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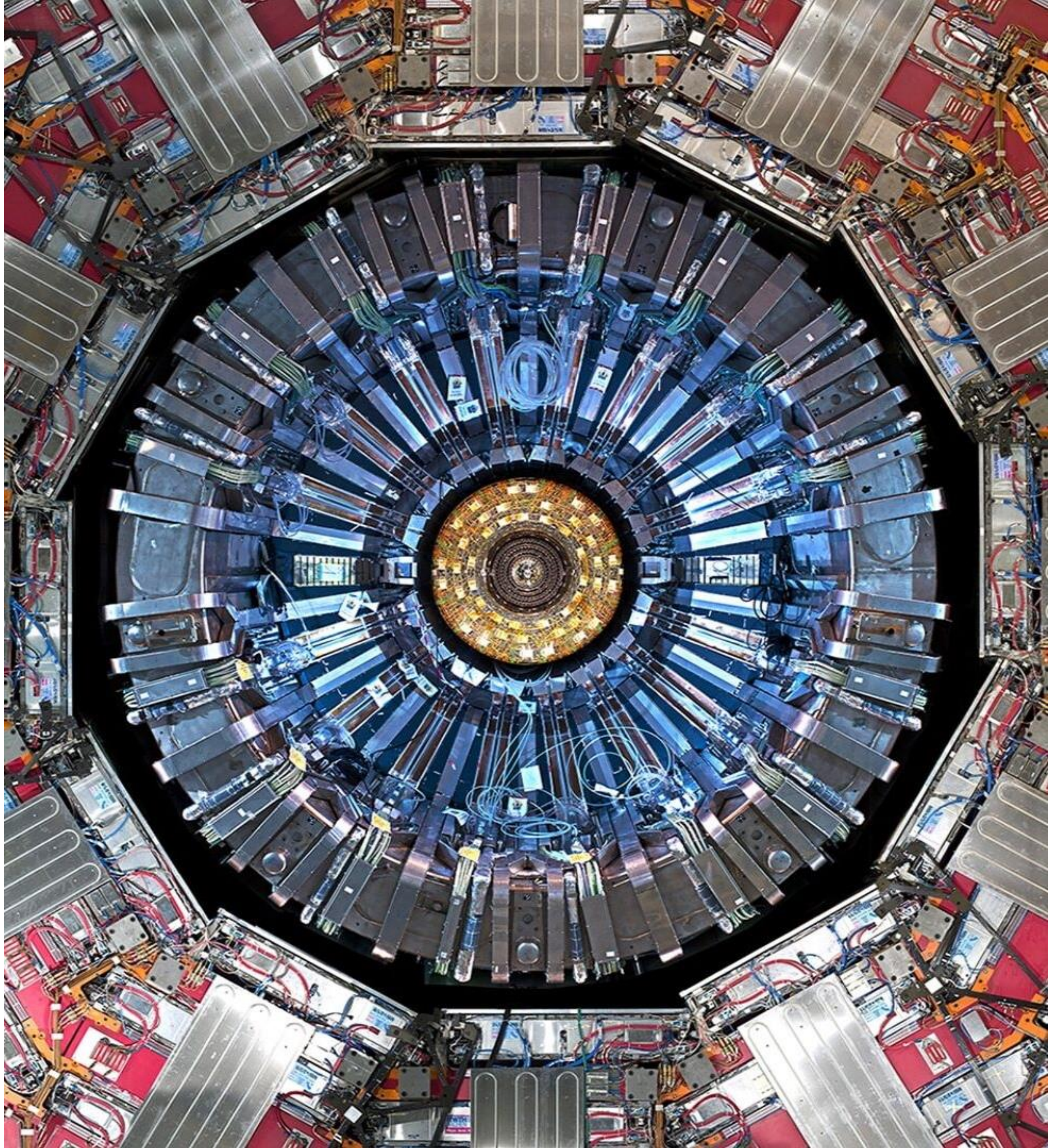

Exploring jet substructure in public LHC data

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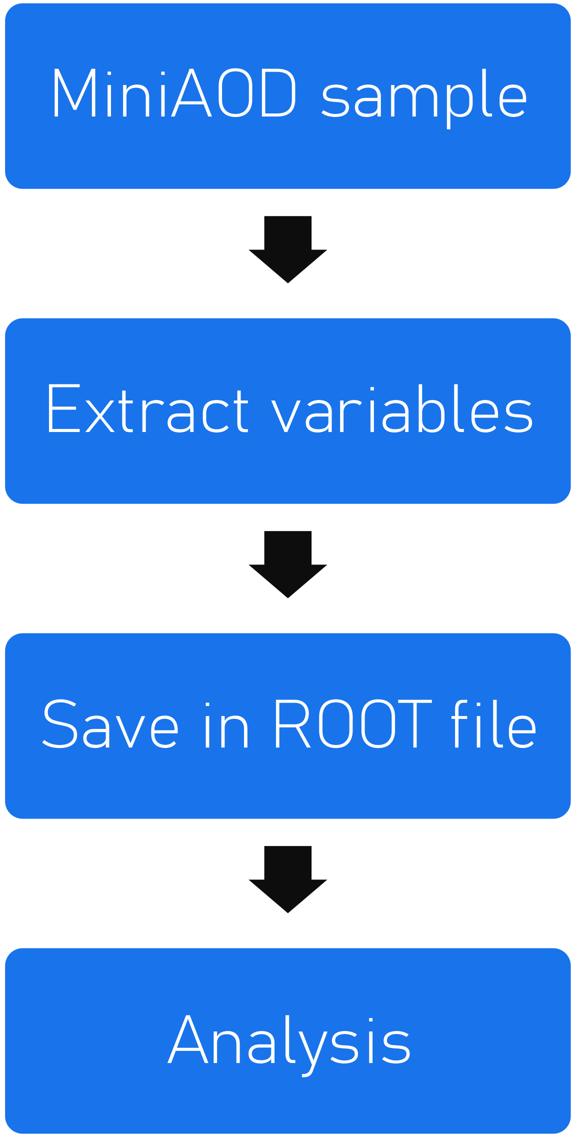
Analysis Workflow

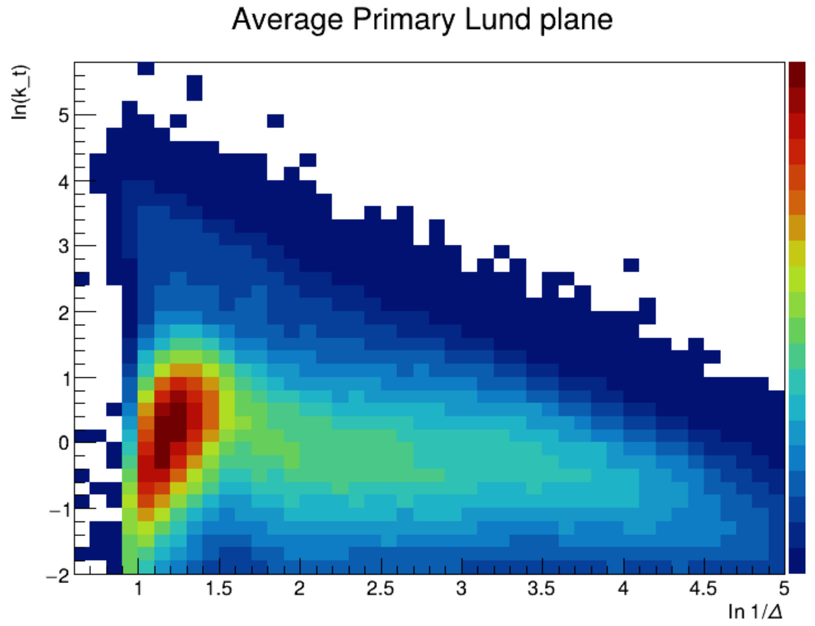
- Using CERN'S Opendata we extract MiniAOD data samples;
- We use CMS docker container to evaluate these samples;
- We retrieve important variables and save them into a ROOT file;
- We analyze this ROOT file in our own environment later.



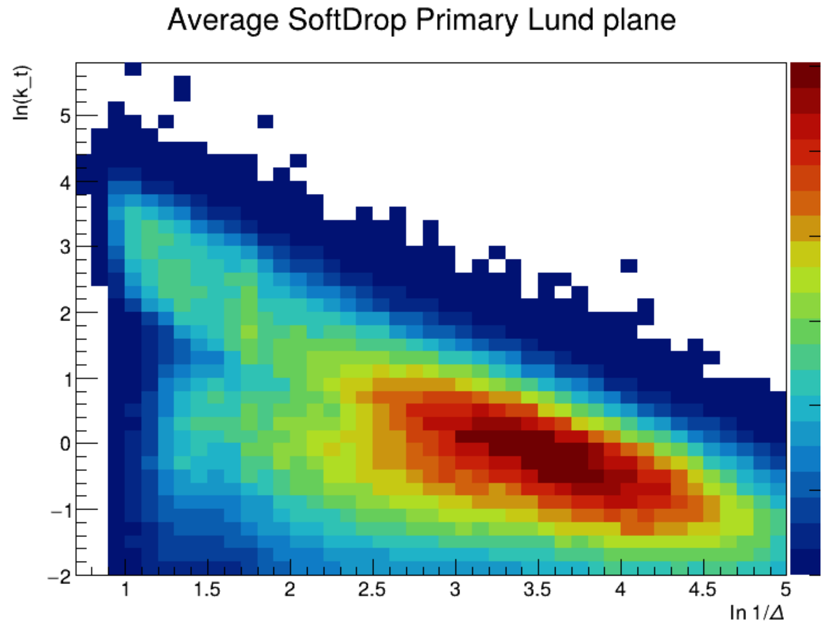
1. Analysis workflow for processing CMS MiniAOD Open Data.

Lund Jet Plane

- With the data we build the average primary and secondary Lund Jet Plane;
- We apply softdrop grooming and compare the planes with and without softdrop;
- Softdrop significantly reshapes the plane by removing soft wide-angle radiation, concentrating the population toward the perturbative core of the jet and making the hard-splitting structure more prominent.



2. Plot of the primary Lund plane.



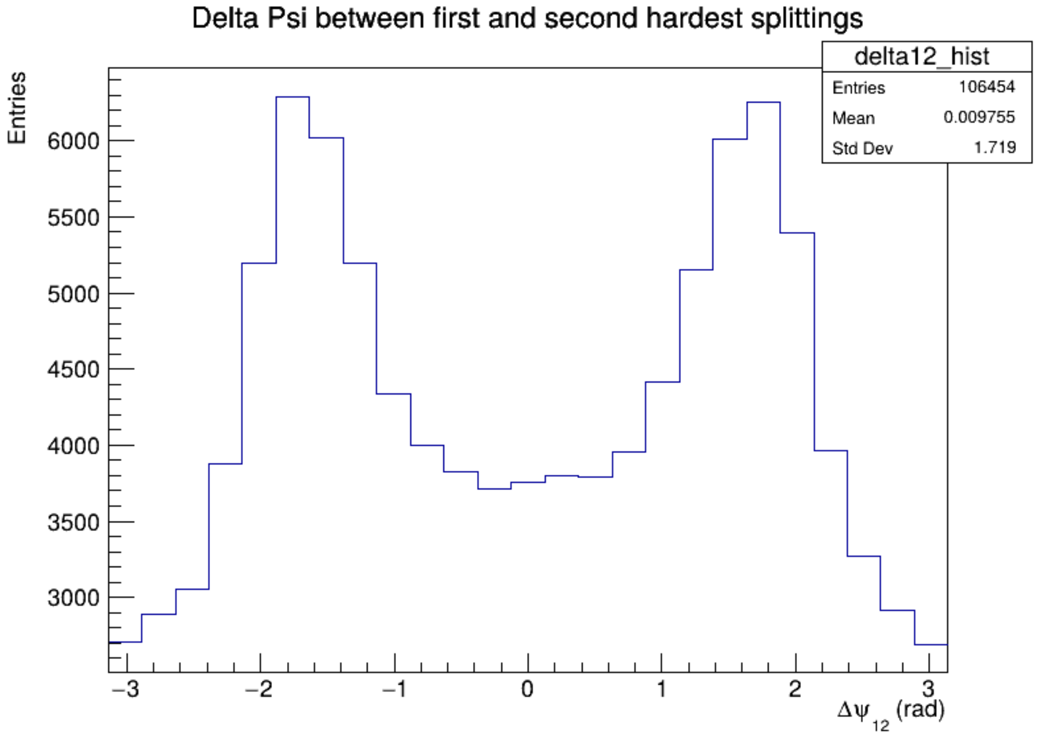
3. Plot of the primary Lund plane with SoftDrop.

Measured $\Delta\boldsymbol{\psi}_{12}$

$$\frac{d\sigma}{d\Delta\boldsymbol{\psi}_{12}} \propto a_0(1 + \frac{a_2}{a_0}\cos(2\Delta\boldsymbol{\psi}_{12})$$

Eq 1. Cross section differential in the observable $\Delta\boldsymbol{\psi}_{12}$.

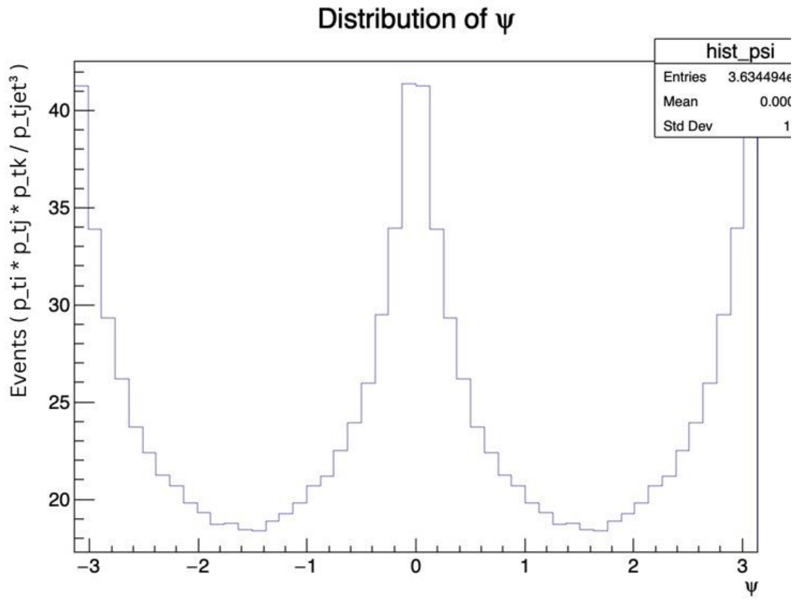
- The observable $\Delta\boldsymbol{\psi}_{12}$ is defined as the relative angle between the planes associated with the hardest primary splitting and the hardest secondary splitting;
- In the collinear limit, the expected functional form can be written as a modulation of the type equation 1;
- In the measured distribution of $\Delta\boldsymbol{\psi}_{12}$ the locations of maxima and minima indicate a negative $\frac{a_2}{a_0}$ and the function the plot reveals a period of 2π;
- However, the function is not a perfect $\cos(2\Delta\boldsymbol{\psi}_{12})$.



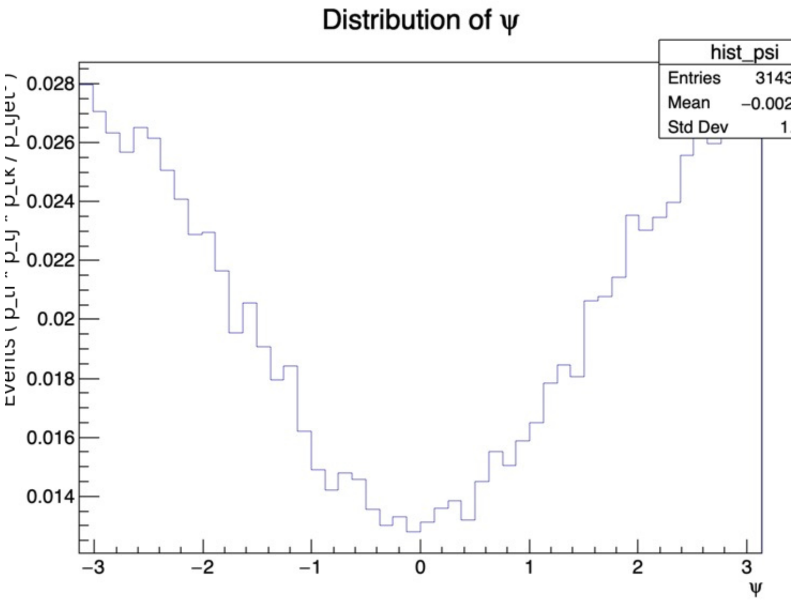
4. $\Delta\boldsymbol{\psi}_{12}$ obtained distribution.

Measured $\Delta\boldsymbol{\psi}$

- The three-point energy correlator (EEEC) provides a complementary probe of collinear spin correlations by encoding the azimuthal orientation between successive emission planes, which can generate a characteristic $\cos(2\Delta\boldsymbol{\psi}_{\mathbf{12}})$ modulation;
- The $\Delta\boldsymbol{\psi}$ distribution obtained from the EEEC calculation over the full $(\theta_{ij}, \theta_{jk})$ integration region follows a $\cos(2\Delta\boldsymbol{\psi}_{\mathbf{12}})$ modulation and yields a positive $\frac{a_2}{a_0}$;
- When restricting the angular integration limit $(0.1 < \theta_L < 1\,, 0.01 < \theta_S < 0.1)$, the distribution changes drastically.



5. $\Delta\boldsymbol{\psi}$ obtained distribution in the full integration limit.



6. $\Delta\boldsymbol{\psi}$ obtained distribution in a specific integration limit.

Conclusions

- A full analysis pipeline based on CMS Open Data MiniAOD was developed to extract jet constituents, build Lund-plane representations, and compute angular observables in a reproducible way;
- The primary/secondary Lund planes and grooming studies show the expected qualitative behavior, while the $\boldsymbol{\Delta\psi_{12}}$ and $\boldsymbol{\Delta\psi}$ distributions exhibit clear modulations that require validation against simulated samples and careful assessment of analysis choices;
- Next steps include performing a detailed data–simulation comparison, improving the EEEC computational performance, and integrating flavour taggers to study $\boldsymbol{\Delta\psi_{12}}$ and $\boldsymbol{\Delta\psi}$ in different flavour channels.