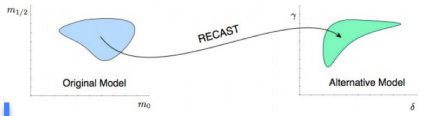


RECAST

Extending the Impact of Existing Analyses

Itay Yavin Theorist

Disclosure:

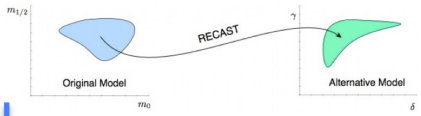
with Kyle Cranmer Experimentalist

McMaster University

PERIMETER INSTITUTE FOR THEORETICAL PHYSICS

CENTER FOR COSMOLOGY AND PARTICLE PHYSICS

TRIUMF Workshop on LHC Results, December 14, 2011

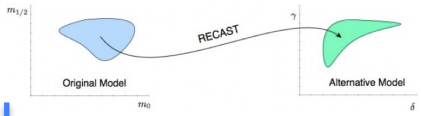


Hypothesis Testing

An important part of scientific progress is hypothesis testing. We construct models of the world and use them to make predictions about processes in nature. We then compare with experiment. We have one extremely important model,

The Standard Model

To go beyond it, we will have to test different hypotheses.



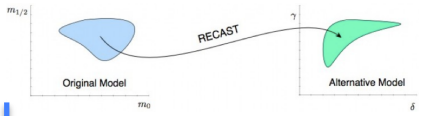
Hypothesis Testing in HEP

Most experiments in high energy physics (HEP) are ultimately counting experiments,

1) Decay rates

2) Cross Sections

What is the process of hypothesis testing in HEP then?

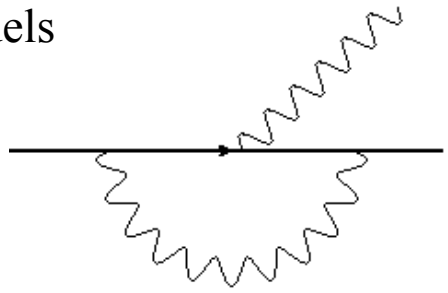


Lepton Flavor Violation

Muons in the Standard Model will never decay into an electron and a photon. That's worth searching for then (MEGA experiment) . . .

$$\mathrm{BR}(\mu^+ \to e^+\gamma) \leq 1.2 \times 10^{-11}$$

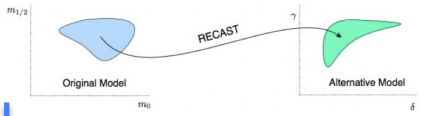
Theorists can calculate in different models



SUGRA,GMSB,AMSB, RS,UED, Little Higgs

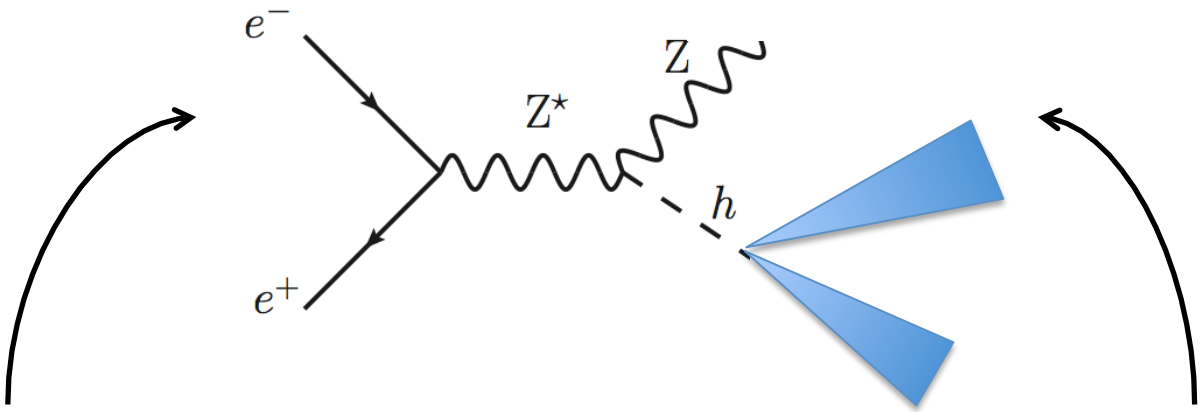
Experimentalists measure independently of models

Hypothesis Testing is straightforward, even long after the original analysis



Exotic Higgs Decay

LEP2 Conducted extensive searches for exotic decays of the Higgs boson,

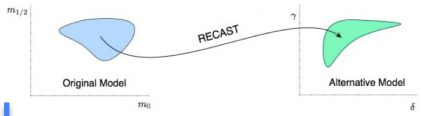


Theorists can calculate in different models

Experimentalists can measure independently of models

SUGRA,GMSB,AMSB, RS, UED, Little Higgs . . .

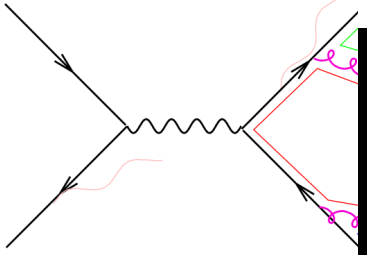
Hypothesis testing is not so straightforward.

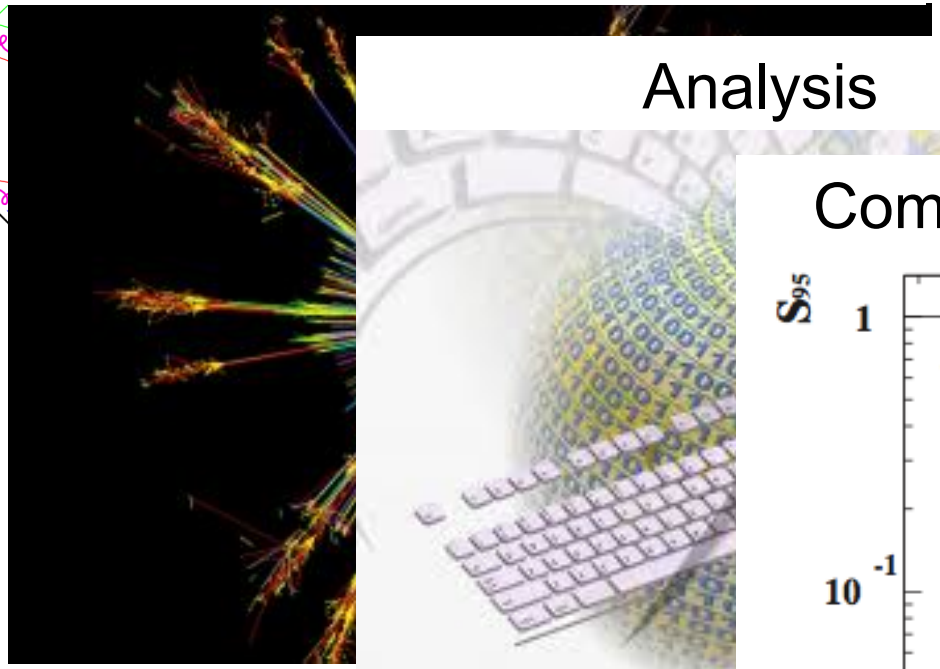


From Theory to Experiment (and back)

- hard scattering
- (QED) initial/final

Detector Simulation

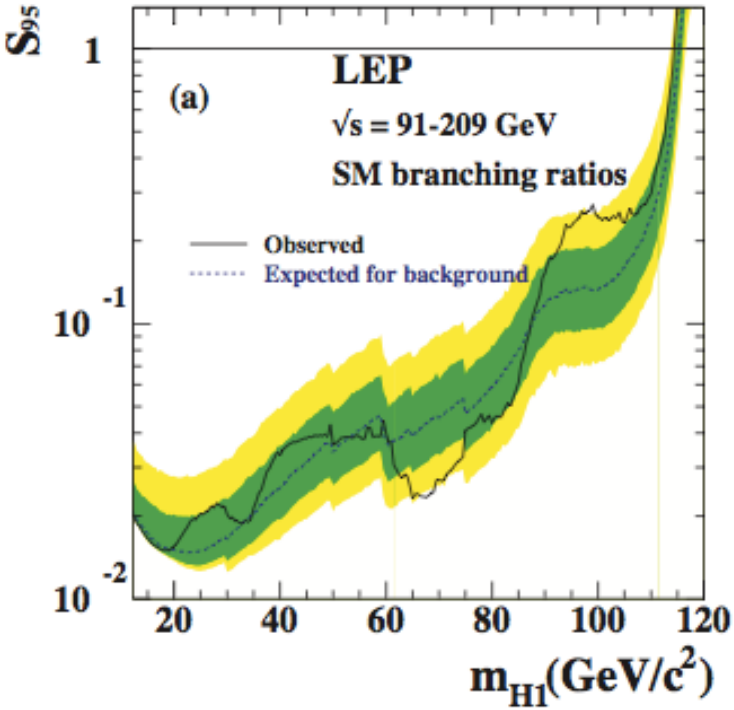


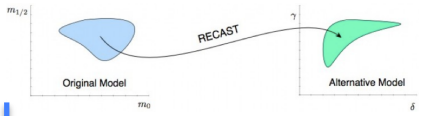


Analysis

Comparison with Data

From D. Zeppenfeld's





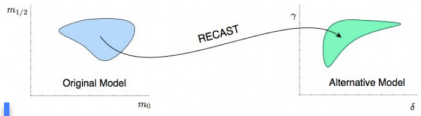
Modern Hypothesis Testing

Many new models going beyond the Standard Model have been suggested:

- SUSY – SUGRA,GMSB,AMSB,…
- RS
- UED
- Little Higgs
- The model not thought of . . .

Many powerful tools were created to allow fast incorporation ***and*** simulation of new particle physics,

- Madgraph/Madevent
- Calchep/Comphep
- PYTHIA,HERWIG
- LHE format

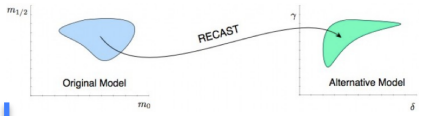


Modern Hypothesis Testing

Considering how many models there are, and the fact that in the future there may be more, how do we test for a new hypothesis?

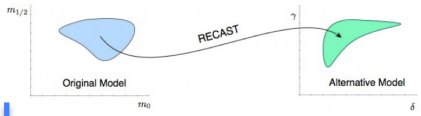
1) Construct a new analysis.

2) Reuse existing analyses.



Question

What do you need to know about an existing analysis to reuse it for testing an alternative model?

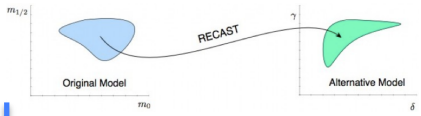


Answer

You only need to know the efficiency of the analysis to an alternative signal.

- No need for data access.
- No need for code access.

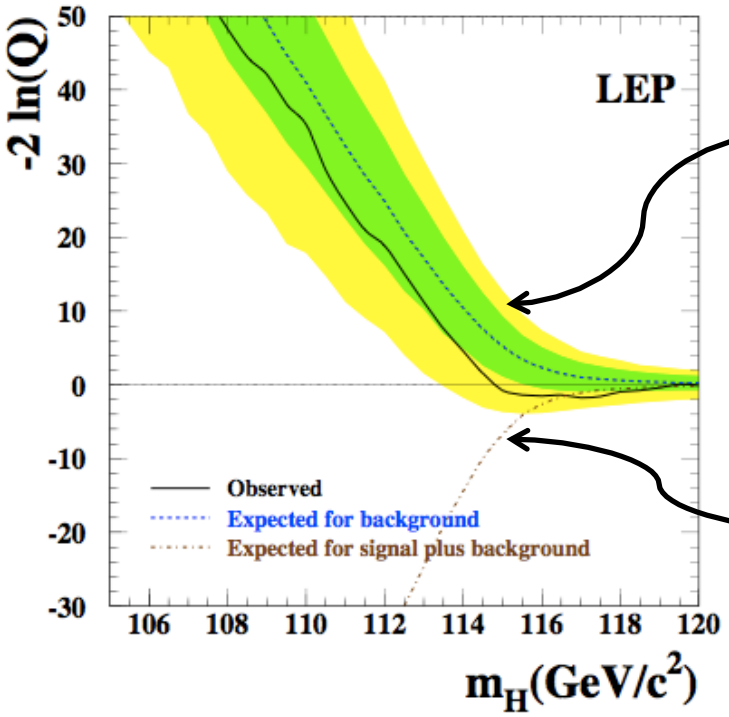
Just the ability to recalculate the efficiency of an alternative hypothesis.



Reporting an Experimental Search

Eve

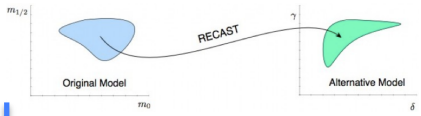
Experimentalist



Signal independent
(a lot of hard work: background estimation, acceptances, and etc.)

Signal dependent

Eve is searching for some signal and reports an exclusion plot based on that signal. The cuts and procedure she employs lead to some signal efficiency which she quotes.



Sometimes in the Future…

Oscar

The Other Experimentalist

Oscar wants to search for a different signal. But, maybe Eve's search already covers his signal in certain regions of the parameter space. If that is true Oscar's job is made much simpler, he can concentrate on these regions which are not already excluded by Eve's analysis…

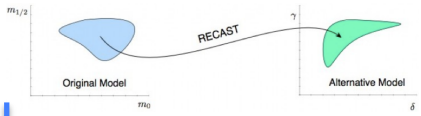
But how will Oscar know? He needs to know what is the efficiency of Eve's search for his new signal!

Theodora

Theorist

Theodora just thought of a new particle that can explain all sorts of things. But, she realizes that this particle may result in a signal which, while not the same as Eve's, does have some overlap with it. Maybe it's already excluded by Eve's analysis. . .

How will Theodora know? She needs to know what is the efficiency of Eve's search for her new signal!



How Does It Work?

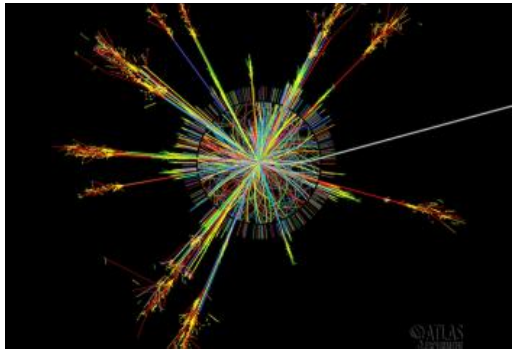
LHE

New signal

Pythia

(Showering & Hadronization)

Detector Simulation

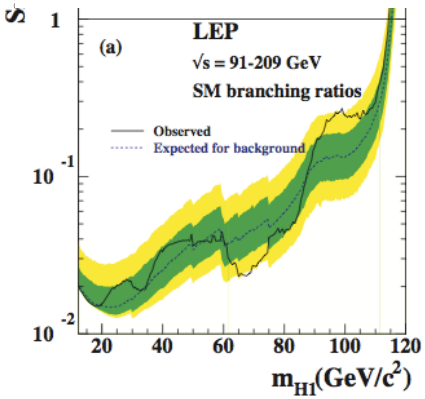


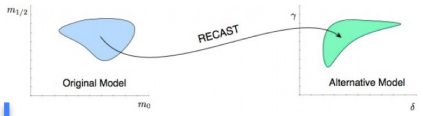
Analysis

Efficiency

for new signal

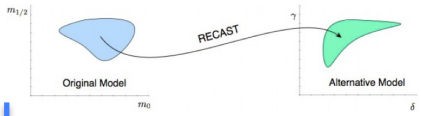
Comparison with data was already done.



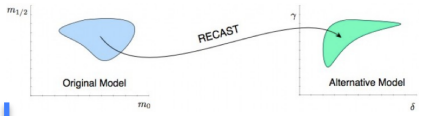


Question

But can existing analyses have anything to say about an alternative signal?



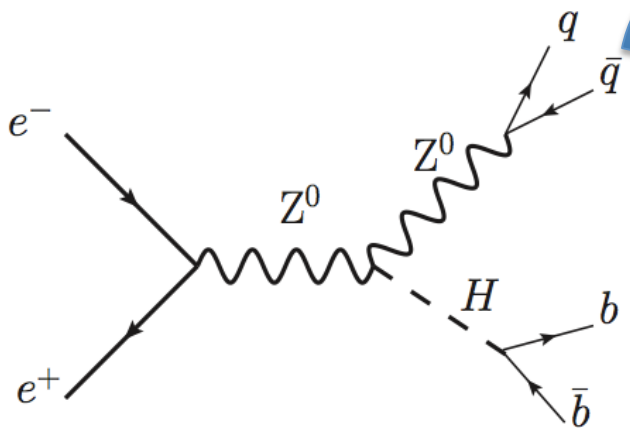
Examples



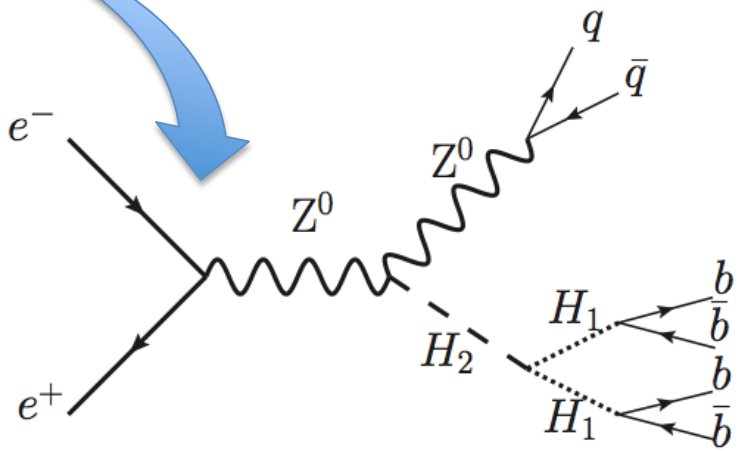
OPAL Higgs Searches

In hep-ex/0406057 OPAL recasted a previous search for Standard Model Higgs to place constraints on MSSM Higgs scenarios

hep-ex/0209078



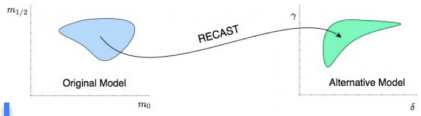
hep-ex/0406057



Importantly, the recasted signal is not even the same topology!

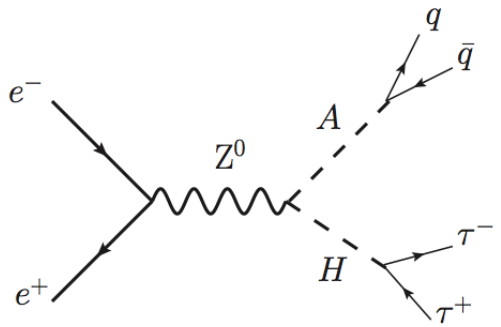
Efficient recasting

$m_{\mathcal{H}_2}$ (GeV)	$m_{\mathcal{H}_1}$ (GeV)	Efficiency for the process $\mathcal{H}_2 Z \to b\bar{b}b\bar{b}q\bar{q}$ at $\sqrt{s}$				
		192 GeV	196 GeV	200 GeV	202 GeV	206 GeV
100.	12.	0.689	0.684	0.717	0.733	0.693
100.	20.	0.651	0.639	0.653	0.659	0.586
100.	30.	0.460	0.461	0.461	0.470	0.480
100.	40.	0.270	0.260	0.283	0.315	0.323
100.	48.	0.328	0.325	0.361	0.392	0.400

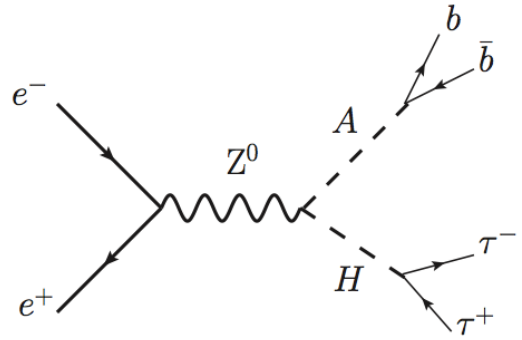


DELPHI Higgs Searches

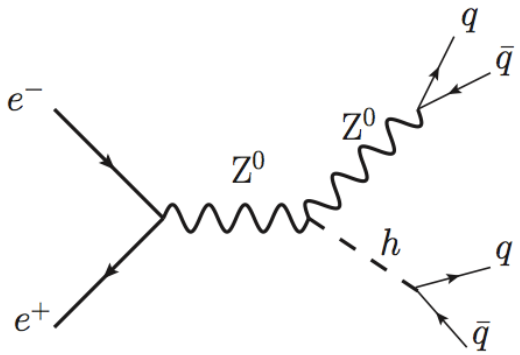
Similar recasting of previous SM Higgs searches was done at DELPHI



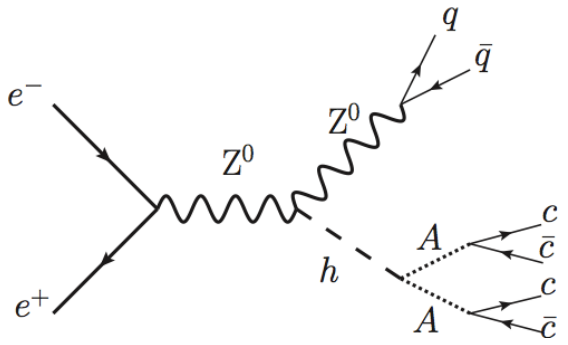
DELPHI Col., Eur. Phys. J. C38 (2004)



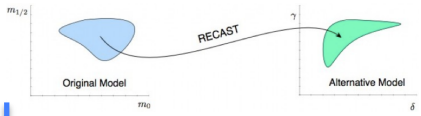
DELPHI Col., Eur.Phys.J. C54 (2008)



DELPHI Col., Eur. Phys. J. C23 (2002)

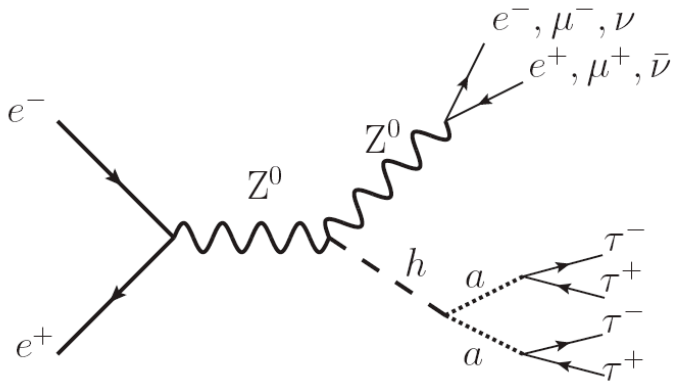


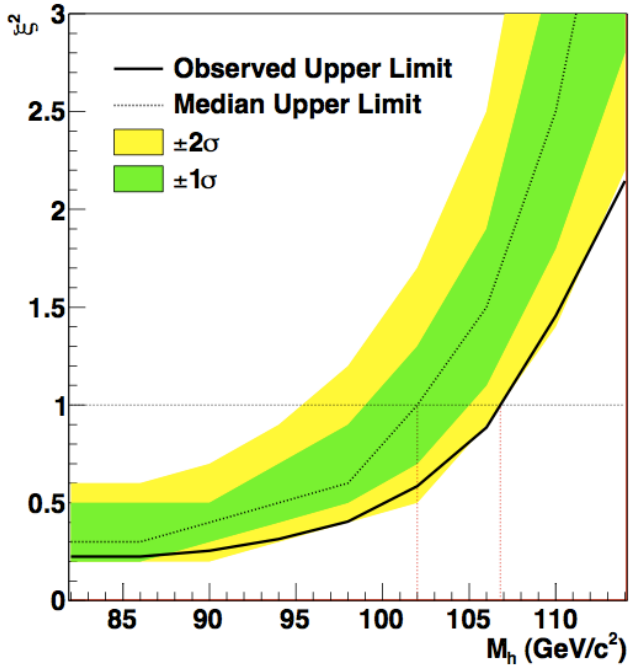
DELPHI Col., Eur.Phys.J. C54 (2008)



Exotic Higgs Searches

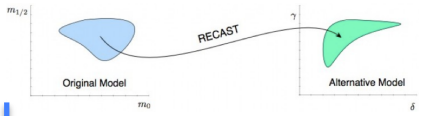
In a recent ALEPH publication we reported on a search for a Higgs boson decay into 4 taus through two light pseudoscalars,





Beacham, Cranmer, and Yavin for the ALEPH collaboration, arXiv:1010.2506, JHEP 1104 (2011) 038

$$\xi^2 = \frac{\sigma\,\mathrm{BR}(h \to aa)\,\mathrm{BR}(a \to \tau\tau)^2}{\sigma_{SM}}$$



RECAST – Other Leptons

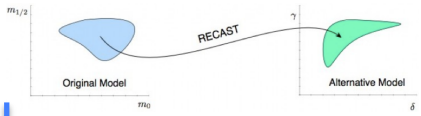
We can recast that analysis to exclude other leptonic decays such as Higgs boson decay into 4 electrons or 4 muons.

m_H=100 GeV, m_a=10 GeV

Original analysis

Decay mode	Efficiency
$a \to \tau^+\tau^-$	0.37
$a \to \mu^+\mu^-$	0.35
$a \to e^+e^-$	0.27

Why is the electron channel efficiency lower? (Hint: GEANT)

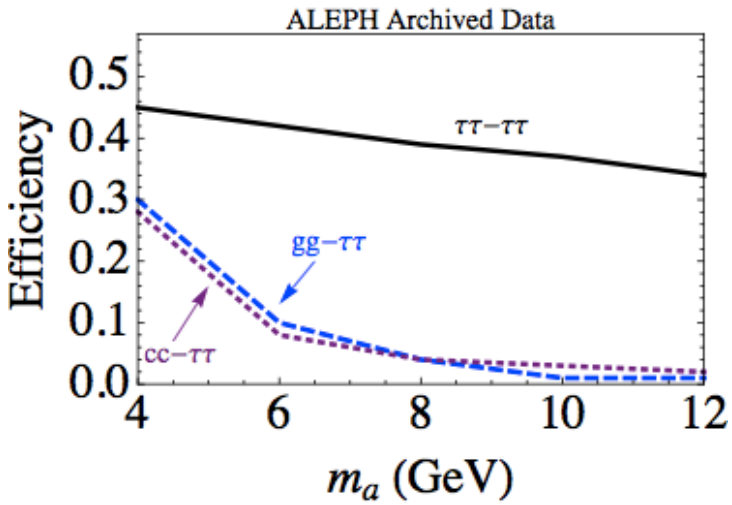


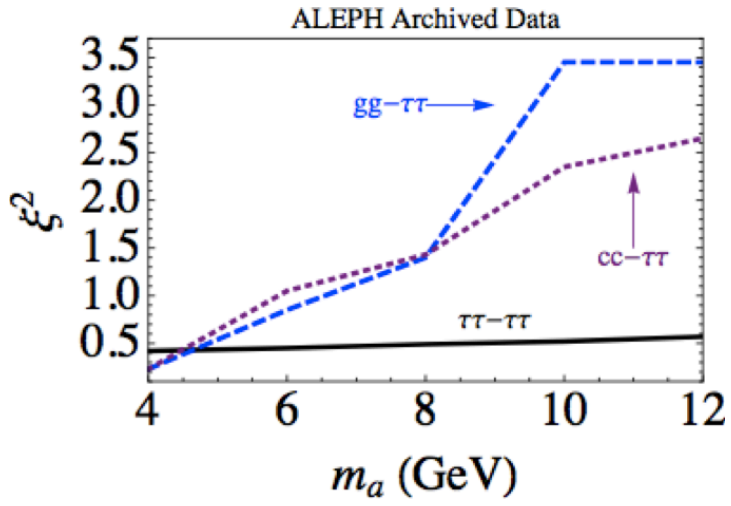
RECAST – Mixed Decays

The NMSSM with a light Higgs boson may still escape the previous search if the branching ratio into taus is reduced. But, in this case one would expect an enhancement in the decay into gluons or charm quarks

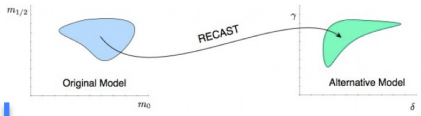
$$h \to aa \to 2\tau 2g$$

$$h \to aa \to 2\tau 2c$$





The lower efficiency is mainly due to the higher multiplicity in hadronic decays.

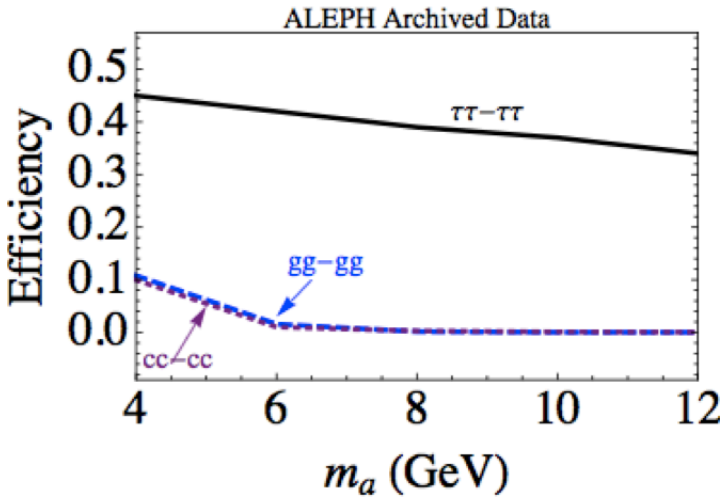


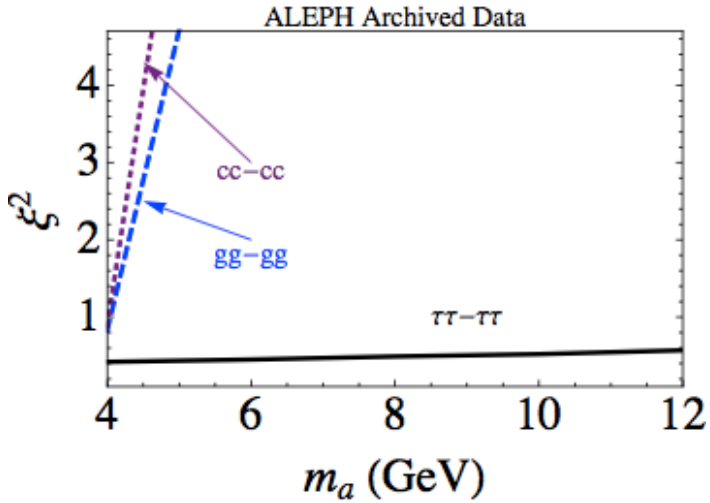
RECAST – Hadronic Decays

Other scenarios (Chang et al., Csaki et al.) contemplate fully hadronic decays of the Higgs boson which might have escaped the canonical searches.

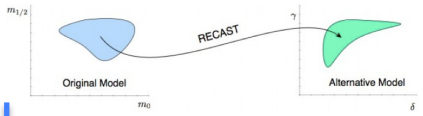
$$h \to aa \to 4g$$

$$h \to aa \to 4c$$



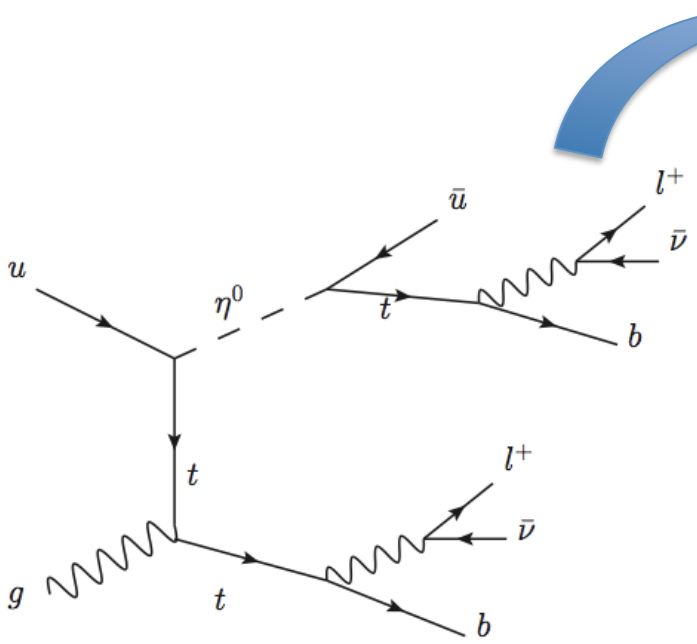


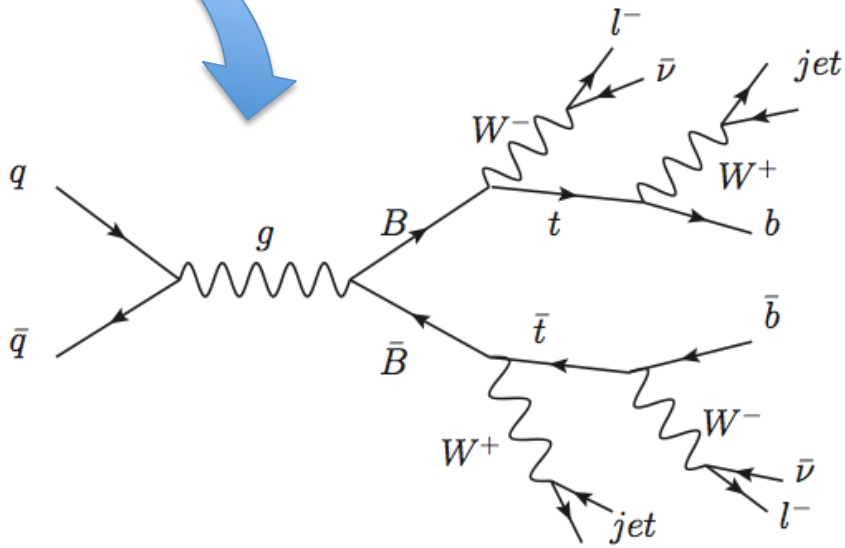
The search is hardly sensitive to these decays except for very light pseudo-scalars.



CDF 4th Generation Search

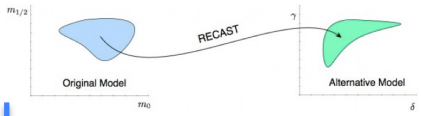
D. Whiteson for CDF recasted a previous search for maximal flavor violating scalars into a search for 4th generation b-quarks. Both scenarios lead to $\ell^{\pm}\ell^{\pm}bj\not{E}_T$





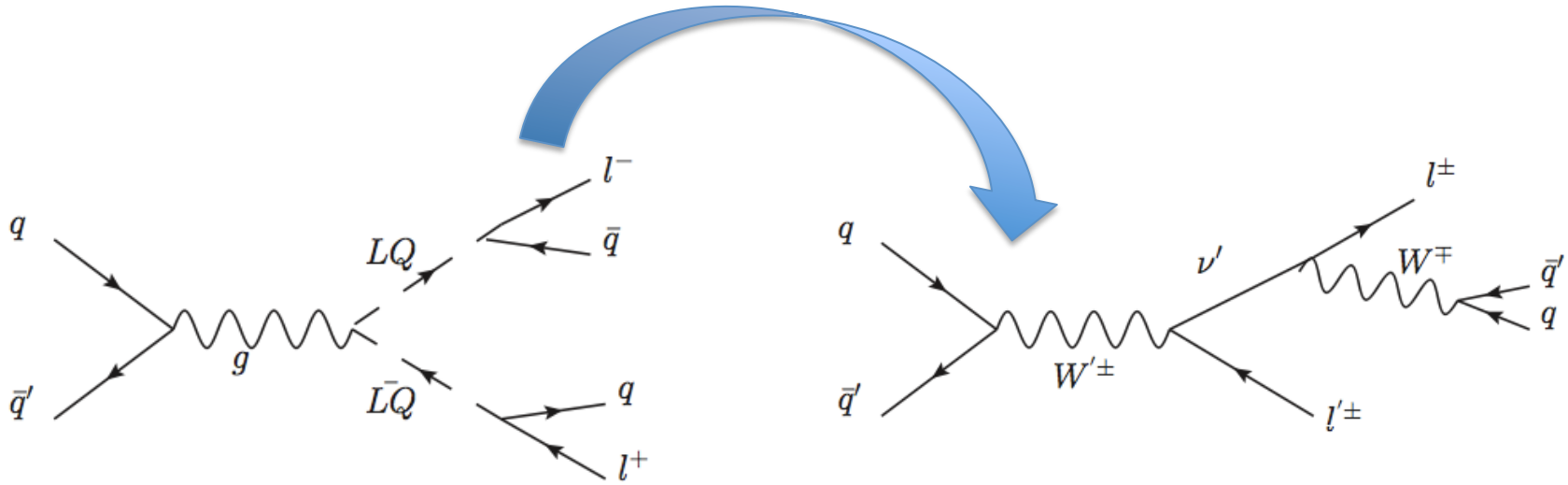
0809.4903

PRL 0912.1057



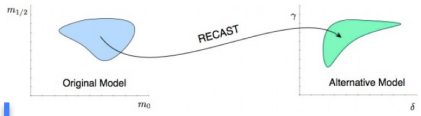
W’ hunt from Leptoquark search

M. Schmaltz and C. Spethmann suggested a recast of a leptoquark search that was done by D0 to place bounds on W’ particles expected in Little Higgs theories,



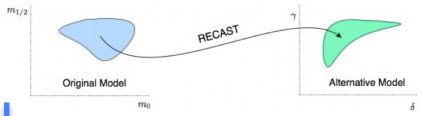
0710.0255

????.????

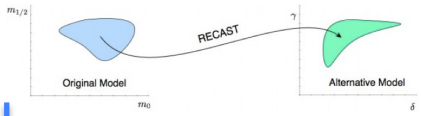


Question

How do we design the framework so as to maintain the collaborations control over their analyses while allowing communication with the community for RECAST requests?



The RECAST Framework



RECAST

Seen only by Eve

Eve's analysis code including all the cuts, detector effects and etc.

Can be submitted by everyone

After collaboration's approval

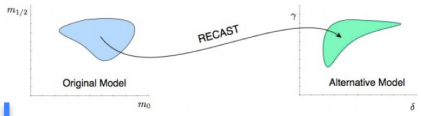
Seen by everyone - no data, no code, only sensitivity

Back-End
controlled by collaboration's protocol

LHE
New signal

Front-End
Communication Broker

Efficiency for new signal



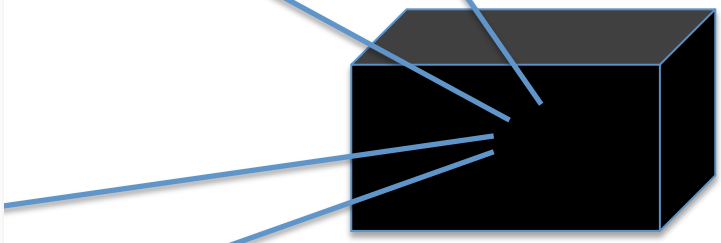
Black Box

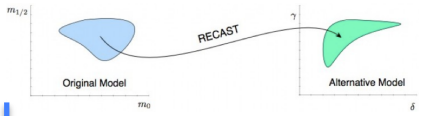
RECAST-demo.h

RECAST-demo.h:15 ZelAgtmCycle::Cut1()

```
/*
 *  RECAST-demo.h
 *
 *
 *  Created by itay on 8/31/11.
 *  Copyright 2011 __MyCompanyName__. All rights reserved.
 *
 */

Bool_t ZelAgtmCycle::Cut1()
{
    // two or three jets and a dielectron
    return (
            (jetn==2 || (jetn==3 && zji>=0 && jettrk[zji]<3)) &&
            elen==2 && // check for di-electrons
            fabs(jetct[j0i])<0.9 &&
            fabs(jetct[j1i])<0.9 && //check jet is well contained
            elech[0] * elech[1] < 0 //check those are opposite sign
            );
}


Bool_t ZelAgtmCycle::Cut2()
{
    return (
            //CONTROL WINDOW - LOOK AWAY FROM Z MASS PEAK
            //(ZLm < 70 || ZLm > 112) &&
            // NEW CONTROL WINDOW - LOOK AWAY FROM H MASS PEAK
            //(HLm < 60 || HLm > 130) &&

            jlcphi_local<0.95 &&
            eleiso[0]>10. &&
            eleiso[1]>10.
            );
}

Bool_t ZelAgtmCycle::Cut3()
{
    return (
            (jettrk[j0i] > 1 && jettrk[j0i] < 19)
            && (jettrk[j1i] == 2 || jettrk[j1i]==4)
            && JJcphi_local < -0.4
            );
}
```

The detector simulation and analysis code can remain a black-box. Outside users can only inquire about efficiency.





Everyone Benefits!!!

Eve

Experimentalist

- More impact for Eve's search!!!
- Eve does not have to worry about interpreting her results under many different signal assumptions.

Oscar

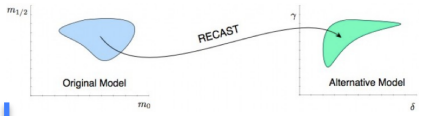
Other Experimentalist

- Oscar can use Eve's results to make sure the new signal he is planning to search for is not already excluded.
- Maybe some regions of his new signal are excluded, so concentrate and optimize his analysis to those which are not!

Theodora

Theorist

- Theodora can confidently estimate the coverage of Eve's analysis on her new model.
- Help to direct the theorist thinking into these regions not already excluded even when considering new models which have not been explicitly searched for.



Recasting

- Does not require access to or reprocessing of the data
- Does not involve design of new event selection criteria
- Does not require additional estimates of background rates or systematic uncertainties

- Extends the impact of existing experimental searches
- Targets physics scenarios of interest to the community
- Provides accurate interpretation of model-independent and signature-based searches in the context of a specific model
- Facilitates the consideration of new models even after the analysis is done
- Allows collaborations to control the approval of new results
- Complements data archival efforts

Front-End Development

Over the past several months we have worked hard on the design, implementation, and testing of the RECAST website. Our efforts were aided by the support and encouragement of the Perimeter Institute. PI has contributed computing expertise as well as funding for a wonderful external software vendor, Nextide, to help with the development.

Blaine Lang
Nextide

Kyle Cranmer
ATLAS, NYU

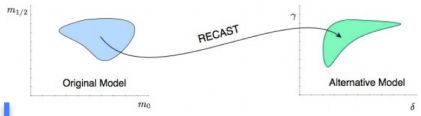
Dustin Windibank
System Architect, PI

Ben Davies
CIO, PI

Randy Kolenko
Nextide

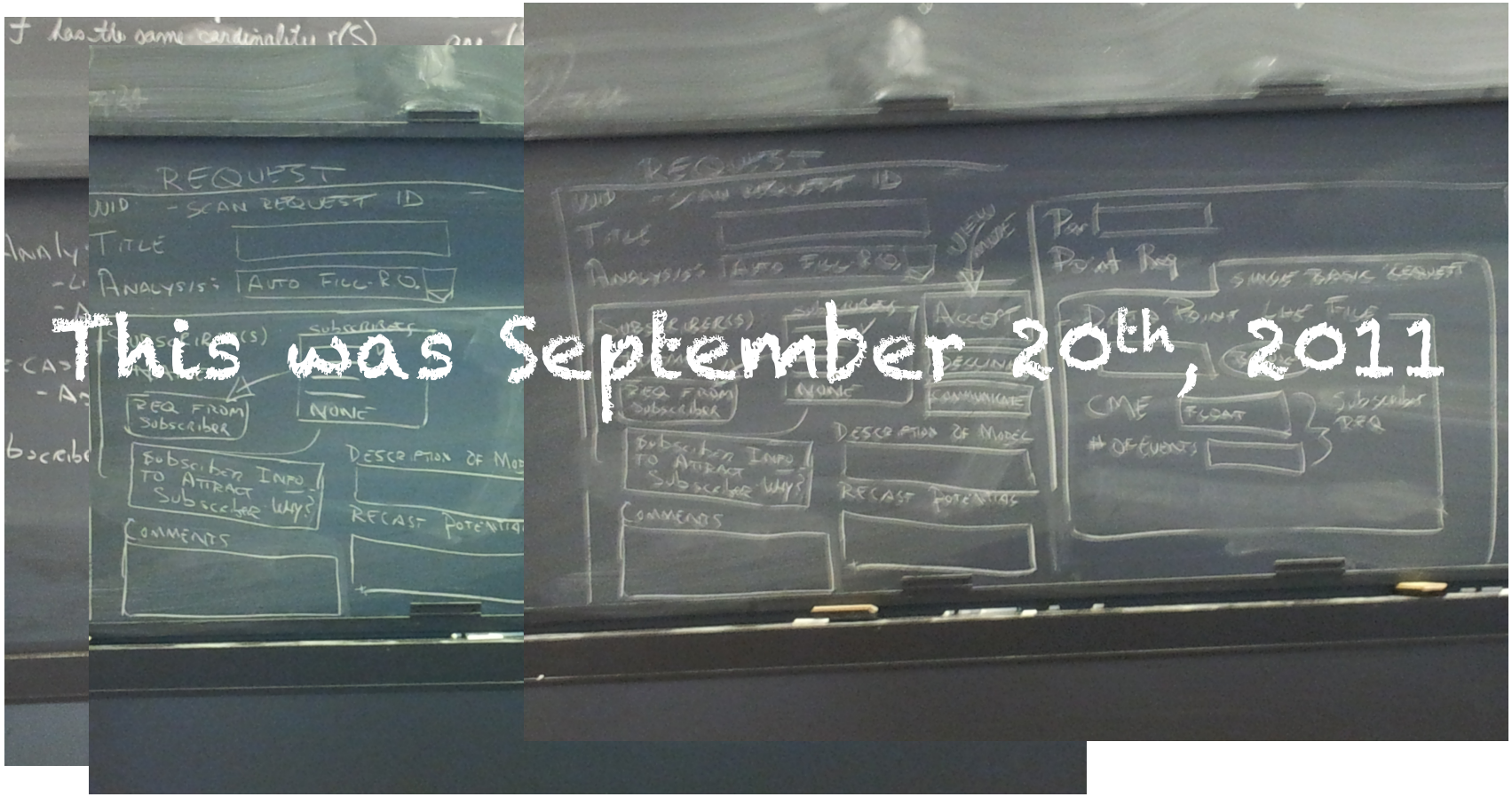
Itay Yavin
McMaster & PI

Erik Schnetter
Research Technologies
Lead, PI

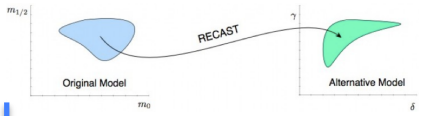


Blackboard Design

In September we all met at the Perimeter Institute to go over the design of the front end,



This was September 20th, 2011



Today – Beta Version

Safari File Edit View History Bookmarks Window Help — Tue 1:54 AM itay

Latest Requests | RECAST [beta]

http://recast.perimeterinstitute.ca/ — higgs decay light quarks

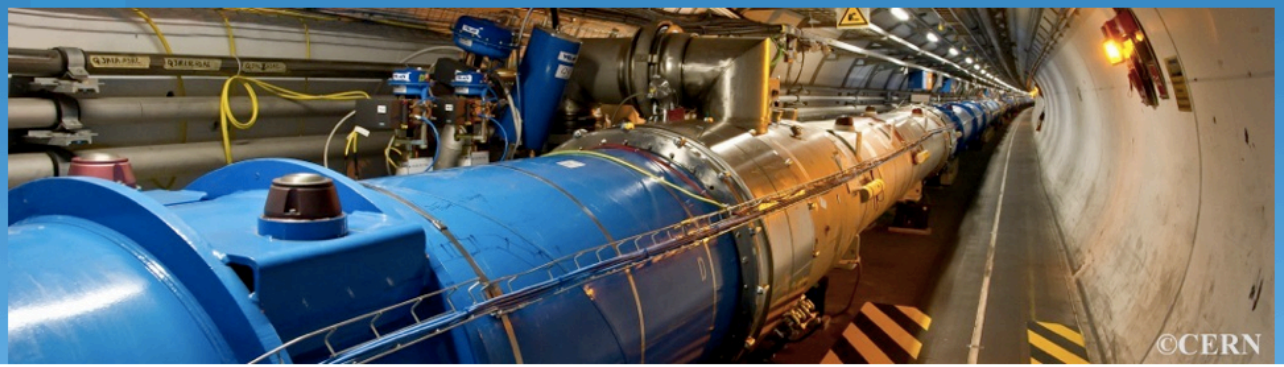
Yavin SPIRES inspires Onion HPC4Mac gfortran arXiv ATLAS CMS PDG CERN nr SAO/ADS SHARCNET Translate Nuclides DW Imgtfy NSERC LeptonJets current pinyin P-value

Latest Requests | RECAST [beta]

Feedback Log out My Account

RECAST [beta]

Home | Analyses Catalog | Requests | My Subscriptions | About | Developers | News | Help



Search

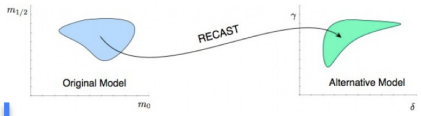
About this site

RECAST is a framework for extending the impact of existing analyses performed by high-energy physics experiments.

1. Anyone can add *analyses* to the Analysis Catalog
2. Anyone can upload alternative signals in the LHE format and *request* that any given analysis is "recast" for their alternative model
3. Anyone can *subscribe* to an analysis to be informed of activity associated with the analysis

Latest Requests

Request	Analysis	Model	Status
1111.0012	Search for Supersymmetry in pp Collisions at 7 TeV in Events with Jets and Missing Transverse Energy	Littlest Higgs with T-Parity	In Progress
1112.0002	Search for Diphoton Events with Large Missing Transverse Momentum in 1 fb^-1 of 7 TeV Proton-Proton Collision Data with the ATLAS Detector	GMSB	Completed



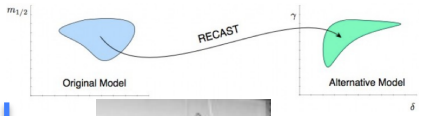
Demonstration

In 1103.3014, *"T-Quarks at the LHC: 2010-12"*, M. Perelstein & J. Shao, recasted a search for SUSY in CMS into a search for T-quarks, which can be thought of as a simplified model for UED and/or Little Higgs models.

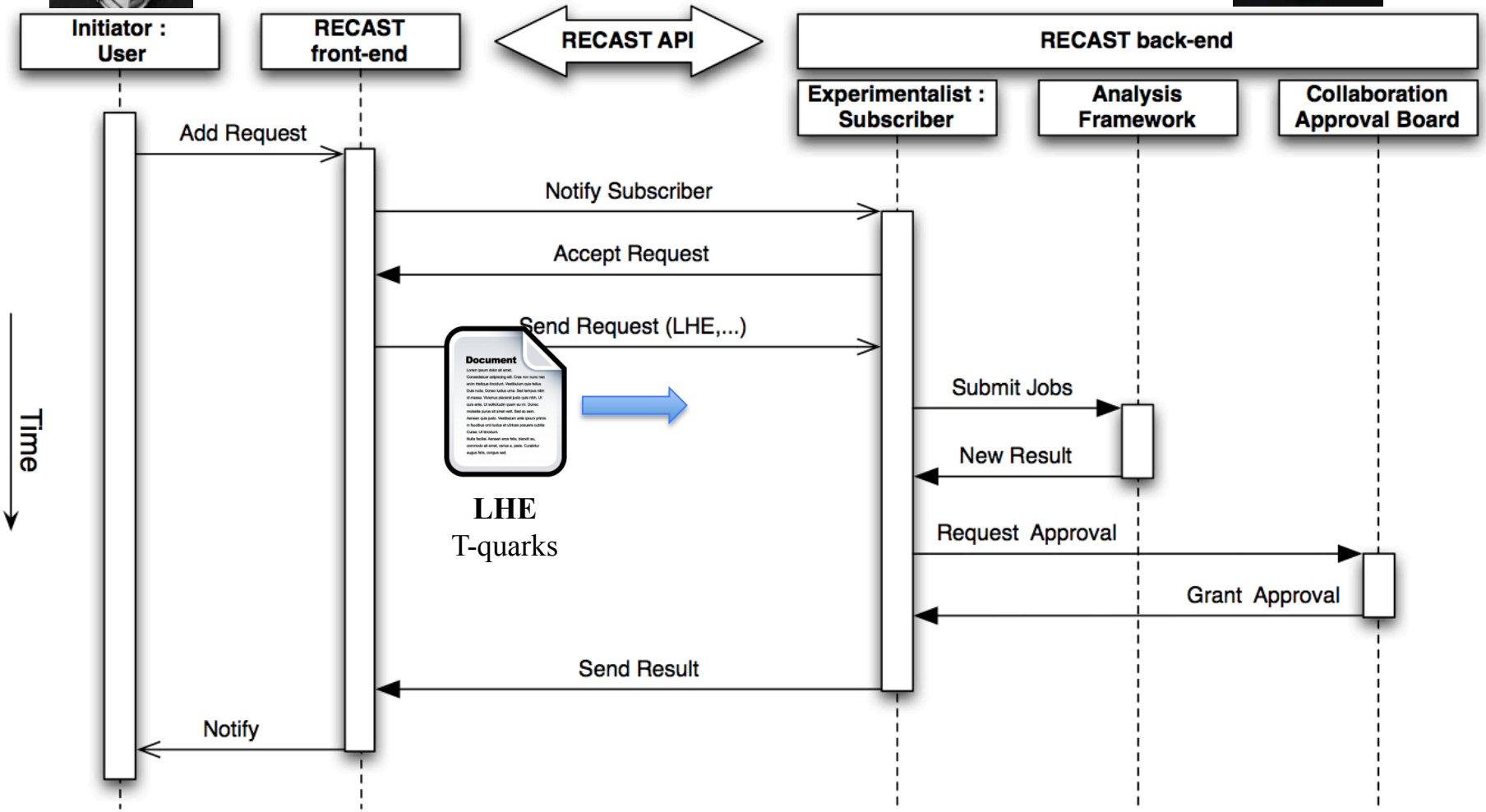
They have reproduced a CMS analysis searching for SUSY in jets + missing energy (1101.1628). Maxim and Jing have kindly agreed to use the mock back-end of the analysis they recreated for a demonstration of the RECAST front-end.

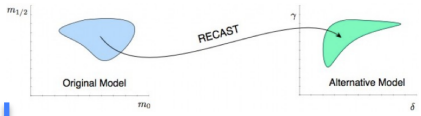
Maxim Perelstein
Requester

Jing Shao
Provider



RECAST - Sequence





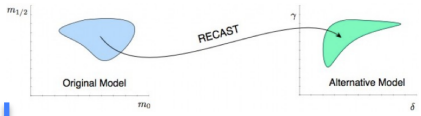
Additional Benefits

Aside from allowing the reuse of analysis, the RECAST framework serves an additional purposes

- It is now considered by the data archival preservation working group as the solution for the analysis archival efforts.

- It satisfies the very basic scientific requirement of reproducibility.

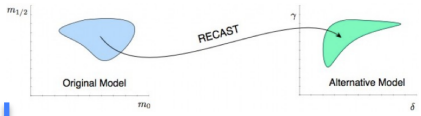
- It begins to address issues of public access without all the usual problems associated with it.



Future Directions

We will enjoy a wealth of data from the LHC over the next several years.

- We hope that analyses' back-ends will be implemented.
- Many more RECAST results.
- inSpire has expressed interest in RECAST and we hope to integrate it into the new inSpire engine in the future.
- A qualitative change in the way we do hypothesis testing of alternative models.

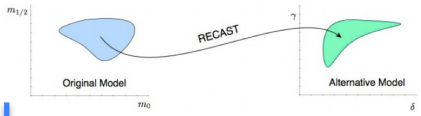


Final Thoughts

• RECAST becomes useful when data is no longer exponentiating. Analysis are more precious.

• RECAST is particularly important once an experiment stops running, e.g. Tevatron, LEP2.

• Huge datasets, very large number of models, complex simulation tools – HEP is at the frontier of hypothesis testing. RECAST is the logical next step.



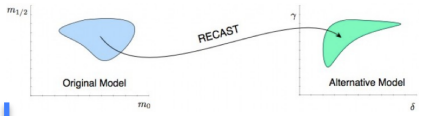
The End

Happy Recasting

Visit us and let us know what do you think @

recast.perimeterinstitute.ca

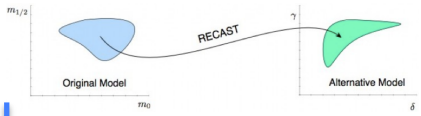
arXiv:1010.2506



CERN workshop

RECAST complements and aids many of the ideas and approaches that were presented in a recent workshop in CERN about the characterization of new physics:

- "It is usually only in the interpretation (i.e. putting limits) that models are assumed." – A. Farbin
- "95% (or even more) of experimental efforts on measurement of the particular signature is taken by reliable background estimations, efficiencies calculations, systematics studies, etc." – F. Ratnikov
- As N. Toro emphasized, part of the issue is whether we are interested in *high-precision* exclusions, or we are satisfied with *approximations*
- S. Mrenna - New MC tools are making it easier and easier to quickly simulate alternatives
- S. Thomas' parameterization of acceptance can be validated
- K. Cranmer's interpolation can be extrapolated with RECAST anchors
- Serves as the natural next step for D. Cote's model-independent emphasis



More Examples

1. The buried/charmed Higgs scenarios of Csaki et al. (0906.3026, 0910.3210) could have been easily constrained by RECASTing existing Higgs to 2 jets flavor independent analyses.

2. Meade, Reece, and Shih (0911.4130) derived limits on prompt decays of general neutralino NLSPs at Tevatron using the limited existing analysis available. Their efforts could have been greatly reduced with RECAST.

3. Falkwoski et al. suggested hiding the Higgs boson through Higgs to lepton-jets. Again, RECASTing existing analyses could have helped in placing better limits on this scenario.