Dielectron measurements with the ALICE experiment at the LHC

New perspectives on Photons and Dileptons in Ultra-relativistic Heavy-Ion Collisions at RHIC and LHC

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ECT* Trento (IT)
Introduction:
- Electromagnetic (EM) radiation & dielectrons

Dielectron measurement in ALICE:
- Analysis strategy
- Results in pp & p-Pb collisions
- Current status in Pb-Pb collisions

ALICE upgrade & future perspectives:
- ITS & TPC upgrade
- Advantages for dielectron measurement
- Foreseen scenario after upgrade
EM radiation & dielectrons
Continuous emission of EM radiation (real & virtual photons)

Only EM interaction: 
\[ \lambda = \frac{1}{n\sigma_{em}} \gg L_{\text{system}} \]
\[ \rightarrow \text{medium is transparent} !! \]

Unaffected information on the **whole history** of the system evolution
Photon sources

High $p_T$: prompt photons from initial hard parton-parton scattering

Low $p_T$: thermal photons

Production rates from:
- Relativistic kinetic theory & hydro (QGP)
- Effective models (HHG)
Dielectrons

High mass region:
- Drell-Yann (pQCD)
- Heavy quarkonia

Intermediate mass region:
- Thermal dielectrons from QGP
- Semi-leptonic heavy flavors

Low mass region:
- Thermal from HHG
- Vector mesons & medium effects
- Quasi-real virtual photons ($p_T^{ee} \gg m_{ee}$)

Different mass domains ↔ different stages & physical processes
Direct photons

Fit a two component function in the kinematic region $p_{T}^{ee} \gg m_{ee}$

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

direct photon shape

cocktail shape

Extrapolation to $m_{ee} \rightarrow 0$

$$\frac{\gamma^*}{\gamma_{\text{incl}}} = \lim_{m_{ee} \rightarrow 0} \left[ \frac{r \cdot f_{\text{dir}}(m_{ee})}{f(m_{ee})} \right]$$

Complementary measurement of real direct photons
Thermal component directly related to the temperature:

\[ \frac{dN_{\gamma}}{dp_T} \propto \exp\left(-\frac{p_T}{T}\right) \]

- contributions from different stages
- blue-shift & flow effects

\[ T = \text{effective average temperature} \]

Inverse slope from IMR:

\[ \frac{dN}{dm_{ee}} \propto m_{ee}^{3/2} \cdot \exp\left(-\frac{m_{ee}}{T}\right) \]

No Doppler shift
In-medium effects

In-medium modification of the spectral functions of low-mass vector mesons:

- connected to Chiral Symmetry Restoration

- First observed by CERES
- Confirmed by NA60 ($\rho$ broadening)
ALICE dielectron measurements
Detectors used in the analysis:

- **ITS (Inner Tracking System)**
  - Tracking & vertexing
  - PID (via dE/dx in silicon layers)

- **TPC (Time Projection Chamber)**
  - Tracking
  - PID (via dE/dx in the gas)

- **TOF (Time Of Flight)**
  - PID (via TOF measurement)

- **V0**
  - Centrality estimator
Analysis strategy

Track selection:
- Electron ID
- Conversion suppression: single track & pair cuts

Background description:
- Combinatorial & correlated background
- Acceptance correction

Efficiency correction:
- Description of detector effects (resolution & bremsstrahlung)

Cocktail comparison (in pp & p-Pb collisions)

Virtual photon extraction (in pp collisions)
Electron ID strategy:

\[
\begin{align*}
|n\sigma^e_{TOF}| &< 3 \\
-4 < n\sigma^e_{ITS} &< 1 \\
|n\sigma^\pi_{TPC}| &> 3 \\
-1.5 < n\sigma^e_{TPC} &< 3
\end{align*}
\]

Purity > 90 % (central Pb-Pb collisions)

→ Minimize effects of hadron contamination in the dielectron spectrum
Background

Background estimated using **like-sign** distribution:

\[ LS = 2 \cdot R \cdot \sqrt{N^{++} \cdot N^{--}} \]

Both combinatorial & correlated background:

\[ LS = B_{corr} + B_{comb} \]

Correction factor from event mixing:

\[ R = \left[ \frac{N^{+-} + N^{-+}}{2 \cdot \sqrt{N^{++} \cdot N^{--}}} \right]_{mix} \]

Correction of **charge asymmetry**
Dielectrons in pp collisions

Hadronic cocktail:

- $\pi^0$, $\eta$, $\phi$, $J/\Psi$: measured by ALICE
- other contributions: $m_T$ scaling
- $c\bar{c}$: PYTHIA scaled to measured $\sigma_{c\bar{c}}$
- $b\bar{b}$ & DY missing (work in progress)

Good agreement with the cocktail
Virtual photons in pp collisions

Fraction of virtual photons from two component fit:

\[ f(m_{ee}) = r \cdot f_{\text{dir}}(m_{ee}) + (1-r) \cdot f_c(m_{ee}) \]

- direct photon shape
- cocktail shape
Direct photon ratio consistent with the measurement from *Photon Conversion Method* (PCM)

Direct photon yield:

\[ dN^{dir}(p_T) = f^{dir} \cdot dN^{incl}(p_T) \]

from PCM
omega & phi mesons reconstructed using dielectron channel

consistent with other measurements
Dielectrons in p-Pb collisions

- Data are consistent with cocktail
- No indication for excess in the LMR
- Virtual direct photon analysis: work in progress
S/B ratio in pp, p-Pb & Pb-Pb collisions

- S/B in Pb-Pb (0-10%) ≈ $10^{-2} \div 10^{-3}$ in LMR
- Conversion suppression: based on tagging & removal of conversion candidates ("pre-filter")

→ reduce main bkg contributor: enhance S/B
Dielectrons in Pb-Pb collisions

- Low S/B in Pb-Pb collisions
- Statistics in Run 1 marginal
  → Focus on low mass and high $p_T$ (virtual photons)
- Efficiency & cocktail: work in progress
Future perspectives: ALICE upgrade
New ITS & TPC

**ITS upgrade:**

- Improved impact parameter resolution ($\times 5$)
  - Closer to IP (39mm $\rightarrow$ 22mm)
  - Reduced material budget (1.14% $\rightarrow$ 0.3/0.8%)
  - Smaller pixels (50µm $\times$ 425µm $\rightarrow$ 30µm $\times$ 30µm)

- Improved tracking efficiency and $p_T$ resolution
  - 6 layers $\rightarrow$ 7 layers (3 inner barrel & 4 outer barrel)
  - Finer granularity

- Fast readout
  - 1 kHz $\rightarrow$ 100 kHz for Pb-Pb collisions

**TPC upgrade:**

**New readout system:**

- Based on GEM foils (continuous readout)
- Higher acquisition rate (up to $\times 100$)
- Less space charge effects

Alberto Calivà for the ALICE collaboration - Universiteit Utrecht
Benefits for dielectron measurement

Reduced ITS material budget:
- Less conversion probability
- Higher efficiency
- Better tracking to low $p_T$
  \[ \rightarrow \text{Larger Dalitz rejection} \]

Higher granularity & closer to IP:
- Better secondary vertex separation
- Better $p_T$ resolution at low $p_T$
  \[ \rightarrow \text{Larger suppression of charm & beauty} \]

Faster readout (GEM TPC):
- Higher rate: Reduce stat uncertainties

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Current detectors

Excess spectrum = after cocktail subtraction
Significant reduction of syst uncertainties

Statistics insufficient without high-rate upgrade
Precise temperature measurement after ITS & TPC upgrade

excess spectrum
Measurement of the temperature

Upgraded ITS:
- Reduction of syst uncertainties
- Large stat uncertainties

Upgraded ITS & TPC:
High precision measurement of the system temperature from IMR (error ~ 30 %)
Run 1: successful pioneering run

Dielectrons measured in all collision systems:
- Good agreement with cocktail in pp & p-Pb collisions
- Virtual photons extracted in pp collisions (consistent with PCM)
- Raw yield extracted in Pb-Pb collisions (low stat, will benefit from upgrade)
- Further analyses ongoing

Future perspectives after ALICE upgrade:
- Better background separation with new ITS
- Larger statistics with new TPC readout
- Towards the full picture in Run 2
- High precision measurement in Run 3
Thank you for your attention
Backup slides
Tracking secondary tracks

- Tracking: propagation to primary vtx
  - Shared clss
  - Random clss (60% not assigned)
  - Matching another global track

Shared clusters in ITS:

\[ \eta \quad \gamma \]
Pre-filter

Di-electrons produced by photon conversion:

- Low mass ($m_{ee} < 100 \text{ MeV}/c^2$)
- Correlation with magnetic field ($\phi_V$)

Pre-filter:

- Definition of conversion pairs
- Tag conversion candidates
- Remove tagged electrons

$\phi_V$ $[60^\circ, 120^\circ]$
Pre-filter: loose cuts on the partner

To enhance probability to find missing daughter:

→ use track sample with **looser cuts**

Tag electrons in sample 1 using partner from sample 2 (also LS)
Electron purity (Pb-Pb)
Scenario after ITS & TPC upgrade

Current detectors

- Significant improvement of stat & syst uncertainties
- Precision measurement in Run 3 after TPC upgrade
  - Improved precision in temperature measurement (T extracted from exponential fit to IMR)

New ITS & TPC

excess spectrum