Soft QCD Regime at the LHC: Light Dimuon Resonances in ALICE

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Outline

- Physics Motivations
- The ALICE detector
- Low Mass Dimuons in pp: 7 TeV and 2.76 TeV
- Low Mass Dimuons in Pb-Pb
- Outlook

Light Vector Mesons in pp and Heavy Ion Collisions

Low mass vector meson (ρ, ω, ϕ) production provides key information on the hot and dense state of strongly interacting matter which is produced in high-energy heavy-ion collisions. Insights on **non-perturbative QCD** are provided:

- Strangeness production investigated via ϕ meson production
- In-medium modifications of hadron properties accessed through ρ spectral function: possible link to chiral symmetry restoration

Why dimuons (= virtual photons)? They are not affected by in-medium effects: information from the deconfined volume is not distorted

Why measurements in pp (and in p-A!) collisions? Needed reference for correctly interpreting in-medium effects

Why measurements at the LHC? Unexplored energy regime, with a hotter and longer living deconfined medium

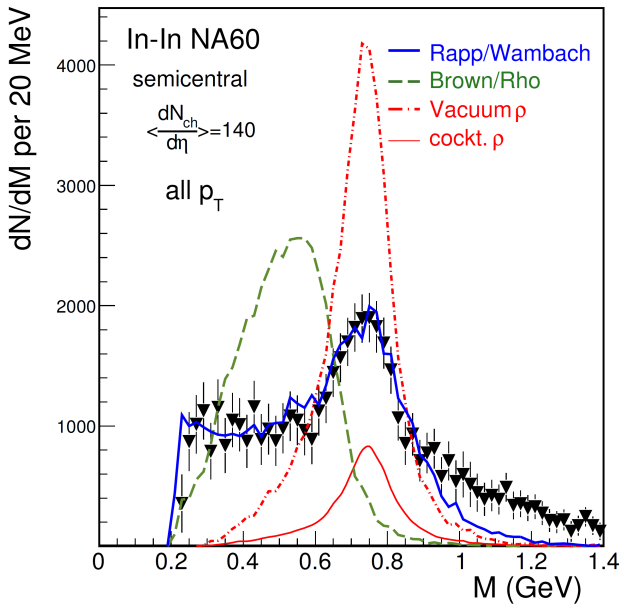
Low Mass Dimuons in QGP: Experimental Status

SPS: excess observed and studied by HELIOS-3, CERES/NA45 (dielectrons) and NA60 (dimuons)

RHIC: excess observed by PHENIX and STAR (dielectrons) with some inconsistencies between the two experiments. Theoretical models from Rapp et al. (cocktail + HG + QGP) and Cassing et al. (QGP radiation within the PHSD model)

LHC: work in progress . . .

http://dx.doi.org/10.1051/epjconf/20123600007



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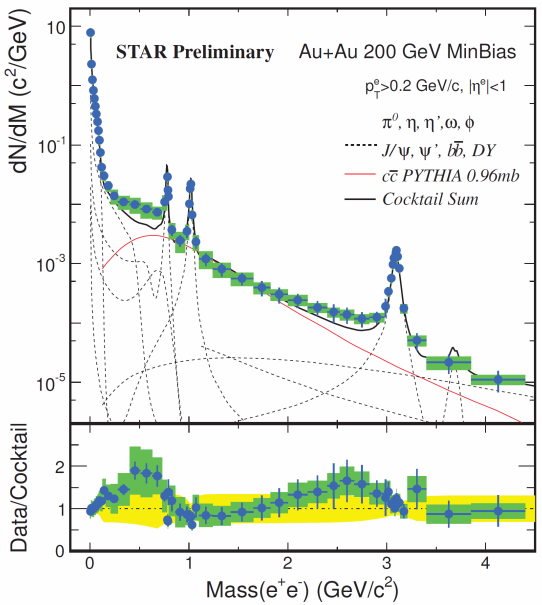

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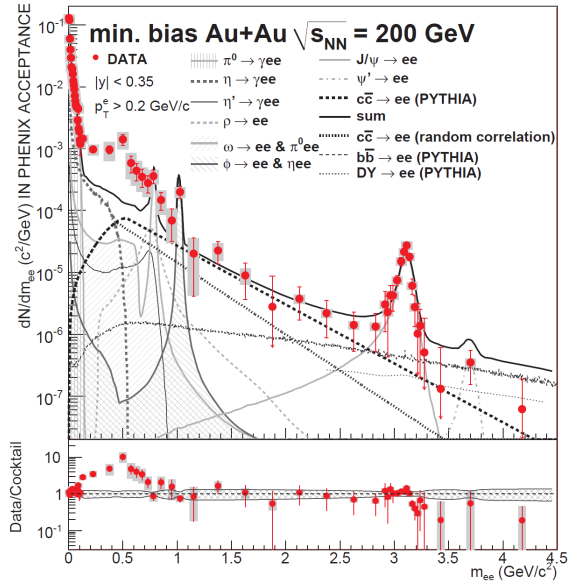


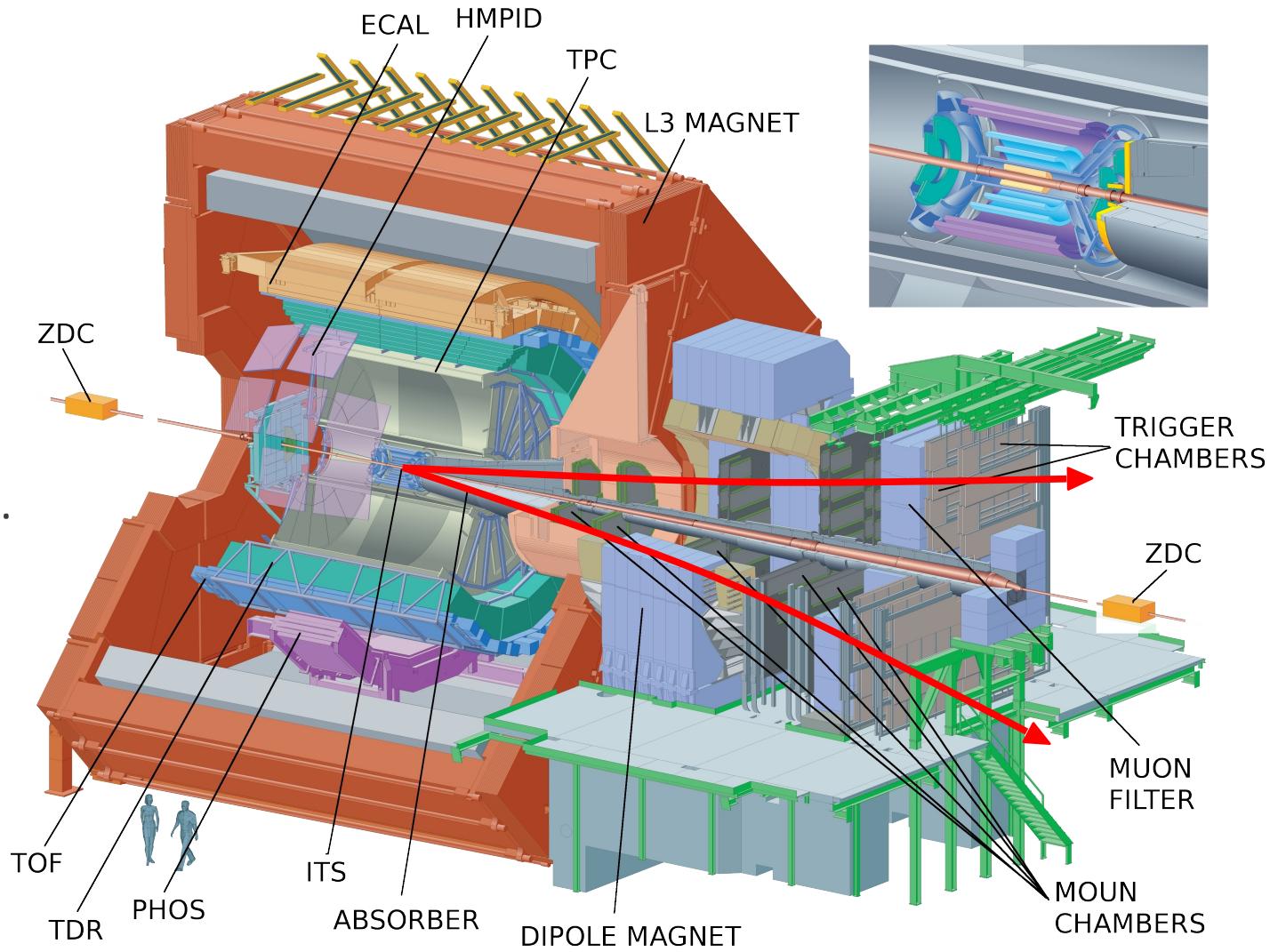
Dimuon Measurements in the ALICE Experiment

We measure light vector meson production in the **rapidity region 2.5 < y_{lab} < 4** via their dimuon decay channel

pp collisions measured at **7 TeV** and **2.76 TeV** in the c.m.

Pb-Pb collisions measured at **2.76 TeV** per nucleon pair in the c.m.

p-Pb and Pb-p collisions measured at **5.02 TeV** per nucleon pair in the c.m.



Low-Mass Dimuon Analysis Strategy

Event and track selection

- Cuts to eliminate beam-gas interactions
- Each muon track is required to match a muon trigger tracklet
- Cut on the acceptance borders: $2.5 < y < 4$
- (further cuts are applied depending on the sample analyzed)

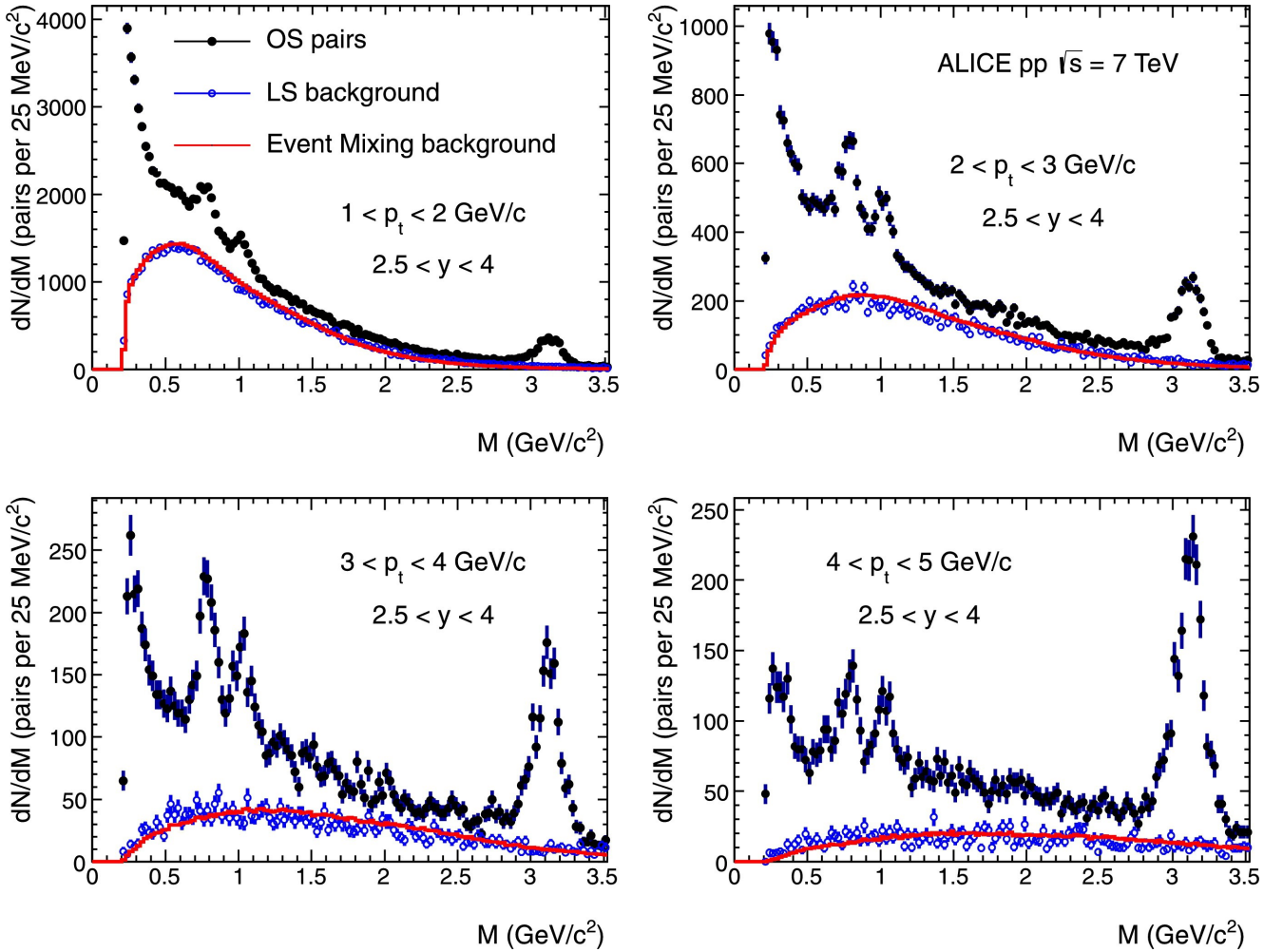
The combinatorial background is evaluated through event mixing

- Shape comes directly from the event mixing
- Normalization is fixed by comparing the Like Sign (LS) dimuon sample from the direct and the mixed data

Signal is compared with the superposition of the expected sources, given by means of realistic Monte Carlo simulations

Dimuon Results in pp @ 7 TeV: PLB 710 (2012)

Comparison between **raw data** and **combinatorial background** from mixing



Combinatorial Background not under control at very low p_T: **analysis is limited to p_T > 1 GeV/c**

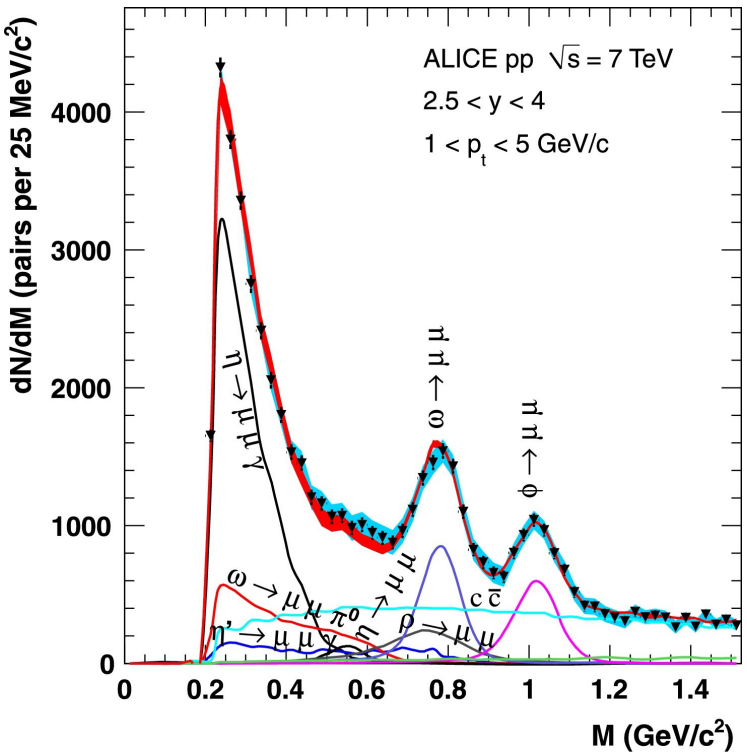
Two methods for evaluating the combinatorial background: evaluation solid enough for p_T > 1 GeV/c

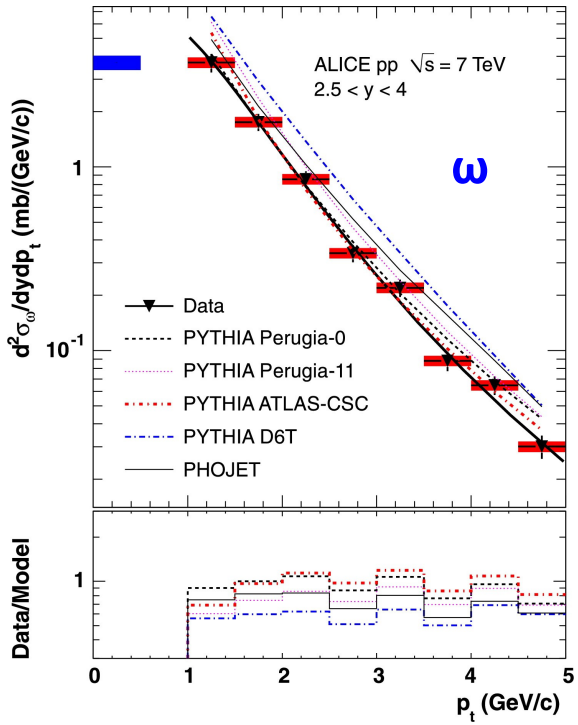
S/B ratio is ~ 1 at the ρ/ω and ϕ peaks for p_T > 1 GeV/c

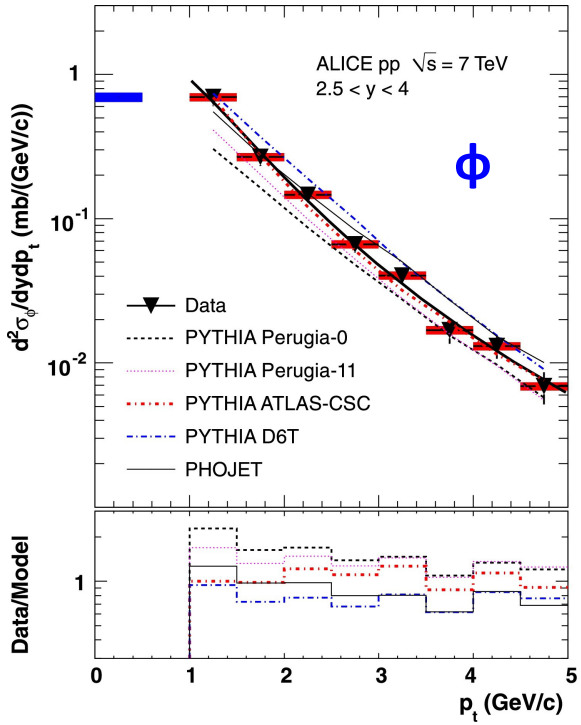
Dimuon Results in pp @ 7 TeV: PLB 710 (2012)

After the subtraction of the combinatorial background, **signal is compared with the expected MC sources:** hadronic cocktail + open charm/beauty

- Good agreement between data and MC
- p_T distributions are extracted for the ω and ϕ mesons: comparison is performed with several PYTHIA and PHOJET settings



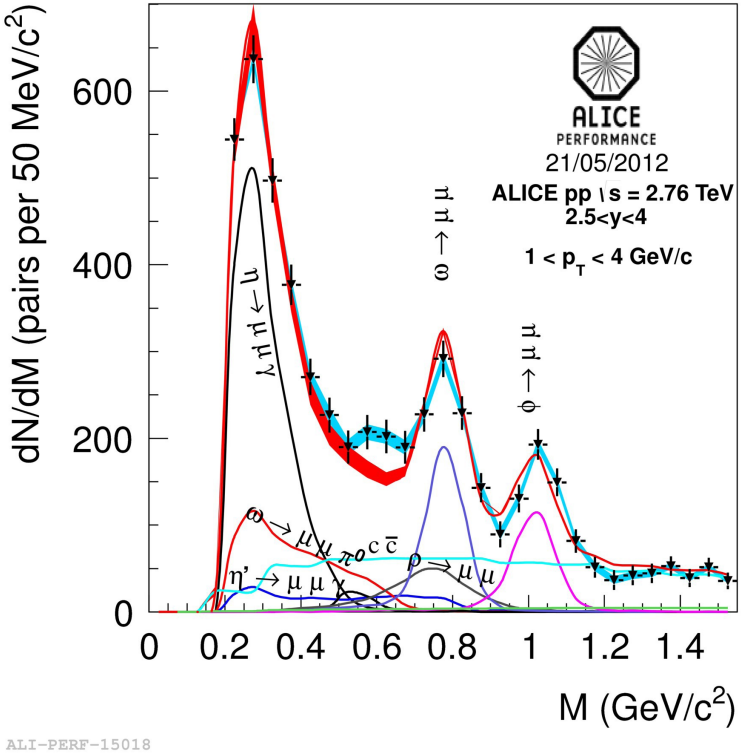


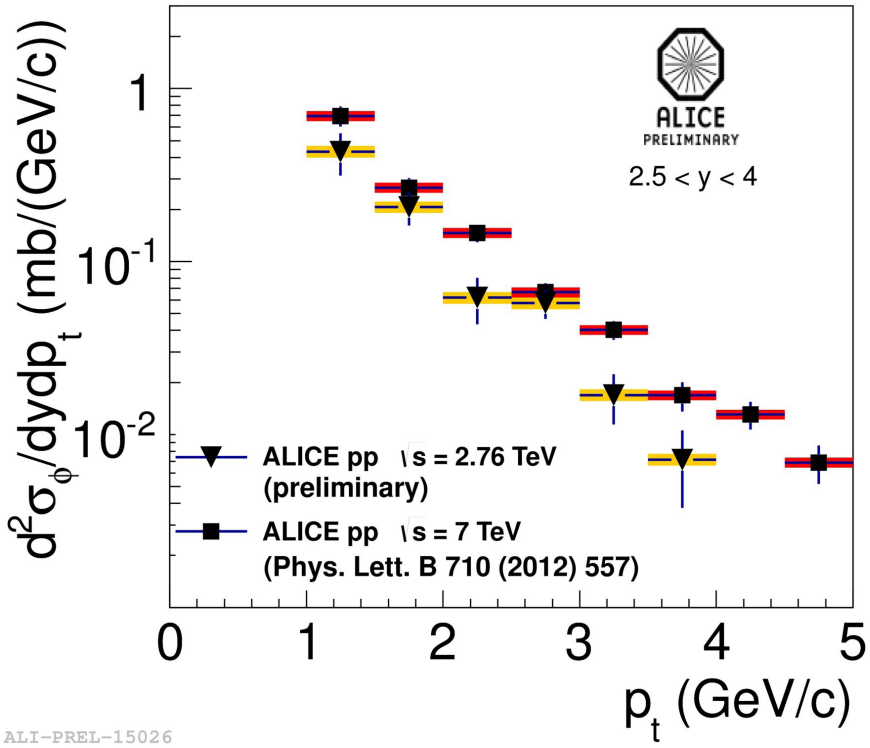


Dimuon Results in pp @ 2.76 TeV

Low mass dimuon production also studied at 2.76 TeV in the c.m.

- Baseline for the Pb-Pb measurements performed at the same energy
- Kinematics distribution for light mesons: comparison with 7 TeV Data
- Tension between data and MC around 0.6 GeV/c²: not fully understood, new 2013 data will clarify the point





Pb-Pb @ 2.76 TeV

This is the **first time** the production of low mass dimuons is being measured in Pb-Pb collisions at the LHC energies

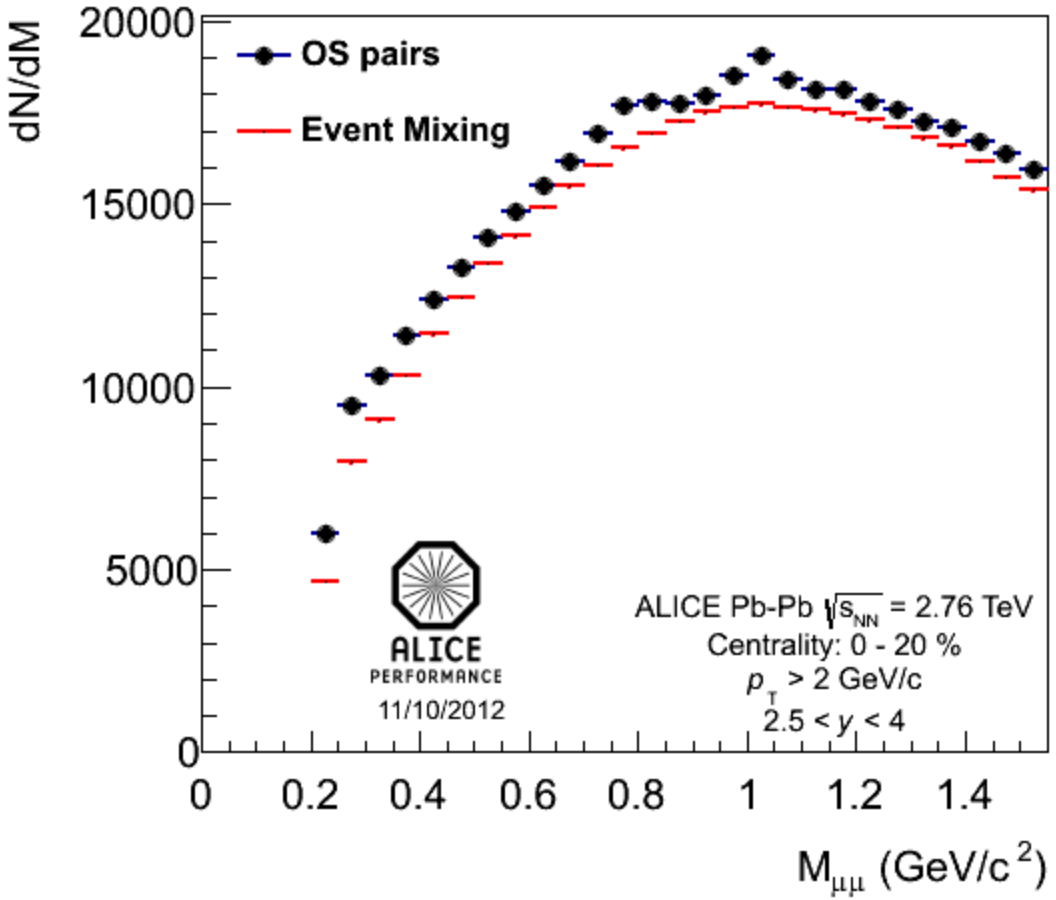
- Data collected in 2010 (statistics not sufficient to perform an analysis) and 2011 (data sample currently analyzed)
- Trigger scheme in 2011 not favorable for low mass dimuon measurements: hardware cut set at ~1 GeV/c for single muons. Dimuon analysis is limited to $p_T(\mu\mu) > 2$ GeV/c

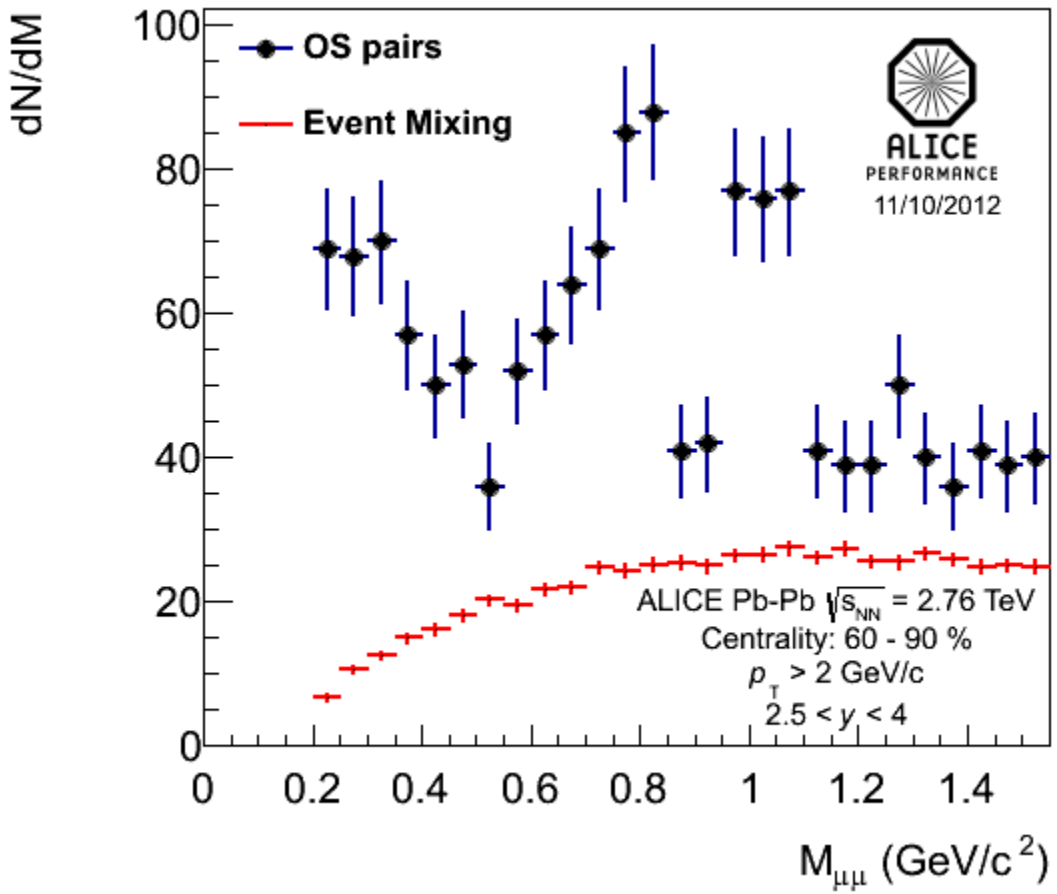
Combinatorial background level much larger than in proton-proton: event mixing must be carefully tuned

- Events are not blindly mixed: they are previously divided into **pools of events sharing similar global properties** (in particular, centrality and event plane orientation)
- **Stricter cuts already at the level of single muons selection:** sharp low p_T threshold at 0.85 GeV/c + additional cuts on the quality of the tracks

Pb-Pb @ 2.76 TeV: Raw Data and Background

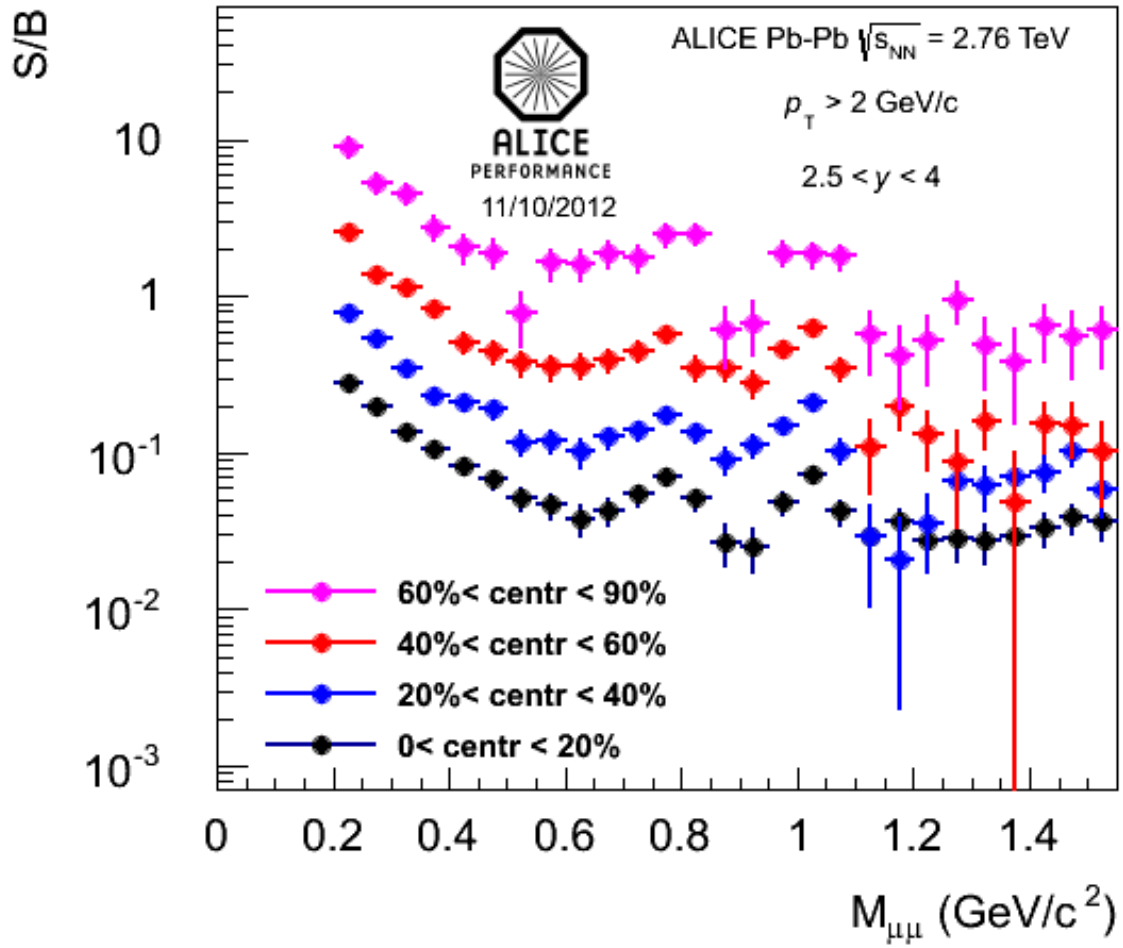
Invariant mass spectra for OS dimuons: **raw data** and **combinatorial background** from mixing, for central (0 – 20%) and peripheral (> 60%) collisions





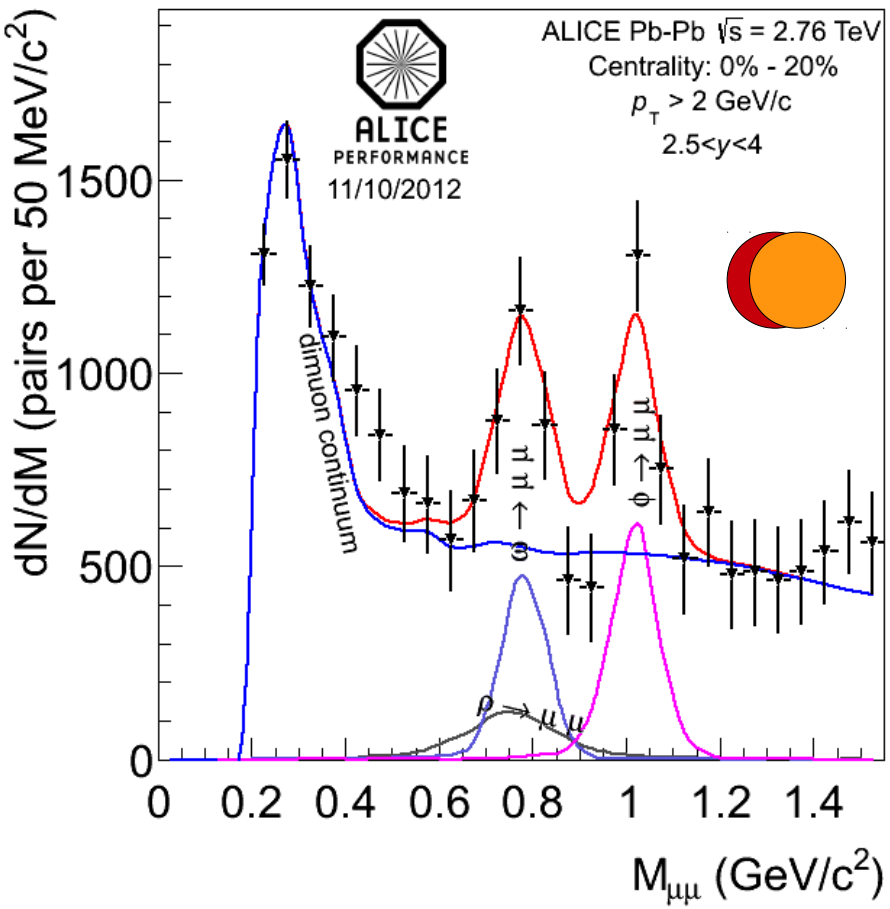
Pb-Pb @ 2.76 TeV: Signal/Background

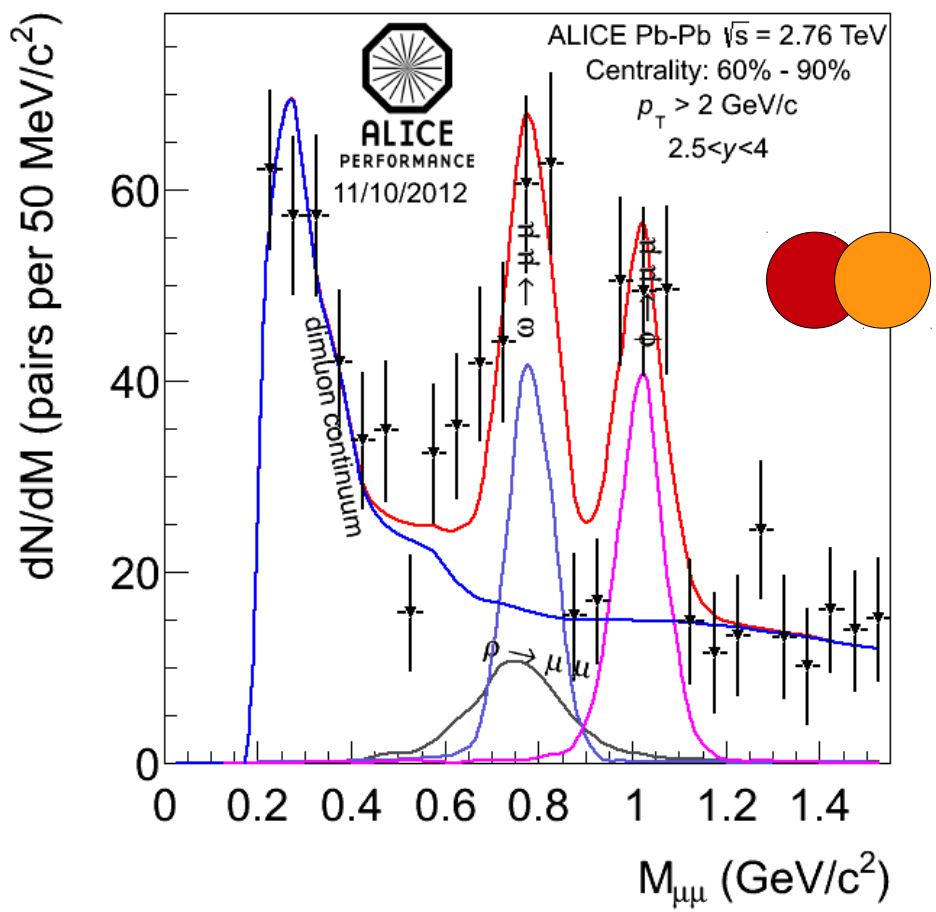
The signal/background ratio strongly depends on the centrality. S/B as low as few percent are typically found for the most central class of events



Pb-Pb @ 2.76 TeV: Fit to the Signal

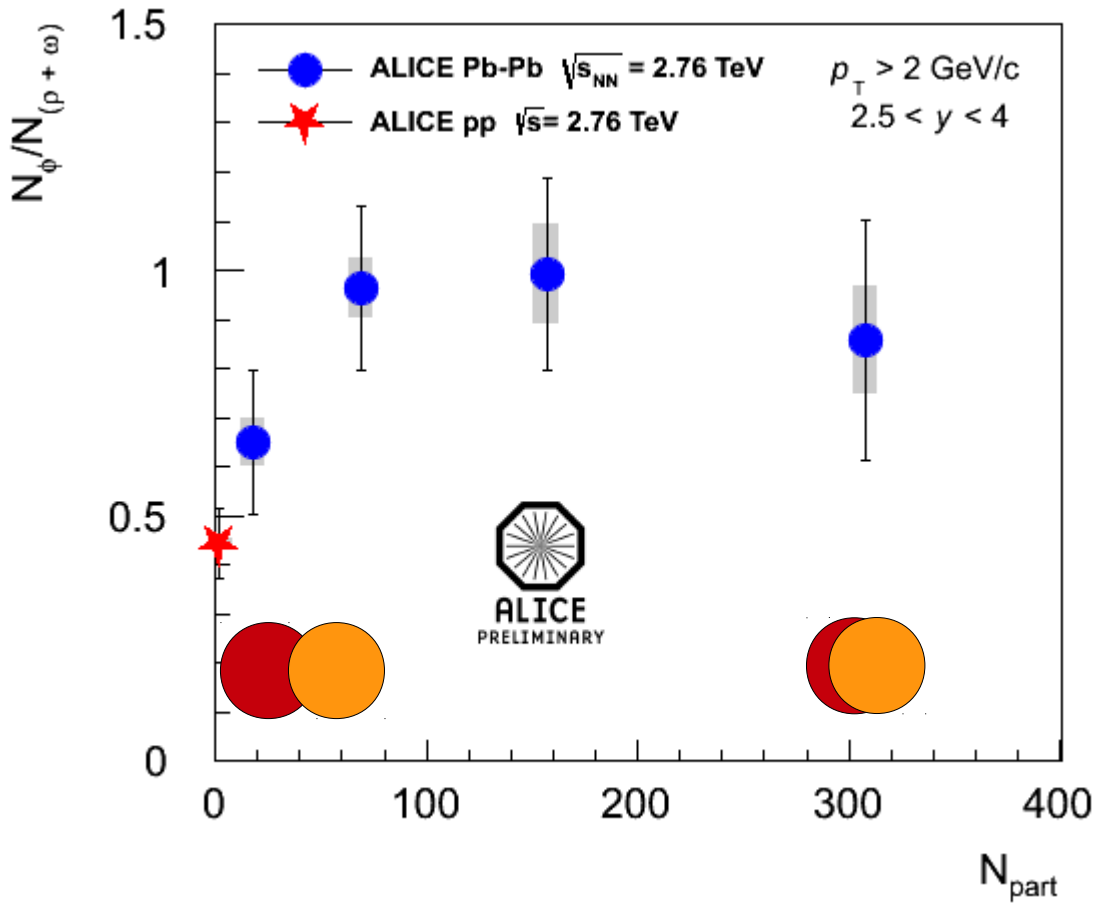
ρ/ω and ϕ signals can be extracted w.r.t. a continuum (open charm/beauty and other hadronic sources). The large statistical uncertainties do not allow a precision study of the underlying continuum. Analysis limited to $p_T(\mu\mu) > 2$ GeV/c





Pb-Pb @ 2.76 TeV: ϕ/(ρ+ω) Ratio

Despite the large statistical uncertainties, the ϕ and ρ/ω signals can be reliably extracted from the mass spectrum: **ϕ/(ρ+ω) ratio as a function of centrality can be measured**



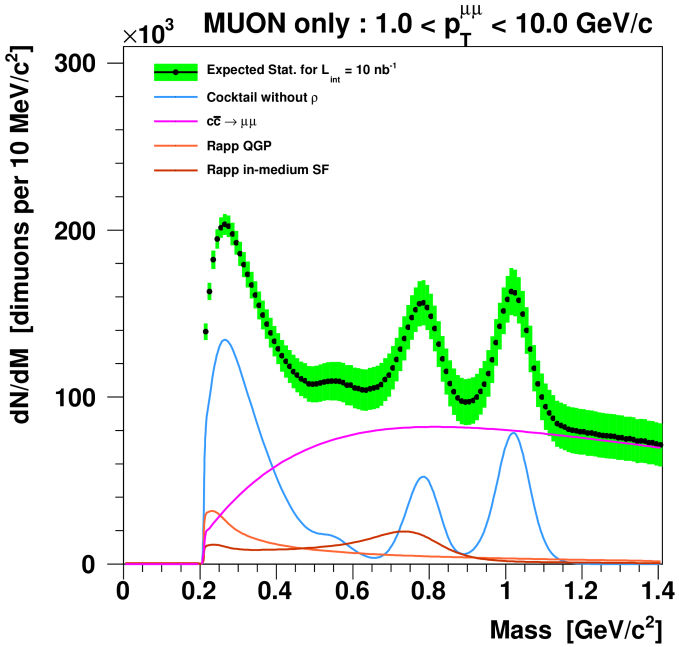
- **Rather robust measurement:** part of the systematic uncertainties on the reconstruction efficiency cancel out in the ratio
- ϕ/(ρ+ω) follows a **rising trend** from pp to Pb-Pb collisions
- The observed trend suggests a **saturation of the ϕ/(ρ+ω) ratio** with the centrality, occurring already in semi-peripheral (40-60%) collisions

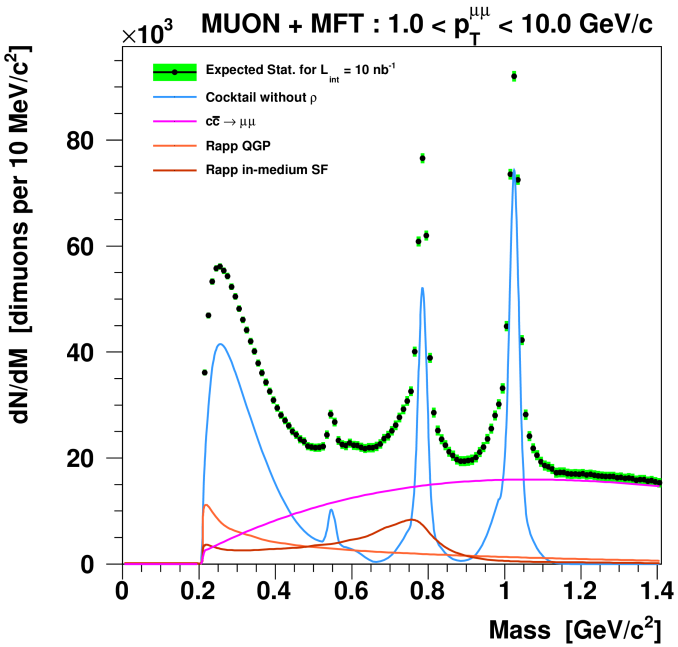
Outlook: p-A Data and Performances with the MFT

During the **p-Pb and Pb-p runs in 2013**, ALICE took data with a dimuon trigger imposing the lowest possible threshold for the single muons (~0.5 GeV/c)

- ~ 9'000'000 triggers for p-Pb
- ~ 16'000'000 triggers for Pb-p

Performance plots still not public. The large statistics and the favorable trigger conditions should allow an analysis down to zero p_T





ALICE low mass dimuon measurements will greatly benefit from the approved MFT upgrade (after 2018):

- Improvement of the S/B ratio by factors ~ 6–7
- Improvement of the mass resolution by factors ~ 3

Summary

- ALICE has successfully studied **low mass dimuon production in pp collisions at 7 TeV:** satisfying comparison data vs event generators without in-medium effects (as expected). **First extensive study of low mass dileptons at the LHC**
- Low mass dimuons also studied at **2.76 TeV**: mandatory reference for the measurements in Pb-Pb

- **Feasibility of the low mass dimuon analysis in Pb-Pb at 2.76 TeV** per nucleon pair, in various centrality classes: first attempt at the LHC energies!
  - More statistics is needed, with dedicated trigger conditions
  - Strangeness production via $\phi/(\rho+\omega)$ and R_{AA} of ϕ already accessible with the currently available data sample

- p-Pb and Pb-p data look extremely promising in quantity and quality
- The MFT will have a major impact on the quality of the future low-mass dimuon measurements in ALICE