Low-mass dimuon production at forward rapidity in pp, p-Pb and Pb-Pb collisions with ALICE

Satoshi Yano
Laboratoire Quark Gluon Plasma
Département de Physique Nucléaire, IRFU, CEA
for the ALICE Collaboration

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Measurement of low-mass dimuons

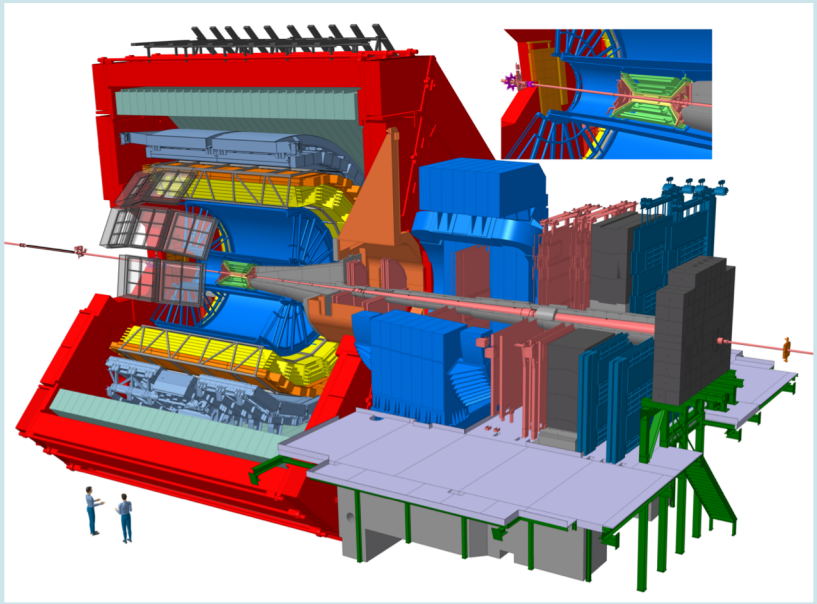
- In pp collisions
  - Test of the strangeness production with QCD
  - Reference for p-Pb and Pb-Pb collision study

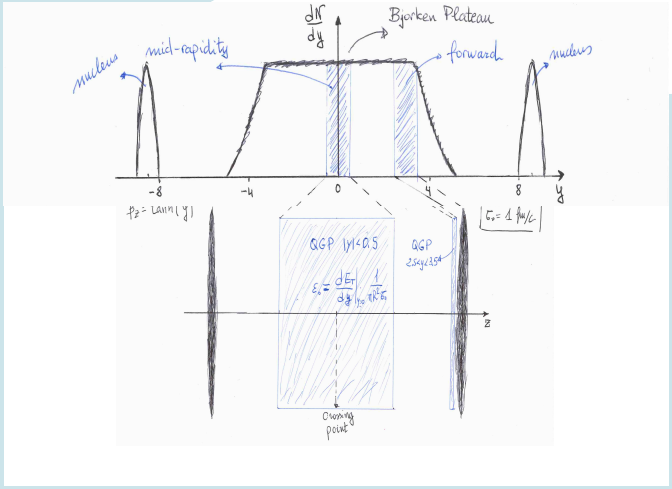
- In p-Pb collisions
  - Investigation of Cold Nuclear Matter (CNM) effect
  - Study of new phenomena at high multiplicity

- Pb-Pb collisions
  - Strangeness production mechanisms in a hot and dense matter
  - Observation of chiral symmetry restoration
  - Thermal dilepton emitted at early stage of the collisions

The ALICE muon detector

- Muon spectrometer ($2.5<\eta_\mu<4.0$)
  - Front absorber ($10\lambda_{int}$, ~$60X_0$)
  - Tracking chambers (5 stations)
  - Dipole magnet (3Tm)
  - Iron wall ($7.2\lambda_{int}$)
  - Trigger chambers (2 stations)





Easier particle identification w.r.t electron

At LHC

Not too forward to measure central physics!

Forward enough to measure low p_T muon!

Access to unique physics, e.g. low-mass and low-p_T region, with clean muon probes for Quark-Gluon Plasma created in PbPb collisions !!!

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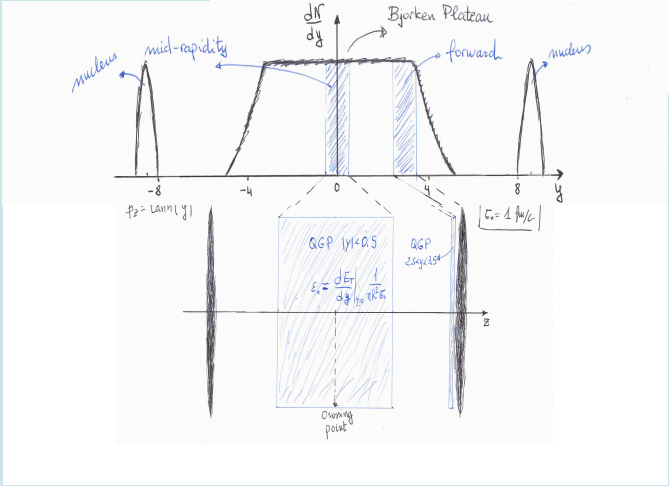

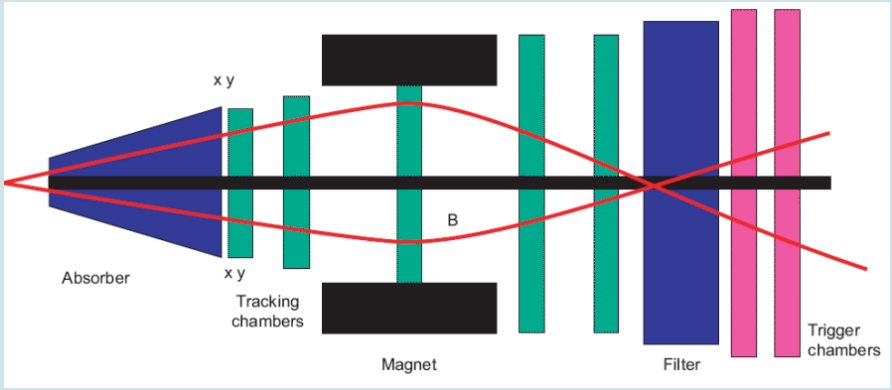

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Signal extraction of low-mass dimuons

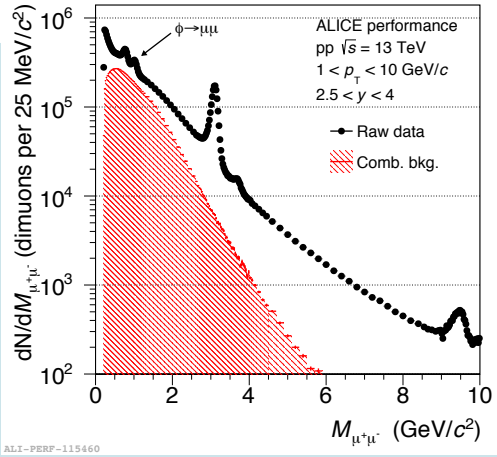
- Invariant mass of unlike sign muon pairs
  - Muon tracks match the muon trigger
  - Within the acceptance $2.5<\eta_{\mu}<4.0$ and $2.5<y_{\mu\mu}<4.0$

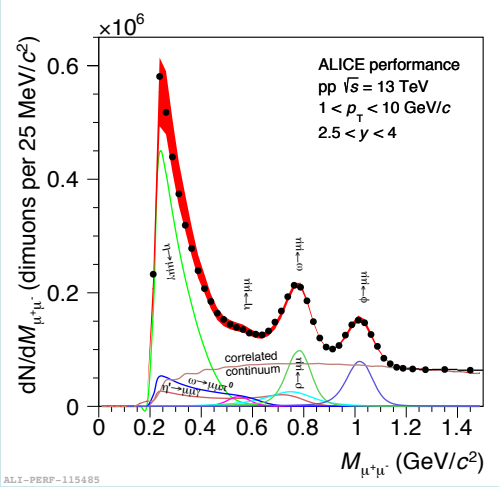
- Estimation of combinatorial background through

$$N_{BKG} = 2R\sqrt{N^{++}N^{--}} \qquad R = \frac{N^{+-}_{\mathrm{mix}}}{2\sqrt{N^{++}_{\mathrm{mix}}N^{--}_{\mathrm{mix}}}}$$

  - S/B ~ 2 in pp collisions (> 1 GeV/*c*)
  - S/B ~ 0.1 in Pb-Pb collisions @ 0-10% (> 2 GeV/*c*)

- Hadronic cocktail fit
  - Direct decay: η, ρ, ω, φ
  - Dalitz decay: η, ω, η′
  - Correlated continuum: open charm

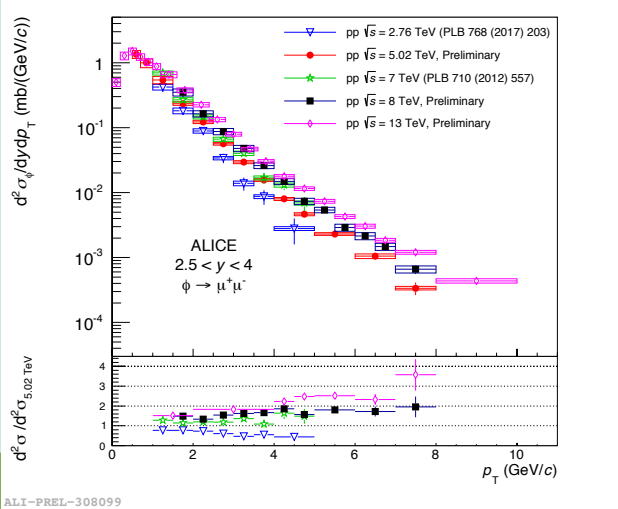


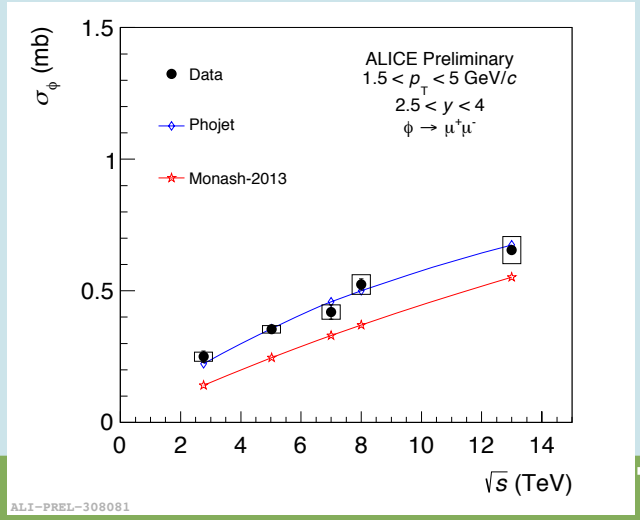


In pp collisions

Energy dependence of φ-meson production cross section in pp collisions

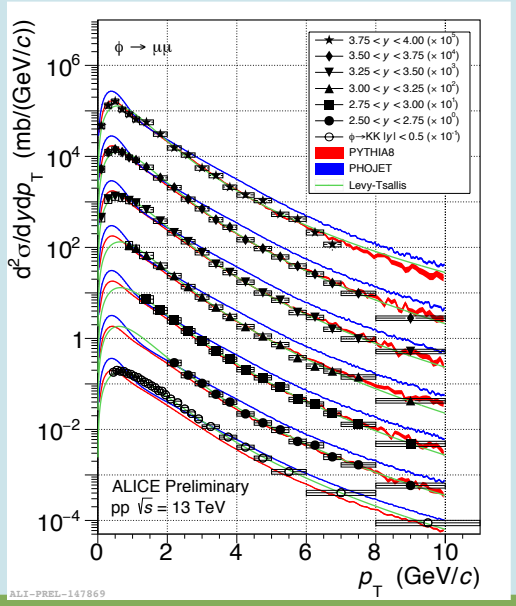
- In pp collisions at
  - 2.76, 5.02, 7, 8 and 13 TeV
- Comparison of the production cross section of φ-meson as a function of p_T and at the several LHC collision energies
  - Production of hidden strangeness in small system
  - Baseline for p-Pb and Pb-Pb study
- The energy dependence of the φ-meson cross section, integrated over the specific phase space
  - PYTHIA8 Monash-2013: Underestimate the cross section for all energies
  - PHOJET: Good description at LHC energies

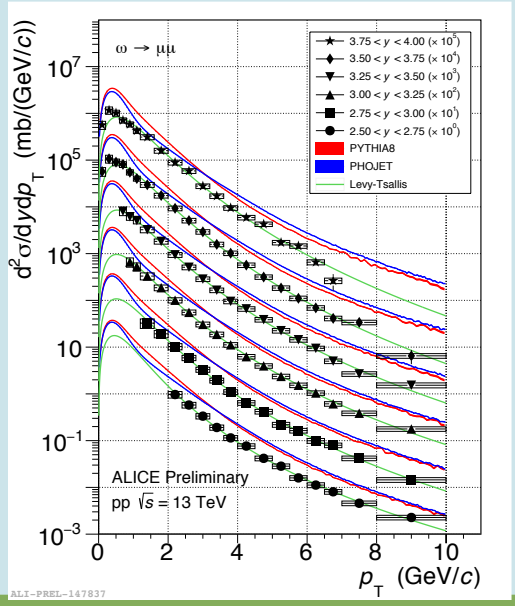


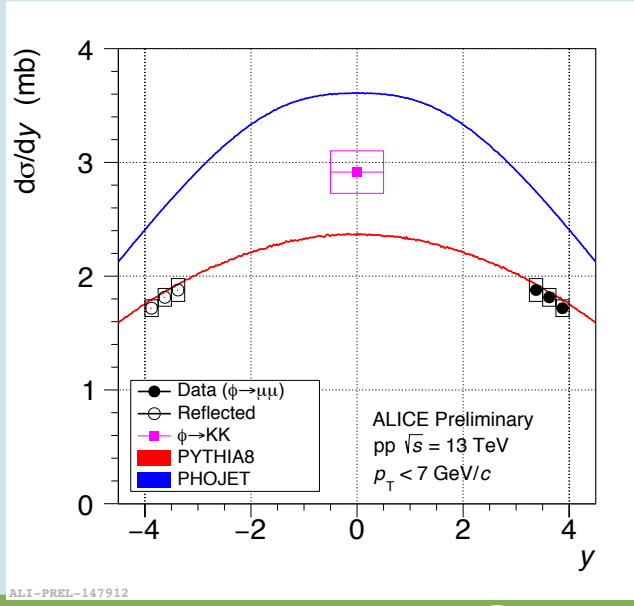


Double differential cross section of ω and φ in pp collisions at $\sqrt{s}$ = 13 TeV

- Measurement of double differential cross section
  - Collected > 30 pb^{-1} during Run2 (2015 - 2018) with dimuon trigger
- Comparison with model predictions for φ-meson
  - PYTHIA8 Monash-2013: Fair description for all p_T and y
  - PHOJET: Good description only p_T = 1~ 2 GeV/*c*
- Comparison with model predictions for ω-meson
  - Pythia8 Monash-2013 and PHOJET: Overestimation across the whole p_T and y



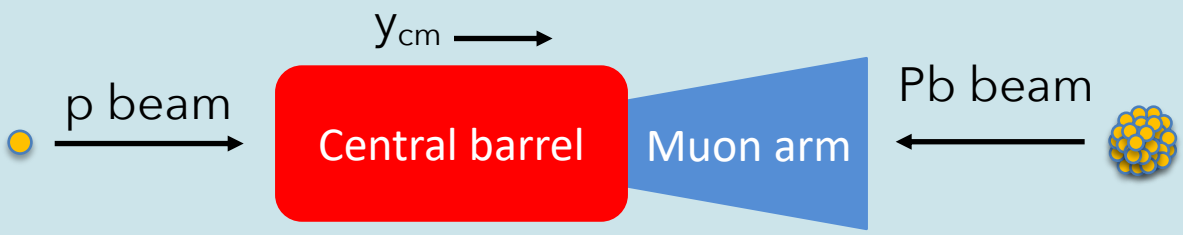




In p-Pb collisions

Muon measurement in p-Pb collisions

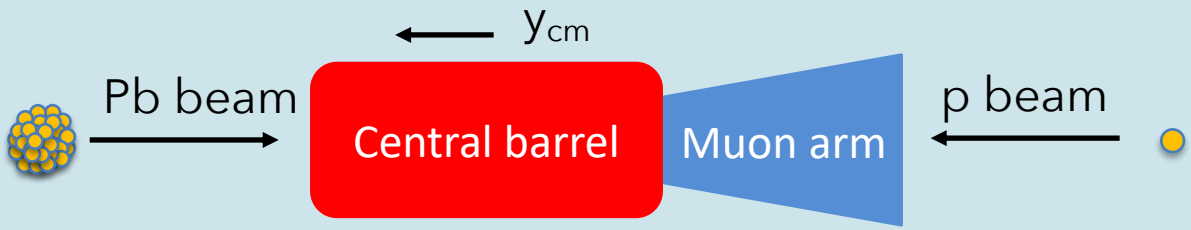
- In p-Pb/Pb-p collisions at $\sqrt{s_{NN}}$ = 5.02 TeV with 5.0 nb^{-1}/5.8 nb^{-1}
- Covered forward/backward rapidity range for p-Pb and Pb-p collisions by muon spectrometer in ALICE
- Shift of y_{cm} by 0.465 in the p-beam direction due to the different energy per nucleon of the the p and Pb beams



Forward rapidity

$$2.5 < y_{LAB} < 4$$

$$2.03 < y_{CM} < 3.53$$



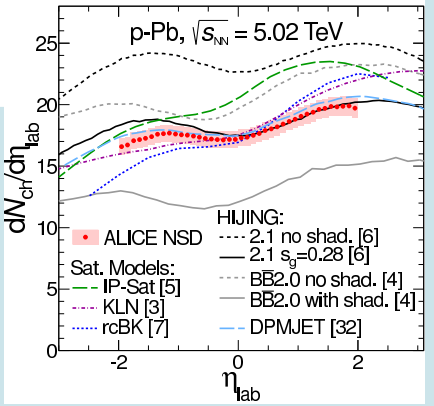
Backward rapidity

$$-4 < y_{LAB} < -2.5$$

$$-4.46 < y_{CM} < -2.96$$

Production cross section and R_{FB} of φ-meson as a function of p_T

- Production cross section as a function of rapidity
  - HIJING and DPMJET: Do not describe the φ-meson production cross section, but describe well the charged particle distribution at mid-rapidity
- Forward-to-backward ratio
  - Common rapidity window: $2.96<|y_{cm}|<3.53$



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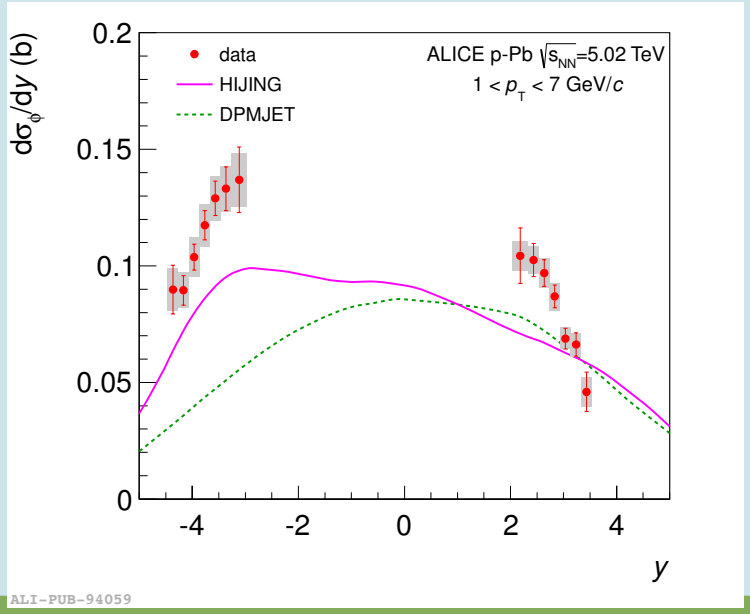
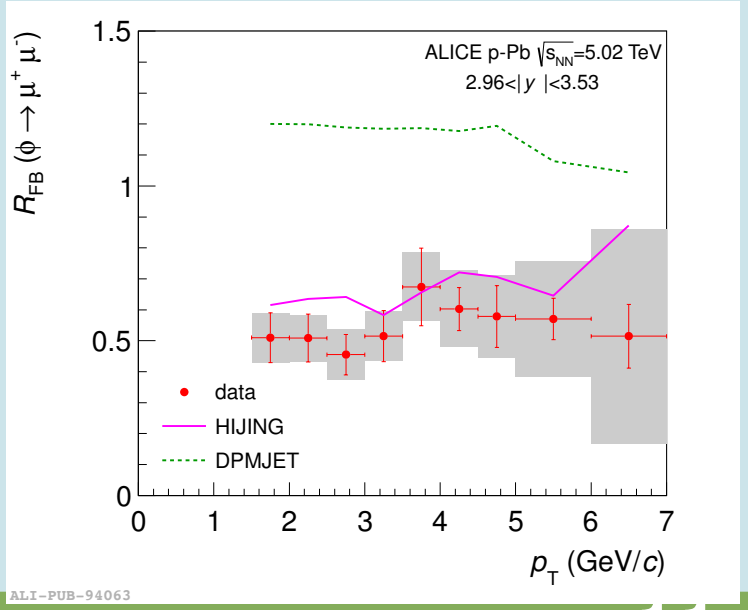
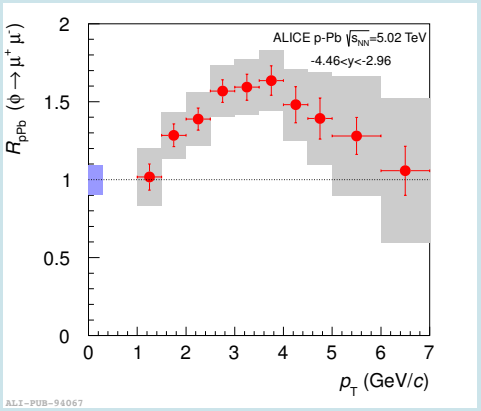




φ-meson nuclear modification factor

- Calculated in each p_T bin as $$R_{\mathrm{pPb}} = \frac{\mathrm{d}N_{\mathrm{pPb}}/\mathrm{d}p_{\mathrm{T}}}{\langle T_{\mathrm{pPb}} \rangle \times \mathrm{d}\sigma_{\mathrm{pp}}/\mathrm{d}p_{\mathrm{T}}}$$
  - $\sigma_{\varphi}^{pp}(p_T)$: Interpolation between measurements of 2.76 and 7 TeV

Backward rapidity



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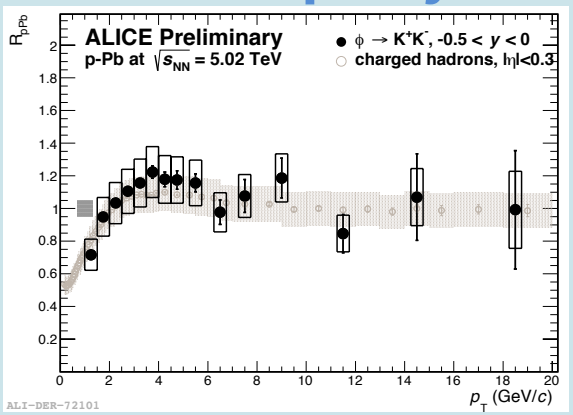
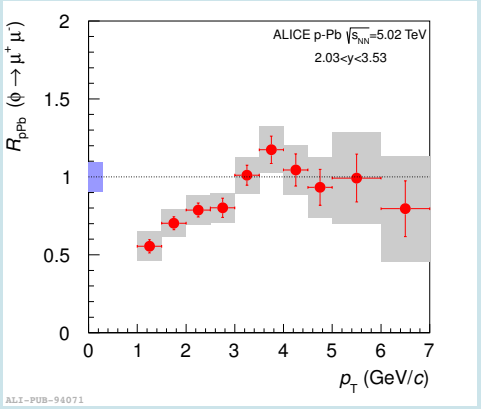
Mid rapidity



Forward rapidity



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- At backward rapidity: $R_{\mathrm{pPb}} > 1$ with a peak at $p_T \sim 3 - 4$ GeV/c
- At mid and forward rapidity: R_{pPb} grows for $p_T < 3$GeV/$_c$
  $R_{\mathrm{pPb}} \sim 1$ for $p_T > 3$ GeV/c

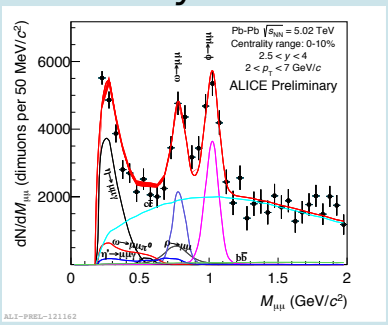
Initial-state effect?
Hint for flow?

In Pb-Pb collisions

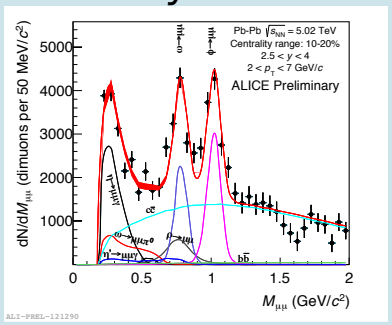
Low-mass dimuons in Pb-Pb collisions

- Integrated luminosity:
  - $\sqrt{s_{NN}}$ = 2.76 TeV: 71μb^{-1}
  - $\sqrt{s_{NN}}$ = 5.02 TeV: 225μb^{-1}
- Online trigger threshold: p_T ~ 1 GeV/c
- Signal extraction procedure: the same as in small systems
- S/B: ~ 0.1 in most central collisions for φ-meson

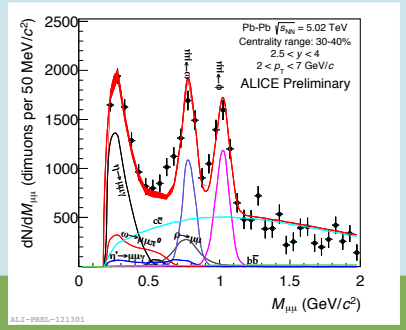
Centrality: 0 – 10%



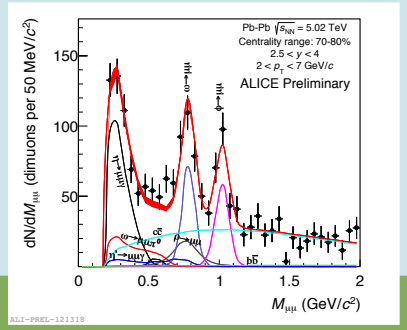
Centrality: 10 – 20%

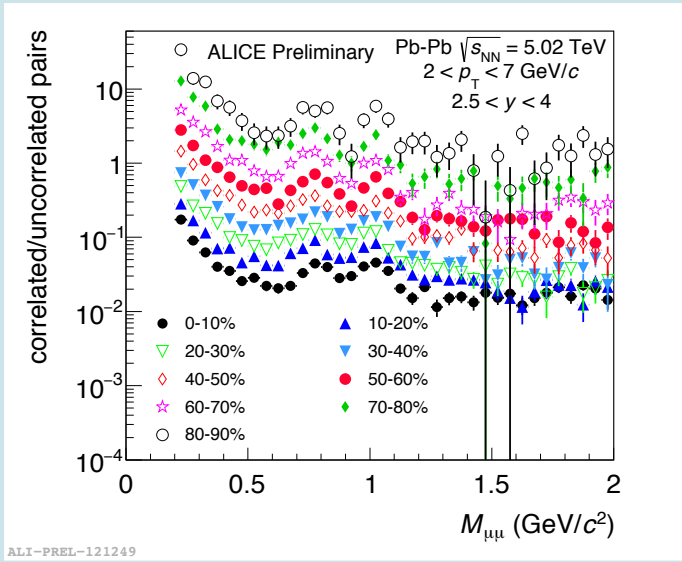


Centrality: 30 – 40%



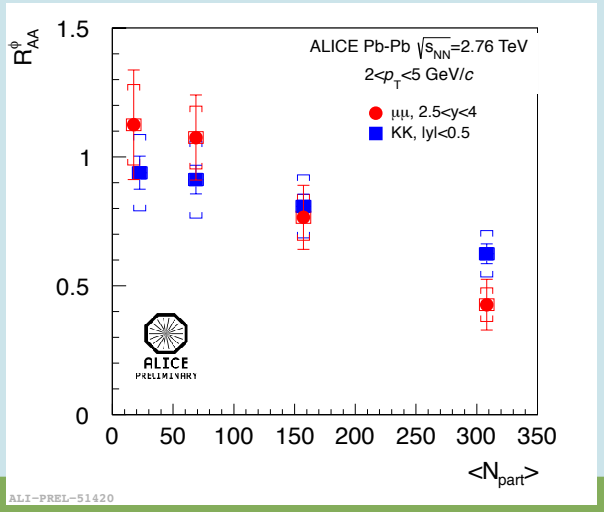
Centrality: 70 – 80%

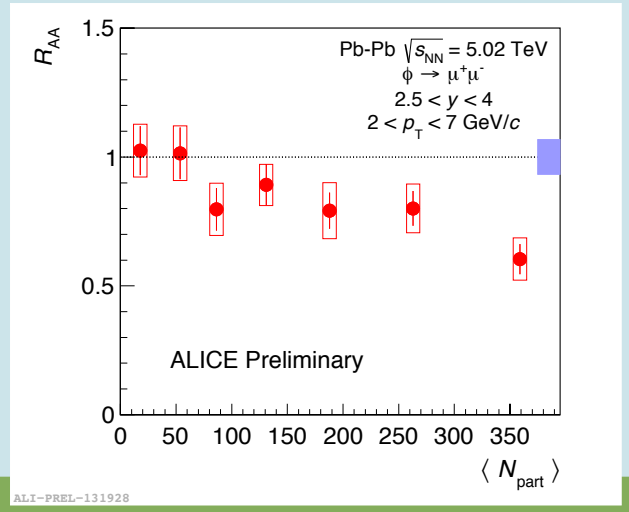


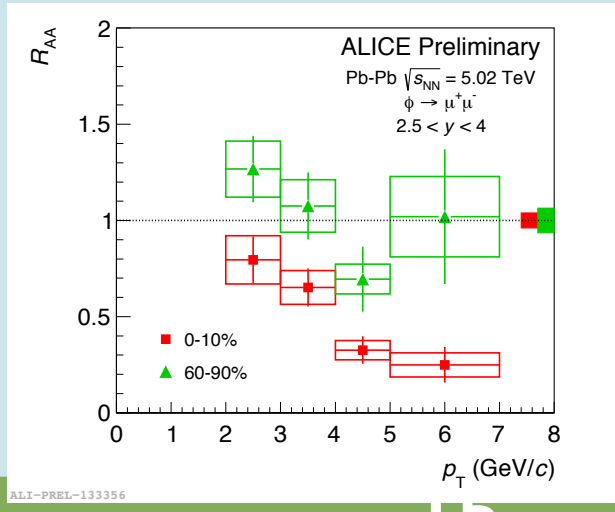


Nuclear modification factor

- Calculated in each p_T bin as $$R_{\mathrm{PbPb}} = \frac{\mathrm{d}N_{\mathrm{PbPb}}/\mathrm{d}p_{\mathrm{T}}}{\langle T_{\mathrm{PbPb}} \rangle \times \mathrm{d}\sigma_{\mathrm{pp}}/\mathrm{d}p_{\mathrm{T}}}$$
- Nuclear modification factor for $\sqrt{s_{NN}}$ = 2.76 TeV
  - Same suppression trend as mid-rapidity
  - R_{AA} < 1 from <N_{part}> ~ 60 corresponding to 50-55 % centrality
- Nuclear modification factor for $\sqrt{s_{NN}}$ = 5.02 TeV
  - Same trend as the $\sqrt{s_{NN}}$ = 2.76 TeV results
  - Larger suppression in most central collisions than in peripheral collisions
  - Increasing suppression with p_T in the measured range

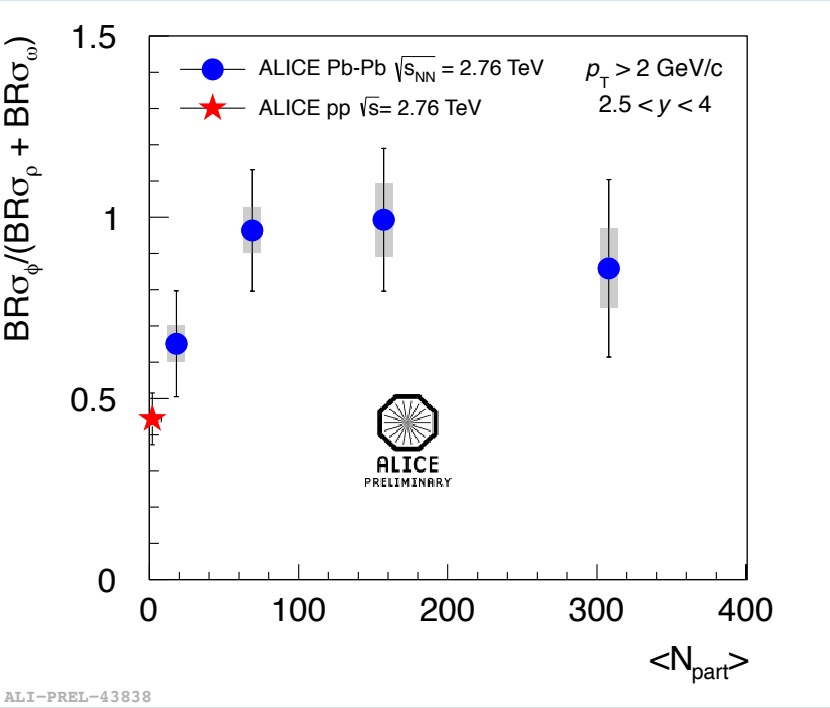






Comparison of ω/ρ and φ mesons

- Ratio of acceptance corrected φ and sum of ω/ρ yields
  - Sensitive to strangeness production mechanism
  - Observation of the saturation from $\langle N_{part} \rangle$ ~ 60



Threshold for strangeness production?

$$\langle N_{\mathrm{part}} \rangle \sim 60$$

$$\langle \mathrm{d}N_{\mathrm{ch}}/\mathrm{d}\eta \rangle \sim 210$$

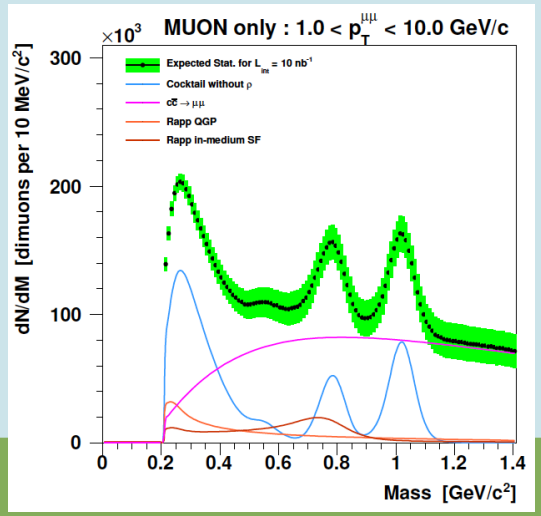
Outlook:
Let's look at small systems and comparable multiplicity!

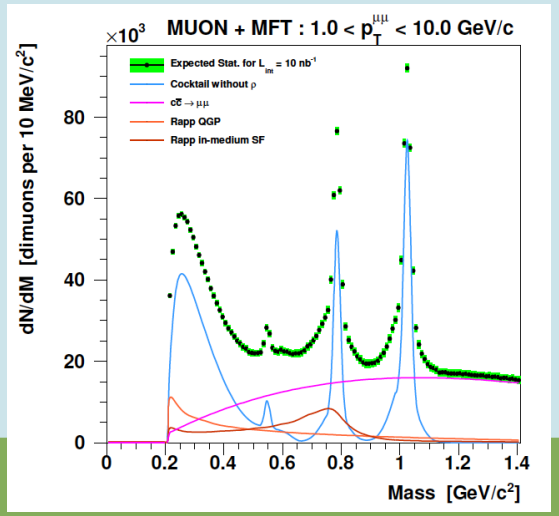
Future plans

- LHC-Run2
  - In total ~30 pb^{-1} data has been collected in pp collisions at $\sqrt{s}$ = 13 TeV
  - Data taking in Pb-Pb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV by muon trigger corresponding to 1 nb^{-1} (2015 + 2018)
  - Higher p_T reach and reduced uncertainties
- After LS2 (2021~)
  - Muon Forward Tracker (MFT)
  - Improvement of mass resolution by factor ~4
  - Improvement of S/B by factor ~10

Kenta Shigaki @ Parallel III.3

Wider physics topic related to low-p_T and low-mass dimuons can be accessed with MFT!





Summary

- In pp collisions
  - Low-mass dimuons has been measured at several collisions energies and provide insights into strangeness production mechanism
- In p-Pb collisions
  - Large forward/backward asymmetry has been observed
  - Enhancement at backward rapidity w.r.t pp collisions has been measured
- In Pb-Pb collisions
  - The R_{PbPb} at $\sqrt{s_{NN}}$ = 2.76 and 5.02 TeV has been measured
  - The forward R_{PbPb} is consistent with mid-rapidity at $\sqrt{s_{NN}}$ = 2.76 TeV
  - $\langle N_{part} \rangle \sim 60$ is the key value for strangeness production mechanism
- Future plans
  - Investigation of new phenomena in small system with the full LHC-Run2 statistics
  - Muon Forward Tracker (MFT) will allow to access wider physics topics