MC4BSM in CMS

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Introduction

Physics generators allow us to connect *ideas* to *measurables*

In practical terms, this means the translation:

$$\mathcal{L}_{int} \leftrightarrow \texttt{HepMC}$$

As a generator *developer* **and** *user* I become frustrated when computing gets in the way

I hope to contribute my experience from Run2 to CMS

- I have made or seen almost every possible mistake!

My Background

I have been involved in these issues for a *long* time

Back in the $e^+e^-\gamma\gamma$-MET events days, I helped hack into the CDF simulation code so that backgrounds and cousin events could be studied

I am in the Computing Division at Fermilab for a reason

The CMSSW Way

We plan to run generators in our software framework our way without hacking

```
cmsRun someConfigurationFile.cfg
```

Why does the experiment's software matter?

1. The Rules of the Game are complicated
2. The treatment of data is obviously complicated. The desire to treat Monte Carlo **like** data is reasonable to prevent bias.

The Old New Physics

At the time of the SSC, you used `Isajet` for Supersymmetry and `Pythia` for exotics (Z' , compositeness, technirho, excited fermions, *etc.*)

- this despite the fact that `Isajet` was not a serious QCD tool

Special cases required special treatment (i.e. a special person)

The current situation is much improved

CMSSW GeneratorInterfaces

Generator	View CVS	Documentation	Responsible	Status
Pythia6	Pythia6Interface	View Twiki	Filip Moortgat, Hector Naves	ready
Herwig6	Herwig6Interface	View Twiki	Fabian Stoeckli	ready
ALPGEN	AlpgenInterface	View Twiki	Maurizio Pierini, Maria Spiropulu	ready
MadGraph	MadGraphInterface	View Twiki	Maria Hansen, Dorian Kcira	ready
CompHEP	CompHEPInterface	View Twiki	Sergey Slabospitsky, Dimitri Konstantinov	in progress
MC@NLO	MCatNLOInterface	View Twiki	Fabian Stoeckli	ready
TopRex	TopRexInterface	View Twiki	Sergey Slabospitsky	advanced (but no doc)
StaGen	StaGenInterface	View Twiki[?]	Sergey Slabospitsky	advanced (but no doc)
Charybdis	CharybdisInterface	View Twiki	Sergey Slabospitsky, Halil Gamsizkan	advanced (but no doc)
Hydjet	HydjetInterface	View Twiki	Camelia Mironov	in progress
Pyquen	PyquenInterface	View Twiki	Camelia Mironov	in progress
EvtGen	EvtGenInterface	View Twiki	Aniello Nappi, Roberto Covarelli	in progress
Phantom	MadGraphInterface	View Twiki	Sara Bolognesi	ready
ResBos	ResBosInterface	View Twiki	NN	??
Cosmic Muon Generator	CosmicMuonGenerator	View Twiki	Philipp Biallass	ready
Beam Halo Muon Generator	BeamHaloGenerator	View Twiki	Emmanuelle Perez	advanced (but no doc)
Beam Gas Generator	BeamGasGenerator[?]	View Twiki	NN	??
Pythia8	Pythia8Interface	View Twiki	Mikhail Kirsanov	in progress
Herwig++	Herwig++Interface	View Twiki[?]	Oliver Oberst	??
ExHume[?]	ExHumeInterface	View Twiki	Antonio Vilela Pereira	ready
Pomwig	PomwigInterface	View Twiki	Antonio Vilela Pereira	ready
EDDE	EDDEInterface	View Twiki	Andrei Sobol et al.	in progress

Reality

This looks bloated

Under the hood, there are only 3 interfaces

1. Pythia
2. Herwig
3. Ways to pass LHE files to 1. or 2.

One of our goals is to streamline the interface to LHE files

LHE Files

L es *H* ouches *E* vent files arose from an accord between MC authors

- eased the task of integrating other codes with (e.g.) `Pythia`
- made ME calculations readily available to the experiments

  Note: We agreed on a /COMMON/ structure, not a file format, but we have worked that out too

This is *the* standard for Theory $\leftrightarrow$ Experiment Communications

Aside

We have special interfaces for `Alpgen` and `MadEvent`, but:
`Pythia6Interface` is ready to take LHE files **out-of-the-box**

```
vstring pythiaCMSDefaults = {
  'MSTP(161)=88',
  'MSTP(162)=88',
  ...

call_pyinit( "USER", "", "", 0.0 );

ln -sf les_houches_filename.txt fort.88
```

Another Aside

We have used the `AlpgenInterface` to generate a sophisticated Standard Model soup in 2007

We are currently preparing for a massive `MadEvent` run using a similar interface

Our first priority is getting a good description of the Standard Model!

The value of LHE files

1. It can take a lot of time to generate these files, and we can use them again for systematic studies
   - e.g. pass them through Pythia again with different parton shower parameters
   - use a **better** UE tune
2. They provide a clear record of what we have done
3. They might be used in an analysis
4. A theorist friend might give you a file that you want to simulate

Our Goals

Primarily:

$$\mathcal{L}_{int} \leftrightarrow \texttt{HepMC}$$

This should be enough for **weakly-coupled** NP

Need to handle **weird** cases too

The dynamics might be significantly complicated

At one point, the maximally weird idea was R-Hadrons

R-Hadron Saga

Long-lived gluino bound states are an *old* idea

A convergence of personalities and new twists brought this idea to the forefront

It is informative to review the necessary steps to study this idea in CMS

The CMS Plan

Run a calorimeter trigger when there is no beam in the LHC (e.g. interfill) to look for long-lived particles which have become stopped in the detector and decay (minutes, hours, months) later

If these events can be triggered on and observed with no beam in the machine, they will be an unambiguous sign of physics beyond the SM

A toy simulation explored the sensitivity to masses, lifetimes, and susy-breaking scales, but a full simulation was lacking

The Steps

Observing the decay should be easy, provided a reasonable trigger threshold is set and the detector is live

Simulating such a decay (and it's reconstruction) is a little bit trickier ... since this decay will happen much much later than the normal simulation time-scale

CMS decided to study this by factorizing the problem

Use CMSSW 1_6_7 (Pythia w/ Rhadronization modifications) to produce gluino hadrons

Use CMSSW 1_6_7 (GEANT + CustomPhysics) for interactions of R-hadrons with material

Trace R-hadron's (and only these - dramatic speed increase in simulation) kinetic energy in GEANT as they pass through the detector

Record stopping points where KE = zero, (x0,y0,z0) for use in decay phase later

With this map in hand, we can then:

Produce an R-hadron but translate its production vertex from (0,0,0) to a position determined by the above map.

Decay that R-hadron instantaneously to ordinary matter

Perform simulation-digitization-reconstruction of decay productions

R-Hadronization

Needed Modifications of Event Generators

These tools are all about quasi-stable particles (pions, kaons, etc.)

In `Pythia`, the string fragmentation routines expect to find u,d,c,s,b or g

Formation of R-Hadrons required special code

The decay of R-Hadrons can be handled by the SLHA

R-Hadron Interactions

Needed Modifications to Detector Simulations

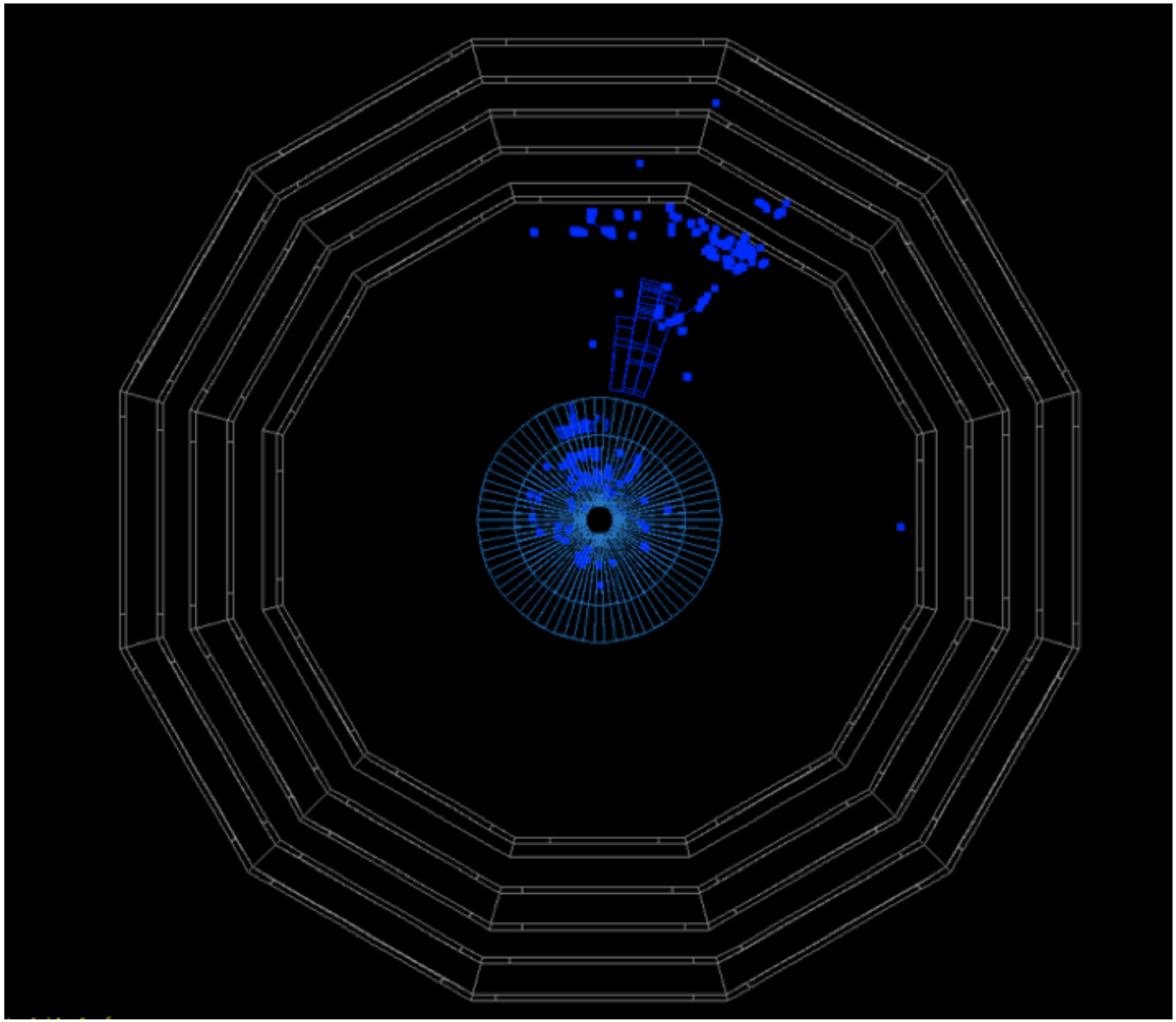
`GEANT4` interface

- how to R-Hadrons interact with matter?

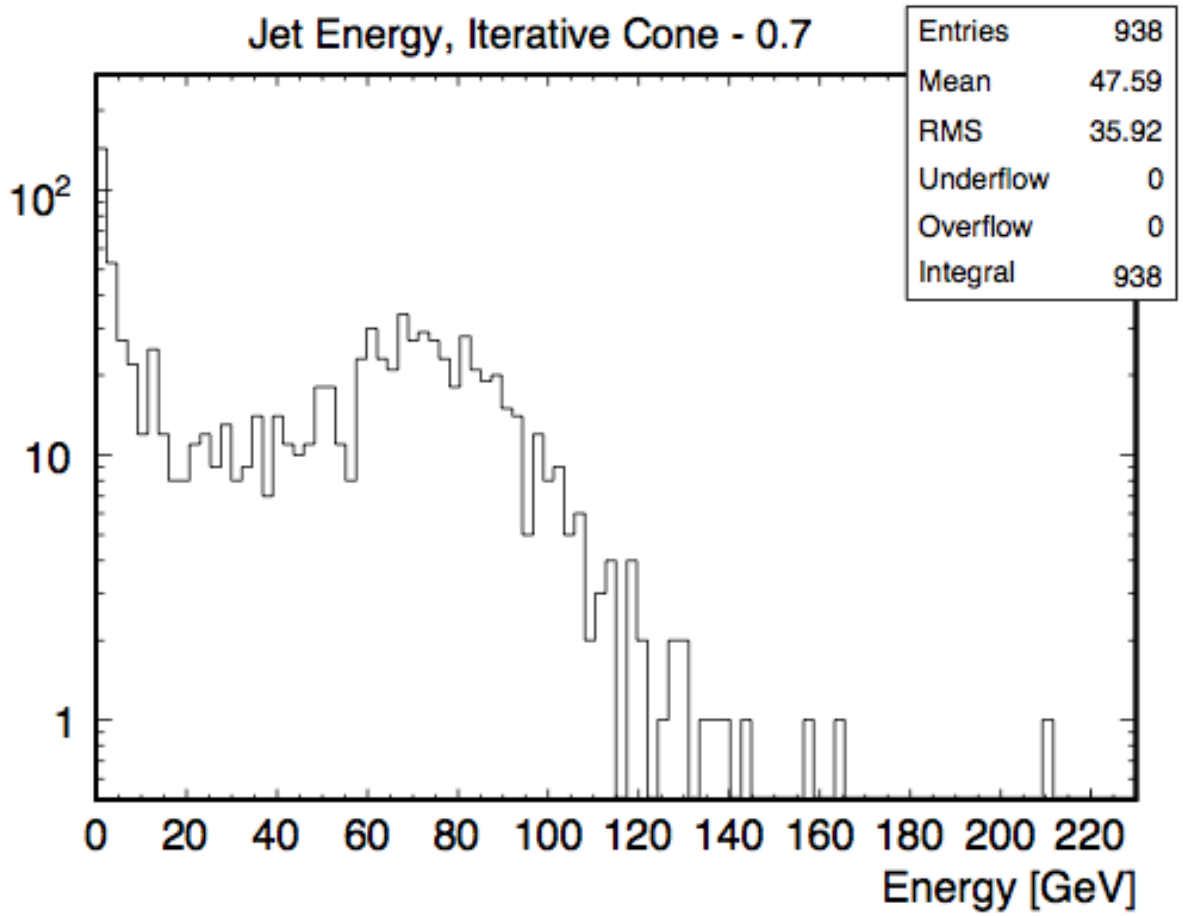
Decay vertex tools

- how to place a lone particle in the middle of your detector?

R-Hadron Decay in Detector



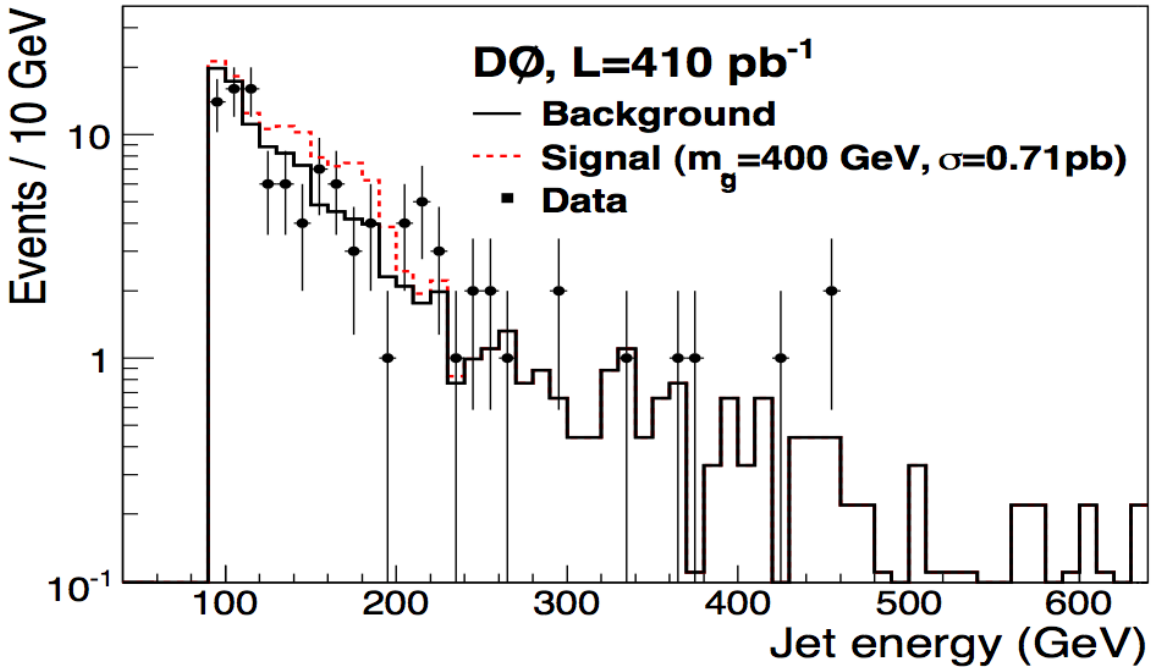
Spectrum of Reconstructed Jets



Reality Check

You don't need all of this sophisticated machinery to do physics

See recent D0 paper : Phys. Rev. Lett. 99, 131801 (2007)



The Point

This is not the *optimal* way to operate

If there is a tweak to the exoticness, it is not clear the D0 analysis can be redone

If there is a *signal*, the methodology will come under greater scrutiny

CMS is prepared to handle such cases before data-taking begins

New Maximally Weird

Hidden Valleys

Quirks

Fireballs

We are getting prepared to handle these cases too

The Message

- LHE files are the standard for Theory $\leftrightarrow$ Experiment conversations
  - our current methodology for handling these files is not ideal, but we are working on this
- Stranger cases are more complicated
  - CMS has the expertise to develop the event generator
    - this is only *part* of the story
  - ... and to do the simulation