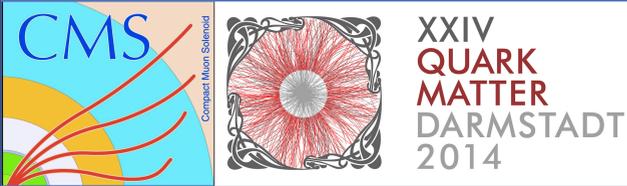# Long-range two-particle correlations with K^0_S and Λ in pPb and PbPb collisions

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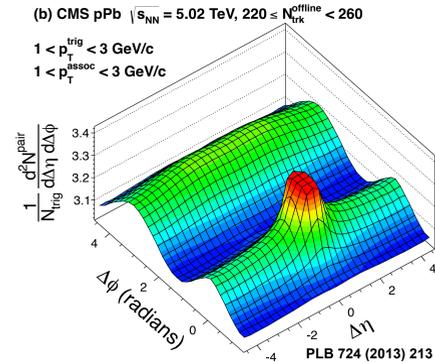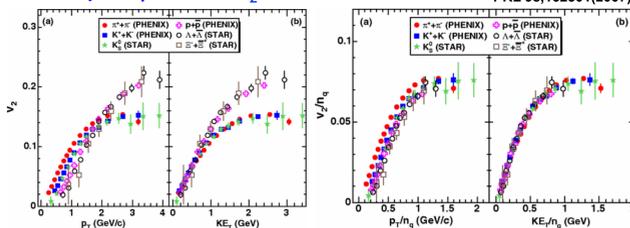
zc11@rice.edu, on behalf of the CMS collaboration

XXIV QUARK MATTER DARMSTADT 2014

Motivation

❑ Observation of a significant long-range near-side two-particle correlation in pPb collisions opened a new avenue of studying novel QCD phenomena in small systems.

❑ In the context of hydrodynamic models, anisotropic flow (v_n) for unidentified charged particles in pPb collisions have been extensively studied by the CMS collaboration.

(b) CMS pPb $\sqrt{s_{NN}}$ = 5.02 TeV, $220 \leq N^{offline}_{trk} < 260$

$1 < p_T^{trig} < 3$ GeV/c
$1 < p_T^{assoc} < 3$ GeV/c

$\frac{1}{N_{trig}}\frac{d^2N^{pair}}{d\Delta\eta\,d\Delta\phi}$

PLB 724 (2013) 213

*Identified particle v_2 in AA at RHIC*

PRL 98,162301(2007)

Elliptic flow (v_2) of identified particles in AA collisions at RHIC:

❑ Mass ordering of v_2 at p_T below 2 GeV, consistent with hydrodynamic models.

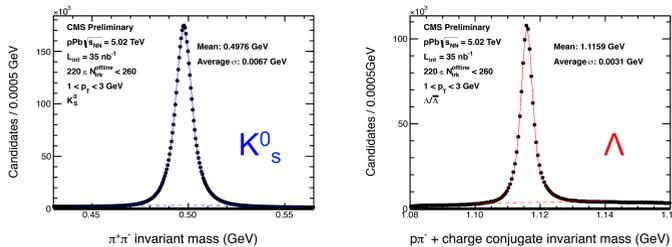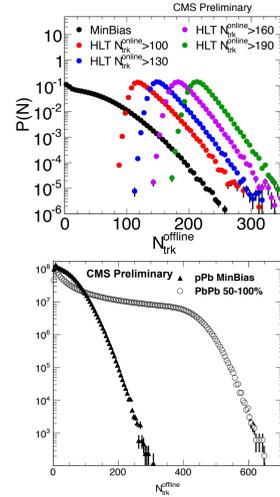❑ Number of constituent quark scaling phenomena – Recombination?

Are the mass ordering and number of constituent quark scaling phenomena of identified particle v_n present in pPb collisions?

V^0 (K^0_s, Λ) Reconstruction and High Multiplicity Triggers

❑ V^0 reconstruction via topological decays in CMS silicon tracker

pointing angle
v_0 momentum
secondary vertex
decay length
primary vertex
DCA
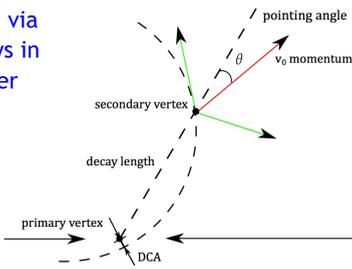
❑ Unique high-level triggers enable precise studies of PID v_n in very high multiplicity pPb events

CMS Preliminary
MinBias
HLT $N^{online}_{trk}>100$ HLT $N^{online}_{trk}>160$
HLT $N^{online}_{trk}>130$ HLT $N^{online}_{trk}>190$

CMS Preliminary
pPb MinBias   PbPb 50-100%

CMS Preliminary
pPb $\sqrt{s_{NN}}$ = 5.02 TeV
L_{int} = 35 nb^{-1}
$220 \leq N^{offline}_{trk} < 260$
$1 < p_T < 3$ GeV
Mean: 0.4976 GeV
Average σ: 0.0067 GeV
K^0_S

CMS Preliminary
pPb $\sqrt{s_{NN}}$ = 5.02 TeV
L_{int} = 35 nb^{-1}
$220 \leq N^{offline}_{trk} < 260$
$1 < p_T < 3$ GeV
Mean: 1.1159 GeV
Average σ: 0.0031 GeV
Λ

Clean reconstruction of K^0_s and Λ over wide range of p_T and η

Analysis Method – Two-particle Correlation

Signal pair distribution:
$$S(\Delta\eta,\Delta\varphi)=\frac{1}{N_{sig}}\frac{d^2N^{same}}{d\Delta\eta\,d\Delta\varphi}$$

Background pair distribution:
$$B(\Delta\eta,\Delta\varphi)=\frac{1}{N_{mix}}\frac{d^2N^{mix}}{d\Delta\eta\,d\Delta\varphi}$$

same event pairs   mixed event pairs
$S(\Delta\eta,\Delta\varphi)$ $B(\Delta\eta,\Delta\varphi)$

Event 1:   Event 2:

$\Delta\eta = \eta^{assoc} - \eta^{trig}$
$\Delta\phi = \phi^{assoc} - \phi^{trig}$

(a) CMS Preliminary, pPb $\sqrt{s_{NN}}$ = 5.02 TeV, L_{int} = 35 nb^{-1}
N < 35
$1 < p_T^{trig} < 3$ GeV
$1 < p_T^{assoc} < 3$ GeV
K^0_S-$h^\pm$

(b) $\Lambda/\bar{\Lambda}$-$h^\pm$

(c) $220 < N < 260$ K^0_S-$h^\pm$

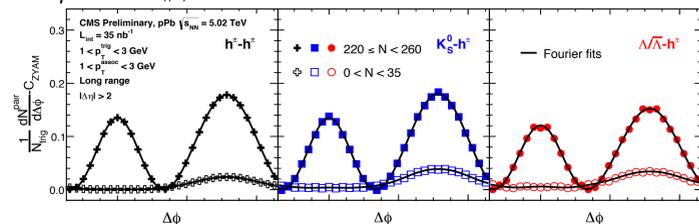(d) $\Lambda/\bar{\Lambda}$-$h^\pm$
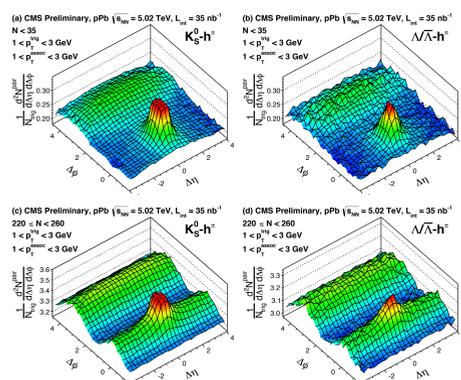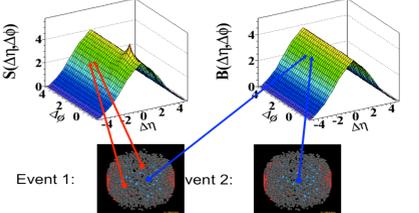
$$\frac{dN^{pair}}{d\Delta\phi} \sim 1+2\sum_{n=1}V_{n\Delta}\cos(n\Delta\phi)$$
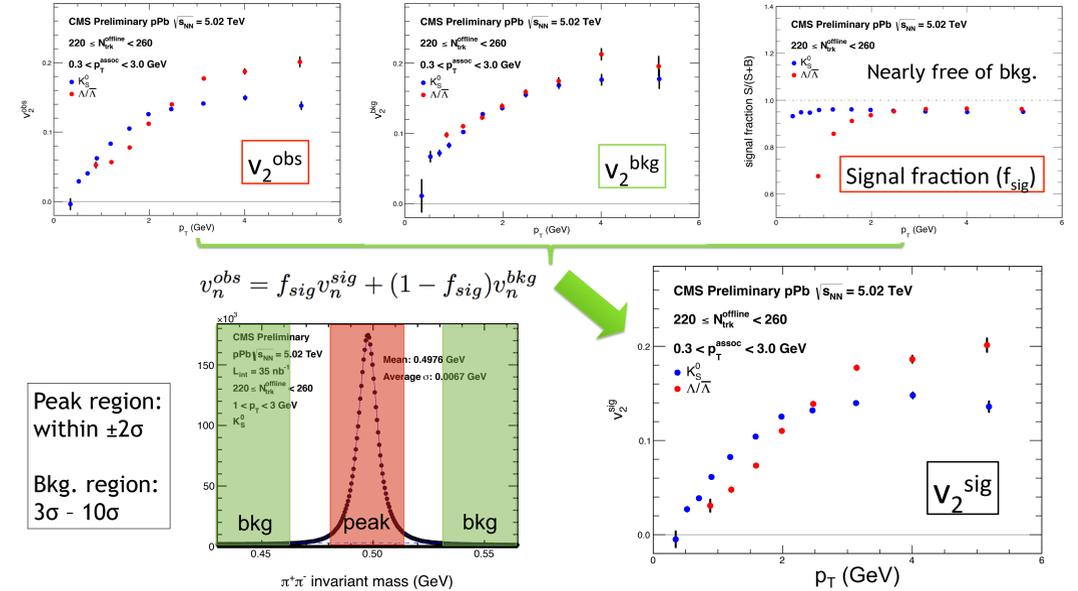
Assuming Factorization:
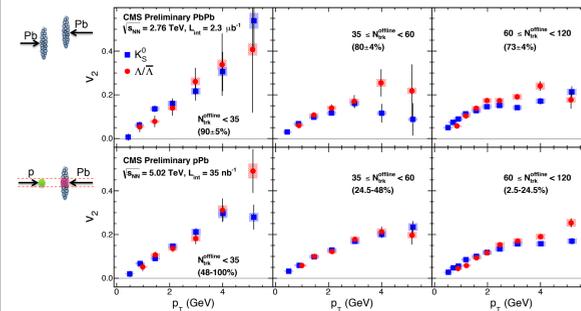$$V_{n\Delta}(p_T^{trig},p_T^{assoc})=v_n(p_T^{trig})\times v_n(p_T^{assoc})$$

$$v_n(p_T^{V^0})=\frac{V_{n\Delta}(p_T^{V^0},p_T^{ref})}{\sqrt{V_{n\Delta}(p_T^{ref},p_T^{ref})}}$$

CMS Preliminary, pPb $\sqrt{s_{NN}}$ = 5.02 TeV
L_{int} = 35 nb^{-1}
$1 < p_T^{trig} < 3$ GeV
$1 < p_T^{assoc} < 3$ GeV
Long range $|\Delta\eta| > 2$
$h^\pm$-$h^\pm$ K^0_S-$h^\pm$ $\Lambda/\bar{\Lambda}$-$h^\pm$
$220 \leq N < 260$ $0 < N < 35$ Fourier fits

Extraction of V^0 signal v_n

CMS Preliminary pPb $\sqrt{s_{NN}}$ = 5.02 TeV
$220 \leq N^{offline}_{trk} < 260$
$0.3 < p_T^{assoc} < 3.0$ GeV
K^0_S $\Lambda/\bar{\Lambda}$
v_2^{obs}

v_2^{bkg}

Nearly free of bkg.
Signal fraction (f_{sig})
signal fraction S/(S+B)

$$v_n^{obs}=f_{sig}v_n^{sig}+(1-f_{sig})v_n^{bkg}$$

CMS Preliminary
L_{int} = 35 nb^{-1}
$220 \leq N^{offline}_{trk} < 260$
$1 < p_T < 3$ GeV
K^0_S
Mean: 0.4976 GeV
Average σ: 0.0067 GeV

Peak region: within ±2σ
Bkg. region: 3σ – 10σ

bkg   peak   bkg

$\pi^+\pi^-$ invariant mass (GeV)

CMS Preliminary pPb $\sqrt{s_{NN}}$ = 5.02 TeV
$220 \leq N^{offline}_{trk} < 260$
$0.3 < p_T^{assoc} < 3.0$ GeV
K^0_S $\Lambda/\bar{\Lambda}$
v_2^{sig}

Results

CMS Preliminary PbPb
pPb $\sqrt{s_{NN}}$ = 2.76 TeV, L_{int} = 2.3 μb^{-1}
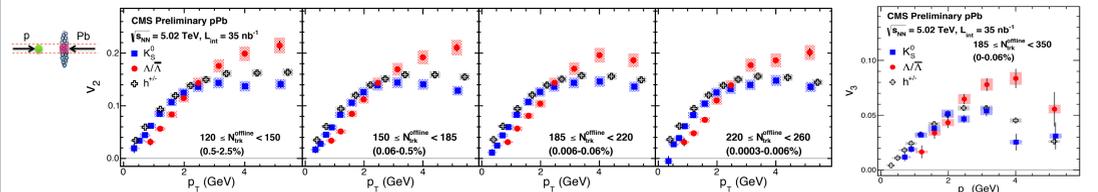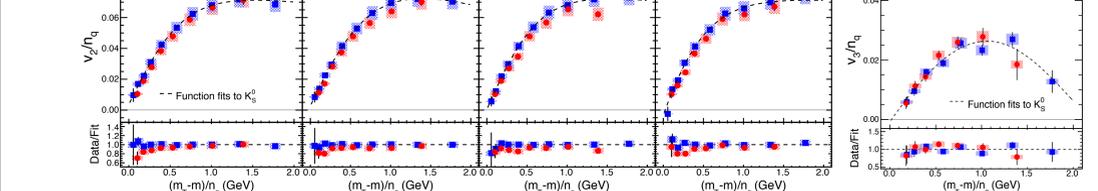K^0_S $\Lambda/\bar{\Lambda}$

Low multiplicity from MinBias trigger

❑ No near-side ridge observed
❑ Dominated by jet correlations with little species dependence
❑ Mass ordering of v_2 emerges at N>60 in pPb and PbPb

**High precision PID v_n data in pPb and PbPb over a broad multiplicity range**

High multiplicity pPb   Elliptic flow (v_2)   Triangular flow (v_3)

CMS Preliminary pPb
$\sqrt{s_{NN}}$ = 5.02 TeV, L_{int} = 35 nb^{-1}
K^0_S $\Lambda/\bar{\Lambda}$ $h^{\pm}$
$185 \leq N^{offline}_{trk} < 350$
$120 \leq N^{offline}_{trk} < 150$ $150 \leq N^{offline}_{trk} < 185$ $185 \leq N^{offline}_{trk} < 220$ $220 \leq N^{offline}_{trk} < 260$

Function fits to K^0_S

Comparison to PbPb at comparable multiplicities

CMS Preliminary PbPb
PbPb $\sqrt{s_{NN}}$ = 2.76 TeV, L_{int} = 2.3 μb^{-1}
K^0_S $\Lambda/\bar{\Lambda}$ $h^{\pm}$

Function fits to K^0_S

❑ Evident mass ordering of v_2 between K^0_s and Λ with larger splitting in pPb than PbPb
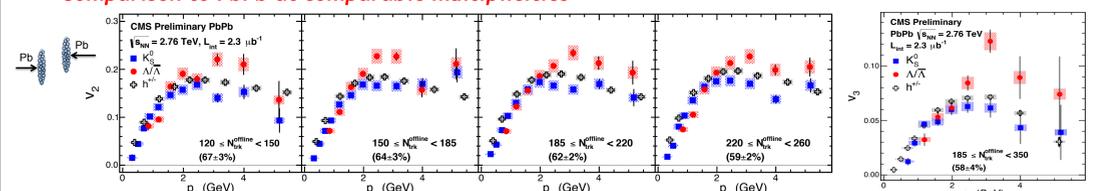
❑ Number of constituent quark scaling for v_n holds within 10-15% in pPb at high multiplicity, which holds less well in peripheral PbPb.