Recent Results on Femtoscopic Correlations with the CMS Experiment

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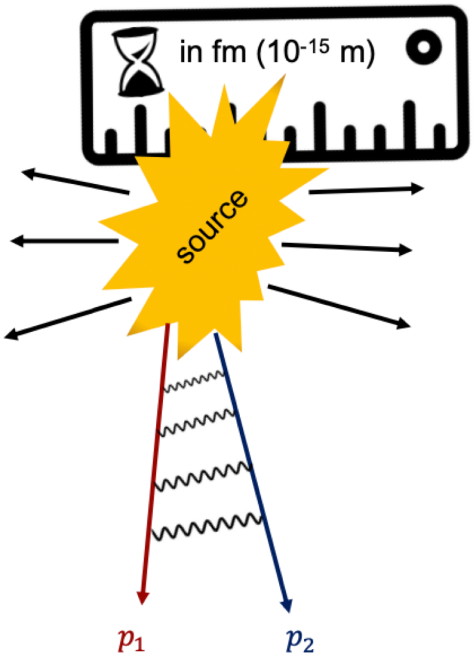
Introduction – femtoscopic correlations (I)

Access to

- Space-time dimensions of the particle emitting source
- Hadron-hadron final state interactions



Sensitive to contributions from

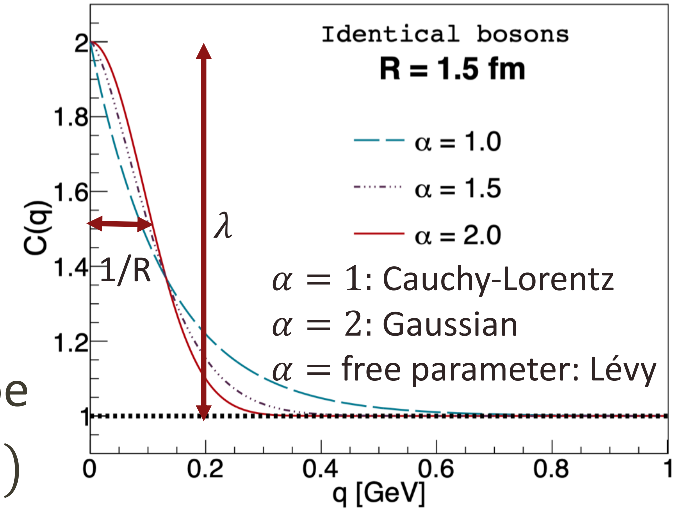
- Quantum statistical effects
  - Bose-Einstein or Fermi-Dirac
- Final state interactions (FSI)
  - Strong & Coulomb

Ann. Rev. of Nucl. and Part. Phys. **55** (2005) 357,
Phys. of Atom. Nucl. **67** (2004) 72, Sov. J. Nucl. Phys. 35 (1982) 770

Introduction – femtoscopic correlations (II)

Two-particle correlations at low-q

- $q^2 = q_{inv}^2 = -(p_1 - p_2)^2$

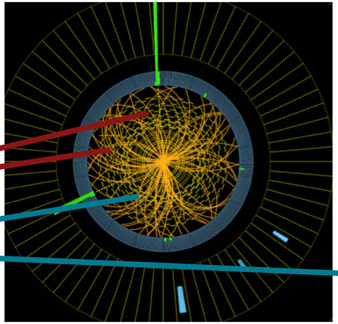


Theoretically

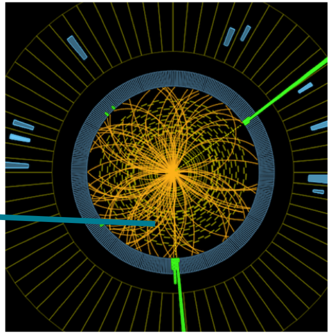
- Fourier transform of the particle source shape
  - $C(q) \sim 1 \pm \lambda |F[\tilde{\rho}(q)]|^2 \rightarrow C(q) = N\left(1 \pm \lambda e^{-|qR|^{\alpha}}\right)$

Experimentally

- Single-ratio (SR): $C(q) = N \frac{A(q)}{B(q)}$



cds.cern.ch/record/2736135



Charged Particles

Length of homogeneity (R or R_{inv})

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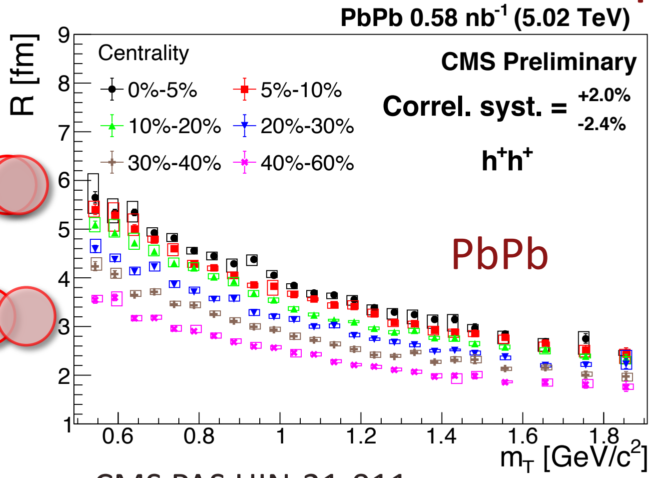
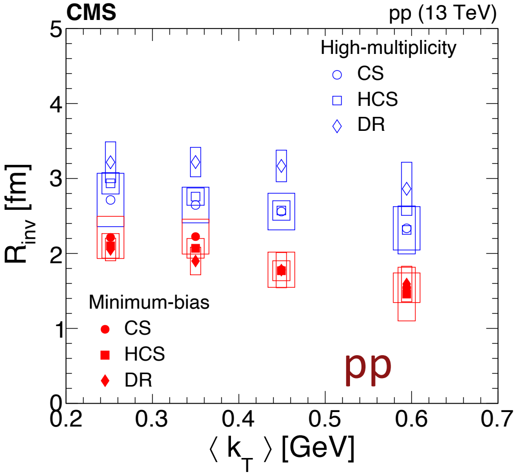
As function of m_T or k_T

- $m_T = \sqrt{m_\pi^2 + k_T^2}$
- Indication of an expanding source
- Smaller sizes in
  - more peripheral PbPb
  - lower multiplicities pp





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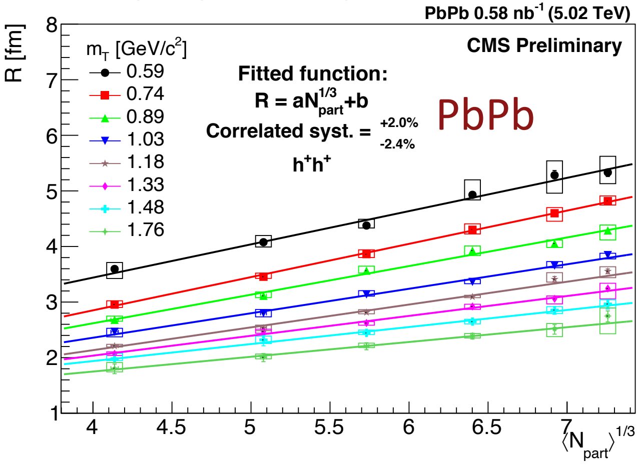
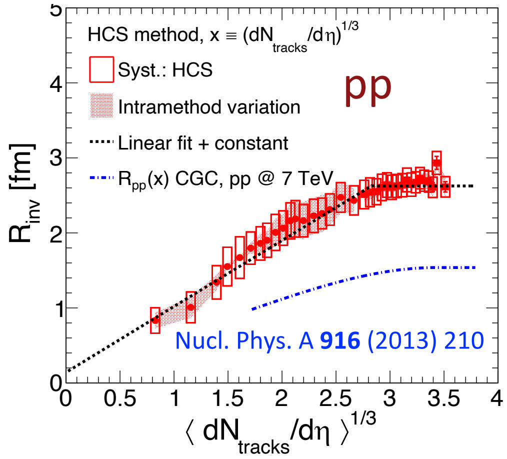
As function of number of participants (N_{part}) and charged particle multiplicity (N_{track})

- Radius proportional to $N_{part}^{1/3}$ in PbPb
- Hint of saturation as function of $N_{tracks}^{1/3}$ for pp





$^1/_{R^2}$ as function of m_T

From hydrodynamics prediction [NPA **946** (2016) 227]

- Extrapolation to $m_T = 0$: source geometrical size (at kinetic freeze-out)
- Slope: radial flow (larger slope → larger flow)

Similar trends between PbPb and pp collisions

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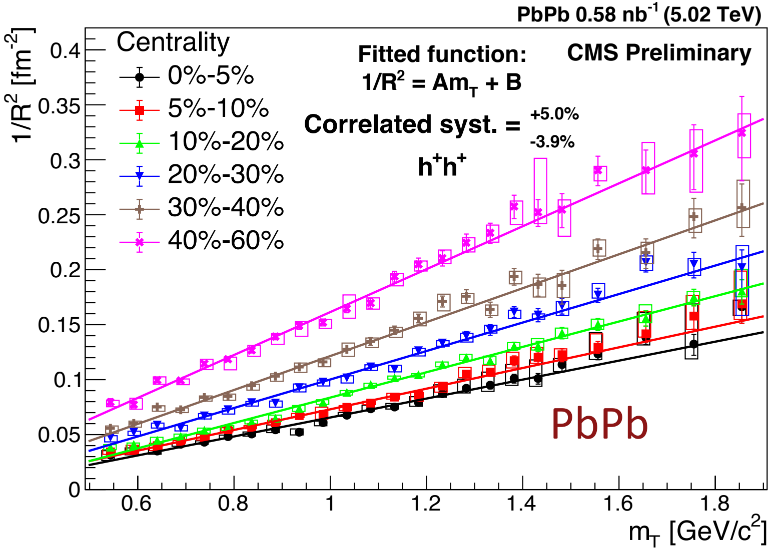

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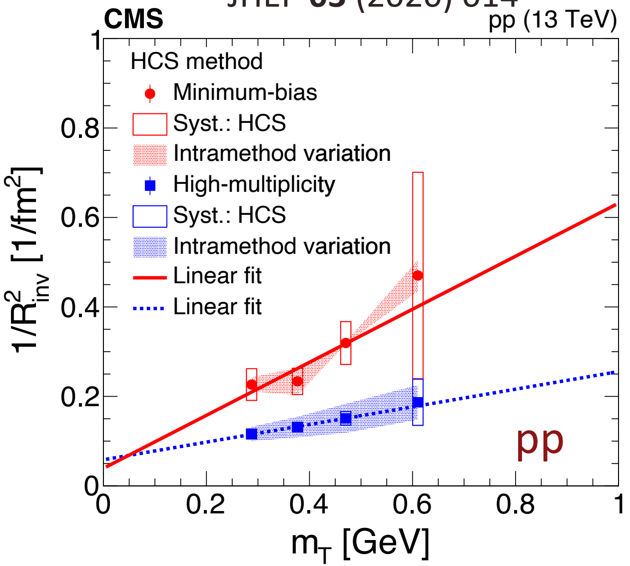
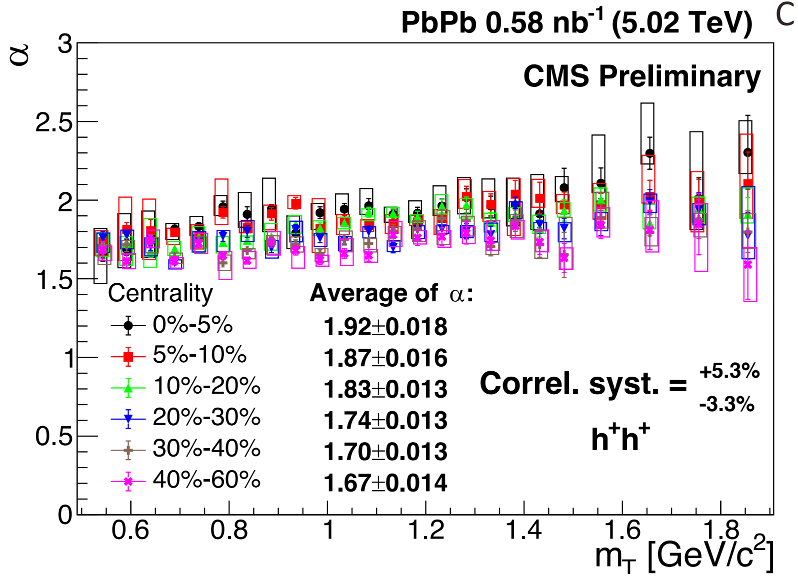


In PbPb: Lévy parameter (α)

Almost constant as function of m_T

Values raging from 1.6 to 2.0 (semi-peripheral to central collisions)

- Particle emitting source shape: deviation from Gaussian



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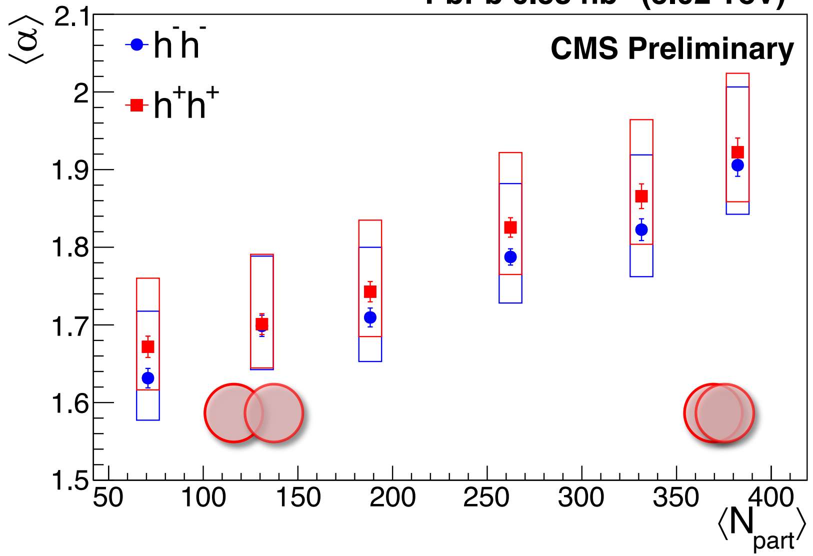

The correlation strength (λ)

Decreases with m_T or k_T

Affected by the lack of particle identification

- Decreasing the correlation strength

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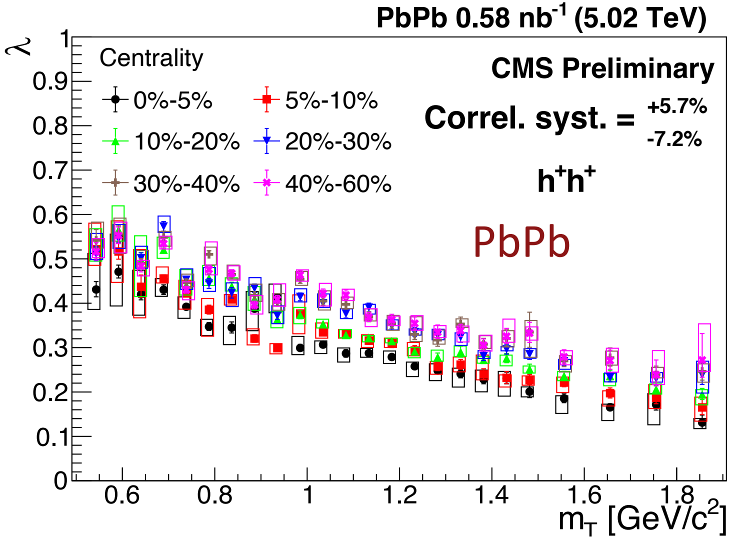

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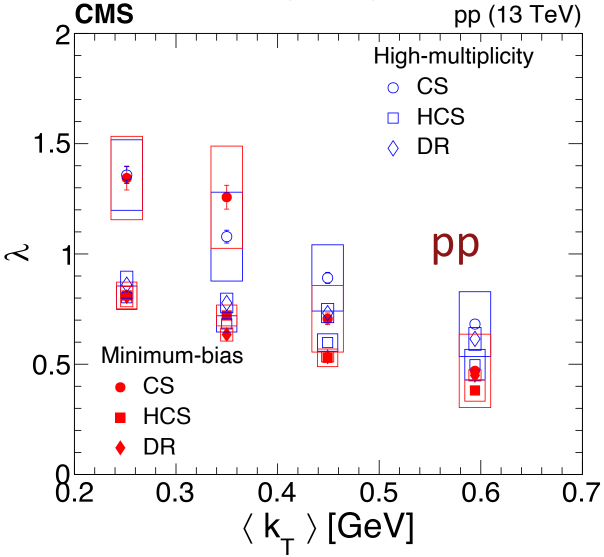

Strange Hadrons

$K_S^0 K_S^0$, $\Lambda K_S^0 \oplus \bar{\Lambda} K_S^0$, $\Lambda\Lambda \oplus \bar{\Lambda}\bar{\Lambda}$

K_S^0 and $\Lambda + \overline{\Lambda}$ in PbPb collisions

Particles selected using Boosted Decision Trees method

- $K_S^0 \rightarrow \pi^+ + \pi^-$, $\Lambda \rightarrow p + \pi^-$

Signal: triple Gaussian

Background: 4^{th} order polynomial

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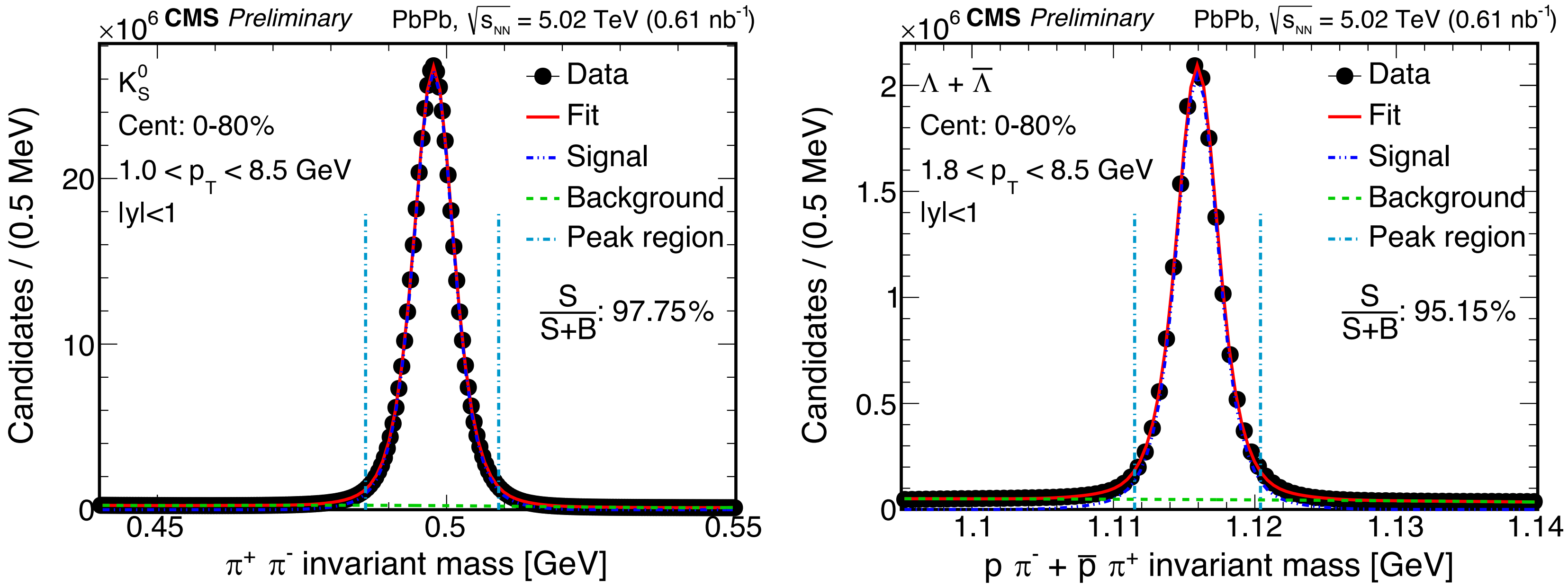

$K^0_S K^0_S$: R and λ as a function of centrality

Inclusion of FSI term in the fit introduce an overall change in R and λ

- Except for λ in peripheral collisions

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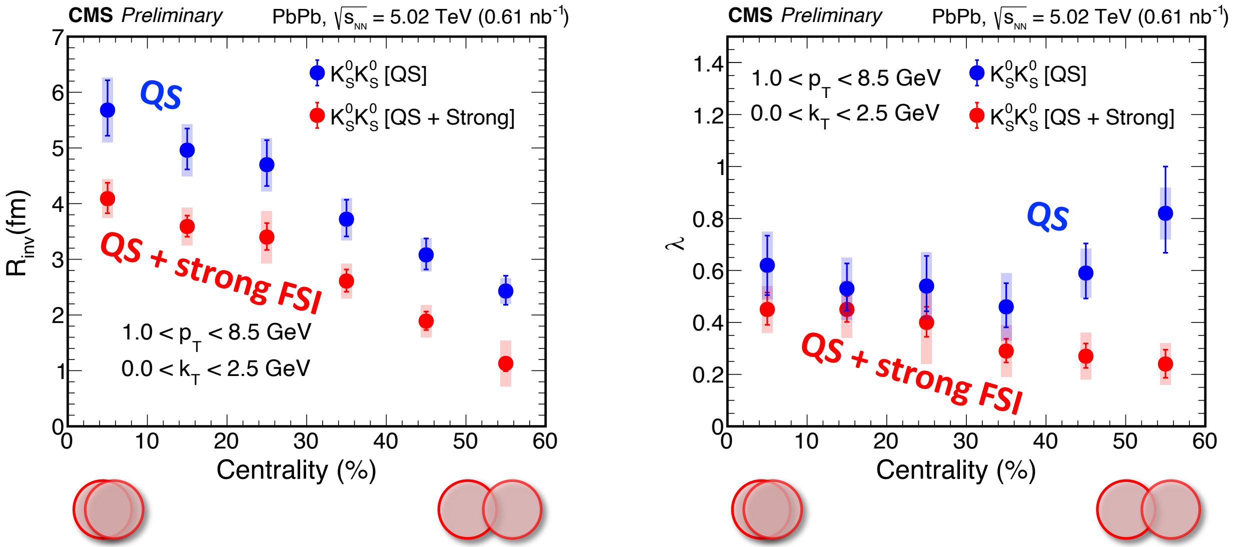

Scattering parameters

Real scattering length ($\Re f_0$)

Effective range (d_0)

Femtoscopy nomenclature

- ❑ $\Lambda K^0_S \oplus \bar{\Lambda} K^0_S$: $\Re f_0 < 0$ → depletion below unity (anticorrelation)
- ❑ $\Lambda\Lambda \oplus \overline{\Lambda\Lambda}$: $\Re f_0 > 0$ → correlation above unity

Correlation above unity

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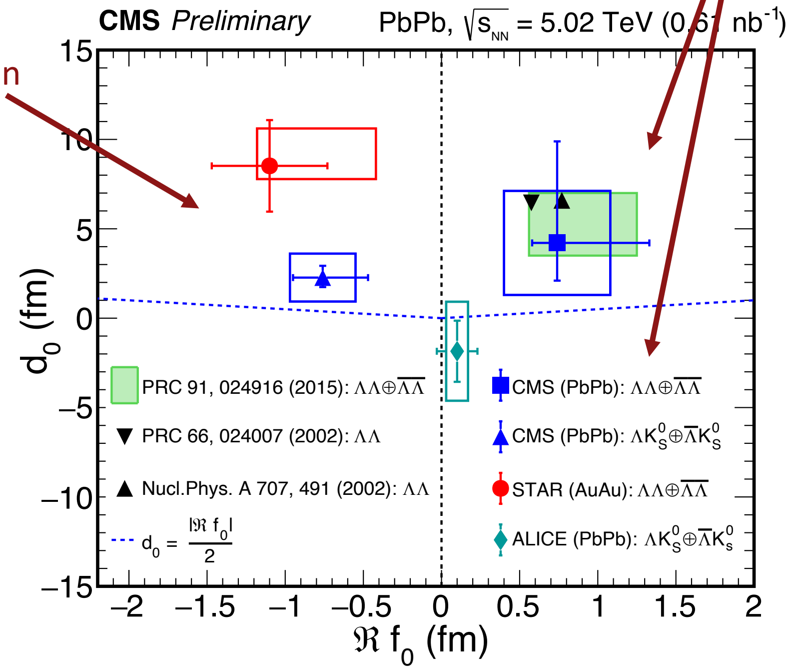
Anticorrelation



Summary

For the studied particle species correlations in pp and PbPb collisions

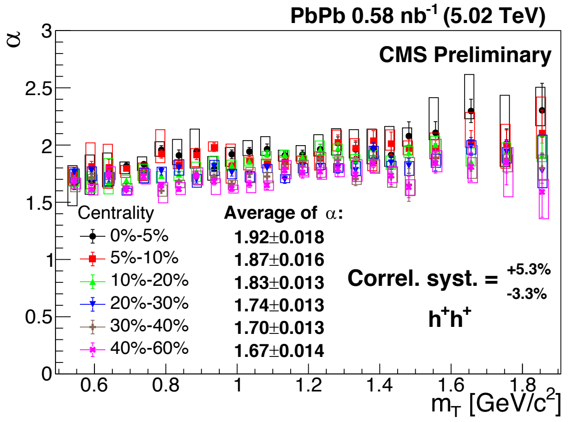
- ❑ Length of homogeneity (R or R_{inv})
  - Increases with N_{track} or more central collisions
  - Decreases with m_T or k_T

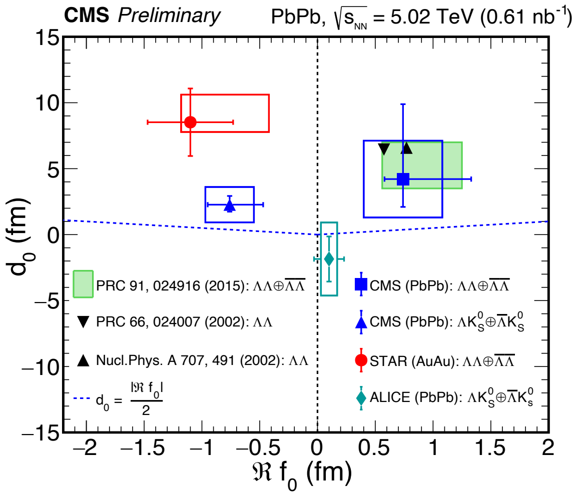
First time Lévy shape is analysed @LHC for PbPb

- ❑ Non-Gaussian behavior: centrality dependent
- ❑ R or R_{inv} shows m_T scaling (hydro) also for Lévy shape

Strange hadrons correlations

- ❑ First measurement of $\Lambda\Lambda \oplus \overline{\Lambda}\overline{\Lambda}$ correlation in PbPb collisions at LHC: correlation above unity
- ❑ $\Lambda K^0_S \oplus \overline{\Lambda} K^0_S$: anticorrelation





Thank You!

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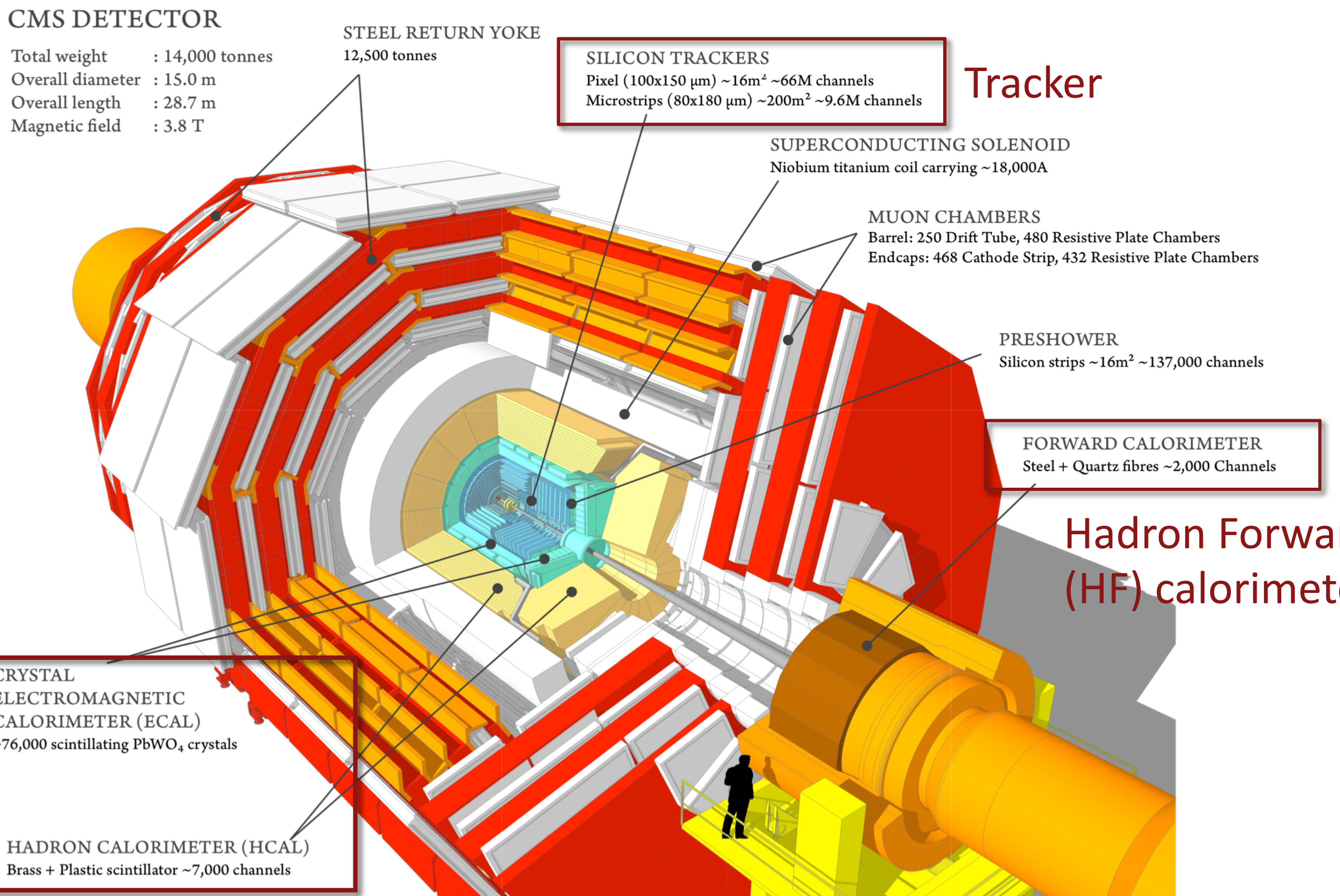
BACKUP

The CMS detector



Tracker

Hadron Forward (HF) calorimeters

ECAL/HCAL

Correlation function in PbPb and pp collisions

Lévy fit in PbPb collisions @5TeV

Exponential fit in pp collisions @13TeV

$$k_T = \frac{1}{2}\left|\vec{p}_{T,1} + \vec{p}_{T,2}\right|$$

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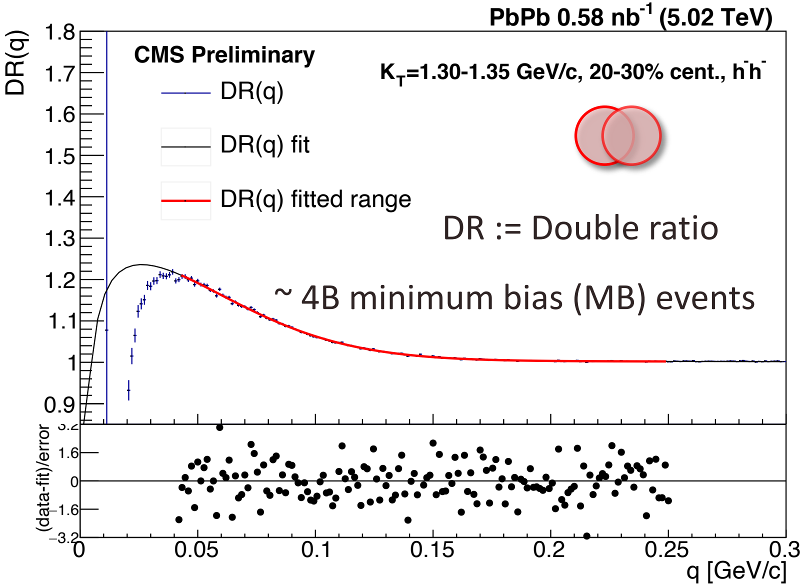

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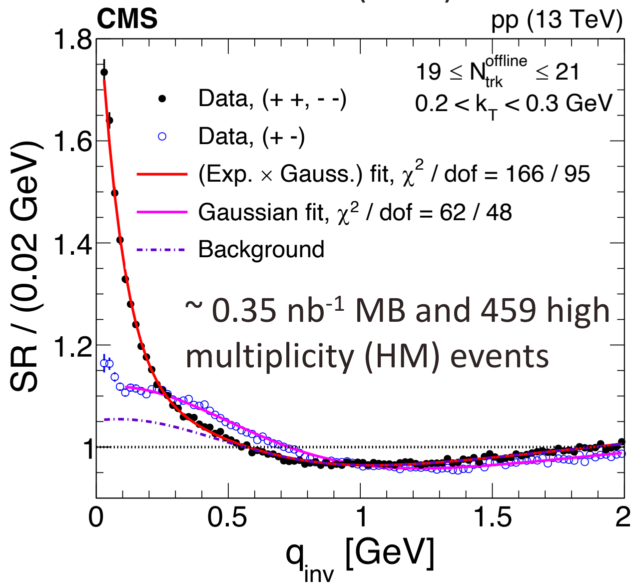

Correlation function in PbPb

$K_s^0 K_s^0$: QS (Bose-Einstein) + strong FSI

$\Lambda K_s^0 \oplus \bar{\Lambda} K_s^0$: strong FSI

$\Lambda\Lambda \oplus \bar{\Lambda}\bar{\Lambda}$: QS (Fermi-Dirac) + strong FSI

Particle emitting source

$$C(q) = \int S(r)|\Psi_{12}(q,r)|^2 \, d^3r$$

Two-particle wave function

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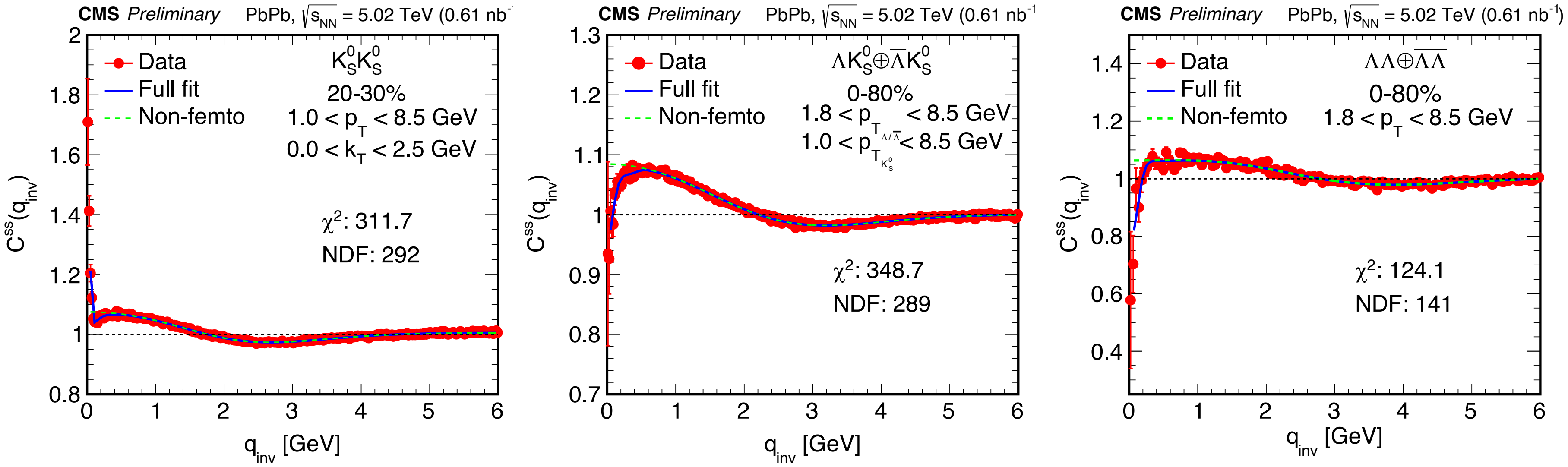
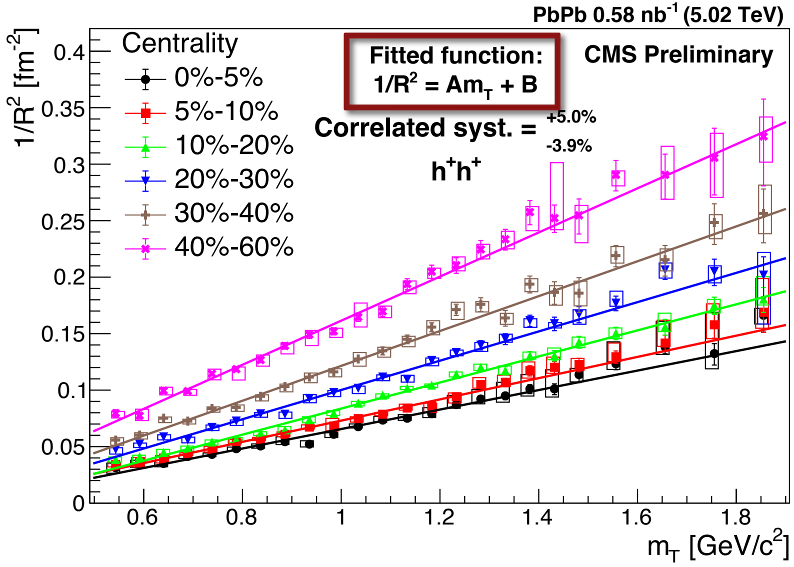
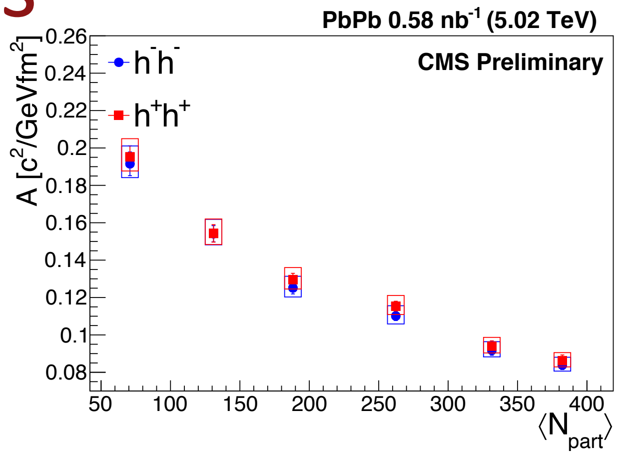
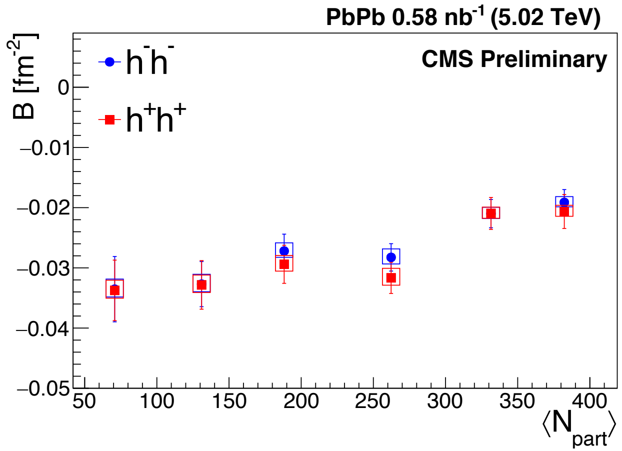


m_T scaling – PbPb collisions

Charged particles





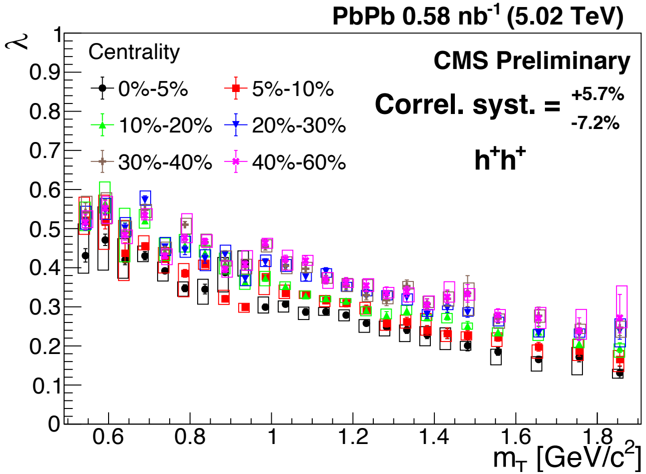


The correlation strength (λ)

Decreases with m_T

The pairs of non-identical particles tend to decrease λ

- Rescaling by pion fraction in the core-halo picture (λ^*)



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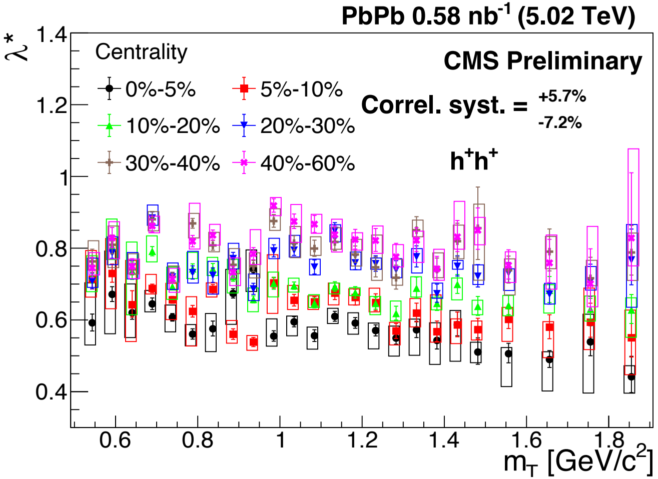

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