Dielectron measurements with ALICE at the LHC

Ralf Averbeck
ExtreMe Matter Institute EMMI and Research Division
GSI Helmholtzzentrum für Schwerionenforschung
Darmstadt, Germany

on behalf of the ALICE Collaboration

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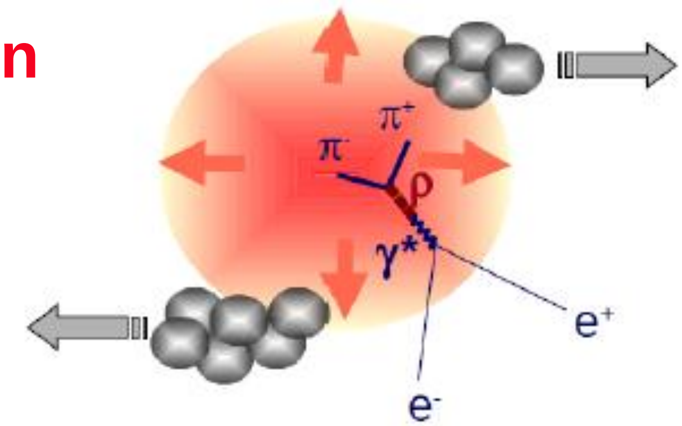
Outline

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

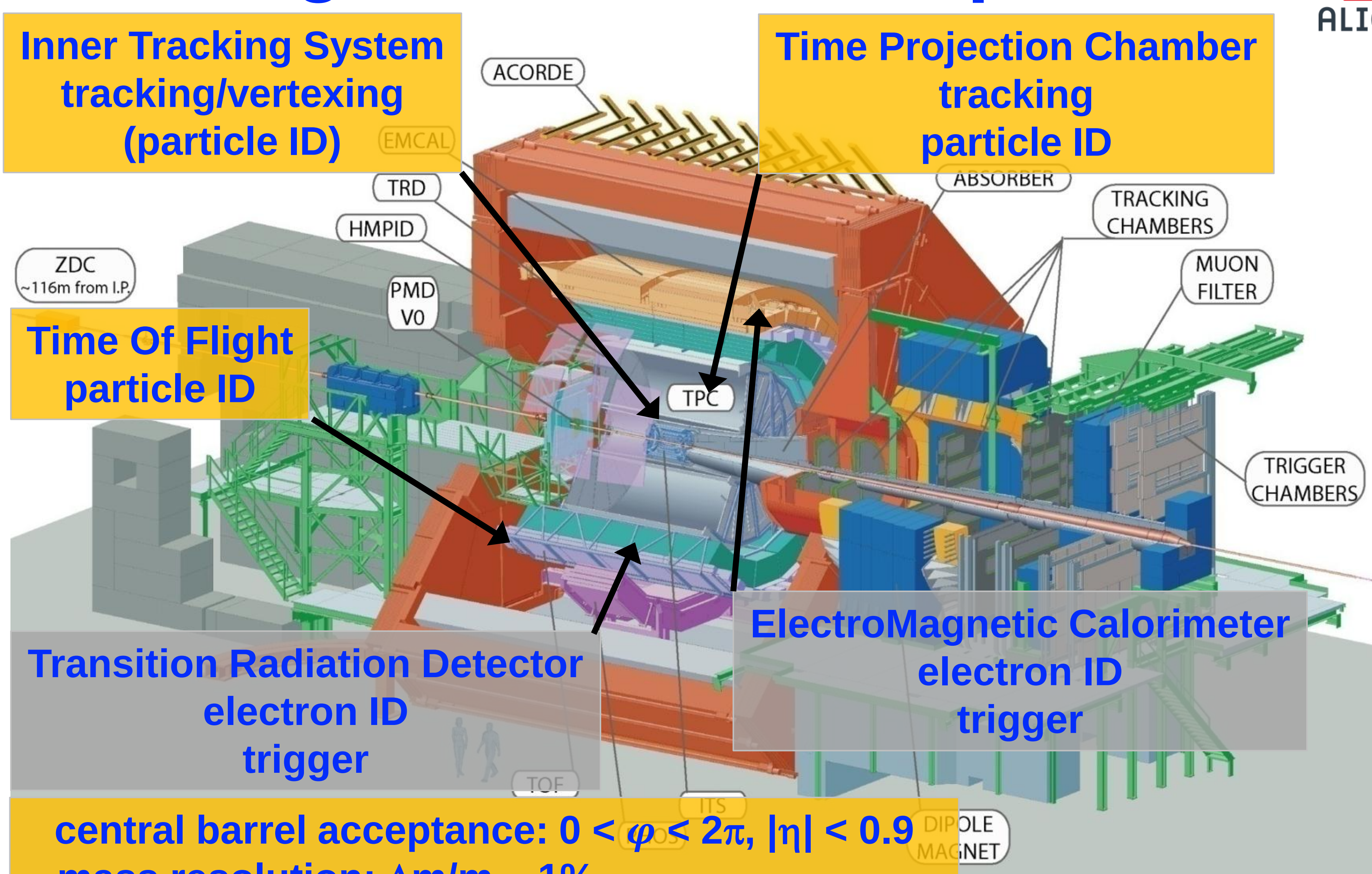
Dielectrons

- 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

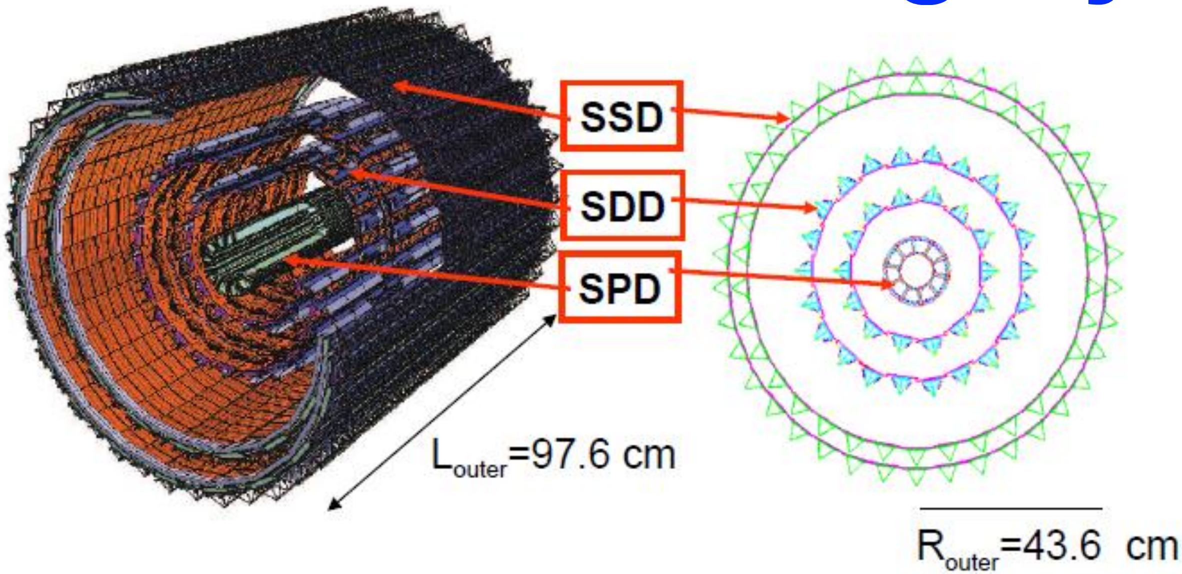
Time Of Flight
particle ID

Transition Radiation Detector
electron ID
trigger

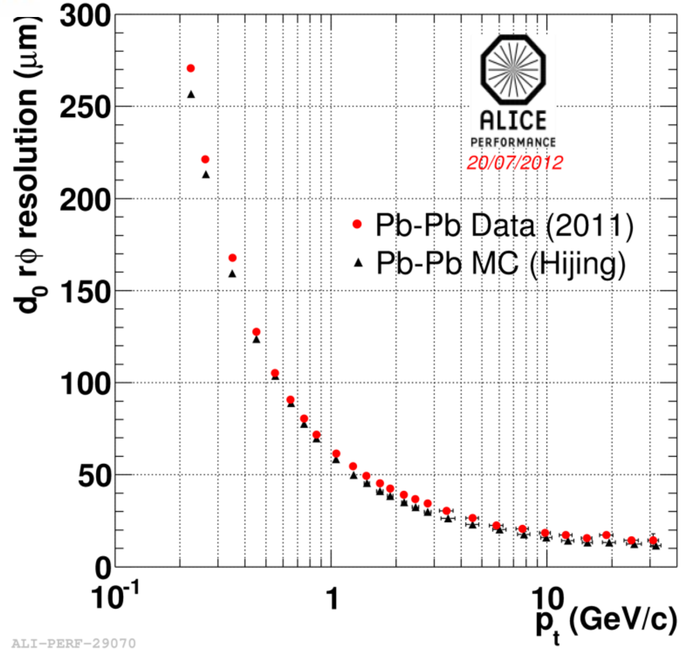
ElectroMagnetic Calorimeter
electron ID
trigger

central barrel acceptance: $0 < \varphi < 2\pi$, $|\eta| < 0.9$
mass resolution: $\Delta m/m \sim 1\%$

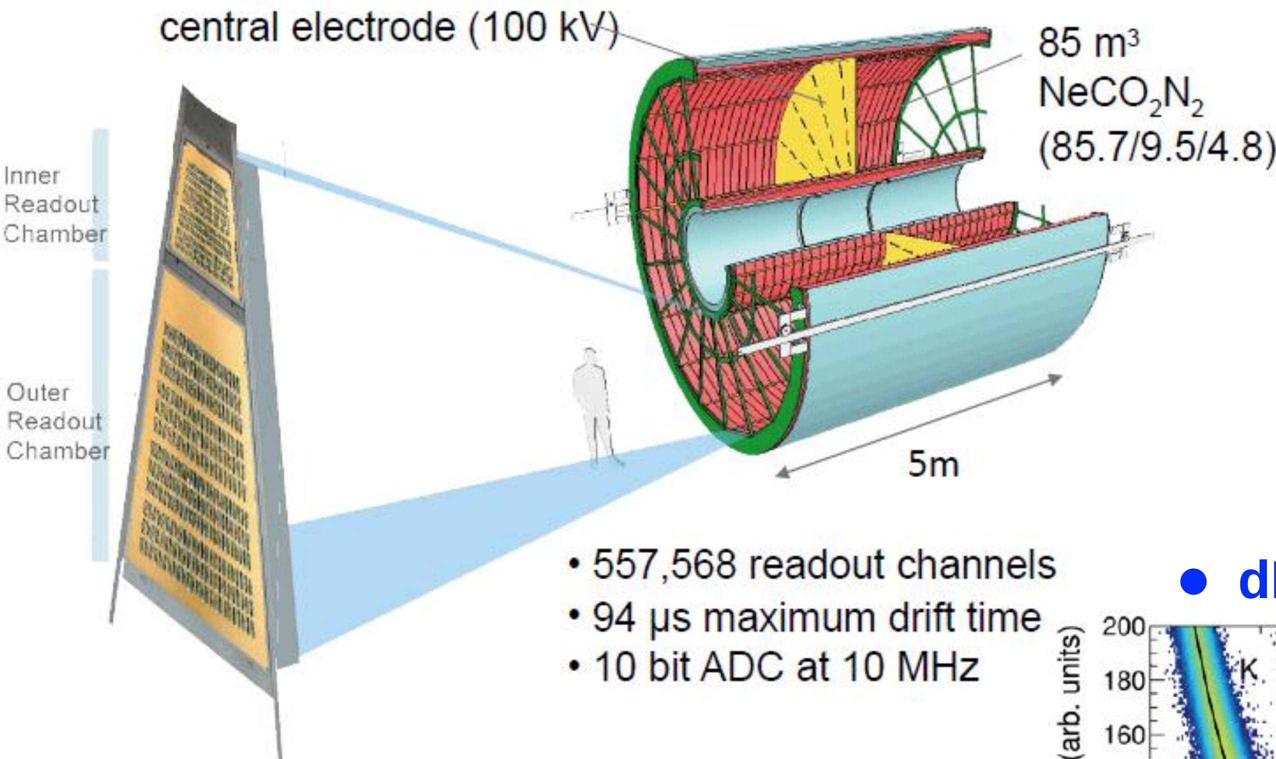
Inner Tracking System (ITS)



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

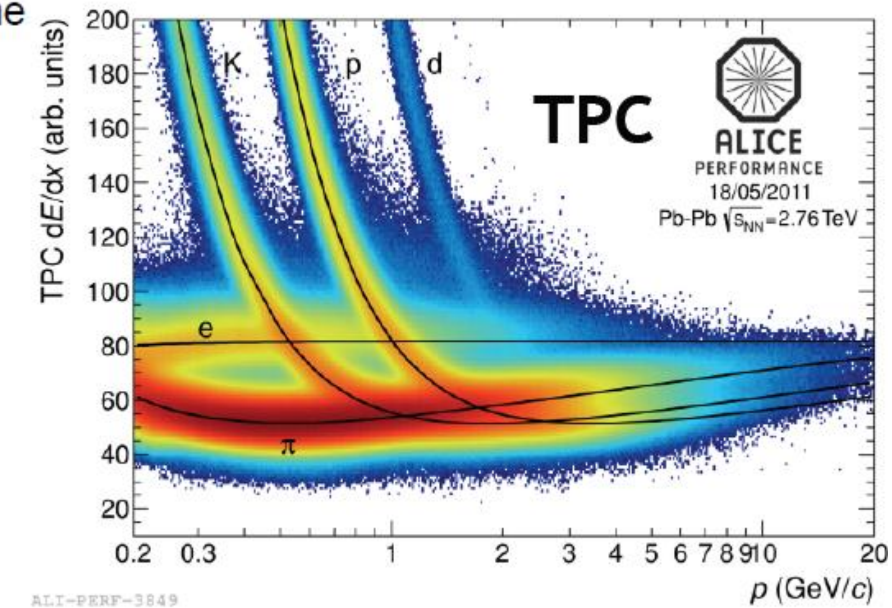


Time Projection Chamber (TPC)

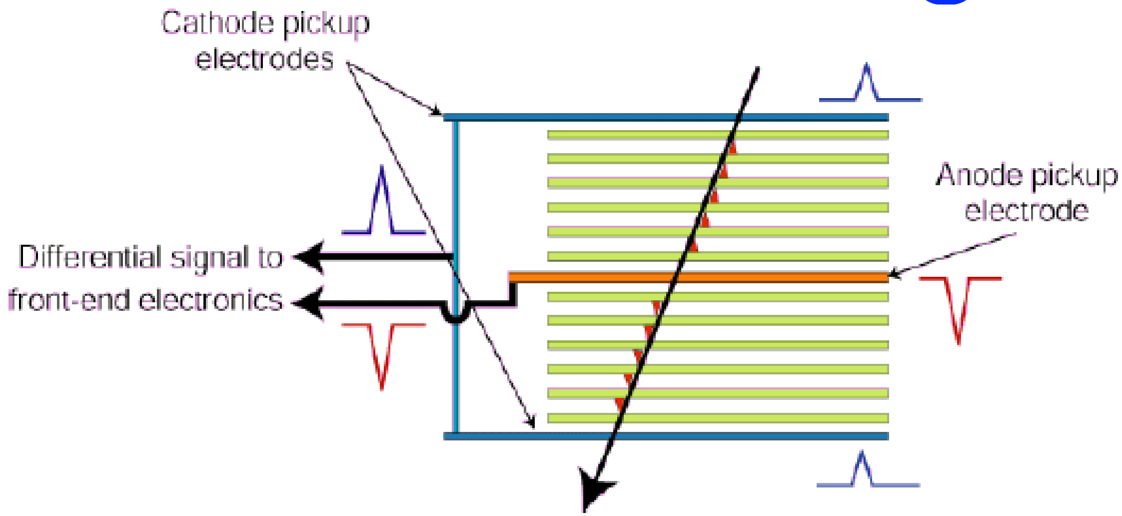


- 557,568 readout channels
- 94 μs maximum drift time
- 10 bit ADC at 10 MHz

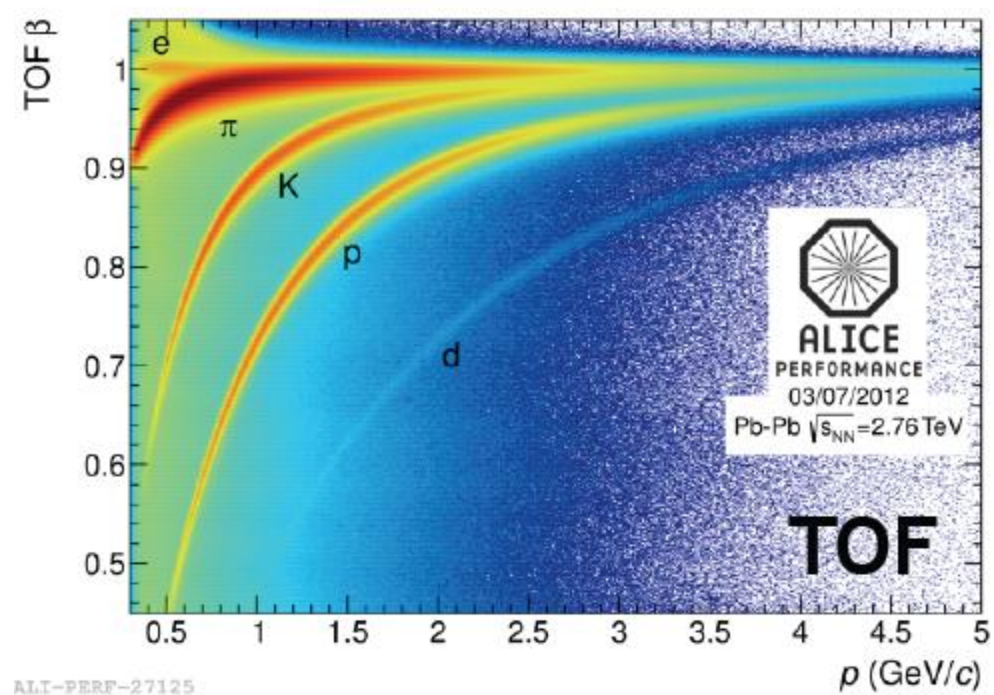
- **dE/dx resolution ~6 %**



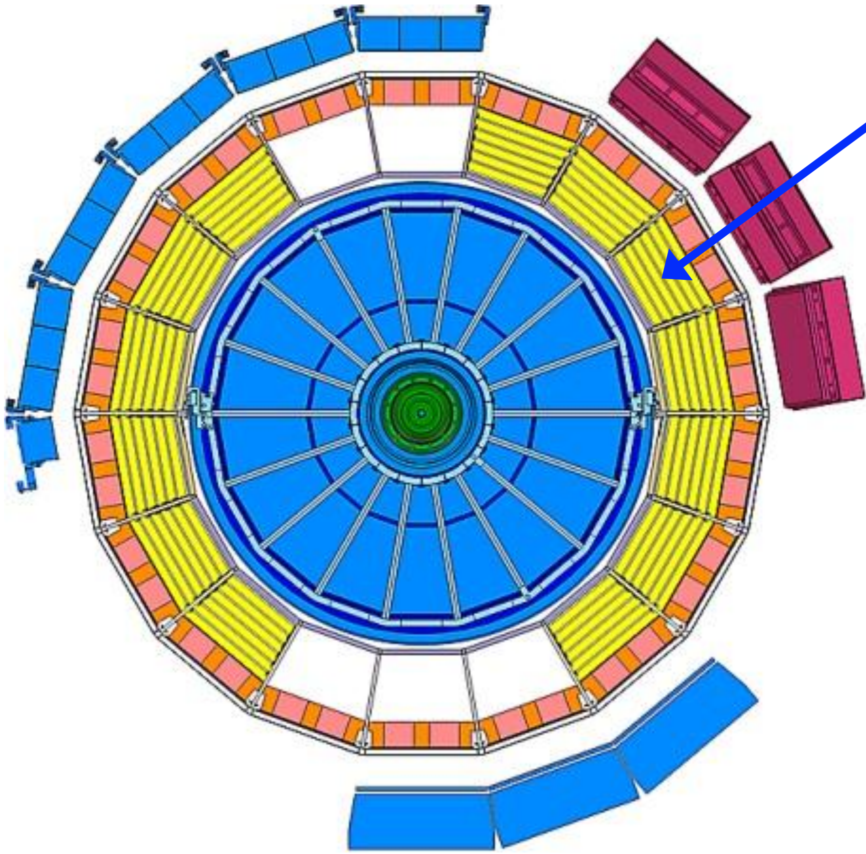
Time of Flight (TOF)



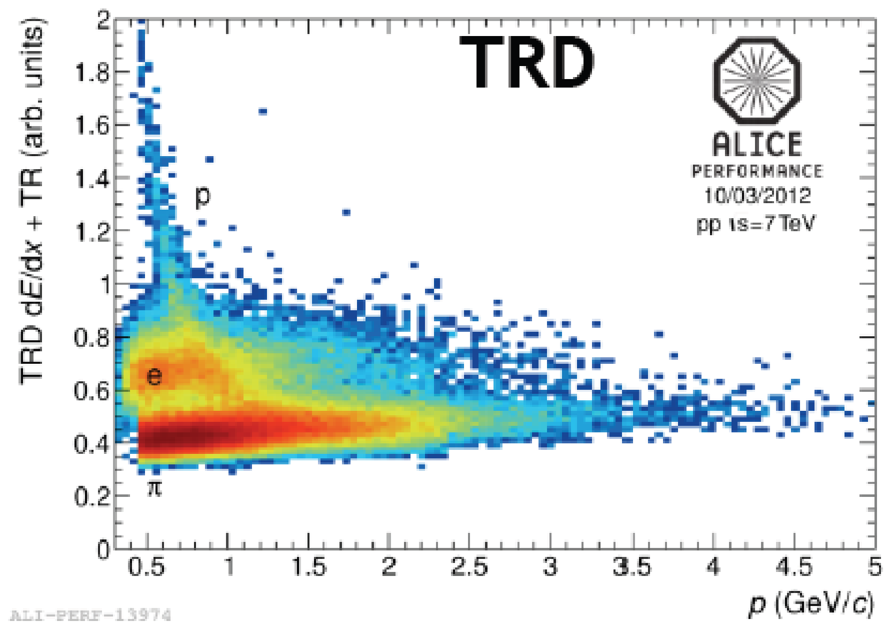
- **hadron rejection at low momenta**



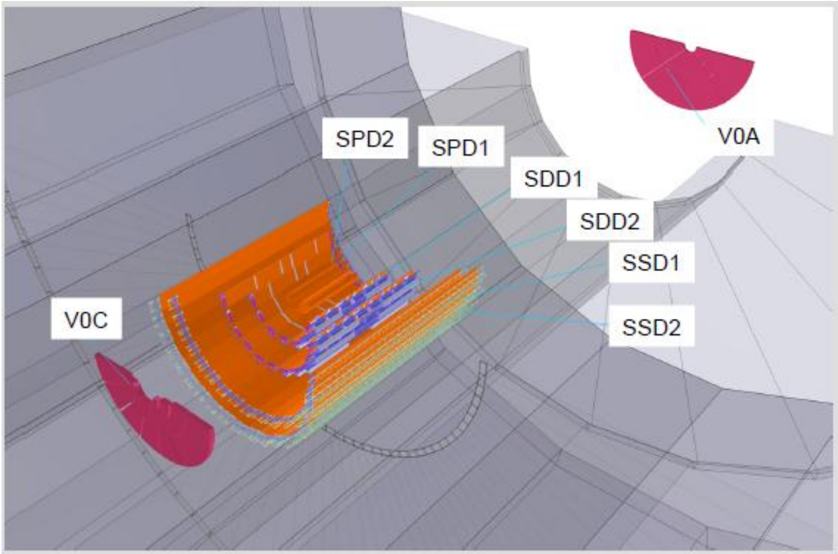
Transition Radiation Detector (TRD)

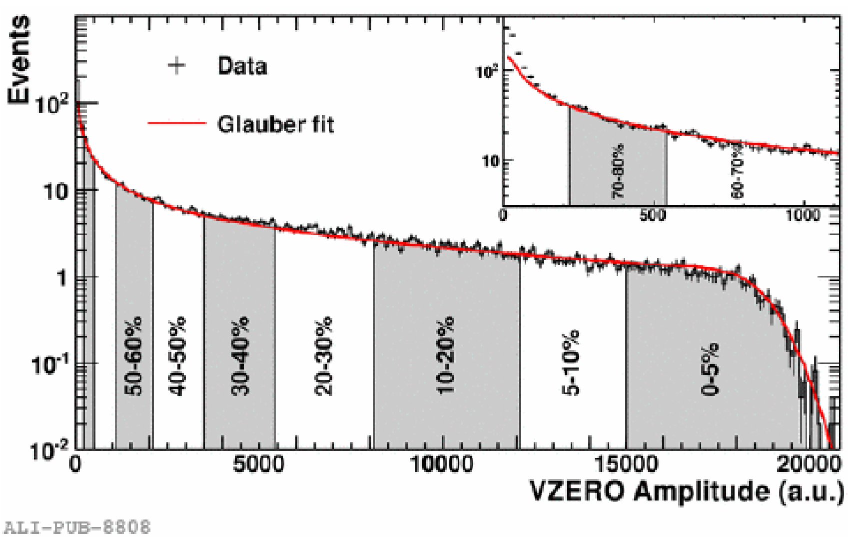


- TRD modules currently installed: 13
  (7 in 2010, 10 in 2011)
  → currently not used in dielectron analysis due to limited acceptance
  (same is true for EMCal)



Triggers and data sets



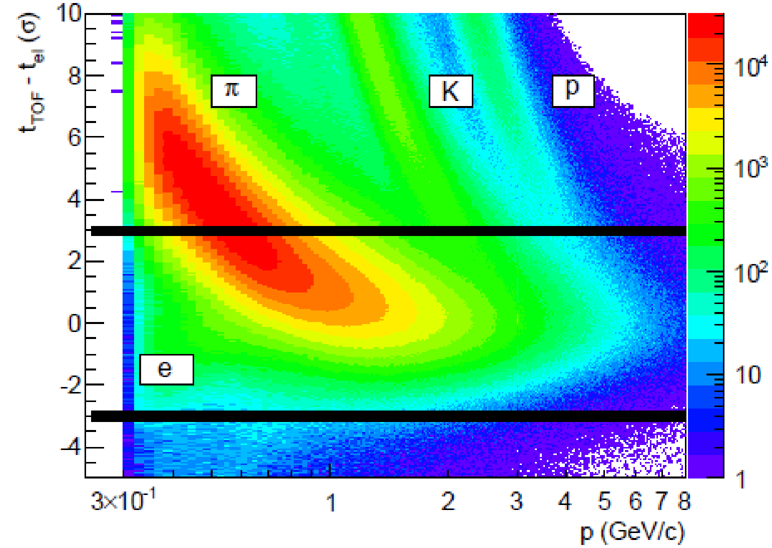


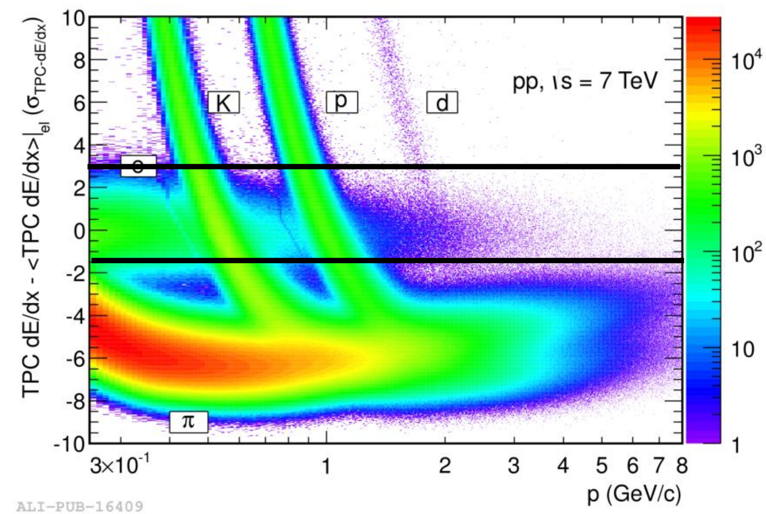
- minimum bias pp collisions
  - coincidence of beam pick-ups and a signal in either the SPD or one of the V0 scintillator arrays
  - efficiency: ~95% of $\sigma_{inel.}$
  - ~350M events (2010 data set)
- Pb-Pb collisions
  - minimum bias trigger: coincidence of V0 arrays and Zero Degree Calorimeters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

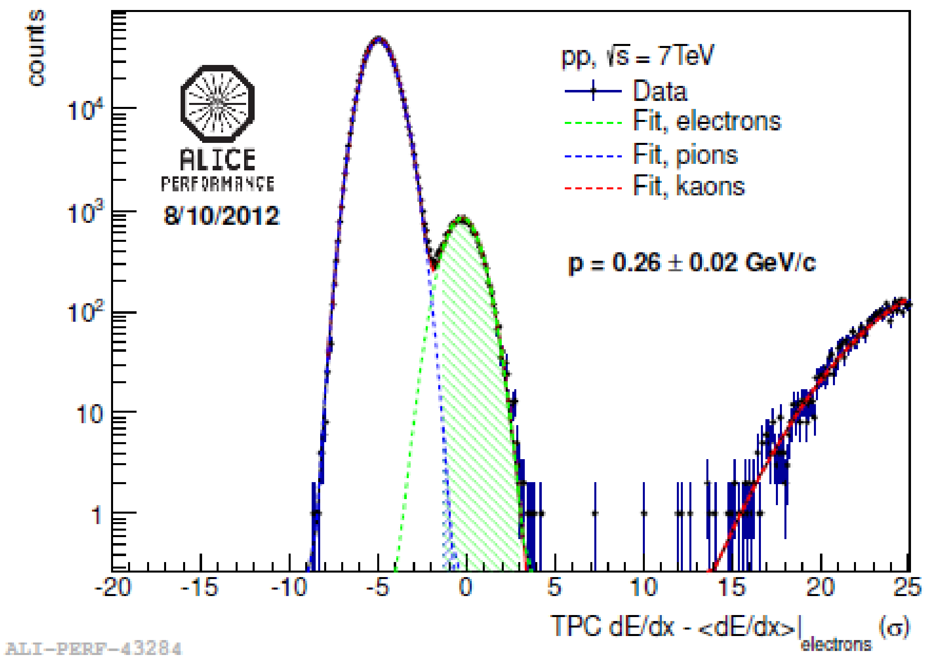
Electron candidate selection

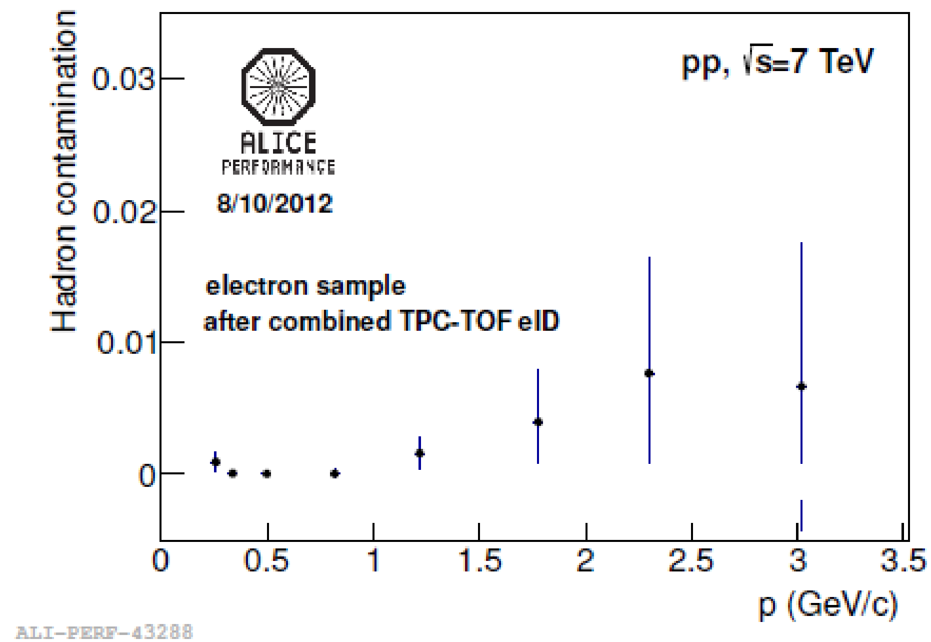
- electron identification is crucial
  - start with high quality tracks
    - $p_T > 0.2$ GeV/c, $|\eta| < 0.8$
    - 'long' tracks in the TPC without 'kinks'
  - require associated hit in the first SPD layer (to minimize contribution from photon conversions)
  - require electron Time of Flight (within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





Purity of candidate sample



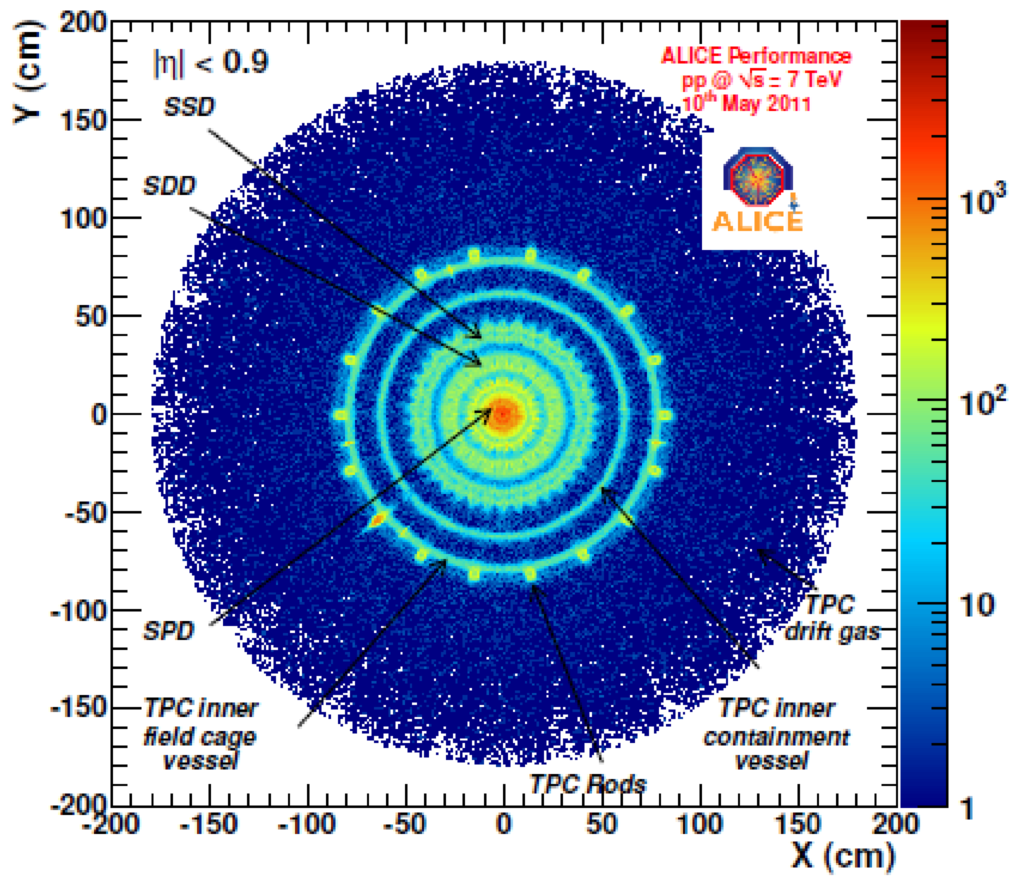


- **fit TPC dE/dx in momentum slices**

→ remaining hadron contamination for p < 3 GeV/c: <~ 1%

Contamination from γ 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

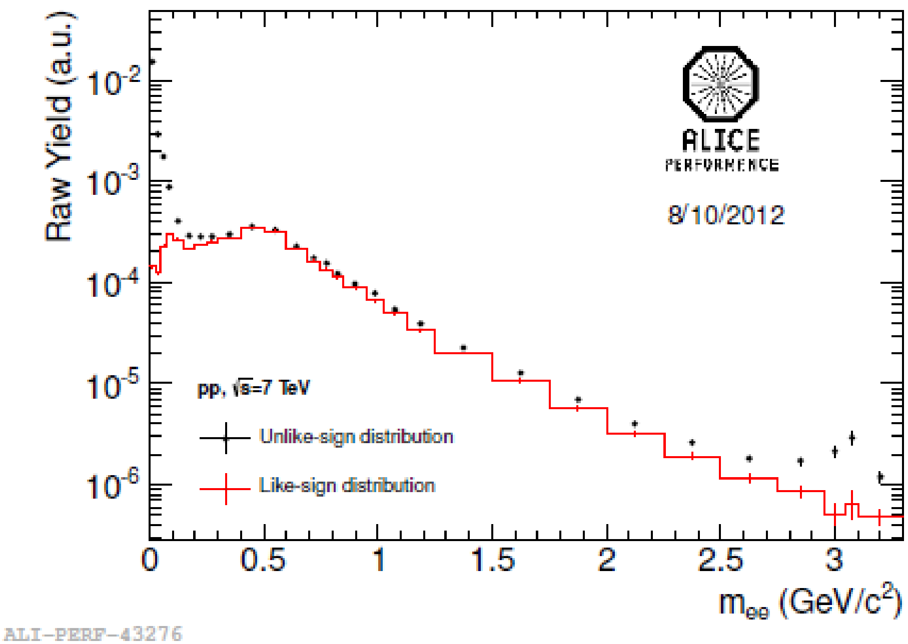
$$\underbrace{N_{+-}}_{\text{measured}} = S_{+-} + N_{+-}^{\text{CombBkg}}$$

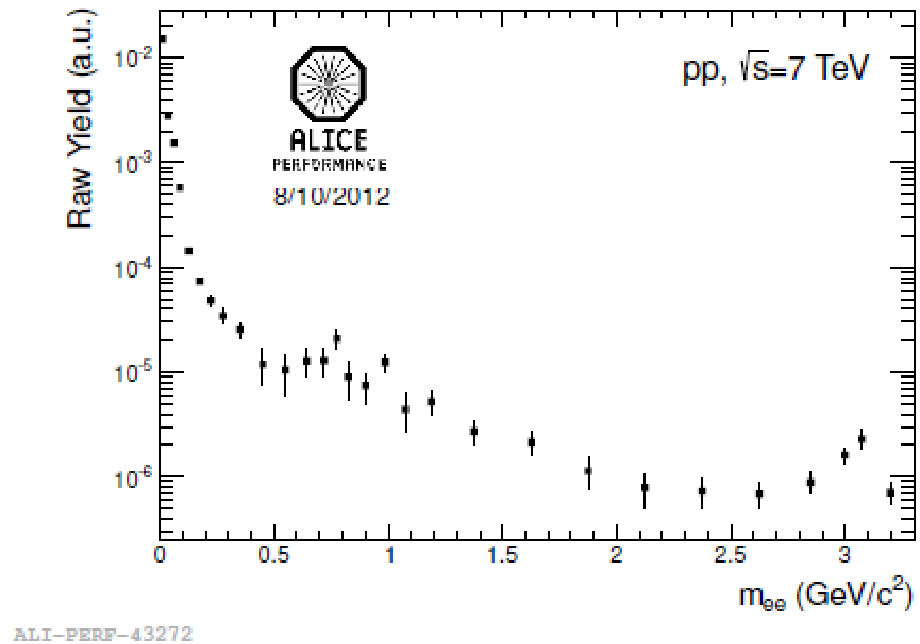
- methods to determine this background
  - mixed event subtraction
  - same-event like-sign subtraction
  - same-event track rotation

$$N_{+-}^{\text{CombBkg}} = \underbrace{2 \times \sqrt{N_{++}N_{--}}}_{\text{Like-sign}} * \overbrace{R_{Acc}}^{\text{from mixed events}}$$

- current approach: like-sign subtraction

Raw mass spectra





- **large background from uncorrelated pairs**
- **subtraction of like-sign combinatorial background**
  → raw signal of correlated pairs

Correction for efficiency

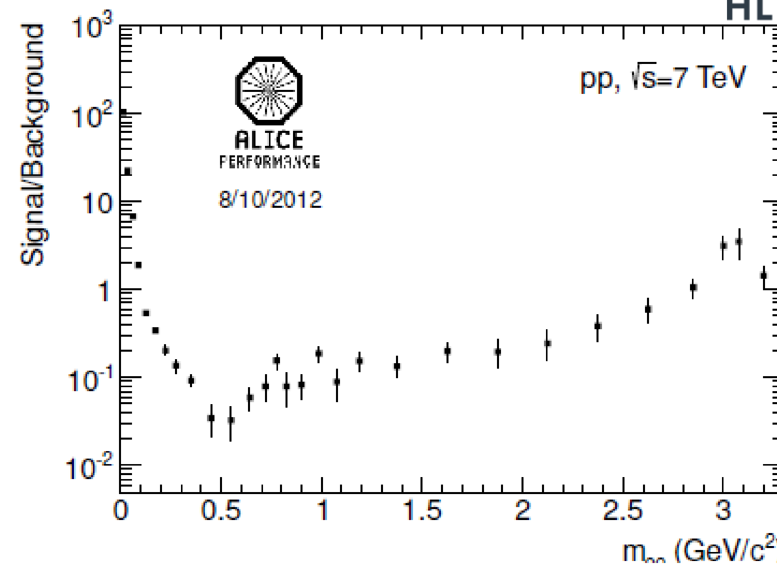
- efficiency correction for detector effects (including Bremsstrahlung in material)
- no acceptance correction into unmeasured region of phase space
- correction based on full MonteCarlo simulations
- efficiency determined for single electron tracks as function of (p_T, η, φ)

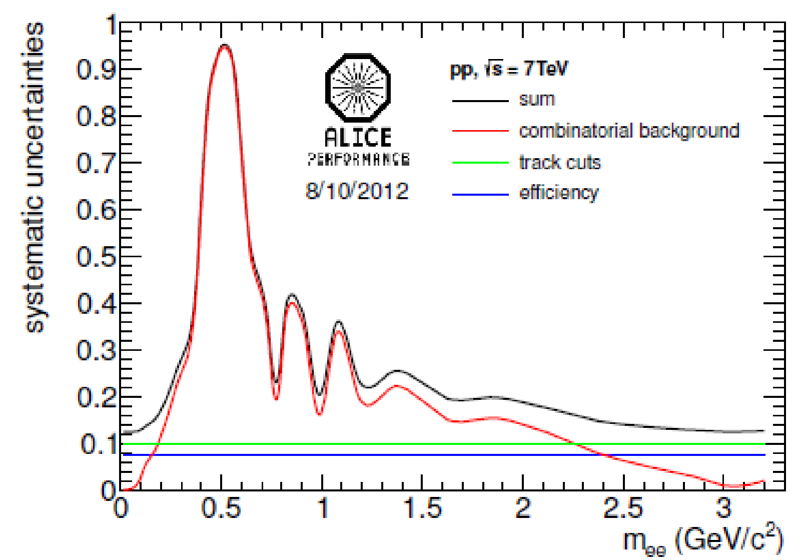
Systematic uncertainties

- 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 GeV/c^2!



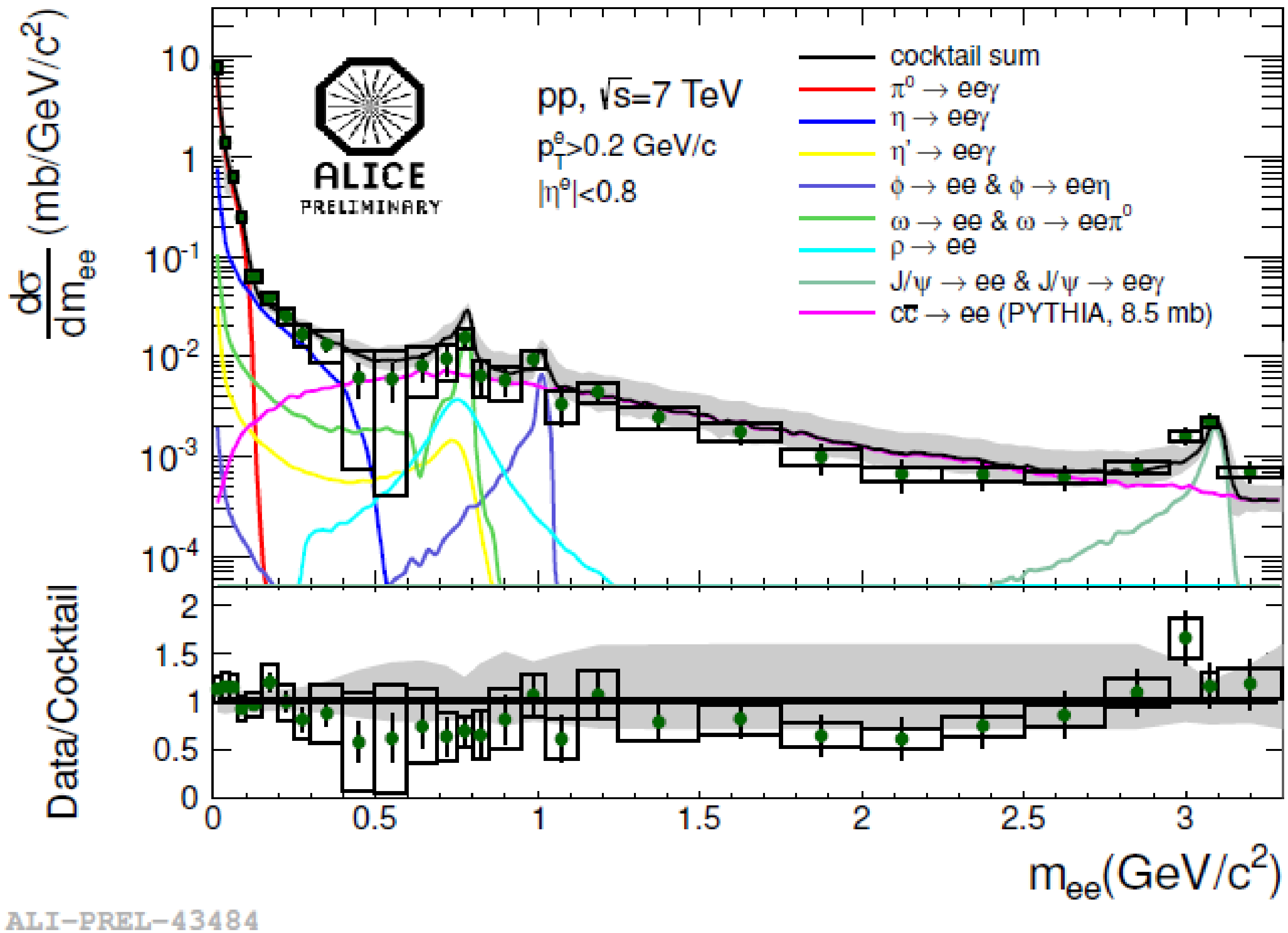


ALI-PERF-43375

Known hadronic e^+e^- sources

- calculation of hadronic cocktail
  - based on:
    measured p_T-differential invariant cross section of π^0
  - contributions from other hadron decays:
    from data (η, ϕ, J/ψ) or via m_T scaling
  - contribution from correlated charm decays:
    from measured charm cross section and
    PYTHIA decay kinematics
- ALICE data used as input
  - π^0, η: Phys. Lett. B717 (2012) 162
  - ϕ: arXiv:1208.5717
  - σ_{cc}: arXiv:1205.4007
  - J/ψ: Phys. Lett. B704 (2011) 442

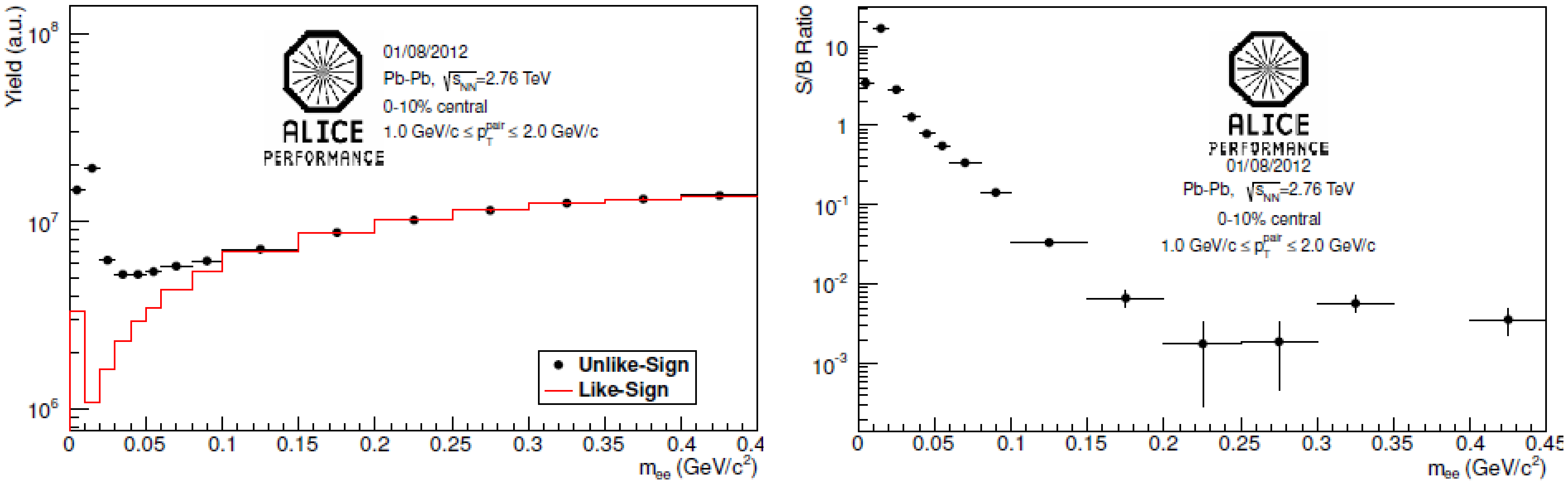
Cocktail versus data



- 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 √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 $\sqrt{s}$ = 7 TeV
- hadronic cocktail calculation agrees within errors with data in the range $0 < m_{ee} < 3.3$ GeV/c^2
- 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?

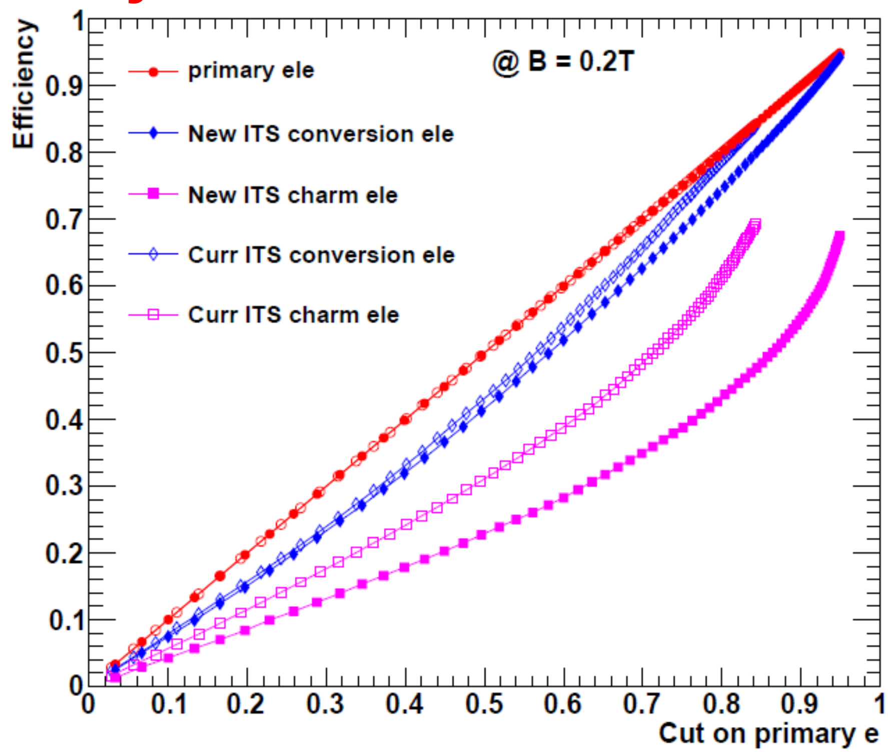
ALICE upgrade - LOI

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

http://cdsweb.cern.ch/record/1475244

Dielectron strategy

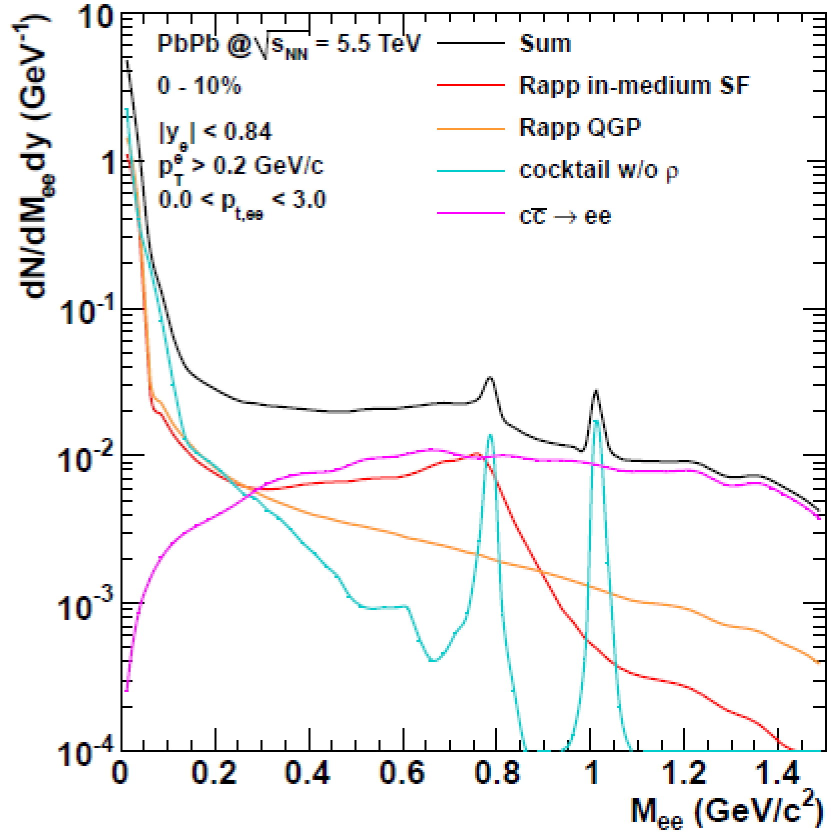
- reduction of central barrel magnetic field from 0.5 T to 0.2 T
  - extend tracking efficiency and electron PID to lower p_T
- high rate upgrade of the TPC
  - improve the data taking rate by a factor 100
- upgrade of the ITS
  - reduced material budget
  - improve tracking efficiency at very low p_T
  - improve capability to identify electrons originating from secondary vertices (DCA cut)



Dielectron performance study

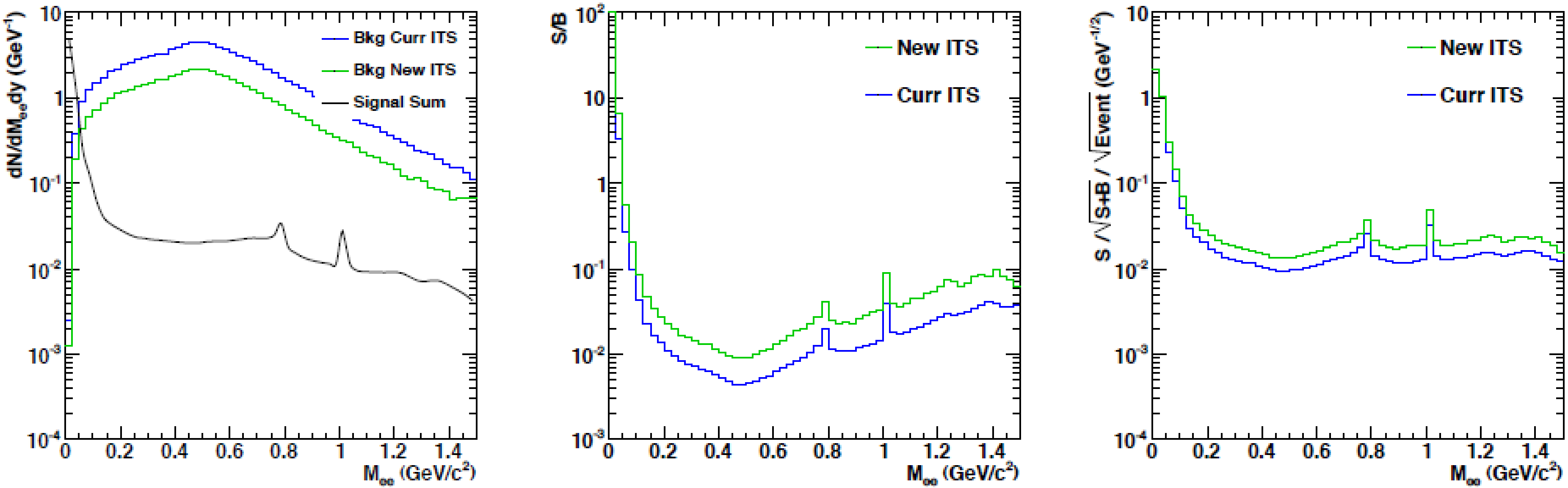
ALICE

- here: focus on 10% most central Pb-Pb collisions ($\langle dN_{ch}/d\eta \rangle = 1750$) 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)



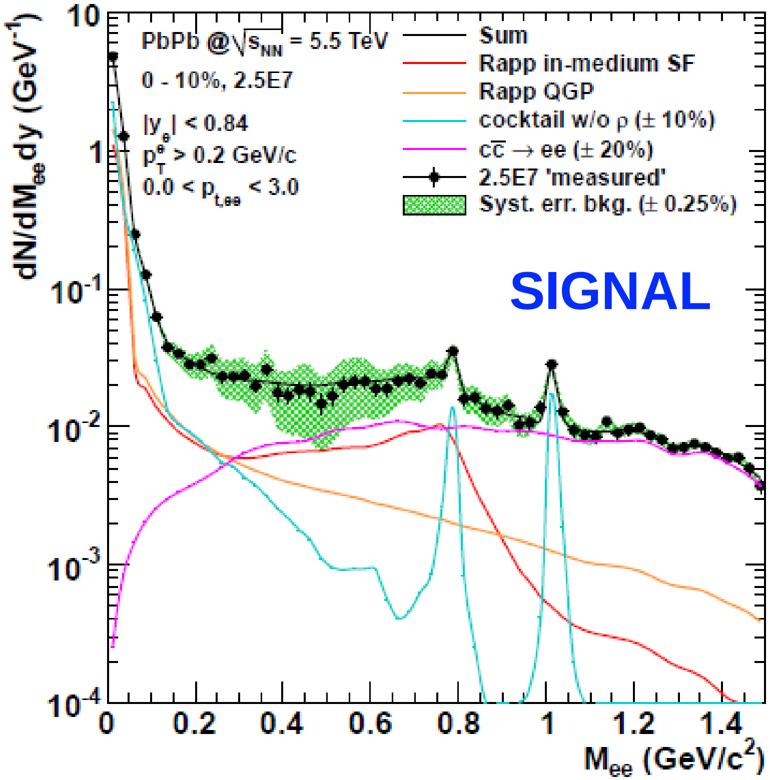
Dielectron performance study

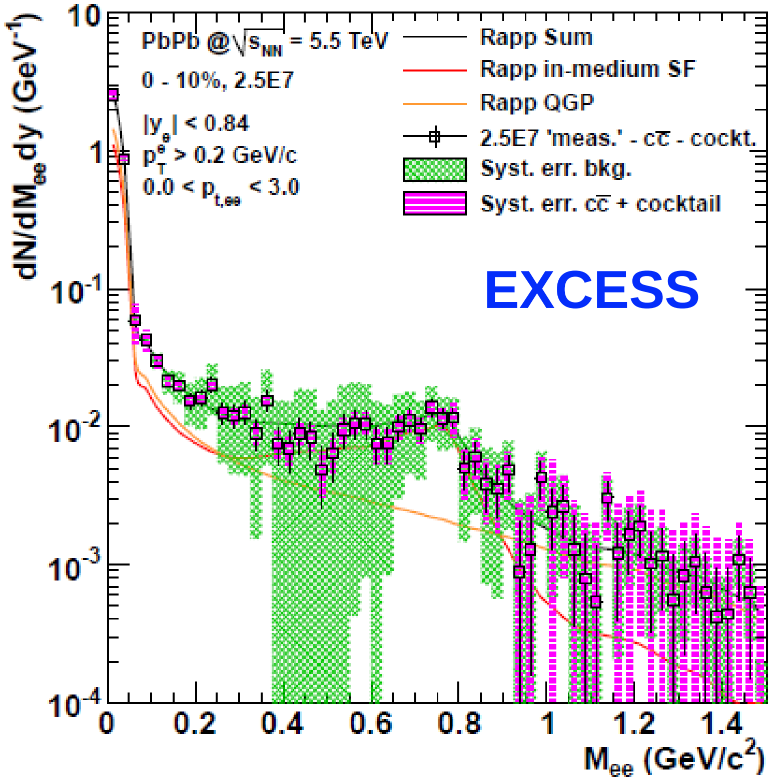
- background
  - PYTHIA pp events superimposed to Pb-Pb <$dN_{ch}/d\eta$>
  - photon conversions from GEANT3
- kinematic cuts
  - $|\eta_e| < 0.84$, $p_{T,e} > 0.2$ (0.06) GeV/c for global (ITS) tracking
- conversion and Dalitz rejection
  - $m_{ee} < 50$ MeV/c^2, opening angle < 100 mrad



Current ITS, no DCA cut

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

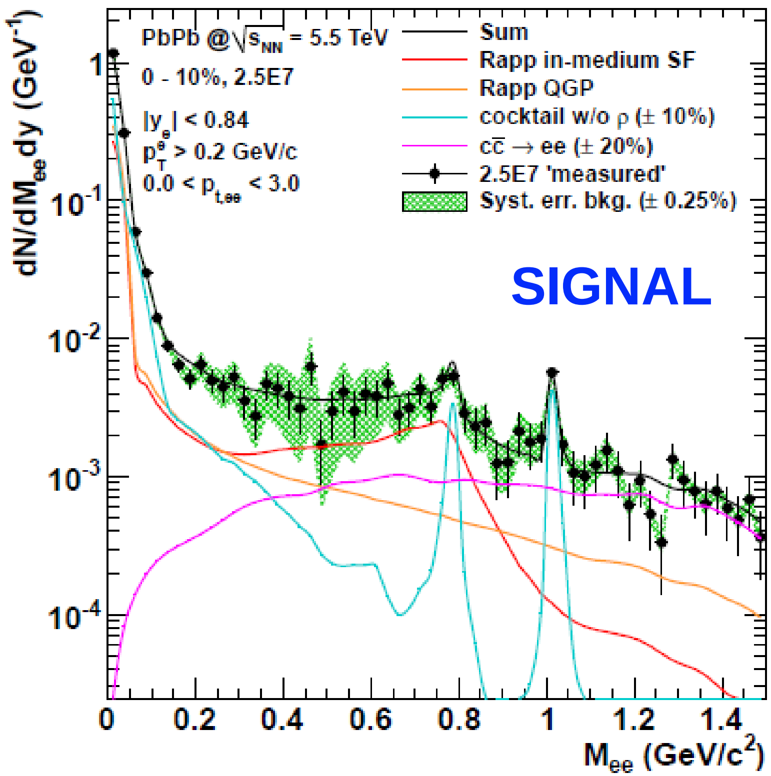


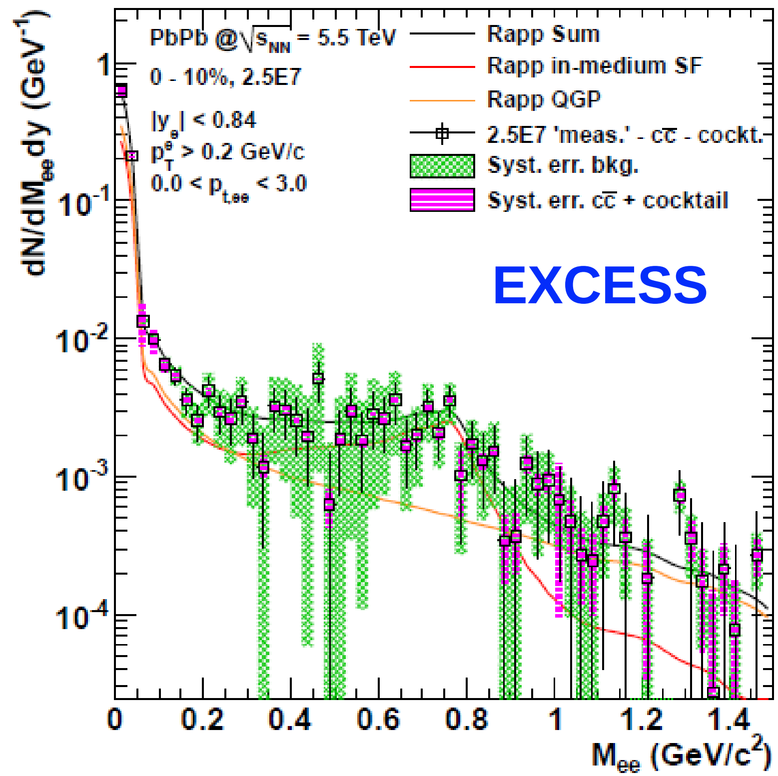


→ no quantitative access to in-medium spectral functions and thermal dielectron emission

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)

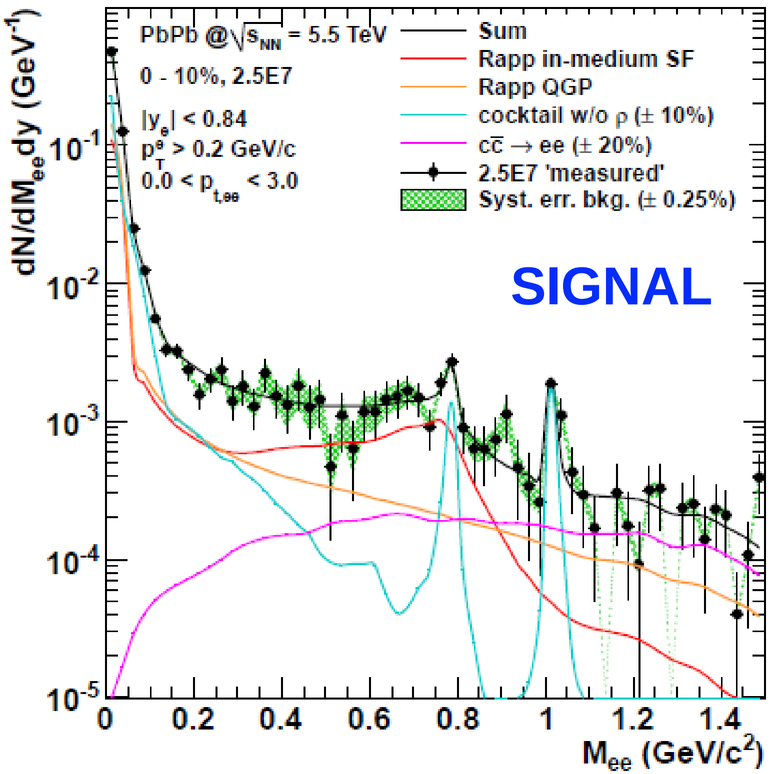


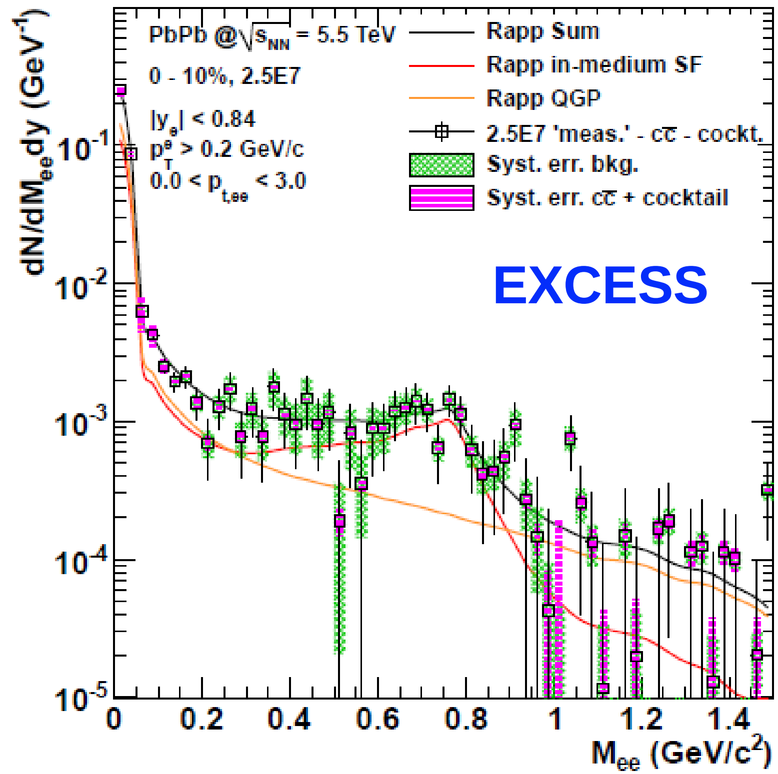


→ marginal improvement only

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)

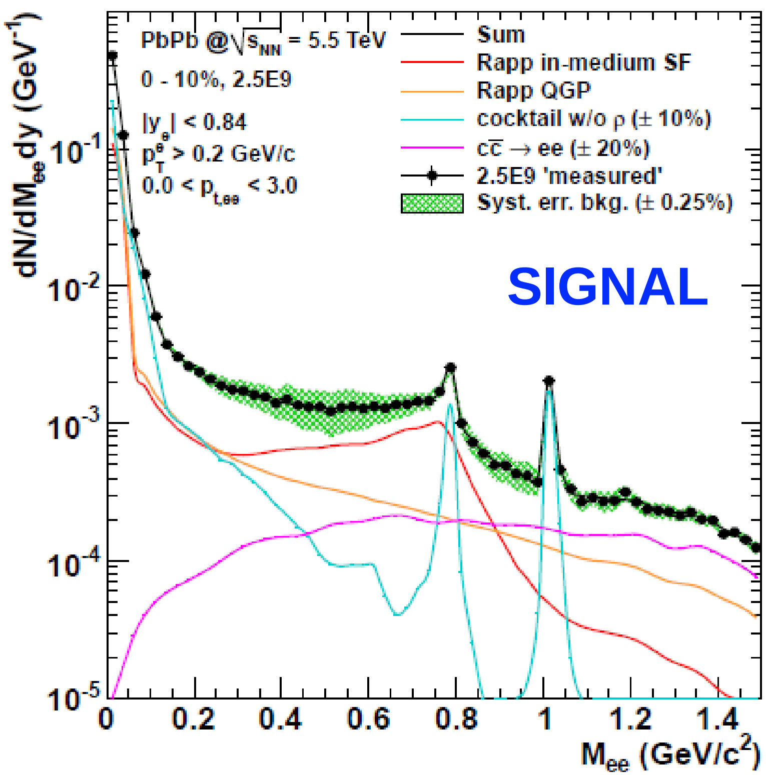


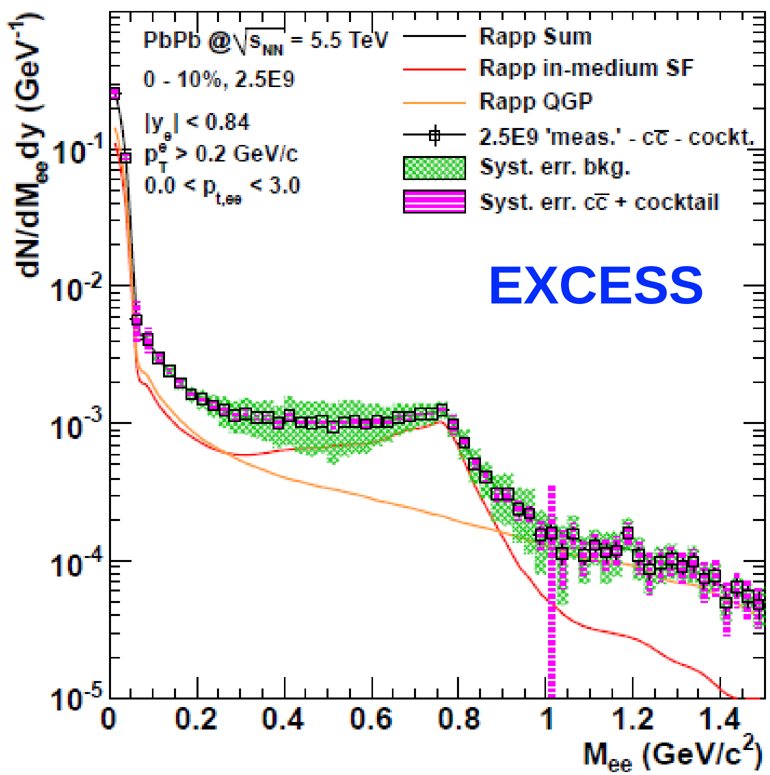


→ significantly reduced systematics, but statistics limited

New ITS, DCA cut, high rate

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





→ **quantitative access to dielectron production beyond hadronic cocktail and correlated charm decays!**

Summary II

- precision measurement of dielectron poduction in Pb-Pb collisions at the LHC beyond the hadronic cocktail and correlated charm decays:
  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
  → improved Signal/Background ratio
  → reduced sys. uncertainty of e^+e^- measurement
- high rate upgrade of the TPC
  → reduced stat. uncertainty of e^+e^- measurement

ALICE upgrade
→ precision low-mass dielectron measurement