Low-Mass Dielectron Production in p-Pb and Pb-Pb Collisions with ALICE

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H-QM | Helmholtz Research School Quark Matter Studies

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Dielectrons in Heavy-Ion Collisions

- Electromagnetic probe
- Do not interact strongly
- Produced throughout the whole collision

Low-mass region:

- Light vector mesons

Intermediate mass region:

- Correlated open heavy flavours

} hadronic „cocktail“

Direct (and thermal) virtual photons

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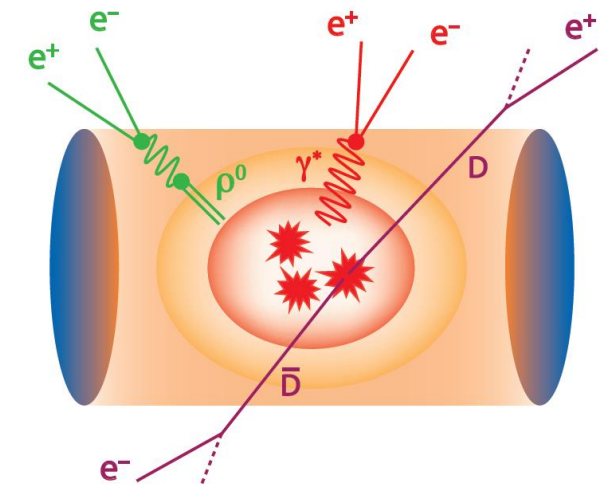
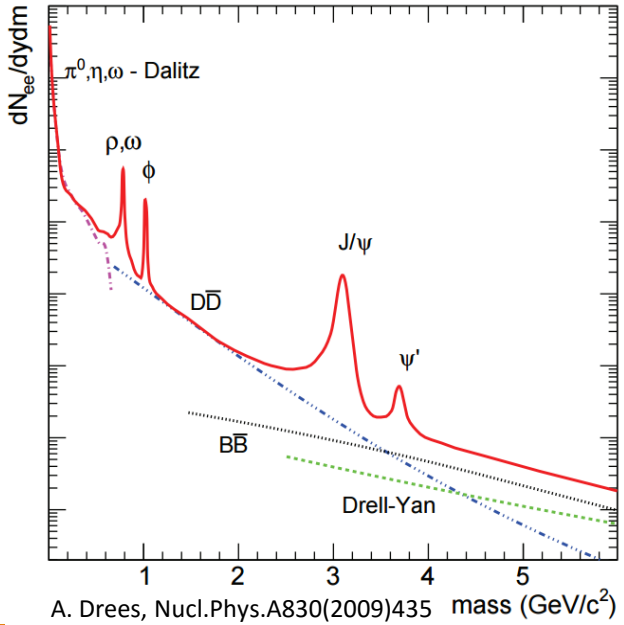
pp: vacuum base line

p-Pb: cold nuclear matter effects

Pb-Pb: thermal radiation and chiral restoration

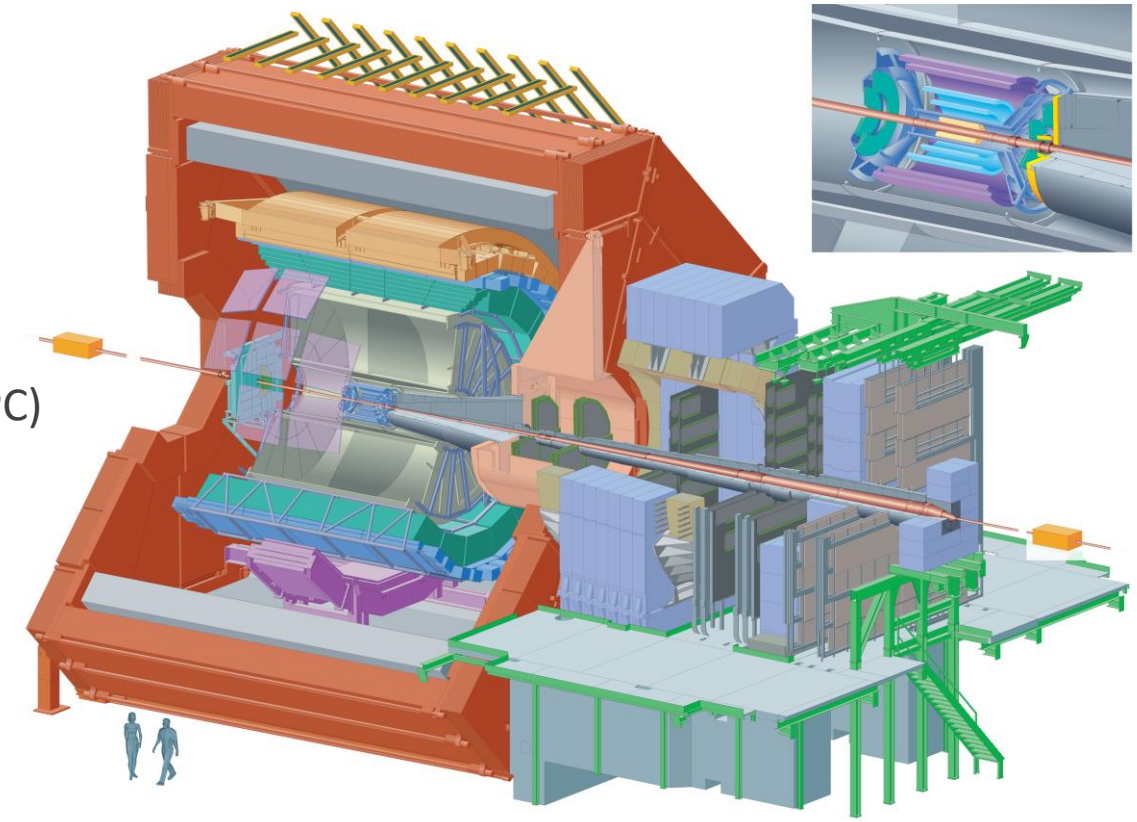




ALICE

Detectors used:

- Inner Tracking System (ITS)
  - Tracking
  - Vertexing
  - Particle Identification
- Time Projection Chamber (TPC)
  - Tracking
  - Particle Identification
- Time of Flight (TOF)
  - Particle Identification



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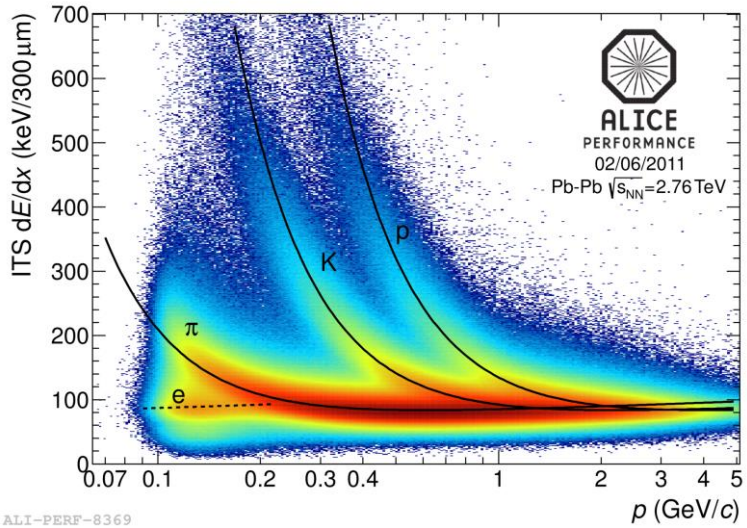
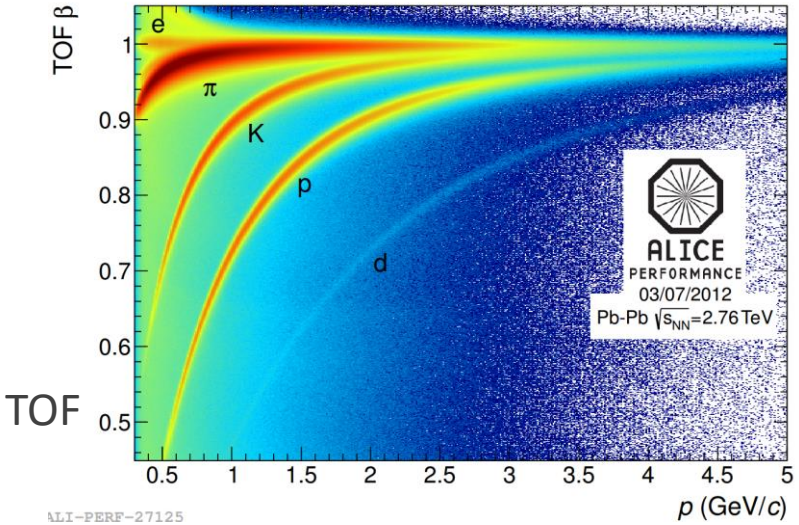
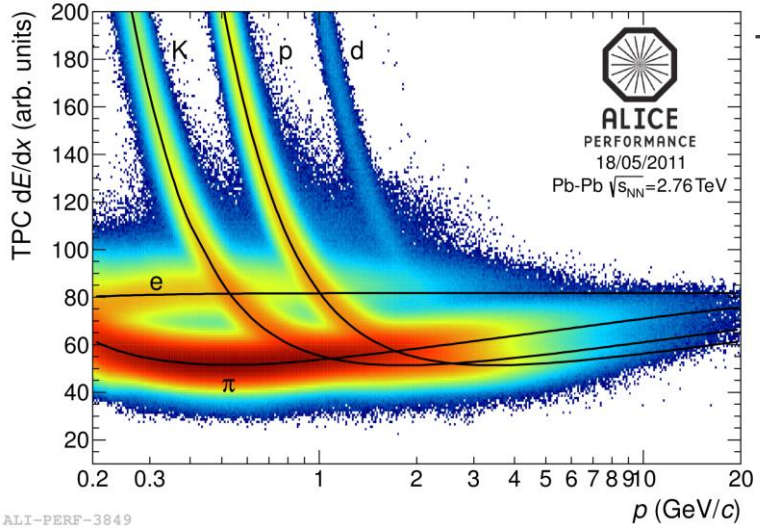


ITS



TOF

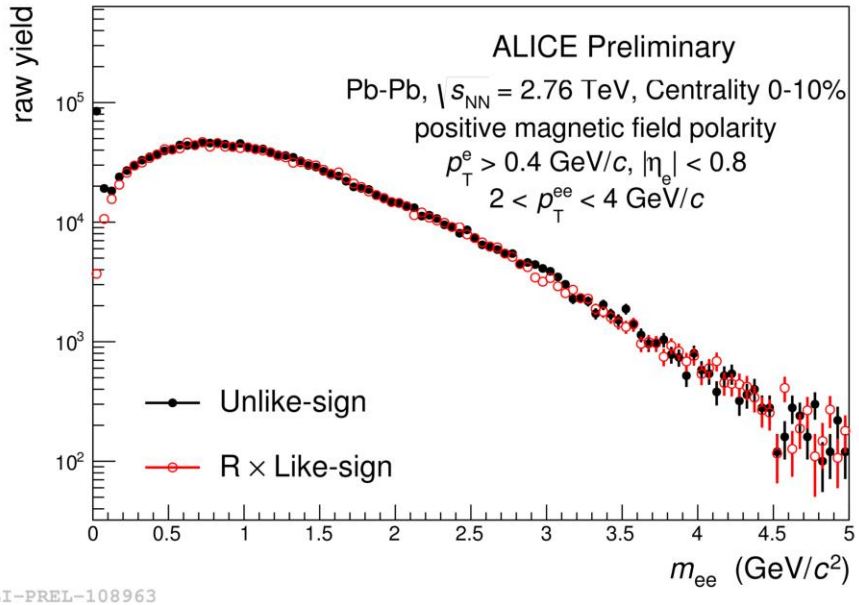


TPC

- Electron identification in TPC
- ITS and TOF reject protons and kaons

Electron Pair Spectra

- **Unlike Sign** (ULS) contains signal and combinatorial (correlated and uncorrelated) background
- **Like Sign** (LS) contains combinatorial background
- Geometric Mean: $\mathrm{LS} = 2 \cdot \sqrt{N_{--} \cdot N_{++}}$
- Signal = ULS – LS · R
- R : Acceptance correction from mixed events $R(m_{\mathrm{ee}}) = \frac{\mathrm{ULS_{mix}}}{\mathrm{LS_{mix}}}$



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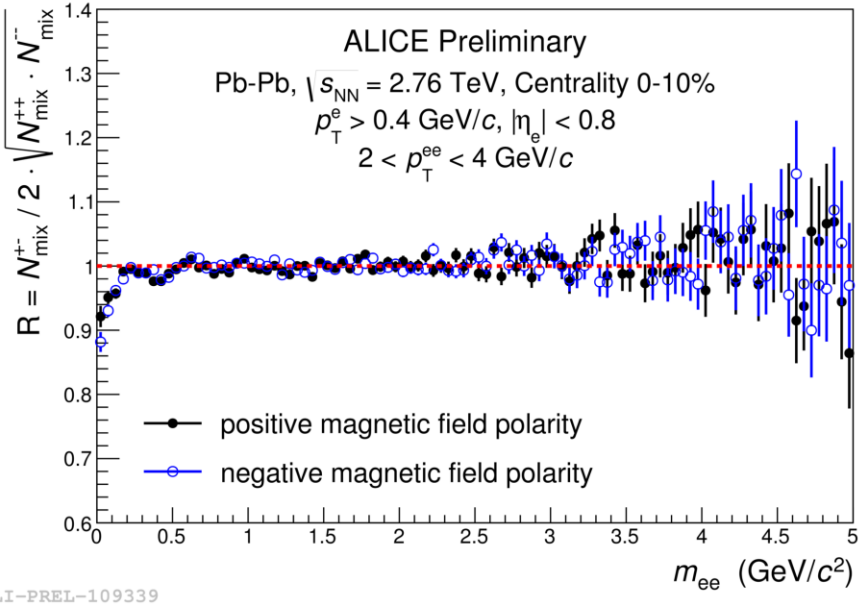

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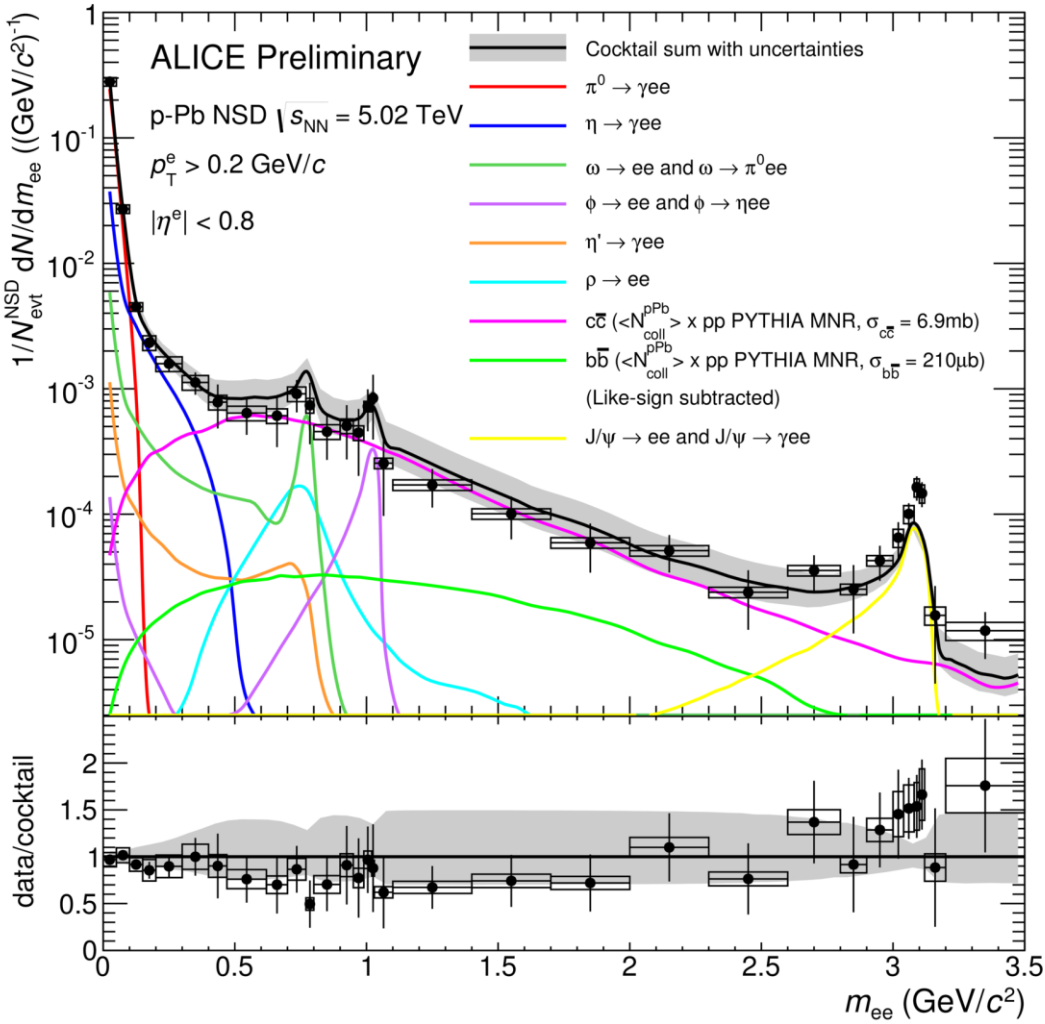
ALICE – Data Set

- Run I (2009-2013)
  - pp
    - 0.9, 2.76, 7, 8 TeV
  - p-Pb
    - **5.02 TeV (105 M events)**
  - Pb-Pb
    - **2.76 ATeV (17 M semi-central, 19 M central events)**
- Run II (2015-2018)
  - pp
    - 5.02, 13 TeV (14 TeV expected)
  - Pb-Pb
    - 5.02 ATeV (160 M minimum bias events)
  - p-Pb
    - 5.02, 8 TeV (end of 2016)
- Run III (>2021)
  - Dedicated dielectron period foreseen

RUN I – p-Pb Collisions

p-Pb Collisions - Cocktail

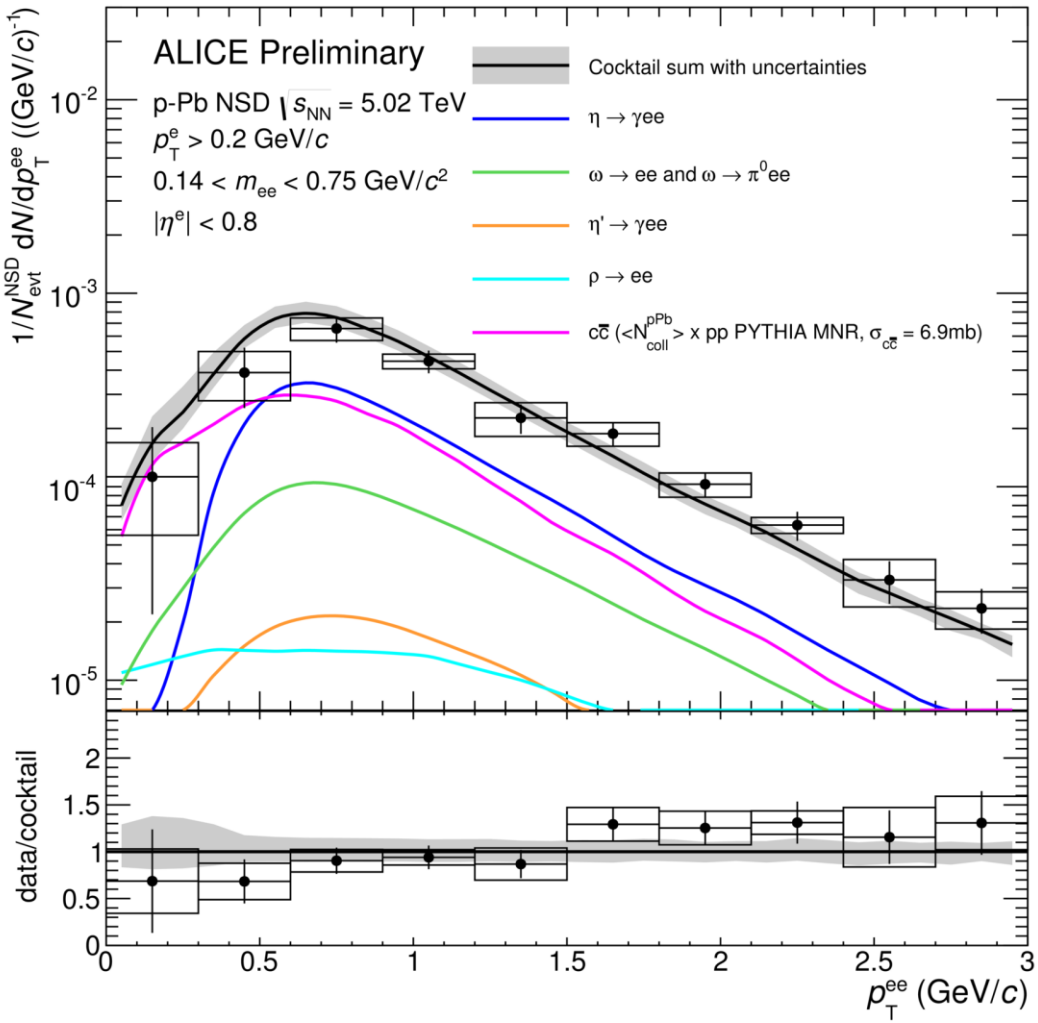
- Comparison of data to expected hadronic sources: “Cocktail“
  - π^0 based on measured charged-pion spectra in p-Pb
  - η, η’, ω, ϕ, ρ from m_T-scaling
  - J/ψ based on measurement
  - Open heavy flavour based on pp measurements and scaled with $\langle N_{coll} \rangle = 6.9$
- Agrees within large uncertainties



ALI-PREL-69715

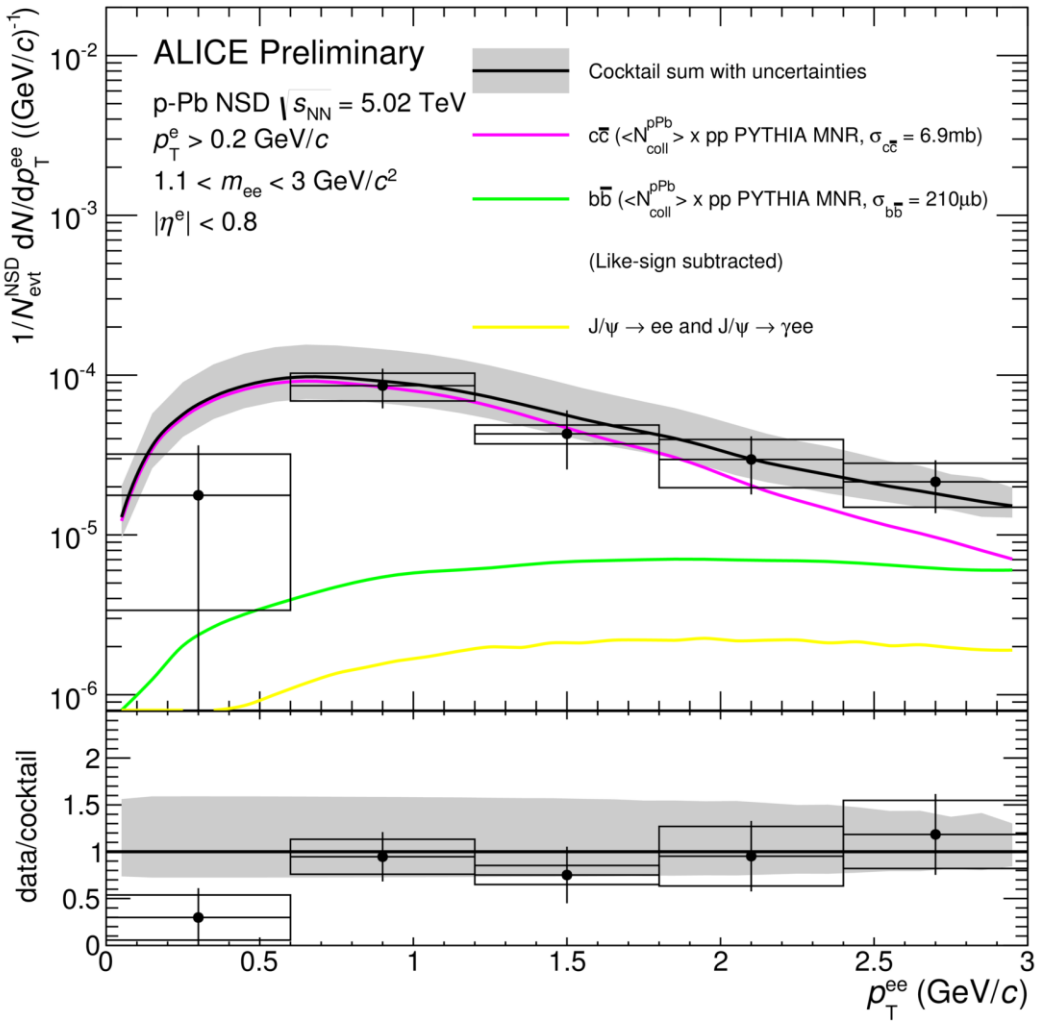
p-Pb Collisions

- $0.14 < m_{ee} < 0.75\,\mathrm{GeV}/c^2$
- Region between π^0 and ω/ρ
- Dominated by η and open charm contribution
- No indication for thermal enhancement but large uncertainties on data and cocktail



p-Pb Collisions

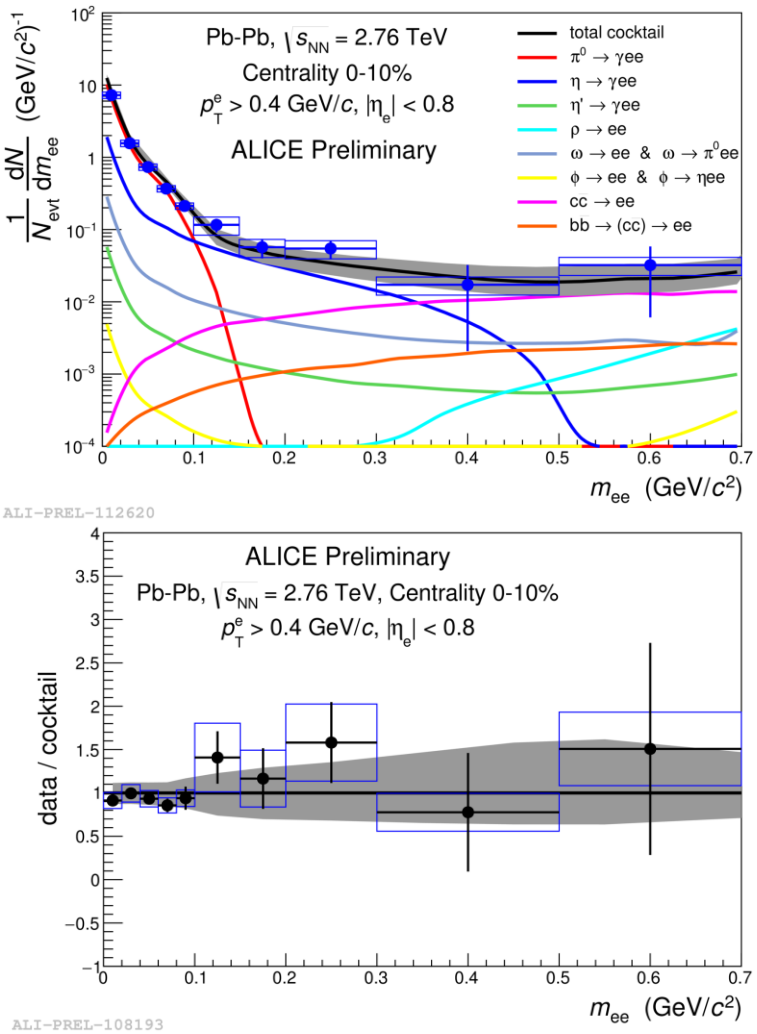
- $1.1 < m_{\mathrm{ee}} < 3.0\ \mathrm{GeV}/c^2$
- Intermediate mass region dominated by open heavy flavour
- Agreement within uncertainties
- Possibility to separate charm from bottom contribution at higher $p_{\mathrm{T,ee}}$



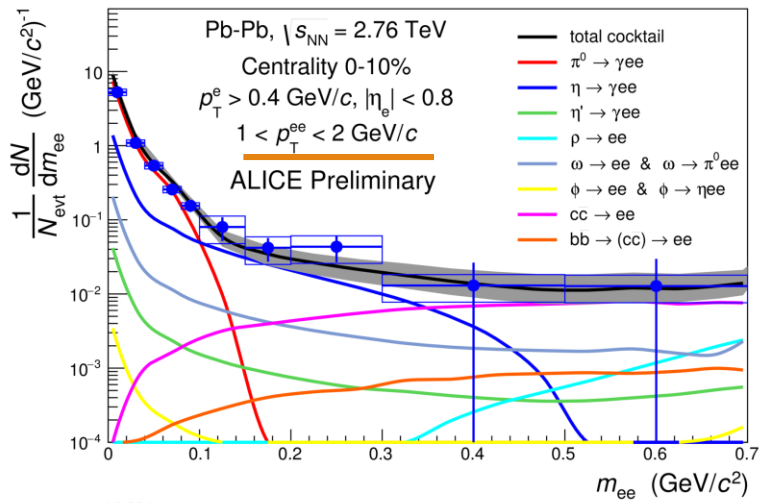
RUN I – Pb-Pb Collisions

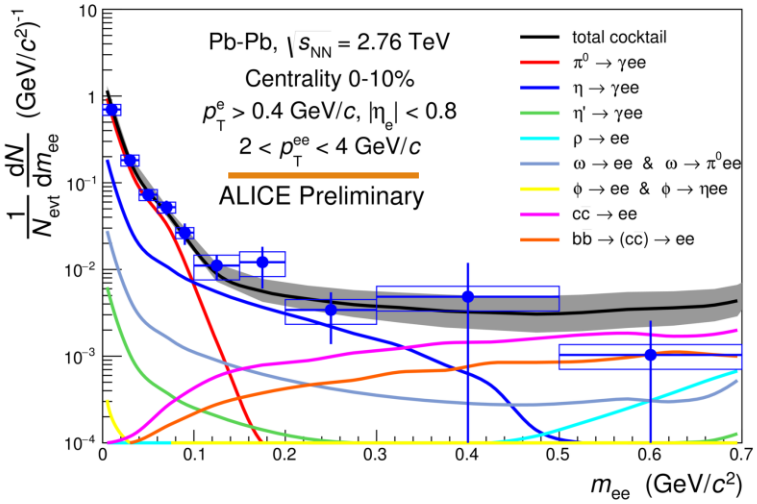
Pb-Pb Collisions

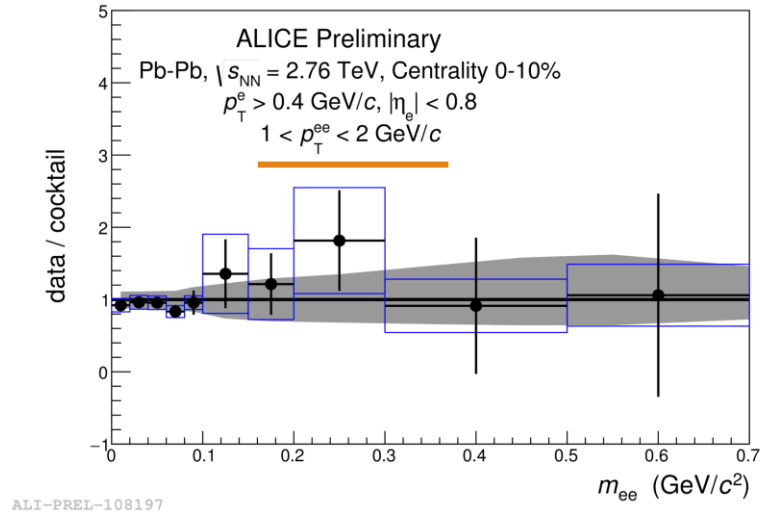
- Focus on low mass region and 0-10% central collisions
- Comparison to expected dielectron sources
  - π^0 based on measured π^0 spectrum in Pb-Pb
  - η, η', ω, ϕ, ρ from m_T-scaling
  - Open heavy flavour based on pp and scaled with N_{coll}
- Present statistics do not allow to conclude on dielectron enhancement

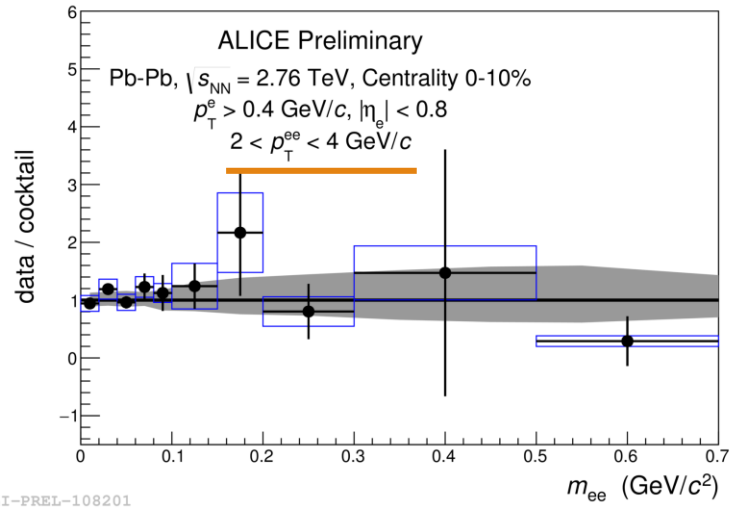


Pb-Pb Collisions – Virtual Photons







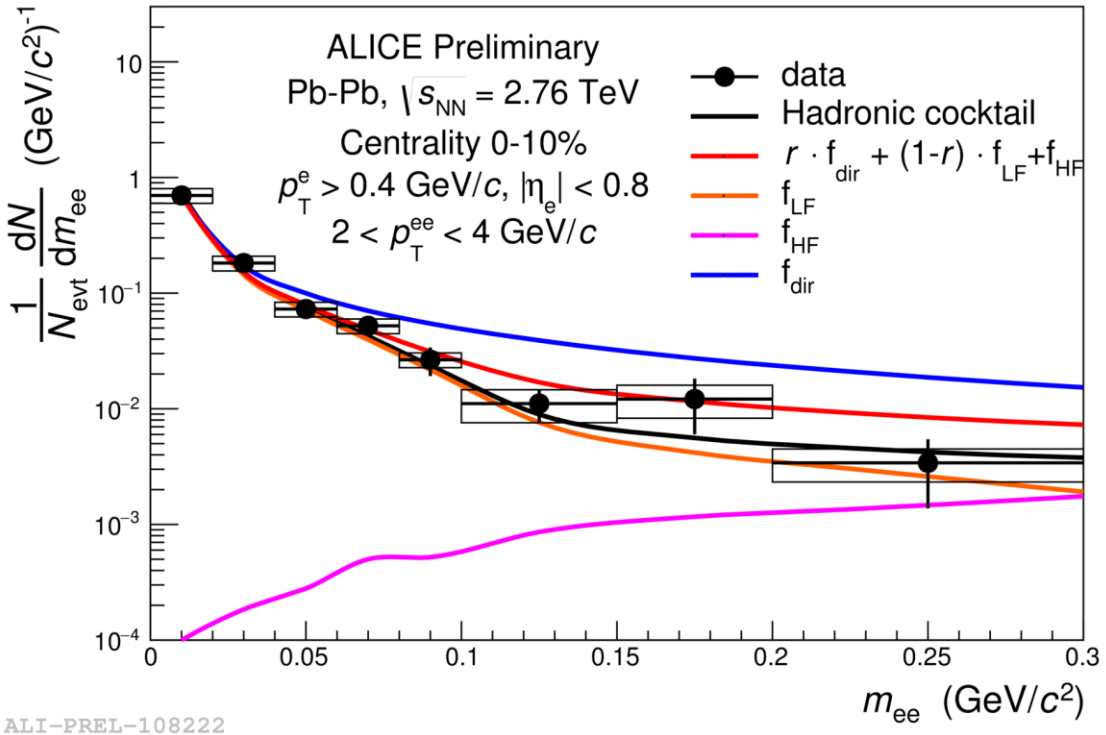


- Contribution from virtual direct photons can be extracted

Virtual Photon Extraction

- Fit in the invariant mass range 100 – 300 MeV/c^2 (based on PHENIX approach)

$$f(m_{ee}) = r \cdot \underbrace{f_{dir}(m_{ee})}_{\text{Direct photons}} + (1-r) \cdot \underbrace{f_{LF}(m_{ee})}_{\text{Light Flavour}} + \underbrace{f_{HF}(m_{ee})}_{\text{Heavy Flavour}}$$



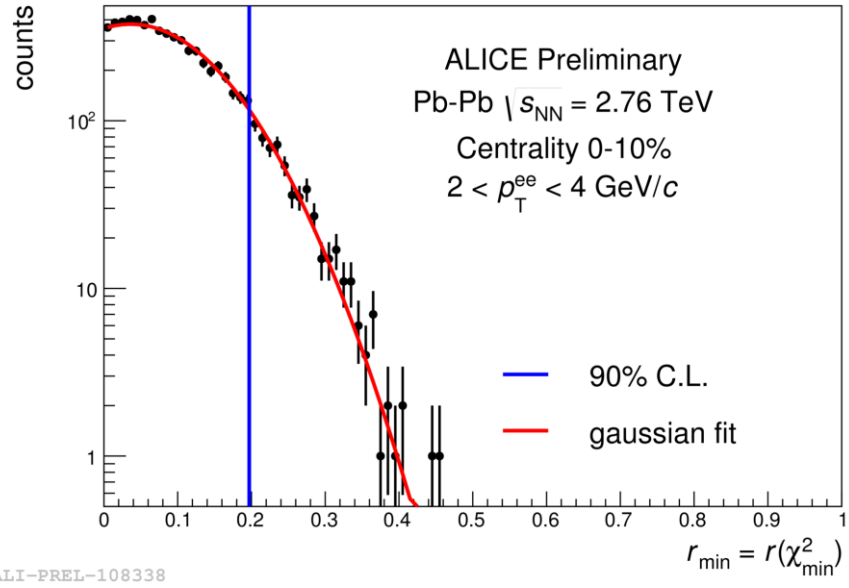
$$r = \frac{f_{dir}}{f_{dir} + f_{LF}} = \frac{\gamma_{dir}}{\gamma_{dir} + \gamma_{decay}}$$

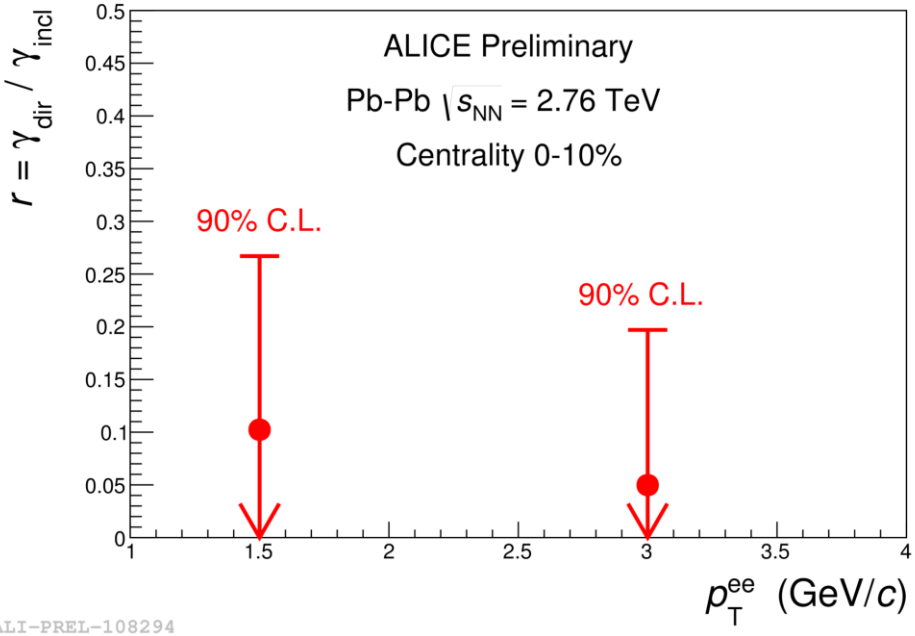
$r = 0.10 \pm 0.10$ for $p_T^{ee} \in [1,2]$ GeV/c^2

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

Virtual Photons – Upper Limit

- Measure fraction of virtual photons in 10 000 simulated experiments
- Random sampling of data around best fit curve and shifting according to fraction of systematic uncertainties
- Integration of obtained *r*-distribution up to 90% gives upper limit of *r*



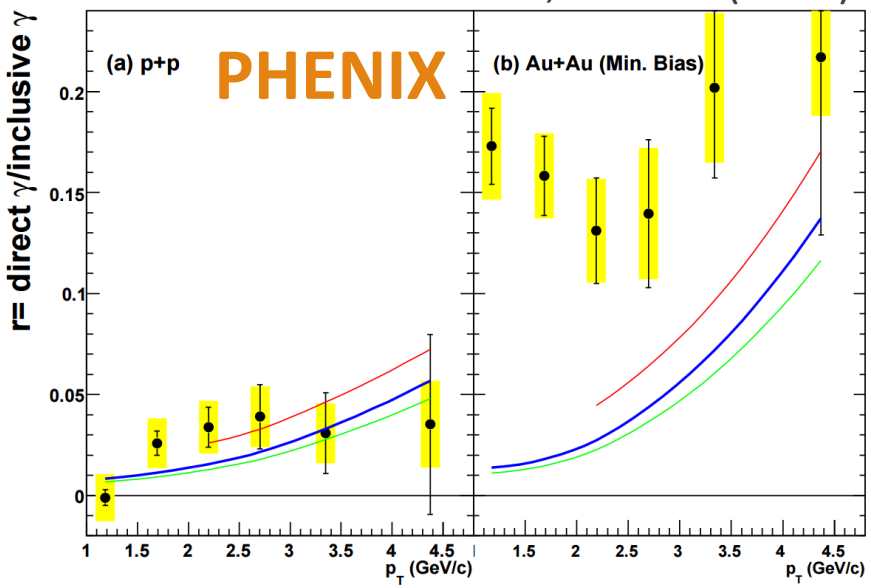


$r \leq 0.27$ for $p_T^{ee} \in [1,2]$ GeV/c^2

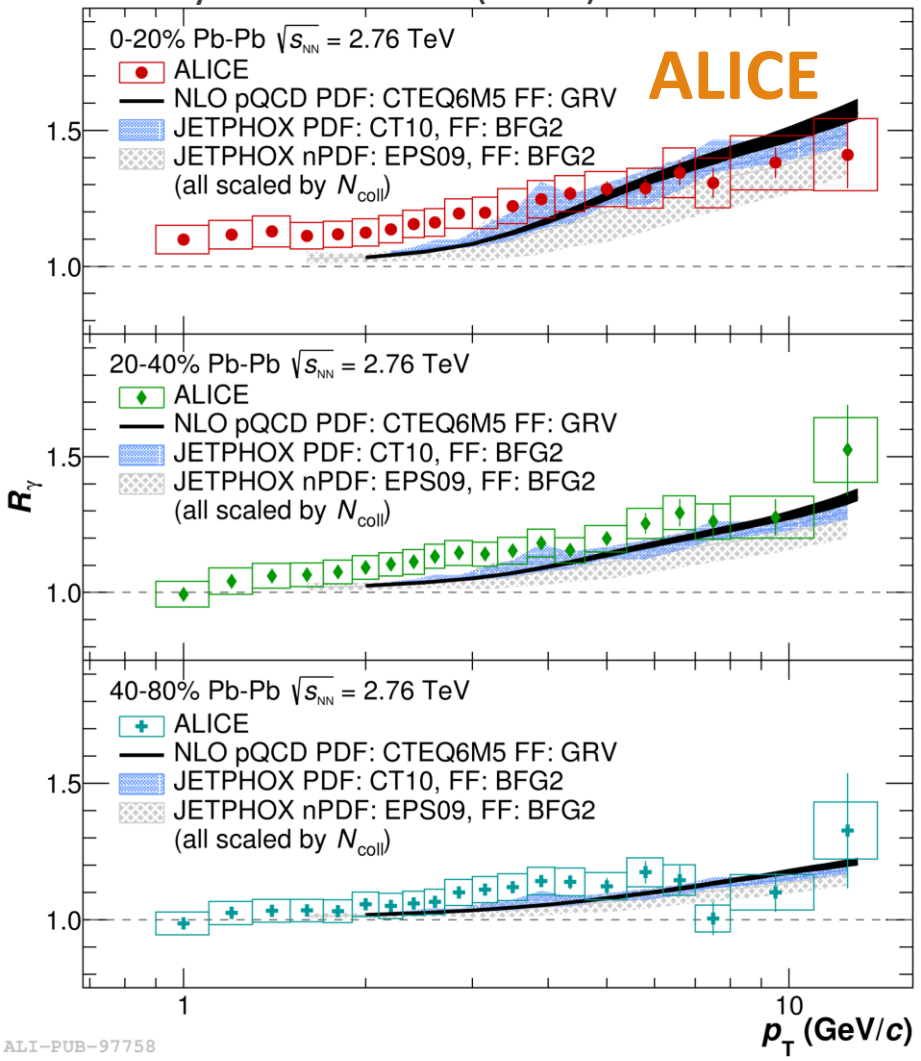
$r \leq 0.20$ for $p_T^{ee} \in [2,4]$ GeV/c^2

Virtual Photons – Comparison

PHYSICAL REVIEW C 81, 034911 (2010)



Phys. Lett. B 754 (2016) 235-248



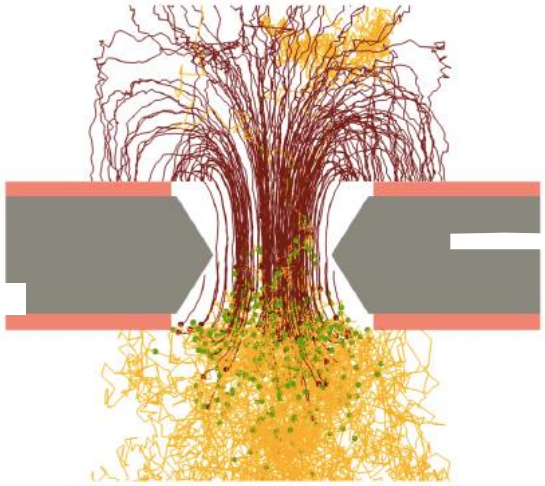
- Compatible with PHENIX Au+Au measurement
- Compatible to ALICE „PCM-PHOS“ measurement: $r = 1 - \frac{1}{R_\gamma} \approx 0.1$

OUTLOOK TO RUN III

Upgrade for Run III

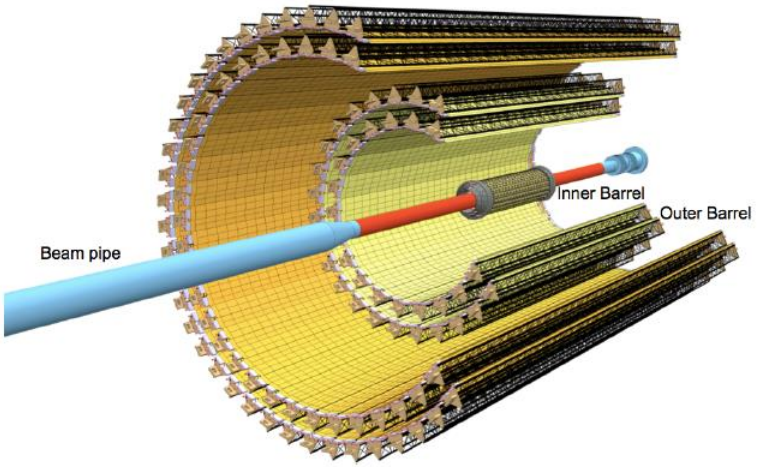
TPC

- GEM technology
- Continuous read-out
- Up to 100x higher data-taking rate (up to 50 kHz in Pb-Pb)



ITS

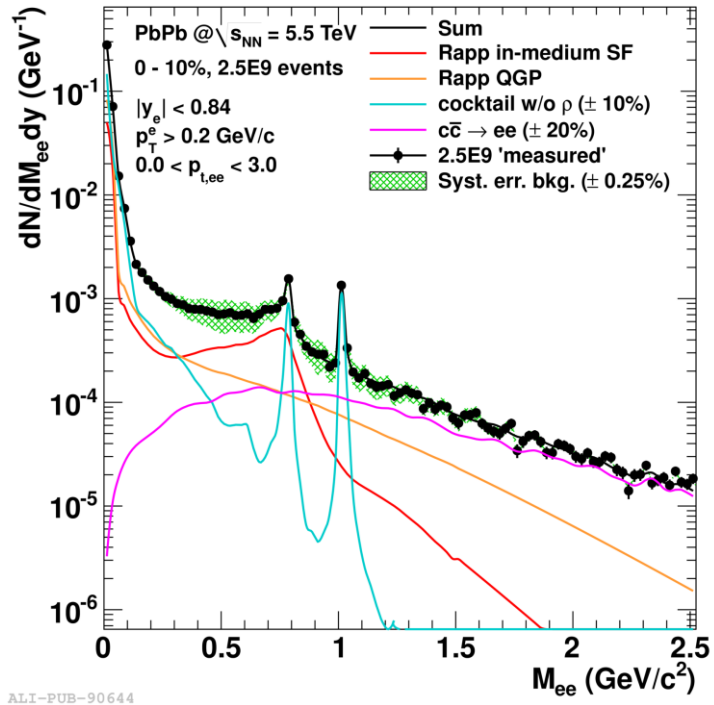
- 7 layers of silicon pixel detectors
- Will improve the precision of the measurement of displaced vertices



Prospects for Run III

Feasibility study to measure QGP temperature in Pb-Pb

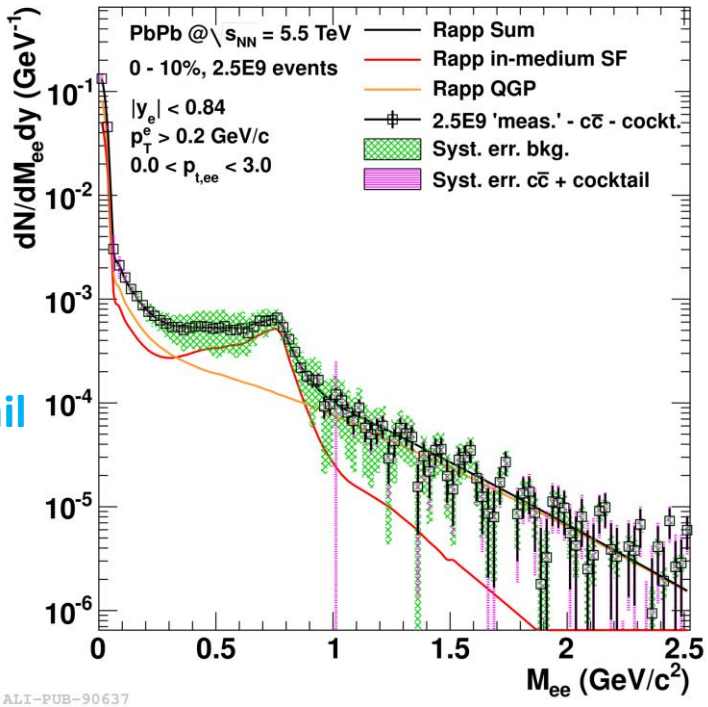
- Simulated invariant mass spectra with expected statistics of $2.5 \cdot 10^9$ central events
- Tight *DCA* cut to reduce $c\bar{c}$ contribution
- Subtraction of known sources including charm



Signal – Charm – Cocktail

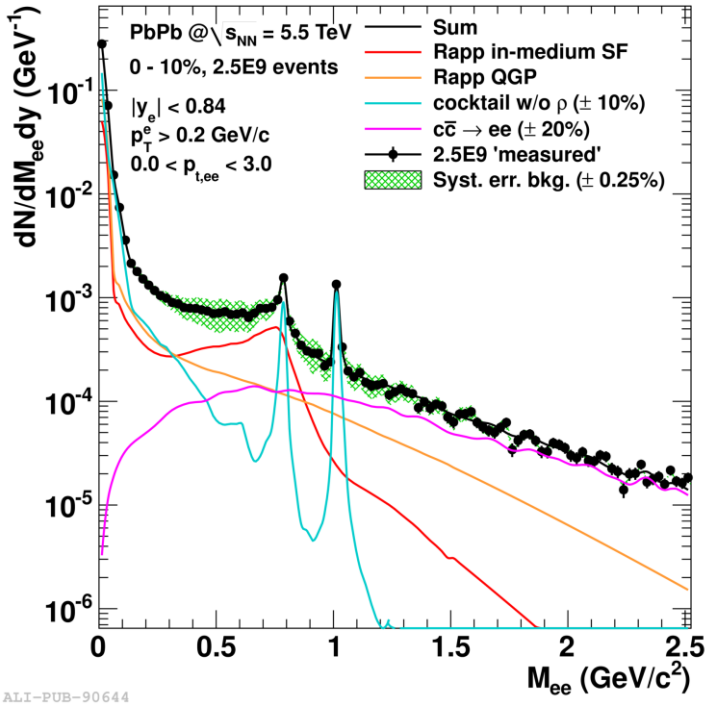
= Excess

J. Phys. G 41 (2014) 087002



Prospects for Run III

- Extract slope of QGP radiation in intermediate mass range via exponential fit:
  - $\frac{\mathrm{d}N}{\mathrm{d}m_{\mathrm{ee}}} \sim \exp\left(-\frac{m_{\mathrm{ee}}}{T_{\mathrm{eff}}}\right)$
- Effective temperature: Averaged over early times and without blue shift
- Expected uncertainties: ± 10% statistical, ± 10-20% systematic



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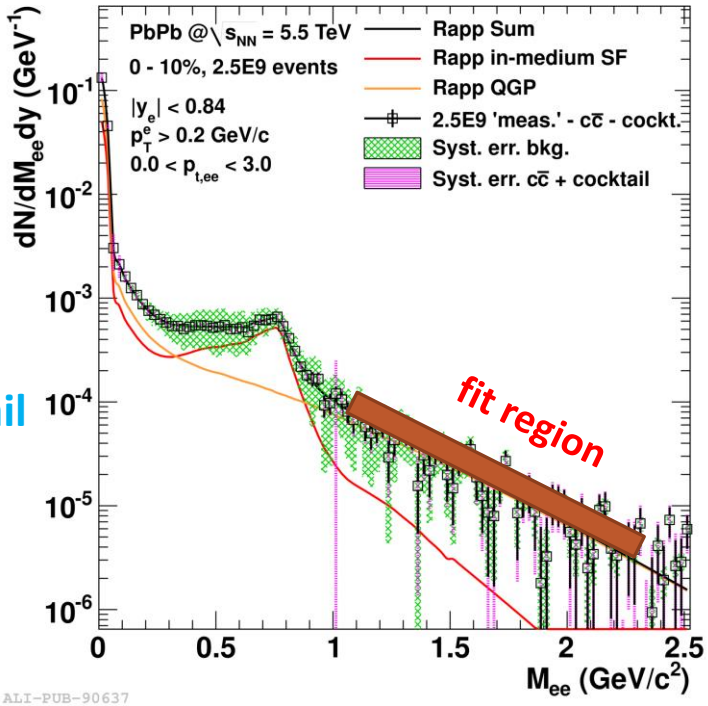

Summary and Outlook

- Run I:
  - p-Pb:
    - No indication for enhancement in low mass region, but large uncertainties
    - Extraction of virtual direct photons is ongoing
  - Pb-Pb:
    - Extraction of upper limits of the virtual direct photons
    - Direct photon yield compatible with hadronic cocktail
- Run III:
  - Major upgrade of ITS and TPC
  - QGP temperature measurement feasible
- Outlook for Run II:
  - Analysis started
  - Higher statistics and better detector performance compared to Run I