BSM with Pythia8

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Current version: Pythia 8.205

ELSEVIER

An introduction to PYTHIA 8.2 ☆

Torbjörn Sjöstrand [a,*], Stefan Ask [b,1], Jesper R. Christiansen [a], Richard Corke [a,2],
Nishita Desai [c], Philip Ilten [d], Stephen Mrenna [e], Stefan Prestel [f,g],
Christine O. Rasmussen [a], Peter Z. Skands [h,i]

Some improvements:

- ▸ Fifteen new tunes (MonashStar, A14)
- ▸ New I/O format ProMC
- ▸ LHEF3 read/write
- ▸ Addition to BSM processes

Role of generators like Pythia

▸ One-stop-shop for modelling physics processes

▸ PS + Hadronisation for processes generated with more specialised generators.

▸ Current state-of-the-art SM calculations use (automated) ME generators + PS with matching followed by hadronisation.

– Pythia 8 provides various interfaces to external ME generators

– LO/NLO matching for processes available

List of internal processes - I

▸ BSM Higgses (2HDM)

Also has anomalous Higgs couplings for EFT-inspired analyses; addition of new parameter for mixing in $h \rightarrow \tau^+ \tau^-$

▸ Fourth generation quarks (t', b')

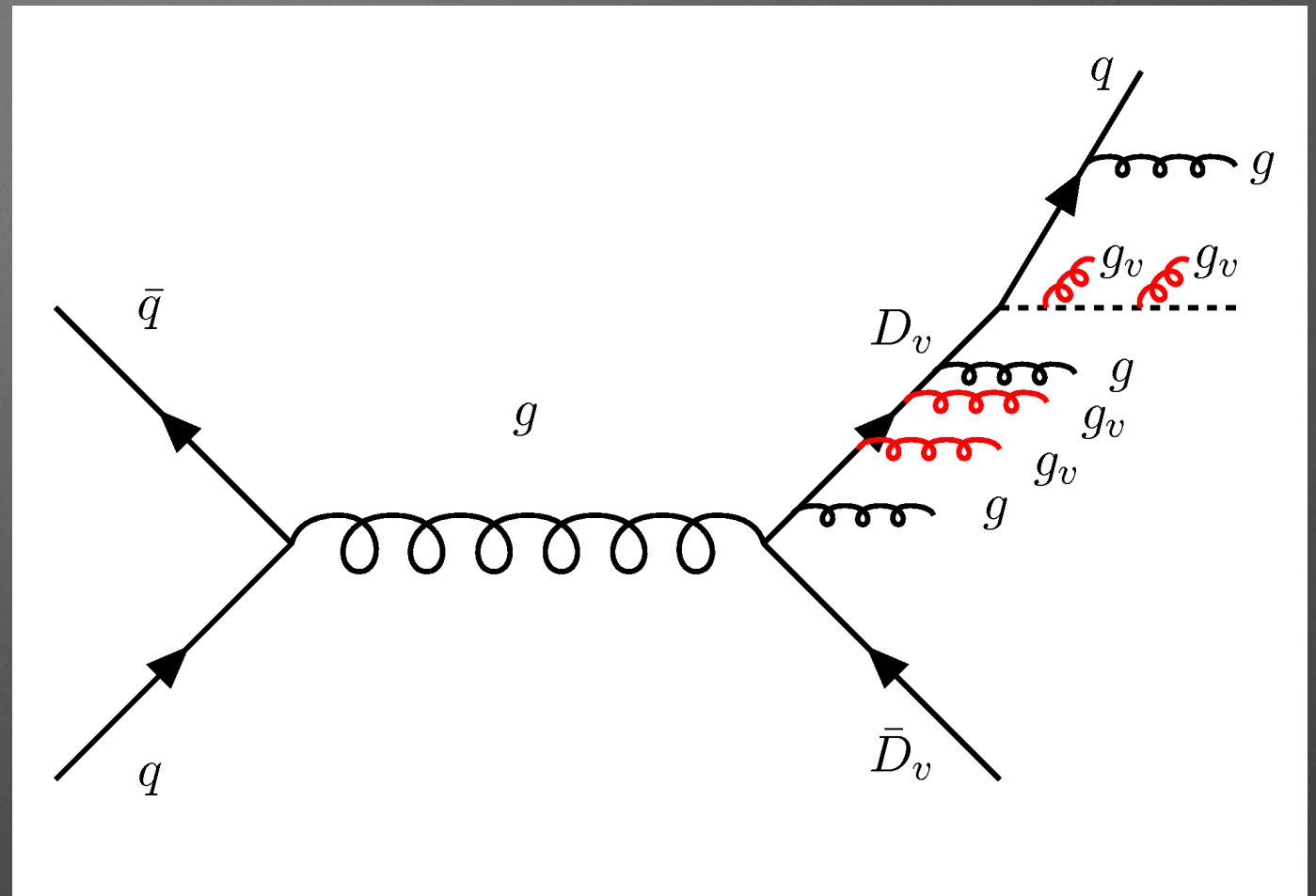▸ New Gauge Bosons (Z', W', R0)

▸ Left-Right symmetric models

▸ Leptoquarks

▸ Compositeness

6 new processes added: excited leptons and neutrinos; Z' can now decay into excited fermions.

List of internal processes - II

- Extra dimensions:
  Randall-Sundrum
  Universal ED
  Large ED
  Unparticles

L. Carloni and T. Sjöstrand, JHEP 1009 (2010) 105
L. Carloni, J. Rathsman and T. Sjöstrand, JHEP 1104 (2011) 091

- Hidden valleys
  Showering and hadronisation
  in the presence of hidden gauge group

Supersymmetry

6x6 squark/slepton matrices allow processes with: CP/Flavour/R-parity violation

Can handle extra Higgses/higgsinos from NMSSM

Cross sections: All pair production (MSSM) is now validated

Many interfaces to external programs:

- Interface to LHAPDF or other external PDF libraries.
- External showers via VINCIA
- Les Houches Accord files for reading events (LHEF) or runtime LHA interface.
- Semi-internal processes for programs like Madgraph5.
- HepMC output for programs like RIVET, Delphes etc.
- Can be compiled as a plugin to ROOT.
- Generalised SLHA input for any BSM model.

LHEF v3 now readable

```
BLOCK QNUMBERS 7654321 # balleron
   1    0   # 3 times electric charge
   2    2   # number of spin states (2S+1)
   3    8   # colour rep (1:singlet, 3:triplet,
        #                   6:sextet, 8:octet)
   4    0   # Distinct antiparticle?
        # (0=own anti)
```

```
BLOCK QNUMBERS 8765432 # yup yupbar
   1    2   # 3 times electric charge
   2    2   # number of spin states (2S+1)
   3    3   # colour rep (1:singlet, 3:triplet,
        #                   6:sextet, 8:octet)
   4    1   # Distinct antiparticle?
        # (0=own anti)

BLOCK MASS
#       ID code   pole mass  in GeV
        7654321    800.0   # m(balleron)
        8765432    600.0   # m(yup)
```

Add new particles by specifying SM gauge couplings, spin, mass and decays.

Interface with external event generators II : semi-internal processes

You can use the entire Pythia internal machinery by supplying only the matrix-element-squared for your process in terms of Pythia's kinematic variables.

Showering and hadronisation of exotic states

‣ R-hadrons

‣ Sextets, octets

‣ Baryon-number violating RPV
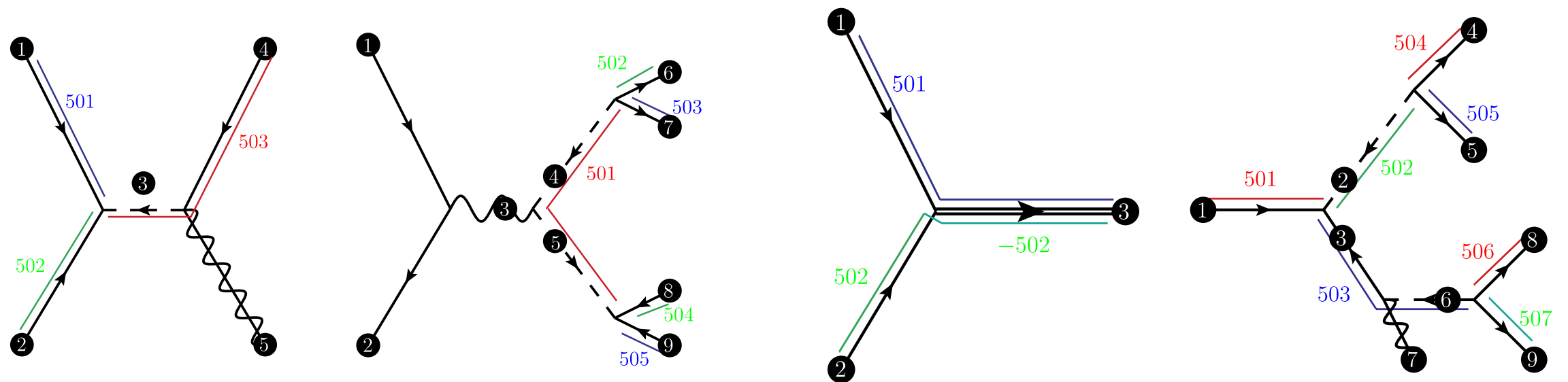
User modifications I : UserHooks

Many places to interrupt Pythia execution:

▸ After setting up beams

▸ After generating hard process

▸ During showers (veto emissions etc.)

▸ After showers (but before hadronisation)

▸ Modify cross section

▸ Reject certain decays

▸ …

User modifications II : Custom SLHA read-in

If you need access to model parameters (e.g. for semi-internal processes)

```
bool slhaPtr->getEntry(string blockName, double& val)
bool slhaPtr->getEntry(string blockName, int indx, double& val)
bool slhaPtr->getEntry(string blockName, int indx, int jndx, double& val)
bool slhaPtr->getEntry(string blockName, int indx, int jndx, int kndx, double& val)
```

Give arbitrary block names, can store up to 3-dim blocks

User modifications III

Possible to modify running of couplings. See e.g. "Emerging Jets" documented in Schwaller et al. JHEP 1505 (2015) 059

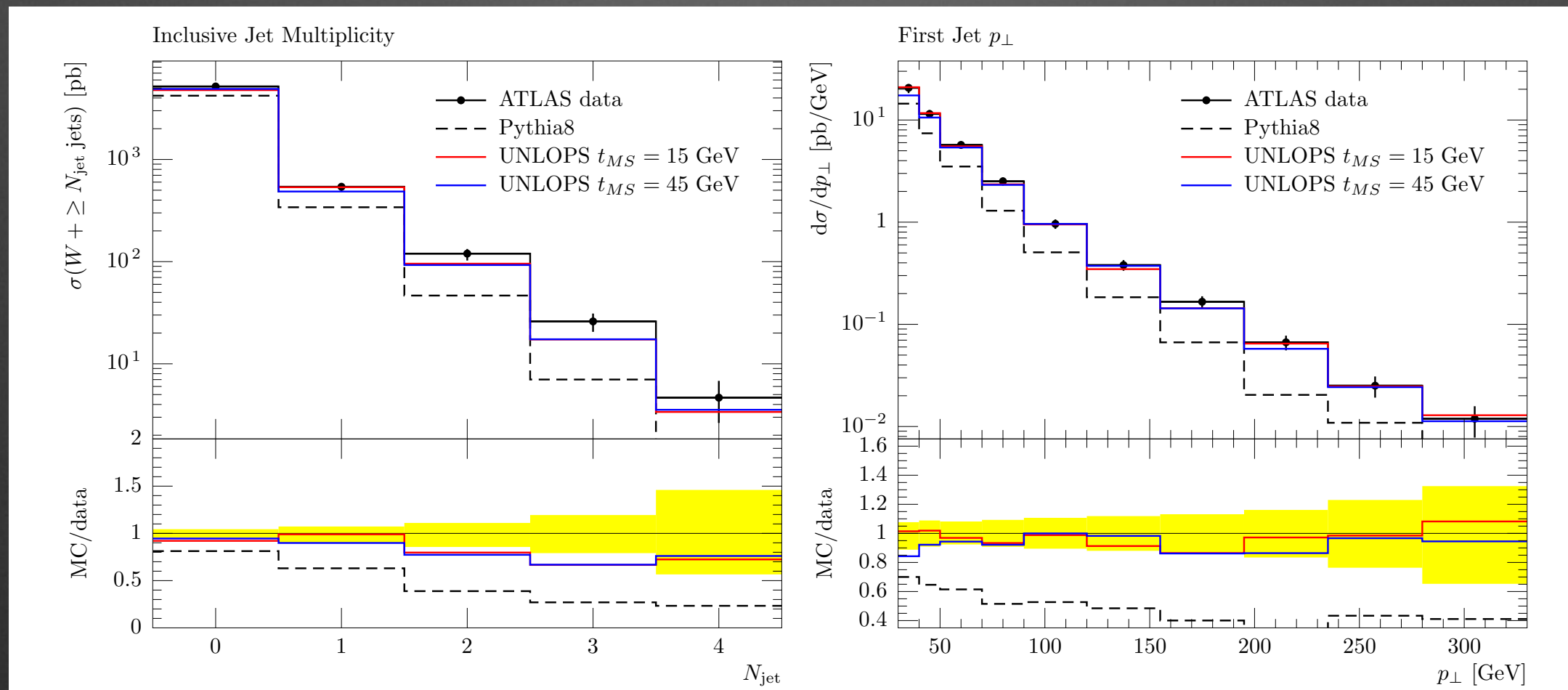They modify the Hidden Valleys model to include running of coupling in the dark sector

Merging multi-jet samples
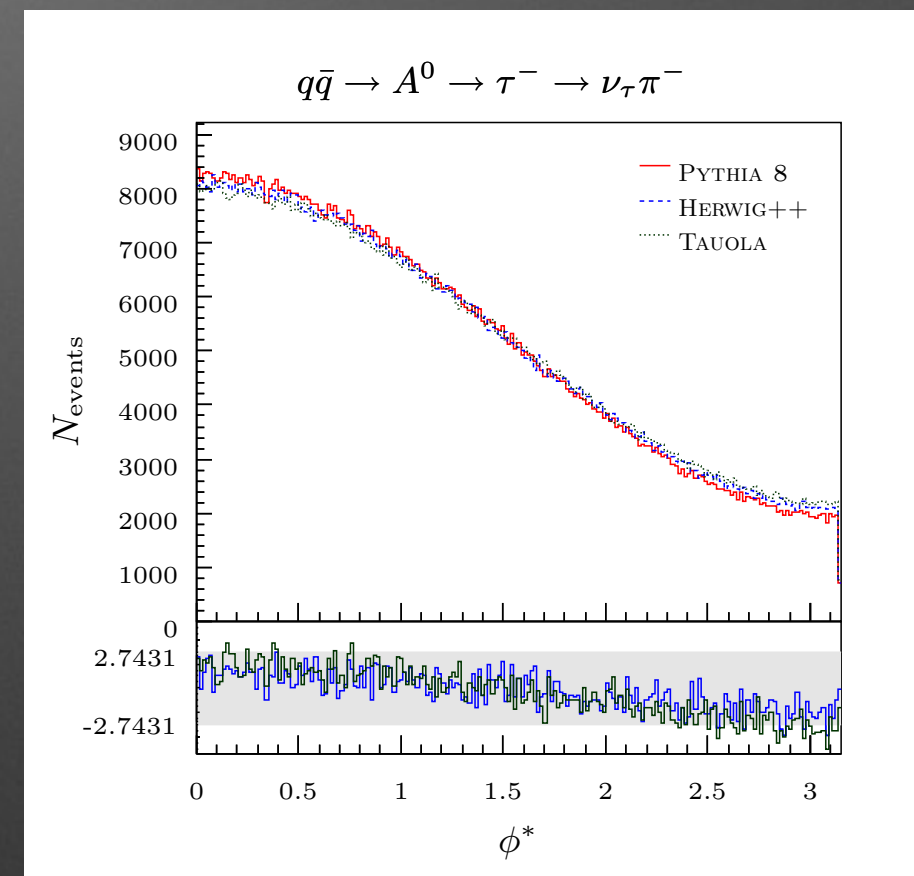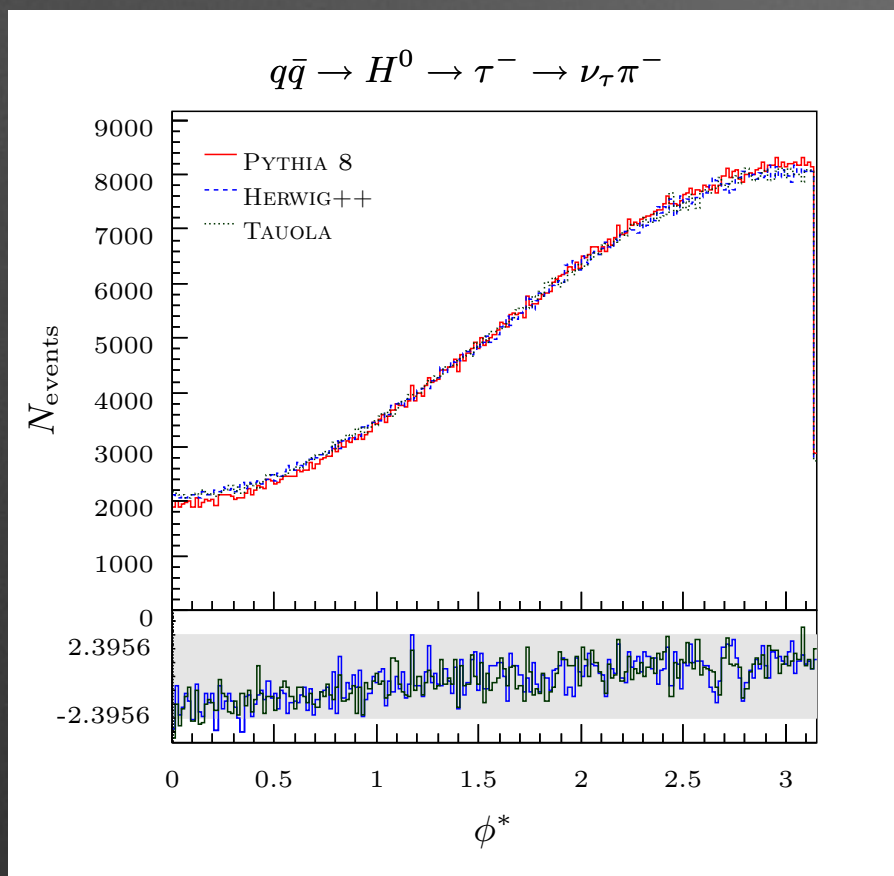
LO merging
- MLM, CKKW-L
- UMEPS

NLO merging
- FxFx
- MC@NLO
- UNLOPS

Lonnblad and Prestel; JHEP(2013) 2013:166

Tau polarisation and decays

Implementation 3- 4- and 6-body decays.

P. Ilten, Nucl.Phys.Proc.Suppl. 253-255 (2014) 77-80

Upcoming improvements

‣ Many processes made ready for e+ e-, more to be added as needed.

‣ New showers (to be released as plugins)

‣ What does the community need?

Looking forward to LHC Run2!