Full Simulation of Black Holes at ATLAS

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Overview

- Black hole production and decay
- Why fully simulate?
- Methodology
- Results
- Conclusions

Acknowledgments:
C. Harris, A. Sabetfakhri, Cambridge SUSY Working Group

Black Hole Production

- Extra-dimensional theories can have $M_P \sim 1$ TeV
- Trans-Planck region accessible at the LHC
- Form a black hole if 2 partons fall within the horizon for their centre-of-mass energy
- $r_S \sim M_P^{-1}(M_{BH}/M_P)^{1/(D-3)}$
- $s \sim \pi r_S^2$ for $M_{BH} >> M_P$

M_{BH}	D	s (M_P=1 TeV)
5 TeV	6	6250 fb
	8	3680 fb
	10	3390 fb
8 TeV	6	580 fb
	8	307 fb
	10	273 fb

Black Hole Decay

- Decay in 3 phases:
  1. Balding Phase: asymmetries and moments lost
  2. Hawking evaporation phase: a brief spin-down followed by a longer Schwarzschild phase
  3. Planck phase: when the mass or Hawking temperature reaches the Planck scale
- Hawking phase is understood.
- Most energy is emitted on the brane (~80% for D=6-10)
- $T_H \sim M_P(M_P/ M_{BH})^{1/(D-3)}$
- $\log(T_H) \sim -1/(D-3) \log (M_{BH}) + \text{const}$
- Energy of emitted particles peaks at T_H

Event Generator

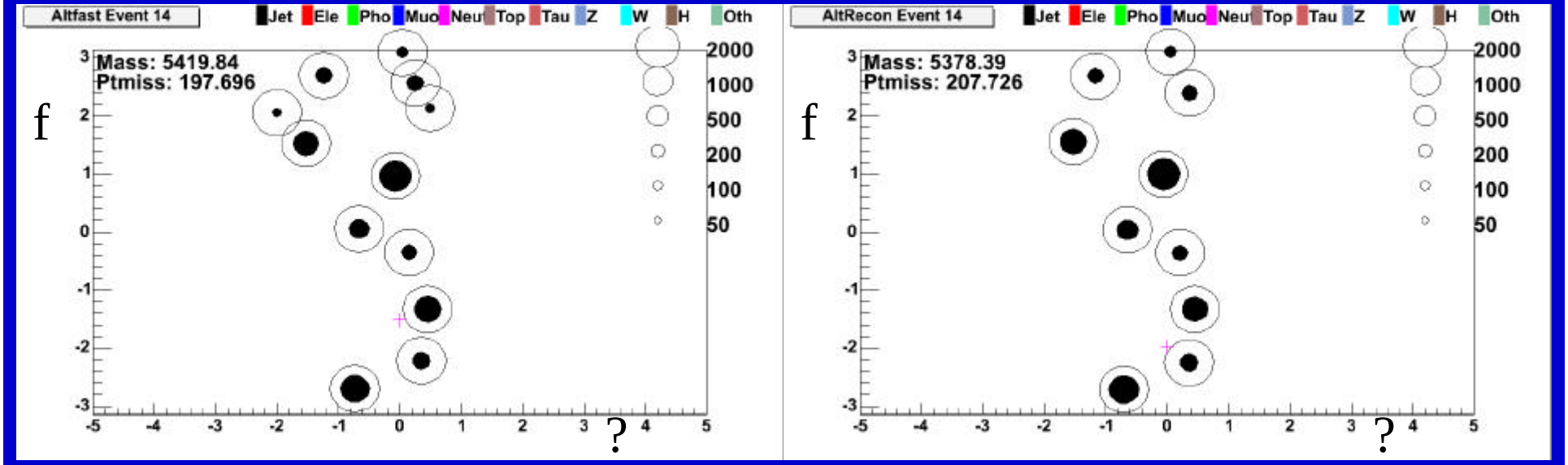
- Models Hawking phase
- Time evolution: black hole changes mass and temperature with time
- Decays black hole to all SM (+Higgs) particles
- Several options for terminating the decay.
- Used the simple 2-body decay when the chosen decay is not kinematically possible

Observables

- Detecting black holes is easy!
- Multiplicity ~ 10, Energy/particle ~ 500 GeV
- Measuring anything is much harder
- Theoretical difficulties
- Experimental difficulties:
  - Worst case for missing Et
  - Few clean events
  - Difficult to resolve many overlapping jets
- Aim to find black hole mass and temperature
- Should allow limits on the number of dimensions

Example Event

ud->BH->WWb?? + 7jets



Fast

Full

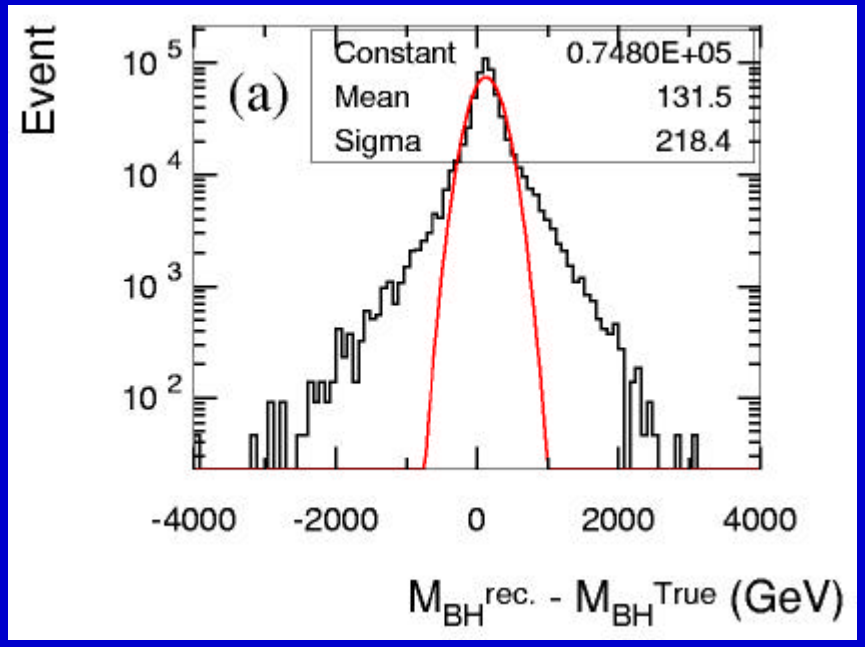
Why fully simulate?

- Suspect that fast simulation is optimistic for this and many exotic signals
- Stresses the whole ATLAS detector
- Difficult case for jet reconstruction
- Worst case for missing Et
- Provide feedback, understanding to software group

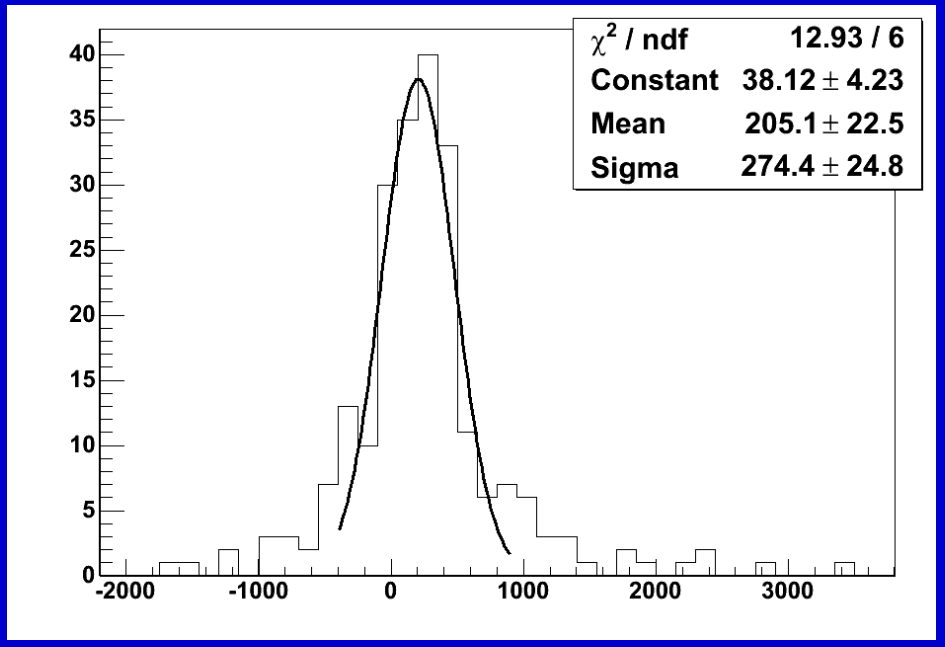
Full Simulation

- 900 6d and 8d events fully simulated using Athena 6.0.4 (GEANT 3 based)
- About 1 month of CPU!
- Jets reconstructed with Kt algorithm (R=0.54)
- Applied jet fudge factor to account for eta dependance
- Corrected jets for EM energy
- Corrected missing Et for muons and jet fudge factor

Mass Resolution



Fast

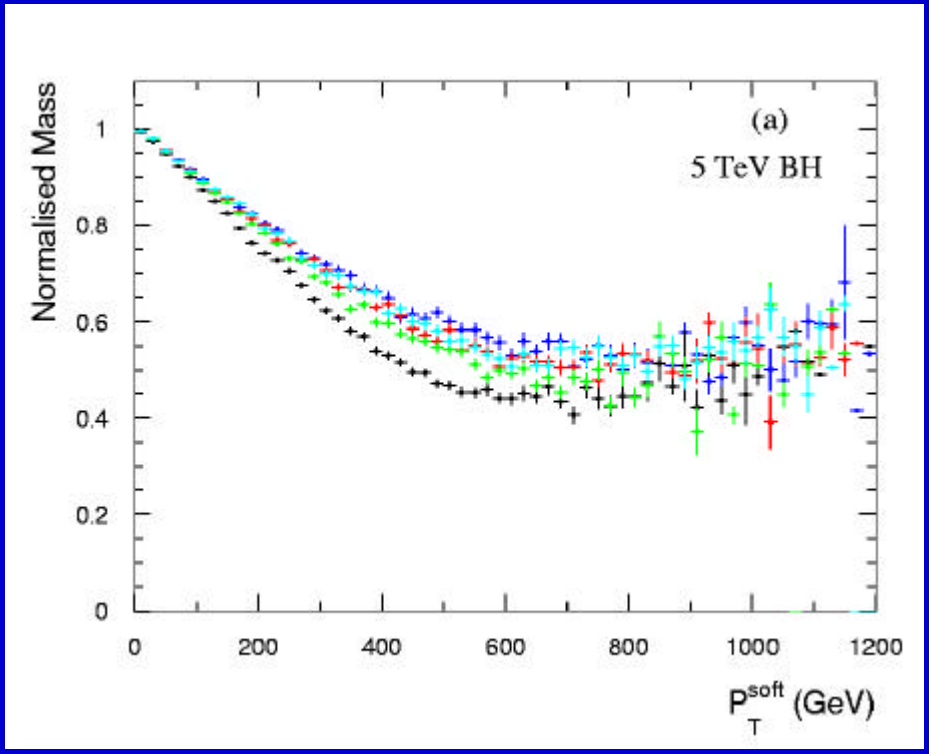


Full

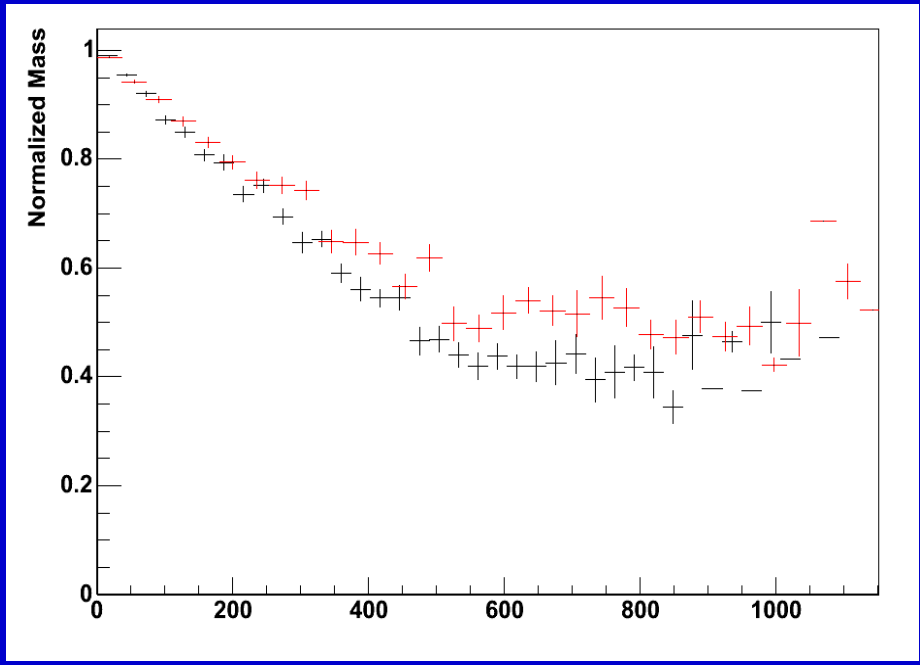
- Reconstructed mass – true mass for 5 TeV black hole
- Fast simulation (left) error is 220 GeV (~ 4%)
- Full simulation (right) error is 280 GeV (~ 6%)
- Both have non-Gaussian tales

Mass Correlation Plots

Mass(i) = Mass of all particles excluding i softest particles



Fast Simulation: 6D (black), 7D (green), 8D (red), 9D (cyan), 10D (blue)



Full Simulation: 6D (black), 8D (red)

- Clear separation for 6D and 8D in fast simulation, but not in full
- Possibly statistically limited for full simulation

Conclusions

- Black hole mass measurable to 4-6%
- Effect of different numbers of dimensions observable in fast simulation
- Full simulation broadly supports fast simulation results for mass measurement
- Differences between fast and full simulation in effect of dimensions