The role of initial state radiation in jet substructure observables

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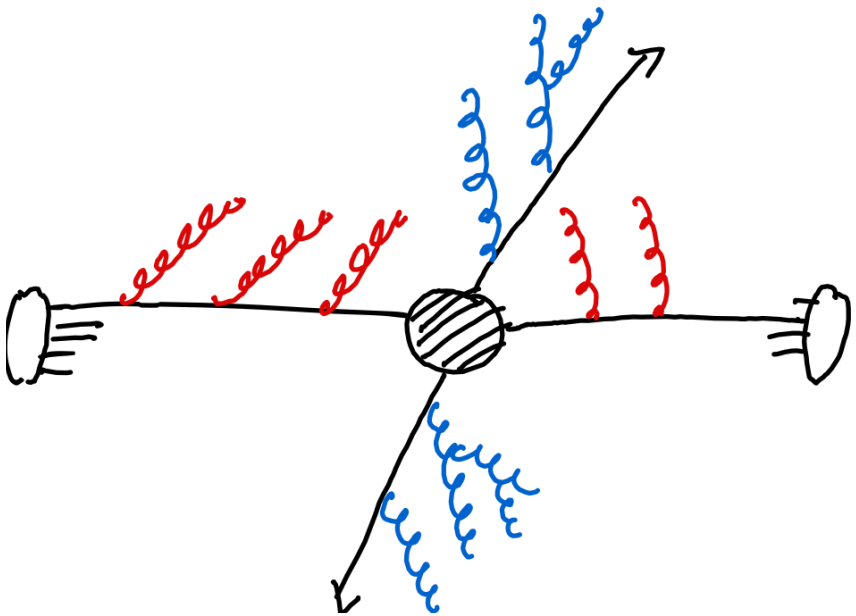
Reminder: initial & final state radiation



$$\mathcal{P}^{(\mathrm{is})}_{\mathrm{em}}(x,t)\,\mathrm{d}Q^2 = \frac{\mathrm{d}f(x,Q^2)}{f(x,Q^2)} = \frac{\mathrm{d}Q^2}{Q^2}\int \mathrm{d}z \frac{\alpha_s}{2\pi} P(z) \frac{x' f(x',Q^2)}{x f(x,Q^2)}$$

$\rightarrow$ DGLAP evolution of PDF's

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- also final state radiation off initial state emissions

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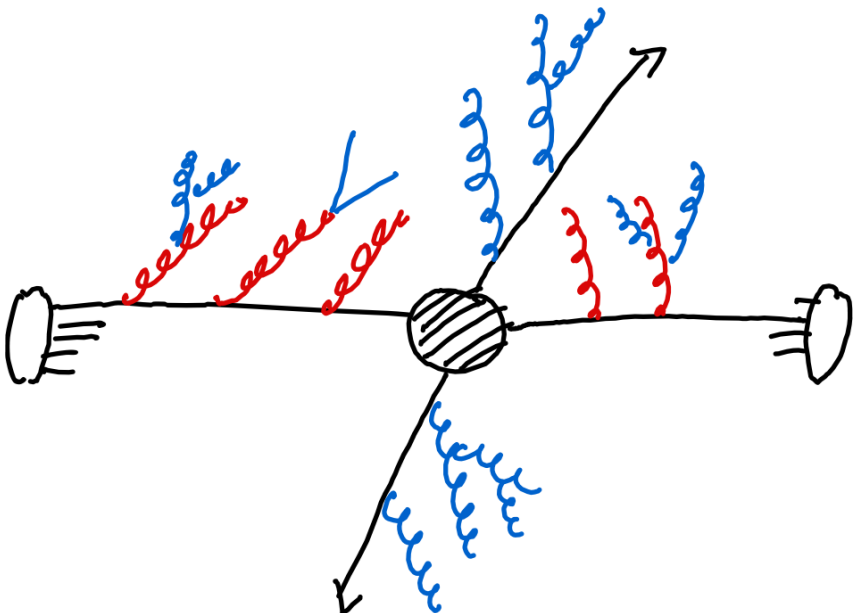

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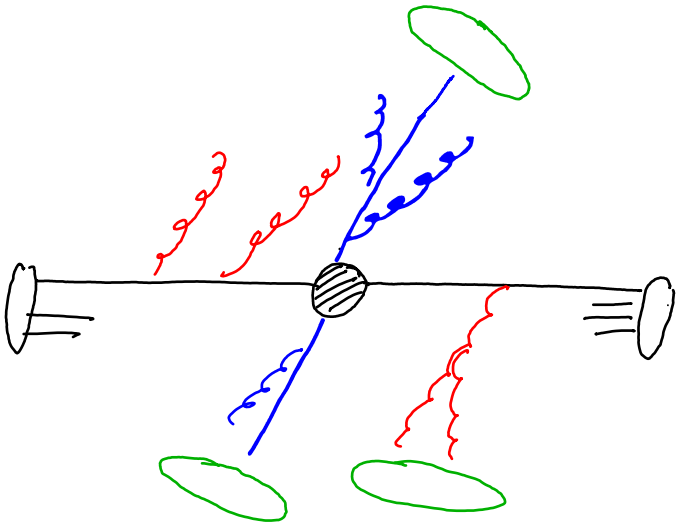
ISR contribution to jets

Two possible ISR effects in jets



1. ISR jets
   → normal jets
2. ISR contribution to FSR jets
   - broad distribution relative to jet axis
   - weakly correlated with jet

   → looks like medium response?
   - semi-hard to hard

   → looks like medium induced radiation?

In JEWEL (version 2.4.0)

- ISR emissions at times earlier than hard scattering

  same formation time as final state emissions
- ISR & FSR off ISR emissions interact in background

  enters medium with time delay

Set-up for quantifying effect of initial state radiation

General idea

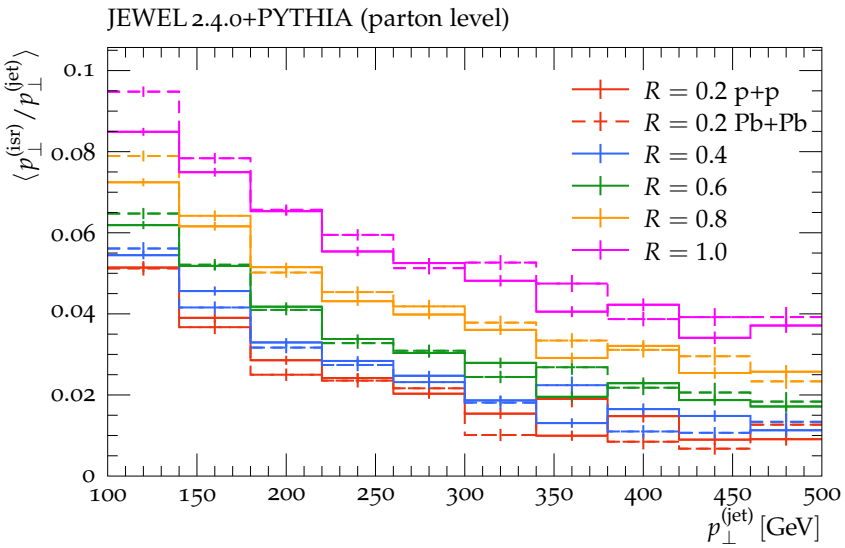
- work at parton level
- label FSR and ISR partons (including FSR off ISR emissions)

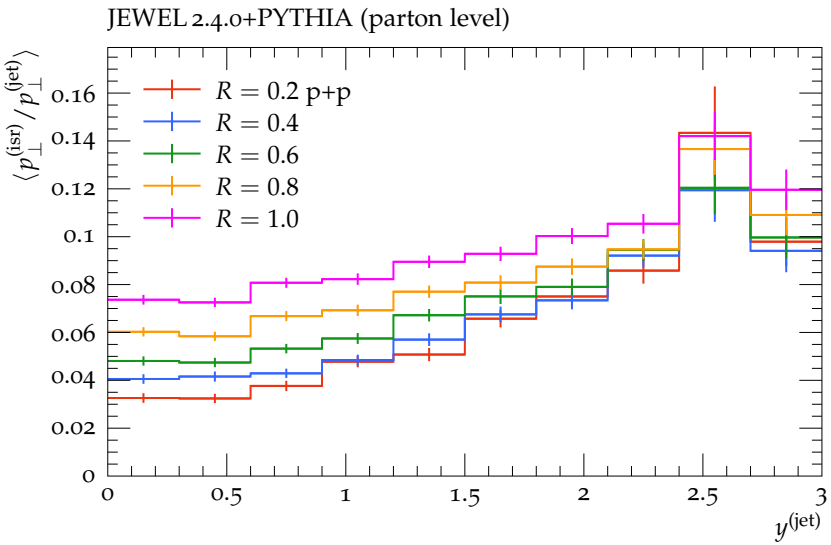
  theoretically not well defined, for illustration only
- classify jets with more than 50% of $p_{\perp}^{(\text{jet})}$ carried by ISR as IS jets

Event & jet sample

- di-jets in p+p and Pb+Pb (0 – 10%) at $\sqrt{s_{\text{NN}}} = 5\,\text{TeV}$
- $p_{\perp}^{(\text{jet})} > 100\,\text{GeV}$; $|\eta^{(\text{jet})}| < 3$
- Pb+Pb: including medium response
- SoftDrop parameters: $z_{\text{cut}} = 0.1$ and $\beta = 0$

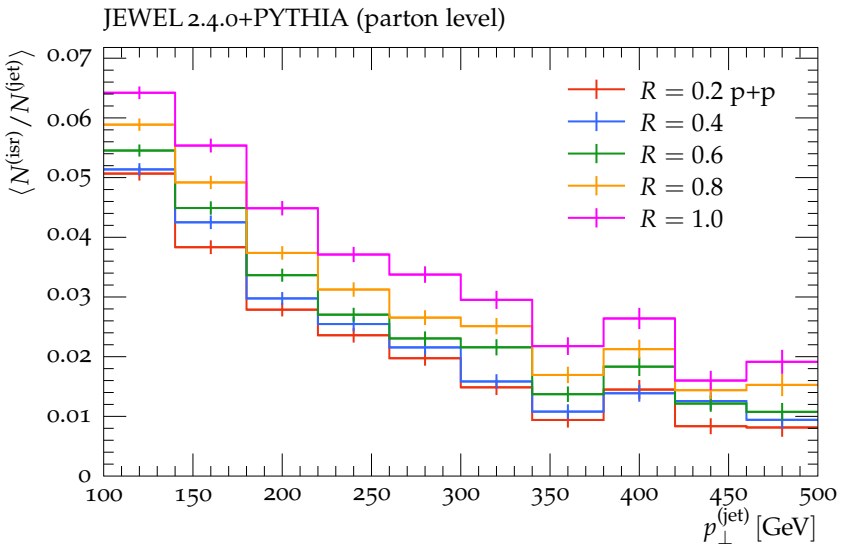
Fraction of jet $p_\perp$ carried by ISR partons

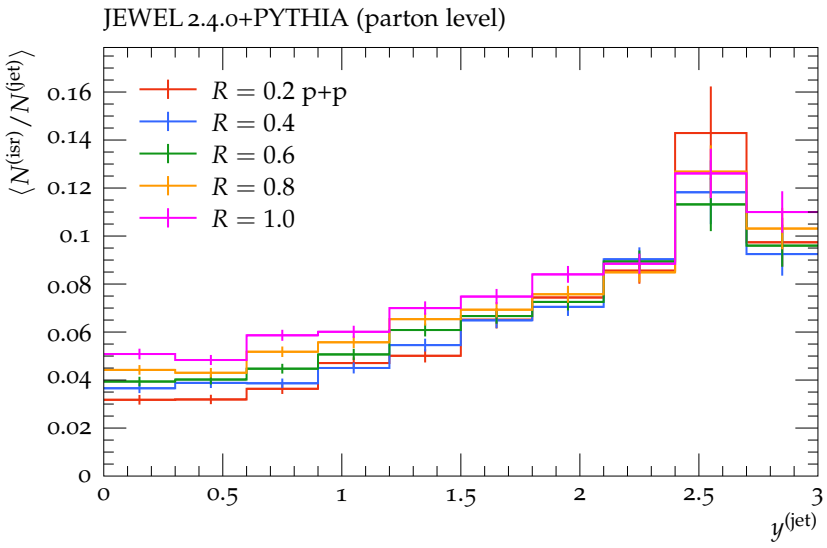




- up to 10% for large R
- increases with R
- decreases with jet $p_\perp$
- increases with jet rapidity
- similar in p+p and Pb+Pb

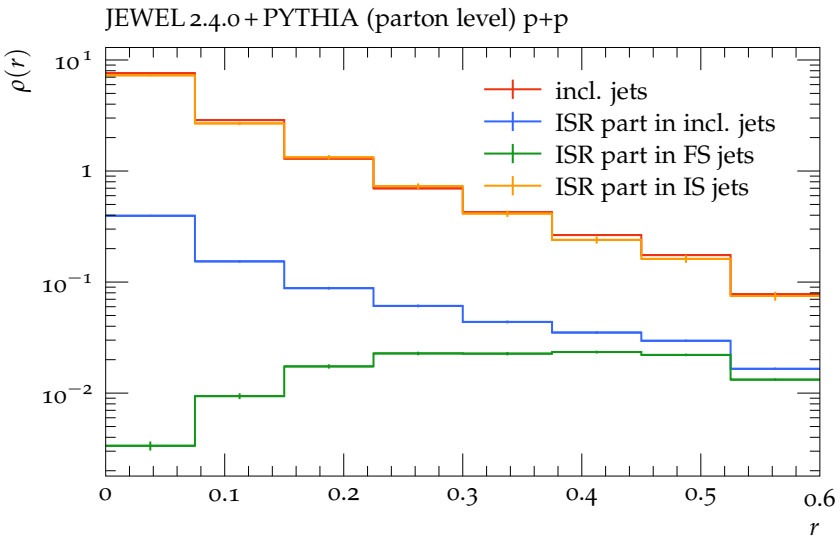
Fraction of IS jets

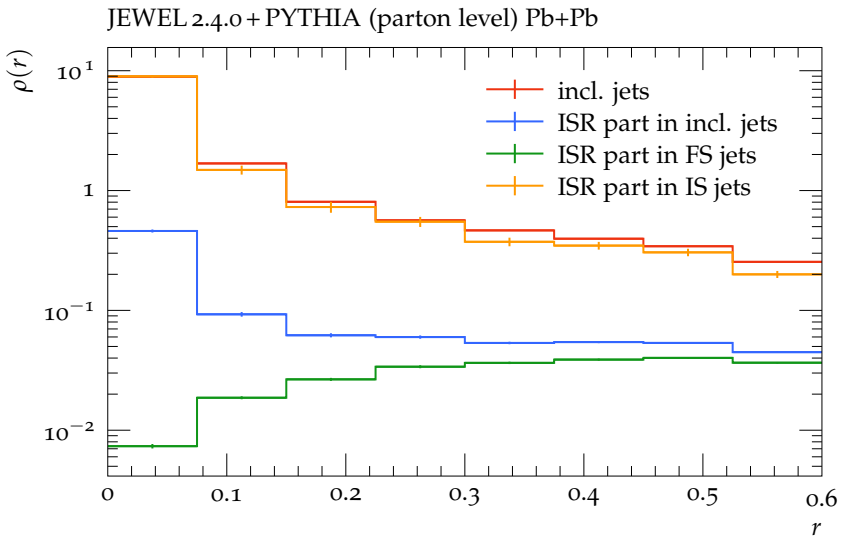


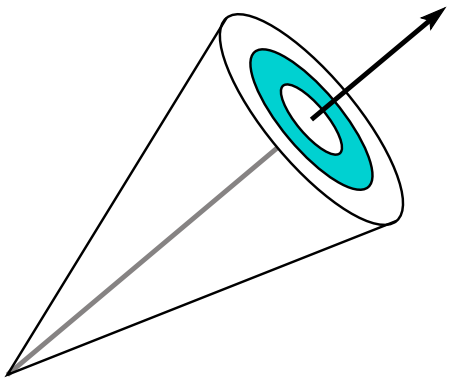


- up to 10% for large R
- milder increase with R
- decreases with jet $p_\perp$
- increases with jet rapidity
- similar in p+p and Pb+Pb

Jet profile

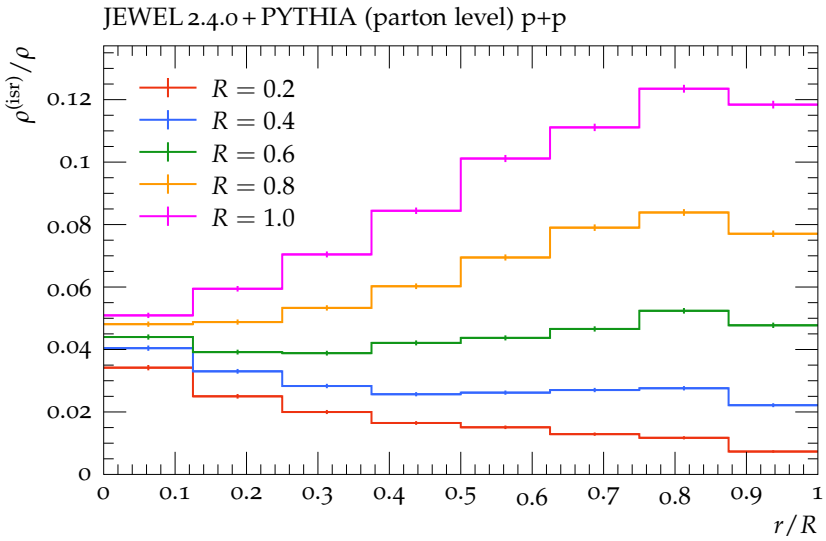


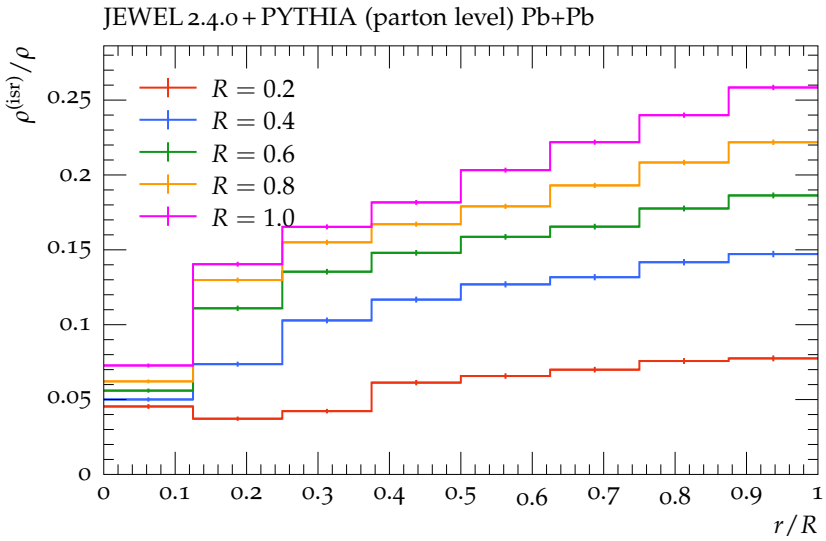




- two components in ISR contribution:
  - in FS jets: normal jet profile
  - in IS jets: increases with r
- in Pb+Pb: ISR component contains medium response to ISR

Jet profile – ISR fraction



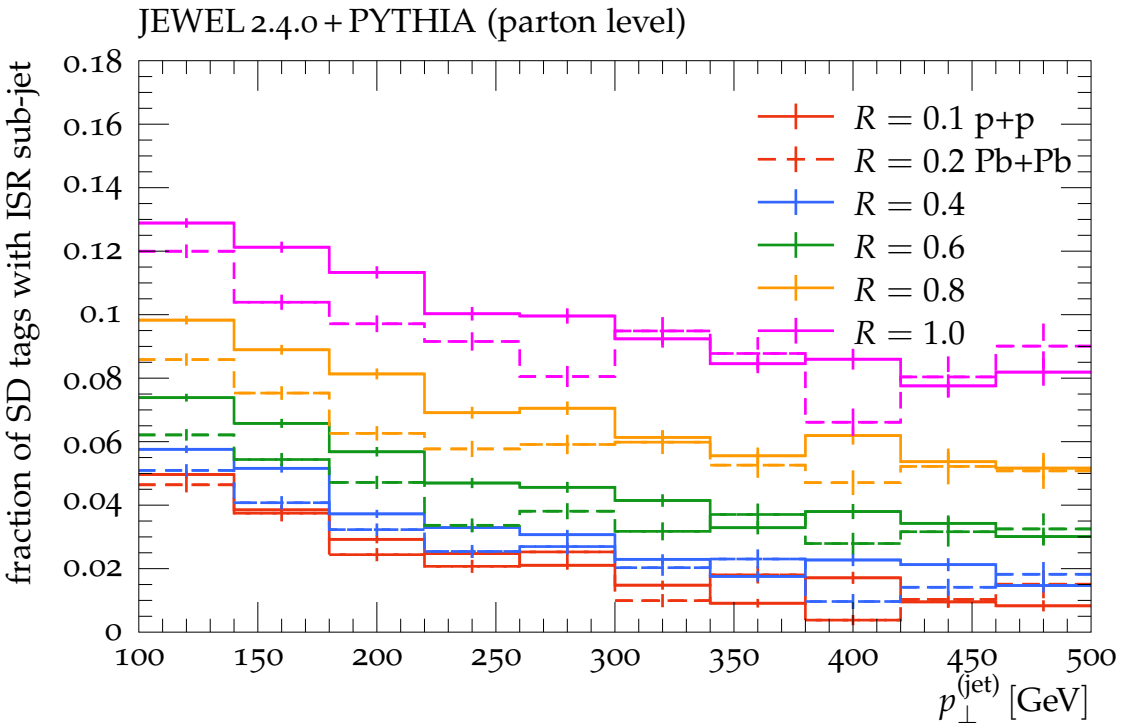


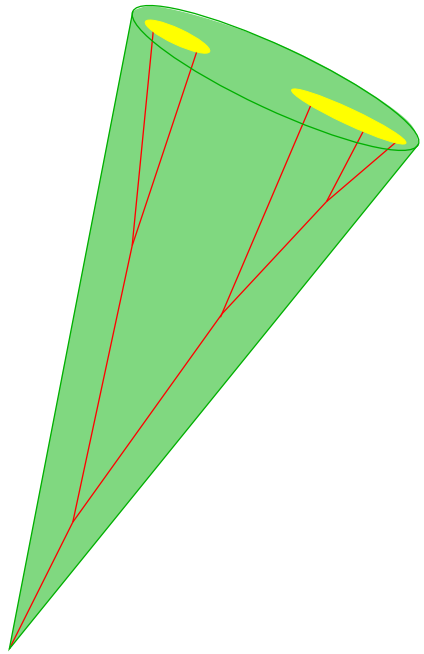
- strong increase with r & R

$\rightarrow$ resembles medium response

- sizable contribution for large R
- much larger in Pb+Pb than in p+p $\rightarrow$ mostly due to medium response

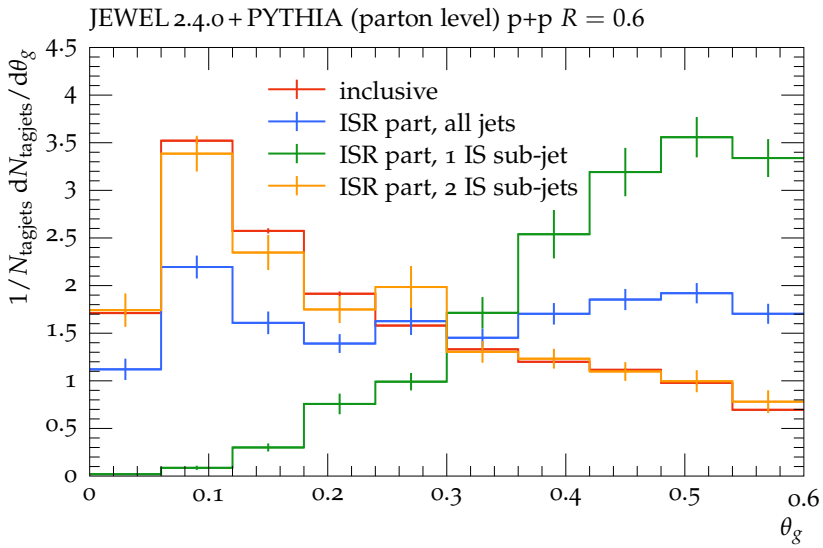
SoftDrop – fraction of tags with at least one IS sub-jet

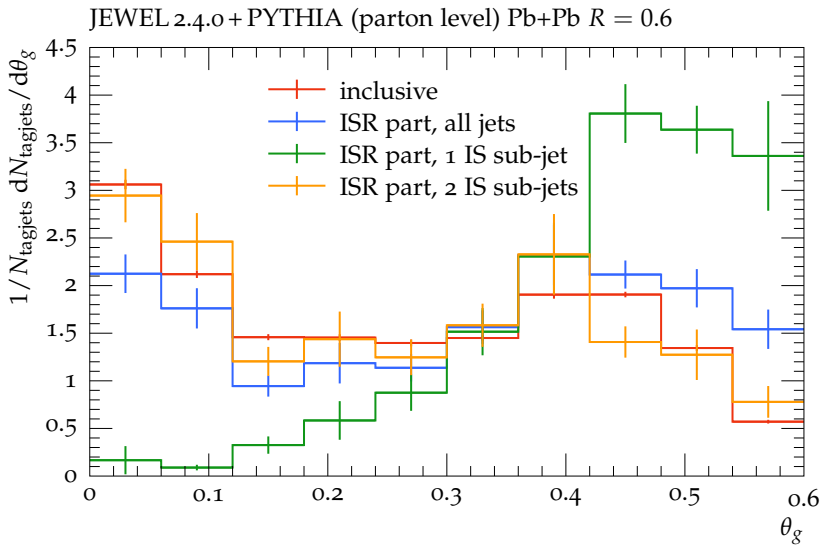


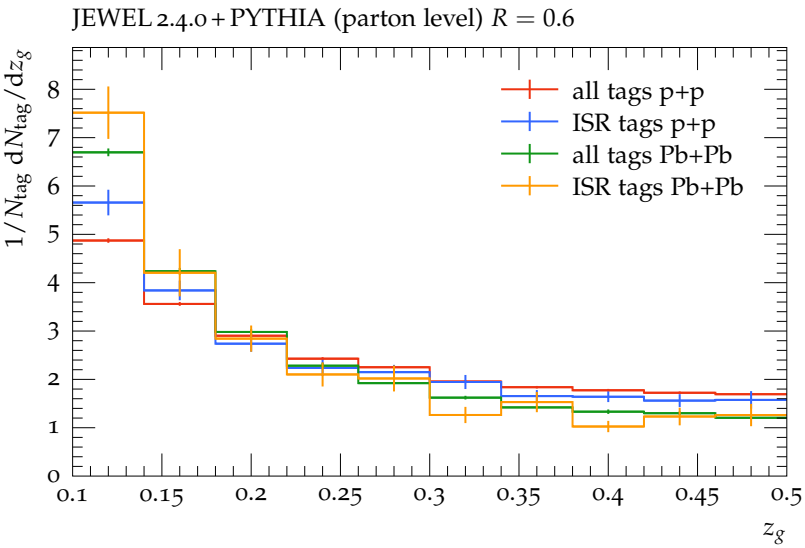


- up to 10% for large R
- similar in p+p and Pb+Pb
- contains double IS sub-jet configurations, i.e. IS jets
- complicates interpretation of z_g in terms of splitting function

SoftDrop – z_g and θ_g





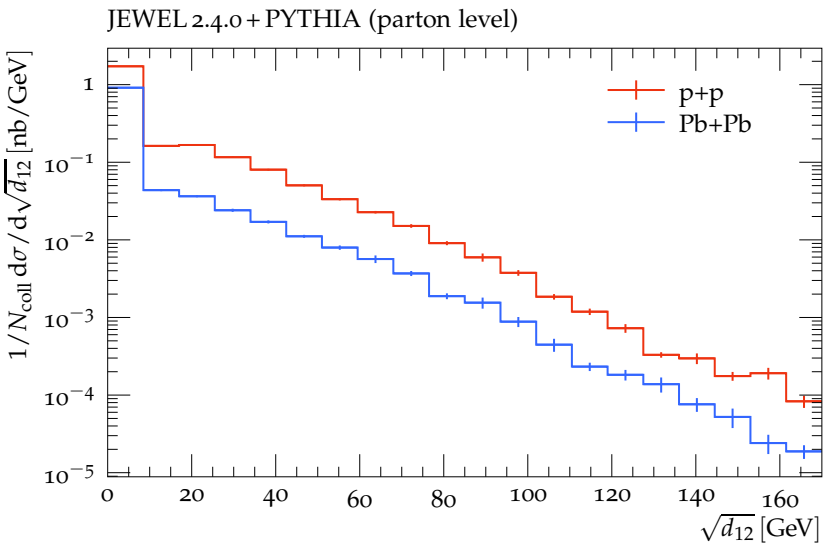


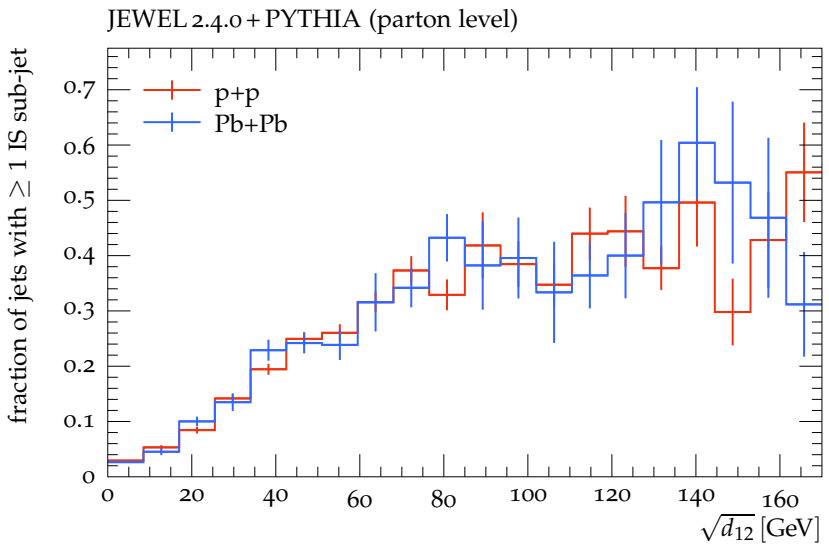
θ_g : clear shift towards large θ_g

- in FS jets: peaked at large θ_g
- in IS jets: peaked at small θ_g
- bump at large resembles medium response

z_g : mild modification

Reclustered large radius jets – preliminary





ATLAS analysis (ATLAS-CONF-2019-056)

1. find $R = 0.2$ anti-$k_\perp$ jets with $p_\perp > 35\,\text{GeV}$
2. cluster $R = 0.2$ jets into $R = 1.0$ anti-$k_\perp$ jets with $p_\perp > 158\,\text{GeV}$
3. recluster with $k_\perp$ algorithm; d_{12}: scale of last clustering step

- large fraction of IS sub-jets at large d_{12}

dominated by single IS sub-jet configurations

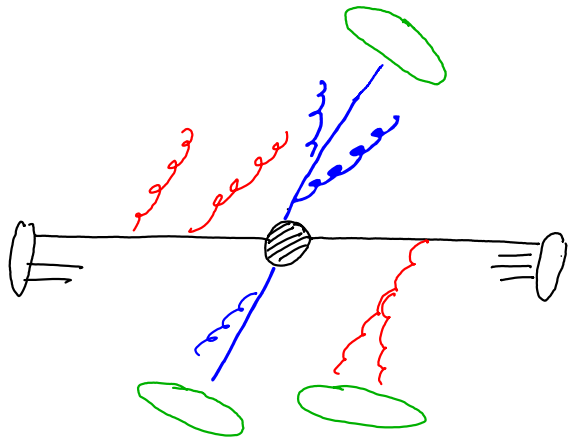
Conclusions

- ISR produces jets and contaminates jets

well known effect

- effect increases with jet radius
- generically up to 10% contributions for large R jets
- details depend on observable
- can fake signatures of medium induced radiation and medium response

$\rightarrow$ has to be taken into account for quantitative understanding



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