Search for top squark pair-production in SUSY models with compressed spectra

Navid K. Rad
HEPHY, Vienna, Austria
(on behalf of CMS Collaboration)

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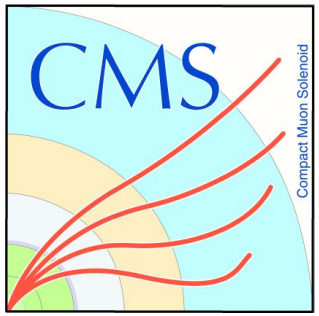
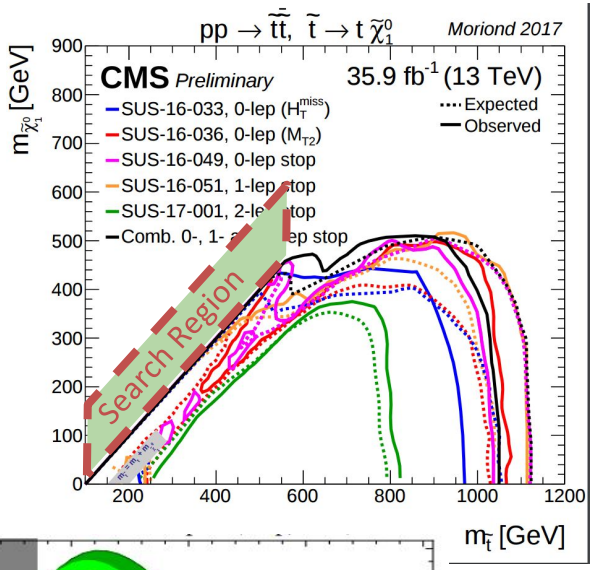


Motivation

Compressed SUSY:

- Relatively light stops are still possible!
- Coannihilation between stop and LSP can predict the right dark matter relic densities

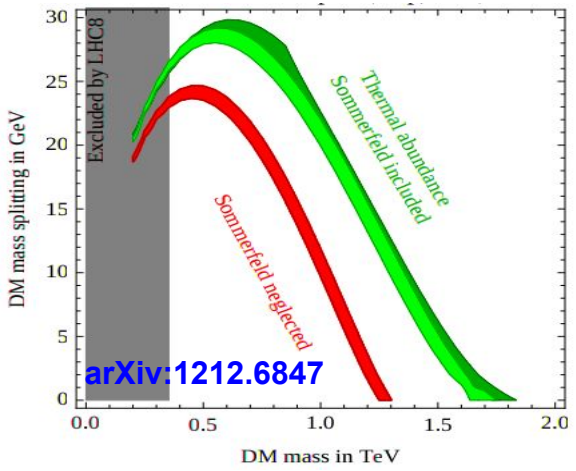


Target Model

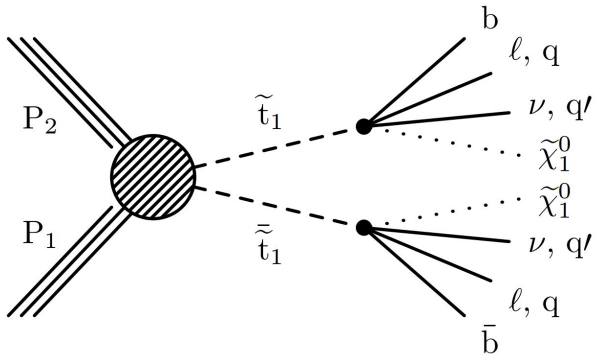
- Direct stop production with a nearly degenerate neutralino as the LSP:

  $\Delta m = m_{stop} - m_{LSP} < 80$ GeV

- two possible decay modes:
  - four-body : $\tilde{t}_1 \rightarrow f f' b \tilde{\chi}_1^0$
  - flavor violating: $\tilde{t}_1 \rightarrow c \tilde{\chi}_1^0$

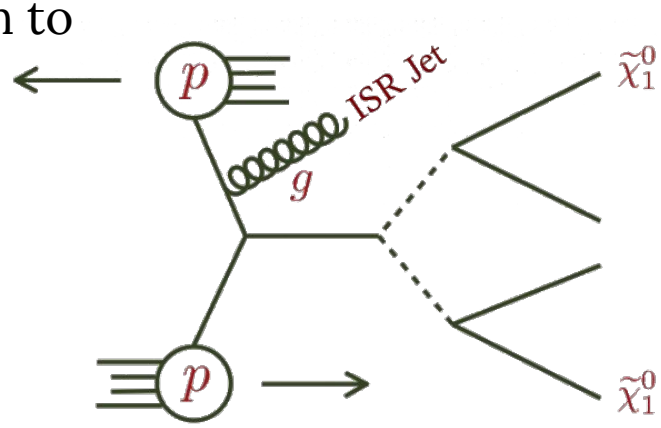


- Assume 100% BR to the four-body decay
- For this search we consider the single leptonic decay channel



Challenges

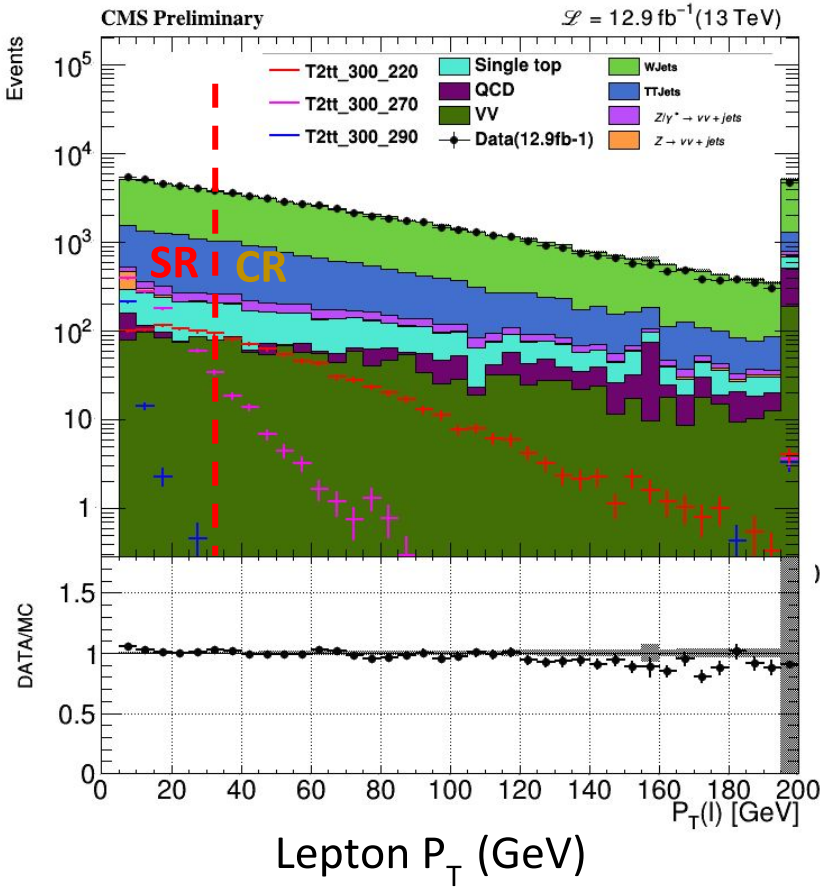
- Signature:
  - (e / mu) , b-jet , missing energy (E_T^{miss}) from neutrino and LSP
- Main Challenge:
  - Small mass difference → soft final state particles (small p_T)
- Too soft to be detected normally!
  - the trigger thresholds are much higher than typical energies of final state particles…
- Initial State Radiations (ISR):
  - radiation from the initial state partons
  - stop-stop system recoils against ISR and becomes boosted
  - final state particles become boosted enough to have a chance of being detected!
  - caveat: probability for a high P_T ISR is low



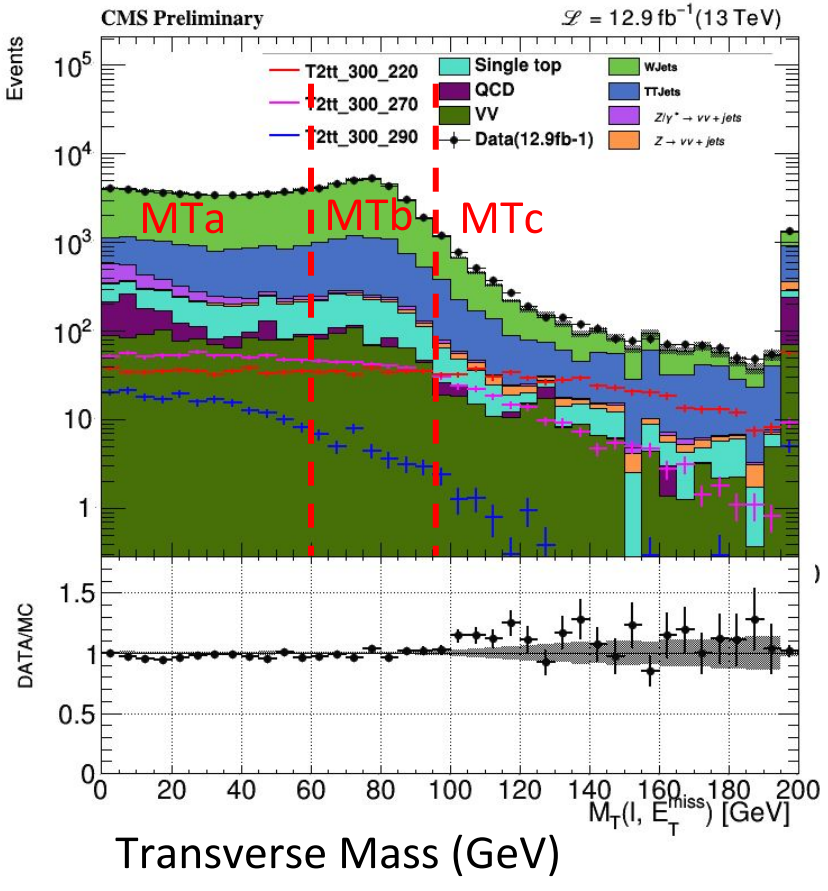
Baseline selection

- Signal characteristics:
  - 1 ISR Jet
  - Soft lepton
  - Moderate-high missing energy (from LSP and neutrino)
  - up to 2 soft b-tagged jets (unlikely for smaller Δm)
- Backgrounds:
  - Main: W+Jets, tt+jets
  - Others: Drell-Yan, Z→vv, QCD, single top production, diboson
- Require events with:
  - ISR: a high P_T jet (>100 GeV)
  - Single Lepton: one isolated lepton
  - moderate-high missing energy and hadronic activity (E_T^{miss} > 200 GeV , H_T > 300 GeV)
  - Soft jets from decay, <= 2 hard jets
- Discriminatory Variables
  - Transverse mass (m_T) $m_T = \sqrt{2 \cdot p_T^{\ell} \cdot E_T^{miss} \left(1 - \cos \Delta\phi(\vec{\ell}, \vec{p}_T^{miss})\right)}.$
  - Lepton Pt

Baseline selection



Lepton P_T (GeV)



Transverse Mass (GeV)

mStop = 300 , mLSP = 220

mStop = 300 , mLSP = 270

mStop = 300 , mLSP = 290

Single top
QCD
VV
Data(12.9fb-1)
W+jets
t $\bar{t}$ +jets
Z/γ* +jets
Z→ νν +jets

Signal and Control Regions

Signal Regions

Lepton P_T < 30 GeV

SR1 (low Δm)

- E_T^{miss} > 300 GeV
- H_T > 400 GeV
- Veto any b-jets
- Split MT in low/med./high: **(SR1a,b,c)**

SR2 (high Δm)

- E_T^{miss} > 300 GeV
- $P_T^{ISR\ Jet}$ > 325 GeV
- allow 1 soft b-jet but no hard b-jet

Control Regions

W+jets

- A CR for each SR but w/ Lepton P_T > 30
- (CR1a,b,c, CR2)

tt+jets

- Dedicated region with 2 b-tags (CRTT)

Validation Regions*

CR1a,b,c, CR2

200 GeV < C_T < 300GeV

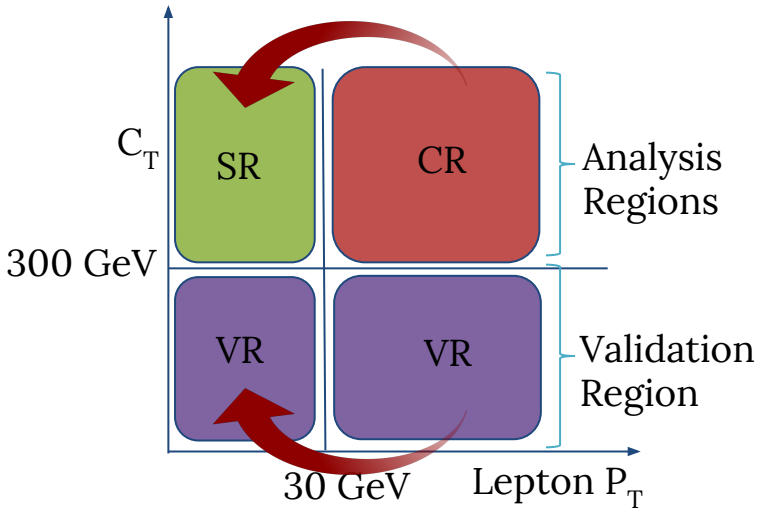
C_T= min(E_T^{miss} , H_T-100)

CRTT

1 hard b-tag & 0 soft b (Exclusive to CR & SR)

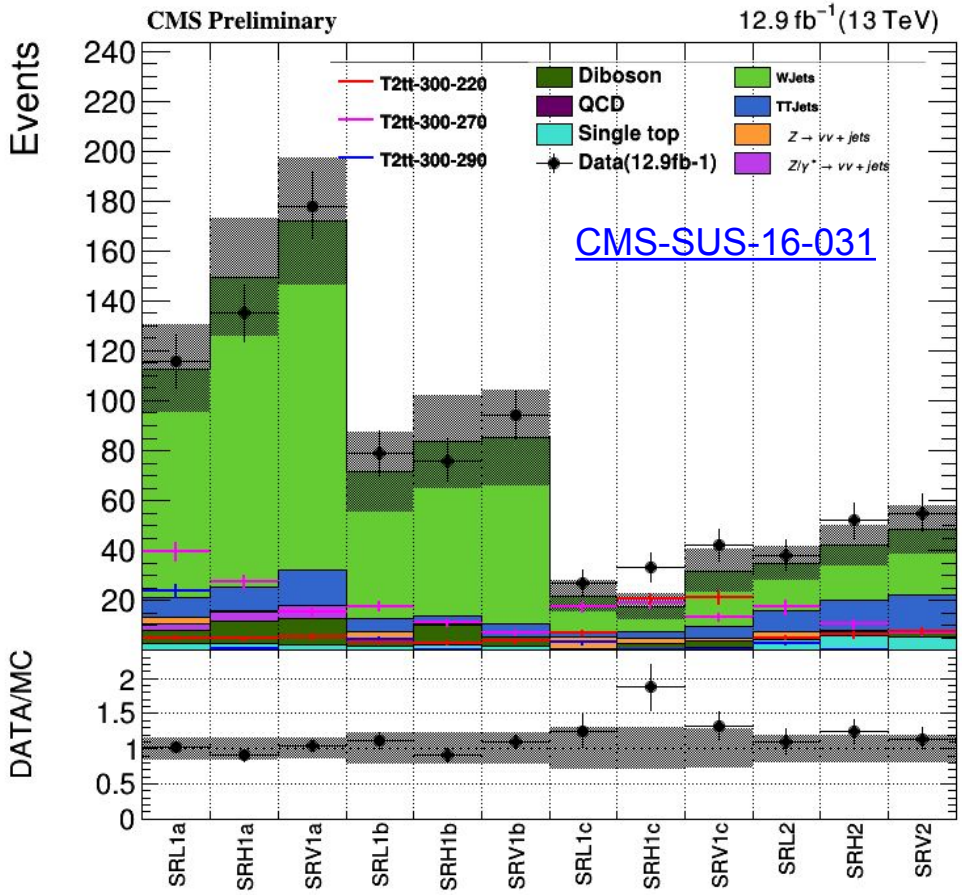
Lepton PT Shape:

All SRs (SR1a,b,c , SR2) are split in 3 different P_T(l) bins to take advantage of shape differences between signal and bkg



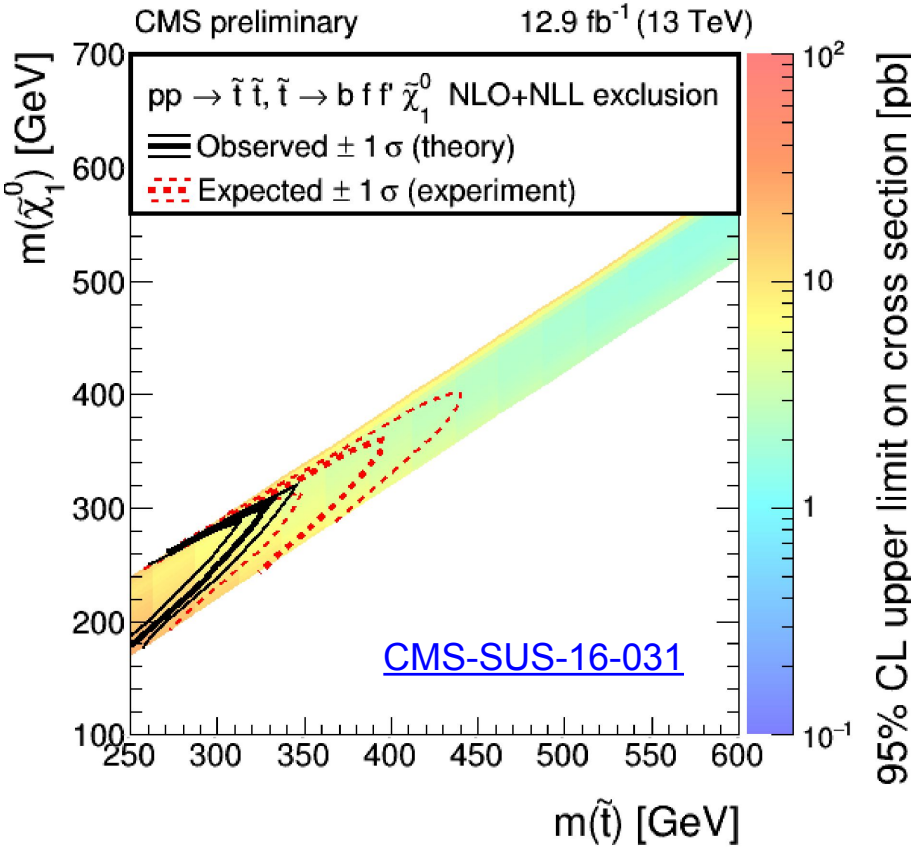
*Validation Regions used to assign systematics on the background estimation method

Results



no significant deviation from SM is observed

Interpretation



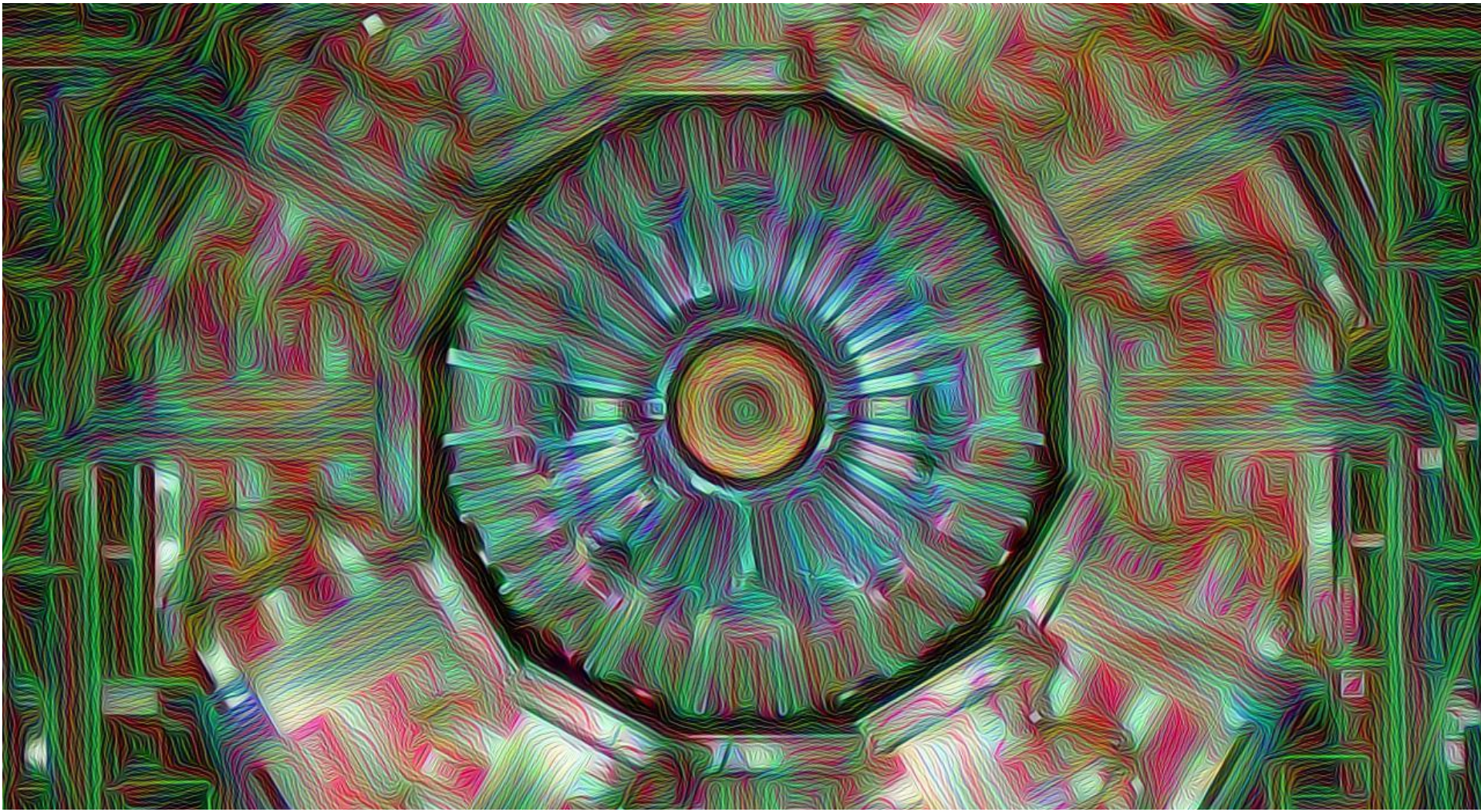
Observed mass limits at 95% CL reach up to ~330GeV in this simplified model

Summary

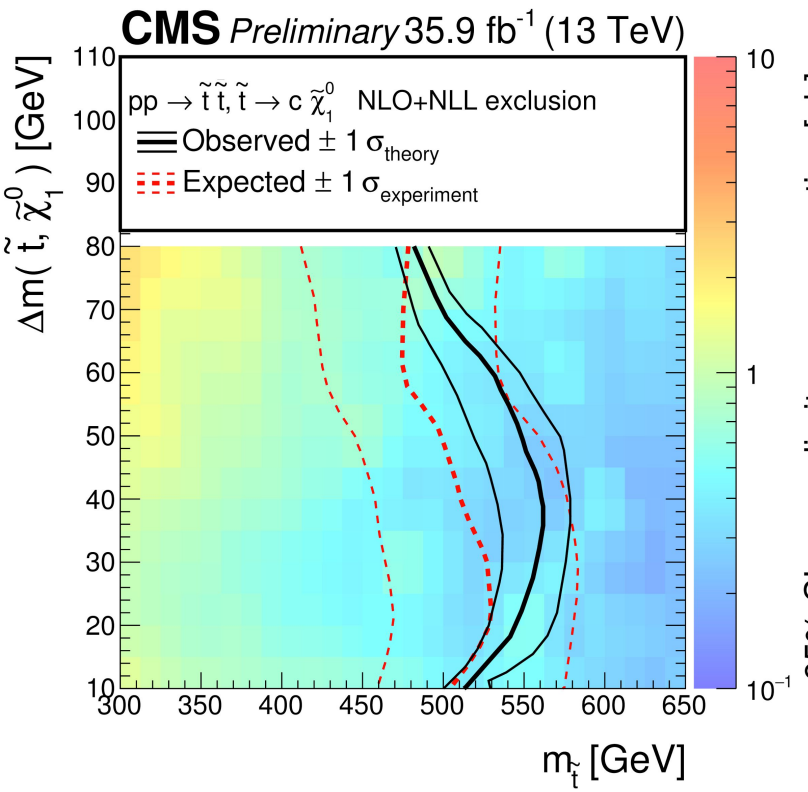
- Compressed spectra are highly motivated by naturalness and cosmological arguments
- Soft final state particles make searches in compressed regions very difficult
- Optimized SRs for sensitivity to different kinematical regimes
- semi-data driven background techniques used for this analysis
- No deviation from SM is observed
- Limits are set on the top squark mass in this simplified model

Improved version of this search is in preparation for the full 2016 dataset!

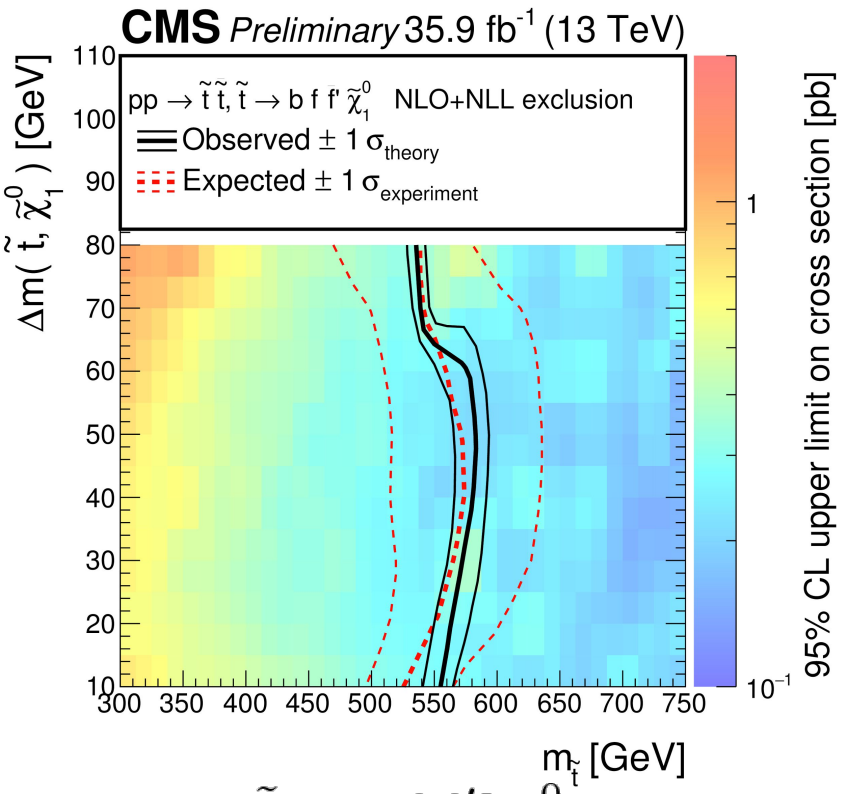
Thank you!



Backup



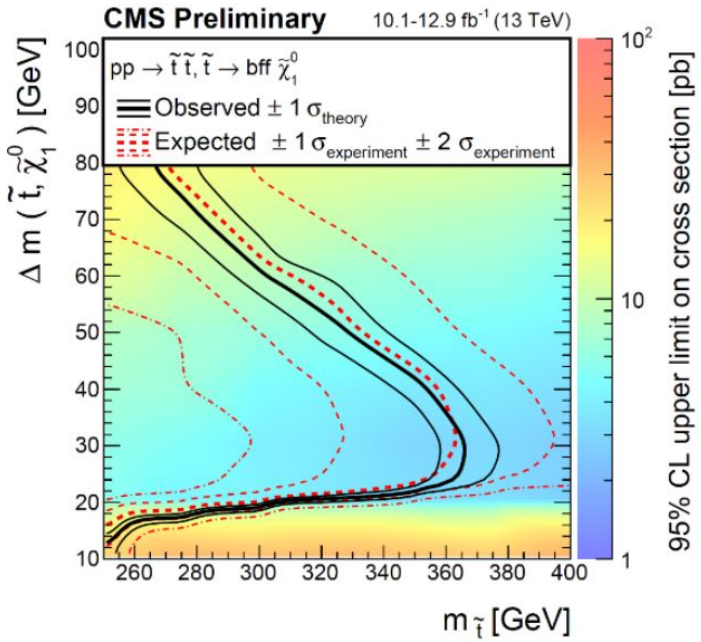
$\tilde{t}_1 \to c\tilde{\chi}_1^0$

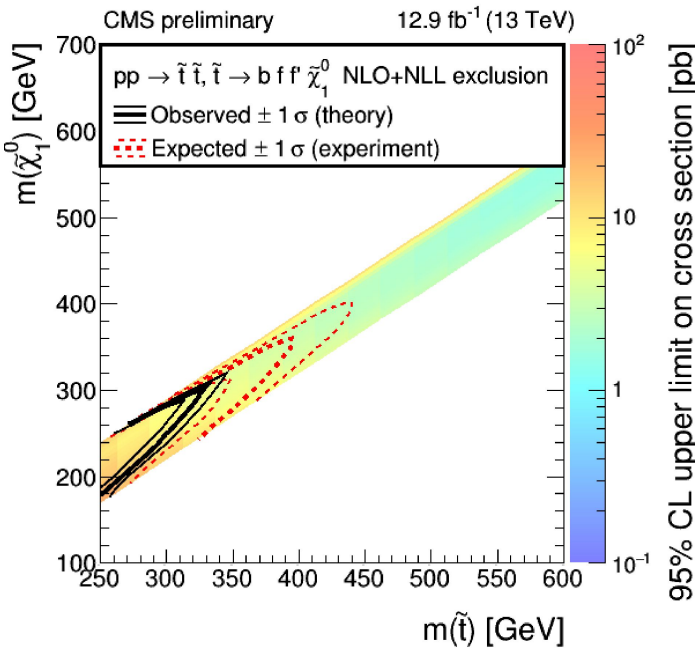


$\tilde{t}_1 \to f f' b \tilde{\chi}_1^0$

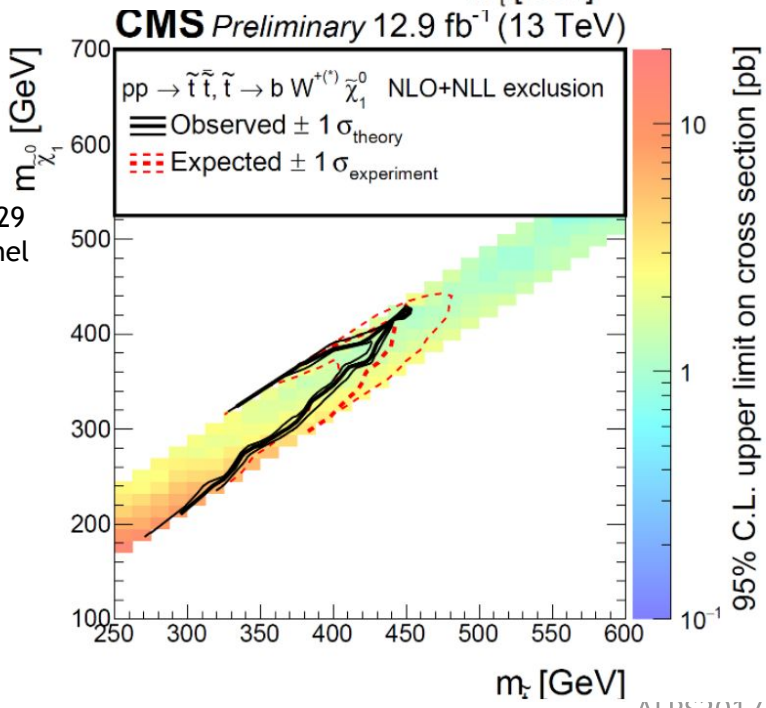
All hadronic stop search: [CMS-PAS-SUS-16-049]

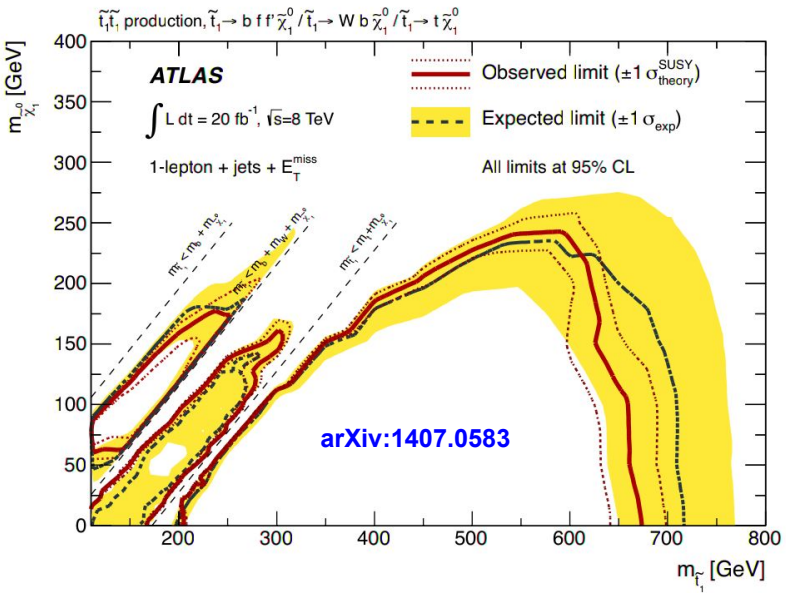
CMS-PAS-SUS-16-025
Di-leptonic





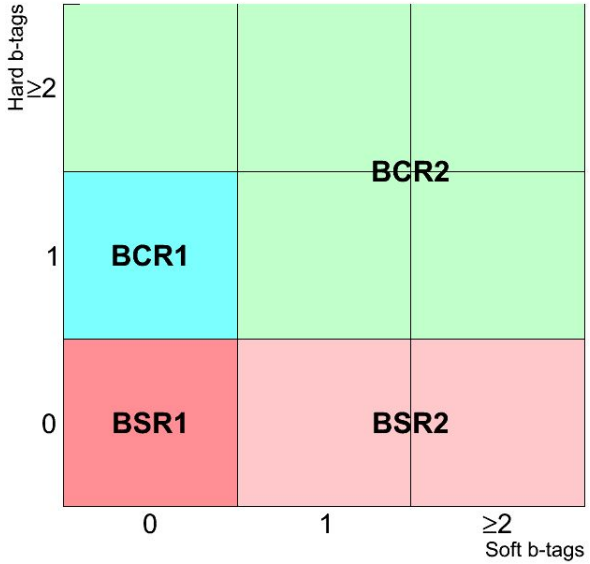
CMS-PAS-SUS-16-029
All Hadronic channel





Background Estimations

Background	CR1a	CR1b	CR1c	CR2	CR($t\bar{t}$)
W+jets	1292±20	697±15	384±10	426.8±5.2	271.9±4.4
$t\bar{t}$	132.2±9.3	66.7±6.3	45.8±5.0	493±17	2222±31
$Z(\rightarrow \nu\nu)+$ jets	0.36±0.07	0.10±0.03	9.0±1.0	0.80±0.08	3.12±0.23
Z/γ^*+jets	51.00±0.83	2.48±0.17	2.05±0.23	8.92±0.18	6.21±0.23
QCD	25.4±5.0	-	15.0±4.1	21.9±3.8	12.5±2.4
Single top quark	35.6±3.1	18.3±2.0	10.3±1.6	111.2±4.2	266.4±6.0
VV	88±11	34.2±6.7	37.0±7.1	18.8±2.6	15.9±2.0
Total SM	1624±25	818±18	503±14	1081±19	2798±32
Data	1594	778	576	905	2150



Variable	SR1a–c, CR1a–c	SR2, CR2	CR($t\bar{t}$)
$E_{\mathrm{T}}^{\mathrm{miss}}$ (GeV)	>300	>300	>200
H_{T} (GeV)	>400	-	>300
p_{T}(ISR jet) (GeV)	>100	>325	>100
Number of hard jets	≤2	≤2	≤2
$\Delta\phi$(hard jets) (rad)	<2.5	<2.5	<2.5
Number of b jets	0	≥1 soft 0 hard	(≥1 soft and ≥1 hard) or (≥2 hard)
$p_{\mathrm{T}}(l)$ (GeV)	[5, 12] [12, 20] [20, 30] (SR) >30 (CR)	[5, 12] [12, 20] [20, 30] (SR) >30 (CR)	>5
$\lvert\eta(l)\rvert$	<1.5	<2.4	<2.4
$Q(l)$	−1 (a,b) any (c)	any	any
Lepton rejection	no τ, or additional l with $p_{\mathrm{T}} > 20$ GeV		
m_{T} (GeV)	<60 (a), 60–95 (b), >95 (c)	-	-

Systematics

Systematic Effect	SR1a [%]	SR1b [%]	SR1c [%]	SR2 [%]	relation btw. SRs
Pile-up	0.6	0.9	0.3	0.3	
JEC	6.1	6.1	7.2	3.6	
JER	0.3	0.5	1.1	0.5	
BTag-l	0.8	0.5	2.8	3.5	
BTag-b	0.5	0.1	1.0	1.5	
Lepton efficiency	5.0	5.0	5.0	5.0	correlated
W p_T	7.5	8.2	7.0	1.7	
tt p_T	0.2	0.4	1.5	2.6	
W polarization	2.1	1.9	0.6	0.5	
Single top xsec	0.9	1.2	0.9	6.5	
Z/γ^*+jets xsec	1.3	0.1	0.1	0.5	
VV xsec	2.9	3.0	3.7	1.2	
CR/SR transf. fact. W	8.2	16.9	19.7	10.7	
CR/SR transf. fact. tt	1.4	1.2	2.4	5.6	uncorrelated
QCD estimation	<0.1	<0.1	0.4	0.1	
Z_{Inv} estimation	0.3	0.6	5.5	1.0	
Total	14.3	20.8	24.2	15.9	

Signal Regions

SR1 (targeting smaller Δm)

- Lepton P_T< 30 GeV
- Higher MET and H_T cuts
  (MET >300 GeV & HT>400 GeV)
- Veto any b-jets (signal b-jets too soft)
- Split in MT around W peak (low, medium, high)

  SR1a: MT < 60 GeV

  SR1b: 60 < MT < 95 GeV

  SR1c: MT > 95 GeV
- in SR1a and SR1b take only events with negative lepton (making use of W charge asym.)

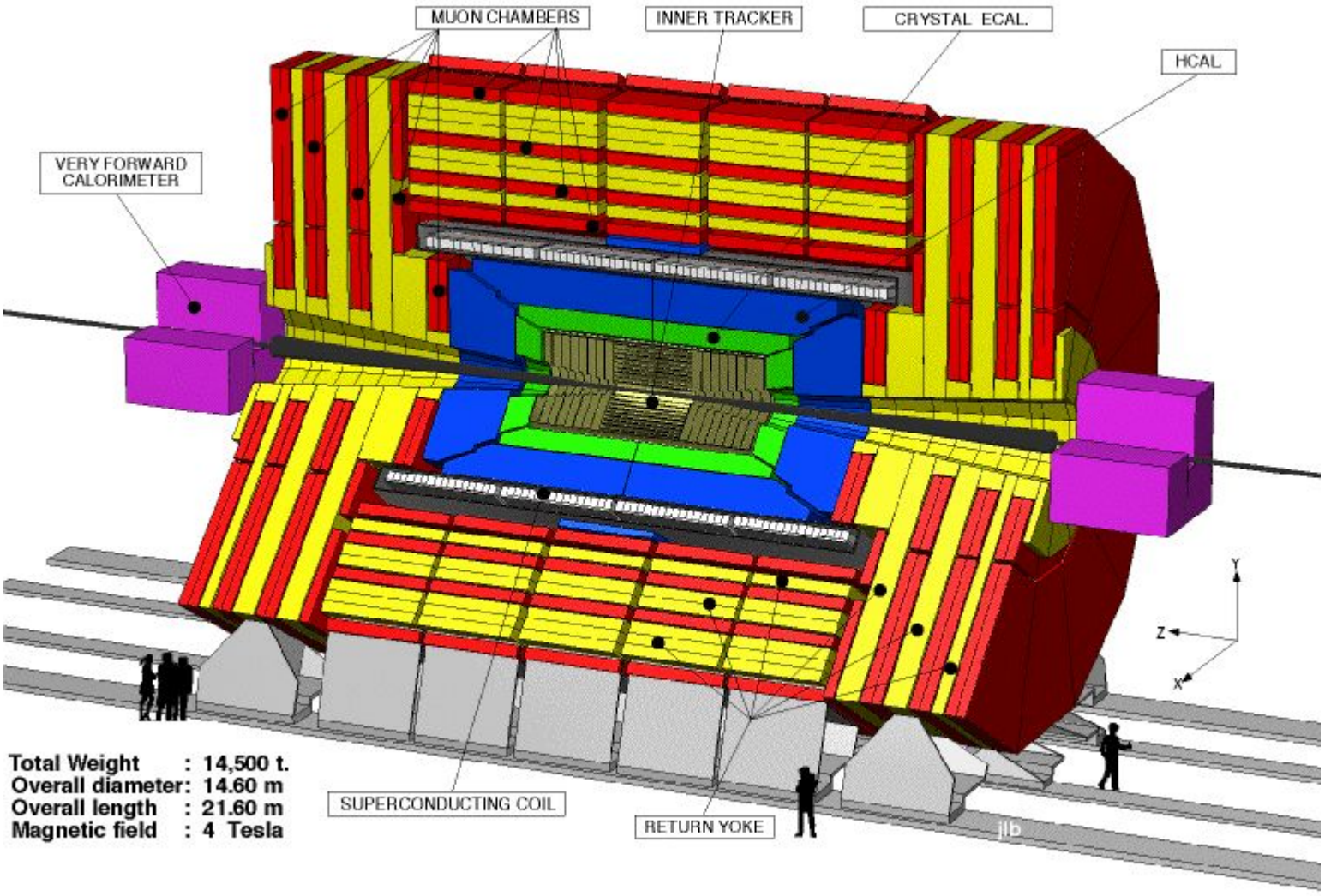
SR2 (targeting larger Δm)

- Lepton P_T< 30 GeV
- Harder ISR Jet (P_T> 325 GeV)
- require 1 soft b-jet (P_T<60 GeV) and no hard b-jet (P_T>60 GeV)

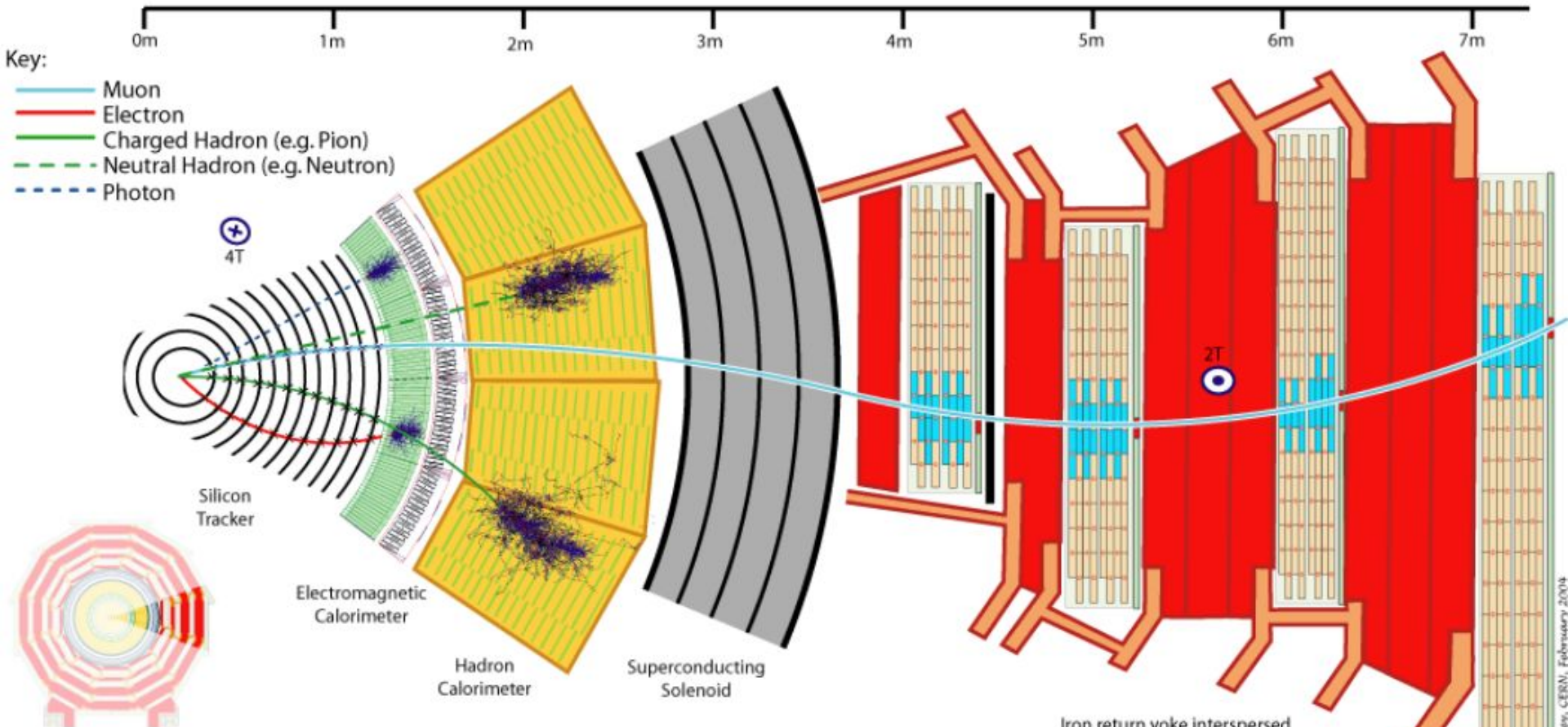
P_T Splitting:

- All SR's are split in 3 P_T bins to take advantage of shape difference between bkg and signal (3*4=12)

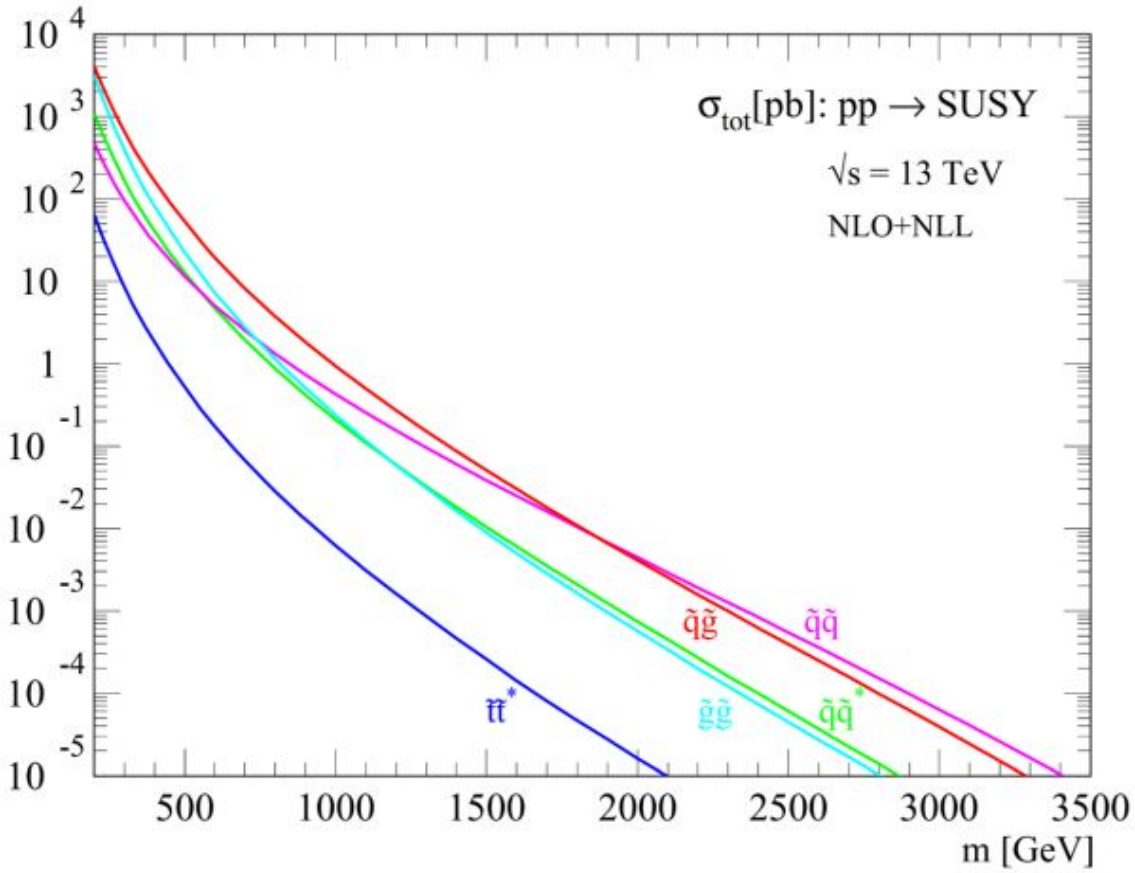
CMS Detector



Compact Muon Solenoid (CMS)



SUSY Cross-Sections



NLO+NLL production cross sections for the case of equal degenerate squark and gluino masses as a function of mass at √ s = 13 TeV (Ref.: arXiv:1407.5066)