Modification of W+jet in Heavy ion collisions

Shan-Liang Zhang

Central China Normal university
In collaboration with Xin-Nian Wang, Ben-Wei Zhang

Hard Probe 2020, Online,
June 3rd, 2020

Outline

➢ Introduction

➢ Jet production within Sherpa

➢ Jet propagation within a Linear Boltzmann Transport (LBT) model

➢ Numerical results

➢ Summary

Introduction

- Z/W+jet: Golden channel to study jet quenching.

  V. Kartvelishvili, R. Kvatadze and R. Shanidze, Phys. Lett. B 356, 589 (1995)

 – High energy parton from hard scattering lose energy due to strong interactions.
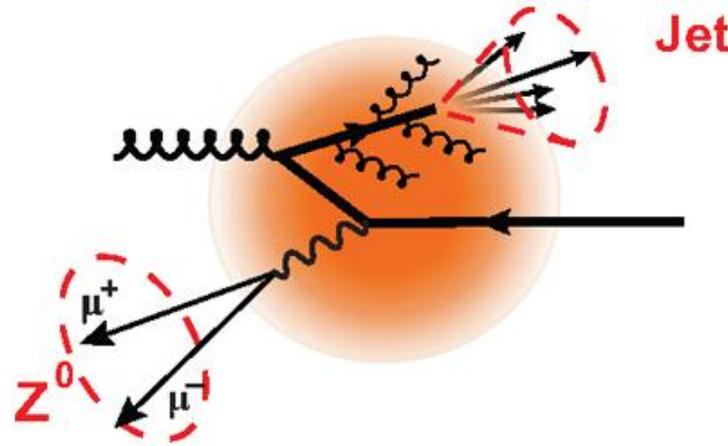
  – Mean-free-path of Z/W boson is longer than the size of QGP.
  – Z/W boson will not participate in strong interactions directly.
  – Large fraction of quark jets (> 70%).
  – No fragmentation contributions due to large mass.
- Important background to new physics, e.g. tops and Higgs.

Z+jet correlations in pp

- Z+jet azimuthal angle correlations
  Shan-Liang Zhang, T. Luo, X. N. Wang and B. W. Zhang, Phys.Rev. C98 (2018) 021901
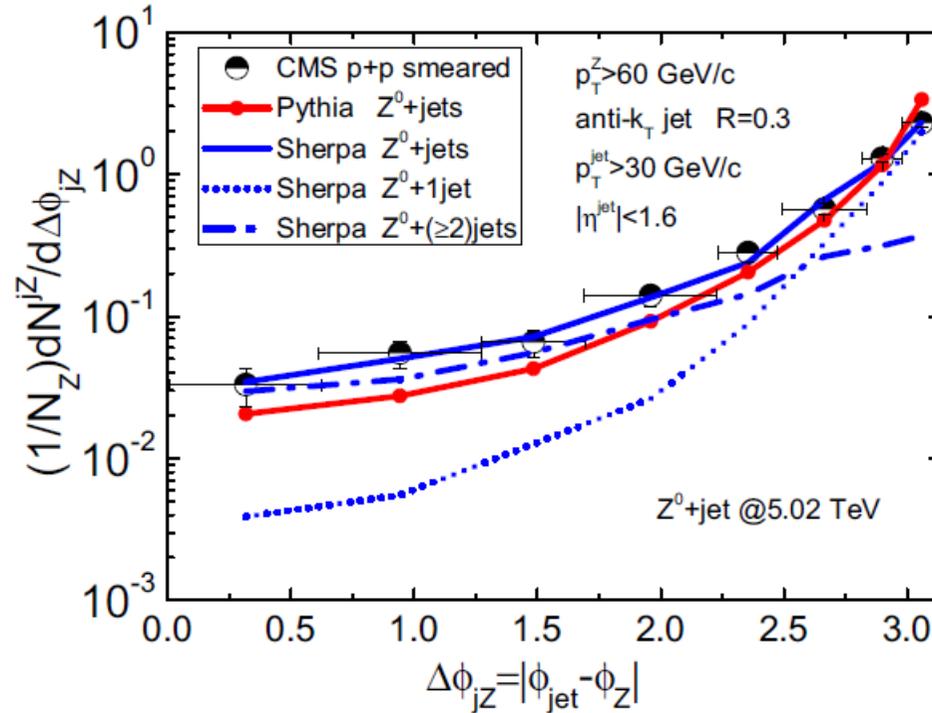
- NLO calculations suffer divergency at $\Delta\phi_{jZ} \approx \pi$.
- LO+PS calculations underestimate in $\Delta\phi_{jZ} < 2$.
- We adopt NLO+PS and Eloss to study Z+jet correlations.

Sherpa

Sherpa: Simulate of High-Energy Reactions of PArticles in the SM.

Merging schemes are provided to calculate multijets.

T. Gleisberg, S. Hoeche, F. Krauss, M. Schonherr, S. Schumann, F. Siegert and J. Winter, JHEP **0902**, 007 (2009);
S. Hoeche,F. Krauss,S. Schumann and F. S,JHEP 0905,053(2009);JHEP 1108,123(2011);JHEP 1304,027(2013).

− Low multiplicities: NLO matched to the parton shower.

− High multiplicities: LO merged on the parton shower.

Matching scheme can be simply formulated as:

$$\langle O \rangle^{(NloPs)} = \int d\Phi_B \left[B + \tilde{V} + I^S \right] (\Phi_B) \widetilde{PS}_B(\mu_Q^2, O)$$
$$+ \int d\Phi_R \left[R - D^S \right] (\Phi_R) \widetilde{PS}_R(t_R, O)$$

- B, $\tilde{V}$ and R is born, virtual and real terms respectively.
- D ($I^S = \int d\Phi_1 D^{(S)}$) is the (Integrated) subtraction term.
- $\widetilde{PS}$: the parton shower branch.

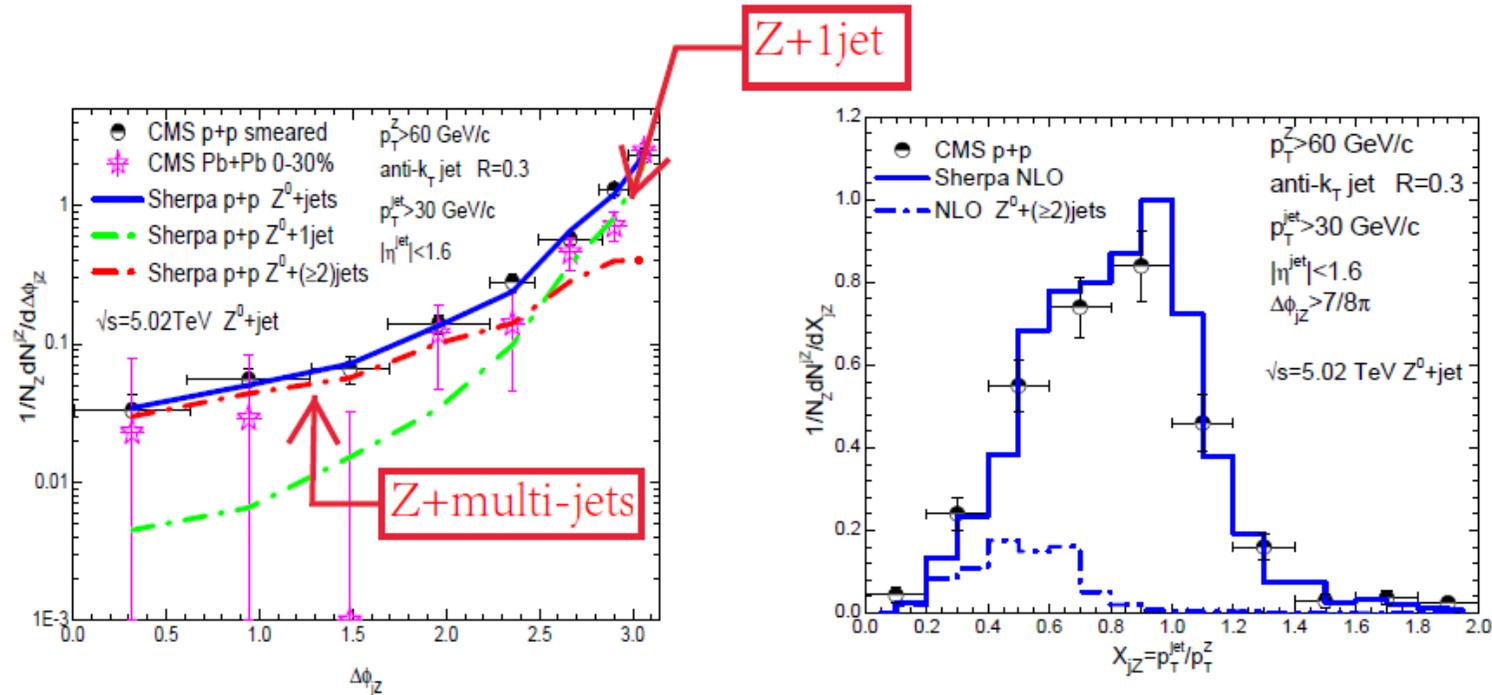Sherpa: Gauge boson(γ, Z, W)+jets, b(c) jets, tops, Higgs...

Z+jets in pp collisions with Sherpa

- Z+jet correlations in p+p collisions.

  Loop ME: OpenLoops. F. Cascioli, P. Maierhofer and S. Pozzorini, Phys. Rev. Lett. 108, 111601
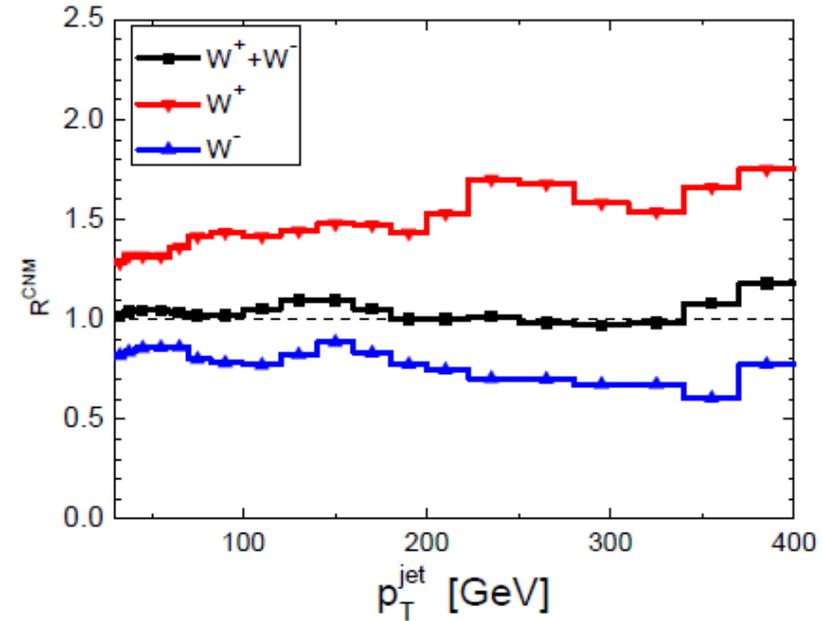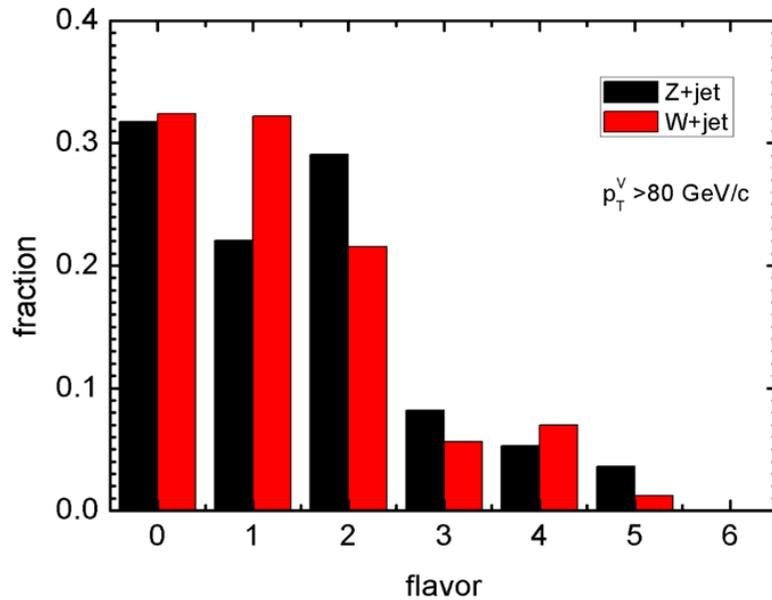
  PDF: CETQ14nlo.

- NLO matched PS calculations show excellent agreement with experimental data in p+p collisions.

Shan-Liang Zhang, T Luo, X Wang, BWZ, PRC 98 (2018) 021901(R)

- Leading parton flavor fraction and CNM effect.

W carry charge, and change the flavor of the parton .
CNM has negligible effect on W+jets spectrums.
   - W^+ is enhanced;
   - W^- is suppressed due to CNM.
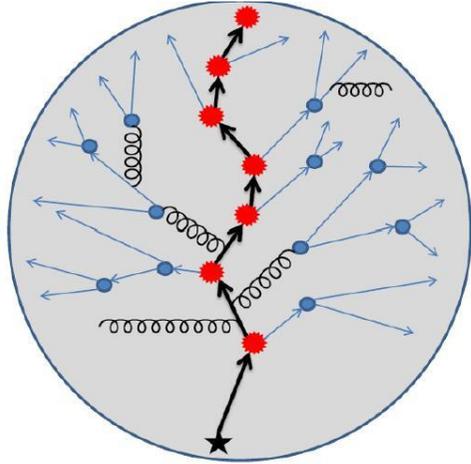
Production mechanism of W+jets

- Comparison with experimental data.
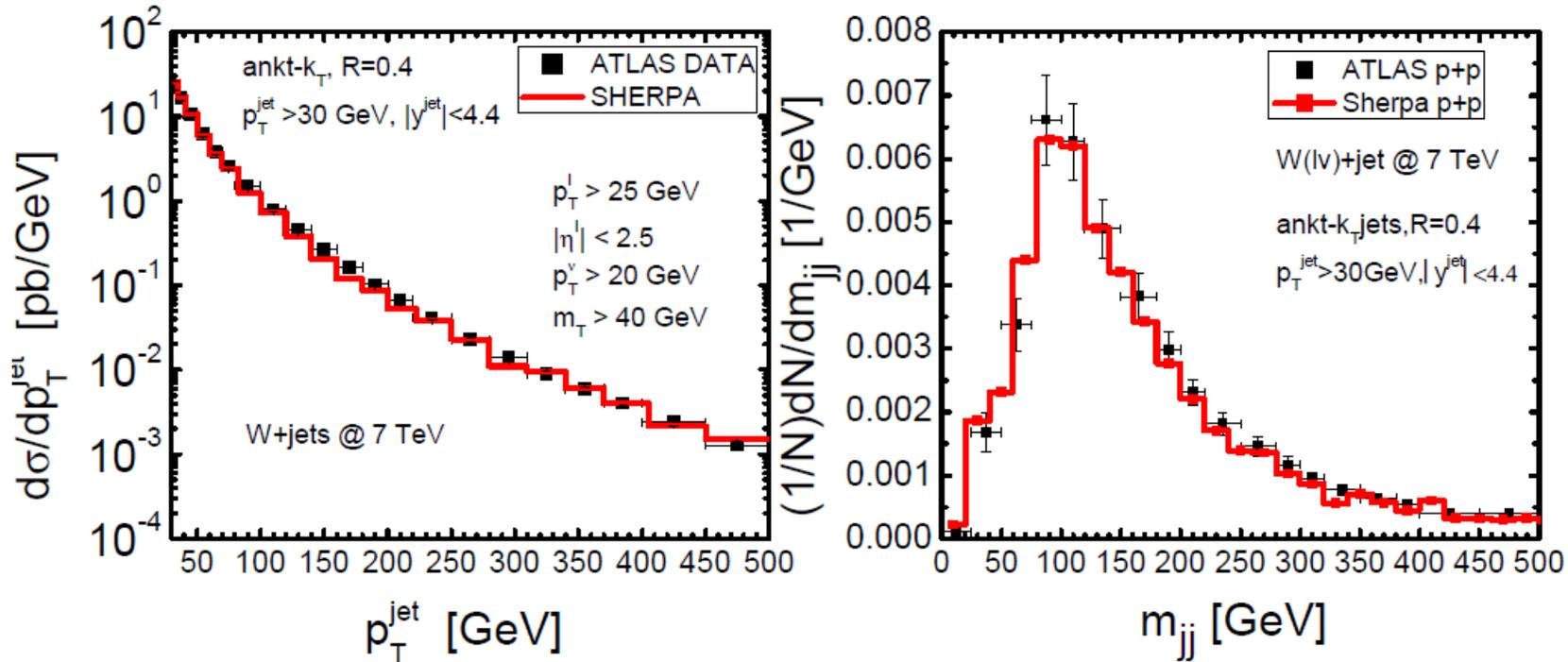
Well agreements with experimental data.

Linear Boltzmann Transport (LBT) model

Linear Boltzmann jet Transport

Elastic collision + Induced gluon radiation.

Follow the propagation of recoiled parton.

Back reaction of the Boltzmann transport.

Medium Excitation

H. Li, F. L, G. l. Ma, X. N. W and Y. Z, PhysRevLett.106.012301; X. N. Wang and Y. Zhu, PhysRevLett.111.062301; Y. He, T. Luo, X. N. Wang and Y. Zhu, PhysRevC.91.054908.

$$p_1 \cdot \partial f_a(p_1) = -\int \frac{d^3 p_2}{(2\pi)^3 2E_2} \int \frac{d^3 p_3}{(2\pi)^3 2E_3} \int \frac{d^3 p_4}{(2\pi)^3 2E_4}$$
$$\times \frac{1}{2} \sum_{b(c,d)} [f_a(p_1)f_b(p_2) - f_c(p_3)f_d(p_4)] |M_{ab \to cd}|^2$$
$$\times S_2(s,t,u)(2\pi)^4 \delta^4(p_1 + p_2 - p_3 - p_4)$$

Elastic Scattering--Complete set of 2-2 scattering processes.

Radiation--Higher Twist: Guo and Wang (2000), Zhang, Wang and Wang (2004), Majumder (2012).

$$\frac{dN_g}{dx dk_\perp^2 dt} = \frac{2\alpha_s C_A P(x) k_\perp^4}{\pi (k_\perp^2 + x^2 M^2)^4} \hat{q} \sin^2 \left(\frac{t - t_i}{2\tau_f} \right)$$

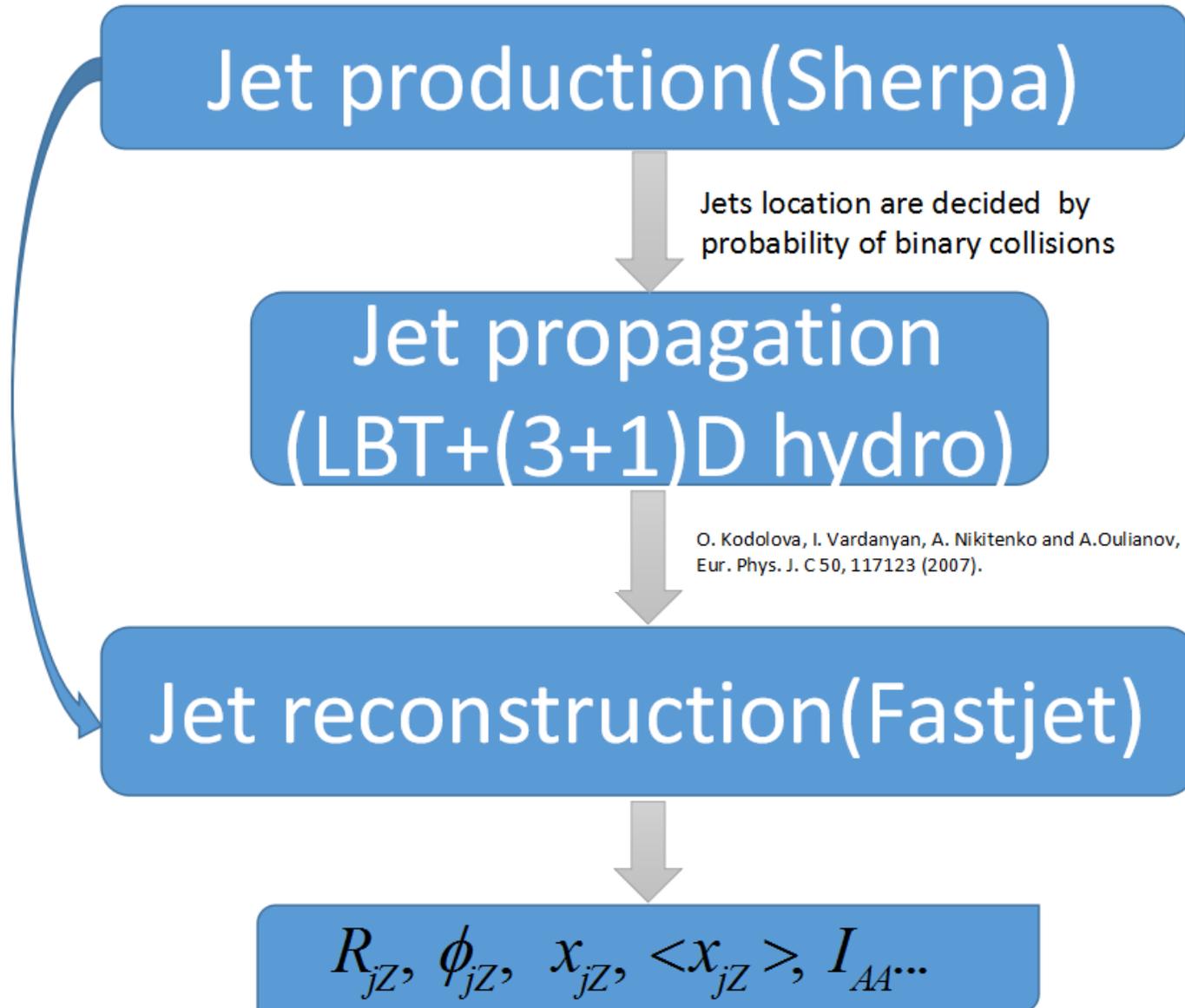LBT: light/heavy flavor hadron, single inclusive jets, γ-hadron/jet, Z-jet.

T. Luo, S. Cao, Y. He and X. N. Wang, arXiv:1803.06785;
W. Chen, S. Cao, T. Luo, L. G. Pang and X. N. Wang, Phys. Lett. B 777, 86 (2018);
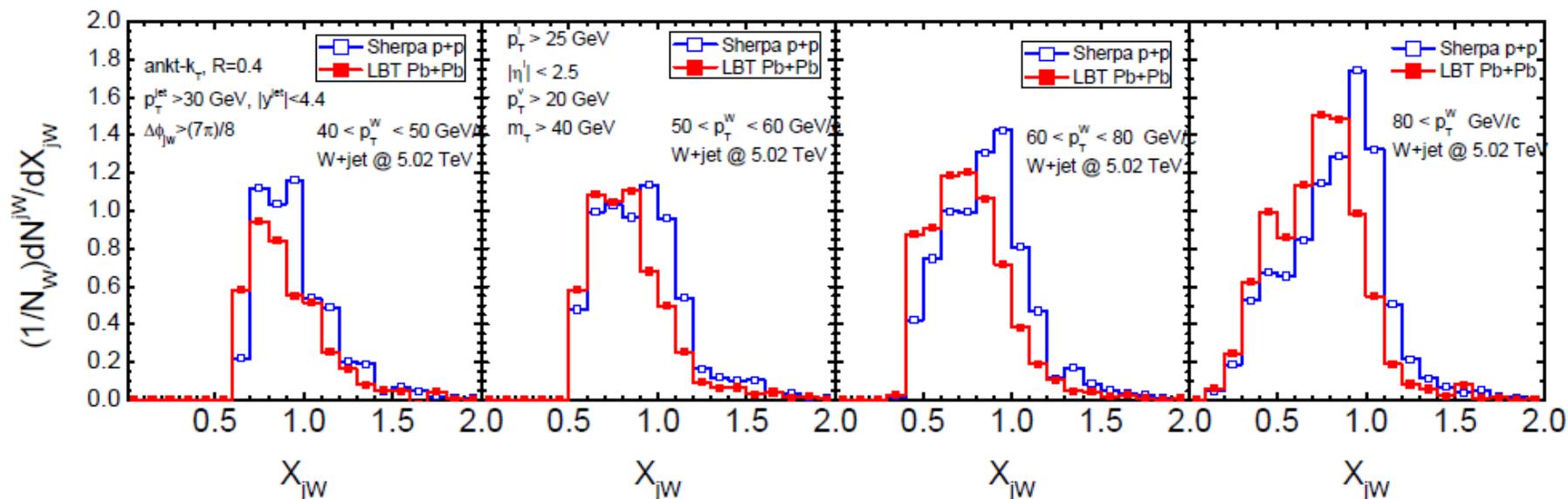S. Cao, T. Luo, G. Y. Qin and X. N. Wang, Phys. Rev. C 94, no. 1, 014909 (2016).
S Zhang, T Luo, X Wang, BWZ, PRC 98 (2018) 021901(R)

9

Framework

Jet production(Sherpa)

Jets location are decided by probability of binary collisions

Jet propagation (LBT+(3+1)D hydro)

O. Kodolova, I. Vardanyan, A. Nikitenko and A.Oulianov, Eur. Phys. J. C 50, 117123 (2007).

Jet reconstruction(Fastjet)

$R_{jZ}, \ \phi_{jZ}, \ x_{jZ}, \ <x_{jZ}>, \ I_{AA}...$

W+jet asymmetry

- Shift of momentum imbalance $x_{jW} = p_T^{jet}/p_T^W$

x_{jW} is shifted to smaller value.
- Transverse momentum of W boson is unattenuated.
- Jet transverse momentum is modified by medium.

Mean value of momentum imbalance

- Reduction of mean value of momentum imbalance and jet partners.
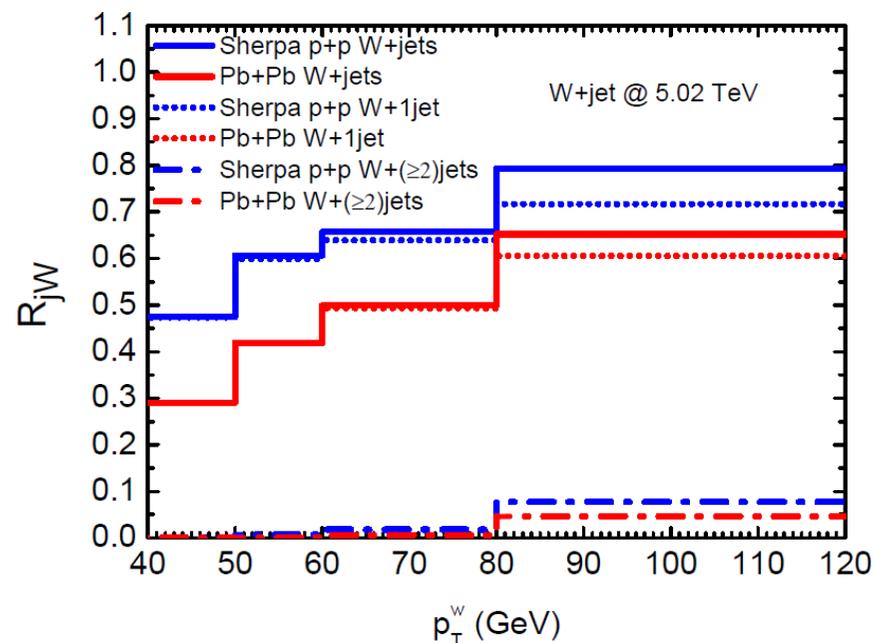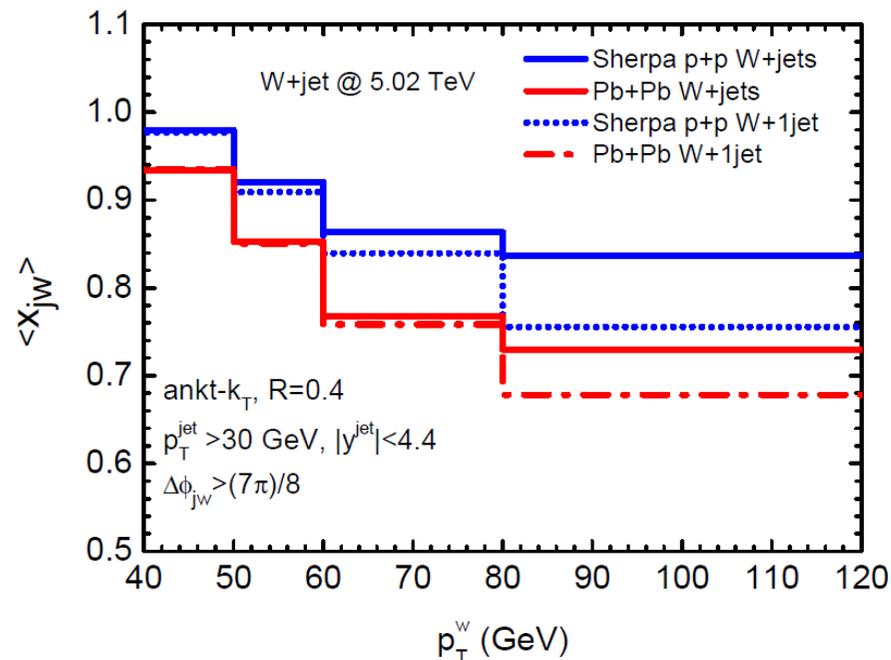
p_T^W (GeV)	40-50	50-60	60-80	80-120
$\Delta\langle x_{jW}\rangle$	0.04514	0.06784	0.09568	0.10666
$\Delta\langle x_{jW}\rangle/\langle x_jw\rangle$pp	4.6%	7.4%	11.1%	12.8%

W+jet azimuthal angle correlations

- The suppression of :

$$\Delta\phi_{jW} = |\phi_j - \phi_W|$$
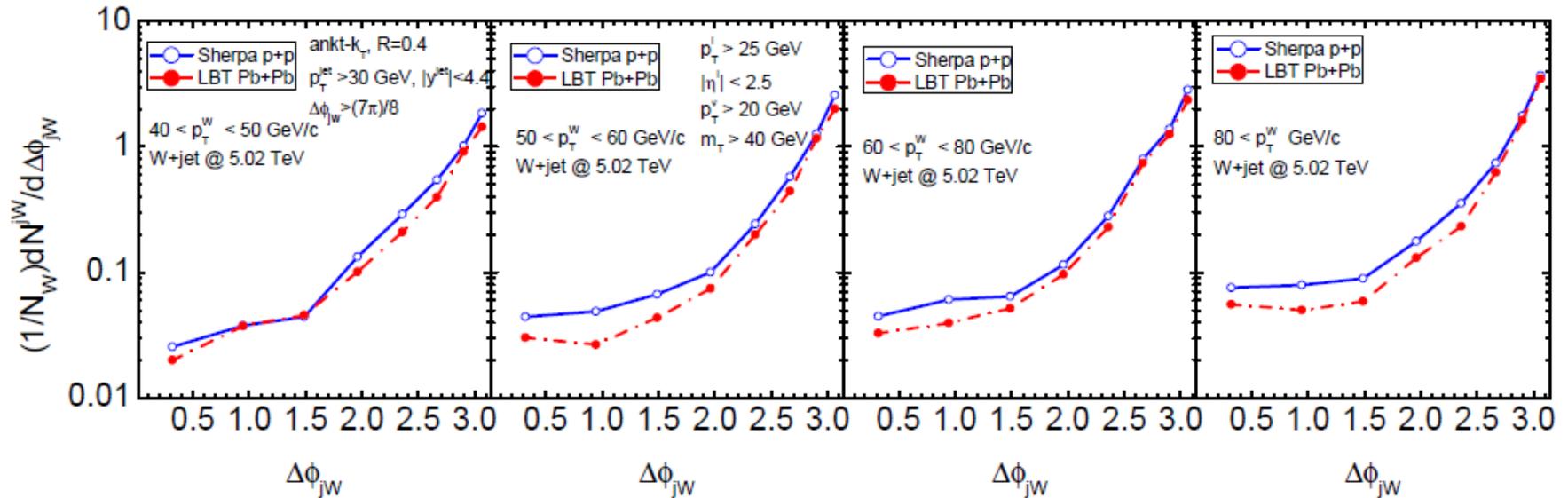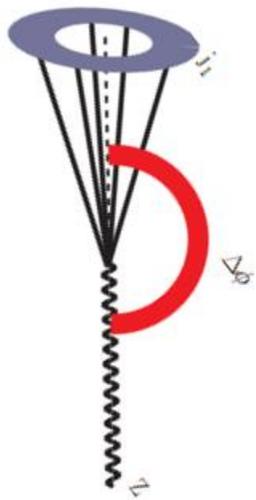
$\Delta\phi_{jW}$ is moderately suppressed in Pb+Pb collisions.
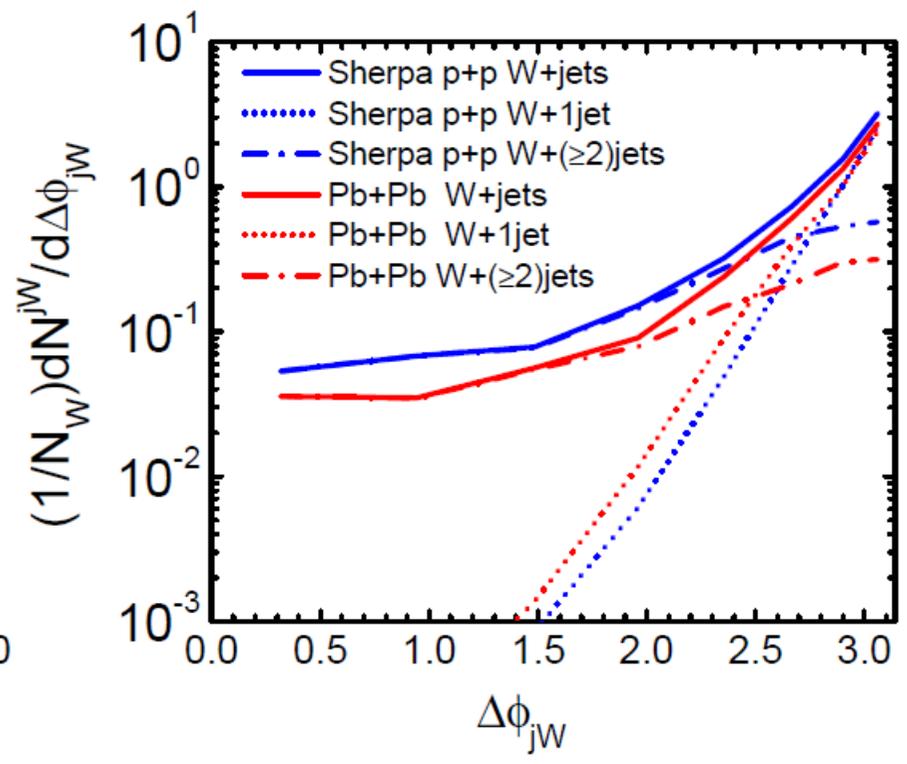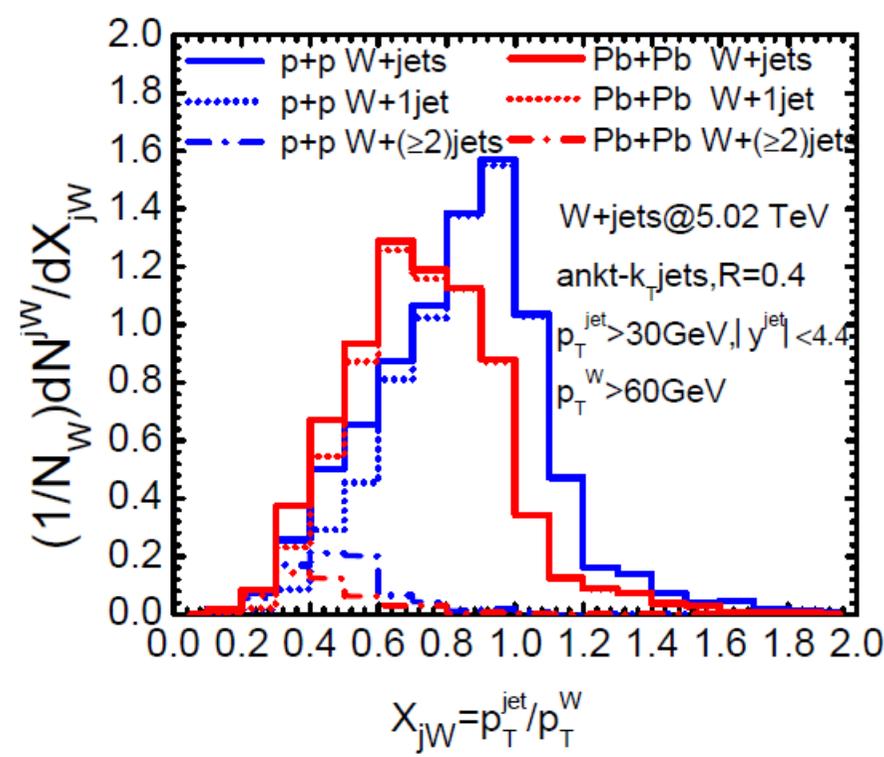
Multi-jets have almost 50% contributions in $x_{jW} < 0.5$ region.

$\Delta\phi_{jW}$ is moderately suppressed in Pb+Pb collisions, almost a constant.

- The suppression of W+1 jet angle correlations is mild.
- W+multi-jets angle correlations is considerably suppressed.

Energy missing of W+jets

- The suppression of energy missing: $\vec{p}_T^{Miss} = -(\vec{p}_T^l + \sum \vec{p}_T^{jets})$

$$R_{AA}(p_T^{Miss}) = \frac{1}{\langle N_{coll} \rangle} \frac{dN^{AA}/dp_T^{Miss}}{dN^{pp}/dp_T^{Miss}}$$
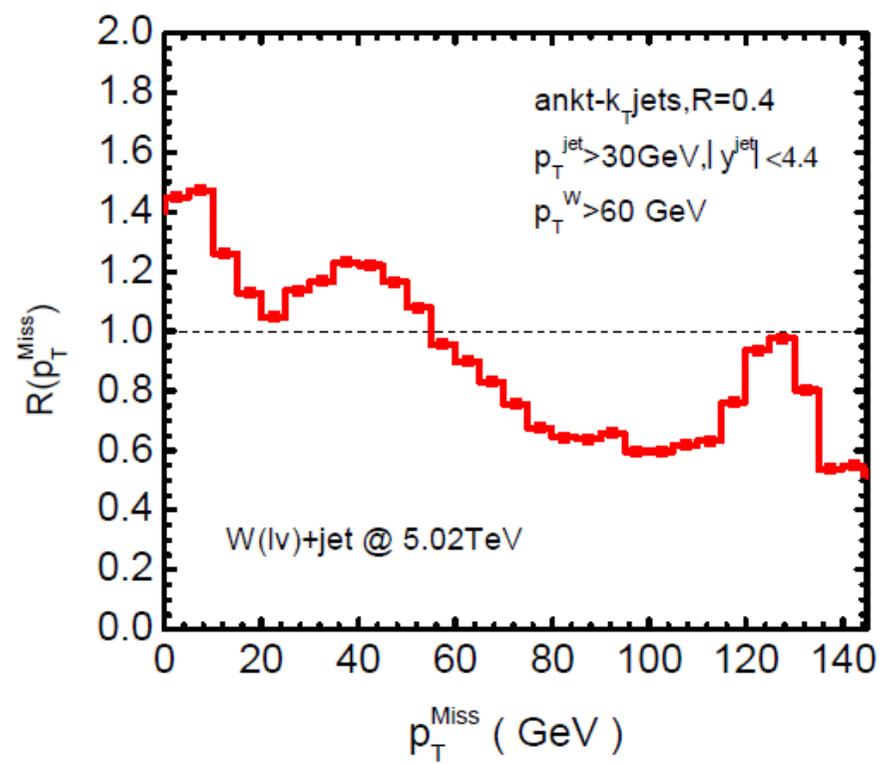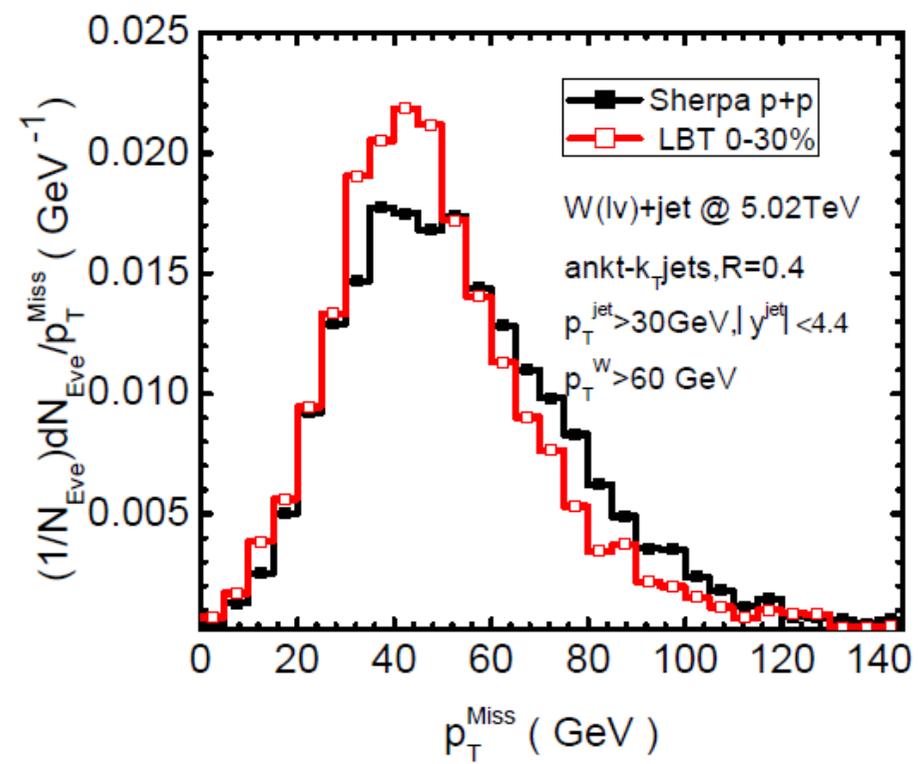
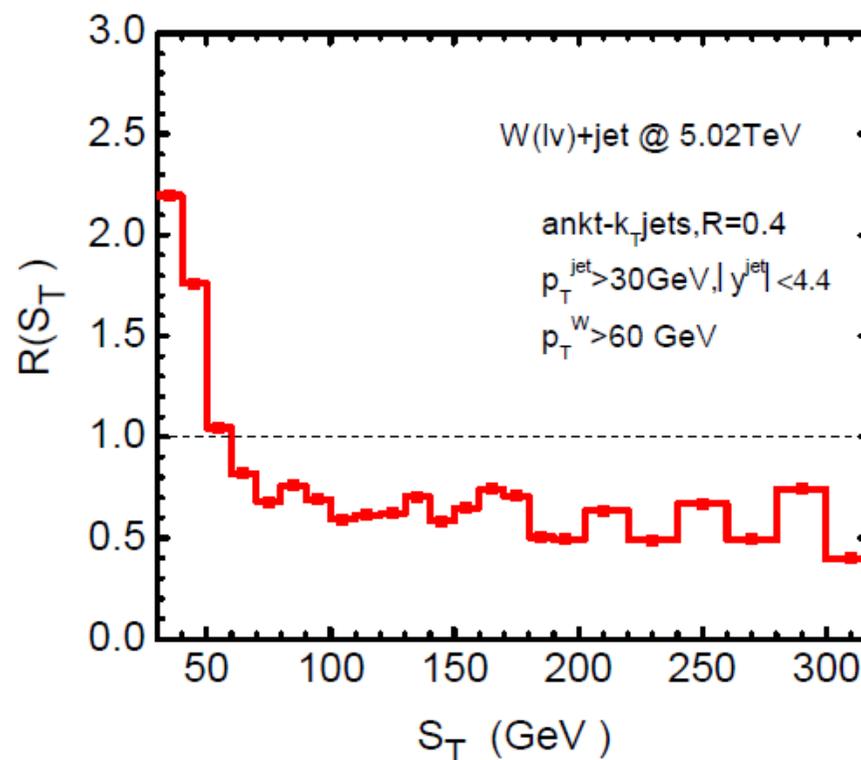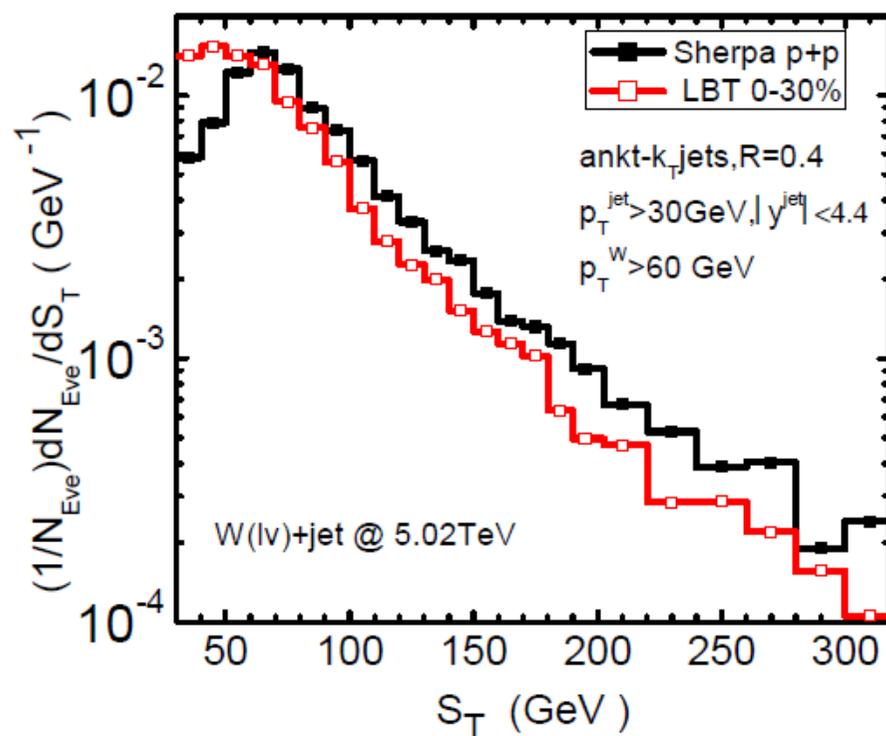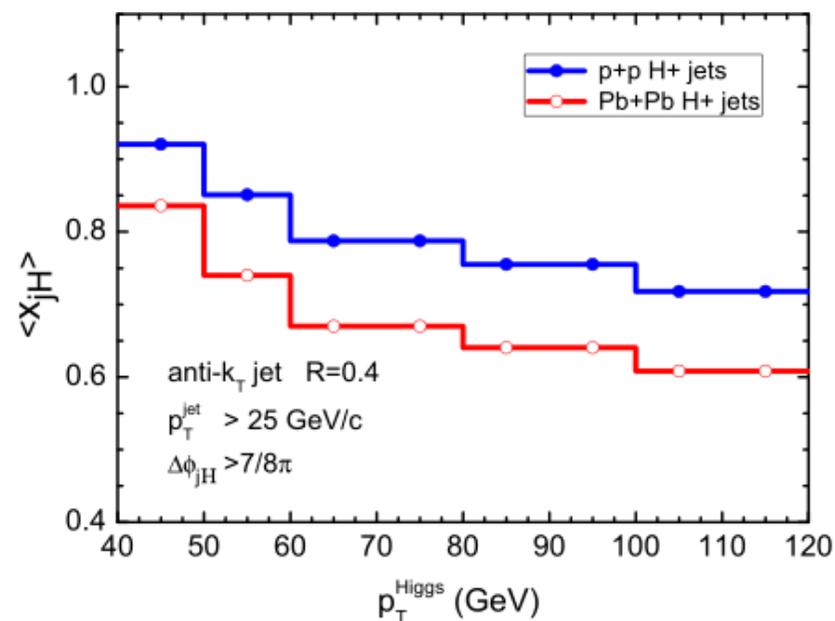Jets lose energy in the opposite direction of the neutrino or W boson.

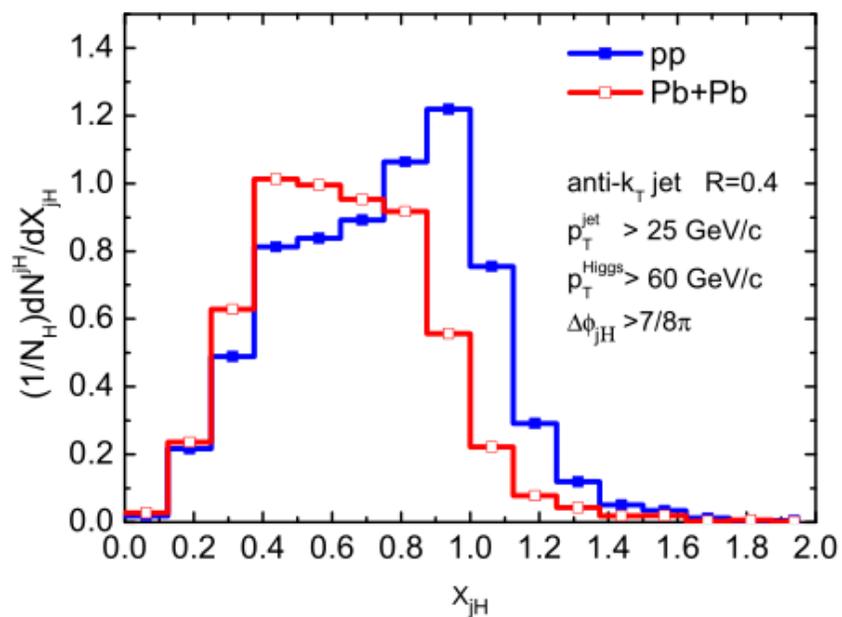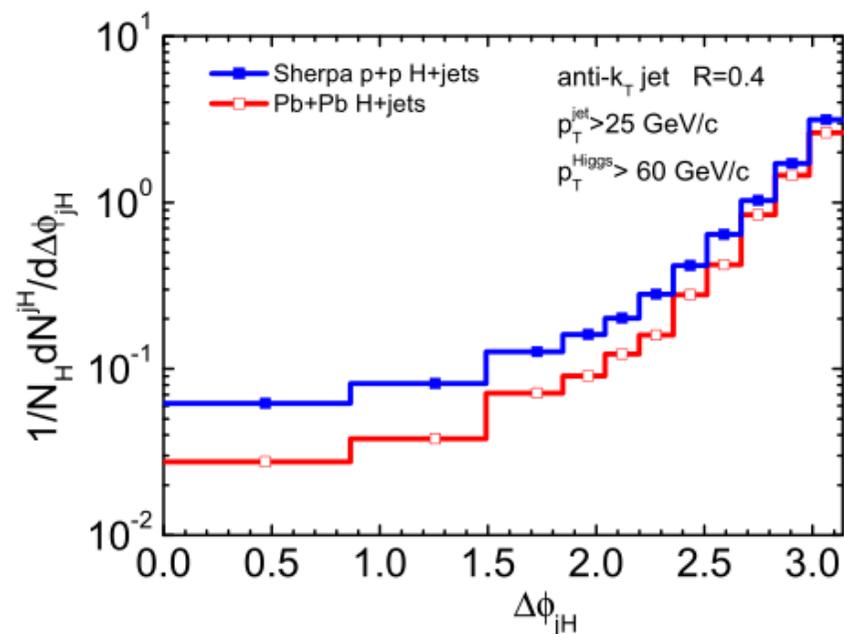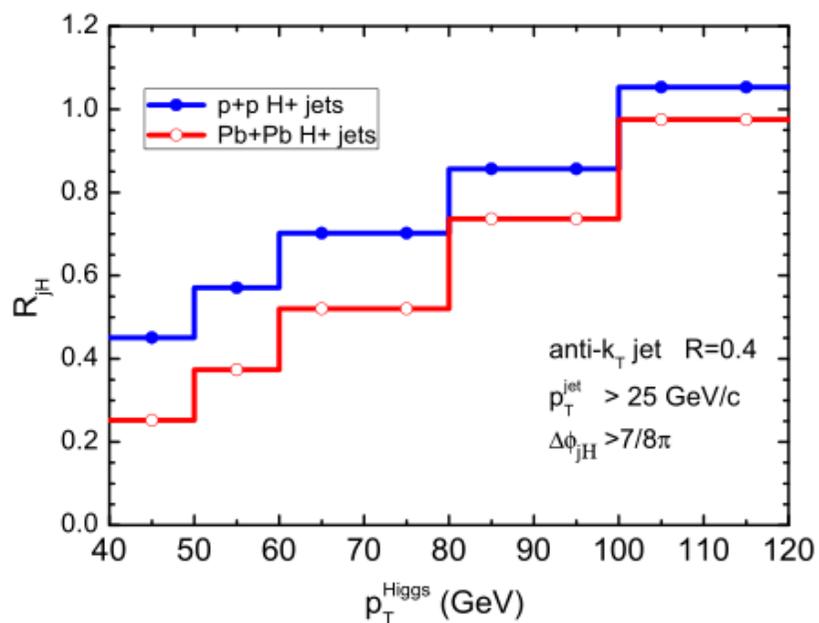# W+jets transverse momentum modification

- The suppression of energy total transverse energy:

$$S_T = \sum p_T^{jets}$$

$$R_{AA}(S_T) = \frac{1}{\langle N_{coll} \rangle} \frac{dN^{AA}/dS_T}{dN^{pp}/dS_T}$$

H+jets correlations

Summary

Z/W+jet correlation in Pb+Pb at the LHC is studied by combining NLO+PS in Sherpa for initial Z/W+jet production and LBT for jet propagation in the expanding QGP from 3+1D hydrodynamics.

- x_{jW} is shifted to smaller value and R_{jW} is smaller in Pb+Pb.

  Large fraction of jets lose energy and fall below 30 GeV threshold.

- $\Delta\phi_{jW}$ is moderately suppressed in Pb+Pb collisions.

  Suppression of multijets lead to the modification of W+jet angle correlations.

- S_T and p_T^{Miss} are shifted to smaller value .

  Jets lose energy at the opposite direction of W boson.
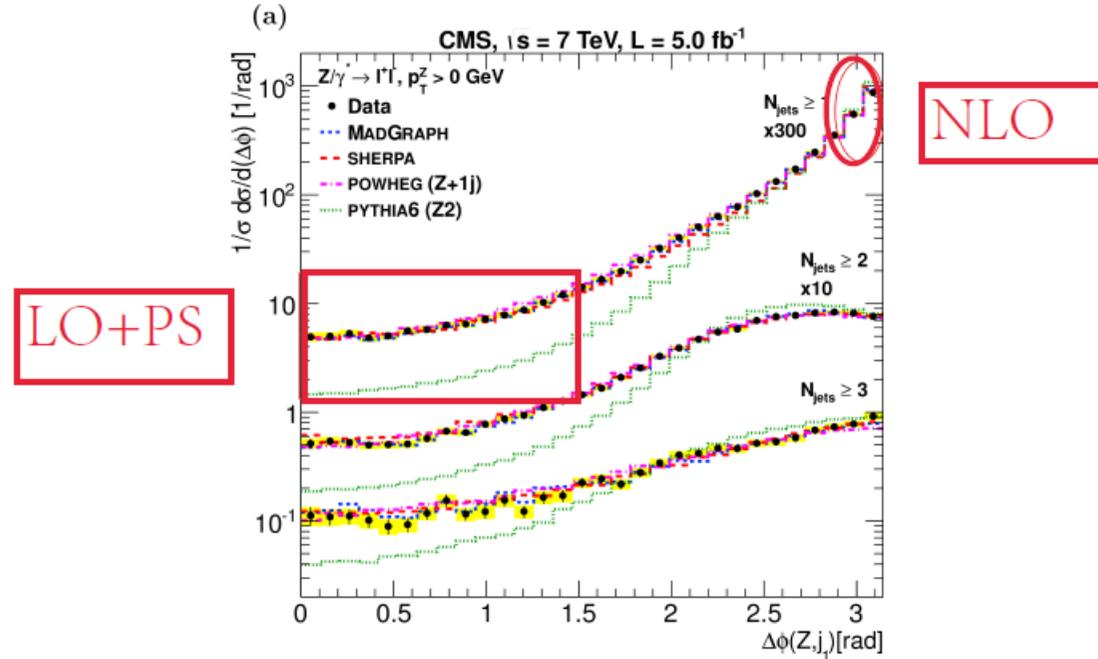
Thanks for your attention!
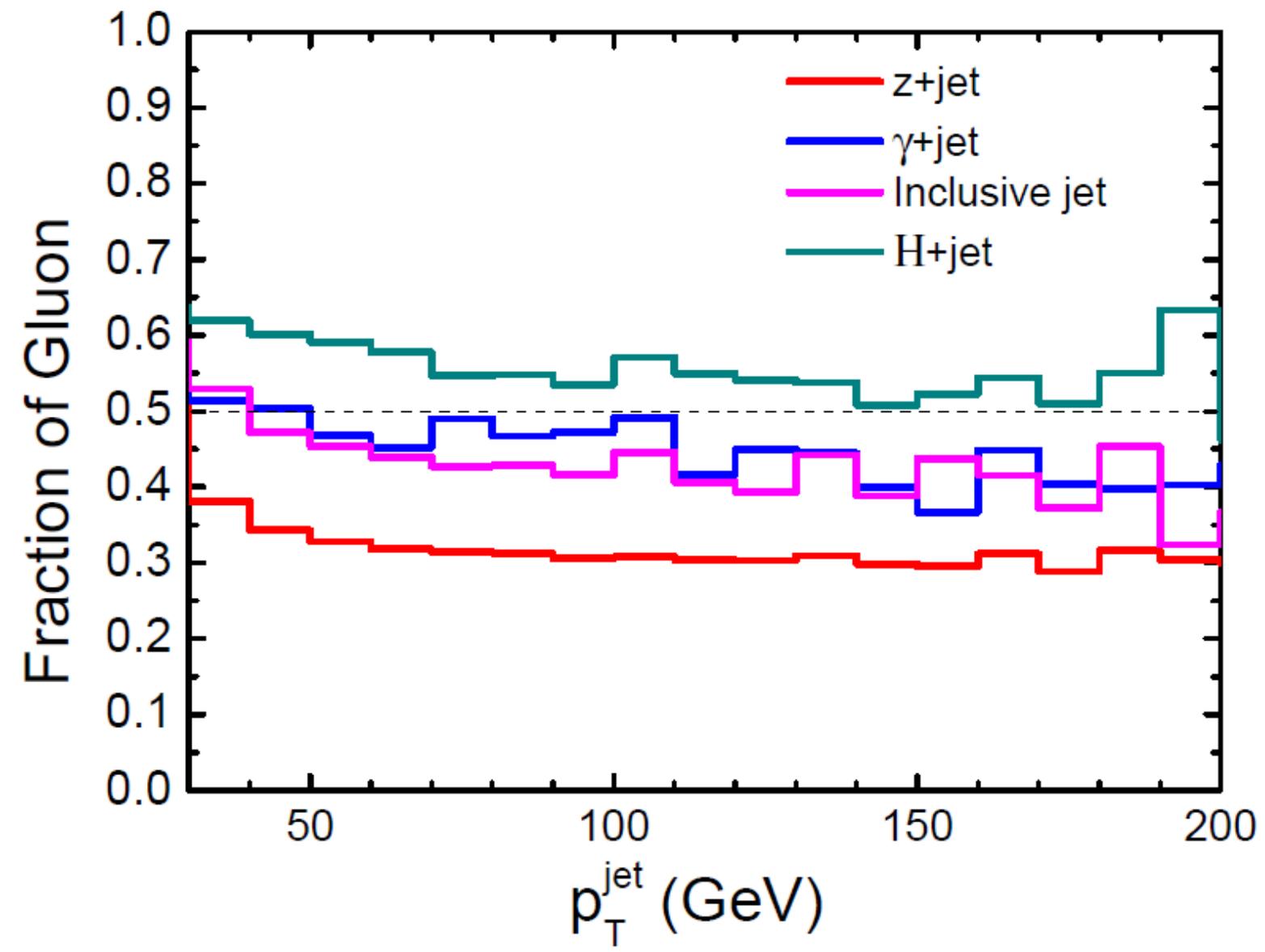
Backup

Z+jet correlations in pp

- Z+jet azimuthal angle correlations

  S. Chatrchyan et al. [CMS Collaboration], Phys. Lett. B **722**, 238 (2013)
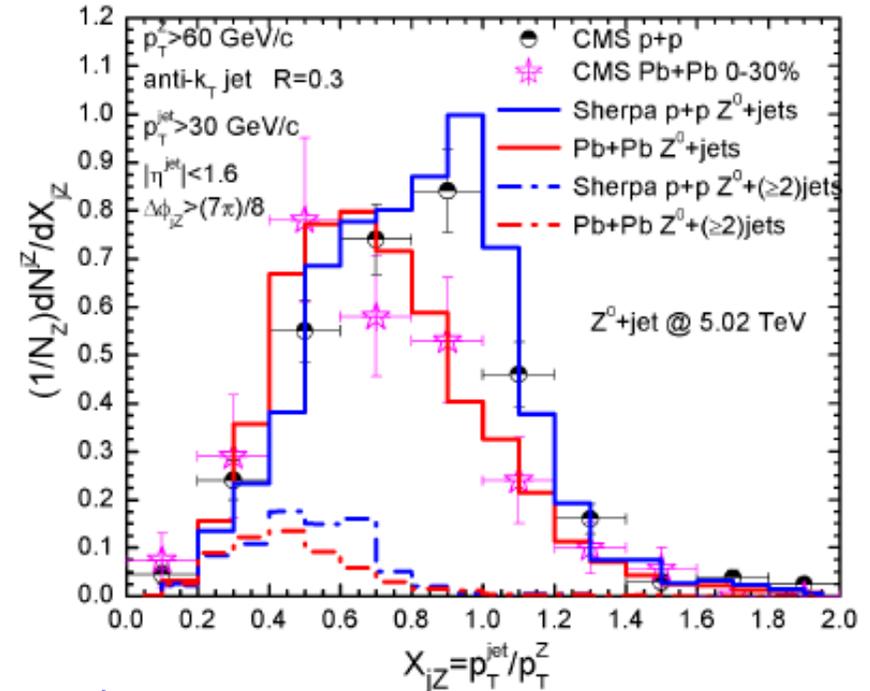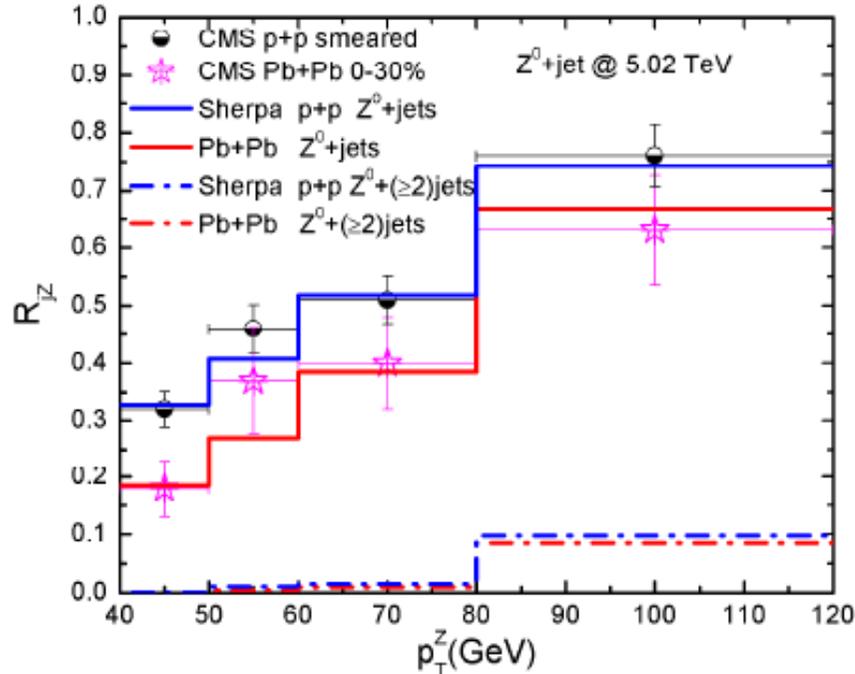

  - NLO calculations suffer divergency at $\Delta\phi_{jZ} \approx \pi$.
  - LO+PS calculations underestimate at $\Delta\phi_{jZ} < 2$.

- We adopt NLO+PS and Eloss to study Z+jet correlations.

Dependence of gluon jet flavor on P_T^jet

- Fix the parameter α_s via the comparison with the Z+jet correlations.

Phys.Rev. C98 (2018) 021901

R_{jz} is overall suppressed .
Shift of momentum imbalance x_{jZ}
-- α_s = 0.20 that best describe experimental data in Pb+Pb collisions.