Probing jet hadrochemistry in Pb–Pb collisions with ALICE

Sierra Cantway (née Weyhmiller) for the ALICE collaboration

Yale University

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9/24/24

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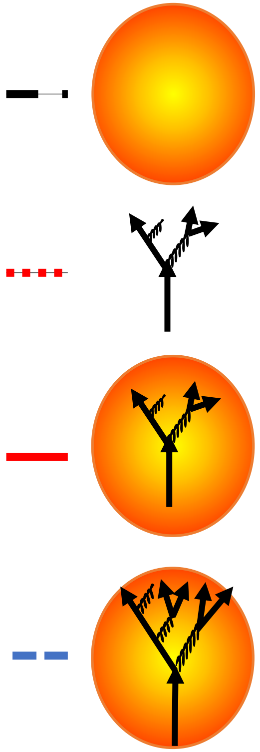
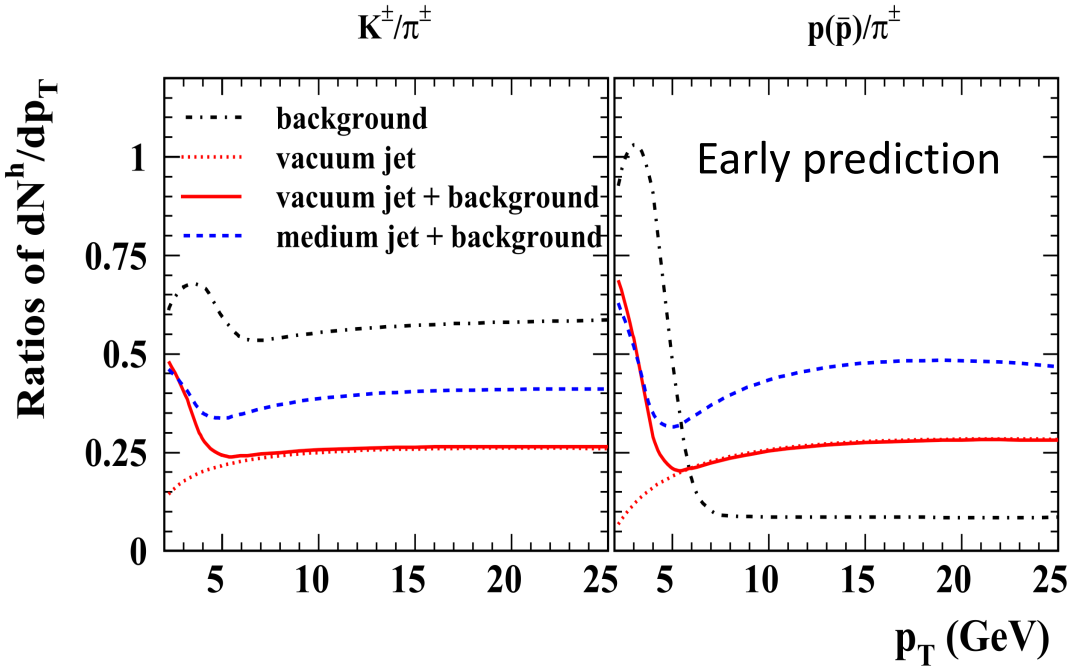
U.S. DEPARTMENT OF ENERGY

Wright Laboratory

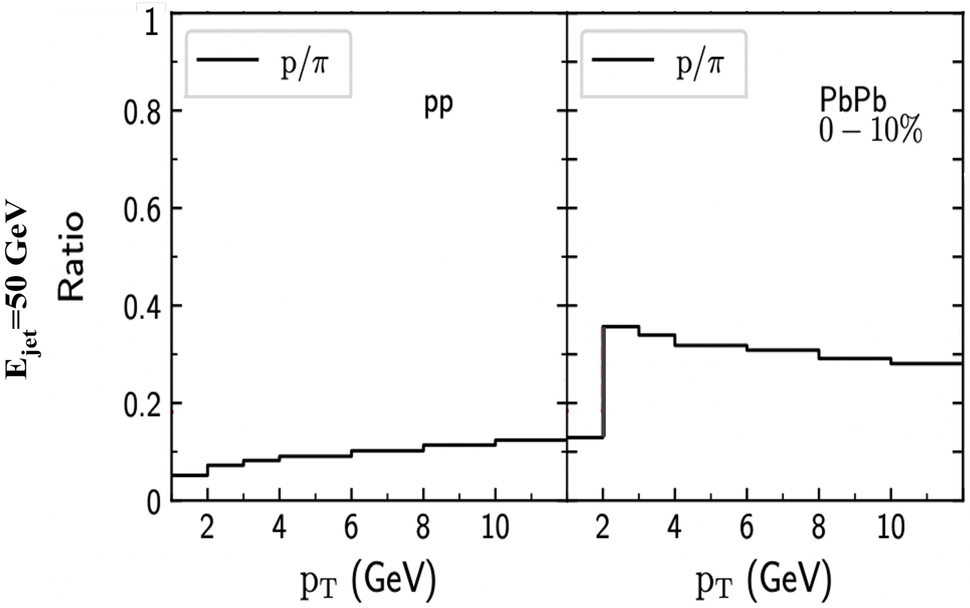
Motivation

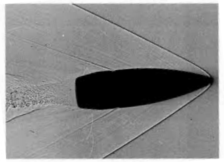
Different underlying physics mechanisms (e.g. **enhanced parton splitting** or **wake response**) → Different jet hadrochemistry modifications





S. Sapeta, U. A. Weidemann, EPJ C 55 (2008) 293-302





A. Luo et al., PLB 837 (2023), 137638

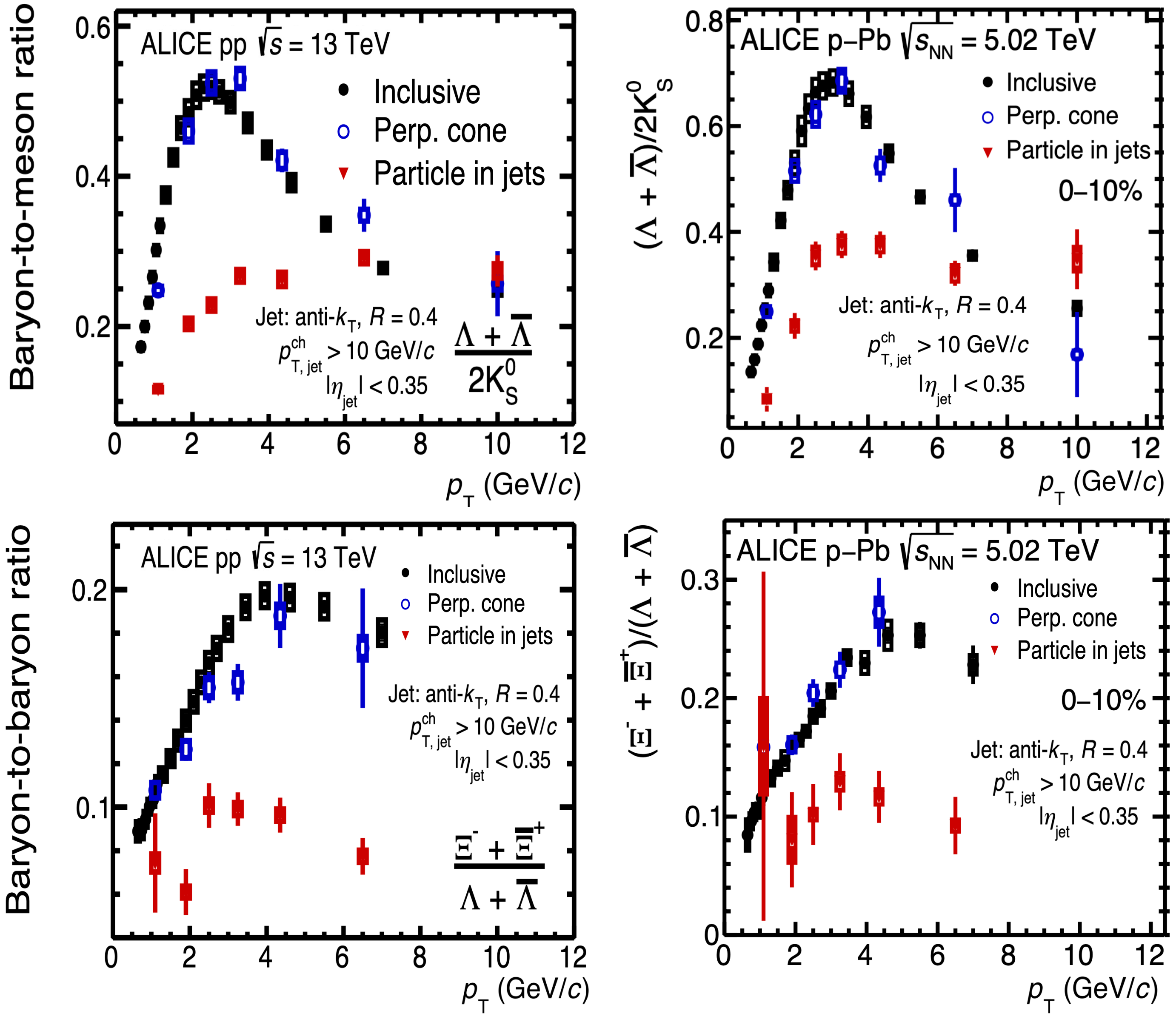
Enhanced parton splitting **Wake response**

Measurements of **K/π and p/π ratios** in pp and Pb–Pb collisions within **jets and the underlying event (UE)**

→ Sensitive to potential **jet-medium interactions**

→ Investigate the relative contributions of **fragmentation and coalescence** in hadronization

Previous measurements



- Inclusive
- Perp. cone ⟵ UE
- Particle in jets

- **Baryon and strangeness production of V^0s/cascades in jets is much lower than UE or inclusive in pp and p–Pb.**
  - Ω production is less clear

ALICE JHEP 07 (2023) 136

Other relevant measurements

ALICE Phys. Rev. C 101 (2020) 044907

ALICE Phys. Lett. B 827 (2022) 136984

STAR Preliminary arXiv:2312.11362

The ALICE detector in Run 2

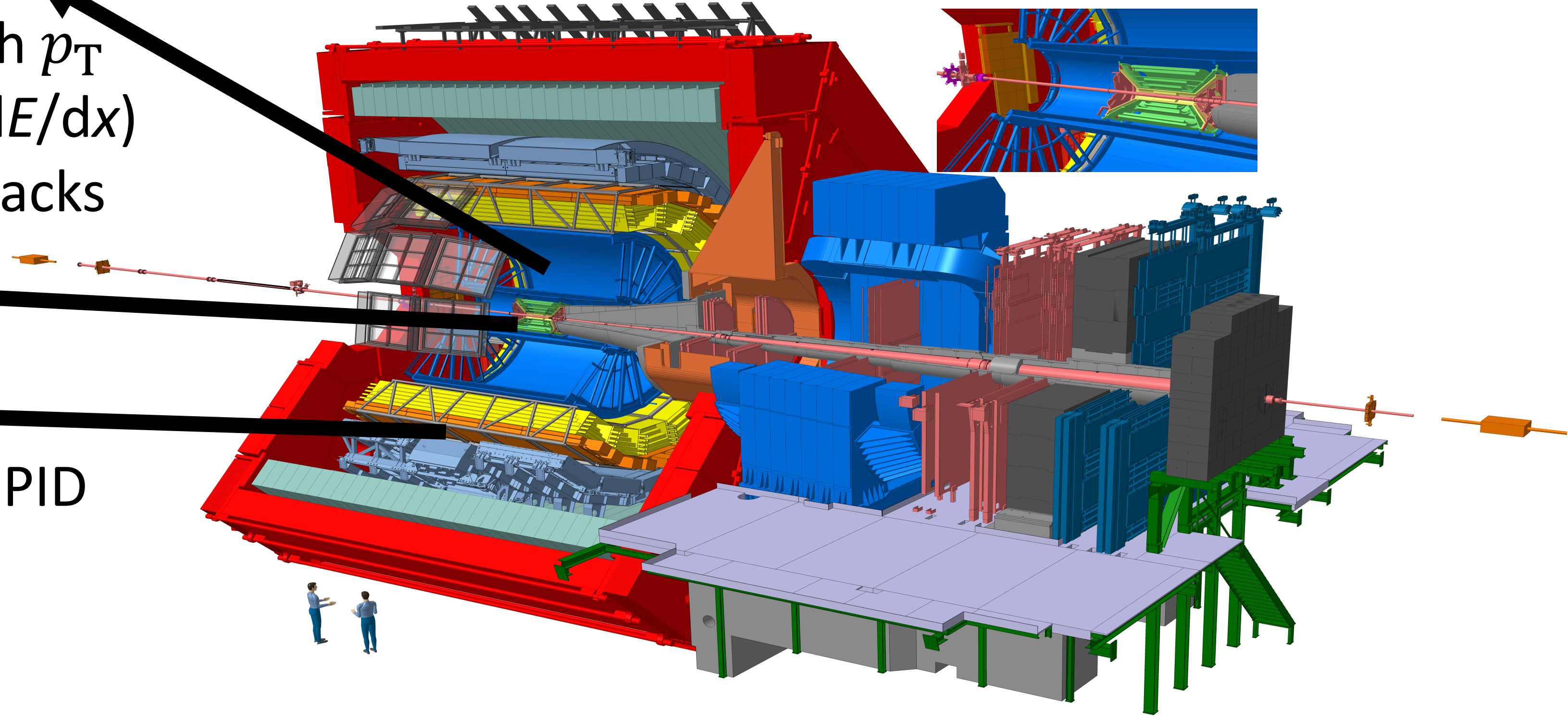
ALICE's excellent particle identification (PID) capabilities are ideal for this measurement!

Time Projection Chamber (TPC)

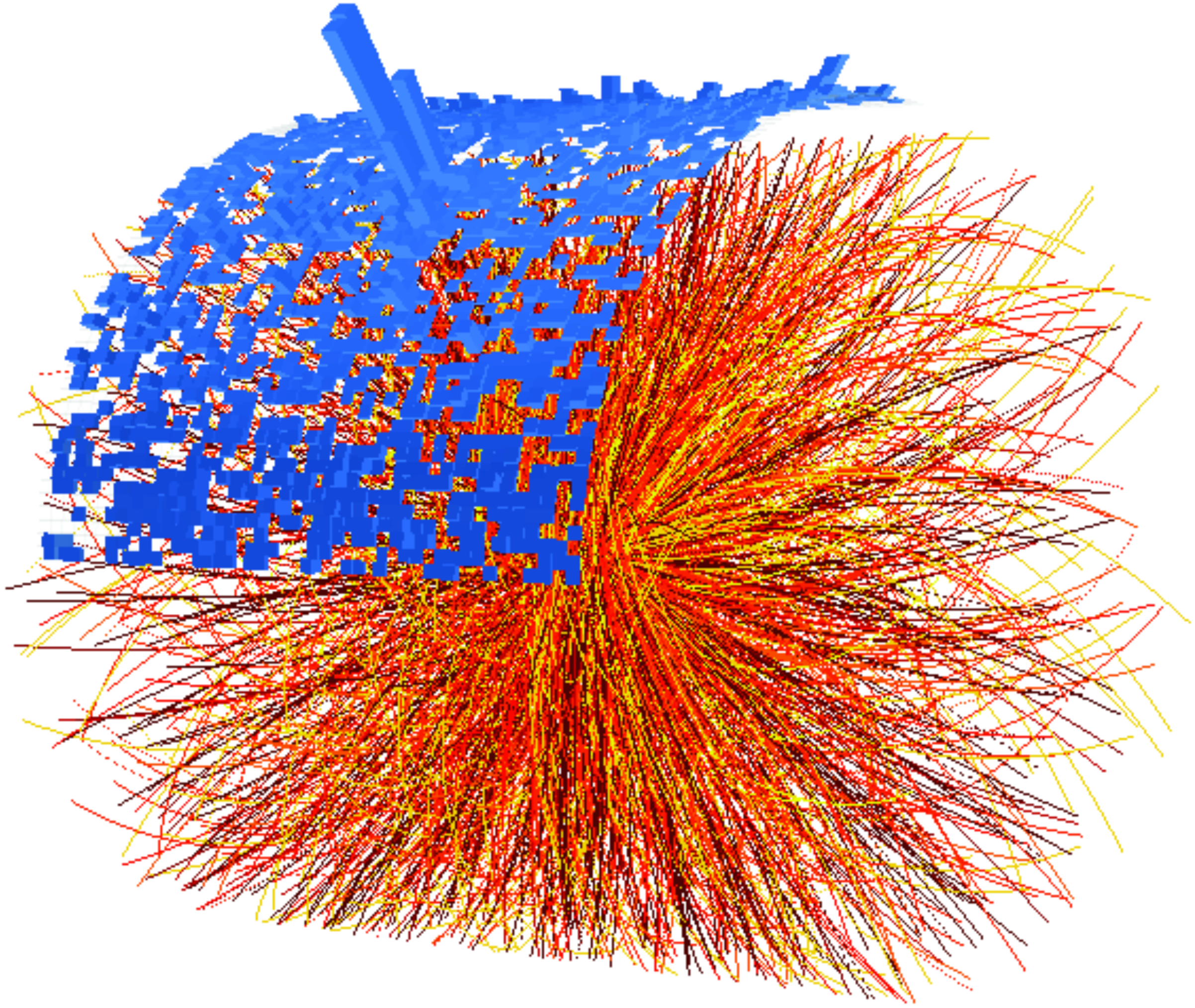
- Low p_{T} (0.25-0.8 GeV/c) and high p_{T} (3-20 GeV/c) PID via energy loss ($\mathrm{d}E/\mathrm{d}x$)
- Jet reconstruction via charged tracks (with **ITS**)

Time of Flight (TOF)

- Intermediate p_{T} (0.6-4.5 GeV/c) PID via particle velocity (β)



Jet reconstruction



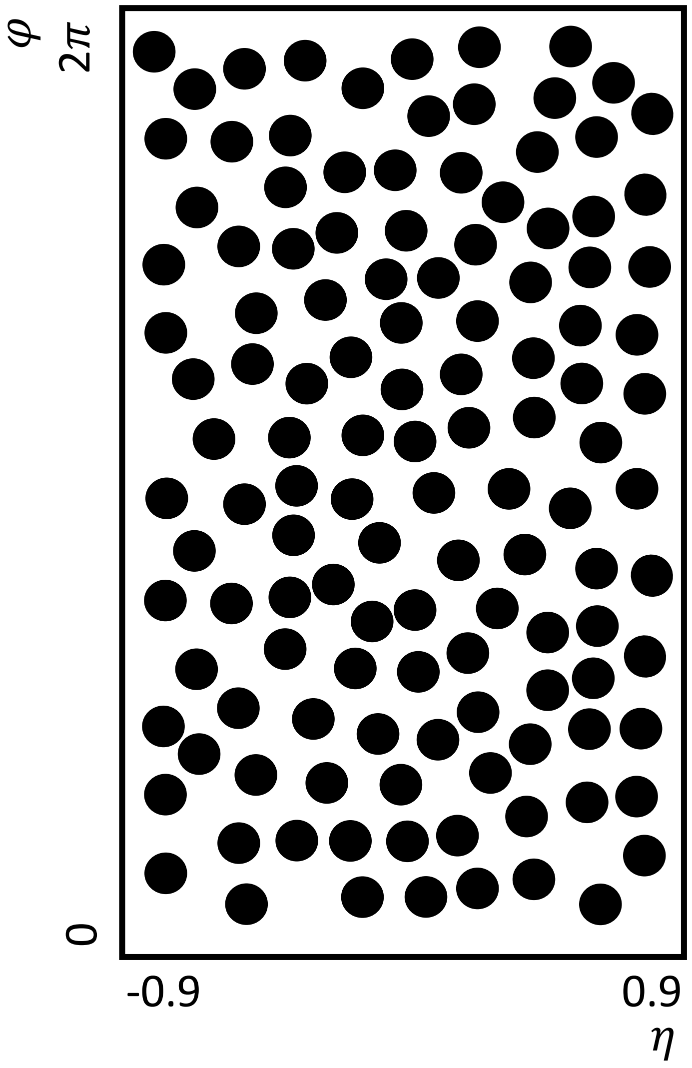
$p_{\mathrm{T\,ch\,jet}}^{\mathrm{raw\,sub}} = p_{\mathrm{T\,ch\,jet}}^{\mathrm{raw}} - A^{\mathrm{jet}}\,\rho$

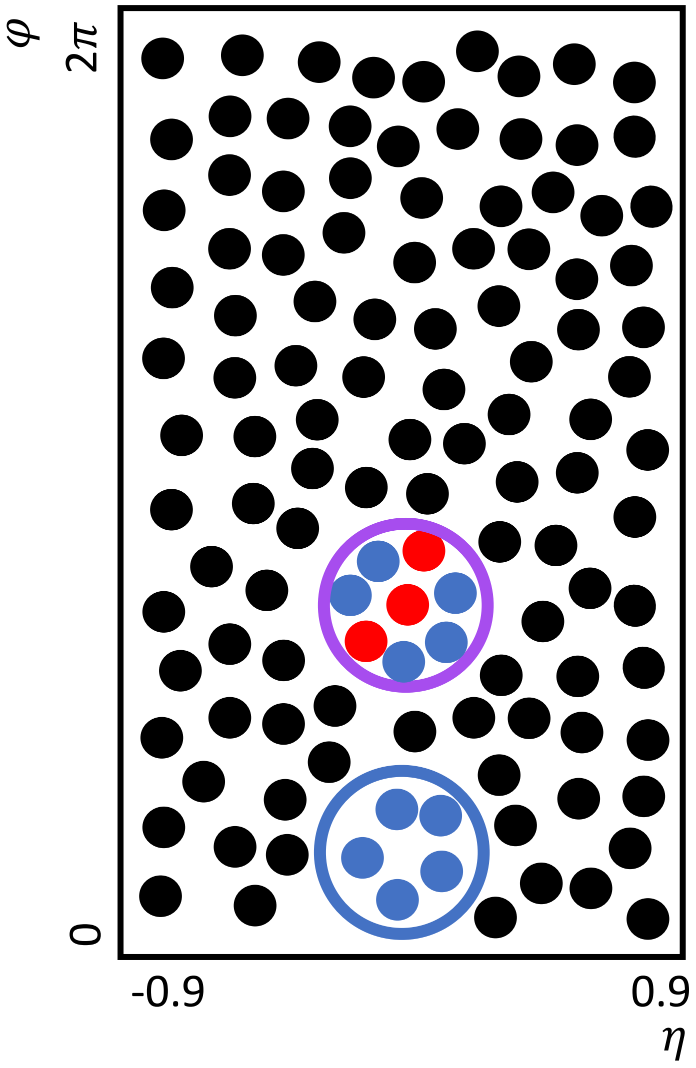
anti-k_{T} R=0.4 charged-particle jets

$\boldsymbol{p_{\mathrm{T\,ch\,jet}}^{\mathrm{raw\,sub}} \neq p_{\mathrm{T}}^{\mathrm{ch\,jet}}}$

- $p_{\mathrm{T\,ch\,jet}}^{\mathrm{raw\,sub}}$: Raw jet p_{T} corrected with area-based pedestal subtraction
- $p_{\mathrm{T\,ch\,jet}}^{\mathrm{raw\,sub}}$ > 60 GeV/c minimizes the effect of purely combinatorial jets
- Expect weak jet p_{T} dependence in particle ratios
  - Currently accounted for in results' systematics

Particle origins

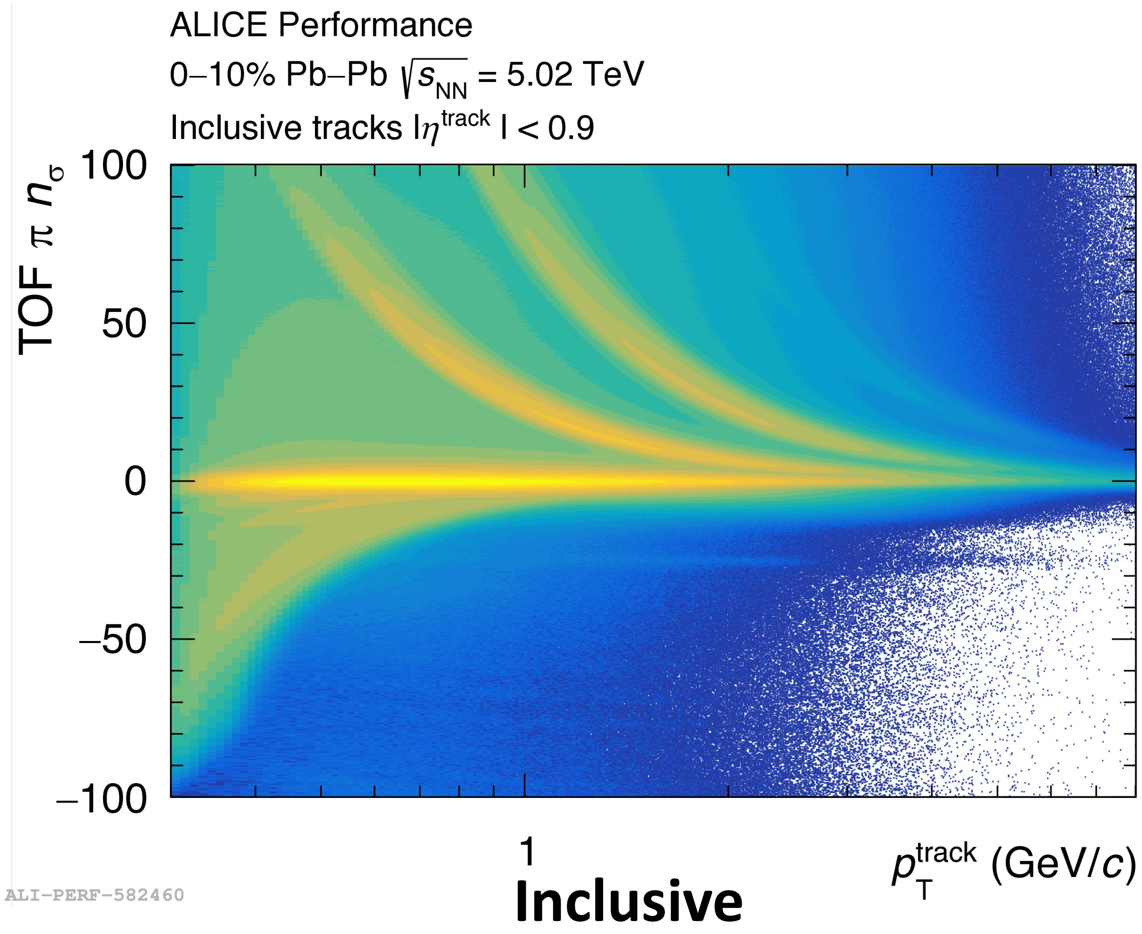


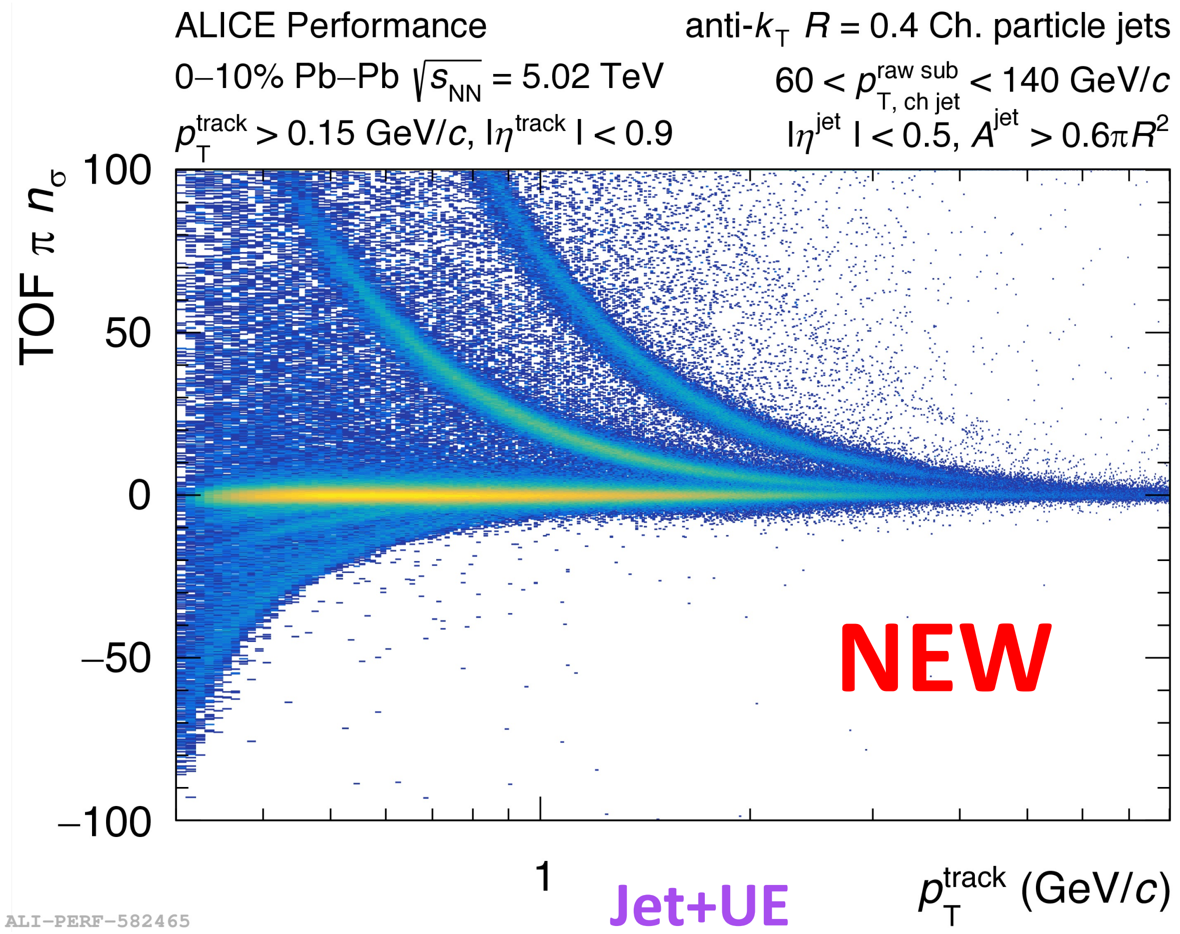


- PID is done on
  - **Inclusive particles** (regardless of jet presence)
  - All particles in anti-k_{T} **jet cone** (**jet**+**UE**)
  - Particles in **perpendicular cones** (**PC**)
    - R=0.4 cones at $\Delta\varphi$ = 90° and $\Delta\eta$ = 0 from selected jet cones
- **Still have UE particles inside the jet cones**
  - Particle-species-based UE subtraction is performed after PID with **PC**

These results: PID is performed via fits to TOF n_σ particle hypotheses

See Taketo Yokoo's poster for studies using TPC PID



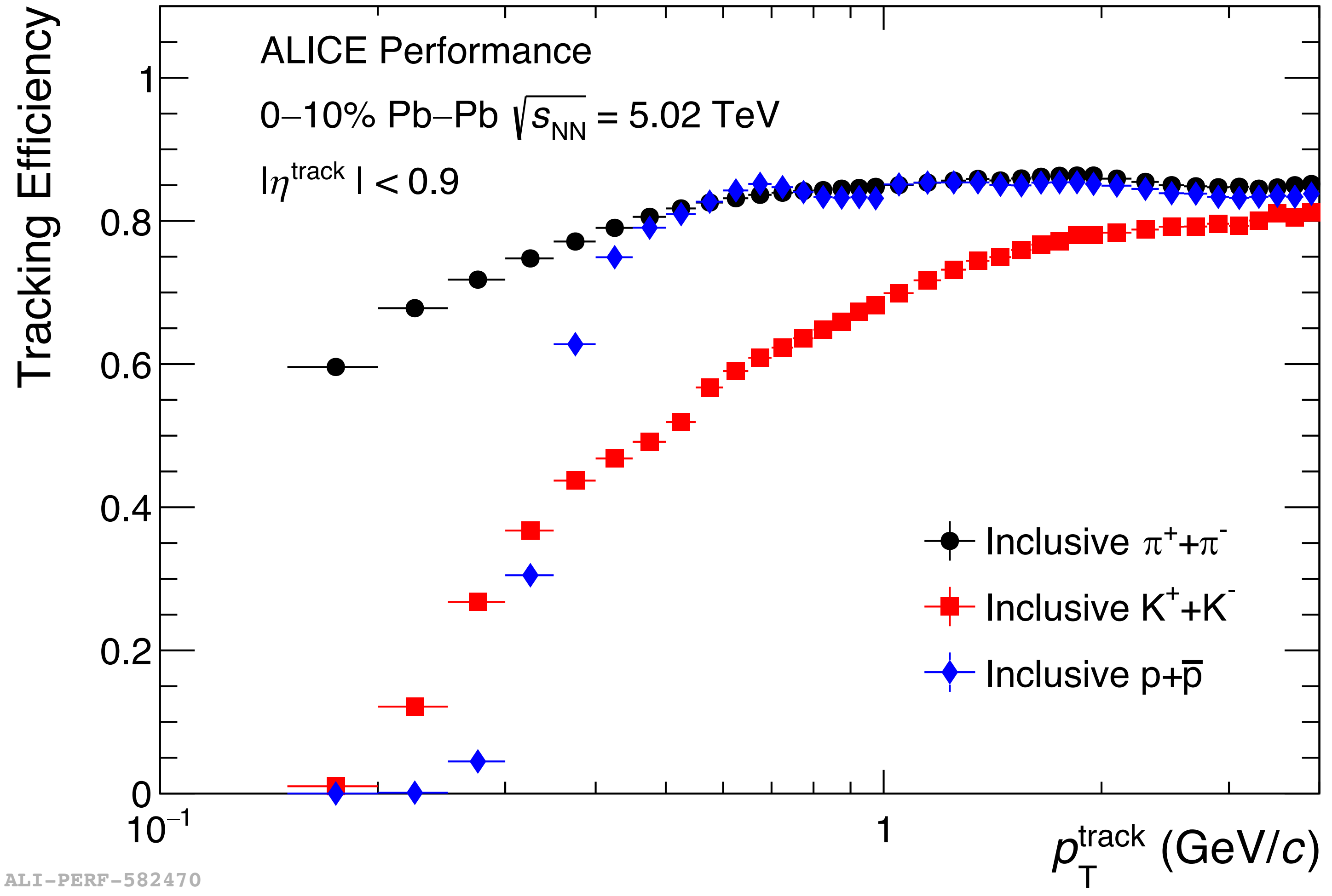


Repeated for K, p particle hypotheses

PID spectra corrections

Standard PID spectra corrections were performed for inclusive, jet+UE, and PC particles

- **Tracking efficiency**
  - MC inclusive tracks measured / MC inclusive particles produced



PID spectra corrections

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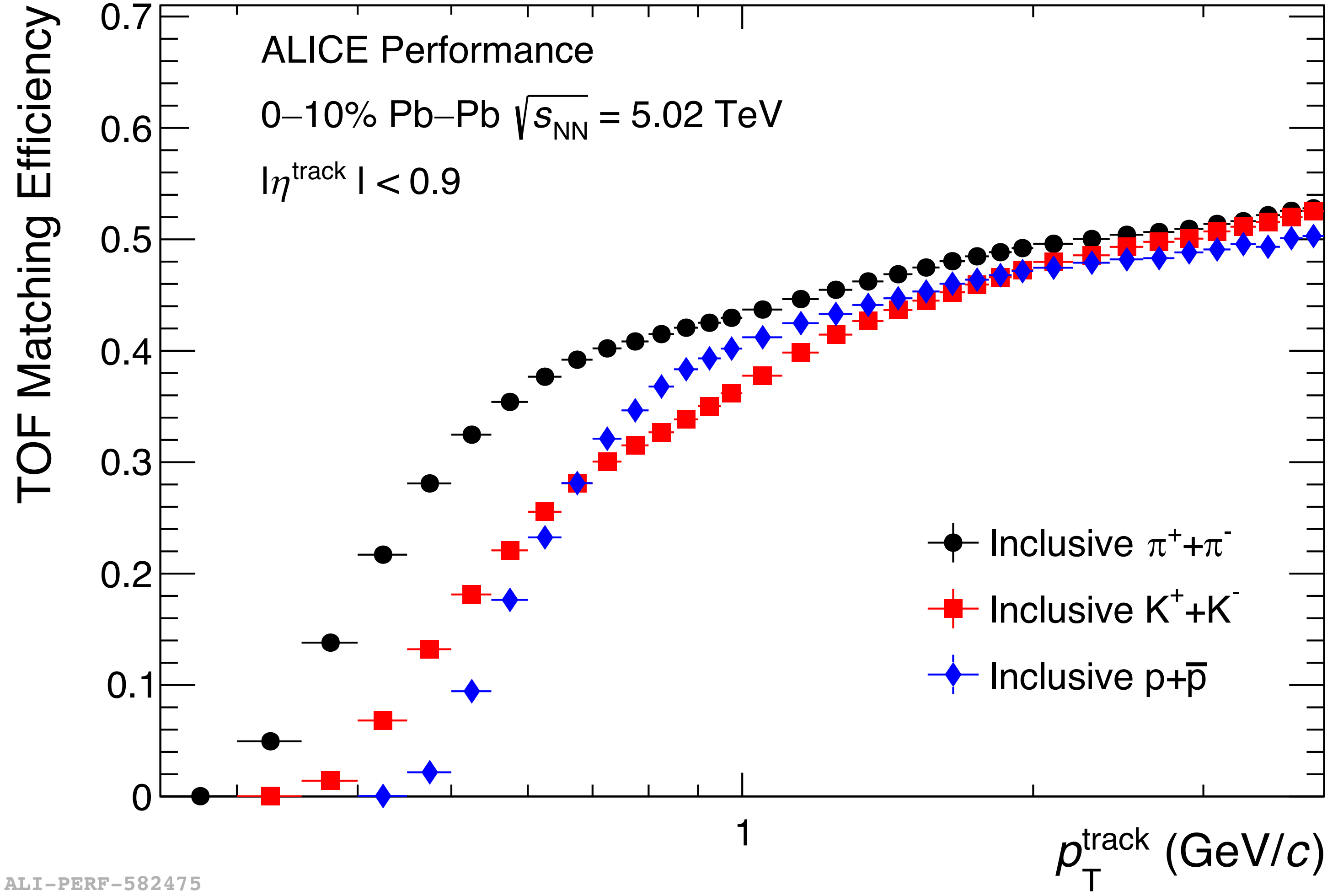
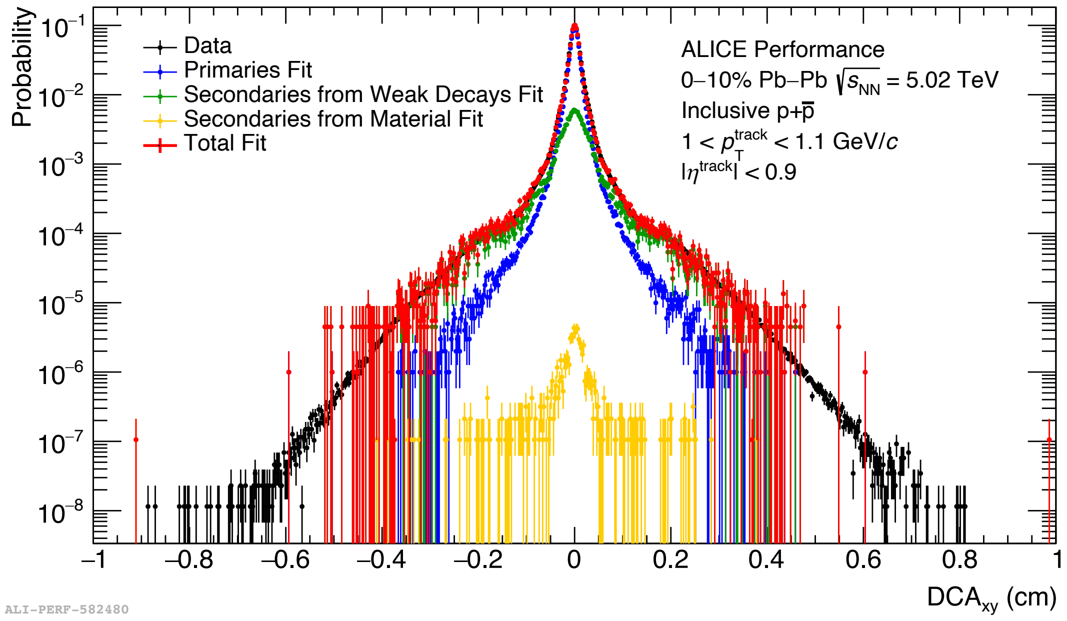
- **TOF matching efficiency**
  - MC inclusive tracks measured and matched to a TOF signal / MC inclusive tracks measured

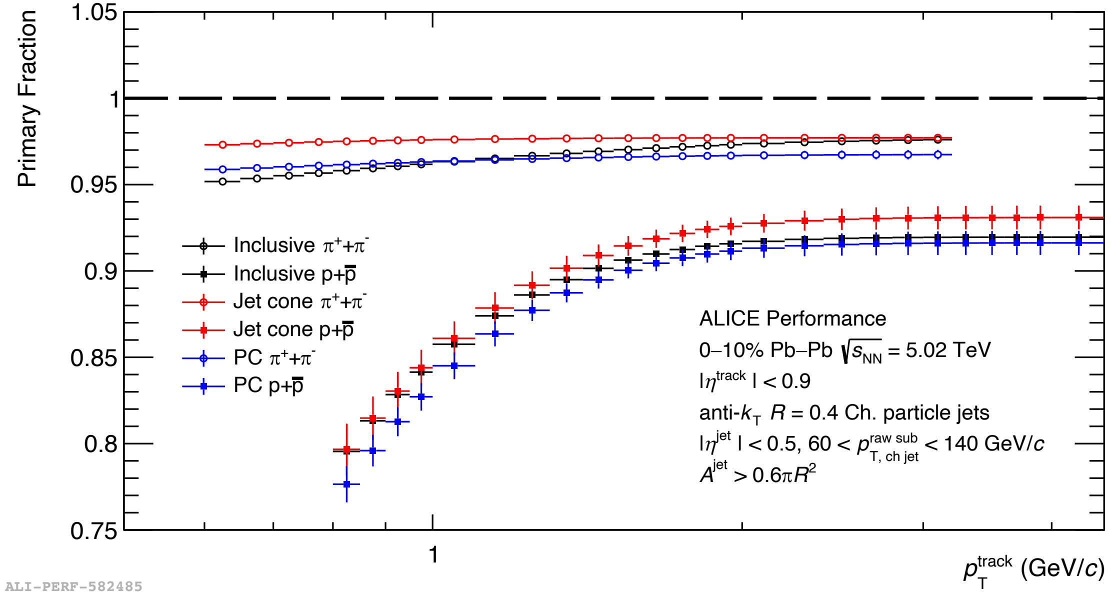


PID spectra corrections

Standard PID spectra corrections were performed for inclusive, jet+UE, and PC particles

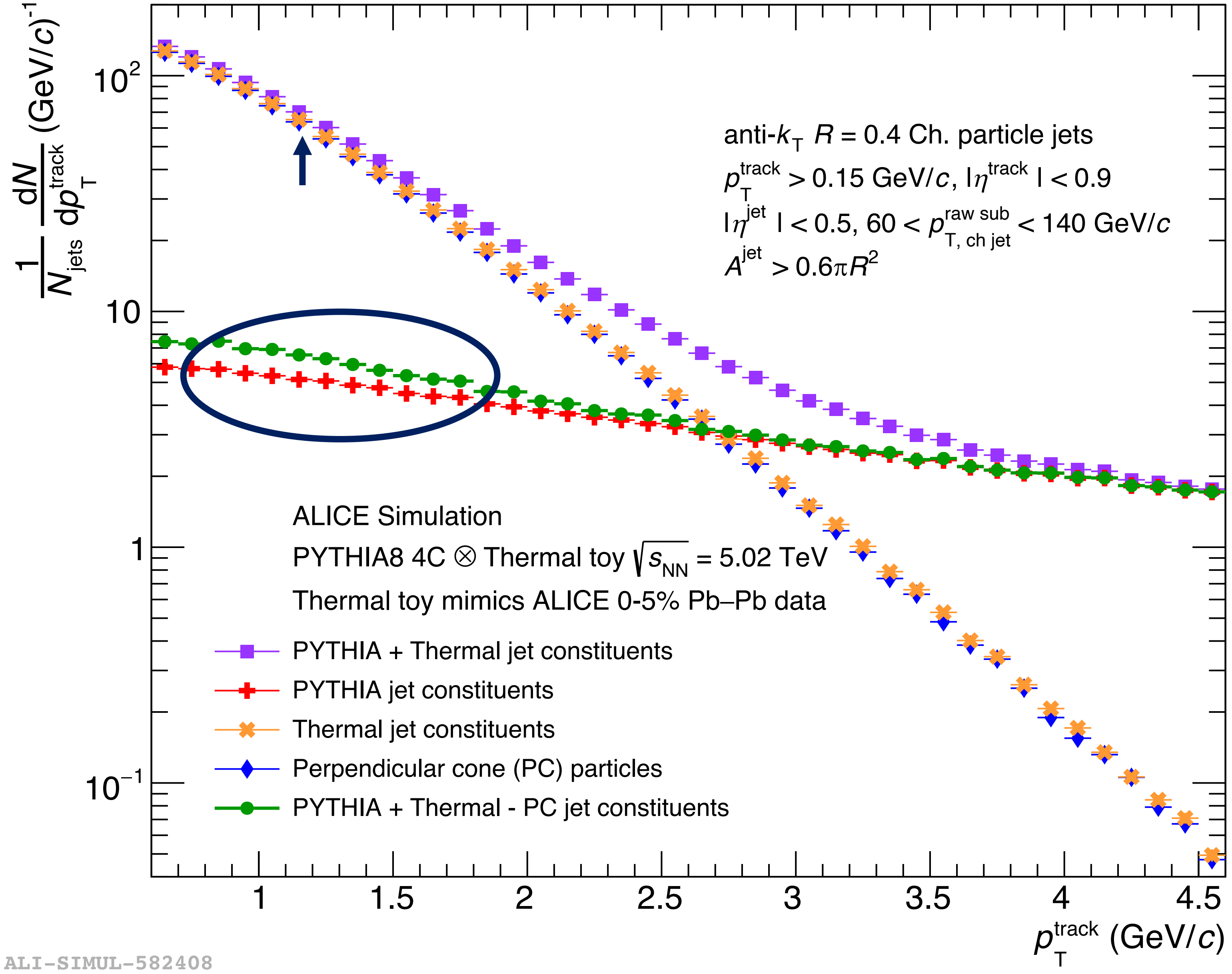
- Tracking efficiency
  - MC inclusive tracks measured / MC inclusive particles produced
- TOF matching efficiency
  - MC inclusive tracks measured and matched to a TOF signal / MC inclusive tracks measured
- **Primary fraction**
  - Data primary tracks / Data tracks measured





Toy model studies of particle species-based UE subtraction

- **Perpendicular cone (PC):** R=0.4 cones at $\Delta\varphi$ = 90° and $\Delta\eta$ = 0 from selected jet cones
- **PC** underestimates the **UE** particles in selected **PYTHIA+thermal** toy model jets



Particle species-based underlying event subtraction

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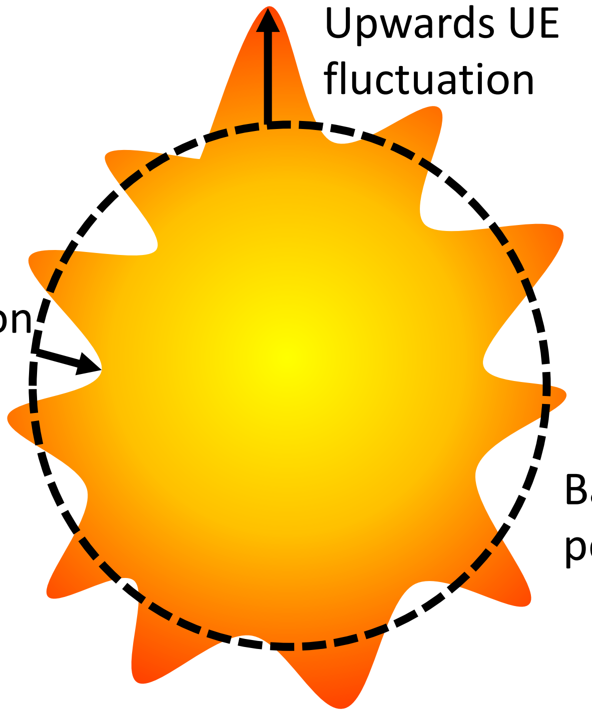

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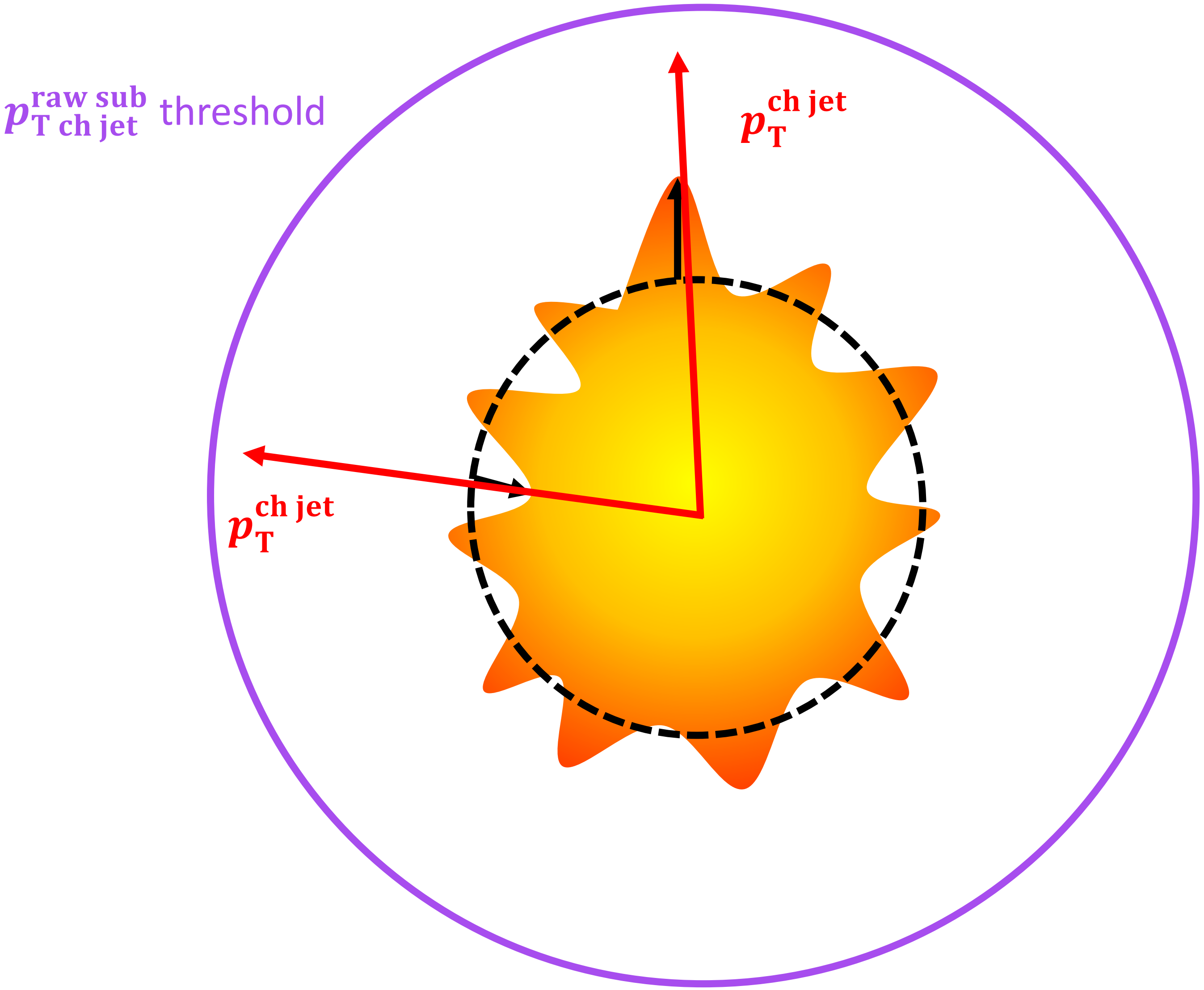

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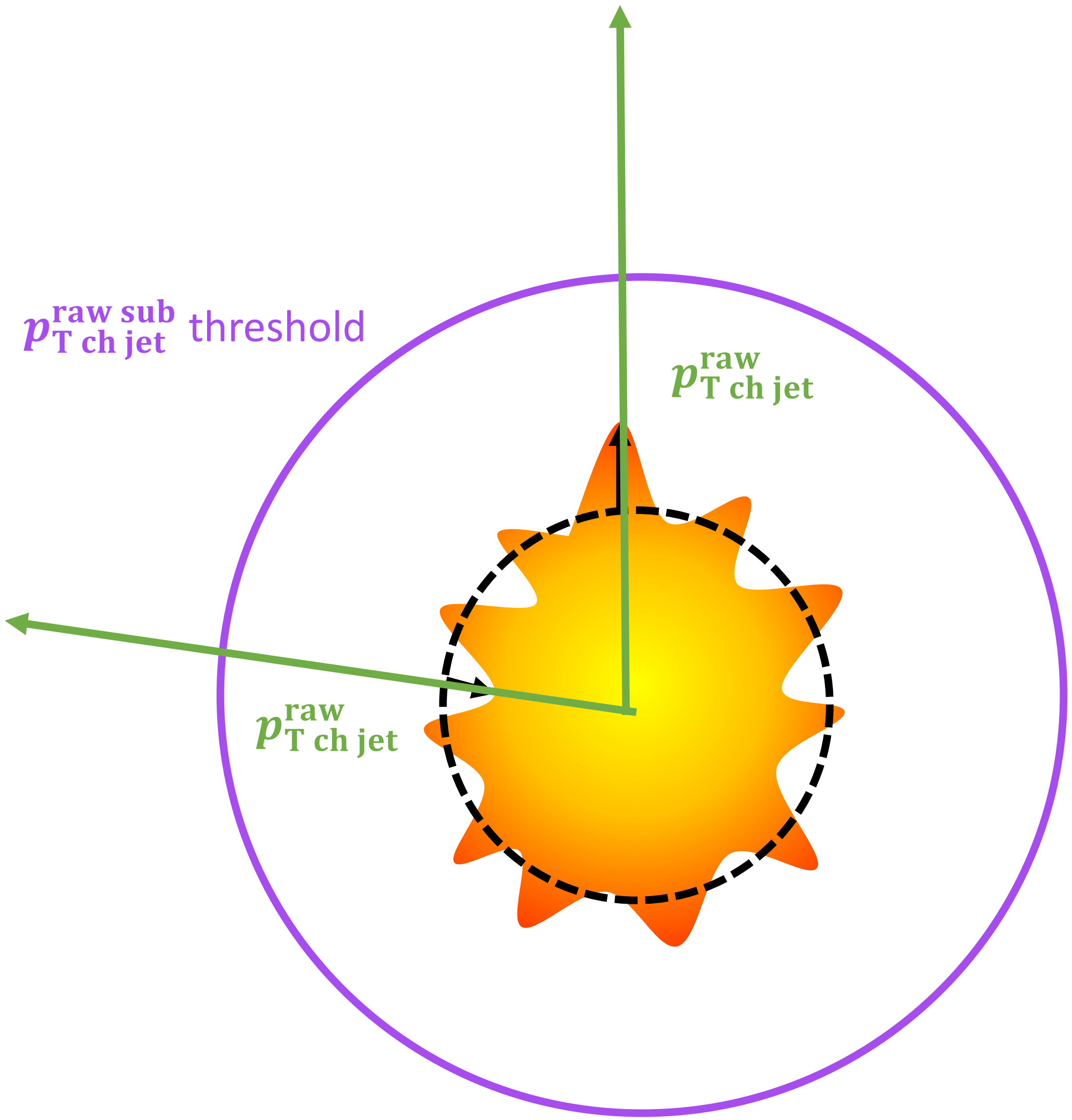
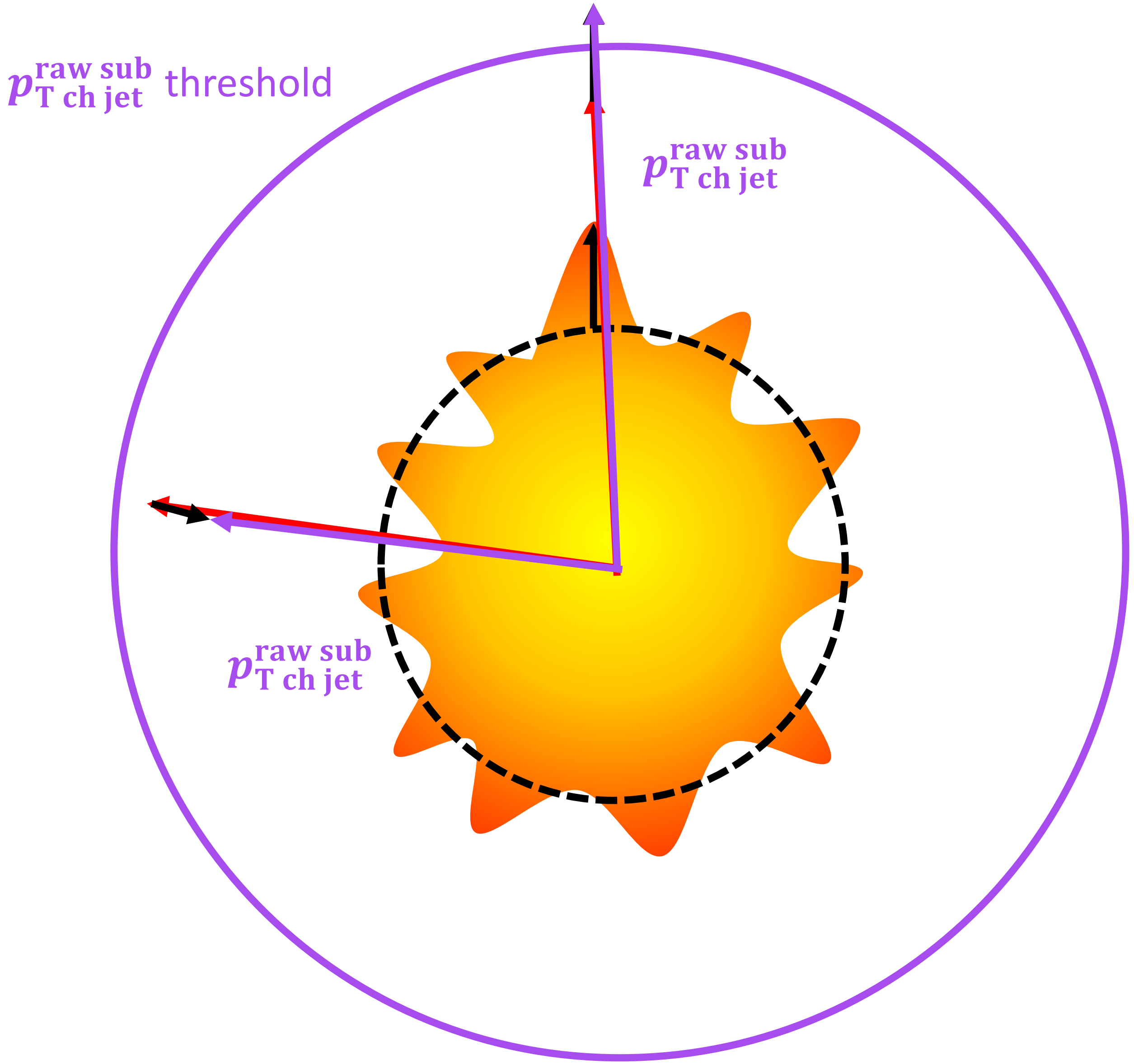


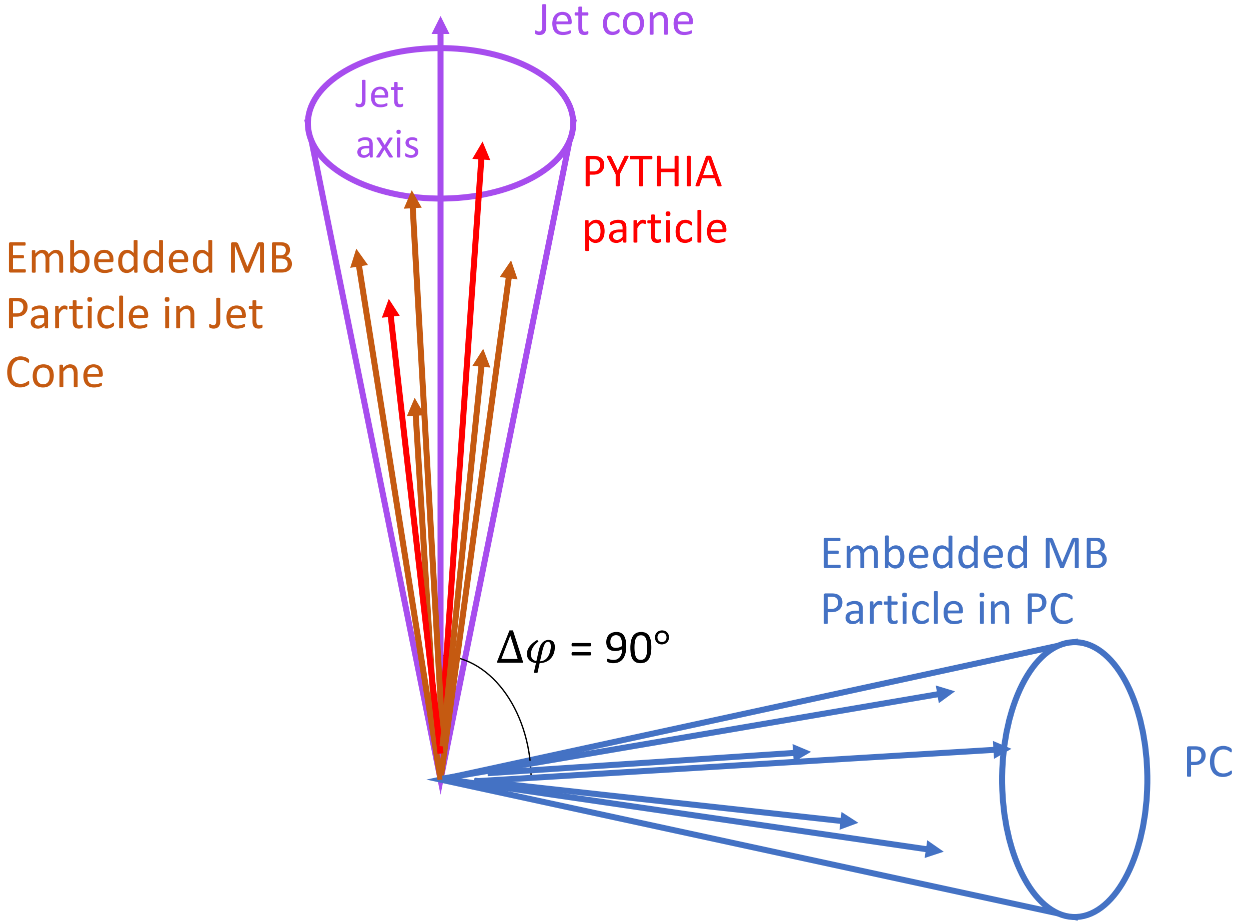
Particle species-based underlying event subtraction

- **Perpendicular cone (PC):** R=0.4 cones at $\Delta\varphi$ = 90° and $\Delta\eta$ = 0 from selected jet cones
- **PC** underestimates the **UE** particles in selected **PYTHIA+thermal** toy model jets
- **Caused by an increased probability of selecting a jet on an upward fluctuation of the background from cutting on $p_{\mathrm{T\,ch\,jet}}^{\mathrm{raw\,sub}}$**



Scaling factor

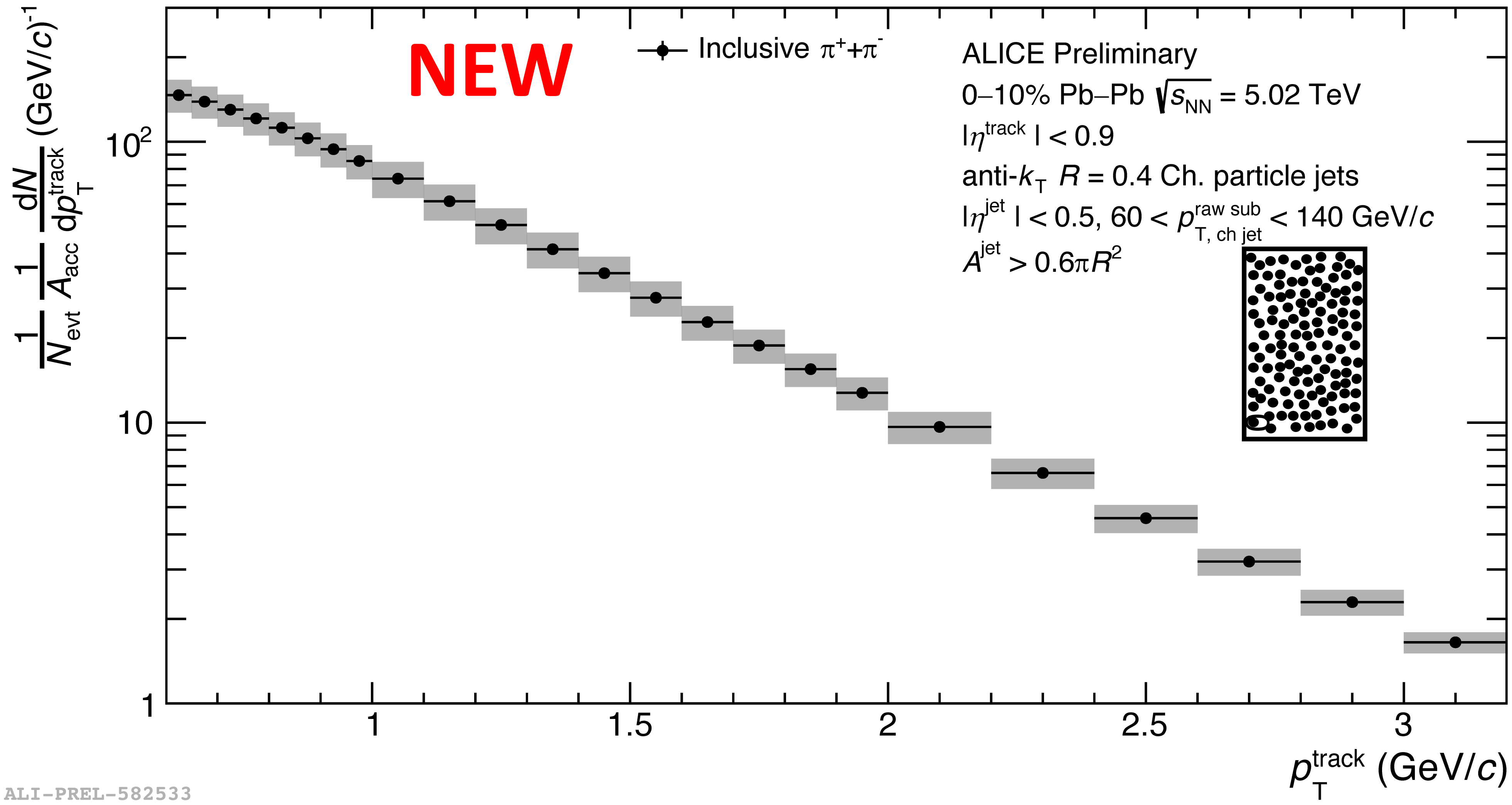
- **Scaling factor (UE in jets / UE in PC) obtained from PYTHIA embedded into ALICE MB data to account for this bias**
  - Separate scaling factor obtained for each particle species
  - Current systematic: Scaling vs no scaling to account for possible contamination from jets in the ALICE MB events used for embedding



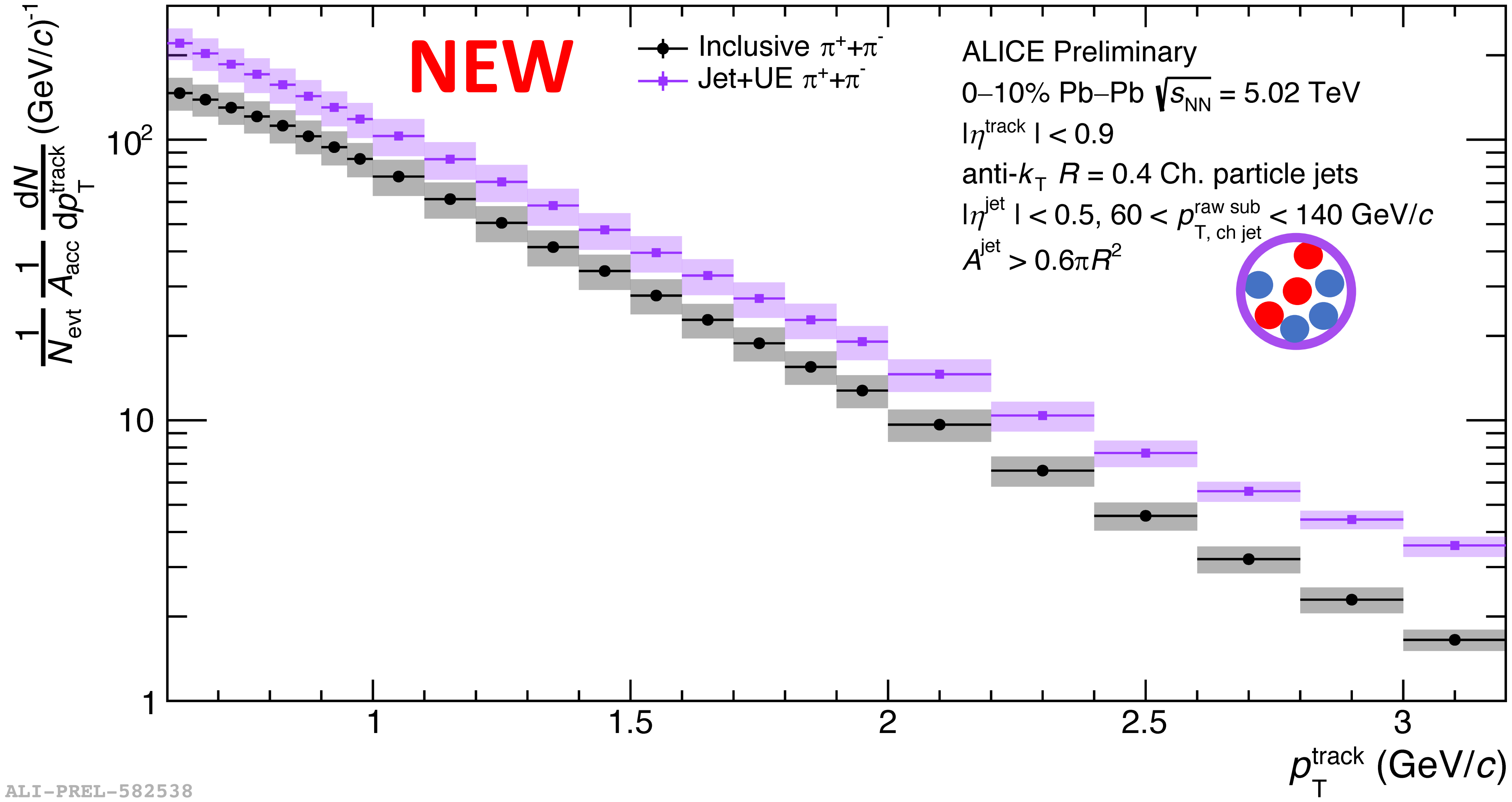
$$\frac{d\rho_{\mathrm{jet}}}{dp_{\mathrm{T}}} = \frac{d\rho_{\mathrm{jet+UE}}}{dp_{\mathrm{T}}} - \frac{d\rho_{\mathrm{PC}}}{dp_{\mathrm{T}}} * c_{\mathrm{UE\ Bias}} \quad c_{\mathrm{UE\ Bias}}(p_{\mathrm{T}}) = \frac{d\rho_{\mathrm{UE\ in\ selected\ jets}}}{dp_{\mathrm{T}}} / \frac{d\rho_{\mathrm{PC}}}{dp_{\mathrm{T}}}$$

π spectra

$$N_{\mathrm{evt}}^{\mathrm{inc}} A_{\mathrm{acc}}^{\mathrm{inc}} = N_{\mathrm{evt}}^{\mathrm{inc}} 1.8 * 2\pi$$



$$N_{\rm evt}^{\rm inc} A_{\rm acc}^{\rm inc} = N_{\rm evt}^{\rm inc} 1.8 * 2\pi \quad N_{\rm evt}^{\rm jet+UE} A_{\rm acc}^{\rm jet+UE} = \sum A_{\rm jet}$$



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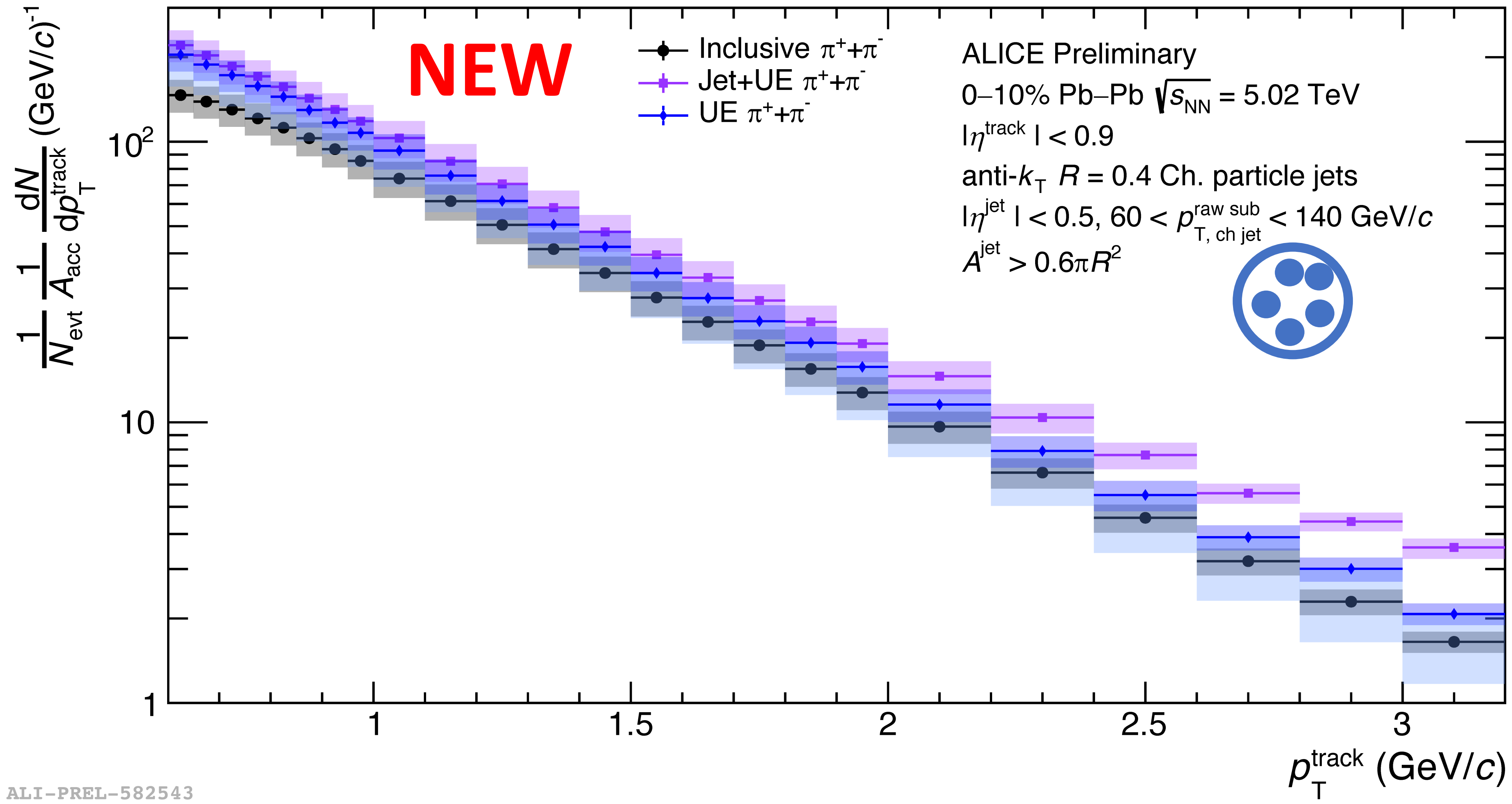

- UE and Inclusive are consistent

π spectra

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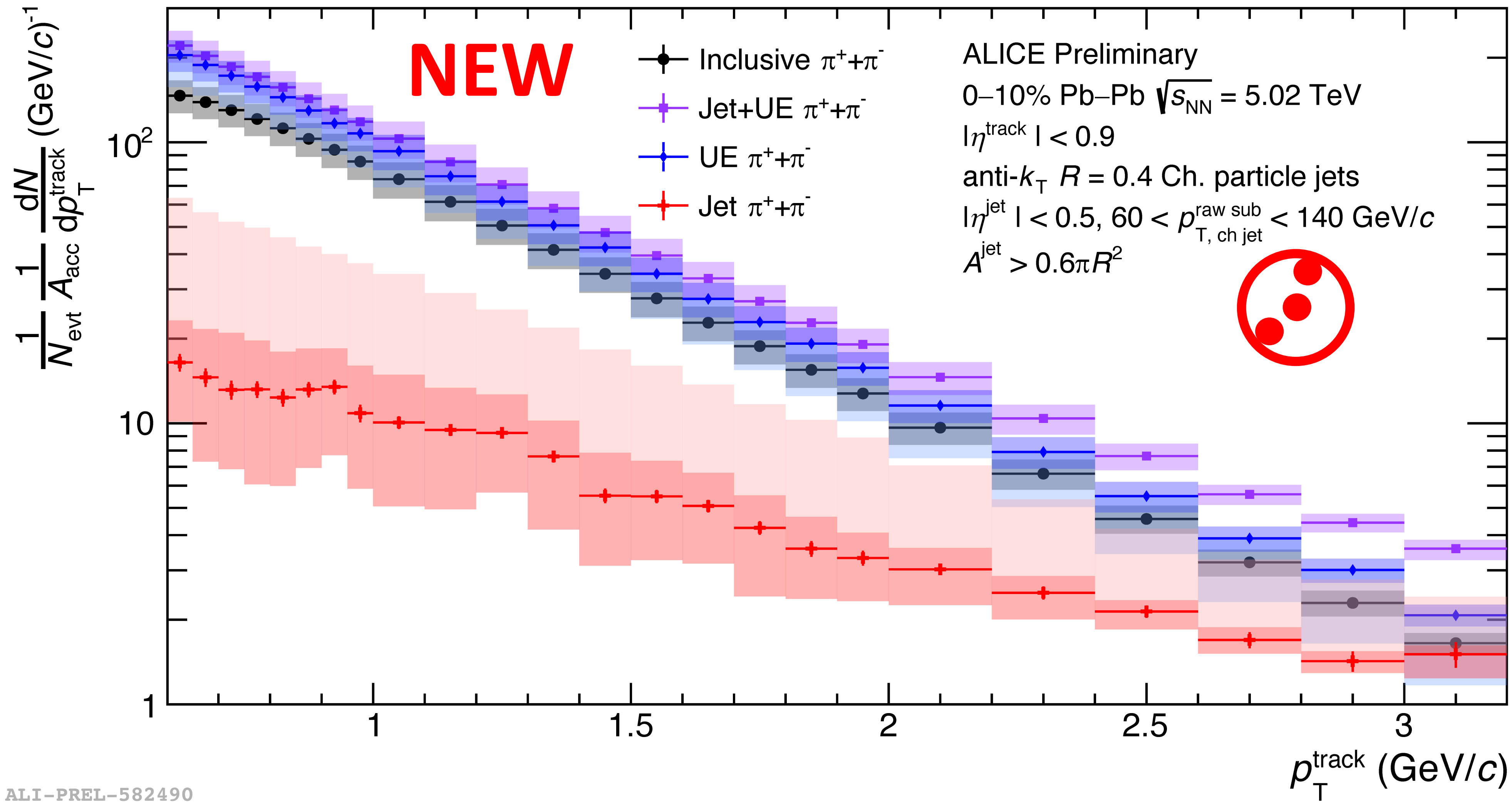
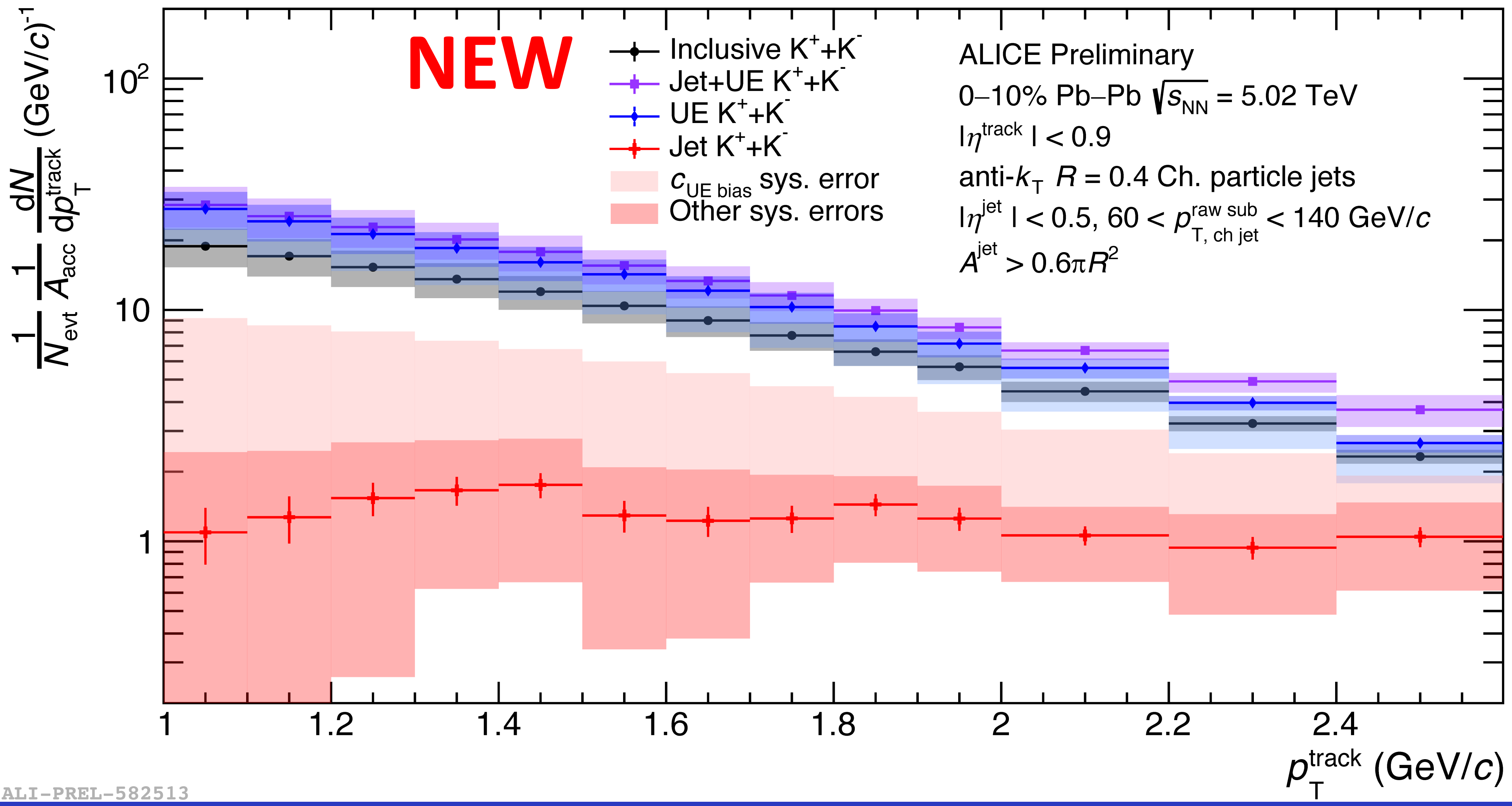


- UE and Inclusive are consistent
- Jet+UE is dominated by UE particles in the p_{T} range considered
  - Jet portion gets fractionally larger as p_{T} increases

K spectra

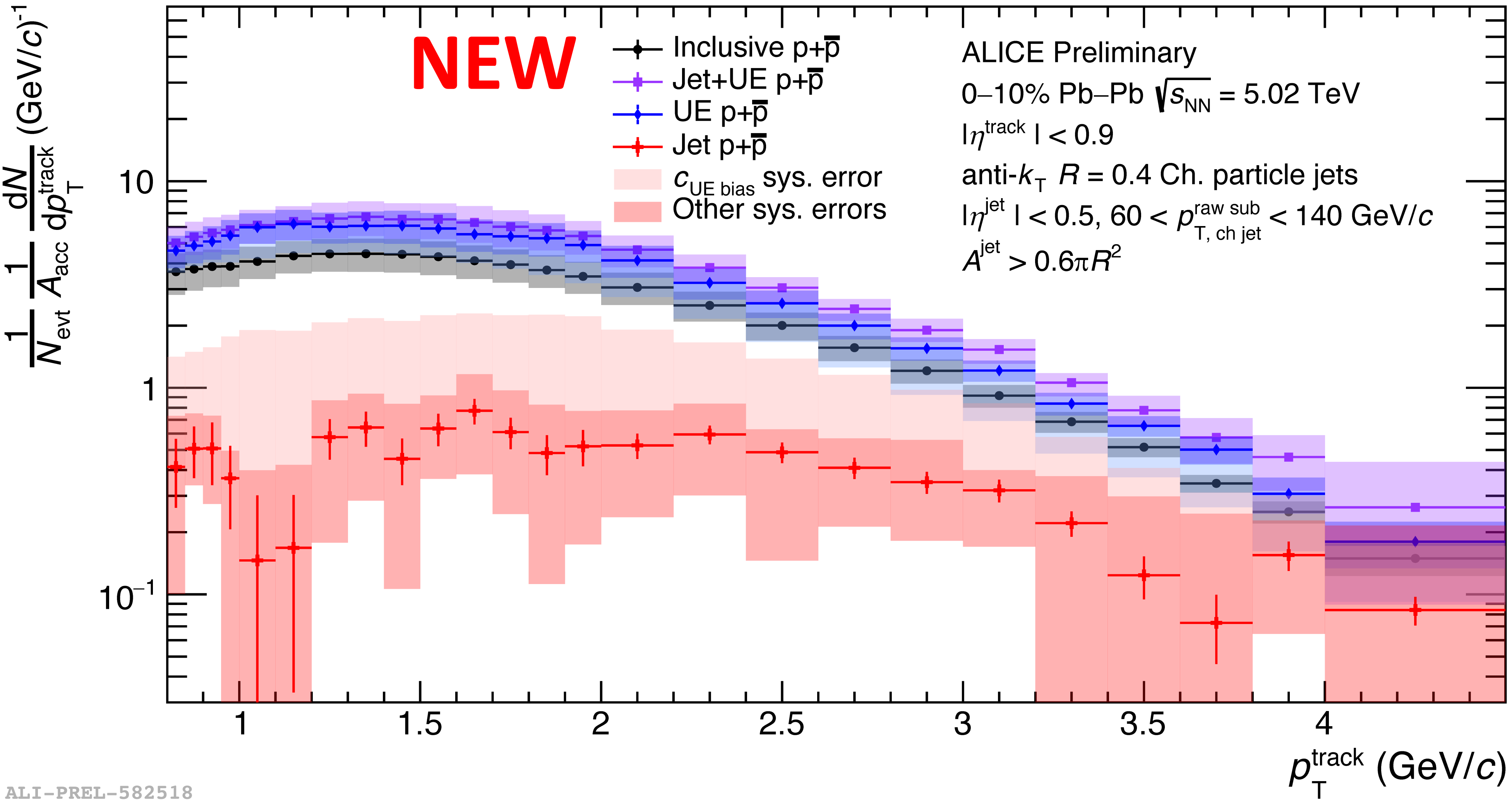
$$N_{\text{evt}}^{\text{inc}} A_{\text{acc}}^{\text{inc}} = N_{\text{evt}}^{\text{inc}} 1.8 * 2\pi \quad N_{\text{evt}}^{\text{jet+UE}} A_{\text{acc}}^{\text{jet+UE}} = \sum A_{\text{jet}} \quad N_{\text{evt}}^{\text{UE}} A_{\text{acc}}^{\text{UE}} = N_{\text{PC}} \pi R^2$$



- **Fewer K than π for all cases**
- UE and Inclusive are consistent
- Jet+UE is dominated by UE particles in the p_{T} range considered
  - Jet portion gets fractionally larger as p_{T} increases

p spectra

$$N_{\text{evt}}^{\text{inc}} A_{\text{acc}}^{\text{inc}} = N_{\text{evt}}^{\text{inc}} 1.8 * 2\pi \quad N_{\text{evt}}^{\text{jet+UE}} A_{\text{acc}}^{\text{jet+UE}} = \sum A_{\text{jet}} \quad N_{\text{evt}}^{\text{UE}} A_{\text{acc}}^{\text{UE}} = N_{\text{PC}} \pi R^2$$



- **Fewer p than π for all cases**
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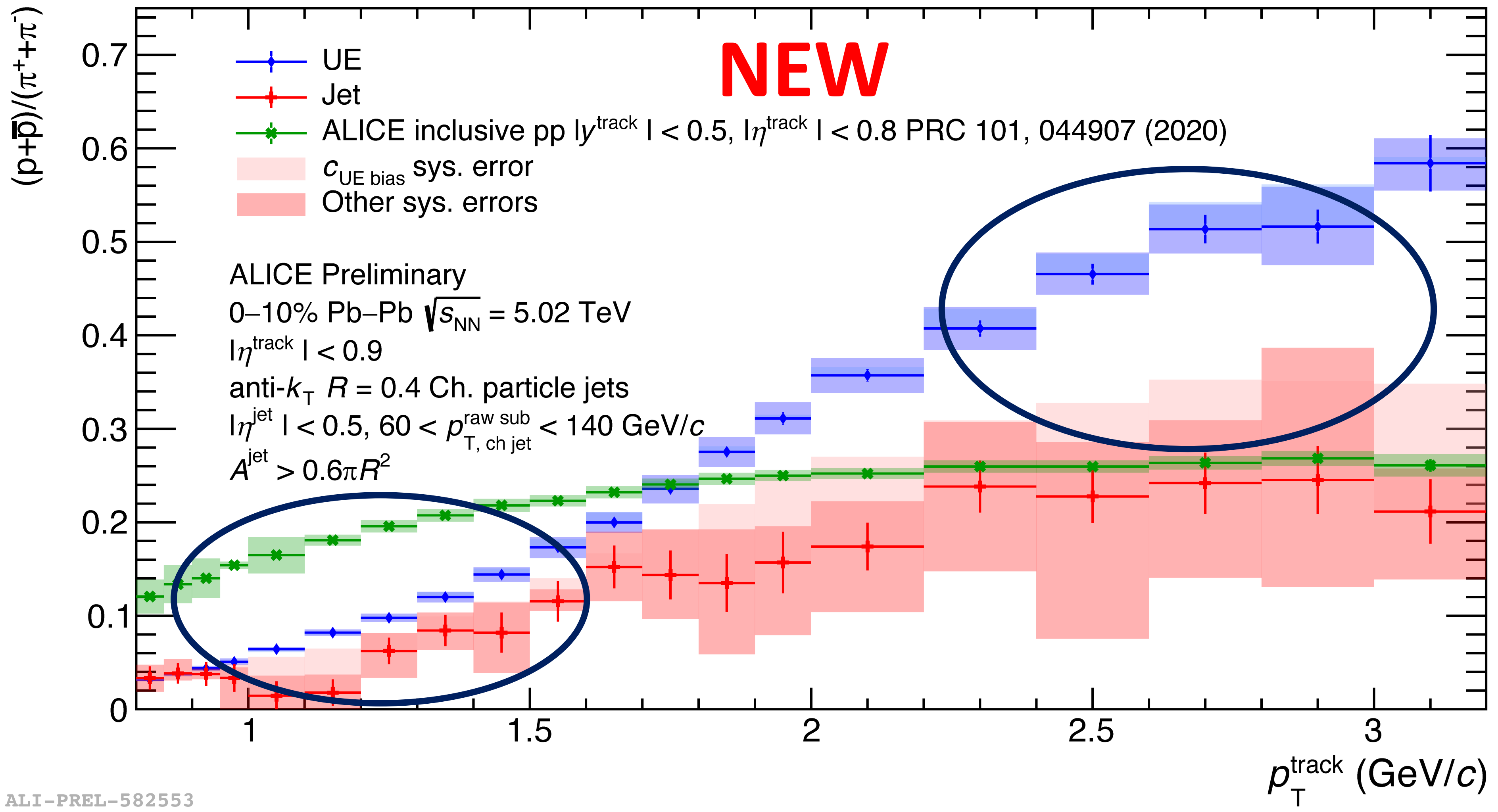
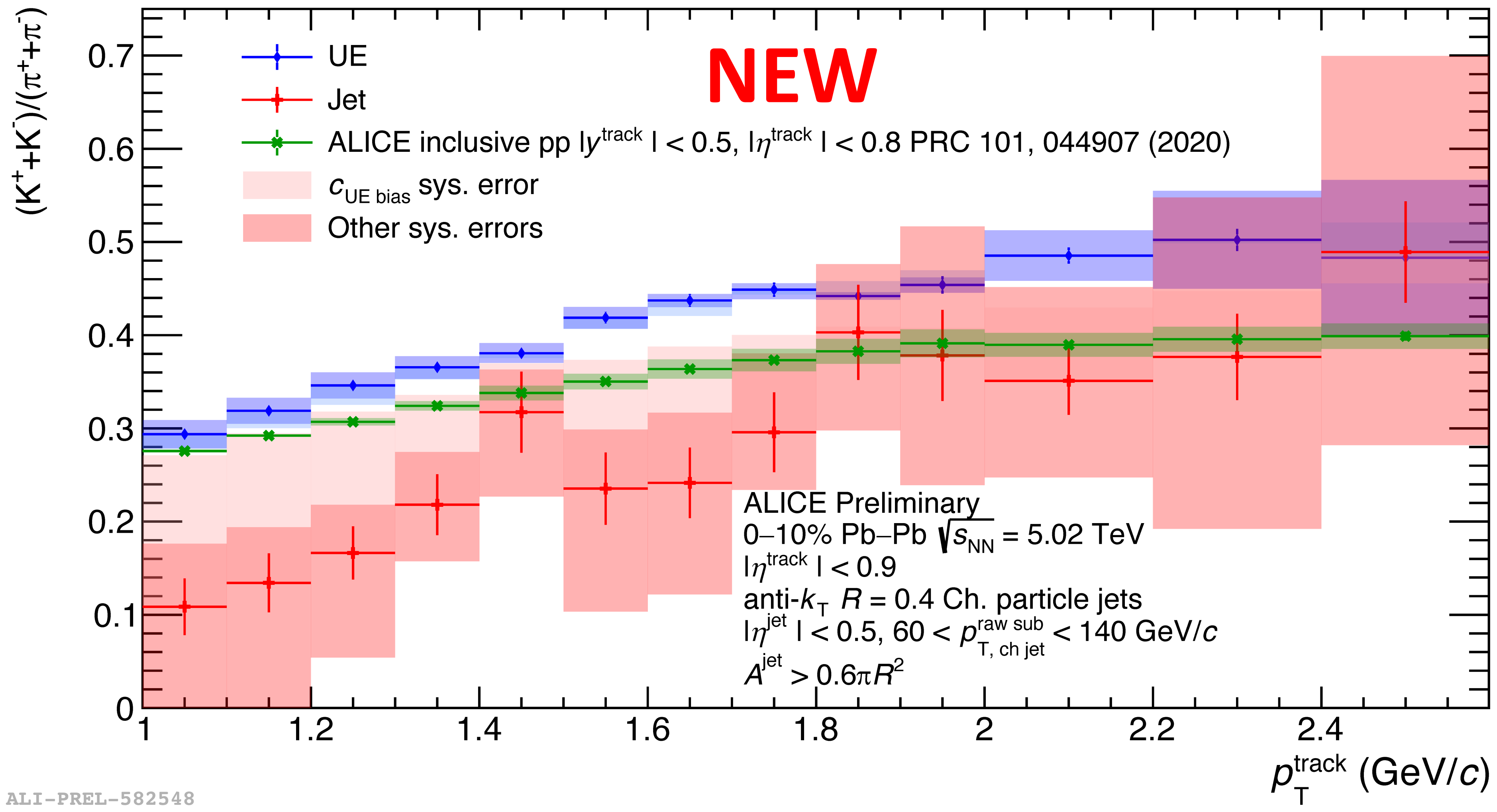
p/π ratio



- Probing baryon production
- **Pb–Pb jet has lower p/π than Pb–Pb UE**
- **Pb–Pb jet has lower p/π than pp inclusive at low p_T**
  - Hints of lower p/π at intermediate p_T
  - Need to measure p/π in pp jets to probe jet modification

See Taketo Yokoo's poster for pp jet progress

K/π ratio



- Probing strangeness production
- **Pb–Pb jets hint at lower K/π than Pb–Pb UE**
- **Pb–Pb jets hint at lower K/π than pp inclusive**
  - Need to measure K/π in pp jets to probe jet modification

$c_{\text{UE Bias}}$ systematic uncertainty expected to be significantly reduced with further studies on the possible contamination from jets in the ALICE MB events used for embedding

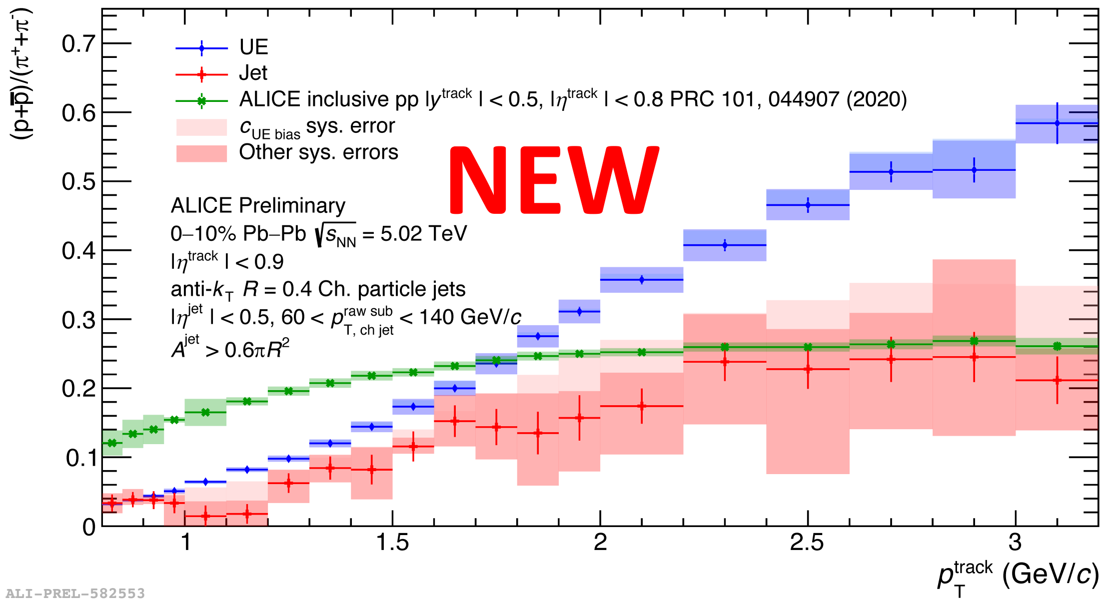
Summary

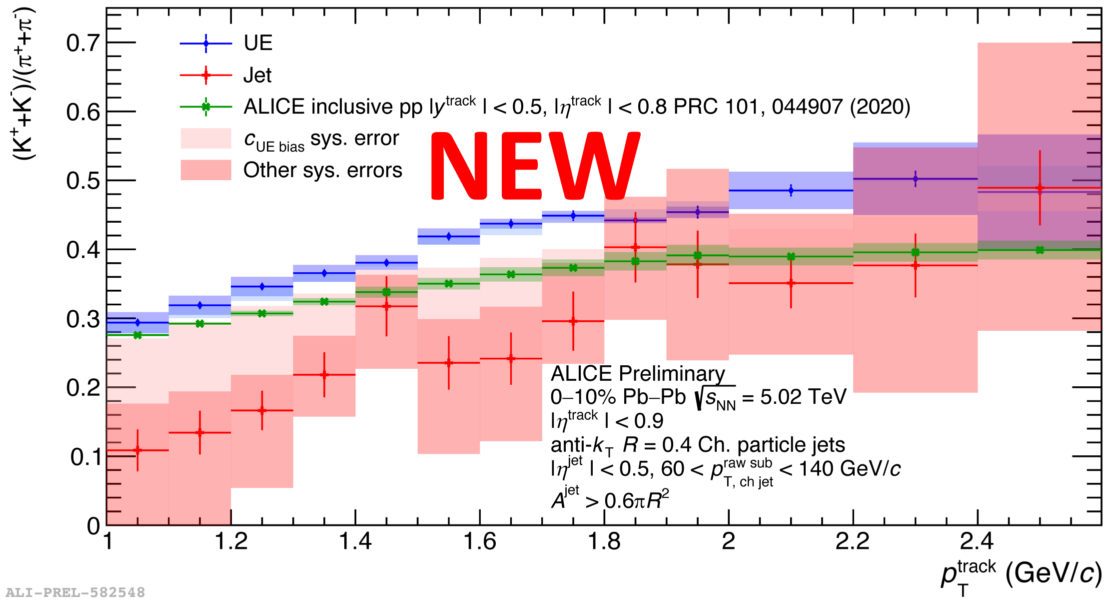
- **First measurement** of π, K, p in jets and UE **in** Pb–Pb collisions
- **Baryon** production in Pb–Pb jets less than Pb–Pb UE
  - Hint of less **strangeness** production in Pb–Pb jets than Pb–Pb UE
- pp jet K/π and p/π measurements needed
  - Probes possible jet hadrochemistry modification due to **modified fragmentation** or **medium response**

Outlook

- Unfold to probe jet p_{T} dependence
- Extend PID p_{T} range with TPC
- Centrality dependence
- Radial distance from jet axis dependence
- Perform measurement in pp

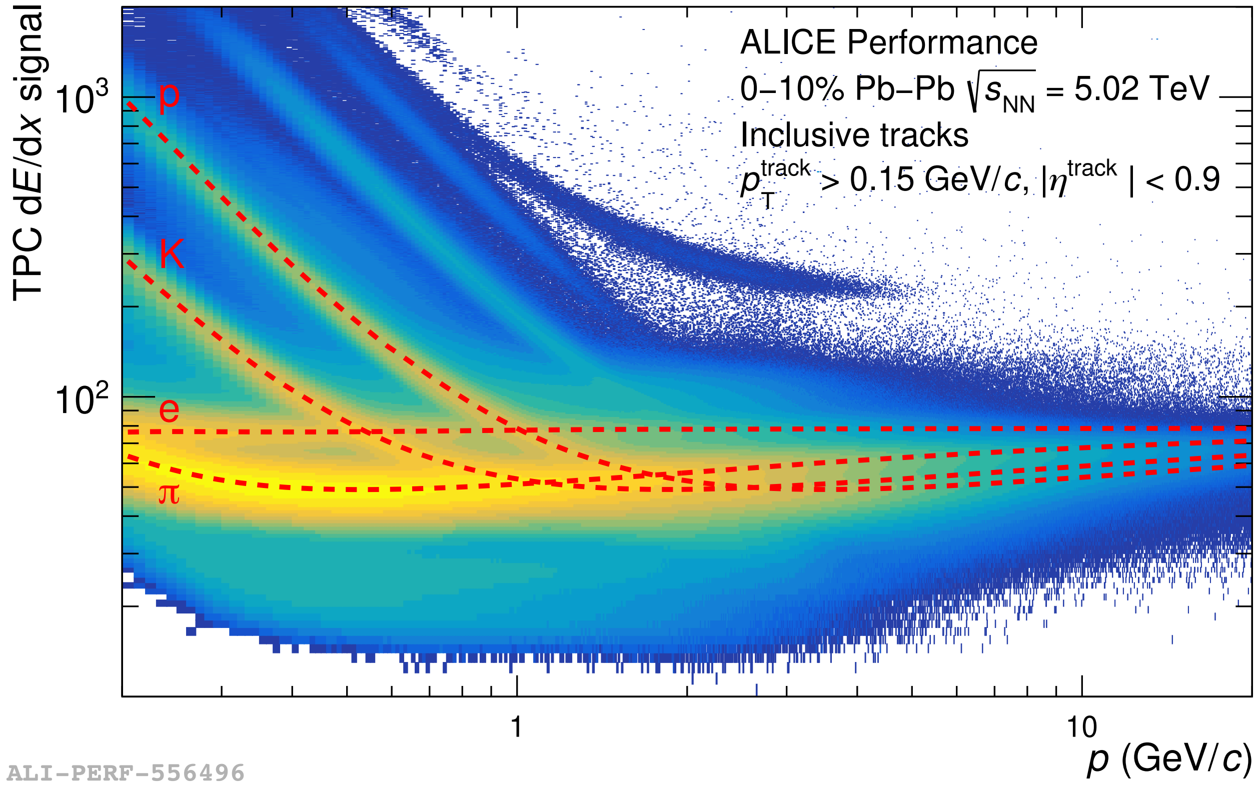
See Taketo Yokoo's poster



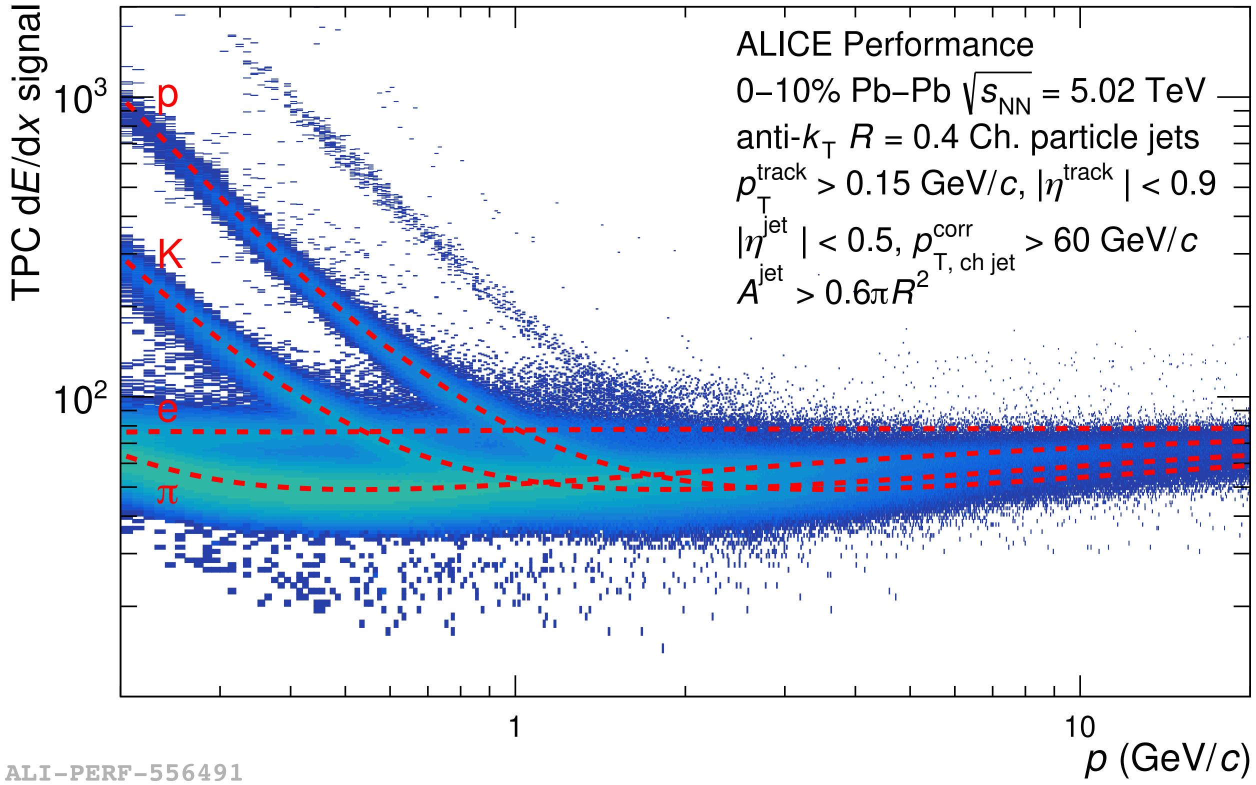


BACKUP

TPC dE/dx PID



Inclusive



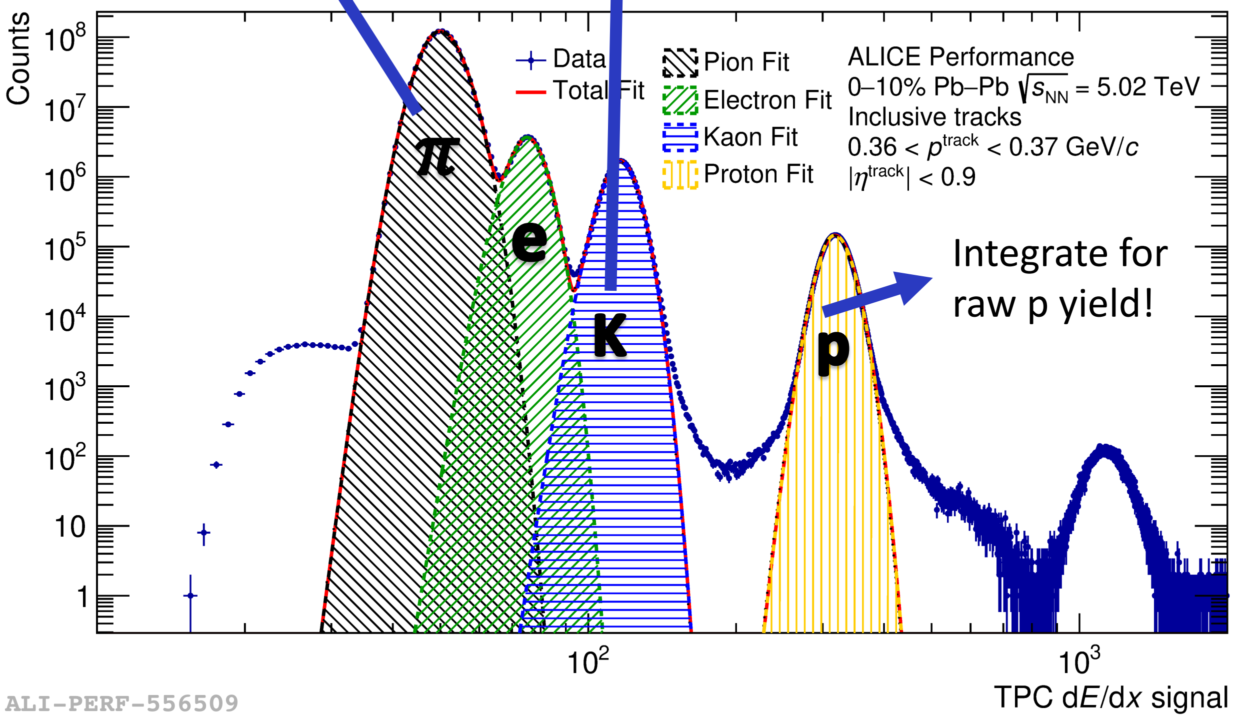
Jets

TPC dE/dx PID fits

$$f(x) = Ae^{-\left(\frac{|x-\mu|}{\sqrt{2}\sigma}\right)^{\beta}}\left(1+\mathrm{erf}\left(\alpha\frac{x-\mu}{\sigma\sqrt{2}}\right)\right)$$

Integrate for raw π yield!

Integrate for raw K yield!



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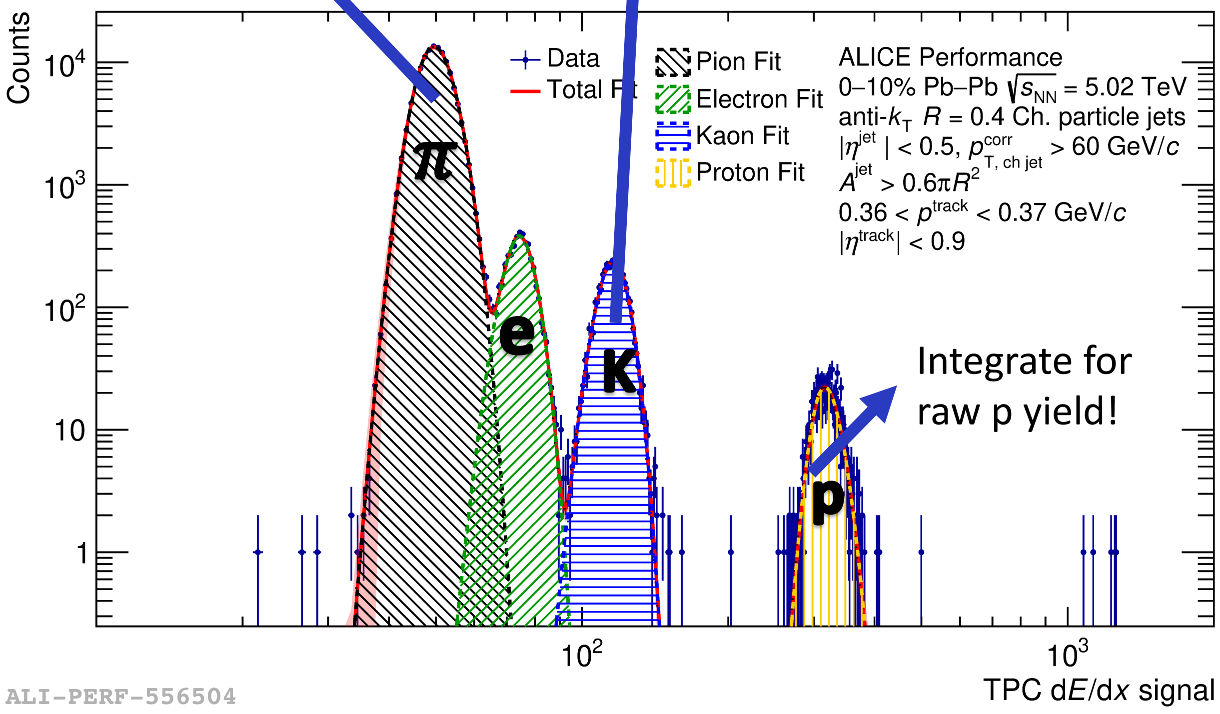
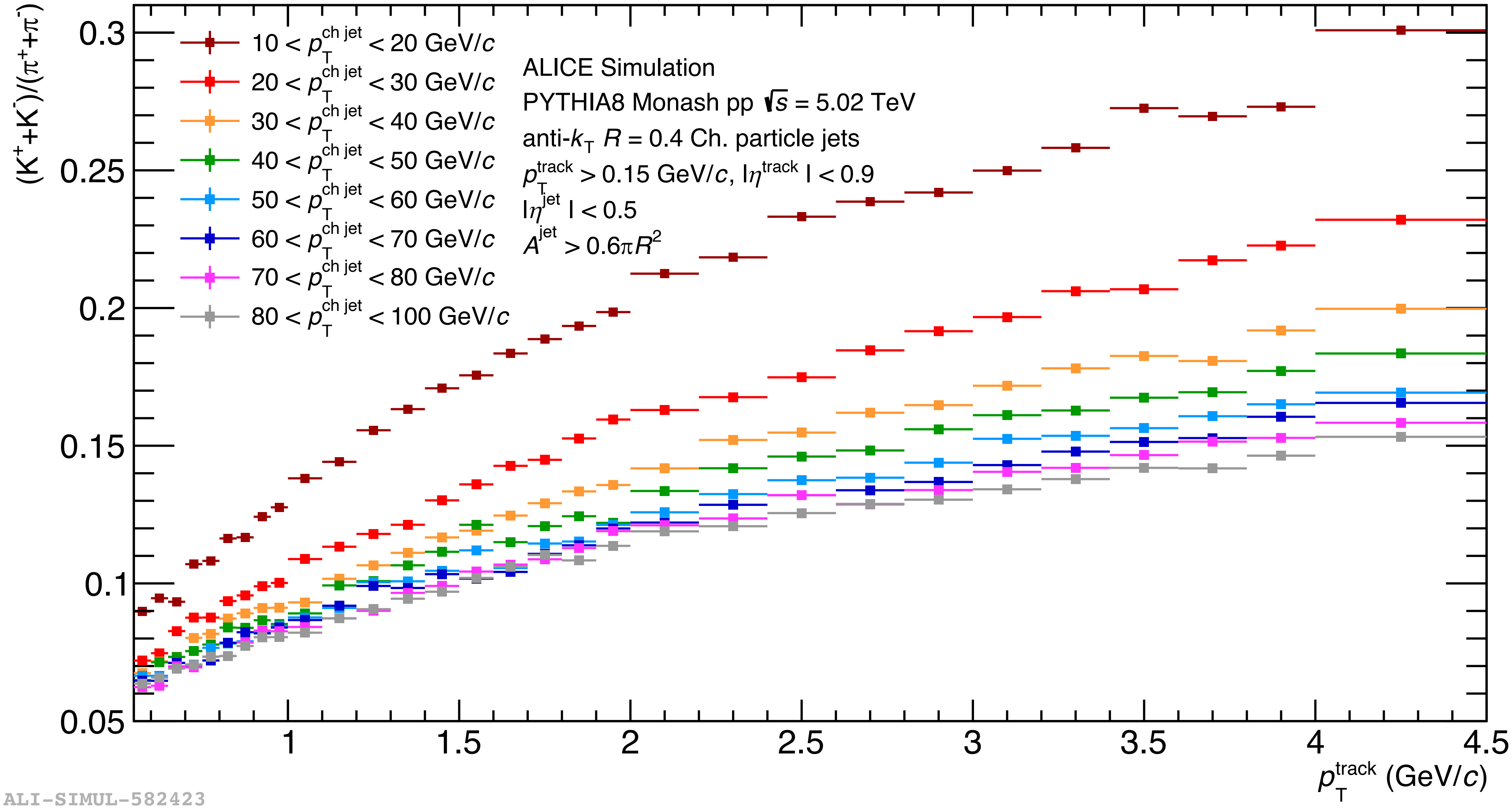
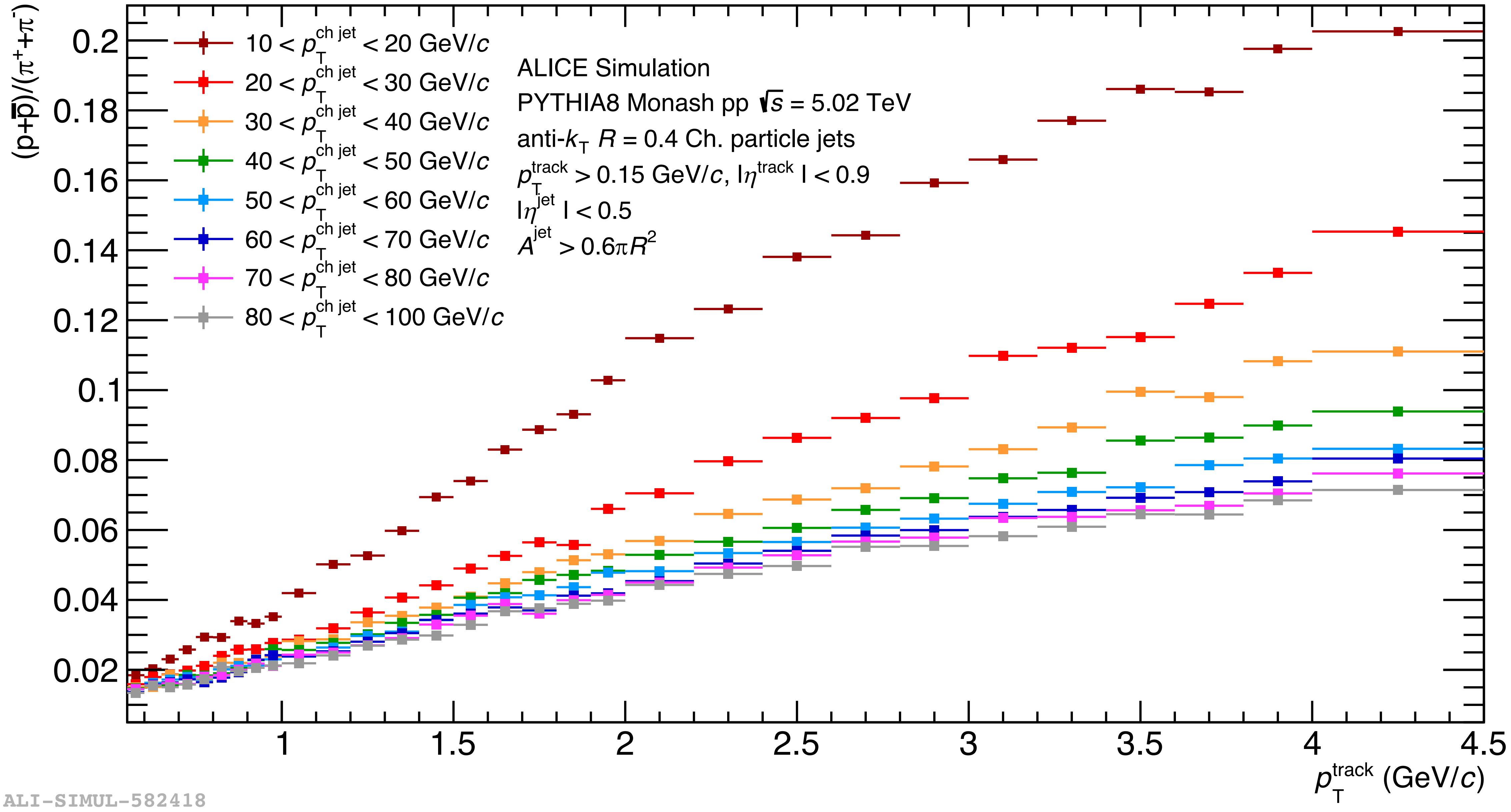


Jets

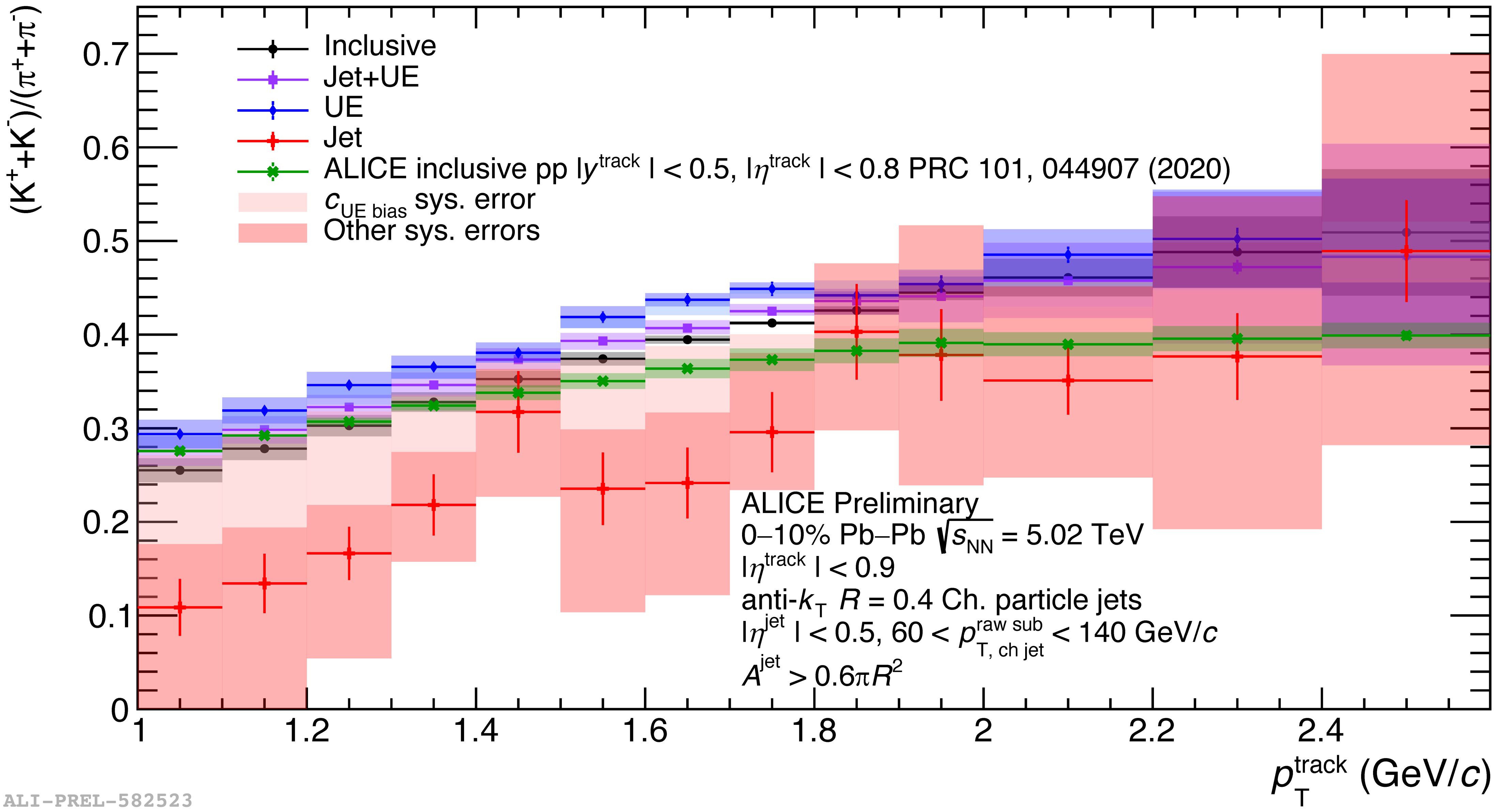
PYTHIA K/π dependence on $p_T^{\text{ch jet}}$



PYTHIA p/π dependence on $p_{T}^{ch\ jet}$



All particle origins K/π



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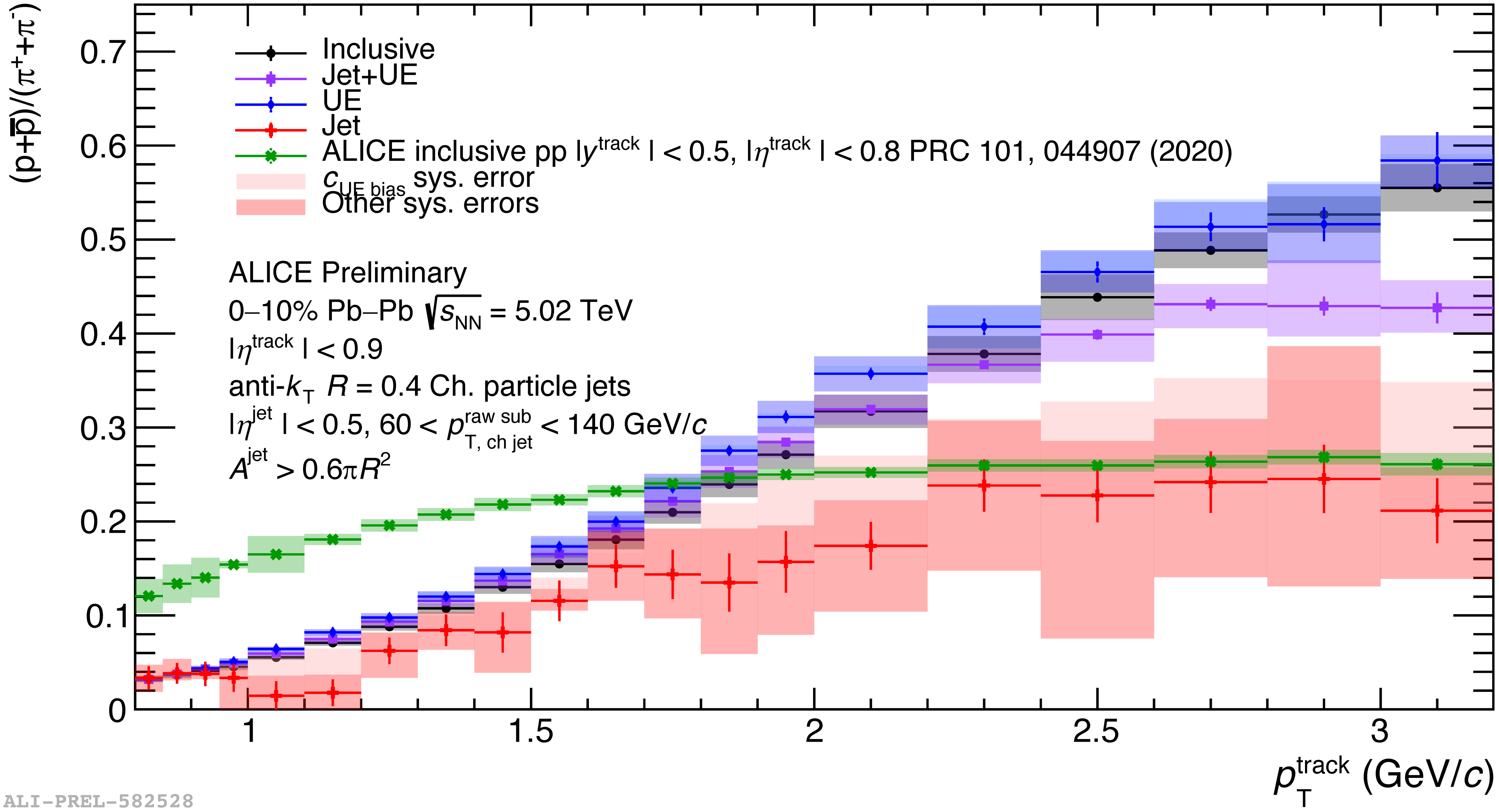
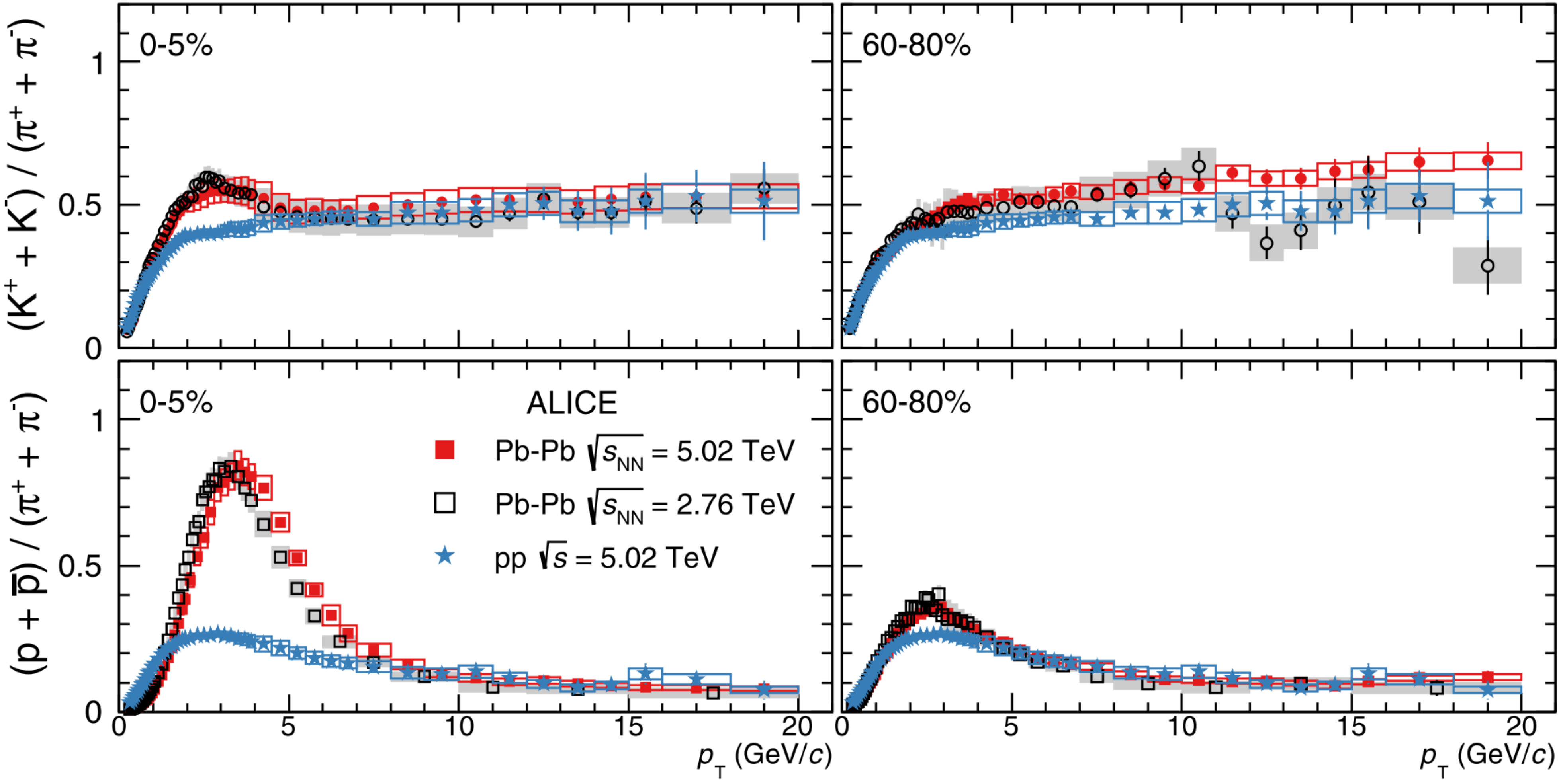


Similar measurements

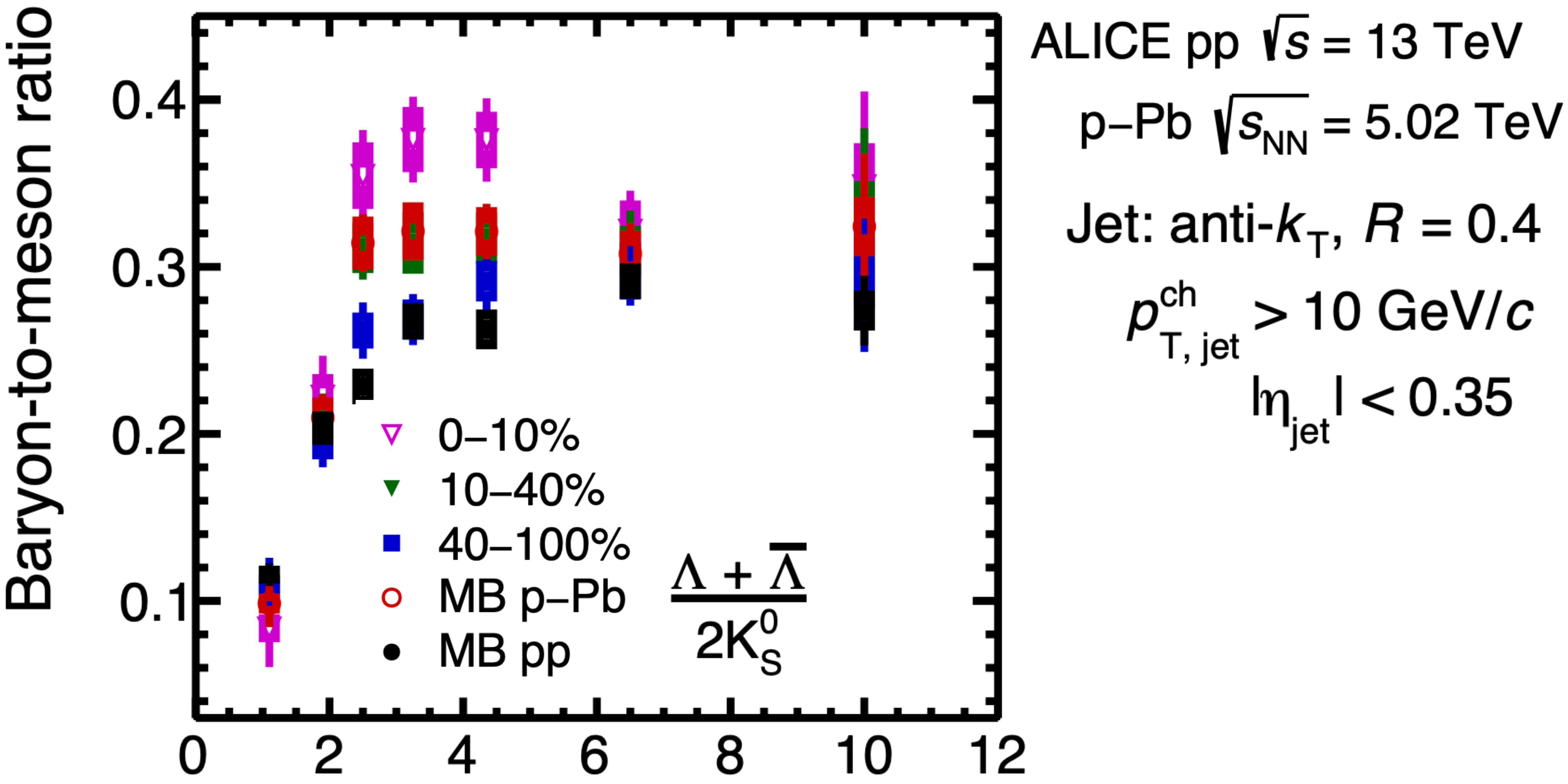
ALICE Collaboration, Phys. Rev. C 101, 044907 (2020)



p/π and K/π enhanced in Pb-Pb inclusive particles at intermediate p_T compared to pp

Similar measurements

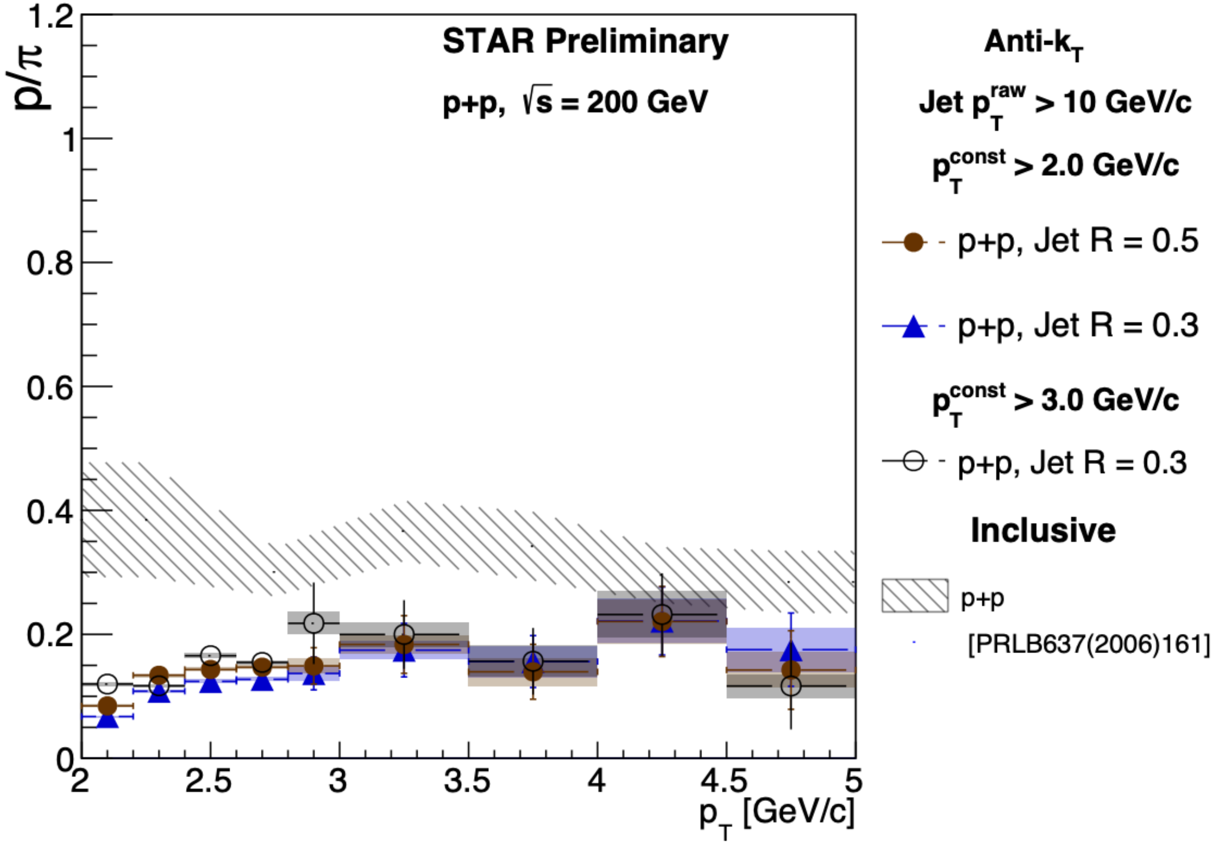
ALICE JHEP 07 (2023) 136

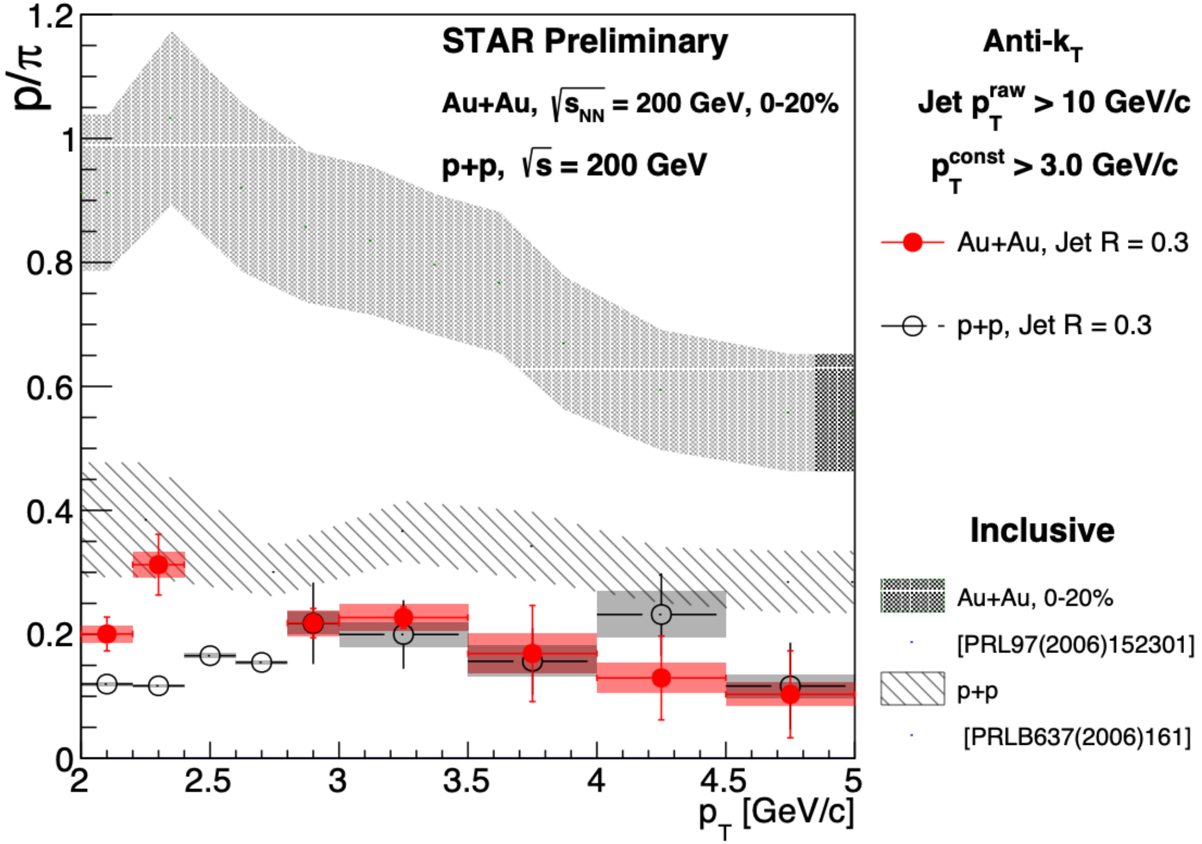


Λ/K^0_S ratio obtained in p–Pb collisions is systematically higher than that in pp collisions for $2 < p_T < 4$ GeV/c

Similar measurements

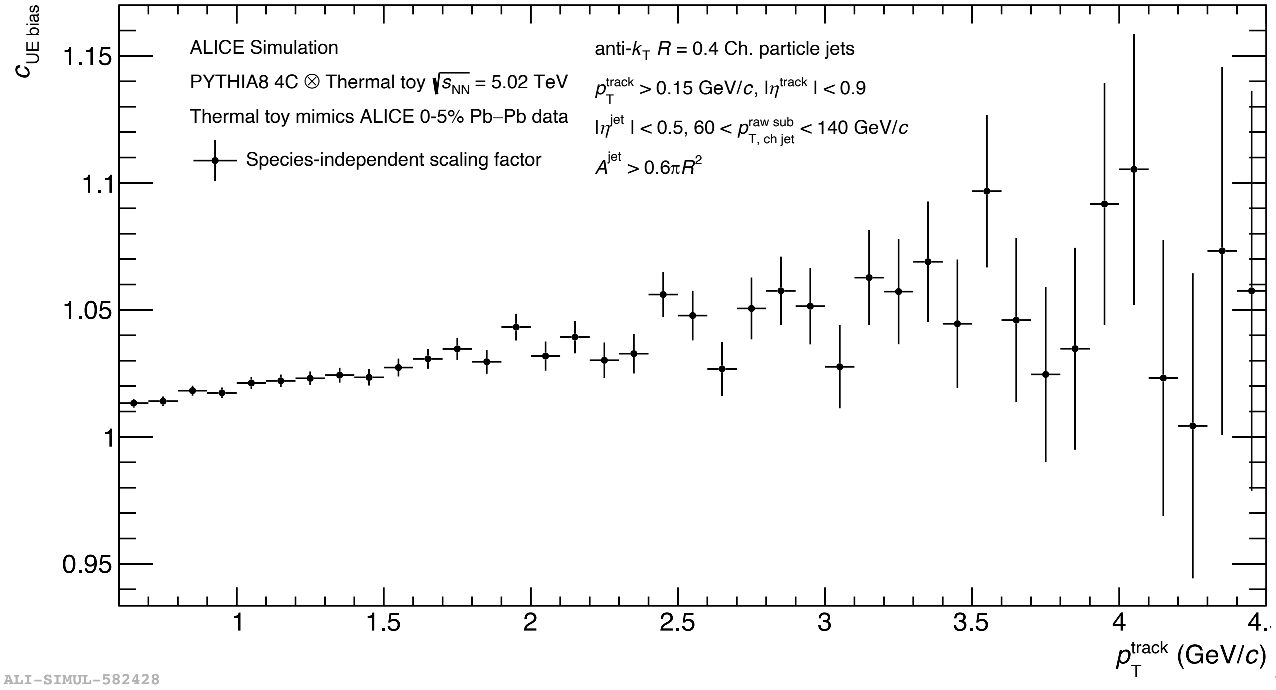
STAR Preliminary arXiv:2312.11362

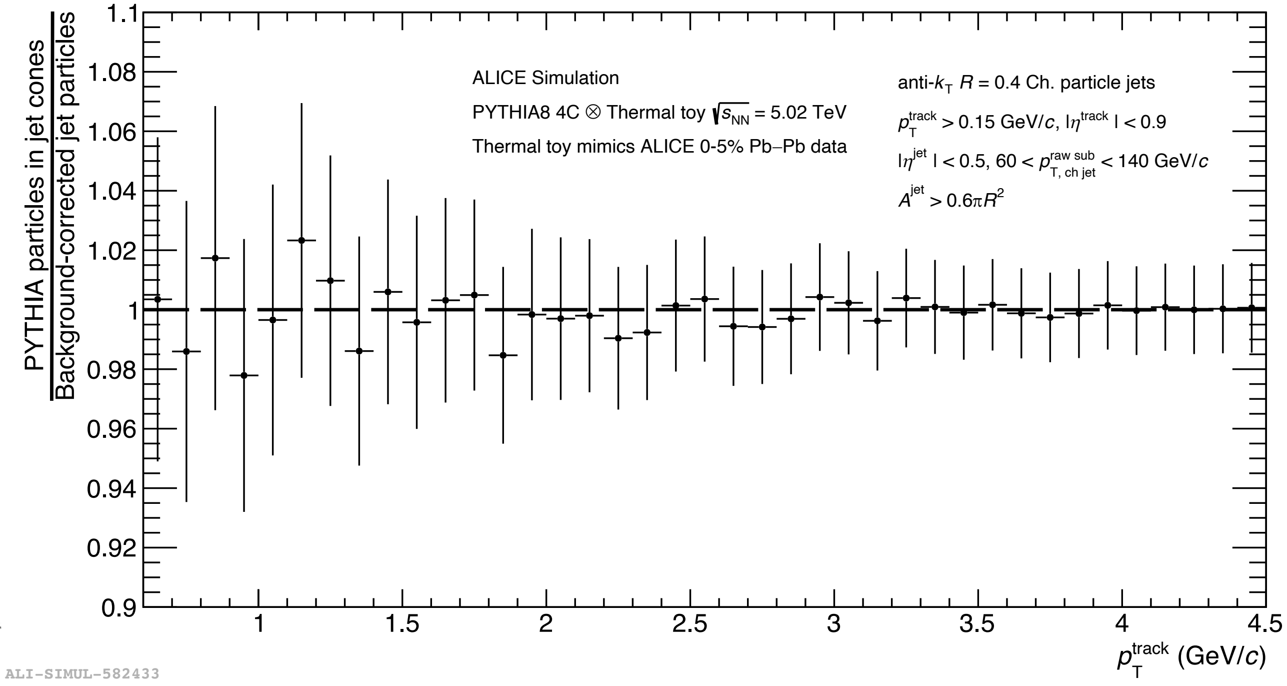




RHIC jets with small R and track bias do not exhibit p/π modification in heavy ion collisions

Toy model scaling factor and closure





$$c_{\mathrm{UE\ Bias}}(p_T) = \frac{d\rho_{\mathrm{UE\ in\ selected\ jets}}}{dp_T} \Big/ \frac{d\rho_{\mathrm{PC}}}{dp_T}$$

$$\frac{d\rho_{\mathrm{jet}}}{dp_T} = \frac{d\rho_{\mathrm{jet+UE}}}{dp_T} - \frac{d\rho_{\mathrm{PC}}}{dp_T} * c_{\mathrm{UE\ Bias}}$$

Closure achieved in toy thermal model