Using Foam as a Matrix Element Method Look-Up Table

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The Matrix Element Method

- Extracts Theoretical Information from Physical Events
- Used to find precise measurements of physical parameters or to search for new phenomena
- This method assigns a probability for each hypothesis, given a sample of events
- Basically, this method combines theory and physical events to accurately determine physical parameters based on complex systems

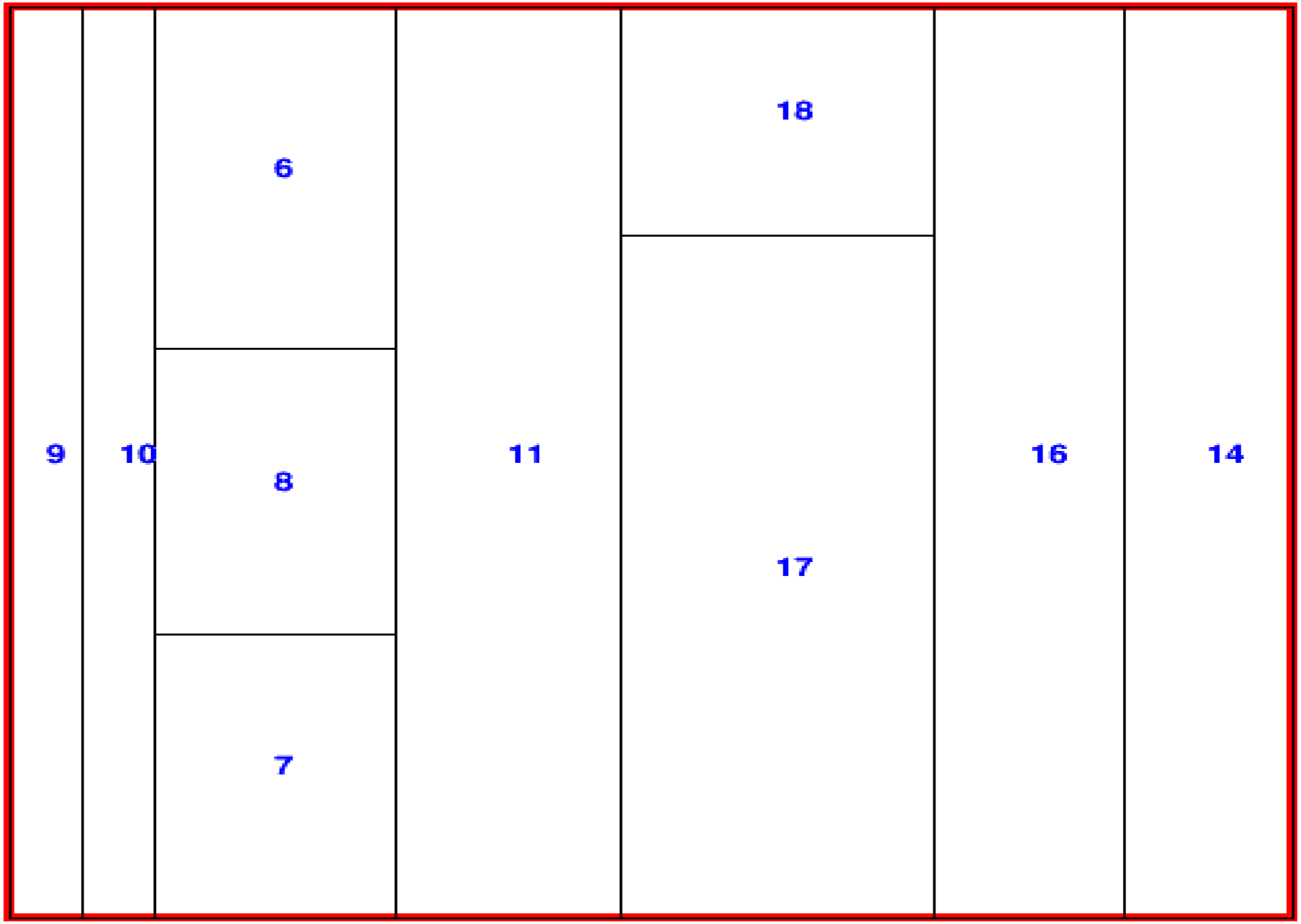
Issues with Matrix Element

- It is not particularly straightforward, as complicated theoretical scattering information and experimental information must be combined
- This makes the calculations very complex, and very inefficient
- Currently, the bottleneck is the calculation times

Solution: Foam

- Instead of calculating the matrix element for every event, store this on a look-up table of n dimensions, where n is the number of parameters
- Our look-up table consists of an n-dimensional data structure with non-equidistant binning, called foam
- This is basically an n-dimensional space consisting of hyperrectangles, inside each of which an integral is calculated referring to the probability of your hypothesis

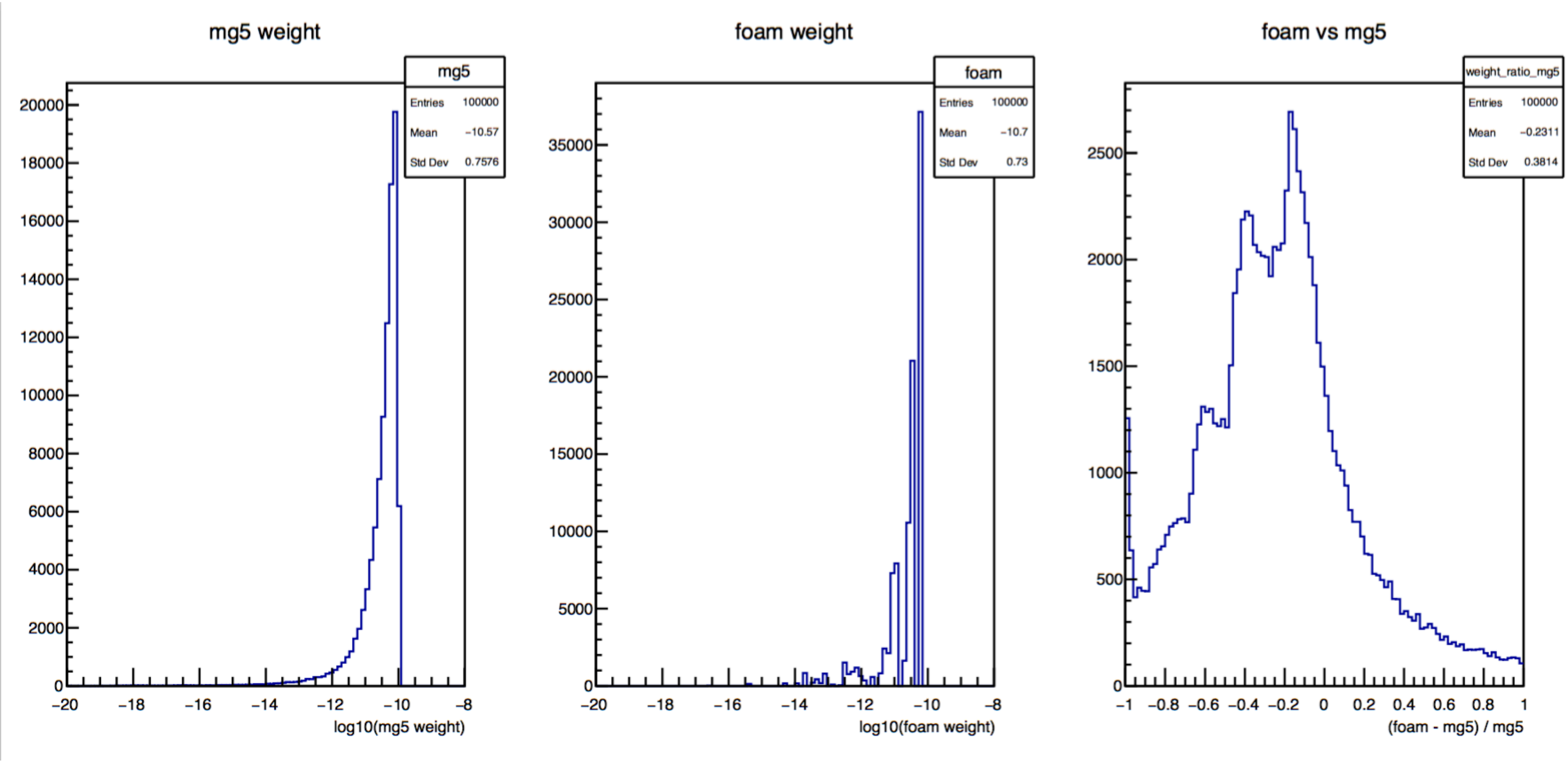
2x2 Foam Example



Optimizing Foam: Adding Cells

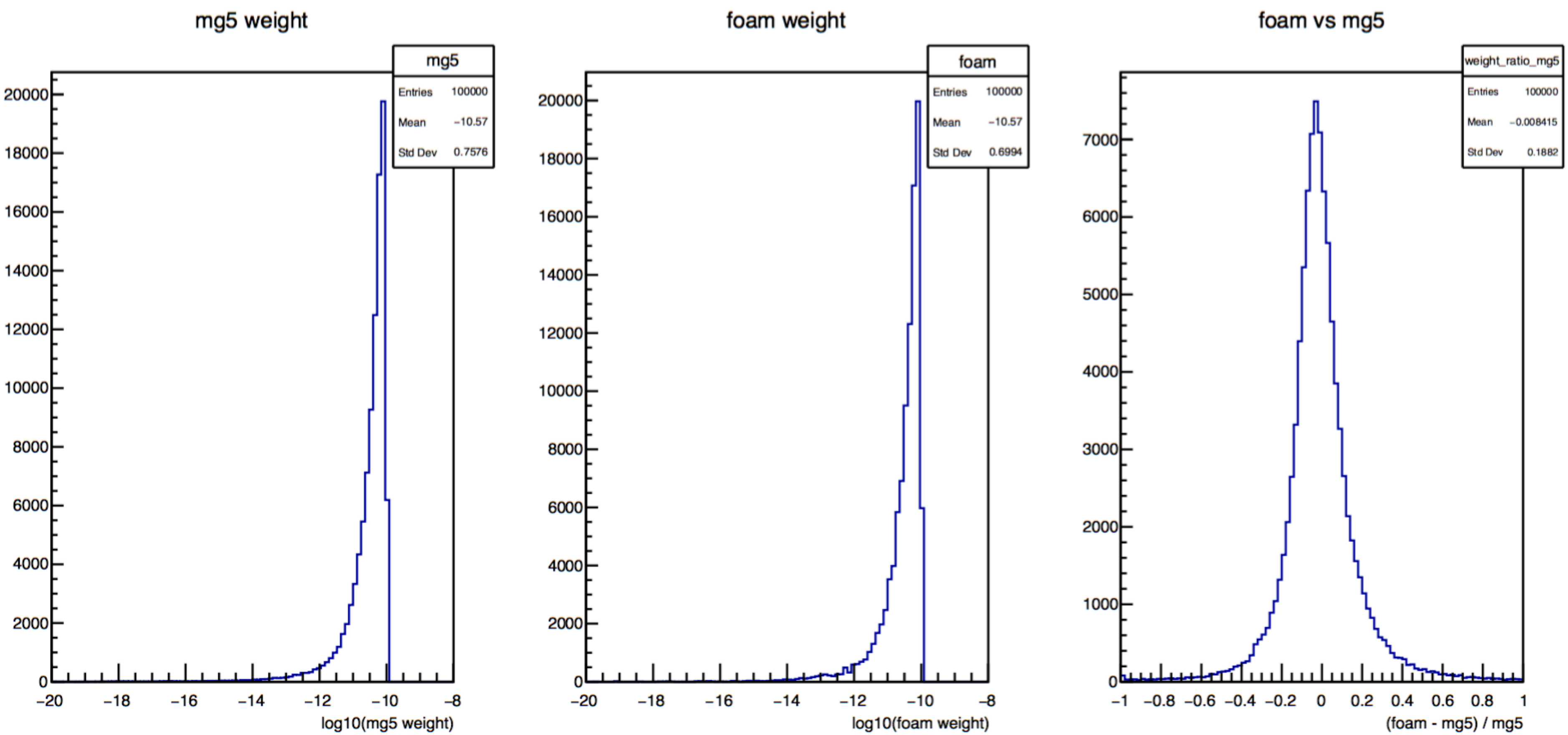
- The foam integral becomes much more accurate when more cells are added
- Unfortunately, it becomes a lot slower too
- My first project was to parallelize foam so that many more cells could be created in an individual foam

100 Cells

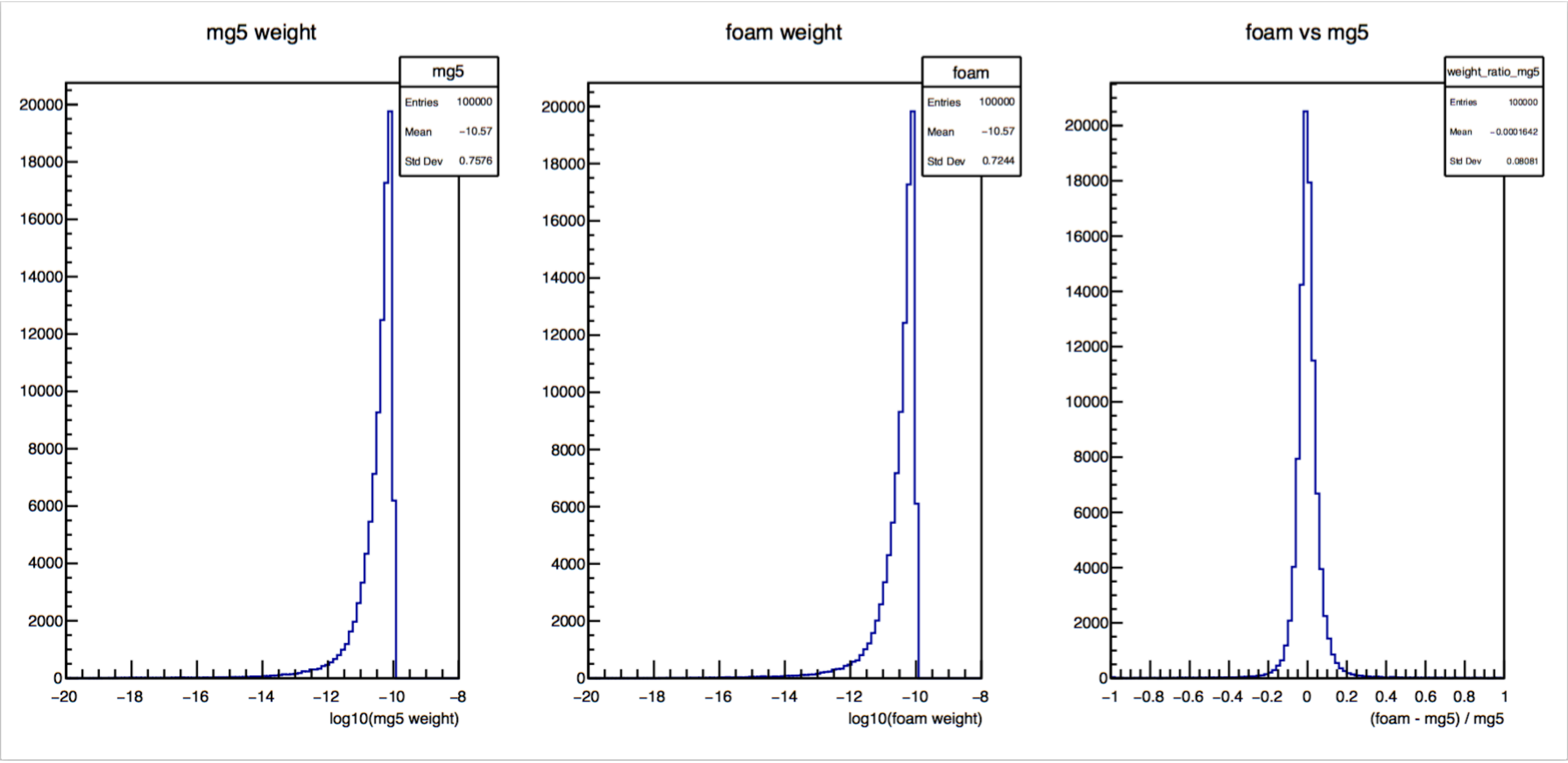


mg5 weight
mg5
Entries 100000
Mean −10.57
Std Dev 0.7576
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
20000
−20 −18 −16 −14 −12 −10 −8
log10(mg5 weight)
foam weight
foam
Entries 100000
Mean −10.7
Std Dev 0.73
0
5000
10000
15000
20000
25000
30000
35000
−20 −18 −16 −14 −12 −10 −8
log10(foam weight)
foam vs mg5
weight_ratio_mg5
Entries 100000
Mean −0.2311
Std Dev 0.3814
0
500
1000
1500
2000
2500
−1 −0.8 −0.6 −0.4 −0.2 0 0.2 0.4 0.6 0.8 1
(foam - mg5) / mg5

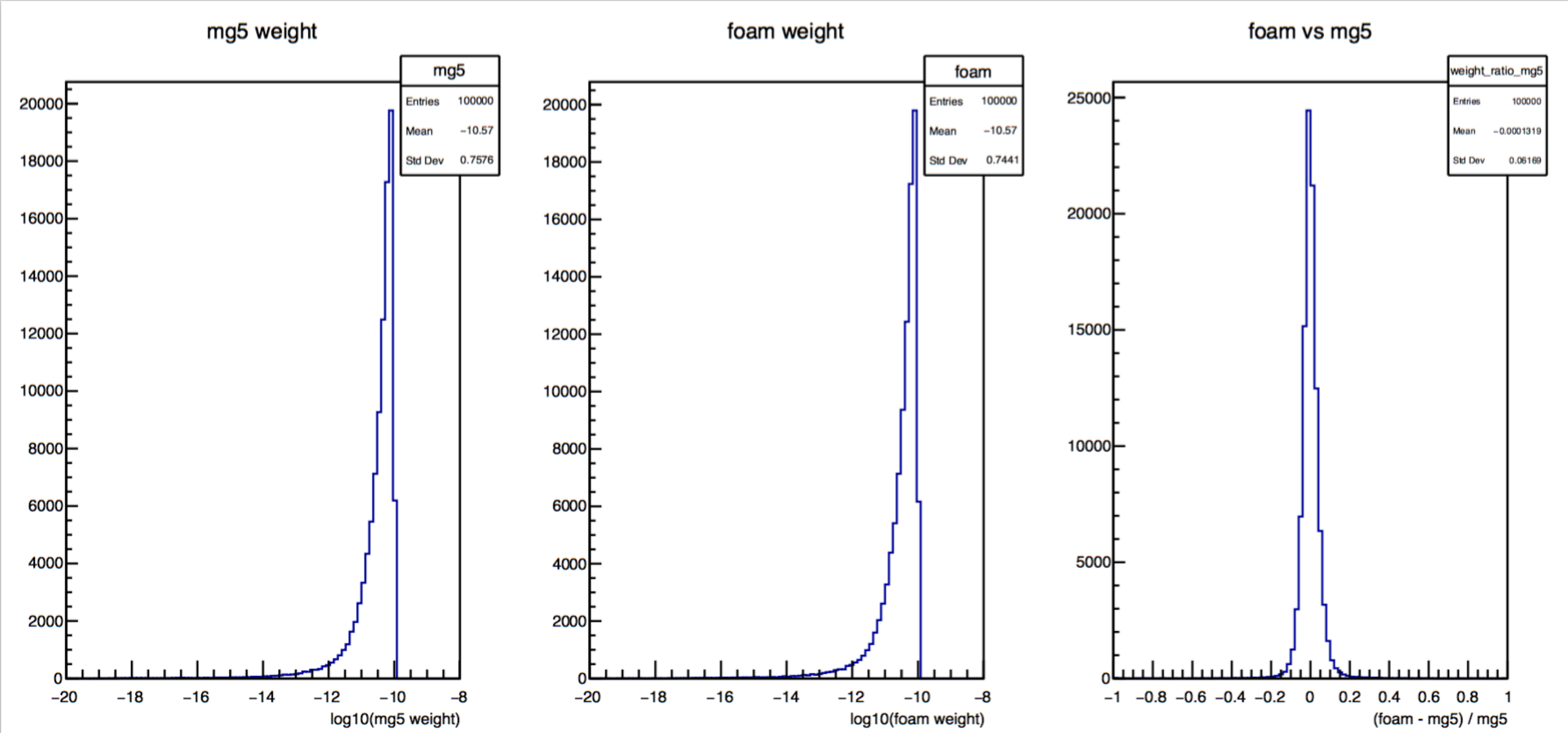
10000 Cells


mg5 weight
mg5
Entries 100000
Mean −10.57
Std Dev 0.7576
log10(mg5 weight)
foam weight
foam
Entries 100000
Mean −10.57
Std Dev 0.6994
log10(foam weight)
foam vs mg5
weight_ratio_mg5
Entries 100000
Mean −0.008415
Std Dev 0.1882
(foam - mg5) / mg5

1000000 Cells



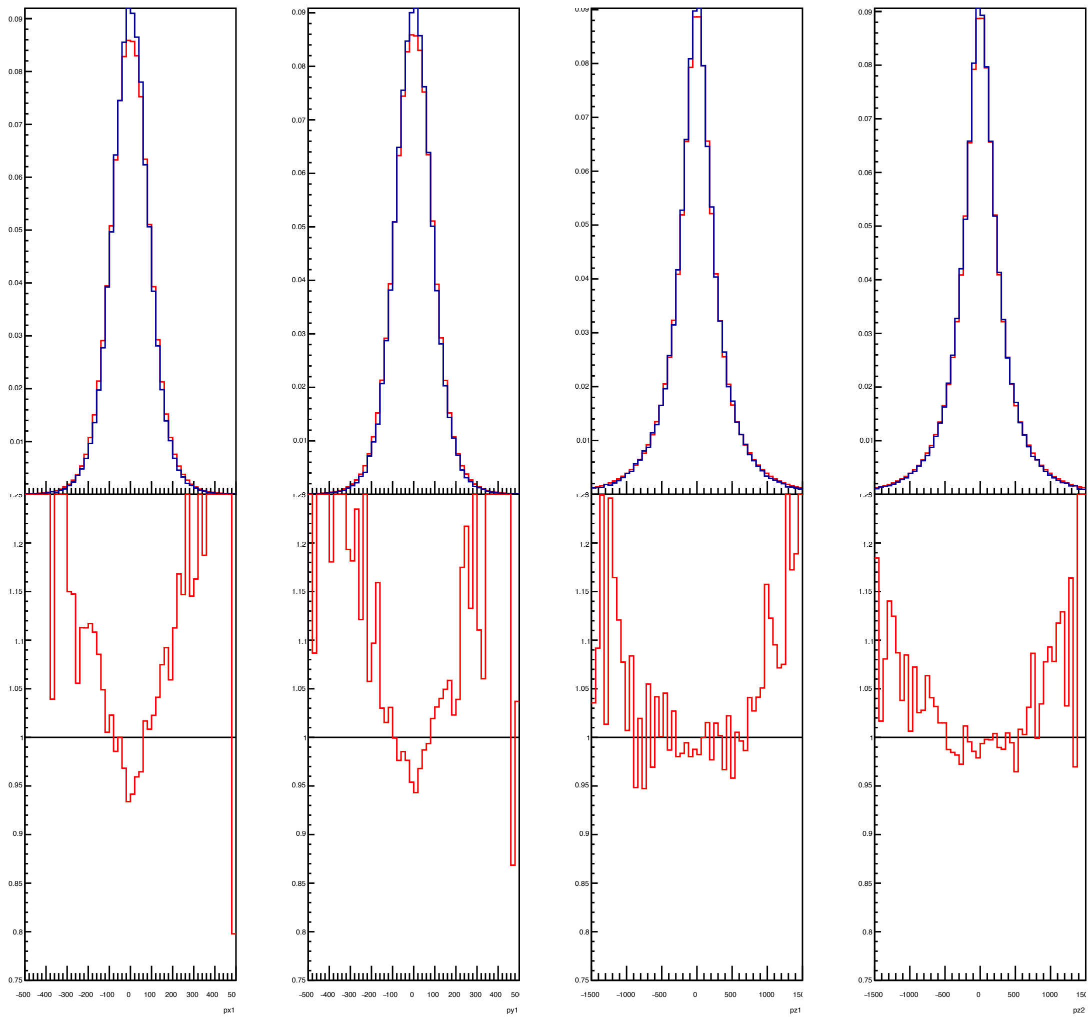
6.4 Million Cells (Biggest Yet)



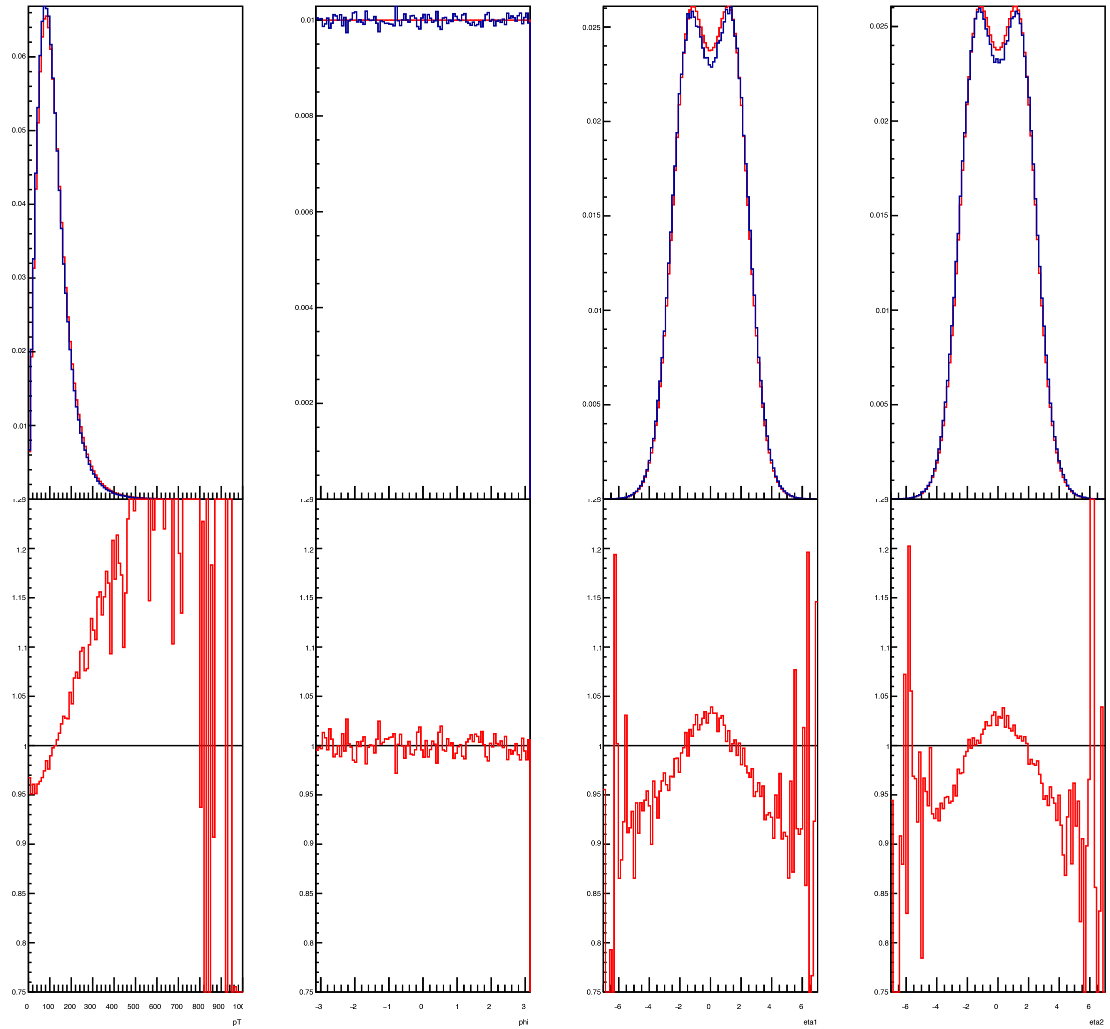
Optimizing Foam: Transforming Variables

- One of foam's weaknesses is measuring the top of sharply peaked variables
- This is because there may never be a hyperrectangle small enough to measure the very top of a peak
- By taking advantage of carefully calculated variable transformations, we can make our peaks much less steep

100000 Cell Foam Modeling ttbar collision (px1, py1, pz1, pz2)



100000 Cell Foam Modeling ttbar collision (pT, phi, eta1, eta2)



Long Term Issues

- There are over 40 different valid Feynman diagrams for ttbar, with different smooth variable choices
- Solution: Build up separate foams for each class of Feynman Diagrams
- Eventually, we'll also need a lot more cells because we'll have a lot more dimensions

Sample Feynman Diagrams for TTbar

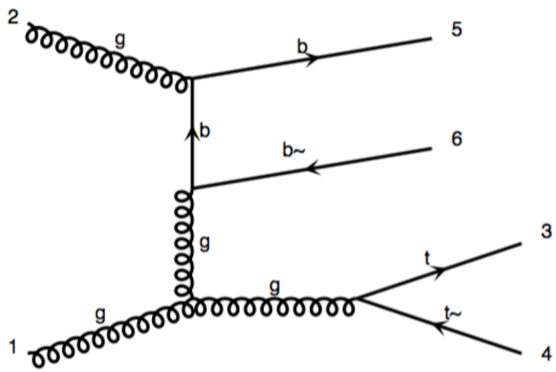


diagram 31 QCD=4, QED=0

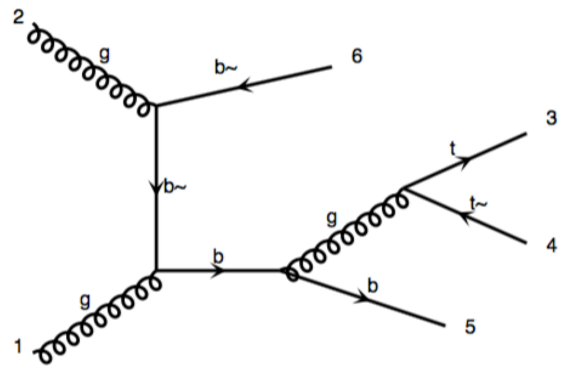


diagram 32 QCD=4, QED=0

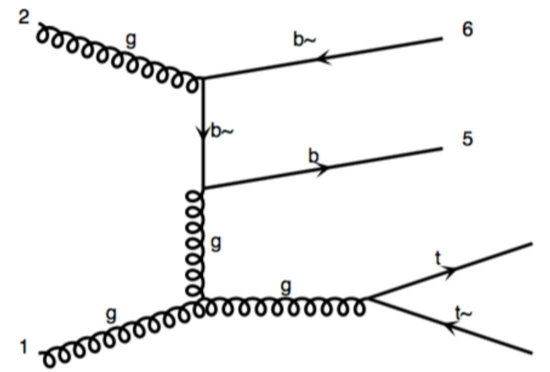


diagram 33 QCD=4, QED=0

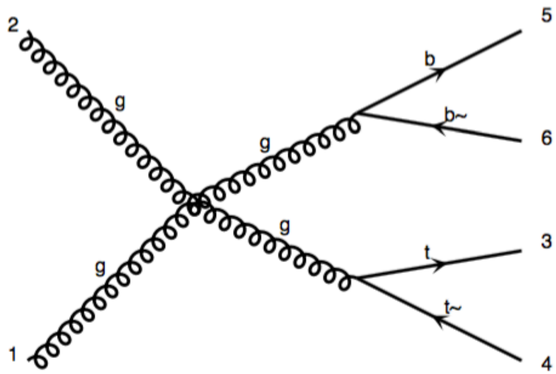


diagram 34 QCD=4, QED=0

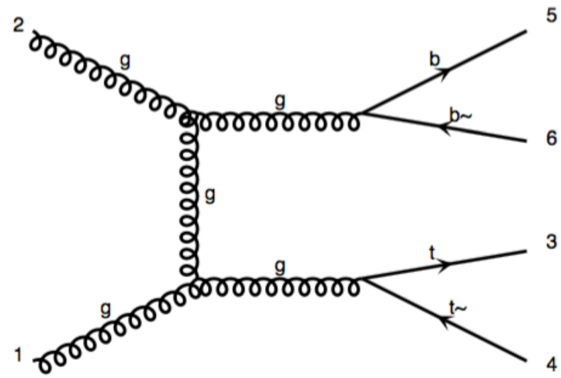


diagram 35 QCD=4, QED=0

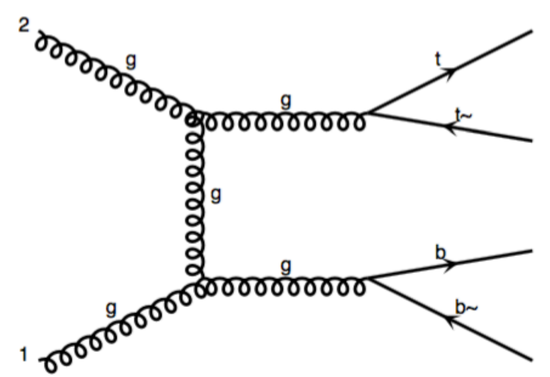


diagram 36 QCD=4, QED=0

Sample Feynman Diagrams for TTH

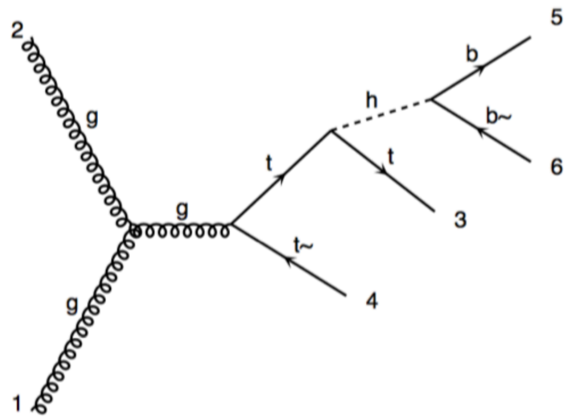


diagram 1 QCD=2, QED=2

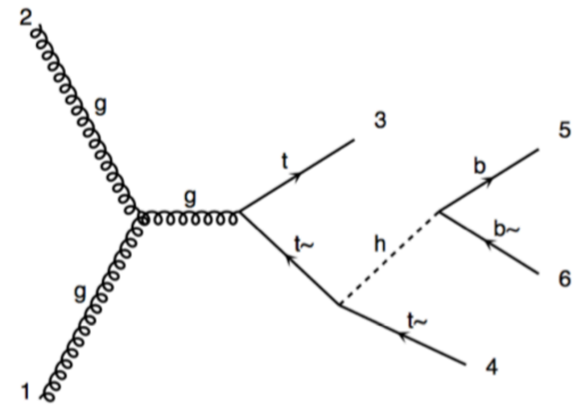


diagram 2 QCD=2, QED=2

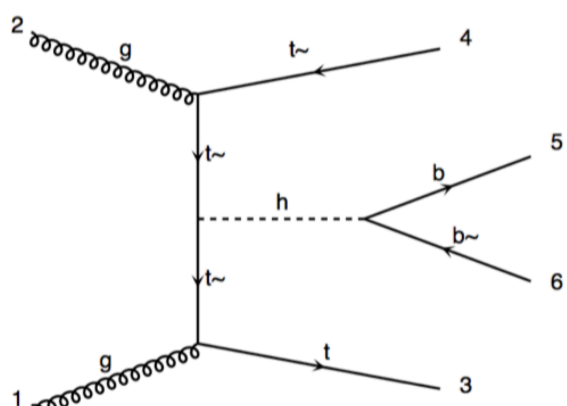


diagram 3 QCD=2, QED=2

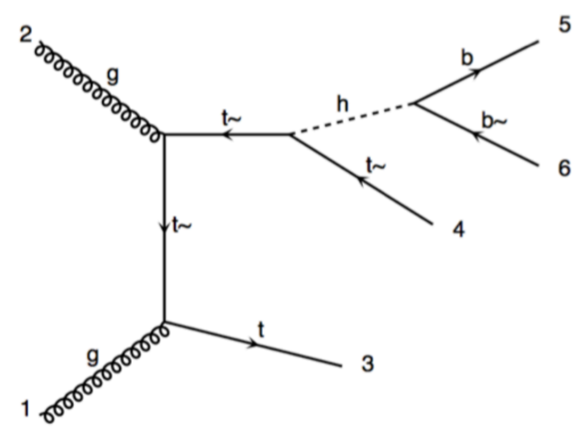


diagram 4 QCD=2, QED=2

European Immersion!