Spin Determination for a "Light" Higgs Boson

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The PARTICLE ZOO

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What a snob. He's the one everyone wants to meet, but for now he's playing hard to get. Higgs Boson is also part of the Theoreticals 4-Pack. and Boson 5-Pack.

Approximately 14 oz/388 grams; 5.5 inches/15 cm across. For ages 5 and up as it contains small parts.

Made in China. Age 3 and up. Along with the electron, this is currently the only member of the Zoo who is **not** handmade. We hope you don't mind.

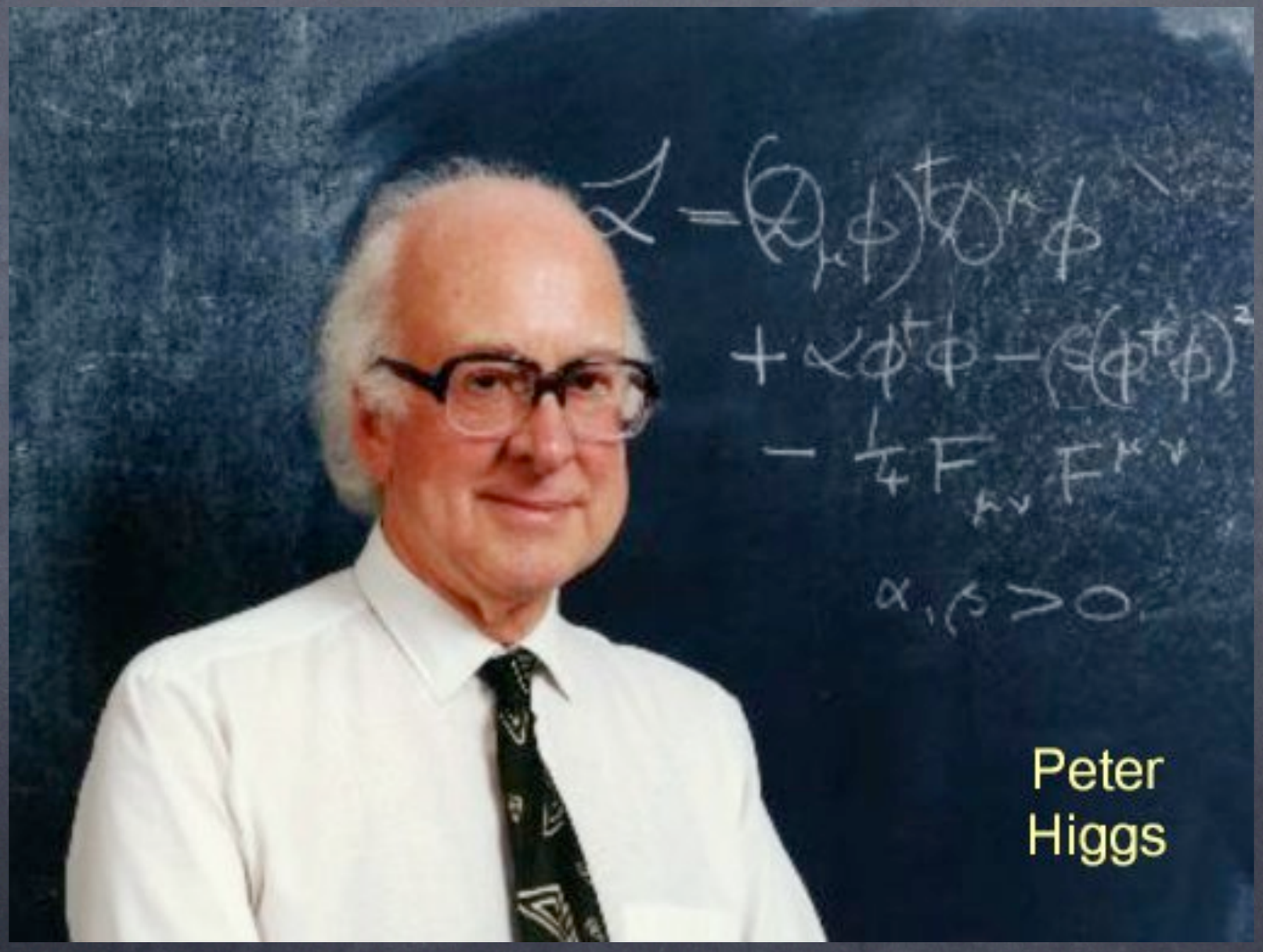
BACK TO SHOP ALL PARTICLES

HIGGS BOSON H

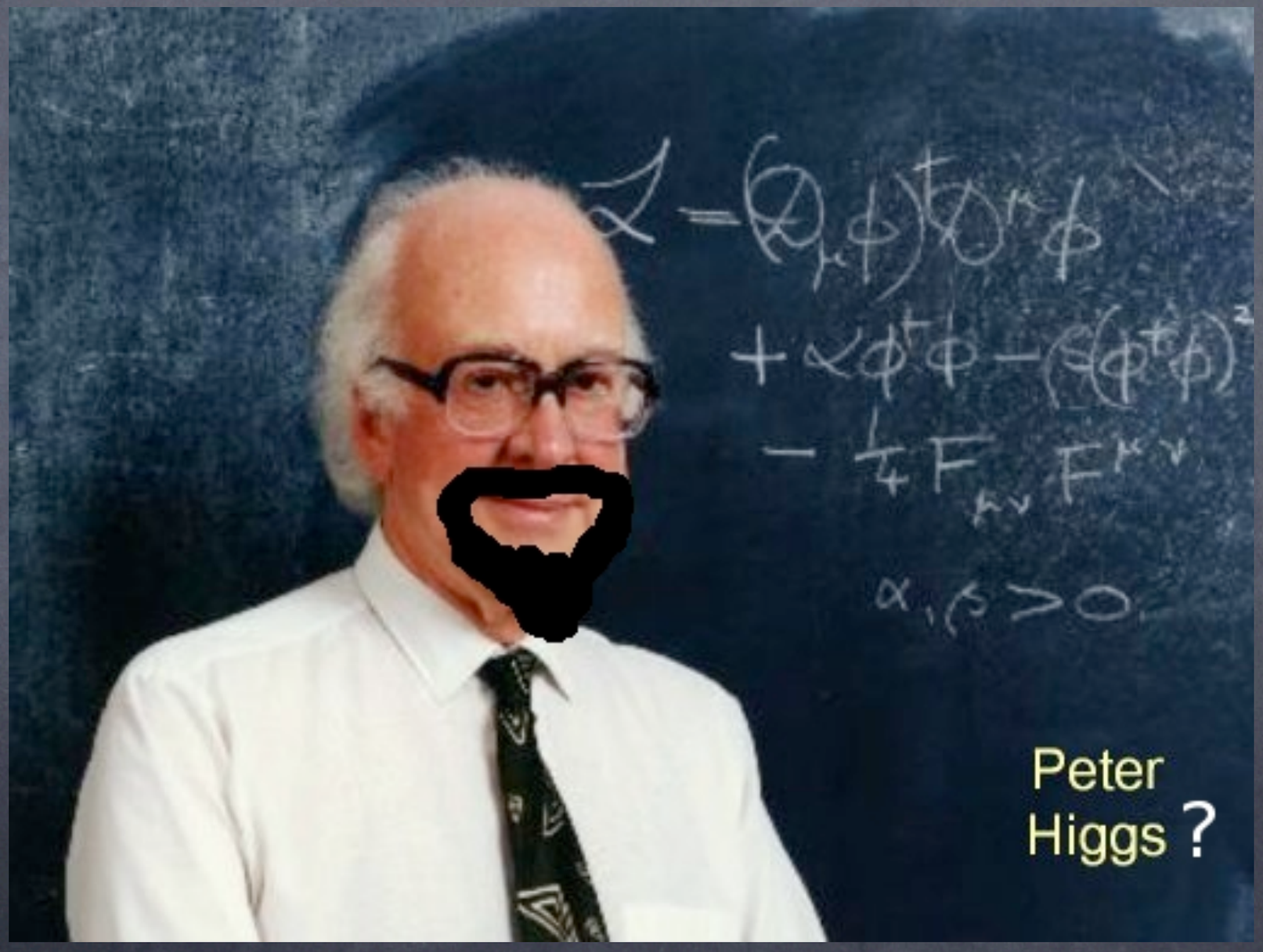
The **HIGGS BOSON** is the theoretical particle of the Higgs mechanism, which physicists believe will reveal how all matter in the universe gets its

TextEdit

Is it the Higgs?



or an Impostor?



Is it the Higgs?

- To tell if a resonance is the Standard Model Higgs boson, we need to verify its
  - Spin
  - CP properties
  - Branching Fractions

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Spin Determination

- Much work exists on spin determination.
- I'll mention two works (for H -> ZZ -> 4l) which employ the approach we will take.
- This channel is best for $m_H > 2\ M_Z$.

- Spin determination of single-produced resonances at hadron colliders:
  Gao, Gritsan, Guo, Melnikov, Schulze, and Tran

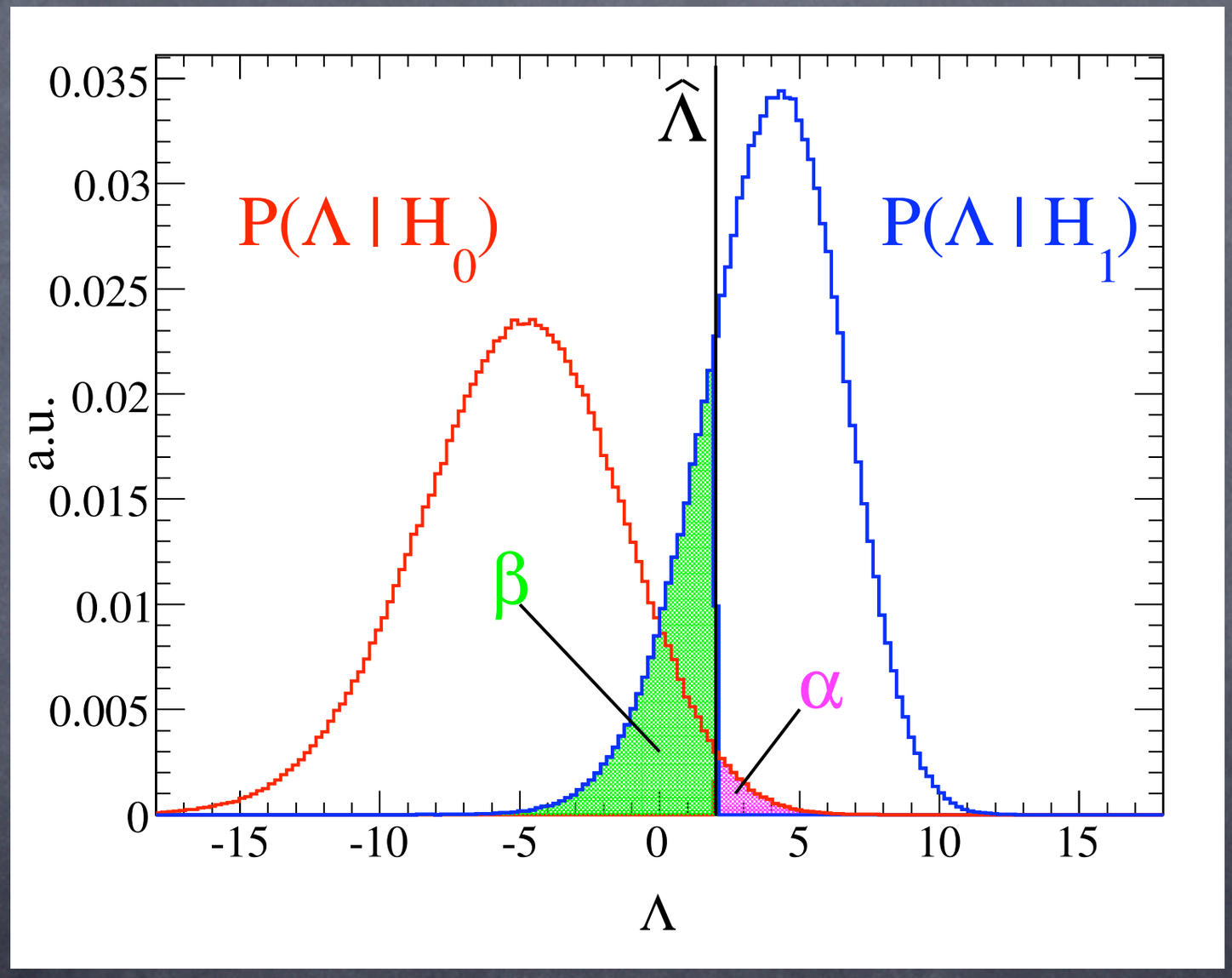
- Higgs look-alikes at the LHC:
  De Rujula, Lykken, Pierini, Rogan, and Spiropulu

- **Approach**: write down general coupling for resonance to initial states, ZZ final state.

- Fix cross section and resonance mass.

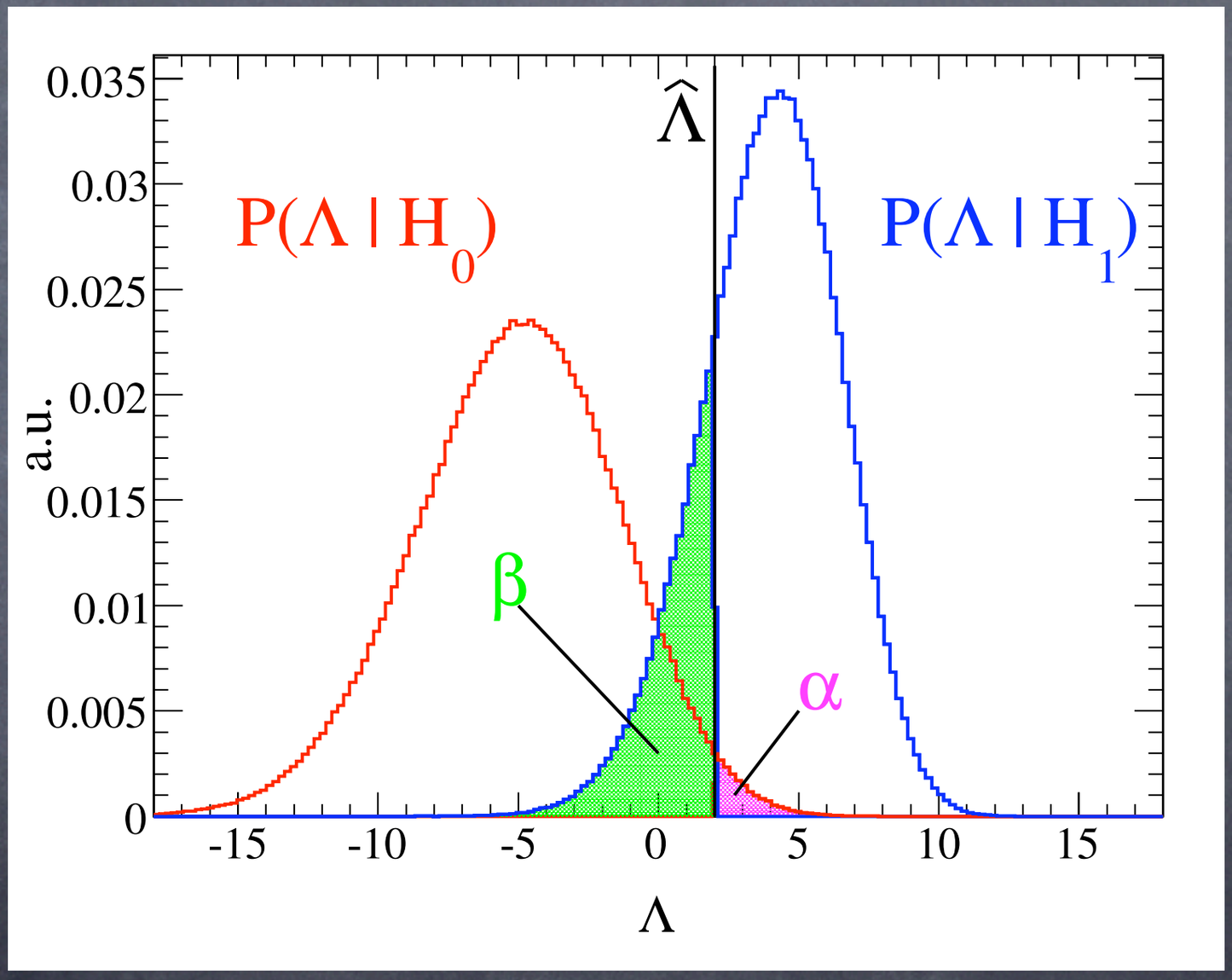
- Generate events (pseudo-experiments) for a particular resonance with specified spin and CP properties.

- For each pseudo-experiment, find (and add to a histogram) the ratio of log likelihood for different spin/ CP hypotheses.



m_H=200 GeV, N_S=23,
10^9 pseudo-experiments.

- Can obtain p-value directly from the log likelihood histograms



H_0: CP even scalar, H_1: CP odd scalar

Likelihood

- The likelihood function is essentially the pdf evaluated with the data one obtains, considered as a function of the model and its parameters.
- Parametrizes the "likeliness" of a model or model parameter given the data observed.

Likelihood

- If the pdf for each event is $f(x_i,\theta)$, then the likelihood for a set of N events is simply

$$L(\theta) = \prod f(x_i,\theta)$$

where the product is over all N events.

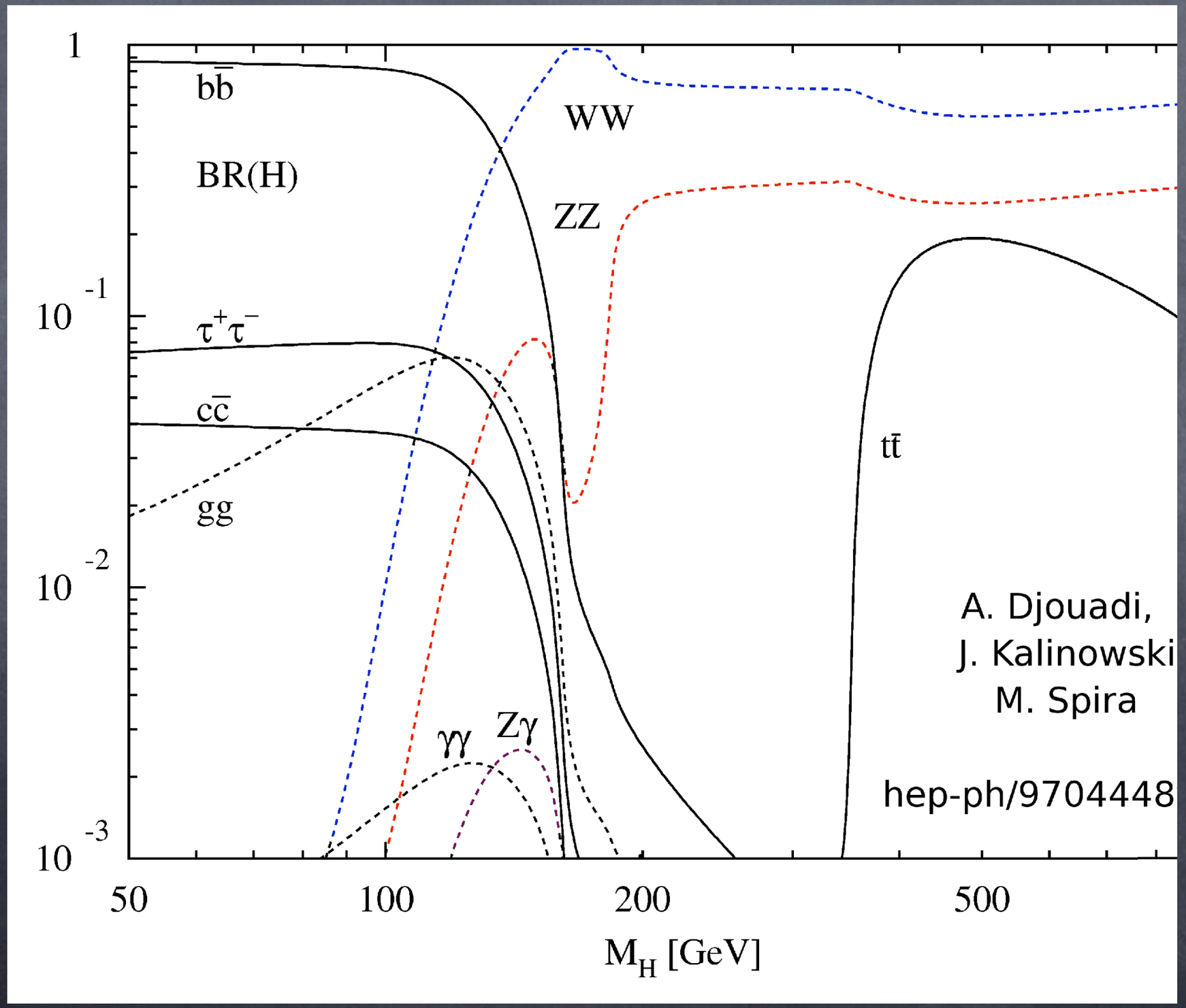
- One obtains a more complicated expressions if the pdf (f) is not normalized.
- If we choose our hypotheses so that f has the same normalization, the above expression suffices.

Matrix Element Method

- In evaluating likelihood ratio, need a pdf which is a function of all the final state observables.
- Differential Cross Section!!!
- Using the differential cross section (matrix element) in calculating the likelihood is the "matrix element method"
- So the differential cross section, evaluated for particular kinematics, is the pdf $f(\mathbf{x}_i,\theta)$ from the previous slide.

Applying this Method to Zγ

Zγ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A. Djouadi,
J. Kalinowski
M. Spira
hep-ph/9704448
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100
200
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M_H [GeV]

Zγ

- BR(h -> Zγ) always less than BR(h -> ZZ*)
- However, demanding leptonic decays enhances Zγ relative to ZZ* (-> 4l) by ~16.
- So BR(h -> Zγ -> llγ) > BR(h -> ZZ* -> 4l) for mh < ~125 GeV. It is within a factor of 2 for mh < ~145 GeV.
- This channel should provide important additional information for spin discrimination in these mass ranges.
- Important to quantify the extent to which this is the case.
- Could be enhanced for non-SM Higgs.

Preliminary Results

- Differential cross section expressions, events from CalcHEP
- Use Mathematica package to read events, run LHAPDF code, calculate differential cross section for particular kinematics using CalcHEP produced .m files.

Preliminary Results

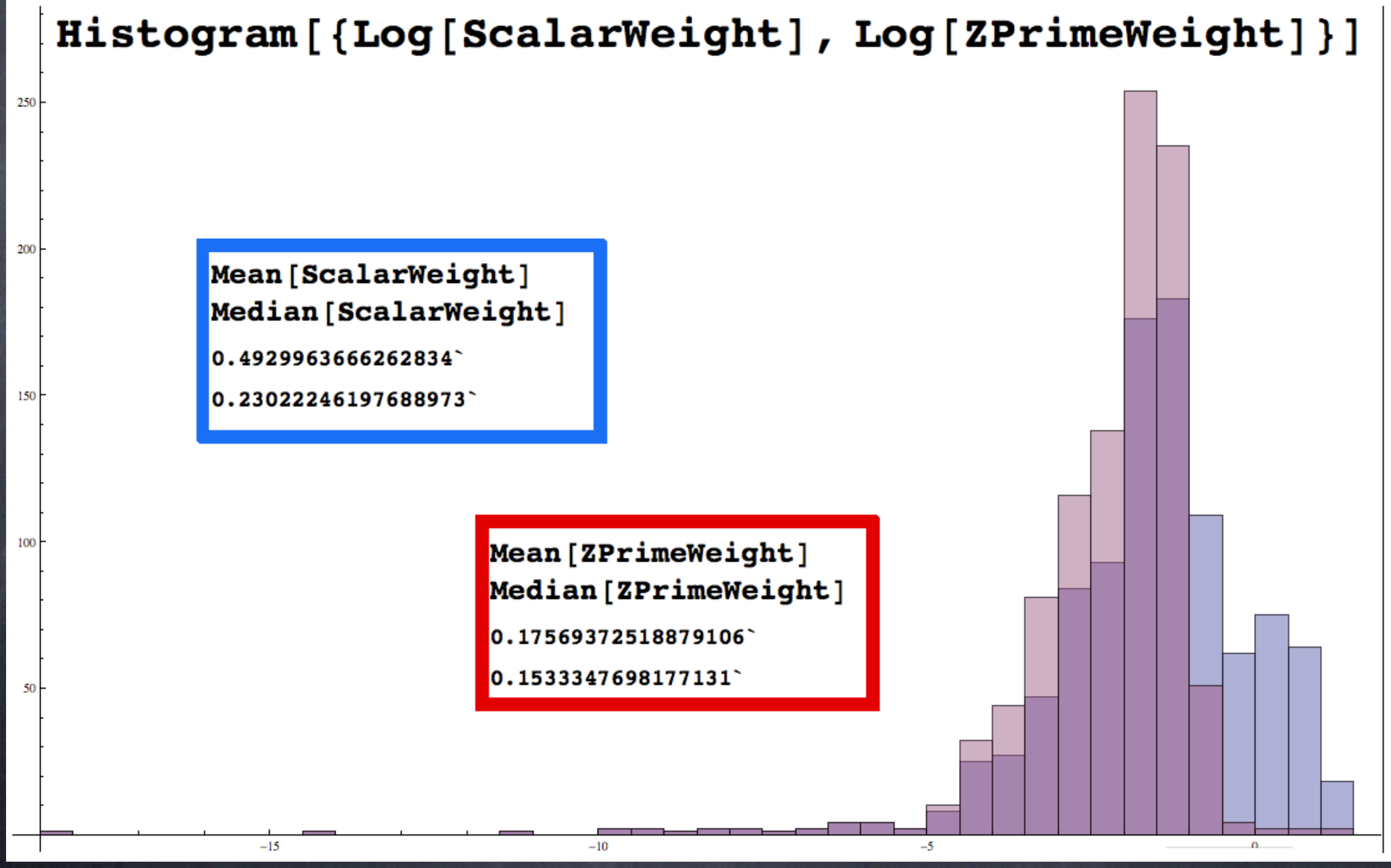
- Z prime versus scalar with
  - same mass (140 GeV)
  - cross section = σ(gg -> H -> Zγ) for mh=140
- Particular values of couplings (esp. Z prime)
- Have not yet run pseudoexperiments. Will show plot of log likelihood. Run on 1000 events generated in the scalar model.

Preliminary Results

- Both the events generated, and the cross section expressions used are for the entire model.
- I.e. include both signal and background.
- Needed since e.g. for Z prime there is interference with background (which has only quark-anti-quark initial state at LO).
- To get visible results with 1000 events, used a very hard cut on invariant mass (so not all events are background).

  In principle, the matrix element method does this for you.

Preliminary Results



Summary

- I described a study of spin measurement using the Matrix Element Method and the Zγ final state
- Potentially helpful for light/ intermediate mass Higgs spin measurement- we'll see!