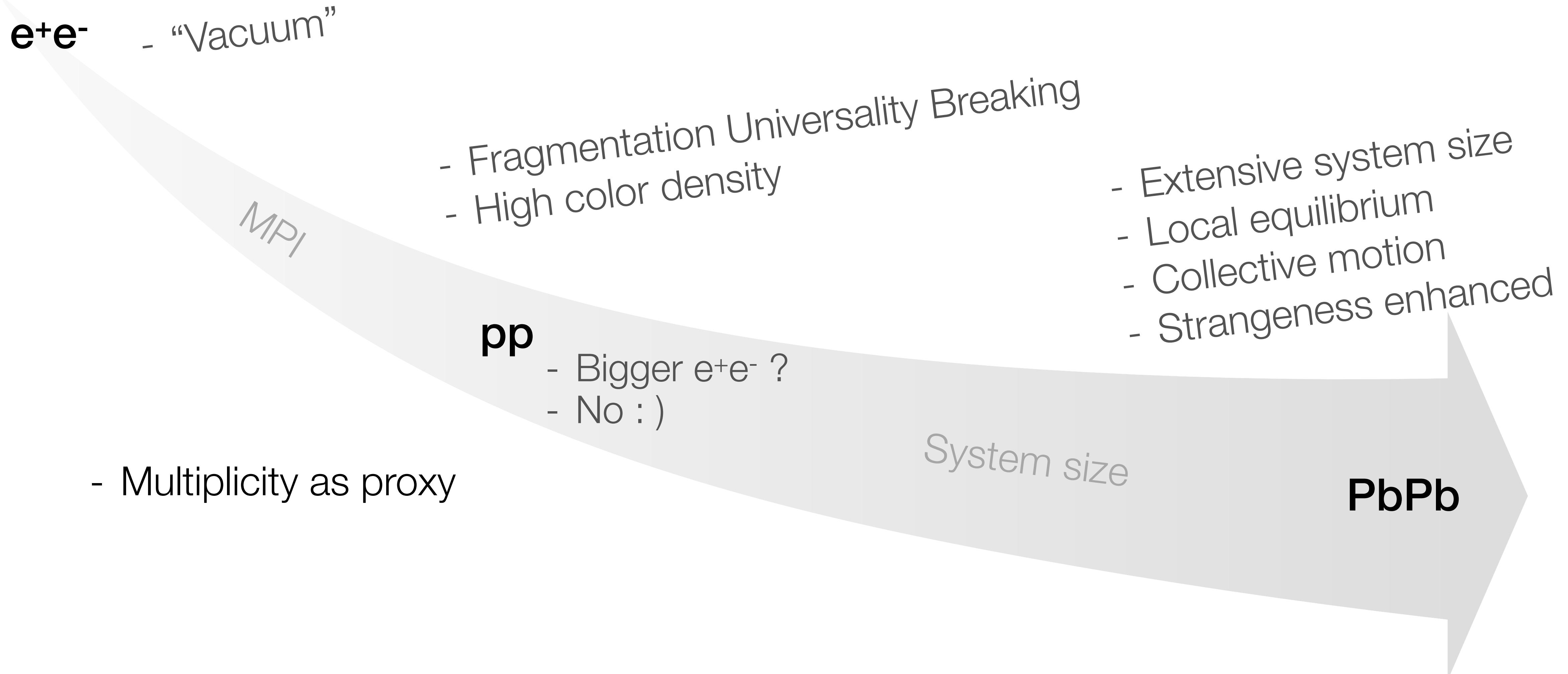


Recap: Hadronization

Anton Andronic, Jing Wang, Peter Skands, Vincenzo Greco

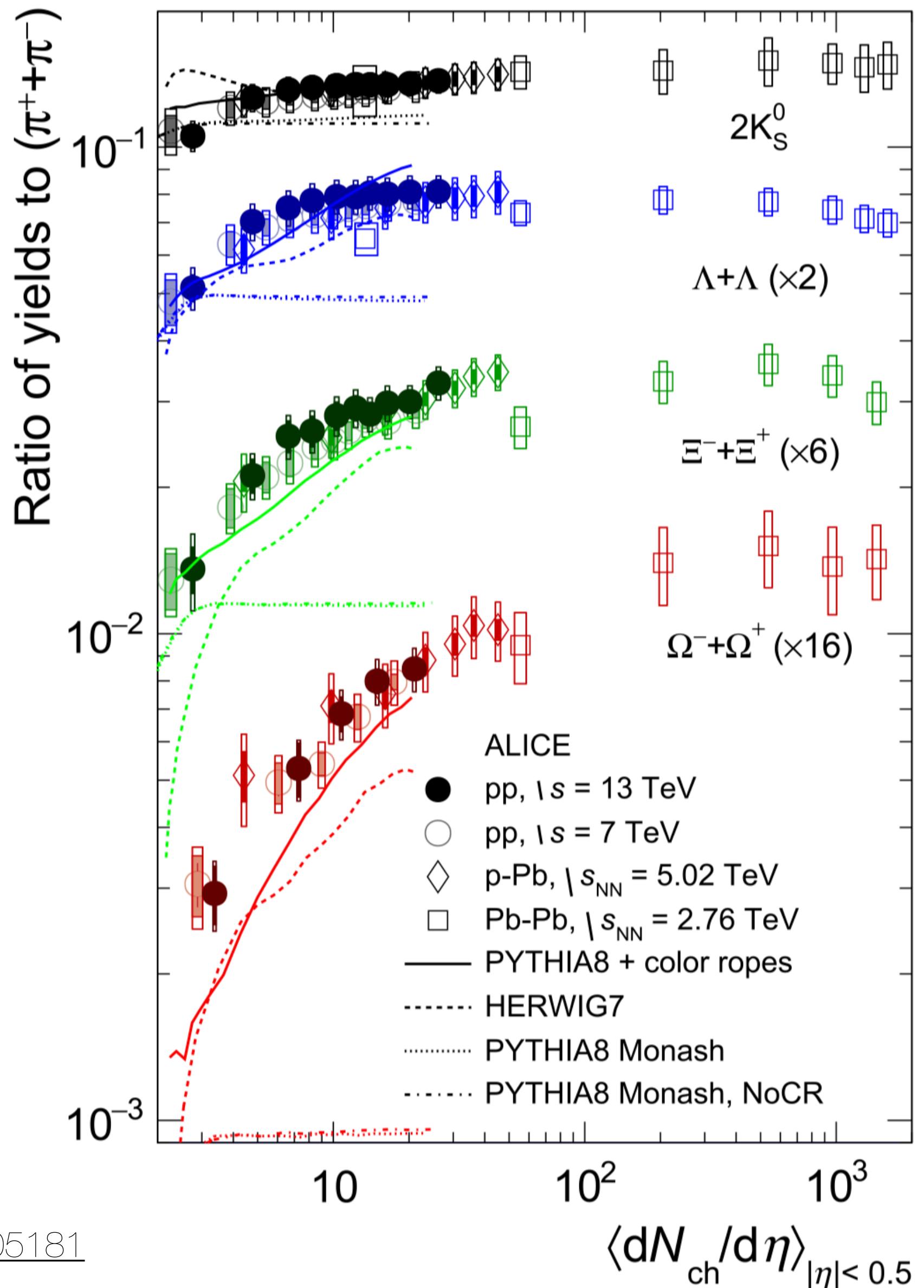
QCD challenges from pp to AA collisions (Padova, Italy)

Hadronization



*Revised from A. Rossi slide

Fragmentation Universality Breaking



Facts

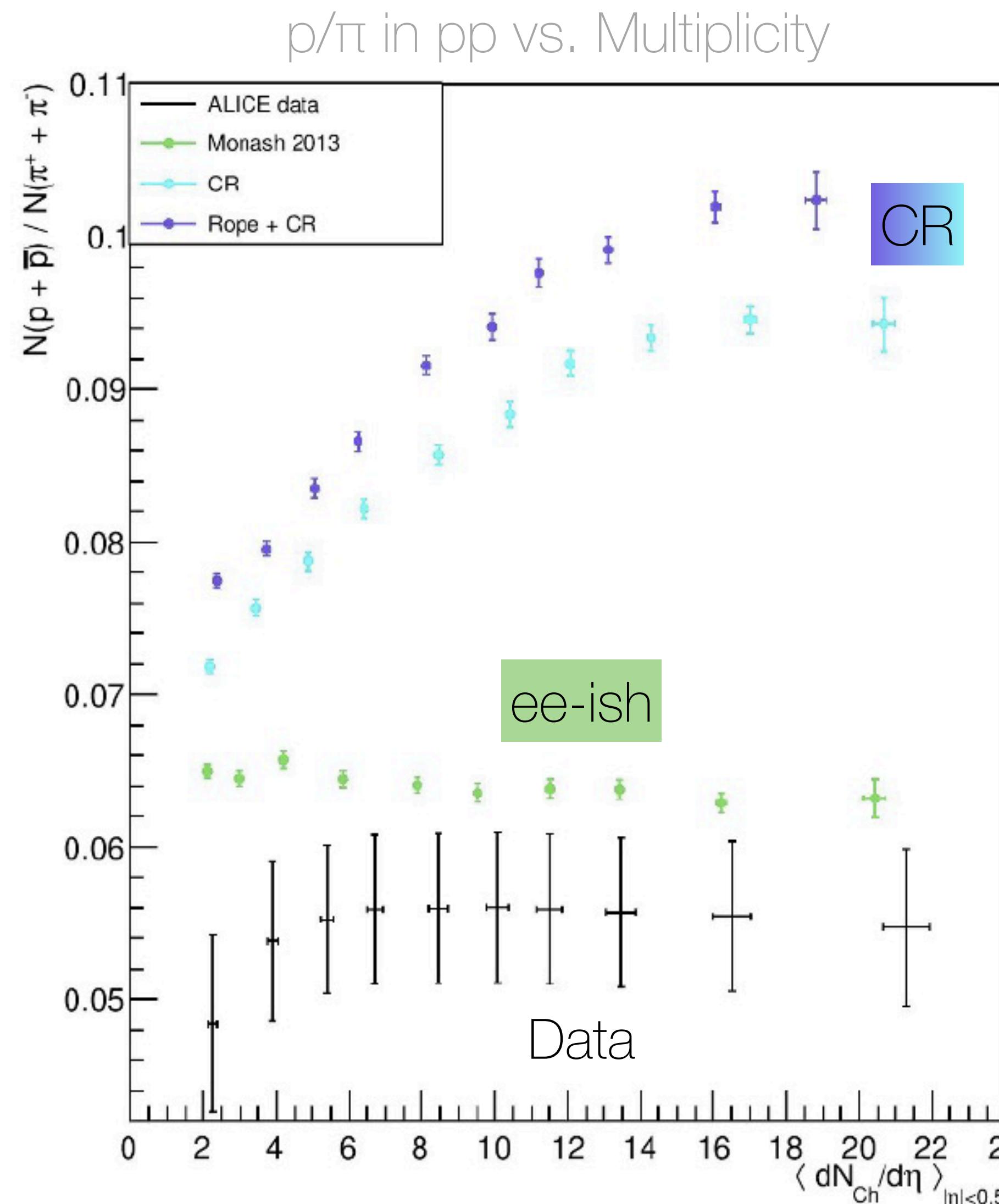
- Strong multiplicity dependence of yield ratio to π for various strange particle species
 - Yields have more info than ratio: e.g. Intercept reflects relevant significance of hard processes [1]
- Enhancement wrt e^+e^-

Models

- String/Cluster fragmentation
 - Color reconnection
- Coalescence
- Statistical hadronization
 - Additional excited baryons
- Core-corona

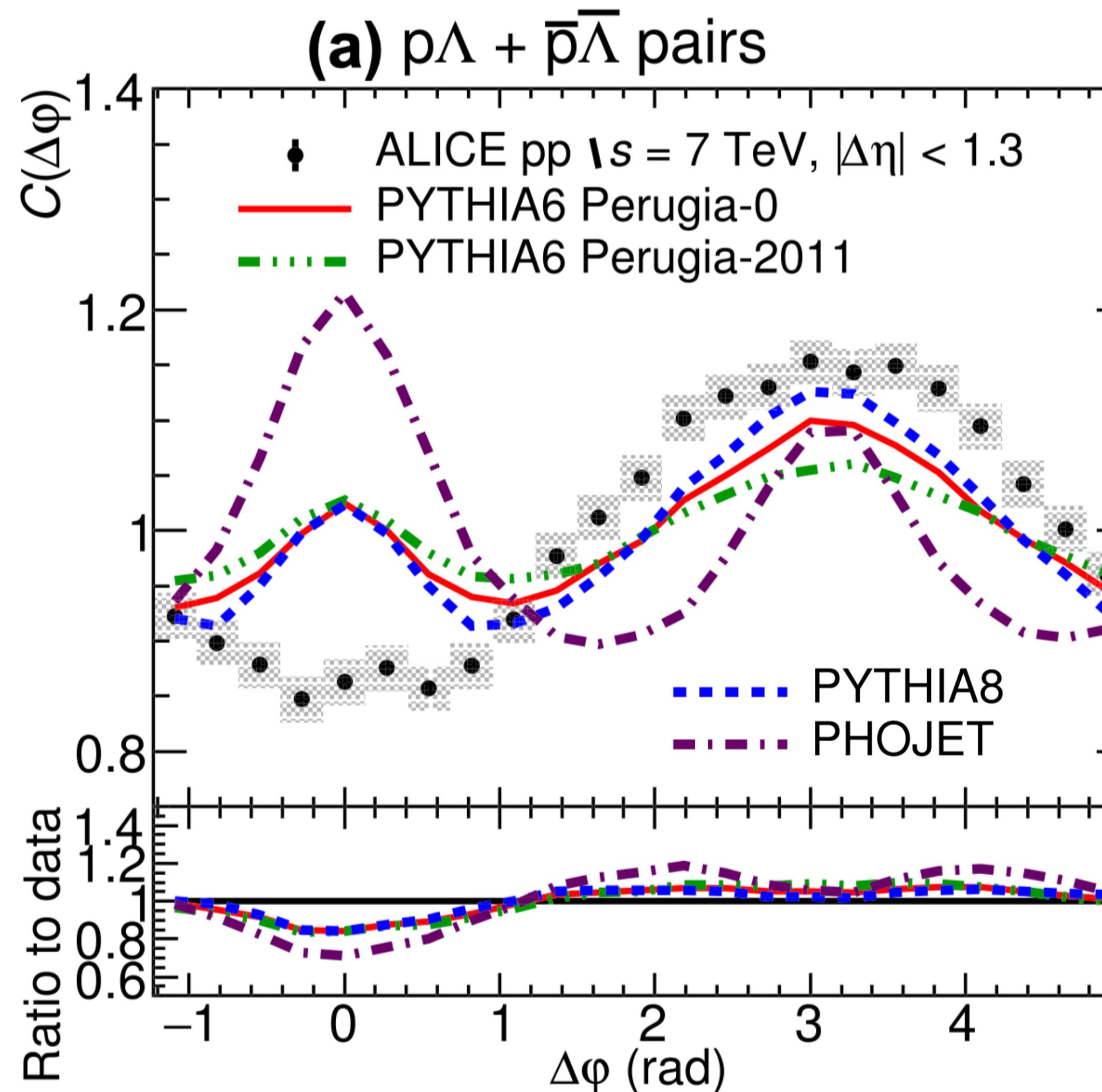
[1] [arXiv:2109.05181](https://arxiv.org/abs/2109.05181)

Multiplicity Dependence: Not Always...



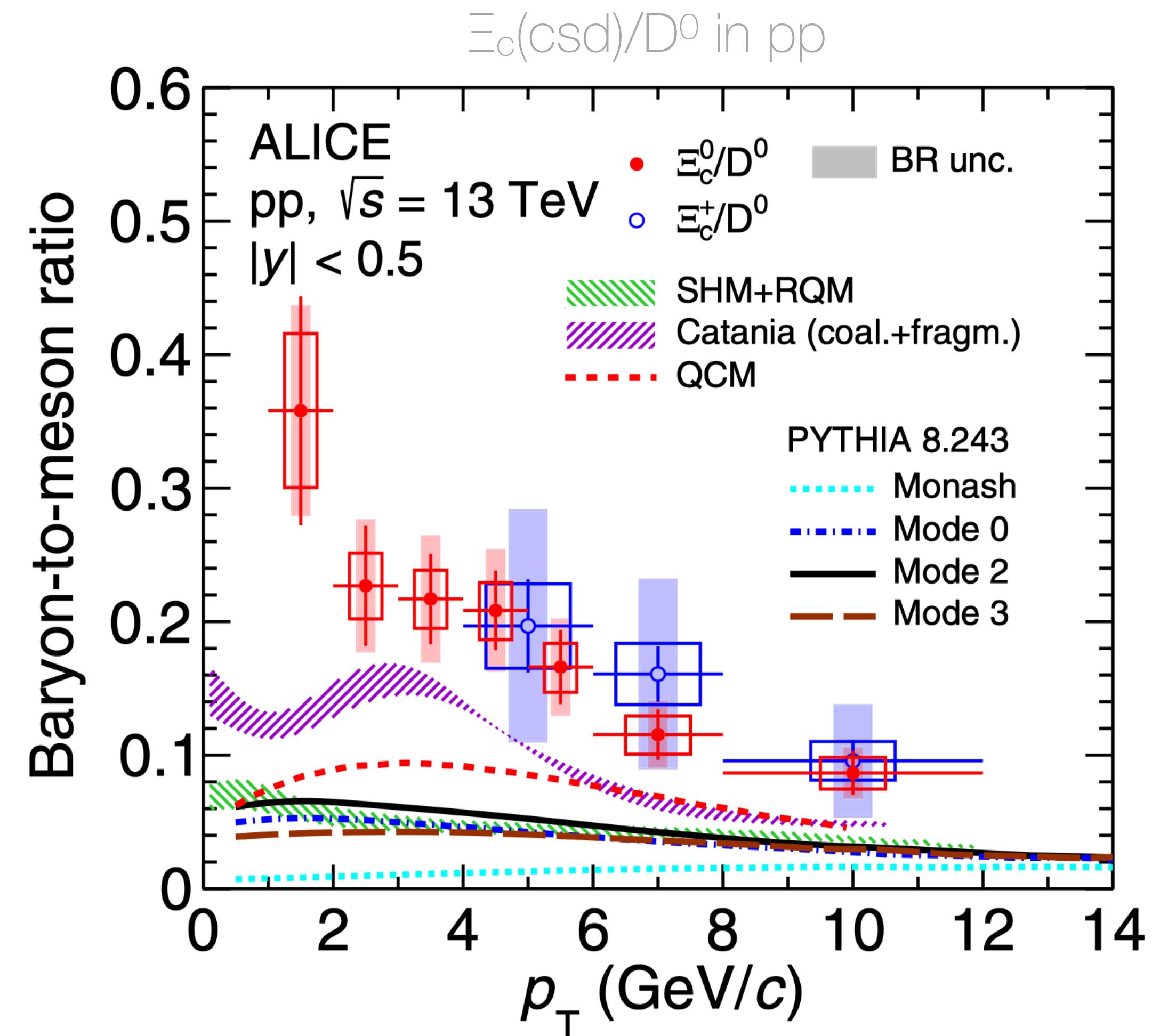
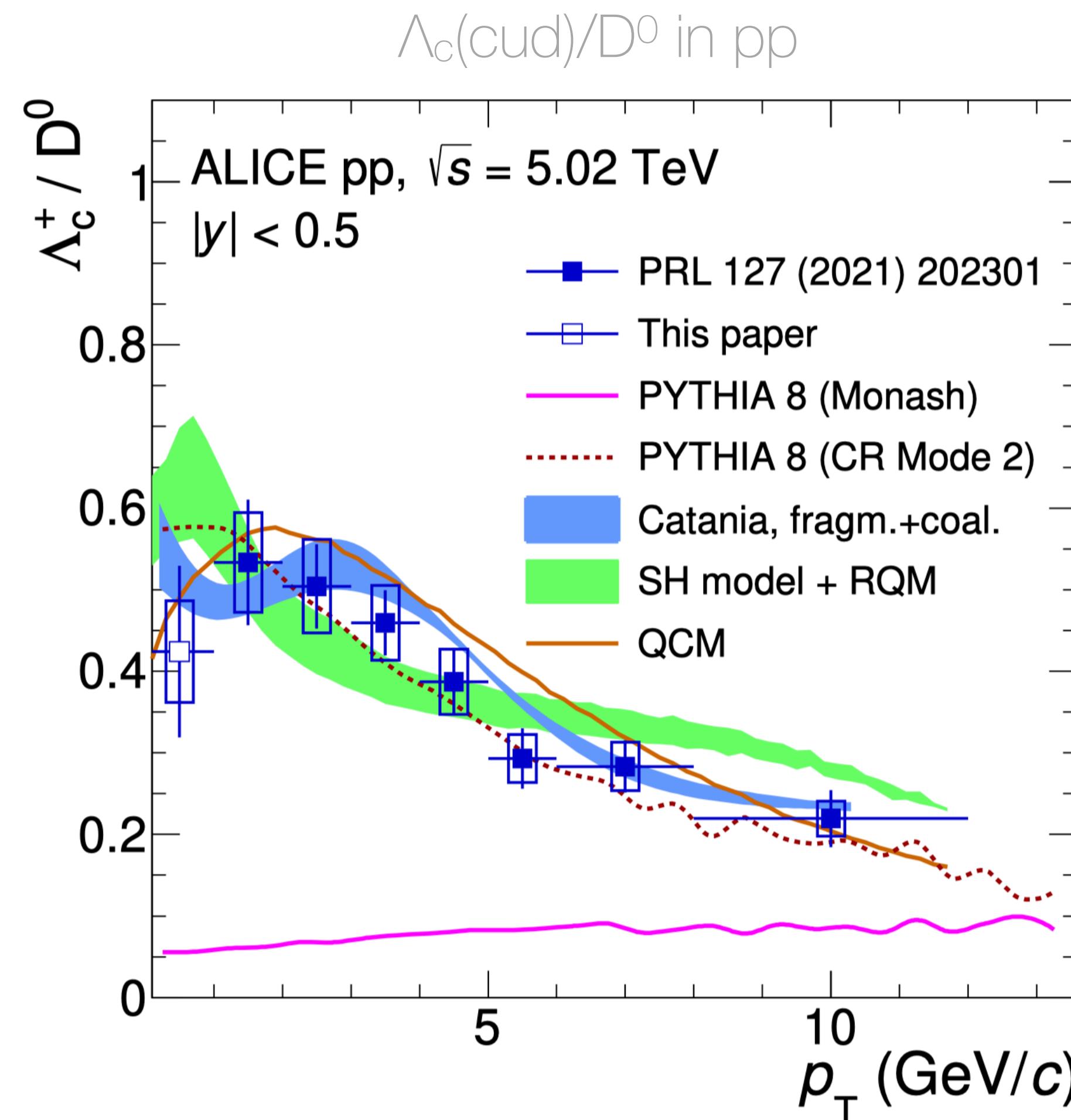
- p/π not strongly dependent of multiplicity
- PYTHIA8 + junctions (CR) naturally scaled with multiplicity → not wanted here
 - Already higher than data even no CR
- Yield only → confirm π is good at least
- Other non-strange baryons, e.g. Δ^{++}
 - Study effects with mass scale
- Correlation in addition to single particle yield

Correlation Between Baryons



- Dip around $\Delta\phi \sim 0$ not expected
- Very low- p_T particles ($p_T > 0.6$ GeV)
 - Should be effects in fragmentation
- Similar difference for baryon-antibaryon pairs as well
- Similar study should be extended to heavy flavors

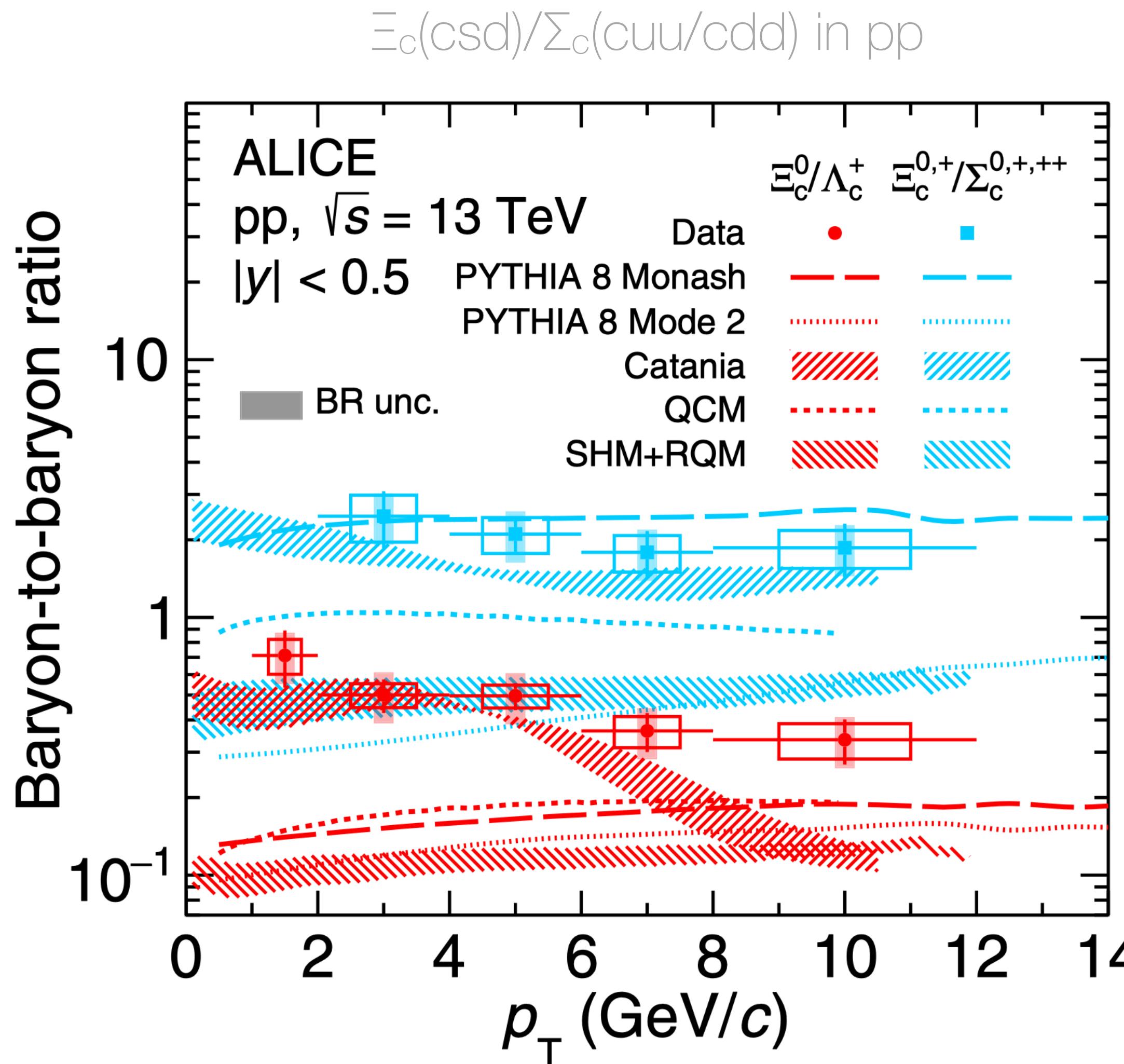
HF Baryons in pp: Success & Failure of Models



- Λ_c/D^0 clearly enhanced in pp vs. e^+e^-
 - Well described by various models

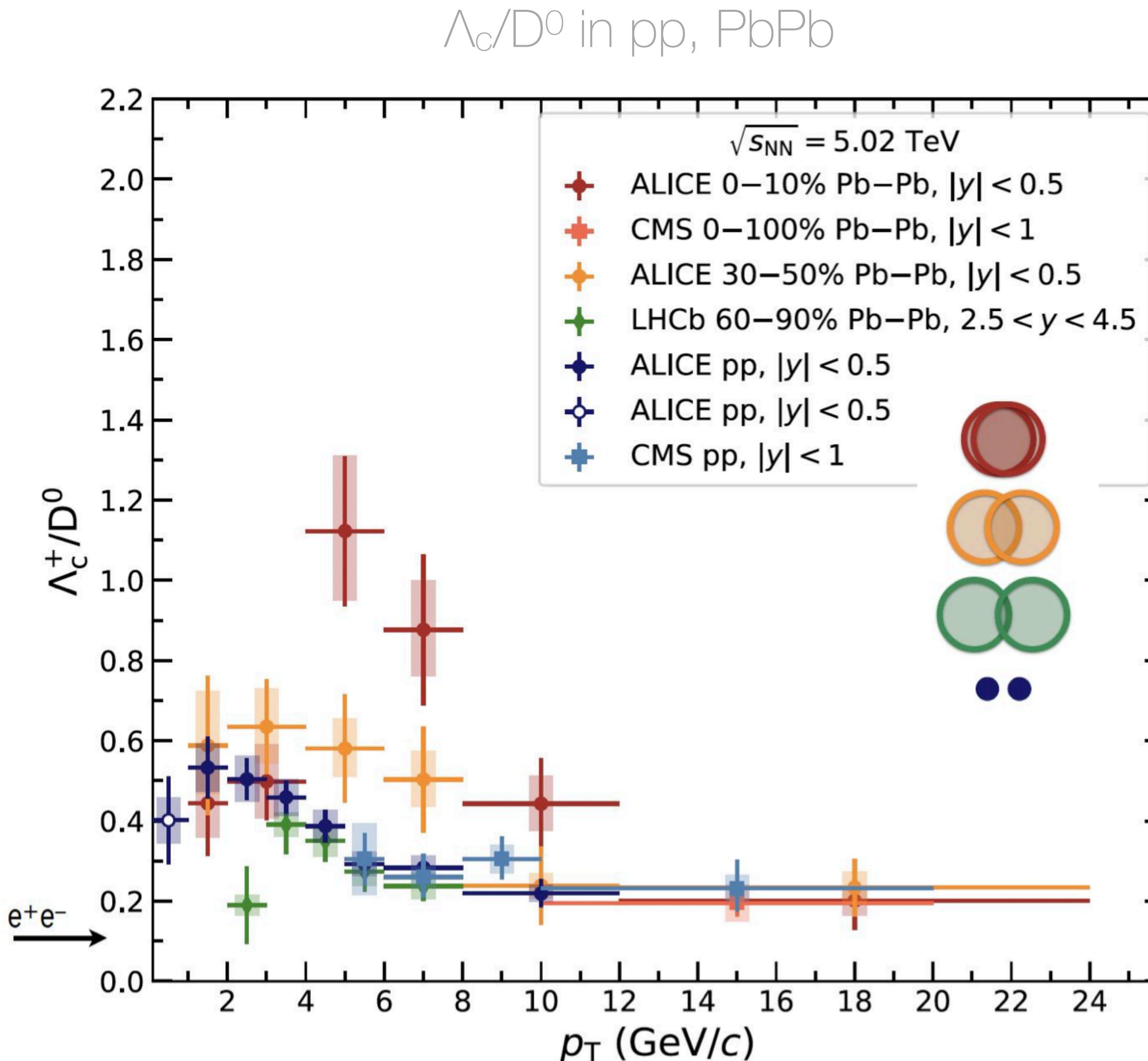
- Ξ_c/D^0 not captured by all models
 - Not necessarily due to strangeness

HF Baryons in pp



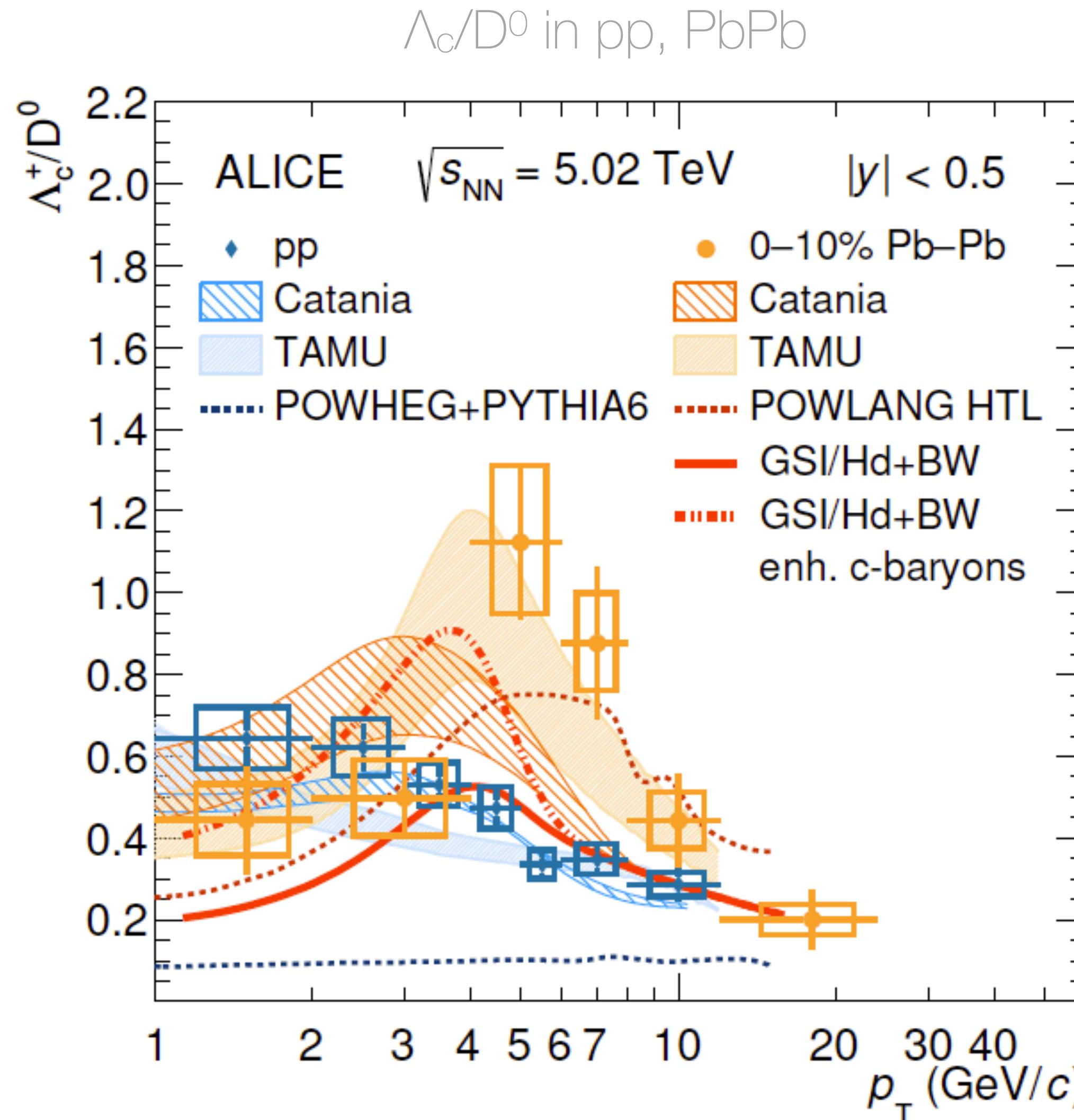
- pp > PYTHIA Monash (~ee)
 - $\Lambda_c(\text{cud}) / D^0(\text{cu})$
 - $\Xi_c(\text{csd}) / \Lambda_c(\text{cud})$
- pp \approx PYTHIA Monash (~ee)
 - $D_s(\text{cs}) / D^0(\text{cu})$
 - $\Xi_c(\text{csd}) / \Sigma_c(\text{cuu}/\text{cdd})$

HF Baryon: Scan System Size



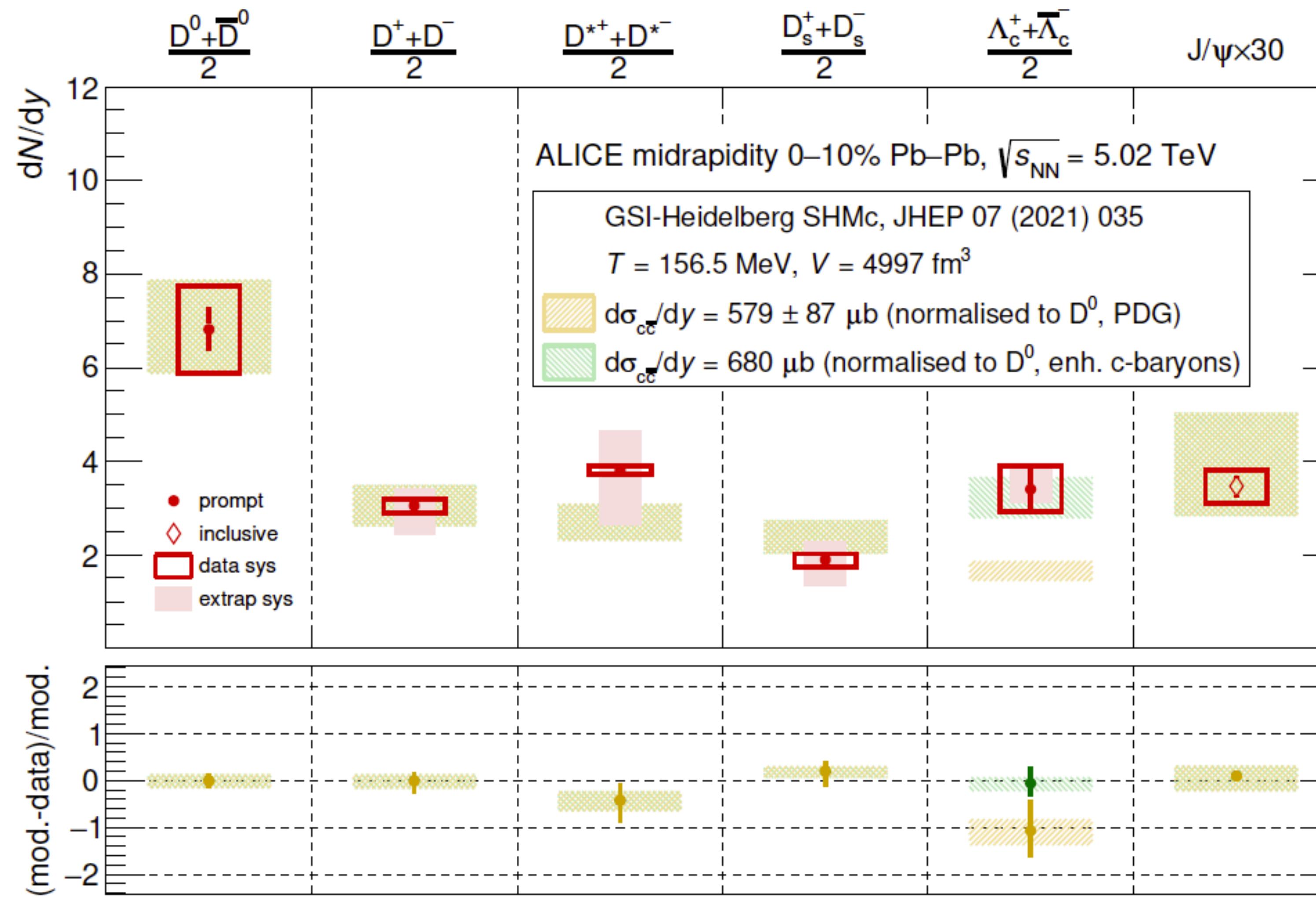
- Impact of flow is limited (diff. fr. LF)
 - Even if the charm thermalization degree is not precisely known
- Recombination should play an important role

HF Baryon: Scan System Size



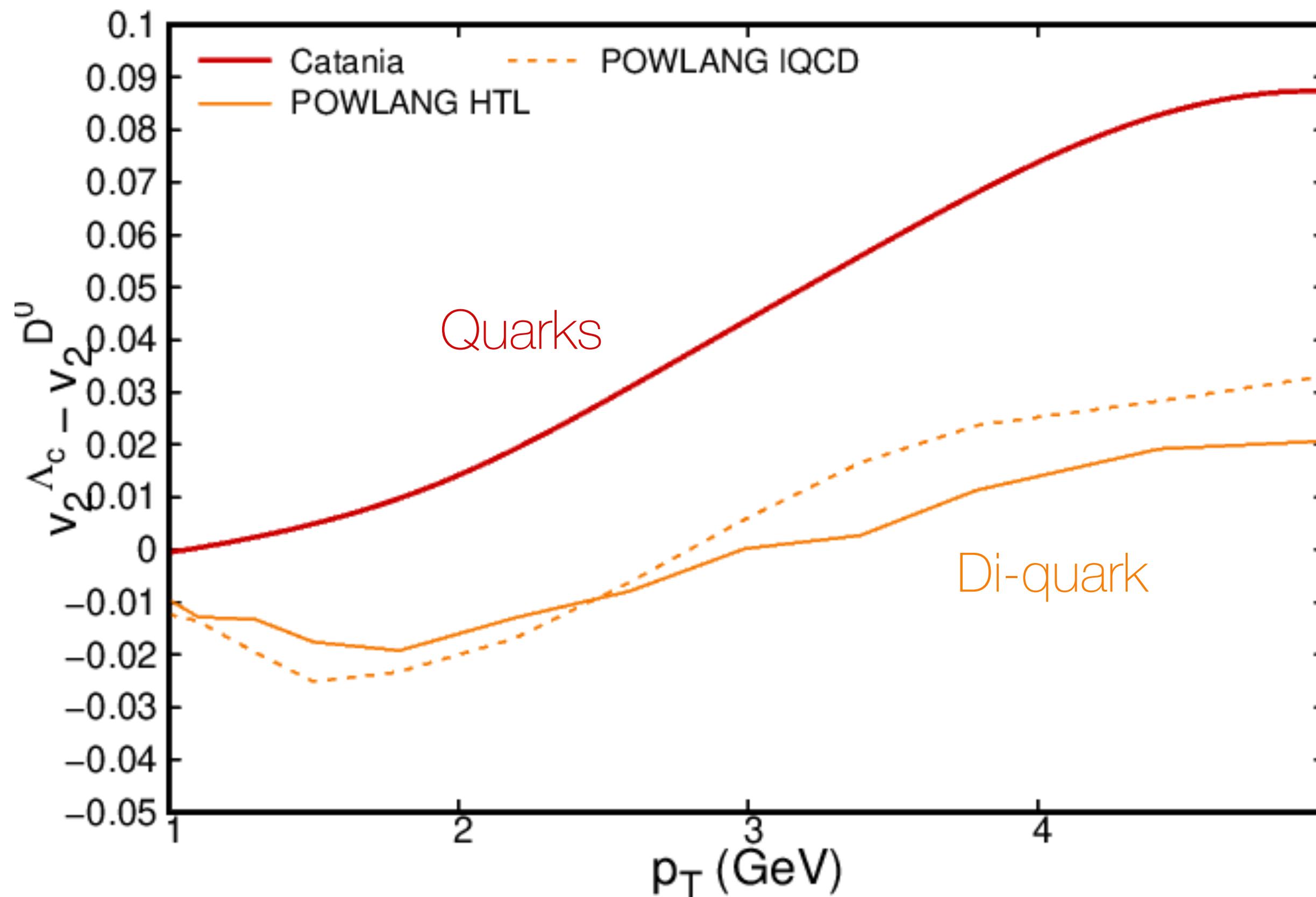
- Impact of flow is limited (diff. fr. LF)
 - Even if the charm thermalization degree is not precisely known
→ Recombination should play an important role
 - Feature can also be caught by including more Λ_c excited states
- Require simultaneous description in different systems

Charm Chemistry in PbPb



Study Coalescence Process with Λ_c Flow

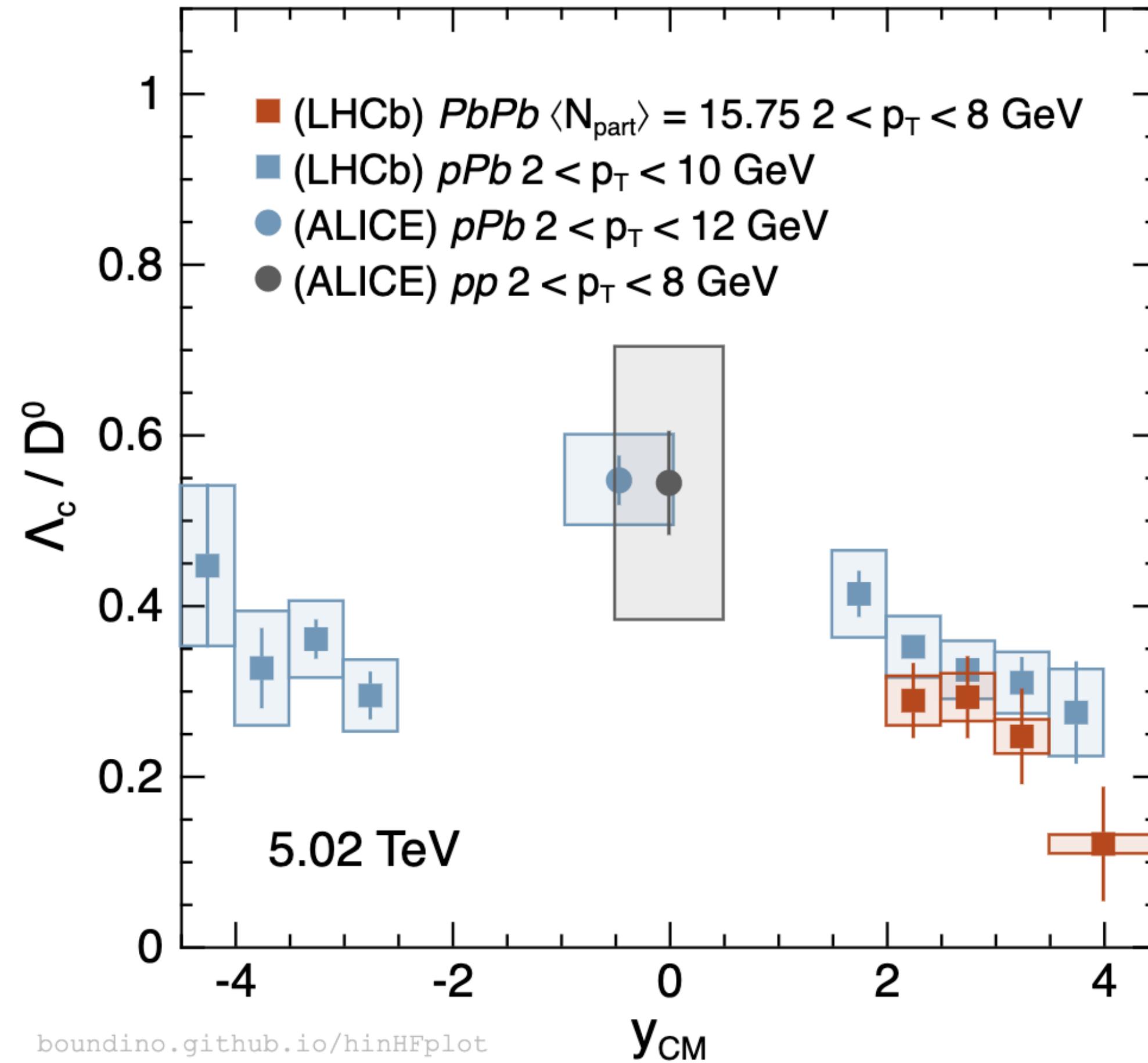
$(\Lambda_c v_2 - D^0 v_2)$ PbPb 30-50%



- Coalescence model
- $\Lambda_c v_2$ reflects how the charm picks flow from light quarks
 - Recombined with quarks (Catania) vs. with diquark (POWLANG)

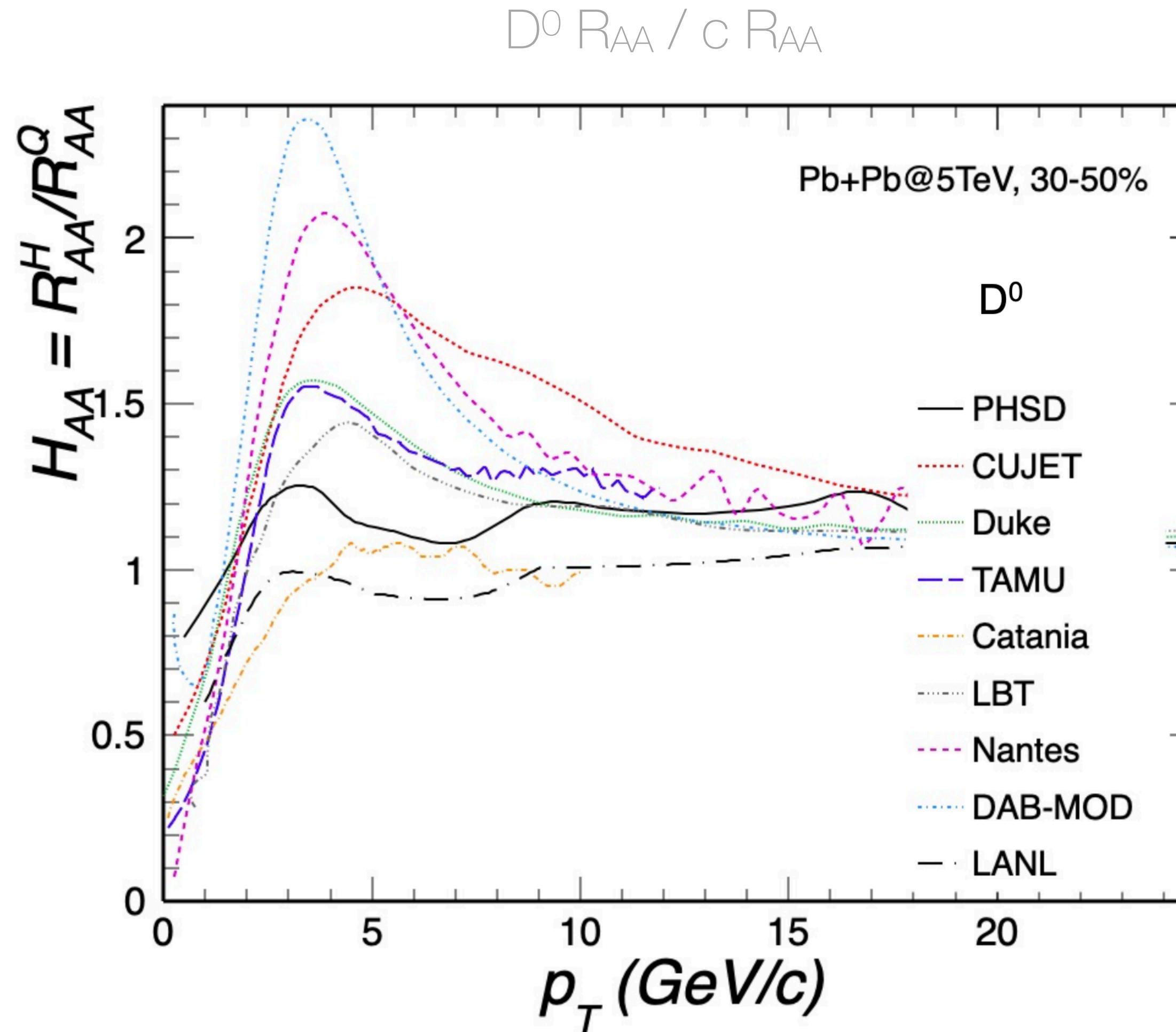
HF Baryon: Rapidity Dependence

Λ_c/D^0 vs. rapidity



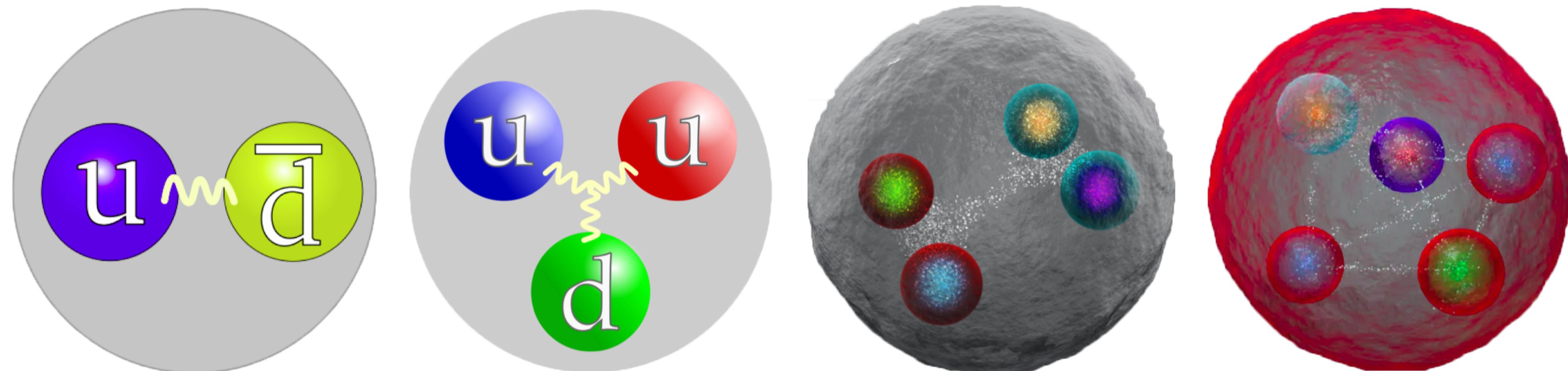
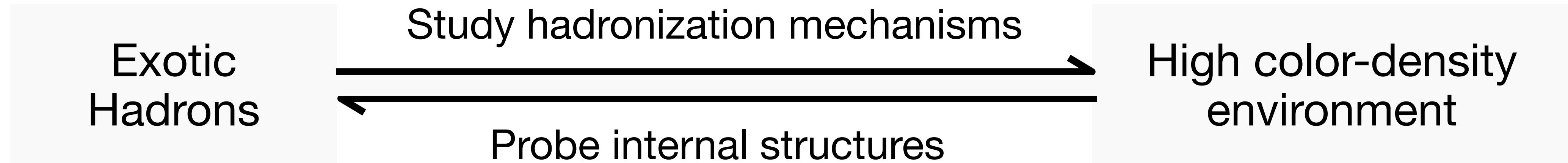
- Source of rapidity dependence not clear yet
 - Commonly in pp, pPb, PbPb
 - Fill the gap

Divergence in Hadronization Models

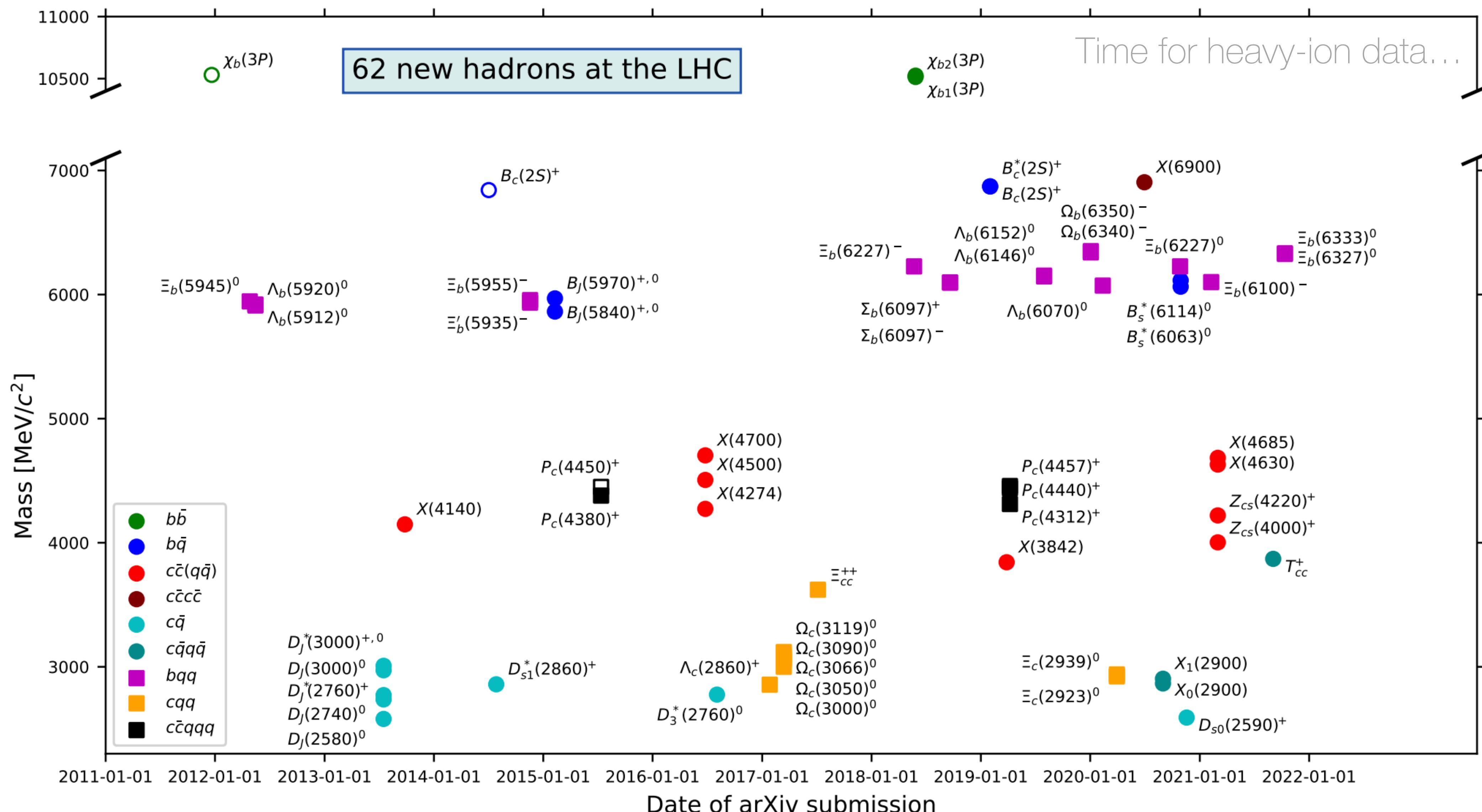


- H_{AA} reflects hadronization effects
- Understanding hadronization is practically useful
 - Essential to extract medium transport properties
 - Largest uncertainty currently

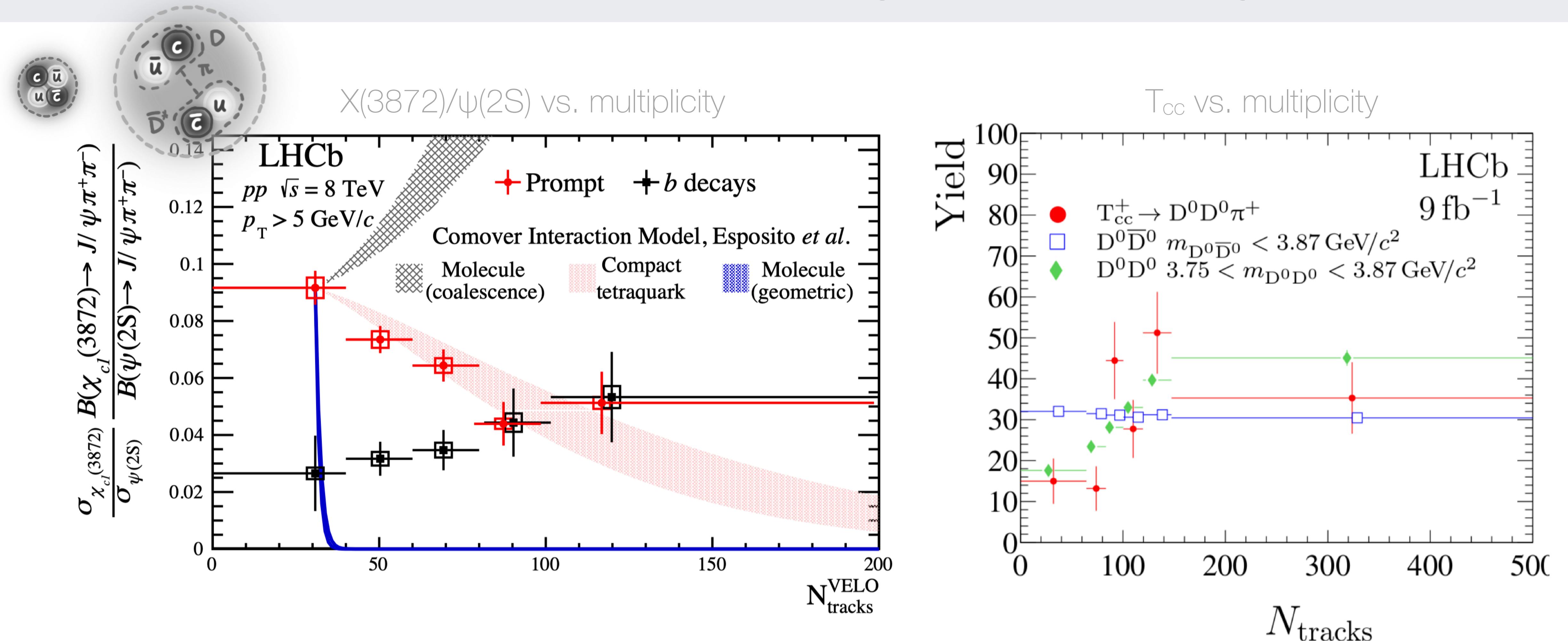
Exotic Hadrons



Exotic Hadrons



Exotic Hadrons in High Multiplicity pp



- Decrease trend fitting breakup picture
 - Better to remove effect from denominator

- No suppression at high multiplicity
 - T_{bb} as a benchmark of compact states

Menu For Next Steps

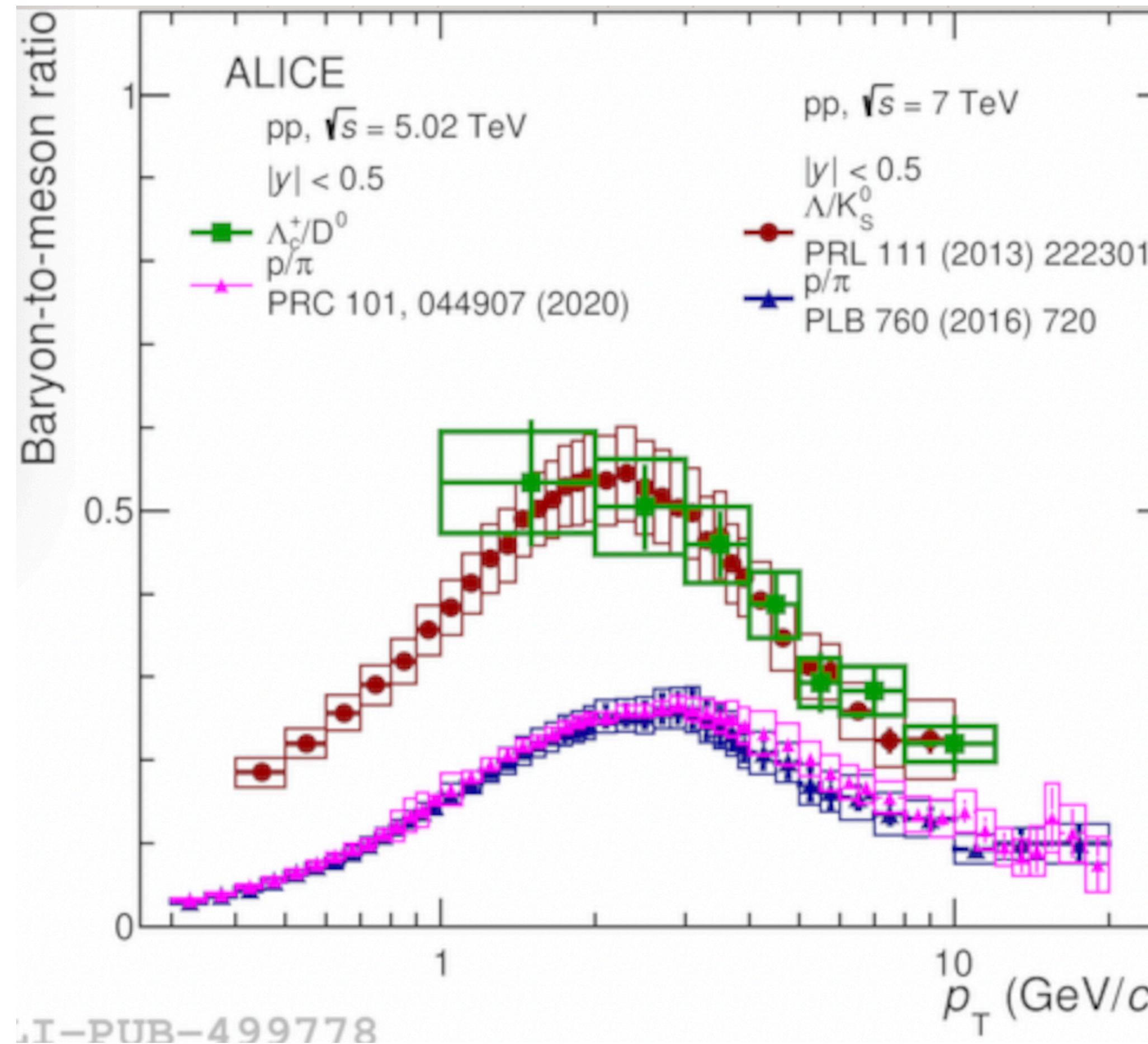
- Other non-strange baryon than proton vs. multiplicity sl4
- Correlation between baryons (LF & HF) sl4
- Λ_c/D^0 recover to e^+e^- from pp
 - Low multiplicity, high p_T sl8
- Λ_c/D^0 at $-2 < y < 2$ sl12
- Λ_c flow sl11
- Search for “extra excited baryon states” sl10
- Hadrochemistry in jets (“rapidity” vs. trust axis) sl4
- Differential X(3872) measurement to cancel BR sl16
- X(3872) yield rather than ratio sl16

“ Measure something... ”
— Su Houn’s remark

Back up

Thanks for your attention!

HF Baryon: Similarity with Strangeness

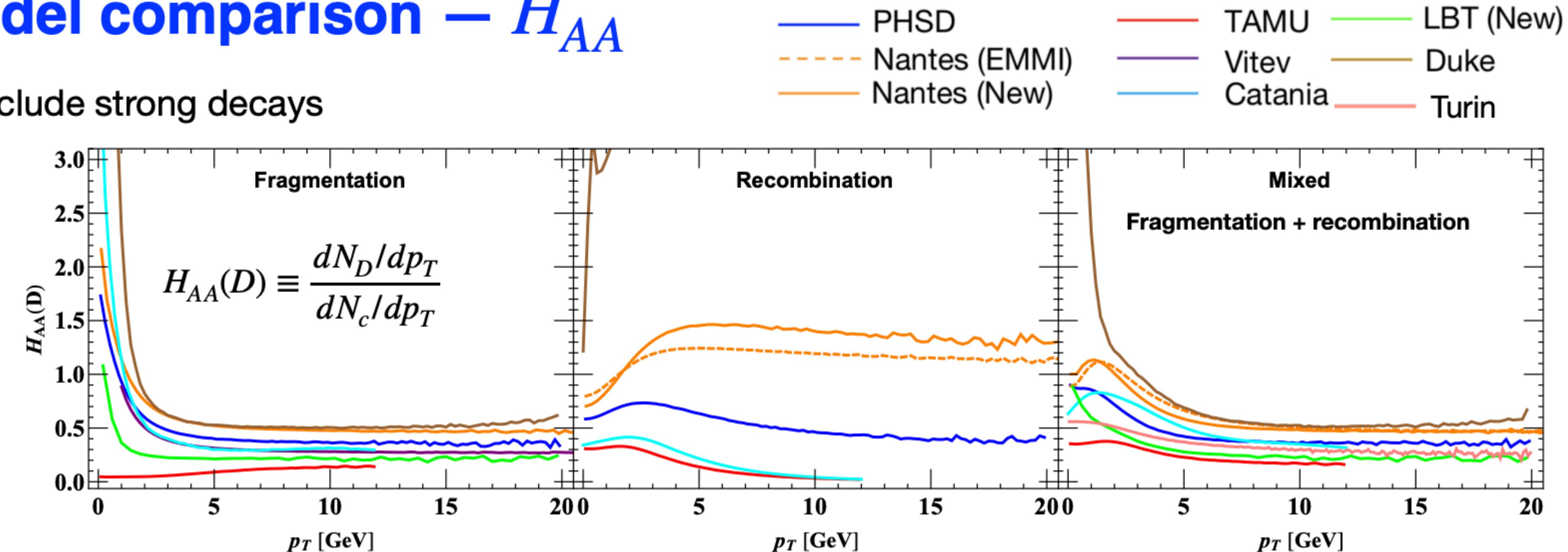


- Feature or coincidence?

Impact and Constraint of Hadronization

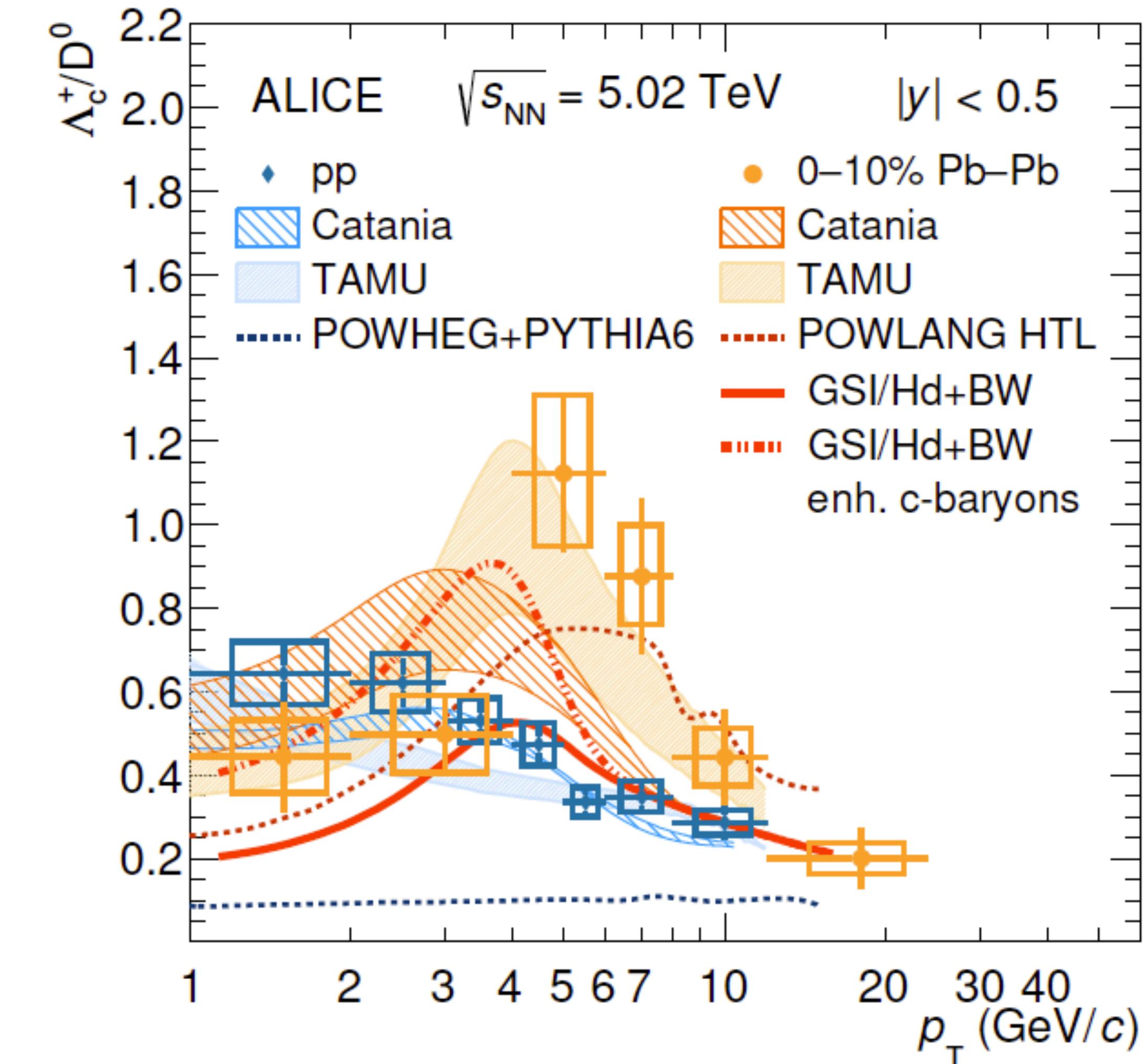
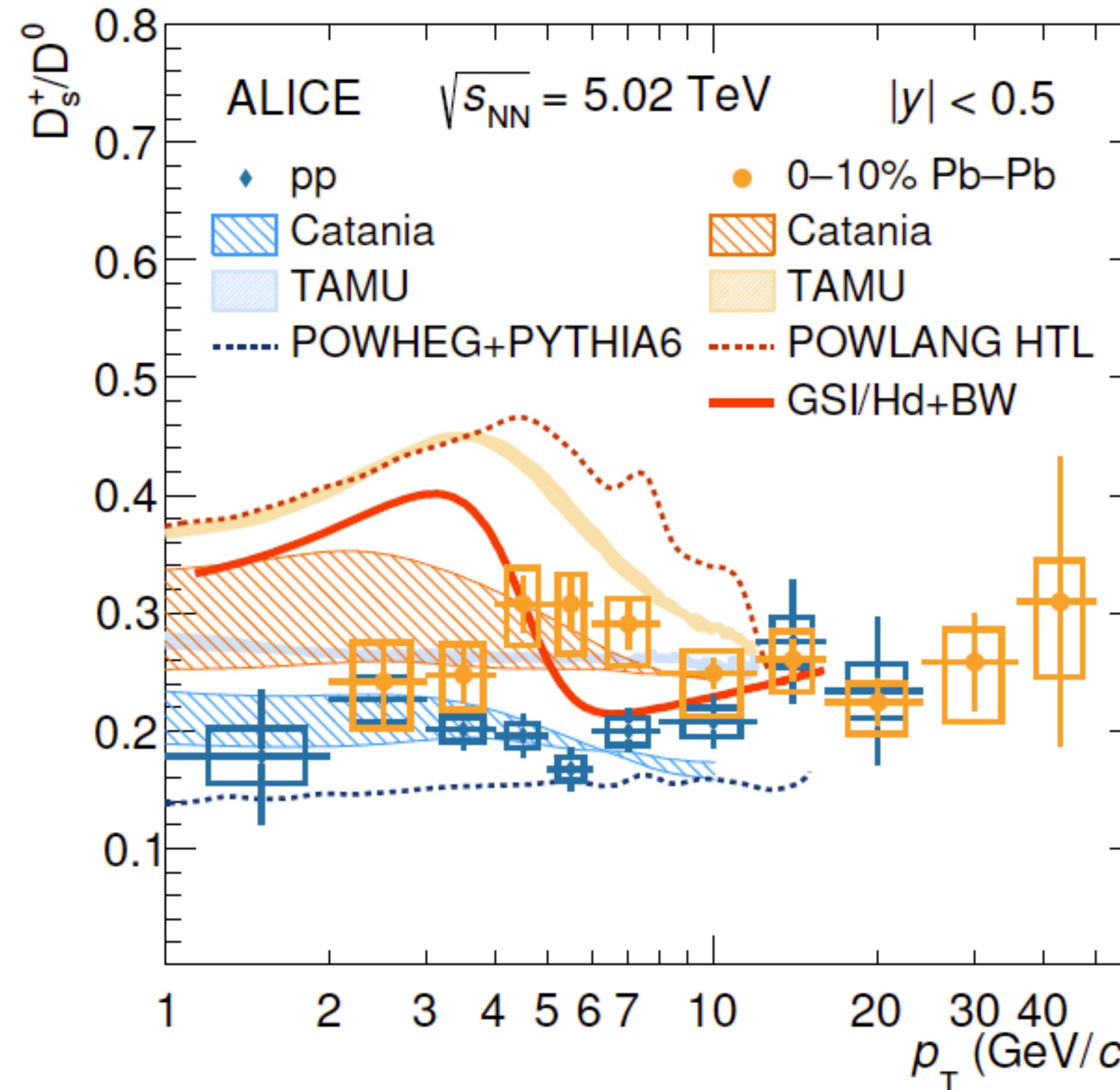
Model comparison – H_{AA}

Include strong decays

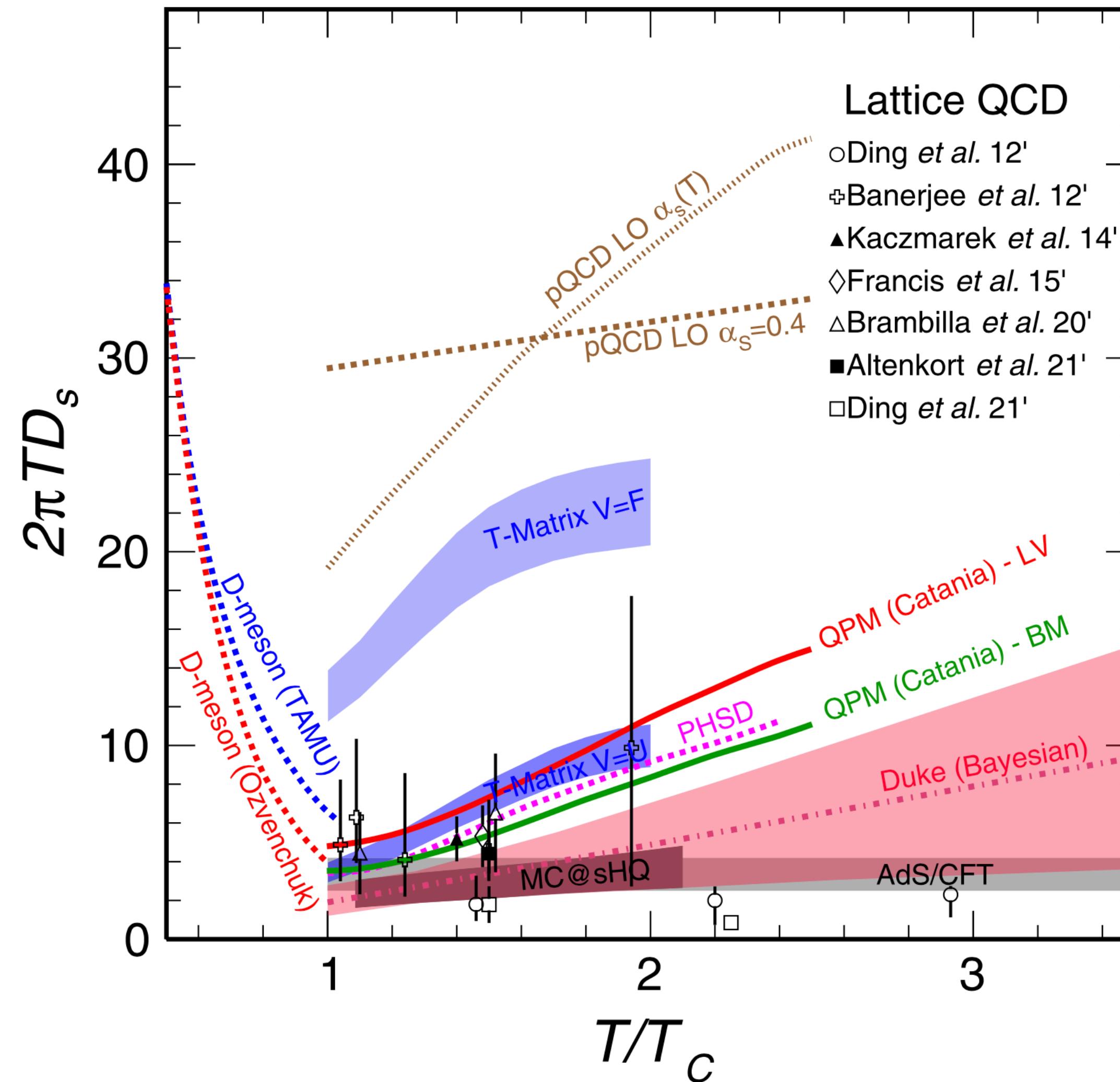


- “Final yield of charm hadrons with given charm distribution at hadronization hypersurface.”

Scan System Size



Summary (2/2)



- Transport coefficients extracted from data
 - Medium properties encoded
 - Disfavors pQCD calculation
- Heavy flavor as unique probe
 - Access phase spaces at higher temperature
 - Sensitive to long-wavelength scale structure
- Precise D_s requires constraint of each ingredient

[arXiv:2203.16352](https://arxiv.org/abs/2203.16352)