Simulating the LHC: Event Generators and Parton Showers

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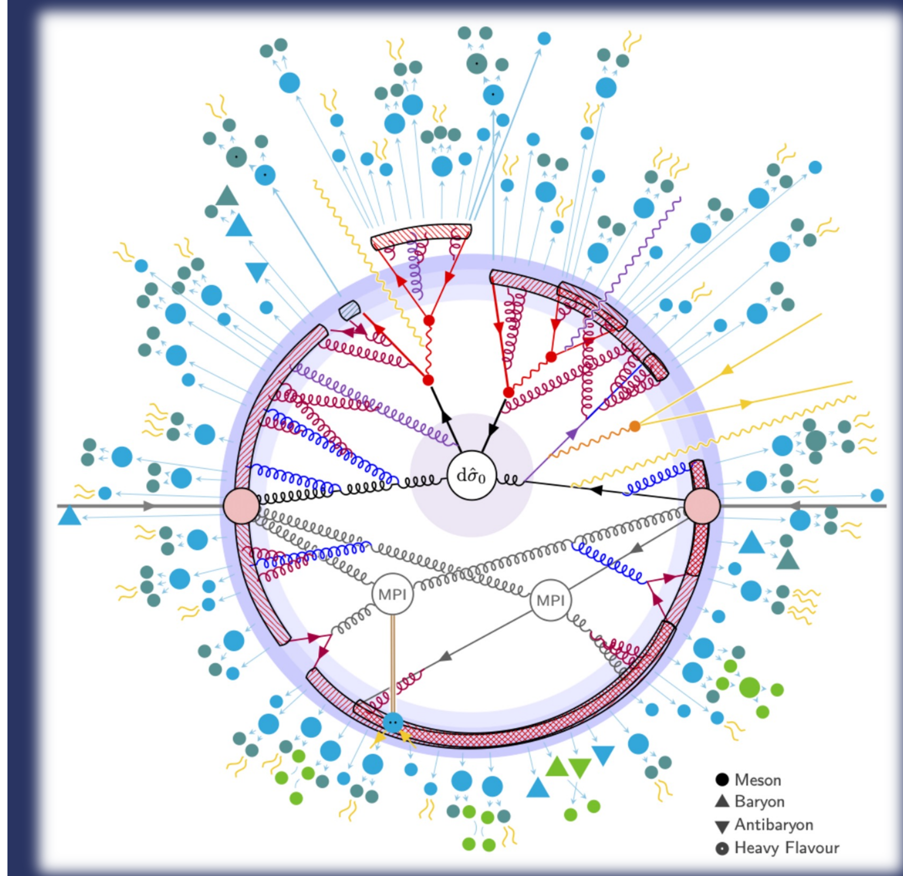
Event Generators

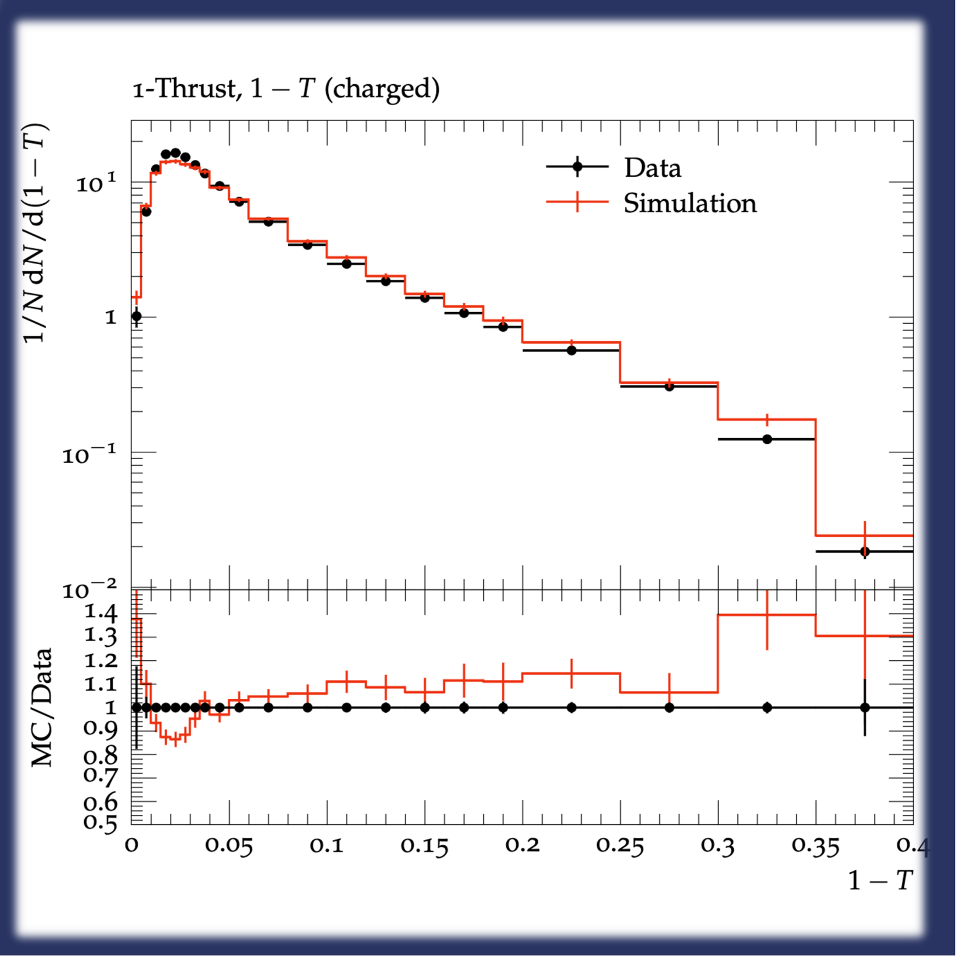


[Pythia 8.3 Manual, 2022]

High-energy physics events can be simulated using a general-purpose event generator.

Monte Carlo techniques are used to generate a theoretical prediction of the data observed by detectors like ATLAS and LHCB

[Simulated on Herwig 7.3]



Particle physicists compare this data to actual detector data to:

- Search for new physics
- Test new theories and models
- Simulate possible detectors before constructing them

[Buckley et al, 2011]

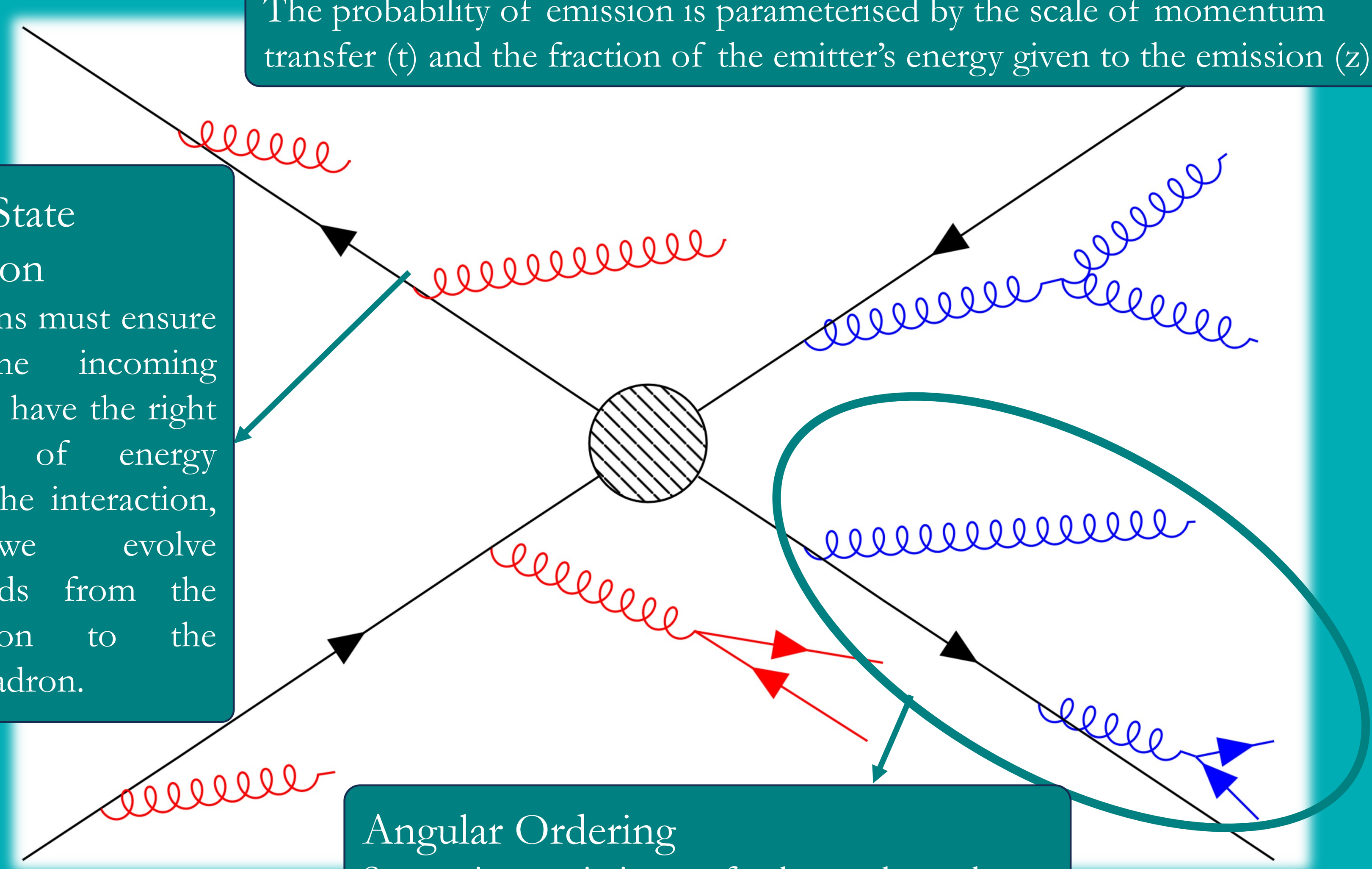
Parton Showers

Parton \ pär-tän \
1. Quarks and Gluons
2. The Last name of a Famous Singer

Parton showers use Monte-Carlo Random Sampling with emission probabilities to generate radiation from the fundamental partons.

An (over)simplified parton shower algorithm, simulating gluon emission:
1. Calculate the emission probability $p^{q\to qg}(t,z)$
2. Generate a random number $r \in [0,1]$
3. If $r < p$, emit a gluon!

The Physics of Emissions
The probability of emission is parameterised by the scale of momentum transfer (t) and the fraction of the emitter's energy given to the emission (z)



Initial State Radiation
Emissions must ensure that the incoming particles have the right amount of energy before the interaction, so we evolve backwards from the interaction to the origin hadron.

Angular Ordering
Successive emissions of gluons have lower energies, but also smaller angles to the emitter!

Current Shower Models

There are **two** popular models of parton showers in use today:

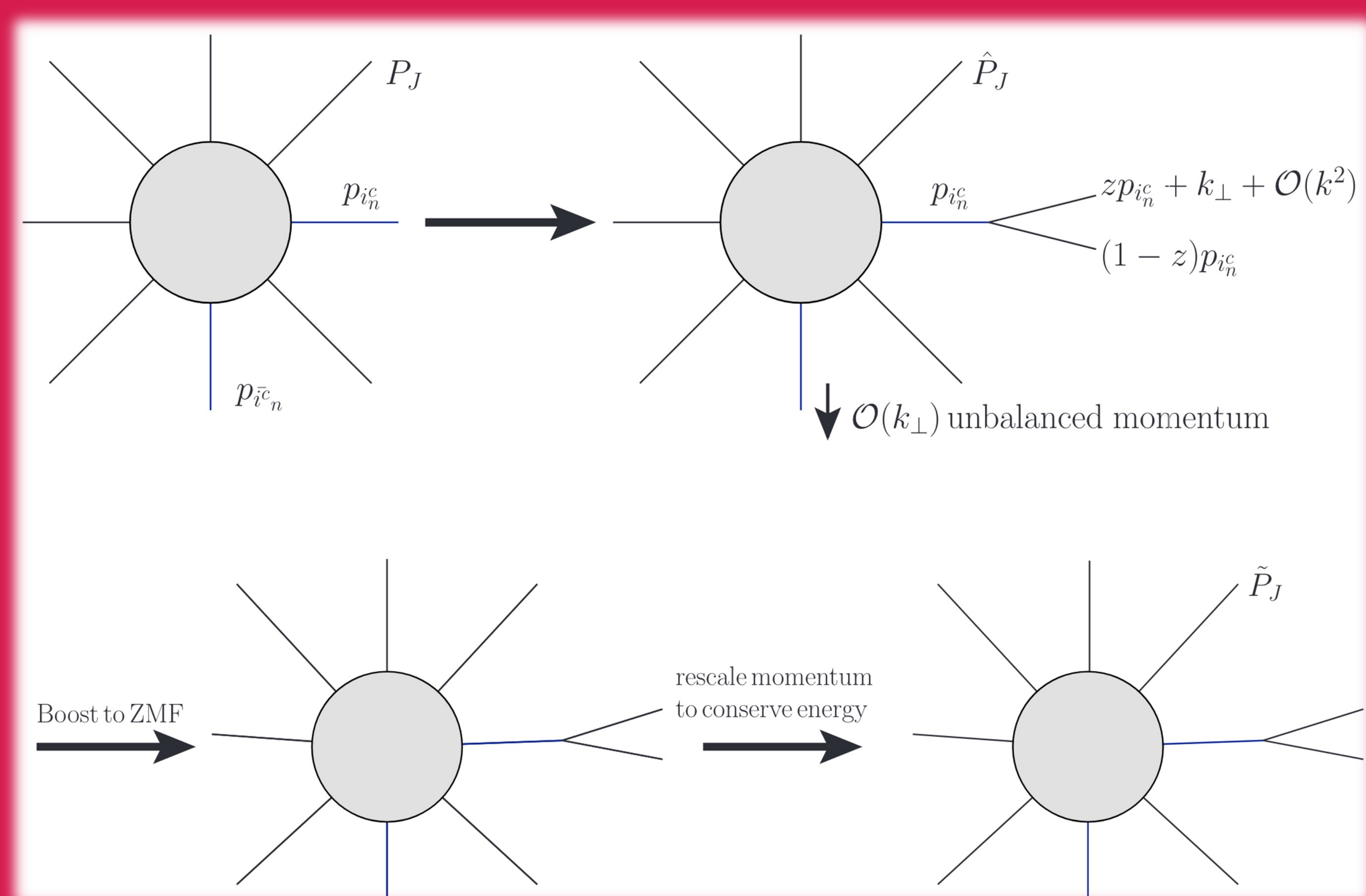
- **The Angular Ordered Shower:** To incorporate the effects of angular ordering, one can use an evolution variable proportional to the angle (the higher t accounts for a bigger angle this way).
- **The Dipole Shower:** While other parton showers consider 1 to 2 splittings, the dipole shower looks at 2 to 3 splittings – besides the emitter and the emission, a spectator parton is added, which experiences recoil from the splitting.

Angular Ordered	Dipole
1 to 2 Splitting	2 to 3 Splitting
$t \propto \theta$	$t = k_\perp^2$
Almost-on-shell kinematics, momentum is reshuffled at end	Kinematics solved locally with spectator... Not Correct!
More accurate for globally measured observables, but issues with non-global ones	Less accurate for globally measured observables, but no issues with non-global ones

For more info, search "Resummation and Logarithmic Accuracy"

(My) Current Research

Models of Global Recoil have been shown to prevent these issues.
One can reshuffle momentum → used in angular ordered showers!



[Forshaw et al, 2020]

Result: a 'best of both worlds' dipole shower

(I am currently implementing this new shower in Herwig, watch this space!)

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