HOT QUARKS 2012

Workshop for young scientists on the physics of ultrarelativistic nucleus–nucleus collisions

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Copamarina, Puerto Rico

Muon Physics in ALICE: The MFT Upgrade Project

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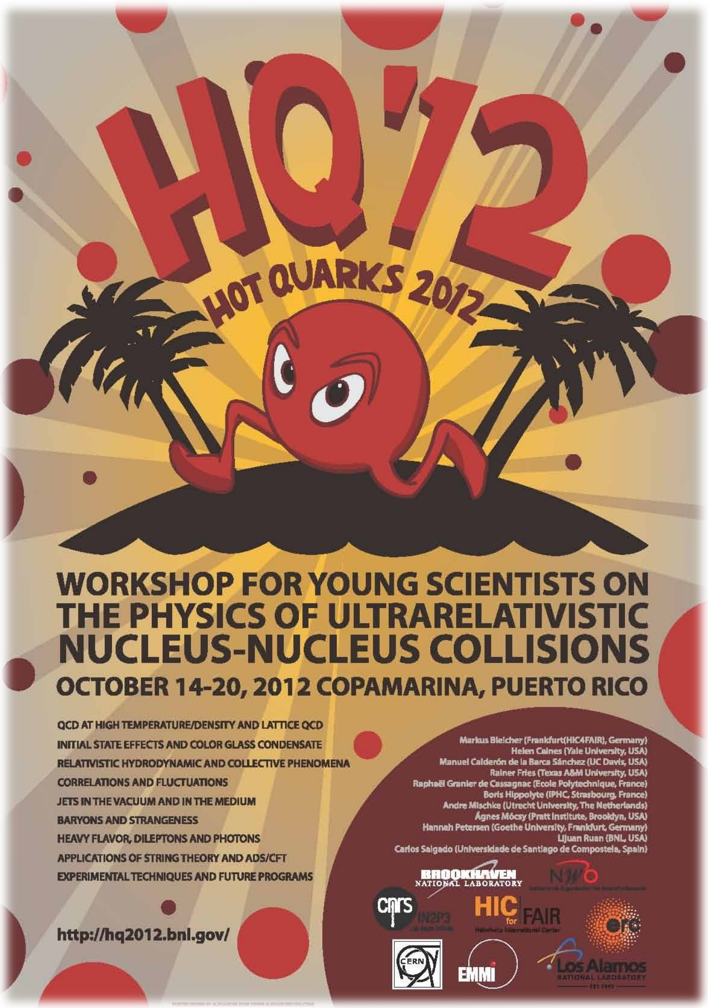
ALICE Lyon group @ IPNL

ALICE

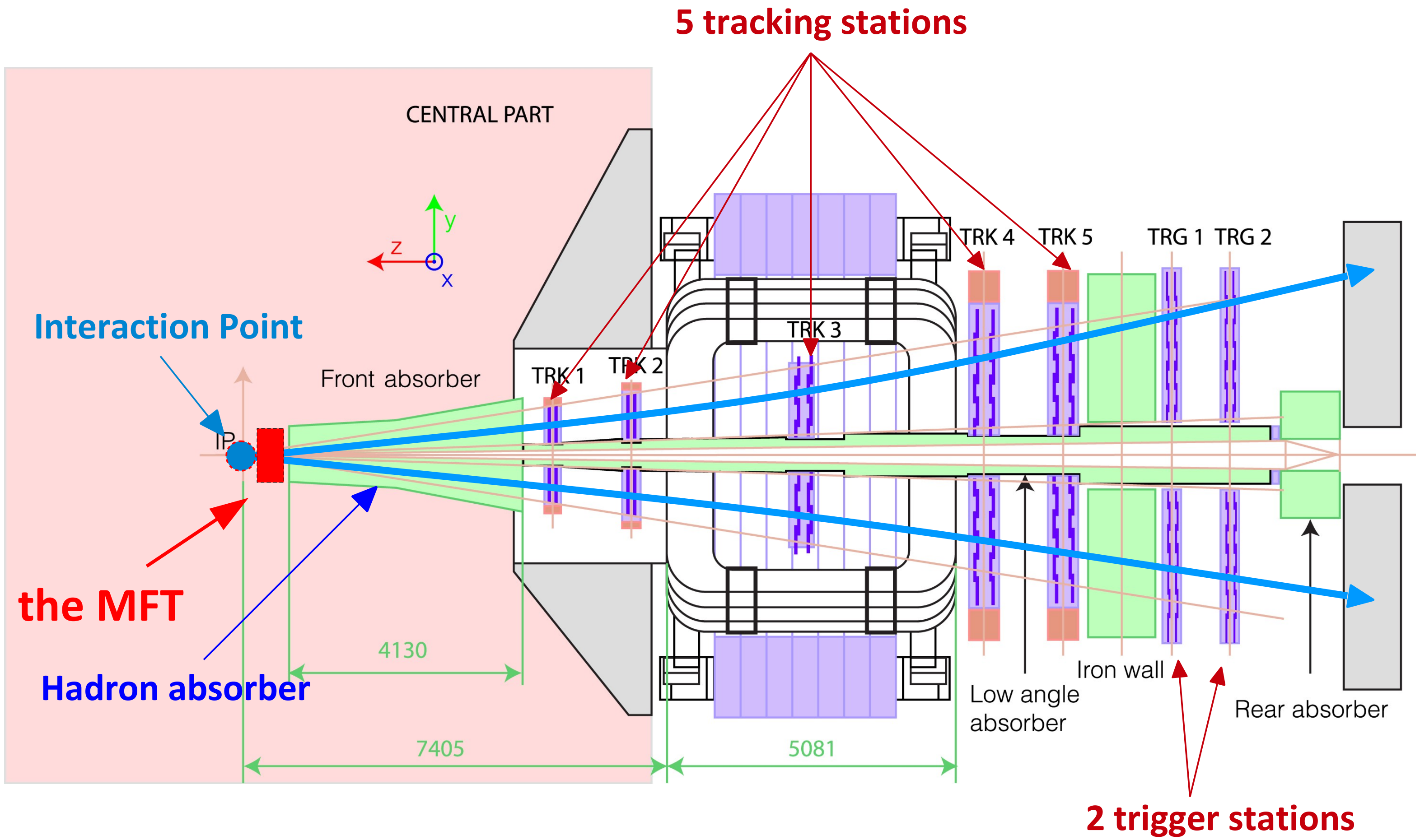
Outline



- What is the MFT?
- Open Heavy Flavors
- Charmonia
- Low Mass Dimuons
- Technological aspects

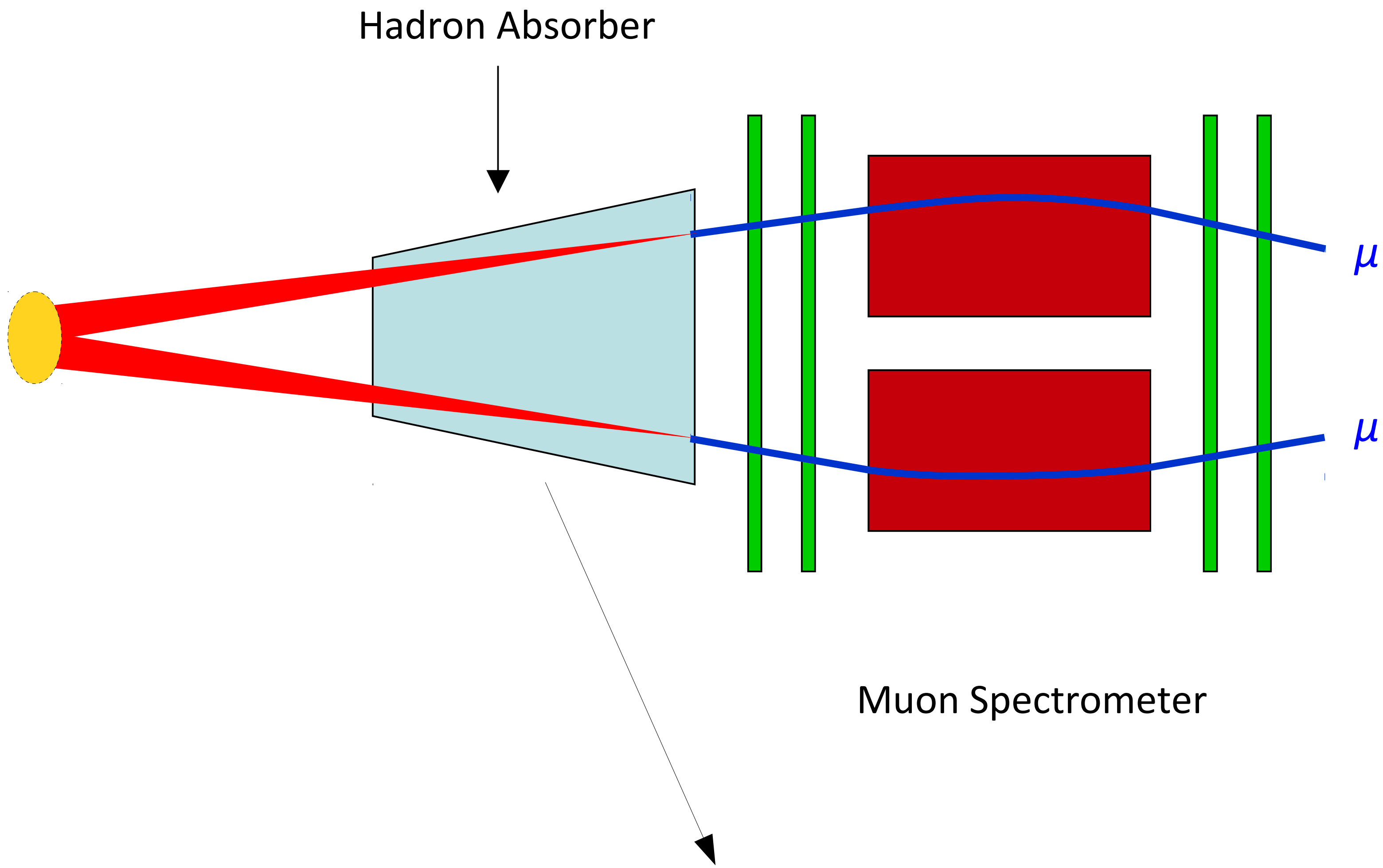
Prelude: Current Muon Arm Setup

Designed to detect muons in the **polar angular range 2 – 9°, i.e. – 4.0 < η < – 2.5** and in the full azimuthal range



Main limitation: it is **blind to the details of the vertex region**, because of the hadron absorber

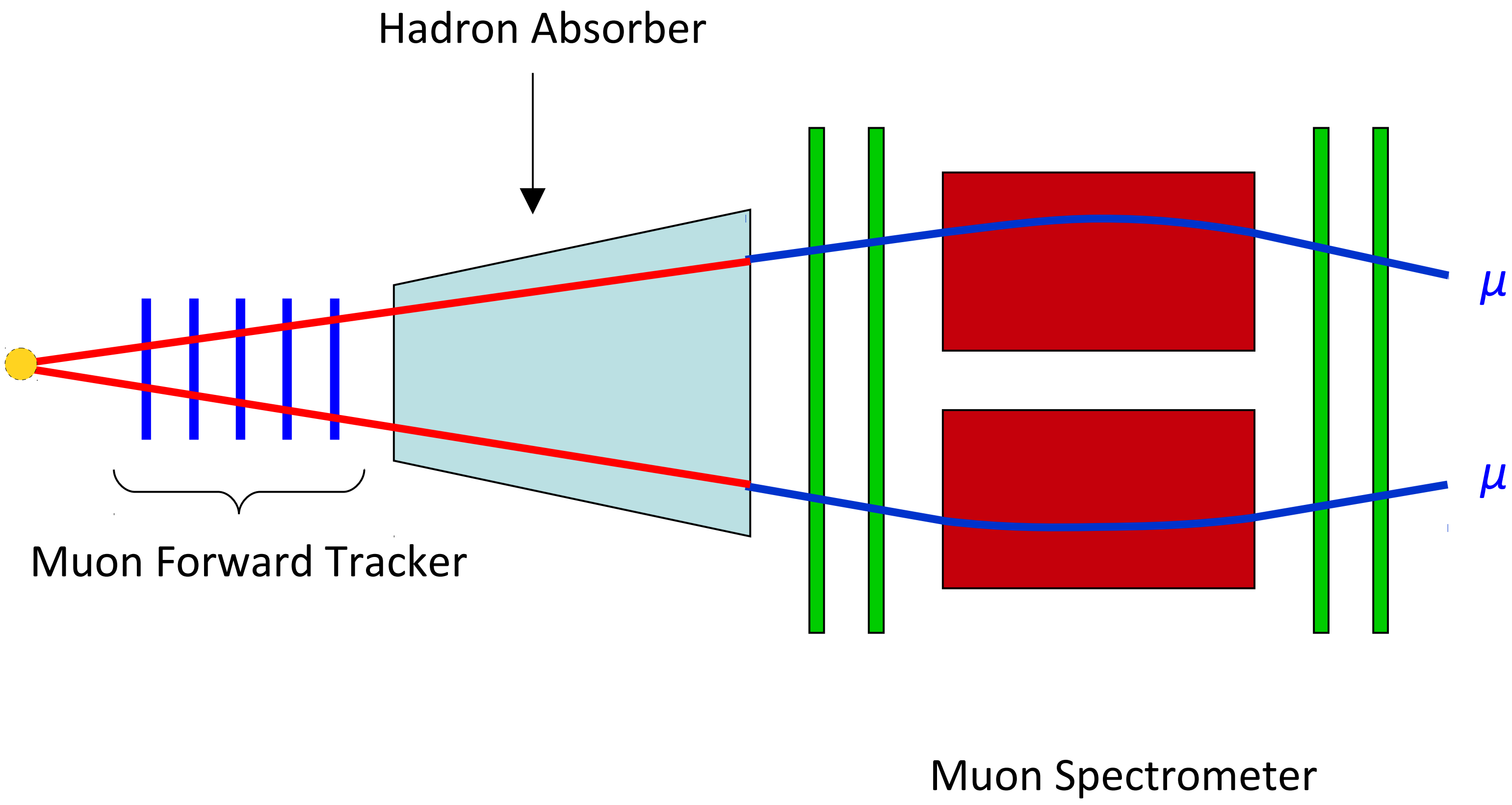
Prelude: the MFT Concept



Extrapolating back to the vertex region **degrades the information** on the kinematics

Prelude: the MFT Concept

Muon tracks are extrapolated and **matched to the MFT clusters** before the absorber

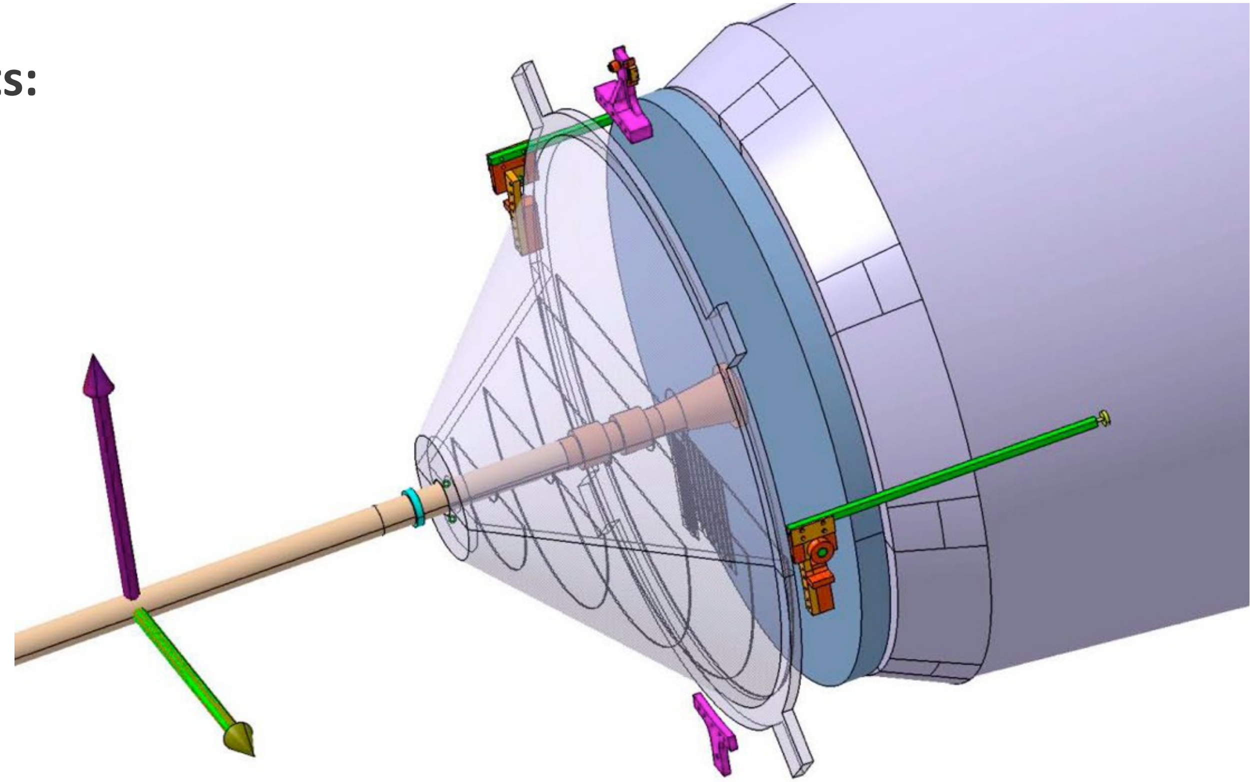


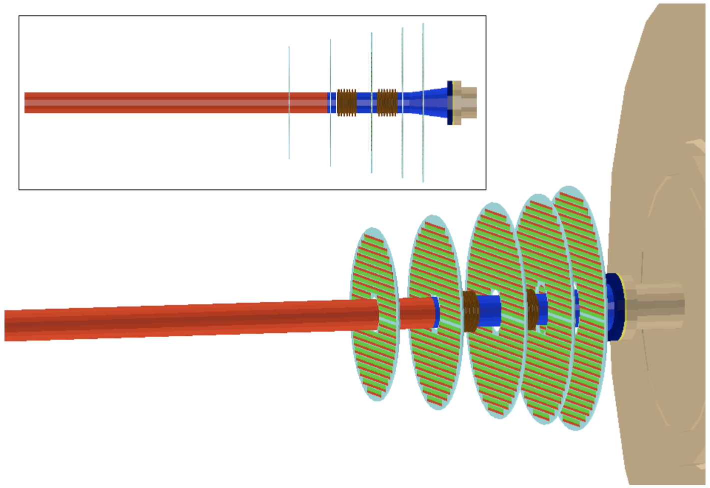
High pointing accuracy gained by the muon tracks after matching with the MFT clusters

Integration of MFT in ALICE

Several mechanical constraints:

- Provide beam pipe support
- No thermal or mechanical perturbations to other detectors located in its vicinity
- Maintenance operations during winter shutdowns





- MFT plans are ladder assembly of active and readout zones with x/X_0 = 0.4% per plane
- CMOS sensor on both sides of the plane: no dead zone
- Current pixel pitch scenario: $25 \times 25\ \mu m^2$

How to Evaluate the MFT Performances?

1) Investigation of MFT performances **in ideal conditions** (low multiplicity, no misalignment, no fake tracks): **DONE**, extremely encouraging

2) Development of **fast tools to introduce realistic conditions in the MFT** simulations: multiplicity expected for central Pb-Pb collisions at 5.5 TeV, pile-up scenario, misalignment, realistic spatial cluster resolution, fake tracks contamination. **DONE** (painful but necessary!)

3) **Large scale simulations for signals and background to extract the final performance plots.** It's the final sprint: **WE ARE HERE**

What I will show today: preliminary plots showing the relative improvement of the Muon Arm physics performances **thanks to the additional MFT information**

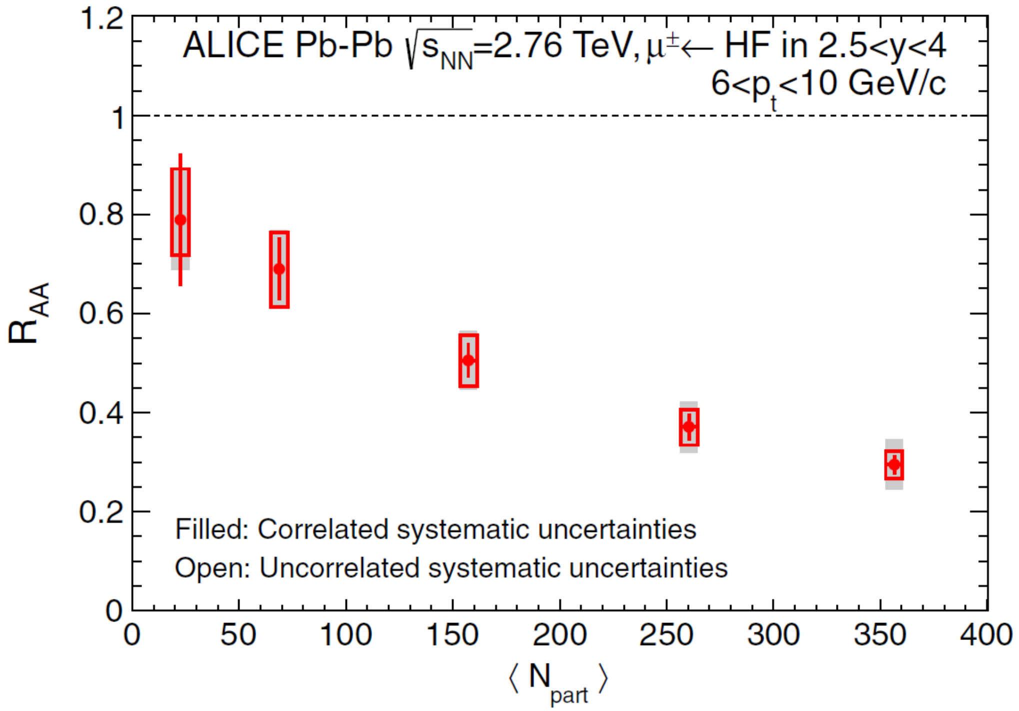
0-10% central Pb-Pb collisions considered here!

Open Heavy Flavors: Motivations

- **Heavy flavor produced in initial hard scattering**: short formation time gives insight on the short time scale of the collision
- **Charmed and beauty hadrons have a long life time** ($c\tau \sim 150$ μm and $c\tau \sim 500$ μm): information on the evolution of the deconfined medium
- **Sensitivity to the density of the medium** is provided by the mechanism of in-medium energy loss of heavy quarks.
- **“Dead-cone” effect:** in-medium gluon radiation is expected to increase with the color-charge of the emitting particle, and to decrease with its mass
- **Open HF provide a reference for the production of quarkonia:** interpreting the modification of the production yield of quarkonia as they arise from the same production mechanisms

Open Heavy Flavors: Current ALICE Performances

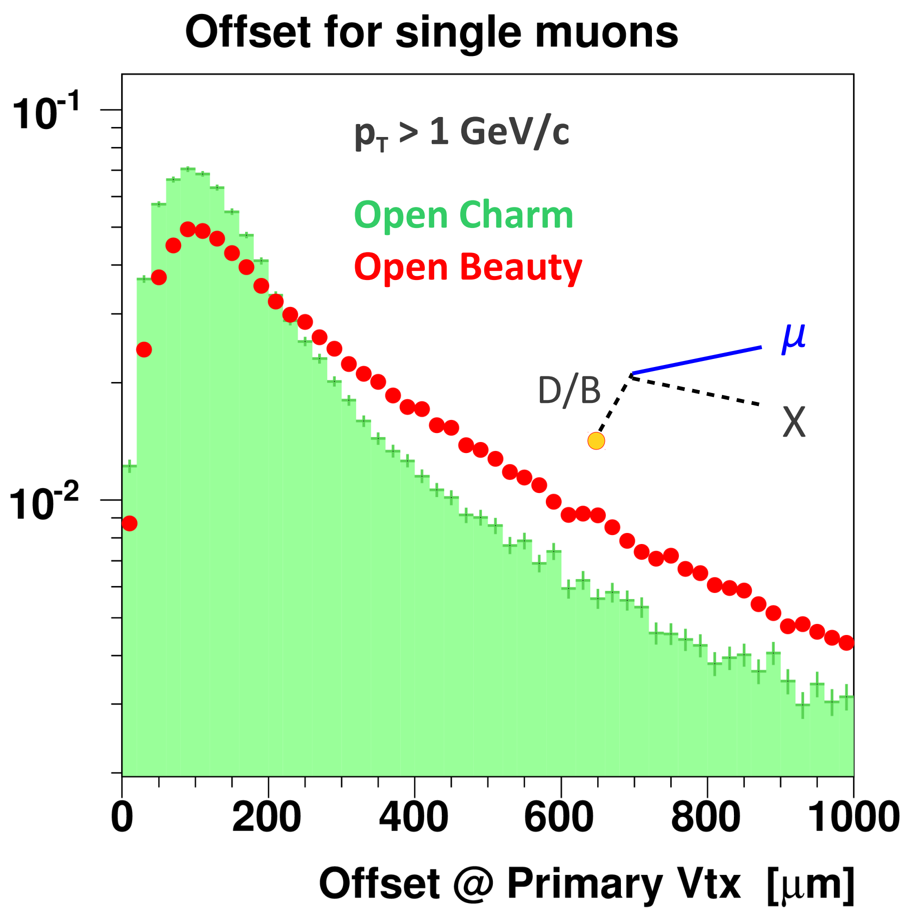
- Analysis of open heavy flavor production in single muons recently published: Physics Review Letter **109**, 112301 **(13 September 2012)**
- **Analysis limited to p_T > 4 GeV/c** because of large contamination from background (muons from light flavors) at lower p_T



- Open charm and open beauty are not separated in the Pb-Pb measurement
- We are missing the low p_T production which is needed to interpret quarkonia production down to zero p_T
- The analysis in the dimuon channel is currently being performed

Open Heavy Flavors with the ALICE MFT

- The basic idea it to **disentangle open charm and open beauty contributions on the basis of their offset distributions** w.r.t. the primary vertex: possible down to low p_T without model dependence



Role of fake matched (di)muons: their contribution to the offset distributions are similar for all the processes

- Preliminary investigations: offset distribution for open charm and open beauty dimuons **can be disentangled even at low p_T**
- Work in progress: **comparison with the offset distribution for background (di)muons** with the proper normalizations

Charmonia: Motivations

Charmonia production is the classical tool to investigate:

- **Suppression mechanisms** due to dissociation of charmonia states in the medium (color screening)
- **Recombination mechanisms** due to the relative abundance of available cc pair in the deconfined medium

To correctly interpret the data, we need precise and comprehensive measurements. In particular:

- Observations over a **broad range of p_T starting from zero p_T** : suppression/recombination mechanisms depend on the p_T of the resonance
- Interaction between charmonia and global event dynamics: different role of **elliptic flow** is expected in suppression/recombination scenarios
- **Disentangle prompt and displaced charmonia production,** measurement of other charmonia states, in particular ψ(2S)

Charmonia: Current ALICE Performances

see talk by A. Lardeux

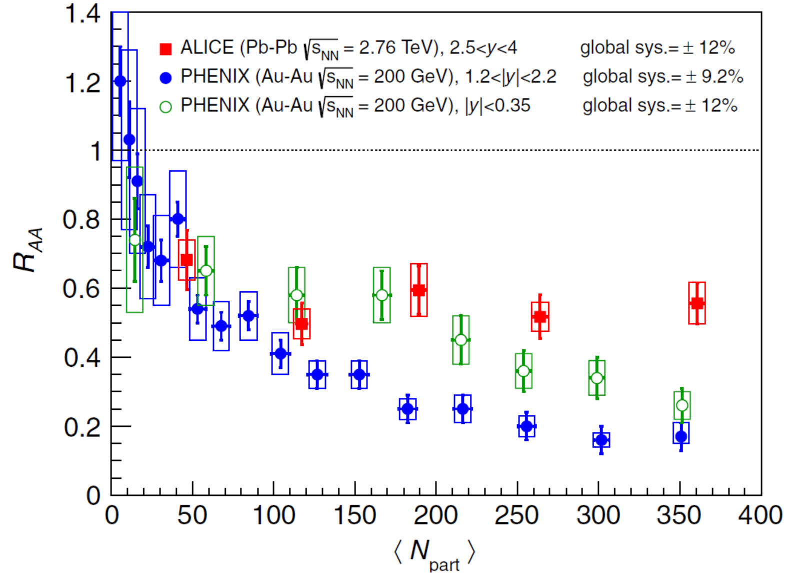
Charmonia production in ALICE studied down to zero p_T

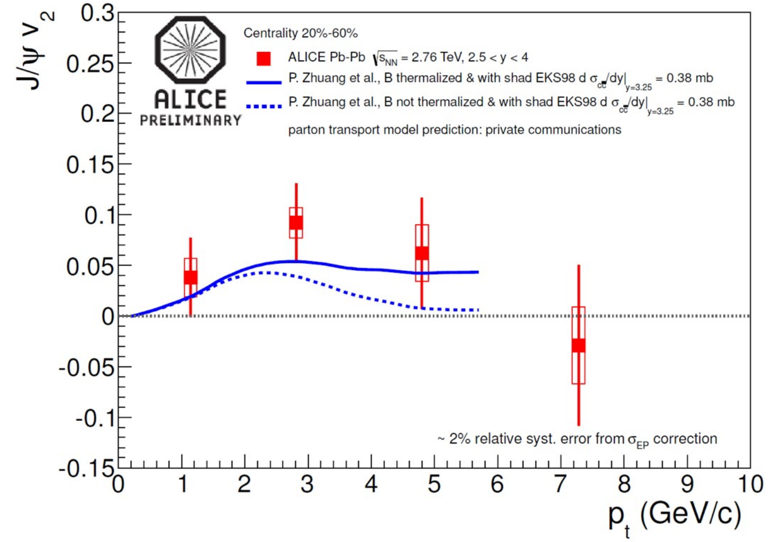
- Physical Review Letters **109**, 072301 **(17 August 2012)**
- Comparison with the PHENIX data and theoretical models

First measurement of elliptic flow of J/ψ: crucial observable to discriminate between theoretical models

Main limitations:

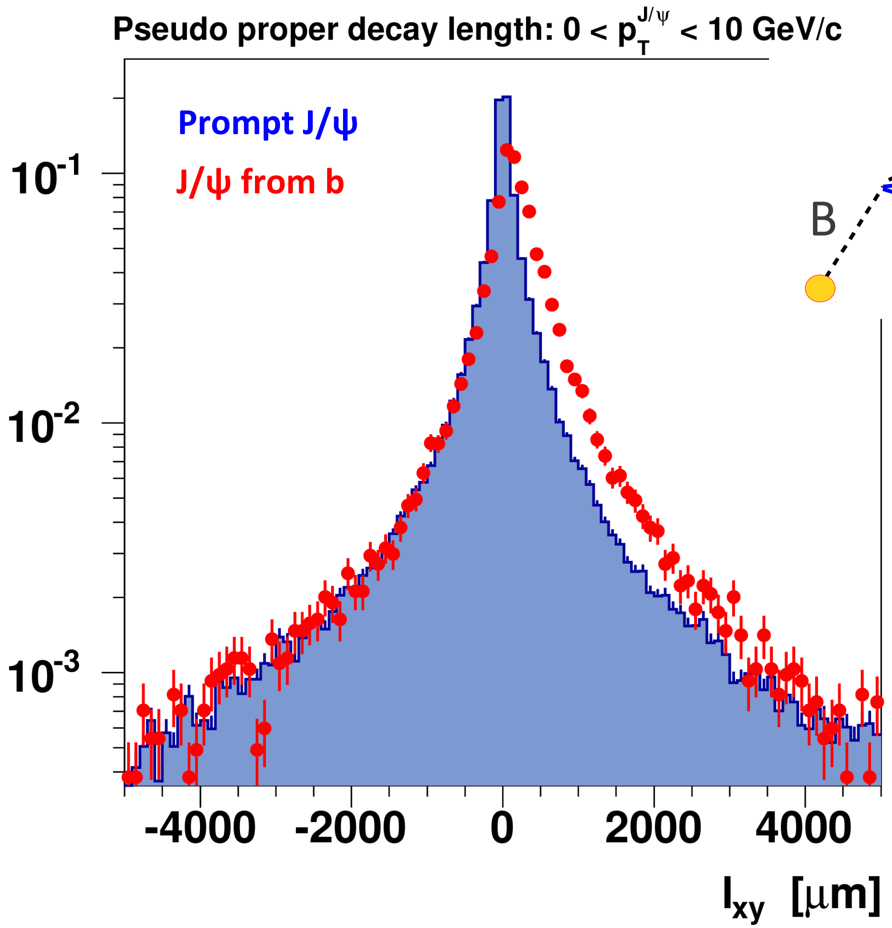
- large combinatorial background
- impossibility to disentangle prompt and displaced production

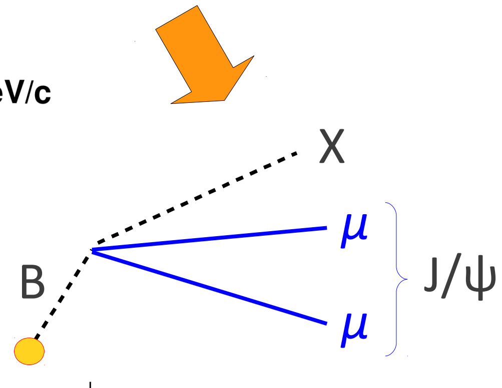




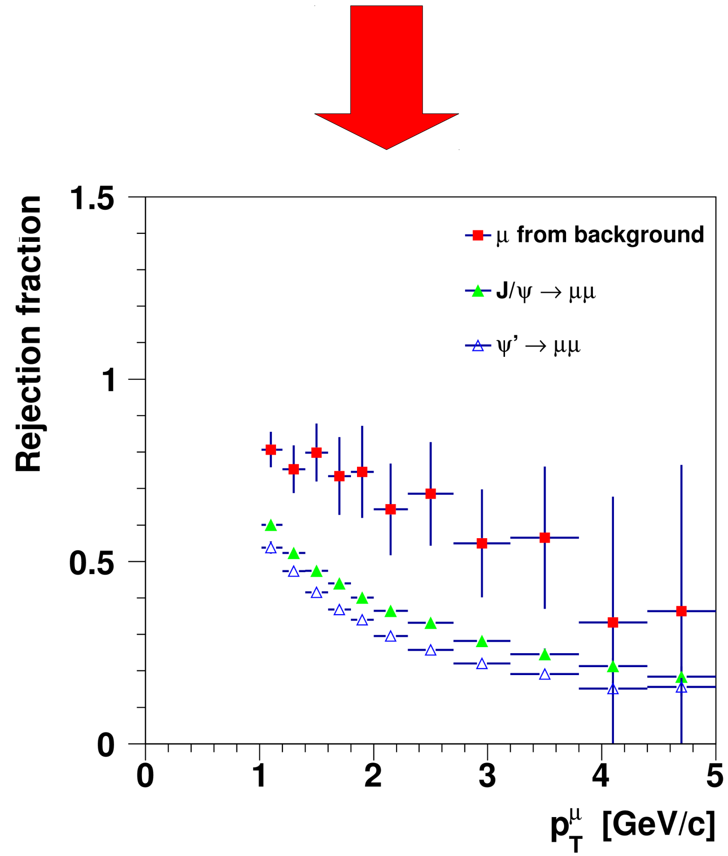
Charmonia with the ALICE MFT

Disentanglement of prompt and displaced J/ψ production: we have to recognize displaced vertices from b



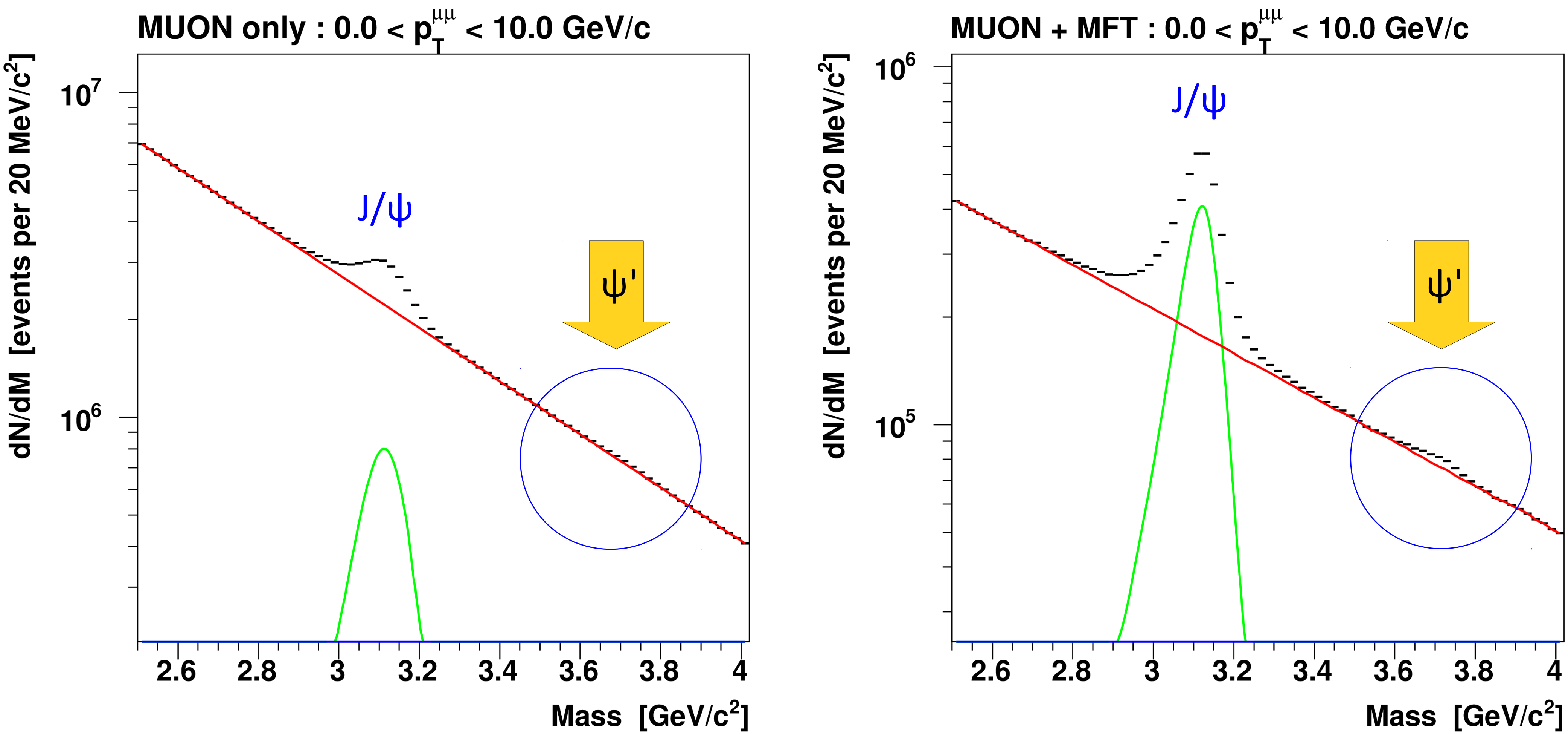


Reduction of the combinatorial background level: we must reject as many muons from pions/kaons as possible (minimizing the signal loss)



Charmonia with the ALICE MFT

S/B improved by a factor **~5 and ~3.5 for the J/ψ and ψ'**. The ψ' is visible even in central Pb-Pb collisions. **MFT cuts and selections still to be optimized!**



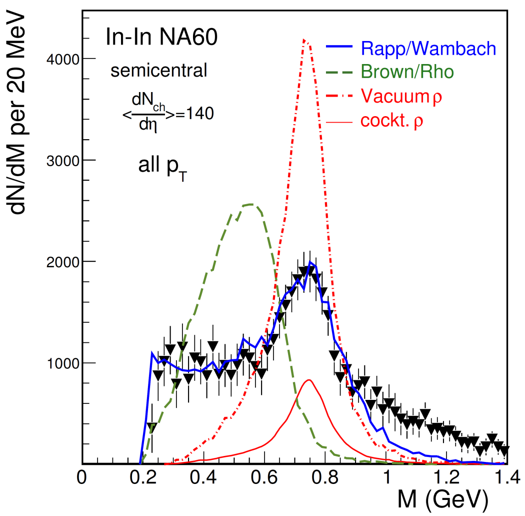
Low Mass Dimuons: Motivations

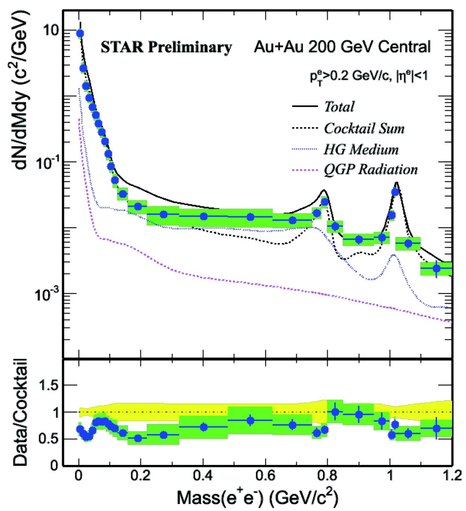
Low mass vector meson (ρ, ω, ϕ) production provides key information on the hot and dense state of strongly interacting matter which is produced in high-energy heavy-ion collisions. Insights on **non-perturbative QCD** are provided

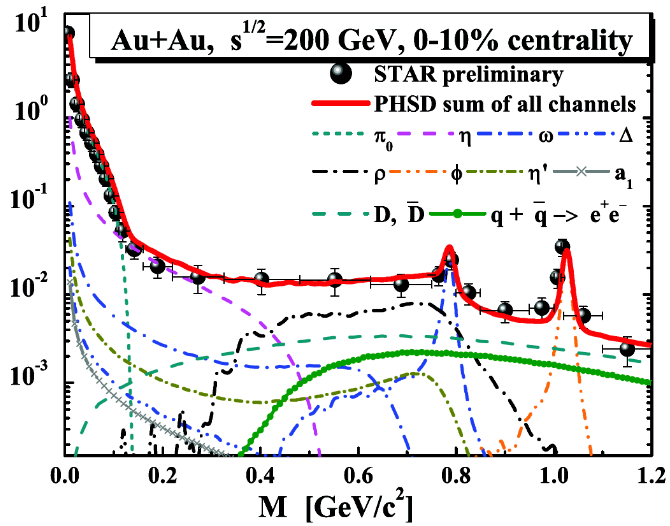
SPS: excess observed and studied by CERES/NA45 (dielectrons) and NA60 (dimuons)

RHIC: excess observed by PHENIX and STAR (dielectrons) with some inconsistencies between the two experiments

LHC: very preliminary results from ALICE in limiting signal/background conditions



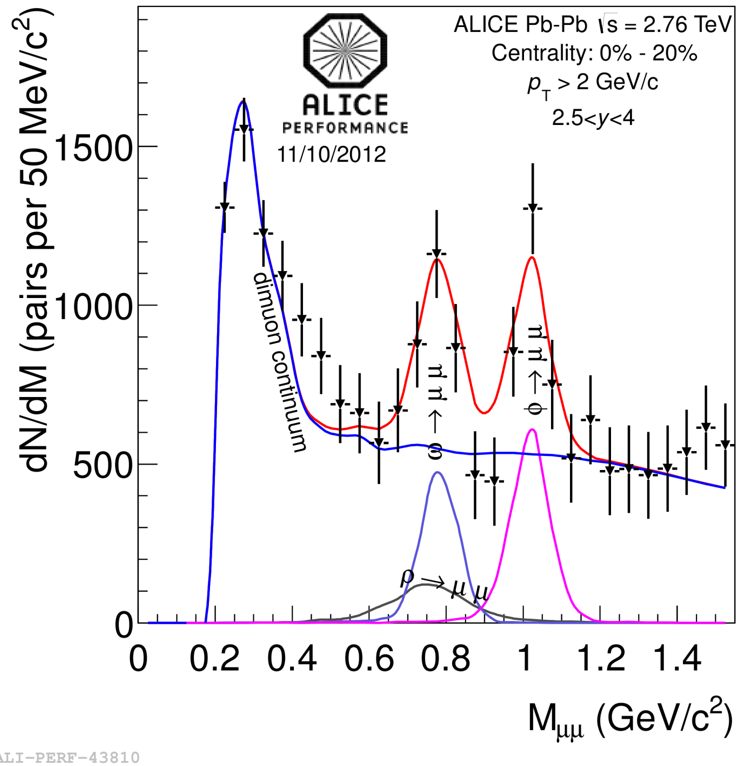




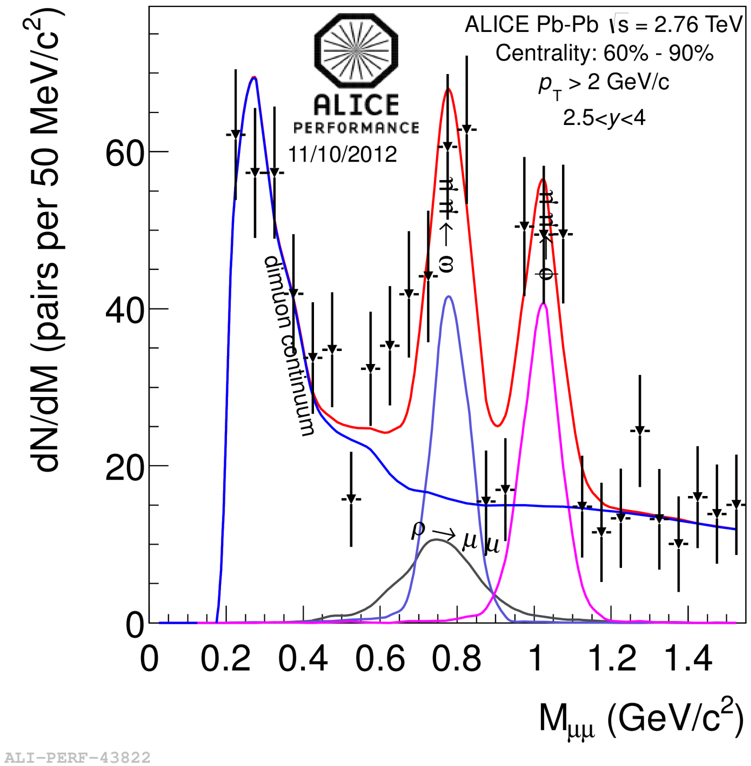
VERY preliminary plots. At the present status, we can describe the data by means of the same sources used in describing the pp data. Precision measurements hard to perform because of the low Signal/Background

see talk by E. Casula

Centrality 0 – 20%

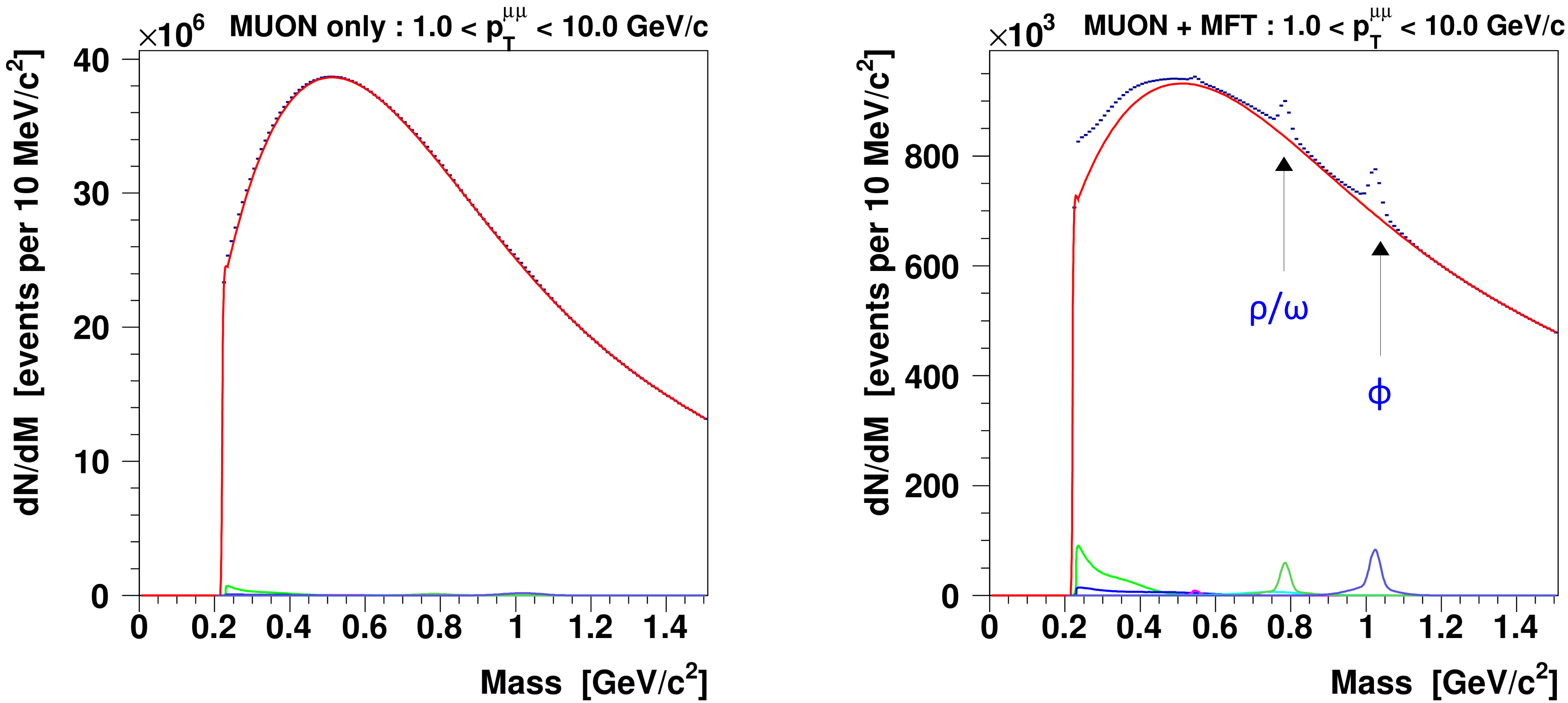


Centrality > 60%



Low Mass Dimuons with the ALICE MFT

- **Cleaner sample of prompt muons** thanks to the offset measurement
- **Improved mass resolution** thanks to the improved measurement of opening angle
- **S/B ratio improved by a factor 3 to 10** depending on the mass region



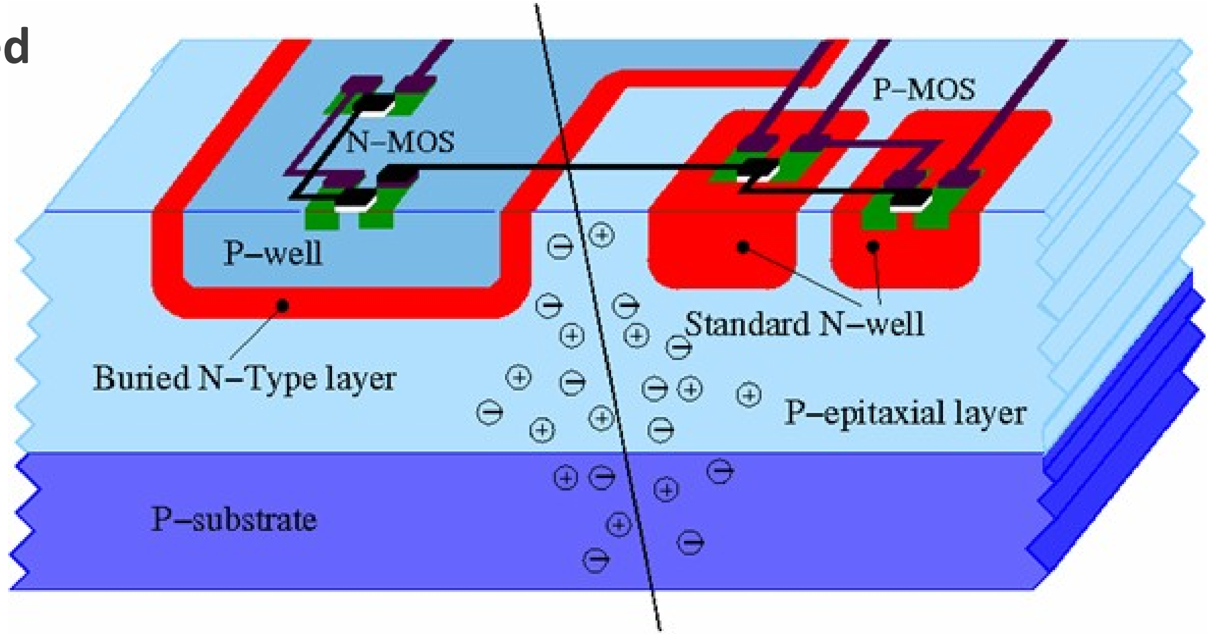
Technological Aspects: Pixels

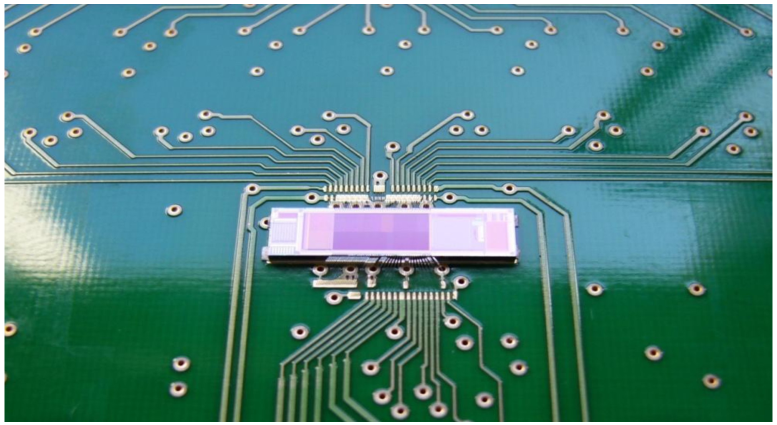
CMOS technology will be used for the pixel sensor.

Same technology as the ITS upgrade (reduced R&D costs)

Good trade-off between:

- High granularity
- Low material budget
- Power consumption
- Radiation tolerance
- Costs





The architecture proposed for the MFT CMOS sensor is mainly based on the **MIMOSA26 CMOS sensor**

- **Pixel size:** 18.4 µm
- **Readout speed:** T ~ 150 ns per row
- **Radiation tolerance:** few 100 kRad

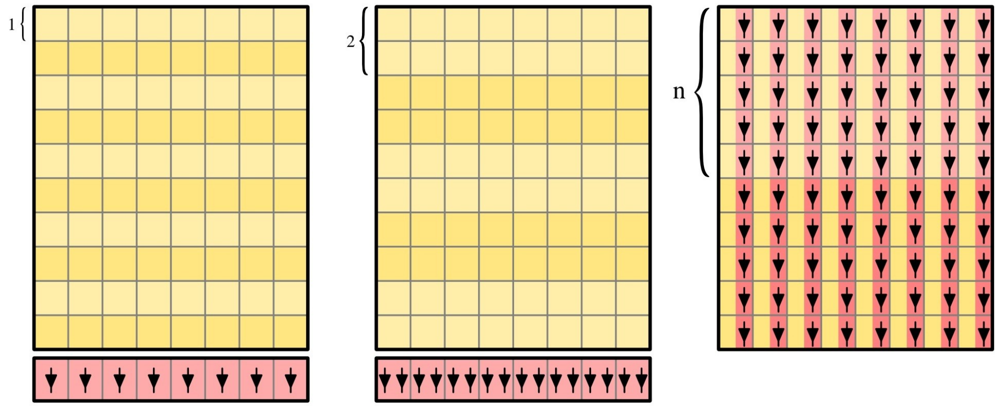
Technological Aspects: Sensor Architecture

Target interaction rate for ALICE after 2018 (high-luminosity Pb-Pb):
Pb-Pb interactions at 50 kHz (interactions every 20 μs)

Target for the MFT:

- no pile-up in Pb-Pb collisions (interactions every 20 μs)
- no ambiguity in assigning muon tracks to vertex

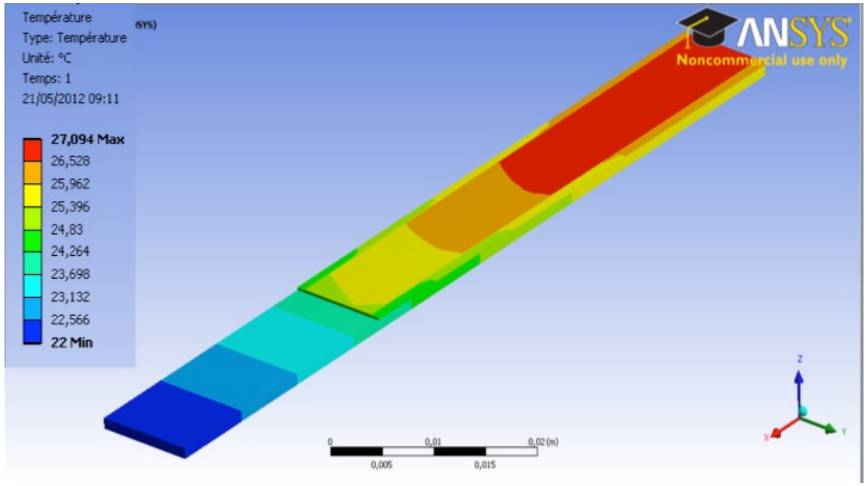
For the MFT project, the main parameter of the sensor to be improved is the **readout time**

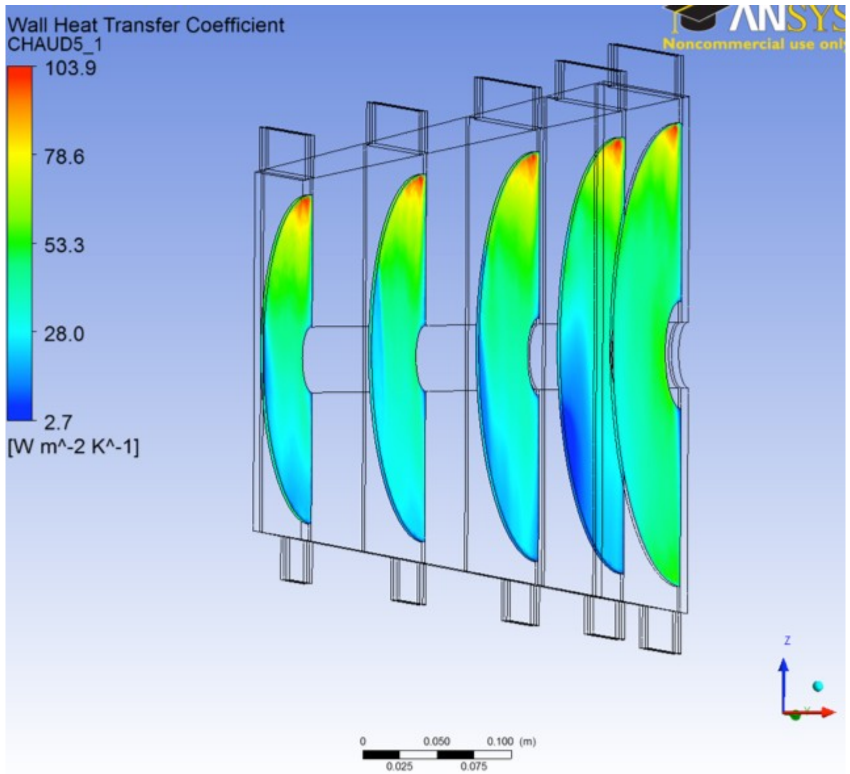


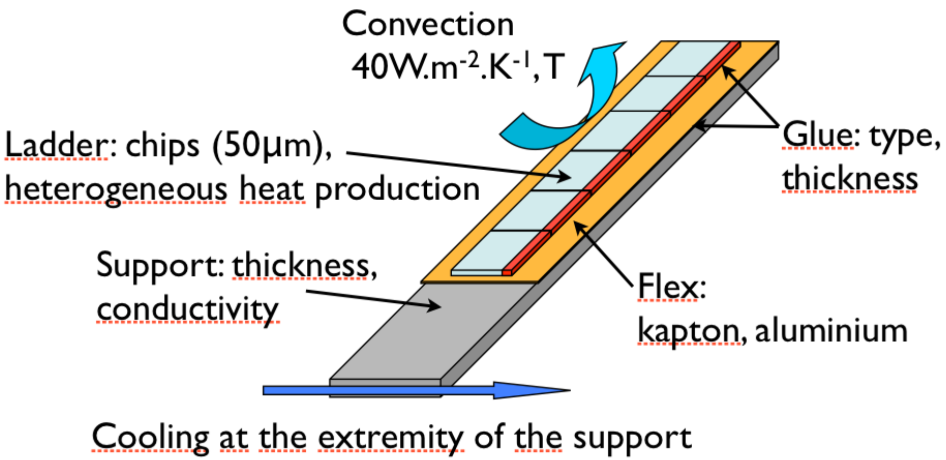
NOMINAL	IMPROVED	NEW CONCEPT
1 discr/column Readout time: $T \cdot n_{row}$	2 discr/column Readout time: $(T \cdot n_{row})/2$	1 discr/pixel Readout time: $(T \cdot n_{row})/n$

Readout schemes under consideration

Technological Aspects: Cooling







- **Operational temperature: 35 °C**
- **Power consumption to be dissipated: ~1 kW**

Conclusions...

The MFT is expected to give several contributions to the ALICE Muon Arm physics:

- Open heavy flavors physics: offset resolution for single muons and dimuons allows a disentanglement of charm and beauty production on a model-independent basis
- Charmonia physics: possibility to disentangle prompt and displaced charmonia production, possibility to perform a study of the ψ' state even in central Pb-Pb
- Low mass dimuon physics: more precise study of low mass vector mesons because of the reduced background and the drastically improved mass resolution

Main technological aspects:

- Integration in the ALICE detector: mechanics and cooling
- Development of a pixel sensor and a fast readout architecture

Currently involved institutions: **France** (IPNL, IPNO, LPC, Subatech, CEA-IRFU)
India, South Africa, Russia, Armenia

Conclusions... with the MFT

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Backup Slides

Background Reduction

Main sources of background:

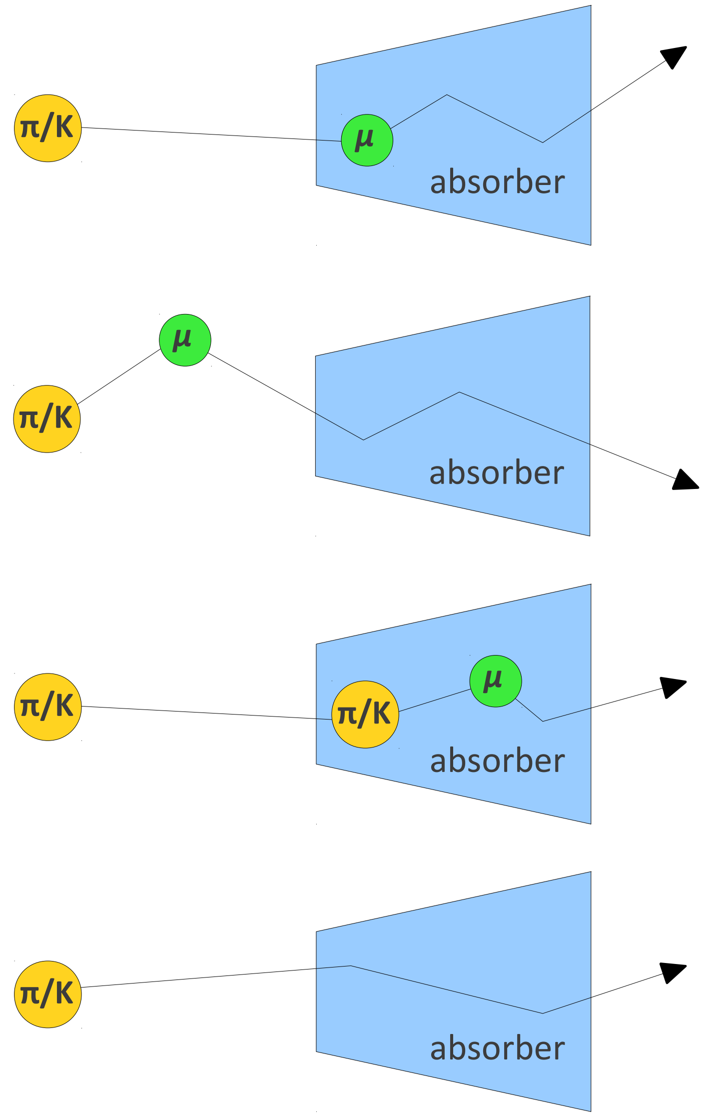
- μ from primary π/K decaying **inside** the absorber
- μ from primary π/K decaying **before** the absorber
- μ from **secondary** π/K decaying inside the absorber
- punch-through hadrons

Current limitations imposed by background:

- contamination of open charm/beauty measurement in the single muon measurements
- huge dimuon contamination at low mass and low p_T

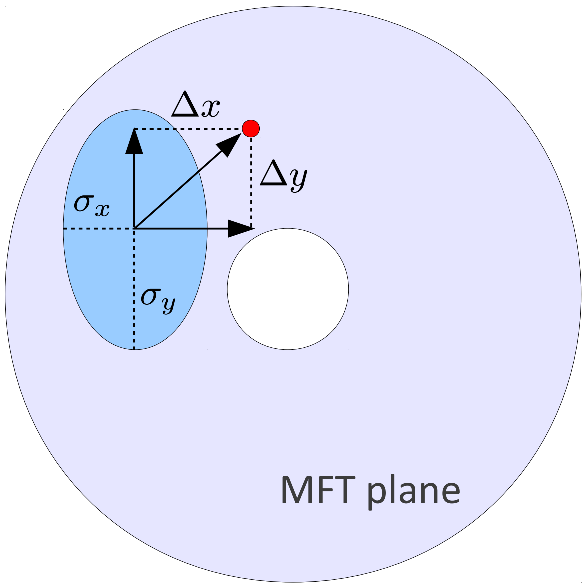
Background rejection with the MFT:

a fraction of background muons will be discarded applying a **quality cut on the match with the MFT clusters**



Matching with MFT Clusters

For each **cluster** in the plane, its compatibility with the parameters of the **extrapolated track** is checked, in terms of the quantity:



$$\chi^2_{\text{clust}} = \frac{\Delta x^2 \cdot \sigma_y^2 + \Delta y^2 \cdot \sigma_x^2 - 2 \cdot \Delta x \Delta y \cdot \text{cov}(x,y)}{\sigma_x^2 \cdot \sigma_y^2 - \text{cov}^2(x,y)}$$

Distance between the cluster and the track at the plane along X and Y

Covariance matrix elements of the track parameters after extrapolation (+ cluster size along X and Y)

If the X and Y coordinate parameters of the track are not correlated, we simply have:

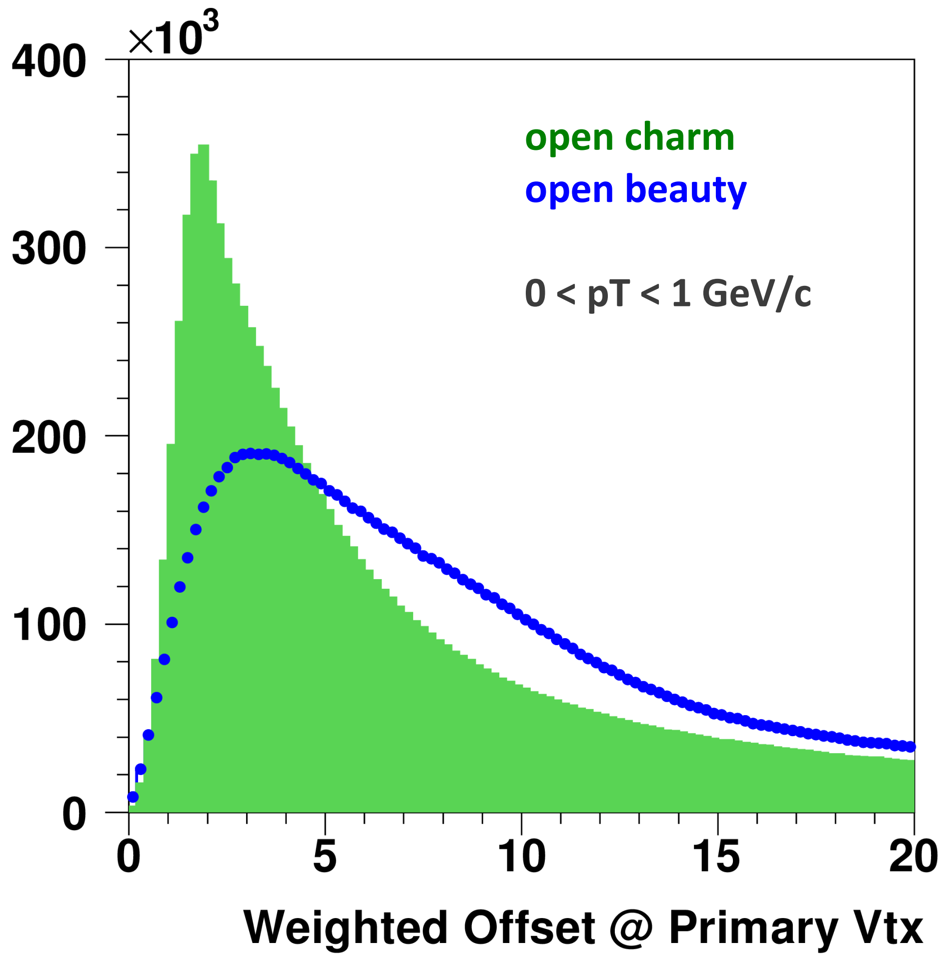
$$\chi^2_{\text{clust}} = \frac{\Delta x^2}{\sigma_x^2} + \frac{\Delta y^2}{\sigma_y^2}$$

The cut is expressed as: $\chi^2_{\text{clust}} < 2 \cdot n_\sigma^2$

Currently used: $n_\sigma = 4$

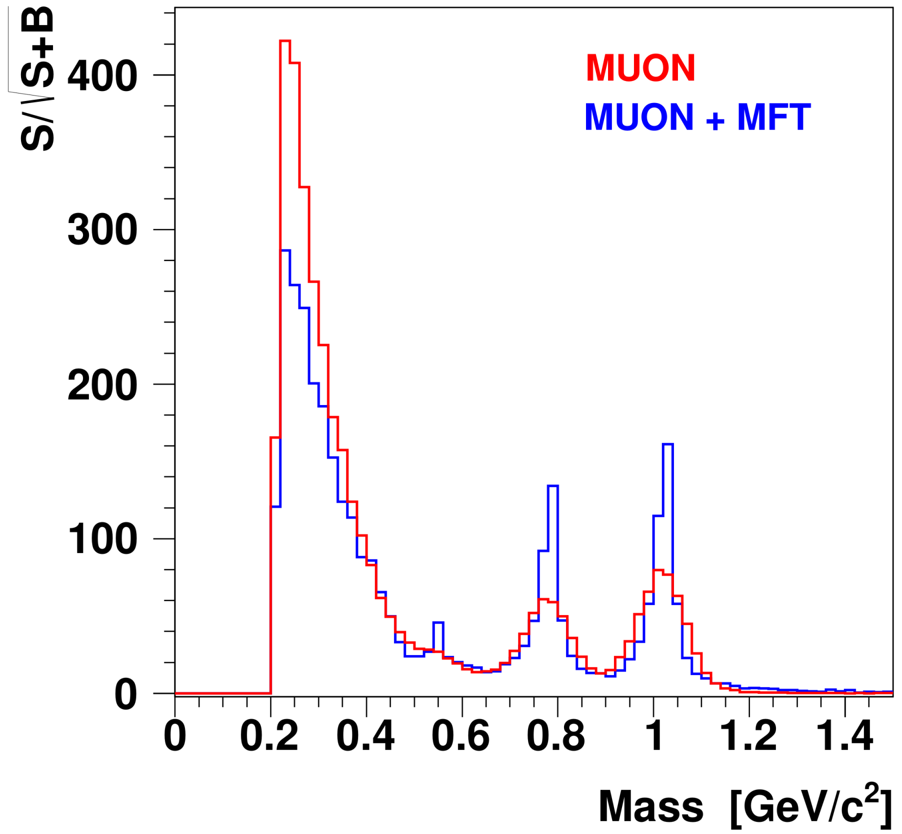
Open Heavy Flavors: Dimuons

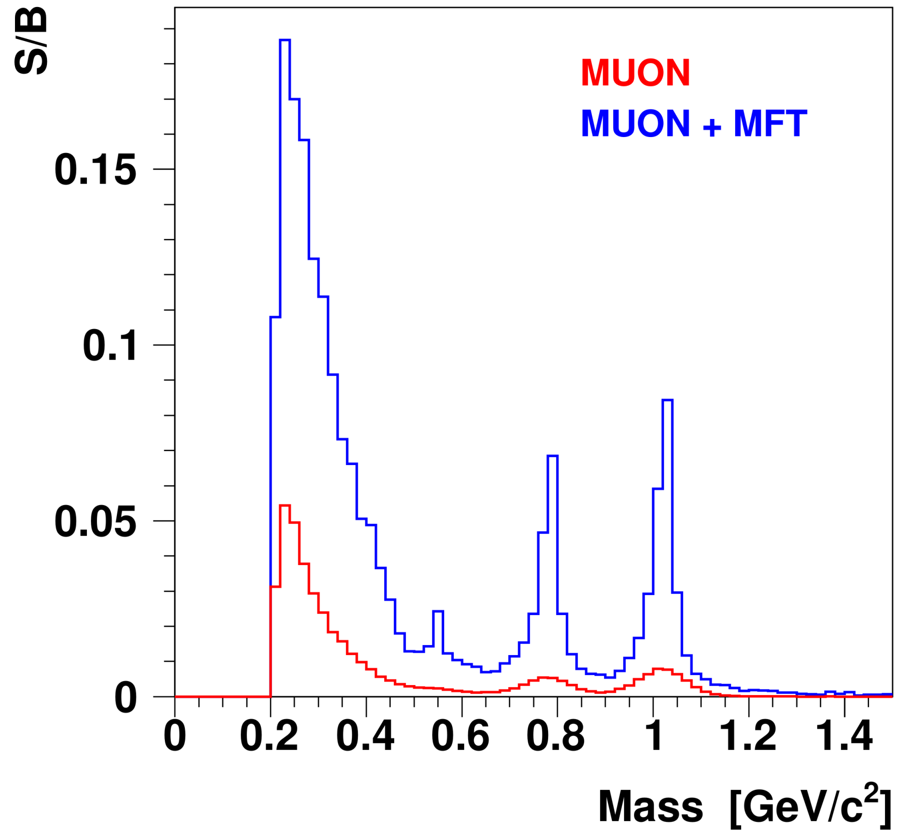
Weighted offset for open heavy flavor dimuons



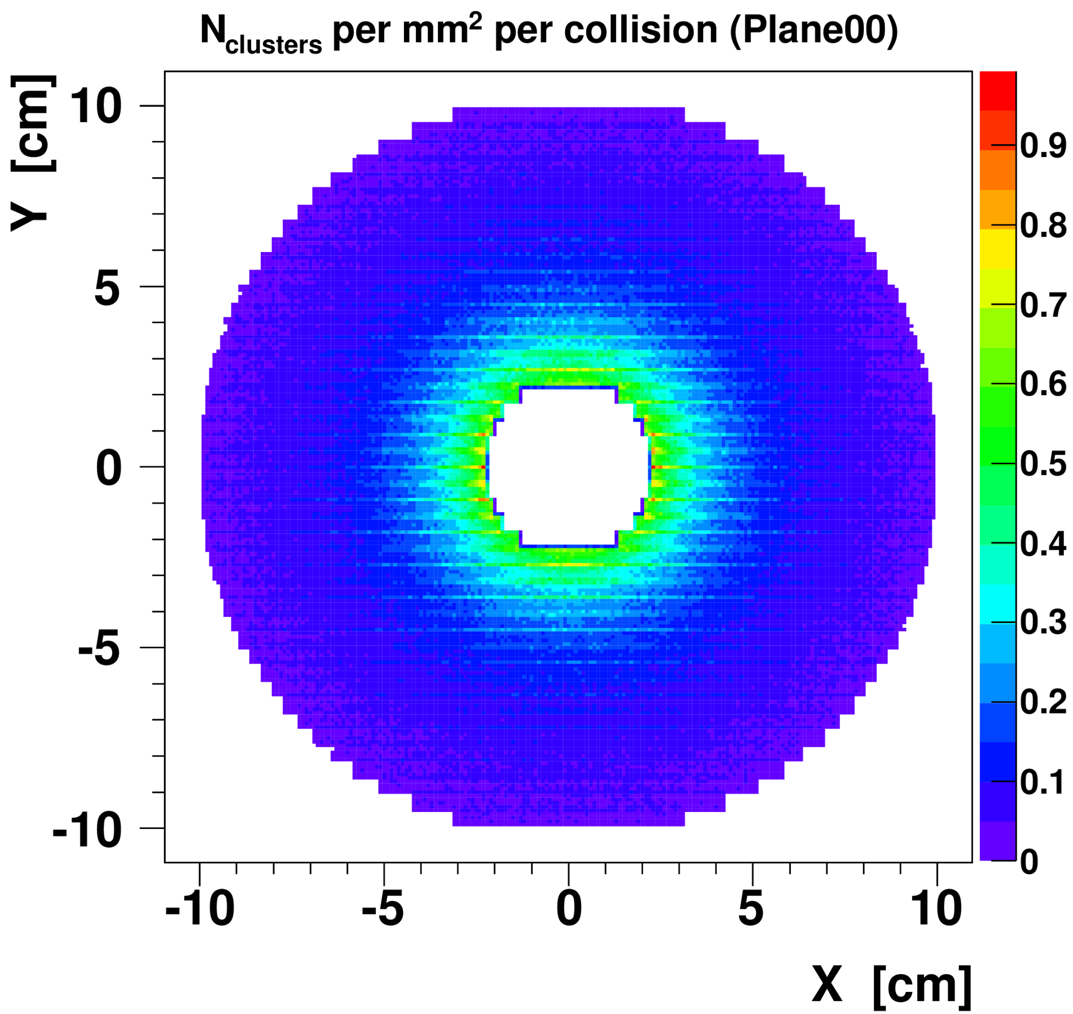
Low Mass Dimuons: S/B and Significance

We gain in S/B (which will limit the systematic uncertainties) without loosing the significance (already sufficient to have low statistical uncertainties)



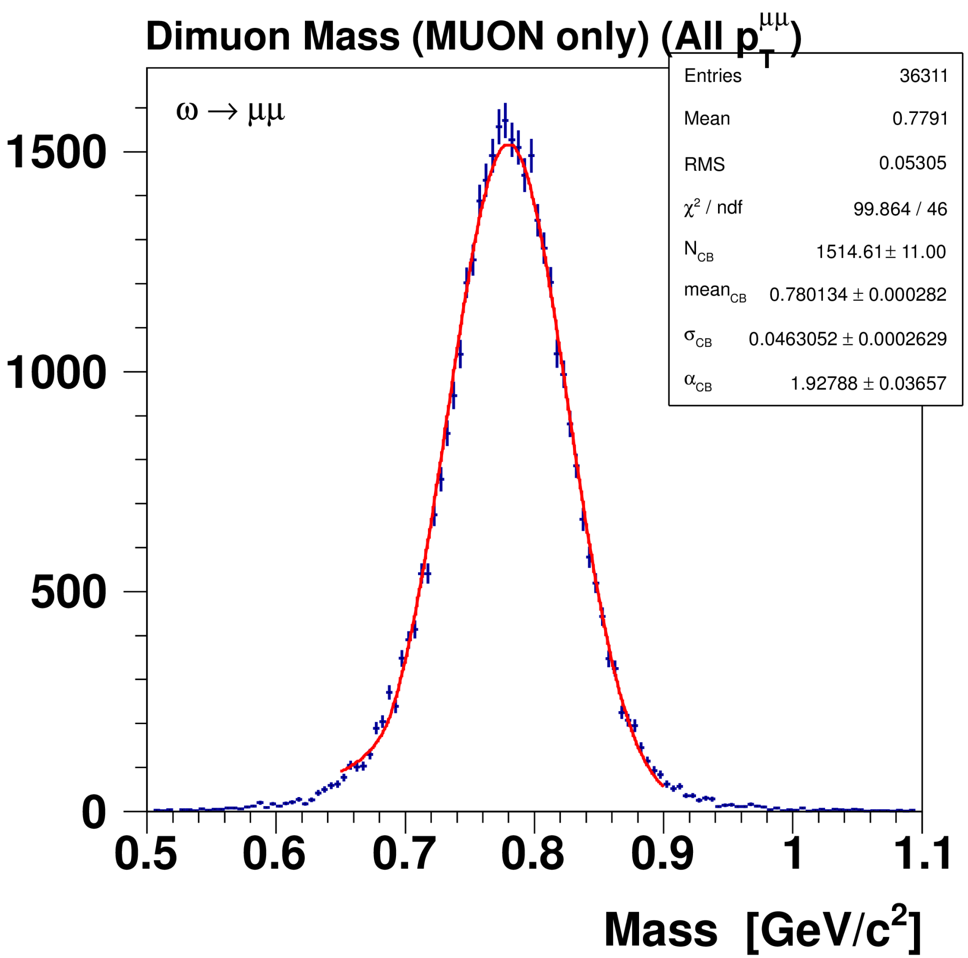


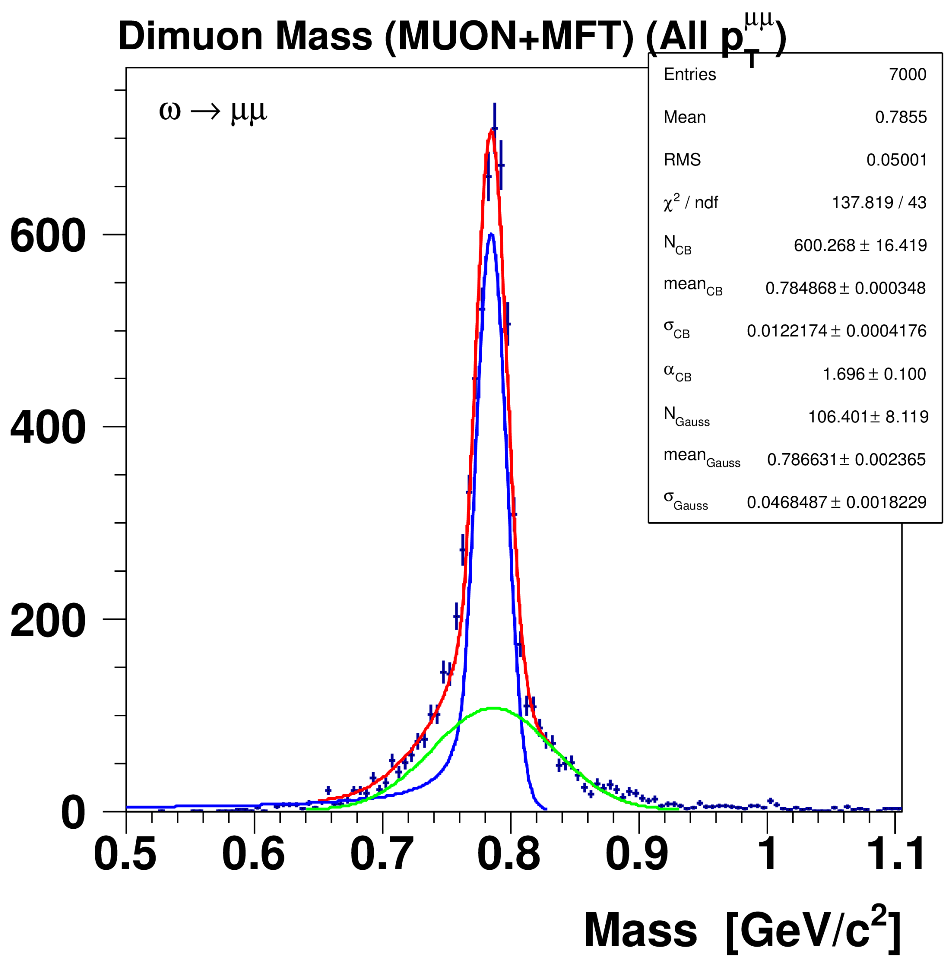
MFT Planes Occupancy



- **Track density below 1 track per mm²** in central Pb-Pb collisions even in the tracking planes closest to the I.P.
- **Residual misalignments to be estimated:** preliminary studies suggest that it should have a negligible impact on the MFT physics. Systematic studies are ongoing

Low Mass Resolution: ω Meson





Low Mass Resolution: φ Meson