# D-meson production in jets in pp and PbPb collisions with the CMS detector

**Jing Wang** on behalf of the CMS Collaboration

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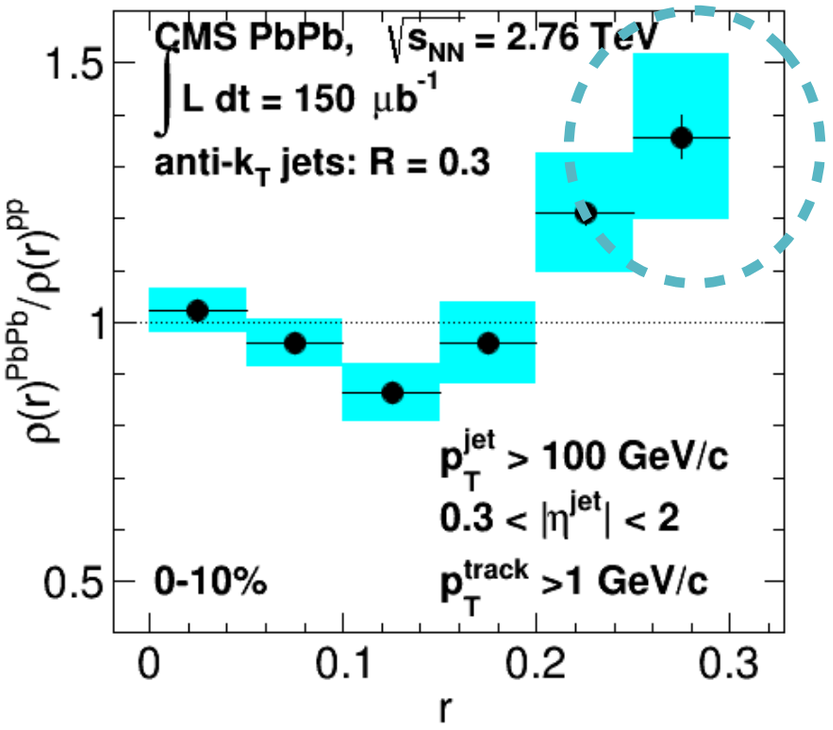
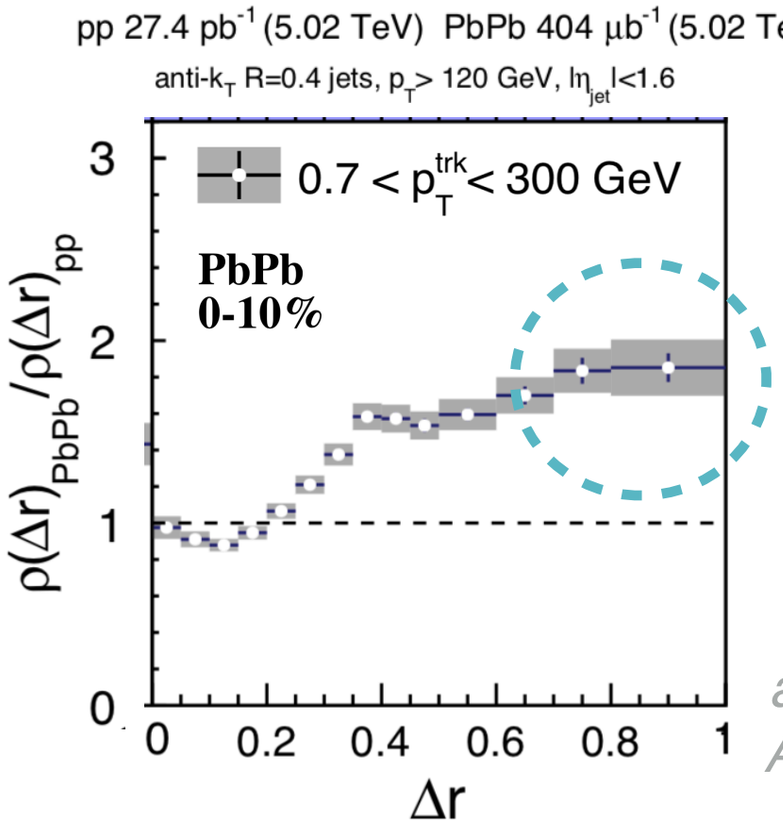
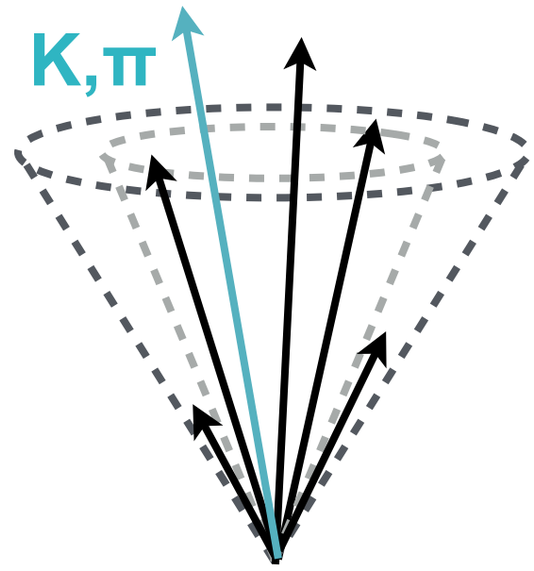
Lido di Venezia (Italy)

# 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

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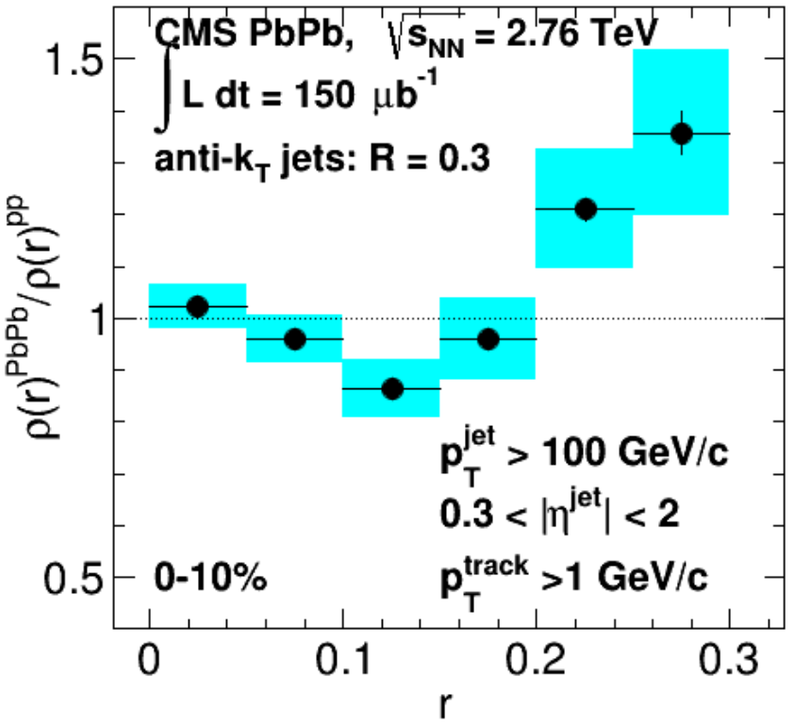


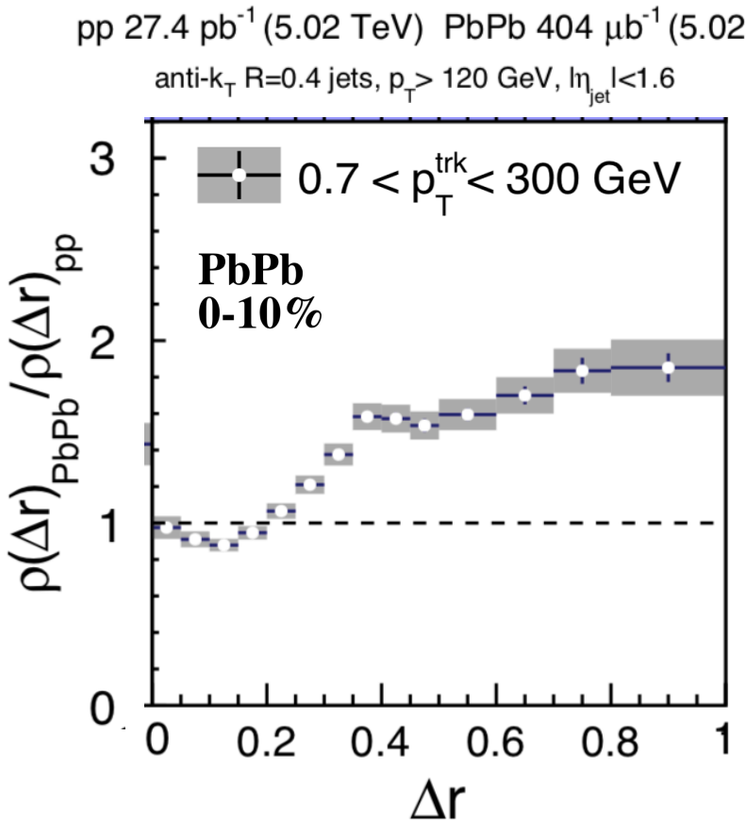


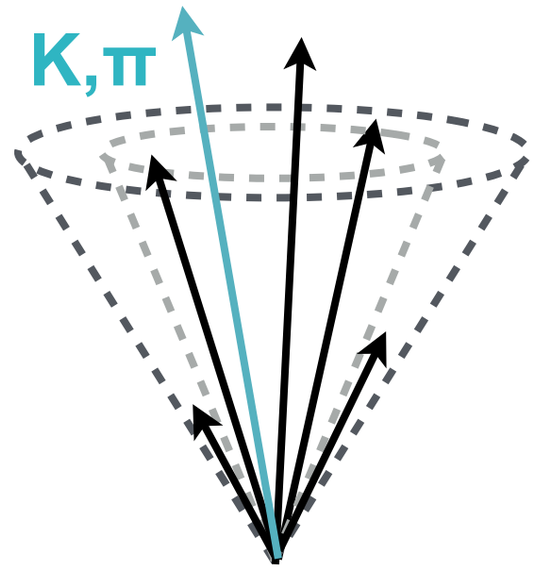


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- Enhancement of low $p_T$ light hadrons at large angles about jets
  - ➡ Light hadron jet shape analysis
- **How to explain**
  - ➡ medium-induced gluon radiation?
  - ➡ medium response?
  - ➡ multiple scatterings?
  - ➡ ……

# Why study D meson production in jets?

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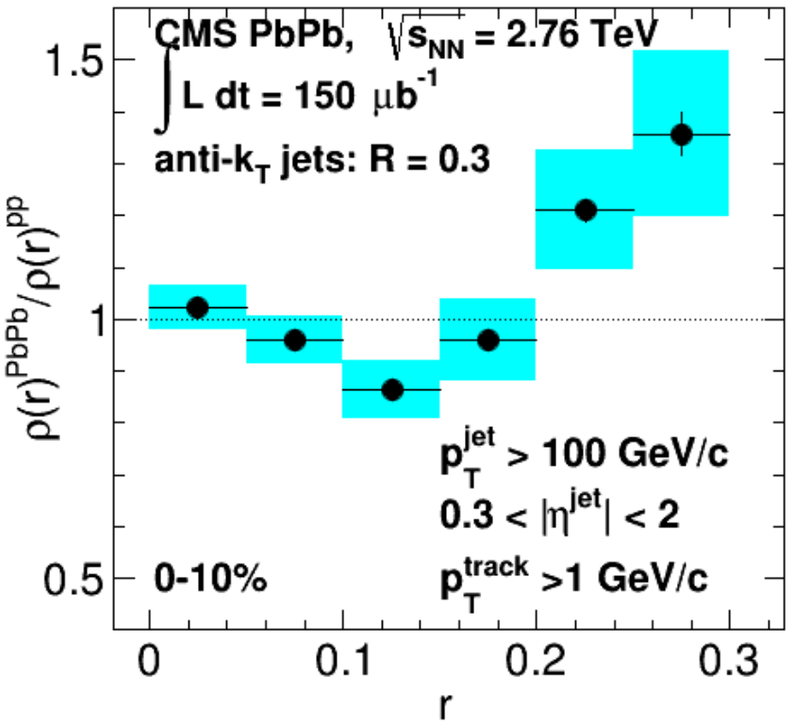


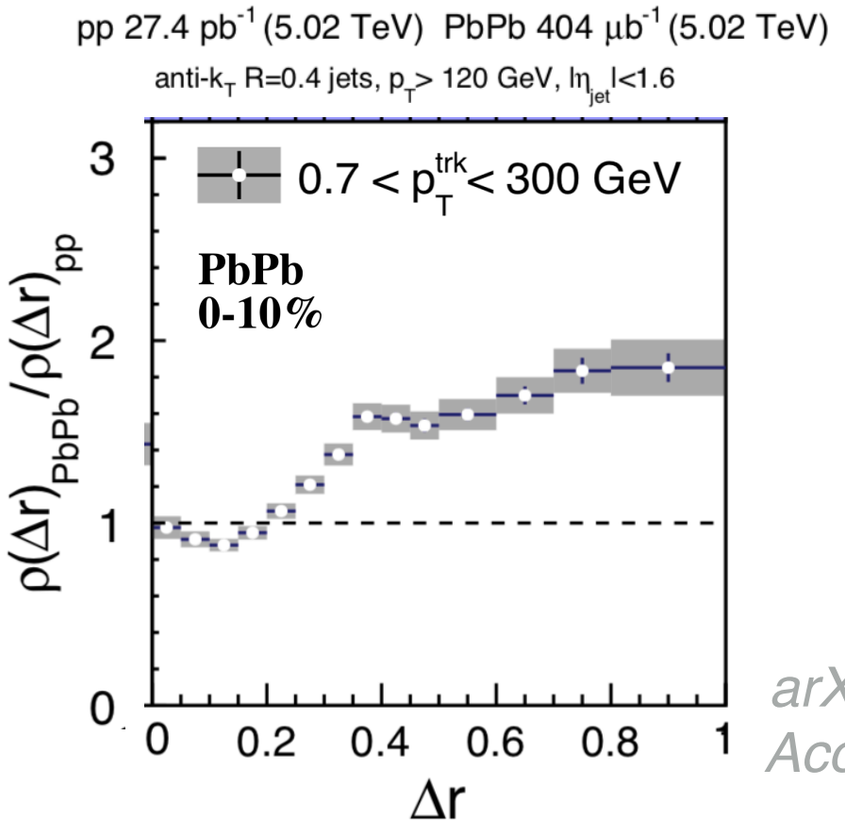


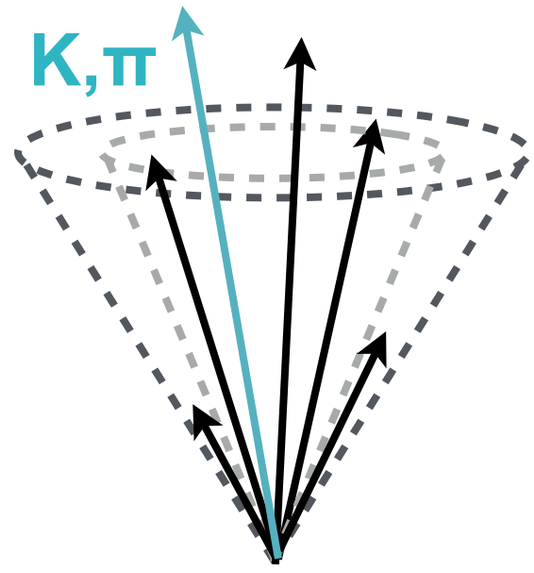


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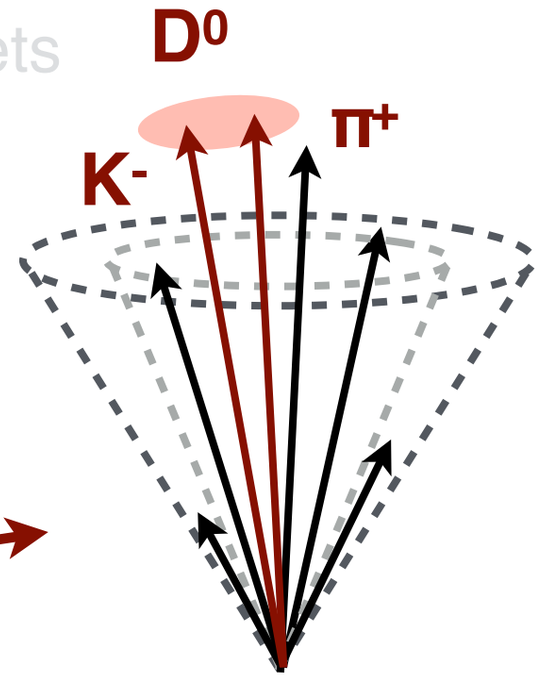
- Enhancement of low $p_T$ light hadrons at large angles about jets
  - ➡ Light hadron jet shape analysis
- How to explain
  - ➡ medium-induced gluon radiation?
  - ➡ medium response? $m_c \gg T_{QGP}$
  - ➡ multiple scatterings?
  - ➡ ……
- **Vary mass of the associated hadrons!**
  - ➡ **Heavy flavor**



# Why study D meson production in jets?

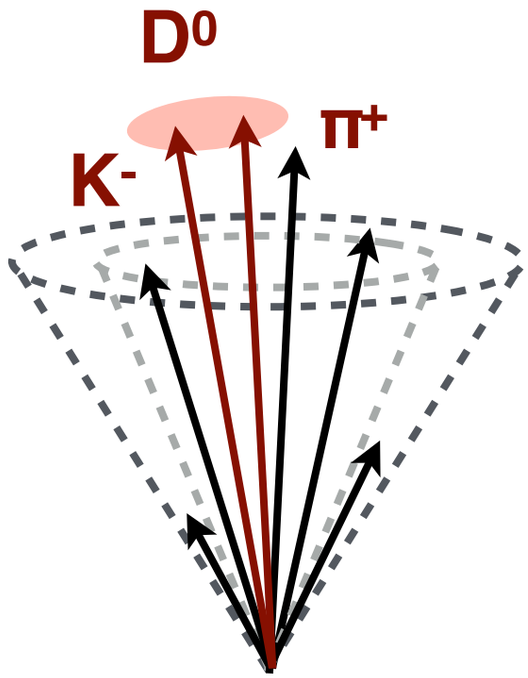
**Even more …**

## 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 $\mu b^{-1}$) 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

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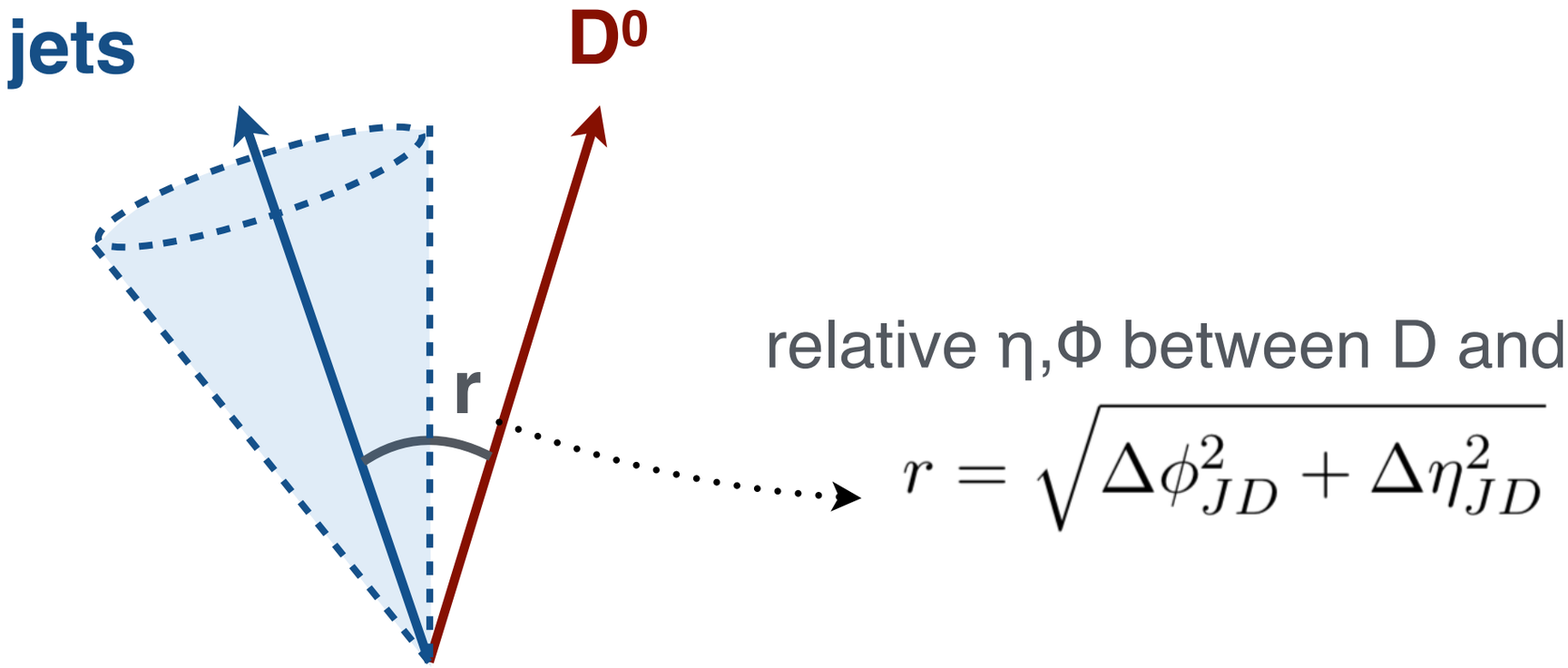



relative η,Φ between D and jets

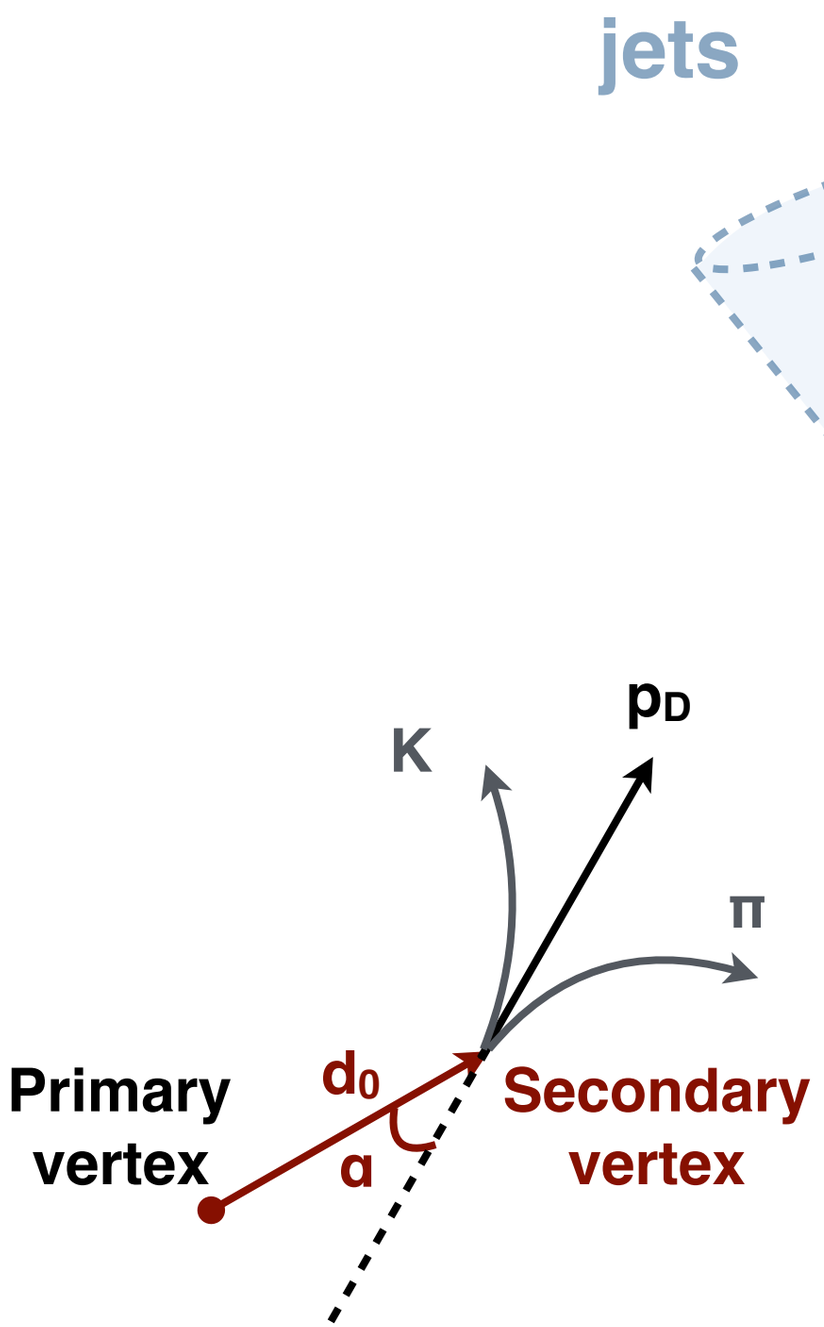
- **Angular distribution of $D^0$ with respective to the jet axis:**

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

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



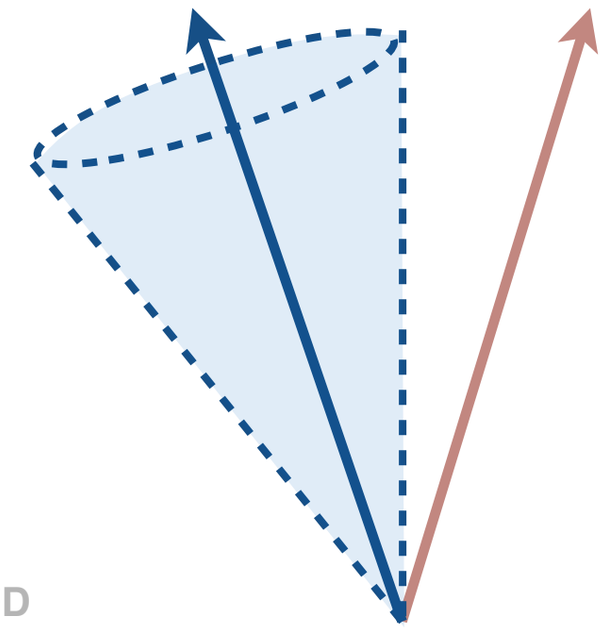

- $D^0 \rightarrow K\pi$
- $D^0$ vertex reconstruction
  - pairing two tracks
  - kinematic fitter
- Topological selections
  - Pointing angle ($\alpha$) < ~0.04
  - 3D decay length ($d_0$) normalized by its error > ~3
  - Secondary vertex prob > ~0.05
- $|y^D| < 2$
- Two $p_T$ bins
  - $4 < p_T^D <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

# D and jets reconstruction and selections

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

**jets**

**$D^0$**



- 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
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  - ➡ Pointing angle ($\alpha$) < ~0.04
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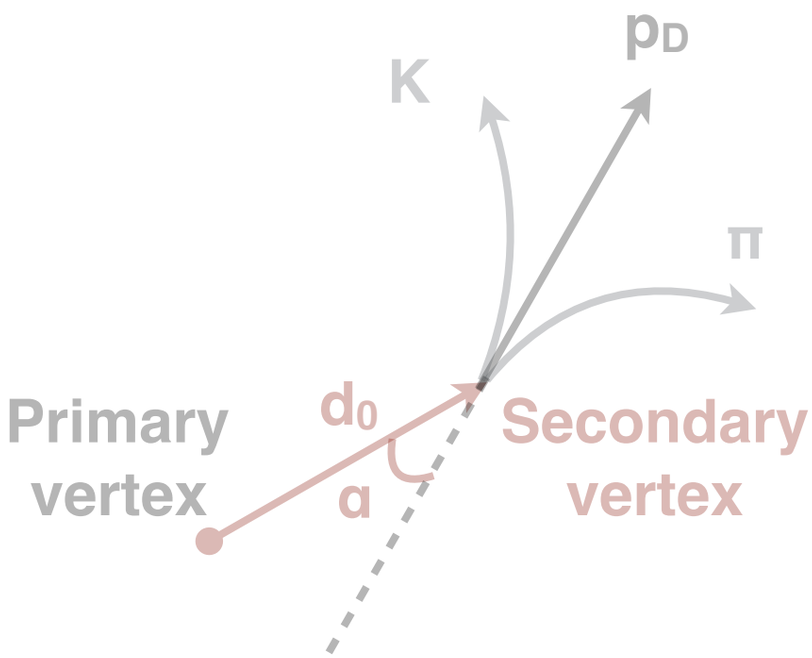
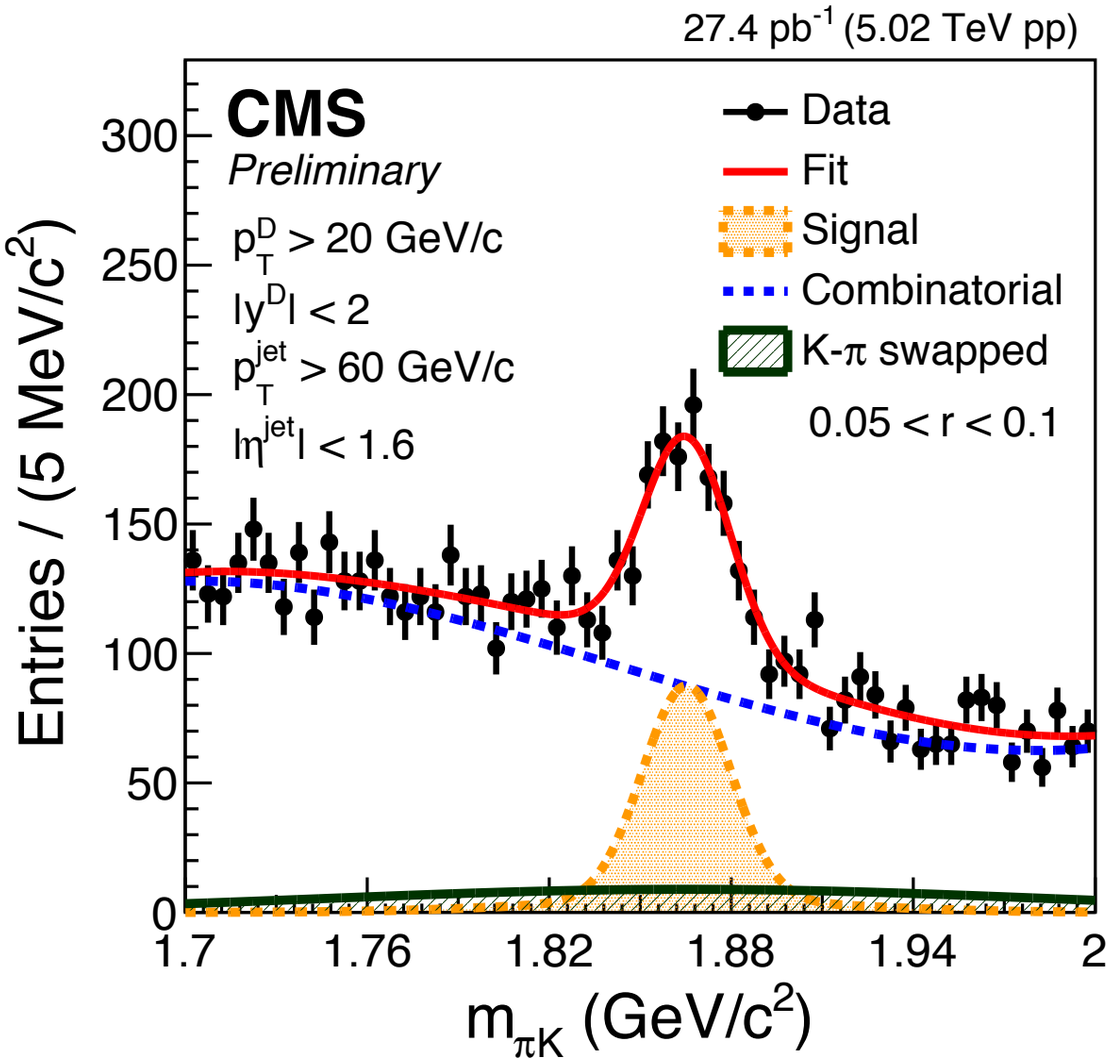


# Analysis strategy

- **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



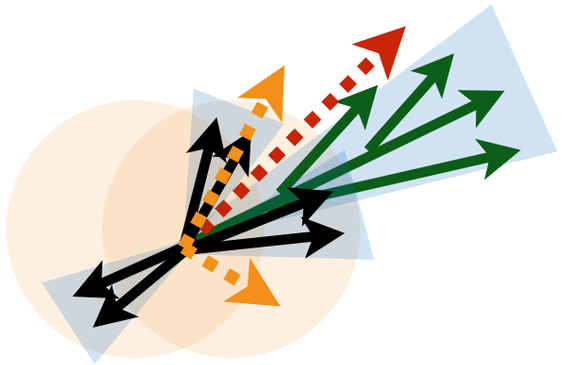

Mass distributions fitted by

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

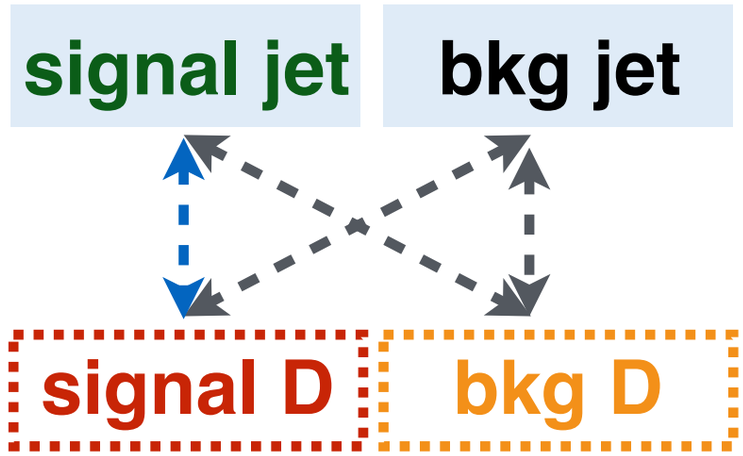
*CMS-PAS-HIN-18-007*

# Event mixing technique

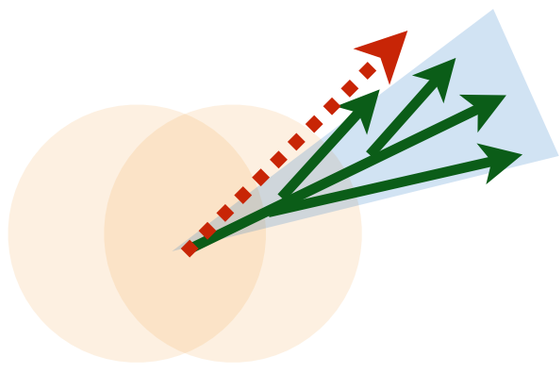
- **Signal**: jets and $D^0$ mesons from the same hard scattering
- **Background**: fake jets, jets and $D^0$ mesons in underlying events, …



before subtraction

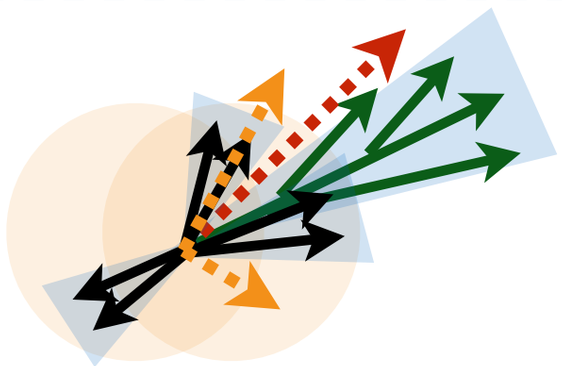



pure signal



# Event mixing technique

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

| Raw D | MB D | |
|---|---|---|
|  | | Raw jets |
| | | MB jets |
| | |  |

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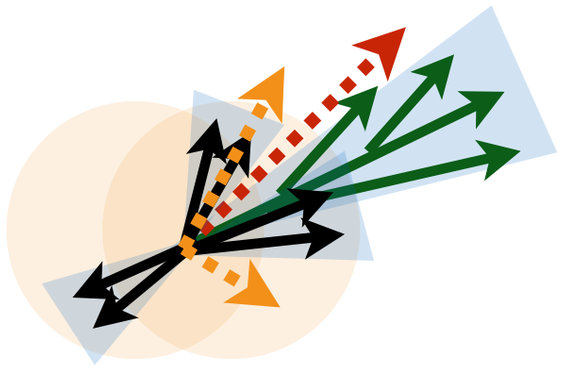
**Raw D**



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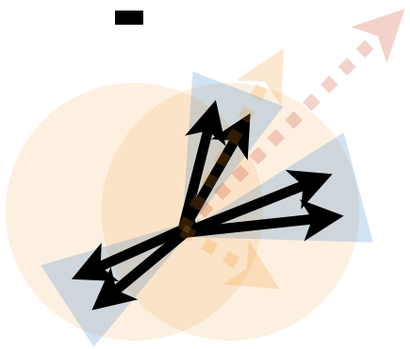
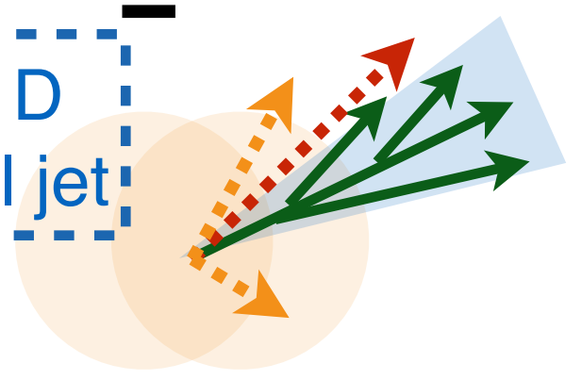


=

raw D
signal jet



MB D

Raw jets

MB jets

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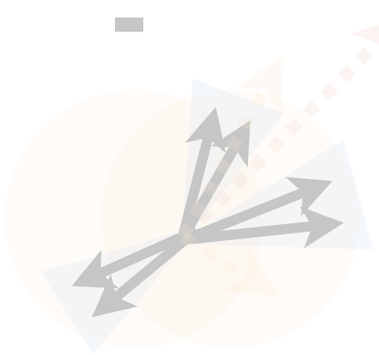
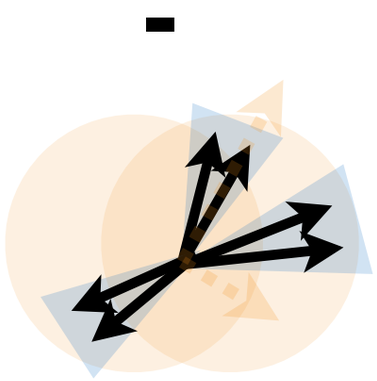
Raw D

**MB D**

Raw jets



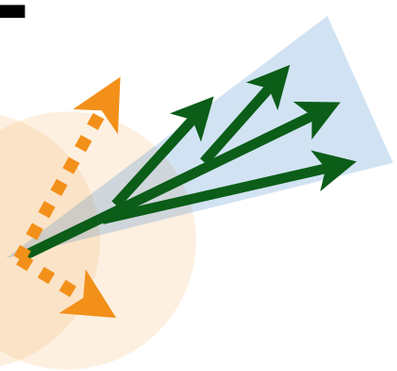


MB jets

raw D
signal jet



bkg D
signal jet



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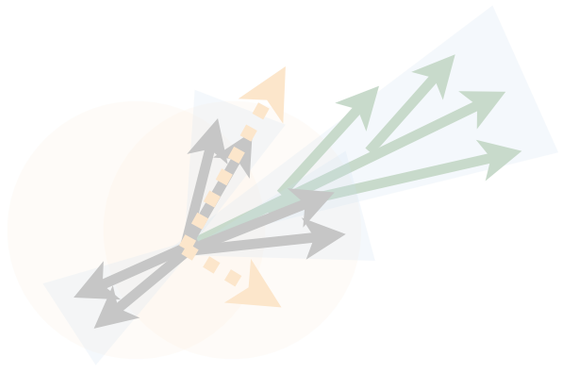
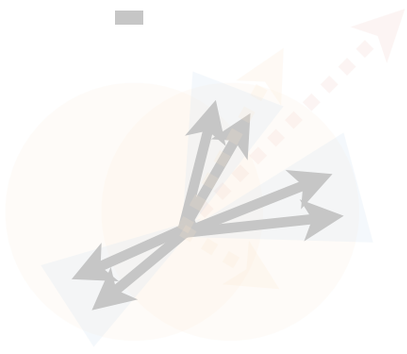
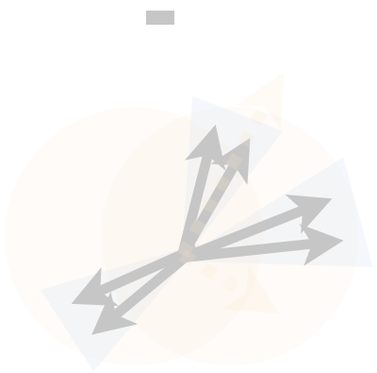
MB D



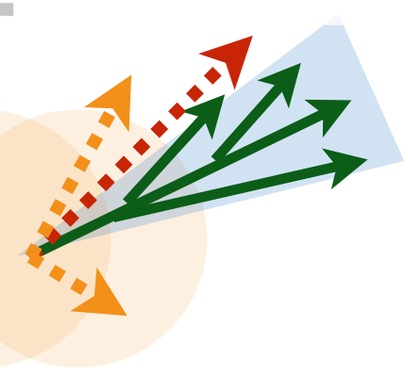
Raw jets



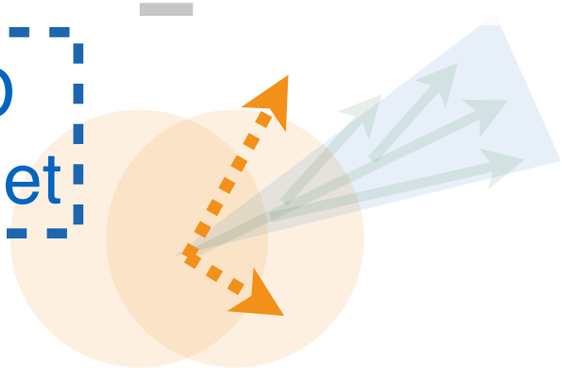


MB jets

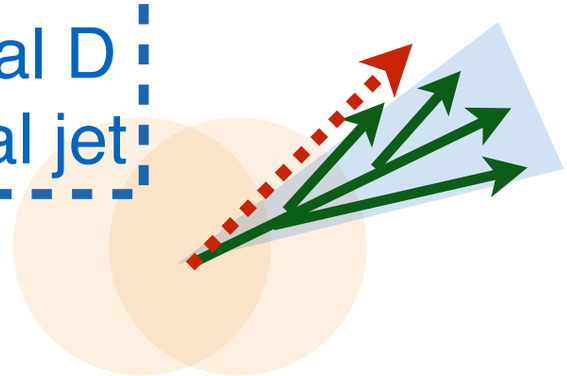
raw D
signal jet



bkg D
signal jet

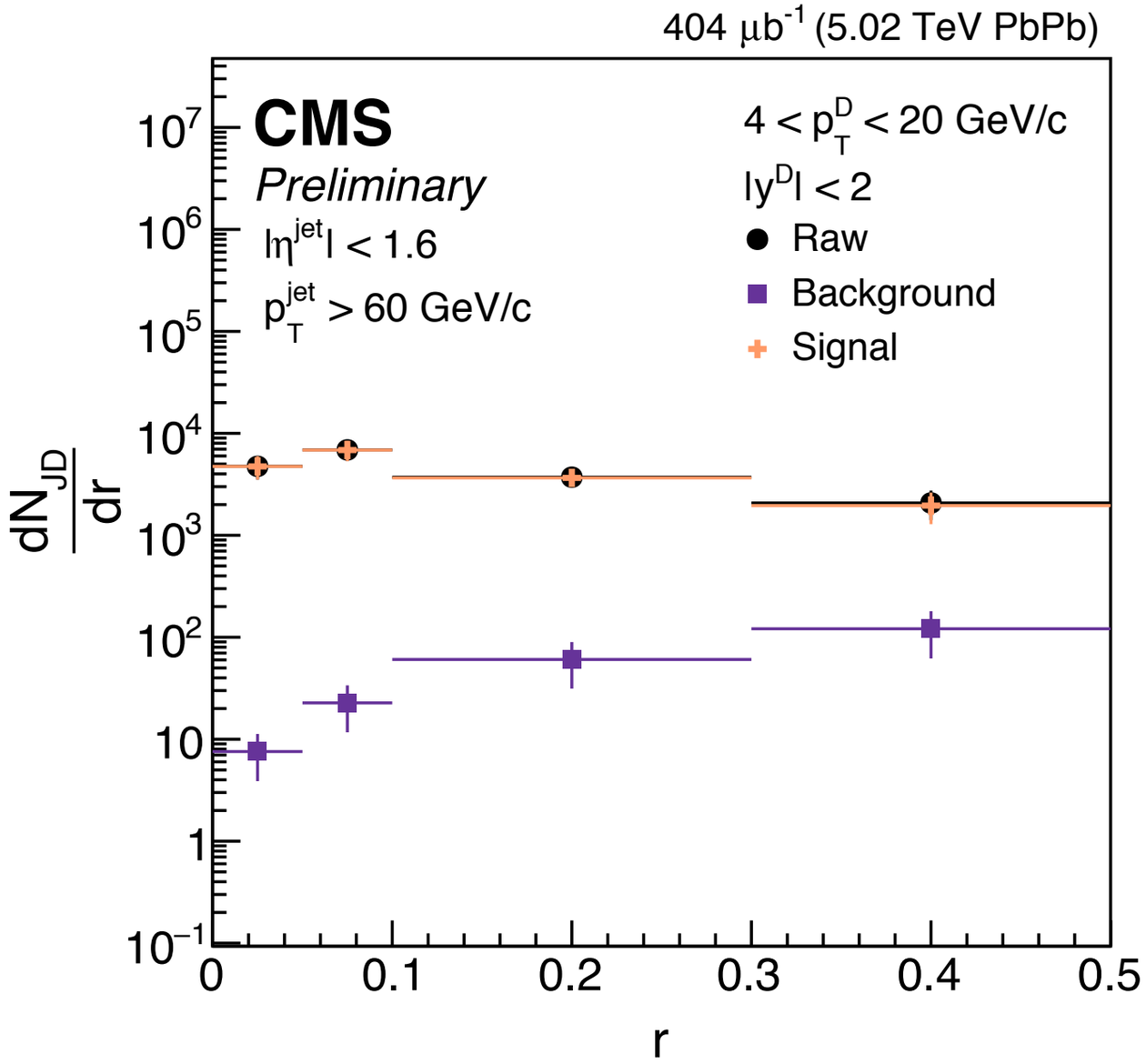


signal D
signal jet



# Background subtraction

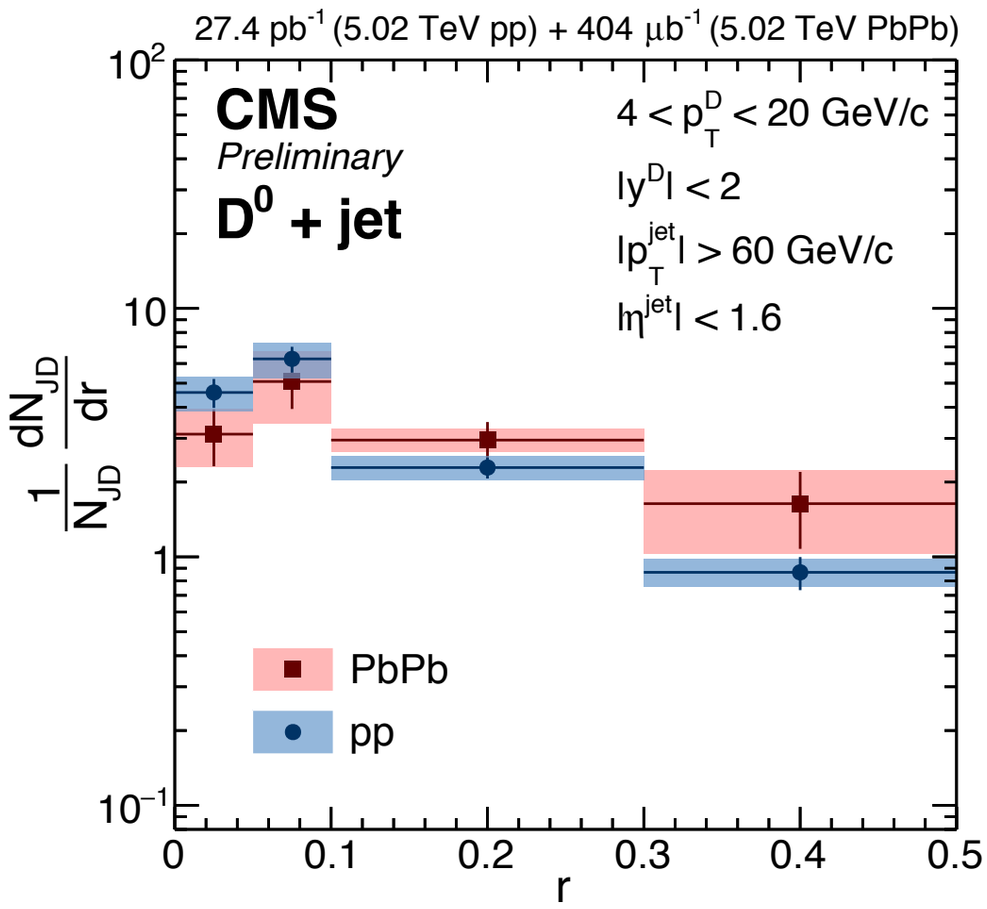
- Signal = Raw - Background
- Background contributions are much smaller than signal



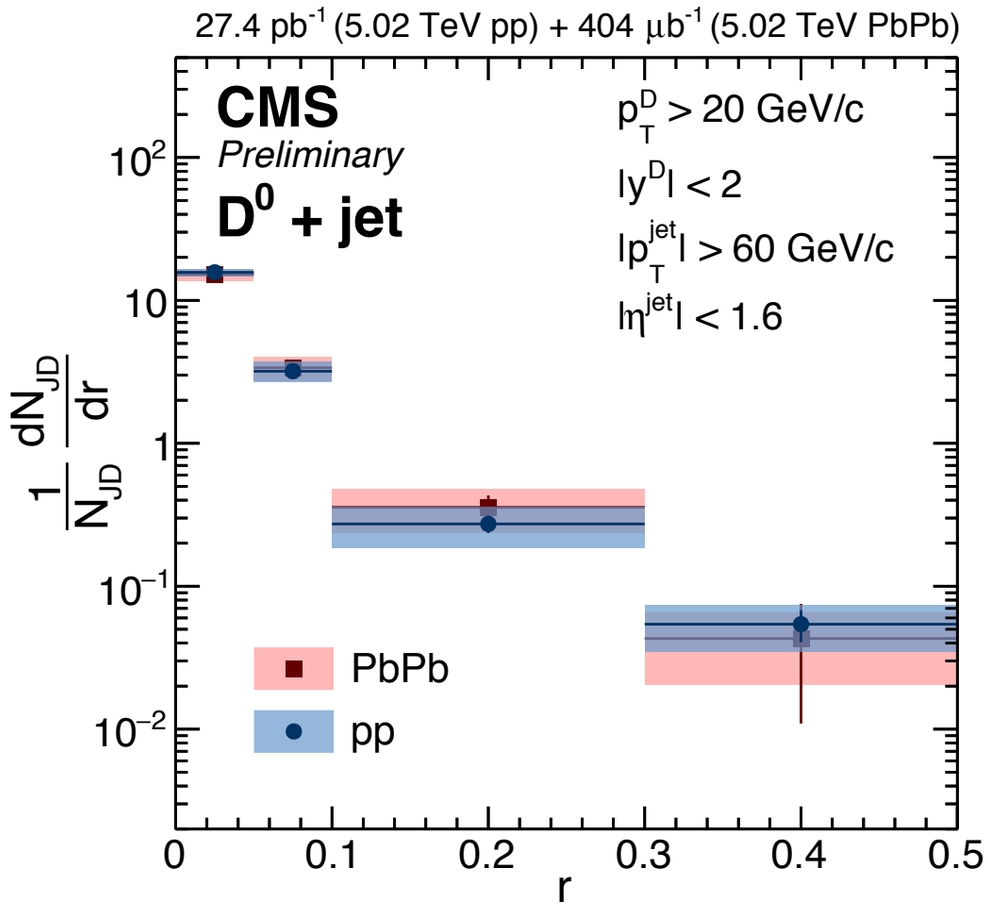

*CMS-PAS-HIN-18-007*

# Results

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




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




CMS NEW RESULT QM18

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

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# Results

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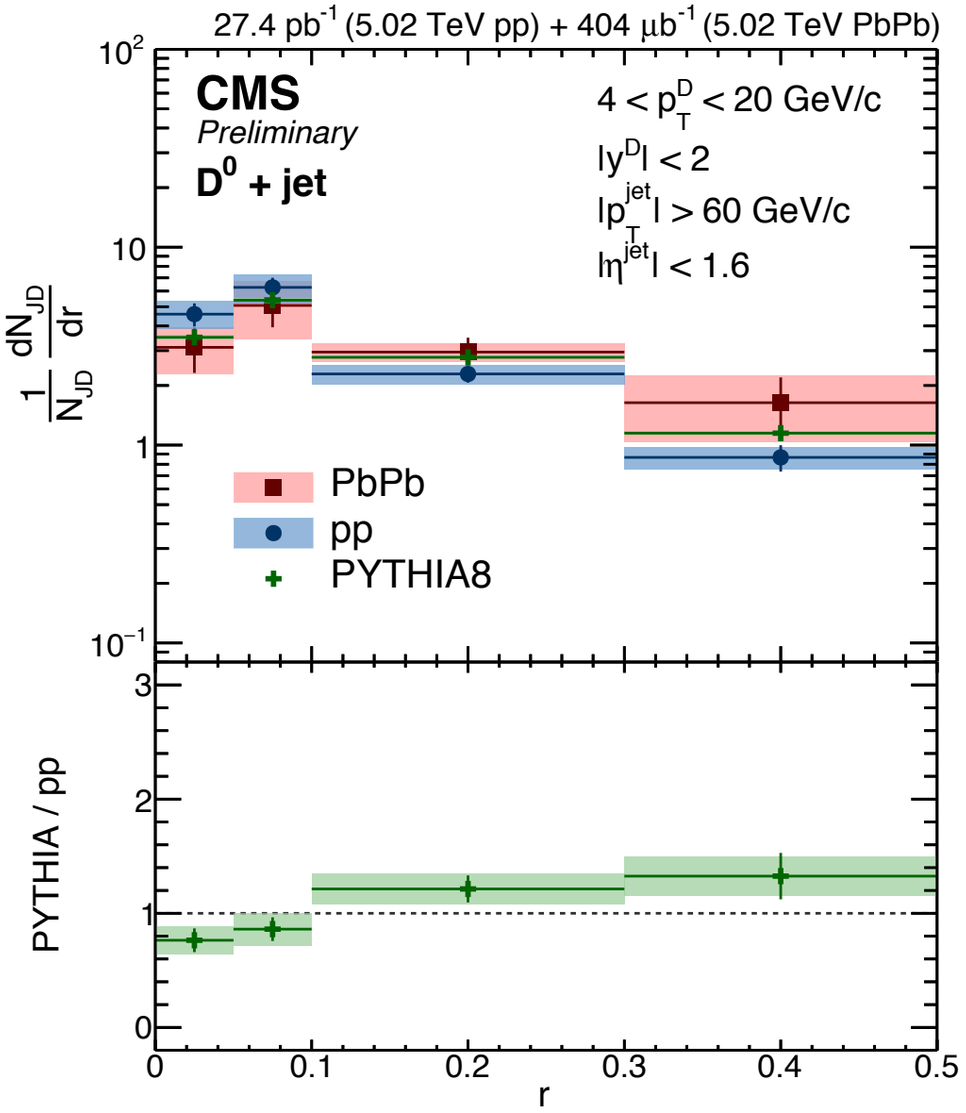
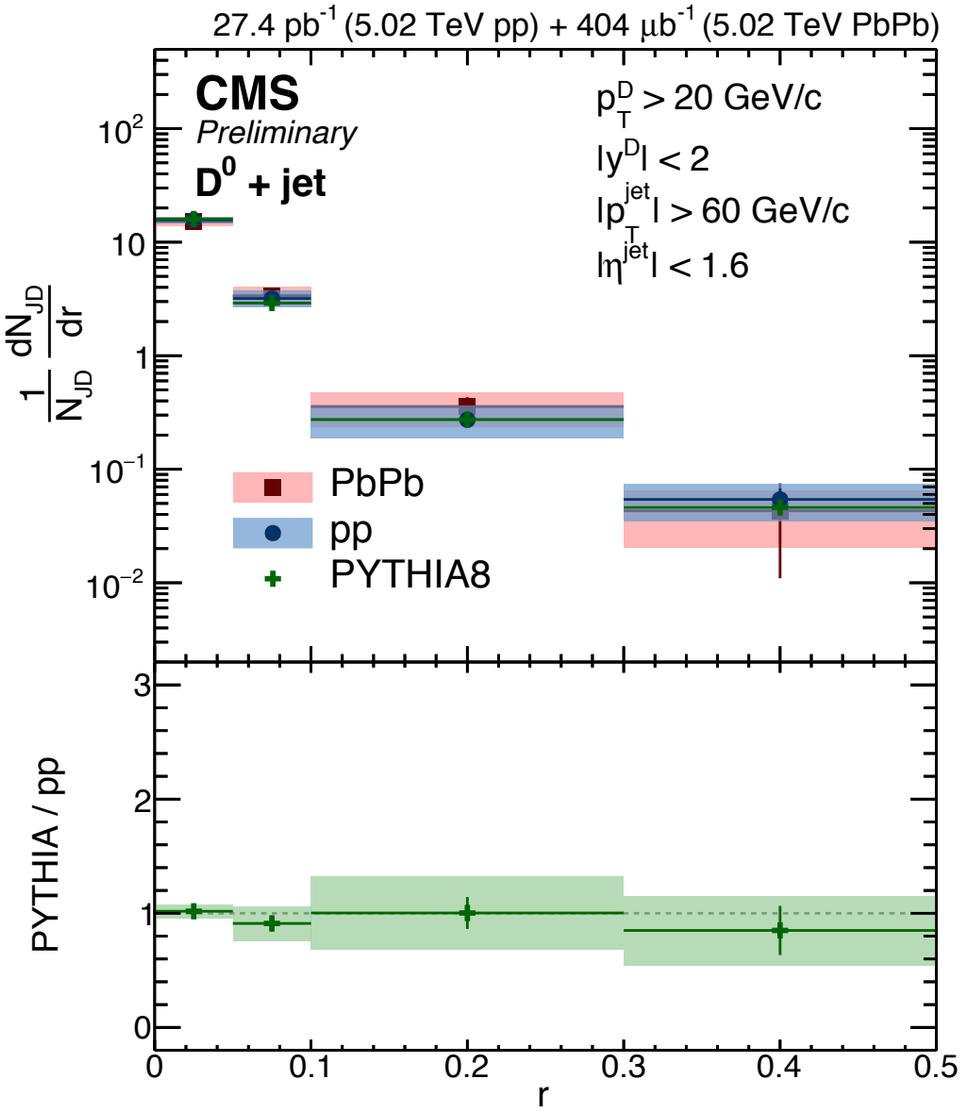



## High D $p_T$: $p_T^D > 20$ GeV/c




CMS NEW RESULT QM18

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

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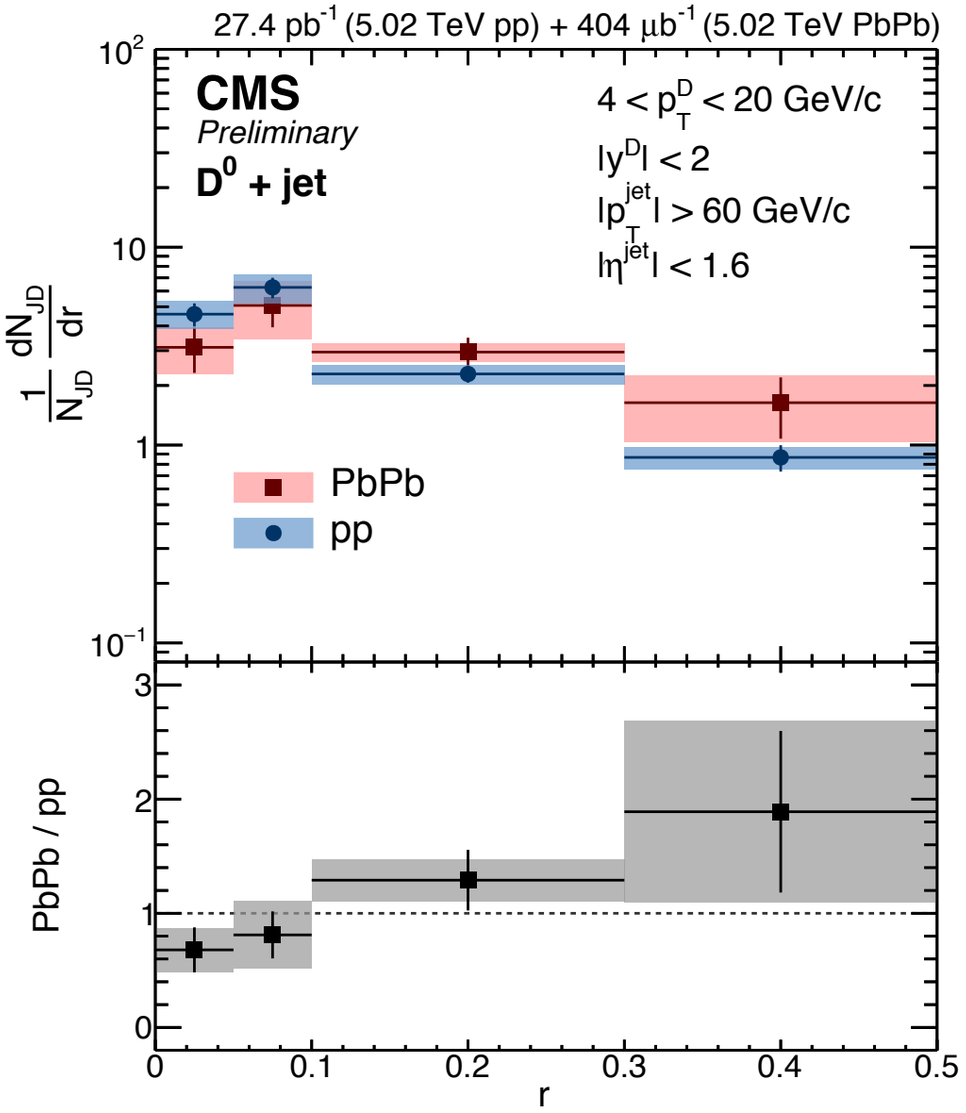
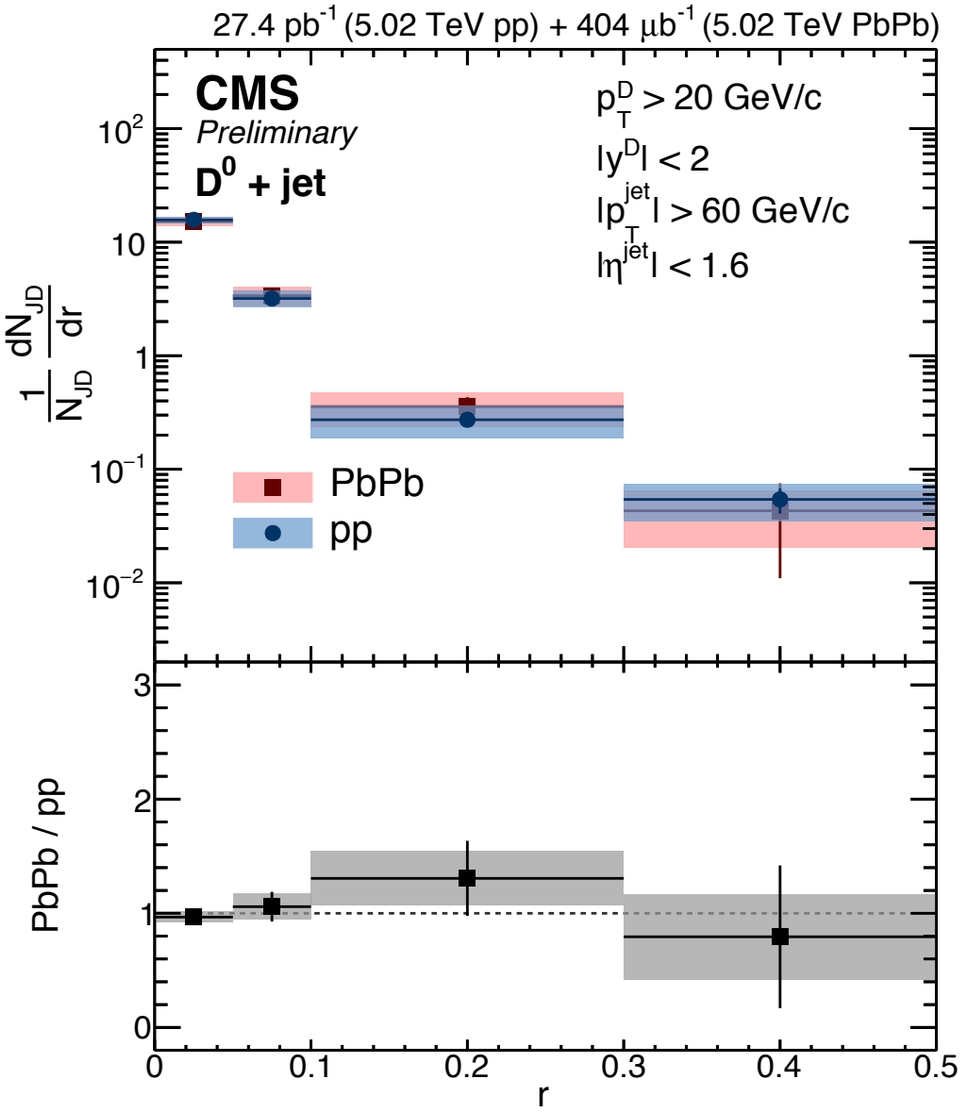
# Results

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




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





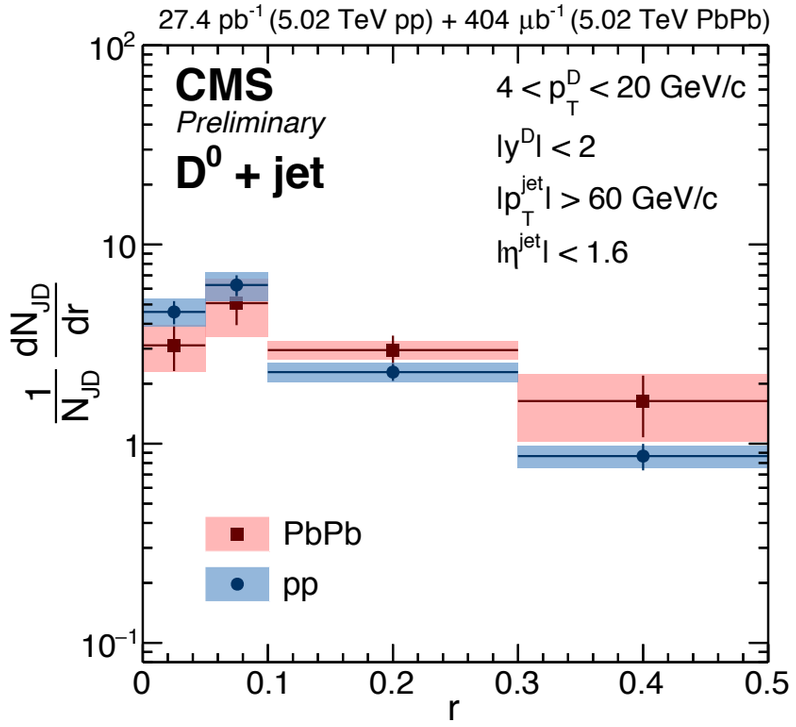
- The ratio of PbPb over pp:
- Low D $p_T$: increases as a function of r
  - ➡ Hint that $D^0$ are further from jet axis in PbPb than pp
- High D $p_T$: consistent with unity

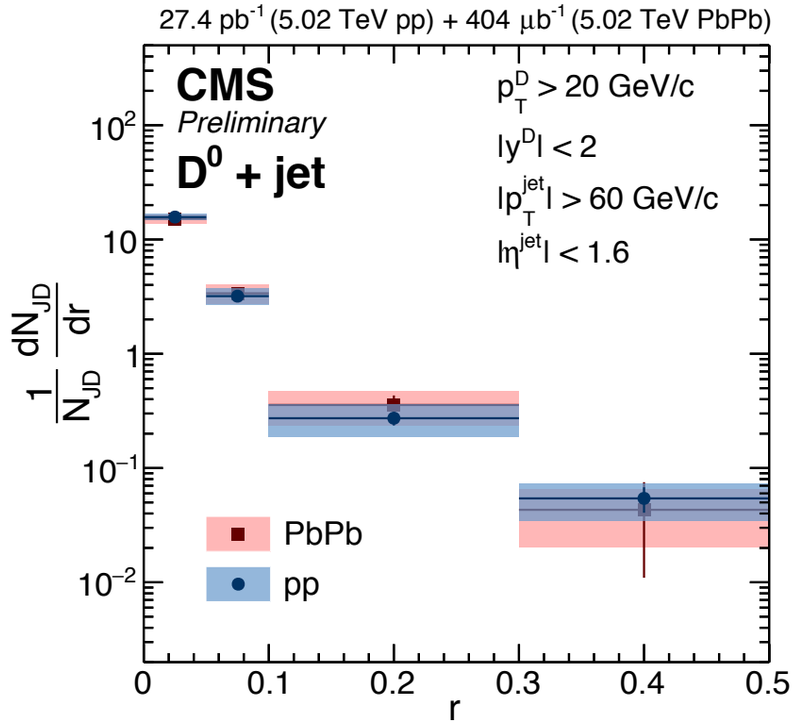
*CMS-PAS-HIN-18-007*

# 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



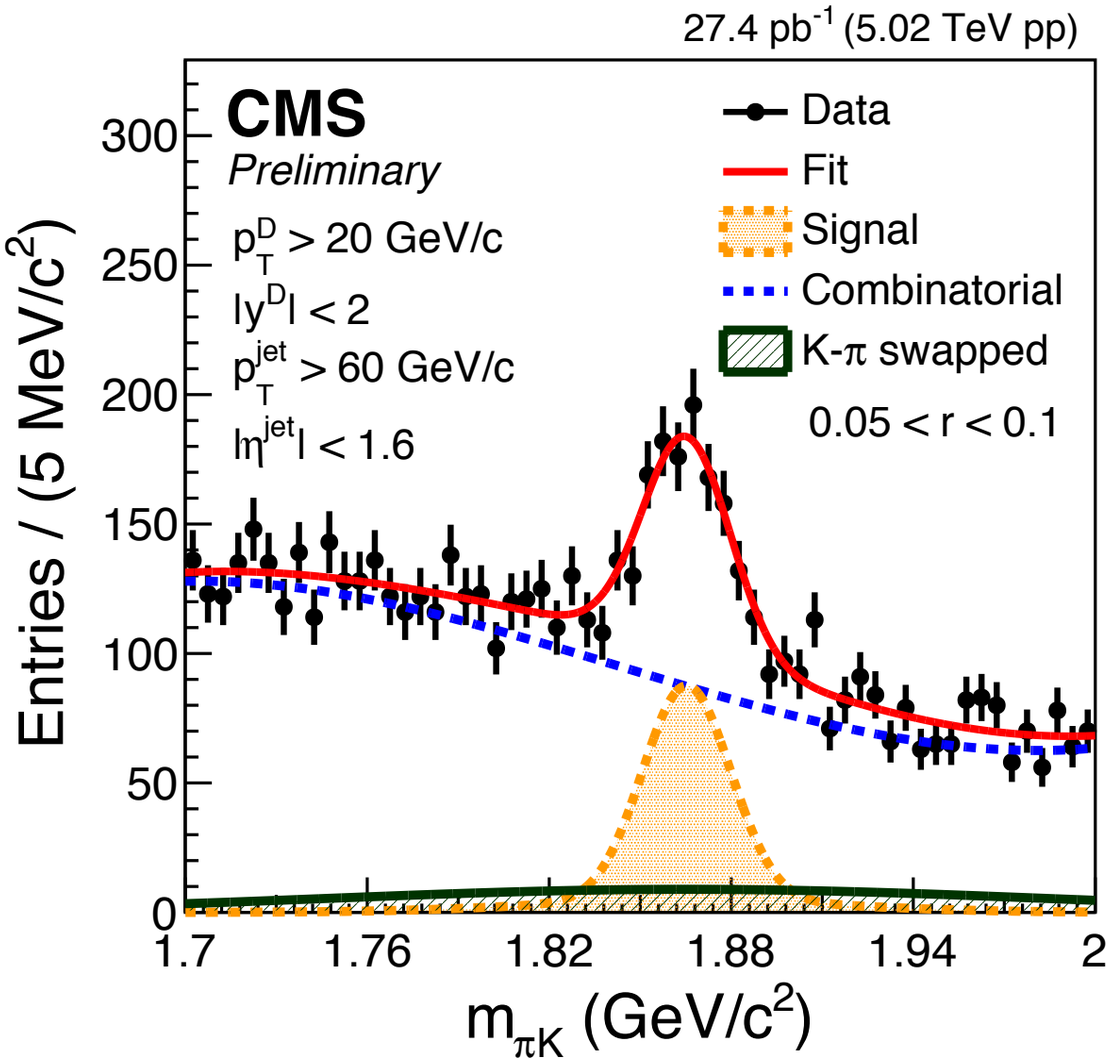

*The MIT group's work was supported by US DOE-NP*

# Back up

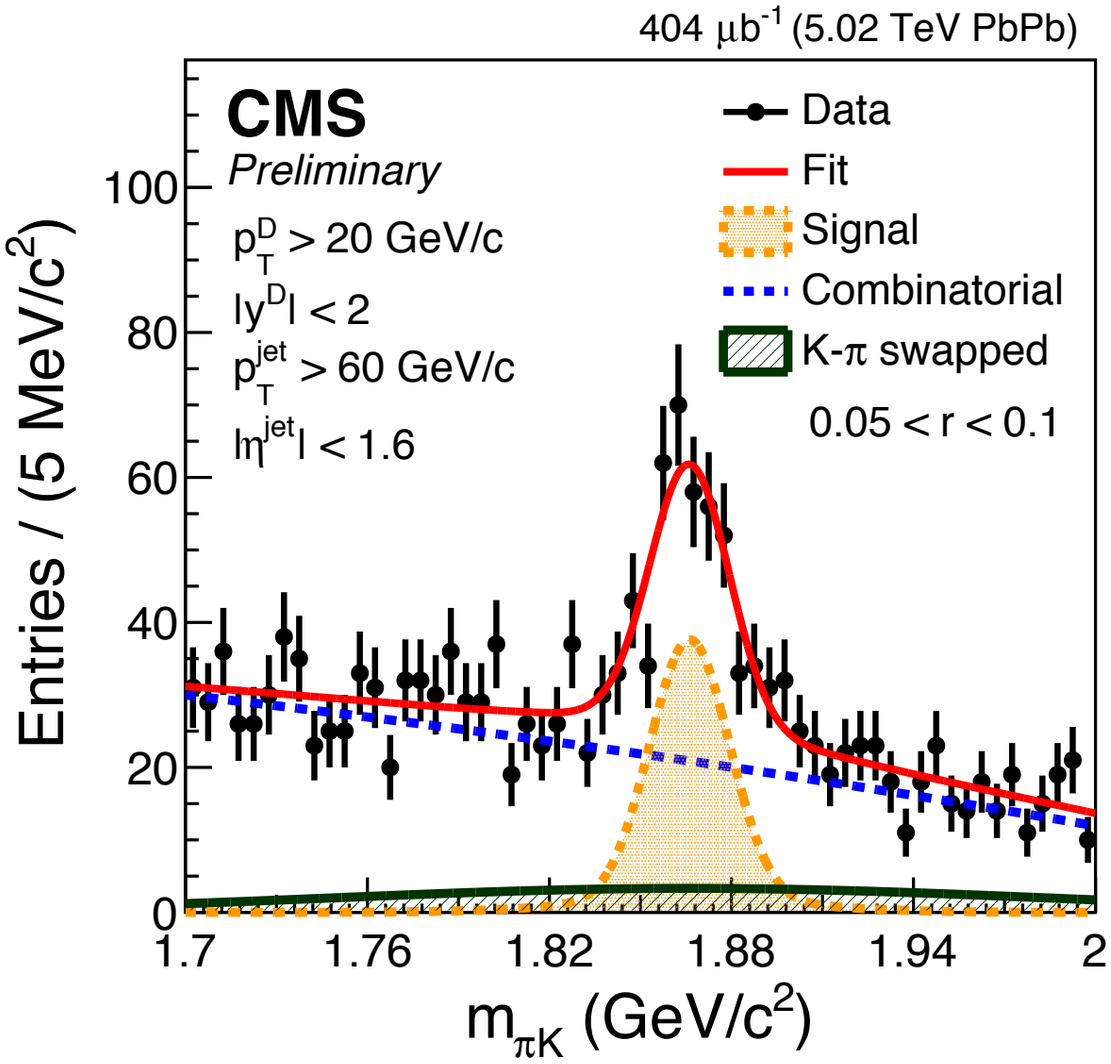
Thanks for your attention!

# Raw $D^0$ yield extraction

## pp



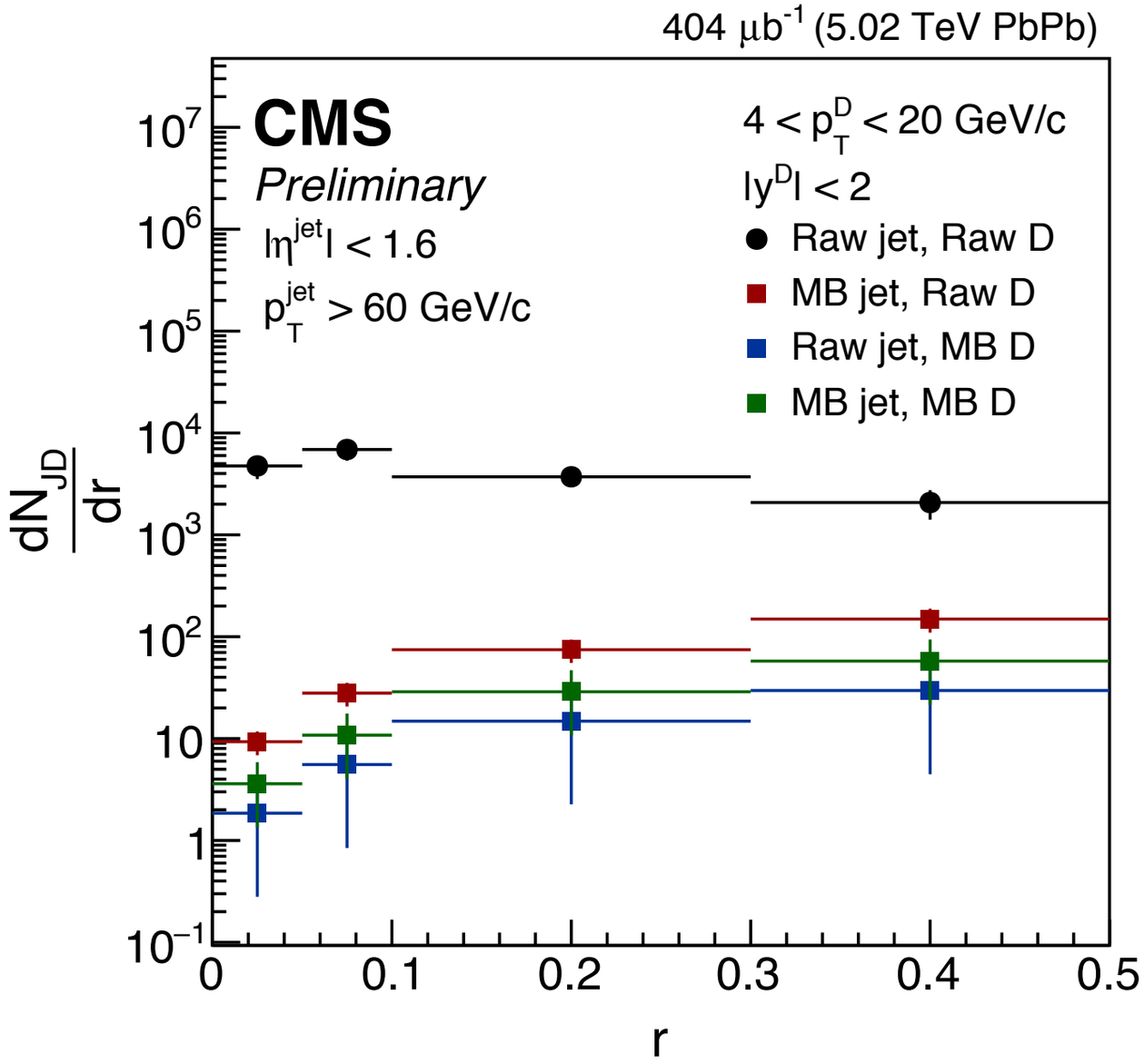

## PbPb




*CMS-PAS-HIN-18-007*

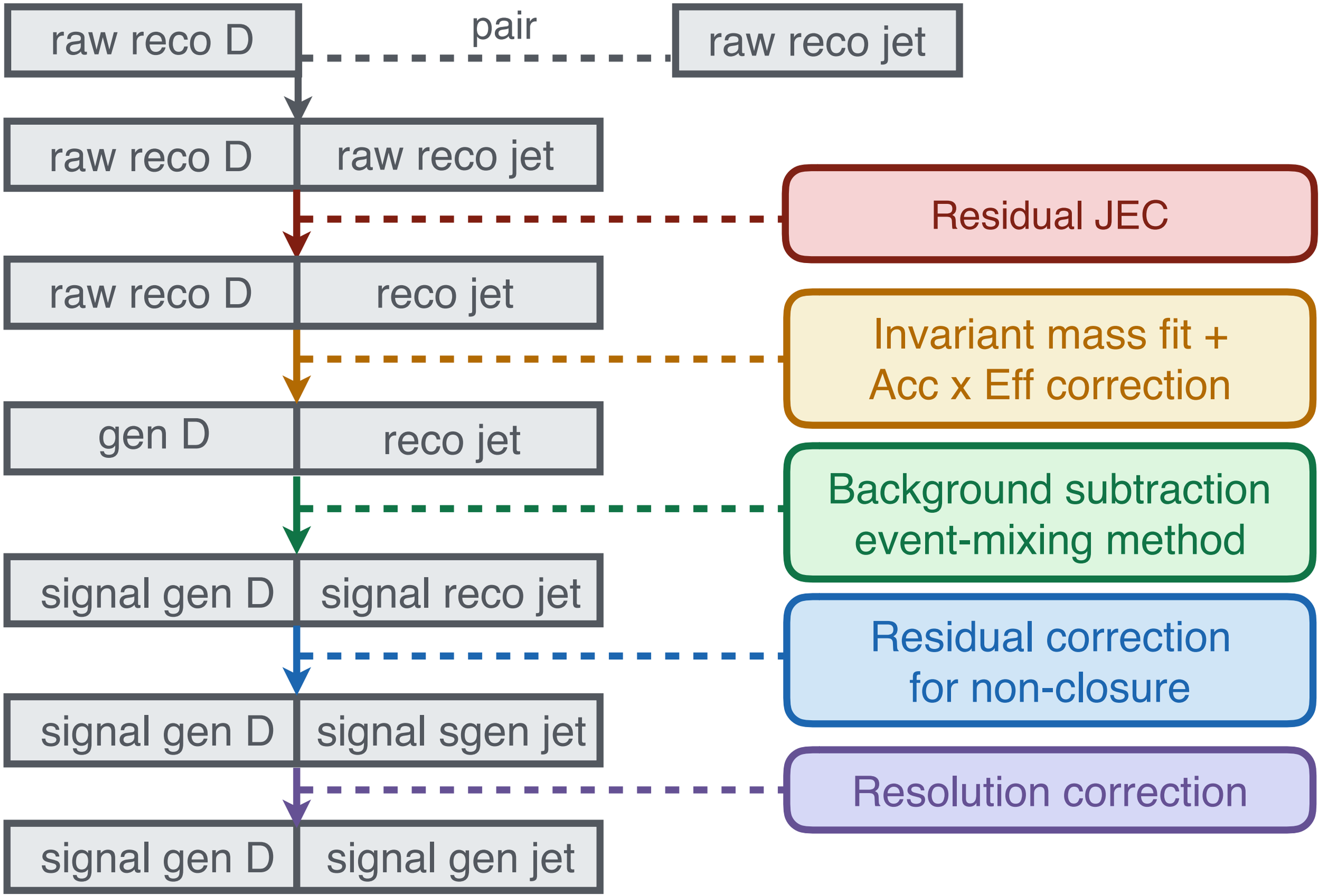
# Background subtraction

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



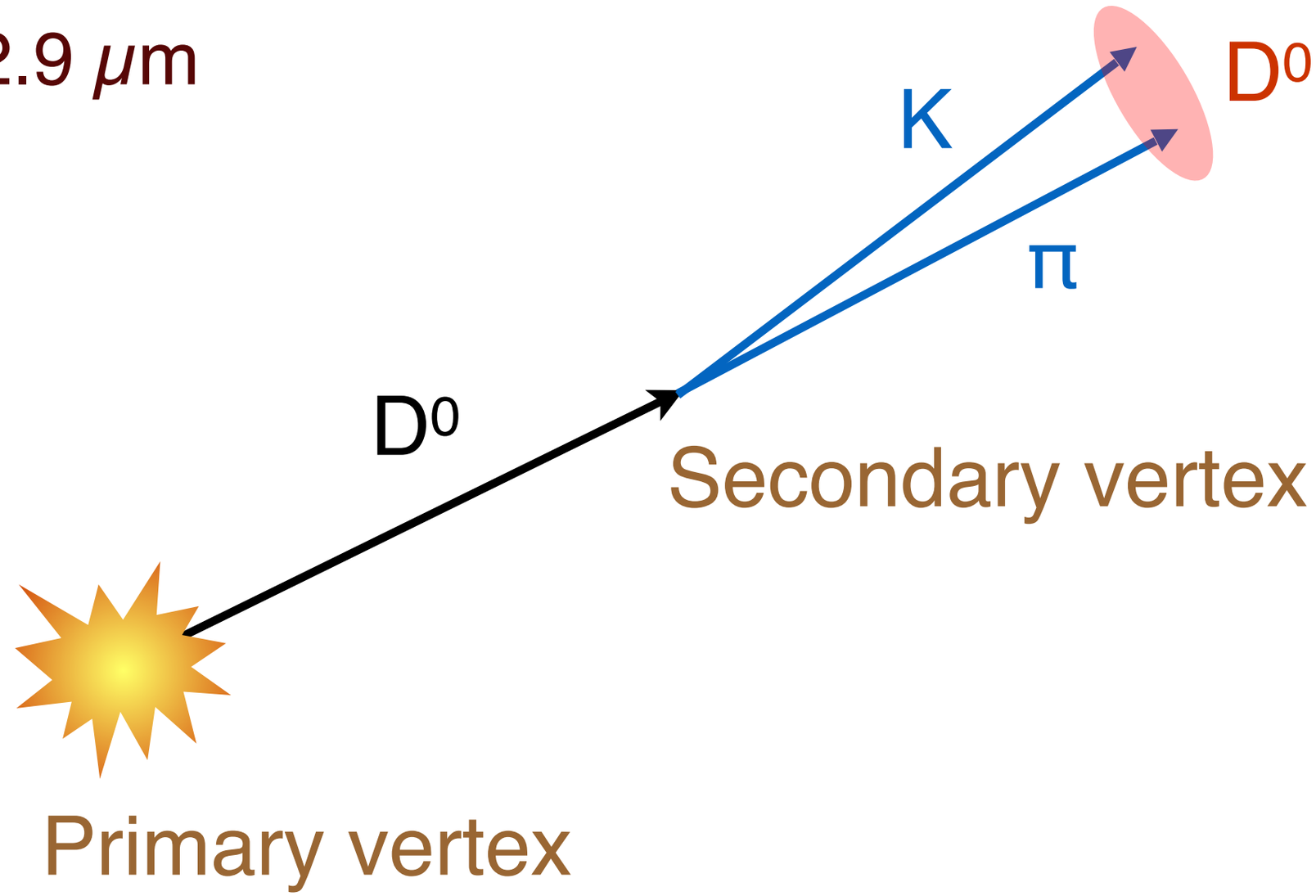

*CMS-PAS-HIN-18-007*

# Analysis strategy



# $D^0$ meson production

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



# 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