Dielectron production in high-multiplicity pp collisions at √s = 13 TeV with ALICE

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on behalf of the ALICE collaboration

Physics opportunities of Dielectron

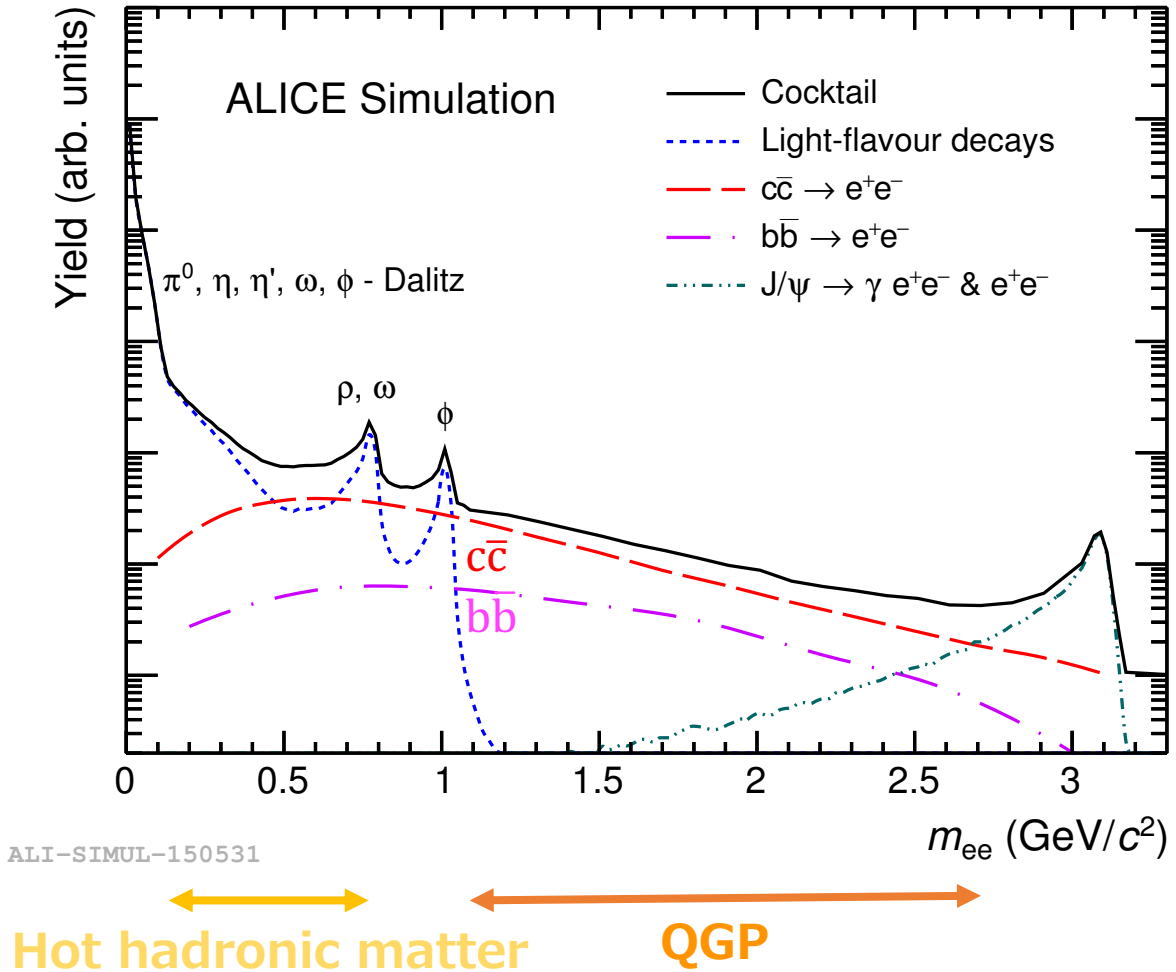
Pb–Pb
- Thermal radiation from QGP and HG
- Chiral symmetry restoration (ρ modification)
- Coherent photoproduction ($\gamma\gamma \rightarrow e^{-}e^{+}$)

p–Pb
- Cold nuclear matter (CNM) effects
- Search for new phenomena in central collisions

pp
- Vacuum baseline for p–Pb and Pb–Pb
- Search for small QGP droplet

Thermal radiation can be addressed:

- m_{ee} and DCA_{ee} analysis
  - At intermediate mass region for QGP
  - At low mass region for hot hadronic matter
- Direct virtual-photon γ* analysis (m_{ee}→0)

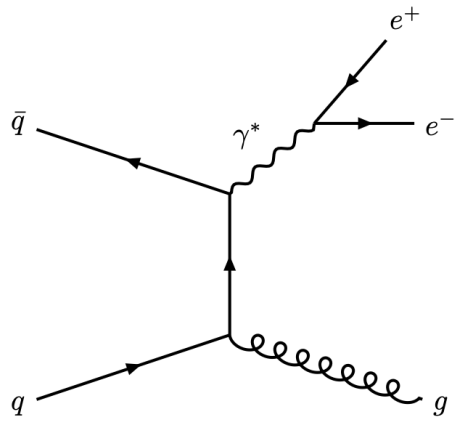


Motivation for pp collisions

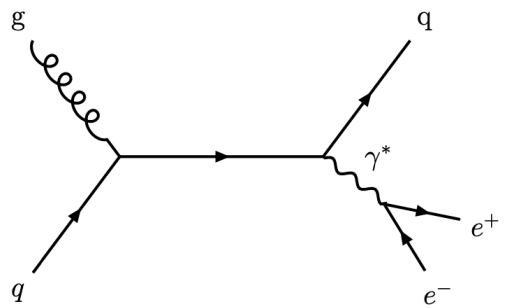
QGP in small systems ?

- Collectivity in small systems observed at RHIC and LHC
- No energy loss observed in R_{AA} measurements
- *Does the system thermalize or not ?*
  - Onset of thermal photon production at $dN_{ch}/d\eta \sim 10$?
  - Search for thermal photons in small systems at LHC energies

→ Measure direct virtual photon γ^* in min. bias (MB) and high-multiplicity (HM) pp at $\sqrt{s}$ = 13 TeV

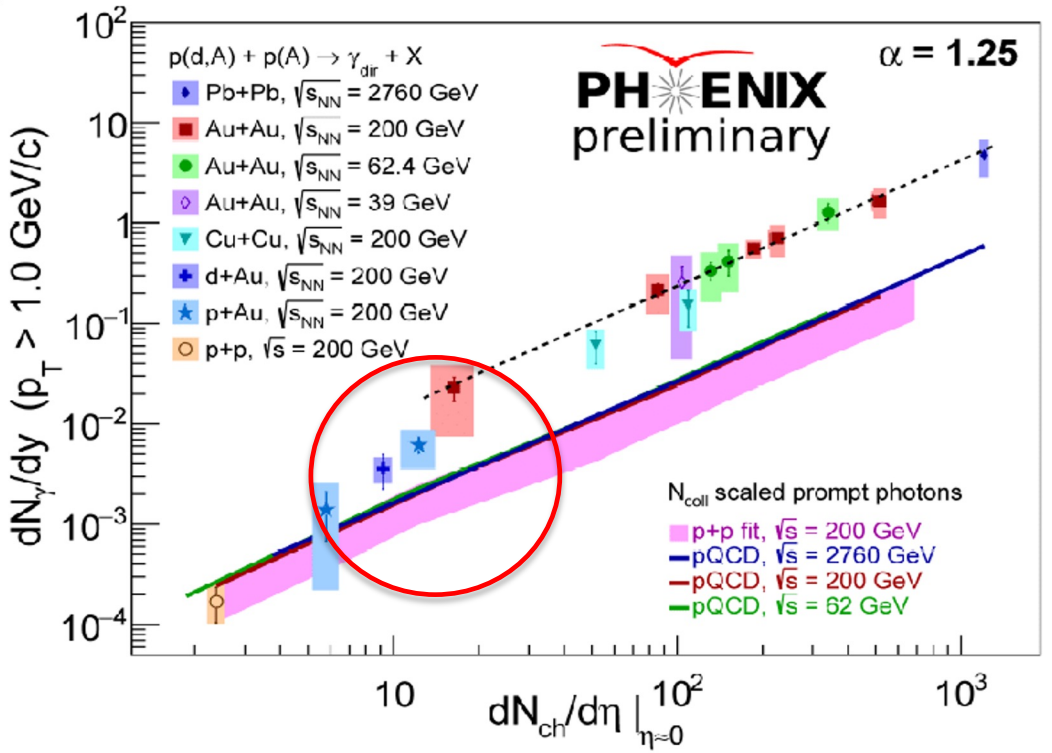


Quark annihilation



Gluon-Compton scattering

Photon yield vs multiplicity

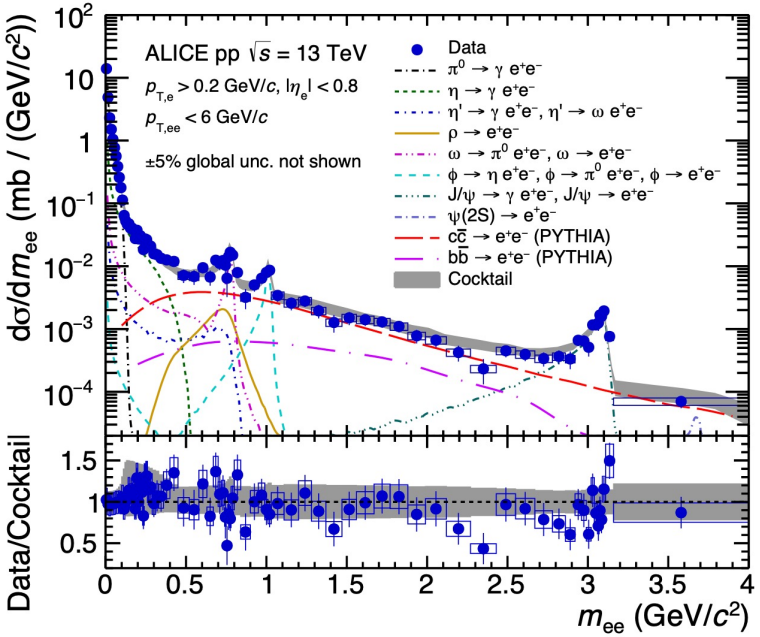


pp collisions at $\sqrt{s}$ = 13 TeV

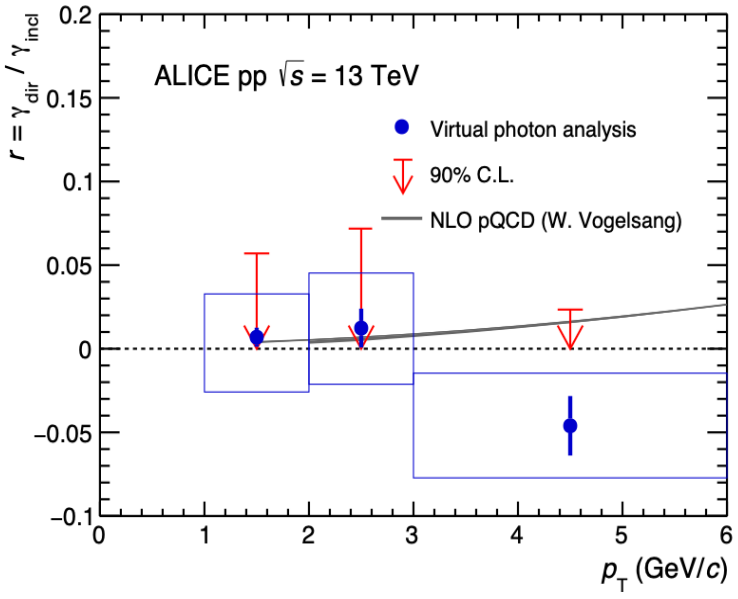
- $dN_{ch}/d\eta \sim 7$ (MB)
- $dN_{ch}/d\eta \sim 30$ (HM, top 0.1%)

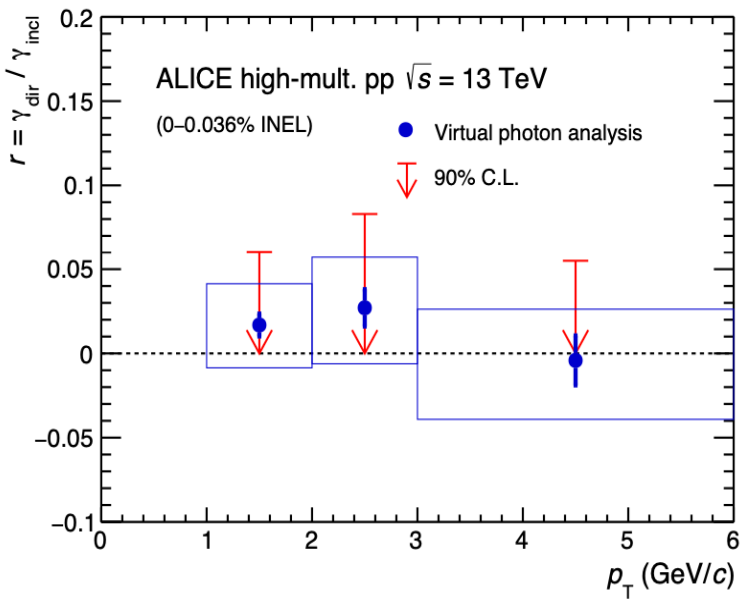
Previous publication

Dielectron spectrum



Direct photon fraction $r = \gamma_{dir} / \gamma_{incl}$ as a function of p_T





- Dielectron invariant mass spectrum [1] and direct photon fraction r vs p_T [2]
- Improvements w.r.t the these results
  - Published data is based on 2016 pp data only and this results on full Run 2 data

  → Factor 3.8 (4.4) in MB (HM) compared to the publication.
  - Use as input measured π^0 & η spectra

[1] ALICE PLB 788 (2019) 505
[2] ALICE-PUBLIC-2018-009

ALICE

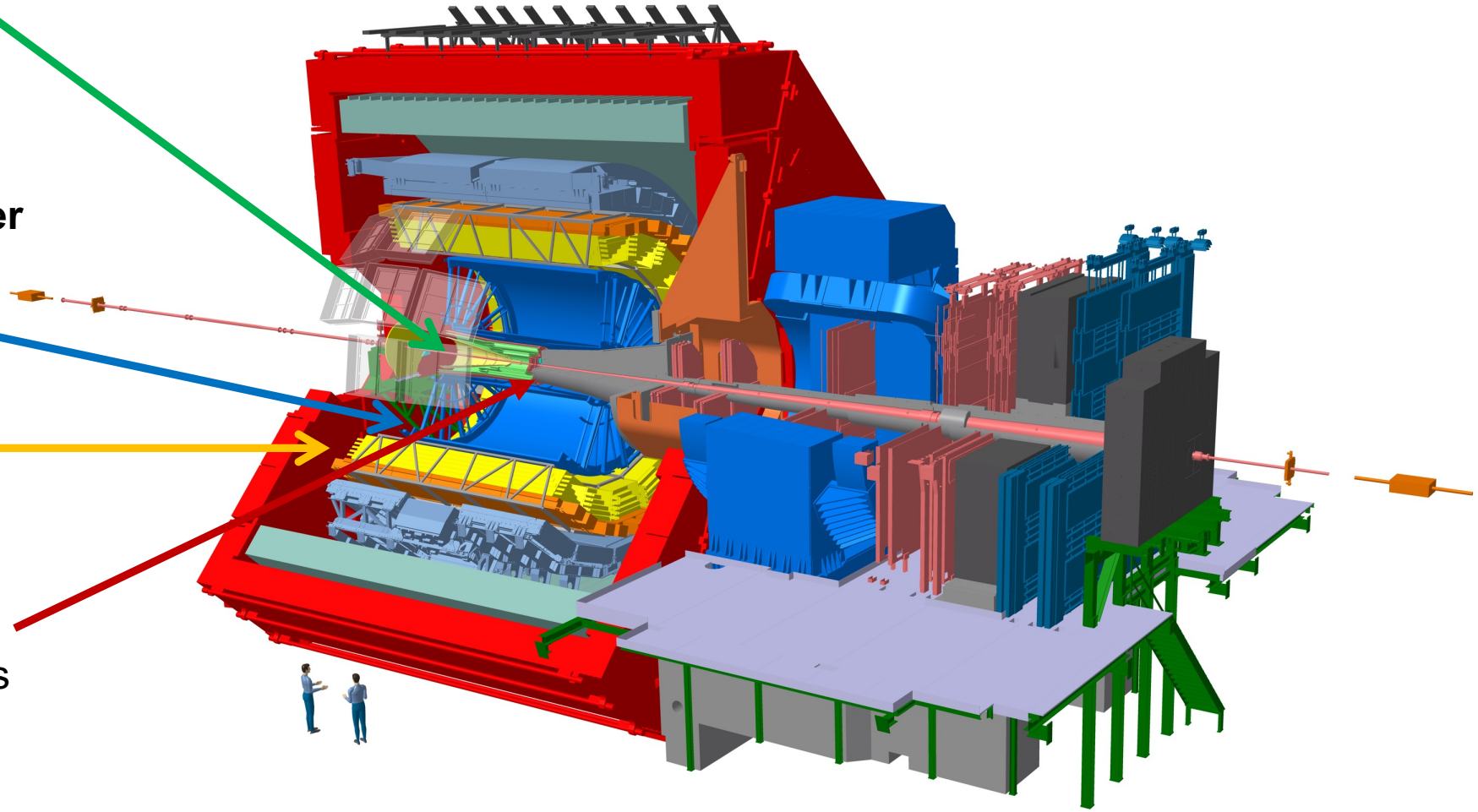
Analyzed luminosity	Number of Events
$L_{int} = 30\ nb^{-1}$ (MB)	1.76×10^9
$L_{int} = 6\ pb^{-1}$ (HM, top 0.1%)	3.52×10^8

Inner Tracking System
- Vertexing
- Tracking

Time Projection Chamber
- Tracking
- Particle identification

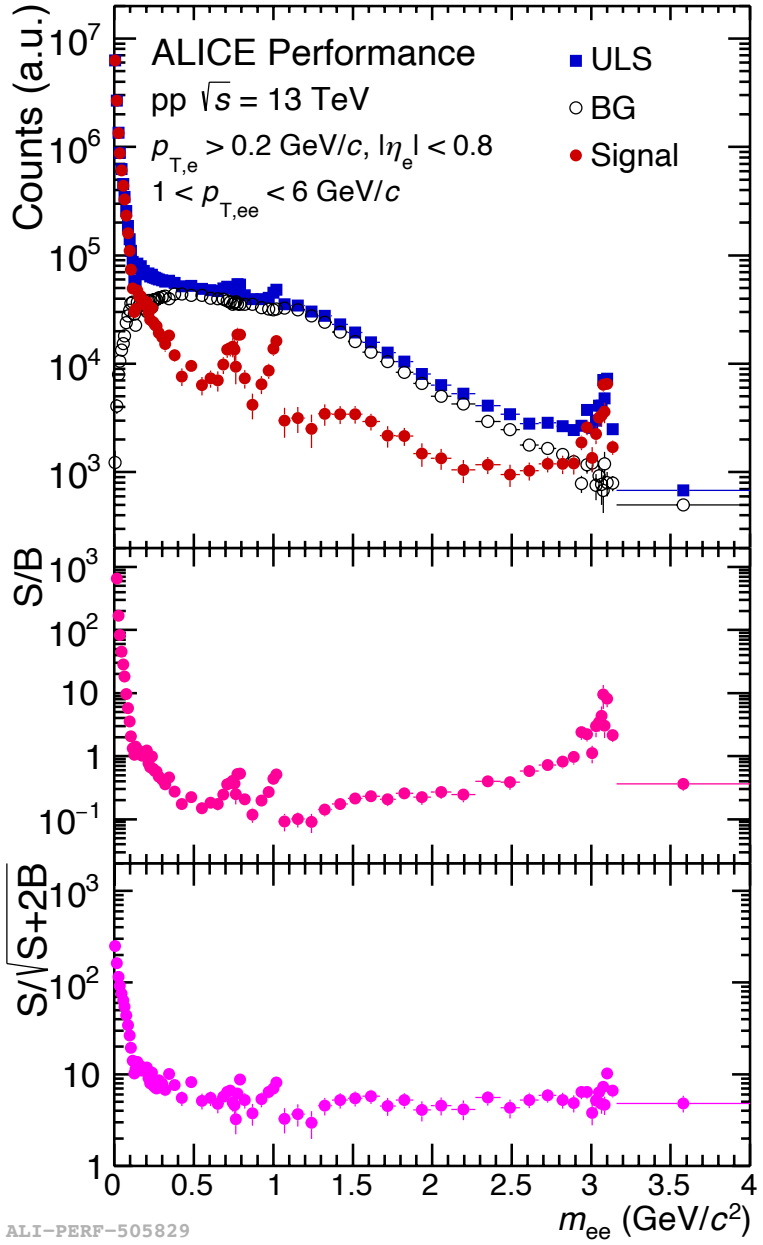
Time-Of-Flight
- Particle identification

V0 scintillation counter
- Trigger: MB & HM events
- Multiplicity determination
- Centrality estimation



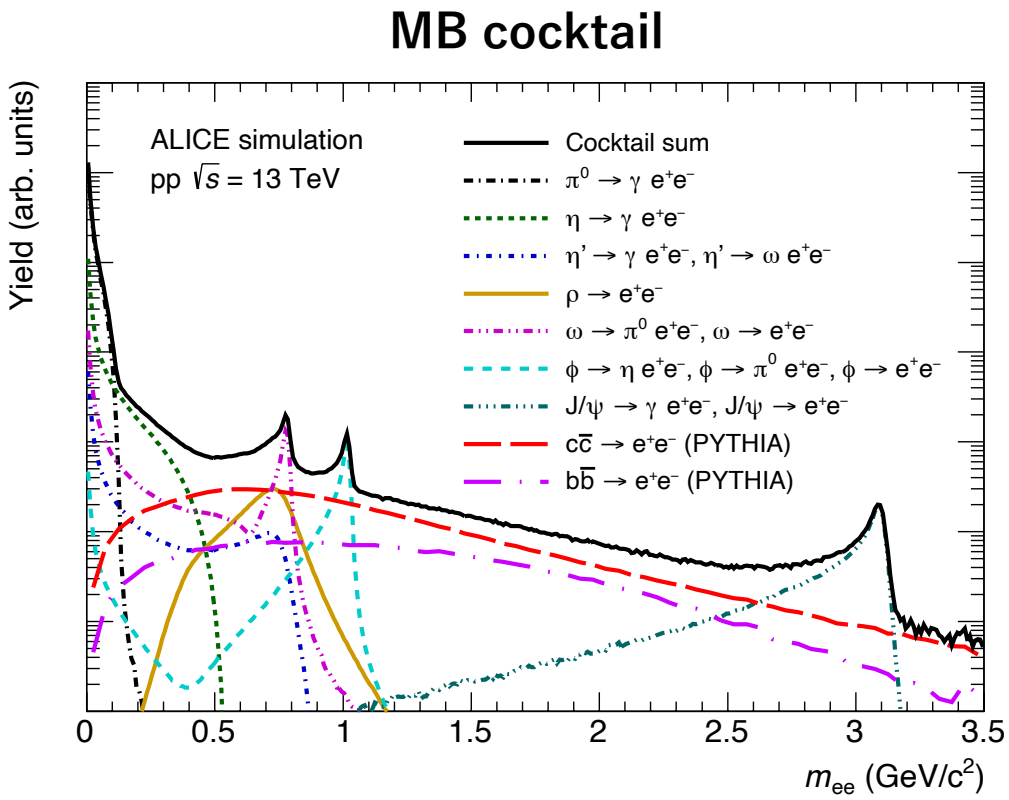
Tracking, PID, Signal extraction

- Primary track: $|\eta_e| < 0.8$ and $p_{T,e} > 0.2$ GeV/c
- Electron ID : dE/dx in TPC and time of flight of TOF detector
- Signal (S) extracted using like-sign method:
  - $S = ULS - LS*R$,
  - *ULS :* e^+e^- from same events
  - *LS :* e^+e^+ & e^-e^- from same events
  - *R :* acceptance correction factor determined with mixed events
- To suppress conversion electrons → Rejected via opening angle cut
- Efficiency corrected for correlated e^+e^- pairs
  - Resonance, open charm & beauty hadron decays



Hadronic cocktail simulation

- Expected dielectron yield from known hadron decays
- Light-flavors and J/ψ [1] :
  - (π^0/η/ϕ) and J/ψ → fit to measured spectra at $\sqrt{s}$ = 13 TeV
  - (η'/ρ/ω) → m_T scaling
- Heavy-flavors ($c\bar{c}$ and $b\bar{b}$) generated with PYTHIA6
  - Cross sections are normalized to published result [2]
- HM cocktail
  - Use π^0 and η spectra in the same multiplicity class
  - Multiply p_T dependent multiplicity scaling factor [3]



[1] π^0,η and ω: ALICE preliminary, ϕ: EPJC 81 (2021) 256, J/ψ: JHEP 03 (2022) 190
[2] ALICE PLB 788 (2019) 505
[3] J/ψ: PLB 810 (2020) 135758, HFs: JHEP 09 (2015) 148

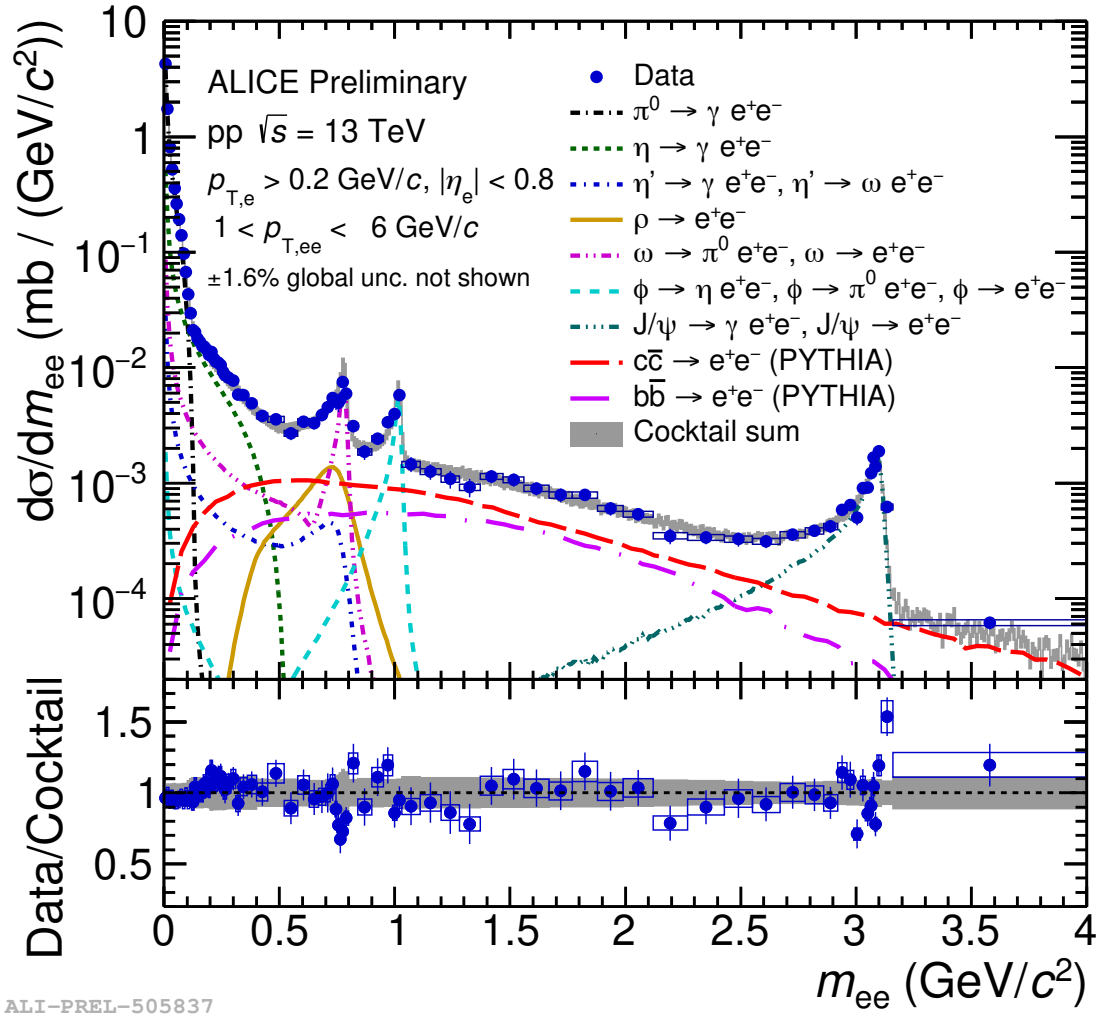
Invariant mass spectrum in minimum bias events

- Full Run 2 datasets analyzed
  - Factor 3.8 more events in MB compared to previous publication [ALICE PLB 788 (2019) 505]

- π^0 & η measured at $\sqrt{s}$ = 13 TeV in MB (preliminary)

→Reduced the sys. unc. of the hadronic cocktail

- Data and cocktail are consistent for $p_{T,ee} > 1$ GeV/c within uncertainties.



Invariant mass spectrum in high-multiplicity events

- Full Run 2 datasets analyzed
  - Factor 4.4 more events in HM compared to previous publication ALICE PLB 788 (2019) 505

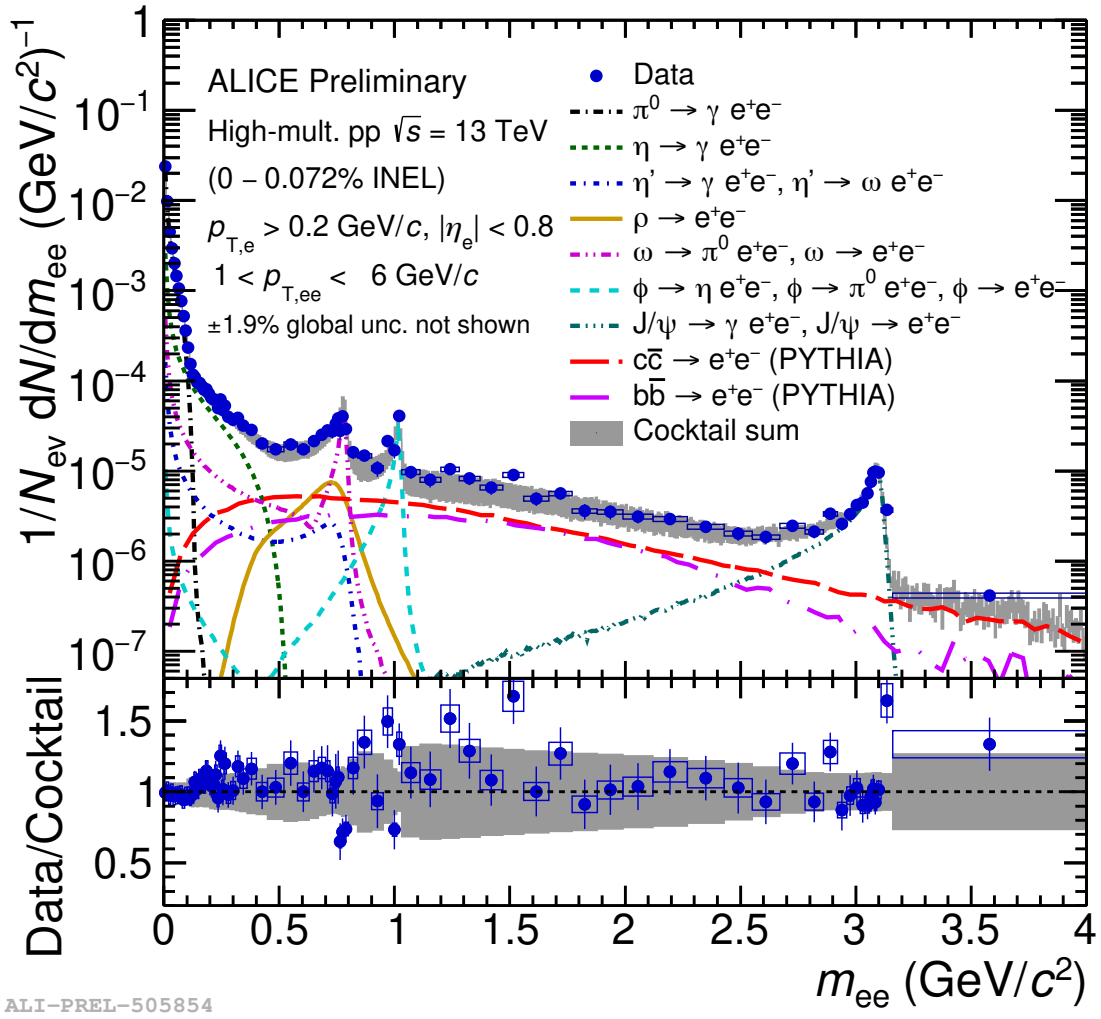
- π^0 & η measured at $\sqrt{s}$ = 13 TeV in the same multiplicity class (preliminary)

→ Reduced the sys. unc. of the hadronic cocktail

- HF cocktail: applied p_T dependent multiplicity scaling factor JHEP 09 (2015) 148

→ Dominant source of cocktail unc. at IMR

- Within uncertainties, no excess w. r. t. data at IMR



Direct photon extraction via virtual photon method

- Yield fitted with : $f = r \times f_{\mathrm{dir}} + (1-r) \times f_{\mathrm{LF}} + f_{\mathrm{HF}}$

  virtual-photon template | light flavor and heavy flavor

  where fit parameter $r = (\gamma^*_{\mathrm{dir}}/\gamma^*_{\mathrm{incl}})_{m_{\mathrm{ee}}\to 0} = (\gamma_{\mathrm{dir}}/\gamma_{\mathrm{incl}})$

- Photon template is approximated by Kroll-Wada formula

  N.M. Kroll and W. Wada PR 98 (1955) 1355

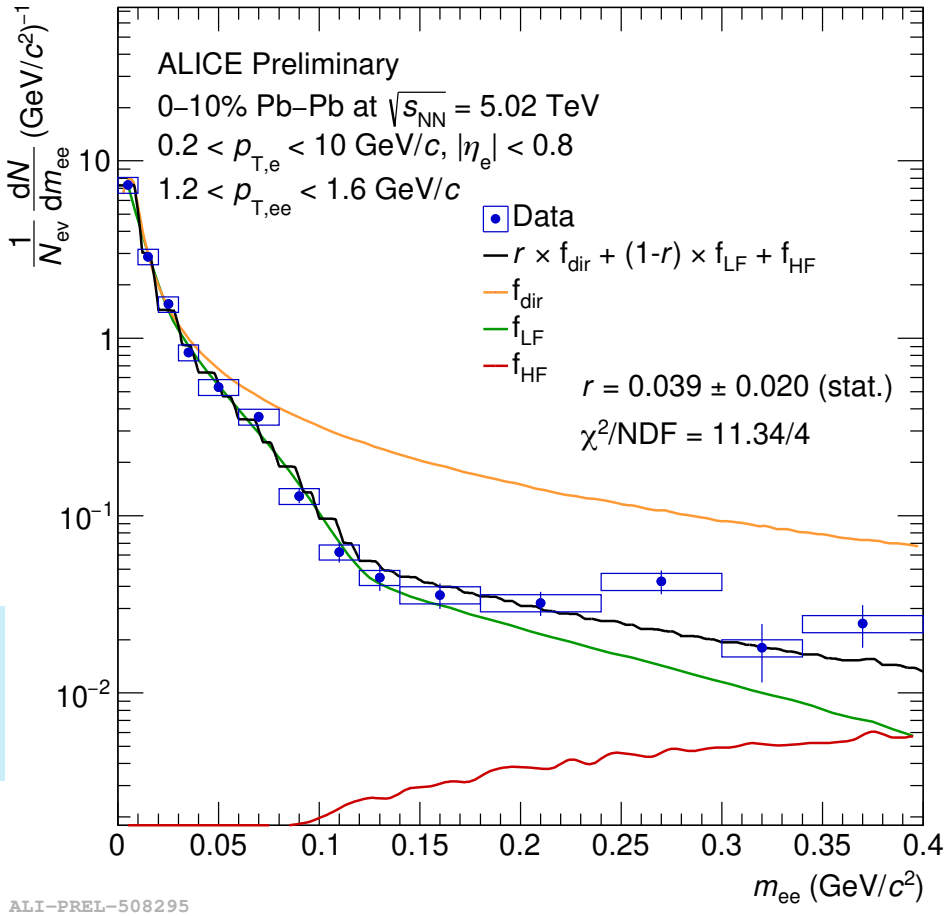
$$\frac{d^2N_{ee}}{dm_{ee}} = \frac{2\alpha}{3\pi}\frac{1}{m_{ee}}\sqrt{1-\frac{4m_e^2}{m_{ee}^2}}\left(1+\frac{2m_e^2}{m_{ee}^2}\right)|F(m_{ee}^2)|^2\left(1-\frac{m_{ee}^2}{M_h^2}\right)^3 dn_\gamma$$

  The factor *S*
  is 0 for m_{ee} → m_{hadron},
  goes 1 for m_{ee} → 0 or $m_{ee} << p_T$

- Assumption only valid for $p_{\mathrm{T,ee}} \gg m_{\mathrm{ee}}$

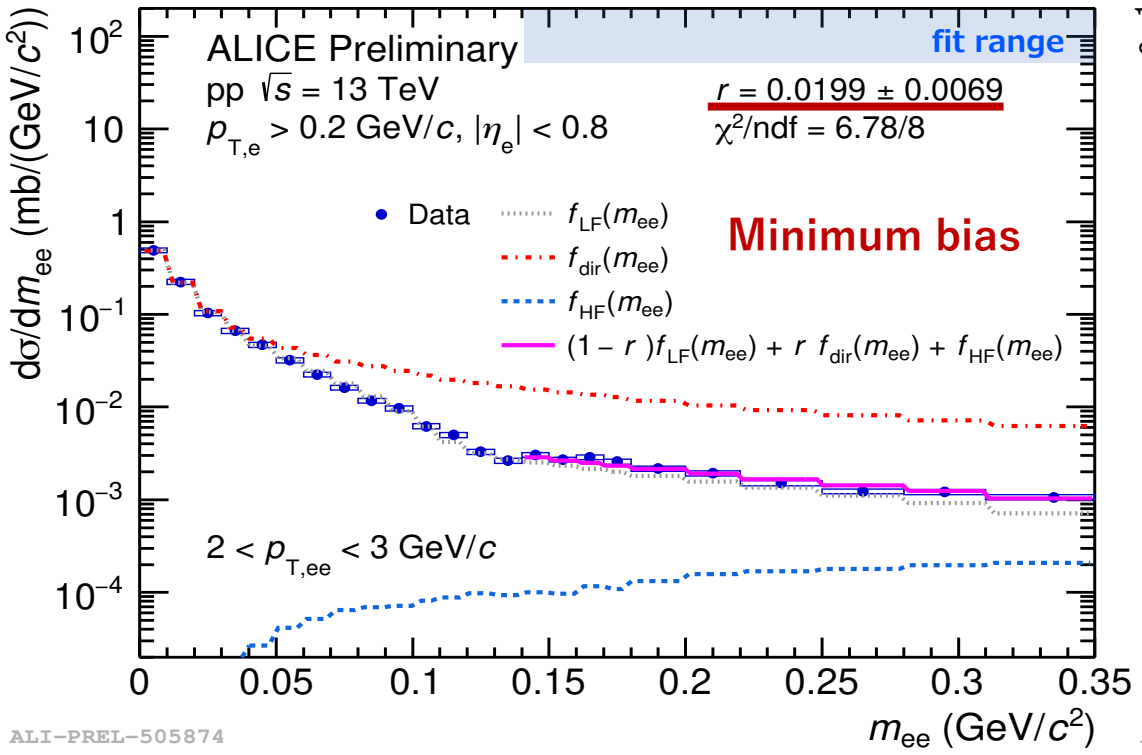
  → Extract r for $p_{\mathrm{T,ee}} > 1\,\mathrm{GeV}/c$

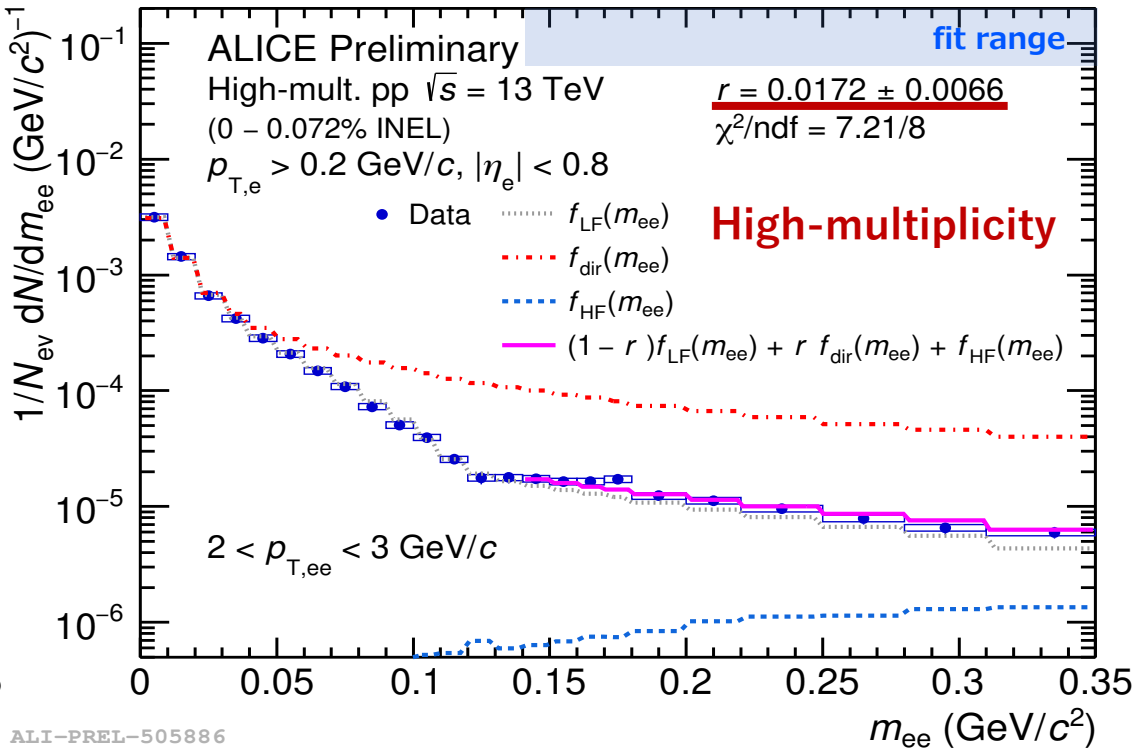
Fitting example



Normalize below 40 MeV/c^2
Fit above π^0 mass

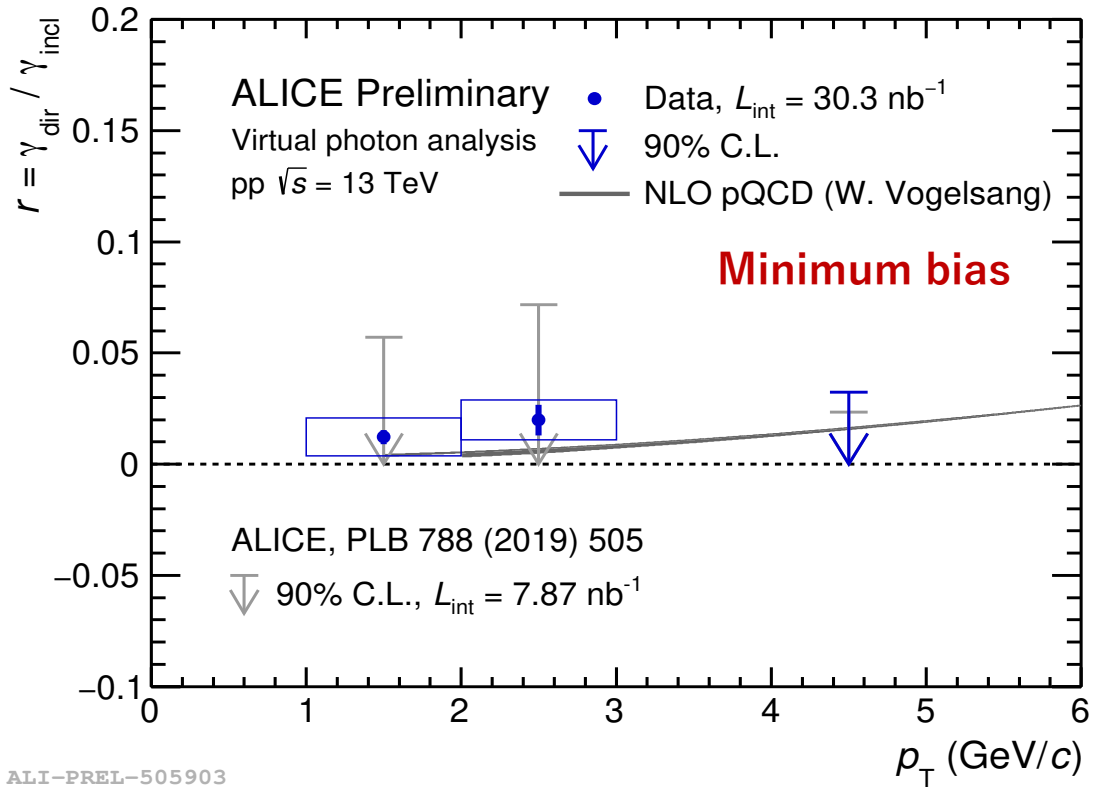
Extraction of direct photon fraction

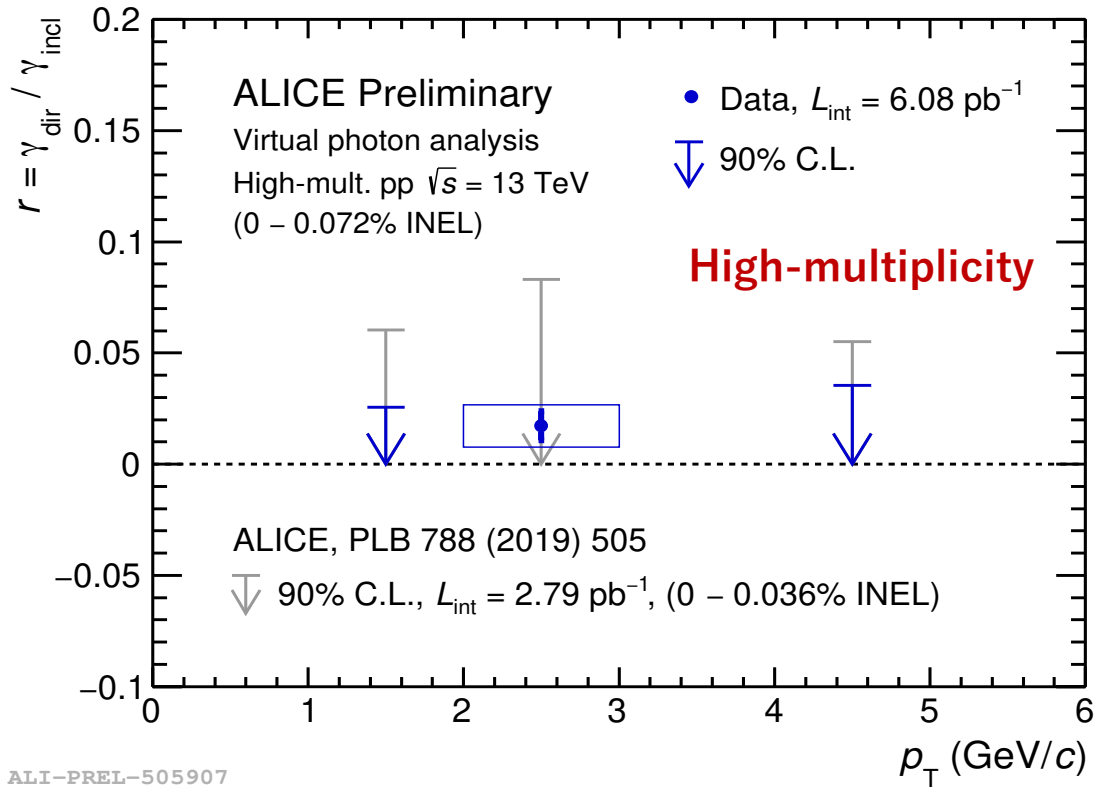




- Increased statistics allows us to extract finite *r* for MB and HM

Direct photon fraction in pp collisions at √*s* = 13 TeV



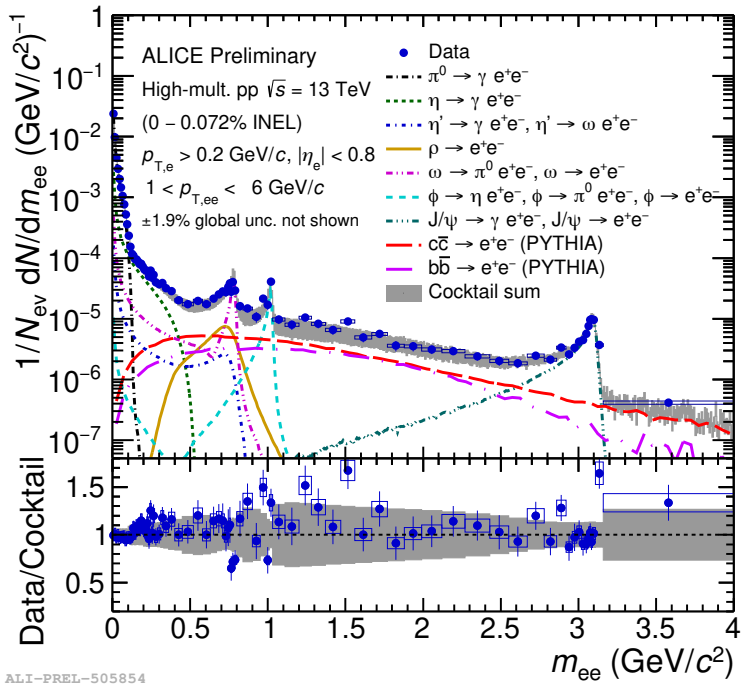


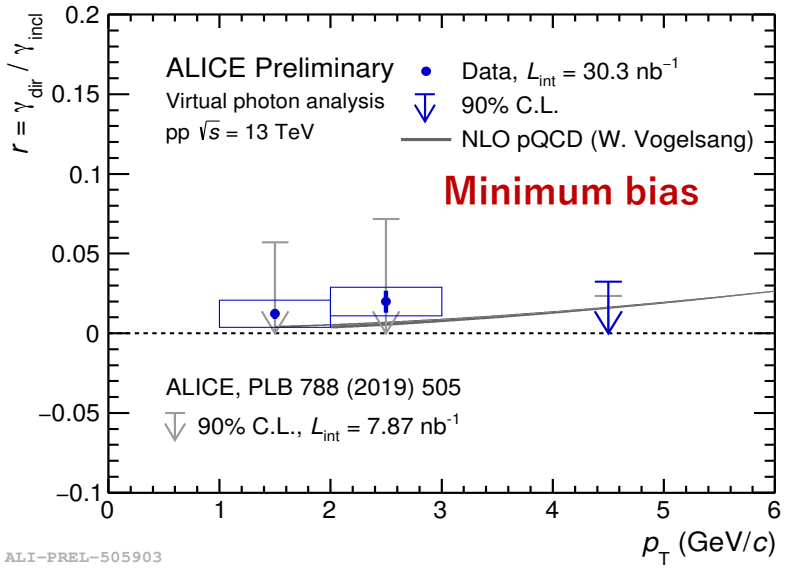
- New results for direct photon fraction with increased precision
- No significant increase w.r.t pQCD photons in MB
- *r* is similar in MB and HM collisions
- Extracted photon yield in HM will be compared with theoretical calculations

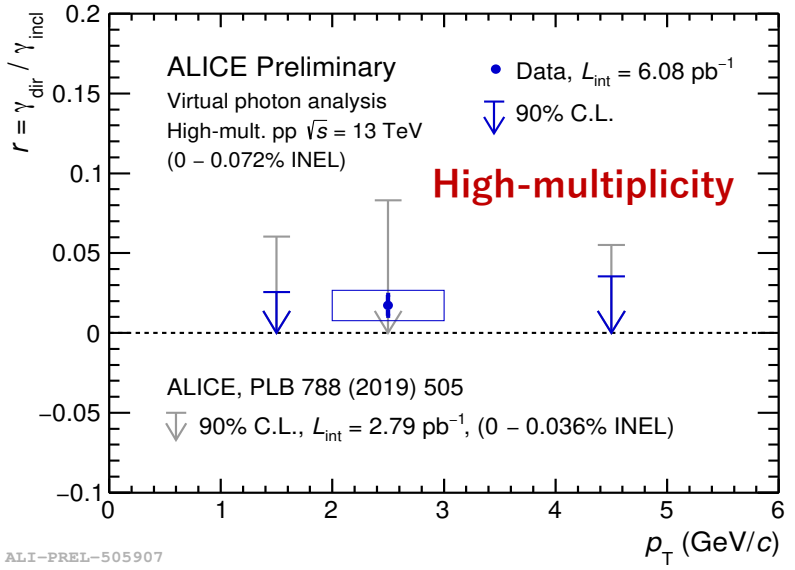
Summary

Virtual photon production was measured in pp collisions at √*s* = 13 TeV in MB and HM events

- Within uncertainty, no excess w.r.t. cocktail at IMR in HM
- No significant increase w.r.t pQCD photons in MB
- *r* is similar in MB and HM collisions
- Extracted photon yield in HM will be compared with theoretical calculations
- Analysis is being finalized







ALICE in Run 3

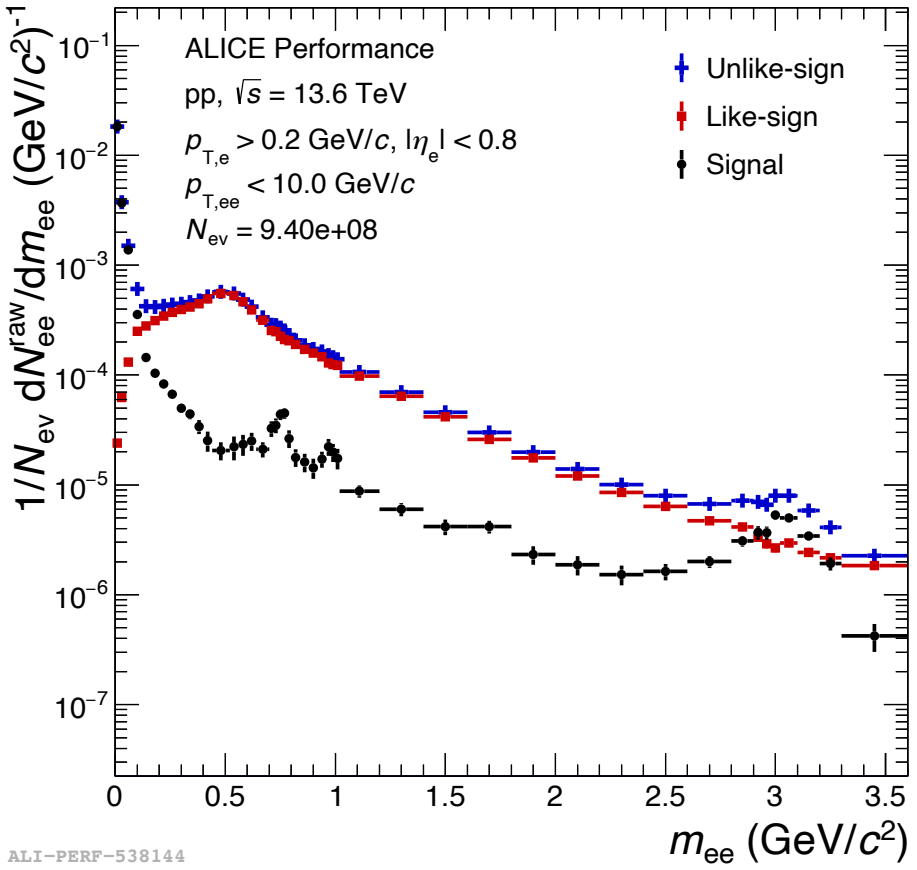
ALICE upgrade during LS2

- New GEM-based TPC read-out [1]
- New Inner Tracking System (ITS2) [2]

pp

- High-energy pp program in Run 3 (2022-)
  - Min. bias pp ~ 3 pb^{-1} (including low magnetic field B = 0.2 T setting)
  - High mult. pp ~ 200 pb^{-1}
- Run 3 data taking at $\sqrt{s}$ = 13.6 TeV has already been started

Raw dielectron spectrum in Run 3



[1] CERN-LHCC-2013-020, CERN-LHCC-2015-002
[2] CERN-LHCC-2012-013


Thank you for your attention !