Using FOAMs to Approximate Probability Densities for ttbar Processes

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Background: Monte Carlo Simulations

- Obtain numerical results for problem via a probabilistic analogue

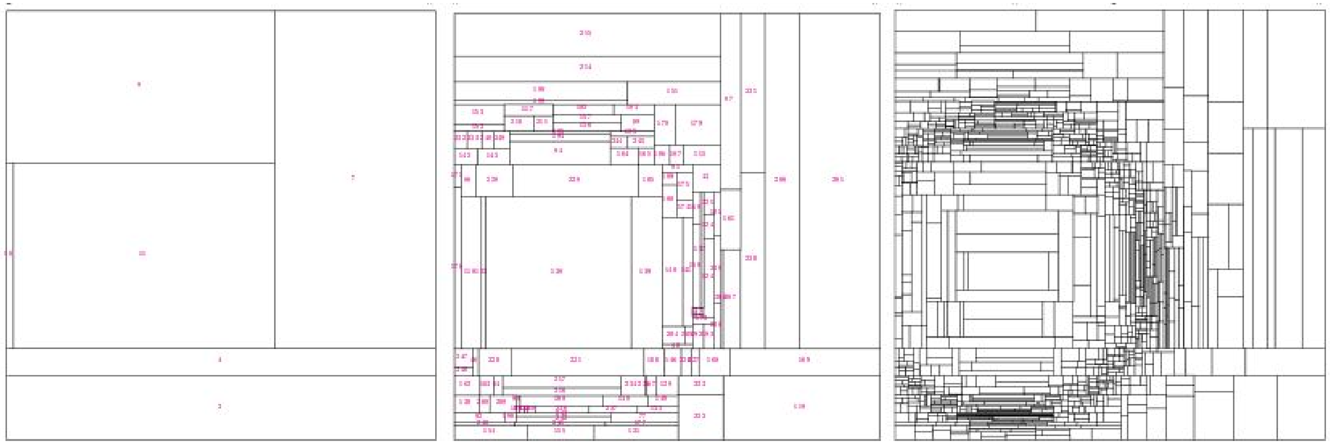
- Applications are incredibly widespread
  - Mathematics: integration and optimization problems
  - Finance: risk analysis, investment predictions
  - Signal processing, fluid dynamics, ion implantation, etc…

- Summer Student Lecture by Bryan Webber (Cambridge) [1]

- Specific to particle physics: want to generate particle collision/decay chains, integrate over them, and extract meaningful parameters.

Background: FOAM

- FOAM models functions via a recursive cellular division algorithm. [2]

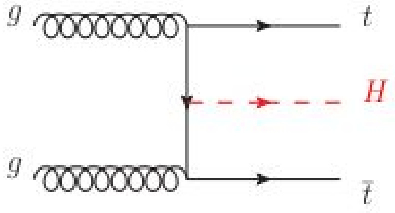


- Specifically, it can store an MC-distribution in a comp. efficient way.
- MC events can be generated very efficiently from this format.
  - But FOAM only converges to distribution after many cell divisions.
  - Number of cells needed is highly dependent on function sampled.

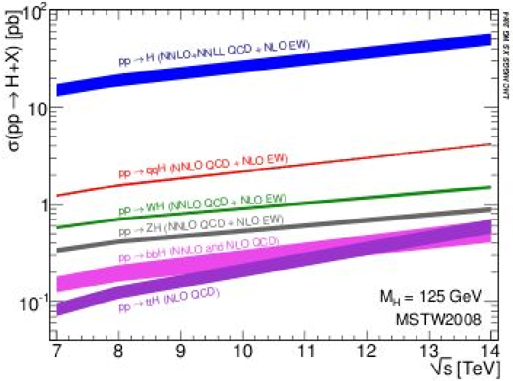
Application: ttH

- ATLAS Experiment: general-purpose detector for SM and BSM physics.

- ttH: rare Higgs production mode, interesting because sensitive to top Yukawa-coupling.



- Matrix Element Method (MEM) is powerful here.
  - Evaluates consistency of measured event with a hypothesis, specifically using the ttH “likelihood ratio” as a discriminant [3].

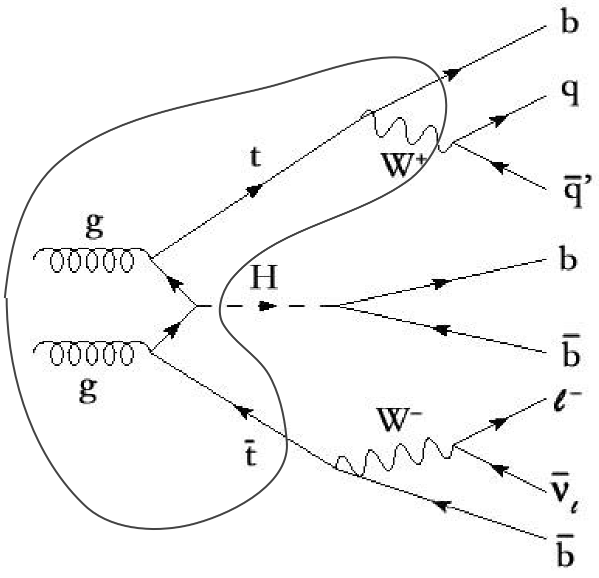


- Effective, but very computationally intensive.

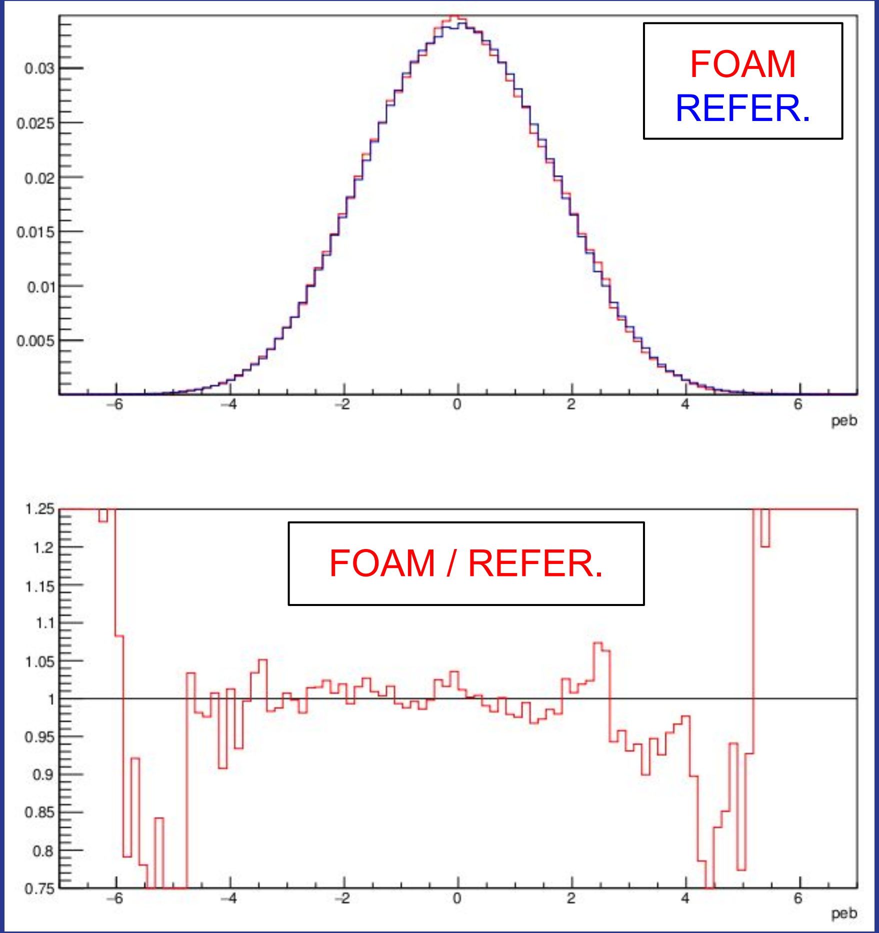
- FOAM should supplement MEM by improving efficiency of MC event generation.

Example simulation

Investigating lower-dimensional subsets of full ttH diagram: Overall success!



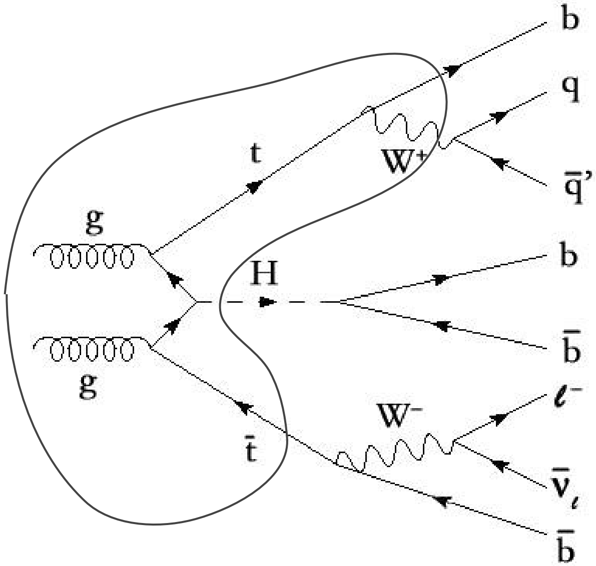
[4]



D = 7 g g > t tbar with (t > b w+)

Example simulation

Lingering asymmetries…
Are they connected?



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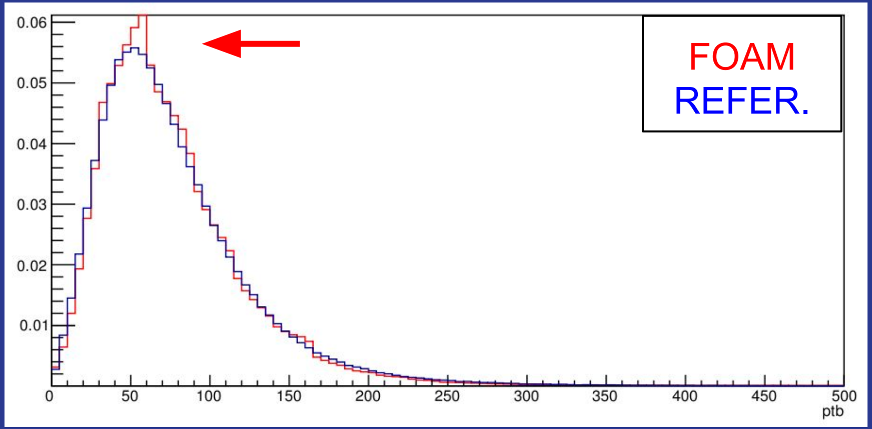
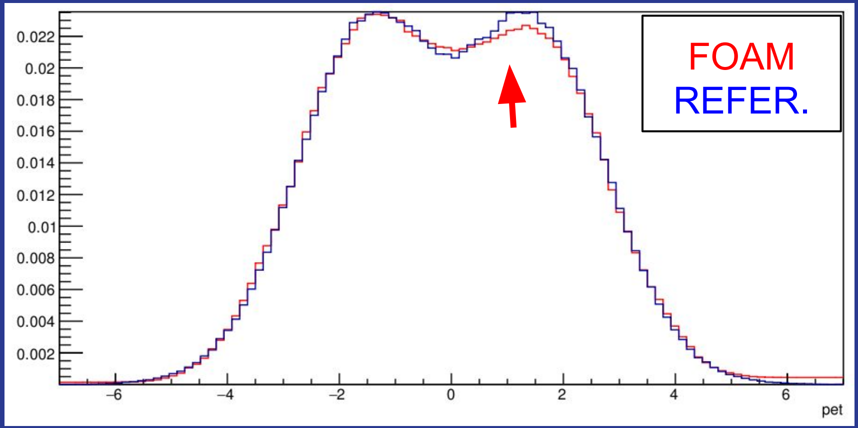


Transverse momentum of b

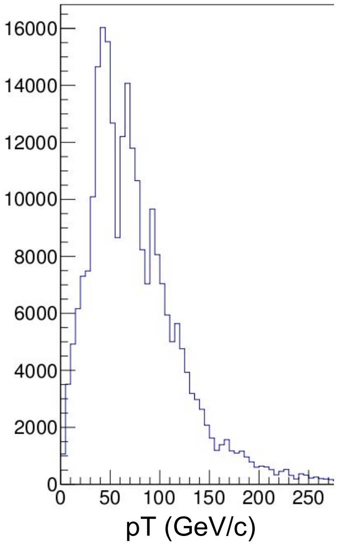


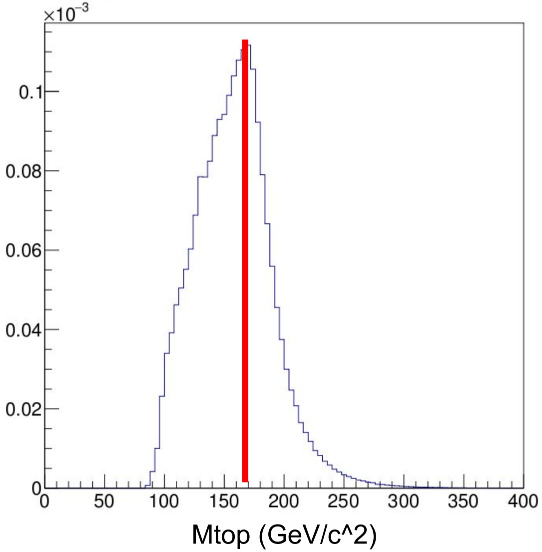
Pseudorapidity of tbar

Investigating further

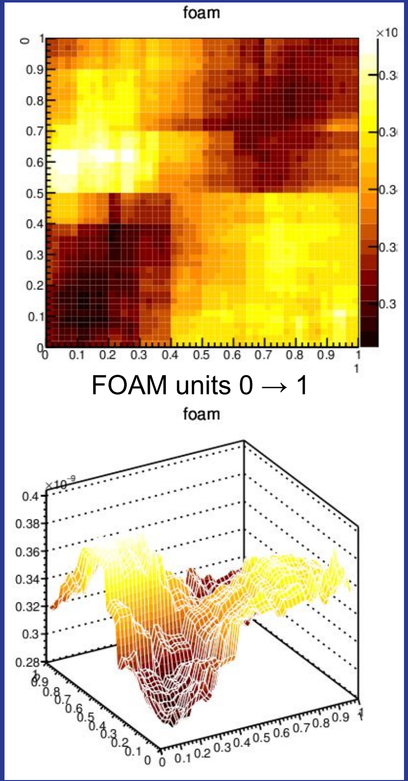
Extracted and plotted split locations for each dimension.

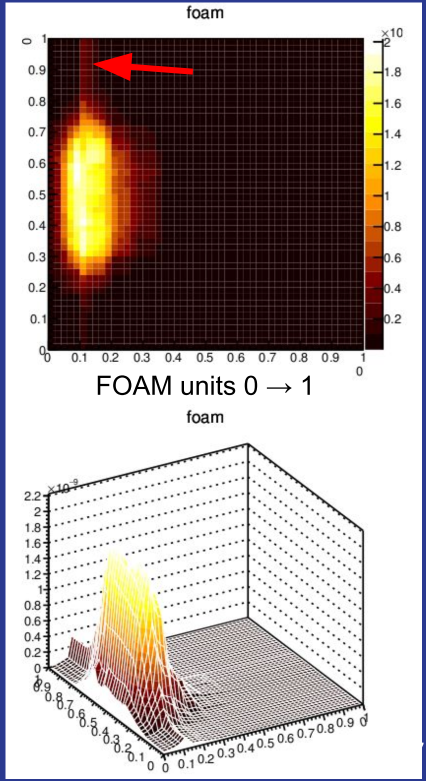
Calculated top resonance mass from b and W+ momenta.





Plotted all 2-d projections of FOAM (only 2/7, but better than 1/7!).
Two interesting features, in
<u>b.phi vs W+.phi</u> & <u>b.pT vs tbar.eta</u>

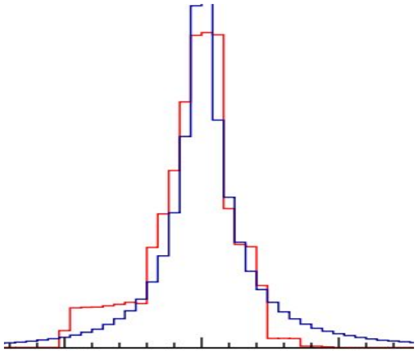




Conclusions

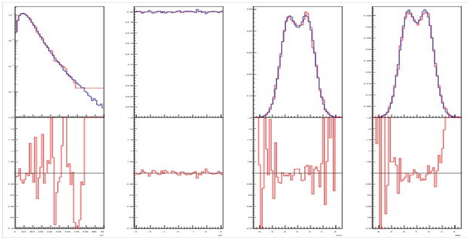
The Challenge

Rate of FOAM convergence decreases rapidly in higher dimensions, especially with strong peaking.



Progress So Far

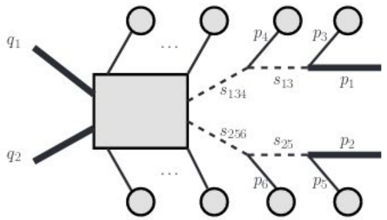
Implementation of 7-dimensional FOAM for g g > (t>bw+) tbar process.



Development of tools for building and evaluating FOAMs with different choices of variables.

Ongoing Work

Extending techniques to g g > (t>bw+)(tbar>bbar w-), general decay chains.



[4]

Assembling all developed tools into cohesive package for interfacing with FOAM.

Works Cited:

- [1]: Webber, Bryan. “Introduction to Monte Carlo Techniques.” CERN Summer Student Lectures. 31 July 2017, Meyrin, Switzerland.
- [2]: Jadach, S. “Foam: A General-Purpose Cellular Monte Carlo Event Generator” arXiv:physics/0203033 [physics.comp-ph]
- [3]: Search for the Standard Model Higgs boson produced in association with tt and decaying into bb at 8 TeV with the ATLAS detector using the Matrix Element Method - Nackenhorst, Olaf CERN-THESIS-2015-186
- [4]: Automation of the matrix element reweighting method - Artoisenet, Pierre et al. JHEP 1012 (2010) 068 arXiv:1007.3300 [hep-ph] CP3-10-27, RM3-TH-10-17

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Any Questions?