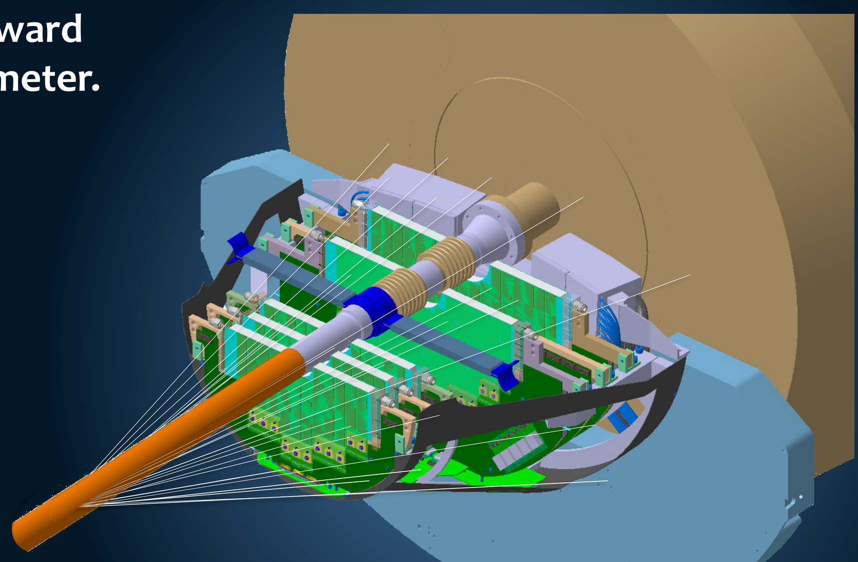
Prospects for ALICE Physics with the Muon Spectrometer Upgrade and the new Muon Forward Tracker

INTRODUCTION

ALICE MFT TDR: CERN-LHCC-2015-001

In the present ALICE setup, muons are detected at forward rapidities ($2.5 < \eta < 4$) by means of the MUON spectrometer. This allows one to study:

- **Quarkonia production:** in-medium color screening and hadronization mechanisms of cc pairs
- **Open Heavy Flavor production** (single muons and dimuons): study of in-medium interactions of heavy quarks (energy loss, flow)
- **Low mass dimuons:** thermal radiation from QGP and search for in-medium modifications of the spectral functions of light vector mesons



The hadron absorber prevents the MUON spectrometer from resolving the details of the vertex region. **The Muon Forward Tracker (MFT) will track the particles before they enter the hadron absorber,** by means of an assembly of silicon pixel planes ➔ To be installed in 2020

With the MFT, by measuring the muons' offset to the primary vertex we can **distinguish between prompt and displaced muons and dimuons.** Open charm ($c\tau \approx$ 120-300 μm) and open beauty ($c\tau \approx$ 500 μm) can be disentangled, prompt and B-decay J/ψ can be separated

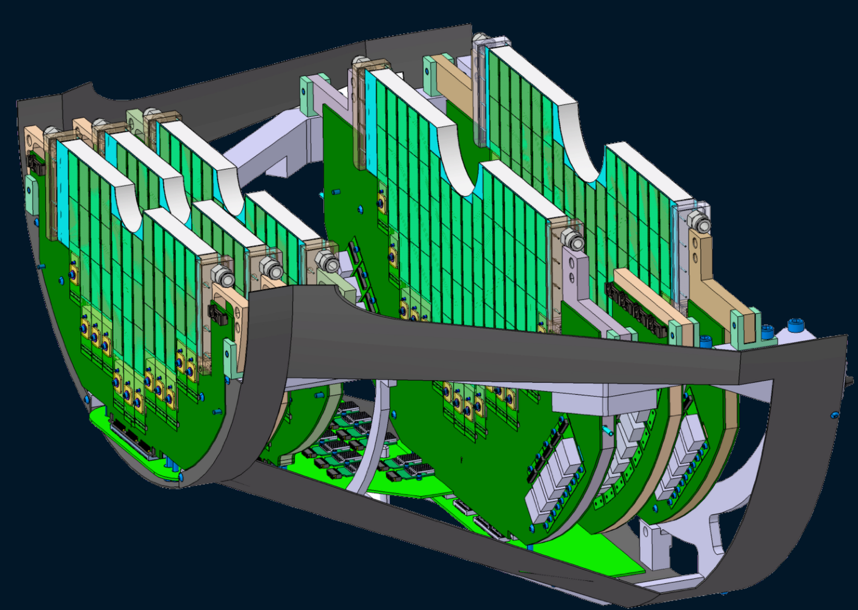
Background coming from semimuonic decays of light-flavored mesons (mainly π and K) can be rejected applying a cut on both the offset and the matching quality between the MUON tracks and the associated MFT clusters. The rejection of the background is crucial to increase the signal to background ratio, improving namely the significance of the ψ(2S) measurements

The readout electronics of the MUON spectrometer will be upgraded to cope with the expected Pb-Pb interaction rate (50 kHz). Performance is evaluated in (0-10%) central Pb–Pb collisions for the 10 nb^{-1} integrated luminosity foreseen after 2021

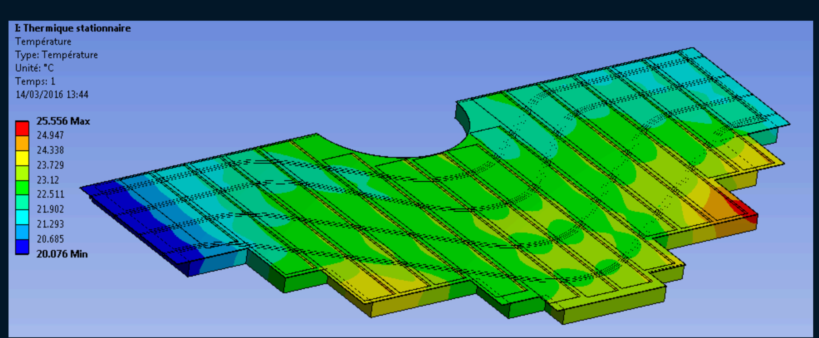
TECHNOLOGY

New Muon Forward Tracker:

- 5 circular pixel silicon double-plane disks
- 28×28 μm² pixels, 0.7% x/X_0 per disk
- z-positions between 50 and 76 cm from I.P. (between the ITS and the hadron absorber)
- Nearly 4000 cm² of active area covered by 912 ALPIDE CMOS sensors (joint development with the Inner Tracking System Upgrade project)
- Pseudorapidity acceptance: $2.5 < \eta < 3.6$

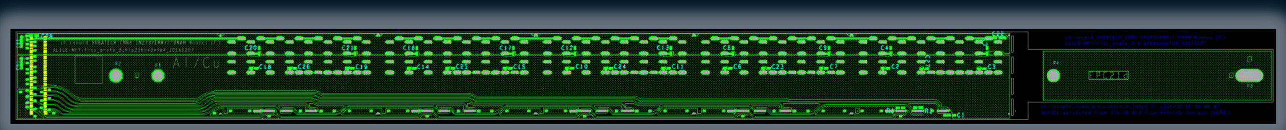


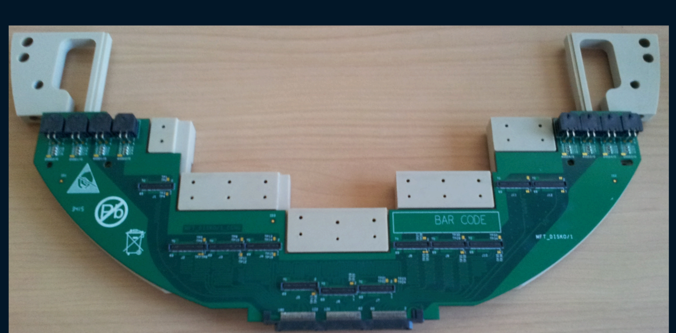
MFT water-cooling studies done through composite coldplate and composite ladder calculations assuming a consumption of 50 mW/cm² for sensors and 20 °C water flowing at 1 m/s:



- T_{max} = 24.9 °C
- Max gradient on a ladder = 1.2 °C
- Gradient over all silicon surface = 2.3 °C
- In case of non-perfect water flow: max 6 °C of increase in T_{max}

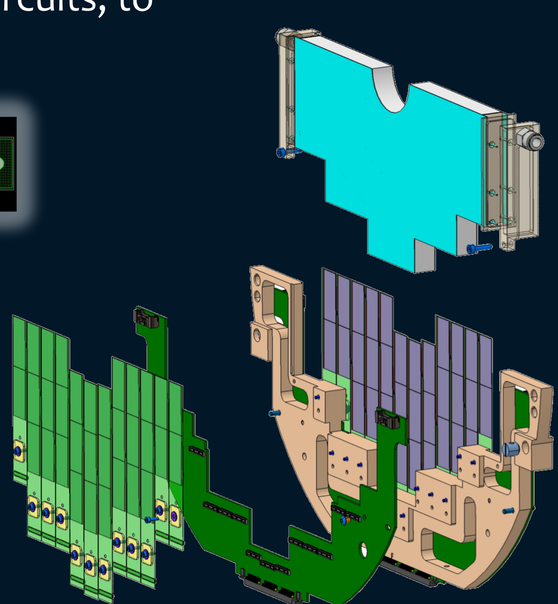
- **ALPIDE pixel chip** specifically designed for the ALICE MFT and ITS-upgrade projects
- **Silicon chips wire-bonded** on specifically developed flexible printed circuits, to compose the ladders covering the acceptance of the MFT disks





Structure of the MFT disks:

- Disk support
- Heat exchanger
- Printed circuit board
- Ladders
- Mechanical elements



MUON spectrometer: upgrade of Front-End and Readout Electronics needed for the tracking and trigger systems, to increase the maximum readout rate from 1 kHz to 100 kHz

- **Tracking:** 17000 Front-End cards with 2 **SAMPA** ASIC (common to Muon Tracking and Time Projection Chamber) each ➔ **1.1 million channels.** 550 GBTs for a maximum expected data flow of 20 Gbps (design value = 1600 Gbps)
- **Trigger:** 2384 Front-End cards, 20992 channels. New **FEERIC** ASIC providing amplification: RPCs operated at lower gain after Run 2 ➔ **reduced aging effects**

PHYSICS PERFORMANCE

Open Heavy Flavors

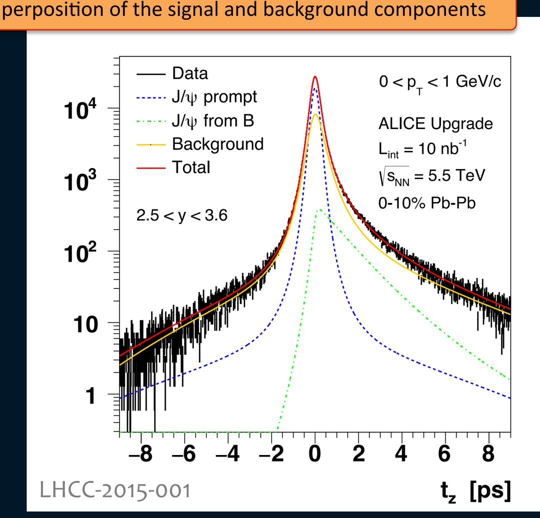
Major item for the ALICE muon physics, needs a dedicated vertex tracker

- Probing QCD matter by measuring the **energy loss of quarks c and b** in the deconfined partonic medium
- Study **thermalization** and **hadronization** mechanisms of heavy quarks
- Measuring total charm and beauty production cross section: **ideal reference for prompt quarkonium studies**

Beauty production can be studied by measuring J/ψ coming from the decay of B hadrons. Main contributors are B^+, B^0, B_s and Λ_b ($c\tau \approx$ 500 μm)

- Secondary vertex must be reconstructed, to disentangle displaced J/ψ production
- At forward rapidity, B-hadrons with vanishing p_T still have sizeable p_z ➔ measurable longitudinal displacement for secondary vertex. Displaced J/ψ production peaked around p_T = 1.5 GeV/c for $p_T(B) \approx 0$

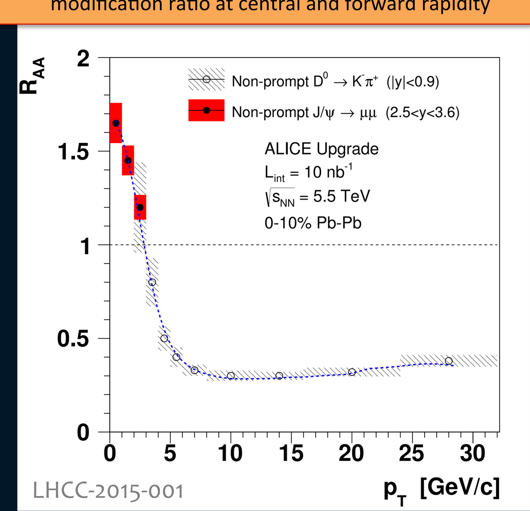
Fit of the pseudo-proper decay time distribution with the superposition of the signal and background components



$$t_z = \frac{(z_0 - z_{J/\psi}) \cdot m_{J/\psi}}{p_z^{J/\psi}}$$

The MFT will allow prompt/displaced J/ψ separation down to zero p_T by measuring the **pseudo-proper decay time** associated to the secondary vertex

Performance for the measurement of the beauty nuclear modification ratio at central and forward rapidity



Beauty measurement at forward rapidity via displaced J/ψ will complement the measurements at central rapidity via displaced D⁰ and J/ψ, and exclusive B reconstruction

Open heavy flavor measurement at forward rapidity also available in the single-muon channel, via the analysis of the transverse offset distributions:

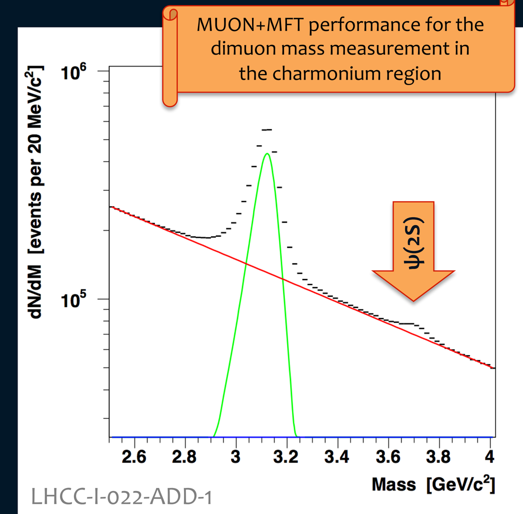
- **Charm** extraction possible starting from $p_T(\mu)$ = 1 GeV/c
- **Beauty** extraction possible starting from $p_T(\mu)$ = 3 GeV/c

Prompt Charmonium

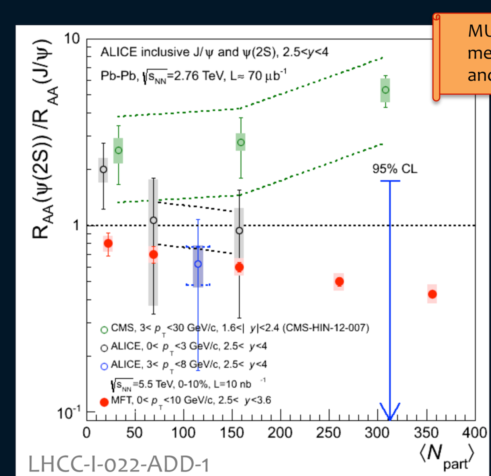
Prompt Charmonium production as a probe of the Quark-Gluon Plasma phase:

- Dissociation due to color screening of the heavy-quark potential in deconfined QCD matter
- Recombination of charm and anti-charm quarks occurring for sufficiently high densities of charm quarks created in the initial stages of the collisions

MUON+MFT performance for the dimuon mass measurement in the charmonium region



MUON+MFT performance for the ψ(2S)/J/ψ measurement, compared to the available CMS and ALICE measurements



Dissociation/Recombination models for charmonia can be tested by comparing the nuclear modification factors of J/ψ and ψ(2S) down to zero p_T

- MFT will give a robust ψ(2S) measurement by improving the S/B by a factor 5 to 6 w.r.t. the current MUON spectrometer
- Measurement of the fractions of prompt and non-prompt J/ψ

Low-Mass Dimuons

Ultimate goal: inferring signatures of the QCD phase transition to QGP, possibly accompanied by chiral symmetry (partial) restoration. Key observables:

- In-medium modifications of vector meson spectral functions
- Dilepton radiation from the partonic phase (QGP) exploiting the double degree of freedom given by the mass and the p_T

Challenging measurements due to large background and systematic uncertainties on continuum shape from open HF. The MFT will significantly contribute to the precision of the measurement:

- By increasing the S/B, thanks to the measurement of the offset at the primary vertex
- By improving the mass resolution for light resonances decaying into dimuons

Low-mass prompt signals from QGP (thermal dimuons, in-medium modified ρ line shape) measurable within 20% uncertainty. Better performance expected for prompt signals at intermediate and high dimuon masses (thermal radiation, Drell-Yan and possibly existing beyond-standard-model light bosons)

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