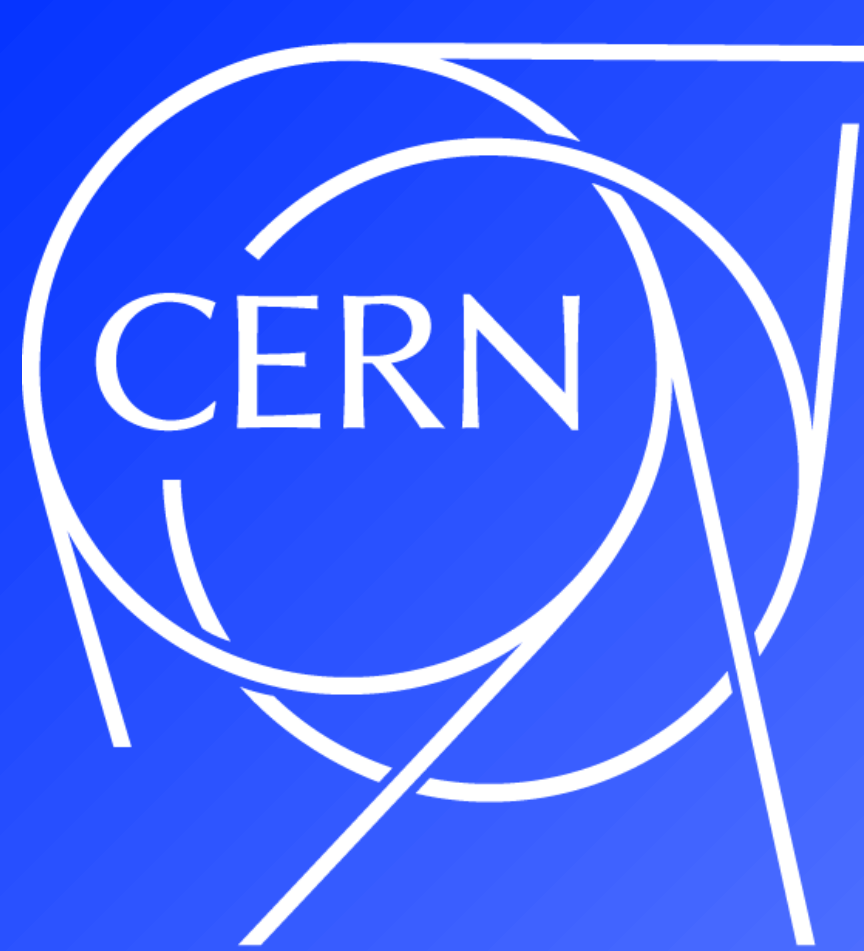




Thermal radiation from small to large systems via low-mass dielectrons with ALICE



I. Vorobyev for the ALICE Collaboration
EPS-HEP 2025, Marseille, France

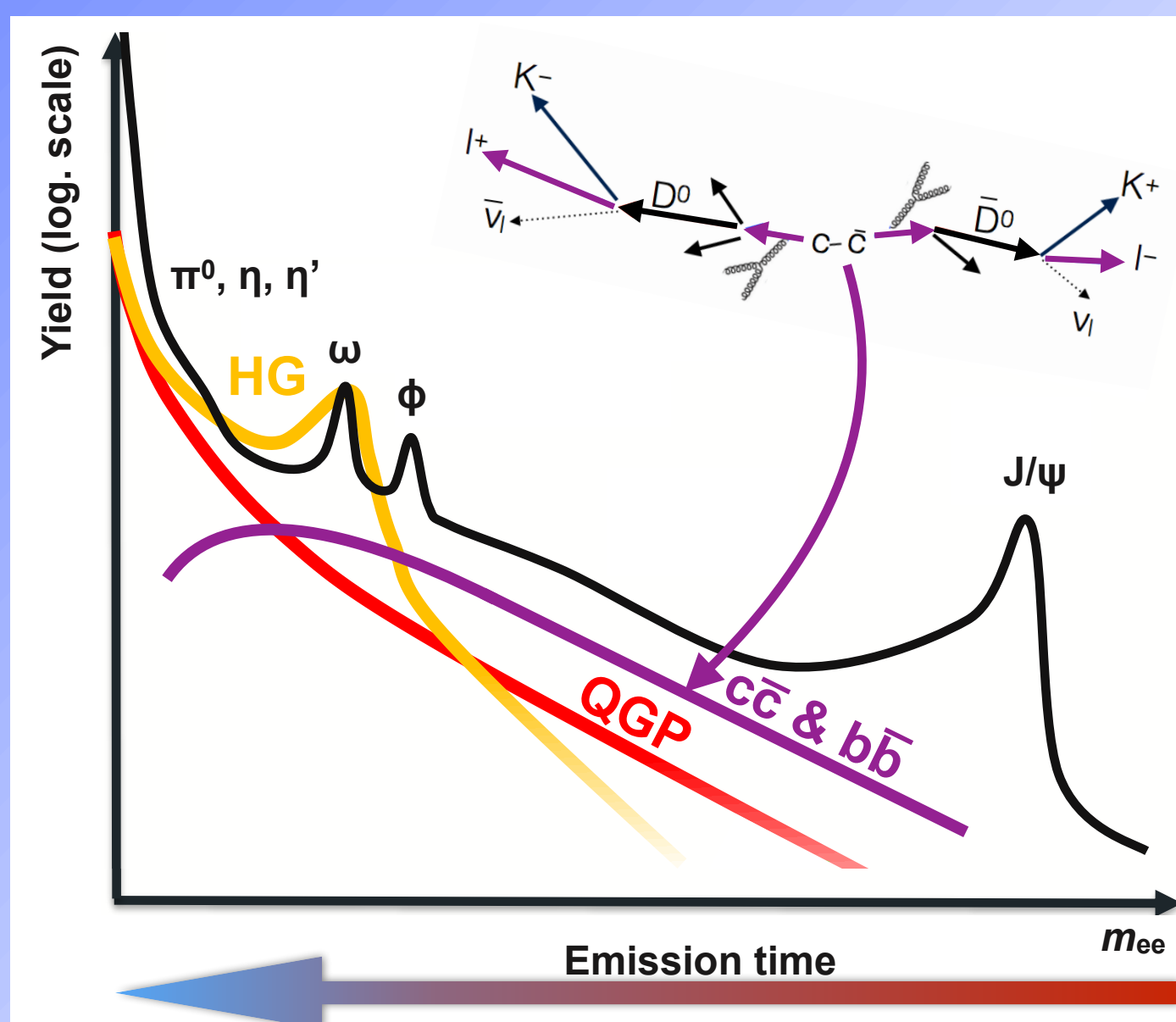
Dielectron mass spectrum in heavy-ion collisions

Low-mass region ($m_{ee} < 1.1 \text{ GeV}/c^2$)

- Thermal radiation from hadron gas (HG) via in-medium ρ
- Pseudoscalar and vector mesons

Intermediate-mass range (IMR) ($1.1 < m_{ee} < 2.7 \text{ GeV}/c^2$)

- Thermal radiation from quark-gluon plasma (QGP)
- Semileptonic decays of correlated heavy-flavour hadrons



Dielectron spectrum from thermalised source: $\sim e^{-m/T}$

Approximate time ordering of the mass spectrum

Extraction of direct photons

Any source of real photons can produce $\gamma^* \rightarrow e^+e^-$

Invariant mass as an additional information!

Fit e^+e^- mass spectrum above π^0 with:

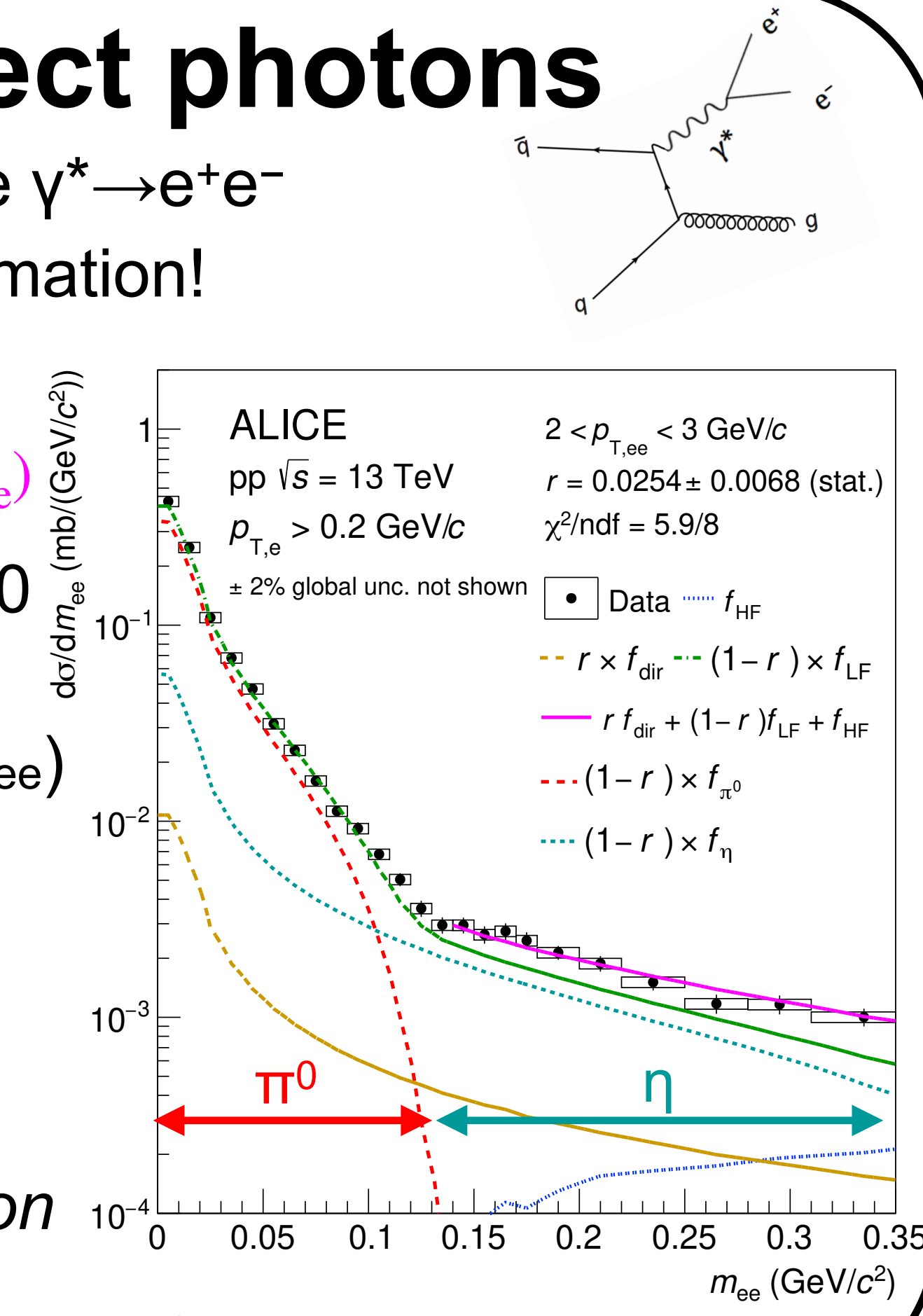
$$f(m_{ee}) = r \cdot f_{\text{dir}}(m_{ee}) + (1-r) \cdot f_{\text{LF}}(m_{ee}) + f_{\text{HF}}(m_{ee})$$

- f_{dir} and f_{LF} normalised to data at $m_{ee} = 0$
- r = (virtual) direct γ / inclusive γ
- γ^*_{dir} from Kroll-Wada: $\sim 1/m_{ee}$ ($p_{T,ee} \gg m_{ee}$)

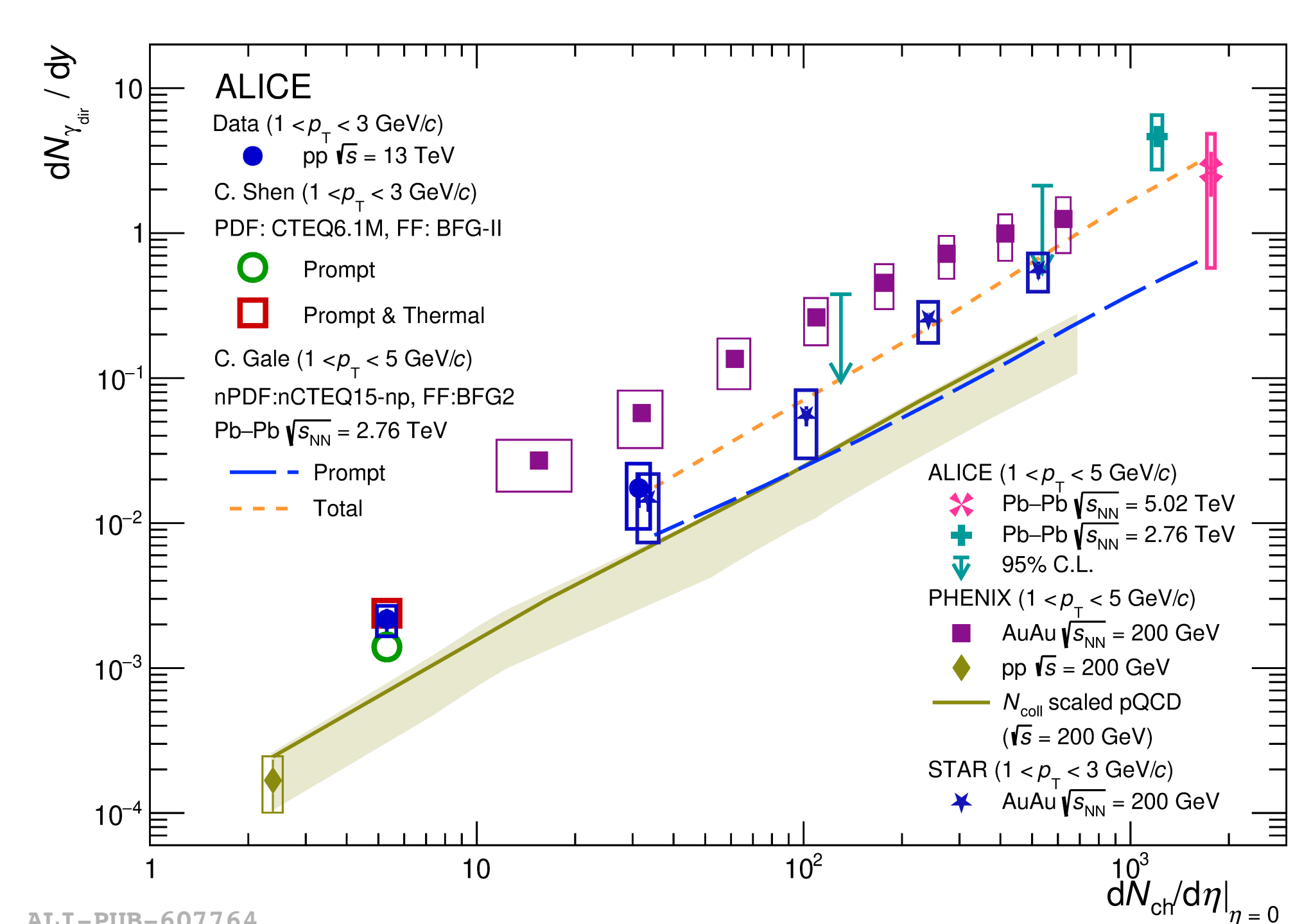
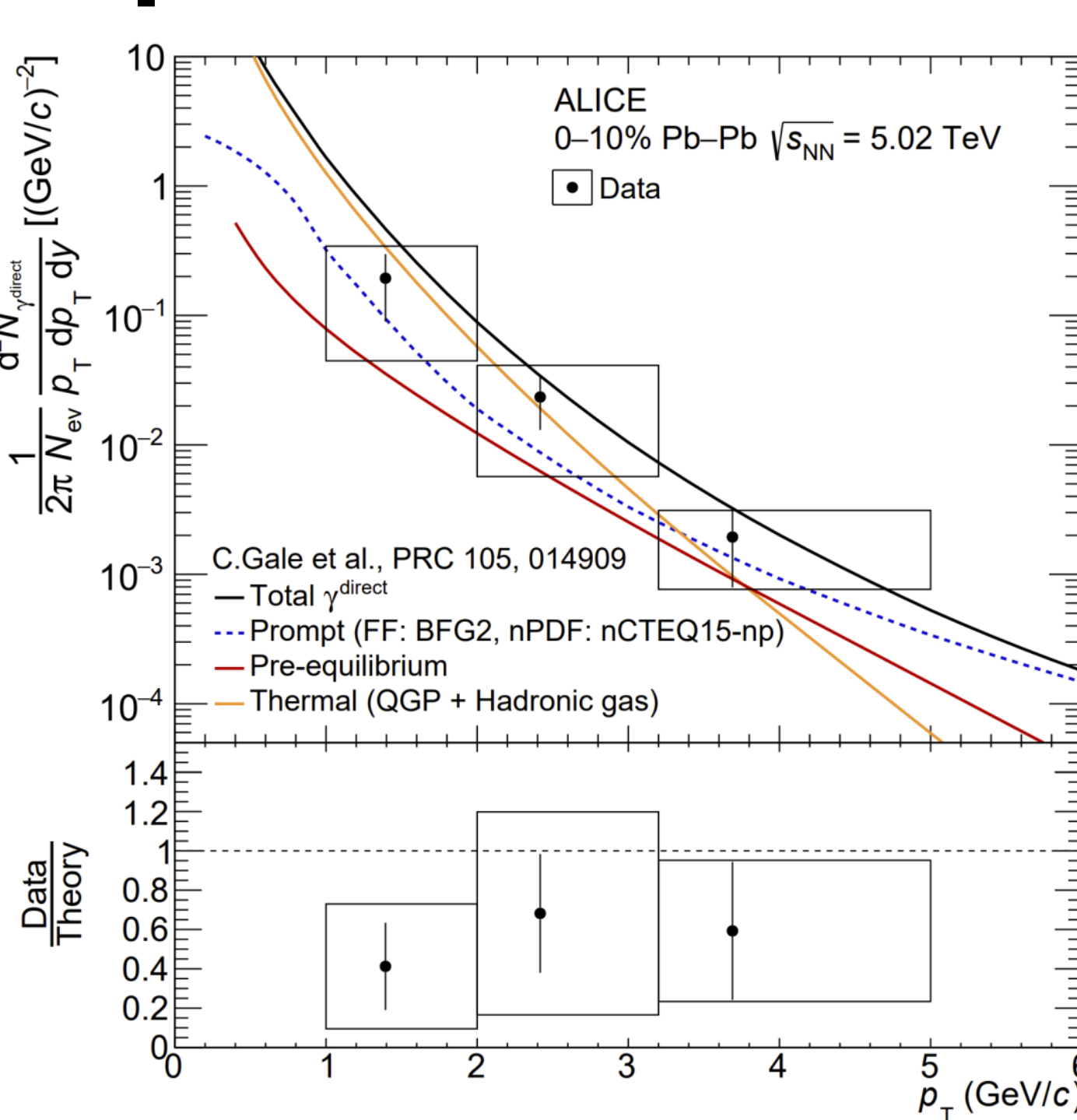
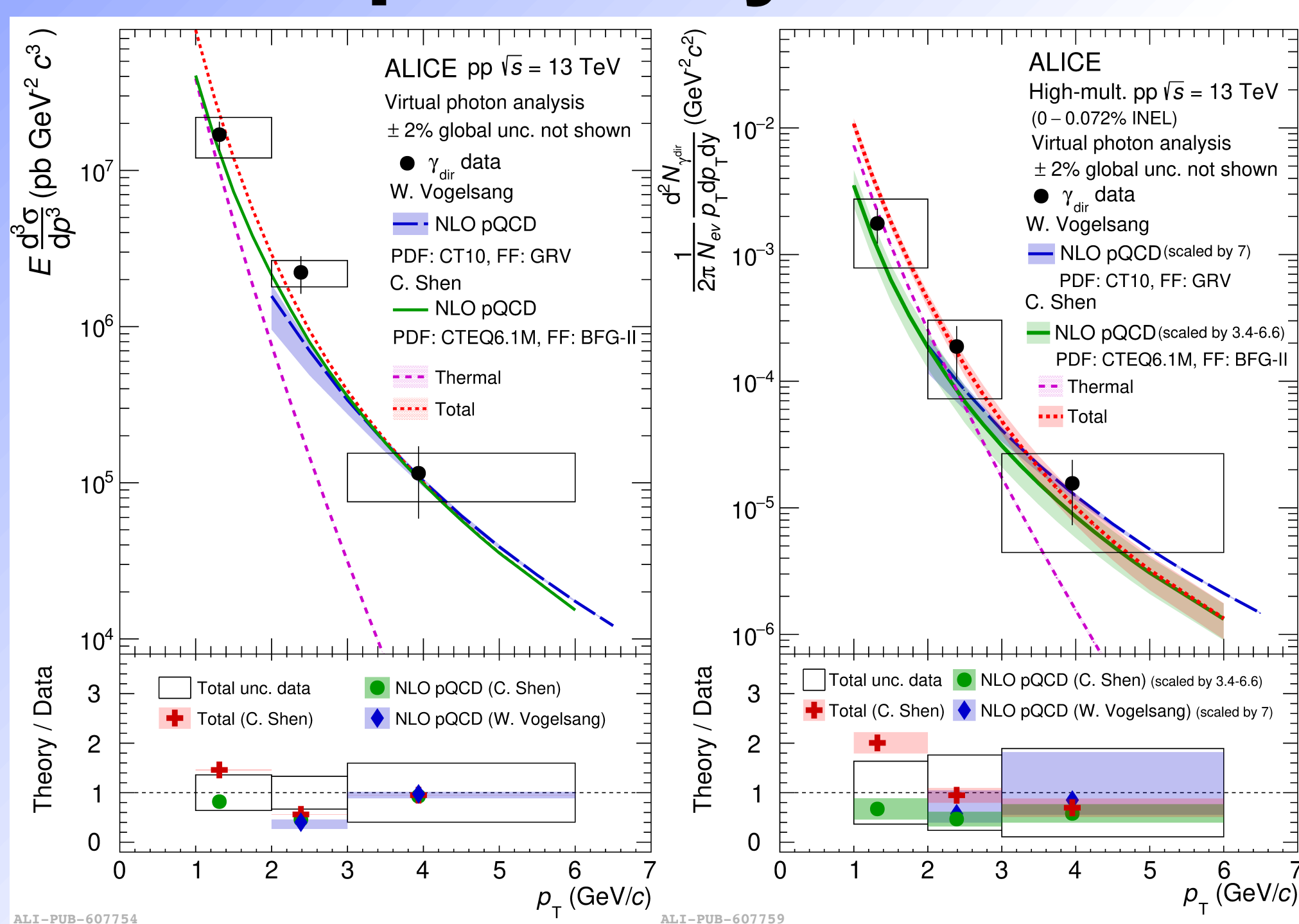
$$\frac{1}{N_\gamma} \frac{dN_{ee}}{dm_{ee}} = \frac{2\alpha}{3\pi} \sqrt{1 - \frac{4m_e^2}{m_{ee}^2}} \left(1 + \frac{2m_e^2}{m_{ee}^2} \right) \frac{1}{m_{ee}}$$

→ direct-photon yield: $\gamma_{\text{dir}} = r \times \gamma_{\text{incl}}$

!! Precise knowledge of π^0 and η meson production is vital for this method! [1]



Direct-photon yield and comparison to models with thermal contribution



First measurement of direct photons in pp collisions at low p_T at the LHC! [2]

INEL pp data in agreement with both prompt or prompt + thermal calculations [3, 4]

Challenging theoretical calculations of direct-photon yield in high-mult. pp events!

First direct-photon p_T spectrum in Pb-Pb at $\sqrt{s_{NN}} = 5.02 \text{ TeV}$! [5]

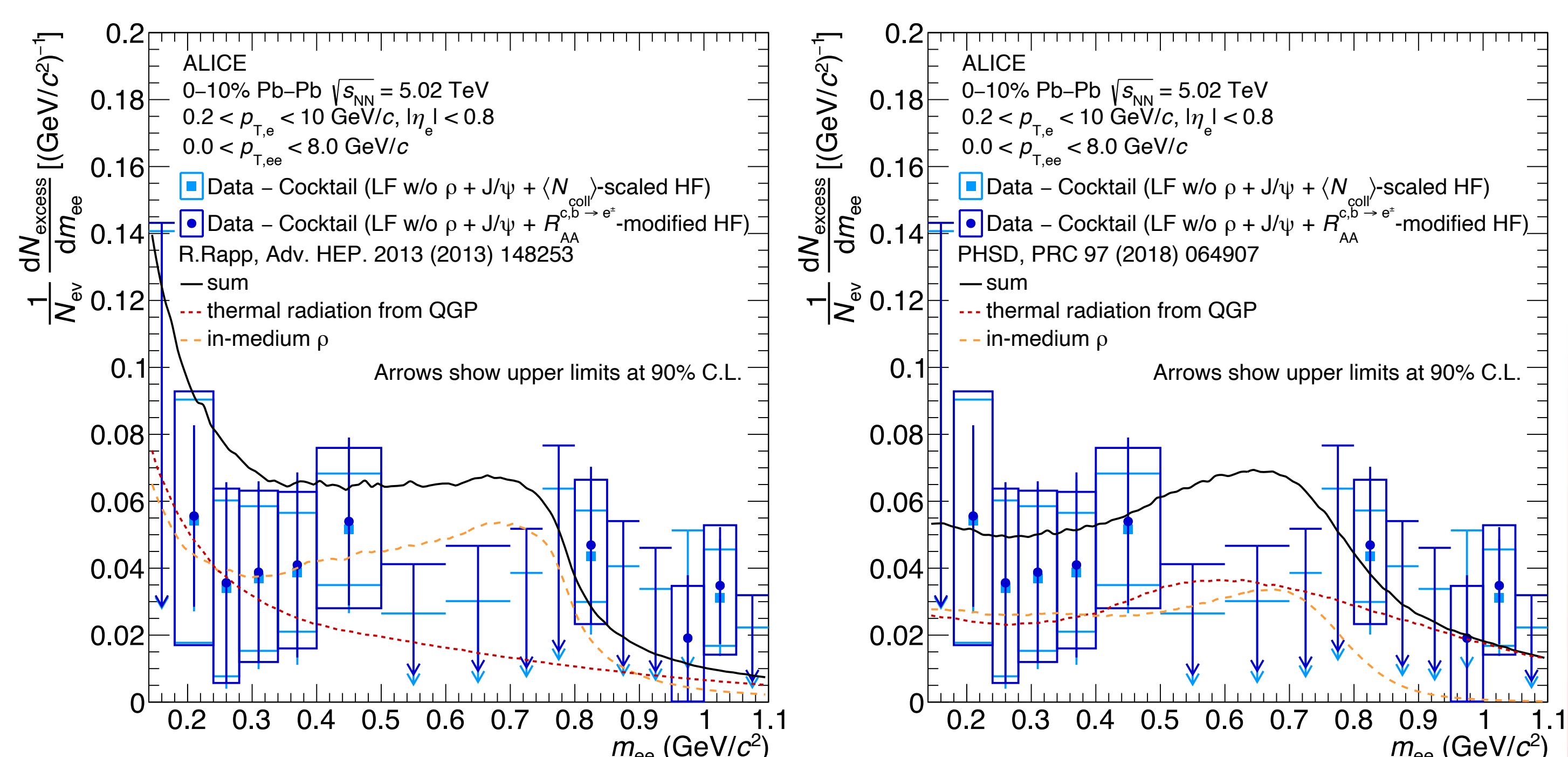
Sum of all contributions (prompt, pre-equilibrium, thermal) overestimates data by $\sim 1\sigma$

? Is there a universal scaling of γ_{dir} with $dN_{\text{ch}}/d\eta$?

? Where is the onset of thermal radiation?

! Measurements in small systems are a crucial input for theoretical models!

Dielectron excess spectrum in Pb-Pb



Subtraction of all known hadronic sources except ρ meson

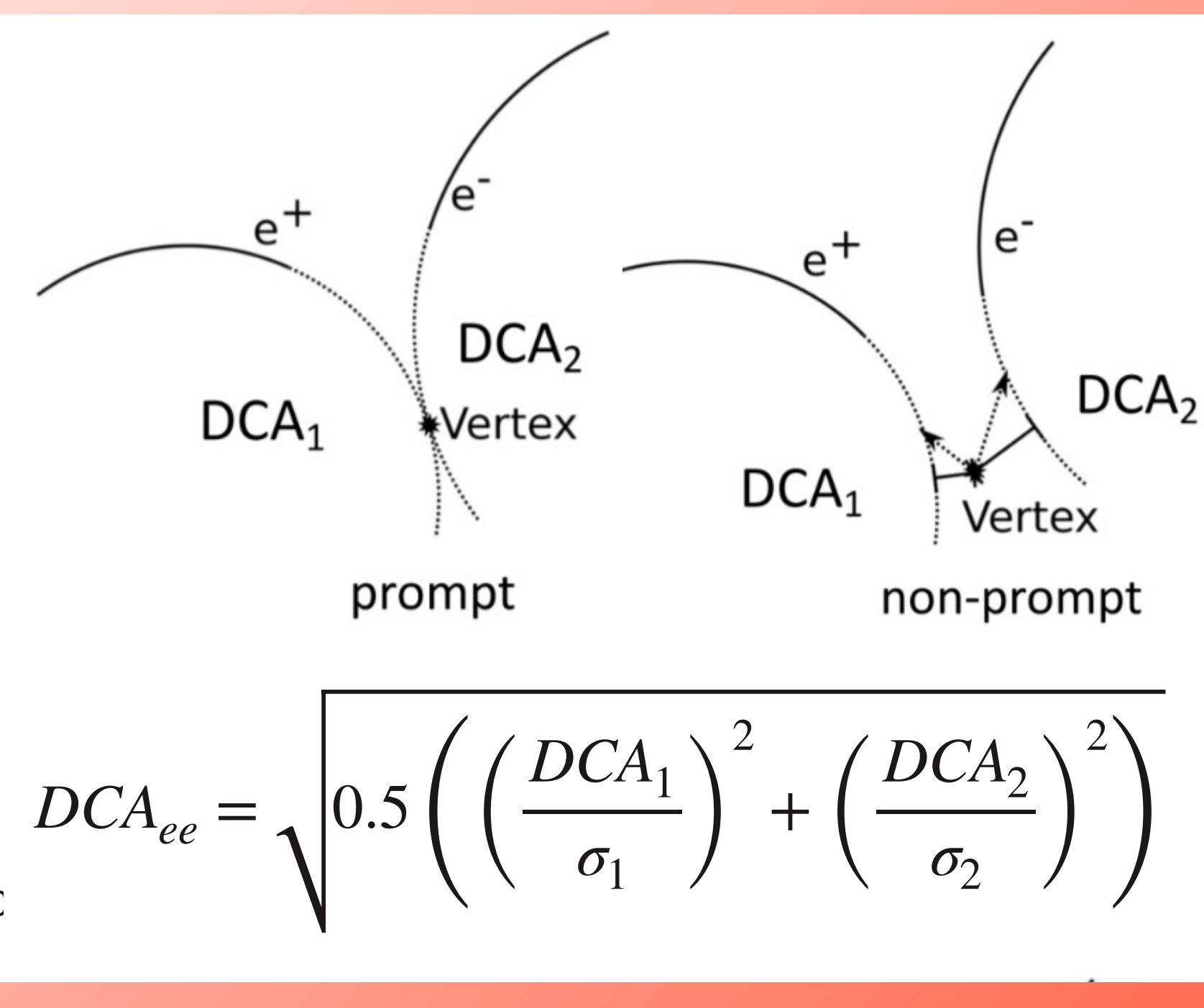
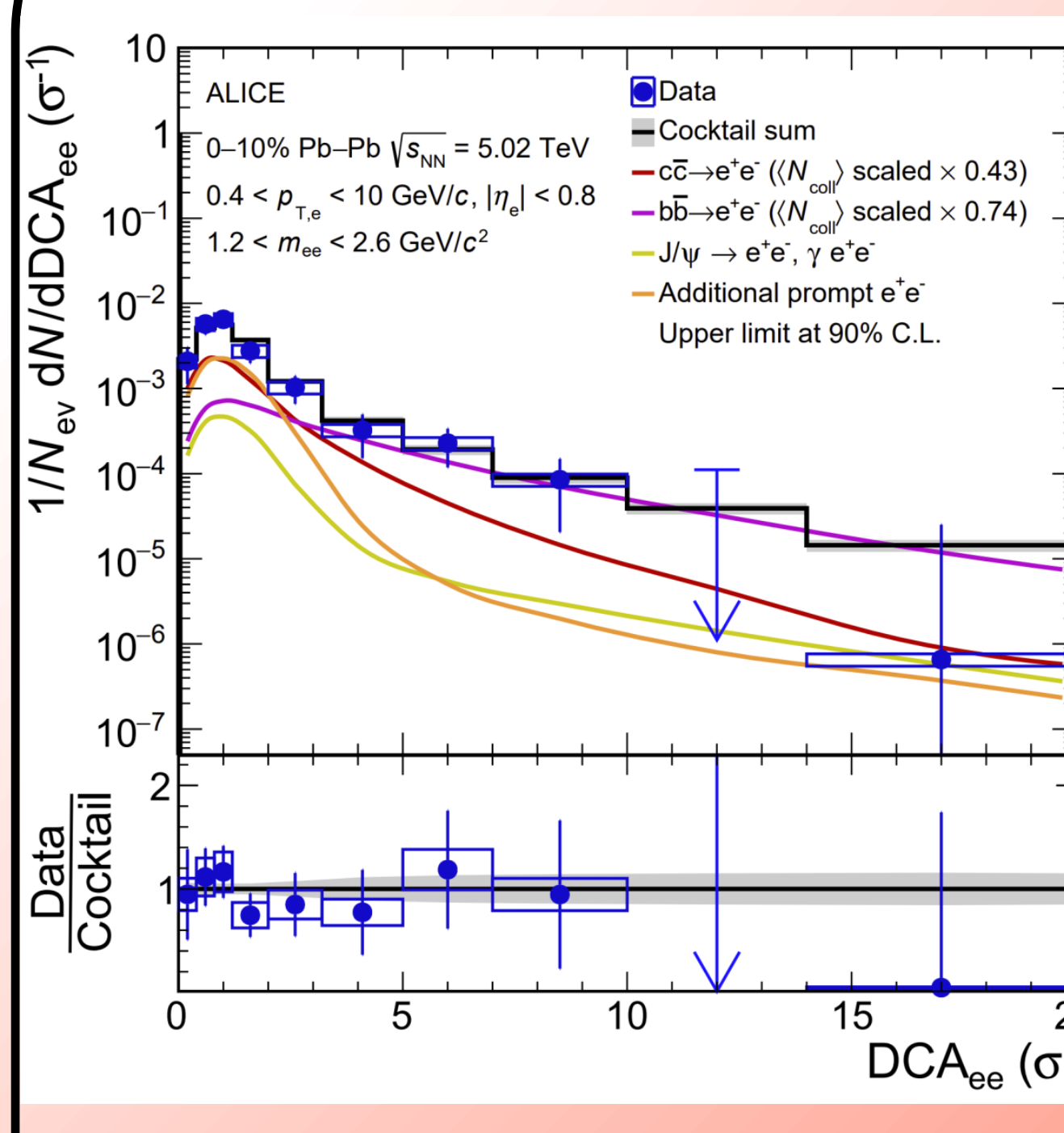
Data compared to the sum of thermal QGP radiation and in-medium ρ

Overall in a good agreement with theoretical models: expanding fireball [6], Parton-Hadron-String Dynamics [7]

Tension between data and theory in $0.5 < m_{ee} < 0.7 \text{ GeV}/c^2$ range

4.0 σ (2.7 σ) using N_{coll} -scaled (modified) heavy-flavour cocktail

Prompt / non-prompt sources in IMR



Extraction of prompt thermal signal with DCA_{ee} template fit in IMR:

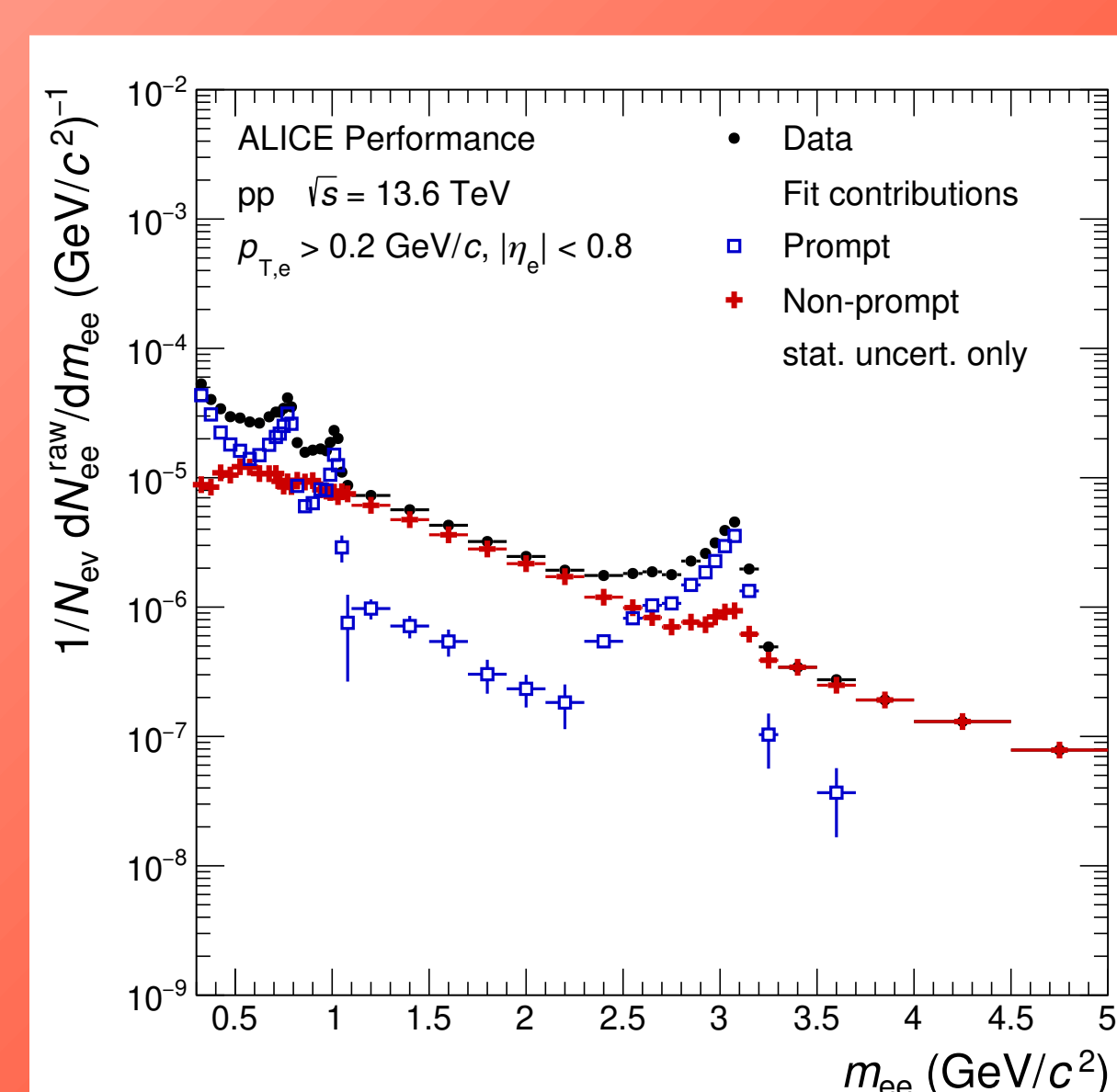
- charm: $0.43 \pm 0.40 \text{ (stat.)} \pm 0.22 \text{ (syst.)}$ w.r.t. N_{coll} scaling
- prompt: $2.64 \pm 3.18 \text{ (stat.)} \pm 0.29 \text{ (syst.)}$ w.r.t. Rapp's model

Method independent of hadronic cocktail calculations!

Outlook: dielectron analysis in Run3 data (2022–2026)

More statistics and better topological separation will enable the extraction of thermal contribution

More details in EPS 2025 talk by E. Ege [8]



References

- [1] ALICE, "Light neutral-meson production in pp collisions at $\sqrt{s} = 13 \text{ TeV}$ ", arXiv:2411.09560
- [2] ALICE, "Direct-photon production in INEL and HM pp collisions at $\sqrt{s} = 13 \text{ TeV}$ ", Phys. Lett. B 868 (2025) 139645
- [3] W. Vogelsang et al., "Polarized and unpolarized γ_{prompt} beyond the leading order", Phys. Rev. D 48 (1993) 3136
- [4] C. Shen et al., "Collectivity and electromagnetic radiation in small systems", Phys. Rev. C 95 (2017) 014906
- [5] ALICE, "Dielectron production in central Pb-Pb collisions at $\sqrt{s_{NN}} = 5.02 \text{ TeV}$ ", arXiv:2308.16704
- [6] R. Rapp, "Dilepton Spectroscopy of QCD Matter at Collider Energies", Adv. in HEP 2013 (2013) 148253
- [7] T. Song et al., "Open charm and dileptons from relativistic HI collisions", Phys. Rev. C 97 (2018) 6, 064907
- [8] E. Ege for the ALICE Collaboration, "Dielectron production in pp and Pb-Pb collisions with ALICE in Run 3", <https://indico.in2p3.fr/event/33627/contributions/155140/> (8 Jul 2025, 09:50, Salle Lacydon)