Flow analysis methods in small multiplicity events

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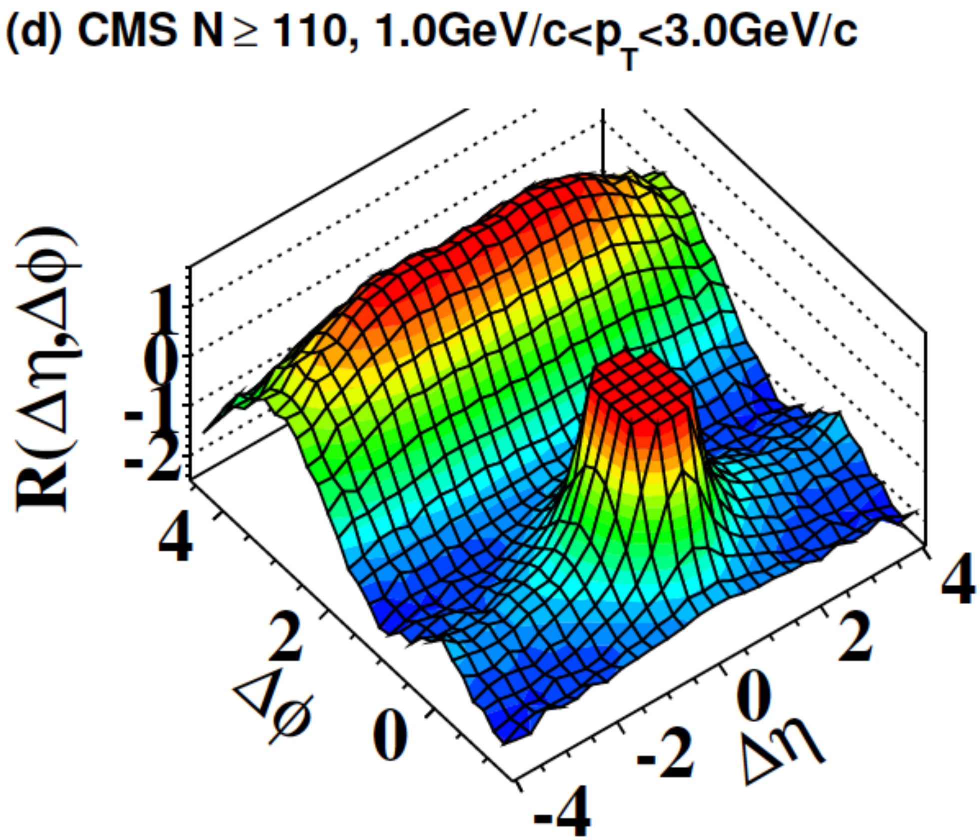
Outline

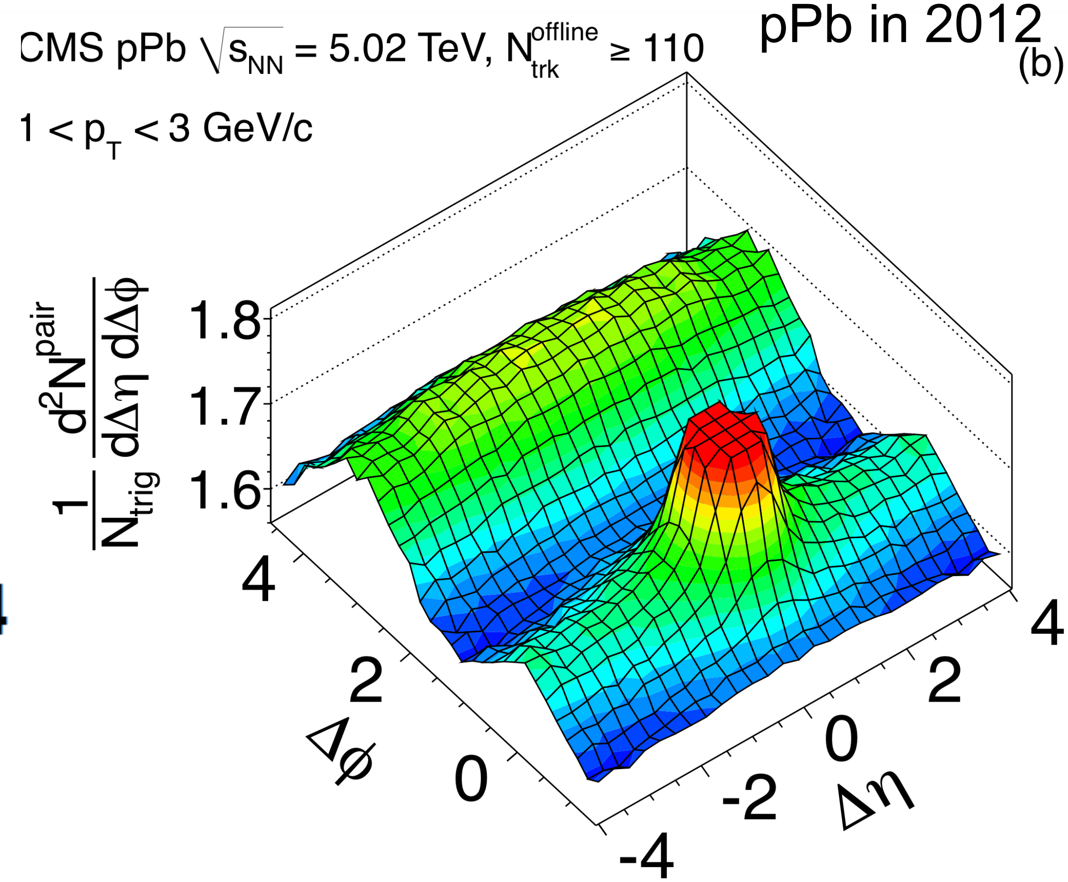
- Motivations
- Toy model and Analysis methods
- Similar studies using AMPT
- Summary

Ridge in high multiplicity pp and pPb

pp 7 TeV in 2010



pPb in 2012

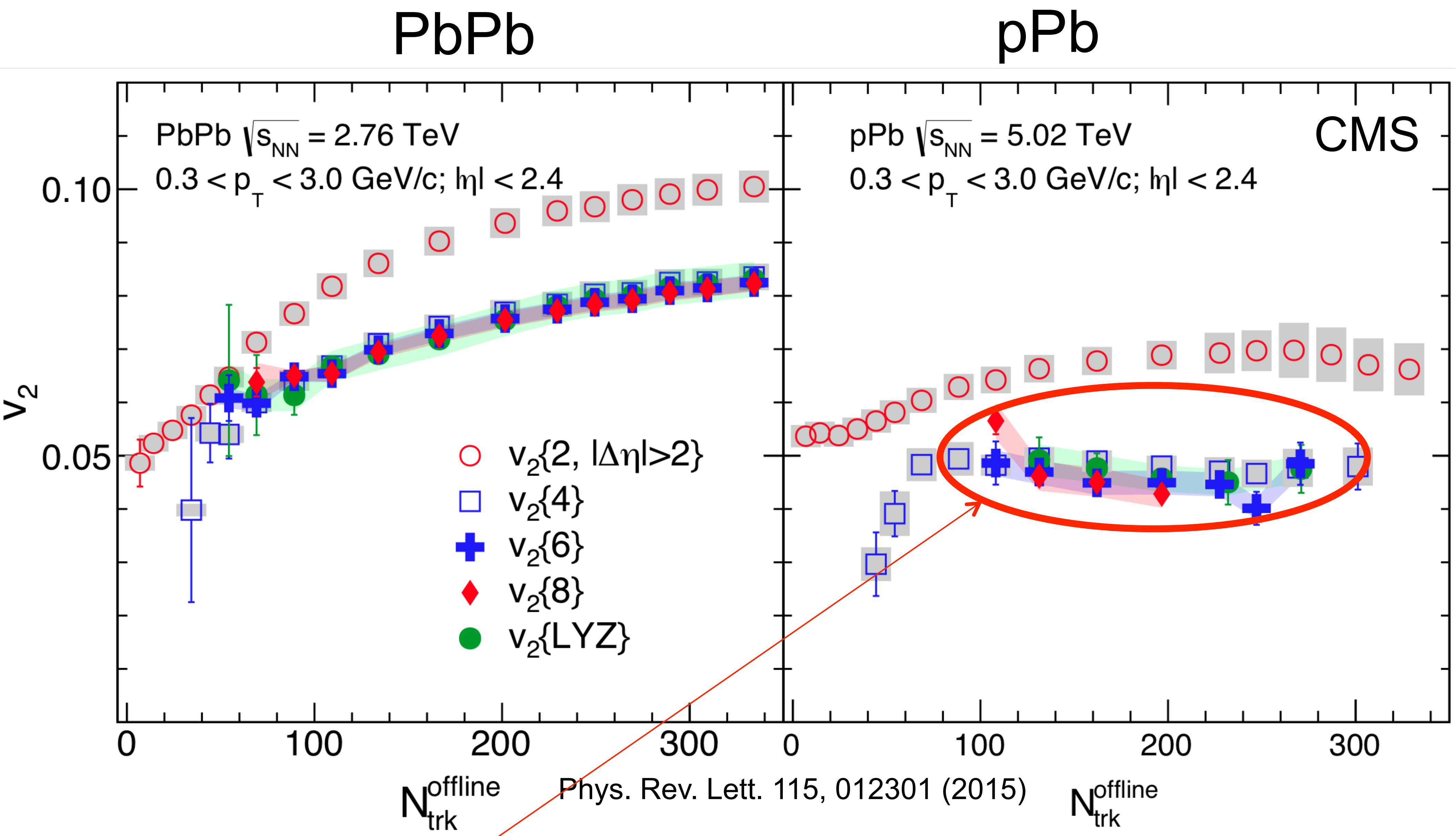


N >= 110

N >= 110

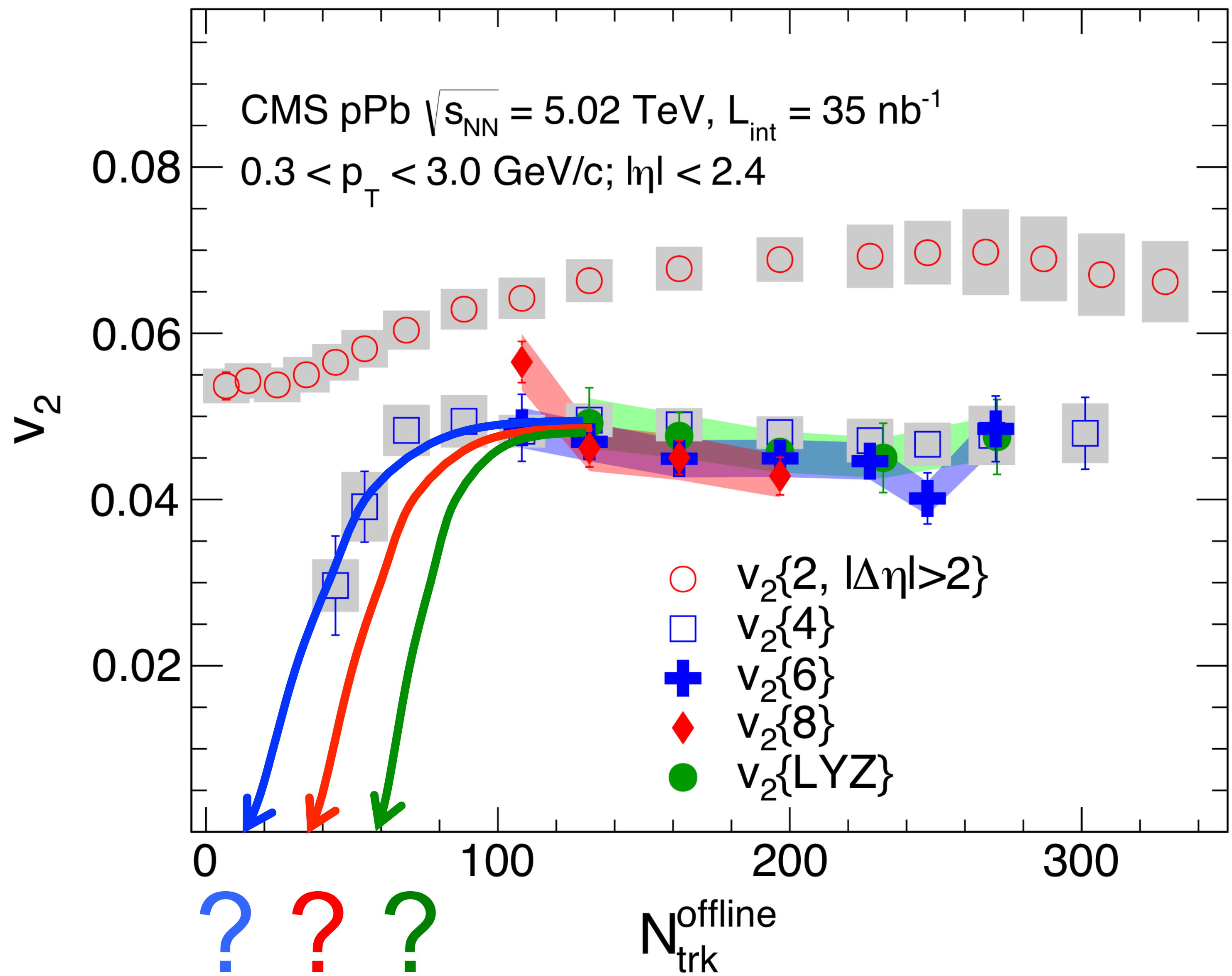
Require high multiplicity

Multiparticle correlation analysis



N>= 100 for $v_2\{6\}$, $v_2\{8\}$ and $v_2\{LYZ\}$ in pPb

Low multiplicity ?



How low can we go ? Flow Turn-On ?

Smallest droplet?

The Hot QCD White Paper:

arXiv:1502.02730

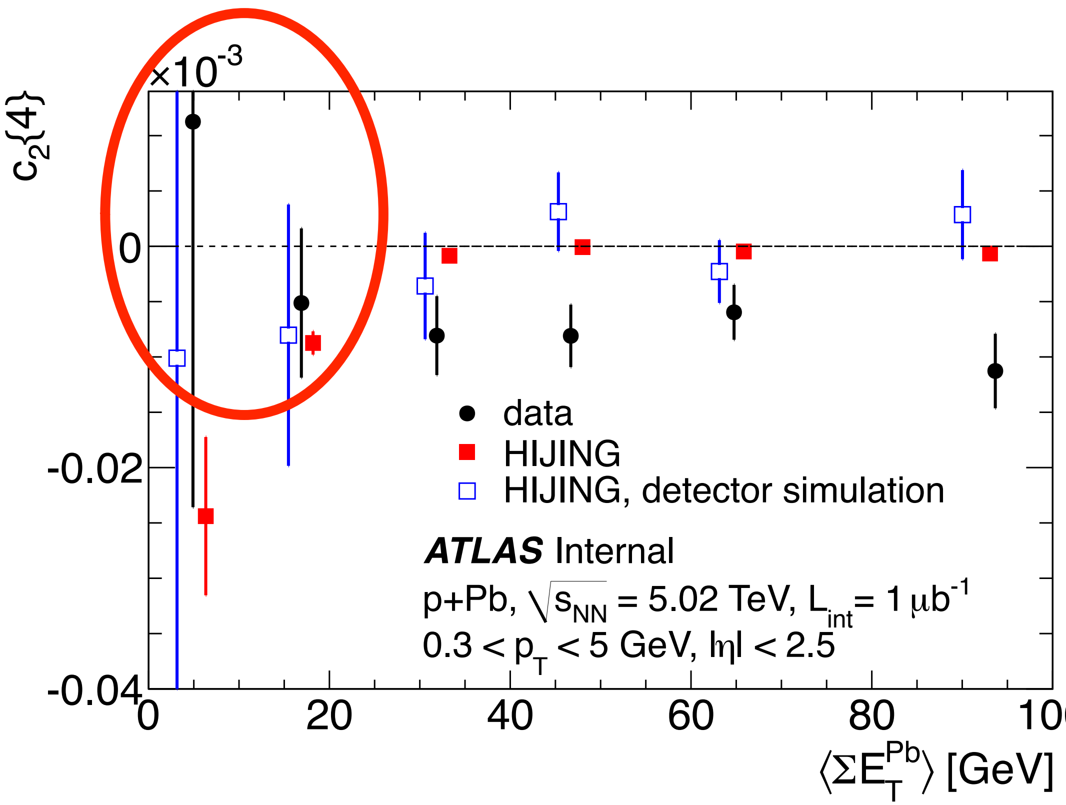
At the same time, the discovery of strongly coupled QGP poses many questions. How do its properties vary over a broad range of temperature and chemical potential? Is there a critical point in the QCD phase diagram where the hadron gas to QGP phase transition becomes first-order? What is the smallest droplet of hot QCD matter whose behavior is liquid-like? What are the initial

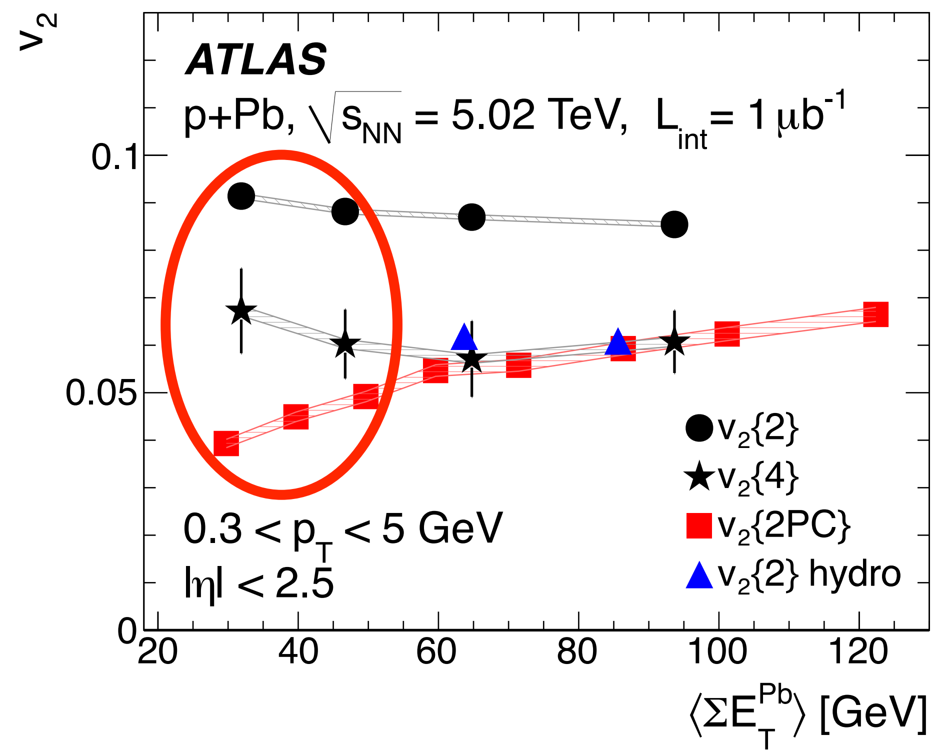
What is the smallest droplet of hot QCD matter whose behavior is liquid-like ?

Status from ATLAS

Phys. Lett. B 725 (2013) 60-78

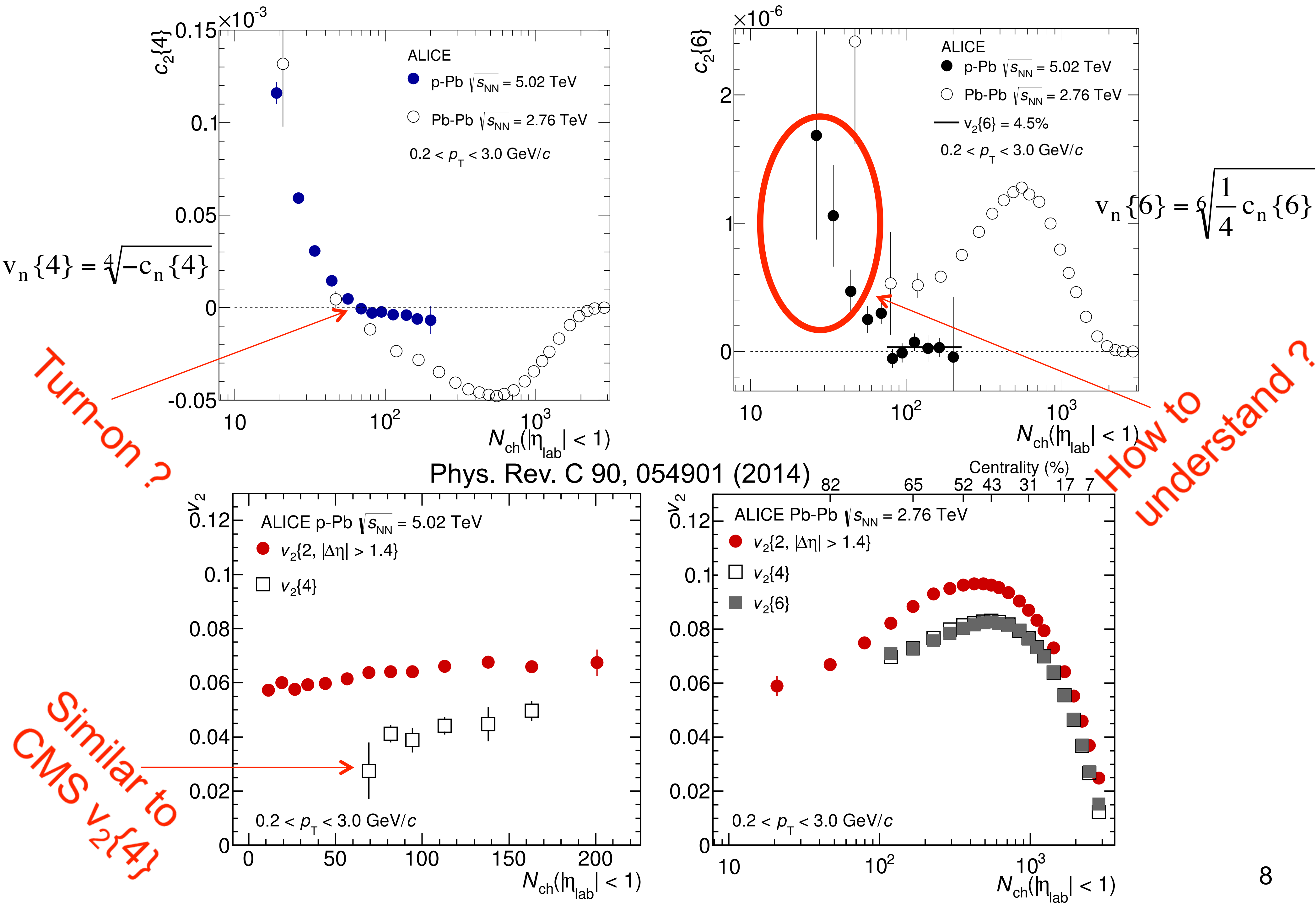
$$v_n\{4\} = \sqrt[4]{-c_n\{4\}}$$





- Studied vs. forward calorimeter energy
- Signal exists at low E_T (~30 GeV)

Status from ALICE

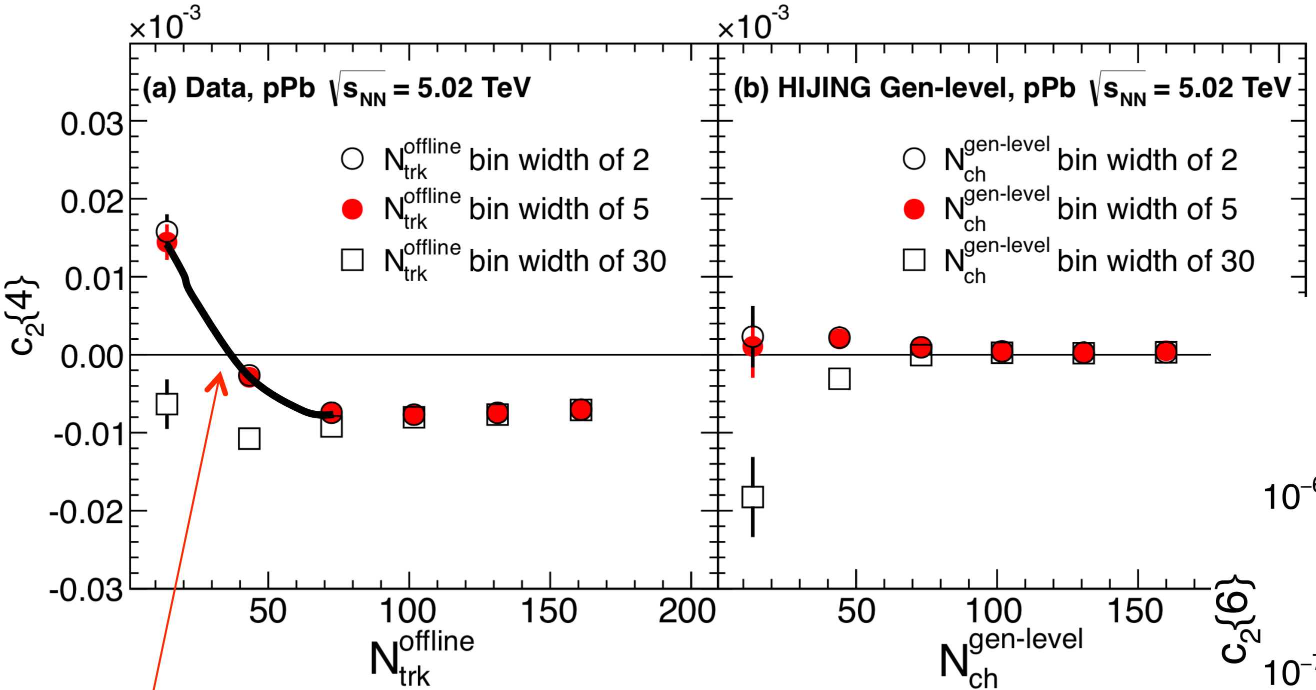


$$v_n\{4\} = \sqrt[4]{-c_n\{4\}}$$

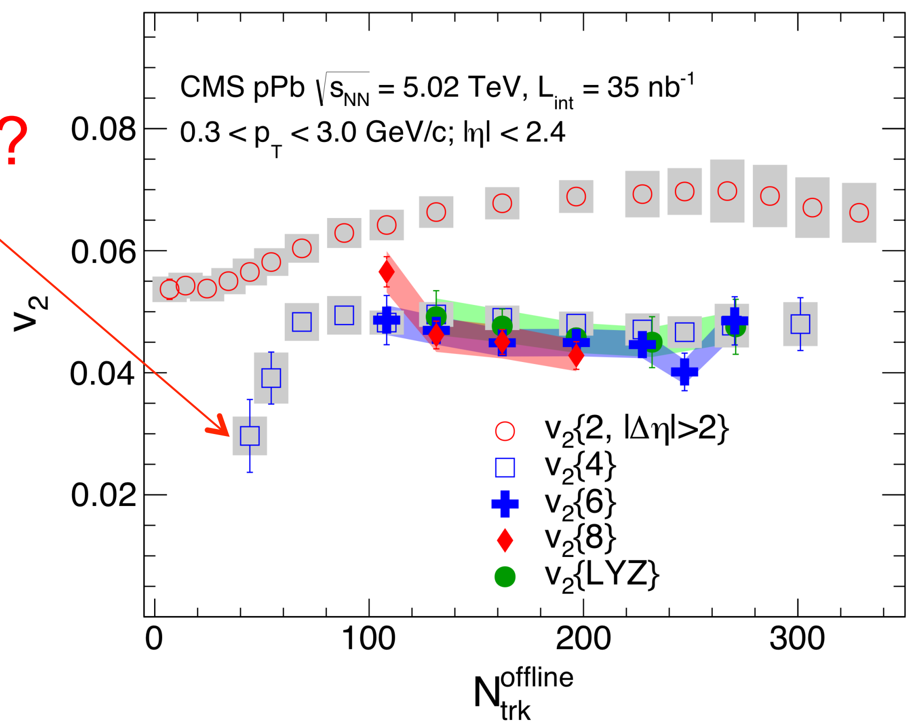
$$v_n\{6\} = \sqrt[6]{\frac{1}{4} c_n\{6\}}$$

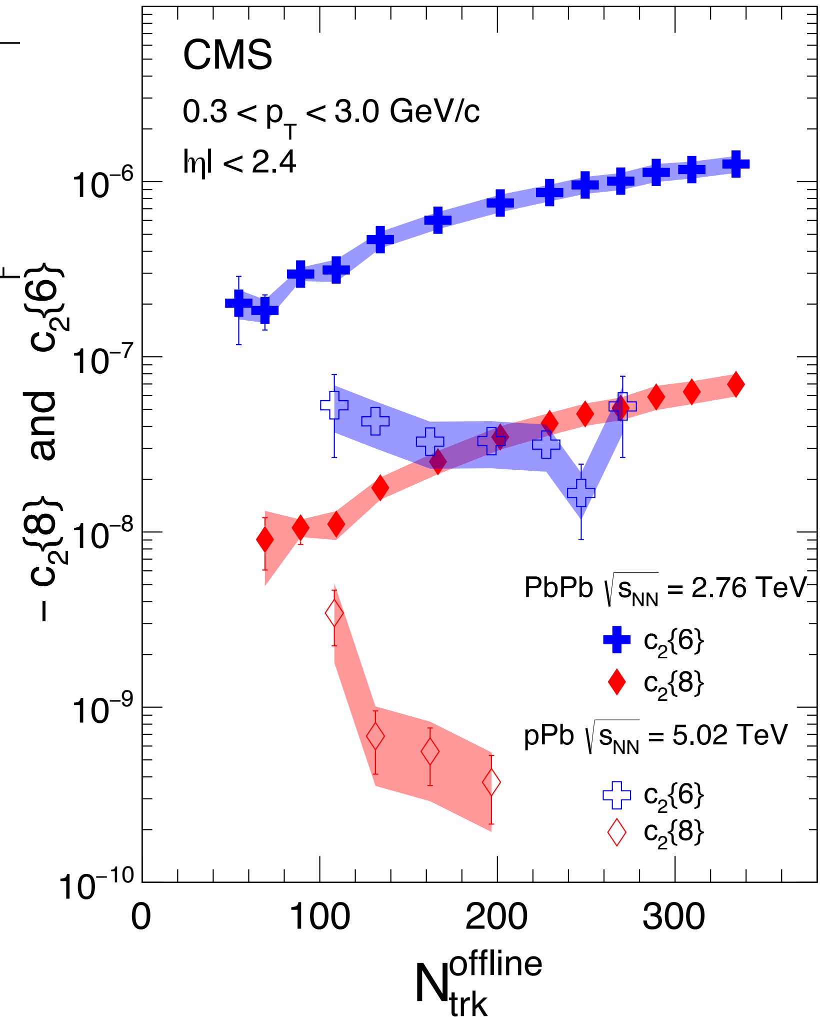
Phys. Rev. C 90, 054901 (2014)

Status from CMS

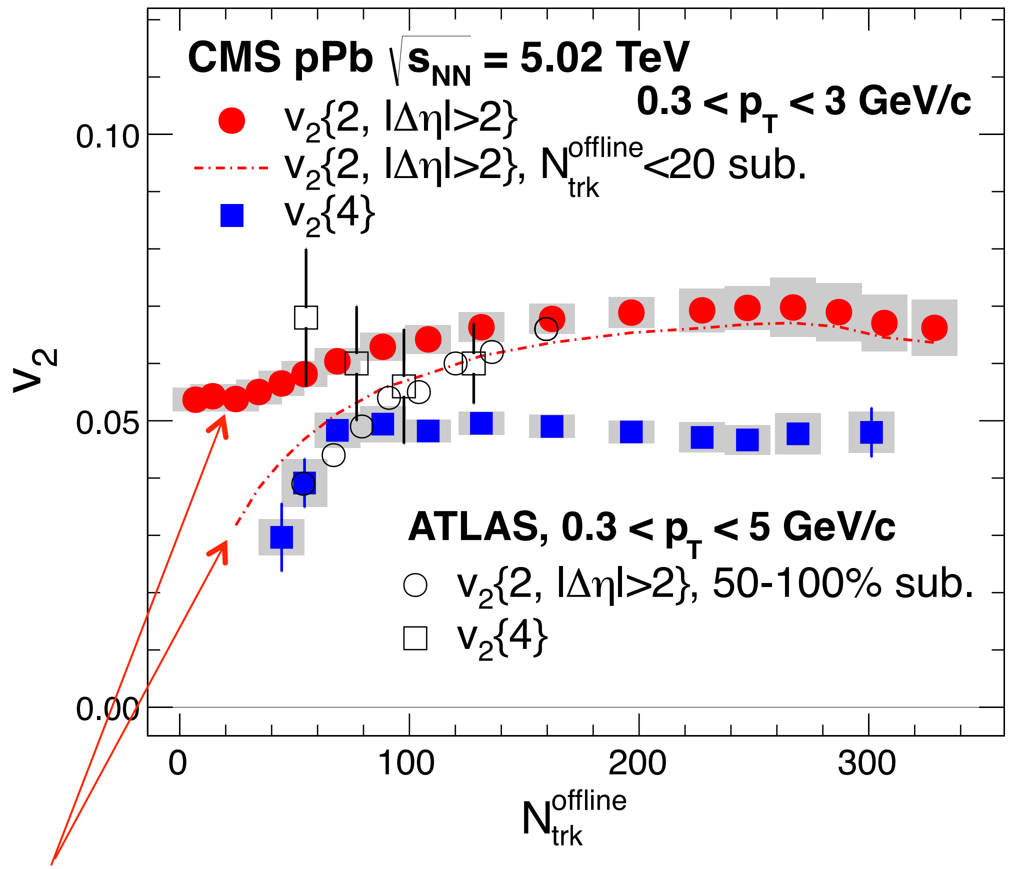


Turn-on ?



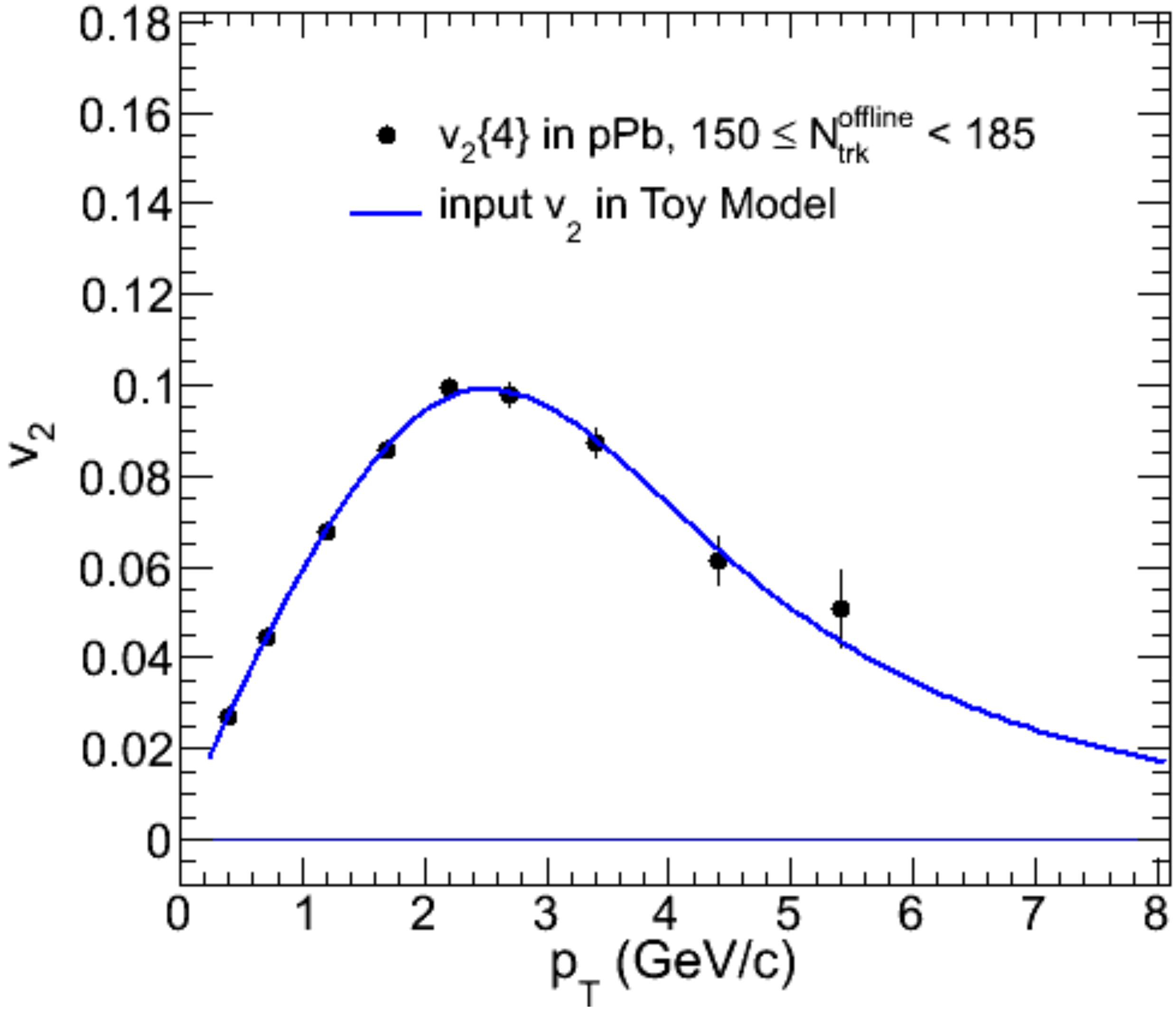


Analysis methods in small multiplicity



- Large difference between with and without peripheral subtraction in long-range two-particle correlation method
- Non-flow is important in this range
- Need multi-particle correlation methods

Toy model with input flow



- Change event multiplicity in Toy model
- Study the behavior of different methods in low multiplicity range
- The Toy model does not include flow fluctuation and non-flow

Q-cumulant method

Six- and eight-particle correlations, averaged over all events:

$$\langle\langle 6\rangle\rangle \equiv \langle\langle e^{in(\phi_1+\phi_2+\phi_3-\phi_4-\phi_5-\phi_6)}\rangle\rangle,$$
$$\langle\langle 8\rangle\rangle \equiv \langle\langle e^{in(\phi_1+\phi_2+\phi_3+\phi_4-\phi_5-\phi_6-\phi_7-\phi_8)}\rangle\rangle.$$

Six- and eight-particle cumulants:

$$c_n\{6\} = \langle\langle 6\rangle\rangle - 9\cdot\langle\langle 4\rangle\rangle\langle\langle 2\rangle\rangle + 12\cdot\langle\langle 2\rangle\rangle^3,$$
$$c_n\{8\} = \langle\langle 8\rangle\rangle - 16\cdot\langle\langle 6\rangle\rangle\langle\langle 2\rangle\rangle - 18\cdot\langle\langle 4\rangle\rangle^2 + 144\cdot\langle\langle 4\rangle\rangle\langle\langle 2\rangle\rangle^2 - 144\langle\langle 2\rangle\rangle^4,$$

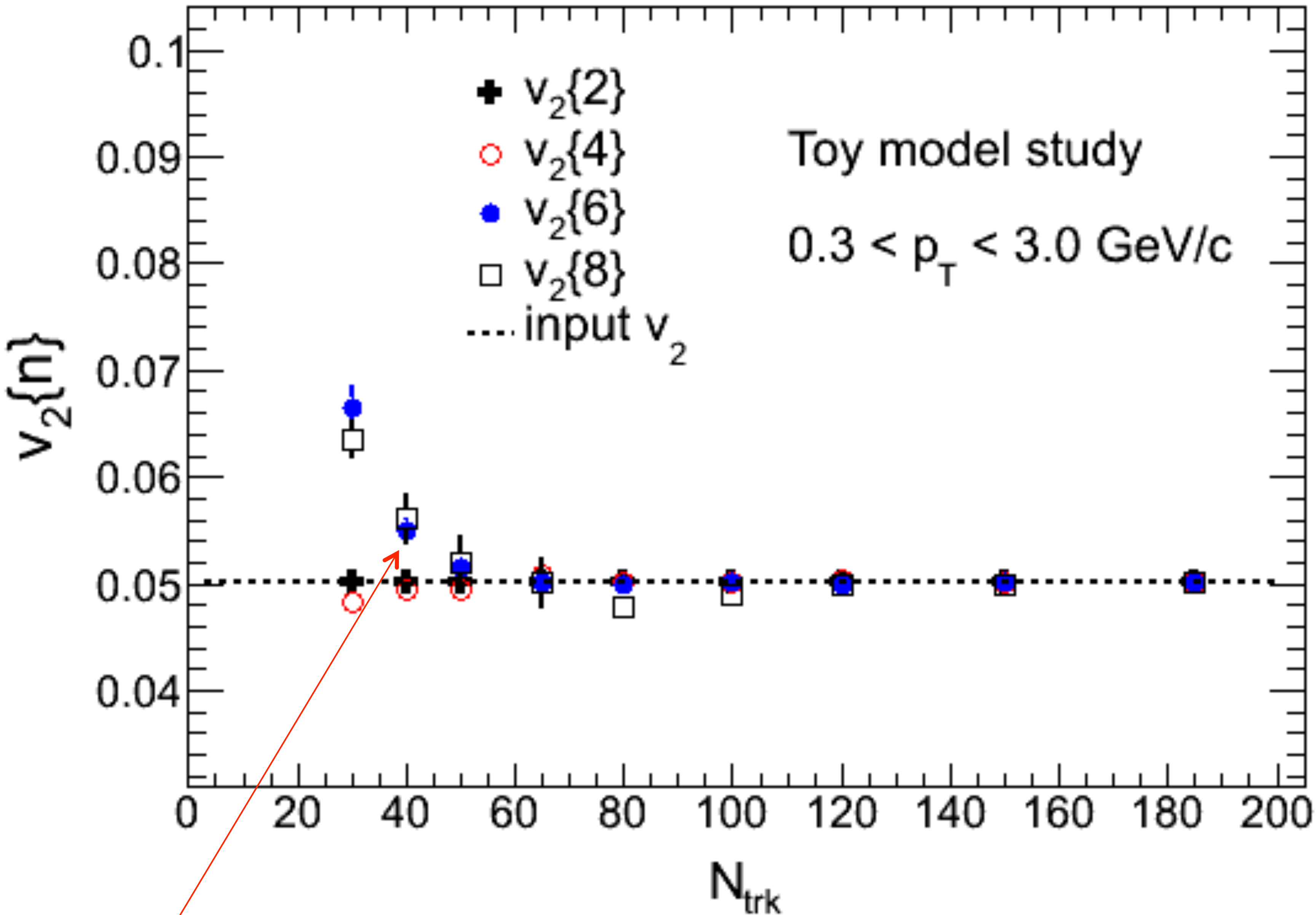
Six- and eight-particle v_2:

$$v_n\{6\} = \sqrt[6]{\frac{1}{4}c_n\{6\}},$$
$$v_n\{8\} = \sqrt[8]{-\frac{1}{33}c_n\{8\}}.$$

Correlations and cumulants are expressed in terms of moments of Q-vector

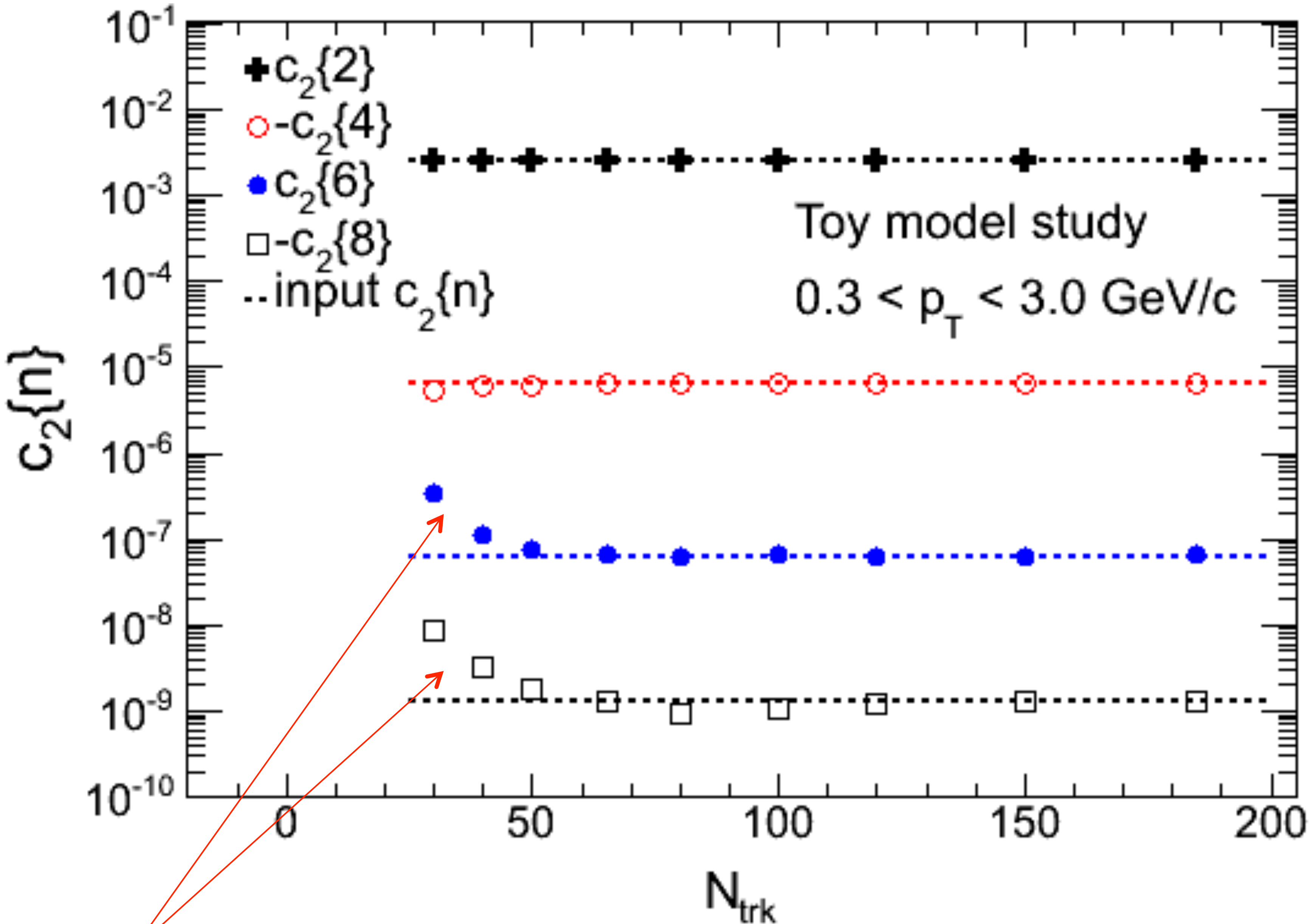
$$Q_n \equiv \sum_{i=1}^{M} e^{in\phi_i}$$

$v_2\{n\}$ in Toy model



- $v_2\{6\}$ and $v_2\{8\}$ over estimate the signal in low multiplicity events

Cumulants in Toy model



- $c_2\{6\}$ and $-c_2\{8\}$ over estimate the signal in low multiplicity events

Lee-Yang Zeros method

All-particle correlations, per event:

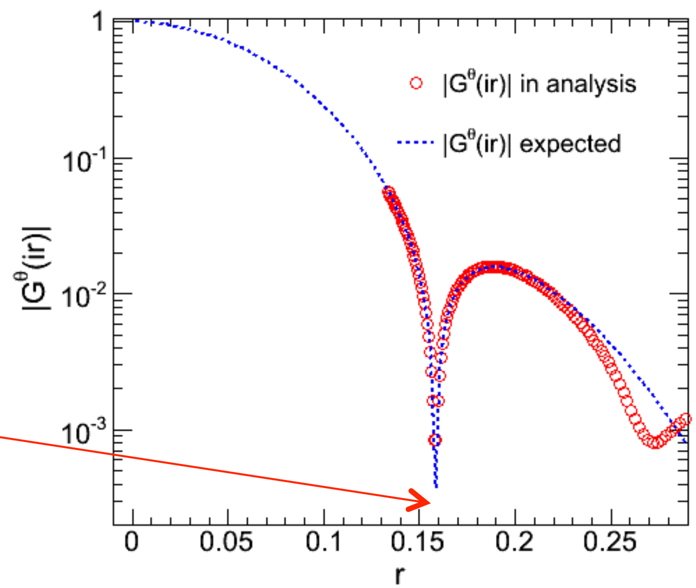
$$g^{\theta}(ir) \equiv \prod_{j=1}^{M} [1 + ir\, w_j \cos(n(\phi_j - \theta))]$$

Generating function, all events:

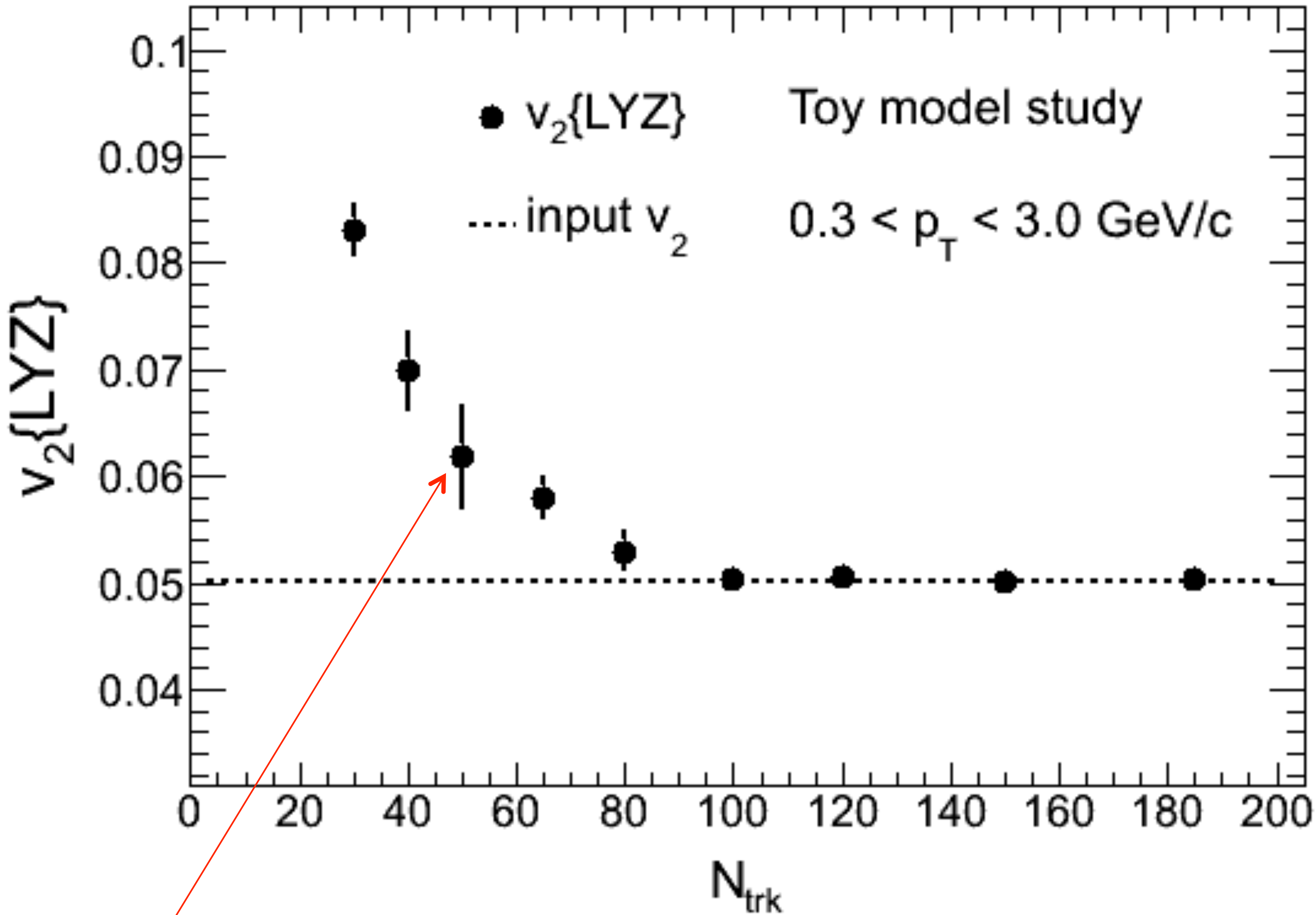
$$G^{\theta}(ir) \equiv \left\langle g^{\theta}(ir) \right\rangle_{\mathrm{evts}} \equiv \frac{1}{N_{\mathrm{evts}}} \sum_{\mathrm{events}} g^{\theta}(ir)$$

Integrated flow, V_n\{LYZ\}:

$$V_n^{\theta}\{\mathrm{LYZ}\} \equiv \frac{j_{01}}{r_0^{\theta}}$$

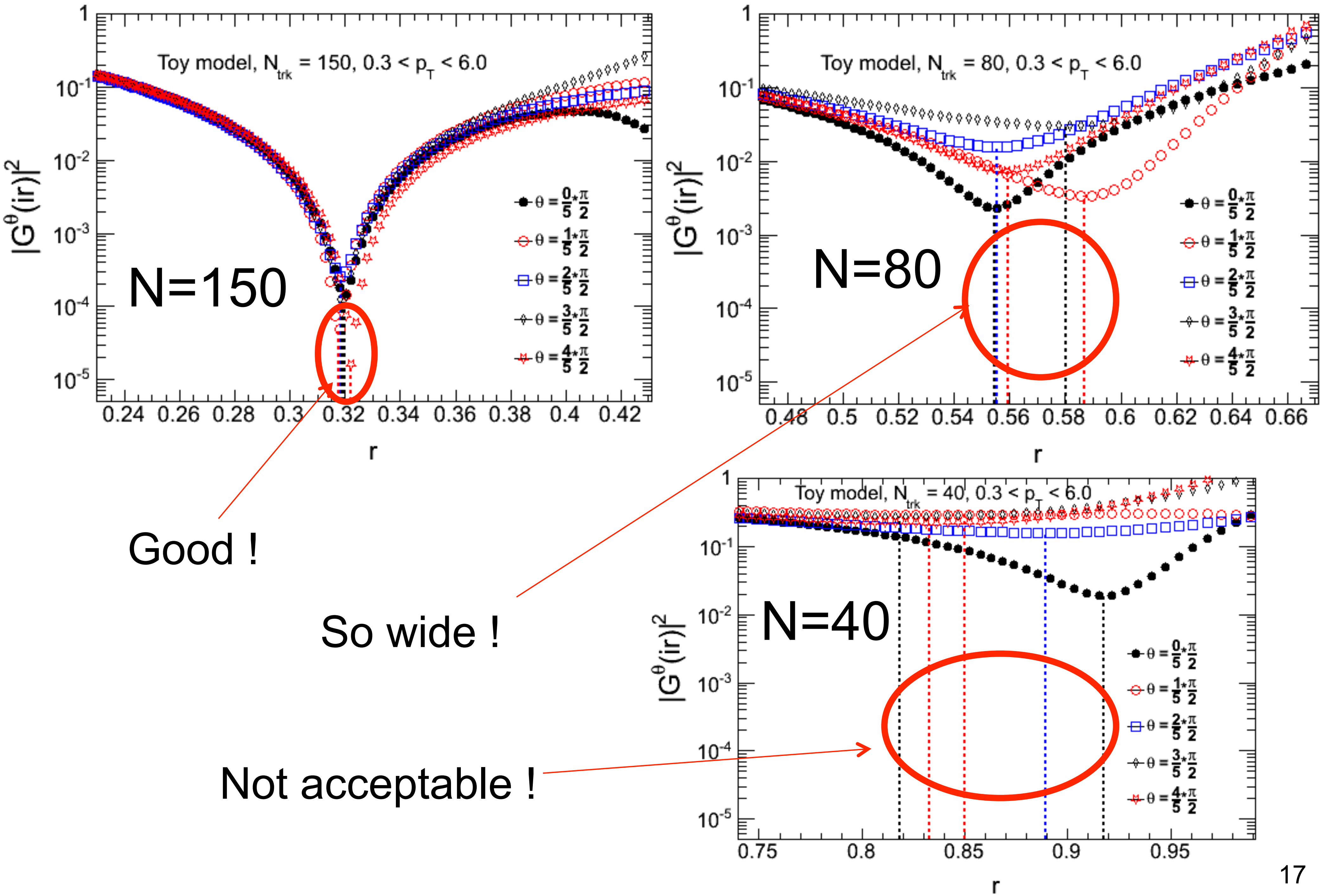


$v_2\{LYZ\}$ in Toy model



- $v_2\{LYZ\}$ over estimates the signal in low multiplicity events

The first minimum of the generating function



Some similar studies using AMPT

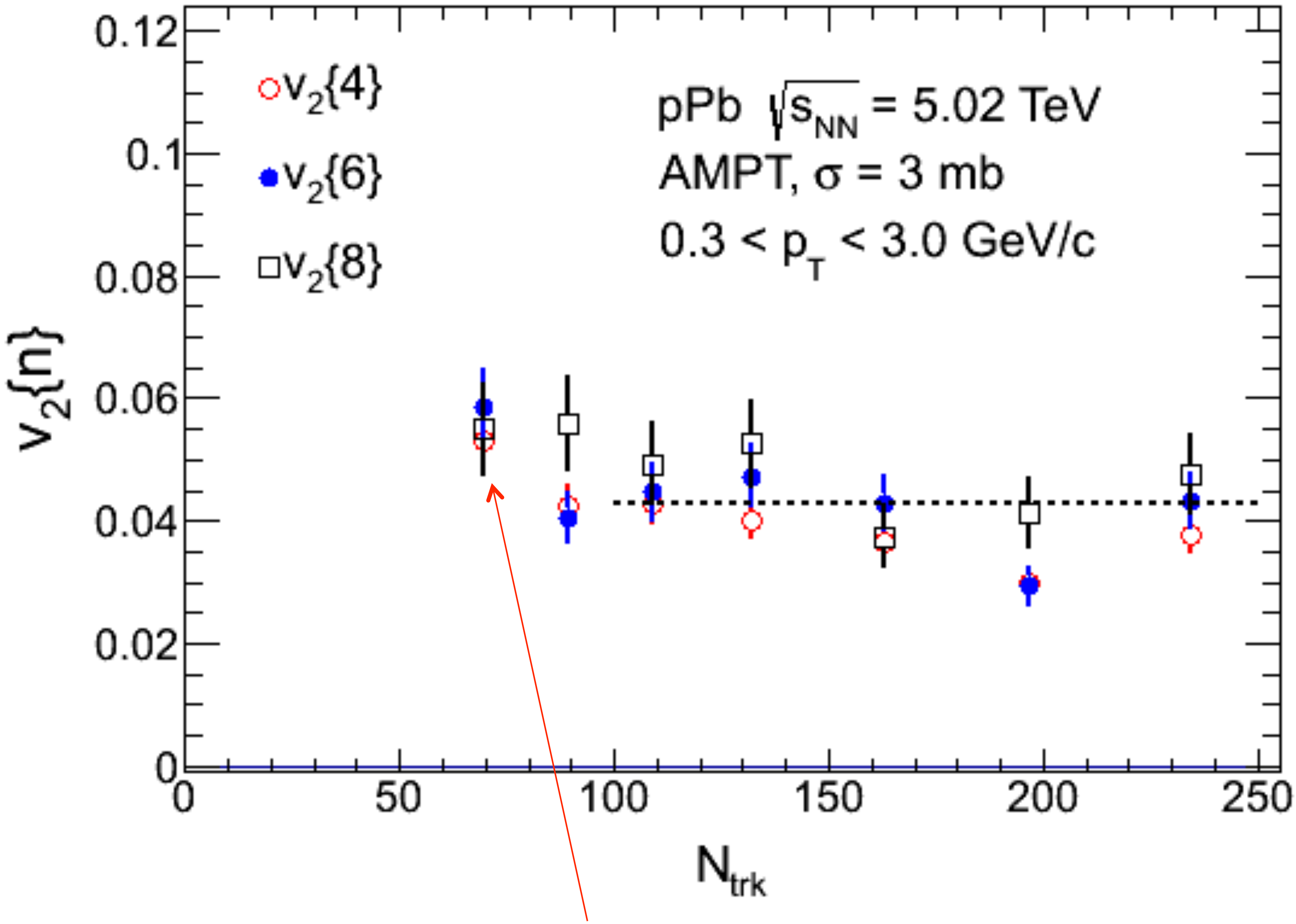
- Using the latest version of AMPT
http://myweb.ecu.edu/linz/ampt/
(ampt-v1.26t5-v2.26t5.zip)

- The input parameters (input.ampt) are the same as Adam and Guo-Liang's PRL paper (Phys. Rev. Lett. 113, 252301 (2014)) in pPb and PbPb

- The parton-parton cross section σ = 3 mb

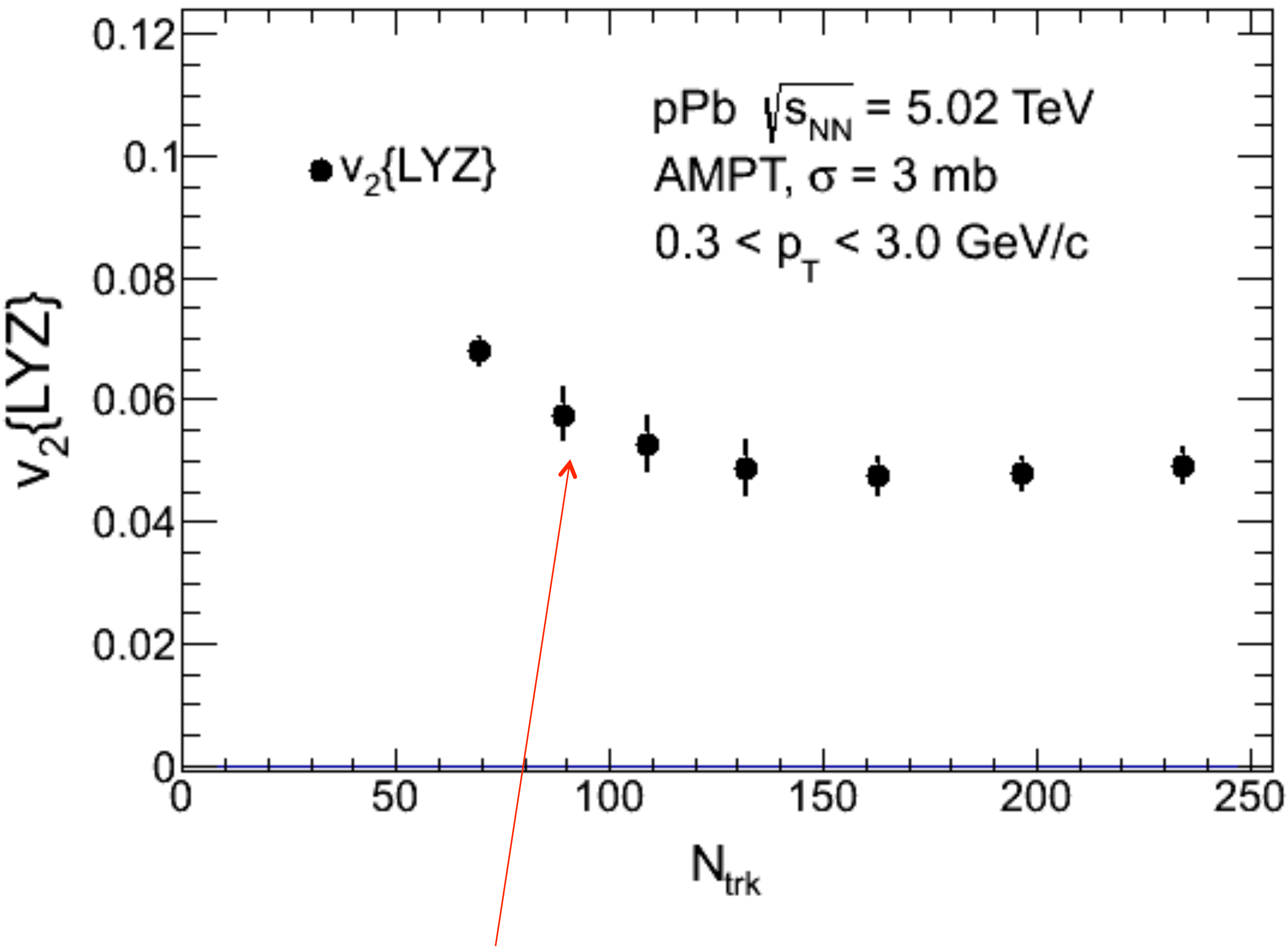
- Results are very preliminary !

$v_2\{n\}$ in AMPT



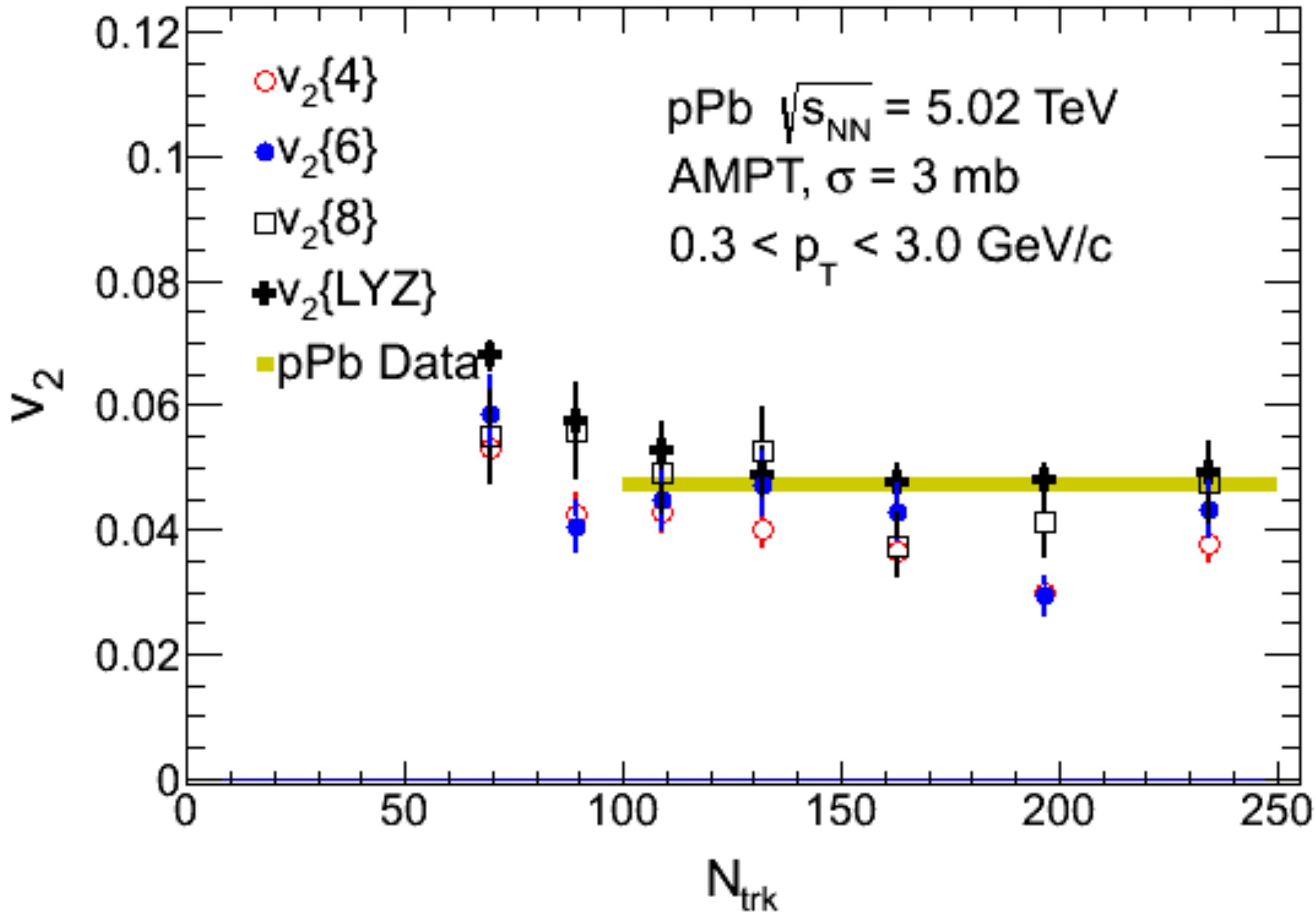
- Already showing the overestimate at N_{trk} ~ 70

V_2\{LYZ\} in AMPT



- Over estimate, not the true signal !

$v_2\{n\}$ and $v_2\{LYZ\}$ in AMPT



- Results are very close to pPb data

Summary

- Studying flow in low multiplicity events can tell us the size of the smallest droplet of hot QCD matter with liquid-like behavior
- Toy model studies show that current multi-particle correlation methods tend to fail in low multiplicity, giving fake signals
- The low multiplicity fake signals also appear in AMPT
- With parton-parton cross section σ = 3 mb in AMPT, the multi-particle correlation results are comparable with real pPb data in high multiplicity

Backup