The Standard Model as a Discovery Tool

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Outline and disclaimer

✤ Focus of this talk will be possible SM analysis methods for future measurements

✤ Highly biased to my personal tastes

✤ Equally interesting are precision tests of the SM (mW, polarization, EFTs, etc) which I have left away completely here
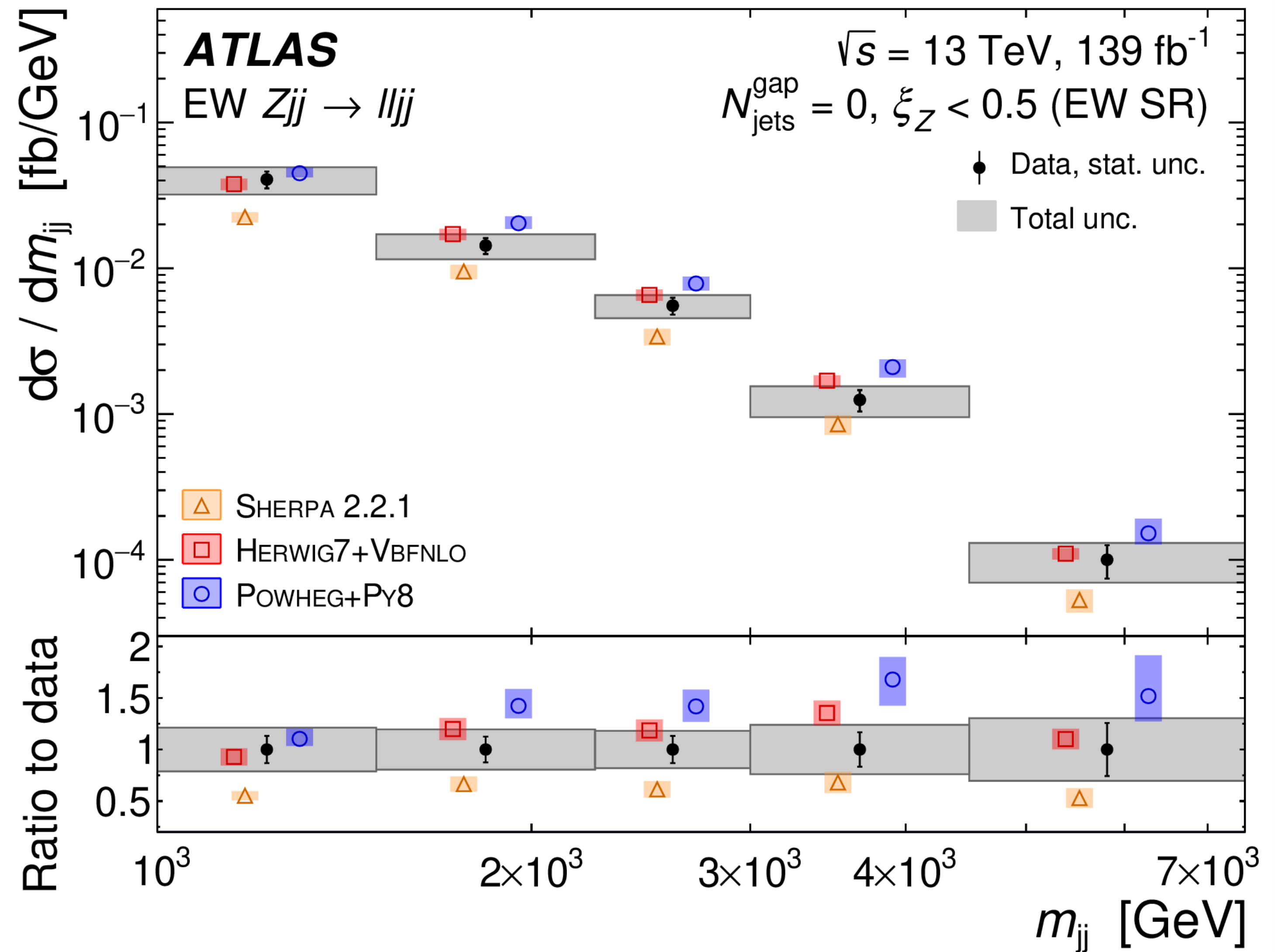
A short walk down memory lane

- ✤ In the pre-LHC era this was precision

  - ✤ Limited predictions

  - ✤ Inclusive phase-spaces
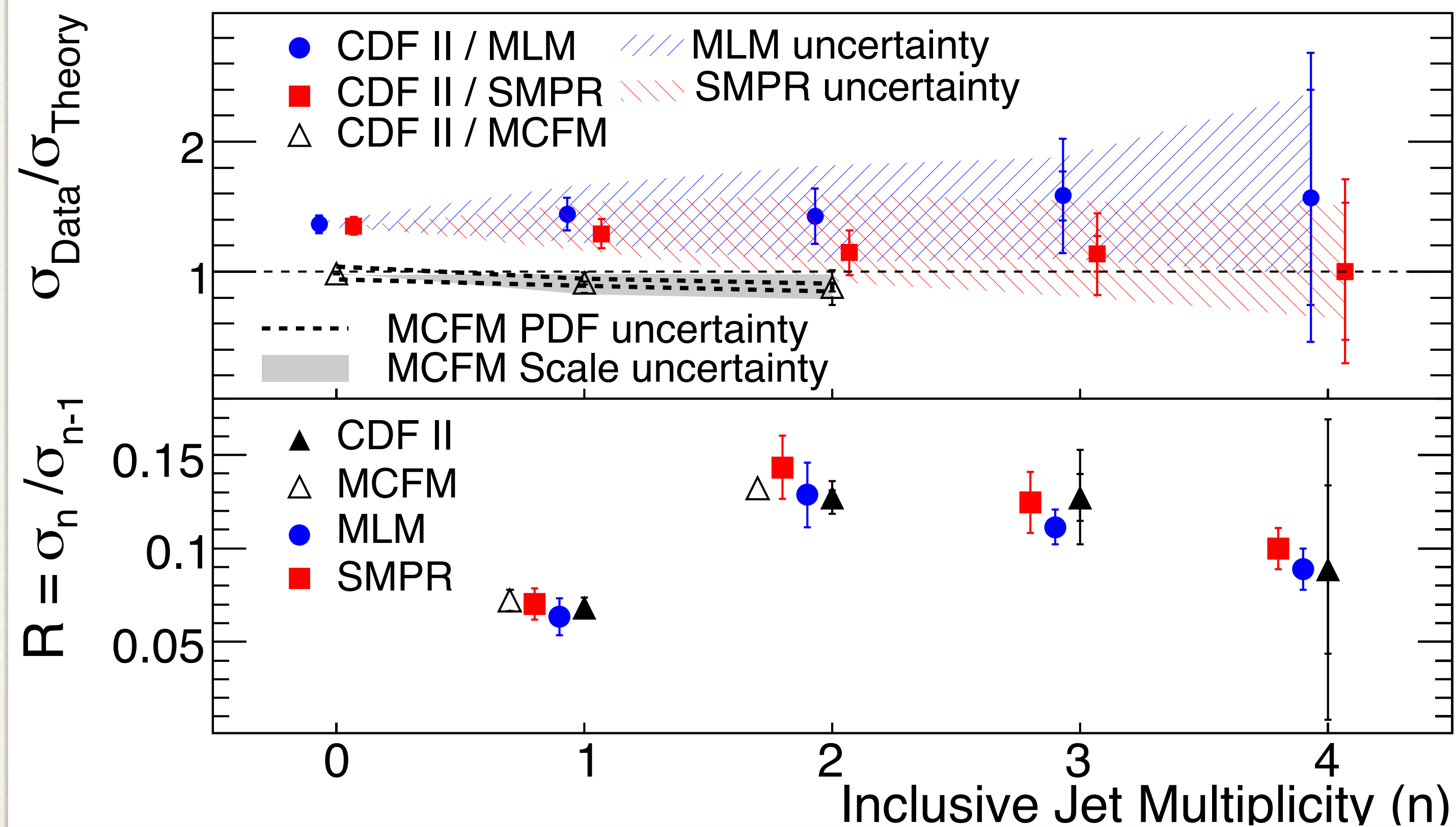
Today

* VBF Z+jets production

  ❖ High data statistics

  ❖ Multiple NLO predictions


ATLAS

EW $Zjj \rightarrow lljj$

$\sqrt{s}$ = 13 TeV, 139 fb^{-1}

$N_{\mathrm{jets}}^{\mathrm{gap}}$ = 0, ξ_Z < 0.5 (EW SR)

Data, stat. unc.

Total unc.

SHERPA 2.2.1

HERWIG7+VBFNLO

POWHEG+PY8

$\mathrm{d}\sigma / \mathrm{d}m_{\mathrm{jj}}$ [fb/GeV]

Ratio to data

m_{jj} [GeV]

As a discovery tool…

✤ Future SM measurements are

    ✤ Not inclusive

    ✤ Not categorized

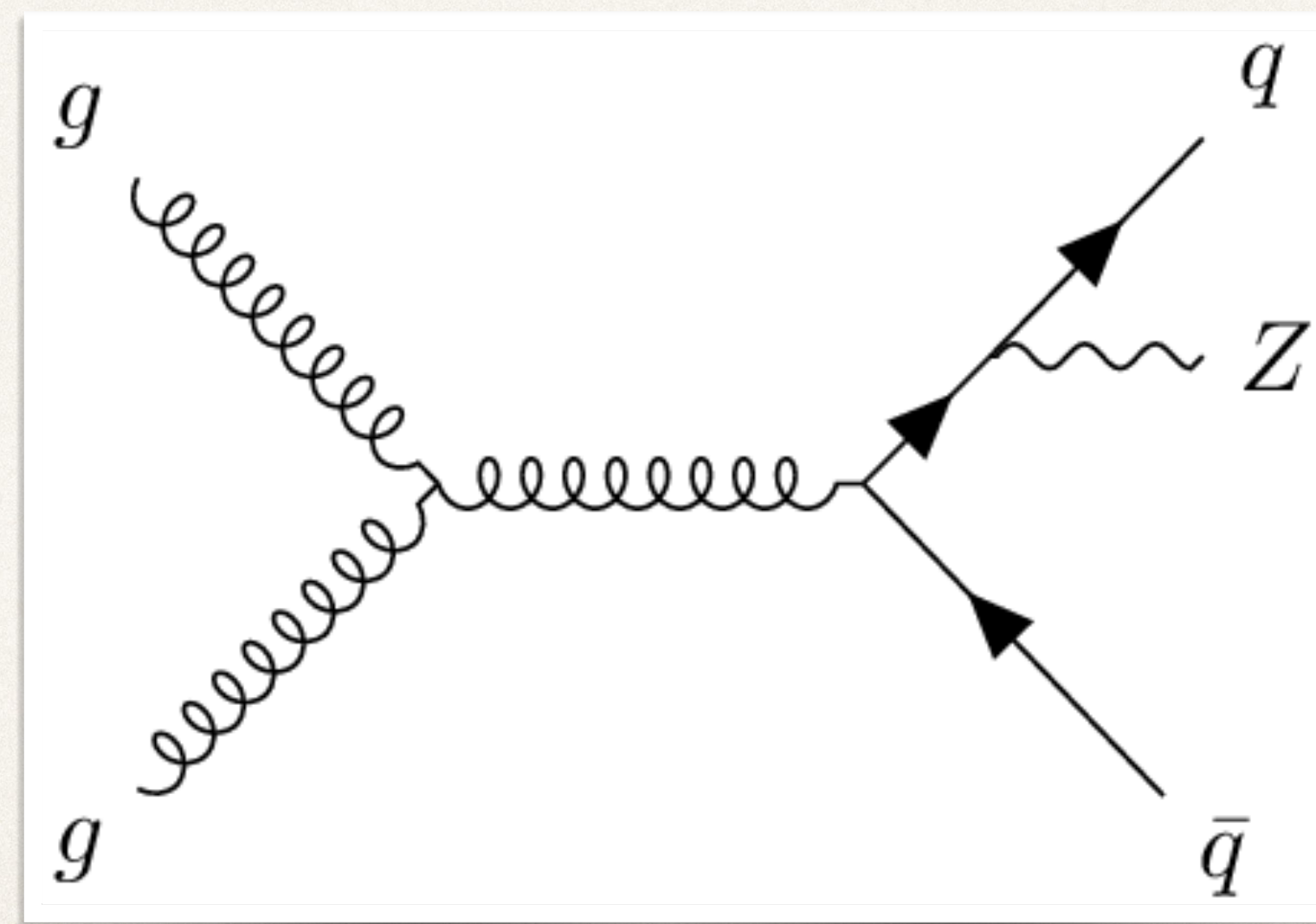   ✤ Not binned

    ✤ Not always standard running

We have the big data samples and the powerful tools to break past these restrictions

Not inclusive

✤ Large data samples mean that we have both the kinematic reach and the precision to probe the extreme phase spaces
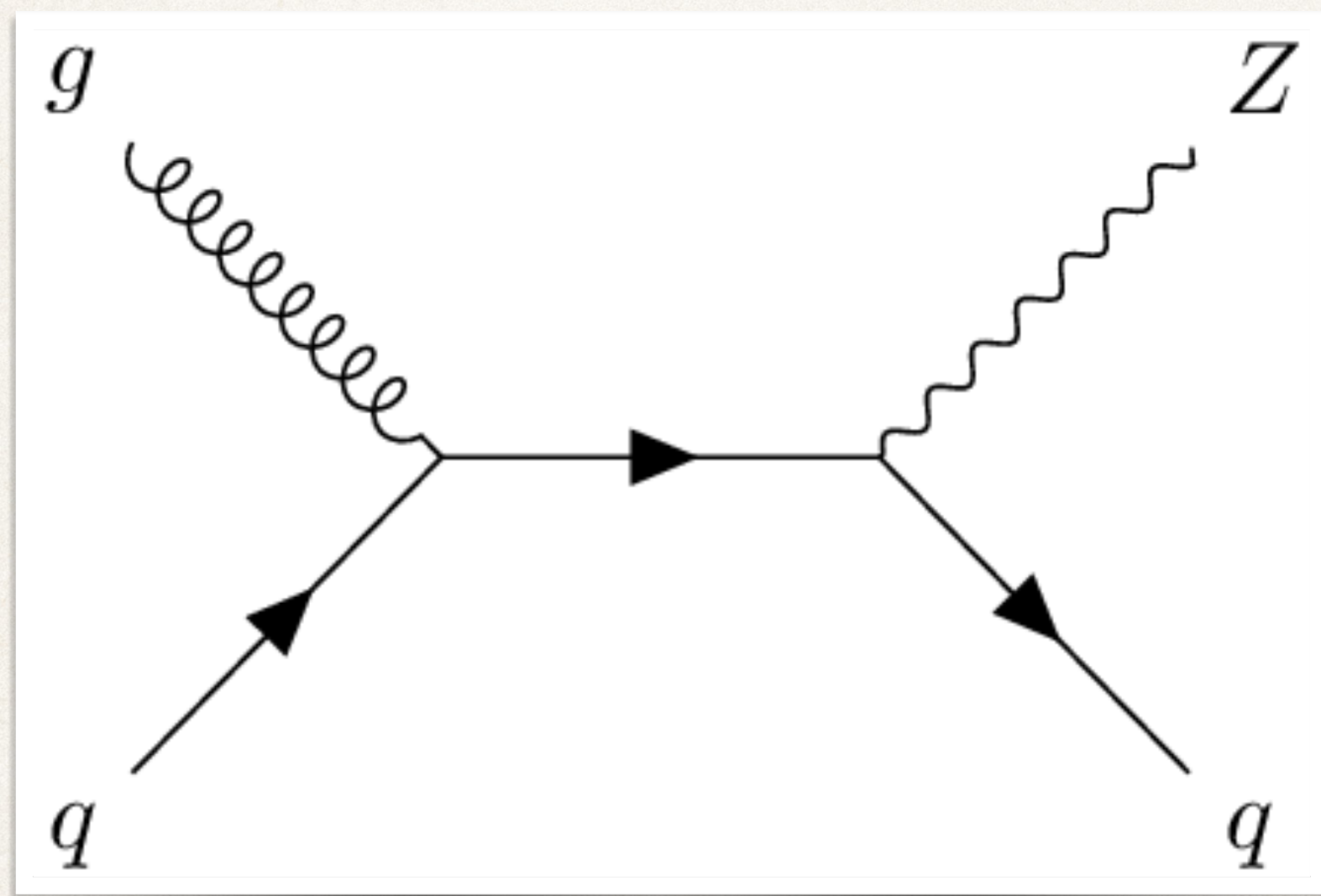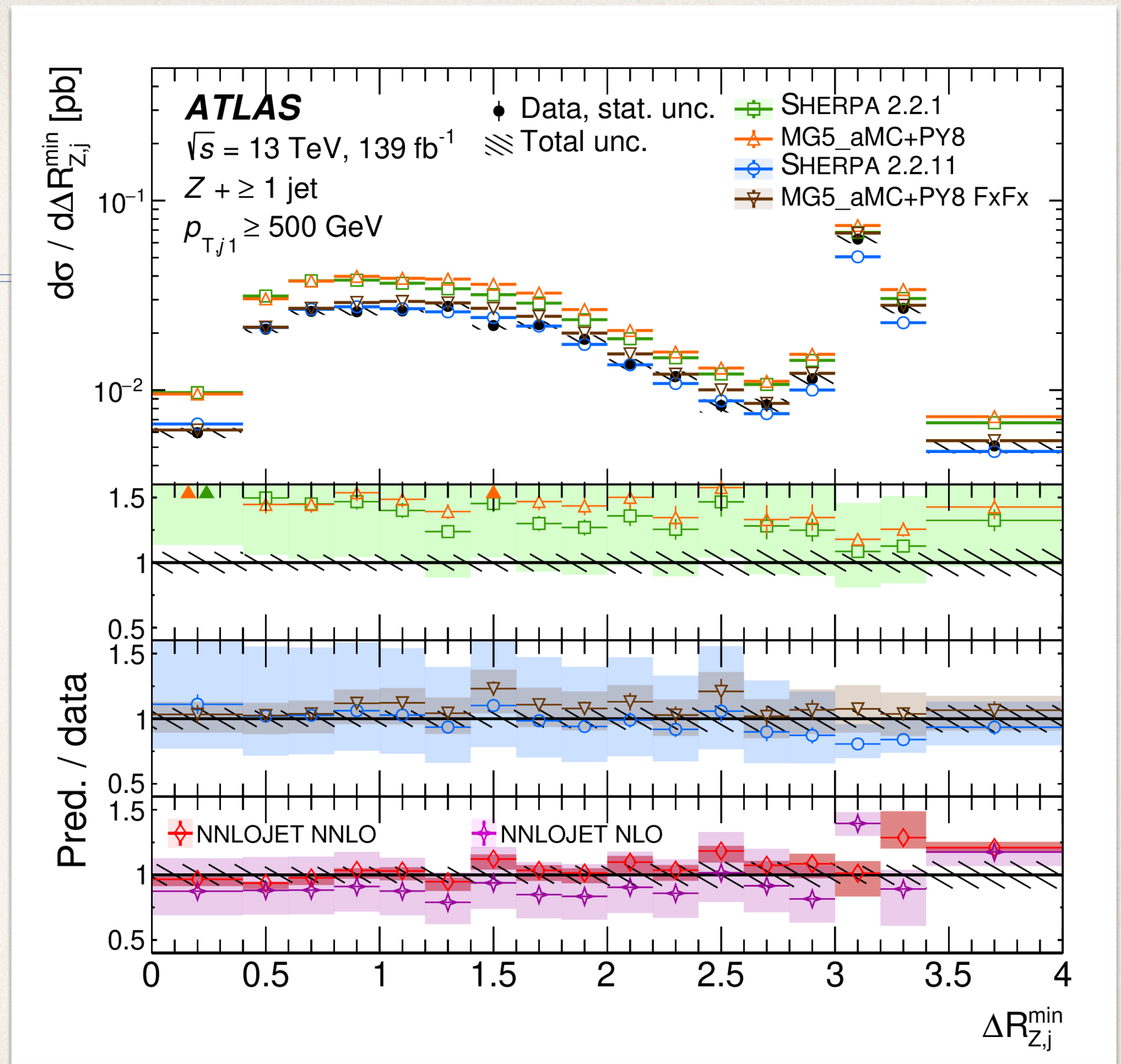
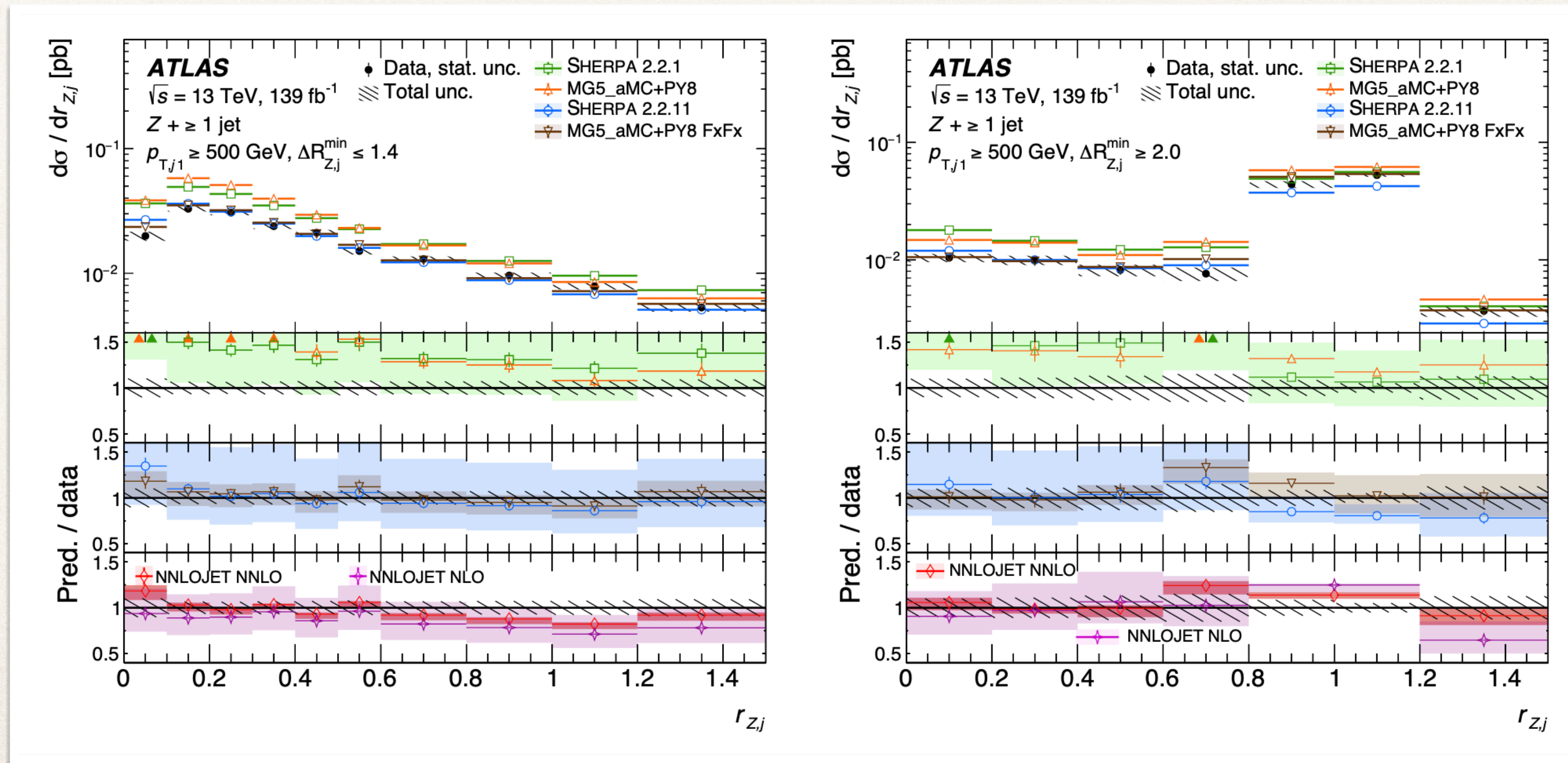The 'standard' back-to-back   Z 'radiated' from a quark line

Not inclusive

- Low region means Z-radiation, high means back-to-back

- Have sufficient statistics to selection on these regions

Not inclusive

✤ Collinear events have much softer Z's. Get remarkable agreement with theory
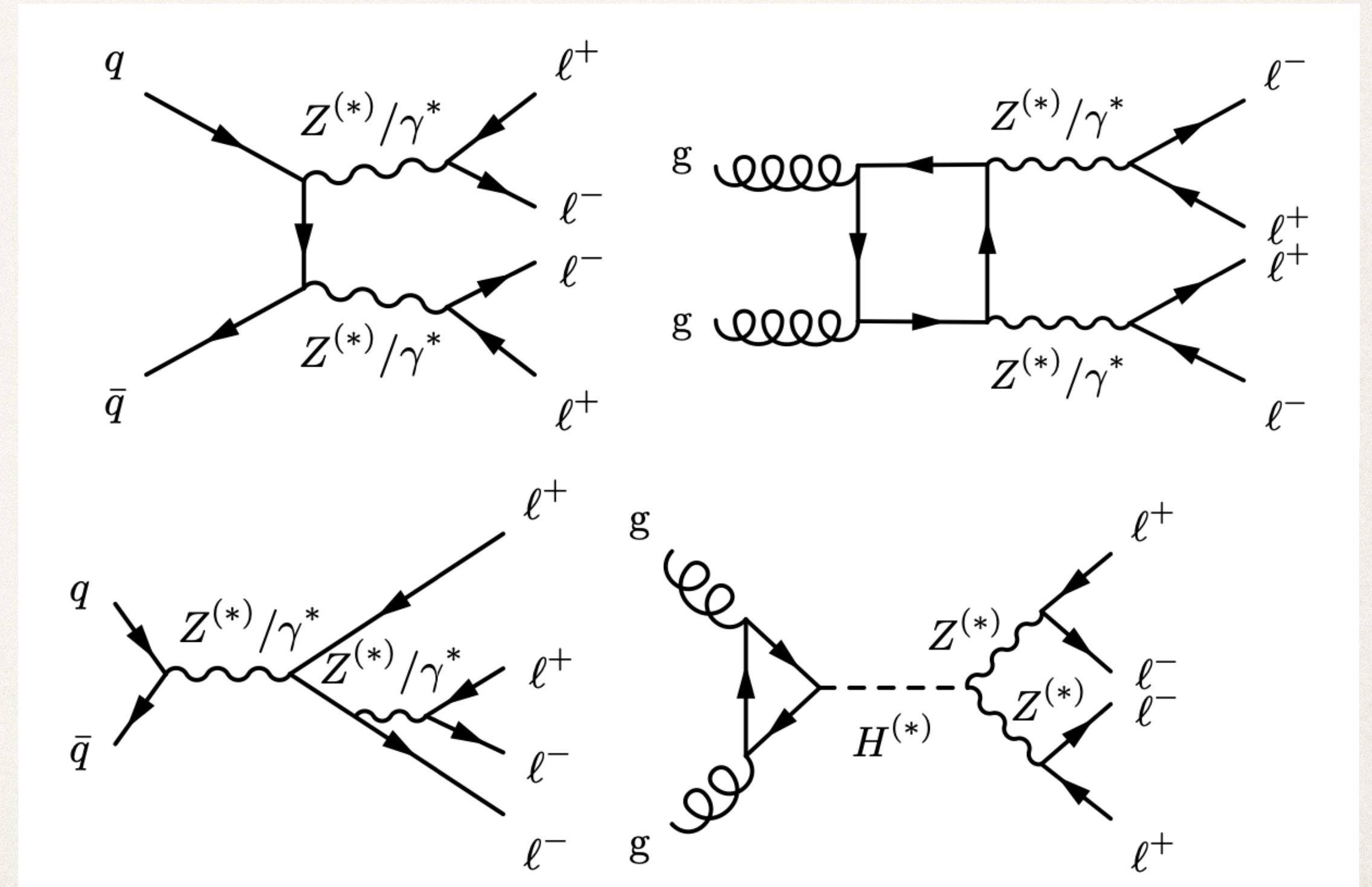

Collinear

Back-to-back

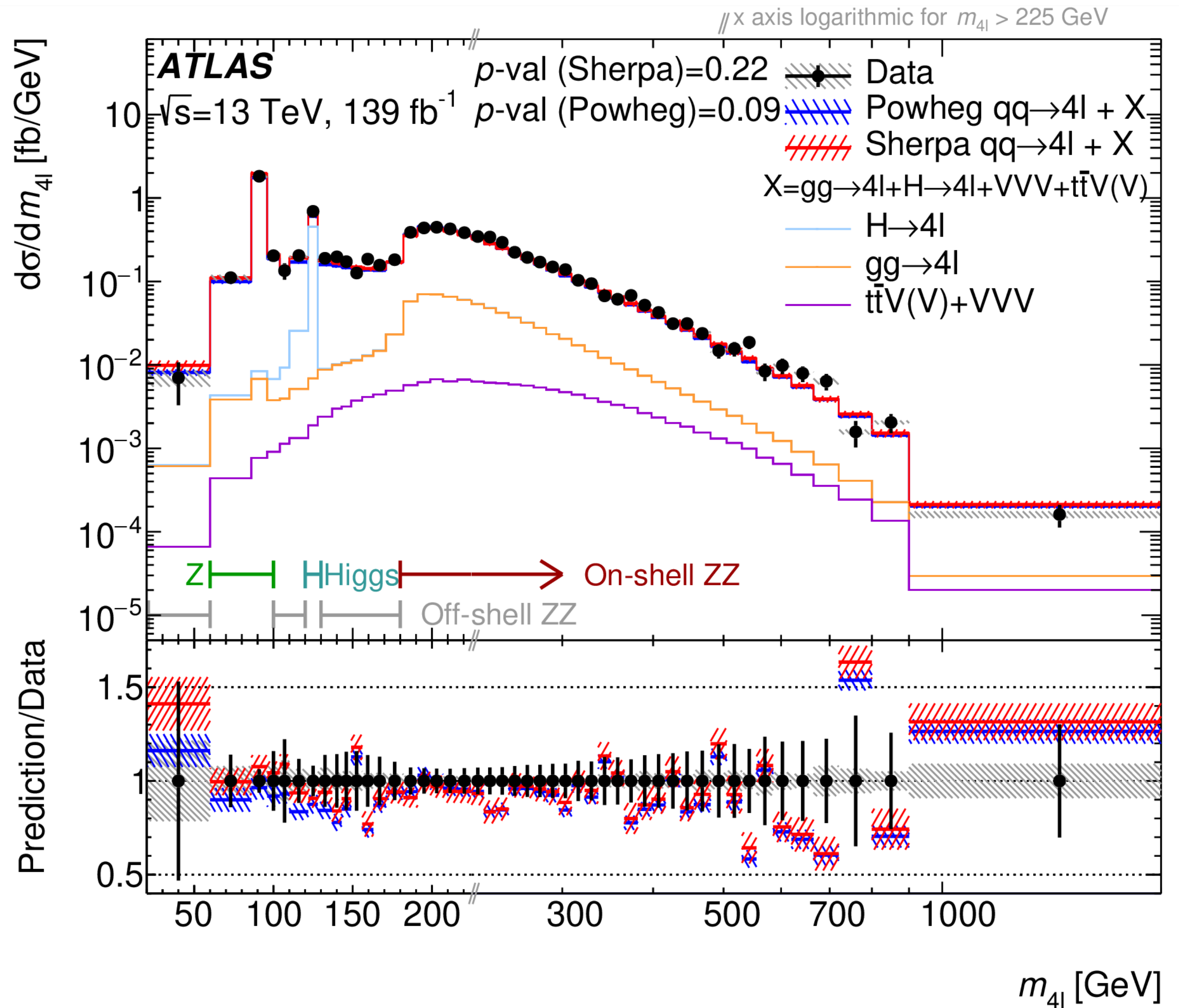$$r_{Z,j} \equiv \frac{p_{T,\ell\ell}}{p_T(\text{closest jet})}.$$

Not categorized

✤ An awesome analysis in which we need many more of!

✤ Single Z, Higgs boson production and on-shell ZZ in one
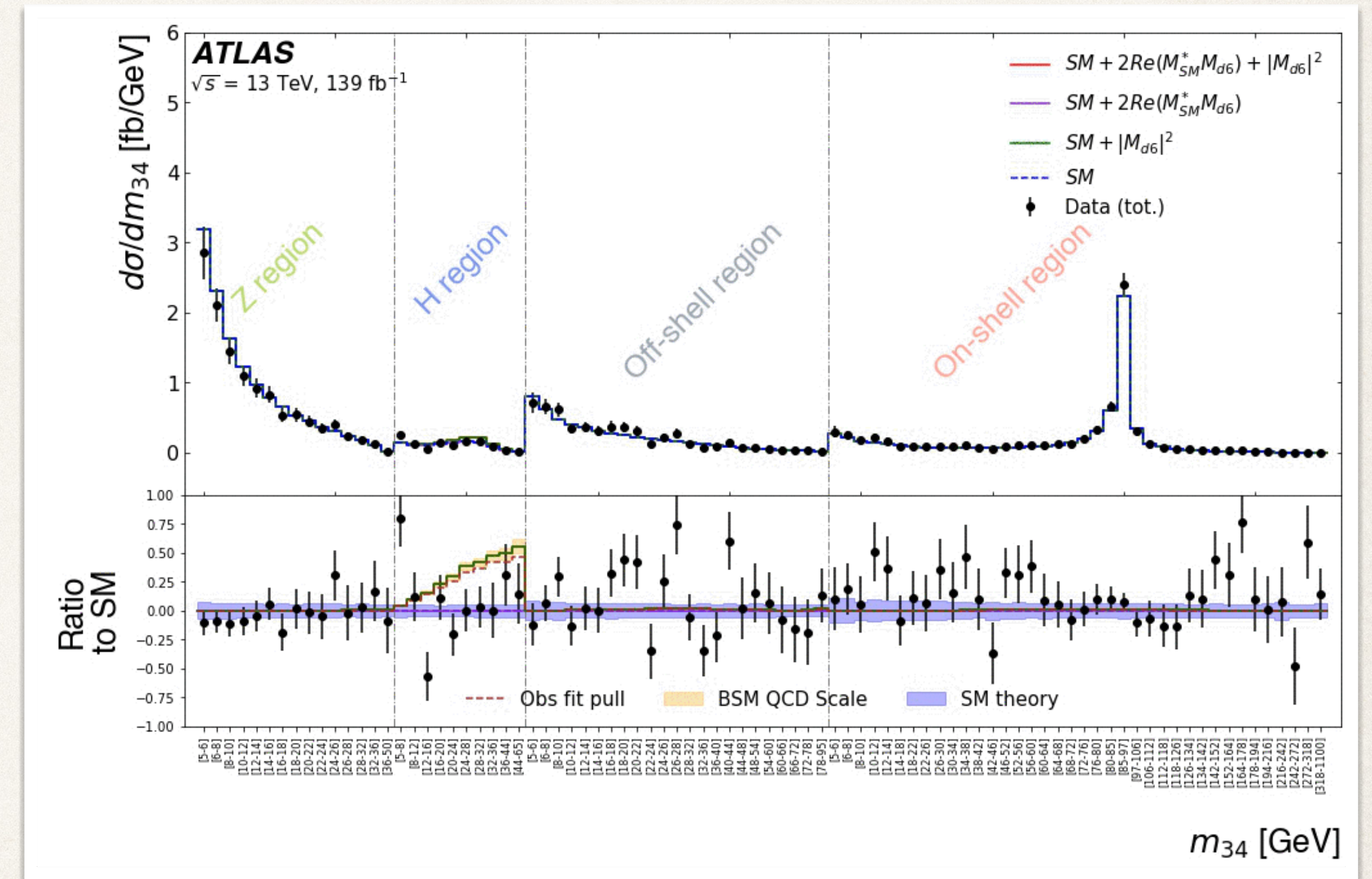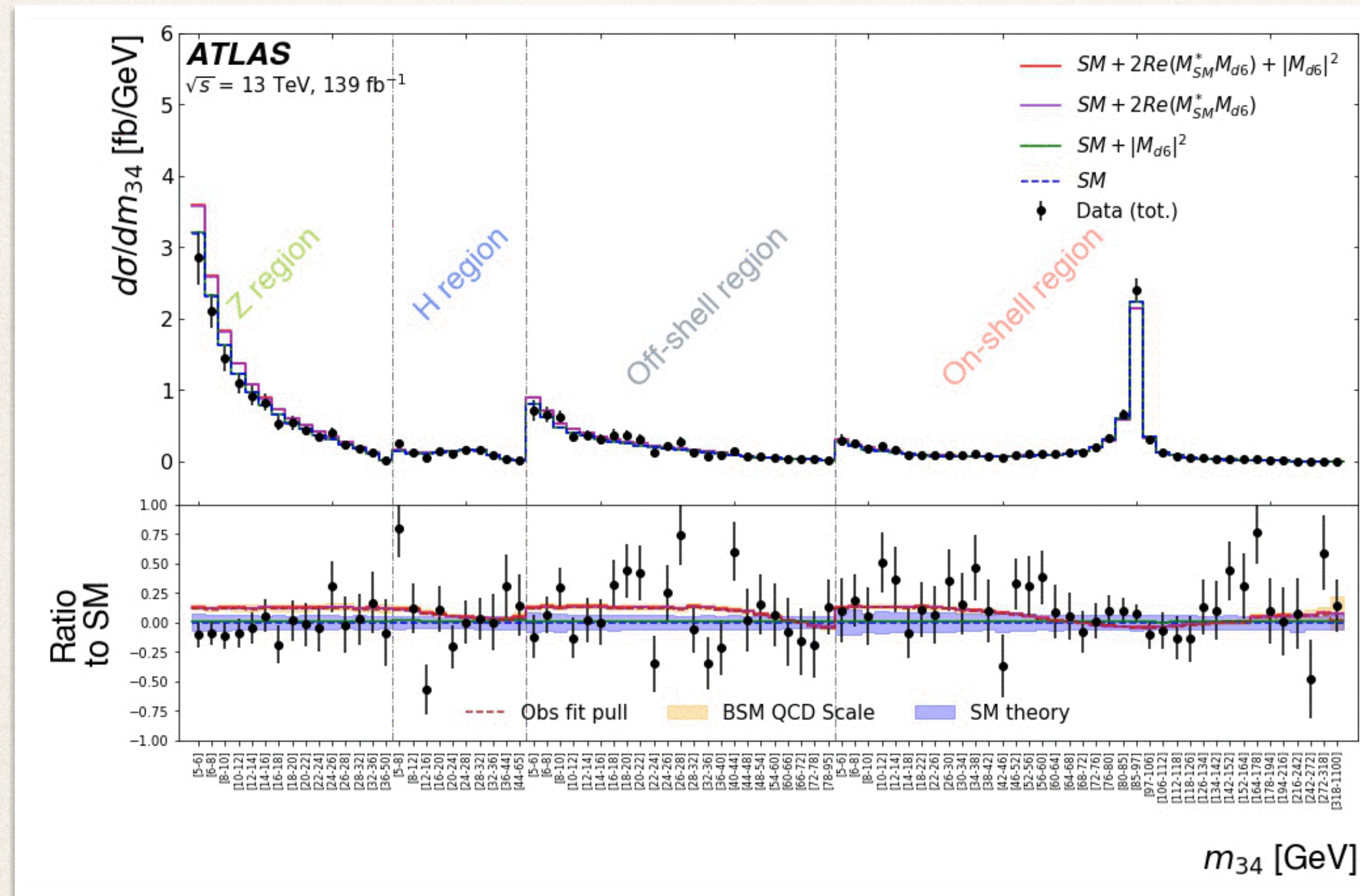
✤ Massively re-interpretable

Not categorized

* Multi-dimensional measurements - second observable for different mass regions
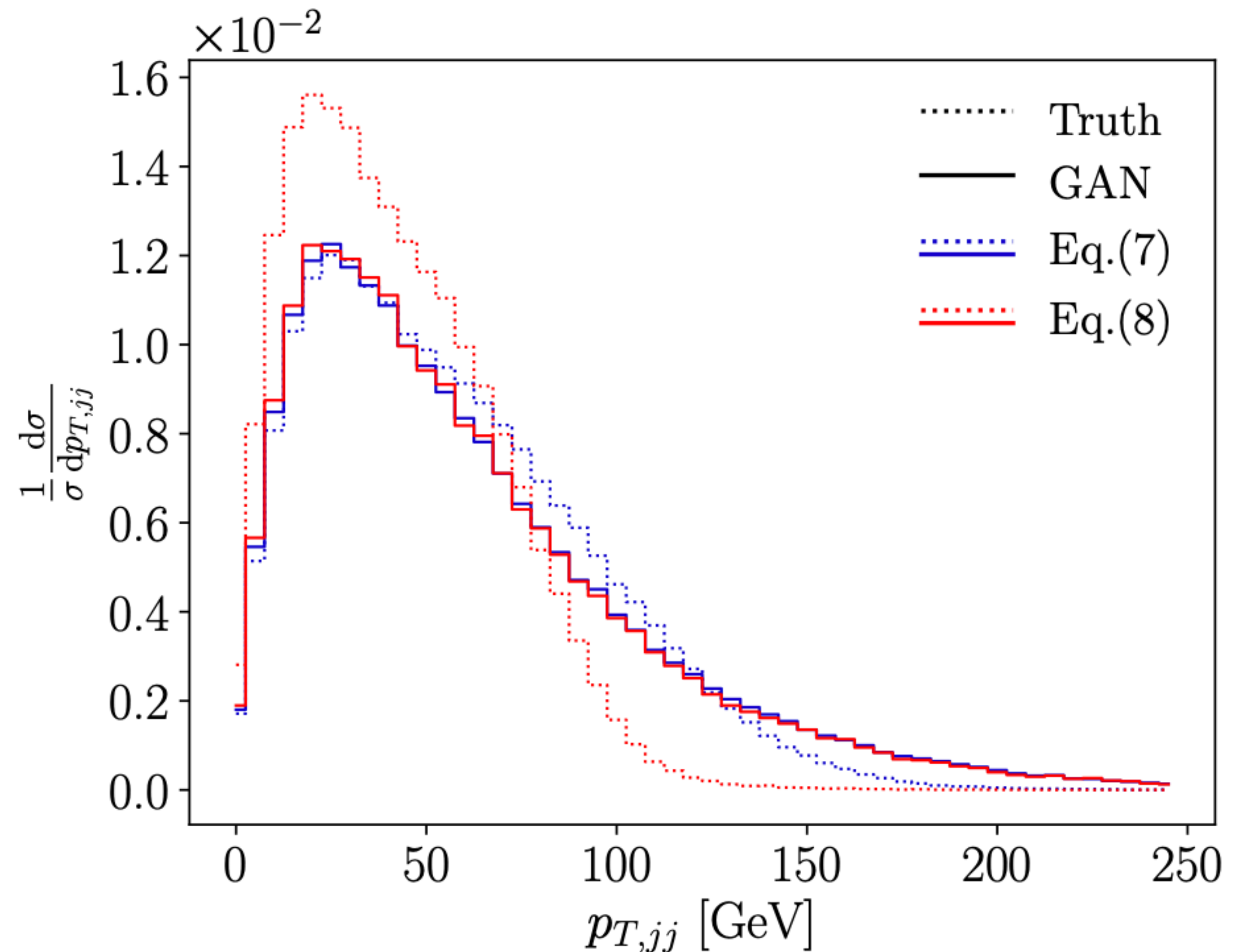
* Improves BSM and EFT potential

Not categorized

✤ Much better limits on cHWB compared to Higgs 4l paper alone

Not binned
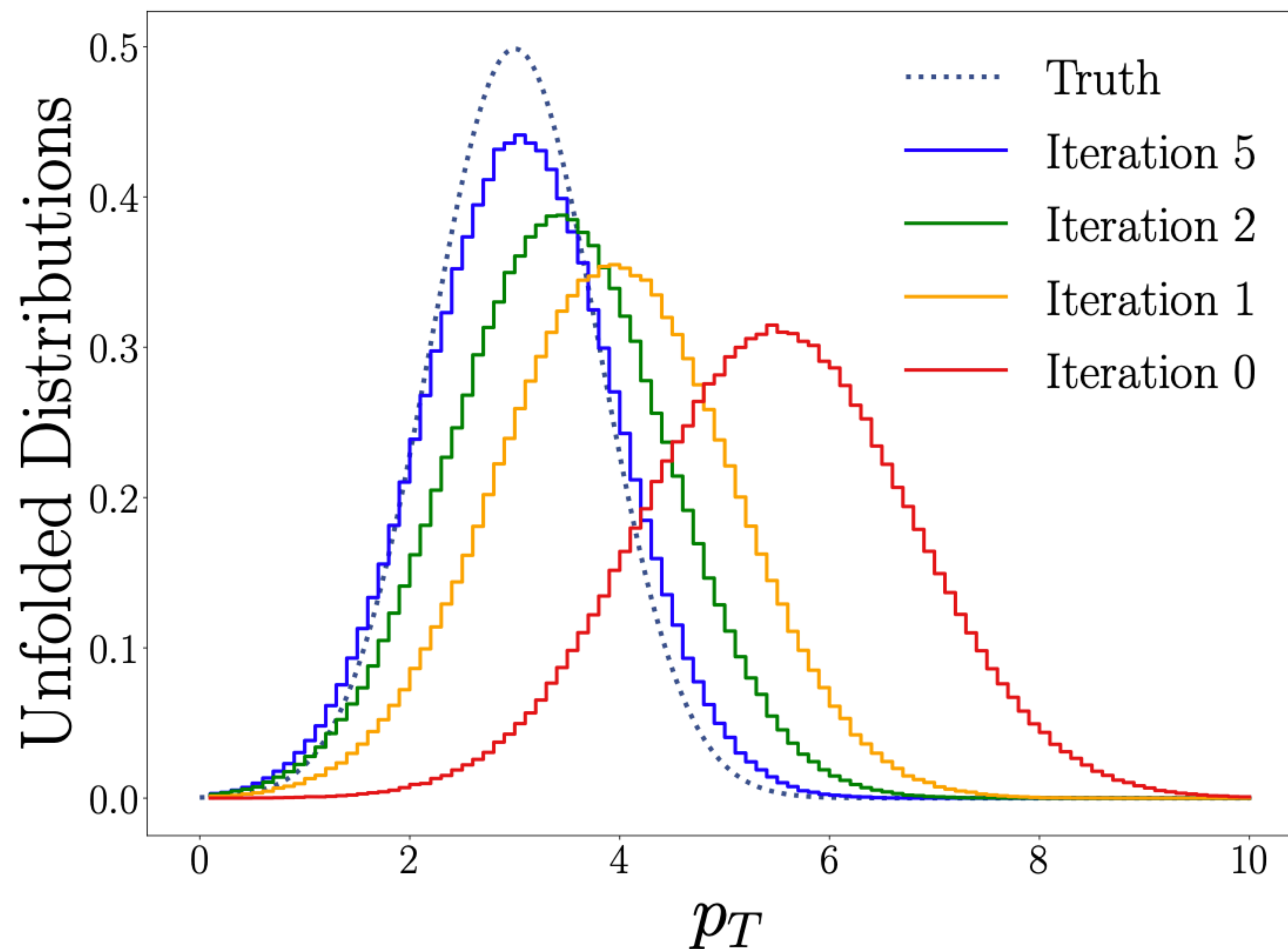
✤ Machine learning is a pathway to high dimensionality

✤ But in contrast to all the great results before, we don't trust the model

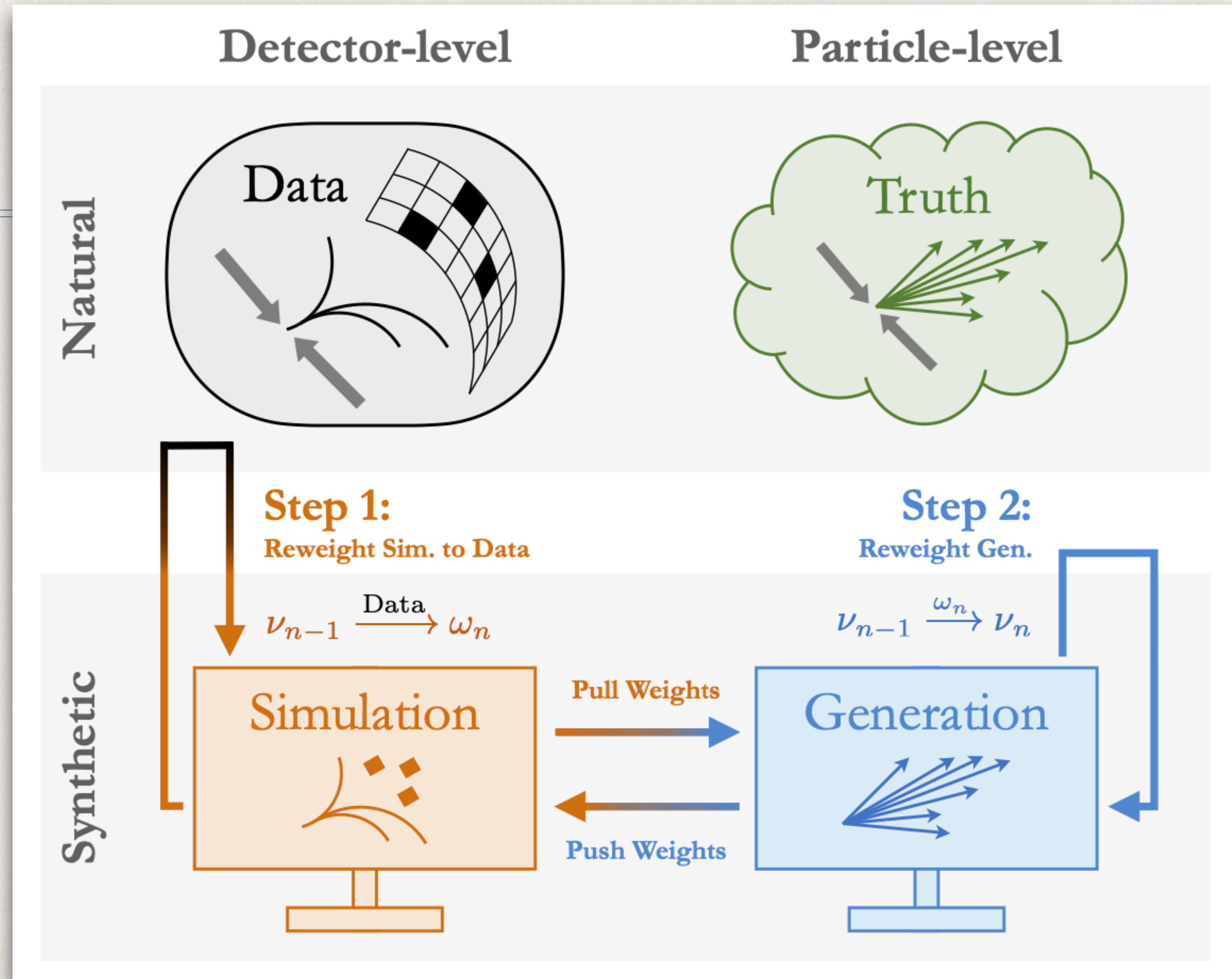Note: I have selected here a ML model that is known to look bad

Not binned

- One of the powers of our unfolding methods is the iteration

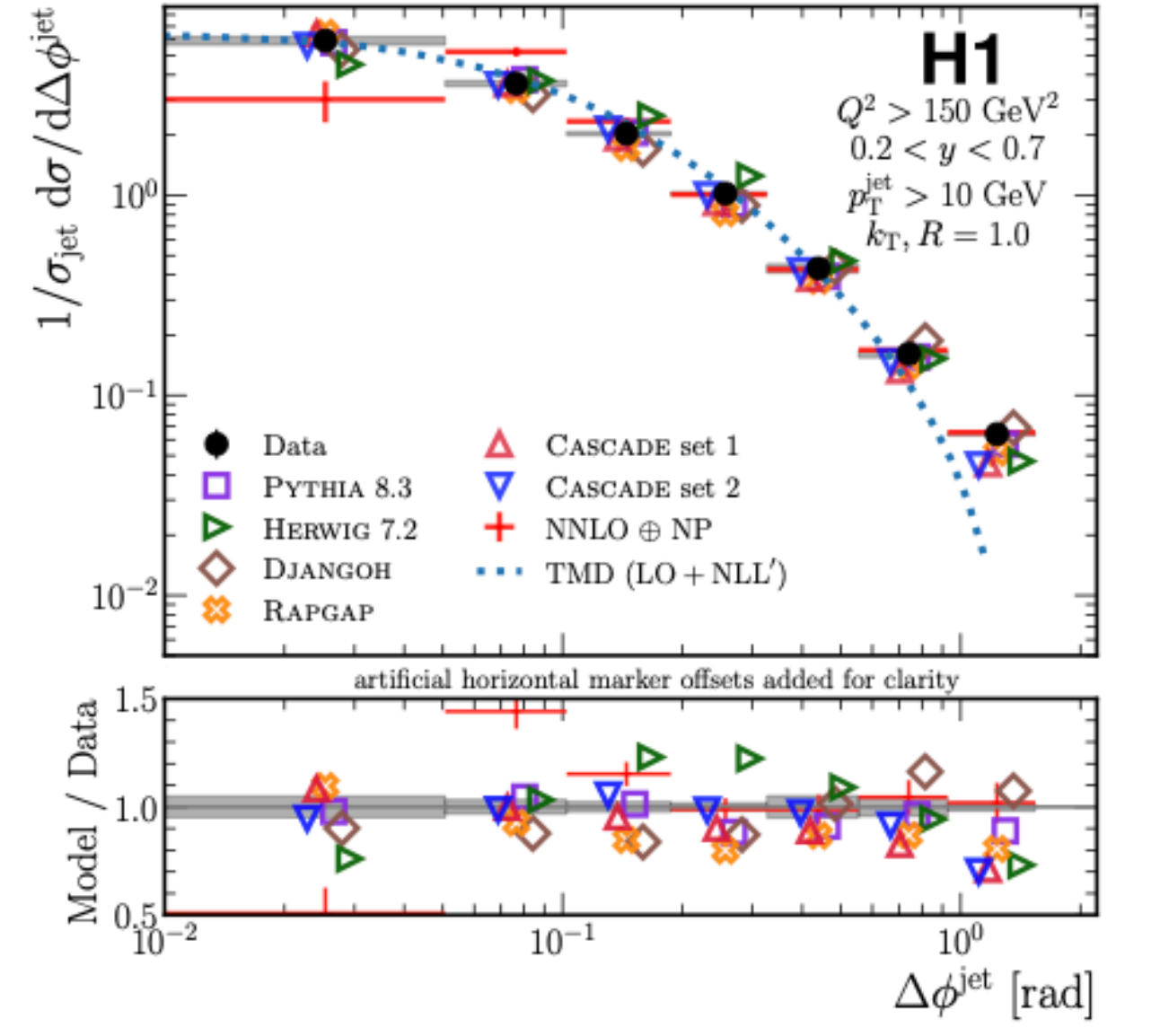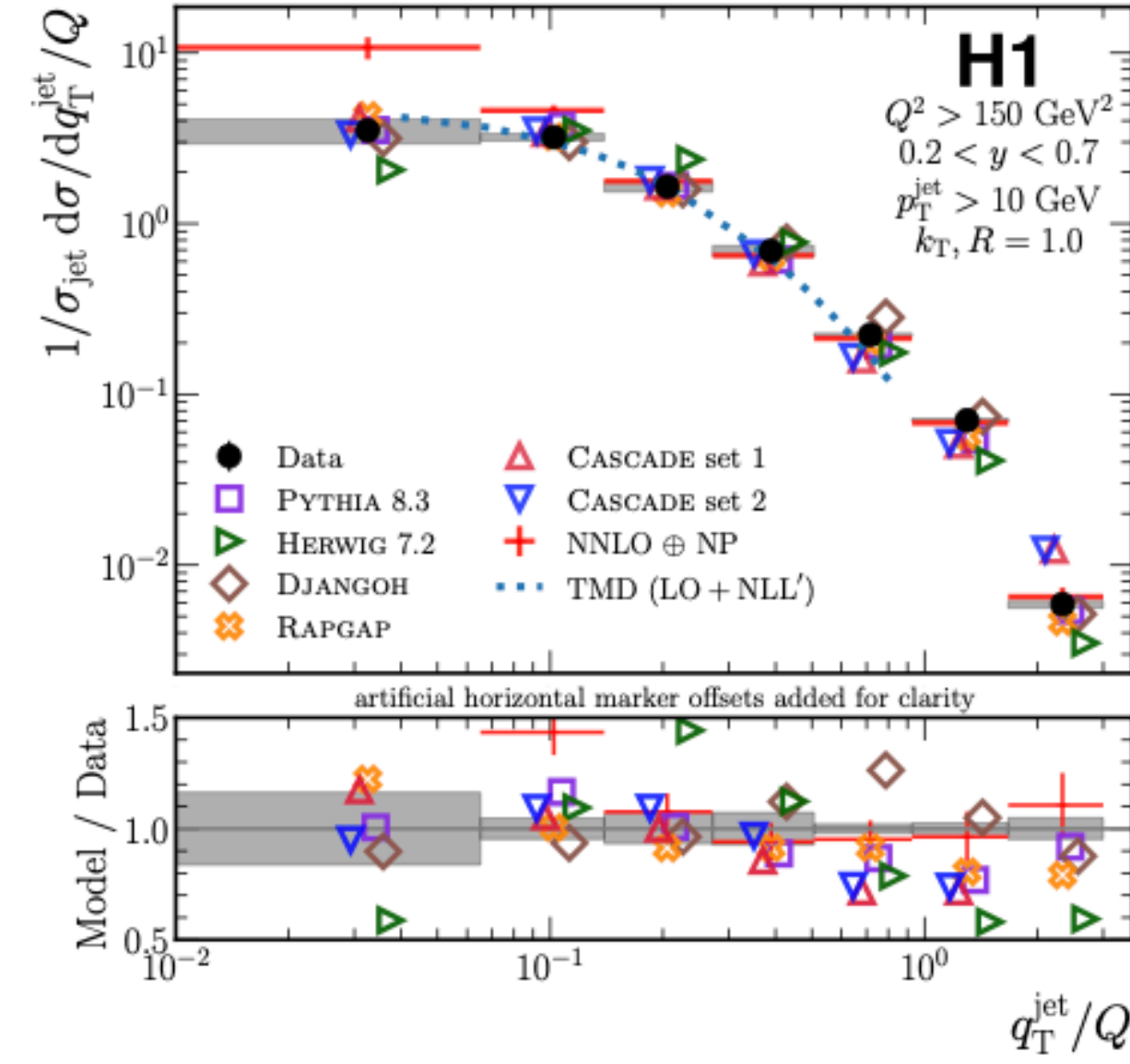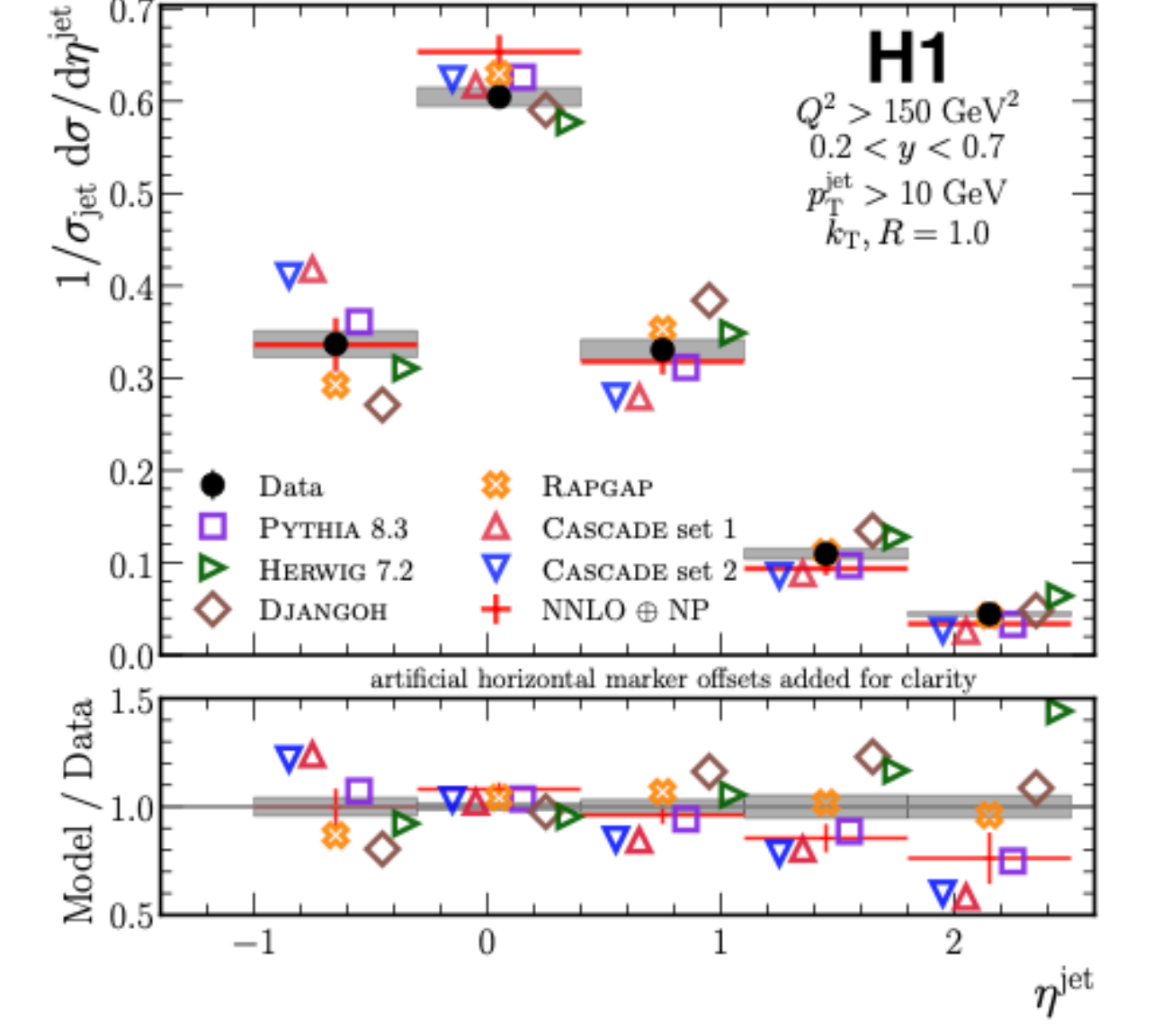- Can we take this experience and go high dimensional and no binning?
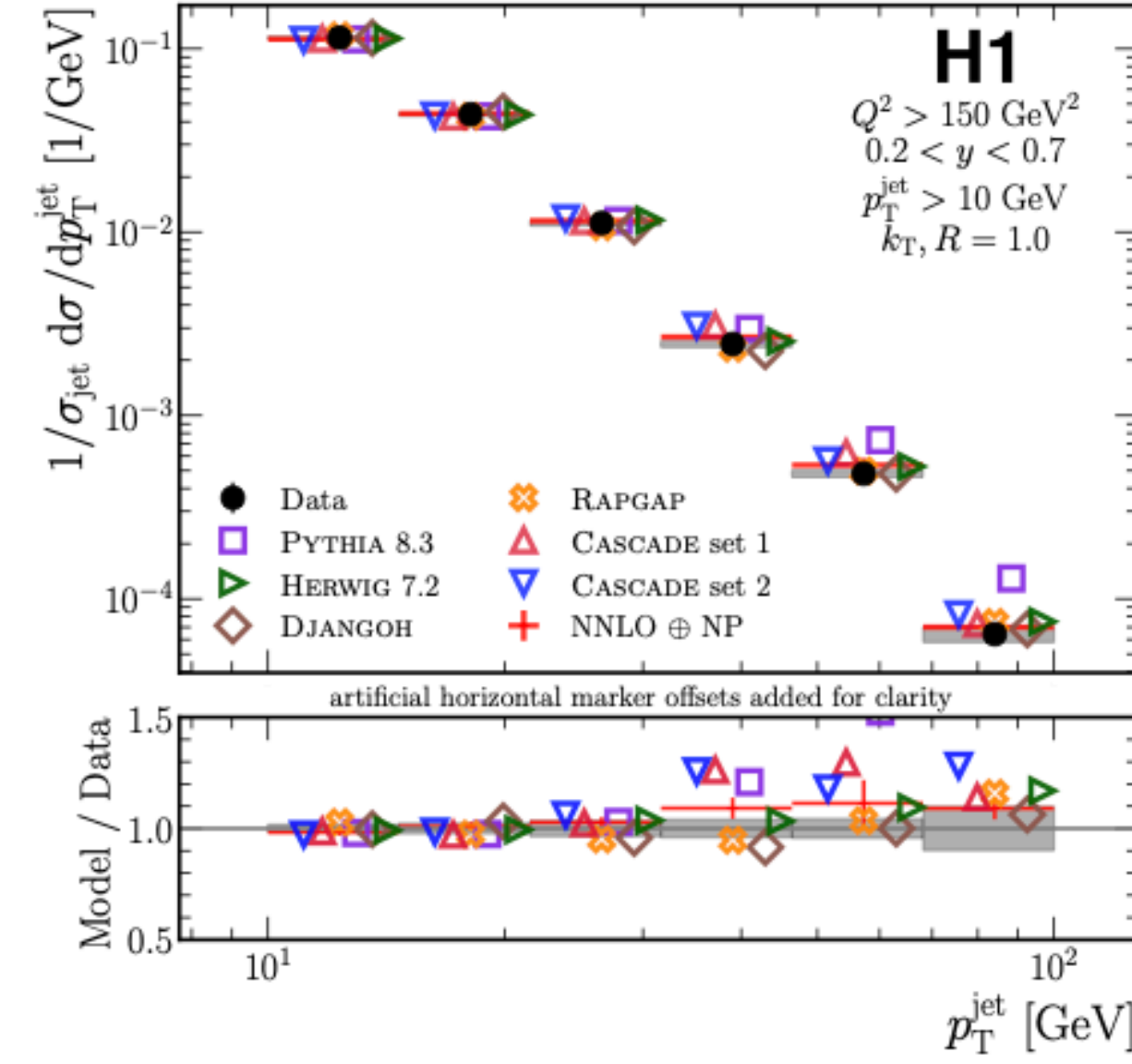
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* Omnifold is an iterative approach to ML unfolding

* Utilizes that there is a one-to-one mapping between a generated and simulated event

Not binned

✤ The results on HERA data

✤ Fully unfolded objects

$(\vec{p}_T^{\,e},\ p_z^e,\ p_T^{\text{jet}},\ \eta^{\text{jet}},\ \phi^{\text{jet}},\ q_T^{\text{jet}}/Q,\ \text{and}\ \Delta\phi^{\text{jet}})$
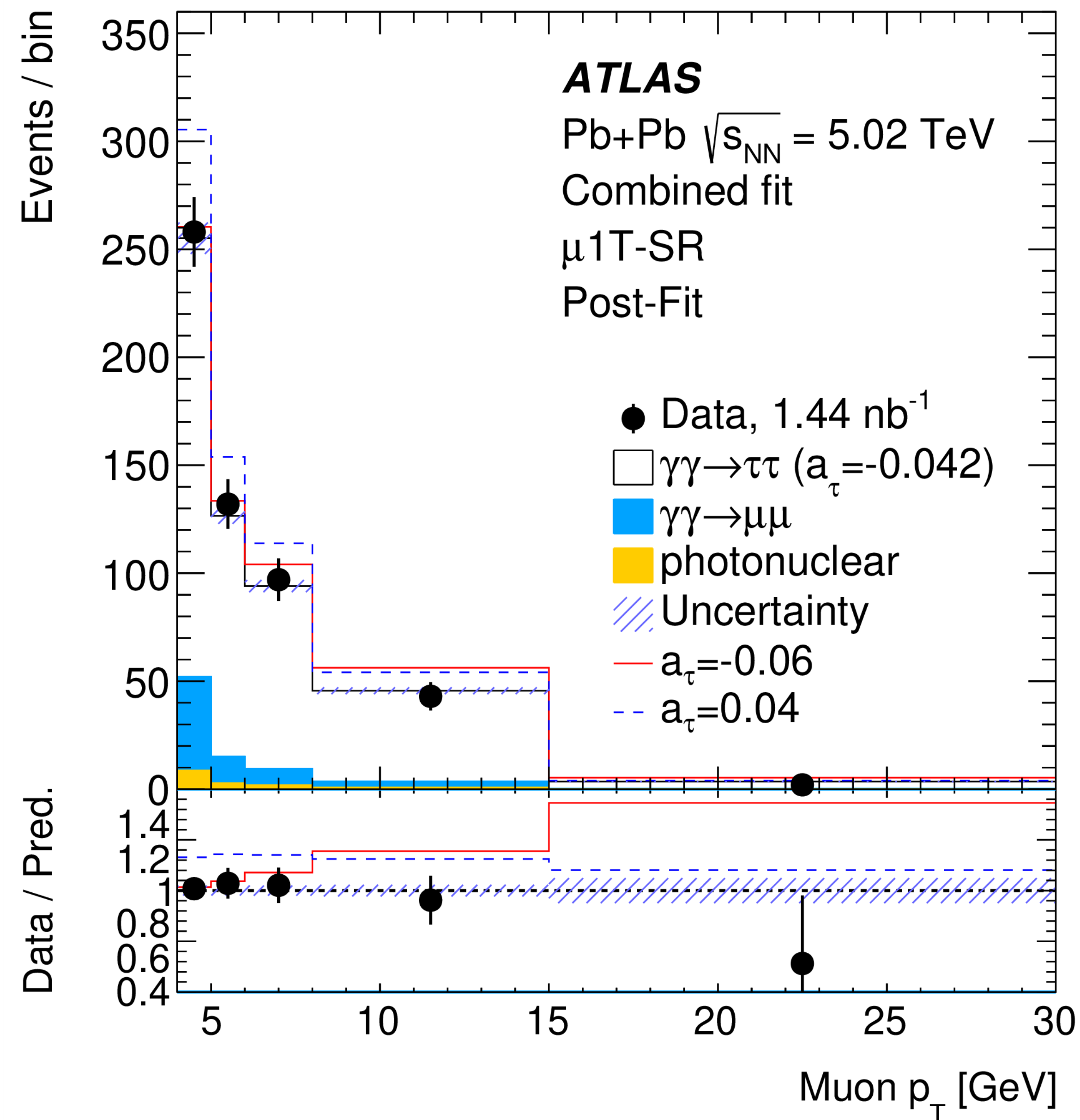
Not standard running

- The LHC is more than just protons

  - Heavy ion, proton-oxygen, low mu, CMS energy

- And our detector is configurable

  - Lower trigger thresholds, smaller magnetic fields, trigger-level readout

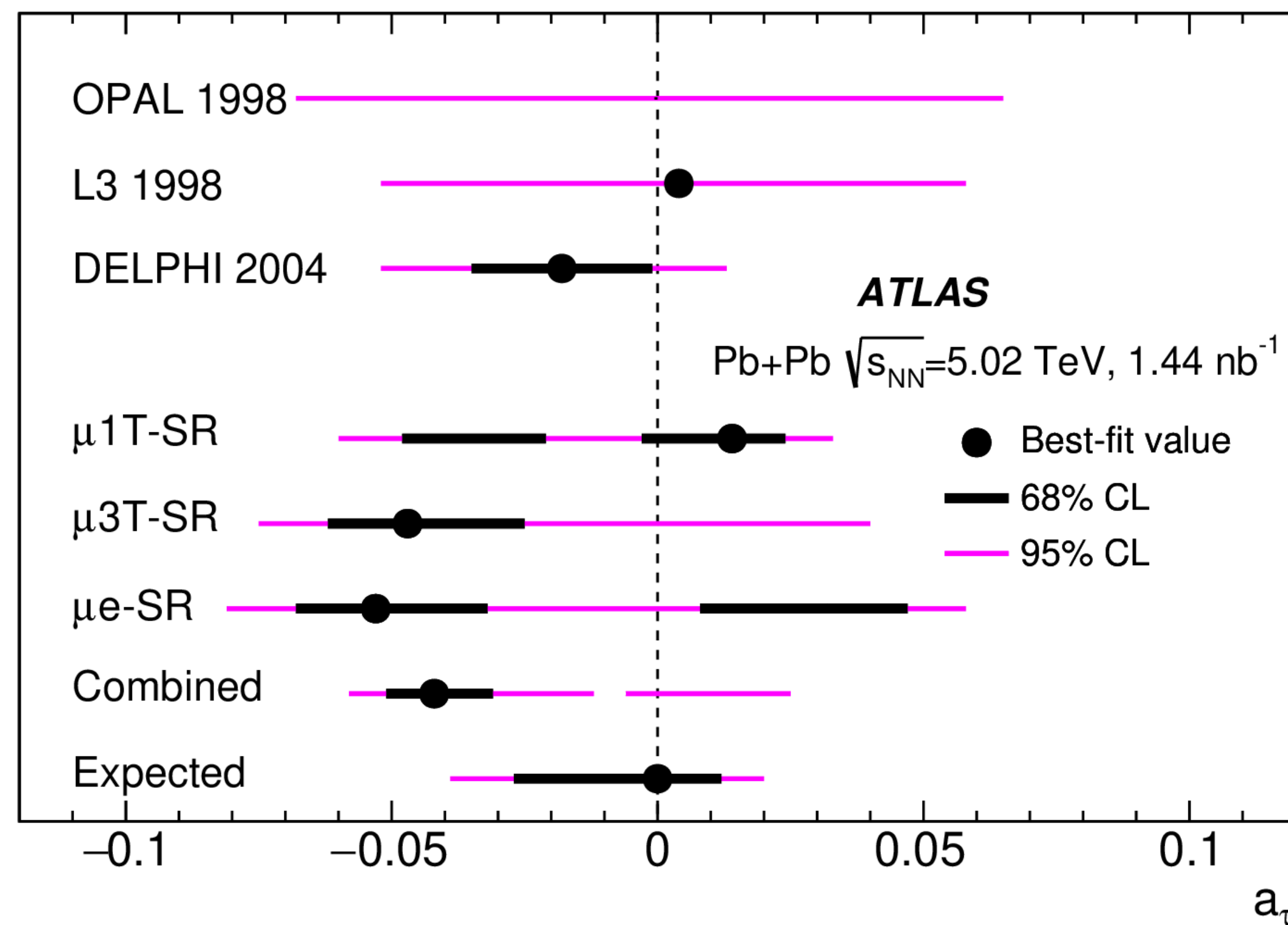- An example of lead collisions to do light-by-light scattering
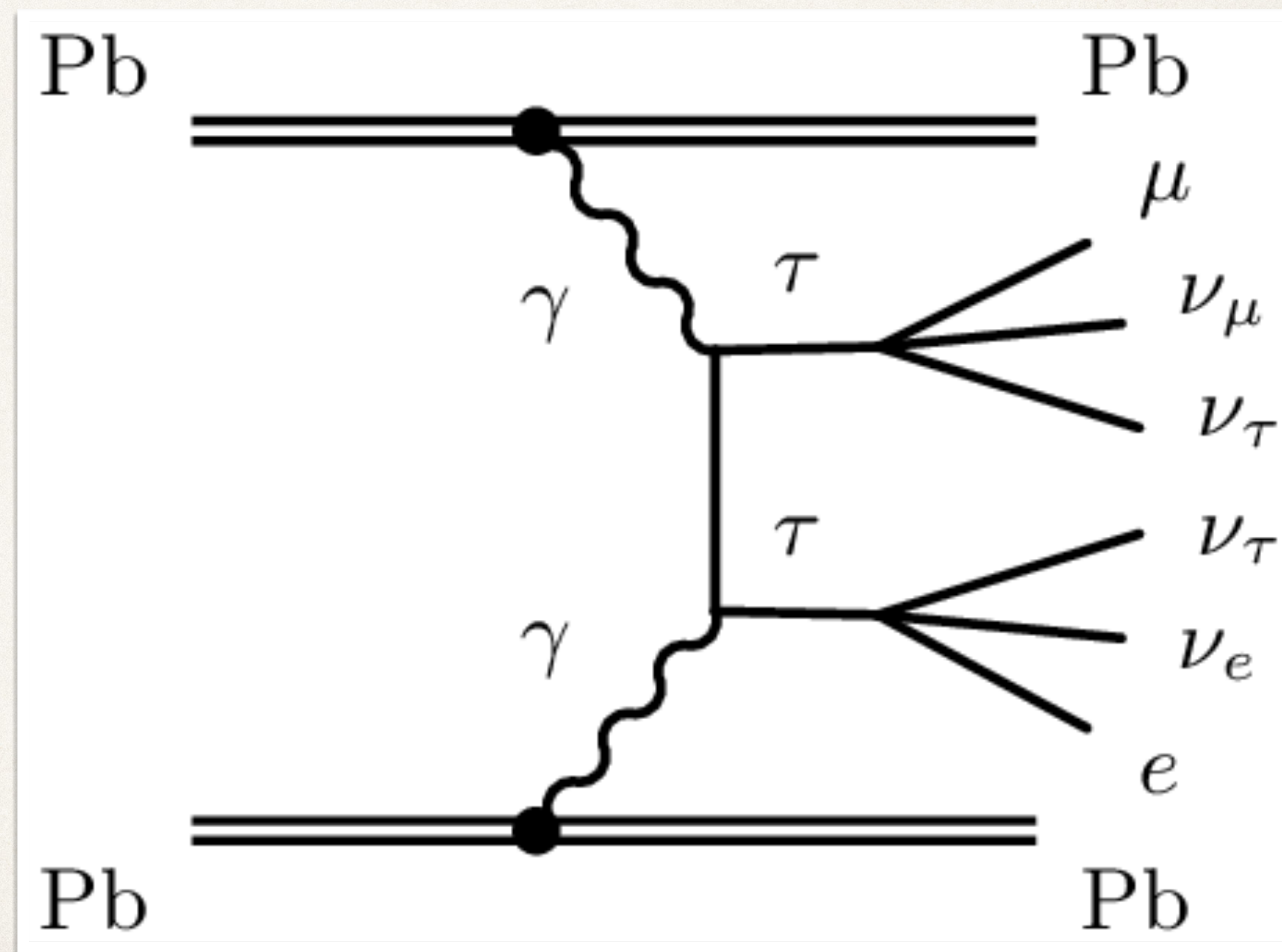
Not standard running

* Statistics are limited but not exploiting all channels yet

* Even so, we are still sensitivity to anomalous tau magnetic moment

Not standard running

* Still dominated by statistics

* Competitive to LEP

Conclusions

✤ We are in a lucky position - with powerful data samples, powerful tools, powerful simulations, powerful predictions

✤ For SM and BSM, we need to think big and outside the traditional SM analyses

✤ I personally feel that the potential is huge