# Introduction to (CMS) Generators

JTerm IV

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Todd Adams

Florida State University

# Outline

- What are generators?
- What do generators do?
- How do I use generators in CMS?
- How do I get help with generators in CMS?
- What if I want to work in this area?

# What Are Generators?

Physics Generation → Detector Simulation → Reconstruction → Analysis

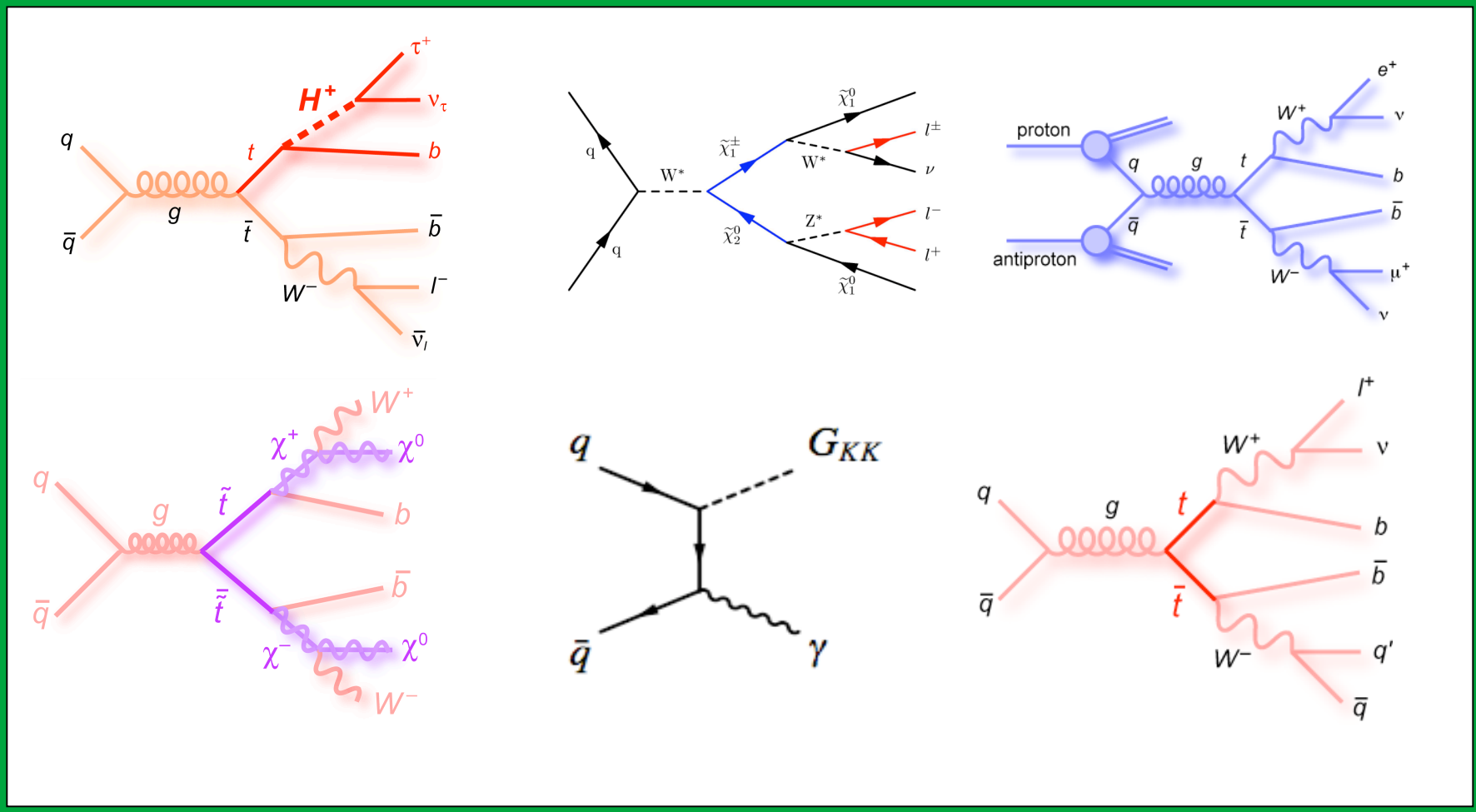
- Physics generators get you from

I want to simulate production and decay of [Higgs bosons] → list of particles with 4-vectors of vertex and momentum

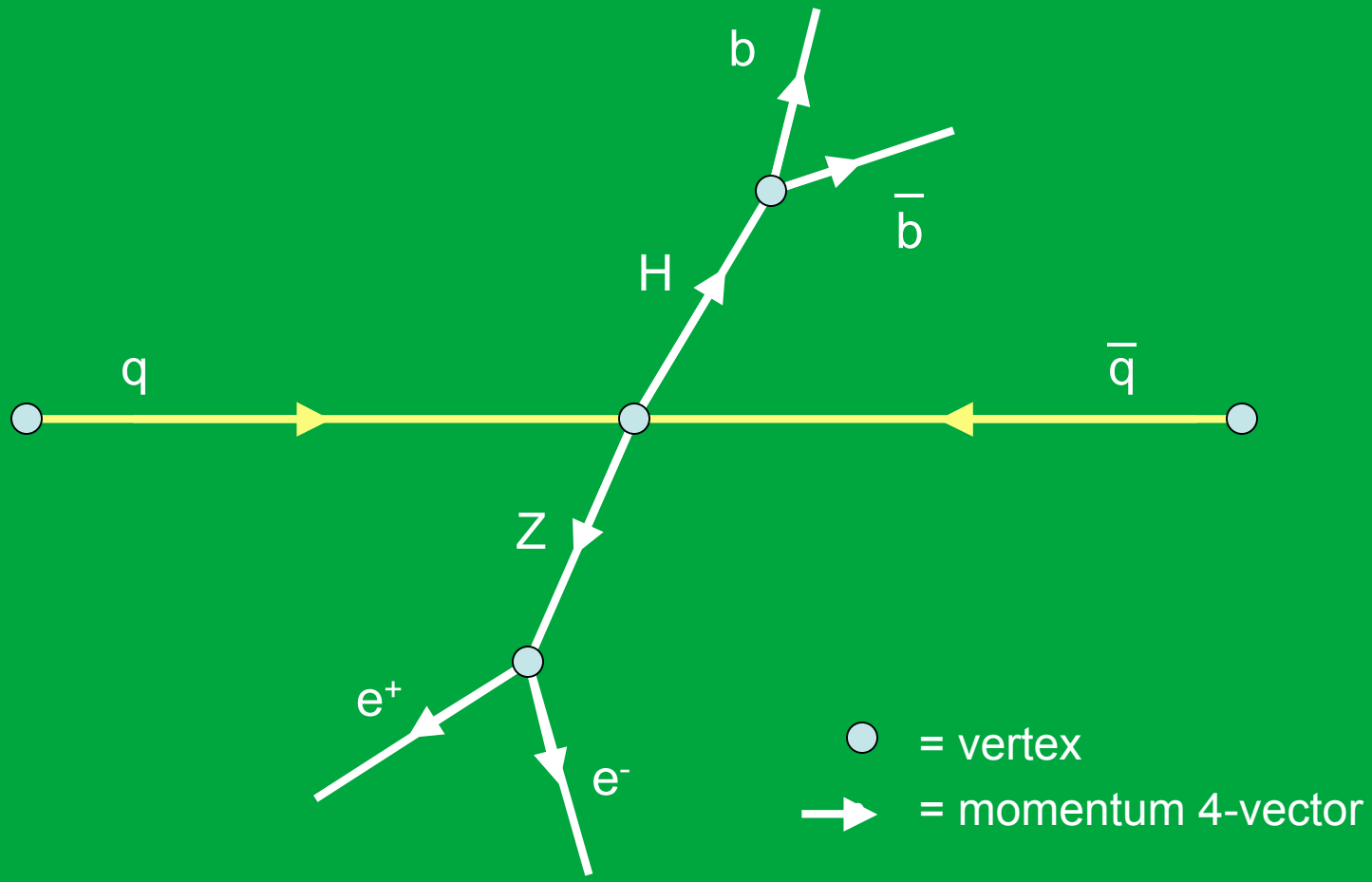
Use Monte Carlo techniques (random numbers) to decide what happens for each simulated collision

# The Simple View

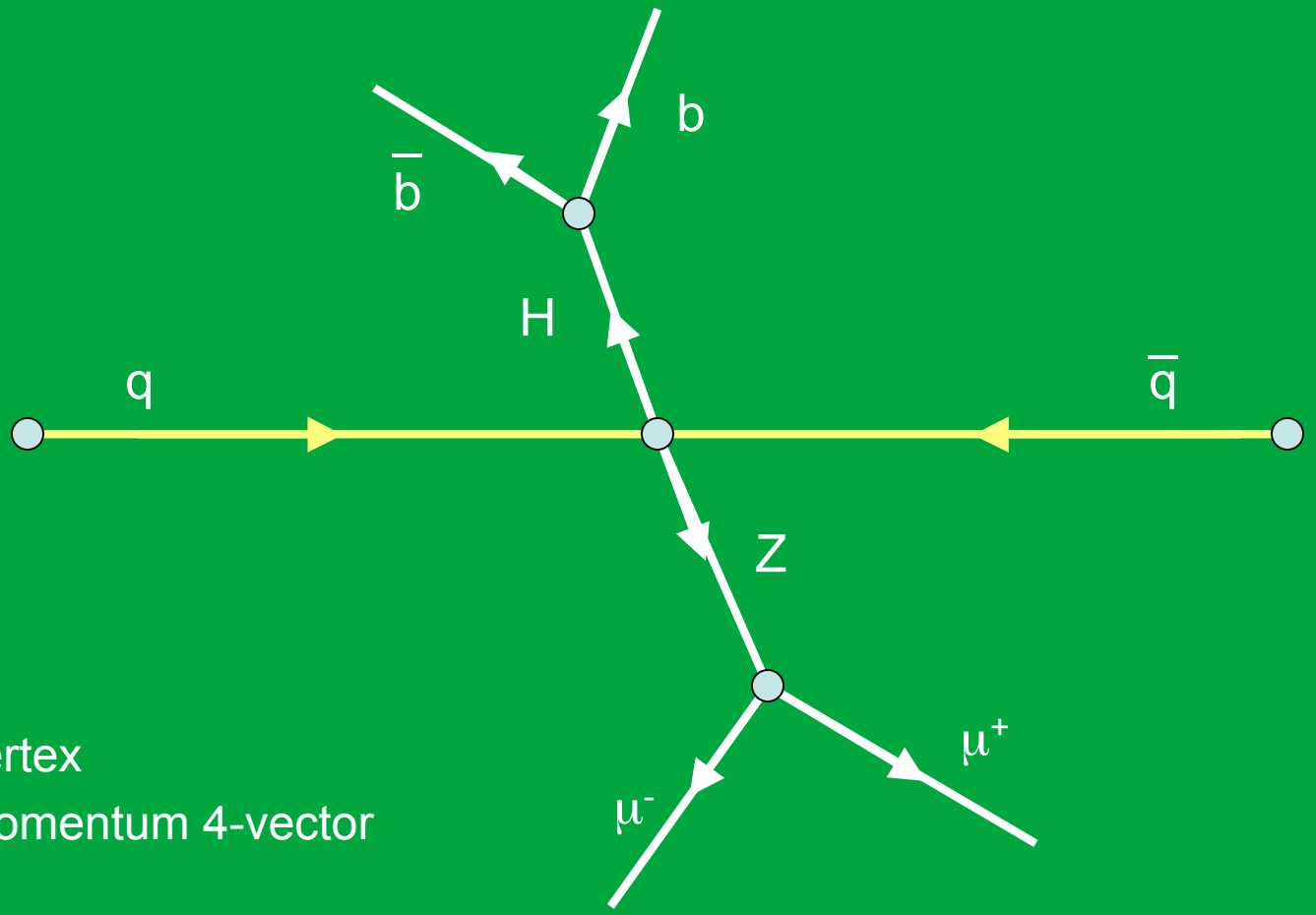
- Basically, generators simulate Feynman diagrams



# Event #1



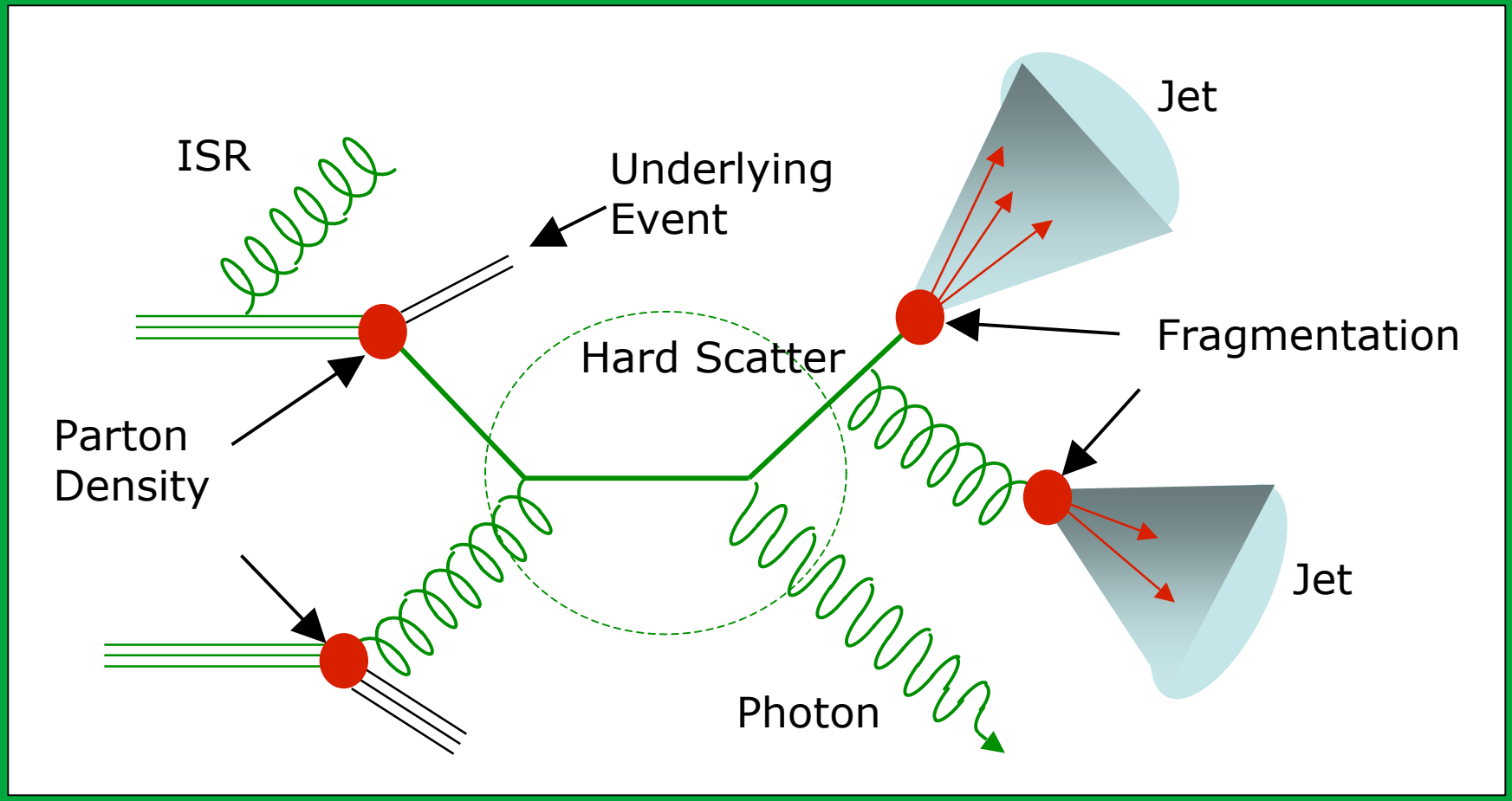
# Event #2




= vertex

= momentum 4-vector

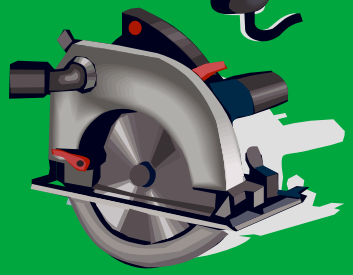
# Much More Complicated

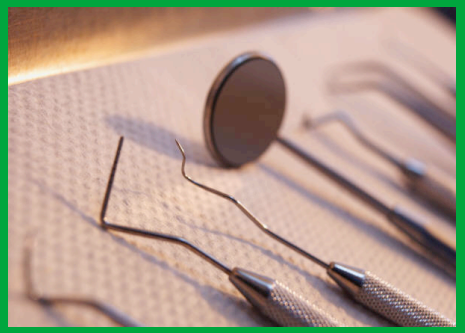
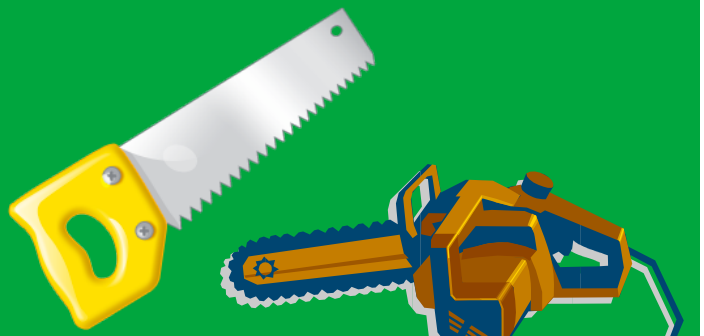


# Available Generators

- Warning: No generator does it all!
- Therefore, we have a number of available MC generators
  - pick the easiest, best one for you
- Need to learn what does what



# Available Generators

| Generator | Documentation | Interface | Responsible | Status |
|---|---|---|---|---|
| Pythia6 | View Twiki | yes | Julia Yarba | ready |
| Herwig6 | under construction | yes | Fabian Stoeckli | ready |
| Pythia8 | under construction | yes | Mikhail Kirsanov | ready |
| ThePEG (Herwig++, Ariadne 5) | under construction | yes | Christoph Hackstein, Oliver Oberst, Fred Stober | ready |
| ALPGEN | View Twiki | yes | Thiago Tomei | ready |
| MadGraph | View Twiki | no | Roberto Chierici, Silvano Tosi | ready |
| MC@NLO | under construction | yes | Fabian Stoeckli | ready |
| POWHEG | under construction | no | Martina Malberti | ready |
| SHERPA | View Twiki | yes | Martin Niegel, Markus Merschmeyer, Altan Cakir | ready |
| Phantom | under construction | no | Sara Bolognesi | ready |
| Hydjet | under construction | yes | Yetkin Yilmaz | ready |
| Pyquen | under constructions | yes | Yetkin Yilmaz | ready |
| Cosmic Muon Generator | under construction | yes | Lars Sonnenschein , Kerstin Hoepfner | ready |
| Beam Halo Muon Generator | no doc | yes | ? | ready |
| ExHuME | View Twiki | yes | Antonio Vilela Pereira | ready |
| Pomwig | View Twiki | yes | Antonio Vilela Pereira | ready |
| BcGenerator | View Twiki | no | Silvia Taroni | ready |

# Other Generator Programs

- Generators in development
- Generator related programs:

| Generator | Documentation | Interface | Responsible | Status |
|---|---|---|---|---|
| CompHEP | under construction | no | Sergey Slabospitsky, Dimitri Konstantinov, Lev Dudko | in progress |
| TopRex | no doc | no | Sergey Slabospitsky | in progress |
| Charybdis | in progress | under consideration | Halil Gamsizkan | advanced |
| EDDE | in progress | under consideration | Andrei Sobol et al. | in progress |
| HELAC | no doc | no | Dimitrios Loukas | in progress |

- EvtGen
  - decays of hadrons with heavy quarks (b's and c's)
- tauola + photos
  - decays of tau's (tauola) and radiative corrections (photos)
- Les Houches Event (LHE)
  - method to read MC generated events written in LHE format

# The Most Important Pieces

- Pythia and Herwig
  - general purpose generators (lots of processes)
  - generally only leading order
  - include hadronization
    - same basic idea, but different models implemented
- Alpgen, MadGraph, MC@NLO, etc
  - generate hard scatter only
  - need to be joined to another package to do hadronization (ex. Alpgen+Pythia, Alpgen+Herwig)
    - ⇒ parton level matching to remove duplication
  - better than Pythia or Herwig at high jet multiplicity

# Monte Carlo Production

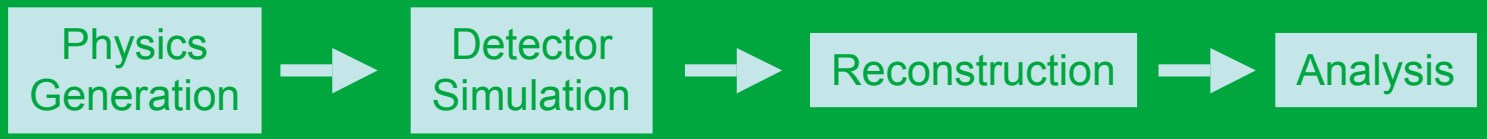
1) Use MC commonly produced by collaboration
2) Produce MC via cmsRun
3) Read LHE events from external generator into cmsRun

# 1. Common MC

- Lots of MC generated for everyone's use
  - Tier-2 sites
- See previous talks about DBS/PhedEx
  - examples: Dave Mason, Oliver Gutsche, Eric Vaandering
- These are the easiest samples to use, the work is already done

# 2. Generate for Yourself: cmsRun

- cmsRun can process the full simulation chain




- Just need a config file
  - can write it yourself
- cmsDriver is easy way to create config file
  - "cmsDriver.py PythiaH190ZZ4mu_cfi.py -s GEN:ProductionFilterSequence --conditions FrontierConditions_GlobalTag,MC_31X_V1::All --datatier 'GEN-SIM-RAW' --eventcontent RAWSIM -n 1000 --no_exec"
  - PythiaH190ZZ4mu_cfi.py is a generator config file
    - located in local directory or Configuration/Generator/python
  - produces a .py file that can be modified (if desired) and run with cmsRun
- This is the most flexible and powerful method
  - you can do just about anything

# Example

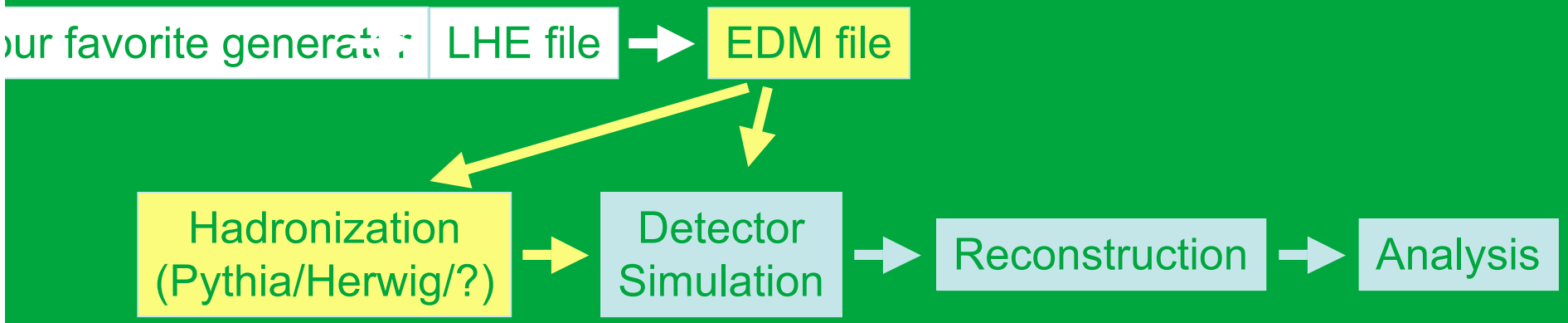
```
PythiaParameters = cms.PSet(
   pythiaHZZmumumumu = cms.vstring('PMAS(25,1)=190.0  !Higgs mass',
        'MSEL=0             !(D=1) to select between full user control (0, then
use MSUB) and some preprogrammed alternative: QCD hight pT
processes (1, then ISUB=11, 12, 13, 28, 53, 68), QCD low pT processes
(2, then ISUB=11, 12, 13, 28, 53, 68, 91, 92, 94, 95)',
        'MSTJ(11)=3        !Choice of the fragmentation function',
        'MSTJ(41)=1        !Switch off Pythia QED bremsshtrahlung',
        'MSTP(51)=7        !structure function chosen',
        'MSTP(61)=0        ! no initial-state showers',
        'MSTP(71)=0        ! no final-state showers',
        'MSTP(81)=0        ! no multiple interactions',
        'MSTP(111)=0       ! no hadronization',
        'MSTU(21)=1        !Check on possible errors during execution',
        'MSUB(102)=1       !ggH',
        'MSUB(123)=1       !ZZ fusion to H',
        'MSUB(124)=1       !WW fusion to H',
        'PARP(82)=1.9      !pt cutoff for multiparton interactions',
        'PARP(83)=0.5      !Multiple interactions: matter distrbn param',
        'PARP(84)=0.4      !Multiple interactions: matter distrbn param',
        'PARP(90)=0.16     !Multiple interactions: rescaling power',
        'CKIN(45)=5.       !high mass cut on m2 in 2 to 2 process',
        'CKIN(46)=150      !high mass cut on secondary resonance m1 in
2->1->2 process',
        'CKIN(47)=5.       !low mass cut on secondary resonance m2 in 2-
>1->2 process',
        'CKIN(48)=150.     !high mass cut on secondary resonance m2 in
2->1->2 process',
    'MDME(174,1)=0         !Z decay into d dbar',
    'MDME(175,1)=0         !Z decay into u ubar',
    'MDME(176,1)=0         !Z decay into s sbar',
    'MDME(177,1)=0         !Z decay into c cbar',
    'MDME(178,1)=0         !Z decay into b bbar',
    'MDME(179,1)=0         !Z decay into t tbar',
    'MDME(182,1)=0         !Z decay into e- e+',
    'MDME(183,1)=0         !Z decay into nu_e nu_ebar',
    'MDME(184,1)=1         !Z decay into mu- mu+',
    'MDME(185,1)=0         !Z decay into nu_mu nu_muba
    'MDME(186,1)=0         !Z decay into tau- tau+',
    'MDME(187,1)=0         !Z decay into nu_tau nu_tauba
    'MDME(210,1)=0         !Higgs decay into dd',
    'MDME(211,1)=0         !Higgs decay into uu',
    'MDME(212,1)=0         !Higgs decay into ss',
    'MDME(213,1)=0         !Higgs decay into cc',
    'MDME(214,1)=0         !Higgs decay into bb',
    'MDME(215,1)=0         !Higgs decay into tt',
    'MDME(216,1)=0         !Higgs decay into',
    'MDME(217,1)=0         !Higgs decay into Higgs decay
    'MDME(218,1)=0         !Higgs decay into e nu e',
    'MDME(219,1)=0         !Higgs decay into mu nu mu',
    'MDME(220,1)=0         !Higgs decay into tau nu tau',
    'MDME(221,1)=0         !Higgs decay into Higgs decay
    'MDME(222,1)=0         !Higgs decay into g g',
    'MDME(223,1)=0         !Higgs decay into gam gam',
    'MDME(224,1)=0         !Higgs decay into gam Z',
    'MDME(225,1)=1         !Higgs decay into Z Z',
    'MDME(226,1)=0         !Higgs decay into W W',
    'MSTP(128)=2          !dec.prods out of doc section, p
          at parents in the main section'),
   parameterSets = cms.vstring('pythiaHZZmumumumu')
```

# Why So Complicated?

- Lots of parameters to control
  - PDFs, particle masses, decay modes, kinematic cuts, etc
  - Primary parameter: what to produce
- Most generators can do a lot of things, therefore have lots of controls
  - you only need some of them, trick is to figure out which ones
- Each generator has different controls
- Won't try to explain any one generator here

# 3. Use Pre-generated LHE Files

- Many MC generators will produce events and write them out in LHE format files
  - even if generator is not integrated into CMSSW
- CMSSW can read LHE files and send them through the rest of the simulation chain
  - files can be read from disk or from MCDB



# Example

```
process = cms.Process("LHE")

process.source = cms.Source("LHESource",
    fileNames = cms.untracked.vstring('file:ttbar.lhe')
)

process.configurationMetadata = cms.untracked.PSet(
    version = cms.untracked.string('alpha'),
    name = cms.untracked.string('LHEF input'),
    annotation = cms.untracked.string('ttbar')
)

process.LHE = cms.OutputModule("PoolOutputModule",
    dataset = cms.untracked.PSet(dataTier = cms.untracked.string('LHE')),
    fileName = cms.untracked.string('lhe.root')
)

process.outpath = cms.EndPath(process.LHE)
```

# Help!!!!

- CMS Generators group
  - led by Roberto Chierici and Fabian Stoeckli
  - responsible for all MC generators in CMSSW
  - meets about every two weeks
- Hypernews
  - https://hypernews.cern.ch/HyperNews/CMS/get/generators.html
- Documentation
  - Twiki: https://twiki.cern.ch/twiki/bin/view/CMS/SWGuideEventGeneration
  - Workbook: https://twiki.cern.ch/twiki/bin/view/CMS/WorkBookGeneration
  - 30 second intro: https://twiki.cern.ch/twiki/bin/view/CMS/WorkBookGenIntro

# Local Help

- Some local experts:

Steve Mrenna
Fermilab

Julia Yarba
Fermilab

Avto Kharchilava
U. of Buffalo

Todd Adams
Florida State U.

- There are numerous other people around who have expertise that may help you.
- Don’t be afraid to ask!

# What If I Want to Help?

- Join the CMS generators group
  - plenty of projects
- Talk to a local expert who can give guidance

# Summary

- At some point, you will need MC events
  - you will need some understanding of what these events are to use them properly
- There is a decent chance you will need/want to generate your own events
  - you will definitely need some knowledge of what to do here
- There is lots of help available
  - experts, Generator group, webpages, hypernews
- Don’t be afraid to ask for help