D meson v_2 measurement with Q-Cumulants and Scalar Product methods in Pb-Pb collisions at $\sqrt{s_{NN}}$=2.76 TeV with the ALICE experiment

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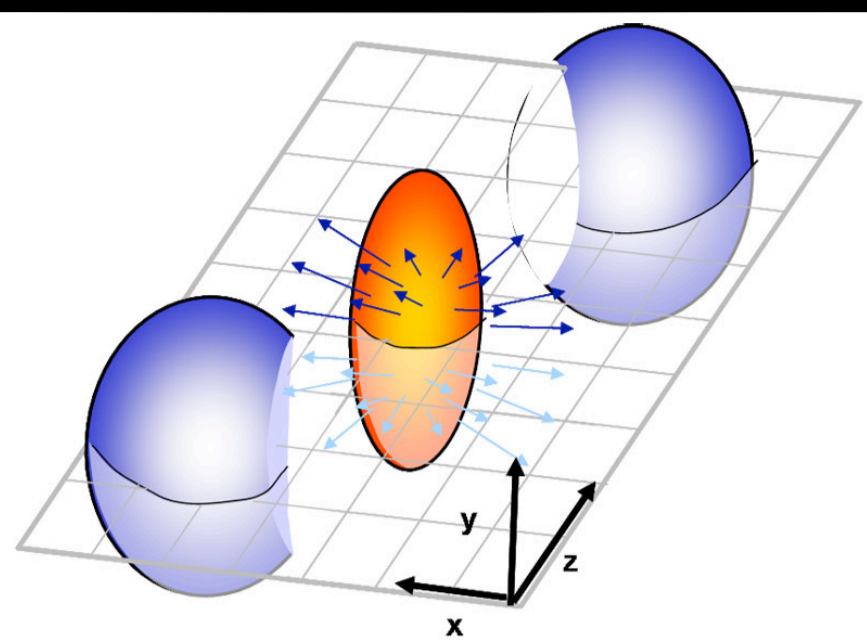
Motivations

✦ In non-central heavy-ion collisions the overlap region features a geometric anisotropy.
✦ Pressure gradients convert it into momentum anisotropy, reflected in the azimuthal distribution of final particles:
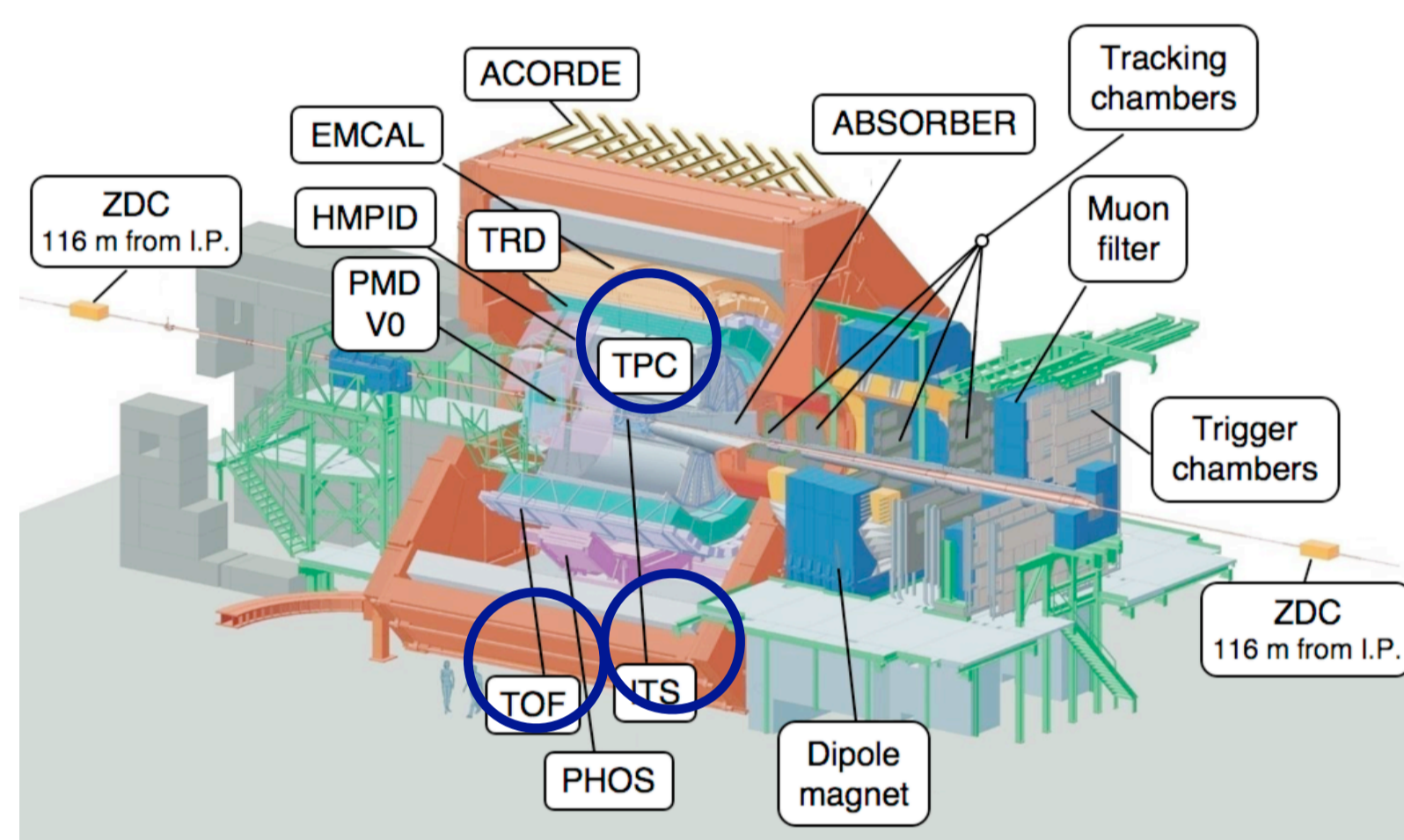
$$\frac{dN}{d\varphi} = \frac{N_0}{2\pi} + \frac{N_0}{\pi} \sum_n^\infty v_n \cos(n(\varphi - \psi_n))$$

where ψ_n is the n-th order symmetry plane and v_2 is the anisotropic flow parameter.

✦ The measurement of open charm v_2 can help in understanding the properties of the produced medium:
- At **low p_T** the collective flow is due to the pressure gradients and is sensitive to the degree of thermalization of the c quark in the medium.
- At **high p_T** v_2 is sensitive to the path length dependence of heavy quark energy loss.

Open-charm reconstruction in ALICE

✦ D mesons hadronic decays are reconstructed in Inner Tracking System (ITS), Time Projection Chamber (TPC) and Time Of Flight (TOF) detectors in the central rapidity region from their hadronic decay channels:
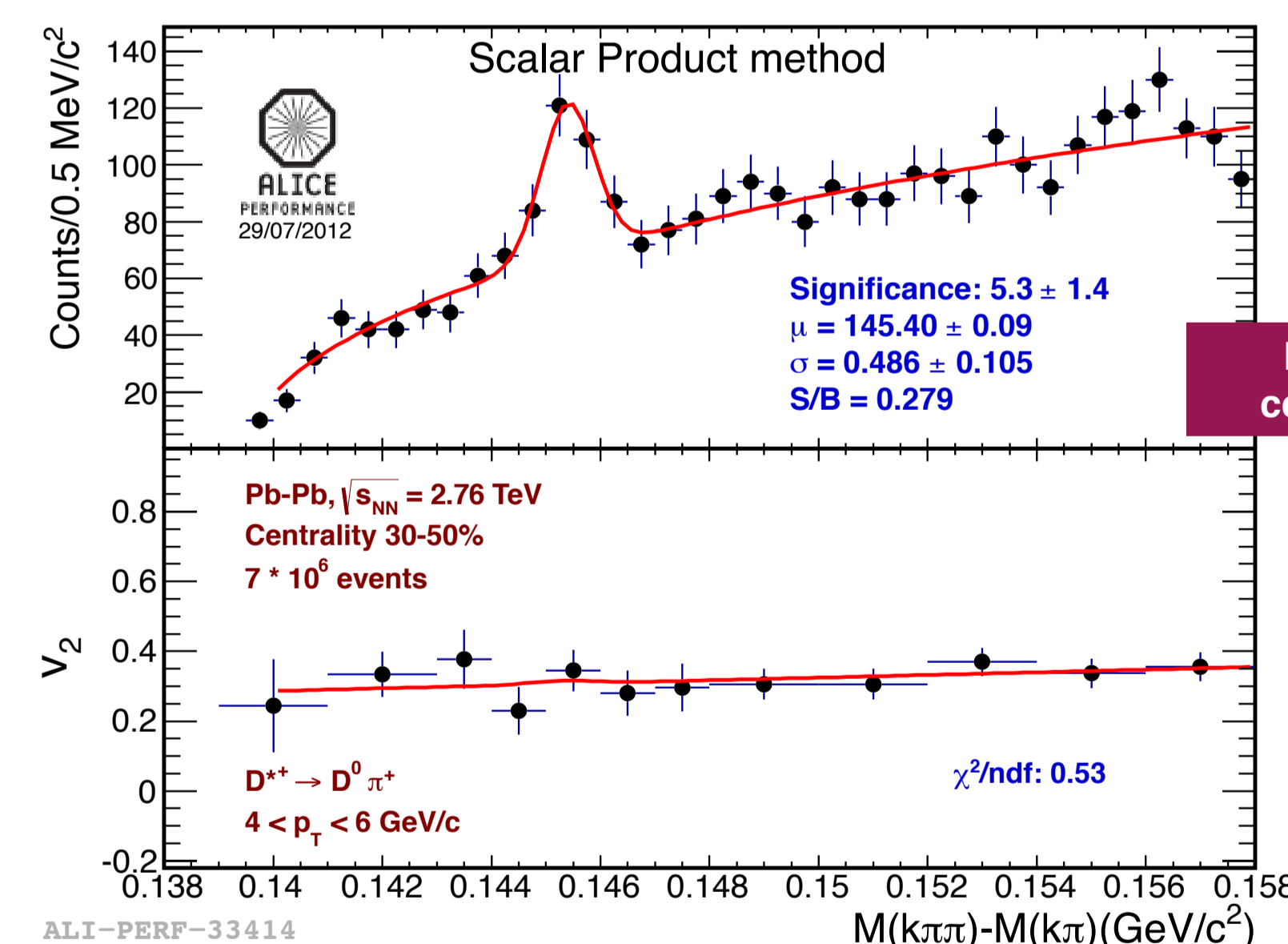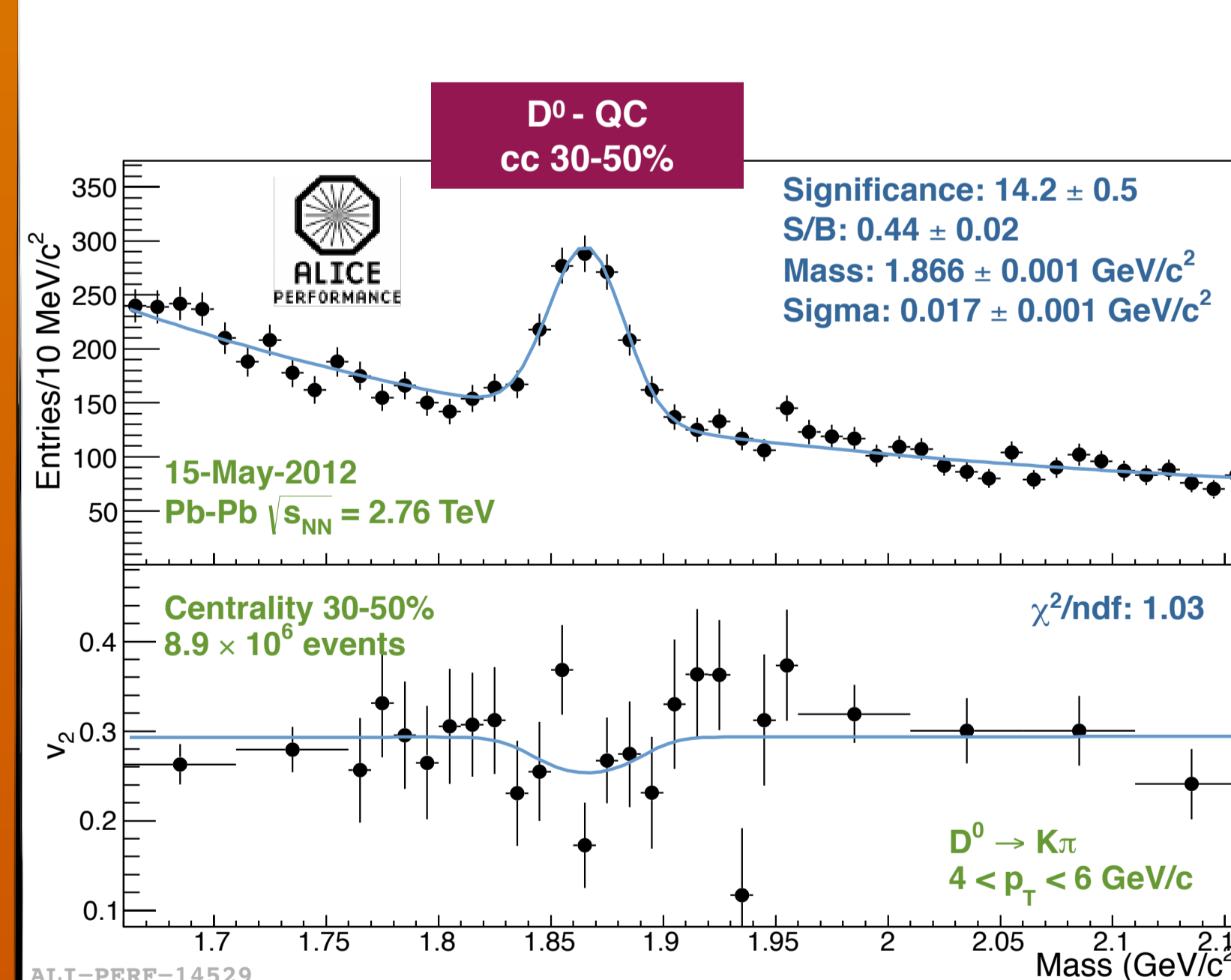- $D^0 \rightarrow K^- + \pi^+$ (BR=3.87±0.5%, $c\tau \approx 312$ μm)
- $D^{*+} \rightarrow D^0 + \pi^+$ (BR=67.7±0.5%)

✦ The D mesons are reconstructed from an invariant mass analysis of fully reconstructed decay topologies displaced with respect to the primary vertex.
✦ In case of D^{*+} which decays at the primary vertex, D^0 candidates are attached to π candidate tracks from the primary vertex.
✦ Background with same topology as signal is suppressed by using topological selections and particle identification in TPC and TOF.

Data sample

- $7*10^6$ events in 30-50% centrality for D^{*+},
- $8.9*10^6$ events in 30-50% for D^0,
- $7.1*10^6$ events in 15-30% for D^0.

2-Particle correlation methods

✦ **Scalar product (SP)[1]**
Allows for Δη separation between particles of interest (POI) and reference particles (RP) suppressing non-flow correlations. For this analysis, RPs are TPC tracks and no Δη gap is used since with the present statistics the measurement is not sensitive to non-flow contribution.

$$v_{2,SP} = \frac{\langle u \cdot Q \rangle}{\sqrt{\langle Q_a \cdot Q_b \rangle}}$$

a, b denote two sub-events

$Q = \sum_{j=1}^{M_{RP}} \exp^{i2\phi_j} \longrightarrow$ Q-vector

$u = e^{i2\phi} \longrightarrow$ Unity vector of the D meson

✦ **Q-Cumulants (QC)[2]**
In principle, increasing the number of particles involved in the correlation it is possible to reduce non-flow and flow-fluctuations. D meson analysis is statistics-limited and allows only for 2-particles cumulant.

$$v_{2,QC} = \sqrt{\langle \sum_{i \neq j}^M \frac{u_i \cdot u_j}{P_{M,2}} \rangle}$$

($P_{M,2}$ = normalization factor)

D^0 and D^{*+} v_2 measurement

✦ D meson candidates are reconstructed in bins of η, p_T and mass.
✦ Independent particle correlations are calculated for each bin.
✦ The v_2 of D mesons (v_2^S) is obtained by using the expression:

$$v_2^{meas}(x) = \frac{N^S}{N^S + N^B} v_2^S(x) + \frac{N^B}{N^S + N^B} v_2^B(x)$$

N^S candidates in the signal region, N^B candidates in the background region, v_2^S = v_2 of the signal, v_2^B = v_2 of the background

✦ The v_2^B subtraction and the N^S and N^B evaluation is obtained by a simultaneous fit of the counts and v_2 as a function of invariant mass.
- Same method for v_2 extraction is applied to both D^0 and D^{*+} and to QC and SP methods.

Systematic uncertainties

✦ Main systematic uncertainties taken into account are:
- Yield extraction (estimated by changing the background fit function and the fit range).
- Different sets of topological cuts for D meson selection.
- Use of different centrality estimators.
✦ The total systematic is ~20%.
✦ In addition a systematic uncertainty to account for the feed-down from B meson decays (~15%) is estimated based on FONLL calculations and an hypothesis on the v_2 and R_{AA} of the feed-down component.
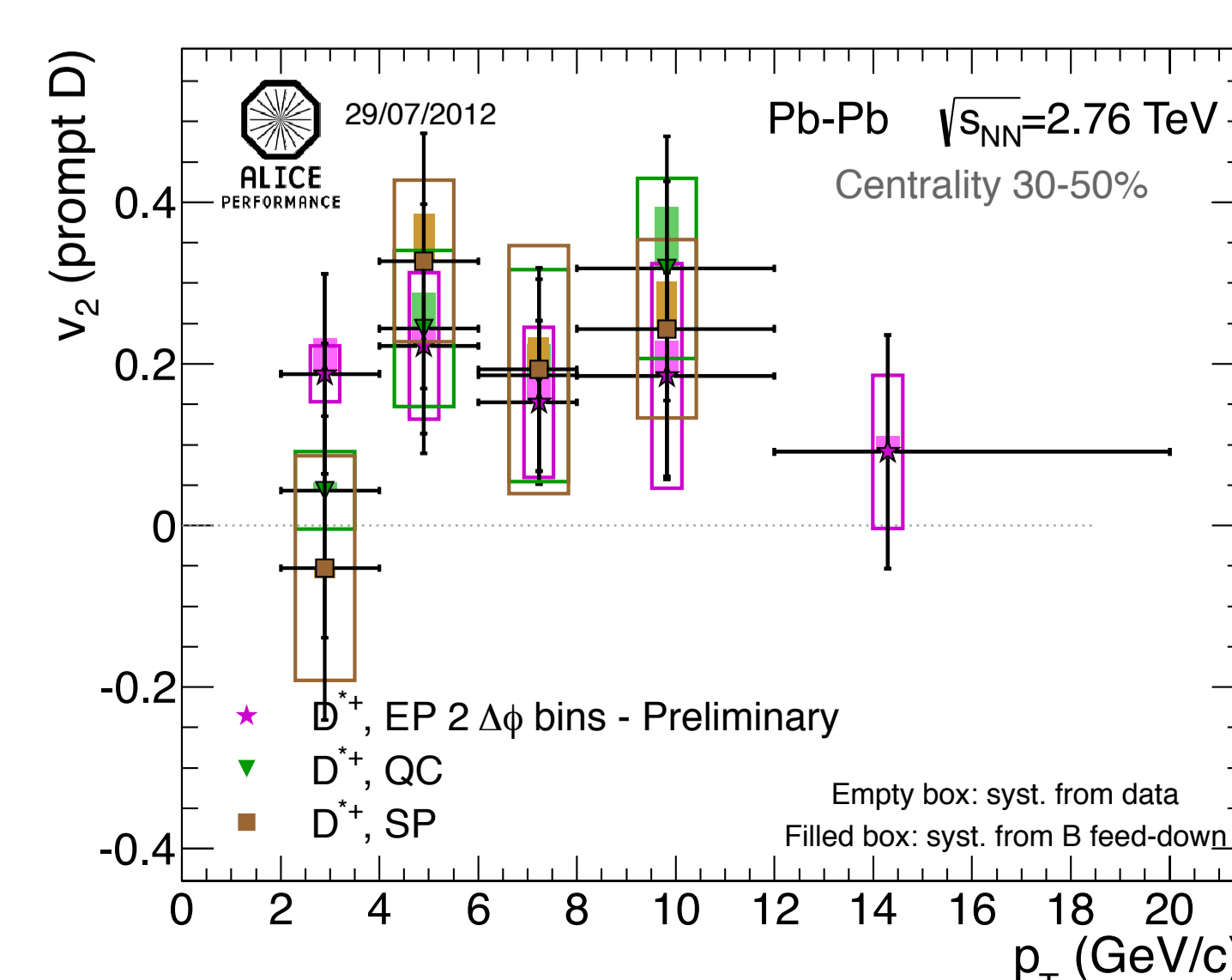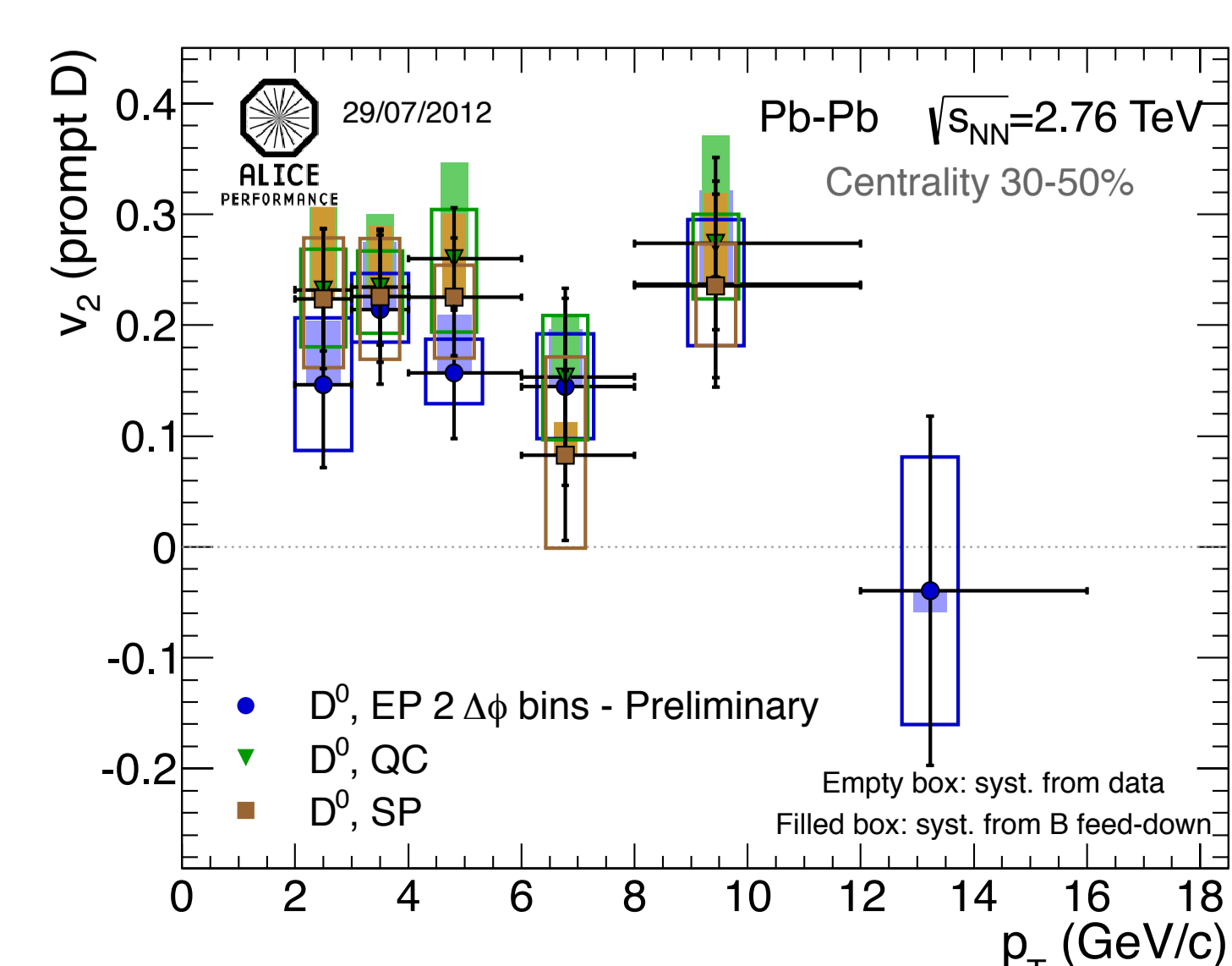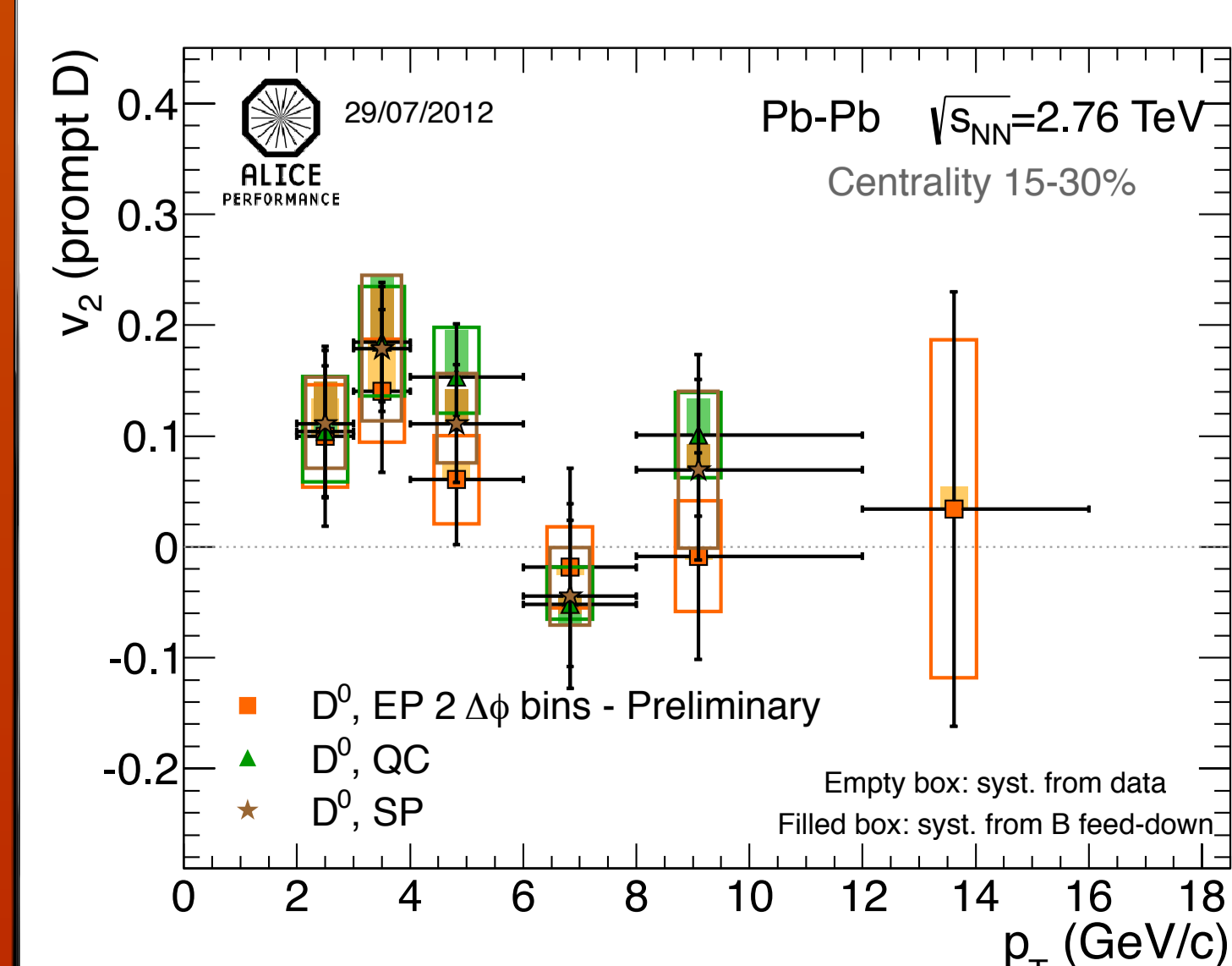
Examples of simultaneous fits

D⁰ - QC cc 30-50%
Significance: 14.2 ± 0.5
S/B: 0.44 ± 0.02
Mass: 1.866 ± 0.001 GeV/c²
Sigma: 0.017 ± 0.001 GeV/c²
15-May-2012 Pb-Pb √s_NN = 2.76 TeV
Centrality 30-50% 8.9 × 10⁶ events
χ²/ndf: 1.03
$D^0 \rightarrow K\pi$ $4 < p_T < 6$ GeV/c
ALI-PERF-14529

Scalar Product method
Significance: 5.3 ± 1.4
μ = 145.40 ± 0.09
σ = 0.486 ± 0.105
S/B = 0.279
Pb-Pb, √s_NN = 2.76 TeV Centrality 30-50% 7 * 10⁶ events
D*⁺ - SP cc 30-50%
$D^{*+} \rightarrow D^0 \pi^+$ $4 < p_T < 6$ GeV/c
χ²/ndf: 0.53
ALI-PERF-33414

Results and Conclusions

✦ QC and SP methods have been used to measure the D^0 v_2 in CC 15-30% and 30-50% and the D^{*+} v_2 in CC 30-50%.
✦ The measurements are consistent with each other and with those based on the event plane method.
✦ The results are also consistent between D^0 and D^{*+}.
✦ The results indicate $v_2^D > 0$ in $2 < p_T < 6$ GeV/c for the 30-50% centrality class (3σ effect).

See D. Caffarri talk

Pb-Pb √s_NN=2.76 TeV Centrality 15-30%
D^0, EP 2 Δφ bins - Preliminary
D^0, QC
D^0, SP
Empty box: syst. from data
Filled box: syst. from B feed-down
ALI-PERF-33422

Pb-Pb √s_NN=2.76 TeV Centrality 30-50%
D^0, EP 2 Δφ bins - Preliminary
D^0, QC
D^0, SP
Empty box: syst. from data
Filled box: syst. from B feed-down
ALI-PERF-33418

Pb-Pb √s_NN=2.76 TeV Centrality 30-50%
D^{*+}, EP 2 Δφ bins - Preliminary
D^{*+}, QC
D^{*+}, SP
Empty box: syst. from data
Filled box: syst. from B feed-down
ALI-PERF-33375

References
1) C. Adler et al. (STAR Collaboration), Phys. Rev. C66, 034904 (2002)
2) A.Bilandzic, R. Snellings and S. Valoshin, Phys. Rev. C83, 044913 (2011)