LHCb Z+flavoured jets

Setup Z+charm [2109.08084]:

Table 1: Definition of the fiducial region.

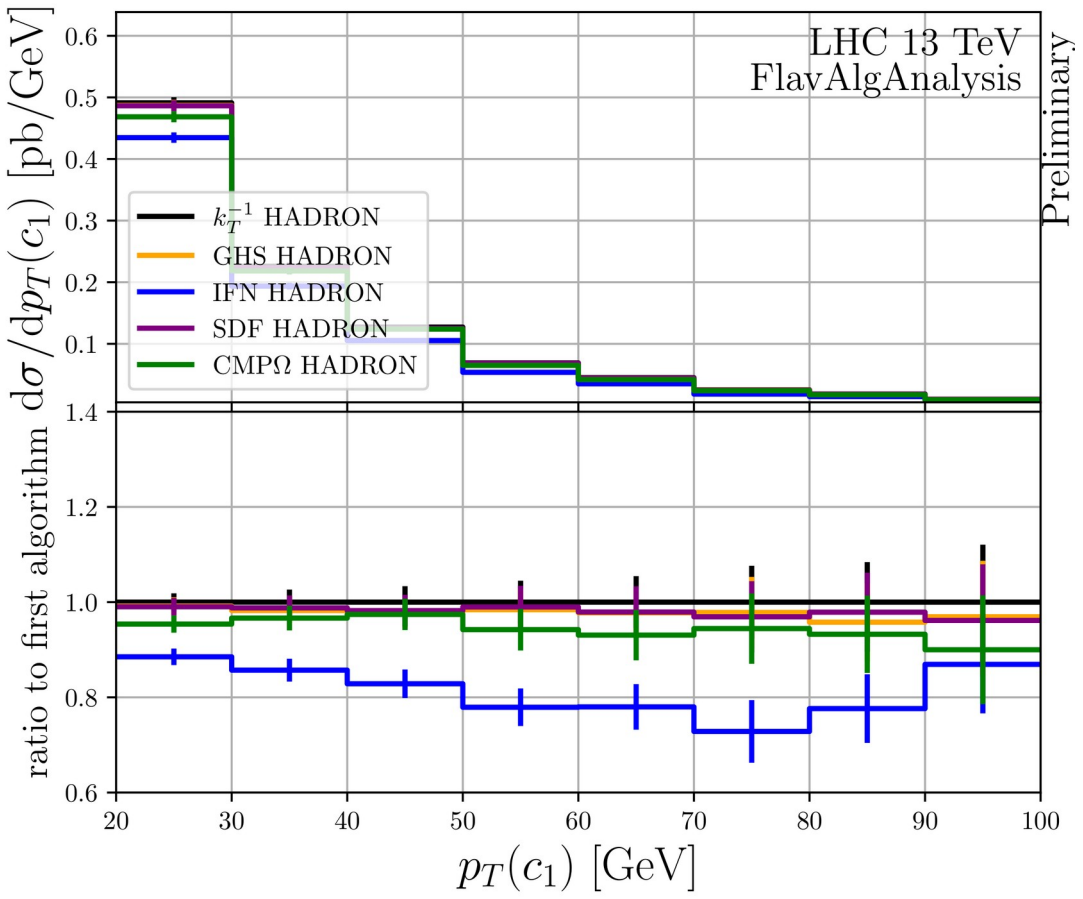
Z bosons	$p_{\mathrm{T}}(\mu) > 20\,\mathrm{GeV}$, $2.0 < \eta(\mu) < 4.5$, $60 < m(\mu^+\mu^-) < 120\,\mathrm{GeV}$
Jets	$20 < p_{\mathrm{T}}(j) < 100\,\mathrm{GeV}$, $2.2 < \eta(j) < 4.2$
Charm jets	~~$p_{\mathrm{T}}(c\text{ hadron}) > 5\,\mathrm{GeV}$, $\Delta R(j, c\text{ hadron}) < 0.5$~~
Events	$\Delta R(\mu, j) > 0.5$

Replaced by the respective algorithms

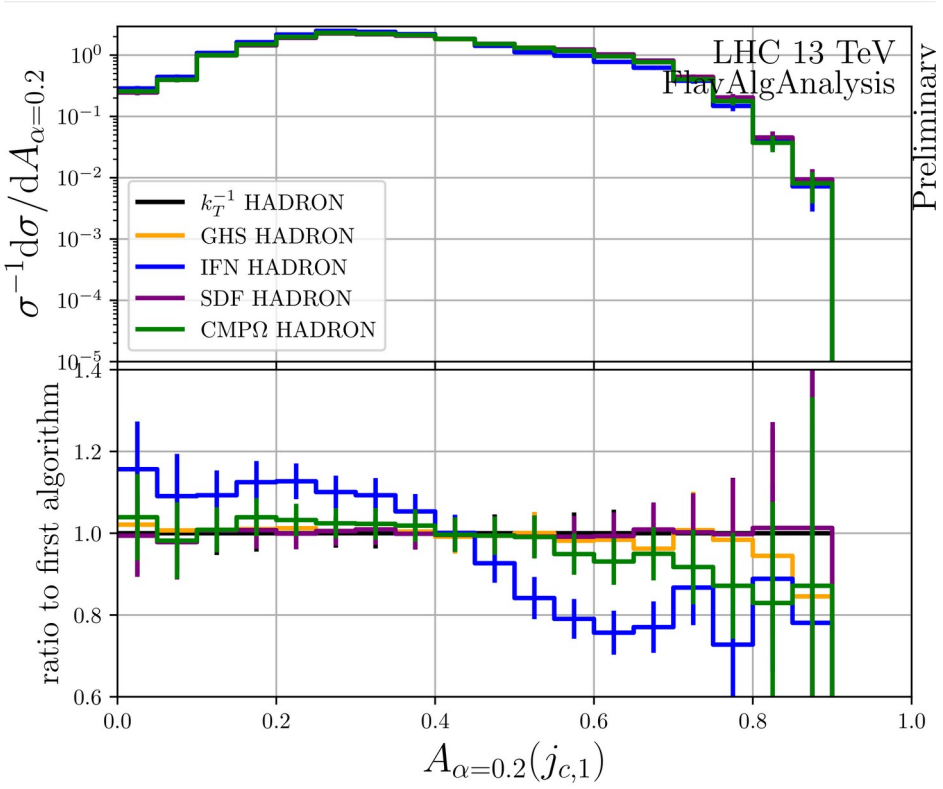
Sample: Powheg+Pythia (NLO+PS) → Giovanni

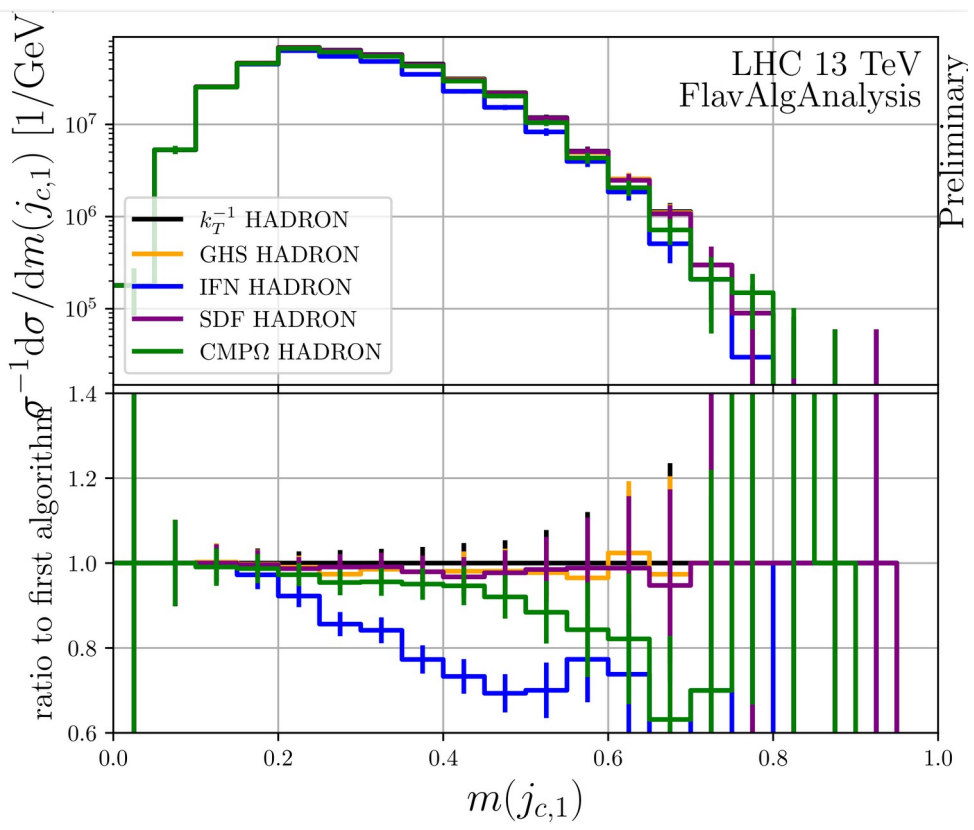
→ Only hadron level for now….

Charm - jet pT

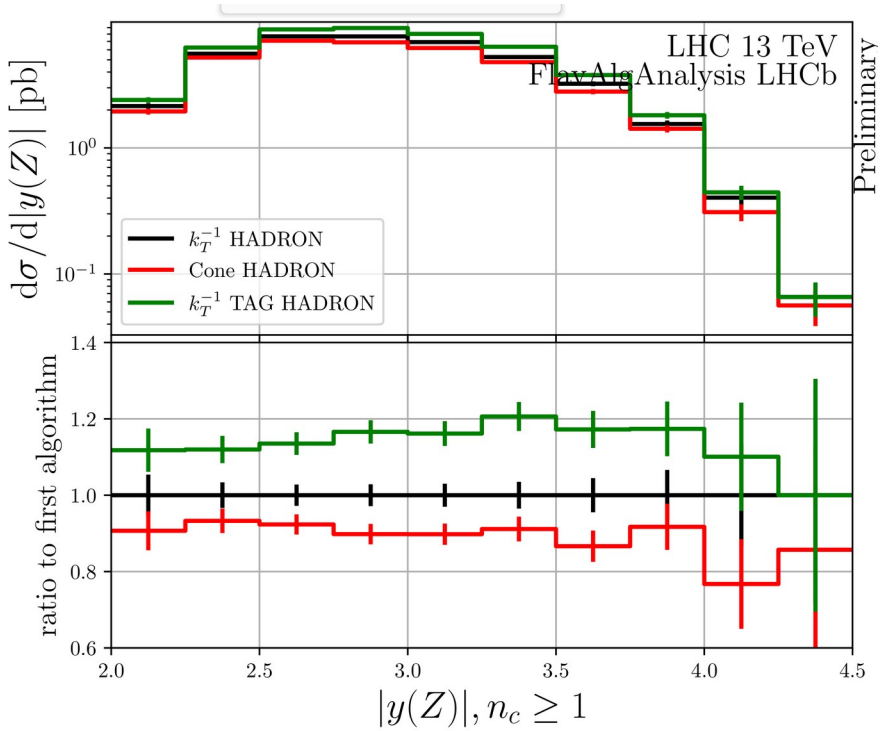

LHC 13 TeV
FlavAlgAnalysis
Preliminary
k_T^{-1} HADRON
GHS HADRON
IFN HADRON
SDF HADRON
CMPΩ HADRON
$\mathrm{d}\sigma/\mathrm{d}p_T(c_1)$ [pb/GeV]
ratio to first algorithm
$p_T(c_1)$ [GeV]
0.6
0.5
0.4
0.3
0.2
0.1
1.4
1.2
1.0
0.8
0.6
20
30
40
50
60
70
80
90
100

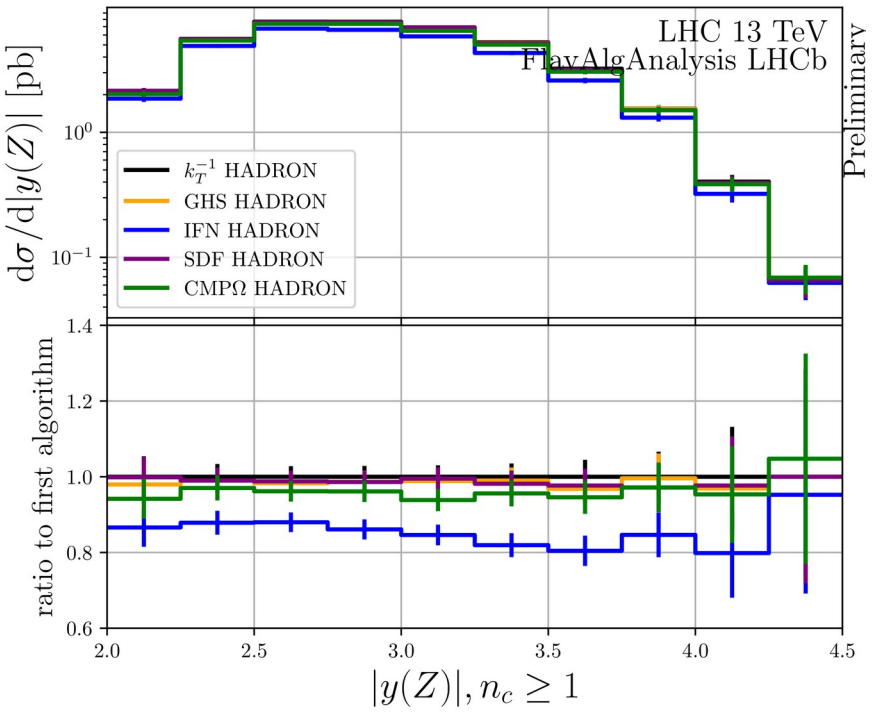
Some JSS


LHC 13 TeV
FlavAlgAnalysis
Preliminary
k_T^{-1} HADRON
GHS HADRON
IFN HADRON
SDF HADRON
CMPΩ HADRON
$\sigma^{-1}\mathrm{d}\sigma/\mathrm{d}A_{\alpha=0.2}$
ratio to first algorithm
$A_{\alpha=0.2}(j_{c,1})$


LHC 13 TeV
FlavAlgAnalysis
Preliminary
k_T^{-1} HADRON
GHS HADRON
IFN HADRON
SDF HADRON
CMPΩ HADRON
$\sigma^{-1}\mathrm{d}\sigma/\mathrm{d}m(j_{c,1})$ [1/GeV]
ratio to first algorithm
$m(j_{c,1})$

Z-boson rapidity

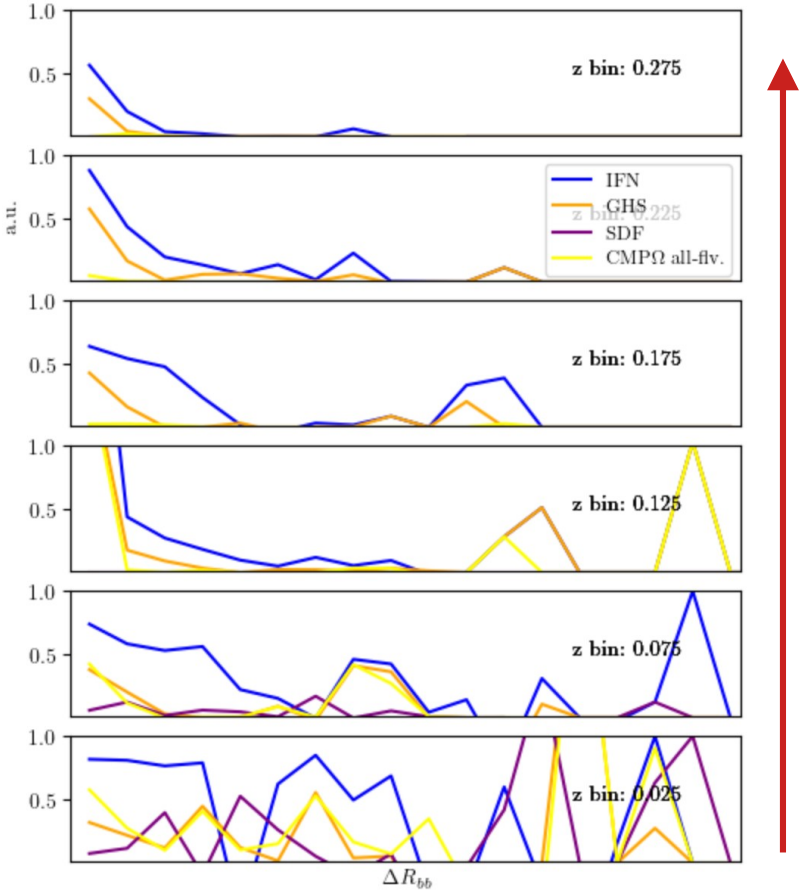




Update on central analysis
DeltaR vs pT(b)/pT(jet) correlations

Leading b-jets
with exactly 2-fl. partons

Fraction of
jets “mis-identified”
(
flavour algorithm → no flavour
anti-kT → flavour
)



Higher
pT(b)/pT(jet)

Preliminary results for Z+(b/c-)jets at MC@NLO

- 13 TeV Z+jets SHERPA sample (1/5th of it → ~20M events) **(thanks to Davide Napoletano)**
  - Generation phase space:
    1) pT(l) > 20 GeV, 71 GeV < m(ll) < 111 GeV, |y(l)| < 2.4
    2) pT(ll) > 20 GeV
       → avoid jet requirements at generation level
       → 'inclusive' over the choice of algorithm in the analysis
  - Hadron and Parton level
- Rivet analysis: FlavAlgAnalysis
  - Based on CMS_2017_I1499471_flakt + new FastJet flavoured jet implementations
  - Lepton + Jet requirement: R=0.5, pT(jet) > 30 GeV, |y(jet)| < 2.4
  - Various jet-algorithms + tagging procedures

Disclaimer: all results/observations are preliminary

Flavoured Jet algorithms

- SDF (beta = 1, zcut = 0.1)
- GHS (omega = 2, alpha = 1, ptcut = 15 GeV)
- IFN (alpha = 2, omega = 3 – alpha)
- CMP (a = 0.1)
- All with |#b/B| mod 2 == 1 flavour tag

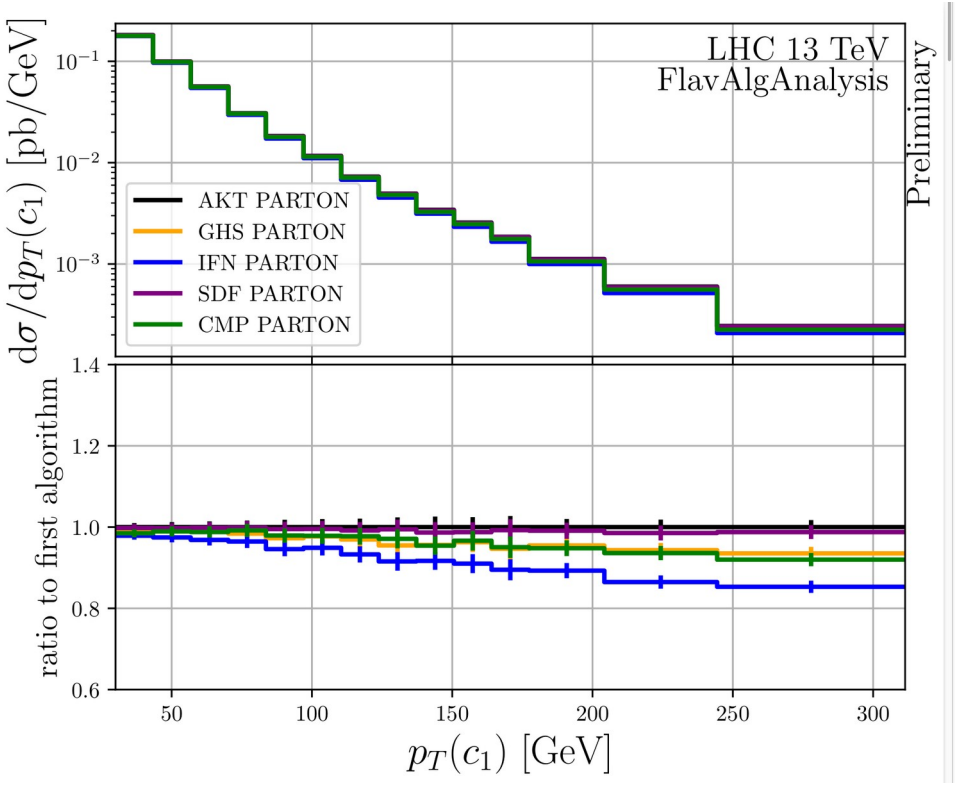
Anti-kT for comparison:

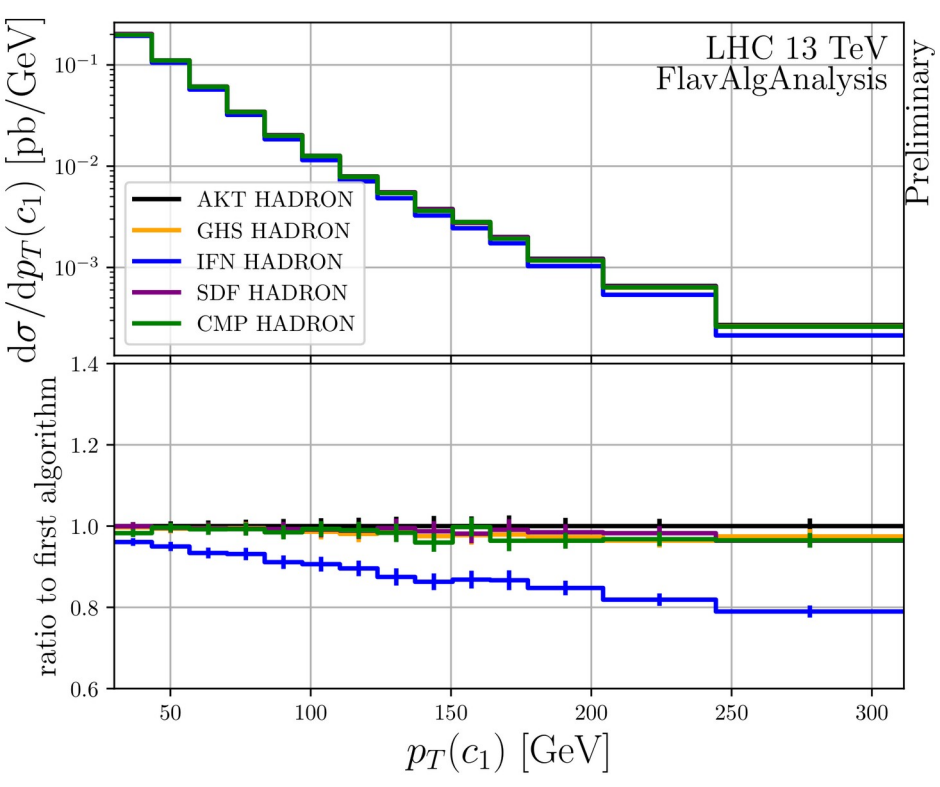
- ATLAS style truth-level ghost-tagging → CONE
- Anti-kT CMS truth level tag → TAG
- Anti-kT odd #B-hadron tag → AKT

Charm Analysis

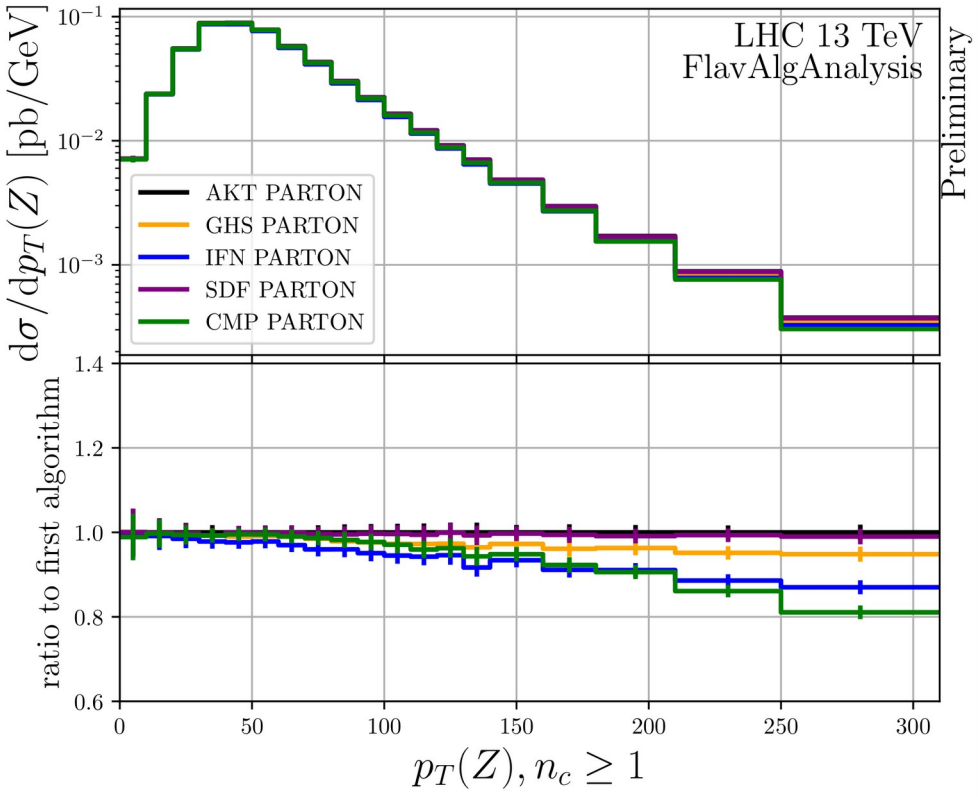
- Using charm tags instead of bottom tags but everything else stays the same: observables, cuts etc.

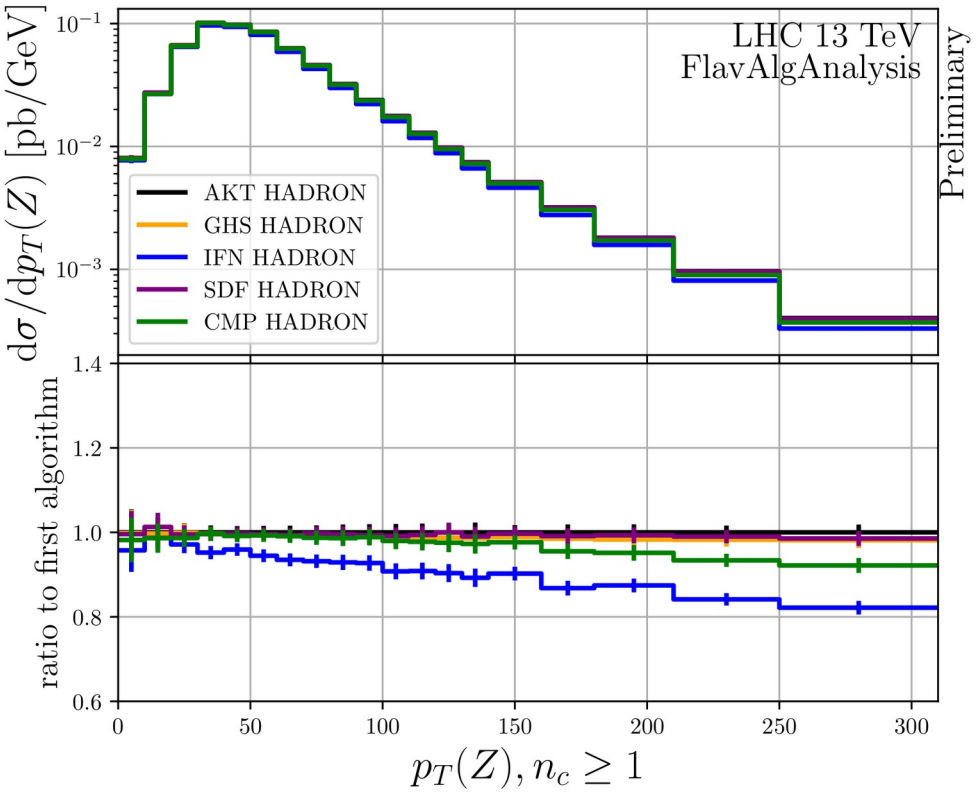
pT of leading charm-jet





pT of leading charm-jet



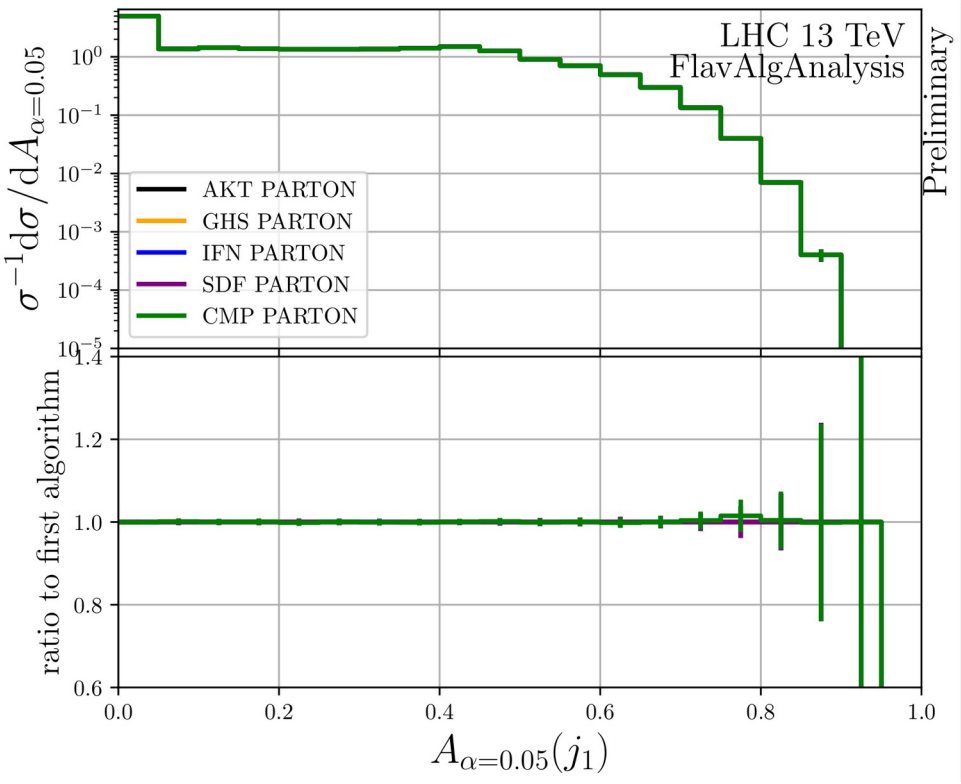


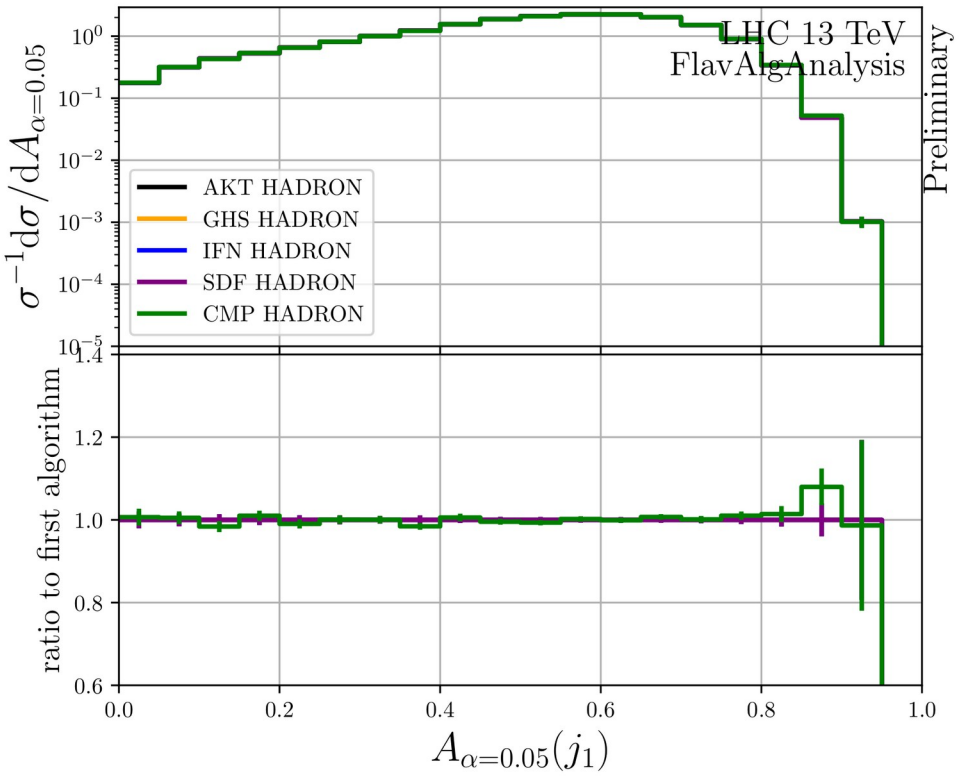
JSS

- Angularity: $A_{\alpha=0.05,0.1,0.2}$
- Jet-mass: $m(j_1)$
- Both for the leading jet and leading tagged jet

Angularity

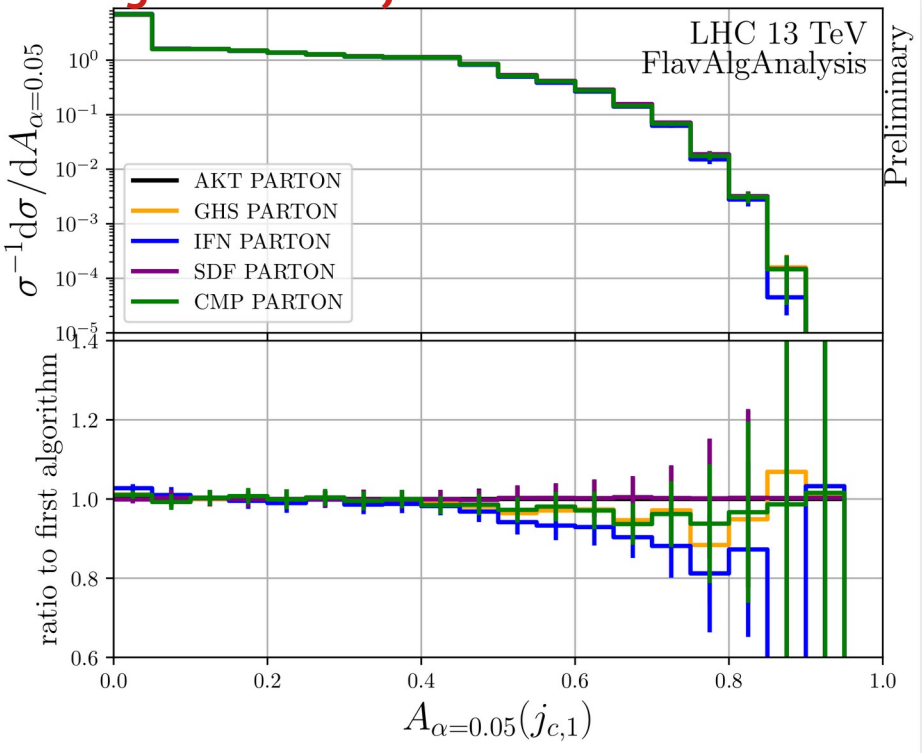
Leading jet

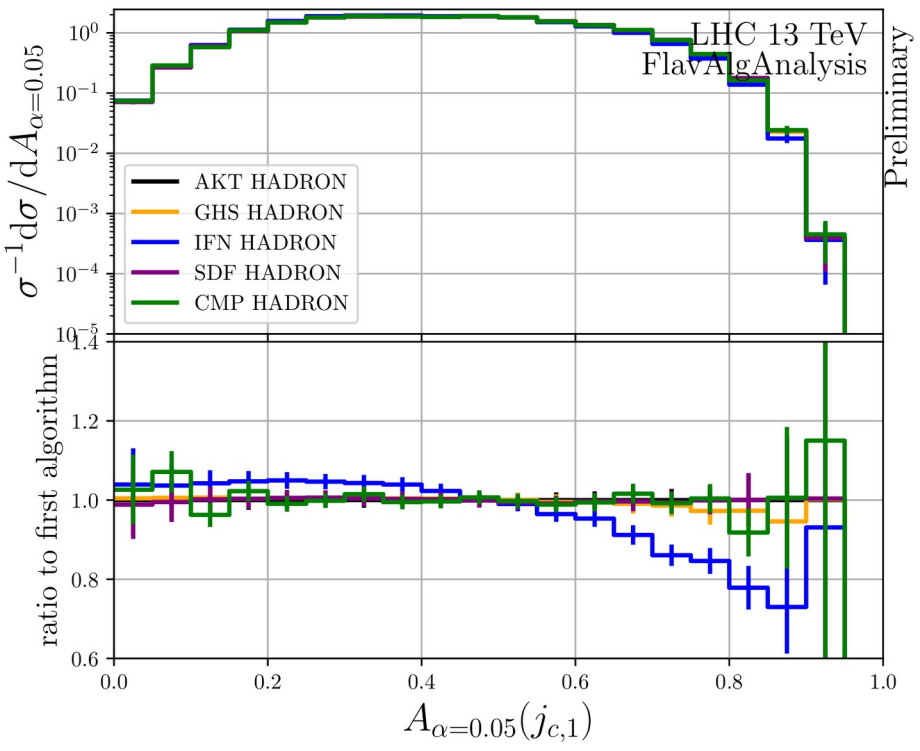




Angularity

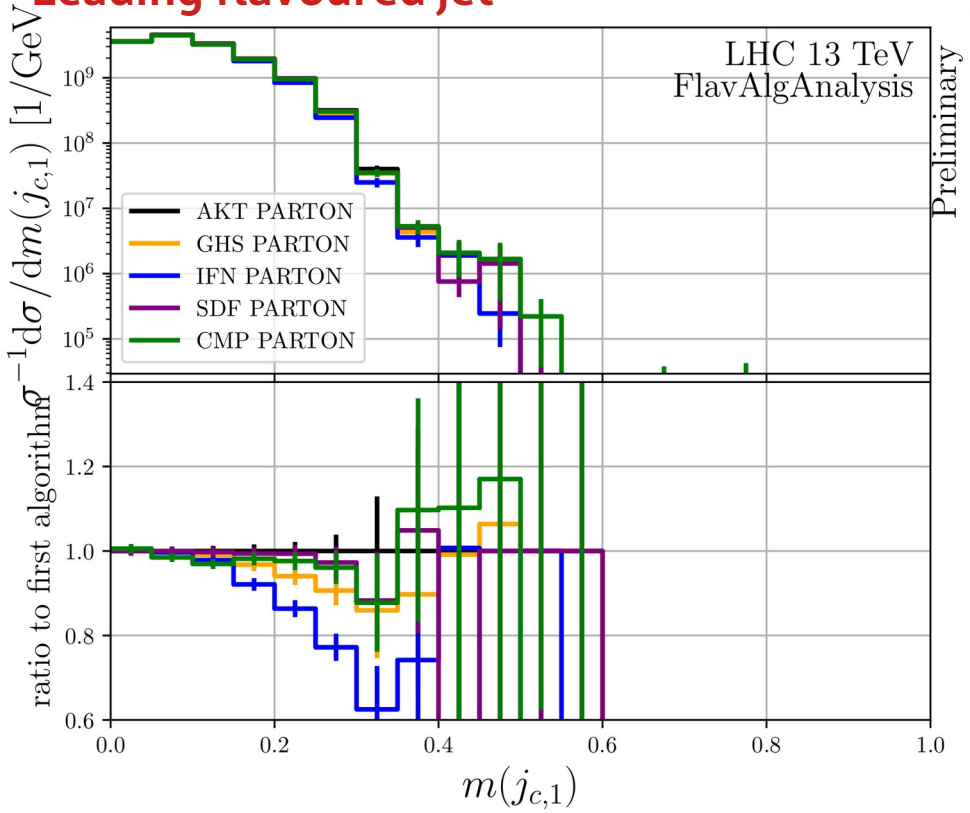
Leading flavoured jet

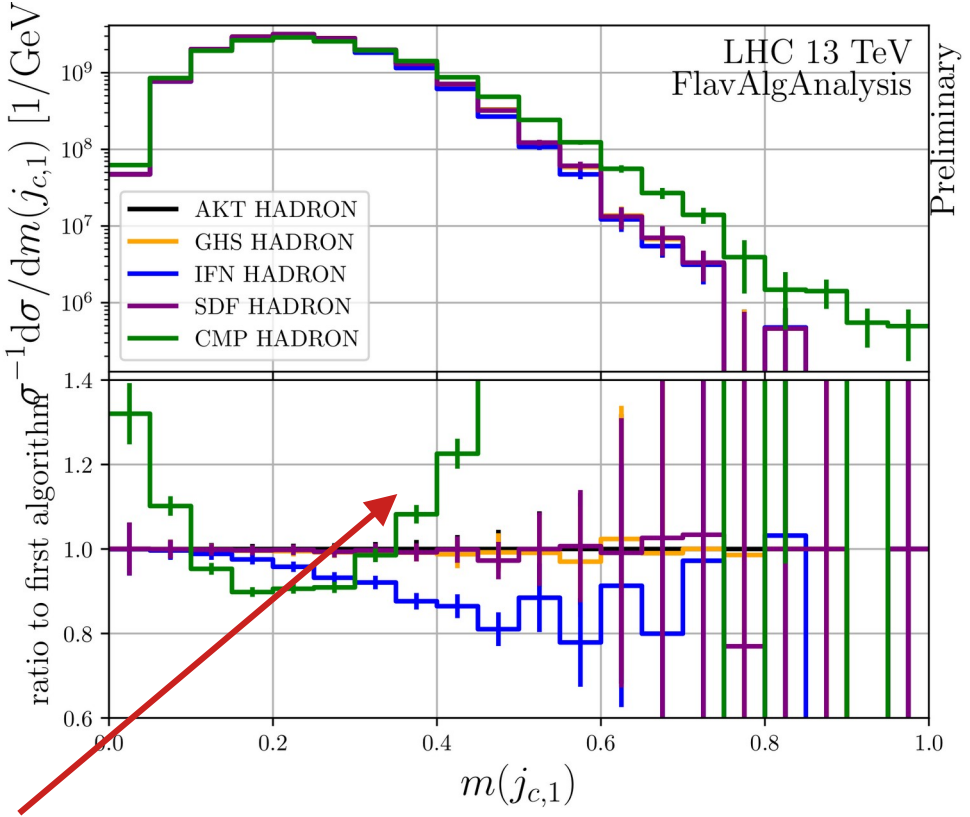




Jet mass

Leading flavoured jet

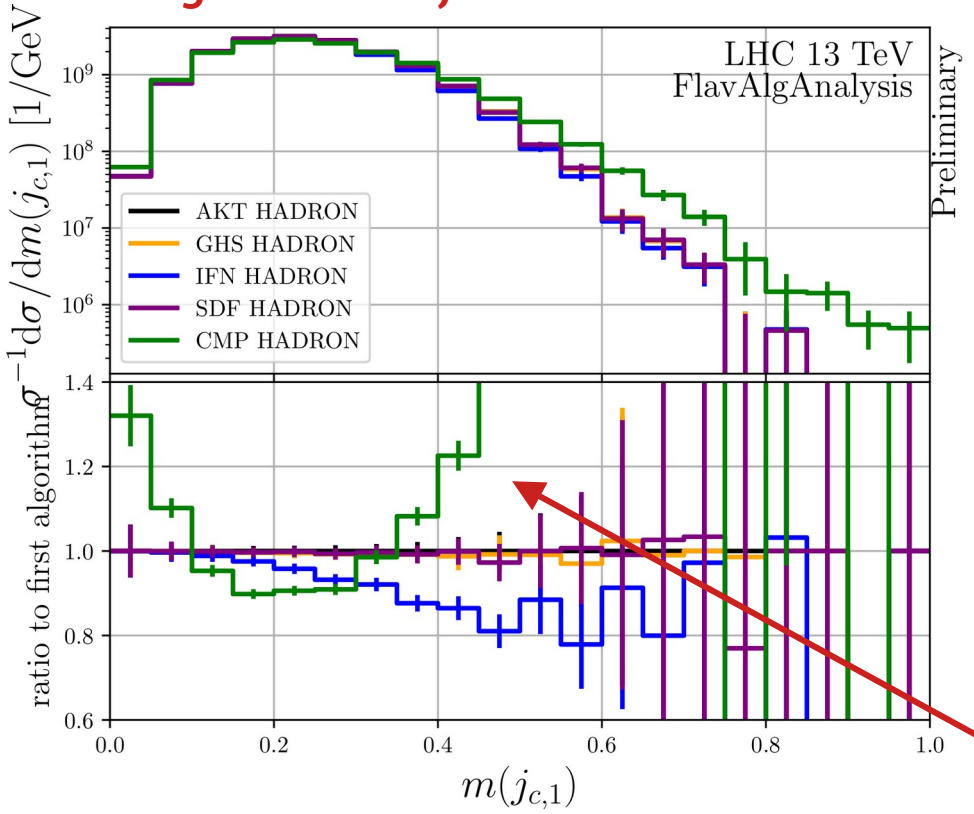




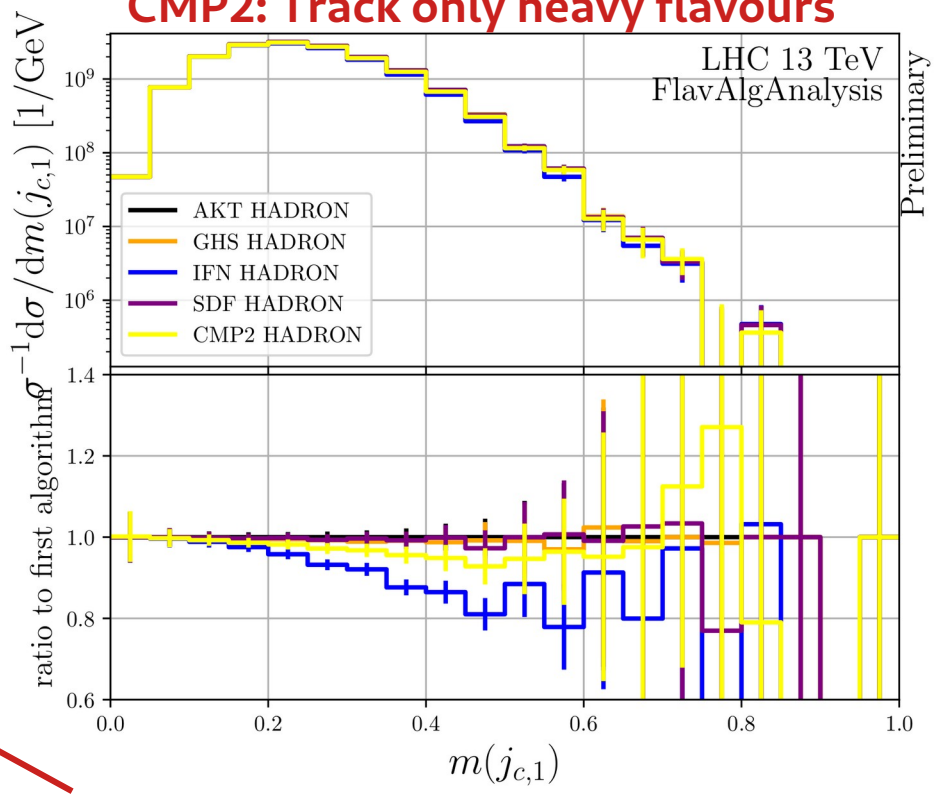
!?

Jet mass

Leading flavoured jet



CMP2: Track only heavy flavours



→ **Distortion due to modified clustering of light flavours from hadronisation**

CMP

Infrared-safe flavoured anti-kT jets, Czakon, Mitov, Poncelet 2205.11879

Anti-kT: $d_{ij} = \min(k_{T,i}^{-2}, k_{T,j}^{-2}) R_{ij}^2 \qquad d_i = k_{T,i}^{-2}$

The energy ordering in anti-kT prevents correct recombination of flavoured pairs in the double soft limit.

Proposed modification:

A soft term designed to modify the distance of flavoured pairs.

$$d_{ij}^{(F)} = d_{ij} \begin{cases} \mathcal{S}_{ij} & \text{i,j is flavoured pair} \\ 1 & \text{else} \end{cases}$$

$$\mathcal{S}_{ij} \equiv 1 - \theta\,(1 - \kappa_{ij}) \cos\left(\frac{\pi}{2}\kappa_{ij}\right) \quad \text{with} \quad \kappa_{ij} \equiv \frac{1}{a} \frac{k_{T,i}^2 + k_{T,j}^2}{2k_{T,\max}^2}.$$

A scale to define "soft" → Can be any hard scale

Allow systematic variations

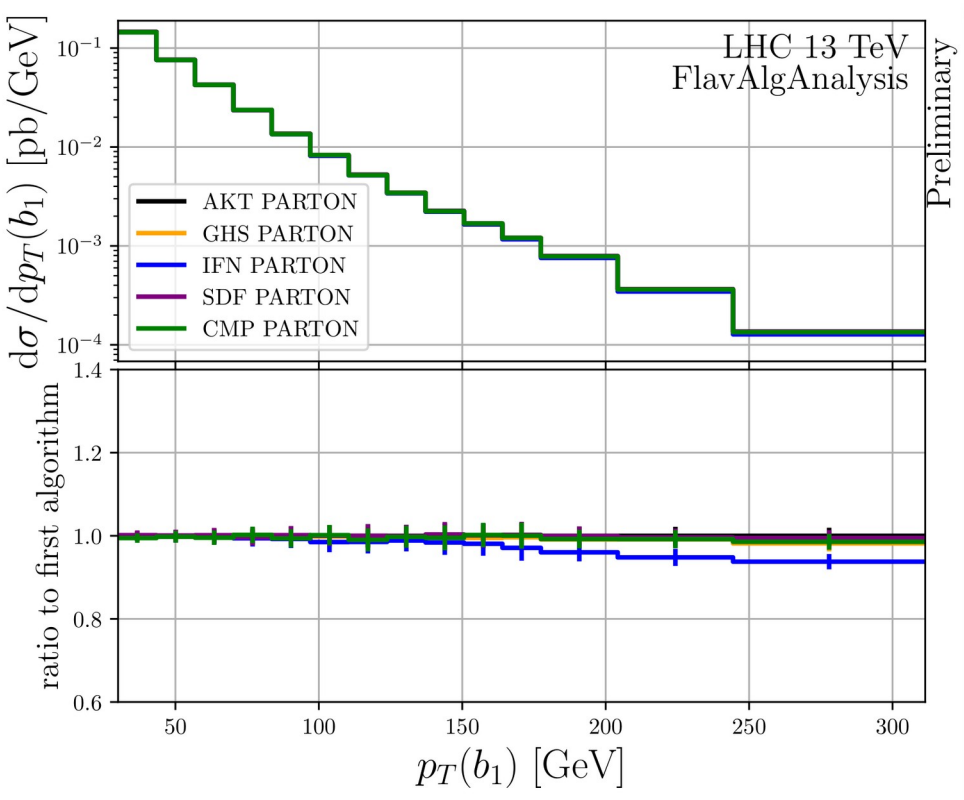
$$\mathcal{S}_{ij} \to \overline{\mathcal{S}}_{ij} = \mathcal{S}_{ij} \frac{\Omega_{ij}^2}{\Delta R_{ij}^2} \qquad \Omega_{ik}^2 \equiv 2\left[\frac{1}{\omega^2}\left(\cosh(\omega \Delta y_{ik}) - 1\right) - \left(\cos \Delta\phi_{ik} - 1\right)\right]$$

Caola, Grabarczyk, Hutt, Salam, Scyboz,Thaler 2306.07314

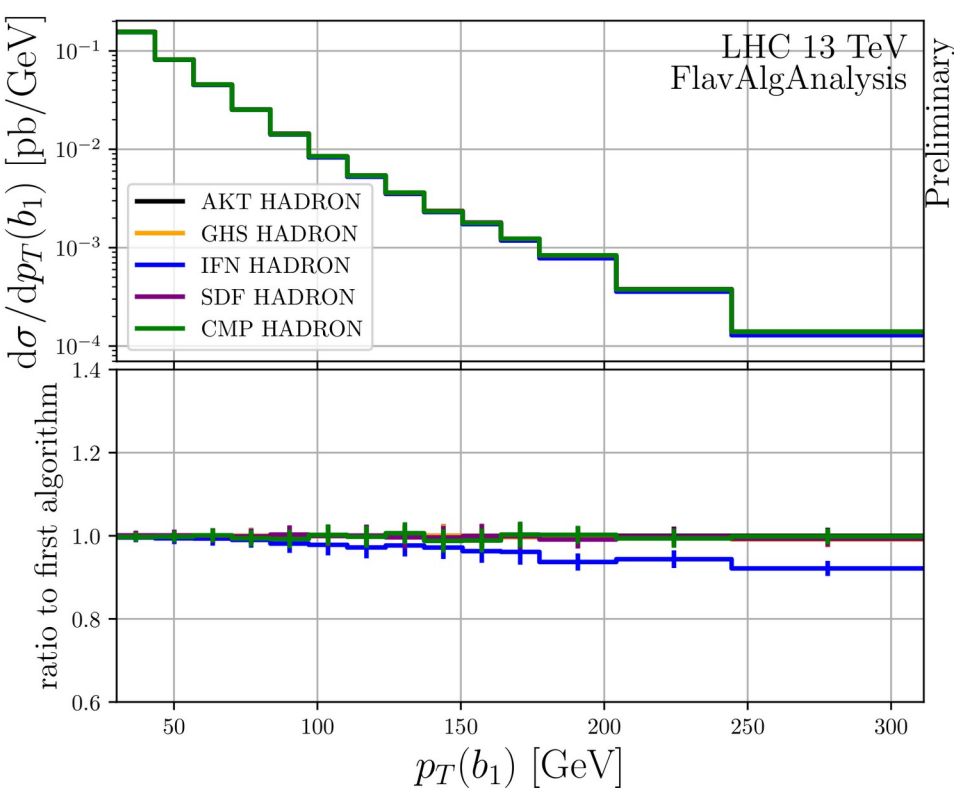
Updated slides from 12.1.24

Comparison flavoured algorithms

PARTON Level

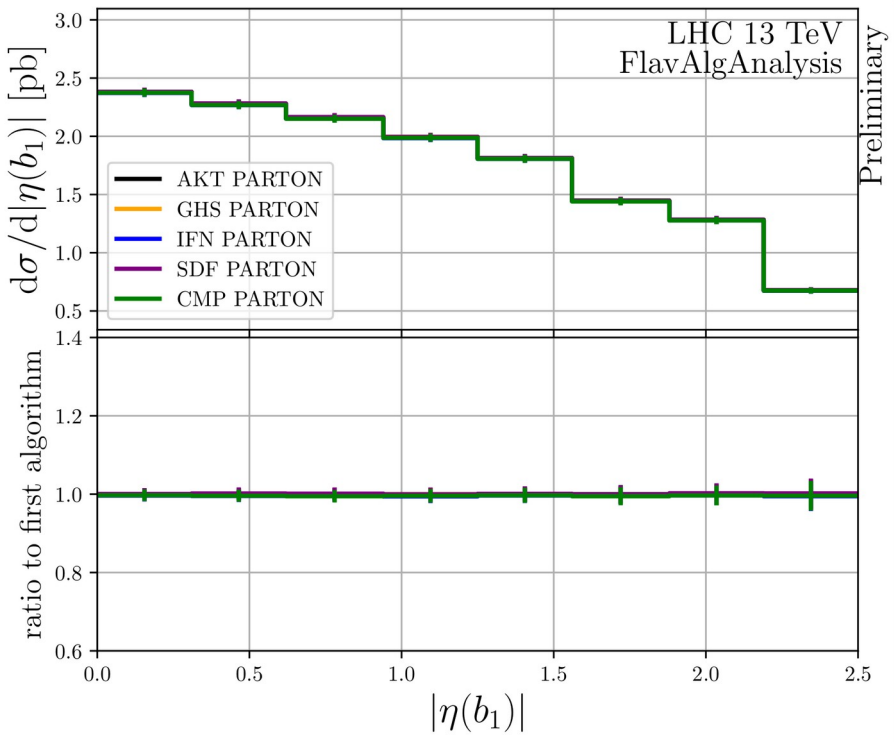


HADRON Level

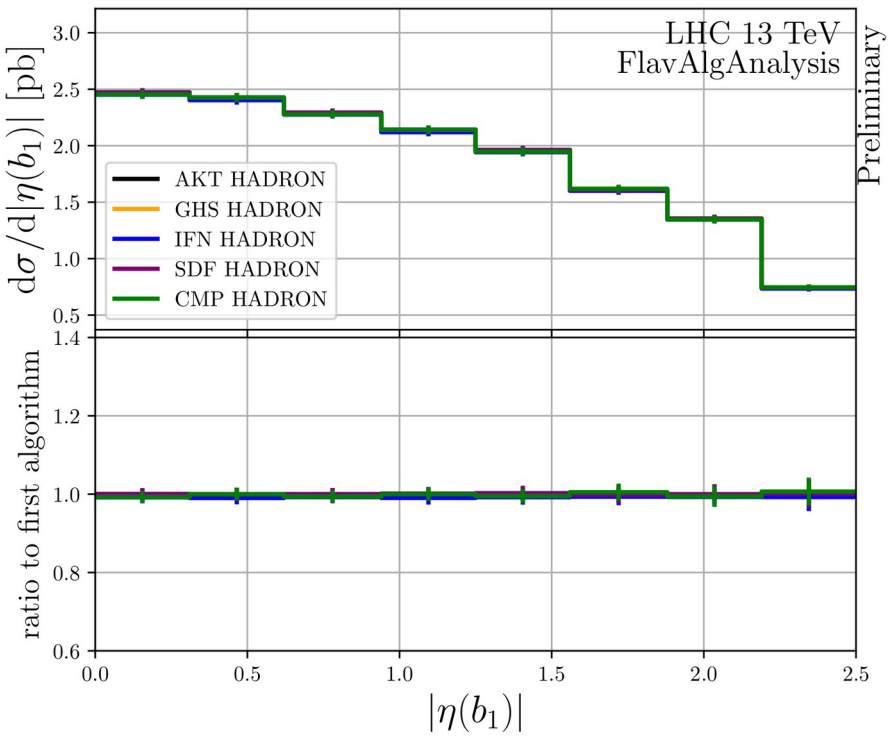


Comparison flavoured algorithms

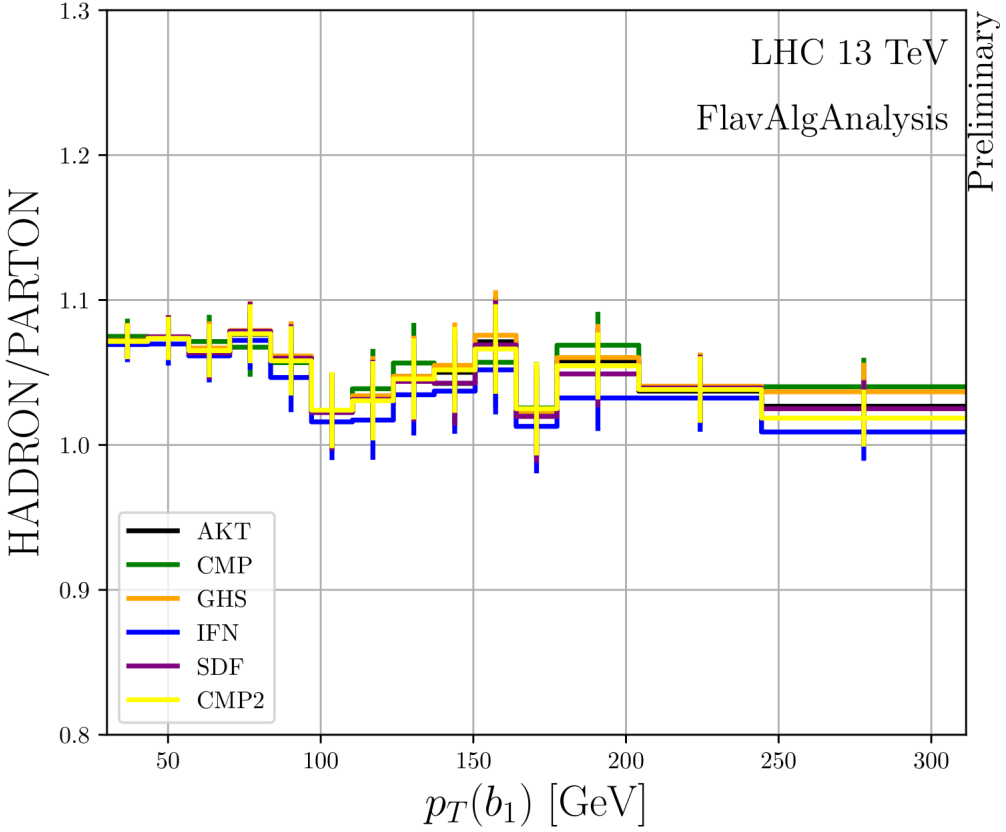
PARTON Level

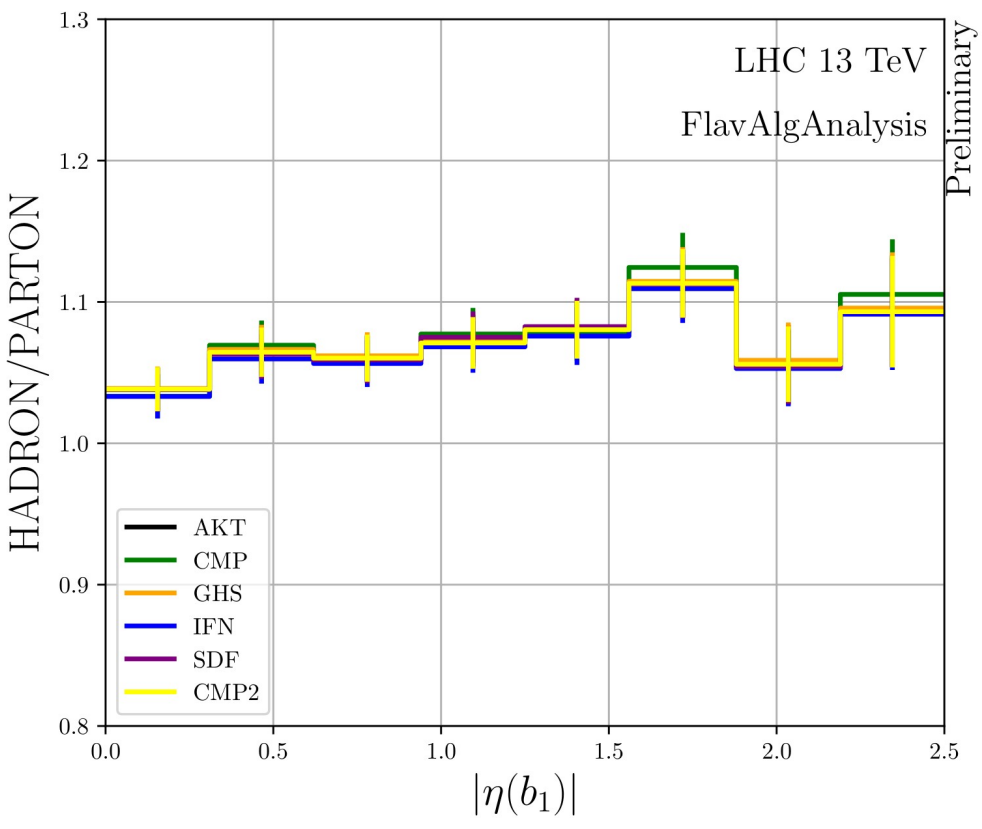


HADRON Level

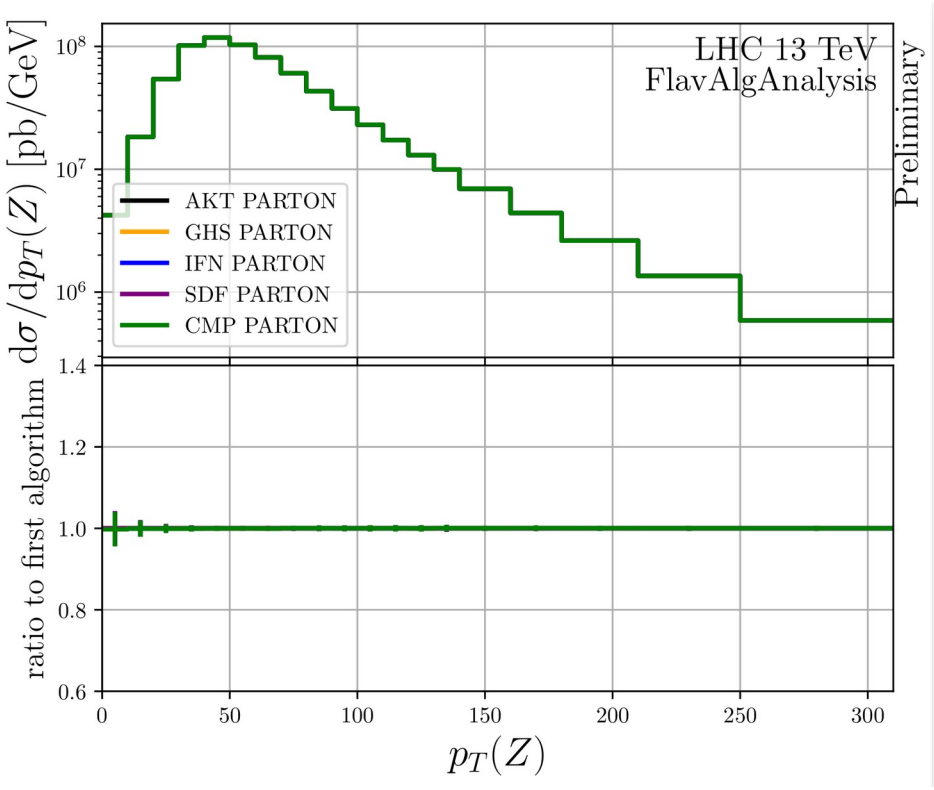


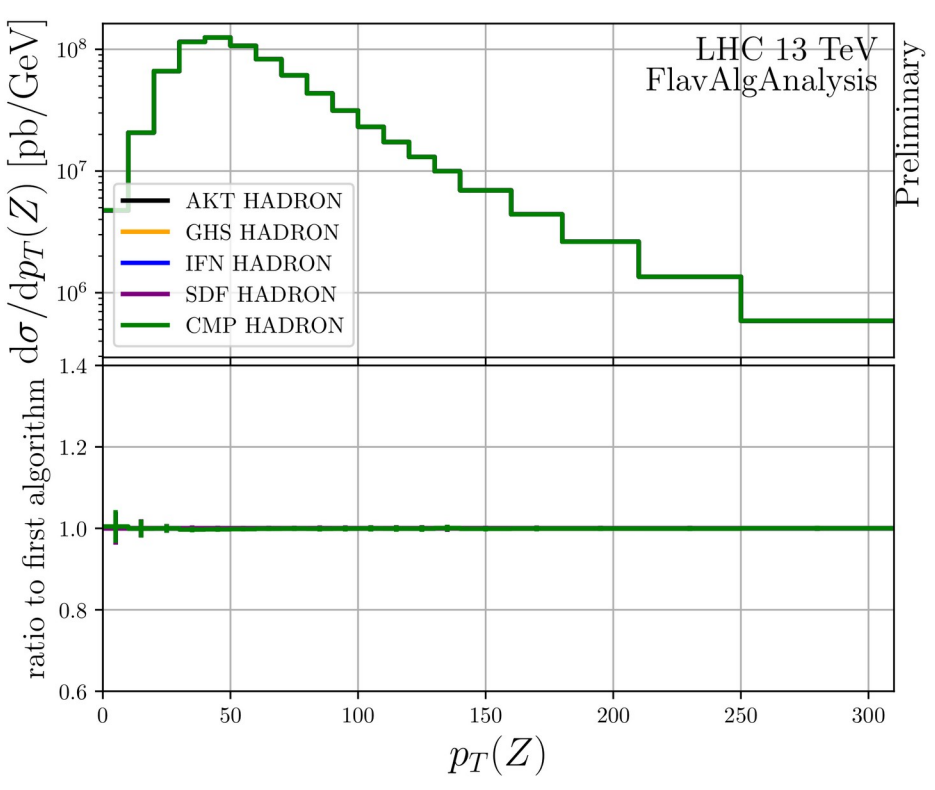
Unfolding → simple k-factor analysis



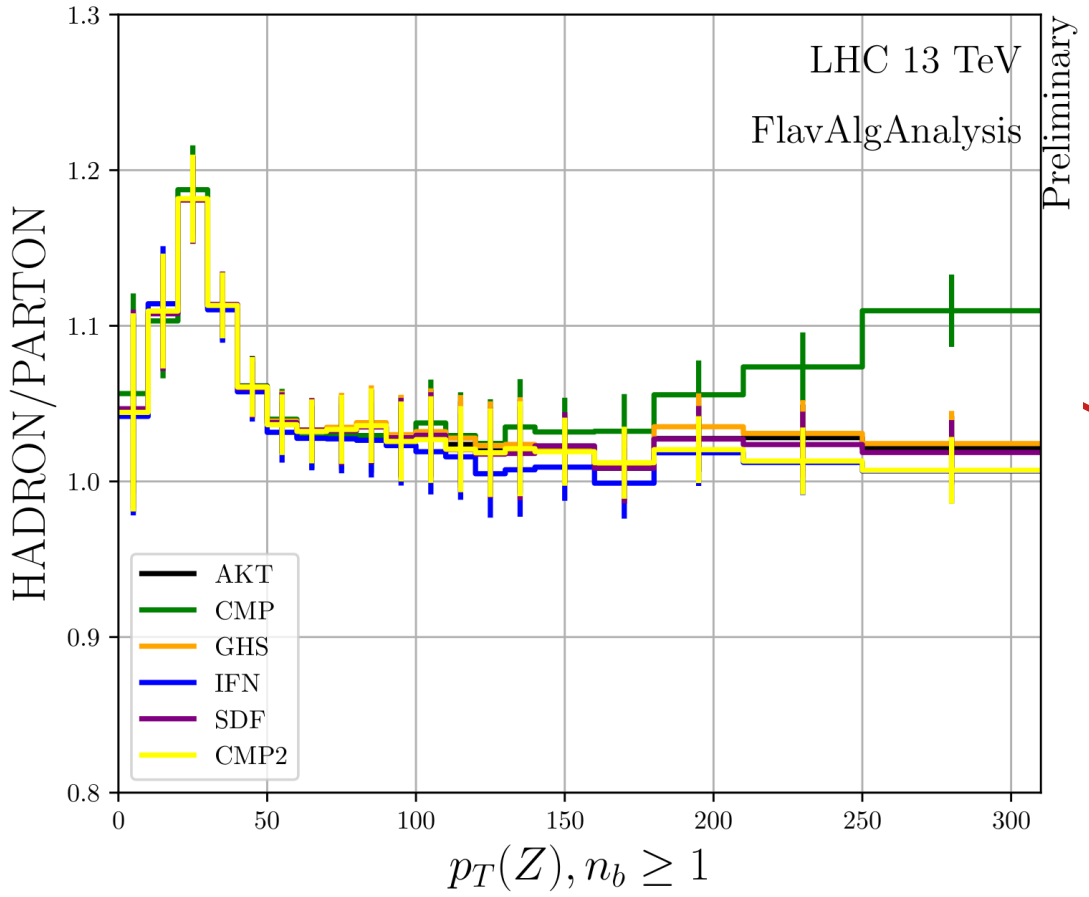


pT(Z) distribution





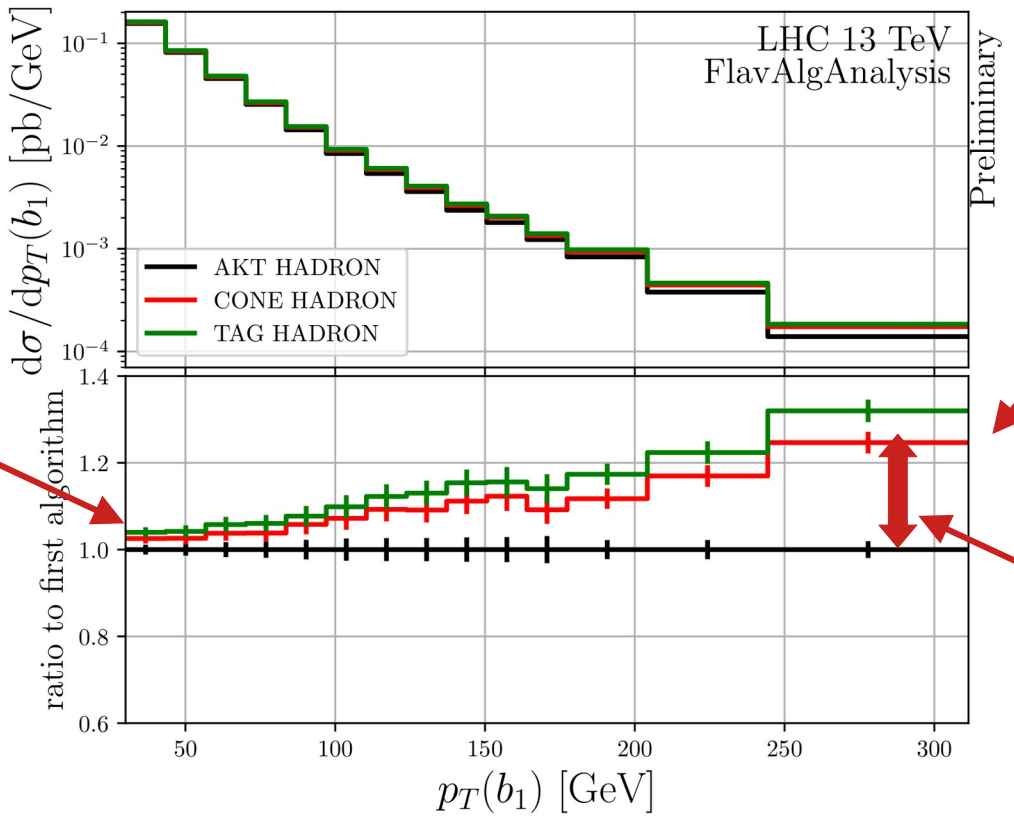
Unfolding → simple k-factor analysis



Finally a shape…
→ related to choice of kT_max?
No, related to light flavour clustering

Comparison anti-kT tagging

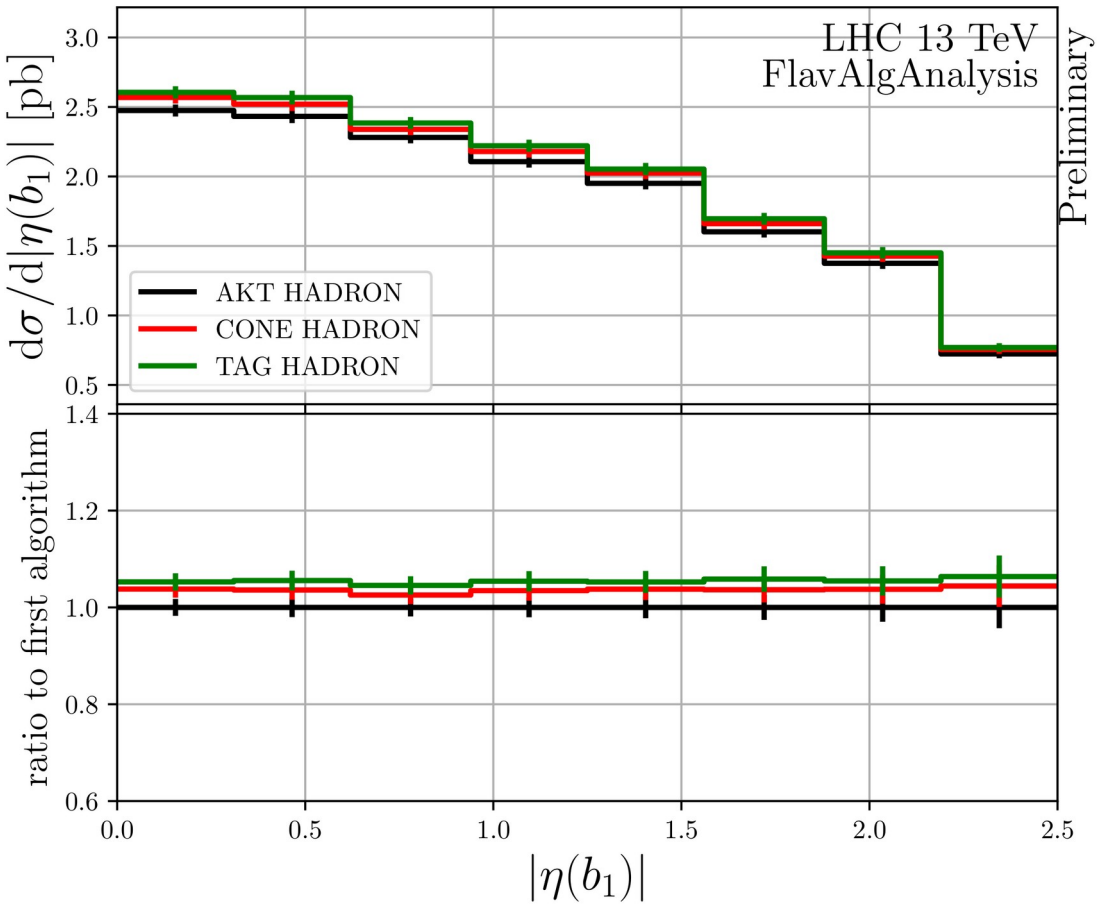
AKT
→ same as for the flavoured jet comparison



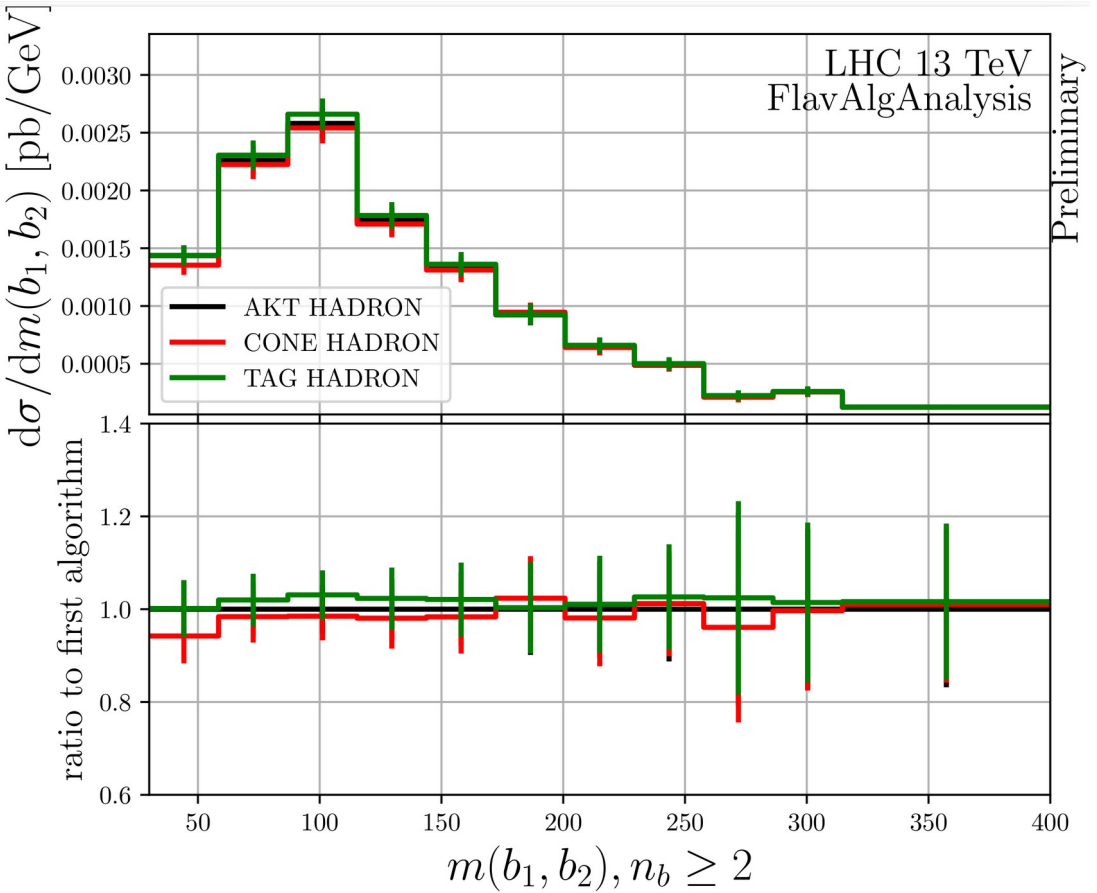
Note:
comparable results for ATLAS and CMS tagging

Impact of double tags?

Comparison anti-kT tagging



Comparison anti-kT tagging



Little difference
→ reduced probability of double tags
→ double tags come from first splitting

Summary

- Comparable results for all flavoured jet algorithms
  → even for high b-jet multiplicities
- Effect of multi-b tags important at high pT
  → dominated by first splitting
  → much larger than any effect from the algorithms
- First look at unfolding corrections
  → also rather jet-algorithm independent
  → pT(Z) distribution…?

Comparison flavoured algorithms