MadAnalysis5: Recast of LHC searches

Overview and applications

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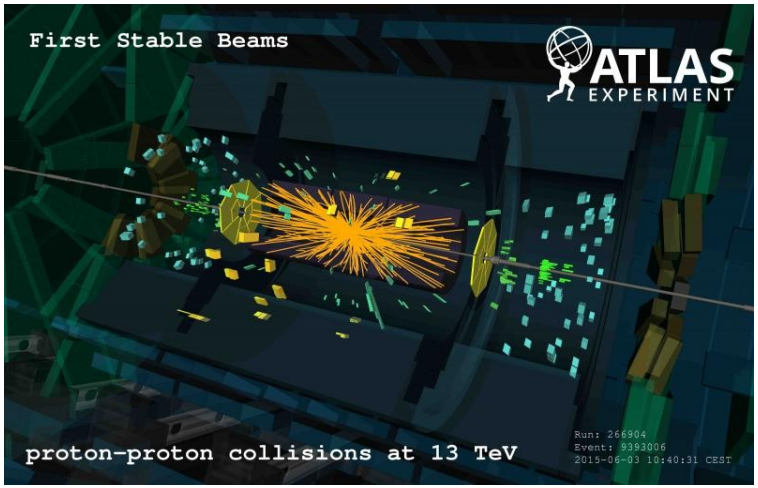
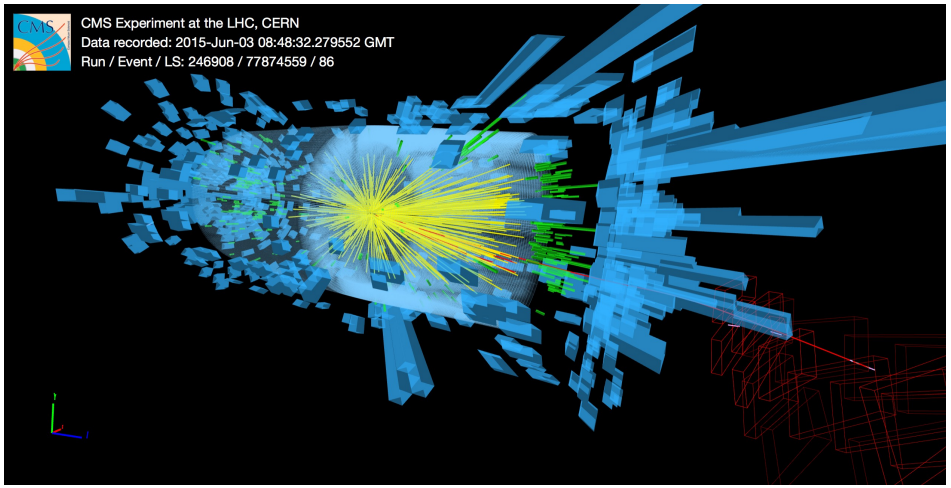
Outline

- Introduction and motivations to LHC analyses recast
- The MadAnalysis 5 framework and the PAD
- An example: wide vector resonances in composite Higgs models
- Conclusions and prospects

Why recast LHC searches?

The 13 TeV LHC era just started with the first 13 TeV collisions!!!





Great expectations for the LHC to improve our understanding of the mechanism behind EWSB

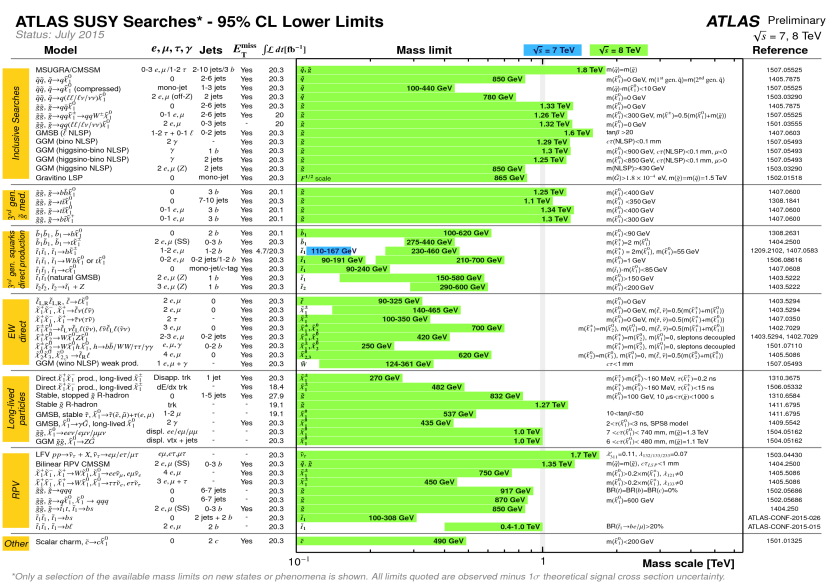
Why recast LHC searches?

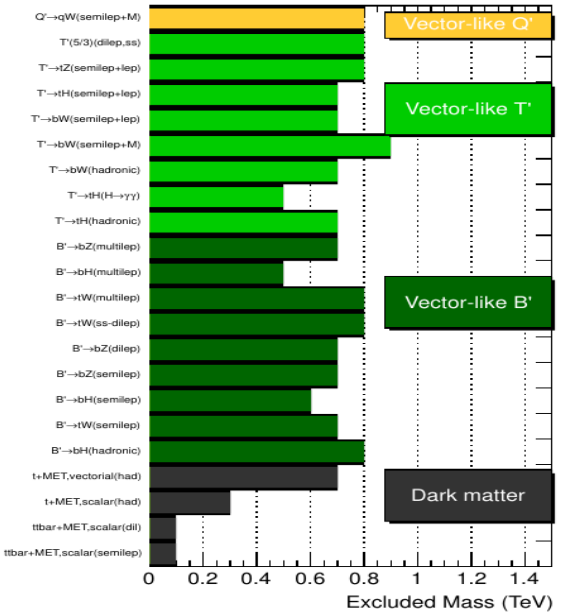
The discovery of a scalar boson has been the major outcome of the 7 and 8 TeV run of the LHC

It has however also been the "only" new discovery made at the LHC so far

No clear direct signs of new physics have emerged from 7+8 TeV collisions (yet some little excess…)

ATLAS and CMS has therefore set limits on common BSM scenarios (SUSY, CHMs, ED…)

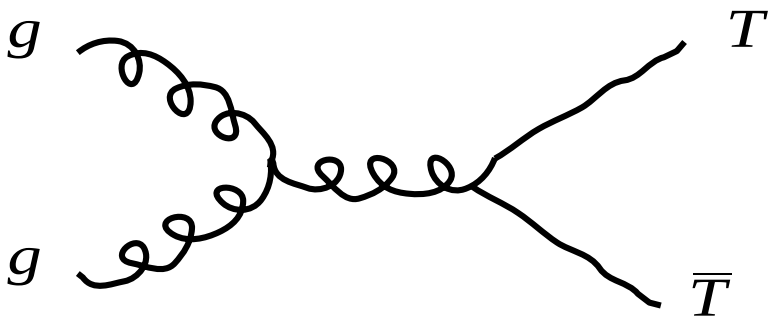




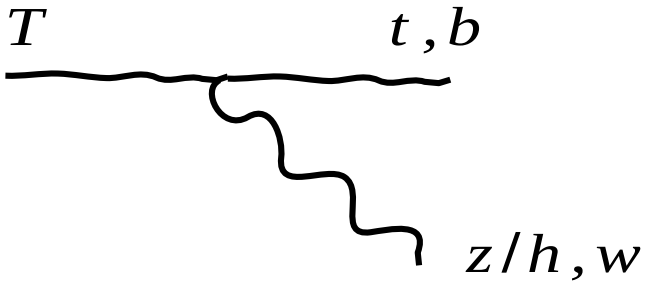
Caveat : These limits are strongly dependent upon the underlying (simplified) model assumptions!

Why recast LHC searches?

Example: The case of Vector-Like Quarks in Composite Higgs models

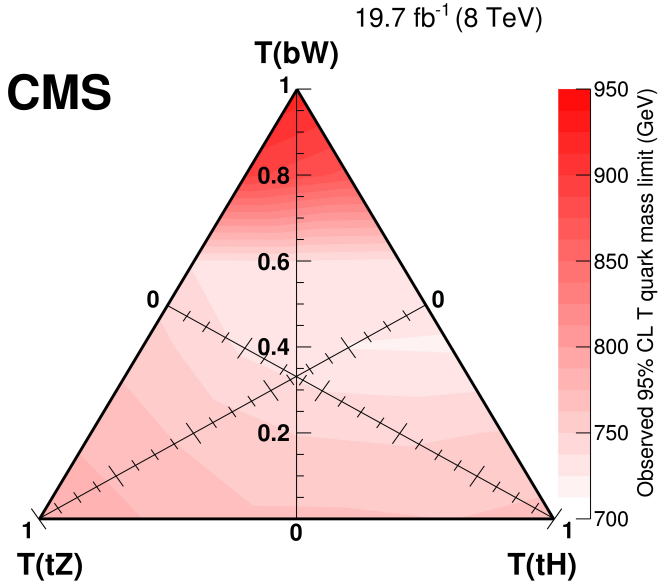


One VLQ pair produced via QCD



The VLQ decays into 3rd generation SM quarks

Bounds on the T mass in function of the various branching ratios into given final state



These limits do not apply if

- More than one VLQ (also of different charge) is present
- The VLQ can decay in other channels (light gen, DM…)
- Other production mode are relevant (EW production)
- Different models can give the same final state signal

$$\frac{N_{theo.models}}{N_{\exp.analyses}} \rightarrow \infty$$

How can one apply LHC results to a given BSM scenario?

Why recast LHC searches?

Various groups have investigated the problem and developed tools based on two different approaches

SMS approach

Decompose a model signal in terms of simplified models (SMS) topologies

Through efficiency maps or comparing with cross sections upper limits determine if a given model is allowed or excluded

Fastlim [Papucci et al. 1402.0492]
SModelS [Kraml et al. 1312.4175]
XQCAT [DB et al. 1409.3116]

Recast approach

Implement analysis selections in a computer code that allows to test MC events for any given model

For the same models interpreted by ATLAS and CMS, the code should give consistent results: **validation**

Checkmate [Drees et al. 1312.2591]
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Simplified model do not cover all possibilities ✗

Fast method, but with limitation

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Need to generate MC events ✗

Can cover **any BSM model** ✓

Analyses can be **shared** ✓✓✓

Maybe slower, but huge potential !!!

MadAnalysis 5

MA5 is a public framework for phenomenological analyses

Analyse MC events at different particle level: parton, hadronic or detector reconstructed

Analyse MC events in a normal or expert mode

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NEW MA5 v1.2
No need to use a tuned version of Delphes for detector level studies

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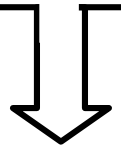
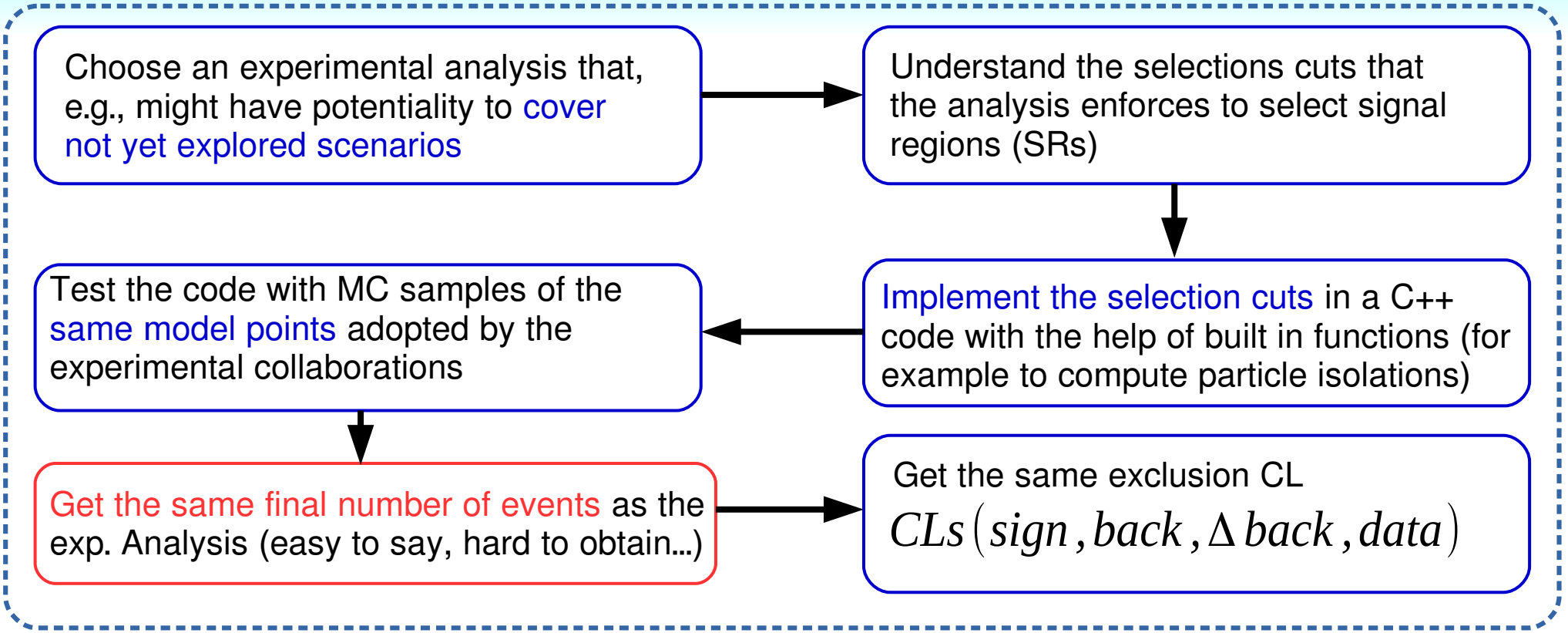
Normal mode: simple commands in a python interface
output of analysis in a human-readable output (HTML and LaTeX)
built in function for basic kinematic variables
ideal for preliminary/simple event analysis

Expert mode: Code an analysis in a C++ format within the SampleAnalyzer framework
Possibility to implement (almost) all the selections adopted in LHC searches
Ideal for high level phenomenological analysis



This leads to the idea of a Public Analyses Database (PAD)

MadAnalysis 5 PAD



MadAnalysis 5 PAD

Choose an experimental analysis that, e.g., might have potentiality to cover not yet explored scenarios

Understand the selections cuts that the analysis enforces to select signal regions (SRs)

Implement the selection cuts in a C++ code with the help of built in functions (for example to compute particle isolations)

Test the code with MC samples of the same model points adopted by the experimental collaborations

Get the same final number of events as the exp. Analysis (easy to say, hard to obtain…)

Get the same exclusion CL

$$CLs\left(sign, back, \Delta back, data\right)$$

Share the code with the hep community for other pheno studies

Apply it to your model and obtain your results (easy/hard task… depends…)

Create a public database of analyses MA5 PAD [Dumont et al. 1407.3278]

This might show some blind spots of present analyses to certain models
Possibility to propose different selections more sensitive to a particular scenario

MadAnalysis 5 PAD

The construction of a PAD is well under way `https://madanalysis.irmp.ucl.ac.be/wiki/PublicAnalysisDatabase`

Analysis	Short Description	Implemented by	Code	Validation note	Version
ATLAS-SUSY-2013-05 (published)	stop/sbottom search: 0 leptons + 2 b-jets	G. Chalons	Inspire	PDF (figures)	MA5tune
ATLAS-SUSY-2013-11 (published)	EWK-inos, 2 leptons + MET	B. Dumont	Inspire	PDF (source)	MA5tune
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ATLAS-EXOT-2014-06 (published)	mono-photons + MET	D. Barducci	Inspire	PDF MadGraph cards	MA5tune
ATLAS-SUSY-2014-10 (published)	2 leptons + jets + MET	B. Dumont	Inspire	PDF (source)	MA5tune
ATLAS-SUSY-2013-21 (published)	0 leptons + mono-jet/c-jets + MET	G. Chalons, D. Sengupta	Inspire	PDF (source)	MA5tune
ATLAS-SUSY-2013-02 (published)	0 leptons + 2-6 jets + MET	G. Chalons, D. Sengupta	Inspire	PDF	MA5tune

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CMS-SUS-13-016 (PAS)	search for gluinos using OS dileptons and b-jets	D. Sengupta, S. Kulkarni	Inspire	PDF (source)	MA5tune
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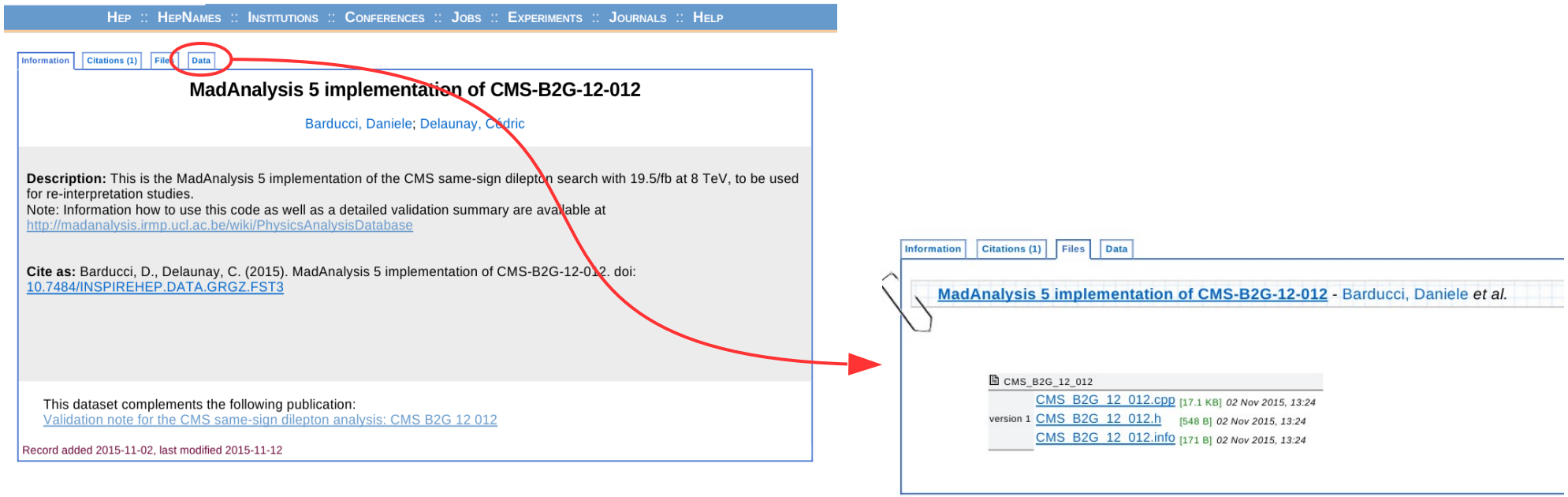

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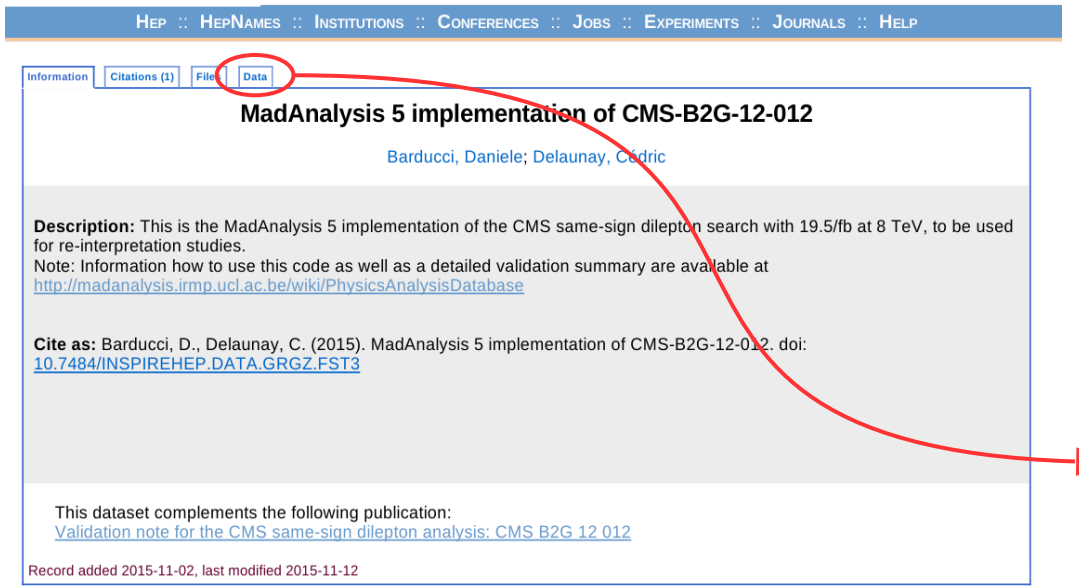

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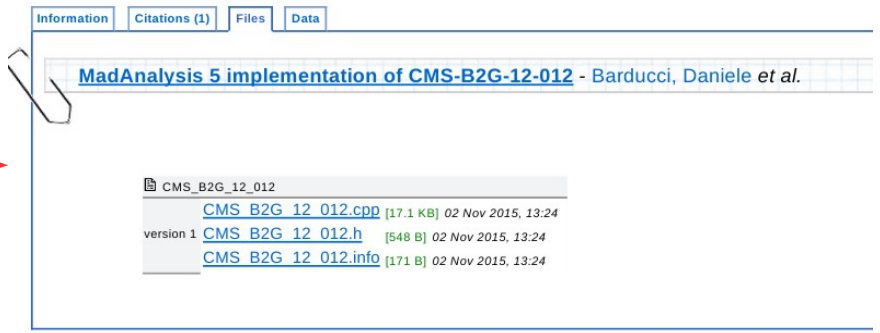

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Soon on the PAD

CMS: eejj (excess)
mono-j mono-gamma

ATLAS: multi-jet

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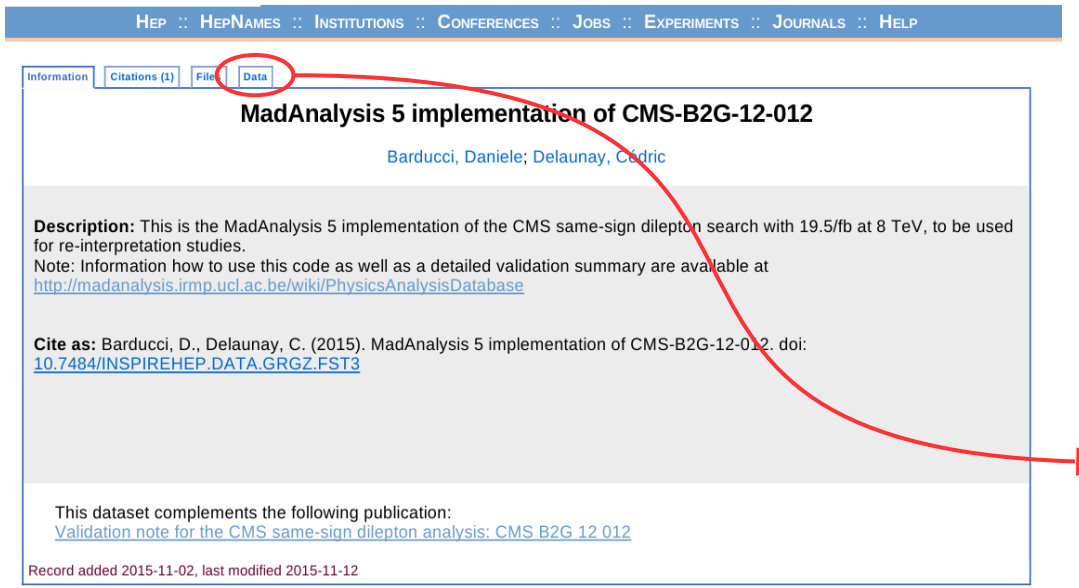

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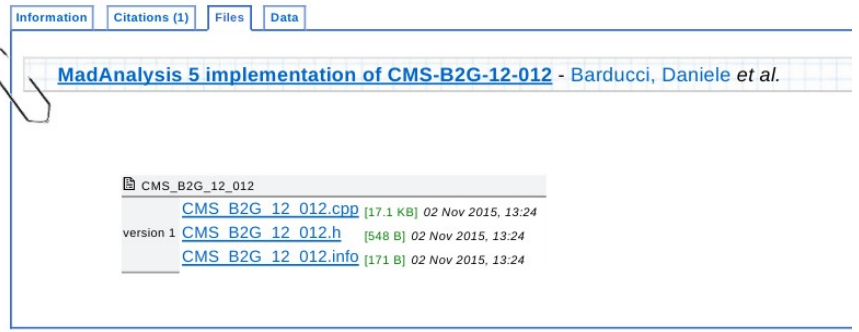


Validation of a search

Reproducing (with some degree of accuracy) the experimental results is not always a trivial task

Problem 1. Fast detector simulation tools (e.g. Delphes) can not reproduce the degree of accuracy of full experimental simulations.

This is an intrinsic difference between a theory/pheno and an experimental study

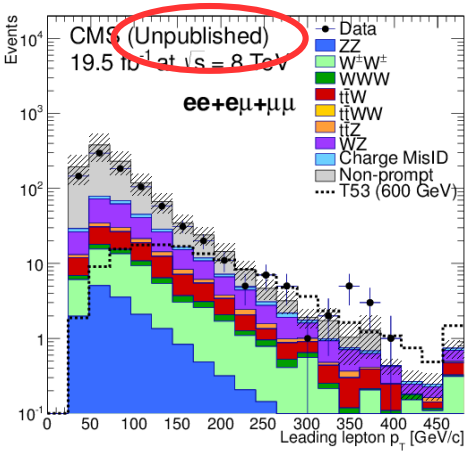
We accept this and we aim to reproduce exp. results within a certain accuracy

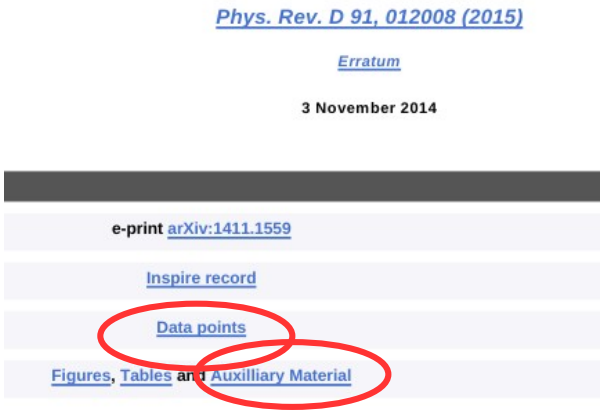
Problem 2. Sometimes (often…) not enough details of exp. analyses are provided

This is an problem that can be overcome by working close with exp. colleagues

- Exact configuration of MC tools used for signal generation (cards settings)
- Benchmark points used for signal generation (SLHA or, better, LHE)
- Cutflows and Histograms for the given benchmark points

This can be easily provided (HEPdata, Twiki…) and is sometimes done





Nominal	9989
Pre-selected:	
1. Trigger	8582
2. Good vertex	8574
3. Cleaning cuts	8213
SR Cuts:	
1. $E_{\rm T}^{\rm miss}$> 150 GeV	4131
2. At least one loose photon with $p_{\rm T}$> 125 GeV($\|\eta\|$ < 2.37)	2645
3. The leading photon is tight with $\|\eta\|$ < 1.37	2068
4. The leading photon is isolated	1898
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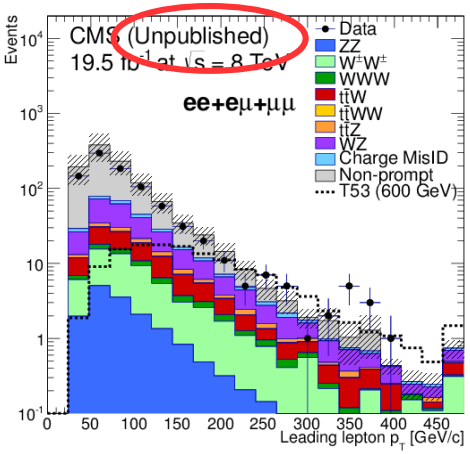

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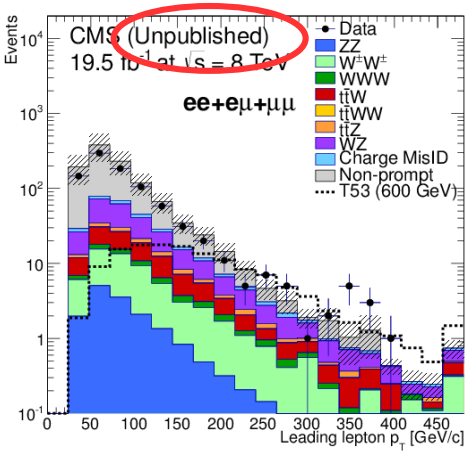

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Example: CMS search for top partners of charge 5/3 in a same-sign dilepton (SS2L) final state
CMS-B2G-12-012

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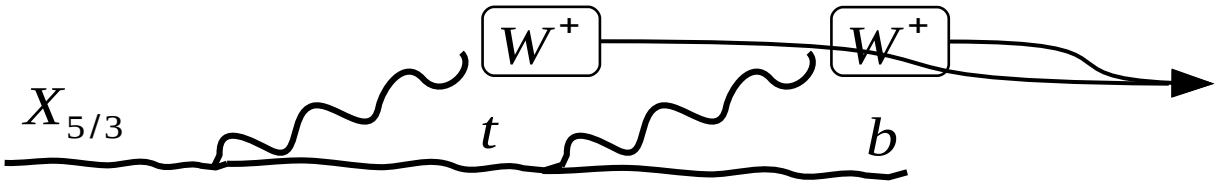

Leptonic decays of W give rise to a SS2L signature

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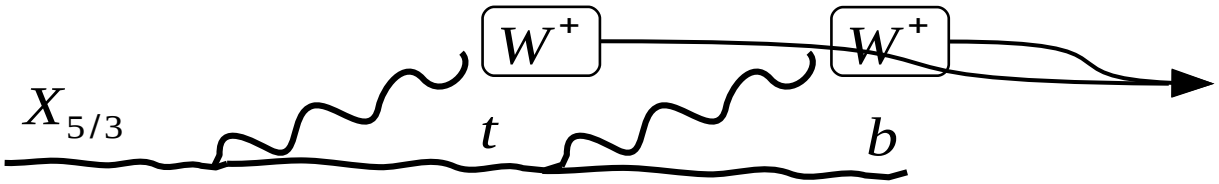

Leptonic decays of W give rise to a SS2L signature

- Isolation for leptons $\sum_{n_i \in \Delta R<0.3} p_T^{n_i}/p_T^e<0.15 \quad \sum_{n_i \in \Delta R<0.4} p_T^{n_i}/p_T^{\mu}<0.2$
- At least 2 isolated same sign lepton
- Veto on Z boson mass window
- $H_T = E_T^{miss.} + \sum p_T^j + \sum p_T^l > 900\,GeV$

Validation of a search

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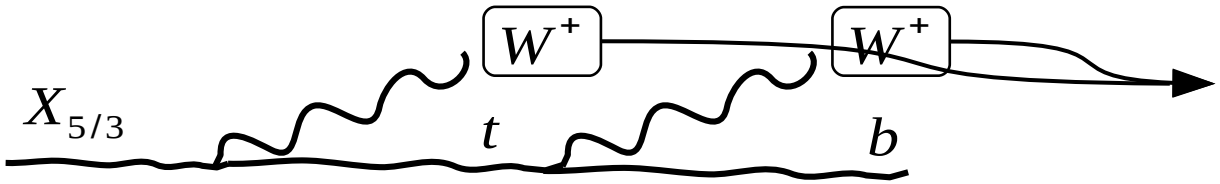

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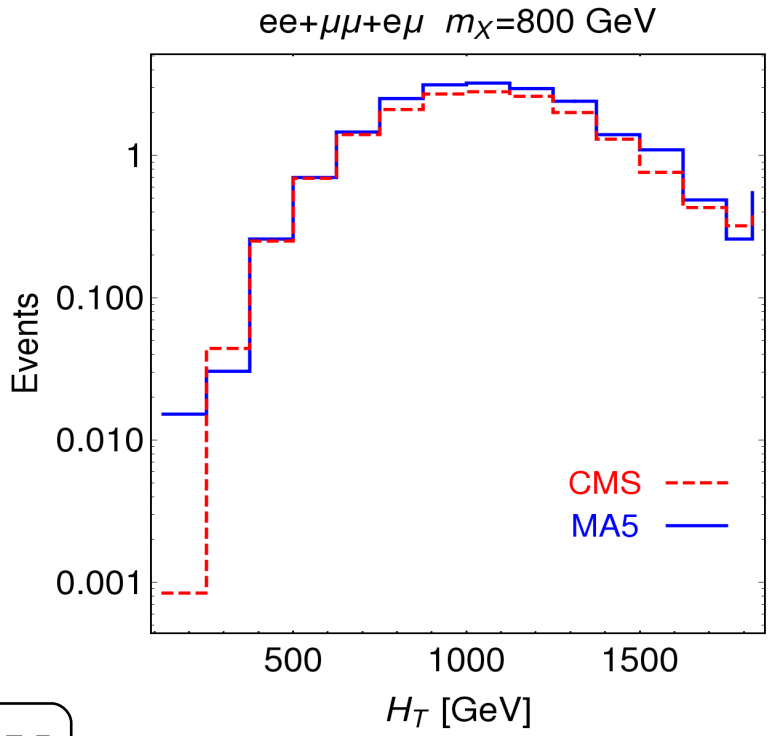
```
// Select electrons with pT>7, |eta|<2.47
for(unsigned int ie=0; ie<event.rec()->electrons().size(); ie++){
  const RecLeptonFormat * CurrentElectron = &(event.rec()->electrons()[ie]);
  if(CurrentElectron->pt()>30.0 && fabs(CurrentElectron->eta())<2.4){
    SignalElectrons.push_back(CurrentElectron);
  }
}
// We apply a tight isolation criteria to electrons
SignalElectrons = PHYSICS->Isol->tracker->getRelIsolated(SignalElectrons,event.rec(),0.15,0.3,0.5);
```

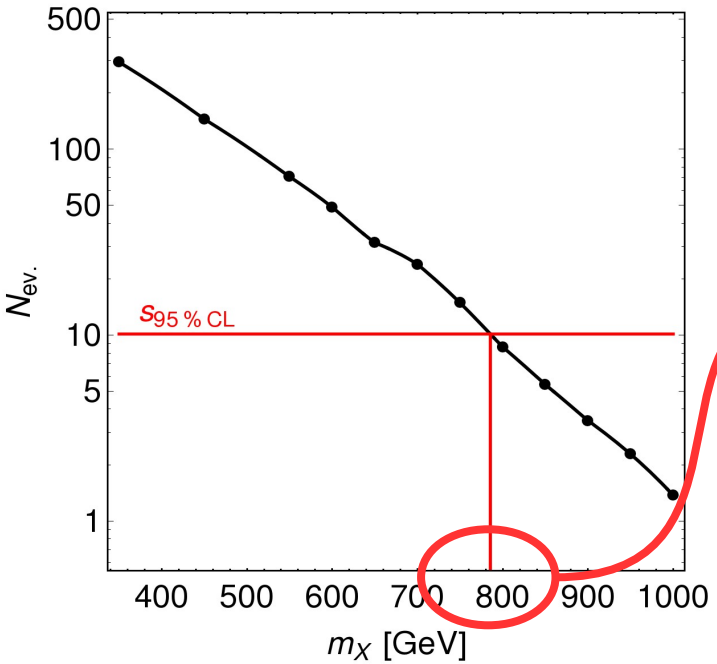
PHYSICS contains special functions
- α_T
- M_{T2}
- Isolations
- ...

Validation of a search

Compare simulations with the available information: efficiency, histograms, exclusion plots…

Signal Region	CMS official results	MA5 results
ee	2.1	2.3
$\mu\mu$	2.8	2.1
$e\mu$	4.7	4.2





$m_{X_{5/3}} > 790\,GeV$

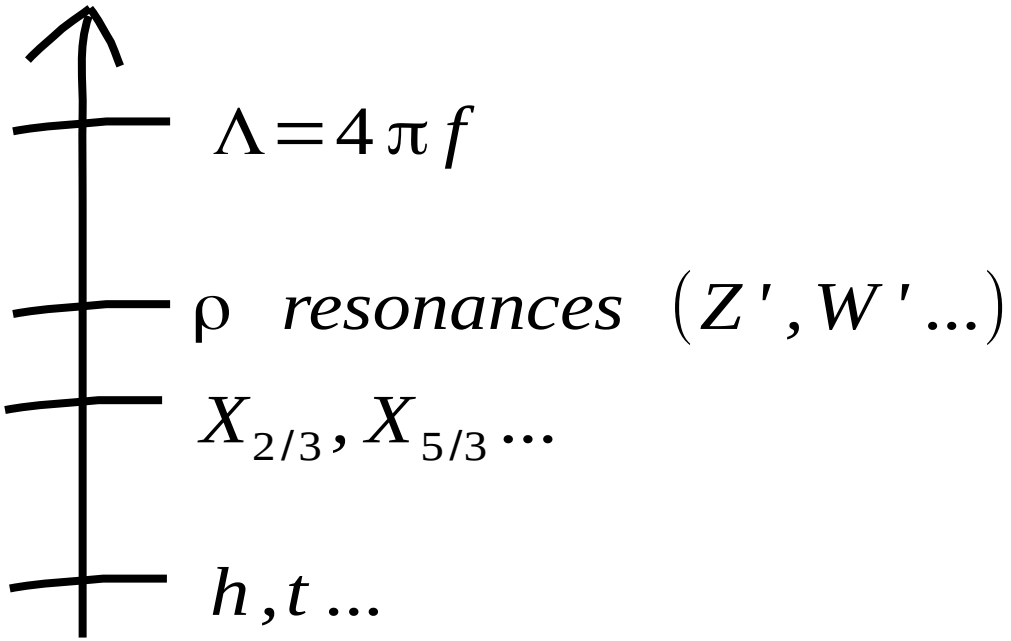
CMS results is 800 GeV

Validated!!!

Reinterpretation of a search

Wide electroweak vector resonances in Composite Higgs Models

Composite Higgs Models in a nutshell
- The Higgs is assumed to be a bound state of a new strongly interacting sector at a scale f~TeV
- The Higgs is light with respect to the scale f since it is assumed to be a (pseudo) GB
- Similar pattern for which pions can be described as pNGB of chiral symmetry breaking
- Many interesting phenomenological consequence, actively searched for at the LHC



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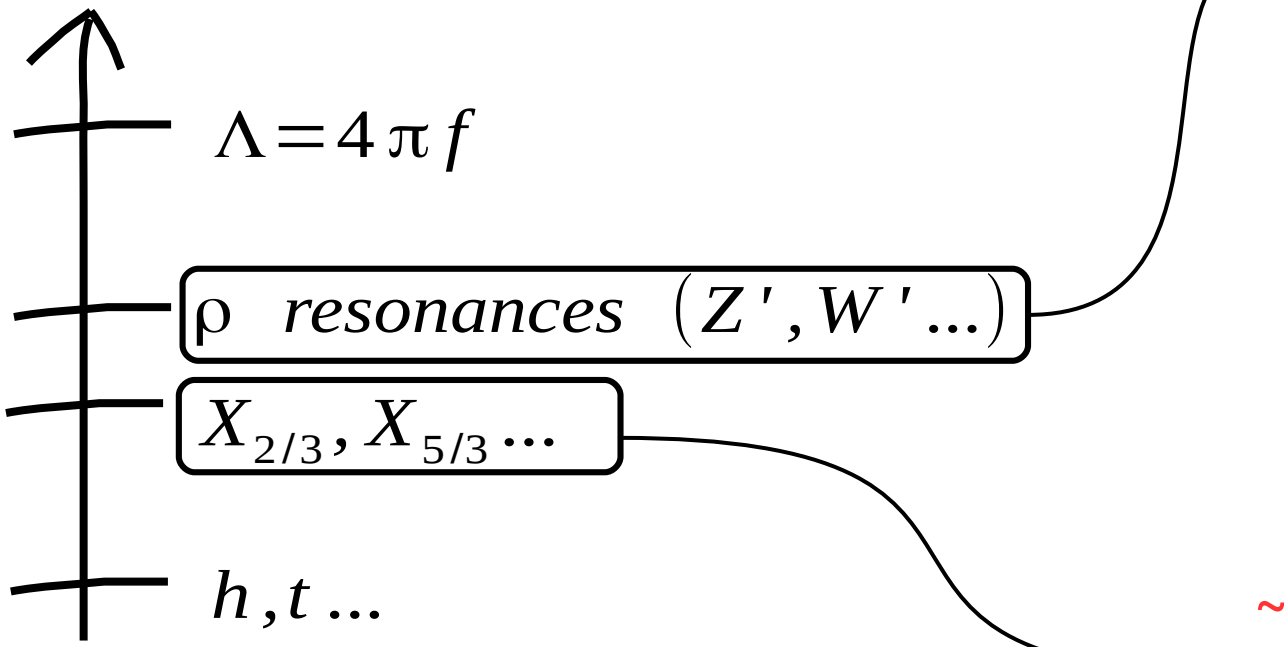

~ 2 TeV (EWPTs)
[Contino et al. 1504.02750]

~ 1 TeV (Light Higgs)
[Matsedonskyi et al. 1204.6333, Redi et al. 1205.0232]

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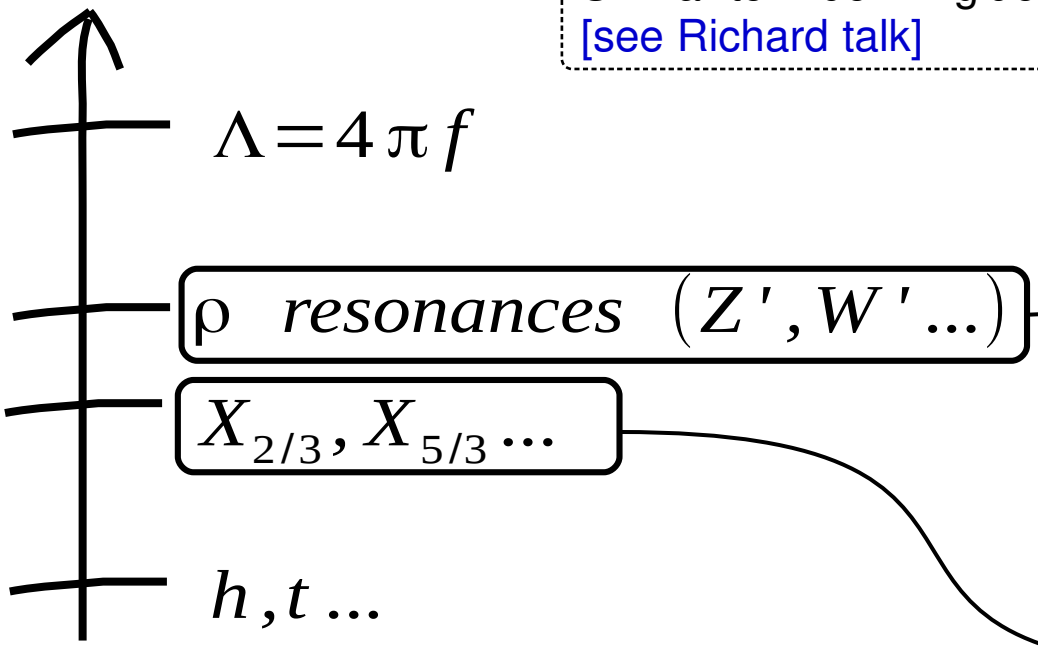

Similar to wide KK gluons
[see Richard talk]

~ 2 TeV (EWPTs)
[Contino et al. 1504.02750]

$\rho \to X_{5/3}\overline{X}_{5/3}$

$g_\rho \gg g_{EW}$

$Br(\rho \to X_{5/3}\overline{X}_{5/3}, X_{2/3}\overline{X}_{2/3}) \sim O(1)$

[DB et al. 1210.2927,
Greco et al 1410.2883]

~ 1 TeV (Light Higgs)
[Matsedonskyi et al. 1204.6333,
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Reinterpretation of a search

At the LHC vector resonances are searched for in dilepton and diboson channels
Increased BRs into top partners make these search lose sensitivity
The stronger bound is generally onset by the S-parameter [Greco et al 1410.2883]

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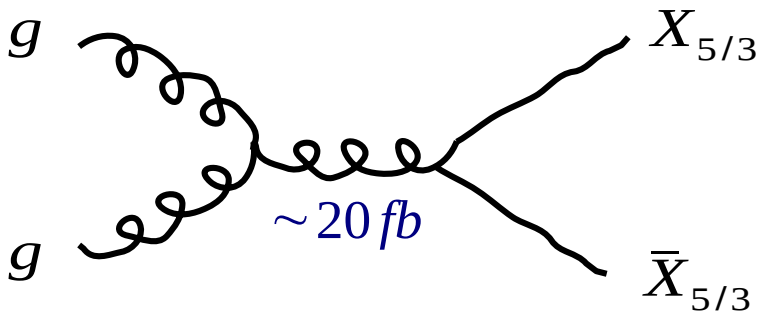
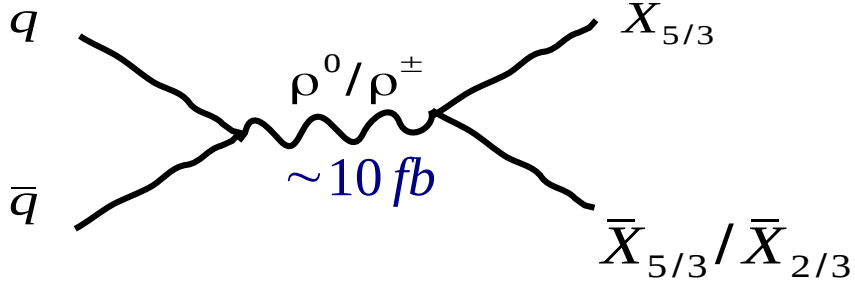


$m_{X_{5/3}} \sim 800\,GeV$
$m_{\rho} \sim 2\,TeV$



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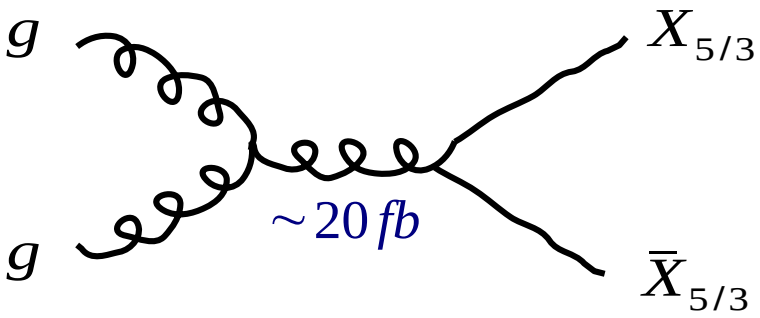

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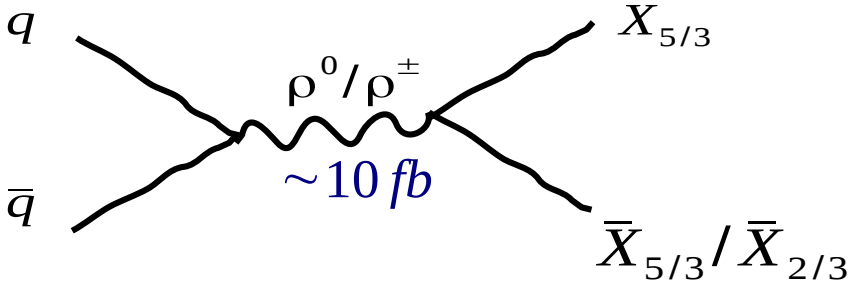
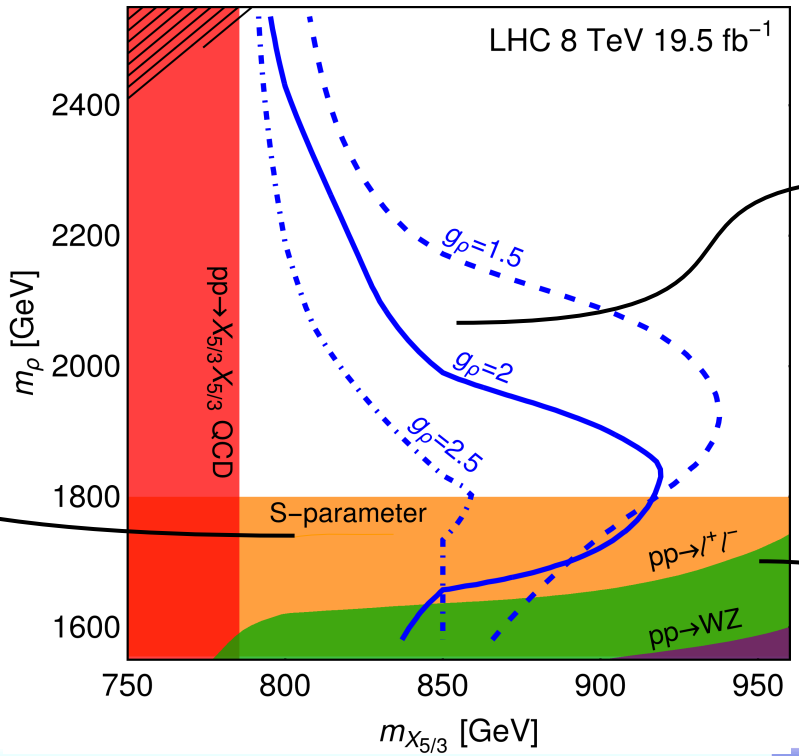




S-parameter sets the stronger bound

LHC 8 sets limits on this naturalness favoured regime [DB et al1511.01101]

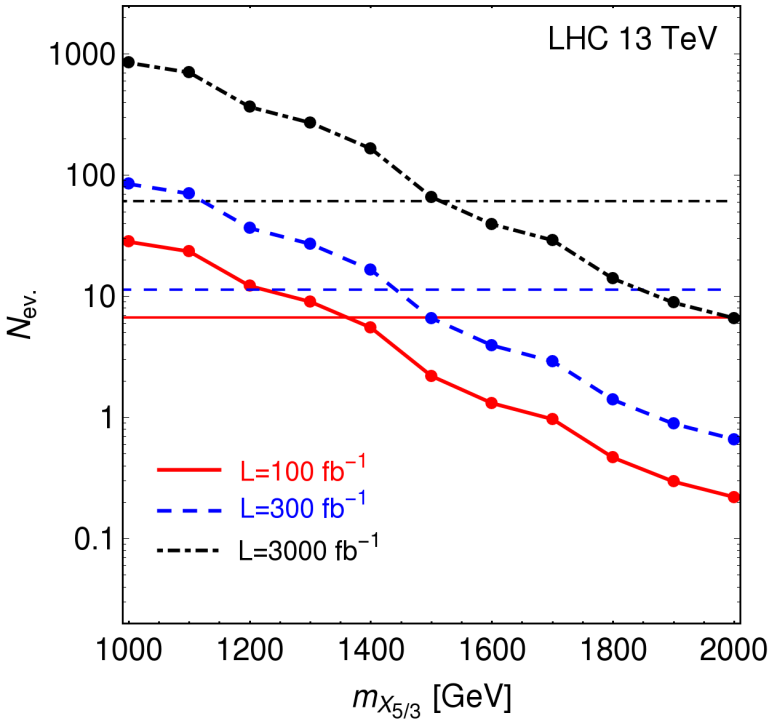
Direct searches not effective if $m_\rho > 2\,X_{5/3}$

Projections for a search

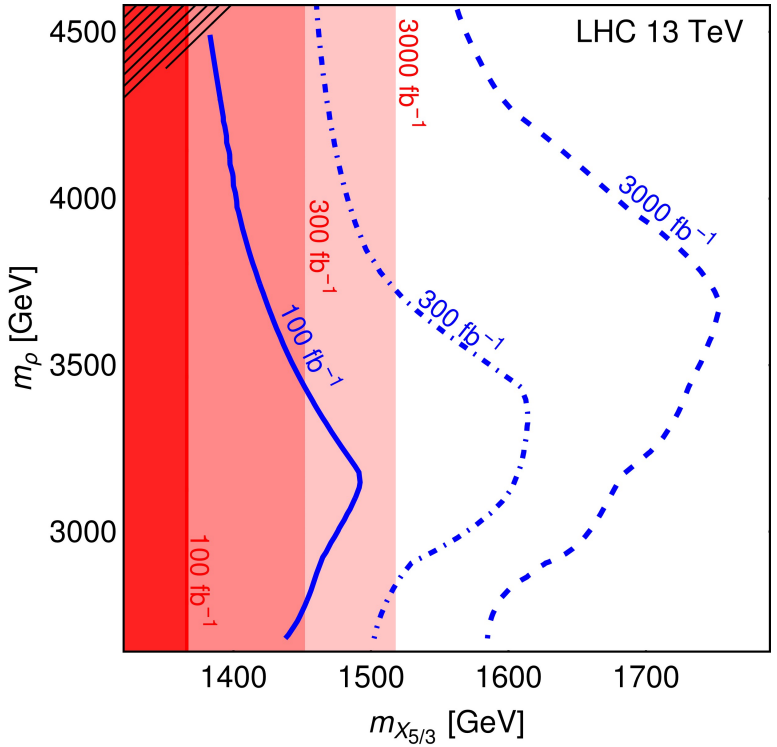
Projections for the 13 TeV LHC, increased cut threshold [DB et al1511.01101]

- $H_T > 1500\,GeV$
- $H_T + E_T^{miss} > 2000\,GeV$
- Main backgrounds ttZ, ttW, WW, WZ, WWW

Only QCD pair production



QCD + EW production



Conclusions

- Reinterpreting the LHC analyses is crucial to fully exploit the data that the LHC has delivered
- Two complementary approach are possible: simplified models and data recast
- Through the recast approach we can aim at the creation of a database of recast analyses
- These analyses are available for all the hep community for pheno studies
- Reinterpreation of dedicated searches useful to constrain otherwise elusive particle

- The MadAnalysis 5 framework is an active project
- Soon new features within the package, that will allow an easier and more automatic recast of the searches present in the PAD
- MadAnalysis 5 PAD is a project that requires manpower to expand: we encourage colleagues to validate their search and share the results on the PAD database
- The shared analyses can be cited by other studies

Thank you!!!