FCPPL 2015

8th Workshop of the France-China Particle Physics Laboratory

Hefei, China
April 8-10 2015

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ALICE Lyon Group @ IPNL

The ALICE Upgrade Program

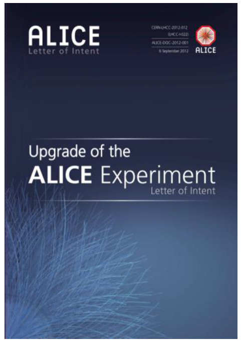
IN2P3

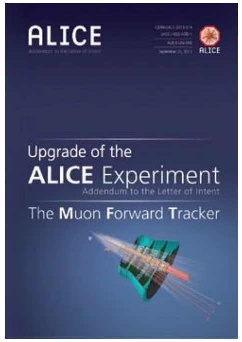
ALICE

Outline

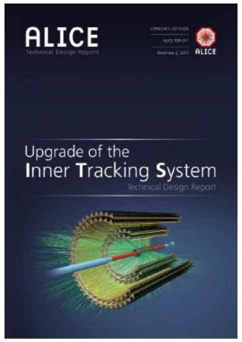
- **ALICE Upgrade Strategy** for the 2nd LHC Long Shutdown: 2018/2019

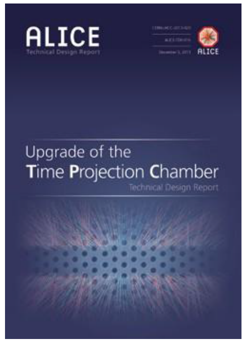
- **Selected detector upgrades**

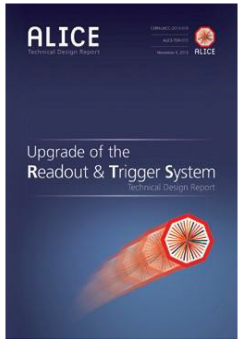




- **Target physics topics:**
  - Heavy Flavor physics
  - Quarkonia physics
  - Low-mass & continuum dilepton physics







ALICE Physics Program: Motivations

- **Long-term goal of the ALICE physics program:** providing a precise characterization of the Quark-Gluon Plasma (QGP) state:
  - Initial temperature
  - Degrees of freedom
  - Transport coefficients
- **Better understanding of QCD as a genuine multi-particle theory**
- **High-statistics, precision measurements are required:** access to the very rare physics channels needed to understand the dynamics of this condensed phase of QCD

ALICE Physics Program: Motivations

- **Primary physics topics:**
  - Charm and beauty mesons and baryons
  - Charmonia states
  - Low-mass and thermal lepton pairs
  - Gamma-jet and jet-jet with PID down to low momenta

- **Focus on low-p_T and untriggerable probes → need to examine full statistics** (complementary/orthogonal to general-purpose detectors)
  - New O^2 framework (Online-Offline) combining new High Level Trigger, Data Acquisition, Trigger system and Offline systems

- **Operate ALICE at high rates**
  - Preserving its uniqueness, precision tracking and PID down to low-p_T
  - Enhancing secondary vertex identification from heavy flavor production

ALICE Upgrade Strategy

- **ALICE will run at 50 kHz in Pb-Pb** (i.e. $L = 6\times10^{27}\ cm^{-1}\ s^{-1}$) with minimum bias (pipeline) readout (max readout with present ALICE set-up: ≈ 0.5 kHz)
  - Gain a factor of 100 in statistics over current program: **×10** from the integrated luminosity ($1\ nb^{-1} \rightarrow 10\ nb^{-1}$) and **×10** from the pipelined readout allowing inspection of all collisions. Inspect $o(10^{10})$ central collisions instead of $o(10^{8})$

- **Improve vertexing and tracking at low p_T:** better spatial resolution is needed on track reconstruction to improve secondary vertex reconstruction

- **This entails a major upgrade of the whole apparatus:**
  - New, smaller radius beam pipe
  - New inner tracking system: upgraded ITS + MFT
  - High-rate upgrade for the readout of the TPC, TRD, TOF, CALs, DAQ/HLT, Muons and Trigger detectors

ALICE Upgrade Strategy

- **LS2 starting in 2018 (July)** ⟶ **18 months + 3 months BC (Beam Commissioning)**
- LS3 LHC: starting in 2023 ⟶ 30 months + 3 BC
  (injectors: in 2024 ⟶ 13 months + 3 BC)

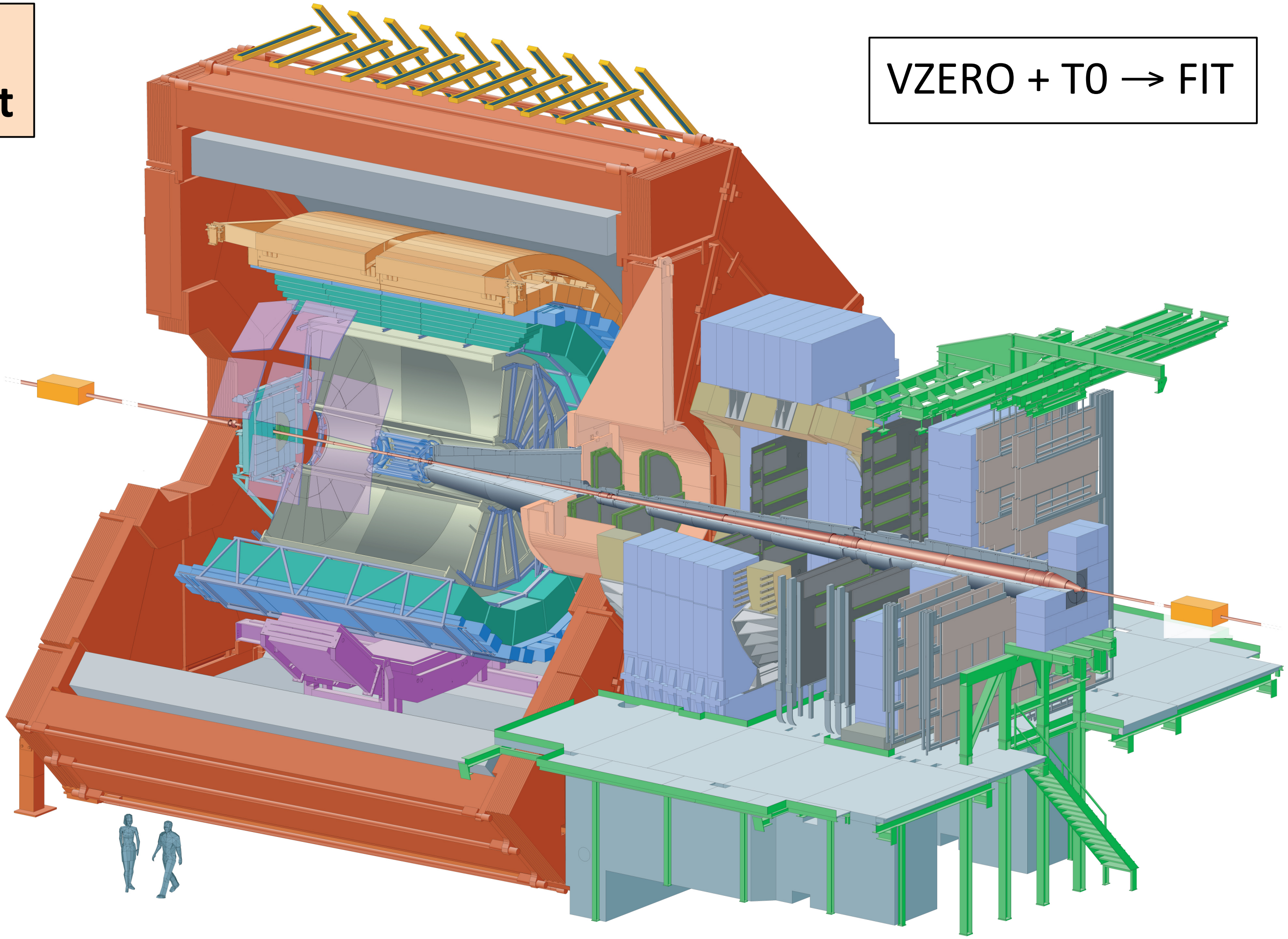
ALICE Upgrade Strategy

Muon Forward Tracker

TPC: new GEM readout chambers, pipelined readout

VZERO + T0 → FIT

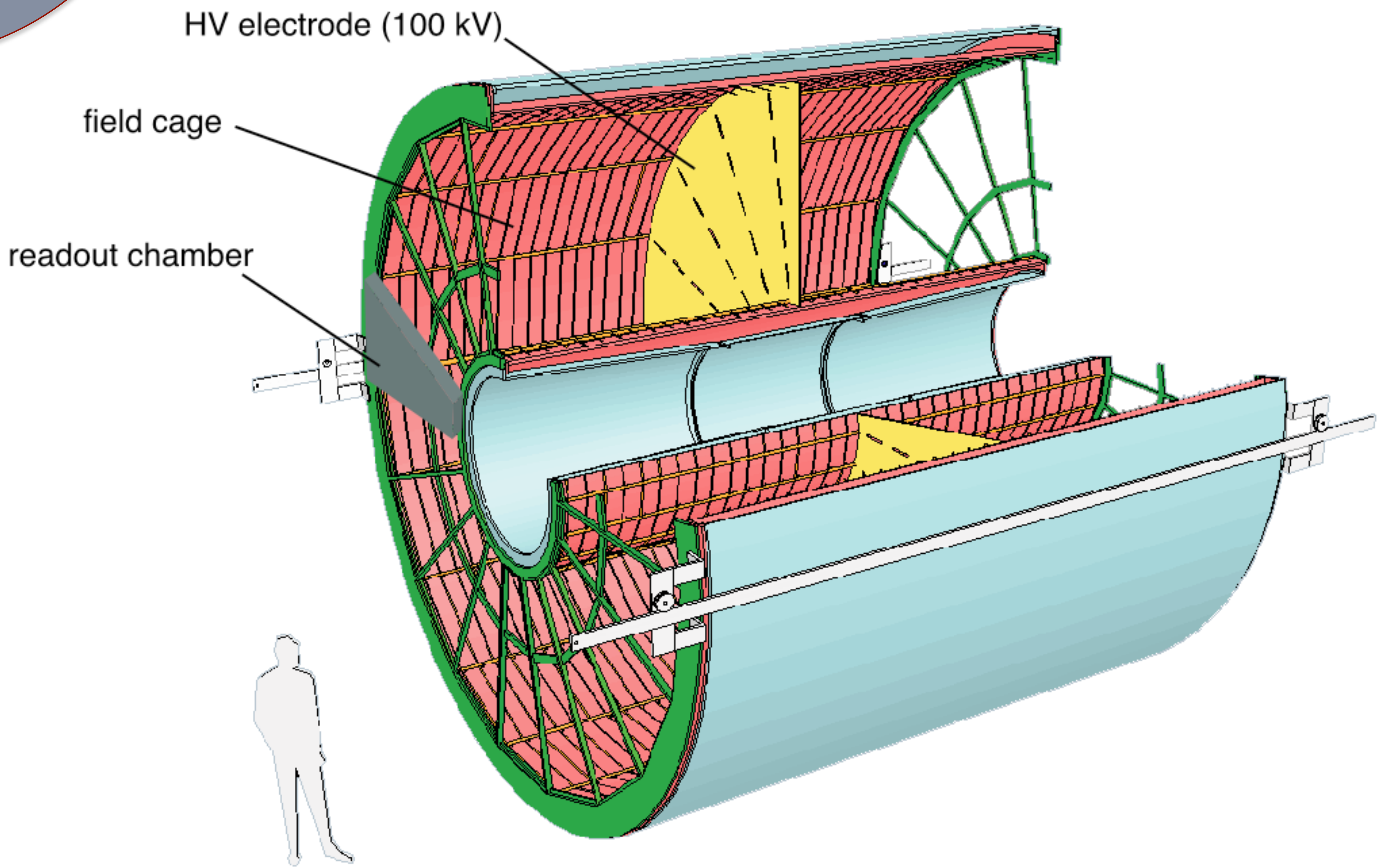
TRD, TOF, PHOS, EMCAL, Muon spectrometer: New readout electronics



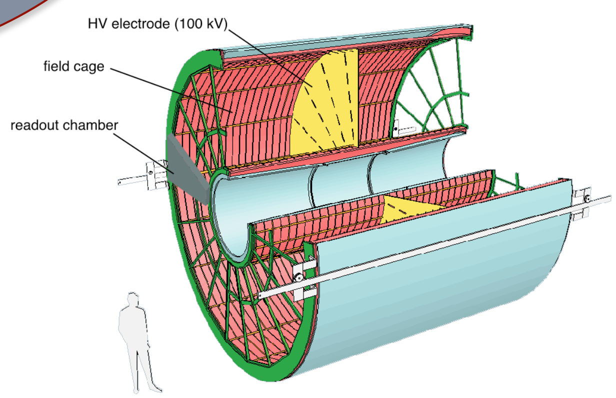
New beam pipe: smaller diameter

New ITS: high resolution, low material budget

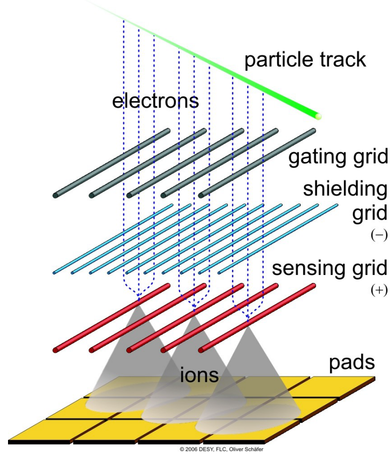
The ALICE Upgraded TPC



The ALICE Upgraded TPC

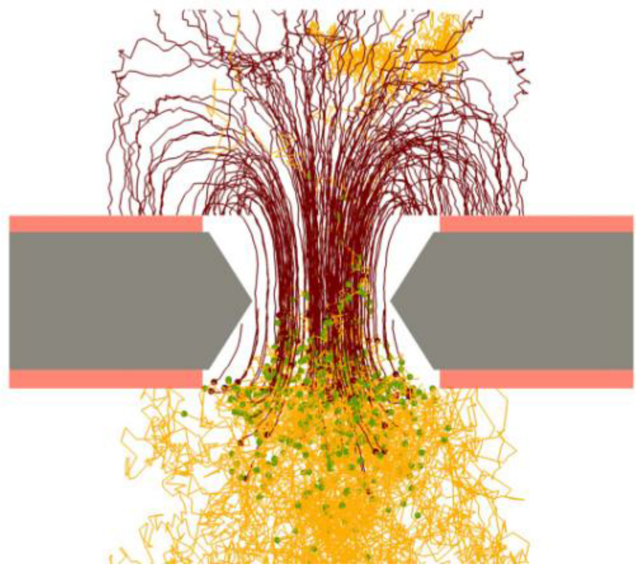


- **At the readout plane**, the signal is amplified and collected on a segmented readout structure
- Traditionally, ions from amplification are collected on a **gating grid which limits rate capability**

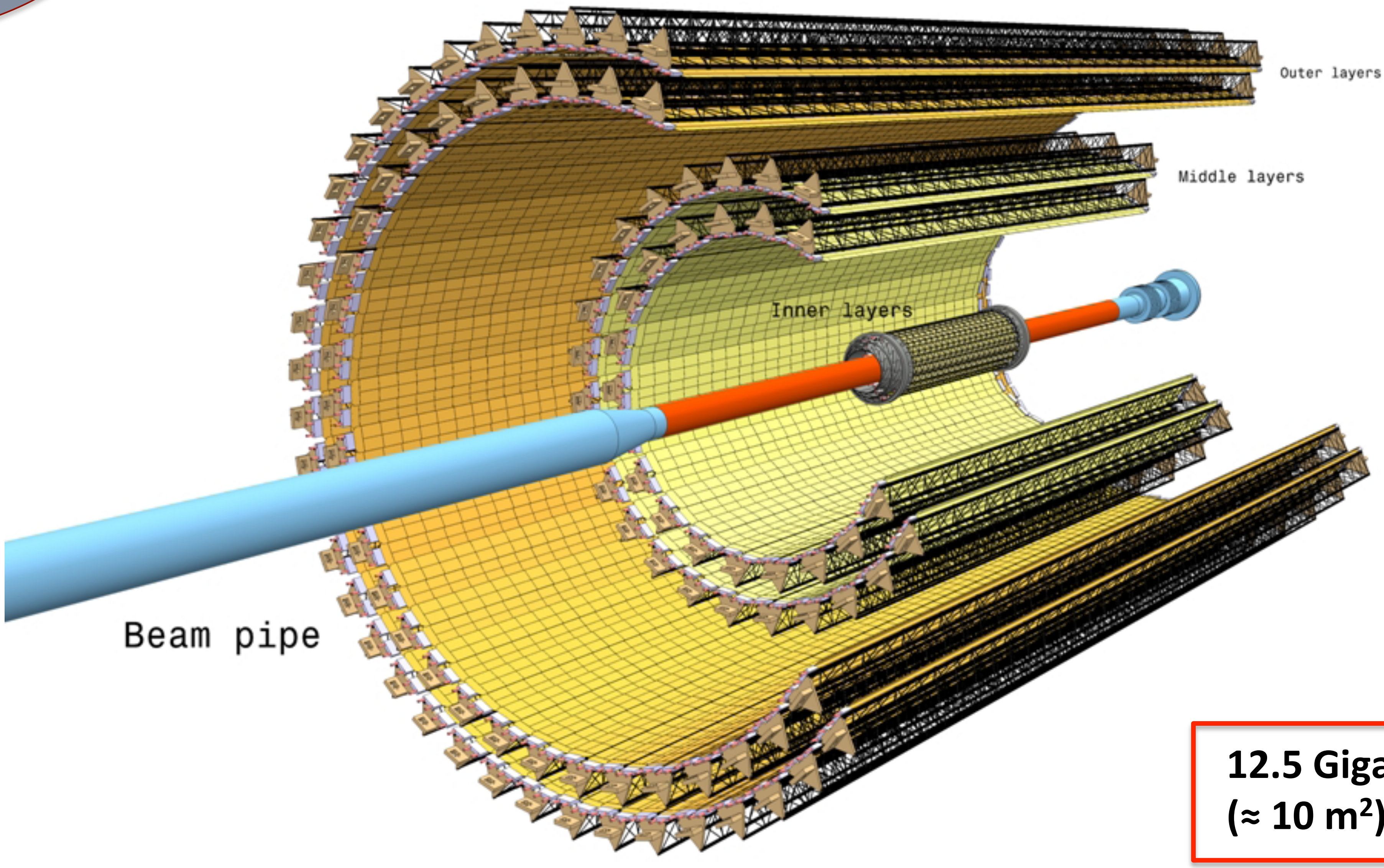


- **MWPCs:** ion clearing time (drift from readout to gating grid) introduces dead time. Max. readout rate: 3.5 kHz

- **GEMs:** Intrinsic Ion BackFlow (IBF) suppression ➜ no gating required, continuous readout possible. **However, residual 1% IBF** induces a non-negligible space charge distribution inside the TPC drift volume (7500 piled-up events @ 50 kHz) to be carefully accounted for

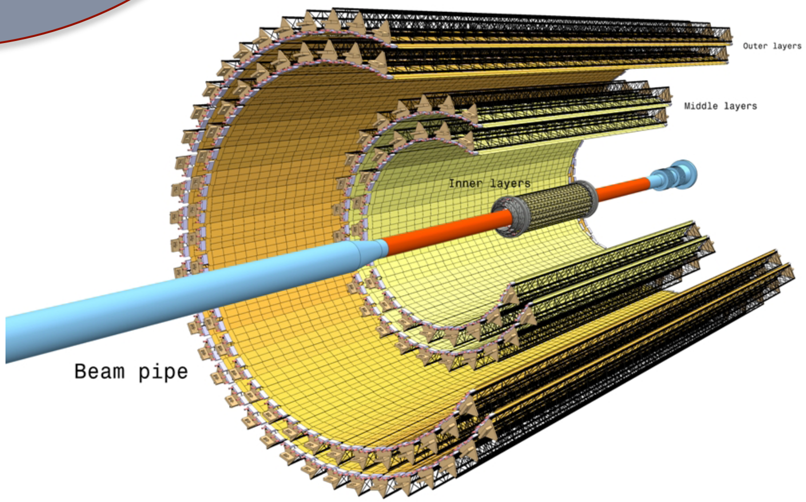


The ALICE Upgraded ITS



12.5 Giga pixel
(≈ 10 m^2)

The ALICE Upgraded ITS



Improve impact parameter resolution by a factor ~3

- Smaller beam pipe (R = 1.9 cm)
- Inner layer as close as possible (R = 2.2 cm)
- Thinner beam pipe (ΔR = 800 μm)
- Less material budget: thin sensors, 7 layers of monolithic pixel detectors (goal: 0.3% X_0 for inner layers, 0.8% X_0 for outer layers)
- Smaller pixel size: ≈ 28×28 μm² for the inner layers

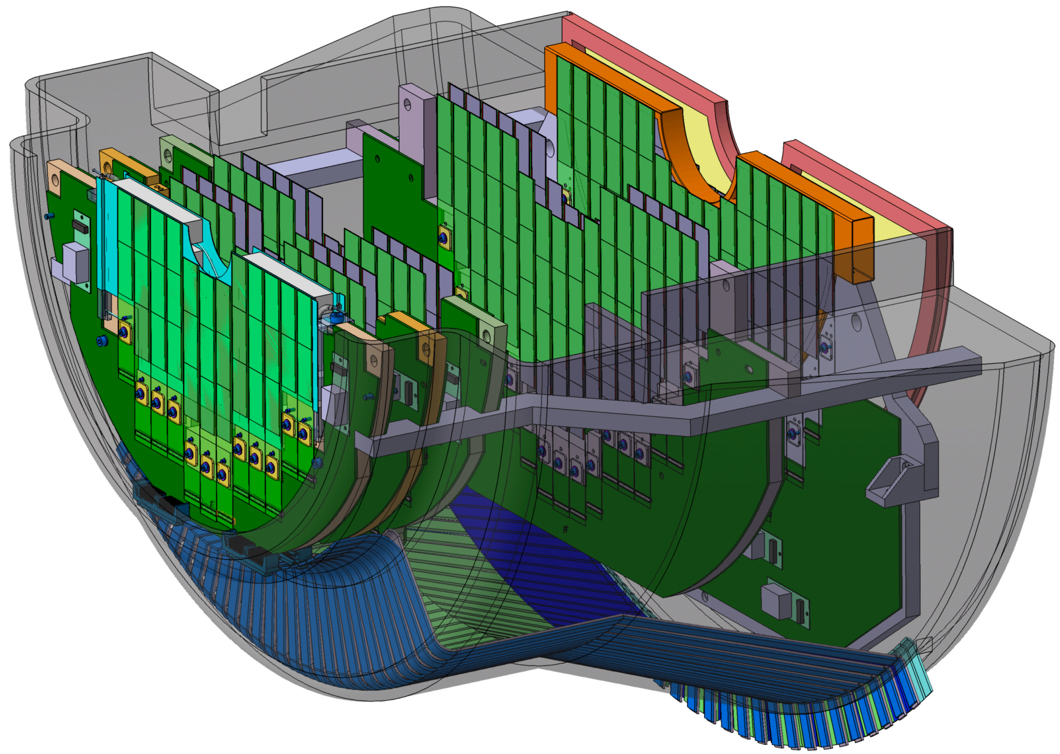
High standalone tracking efficiency and p_T resolution

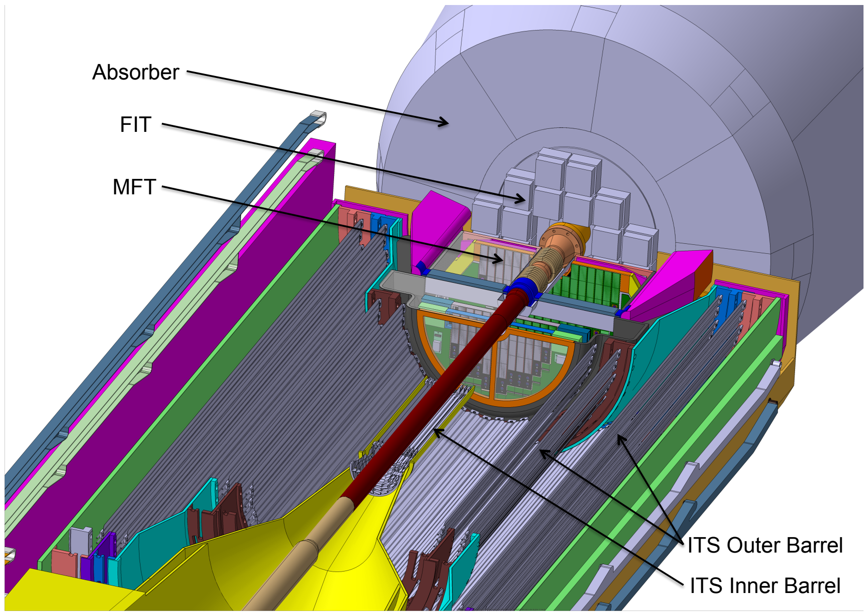
- Increase granularity: 6 layers → 7 layers with spatial resolution σ(rϕ,z) = 4-6 μm
- Fast readout: readout of Pb-Pb interactions at 50 kHz and pp up to 1 MHz

	current ALICE	ALICE upgrade	ATLAS upgrade	CMS upgrade
innermost point (mm)	39.0	22.0	25.7	30.0
x/X_0 (innermost layer)	1.14%	0.3%	1.54%	1.25%
d_0 res. $r\varphi$ (μm) at 1 GeV/c	60	20	65	60
hadron ID p range (GeV/c)	0.1–3	0.1–3	–	–

The ALICE Muon Forward Tracker (MFT)

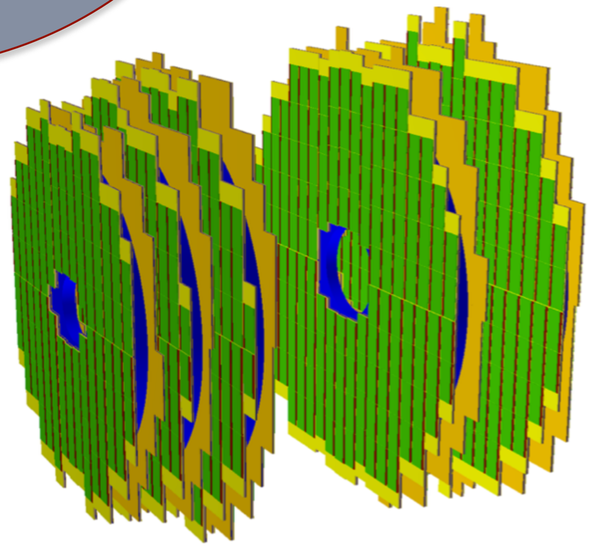
- **MFT: vertex tracker for the Muon Spectrometer**, to be installed between the interaction point and the hadron absorber





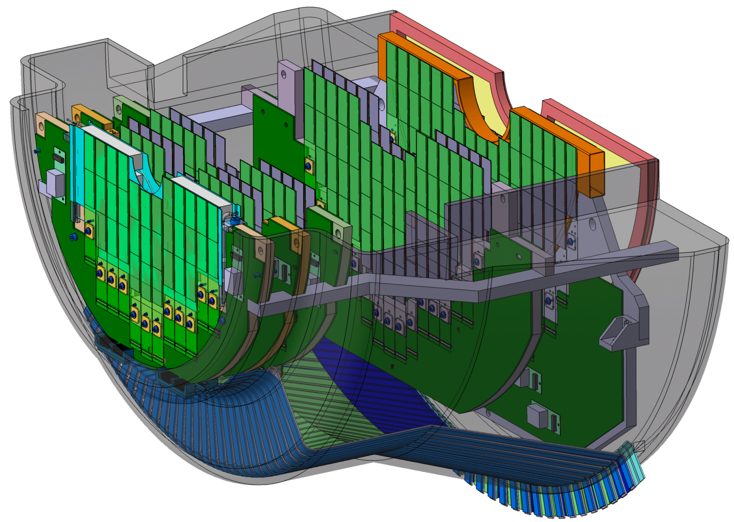
- **Precise tracking of muons:** identification of secondary vertices (J/ψ from B), measurement of single muon offset at the primary vertex

The ALICE Muon Forward Tracker (MFT)

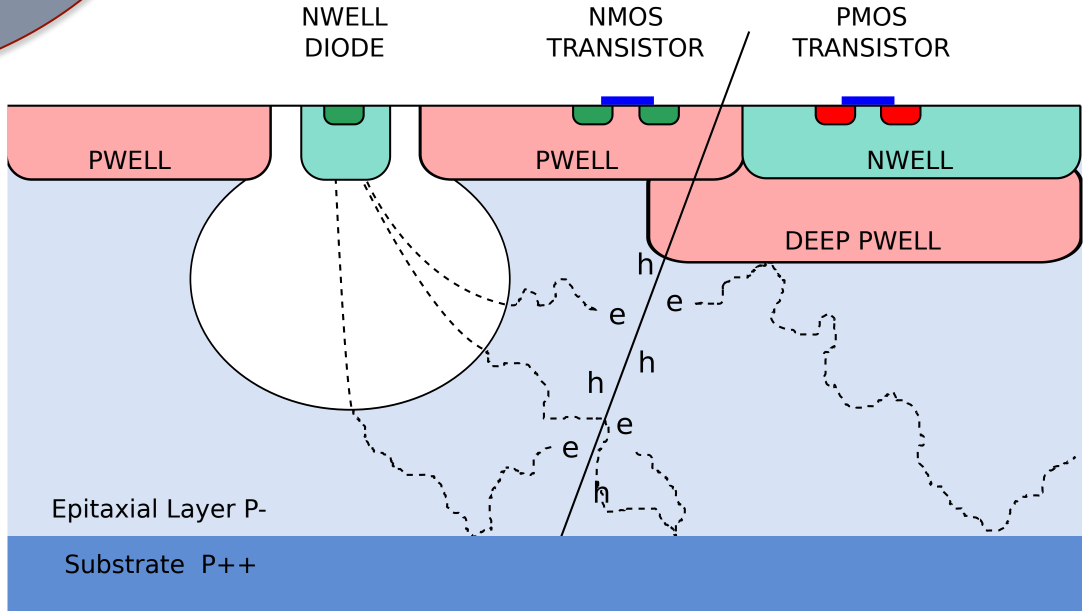


- **896 silicon pixel sensors (0.4 m²)** in 280 ladders of 1 to 5 sensors each
- **10 half-disks, 0.6% x/X_0 and 2 detection planes each**
- **5% of the ITS surface, twice the ITS inner barrel**

- **Nominal acceptance:** { $2.5 < \eta < 3.6$; Full azimuth }
- **Inner radius limited by the beam pipe**. Combined MFT+MUON acceptance will be 0.4 unity of rapidity smaller than current MUON one



ITS & MFT Pixel Technology



- **CMOS Monolithic Active Pixel Sensor (MAPS):** Tower Jazz 0.18 µm CIS technology
- **High-resistivity** (1-8 kΩ·cm) p-type epitaxial layer (20-40 µm thick) on p-type substrate
- **Sensor size:** 15 mm × 30 mm

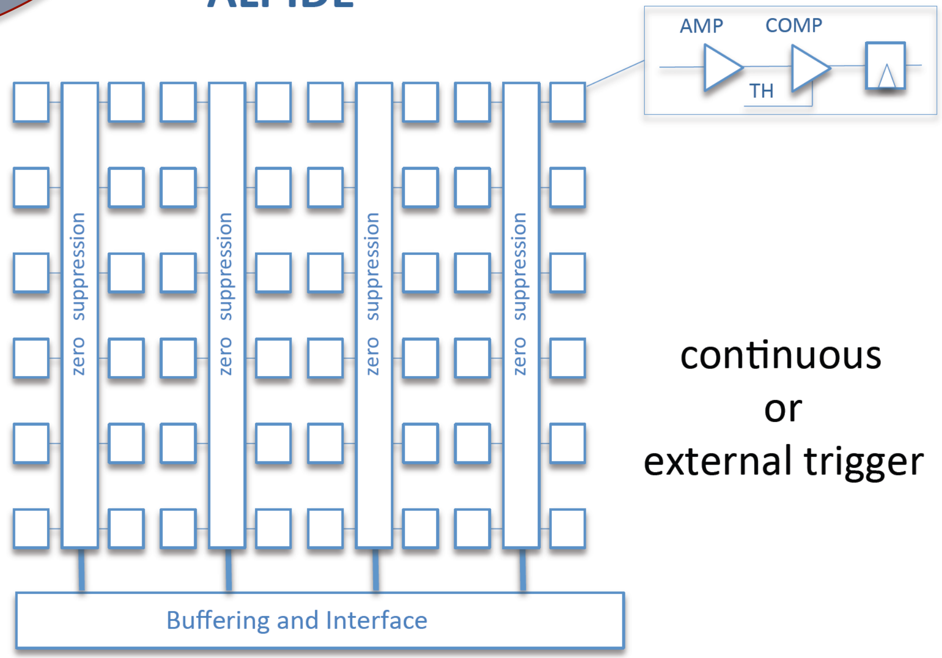
- **Different requirements** for **ITS Inner Barrel + MFT** and **ITS Outer Barrel:**
  - Total surface: (0.6 m^2 for ITS-IB + MFT, > 10 m^2 for ITS-OB)
  - Power consumption
  - Material budget per disk
  - Spatial and time resolution

  } Looser constraints for ITS-OB due to the distance from I.P.

- **R&D ongoing** to identify the most appropriate(s) chip(s). Current "baseline" scenario: **ALPIDE chip for ITS-IB + MFT, MISTRAL-O chip for ITS-OB**

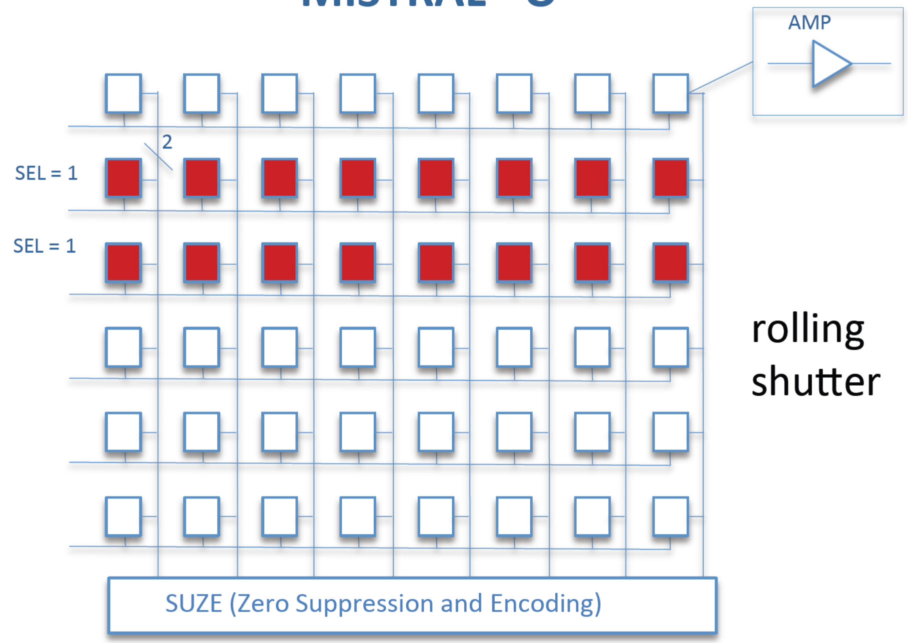
ITS & MFT Pixel Technology

ALPIDE



continuous
or
external trigger

MISTRAL - O



rolling
shutter

Pixel pitch	**≈ 28 µm × 28 µm**
Event time resolution	**≈ 2 µs**
Power consumption	**39 mW/cm²**
Inactive area	**1.1 mm × 30mm**

Pixel pitch	**36 µm × 64 µm**
Event time resolution	**≈ 20 µs**
Power consumption	**97 (⟶73?) mW/cm²**
Inactive area	**< 1.5 mm × 30mm**

- **ALPIDE and MISTRAL-O have same dimensions (15 mm × 30 mm), similar physical and electrical interfaces:** position of interface pads, electrical signaling, protocol

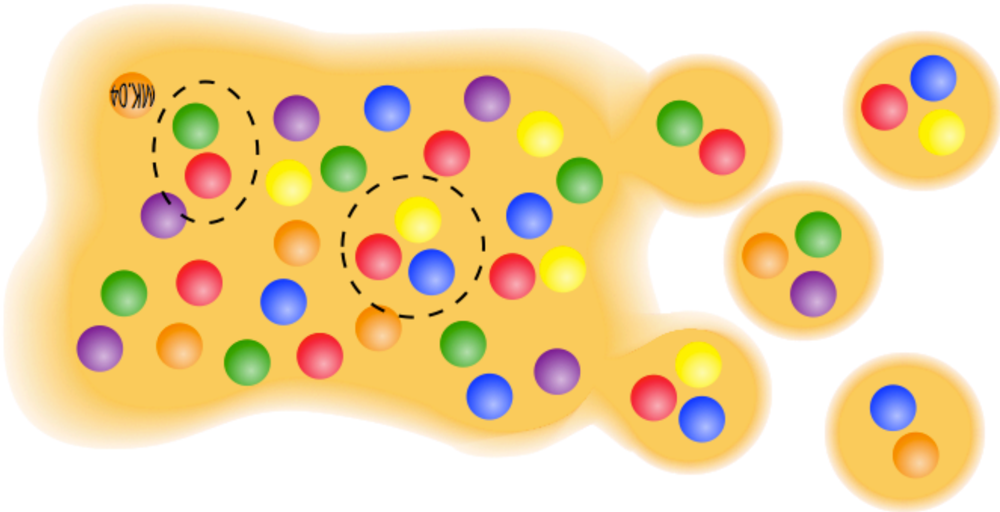
Heavy Flavor Physics

- Probing QCD medium by measuring the energy loss of quarks c and b
- Thermalization and hadronization of heavy quarks
- Measuring total charm and beauty production cross-section: gold reference for quarkonia studies

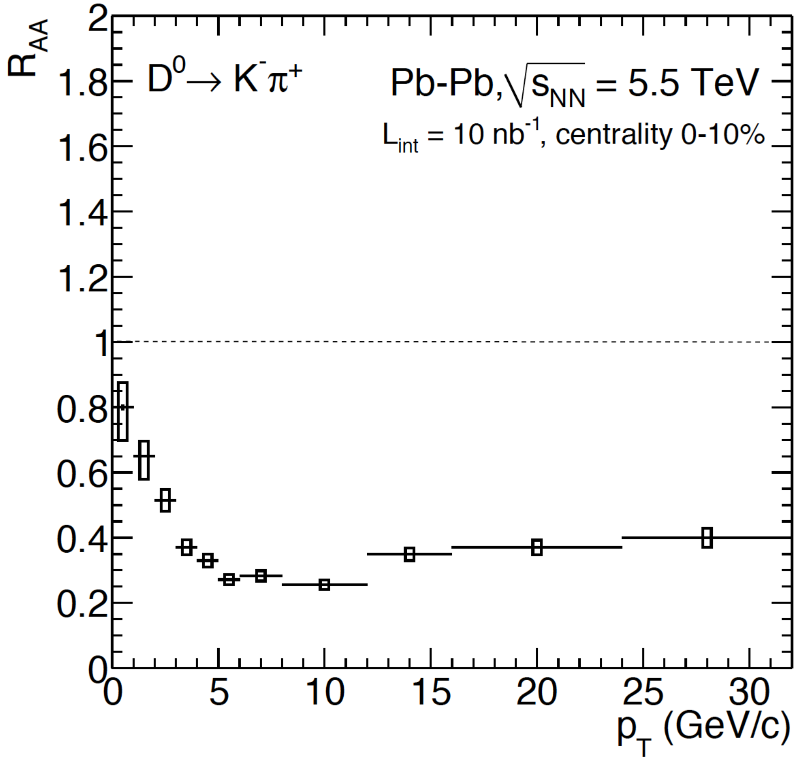
Heavy Flavor Physics

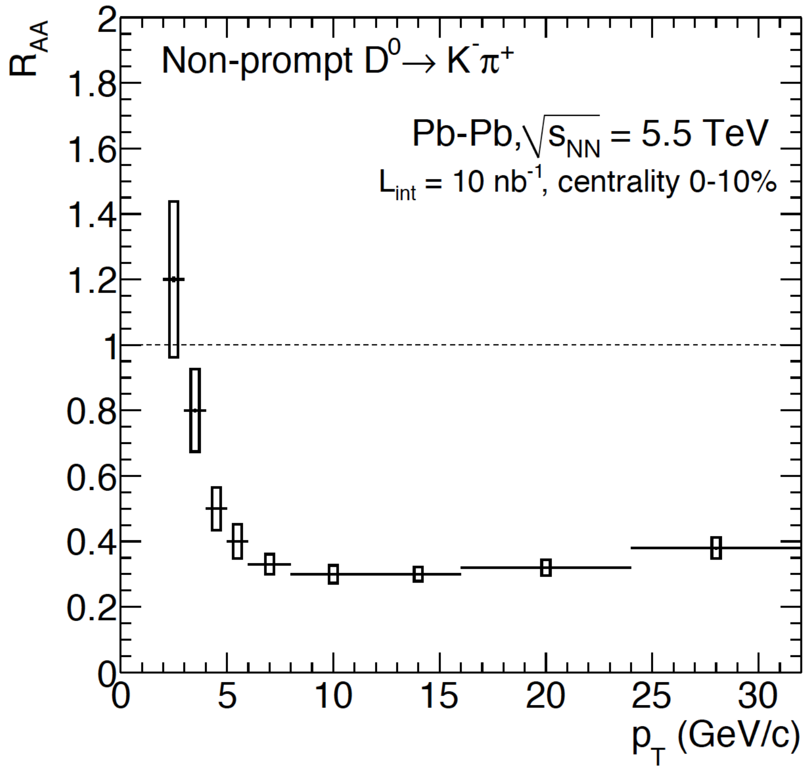
- **Heavy quarks are produced mainly at the beginning of the collision** in hard-scattering processes (high $Q^2 \rightarrow$ large virtuality)
  - **Possible charm thermal production?** → May increase the yield of charm hadrons at low p_T by up to 50-100%
- Need to measure open charm production **down to $p_T = 0$** → ITS upgrade fundamental
- **Measuring total charm cross section:** natural normalization for charmonium production (main uncertainty for regeneration models)

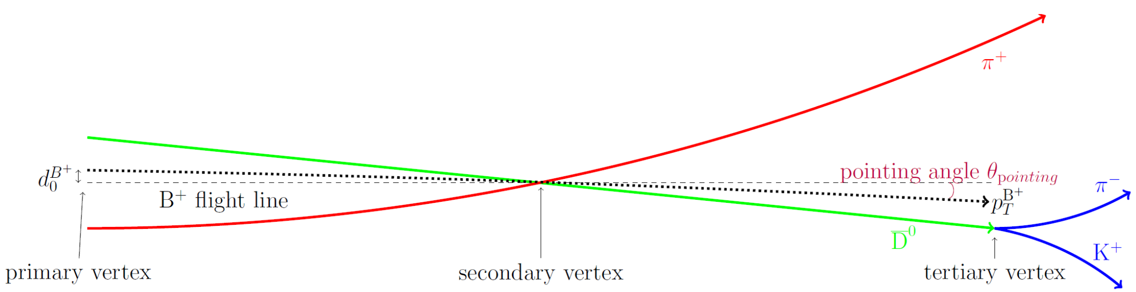
- **Coalescence models →** increase of baryon-to-meson ratio for light flavor and strange hadrons
  - Observed for p/π and Λ/K ratio at intermediate p_T
  - Prediction also for heavy flavor Λ_c, Λ_b



Prompt and Displaced D^0 with the ITS



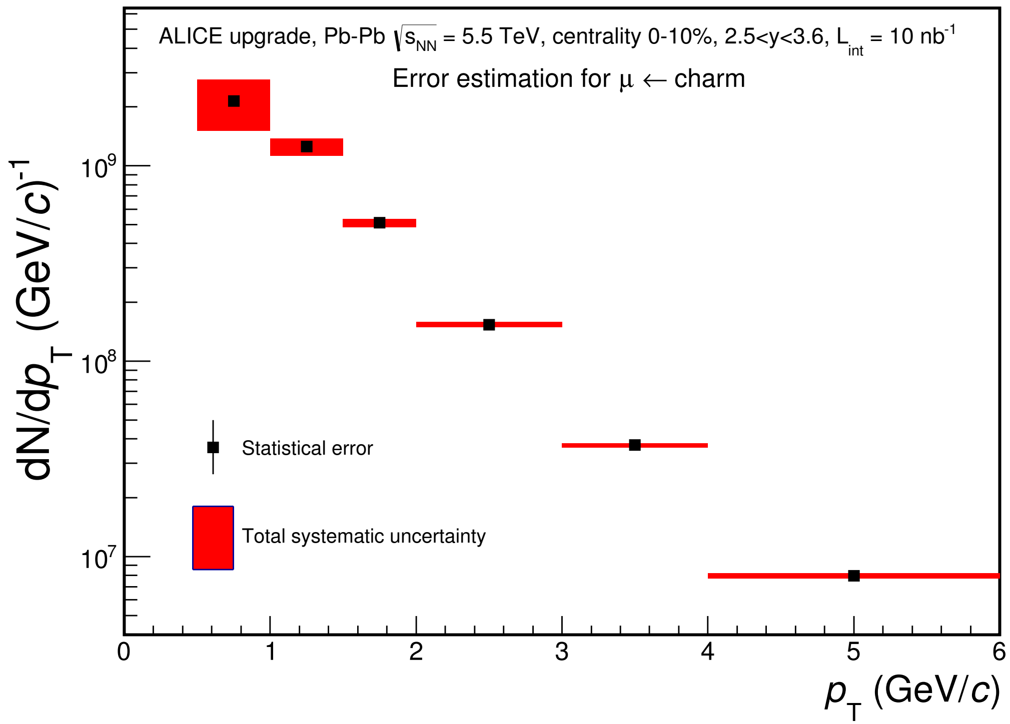


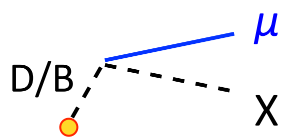


- **Prompt D^0 (charm)** production accessible down to zero p_T
- **Non-prompt D^0 (beauty)** production accessible down to p_T = 2 GeV/c

Muons from Charm with the MFT

- **Analysis based on the transverse offset measurement:** distance between the primary vertex (measured with the ITS) and the transverse position of the muon tracks extrapolated to the z of the primary vertex
- Pointing resolution requested to be better than 100 μm down to $p_T(\mu)$ = 1 GeV/c



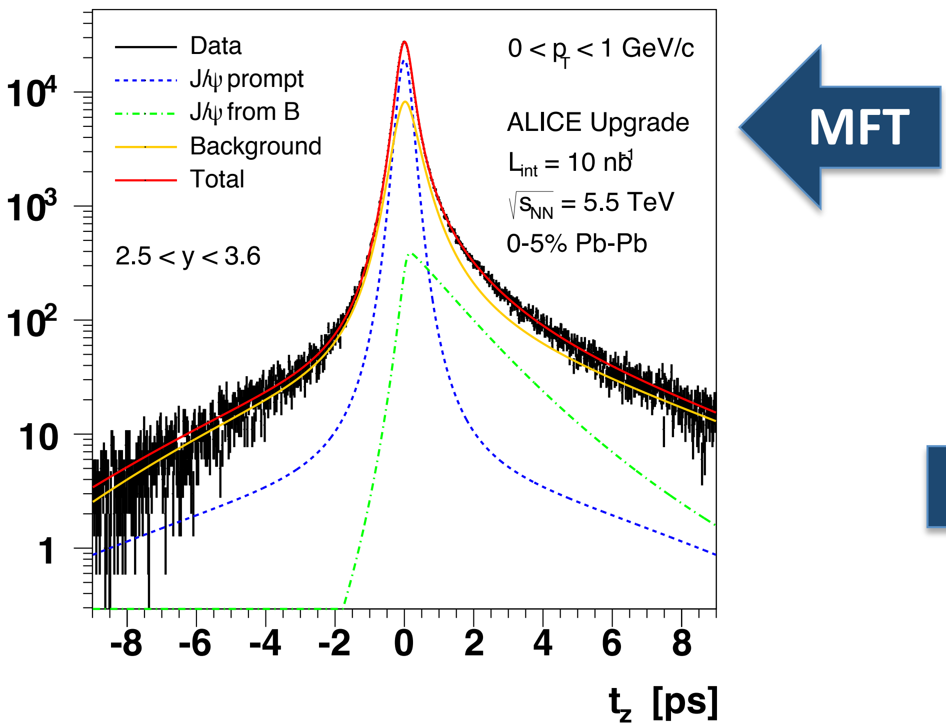


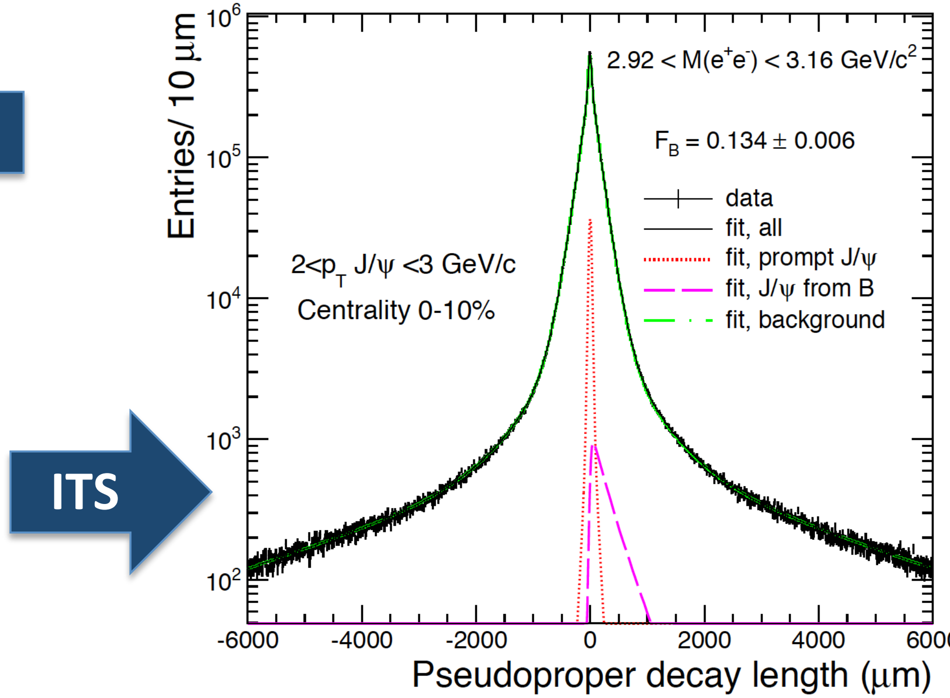
- **Charm yield** accessible starting from $p_T(\mu)$ = 1 GeV/c (at least)
- **Important baseline** for charmonium measurements

Displaced J/ψ Measurement

Based on the reconstruction of J/ψ (to dileptons) secondary vertex: transverse (ITS) and longitudinal (MFT) distance to primary vertex

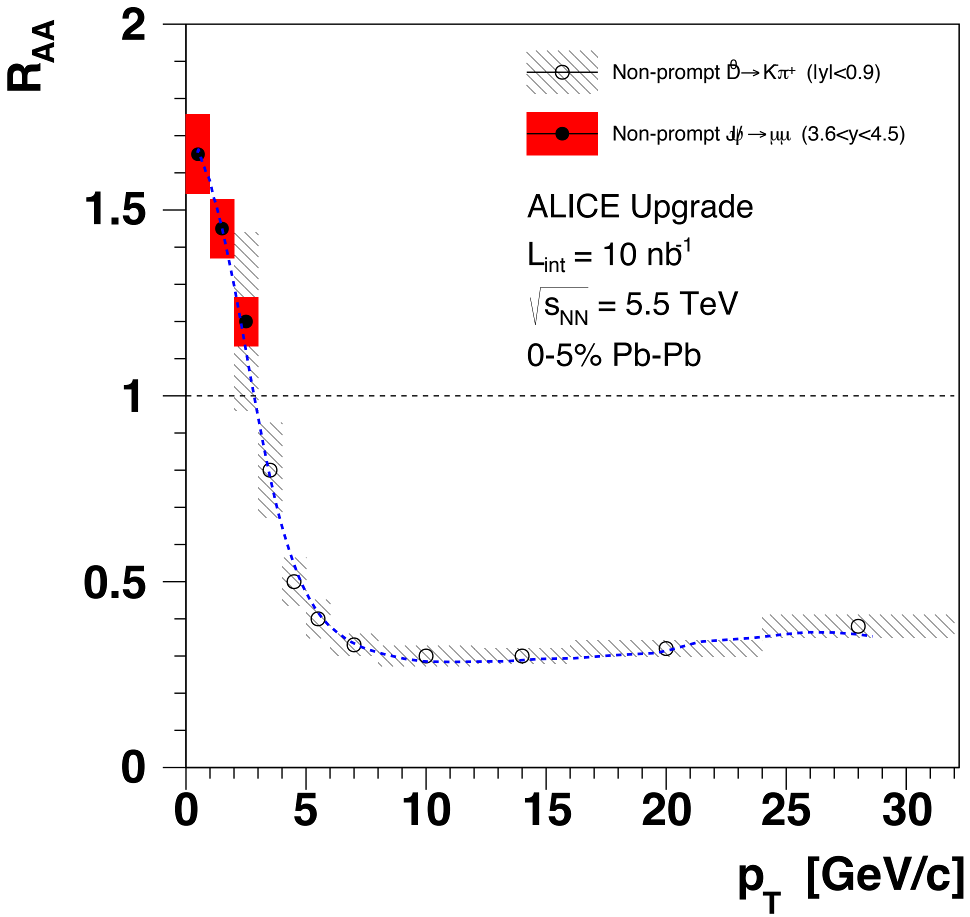
- **Complementary rapidity ranges** from central barrel (dielectron) and muon arm (dimuon) measurements
- **Dimuon signal advantaged** because of the better signal/background ratio





Beauty from Displaced J/ψ

- **ALICE can combine beauty measurements at mid- and forward-rapidity** to better constrain theoretical models. Golden channels: displaced D^0 at mid-rapidity, displaced J/ψ at forward rapidity

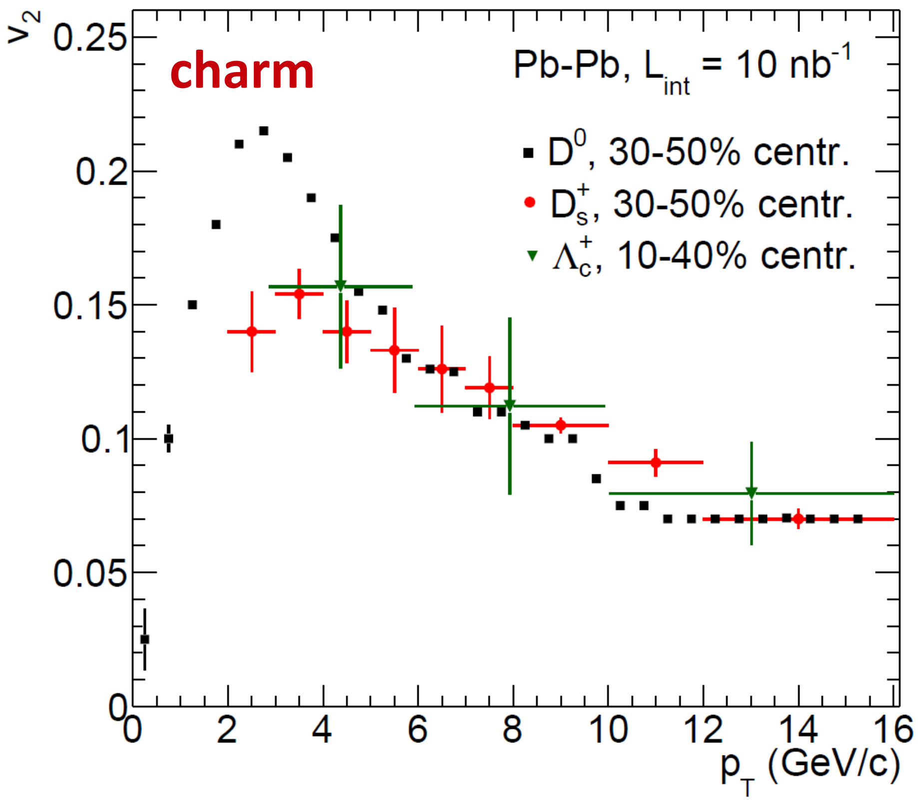


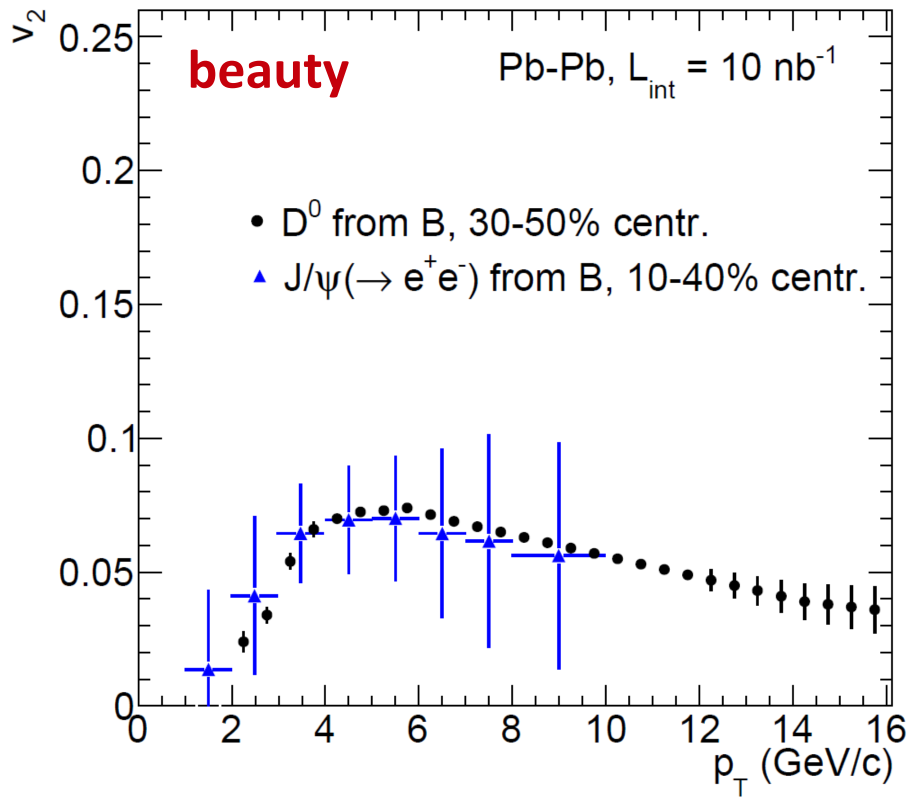
- **Displaced/prompt separation** possible at forward rapidity down to zero p_T(J/ψ) within 5% stat. + syst. uncertainties
- **Beauty R_{AA} measurement** possible down to zero p_T(J/ψ) within 7% stat. + syst. uncertainties even in central Pb-Pb
- Further studies are ongoing to **extend predictions at forward rapidity to larger p_T**

Elliptic Flow of Charm and Beauty

Elliptic flow measurement will be addressed both at mid- and forward-rapidity for both charm and beauty sectors

- **Central barrel:** prompt charm mesons/baryons; D mesons and J/ψ from B (figures)
- **Muon arm:** single muons from D; J/ψ from B + single muons from B (in evaluation)

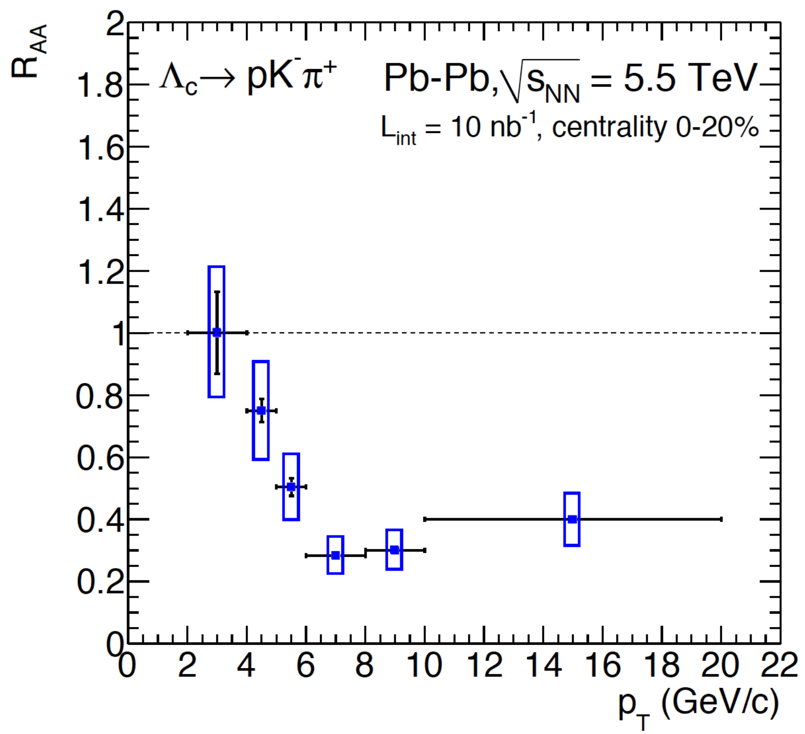


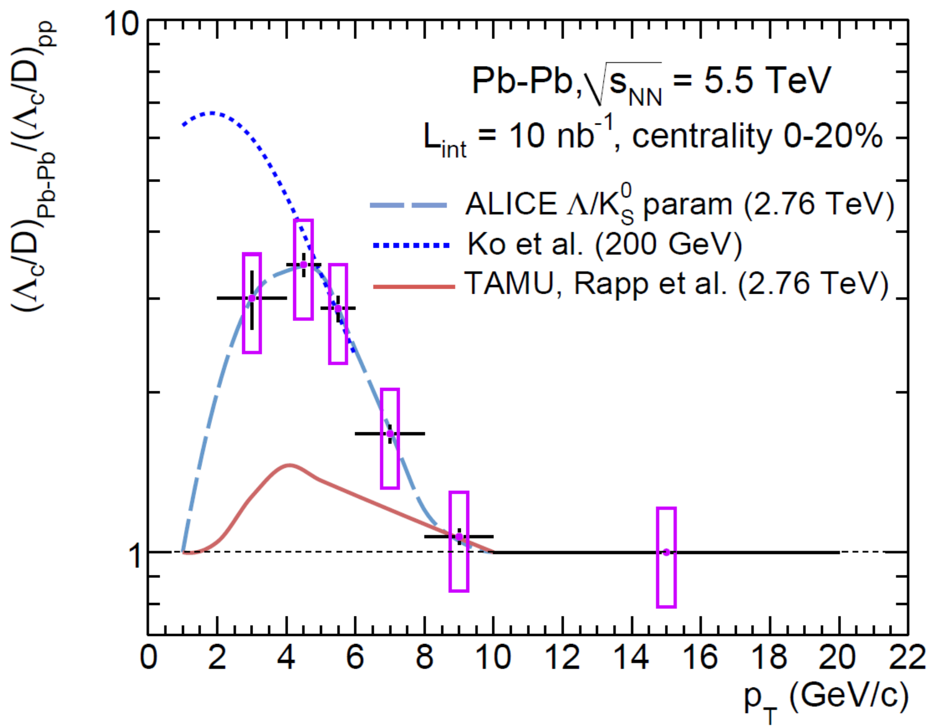


Charm Baryons

Baryon/meson ratio and baryon R_{AA} in charm sector with the upgraded ITS

- Λ_c measurement needed, but...
- ... $\Lambda_c \rightarrow pK\pi$ not accessible with the current ITS in Pb-Pb
- **Upgrade improvement in resolution** allows for cleaner vertex separation: Λ_c production measurable down to p_T = 2 GeV/c



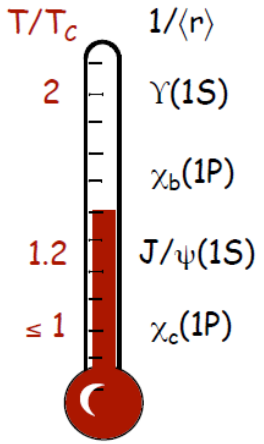


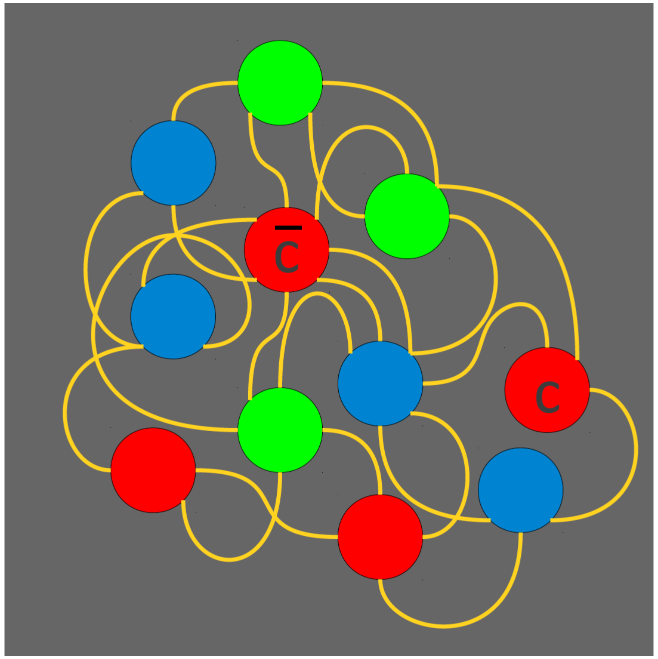
Prompt Charmonium Physics

- Evaluation of the contribution of c-cbar recombination to the production of charmonium at LHC energies
- Direct observation of the deconfined phase of matter

Prompt Charmonia: J/ψ and ψ'

- **Direct probe of medium deconfinement and temperature**
- Test for recombination models
- Two key observables: **nuclear modification factors** and **elliptic flow**





- Precision measurement for J/ψ at forward and mid rapidity already in LHC Run 2, but...
- ... No insight on ψ' physics
- ... Only inclusive measurement available at forward rapidity

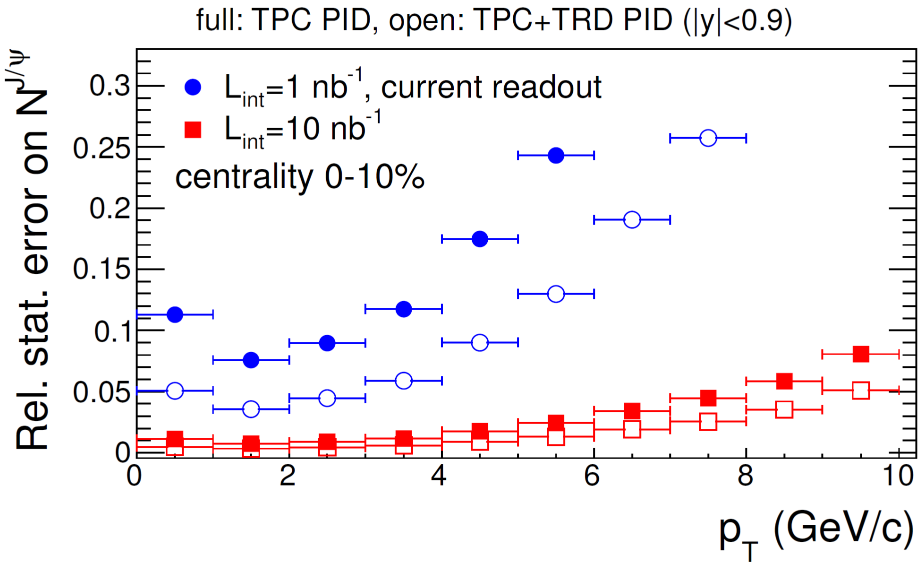
LHC Runs 3-4-5 data taking needed, with the ALICE upgrades

Prompt Charmonia: J/ψ and ψ'

Statistical uncertainties for prompt charmonia: L_{int} = 10 nb^{-1}

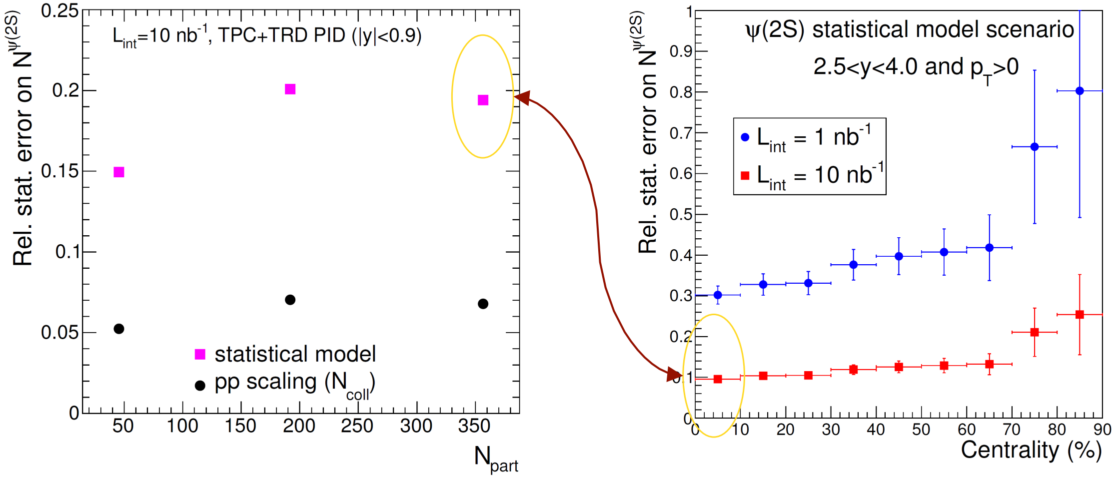
J/ψ

- **Central Barrel:** between 1% and 5% with the full TPC+TRD PID
- **MUON:** below 0.3% independently of the MFT



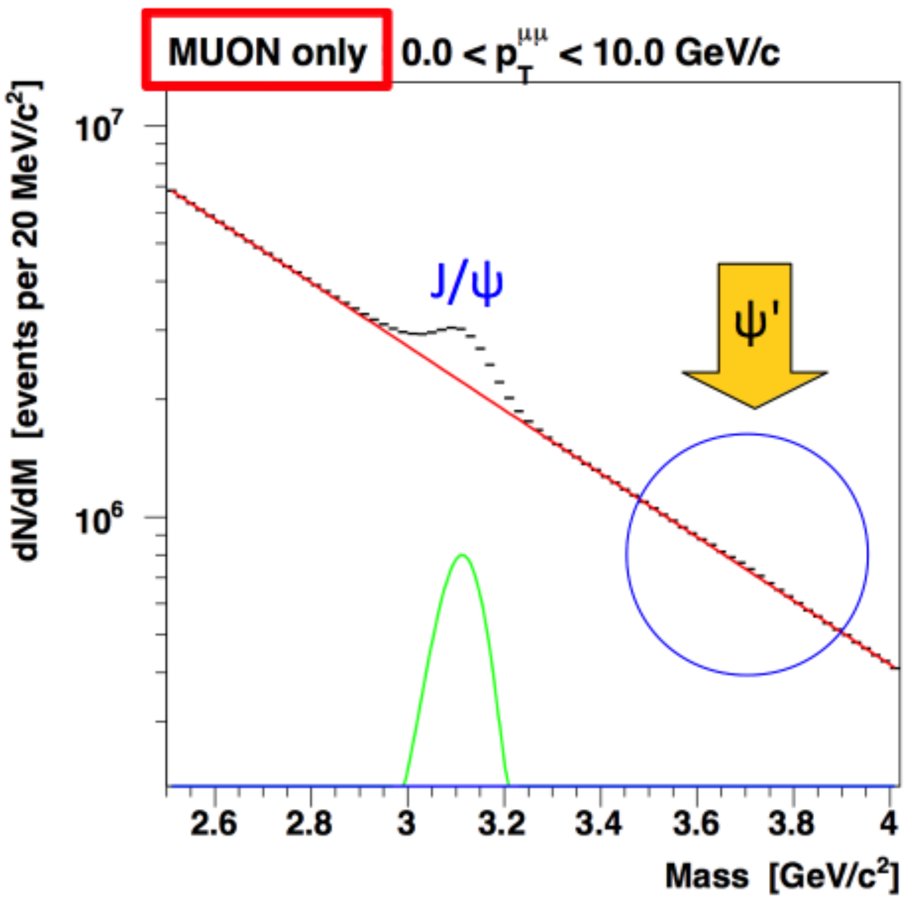
ψ'

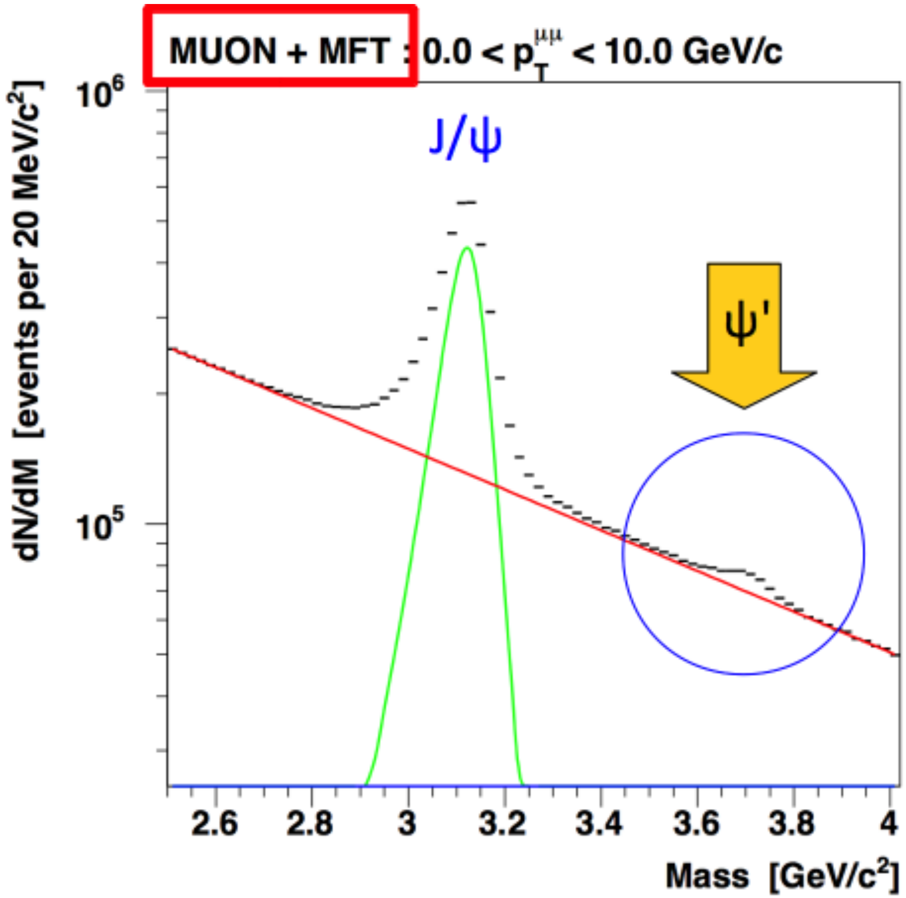
- **Central Barrel:** about 20% with the full TPC+TRD PID
- **MUON:** about 10% independently on the MFT



Prompt Charmonia: J/ψ and ψ'

- **S/B improved by a factor 6-7**, significance improved by a factor up to 1.5
- The ψ' is visible even in central Pb-Pb collisions: **signal extraction more robust, systematic uncertainties significantly reduced**





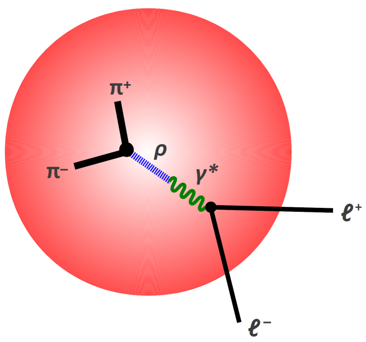
Low Mass & Continuum Dilepton Physics

- Modification of spectral functions of vector mesons in the medium, linked to the chiral symmetry restoration
- Dilepton (virtual photon) radiation from the partonic phase

Low Mass & Continuum Dileptons

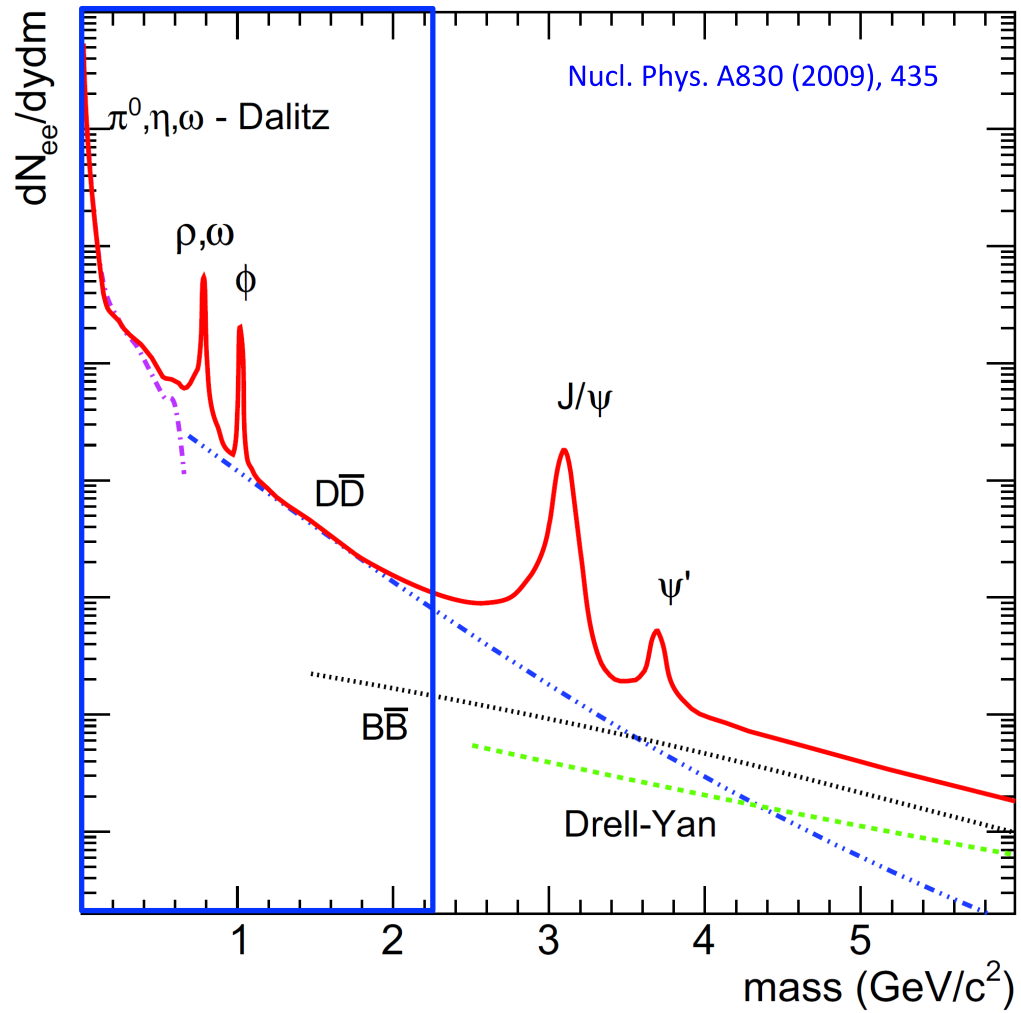
- **Ultimate goal:** inferring signatures of QCD phase transitions (chiral symmetry restoration and/or deconfinement)

- **Two more imminent (and relatively easier objectives:**
  - Describing medium modifications of the vector mesons spectral functions



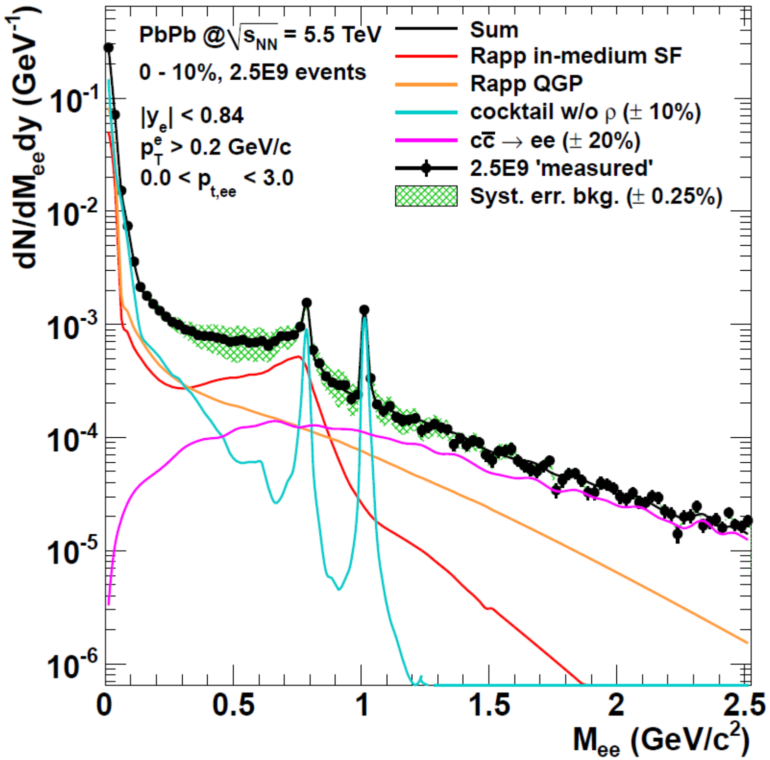
  - Measure the dilepton radiation from the partonic phase (QGP) exploiting the double degree of freedom given by the mass and the p_T

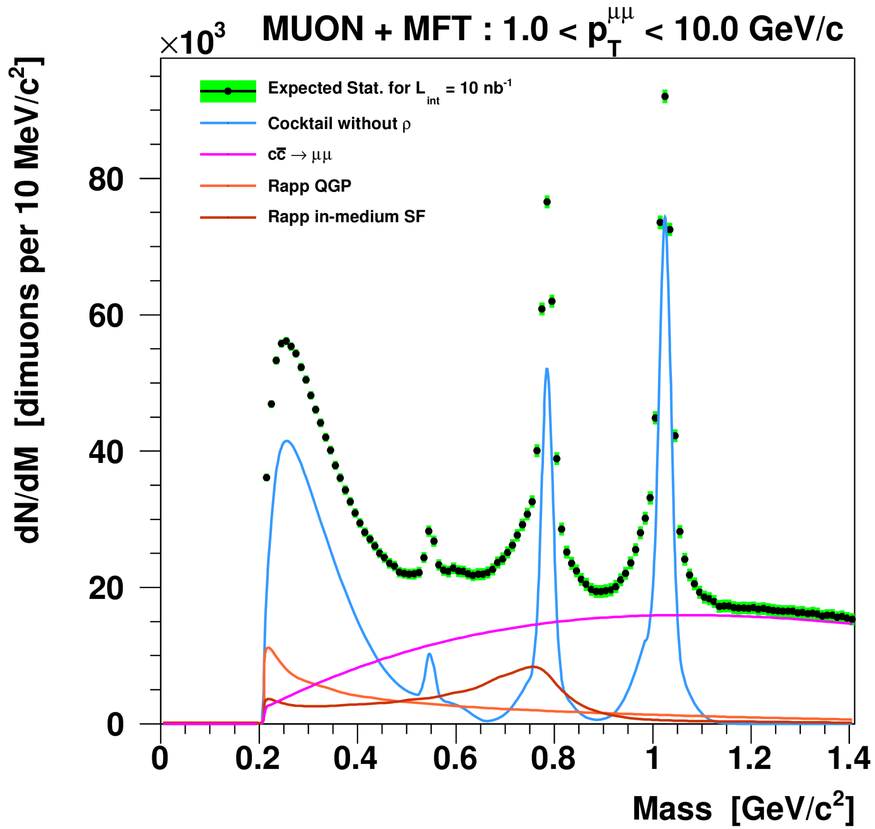
- **Delicate measurement** due to large background and systematic uncertainties on continuum shape from open HF



Low Mass & Continuum Dileptons

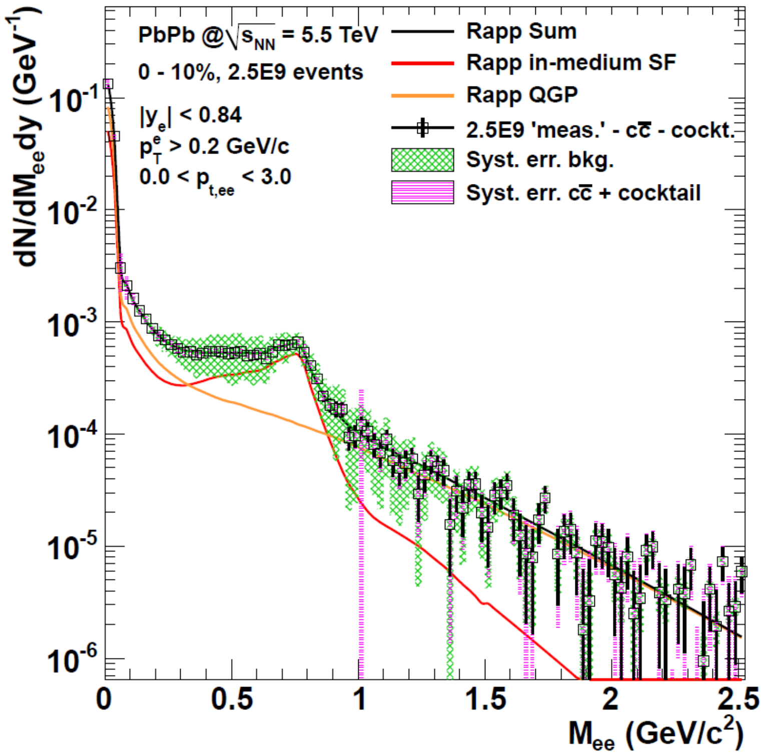
- **Low and intermediate mass dileptons** both in the dielectron (mid rapidity) and dimuon (forward rapidity) channels
  - Isolation of prompt sources needs **precise measurement of dilepton offset**
- In addition, **MFT will improve the mass resolution** for light resonances in dimuons

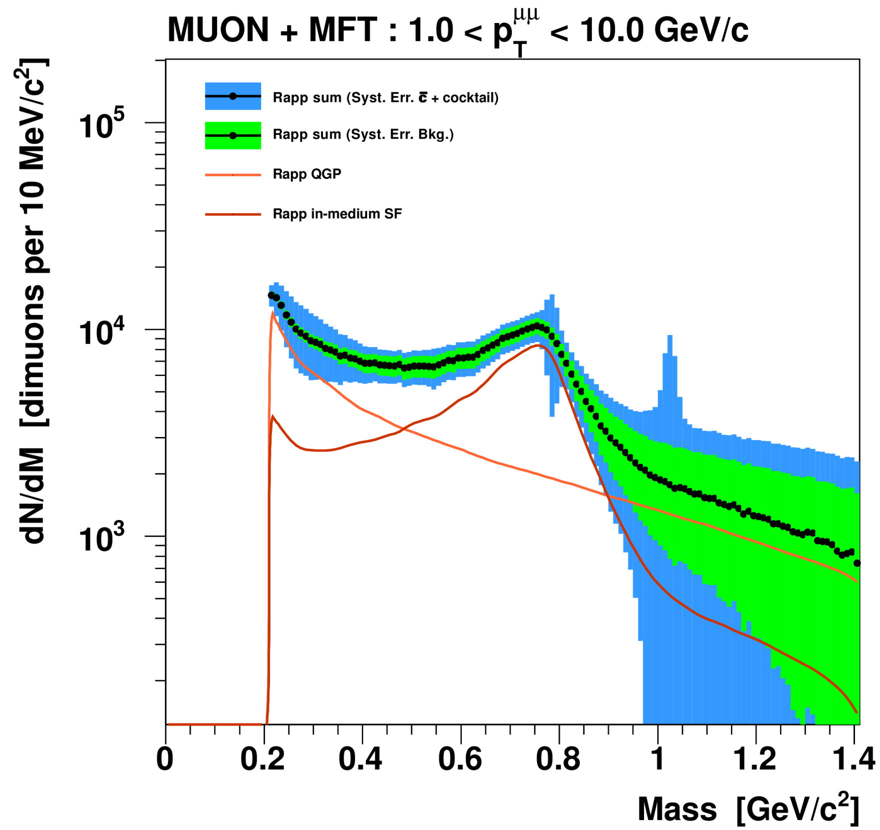




Low Mass & Continuum Dileptons

- **Precise measurement of dilepton offset** to remove charm and π/K continuum
- **Dielectron channel advantaged** thanks to the excellent offset resolution of the upgraded ITS, but dedicated low magnetic field needed for low p_T acceptance
- Charm rejection strategy for the MFT being optimized...





Conclusions

The ALICE LS2 Upgrade represents the **transition from exploratory to precision measurement of the Quark-Gluon Plasma** in a broad range of physics observables including Heavy Flavors, Quarkonia, Dilepton low masses and continuum

Preserving ALICE uniqueness:

- Precision tracking and PID down to low-p_T at mid-rapidity
- Precision dimuon measurement at forward rapidity

Enhancing ALICE physics reach:

- Better secondary vertex identification from heavy flavor production both at mid and forward rapidity
- Accessing rare probes by increasing data taking rates: facing both hardware and software challenges

Conclusions

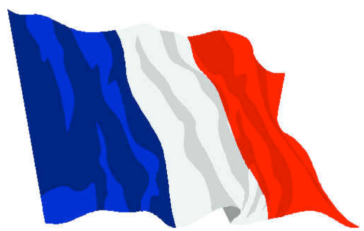
Table 9.2: Institutes participating in the ITS Upgrade Project.

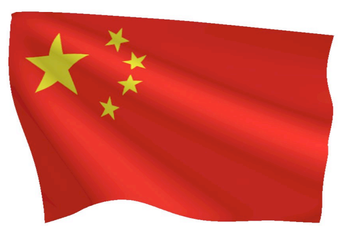
Country	City	Institute
CERN	Geneva	European Organization for Nuclear Research
China	Wuhan	Central China Normal University (CCNU)
Czech Republic	Prague	Faculty of Nuclear Science and Physical Engineering, Czech Technical University
Czech Republic	Řež u Prahy	Nuclear Physics Institute of the ASCR
France	Grenoble	Laboratoire de Physique Subatomique et de Cosmologie (LPSC), CNRS-IN2P3, Université Joseph Fourier, Institut Politechnique de Grenoble
France	Strasbourg	Institut Pluridisciplinaire Hubert Curien (IPHC), Université de Strasbourg, CNRS-IN2P3
Italy	Alessandria	Gruppo collegato INFN e DiSIT – Università del Piemonte Orientale
Italy	Bari	Sezione INFN e Dipartimento di Fisica dell'Università e del Politecnico di Bari
Italy	Cagliari	Sezione INFN e Dipartimento di Fisica dell'Università di Cagliari
Italy	Catania	Sezione INFN e Dipartimento di Fisica dell'Università di Catania
Italy	Frascati	Laboratori Nazionale INFN di Frascati (LNF)
Italy	Padova	Sezione INFN e Dipartimento di Fisica e Astronomia dell'Università di Padova
Italy	Roma	Sezione INFN e Dipartimento di Fisica dell'Università "La Sapienza" di Roma
Italy	Torino	Sezione INFN e Dipartimento di Fisica dell'Università di Torino
Italy	Trieste	Sezione INFN e Dipartimento di Fisica dell'Università di Trieste
Netherlands	Amsterdam and Utrecht	NIKHEF and Institute for Subatomic Physics, Utrecht University
Pakistan	Islamabad	Faculty of Sciences, COMSATS, Institute of Information Technology
Rep. of Korea	Incheon	Inha University, College of Natural Sciences
Rep. of Korea	Pusan	Pusan National University
Rep. of Korea	Seoul	Yonsei University
Russia	St. Petersburg	Institute of Physics, St. Petersburg State University
Slovakia	Košice	Slovak Academy of Sciences (IEP) and Technical University
Thailand	Nakhon Ratchasima	Suranaree University of Technology
Ukraine	Kharkov	Scientific Research Technological Institute of Instrument Engineering SRTIIE
Ukraine	Kharkov	Ukrainian Academy of Sciences, KIPT-KFTI
Ukraine	Kiev	Bogolyubov Institute for Theoretical Physics (BITP)
United Kingdom	Birmingham	University of Birmingham
United Kingdom	Chilton	Rutherford Appleton Laboratory (RAL)
United Kingdom	Warrington	STFC Daresbury Laboratory
United States	Austin, TX	University of Texas Austin
United States	Berkeley, CA	Lawrence Berkeley National Laboratory (LBNL)
United States	Chicago, IL	Chicago State University
United States	West Lafayette, IN	Purdue University

Table 7.1: Institutes participating or planning to participate in the MFT Project.

Country	City	Institute
China	Wuhan	Central China Normal University (CCNU)
France	Clermont-Ferrand	Laboratoire de Physique Corpusculaire (LPC), Clermont Université, Université Blaise Pascal, CNRS/IN2P3
France	Nantes	SUBATECH, Ecole des Mines de Nantes, Université de Nantes, CNRS/IN2P3
France	Saclay	Commissariat à l'Energie Atomique, IRFU
France	Villeurbanne	Université de Lyon, Université Lyon 1, CNRS/IN2P3, IPN-Lyon
India	Kolkata, Aligarh	Saha Institute of Nuclear Physics and Aligarh Muslim University
Japan	Hiroshima	Hiroshima University
South Korea	Pusan, Incheon, Yonsei	Pusan National, Inha University and Yonsei Universities
Spain	Valencia	Instituto de Física Corpuscular
Peru	Lima	Pontificia Universidad Católica del Perú
Russia	Gatchina	Petersburg Nuclear Physics Institute
Thailand	Nakhon Ratchasima, Chachoengsao	Suranaree University of Technology and Thai Microelectronics Center

ALICE ITS and MFT upgrades: new opportunity for the France-China scientific collaboration



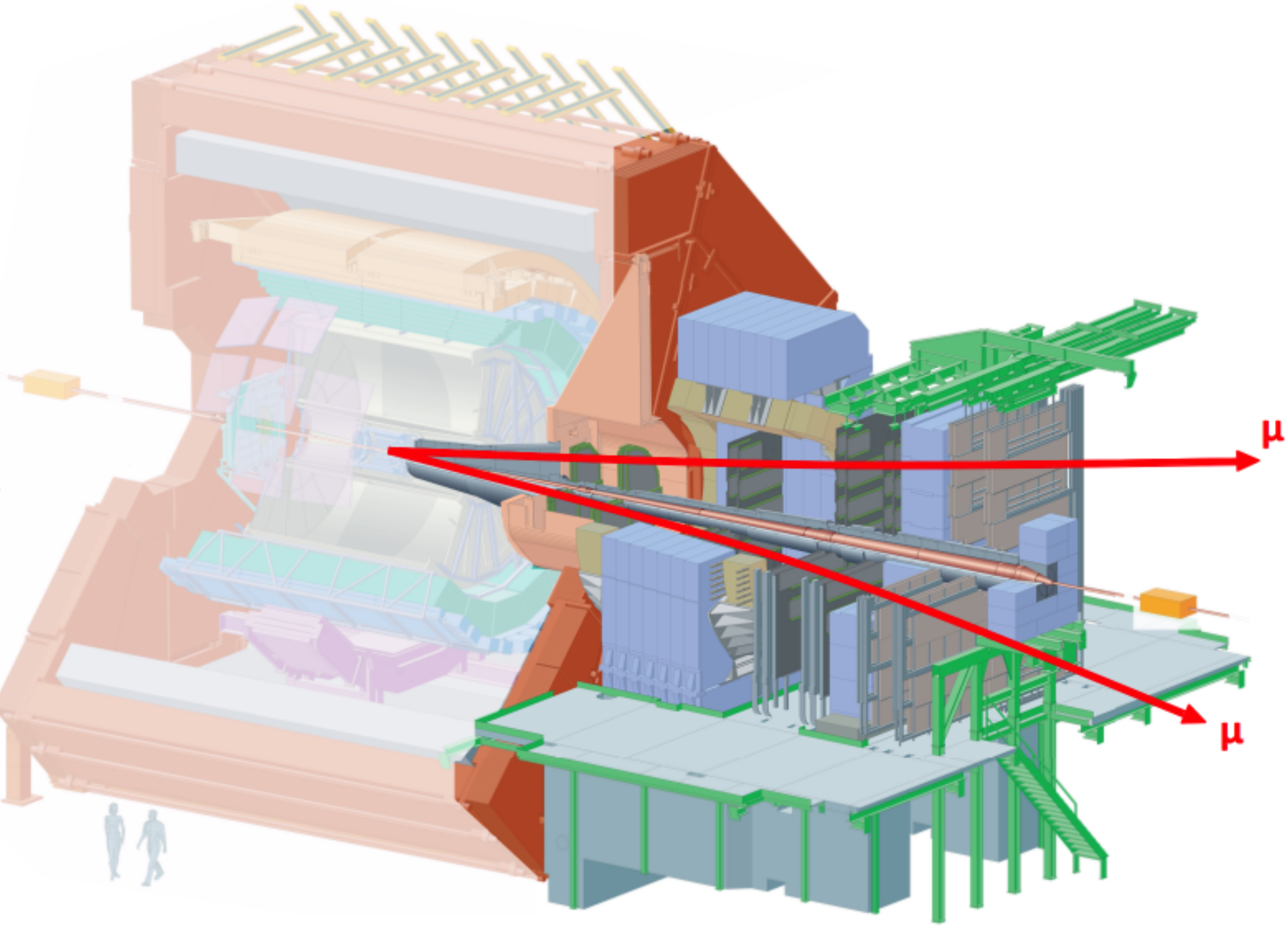


Backup Slides

Muon Measurements with the ALICE Muon Arm

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

- Hadron Absorber
- Dipole Magnet
- 10 tracking chambers
- Iron wall
- 4 trigger chambers



Main Design Limitations of the Current Muon Arm

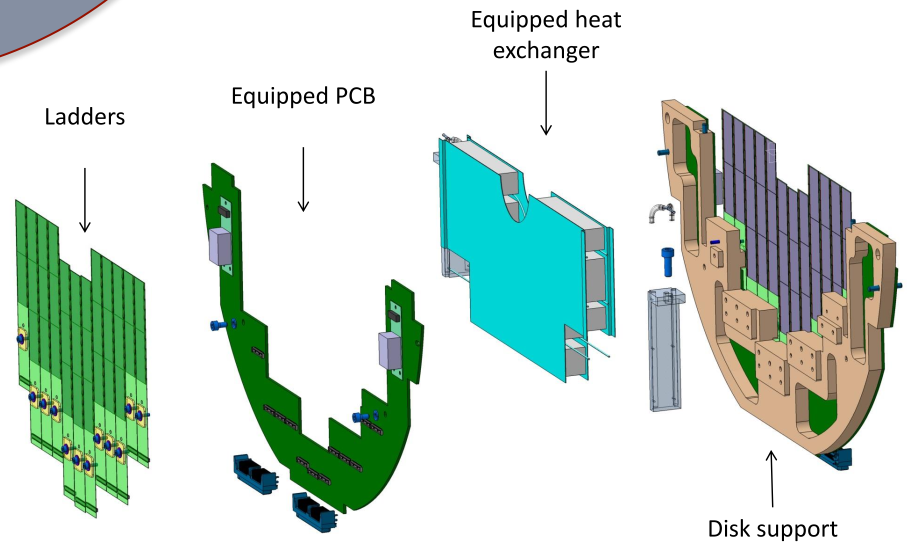
- **High level of background from π/K decays**
  - Large systematic uncertainties induced by background subtraction for all physics topics. Open HF analysis in single muons cannot descend below p_T = 4 GeV/c. ψ(2S) cannot be easily observed
- **Impossibility to determine muon production vertex**
  - No charm/beauty separation in single muons
  - No beauty measurement from non-prompt J/ψ: we miss an important source of information for the study of beauty
- **Limited mass resolution for light neutral resonances**

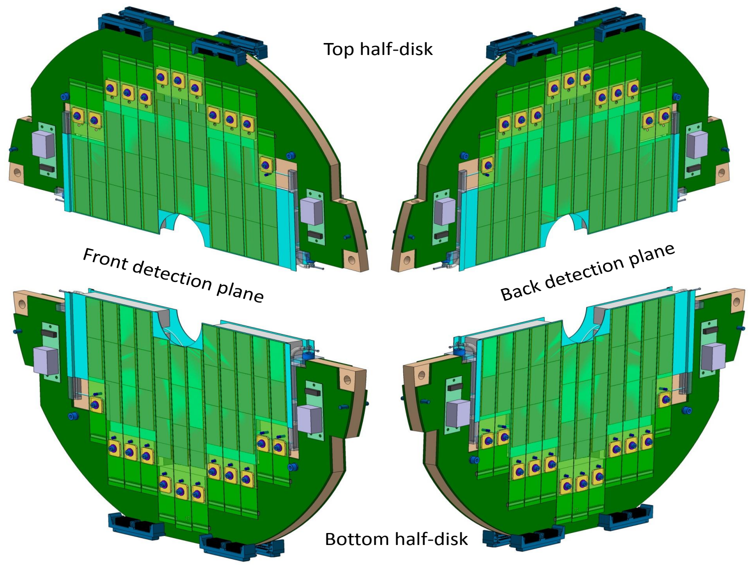
MFT

- **Readout not designed for the interaction rates expected after LS2**

→ Muon Spectrometer Electronics upgrade

MFT Half-Disk Design

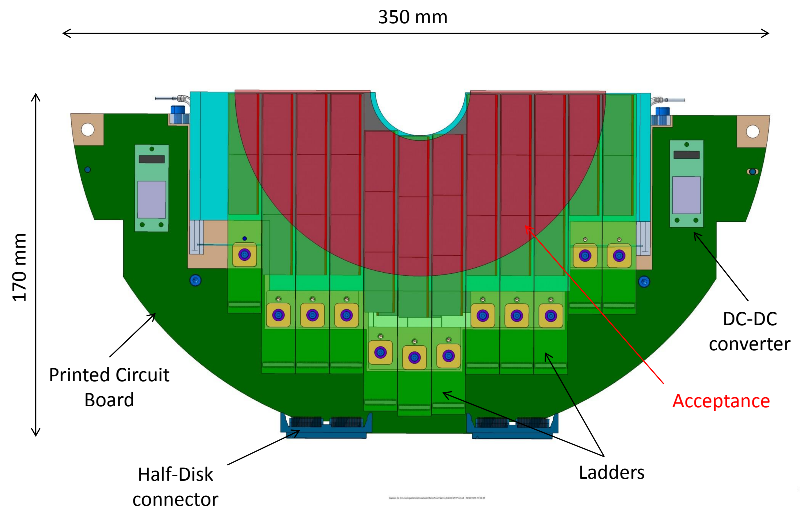




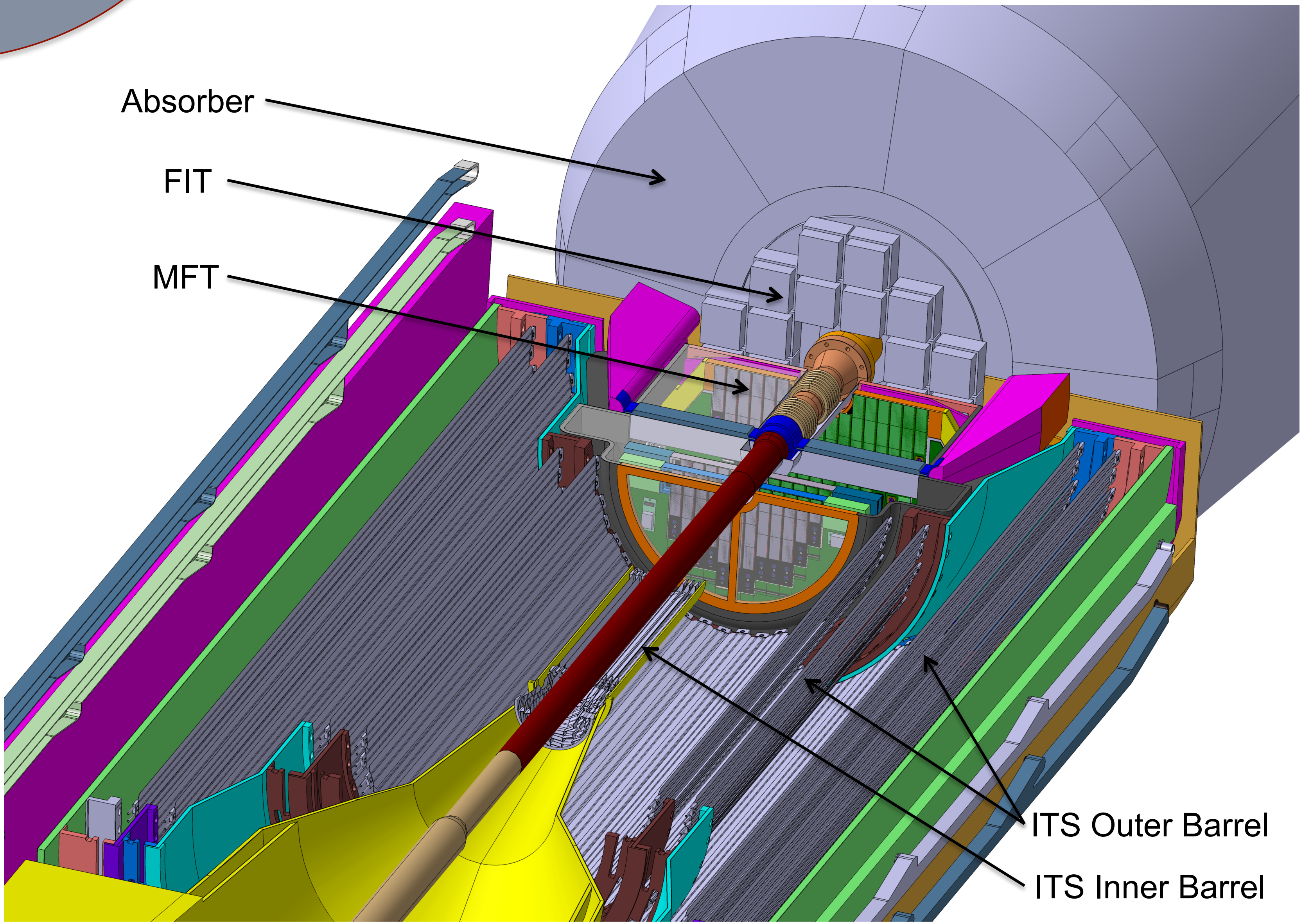
- **Two detection half-planes (front/back):**
  - Coverage around the beam pipe
  - Support and water cooled plate in between
  - Redundancy (50%)

- **Two PCBs** containing the regulators, data, clock and slow control lines

- **Ladder assembly:** See Kenta's talk



MFT Integration

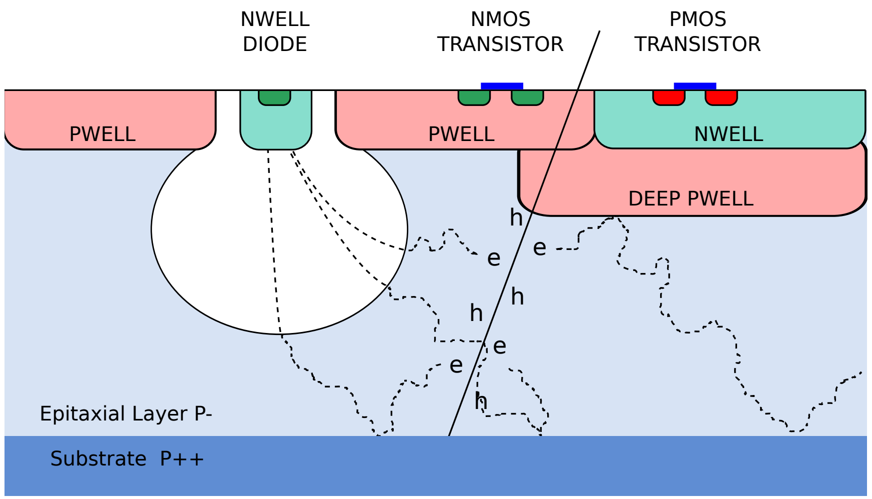


The MFT will be installed between the end of the ITS inner barrel and the FIT

Dismounting will be possible during the LHC winter stops

MFT Pixel Technology

➢ **ITS inner barrel and MFT will consist of the same silicon pixel sensor**



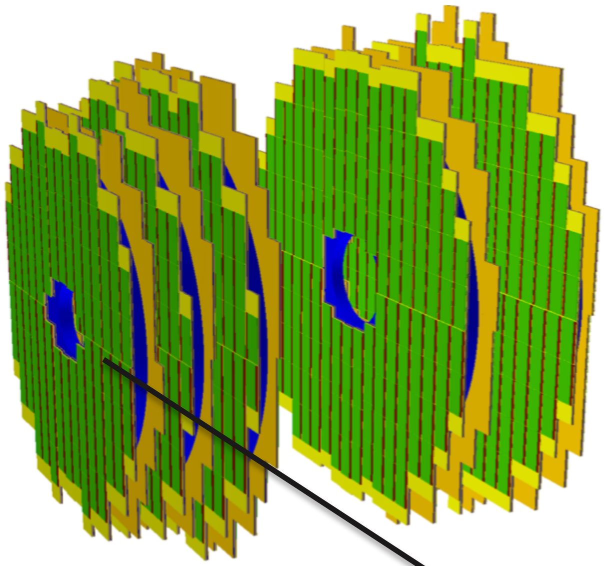
Parameter	Value
Spatial Resolution	~ 5 µm
Detection Efficiency	> 99.5%
Integration Time	< 20 µs
Sensor Thickness	50 µm
Power dissipation	≤ 150 mW/cm²
Radiation Tolerance (10-years operation)	~ $o(10^{13})$ n_{eq}/cm² ~ $o(700)$ krad

- **CMOS Monolithic Active Pixel Sensor (MAPS):** Tower Jazz 0.18 µm CIS technology
- **Sensor size:** 15 mm × 30 mm
- **The Alpide architecture exhibits good performance for the MFT:**
  - Event time resolution below 4 µs
  - Low power consumption < 50 mW/cm²
- **MFT participates into Alpide ASIC design and characterization**

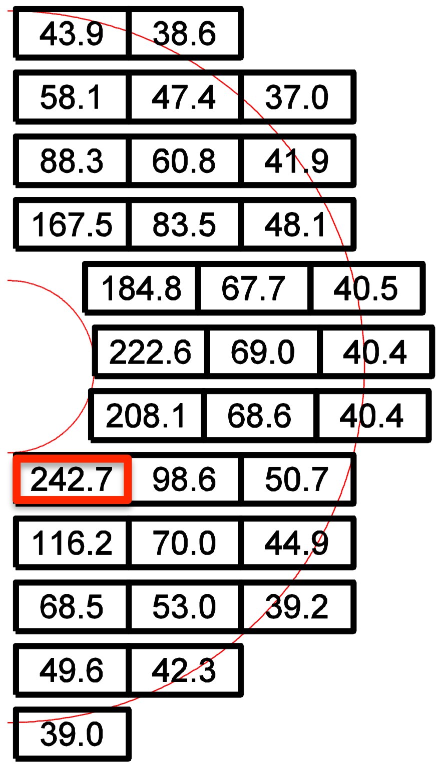
MFT Data Throughput

Average data throughput estimation includes MB Pb-Pb collisions, QED, noisy pixels

Collision Rate	100 kHz
Integration Time	4 μs
Fake Hit Rate	10^{-5}
Average Hit Encoding	35.1 bits



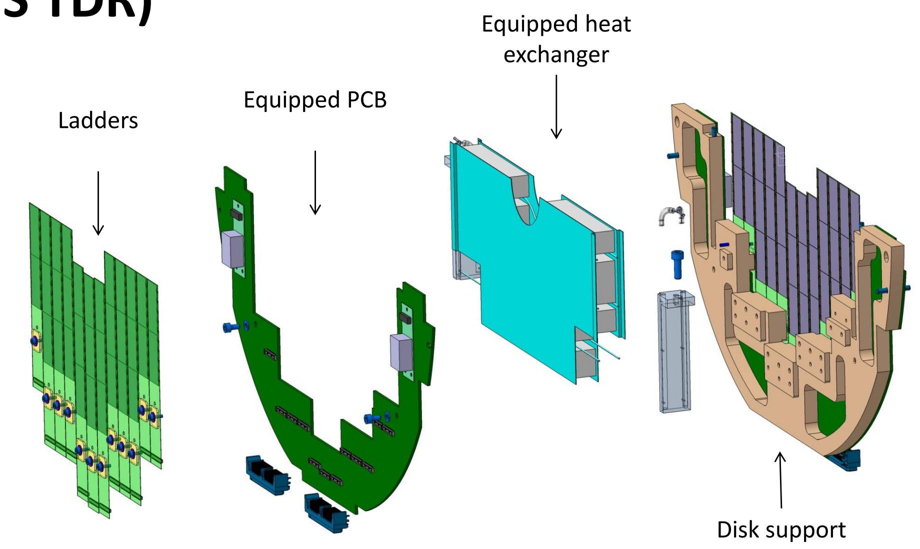
Half-disk 0



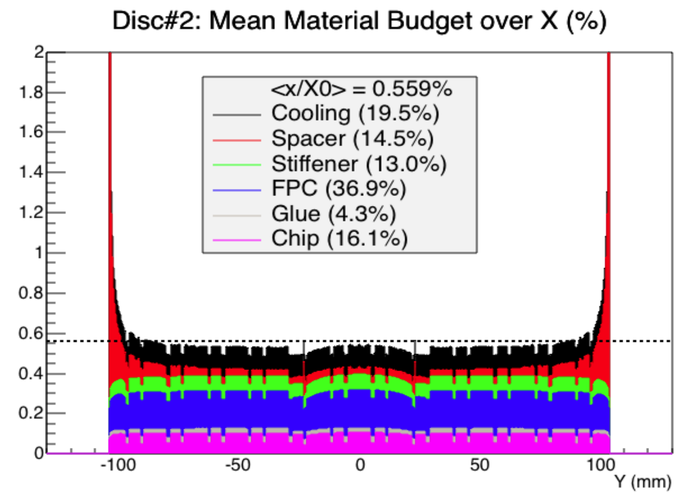
- **Maximum average data throughput of 243 Mb/s** for the sensor closest to the beam-pipe in disk #0
- High speed 1.2 Gb/s lines comply with MFT requirements
- Full MFT data throughput 57 Gb/s

MFT Cooling

- **Water-cooling technique is robust (ITS TDR)**



- **MFT is considering water cooling as the ITS**
  - Decision taken in December 2014
  - Assumed 50 mW/cm^2 for the sensor
  - Polyimide pipes are foreseen for half-disk plane: half-disk cold-plate
  - Perpendicular and axial water cooling option are being considered
  - Preliminary thermal studies confirm the robustness of the water cooling option
  - Material budget still acceptable (0.6% x/X_0 per disk)

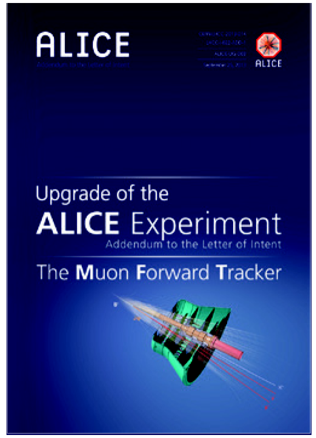


MFT Upgrade Physics Program

As a vertex tracker for the Muon Spectrometer, the MFT will have a major impact on several items of the ALICE muon physics

- **Open heavy flavors:**
  - Charm measurement down to p_T = 1 GeV/c in the single muon channel
  - Beauty measurement down to p_T = 0 in the non-prompt J/ψ channel
- **Prompt Charmonium production**
  - Prompt/non-prompt J/ψ separation down to p_T = 0
  - ψ(2S) measurement in central Pb-Pb collisions, down to p_T = 0
- **Low-mass dimuons**
  - Improved mass resolution for resonances
  - Sensitivity to prompt continuum

See Kenta's talk



CERN-LHCC-2013-014

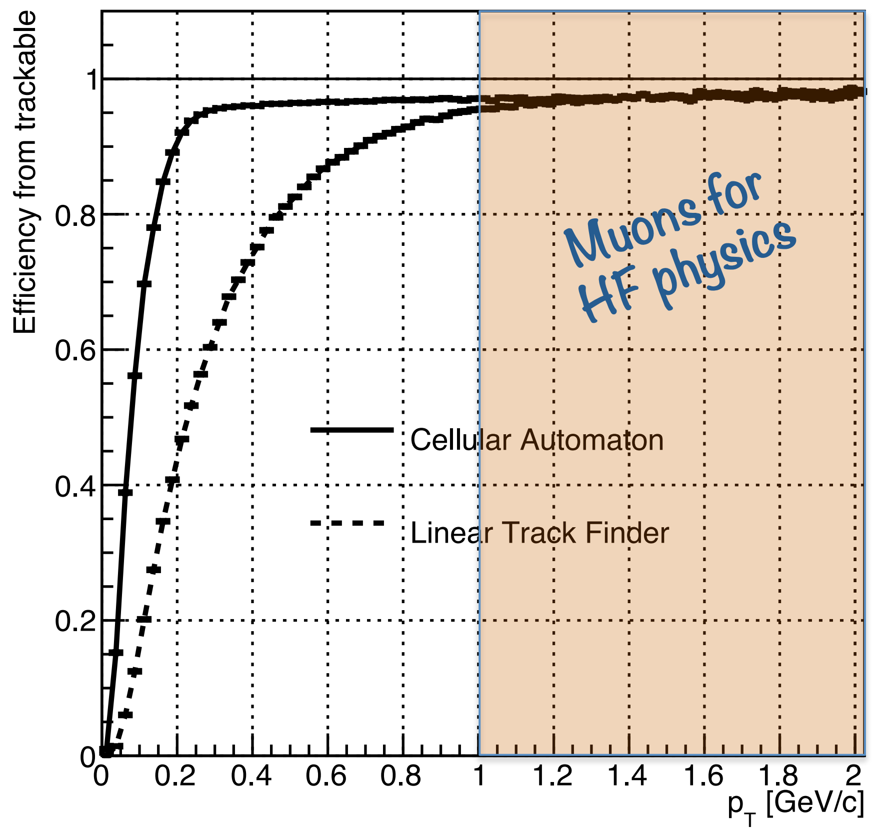
MFT Standalone Tracking Strategy

- **Two standalone tracking algorithms have been developed**

- **Cellular automaton (CA) algorithm:**
  - Needed for charge particle multiplicity, reaction plane measurements, correlation studies

- **Linear track finding (LTF) algorithm:**
  - Faster, optimizing the MS-MFT matching efficiency

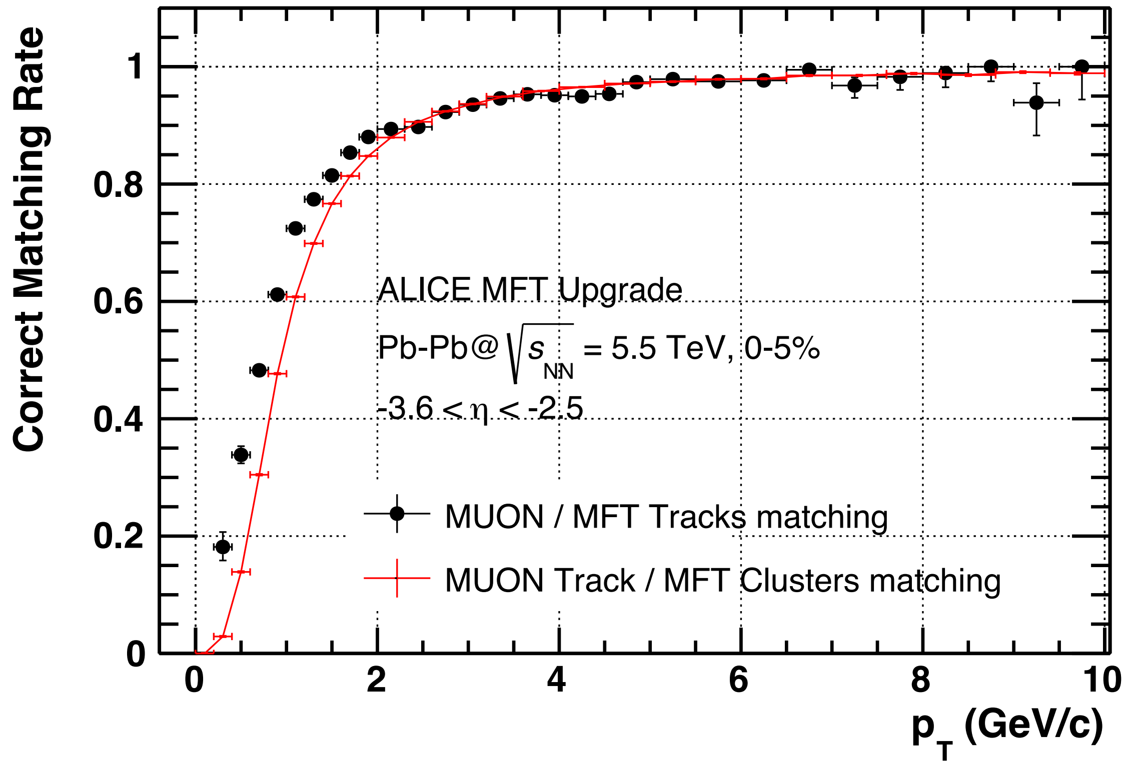
- **Final standalone tracking strategy:** first step with the LTF, then CA on the remaining clusters



MUON/MFT Matching

- **MUON tracks** are extrapolated back to the vertex region and matched either with the lowest-χ^2 combination of MFT clusters or with the lowest-χ^2 MFT standalone track

- **Final strategy for the MUON+MFT global tracking** still under discussion



- **The MUON/MFT correct matching rate depends on the p_T**

- Impact of fake MUON/MFT combinations can be reduced by imposing cuts on the p_T and the χ^2 of the global tracks

- **Fake matches automatically included in the analyses**

Beauty Measurement with non-prompt J/ψ

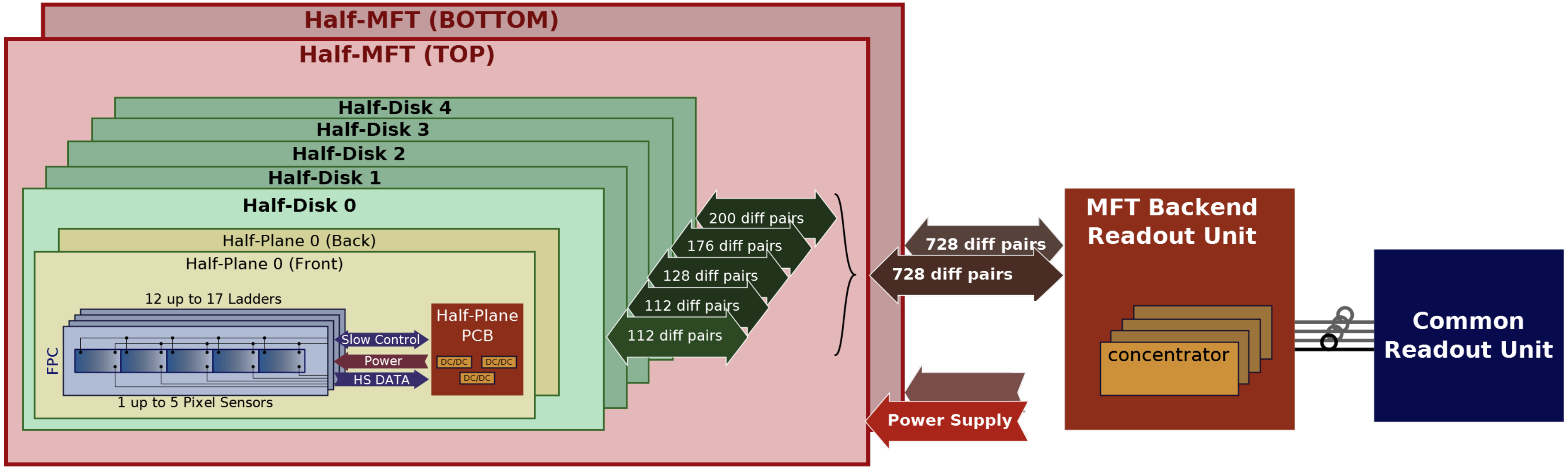
- **Prompt/displaced J/ψ discriminating variable:** longitudinal projection of the primary-secondary vertex distance considered for the analysis (step forward in performance w.r.t. LoI)

$$t_z = \frac{\left(z_{J/\psi} - z_{\rm vtx}\right) \cdot M_{J/\psi}}{p_z}$$

- **Analysis Strategy: double (possibly simultaneous) fit** on the dimuon invariant mass spectrum and the t_z distribution of the dimuons falling within the chosen J/ψ mass window
  - **The fit on the invariant mass spectrum** fixes the normalization of the background and the inclusive J/ψ signal. **The fit on the t_z distribution** then separates the two J/ψ contributions

MFT Readout

➢ **Identical to ITS inner barrel read-out. One single line per sensor**



- Between **128-264 high speed data signals** (1.2 Gb/s) per disk
- Between **96-136 clock and slow control signals** per disk
- **Total of 1456 twinax cables** for read-out
- **Concentrator board ≈ 4 m away:** integrated dose about 10 krad

MC Simulations

- **Dedicated MC simulations run(s):** LHC14j5, LHC14j5_new, LHC14j5_new_plus, LHC14j5_extra

- **Pb-Pb HIJING (0-10%)** @ 5.5 TeV + **injected HF signals** at mid- and forward rapidity

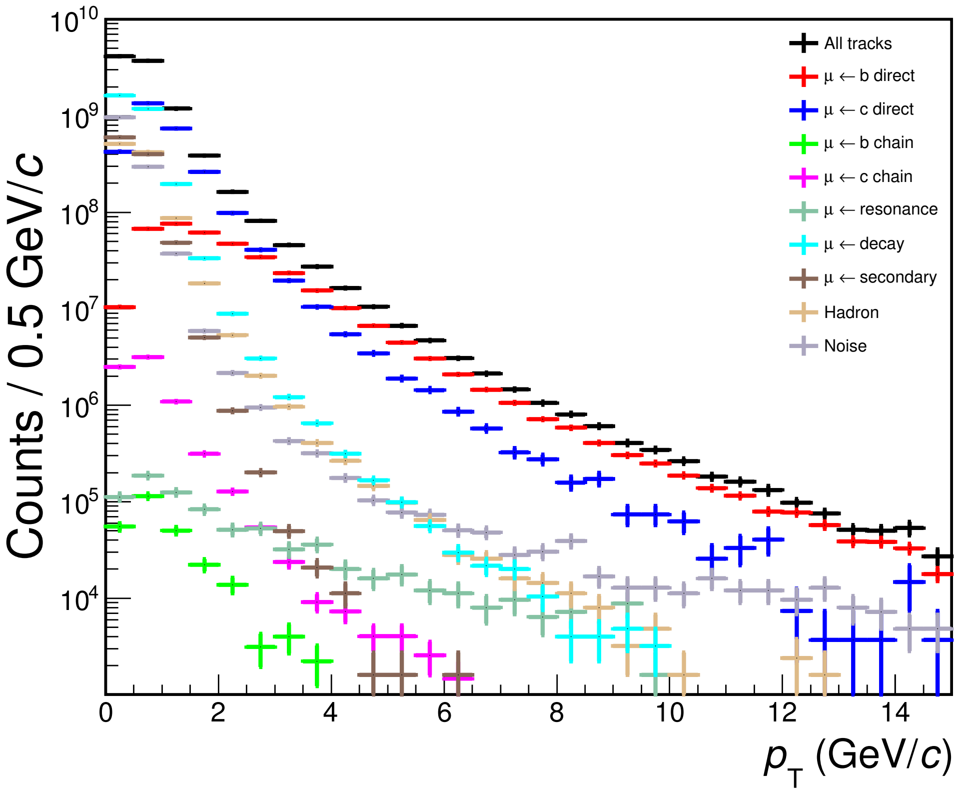
- 1 Million events anchored to Pb-Pb 2010

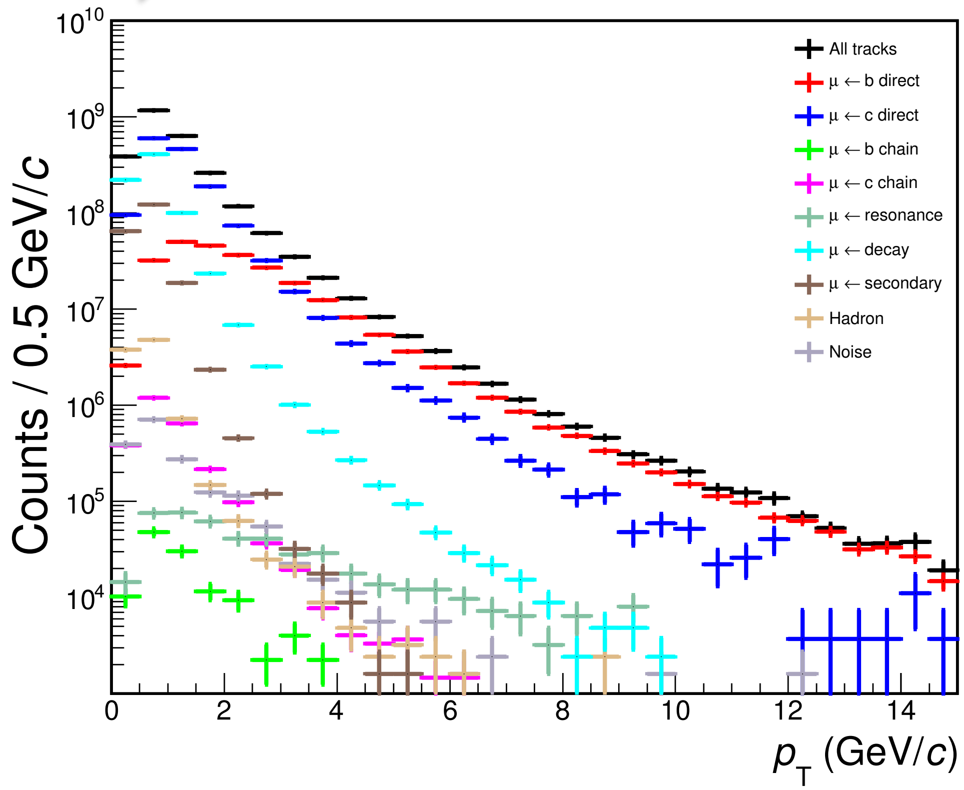
- **Injected signals at forward rapidity:**
  - Correlated muons from semi-muonic decays of **charmed** hadrons: AliGenCorrHF
  - Correlated muons from semi-muonic decays of **beauty** hadrons: AliGenCorrHF
  - Prompt J/ψ signal: AliGenParam
  - J/ψ from beauty hadrons: AliGenPythia (Perugia-0 tune)

Single Muons: Track Selection

- **MFT geometrical acceptance:** $2.5 < \eta < 3.6$
- **Matching with the MUON-ID** (currently MUON trigger) chambers
- **Track χ^2/ndf < 3** (evaluated from the MUON+MFT global fit)

BEFORE CUTS → **AFTER CUTS**





Single Muons: Analysis Strategy

- **Analysis not possible above p_T = 6 GeV/c** because of the limited MC statistics for the background

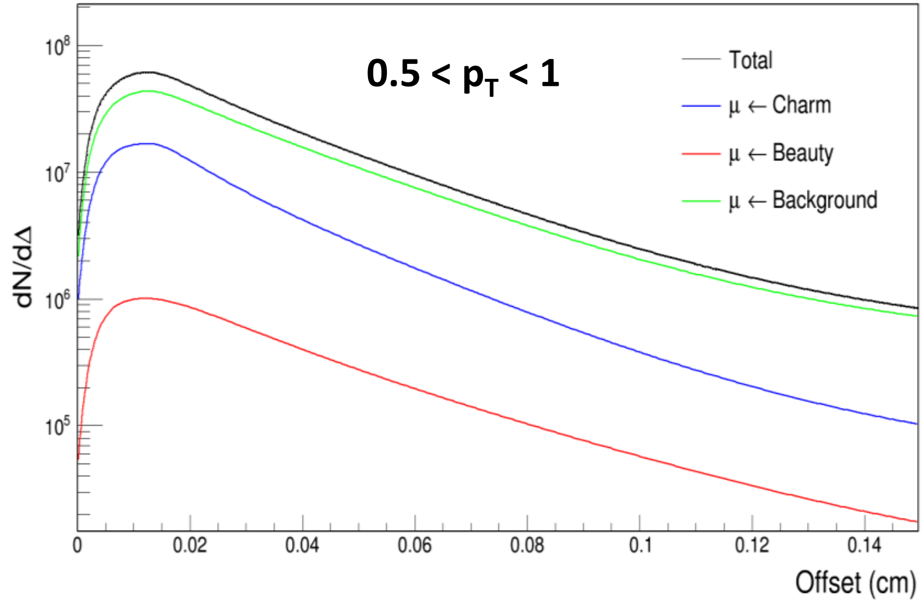
- **Analysis strategy:** fit of the total transverse offset distribution with the three expected contributions: background, charm and beauty. Templates for each component are extracted form the MC simulations

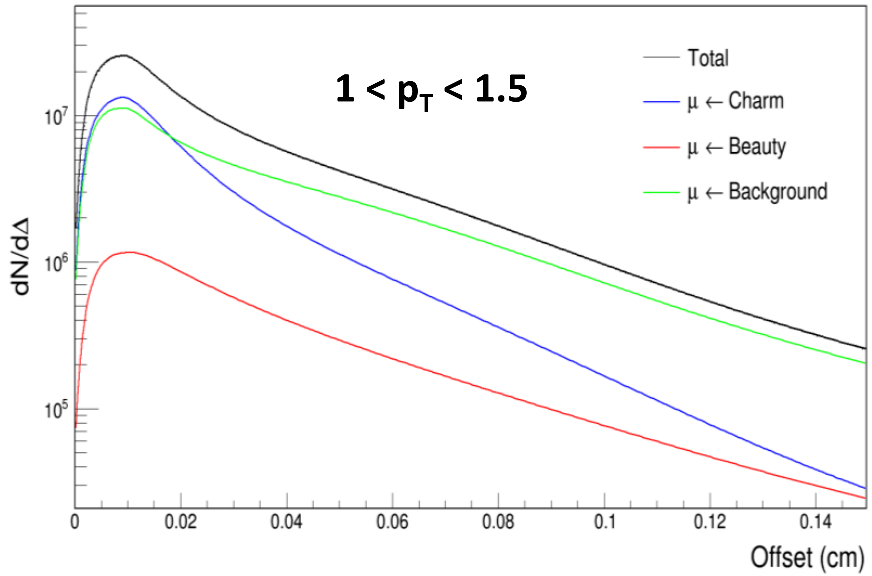
- **Transverse offset:** distance between the primary vertex (measured with the ITS) and the transverse position of the muon tracks extrapolated to the z of the primary vertex

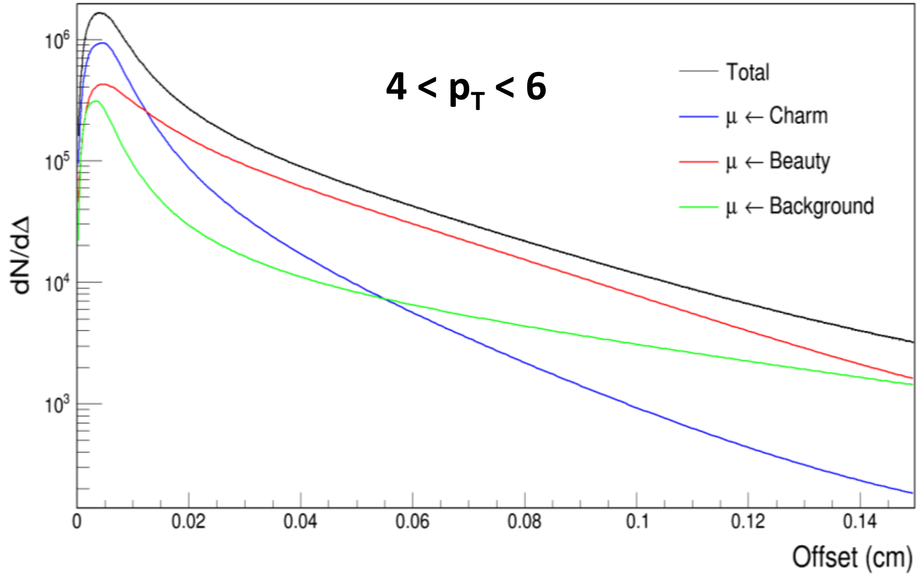
$$\Delta = \sqrt{(x_{\rm V} - x_{\rm Extrap})^2 + (y_{\rm V} - y_{\rm Extrap})^2}$$

Single Muons: Offset Templates

- **MC Offset distributions are parameterized vs p_T**
- Charm clearly distinguishable for $p_T > 1$ GeV/c
- At low-p_T background mimics beauty template: large uncertainties in beauty extraction







Non-prompt J/ψ: Track and Dimuon Selection

Single μ

- **MFT geometrical acceptance:** $2.5 < \eta < 3.6$
- **Matching with the MUON-ID** (currently MUON trigger) chambers
- **$p_T > 1$ GeV/c**
- **Track χ^2/ndf < 1.5** (evaluated from the MUON+MFT global fit)

Dimuons

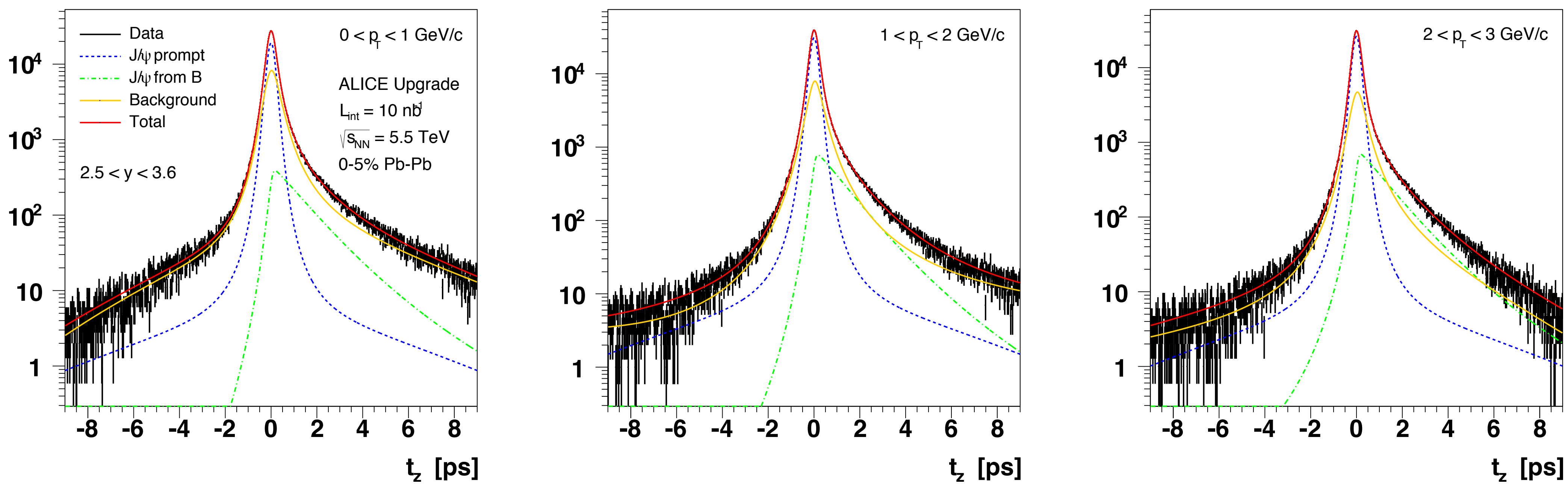
- **MFT geometrical acceptance:** $2.5 < y < 3.6$
- **PCA Quality > 0.5**

> - **PCA:** Point of Closest Approach between two muon tracks
> - **PCA Quality:** Estimates the probability that both muons are coming from the PCA

Non-prompt J/ψ: t_z Template Fits

- **Weak p_T dependence of the t_z templates:** prompt/non-prompt J/ψ effective down to zero p_T

- **Background template:** cross-check possible between mixed event technique and data-driven side-band method. Normalization fixed by the fit on the invariant mass spectrum



Non-prompt J/ψ: Systematic Sources

- **Systematic sources considered:**
  - 1% systematic error on the background normalization (as expected extrapolating current results on J/ψ analysis)
  - Residual uncertainty on MC templates

- **The residual uncertainty on the MC templates** comes from the limited knowledge of the MFT t_z resolution. However:
  - t_z resolution can be studied considering prompt dimuon sources (e.g. ϒ dimuons)
  - The residual uncertainty on the t_z resolution **can be recovered** by defining it as a free parameter of the MC templates. Gaussian as well as more complicated t_z smearing modeling can be adopted

Non-prompt J/ψ: Analysis Strategy

- **Prompt/displaced J/ψ discriminating variable:** longitudinal projection of the primary-secondary vertex distance considered for the analysis (step forward in performance w.r.t. LoI)

MFT LoI

$$t_{xy} = \frac{\sqrt{\left(x_{J/\psi} - x_{\rm vtx}\right)^2 + \left(y_{J/\psi} - y_{\rm vtx}\right)^2} \cdot M_{J/\psi}}{p_{\rm T}}$$

$$t_z = \frac{\left(z_{J/\psi} - z_{\rm vtx}\right) \cdot M_{J/\psi}}{p_z}$$

MFT TDR

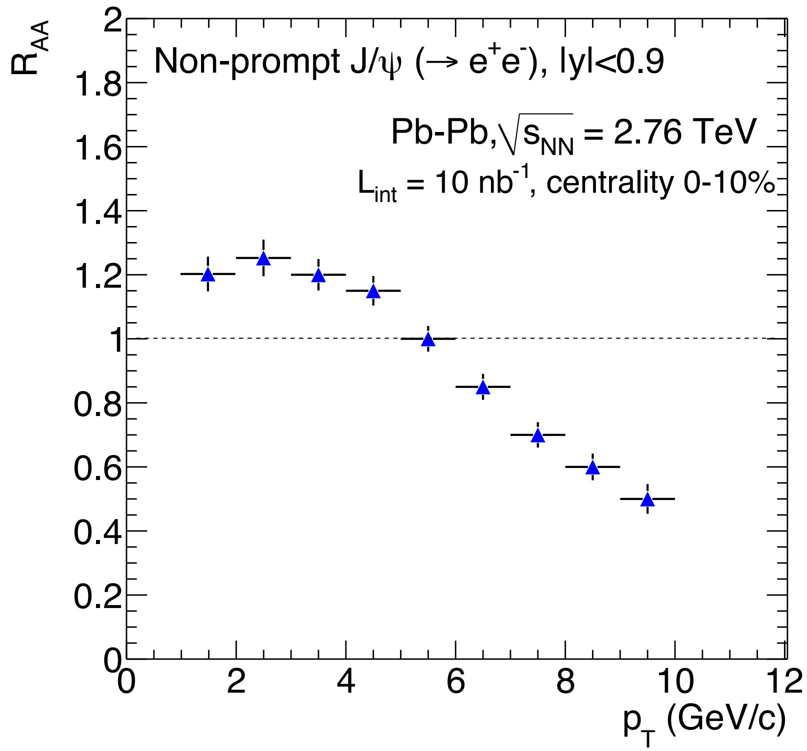
- **Analysis Strategy: double (possibly simultaneous) fit** on the dimuon invariant mass spectrum and the t_z distribution of the dimuons falling within the chosen J/ψ mass window

  - **The fit on the invariant mass spectrum** fixes the normalization of the background and the inclusive J/ψ signal. **The fit on the t_z distribution** then separates the two J/ψ contributions

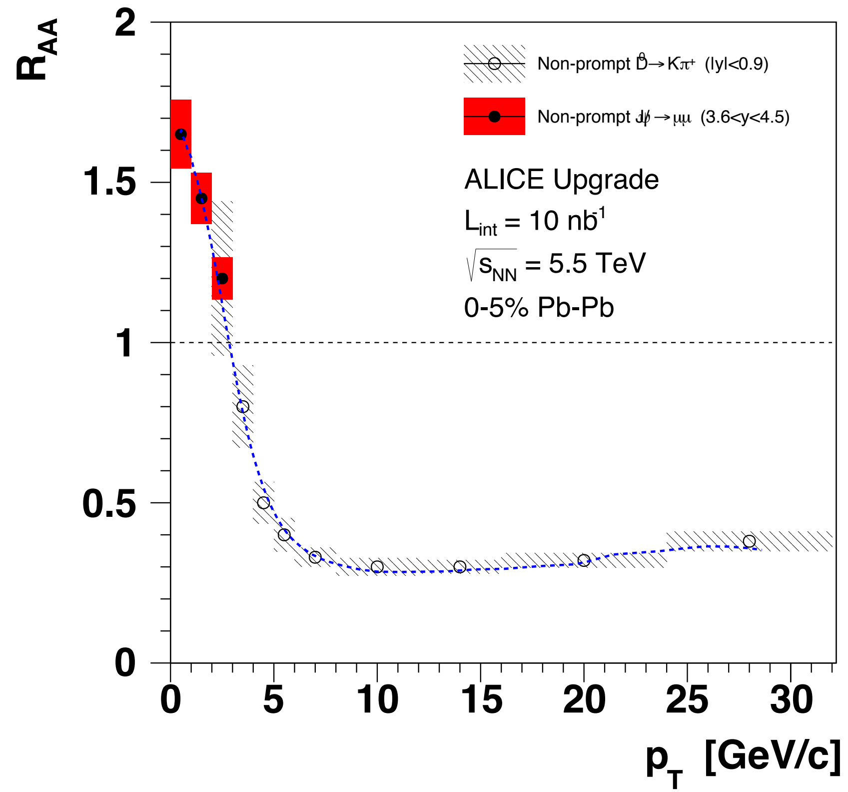
Beauty R_{AA} : Performance Plot

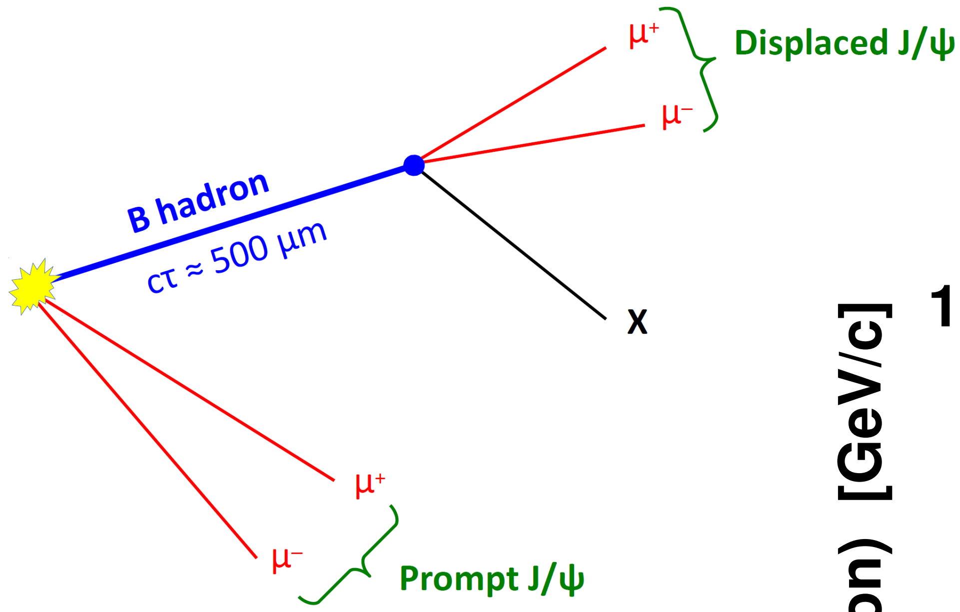
- **Performance plot** corresponding to Fig. 2.20 of the LoI Addendum
- **Beauty R_{AA} measurement** possible down to zero $p_T(J/\psi)$ within 7% stat + syst uncertainties even in central Pb-Pb

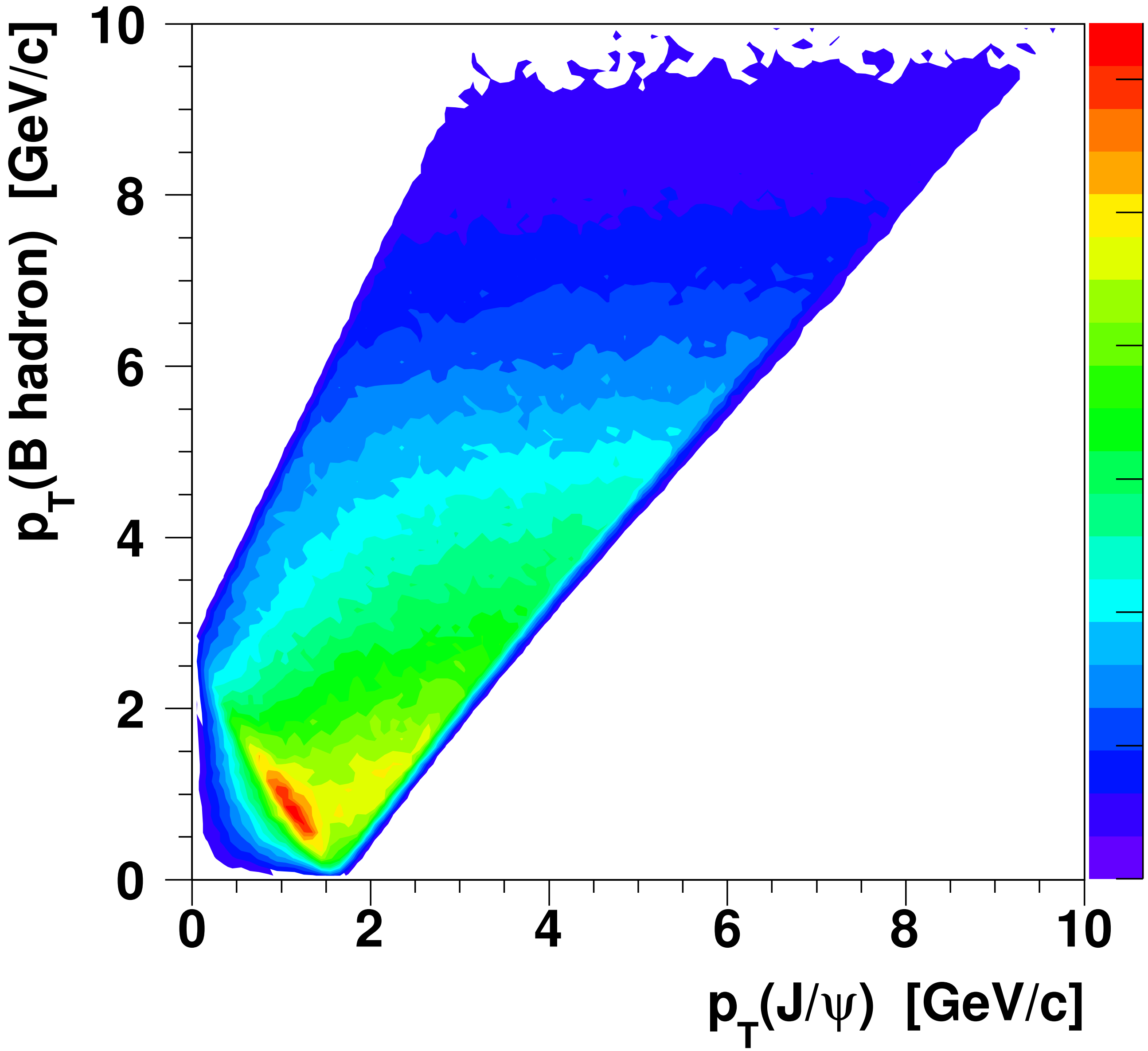
ITS TDR



MFT TDR




μ+
μ−
Displaced J/ψ
B hadron
cτ ≈ 500 μm
X
μ+
μ−
Prompt J/ψ


10
8
6
4
2
0
0
2
4
6
8
10
p_T(B hadron) [GeV/c]
p_T(J/ψ) [GeV/c]