

MHC MET Constraints on (a) UED model

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GDR Terascale
Montpellier, 15/05/2013

Supersymmetry has been carefully studied,
however...

BSM has a rich zoology of models!

Composite Higgs,
tops

Low scale
gravity

Gauge-Higgs
Unification

Little Higgs

Minimal
Dark Matter

Technicolour

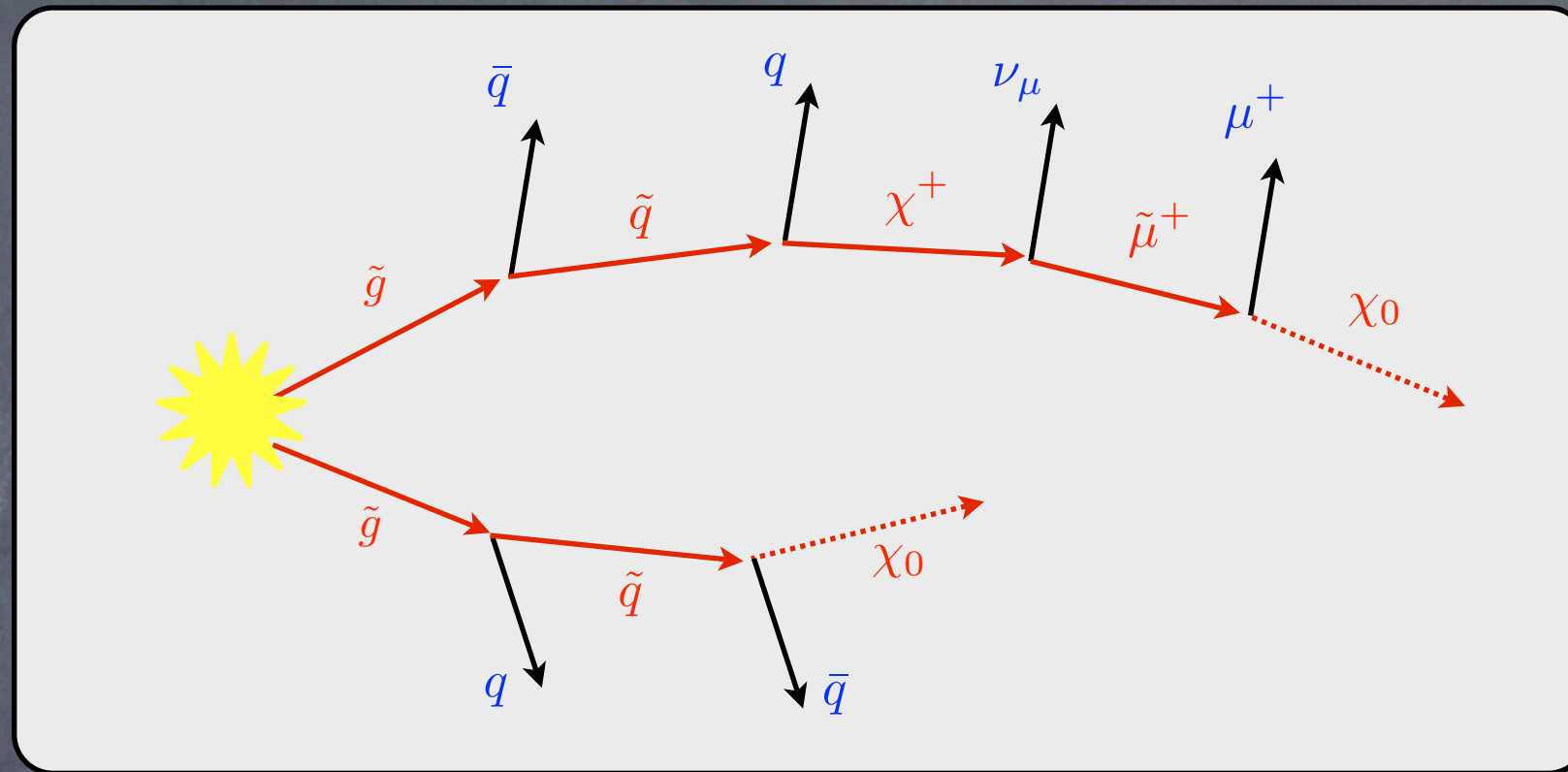
Dark Matter
in Extra dimensions
(UED)

Low scale
see-saw

Naturalness!

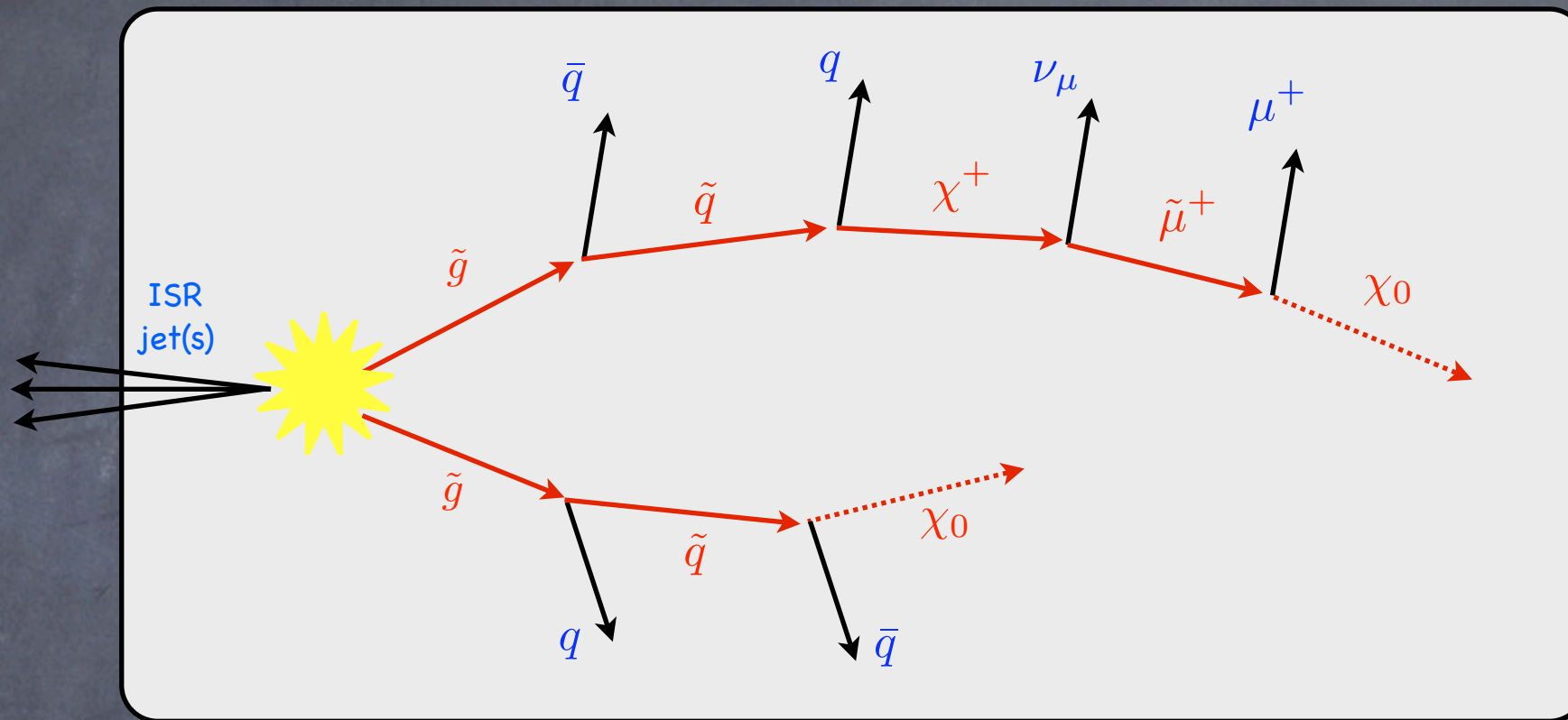
Dark Matter!

Search for Supersymmetry:



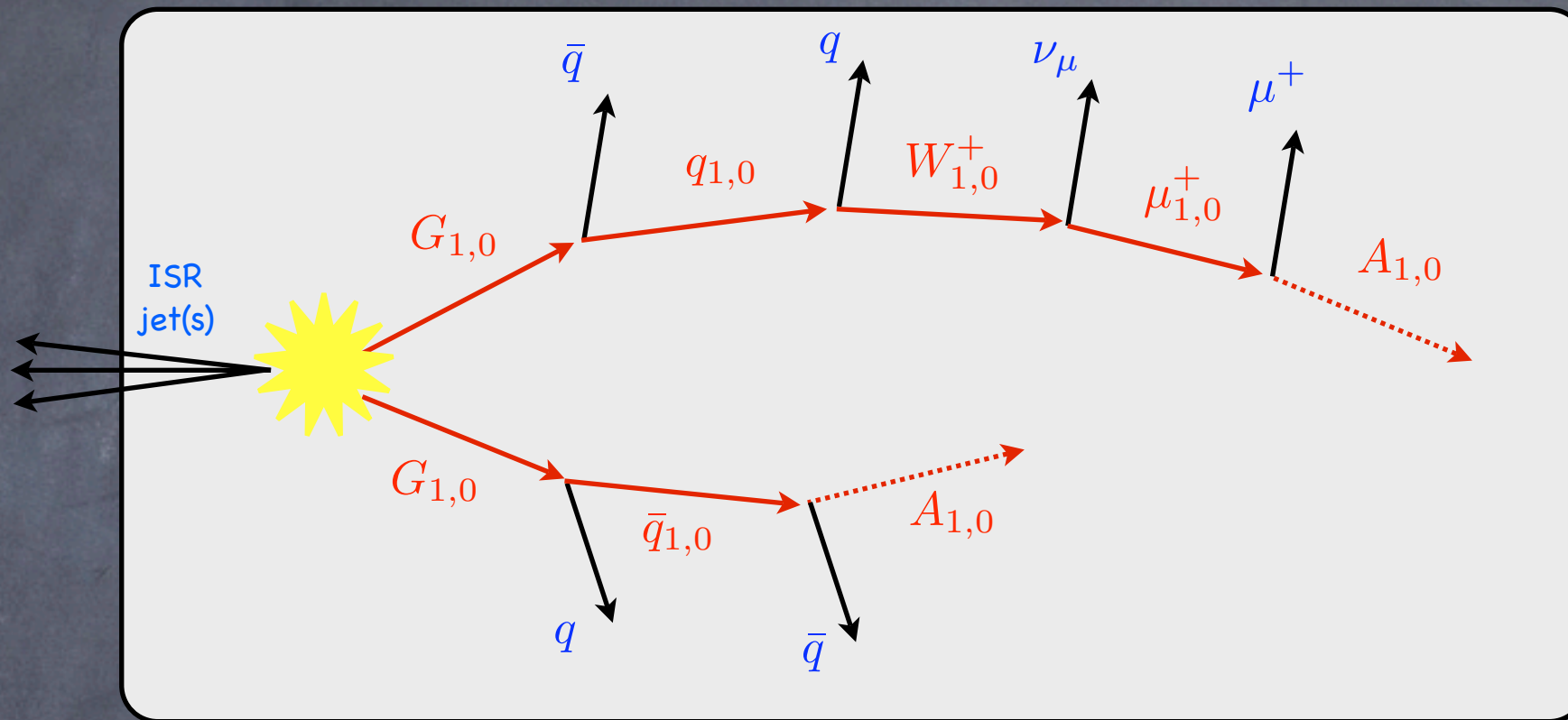
- Susy searches mostly based on energetic jets + MET (missing transverse momentum).
- Classic spectra have enough splitting! (from running or couplings)
 \Rightarrow strong bounds!!!
- What if the spectra are compressed?

Search for Supersymmetry:



- What if the spectra are compressed?
- We need to rely on Initial State Radiation to boost the event!
- The cuts on p_T become much more pricey on the signal!

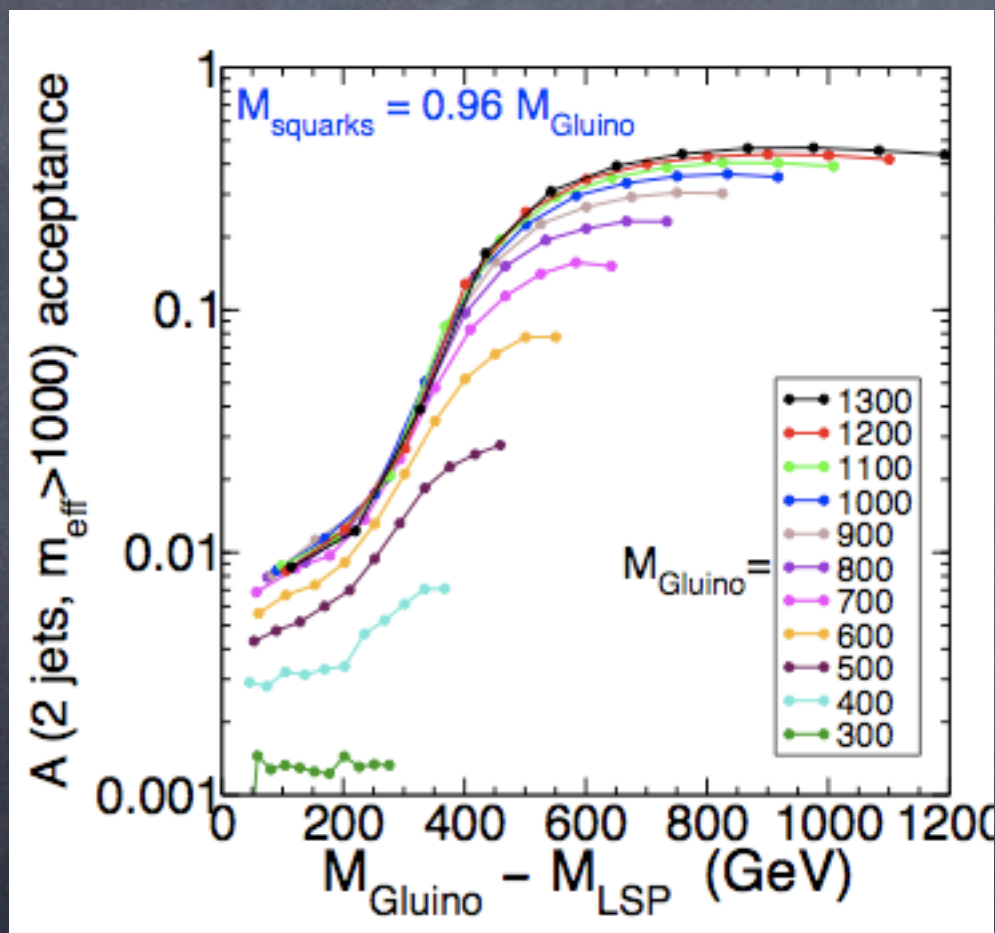
Dark Matter in extra Dimensions:



- Same topology as Susy, different spins!
- Small splitting! Searches based on ISR!
- Distinctive signatures from even tiers...

Compressed Susy searches

- Acceptance of standard SUSY searches are very low!

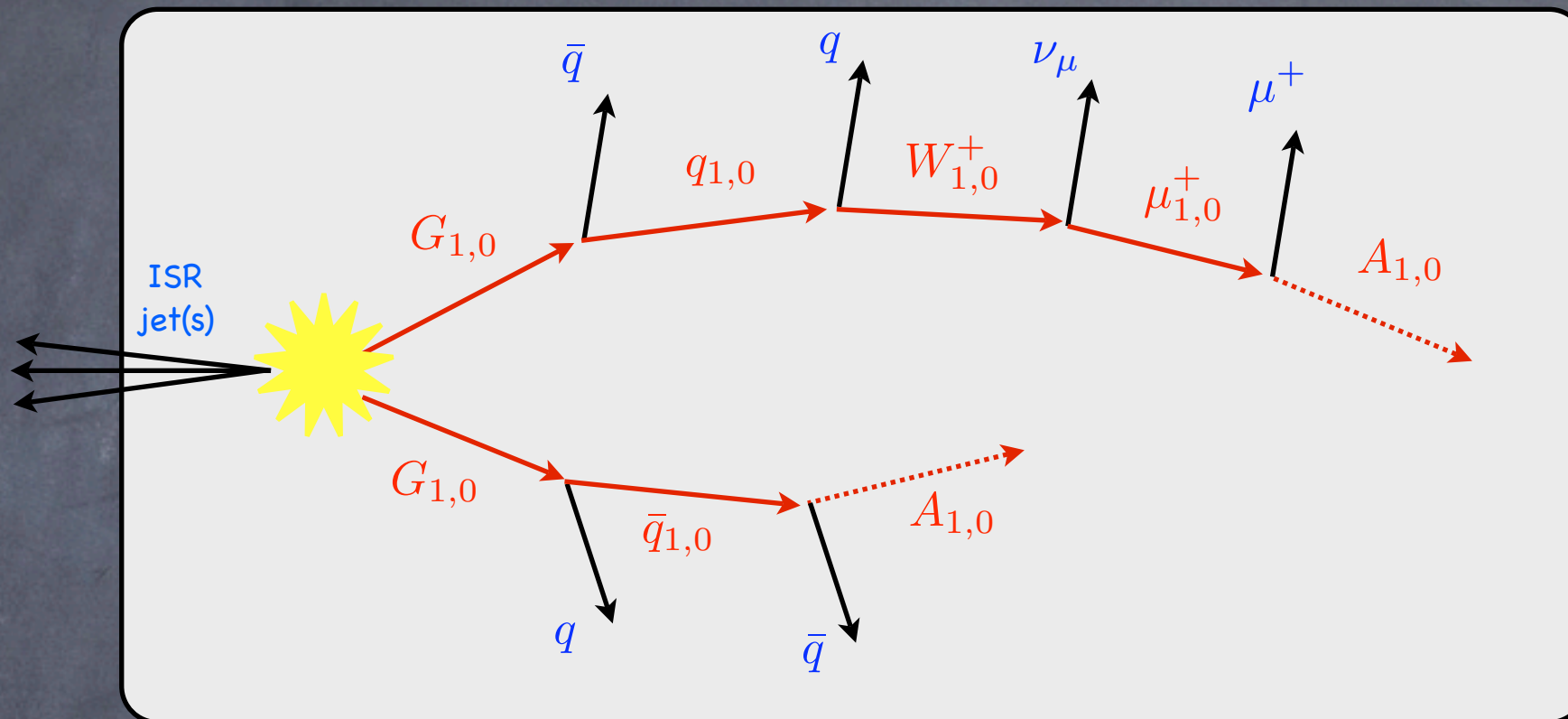


ATLAS jets+MET searches:
acceptance drops to 1÷0.1%

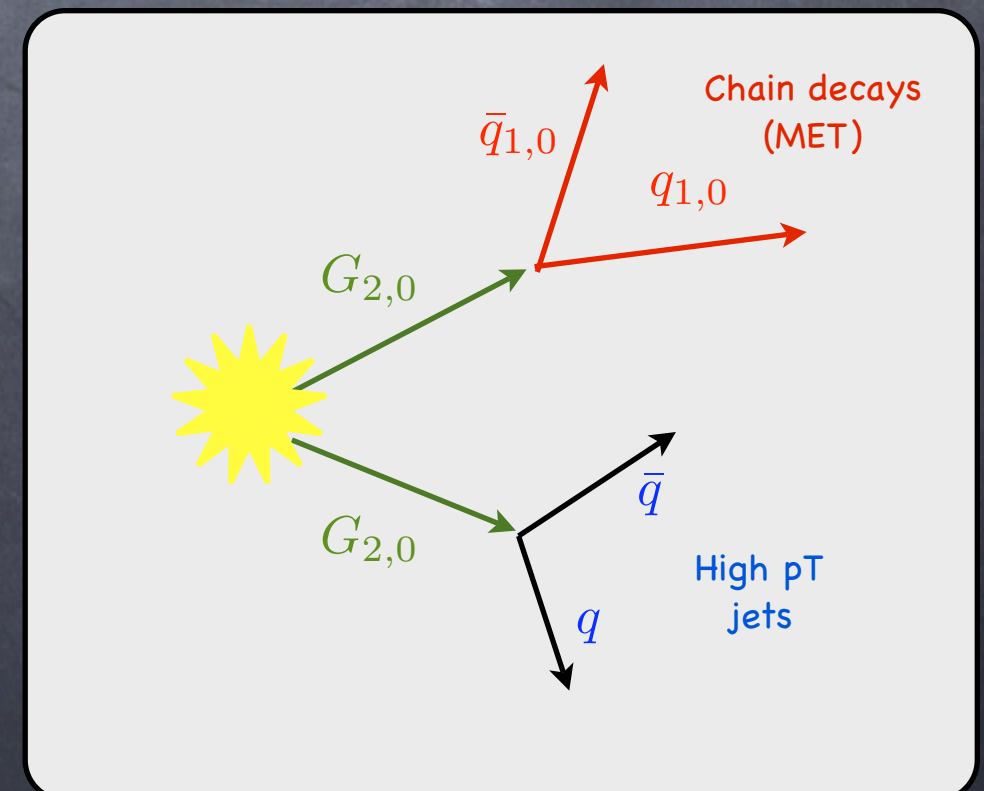
p_T leading jet > 120 GeV!!!

Le Compte, Martin, 1105.4304 & 1111.6897

Dark Matter in extra Dimensions:



- Same topology as Susy, different spins!
- Small splitting! Searches based on ISR!
- Distinctive signatures from even tiers...



Conclusion 1:

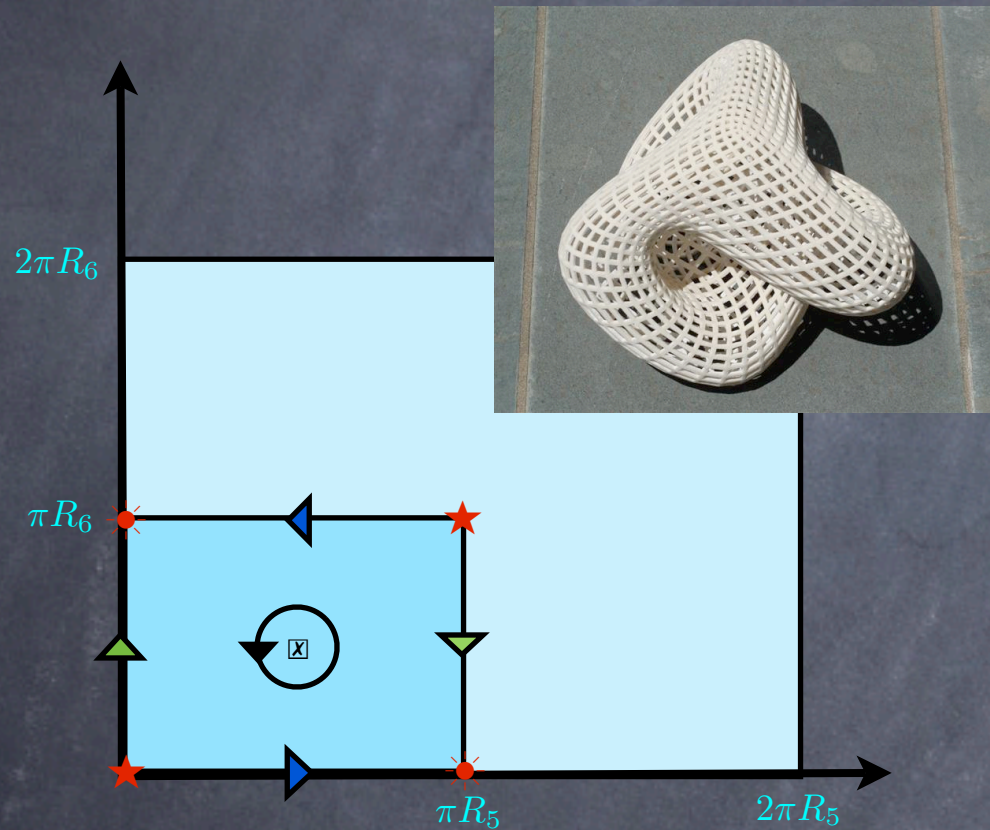


- A lot of information is still to be extracted by the data.
- New physics may be there: are we properly looking for it?

Dark Matter in extra Dimensions:

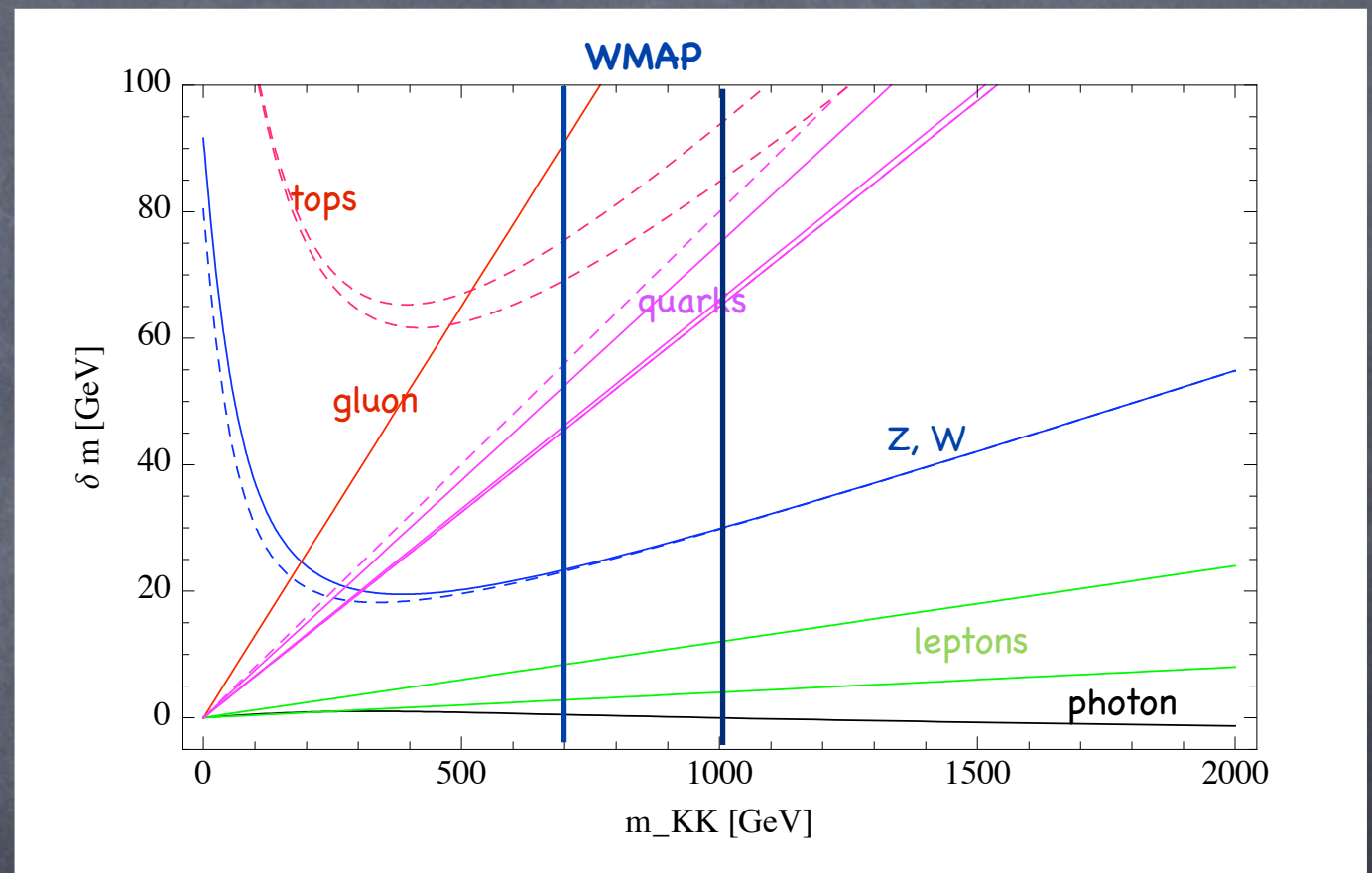
- Compressed spectra arise naturally in extra dimensions!

G.C., A.Deandrea, J.Llodra-Perez, 0907.4993



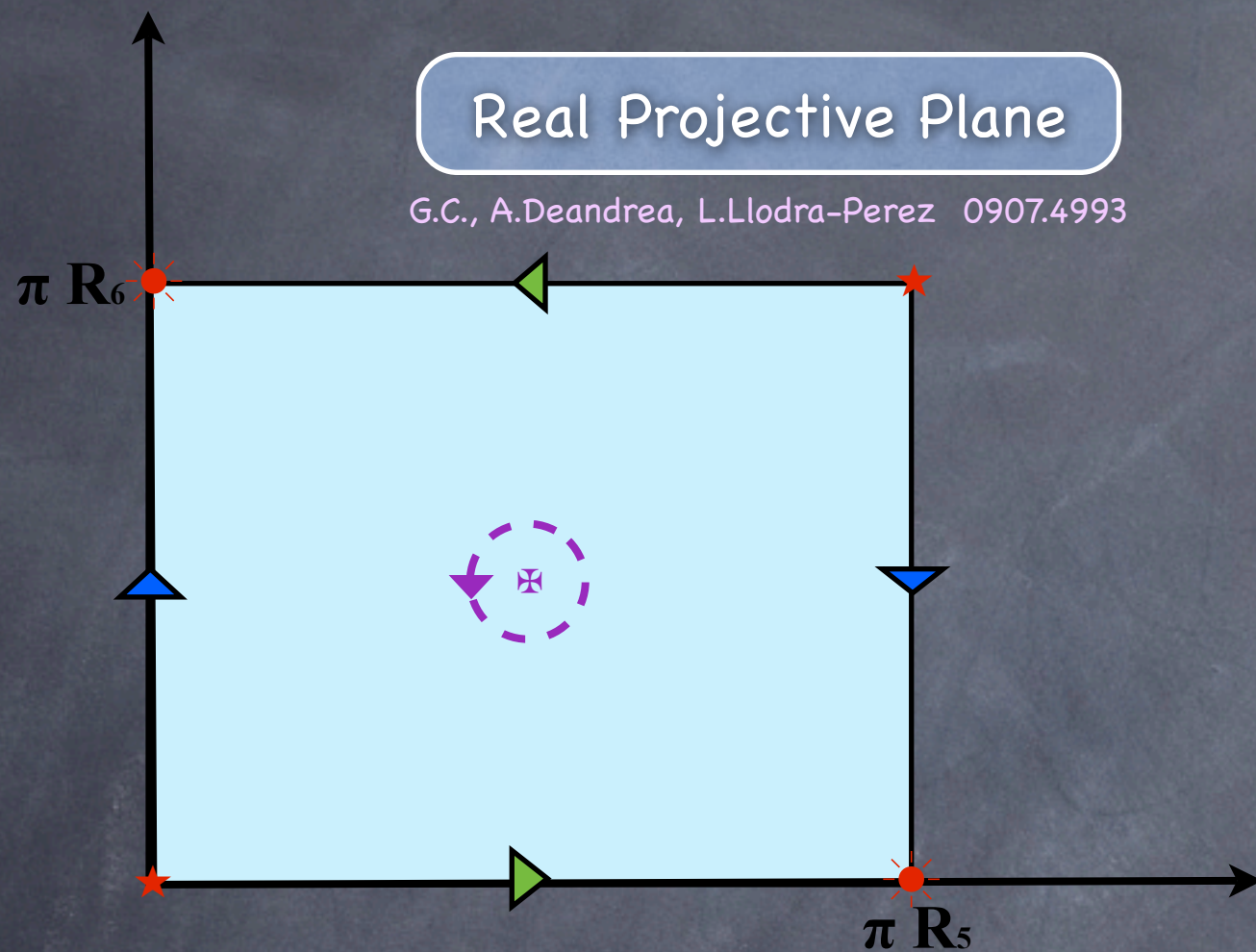
symmetry of the space \Leftrightarrow parity

bulk field \Leftrightarrow same-spin recurrences

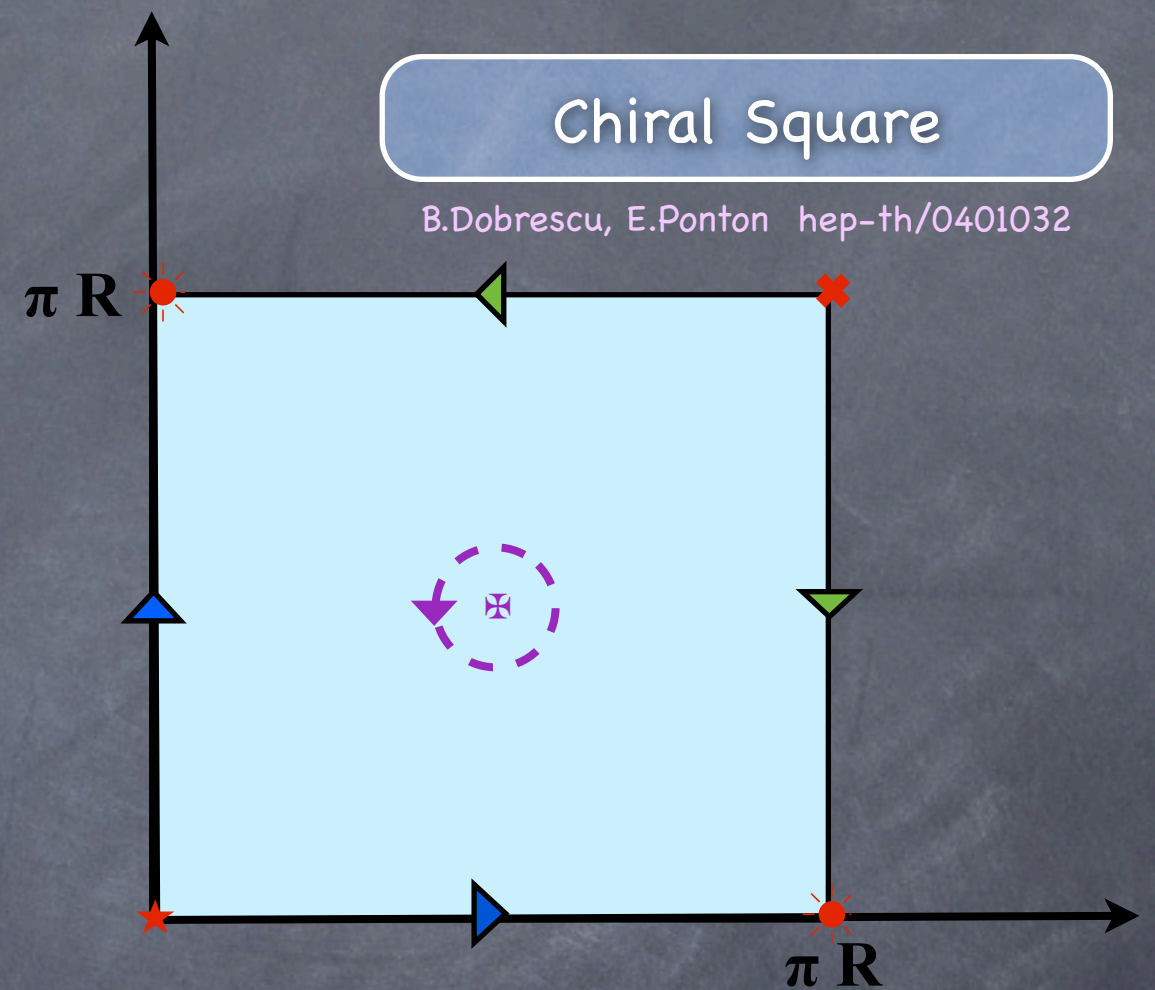


Loop induced splitting are smaller than typical SUSY, and smaller than other UED models (5D, T2/Z2...)

RPP vs Chi2



- ☞ Natural KK parity (no assumptions!)
- ☞ 2 independent radii



- ☞ KK parity only if ★ = ✖
- ☞ 1 radius

KK modes labelled by two integers!
 KK parity defined as $(-1)^{k+l}$
 Spectra are NOT the same!!!

Tree level spectra

	+	-	-	+	+	+
$p_{KK} = (-1)^{k+l}$	(0,0) m = 0	(1,0) m = 1	(0,1) m = 1	(1,1) m = 1.41	(2,0) m = 2	(0,2) m = 2
Gauge bosons G, A, Z, W	RPP ✓ Chi2	✓		✓ ✓	✓ ✓	✓
Gauge scalars G, A, Z, W		✓ ✓	✓	✓ ✓	✓	
Higgs boson(s)	✓ ✓	✓		✓ ✓	✓ ✓	✓
Fermions	✓ ✓	✓ ✓	✓	✓ ✓ ✓	✓ ✓	✓

Mass splitting given by loops and...
VERY DIFFERENT in the two cases!

Loop-corrected spectra Tier (1,0)

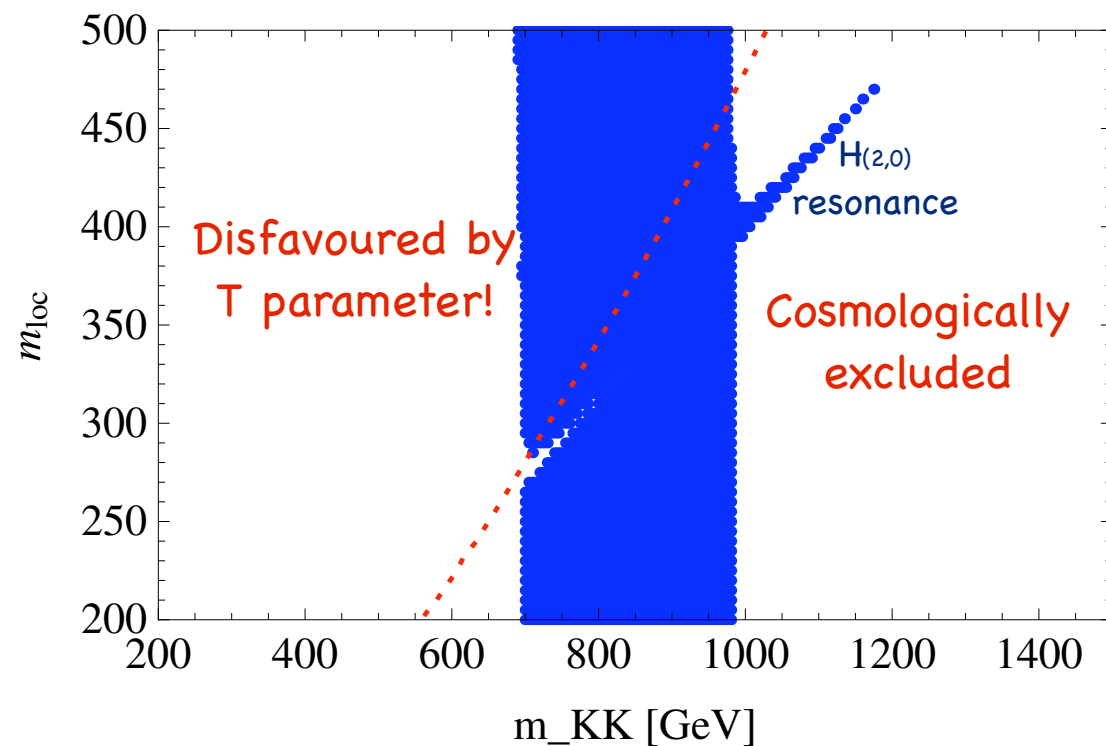
	RPP	Chi2
G_s	678	516
G_μ	–	717
Z_s, W_s	615	475
Z_μ, W_μ	–	547
DM- $\rightarrow A_s$	600	444
A_μ	–	500
H	–	542

	RPP	Chi2
mKK	600	516
★ Q	645	645
U	642	630
D	639	625
L	607	537
E	602	537

Mass splittings are
much larger for the Chi2!!

Preferred mass ranges: WMAP data

Real Projective Plane

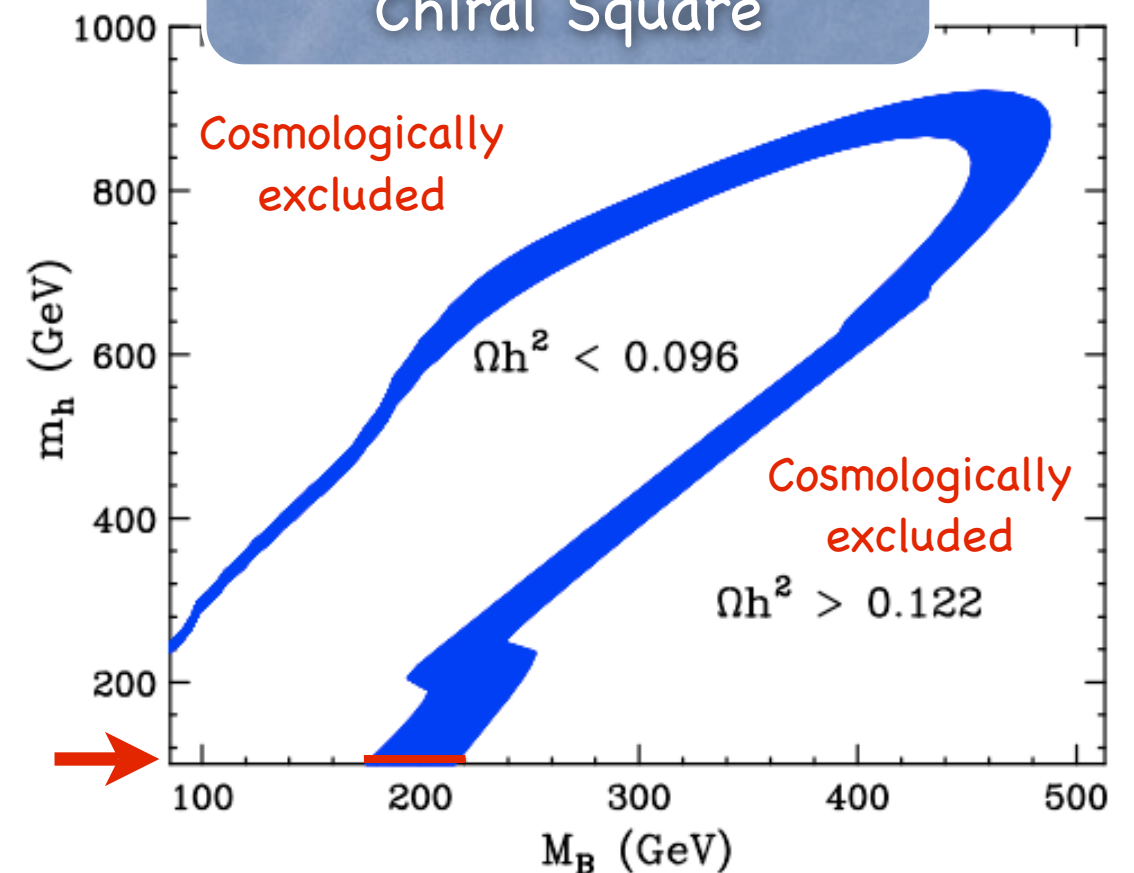


A.Arbey, G.C., A.Deandrea, B.Kubik 1210.0384

$$700 < m_A < 1000$$

$$700 < m_{\text{KK}} < 1000$$

Chiral Square



B.Dobrescu, D.Hooper, K.Kong, R.Mahbubani 0706.3409

$$180 < m_A < 220$$

$$210 < m_{\text{KK}} < 255$$

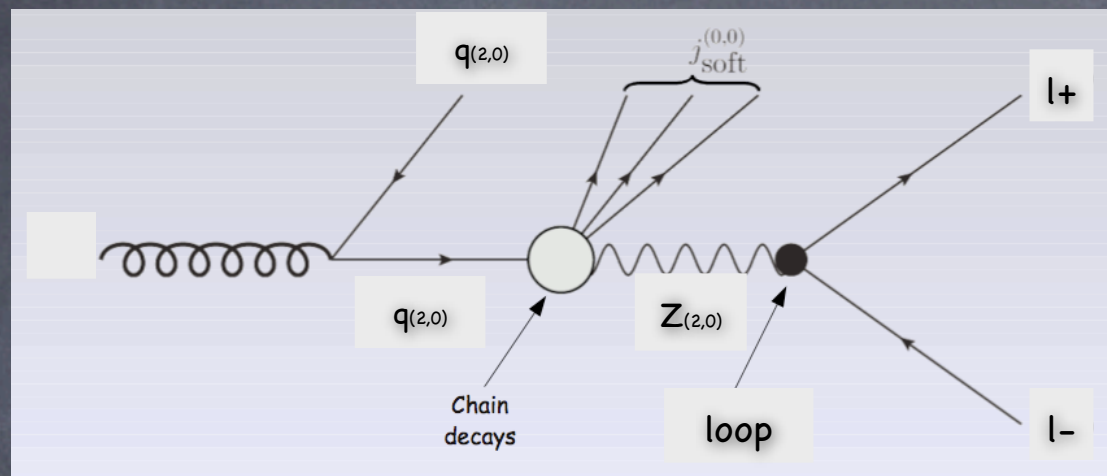
LHC signatures without MET:

Real Projective Plane

tier (2,0)

G.C., B.Kubik 1209.6556

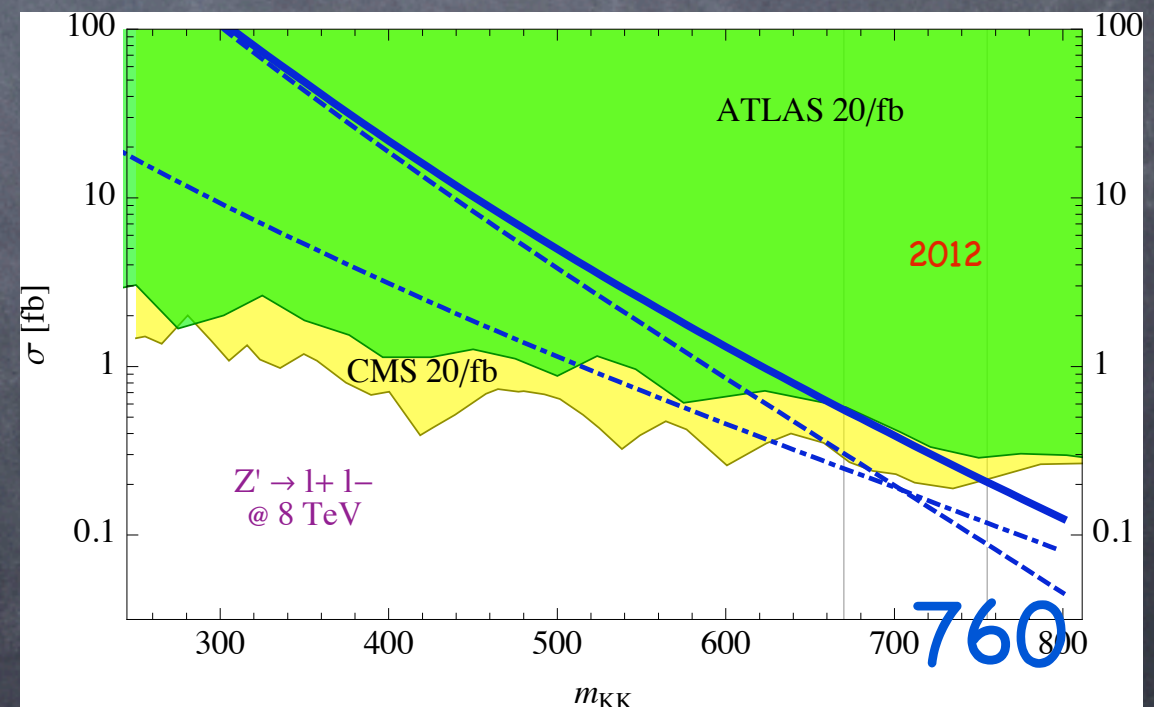
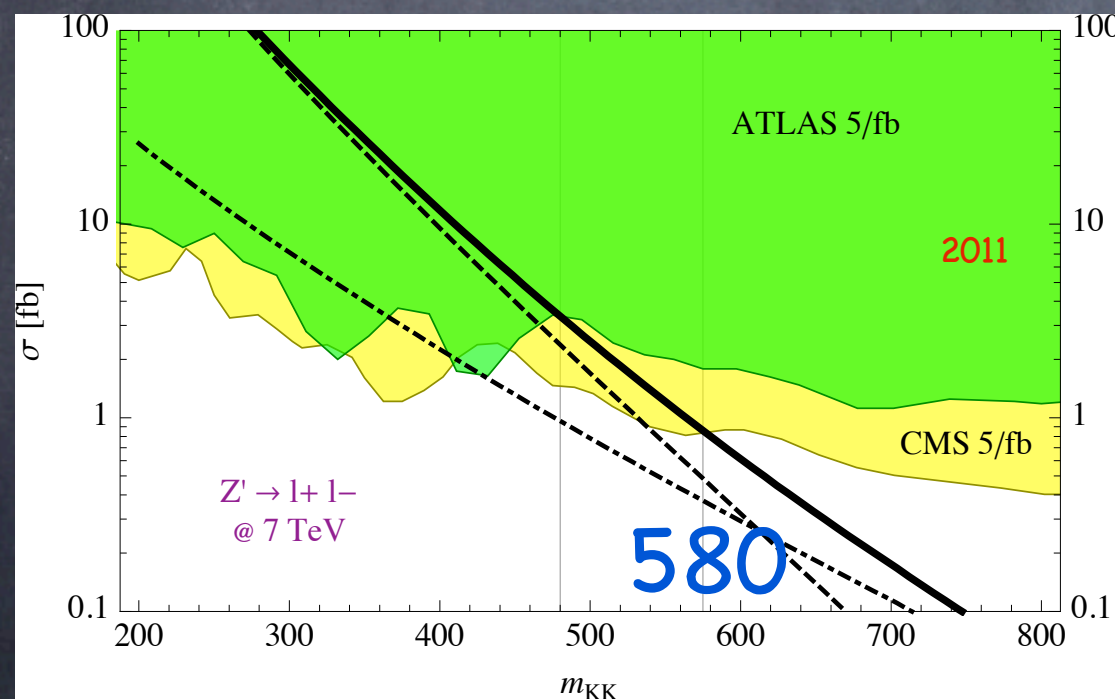
- Cleanest channels are di-lepton (Z') and single lepton + MET (W'):



$$Z_{(2,0)}, A_{(2,0)} \rightarrow l l$$

BR: 0.2% !!

$$W_{(2,0)} \rightarrow l \nu$$



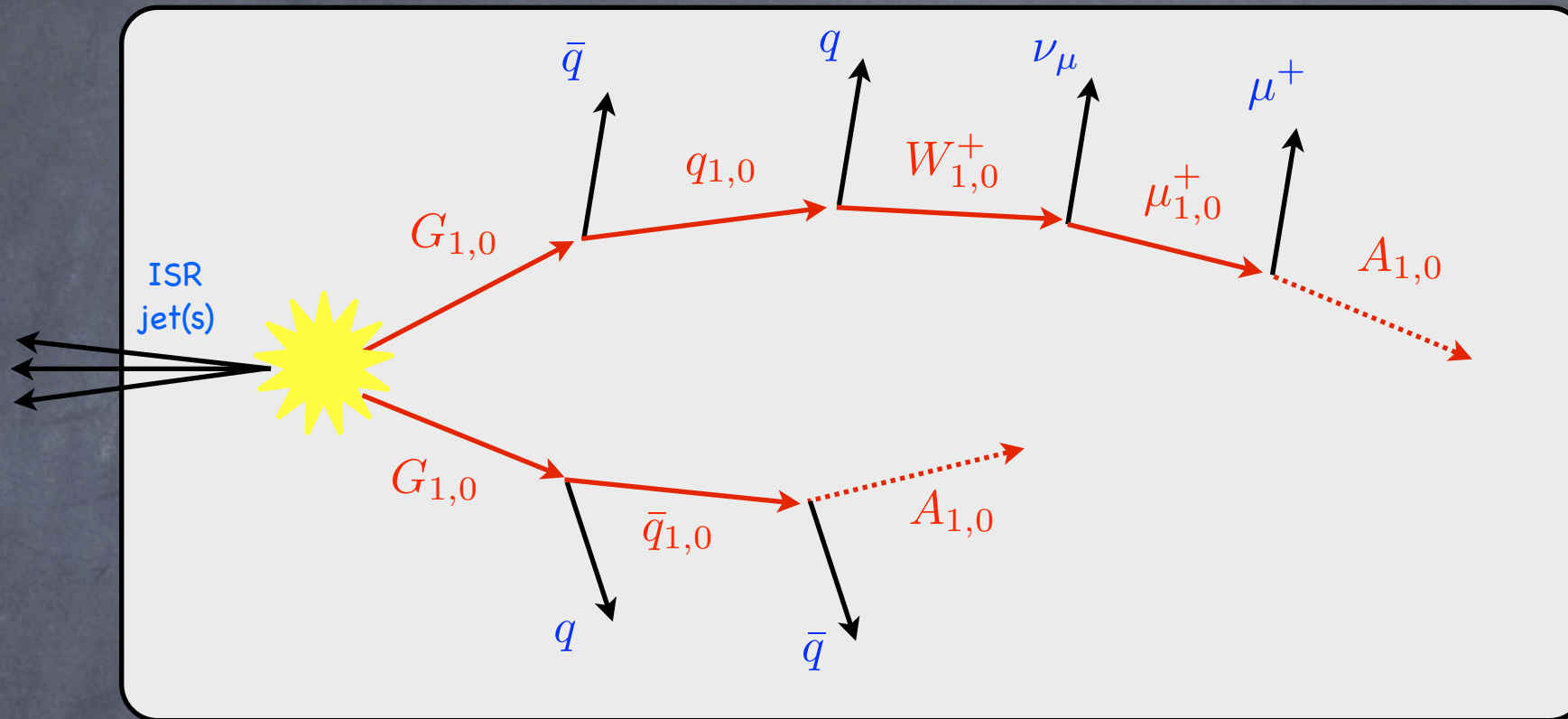
$$R_5 > R_6$$

LHC signatures with MET:

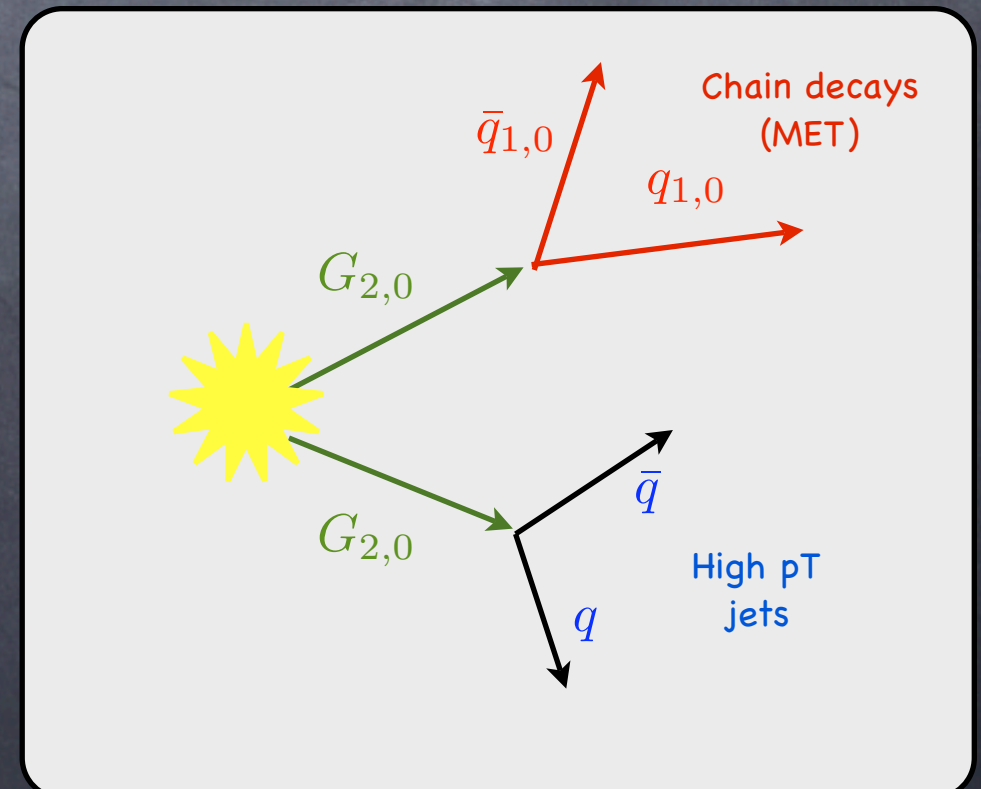
Real Projective Plane

tiers (1,0) and (2,0)

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L.Panizzi 1302.4750



- We needed a full simulation of the UED signal, including matching with extra jet (ISR and FSR), and complicated decay chains!



LHC signatures with MET:

results

Real Projective Plane

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L.Panizzi 1302.4750

- Large production cross sections:

$M_{KK}(GeV)$	Odd tier				Even tier				fb
	$Q_1 Q_1$	$Q_1 \bar{Q}_1$	$G_1 Q_1$	$G_1 G_1$	$Q_2 Q_2$	$Q_2 \bar{Q}_2$	$G_2 Q_2$	$G_2 G_2$	
400	1,630	7,440	4,780	418	718	159	476	43	15,700
600	221	531	327	18	25.8	2.6	7.2	0.4	1,130
700	99	179	119	5.7	5.2	0.36	1.08	0.05	409

- (1,0) dominated by $Q \bar{Q}$.
- (2,0) dominated by QQ .
- (2,0) decreases faster than (1,0) for larger masses.
- Large total cross sections!

LHC signatures with MET:

results

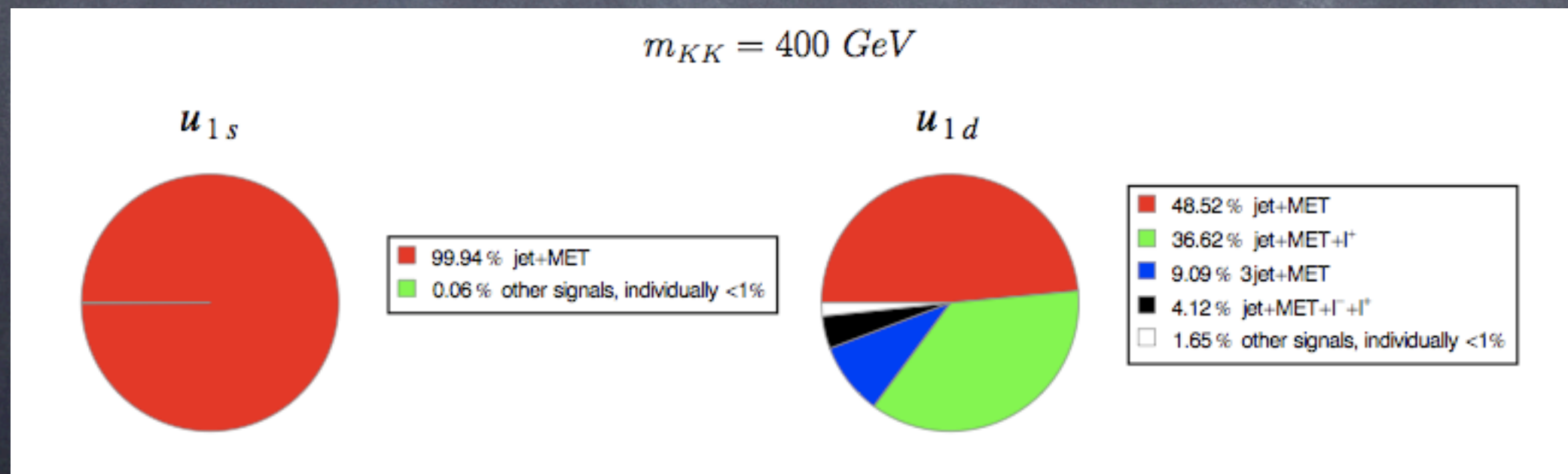
Real Projective Plane

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- Decay chains: (1,0) dominated by jet + MET



LHC signatures with MET:

results

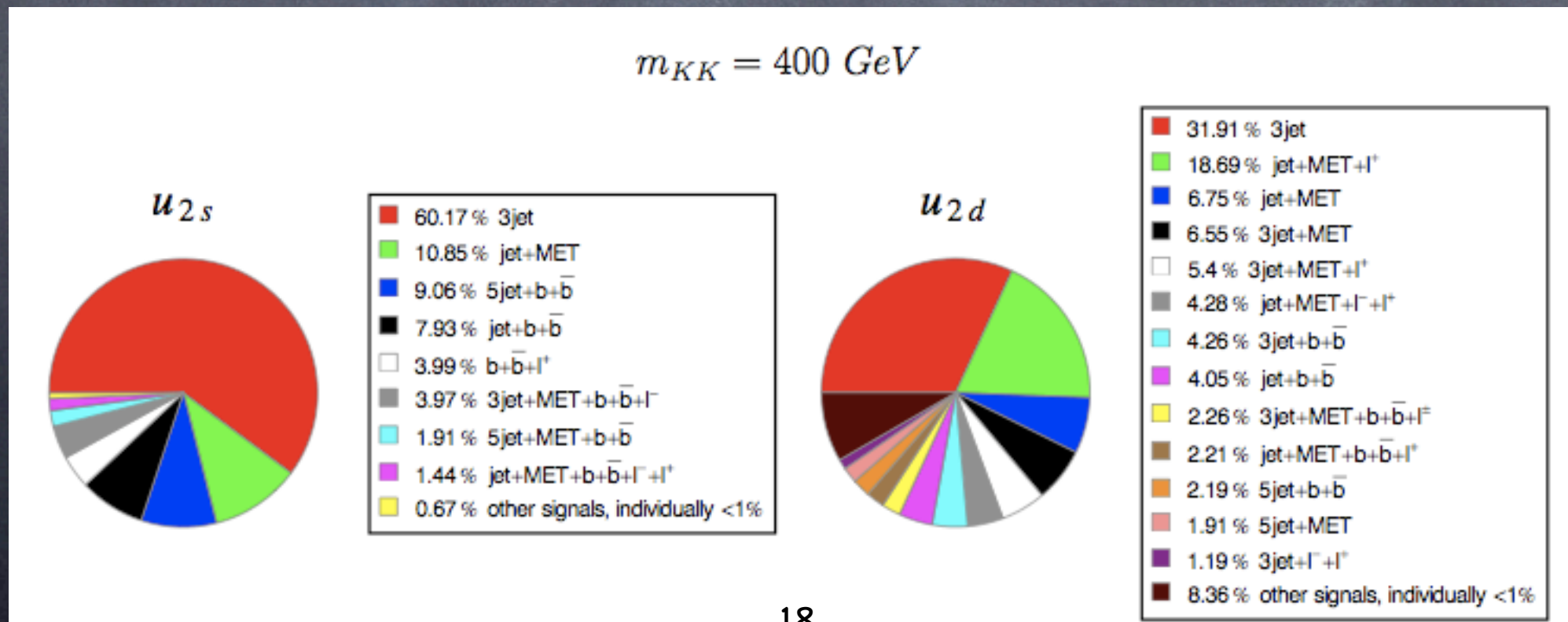
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400	1,630	7,440	4,780	418	718	159	476	43	15,700
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- Decay chains: (2,0) has more complex final states (dominant without MET)



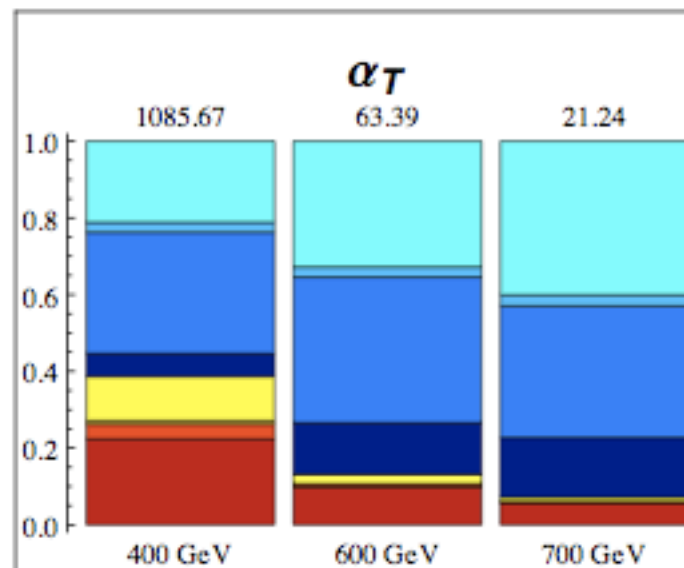
LHC signatures with MET:

results

Real Projective Plane

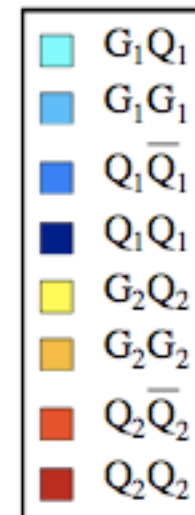
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- We implemented the CMS Susy searches to compute the signal yield for 3 benchmark mass values:

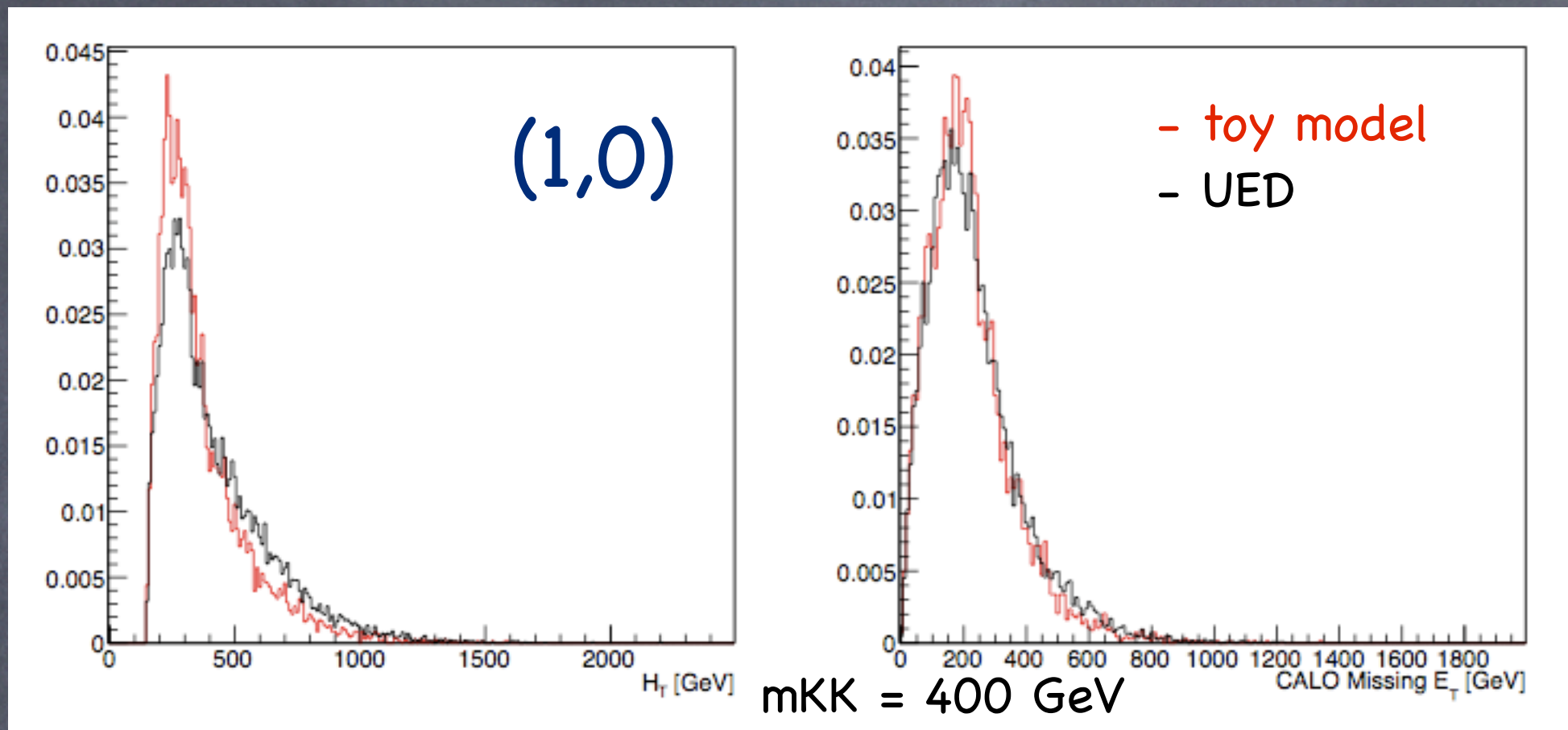


400 and 600 excluded
at more than 3 sigma

Bounds dominated by
(1,0) tiers.

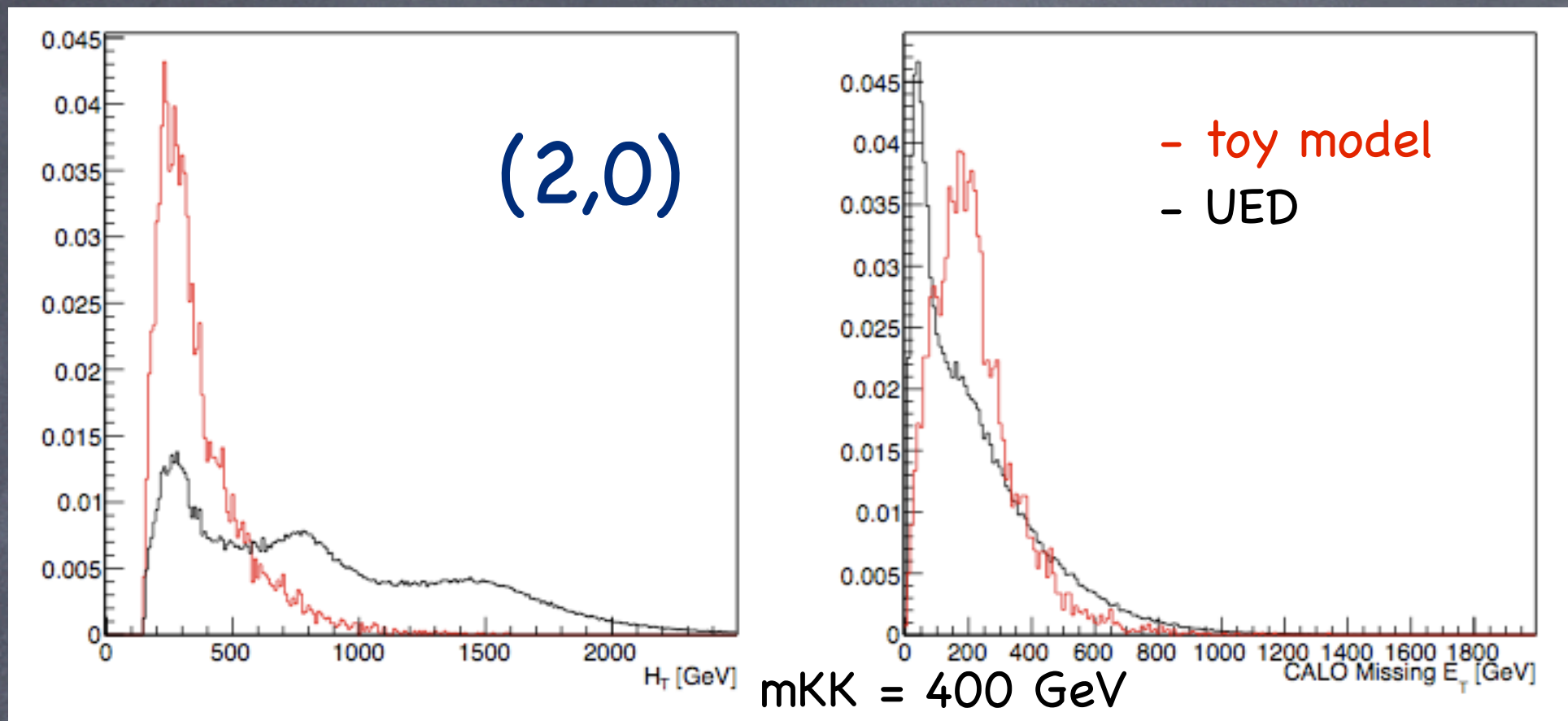


Understanding the result:



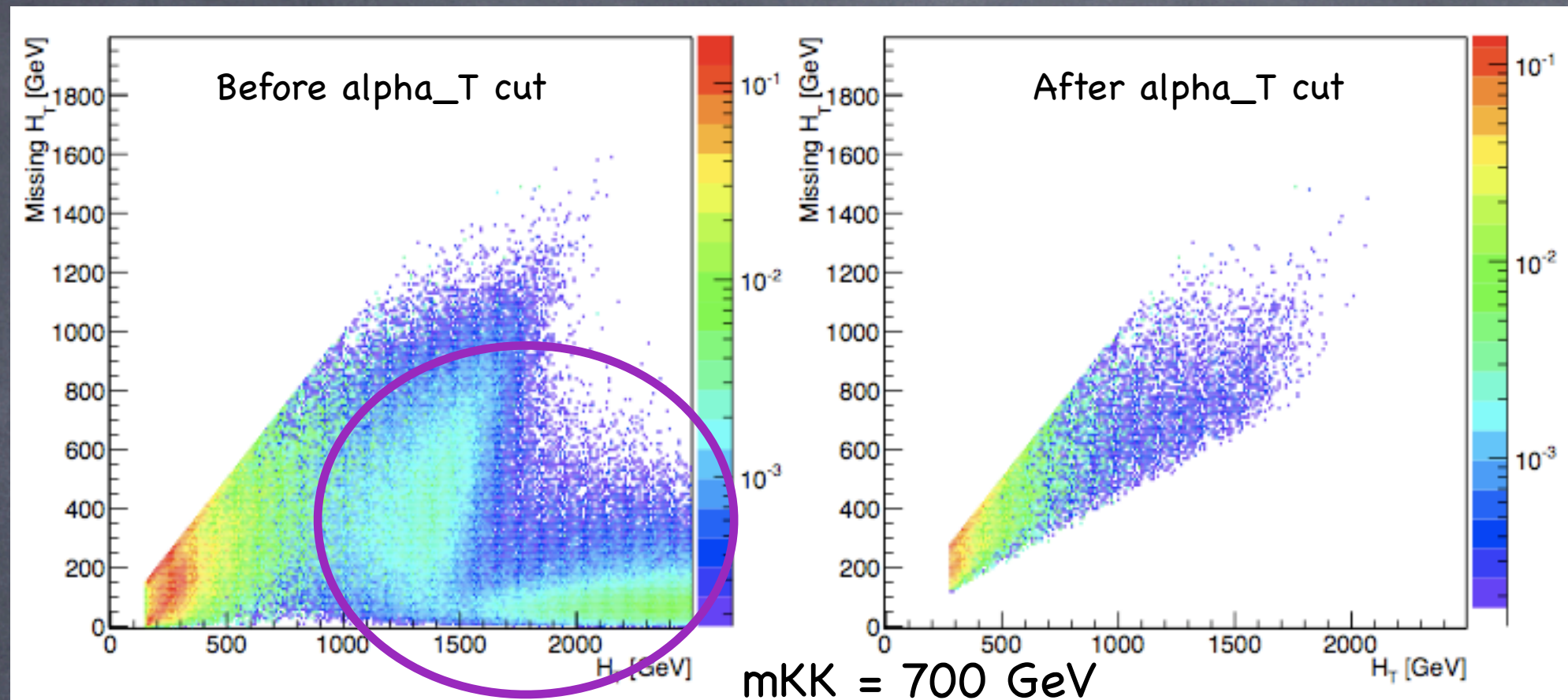
- Distributions of (1,0) match toy model of $Q \rightarrow q A$ (where $A = \text{MET}$)

Understanding the result:



- Distributions of (1,0) match toy model of $Q \rightarrow q A$ (where $A = \text{MET}$)
- Distributions of (2,0) have different features
 - events with higher HT
 - events with less MET

Understanding the result:



- Distributions of (2,0) have different features

- events with higher HT
- events with less MET

Events removed by
the alpha_T cut!

LHC signatures with MET:

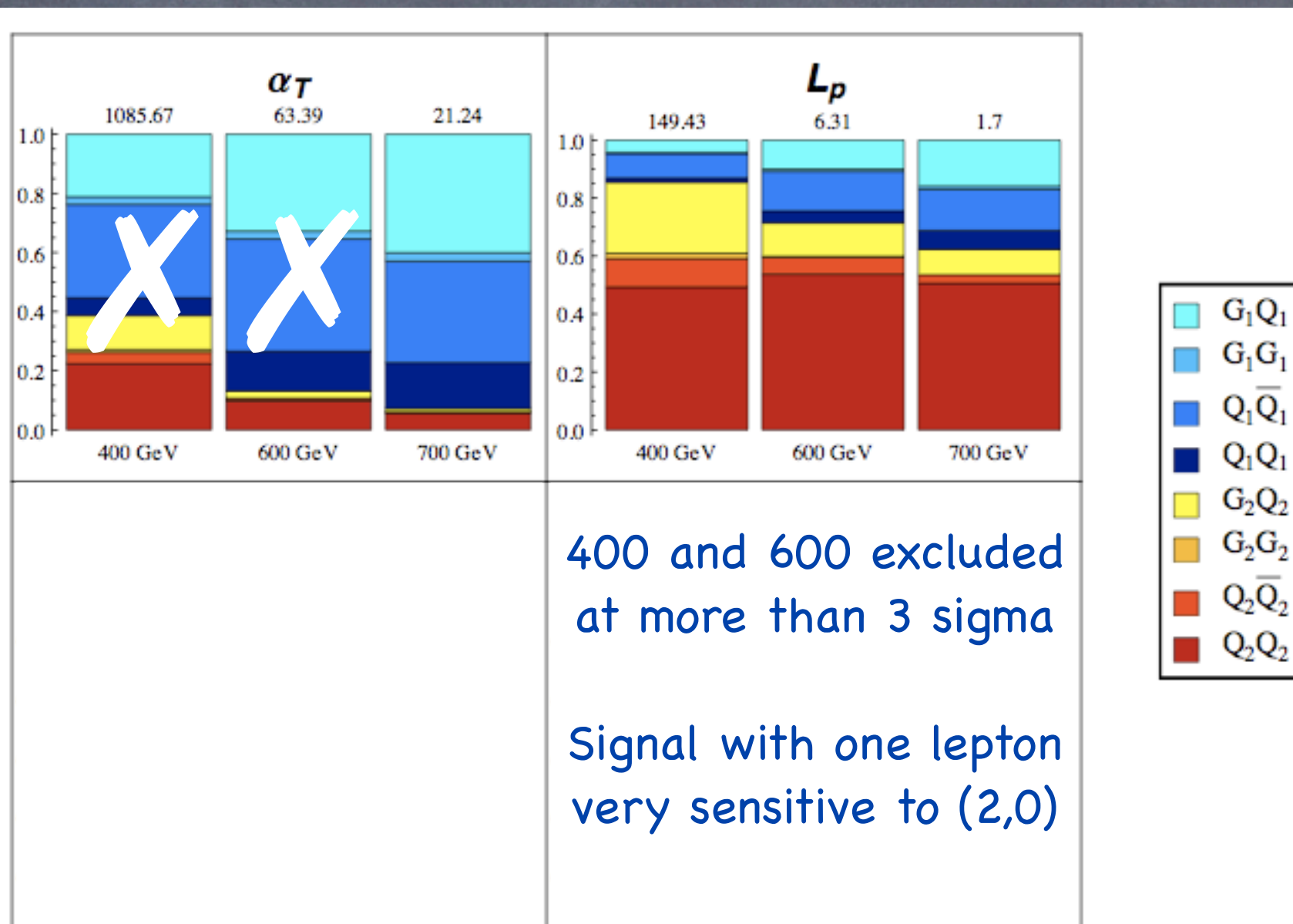
results

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$W_{(2,0)} \rightarrow l \nu$?



LHC signatures with MET:

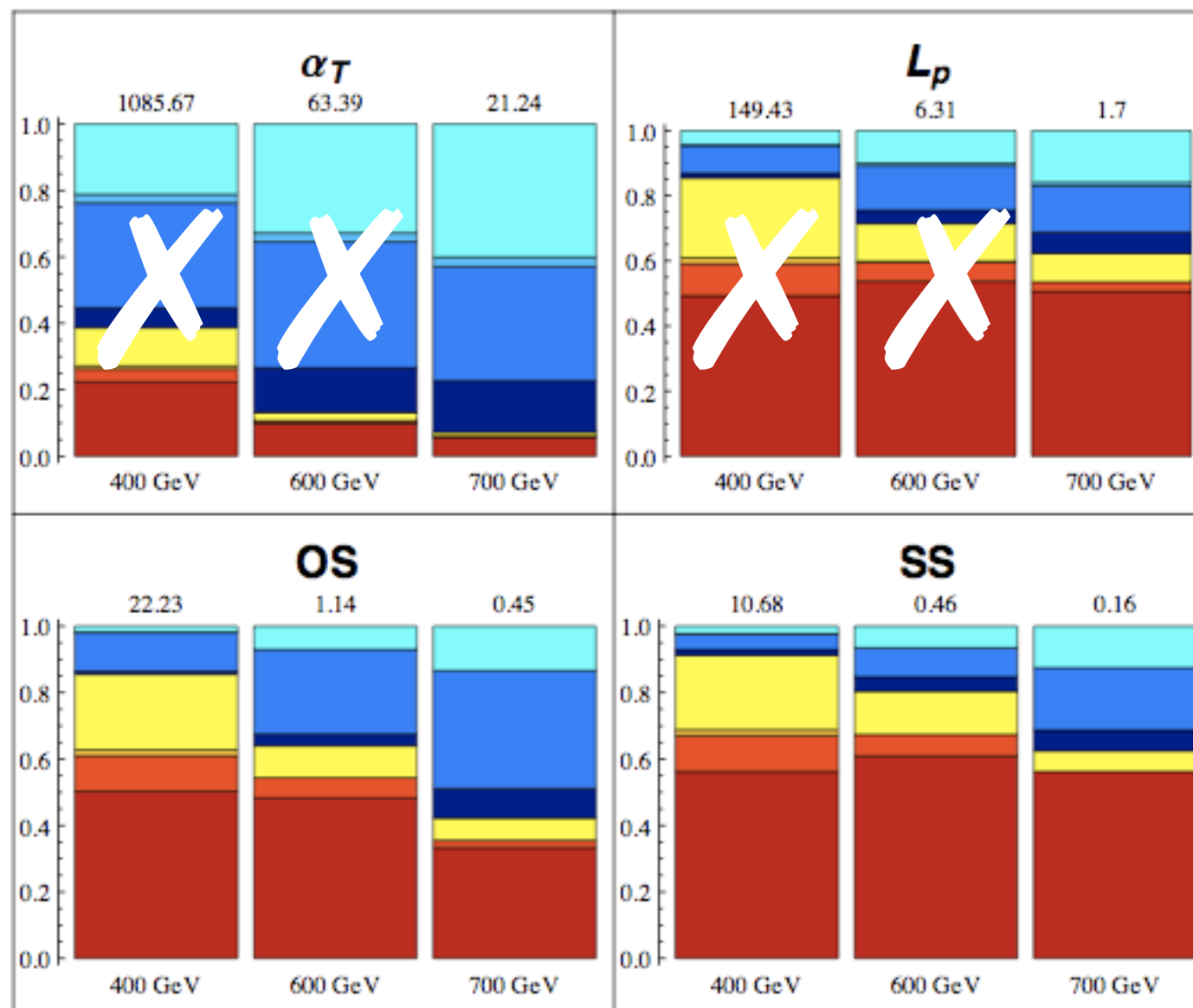
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Lesser impact
from dilepton
searches



LHC signatures with MET:

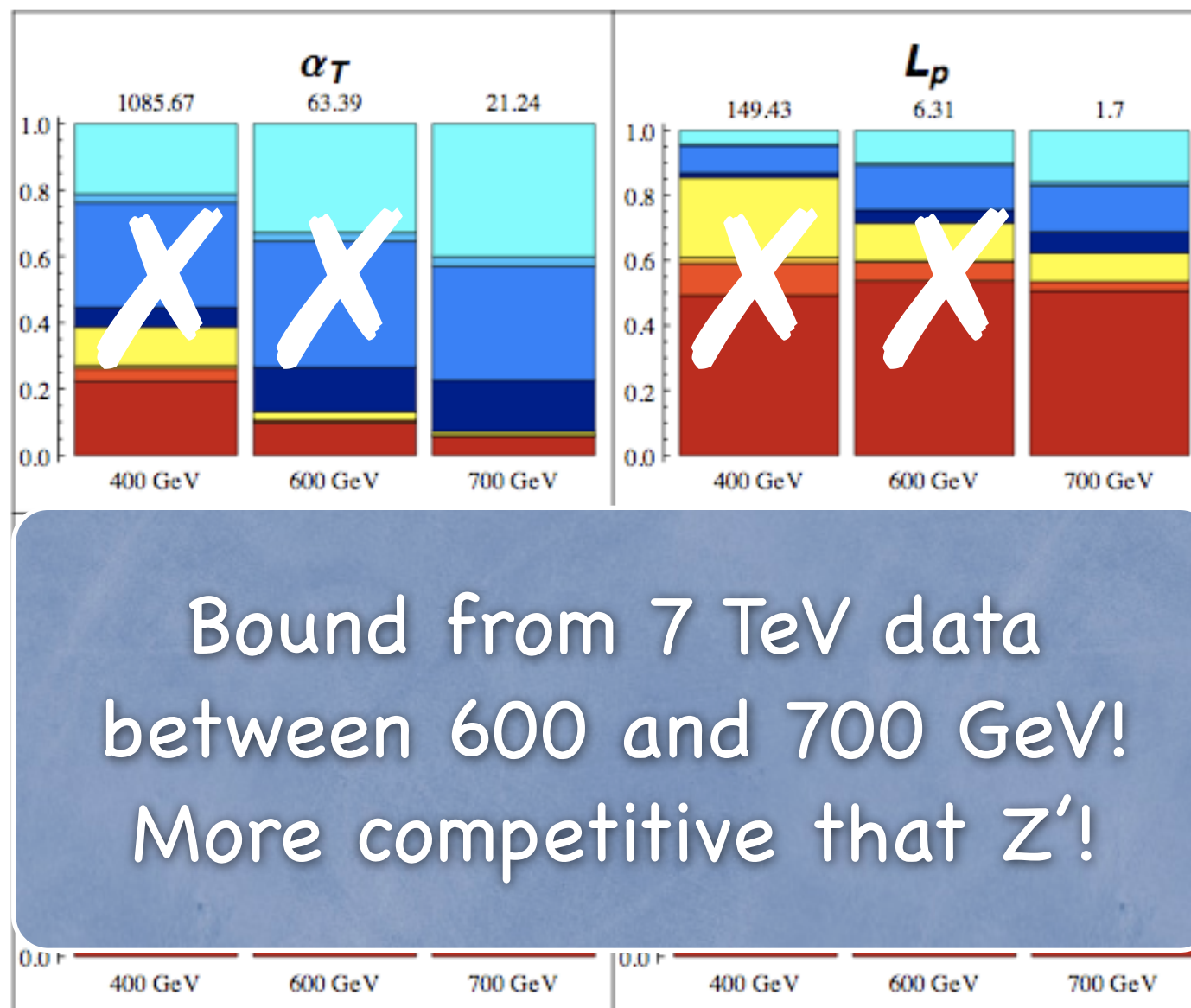
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Conclusions and outlook

- SUSY searches very effective to constraint UED models with compressed spectra!
- Bounds start probing the interesting mass range (for DM relic abundance).
- However, signals from the (2,0) are typically cut away... can this be improved?
- Study at 8 TeV in progress (long generation time for signal!)

WMAP/Planck	$700 < m_{KK} < 1000$
$Z' \rightarrow ll$ (7 TeV)	$m_{KK} > 580$
SUSY (MET) 7 TeV	$m_{KK} \geq 700$
$Z' \rightarrow ll$ (8 TeV)	$m_{KK} > 760$