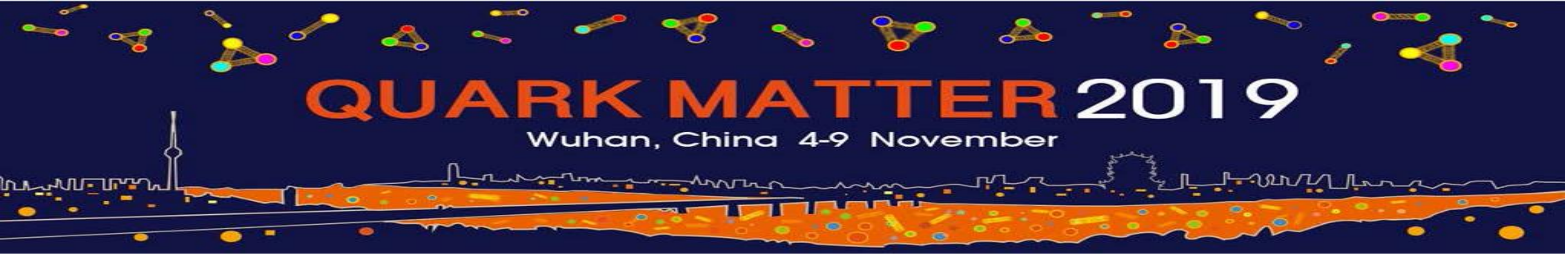

Charm-Hadron Production in pp & AA Collisions

Min He

Nanjing University of Sci. & Tech., Nanjing, China

Based on recent work done in collaboration with Ralf Rapp of Texas A&M University

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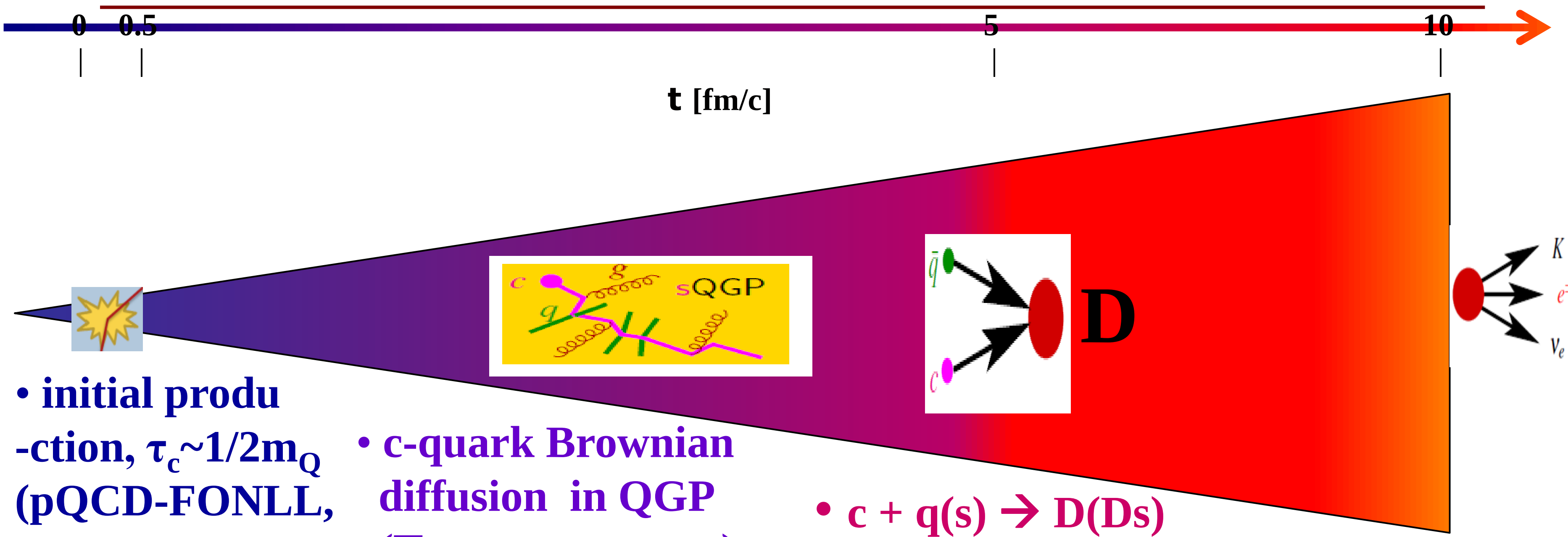
Heavy flavor transport in hot QCD matter



- initial produ -ction, τ_c~$1/2m_Q$ (pQCD-FONLL, shadowing)

- c-quark Brownian diffusion in QGP (T-mat. reso. corr.) low p_T thermalization high p_T e-loss

- c + q(s) → D(Ds)
- c + q + q → Λ_c resonance recombination

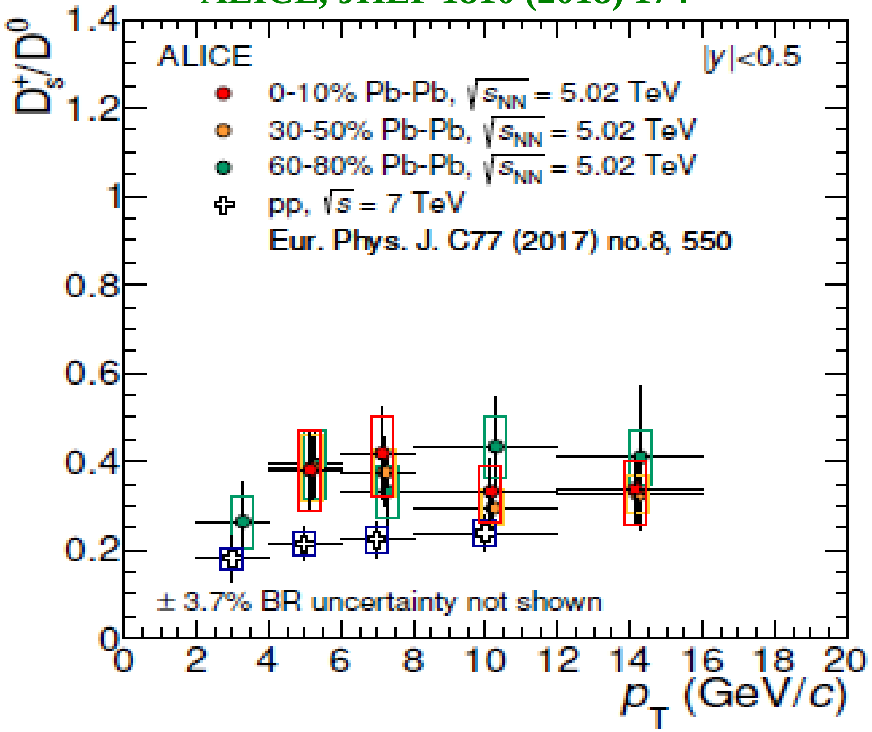
- D-meson diffusion in hadronic liquid

□ Controled baseline (pQCD), delayed thermalization by m_Q/T , tagged probe participating in the full fireball history ➔ spectrum & chemistry modifications

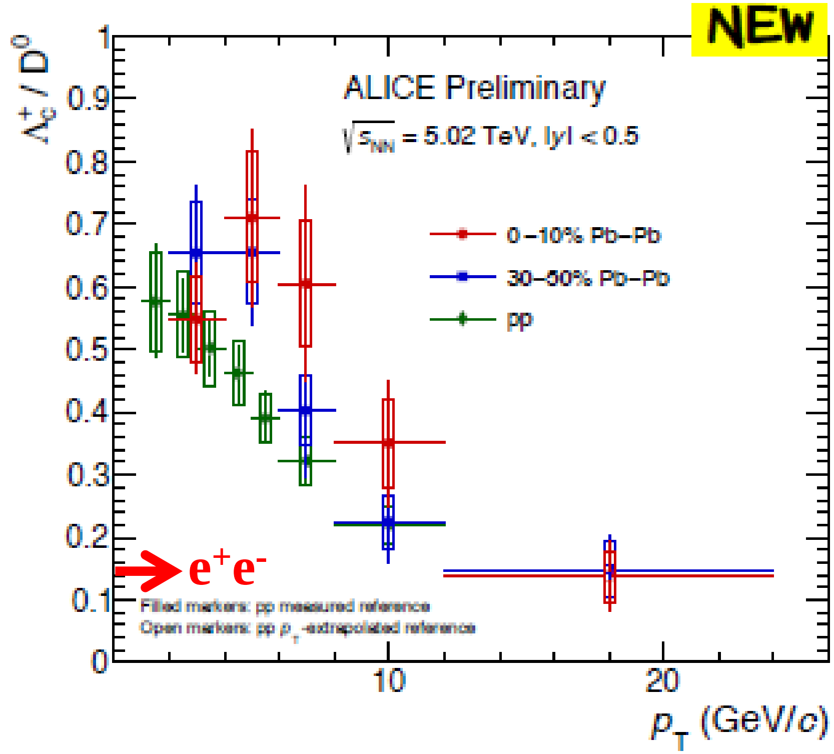
□ Transport coeffi., + diffusion/hadronization simulation on top of bulk hydro ➔ Micro & Macro physics combined vs quantum effects

D_s & Λ_c : Probing charm hadronization

ALICE, JHEP 1810 (2018) 174



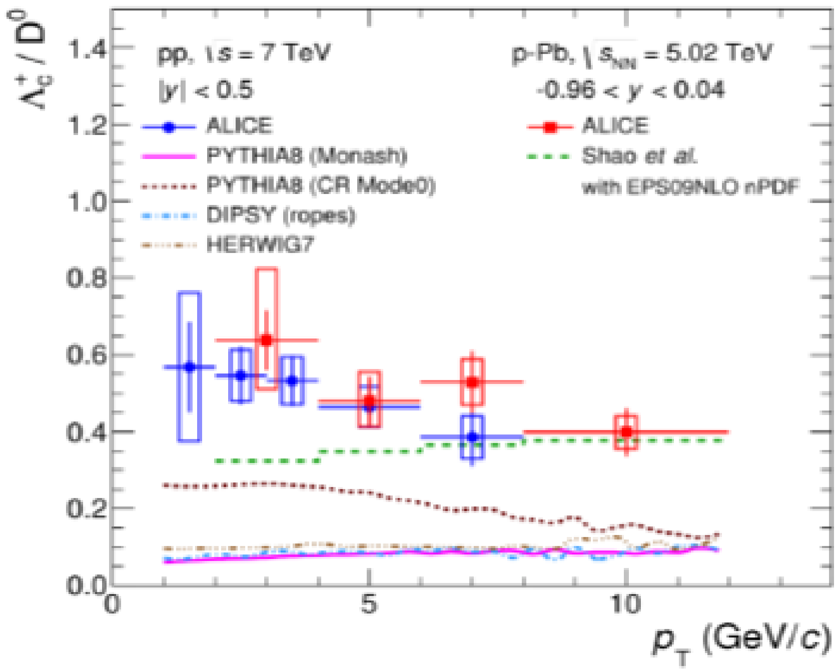
ALICE, SQM19

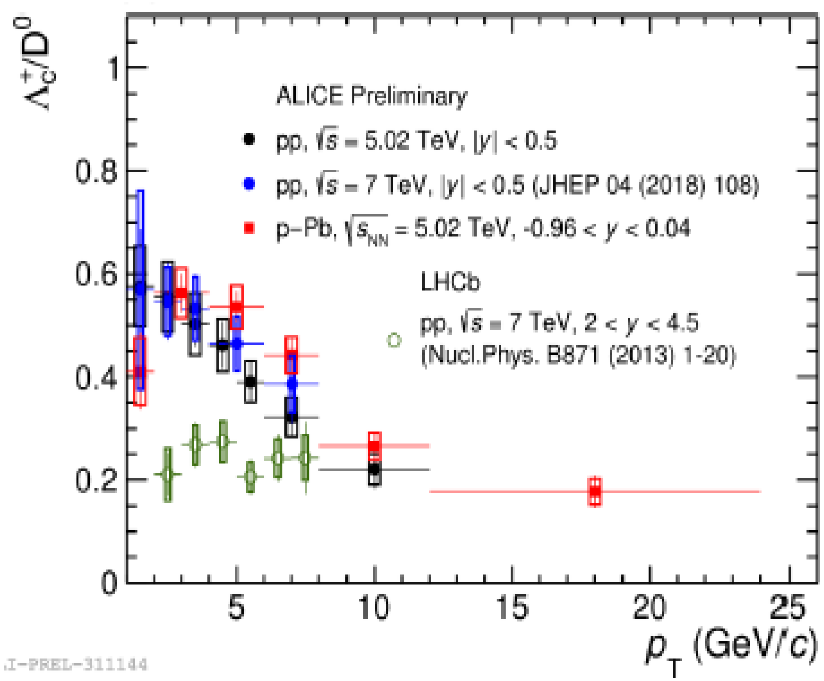


- ☐ e^+e^- : vacuum fragmentation, costly to excite ssbar-pair or diquark-antidiquark pair from vacuum ➔ Ds and Λ_c much suppressed
- ☐ high-energy pp: likely coalescence for Λ_c in a quark-rich environment!
- ☐ AA: recombination hadronization in QGP ➔ modifying charm hadro-chemistry

Charm-hadron production in pp collisions

- Enhanced Λ_c^+/D^0 w.r.t. pQCD based MC event generators
- Already a puzzle in pp? ➔ statistical coalescence (SHM) in a quark-rich environment?!





- Standard SHM (with PDG only spectra) Λ_c^+/D^0 ~0.22 too small **P. B.-M.**
- Tension between ALICE (mid-rapidity) vs LHCb (forward-rapidity)?

Charm-hadron production: pp SHM

- **PDG: 5 Λ_C (I=0) , 3 Σ_C (I=1), 8 Ξ_C (I=1/2), 2 Ω_C (I=0)➔ missing baryons?!**
  RQM: 18 extra Λ_C , 42 extra Σ_C, 62 extra Ξ_C, 34 extra Ω_C up to 3.5 GeV
  ➔ supported by lattice PRD 84 (2011) 014025; PoS LAT. 2014 (2015) 084; PLB 737 (2014) 210

- **Statistical Hadronization Model (SHM):** $$n_i = \frac{d_i}{2\pi^2} m_i^2 T_H K_2(\frac{m_i}{T_H})$$

Thermal densities of "prompt" ground-state charmed hadrons for hadronization temperatures of $T_H = 170$ and 160 MeV (including strong feeddowns) in the PDG and RQM scenarios (assuming 100% BR of Λ_c's and Σ_c's above the DN threshold into Λ_c^+).

n_i ($\cdot 10^{-4}$ fm^{-3})	D^0	D^+	D^{*+}	D_s^+	Λ_c^+	$\Xi_c^{+,0}$	Ω_c^0
PDG(170)	1.161	0.5098	0.5010	0.3165	0.3310	0.0874	0.0064
PDG(160)	0.4996	0.2223	0.2113	0.1311	0.1201	0.0304	0.0021
RQM(170)	1.161	0.5098	0.5010	0.3165	0.6613	0.1173	0.0144
RQM(160)	0.4996	0.2223	0.2113	0.1311	0.2203	0.0391	0.0044

- **Strong feeddowns of excited states all included: BR=100% to Λ_C^+ for all Λ_C & Σ_C even above DN (2805 MeV) threshold**

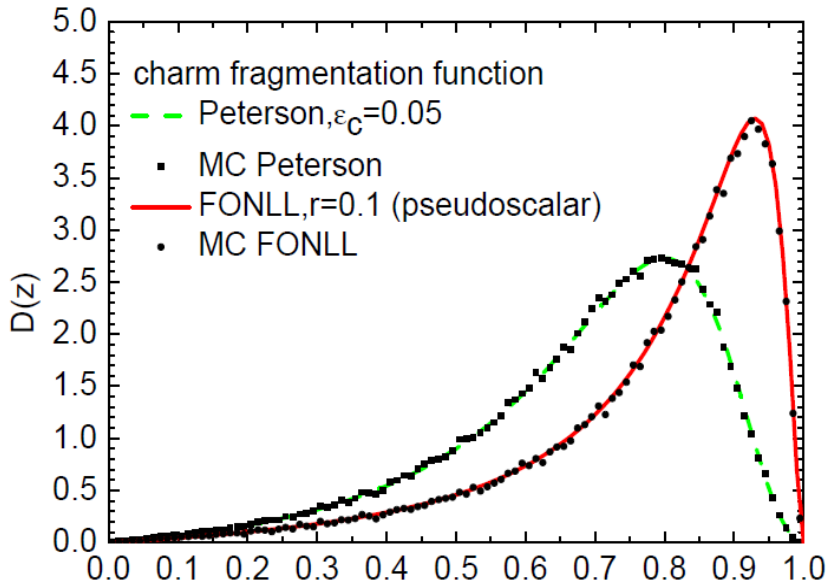
- **Strangeness supp. γ_s=0.6**

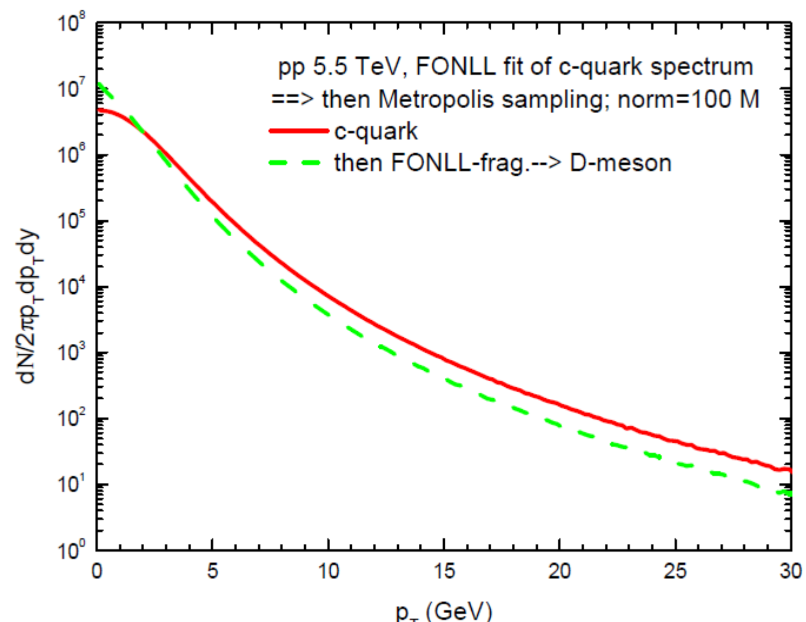
Ratios of D^+, D^{*+}, D_s^+ and Λ_c^+ to D^0 at $T_H = 170$ and 160 MeV (including strong feeddowns) in the PDG and RQM scenarios.

r_i	D^+/D^0	D^{*+}/D^0	D_s^+/D^0	Λ_c^+/D^0
PDG(170)	0.4391	0.4315	0.2736	0.2851
PDG(160)	0.4450	0.4229	0.2624	0.2404
RQM(170)	0.4391	0.4315	0.2726	0.5696
RQM(160)	0.4450	0.4229	0.2624	0.4409

Charm fragmentations and decays

- FONLL fragmentation of charm quarks into all kinds of charm-hadron
  relative weight: according to the SHM thermal densities





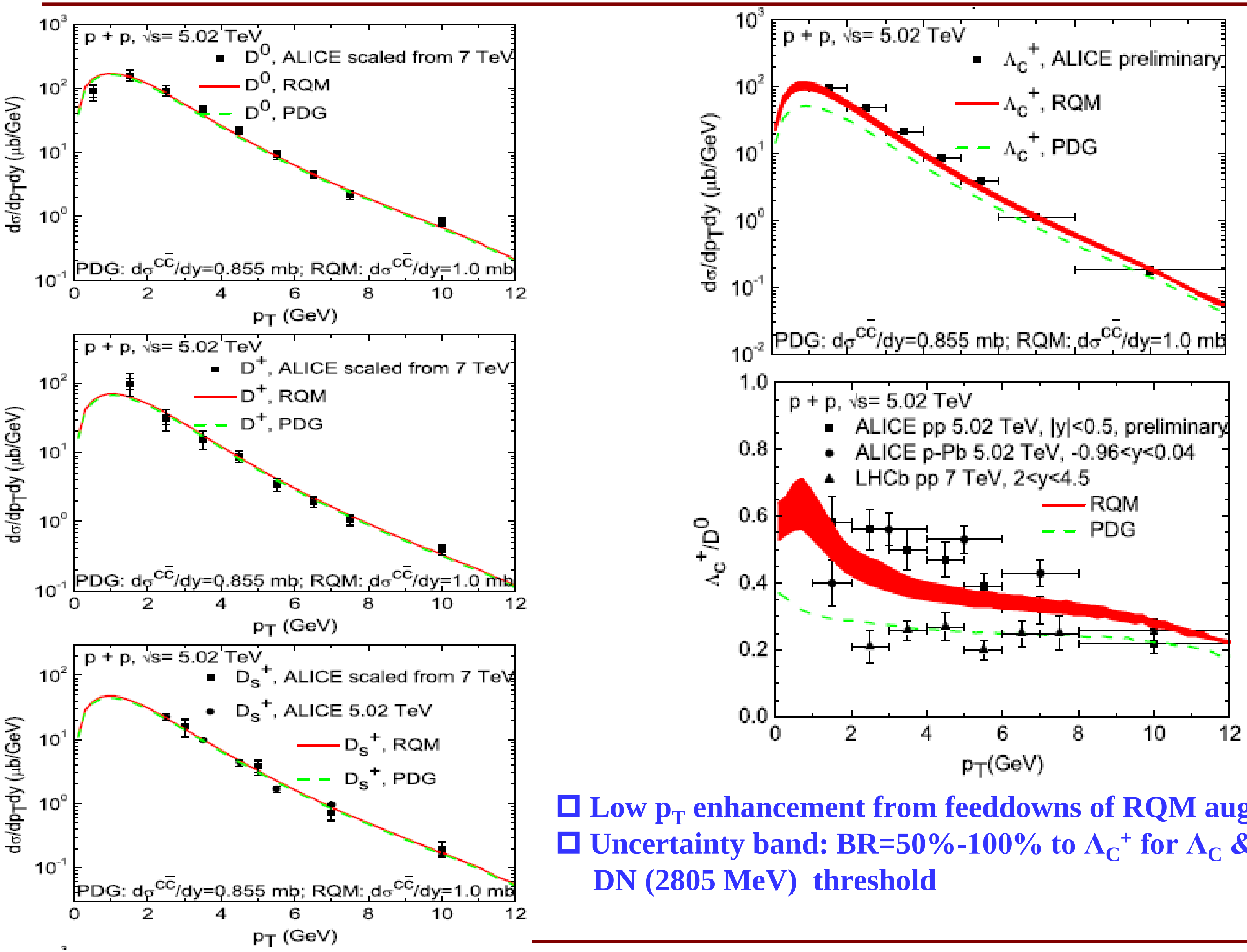
$$D_{c\to H}(z) = N_H \frac{rz(1-z)^2}{[1-(1-r)z]^6}[(6-18(1-2r)z + (21-74r+68r^2)z^2 - 2(1-r)(6-19r+18r^2)z^3 + 3(1-r)^2(1-2r+2r^2)z^4] ,$$

$$r_M/r_{D^0} = ((m_M - m_c)/m_M)/((m_{D^0} - m_c)/m_{D^0})$$

$$r_B/r_{\Lambda_c^+} = ((m_B - m_c)/m_B)/((m_{\Lambda_c^+} - m_c)/m_{\Lambda_c^+})$$

- Decay simulations of all excited states to ground state D^0, D^+, D_s^+, Λ_C^+, Ξ_C & Ω_C

Results: pp 5.02 TeV collisions



- Low p_T enhancement from feeddowns of RQM augmented baryons
- Uncertainty band: BR=50%-100% to Λ_C^+ for Λ_C & Σ_C above DN (2805 MeV) threshold

Charm-hadron production in AA collisions

- Charm quark diffusion in QGP: T-matrix & Langevin
- 2- & 3-body RRM, equilibrium mapping
- Space-momentum correlations (SMCs)
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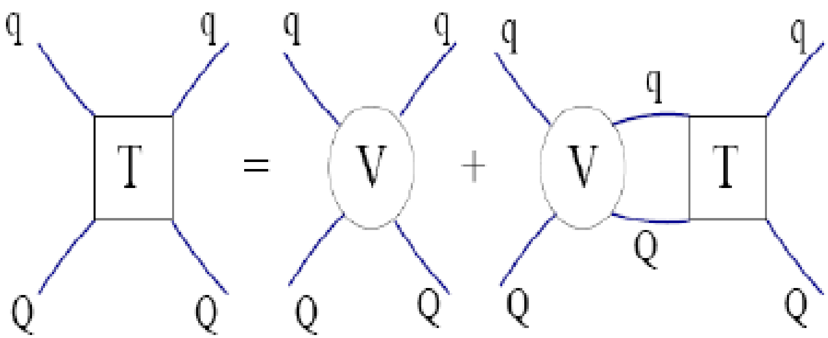
Charm in QGP: transport coeffi. & diffusion

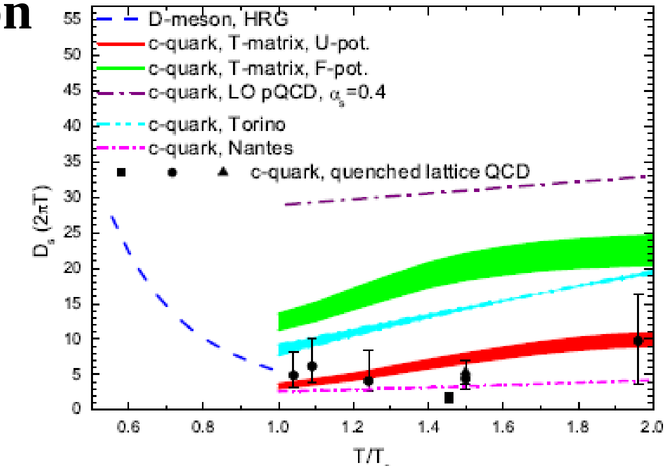
Langevin + hydro simulation down to Tc=170 MeV
fluid rest frame updates → boost to lab frame

$$dx_j = \frac{p_j}{E}dt,$$

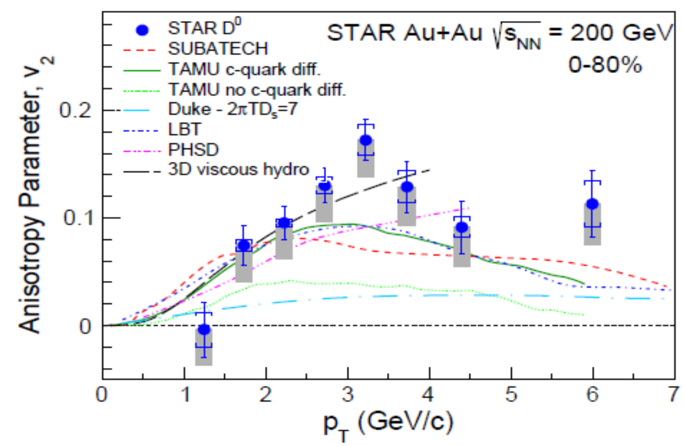
$$dp_j = -\Gamma(p)p_j dt + \sqrt{2dt\, D(|p+\xi dp|)}\rho_j.$$

- ☐ Lattice HQ U-pot. T-matrix resummation





- ☐ p- and T-dependent transport with $\mathcal{D}_s(2\pi T) \sim 2\text{-}4$ near T_{pc}



- ☐ Observed large D-meson v_2 --- strong coupling of charm with QGP near T_{pc} He, Fries, Rapp

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Resonance Recombination Model (RRM)

- **Hadronization = Resonance formation** $c\bar{q} \longrightarrow D$

  → ***consistent with T-matrix findings of resonance correlations towards T_c***

- **Realized by Boltzmann equation** **Ravagli & Rapp,2007**

$$p^{\mu}\partial_{\mu} f_M(t,\vec{x},\vec{p}) = -m\Gamma f_M(t,\vec{x},\vec{p}) + p^0\beta(\vec{x},\vec{p})$$

$$\beta(\vec{x},\vec{p}) = \int \frac{d^3p_1 d^3p_2}{(2\pi)^6} f_q(\vec{x},\vec{p}_1) f_{\bar{q}}(\vec{x},\vec{p}_2) \times \sigma(s) v_{\mathrm{rel}}(\vec{p}_1,\vec{p}_2)\delta^3(\vec{p}-\vec{p}_1-\vec{p}_2)$$

gain term

Breit-Wigner

$$\sigma(s) = g_\sigma \frac{4\pi}{k^2} \frac{(\Gamma m)^2}{(s-m^2)+(\Gamma m)^2}$$

- **Equilibrium limit** $f_M(\vec{x},\vec{p}) = \frac{\gamma_{p,M}}{\Gamma_M}\int \frac{d^3\vec{p}_1 d^3\vec{p}_2}{(2\pi)^3} f_q(\vec{x},\vec{p}_1) f_{\bar{q}}(\vec{x},\vec{p}_2) \times \sigma_M(s) v_{\mathrm{rel}}(\vec{p}_1,\vec{p}_2)\delta^3(\vec{p}-\vec{p}_1-\vec{p}_2)$,

- **Energy conservation** + **detailed balance**

→ **equilibrium mapping between quark & meson distributions**

Generalization to 3-body RRM

- **The 1st step: $q_1(p_1) + q_2(p_2) \rightarrow$ diquark (p_{12})**

$$f_d(\vec{x},\vec{p}_{12}) = \frac{E_d(\vec{p}_{12})}{\Gamma_d m_d}\int \frac{d^3p_1 d^3p_2}{(2\pi)^3} f_1(\vec{x},\vec{p}_1) f_2(\vec{x},\vec{p}_2)\sigma_{12}(s_{12})v_{\rm rel}^{12}(\vec{p}_1,\vec{p}_2)\delta^3(\vec{p}_{12}-\vec{p}_1-\vec{p}_2)$$

- **The 2nd step: diquark (p_{12}) $+ q_3(p_3) \rightarrow$ baryon (p)**

$$f_B(\vec{x},\vec{p}) = \frac{E_B(\vec{p})}{\Gamma_B m_B}\int \frac{d^3p_{12} d^3p_3}{(2\pi)^3} f_d(\vec{x},\vec{p}_{12}) f_3(\vec{x},\vec{p}_3)\sigma_B(s_{d3})v_{\rm rel}^{d3}(\vec{p}_{12},\vec{p}_3)\delta^3(\vec{p}-\vec{p}_{12}-\vec{p}_3)$$

$$= \frac{E_B(\vec{p})}{\Gamma_B m_B}\int \frac{d^3p_1 d^3p_2 d^3p_3}{(2\pi)^6}\frac{E_d(\vec{p}_{12})}{\Gamma_d m_d} f_1(\vec{x},\vec{p}_1) f_2(\vec{x},\vec{p}_2) f_3(\vec{x},\vec{p}_3)$$

$$\times\, \sigma_{12}(s_{12})v_{\rm rel}^{12}(\vec{p}_1,\vec{p}_2)\sigma_B(s_{d3})v_{\rm rel}^{d3}(\vec{p}_{12},\vec{p}_3)|_{\vec{p}_{12}=\vec{p}_1+\vec{p}_2}\delta^3(\vec{p}-\vec{p}_1-\vec{p}_2-\vec{p}_3)$$

--- **baryons formed via "dynamically" generating an intermediate diquark resonance, finally still depending on 3 quark distributions on equal footing**

- **Meson/baryon invariant spectra on hydrodynamic Cooper-Frye hypersurface at T_H=170 MeV**

$$\frac{dN_{M,B}}{p_T dp_T d\phi_p dy} = \int \frac{p\cdot d\sigma}{(2\pi)^3} f_{M,B}(\vec{x},\vec{p})$$

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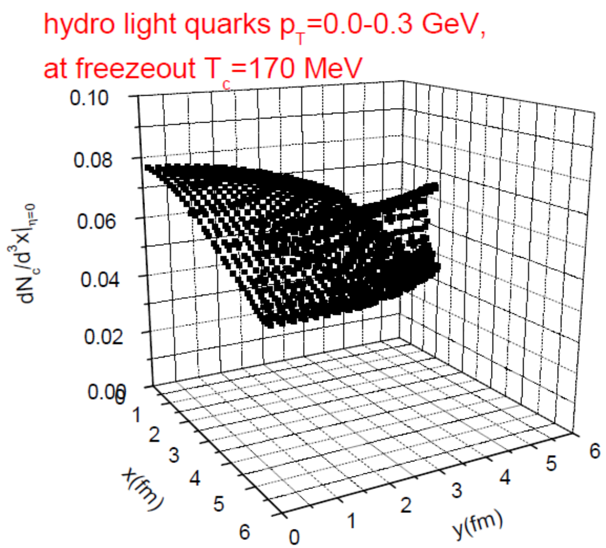
Space-momentum correlations (SMCs)

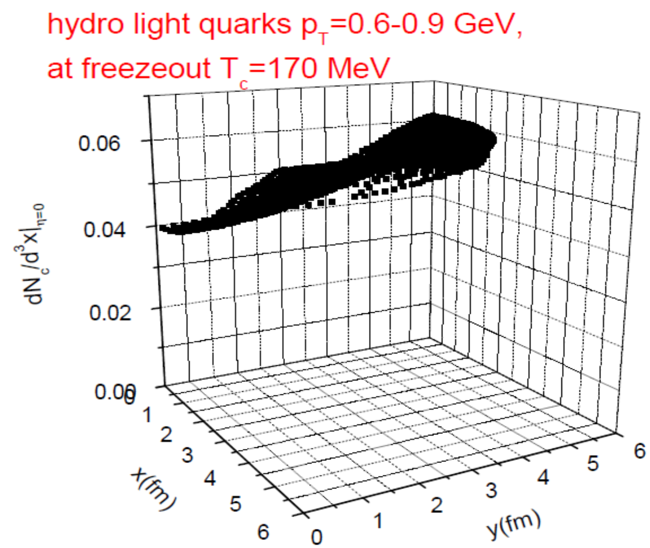
- **hydro: a manifestation of SMCs**

$$f_q^{eq}(\vec{x},\vec{p}) = g_q e^{-p\cdot u(x)/T(x)} = g_q e^{-\gamma_T(x)[m_T\cosh(y-\eta)-\vec{p}_T\cdot\vec{v}_T(x)]/T(x)}$$

longitudinal boost invariance: y- η **transverse SMCs $p_T \cdot v_T$**

- **hydro-q density: low (high) p_T-q more concentrated in center (boundary)**



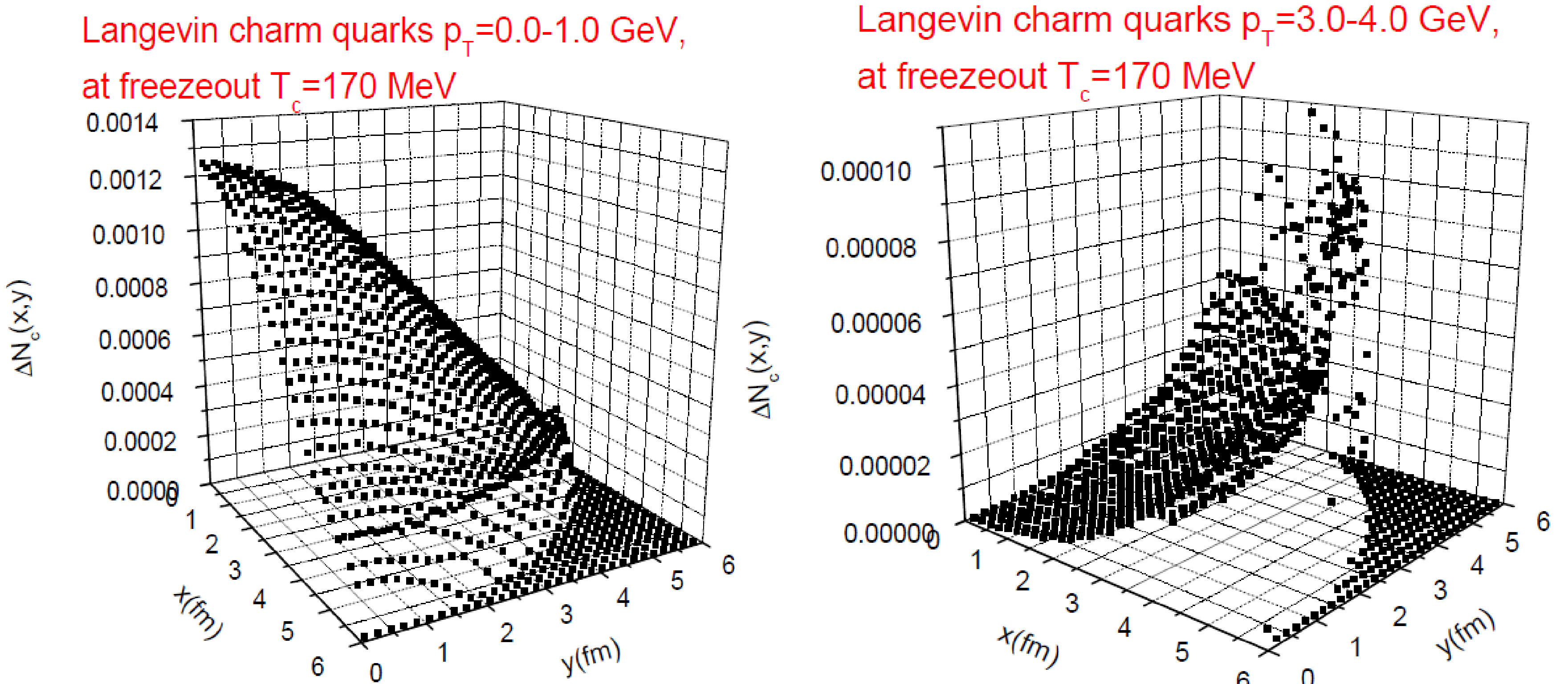


- **what if neglecting SMCs: uniformly distributed independent of p_T as usually done in conventional instantaneous coalescence models**

$$f_{c,q}(\vec{x},\vec{p}) = (2\pi)^3\frac{dN_{c,q}}{d^3\vec{x}d^3\vec{p}} = \frac{(2\pi)^3}{V E_{(\vec{p})}}\frac{dN_{c,q}}{p_T dp_T d\phi_q dy} \quad \& \quad \int p\cdot d\sigma = E(\vec{p})V$$

SMCs: Langevin charm quarks

- Langevin simulation of charm quark diffusion in a hydrodynamically expanding QGP with T-matrix charm thermalization rate
- c-quarks: low (high) p_T-c more populated in central (outer) region



- SMCs usually neglected in ICMs: uniformly distributed independent of p_T
- what will be the role of SMCs in recombination/RRM?

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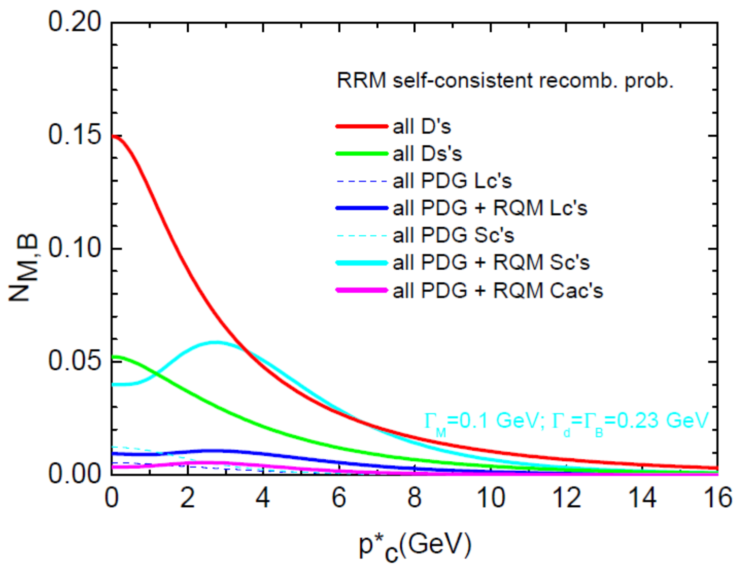
Charm quark recombination probability

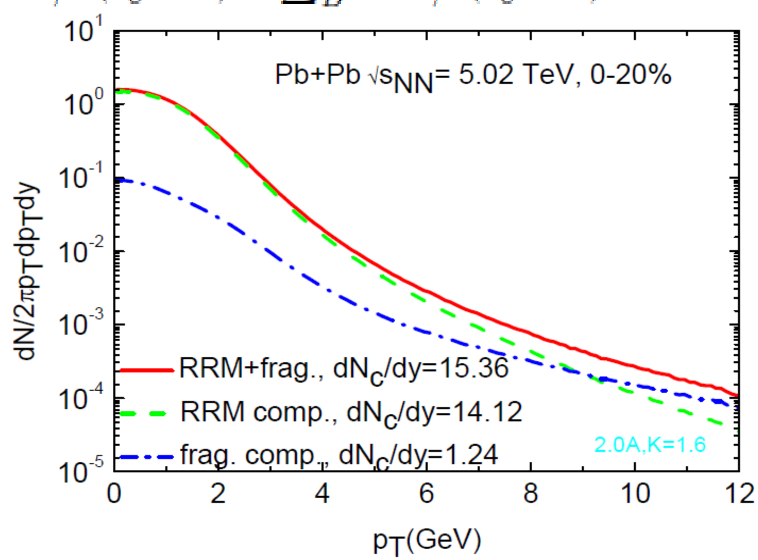
- No. of mesons/baryons formed from a single c-quark of rest frame p_c^*

$$N_M(p_c^*) = \int \frac{d^3\vec{p}_1^*}{(2\pi)^3} g_q e^{-E(\vec{p}_1^*)/T_{\rm pc}} \frac{E_M(\vec{p}^*)}{m_M\Gamma_M}\sigma(s)v_{\rm rel},$$

$$N_B(p_c^*) = \int \frac{d^3p_1 d^3p_2}{(2\pi)^6} g_1 e^{-E(\vec{p}_1)/T_c} g_2 e^{-E(\vec{p}_2)/T_c} \frac{E_d(\vec{p}_{12})}{m_d\Gamma_d}\sigma(s_{12})v_{\rm rel}^{12}(\vec{p}_1,\vec{p}_2)\frac{E_B(\vec{p})}{m_B\Gamma_B}\sigma(s_{d3})v_{rel}^{d3}(\vec{p}_{12},\vec{p}_{30}),$$

- Renormalizing $N_M(p_c^*)$ and $N_B(p_c^*)$ by a common factor~3.6 for all charmed mesons/baryons such that $\sum_M P_{{\rm coal},M}(p_c^*=0) + \sum_B P_{{\rm coal},B}(p_c^*=0) = 1$





--- charm conservation consistently built in, in a (e-by-e) way without spoiling the relative chemical equilibrium realized by RRM

Event-by-event Langevin-RRM simulation

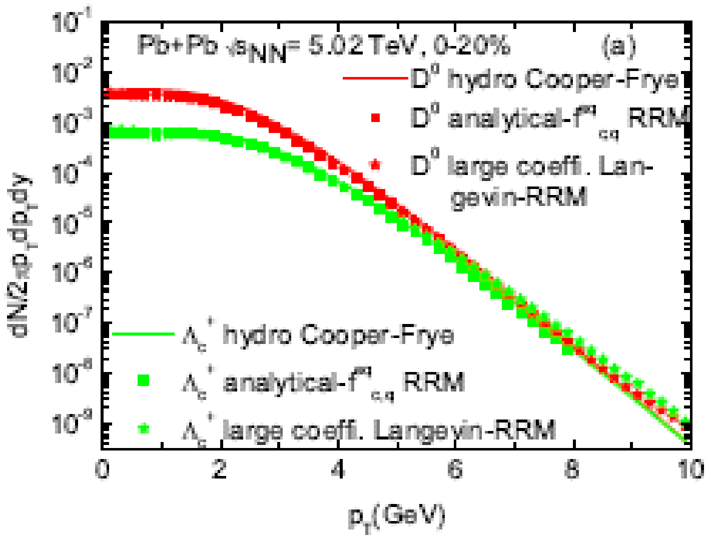
- **for a single Langevin c-quark, sample a/two thermal light-q distribution(s)**

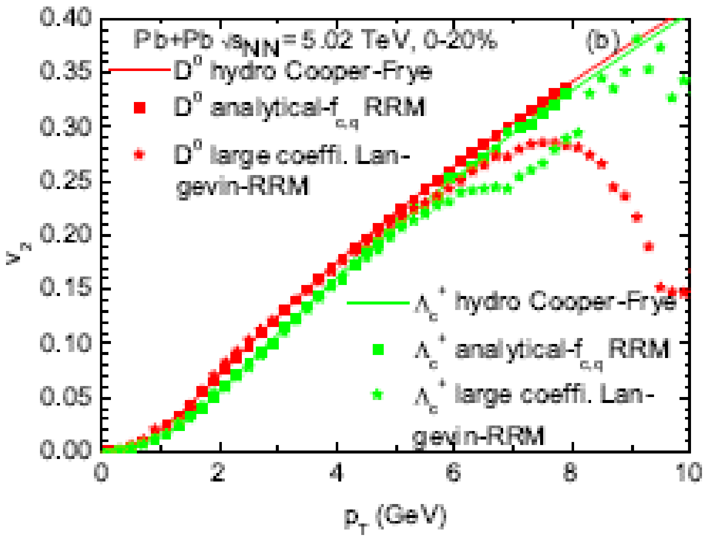
$$\frac{dN_M}{d\eta}|_{\eta=0} \equiv \sum_n \Delta N_M[n] = \sum_n \frac{p \cdot d\sigma(j_0)}{m_M \Gamma_M} \sigma(s) v_{\rm rel} \qquad \vec{p} = \vec{p}_{1n} + \vec{p}_c$$

$$\frac{dN_B}{d\eta}|_{\eta=0} \equiv \sum_{n_1} \sum_{n_2} \Delta N_B[n_1, n_2]$$

$$= \sum_{n_1} \sum_{n_2} \frac{p \cdot d\sigma(j_0)}{m_B \Gamma_B} \frac{E_d(\vec{p}^*_{12})}{m_d \Gamma_d} \sigma(s_{12}) v^{12}_{\rm rel}(\vec{p}^*_{1n_1}, \vec{p}^*_{2n_2}) \sigma(s_{d3}) v^{d3}_{rel}. \qquad \vec{p} = \vec{p}_{1n_1} + \vec{p}_{2n_2} + \vec{p}_c$$

- **equil. mapping with large transport coeffi. checks out: SMCs incorporated**





- **equil. mapping: both kinetic & chemical ➔ observables come out as RRM predictions with realistic T-matrix transport coefficient**

Charm-hadron production in AA collisions

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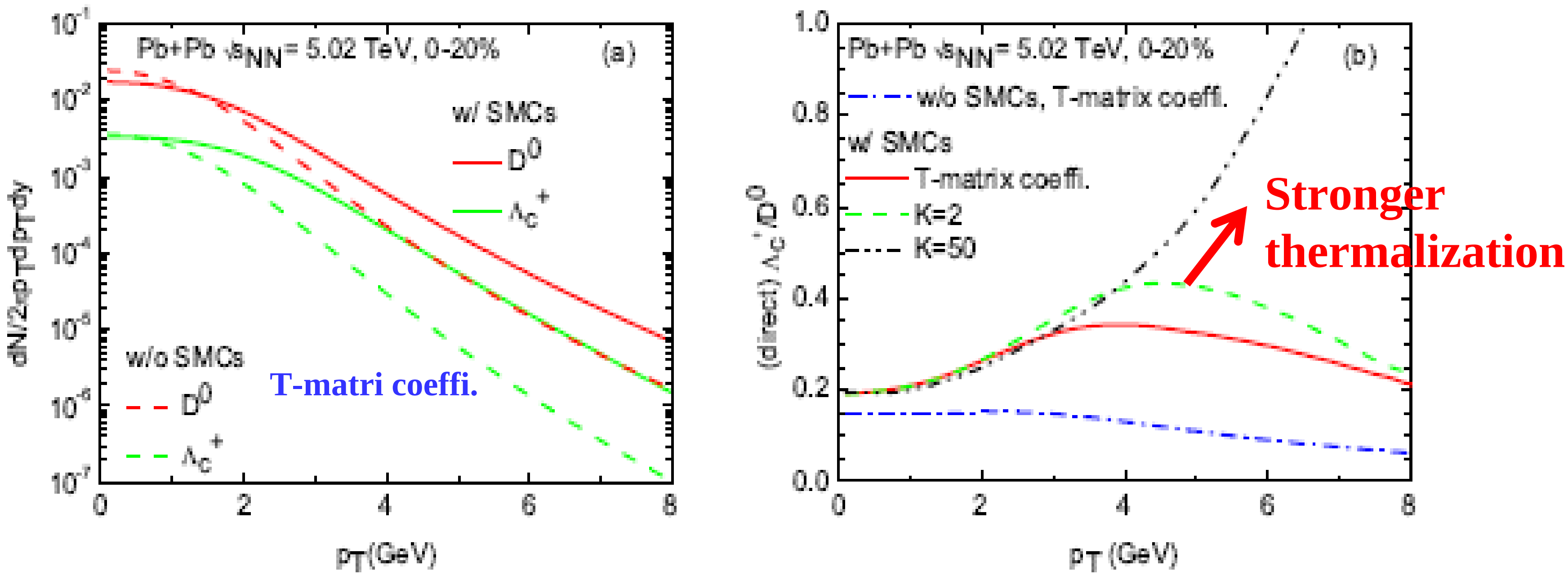
Direct D^0 & Λ_c^+ production via RRM

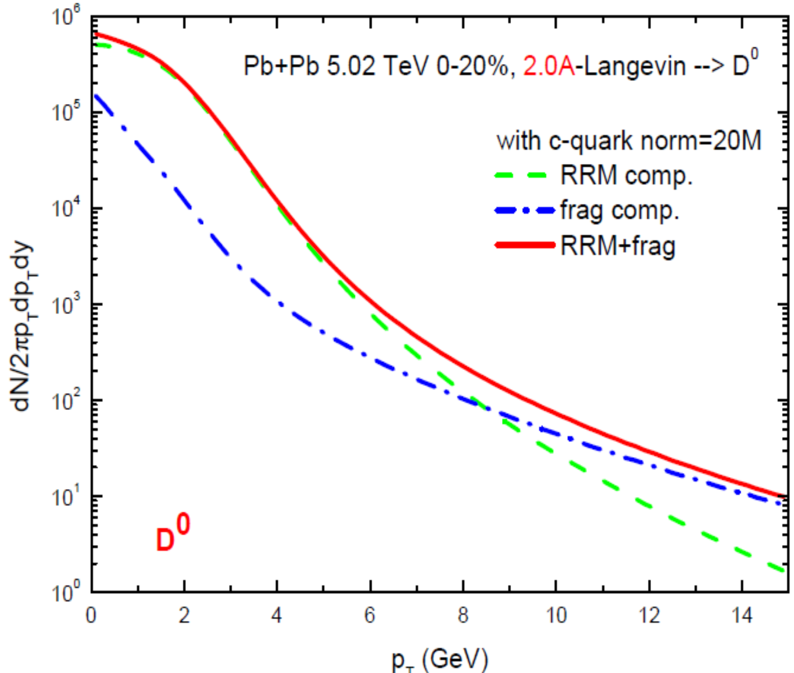
- ☐ Including **SMCs** makes the spectra harder & enhances the ratio Λ_c^+/D_0

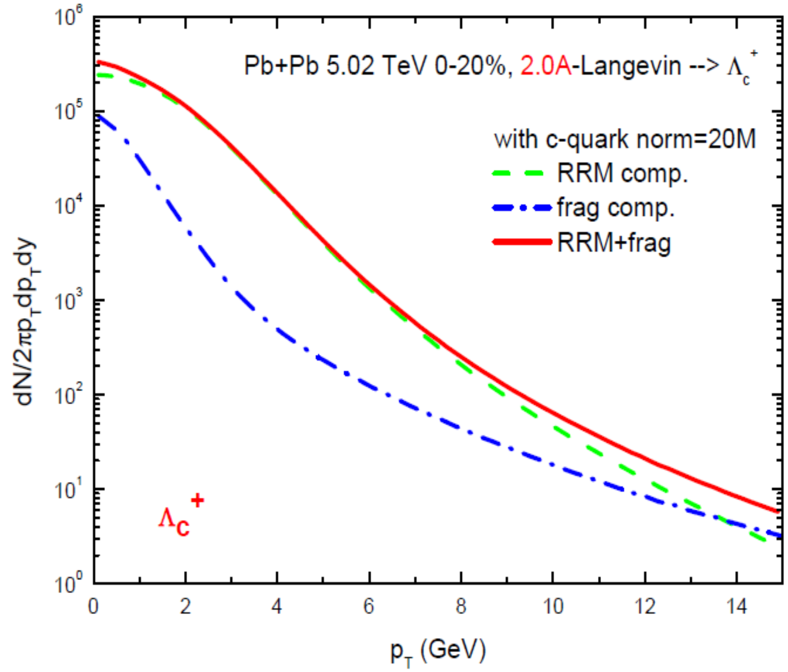


- ☐ Relatively fast-moving c-quarks [p_T~ 3-4 GeV] moving to the outer part of the fireball find higher-density of harder [p_T~ 0.6-0.9 GeV] light quarks for recombination
- ☐ An effect entering squared for the recombination production of Λ_c^+

Recombinant vs fragmenting spectra

- **Hydro-Langevin-RRM(+fragmentation): for all charm-mesons/baryons**
  ➔ higher states decay into ground state D^0 , D^+ , D_s^+ , Λ_C^+

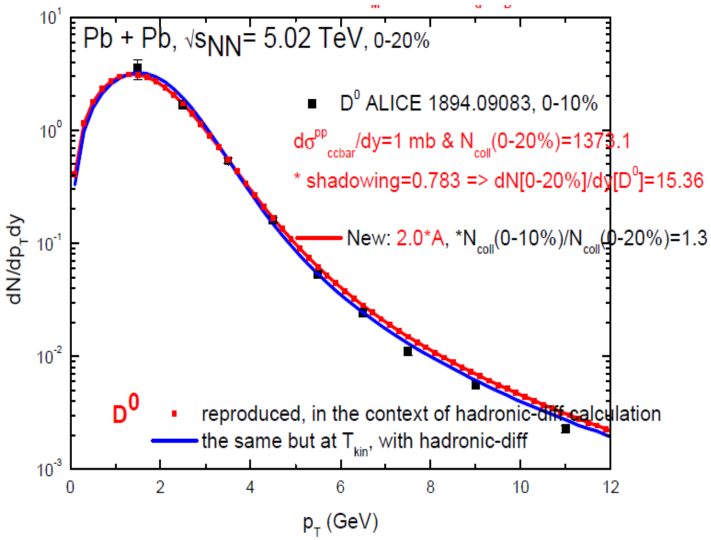


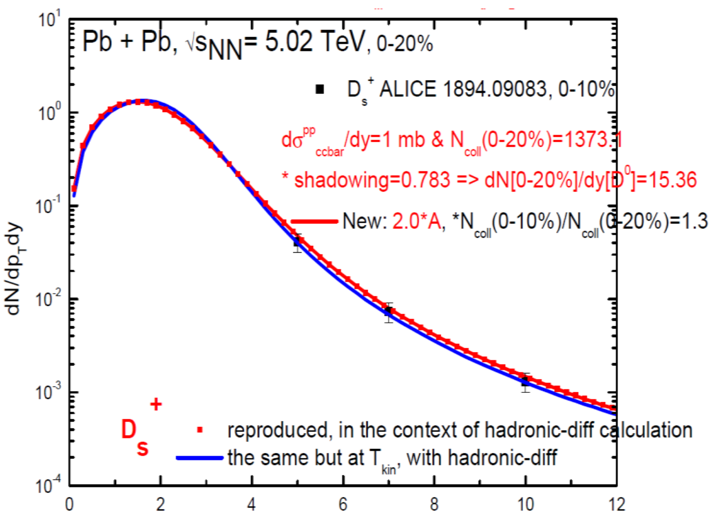


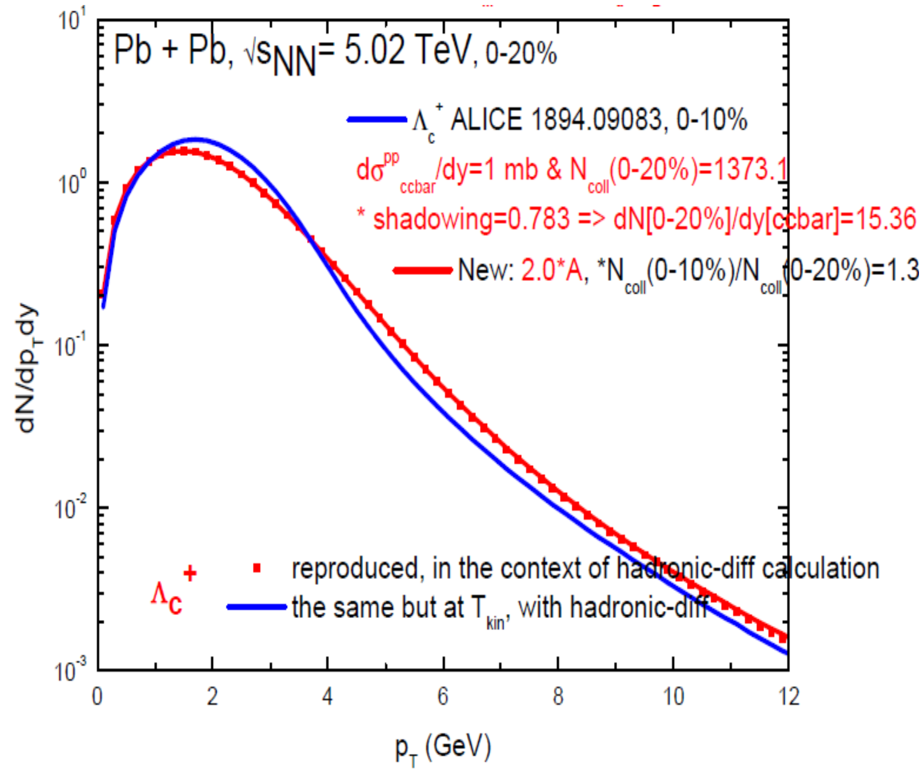
- **SMCs extend the recombinant component toward (quite) higher p_T; RQM augmented higher baryon states' RRM spectra even harder (also thanks to SMCs) ➔ RRM & frag. cross at p_T ~8.5 (13) GeV for D^0 (Λ_C^+)**

- **Helpful for large total v_2 (weighted between RRM vs frag. components)**

Further interaction in hadronic phase







- **Charm-meson/baryon hadronic diffuion coeffi.: empirical cross sections** He, Fries, Rapp'12
- **Further mild suppression & mild increase in v_2**

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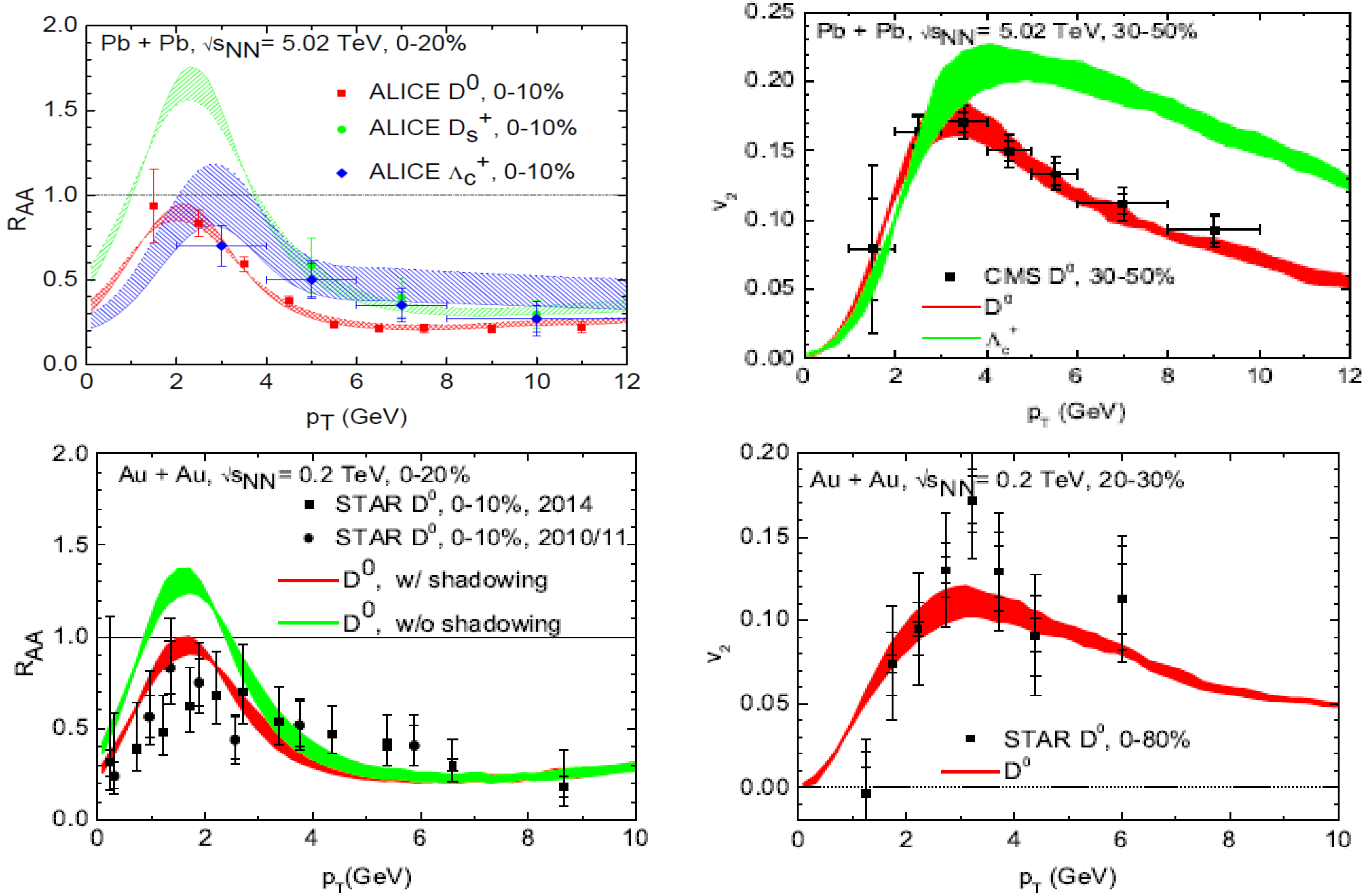
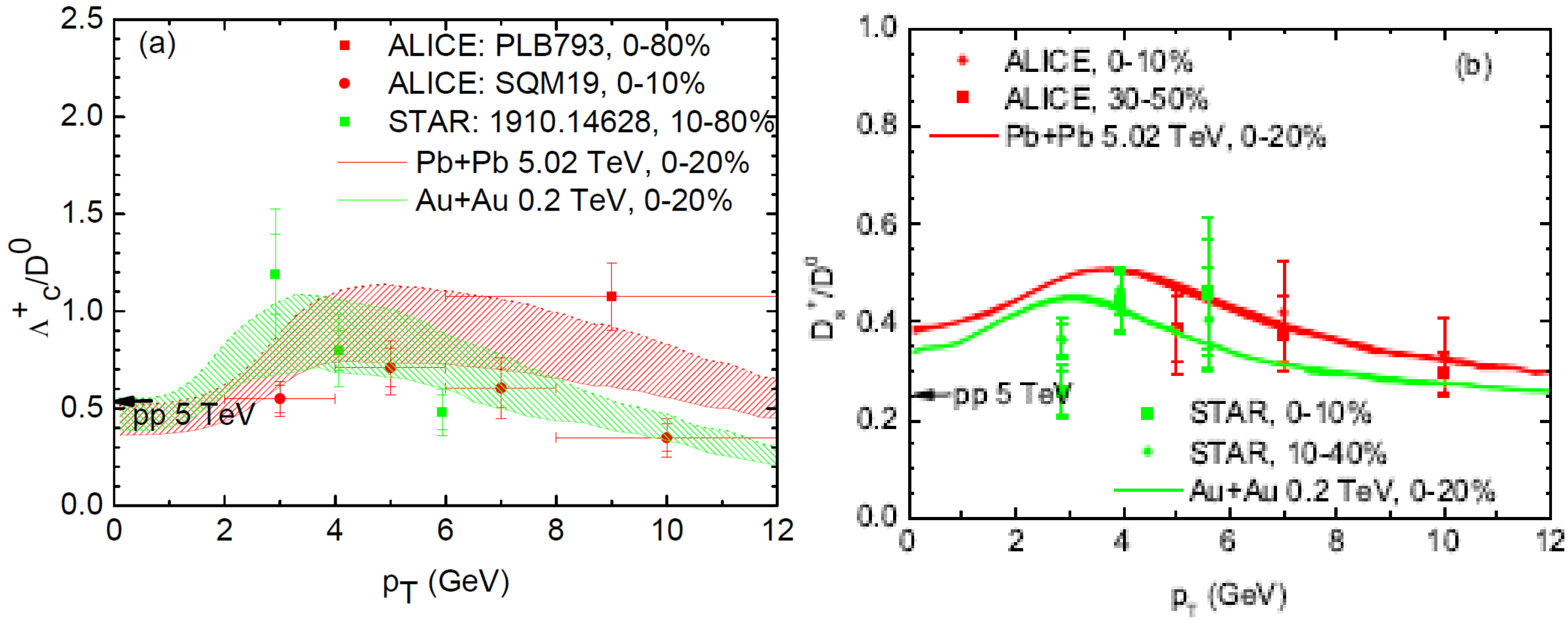
D^0, D_s^+ & Λ_c^+ suppression & elliptic flow

- **Final total D^0 , D_s^+ & Λ_c^+, including feeddowns from all RQM baryons**



- **T-matrix coefficient*K-factor(=1.6), to compensate for radiative e-loss; uncertainty: BR=50-100% to Λ_C^+ for Λ_C's & Σ_C's above DN (2805 MeV)**

Total Λ_c^+/D_0 & D_s^+/D^0



- **T-matrix coefficient*K-factor(=1.6), to compensate for radiative e-loss; BR=50-100% to Λ_C^+ for Λ_C's & Σ_C's above DN (2805 MeV) threshold**
- **Λ_c^+/D^0 : low p_T RRM equil. limit = SHM pp; intermediate p_T enhancement from RRM with SMCs; high p_T fragmentation pp value; Data (updated RHIC and LHC) trend largely reproduced**
- **D_s^+/D^0 enhancement: recomb. of charm in a strangeness-equilibrated QGP**

Summary & outlook

>> Charm-hadron production in pp collisions

- **RQM augmented SHM**
- **Low p_T enhancement of Λ_c^+ from "missing" charm-baryons**

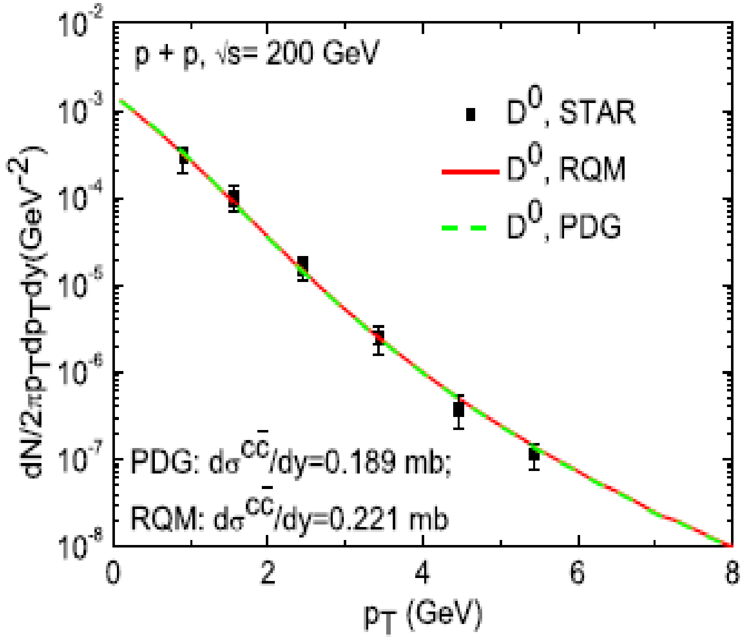
>> Charm-hadron production in AA collisions

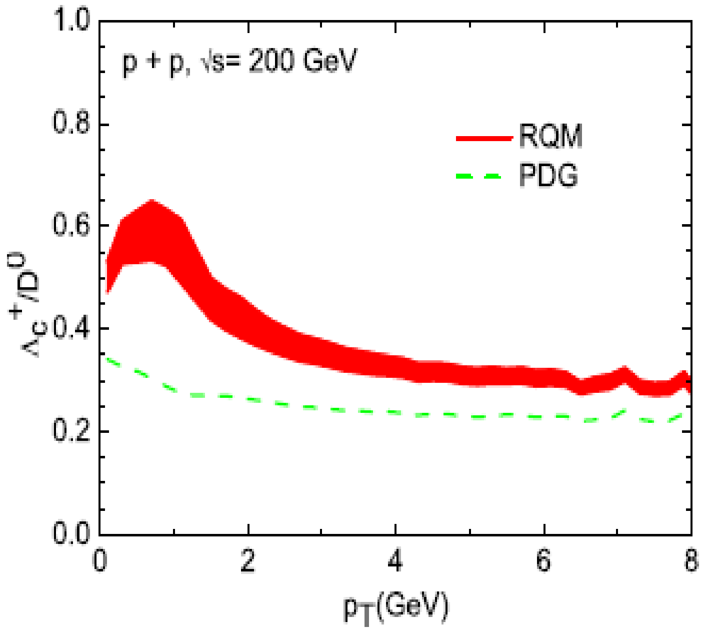
- **3-body RRM developed, equilibrium mapping (both kinetic & chemical) ensured by 4-momentum conservation**
- **Genuine space-momentum correlations (SMCs) enhancing Λ_c^+/D^0; exact charm conservation implemented on an e-by-e basis**

  ➔ **Both have been challenging within conventional instantaneous coalescence models**

- **p_T-dependent Λ_c^+/D^0 & D_s^+/D^0 enhancement emerge from hydro-Langevin-RRM(+fragmentation) simulations; data trend largely reproduced within BR's uncertainties**

Back-up: pp 200 GeV collisions





- Low pT enhancement from feeddowns of RQM augmented baryons
- Uncertainty band: BR=50-100% to Λ_C^+ for Λ_C & Σ_C above DN (2805 MeV) threshold

Conserving charm number: Ko & Greco

of Fig. 3. Being convenient to implement in our event-by-event Langevin-RRM simulation, this *global* renormalization of charm quark coalescence probability does not change the *relative* difference between the p_T spectra of any two charmed hadrons, therefore not affecting the p_T-dependent Λ_c^+/D^0. This point is in marked contrast to the treatment in [14], where the authors reduced the harmonic oscillator frequency in determining the hadron wave functions and thereby significantly increased the radii of charmed mesons and baryons (relative to the quark model predictions), in order to use up low p_T charm quarks in coalescence; the resulting Λ_c^+/D^0 was enhanced as a coincidence of using the *same* reduced frequency parameter for charmed mesons and baryons. The same purpose was achieved in [15] by artificially amplifying the normalization constants of the coalescence Wigner functions (the amplification factor of baryons is the square of that of mesons).

SMCs enhance the Λ_c^+ / D^0 at p_T~ 4.2 GeV(a)

p_{Tc} = 3-4 GeV and light quarks of p_{Tq} = 0.6-0.9 GeV are more densely distributed in the outer region of the fireball. Therefore these quarks occupy an *effectively smaller* (than the whole fireball volume $V_{\rm fb}$) volume $V_{\rm c,eff}$ and $V_{\rm q,eff}$ and thus have *effectively larger* density that can be schematically written as $\Delta N_c(p_{Tc} = 3-4\,\text{GeV})/\text{V}_{\rm c,eff}$ and $\Delta N_q(p_{Tc} = 0.6-0.9\,\text{GeV})/\text{V}_{\rm q,eff}$.

Consider, *e.g.*, the formation via RRM of D^0 and Λ_c^+ of the same p_T = 4.2 GeV. In the most straightforward picture, recombination proceeds by adding the momenta of the participating constituent quarks according to their mass ratio $m_c/m_q = 5$, once they are spatially adjacent. Therefore, charm quarks of p_{Tc} = 3.0-3.5 GeV that are already roaming around the outer region of the fireball, will have good chance to recombine with the light quarks of p_{Tq} = 0.6-0.7 GeV (remember they are also most likely to show up in the outer region) to form D^0 and Λ_c^+ of (almost) the same p_T = 4.2 GeV, roughly following the momentum addition rule $3.5 + 0.7 = 4.2$ GeV and $3.0 + 0.6 + 0.6 = 4.2$ GeV, respectively. Then the RRM production yield of D^0 and Λ_c^+ of the same p_T = 4.2 GeV is schematically expressed as

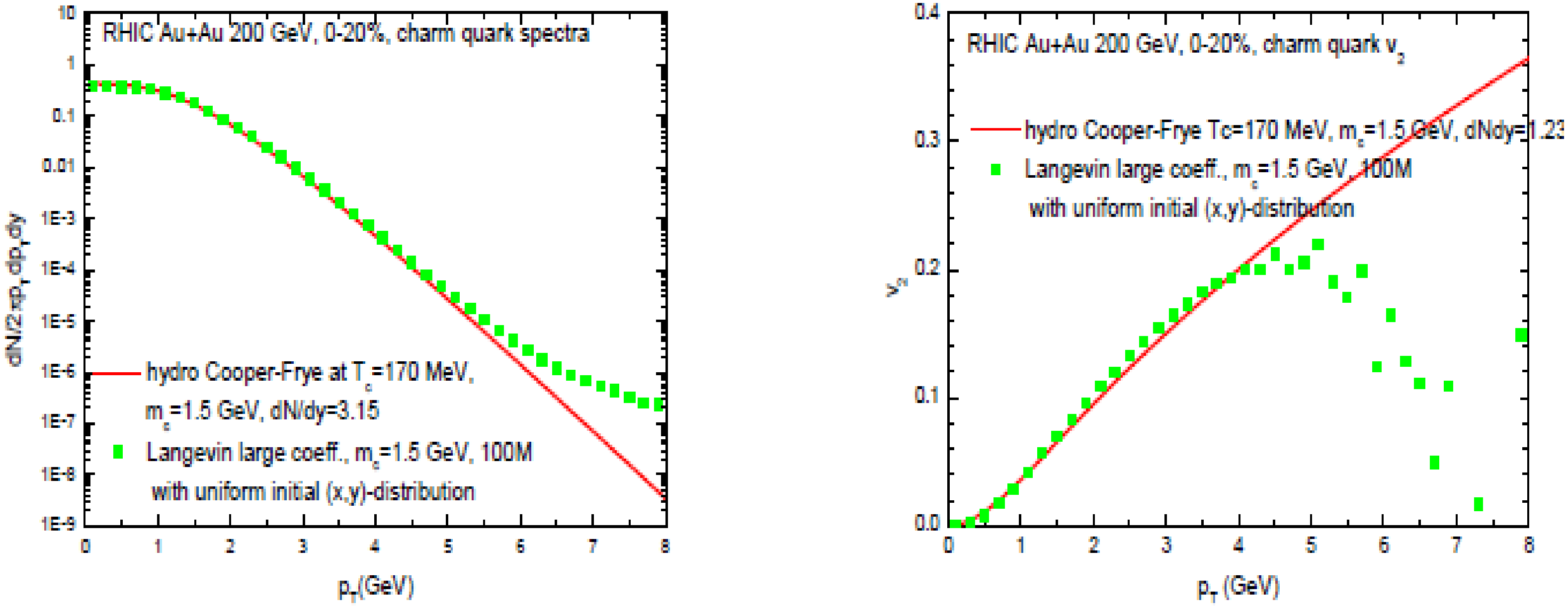
SMCs enhance the Λ_c^+ / D^0 at p_T~ 4.2 GeV(b)

$$\Delta N_{D^0}(4.2) \sim \frac{\Delta N_c(3.0-3.5)}{V_{\mathrm{c,eff}}} \cdot \frac{\Delta N_q(0.6-0.7)}{V_{\mathrm{q,eff}}} \qquad (8)$$

$$\Delta N_{\Lambda_c^+}(4.2) \sim \frac{\Delta N_c(3.0-3.5)}{V_{\mathrm{c,eff}}} \cdot \frac{\Delta N_q(0.6-0.7)}{V_{\mathrm{q,eff}}} \cdot \frac{\Delta N_q(0.6-0.7)}{V_{\mathrm{q,eff}}}$$

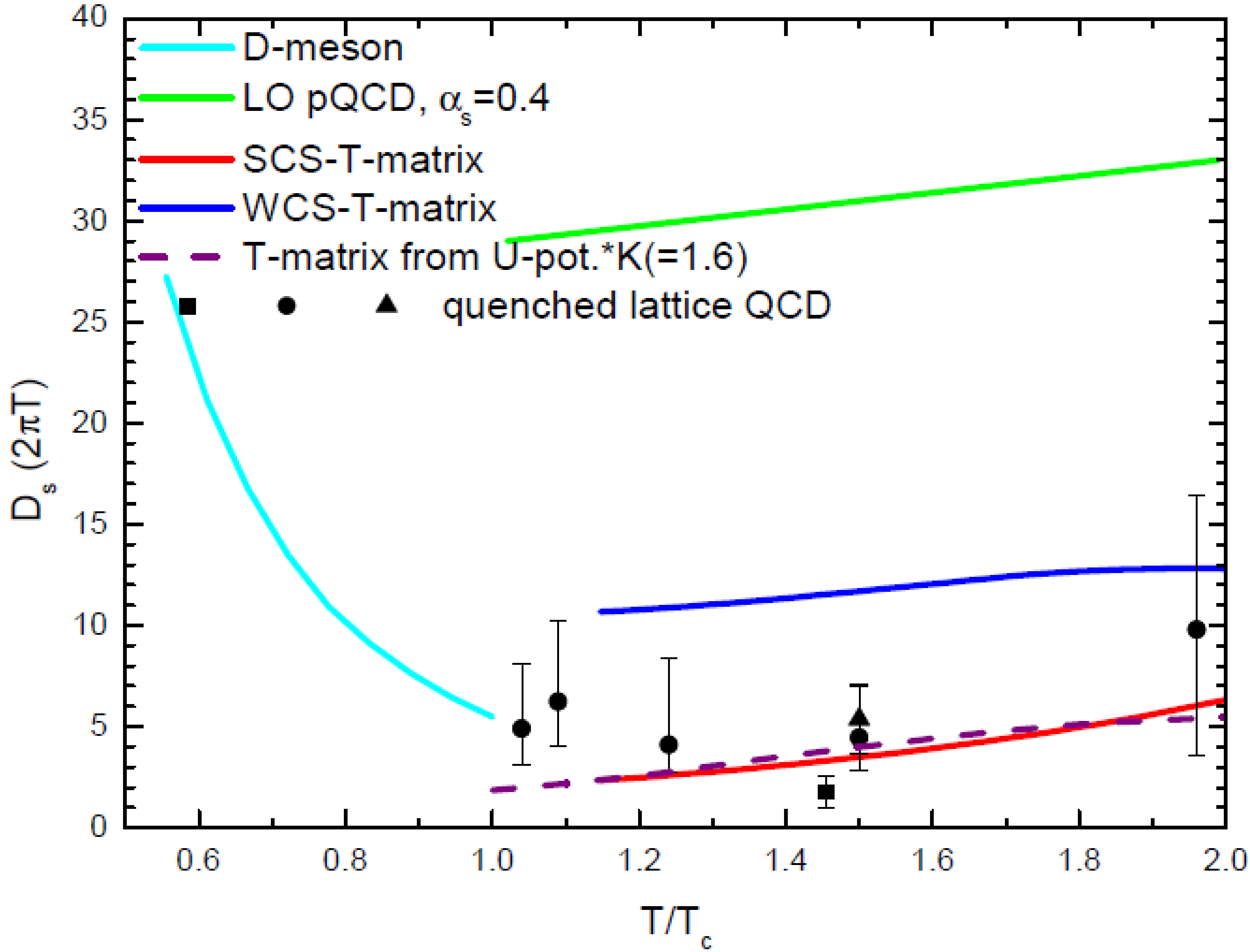
quarks in the specified p_T interval (*i.e.*, p_{Tc} =3.0-3.5 GeV for charm quarks and p_{Tq} =0.6-0.7 GeV for light quarks) becomes higher than the case of RRM neglecting space-momentum correlations, where $V_{c/\mathrm{q,eff}}$ is replaced with the whole fireball volume V_{fb} and the densities thus become *uniform* and *smaller*. Furthermore, while the higher light quark spatial density is counted only once in D^0's RRM, the square of it comes into the Λ_c^+'s RRM, leading to a stronger enhancement in Λ_c^+ spectra and thereby an enhanced Λ_c/D^0 ratio, relative to the case of RRM without incorporating space-momentum correlations.

Langevin equil. Limit with large coeffi.

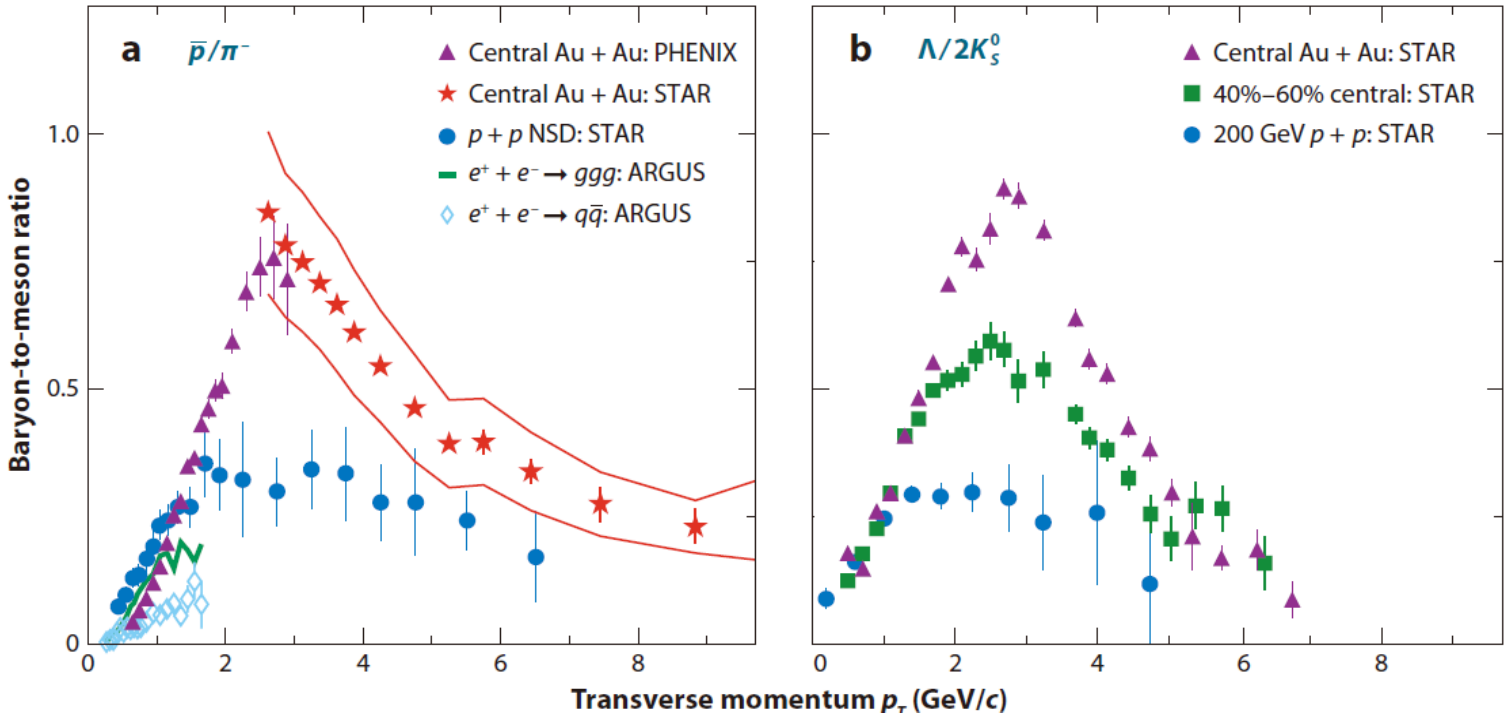


ıre 9. Langevin charm quark p_T spectra and v_2 with large coefficient.

Ds(2piT): K=1.6 vs updated SCS T-matrix



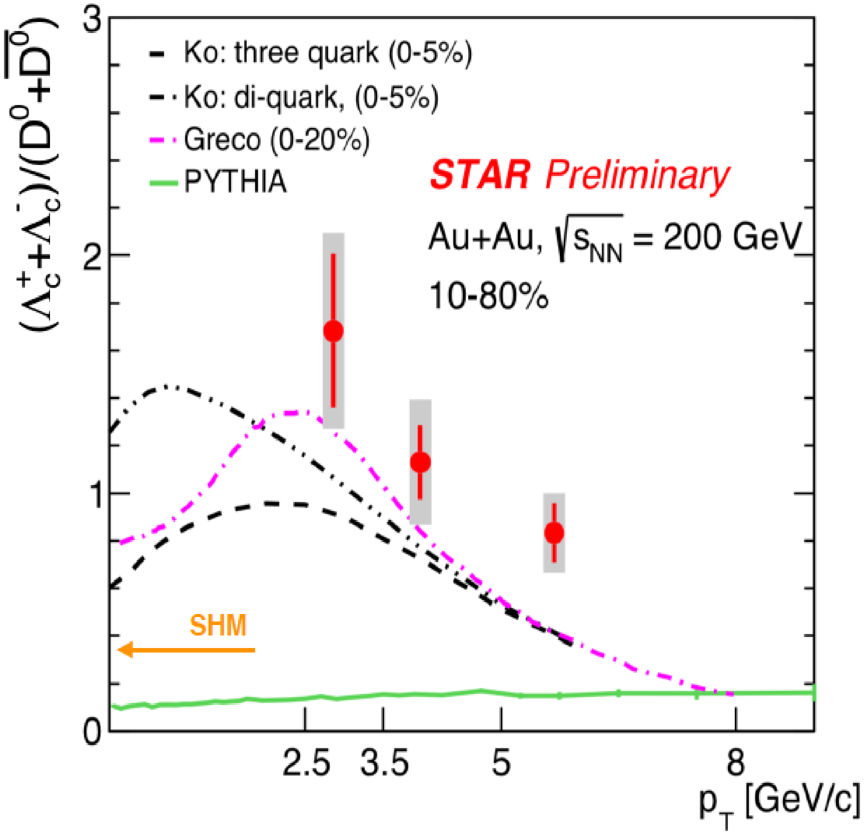
Baryon to meson ratio enhancement



- **B/M enhanced at intermediate p_T in central AA collisions**
- **Nicely (straightforwardly) explained by coalescence models** **Ko, Fries, Hwa**
- **A direct indication of the working of coalescence hadronization**

$$f_M(p_T) \sim f_q(p_T/2)*f_{qbar}(p_T/2) \quad \text{VS} \quad f_B(p_T) \sim f_q(p_T/3)*f_q(p_T/3)*f_q(p_T/3)$$

Does it carry over to the HF sector?



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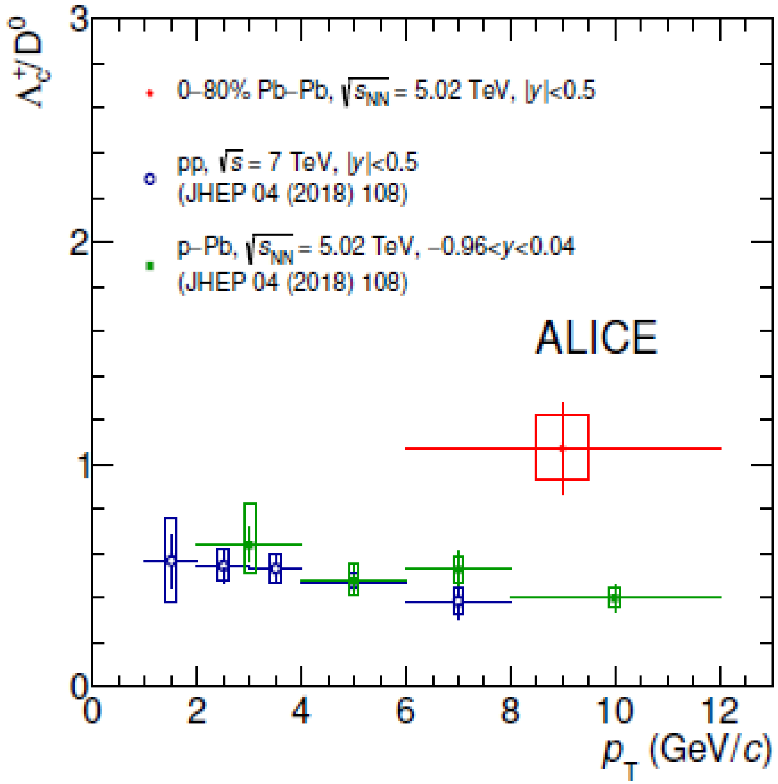
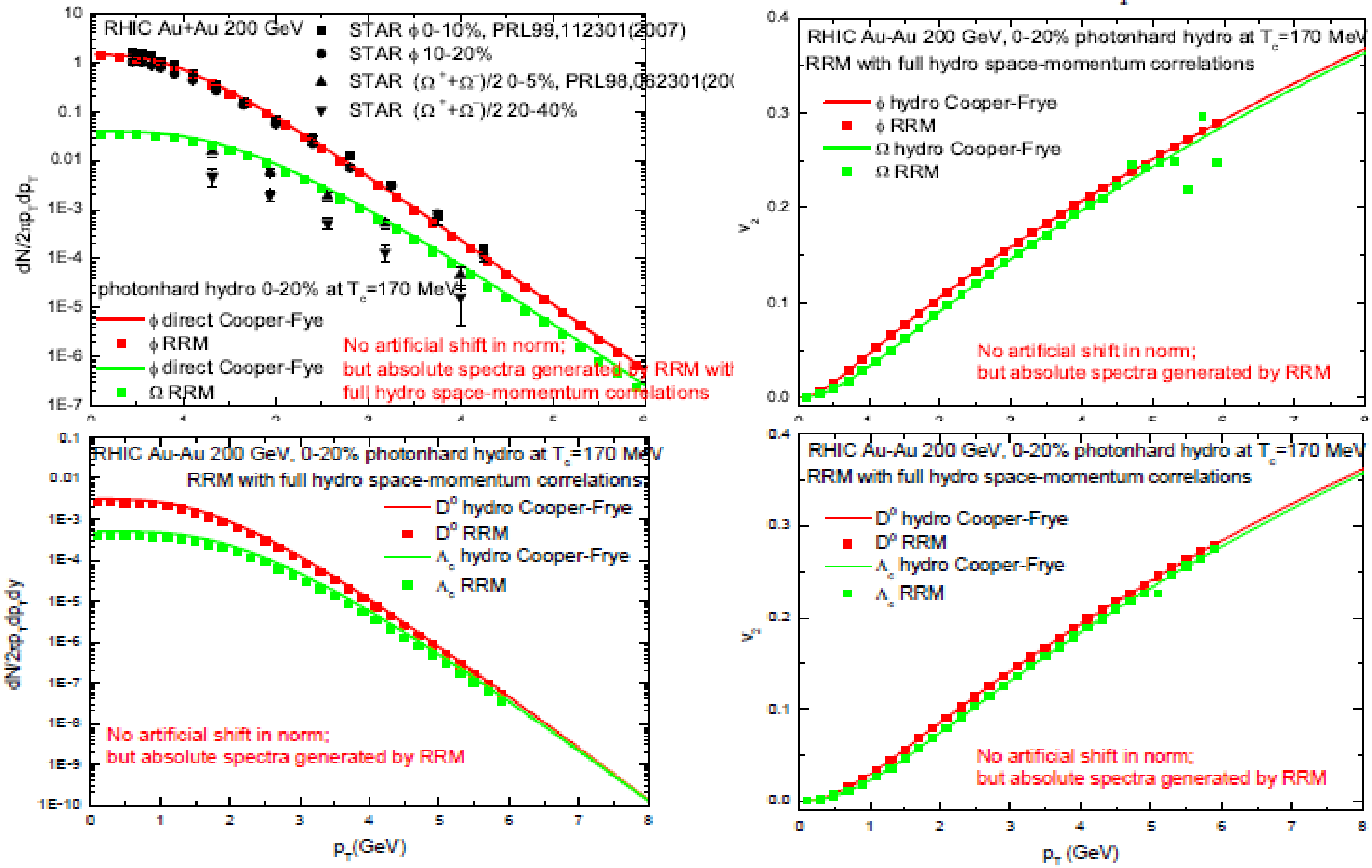


- ☐ **A sensitive probe of HQ hadronization via recombination in the presence of deconfined QGP**
- ☐ **A direct measure of the degree of HQ thermalization/interaction strength**

RRM: equilibrium mapping

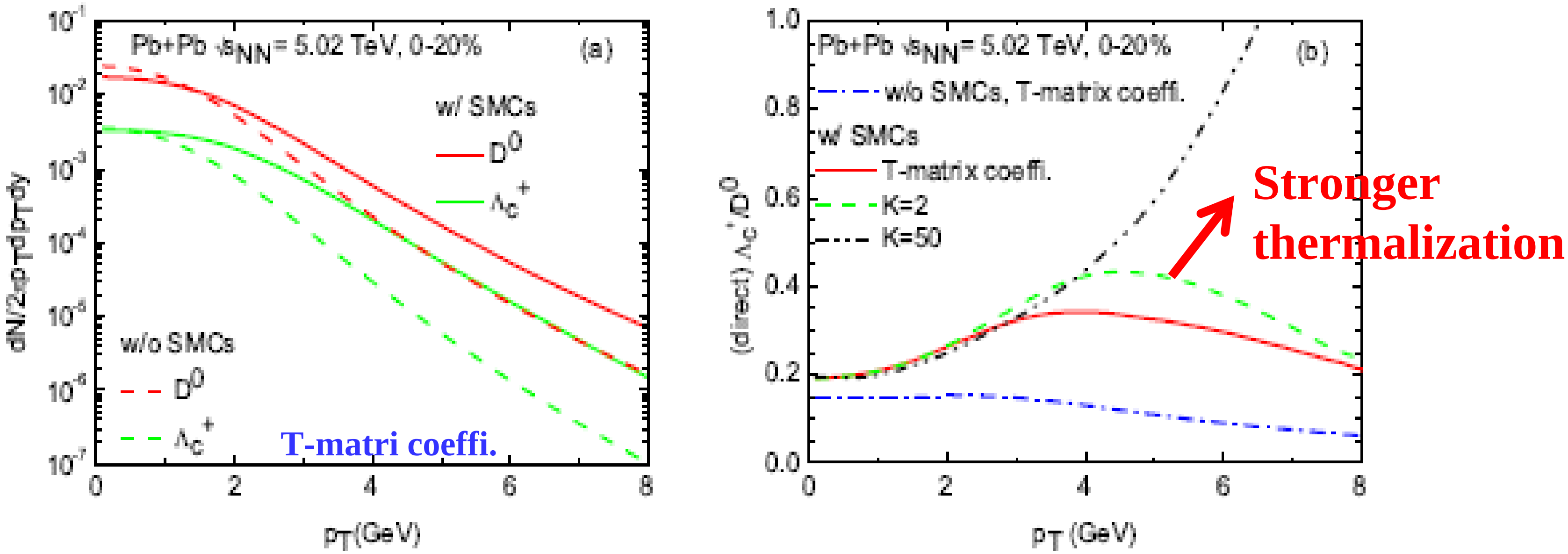
- **RRM on hydrofreezeout hypersurface at T_c with** $f_q^{eq}(\vec{x},\vec{p}) = g_q e^{-p\cdot u(x)/T(x)}$



- **Equilibrium mapping: ensured by 4-momentum conservation in RRM**
  m_q=0.3, m_s=0.4, m_c=1.5, Γ_M~0.1 GeV, Γ_d~0.2 GeV, Γ_B~0.3 GeV

Direct D^0 & Λ_c^+ production via RRM

- **Including SMCs makes the spectra harder & enhances the ratio Λ_c^+/D_0**



- **Consider RRM formation of D^0 (3.5+0.7) & Λ_c^+ (3.0+0.6+0.6) of p_T~4.2 GeV: enhancement of density of light-q of p_T~ 0.6-0.7 GeV & c of p_T~3.0-3.5 GeV**

$$\Delta N_{D^0}(4.2) \sim \frac{\Delta N_c(3.0-3.5)}{V_{\rm c,eff}} \cdot \frac{\Delta N_q(0.6-0.7)}{V_{\rm q,eff}} \qquad (15)$$

--- Rencombinant quark density enhanced vs w/o SMCs: $V_{eff}<V_{fb}$

$$\Delta N_{\Lambda_c^+}(4.2) \sim \frac{\Delta N_c(3.0-3.5)}{V_{\rm c,eff}} \cdot \frac{\Delta N_q(0.6-0.7)}{V_{\rm q,eff}} \cdot \frac{\Delta N_q(0.6-0.7)}{V_{\rm q,eff}}$$

--- Enhanced light-q density entering D^0 RRM only once vs twice (squared) for Λ_c^+ RRM ➔ the ratio Λ_c^+/D^0 enhanced!