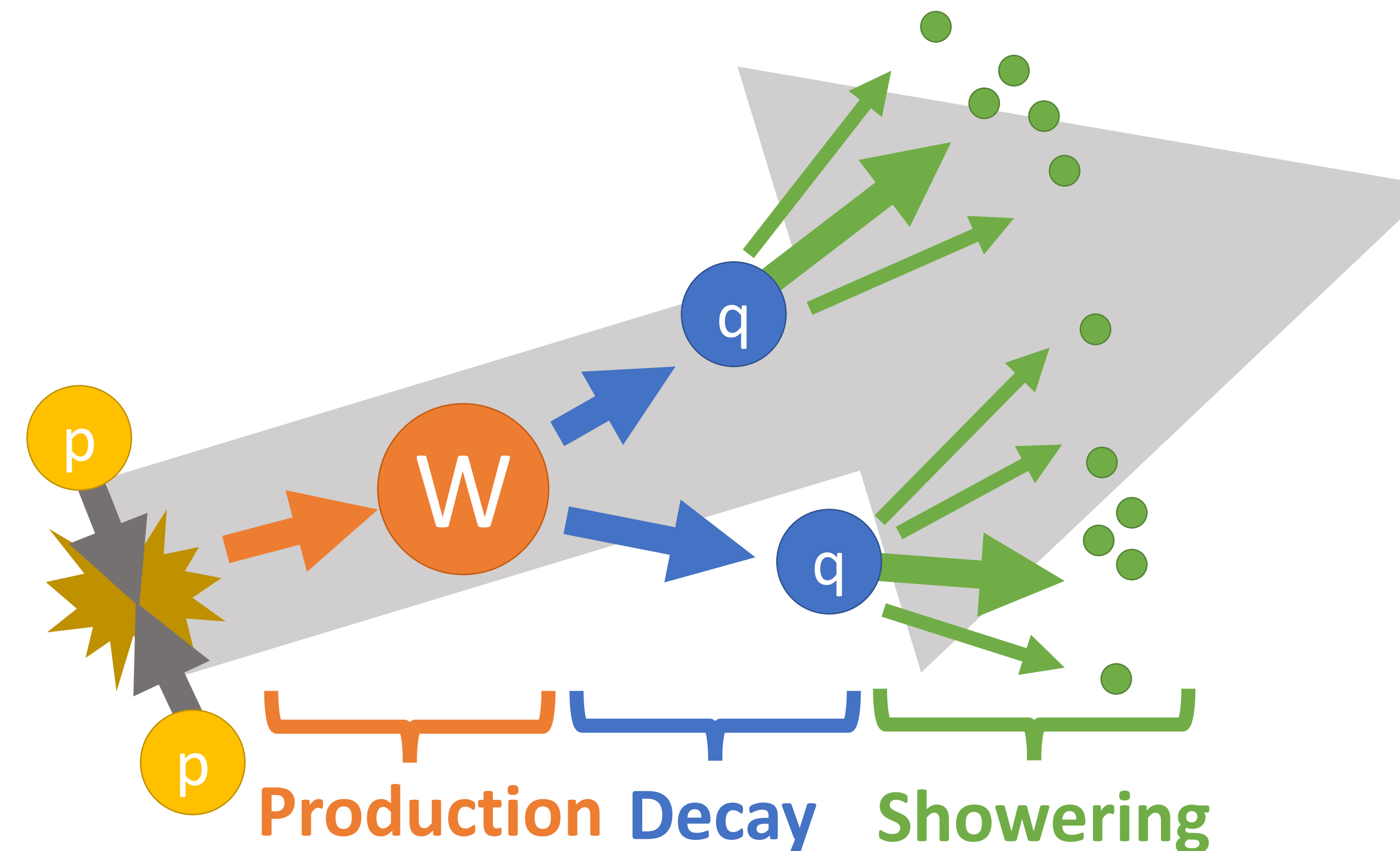


Domain Background

- Decays of high-momentum W bosons at the Large Hadron Collider result in jets (cones) of 10-100 collimated particles, represented as momentum-weighted point clouds.
- The generative processes are **production**, **decay**, and **showering**.
- The **Earth Movers Distance (EMD)** provides a *physically relevant* distance metric between jets.
- Variations in production, decay, and showering are associated with EMDs of order 500 GeV, 80 GeV, and 10 GeV respectively.



Probing the Physical Dimensionality

- The scale-dependent dimensionality of the learnt representations can be probed in a novel way using D_1, D_2 .

$$D_1 = -2 \frac{dR}{d \log \beta}, \quad D_2 = -2 \frac{dD}{d\beta}$$

(Note that in the accompanying paper, these formulae are expressed differently. In the paper a non-standard convention is used for β . The equations above correspond to using the conventional version of β used in the β -VAE literature).

- R is the recall (average KL loss) and D the distortion (average reconstruction error).
- These quantities appear to correlate closely with the scale-dependent correlation dimensions of the datasets themselves.
- It is possible to trace directly the increasing complexity of the learnt representations as beta is decreased to the generative factors which are responsible.

VAE with a Physically Motivated Distance

- I built a **VAE** using the EMD distance between jets as the reconstruction error, with the aim of investigating the structure of the data manifold (which the EMD makes physically interesting).
- The noise variance on the posterior data distribution, or equivalently the β of an equivalent β -VAE provides an EMD resolution at which the VAE probes the data manifold.
- As β is decreased, the VAE learns sequentially the latent variations associated with production, and then decay, and then showering.
- The VAE learns to **disentangle latent directions associated with** production, decay, and showering. This is because they correspond to **hierarchically distinct EMD scales**.

Decay Kinematics in VAE latent space

(production and showering are in other latent directions)

