Probing the dead-cone effect with hadron correlations

László Gyulai

In collaboration with:
Gábor Bíró
Róbert Vértesi
Gergely Gábor Barnaföldi

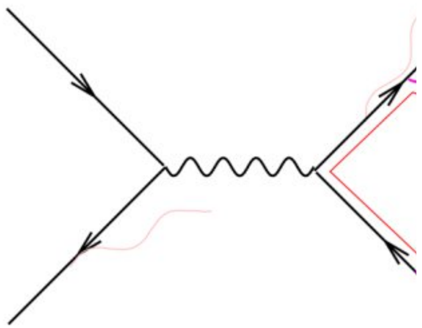
18th Workshop on Particle Correlations and Femtoscopy

Budapest, 19.05.2026

This research was funded by the grant numbers K153456, 2024-1.2.5-TÉT-2024-00022, 2021-4.1.2-NEMZ_KI-2024-00031, 2025-1.1.5-NEMZ_KI-2025-00002, 2025-1.1.5-NEMZ_KI-2025-00005, 2025-1.1.5-NEMZ_KI-2025-00013

Formation of jets in high-energy collisions

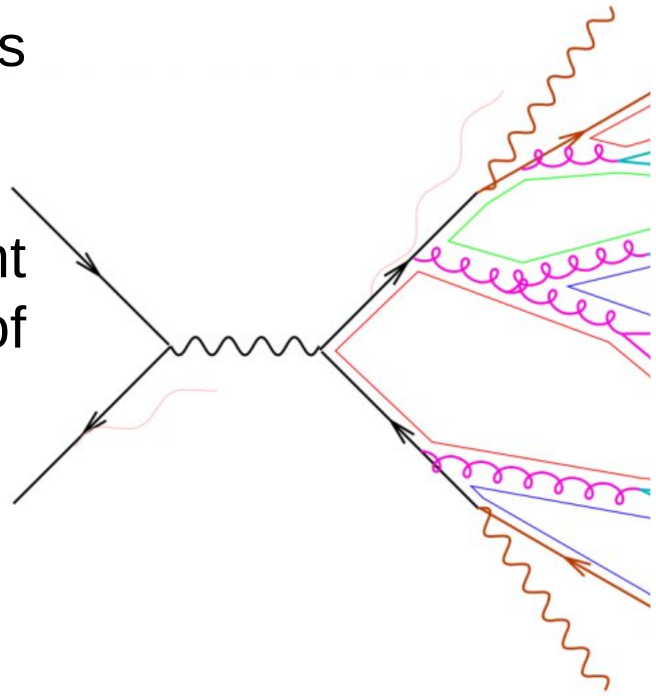
- Initial quarks and gluons are produced in high-energy interactions through processes with large momentum transfer



Formation of jets in high-energy collisions

- Initial quarks and gluons are produced in high-energy interactions through processes with large momentum transfer

- These partons undergo subsequent emissions, resulting in the production of more quarks and gluons — parton shower

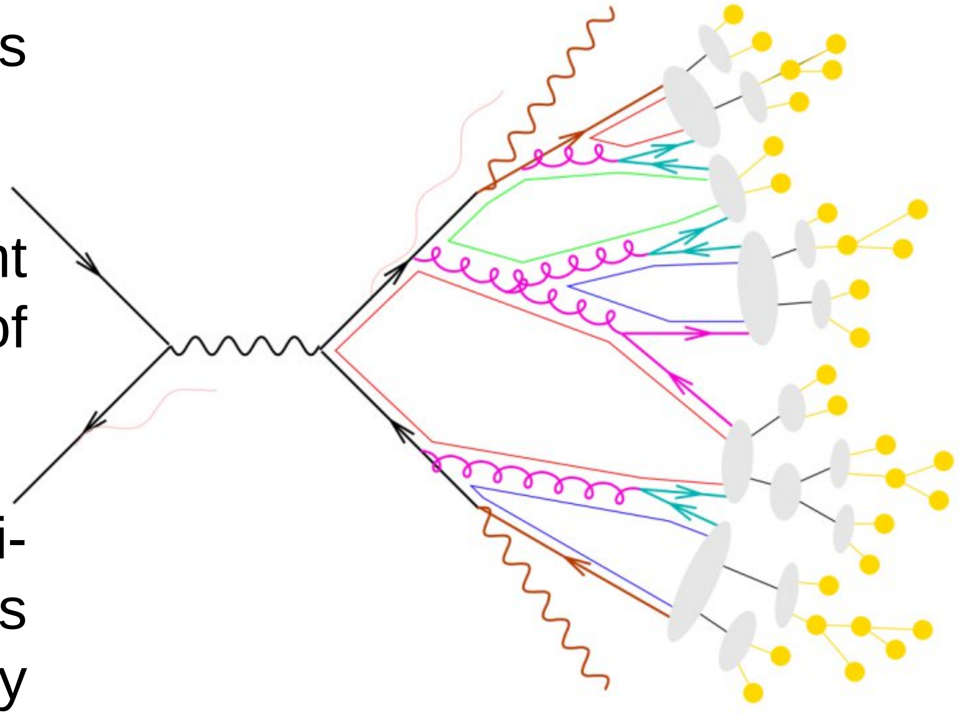


Formation of jets in high-energy collisions

- Initial quarks and gluons are produced in high-energy interactions through processes with large momentum transfer

- These partons undergo subsequent emissions, resulting in the production of more quarks and gluons — parton shower

- The shower then evolves into a multi-particle final state, with the partons combining into a spray of experimentally detectable hadrons — jet



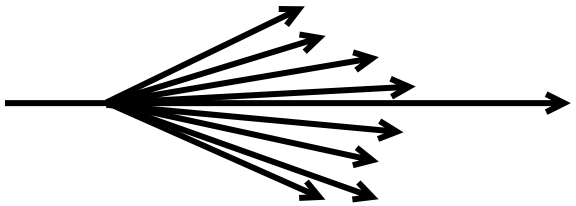
The dead-cone phenomenon

The pattern of the parton shower is expected to depend on the mass of the emitting parton *m* and its energy *E*

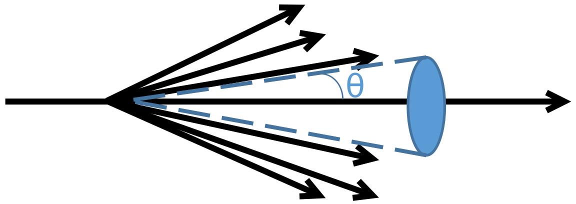
The radiation is suppressed at angular scales smaller than $\theta = m/E$
[J.Phys.G **17**, 1602-1604 (1991)]

The resulting region with depleted particle production is called the **„dead cone”**

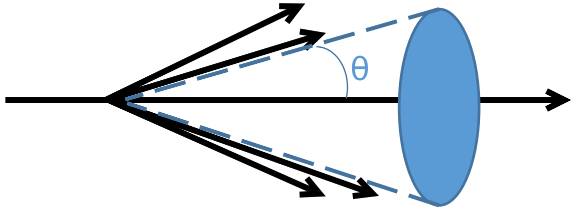
Low parton mass



Intermediate parton mass



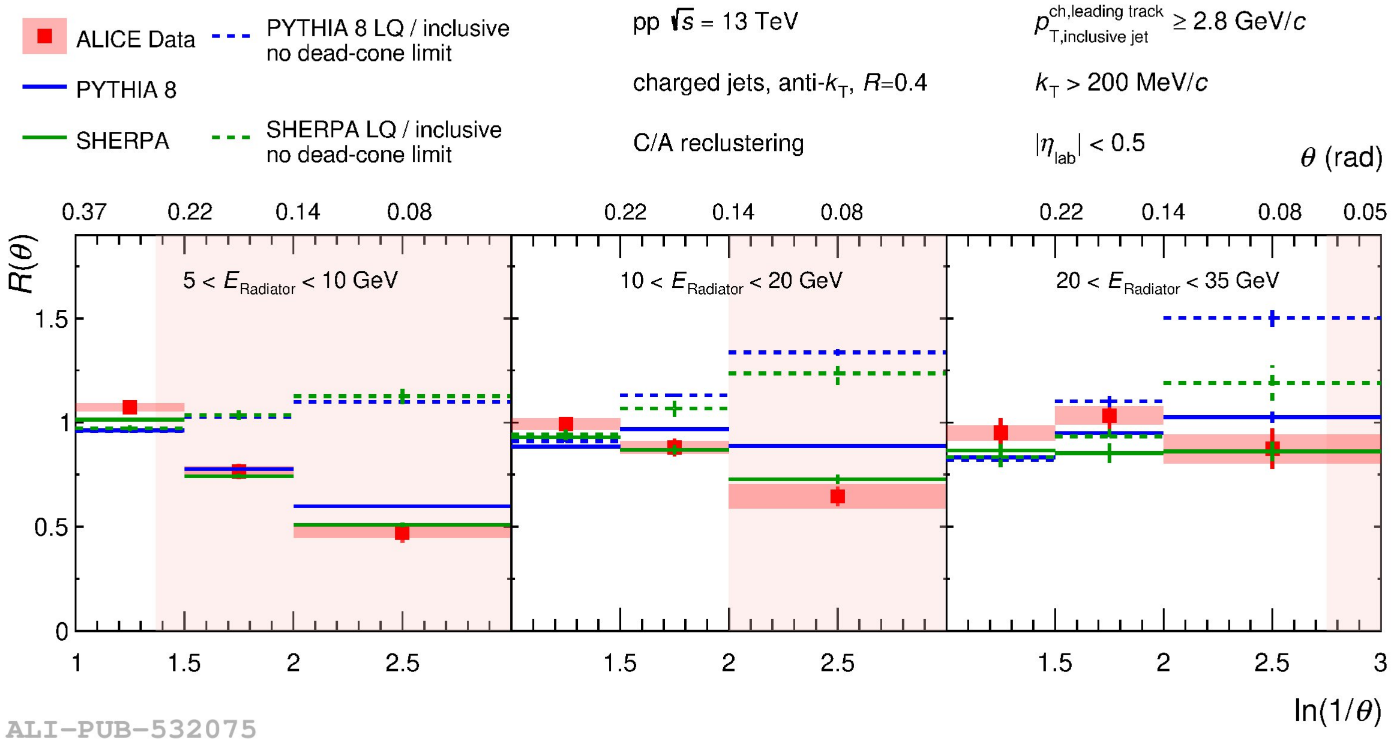
High parton mass



Experimental evidence of the dead cone

R(θ) — ratio of the splitting angle distributions for D^0-meson tagged jets and inclusive jets (alternatively, light-quark-jets for no dead-cone limit)

A significant suppression in the rate of small-angle splittings is observed in D^0-meson tagged jets relative to the inclusive jet population beyond the theoretical limit



Nature **605** (2022) 440-446

In search for a simpler approach

The goal of our study was to find an alternative method for detecting the dead cone:

- No jet reconstruction
- Applicable for both charm and beauty flavours

Suggestion:

- Compare angular hadron production around heavy- and light-flavour triggers
- In such a comparison, flavour-independent contributions are expected to cancel to first approximation, while the residual near-side suppression will reflect the reduced small-angle radiation of heavy quarks

Generation parameters

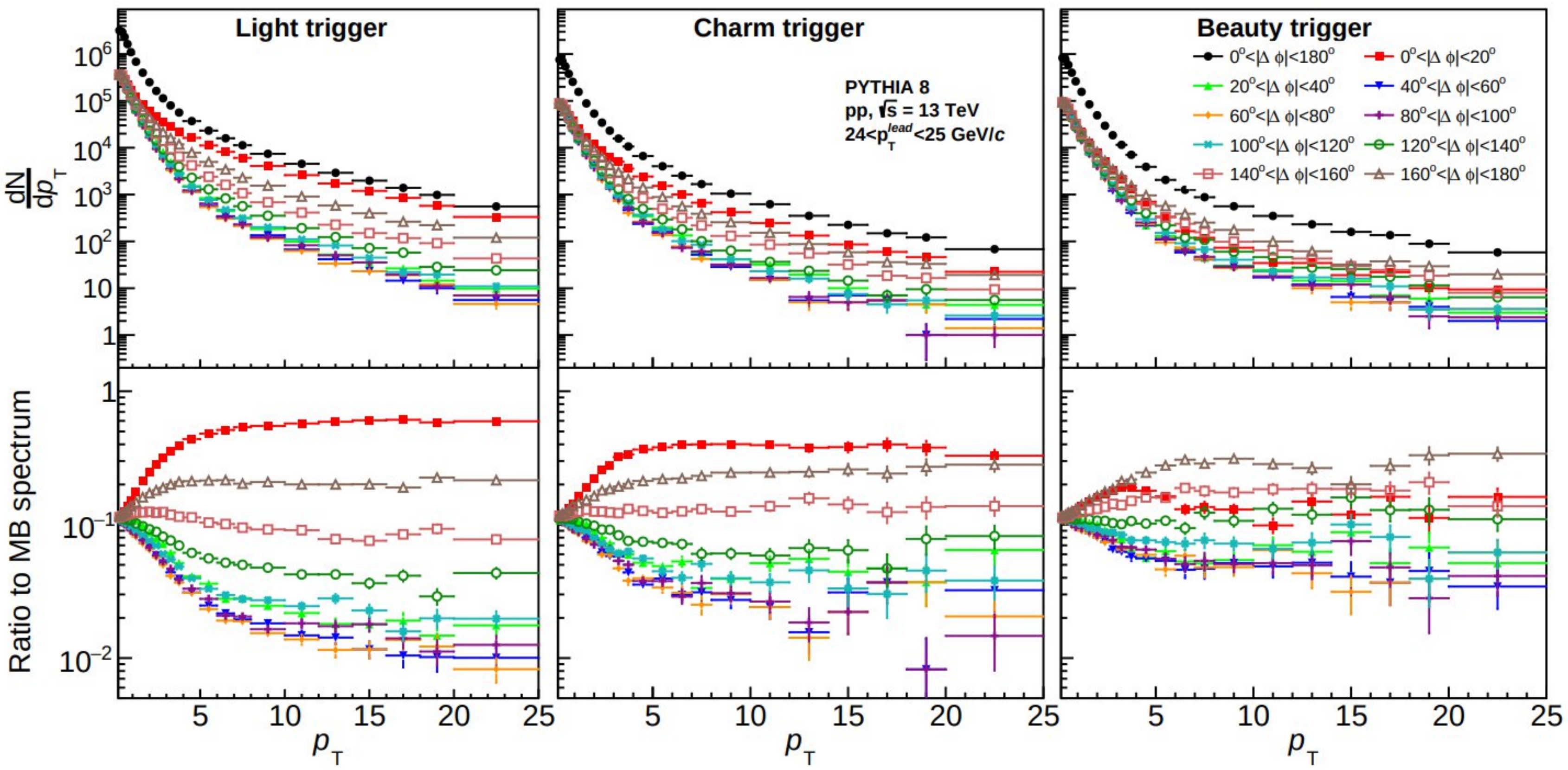
We analysed pp collisions at $\sqrt{s} = 13$ TeV generated with Pythia 8 using the default Monash tune

10 billion events were generated, and decays of open-charm and open-beauty hadrons were disabled in order to preserve the heavy-flavour origin of the trigger and minimise smearing from secondary decay kinematics

Trigger particles are defined as final-state hadrons within $|\eta| < 1$, with no explicit lower cut on trigger transverse momentum

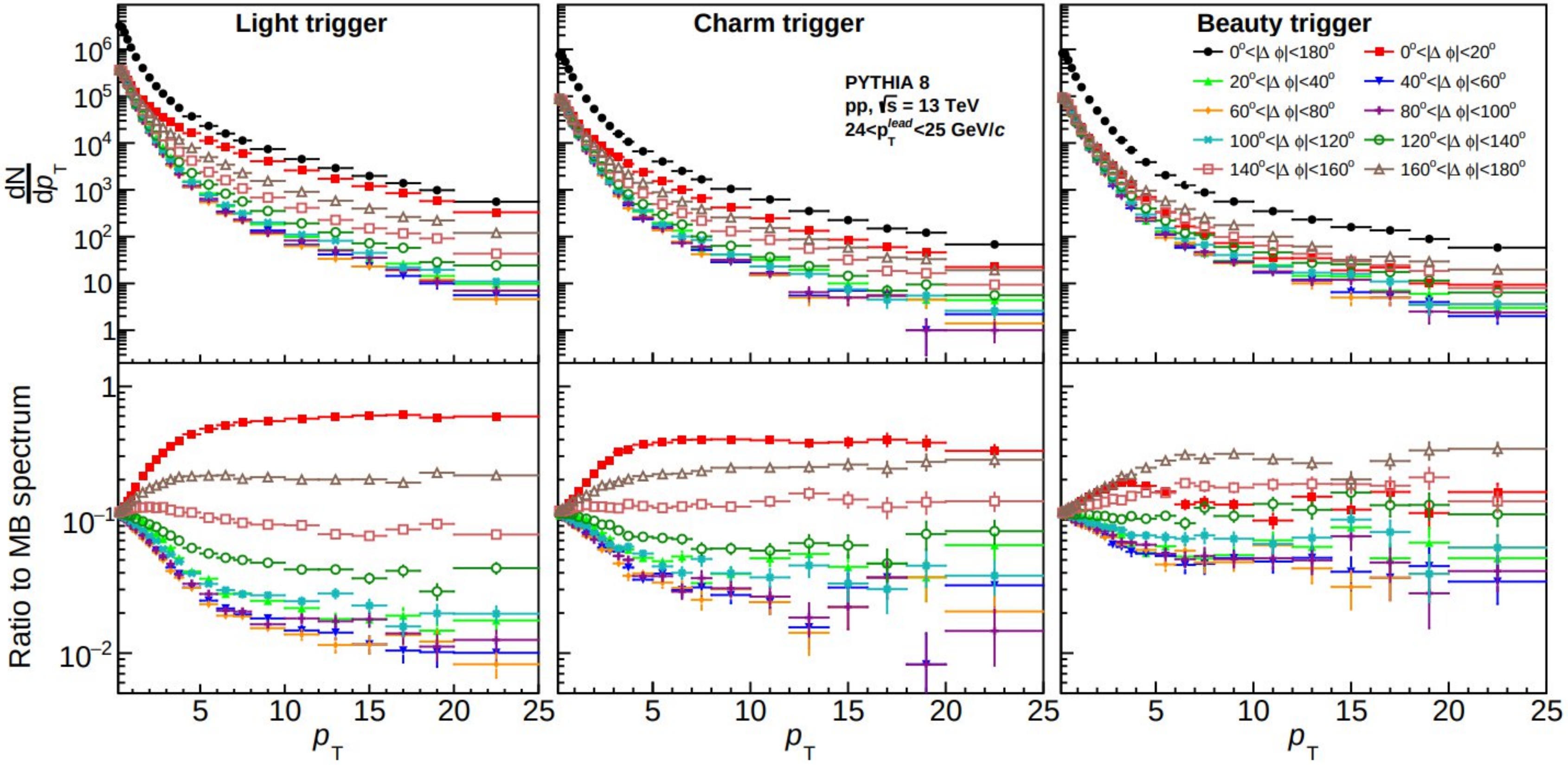
The trigger flavour is assigned from the flavour of the original mother parton: a trigger is labeled charm or beauty if one of its original mother partons is c or b, respectively; otherwise it is classified as light, with only u, d, s quarks and gluons allowed as mothers

Differential spectra



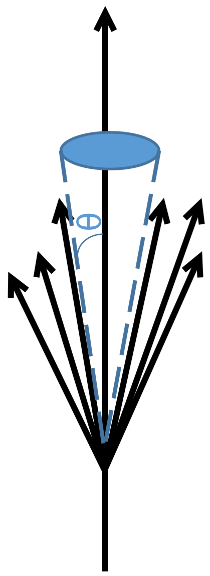
- Particle production around the leading hadron and at the away side is higher compared to the other azimuthal regions
- The production of particles in the 0˚<|Δφ|<20° region becomes relatively lower in case of charm trigger (compared to the light trigger) and is significantly suppressed in events triggered by beauty-hadrons

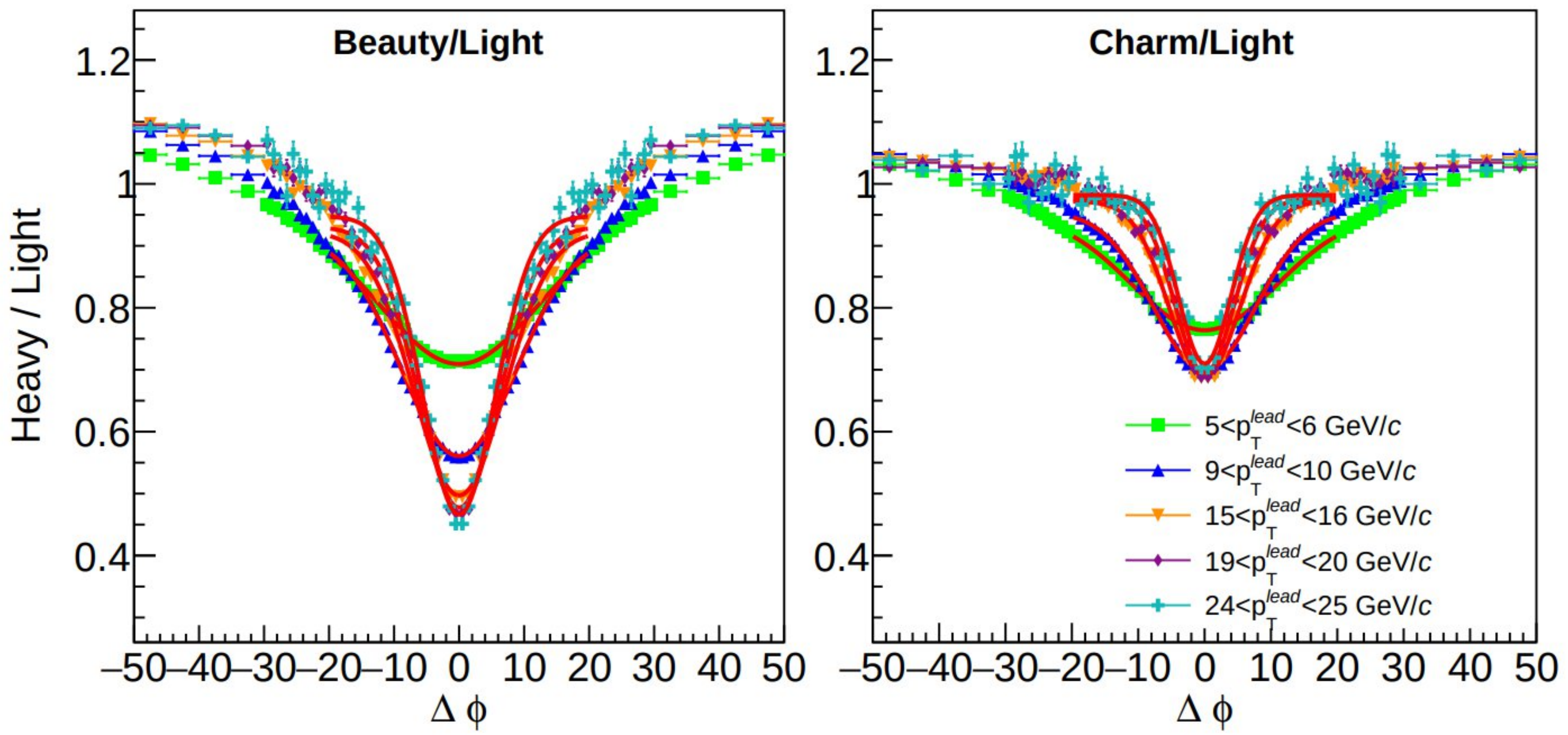
Differential spectra



- To better visualise the change in particle production in different azimuthal region, we compare the relative productions in heavy-flavour-triggered events to the light-flavour-triggered events

Particle depletion near the leading particle



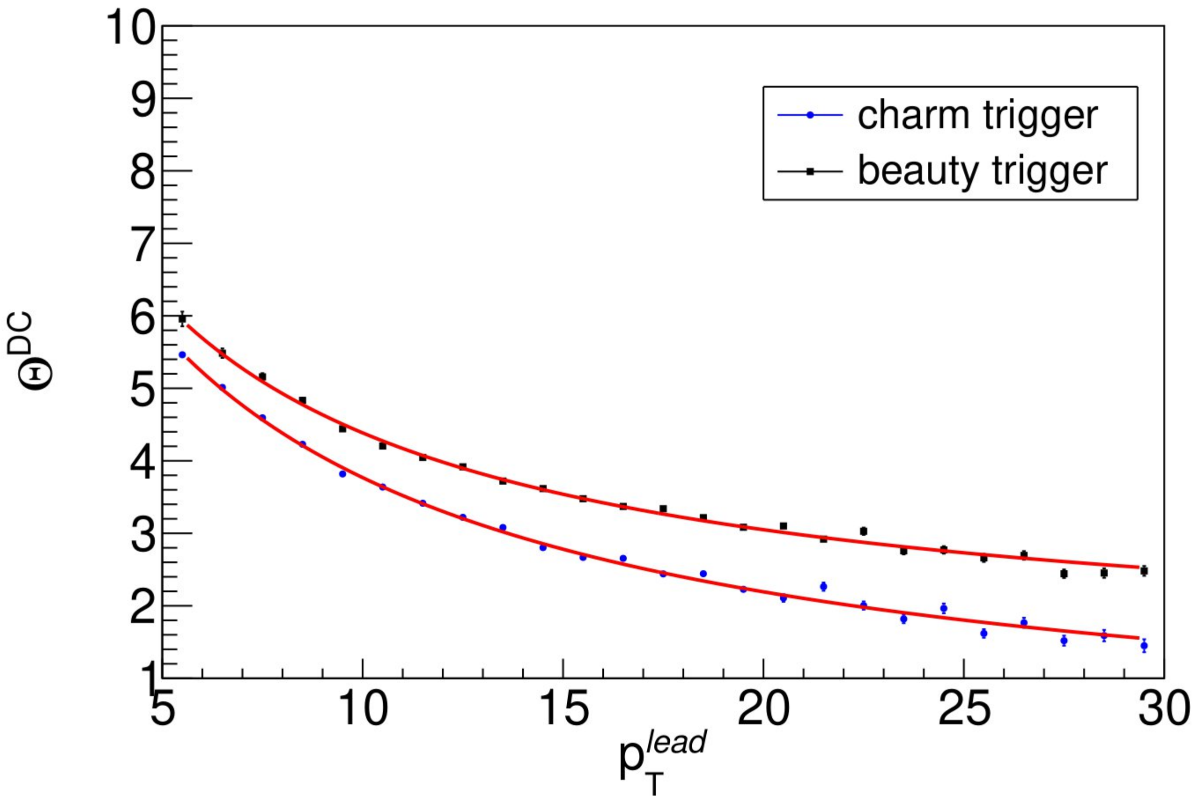


- Fine binning for precise measurement: Δφ bins of 1˚ at low values; p_T^{lead} bins of 1 GeV/*c*
- The size of the dead-cone region was determined by fitting Gauss to the distributions

Size of the dead cone

- The dead-cone angle decreases with the momentum of the leading particle
- The dead cone in beauty-hadron-triggered events is consistently wider than in the cham-hadron-triggered events

- The scaling of the dead-cone size is consistent with theory ($\theta^{DC} \sim m/p_T^{lead}$), however, additional factors are present



Summary

- We presented a Pythia-based strategy for the possible measurement of the QCD dead-cone effect using heavy-flavor-triggered hadron correlations in proton-proton collisions at $\sqrt{s}$ = 13 TeV
- Ratios of charm- and beauty-triggered associated yields to a light-triggered reference exhibit a clear near-side suppression consistent with the dead-cone formation
- Gaussian fits to this suppression define an effective dead-cone angle that decreases with trigger transverse momentum and remains larger for beauty than for charm
- This is in accordance with the expected mass ordering of QCD radiation

- These results motivate an experimental implementation of hadron-level dead-cone observables