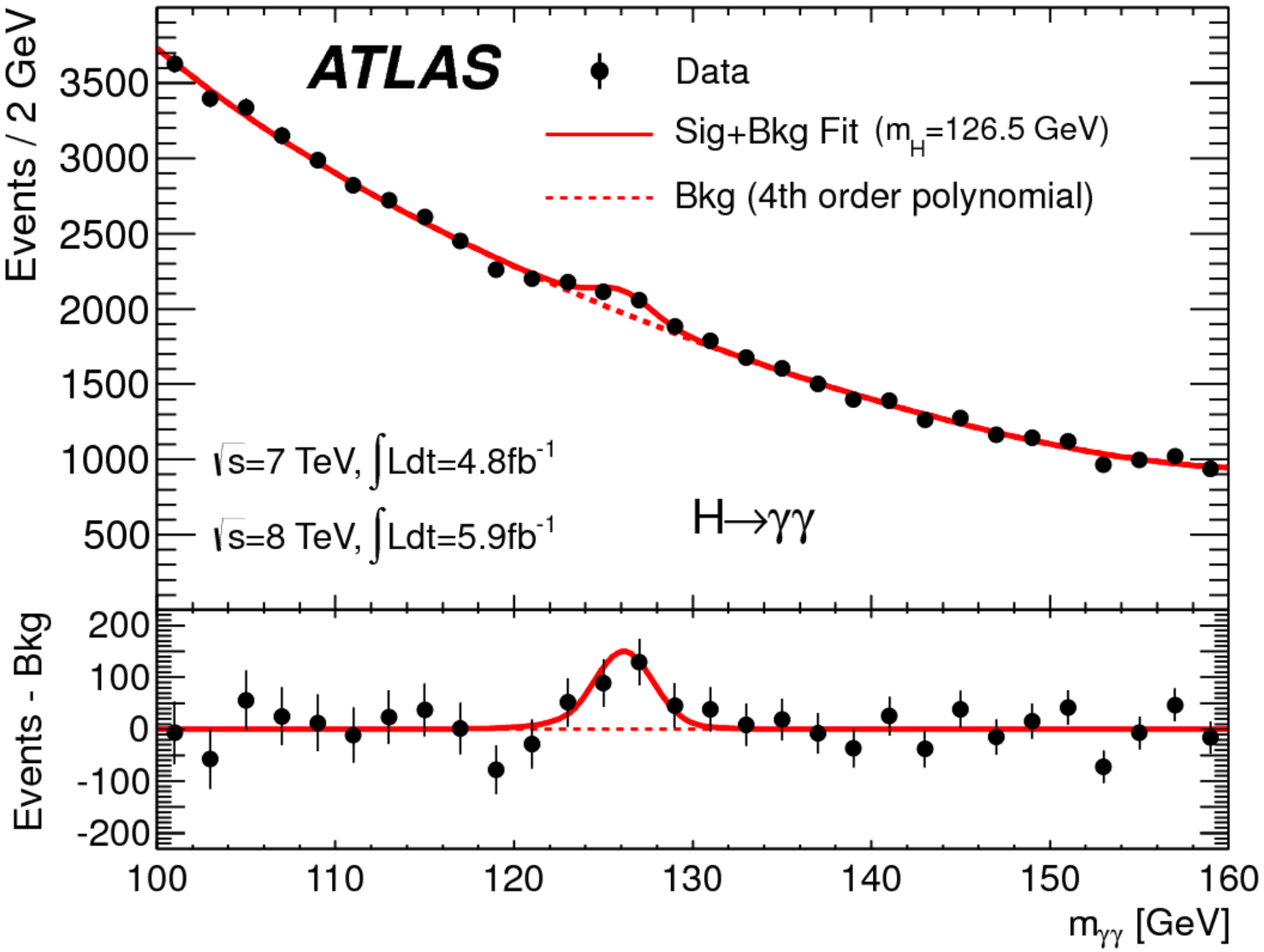


Lecture 9

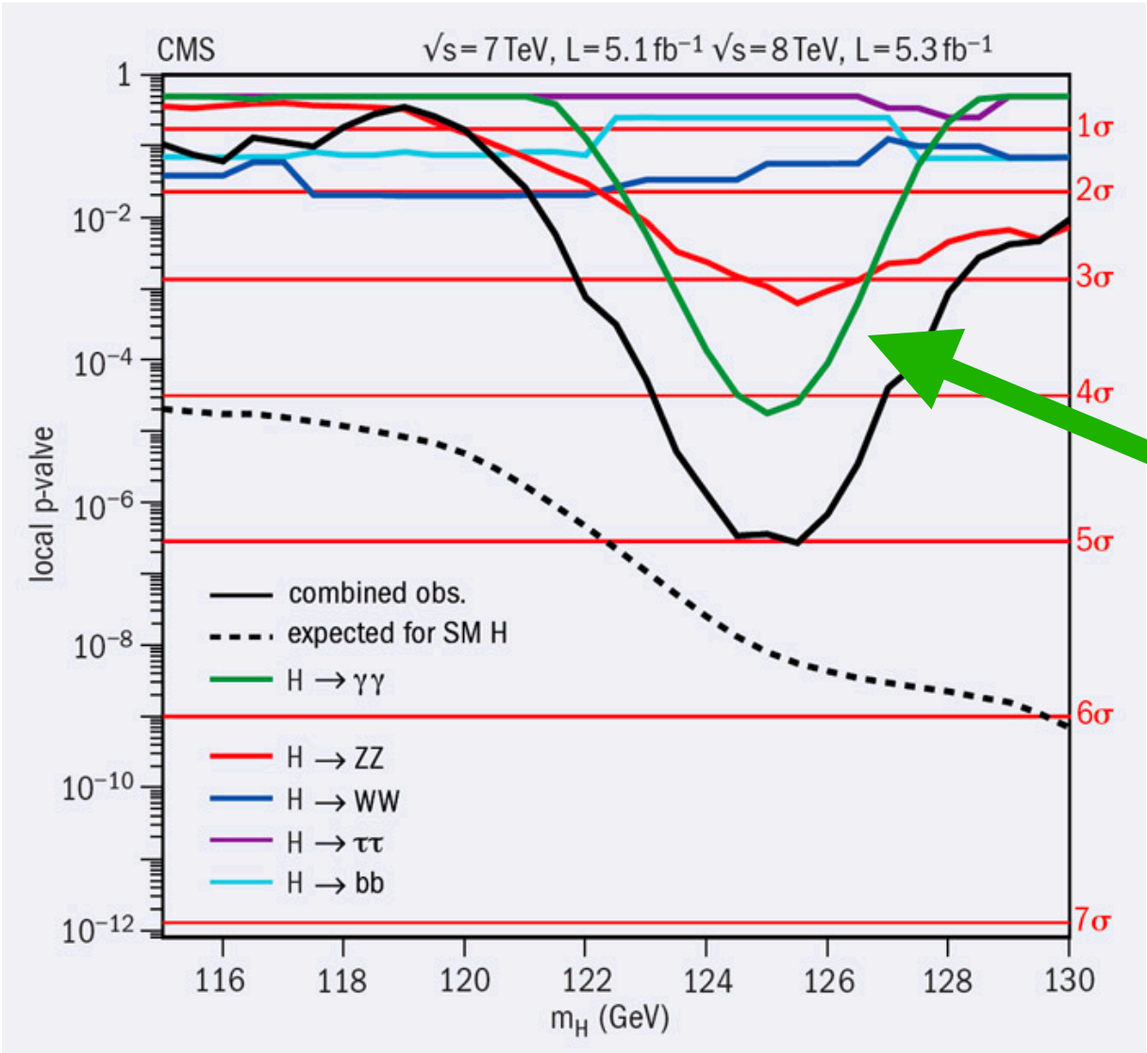
Higgs Boson Discovery
Towards Deep Learning

Higgs Boson

- We discovered the Higgs boson not so long ago

In this lectuere we are going to make the discovery plot

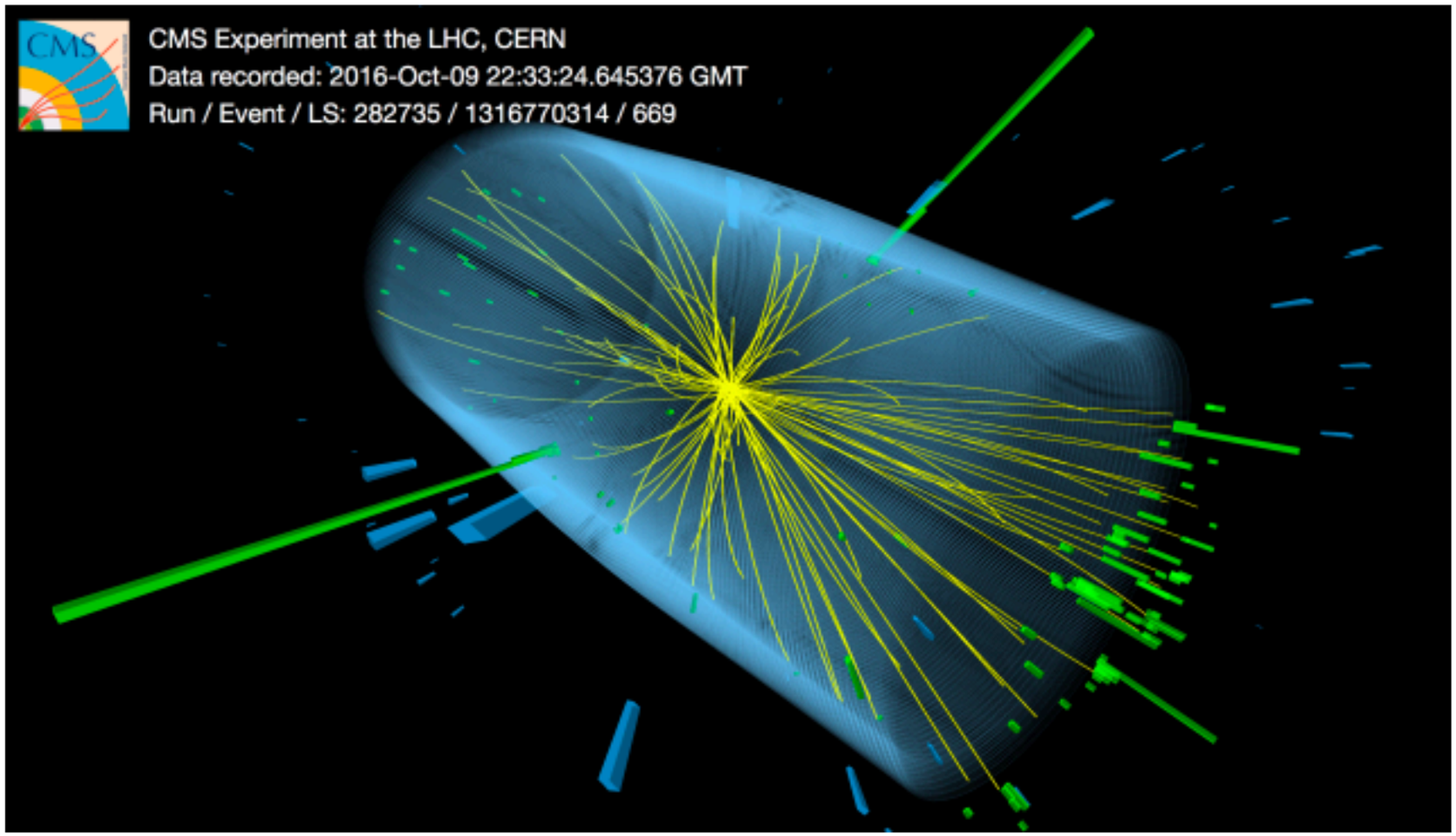
- To discovery it we made a plot like this:

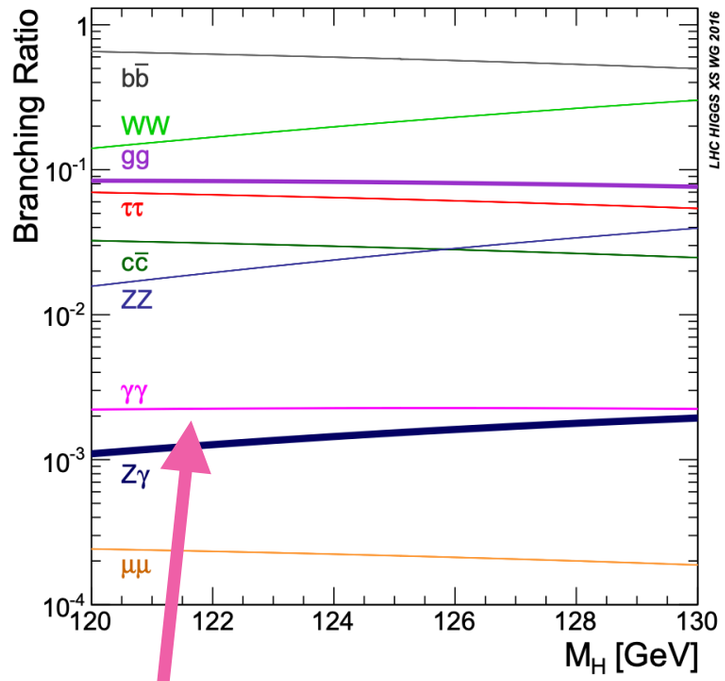


We are going to focus on his object

Higgs to two photons

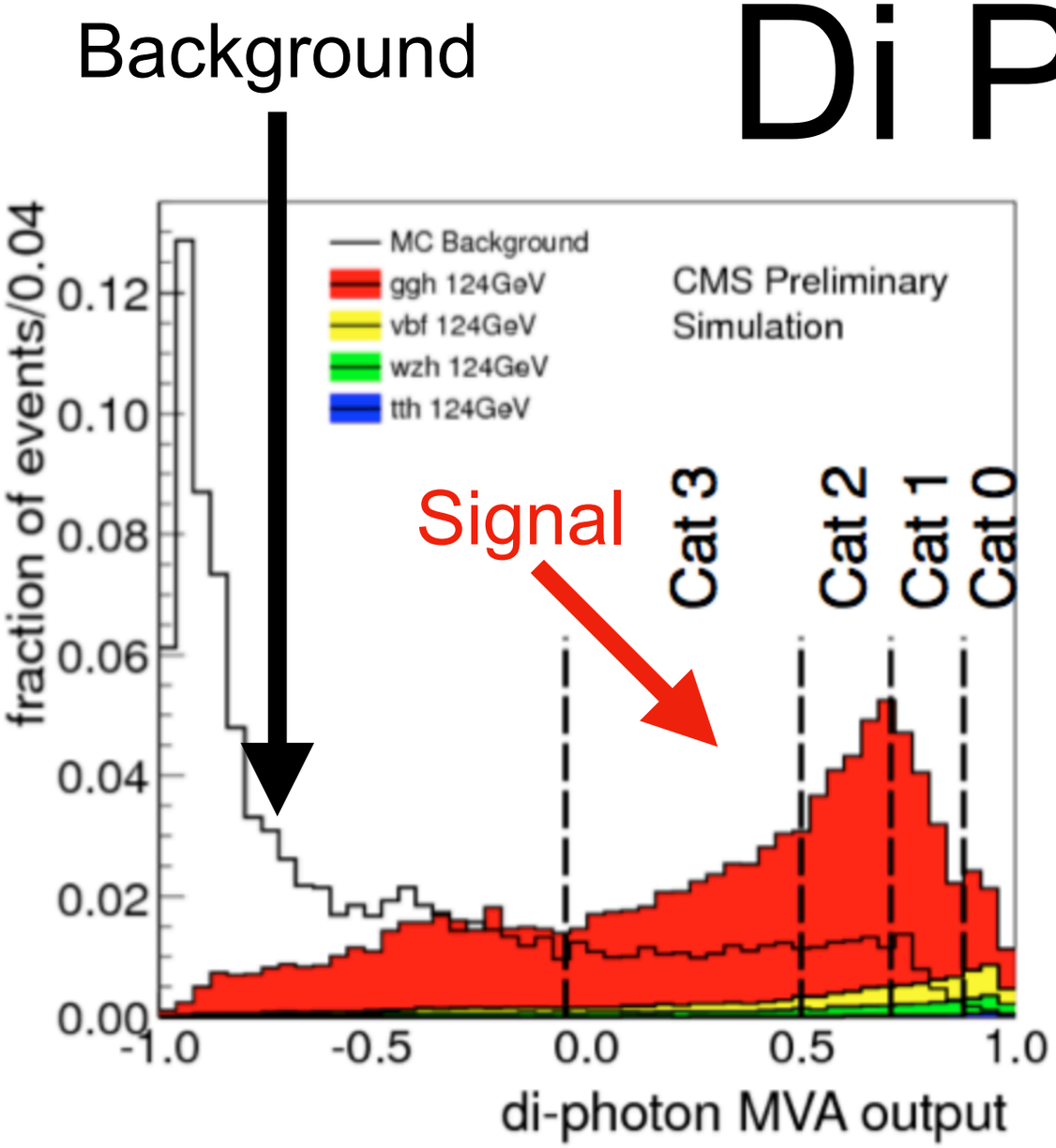
- Higgs to boson decays to nearly every other particle

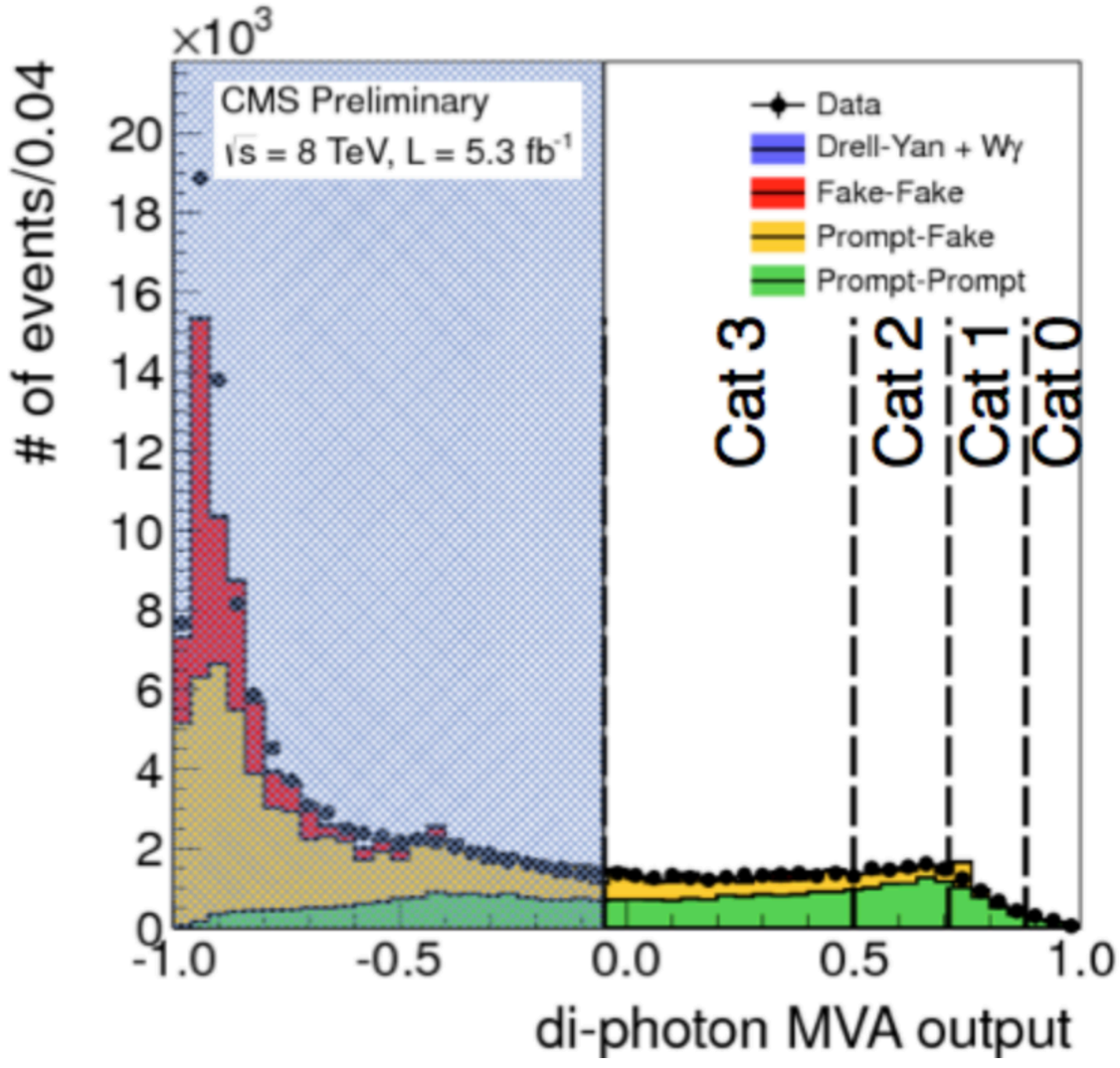




Higgs bosons to two photons occur about 0.3% of the time

Di Photon selection

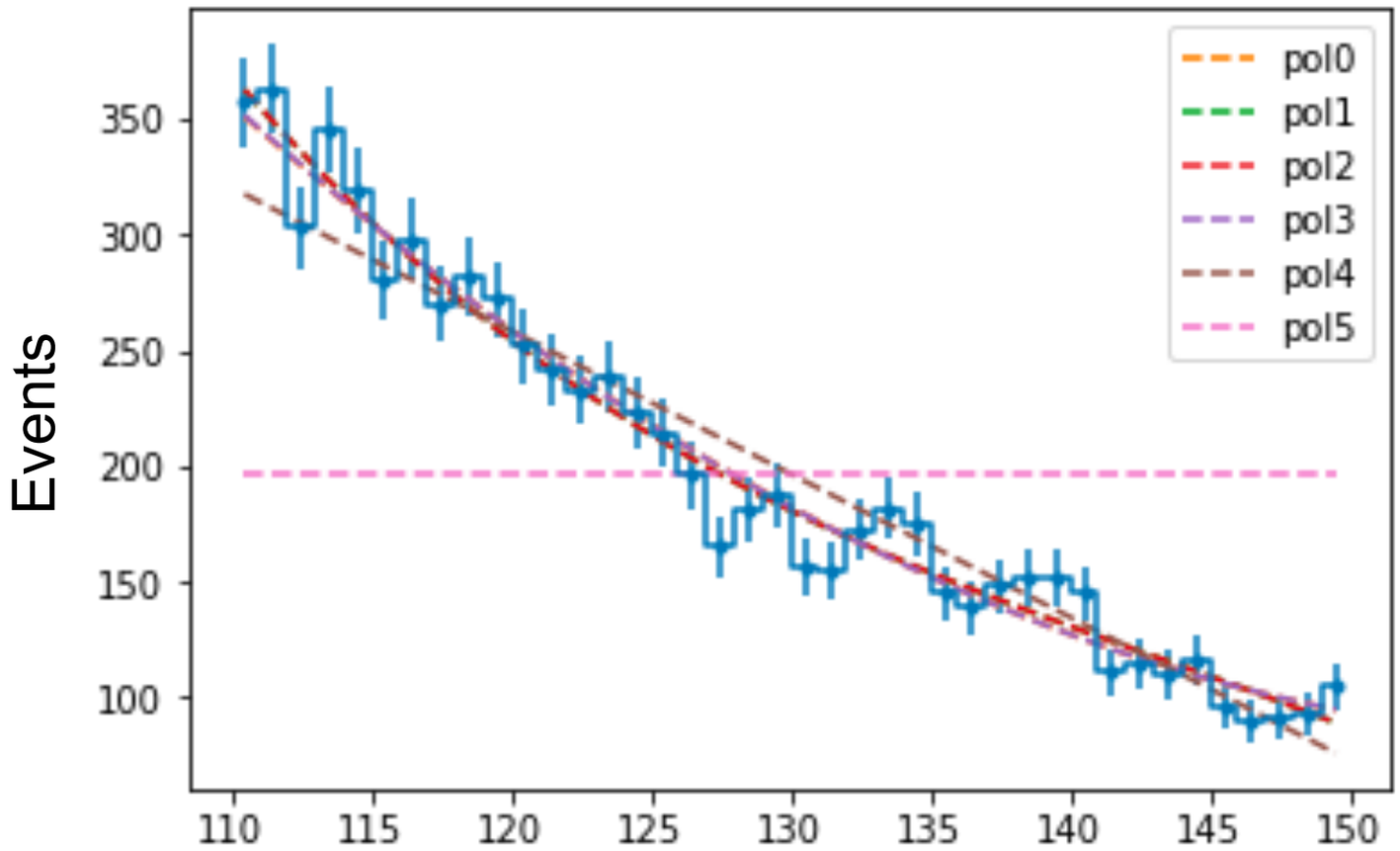




- To select di-photons we build a neural network
  - This takes into account many different Higgs properties

Building a Model

- The frequentist will look at this data and guess a model



Often when we fit, we through a barrage of functions at it
As a rule of thumb we do the “chi-by-eye” (If chi2 is good, we are ok)
A more robust is an f-test (see notes)

F-Statistic

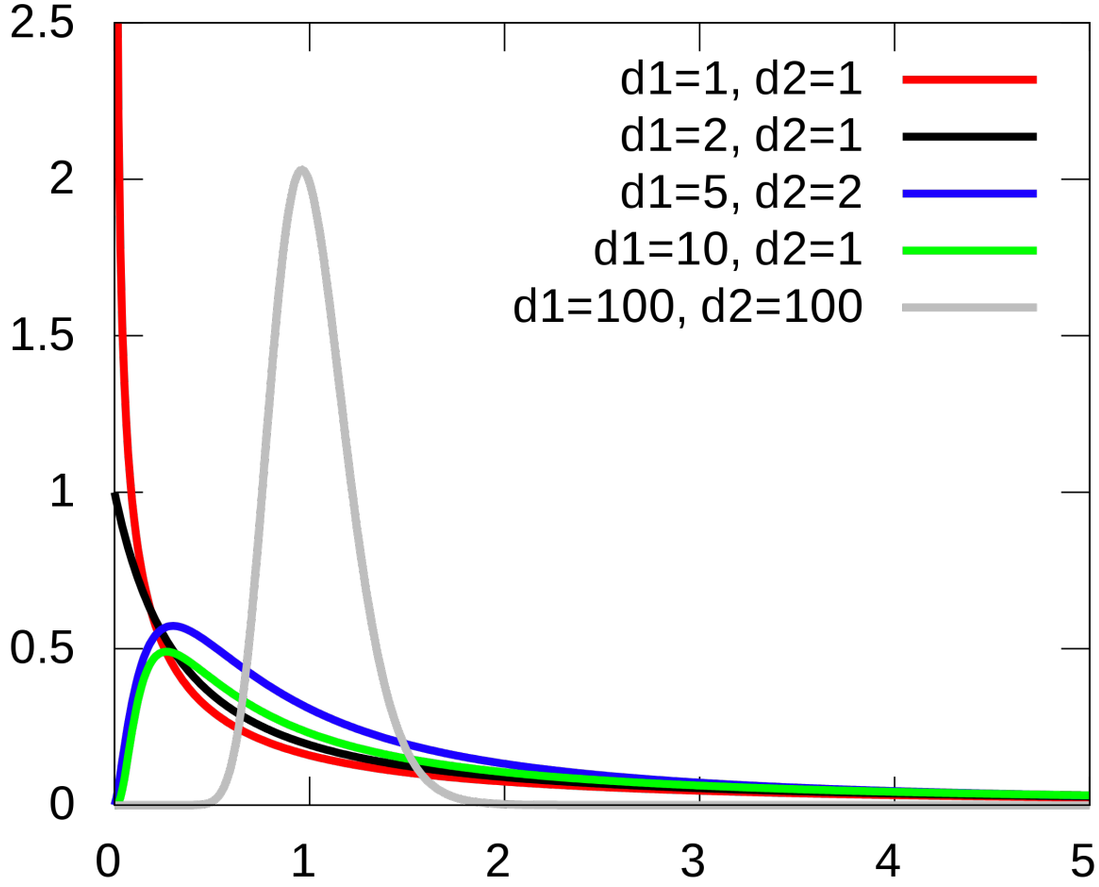
- Reminder and F distribution leads to the
- $$F = \frac{\text{explained Variance}}{\text{Unexplained Variance}} = \frac{\text{Between Group Variability}}{\text{Single Group Variability}}$$
- For fitting functions as a polynomial we can write this as
- $$F = \frac{\frac{1}{\Delta_{DOF}(f,g)}\left(\sum_i \left(y_i - f(x_i)\right)^2 - \sum_i \left(y_i - g(x_i)\right)^2\right)}{\left(\frac{1}{n - p_f}\sum_i \left(y_i - f(x_i)\right)^2\right)}$$

F-Distribution

- Approaches gaussian about 1 for large N

$$f(x; d_1, d_2) = \frac{\sqrt{\frac{(d_1 x)^{d_1}\ d_2^{d_2}}{(d_1 x + d_2)^{d_1 + d_2}}}}{x\,\mathrm{B}\left(\frac{d_1}{2}, \frac{d_2}{2}\right)}$$

$$= \frac{1}{\mathrm{B}\left(\frac{d_1}{2}, \frac{d_2}{2}\right)} \left(\frac{d_1}{d_2}\right)^{\frac{d_1}{2}} x^{\frac{d_1}{2} - 1} \left(1 + \frac{d_1}{d_2}\, x\right)^{-\frac{d_1 + d_2}{2}}$$



The F is for Fisher
He’s the dapper gent above

Now do Frequentist F-test

- *n*-groups of **fits** each with separate fitted likelihoods
- Define : $\bar{X}_j = \frac{1}{m}\sum_{i=1}^{m} X_i$ and $S_j^2 = \frac{1}{m-1}\sum_{i=1}^{m}(X_i - \bar{X}_j)^2$

Likelihood of a fit PolX

- Define: $MS_B = \frac{m}{n-1}\sum_{i=1}^{n}(\bar{X}_j - \bar{X})^2$ and $MS_R = \sigma^2$

Difference in likelihoods

- If $\mu_i = \mu$ or in other words are from the same distribution the
- $\frac{MS_B}{MS_R} \approx 1 = F_{n-1\ m(n-1)}$ where $F_{n-1\ m(n-1)}(x)$ is an F distrib

Higher Order Polynomial

- $$\frac{\frac{RSS_1 - RSS_2}{p_2 - p_1}}{\frac{RSS_2}{n - p_2}} \approx F_{p_2-p_1\ n-p_2}$$ generically

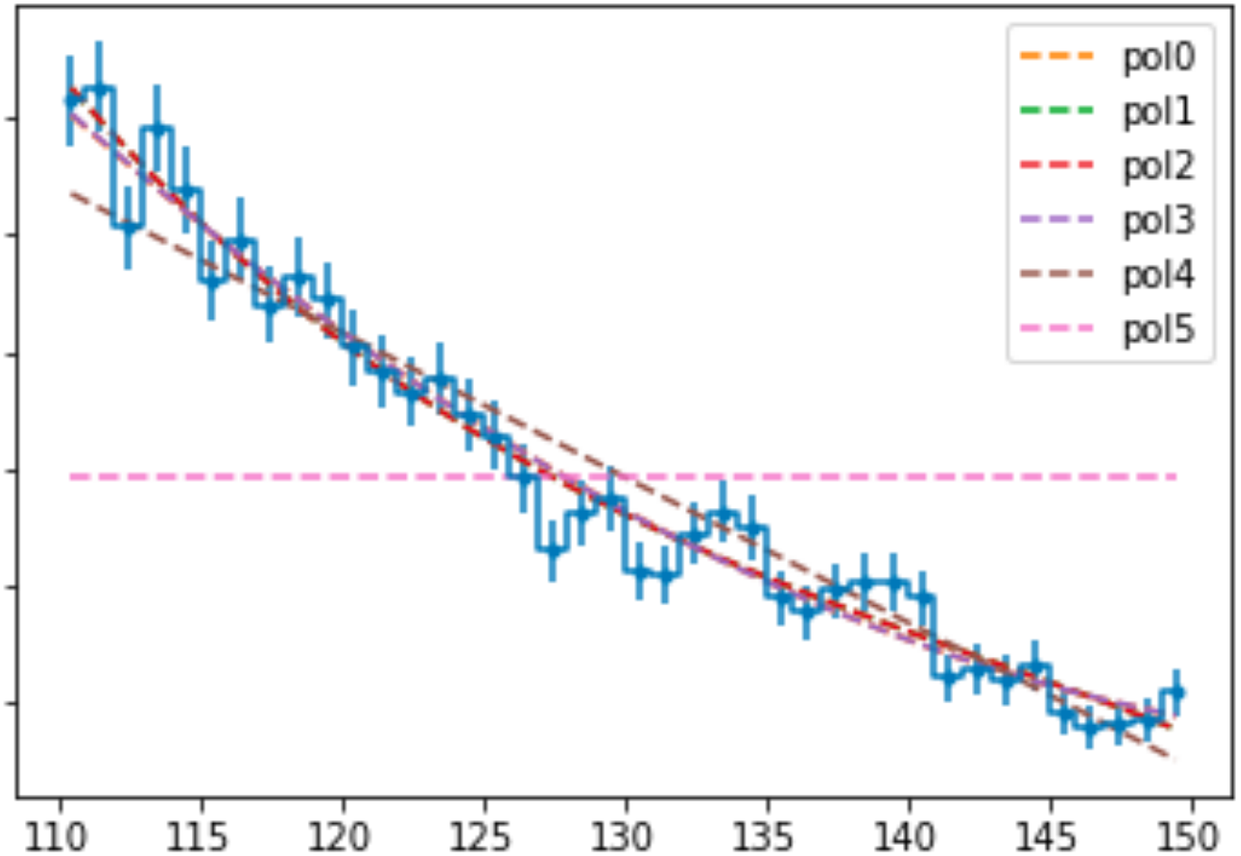
- $$\frac{\frac{\mathscr{L}_1 - \mathscr{L}_2}{p_2 - p_1}}{\frac{\mathscr{L}_2}{n - p_2}} \approx F_{p_2-p_1\ n-p_2}$$

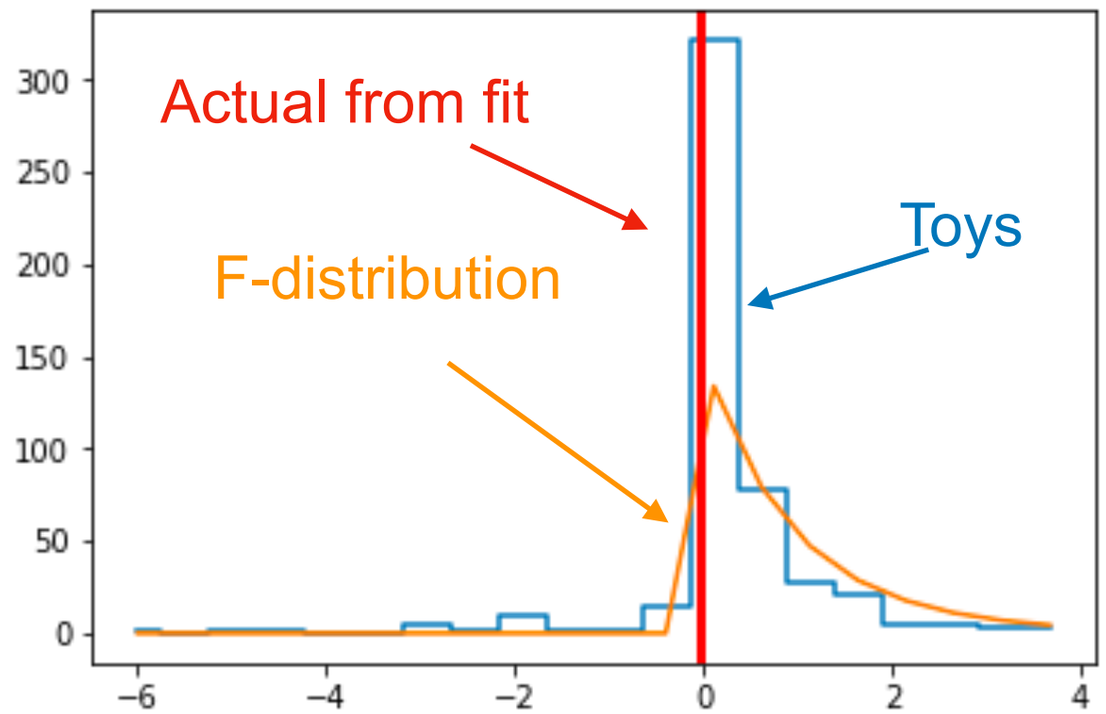
Test of higher polynomial order with F-test form is called the chow test

F-test Example

- Here is an example from previous fit
- Our Actual Δ (x-axis) is consist with a high p-value

Toys: Randomly sample 3rd order dist and fit with 4th order

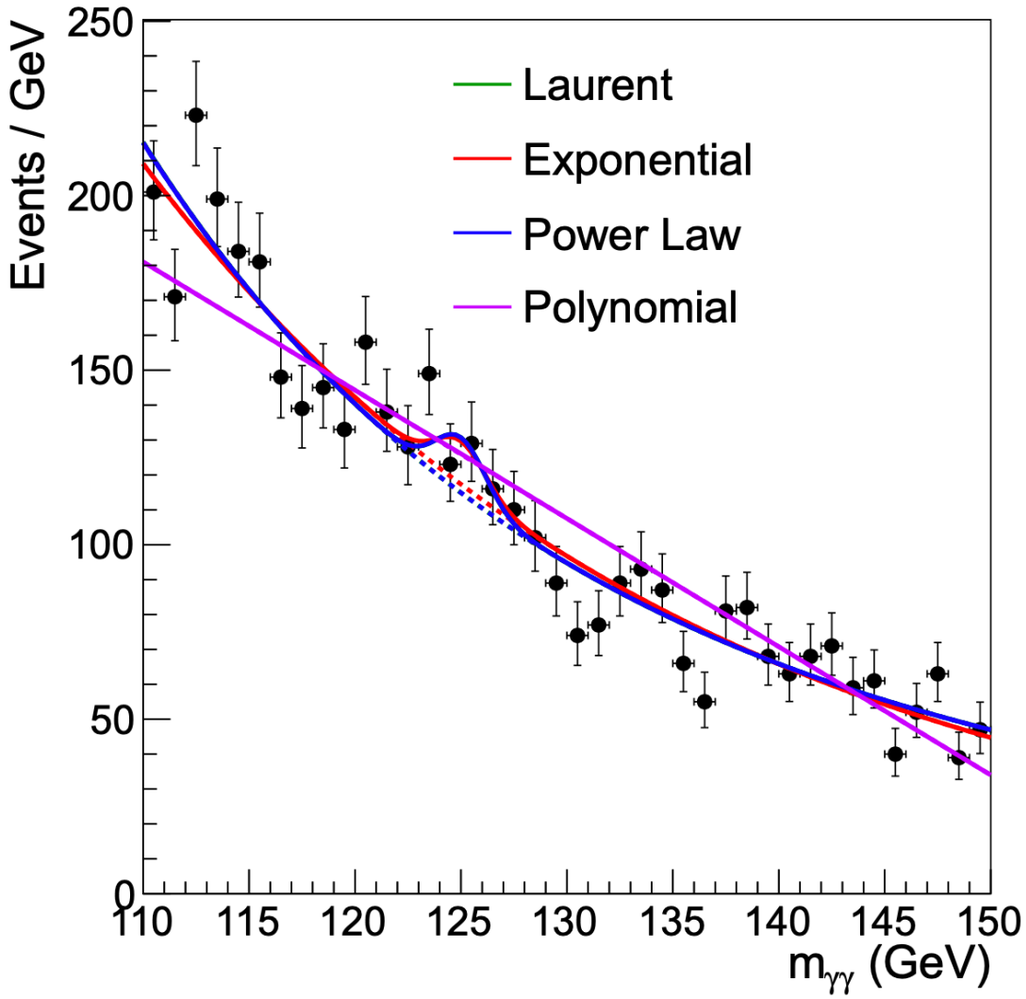


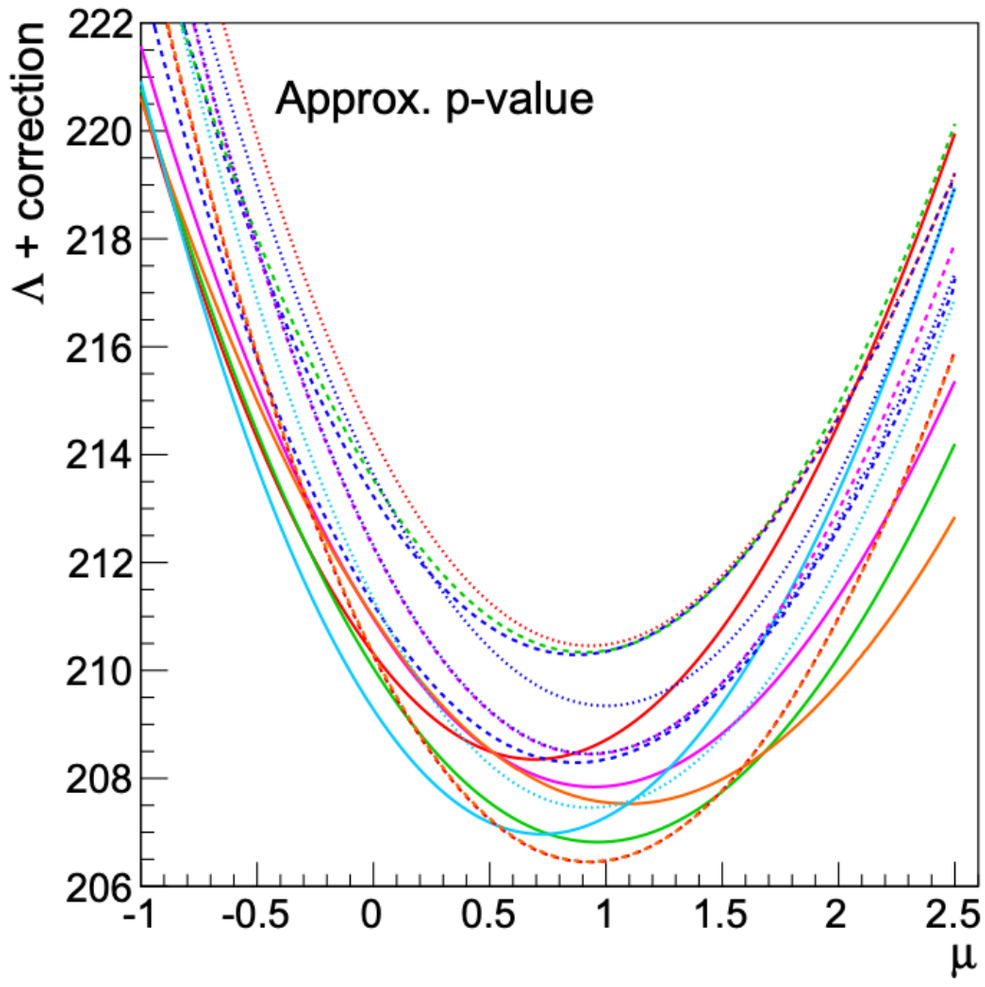


$$\frac{\frac{\mathscr{L}_1 - \mathscr{L}_2}{p_2 - p_1}}{\frac{\mathscr{L}_2}{n - p_2}}$$ For a 4th order to a 3rd order

Building a Model

- Throwing a barrage of functions at the problem

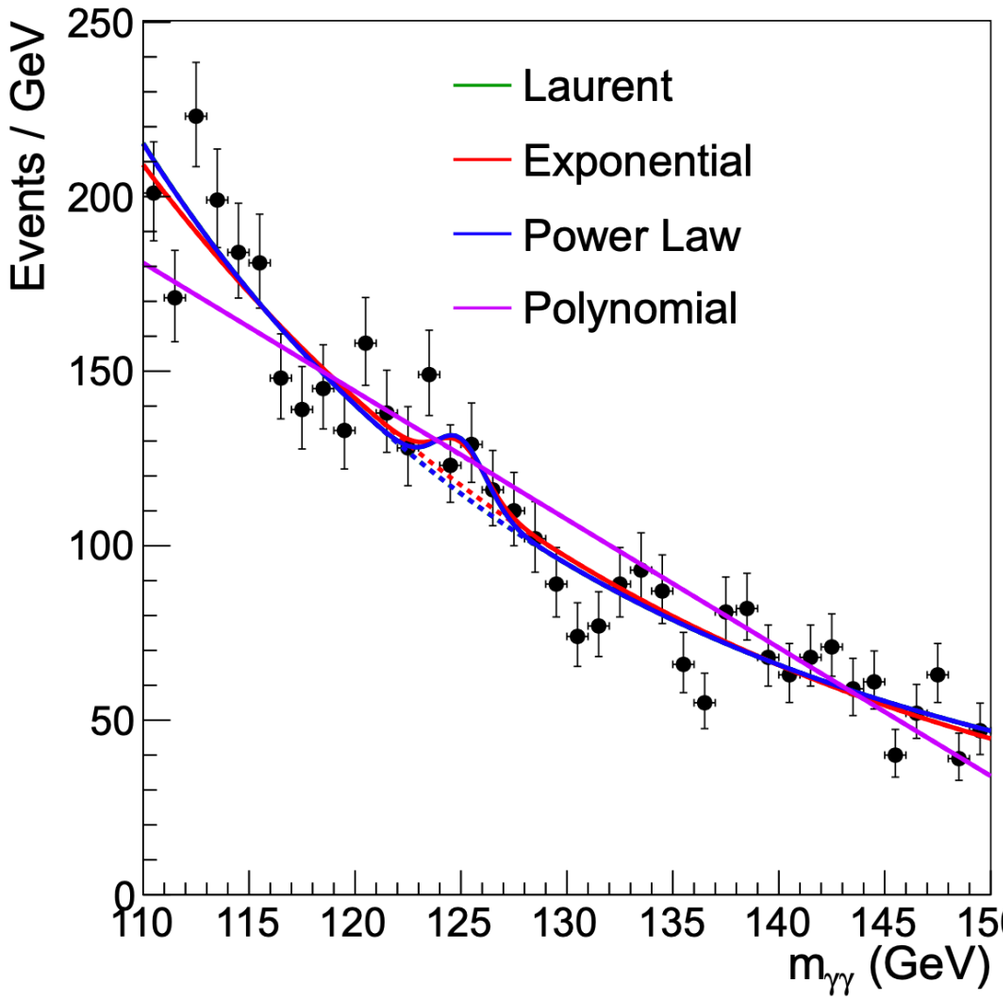


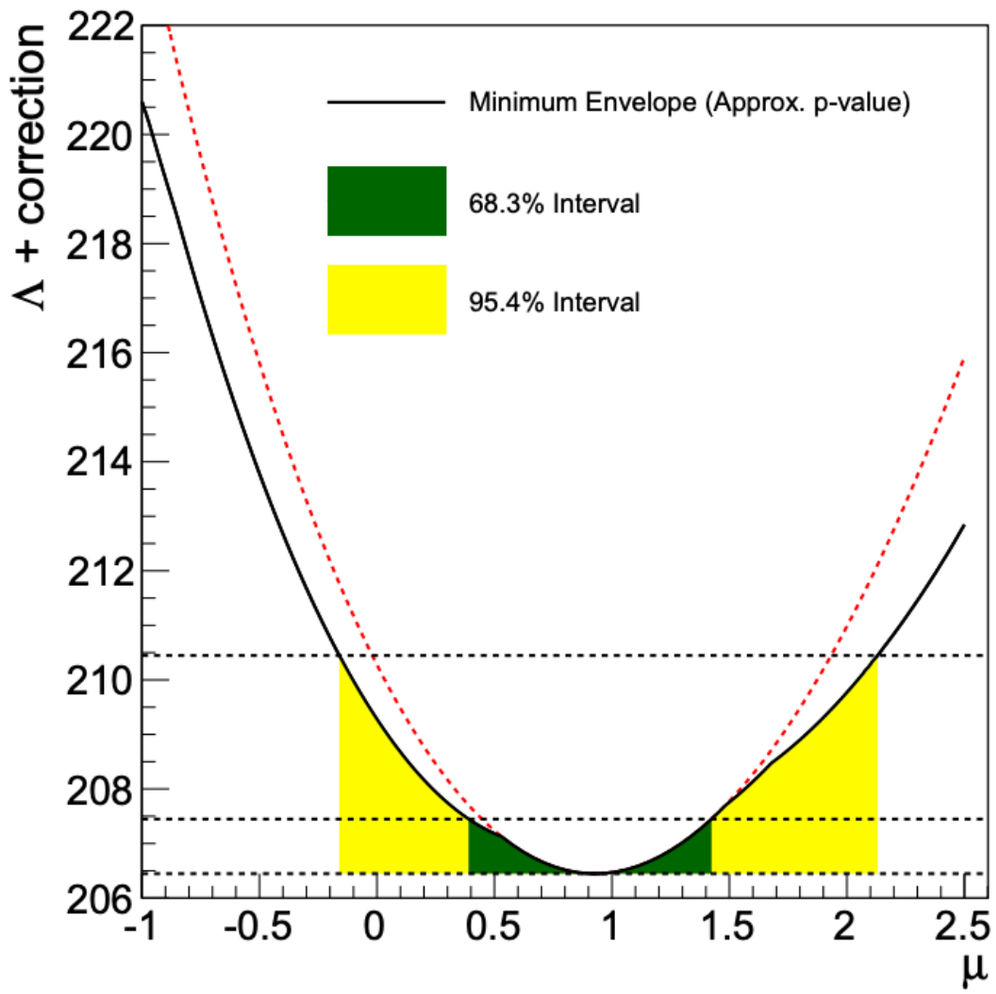


We can try a whole library of functions
The likelihood we get translates to our fit

Building a Model

- Throwing a barrage of functions at the problem

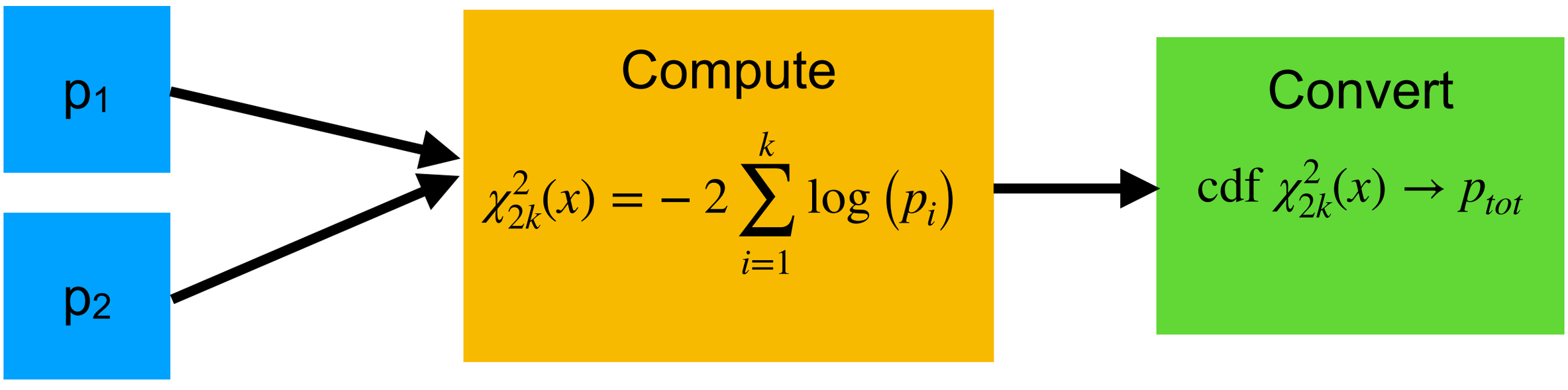




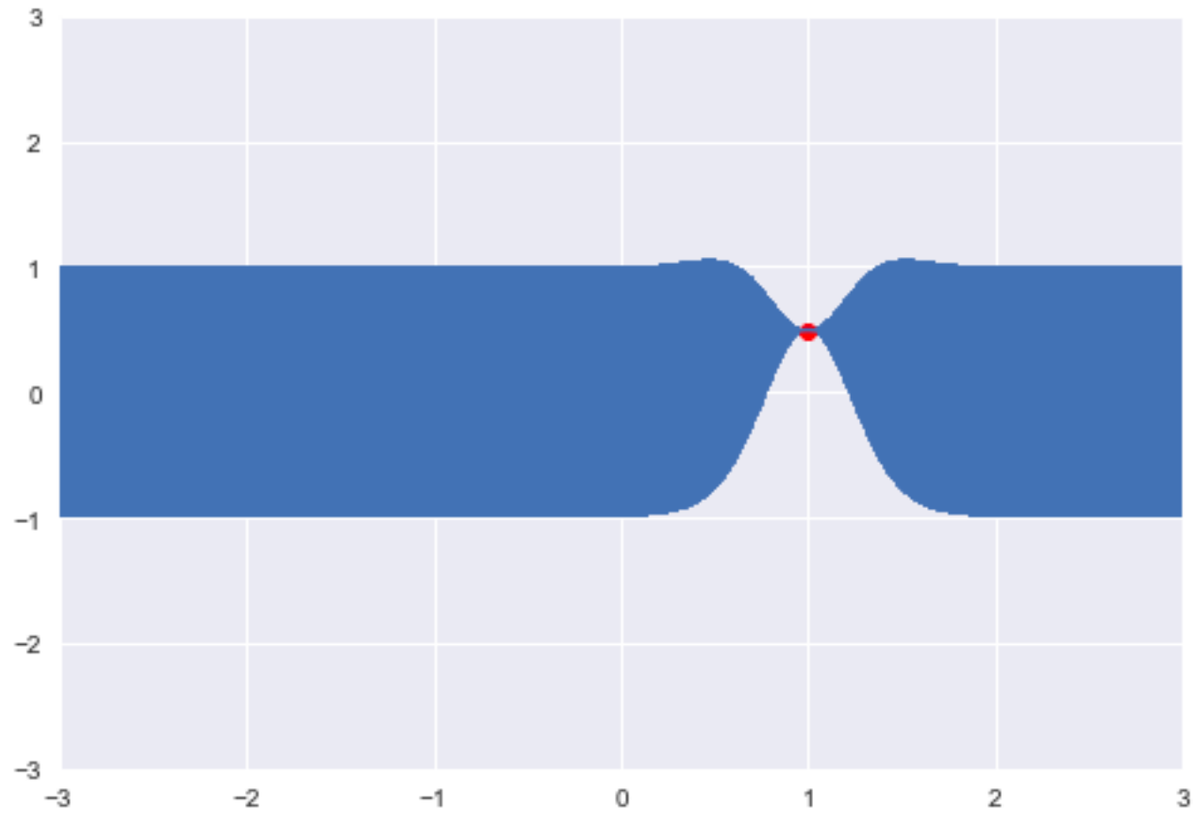
We can try a whole library of functions
The likelihood we get translates to our fit

Combining Categories

- Lets say we have *k* measurements with probability p_i
  - Each measurement is independent of each other
- We can combine categories using the following formula
  - $$\chi^2_{2k}(x) = -2\sum_{i=1}^{k}\log\left(p_i\right)$$
  - Where left is a chi2 distribution with 2k degrees of freedom

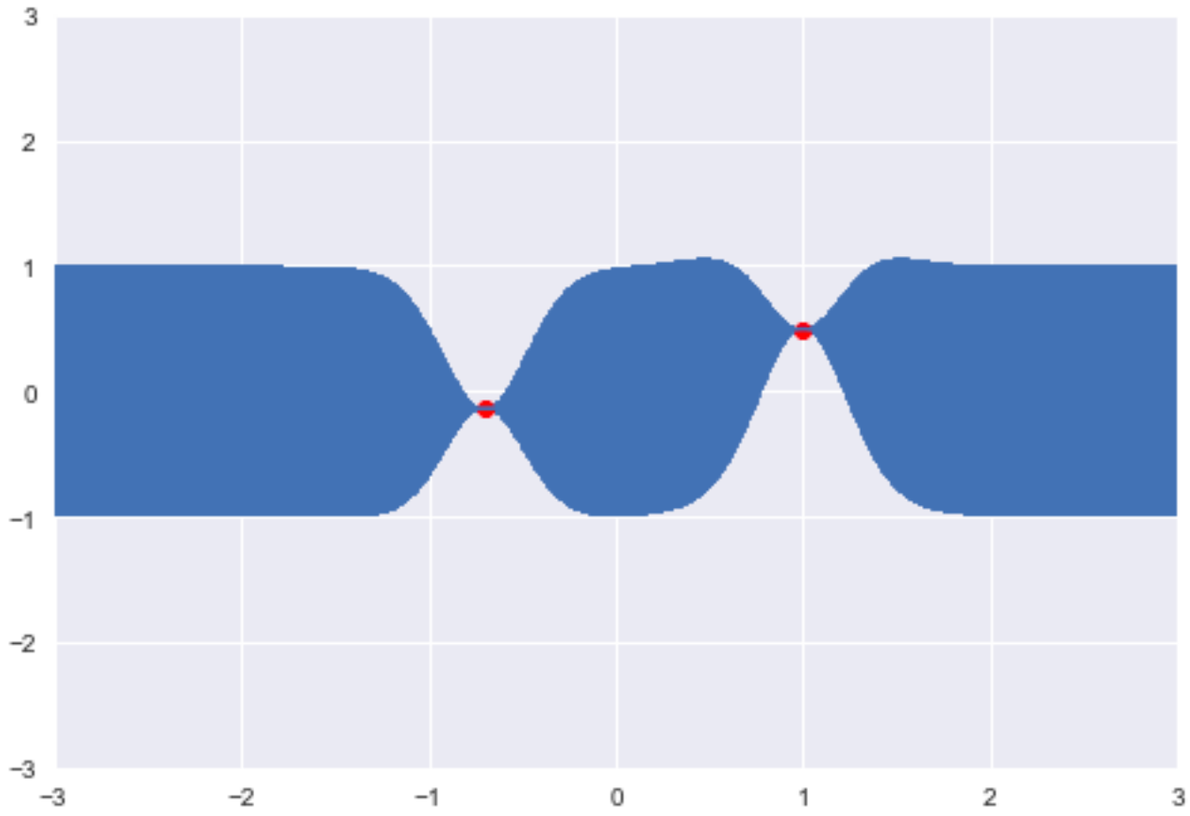


Splines+GaussianProcesses



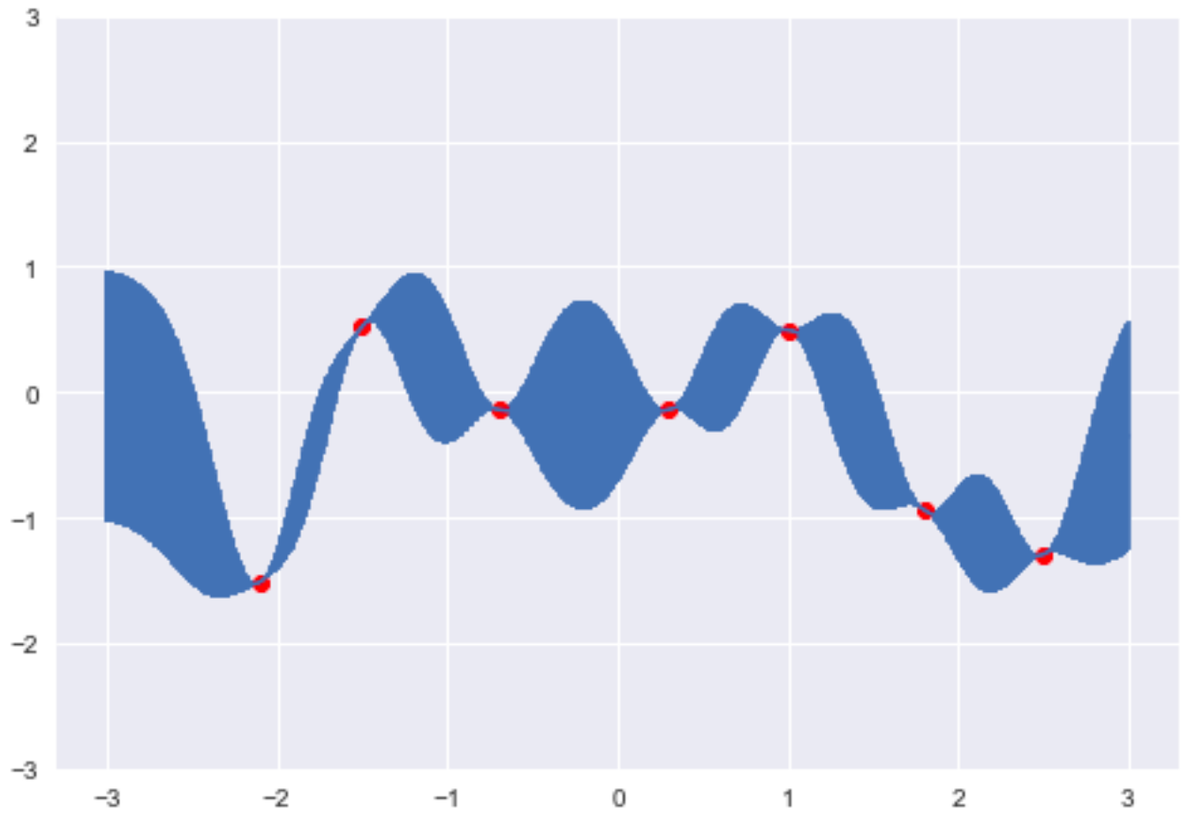
- Gaussian processes allow us to build function choice from the data

Splines+GaussianProcesses



- Gaussian processes allow us to build function choice from the data

Splines+GaussianProcesses



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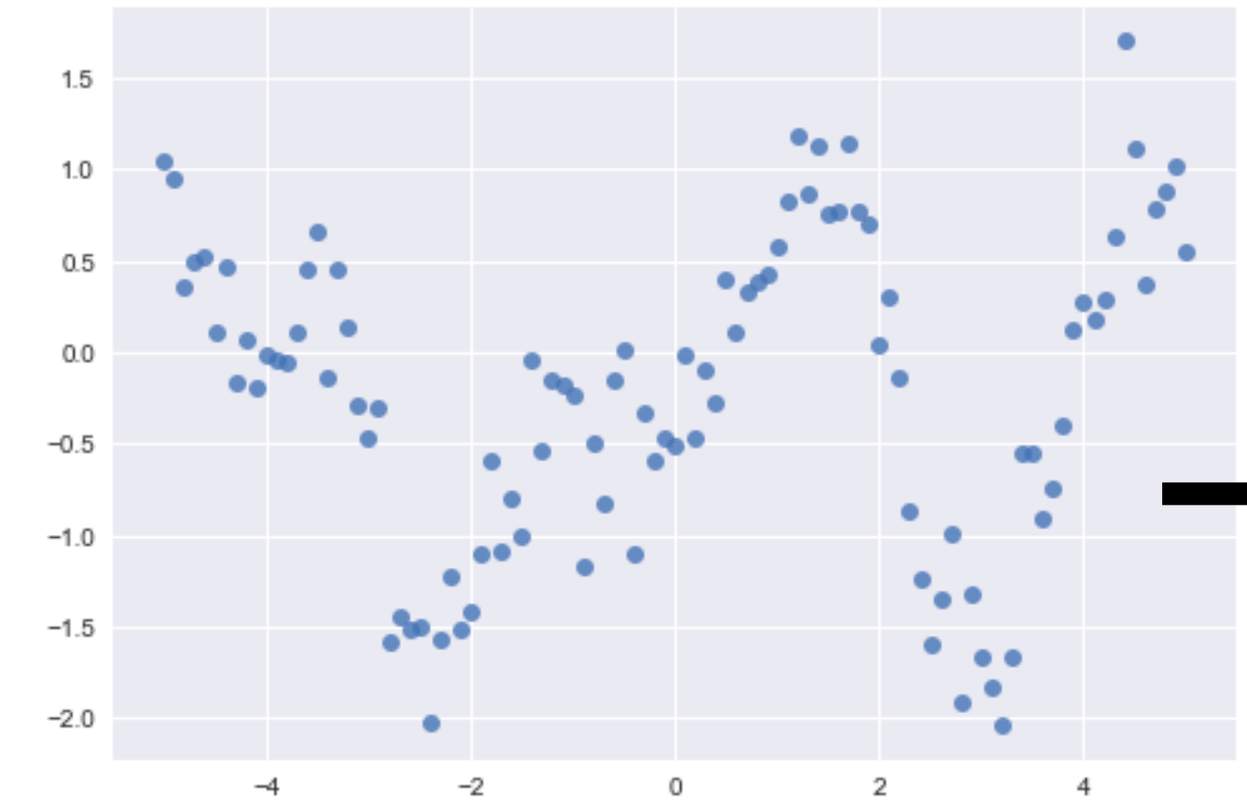
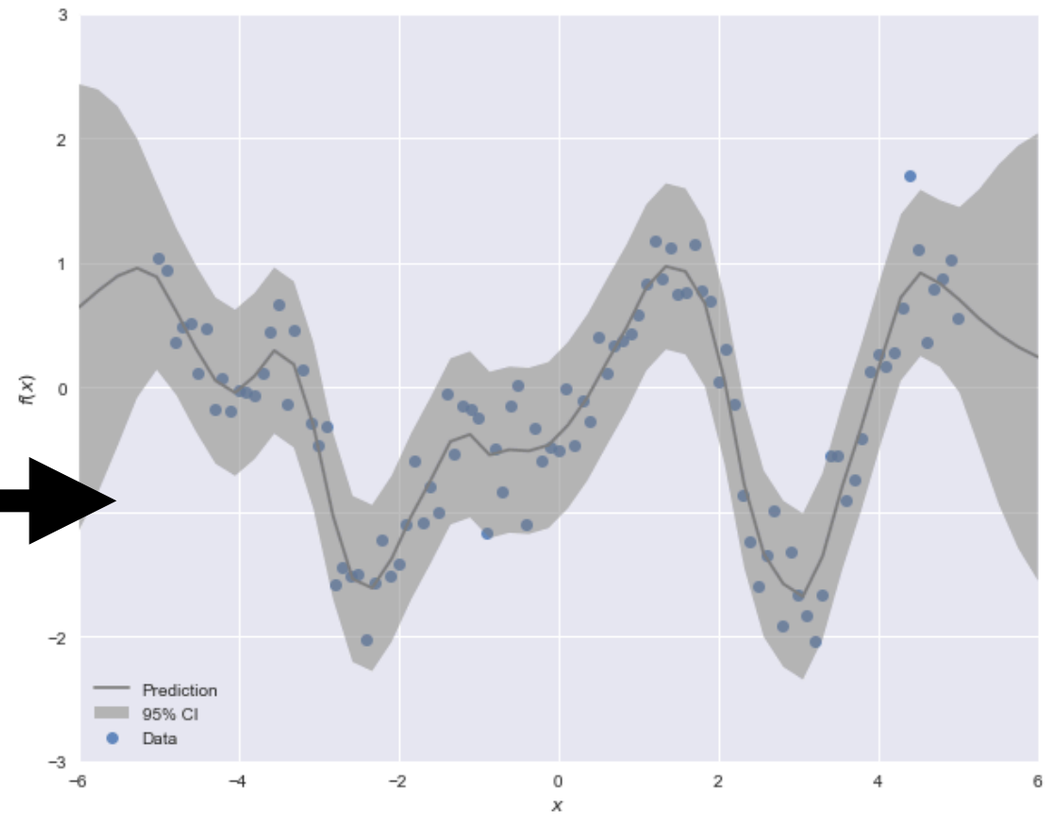
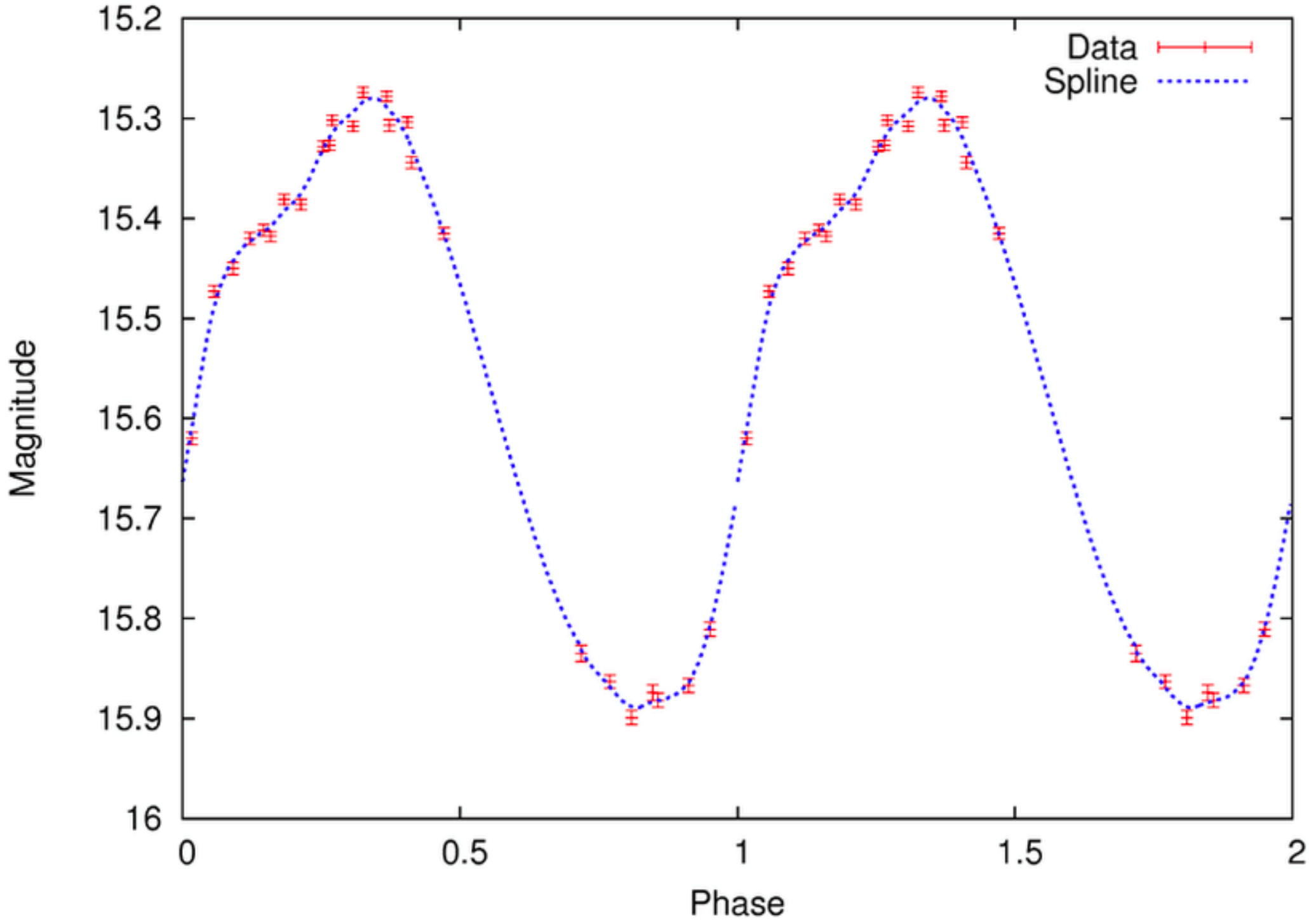
Splines+GaussianProcesses





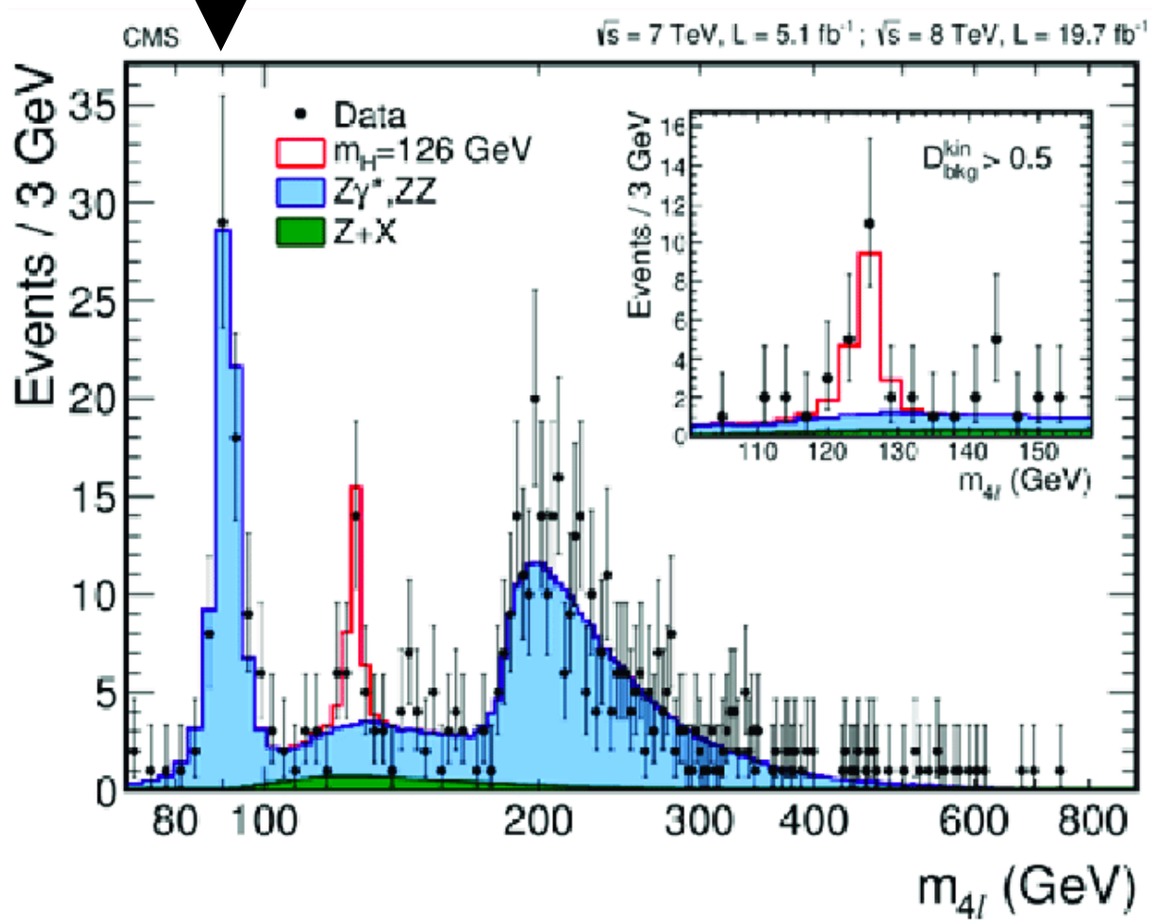
- To go from points to spline automatically

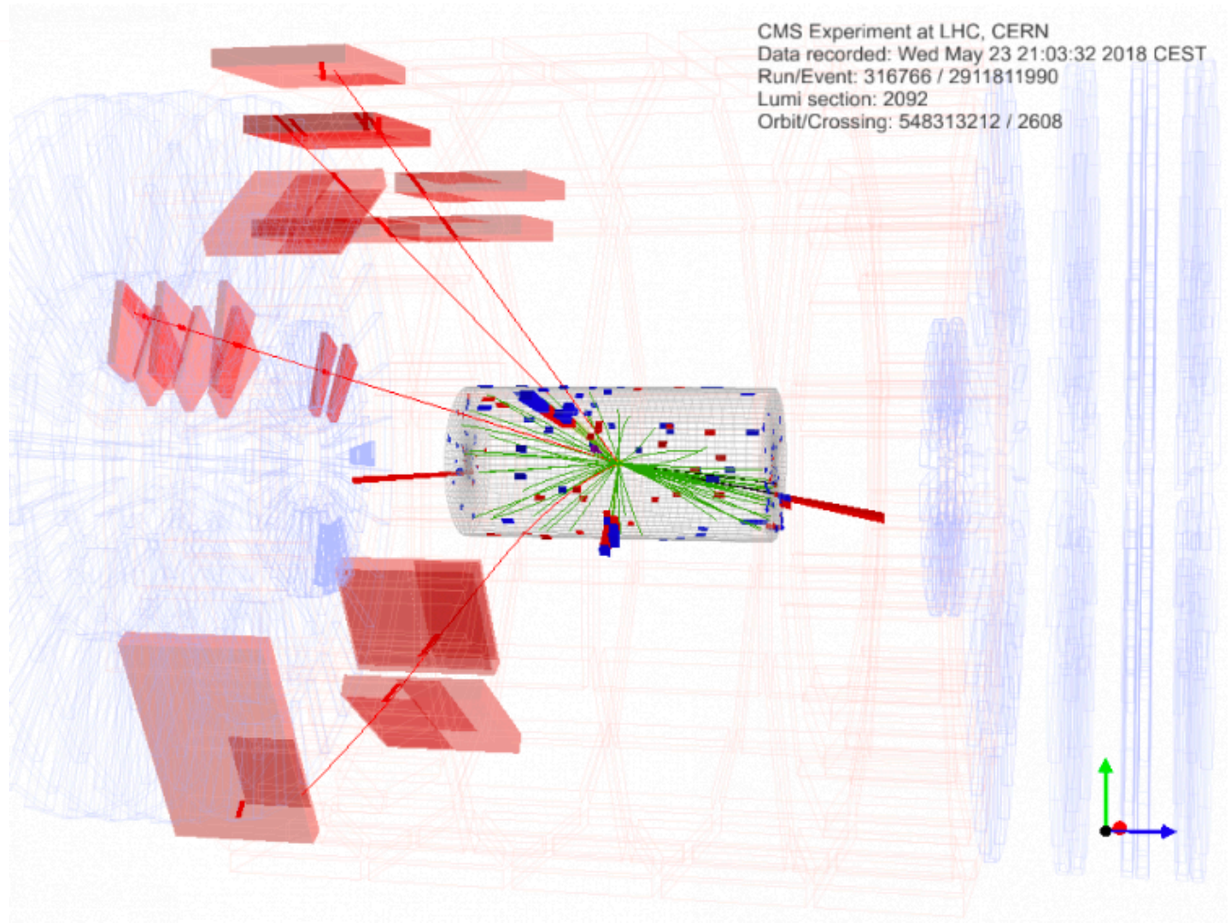
Splines+GaussianProcesses



Z-boson Peak

Higgs to 4 Leptons





- Higgs to 4 leptons aims at taking the mass of 4 leptons
  - A way to test the 4-leptons is the Z boson peak

Backup

Remind me at some point

Explain the Chow Test

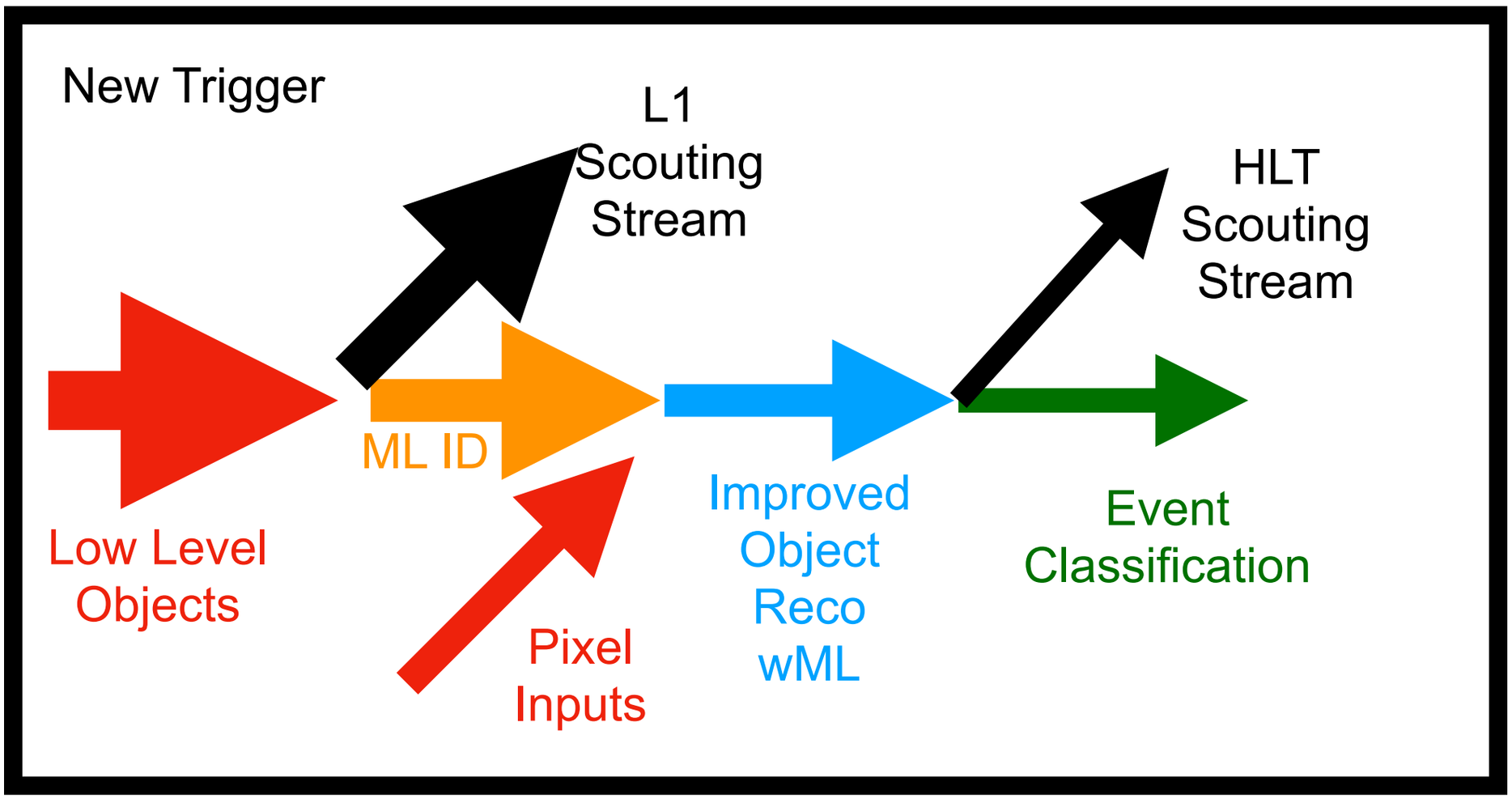
Higher Order Polynomial

- We can evaluate this through an F-test
  - Recall $\frac{MS_B}{MS_R} \approx 1 = F_{n-1\ m(n-1)}$

Test of higher polynomial order with F-test form is called the chow test

- Here we have $\frac{MS_B}{MS_R} \approx 1 = F_{p_2-p_1\ n-p_2}$ $F = \frac{\left(\frac{\mathrm{RSS}_1 - \mathrm{RSS}_2}{p_2 - p_1}\right)}{\left(\frac{\mathrm{RSS}_2}{n-p_2}\right)},$

Title Text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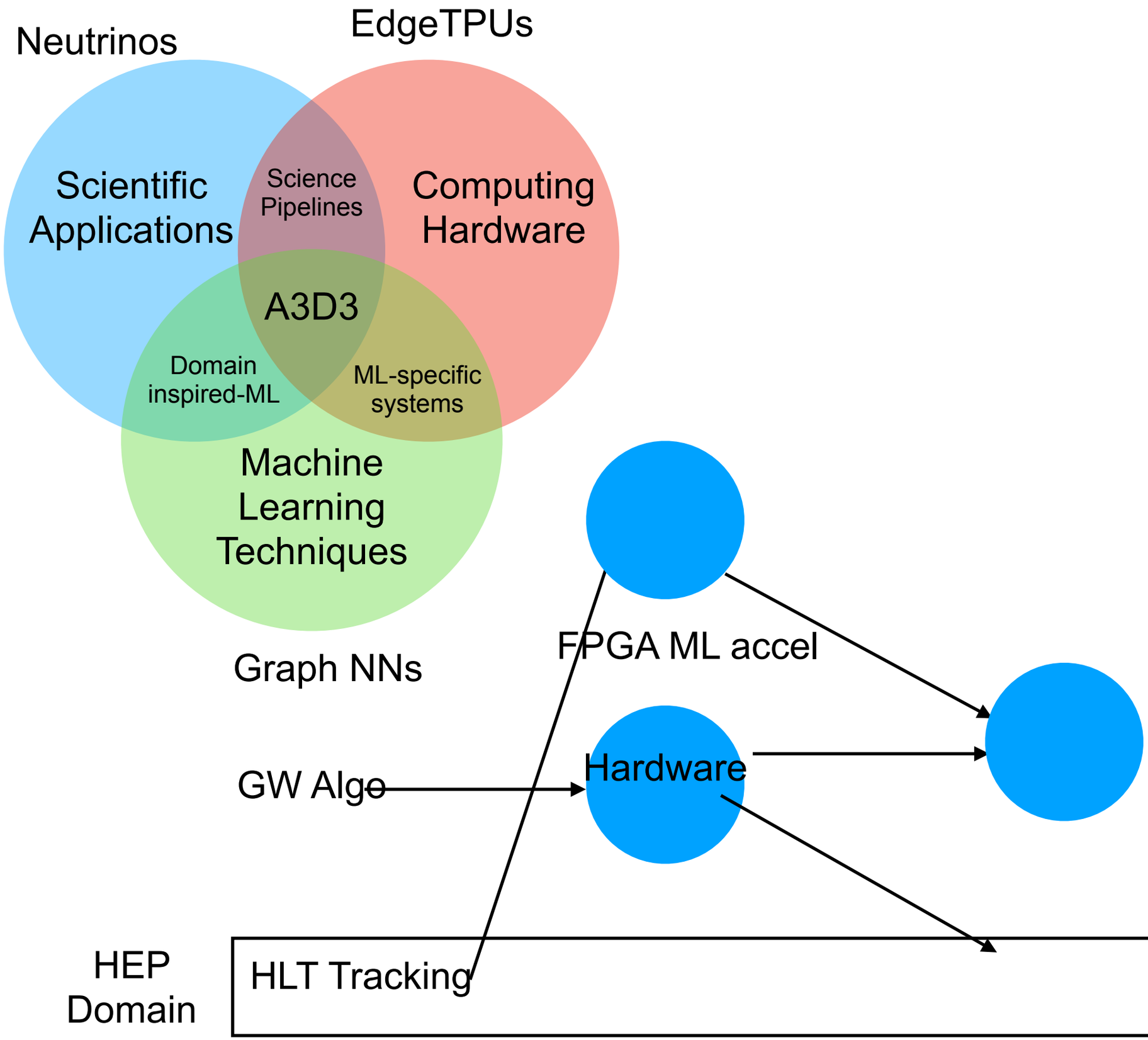
Scouting
Stream
HLT
Scouting
Stream
ML ID
Low Level
Objects
Pixel
Inputs
Improved
Object
Reco
wML
Event
Classification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