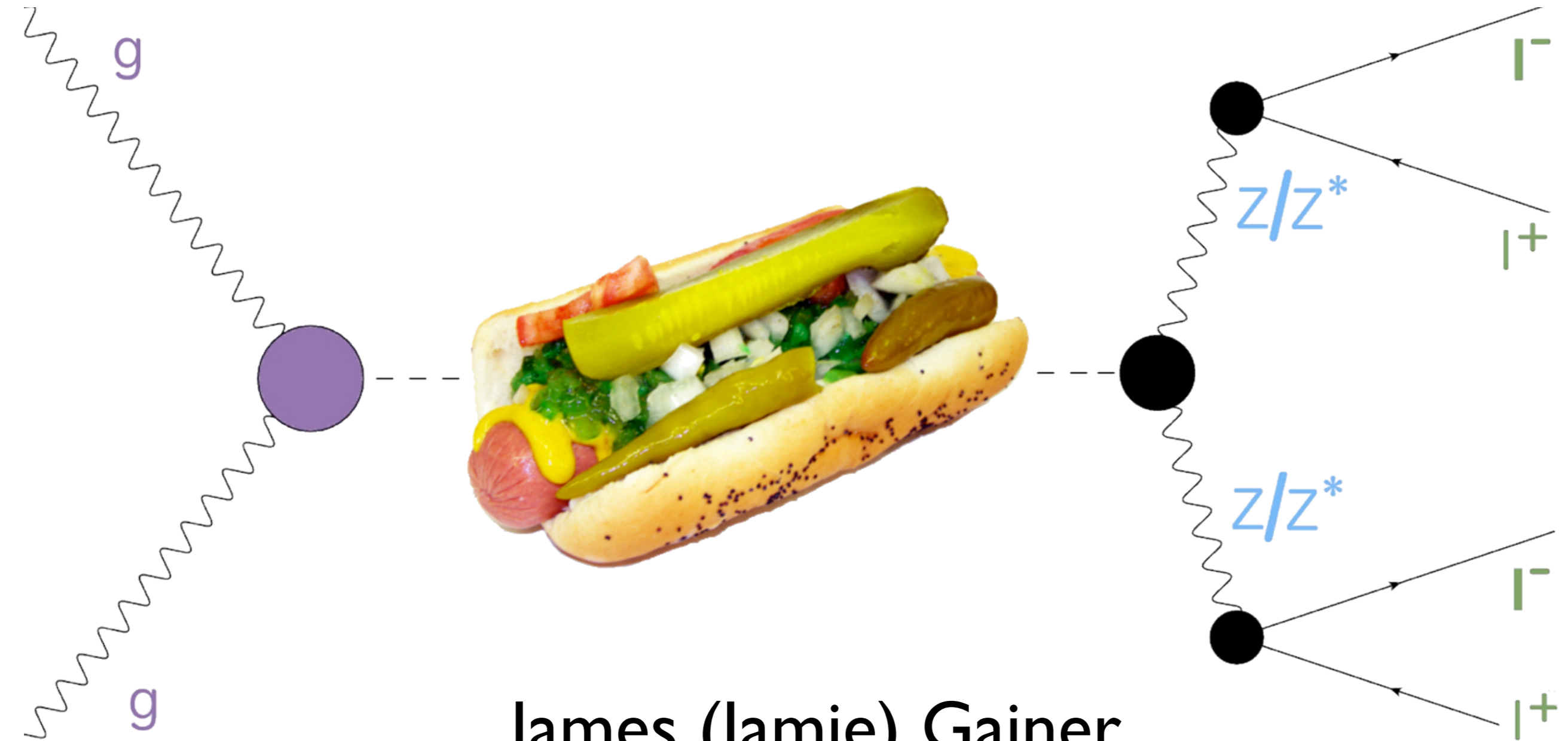


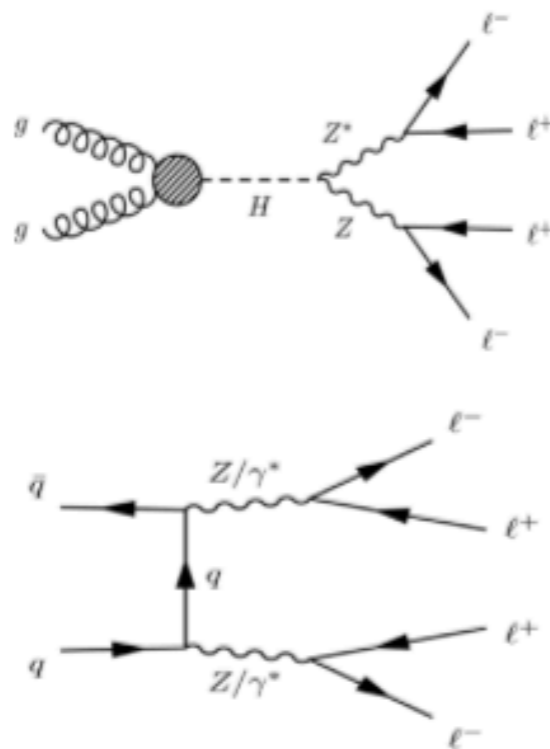
MEKD: A Tool for MEM Analyses in the Higgs Golden Channel



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University of Florida
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What is “MEKD”?

- **M**atrix **E**lement **K**inematic **D**iscriminant
- Tool for performing Matrix Element Method- based analyses in the Higgs Golden Channel- $h \rightarrow ZZ^* \rightarrow 4l$
- Based on code generated from publicly-available, automatized programs (MadGraph, CalcHEP also available)



Matrix Element Method (MEM) in the Higgs "golden" decay channel $H \rightarrow ZZ^* \rightarrow 4l$

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 CERN-PH-TH/2012-251

the advantages of using a multivariate analysis, such as the Matrix Element Method (MEM), in separating the Higgs signal from the irreducible Standard Model background. In that paper we discuss a number of issues that may arise in the use of the MEM and compare existing leading order MEM-based approaches and software.

Code for calculating Matrix Element Kinematic Discriminants in Higgs studies

At this web site we provide a code to calculate a kinematic discriminant KD based on the full leading order matrix elements, which would aid experimentalists and phenomenologists in their continuing studies of the "golden" Higgs channel. The code contains the most general parameterization of the couplings of a spin 0 resonance and can be used for spin and parity studies as well. Download and user instructions can be found in the section dedicated to the [Matrix Element Kinematic Discriminants code](#). The code is based on the **Madgraph 5** libraries.

<http://mekd.ihepa.ufl.edu>

[arXiv:1210.0896](https://arxiv.org/abs/1210.0896) [hep-ph]



MEKD People

- A team of experimentalists and theorists at Florida (+1 at CERN)
- Paul Avery, Dimitri Bourilkov, Mingshui Chen, Tongguang Cheng, Alexey Drozdetskiy, JSG, Andrey Korytov, Konstantin T. Matchev, Predrag Milenovic, Guenakh Mitselmakher, Myeonghun Park, Aurelijus Rinkevicius, Matthew Snowball
- Doubled my career number of co-authors (excluding workshop proceedings :)

Matrix Element Method (MEM)

- What is the Matrix Element Method?
- The use of the likelihood computed using all kinematic variables (essentially, the differential cross section) to determine significance
- Why is this useful?

More Information Helps

- Especially when distinguishing similar hypotheses...

More Information Helps

- For example, both of the following objects is a pizza.



More Information Helps

- But there are important differences!



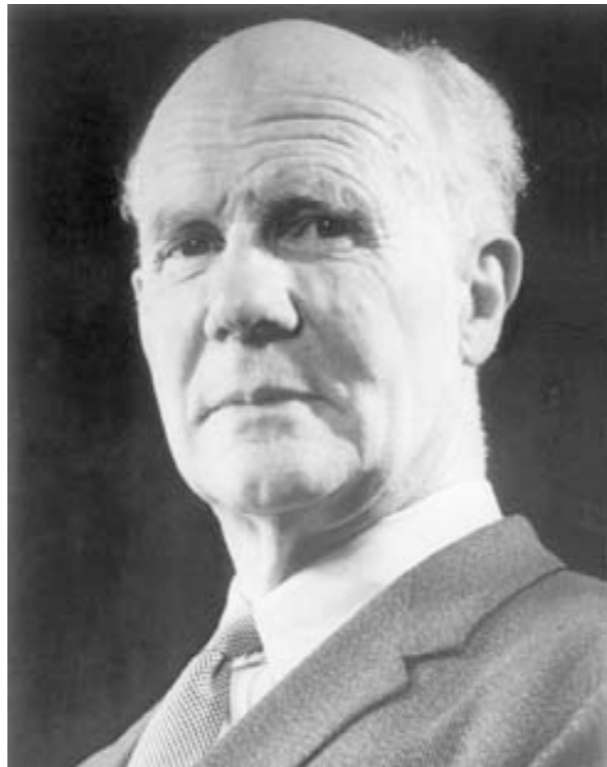
Thin Crust



Deep Dish!!!

Advantages of the MEM

- Uses all available information.
- In some sense, optimal in that the true likelihood is used.
(Neyman - Pearson lemma)



Advantages of the MEM

- **Transparent:**

Unlike e.g. neural net weights, ME has clear physical meaning

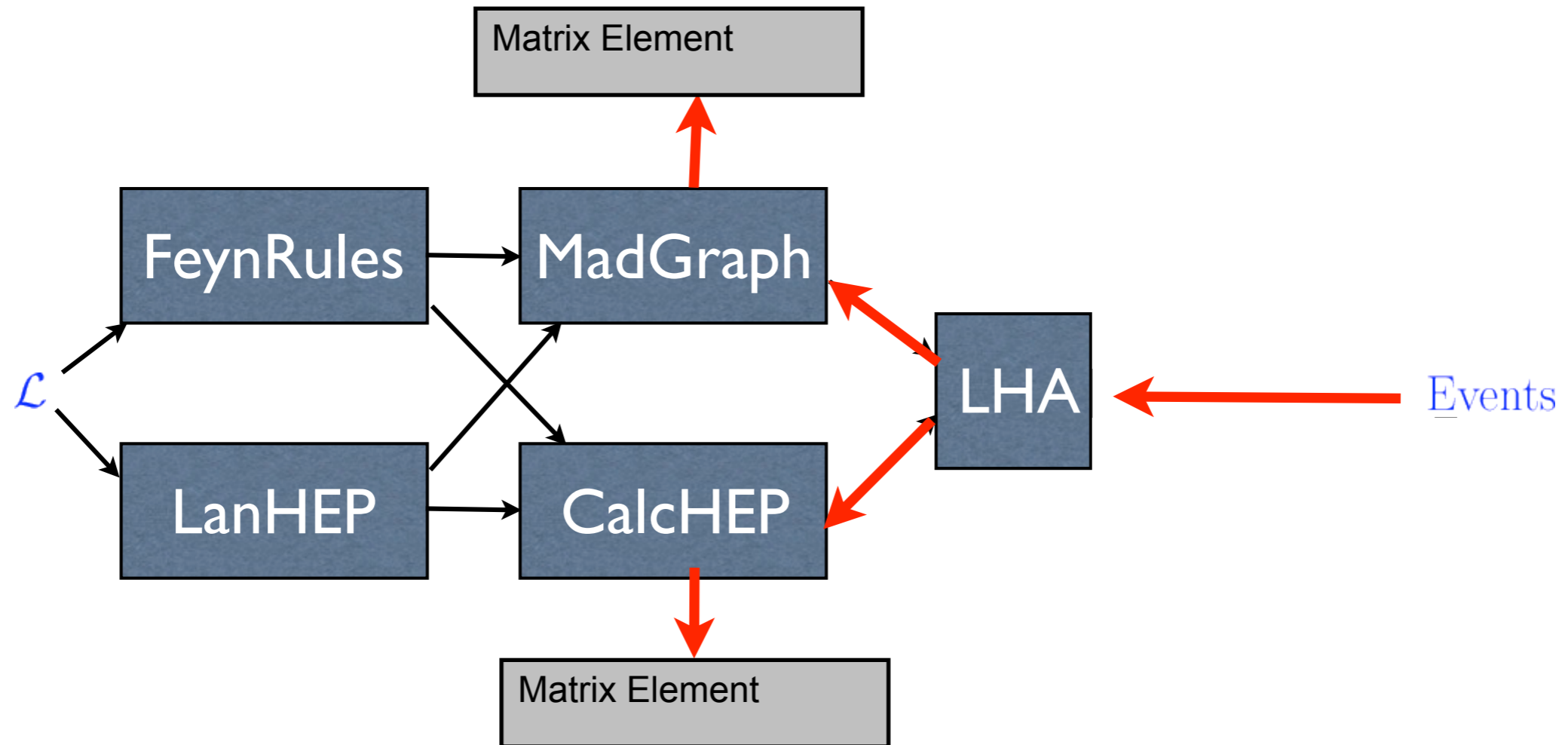
Results independent of training sample.

- **Theorist Input (Mostly) Useful**

Method based on cross section calculations.

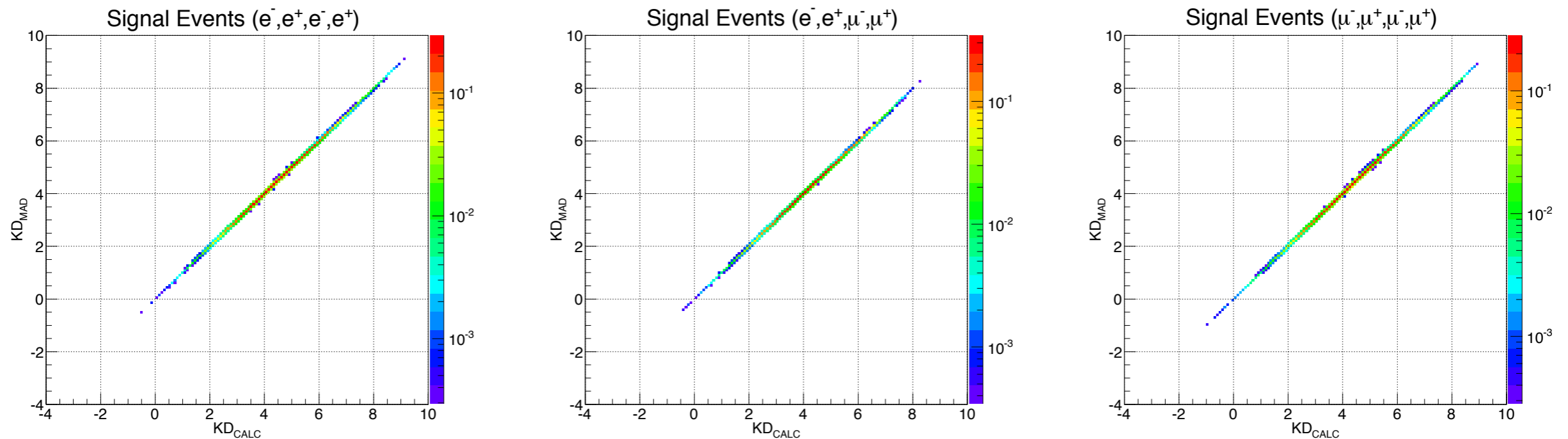
Calculating cross sections is what we do!

From events to ... matrix elements



- As a community, we have developed a standard set of tools for automatically going from Lagrangians to event generation and cross section calculations
- Well-validated, redundant (allows cross checks)
- Can use the same chain to generate matrix elements for events!

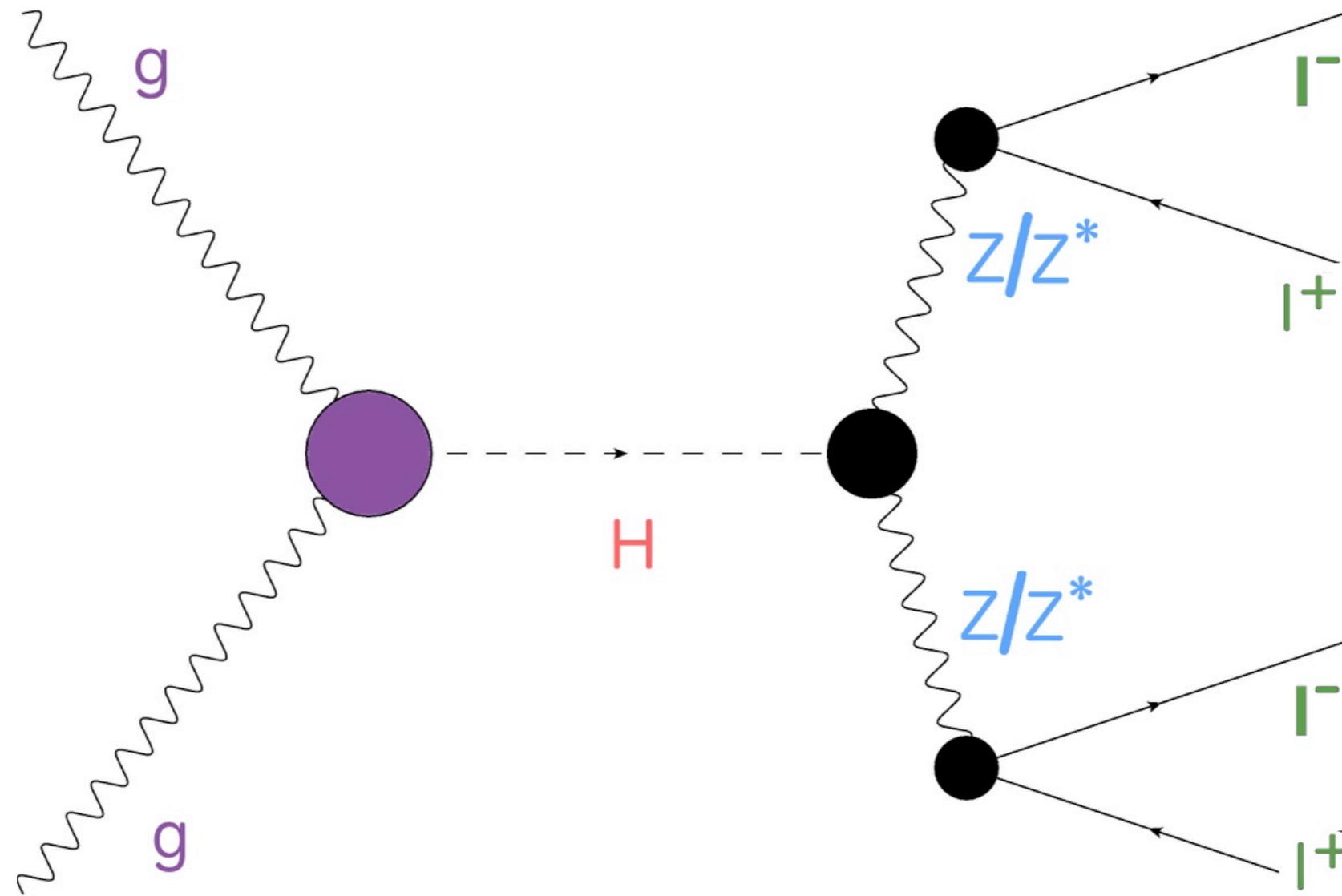
Validation: MadGraph vs. CalcHEP



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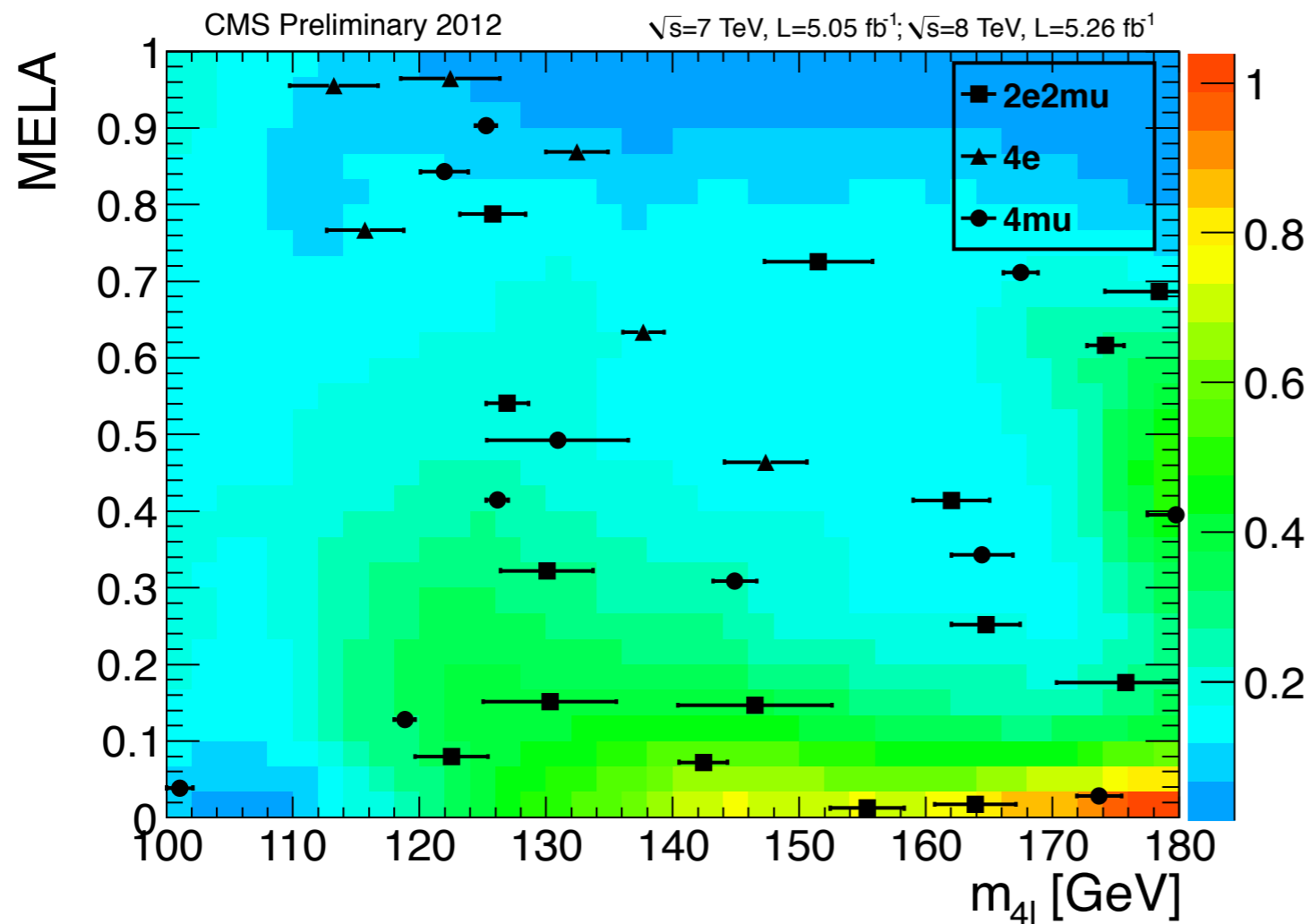
- MEKD is essentially a wrapper (with features) that runs standalone code from MadGraph
- We also have a CalcHEP version and compared the two for validation.

The Golden Channel



- Total Cross Section x Branching Ratio x Detector Efficiencies ~ 1 fb.
- S/B $\sim 1-2$.

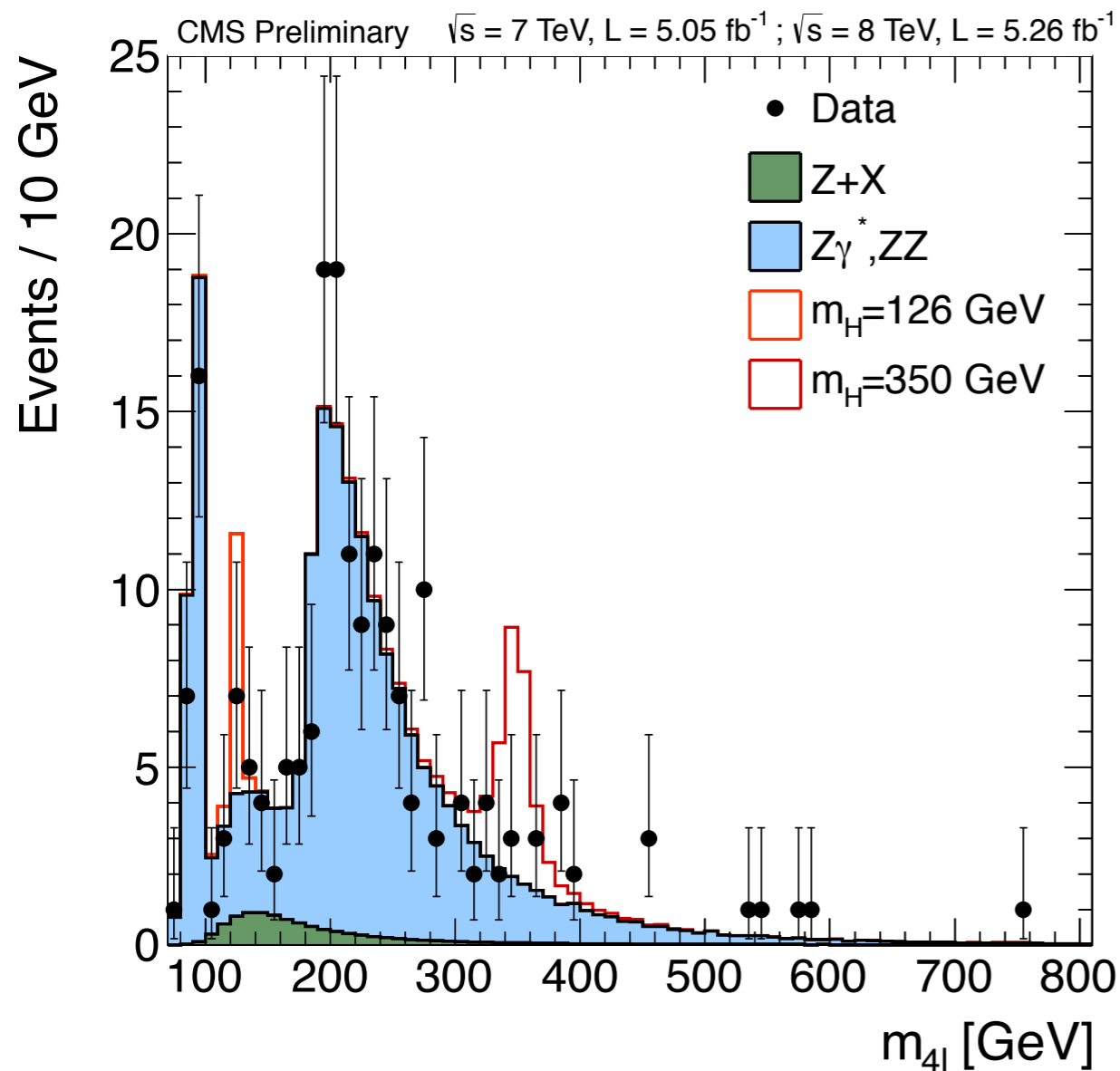
Matrix Element Method/ MELA



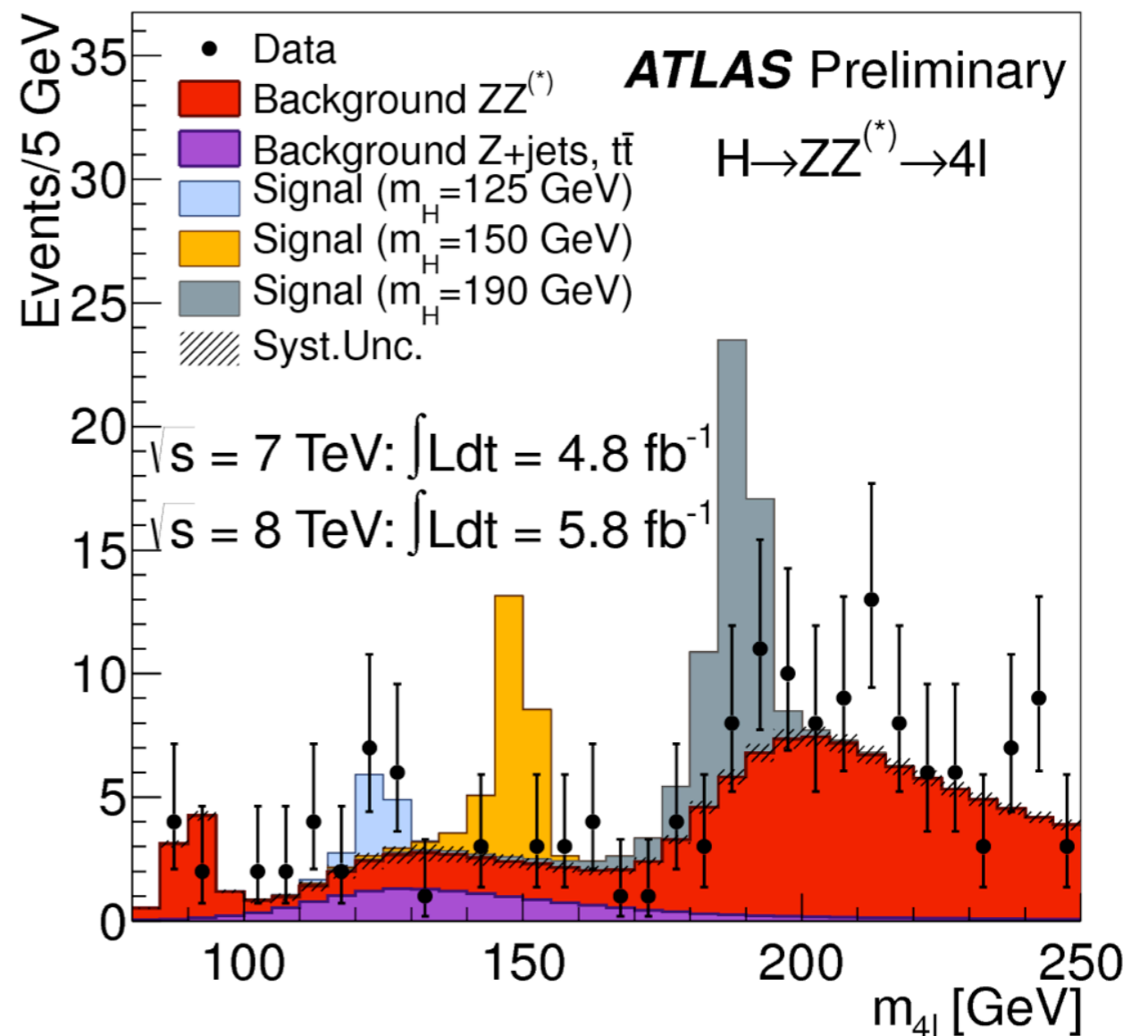
CMS-PAS-HIG-12-016

- CMS used MELA KD
- MELA = Matrix Element Likelihood Analysis
- KD = Kinematic Discriminant
- Quantifies how “signal-like” events are.
- Contours give expected distribution for background events

Important in Higgs Discovery



CMS-PAS-HIG-12-016



ATLAS-CONF-2012-092

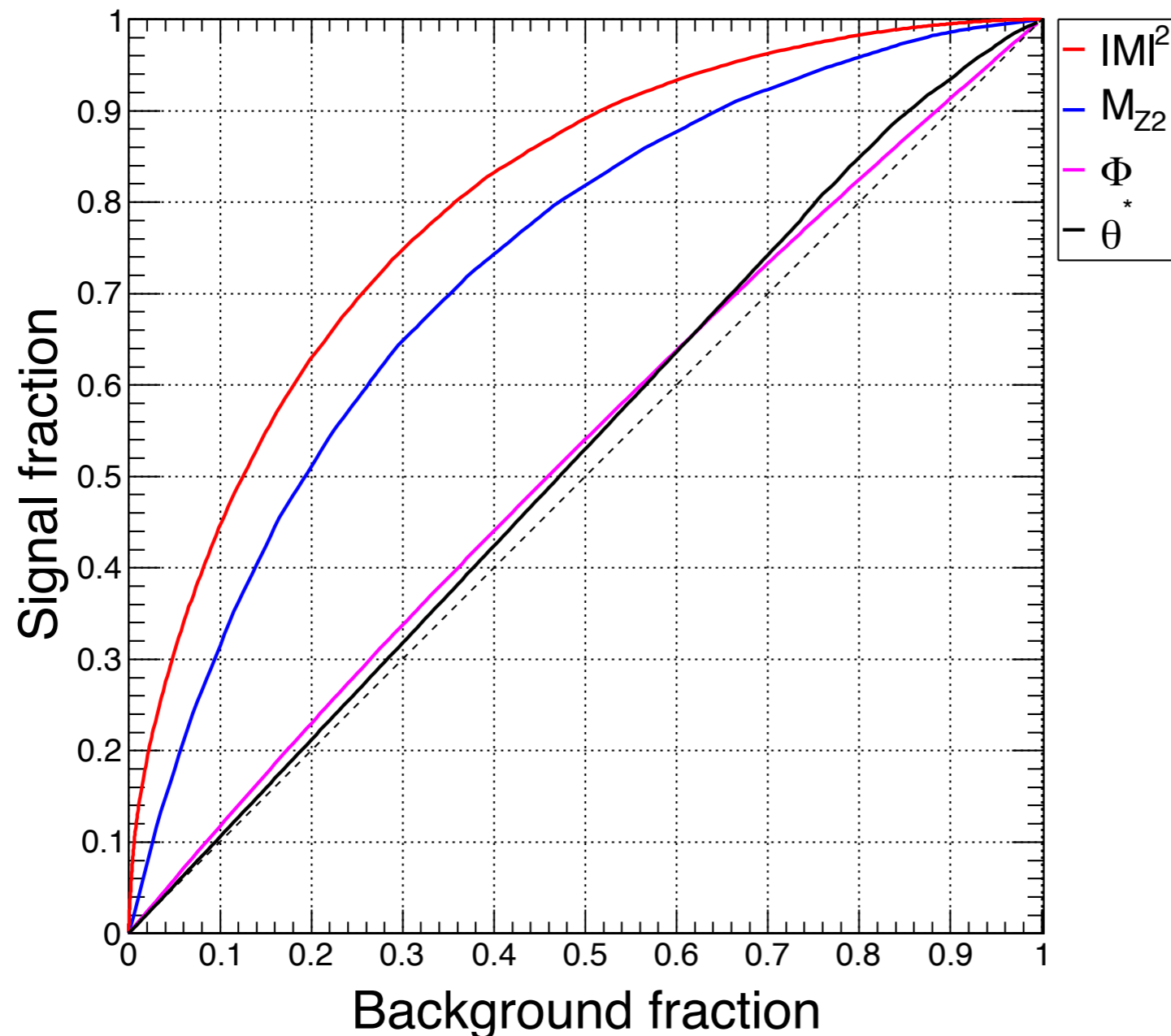
Basic Questions

???

- MEKD already equipped for
 - Signal vs. Background
 - CP even vs. CP Odd
 - Spin-0 vs. Spin-2

Signal versus Background

1210.0896



- MEM is the most sensitive
- Lighter “Z” mass fairly sensitive
- Analyses shown also use invariant mass

See also JSG, Kumar, Low, and Vega-Morales (2011),
Chen, Tran, and Vega-Morales (2012)

CP Properties, Spin

- Perform analyses for general spin-0 resonance (all operators- both CP even and odd), general spin-2 resonance
- De Rujula, Lykken, Pierini, Rogan, Spiropulu (2010)
- Gao, Gritsan, Guo, Melnikov, Schulze, Tran (2010)
- Bolognesi, Gao, Gritsan, Melnikov, Schulze, Tran, Whitbeck (2012)
- Simpler case: SM Higgs versus pure pseudoscalar, graviton



NLO

- For P_T -unbalanced events, the system is transversely boosted to a frame with $P_T=0$ (current)
- Next Step: Including p_T, η information from Monte Carlo-derived templates

NLO

- Further down the road:



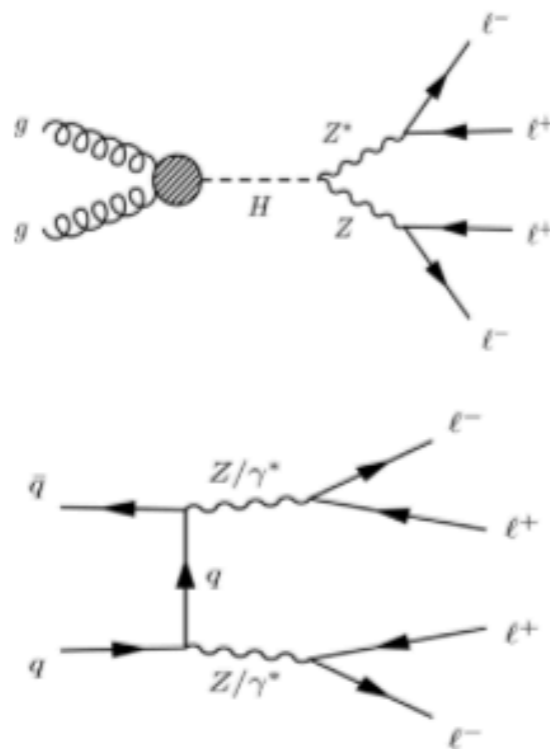
In spirit of giving user as many options as possible, will include approaches developed by/ studying in

- Alwall, Freitas, and Mattelaer (2010)
- Campbell, Giele, and Williams (2012)
- Explicit ME for the $4l + 1j$ final state

The goal is flexibility.

Other Features/ Future

- Can turn on/ off pdfs, or choose different pdf set.
- Plan to add calculation of ME, KD for fixed Higgs mass and include transfer functions in a very flexible way. Currently m_h set to m_{4l} (for 2-D likelihood...)
- Plan to add functionality for measuring fraction of VBF events in $4l 2j$ events
- The only complete public package for MEM in the Golden Channel
 - Includes same flavor as well as opposite flavor final states



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