Effect of initial states on the production of heavy flavors

An insight from azimuthal angular correlations

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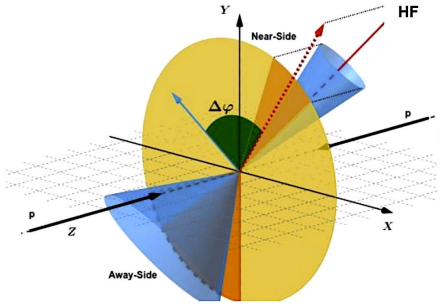
Physics Motivation: An azimuthal angular correlation

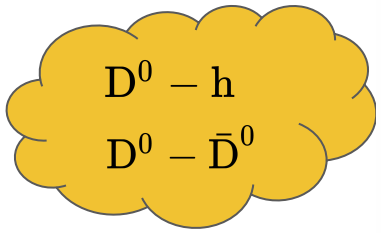
Heavy flavors (HFs) are produced in early stages of collisions via initial hard scattering processes

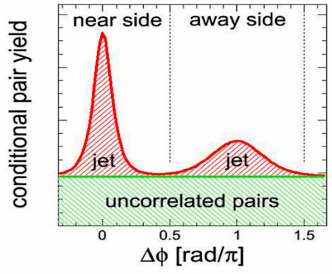
PC: Pair Creation, GS: Gluon Splitting, FE: Flavor Excitation

c/b → Fragmentation → Jet

$$\Delta\phi = \phi_{trig} - \phi_{assoc}$$

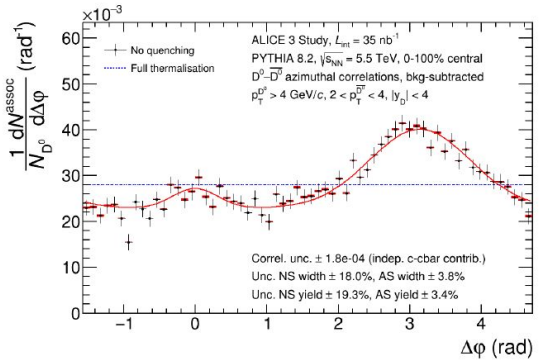






Azimuthal angular correlation probes

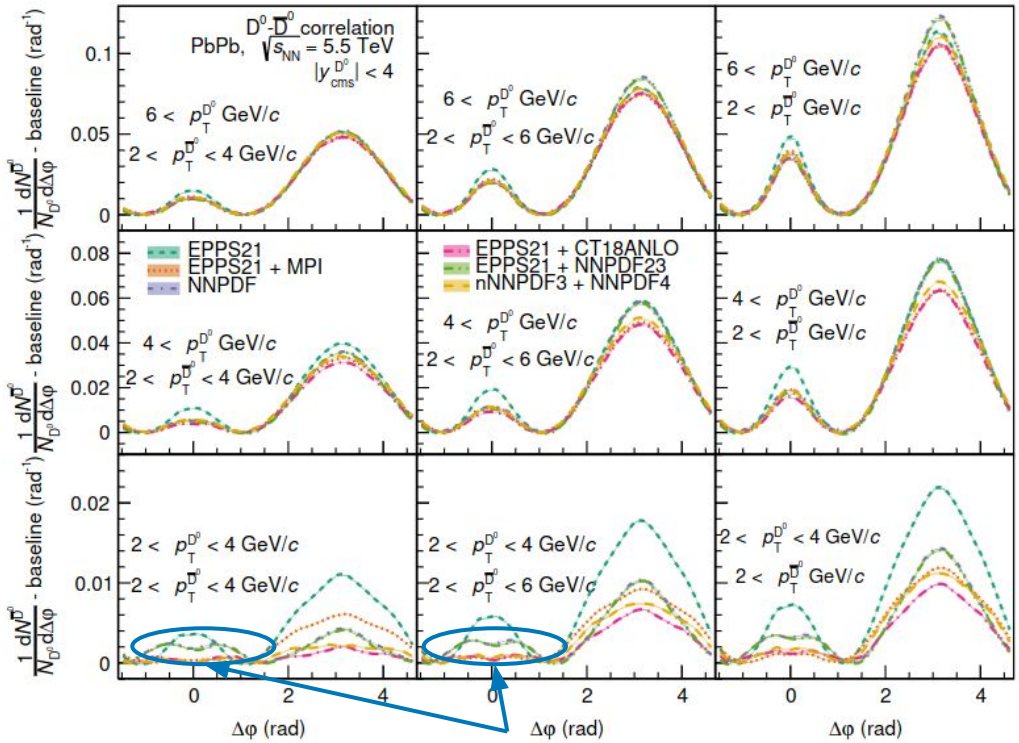
- Production
- Fragmentation
- Properties of QGP
- Thermalization
- Initial state effects



- Studying Initial state using nuclear parton distribution functions (nPDFs)
- Nuclear PDFs change the production and, potentially azimuthal correlation of heavy flavors
- Quantify the effects on correlation for robust comments on degree of thermalization

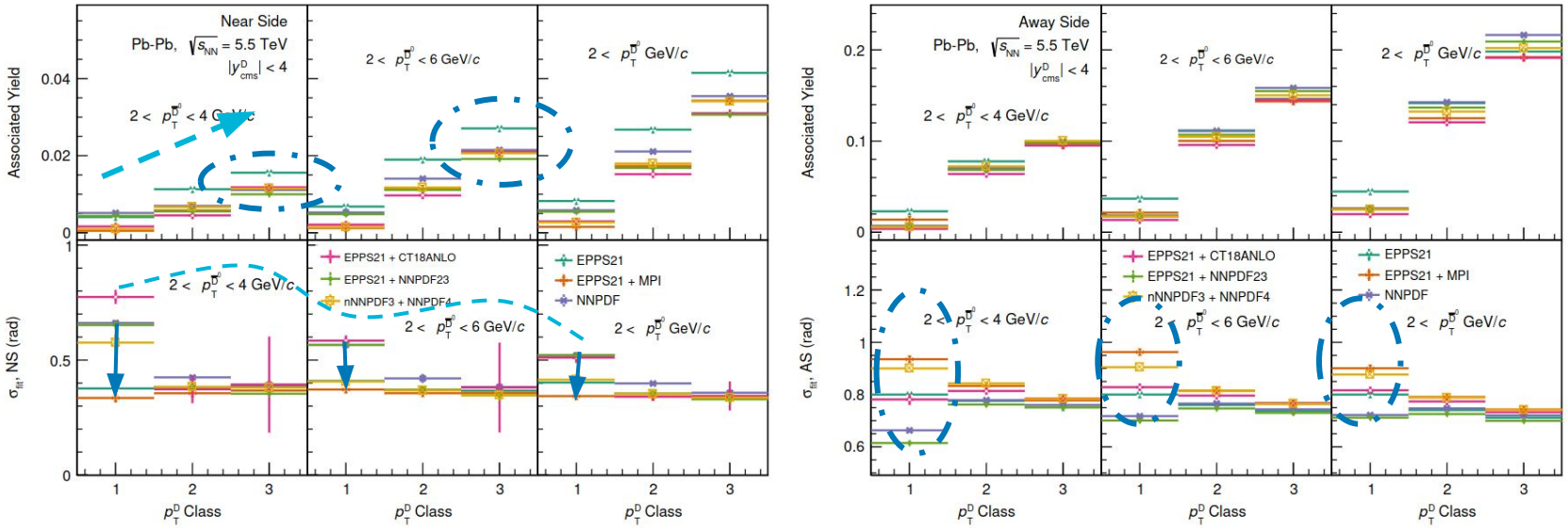
Results: $D^0 - \bar{D}^0$ azimuthal correlation

Azimuthal angular correlation of open heavy flavors originating from same hard scattering



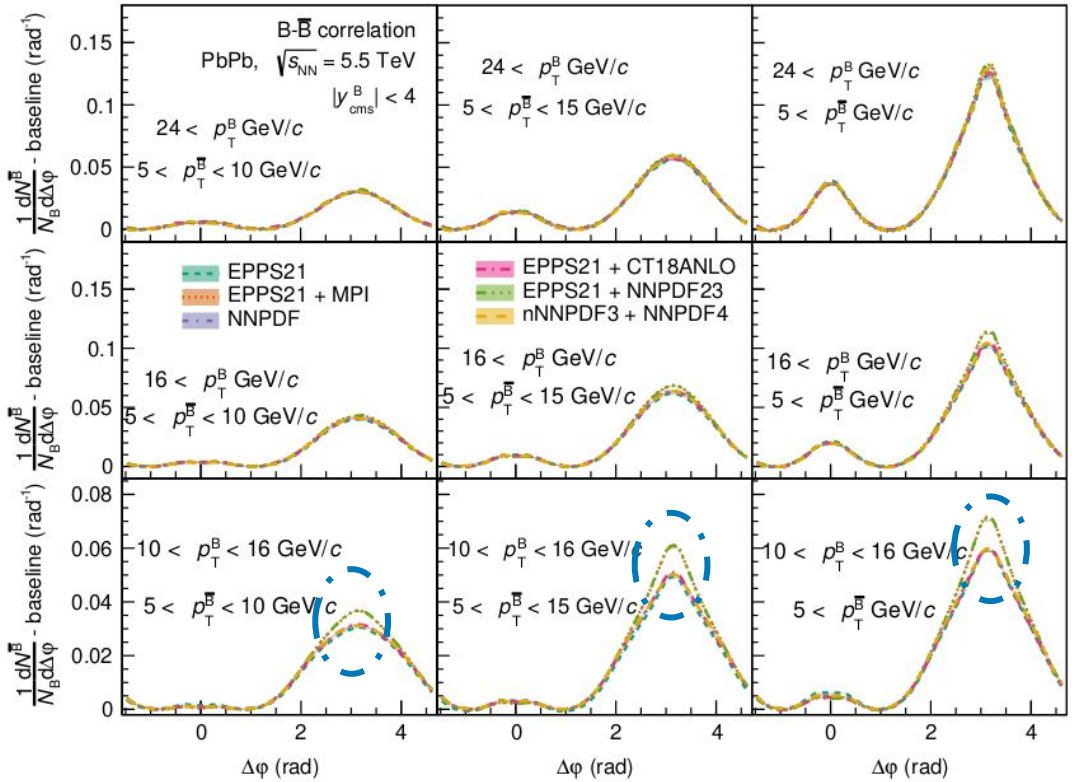
- In PYTHIA8+Angantyr framework, choice of PDFs affects shape, yield and width of azimuthal angular correlation for low transverse momentum of trigger particles.
  - PDFs influence HF production via initial state radiation (ISR), final state radiation (FSR) and multi-partonic interactions (MPI)
- Double near side peak
  - Gluon splitting
  - Multi-partonic interaction at low p_{T}
- PDF used for hard scattering do not affect the correlation
- For $p_{\mathrm{T}}^{\mathrm{Trig}}$ > 4 GeV/c, distribution show small dependence on PDF

Results: $D^0 - \bar{D}^0$ azimuthal correlation



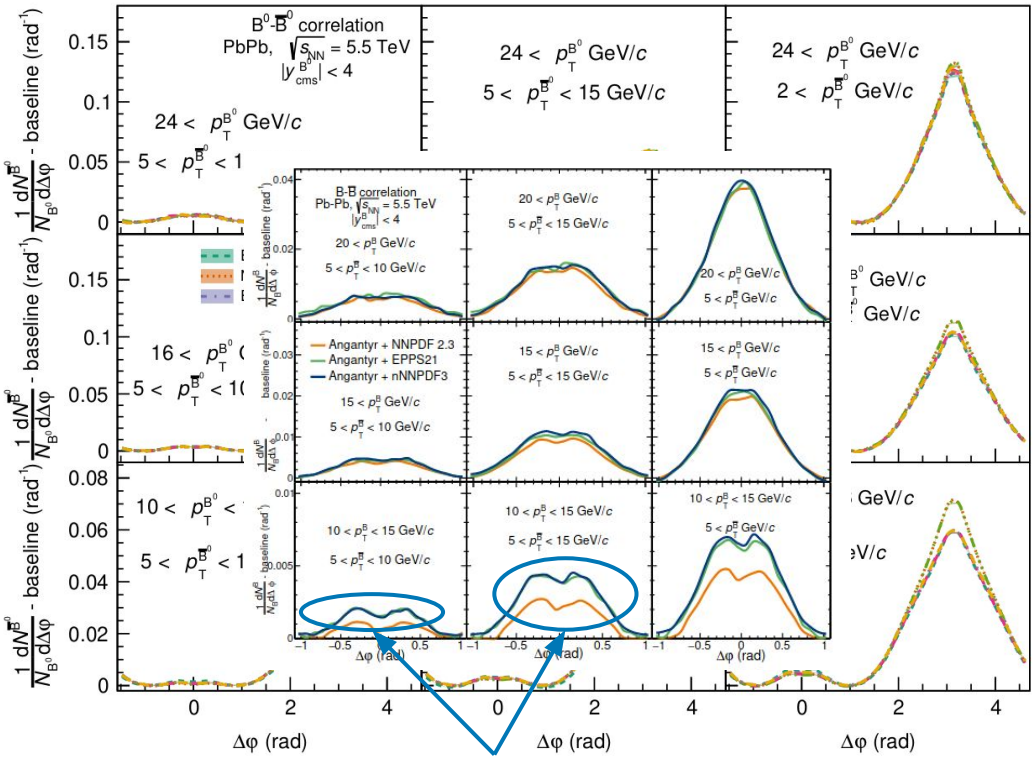
- Near side (NS) and away side (AS) yield shows increasing trend with p_T associate and p_T trigger.
- Maximum deviation from default setting is obtained for the case where nPDFs are used for all processes
- EPPS21+MPI shows narrower NS and broader AS distribution compared to default PYTHIA8

Results: $\mathrm{B} - \bar{\mathrm{B}}$ azimuthal correlation



- Except PYTHIA's default PDF, all other PDFs are consistent with each other
- Size of NS distribution peak compared to AS distribution is smaller for a $\mathrm{B} - \bar{\mathrm{B}}$ correlation compared to $\mathrm{D}^0 - \bar{\mathrm{D}}^0$ the correlation

Results: $\mathrm{B} - \bar{\mathrm{B}}$ azimuthal correlation



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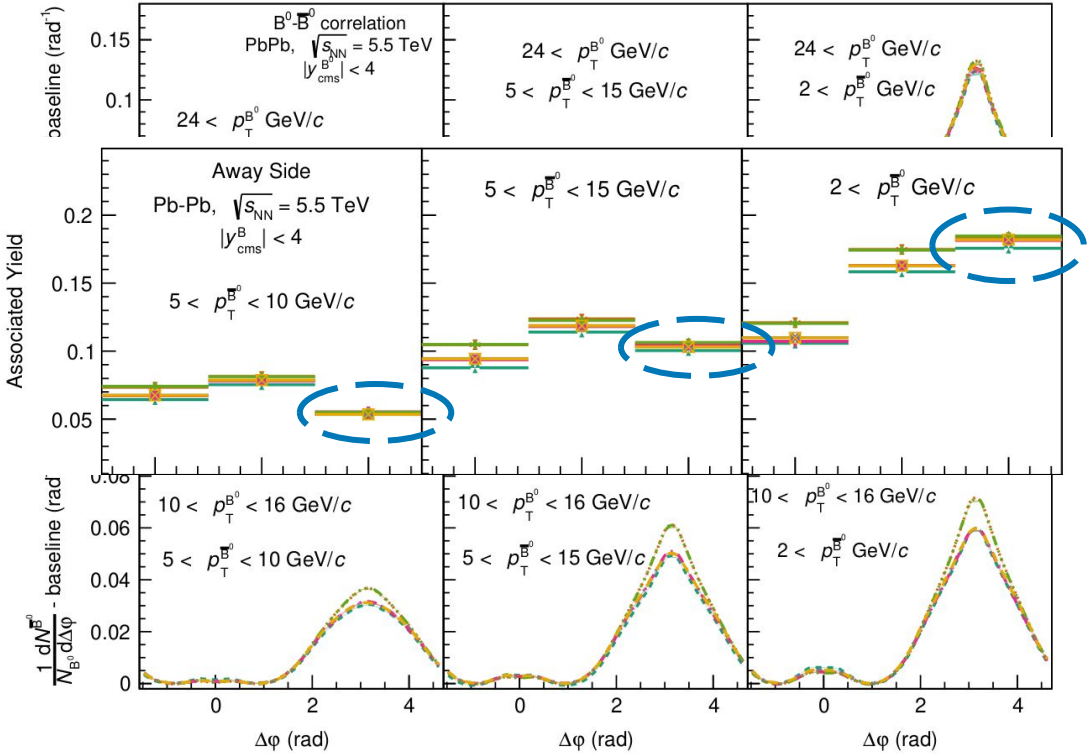
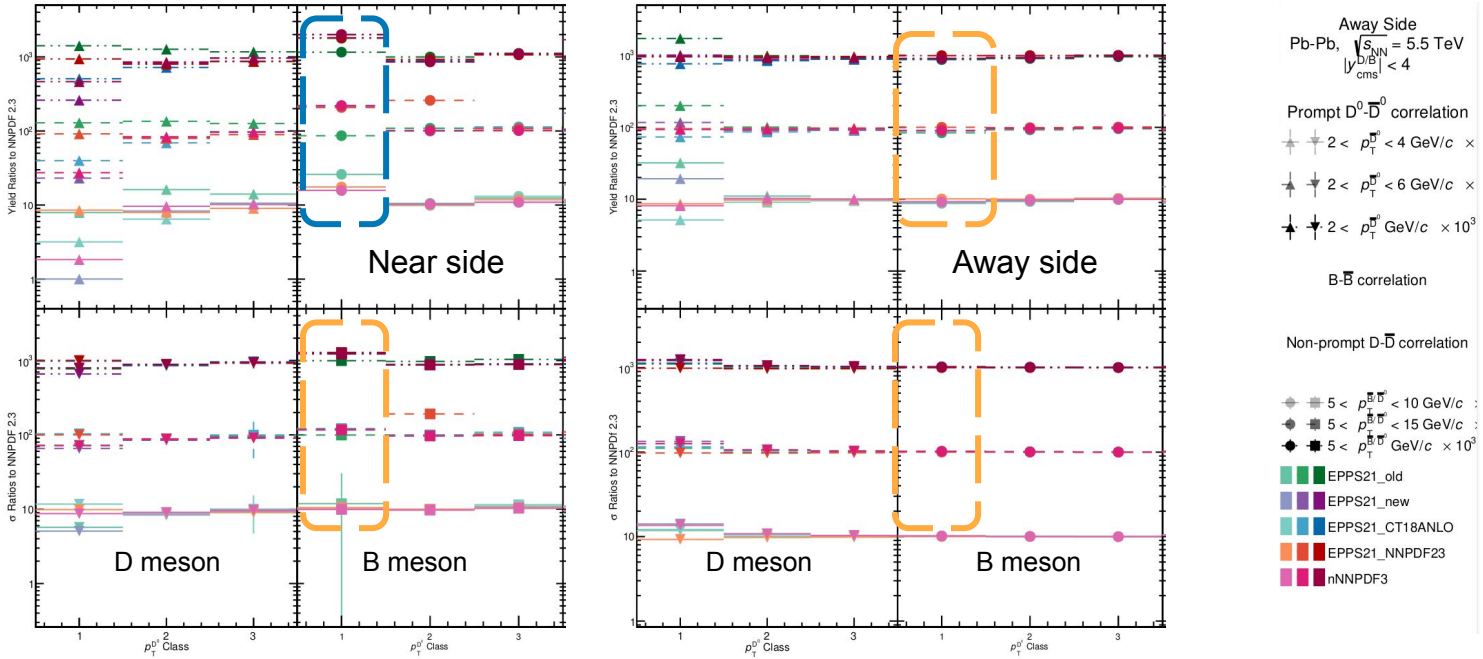
- Size of NS distribution peak compared to AS distribution is smaller for a $\mathrm{B} - \bar{\mathrm{B}}$ correlation compared to $\mathrm{D}^0 - \bar{\mathrm{D}}^0$ the correlation
- Double NS peak

Results: $\mathrm{B} - \bar{\mathrm{B}}$ azimuthal correlation



- Except PYTHIA's default PDF, all other PDFs are consistent with each other
- Size of NS distribution peak compared to AS distribution is smaller for a $\mathrm{B} - \bar{\mathrm{B}}$ correlation compared to $\mathrm{D}^0 - \bar{\mathrm{D}}^0$ the correlation
- Probing kinematics of HF production

Results: yield and width ratio



- NS yield shows more than 50% increase due to PDFs but AS yield remains unchanged.
- No significant change in width of NS and AS due to PDF

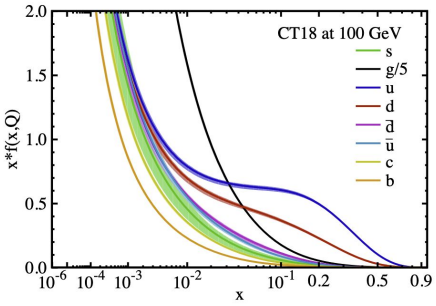
Summary and Outlook

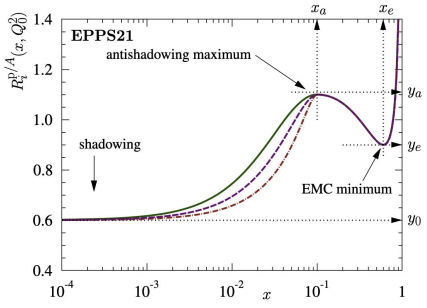
- PDFs/nPDFs have significant influence on the $\mathrm{D}^0 - \bar{\mathrm{D}}^0$ azimuthal angular correlation, especially at low p_{T}
- Double NS gluon splitting peak observed at low p_{T} has dominant contributions from hard MPIs
- No significant difference in distribution width for B-mesons with the choice of PDFs
- Differential study of aimuthal angular correlation with respect to transverse momentum allows the study of production kinematics of heavy flavors
- This observable can be used to put better constraints on nuclear PDFs
- Minimum bias study do not show significant change of distribution width for the $p_{\mathrm{T}}^{\mathrm{Trig}}$ > 4 GeV/c, for themalization, multiplicity dependent study can provide better understanding of PDF effects on azimuthal angular correlation.

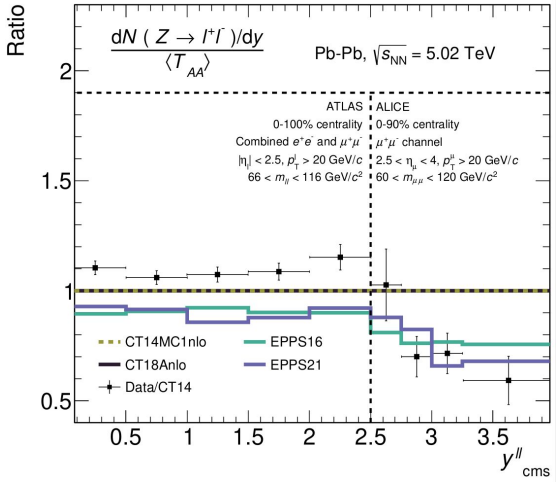
Backup

Physics motivation: Initial state effects

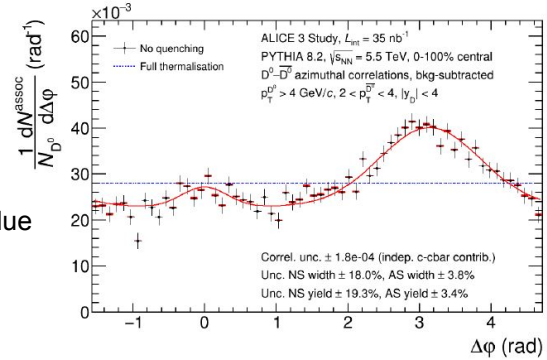
- Study the effect of Initial state using nuclear parton distribution functions (nPDFs)
- Effect of nPDFs is verified by comparing simulation results with Z-boson production as a function of rapidity
- At forward rapidities, nPDFs shows better agreement with data compared to free proton PDFs
- Integrated rapidity yield shows 3.4σ deviation from free proton PDFs



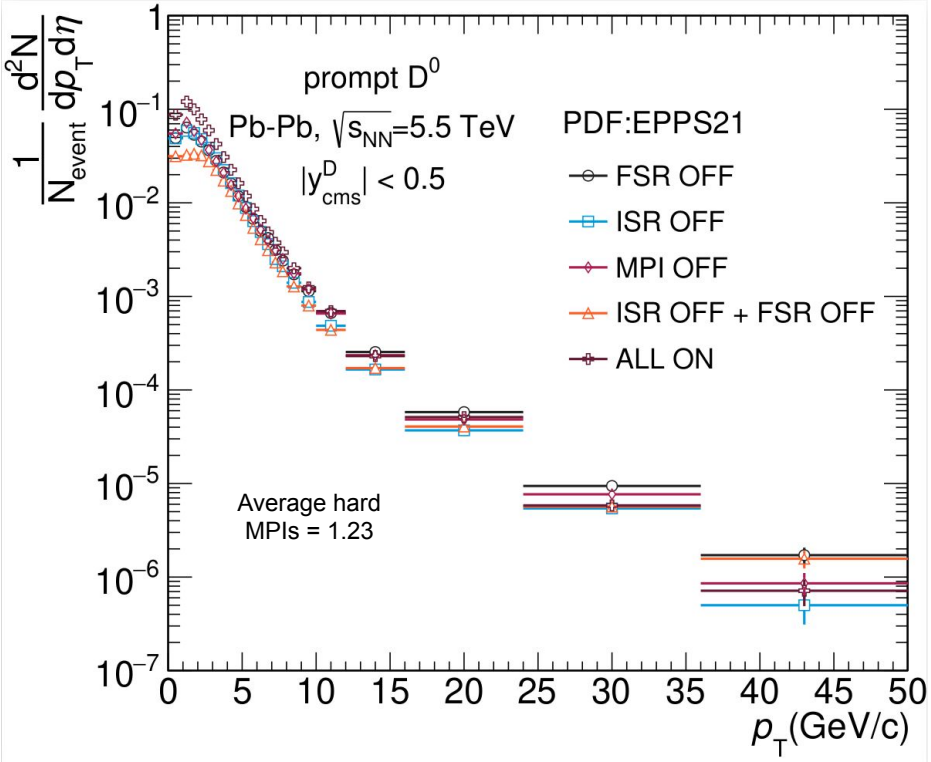


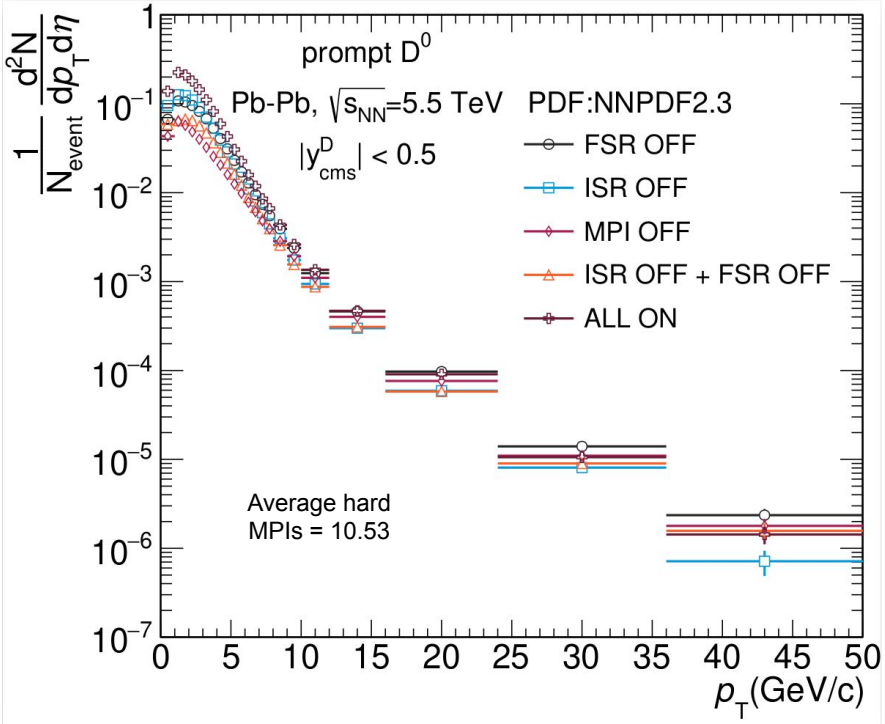


- Non-zero elliptic flow of prompt D-meson implies participation of charm meson in collective motion
- ALICE3, aiming for the measurement of degree of thermalization of charm quarks via azimuthal correlation
- Full thermalization ⇨ flat azimuthal correlation
- Same as Z-boson production, nPDFs can also modify D-meson production and azimuthal correlation
- Quantify modification of azimuthal correlation due to PDFs for robust conclusions of degree of thermalization



Results: pT spectra





Results: $D^0 - \bar{D}^0$ azimuthal correlation

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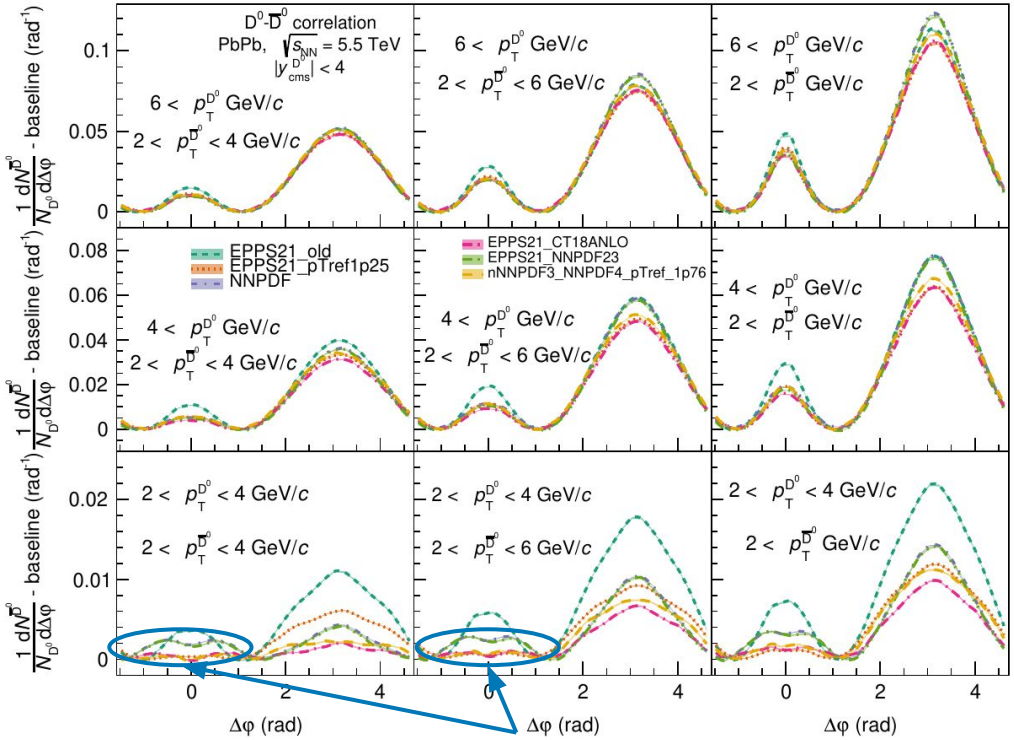

- PDFs affects shape, yield and width of azimuthal angular correlation for low transverse momentum of trigger particles.
- Double near side peak due to gluon splitting
- Absent DNP for EPPS21 implies importance of multi-partonic interaction in production of D-mesons at low pT.

$$f(\Delta\phi) = b + \sum_{n=1}^{2} \frac{Y_{\mathrm{NS_n}}}{\sqrt{2\pi}\sigma_{\mathrm{NS_n}}} \times e^{-\left(\frac{\Delta\phi}{\sqrt{2}\sigma_{\mathrm{NS_n}}}\right)^2} + \frac{Y_{\mathrm{AS}}}{\sqrt{2\pi}\sigma_{\mathrm{AS}}} \times e^{-\left(\frac{\Delta\phi-\pi}{\sqrt{2}\sigma_{\mathrm{AS}}}\right)}$$

Near Side (NS) | Away Side (AS)

$p_{\mathrm{T}}^{\mathrm{assoc}}$ (GeV/c)	Mean of near side peaks (rad)		
	m_1	m_2	$\lvert m_1 - m_2 \rvert$
$2 < p_{\mathrm{T}} < 4$	-0.58	0.56	1.14
$2 < p_{\mathrm{T}} < 6$	-0.51	0.46	0.97
$p_{\mathrm{T}} > 2$	-0.43	0.43	0.86

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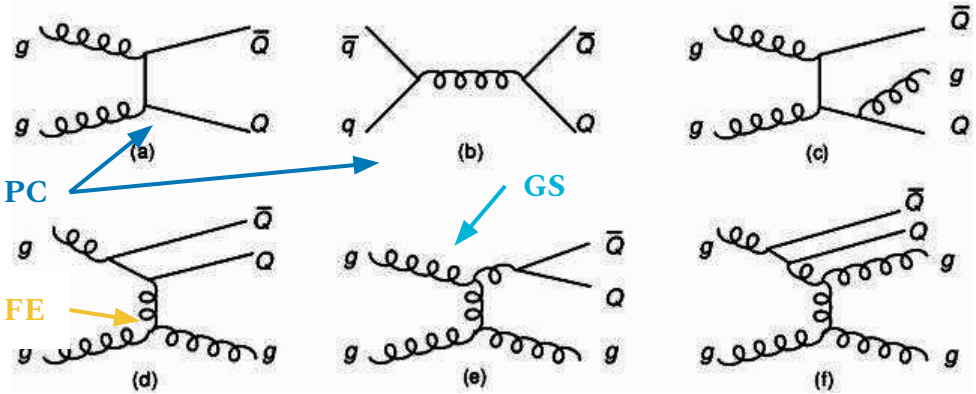
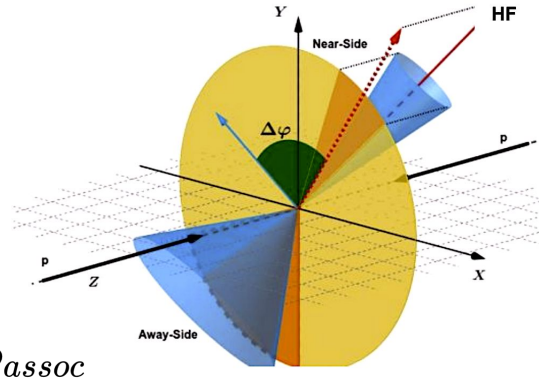


c/b → Fragmentation → Jet



$$\Delta\phi = \phi_{trig} - \phi_{assoc}$$

PC: Pair Creation

GS: Gluon Splitting

FE: Flavor Excitation

Azimuthal angular correlation probes

$D^0 - h$

$D^0 - \bar{D}^0$

- **Production**
- **Fragmentation**
- **Properties of QGP**
- **Thermalization**
- **Initial state effects**