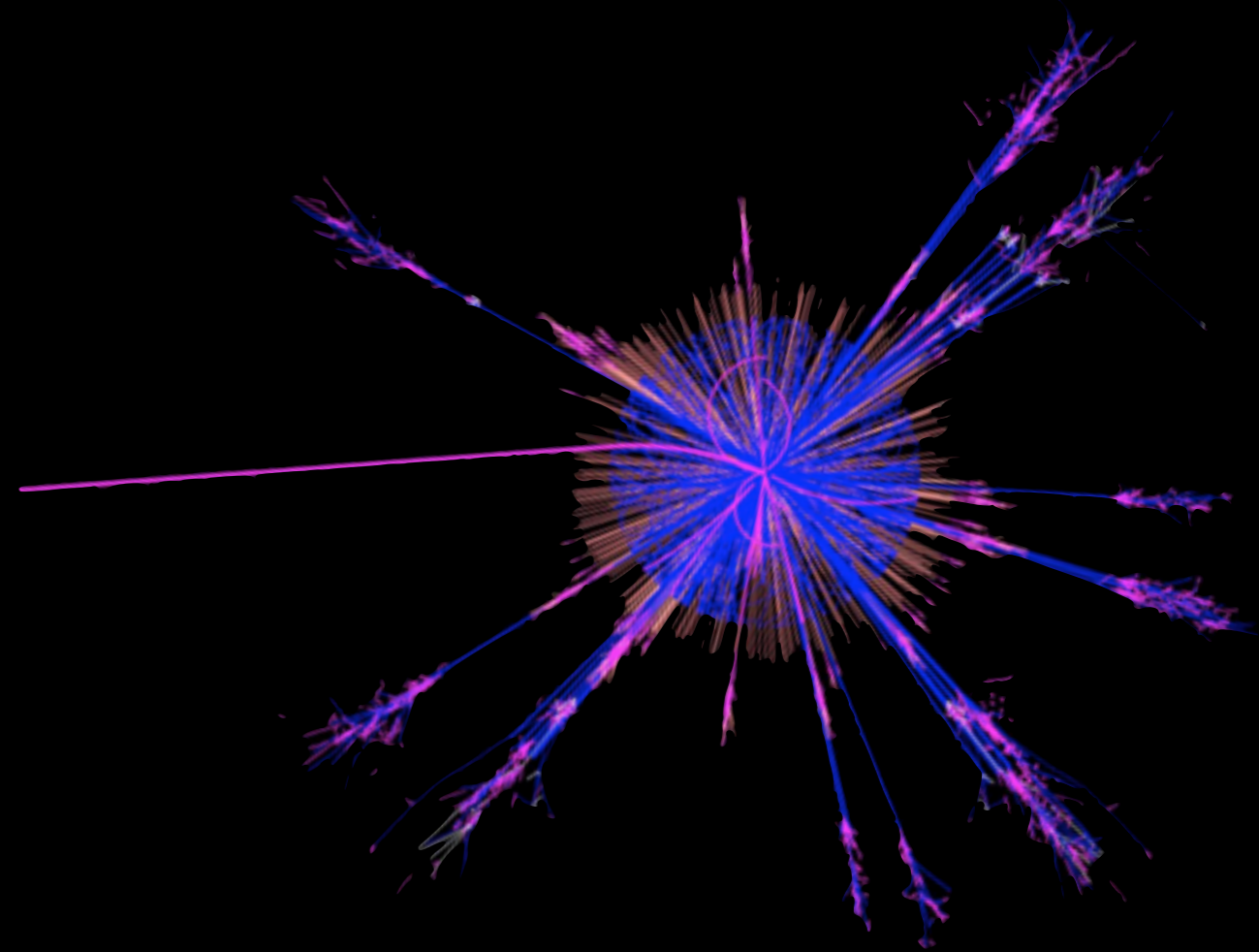


WHAT AM I DOING

WITH DATA

@KyleCranmer
New York University
Department of Physics
Center for Data Science

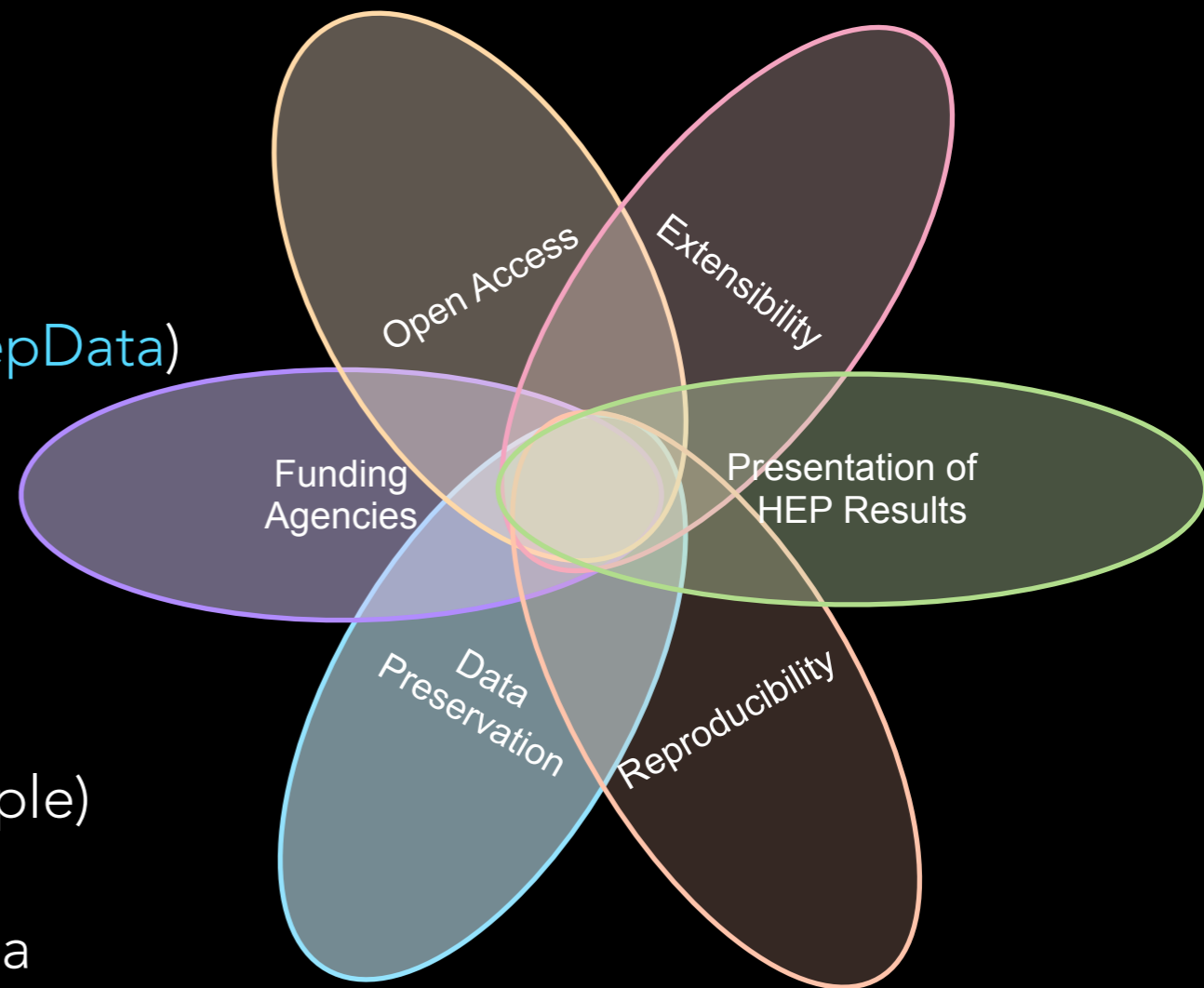


BIO

- Statistics Convener of [ATLAS](#) experiment
- Founder of [RooStats](#) framework (used for Higgs)
- Co-founder of [RECAST](#) framework
- Advisory Board member for [INSPIRE](#)
- Member of [DASPOS](#), [DPHEP](#)
- Open Science working group lead @ NYU [Data Science Environment](#) (funded by Moore+Sloan foundations)

STORY

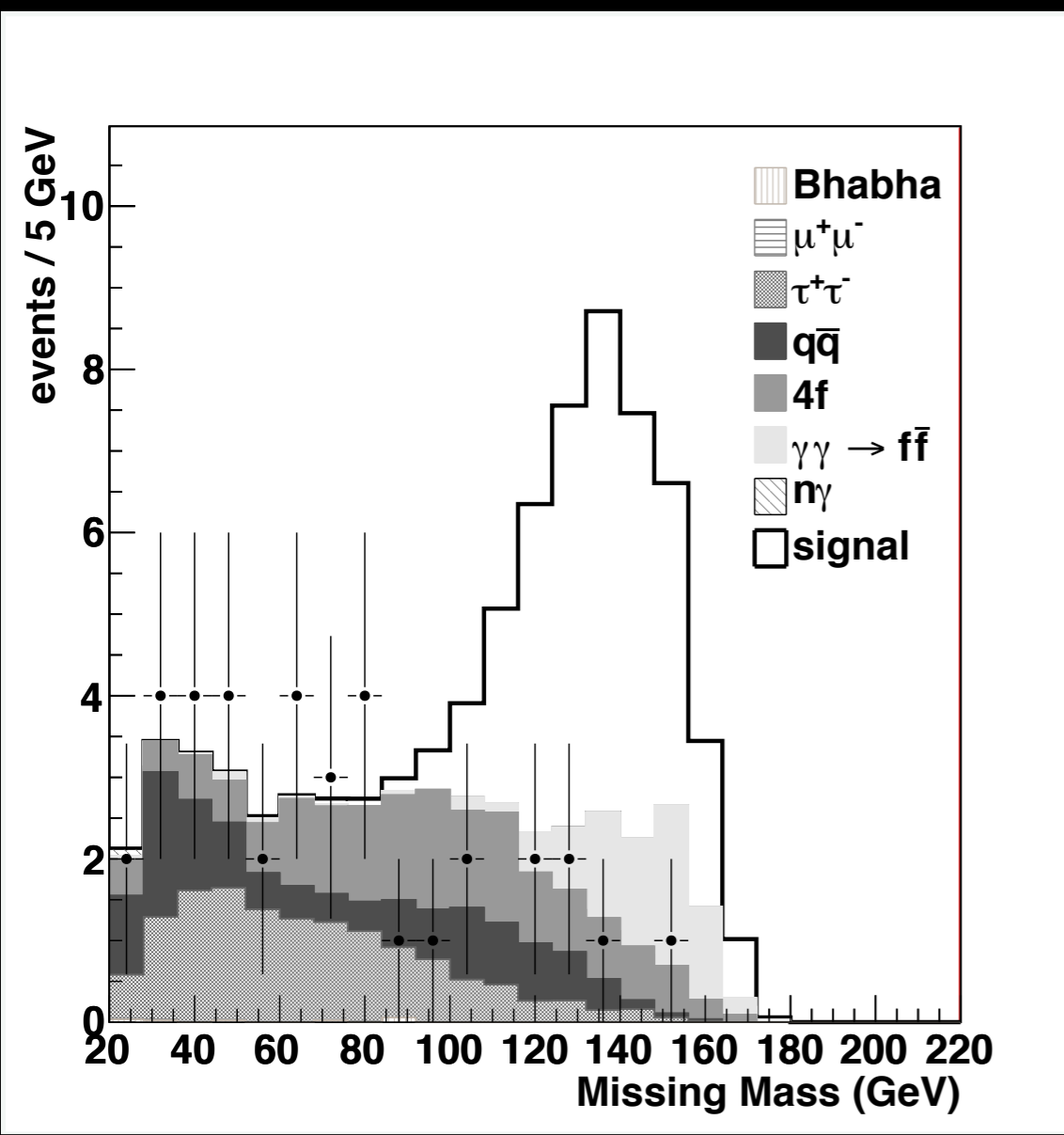
- Higgs search with 10 year old archived [ALEPH](#) data
- [RECAST](#) analysis archival
- Weather forecast → [DataVerse](#)
- Higgs Likelihood (simple and full, XML, [HepData](#))
- [APEX](#) raw data & statisticians
- Recouple paper [figshare](#)
- code [GitHub](#) → [Zenodo](#) (KEYS and Recouple)
- 10 simple rules for care and feeding of data
- Issues: fragmented DOIs, [ImpactStory](#), ...



A LESSON LEARNED

WE WENT BACK TO 10 YEAR OLD ALEPH DATA TO LOOK FOR AN EXOTIC HIGGS

We had sensitivity to discover the Higgs!





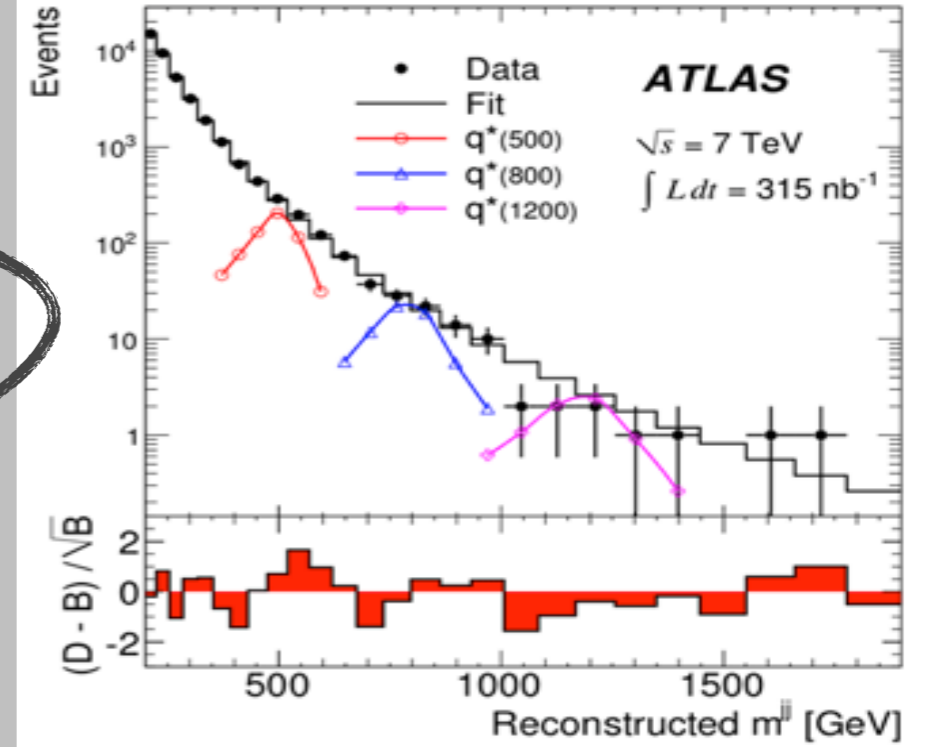
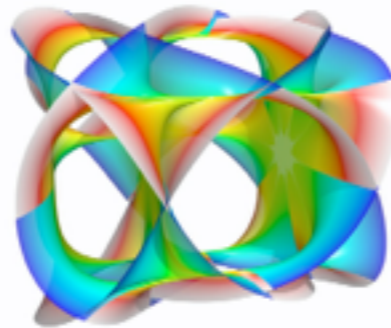
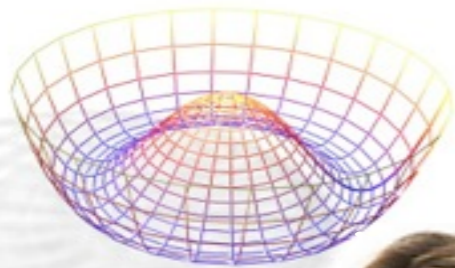
THEORY

SERVICE

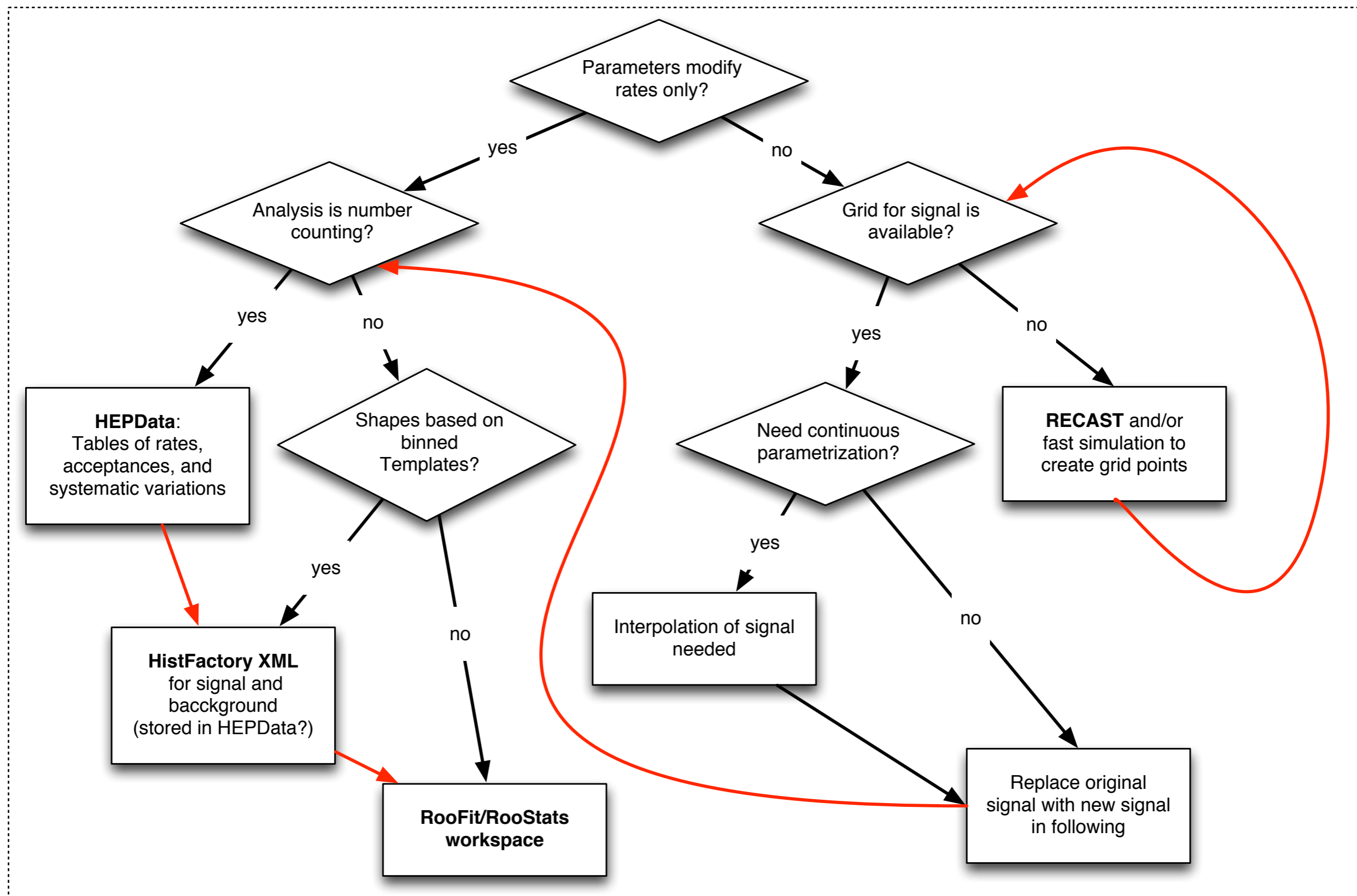
$$\begin{aligned}
 \mathcal{L}_{SM} = & \underbrace{\frac{1}{4} \mathbf{W}_{\mu\nu} \cdot \mathbf{W}^{\mu\nu} - \frac{1}{4} B_{\mu\nu} B^{\mu\nu} - \frac{1}{4} G_{\mu\nu}^a G_a^{\mu\nu}}_{\text{kinetic energies and self-interactions of the gauge bosons}} \\
 & + \underbrace{\bar{L} \gamma^\mu (i \partial_\mu - \frac{1}{2} g \boldsymbol{\tau} \cdot \mathbf{W}_\mu - \frac{1}{2} g' Y B_\mu) L + \bar{R} \gamma^\mu (i \partial_\mu - \frac{1}{2} g' Y B_\mu) R}_{\text{kinetic energies and electroweak interactions of fermions}} \\
 & + \underbrace{\frac{1}{2} |(i \partial_\mu - \frac{1}{2} g \boldsymbol{\tau} \cdot \mathbf{W}_\mu - \frac{1}{2} g' Y B_\mu) \phi|^2 - V(\phi)}_{\text{W}^\pm, \text{Z}, \gamma, \text{ and Higgs masses and couplings}} \\
 & + \underbrace{g'' (\bar{q} \gamma^\mu T_a q) G_\mu^a}_{\text{interactions between quarks and gluons}} + \underbrace{(G_1 \bar{L} \phi R + G_2 \bar{L} \phi_c R + h.c.)}_{\text{fermion masses and couplings to Higgs}}
 \end{aligned}$$

Q

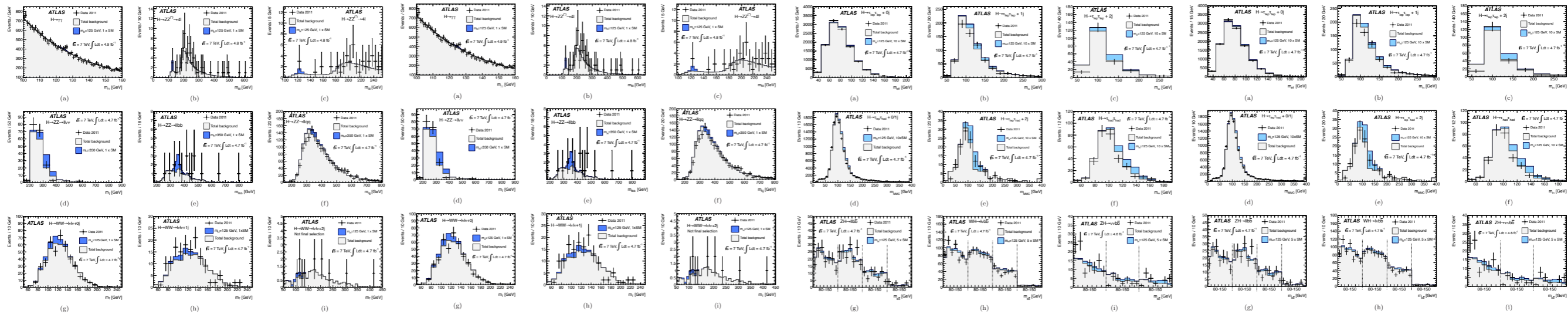
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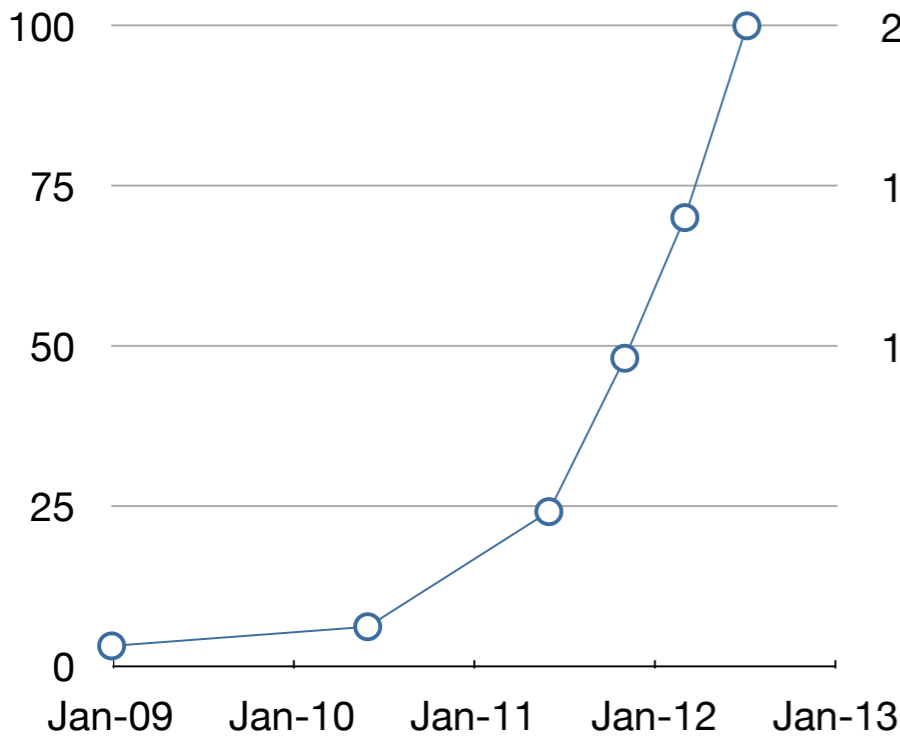
ROADMAP



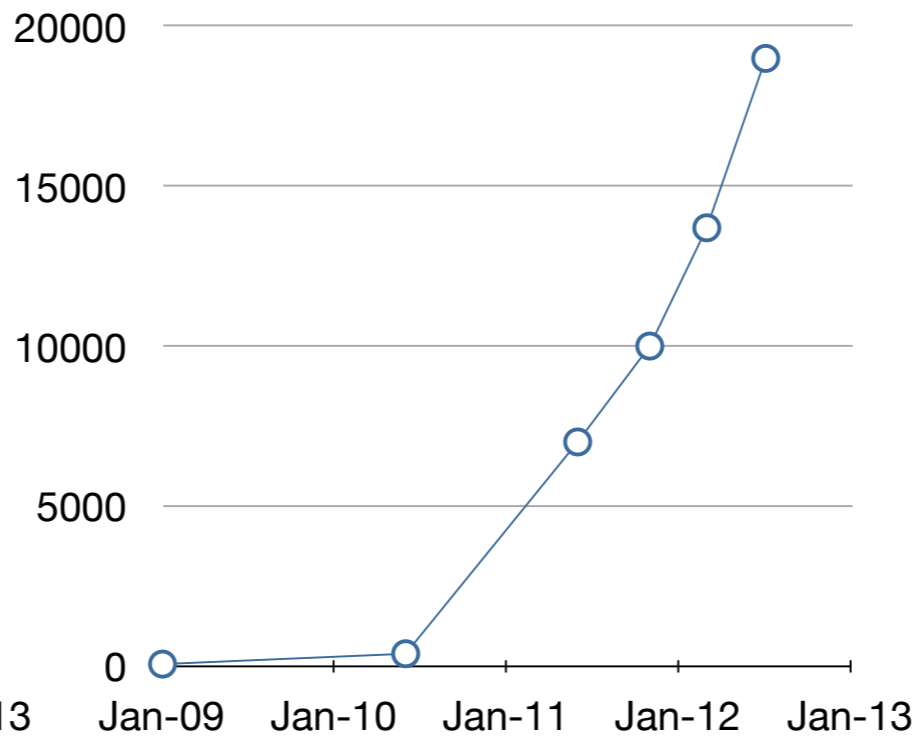
Collaborative Statistical Modeling



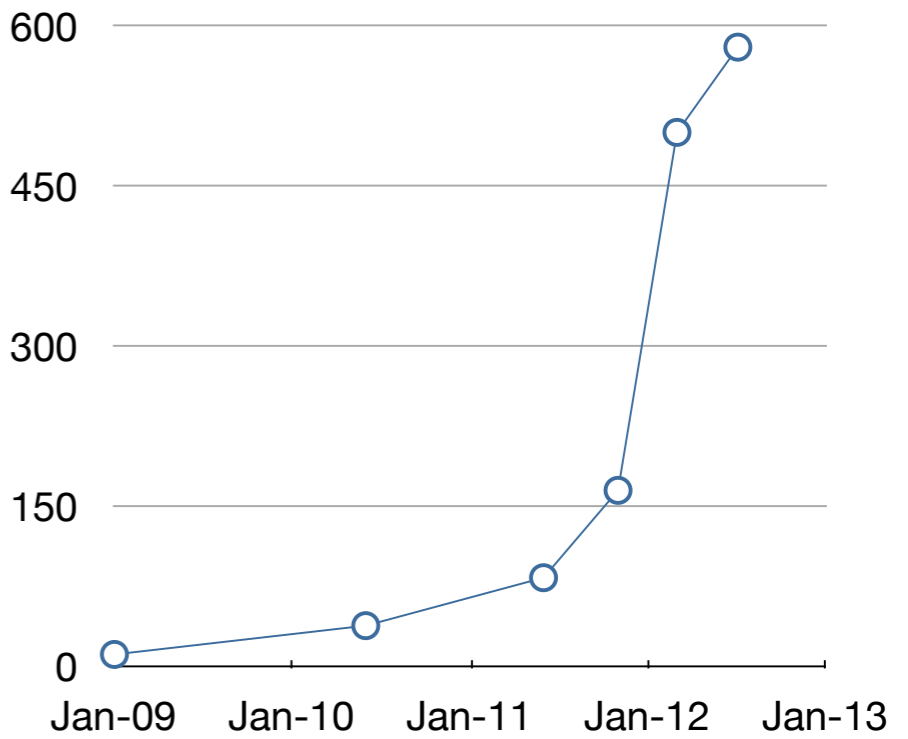
Number of Datasets Combined

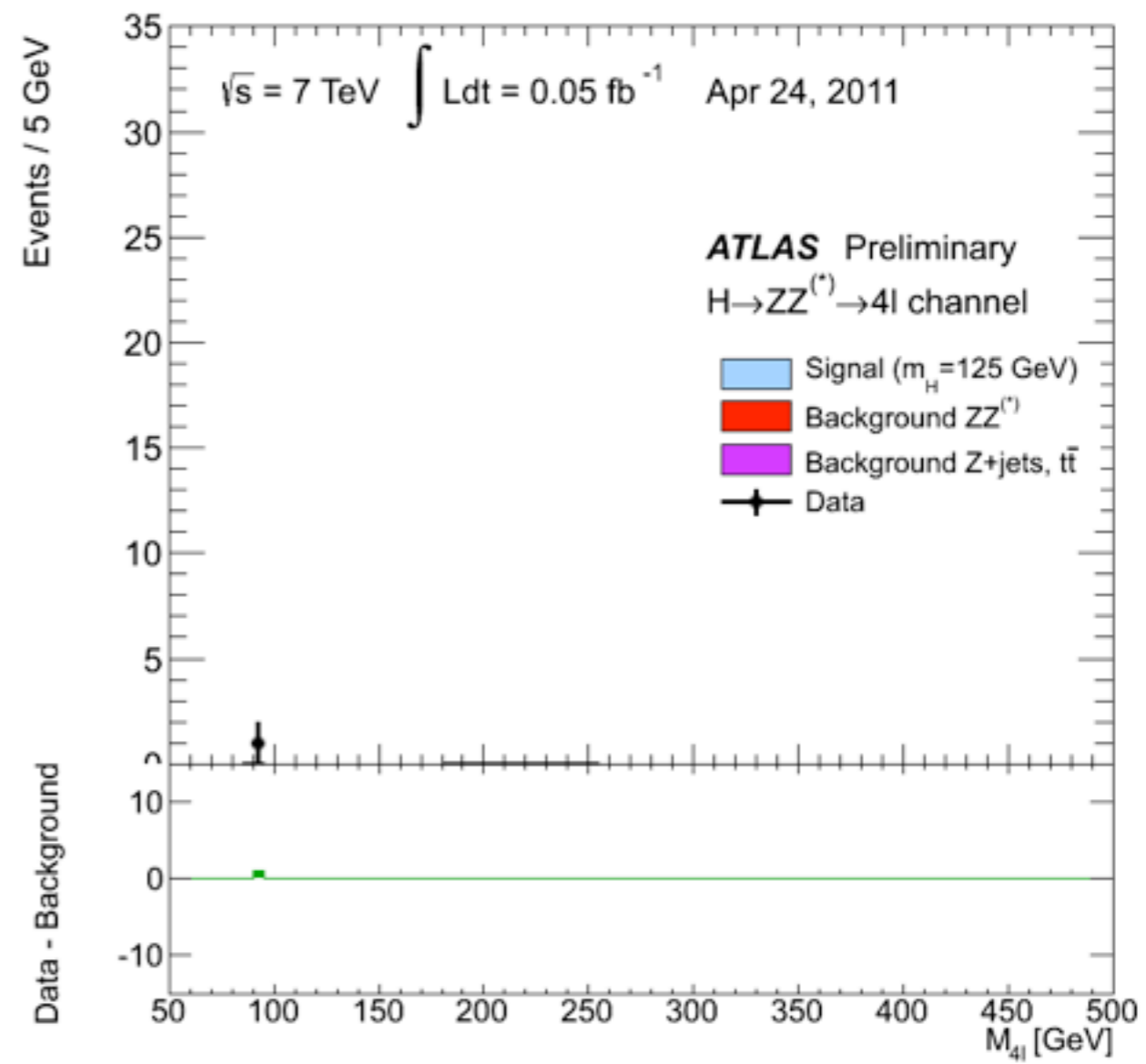
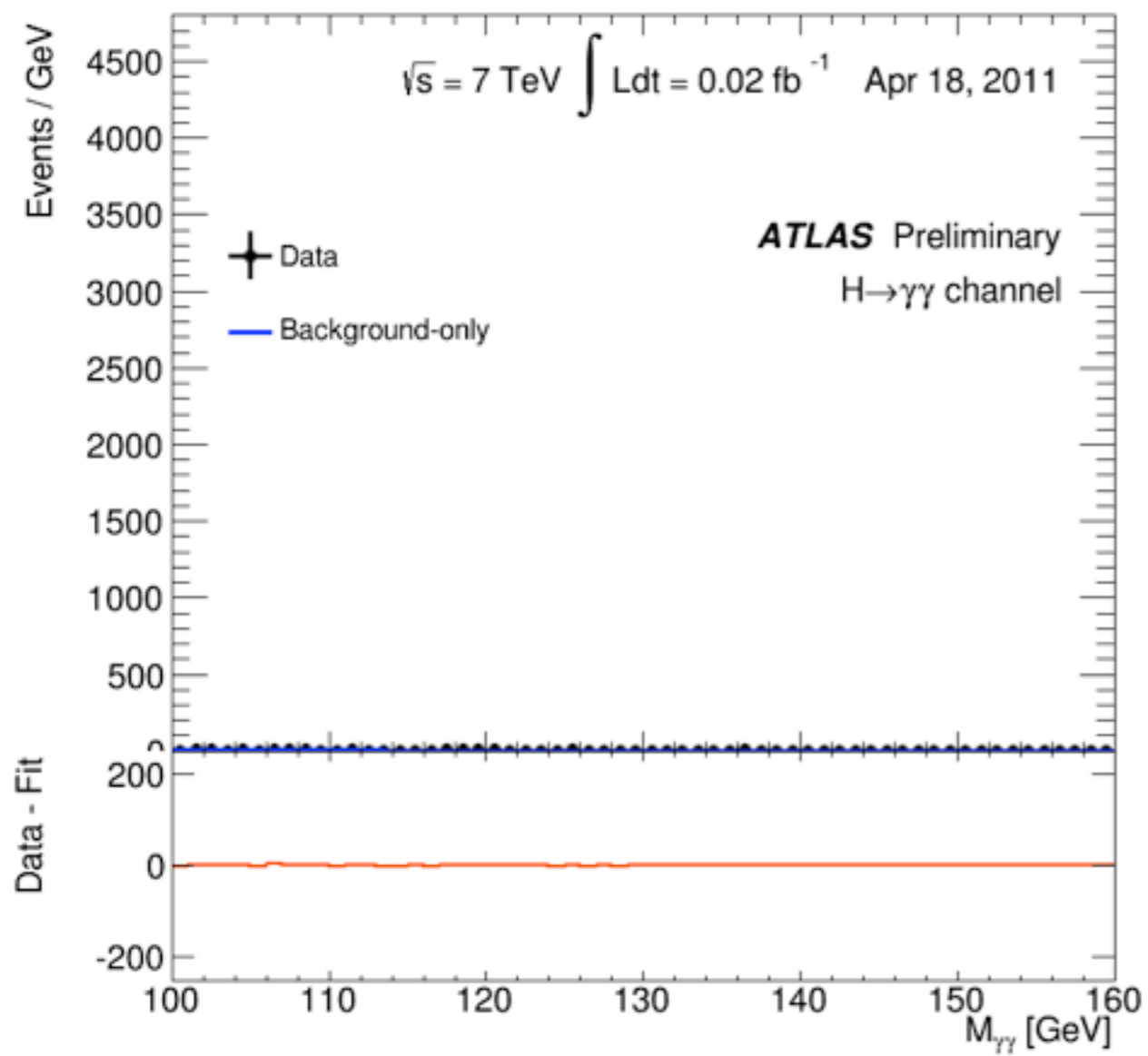


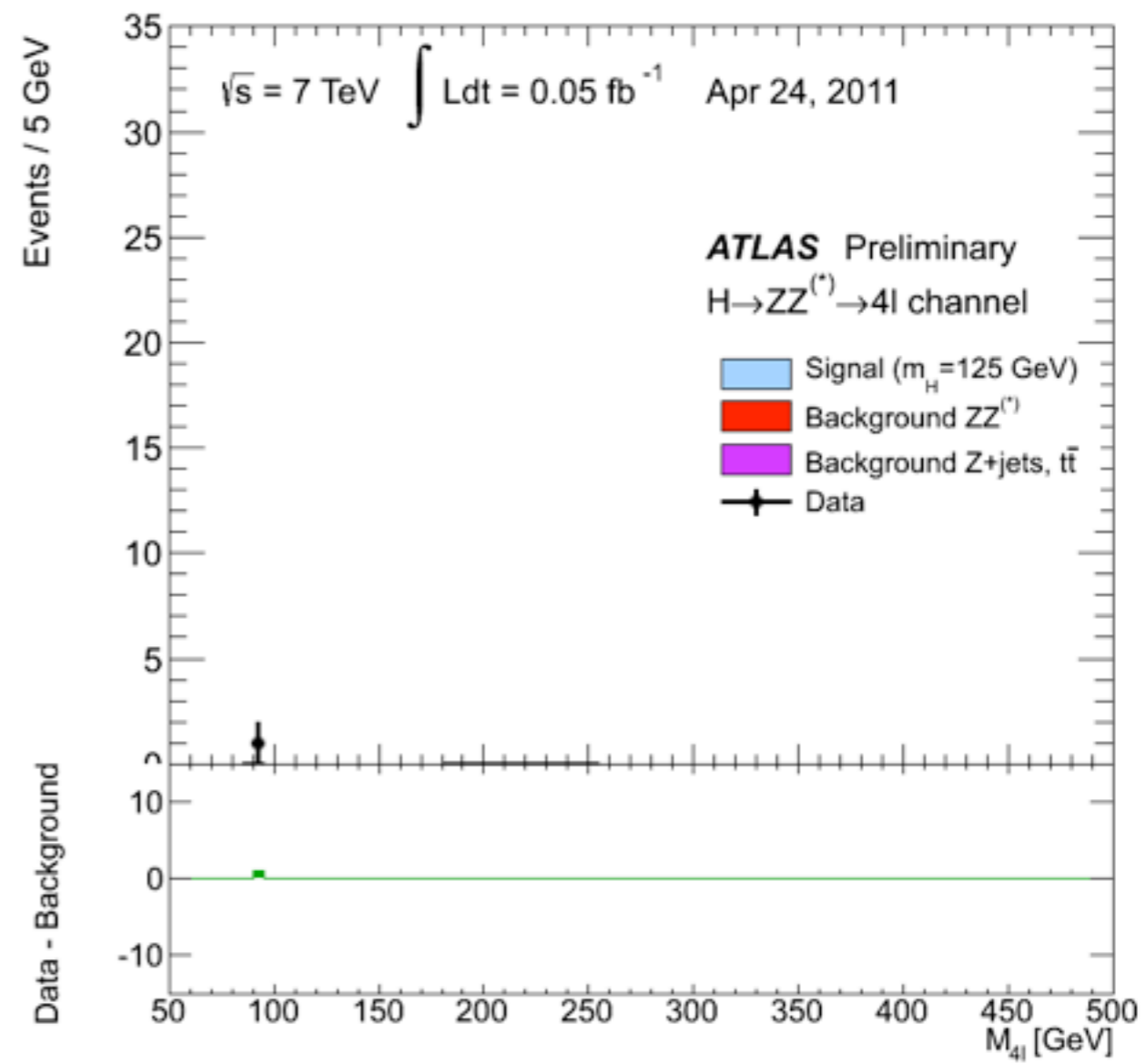
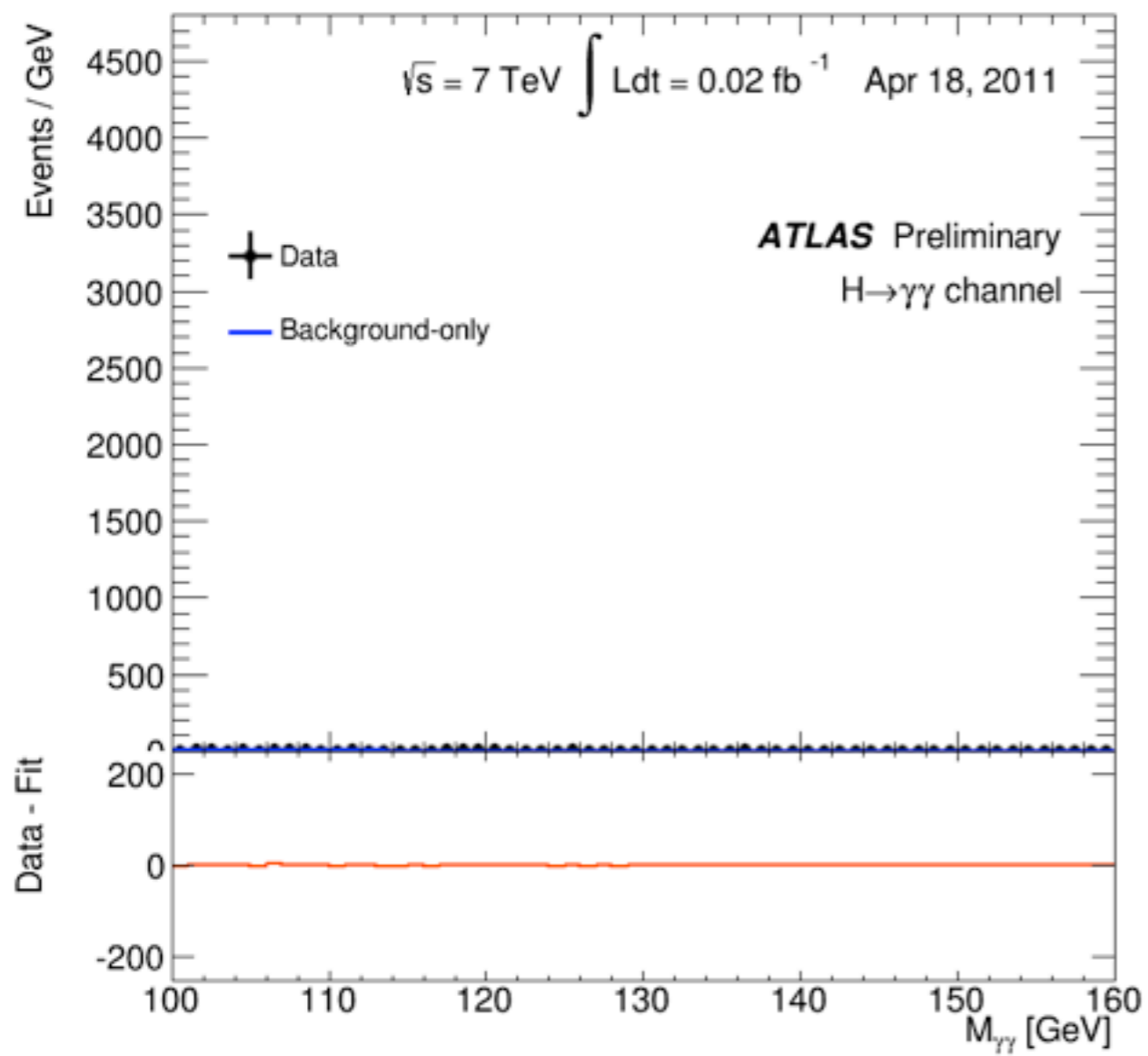
Number of Model Components



Number of Parameters in Likelihood



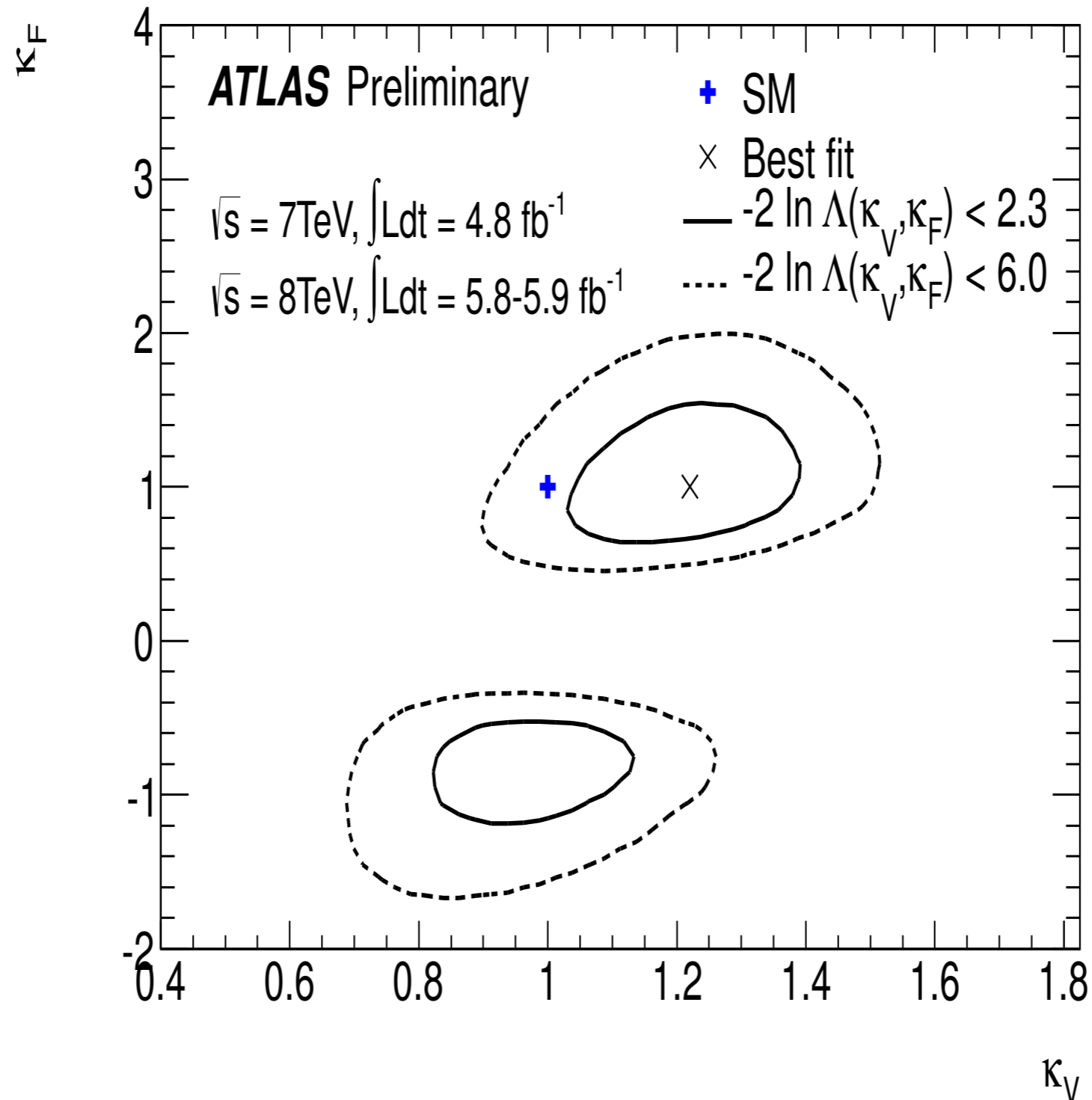






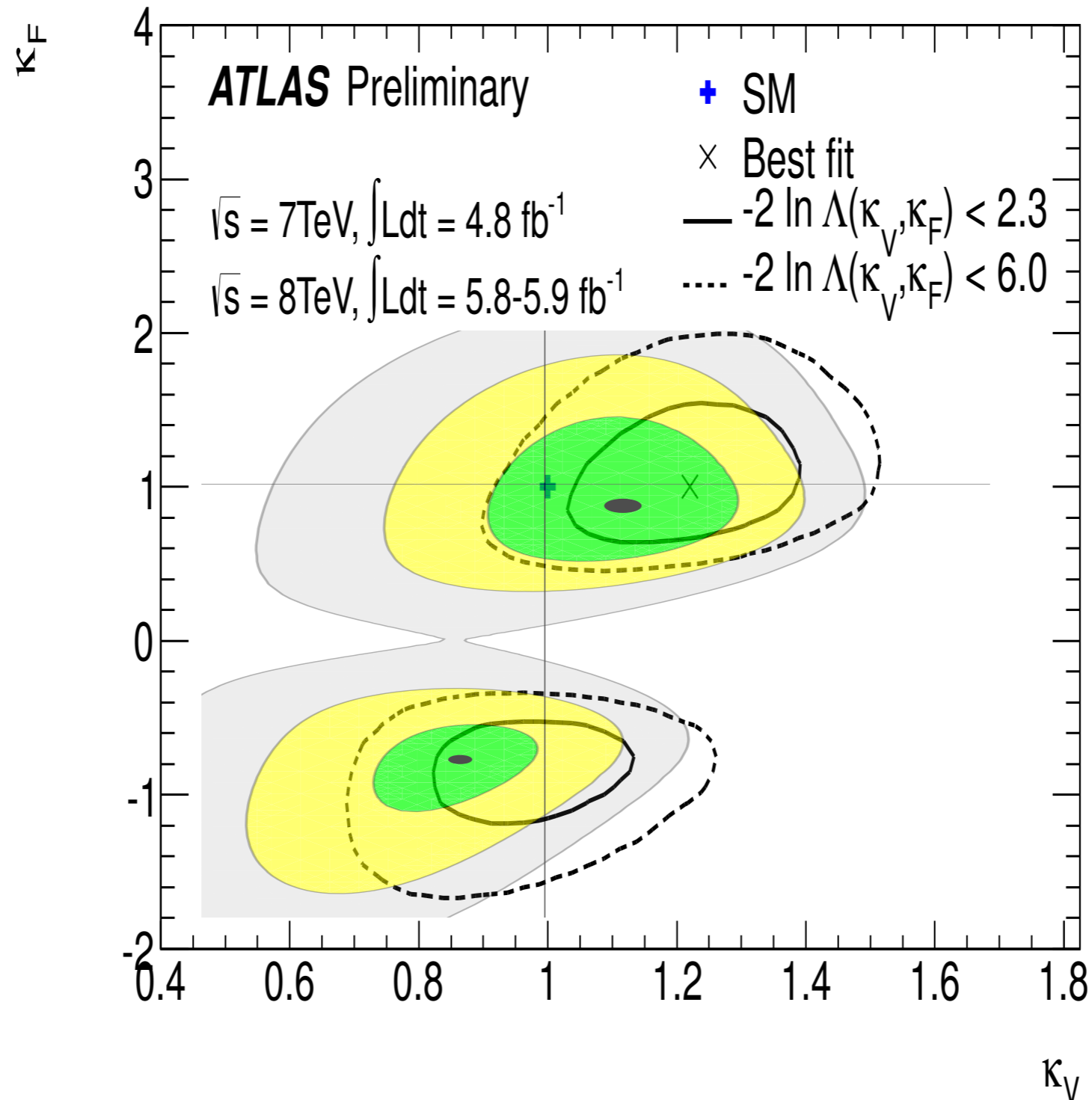
LIKELIHOODS ON HEPDATA

Not possible for others to reproduce results from paper.



LIKELIHOODS ON HEPDATA

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MY FIRST DATA EXAMPLE

Information **References (82)** Citations (106) Files Plots HepData

Natural priors, CMSSM fits and LHC weather forecasts

Ben C. Allanach (Cambridge U., DAMTP), Kyle Cranmer (New York U.), Christopher G. Lester (Cambridge U.), Arne M. Weber (Munich, Max Planck Inst.)

May 2007 - 26 pages

JHEP 0708 (2007) 023
DOI: [10.1088/1126-6708/2007/08/023](https://doi.org/10.1088/1126-6708/2007/08/023)
DAMTP-2007-18, CAVENDISH-HEP-2007-03, MPP-2007-36
e-Print: [arXiv:0705.0487](https://arxiv.org/abs/0705.0487) [hep-ph] | [PDF](#)

Harvard Dataverse Network > CFA Dataverses >

POWERED BY THE **Dataverse Network** PROJECT v. 3.8.2

Kyle Cranmer Dataverse

REPLICATION DATA FOR: "NATURAL PRIORS, CMSSM FITS AND LHC WEATHER FORECASTS"
hdl:1902.1/21804UNF:5:bwv2MoOAT1tX0yfgjF9hJQ==
Version: 1 - Released: Fri Jul 12 21:53:48 EDT 2013

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CATALOGING INFORMATION Data & Analysis Comments (1) Versions

Data Citation

! If you use these data, please add the following citation to your scholarly references. [Why cite?](#)

Cranmer, Kyle; Allanach, Ben; Lester, Christopher; Weber, Arne, "Replication data for: "Natural Priors, CMSSM Fits and LHC Weather Forecasts"", <http://hdl.handle.net/1902.1/21804UNF:5:bwv2MoOAT1tX0yfgjF9hJQ==> V1 [Version]

Citation Format [Print](#)

Original Publication

! Results found in this publication can be replicated using these data.

"Natural Priors, CMSSM Fits and LHC Weather Forecasts", JHEP 0708:023,2007. DOI 10.1088/1126-6708/2007/08/023
ID: DOI:10.1088/1126-6708/2007/08/023
[Link](#)

Information Citations (0) Files

Replication data for: "Natural Priors, CMSSM Fits and LHC Weather Forecasts"

Cranmer, Kyle (New York U.); Allanach, Ben (Cambridge U., DAMTP); Lester, Christopher (Cambridge U.); Weber, Arne (Munich, Max Planck Inst.)

Cite as: Cranmer, Kyle; Allanach, Ben; Lester, Christopher; Weber, Arne, "Replication data for: "Natural Priors, CMSSM Fits and LHC Weather Forecasts"", <http://hdl.handle.net/1902.1/21804>

LIKELIHOODS ON HEPDATA

Information

References (121)

Citations (128)

Files

Plots

HepData

Measurements of Higgs boson production and couplings in diboson final states with the ATLAS detector at the LHC

ATLAS Collaboration (Georges Aad (Freiburg U.) *et al.*) [Show all 2923 authors](#)

Jul 4, 2013 - 32 pages

Phys.Lett. B726 (2013) 88-119
(2013)

DOI: [10.1016/j.physletb.2013.08.010](https://doi.org/10.1016/j.physletb.2013.08.010)

CERN-PH-EP-2013-103

e-Print: [arXiv:1307.1427](https://arxiv.org/abs/1307.1427) [hep-ex] | [PDF](#)

Experiment: [CERN-LHC-ATLAS](#)



LIKELIHOODS ON HEPDATA

Information **References (121)** Citations (128) Files Plots **HepData**

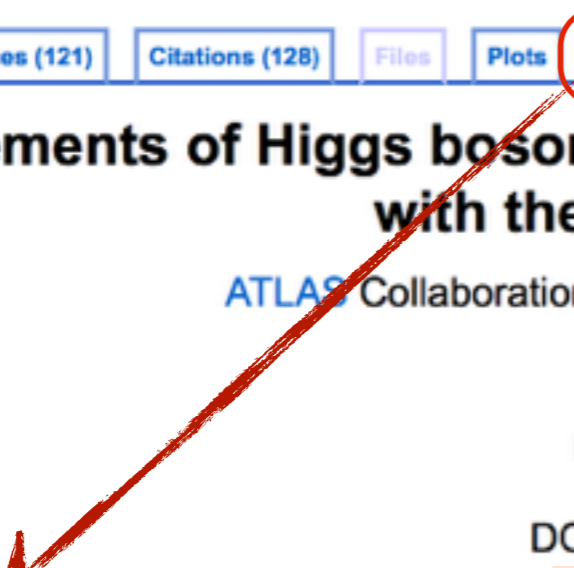
Measurements of Higgs boson production and couplings in diboson final states with the ATLAS detector at the LHC

ATLAS Collaboration (Georges Aad (Freiburg U.) *et al.*) [Show all 2923 authors](#)

Jul 4, 2013 - 32 pages

Phys.Lett. B726 (2013) 88-119
(2013)

DOI: [10.1016/j.physletb.2013.08.010](https://doi.org/10.1016/j.physletb.2013.08.010)



Note, data record itself has 3 citation

Information Citations (3) Files

Data from Figure 7 from: Measurements of Higgs boson production and couplings in diboson final states with the ATLAS detector at the LHC

ATLAS Collaboration (Aad, Georges (Freiburg U.) [...]) [Show all 2923 authors](#)

Cite as: ATLAS Collaboration (2013) HepData, <http://doi.org/10.7484/INSPIREHEP.DATA.A78C.HK44>

Description: -2 log Likelihood for the $H \rightarrow \gamma\gamma$ channel in the $(\mu_{\text{ggF}+\text{ttH}} * B/\text{BSM}, \mu_{\text{VBF}+\text{VH}} * B/\text{BSM})$ plane for a Higgs boson mass $m_H = 125.5$ GeV.

LIKELIHOODS ON HEPDATA

Information References (121) Citations (128) Files Plots **HepData**

Measurements of Higgs boson production and couplings in diboson final states with the ATLAS detector at the LHC

ATLAS Collaboration (Georges Aad (Freiburg U.) *et al.*) [Show all 2923 authors](#)

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Phys.Lett. B726 (2013) 88-119
(2013)

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LIKELIHOODS ON HEPDATA

Information References (121) Citations (128) Files Plots **HepData**

Measurements of Higgs boson production and couplings in diboson final states with the ATLAS detector at the LHC

ATLAS Collaboration (Georges Aad (Freiburg U.) *et al.*) [Show all 2923 authors](#)

Jul 4, 2013 - 32 pages

Phys.Lett. B726 (2013) 88-119 (2013)

DOI: [10.1016/j.physletb.2013.08.010](https://doi.org/10.1016/j.physletb.2013.08.010)

Note, data record itself has 3 citation

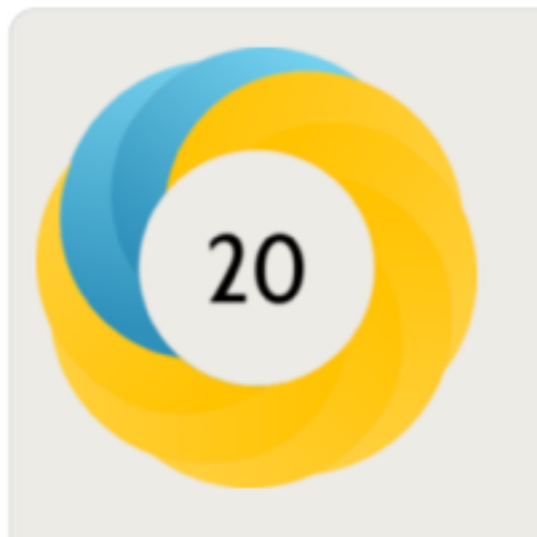
Information Citations (3) Files

Data from Figure 7 from: Measurements of Higgs boson production and couplings in diboson final states with the ATLAS detector at the LHC

ATLAS Collaboration (Aad, Georges (Freiburg U.) [...]) [Show all 2923 authors](#)

Cite as: ATLAS Collaboration (2013) HepData, <http://doi.org/10.7484/INSPIREHEP.DATA.A78C.HK44>

Description: -2 log Likelihood for the $H \rightarrow \gamma\gamma$ channel in the $(\mu_{ggF+ttH} * B/BSM, \mu_{VBF+VH} * B/BSM)$ plane for a Higgs boson mass $m_H = 125.5$ GeV.



 **figshare** 
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The Higgs Boson data is definitely the jewel in the #DataCite crown. Hopefully the first of many!

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THE APEX DATA

This is fabulous -- to me it feels like a break-through. We will be sure to cite the data -- I very much hope we figure out how to use it properly. The invariant mass distribution is interesting in itself.

We are very grateful for your help with this and will keep in touch.

Cheers, Richard [Lockhart]

Information Citations (8) Files

Data from Figure 3 from: Search for a New Gauge Boson in Electron-Nucleus Fixed-Target Scattering by the APEX Experiment

APEX Collaboration (Abrahamyan, S. (Yerevan Phys. Inst.) [...]) [Show all 66 authors](#)

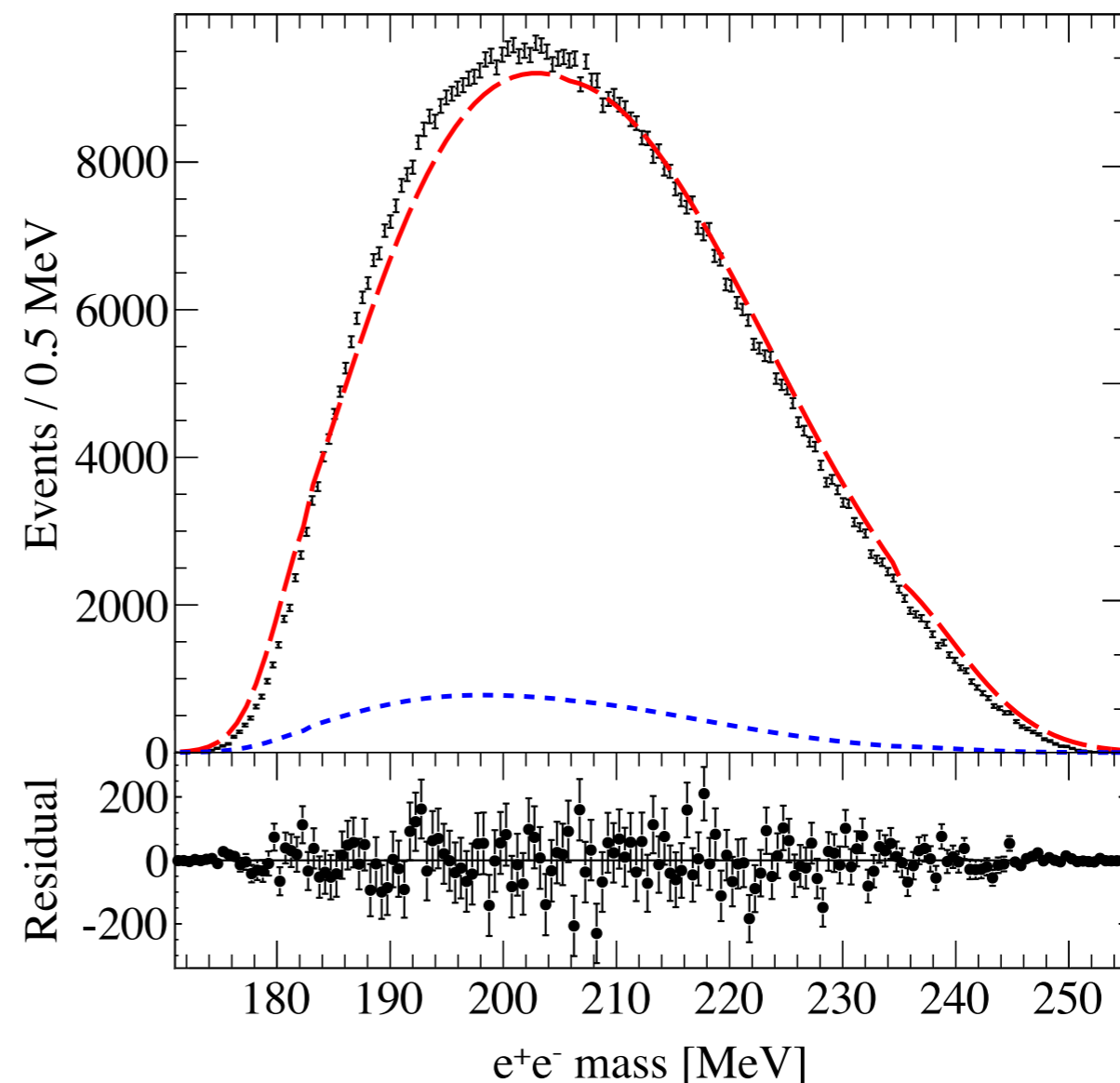
Cite as: APEX collaboration (2011) INSPIRE,
<http://doi.org/10.7484/INSPIREHEP.DATA.PH21.L5RG>

Description: The unbinned invariant mass spectrum of e^+e^- pair events in the final event sample collected by APEX. The data correspond to Figure 3 of the paper.

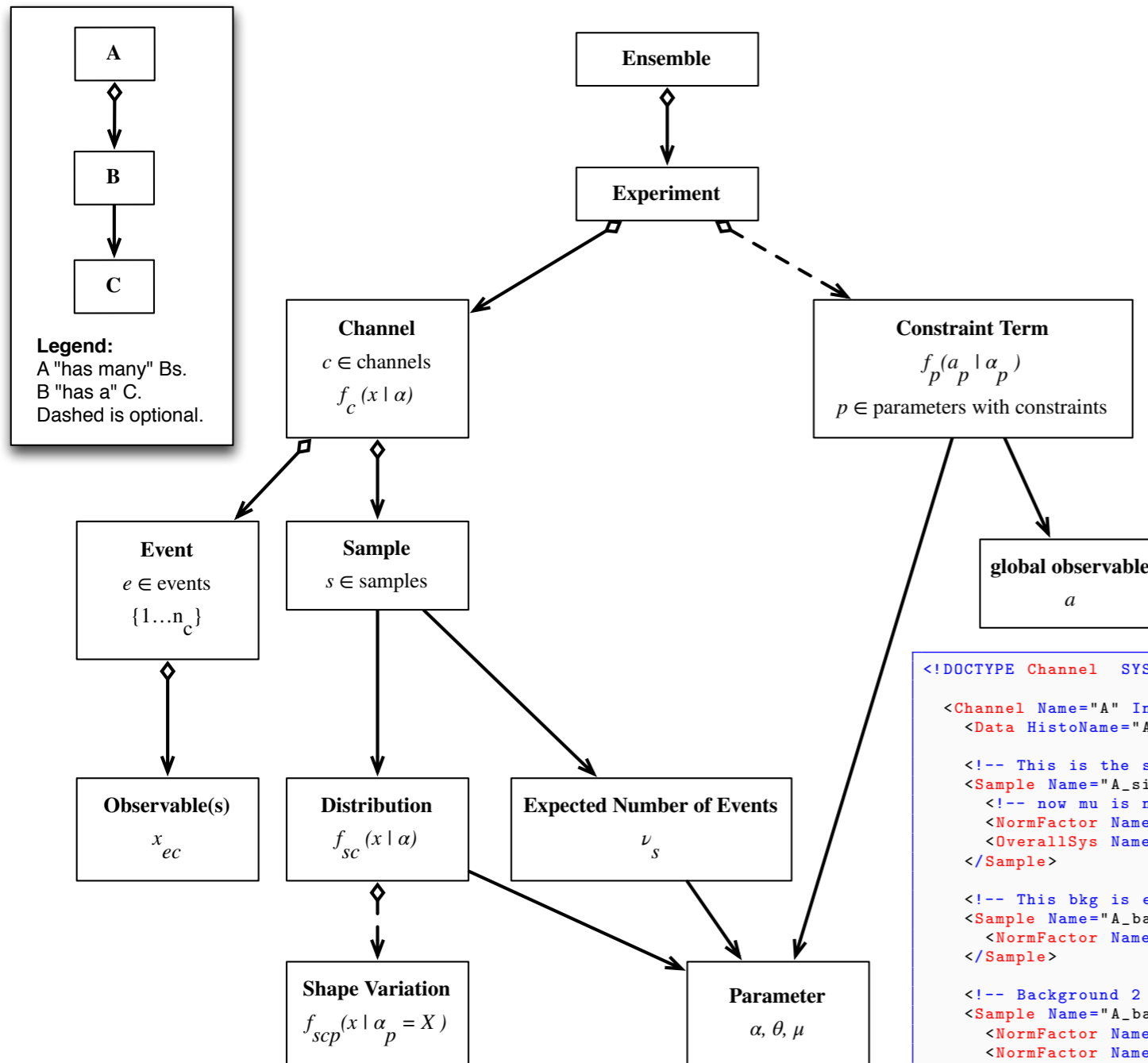
Note: * Temporary entry *

This dataset complements the following publication:
[Search for a New Gauge Boson in Electron-Nucleus Fixed-Target Scattering by the APEX Experiment](#)

Record created 2013-10-02, last modified 2013-10-02



XML FOR LIKELIHOODS



Provides machine-readable semantics for histograms used to build likelihood functions

```
<!DOCTYPE Channel SYSTEM 'HistFactorySchema.dtd'>
<Channel Name="A" InputFile="./data/ABCD.root" >
  <Data HistoName="A_data" HistoPath="" />
  <!-- This is the signal (eg. mu)-->
  <Sample Name="A_signal" HistoPath="" HistoName="unit_histogram" >
    <!-- now mu is number of events-->
    <NormFactor Name="mu" Val="1" Low="0" High="200" />
    <OverallSys Name="syst1" High="1.01" Low="0.99" />
  </Sample>
  <!-- This bkg is estimated from MC (eg. mu_A^K) -->
  <Sample Name="A_backgroundMC" HistoPath="" NormalizeByTheory="True" HistoName="unit_histogram" >
    <NormFactor Name="mu_K_A" Val="100" Low="0" High="200" />
  </Sample>
  <!-- Background 2 is completely Data-Driven -->
  <Sample Name="A_backgroundDD" HistoPath="" NormalizeByTheory="False" HistoName="unit_histogram" >
    <NormFactor Name="mu_D_U" Val="100" Low="24500" High="26000" />
    <NormFactor Name="etaB" Val="1" Low="0." High="0.02" Const="False" />
    <NormFactor Name="etaC" Val="1" Low="0." High="0.3" Const="False" />
    <!-- NormFactor and ShapeFactor same for a 1-bin histogram. But we can name NormFactor-->
  </Sample>
</Channel>
```

$$\mathbf{f}_{\text{tot}}(\mathcal{D}_{\text{sim}}, \mathcal{G} | \alpha) = \prod_{c \in \text{channels}} \left[\text{Pois}(n_c | \nu_c(\alpha)) \prod_{e=1}^{n_c} f_c(x_{ce} | \alpha) \right] \cdot \prod_{p \in \mathcal{S}} f_p(a_p | \alpha_p)$$

A RECENT EXAMPLE

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Beta version: This is a public beta of GitHub integration in Zenodo. Over the coming weeks we will be adding some additional features. Be sure to let us know by tweeting us @zenodo_org if you have ideas for what we should improve.

Repository	Status
cranmer/flask-d3-hello-world	OFF
cranmer/KEYS-historical	ON

zenodo

07 March 2014

decouple software associated to arXiv:1401.0080

Cranmer, Kyle ; Kreiss, Sven

This repository contains the software implementation for our paper **A Novel Approach to Higgs Coupling Measurements** (Cranmer, Kreiss, Lopez-Val, Plehn), arXiv:1401.0080 [hep-ph]. It contains tools to apply the discussed methods to new models and contains a Makefile to recreate the plots in the paper.

A demo for the recoupling stage where the effective likelihood and template parametrization are readily provided is at decoupledDemo.

Name	Date	Size
decouple-v1.2.5.zip	08 Mar 2014	256.6 kB

Publication date: 07 March 2014
DOI: 10.5281/zenodo.8475

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A Novel Approach to Higgs Coupling Measurements - Cranmer, Kyle et al. arXiv:1401.0080 [hep-ph]

Information References Citations Files Plots HepData

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Publication date: 07 March 2014
DOI: 10.5281/zenodo.8475

Related publications and datasets:
Supplement to: arXiv:1401.0080

Mathematica → figshare → INSPIRE


Supplementary Material for "A Novel Approach to Higgs Coupling Measurements"

(2013) figshare.



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Kyle Cranmer

 <http://orcid.org/0000-0002-5769-7094>

▼ Works
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Data from Figure 7 from: Measurements of Higgs boson production and couplings in diboson final states with the ATLAS detector at the LHC 2013-09



Data from Figure 7 from: Measurements of Higgs boson production and couplings in diboson final states with the ATLAS detector at the LHC 2013-09



Data from Figure 7 from: Measurements of Higgs boson production and couplings in diboson final states with the ATLAS detector at the LHC 2013-09



Replication data for: "Natural Priors, CMSSM Fits and LHC Weather Forecasts" 2013-07



Observation of a new particle in the search for the Standard Model Higgs boson with the ATLAS detector at the LHC: Physics Letters B 2012





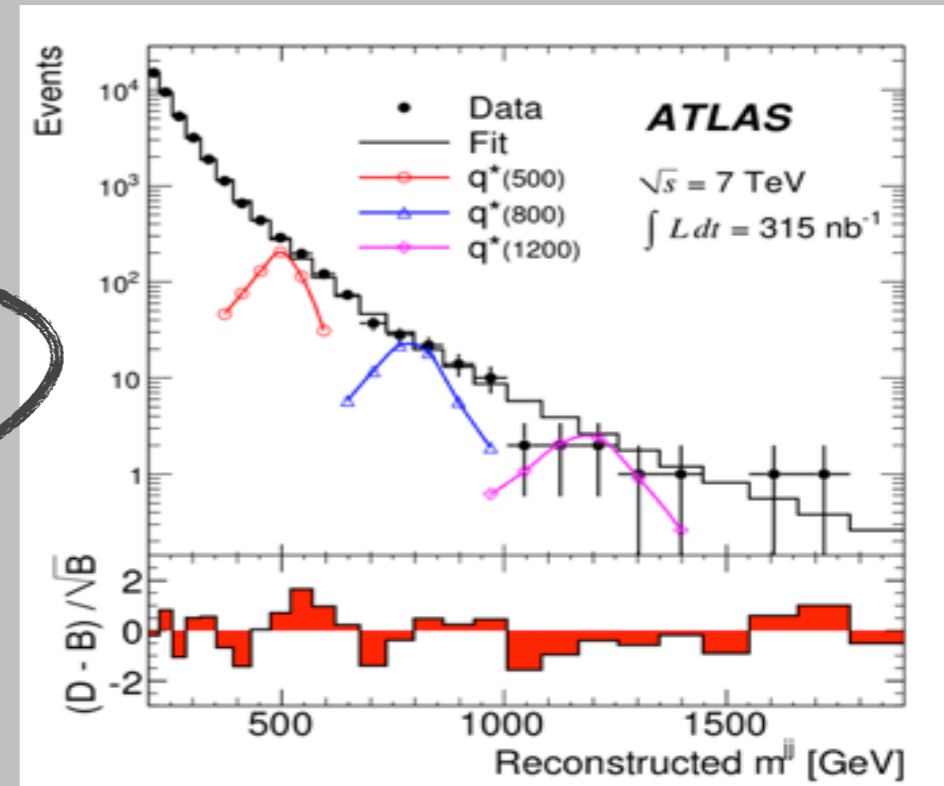
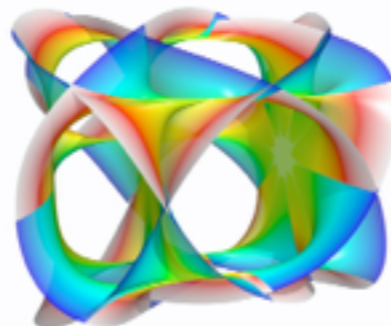
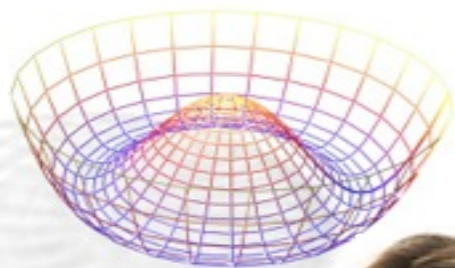
THEORY

SERVICE

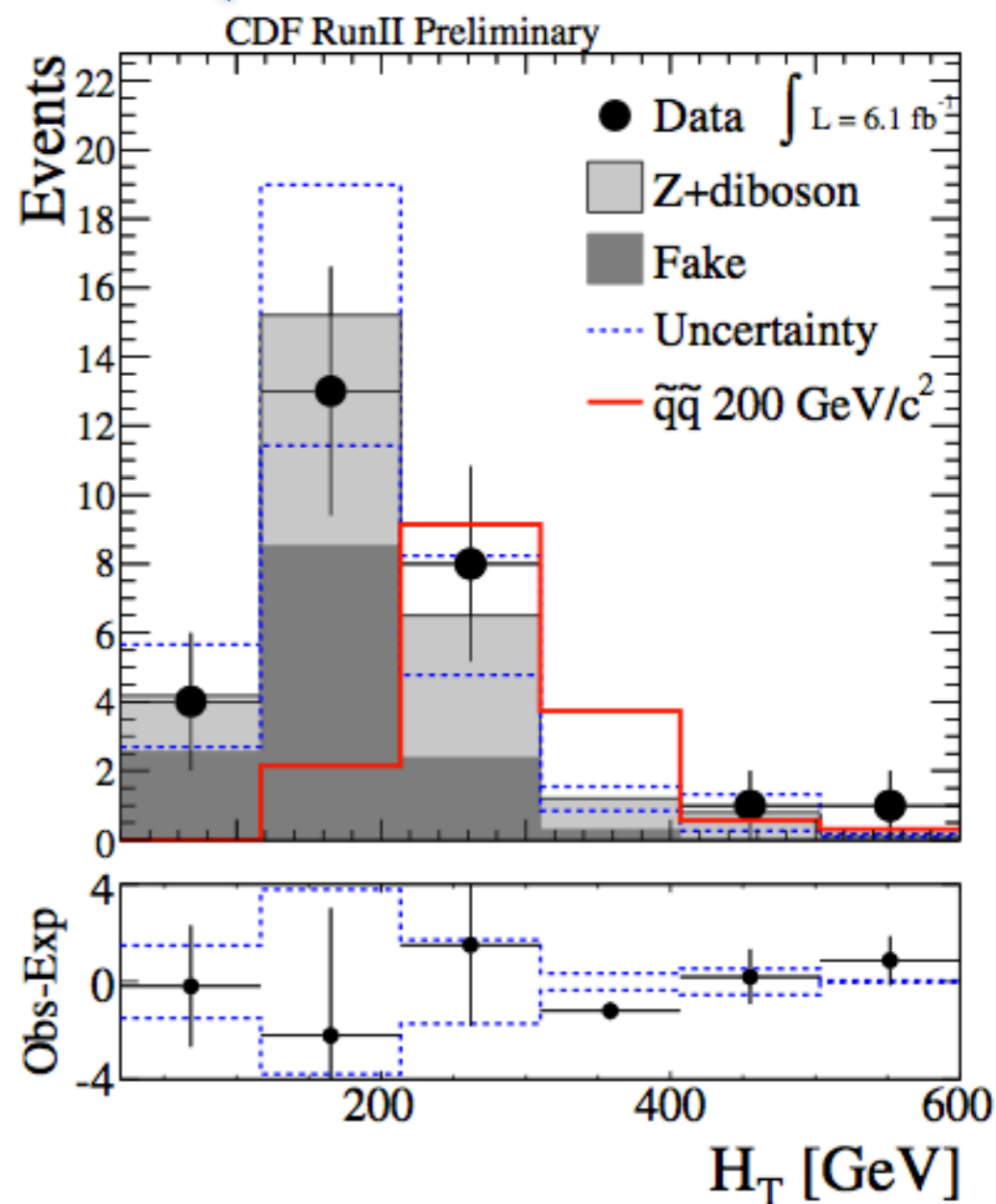
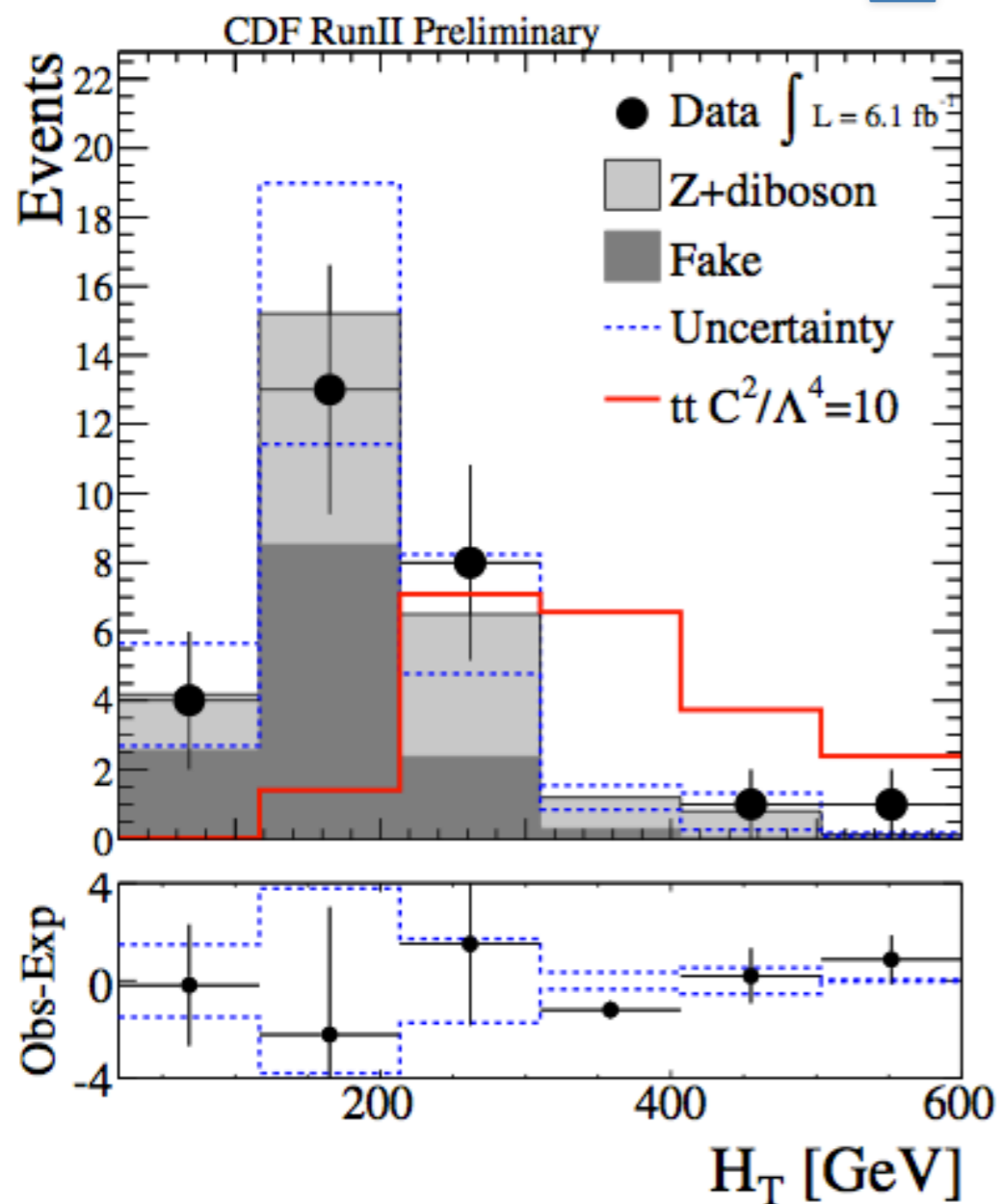
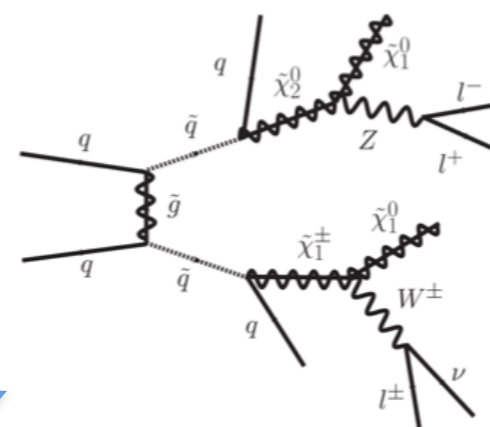
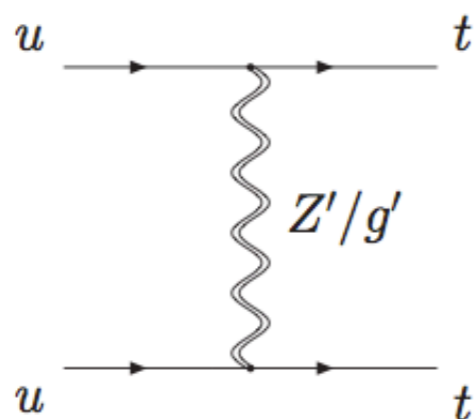
$$\begin{aligned}
 \mathcal{L}_{SM} = & \underbrace{\frac{1}{4} \mathbf{W}_{\mu\nu} \cdot \mathbf{W}^{\mu\nu} - \frac{1}{4} B_{\mu\nu} B^{\mu\nu} - \frac{1}{4} G_{\mu\nu}^a G_a^{\mu\nu}}_{\text{kinetic energies and self-interactions of the gauge bosons}} \\
 & + \underbrace{\bar{L} \gamma^\mu (i \partial_\mu - \frac{1}{2} g \boldsymbol{\tau} \cdot \mathbf{W}_\mu - \frac{1}{2} g' Y B_\mu) L + \bar{R} \gamma^\mu (i \partial_\mu - \frac{1}{2} g' Y B_\mu) R}_{\text{kinetic energies and electroweak interactions of fermions}} \\
 & + \underbrace{\frac{1}{2} |(i \partial_\mu - \frac{1}{2} g \boldsymbol{\tau} \cdot \mathbf{W}_\mu - \frac{1}{2} g' Y B_\mu) \phi|^2 - V(\phi)}_{\text{W}^\pm, \text{Z}, \gamma, \text{ and Higgs masses and couplings}} \\
 & + \underbrace{g'' (\bar{q} \gamma^\mu T_a q) G_\mu^a}_{\text{interactions between quarks and gluons}} + \underbrace{(G_1 \bar{L} \phi R + G_2 \bar{L} \phi_c R + h.c.)}_{\text{fermion masses and couplings to Higgs}}
 \end{aligned}$$

Q

A



RECASTING



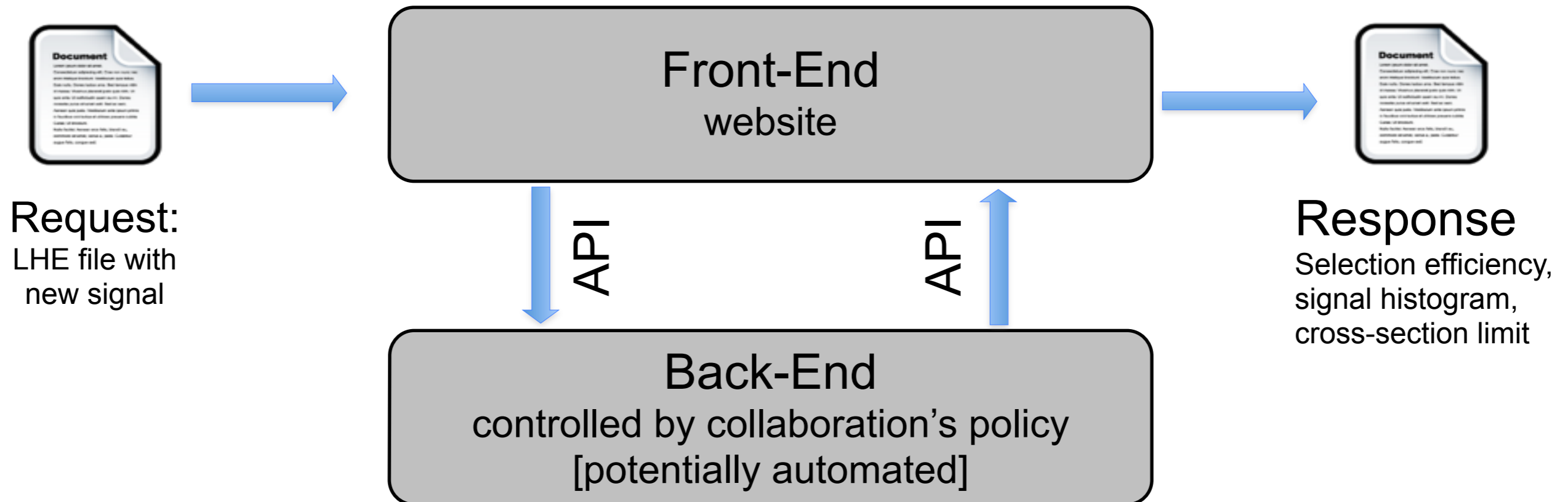


RECAST is a framework for recasting that aims to collect, standardize, and facilitate the processing of recast requests from the community.

- ▶ cuts don't change: re-use background estimates and observation from original analysis
- ▶ what is needed is to archive the analysis cuts & provide a pipeline for new signal
- ▶ data is kept private, still goes through necessary approval process as determined by collaboration, original paper receives citation & recognition (doi's tracked by INSPIRE)

RECAST front-end is a website that collects and organizes the Requests and Responses

- ▶ standardizes request & response format, API allows for process to be automated,
- ▶ back-end implementation is up to collaboration





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Analysis	Collaboration	Subscribers	Requests	Active	Completed	Actions
Search for Diphoton Events with Large Missing Transverse Momentum in 1 fb⁻¹ of 7 TeV Proton-Proton Collision Data with the ATLAS Detector	Atlas	1	1	0	1	view edit un-subscribe add request
Search for New Phenomena in Events with Three or more Charged Leptons	Atlas	0	0	0	0	view edit subscribe add request
Multileptonic SUSY searches	CMS	2	1	1	0	view un-subscribe add request
Search for Anomalous Production of Multilepton Events and R-Parity-Violating Supersymmetry in $\sqrt{s} = 7$ TeV	CMS	0	0	0	0	view subscribe add request
Search for a Vector-like Quark with Charge 2/3 in t + Z Events from pp Collisions at $\sqrt{s} = 7$ TeV	CMS	0	0	0	0	view subscribe add request




Invariant Mass Distribution of Jet Pairs Produced in Association with a W boson in ppbar Collisions at sqrt(s) = 1.96 TeV | RECAST [beta]

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Title:
Invariant Mass Distribution of Jet Pairs Produced in Association with a W boson in ppbar Collisions at sqrt(s) = 1.96 TeV

Collaboration: CDF

E-Print: <http://arxiv.org/pdf/1104.0699>

Journal: Phys.Rev.Lett.106:171801,2011

inSpire URL: <http://inspirehep.net/record/894999>

DOI: 10.1103/PhysRevLett.106.171801

Description:
We report a study of the invariant mass distribution of jet pairs produced in association with a W boson using data collected with the CDF detector which correspond to an integrated luminosity of 4.3 fb^{-1} . The observed distribution has an excess in the 120-160 GeV/c² mass range which is not described by current theoretical predictions within the statistical and systematic uncertainties. In this letter we report studies of the properties of this excess.

A CDF Example



RECAST [beta]

Home Analyses Catalog Requests

Home » Analyses Catalog » Invariant Mass Distribution of Jet Pairs Produced in Association with a W boson in ppbar Collisions at sqrt(s) = 1.96 TeV » List Requests » 1202.0010

View **Contact Requester**

This request is not active, thus it is not accepting requests. Contact the requester for more information.

Request ID: 1202.0010

Analysis: Invariant Mass Distribution of Jet Pairs Produced in Association with a W boson in ppbar Collisions at sqrt(s) = 1.96 TeV

Status: Incomplete

Requester: iyavin

Recast Audience: all

Model Name: Higgsophilic Z'

Selected Subscriber(s):

Request Description and Potential

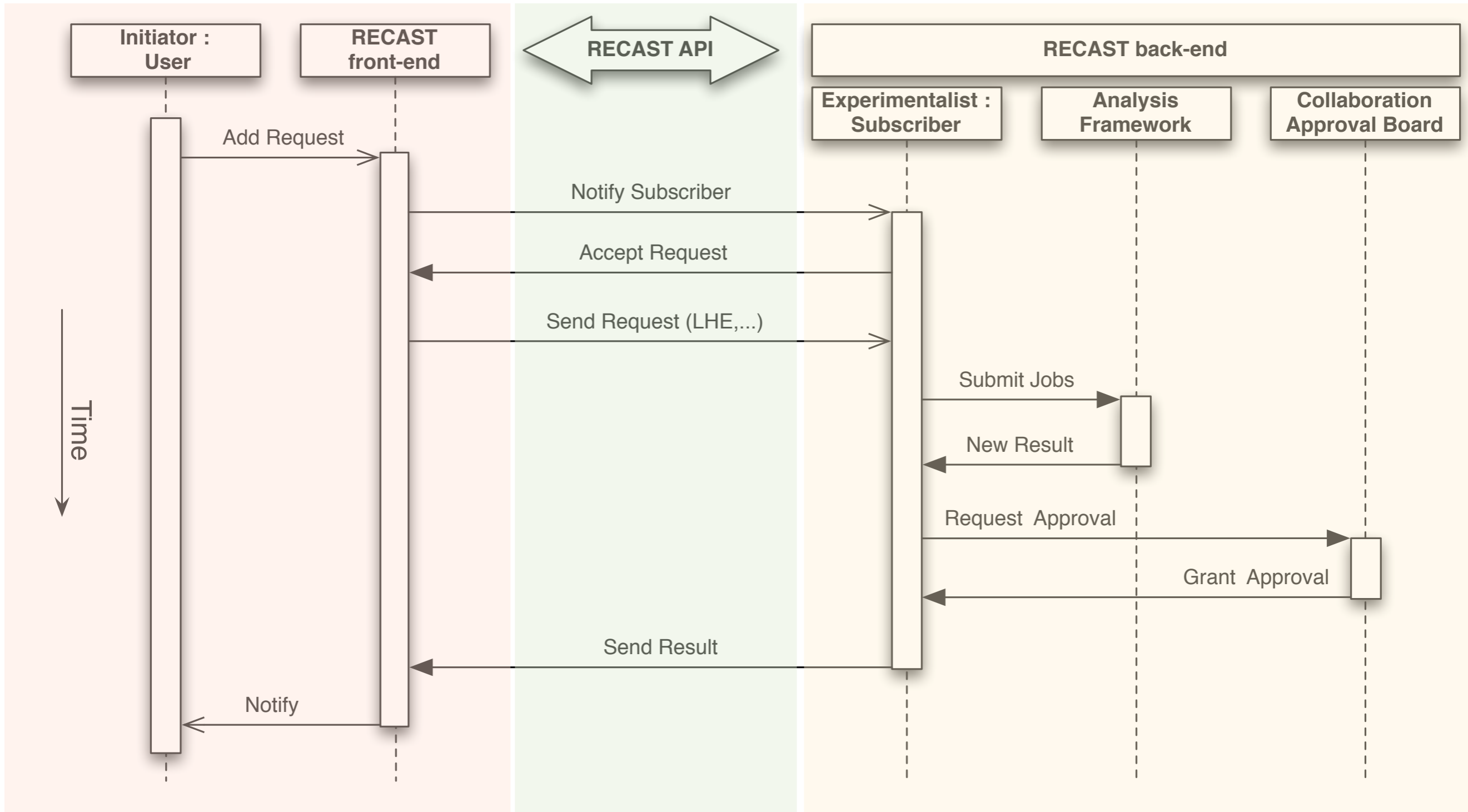
Reason for request: The Higgsophilic Z' of Fan et al. (<http://arxiv.org/pdf/1106.1682v2.pdf>) was constructed to explain the anomalous dijet resonance seen in W+jet production by the CDF collaboration. Unlike most other models constructed to explain the anomaly, this model uses an s-channel resonance production, which results in fairly different kinematical characteristics for the events. The model considered used a resonance produced through the t-channel. It will be interesting to know how sensitive this same search was to the other possibility of an s-channel resonance with its distinct kinematics and whether it can really explain the observed excess.

Additional Information: The basic production mode is qqbar -> Z' -> W+h- (W-h+) with the charged Higgs (h+/-) decaying into quarks. The mass of the Z' is 270 GeV and that of the charged Higgs is 150 GeV. LHE files are available for Tevatron runs.

Request Parameter Points

Run Condition: **Tevatron - 1.96 TeV**
This run was at 1.96 TeV center of mass energy and includes 4.3 fb^-1 of data.

Non Defined



K.C., Itay Yavin [hep-ex/1010.2506], JHEP.

A beta versions of the front-end website and API have been developed thanks to support from the Perimeter Institute.



Documentation: http://recast.perimeterinstitute.ca/sites/default/files/PIRESTfulWebService_v1.1.pdf

```
cranmer@172-26-28-145:~$ curl http://recast.perimeterinstitute.ca/api/recast-analysis
```

```
-  
uid: c3afcb6c-ce2f-9104-ed00-6a5cfb02a401  
title: >  
  Invariant Mass Distribution of Jet Pairs Produced in  
  Association with a W boson in ppbar Collisions at sqrt(s) =  
  1.96 TeV  
number_of_requests: 1  
collaboration: CDF
```

Supports XML, JSON, and YAML

```
cranmer@172-26-28-145:~$ curl http://recast.perimeterinstitute.ca/api/recast-request/71003820-bfec-aae4-25fd-76c713993f50
```

```
---  
-
```

```
uid: 71003820-bfec-aae4-25fd-76c713993f50  
title: 1202.0010  
requestor: iyavin  
status: 0  
analysis-uid: c3afcb6c-ce2f-9104-ed00-6a5cfb02a401  
audience:  
subscribers:  
predefined-model: Higgsophilic Z'  
new-model-information:  
reason-for-request: >  
  The Higgsophilic Z' of Fan et al.  
  (http://arxiv.org/pdf/1106.1682v2.pdf) was constructed to  
  explain the anomalous dijet resonance seen in W+jet  
  production by the CDF collaboration. Unlike most other  
  models constructed to explain the anomaly, this model uses  
  an s-channel resonance production, which results in fairly  
  different kinematical characteristics for the events. The  
  model considered used a resonance produced through the  
  t-channel. It will be interesting to know how sensitive this  
  same search was to the other possibility of an s-channel  
  resonance with its distinct kinematics and whether it can  
  really explain the observed excess.  
additional-information: "The basic production mode is qqbar -> Z' -> W+h- (W-h+) with the charged Higgs (h+/-) decaying into  
quarks. The mass of the Z' is 270 GeV and that of the charged Higgs is 150 GeV. LHE files are available for Tevatron runs."  
model-type:  
parameter-points: [ ]
```