Exploring medium properties with hard transverse momentum splittings using groomed jet substructure measurements in Pb–Pb collisions with ALICE

Raymond Ehlers[1] for the ALICE Collaboration

28 March 2023

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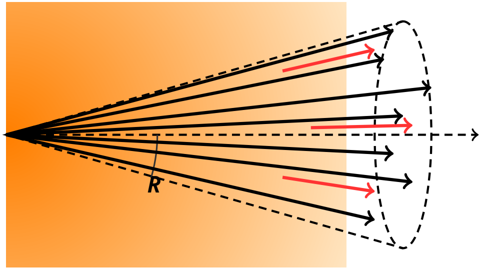
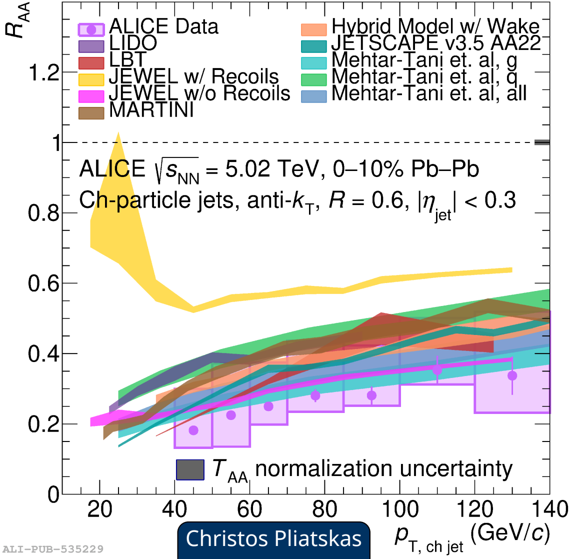
raymond.ehlers@cern.ch

New

ALICE

- Jets are in situ probes of QGP dynamics
- Jet-medium interactions modify the **internal jet structure**
- Jet substructure observables sensitive to **which medium properties?**





Christos Pliatskas
Tuesday 9:00

arXiv:2303.00592

Jets and their substructure

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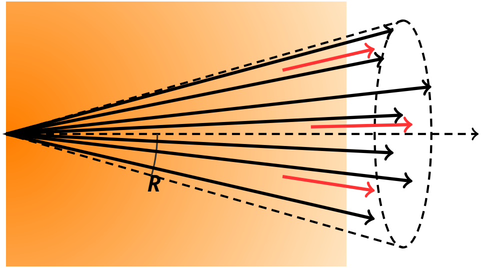
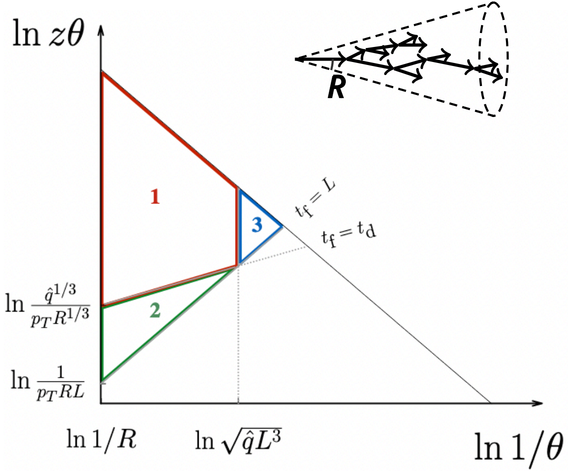




H. Andrews et al., J.Phys.G 47 (2020) 6, 065102

Medium properties from jet substructure

Resolving medium scales

- What are the **relevant length scales**?
- Eg. **When do partons interact coherently**?

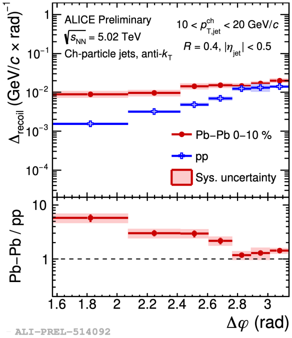
Ezra Lesser
Tuesday 17:10

Reynier Cruz-Torres
Tuesday 17:50

Eg. Medium scattering centers

- Is there **emergent structure, such as quasi-particles**?
- Search via (sub)jet deflection

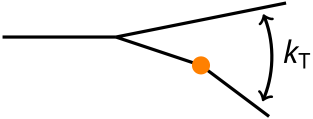
Jet deflection:
Yongzhen Hou
Tuesday 12:10



This presentation

- Search for high k_T emissions as **signature of point-like (Moliere) scattering**

→ Search via groomed jet substructure



→ **Optimal way to find the relevant splittings?**

Identifying hard splittings: Soft Drop

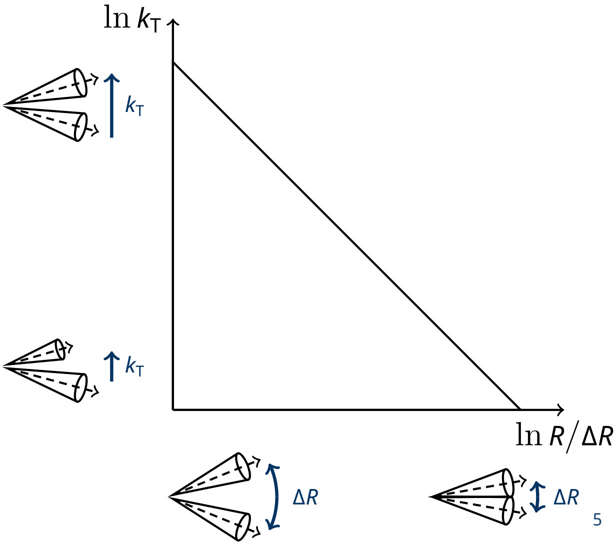
- $k_T = p_T^{\text{sublead}} \sin \Delta R$
- Iteratively follow splitting tree

Soft Drop

Larkoski et al., JHEP 05 (2014) 146

$$\frac{\min(p_{T,1}, p_{T,2})}{p_{T,1} + p_{T,2}} > z_{\text{cut}} \left(\frac{\Delta R}{R}\right)^{\beta}$$

- $z_{\text{cut}} = $ **0.2**
- $\beta = 0$



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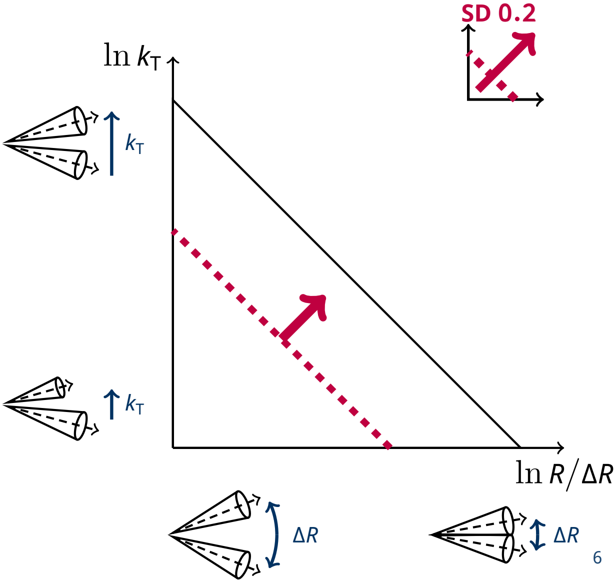

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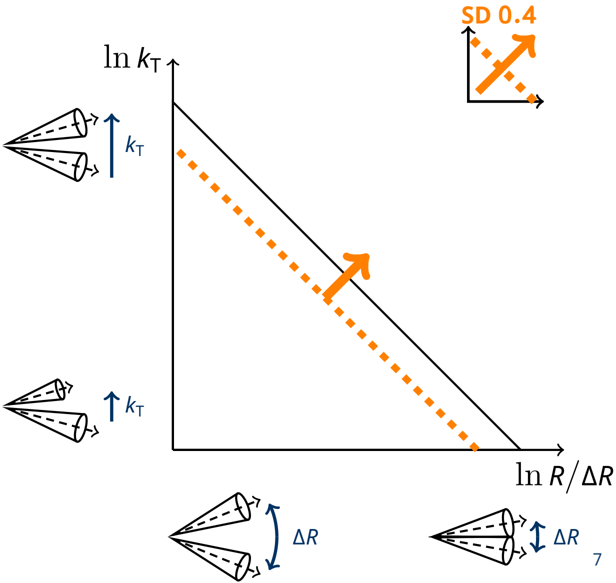
- $z_{\mathrm{cut}} = $ **0.2**, **0.4**
- $\beta = 0$
- $z_{\mathrm{cut}} = 0.4$ trades phase space to focus on **angular dependence**



Identifying hard splittings: Dynamical Grooming

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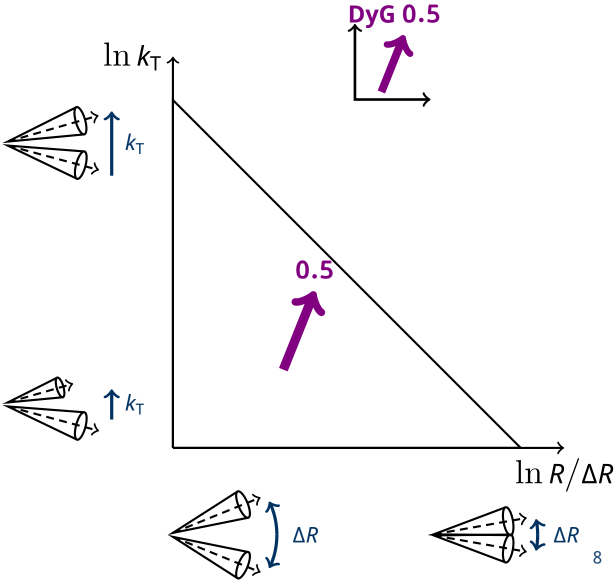
Dynamical Grooming

Mehtar-Tani et al., PhysRevD.101.034004

$$\kappa^{a} \propto \max_{i \in C/A}\left[z_i(1 - z_i) p_{\mathrm{T}i} (\Delta R_i / R)^{a}\right]$$

- $a = 0.5$: **"core"** - more sym., narrow



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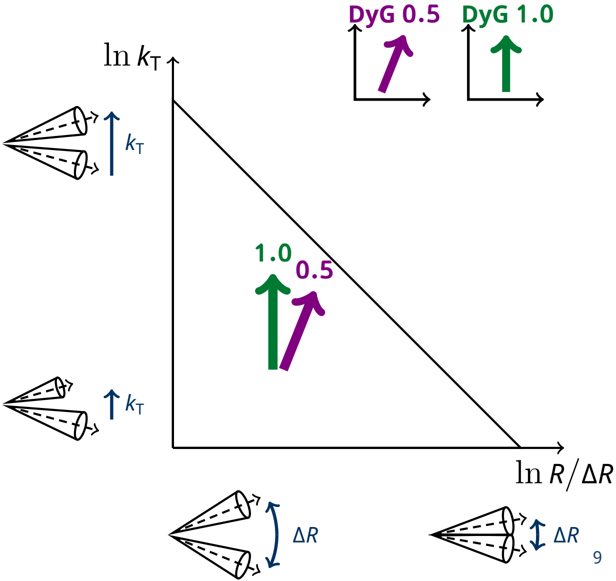

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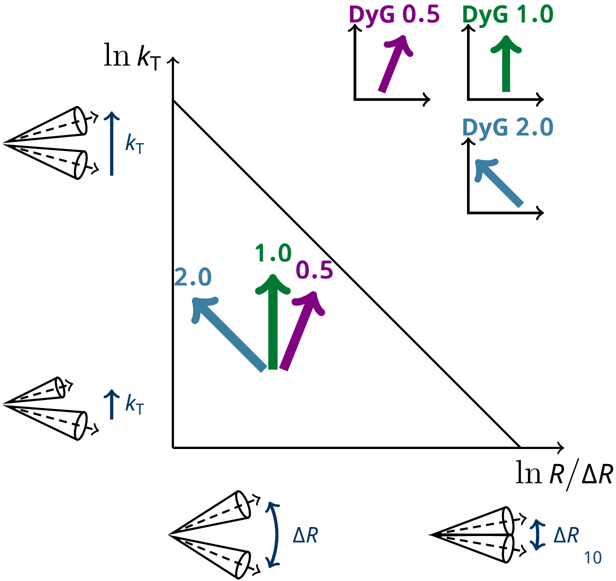

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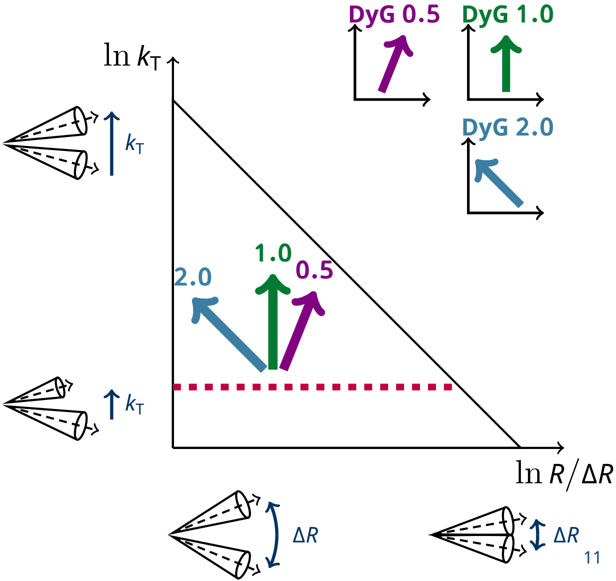
- In practice, need **min k_{T} in Pb–Pb**



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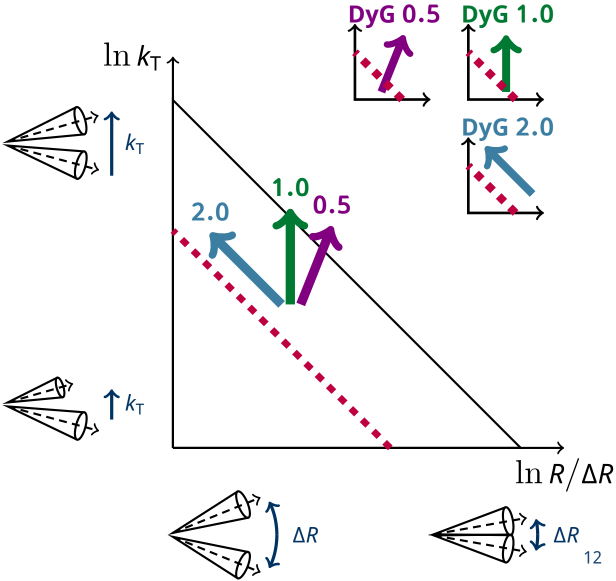
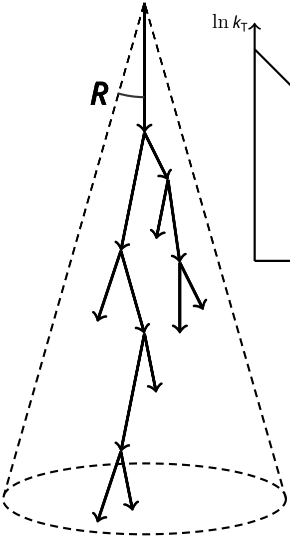
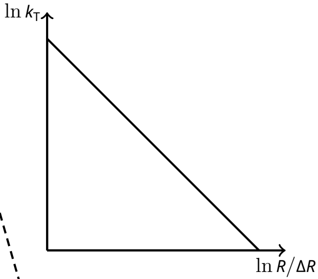
- In practice, need **min k_T in Pb–Pb**
- Alternatively, add **z requirement** (0.2)



Employing the grooming methods

- Consider $p_{\mathrm{T,jet}}^{\mathrm{ch}} = 60\ \mathrm{GeV}/c$ R = 0.2 jet
- Decluster with C/A, select iterative splittings:





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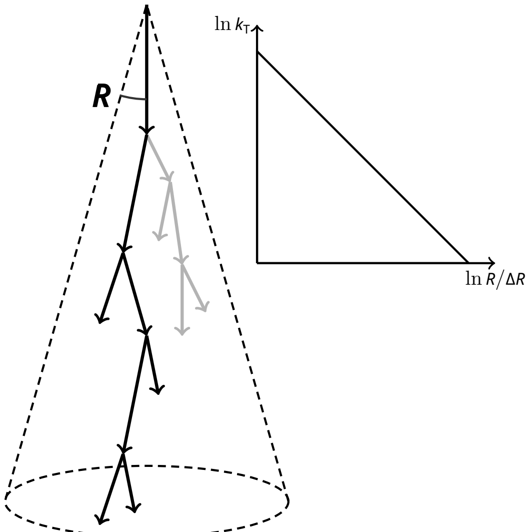
1. $z = 0.175, \Delta R = 0.4, k_{\mathrm{T}} = 4.09$ GeV/c
2. $z = 0.2, \Delta R = 0.3, k_{\mathrm{T}} = 2.93$ GeV/c
3. $z = 0.4, \Delta R = 0.2, k_{\mathrm{T}} = 3.15$ GeV/c
4. $z = 0.1, \Delta R = 0.1, k_{\mathrm{T}} = 0.24$ GeV/c



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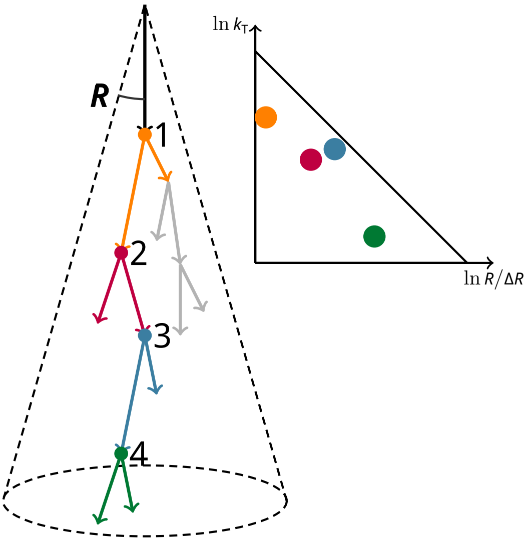
$\rightarrow$ Which method selects which splitting?



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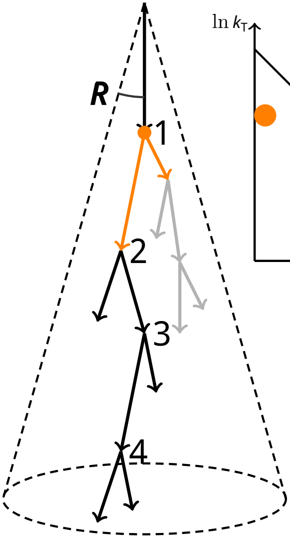
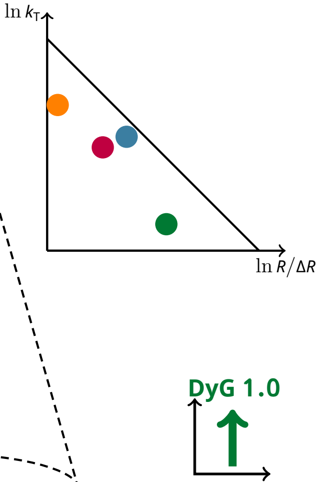
- DyG $a = 1.0$: **#1**





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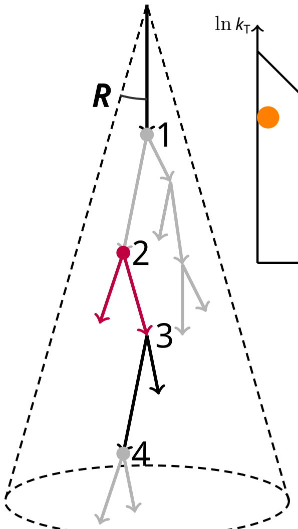
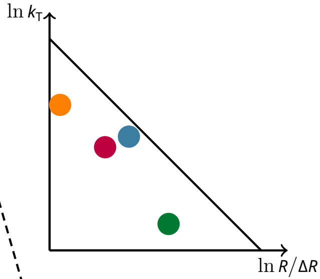
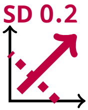
- DyG $a = 1.0$: **#1**
- SD $z_{\mathrm{cut}} = 0.2$: **#2**







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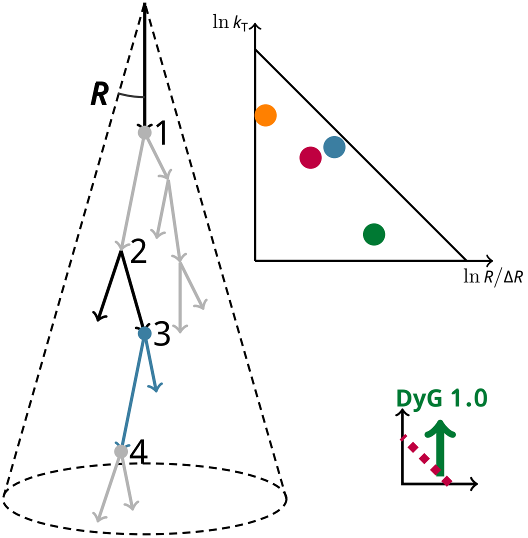

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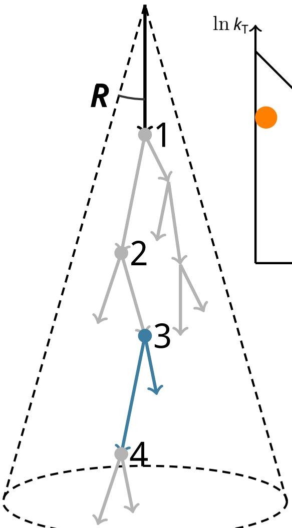
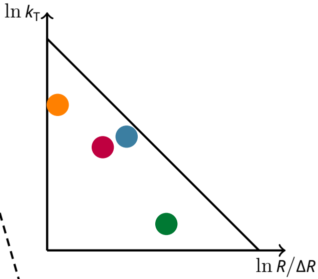


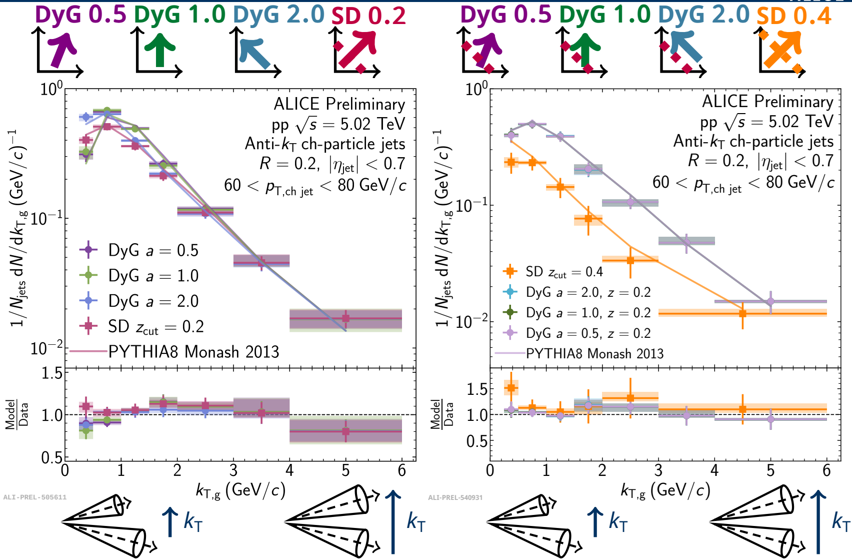


Comparing grooming methods in pp

New

- Shape variations at low k_T
- Grooming methods **converge at high $k_{T,g}$**
- ***z* requirement dominates** over grooming method
- PYTHIA in broad agreement with data

See also: R_g + z_g with DyG: arXiv:2204.10246

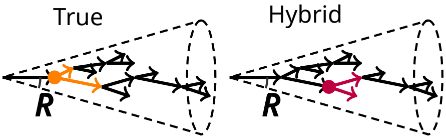


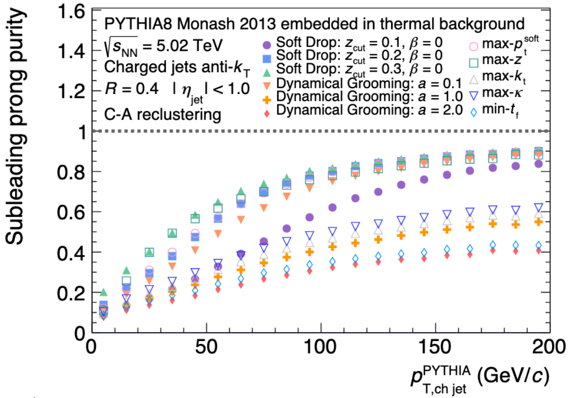
Unfolding Dynamical Grooming in Pb–Pb

- Dynamical Grooming exhibits **reduced subleading subjet purity** in Pb–Pb
- **Off-diagonal mismatched splittings** are major component at low k_T

→ **Problematic for unfolding**

- Caused by **requirement to always select a splitting**
- **Address by minimum measured k_T** requirement
- Trade **improved purity** for **reduced dynamic range** and kinematic efficiency
- **Minimum z** has similar impact





Mulligan, Ploskon, PhysRevC.102.044913

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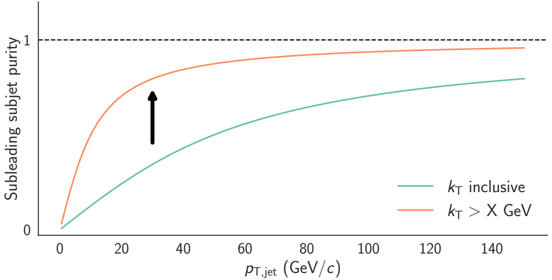
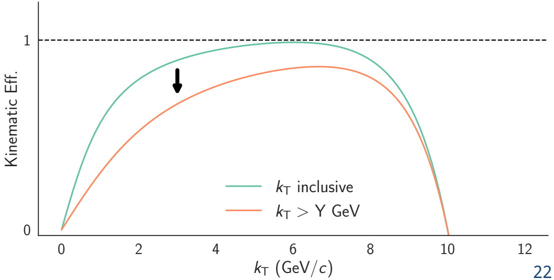
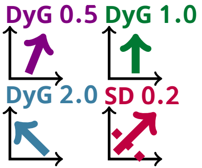




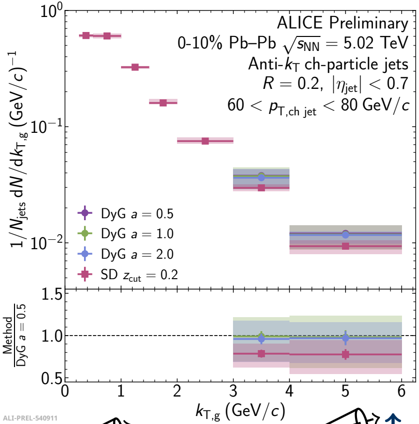
Dynamical Grooming in Pb–Pb

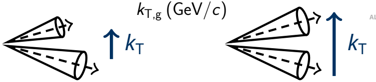
New



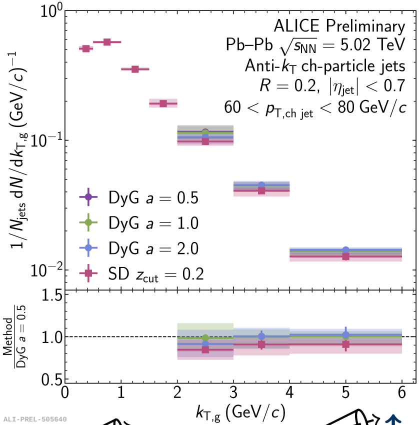
- **First measurements** of Dynamical Grooming in Pb–Pb
- Grooming methods **converge at high $k_{T,g}$**
- **Smaller bkg extends $k_{T,g}$ range** in semi-central

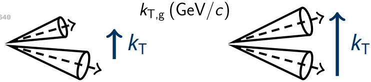
0-10% central





30-50% semi-central

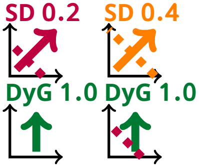




Comparing grooming methods in Pb–Pb

New

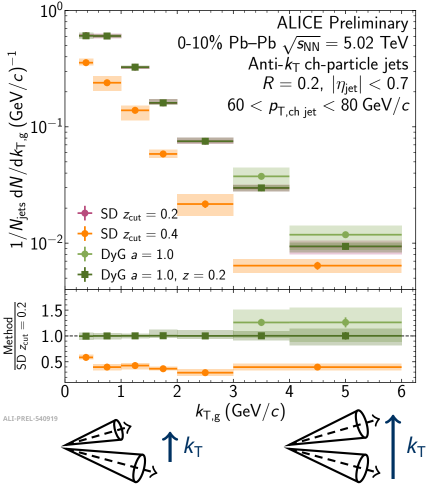
ALICE



- **Similar trends** in 0-10% and 30-50%
- Reduced SD $z_{\mathrm{cut}} = 0.4$ yield due to **phase space**
- **Consistent set of splittings** from all DyG $a = 1.0$, SD $z_{\mathrm{cut}} = 0.2$

→ Suggests **few hard splits further into tree**

0-10% central



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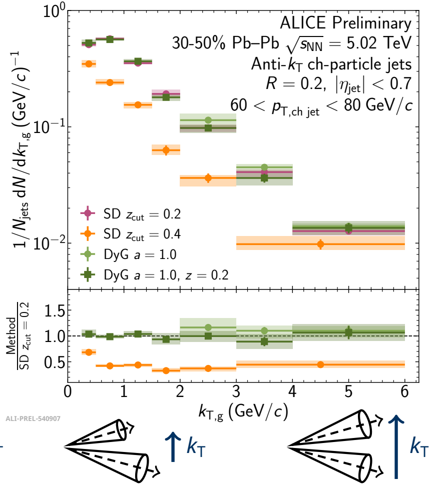
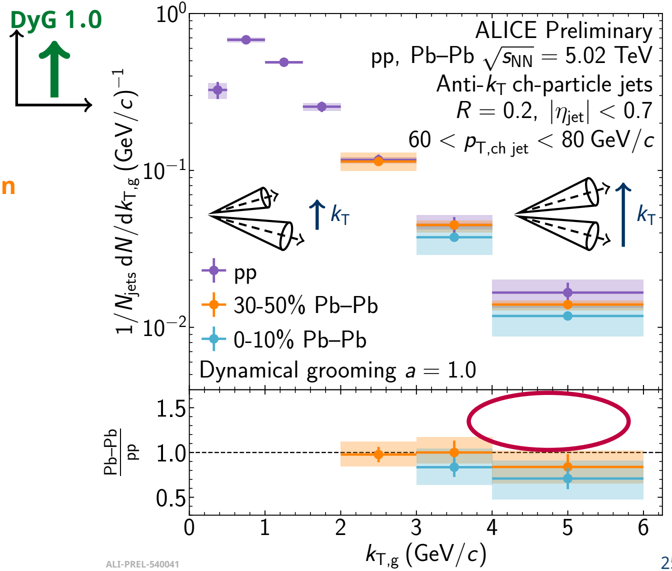


New

ALICE



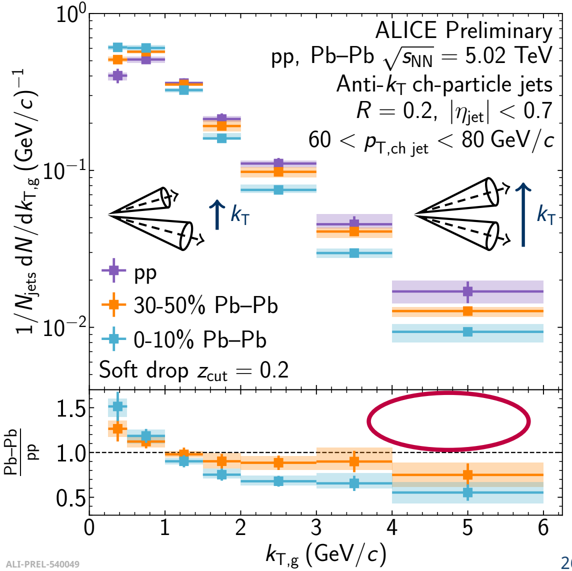
- **No enhancement** at high $k_{T,g}$
- Standard DyG shows **little modification**

Searching for modification

New

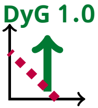
SD 0.2

- **No enhancement** at high $k_{T,g}$
- Standard DyG shows **little modification**
- **Modification** in methods with $z > 0.2$
  - Larger modification in 0-10%
- **Consistent with narrowing picture** seen in many substructure analyses.
  - eg. R_g (Phys.Rev.Lett. 128 (2022) 10, 102001), jet axis difference, angularities, etc
- **No clear evidence of Moliere scattering**

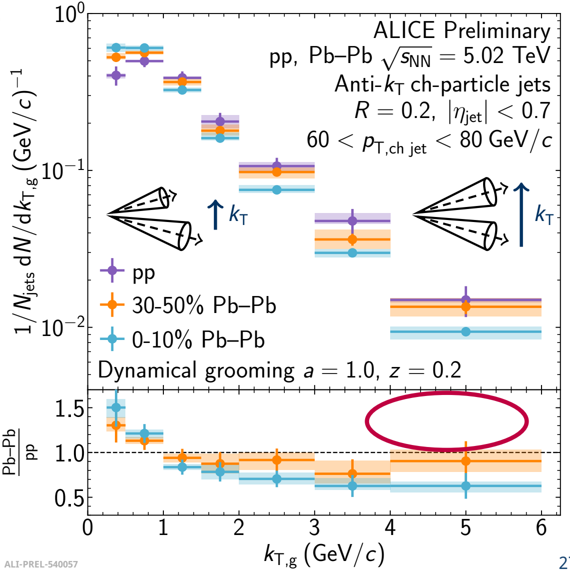


Searching for modification

New



- **No enhancement** at high $k_{T,g}$
- Standard DyG shows **little modification**
- **Modification** in methods with $z > 0.2$
    - Larger modification in 0-10%
- **Consistent with narrowing picture** seen in many substructure analyses.
    - eg. R_g (Phys.Rev.Lett. 128 (2022) 10, 102001), jet axis difference, angularities, etc
- **No clear evidence of Moliere scattering**



How do models fare?

New

ALICE

SD 0.2

JETSCAPEv3.5 AA22 tune

JETSCAPE arXiv:2301.02485

- MATTER+LBT
- **Describes data well**

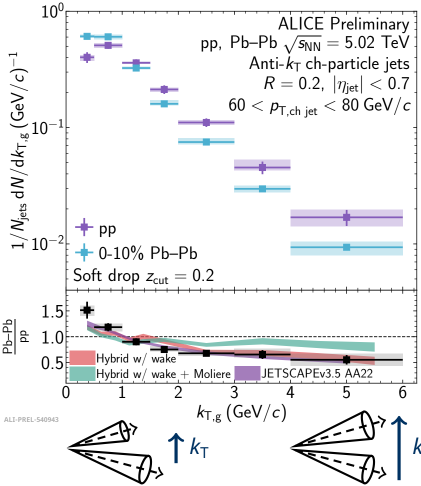
Hybrid model

D'Eramo et al. JHEP 01 (2019) 172

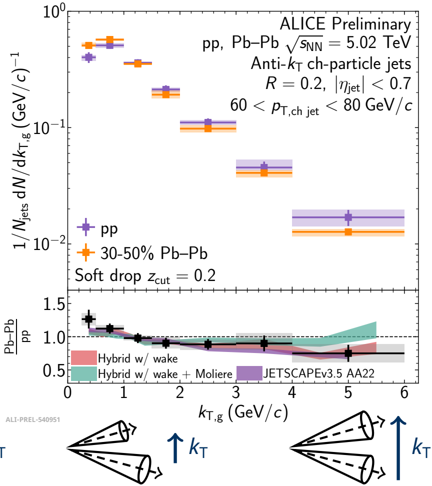
Hulcher et al. QM 22

- With, w/out Moliere
- w/out Moliere **describe 0-10% data better**

0-10% central



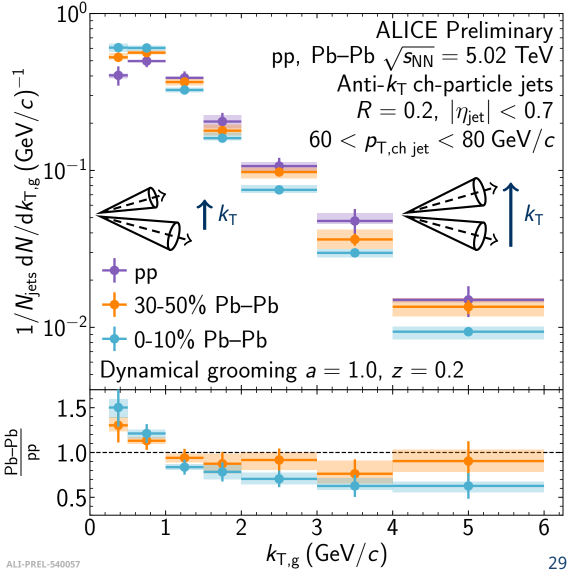
30-50% central



Summary

- **Comprehensive study** searching for Moliere scattering via jet substructure

1. **First measurement of DyG** in Pb–Pb
   - Minimum k_T or z requirement to avoid background dominated component
2. **z_{cut} dominates** over grooming method details
   - **Suggests minimal impact** of splittings far into splitting tree
3. **Modification of $k_{T,g}$**, similar to narrowing seen in other substructure observables
4. **No clear evidence of Moliere scattering**



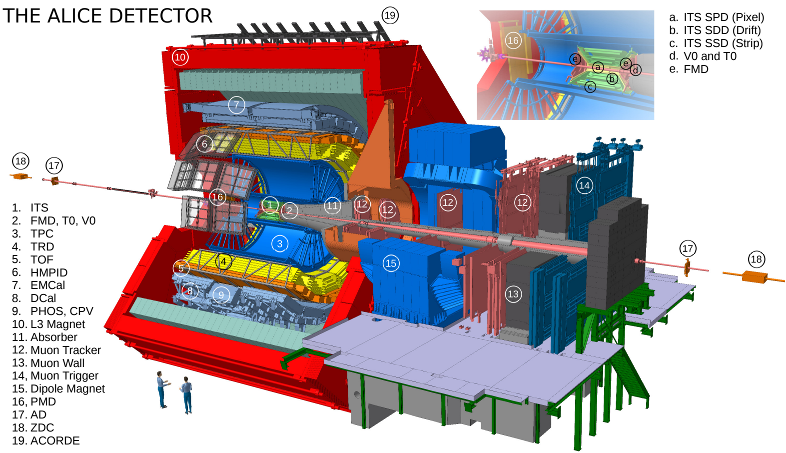
Backup

Jets and their substructure in ALICE

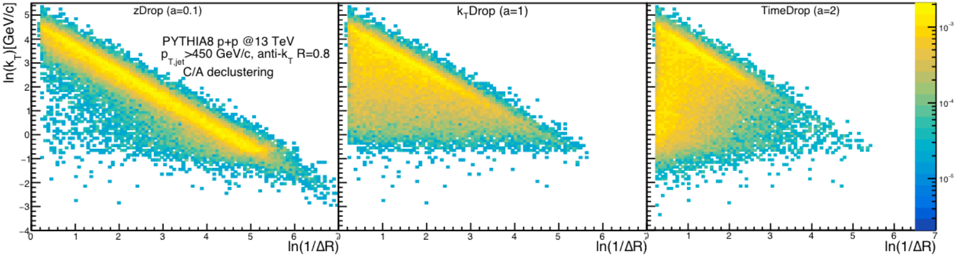
- ALICE well suited for measuring:
- **Low p_{T}** jets
- **Small splitting angles** at high efficiency

→ Enables **strong substructure program**

- Anti-k_{T} **charged-particle jets** measured in pp and Pb–Pb collisions at $\sqrt{s_{\mathrm{NN}}} = 5.02$ TeV

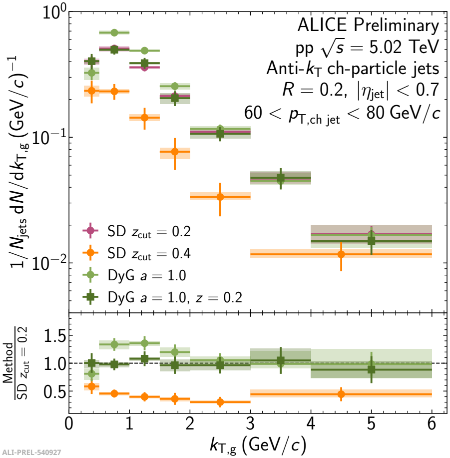


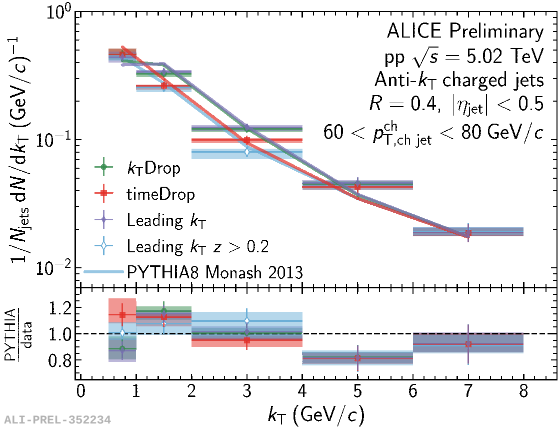
Dynamical Grooming: Lund Planes



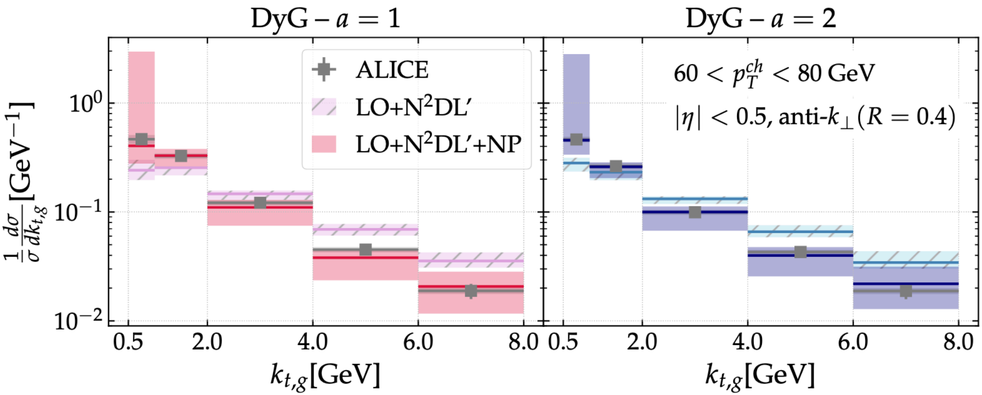
Mehtar-Tani et al., PhysRevD.101.034004

Comparing grooming methods in pp: mixed methods, R = 0.4



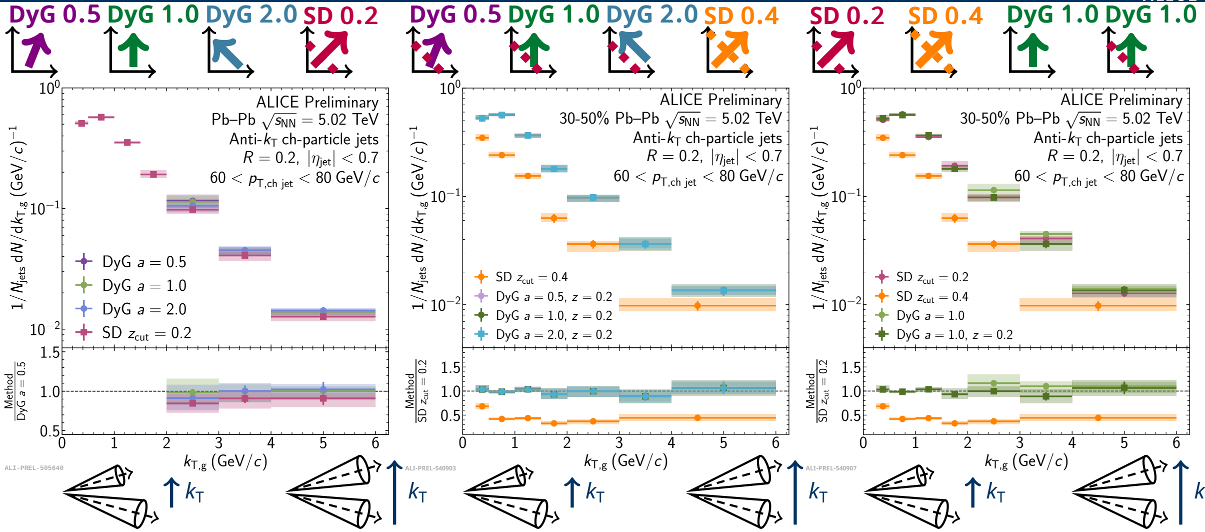


Dynamical Grooming: analytical calculations pp

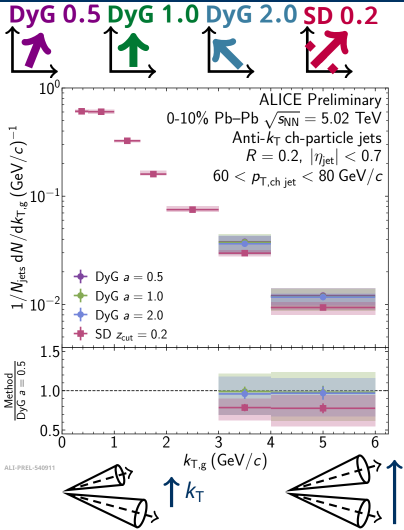


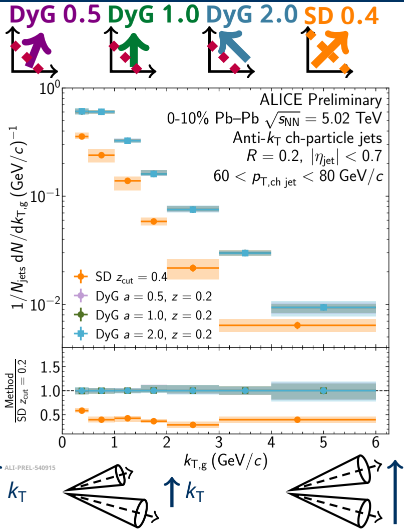
[1] Mehtar-Tani et al., Phys. Rev. D 101, 034004
[2] Caucal et al., JHEP 07 (2021) 020

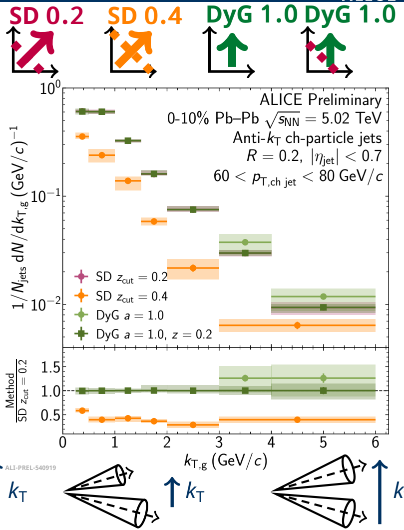
Comparing grooming methods in 30-50% semi-central Pb–Pb



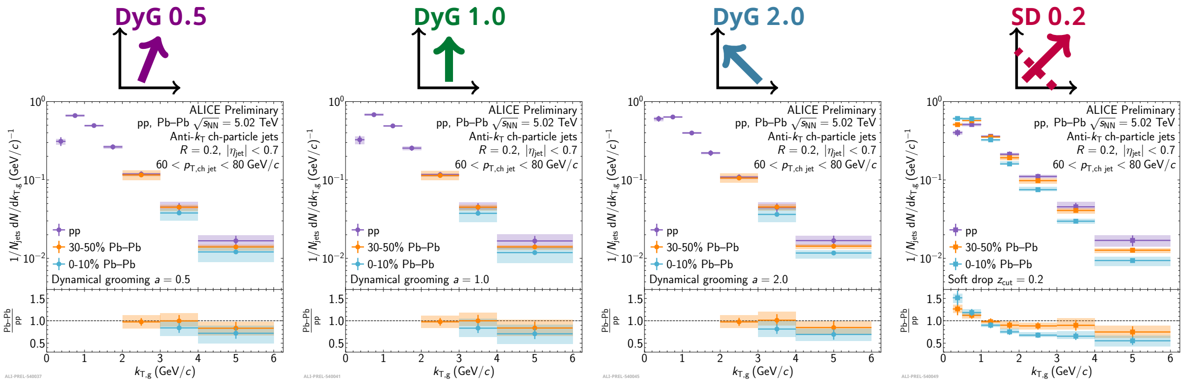
Comparing grooming methods in 0-10% central Pb–Pb





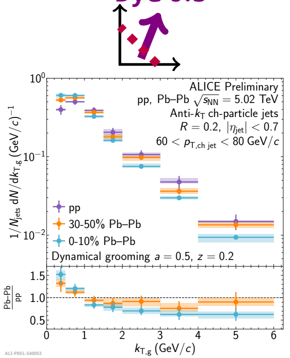


Searching for modification (with more methods)/1

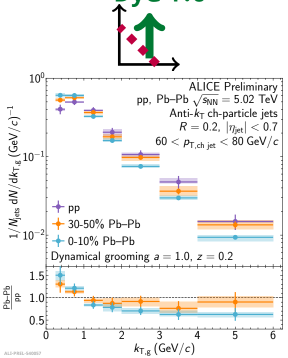


Searching for modification (with more methods)/2

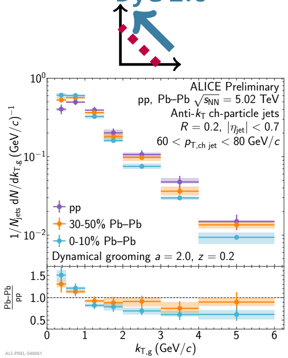
DyG 0.5



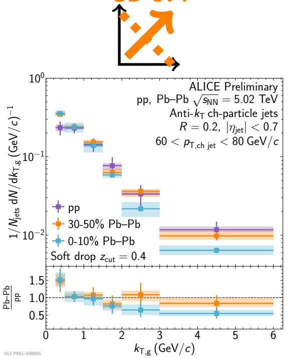
DyG 1.0



DyG 2.0

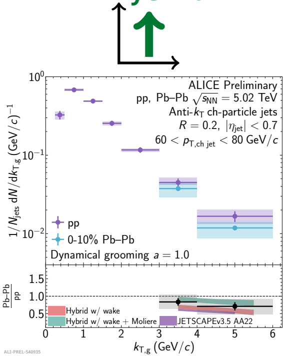


SD 0.4

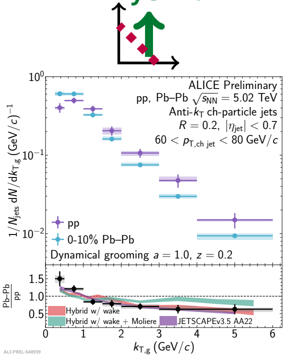


Comparing with models in 0-10% central Pb–Pb

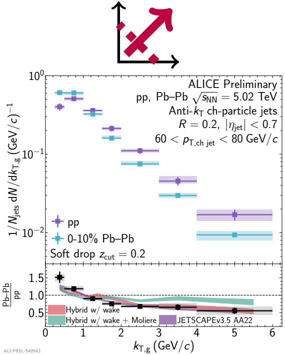
DyG 1.0



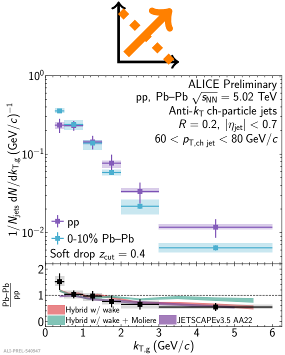
DyG 1.0



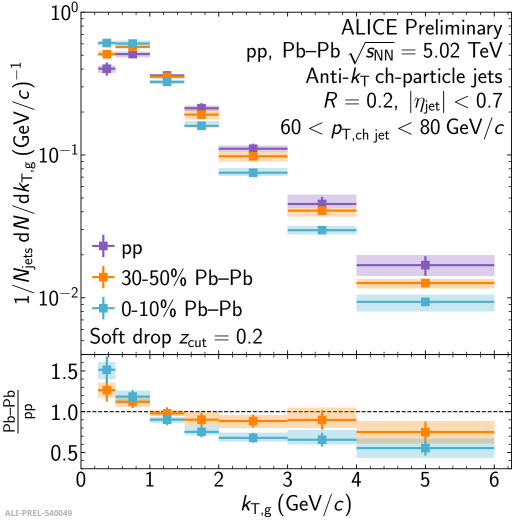
SD 0.2

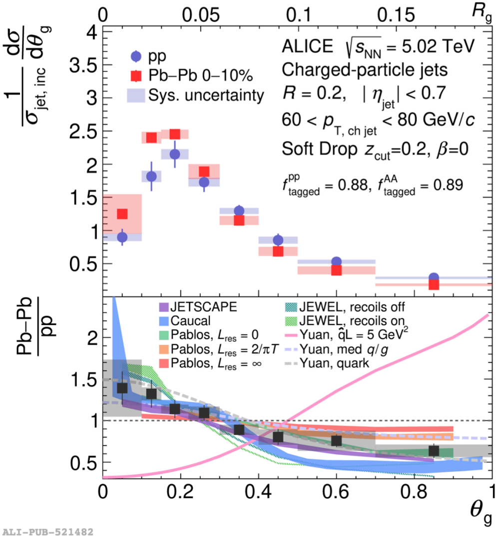


SD 0.4



Narrowing in $k_{T,g}$ vs R_g





Phys.Rev.Lett. 128 (2022) 10, 102001