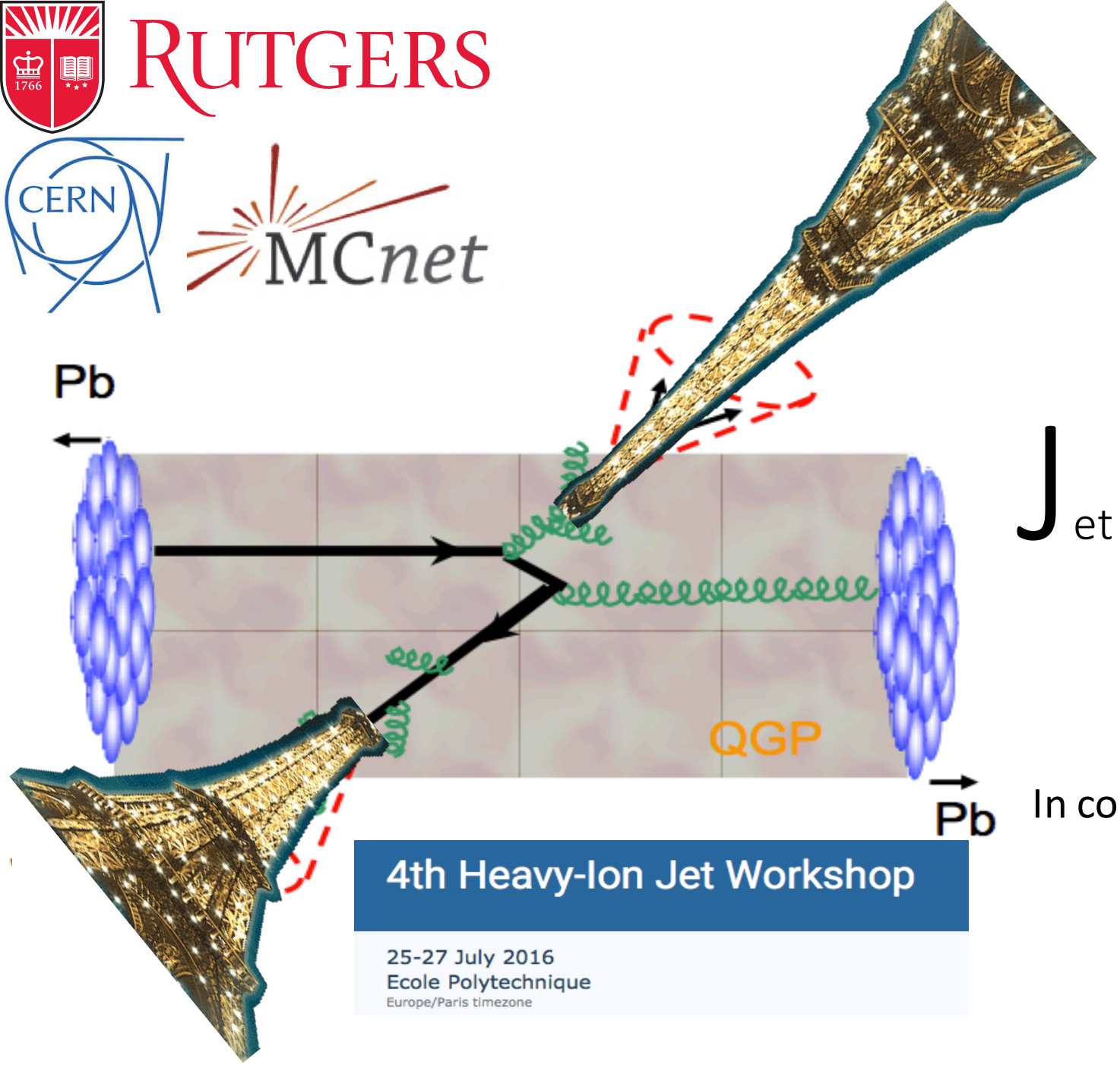


Recent Updates to JEWEL

Jet Evolution With Energy Loss

Raghav Kunnawalkam Elayavalli
Rutgers University, CERN

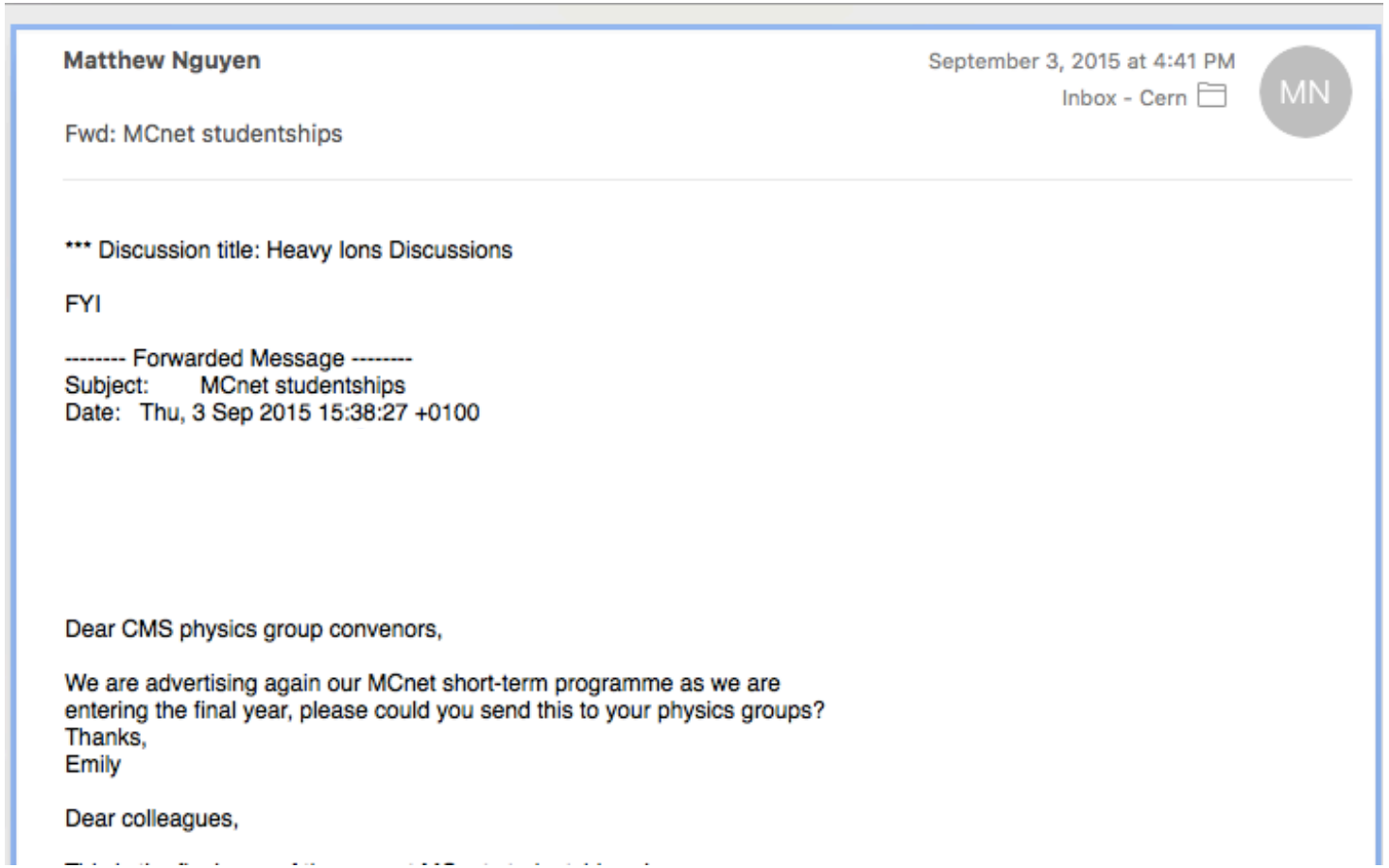
In collaboration with Dr. Korinna Zapp (CERN)

arXiv:160n.nnnn

arXiv:16nn.nnnn

(in preparation)

Thanks for the email Matt! ☺



Matthew Nguyen

September 3, 2015 at 4:41 PM
Inbox - Cern

MN

Fwd: MCnet studentships

*** Discussion title: Heavy Ions Discussions

FYI

-------- Forwarded Message --------
Subject: MCnet studentships
Date: Thu, 3 Sep 2015 15:38:27 +0100

Dear CMS physics group convenors,

We are advertising again our MCnet short-term programme as we are entering the final year, please could you send this to your physics groups?
Thanks,
Emily

Dear colleagues,

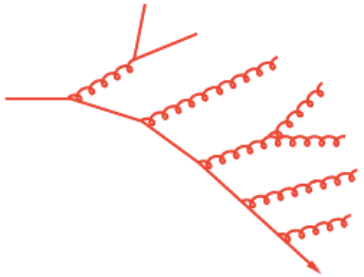
This work was done at CERN funded by the EU Marie Curie early stage researcher program.

- Basics - I
  - Treatment of Jet energy loss
  - Adding bosons + Jet
- V+Jet
  - Photon/Z + Jet
  - W/l + Jet
- Basics - II
  - Treatment of recoils
  - Updates
  - Analysis implementation
- Versatility
  - Differential Jet shapes
  - Splitting functions

What is JEWEL?

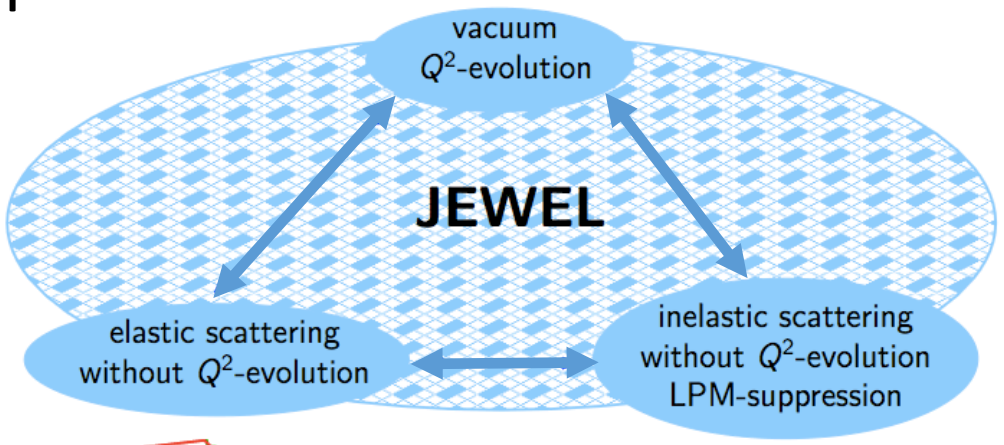
Korinna Zapp, EPJ C, Volume 74, Issue 2, 2014

- MC with in-medium jet energy loss implementation

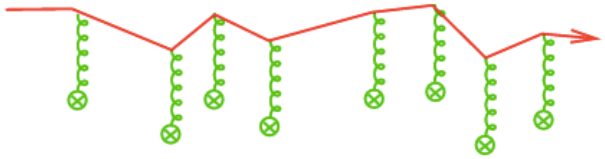


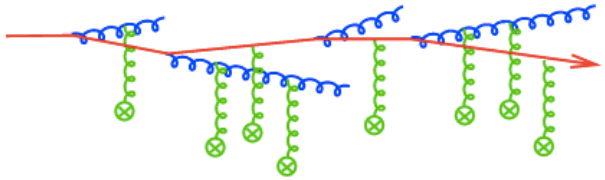
- LPM effect for collinear gluon splitting

- Jet interacts with collection of quasi-free partons



- Consistent with all analytically known limiting cases





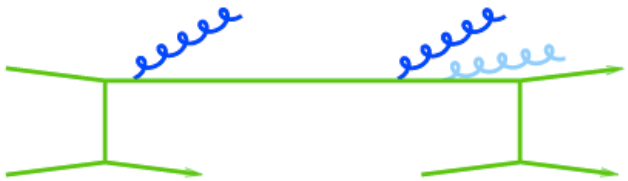
These are very good talks on JEWEL and its finer workings. Pictures taken from there. KZapp Talk1, Talk2,

Radiation in JEWEL

- Virtuality ordered parton shower
- Formation time for every gluon emitted

$$\tau \approx \frac{E}{Q^2} \approx \frac{2\omega}{k_\perp^2}$$

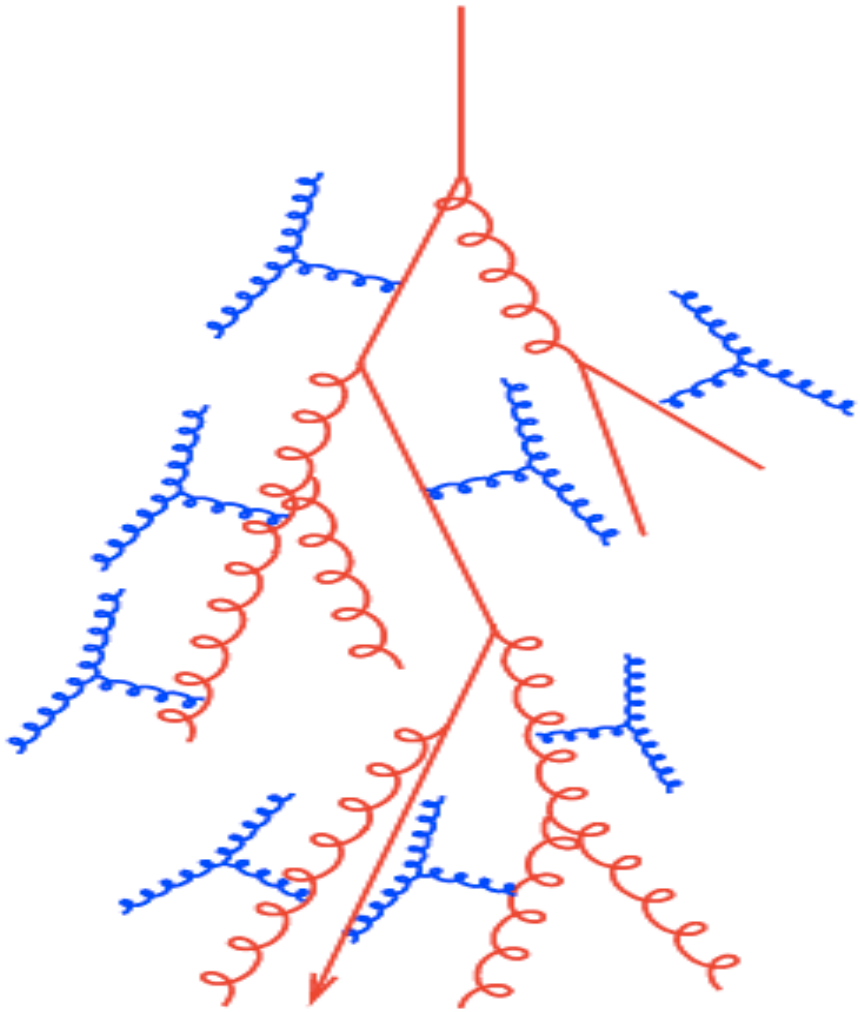
- In case of competing time, the shorter time one gets realized



- Elastic/inelastic scattering from the scattering centers
- At most one emission from ISR for medium scattering

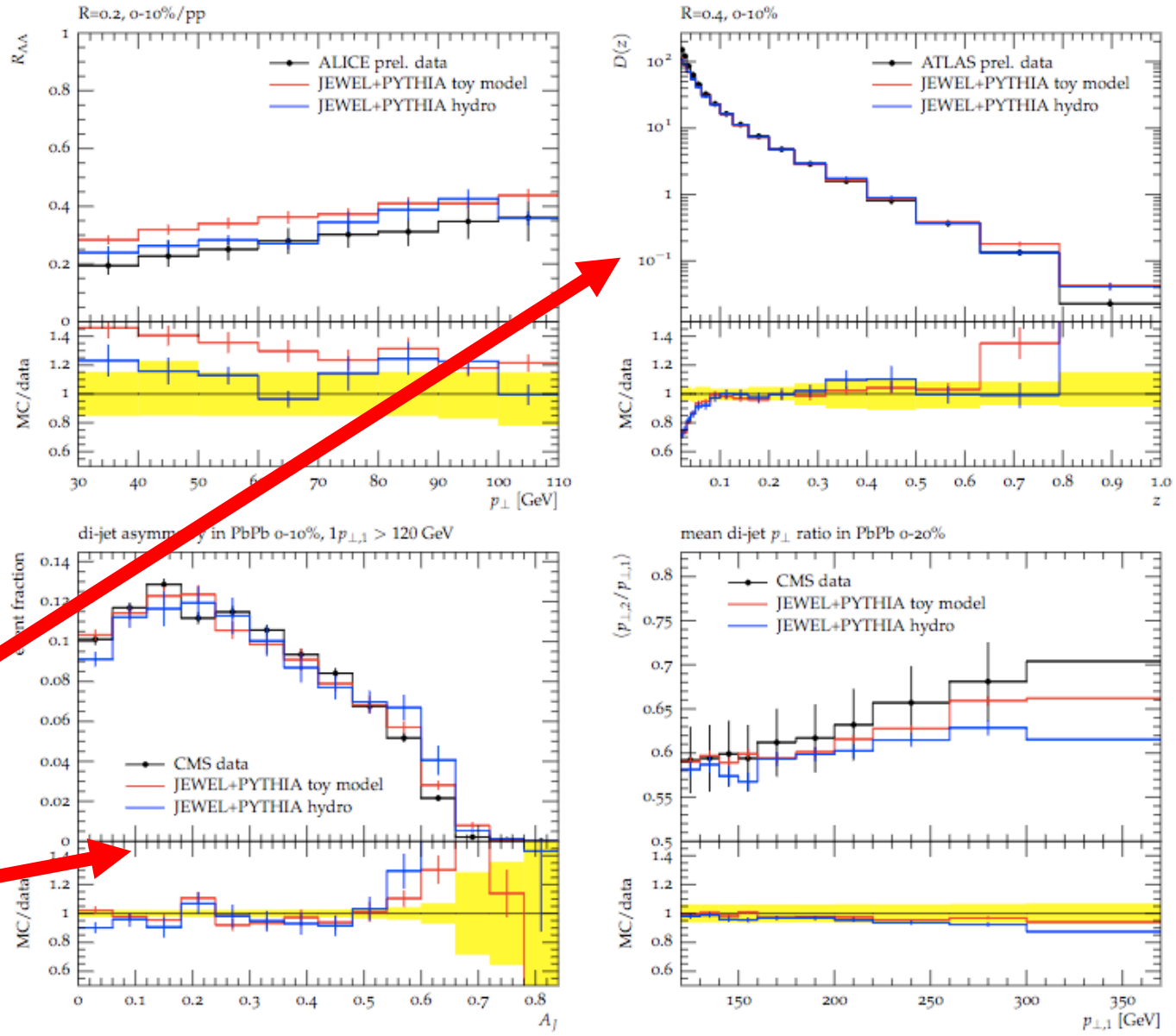
Algorithm in MC

1. create gluon in inelastic process
2. check if scattering during t_f
3. If no gluon is formed
   - Back to 1
4. If yes: scattering after time $\Delta t < t_f$, revaluate formation time and back to 2



Decent description of several jet phenomenon:

1) ALICE RAA
2) ATLAS fragmentation function
3) CMS Dijet asymmetry results



Is there tuning involved?

Parameters	2.76 TeV	5.02 TeV
Initial Temperature	485 MeV	590 MeV
	iEBE package from Chen Shun	
Formation time	0.6 fm	0.4 fm
Inelastic cross section	64 mb	72 mb
	http://dde.web.cern.ch/dde/glauber_lhc.htm	
Debye Mass factor	0.9	0.9
	This was to match hadron RAA at PHENIX	

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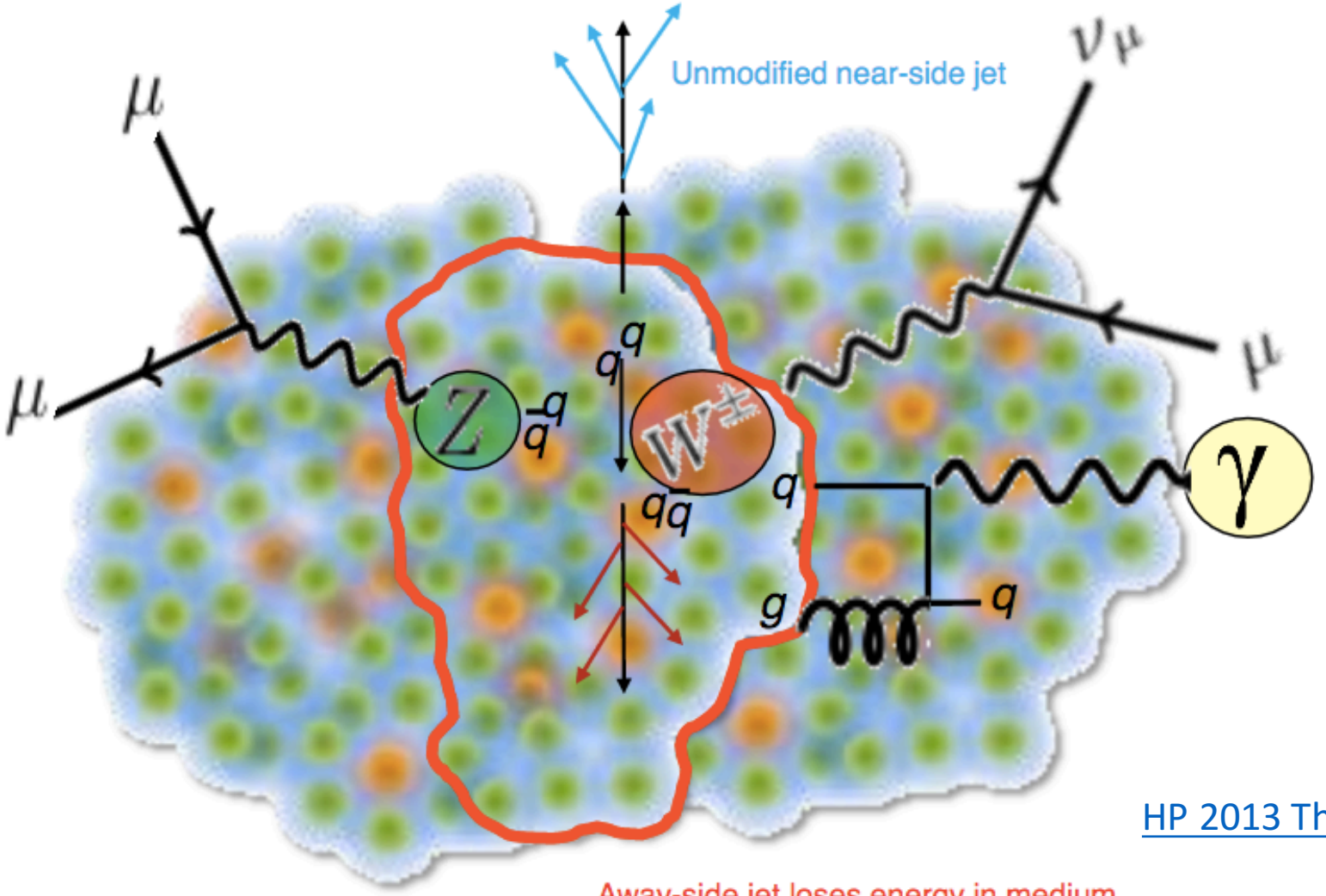
Standard candles in HIN collisions

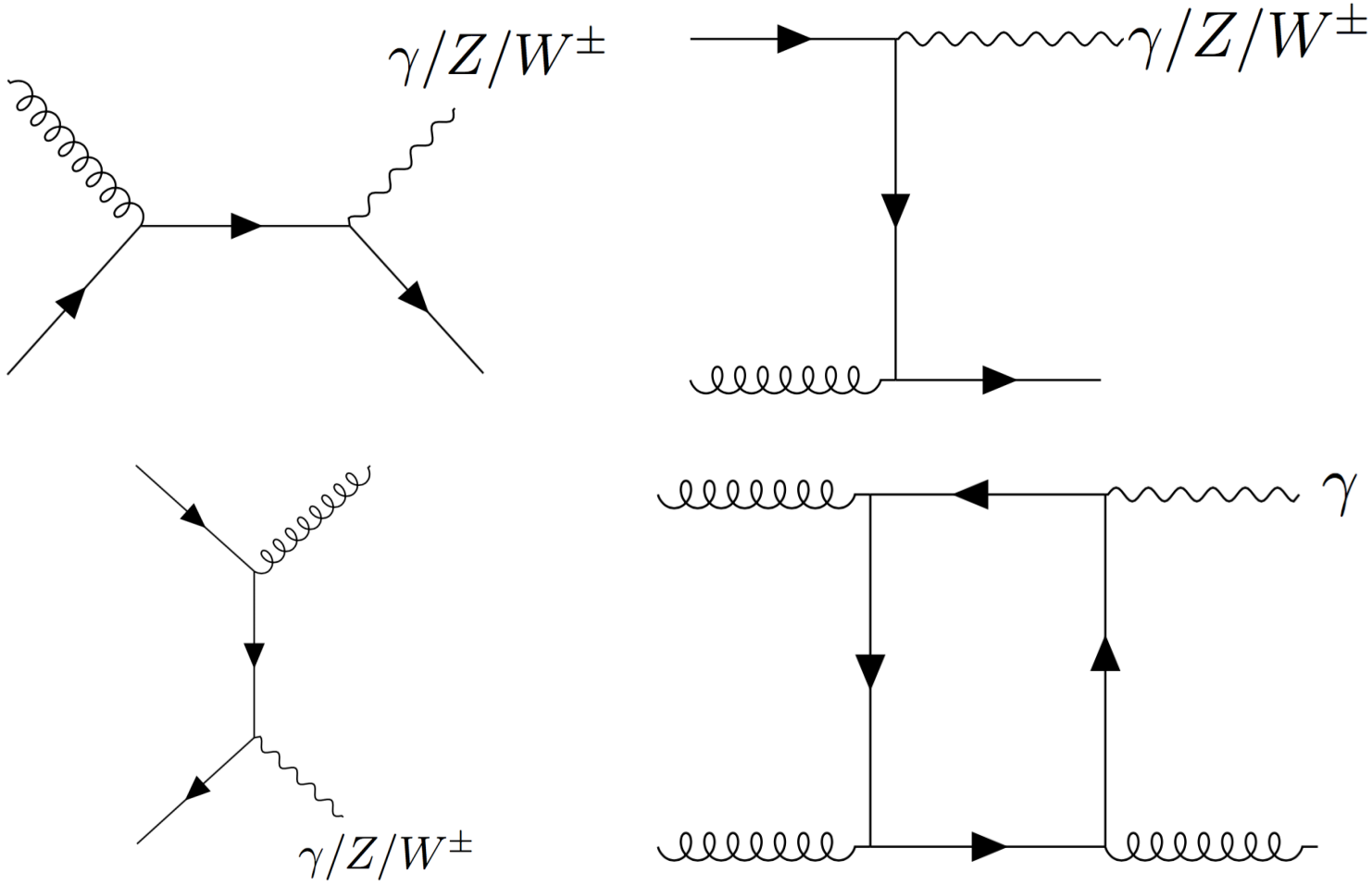


HP 2013 Thomas Balestri

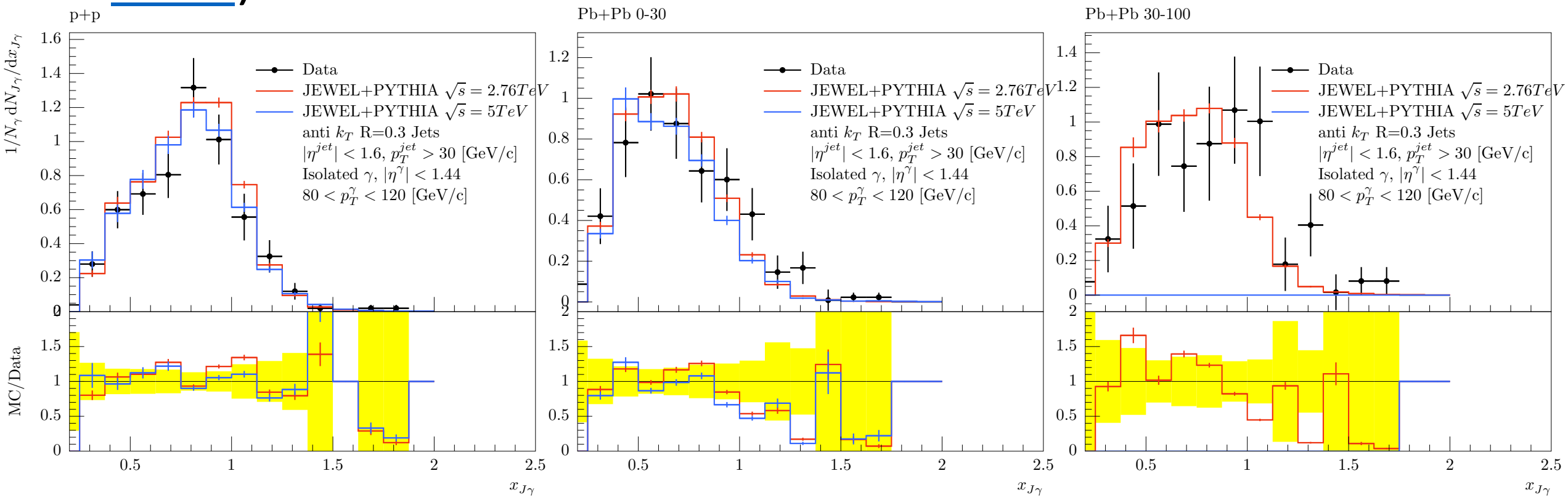
Bosons (γ, Z^0, $W^{\pm}$) + Jets in JEWEL

We add the following processes to JEWEL.

Full list available in the paper (to be published)
PROCESS ('PPZJ')
DECAY ('MUON')

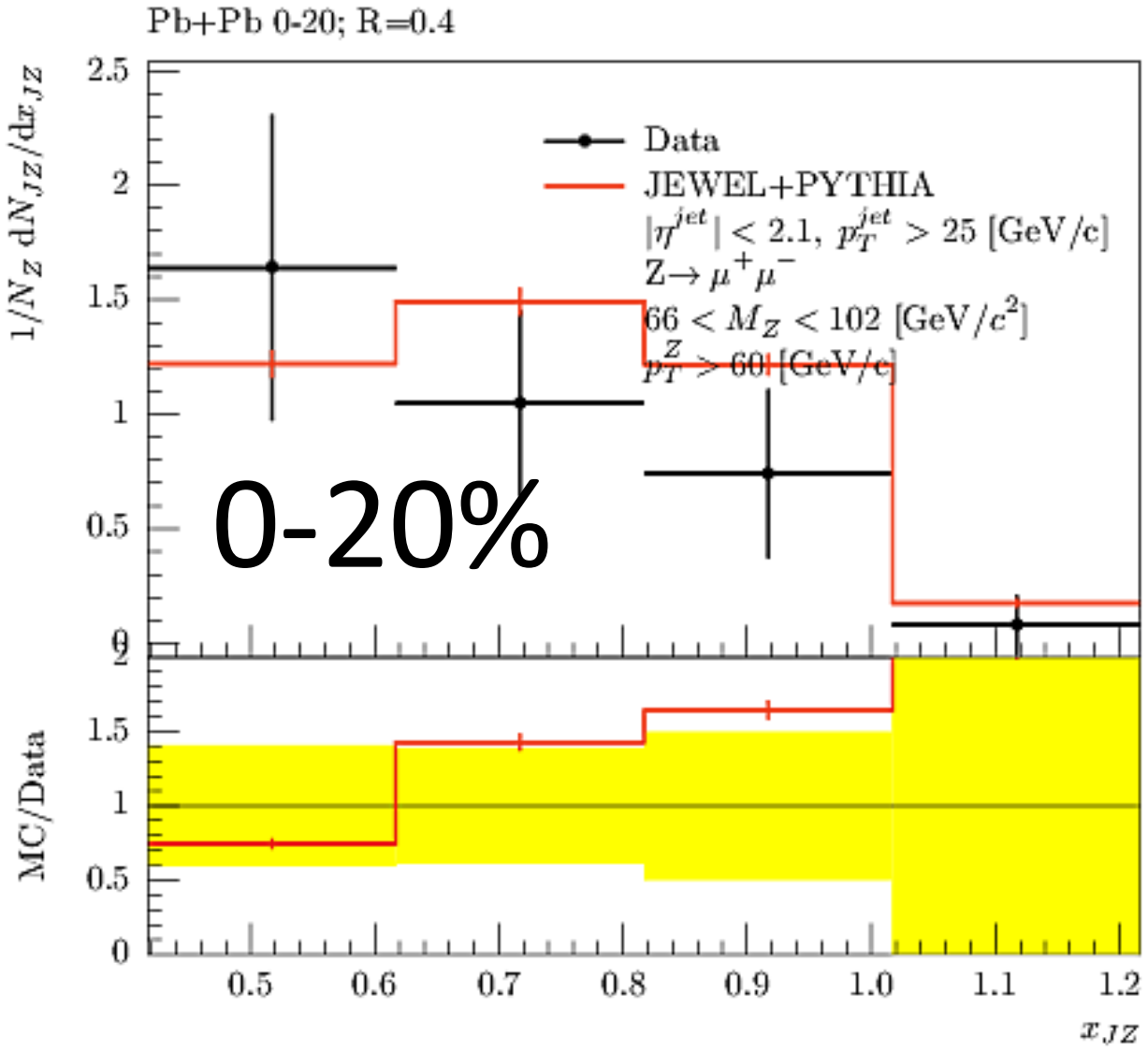


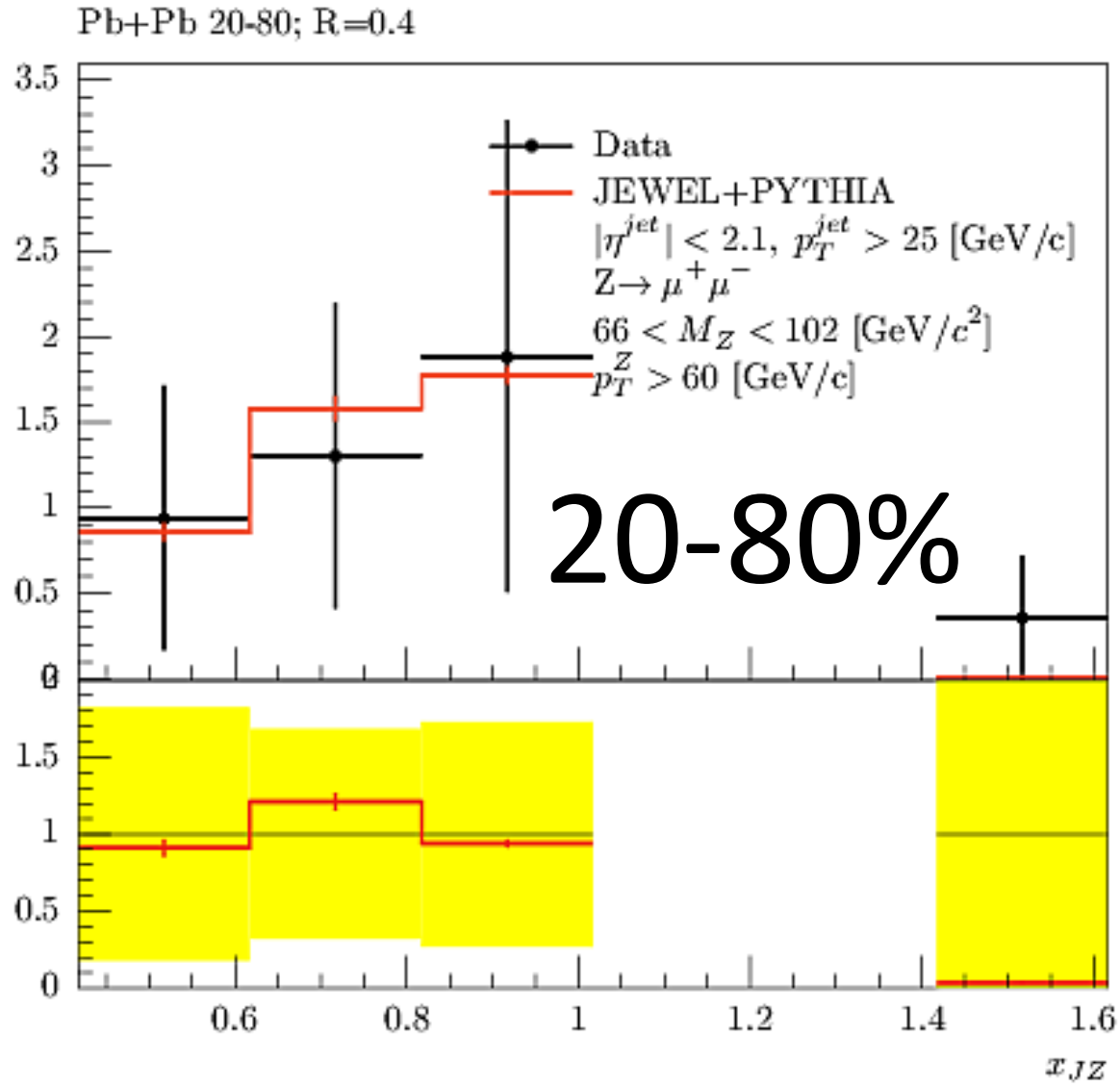
γ + Jets – 2.76 TeV (CMS-PAS-HIN-13-006) and 5 TeV



pp 0-30% 30-100%

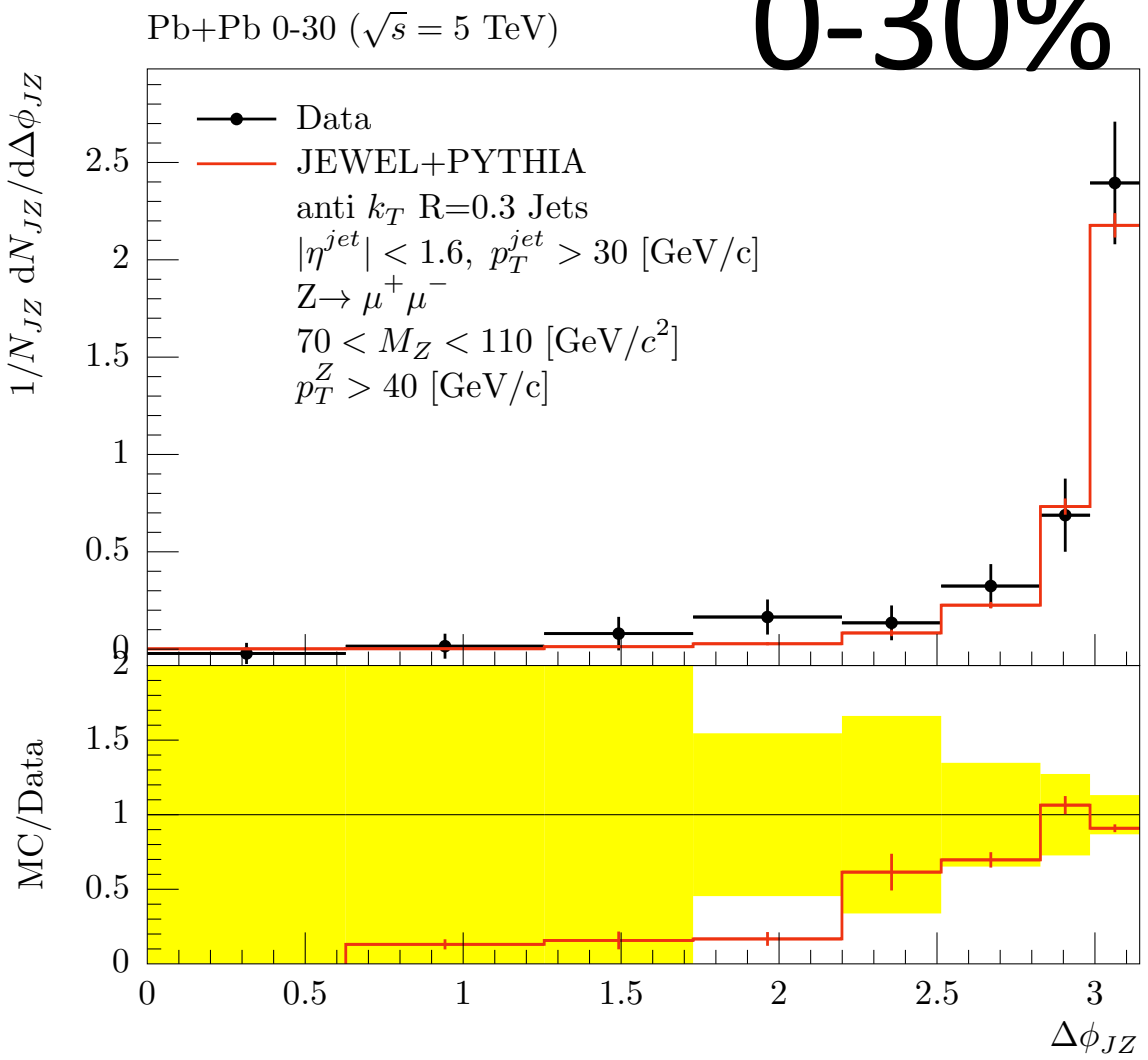
Z + Jets – 2.76 TeV preliminary ATLAS-CONF-2012-119

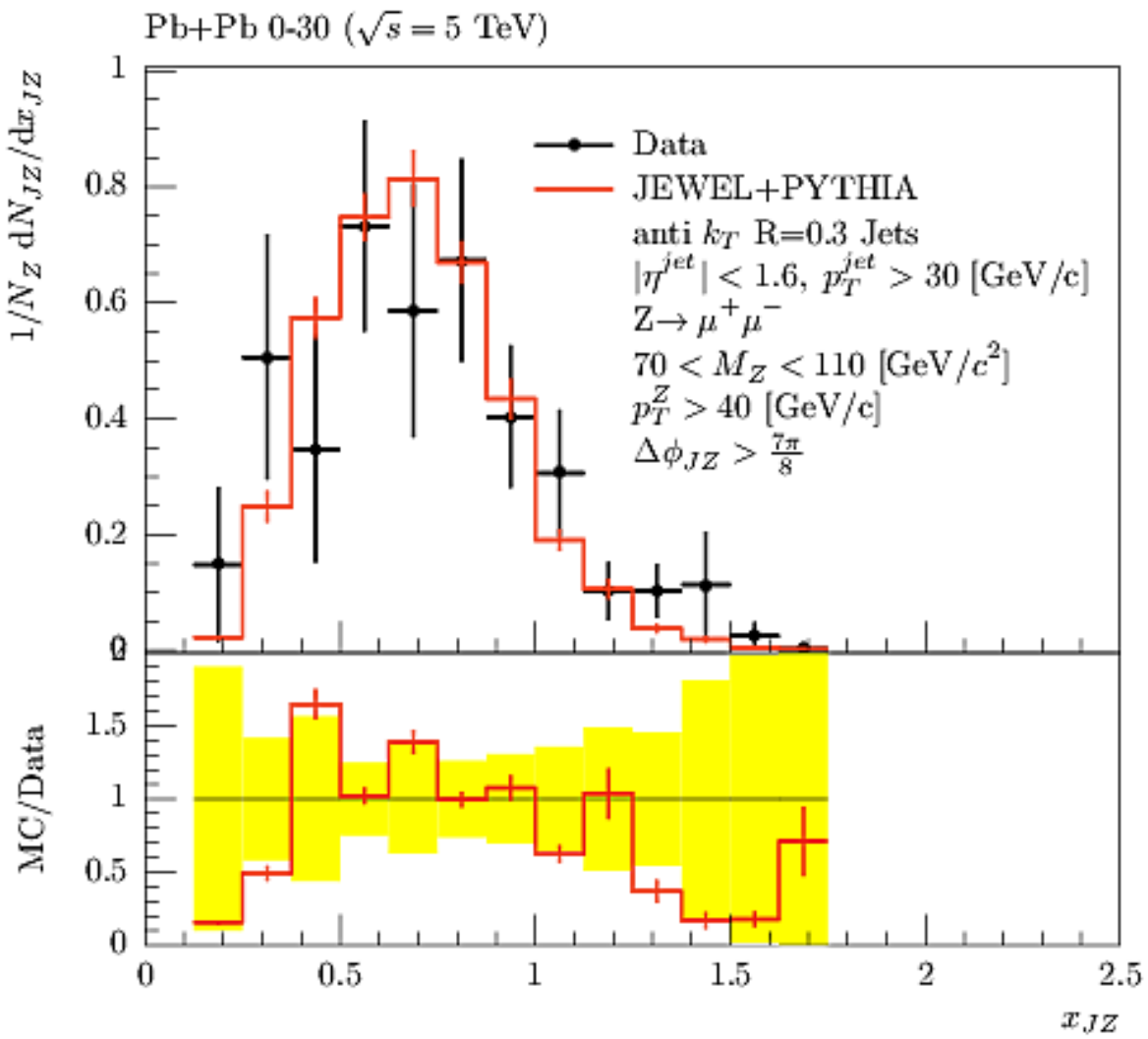




Z + Jets – 5.02 TeV preliminary CMS-PAS-HIN-15-013

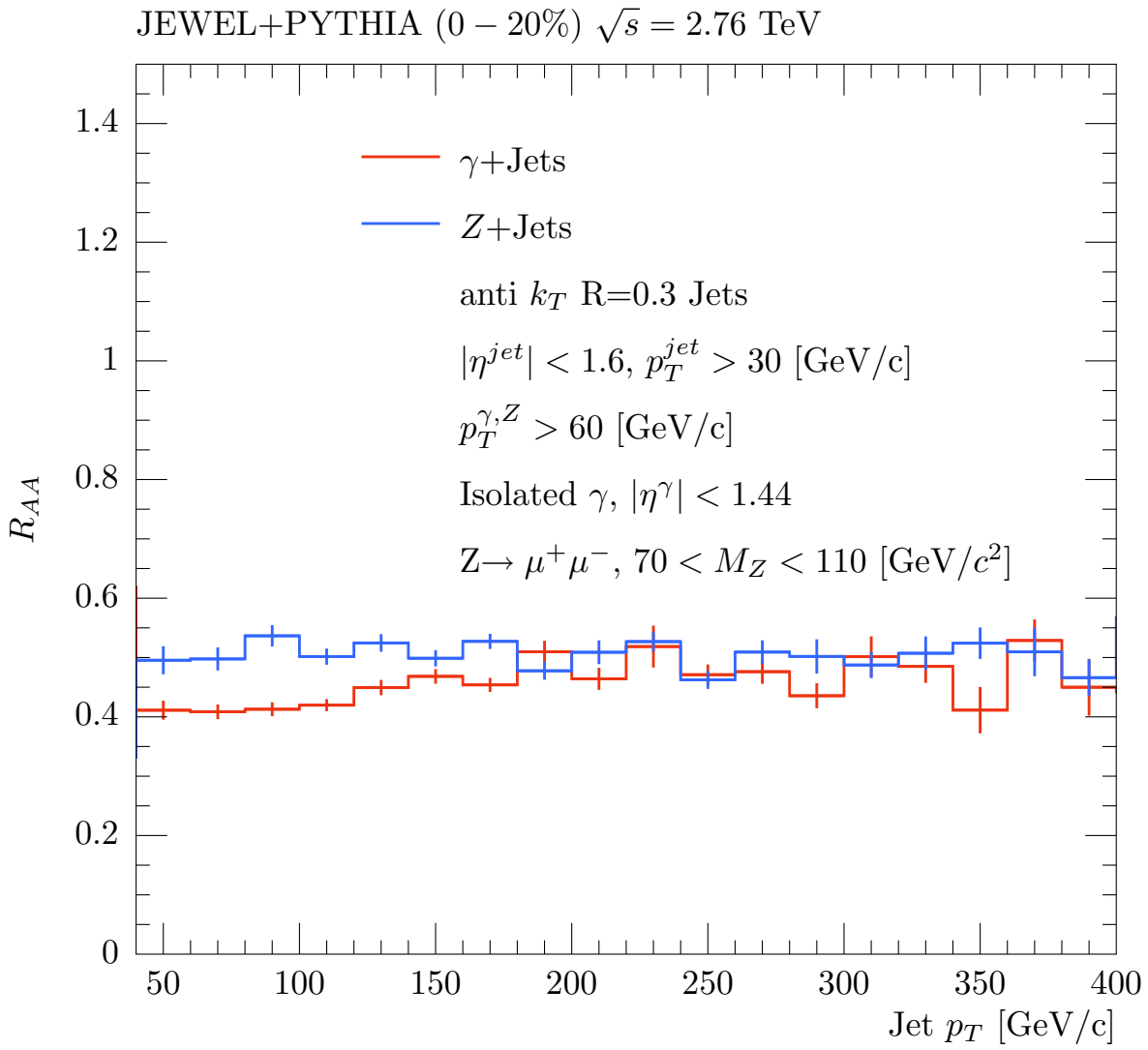
0-30%





What JEWEL tells us from comparing γ + Jets with Z + Jets?

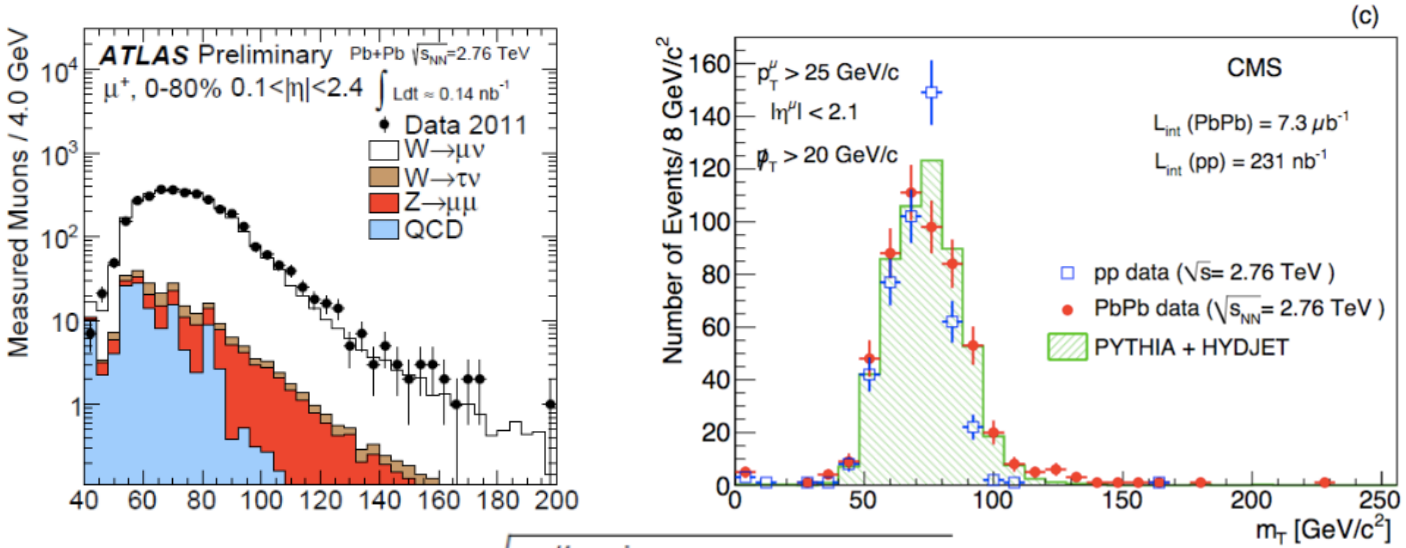
Nuclear modification factors



- RAA for Z + Jets > γ + Jets at low p_T
- Due to high mass of Z
- Comparable at high p_T (and similar to inclusive Jets)

What can we say about $W^{\pm}$ + Jets?

- Reconstruction in heavy ion collisions is technical challenging!!!



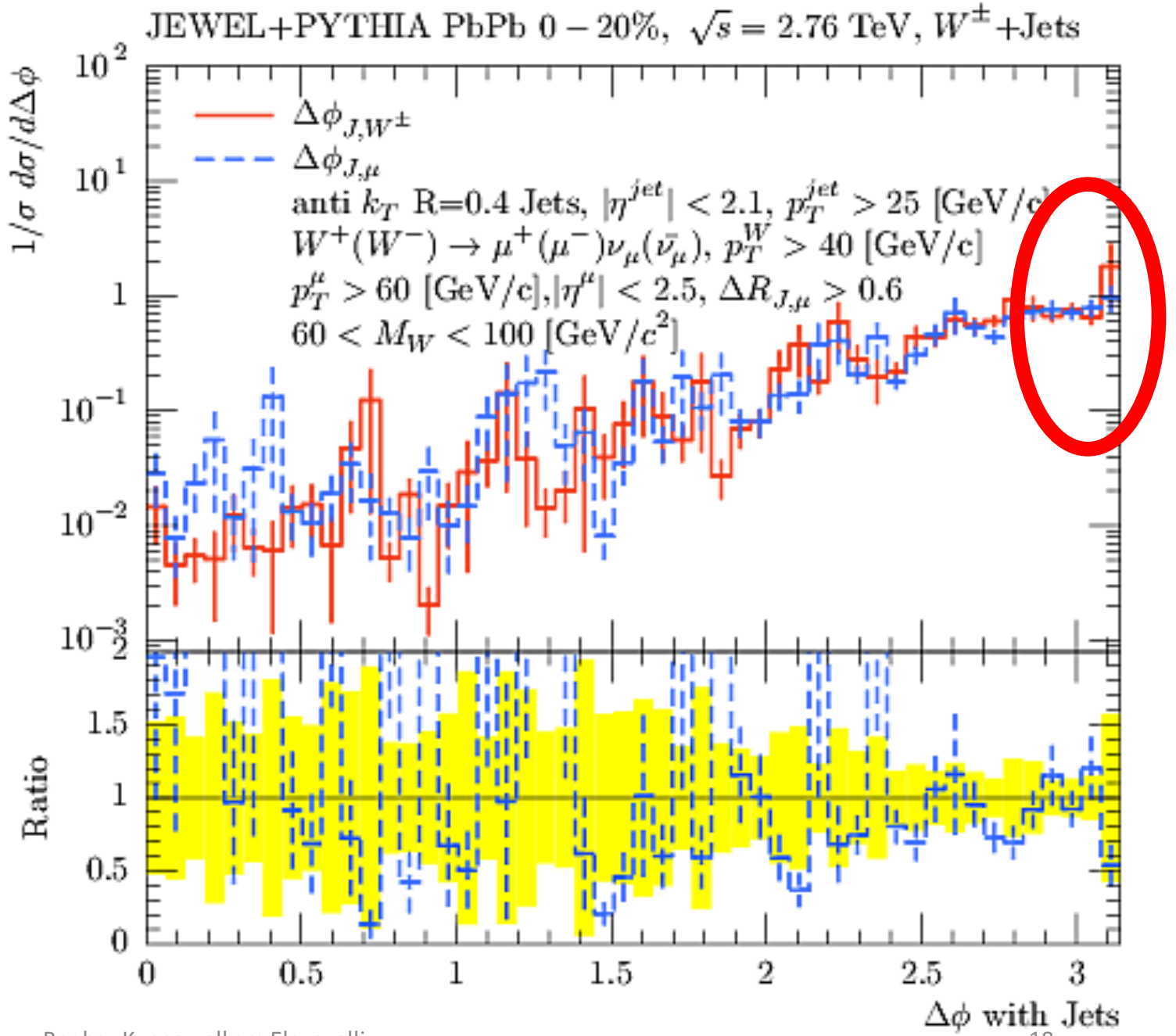
ATLAS $m_T = \sqrt{2p_T^{\mu} p_T^{\text{miss}} (1 - \cos\Delta\phi_{\mu, p_T^{\text{miss}}})}$ CMS

- ATLAS and CMS have some studies on the kinematics, but looking at the delta phi with jets complicated due to inability of precise reconstruction of the direction of the W candidate.

Compare with the leading leptons!

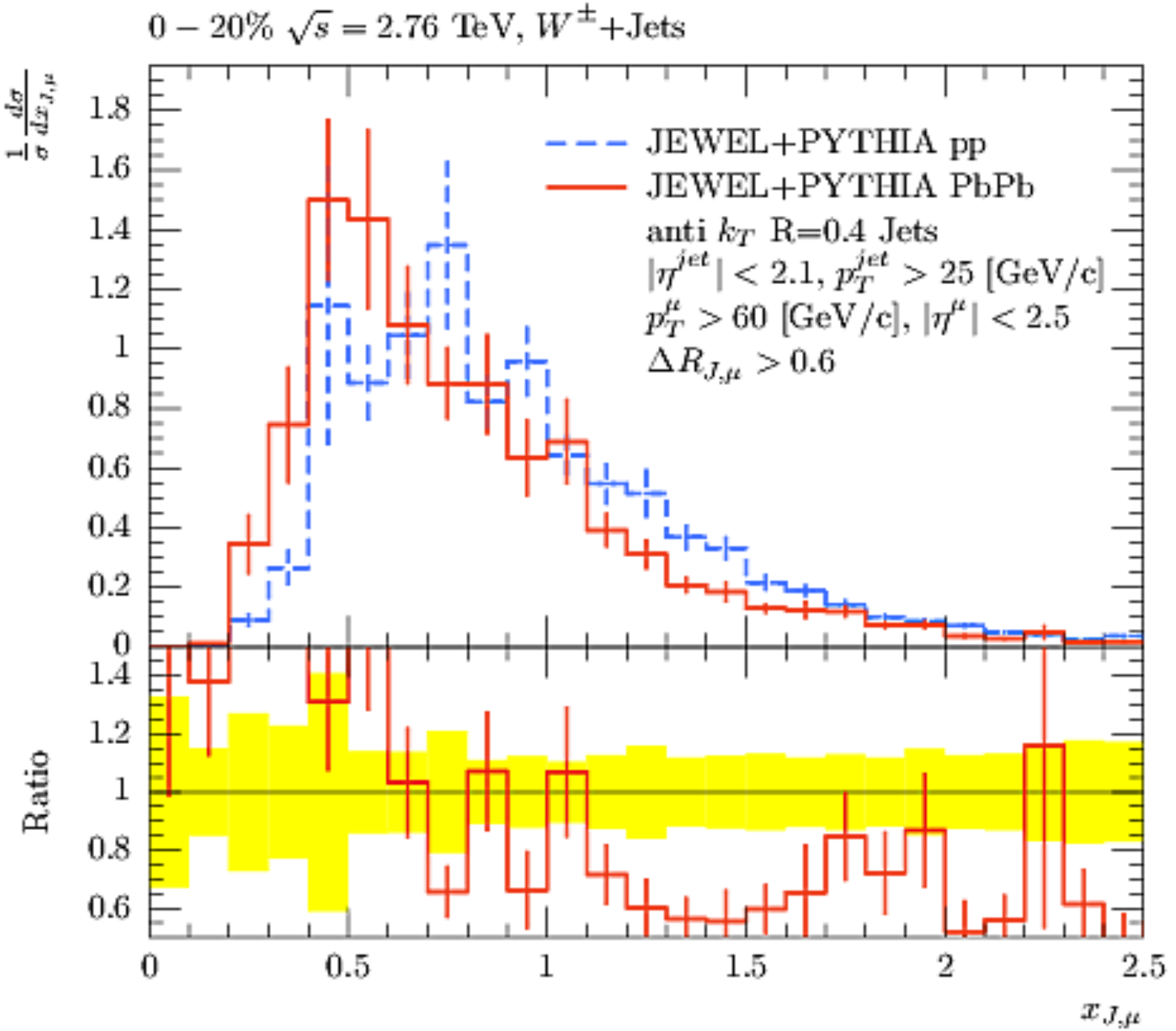
Impost a very large kinematic cut on the muons along with the Z veto.

We observe a good correlation for the delta phi for very hard emission muons and the W with the Jet.



look at $X_{J,\mu}$:

- See a considerable shift comparable to what we see in y+Jet and Z+Jet
- Should be able to do with large kinematic cuts



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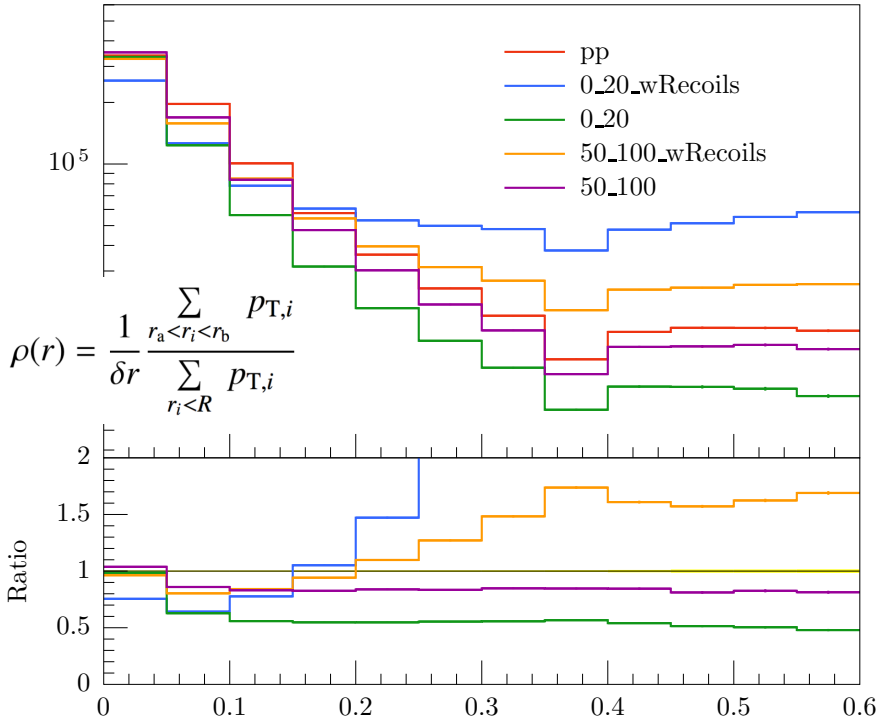
How we did on Jet Shapes?

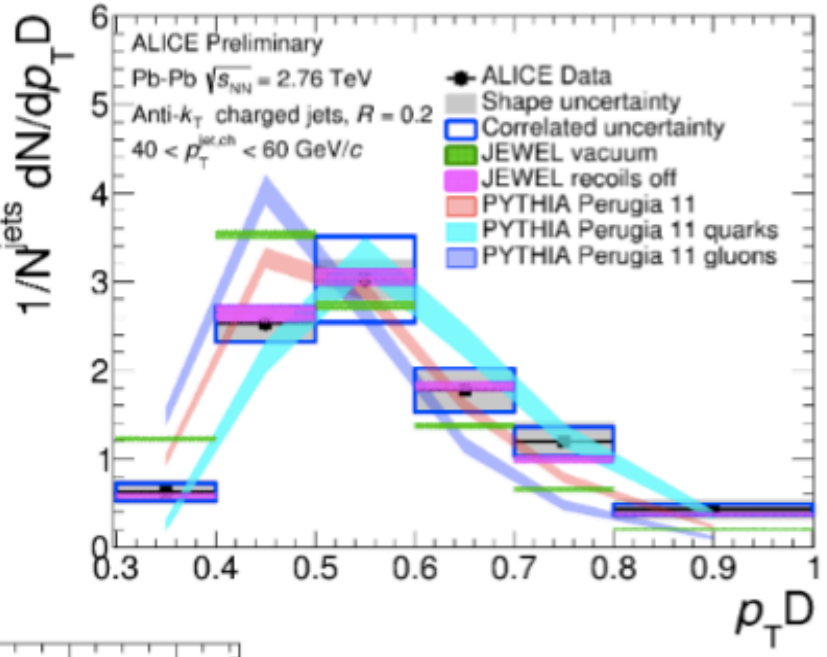
Not good!

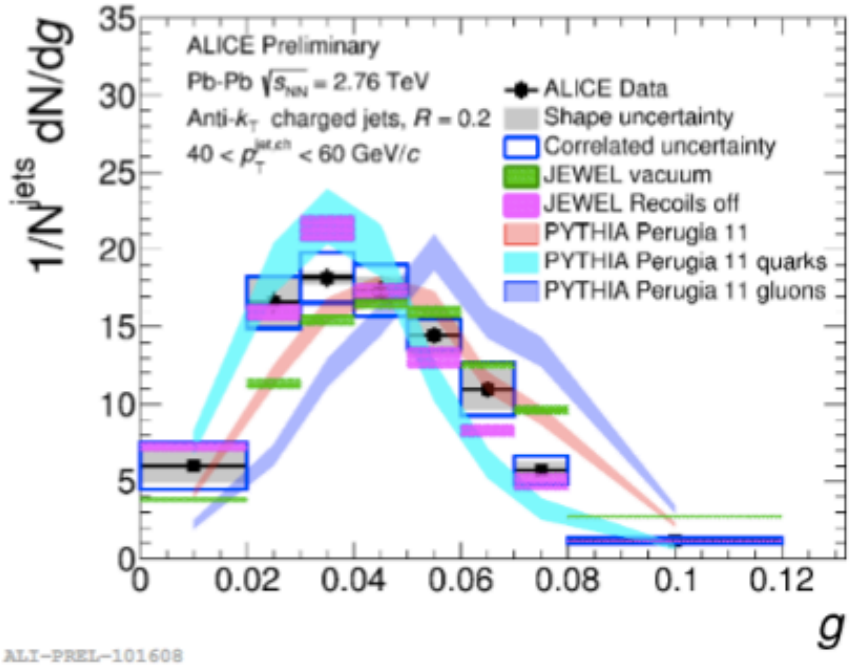


$$p_T D = \frac{\sqrt{\sum_{i \in jet} p_{T,i}^2}}{\sum_{i \in jet} p_{T,i}}$$

arrangement of tracks in the jet

Leticia, ALICE Preliminary





Decent

But still…

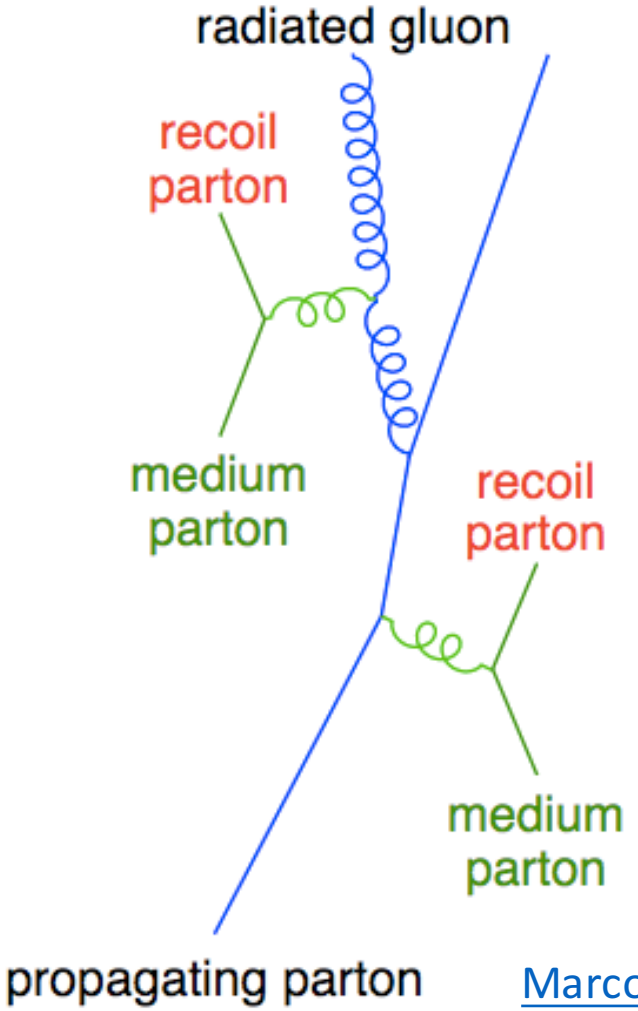
$$g = \sum_{i \in jet} \frac{p_T^i}{p_{T,jet}} |\Delta R_{i,jet}|$$

Radial Moment

Treatment of Recoils

- Scattering centers realized from the interaction of the high energy parton propagating through the medium
- w/ Recoils, as soon as interaction happens and a gluon is emitted, it is stored in the event record.
- Usually we don't store them since it increases the event content
- Now we keep them and check if they belong to a jet

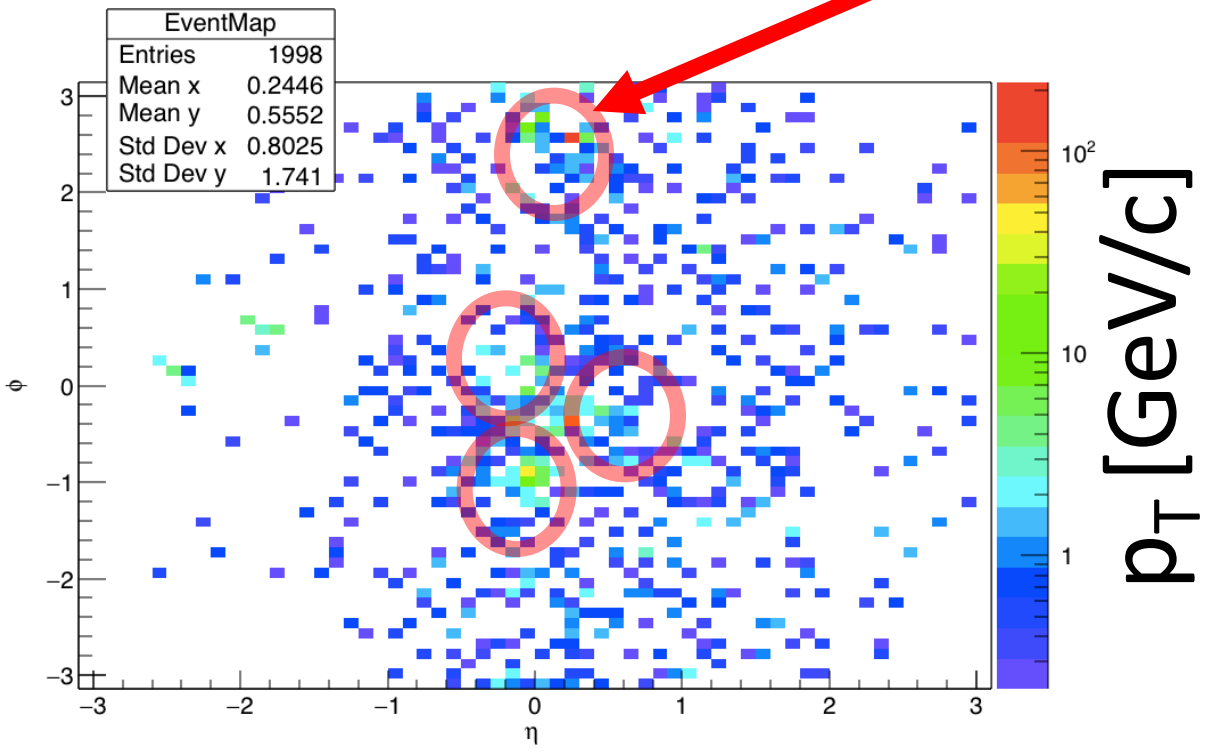
Scattering centers drawn from a thermal distribution



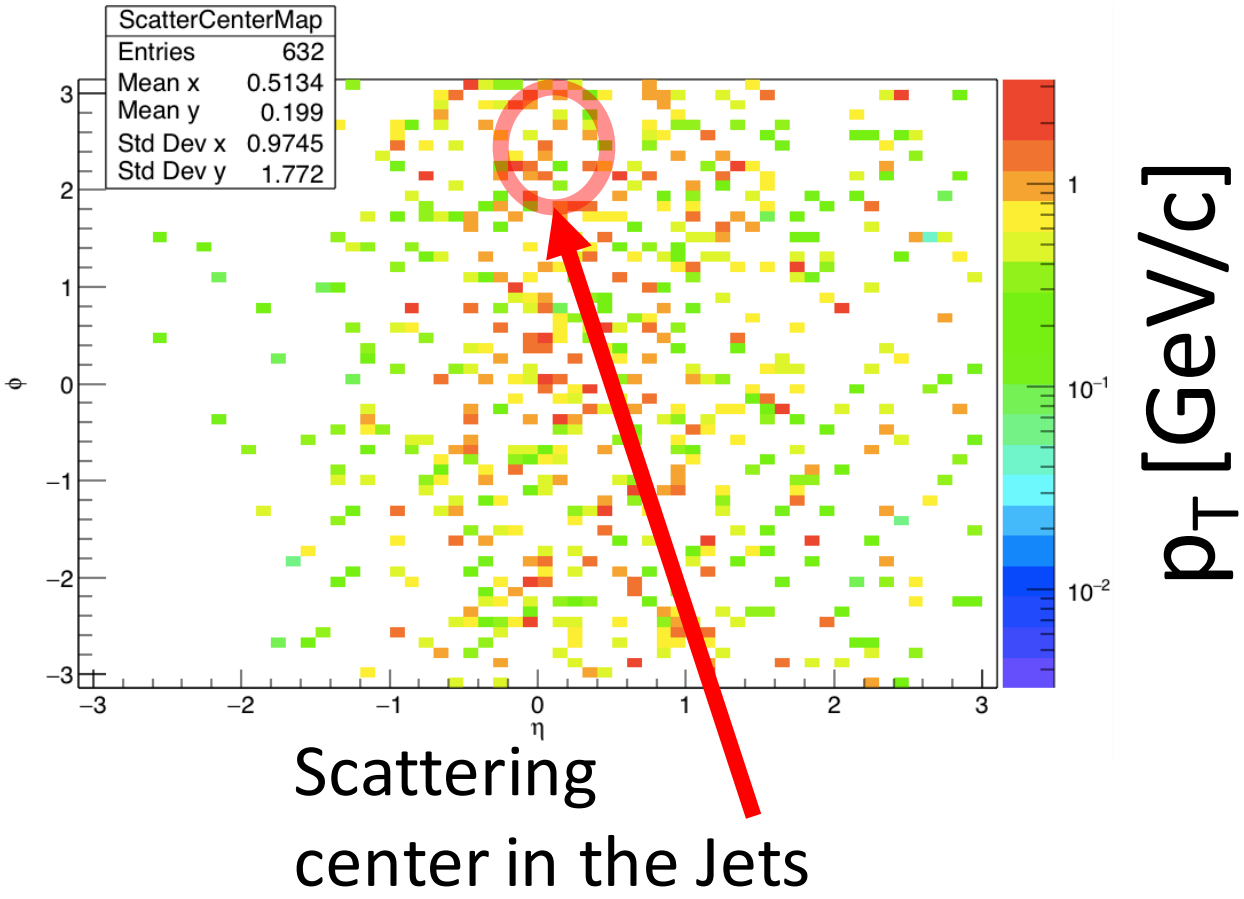
Marco, HP2015

Using that information!

- Event Map

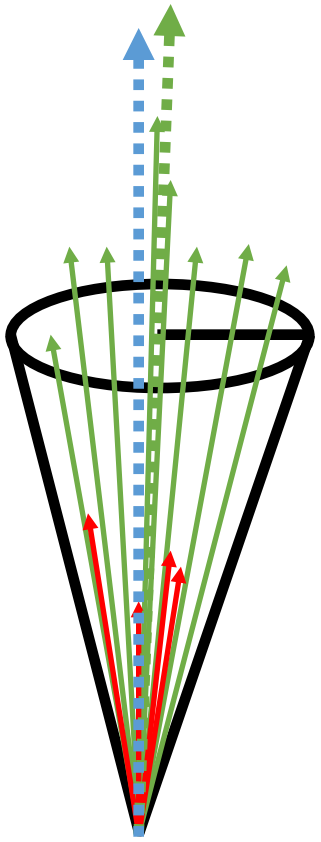


- Scattering centers Map



Background subtraction in JEWEL (two choices)

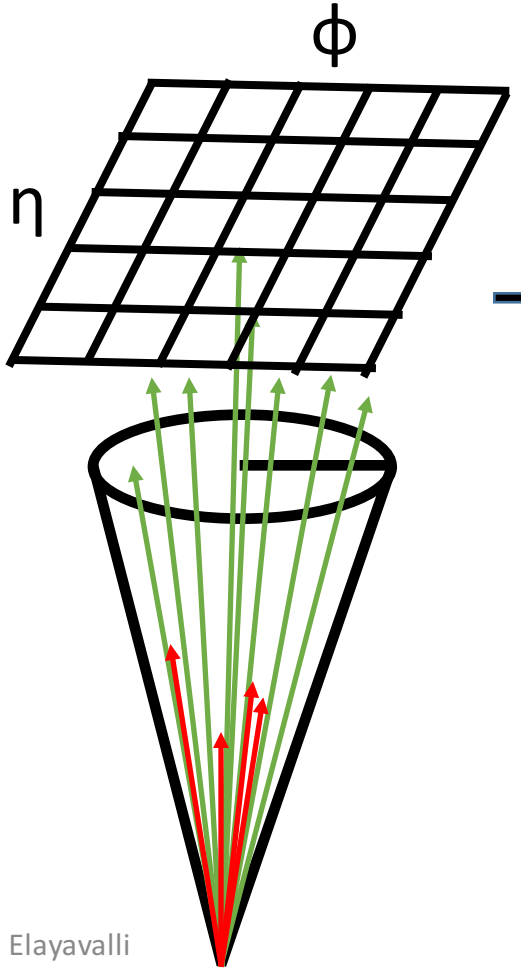
REAL (4MomSub)



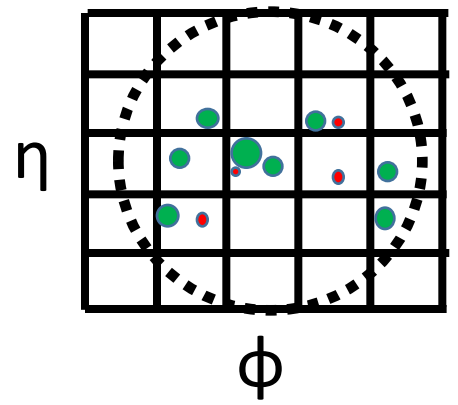
$$p^{\text{4MomSub}} = p^{\text{constituents}} - p^{\text{ScatCenter}}$$

4vector manipulation

DETECTOR-LIKE (GridSub)



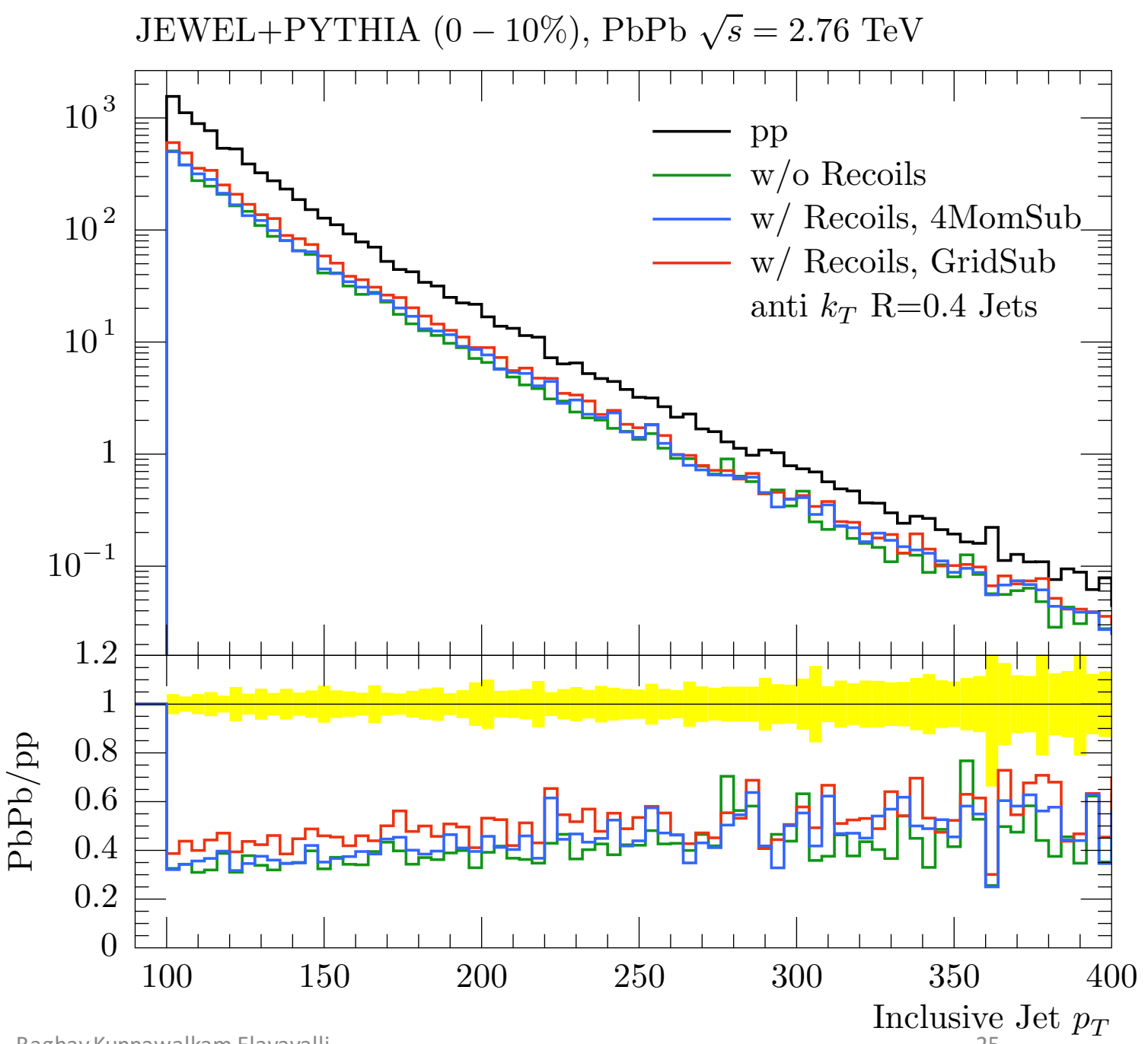
1. 4vector sum inside each box
2. Clustering with boxes as input



How does that look?

1. Perform 4 momenta subtraction from the scattering centers. For a given Jet or annuli (jet shapes). Should be used if possible

2. "Quantize" the event: Detector like finite resolution. Subtract the backgrounds (scattering centers) from the boxes. If box net sum < 0, then set to zero.



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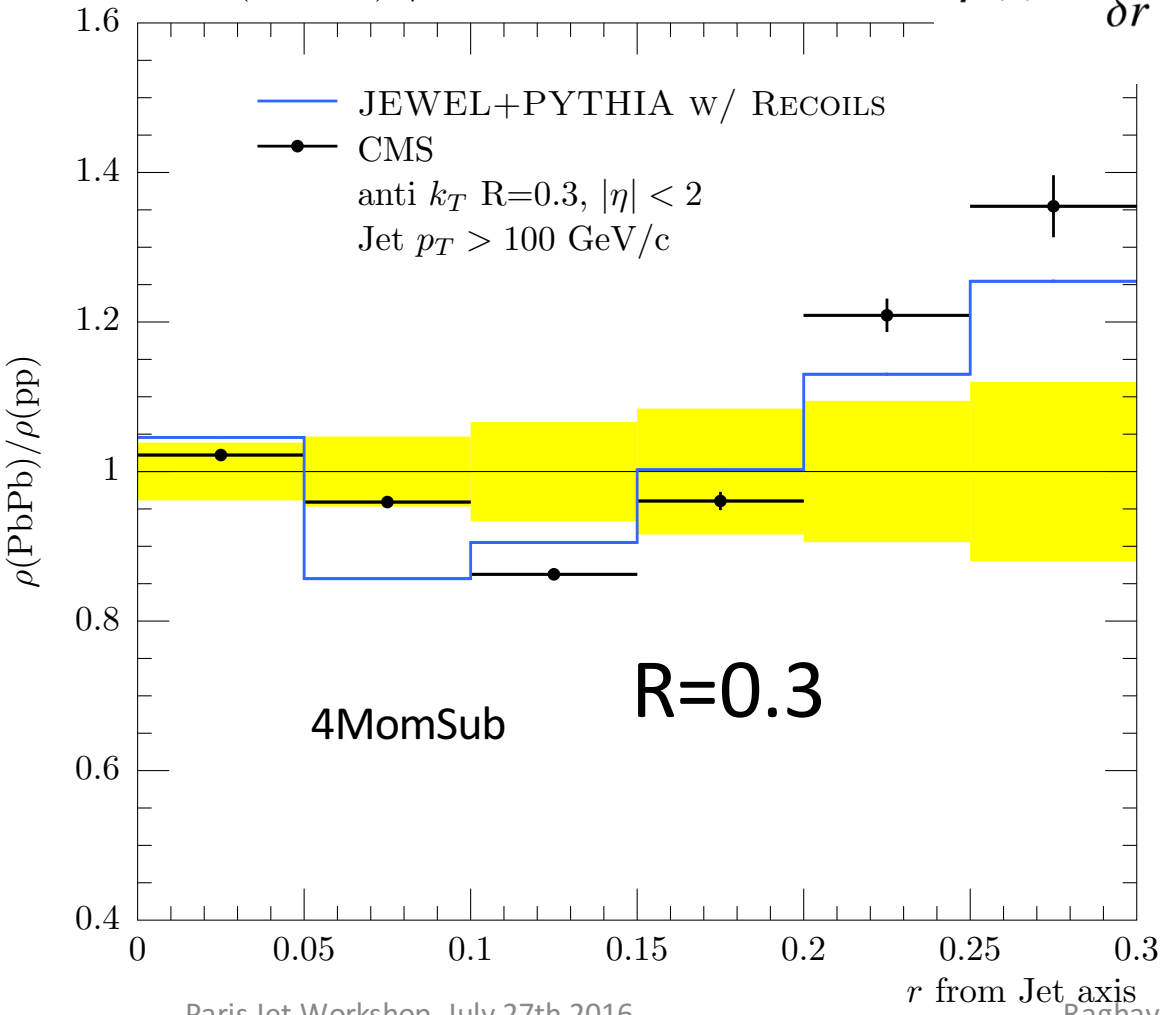
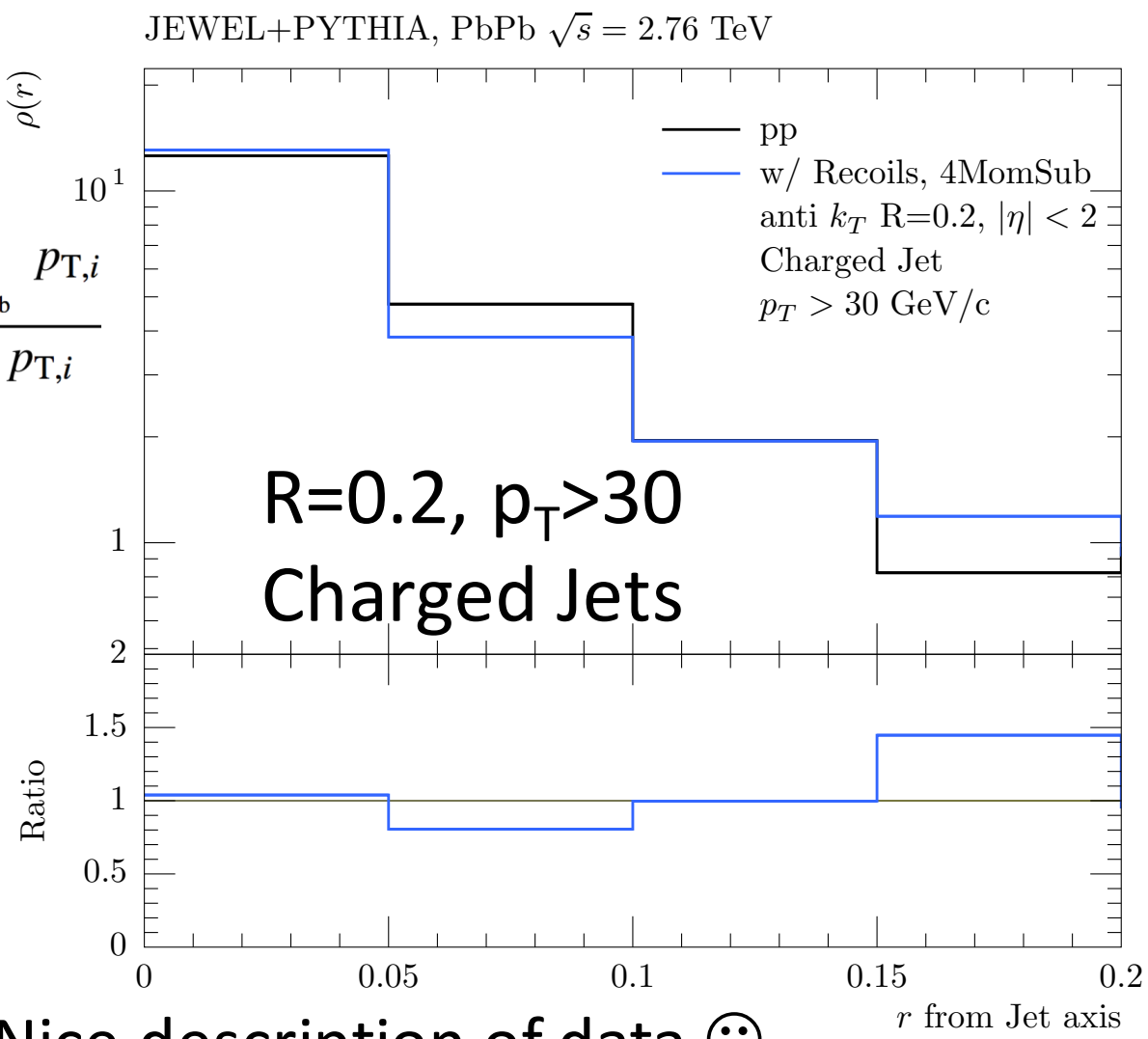
Differential Jet Shapes

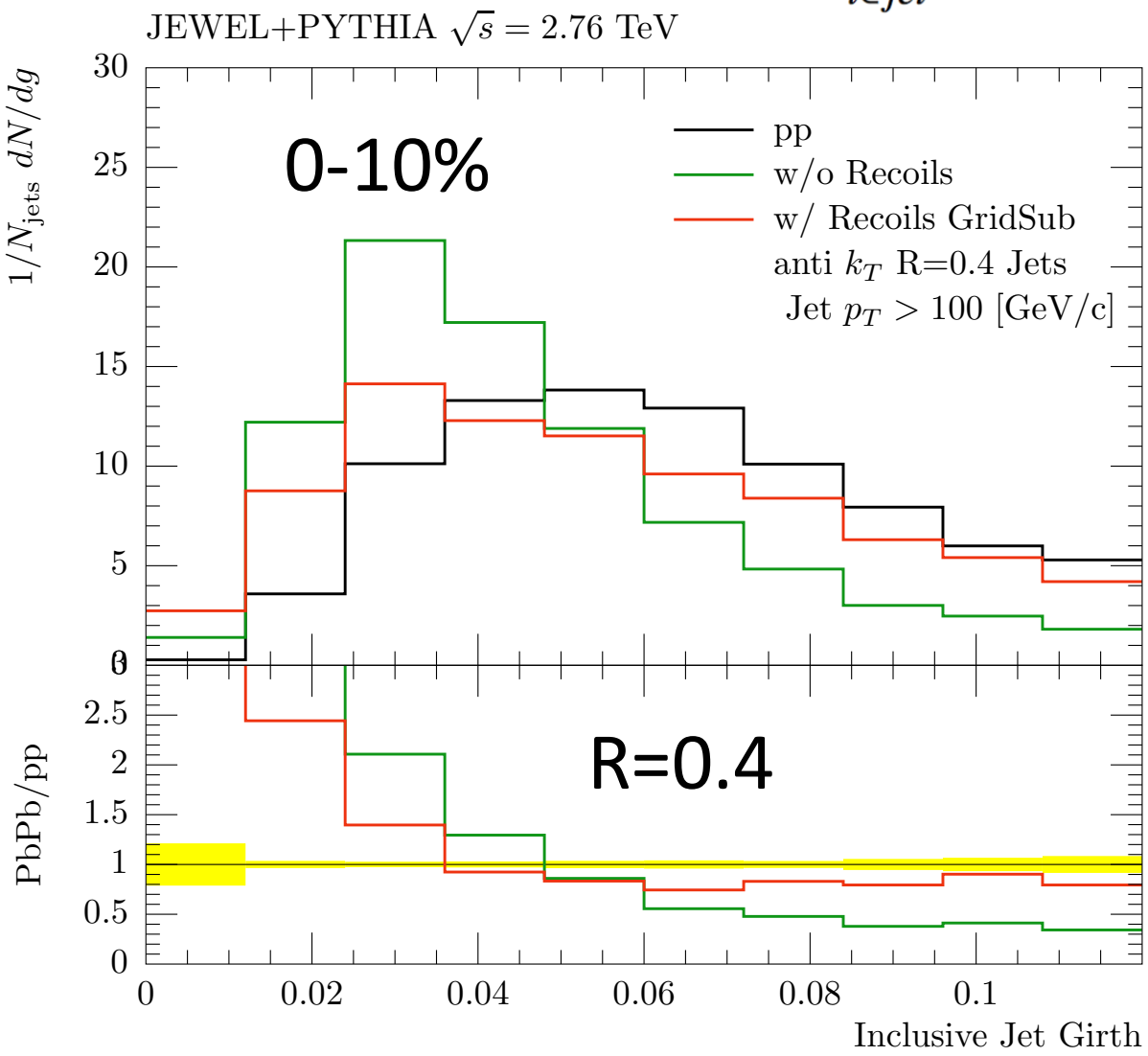
$$\rho(r) = \frac{1}{\delta r} \frac{\sum_{r_a<r_i<r_b} p_{T,i}}{\sum_{r_i<R} p_{T,i}}$$

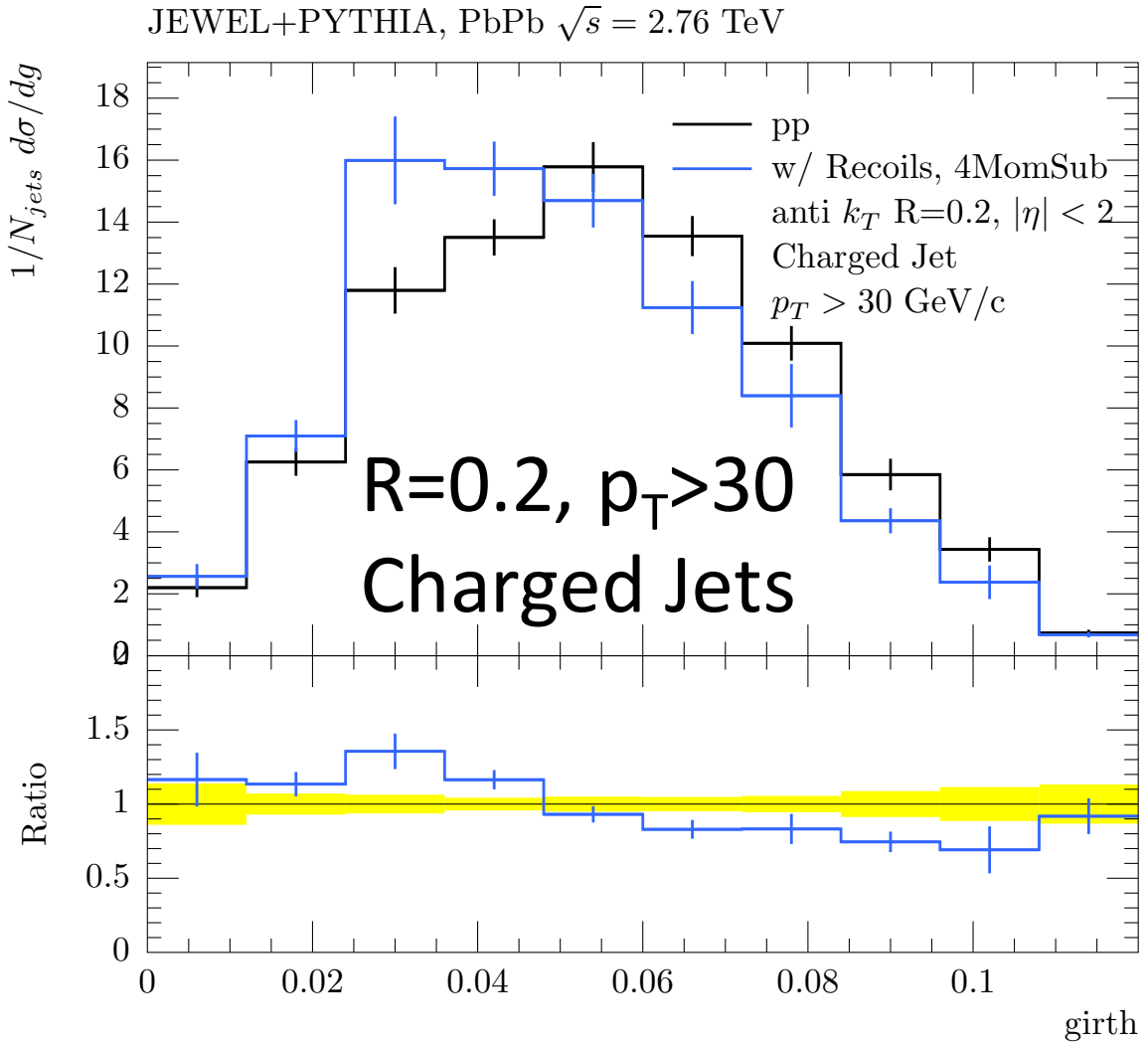




Nice description of data ☺
Although we estimate a larger subtraction in one Δr bin

Radial Moment $g = \sum_{i \in jet} \frac{p_T^i}{p_{T,jet}} |\Delta R_{i,jet}|$

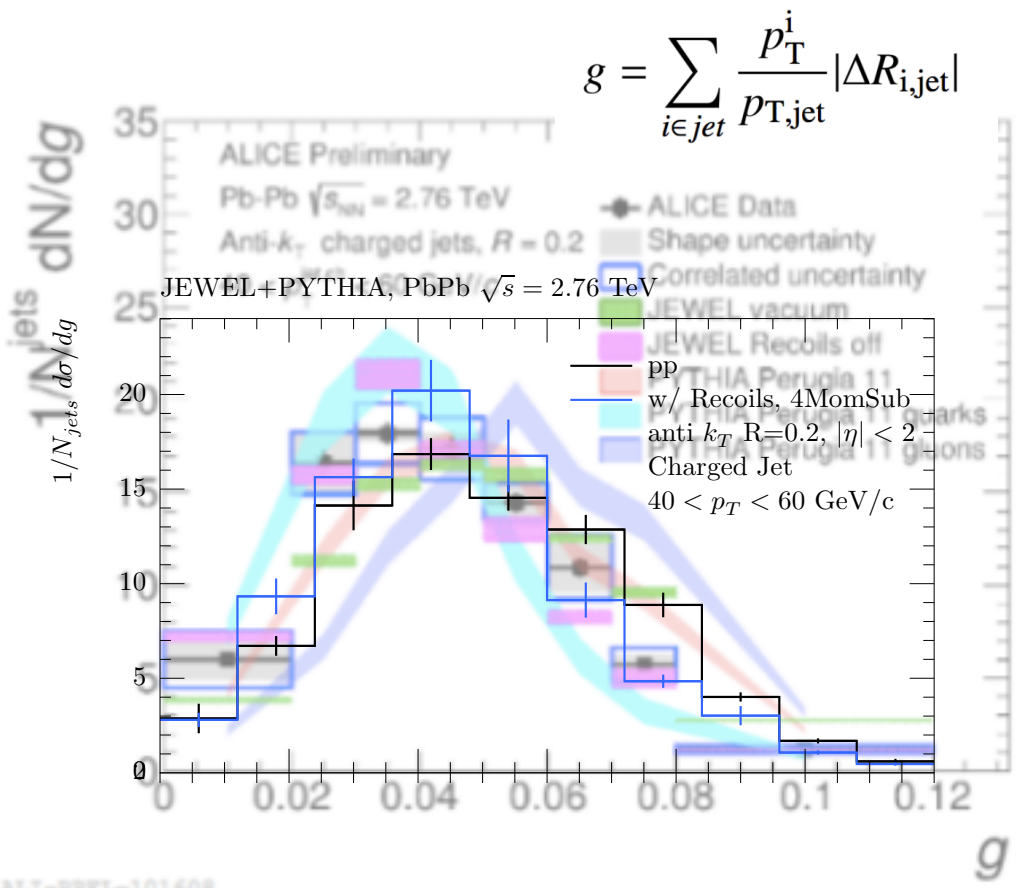


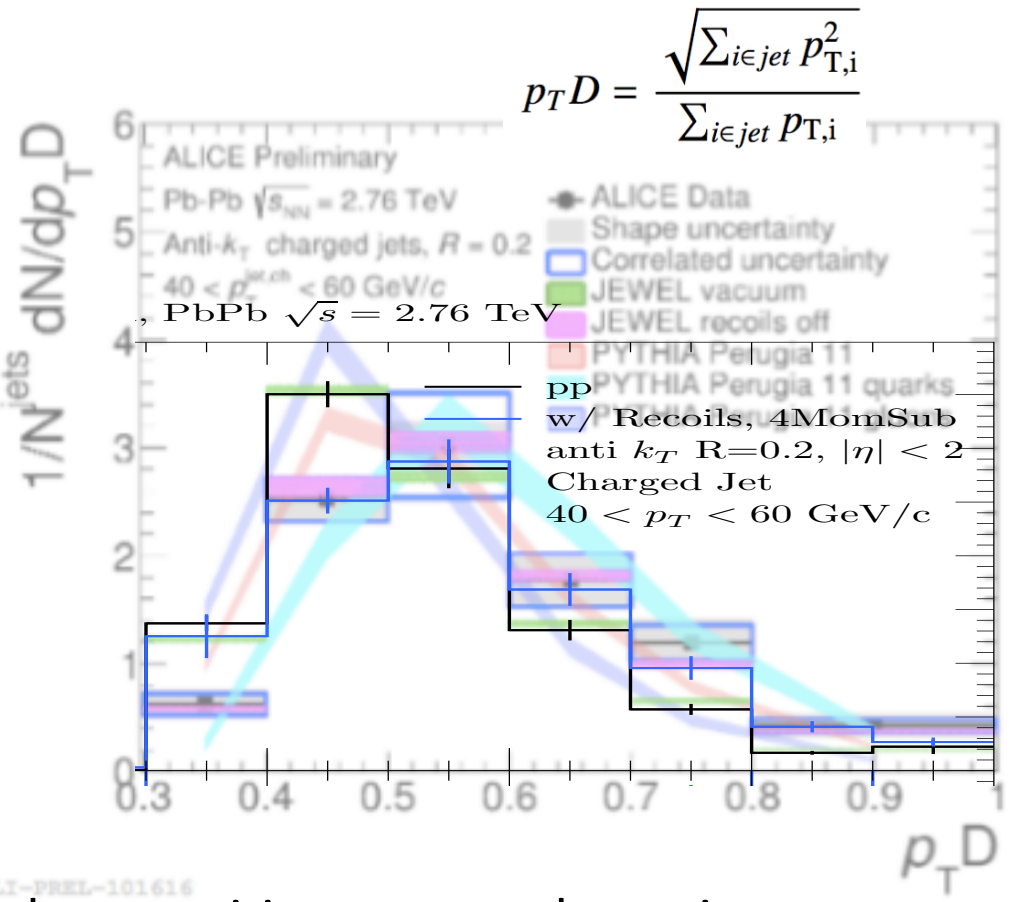


We see a very nice shift in the PbPb jet girth compared to pp. Jets are more evenly filled!

Comparing with ALICE preliminary results

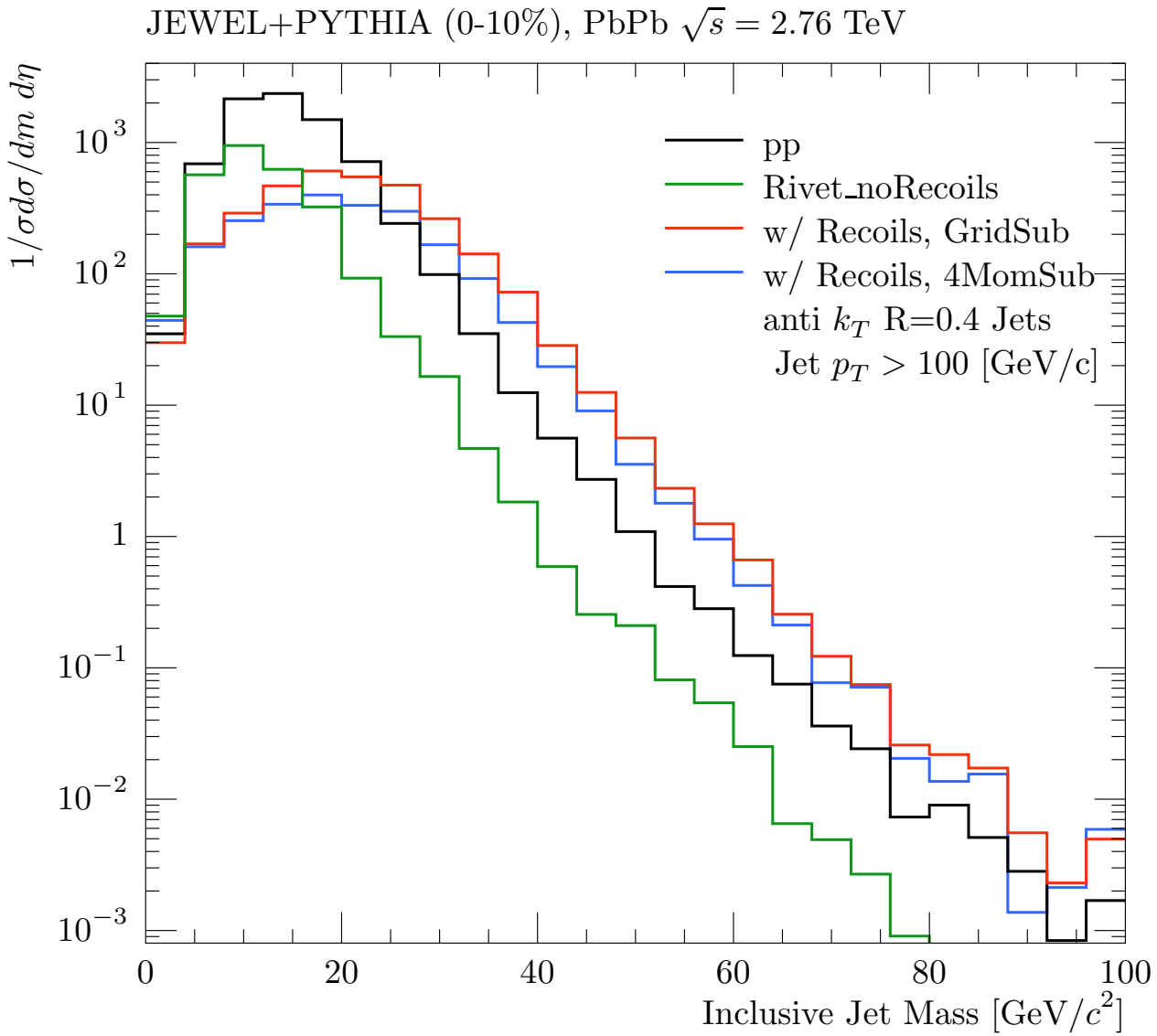
- NOTE: R = 0.2 and Charged Jets (40 < jet p_T < 60 GeV/c)



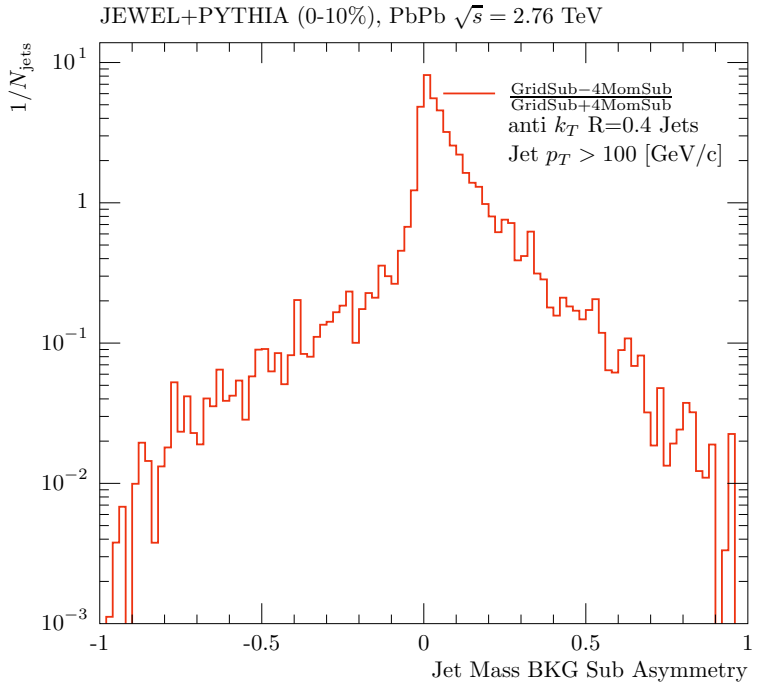


- Marginally better. These observables are not that sensitive to our subtraction

Jet Mass, another useful observable



Background subtracted JEWEL provides a shift in pp vs PbPb
Would be interesting to see at low p_T….

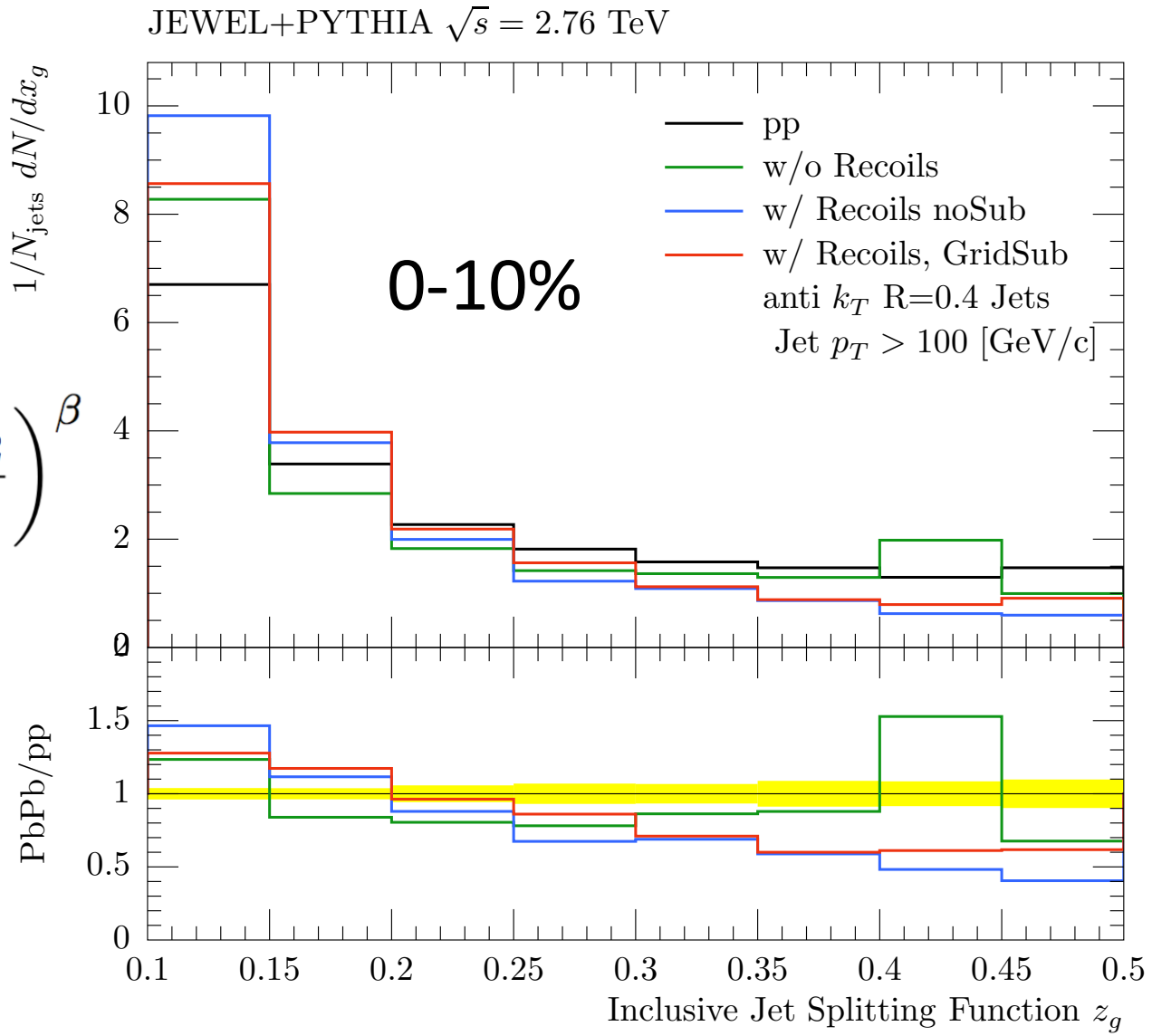


Structure of Jet splitting with JEWEL

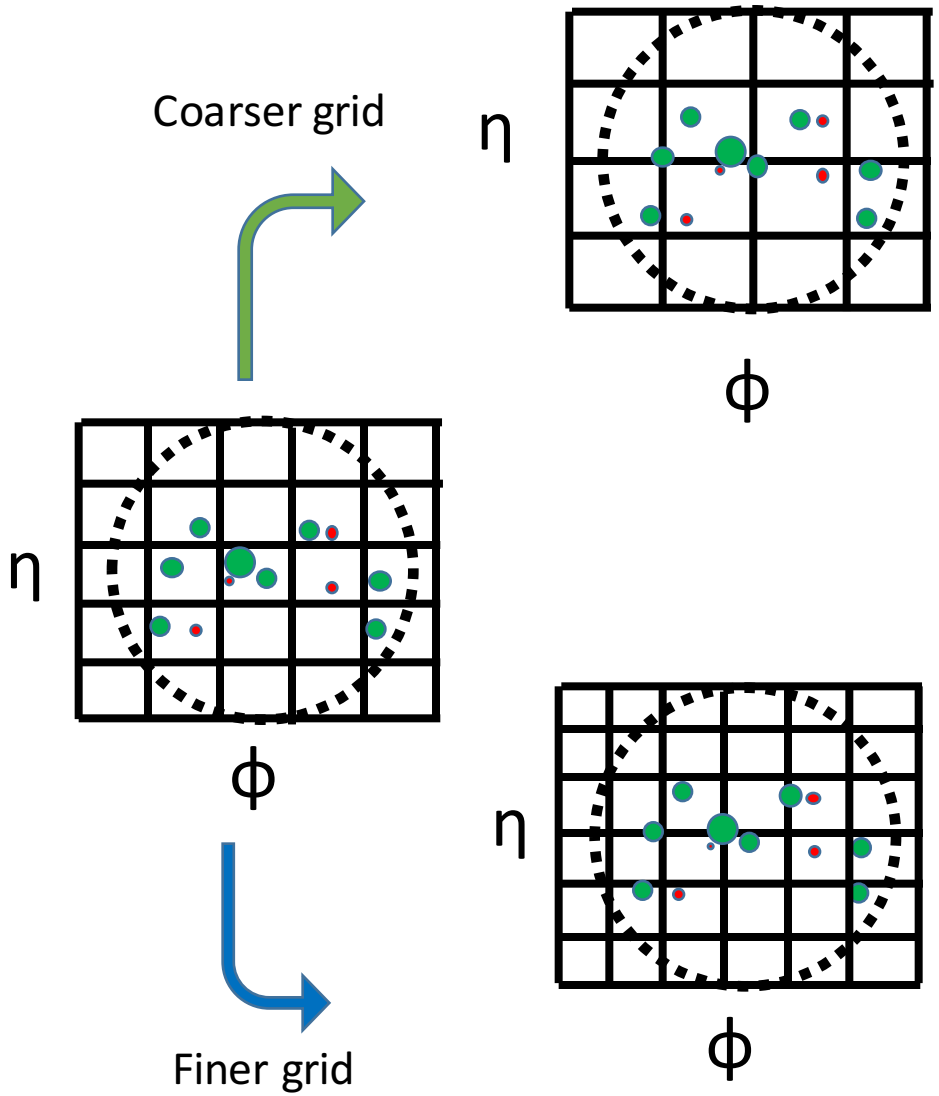
See Marta's talk for more experimental details

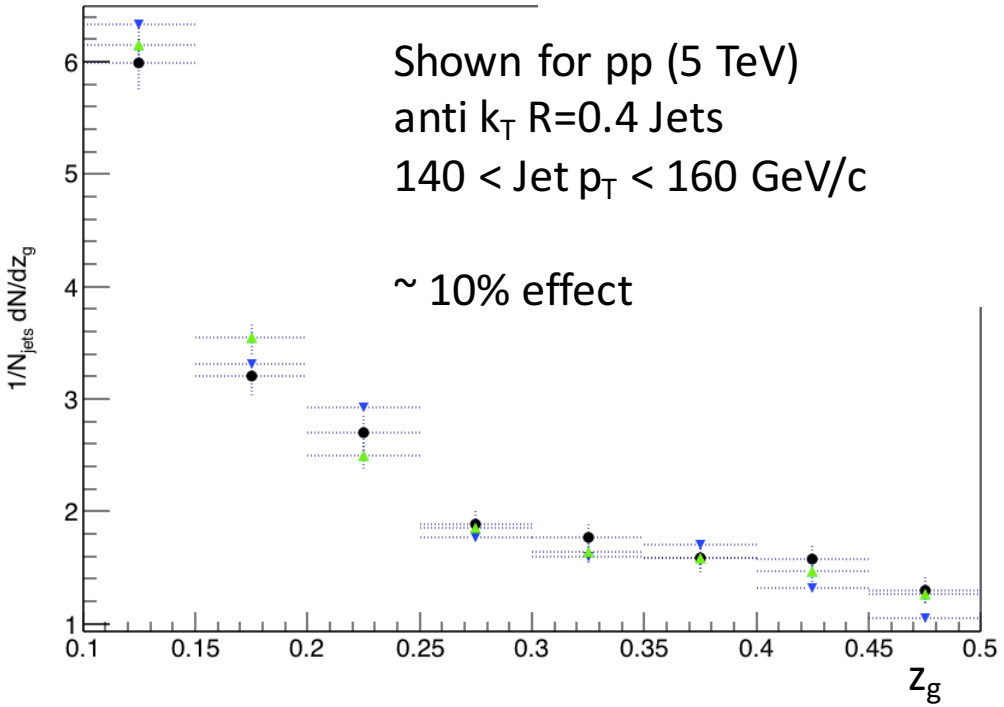
- mMDT (with β= 0 and z_{cut} = 0.1)
- $z_g = \frac{\min(p_{T1}, p_{T2})}{p_{T1} + p_{T2}} > z_{\text{cut}} \left(\frac{\Delta R_{12}}{R_0}\right)^{\beta}$

  softdrop
- Calculated using softdrop plugin from FastJet
- Determine systematics using variation of the grid size



Systematics of varying the grid size

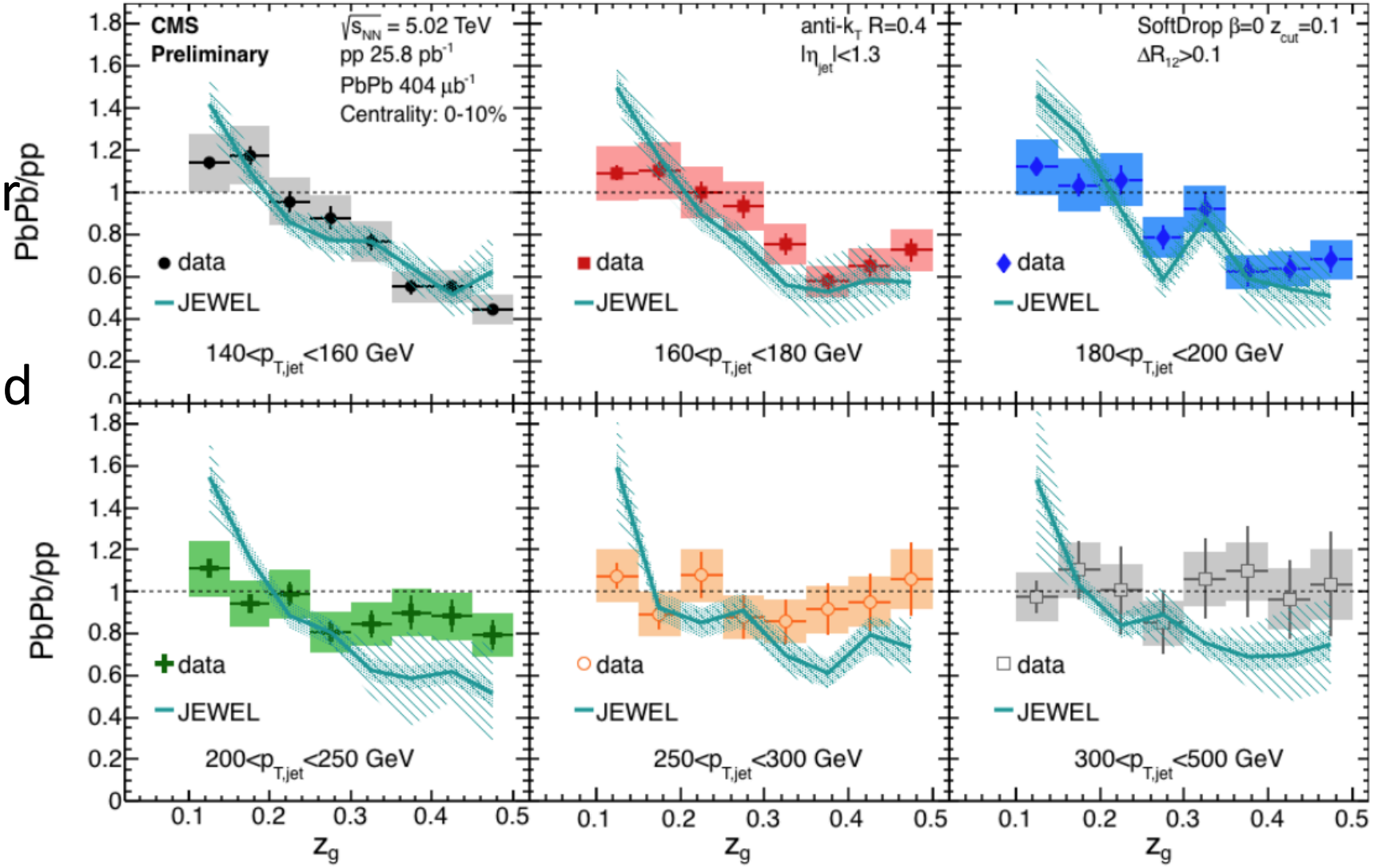




Comparing with Data

CMS-PAS-HIN-16-006

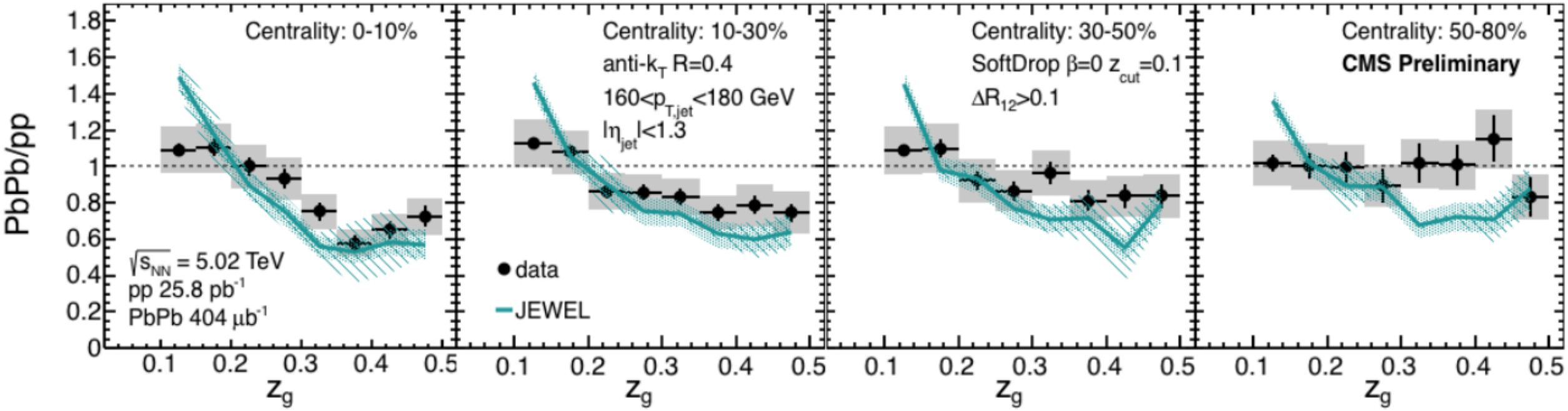
- Good description!
- The PbPb jets prefer to be more asymmetric as compared to pp (and general qcd) which features harder splitting



Comparing with Data

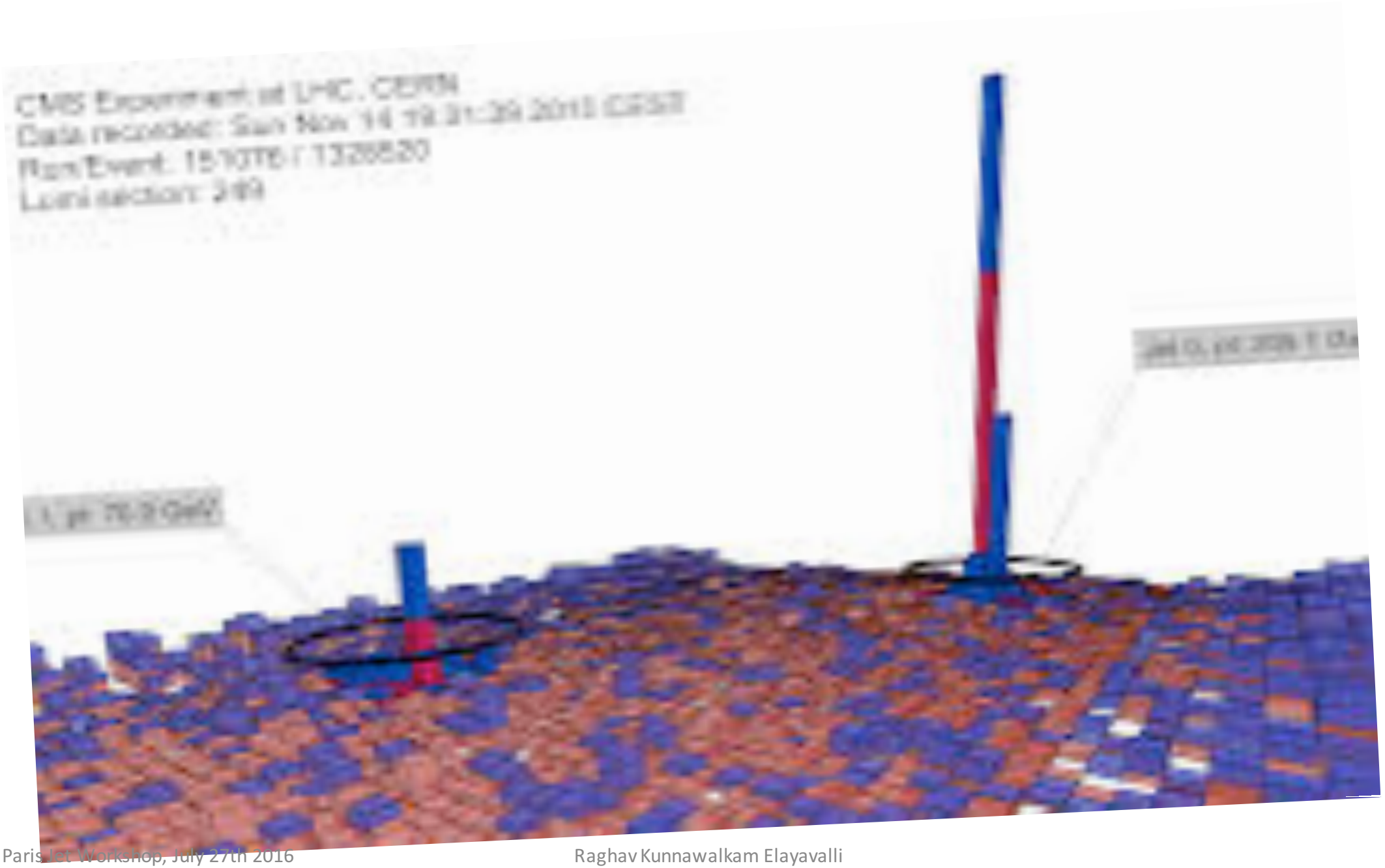
CMS-PAS-HIN-16-006

- Good general description!
- Centrality dependence clear but JEWEL Peripheral are a bit iffy due to the medium model.



- JEWEL is now capable of producing and predicting momentum asymmetry in V+Jet events !
- Improved analysis strategy including the recoils in the event record helps in calculating differential observables
- Background subtraction with JEWEL does the job well!

- Paris is a natural place to study Jet Quenching phenomenon ☺


CMS Experiment at LHC, CERN
Data recorded: Sun Nov 14 19:31:39 2011 CEST
Run/Event: 151076 / 1328820
Lumi section: 249


Thank you for
your attention!

- About the network
- Monte Carlo schools
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- The projects
- The teams
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Short-term studentships

The MCnet short-term studentship programme started again in 2013. These can be held at any MCnet node for a period of three to six months. Please see the links on the right for information on the scheme and on how to apply, or contact Mike Seymour if you cannot find the information there.

There is no formal deadline, the last few studentships will be studentships will be allocated on a **first come first served** basis. Applicants will receive a response within one month of submitting their application.

- on-line application form

Information on:

- Who can apply?
- What are they for?
- Where can they be held?
- When are they for?
- What is offered?
  - Research projects
  - Private sector secondments
  - Outreach projects
- How to apply?
- What happens next?

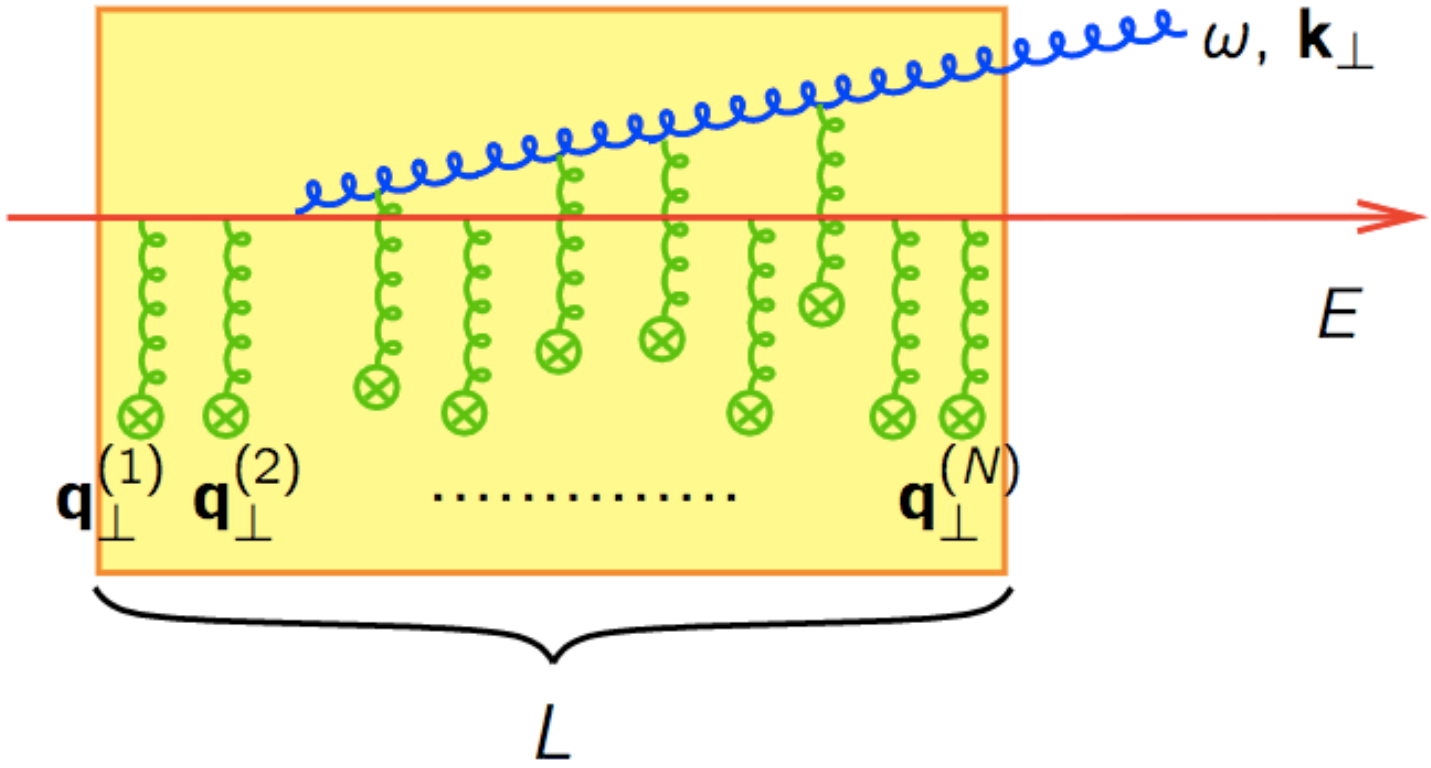
- All information on a single printable page.

MC Net funding approved for 2017-2020!

Please think about applying ☺

Bonus Slides!

Collinear gluon LPM in eikonal limit

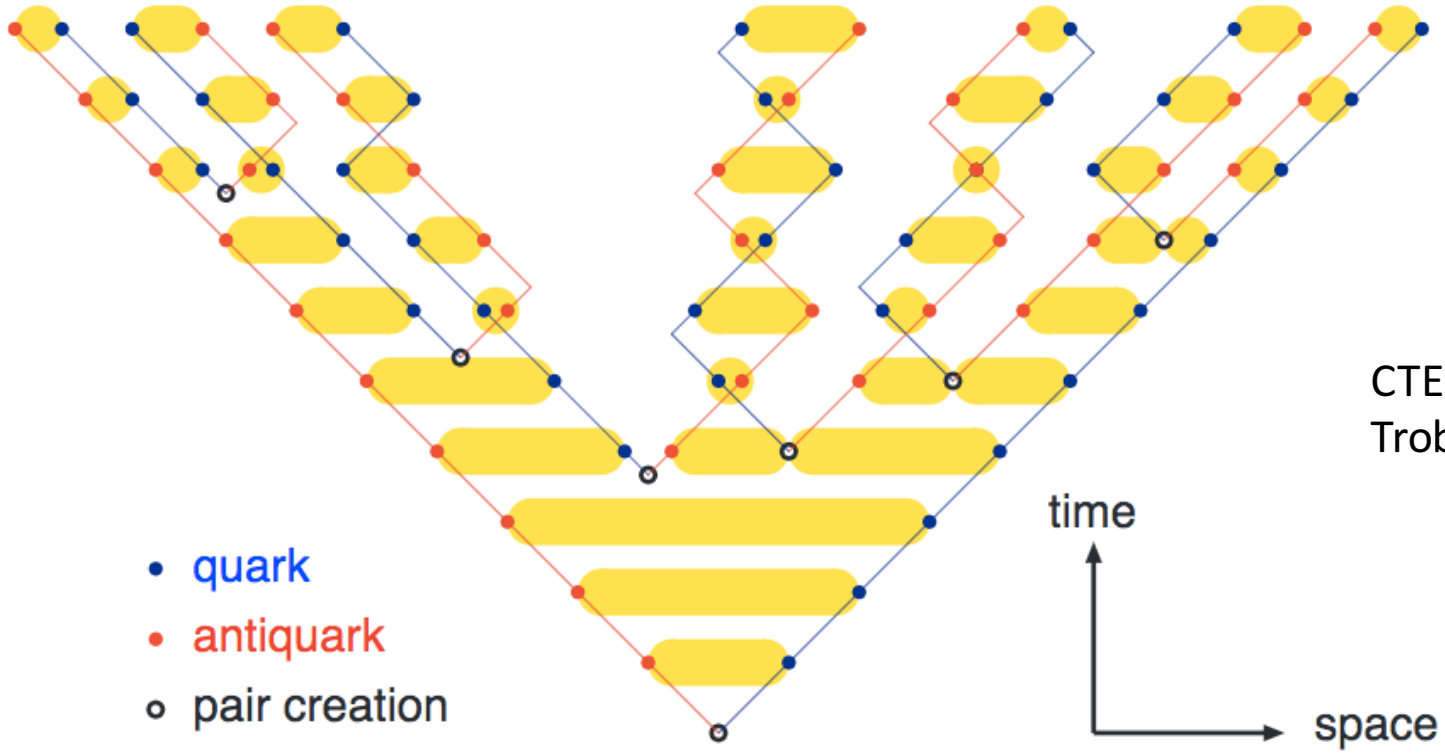


- High energy approx
  - E >> w >> k, q
- Elastic scattering centers
- Transport coefficient characterizes the medium

The Lund Model

Combine yo-yo-style string motion with string breakings!

Motion of quarks and antiquarks with intermediate string pieces:



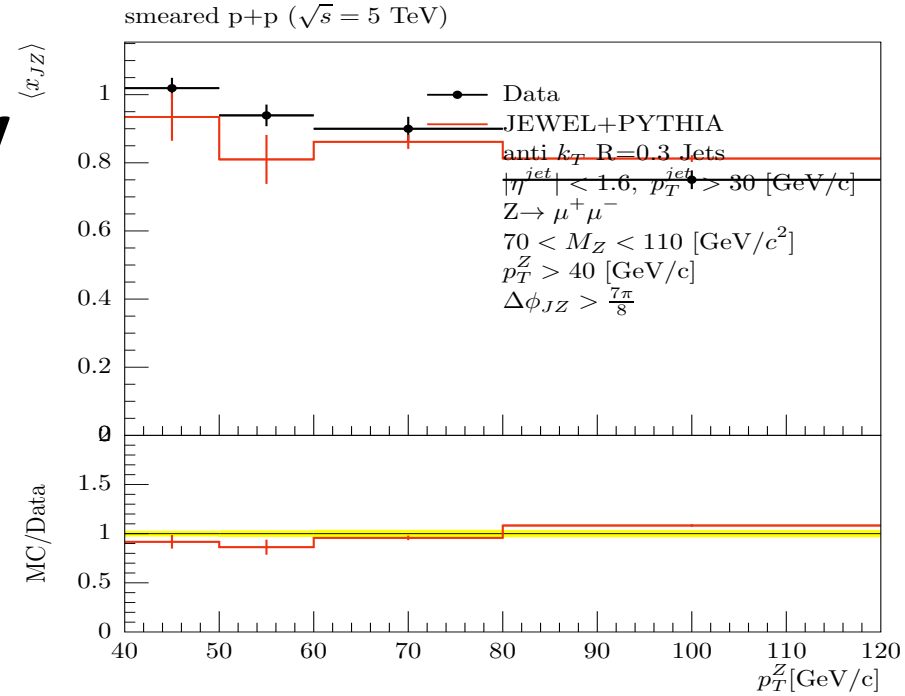
CTEQ School 2016, Trobjorn

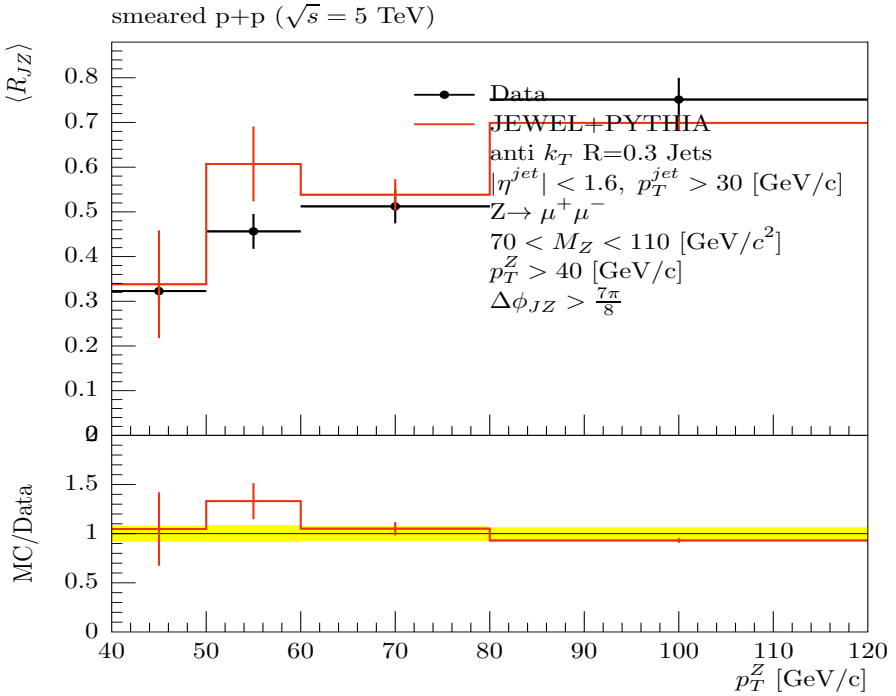
A q from one string break combines with a $\bar{q}$ from an adjacent one.

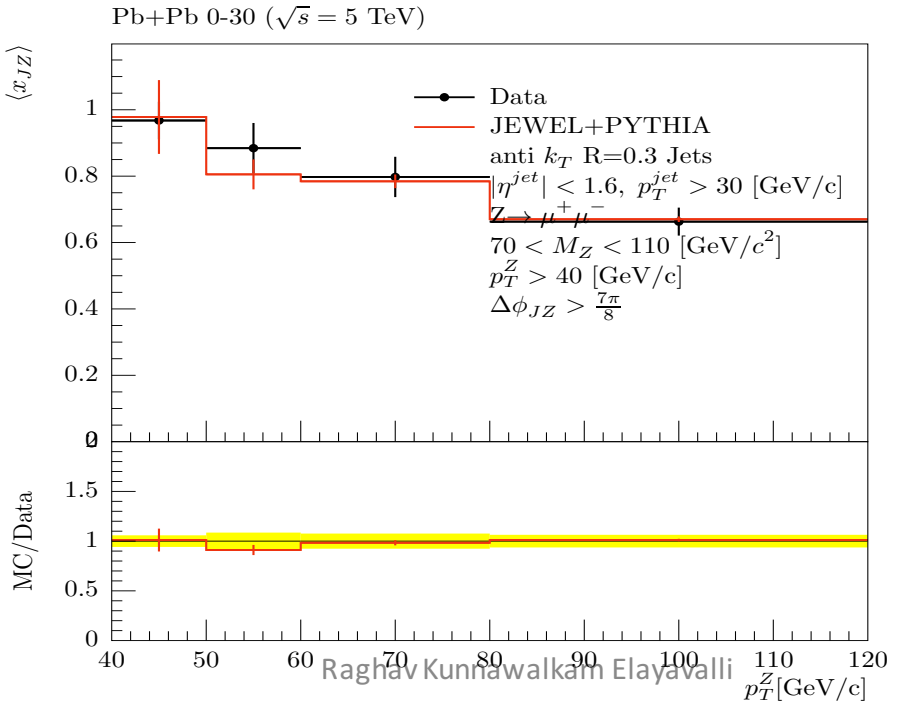
Gives simple but powerful picture of hadron production.

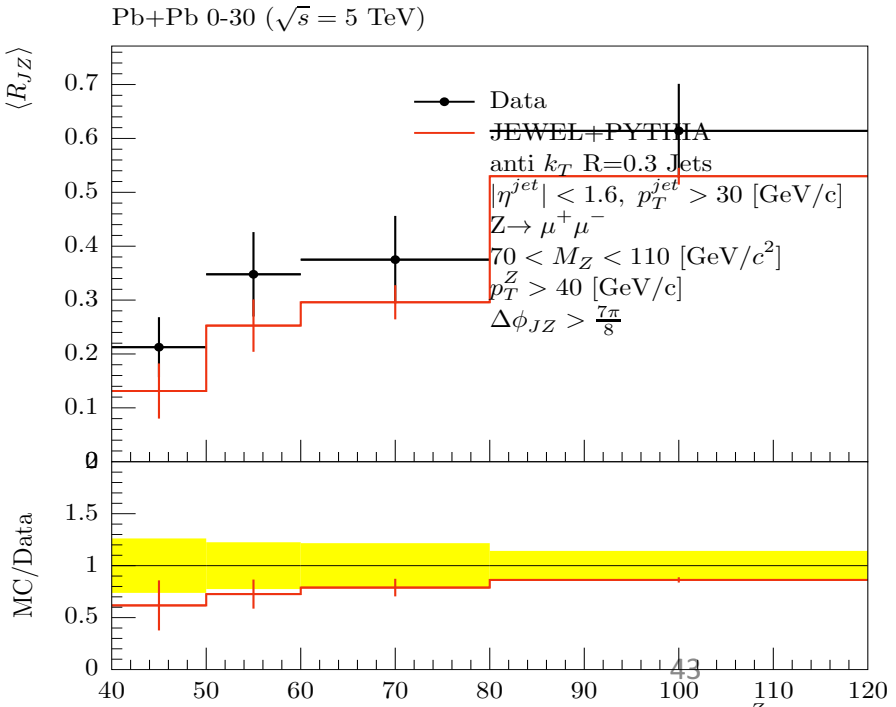
CMS 5 TeV

$\langle X_{JZ} \rangle$, R_{JZ}

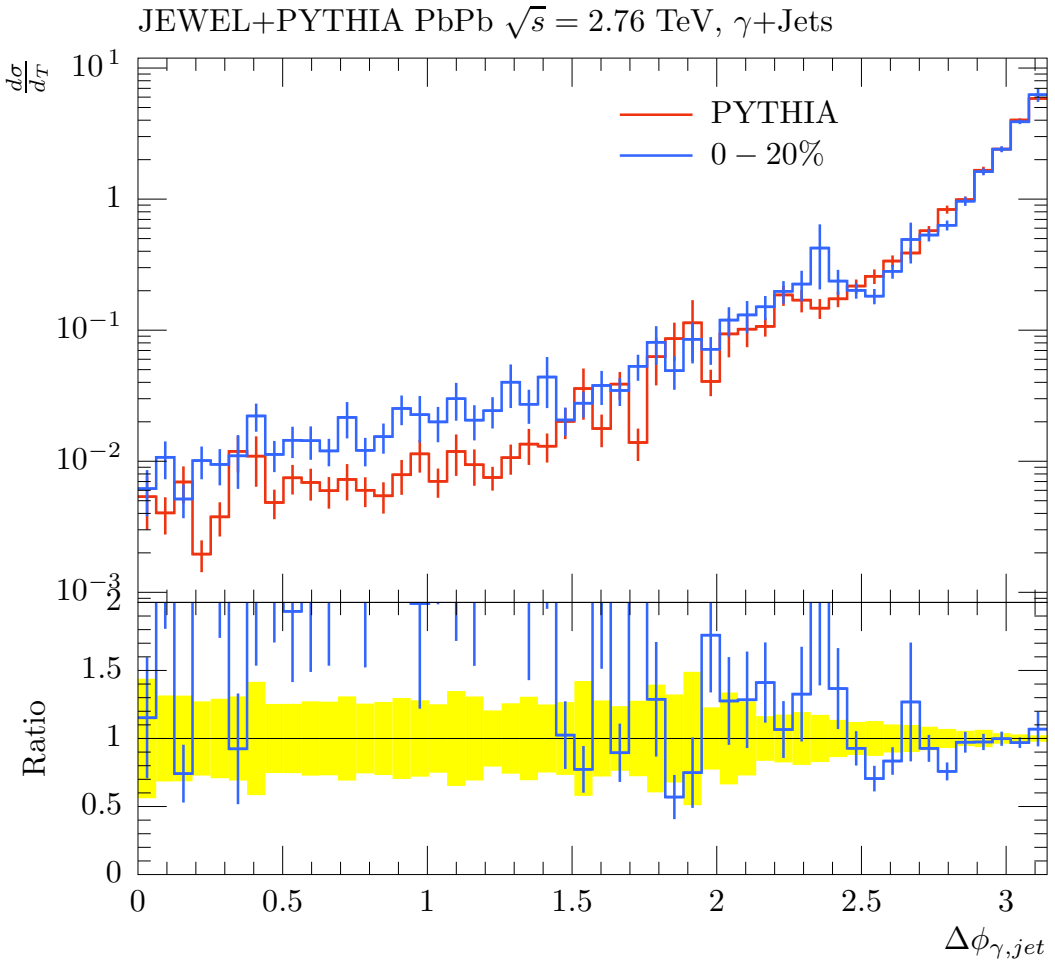


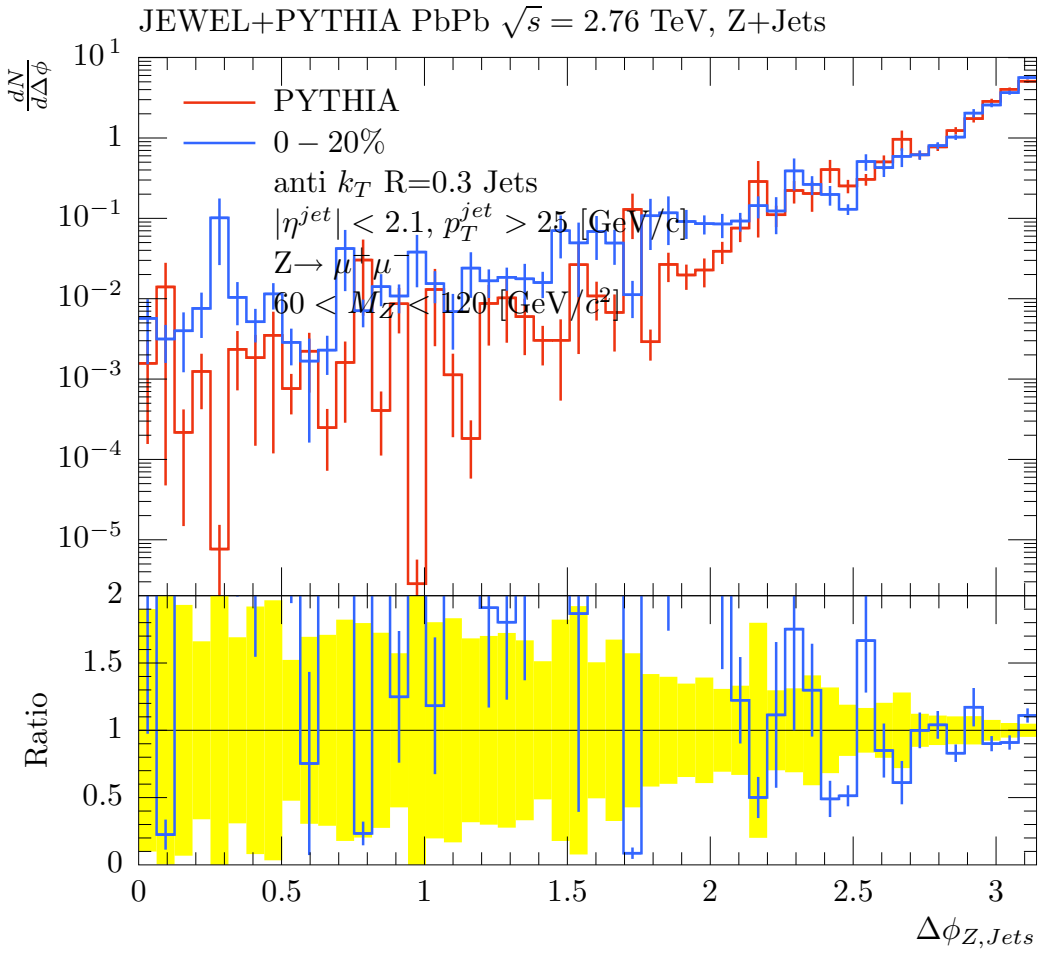




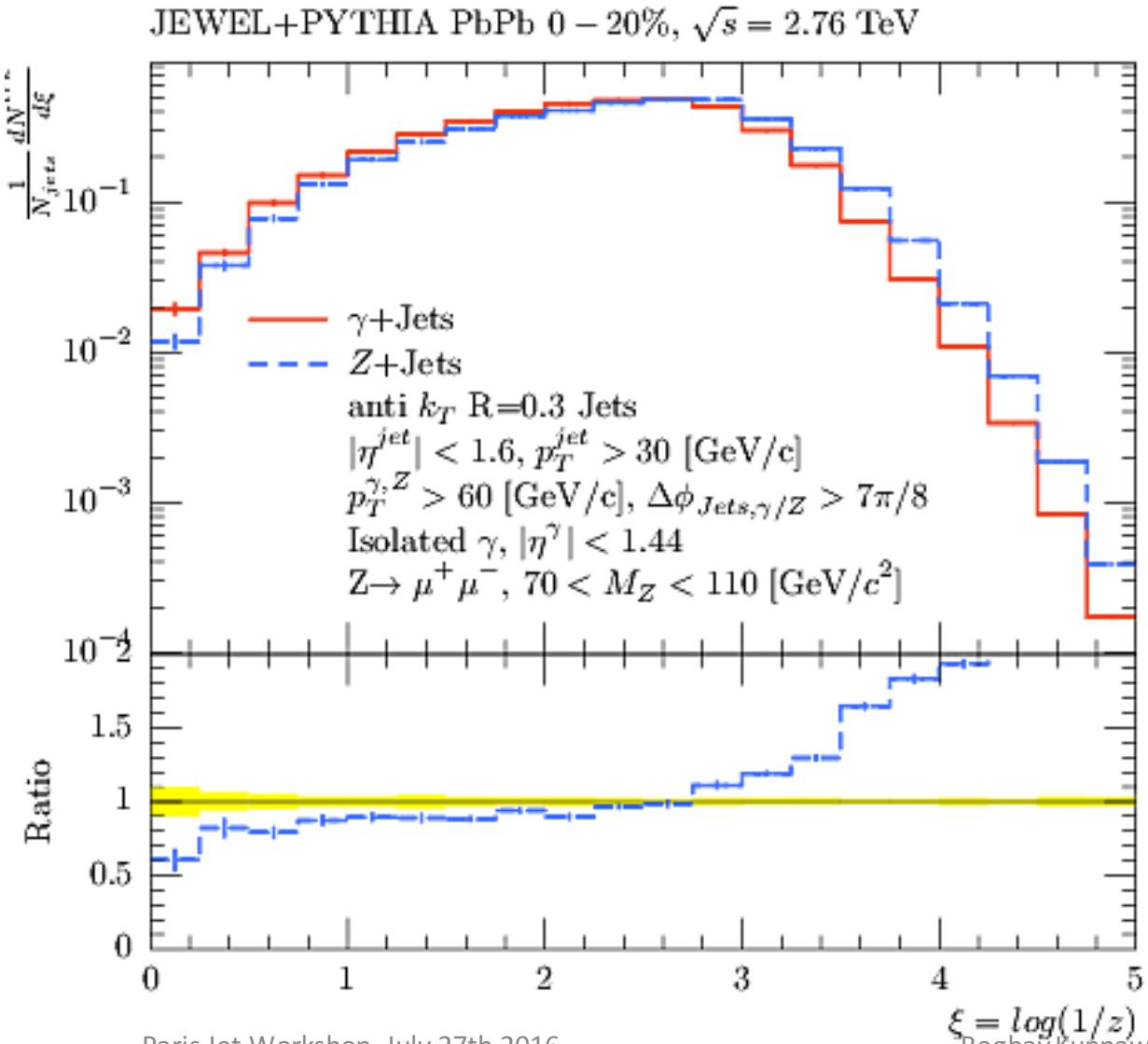


Delta Phi between pp and PbPb in JEWEL V+Jet

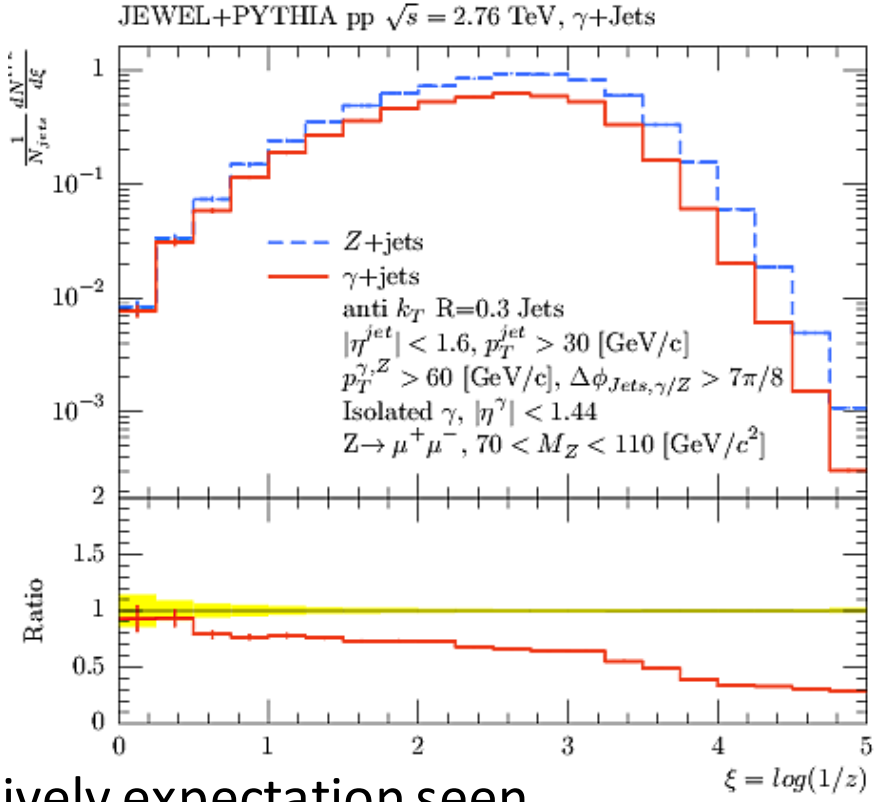




Fragmentation Function comparison

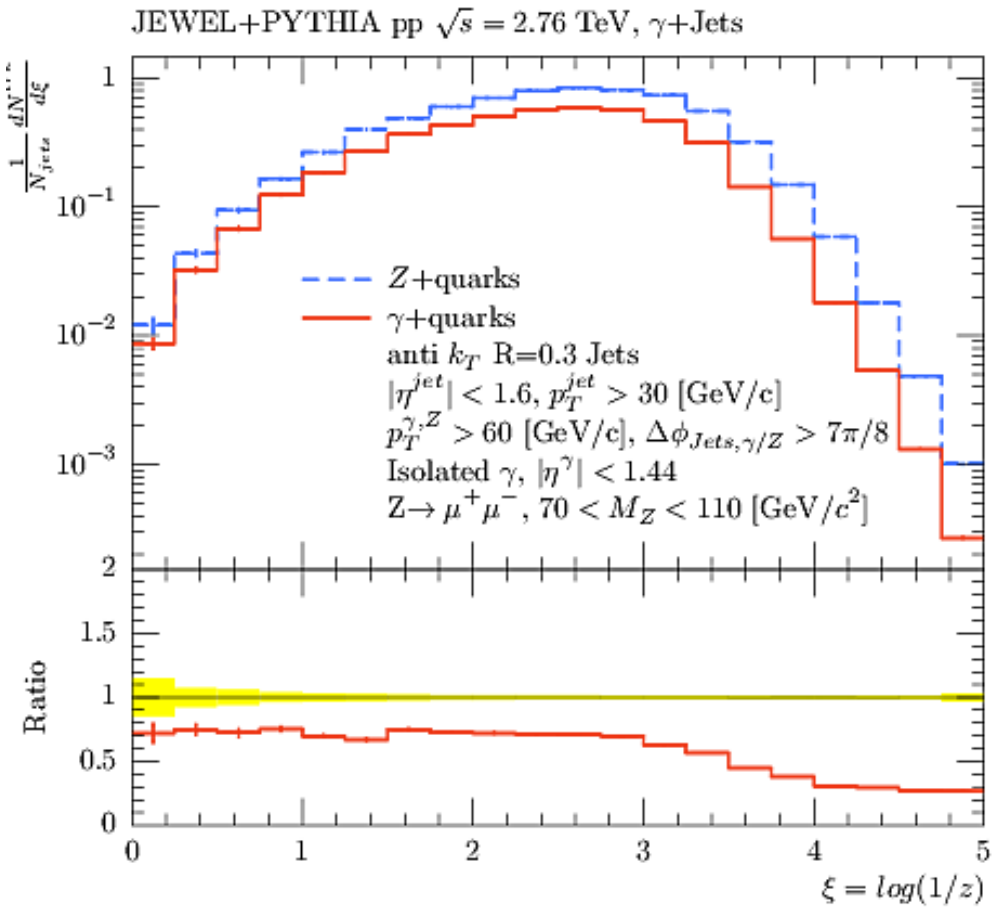


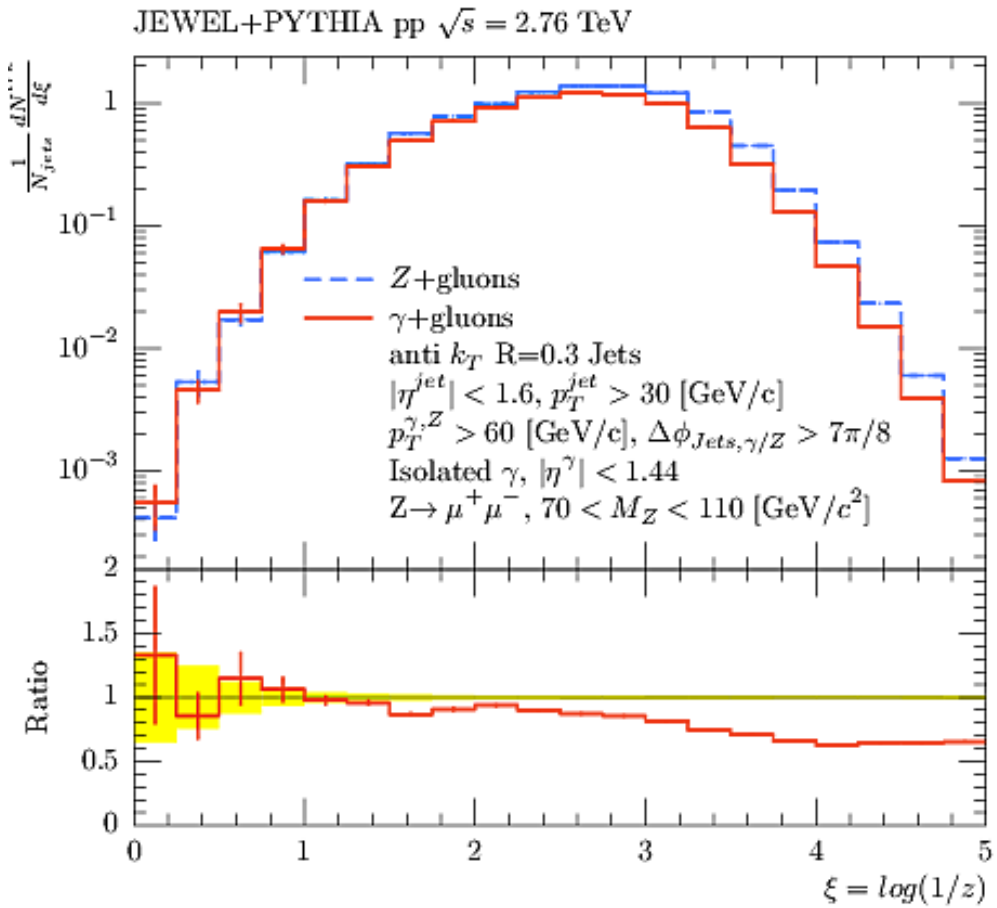
- Take with pinch of salt: underlying spectrum more harder for Z Jets



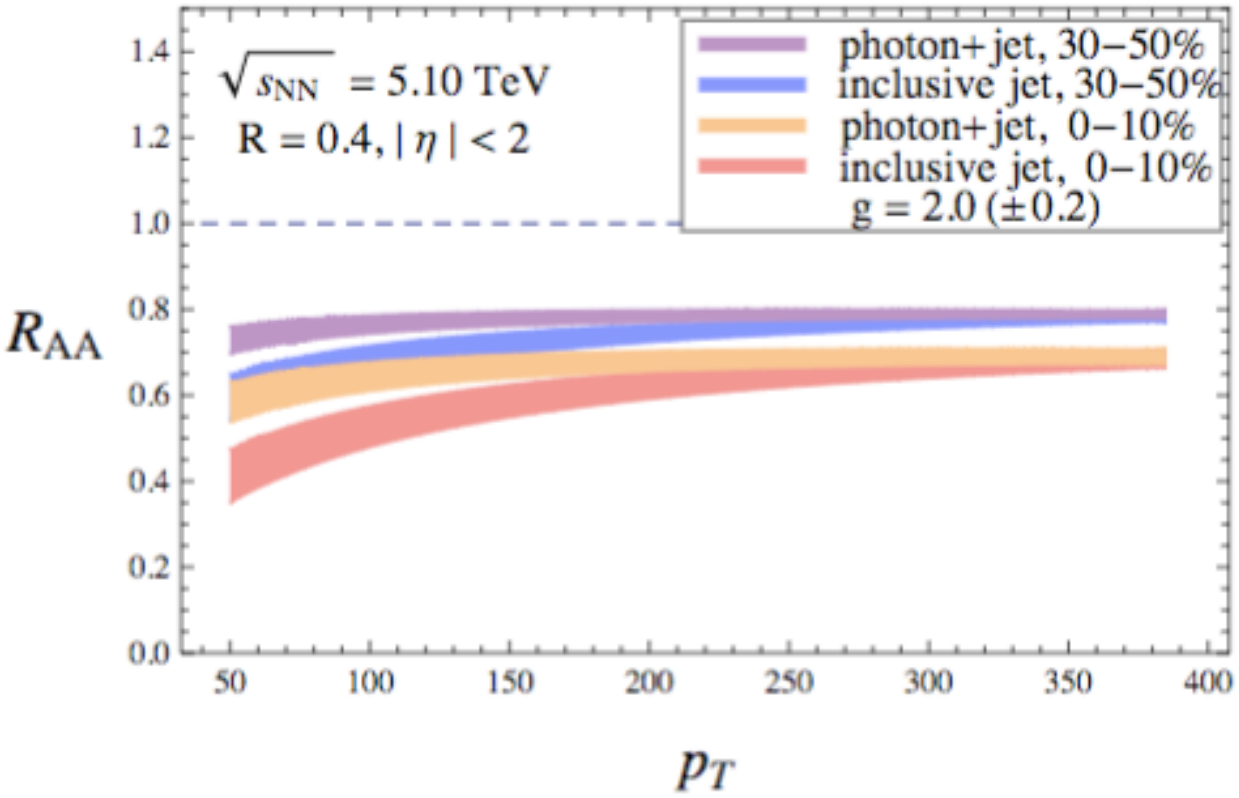
- Naively expectation seen
- Decrease of hard scattered tracks in the Z vs gamma
- Opposite trend in the low pT tracks.

What's causing the difference in pp?

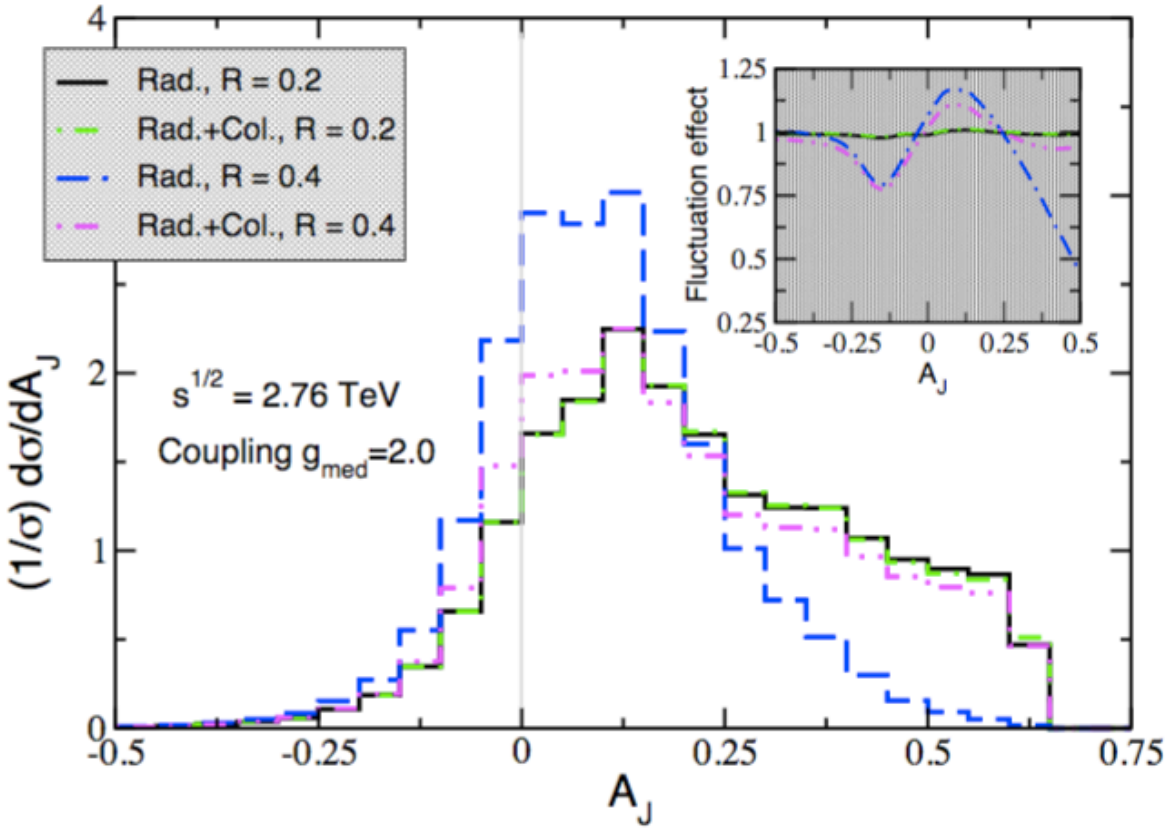




Other theoretical calculations

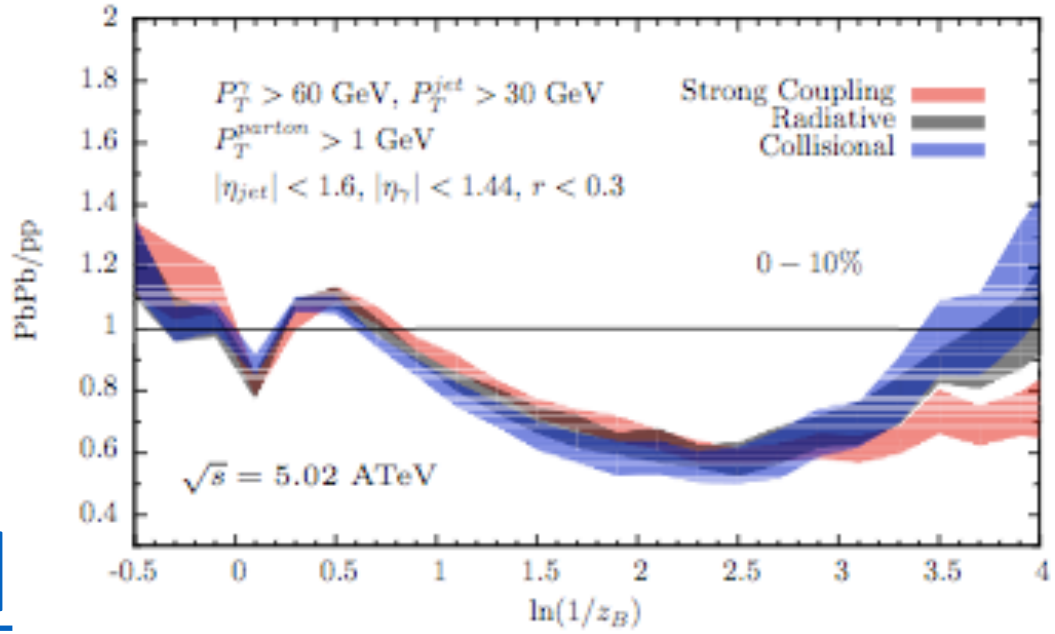


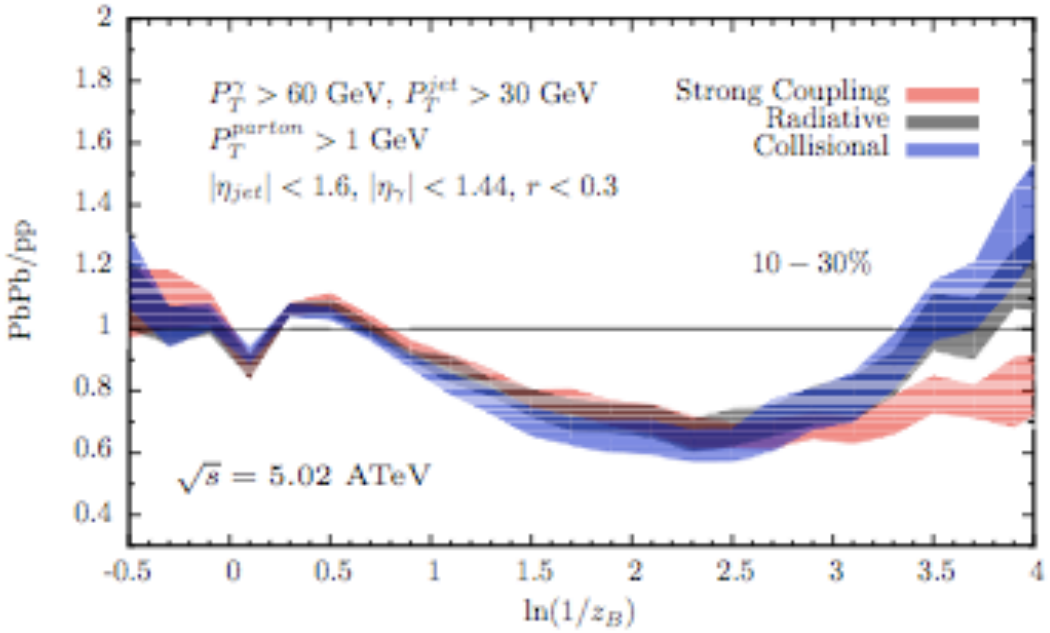
YTChein, SCET prediction

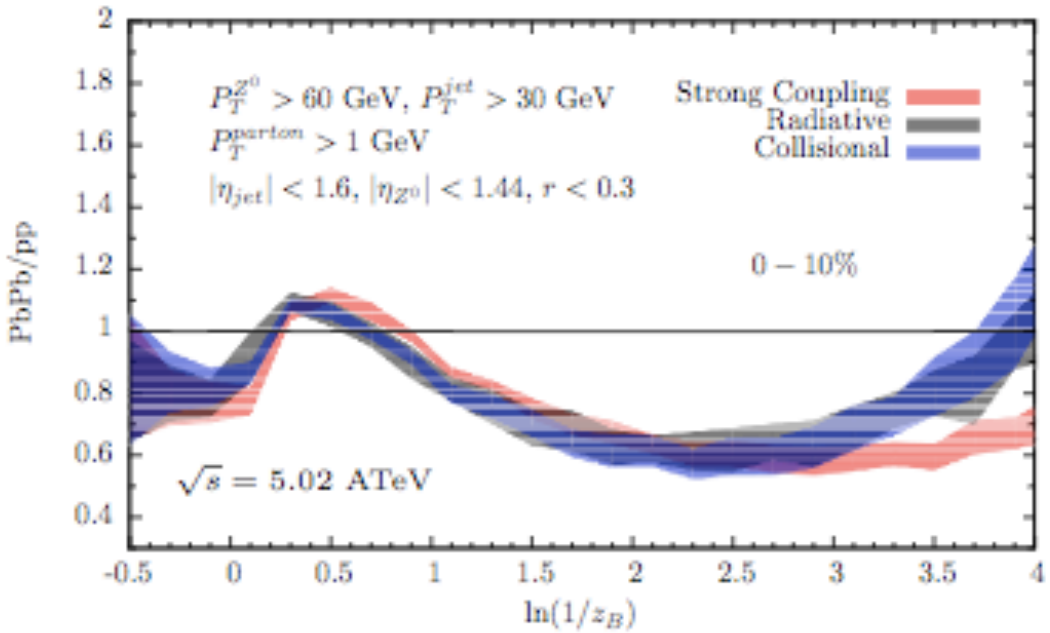


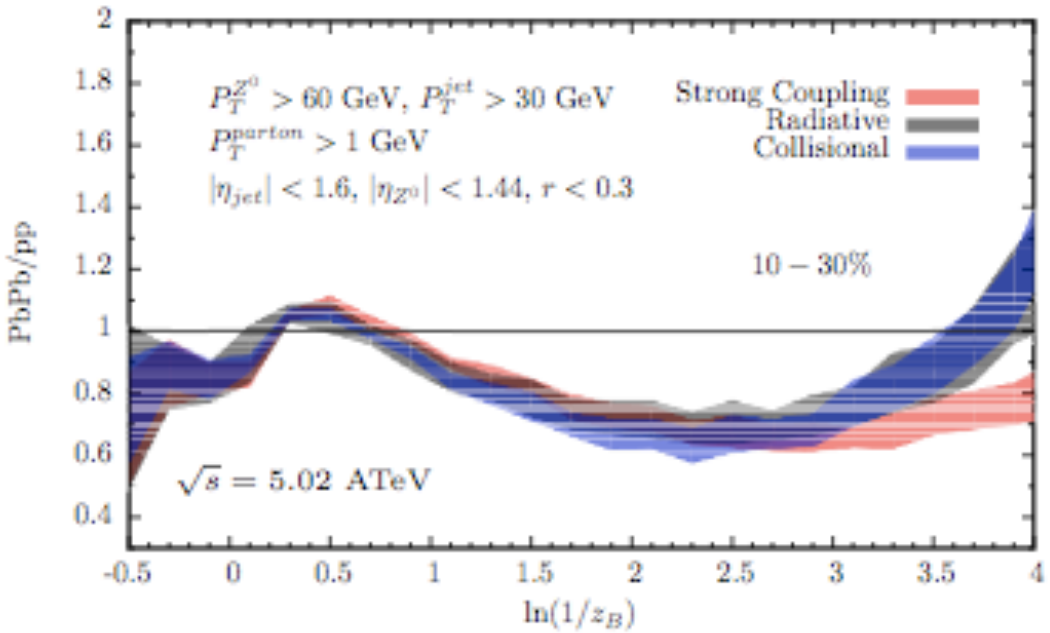
I Vtev, Z+Jet

Hybrid model







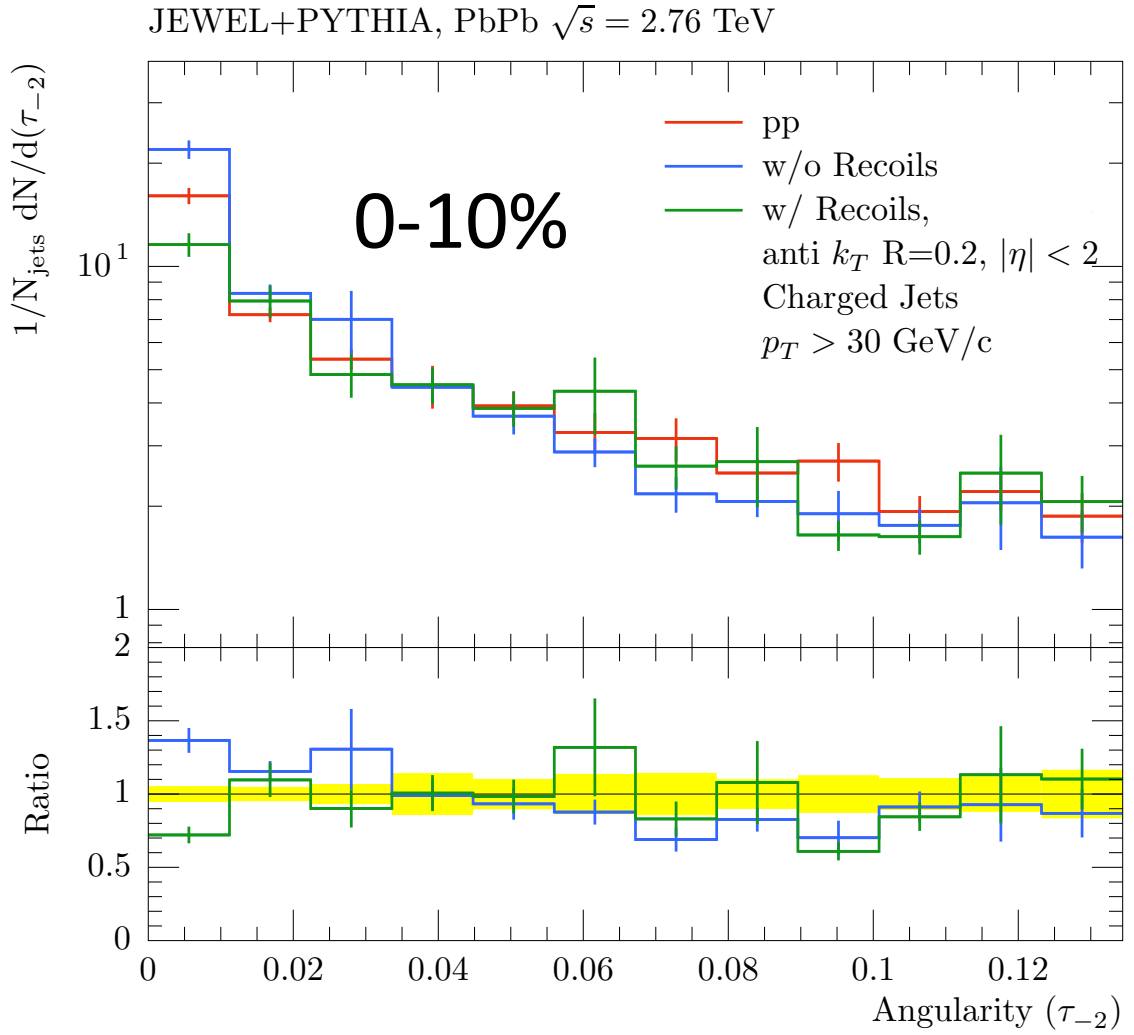


Another fancy measurement: Jet Angularity

$$\tilde{\tau}_a(R, p_T) = \frac{1}{m_J} \sum_{i \in jet} \omega_i \sin^a\left(\frac{\pi\theta_i}{2R}\right) \left[1 - \cos\left(\frac{\pi\theta_i}{2R}\right)\right]^{1-a}, \quad (7)$$

0807.0234

- Originally looked at in e^+e^- collisions in dijet events
- Thought useful for distinguishing boosted objects vs QCD
- Jet Shape quantity
- JEWEL seems to be insensitive to this (or is it??? Next page!)
- Expectation: would tell us that HIN jets are more broader than pp jets



But wait! Inclusive jets at a larger radii?