Dielectron measurements with ALICE at the LHC

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Outline

- introduction
- ALICE
- dielectron measurements with ALICE
  - pp collisions
  - Pb-Pb collisions
- summary of current status
- future perspectives
  - dielectron performance with ALICE upgrade
Dielectrons

- measurement of dielectrons from AA collisions
  - electromagnetic probe
    - negligible final state interaction
  - information from all phases of the collision
  - sensitivity to
    - electromagnetic structure of the hot and dense medium
    - in-medium modification of low-mass vector mesons
    - thermal radiation
    - heavy-flavor hadron decays (at intermediate mass)
    - heavy quarkonia suppression/enhancement

- measurement of dielectrons from pp collisions
  - provides necessary baseline for AA studies
A Large Ion Collider Experiment

Inner Tracking System
tracking/vertexing (particle ID)

Time Projection Chamber
tracking particle ID

Time Of Flight
particle ID

Transition Radiation Detector
electron ID trigger

ElectroMagnetic Calorimeter
electron ID trigger

central barrel acceptance: \(0 < \varphi < 2\pi, |\eta| < 0.9\)
mass resolution: \(\Delta m/m \sim 1\%\)
Inner Tracking System (ITS)

- 2 silicon pixel detector (SPD) layers
  - $X/X_0 = 1.14\%$
  - $R_{\text{inner}} = 3.9\text{ cm}$
  - 9.8M channels, 0.2 $\text{m}^2$
- 2 silicon drift detector (SDD) layers
  - 133k channels, 1.3 $\text{m}^2$
- 2 silicon strip detector (SSD) layers
  - 2.6M channels, 4.75 $\text{m}^2$
Time Projection Chamber (TPC)

- 557,568 readout channels
- 94 µs maximum drift time
- 10 bit ADC at 10 MHz
- dE/dx resolution ~6 %
Time of Flight (TOF)

- hadron rejection at low momenta
TRD modules currently installed: 13
(7 in 2010, 10 in 2011)
→ currently not used in dielectron analysis due to limited acceptance
(same is true for EMCal)
Triggers and data sets

- minimum bias pp collisions
  - coincidence of beam pick-ups and a signal in either the SPD or one of the V0 scintillator arrays
  - efficiency: ~95% of $\sigma_{\text{inel}}$.
  - ~350M events (2010 data set)

- Pb-Pb collisions
  - minimum bias trigger: coincidence of V0 arrays and Zero Degree Calorimeters
  - in addition: centrality triggers defined via total charge measured in V0
  - 2010: ~12M MB events
  - 2011: ~8M MB, ~27M central, ~32M semicentral events
Dielectrons in pp collisions at $\sqrt{s} = 7$ TeV
Electron candidate selection

- electron identification is crucial
  - start with high quality tracks
    - $p_T > 0.2$ GeV/c, $|\eta| < 0.8$
    - ‘long’ tracks in the TPC without ‘kinks’
  - require associated hit in the first SPD layer (to minimize contribution from photon conversions)
  - require electron Time of Flight (within $3\sigma$) to reject K, p
  - require electron $dE/dx$ (-1.5 < $\sigma$ < 3) and reject tracks with pion $dE/dx$ (within $4\sigma$) to reject pions
- how well does this work?
Purity of candidate sample

- fit TPC $dE/dx$ in momentum slices
  - remaining hadron contamination for $p < 3$ GeV/c: $\sim 1\%$
Contamination from $\gamma$ conversions

- how to identify photon conversion candidates
  - displaced secondary vertex
  - orientation of the ‘pair plane’ with respect to the magnetic field direction

- remaining contamination from photon conversions: few percent at low mass ($m_{ee} < 0.1$ GeV/c$^2$)
Combinatorial background

- pairing of all electrons and positrons gives rise to combinatorial background

\[ N_{+-} = S_{+-} + N_{+-}^{\text{CombBkg}} \]

- methods to determine this background
  - mixed event subtraction
  - same-event like-sign subtraction
  - same-event track rotation

- current approach: like-sign subtraction

\[ N_{+-}^{\text{CombBkg}} = 2 \times \sqrt{N_{++} N_{--}} \times R_{\text{Acc}} \]

Like-sign

from mixed events
Raw mass spectra

- large background from uncorrelated pairs
- subtraction of like-sign combinatorial background → raw signal of correlated pairs
Correction for efficiency

- efficiency correction for detector effects (including Bremsstrahlung in material)
- no acceptance correction into unmeasured region of phase space
- correction based on full MonteCarlo simulations
- efficiency determined for single electron tracks as function of ($p_T$, $\eta$, $\phi$)
Systematic uncertainties

- relevant sources
  - track selection
  - electron ID
  - efficiency correction
  - normalization
  - most important: combinatorial background

\[
\frac{dS}{S} = \frac{dB}{B} \times \frac{B}{S}
\]

→ currently NO significant measurement close to \( m_{ee} = 0.5 \text{ GeV/c}^2 \)!
Known hadronic $e^+e^-$ sources

- calculation of hadronic cocktail
  - based on: measured $p_T$-differential invariant cross section of $\pi^0$
  - contributions from other hadron decays:
    from data ($\eta$, $\phi$, $J/\psi$) or via $m_T$ scaling
  - contribution from correlated charm decays:
    from measured charm cross section and PYTHIA decay kinematics

- ALICE data used as input
  - $\pi^0$, $\eta$: Phys. Lett. B717 (2012) 162
  - $\phi$: arXiv:1208.5717
  - $\sigma_{cc}$: arXiv:1205.4007
Cocktail versus data

- cocktail in reasonable agreement with data
Outlook for Pb-Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV
Signal extraction

- similar analysis as for pp collisions at $\sqrt{s} = 7$ TeV (but: $p_T^e > 0.4$ GeV/c)
- S/B ratio few $10^{-3}$ at low mass ($0.2 - 0.4$ MeV/c$^2$)
- detailed study of background systematics ongoing
**Summary I**

- first dielectron continuum measurement with ALICE for pp collisions at √s = 7 TeV
- hadronic cocktail calculation agrees within errors with data in the range 0 < m_{ee} < 3.3 GeV/c²
- analysis is difficult for Pb-Pb collisions → requires improved knowledge of background
- unique strength of ALICE at the LHC
  - access to the low mass & low p_T region!
  - how can this be improved further?
ALICE upgrade - LOI

http://cdsweb.cern.ch/record/1475243

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Dielectron strategy

- Reduction of central barrel magnetic field from 0.5 T to 0.2 T
  - Extend tracking efficiency and electron PID to lower $p_T$
- High rate upgrade of the TPC
  - Improve the data taking rate by a factor 100
- Upgrade of the ITS
  - Reduced material budget
  - Improve tracking efficiency at very low $p_T$
  - Improve capability to identify electrons originating from secondary vertices (DCA cut)
Dielectron performance study

- here: focus on 10% most central Pb-Pb collisions ($<dN_{ch}/d\eta> = 1750$) at $\sqrt{s_{NN}} = 5.5$ TeV (peripheral case was studied as well)

- dielectron signal
  - hadronic cocktail
  - open charm decays based on PYTHIA, interpolated total charm production cross sections for pp collisions, and binary collision scaling
  - thermal signal (R. Rapp & J. Wambach, EPJA 6(1999)425)
Dielectron performance study

- **background**
  - PYTHIA pp events superimposed to Pb-Pb $\langle dN_{\text{ch}}/d\eta \rangle$
  - photon conversions from GEANT3

- **kinematic cuts**
  - $|\eta_e| < 0.84$, $p_{T,e} > 0.2$ (0.06) GeV/c for global (ITS) tracking

- **conversion and Dalitz rejection**
  - $m_{ee} < 50$ MeV/c$^2$, opening angle $< 100$ mrad
Current ITS, no DCA cut

- $2.5 \times 10^7$ Pb-Pb collisions at 5.5 TeV
- Precision of comb. background measurement: 0.25%
- Background precision: 10% (20%) for cocktail (charm)

→ No quantitative access to in-medium spectral functions and thermal dielectron emission
Current ITS, tight DCA cut

- 2.5 x 10^7 Pb-Pb collisions at 5.5 TeV
- precision of comb. background measurement: 0.25%
- background precision: 10% (20%) for cocktail (charm)

\[ \text{Precision of comb. background measurement: 0.25\%} \]

\[ \text{Background precision: 10\% (20\%) for cocktail (charm)} \]

\[ \rightarrow \text{marginal improvement only} \]
New ITS, DCA cut

- 2.5 x 10^7 Pb-Pb collisions at 5.5 TeV
- precision of comb. background measurement: 0.25%
- background precision: 10% (20%) for cocktail (charm)

→ significantly reduced systematics, but statistics limited
New ITS, DCA cut, high rate

- $2.5 \times 10^9$ Pb-Pb collisions at 5.5 TeV
- Precision of comb. background measurement: 0.25%
- Background precision: 10% (20%) for cocktail (charm)

$\rightarrow$ quantitative access to dielectron production beyond hadronic cocktail and correlated charm decays!
Summary II

- precision measurement of dielectron production in Pb-Pb collisions at the LHC beyond the hadronic cocktail and correlated charm decays:
  \textbf{NOT possible with the current ALICE setup!}
  (even with increased kinematic coverage due to a reduced B field)
- current limitations: addressed by ALICE upgrade
  - new ITS
    \textbf{\rightarrow} improved Signal/Background ratio
    \textbf{\rightarrow} reduced sys. uncertainty of $e^+e^-$ measurement
  - high rate upgrade of the TPC
    \textbf{\rightarrow} reduced stat. uncertainty of $e^+e^-$ measurement

ALICE upgrade
  \textbf{\rightarrow} precision low-mass dielectron measurement