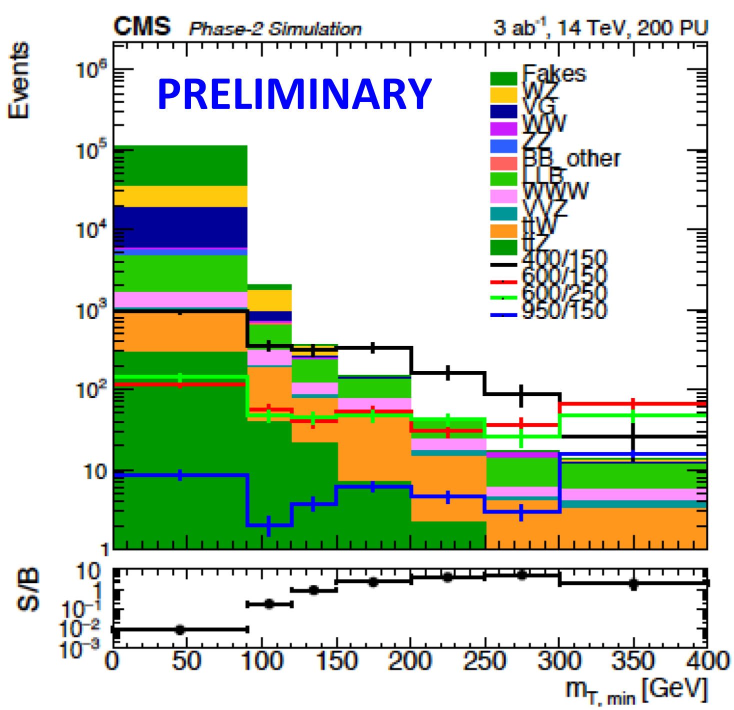
CMS TDR-17-007



Forward calorimeter (HGCAL) is a critical subdetector for this analysis as optimal MET and jet reconstruction.
Two high quality and isolated leptons with p_T >20 GeV, $|\eta|<$ 1.6, and same charge, veto of the third lepton and jets. DELPHES simulation

Cut on transverse mass

$$m_{T,min} = \min[m_{T(lep_1, p_T^{miss})}, m_{T(lep_2, p_T^{miss})}].$$



μ = 150 GeV outside the reach of the Run 2
μ = 250 GeV outside the sensitivity of SS extrapolated to HL-LHC

M2 (GeV)	$\sigma_{\tilde{\chi}_2^{\pm}\tilde{\chi}_4^0}$ (fb)	r (μ = 150 GeV)	r (μ = 250 GeV)
500	56.42	0.4452	0.2568
600	25.05	0.253	0.3448
700	12.11	0.4238	0.4512
800	6.19	0.6464	0.576
900	3.30	1.043	0.957
950	2.44	1.1758	1.332

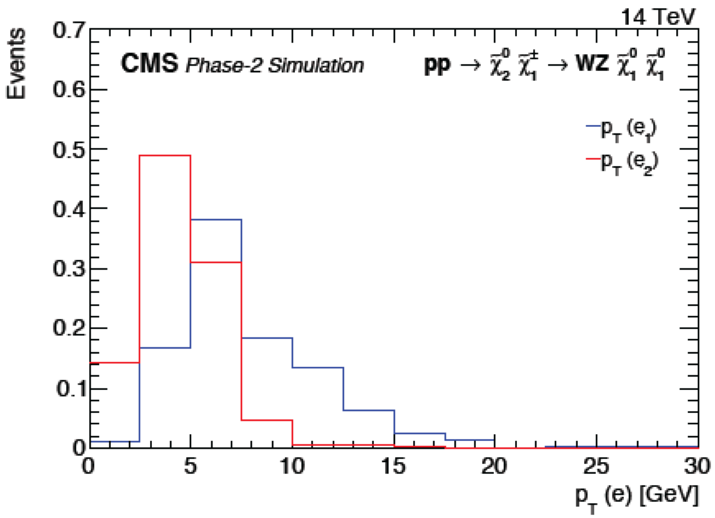
SUSY: electroweakino pair-production

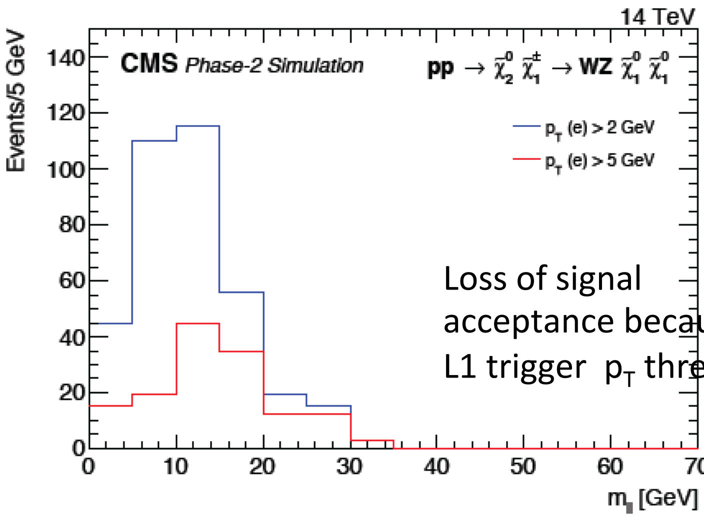
SUSY in a natural scenario with higgsino, bino, and wino at a few hundred GeV scale or below, and almost mass degenerate higgsino-like

CMS TDR-17-002

$\chi^{\pm}_1 \chi^0_2$ highest cross section, multiple leptons final state with low p_T leptons ← triggering on low leptons

Analysis performed in DELPHES with an average of 200 pileup events



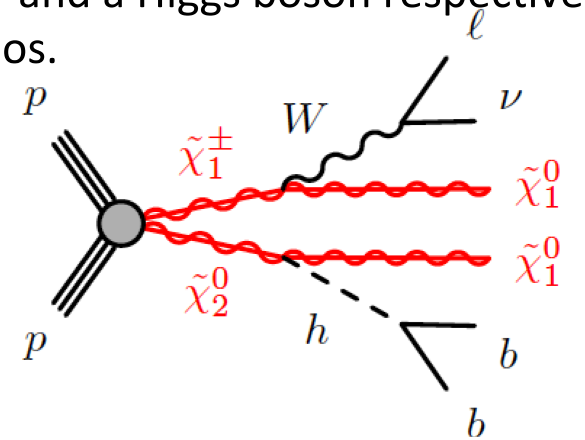


CMS upgraded calorimeter → highest crystal granularity information at L1 for better precision in the association to the tracker information → improved identification and isolation of the electromagnetic objects

SUSY: Chargino + neutralino pair production

ATL-PHYS-PUB-2015-032

Production of a neutralino and a chargino which decay to a W and a Higgs boson respectively and the LSP. Scenarios with heavy sleptons, squarks and gluinos.

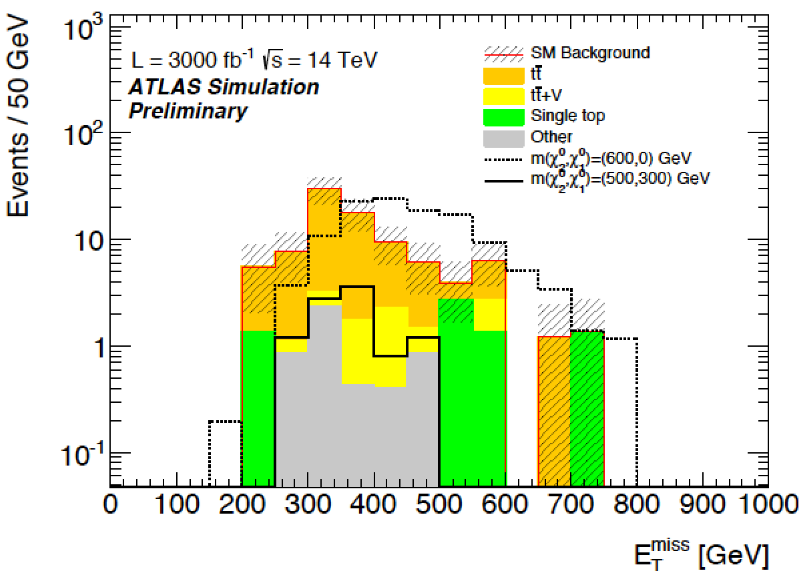


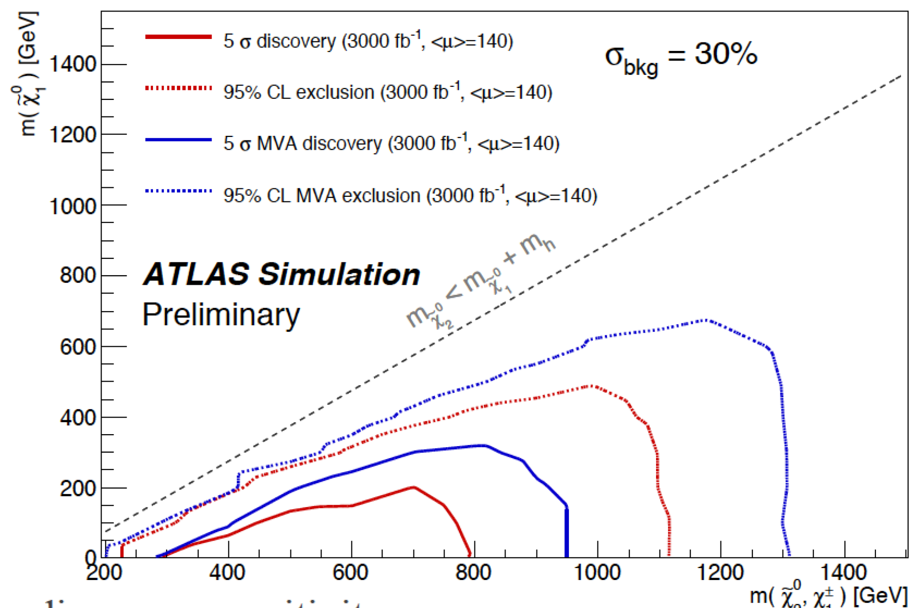
Signature:

- Chargino decaying to leptonic W
- Neutralino decaying to lightest Higgs boson, h→bbar
- Large MET

Largest background: ttbar, single top, ttV

- Cut-based and MVA analyses



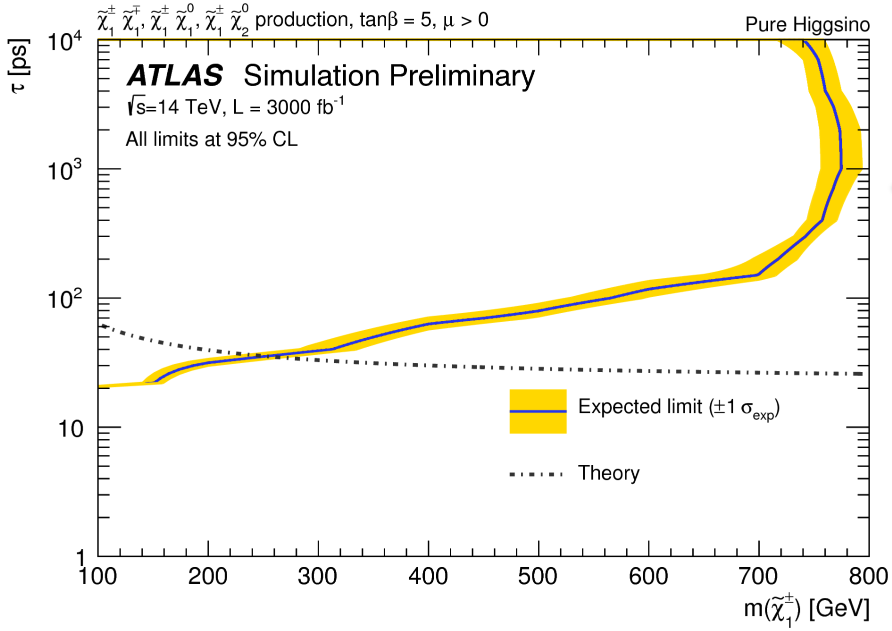


- 95% CL exclusion limits:
  - 1310 GeV in $\tilde{\chi}_2^0\,\tilde{\chi}_1^\pm$ mass
- 5σ discovery sensitivity:
  - 950 GeV in $\tilde{\chi}_2^0\,\tilde{\chi}_1^\pm$ mass

SUSY: Chargino/neutralino pair production

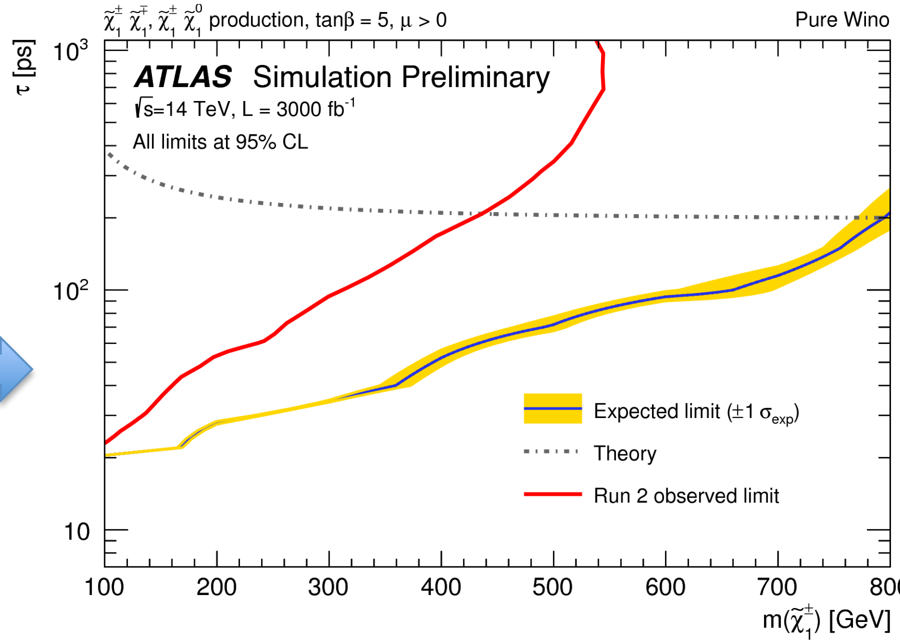
ATLAS-TDR-030
Pixel TDR

Simplified models are considered, including both $\chi^{\pm}_1$ pair production and associated production of a $\chi^{\pm}_1$ with a χ^{0}_1.



- Pure Higgsino LSP scenario
- 95%CL exclusion limit as a function of the $\chi^{\pm}_1$ mass and lifetime.

In the case of pure higgsino models, the associated production of a $\chi^{\pm}_1$ with a χ^{0}_2 is also included.

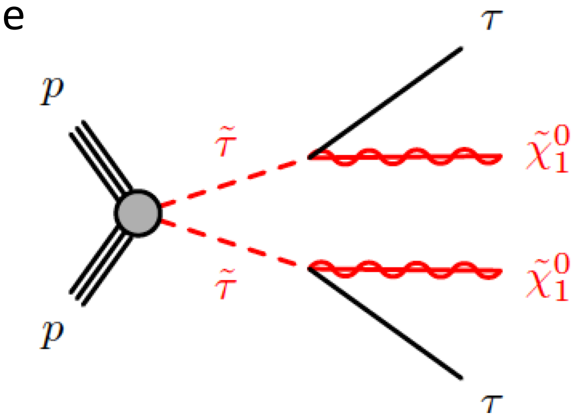


- Pure wino LSP scenario
- 95%CL exclusion limit as a function of the $\chi^{\pm}_1$ mass and lifetime.

SUSY: Direct production of stau pairs

ATL-PHYS-PUB-2016-021

If charginos and next-to-lightest neutralinos are too heavy to be produced at the LHC → production of stau pairs might become the dominant electroweak production process

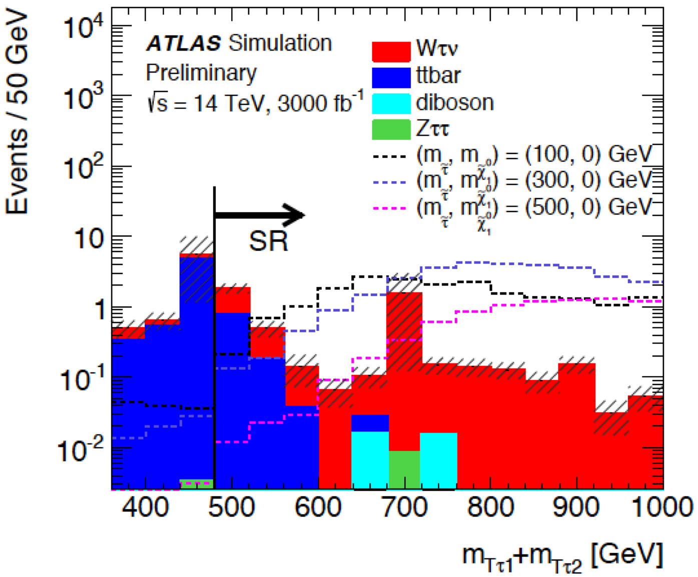


Signature:

- 2 tau jets (hadronically decaying)
- Large MET

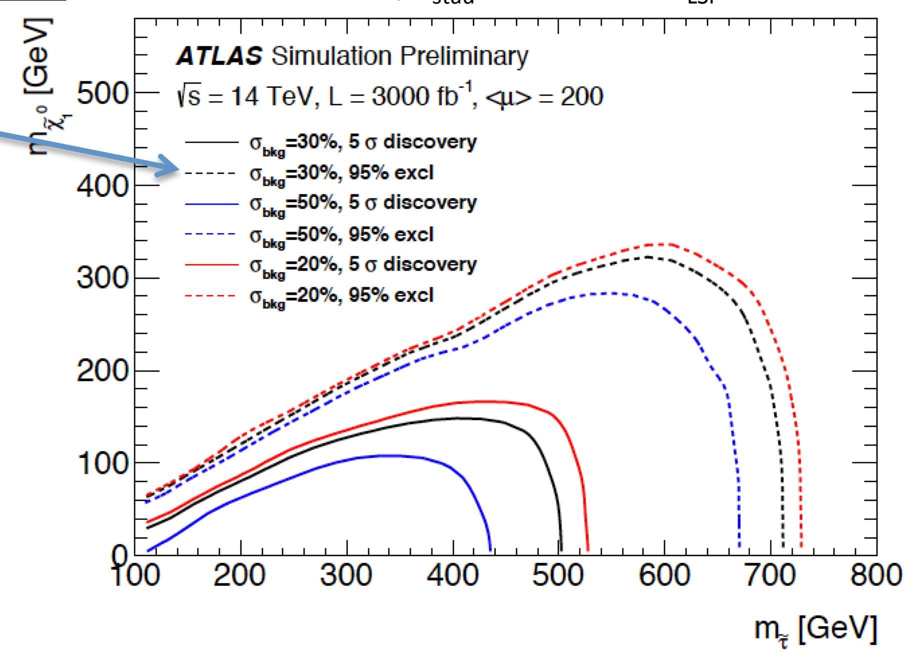
Main background: W+jets, ttbar

SR Definition
$\geq$ 2 OS taus
loose jet-veto
Z-veto
$\Delta R(\tau 1, \tau 2) < 3.5$
$E_{\mathrm{T}}^{\mathrm{miss}} > 280$ GeV
$m_{\mathrm{T2}} > 40$ GeV
$m_{\mathrm{T}\tau 1} + m_{\mathrm{T}\tau 2} > 480$ GeV



Different systematics on SM bkg

Current LHC results → no exclusion aside for one scenario (m_{stau} = 100 GeV, m_{LSP}=0 GeV



30% systematic →

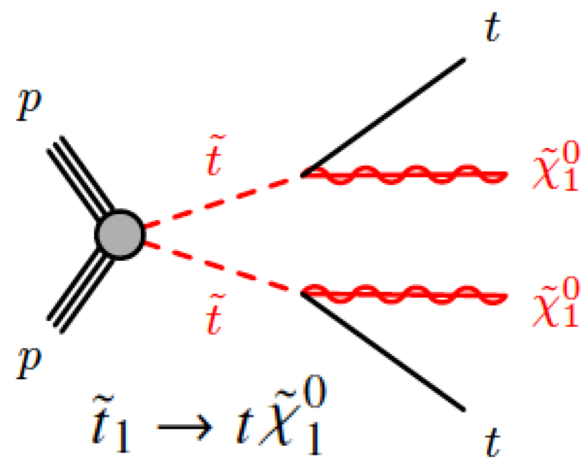
- 95% CL exclusion contour reaches 700 GeV
- discovery sensitivity reaches 500 GeV

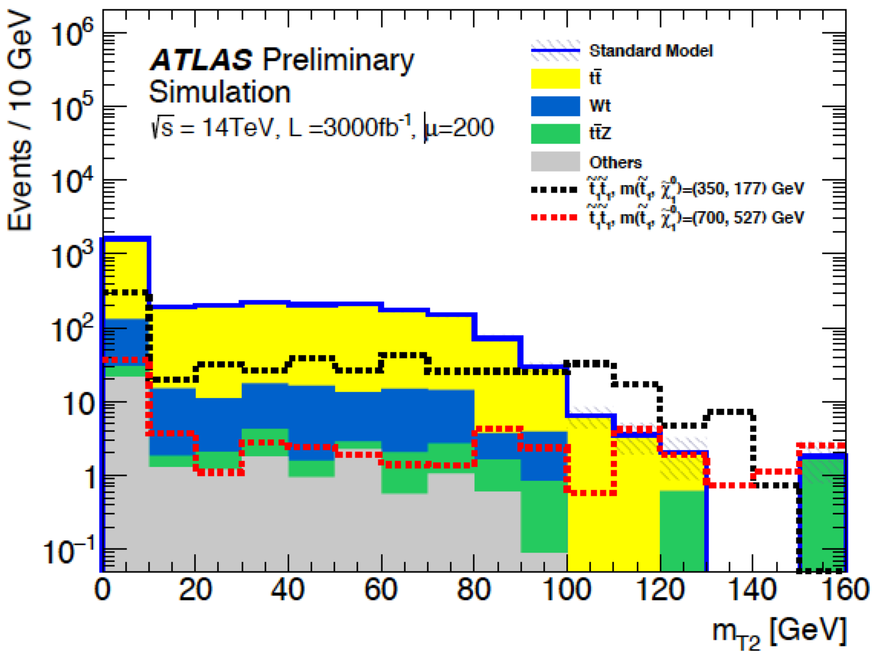
in stau mass for the combined left and right prod.

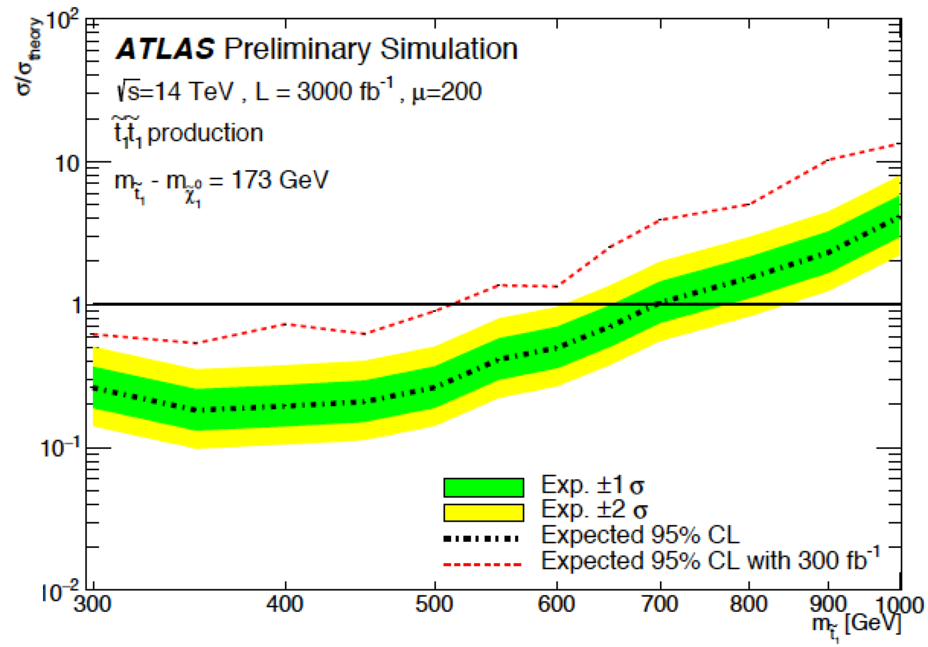
SUSY: Direct production of stop pairs

ATL-PHYS-PUB-2016-022

- Target models with compressed mass spectra
- Pair production of the lightest top squark mass eigenstate
- Xsection of top squark 1 pairs with a mass of 350 GeV and 700 GeV, are 4676 fb and 88 fb.
- exactly two electrons, two muons or one electron and one muon + 2 b-jets
- Transverse mass m_{T2} (l, MET) used as discriminating variable + other topological/kinematical cuts







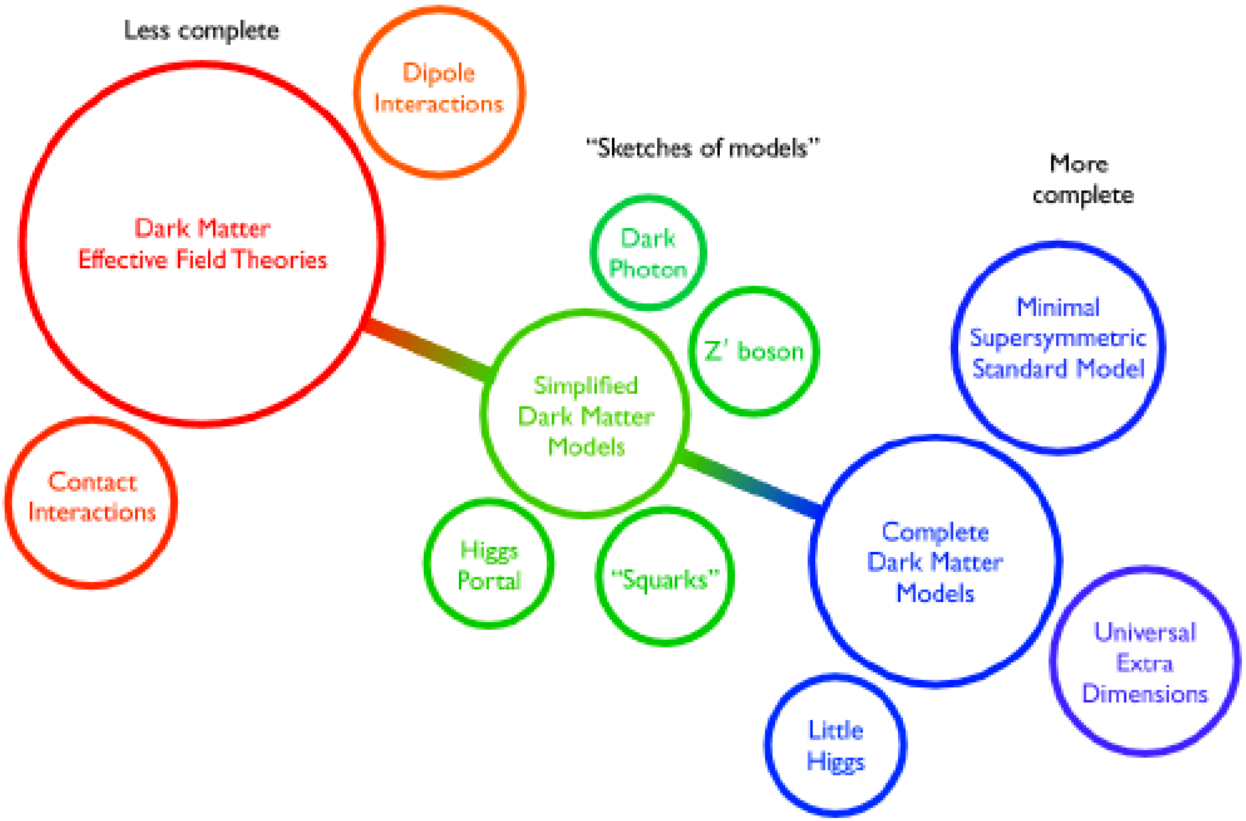
Masses up to 700 GeV excluded @ 95%CL

(currently [m_{top}, 191] and [230,380] GeV)

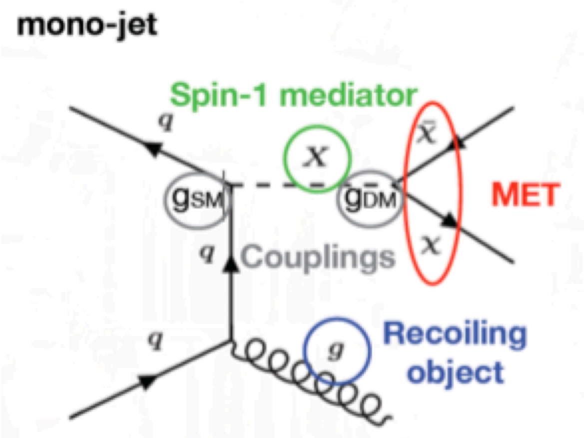
Dark matter

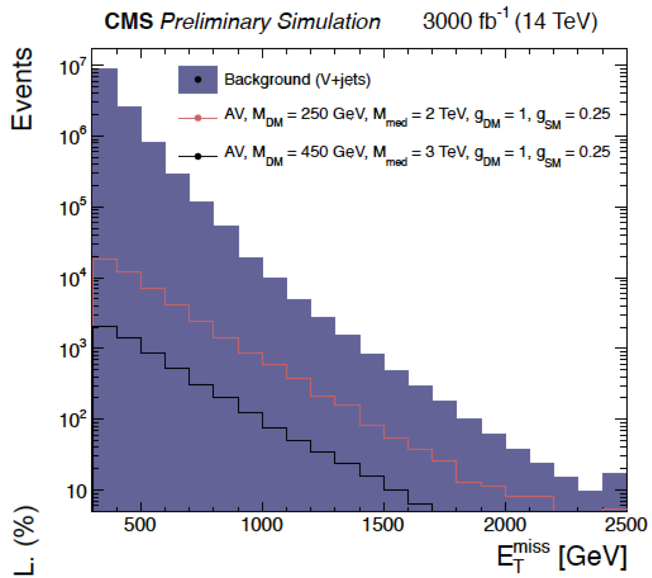
Dark matter searches

arXiv:1506.03116



Dark matter: mono-jet



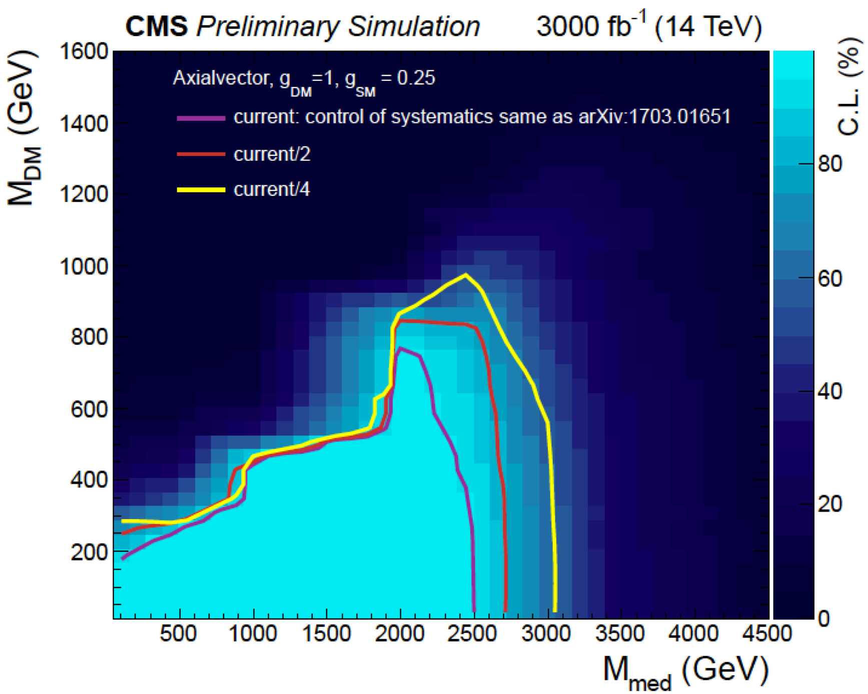


CMS FTR-16-005

Dominant bkg:

- $Z(\rightarrow \nu\nu)$ + jets
- $W(\rightarrow l\nu)$ +jets

→ V+jets



Comprehensive re-assessment of current efforts for HL-LHC not yet done

[analyses are often systematics limited, experimental sources hard to estimate, theoretical uncertainties might be conservative]

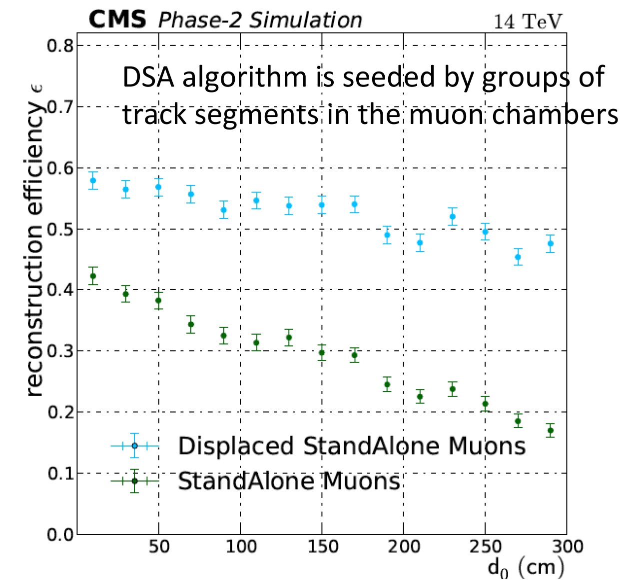
Long-lived particles

SUSY: Long lived particles (LLP)

CMS TDR-17-003

One of the possible signatures are: **displaced muons**

- $|d_0|$ can reach up to approximately one meter (or longer) for sufficiently large lifetimes → Trigger/reco of muons is challenging.
- Additional hits in the new endcap muon stations + improved algorithms, permit efficient triggering on displaced muon tracks

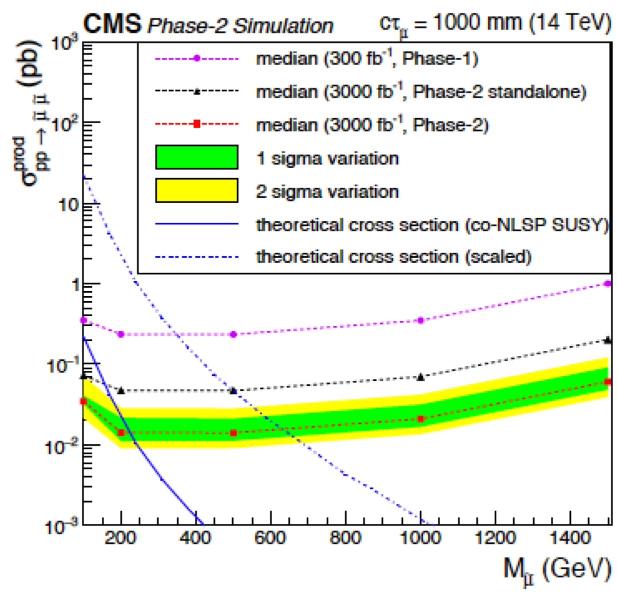


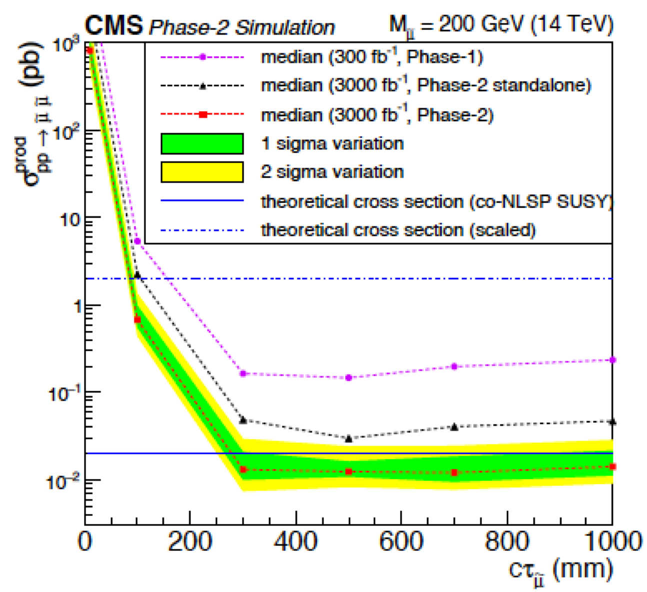
Gauge-mediated SUSY breaking models, smuons can be (co-)NLSPs and decay to a muon and a gravitino

$$q\bar{q} \rightarrow \tilde{\mu}\tilde{\mu}.$$

- Main background: QCD, tt and Z/DY→ll events

- Improved sensitivity with the new displaced muon algo (DSA)





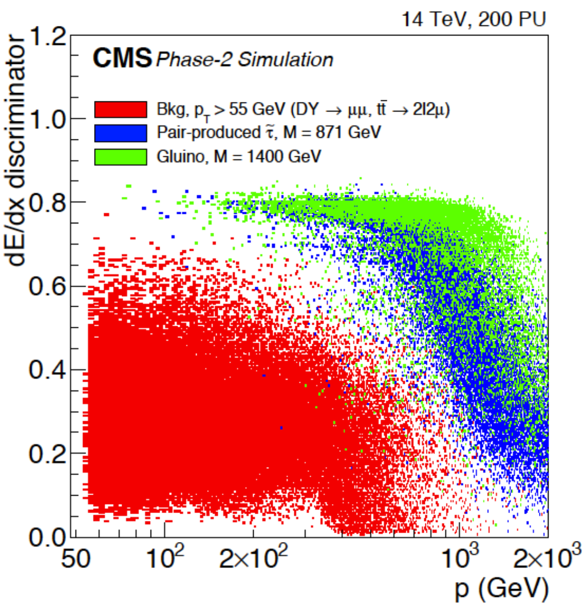
SUSY: Heavy stable charged particles (HSCPs)

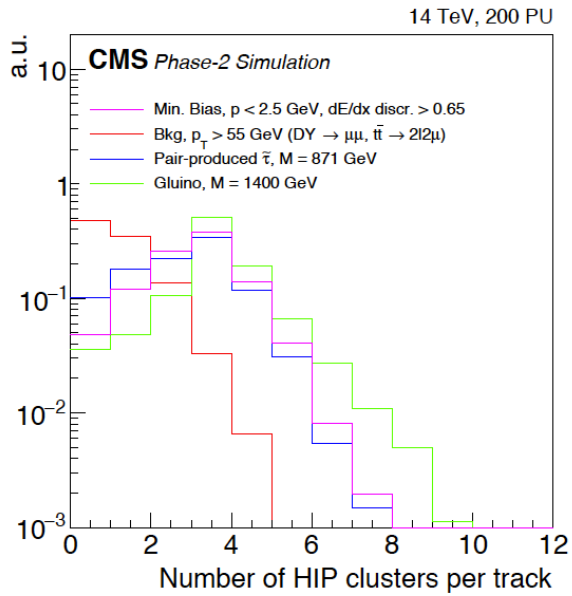
CMS TDR-17-001

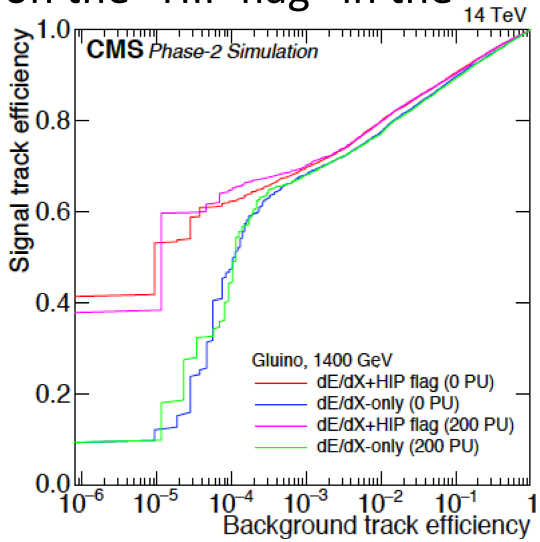
In **Split SUSY** all scalars are very heavy (~ PeV) while the spin-1/2 SUSY particles could be at the TeV scale → gluino can be heavy stable charged particles with long lifetimes that move slowly through the detector, heavily ionizing the sensor material as they pass through.

- Anomalously high energy loss through ionization (dE/dx) in the silicon sensors with respect to the typical energy loss for SM particles → need to keep dE/dx capabilites in Phase 2 Tracker
- Discriminating HSCPs from minimum ionizing particles based on the "HIP flag" in the readout system of the Outer Tracker.

p_T > 55 GeV tracks







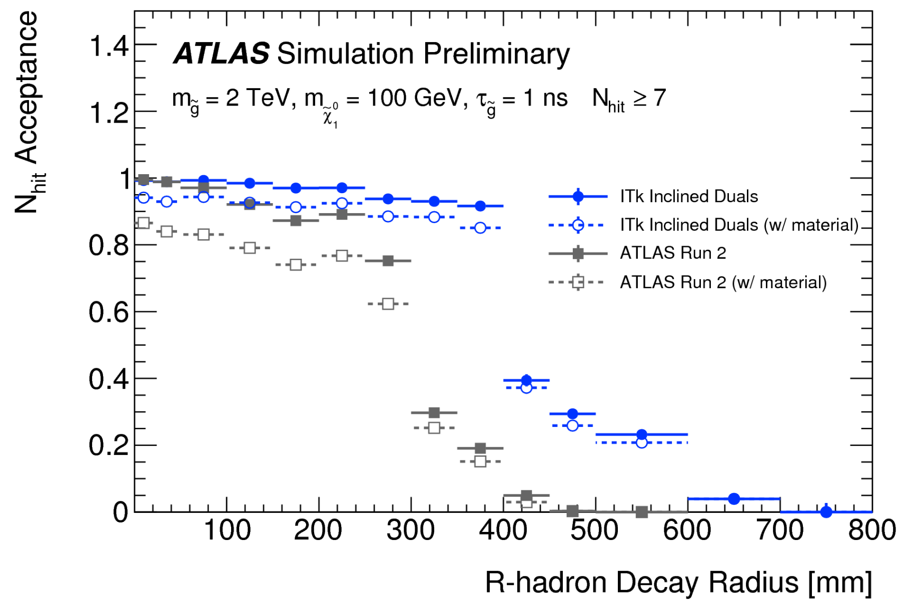
Additional CMS studies for HSBC via the Muon system also available, CMS TDR-17-004 (more in a dedicated talk)

Impact of the HL-LHC Pixel

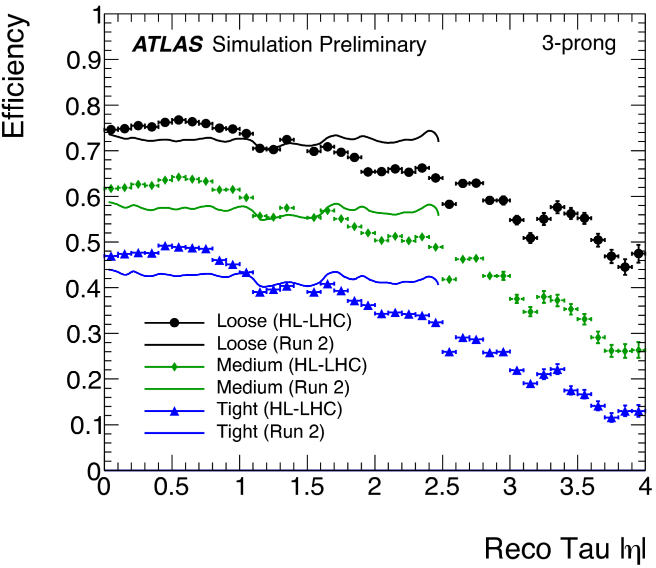
Courtesy of ATLAS collaboration

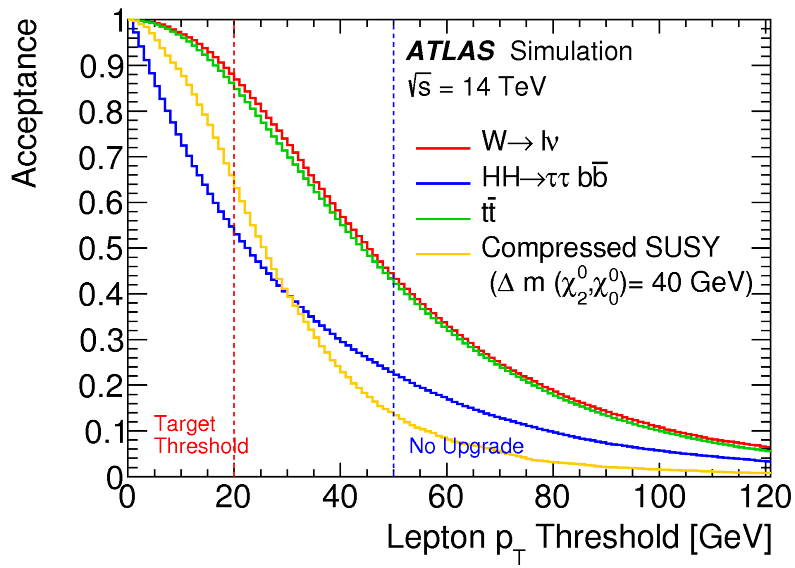
ATLAS-TDR-030, Pixel TDR

Potential to reconstruct decay products (displaced tracks) from displaced decays as a function of decay radii.



Tau reco efficiency





Lepton acceptance

Dark photon search at LHCb

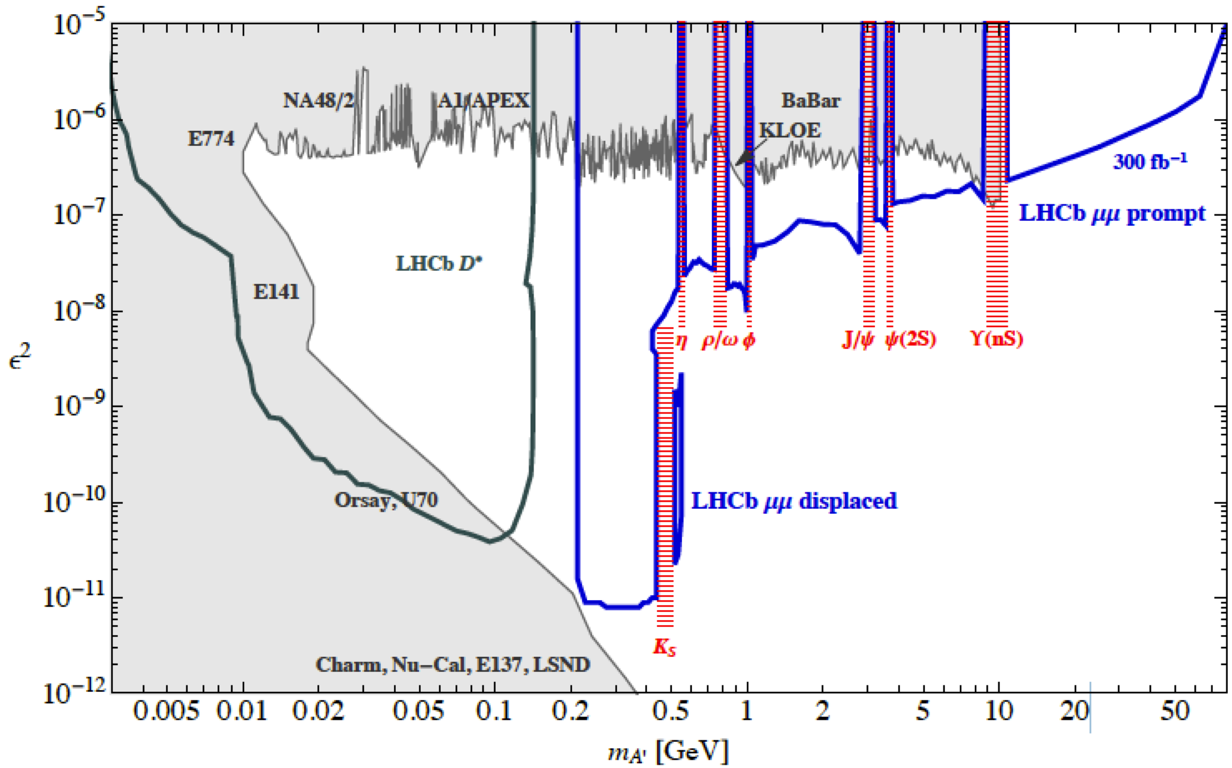
LHCb-PAPER-2017-038

arxiv 1608.08632

Dark sector couples to the SM only through a dark photon **A'**, which shares quantum numbers, and therefore mixes, with the SM photon
→ **A'** massive spin-1 particle, whose coupling to the electromagnetic current is suppressed relative to that of the ordinary photon, by a factor of ε .

Exploring the [m(A'), ε^2] parameter space

- inclusive search for $A' \rightarrow \mu^+\mu^-$ decays with the LHCb experiment
- pp → XA' → XA' with background coming from pp → $X\gamma^* \rightarrow X\mu^+\mu^-$ + other sources
- LHCb sensitivity for both prompt and displaced muons



Looking forward to Run 3:

- increase in luminosity
- removal of the hardware trigger

→ Increase the number of expected $A' \rightarrow \mu^+\mu^-$ decays in the low-mass region by a factor of O(100/1000) compared to the 2016 data sample.

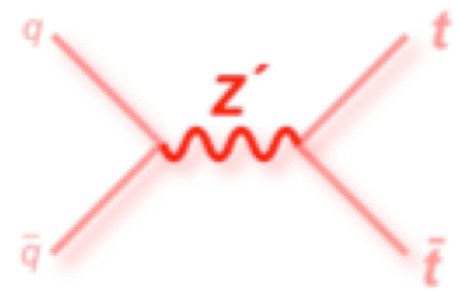
Heavy resonances

New heavy bosons: Z’→ttbar

Topcolour model containing a spin-1 leptophobic Z’ boson **ATL-PHYS-PUB-2017-002**

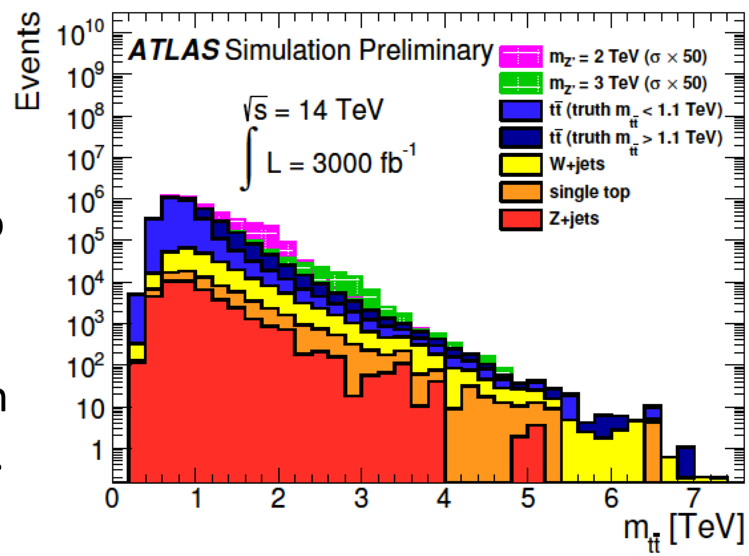
Analysis done for Z´→tt→WbWb→lνbqqb semi-leptonic decay cl

- $m_{Z'}$ = 1-7 TeV
- signal width of 1.2%.
- main background is SM ttbar production
- Search for local excess or deficit in the ttbar mass spectrum

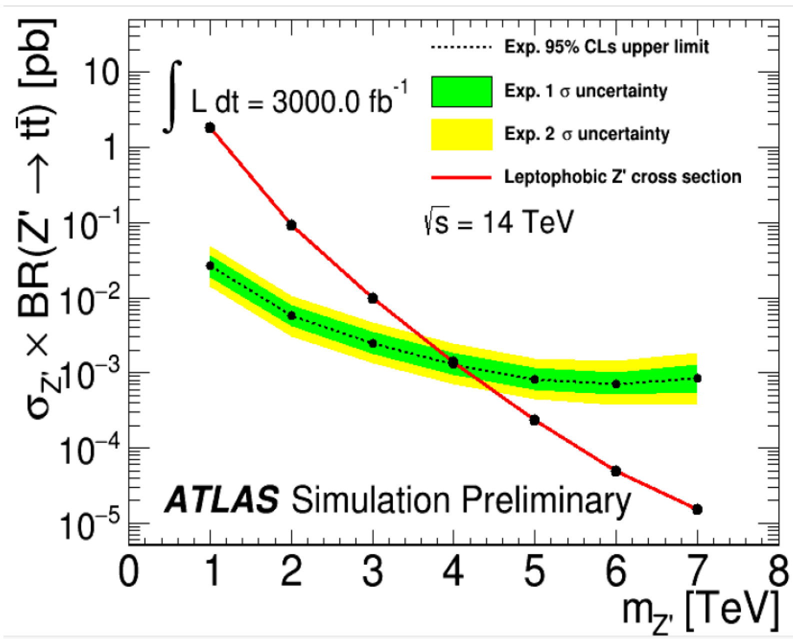


Effects of an upgraded ATLAS detector taken into account by applying energy smearing, efficiencies and fake rates to truth level quantities, following parameterizations based on detector performance studies with full simulation and HL-LHC conditions.

- **Resolved** and **boosted**
- Exclusion up to **4 TeV**
- 1 TeV gained in exclusion w.r.t. 300 fb^{-1} scenario



(d) Boosted Muon Channel.



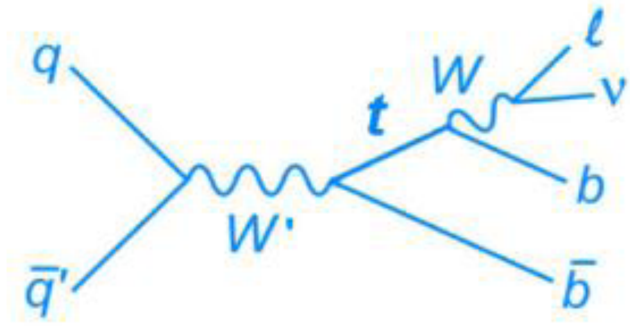
CMS projections → Either with equal uncertainties or improved wrt current analysis → O(4 TeV) exclusions

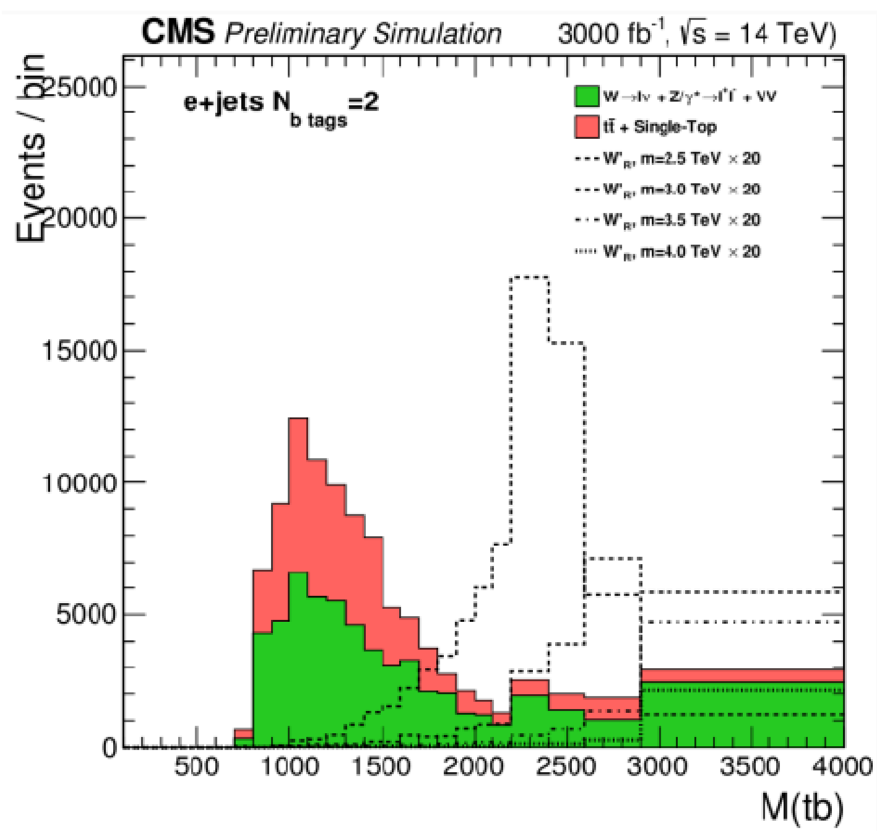
New heavy bosons: W'→tb

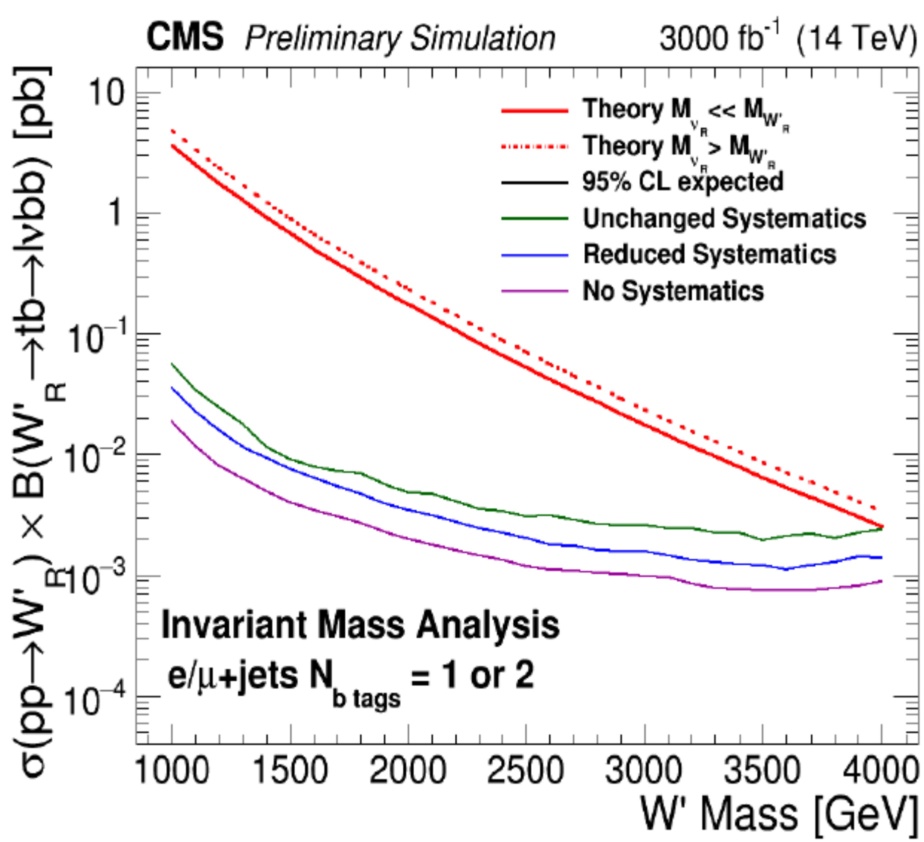
CMS-PAS-FTR-16-005

Signature:

- e/mu plus 1 or 2 bjets
- Discriminating variable M(tb)
- Projections performed assuming NWA using 2015 and 2016 analyses

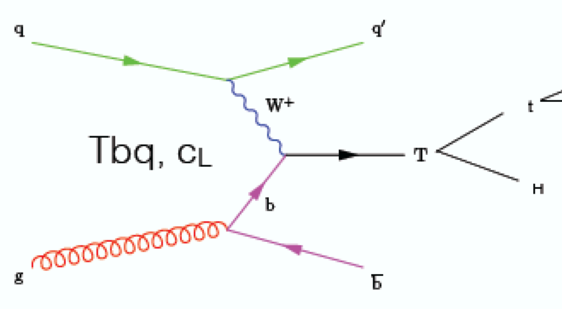


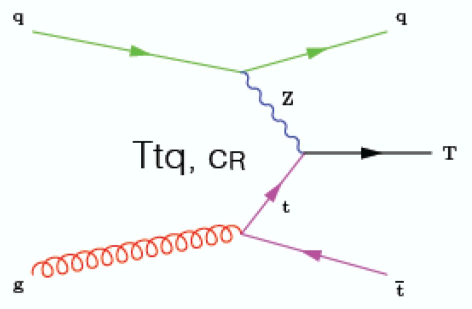


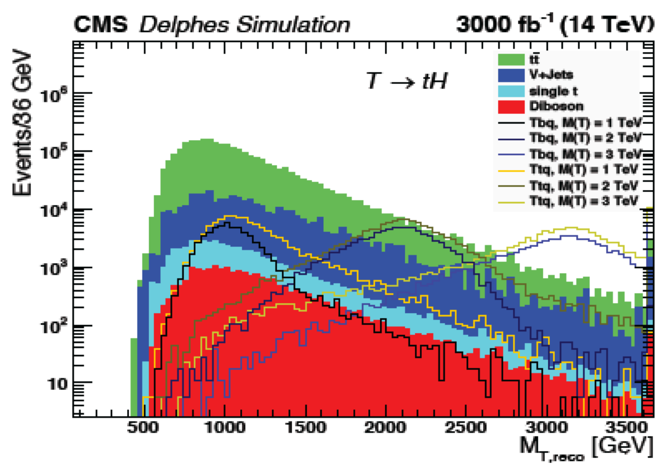


Vector-like quarks: T→tH

CMS–PAS–FTR–16–005



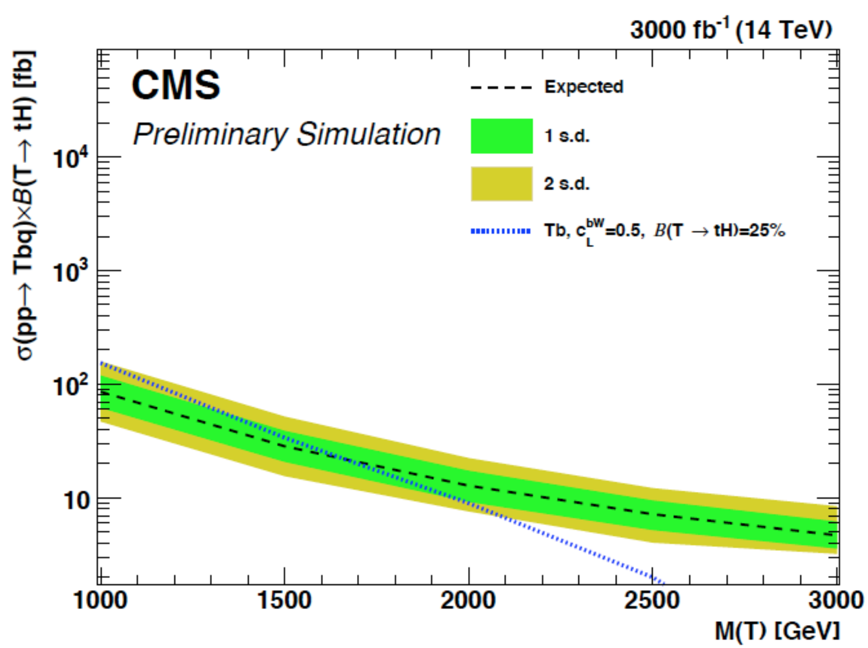


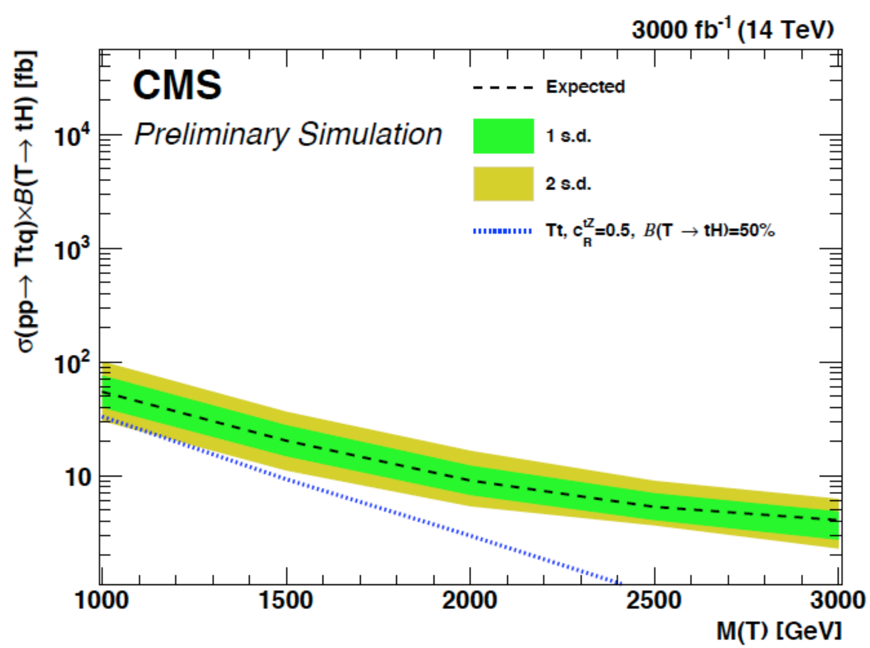


Signal topology:

- T → t H → (lvb) (bb) : single lepton + jets + Higgs

Backgrounds: tt+jets, V+jets, single top and dibosons





Contributors to WG3 (1)

Contributors **Tentative list of authors**		**Title** **Tentative title of the contribution**	
F. Meloni, P. Pani, M. Rimoldi	ATLAS	Prospects for associated production of dark matter and top quark pairs at the HL-LHC	
M. McDonald, F. Ungaro	ATLAS	Prospects for associated production of dark matter and bottom quark pairs at the HL-LH	
S. Biswas, E. Gabrielli, M. Heikinheimo, B. Mele		Searching for dark photons via Higgs-boson production at the HL-LHC and HE-LHC	
S.Amoroso		Sphalerons in proton-proton collisions	
S. Chekanov, J. Childers, D. Frizzell, J. Proudfoot, R. Wang		Precision searches in dijets at the HL-LHC and HE-LHC	
C. Scherb, F. Yu		Sensitivity to SM HH in bb+gamma gamma at HE-LHC	
H. Alhazmi, B. Fuks, J.H. Kim and K. Kong		Prospects for triple Higgs production at the HE-LHC	
J.K. Anders, F. Meloni, C. Merlassino, M. Saito, R. Sawada		Prospects for disappearing track analysis at HL-LHC	ATLAS
M. Saito, R. Sawada, K. Terashi		Prospects for disappearing track analysis at HE-LHC	
H. Dreiner, M.E. Krauss, V. Martin-Lozano		Displaced R-Parity Violation at the LHC	
Tao Han, Tong Li, Richard Ruiz			
D. Buttazzo, F. Sala, A. Tesi		Singlet-like scalars at HL and HE LHC	
B.C. Allanach, D. Bhatia, A. Iyer		Dissecting Multiphoton Resonances at the LHC	
R.Les, T.Nitta, K.Terashi, V.Cavaliere	ATLAS	Prospects for diboson resonance at HL-LHC and HE-LHC	
D. Debnath, J. Gainer, D. Kim		Improving sensitivity to heavy resonance decaying 4 leptons at the HL-/HE-LHC	
S. Heinemeyer, J. Kalinowski, M. Mondragon, N. Tracas, G. Zoup		Prospects for realistic SUSY models at the HL-/HE-LHC	
Howard Baer, V. Barger, J. Gainer, Xerxes Tata		Prospects for radiative natural SUSy at HL- and HE-LHC	
S.Amoroso, B.Petersen, P. Tornambe	ATLAS	Compressed electroweakinos at HL- and HE-LHC	
S. Carrà, T. Lari	ATLAS	Prospects for chargino pair production at HL- and HE-LHC	
C.Zhu, X. Zhuang	ATLAS	Prospects for direct stau production at the HL-LHC	
P. Konar, T. Mondal, A. K. Swain		Constraining slepton and chargino through compressed top squark search	

→ **more people contributing…**

Contributors to WG3 (2)

T. Han, A. Ismail, B. Shams Es Haghi	Probing SUSY at HL- and HE-LHC	
H. Alhazmi, J.H. Kim, K. Kong, I. Lewis	Radiative Decays of Top-partners at the LHC	
R. Dermisek, E. Lunghi, S. Shin	Vectorlike quarks and leptons in extended Higgs sector	
D. Barducci, L. Panizzi	VLQs at HL- and HE-LHC: discovery and characterization	
B.C. Allanach, B. Gripaios, T. You	New Physics Prospects From B->K(*) mu mu	
A. Deandrea, G. Cacciapaglia, A. Iyer	Search for light composite objects at LHC	
L. Jeanty, E.D. Frangipane, H. Oide, S. Pagan Griso, N.E. Petters	Prospects for LLP->DV+MET	ATLAS
A. Mariotti, D. Redigolo, F. Sala, K. Tobioka	Axion-like particles at the LHC	
I. Vivarelli, K. Suruliz, M. Spina	Prospects for third generation squark production at the HL-LHC and HE-LHC	ATLAS
A. De Santo, I. Vivarelli, B. Safardazeh, F. Trovato	Prospects for C1N2 via WZ and Wh in multilepton at the HL-LHC and HE-LHC	ATLAS
C. Sebastiani, S. Giagu, M. Corradi, A. Policicchio	Prospects for long-lived dark-photon decays (lepton-jets) at HL-LHC and HE-LHC	ATLAS
G. Gustavino	Prospects for DM interpretations in jet+MET analysis at HL/HE-HLC	ATLAS
M.D'Onofrio, Y. Gao, M. Sullivan	Search for charg-neut in Wh channel using 1Lbb final states	ATLAS
F. Meloni, P. Pani	Prospects for 4 top signatures at the HL/HE-LHC	
Y.Ng, D. Guest, J.Gramling	Fitting techniques using Gaussian Processes for resonance searches	
G. Cacciapaglia, G. Ferretti, T. Flacke, H. Serodio	Search for light pseudo-scalar with taus	
L. Carminati, M. Cirelli, A. Demela, M. Perego, S. Resconi, F. Sala	Prospects for pure WIMP (pure triplet) Dark Matter at HL-LHC	ATLAS
P. Pani, G. Polesello	HL/HE-HLC prospect for DM and a single top-quark production in a 2HDM model with a pseudoscalar mediator	
U. Haisch, P. Pani, G. Polesello	HL/HE-HLC prospect for determining the CP nature of spin-0 mediators in associated production of dark matter and top pairs	

X. Cid Vidal, C. Vázquez Sierra	Prospects for LLP->mu+jets at the HL-LHC	LHCb
X. Cid Vidal, C. Vázquez Sierra	Prospects for LLP->dijets at the HL-LHC	

P.Azzi, R.Leonardi, M.Narain, O.Panella, M.Presilla, F.Simonetto	Production of exotic composite quarks at HL-LHC and HE-LHC	CMS

→ more people contributing…

Contributors to WG3 – more topics

CMS

- Vector-like quark discovery reach
- light Higgsino - ISR + 2leptons
- light Higgsino - VBF + leptons
- same-sign dilepton SUSY
- staus (had-had and had-lepton channels)
- DM in single top + MET
- tt resonance (hadronic with substructure)
- fast timing signatures for long-lived particles
- resonances -> 4b
- heavy stable charged particles (dE/dx and TOF)
- displaced muons
- DM monojet (from ECFA2016)
- W'->tb discovery reach (ECFA2016)
- Z' property studies
- W'->l,nu discovery reach and weak couplings
- various older SUSY studies (from ECFA2016)

ATLAS EXPERIMENT

- SUSY strong - improved searches for squark/gluinos
- DM + bb searches
- SUSY 3rd generation in 2 lepton (2016)
- Chargino neutralino2 pair production in WH final states (2016)
- direct stau production (2016)
- semileptonic ttbar resonances (2017)
- dijet resonances (2015)
- jet+MET DM searches (2014)

Documentation/Public references

CMS

CMS TDR-17-001 ”The Phase-2 Upgrade of the CMS Tracker”
CMS TDR-17-002 ”TDR for the Phase-2 Upgrade of the CMS Barrel Calorimeter”
CMS TDR-17-003 ”TDR for the Phase-2 Upgrade of the CMS Muon Detectors”
CMS TDR-17-007 ”The phase-2 upgrade of the CMS endcap calorimeter”
CMS FTR-16-005 “Estimated Sensitivity for New Particle Searches at the HL-LHC”

ATLAS

ATLAS-TDR-030 “Technical Design Report for the ATLAS Inner Tracker Pixel Detector**”**
ATL-PHYS-PUB-2017-002 “Study on the prospects of a *tt*bar resonance search in events with one lepton at a High Luminosity LHC”
ATL-PHYS-PUB-2016-021 “Prospects for a search for direct stau production in events with at least two hadronic taus and missing transverse momentum at the High Luminosity LHC with the ATLAS Detector”
ATL-PHYS-PUB-2016-022 “Prospects for a search for direct pair production of top squarks in scenarios with compressed mass spectra at the high luminosity LHC with the ATLAS Detector”
ATL-PHYS-PUB-2016-021 “Prospects for a search for direct stau production in events with at least two hadronic taus and missing transverse momentum at the High Luminosity LHC with the ATLAS Detector”
ATL-PHYS-PUB-2016-026 “Expected performance for an upgraded ATLAS detector at High-Luminosity LHC”
ATL-PHYS-PUB-2015-032 “Prospect for a search for direct pair production of a chargino and a neutralino decaying via aW boson and the lightest Higgs boson in final states with one lepton, two b-jets and missing transverse momentum at the high luminosity LHC with the ATLAS Detector.”

LHCb

CERN-LHCC-2017-003 “Expression of Interest for a Phase-II LHCb Upgrade”
LHCb-PAPER-2017-038 “Search for dark photons produced in 13TeV pp collisions”

Conclusions

- A new energy domain with a vast potential for new physics discoveries and precision measurements will open with the HL-LHC @ $\sqrt{s}$=14 TeV
  - with instantaneous luminosities up to $5\times10^{34}cm^{-2}s^{-1}$
  - integrated luminosity up to 3000 fb^{-1}
- It is a challenging project involving upgrades of ATLAS, CMS and LHCb detectors and the experience gained in Run 1/2 gives us confidence that the experiments will meet the physics prospects.
- New documents released by CMS/ATLAS/LHCb with benchmark studies (also complementary) carried out, with continued efforts to evaluate the prospects of BSM searches in parallel to data analyses
- Analyses carried out using different approaches (full simulation/projections/ truth-smearing/DELPHES) or assumptions (PU, modeling uncertainties, treatment of rare backgrounds)
- Synergic approach across HL-LHC experiments for the YR i.e. in new physics scenarios characterized by long-lived particles, for dark matter and dark sectors
- Projections for HE-LHC proceeding in parallel with theorists.

Backup

Modeling projections for HL-LHC

CMS extrapolation scenarios:

- S1: Systematic uncertainties constant, unchanged detector performances
- S2: Theoretical uncertainties scaled by 0.5, experimental uncertainties scaled by luminosity
- S1/S2+: Includes higher PU and detector upgrades effects

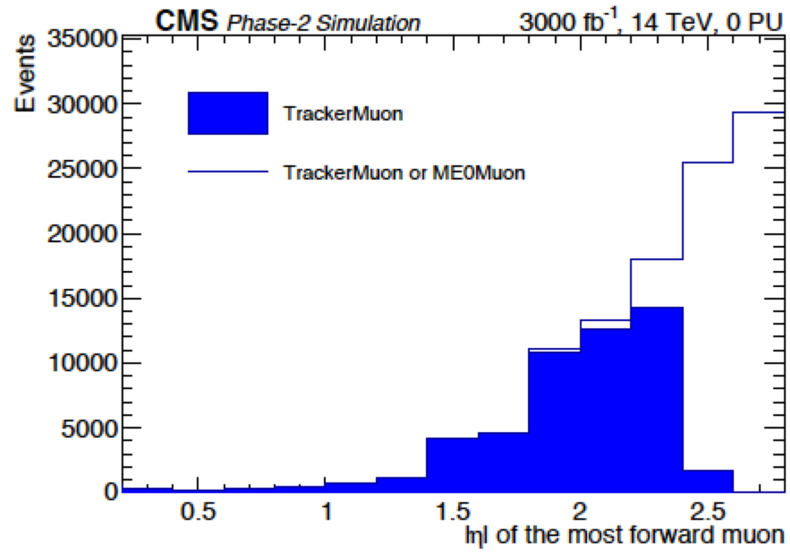
ATLAS extrapolation scenarios:

- Reference, middle and low scenario corresponding to different upgrade designs (from more to less performant)
- PU and upgrades taken into account for projections
- Theoretical uncertainties scaled by 1,0.5 or 0

Search for lepton flavour violating decay

$\tau \rightarrow 3\mu$ one of the "cleanest" LFV decay channel

- BR ($\tau \rightarrow 3\mu$) < 2.1×10^{-8} @90%CL by Belle experiment
- 10^{15} τ leptons will be produced over the lifetime of HL-LHC
- $\tau \rightarrow 3\mu$ decays have very low momenta and are significantly boosted in the forward direction
- The ME0 chambers, a part of the muon system upgrade, extend the CMS muon coverage in the first muon station from $|\eta| < 2.4$ to 2.82, which increases the signal fiducial acceptance by a factor of 2.0



Events in mass window 1.55–2.00 GeV

	Category 1	Category 2
Number of background events	2.4×10^6	2.6×10^6
Number of signal events	4 580	3 640
Trimuon mass resolution	18 MeV	31 MeV
$B(\tau \to 3\mu)$ limit per event category	4.3×10^{-9}	7.0×10^{-9}
$B(\tau \to 3\mu)$ 90%C.L. limit	3.7×10^{-9}	
$B(\tau \to 3\mu)$ for 3σ-evidence	6.7×10^{-9}	
$B(\tau \to 3\mu)$ for 5σ-observation	1.1×10^{-8}	

ME0 gives an effective gain in integrated luminosity (4.3/3.7)~ 1.35, i.e. from 3000 to 4000 fb^{-1}.