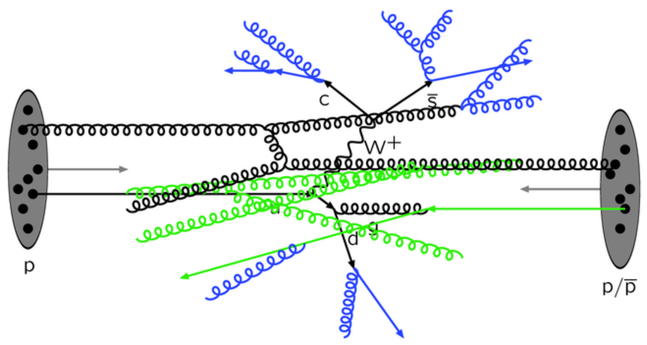
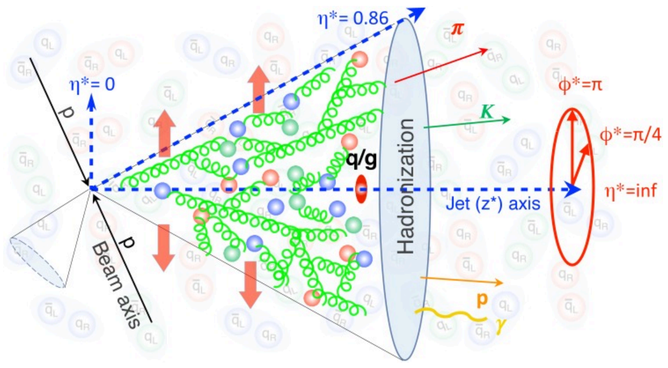
What happens when two protons collide

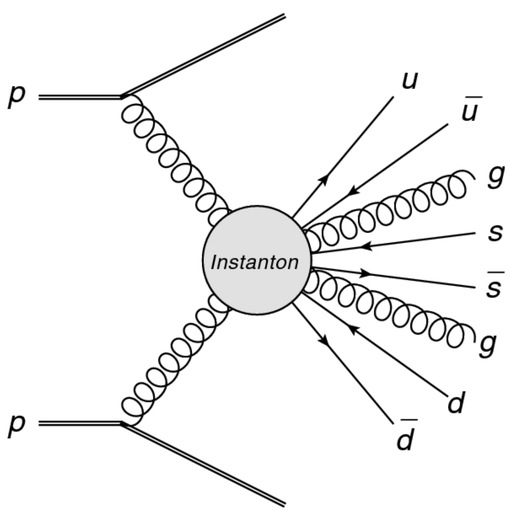
- Protons are composite particles of partons (quarks & gluons)
- The most common interactions are quantum chromodynamics (QCD) processes
- The products are largely affected by proton structures
  - Mass density of the proton
  - Momentum distributions of the partons



Multiple-parton interactions



Quark-gluon plasma
→ soup of strongly interacting quarks & gluons

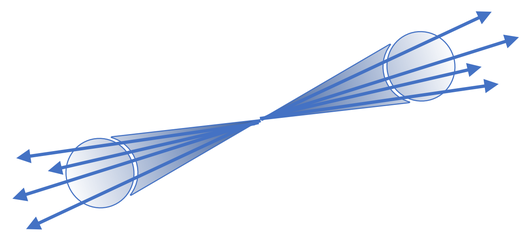


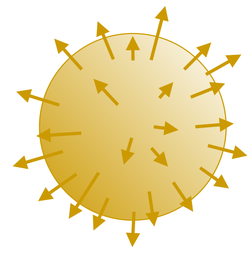
QCD instantons
→ quantum tunnelling among the QCD multi-well potential

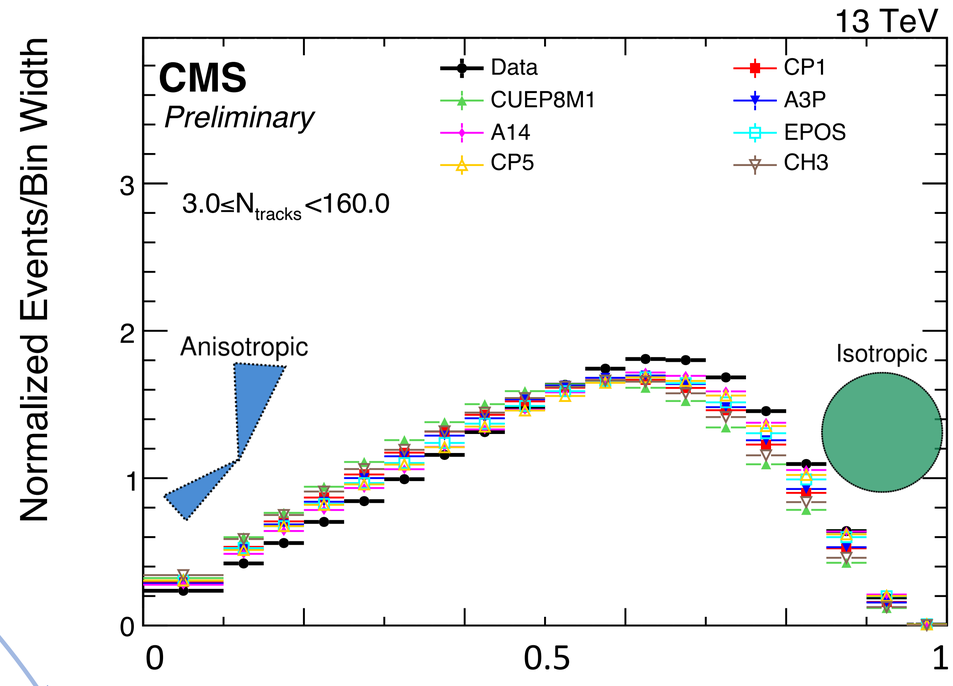
Hard to predict in theory? Let's just measure it!

- We use "**event shape**" variables to study the shapes of the collisions
- Does it look like a **pencil**? a **hedgehog**?

→ We define shape variables to **distinguish** them







Example: **transverse sphericity**

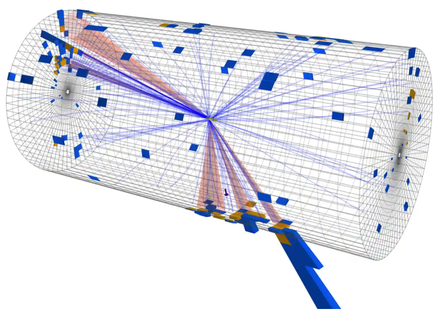
Unfold the shapes of proton collisions

Proton beam — Proton beam

Understand the proton structure & QCD processes with machine learning

Unfolding: Recover the truth from experiment

Detector information:
hits, trajectories, energy depositions

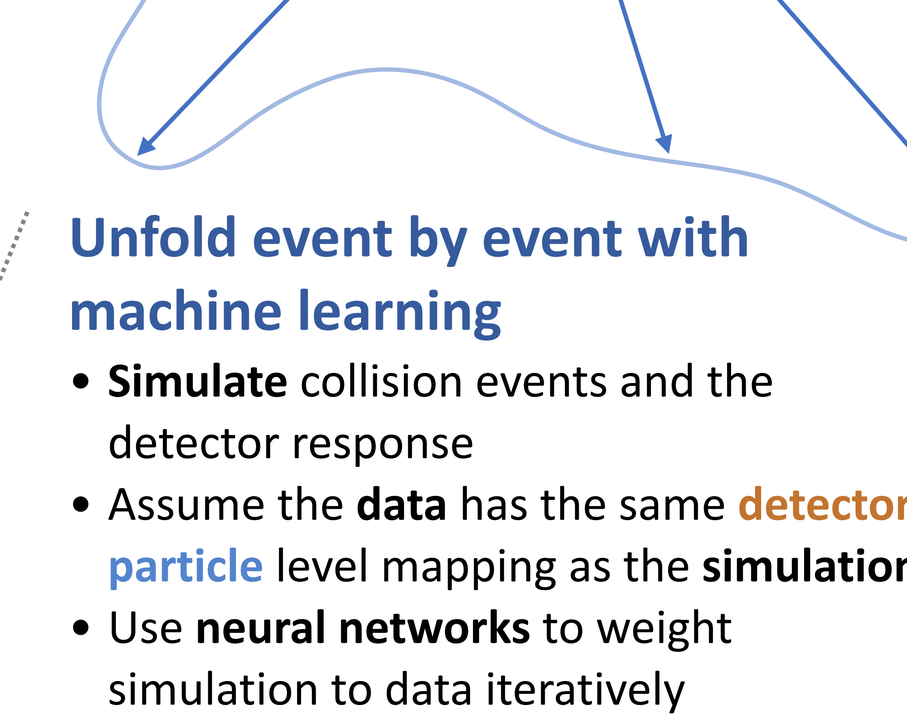


Unfold

Particle level information:
particle identities, momentum

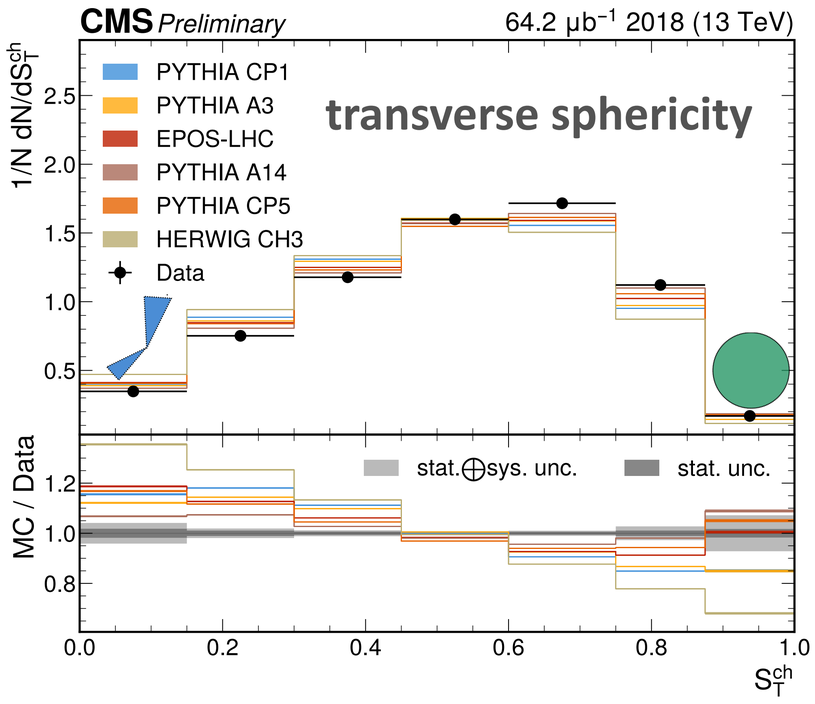
Unfold event by event with machine learning

- **Simulate** collision events and the detector response
- Assume the **data** has the same **detector-particle** level mapping as the **simulation**
- Use **neural networks** to weight simulation to data iteratively



Unfolded event shapes

Event-wise unfolded data
→ Visualise as distributions of event shapes



- The data is **more spherical** than predictions ← higher sphericity

➡ We found **more hedgehog** events than expected

➡ The origin of these hedgehogs to be studied in detail …

More multiple parton interactions? instantons?

Florencia Canelli, Weijie Jin, Kyle Cormier

Join us in playing the neural networks and analysing the hedgehogs
Opportunities for student projects