Dielectron measurements in pp, p-Pb and Pb-Pb collisions with ALICE at the LHC

Markus K. Köhler
for the ALICE collaboration

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

May 19, 2014

XXIV QUARK MATTER
DARMSTADT 2014

Motivation

Dielectrons: a penetrating probe of the medium

- ▶ Production cross section accessible in m_{ee} and p_{T}^{ee}
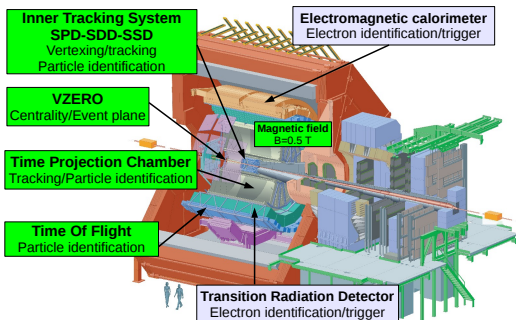- ▶ Reflect entire space-time evolution of heavy-ion collisions

- ▶ Sensitivity on microscopic (m_{ee}) and macroscopic (p_{T}^{ee}) properties of the medium
- ▶ Disentanglement of vacuum and medium sources
- ▶ Understanding of pp and p–Pb spectra necessary to evaluate Pb–Pb measurements
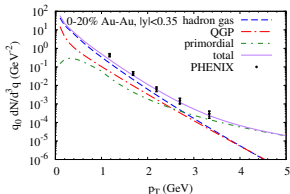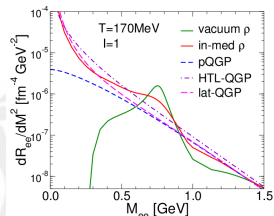
R. Rapp, 1306.6394
H.v. Hees, C. Gale, R. Rapp, Phys. Rev. C 84, 054906 (2011)

A Large Ion Collider Experiment

Data samples for this analysis (events)

pp, $\sqrt{s} = 7$ TeV

- ▶ 3.5×10^8 (min. bias)

p–Pb, $\sqrt{s_{NN}} = 5.02$ TeV

- ▶ 1.1×10^8 (min. bias)

Pb–Pb, $\sqrt{s_{NN}} = 2.76$ TeV

- ▶ 16×10^6 $(0 - 10\%)$
- ▶ 11×10^6 $(20 - 50\%)$

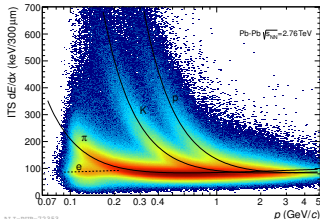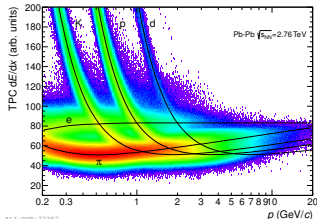|	
coverage of central barrel	$0 < \varphi < 2\pi \qquad |\eta| < 0.9$
mass resolution ($m_{ee} \lesssim 4$ GeV/c^2)	$\Delta m_{ee}/m_{ee} \approx 1\%$

Electron Identification

Inner Tracking System
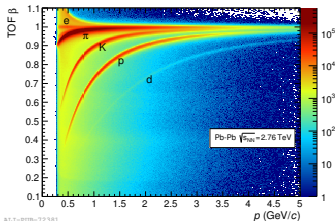$\sigma_{dE/dx} \approx 12\ \%$

Time Projection Chamber
$\sigma_{dE/dx} \approx 5 - 8\ \%$

Time-Of-Flight detector
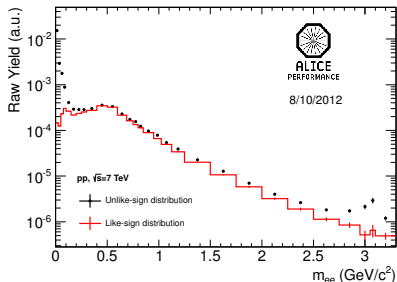$\sigma_T \approx 80 - 120$ ps
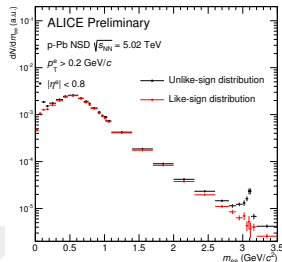

ALICE Performance paper, arXiv:1402.4476

- ▶ TPC ($p_T > 0.2$ GeV/c)
  → pion rejection
- ▶ ITS ($p_T > 0.2$ GeV/c)
- ▶ TOF ($p_T > 0.4$ GeV/c)
  → kaon/proton rejection
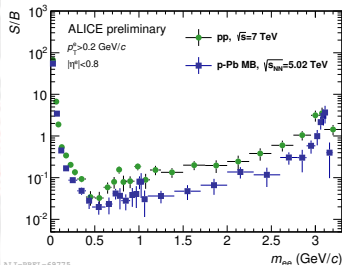- ▶ Hadronic contamination
  → 1(pp) − 7(Pb–Pb) %

Combinatorial background

$$N_{+-}^{\text{CombBkg}} = 2\sqrt{N_{++}N_{--}} \times \frac{B_{+-}}{2\sqrt{B_{++}B_{--}}}$$

$N \to$ real events
$B \to$ mixed events

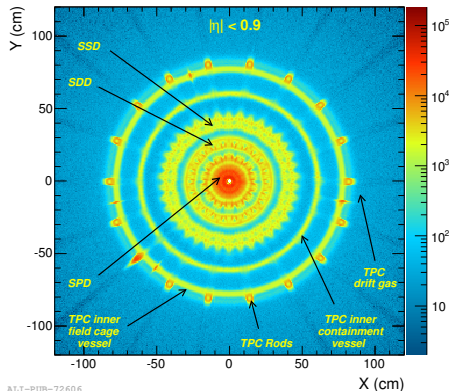$S/N_{+-}^{\text{CombBkg}}$ at 0.5 GeV/c^2
pp : $3 - 4$ %
p–Pb : $1.5 - 2$ %
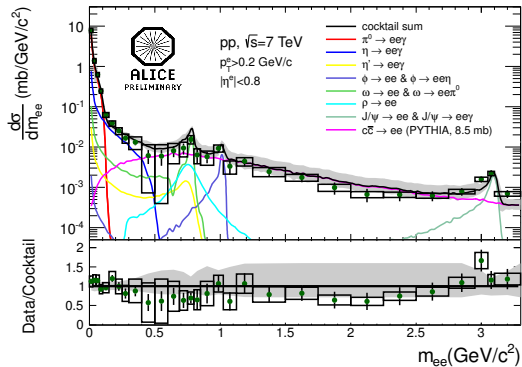
Photon conversions

Two independent ways to identify photon candidates

1. Displaced vertex
2. Dielectron pair plane orientation with respect to magnetic field

- Contamination of photon conversions a few percent in the low-mass region ($m_{ee} \lesssim 0.1$ GeV/c^2)

Mass continuum in pp collisions

ALI-PREL-43484

Hadronic cocktail

- ► Tsallis parametrization of π^0, η, ϕ and J/ψ
- ► Other mesons: m_T scaling
- ► $c\bar{c}$ dynamics from PYTHIA
- ► $c\bar{c}$ normalized to measured cross section
- ► Systematic uncertainty determined by systematic uncertainty of input spectra

- ► Hadronic cocktail is consistent with data for p_T-integrated dielectron spectrum

Dielectron sources beyond the hadronic cocktail

▶ Kroll-Wada equation relates the dielectron mass to the virtual direct photon production rate

▶ for $p_T^{ee} \gg m_{ee} \rightarrow$ $\boxed{\frac{1}{N_\gamma} \frac{\mathrm{d}N_{ee}}{\mathrm{d}m_{ee}} = \frac{2\alpha_{e.m.}}{3\pi} \sqrt{1 - \frac{4m_e^2}{m_{ee}^2}} \left(1 + \frac{2m_e^2}{m_{ee}^2}\right) \frac{1}{m_{ee}}}$

▶ Kroll-Wada like mass distribution filtered through acceptance
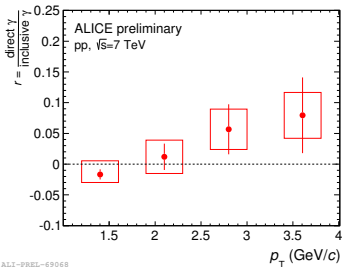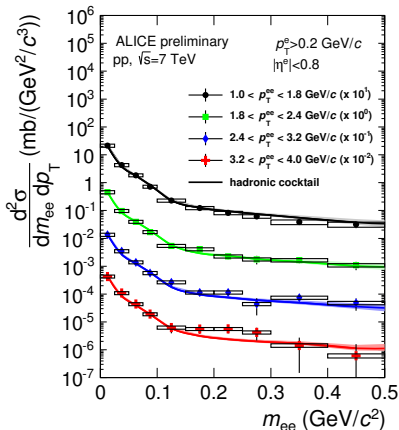$p_T > 0.2$ GeV/c and $|\eta| < 0.8$
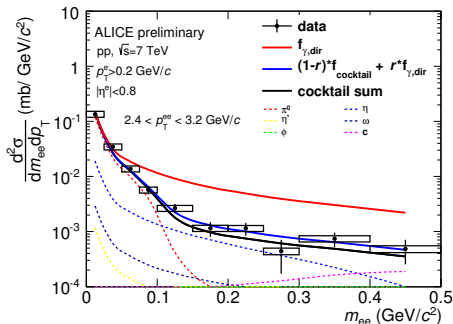
ALI-PREL-69064

Shape comparison

▶ Assume internal conversion of direct photons

▶ Fit function
$f_{comb} = (1-r) \times f_c + r \times f_{\gamma,\mathrm{dir}}$
$f_c \quad \rightarrow$ cocktail
$f_{\gamma,\mathrm{dir}} \rightarrow$ photon input from Kroll-Wada equation

▶ Fit parameter r reflects the ratio of direct over inclusive photons

Extraction of direct photon fraction vs p_T

- ▶ Fit mass spectra in p_T bins
- ▶ Systematic uncertainty on r: refit spectra distorted by systematic uncertainties of data and cocktail
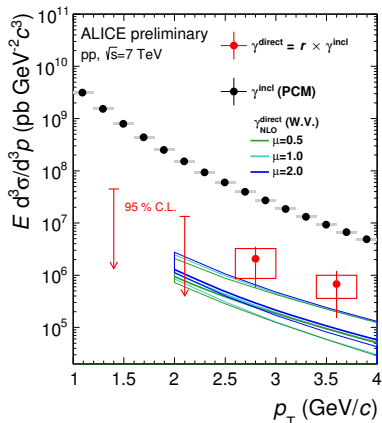

ALICE preliminary
pp, $\sqrt{s}$=7 TeV

ALI-PREL-69068

ALICE preliminary
pp, $\sqrt{s}$=7 TeV

p_T^e>0.2 GeV/c
|η^e|<0.8

- $1.0 < p_T^{ee} < 1.8$ GeV/c (x 10^1)
- $1.8 < p_T^{ee} < 2.4$ GeV/c (x 10^0)
- $2.4 < p_T^{ee} < 3.2$ GeV/c (x 10^{-1})
- $3.2 < p_T^{ee} < 4.0$ GeV/c (x 10^{-2})
- hadronic cocktail

ALI-PREL-69060

- ▶ Under the condition

  $$\gamma_{\mathrm{dir}}/\gamma_{\mathrm{incl}} = \gamma_{\mathrm{dir}}^*/\gamma_{\mathrm{incl}}^*$$

  direct photon spectrum can be calculated by

  $$\rightarrow \boxed{\gamma_{\mathrm{dir}} = r \times \gamma_{\mathrm{incl}}}$$

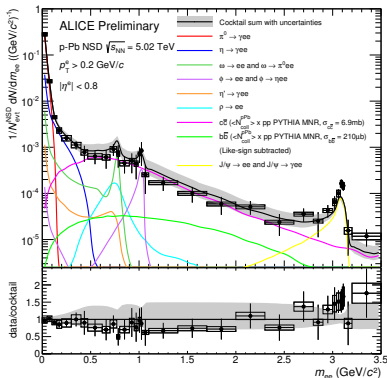# Direct photon p_{T} spectrum in pp collisions

ALI-PREL-69076

- $\gamma_{\mathrm{dir}} = r \times \gamma_{\mathrm{incl}}$
- Inclusive photon spectrum measured via photon conversion method

  F. Bock, Talk today 15.00
- Arrows indicate upper limits at $95\ \%$ confidence level

- pQCD NLO calculations consistent with direct photon production

Mass continuum in p–Pb collisions

T. Bröker, Poster G-06


ALI-PREL-69715

Hadronic cocktail

- ► Tsallis parametrization for π^0 and η
- ► Other mesons: m_T scaling
- ► $c\bar{c}$ and $b\bar{b}$ dynamics from PYTHIA
- ► $c\bar{c}$ and $b\bar{b}$ cross sections measured in pp and scaled by N_{coll}
- ► Systematic uncertainty determined by systematic uncertainty of input spectra

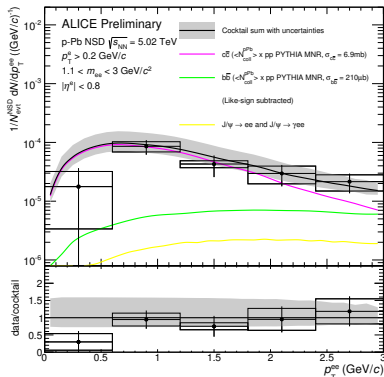- ► Hadronic cocktail is consistent with dielectron data over mass range $0 < m_{ee} < 3.5$ GeV/c^2

Transverse momentum spectra in p–Pb collisions

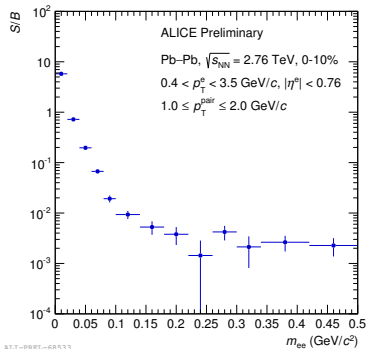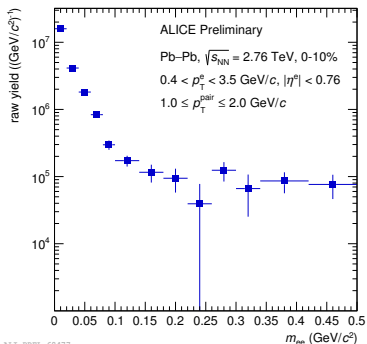T. Bröker, Poster G-06
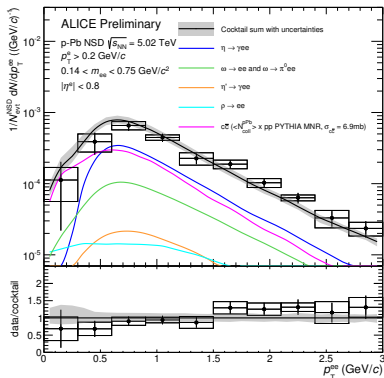
$0.14 < m_{ee} < 0.75$ GeV/c^2 $\qquad\qquad$ $1.1 < m_{ee} < 3.0$ GeV/c^2

▶ Hadronic cocktail consistent with dielectron data

Dielectron measurements in Pb–Pb collisions

A. Caliva & P. Reichelt, Poster G-22

- Small S/B ratio requires a precise determination of the background shape and normalization $\rightarrow$ Work in progress
- Focus is on virtual photon production

Summary, conclusions and outlook

pp collisions at $\sqrt{s} = 7$ TeV

- ▸ Hadronic cocktail consistent with mass spectrum
- ▸ pQCD NLO calculations consistent with direct photon production

p–Pb collisions at $\sqrt{s_{\mathrm{NN}}} = 5.02$ TeV

- ▸ Hadronic cocktail consistent with mass spectrum and p_{T} spectra

Pb–Pb collisions at $\sqrt{s_{\mathrm{NN}}} = 2.76$ TeV

- ▸ Work in progress $\rightarrow$ Stay tuned

Outlook

- ▸ Analysis of TRD and EMCal triggered data
- ▸ Significant reduction of statistical uncertainties in Run2
- ▸ Upgrade of ALICE central barrel will allow detailed measurement after second long shut-down (> 2018)

  T. Gunji, Talk Wednesday 12.30

Summary, conclusions and outlook

pp collisions at $\sqrt{s} = 7$ TeV

- ▶ Hadronic cocktail consistent with mass spectrum
- ▶ pQCD NLO calculations consistent with direct photon production

p–Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV

- ▶ Hadronic cocktail consistent with mass spectrum and p_T spectra

Pb–Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV

- ▶ Work in progress $\rightarrow$ Stay tuned

More posters on dielectrons

- ▶ Low-mass resonances in pp collisions | M. Özdemir, J-10
- ▶ Analysis of TRD triggered data in p–Pb collisions | S. Hayashi, G-16
- ▶ Dielectron v_2 analysis in Pb–Pb collisions | H. Yang, G-29
- ▶ Strong magnetic field measurement via virtual photon polarization in Pb–Pb collisions | K. Shigaki et al., G-23
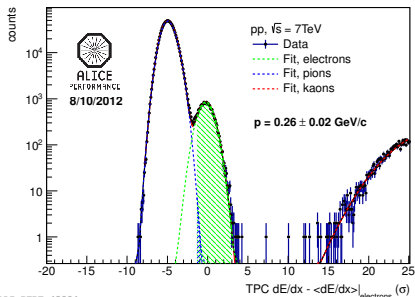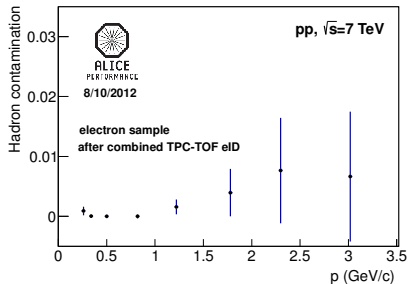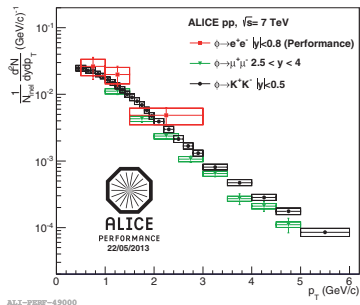
BackUp

ALICE in detail
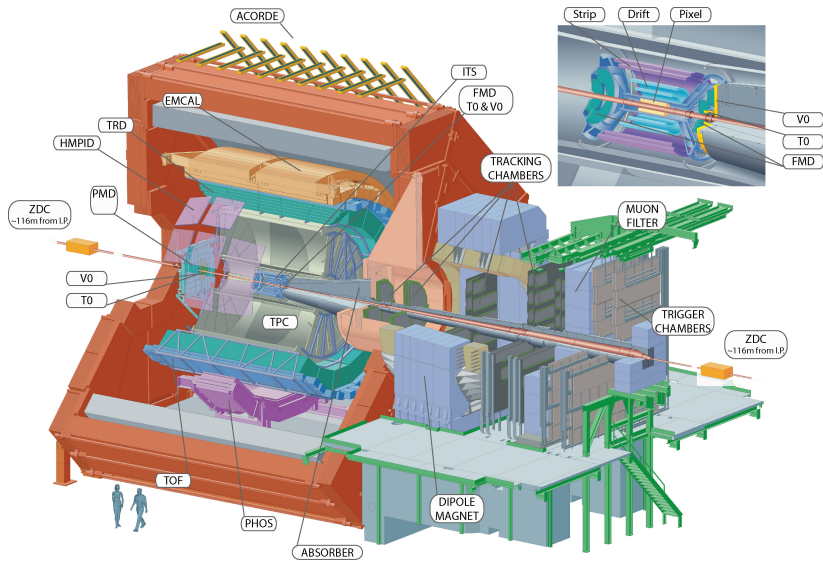
Hadron contamination
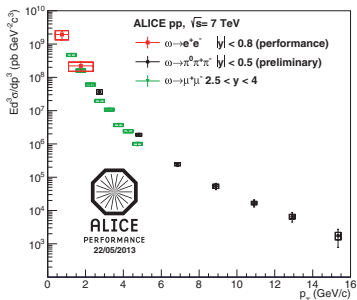

- About 1 % misidentified electrons at most
- negligible amount to be subtracted by combinatorial background

Vector meson ω and ϕ transverse momentum spectra in pp collisions

M. Özdemir, Poster J-10

► Transverse momentum spectra of low-mass resonances in the dielectron channel consistent with other decay channels

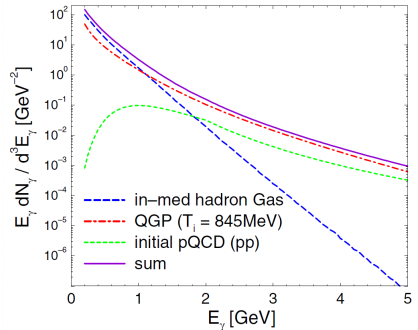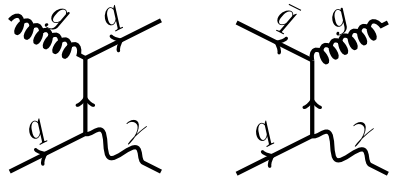# Direct photon production in pp and Pb–Pb

Direct photons – definition

Photons, that are not produced by particle decays

Predominant sources in pp

- ▶ Quark-gluon scattering
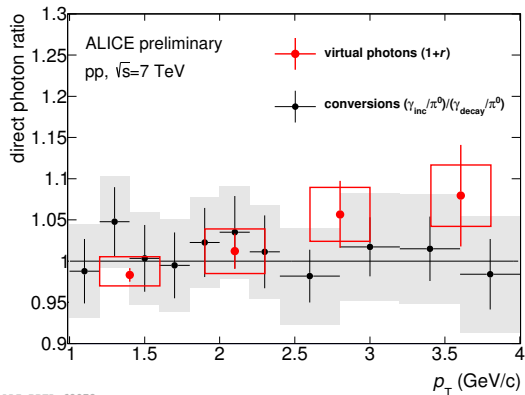- ▶ Quark-antiquark annihilation

Predominant source in Pb–Pb

- ▶ Jet-Medium interaction
- ▶ Thermal photons (QGP, HHG)

ALICE PPR, 2006 J. Phys. G: Nucl. Part. Phys. 32 1295

Direct photon ratio in comparison to photon conversion results
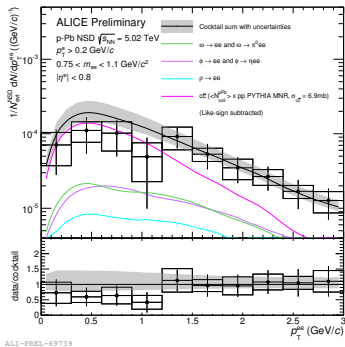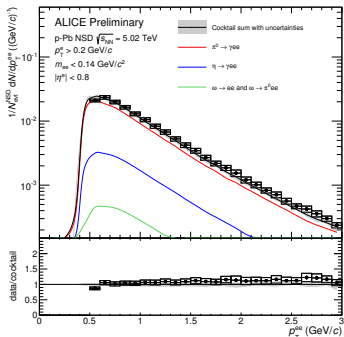

ALI-PREL-69072

▶ Nice agreement between the two measurements

Transverse momentum spectra in p–Pb collisions (2)
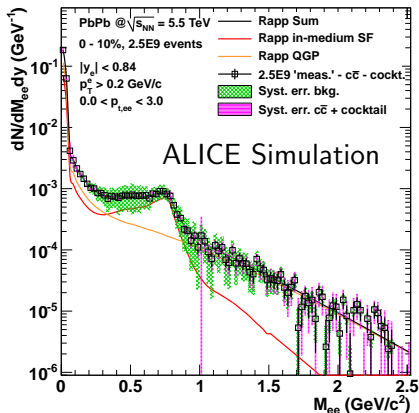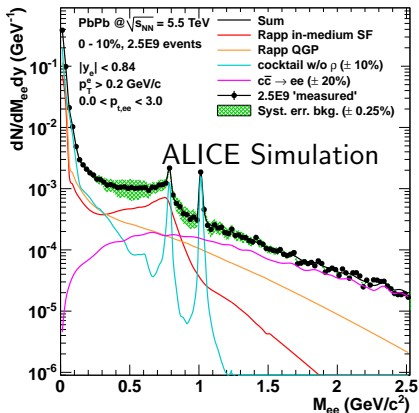
T. Bröker, Poster G-06

$m_{ee} < 0.14$ GeV/c^2 $\qquad\qquad$ $0.75 < m_{ee} < 1.1$ GeV/c^2

ALI-PREL-69723

ALI-PREL-69739

▶ Hadronic cocktail consistent with dielectron data

The ALICE central barrel upgrade

Signal and excess

Letter of Intent for the Upgrade of the ALICE Experiment,

CERN-LHCC-2012-012 ; LHCC-I-022