Measurement of $R_2(\Delta \eta, \Delta \varphi)$ and $P_2(\Delta \eta, \Delta \varphi)$ correlation functions in pp collisions at $\sqrt{s} = 13$ TeV using ALICE data

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• 4 different charge combinations for $R_2$ and $P_2$:

$O^{(+,-)}, O^{(-,+)}, O^{(+,+)}$ and $O^{(-,-)}$; $O \equiv \{R_2, P_2\}$

1. $O^{US} = \frac{1}{2}(O^{(+,-)} + O^{(-,+)}) \rightarrow \text{Unlike-Sign (US)}$

2. $O^{LS} = \frac{1}{2}(O^{(+,+)} + O^{(-,-)}) \rightarrow \text{Like-Sign (LS)}$

3. $O^{CI} = \frac{1}{2}(O^{US} + O^{LS}) \rightarrow \text{Charge-Independent (CI)}$

4. $O^{CD} = \frac{1}{2}(O^{US} - O^{LS}) \rightarrow \text{Charge-Dependent (CD)}$

For pp $\sqrt{s} = 13$ TeV

ALICE, PRL 116, 222302 (2016)

ALICE, PRL 118, 162302 (2017),
ALICE, PRC 100, 044903 (2019)
$R_2$ and $P_2$ correlation functions in Pb-Pb @ $\sqrt{s_{NN}} = 2.76$ TeV

Balance Function

$$R_2(\Delta \eta, \Delta \phi) = \frac{\rho_2(\Delta \eta, \Delta \phi)}{\rho_1(\Delta \eta, \Delta \phi)} - 1$$

Charge Balance, Diffusivity

Radial flow

$\mathcal{R}_{2}^{\text{CD}} = \frac{1}{2} (R_{2}^{US} - R_{2}^{LS})$

$\mathcal{P}_{C}^{\text{I}} = \frac{1}{2} (P_{2}^{US} + P_{2}^{LS})$

$\mathcal{P}_{2}(\Delta \eta, \Delta \phi) = \frac{1}{\langle p_T \rangle^2} \int_{p_T,\text{min}}^{p_T,\text{max}} \rho_2( p_{T,1}, \eta_1, \phi_1; p_{T,2}, \eta_2, \phi_2 ) \Delta p_{T,1} \Delta p_{T,2} \, dp_{T,1} dp_{T,2}$

Where $\Delta p_{T,i} = p_{T,i} - \langle p_T \rangle$

Related to Temperature Fluctuations: $P_2^{\text{CI}} \propto \frac{\Delta T}{T}$

Why did we use $R_2$ & $P_2$?

1. Dimensionless quantity.
2. Robust observable:
   Independent of detection efficiency\textsuperscript{[1]}

\textsuperscript{[1]} M. Sharma and C. A. Pruneau, PRC 79, 024905 (2009)

ALICE, PRL 118, 162302 (2017)

\textsuperscript{ALICE, PRC 100, 044903 (2019)}
$R_{2}^{CD}$ and $P_{2}^{CD}$ correlation functions in pp MB @ $\sqrt{s} = 13$ TeV

**pp MB @ $\sqrt{s} = 13$ TeV using 2018 ALICE data**

$0.2 \leq p_T \leq 2.0$ GeV/c $|\eta| \leq 0.8$

$O^{CD} = \frac{1}{2}(O^{US} - O^{LS})$; $O \equiv \{R_{2}, P_{2}\}$

### Angular ordering

- Dip in $R_{2}^{CD}$ and $P_{2}^{CD}$ is expected to result largely from HBT effect.
- Difference in shape and width between $R_{2}^{CD}$ and $P_{2}^{CD}$.
- $P_{2}^{CD}$ is narrower than $R_{2}^{CD}$ \( \rightarrow \) Angular ordering$^{[1]}$

Width of the correlation functions

- The widths decrease monotonically in Pb-Pb collisions from peripheral to central regions for both $R_2$ (strong) and $P_2$ (modest) → Radial flow, Diffusivity
- For p-Pb case, the widths have noticeable reduction for $R_2$ whereas widths of $P_2$ have reverse trend.

- The widths increase monotonically in Pb-Pb collisions from peripheral to central regions for both $R_2$ and $P_2$ except for $P_2$ in peripheral region → Anisotropic flow
- For p-Pb case, the widths have weak dependence.

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**Summary**

- Widths of $R_2$ show $\sqrt{s}$ dependence.
- Widths of $P_2$ show $\langle p_T \rangle$ and $\sqrt{s}$ dependence.
- $P_2$ is narrower than $R_2$ due to angular ordering.
- Widths for different system show consistence.