Hands-On Vincia Tutorial

Will look at

Top Quark Mass
- With and without interleaved resonance decays.
- Compared to Pythia with and without top coherence hook.

Electroweak Showers
- Cosmic-ray spectra from ultra-heavy Dark Matter decays, with Vincia compared to Pythia's Weak Shower

Sector Merging
- Example: Weak Boson Fusion at LHC

Summary — Vincia as of Pythia 8.304

Defaults for Vincia (partonShowers:Model = 2):

- **Sector antenna showers** [2003.00702]
  with built-in coherence, in particular for **Initial-Final (IF)** and **Resonance-Final (RF)** colour flows, which are challenging for the SimpleShowers Model.
- **Interleaved resonance decays** [paper in progress]
  ON by default in Vincia; available as option in SimpleShowers
- Mass corrections (pseudo-collinear limits & massive phase space) [1108.6172]
  for b quarks and heavier (can be extended to c quarks)
- Coherent QED radiation [2002.04939]
  with multipole interference, correct $W \to W\gamma$ kernels, etc.
- Dedicated default tuning
  Used similar setup as Monash tune though not at same extensive level

+ several options, eg for helicity showers, **electroweak showers**, **sector merging**, enhanced splittings, …

Note, however, that automated uncertainty variations have yet to be (re)implemented. On the todo-list…

Tutorial Part 3 (VBF)

Tutorial Part 1 (Top Mass)

Tutorial Part 2

Tutorial Part 3 (Merging)

Hands-On Vincia Tutorial

Download & unpack tutorial tarball (~100MB)

```
http://skands.physics.monash.edu/slides/files/vincia8304-tutorial.tgz
tar -xzf vincia8304-tutorial.tgz
cd vincia8304-tutorial/
```

Configure and compile, with MG5 libraries:

```
./configure --with-mg5mes
make -j8          (or -jN with N = how many threads you have)
```

While it compiles,

```
open Pythia83-VinciaTute.pdf      (these instructions)
```

Then move to the examples/ directory:

```
cd examples/
```

Tutorial Part I: Top Mass

Simple reconstruction of the top quark mass.

Will Compare:

- Pythia (default settings)
- Pythia (with top coherence hook)
- Vincia (default settings)
- Vincia (without interleaved resonance decays)

Example program: testTop.cc

- Starting point: setup for default Pythia

  ```
  make testTop
  ./testTop
  ```

- (Write down the mean of the m_t error, for later comparison)

  ```
  python3 plotTop.py
  ```

2) Now enable the top coherence hook

Will give us something more interesting to compare with Vincia.

- If you want to look at it, it's in `topCoherenceHook.h`
- But for this tutorial you can use it as a black box

The top coherence hook needs:

```
TimeShower:recoilToColoured=off
```

Set the local (main-program) variable

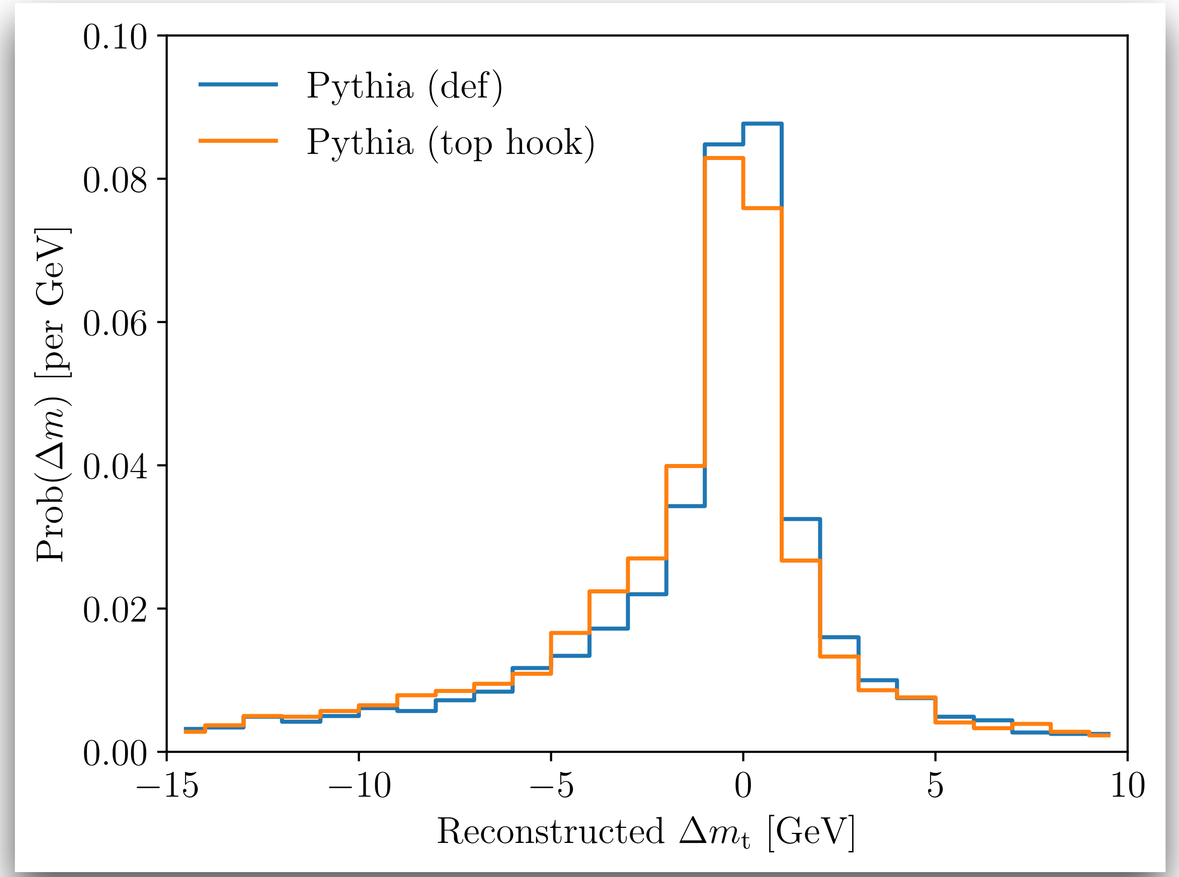
```
doTopCoherence=true;
```

- (Will create the hook and pass it to Pythia)

Change the output file:

```
"topHook.dat"
```

Repeat the run, note down the new mean Δm_t, and edit `plotTop.py`



Peak position shifts (considerably) to lower masses

3) Now let us see what Vincia says

To change to Vincia, all you need is:

PartonShowers:Model = 2

- (Vincia then automatically initialises its own default tune, etc.)

Change the output file name:

"vincia.dat"

Repeat the run and note down mean Δm_t.

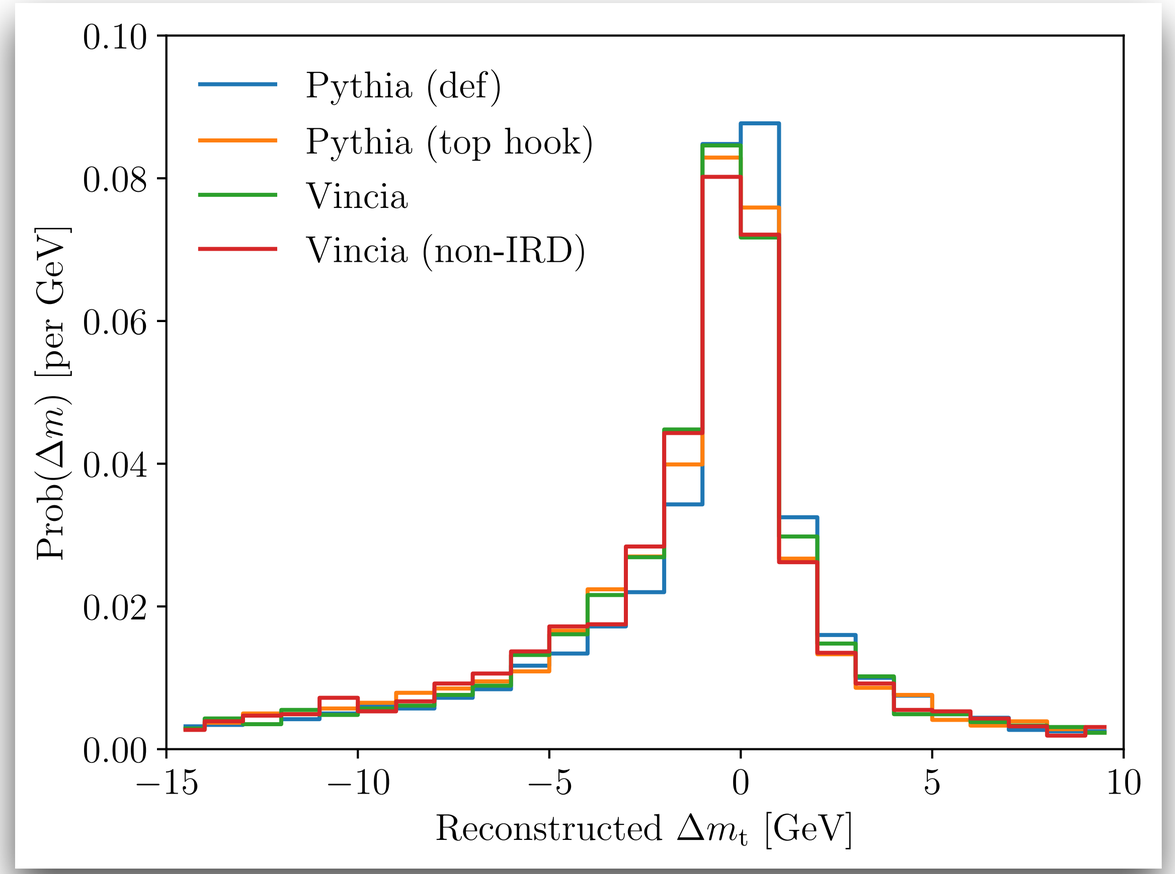
- (Apologies: Vincia's current ISR algorithm is quite slow. Did not have time to optimise yet; expect improvements in future.)

Also note that interleaved resonance decays are ON by default in Vincia (while they are OFF in Pythia).

- Let's check how things look without IRD in Vincia.
  Vincia:interleaveResDec = Off
- Change file name to "vincia-nonIRD.dat"
- Rerun, note down mean Δm_t, and replot.

(Note: equivalent for Pythia is TimeShower:interleaveResDec = on/off)

Results



Summary: Top coherence hook makes a big difference

- Pythia + top hook and Vincia are more similar; encouraging.
- InterleavedResDec on/off not a huge effect.
- Not really enough stats in our small runs to say more.

Exercise: Dark Matter Spectra

Dark Matter Spectra from the Electroweak to the Planck Scale

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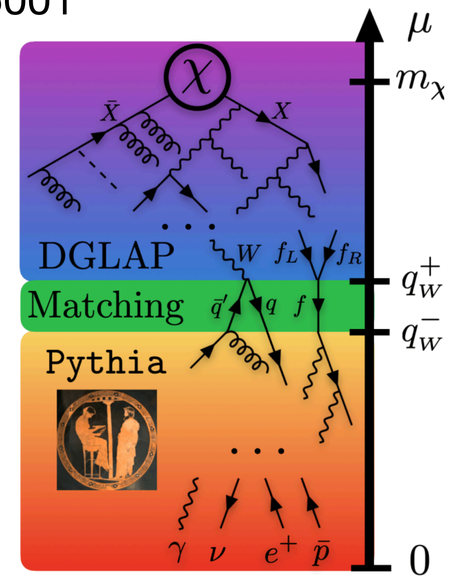
We are going to compare Pythia's & Vincia's EW shower with some results from a recent paper: 2007:15001

They compute decay spectra for heavy DM that decays to SM particles → Cosmic rays



- Use testVinciaEW.cc to generate a prediction of Pythia's EW shower
- This generates a bunch of files in the vinciaEWSpectra directory
- Run plotSpectra.py in that same directory to generate plots with the results from 2007:15001

Next, we want to produce similar plots for Vincia's EW shower

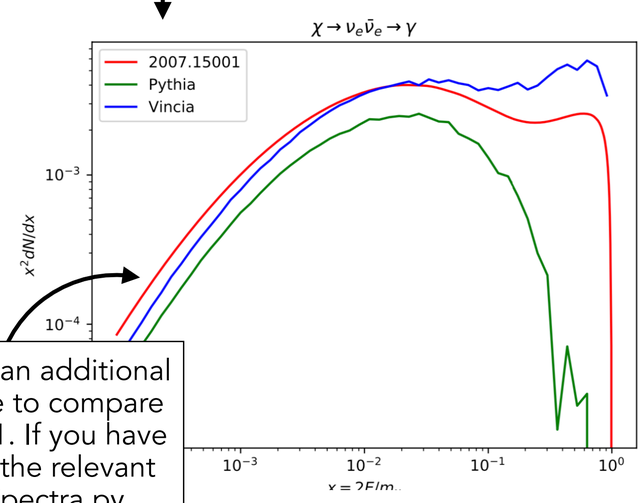
We need to:

- Have configured with mg5mes: ./configure —with-mg5mes
- Enable Vincia (PartonShowers:model = 2)
- Enable the EW shower (Vincia:ewMode = 3)
- Point Vincia to the correct mg5mes directory (Vincia:mePlugin = procs_ew_sm-ckm)

Then just run the main program again (change the output file!)
and run the plotting script again

Note that Pythia undercounts most of the spectra because it doesn't have triple-gauge interactions

Expected result



Note: you need an additional python package to compare with 2007.15001. If you have it, uncomment the relevant lines in plotSpectra.py

Tutorial Part III: Vincia's Sectorised Merging

Vincia comes with its own merging implementation [2008.09468]

- Designed for efficient multi-jet merging especially at high multiplicities. This is facilitated by the use of sector showers, which bypass the factorial growth of the number of histories.

It can be switched on by:

```
PartonShowers:model = 2
Merging:doMerging   = on
```

To ensure consistency in the merging, a few more settings are needed:

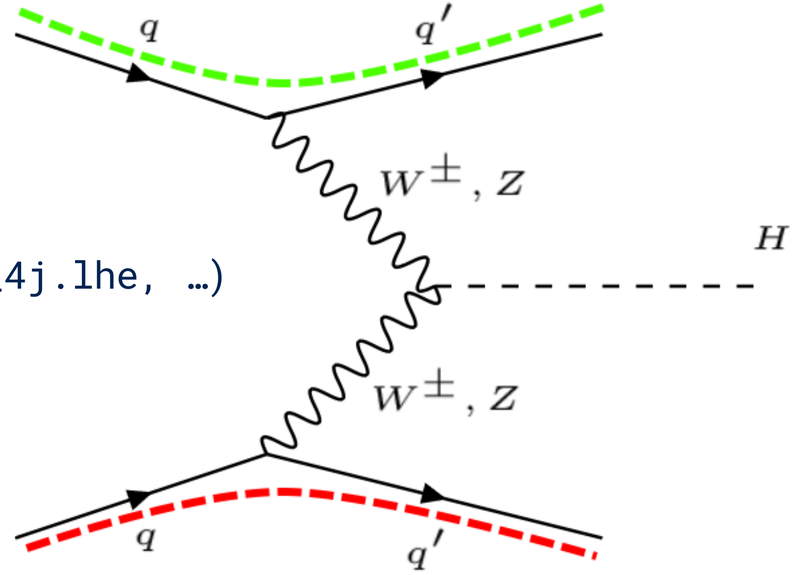
```
Vincia:ewMode           = 0
Vincia:doRF             = off
Vincia:kineMapFFsplit   = 1
Vincia:pTmaxMatch       = 1
```

- These switch off EW/QED & resonance-final (RF) showers, ensure only kinematic maps are used for which the inverse is implemented, and showers are started at the factorisation scale.

Hands-on: CKKW-L Merging in VBF with Vincia

This tutorial is less focussed on physics.

- Main aim is to show how to get it to run and highlight differences to default merging.



The examples directory contains a compressed file containing five event files (hvbf_2j.lhe, hvbf_3j.lhe, hvbf_4j.lhe, …)

- Before you start, unpack these with

```
tar -xzf testMerging-samples.tgz
```

The events are regularised by a kT cut, so we have to enable kT-merging and set the merging scale (in GeV):

```
Merging:doKTMerging   = on
Merging:TMS           = 20.
```

- (Different to default merging, both doMerging and doKTMerging should be ON here)

Defining the Born process again works slightly differently:

```
Merging:Process       = { p p > h0 j j }
Vincia:MergeVBF       = on
```

- The flag ensures that the colour flow of the input event can be mapped to the VBF topology (two initial-final quark lines) and aborts those which cannot.

Lastly, we set the number of additional jets in same way as for default merging.

- E.g. for 1 additional jet:

```
Merging:nJetMax       = 1
```

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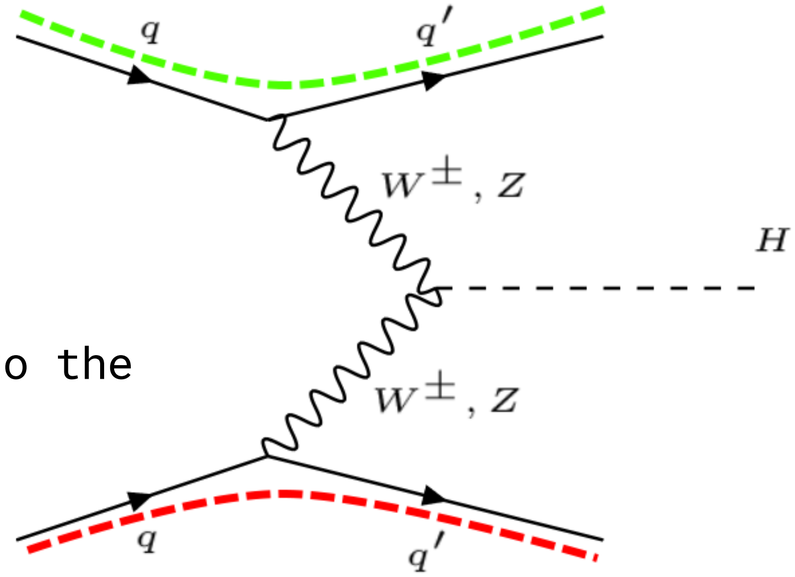

Exercises

- Add the Vincia merging settings from the last slides to the `testMerging.cmnd` file and run the `testMerging` example.

  After each sub-run (corresponding to a certain jet multiplicity), merging statistics are printed, informing about the number of vetoed events.

- Change the input file so that four-jet merging is performed, using the `hvbf_4j.lhe`, `hvbf_5j.lhe`, and `hvbf_6j.lhe` files.

  How does the CPU time of each sub-run change with increasing jet multiplicity?

Note: During the preparation of this tutorial, we discovered an inconsistency related to the treatment of the Vincia:MergeVBF flag. While this flag enables a check whether the input event can be mapped to a VBF process, non-VBF histories are allowed during the clustering steps, resulting in a small number of incomplete histories. (Visible e.g. in the number of vetoed events with lower multiplicity than the current one in the merging statistics.)

Note on α_s: yet another way to skin that cat

In Pythia

- Effective value of α_s in showers is governed by `TimeShower:alphaSvalue` and `SpaceShower:alphaSvalue` + corresponding running orders and CMW on/off.

In Vincia

- Instead there is a single `Vincia:alphaSvalue` (which you can set to the PDG value if you like, done by default)
- Effective coupling in showers instead controlled by renormalisation-scale prefactors:

```
parm  Vincia:renormMultFacEmitF  (default = 0.66; minimum = 0.1; maximum = 10.0)
parm  Vincia:renormMultFacSplitF  (default = 0.8; minimum = 0.1; maximum = 10.0)
parm  Vincia:renormMultFacEmitI  (default = 0.66; minimum = 0.1; maximum = 10.0)
parm  Vincia:renormMultFacSplitI  (default = 0.5; minimum = 0.1; maximum = 10.0)
parm  Vincia:renormMultFacConvI  (default = 0.5; minimum = 0.1; maximum = 10.0)
```

- Also choose loop order (default 2), whether to translate to the CMW scheme (default ON), and some options to regulate the coupling near the IR boundary.