MET Look-alikes

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HEFTI MET Workshop
4/2/2009

arXiv: 0805.2398 [hep-ph]

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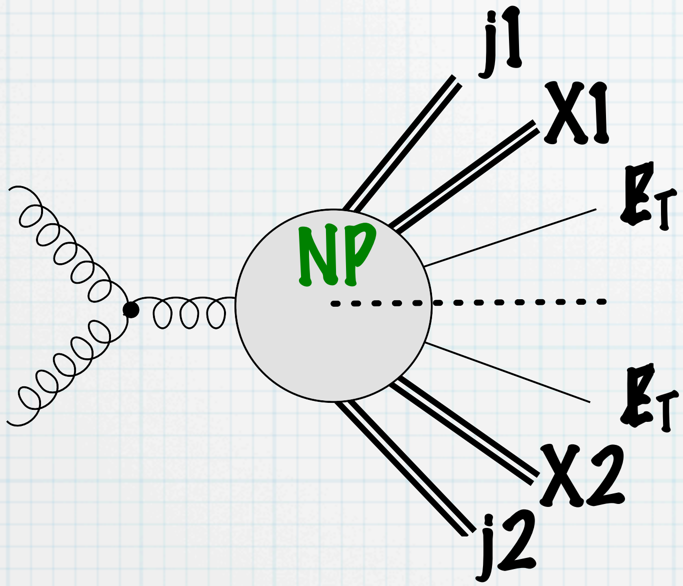
First "understood" data

* Won't be well understood
* will have some handle on detector response to jets from earliest studies
* won't have sophisticated jet corrections (partonic jets), just raw/uncorrected jets
* primitive flavor tagging (enrichment)
* observables that are available will be strongly correlated by both physics and systematics
    * want to keep these errors to a minimum
    * bad time for a global analysis

E_T(miss) + jets @ LHC



* New Physics + Parity
  * SUSY: R-parity (baryon #)
  * Little Higgs: T-parity (cust. SU(2))
  * Universal Extra Dim.: KK-parity

Parities keep protons from decaying, prevent gross violation of flavor constraints, keep M_W consistent with exp., and (if exact) provide dark matter

Starting point

* There is a 5 sigma excess in a MET+jets search with $100pb^{-1}$
* We don't utilize any other potential search channels (i.e. that don't trigger on MET)
* Goal: design an analysis efficient for model discrimination and robust considering limitations of early data

What will be in early data sets? (CMSPTDR)

* Study of SUSY benchmark scenarios
* series of cleanup/analysis/bkgd rej. cuts on E_T trigger sample
    * up to 25% eff. on signal
* for σ~5pb, > 5σ discovery in 100pb^{-1}!
* we adopt very similar analysis path (bkgds are done)
* New: we go **beyond** the benchmarks (even non-SUSY) and **refine/develop** the analysis for efficiency in model discrimination

CMSPTDR MET analysis path

Cut/Sample	Signal	$t\bar{t}$	$Z(\rightarrow \nu\bar{\nu})+$ jets	EWK + jets
All (%)	100	100	100	100
Trigger	92	40	99	57
$E_T^{\text{miss}} > 200$ GeV	54	0.57	54	0.9
PV	53.8	0.56	53	0.9
$N_j \geq 3$	39	0.36	4	0.1
$\lvert\eta_d^{j1}\rvert \geq 1.7$	34	0.30	3	0.07
EEMF ≥ 0.175	34	0.30	3	0.07
ECHF ≥ 0.1	33.5	0.29	3	0.06
QCD angular	26	0.17	2.5	0.04
$Iso^{lead\ trk} = 0$	23	0.09	2.3	0.02
$EMF(j1)$, $EMF(j2) \geq 0.9$	22	0.086	2.2	0.02
$E_{T,1} > 180$ GeV, $E_{T,2} > 110$ GeV	14	0.015	0.5	0.003
$H_T > 500$ GeV	13	0.01	0.4	0.002
events remaining per 1000 pb^{-1}				
	6319	54	48	33

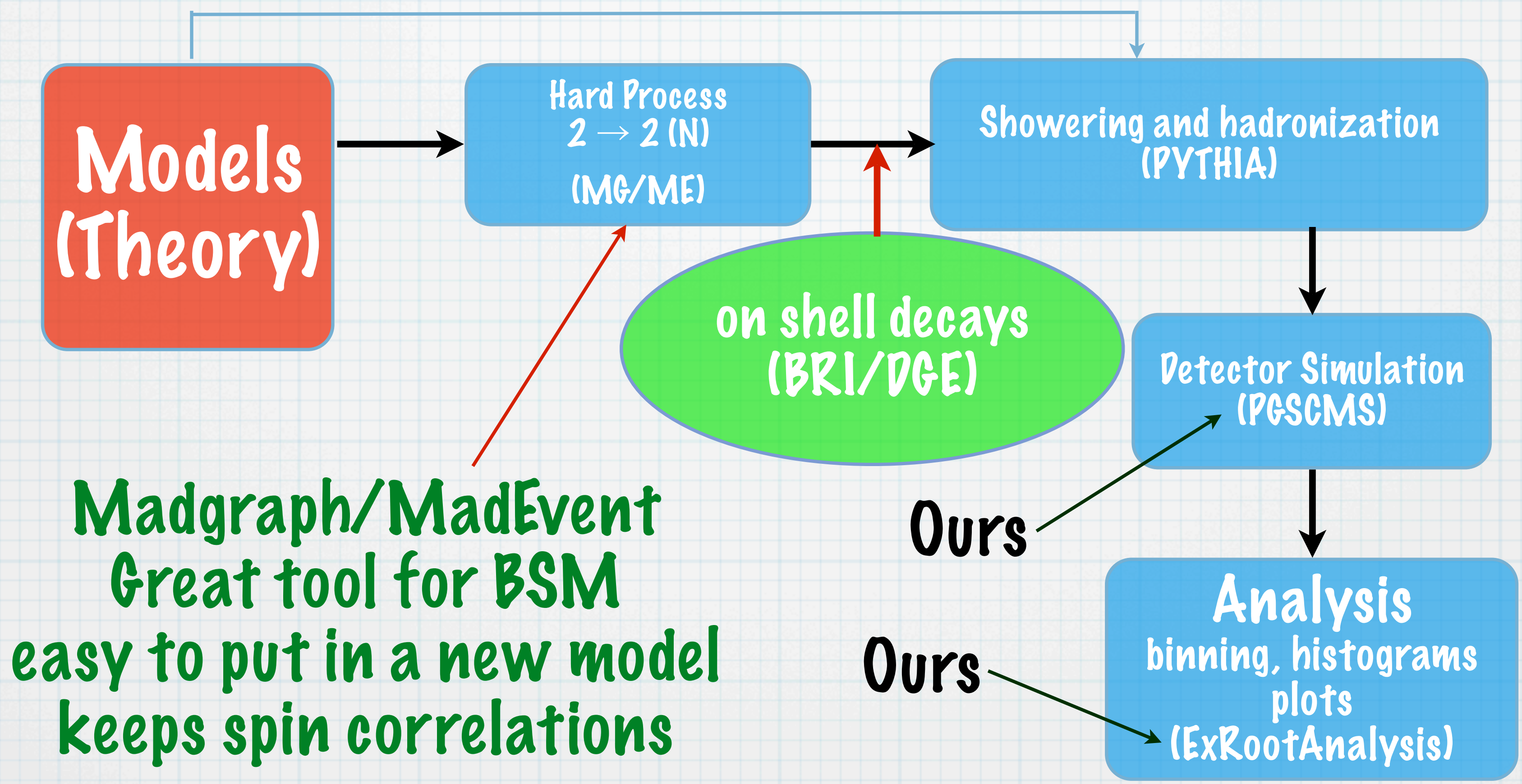
- focuses on 2 WIMP final states ($N_{jets} \geq 2$)
- QCD pileup, radiation often gives a third jet
- efficient for signal, strong reduction of background

Models

SUSY	Little Higgs
produce squarks + gluinos	produce heavy T-odd quarks
decay to lightest R-odd particle (neutralino)	decay to lightest T-odd particle (neutral vector boson)
Hierarchy problem saved by spin statistics and SUSY coupling relations	Hierarchy problem saved by global symmetries
cancellations with opp. spin	cancellations with same spin

Lookalikes: Same # events in MET analysis path

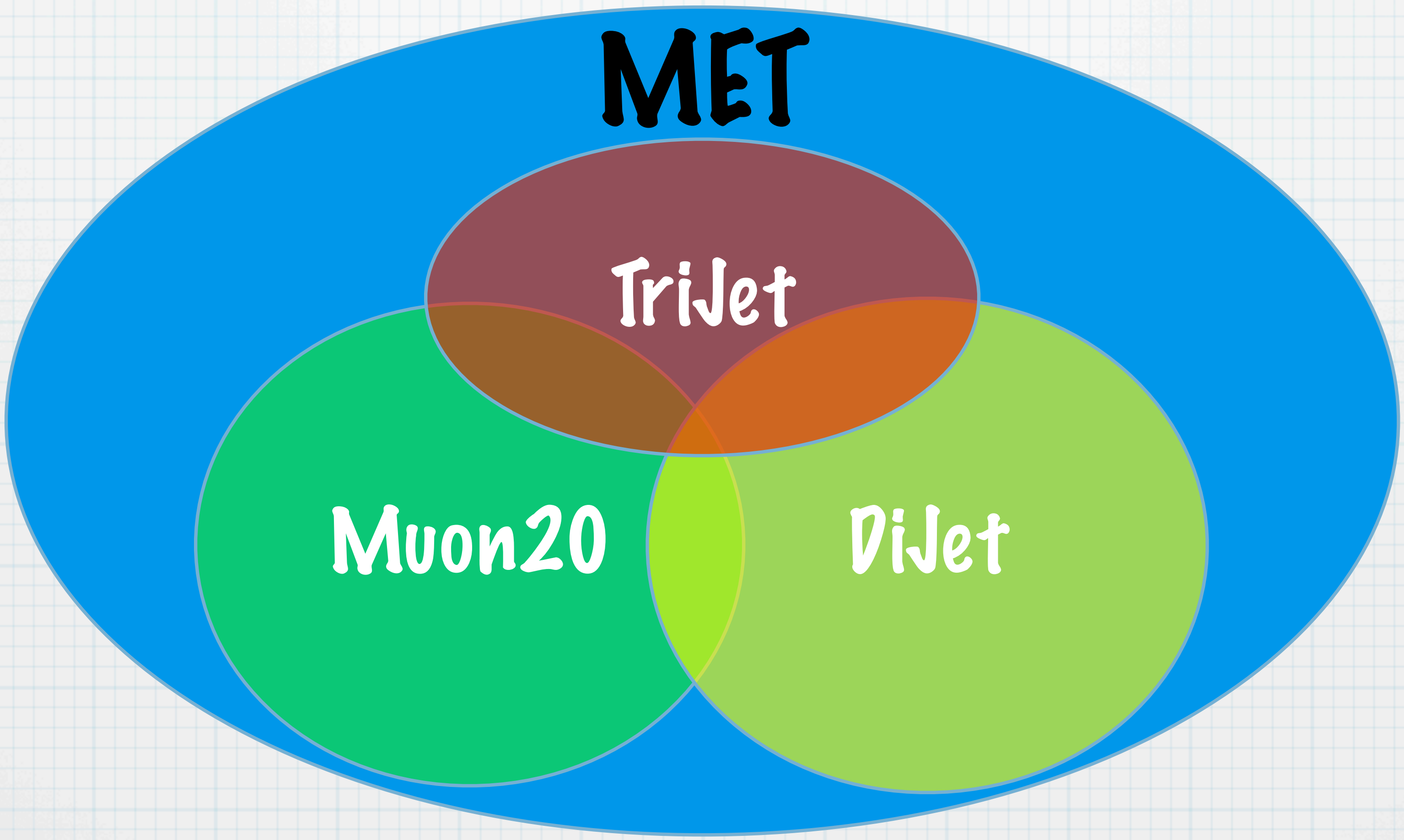
Our Toolkit


Models
(Theory)
Hard Process
2 → 2 (N)
(MG/ME)
Showering and hadronization
(PYTHIA)
on shell decays
(BRI/DGE)
Detector Simulation
(PGSCMS)
Analysis
binning, histograms
plots
(ExRootAnalysis)
Ours
Ours
Madgraph/MadEvent
Great tool for BSM
easy to put in a new model
keeps spin correlations

Observables

* Want to focus on robust objects
  * shapes, distributions, too sensitive to systematics, poor simulation, etc.
    * not good for moment of discovery
* Large bins bring this problem under better control
  * "Boxes" - Hide the distributions
* Ratios of counts in diff. boxes
  * lower systematics since many are common to all boxes - cancel out

Simplest Boxes



Observables: Ratios

* systematics cancel effectively
  * from about 20% down to about 5%
    * luminosity uncertainty - completely
    * pdf uncertainty - partially
    * higher order corrections - partially

Flavor Enrichment

Very low level “tagging”

* tau enrichment
  * for each jet, .375 cone, count tracks > 2 GeV, if only one, and > 15 GeV, call tau

	LM2p	LM5	LM8	CS4d	CS6
τ jets per fb^{-1}	409	144	171	112	34
tags per fb^{-1}	157	110	122	102	59
correct tags per fb^{-1}	86	25	21	14	5
efficiency	21%	18%	12%	13%	16%
purity	55%	23%	17%	14%	8%

* b enrichment
  * if muon within .2 of jet axis, call b

	LM2p	LM5	LM8	CS4d	CS6
b jets per fb^{-1}	1547	1693	2481	1596	748
tags per fb^{-1}	115	112	148	105	106
correct tags per fb^{-1}	82	81	112	75	41
efficiency	5%	5%	5%	5%	5%
purity	72%	72%	75%	71%	39%

Our Ratios

- r(nj)(3j), with n=4,5
- r(MET320)
- r(MET420)
- r(MET520)
- r(HT900)
- r(Meff1400)
- r(M1400)
- r(M1800)
- r(Hem$j$) with j=1,2,3
- r(2μ-nj)(1μ-nj) with n=3,4
- r(τ-tag)
- r(b-tag)
- r(mT2-300) with the theory LSP mass
- r(mT2-400) with the theory LSP mass
- r(mT2-500) with the theory LSP mass
- r(mT2-600) with the theory LSP mass
- r(DiJet)
- r(TriJet)
- r(Muon20)
- r(mT2-400/300) with the theory LSP mass
- r(mT2-500/300) with the theory LSP mass
- r(mT2-600/300) with the theory LSP mass
- r(nt-cα) for n=10,20,30,40 and $\alpha = 30°,45°, 60°$, 75°, 90°
- r(ntdiff-cα) for for n=10,20,30,40 and $\alpha = 30°, 45°$, 60°, 75°, 90°

Results (Group 2)

		LH2		NM4		CS7	
LH2							
	100			r(mT2-500)	4.9σ	r(mT2-500)	6.7σ
				r(Meff1400)	3.0σ	r(MET420)	6.5σ
				r(M1400)	2.7σ	r(4j)(3j)	4.0σ
	1000			r(mT2-500)	14.1σ	r(mT2-500)	18.9σ
				r(mT2-300) [TriJet]	11.0σ	r(MET420)	16.7σ
				r(mT2-400) [DiJjet]	7.9σ	r(mT2-500) [TriJet]	8.8σ
				r(Meff1400)	7.2σ	r(4j)(3j) [DiJet]	7.3σ
				r(M1400)	6.6σ	r(mT2-300) [DiJet]	6.7σ
NM4							
	100	r(Meff1400)	4.2σ			r(Meff1400)	4.3σ
		r(M1400)	4.0σ			r(DiJet)	4.1σ
		r(mT2-400)	3.8σ			r(MET420)	4.0σ
	1000	r(Meff1400)	10.8σ			r(Meff1400)	11.2σ
		r(TriJet)	10.4σ			r(MET520)	10.6σ
		r(M1400)	9.8σ			r(DiJet)	10.6σ
		r(DiJet	8.2σ			r(HT900)	9.0σ
		r(HT900)	8.0σ			r(4j)(3j)	6.1σ
CS7							
	100	r(MET420)	4.9σ	r(4j)(3j)	4.4σ		
		r(4j)(3j)	4.6σ	r(MET420)	3.3σ		
		r(mT2-400)	4.1σ	r(Hem1)	3.2σ		
	1000	r(5j)(3j) [DiJet]	16.8σ	r(4j)(3j)	9.4σ		
		r(TriJet)	10.4σ	r(5j)(3j) [DiJet]	7.4σ		
		r(MET420)	9.6σ	r(Meff1400)	7.4σ		
		r(4j)(3j)	9.5σ	r(DiJet)	6.9σ		
		r(mT2-500)	8.3σ	r(HT900)	6.2σ		

Conclusions

* We will hopefully have 5 sigma discovery by the end of the 100pb^{-1} era
  * we've developed techniques to discriminate models efficiently with small amounts of data
  * set of robust observables (ratios of inclusive counts)
  * "realistic" in that we minimize systematics, and stick to things that are (or should be) achievable in first year of physics running
* Compelling evidence for spin discrimination at moment of discovery