SMEFT Effects on the Orientation of Splitting Plane of Narrow Dijets.

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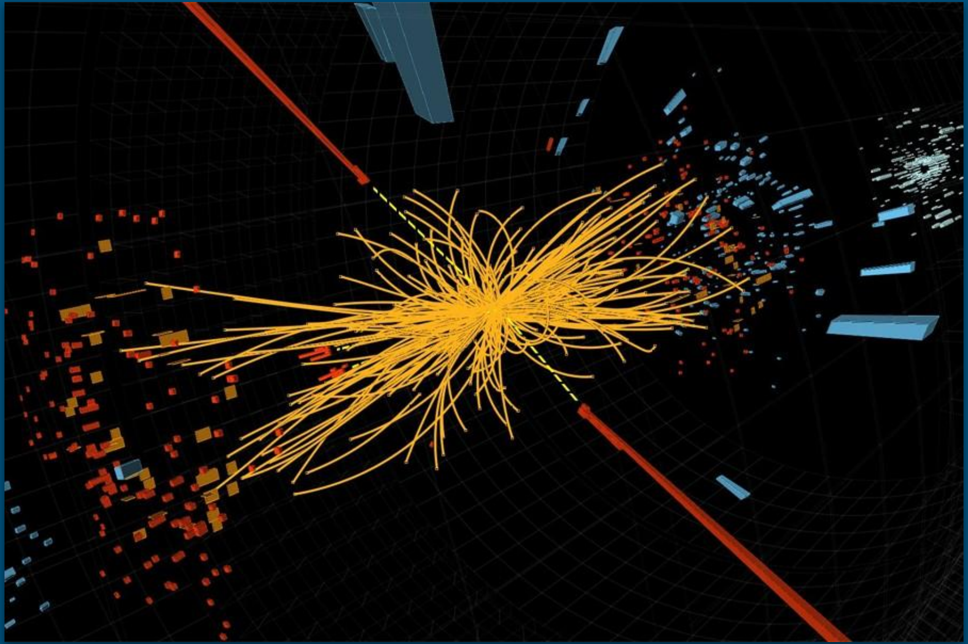
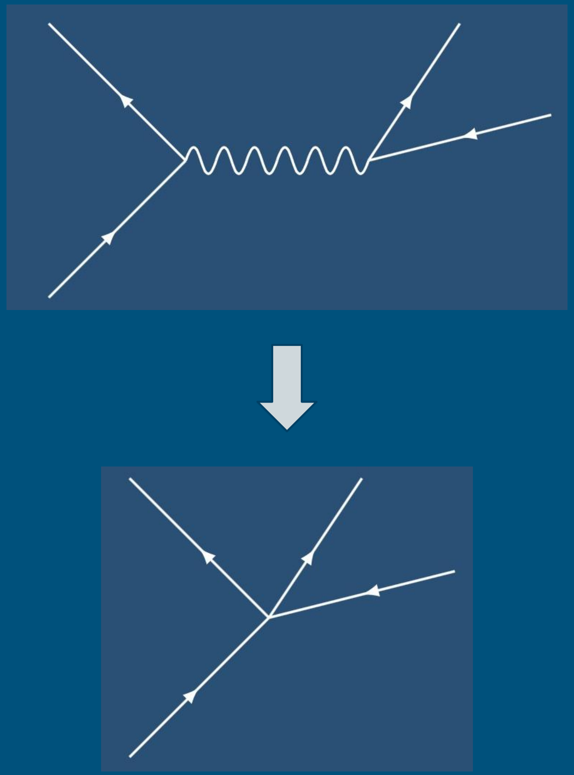
Outline

- EFT
- SMEFT
- Operator
- Geometry
- Asymmetry Variable
- Analysis
- Error
- Conclusions



Effective Field Theory

- A prototype EFT is Fermi's Theory of weak decay
- Point like interactions approximate well the UV theory at low energy
- This yields a perturbation series in powers of E/M



SMEFT: Standard Model Effective Field Theory

- SMEFT assumes the absence of light new particles and sets up an expansion in E/Λ

- SMEFT effects are organized by operator dimension

$$\mathcal{L}_{\text{SMEFT}} = \mathcal{L}_{\text{SM}} + \mathcal{L}^{(5)} + \mathcal{L}^{(6)} + \mathcal{L}^{(7)} + \mathcal{L}^{(8)} + \dots$$

- Operators are built from SM fields

$$\mathcal{L}^{(i)} = \sum_{k=1}^{N_i} \frac{c_k^{(i)}}{\Lambda^{i-4}} Q_k^{(i)}$$

Operator of interest

$$f^{abc} G_{\nu}^{a\mu} G_{\rho}^{b\nu} G_{\mu}^{c\rho}$$

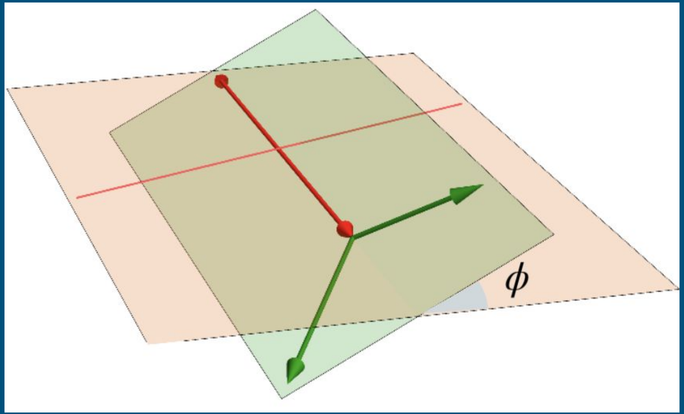
- This operator, which modifies gluon scattering, does not interfere at the tree level with any SM 2-to-2 process.
- This operator couples a combination of gluon helicities that does not interact through SM couplings.
- The interference returns for scatterings with more legs, but leads to subtle patterns in “nearly 2-to-2” processes.
- Other operators in the SMEFT can affect 2-to-2 dijet production but don’t lead to the same pattern.

Dixon and Shadmi, hep-ph/9312363+NPB, Azatov et al 1607.05236+PRD

Geometry

- Those subtle patterns arise in the angle ϕ between the production and jet splitting plane.

- The process is, “nearly 2-to-2”, if the secondary splitting (green arrows) is narrow.



Orange line - beam line

Orange plane - production plane

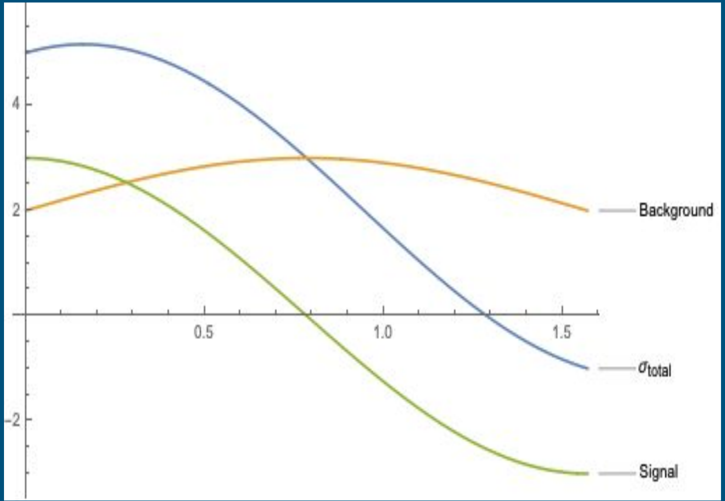
Green plane - jet splitting plane

Red arrow - jets

Green arrows - split jets

Asymmetry Variable

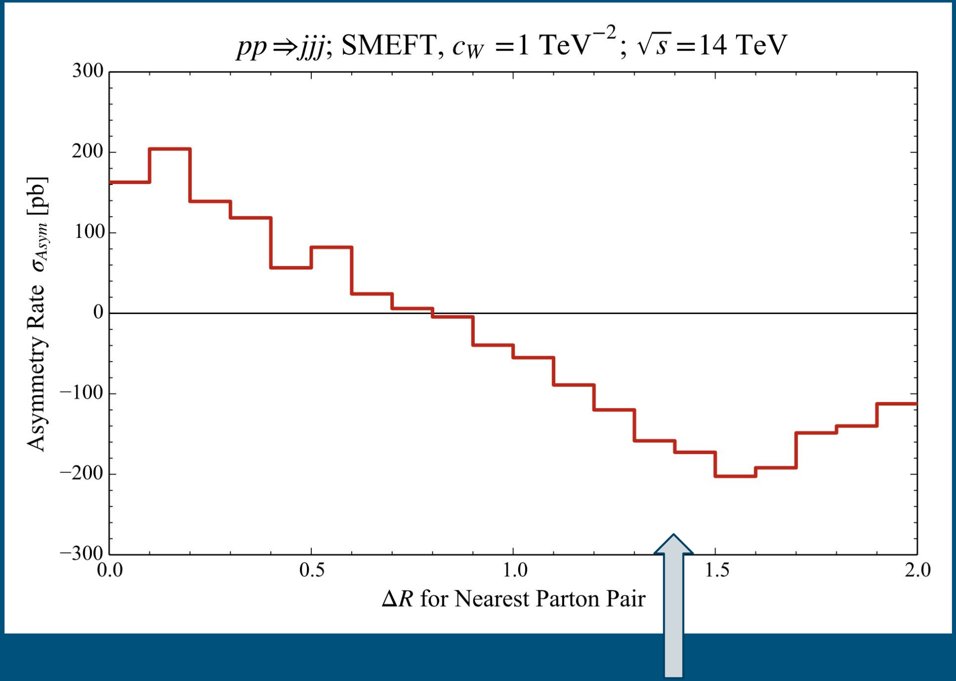
- Angular behaviors emerge due to gluon helicity.
  - The signature dependence arises only from interference of different-helicity gluons.
- Signal is sensitive to just G^3 operator at parton tree level.
- Dimension 8 SMEFT effects (using v-improved matching) are projected out by the asymmetry variable as well.
- Similar analyses in decays of weak dibosons have already been proposed. (Azatov et al, 1707.08060+JHEP, 1901.04821+JHEP)



$$\sigma_{Asym} = \int_0^{\frac{\pi}{2}} \cos(2\phi)\sigma_{BSM}(\phi)d\phi$$

ΔR distribution of asymmetry at parton level

- We are focused on the narrow splittings of the gluons. This is where non-G^3 effects are most clearly projected out by the asymmetry.
- This will provide independent complimentary information to previous analyses.



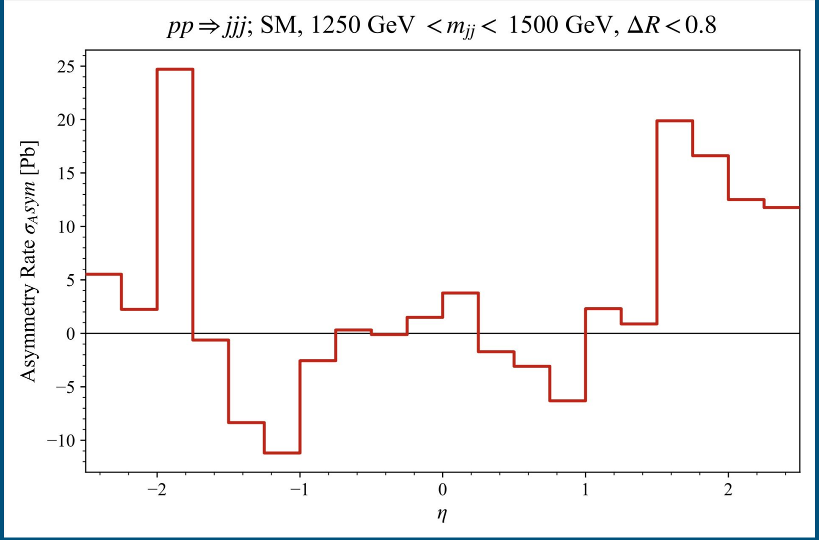
Dixon and Shadmi, hep-ph/9312363+NPB, Hirschi et al 1806.04696+JHEP

Reconstructed event analysis

- Showering, hadronization, and detection effects are included at this level.
- We require 2 fat jets of p_T > 100 GeV and tag the one with lesser τ_{21} ratio as having the interesting splitting.
- We compute the splitting plane rotation angle ϕ from the N-subjetiness subjet axes.
- Motivated by angular behavior at parton level (previous slide), we require ΔR between subjet axes less than 0.8.
- We bin in difatjet invariant mass and in eta of the jet with lesser τ_{21}.

Reco level background

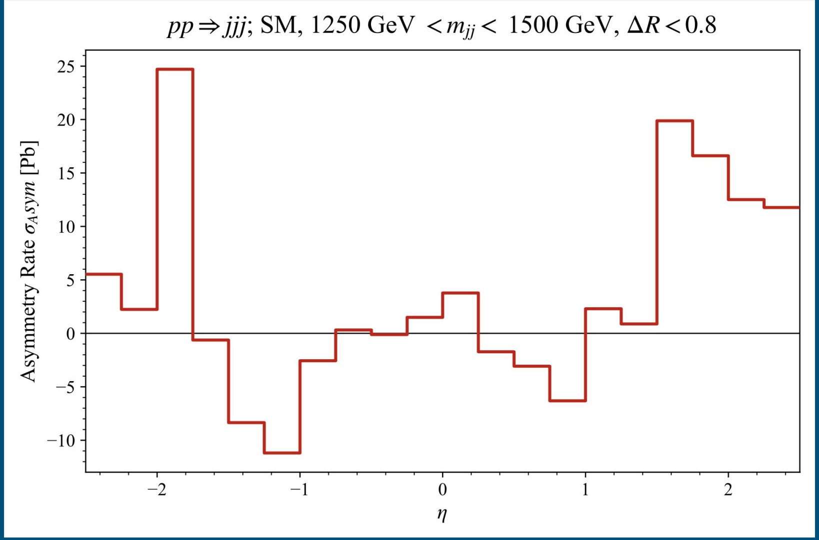
- SM asymmetry rate



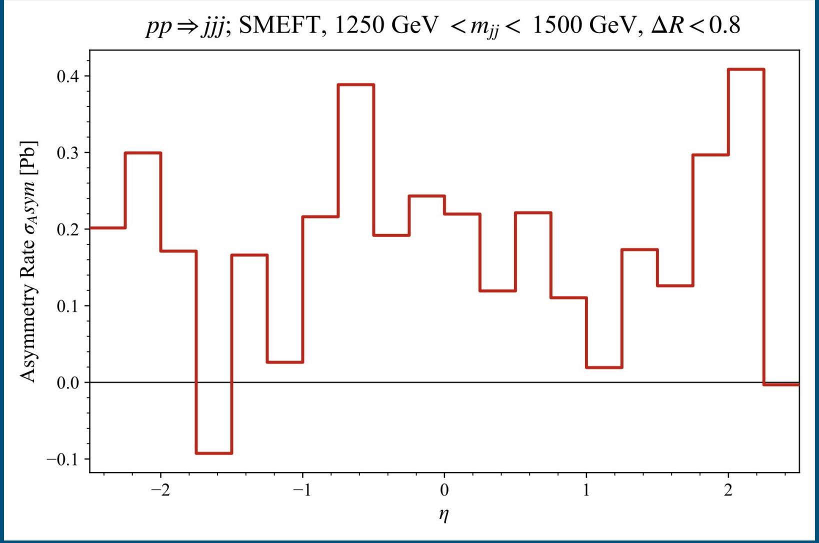
- Systematic non-zero asymmetry in the SM appears to reemerge due to showering.
- We suspect this is understandable as the misalignment between the dipole radiation axes and jet axes.

η distribution of asymmetry (Preliminary)

- SM asymmetry rate

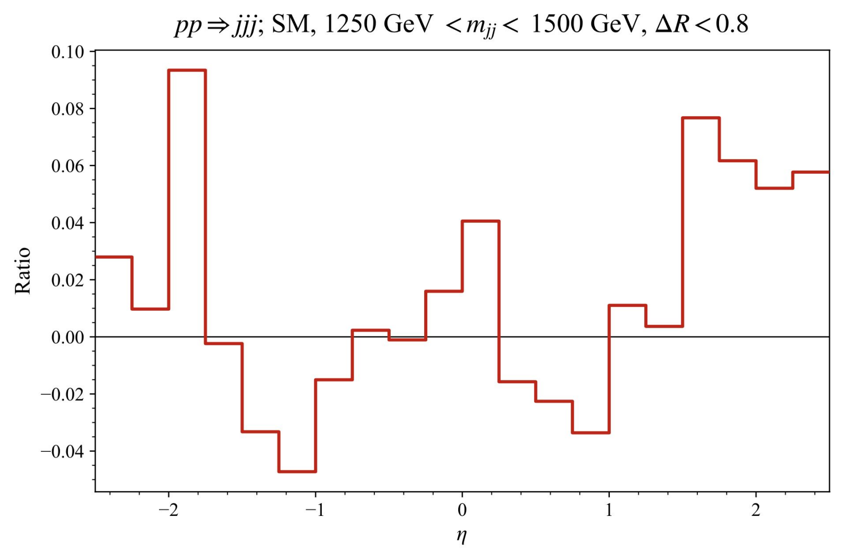


- SMEFT asymmetry rate

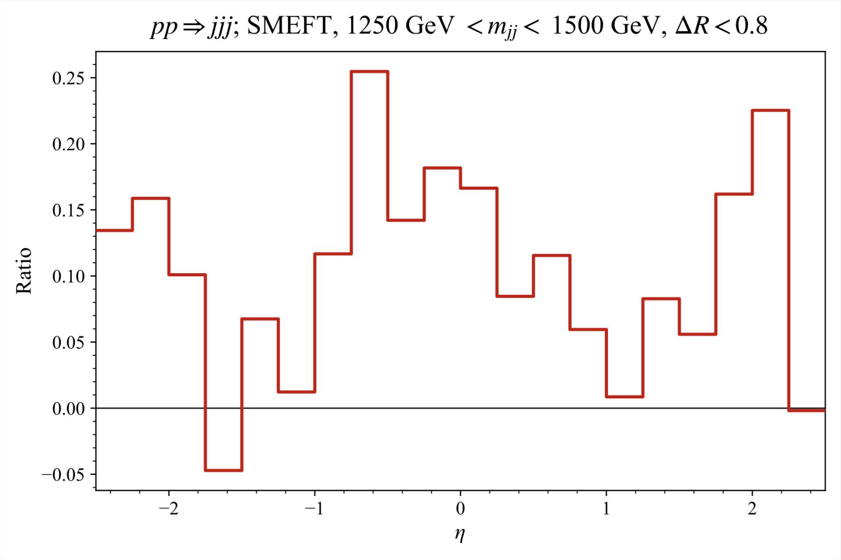


Asymmetry fractions (Preliminary)

Ratio of the asymmetry rate and event rate for SM



Ratio of the asymmetry rate and event rate for SMEFT



Error

A consistent EFT expansion is for an OBSERVABLE (e.g. cross-section, not amplitude), and includes ALL contributions at a given order

Amplitudes for dimension-6 EFT operators go like Λ^{-2} and dim-8 go like Λ^{-4}

Squaring to get the cross-section, the dim-6 cross-term with the SM gives leading contributions. This interference vanishes without considering distribution in phi.

Remember the fourier analysis suppresses higher order EFT effects as well as SM effects.

Rare that we have one operator, and rare that it is insensitive to higher order effects

Results

- Neglecting (integrating over) eta distribution, a single bin detection would require systematic understanding of QCD asymmetry in SM at per mille level.
- Exploiting shape information in the asymmetry ratio will loosen this requirement.

Conclusion

This is a distinct technique to detect the G^3 operator at order $1/\Lambda^2$.

We are looking at subjet information to detect splitting planes of jets and constructing an asymmetry which washes out the background and theoretical error contributions.

With per mille precision on QCD ratio, we could detect this operator without any subtlety. Using shape information, this precision requirement will be reduced.

Open question: How attainable is this precision in QCD?

Thank you