A Large Ion Collider Experiment

ALICE

Low mass dielectron measurements in pp, p-Pb and Pb-Pb collisions with ALICE at the LHC

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On behalf of the ALICE Collaboration

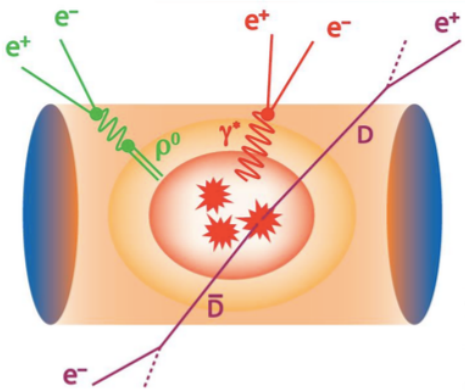
ALICE

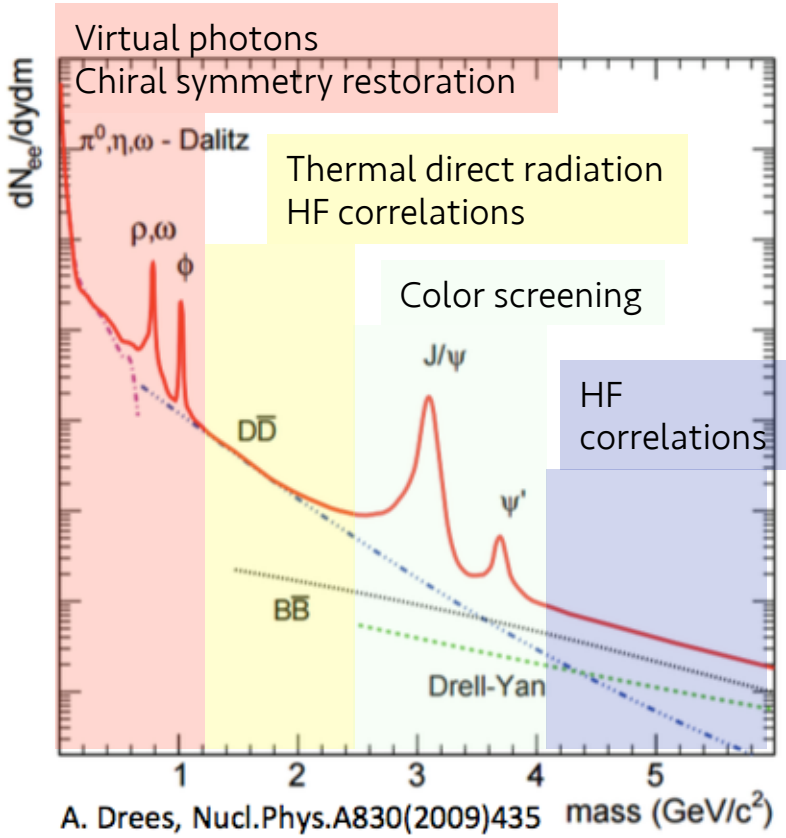
Presentation Outline

- Physics Motivation
- ALICE detectors and electron analysis
- Results from Run1 analyses
  - Dielectron spectra in pp, p-Pb, and Pb-Pb collisions
  - Virtual photons in pp and Pb-Pb collisions
- Future Prospects
  - Run2, Run3 & Run4 with ALICE upgrades
- Summary

Physics Motivation

- Dielectrons = EM & transparent probe
  - Carry the information of the medium when they are produced.
- Physics topics:
  - Virtual photons (p_T>>m_{ll}, m_{ll}<M_η)
    - Thermodynamical properties
  - Low mass vector mesons (ρ, ω, ϕ)
    - Chiral symmetry restoration
  - Thermal radiation (1<m_{ll}<3 GeV/c^2)
    - Space-time evolution, EoS
    - T-dependent medium properties
  - Heavy flavor correlations (c,b→ee)
    - Energy loss of HF
- ALICE's mission is to study these items at the highest collision energies.

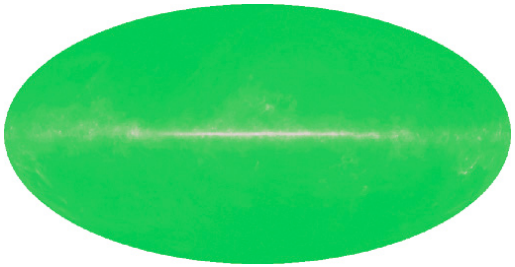




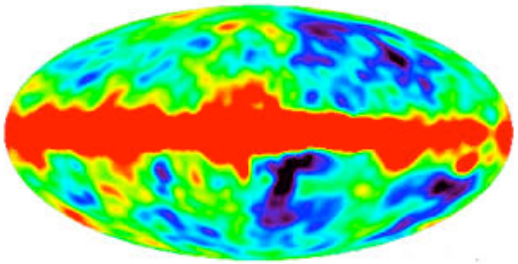
LMee measurements in ALICE

- Challenging analyses due to small S/B (~10^{-3})
- Run1 (2010-2013) "Evaluation era"
  - Development of dielectron analyses
    - eID, background rejection, systematics
  - pp: MB(300M), p-Pb: MB(100M)
  - Pb-Pb: 0-10%(17M), 20-50%(12M)

Penzias and Wilson



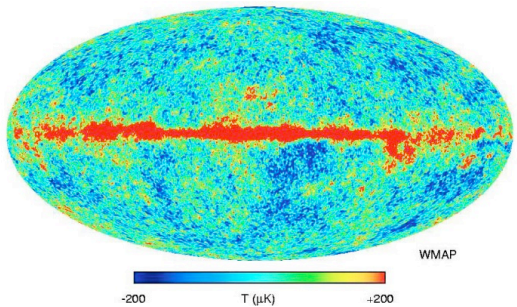
COBE



- Run2 (2015-2018) "Qualitative era"
  - pp & p-Pb: MB, HM, rare trigger
  - Pb-Pb: MB(~100M), centrality/rare trigger

- Run3 and Run4 (>2021) "Quantitative/Precision era"
  - ALICE upgrades for LHC high luminosity
  - pp & p-Pb:
  - Pb-Pb: MB (plan~$10nb^{-1}$)

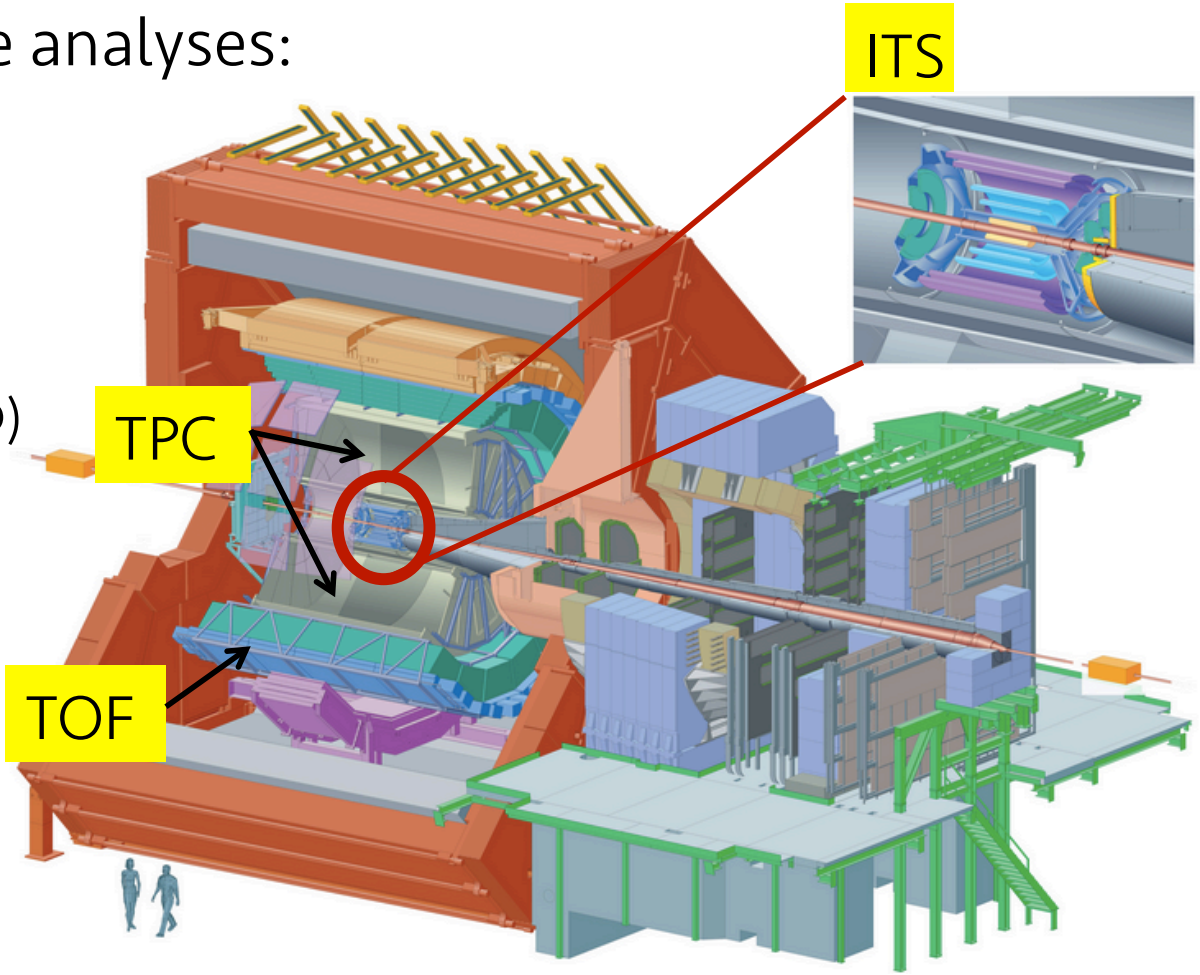
WMAP



ALICE detectors

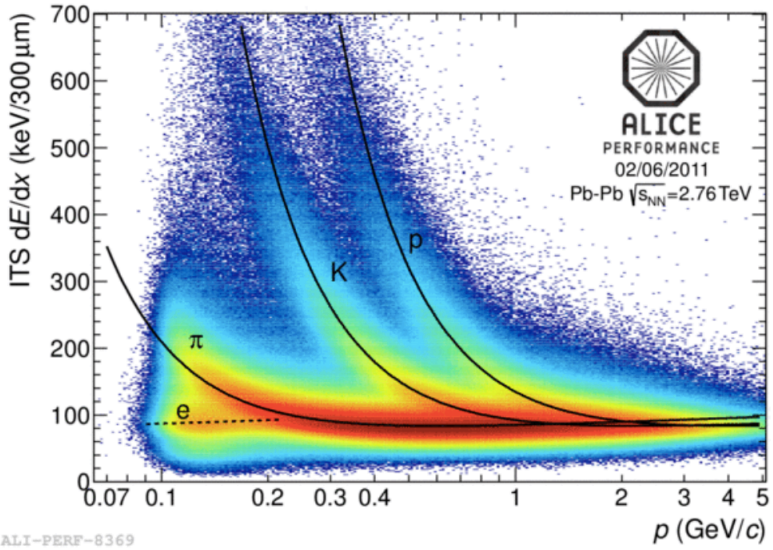
Detectors used in these analyses:

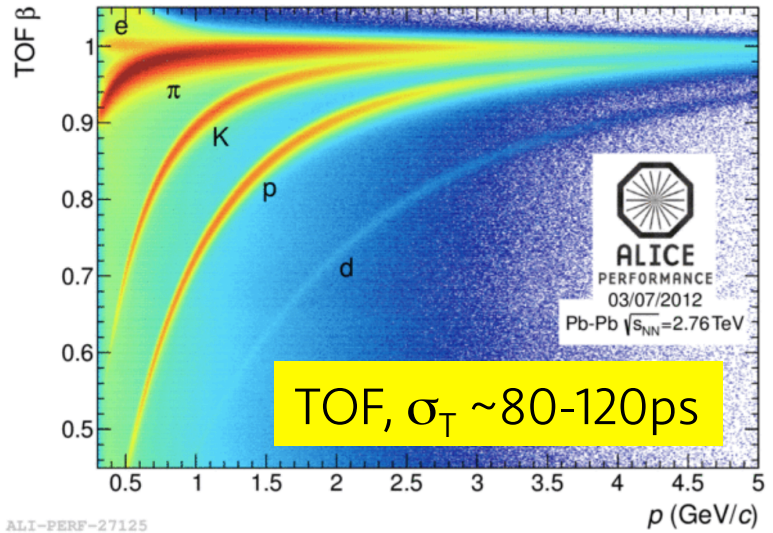
- Inner Tracking System (ITS)
  - Tracking
  - Vertexing
  - PID (d*E*/d*x* in SDD/SSD)
- Time Projection Chamber (TPC)
  - Tracking
  - PID (d*E*/d*x* in Ne/CO_2)
- Time of Flight (TOF)
  - PID (hadron rejection)



eID performance

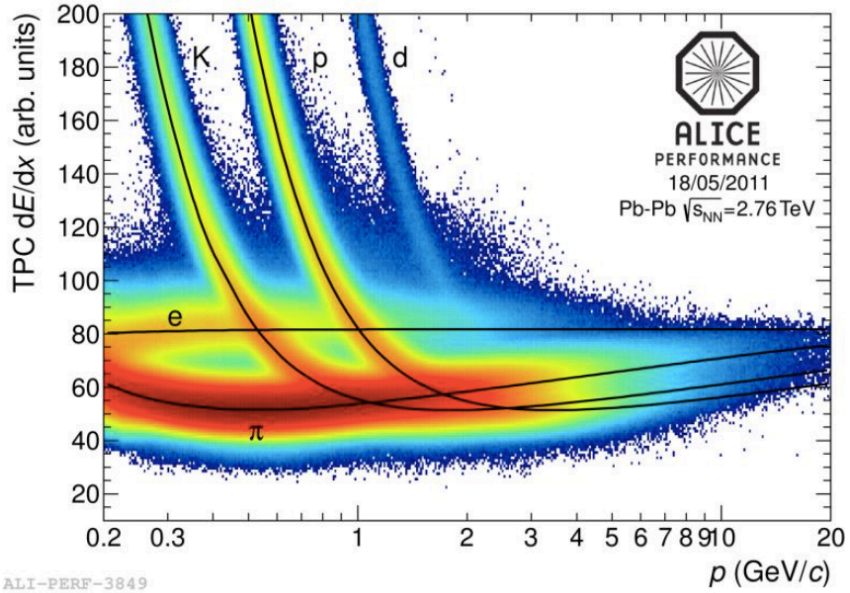
ITS d*E*/d*x*, σ(d*E*/d*x*) ~12%





TOF, σ_T ~80-120ps

TPC d*E*/d*x*, σ(d*E*/d*x*) ~8(pp)-12(Pb-Pb)%

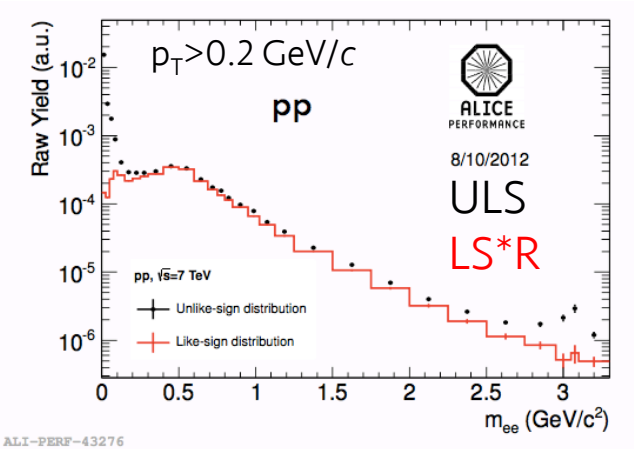


- Track cuts + eID Cuts using ITS, TPC, and/or TOF
  - p_T>0.2 GeV/*c* (w/o TOF)
  - p_T> 0.4 GeV/*c* (with TOF)
- Hadron contamination: 1-10% from pp to Pb-Pb

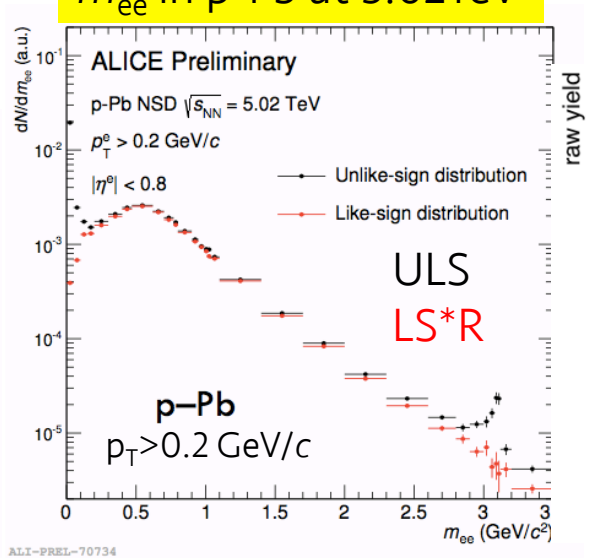
Dielectron Pair analysis

- Rejection of conversion electrons
  - V0 tagging, orientation pair angle in the magnetic field
- Physics signal = ULS – LS * R
  - Unlike-sign (ULS) : real signal + combinatorial background
  - Like-sign (LS) : combinatorial background estimate
  - R = pair acceptance correction (from mixed-events)

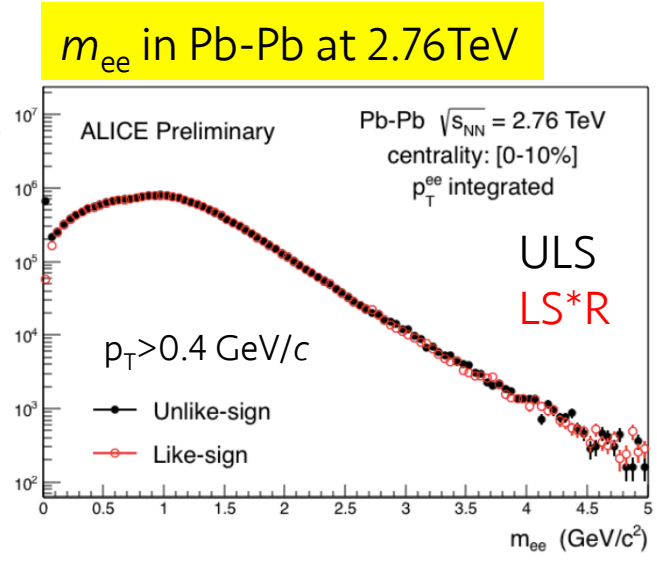
m_{ee} in pp at 7TeV



m_{ee} in p-Pb at 5.02TeV

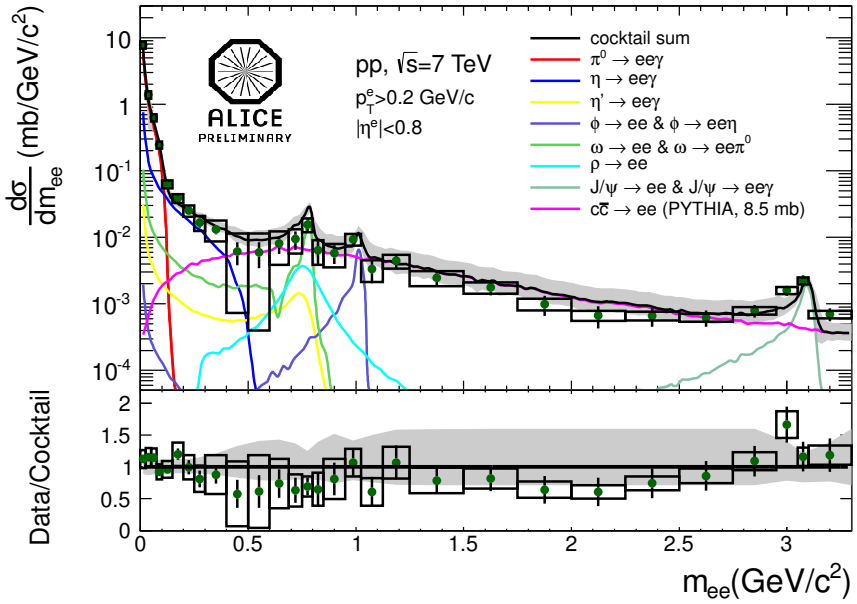


m_{ee} in Pb-Pb at 2.76TeV



Signal yields in Run1 pp and p-Pb collisions

- Corrected signal yields in pp at 7 TeV and p-Pb at 5.02 TeV
- Hadronic cocktails:
  - LF (π^0, η, ϕ, ω, J/ψ): ALICE measurements, m_T scaling for others
  - HF: PYTHIA. σ_{cc} and σ_{bb} from ALICE (and interpolation)



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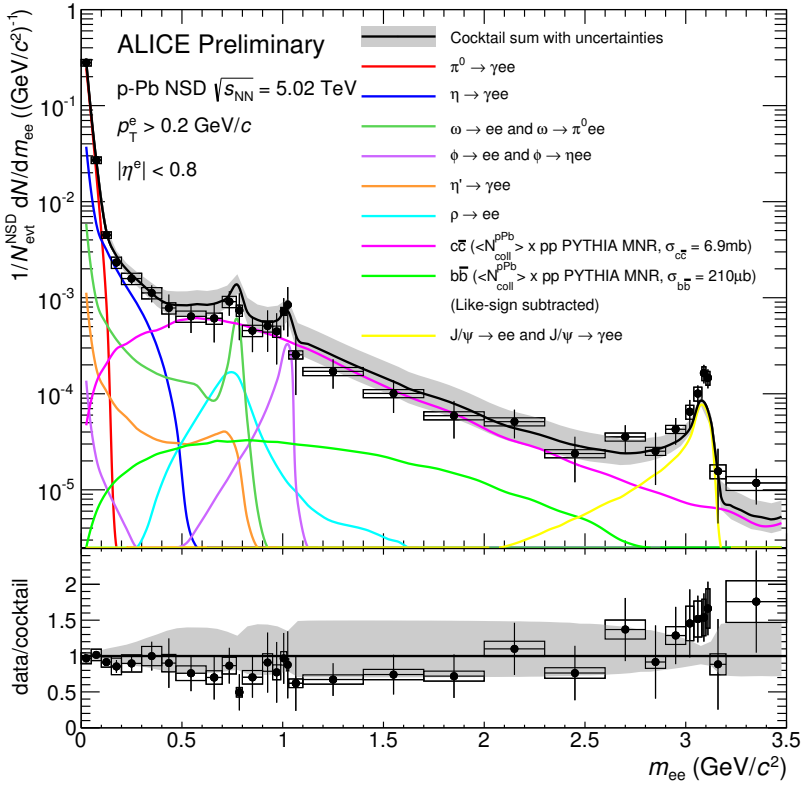

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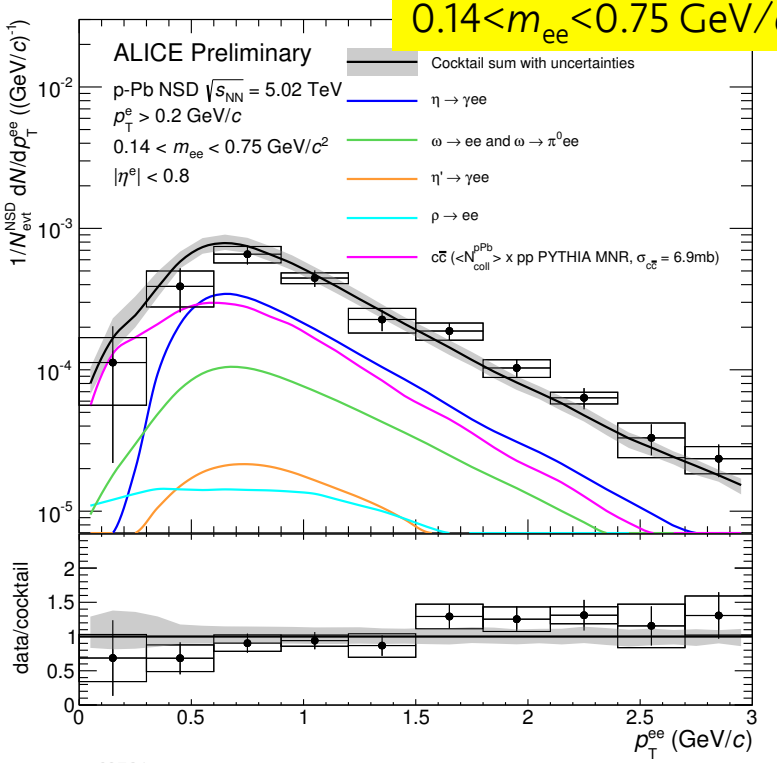
Data are in agreement with cocktail within data & cocktail uncertainties

Signal yields in Run1 pp and p-Pb collisions

- Pair p_T spectra in p-Pb collisions at 5.02 TeV

$0.14<m_{ee}<0.75$ GeV/c^2



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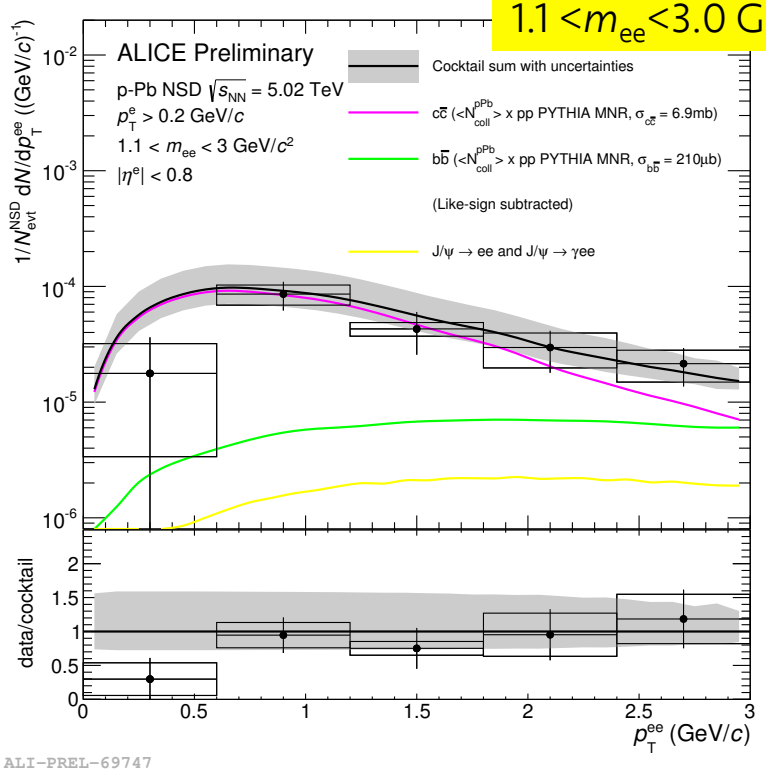
$1.1<m_{ee}<3.0$ GeV/c^2



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Data are in agreement with cocktail within data & cocktail uncertainties

Finalization of pp and p-Pb is on-going

- Virtual photons
- HF cross-section and correlations
- Less systematic errors, larger p_T reach

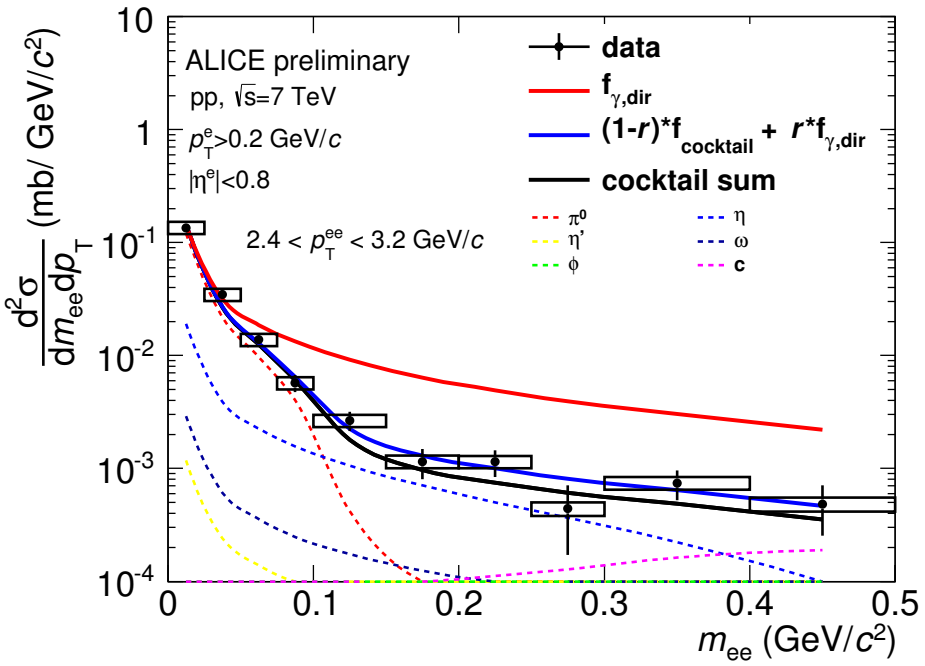
Virtual photons in pp collisions

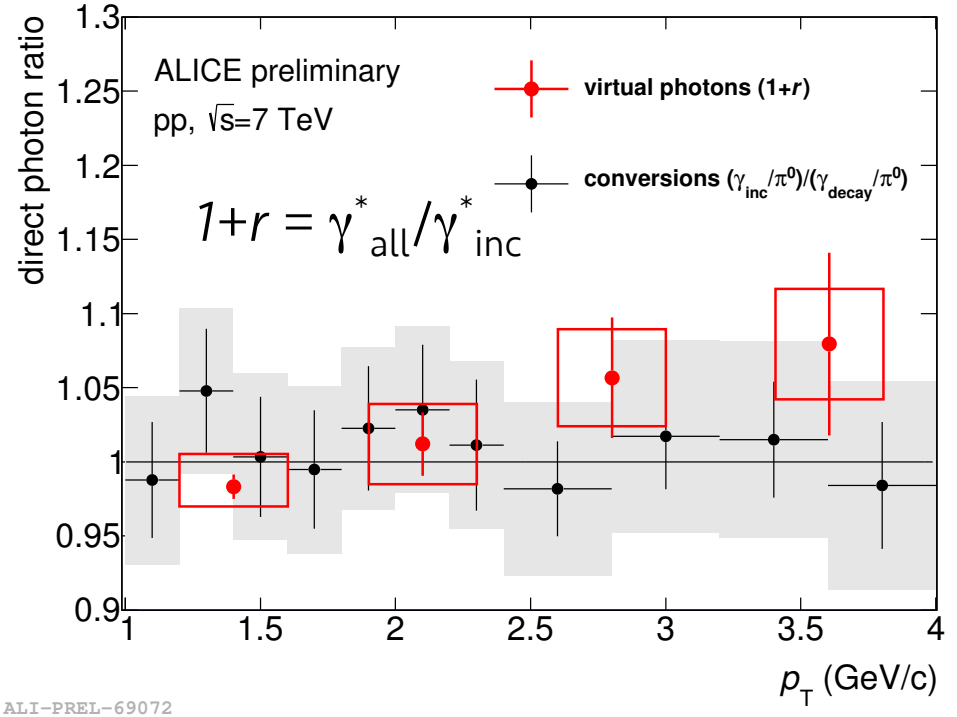
- Extraction of virtual photon fractions
  - $f(m_{ee}) = r * f_{dir}(m_{ee}) + (1-r) * f_{cocktail}(m_{ee})$
  - $r = \gamma^*_{dir} / \gamma^*_{inc}$

$f_{dir}(m_{ee})$ = virtual γ shape
$f_{cocktail}(m_{ee})$ = known hadronic sources

$$\frac{d^2N}{dM_{ee}dN_\gamma} = \frac{2\alpha}{3\pi}\sqrt{1-\frac{4m_e^2}{M_{ee}^2}}\left(1+\frac{2m_e^2}{M_{ee}^2}\right)\frac{1}{M_{ee}}S$$

Fraction of direct photons consistent with the measurement from **Photon Conversion Method.**



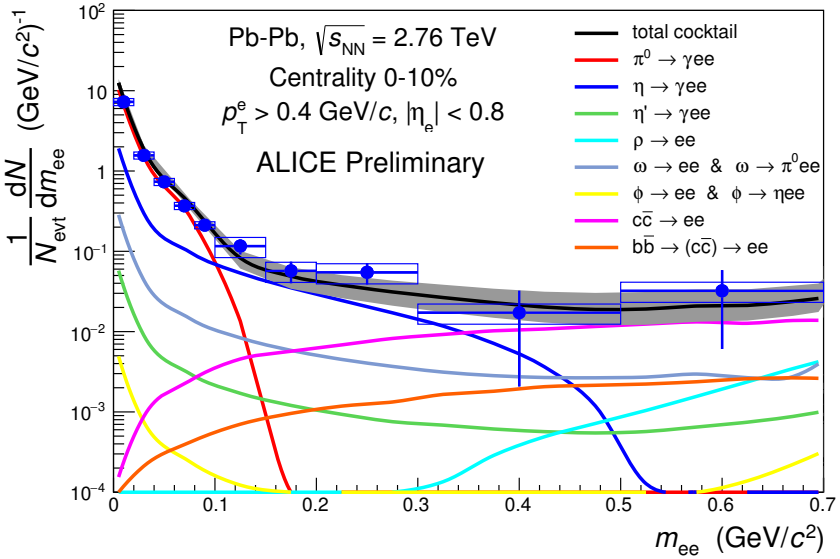


Signal yields from Run1 Pb-Pb collisions

- Focus on low mass region
  - m_{ee}<0.7 GeV/c^2
- Hadronic cocktail:
  - π^0: measured by ALICE,
  - other mesons : m_T scaling
  - HF: PYTHIA x binary scaling of measured cross-sections in pp collisions

No enhanced dielectron production in the low-mass region over the cocktail

- Large statistical, systematic uncertainties, cocktail uncertainties



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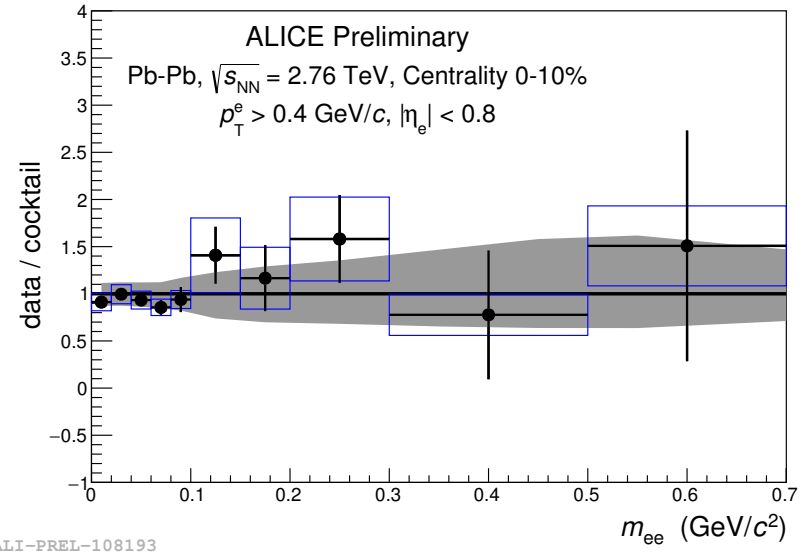

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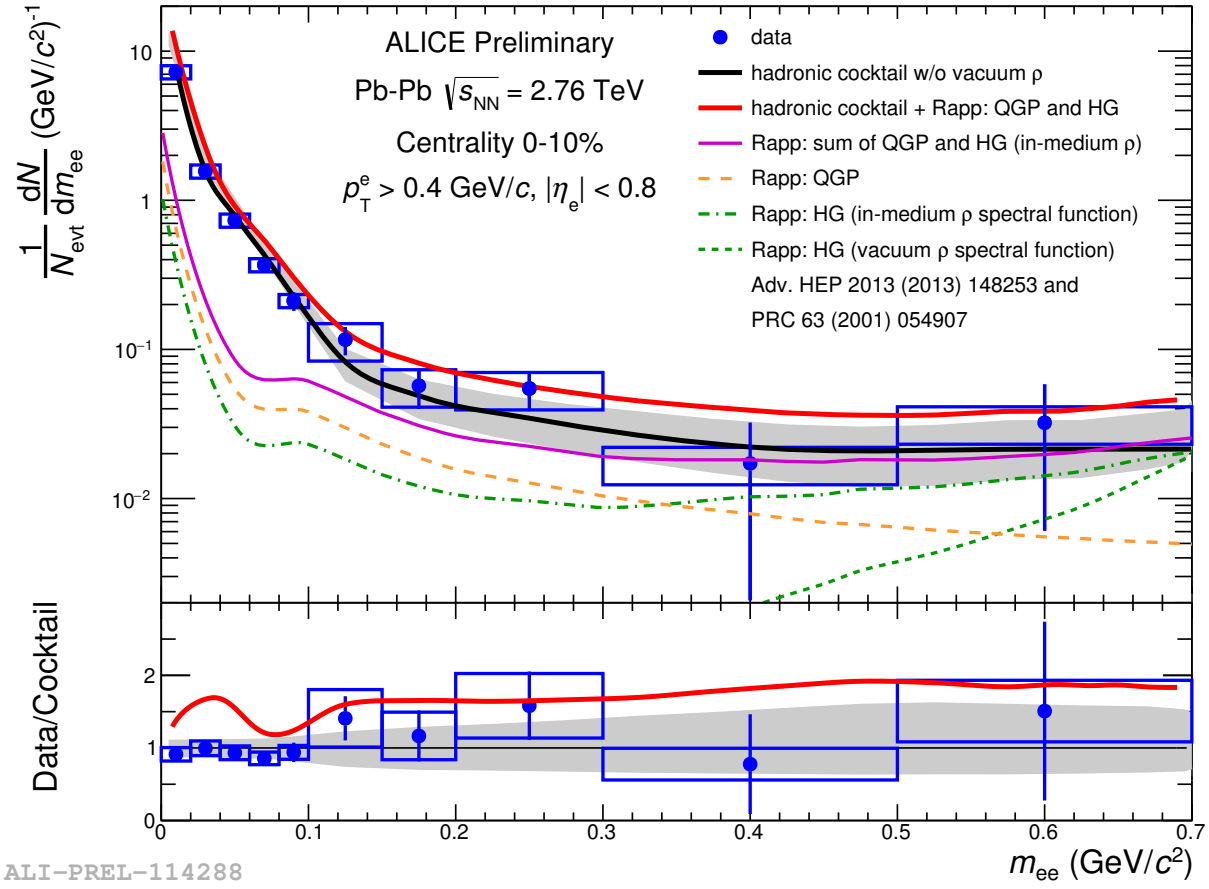
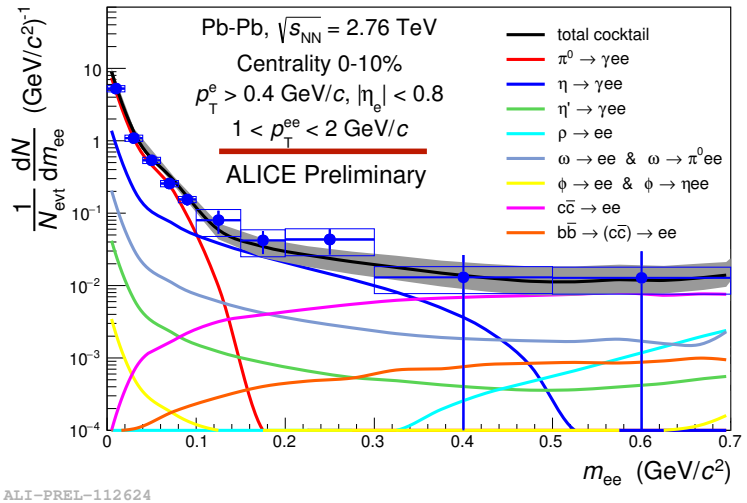
Comparison with Theory calculation

R. Rapp, priv. comm.



Quantitative calculations with medium effects (thermal radiation and in-medium ρ) by R. Rapp.
Our data are consistent to the calculation with medium effects.

Pair p_T dependence of LMee spectra



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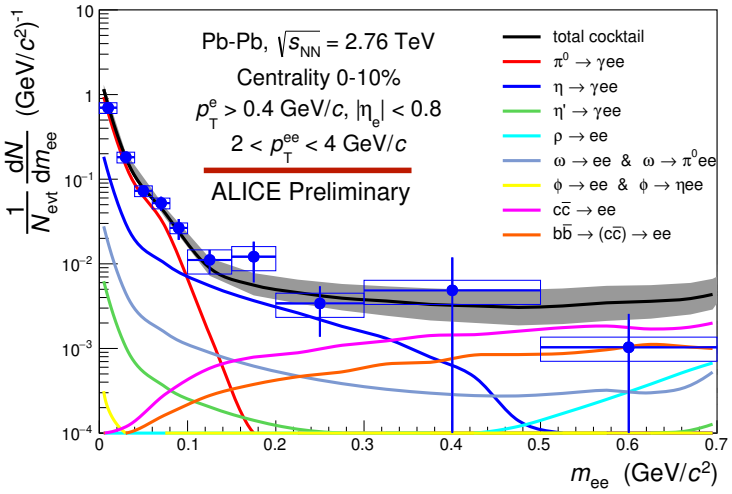

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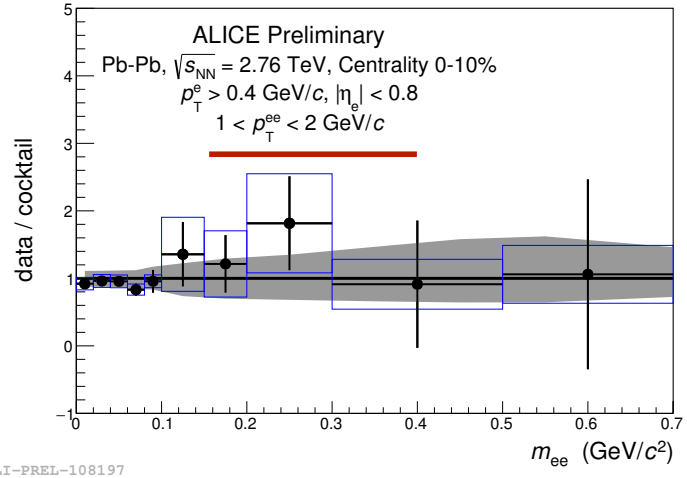

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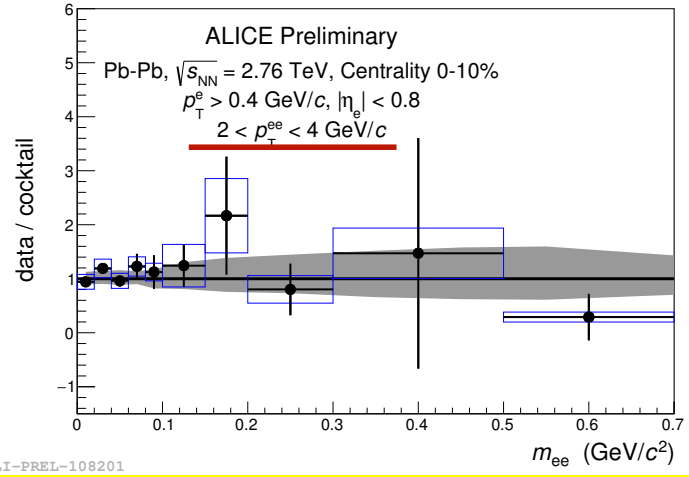

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Additional dielectron sources are not excluded:
→ Contribution from virtual direct photons has been extracted.

Virtual photons in Pb-Pb collisions

$f_{dir}(m_{ee})$ = virtual γ shape
$f_{cocktail}(m_{ee})$ = known hadronic sources
$f_{HF}(m_{ee})$ = cc->ee pairs (PYTHIA+N_{col})

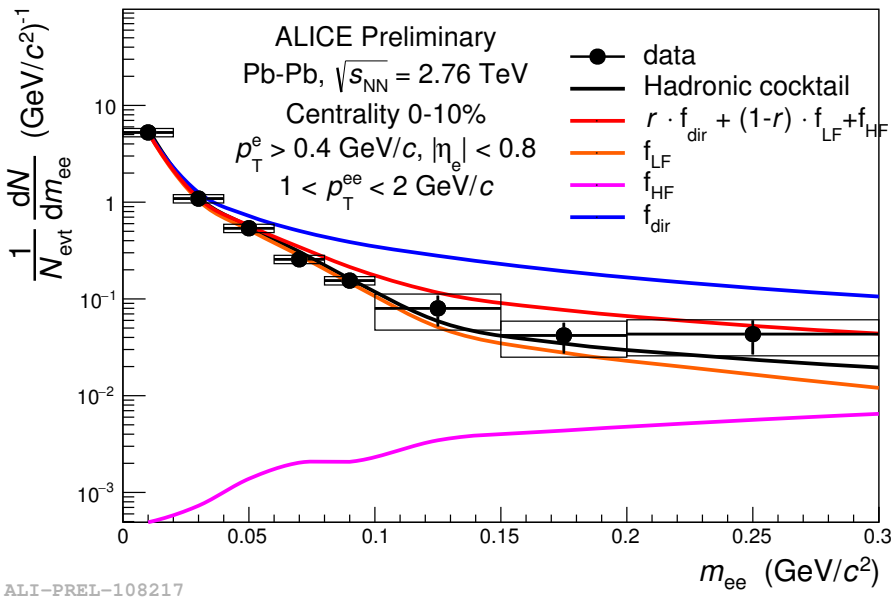
- Fit the mass ($100<m_{ee}<300$ MeV/c^2)
  - $f(m_{ee}) = r*f_{dir}(m_{ee}) + (1-r)*f_{cocktail}(m_{ee}) + f_{HF}(m_{ee})$

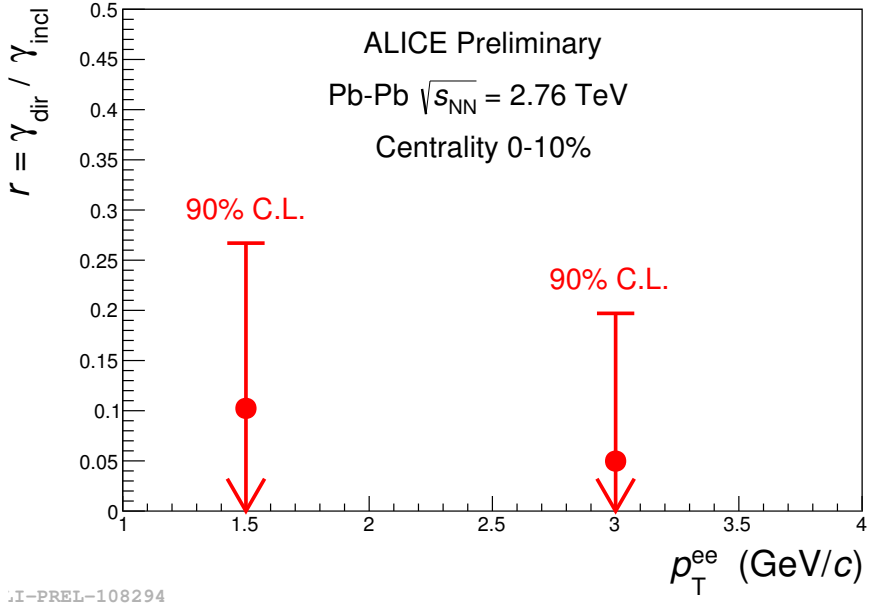
$$r = \gamma^*_{dir}/\gamma^*_{inc}$$

$$r = 0.10 \pm 0.10 \text{ for } p_T^{ee} \in [1,2] \text{ GeV}/c$$
$$r = 0.05 \pm 0.12 \text{ for } p_T^{ee} \in [2,4] \text{ GeV}/c$$

- Estimation of 90% CL by MC toy simulations
  - Comparable with PHENIX/STAR (10-30%) and ALICE-PCM (~10%) results

PRL 104, 132301, (2010), arXiv:1607.01447 Phys. Lett. B 754 (2016) 235-2480

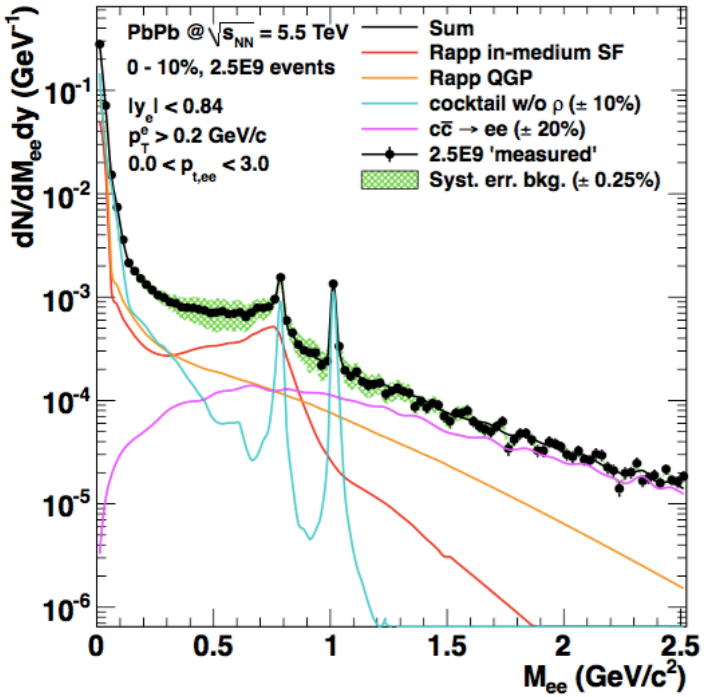


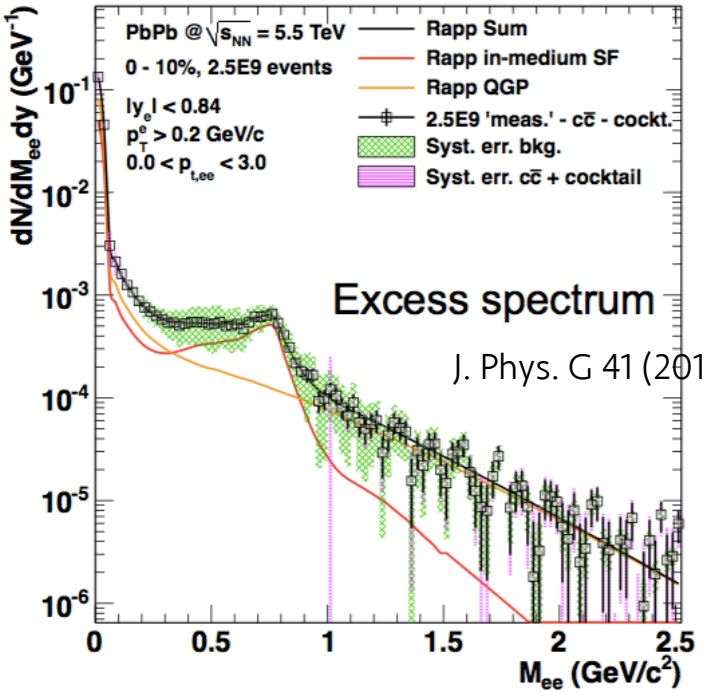


ALICE

Future Prospects of LMee measurements

- More results will come from Run2 data
  - Pb-Pb with more statistics, high multiplicity in pp and p-Pb
- ALICE Upgrades for Run3 and Run4 → Precision Era!!
  - New ITS with conversions, Dalitz, and HF rejection
  - New GEM-based TPC for x100 high rate data taking





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Summary

- ALICE measured dielectrons in pp, p-Pb, and Pb-Pb collisions in Run1.
- Run1 pp & p-Pb collisions:
  - Data are consistent with known hadronic sources.
  - pQCD photons via virtual photon measurements in pp collisions
  - Finalization of the analyses is on-going including virtual photons and HF cross-section and correlations.
- Run1 Pb-Pb collisions:
  - Data are not significantly larger than the known hadronic sources.
  - No yet sensitive to the modification of LVM (ρ, ϕ, ω) due to large uncertainty and large charm contributions
  - Extraction of an upper limit on virtual photon production
    - Comparable with real photon measurements from ALICE and virtual photons from PHENIX and STAR
- More will come from Run2 data and ALICE upgrades for Run3 & Run4 will allow us to measure LMee precisely.

Backup slides

ALICE

Low p_T Photon spectrum in pp collisions

- Virtual photons