

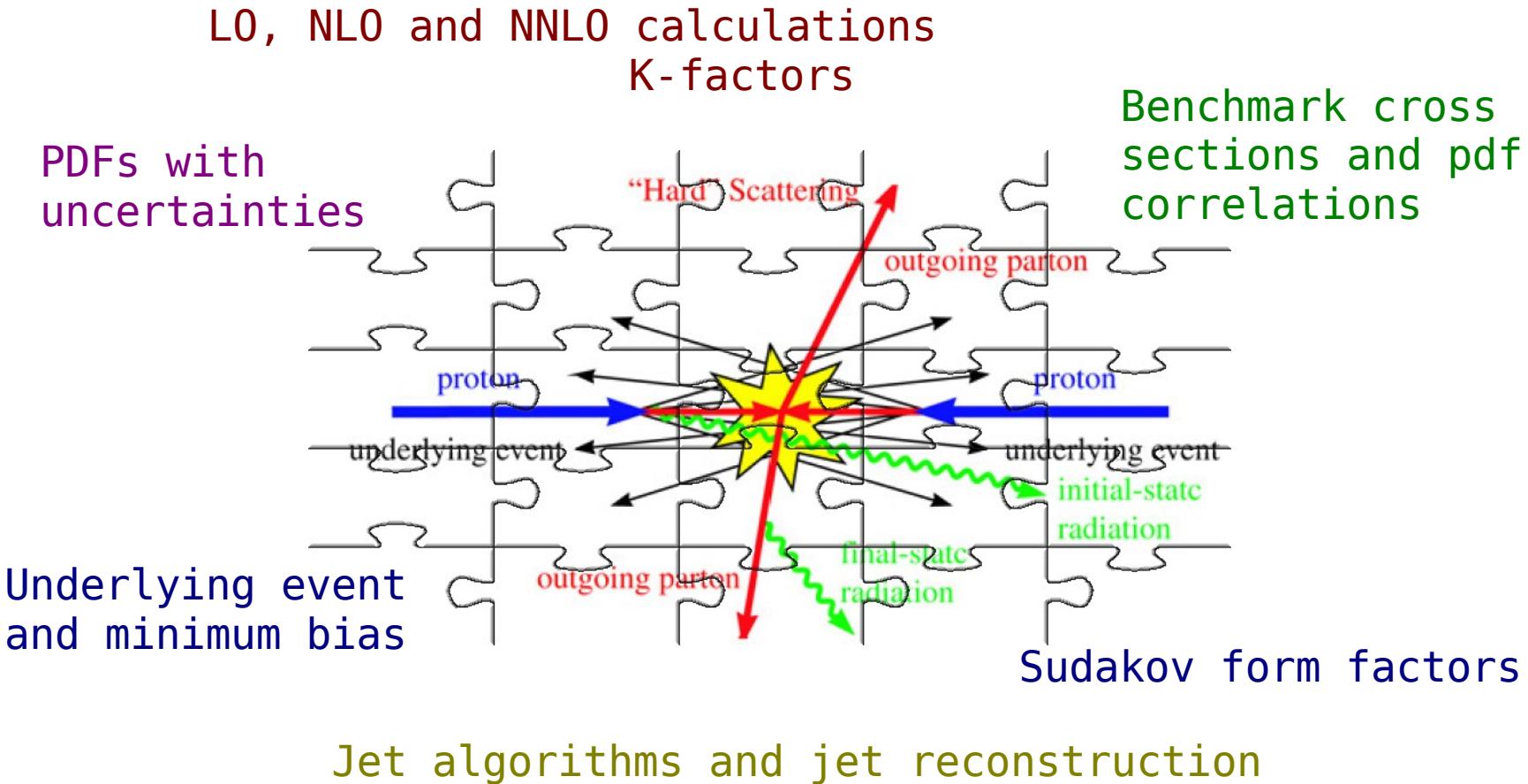


# Physics Monte Carlos

Stephen Mrenna  
FNAL, CMS



# Understanding Cross Sections at the LHC: many pieces to the puzzle



# Some possible topics . . . (FC)



- What generators are available and interfaced to the CMS detector simulation
- What are the fundamental model differences between the available generators (herwig vs pythia vs madgraph)
- Which is better/appropriate to use at CMS? Why?
- What input/handles are available and how are they tuned?  
pdf... underlying event...
- Point out that some uncertainties are determined by looking at the difference one gets when using different models ...
- How easy is it to add a new generator and pass the results through the CMS detector simulation? Is there a standard interface?
- Can I take a file of generator results and pass it through the simulation? Pointer to an example...
- Tricks for simulating rare processes ...
- How do you access generator level quantities in the (edm)?



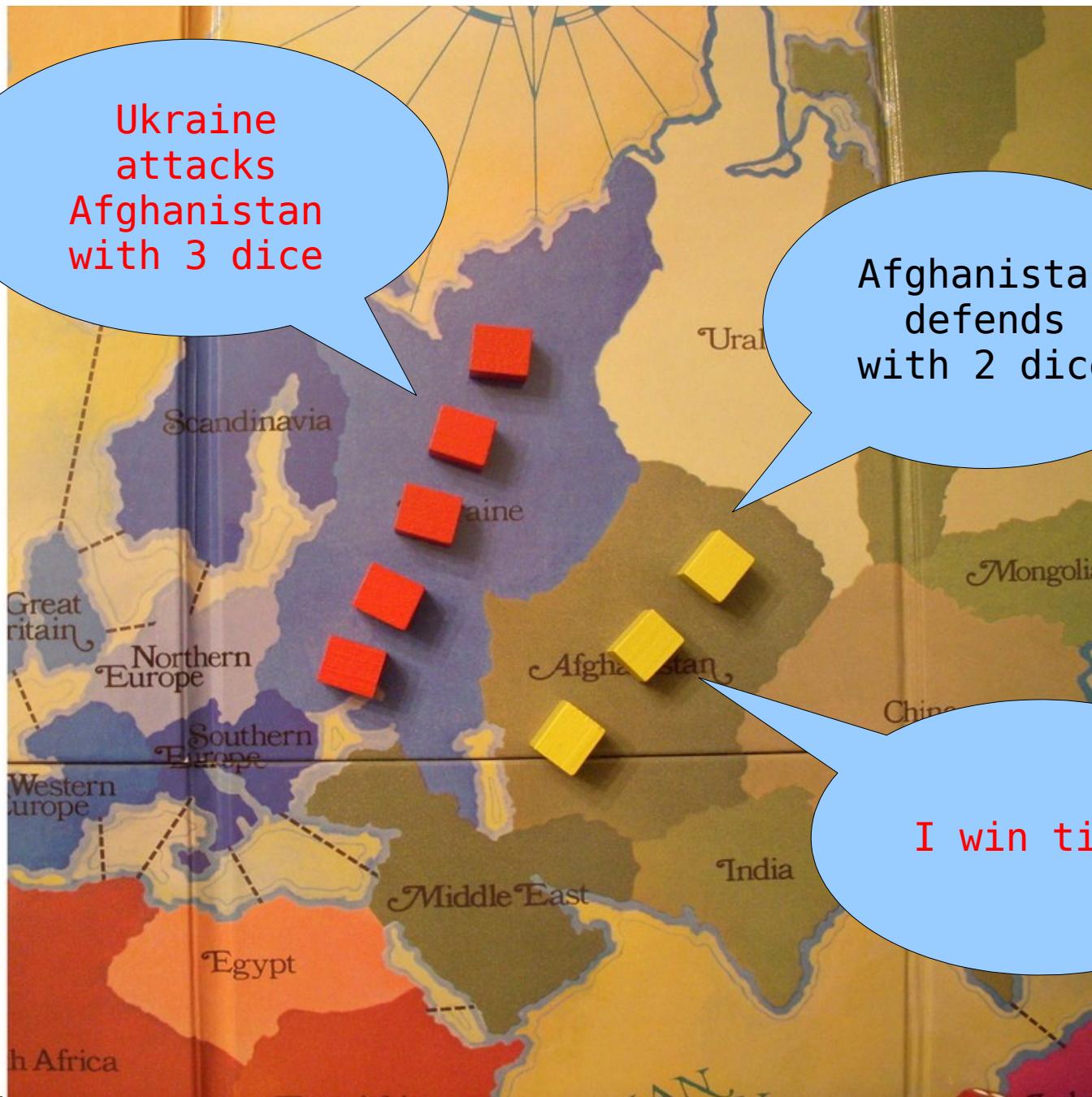
First of all,  
what are we doing?



Ukraine  
attacks  
Afghanistan  
with 3 dice

Afghanistan  
defends  
with 2 dice

I win ties!





# These are the single battle probabilities.

Attacker rolls:	Defender rolls: 2 dice		1 die
	Att lose 2: 29.26% (2275/7776)	Att lose 1: 34.03% (441/1296)	Def lose 1: 65.97% (855/1296)
3 dice	Def lose 2: 37.17% (2890/7776)	Def lose 1: 65.97% (855/1296)	Each lose 1: 33.58% (2611/7776)
2 dice	Att lose 2: 44.83% (581/1296)	Att lose 1: 42.13% (91/216)	Def lose 1: 57.87% (125/216)
1 die	Def lose 2: 22.76% (295/1296)	Def lose 1: 41.67% (15/36)	Each lose 1: 32.41% (420/1296)
	Att lose 1: 74.54% (161/216)	Att lose 1: 58.33% (21/36)	Def lose 1: 25.46% (55/216)

When this is convoluted with all possible outcomes, there is a 64% chance of success for 5 attackers versus 3 defenders.











How often  
does this  
happen?

Our dice and  
rules are more  
complicated



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

This is how we  
roll dice in  
CMS



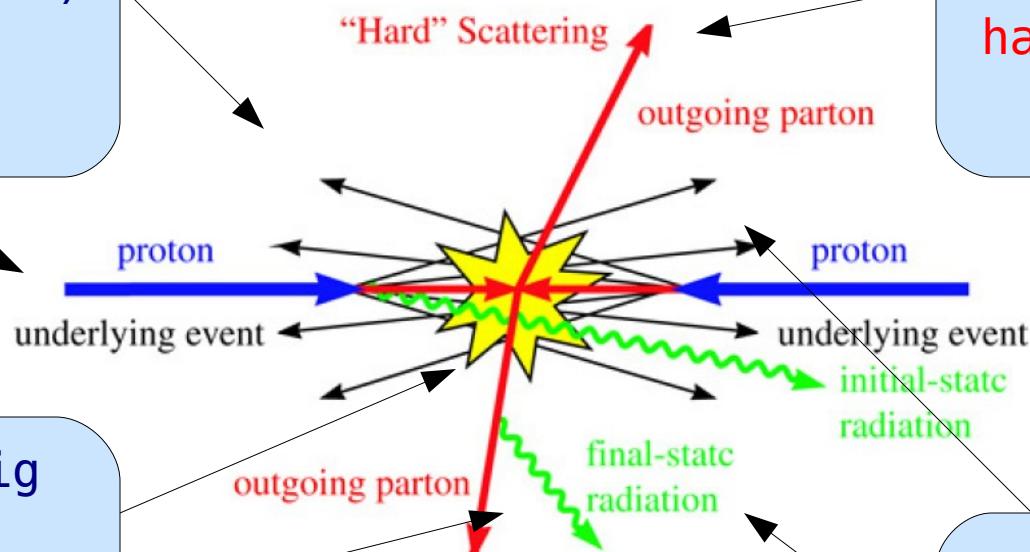
# Why different generators?

Pythia/Herwig have (different) models for this

MG/Alpgen describe hard partons well

Pythia/Herwig describe soft partons well, but with different theory implementations

MG/Alpgen have no model of this





# Can we add new generators?

- Yes, but “Be Prepared”
- Many codes are a square peg that we try to fit into a round hole
- Much labor is spent making, e.g., Alpgen+Pythia work in Production jobs
- We are redesigning the generator interface to make this easier, but things are still not ideal



# Driving the generators

```
pythiaUESettings = cms.vstring(
    'MSTJ(11)=3      ! Choice of the fragmentation function',
    'MSTJ(22)=2      ! Decay those unstable particles',
    'PARJ(71)=10 .   ! for which ctau 10 mm',
    'MSTP(2)=1       ! which order running alphaS',
    'MSTP(33)=0       ! no K factors in hard cross sections',
    'MSTP(51)=10042  ! structure function chosen (external PDF CTEQ6L1)',
    'MSTP(52)=2       ! work with LHAPDF',
    'MSTP(81)=1       ! multiple parton interactions 1 is Pythia default',
    'MSTP(82)=4       ! Defines the multi-parton model',
    'MSTU(21)=1       ! Check on possible errors during program execution',
    'PARP(82)=1.8387  ! pt cutoff for multiparton interactions',
    'PARP(89)=1960.   ! sqrts for which PARP82 is set',
    'PARP(83)=0.5     ! Multiple interactions: matter distrbn parameter',
    'PARP(84)=0.4     ! Multiple interactions: matter distrbn parameter',
    'PARP(90)=0.16    ! Multiple interactions: rescaling power',
    'PARP(67)=2.5     ! amount of initial-state radiation',
    'PARP(85)=1.0     ! gluon prod. mechanism in MI',
    'PARP(86)=1.0     ! gluon prod. mechanism in MI',
    'PARP(62)=1.25    ! ',
    'PARP(64)=0.2     ! ',
    'MSTP(91)=1       ! ',
    'PARP(91)=2.1     ! kt distribution', 'PARP(93)=15.0 ! ')
```



# Why so many parameters? Theory uncertainties:

- Higher orders of perturbation theory (fixed order and resummed) than have been implemented
- Incomplete application of known physics due to approximations
- Simplified models of complex semi-hard or non-perturbative physics
- Unsimulated phenomenon



# Error estimates needed for:

- Measurements (signals)
  - Inclusive jet cross section
  - $W$ , Top mass
- Limit setting
  - Higgs mass
- Data-driven background estimates



# What is done in practice? Top Mass Systematics (CDF/D0)

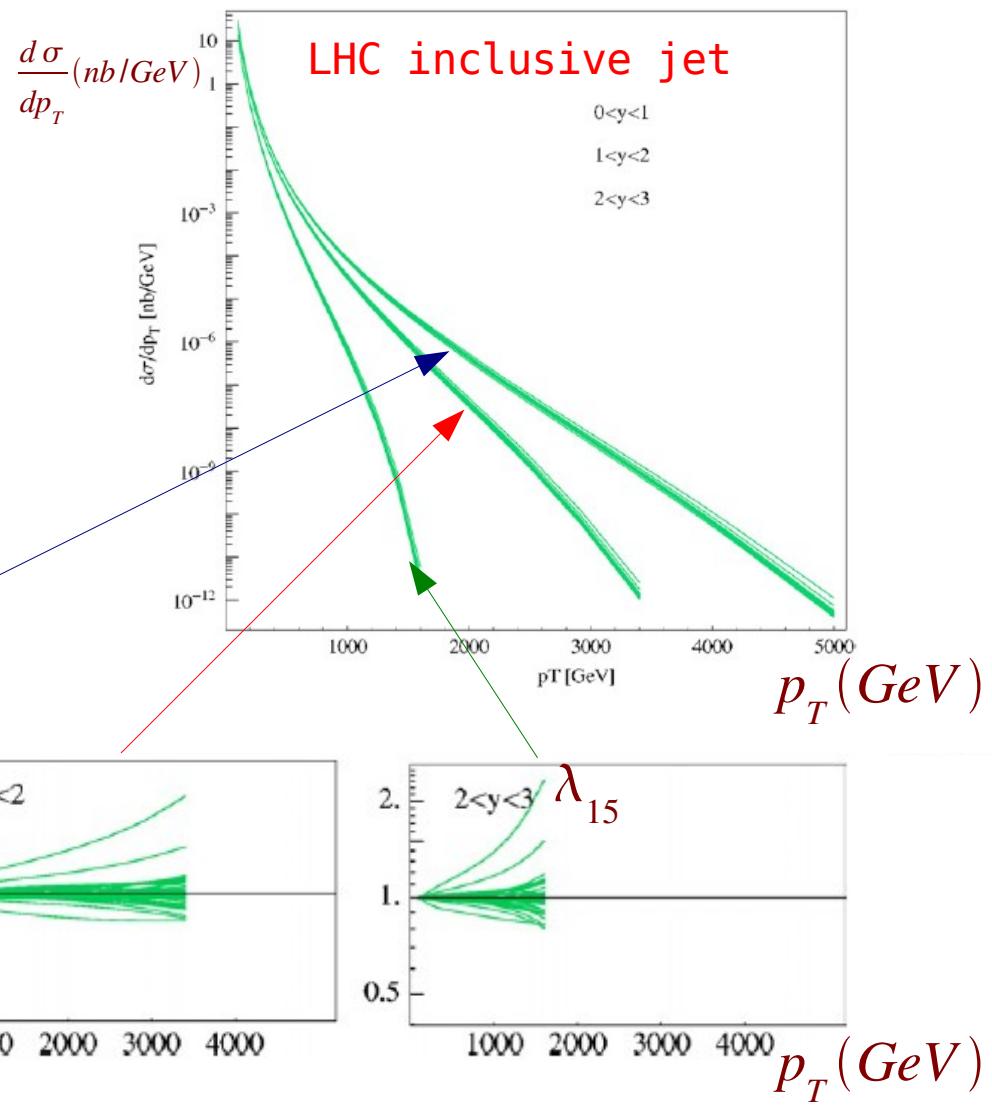
- Radiation (ISR/FSR)
  - Variation of Lambda\_QCDs
- PDF
  - Shift in hard kinematics ( $y_W$ )
- Generator
  - Different implementations, logs
- UE
  - Ave. of several models
- Jet Energy Corrections
  - Variation of parton->hadron map

# PDF errors: now an old story



- Ensembles
- Constrains parameters of chosen form:

$$F(x, Q_0) = A_0 x^{A_1} (1-x)^{A_2} P(x; A_3)$$





# Correlation of Parameters

Parameter	Name	Default	ALEPH	DELPHI	L3	OPAL
Fragmentation function	MSTJ(11)	4	3	3	3	3
Baryon model option	MSTJ(12)	2	2	3	2	2
Azimuthal correlations	MSTJ(46)	3	0	3	3	3
$\mathcal{P}(\text{qq})/\mathcal{P}(\text{q})$	PARJ(1)	0.100	0.095	0.099	0.100	0.085
$\mathcal{P}(\text{s})/\mathcal{P}(\text{u})$	PARJ(2)	0.300	0.285	0.308	0.300	0.310
$(\mathcal{P}(\text{us})/\mathcal{P}(\text{ud})) / (\mathcal{P}(\text{s})/\mathcal{P}(\text{d}))$	PARJ(3)	0.400	0.580	0.650	0.400	0.450
$(1/3)\mathcal{P}(\text{ud}_1)/\mathcal{P}(\text{ud}_0)$	PARJ(4)	0.050	0.050	0.070	0.050	0.025
$\mathcal{P}(S=1)_{\text{d,u}}$	PARJ(11)	0.500	0.550	—	0.500	0.600
$\mathcal{P}(S=1)_s$	PARJ(12)	0.600	0.470	—	0.600	0.400
$\mathcal{P}(S=1)_{\text{c,b}}$	PARJ(13)	0.750	0.600	—	0.750	0.720
Axial, $\mathcal{P}(S=0,L=1;J=1)$	PARJ(14)	0.000	0.096	—	0.100	0.430
Scalar, $\mathcal{P}(S=1,L=1;J=0)$	PARJ(15)	0.000	0.032	—	0.100	0.080
Axial, $\mathcal{P}(S=1,L=1;J=1)$	PARJ(16)	0.000	0.096	—	0.100	0.080
Tensor, $\mathcal{P}(S=1,L=1;J=2)$	PARJ(17)	0.000	0.160	—	0.250	0.170
Extra baryon suppression	PARJ(19)	1.000	1.000	0.500	1.000	1.000
$\sigma_q$	PARJ(21)	0.360	0.360	0.408	0.399	0.400
extra $\eta$ suppression	PARJ(25)	1.000	1.000	0.650	0.600	1.000
extra $\eta'$ suppression	PARJ(26)	0.400	0.400	0.230	0.300	0.400
$a$	PARJ(41)	0.300	0.400	0.417	0.500	0.110
$b$	PARJ(42)	0.580	1.030	0.850	0.848	0.520
$\epsilon_c$	PARJ(54)	-0.050	-0.050	-0.038	-0.030	-0.031
$\epsilon_b$	PARJ(55)	-0.0050	-0.0045	-0.00284	-0.0035	-0.0038
$\Lambda_{\text{LLA}}$	PARJ(81)	0.290	0.320	0.297	0.306	0.250
$Q_0$	PARJ(82)	1.000	1.220	1.560	1.000	1.900

Effects on other parameters ignored in Lambda\_QCD +/- (or other) variation

No unique separation between radiation, hadronization, UE either in data or MC  
Tune A == event tune != UE tune

# Global Analysis Results

[http://uscms.org/uscms\\_at\\_work/physics/lpc/organization/enab  
generators/mcphysval/2008\\_05/overview.html](http://uscms.org/uscms_at_work/physics/lpc/organization/enab generators/mcphysval/2008_05/overview.html)

$pt_j > 25$  GeV

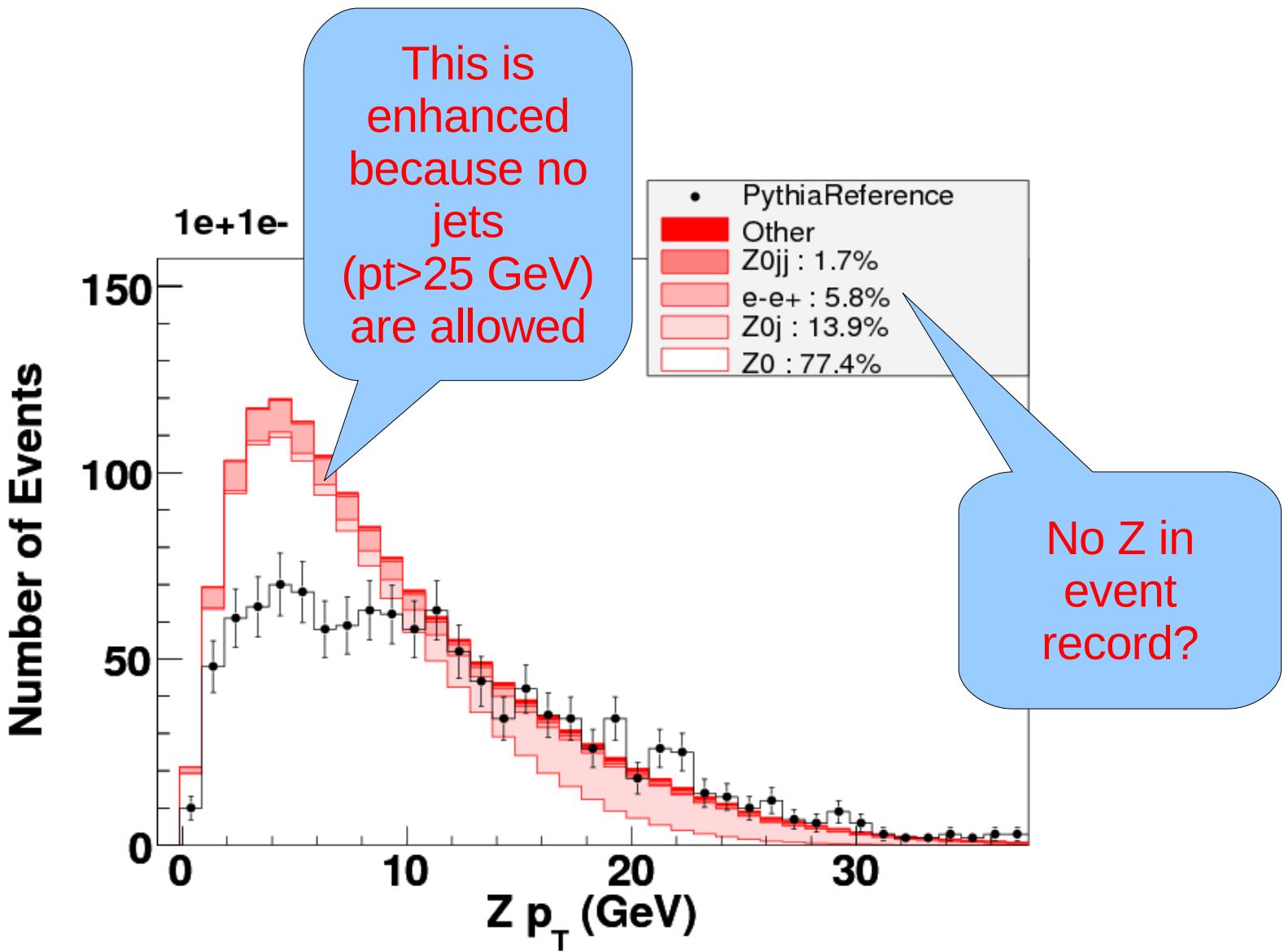
~.1M Pythia

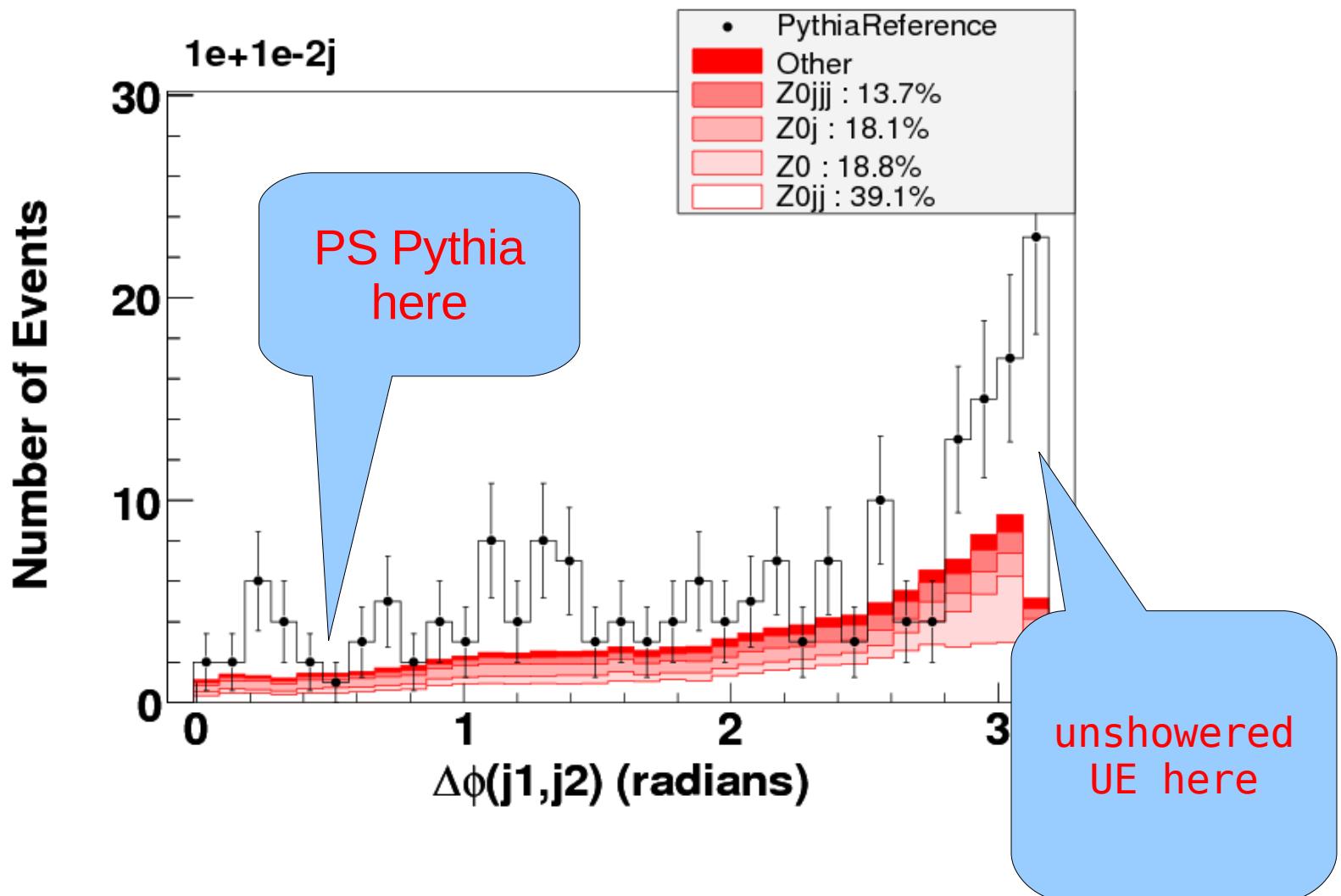
~ 5M MG

Key Shapes

### Table of final states

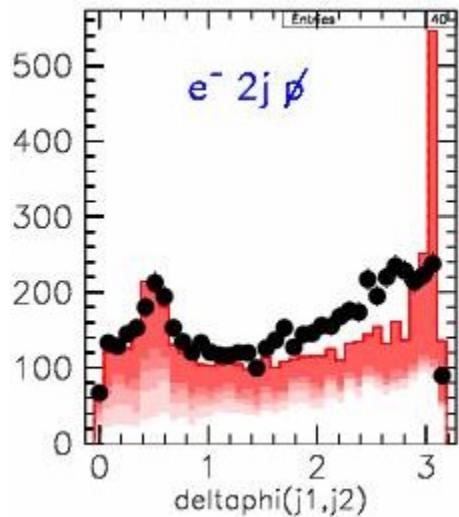
Final State	Plots	Observed	Expected	Discrepancy ( $\sigma$ )	SM composition	Discrepant Distributions ( $\sigma$ )	Bumps
* 1e+1e-	[plots]	1155.1	$1472.7 \pm 2.8$	-7.8	$Z0 = 1139.6, Z0j = 204.5, e+e- = 86.1, Z0jj = 24.8, e+e+j = 13.4, Z0jjj = 2.4, e+e+jj = 1.5, Z0jjjj = 0.2, \tau\tau-\tau\tau+ = 0.1, e-e+jjj = 0.1$	$Z_{-pt}$ 9.9 $\delta\phi(e+,e-)$ 9.9 $\delta R(e+,e-)$ 9.9 $\text{sumPt}$ 6.3	
* 1mu+1mu-	[plots]	1212.6	$1529.9 \pm 2.9$	-7.6	$Z0 = 1183.7, Z0j = 212.3, \mu+\mu- = 91, Z0jj = 24.9, \mu+\mu+j = 13.6, Z0jjj = 2.4, \mu+\mu+jj = 1.5, Z0jjjj = 0.2, \mu+\mu+jjj = 0.1$	$Z_{-pt}$ 9.9 $\delta\phi(\mu+,\mu-)$ 9.9 $\delta R(\mu+,\mu-)$ 9.9 $\text{sumPt}$ 9.8 $\mu+_{-pt}$ 4.7 $\mu-_{-pt}$ 3.2	
* 1e+1e-2j	[plots]	196.9	$110.3 \pm 1.5$	+6.4	$Z0jj = 43.1, Z0 = 20.7, Z0j = 19.9, Z0jjj = 15.1, Z0jjjj = 4.1, e+e+jj = 3.2, e+e- = 1.4, e+e+j = 1.3, e+e+jjj = 1.1, e+e+jjjj = 0.3$	$\min\Delta R(j,j)$ 9.9 $\Delta R(j1,j2)$ 9.9 $\text{mass}(e-,e-,j1,j2)$ 7.1 $\text{mass}(e-,j1,j2)$ 7.1 $\text{mass}(e+,j1,j2)$ 6.6 $\text{minMass}(j)$ 6.1 $\text{mass}(e+,e-,j2)$ 6.1 $\delta\phi(j1,j2)$ 5.9 $\text{mass}(j2)$ 5.7 $\text{mass}(j1,j2)$ 5.4 $\min\Delta R(e+,j)$ 5 $\Delta R(e+,j2)$ 4.7 $\text{mass}(e+,j2)$ 4.1 $\Delta R(e-,j2)$ 4 $\text{mass}(e-,j2)$ 3.7 $\min\Delta R(e-,j)$ 3.2 $\text{sumPt}$ 3.2	
* 3j1pmiss	[plots]	161	$95.4 \pm 1.5$	+4.9	$Z0j = 27.5, Z0jj = 26, Z0 = 17.4, Z0jjj = 12.2, Z0jjjj = 4.5, \tau\tau-\tau\tau+ = 2.3, \tau\tau-\tau\tau+j = 2.1, \tau\tau-\tau\tau+j = 1.4, \tau\tau-\tau\tau+jjj = 1, \tau\tau-\tau\tau+jjjj = 0.5$	$\text{mass}(j1,j2,j3)$ 5.8 $\Delta R(j2,j3)$ 4.2 $\Delta R(e-,j2)$ 3.4 $\text{mass}(j2,j3)$ 3.3	



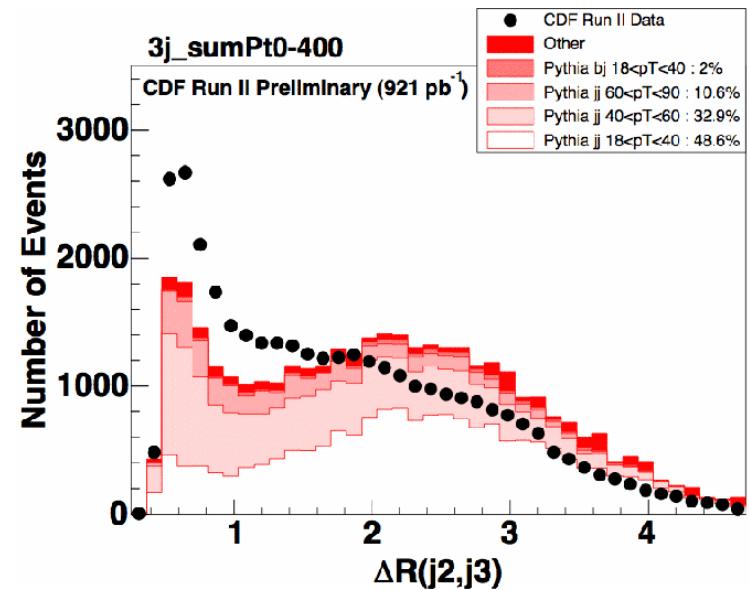
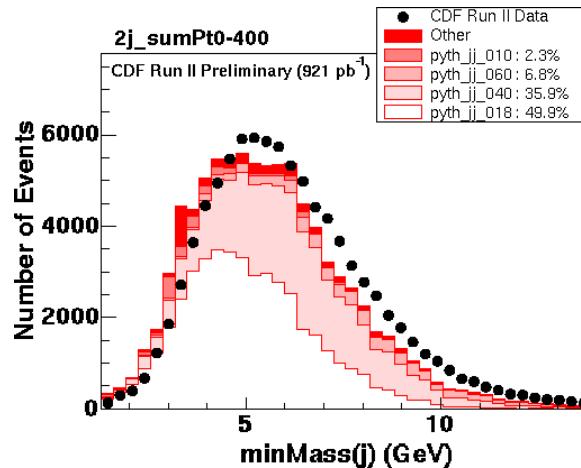




# Looking Globally



Results for Run2 Vista analysis





# How to access information?

```
Handle<GenParticleCollection> particles;
evt.getByLabel( src_, particles );

size_t idx = 0;

for( GenParticleCollection::const_iterator p = particles->begin();
      p != particles->end(); ++ p, ++ idx ) {
    int idabs = abs( p->pdgId() );
    int nMo = p->numberOfMothers();
    int nDa = p->numberOfDaughters();

    // Check for undecayed taus
    if( p->status()==1 && idabs == 15 ) foundUndecayedTau = true;

    if( p->status()==1 && p->pt()>ptMinParticle_ &&
fabs(p->eta())< etaMaxParticle_ ) {

        // Do your work here!

    }
}
```



# The take-home message

- A wide range of tools are available in CMSSW
- Unfortunately, they are needed to do most physics analyses
- No first principle predictions: need to specify parameters
- Tuning will be an early and important physics activity