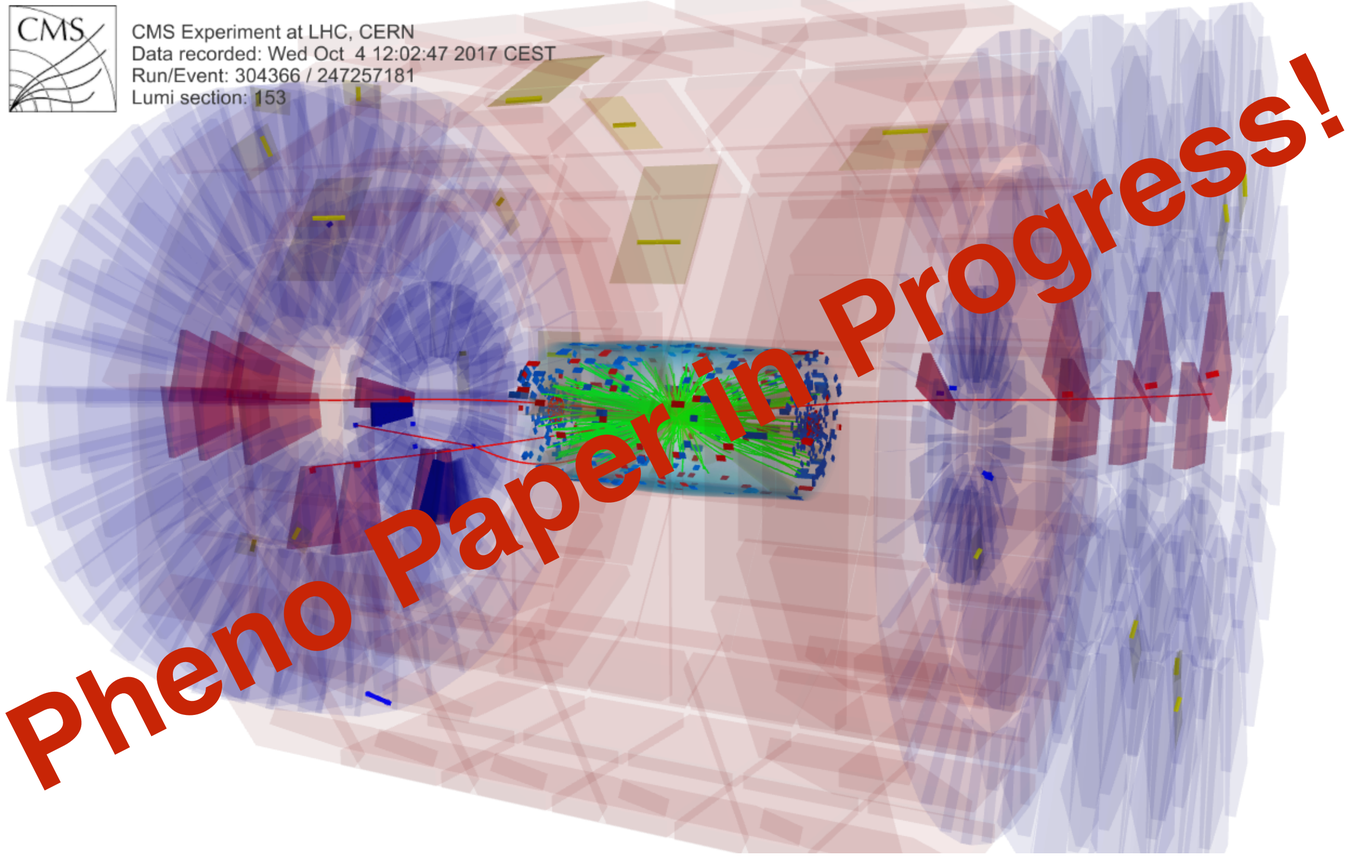


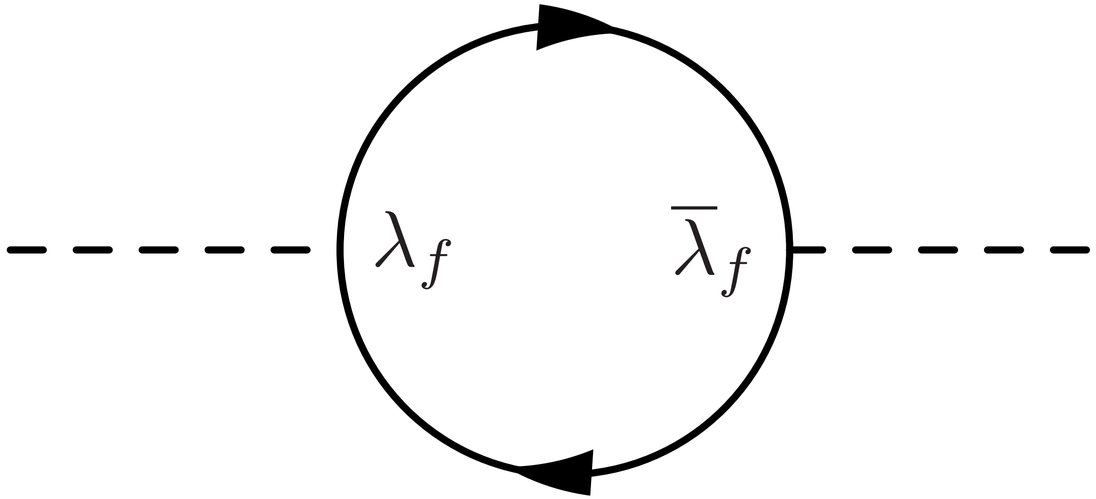
Searches for NMSSM Signatures with Low Missing ET at the CMS Detector

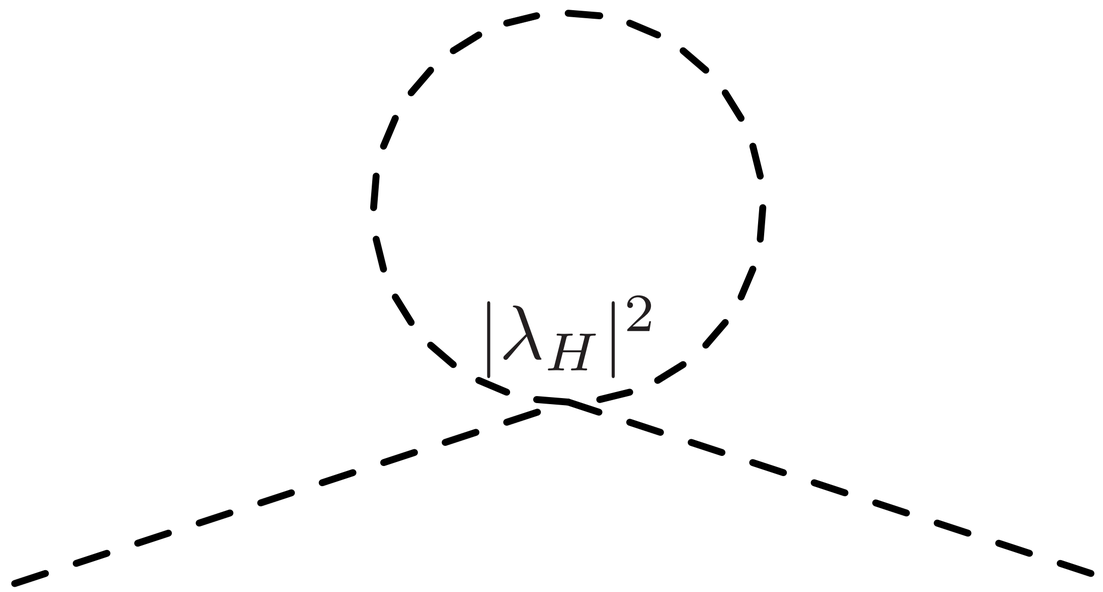
Alexander Titterton

YTF, Durham 2018

Motivation: A problem with the Standard Model

- Hierarchy problem: Why is Higgs mass 125GeV, not Planck mass or zero?
- Can Supersymmetry fix this?





$$\delta V_{Higgs} \sim (|\lambda_H|^2 - |\lambda_f|^2) H^2 \Lambda^2$$

Minimally Supersymmetric

- MSSM = Minimal Supersymmetric Standard Model.
- Gives solution to hierarchy problem but at low energies appears similar to SM.
- But has a term which is not very natural, involves setting *by hand* parameters which are **not** dimensionless…

$$W_{MSSM} = \text{Yukawa couplings } (q, l^+, l^- \text{ masses})$$
$$+ \mu H_u H_d + ...$$

(Almost) Minimally Supersymmetric

- **N**MSSM = **Next to** Minimal Supersymmetric Standard Model.
- Gives solution to hierarchy problem but at low energies appears similar to SM.
- But has a term which is more natural, **does not** involve setting *by hand* parameters which are not dimensionless…

$$W_{NMSSM} = \text{Yukawa couplings } (q, l^+, l^- \text{ masses})$$
$$+ \lambda \hat{S} \hat{H}_u \hat{H}_d + \frac{1}{3} \kappa \hat{S}^3 + \text{...}$$

So we want to search for this…

- Large MET searches have ruled out many areas of parameter space.
- How about scenario for Lightest Supersymmetric Particle (LSP) production with low MET.
- Idea: What if LSP is Singlino — SUSY counterpart of singlet Higgs?
- Consider NLSP —> LSP + X decay, where X decays into Standard Model particles.
- If $M_X \approx M_{NLSP}$ then LSP will carry little momentum, giving small MET signal [3].

So we want to search for this…

- Low MET: Looking at NMSSM cascades ending in

$$NLSP \rightarrow \text{Higgs} \; + LSP$$

$$\text{Higgs} \; \rightarrow \; b\bar{b} \; (\text{jets})$$

- Looking at p p --> squarks, gluinos in initial state.
- Want to turn this into experimental analysis.

Gloucester
Cinderford
Coleford
Painswick
Stroud
Chalford
Cirencester
Lydney
Dursley
Tetbury
Thornbury
Malmesbury
Newport
Cardiff
Portishead
Clevedon
Bristol
Chippenham
Corsham
Calne
Bath
Melksham
Devizes
Bradford on Avon
Trowbridge
Midsomer Norton
Cheddar
Westbury
Wells
Frome
Warminster
Shepton Mallet
Glastonbury
Street
Mere
Shaftesbury
Martock
Yeovil
Sherborne
Wellington
Crewkerne
Chard
Honiton
Blandford Forum
Lyme Regis
Bridport
Seaton
Sidmouth
Dorchester
Wool
Wareham
Poole
Weymouth
Lulworth Cove
Tyneham Village
Swanage
Portland
St. Malo (FR)
Guernsey
Jersey
Cherbourg (FR)
Witney
Oxford
Wheatley
Abingdon
Didcot
Wantage
Ogbourne St George
Marlborough
Avebury
Silbury Hill
Newbury
Amesbury
Andover
Basingstoke
Winchester
Southampton
Fareham
Gosport
Portsmouth
Havant
Cowes
Ryde
Newport
Sandown
Shanklin
Ventnor
Chichester
Bognor Regis
Littlehampton
Arundel
Worthing
Brighton
Rottingdean
Newhaven
Lewes
Steyning
Ashington
Henfield
Pulborough
Billingshurst
Horsham
Haywards Heath
Burgess Hill
Uckfield
Crawley
East Grinstead
Cranleigh
Haslemere
Midhurst
Godalming
Guildford
Dorking
Reigate
Redhill
Limpsfield
Gatwick Airport
Leatherhead
Cobham
Woking
Farnborough
Fleet
Sandhurst
Chertsey
Bracknell
Ascot
Egham
Staines
Wokingham
Reading
Earley
Henley-on-Thames
Maidenhead
Slough
Windsor
Heathrow Airport
Kingston upon Thames
Croydon
London
Islington
Westminster
Greenwich
Harrow
Barnet
Watford
Bushey
High Wycombe
Amersham
Chesham
Princes Risborough
Wendover
Tring
Aylesbury
Waddesdon
Hemel Hempstead
St Albans
Harpenden
Garden City
Hatfield
Hertford
Ware
Harlow
Sawbridgeworth
Hoddesdon
Cheshunt
Potters Bar
Waltham Abbey
Epping
Loughton
Brentwood
Caen (FR)
Le Havre (FR)
Bilbao (ES)
Dieppe (FR)
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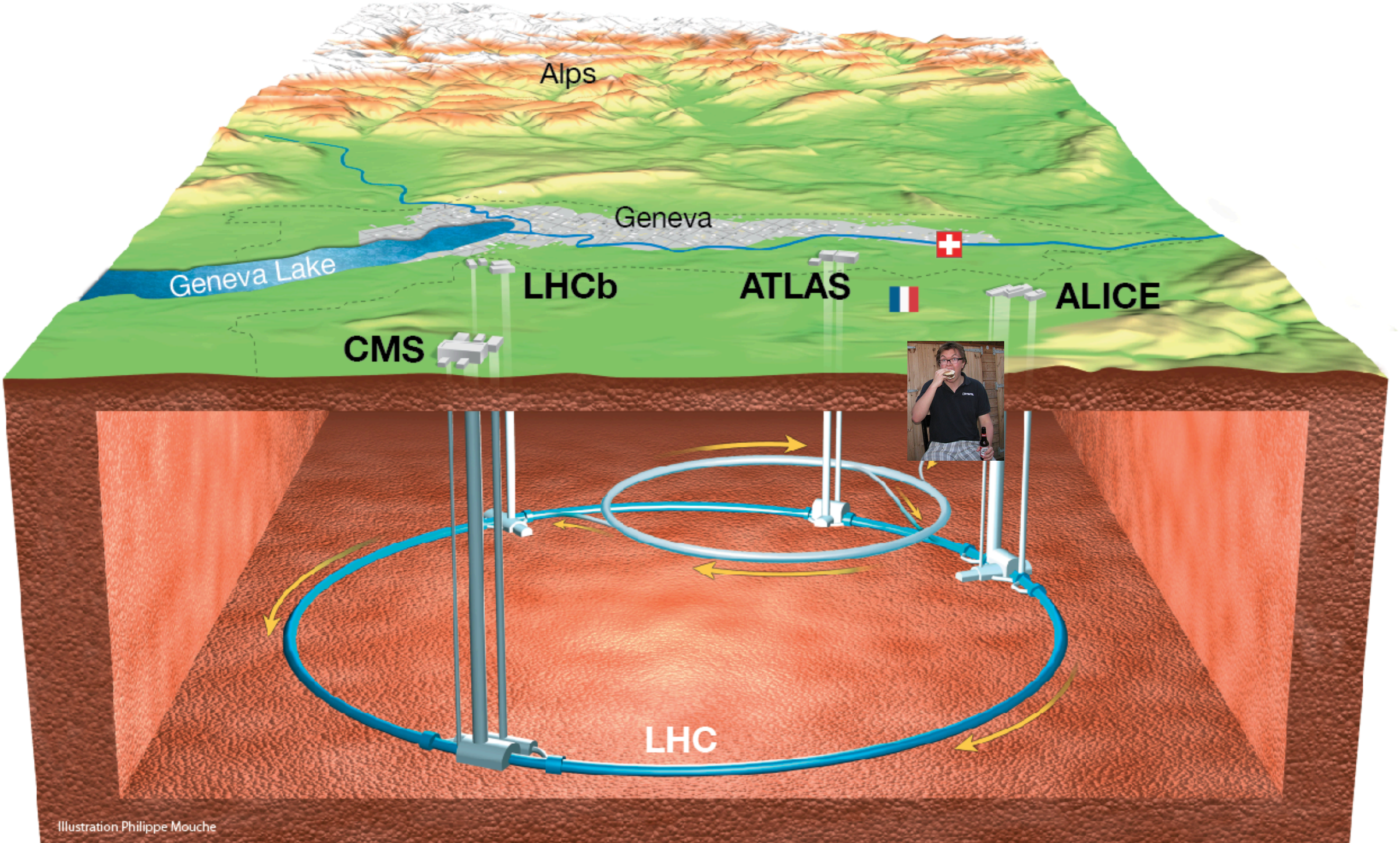
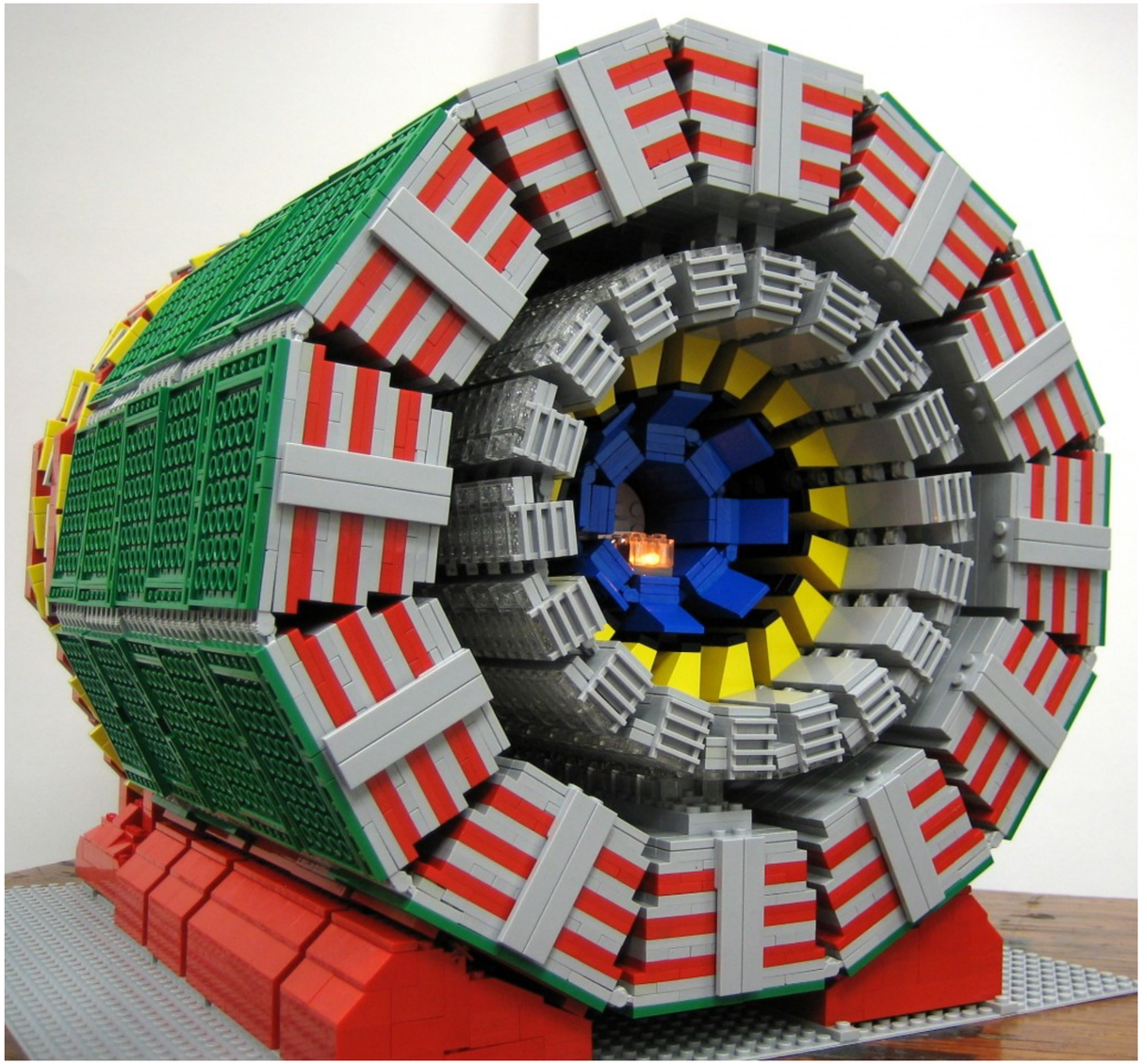
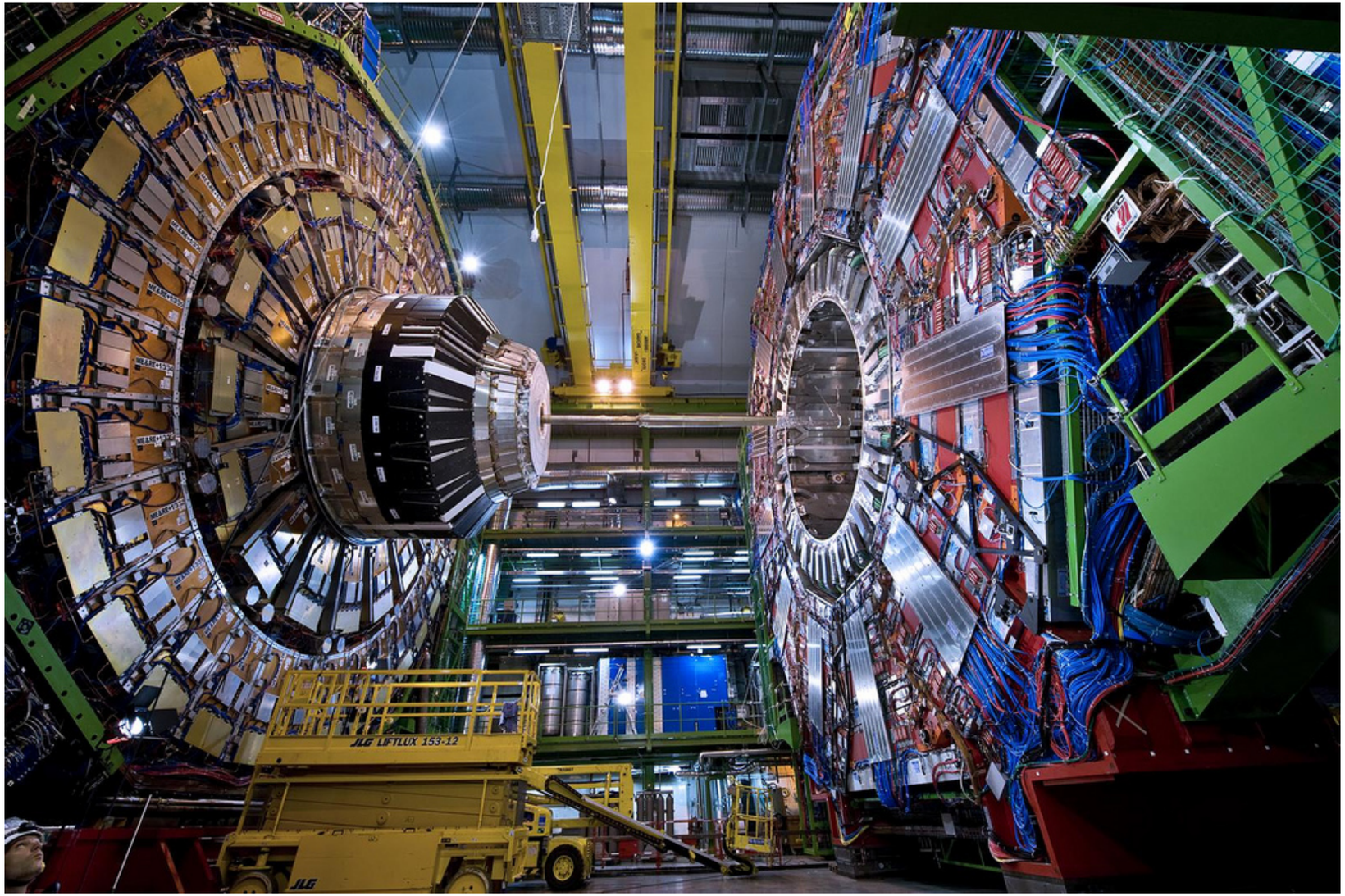

Alps
Geneva
Geneva Lake
LHCb
ATLAS
ALICE
CMS
LHC
Illustration Philippe Mouche

Propaganda



- Fig. 1: The CMS detector

Propaganda



- Fig. 2: Oversized novelty version for outreach purposes

Simulation Tools

- Generate mass spectrum from Lagrangian parameters using NMSSMTools.
- Fairly new: All cross-sections now at NLO!
- Compute diagrams and matrix elements using MADGraph.
- Decay/shower particles using Pythia 8.
- Simulate the detector measurements using Delphes.

Simulation

- Benchmark points: (From Arxiv:1412.6394)

	$M_{\tilde{q}}$ [GeV]	$M_{\tilde{g}}$ [GeV]	$M_{\tilde{t}}$ or $M_{\tilde{b}}$ [GeV]	σ [pb]
P1	1000	1010	decoupled	~ 1.362
P2	1400	1410	decoupled	~ 0.1377
P3	1100	900	decoupled	~ 2.312
P4	1500	1300	decoupled	~ 0.2018
P5	1400	1410	$M_{\tilde{t}} = 750$	~ 0.1378
P6	1100	1110	$M_{\tilde{b}} = 750$	~ 0.737
P7	1500	1300	$M_{\tilde{t}} = 750$	~ 0.202
P8	1400	1200	$M_{\tilde{b}} = 750$	~ 0.3577

Cut & Count Analysis

- Compare with existing analysis (CMS-SUS-16-038 @ 36.3fb^{-1}) for now to try to find regions of parameter space invisible to current searches.

- Calculate strength parameters at 95%CL for where our signal can realistically sneak in under the radar.

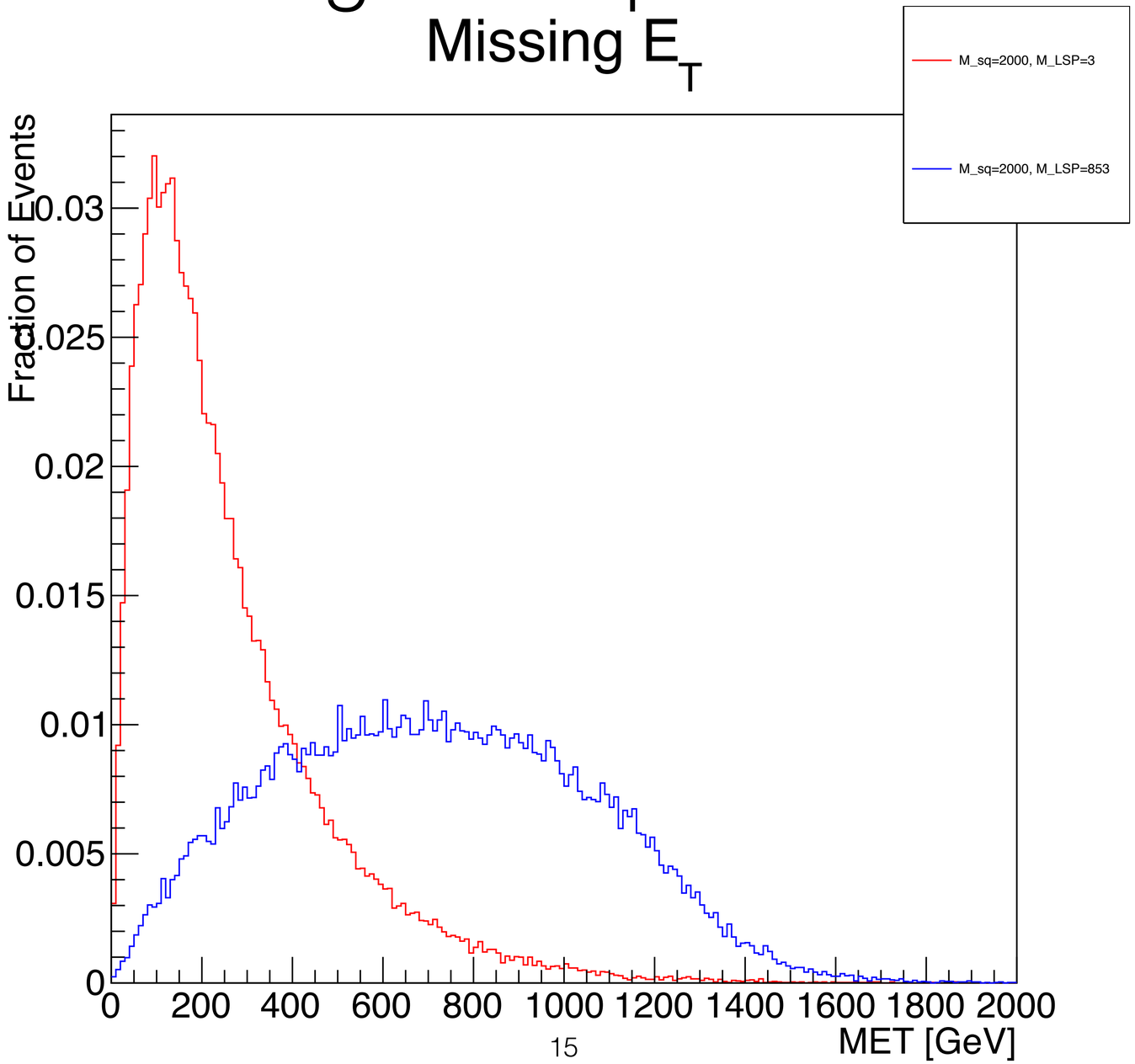
- Depending on the shape of the resulting plots we can then see whether the efficiency of the cuts or the cross-section dominates.

Cut & Count Analysis

- Applying same cuts as per high-HT, many jets & b-jets regions in CMS SUS-16-038:
- >=6 jets, jets each require >40GeV PT
- >1200GeV HT
- >200GeV MHT
- Biased Delta Phi > 0.5
- == 2, == 3 b-jets (separate categories, will look at both).
- Luminosity = 36.3fb^{-1} @ 13TeV

Signal Properties

Missing E_T



Signal Properties

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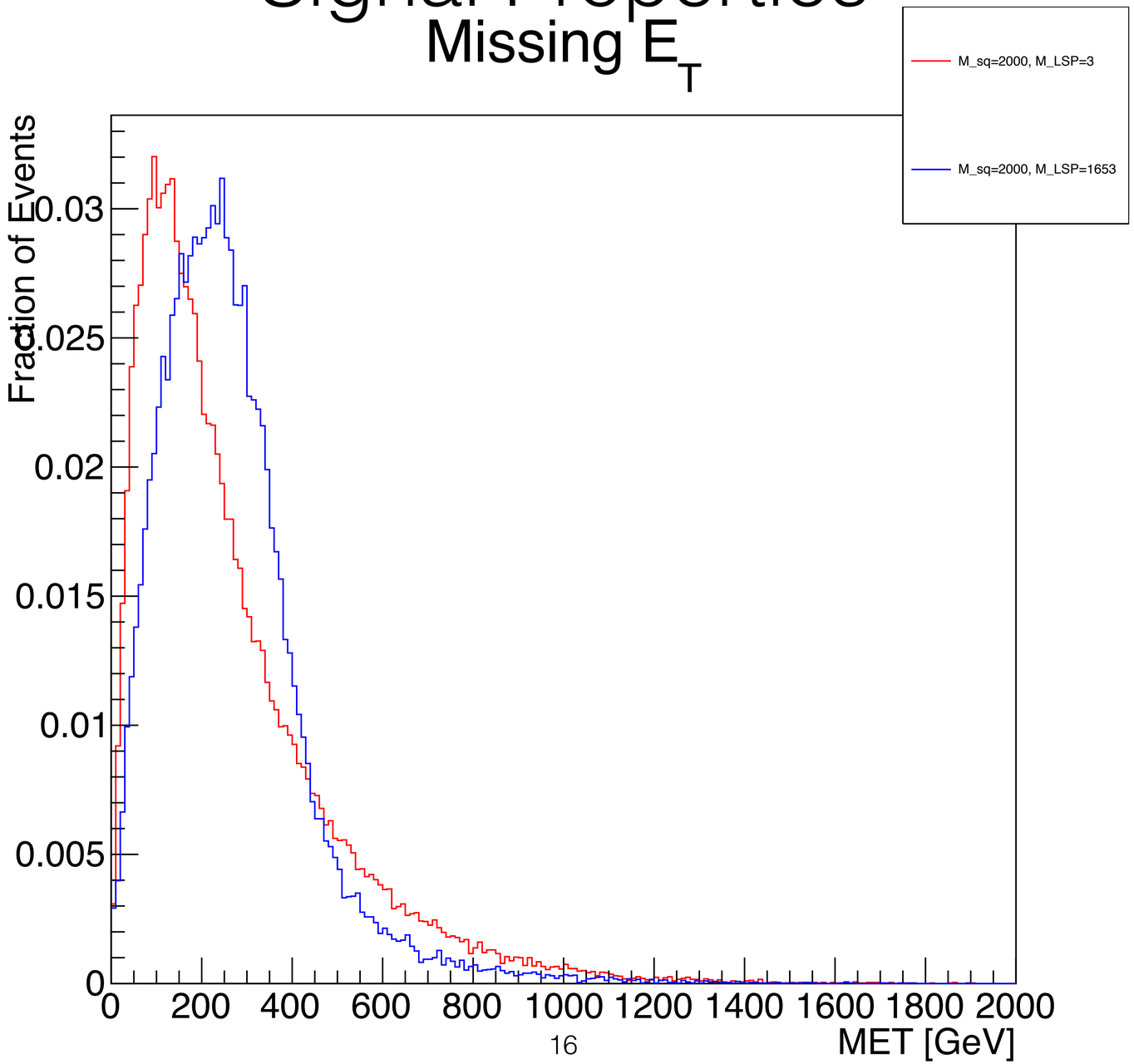
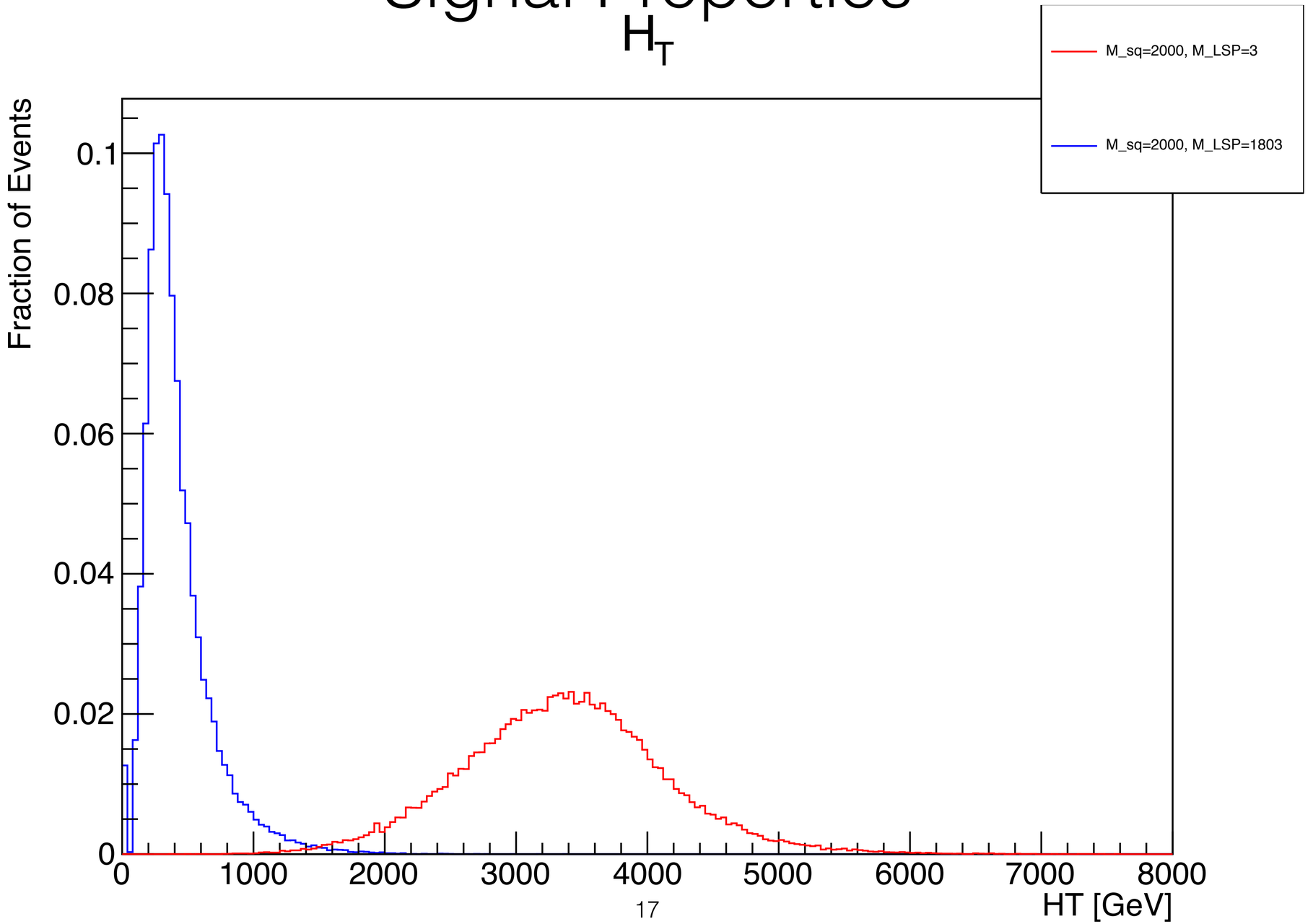
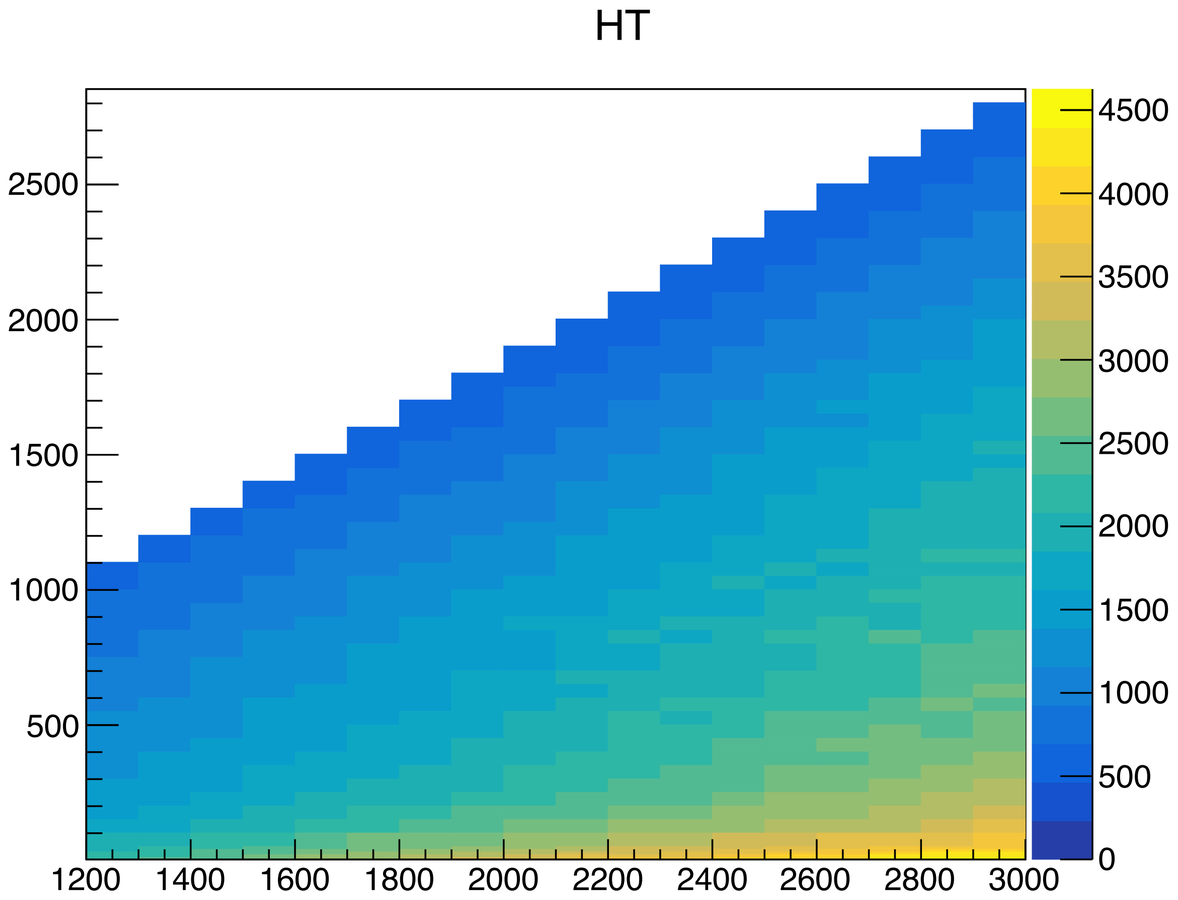


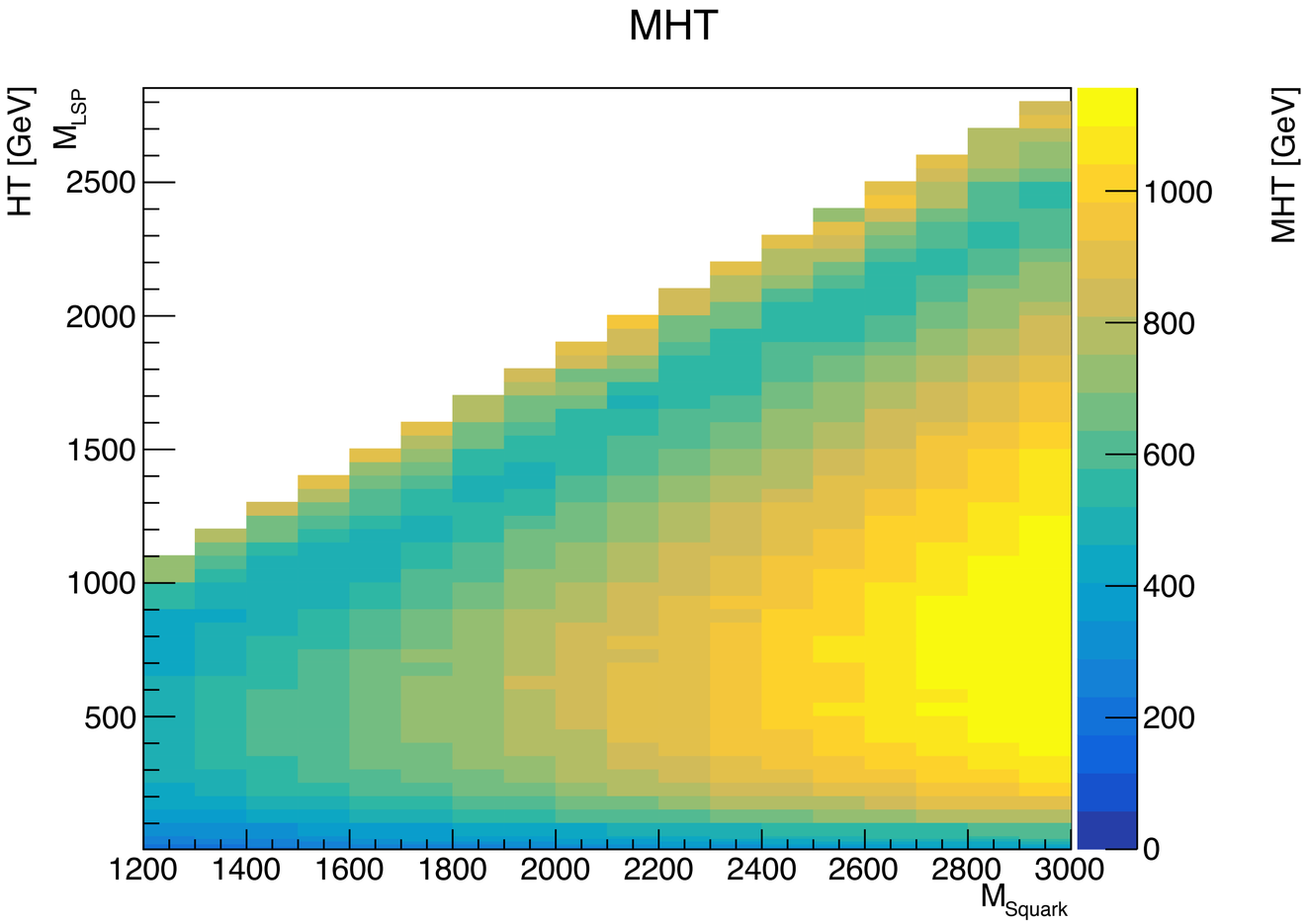
Signal Properties

H_T

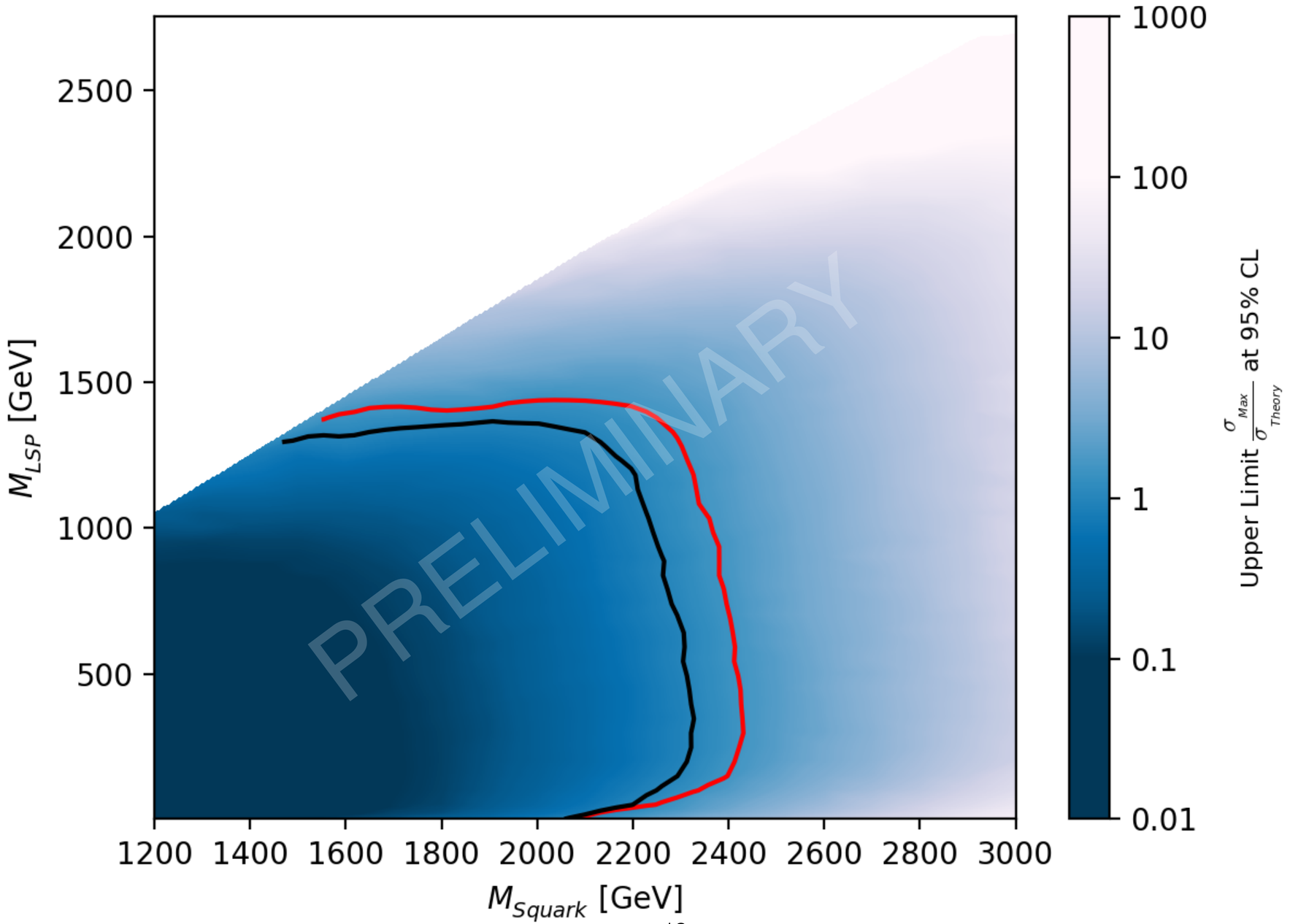


Signal Properties

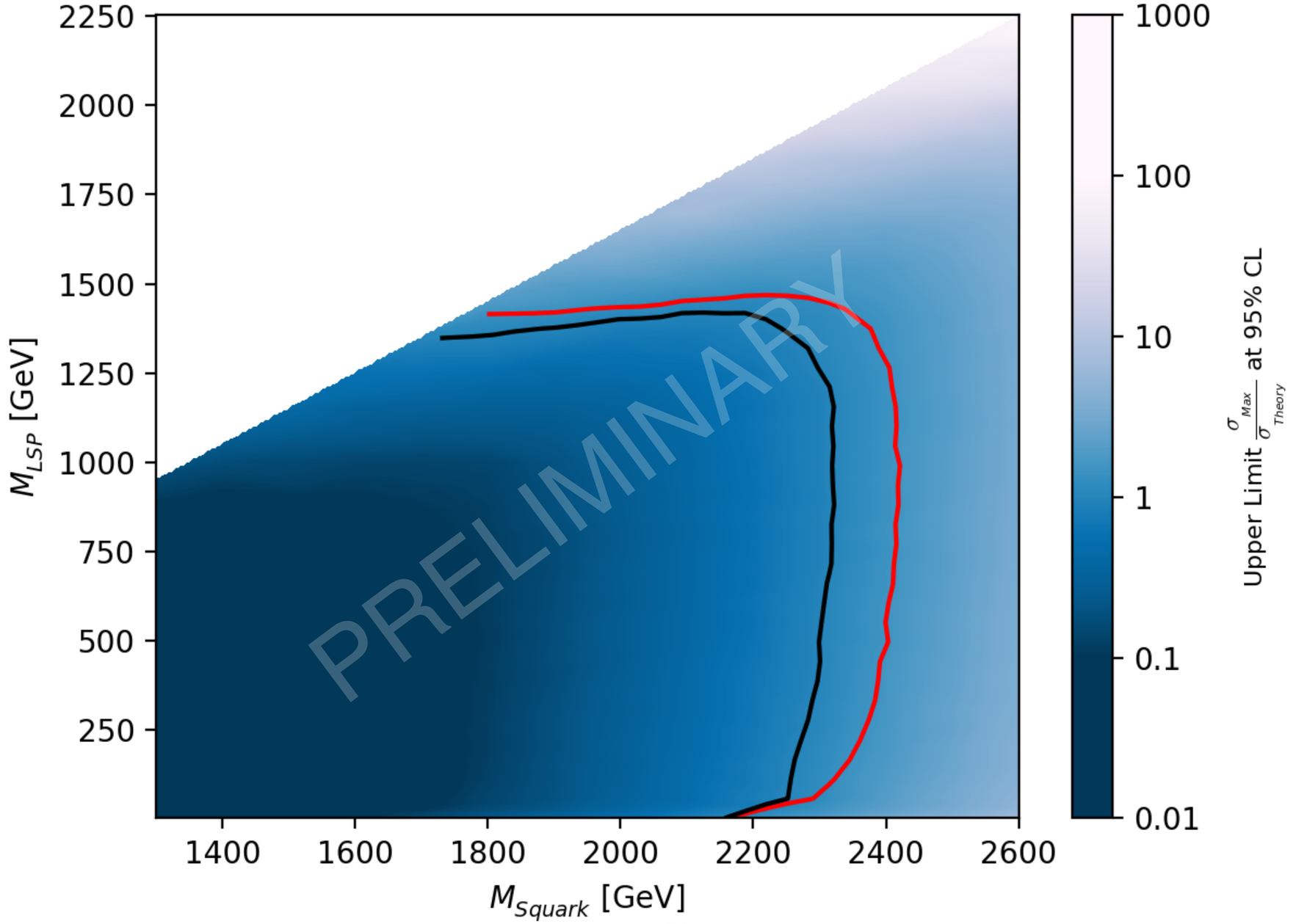




Simulation


2500
2000
1500
1000
500
M_{LSP} [GeV]
1200 1400 1600 1800 2000 2200 2400 2600 2800 3000
M_{Squark} [GeV]
PRELIMINARY
1000
100
10
1
0.1
0.01
Upper Limit $\frac{\sigma_{Max}}{\sigma_{Theory}}$ at 95% CL

Simulation


2250
2000
1750
1500
1250
1000
750
500
250
M_{LSP} [GeV]
1400
1600
1800
2000
2200
2400
2600
M_{Squark} [GeV]
PRELIMINARY
1000
100
10
1
0.1
0.01
Upper Limit $\frac{\sigma_{Max}}{\sigma_{Theory}}$ at 95% CL

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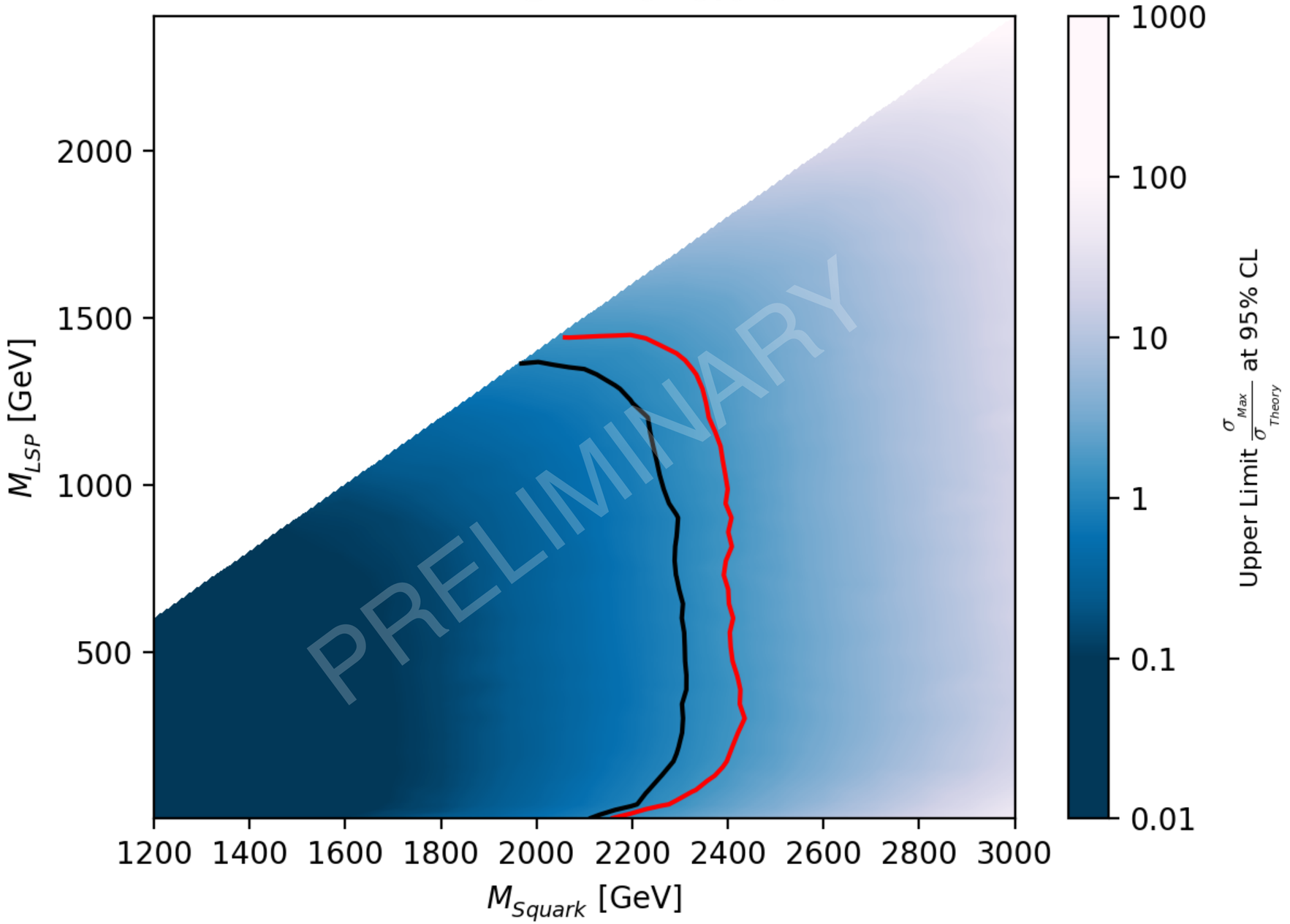
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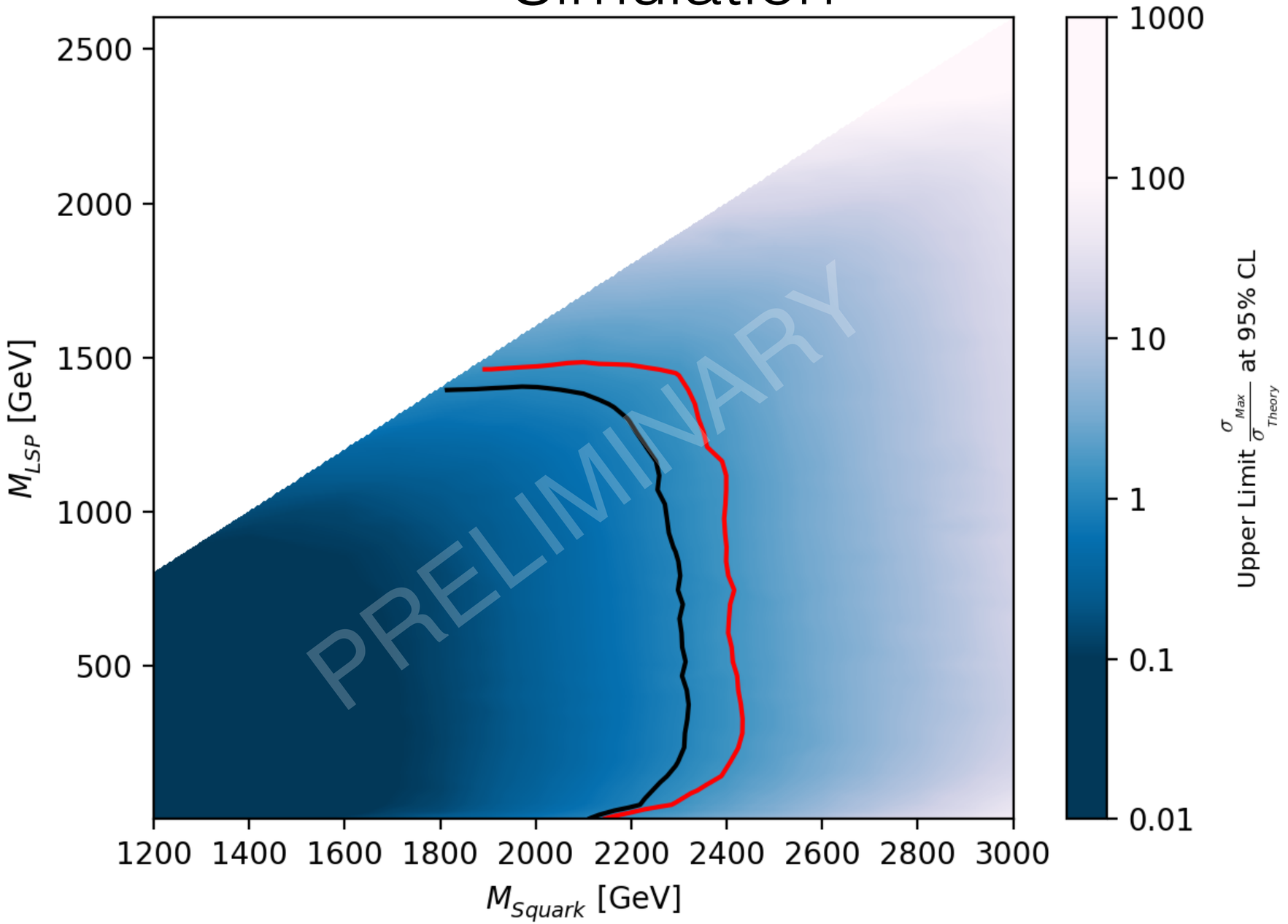
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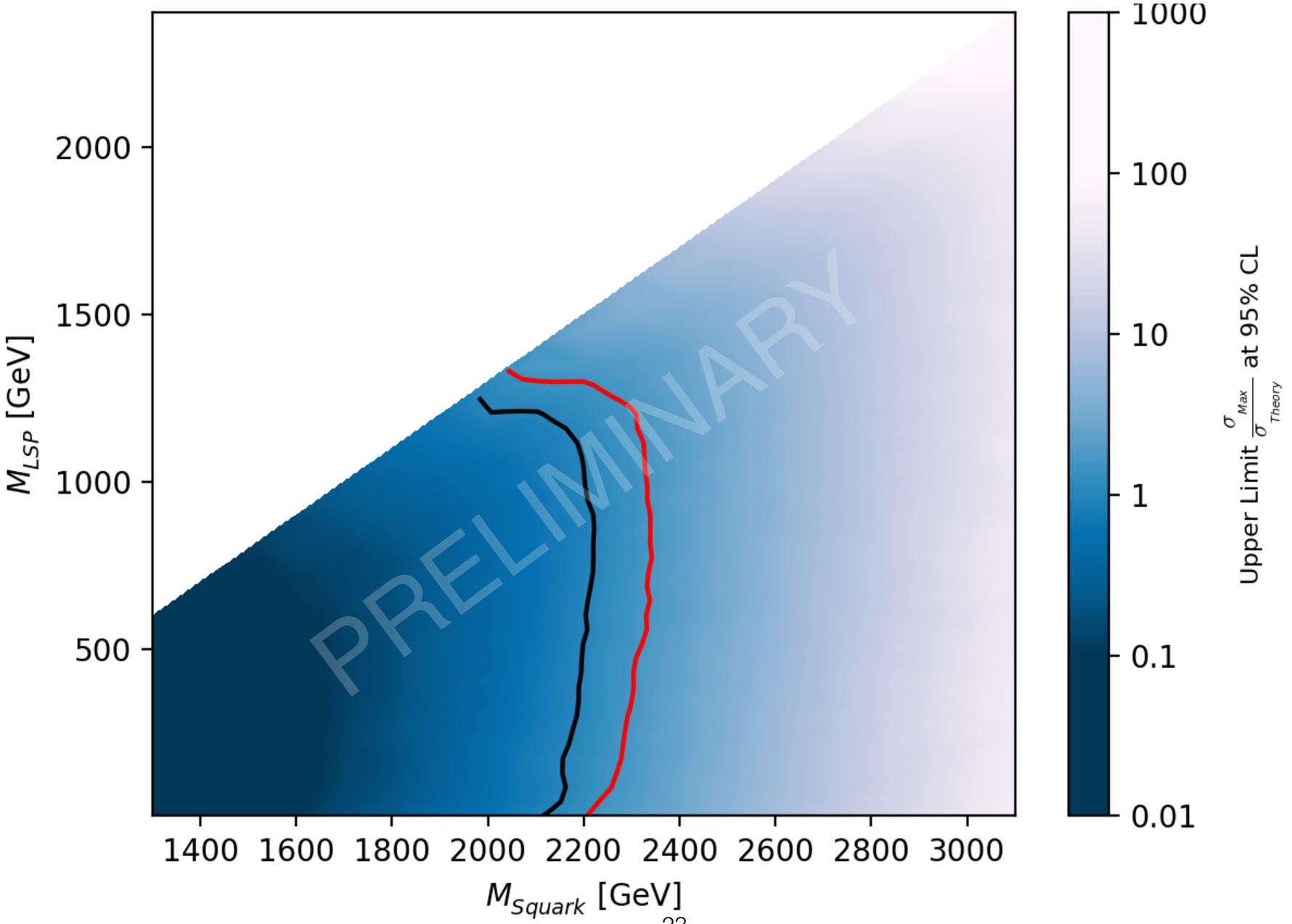
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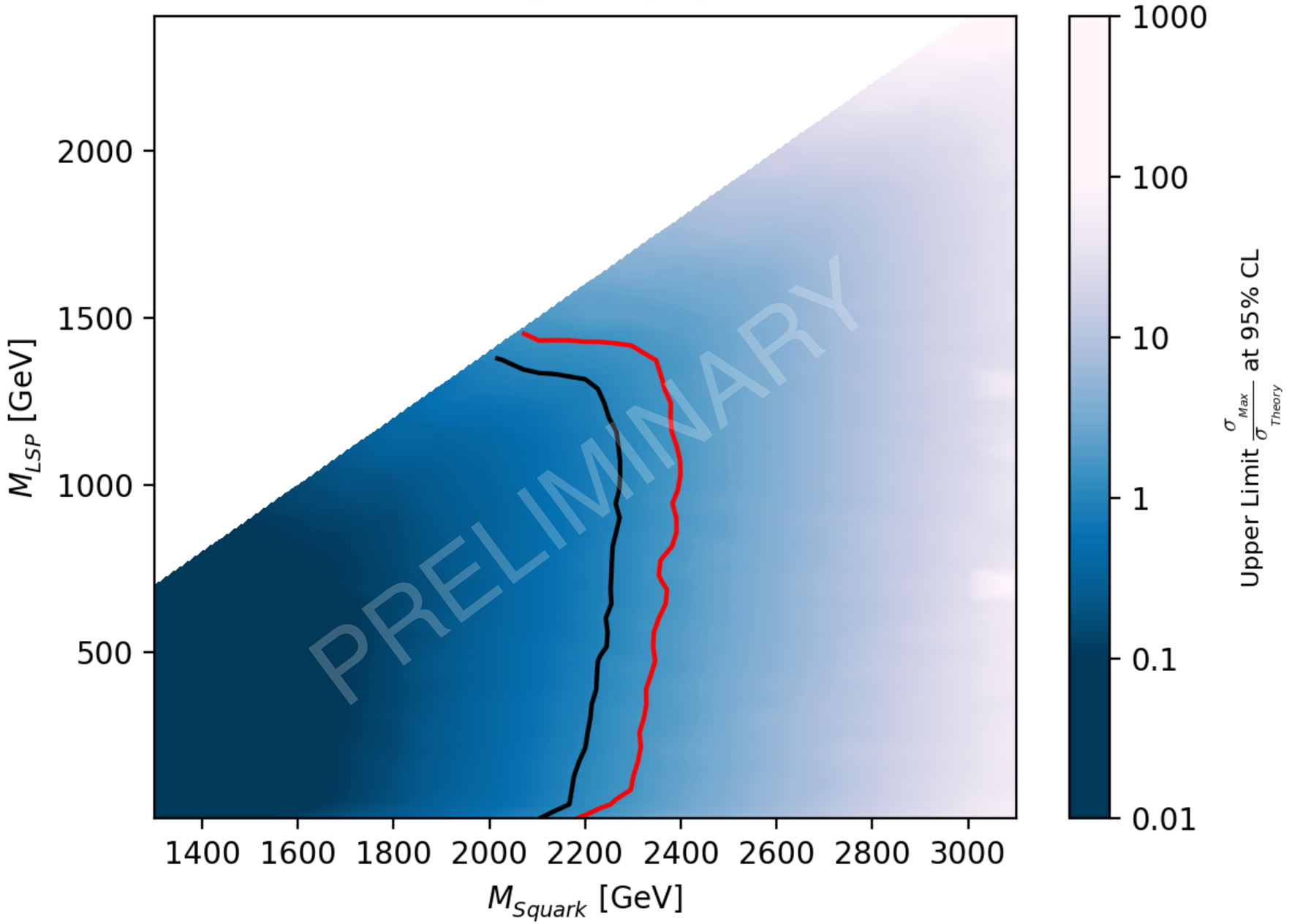
PRELIMINARY
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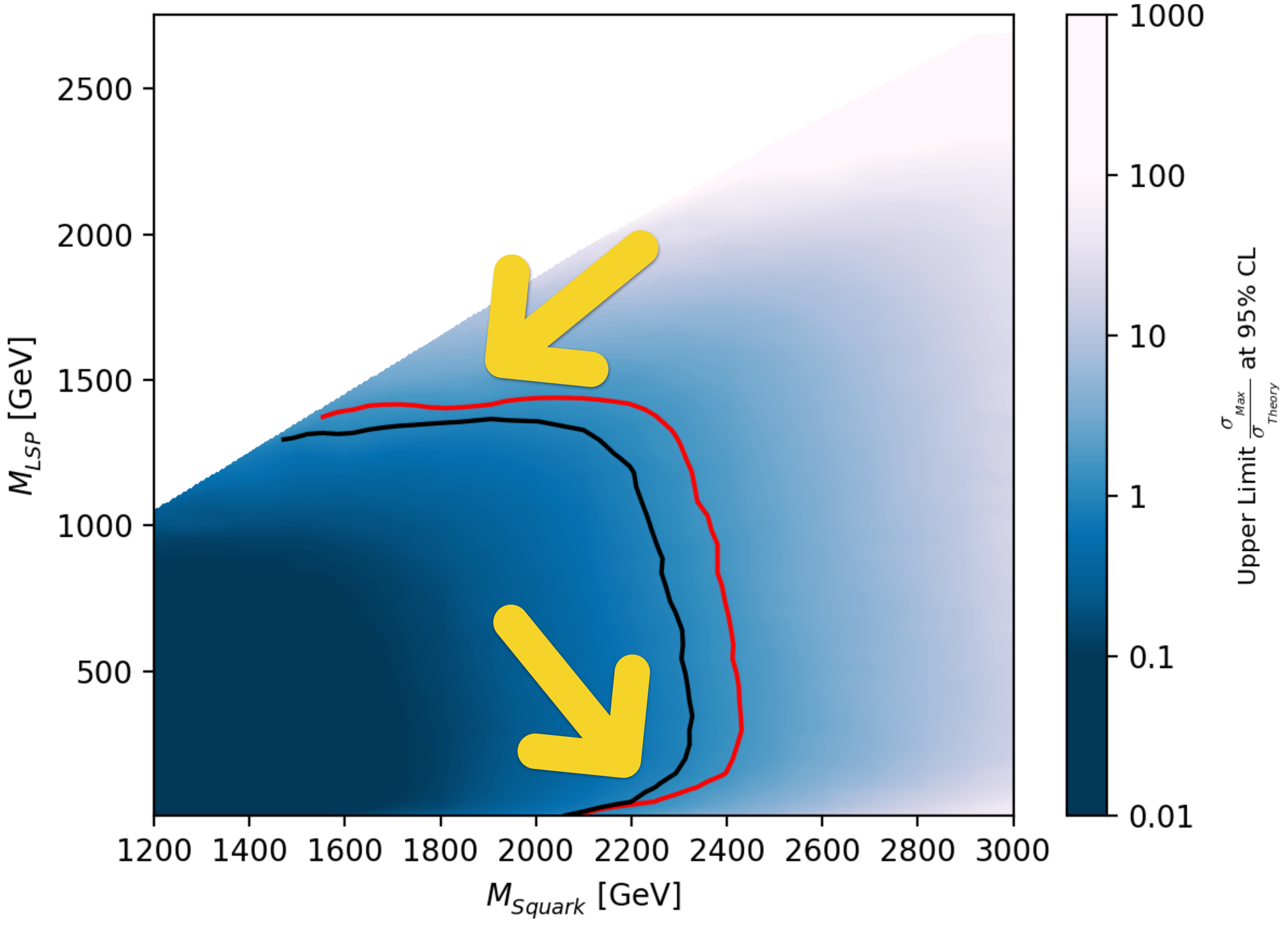
1500
1000
500
1400 1600 1800 2000 2200 2400 2600 2800 3000
M_{Squark} [GeV]
1000
100
10
1
0.1
0.01
Upper Limit $\frac{\sigma_{Max}}{\sigma_{Theory}}$ at 95% CL

Conclusions and the Plan Going Forward

- Cross-section seems dominant over current searches: Low SUSY mass gives too high cross-section despite the efficiencies of the cuts.
- However we see the limits are less harsh for very light LSP.
- This region we would like to explore further.
- Current searches not so well equipped to look at low-MET final states, so in the lower cross-section areas we should expect to see a drop in sensitivity.
- Heavy squarks and light LSP means very boosted topologies, can be tricky!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2000
1500
1000
500
M_{LSP} [GeV]
1200 1400 1600 1800 2000 2200 2400 2600 2800 3000
M_{Squark} [GeV]
1000
100
10
1
0.1
0.01
Upper Limit $\frac{\sigma_{Max}}{\sigma_{Theory}}$ at 95% CL

Conclusions and the Plan Going Forward

- Want to explore low-sensitivity region with light-LSP.
- Boosted b-jets: CMS boosted double-b tagger could be used.
- Preliminary approach shows QCD bkg reduced a lot by asking for hard AK4 jets plus 2 AK8 double-b jets.

Thanks!


TELL US ABOUT YOUR PROPOSAL.
WE'RE REQUESTING $3 BILLION IN FUNDING TO FIND THE HIGGS BOSON.
...WAIT. DIDN'T YOU ALREADY FIND IT A YEAR OR TWO AGO?
YES, WELL, UM.
... OK, THIS IS EMBARRASSING.
SEE, THE THING IS-
DON'T TELL US YOU LOST IT ALREADY.
LOOK. IN OUR DEFENSE, IT'S REALLY SMALL.

First Mass Scan

- Squarks 10GeV lighter than Gluino.
- LSP 127GeV (SM Higgs plus a bit) lighter than NLSP.
- Squarks in 50GeV steps from 1000 to 2000.
- LSP in 50GeV steps from 3 to 853.
- When M_sq=1000 and M_LSP=853, we only have 10GeV between gluino and squark, and 20GeV between Squark and NLSP…
- This could give us low MET and low HT…
- Then also scan in styles of other points — P3, P5, P7.