

# New Vectors: document plan and discussion

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Implications of LHC results for TeV-scale physics WG3  
CERN March 26-30, 2012

# New Vectors: document plan and discussion

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MPV

## Aim of the working groups:

“Evaluating the implications of recent results from the LHC, and elsewhere, for TeV-scale physics, and to discuss the impact of these results on the future strategy for particle physics.”

“The results will be summarised in a document, to be submitted as input to the planned 2012 update of the European Strategy for Particle Physics.”

This section of WG3 ~ 3 pages

### 1. Classification and Parametrization

$SU(3) \times SU(2) \times U(1)$  irreps  $\xrightarrow{\text{EWSB}}$  •Components (charge)  
•Mixtures  
•Mass Splittings

- Assumptions: •Tree level, dim 4 interactions  
•Single production

- Classification

- Parameters: Mass, Couplings (Flavour), Width

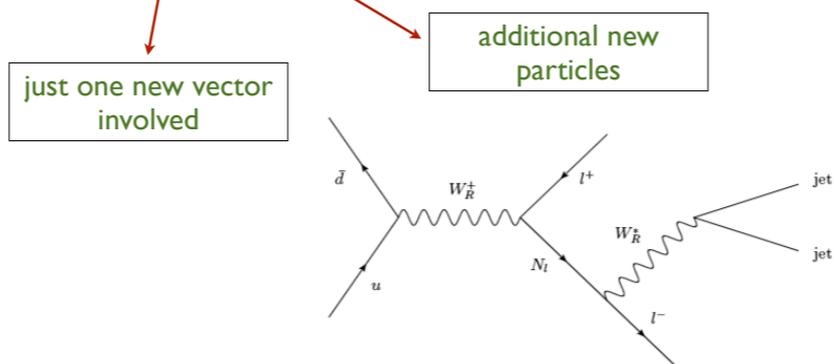
$$W_\mu^a [g_l \bar{l}_L \gamma^\mu \tau_a l_L + g_q \bar{q}_L \gamma^\mu \tau_a q_L + g_\phi (\phi^\dagger \tau_a i D^\mu \phi + h.c.)]$$

mixing

Relax?

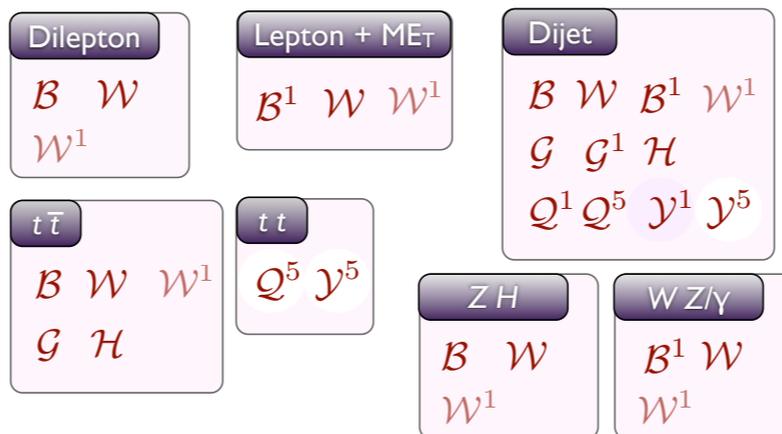
### 3. LHC: basics

- Simple vs Complex Processes



Is a general discussion feasible?  
(simplified complex models)

#### Resonant Signals of Vector Bosons at LHC

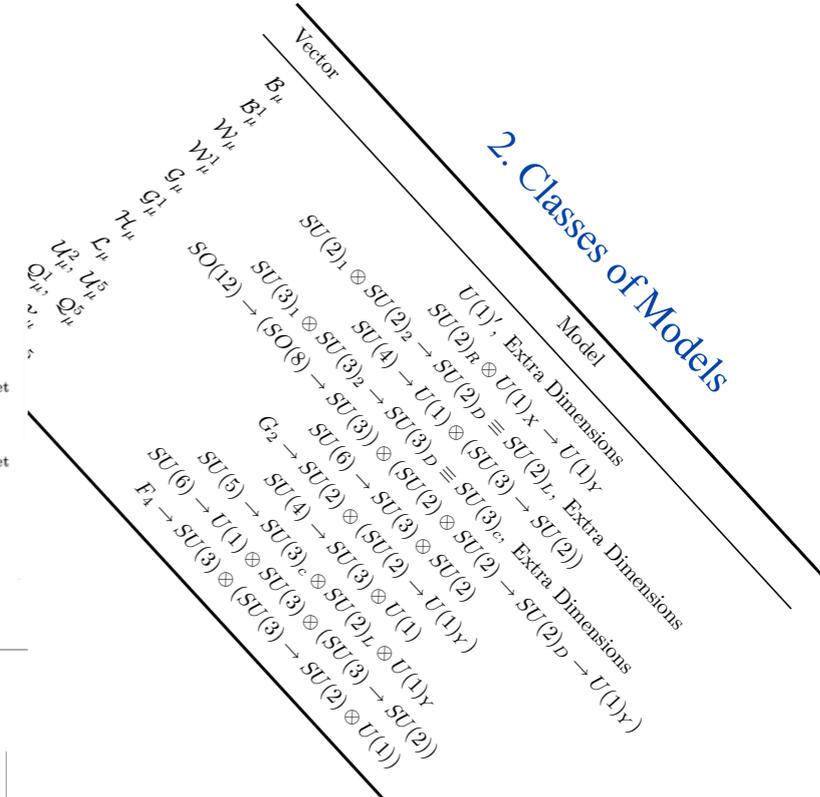


Chiang, Christensen, Ding, Han '11: Drell Yan

Han, Lewis, Liu '11: Colored

Additional possibilities for non-resonant signals

### 2. Classes of Models



### 4. LHC: phenomenological issues

- Interference
- Sliding window searches
- Angular distributions
- Resonances with large widths
- Boosted objects (yesterday)
- ...

- Simple vs Complex Processes

- Resonant or Non-Resonant

- Narrow resonance
- Wide resonance
- Overlapping resonances

- Heavy (effective operators?)
- t and u channels

- Single Production requires couplings to light quarks

- Decay:

- Leptons / MET
- Jets, b's, t's
- W, Z, \gamma, H

### 5. LHC: Bounds

- Mass - Coupling Plots
- Phenomenological parameters
- General limits from specific experimental analyses?
- Reconstructing multiplets
- Pair production, complex scenarios, exotic limits
- Implications for (classes of) models

### 6. LHC: E and L upgrade

What to expect (hope for)?

- New regions of parameter space to be explored
- General expectations from classes of models
- Implications of Higgs results

### 7. Beyond LHC (LC, ...)

What to expect (hope for)...

- if New Vectors (New Physics) found?
- if New Vectors (New Physics) not found?

Hadrophobic Vectors

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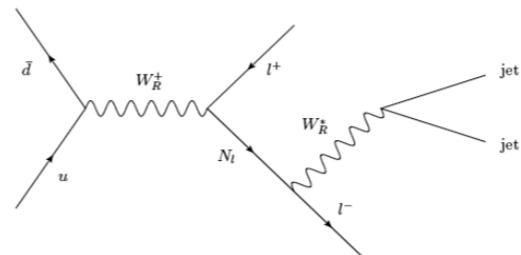
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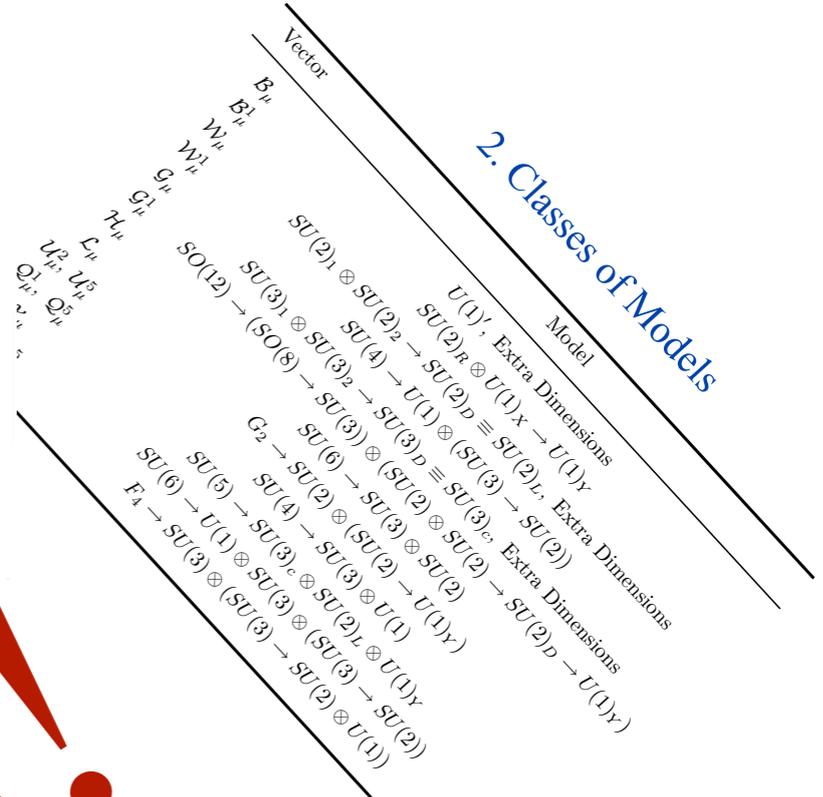
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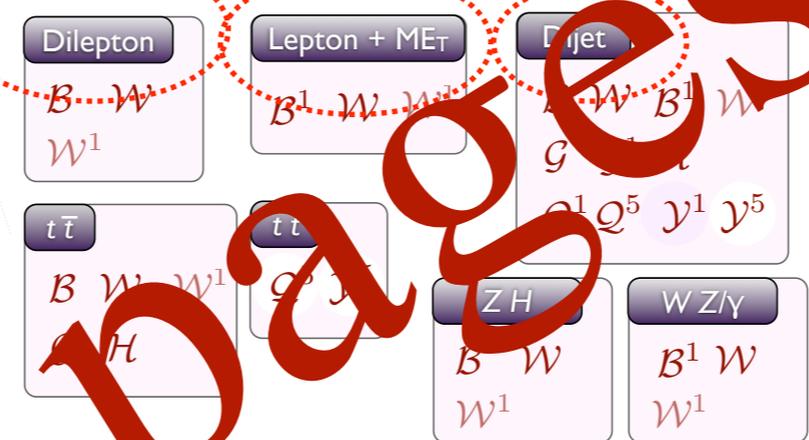


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### Resonant Signals of Vector Bosons at LHC



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Hadrophobic Vectors

3 papers!

# 1. Basic model-independent description of new vectors

- Quantum numbers
- Couplings
- Mixing
- Width

Before/after EWSB

## 2. Classes of Models: Expectations (in view of LHC and previous results)

- Gauge group extensions: GUT, little Higgs, LR, ...
  - Extra dimensions
  - Composite
- 
- In general, arbitrary masses and couplings
  - Limits from hadron colliders, EWPT, flavor
  - If associated to hierarchy problem, expected at LHC scale
  - If involved in EWSB, couple mainly to longitudinal gauge bosons, Higgs and top (more difficult to see)

## 2. Classes of Models: Expectations (in view of LHC and previous results)

- Gauge group extensions: GUT, little Higgs, LR, ...)
- Extra dimensions
- Composite

**Tight relation to Higgs results**

No Higgs or Higgs with nonstandard couplings



Extra vector (or scalar) bosons at TeV scale very well motivated by perturbative unitarity

### 3. LHC: present and future

**Make quantitative  
(approximate)  
statements**

**Be as model-  
independent and  
general as possible**

### 3. LHC: present and future

Make quantitative  
(approximate)  
statements

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*3 pages!*

### 3. LHC: present and future

Make quantitative  
(approximate)  
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Be as model-  
independent and  
general as possible

- i) Make simplifying assumptions
- ii) Try to work in model-independent fashion (within assumptions)
- iii) Present in a unified way the discovery reach for foreseen collider energies and luminosities
- iv) Comment on what is left out

# Make simplifying assumptions

- Only one extra *vector* boson contributes
- Single production
- Narrow resonance
- Drell-Yan production
- Decay into dilepton, lepton+MET, dijet

# Work in (roughly) model-independent fashion, within assumptions

- For each channel, concentrate in production:

$$\begin{aligned} N_s &= \sigma_{V'}(pp \rightarrow X) A_X \epsilon_X L \\ &= \sigma(pp \rightarrow V') \text{BR}(V' \rightarrow X) A_X \epsilon_X L \\ &= g^2 \sigma^{g=1}(pp \rightarrow V') \text{BR}(V' \rightarrow X) A_X \epsilon_X L \end{aligned}$$

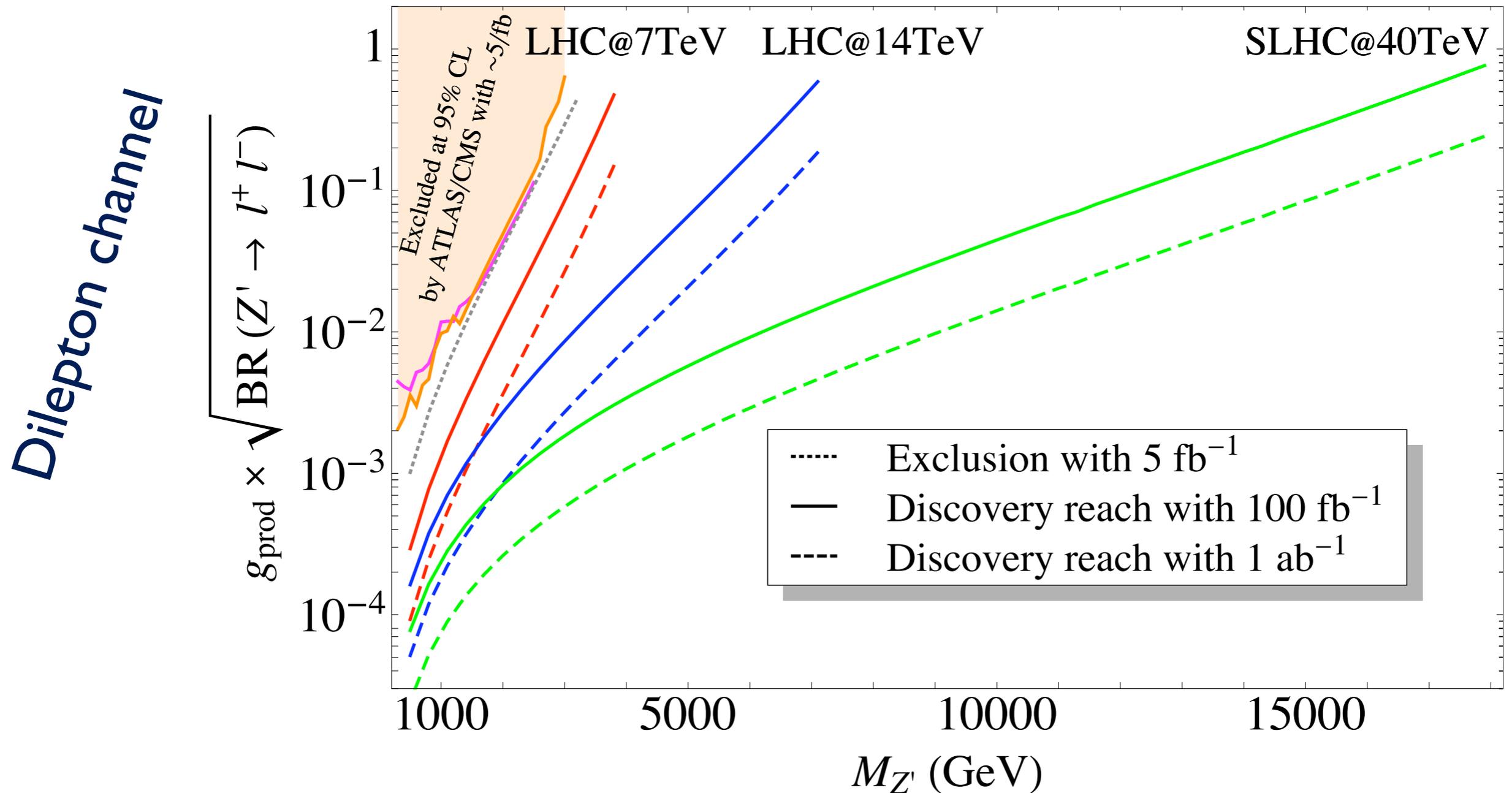
Coupling to quarks  
(assume LH &  
universal)

Branching ratio,  
depending on other  
couplings

Narrow width approx.

- For each mass, luminosity, energy, and required sensitivity, find minimal value of  $g^2 \text{BR}(V' \rightarrow X)$

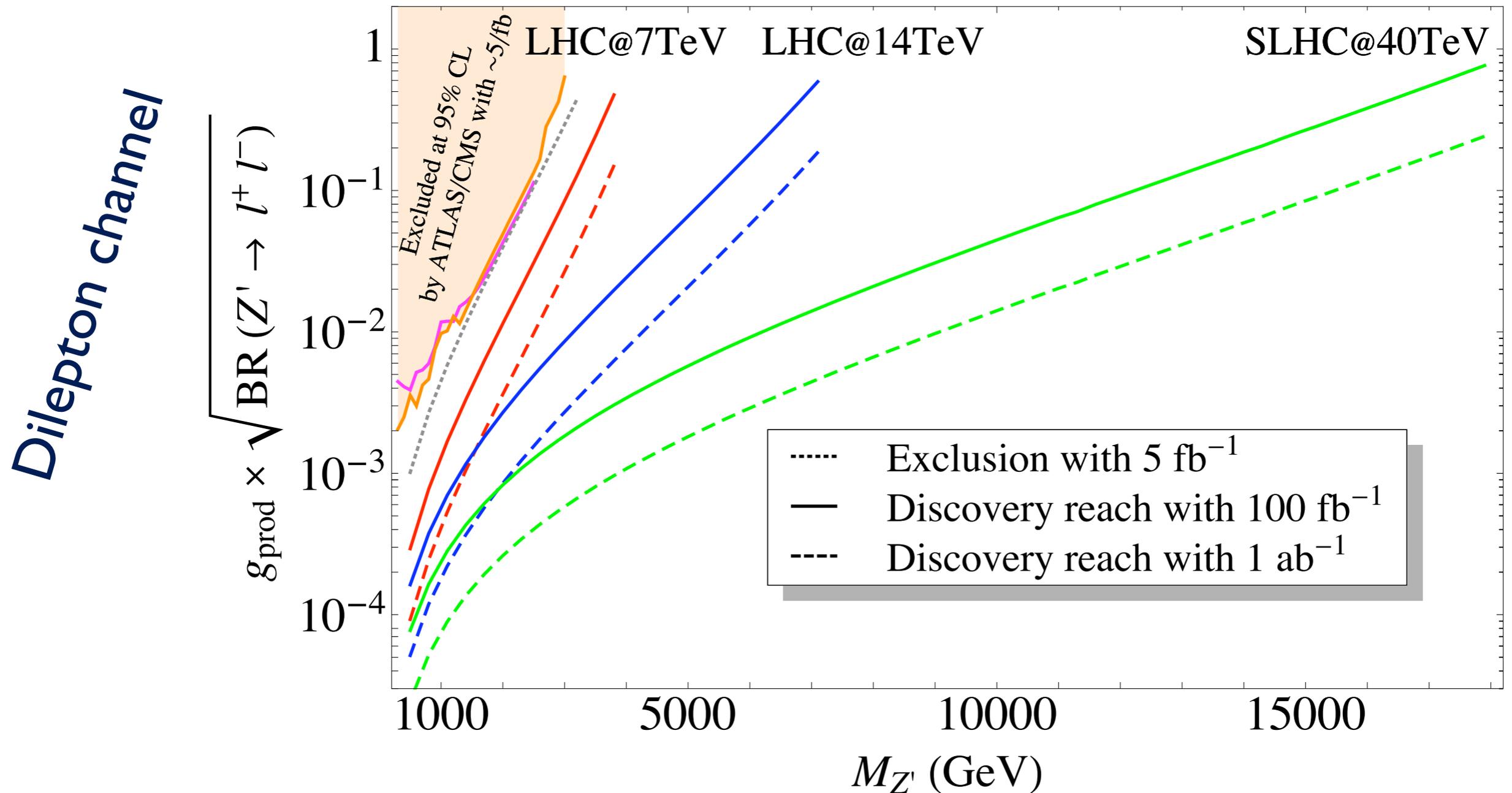
# Present in a unified way the discovery reach for foreseen collider energies and luminosities



Negligible background  $\rightarrow$  5 events required for discovery,  
less than 3 for 95% C.L. exclusion

Extrapolation beyond NWA (large couplings)

# Present in a unified way the discovery reach for foreseen collider energies and luminosities



Negligible background  $\rightarrow$  5 events required for discovery,  
less than 3 for 95% C.L. exclusion

Include (model-dependent) EWPT?

## Comment on what is left out (with qualitative expectations?)

- Production by VBF
- Decay into gauge bosons
- Derivative couplings
- Non-resonant (angular analysis)
- Very broad resonances
- Pair production (e.g., leptoquarks)
- Scalars
- ...

Hopefully, the cases we study in greater detail are, to some extent and in some cases, representative of the capabilities of LHC upgrades to study new physics.

# Measuring properties of extra bosons at LHC if discovered (in view of present limits)

- Spin
- Couplings
- Multiplets

Quantum numbers

Discriminate models

Example: Discriminating  $W'_L$  vs  $W'_R$

[Rizzo, JHEP 0705 (2007), 037]

CMS talk by Leonidopoulos

14 TeV  
SM strength couplings  
Based on interference



2.5 TeV  $\rightarrow$  60 fb<sup>-1</sup>  
3.5 TeV  $\rightarrow$  300 fb<sup>-1</sup>

## 4. Beyond LHC: linear collider

- If New Vectors (New Physics) found
  - If light enough, scan/autoscan resonance
  - Study their properties in clean environment
- If New Vectors (New Physics) not found
  - Precision study of their indirect effects on electroweak observables

Sensitivity up to  $\sim 30$  TeV for “minimal” models @ 3 TeV CLIC [ Battaglia et al, arXiv:1203.0416 ]

- Suitable for leptophilic vector bosons

# Sketch of document

# Title: New Vector Bosons

Basic model-independent description of  
new vectors

Classes of Models: Expectations (in view  
of LHC and previous results)  
Relation with Higgs

# LHC: present and future

## Strategy and basic NWA formulas

Plot  $g$ - $M$   
dilepton

Plot  $g$ - $M$   
Lepton neutrino  
or dijet

Comment on what is left out

Measurement of properties

# Linear Collider

# References

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