Simulating Physics at High-p_T

Monte Carlo Experience from RunII

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- Why do we need Monte Carlo?
- How will we do this?

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Disclaimer:  based on my (limited) experience in RunII
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- MC will not be used to discover

  It will play a part, but not indispensable

- It will be used to understand

  It will give confidence

  Can be used for interpretation

Most asked MC questions

1. How can I estimate the "theoretical" systematic uncertainty in a MC prediction?
   - Setting a limit, measuring a physics quantity
2. How can I add different "exclusive" MC samples to make a more inclusive one?
   - i.e. 3 jets + PS $\oplus$ 4 jets + PS
   - setting a better limit, making a more powerful discovery

These are not unrelated!

Prime goal for LHC physics

Q1: Estimating "Theoretical" Uncertainty

Dissection of a MC Prediction

$$d\sigma \sim \sigma_0 H(Q) \exp\left\{ -\int_{C_2 Q_0^2}^{C_1 Q^2} \frac{d\mu}{\mu} \left(A(\alpha_s) \ln\left(\frac{C_1 Q^2}{\mu^2}\right) + B(\alpha_s) \right) \right\} F_{\text{NP}}[C_1, C_2] \text{ SGA}$$

$$+ \left(\text{Fixed Order - Asymptotic} \right) [C_1, C_2] \text{ HGC}$$

C_1, C_2 set the infrared cutoff and hard scale

SGA $\equiv$ Soft Gluon Approximation; HGC $\equiv$ Hard Gluon Correction

- "Standard" Practice is to turn off ISR (FSR) to evaluate uncertainty
  - $C_1 \to C_2 (Q_0/Q)^2$ everywhere

1. HGC missing except for special (simple) cases
2. Refitting F_{NP} is no easy task (could be automated)

Ask the right questions

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ii. What is inherently lacking in the description? What approximations were made?

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PYTHIA vs. HERWIG

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How are we doing better?

MC@NLO (matching a NLO calculation to HERWIG)

Tree Level-Parton Shower Matching

Q2: Adding different MC samples

W+3 partons + PS $\oplus$(?) W+4 partons + PS

W+3 hard jets + b-tags $\equiv$ B

W+4 hard jets + b-tags $\equiv$ S

How much of "top" is W+4 hard jets? Can we use W+3 hard jets?

How do I add MC samples without over/under counting?

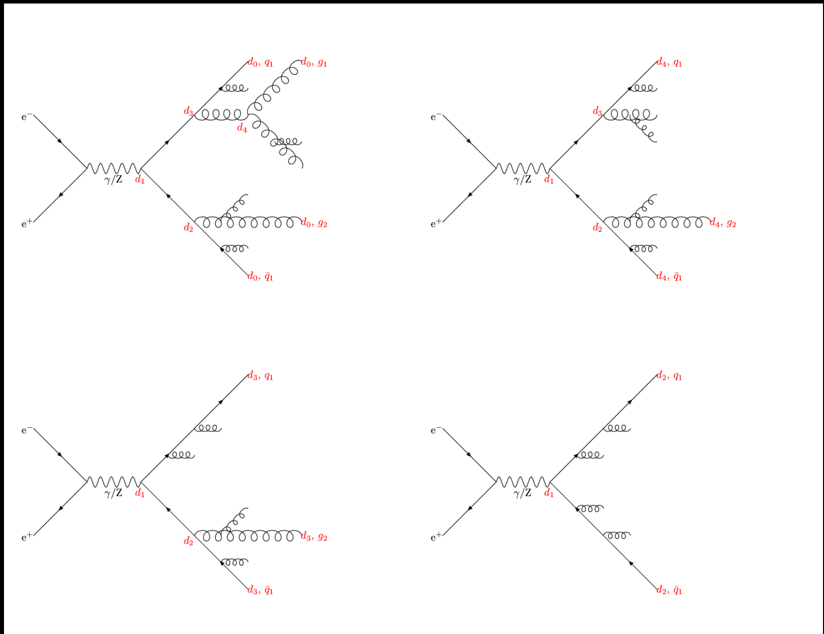
- In PS, (continuous) variation of topologies comes from Sudakov Form Factor (probability for no emission)
- Matrix Element calculation can be "mapped" into a PS history and reweighted with Sudakov FFs

  in soft/collinear limit, recover SGA

  in hard limit, apply HGC

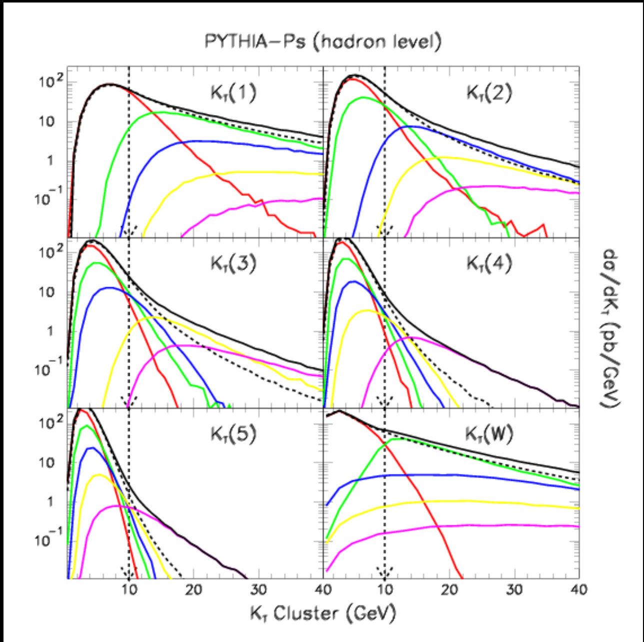
Pseudo–Showers and Sudakov Weight

Rerun the PS history and reject events with “bad” emissions



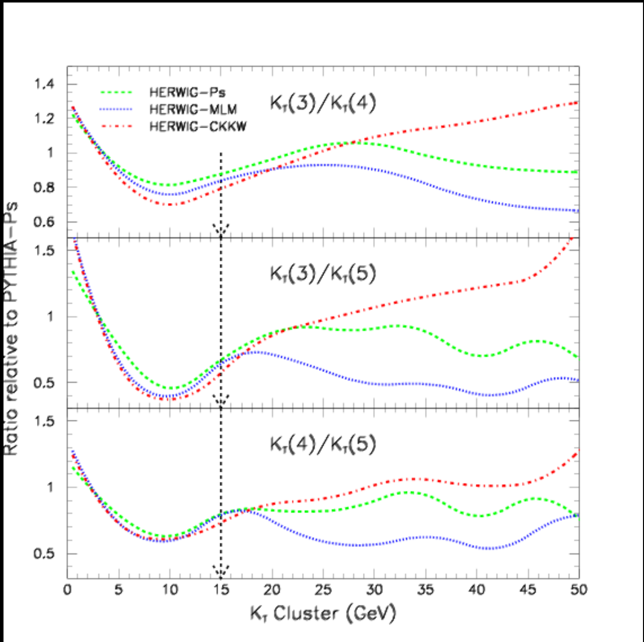
Reweighting allows smooth matching with lower topology

W+0 $\oplus \cdots \oplus$ W+4 hard partons



$$k_T^2 = 2\mathrm{min}(E_i, E_j)^2(1-\cos\theta_{ij}) \sim \mathrm{min}(E_i/E_j, E_j/E_i)m^2$$

Variation of Scheme yields a Theory Error



Variation with hard parton cutoff is also relevant

Lessons

- These calculations are not trivial

  My conviction is that experts should do expert work

  Theory/Phenos need to carry work through to where the experiment can take over

- Those who do this work are necessary and must be supported

  given resources (computing farms, mass storage, etc.)

- Nature of these calculations begs for databases and interface with experimental software

- mass storage
- standard format for files
- writeable from a computing farm
- searchable
- reasonably safe/secure
- easy to access by experiments, theorists
- files downloadable on hits

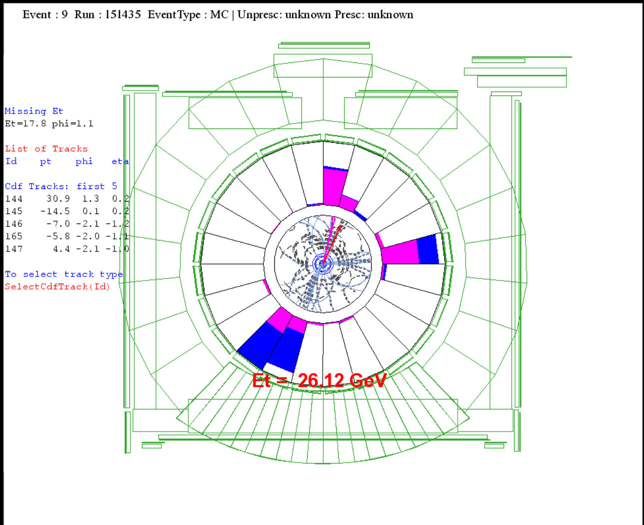
Patriot at FNAL

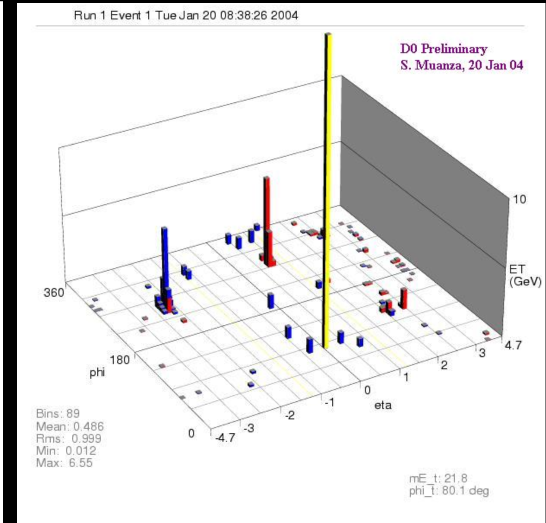
Physics Analysis Tools Required to Investigate Our Theories

- 1 TB Enstore repository
  - STDHEP + extra information + MCFIO
- Several different generators
  - Herwig, Pythia
  - Madgraph, Gr@ppa, CompHep, Alpgen
- Several different levels of generation
  - partons $\leftrightarrow$ showered partons $\leftrightarrow$ hadron level
- interface to SAM through disk cache
  - SAM $\equiv$ Sequential data Access via Meta-data
  - Oracle database (mcdb $\rightarrow$ Oracle)

Processed Events

Theorist → Patriot → Experiment





Predictions

- "Theory" databases will play an important role in LHC analyses
  - new and developing MC predictions from theorists
  - quality not quantity
- Tricks will be developed to fully exploit them
  - e.g., look tables from fully simulated events to allow a quick scan of different theory predictions
- Theory/Pheno types will organize more along the lines of experimental collaborations
  - ensure that calculations are performed, legacy is maintained
- calculations will be done differently
  - Effective field theory more suitable for parton showers will be used in HO calculations

For LHC physics analyses, MC must:

- · · · give a reasonable estimate of theoretical uncertainty
- · · · be improved beyond the present level of approximation

Important for:

Setting limits

Qualifying an anomaly

Quantifying a measurement

Progress has been made

In RunII, we are learning what we need to do this

Ideas, farms, databases