Study of full event energy-energy correlation in high-p_T Z tagged events in PbPb collisions in CMS

Yi Chen (Vanderbilt) for the CMS Collaboration

Hard Probes 2024, Sep 23 2024, Nagasaki, Japan

The Vanderbilt HENP group's work is supported by US DOE-NP

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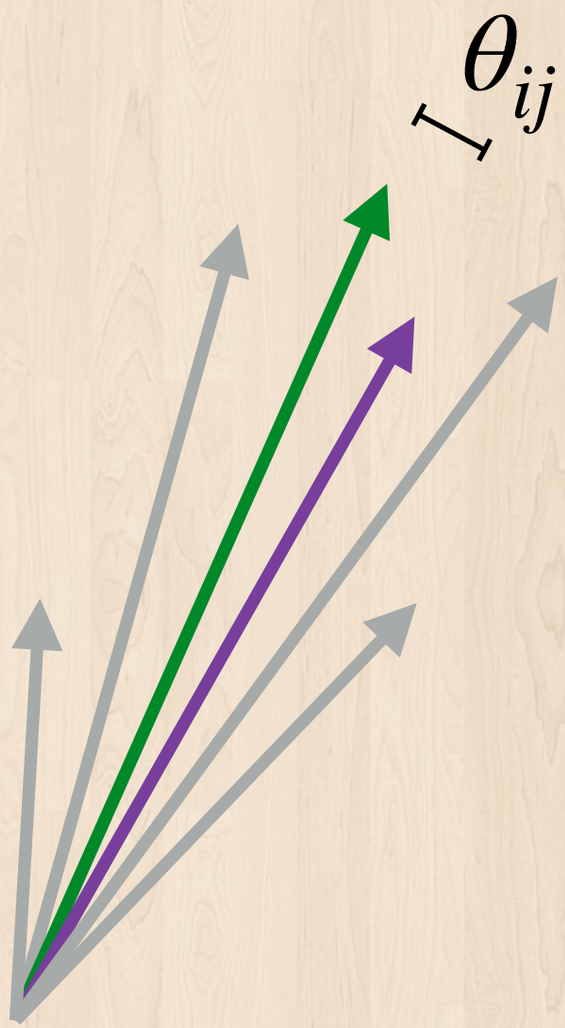
Energy-energy correlator



Two-point correlator:
Loop over all pairs
and tally them up

Renewed interest in recent years

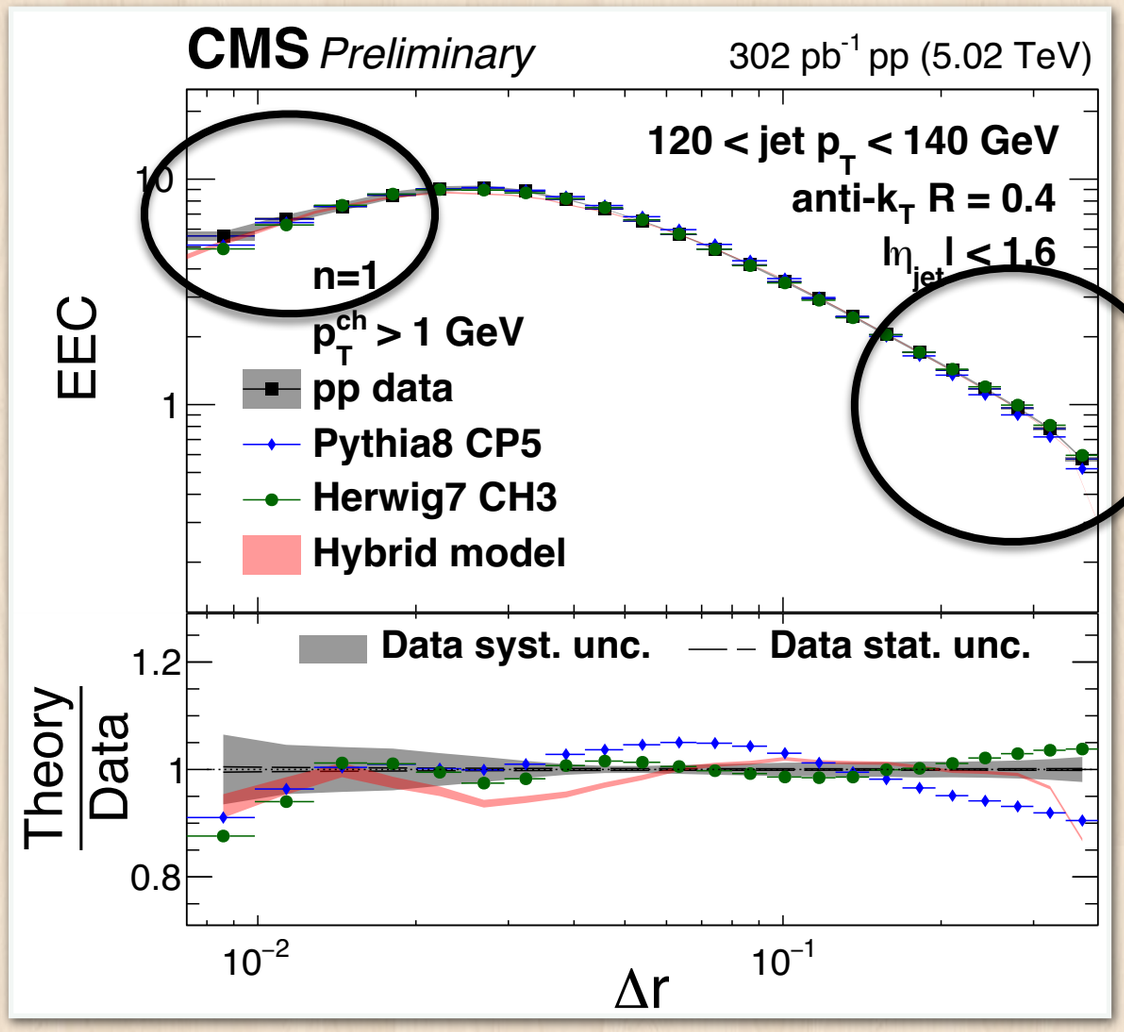
$$\mathrm{EEC}(\theta) = \frac{1}{N}\sum_{i,j}\frac{\mathcal{E}_i\,\mathcal{E}_j}{Q^2}\,\delta(\theta_{ij}-\theta)$$

At RHIC/LHC: p_T, ΔR

Energy-energy correlator in jets

Example recent measurement with jets from CMS

Small angle: hadronization



Large angle: pQCD

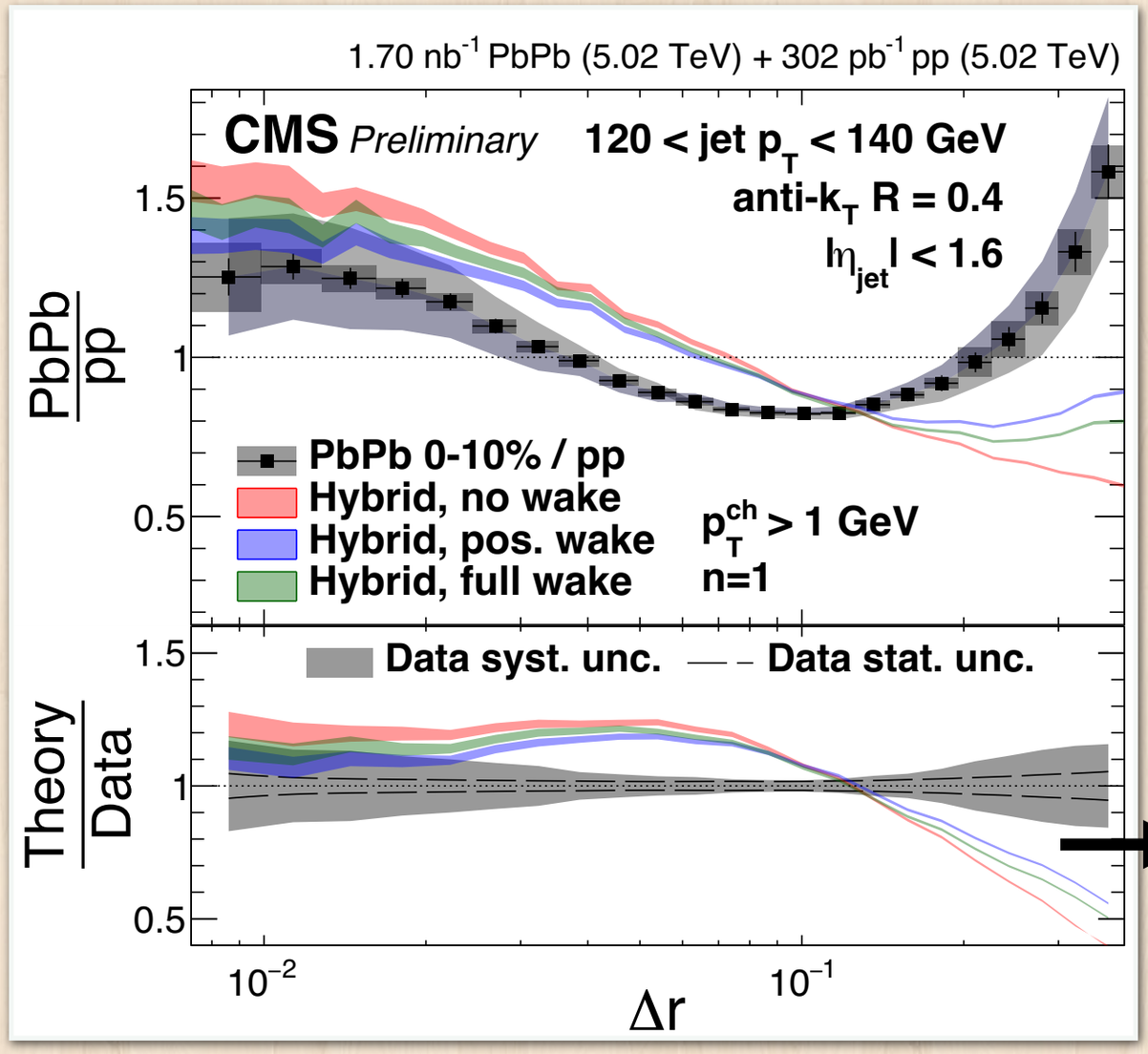
Different physics manifest at different angular scale

See Jussi Viinikainen's talk for details!

CMS-PAS-HIN-23-004

Energy-energy correlator in jets

Example recent measurement with jets from CMS



A lot of rich physics encoded in shape

(de)coherence effect

medium response

wake

...

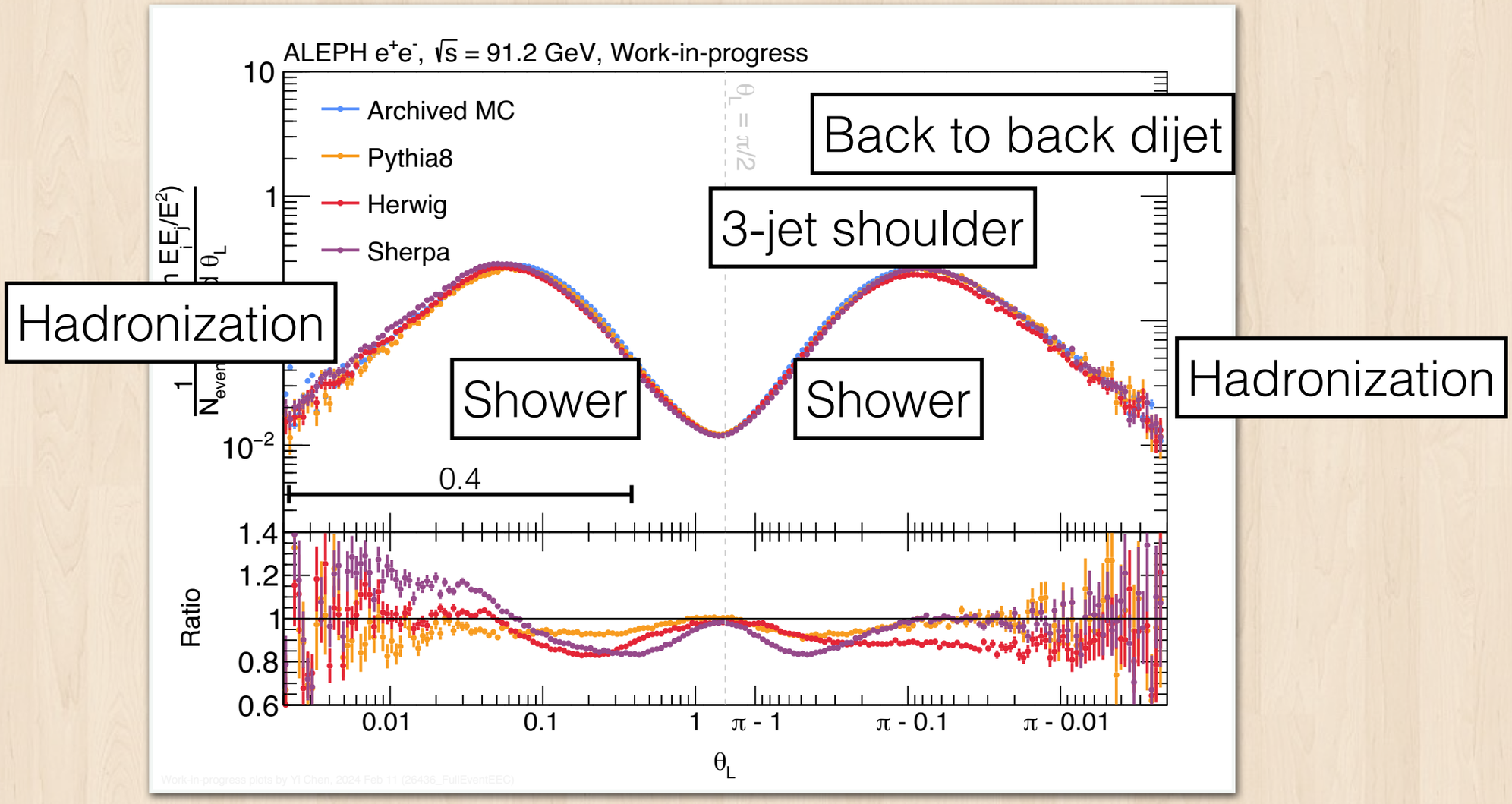
Can we go further (Δr)?
What else can we learn?

See Jussi Viinikainen's talk for details!

CMS-PAS-HIN-23-004

Extending to large angle

Ongoing effort to measure this in $e^+e^- \to Z$

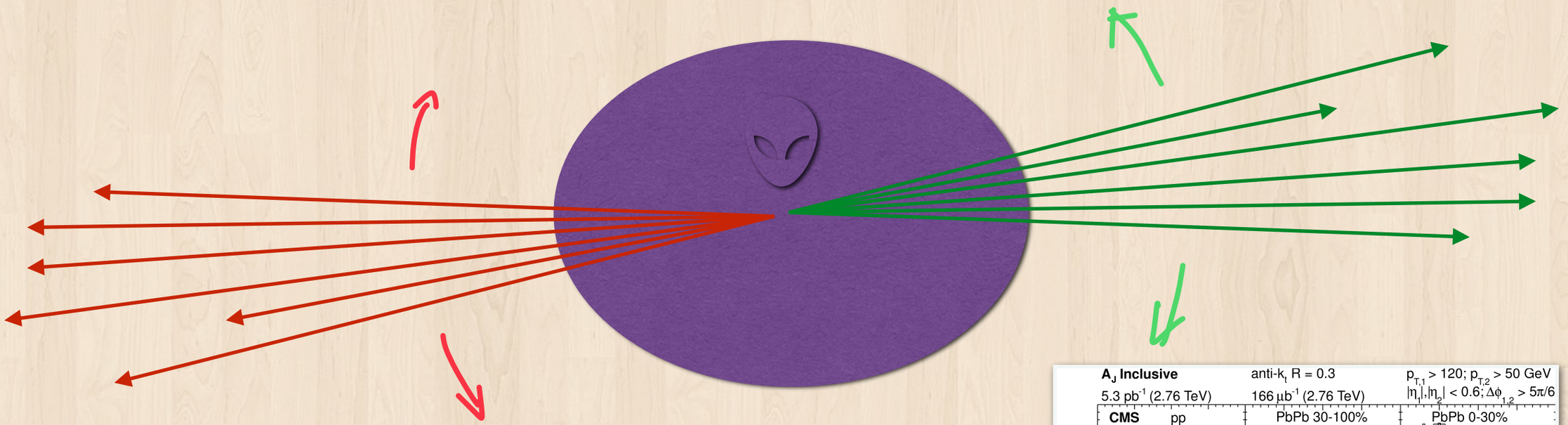


Interesting structure with features

See Yu-Chen Chen's talk for details!

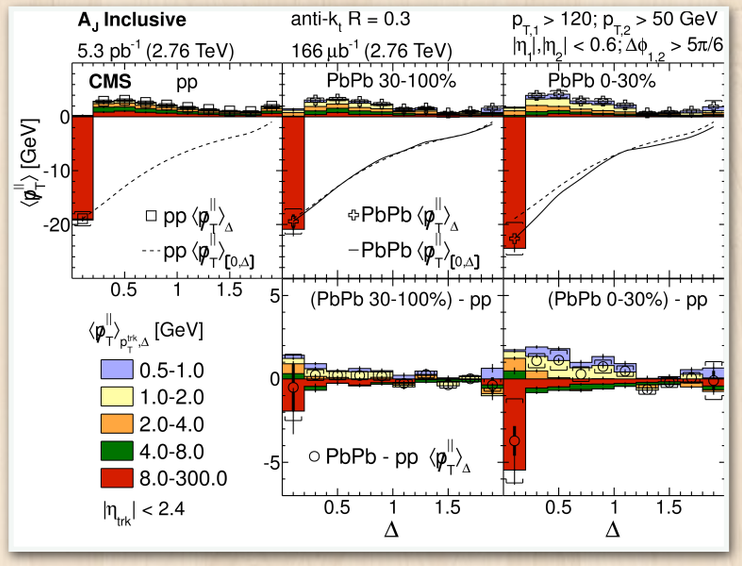
How to do this in heavy ion?

Jet quenching = energy pushed away from jets



Typically quite far
→ two sides will interfere

Event selection can cause bias



Effect can go beyond $\pi/2$

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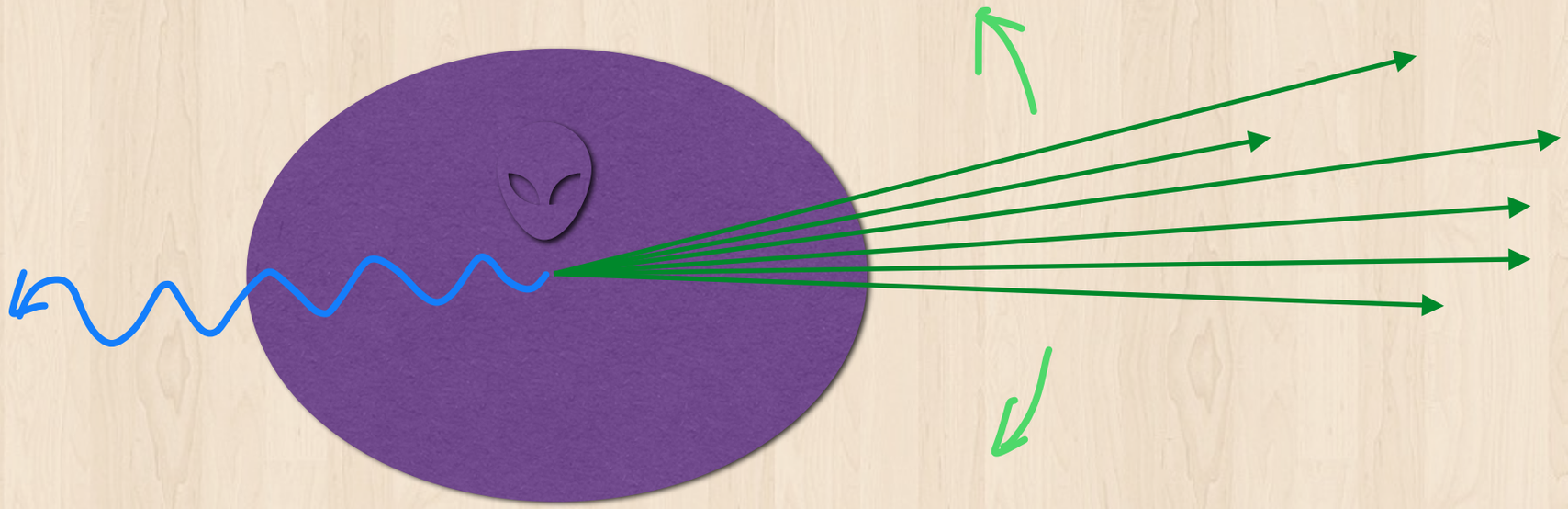
How to do this in heavy ion?

Cleaner physics if we only have one side

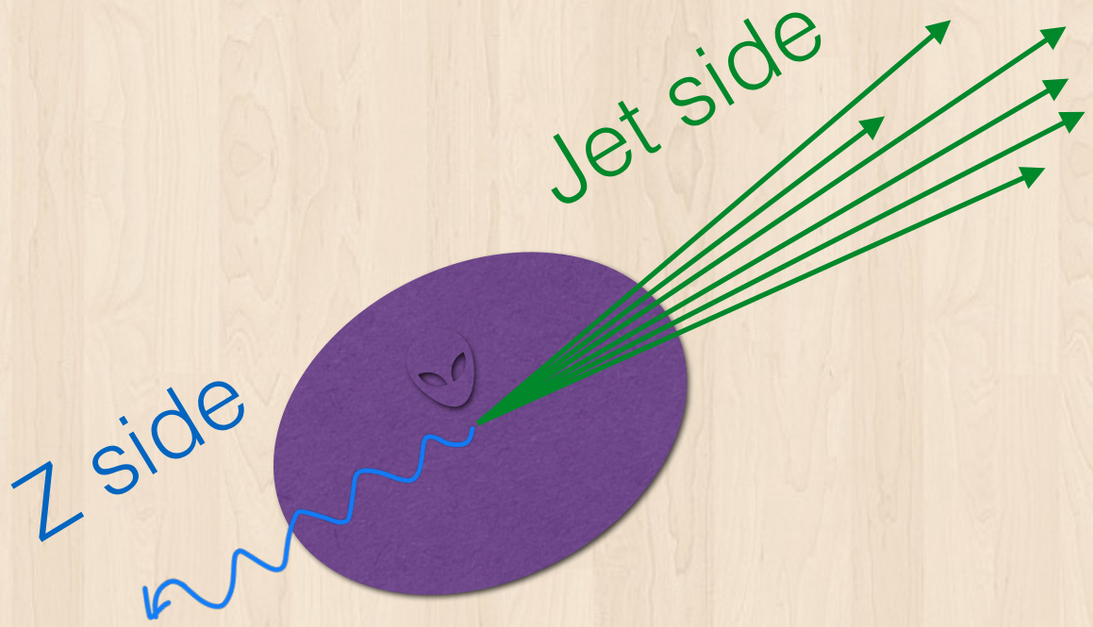


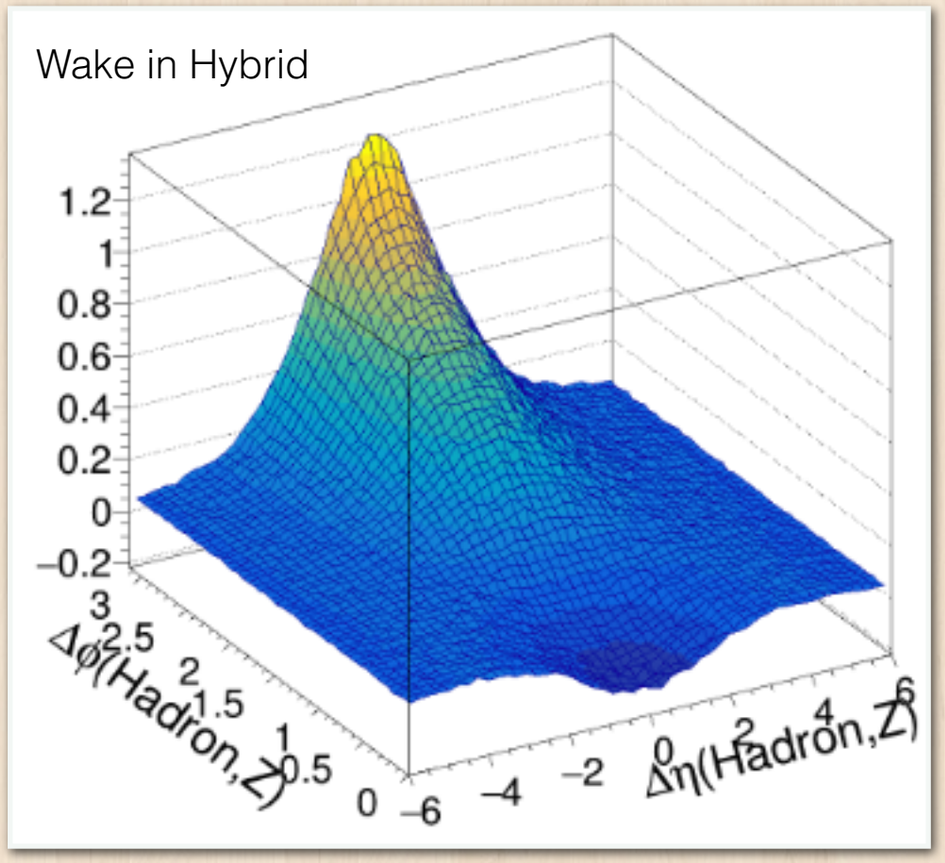
Look into Z/γ-tagged events

Can check all the way to the Z/γ side — chance to map out large angle structure of jet quenching effect without identifying the jet

Example: Z-hadron correlation

By opening up the phase space we can gain sensitivity to the **medium wake contribution** — including the depletion on Z side





Interesting to apply to EEC to study angular structure!

See Yen-Jie Lee's talk for details!

Pablos, Rajagopal, Lee

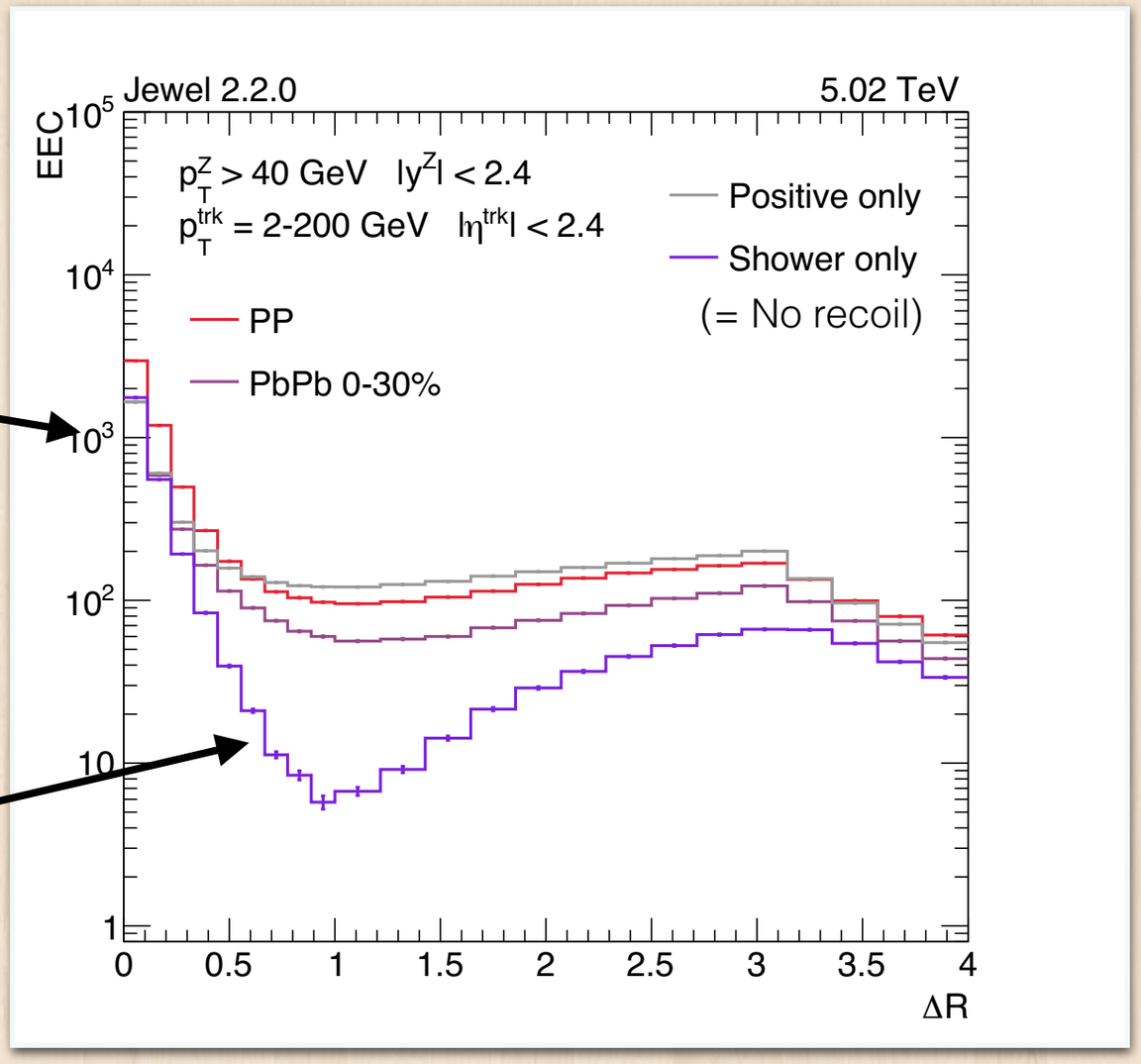
What do models say?

Overall suppression: jet quenching effect

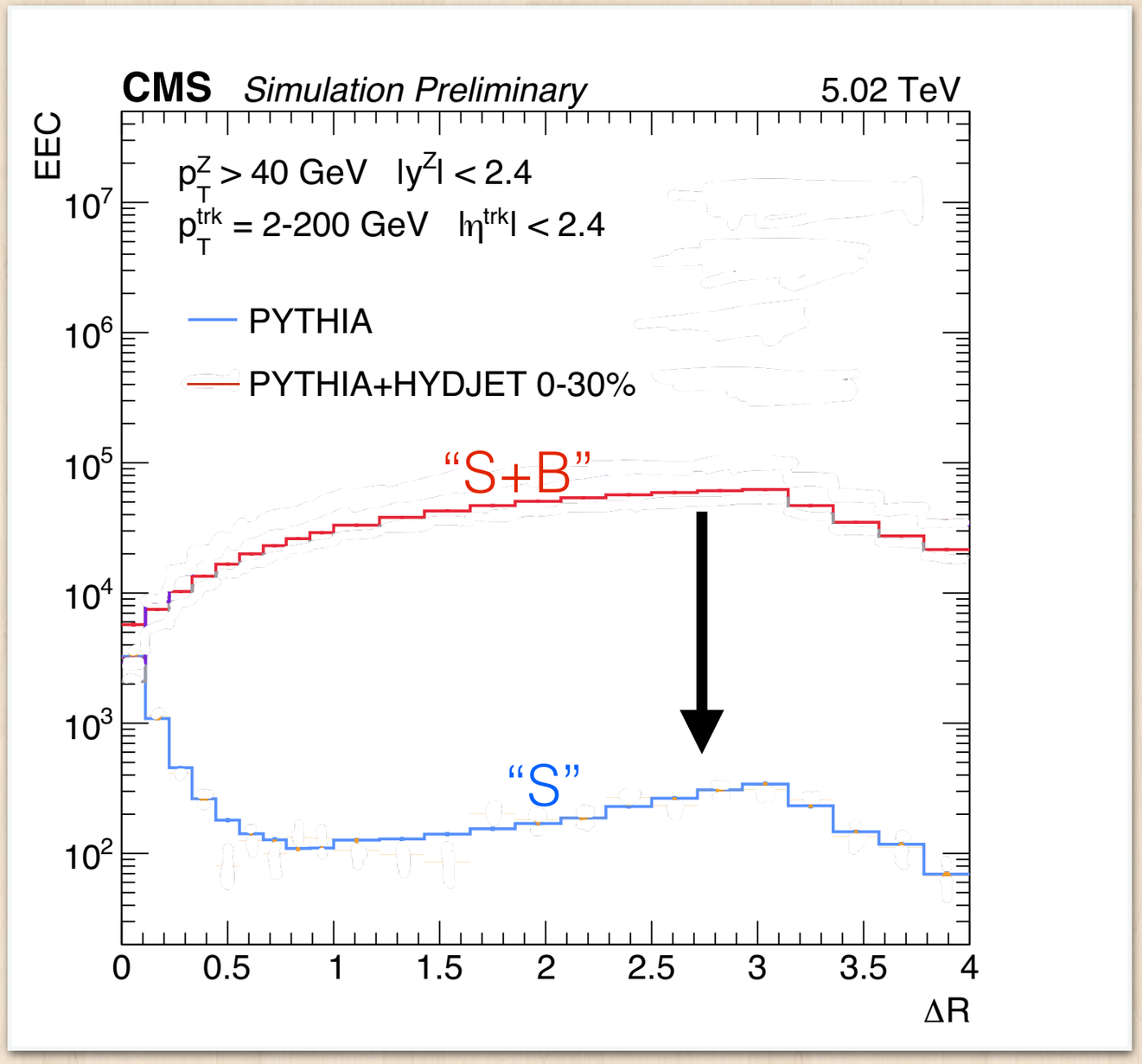
At small angle recoil does not make a difference

Recoil effect shows up prominently at larger angle

For example JEWEL



Experimental challenges



Huge amount of combinatorics for full event track pair correlation

S/B ~ O(0.3%)

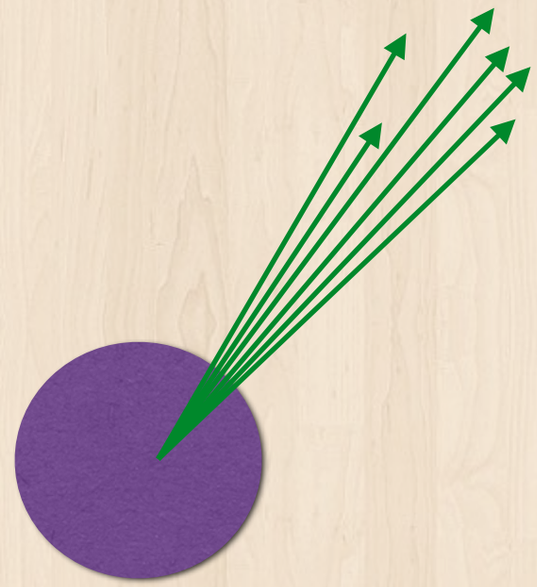
How can we reliably isolate signal?

Analysis strategy

Mixed-event background subtraction

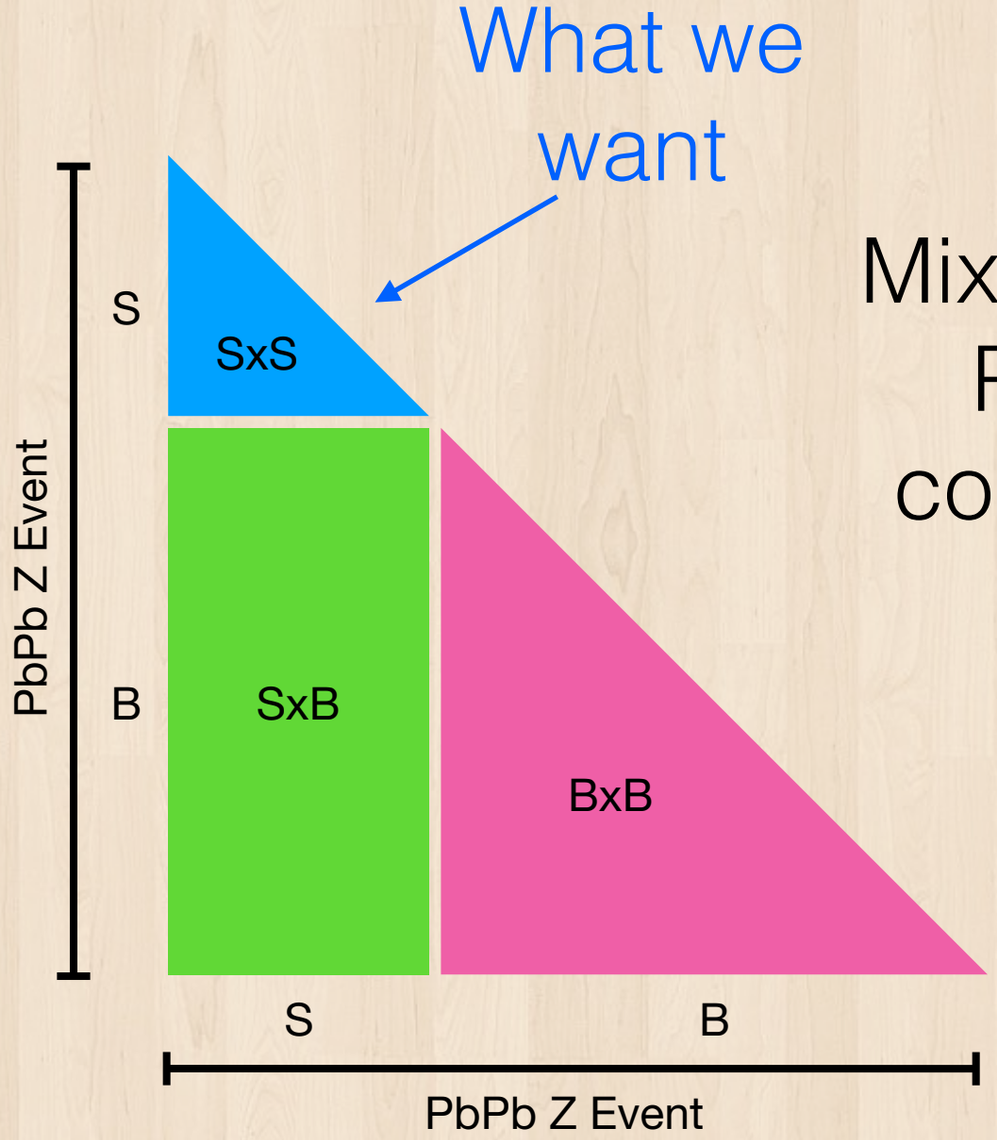
Recall that we tag events with Z and look at track pairs

PbPb Z event = **S**+**B**
"**B**" = uncorrelated part
= MinimumBias triggered event
"**S**" = correlated (to Z) part



Target contribution = **SxS**:
Two particles from "**S**" contribution paired together

Event mixing scheme



Mixing particles from the same PbPb Z event gives three contributions: (S+B)x(S+B) =

SxS + **SxB** + **BxB**

See next page

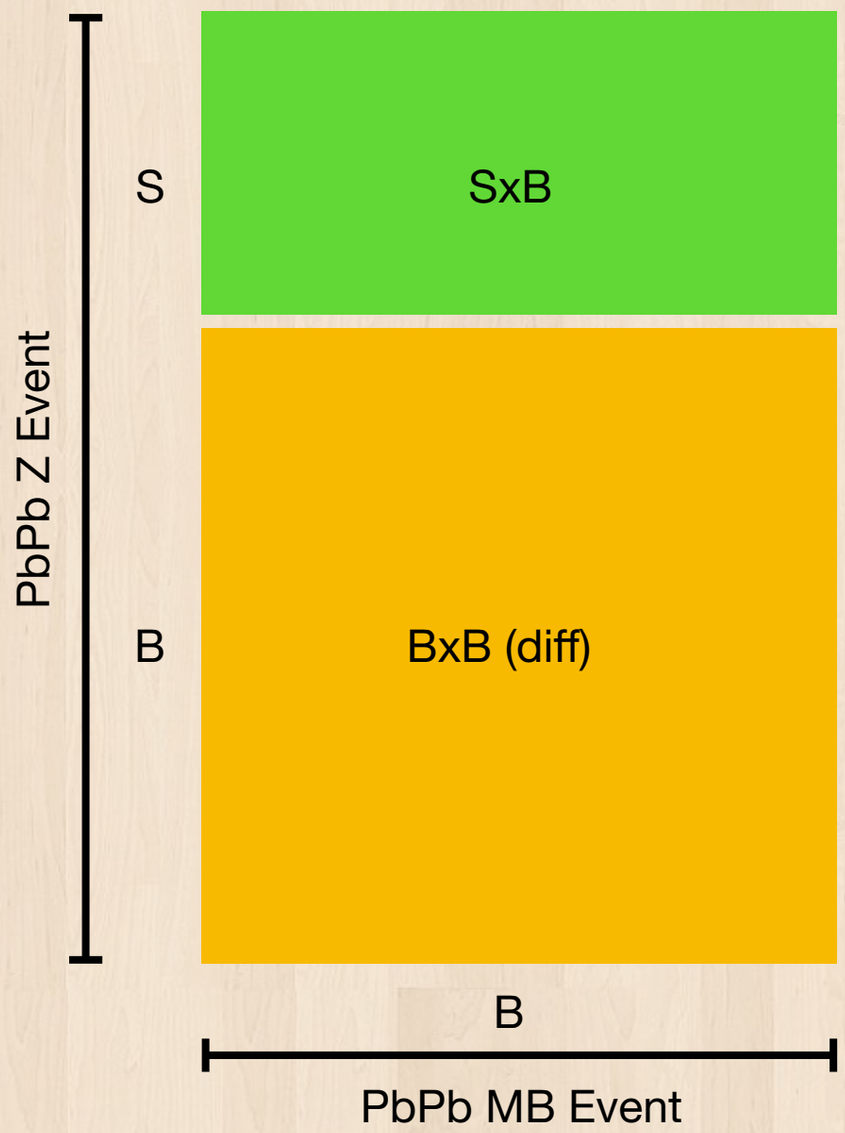
Self-mixing in background events

Event mixing scheme

Mixing PbPb Z event with background event gives two contributions:

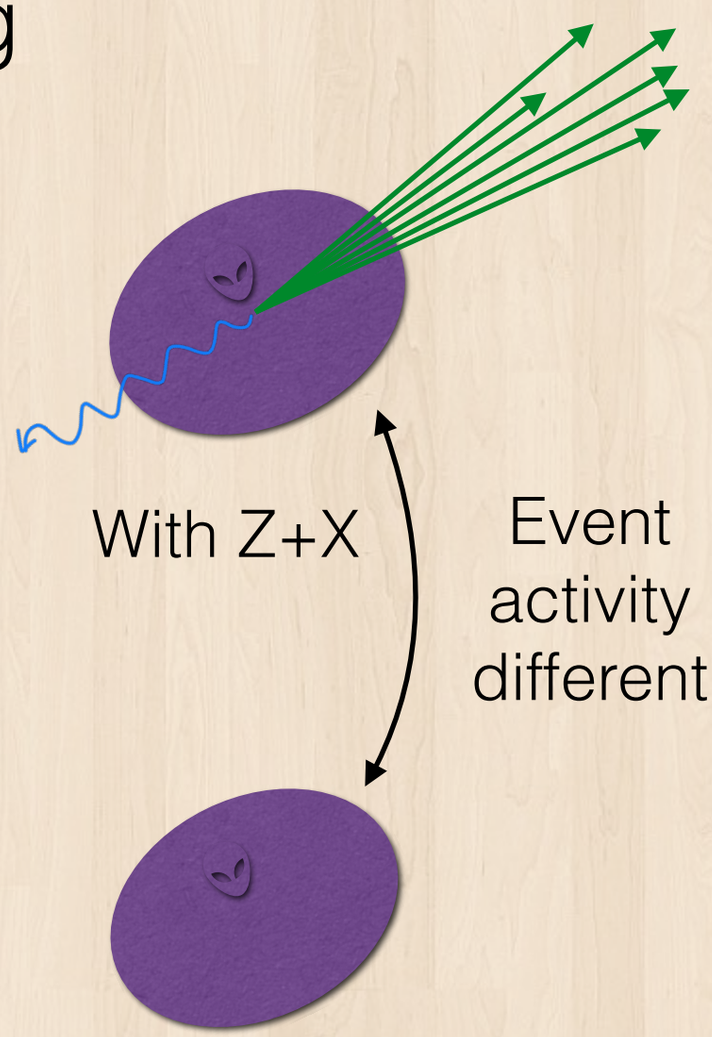
(S+B)xB = **SxB** + **BxB (diff)**

Mixing with different background events



Event matching

- The procedure involves matching events together
  - We use forward hadron calorimeter ($3 < |\eta| < 5$) as the "event activity"
- Activities associated with Z (higher Q^2) can cause bias
  - Estimate with pp data events



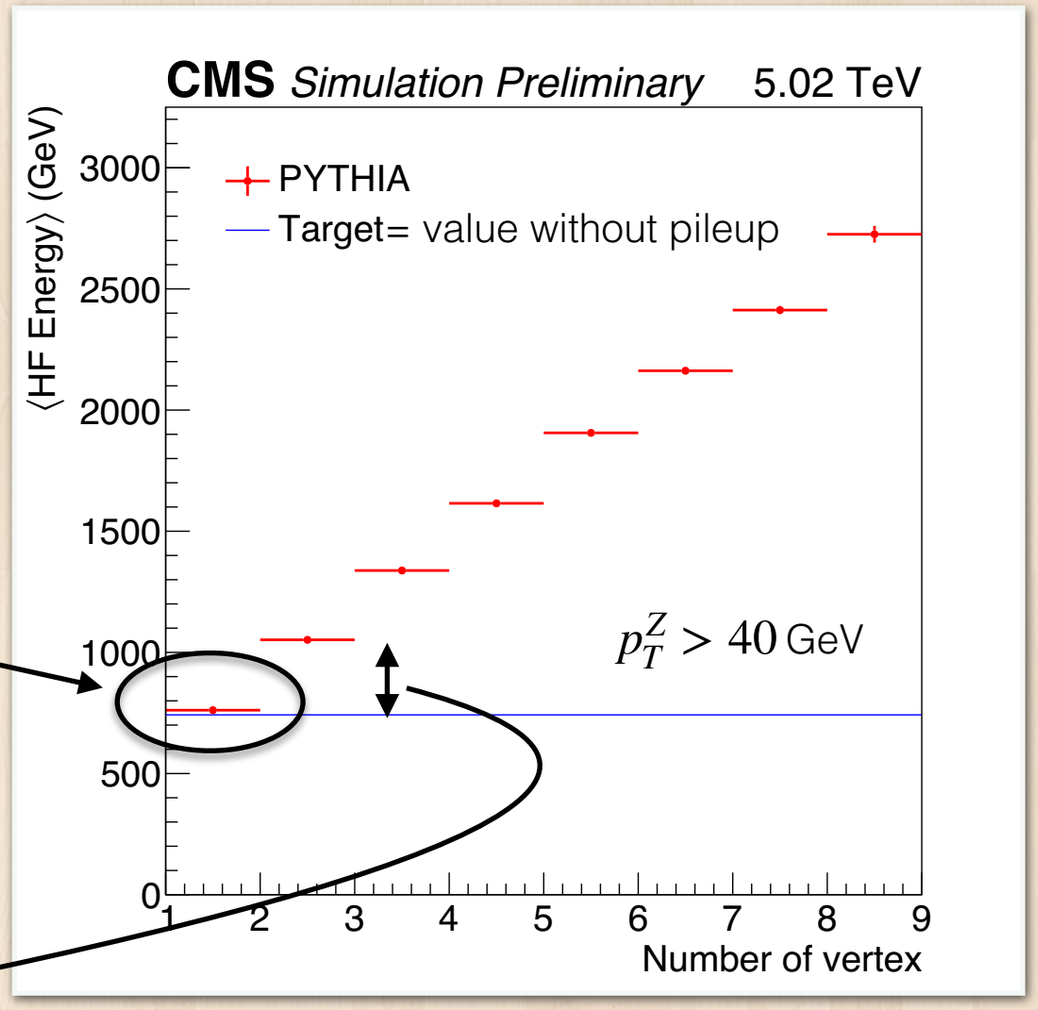
Event matching

However pp data has pileup

Use events with one reconstructed vertex as the proxy

Verified in simulation that it gets very close to the true value

Each extra vertex further shifts things by ~40%

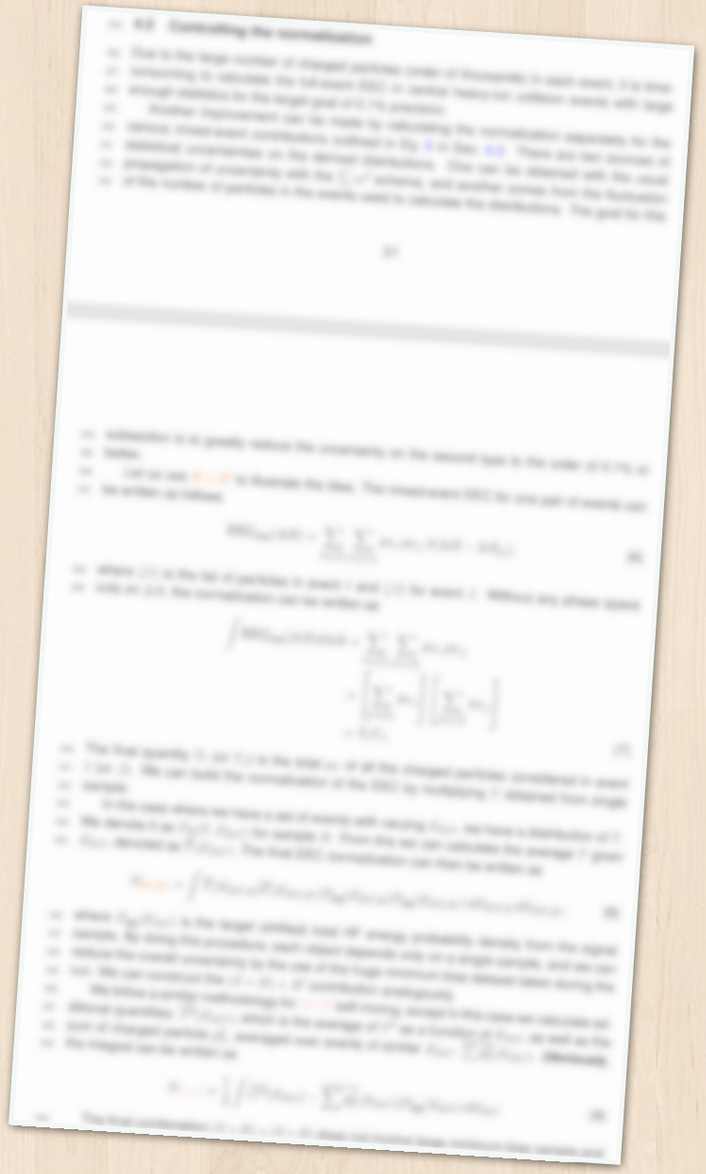


Controlling normalization

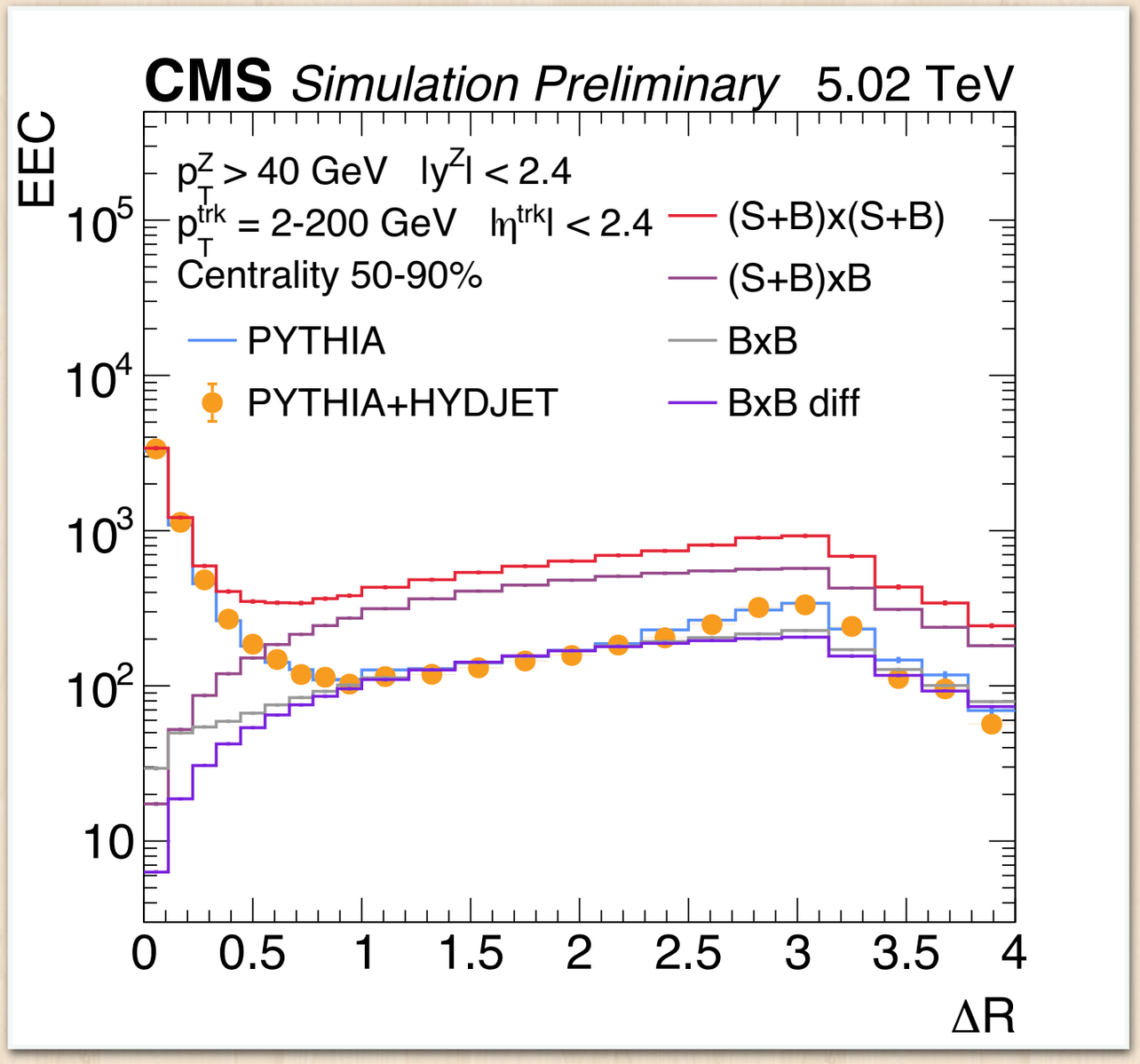
- Another key analysis piece is on the **normalization** for different event mixing combinations

- Normalization converges slowly, causing fluctuations

- **Derive them separately** gives finer control on the procedure



Analysis closure: 50-90%

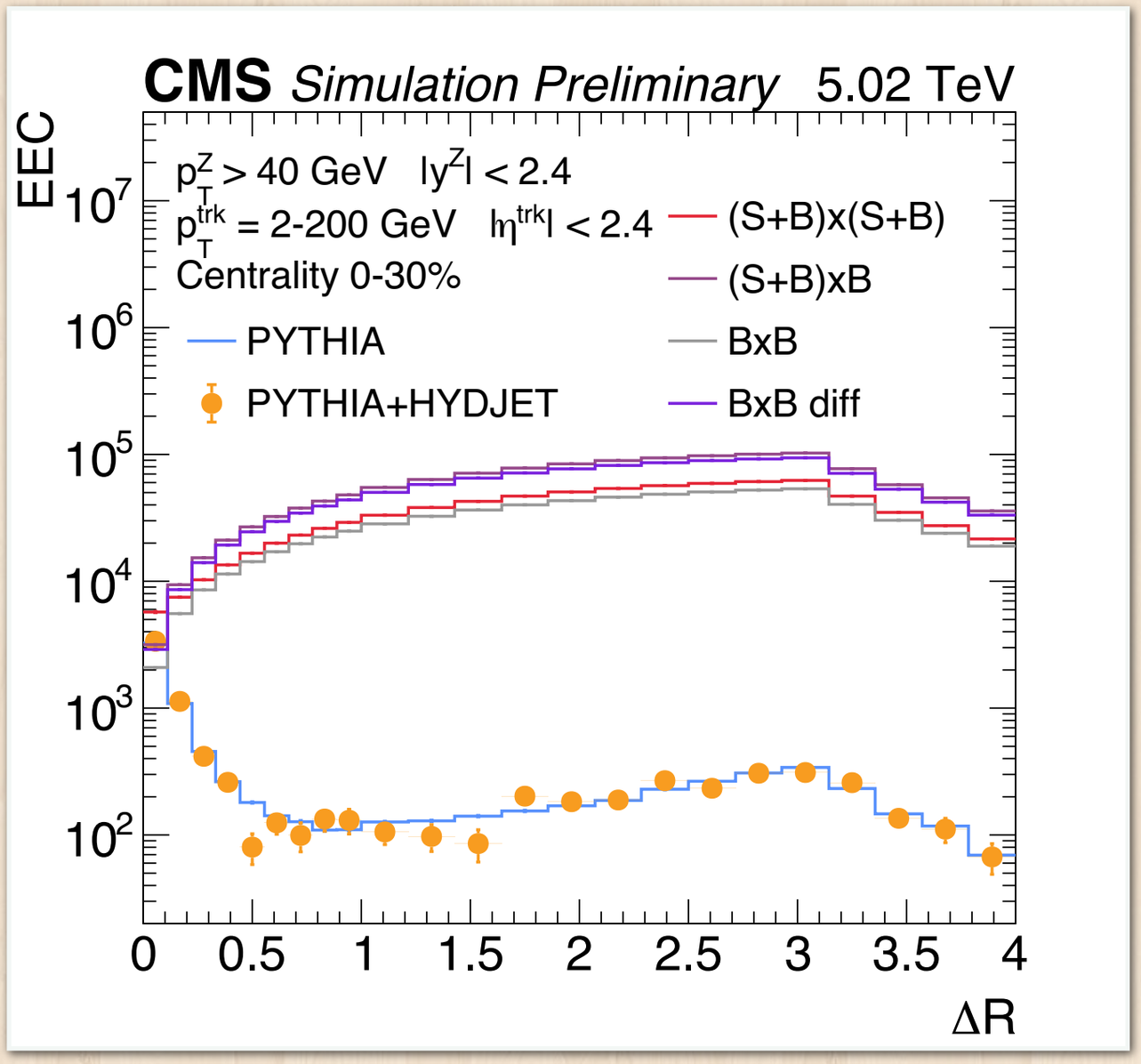


In peripheral S/B ~ 0.2 at large angle

Blue: Generator-level pp

Orange: after subtraction, detector-level

Analysis closure: 0-30%



Blue:
Generator-level pp

Orange:
after subtraction,
detector-level

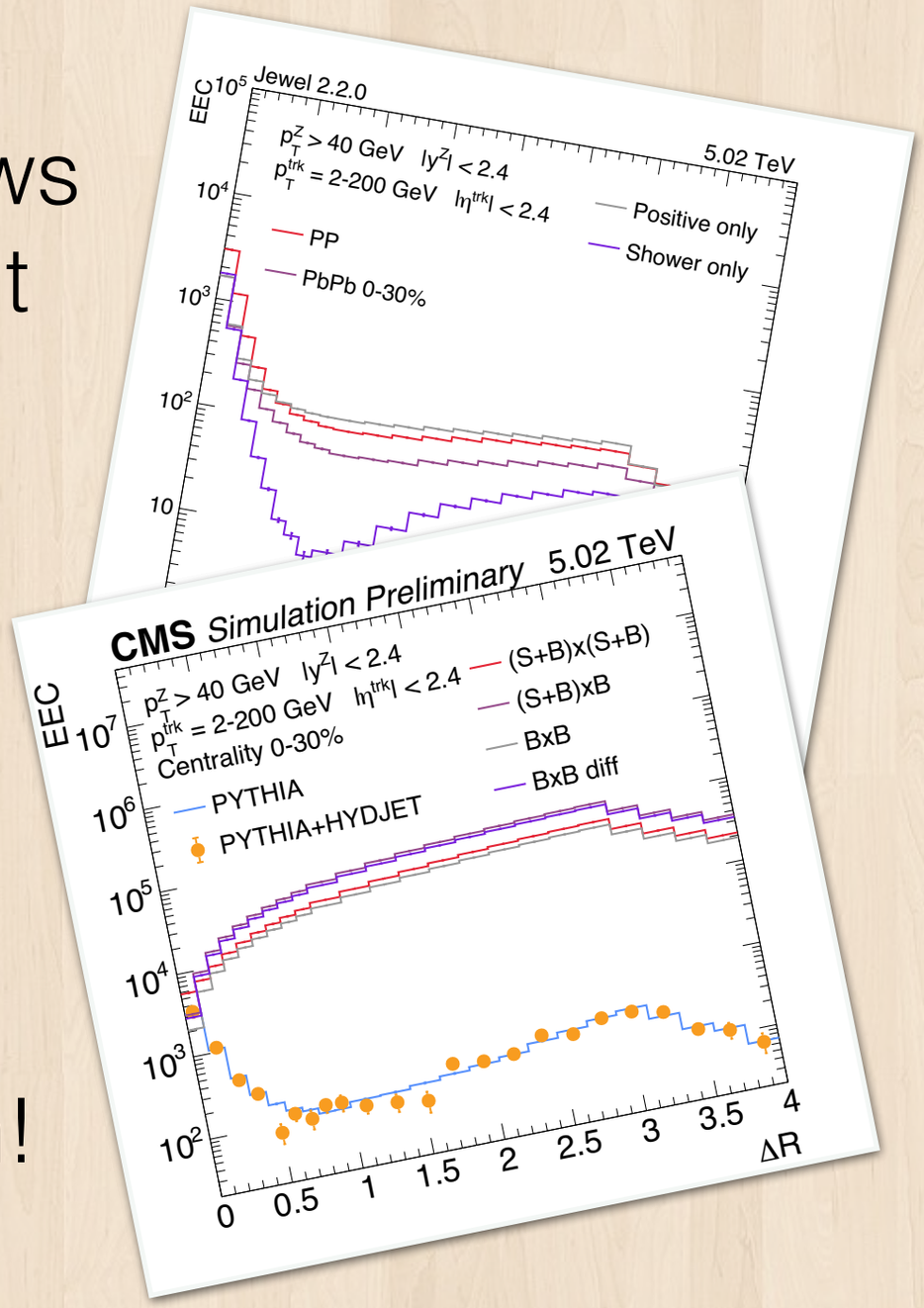
Event mixing strategy works

Concluding remarks

- Energy-energy correlator allows us to study physics at different angular scales

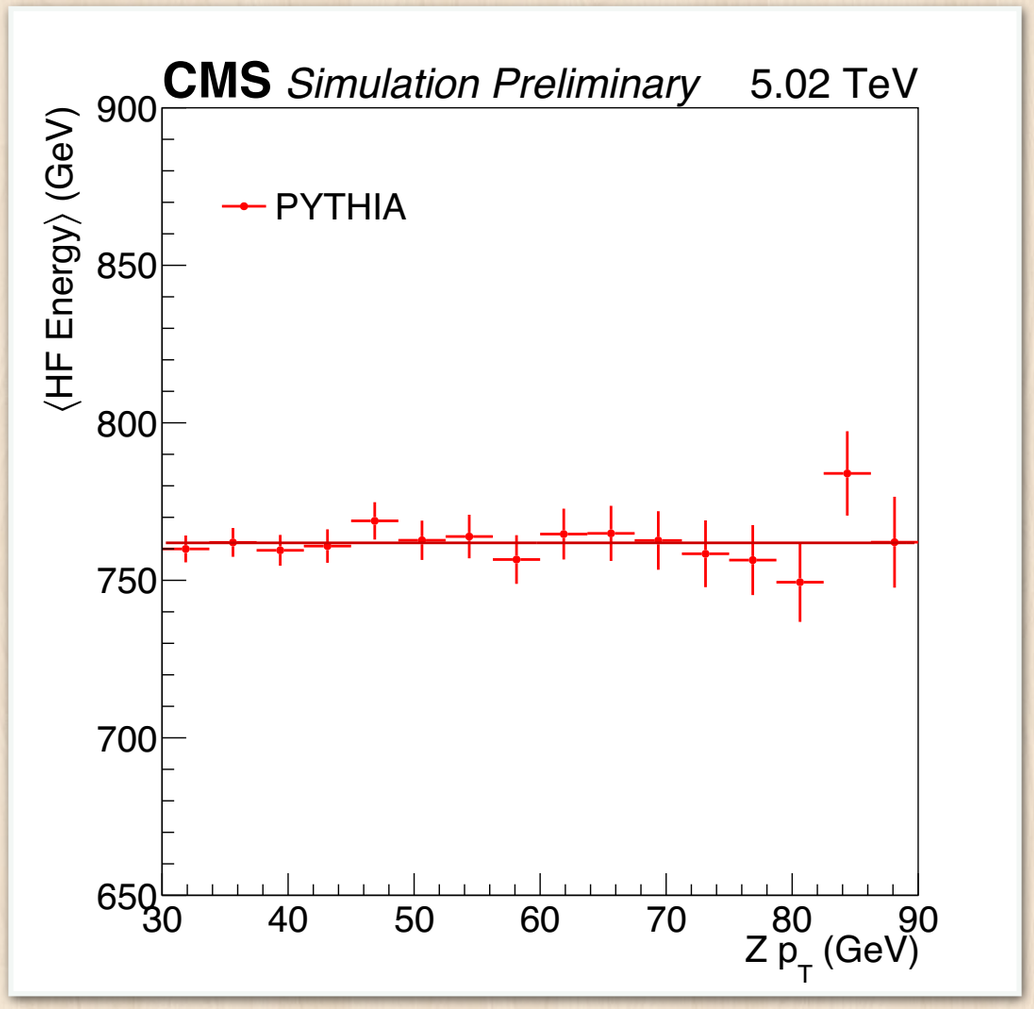
- Z-tagged events provide excellent chance to study what happens at large angle

- Presented key analysis pieces: results will come soon!



Backup Slides Ahead

Event activity estimate



The event activity in $3 < |\eta| < 5$ does not depend on Z kinematics in the phase space we consider