Topological Approach to New physics

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with P. Konar, K.T. Matchev and G. K. Sarangi

1. How to look for supersymmetry under the lamppost at the LHC. with P. Konar, K. T. Matchev, G. K. Sarangi, Phys.Rev.Lett.105:221801,2010. (arXiv:1008.2483[hep-ph])
2. Follow up paper with P. Konar, K. T. Matchev, G. K. Sarangi

SUSY Recast 2011
University of California Davis

Different view of Searches

- Problem: Every model has (large) parameter space.
  - Especially MSSM: lots of particles

- (Mass) Parameter space: each mass from 0 to ∞

$$\boxed{\text{Mass spectrum of particles}} = \boxed{\text{Hierarchical ordering of the particles}} \otimes \boxed{\text{Mass splitting}}$$

R^n S_n **Qualitative (finite)** **Quantitative (infinite)** R^n/S_n

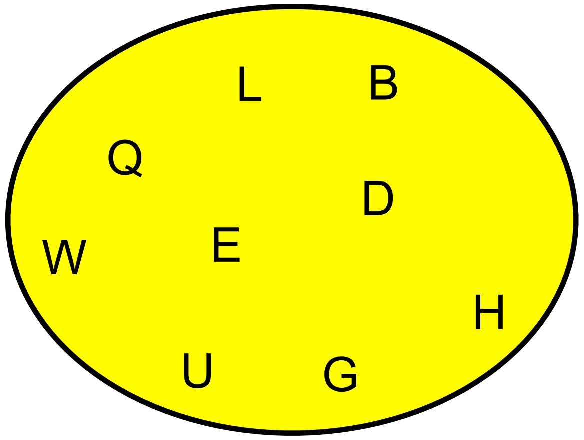
- We focused on the finite structure of the parameter space. This approach enables us to cover all possible scenarios.

Topological approach

- Model with 9 particles motivated by Supersymmetry
  - UED looks same. (H.Cheng, K.T. Matchev, M. Schmaltz, 2002)
  - We ignore the mass splitting within a multiplet.

$\tilde{u}_L, \tilde{d}_L$	$\tilde{u}_R$	$\tilde{d}_R$	$\tilde{e}_L, \tilde{\nu}_L$	$\tilde{e}_R$	$\tilde{h}^\pm, \tilde{h}_u^0, \tilde{h}_d^0$	$\tilde{b}^0$	$\tilde{w}^\pm, \tilde{w}^0$	$\tilde{g}$
Q	U	D	L	E	H	B	W	G
M_Q	M_U	M_D	M_L	M_E	M_H	M_B	M_W	M_G

- There are 9! = 362,880 possible permutations.



Analyzing hierarchies

- First: who is the **LSP** (lightest stable particle)
  - CHAMP (8!=40,320) if LSP=E
  - R-hadron (4x8!=161,280) if LSP=G, Q, U or D
  - Missing energy (4x8!=**161,280**) if LSP=L, H, W or B
- Second: who is the **LCP** (lightest colored particle): G,Q,U, or D
  - most abundantly produced at hadron colliders
- Total number of distinct hierarchies, starting from LCP ($x_1x_2x_3$ $\boxed{\mathbf{C}\ \mathbf{y_1y_2y_3y_4}\ \mathrm{L}}$) Possible cases = **1,040**.
- For a given hierarchy, how does the LCP decay into LSP?

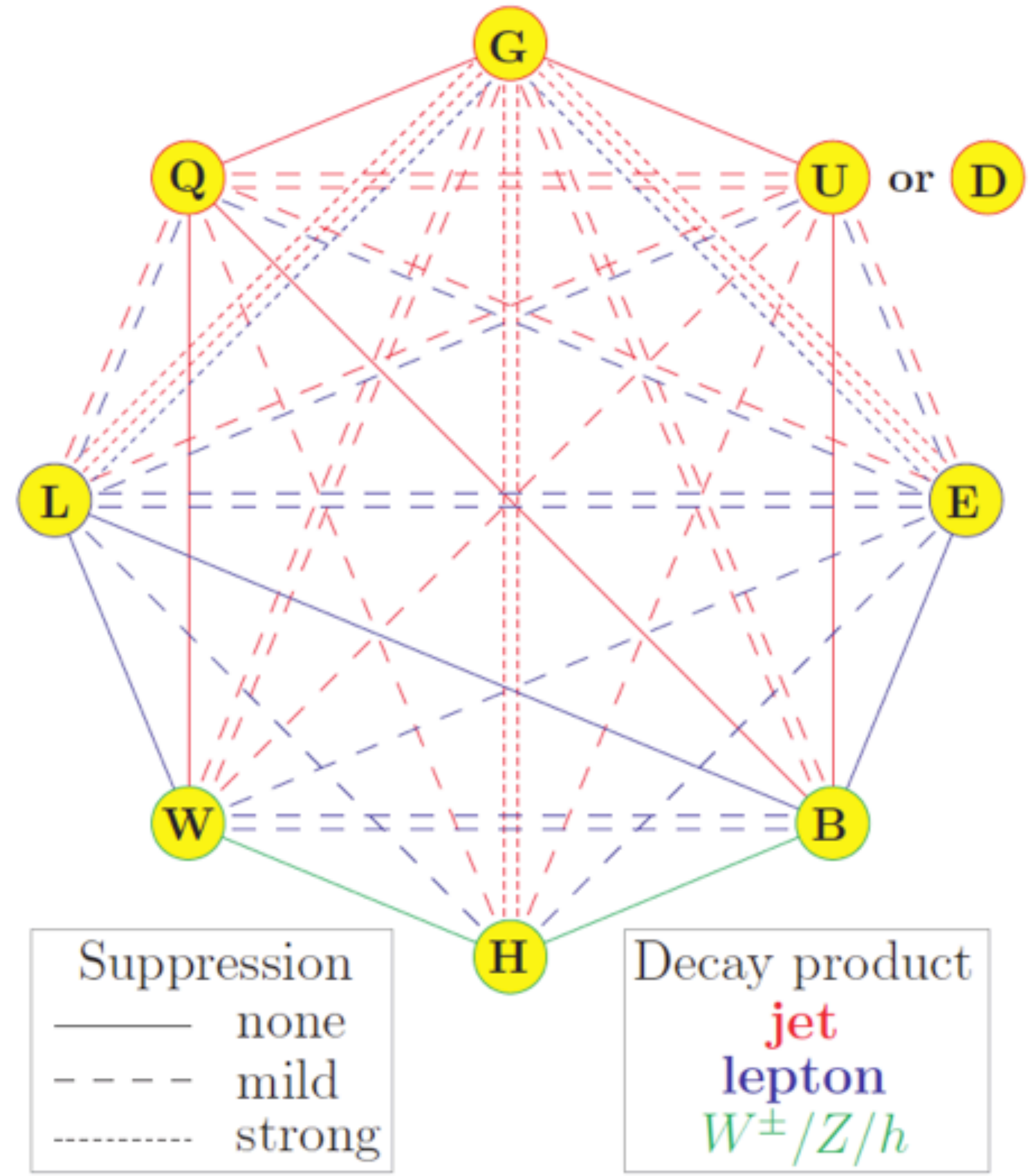
SUSY-like framework

- How do particles decay into each other ?
  - Dominant decay: ————————

    unsuppressed two body decay
  - Mild suppression: - - - - - - - - - - - -

    suppression by multibody phase space

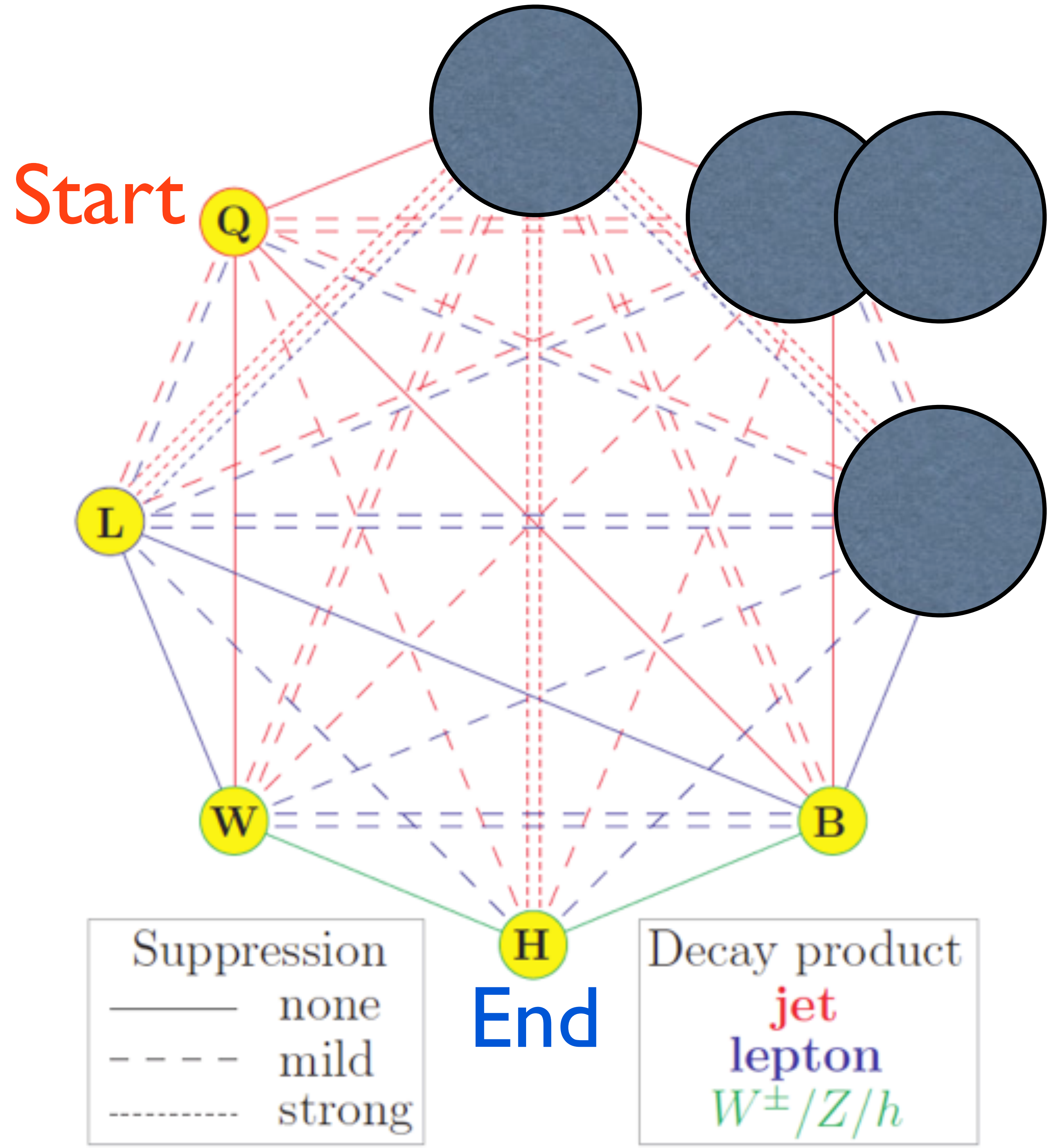
    suppression from mixing angle
  - Strong suppression: ···············
- What are the standard model decay products ? **Jet**, **lepton**, **W/Z/h**



Traveling Salesman

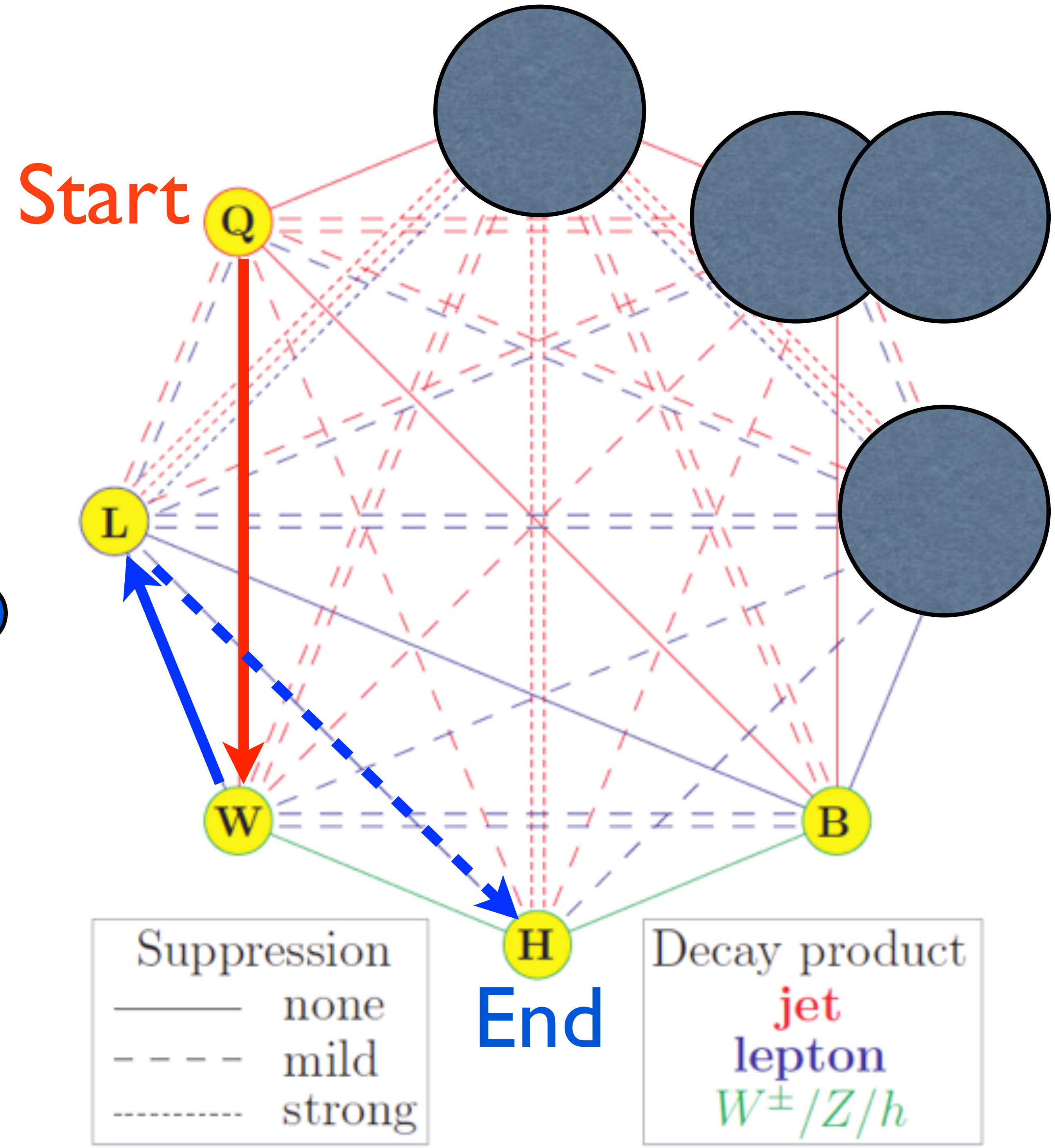
- Example:
  G>U>D>E>**Q**>W>B>L>**H**
  - start from Q
  - go to H
  - in all possible ways

- Then ask: what is the best way?



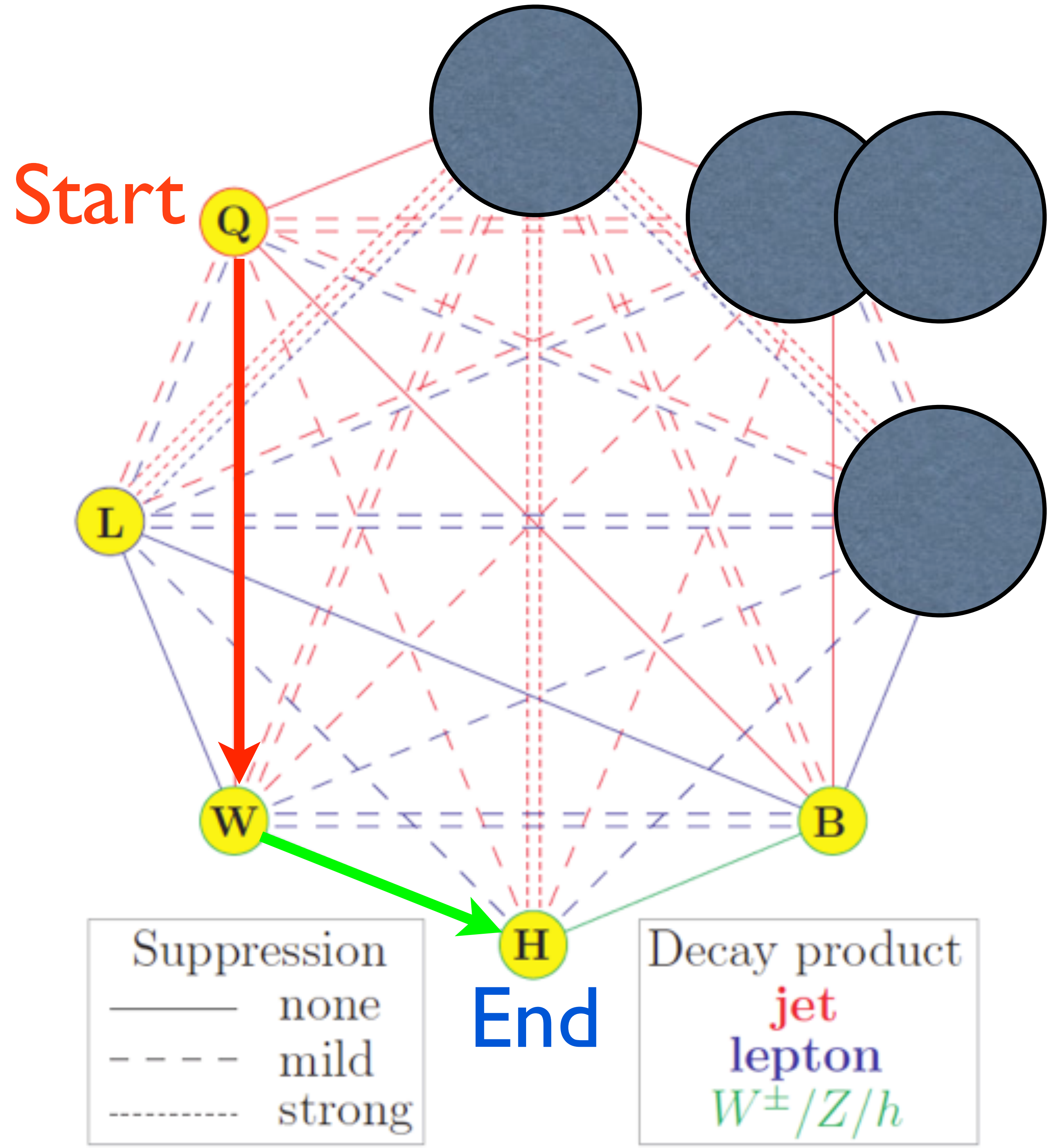
Traveling Salesman

- Example:
  G>U>D>E>**Q**>W>B>L>**H**
  1) **Q→W→L→H**



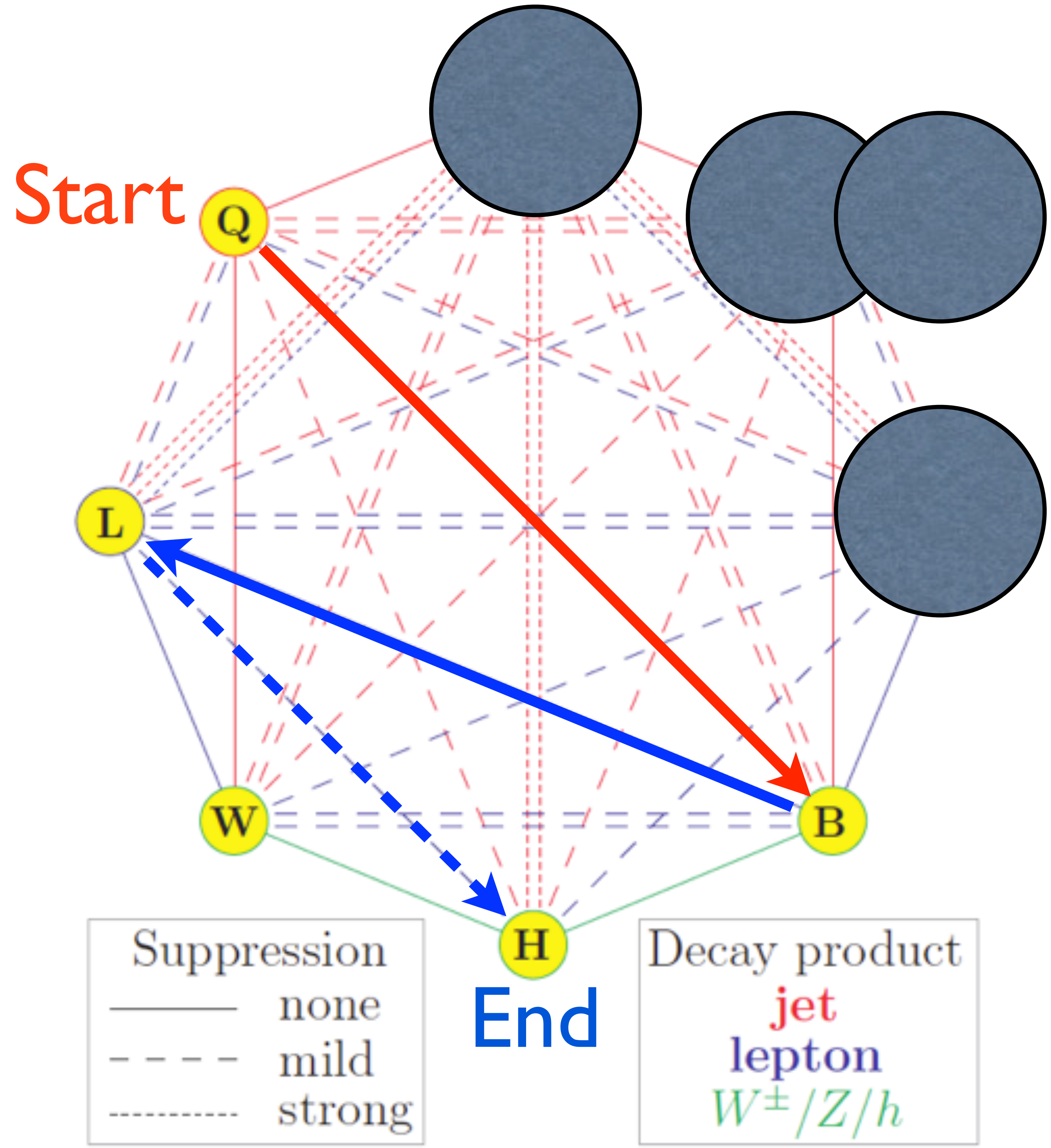
Traveling Salesman

- Example :
  G>U>D>E>**Q**>W>B>L>**H**
  1) Q→W→L→H
  2) **Q→W→H**



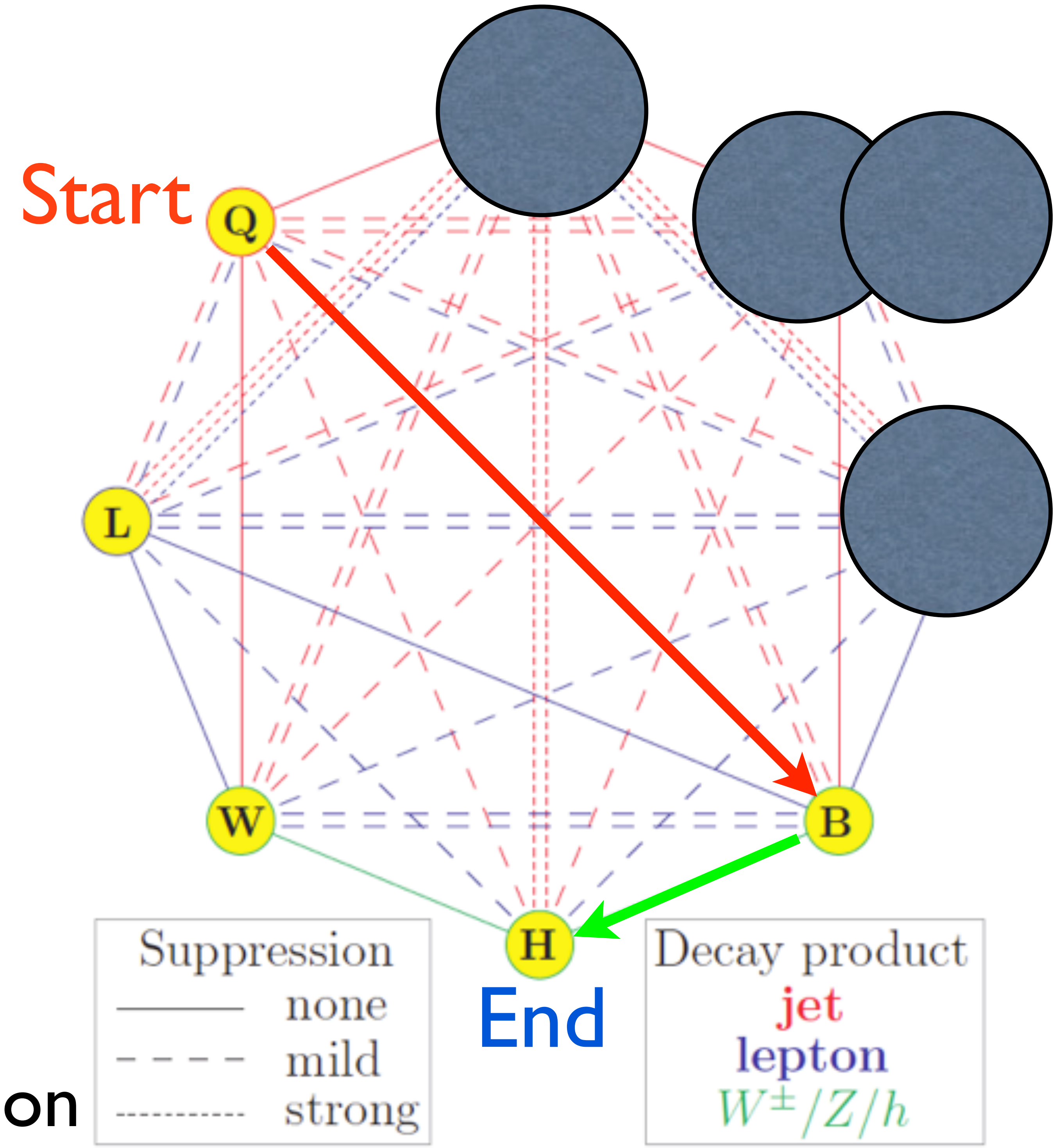
Traveling Salesman

- Example :
  G>U>D>E>**Q**>W>B>L>**H**
  1) Q→W→L→H
  2) Q→W→H
  3) **Q→B→L→H**



Traveling Salesman

- Example :
  G>U>D>E>**Q**>W>B>L>**H**
  1) Q→W→L→H
  2) Q→W→H
  3) Q→B→L→H
  4) **Q→B→H**



- This given hierarchy has two equally dominant decay modes,
  1. One jet+ Two leptons
  2. One jet+ One Vector boson

Checking all possibilities

- 1,040 theory model hierarchies from LCP to LSP
- Within our SUSY-like framework, there are 26 experimental channels (LCP decay modes)
- Obviously the inverse map will not be unique (?)

		Channels of the LCP decay					
Hierarchies		C_1	C_2	C_3	C_4	...	C_{24}
	H_1	V		V			
	H_2	V			V		V
	H_3		V				
	...						
	H_{1040}	V			V		V

LHC experiments (ATLAS / CMS)

Allowed theory Models

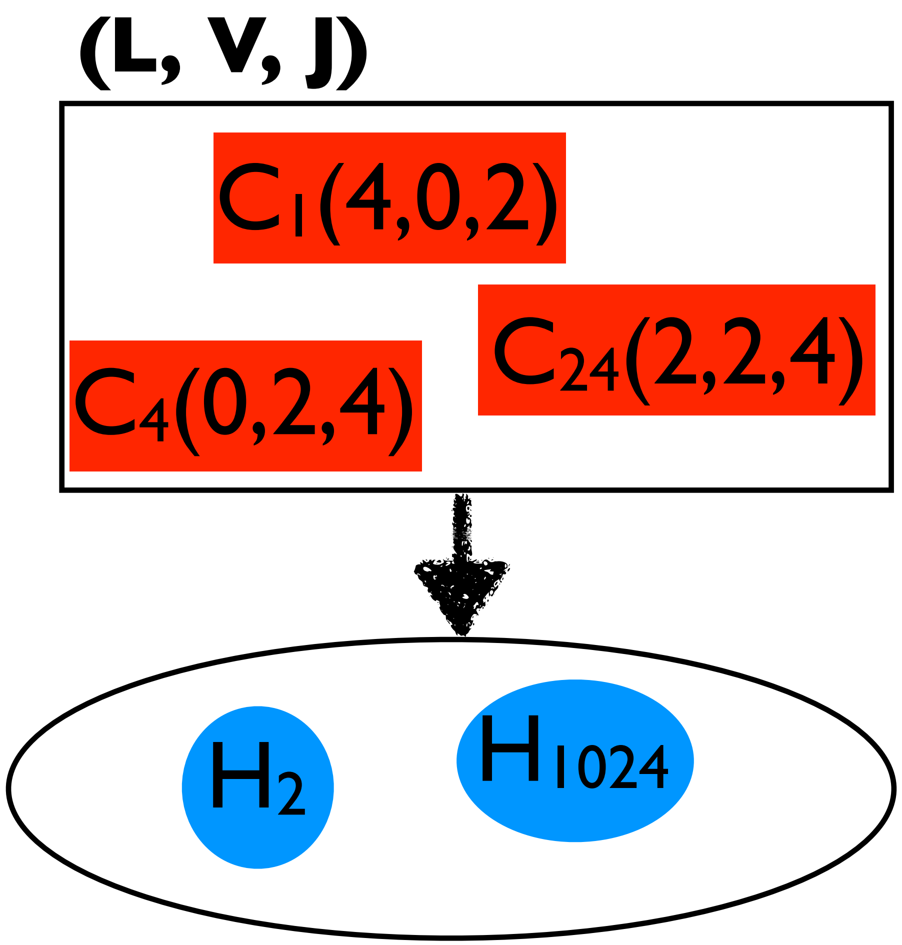
	C_1	C_2	C_3	C_4	...	C_{24}
H_1	V		V			
H_2	V			V		V
H_3		V				
H_4	V		V	V		
H_5		V				V
...						
H_{1037}	V	V		V		V
H_{1038}			V			
H_{1039}				V		
H_{1040}	V			V		V

LHC experiments (ATLAS / CMS)

Allowed theory Models

	C_1	C_2	C_3	C_4	...	C_{24}
H_1	V		V			
H_2	V			V		V
H_3		V				
H_4	V		V	V		
H_5		V				V
...						
H_{1037}	V	V		V		V
H_{1038}			V			
H_{1039}				V		
H_{1040}	V			V		V

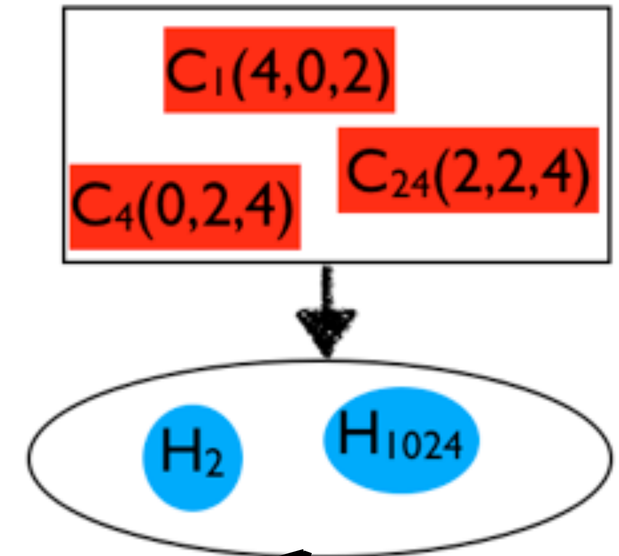
The LHC inverse problem

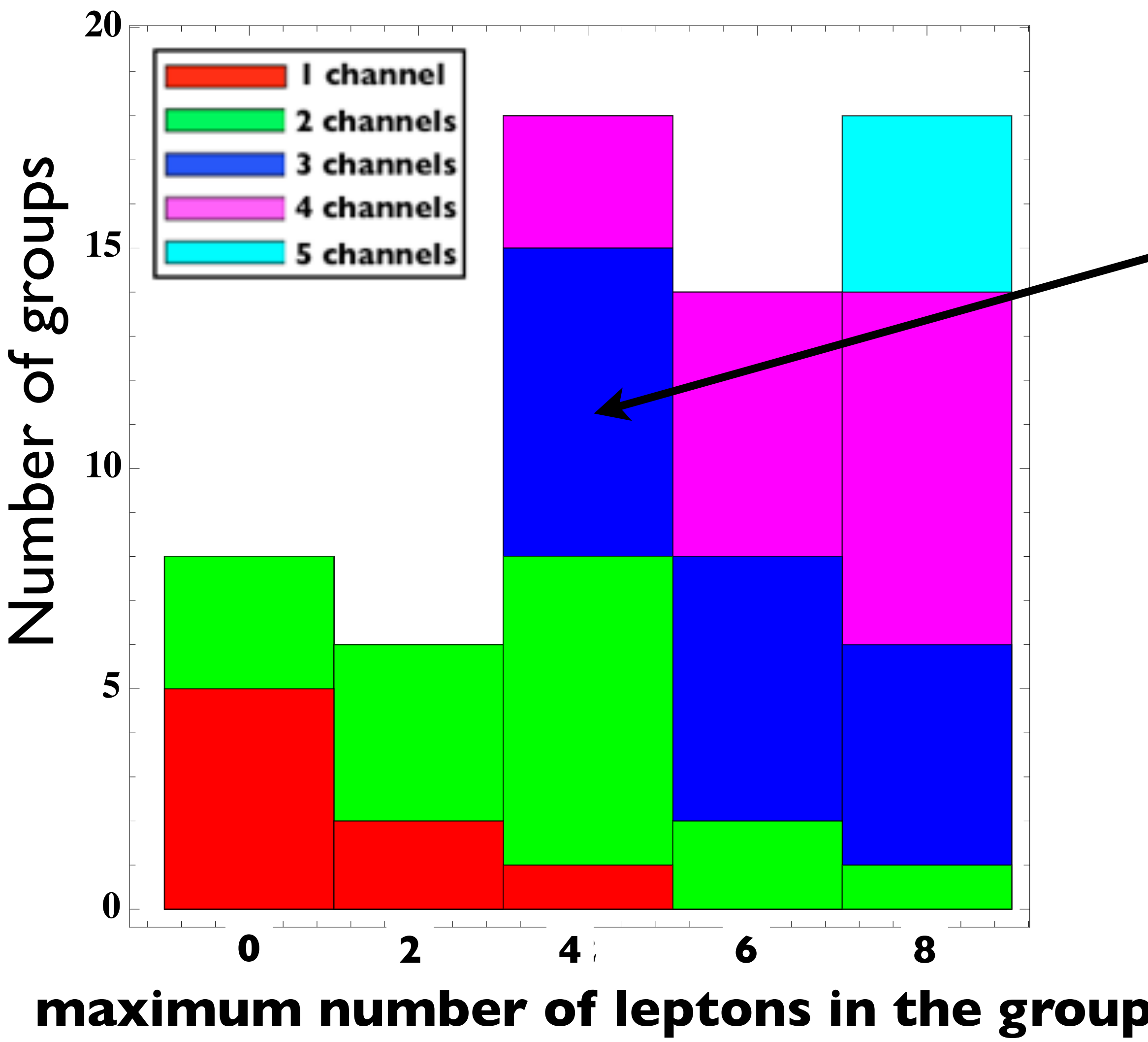


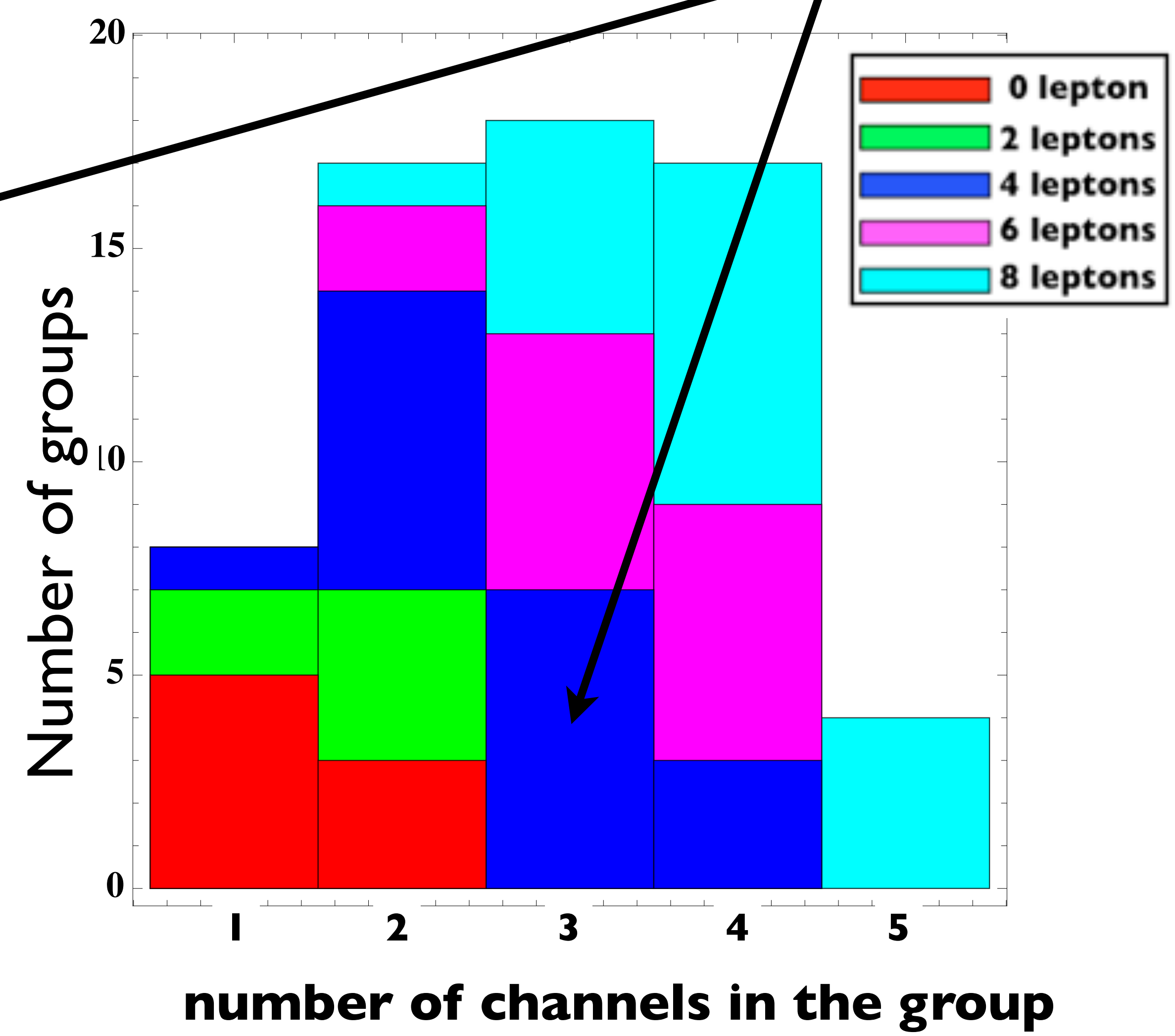
- This procedure is very generic and covers all possibilities in a model-independent way.
- We form groups of hierarchies which share the same set of channels.
  - We find 64 groups.
- Any group may contain one or many hierarchies. (As many as 167)
- The size of a group characterizes the uniqueness of inverse mapping.
  - Large group has more ambiguities.
  - Small group is more unique.

More details

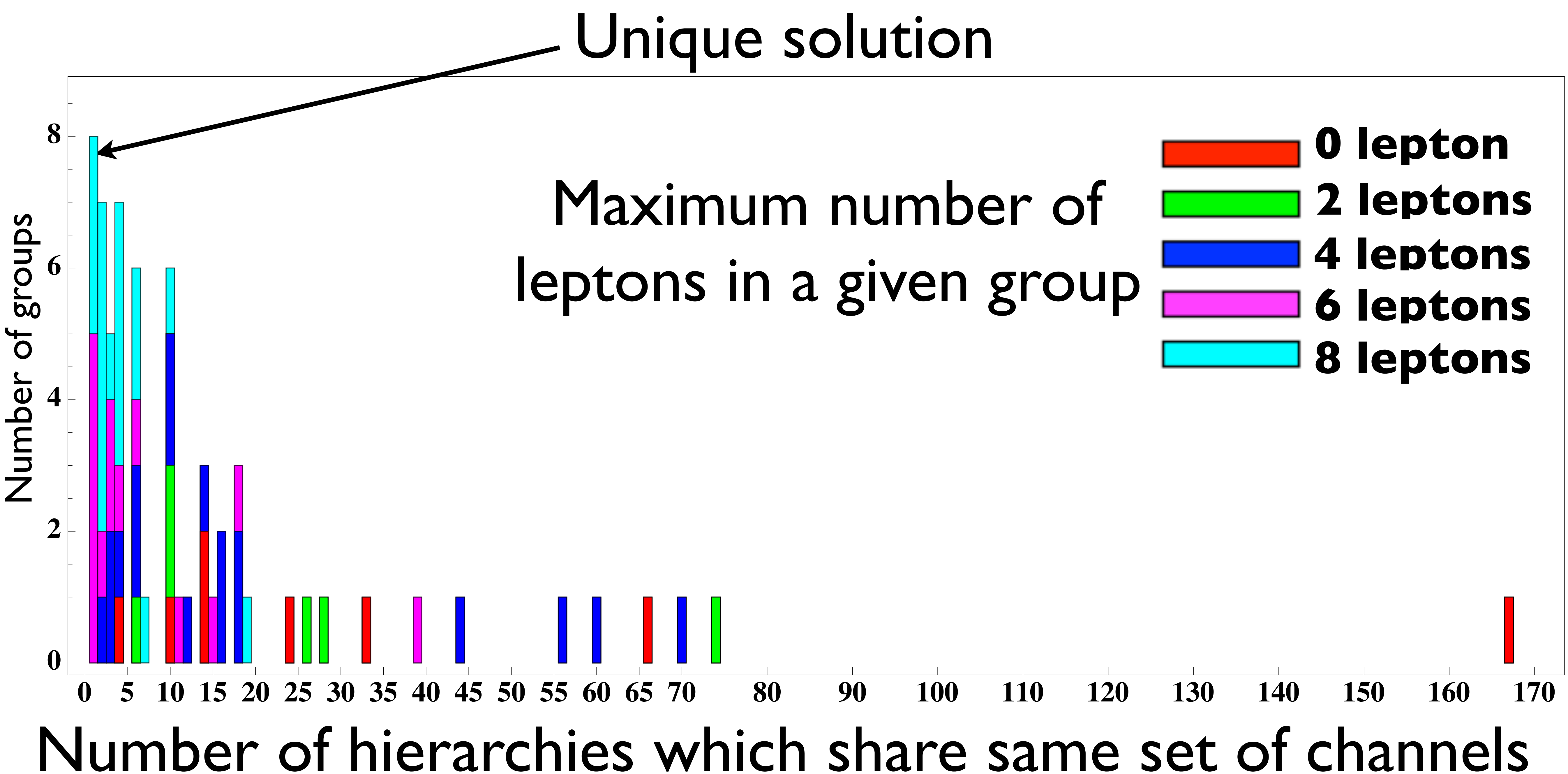
- A group of (H_2, H_{1040}) has 3 channels.
  - The maximum of leptons in this group: 4
  - The number of channels in this group:3







Solution of inverse problem



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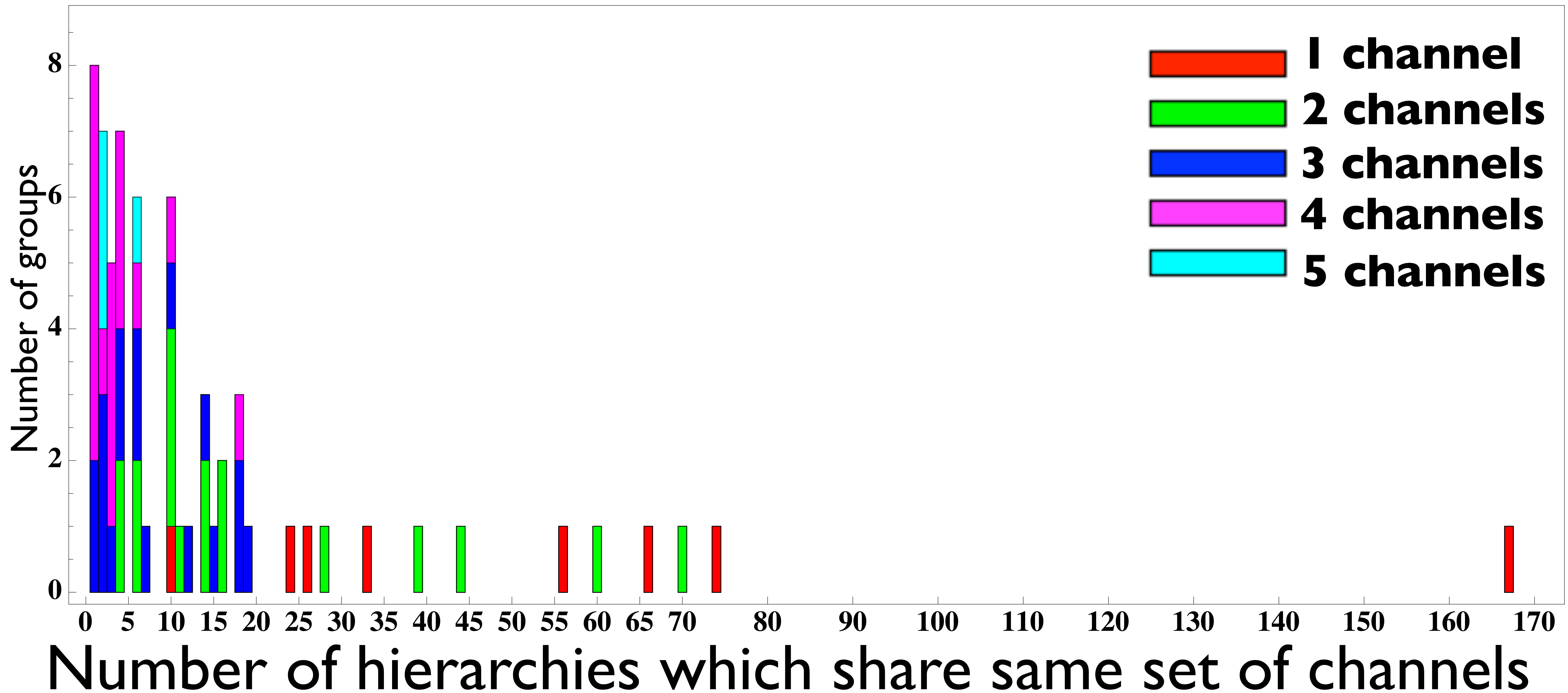
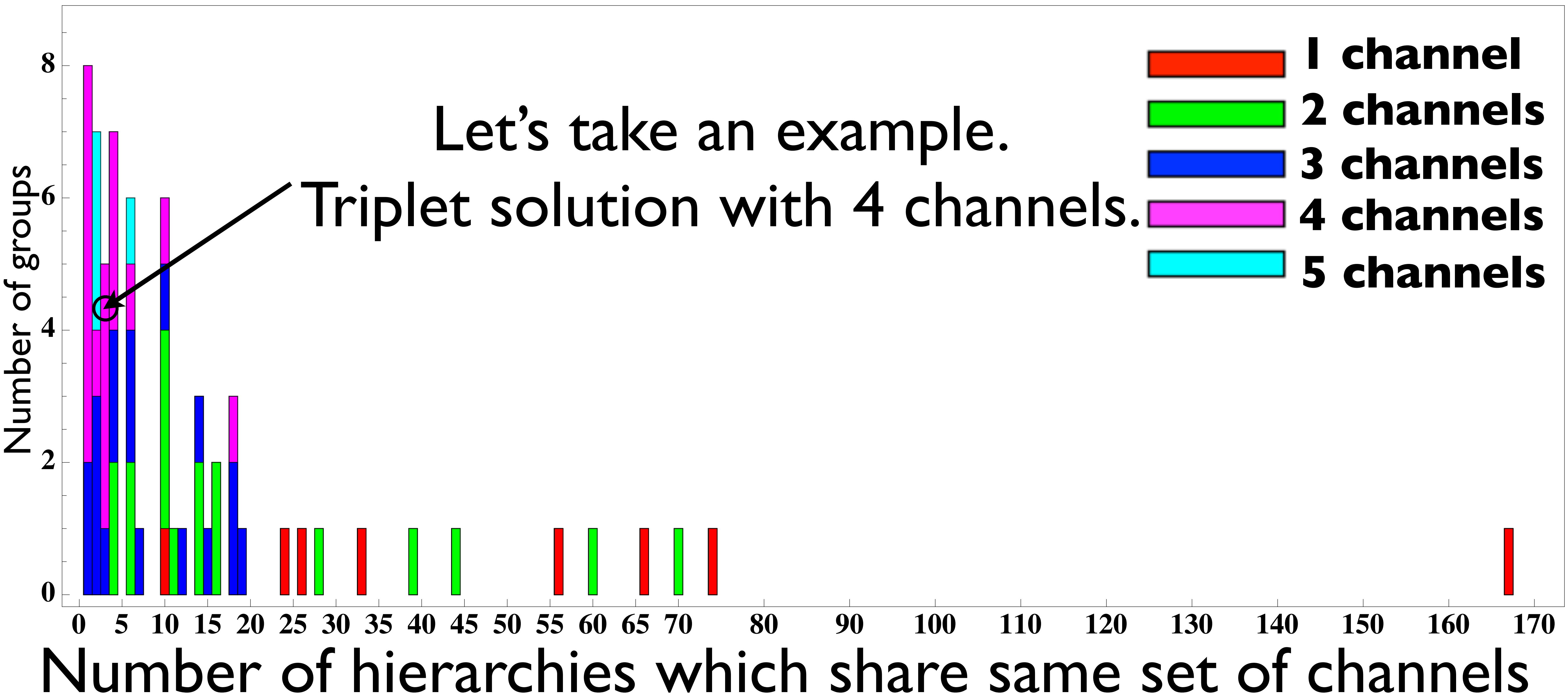


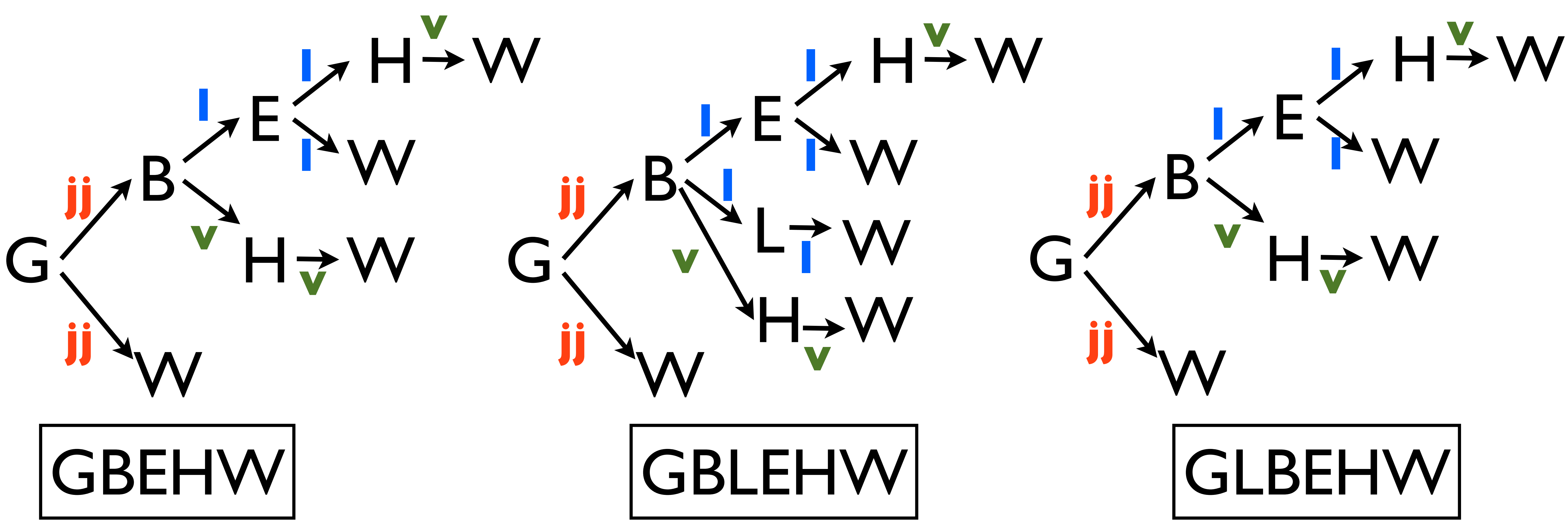
Solution of inverse problem



Example of triplet

G>B>E>H>W
G>B>L>E>H>W
G>L>B>E>H>W

(leptons, W/Z/H, jets)
(2, 1, 2)
(2, 0, 2)
(0, 2, 2)
(0, 0, 2)



Link to "Simplified Model"

Example: Two leptons + (# jets) channels

93 Hierarchies

$|Hierarchy| \leq 3$

length of hierarchy: number of particles from LCP to LSP

21 Hierarchies

$|Hierarchy| = 2$

$|Hierarchy| = 3$

3 Hierarchies

(G,L), (Q,L), (U/D, L)

18 Hierarchies

Starting with G

6 Hierarchies

(G,B,L), (G, B,W), (G, H, L), (G, L, H), (G,W, B), (G,W, L)

Conclusion

- By focusing on the finite structure of parameter space, we can cover all possible scenarios.
- We found the inverse map from the signature space to the theory space.
  - We identify the unique solutions.
  - We identify duplicated solutions.
- We provide the relevant topologies to the "simplified model approach" systematically.

Thank you ! / BACK UP

Real GATOR passing by a road next to our physics department in UF.
This photo was taken by Michael Burns in 2008.

Checking all possibilities

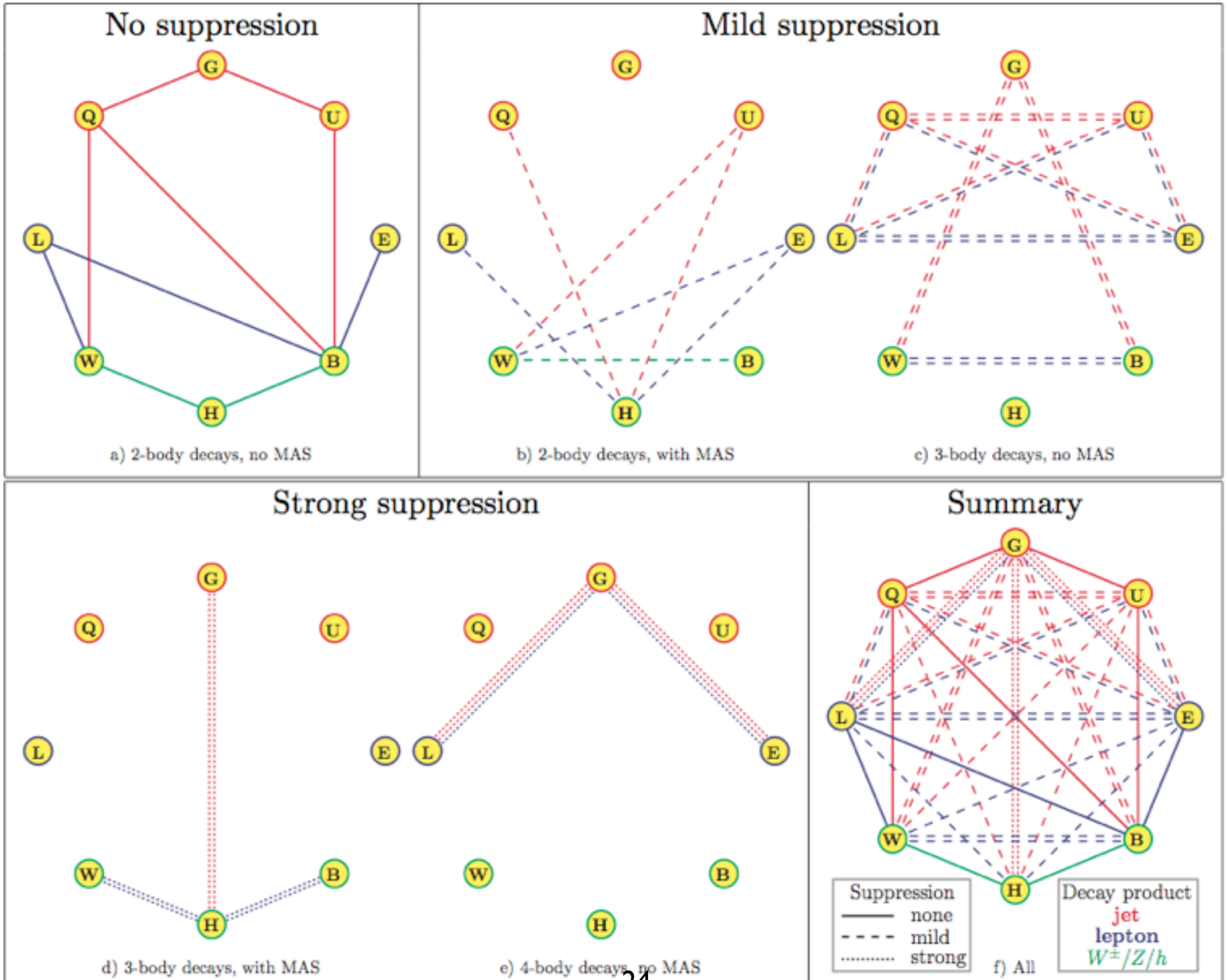
- By focusing on finite structure of parameter space, we can cover all possible scenario.

Out of 4x8! possible cases, a number of hierarchies for the given signals from LCP decay

	$n_v = 0$		$n_v = 1$		$n_v = 2$	
n_ℓ	$n_j = 1$	$n_j = 2$	$n_j = 1$	$n_j = 2$	$n_j = 1$	$n_j = 2$
0	79296	26880	12768	3360	1344	672
1	30240	10080	1824	480	192	96
2	19770	6030	1500	180	0	0
3	4656	1296	312	72	6	6
4	1656	396	66	6	0	0

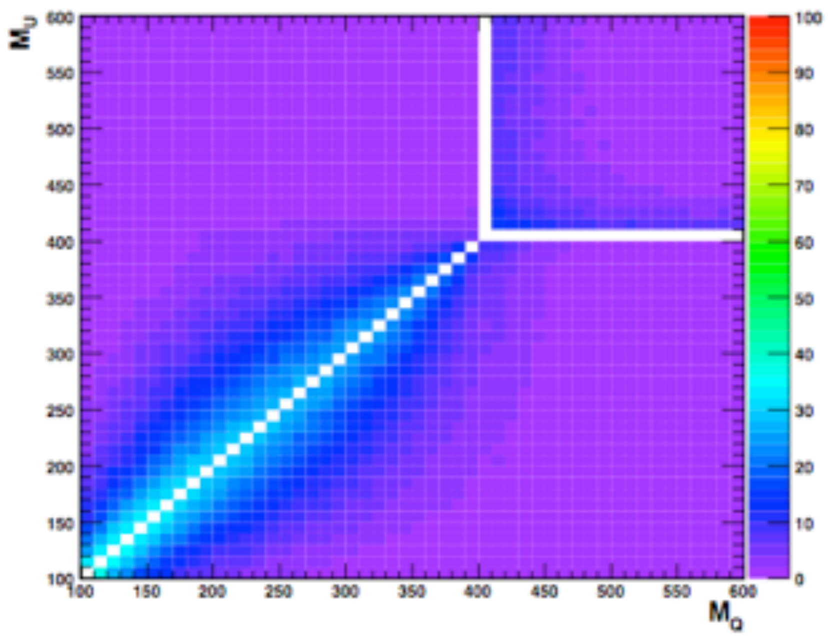
x2 from two cascade decay chains

Relations for transitions

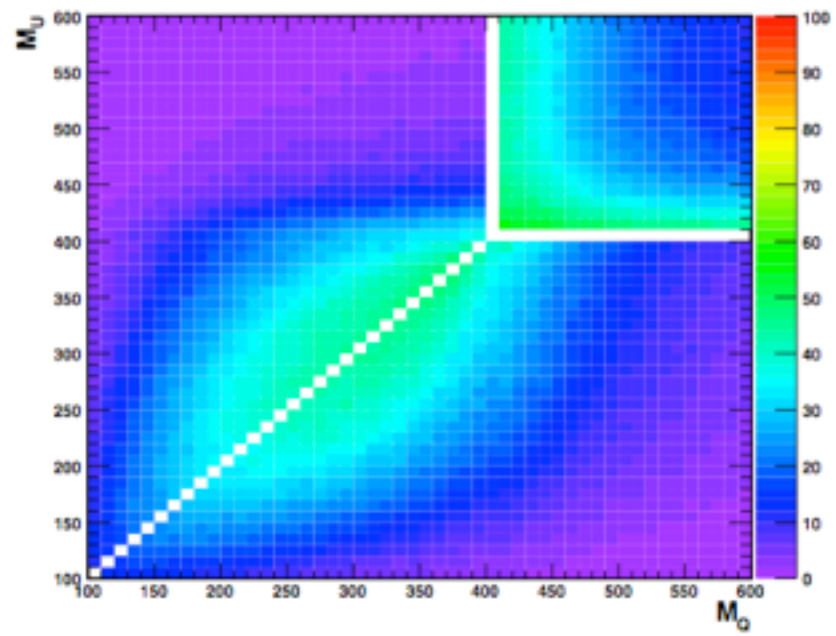


Rate of LCP production

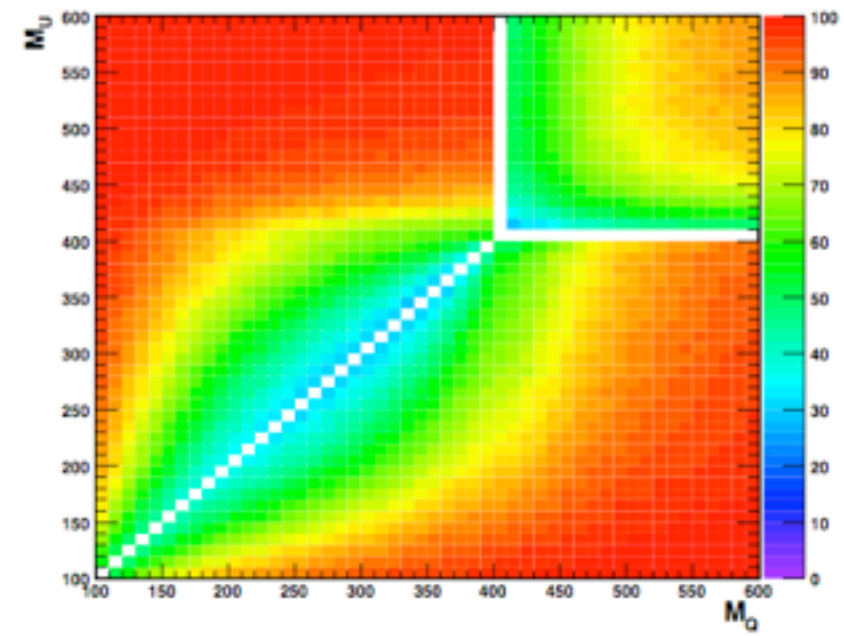
0- LCP production



1- LCP production



2- LCP production



- In MSSM with gaugino unification by fixing (M_B, M_W, M_G) ~ (100, 200, 400) GeV

A group of length 167

d	b
d	h
d	w
q	b
q	h
q	w
u	b
u	h
u	w

d	e	b
d	h	b
d	l	b
d	w	b
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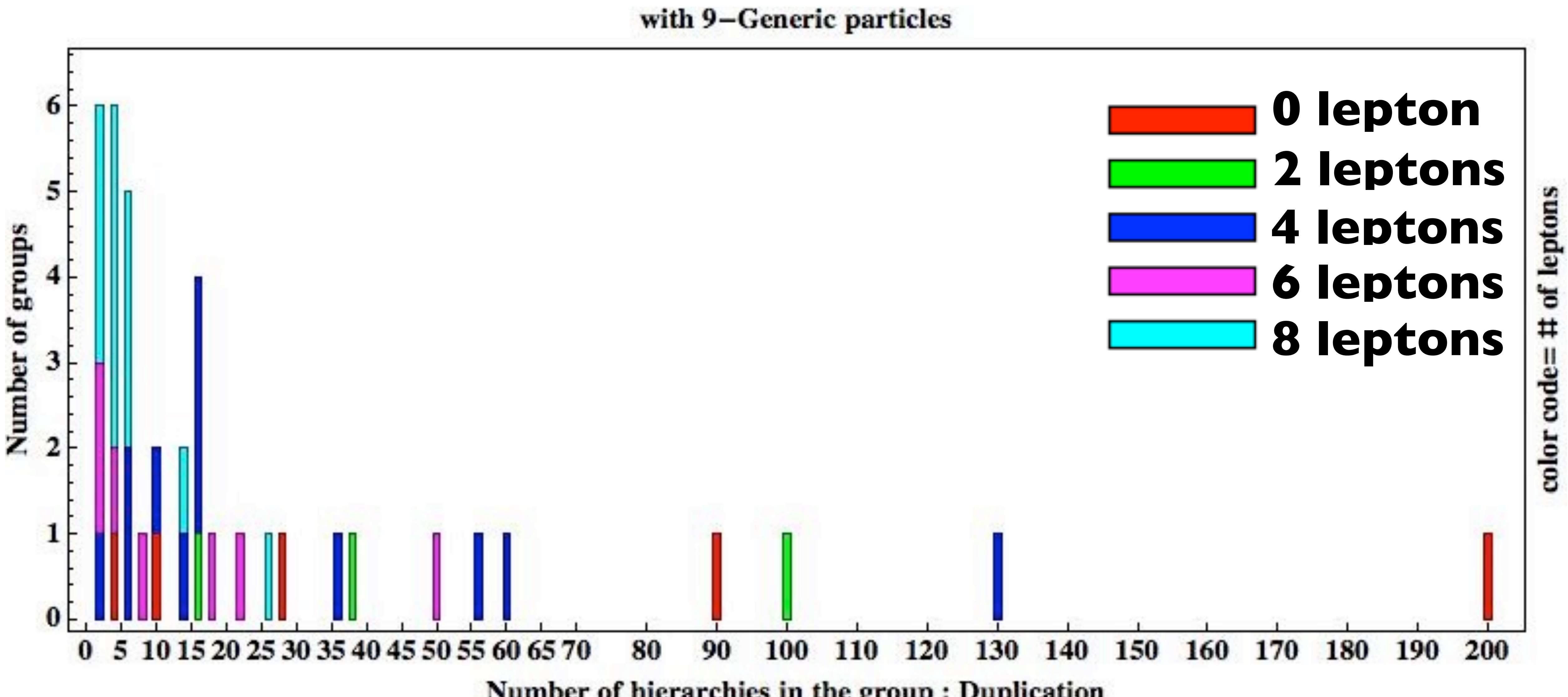
u	w	l	h	e	b

This group corresponds to two jets channel.

Solution of inverse problem

- Inclusive search (disregard number of jets. only consider leptons and vector-bosons)



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