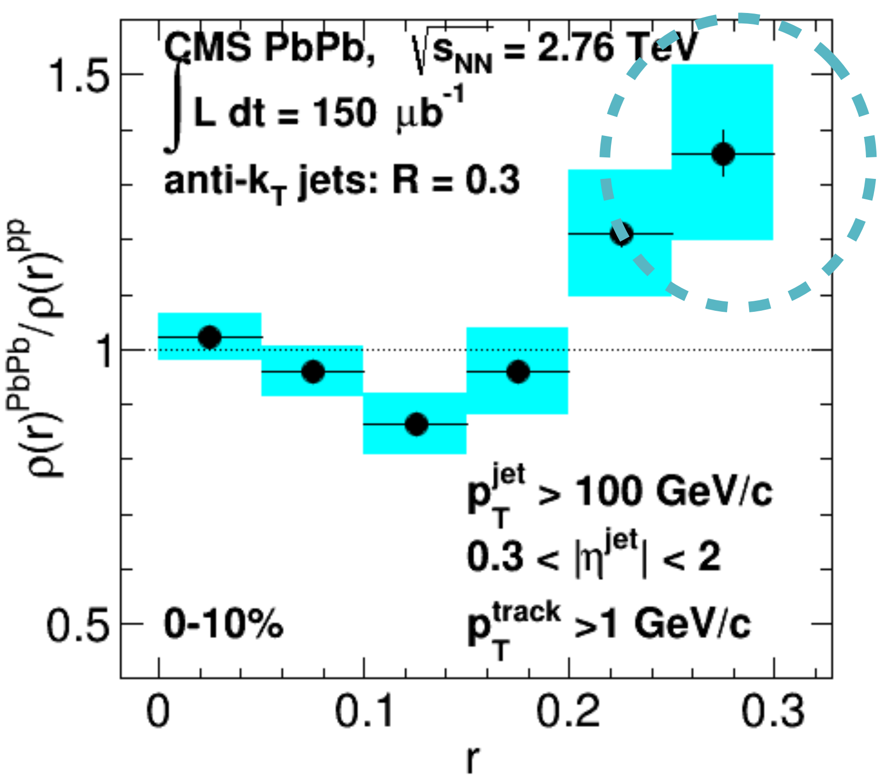
Measurement of D mesons in jets in pp and PbPb with the CMS detector

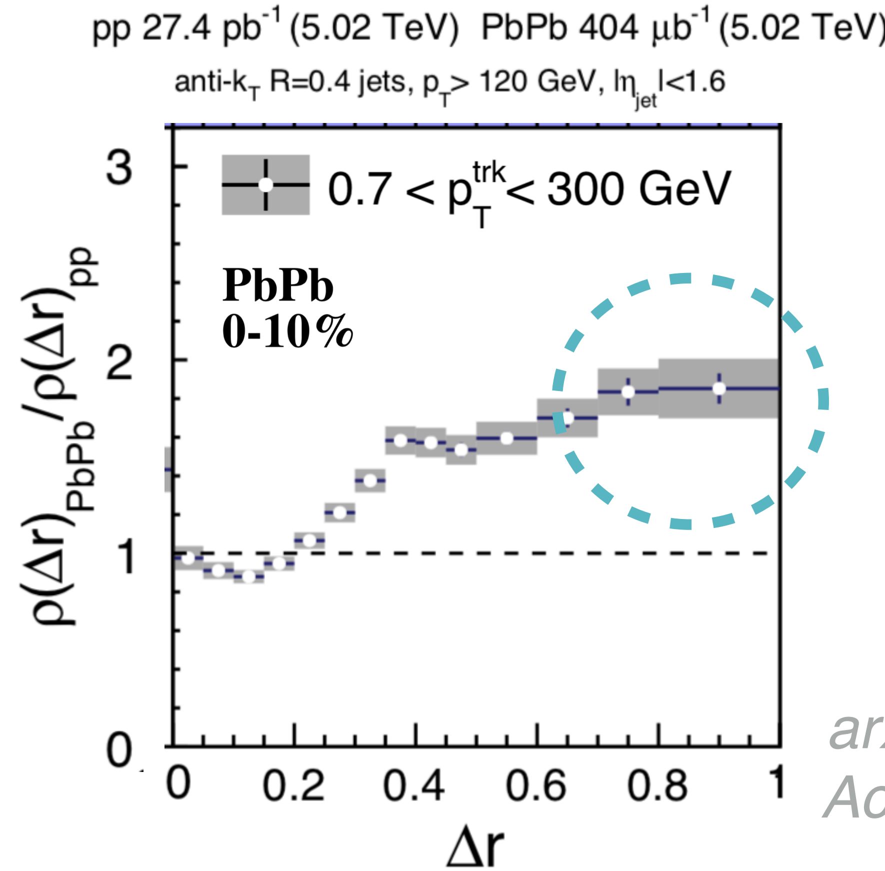
Jing Wang on behalf of the CMS Collaboration

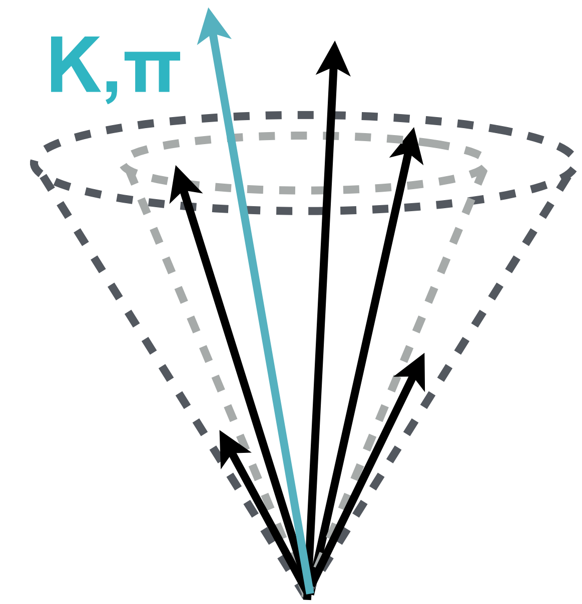
2018 Workshop on Probing Quark-Gluon Matter with Jets
23-25 July 2018
Brookhaven National Laboratory (Upton)

Why study D meson production in jets?

Phys. Lett. B 730 (2014) 243





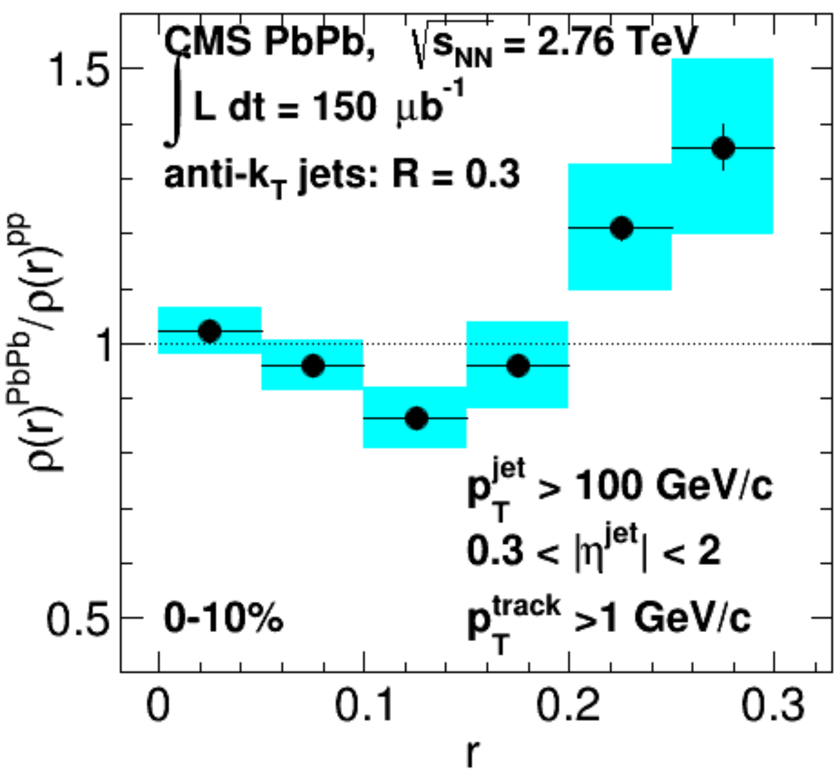


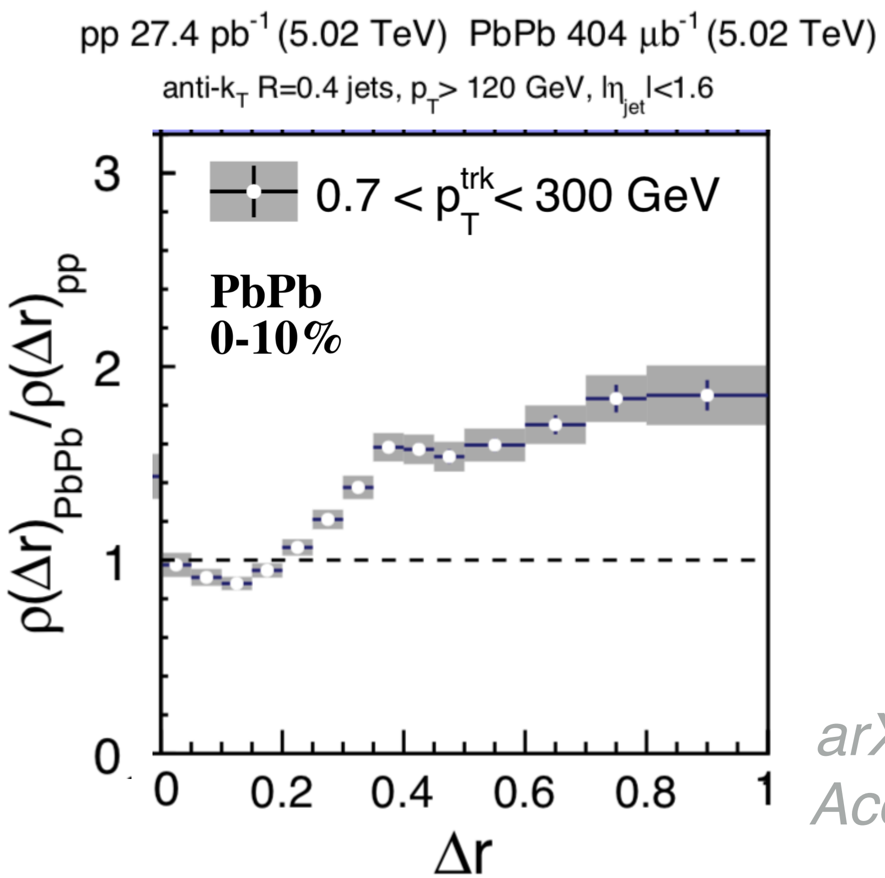
arXiv:1803.00042, Accepted by JHEP

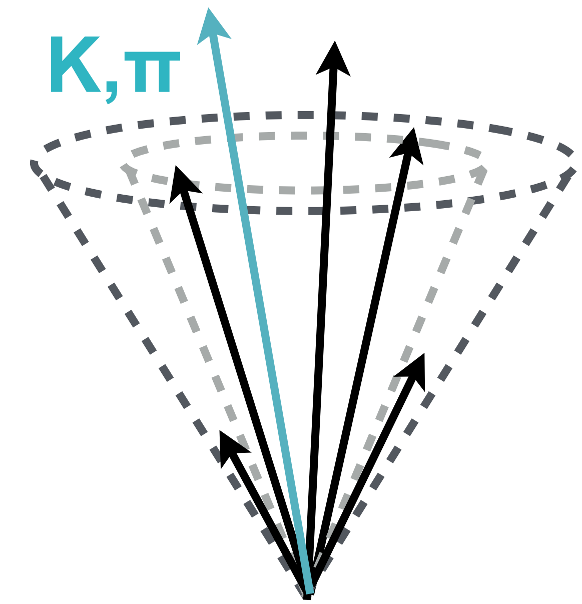
- **Enhancement of low p_T light hadrons at large angles about jets**
  - ➡ Light hadron jet shape analysis

Why study D meson production in jets?

Phys. Lett. B 730 (2014) 243





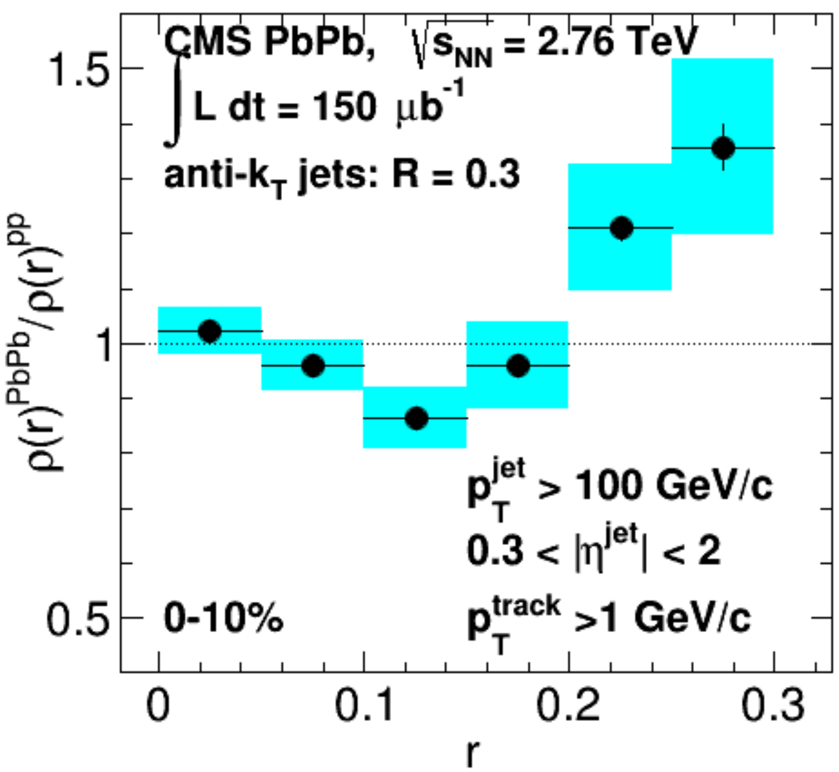


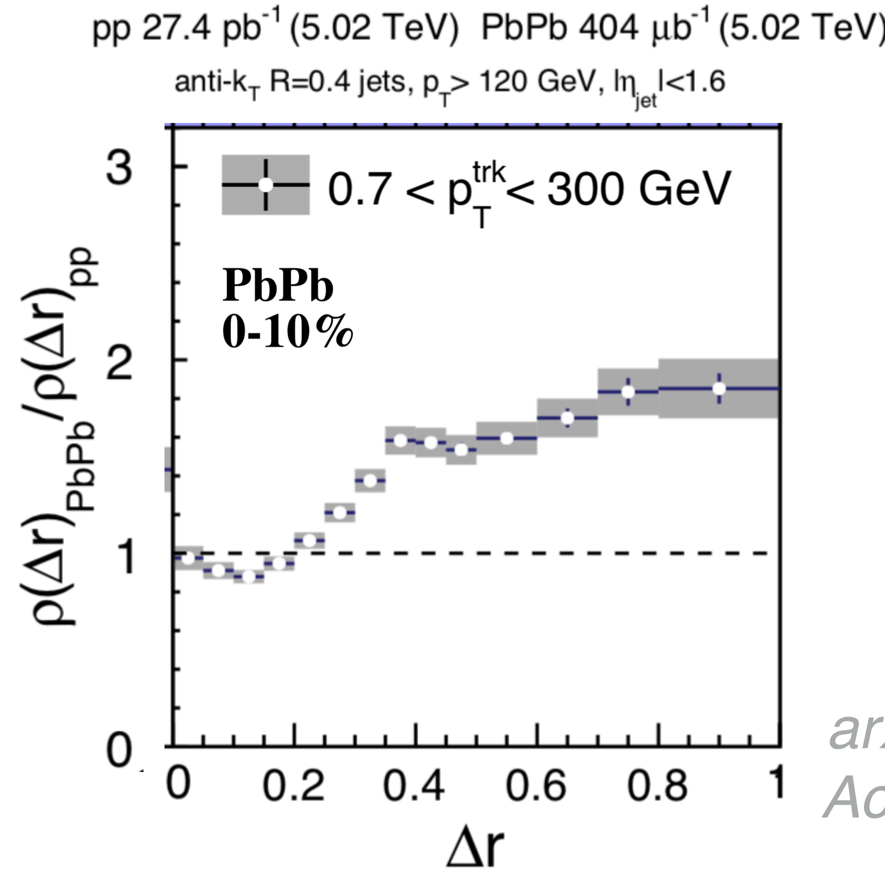
arXiv:1803.00042, Accepted by JHEP

- Enhancement of low p_T light hadrons at large angles about jets
  - ➡ Light hadron jet shape analysis
- **How to explain**
  - ➡ medium-induced gluon radiation?
  - ➡ medium response?
  - ➡ multiple scatterings?
  - ➡ ……

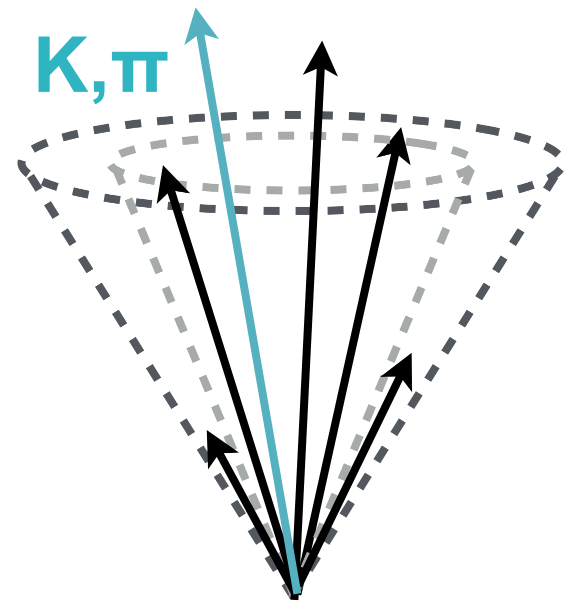
Why study D meson production in jets?

Phys. Lett. B 730 (2014) 243

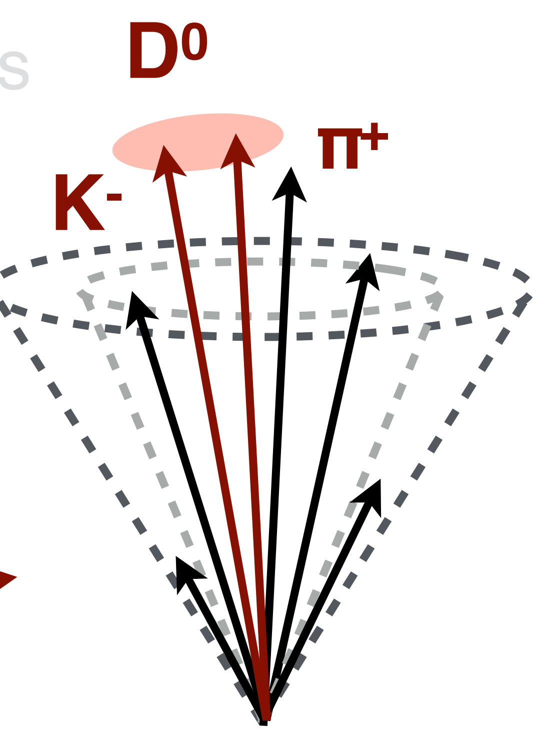




arXiv:1803.00042,
Accepted by JHEP



- Enhancement of low p_T light hadrons at large angles about jets
  - ➡ Light hadron jet shape analysis
- How to explain
  - ➡ medium-induced gluon radiation?
  - ➡ medium response? $m_c \gg T_{QGP}$
  - ➡ multiple scatterings?
  - ➡ ……
- **Vary mass of the associated hadrons**
  - ➡ **Heavy flavor!**



Why study D meson production in jets?

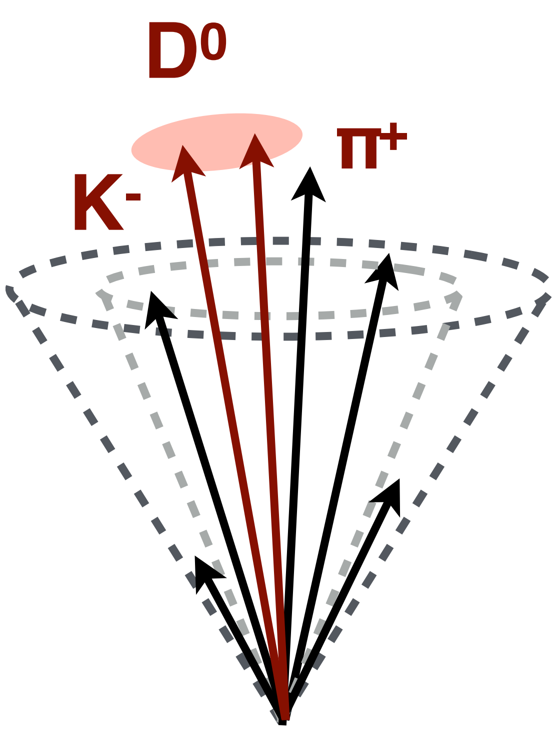
Even more …

Production mechanism of charm

- The role of gluon splitting
- Recombination in the medium

Heavy quark behavior and interactions in the medium

- Energy loss
  - Inclusive measurements:
    - ➡ heavy-flavor hadrons spectra, azimuthal anisotropy, heavy flavor tag jets
  - Details on interaction of heavy quarks about jet directions
- Diffusion

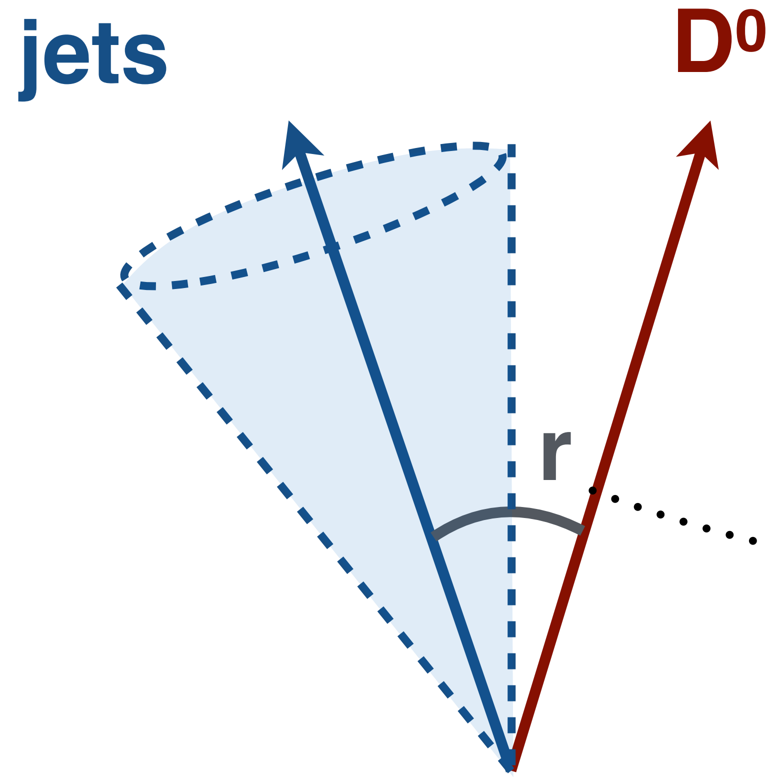


Dataset and observables

- **Jet-triggered** events in **pp** (27.4 pb^{-1}) and **PbPb** (404 μb^{-1}) collisions at $\sqrt{s_{NN}}$ **= 5.02 TeV** collected in 2015 with the CMS detector
- **MinimumBias** events are used for background subtraction
- Cross-checked with **D-triggered events**

Dataset and observables

- **Jet-triggered** events in **pp** (27.4 pb^{-1}) and **PbPb** (404 μb^{-1}) collisions at $\sqrt{s_{NN}}$ **= 5.02 TeV** collected in 2015 with the CMS detector



relative η,Φ between D and jets

$$r = \sqrt{\Delta\phi_{JD}^2 + \Delta\eta_{JD}^2}$$

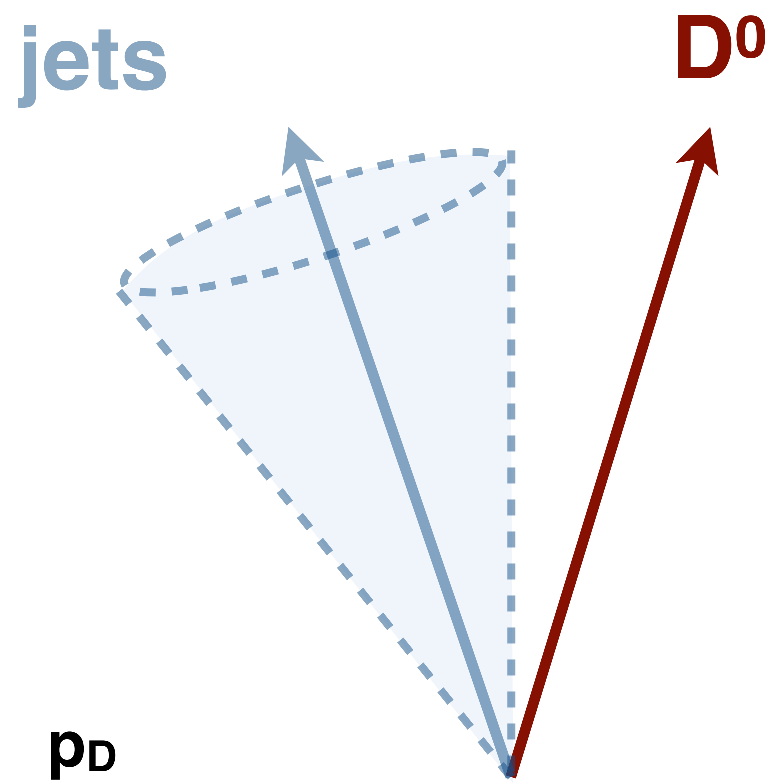
- **Radial distribution of D^0 with respective to the jet axis:**

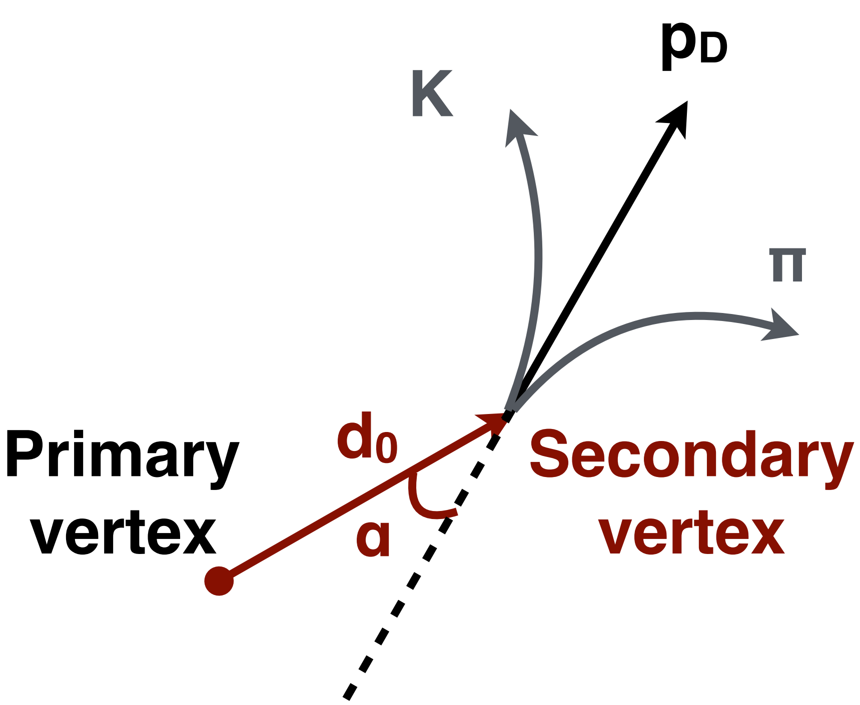
$$\frac{1}{N_{JD}}\frac{dN_{JD}}{dr}$$

- The final distribution is normalized to unity in $r < 0.3$
- No p_T weight as light-hadron jet shape analysis

D and jets reconstruction and selections

- **Jet-triggered** events in **pp** ($27.4\ \mathrm{pb}^{-1}$) and **PbPb** ($404\ \mu\mathrm{b}^{-1}$) collisions at $\sqrt{s_{NN}}$ **= 5.02 TeV** collected in 2015 with the CMS detector



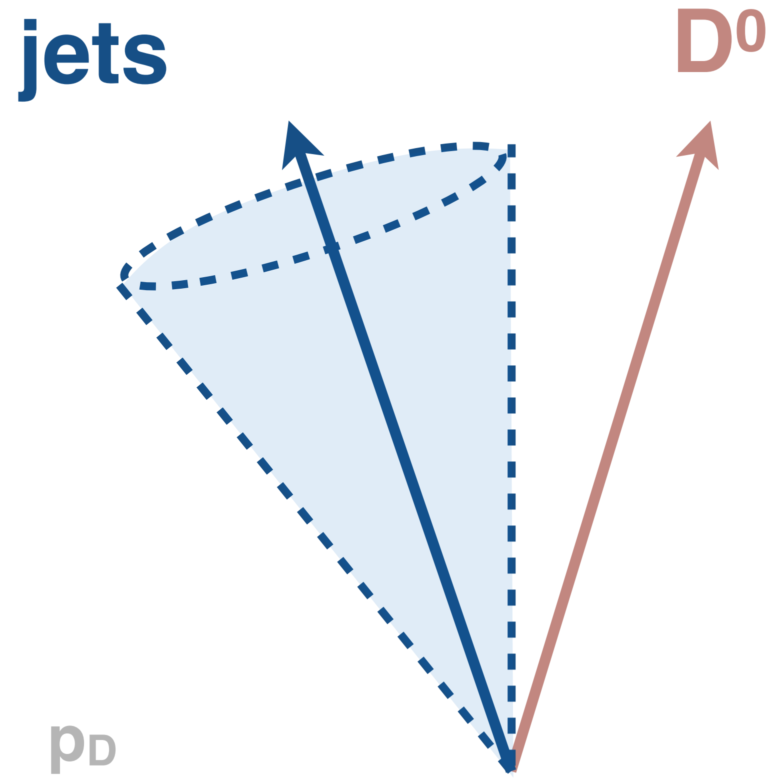


- $D^0 \to K\pi$
- D^0 vertex reconstruction
  - pairing two tracks
  - kinematic fitter
- Topological selections
  - Pointing angle (α) $< \sim 0.04$
  - 3D decay length (d_0) normalized by its error $> \sim 3$
  - Secondary vertex prob $> \sim 0.05$
- $|y^D| < 2$
- Two p_T bins
  - $4 < p_T^D < 20$ GeV
  - $p_T^D > 20$ GeV

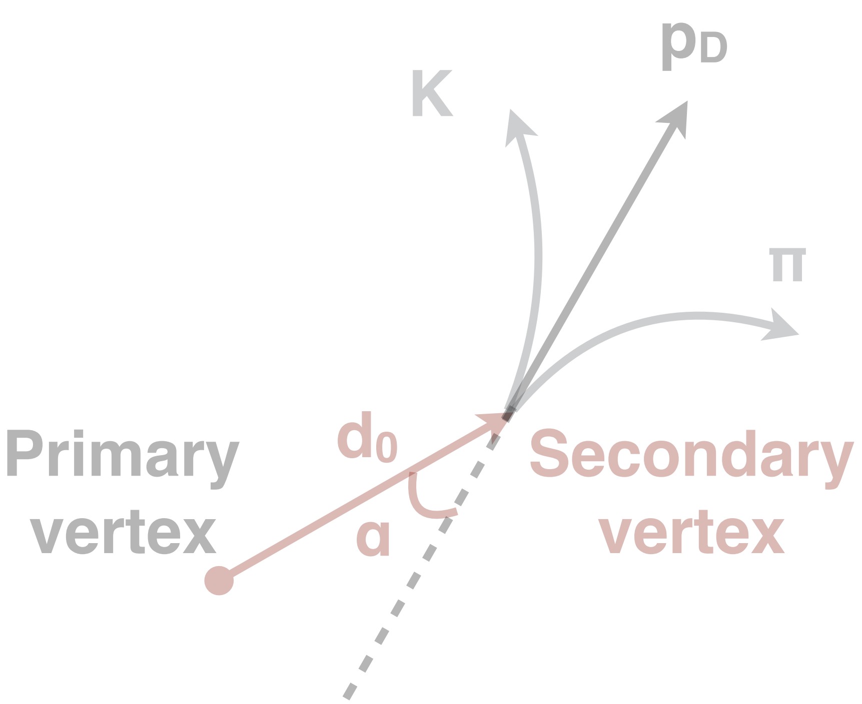
D and jets reconstruction and selections

- **Jet-triggered** events in **pp** (27.4 pb^{-1}) and **PbPb** (404 μb^{-1}) collisions at $\sqrt{s_{NN}}$ **= 5.02 TeV** collected in 2015 with the CMS detector

- Particle flow jets
- anti-k_T, R = 0.3
- $p_T^{jet} > 60$ GeV/c
- $|\eta^{jet}| < 1.6$



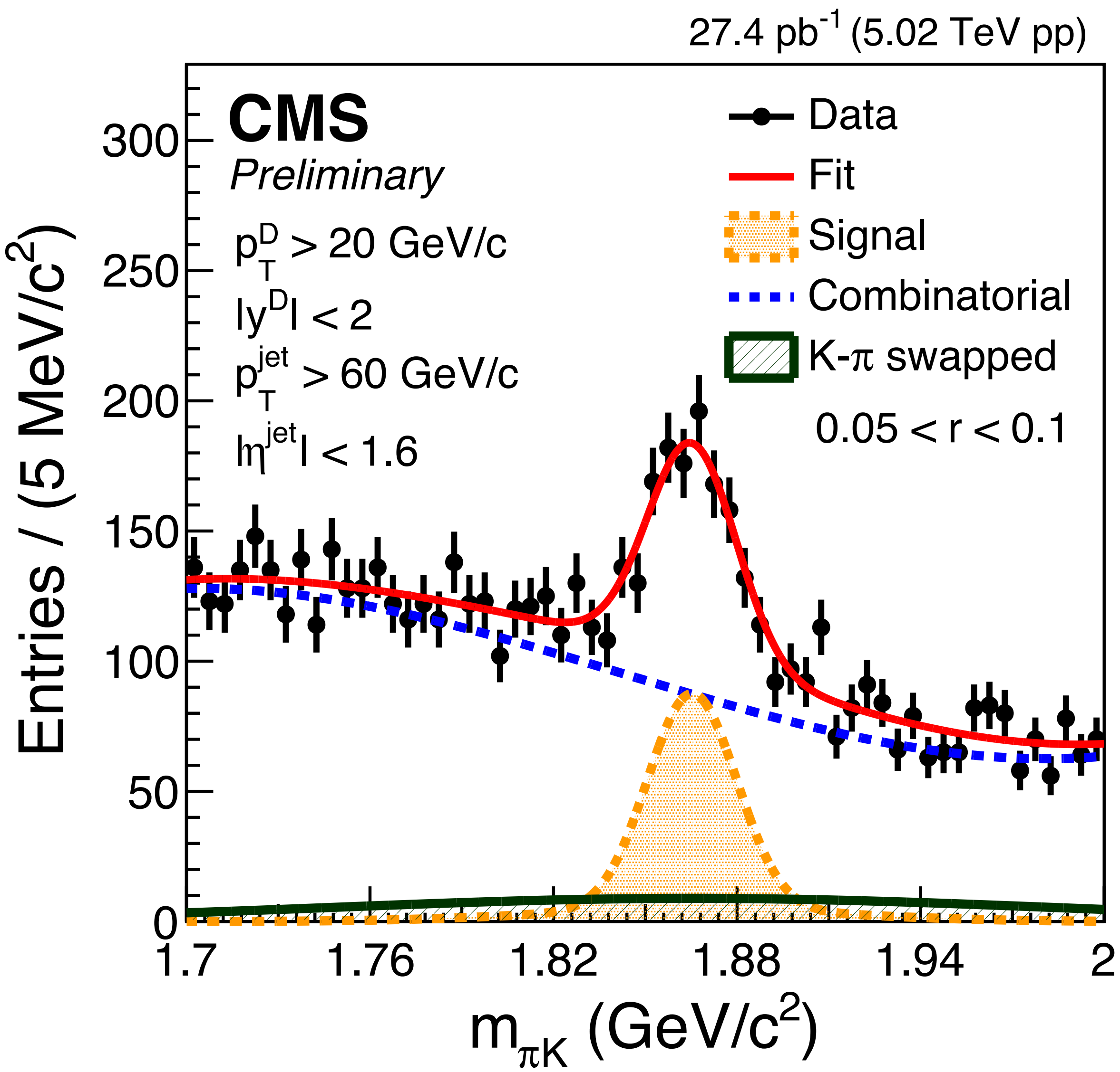
- $D^0 \rightarrow K\pi$
- D^0 vertex reconstruction
  - pairing two tracks
  - kinematic fitter
- Topological selections
  - Pointing angle (α) < ~0.04
  - 3D decay length (d_0) normalized by its error > ~3
  - Secondary vertex prob > ~0.05
- $|y^D| < 2$
- Two p_T bins
  - $4 < p_T^D < 20$ GeV
  - $p_T^D > 20$ GeV



Analysis strategy

- **Reconstruct** jets and D^0 candidates
- **Jet energy correction**
- **Pair** selected D^0 candidates with *every* selected jet in the same event
- Extract raw yield via **fitting invariant mass** in bins of r
- Correct **acceptance** and **efficiency** by simulations in bins of r
- **Subtract background** via event mixing technique
- Correct the **resolution effect** by the jet resolution from simulations

Raw D^0 yield extraction



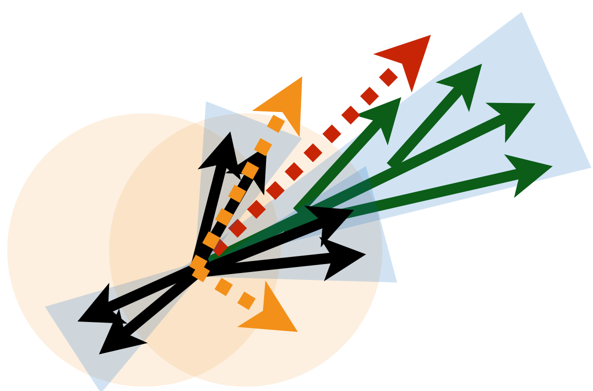
Mass distributions fitted by

- Double gaussian (Signal)
- 3rd order polynomial (Combinatorial)
- Single gaussian (K-π swapped)
    - Candidates with wrong mass assignment

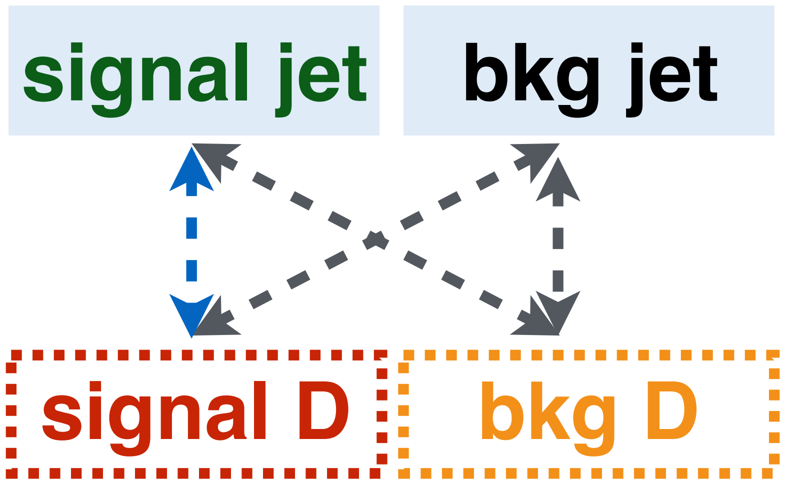
CMS-PAS-HIN-18-007

Event mixing technique

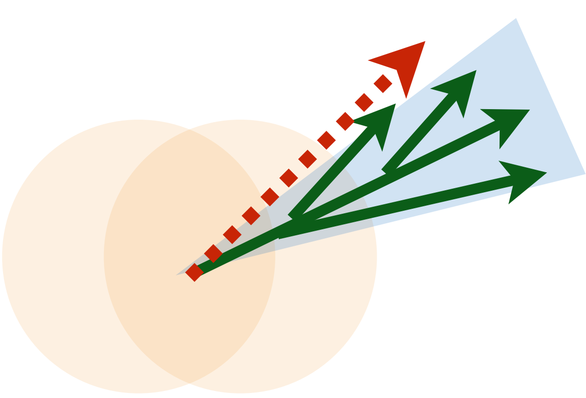
- **Signal**: jets and D⁰ mesons from the same hard scattering
- **Background**: fake jets, jets and D⁰ mesons in underlying events, …



before subtraction

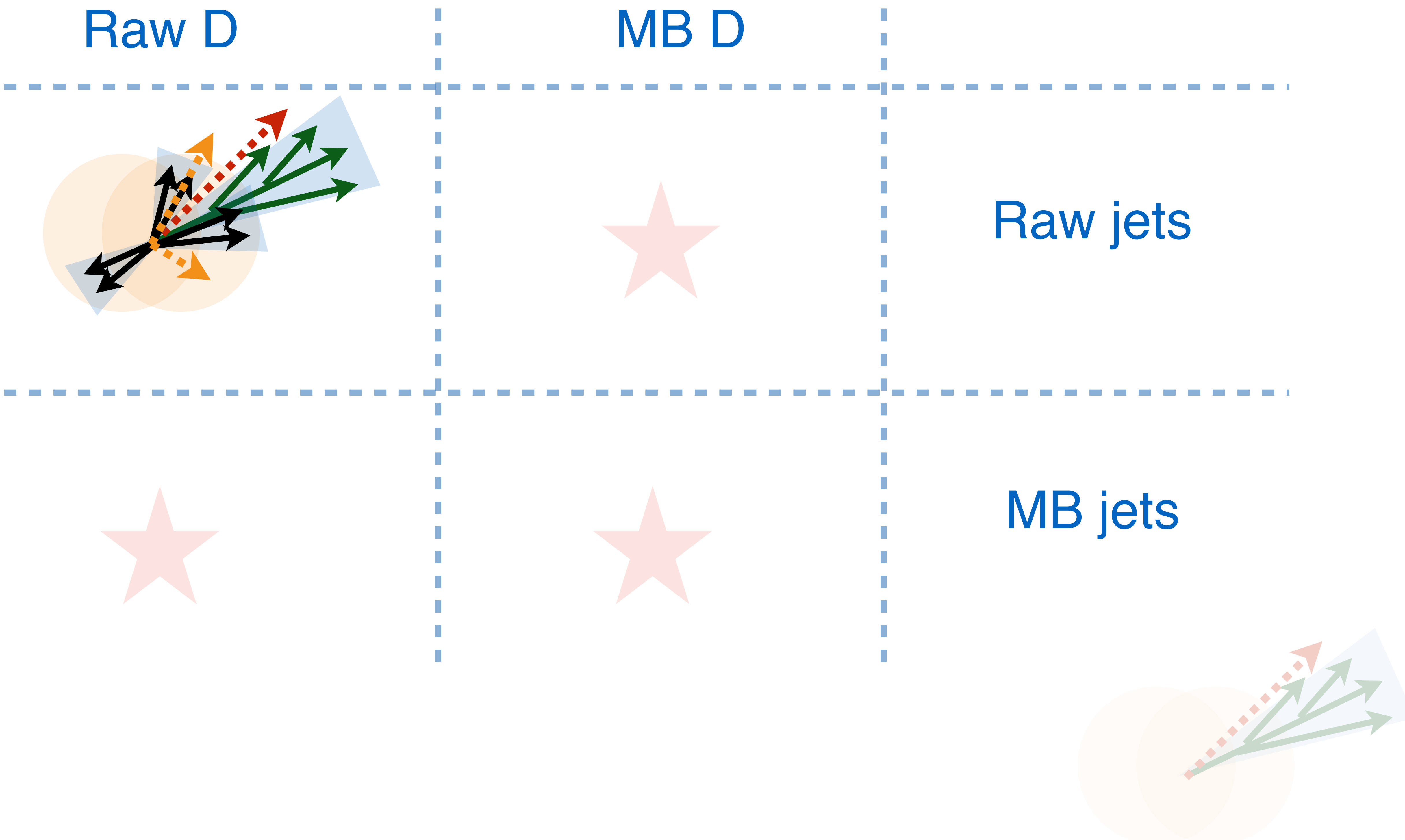


pure signal



Event mixing technique

- Correlate D^0 mesons and jets in **triggered events (raw)** and **MB events (bkg)**



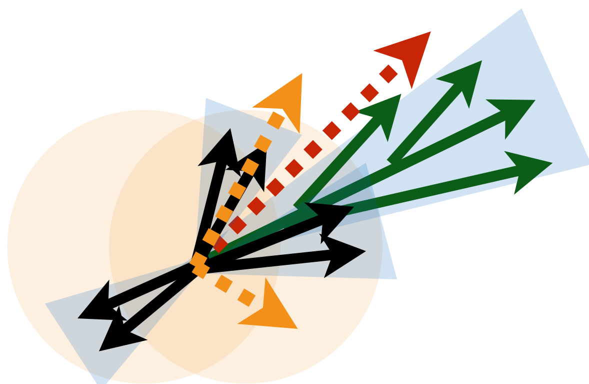
Event mixing technique

- Correlate D^0 mesons and jets in **triggered events (raw)** and **MB events (bkg)**

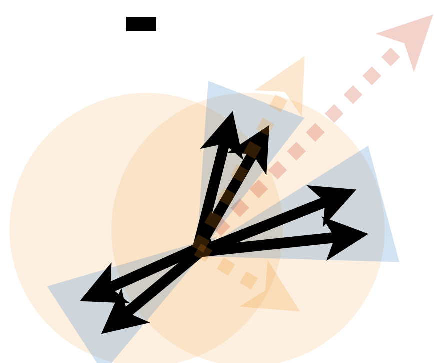
Raw D

MB D

Raw jets



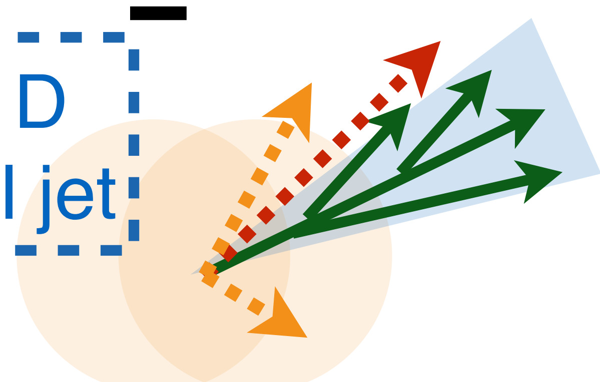
-



MB jets

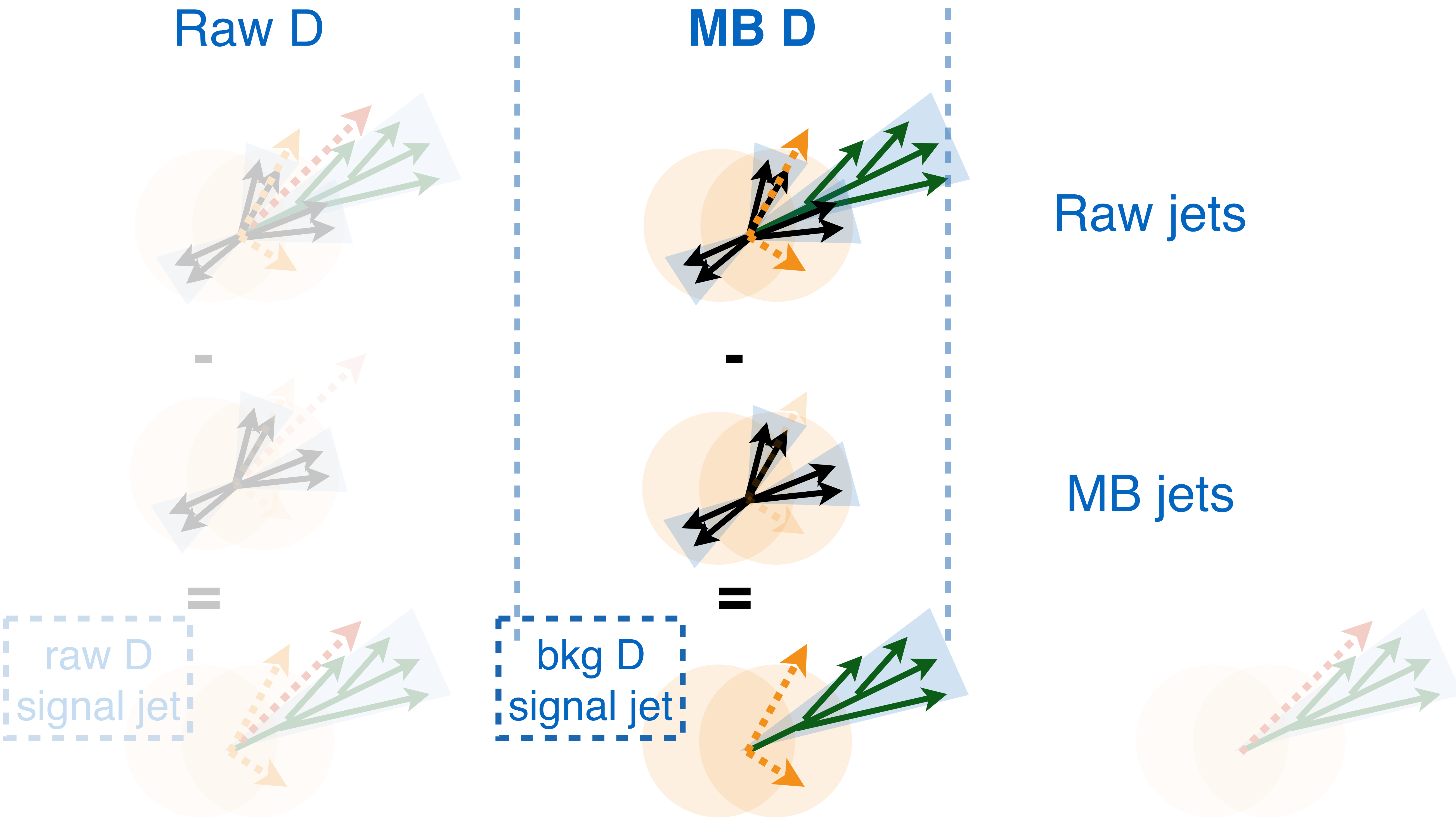
=

raw D signal jet



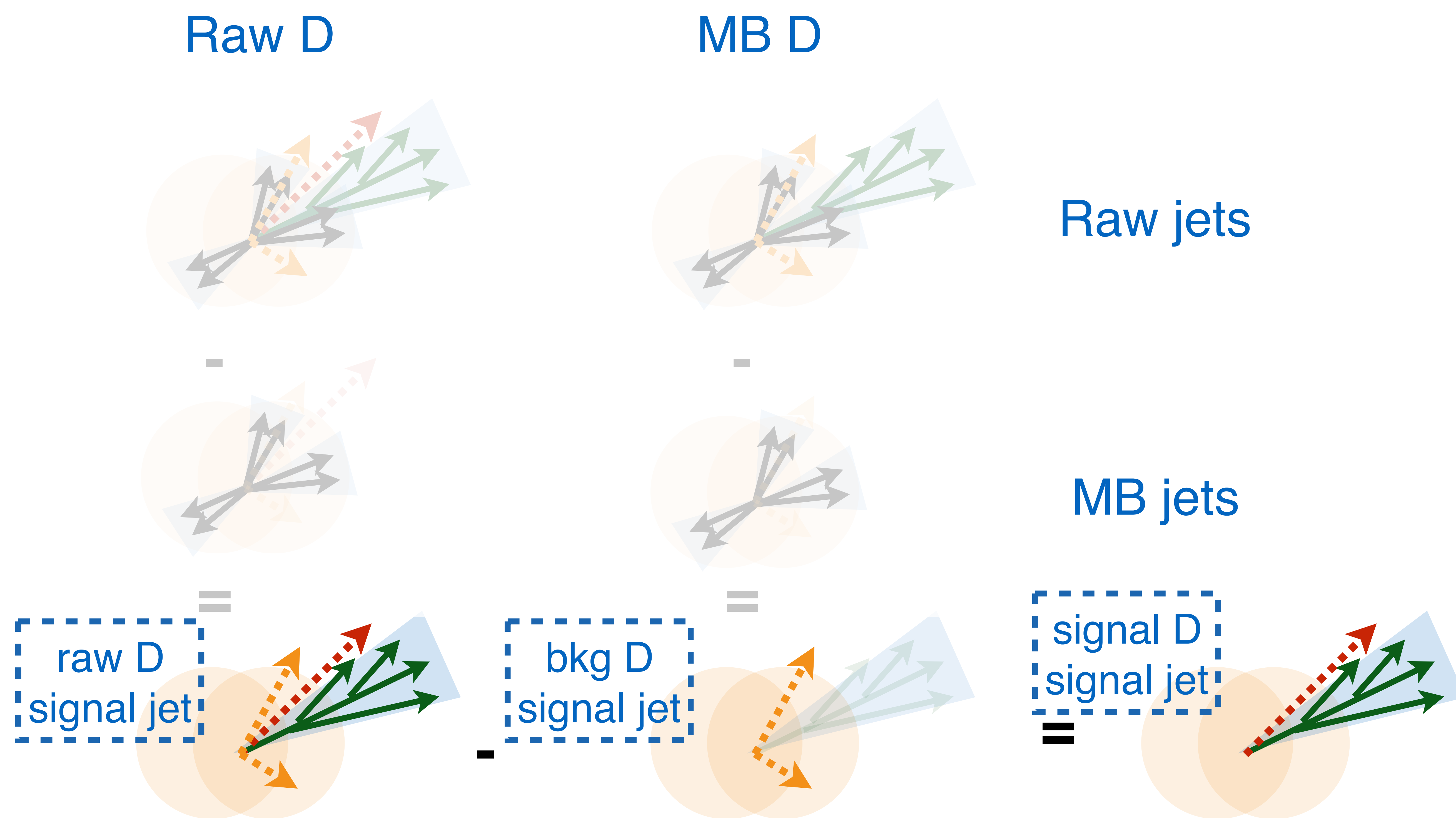
Event mixing technique

- Correlate D^0 mesons and jets in **triggered events (raw)** and **MB events (bkg)**



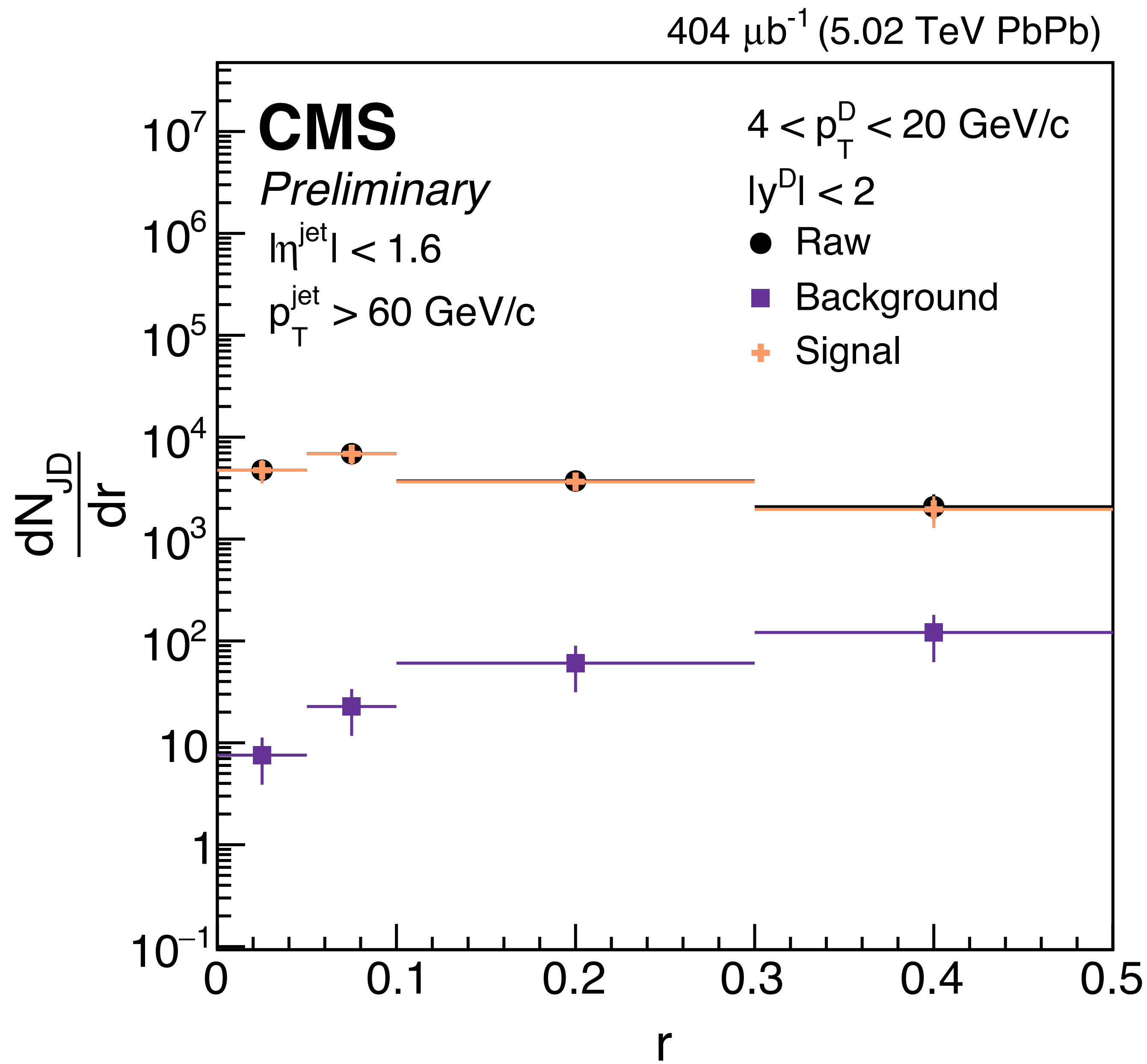
Event mixing technique

- Correlate D^0 mesons and jets in **triggered events (raw)** and **MB events (bkg)**



Background subtraction

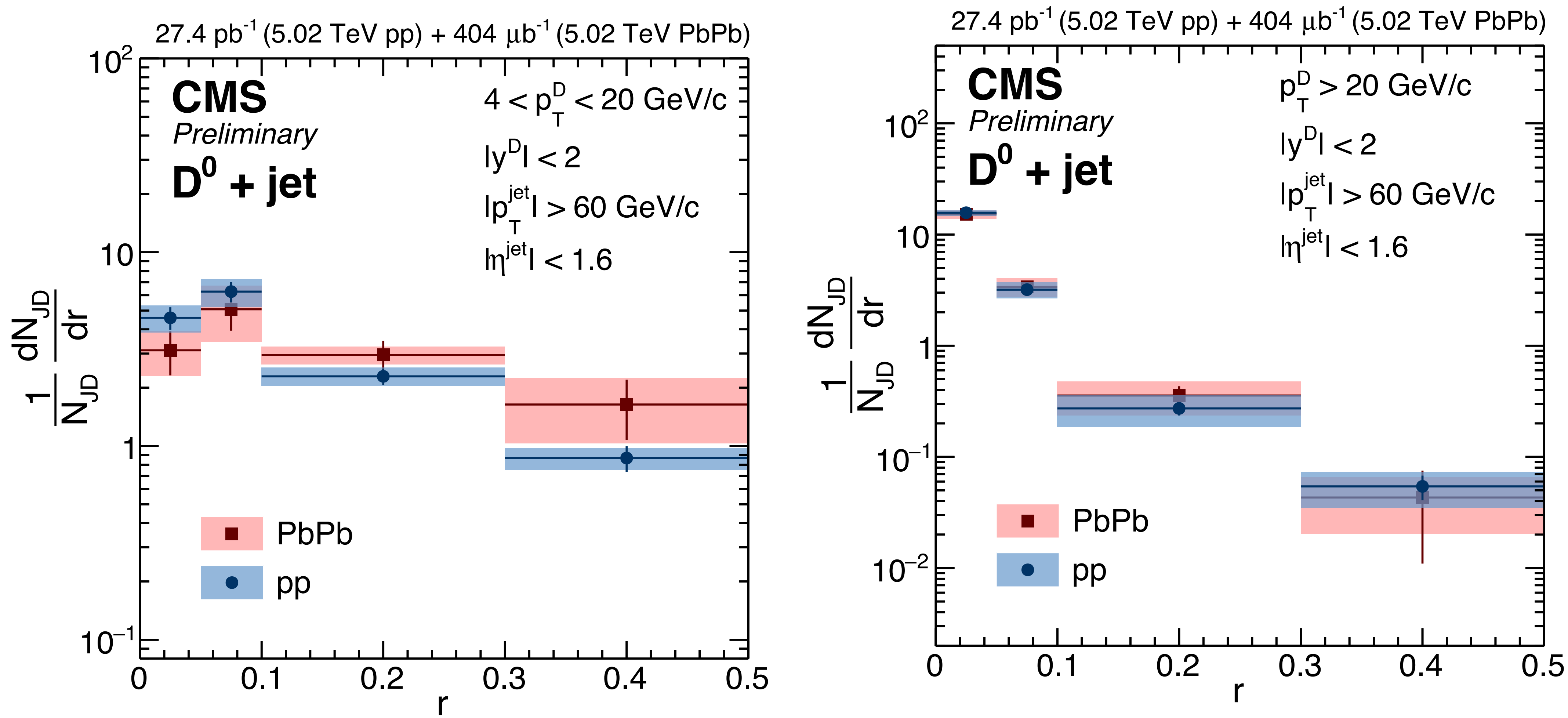
- Signal = Raw - Background
- Background contributions are much smaller than signal



CMS-PAS-HIN-18-007

Results

Low D p_T: $4 < p_T^D < 20$ GeV/c | **High D p_T**: $p_T^D > 20$ GeV/c

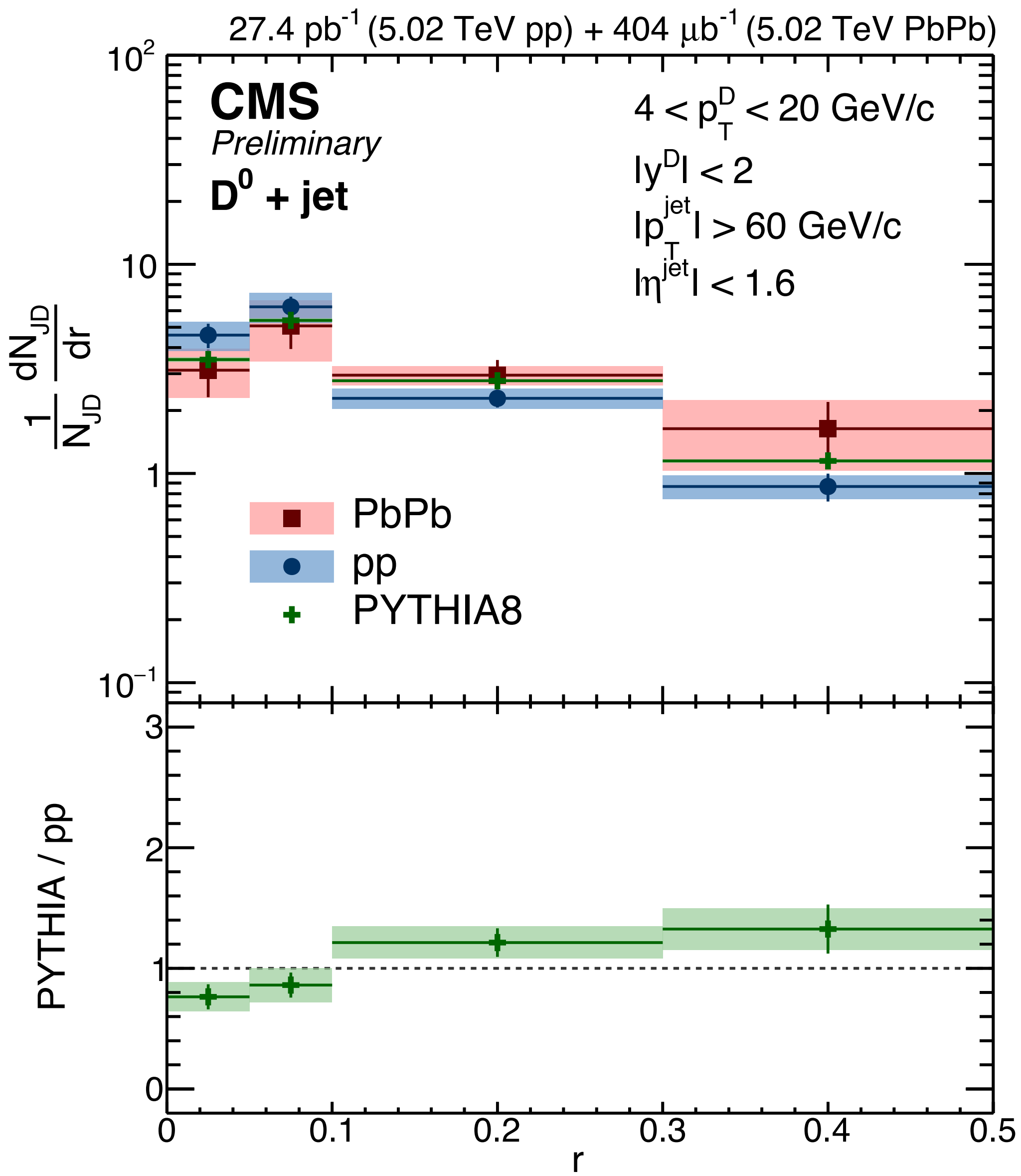


- Low D p_T: reach maximum at $0.05 < r < 0.1$
- High D p_T: fall rapidly as a function of r

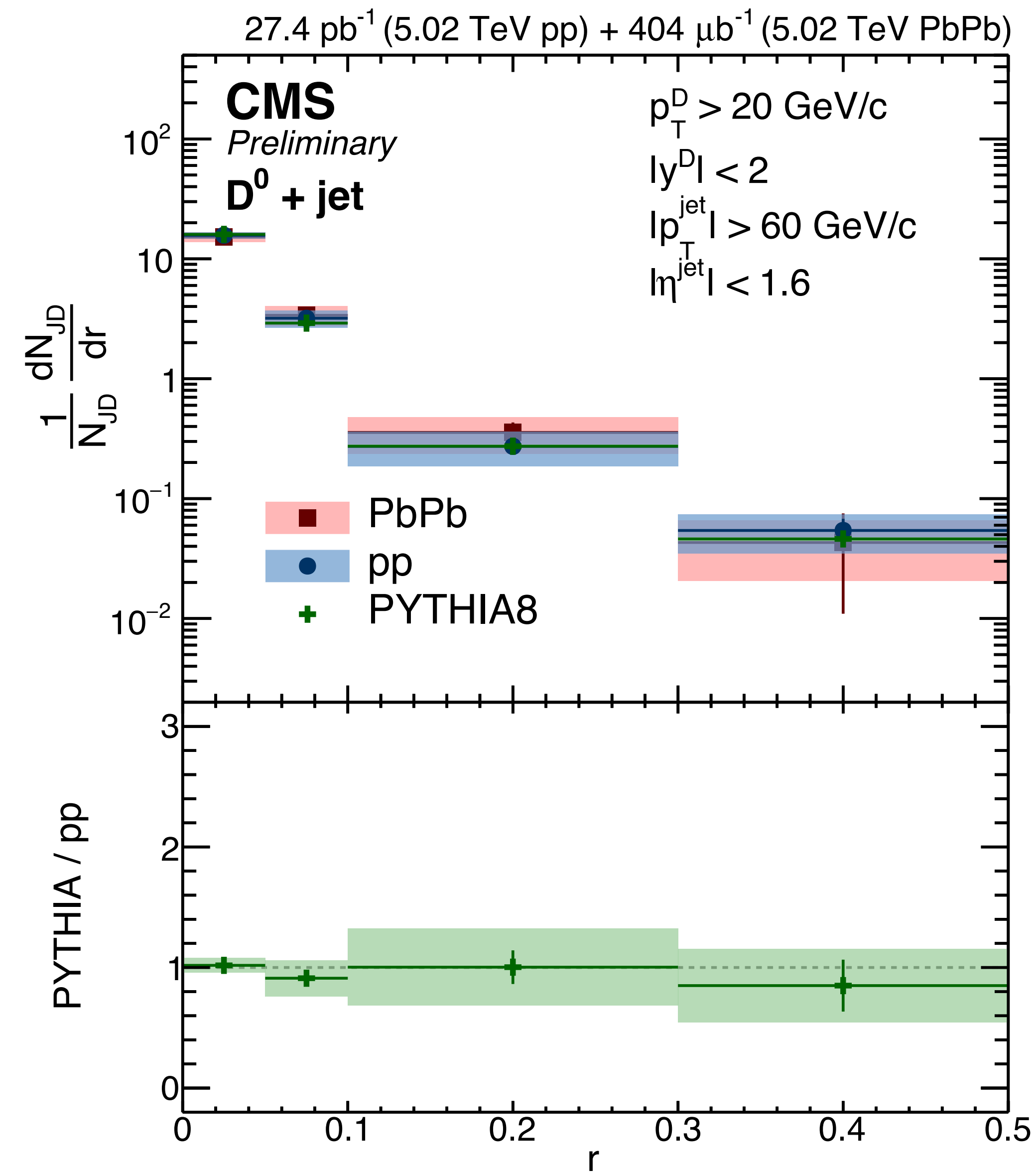
CMS-PAS-HIN-18-007

Results

Low D p_T: $4 < p_T^D < 20$ GeV/c



High D p_T: $p_T^D > 20$ GeV/c

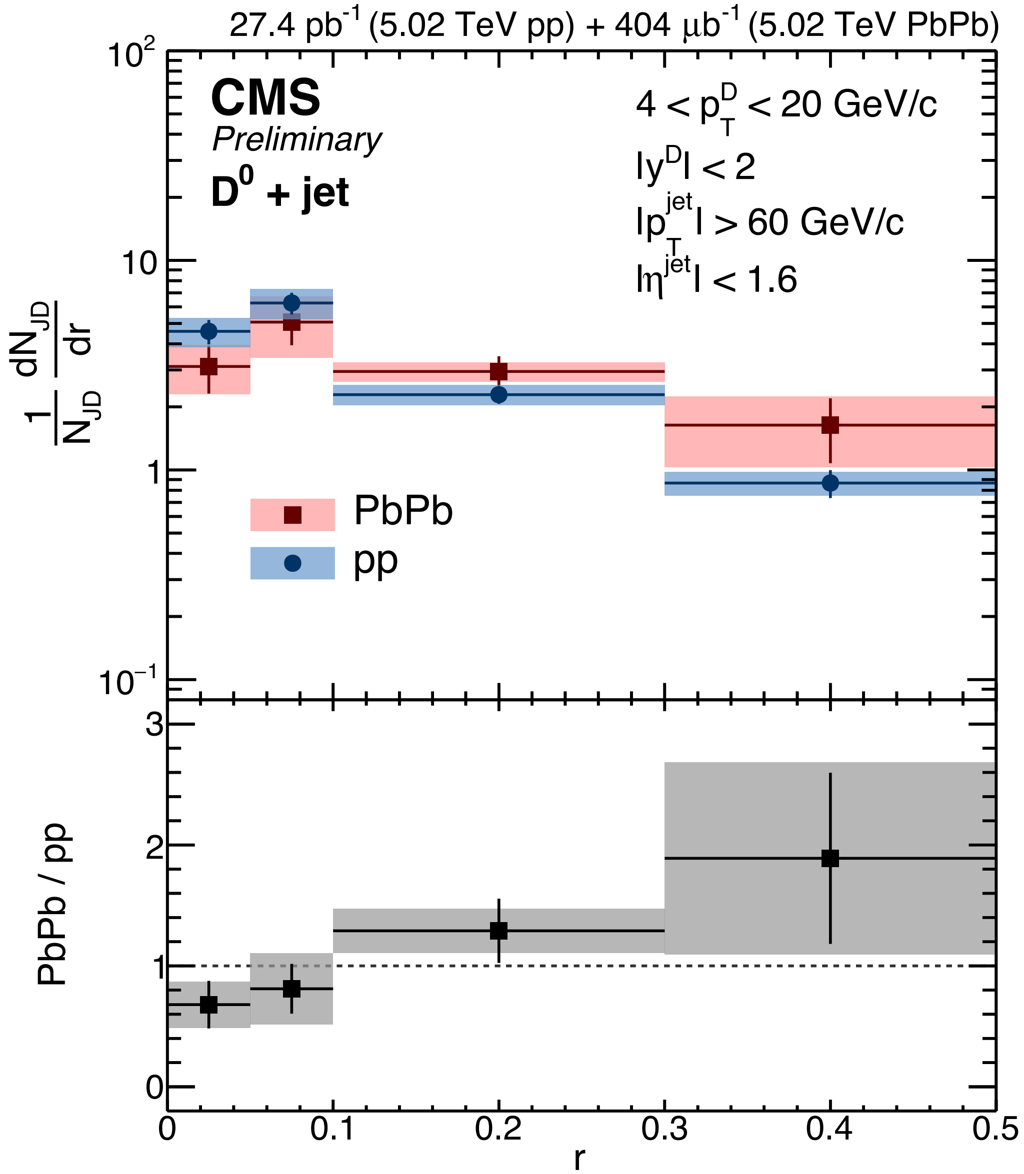


- predictions from PYTHIA 8
  - ➡ Low D p_T: produce a wider radial profile than measurements
  - ➡ High D p_T: agree with measurements

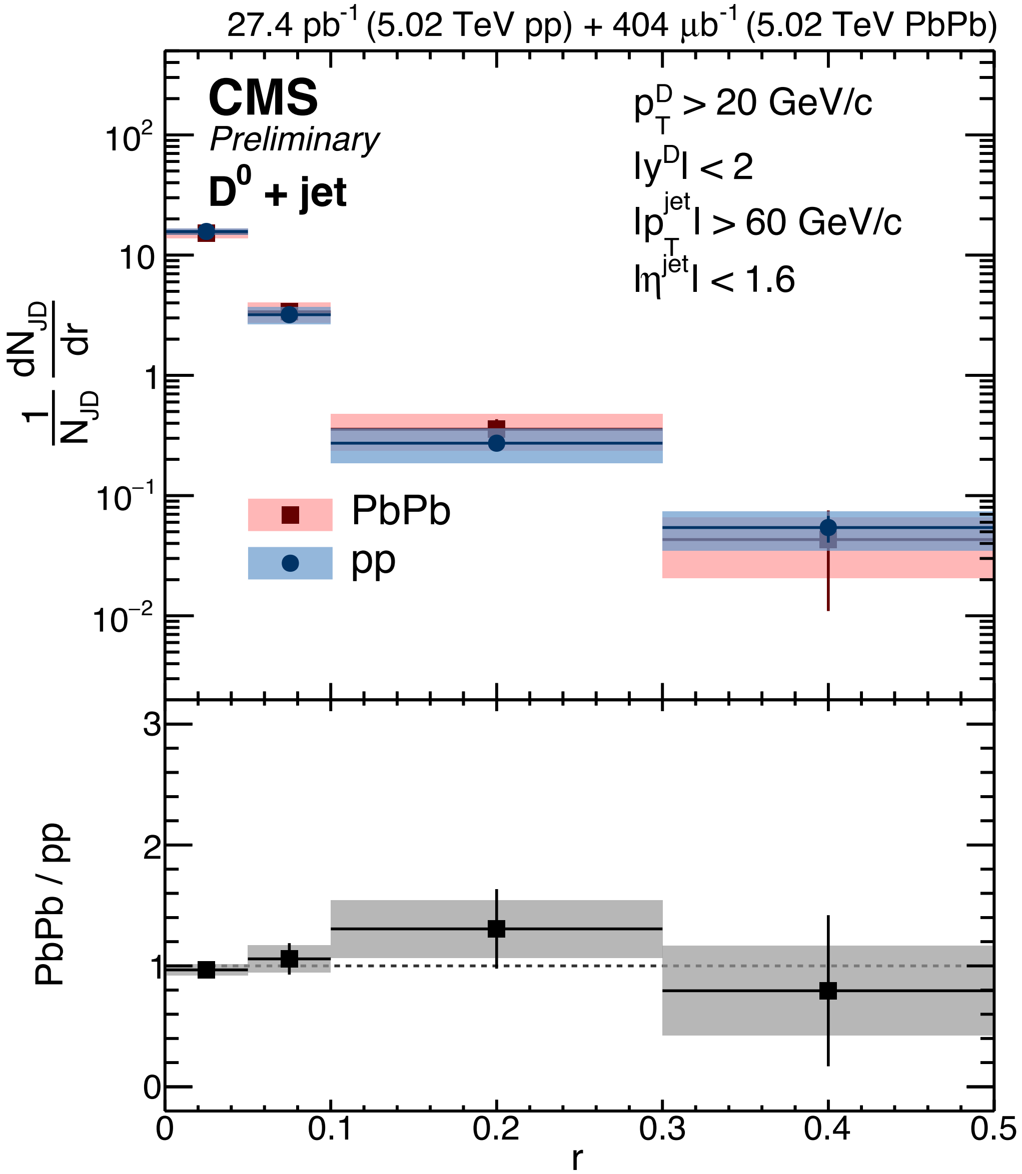
CMS-PAS-HIN-18-007

Results

Low D p_T: $4 < p_T^D < 20$ GeV/c



High D p_T: $p_T^D > 20$ GeV/c



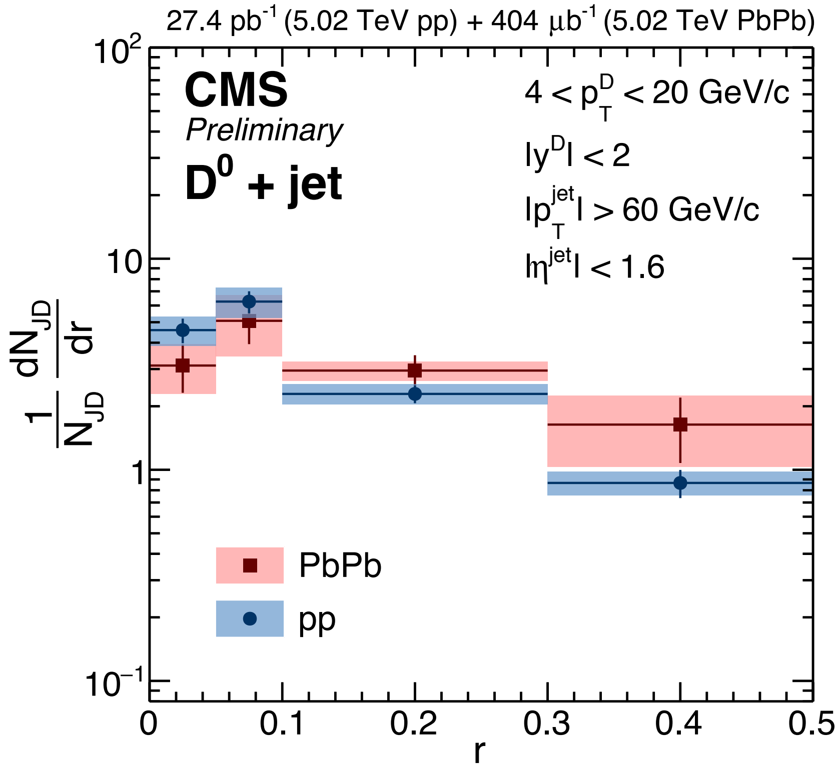
- The ratio of PbPb over pp:
- Low D p_T: increases as a function of r
  - ➡ Hint that D^0 are further from jet axis in PbPb than pp
- High D p_T: consistent with unity

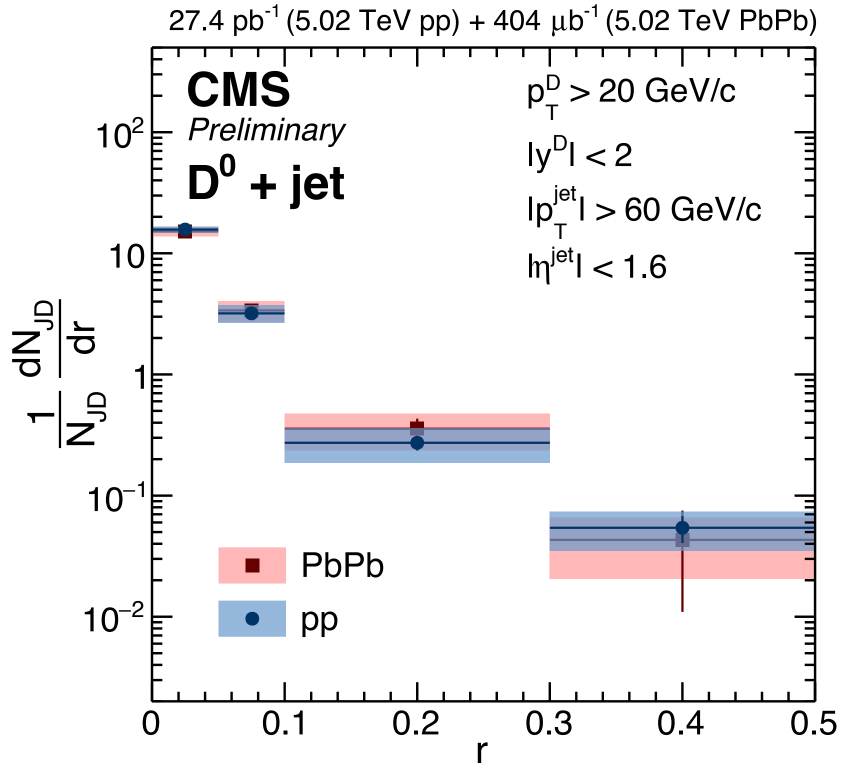
CMS-PAS-HIN-18-007

Last slide

Summary

- First measurement of the **radial profile of D^0 mesons in jets** in PbPb and pp
  - ➡ Hint of wider D^0 radial profile in PbPb collisions at $4 < p_T^D < 20$ GeV/c
  - ➡ Ratio of PbPb/pp is consistent with unity at $p_T^D > 20$ GeV/c
- Provides new experimental constraints on
  - ➡ heavy-flavor production
  - ➡ heavy quark energy loss and diffusion





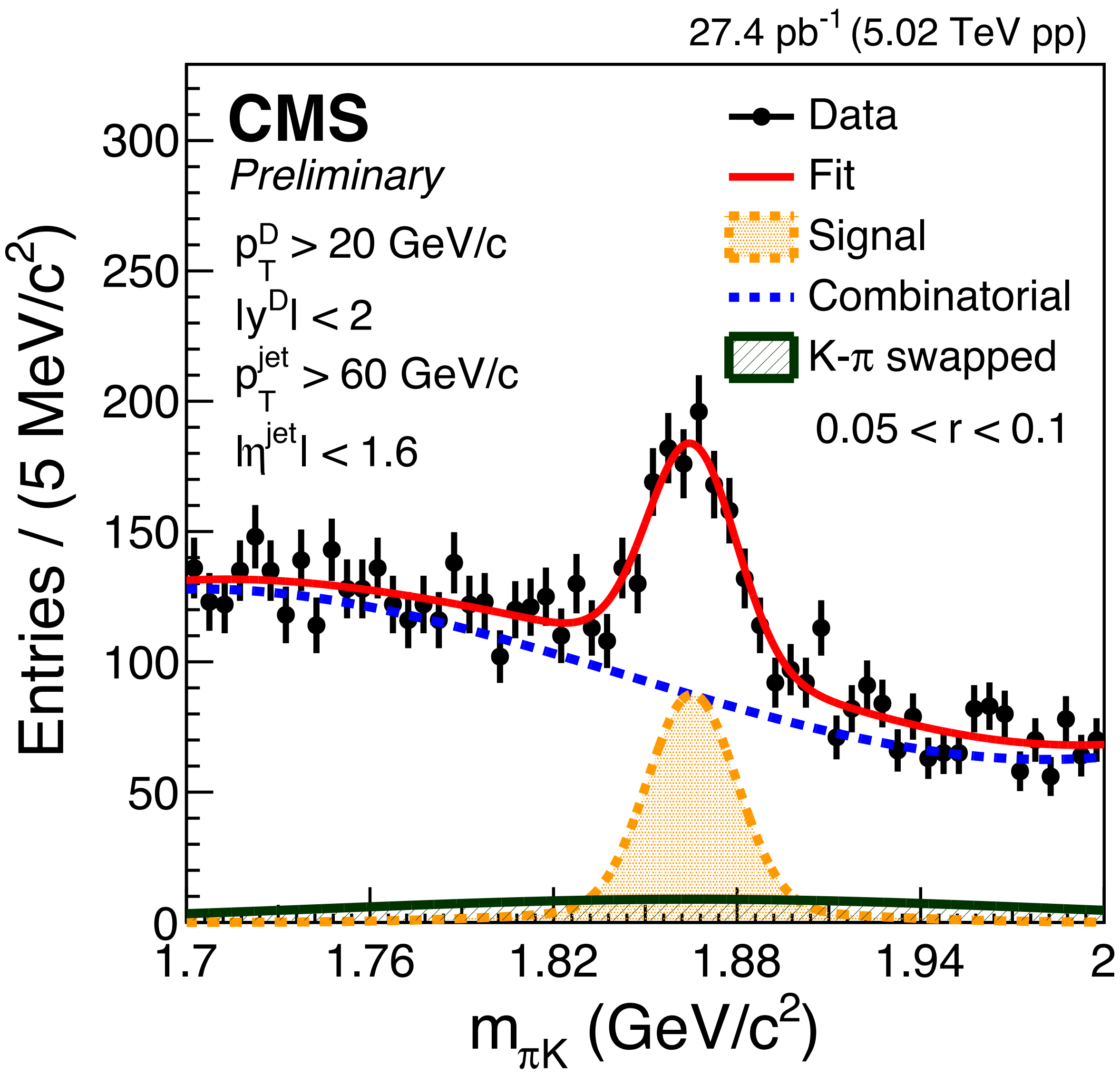
The MIT group's work was supported by US DOE-NP

Back up

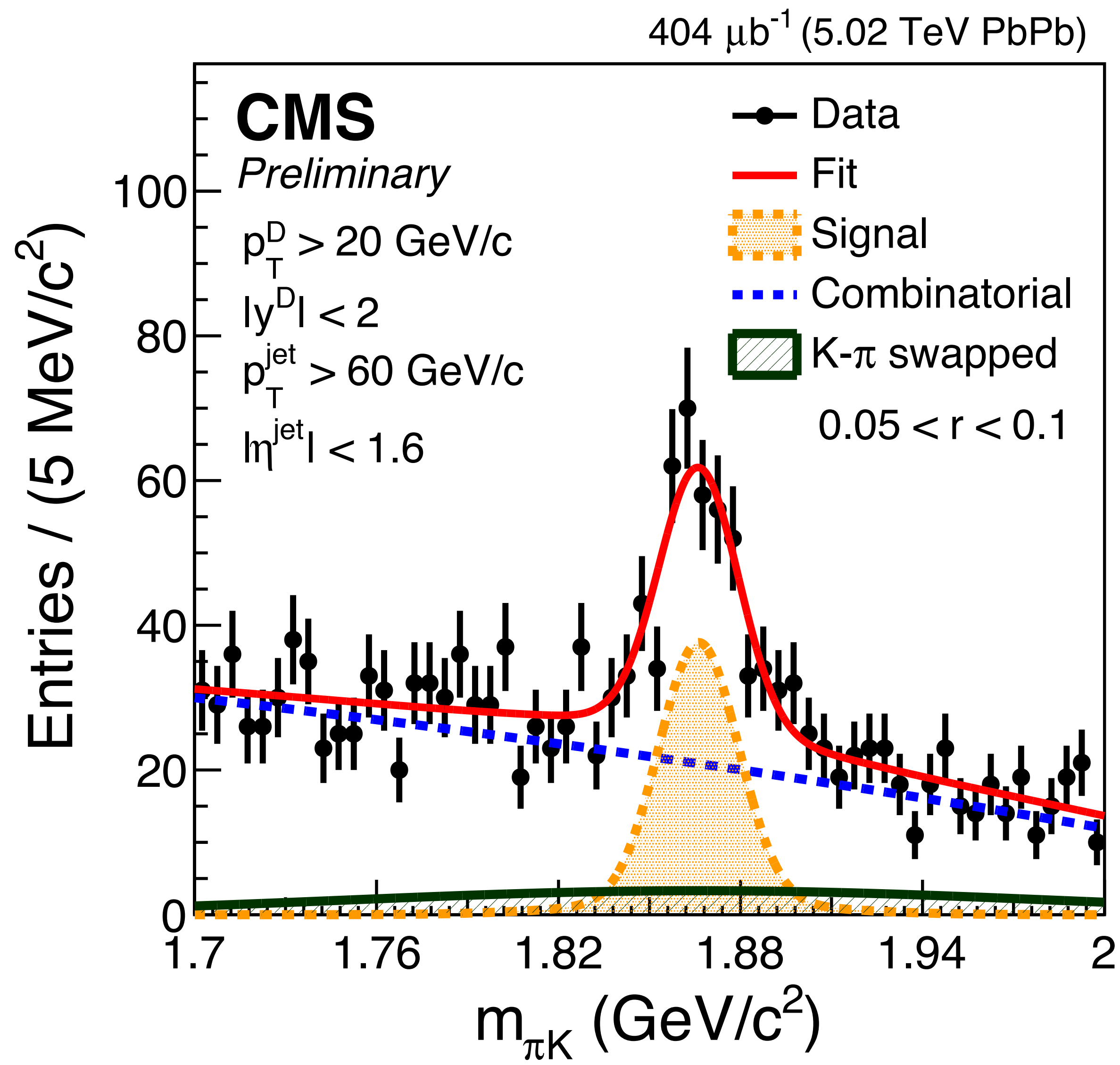
Thanks for your attention!

Raw D^0 yield extraction

pp



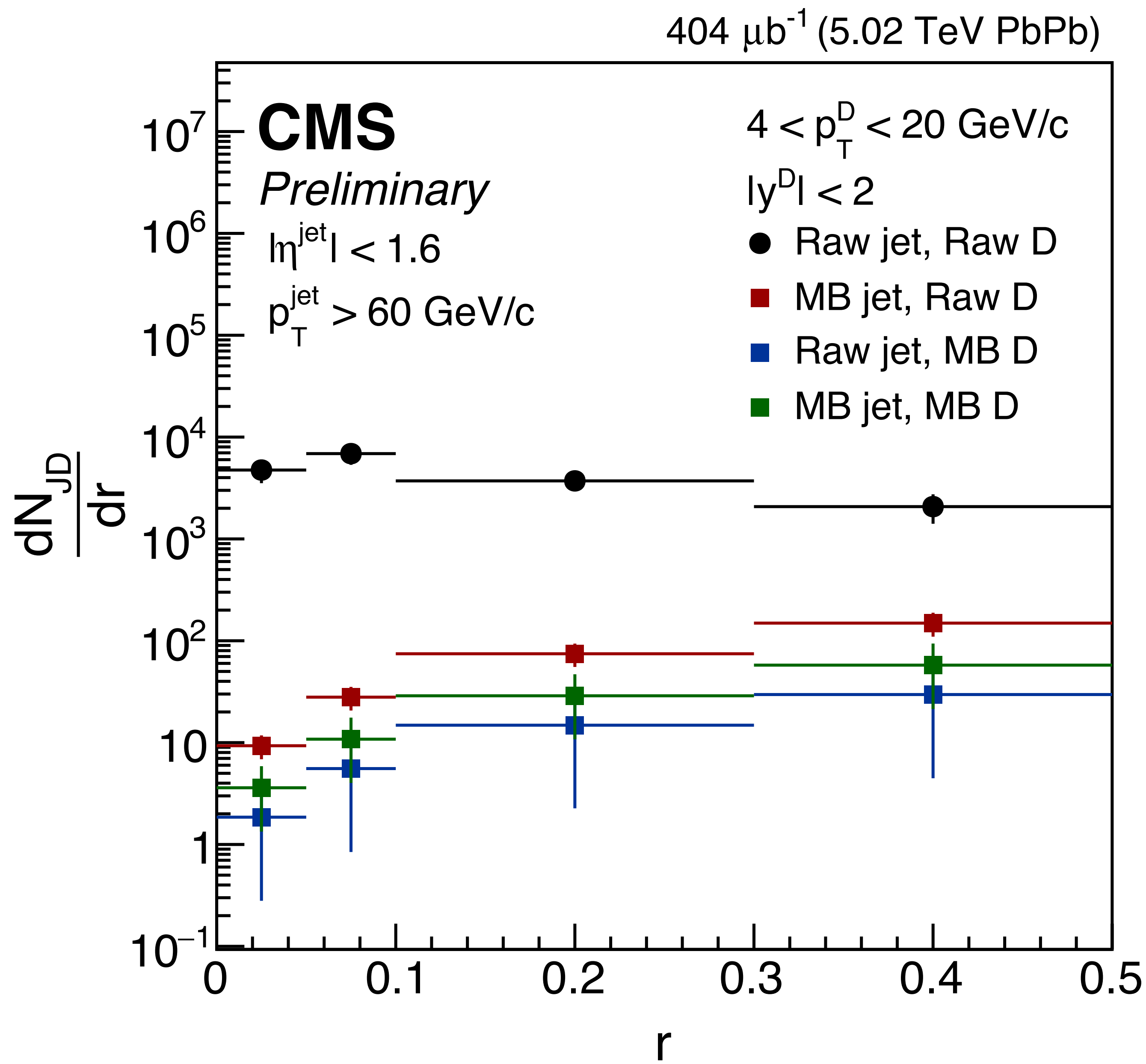
PbPb



CMS-PAS-HIN-18-007

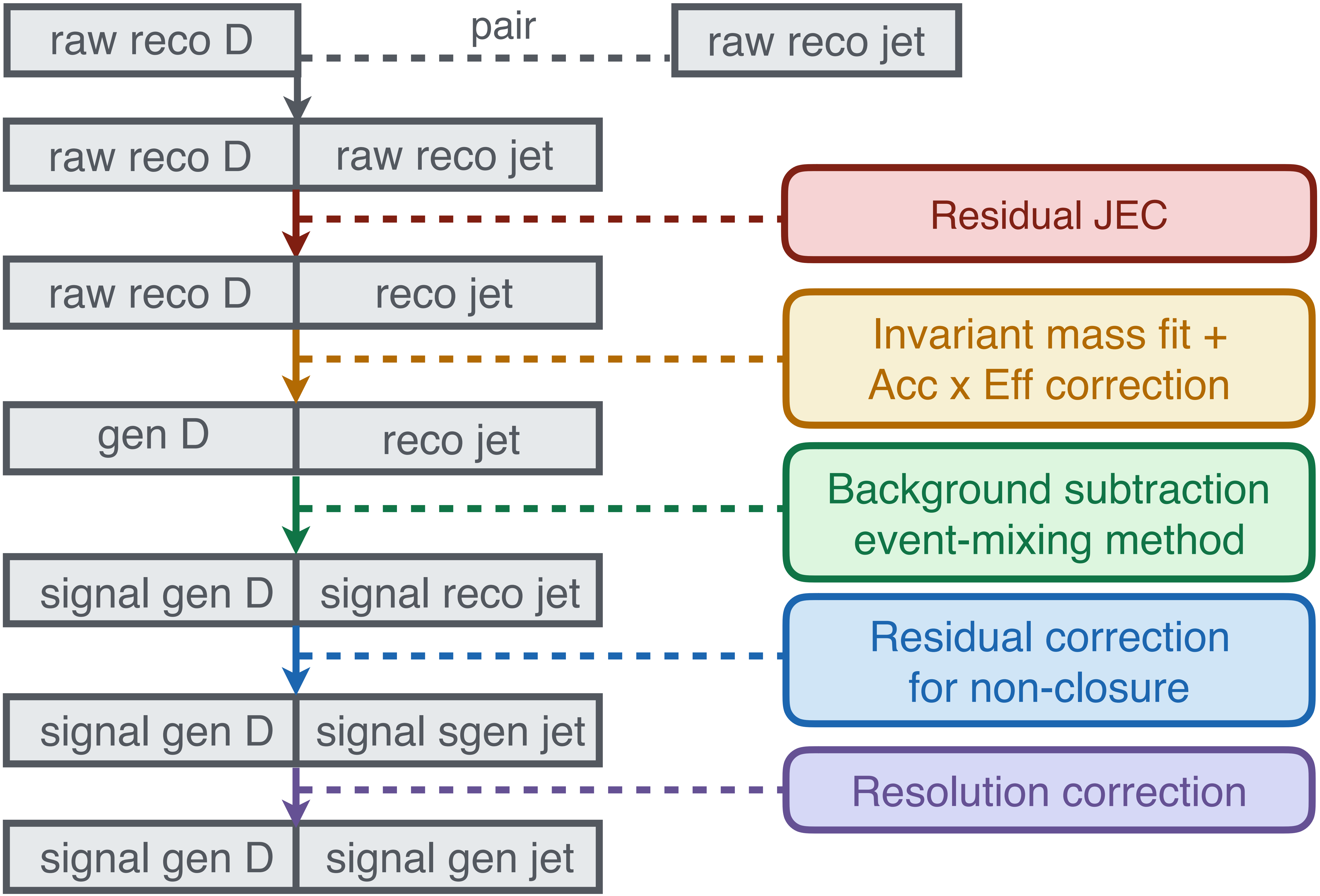
Background subtraction

- Raw = signal + background
- Four correlations
  - ➡ Raw jet + Raw D
  - ➡ MB jet + Raw D
  - ➡ Raw jet + MB D
  - ➡ MB jet + MB D



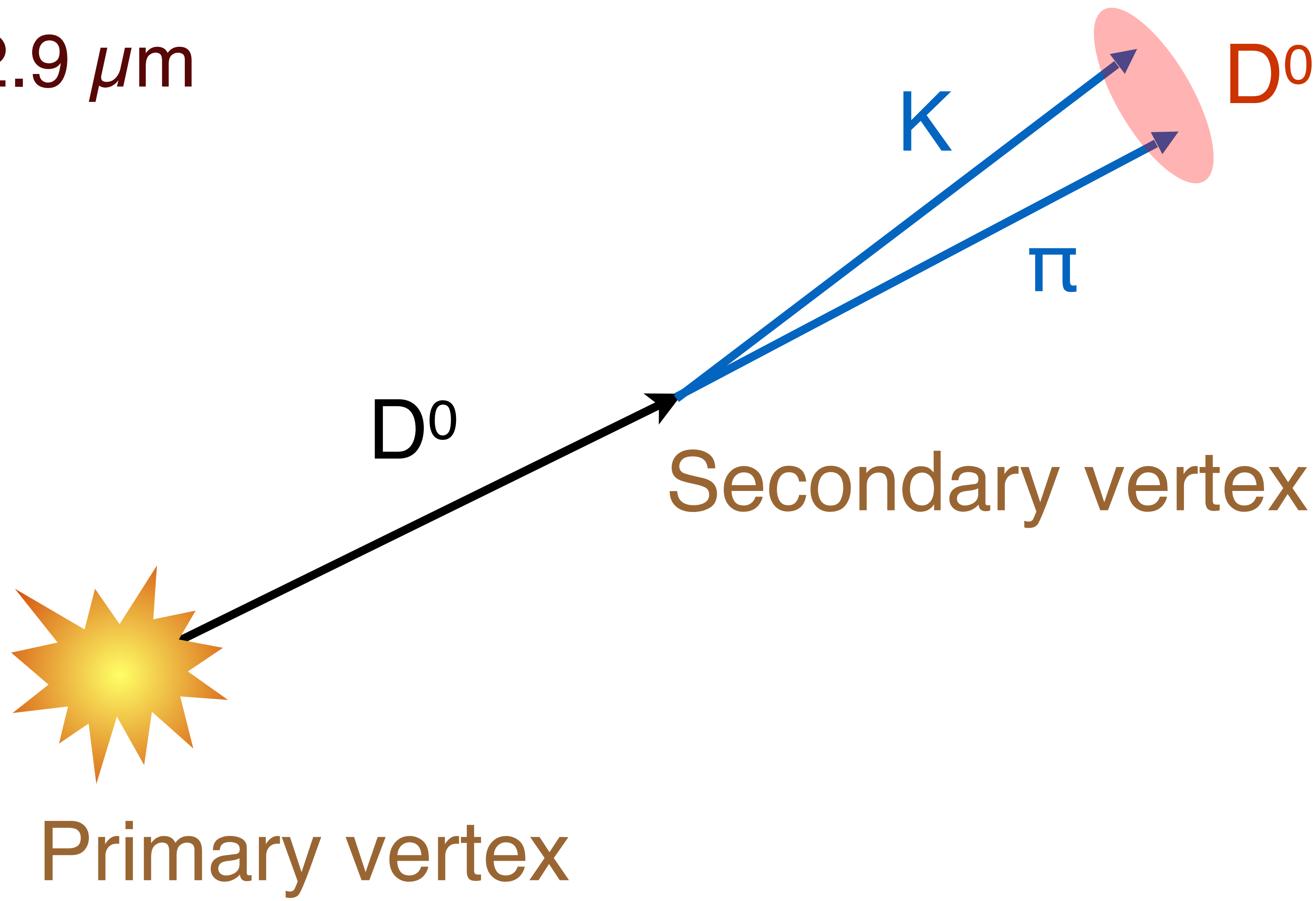
CMS-PAS-HIN-18-007

Analysis strategy



D^0 meson production

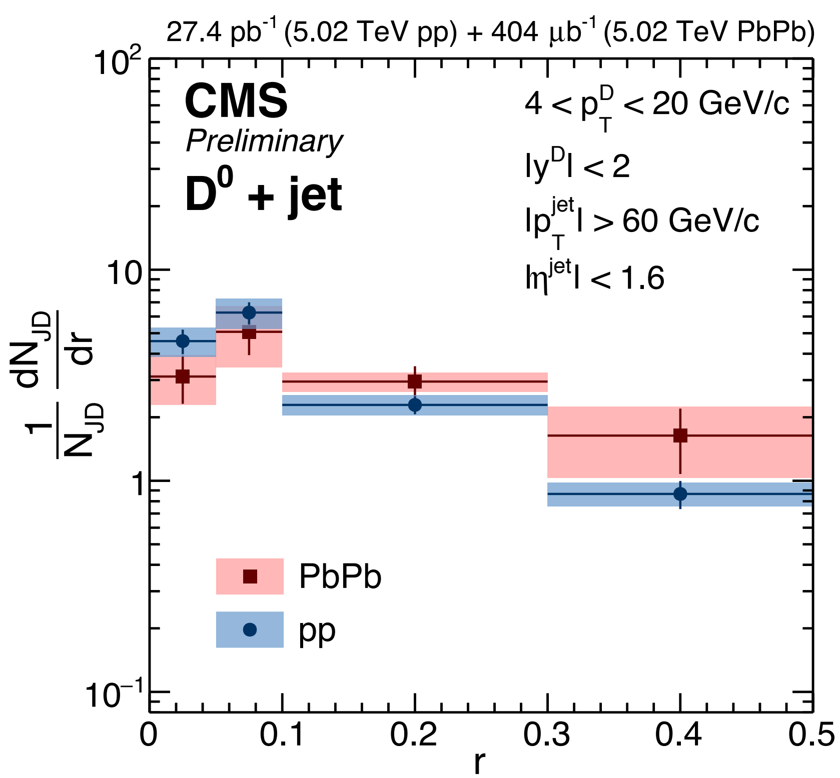
- $c \rightarrow D^0$: O(50%) of c cross-section
- $D^0 \rightarrow K\pi$: $3.93 \pm 0.04\%$
- D^0 $c\tau = 122.9\ \mu m$

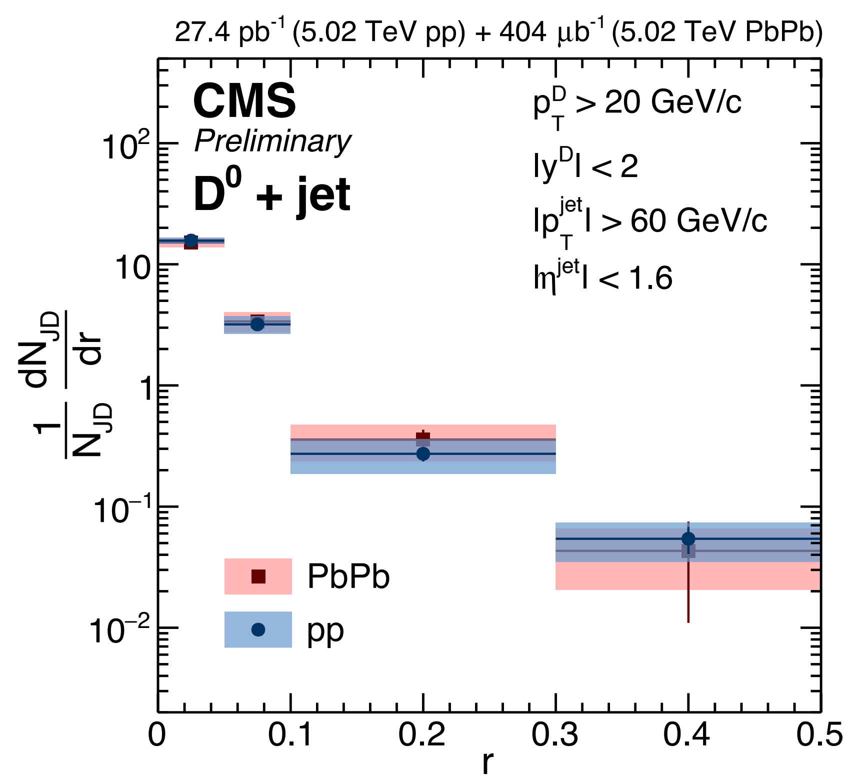


Last slide

Outlook

- Higher statistics with 2018 PbPb data
- Centrality dependence of the radial profile of D^0 mesons
- Fragmentation function of D^0 mesons in jets





The MIT group's work was supported by US DOE-NP

Outlook

Outlook

- Higher statistics with 2018 PbPb data
- Centrality dependence of the radial profile of D^0 mesons
- Fragmentation function of D^0 mesons in jets