

Measuring heavy-quark production via dielectrons in pp and p-Pb with ALICE

Sebastian Scheid

Goethe University, Frankfurt

on behalf of the ALICE Collaboration

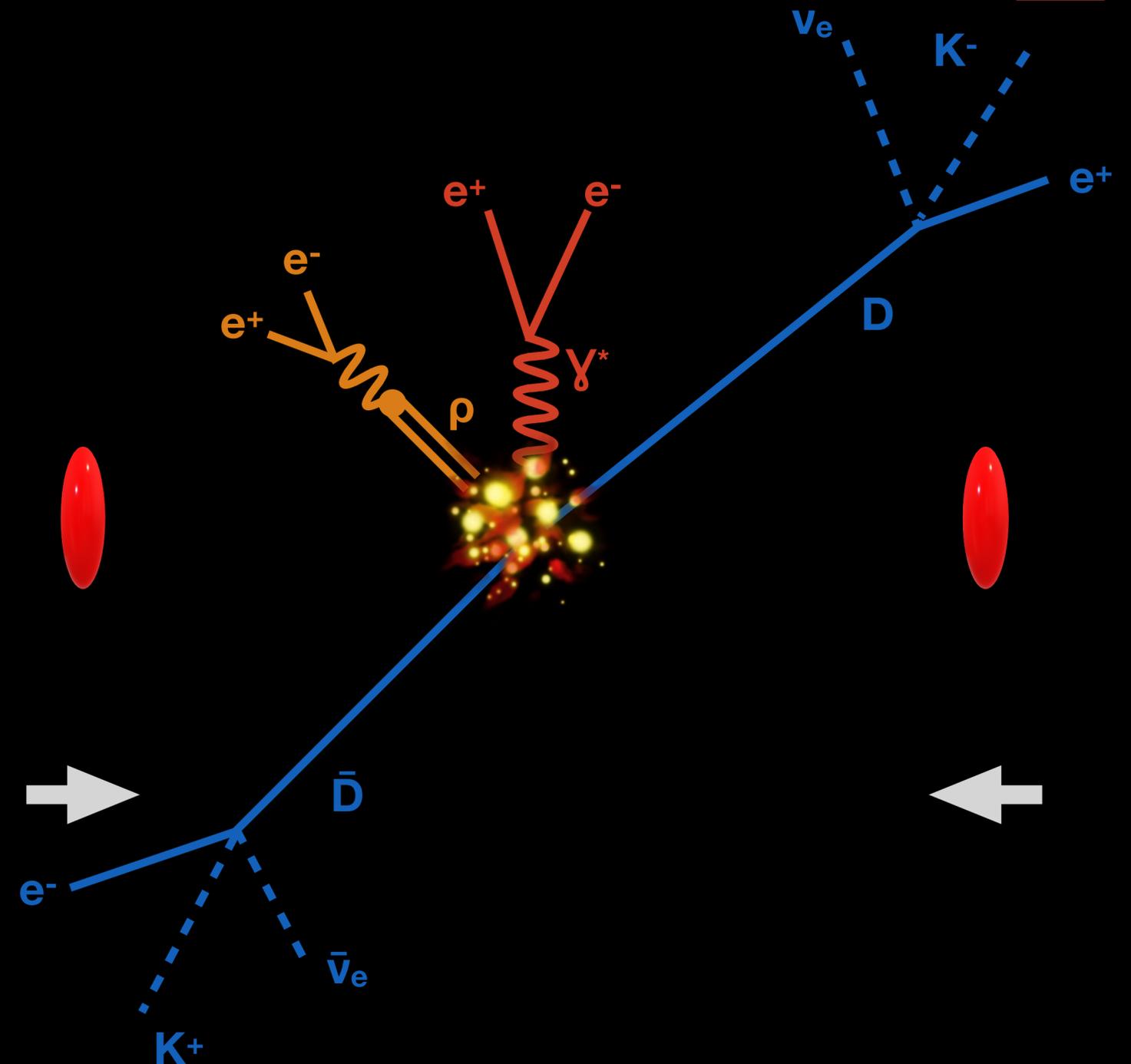
EPS-HEP 2019, GHENT, BE

Motivation - Dielectrons



Various sources produce correlated pairs of electrons:

- Pseudoscalar and vector mesons (π , η , ρ , ω , ϕ , J/ψ) via direct (e^+e^-) or Dalitz ($X e^+e^-$) decays
- Internal conversion of direct photons
- Semi-leptonic decays of open heavy-flavour hadrons ($c\bar{c} \rightarrow D\bar{D} \rightarrow XY e^+e^-$)
→ **Sensitive to correlation and soft production of heavy-quark pair**



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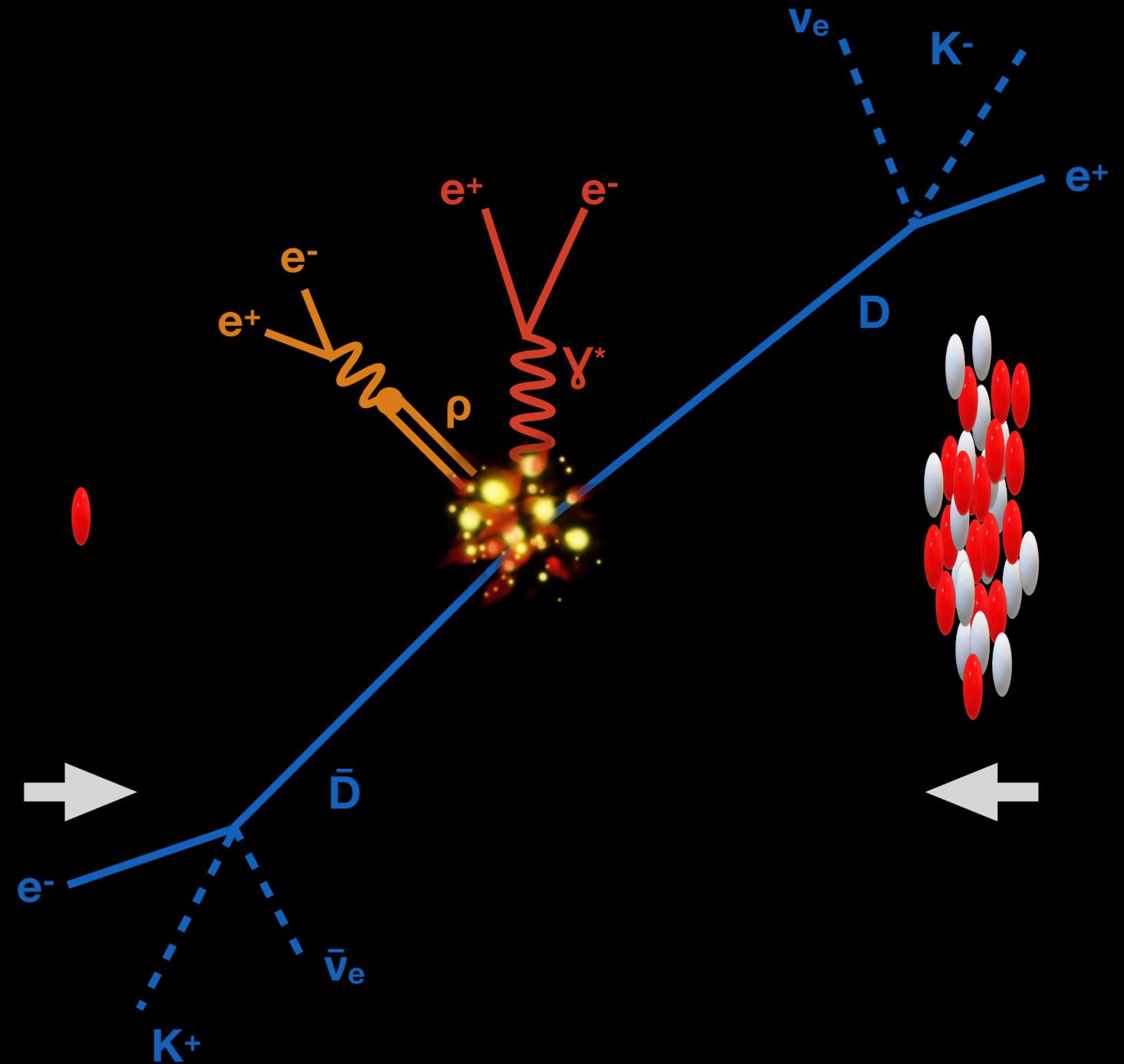


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In pA:

- Modification of production cross section of heavy-flavour quarks via cold nuclear matter effects (e.g. shadowing)
- Additional sources from a possible hot medium in small systems (Hadron Gas or Quark Gluon Plasma droplets)



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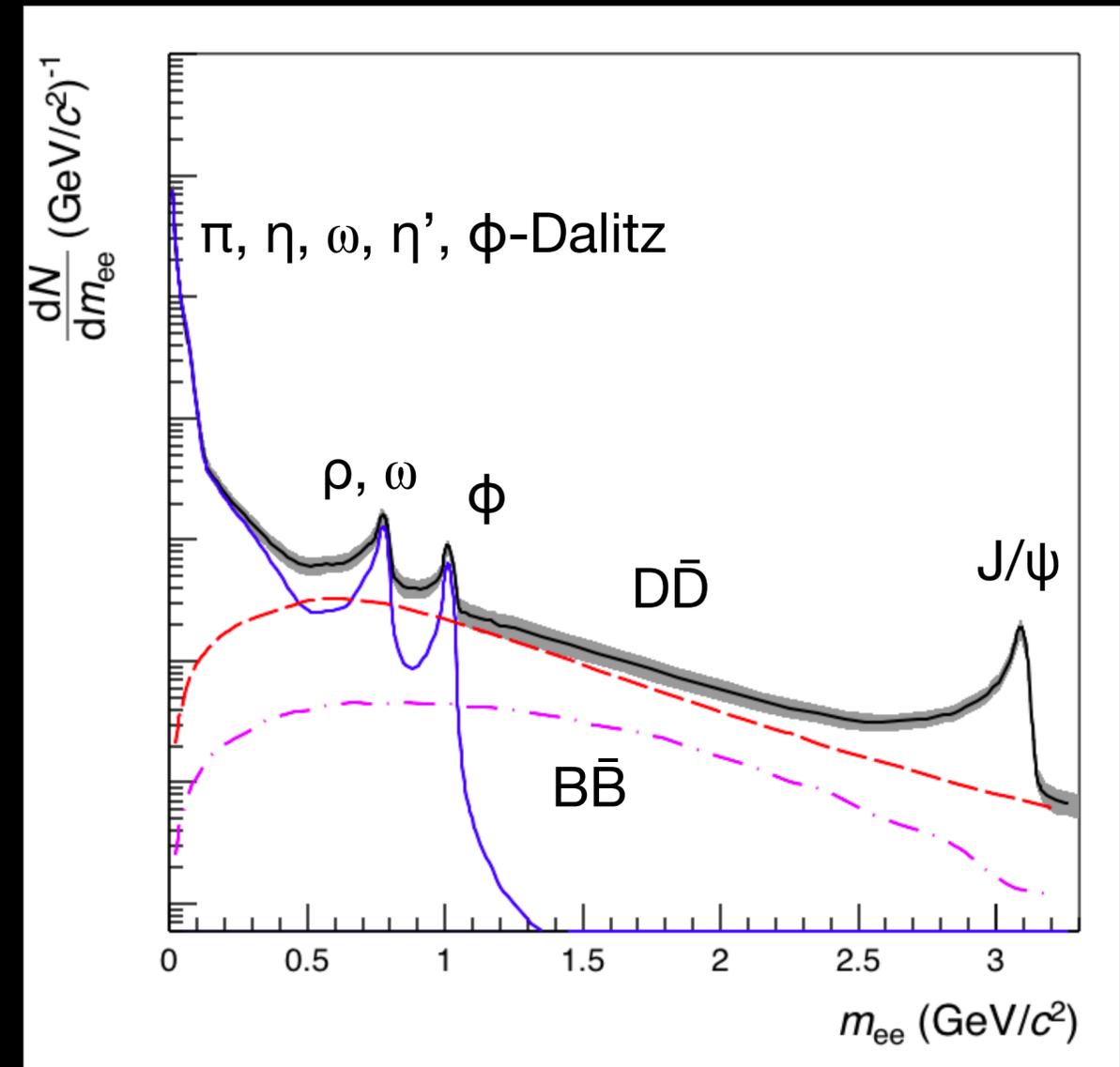


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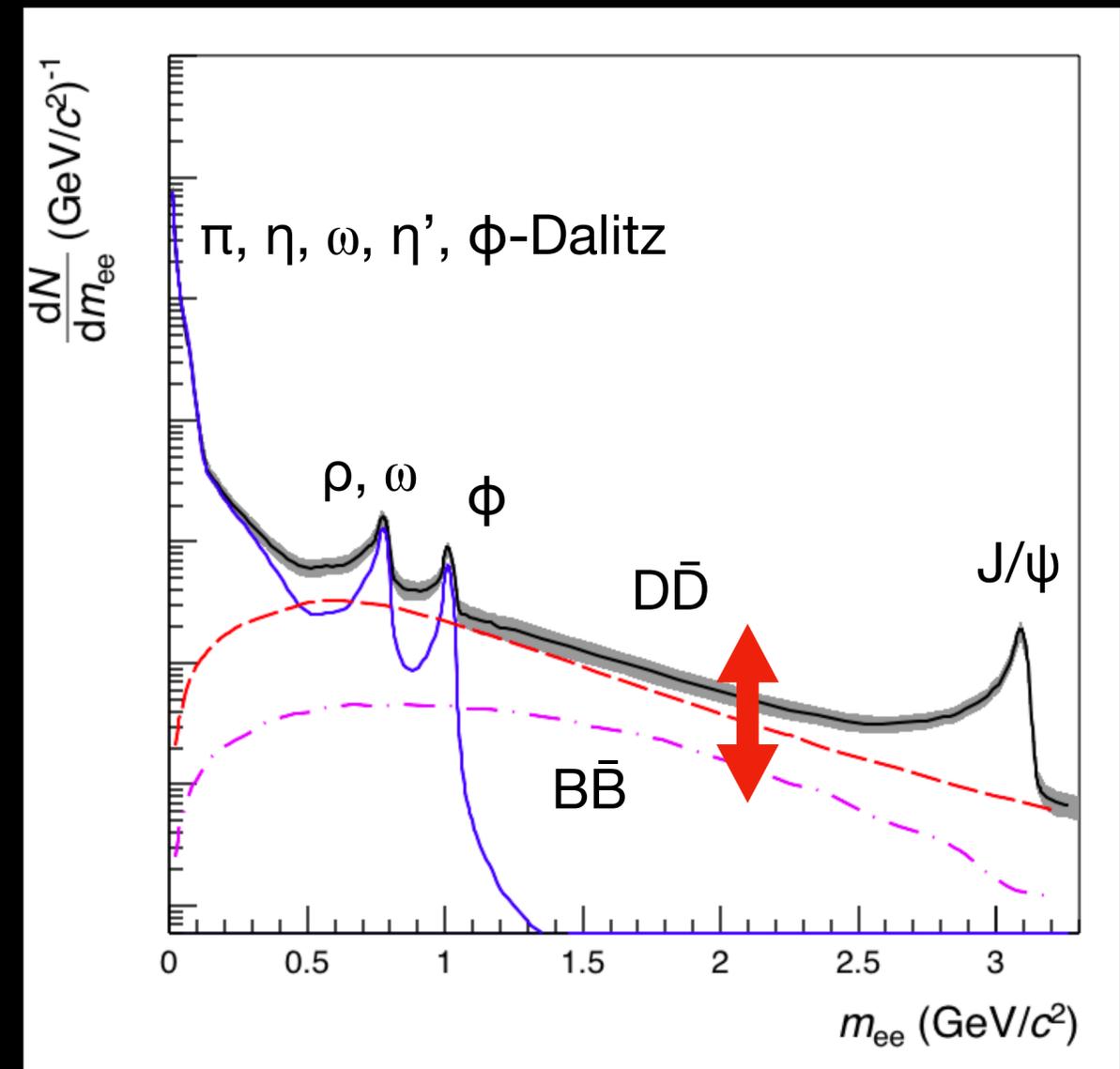


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Motivation - Dielectrons



pp

- Vacuum baseline for p–Pb and Pb–Pb
- Heavy-flavour and direct-photon production

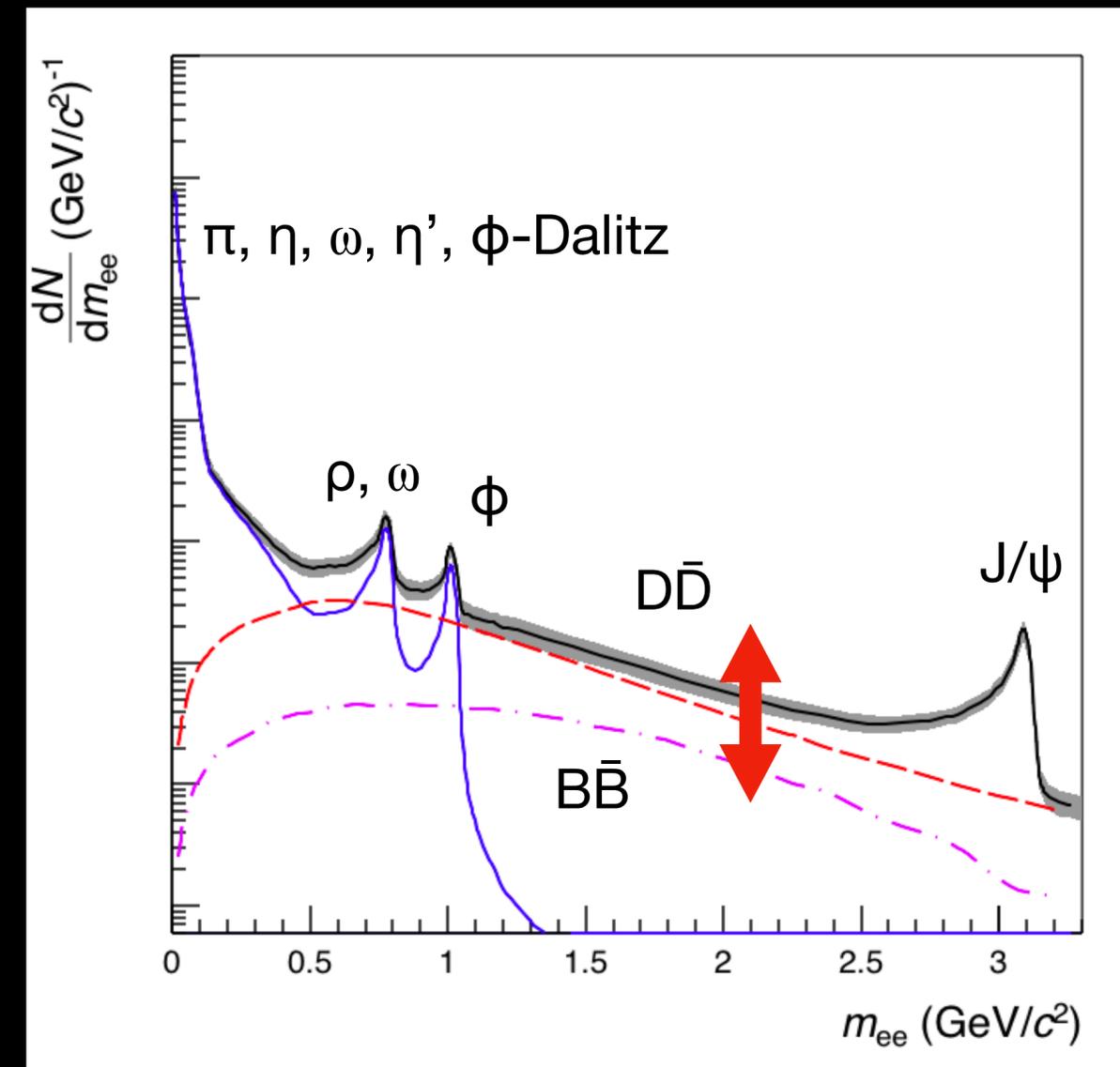
p–Pb

- Cold nuclear matter effects
- Possible thermal radiation

Pb–Pb

- QGP radiation
- Chiral-symmetry restoration

*Talk by R. Bailhache
on Friday*



The ALICE Detector



Time Projection Chamber

- Particle identification via dE/dx
- Tracking

Inner Tracking System

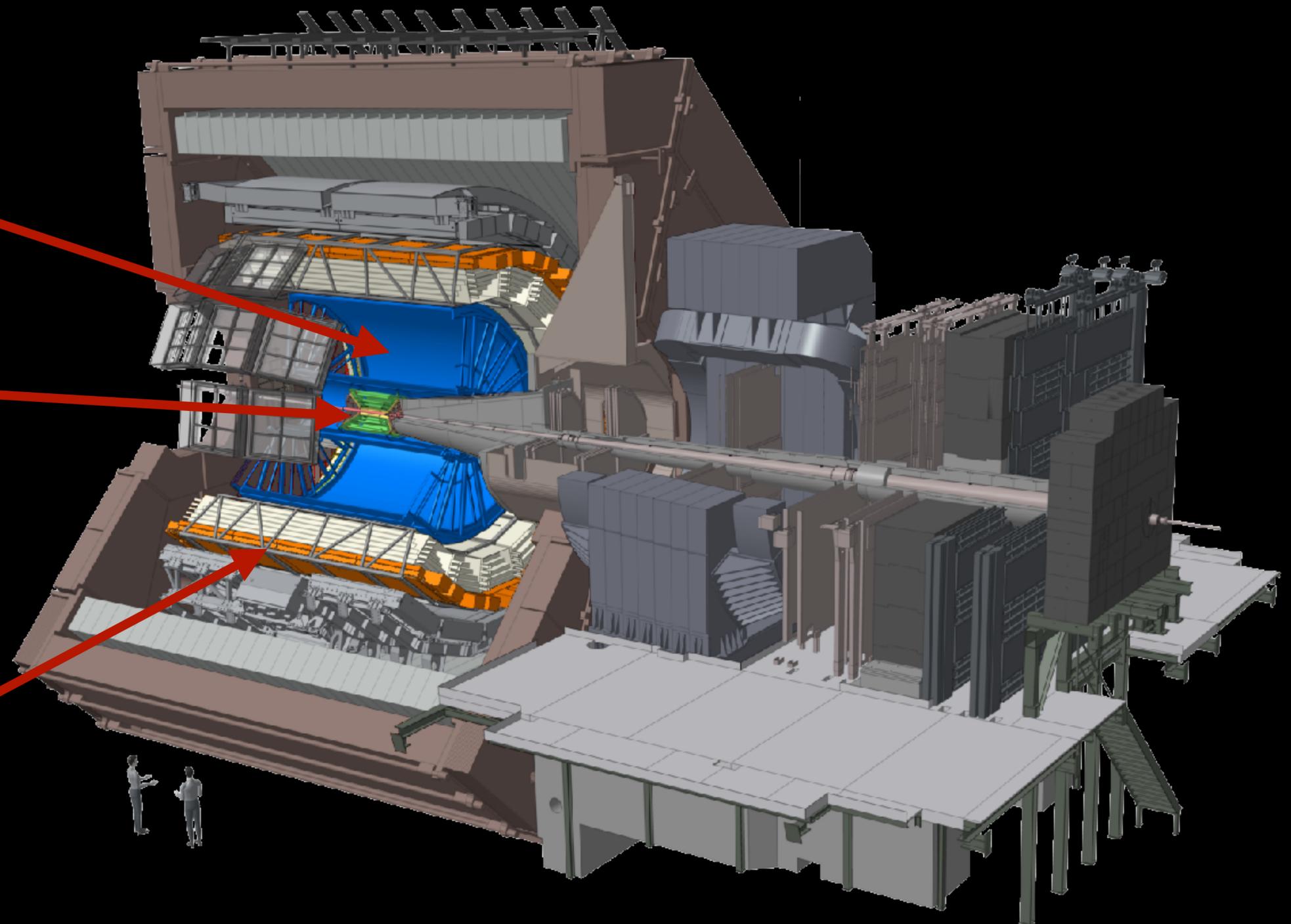
- Particle identification via dE/dx
- Tracking
- Vertex determination

V0

- Centrality estimation
- Trigger

Time Of Flight

- Particle identification via Time-Of-Flight



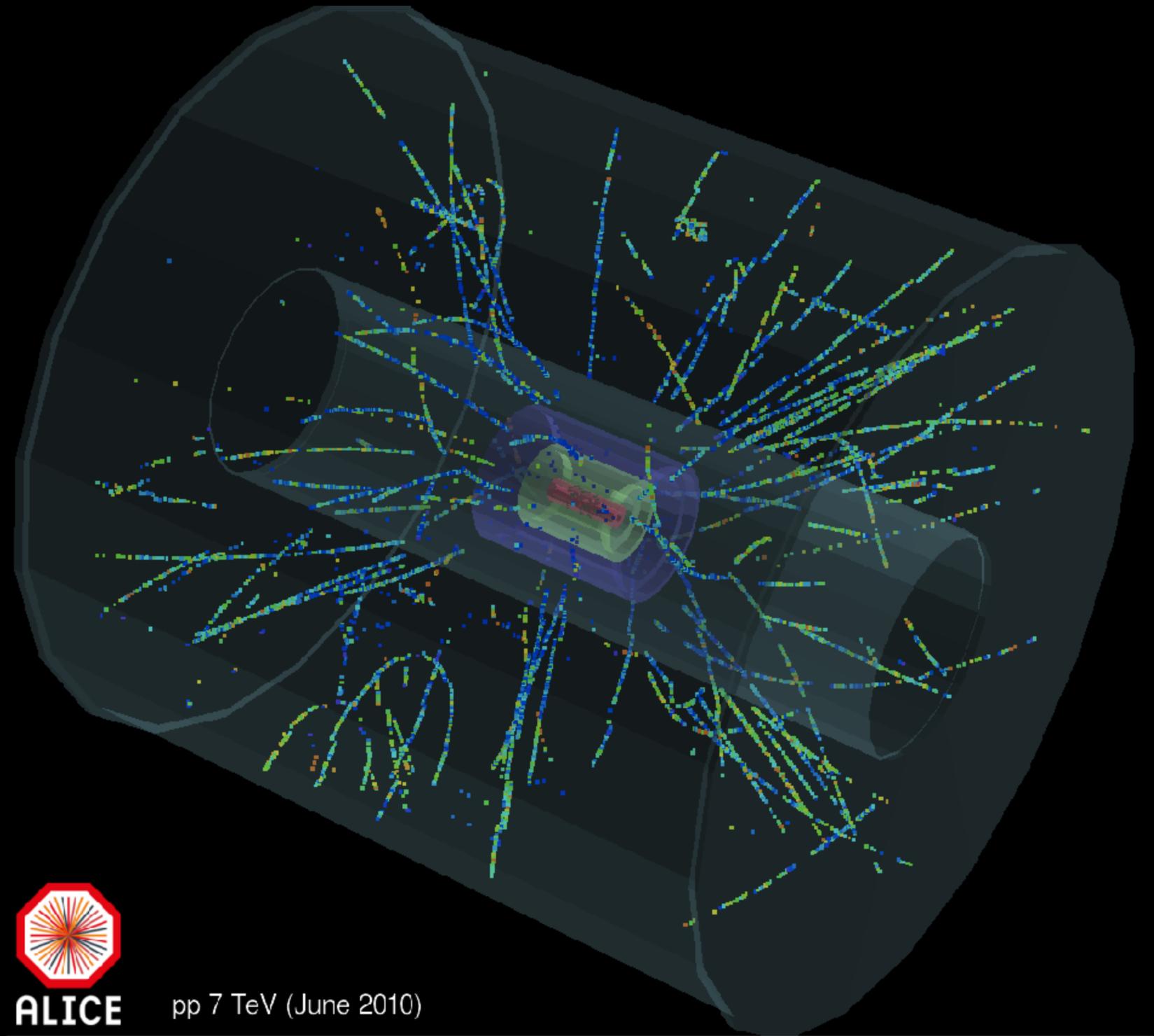
pp Collisions

Run 1

- $\sqrt{s} = 7$ TeV (min bias)
JHEP 1809 (2018) 064

Run 2

- $\sqrt{s} = 13$ TeV (min bias and HM)
PLB 788 (2019) 505



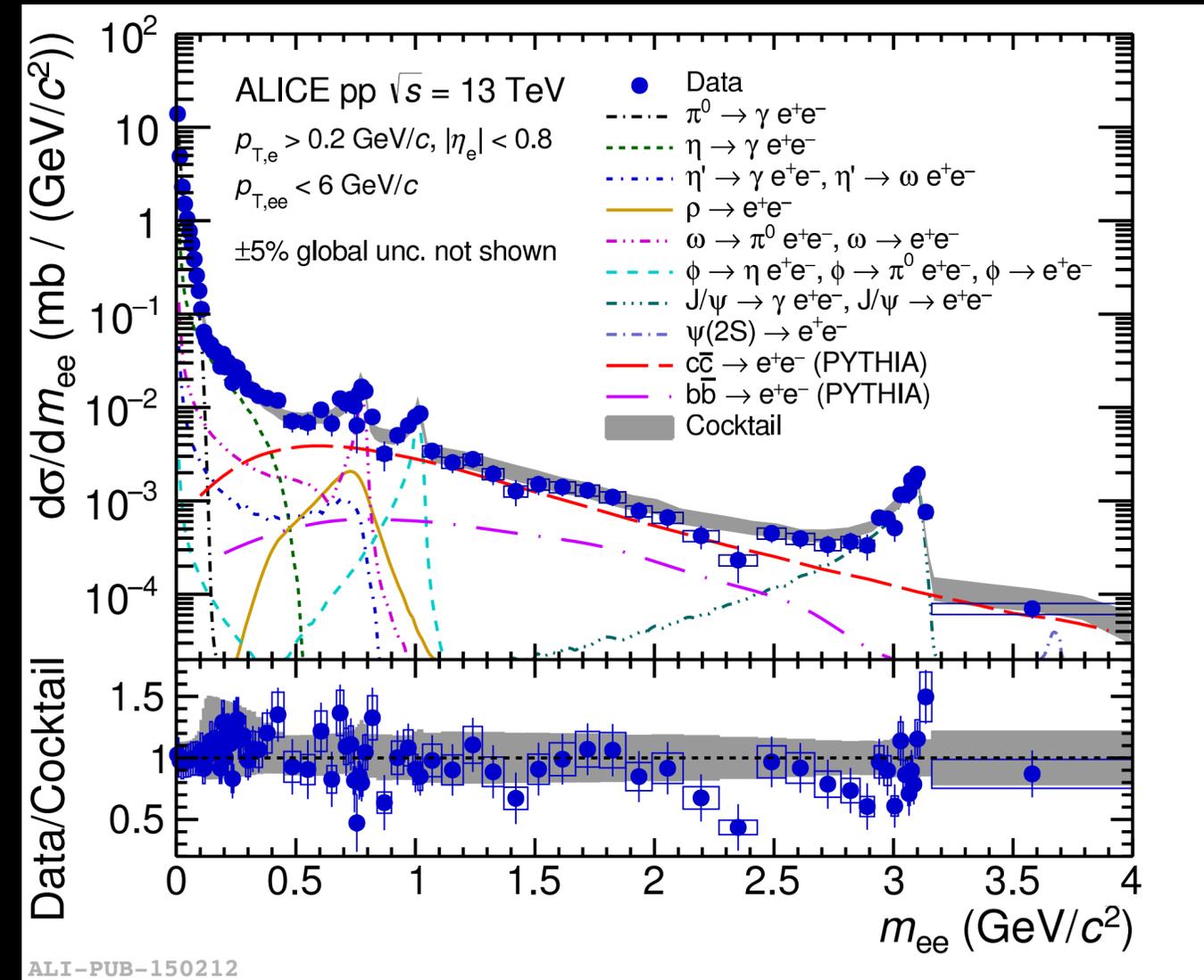
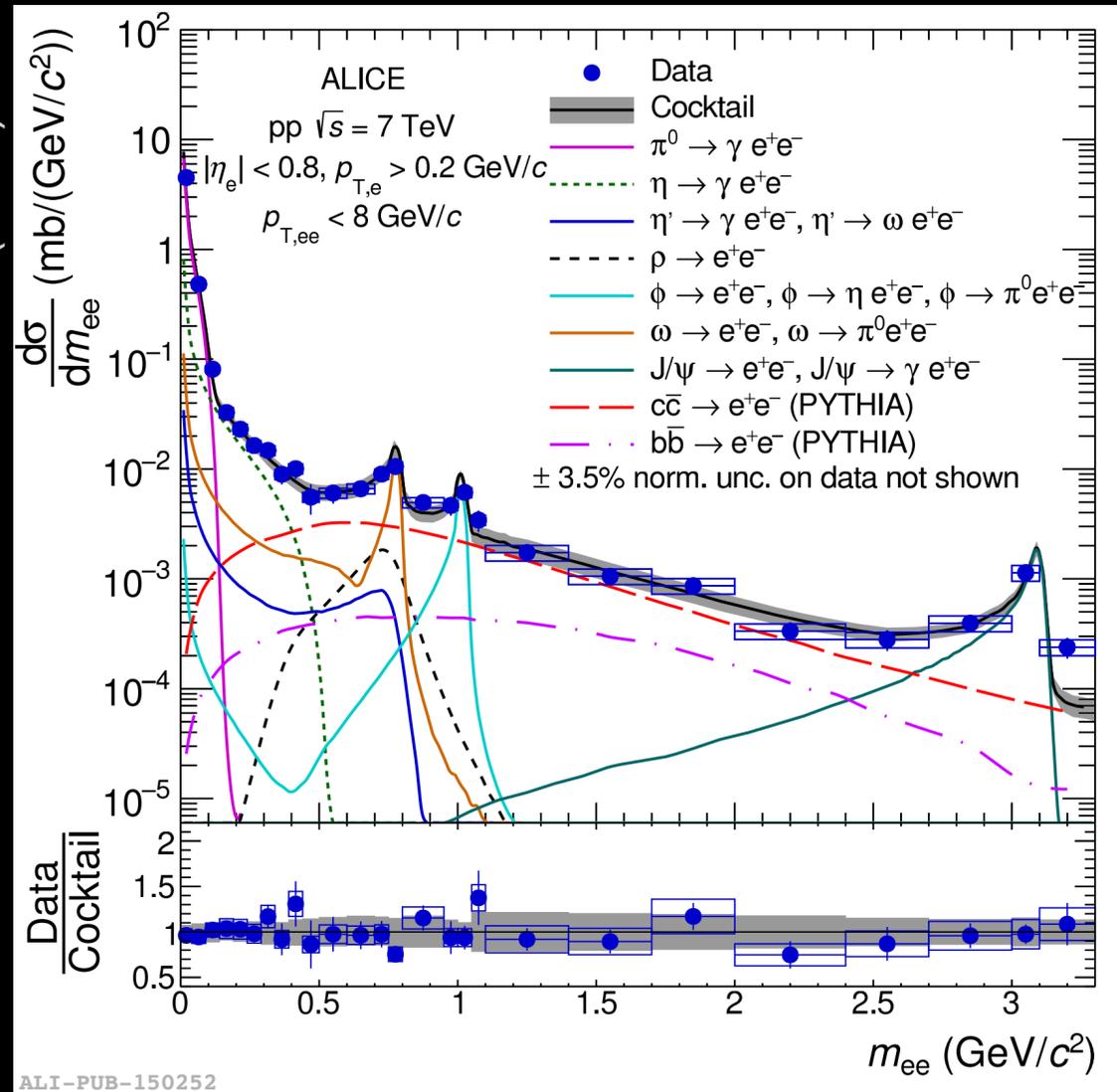
ALICE

pp 7 TeV (June 2010)

Dielectron mass spectra



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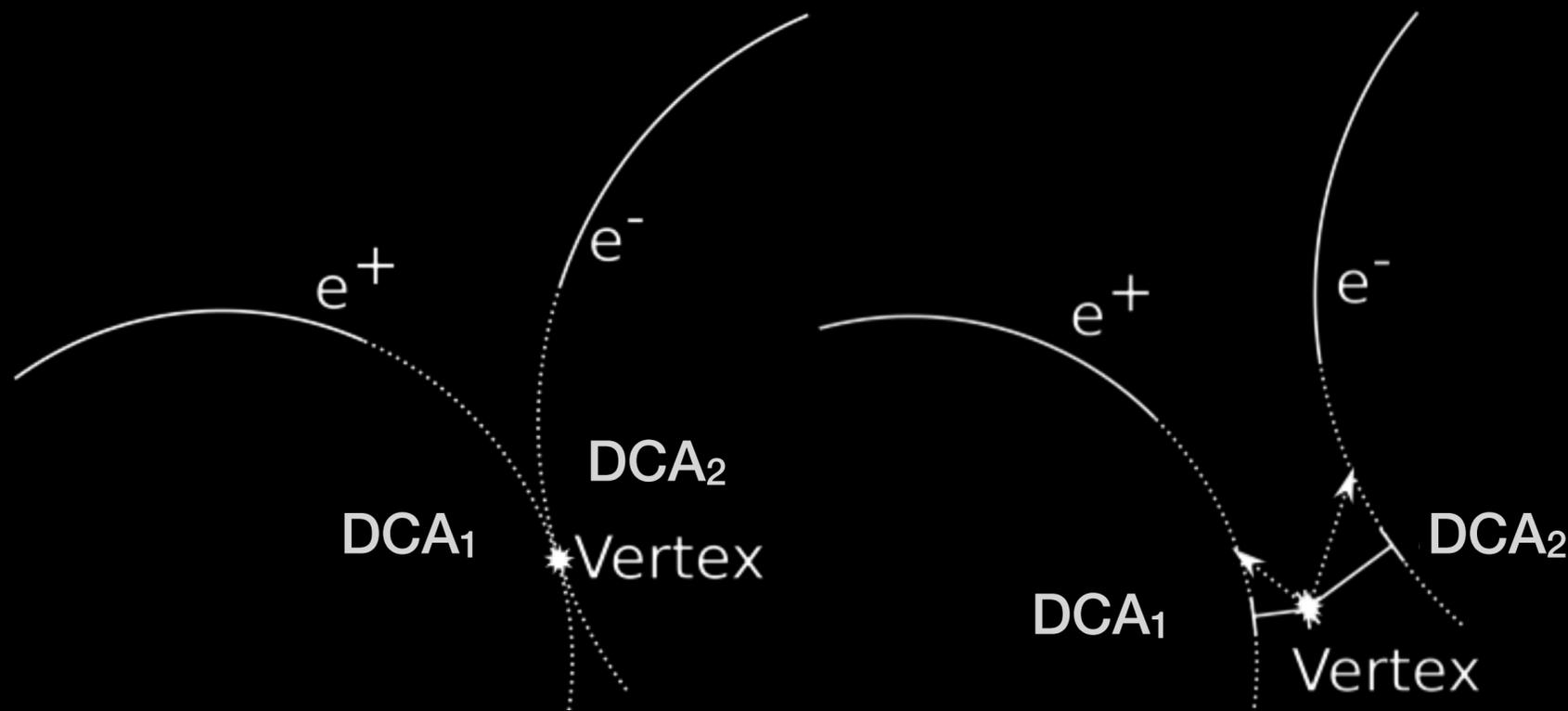
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- Dielectron production well understood
- Heavy flavour dominates for $m_{ee} > 0.5$ GeV/c²
→ Very large background for thermal-radiation studies in Pb–Pb

Topological separation of e^+e^- sources



Pair distance-of-closest-approach (DCA_{ee})

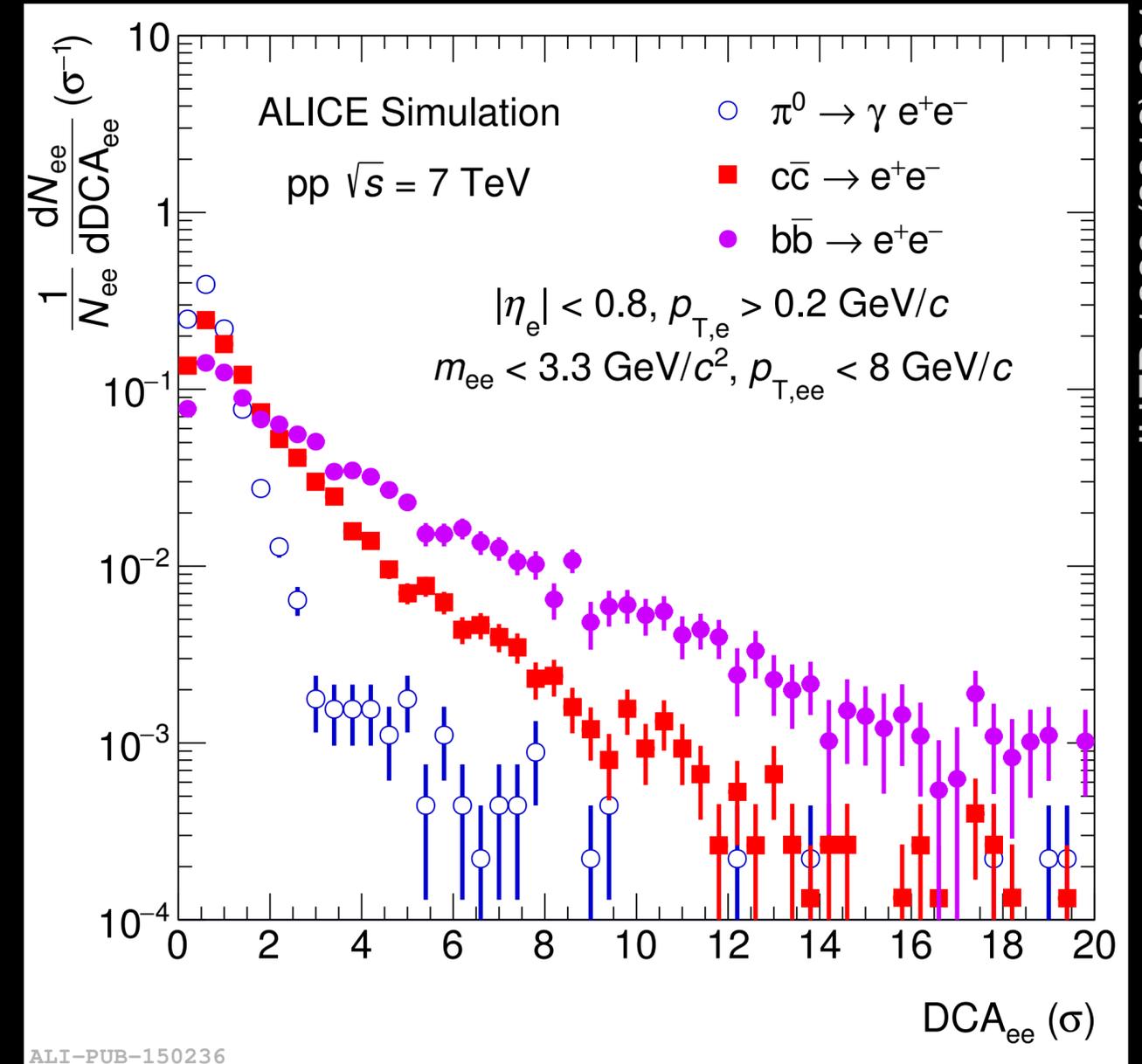


$$DCA_{ee} = \sqrt{\frac{DCA_1^2 + DCA_2^2}{2}}$$

→ Normalise track DCA to resolution

DCA_{ee} allows us to separate prompt from delayed dielectron sources:

$$DCA_{ee}(\text{prompt}) < DCA_{ee}(\text{charm}) < DCA_{ee}(\text{beauty})$$

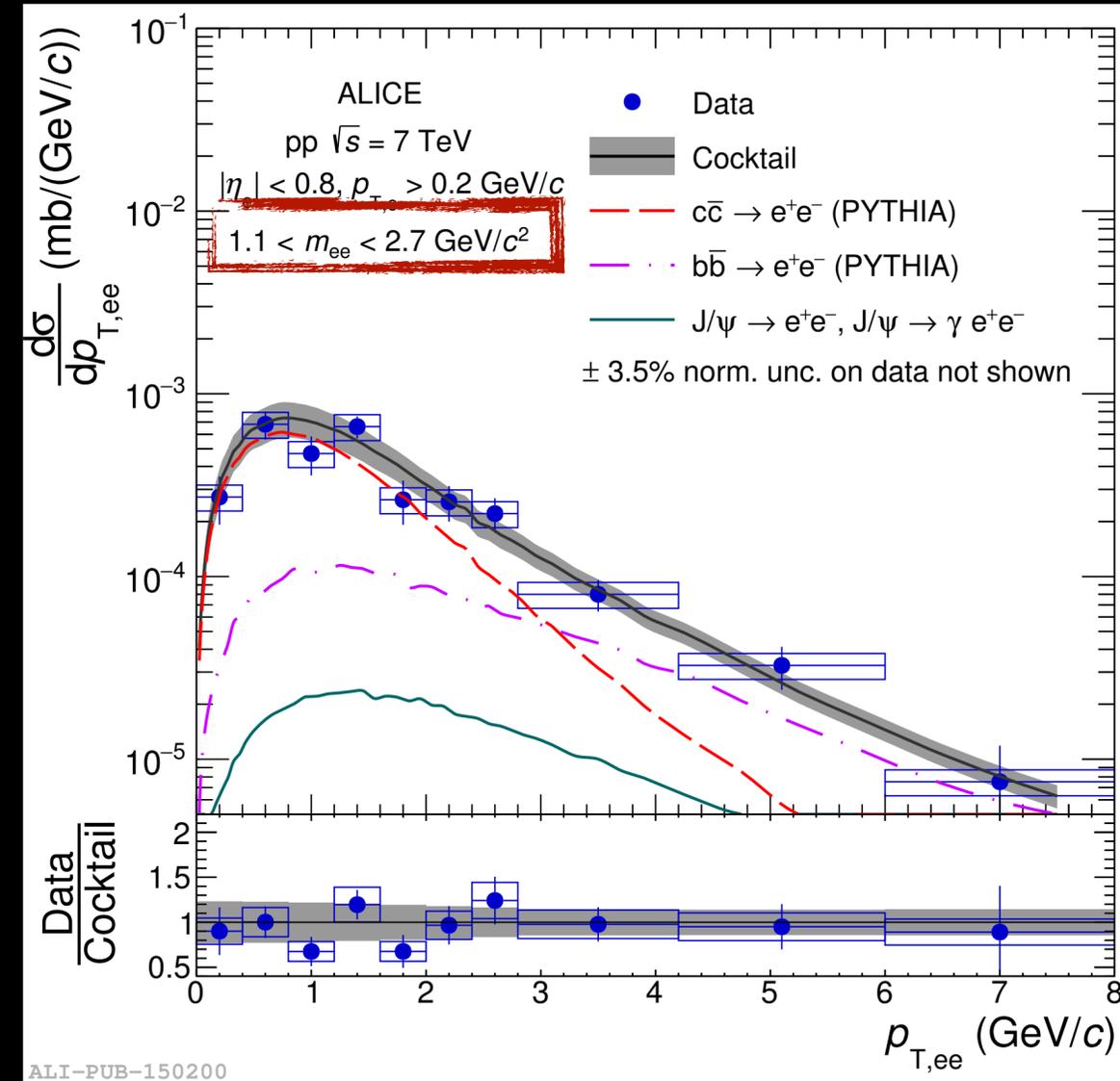
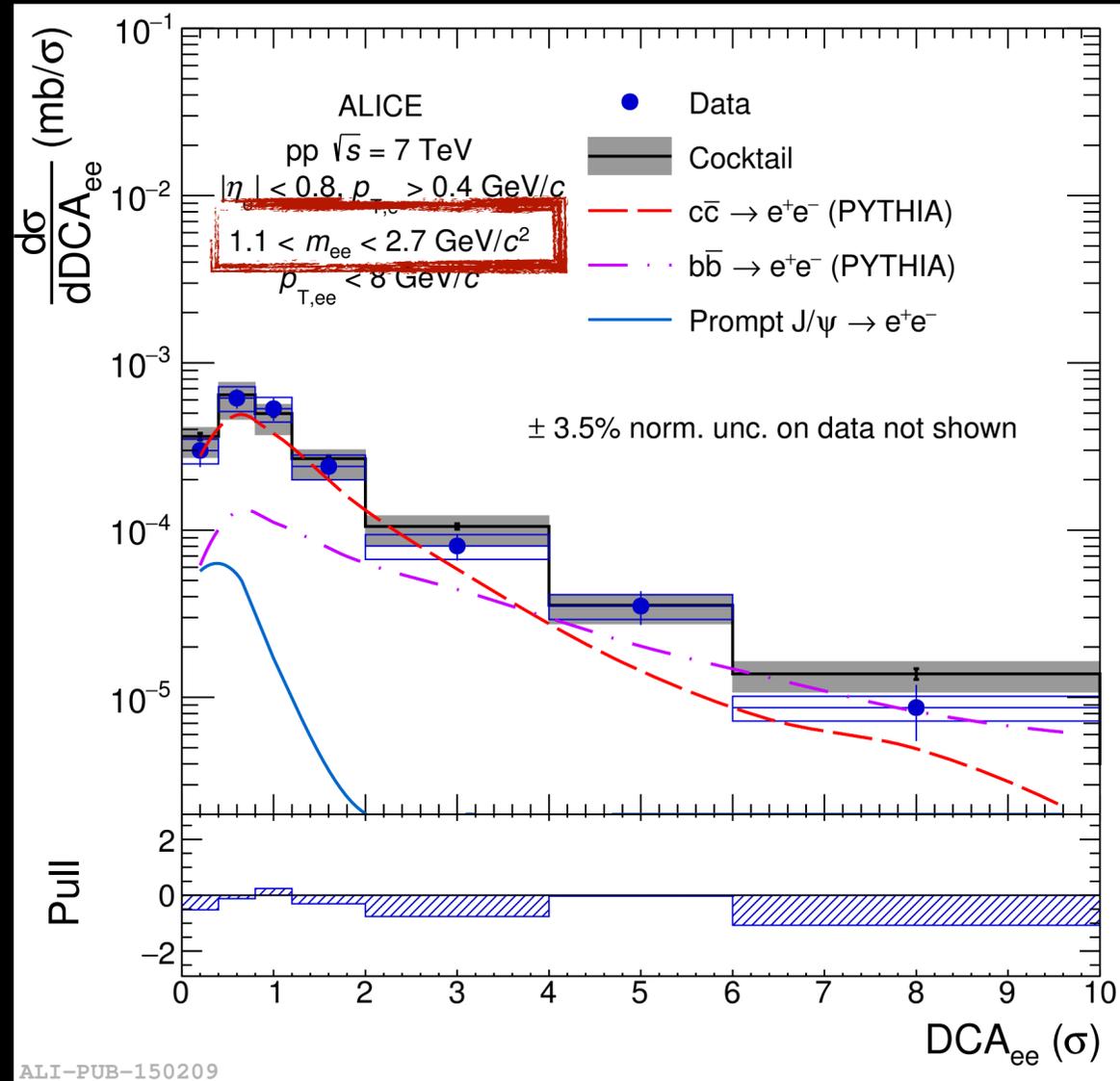


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Heavy flavour in pp at $\sqrt{s} = 7$ TeV



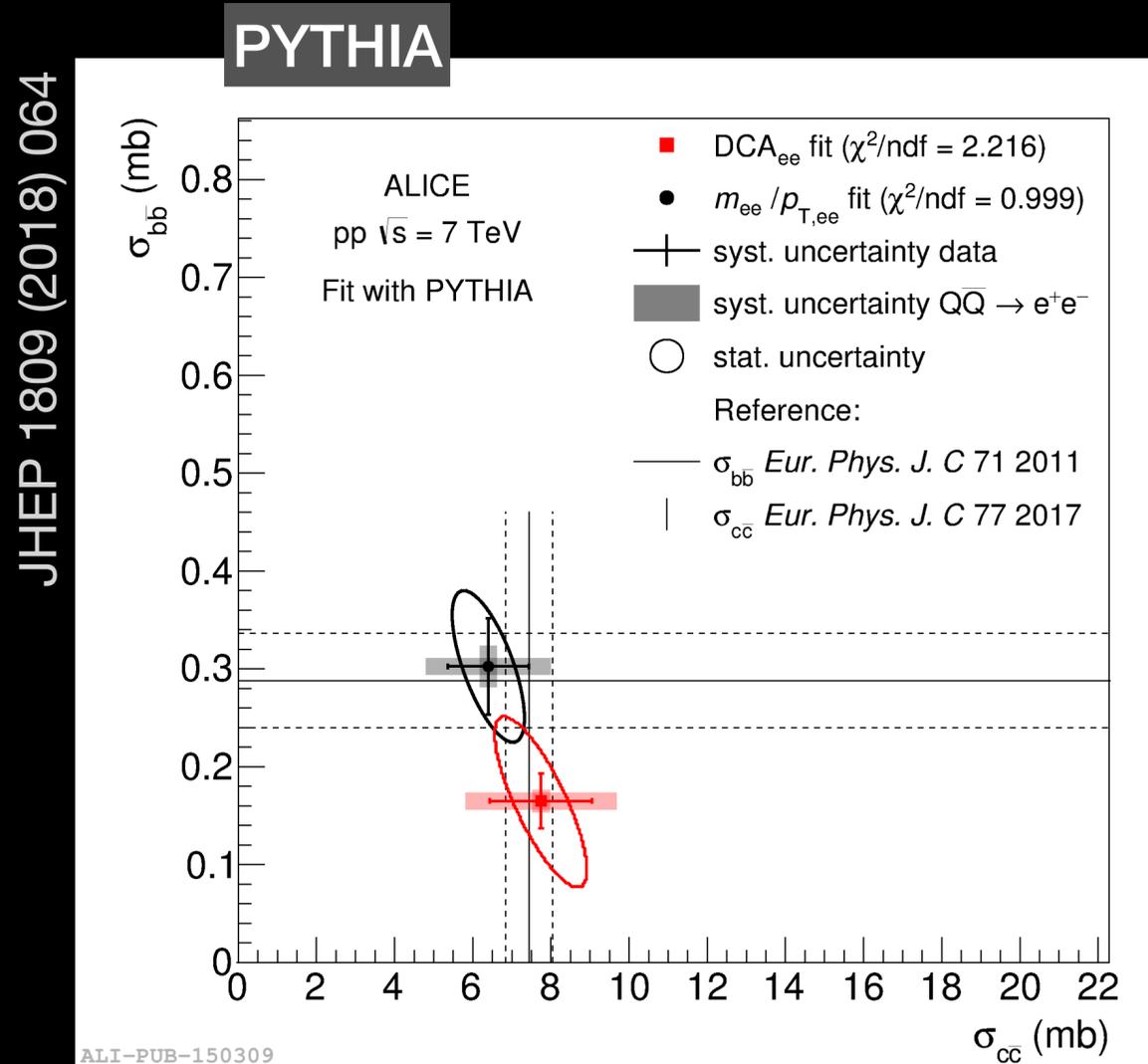
HF dominated mass region



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- No indication of prompt source — as expected in pp at LHC energies (Drell-Yan negligible in the IMR)
- Extract heavy-flavour cross sections from fits of MC templates to either DCA_{ee} or $m_{ee}/p_{T,ee}$ distributions

Heavy-flavour in pp at $\sqrt{s} = 7$ TeV

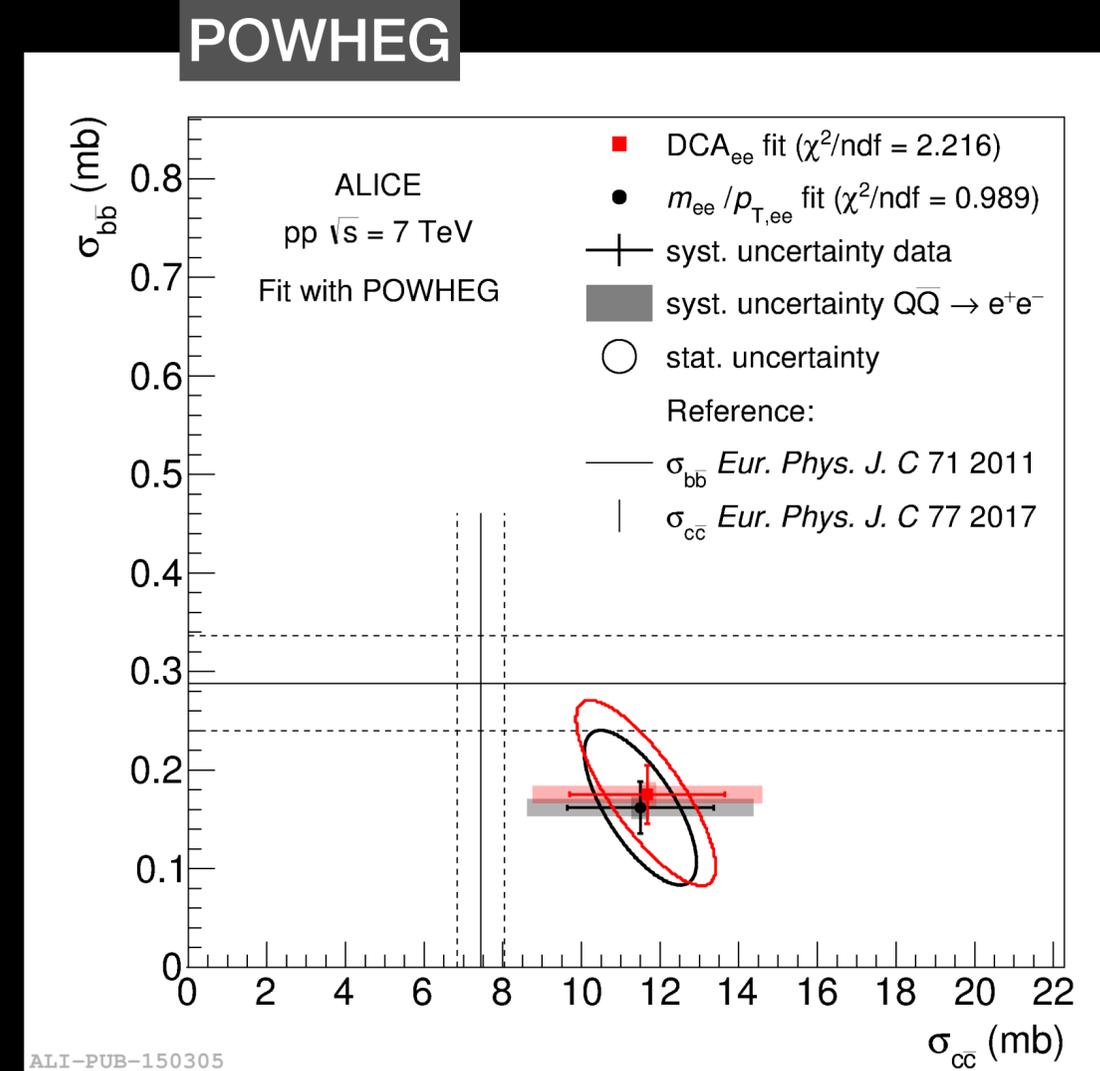
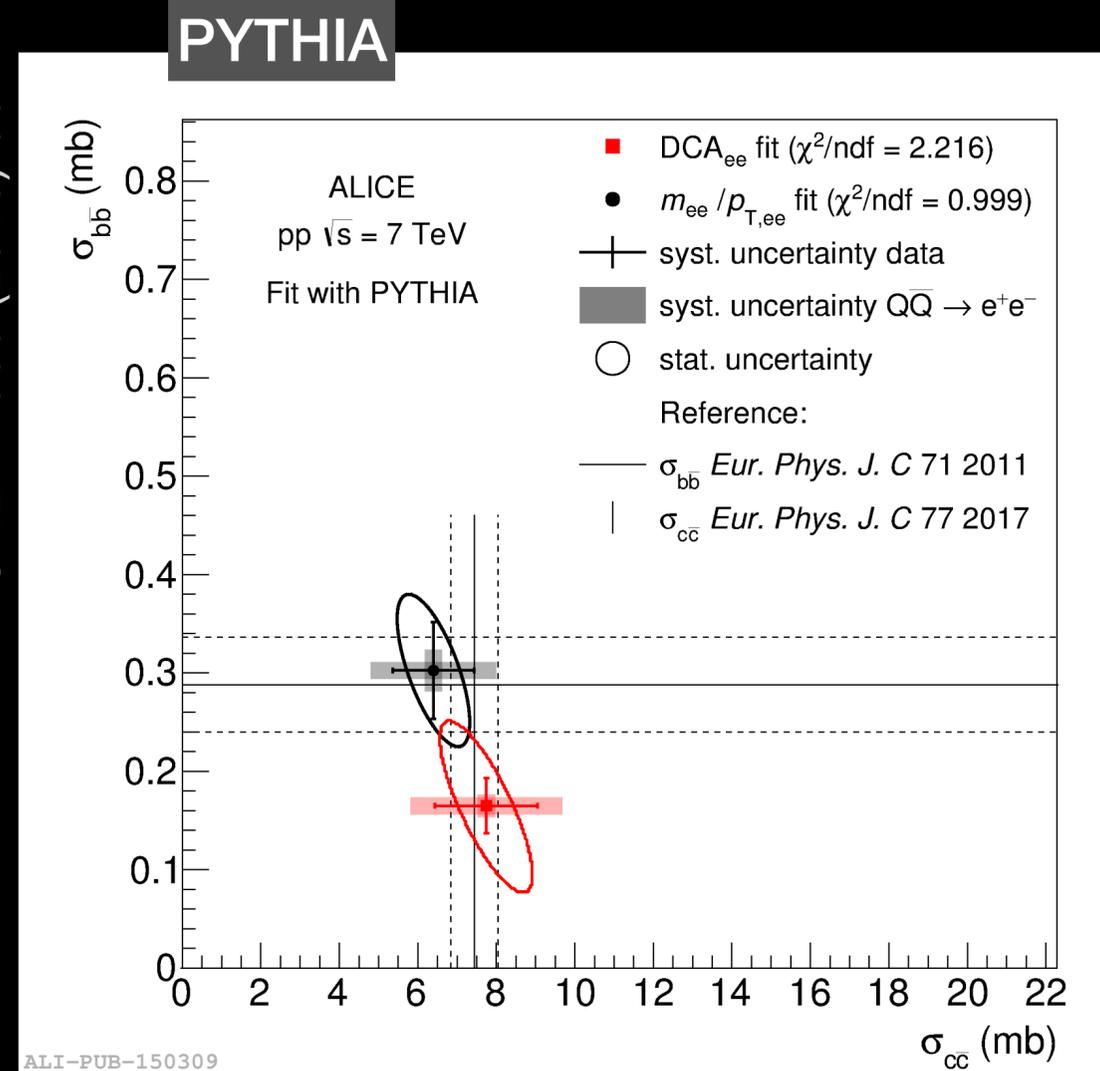


- DCA_{ee} and $m_{ee}/p_{T,ee}$ fits in agreement
- $\sigma_{c\bar{c}}$ and $\sigma_{b\bar{b}}$ consistent with independent measurement using single open heavy-flavour hadrons
- Dominant systematic uncertainty: 22% from $c\bar{c} \rightarrow ee$ branching ratio

Heavy-flavour in pp at $\sqrt{s} = 7$ TeV



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- DCA_{ee} and $m_{ee}/p_{T,ee}$ fits in agreement
 - σ_{cc} and σ_{bb} consistent with independent measurement using single open heavy-flavour hadrons
 - Dominant systematic uncertainty: 22% from $c\bar{c} \rightarrow ee$ branching ratio
- DCA_{ee} and $m_{ee}/p_{T,ee}$ fits in agreement
 - Tension between σ_{cc} and σ_{bb} from PYTHIA and POWHEG → Sensitivity on different production mechanisms for heavy-flavour quarks

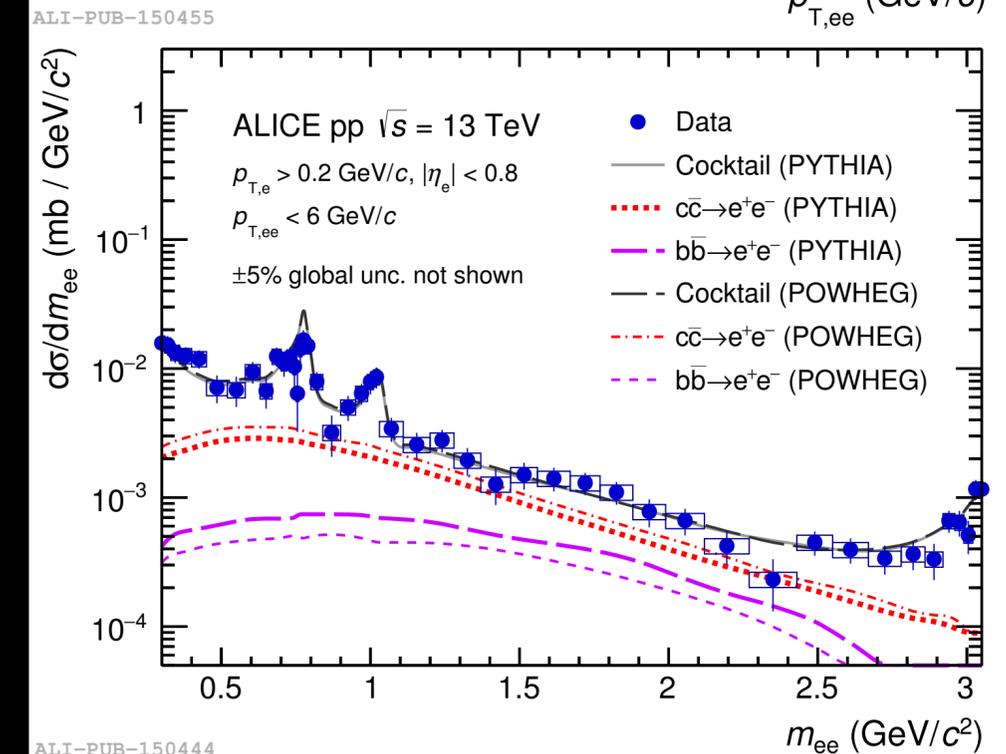
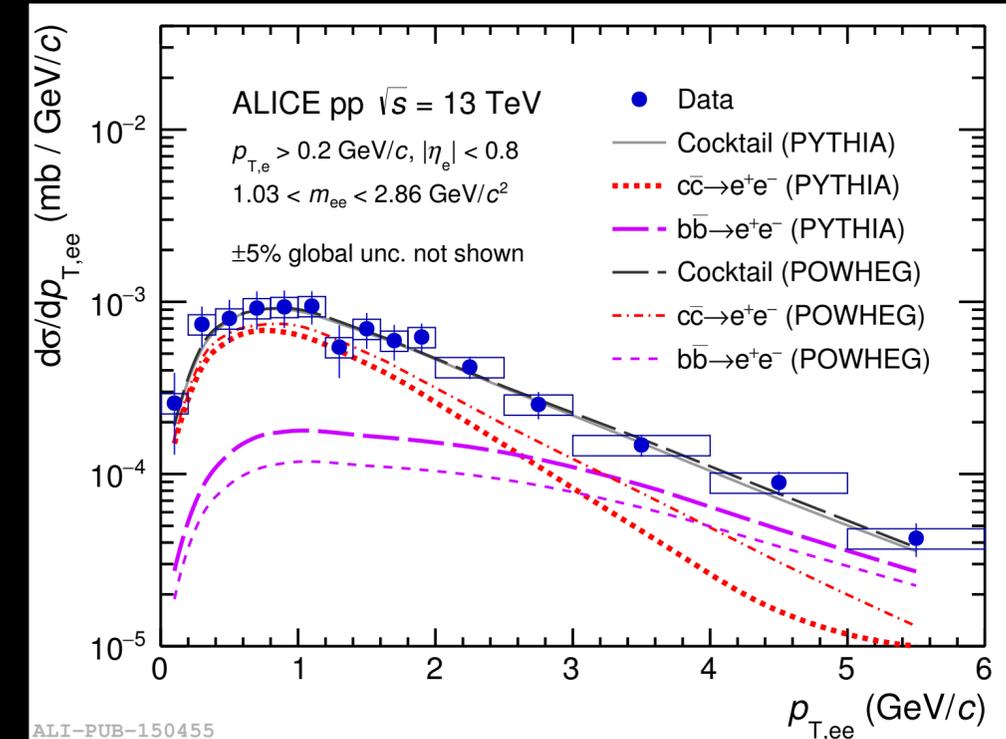
Heavy flavour in pp at $\sqrt{s} = 13$ TeV



Similar findings in 13 TeV min bias and high-multiplicity analysis

	PYTHIA	POWHEG
$d\sigma_{c\bar{c}}/dy _{y=0}$	974 ± 138 (stat.) ± 140 (syst.) μb	1417 ± 184 (stat.) ± 204 (syst.) μb
$d\sigma_{b\bar{b}}/dy _{y=0}$	79 ± 14 (stat.) ± 11 (syst.) μb	48 ± 14 (stat.) ± 7 (syst.) μb
$d\sigma_{c\bar{c}}/dy _{y=0}^{\text{HM}}$	4.14 ± 0.67 (stat.) ± 0.66 (syst.) μb	5.95 ± 0.91 (stat.) ± 0.95 (syst.) μb
$d\sigma_{b\bar{b}}/dy _{y=0}^{\text{HM}}$	0.29 ± 0.07 (stat.) ± 0.05 (syst.) μb	0.17 ± 0.07 (stat.) ± 0.03 (syst.) μb

First measurement of charm and beauty cross sections at mid rapidity in pp at $\sqrt{s} = 13$ TeV

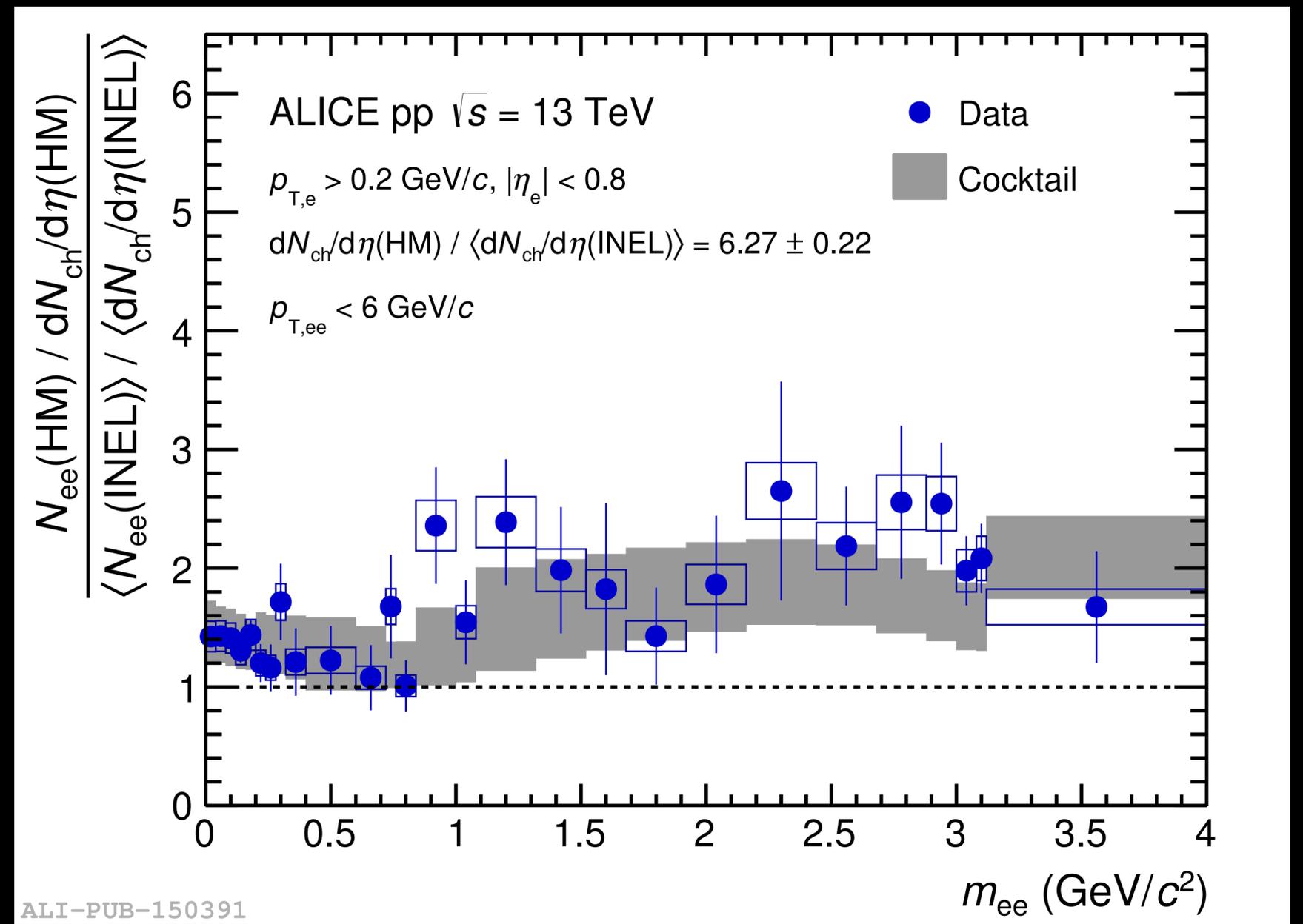


High multiplicity (HM) in pp at $\sqrt{s} = 13$ TeV



Medium effects HM pp collisions?

- Trigger & offline selection HM events
→ 0.036% highest multiplicity
 - Ratio of HM to inelastic pp collisions scaled by multiplicity (cancels some uncertainties)
 - Cocktail reflects stronger than linear increase in HF production with multiplicity (from D-meson measurement) and hardening of p_T spectra
- **No sensitivity (yet) for medium radiation in HM pp data**

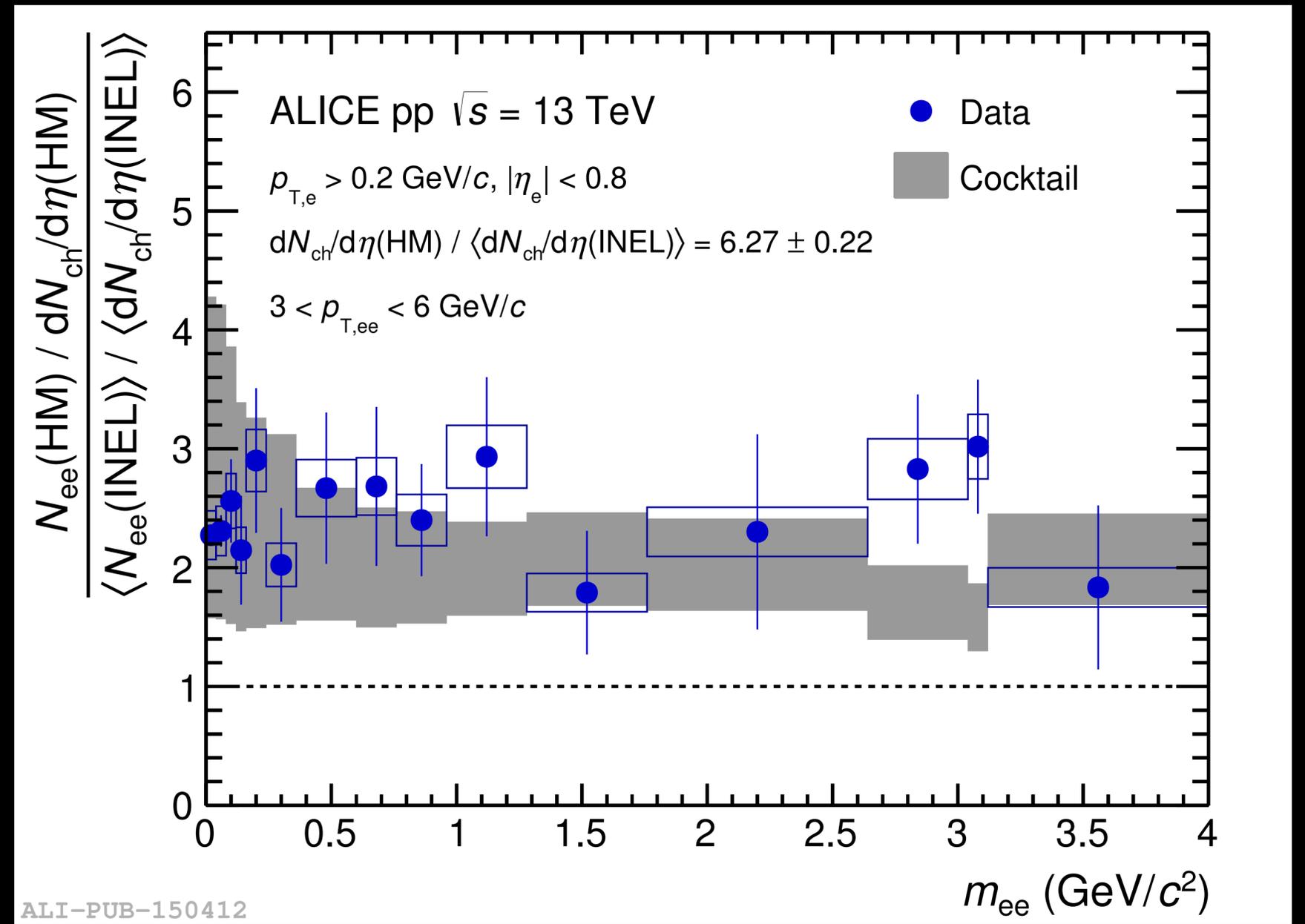


High multiplicity in pp at $\sqrt{s} = 13$ TeV



Medium effects in HM pp collisions?

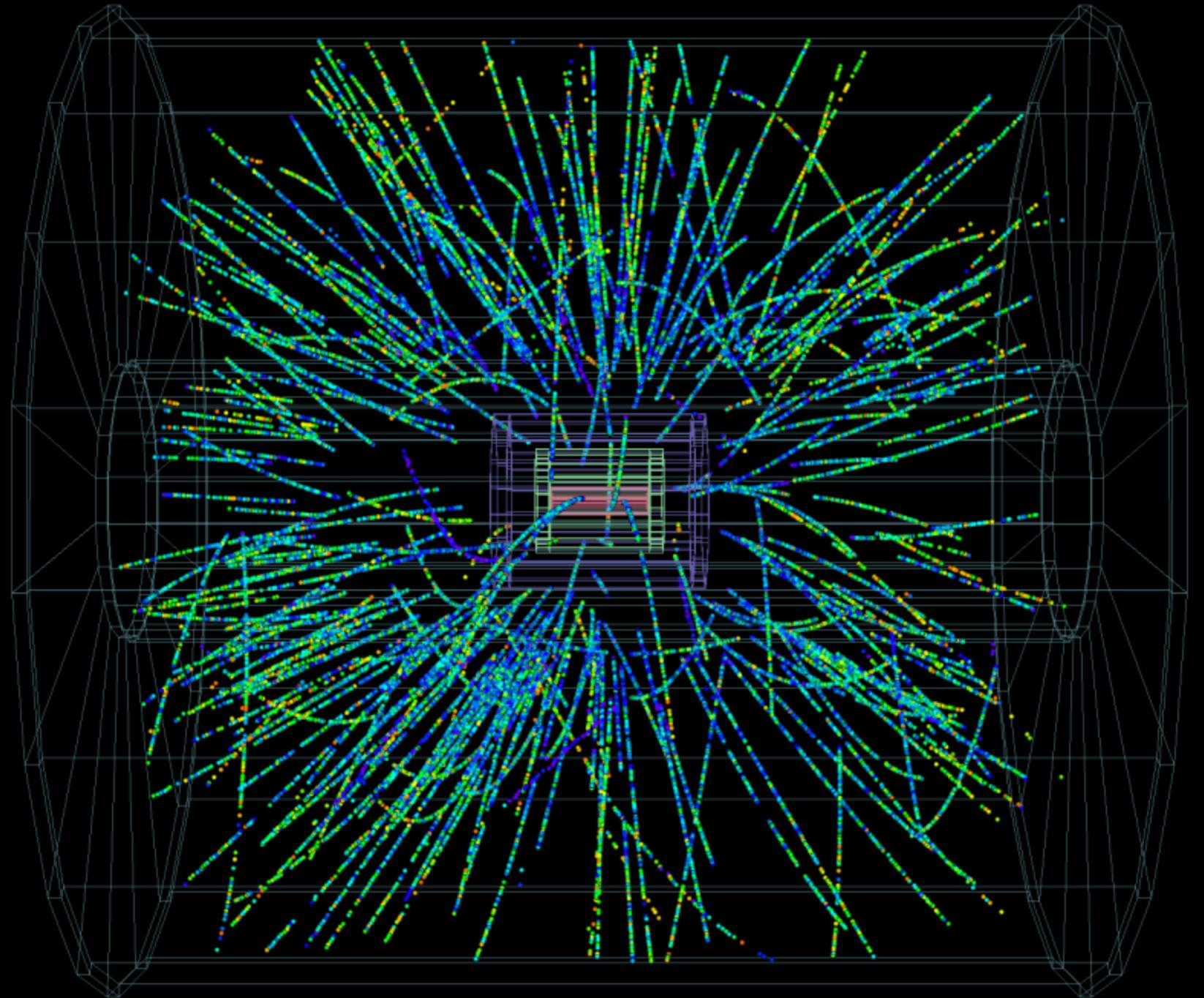
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- **No sensitivity (yet) for medium radiation in HM pp data**
- **Scaling of beauty similar to charm at high $p_{T,ee}$**



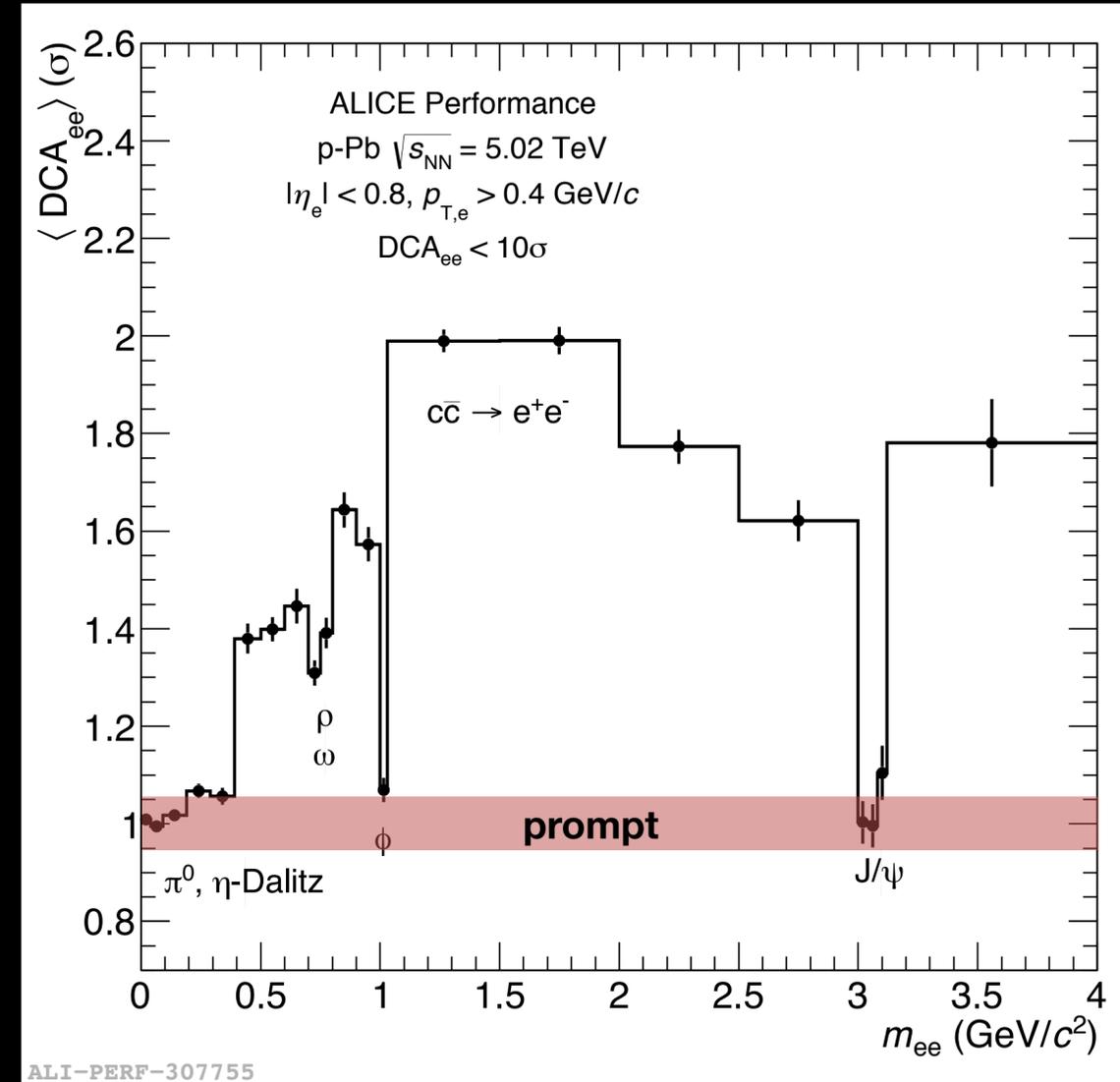
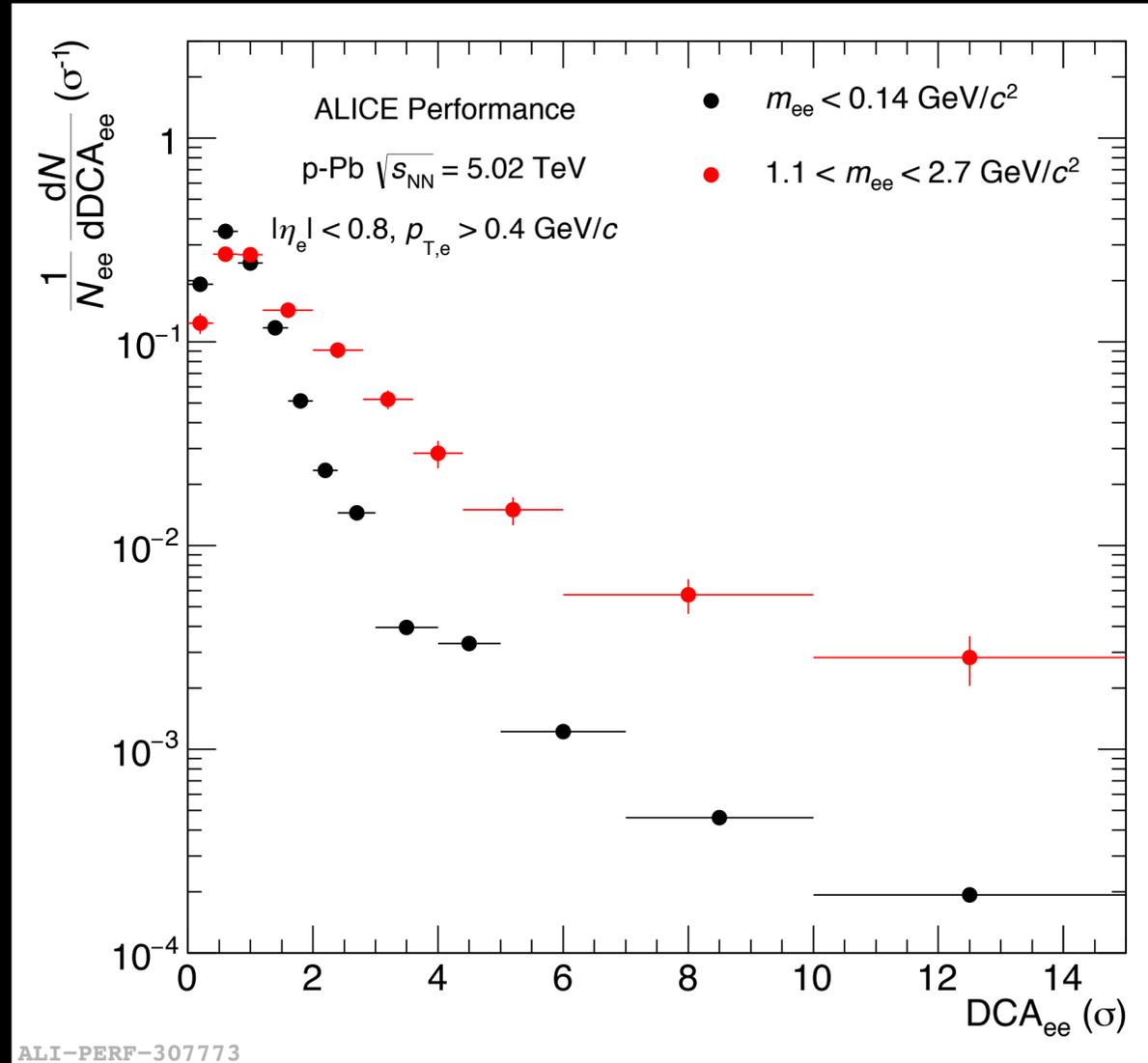
p–Pb Collisions

Run 2

- $\sqrt{s_{NN}} = 5.02$ TeV (min bias)
Factor 5 more statistics than Run 1
analysis ongoing



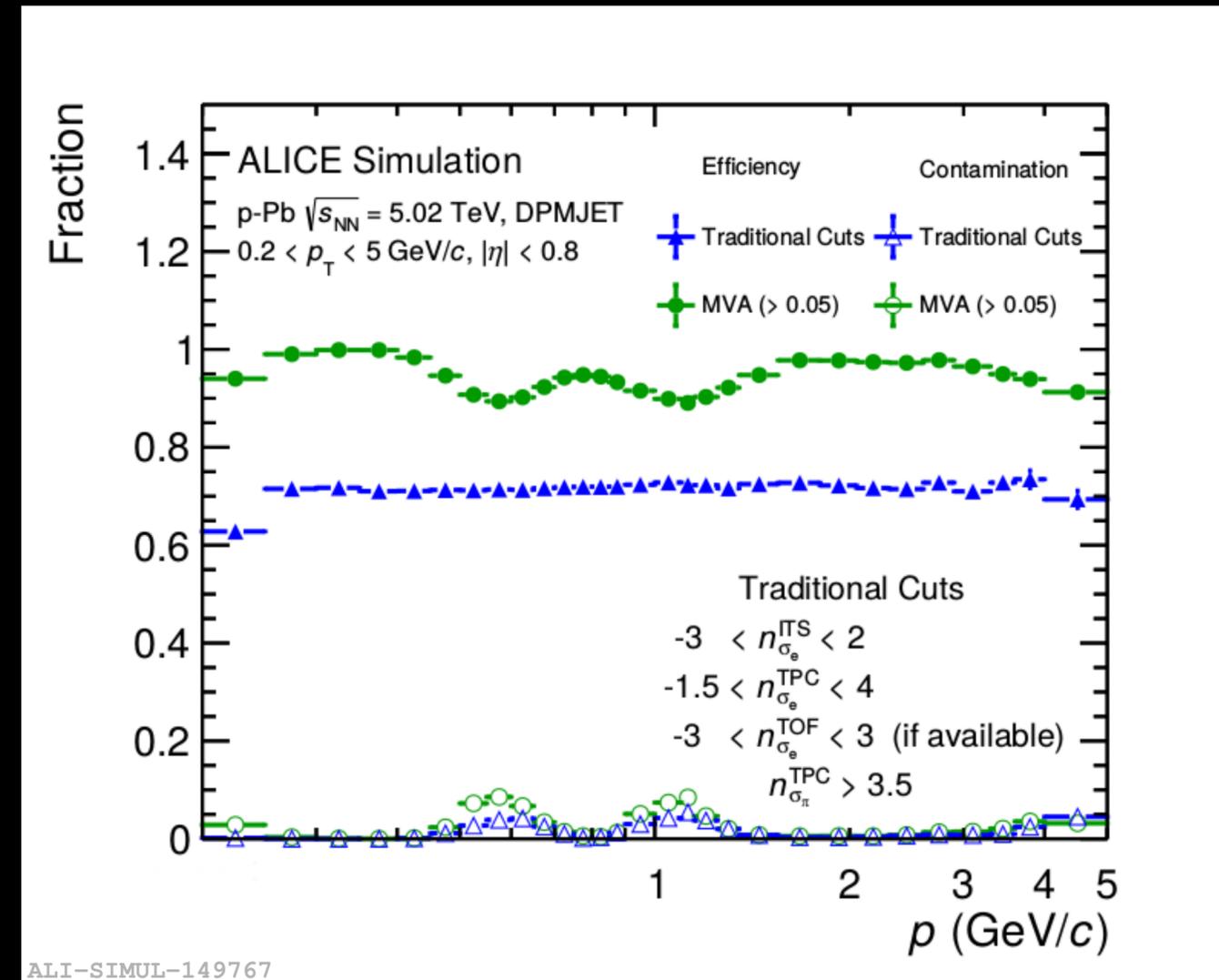
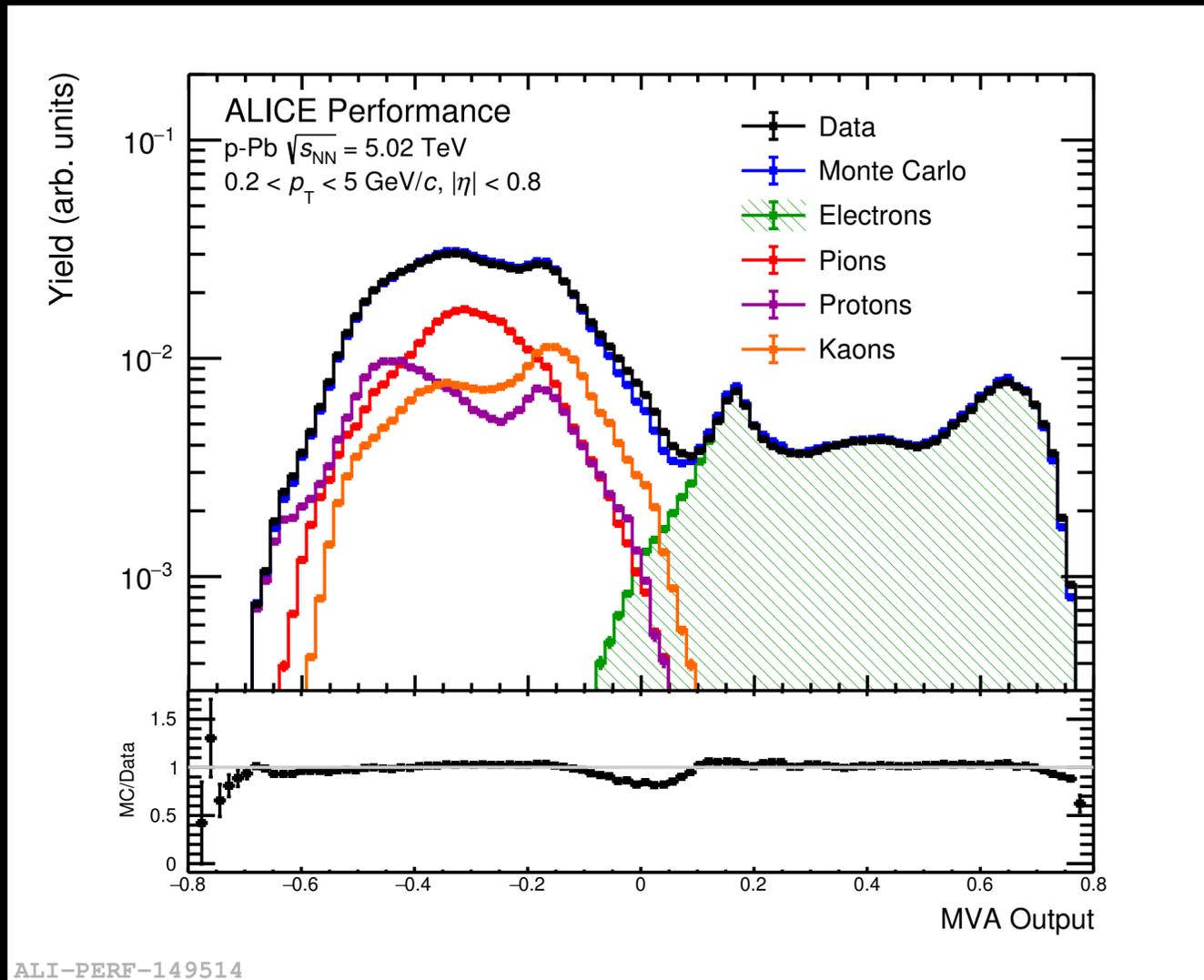
p-Pb in $\sqrt{s_{NN}} = 5.02$ TeV (Run 2)



DCA_{ee} analysis

- Study Cold Nuclear Matter effects on HF production
- Multiplicity dependent analysis: Possible thermal radiation in high-multiplicity p-Pb collisions

p-Pb in $\sqrt{s_{NN}} = 5.02$ TeV (Run 2)



Multivariate Analysis:

- Machine learning in form of BDTs
- Excellent PID performance compared to traditional cut based PID

Summary



- Dielectron measurements can give insight to heavy flavour production mechanisms
- First results from Run 1 and Run 2 available:

Dielectron production in proton-proton collisions at $\sqrt{s} = 7$ TeV

ALICE Collaboration, JHEP 1809 (2018) 064

Dielectron and heavy-quark production in inelastic and high-multiplicity pp collisions at $\sqrt{s} = 13$ TeV

ALICE Collaboration, PLB 788 (2019) 505

- High-statistics data sets for pp and p-Pb at $\sqrt{s_{NN}} = 5.02$ TeV available from Run 2
- Implementation of machine learning techniques ongoing

Outlook

Major upgrades under construction for Run 3 and 4

- Higher data acquisition rate (x100) and reduced ITS material budget (x4) with better DCA resolution (x3)
 - More statistics and better background rejection

Future physics opportunities for high-density QCD at the LHC with heavy-ion and proton beams

Citron, Z. *et al*, 1812.06772