ALICE upgrades

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for the ALICE Collaboration

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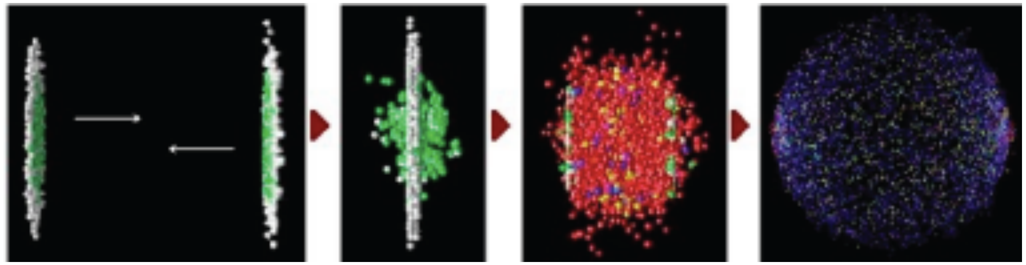
Outline

- Introduction
- ALICE detector specificities
- Physics target of ALICE
- ALICE running scenario and upgrade strategy
- ALICE detector upgrade
  - Upgrade of the ITS
  - Upgrade of the TPC
  - Upgrade of the HLT, DAQ and offline
  - Other upgrade proposals (VHMPID, FoCAL, MFT, upgrade of trigger detectors T0/VZERO/ZDC)
- Expected performances on different physics topics
  - Heavy flavours
  - Quarkonia
  - Low mass dielectron
- Conclusion

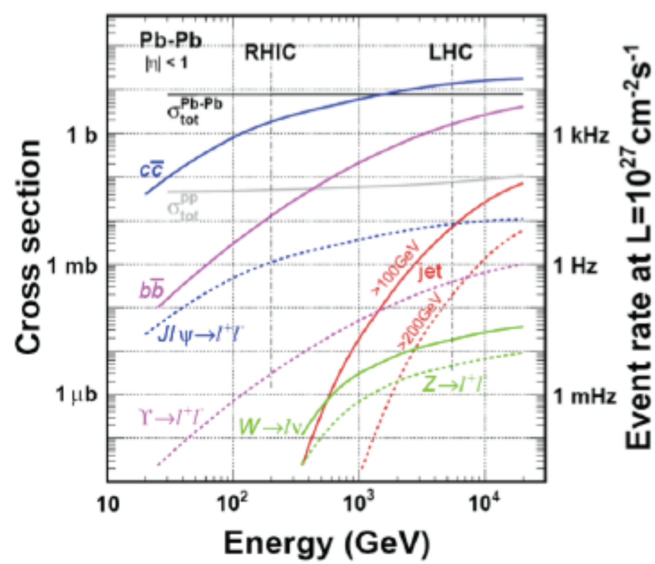
Study of the Quark Gluon Plasma

- Studying the QGP expanding fireball
  - ➢ Phase transition to a deconfined phase (Quark Gluon Plasma)



- 2 years of ALICE results confirmed the creation of hot hadronic matter at **unprecedented values of temperatures, densities and volumes**

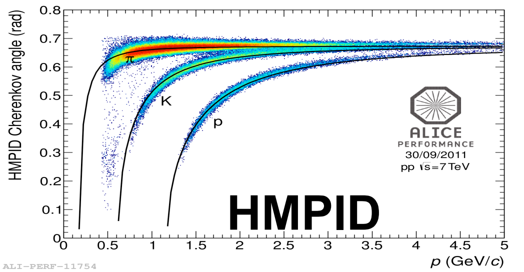
- At LHC:
  - ➢ Heavy ion collisions at high energy
  - ➢ High luminosity
  - ➢ $\mu_b = 0$
  - ➢ Initial temperature and density the highest achievable in the laboratory
  - ➢ Large collision energy → abundance of perturbatively calculable hard QCD processes (heavy flavors, quarkonia, jets…)

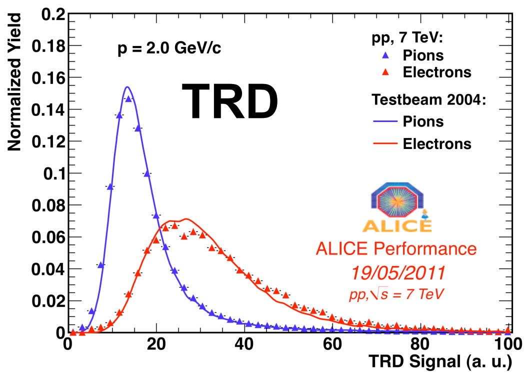


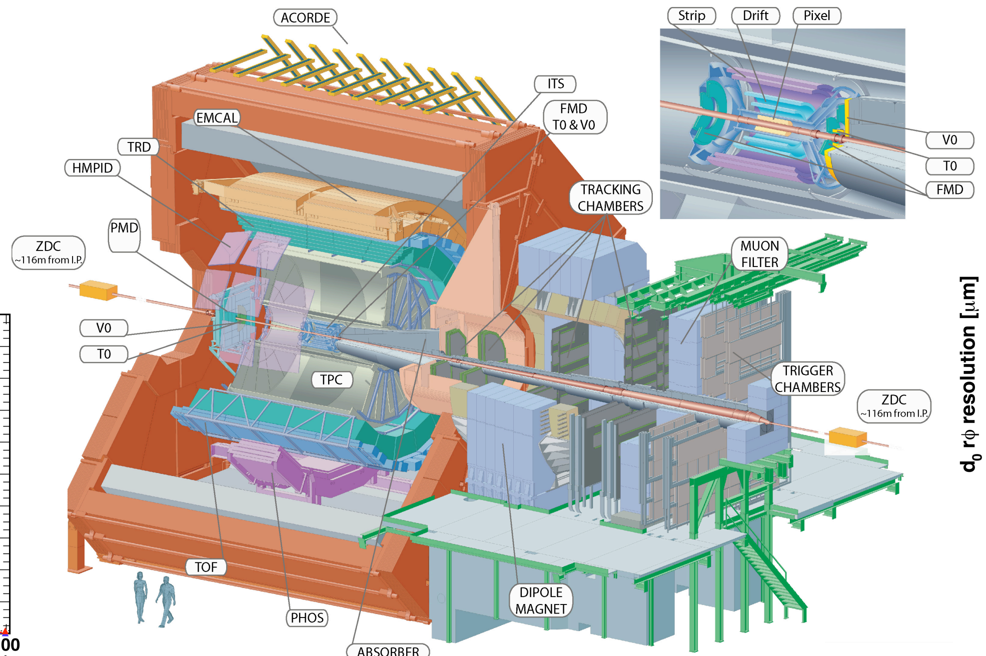
ALICE detector specificities

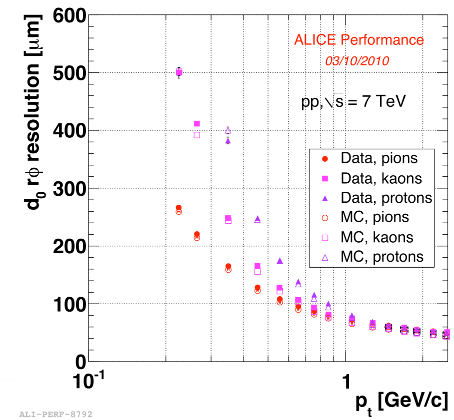
- **Excellent tracking performances** in high-multiplicity environment and **particle identification** over a large momentum range using **all known techniques**

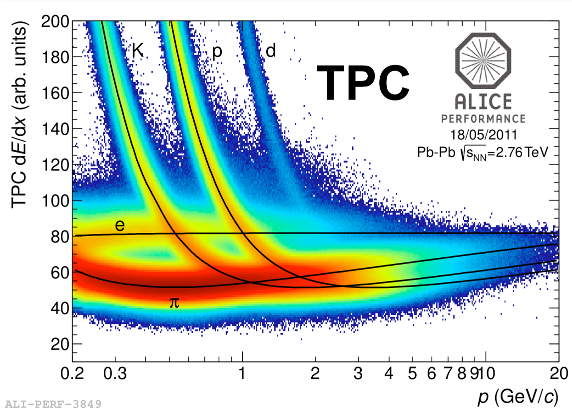
Central barrel mid-rapidity Vertexing, tracking, PID B = 0.5 T

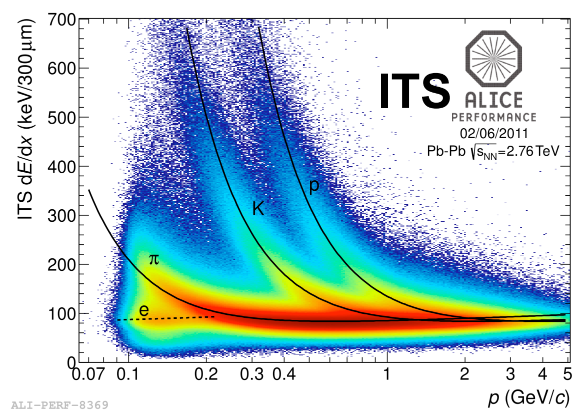


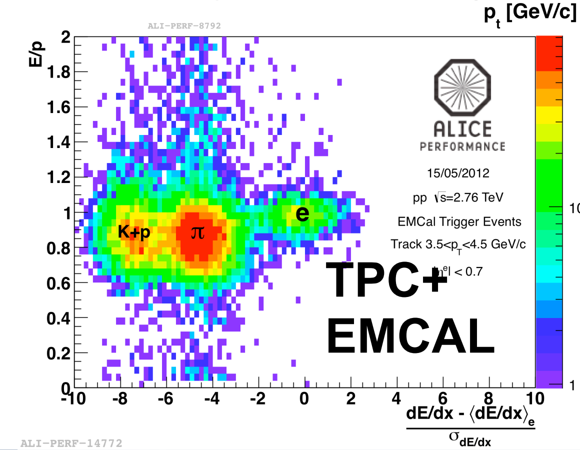








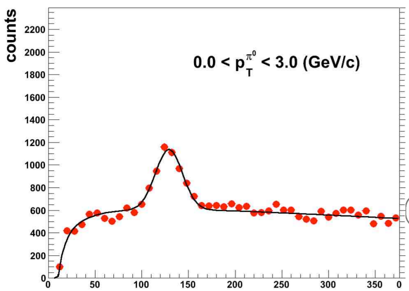


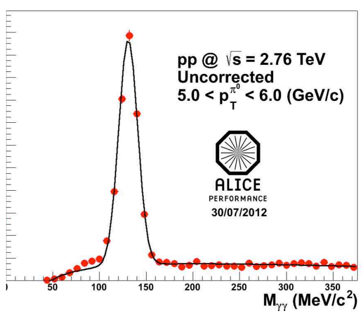


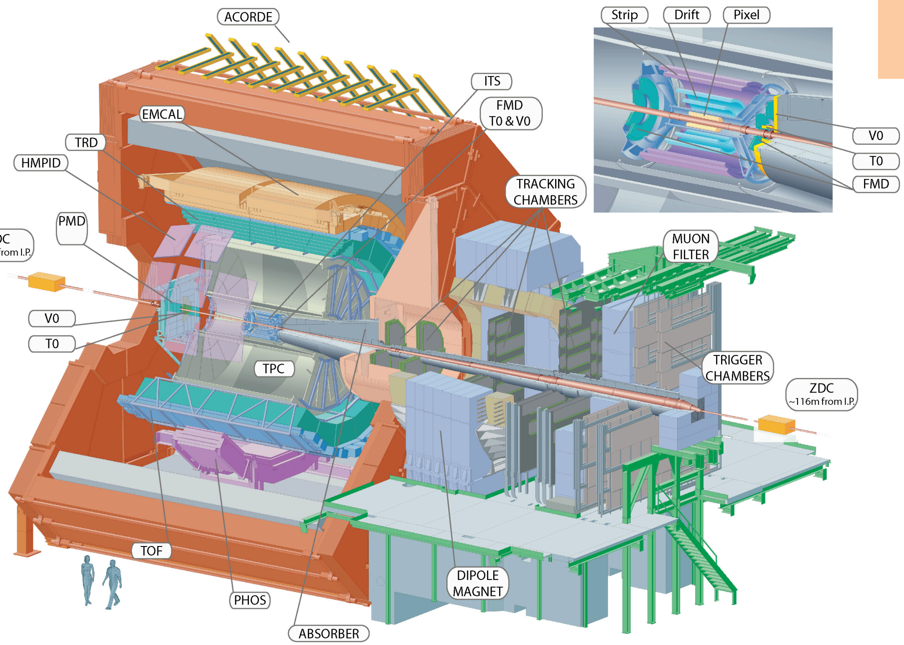
ALICE detector specificities

- Muon identification and reconstruction down to **low p_T** at **forward rapidity**

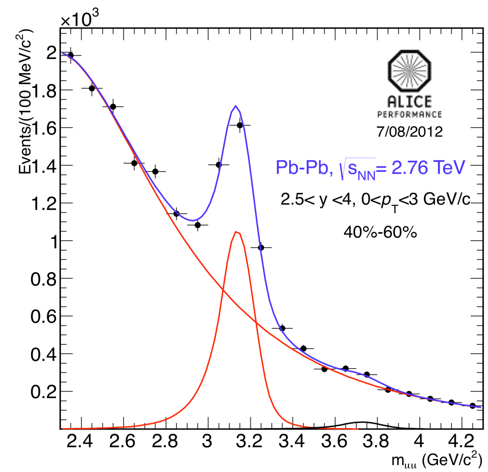
2 calorimeters
EMCAL + PHOS

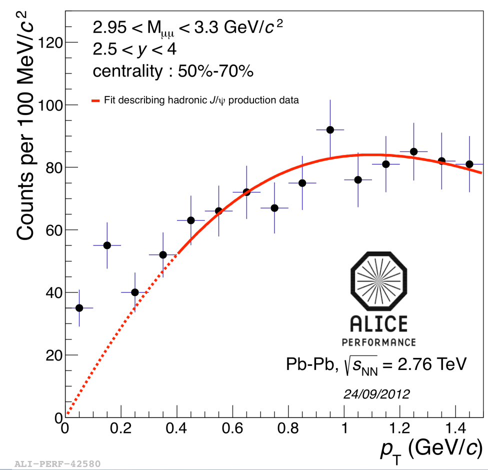




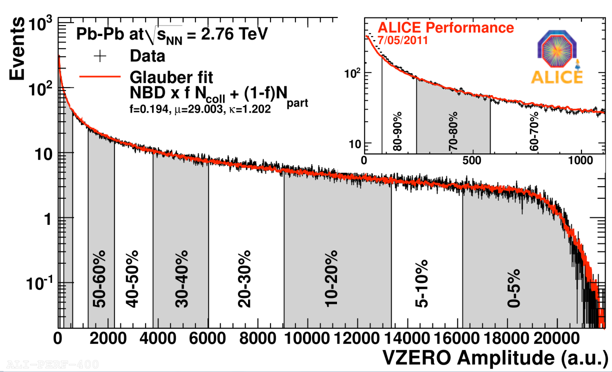


Muon spectrometer
$-4 < \eta < -2.5$
quarkonia down to $p_T = 0$





Forward detectors
(VZERO, TZERO, ZDC, FMD, PMD)
Triggering, multiplicity and centrality measurement



Physics target of ALICE

- **Main physics topics uniquely accessible with the ALICE detector**

  - **Measurement of heavy-flavour in a wide momentum range and down to low p_T**
    - **Study of QGP properties via transport coefficients of HQ**
    - **Study degree of charm thermalization and possible hadronization via coalescence**
    - **Charm/beauty in-medium energy loss**
    - **Detect possible charm thermal production**
  - **Measurement of low-mass and low-p_T di-leptons**
    - **Chiral-symmetry restoration**
    - **Space time evolution and equation of state of the QGP**
  - **J/ψ, ψ' (and χ_c) states down to zero p_T in wide rapidity range**
    - **Studying the deconfined matter via the recombination of $c\bar{c}$ quarks**
    - **Statistical hadronization versus transport models**

- And more (not covered)
  - Jet quenching and fragmentation
  - Heavy nuclear states

ALICE running scenario and upgrade strategy

- Approved ALICE running scenario : collection of **1 nb^{-1} Pb-Pb data** was foreseen up to 2021 (10^{10} interactions for triggered-events, 10^9 interactions for minimum bias events)
  - ➢ Plans until the Long Shut Down 2 in the approved ALICE running scenario
    - ❑ **2013-2014: Long Shut Down 1 (completion of TRD and CALs)**
    - ❑ **2015: Pb-Pb collisions at $\sqrt{s_{NN}}$ = 5.1 TeV**
    - ❑ **2016-2017: Pb-Pb collisions at $\sqrt{s_{NN}}$ = 5.5 TeV**
    - ❑ **2018: Long Shut Down 2**

    (Ar-Ar run, p-Pb run at full energy and Pb-Pb run to complete the 1nb^{-1} goal were foreseen after LS2)

- Most physics signal of interest can not be selected by an online trigger and **inspection of all collisions** is needed (low p_T, high combinatorial background)

ALICE running scenario and upgrade strategy

- ALICE upgrade strategy:
  - **High-rate upgrade:**
    - ❑ modification of ALICE detectors in order to inspect all collisions
    - ❑ increase of the luminosity of the Pb beam by the LHC:
      - **50kHz interaction rate**
      - instantaneous luminosity $L = 6\times10^{27}\ cm^{-2}\ s^{-1}$
      - Collection of 10 nb^{-1} integrated luminosity of Pb-Pb collisions in ALICE (10^{11} minimum bias collisions)

        → increase by a factor 100 the statistic for untriggered probes

        → increase by a factor 10 the statistic for rare probes
  - **Preserve ALICE uniqueness**: low p_T measurements and particle identification

	2019	2020	2021	2022-2023	2024	2025	2026
LS2	Pb-Pb 2.85 nb^{-1}	Pb-Pb 2.85 nb^{-1}	pp run 6 pb^{-1}	LS3	Pb-Pb 2.85 nb^{-1}	Pb-Pb 1.42 nb^{-1} p-Pb 50 nb^{-1}	Pb-Pb 2.85 nb^{-1}
		Low magnetic field	Reference pp run at $\sqrt{s}$ = 5.5 TeV				

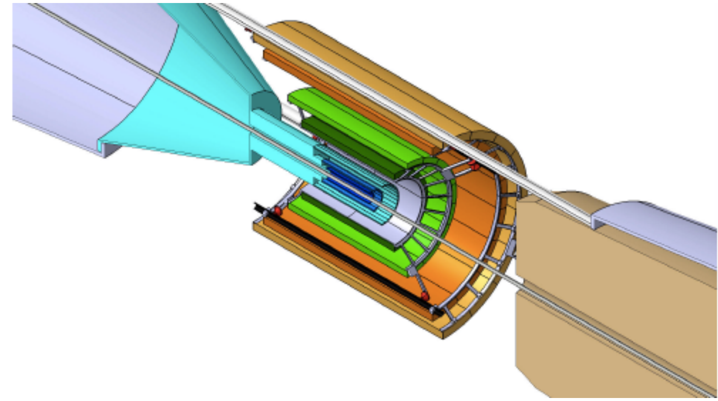
ALICE detector upgrade

ALICE Detector Upgrade

- Improve vertexing and tracking capabilities of ALICE **at low transverse momentum**

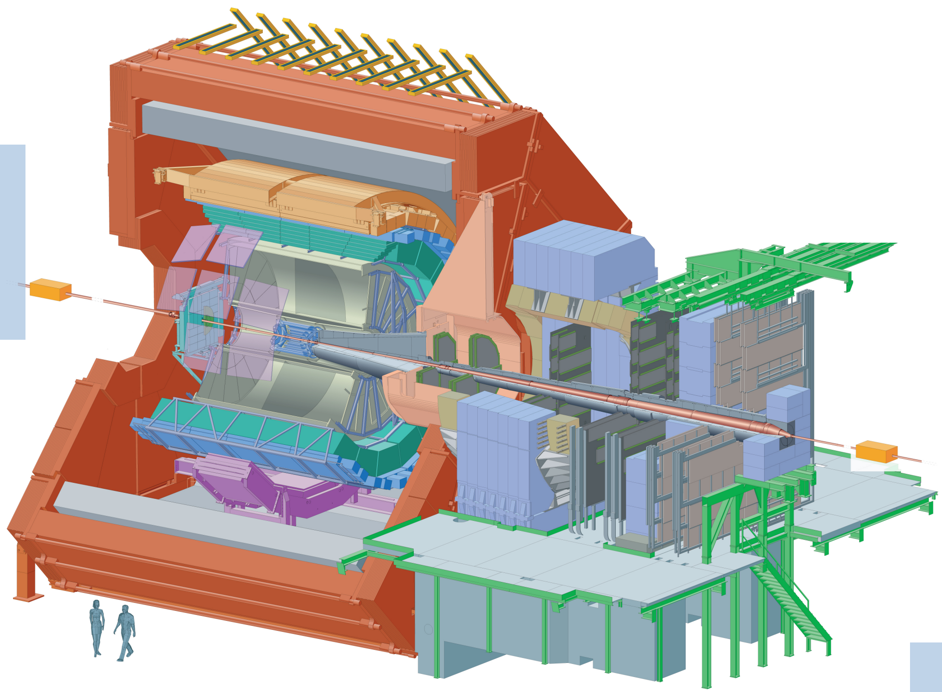
Extension of **EMCAL** (DCAL) LS1

TPC: replacement of the readout multi-wire chambers (MWC) with Gas Electron Multiplier (GEM) detectors and new pipelined readout electronics



TRD, **TOF**, **PHOS** : upgrade of the readout electronics

New **beam pipe** with smaller diameter
29 mm → 17.2 mm



New high resolution, low-material-thickness Inner Tracking System

FoCAL project

Upgrade of the forward detector triggers (**ZDC**, **T0**, **VZERO**) for high rate operations

MFT project

VHMPID project

Muon spectrometer upgrade of the readout electronics

ALICE Detector Upgrade

Upgrade program endorsed by LHCC:

- **A new high-resolution, low-material-thickness Inner Tracking System (ITS)**
  - Resolution on the distance of closest approach between a track and primary vertex improvement by a factor 3
- **Upgrade of the readout end cap detectors of the time projection chamber TPC**
- **Upgrade of the online systems: High Level trigger (HLT), data acquisition (DAQ) and offline data processing software**
  - Improvement needed to treat the large amount of data collected
- **Smaller beam pipe**
- Upgrade of the readout electronics of the TRD, TOF, PHOS, EMCAL, Muon Spectrometer

Other projects under discussion:

- VHMPID
- MFT
- Focal
- One single forward detector with the performances of V0, T0 and FMD, all together

Upgrade of the ITS

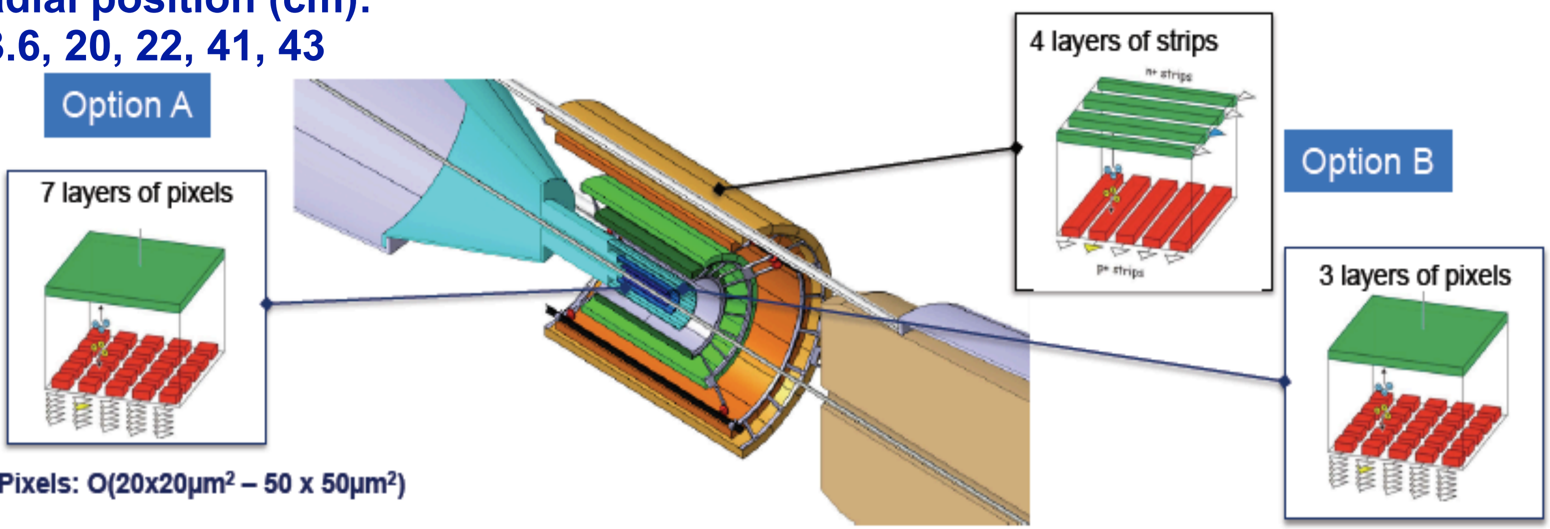
- **Main goals:**
  - **Improve impact parameter resolution by a factor ~ 3 (5) in rϕ (z)**
    - Get closer to IP (position of the first layer from IP reduced: 39mm → 22mm)
    - Reduction of material budget (X/X_0 per layer from 1.14% to 0.3%)
    - Reduce pixel size (present configuration: 50 μm × 425 μm)
      - 2 technologies under study:
        - » monolithic pixels (20μm × 20μm)
        - » hybrid pixels (50μm × 50μm)
  - **High standalone tracking efficiency and p_T resolution**
    - Increase granularity: 6 layers → 7 layers and smaller pixels
    - Increase radial extension: 39-430mm → 22-430 (500) mm
  - **Fast readout**
    - Pb-Pb interactions at 50kHz and pp interactions at ~ MHz
  - **Fast removal/insertion for yearly maintenance**
    - Possibility to replace non functioning detector modules during yearly maintenance

Upgrade of the ITS

- **2 layout considered:**
  - **Option A: 7 pixel layers**
    - Resolutions: $\sigma_{r\phi}$ = 4 µm, σ_z = 4µm for all layers
    - Material budget: X/X_0 = 0.3% per layer
  - **Option B: 3 pixel layers + 4 strip layers**
    - Resolutions: $\sigma_{r\phi}$ = 4 µm, σ_z = 4µm for pixels
      $\sigma_{r\phi}$ = 20 µm, σ_z = 830µm for strips
    - Material budget: X/X_0 = 0.3% for pixels
      X/X_0 = 0.83% for strips

- Option A:
  - Better standalone tracking efficiency and p_T resolution
  - Worse PID
- Option B:
  - Worse standalone tracking efficiency and momentum resolution
  - Better PID

Layers radial position (cm):
2.2, 2.8, 3.6, 20, 22, 41, 43



Pixels: O(20x20µm² – 50 x 50µm²)

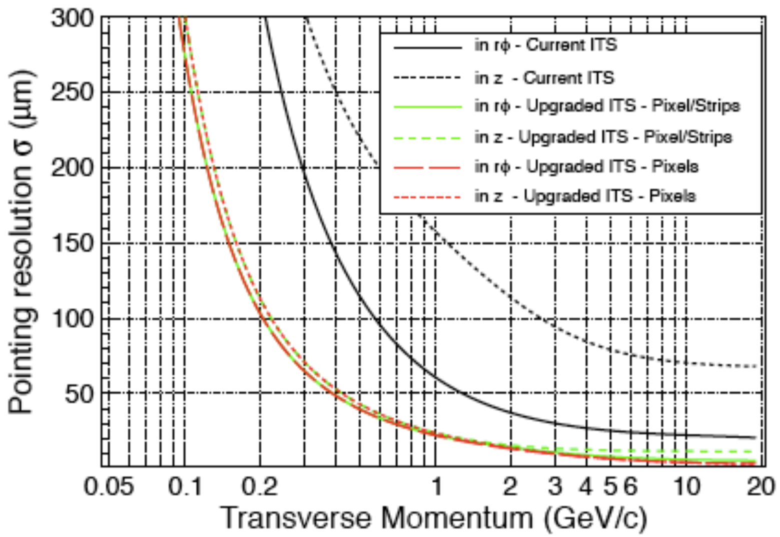
Pixels: O(20x20µm² – 50 x 50µm²)
Strips: 95 µm x 2 cm, double sided

Upgrade of the ITS

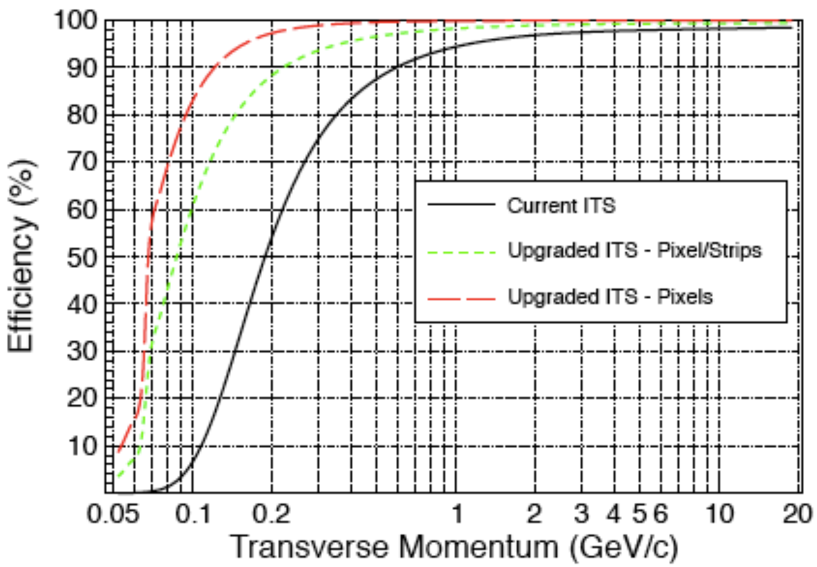
- **New ITS performances**

Pointing resolution significantly improved:

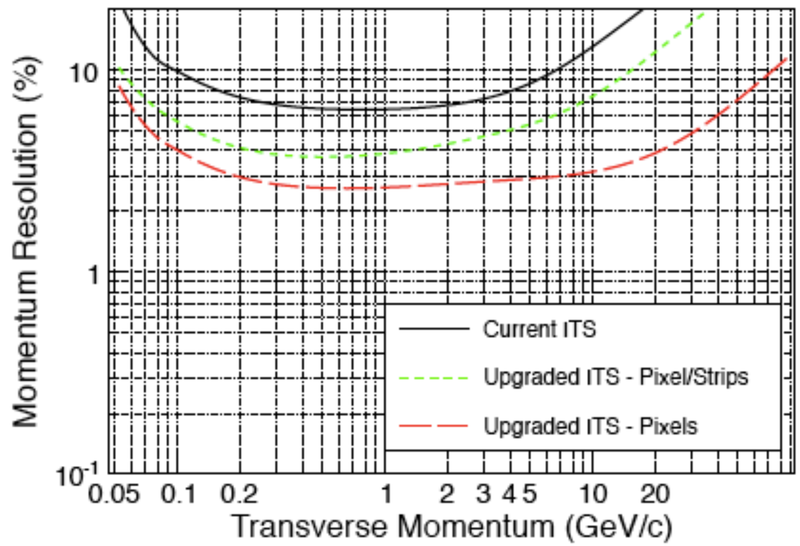
- Factor 3 in rϕ plane at 0.5 GeV/c
  120 μm → 40 μm
- Factor 5 along Z axis at 0.5 GeV/c
  200 μm → 40 μm



Tracking efficiency significantly improved at low p_T: almost a factor 2 at 0.2 GeV/c

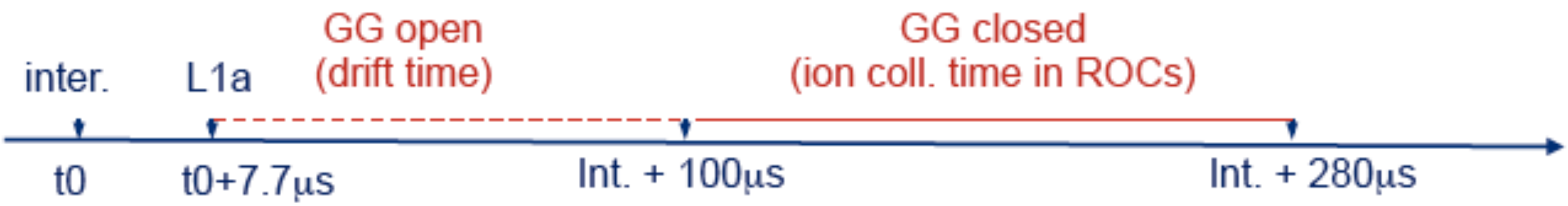


p_T resolution improved by at least a factor 2



Upgrade of the TPC

- **Limits of current TPC:**



- Gating grid of readout chambers closed to avoid ion feedback
  - Limit space charge to tolerable level
  - Effective dead time ≈ 280 μs, maximum readout rate ≈ 3.5 kHz

- Alternative: gating grid always open
  - Ion feedback ≈ 10^3 ions per track generated in drift volume
  - Large space charge effects (of the order of electrical field)
  - → **Space point distortions of order of 1m not tolerable**

Upgrade of the TPC

- New readout chambers
  - ➢ Replace MWPC with GEMs

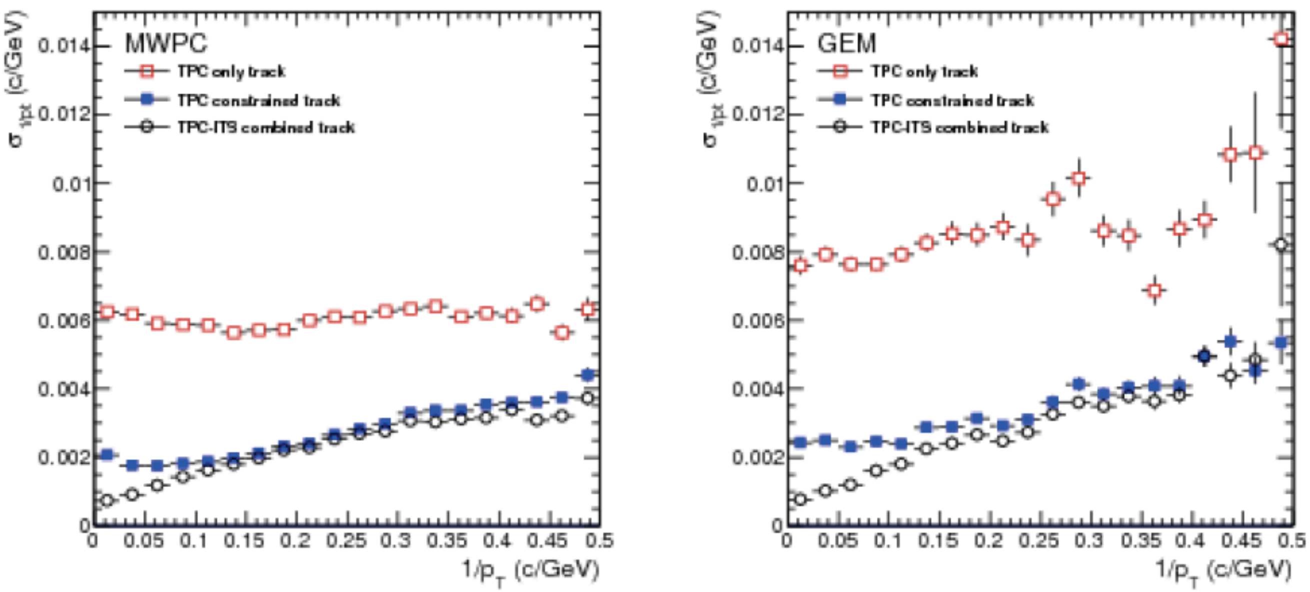
    - No gating

    - Higher rate capability

    - Possibility to efficiently block ions

    - lower (effective) gain: 1000-2000 since all (electron) signal is collected

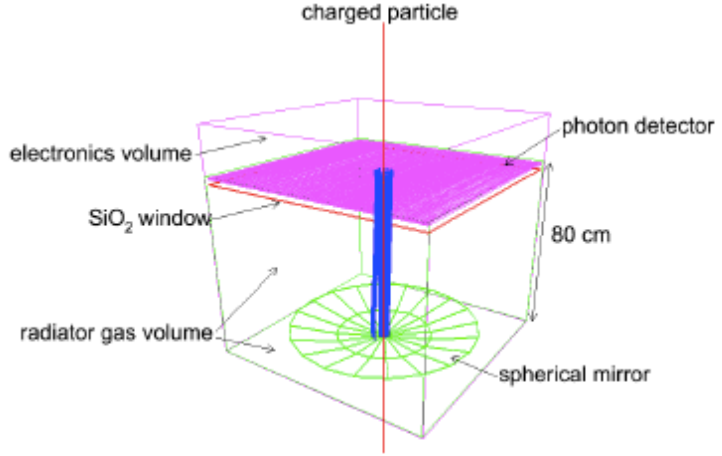
R & D still needed on ion back-flow, gain stability, position and momentum resolution….

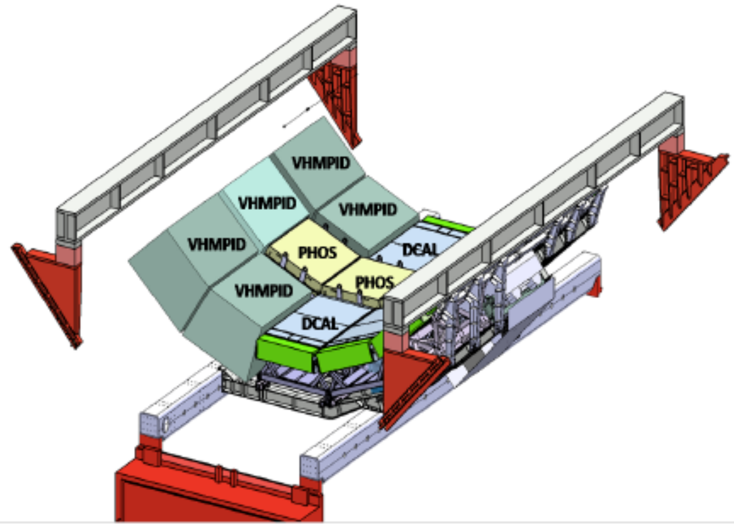


Other upgrade proposals

VHMPID

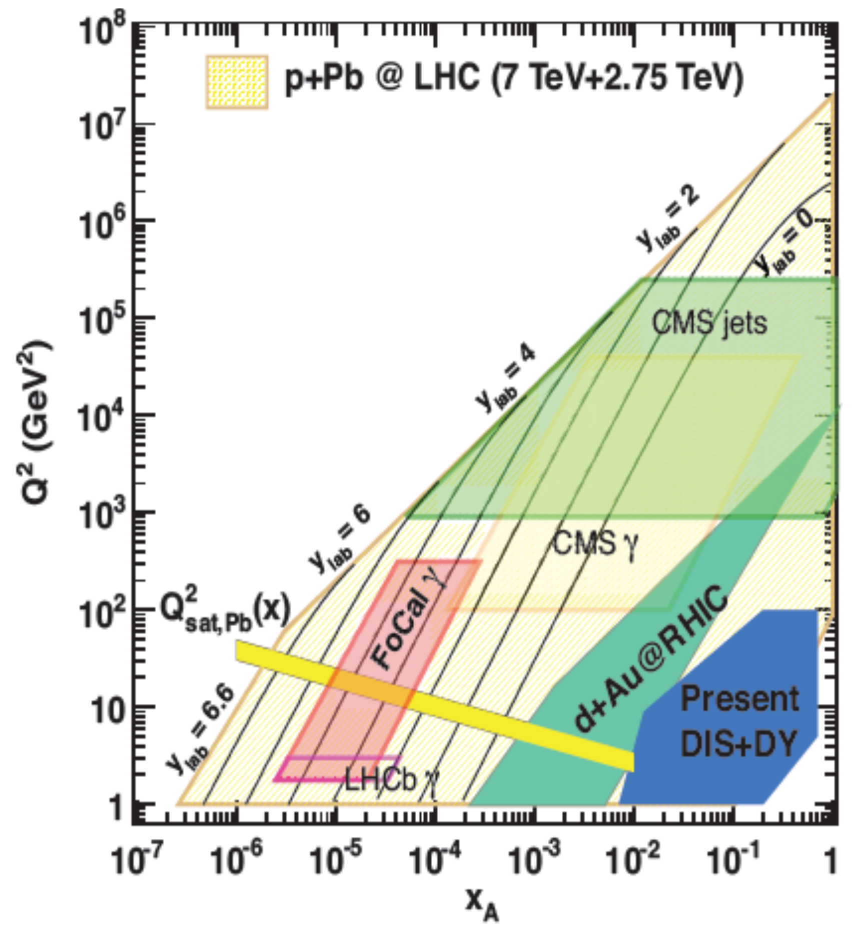
- **Very High Momentum Particle Identification**
- Study the high momentum hadrons which carry information on the dense and hot matter created in collisions
- Provide a track-by-track charged hadron identification in the 5 GeV/c < p_T< 25 GeV/c region
- Ring Imaging Cherenkov detector
- VHMPID coverage : up to 30% of ALICE central barrel
- Sufficient acceptance for triggered and tagged-jet studies allowing identified charged hadron measurement in jets





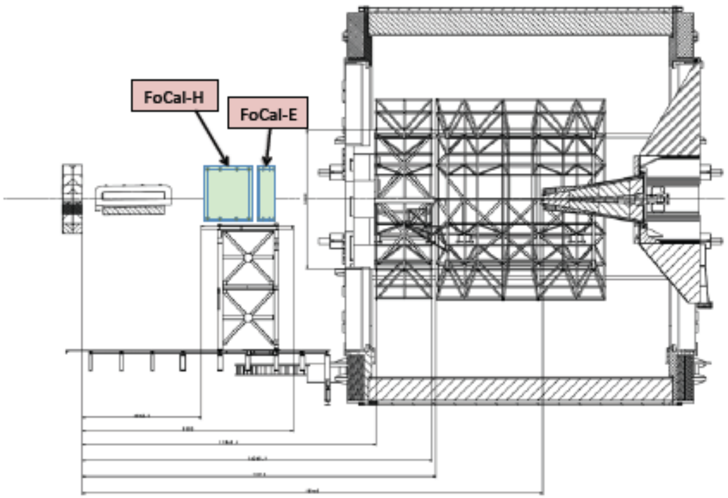
FoCal

- **Forward calorimeter**
  - Study cold dense partonic matter
  - investigate PDFs in a new regime at small Bjorken-x and low Q^2 (study of gluon saturation)
  - High precision measurement of direct photons and jets
  - Discrimination between direct photons and decay photons (direct photon measurement at low momentum)
  - Coincident gamma-jet and jet-jet measurement in p-p and p-A
  - Enhance the capabilities of ALICE for jet quenching studies in A-A
- **Technology: compact Silicon-Tungsten sampling electromagnetic calorimeter with longitudinal segmentation (2 options)**

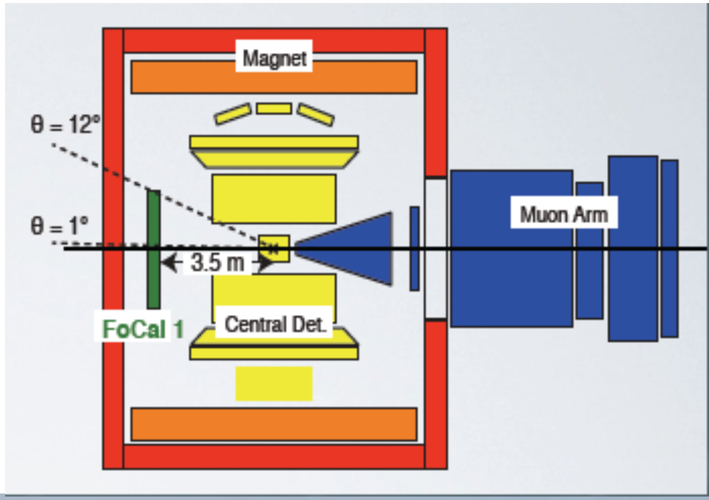


FoCal

- **Two alternative implementation**
  - First implementation:
    - Fine granularity electromagnetic calorimeter backed by a hadron calorimeter
    - Located at 8 meters from the interaction point
    - Direct photons and jet measurements in y ~ 3.3 – 5 probing x values as low as ~ 10^{-6}
    - Modification of ALICE infrastructure and beam pipe



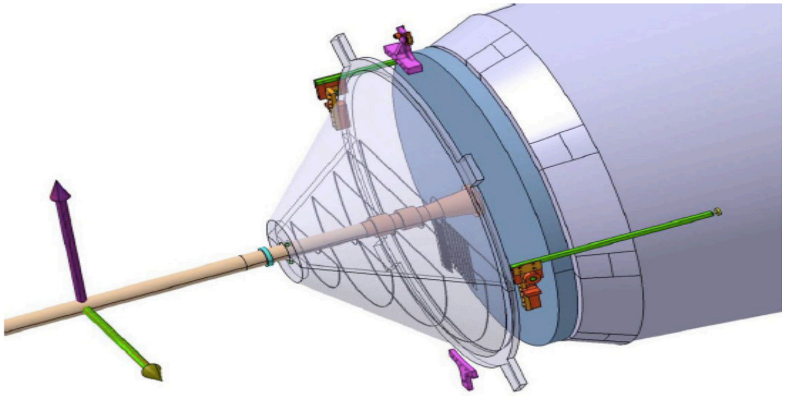
  - Second implementation
    - Replace the actual ALICE Photon Multiplicity Detector (PMD)
    - Location at 3.5m from the interaction point
    - Fine granularity electromagnetic calorimeter, no hadron calorimeter
    - High precision direct photon measurement, **modest jet measurement** in y~ 2.5-4.5 probing x values as low as $5*10^{-6}$



MFT

- A Muon Forward Tracker to complement the muon spectrometer:

  « the glasses of the muon spectrometer»
- **Better precision on the muon track in the vertex region → possibility to disentangle between prompt muons, muons from B and D decays and muons from π, K decays**
- **Improvement of the dimuon invariant mass resolution**
- **Rejection of combinatorial background**

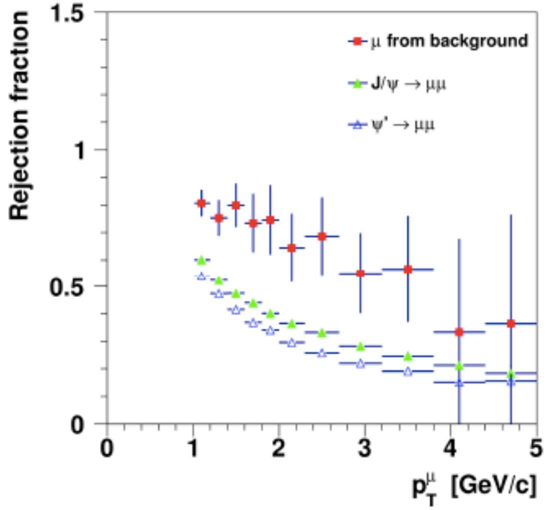


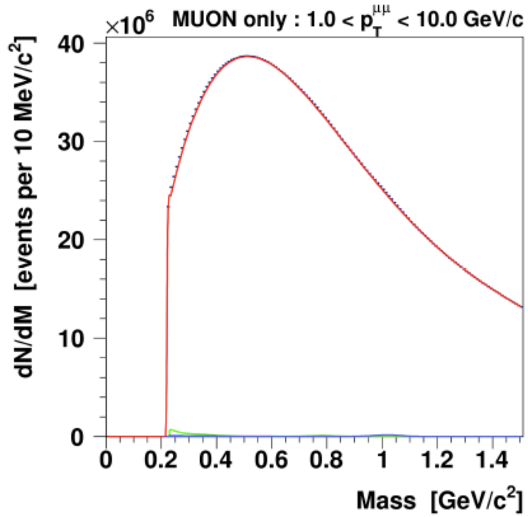
5 Si planes upstream the hadron absorber covering the muon spectrometer acceptance
Pixel size: 25 μm × 25 μm
monolithic pixel sensor technology considered (also candidate technology for ITS upgrade)

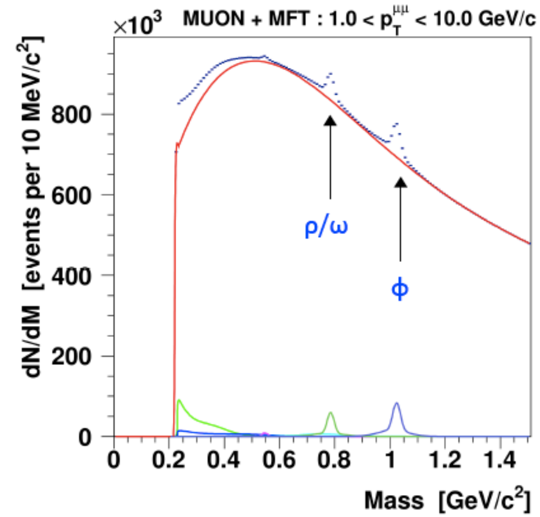
- **Physics cases:**
  - Open heavy flavor: offset resolution for single muons and dimuons allows a disentanglement of charm and beauty production on a model-independent basis
  - Charmonia: possibility to disentangle prompt and displaced charmonia production, possibility to perform a study of ψ' even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

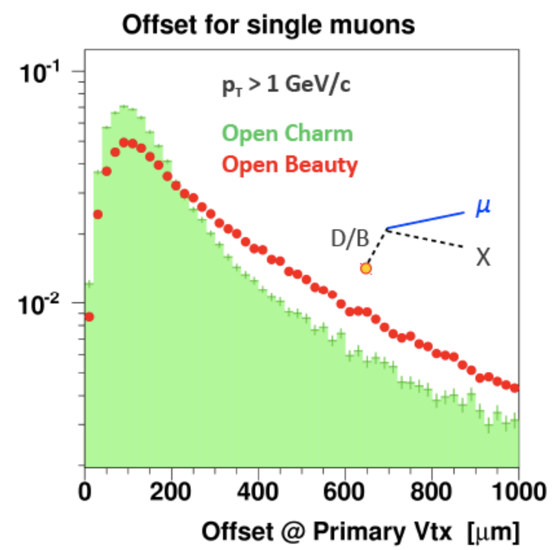
MFT

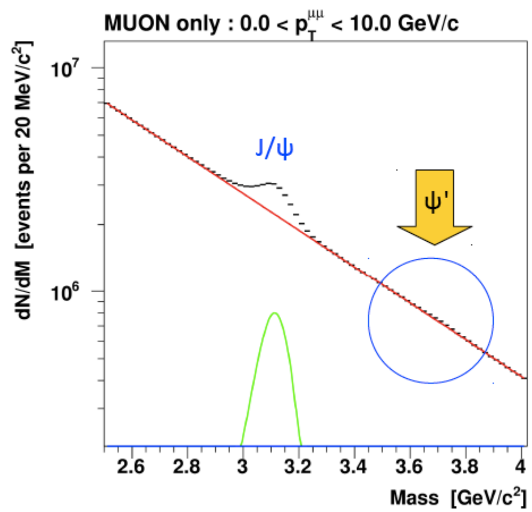
- MFT expected performances on invariant mass resolution, offset distribution, background rejection:

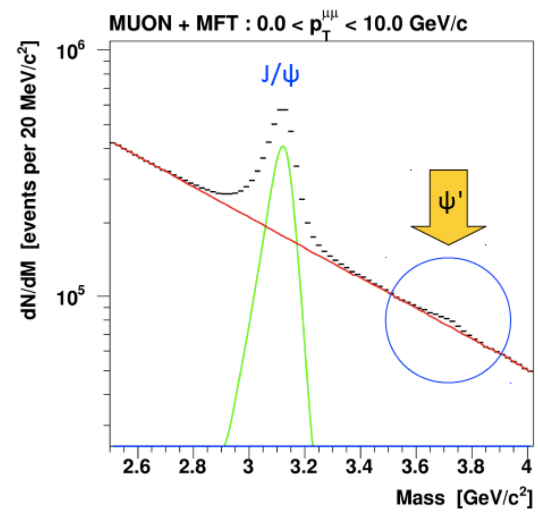












Expected performances on different physics topics

Physics performances: Heavy flavours

- **Two main topics under study:**
  - **Thermalization of heavy quarks in the medium**
    - baryon to meson ratio: Λ_c/D, Λ_b/B
    - azimuthal anisotropy v_2
    - possible thermal charm production?
  - **In medium energy loss**
    - Partonic energy loss expected to be different for gluons, light quarks and heavy quarks (mass hierarchy)
    - Separate B and D mesons
    - Study at low p_T and in wide p_T range

Two topics connected by transport coefficients

Significant differences between c and b predicted

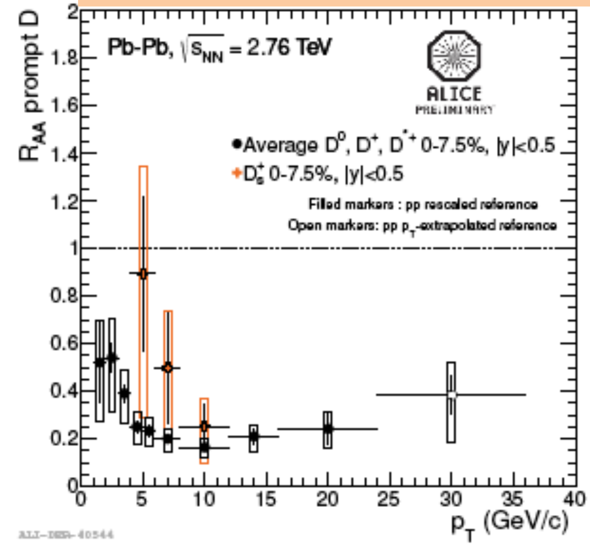
- **Performances for 3 benchmark analyses presented in the following:**

Charm meson production: $D^0 \rightarrow K^- \pi^+$
Beauty meson production: $B \rightarrow D^0 (\rightarrow K^- \pi^+) + X$
Charm baryon production: $\Lambda_c \rightarrow p K^- \pi^+$

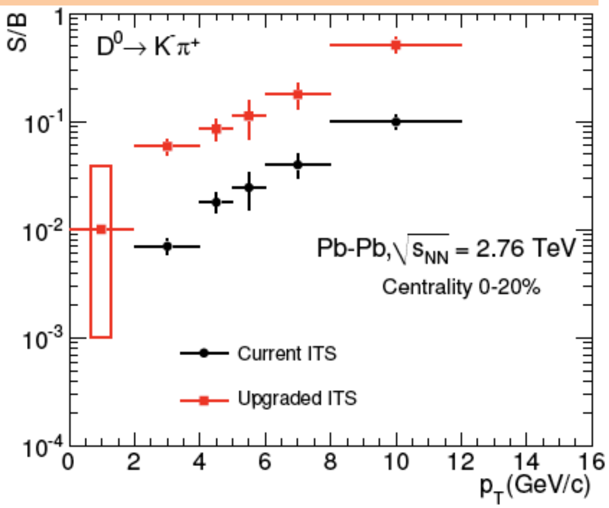
$D^0 \rightarrow K^- \pi^+$

- Benchmark for all D meson studies
- Current D meson R_{AA} measurement
  - **Large systematic uncertainties at low p_T**
- With new ITS, background rejection improved by a factor of 6 for p_T > 2 GeV/c and by 25 for p_T < 2 GeV/c
- Considering L_{int} = 10 nb^{-1} → ~ 1.7 × 10^{10} events, significance of several hundreds at any p_T
- Better precision on R_{AA} measurement at low p_T expected in the upgrade scenario

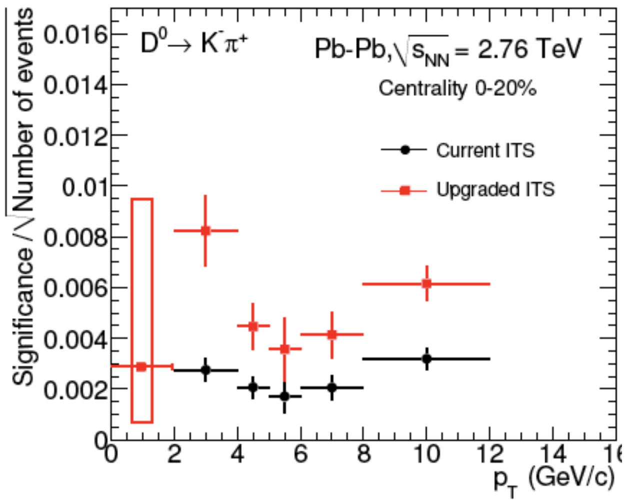
Current D meson R_{AA}



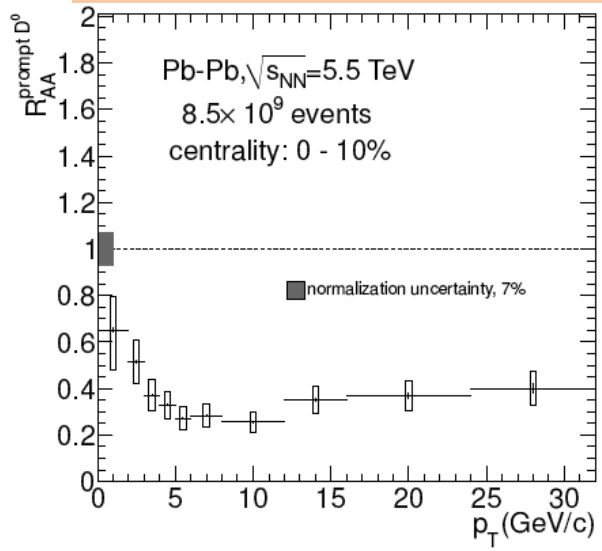
Signal over background ratio



significance



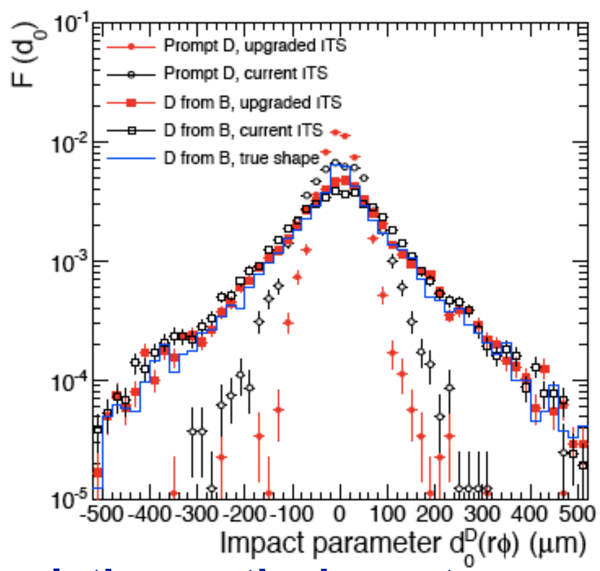
D meson R_{AA} for L_{int} = 10nb^{-1}



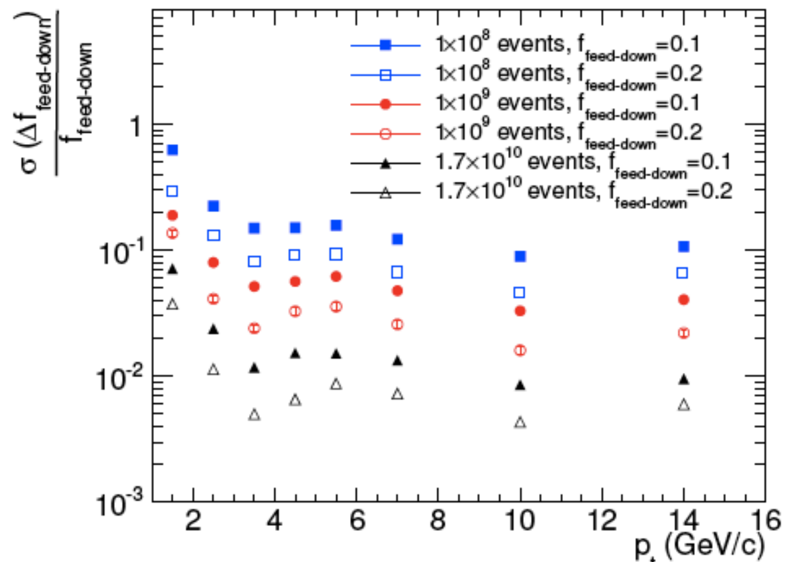
$B \rightarrow D^0 (\rightarrow K^- \pi^+) + X$

- Large fraction of B meson decays to D^0 (~ 60%)
- Long lifetime of B meson ($c\tau$ ~ 500 μm)
- Fraction of prompt and displaced D^0 mesons can be measured by exploiting the different shapes of the impact parameter distributions of primary and secondary mesons

Impact parameter distribution for prompt and secondary D^0



Statistical uncertainty on the fraction of D^0 from B

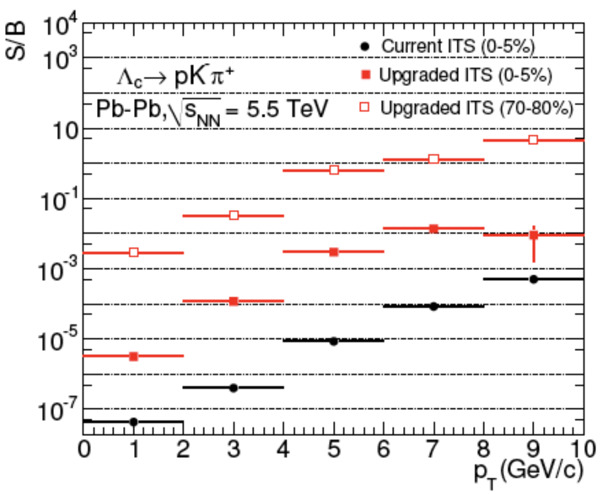


- **Resolution on the impact parameter of the D^0 meson improved by a factor 2**
- **Statistical uncertainty on the fraction of D^0 coming from B smaller than 10% down to p_T = 1 GeV/c with L_{int}= 10 nb^{-1}**

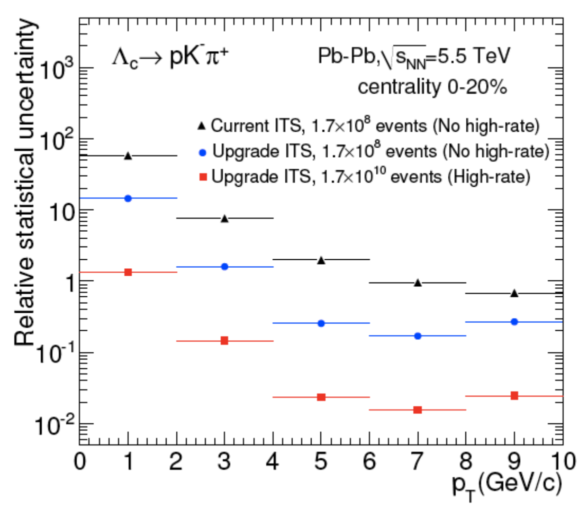
$\Lambda_c \rightarrow pK^-\pi^+$

- Branching ratio ~ 5%
- Short mean proper decay length for Λ_c ($c\tau$ ~ 60µm)
- Currently : signal seen in invariant mass distribution in pp collisions at $\sqrt{s}$ = 7 TeV (significance ~ 5)
- Large combinatorial background in Pb-Pb collisions

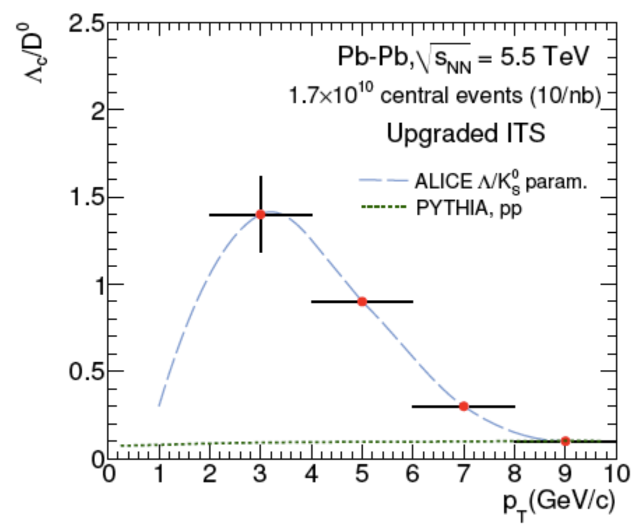
Signal over background ratio



Relative statistical uncertainty

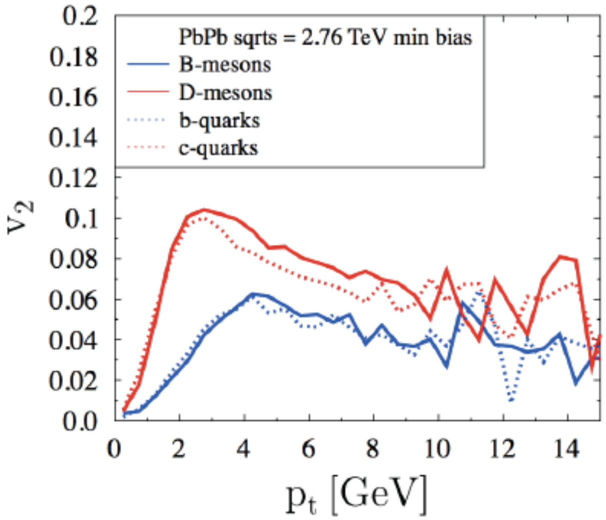


Λ_c/D^0 ratio for L_{int}= 10nb^{-1}



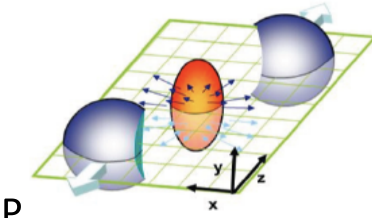
- **For central collisions, improvement of the signal over background ratio by a factor 400 (2 < p_T < 4 GeV/c) from current to upgraded ITS**
- **In high rate scenario, Λ_c measurable down to 2 GeV/c in central collisions**

Heavy flavours elliptic flow

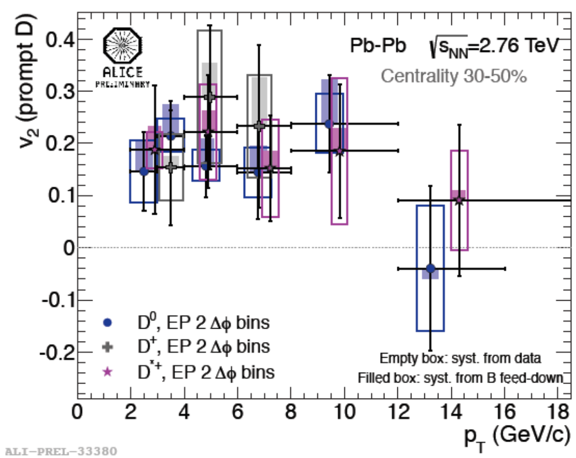


J. Aichelin et al. arXiv:1201:4192

- Initial azimuthal anisotropy converted to a momentum anisotropy
- HF elliptic flow (v2) sensitive to:
  - Thermalization of c and b quarks in the QGP
  - Heavy-quark diffusion coefficient of the QGP which characterizes it coupling strength

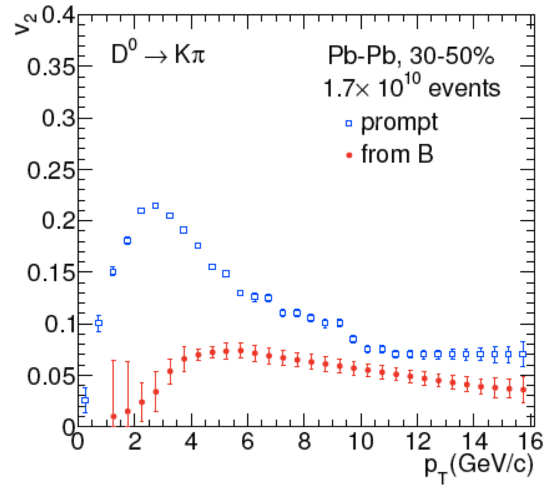


ITS upgrade and large luminosity ($10nb^{-1}$) needed to reach high precision on prompt D meson v_2 and D from B meson v_2

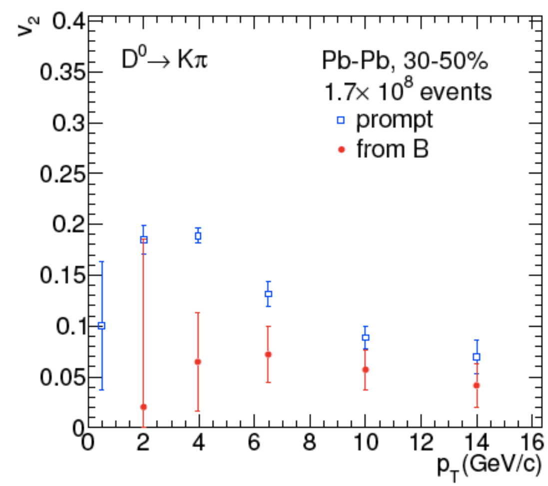


Current D meson measurement :
large uncertainties

New ITS. High rate



New ITS, low rate



Physics performances : Quarkonia

- **Study of charmonia production mechanisms:**

  - **High statistic measurement of J/ψ in wide rapidity range and p_T range**
    - Test recombination scenarios: statistical hadronization vs transport model:
      New high precision measurement needed (10 nb^{-1}):
      - J/ψ nuclear modification factor at mid-rapidity
      - High precision measurement of J/ψ v_2
    - Improve actual measurement precision:
      - Electromagnetic production of J/ψ in UPC
      - J/ψ polarization
    - Study novel observable:
      - J/ψ low p_T excess in hadronic Pb-Pb collisions

  - **Study ψ' production**
    - Nuclear modification factor
    - v_2
    - ψ' production in UPC

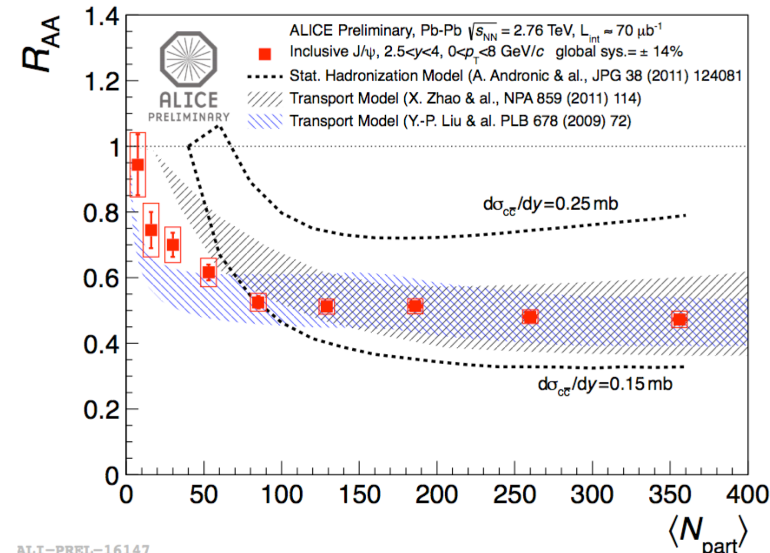
  - Access to χ_c under study

  - Measurement in e^+e^- (central barrel) and $\mu^+\mu^-$ (muon spectrometer)

Nuclear modification factor of J/ψ

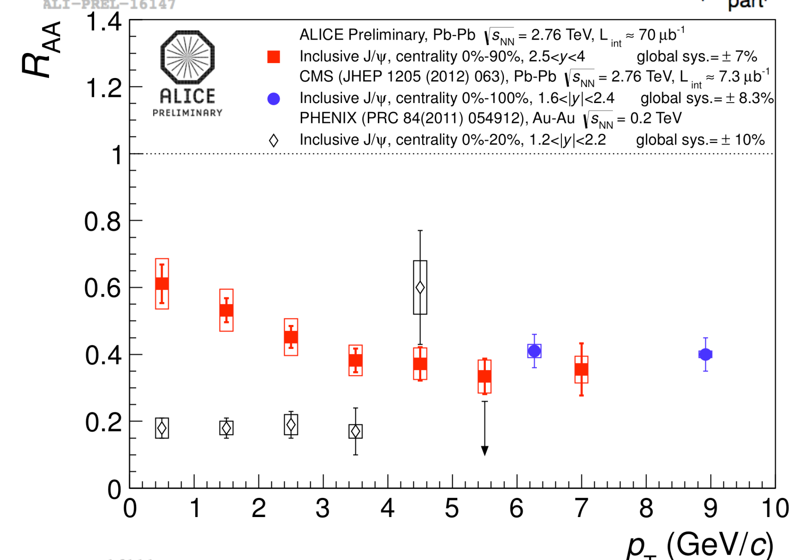
- **J/ψ R_{AA} vs $<N_{part}>$**

  - Different pattern of J/ψ suppression between RHIC and LHC at forward and mid-rapidity vs $<N_{part}>$ (all p_T)
  - Less suppression observed at LHC
  - Transport model and statistical hadronization can reproduce the data
  - J/ψ production mechanism at LHC determined by regeneration in the QGP or by generation at chemical freeze-out



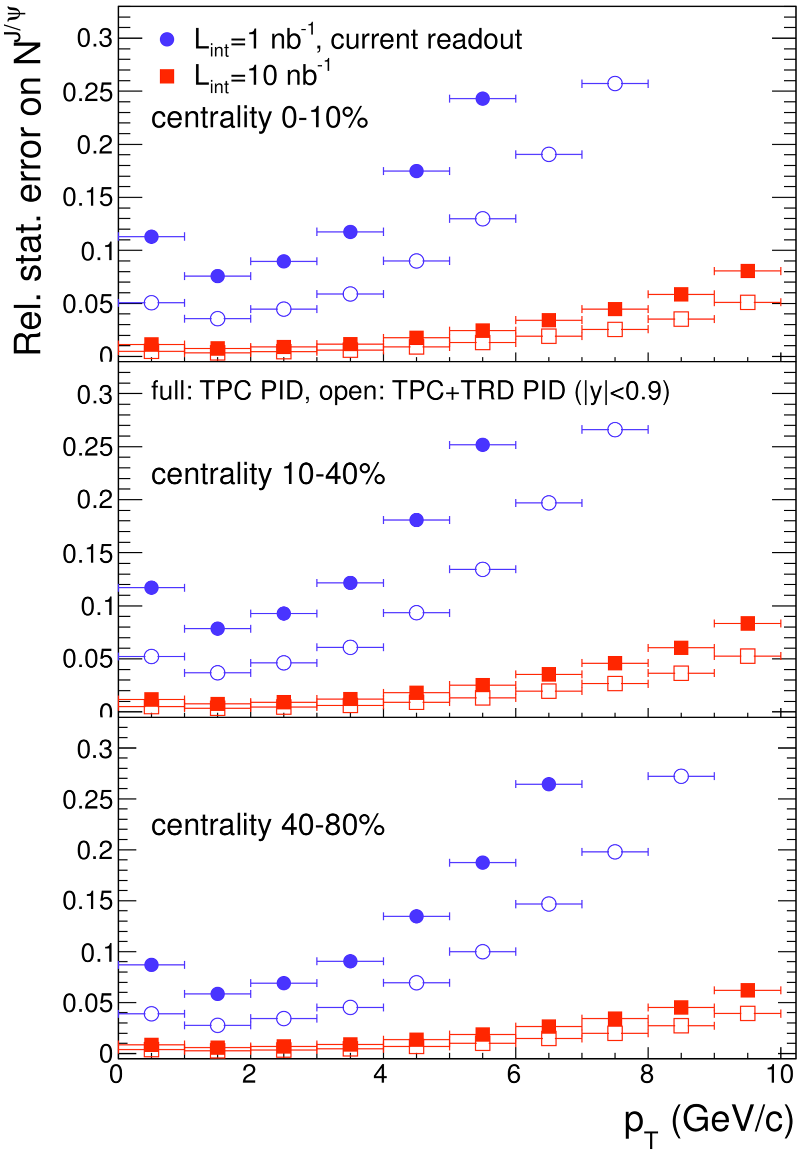
- **J/ψ R_{AA} vs p_T**

  - Transverse momentum dependence of J/ψ R_{AA} different between RHIC and LHC
  - Less suppression at low p_T at the LHC
  - Transport model assuming 50% of low p_T J/ψ produced by recombination of charmed quarks in the QGP can describe the data



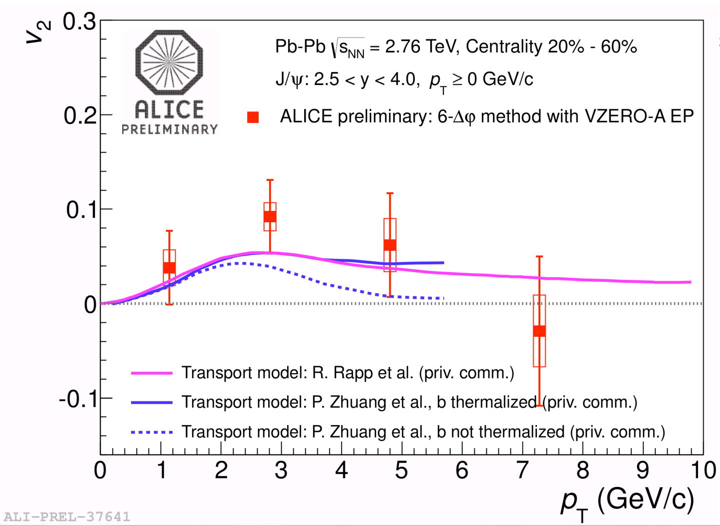
Nuclear modification factor of J/ψ

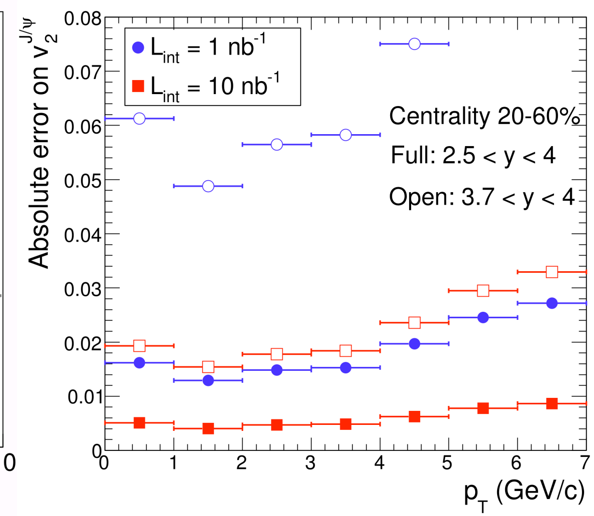
- Measurement of the nuclear modification factor of J/ψ versus p_T and rapidity already feasible with a good accuracy before LS2 upgrade in the muon spectrometer (systematic uncertainty dominant)
- Upgrade will allow a detail R_{AA} measurement vs <Npart> and p_T in the central barrel
- Good accuracy of measurement up to ~ 6 GeV/c with complete TRD electron identification
- Measurement of J/ψ from B decay feasible in the central barrel after the upgrade

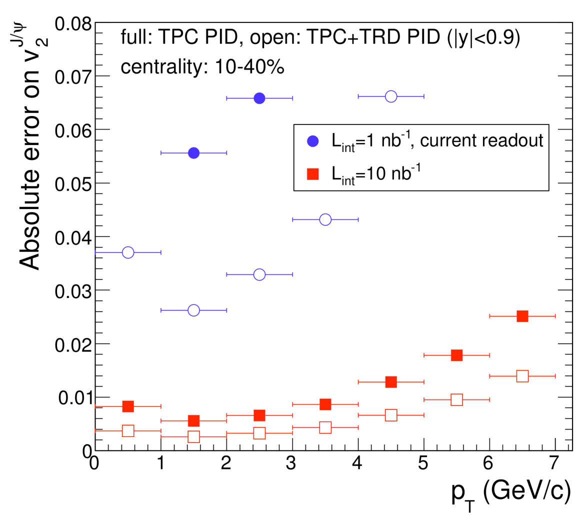


J/ψ Elliptic flow

- **J/ψ elliptic flow vs p_T (and centrality)**
  - Recombination and statistical hadronization models require thermalization of charm quark in the QGP → non zero elliptic flow expected for charmed hadrons and quarkonia
  - **First measurement of elliptic flow at LHC energies**
  - **Hints for non-zero J/ψ elliptic flow** in the p_T range 2-4 GeV/c, centrality range 20-60% (significance 2.2σ). Flow magnitude described by transport models.
  - Precision data needed to extract information on the QGP properties and the amount of regeneration
- Muon spectrometer: L_{int} = 1nb^{-1} reach 5σ significance on present measurement
  Upgrade: **precise measurement of $v_2(p_T)$ as a function of the rapidity**
- **Central barrel:** flow measurement only possible with the upgrade





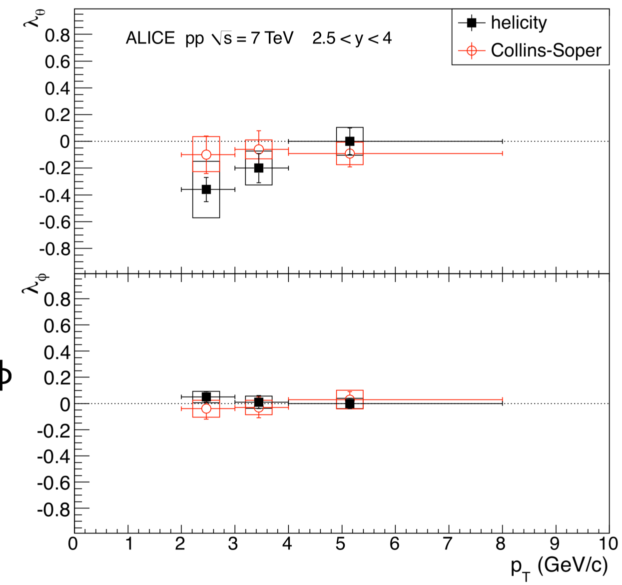


Polarisation of J/ψ

- Distribution of J/ψ decay products expressed as:

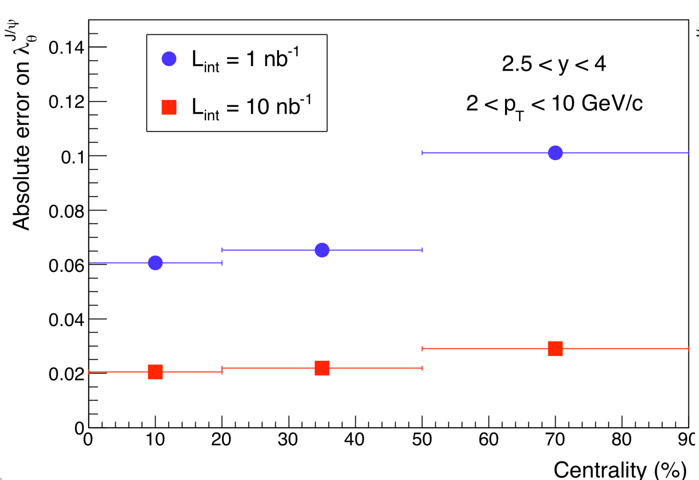
$$W(\theta,\phi) = \frac{1}{3+\lambda_\theta}\left(1+\lambda_\theta \cos^2\theta + \lambda_\phi \sin^2\theta \cos 2\phi + \lambda_{\theta\phi} \sin 2\theta \cos\phi\right)$$

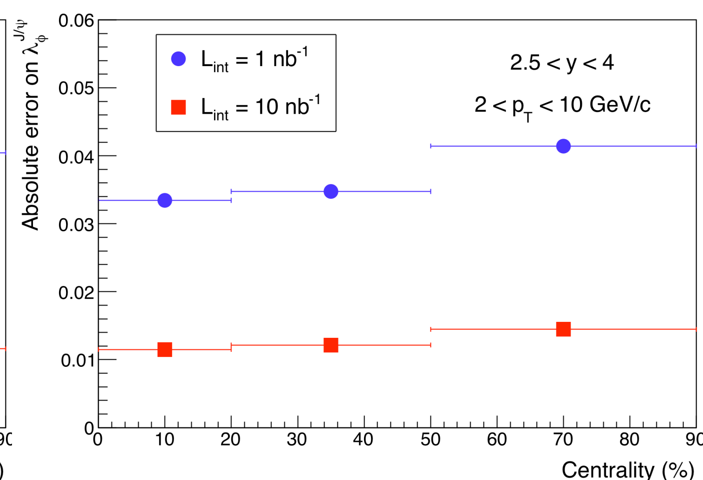
- θ and ϕ polar and azimuthal angles, λ parameter describing the spin state of J/ψ in a given reference frame
- First polarization measurement in pp collisions: : λ_θ and λ_ϕ consistent with 0 in helicity and Collins-Soper reference frames
- Challenging measurement of J/ψ polarization parameters in Pb-Pb collisions at low p_T



Phys. Rev. Lett. 108 (2012) 082001

Absolute error on λ_θ and on λ_ϕ parameters lower than 0.1 (factor 3-4 improvement in the upgrade scenario with respect to the $1nb^{-1}$ scenario)





J/ψ low p_T excess

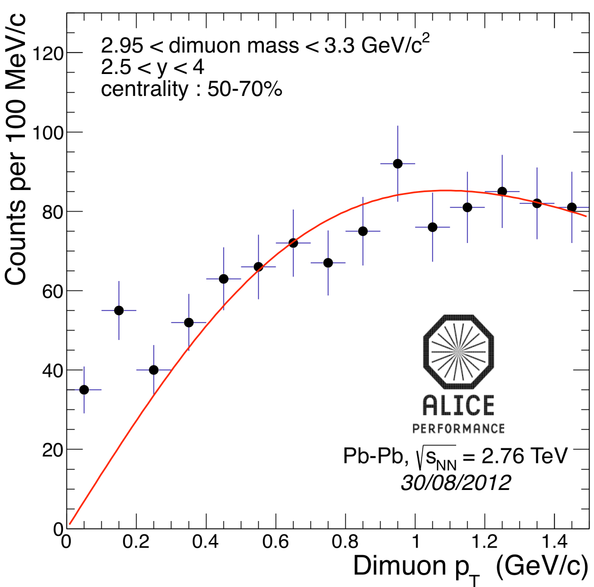
- **J/ψ low p_T excess in hadronic Pb-Pb collisions**

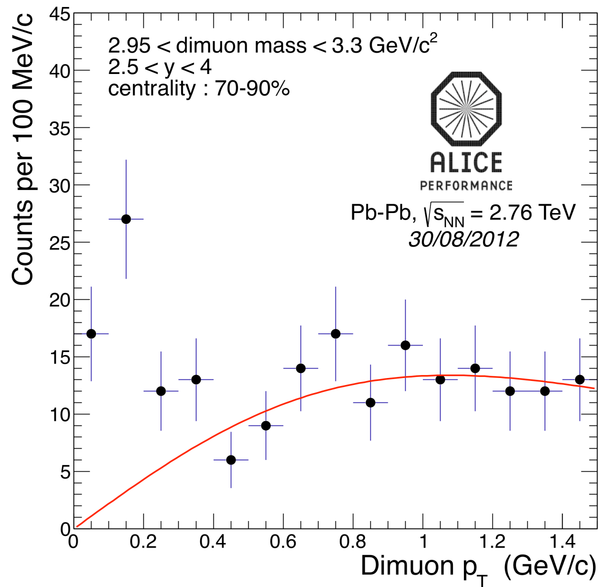
➢ Low p_T excess observed below 300 MeV/c in Pb-Pb nuclear collisions

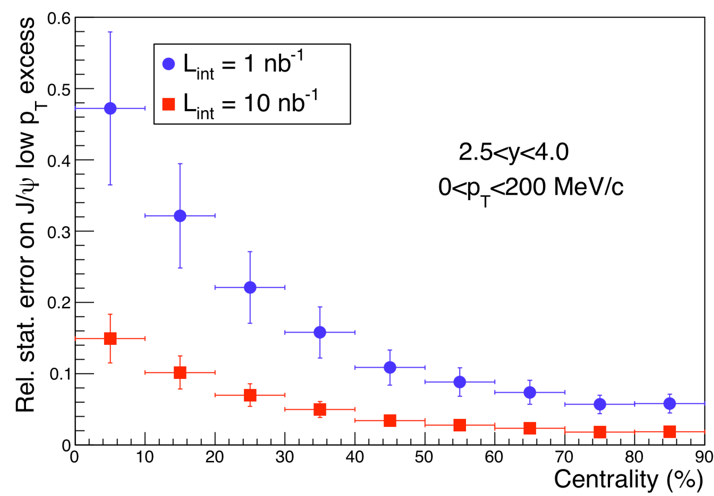
➢ Understanding the phenomena : coherent J/ψ photo-production during the nuclear collision? How can coherent photo-production and hadronic interaction cohabit? How photo-produced J/ψ can interact with the QGP?

➢ Study with better precision the low p_T excess observed versus the centrality of the collision

➢ Low-p_T excess can be studied in most central collisions with L_{int} = 10 nb^{-1}







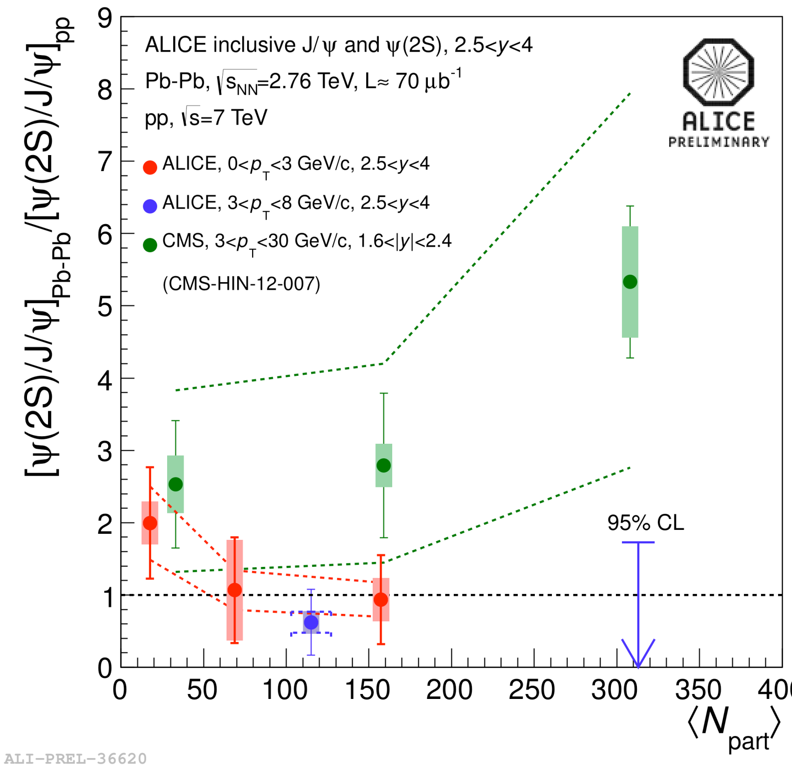
ψ' measurement

- **ψ' over J/ψ double ratio vs N_{part}**

➢ CMS measurement (3 < pt < 30 GeV/c) enhancement of ψ' production with respect to J/ψ in Pb-Pb compared to pp collisions. ALICE data seems to disfavour the enhancement

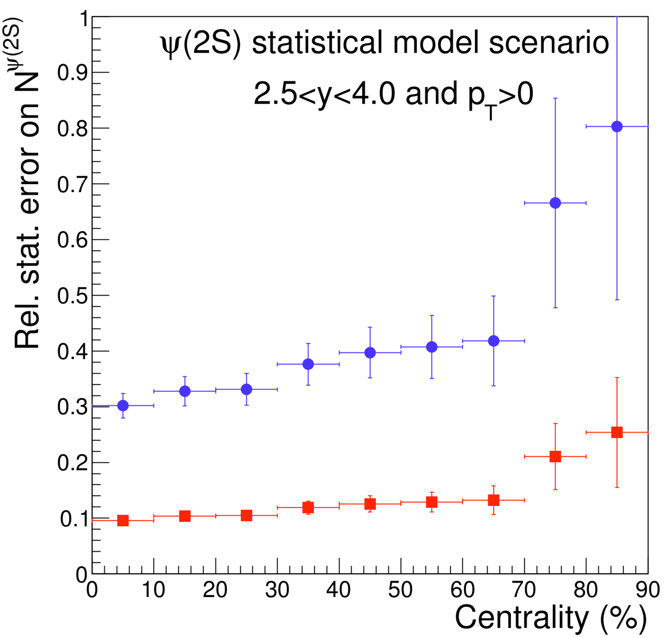
➢ **No firm conclusion on ψ' enhancement or suppression with centrality within current statistical and systematic uncertainties**

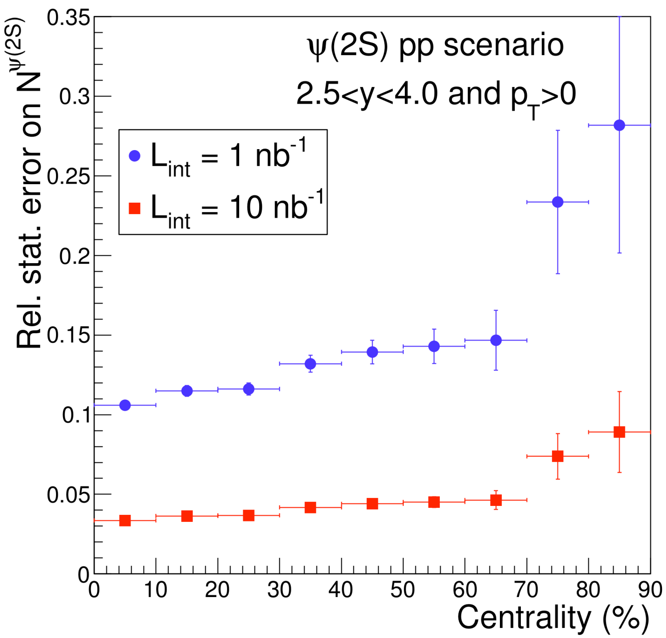
➢ Key measurement which allows to disentangle between statistical hadronization model and transport model



ψ’ measurement

- Challenging measurement due to low cross sections and small branching ratio in dileptons
- 2 scenarios considered for the estimations of the relative statistical error on ψ’ in the muon spectrometer :
  - Production yields given by statistical models
  - Scaling from pp collisions to Pb-Pb with the number of binary collisions



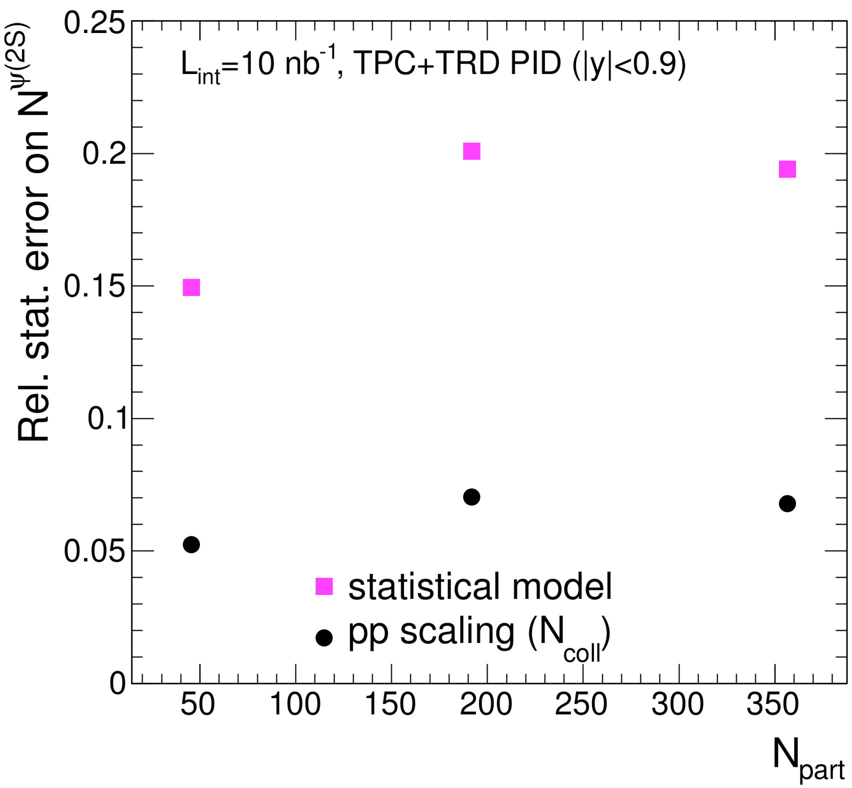


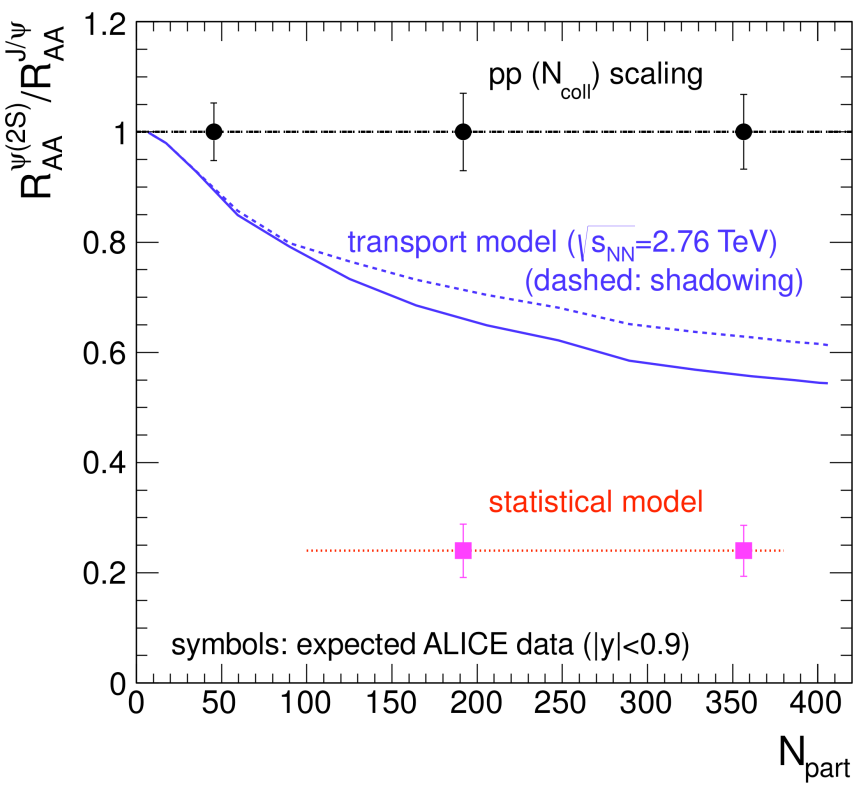
Good precision reached in the upgrade scenario even in the hypothesis of low ψ’ production in thermal model scenario

→Possibility to study ψ’ elliptic flow

ψ’ measurement

- Dielectron channel : measurement even more challenging
- **Good significance only reached with the upgrade at L_{int} = 10nb^{-1}**
- 5% precision can be reached on the number of ψ’ in the pp scaling hypothesis





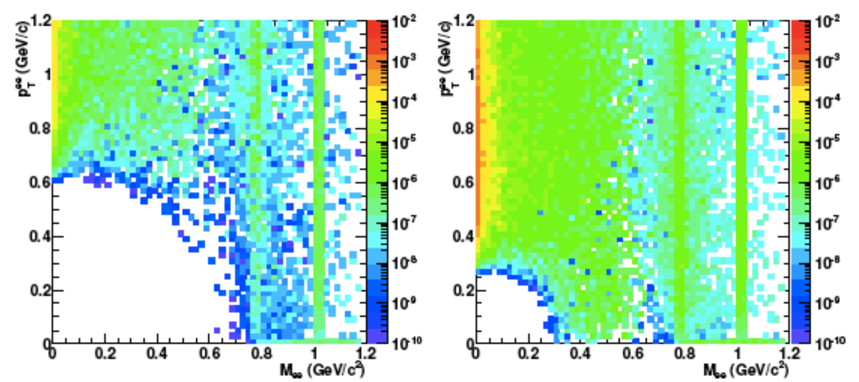
Physics performances: low mass dielectrons

- **One of the most fundamental (and difficult measurement)**, potentially giving access to:
  - Chiral symmetry breaking mechanism by modification of ρ-meson spectral function
  - Direct photon thermal emission extrapolating to zero dilepton mass
  - Partonic equation of state studying space-time evolution with invariant-mass and p_T distributions of dileptons

- Measurements:
  - Subtract all backgrounds with data driven methods
  - Mapping of dilepton yields in invariant mass and p_T
  - Elliptic flow

Requires a run at lower magnetic field (B = 0.2T) to enhance acceptance at low p_T → L_{int} = 3 nb^{-1}

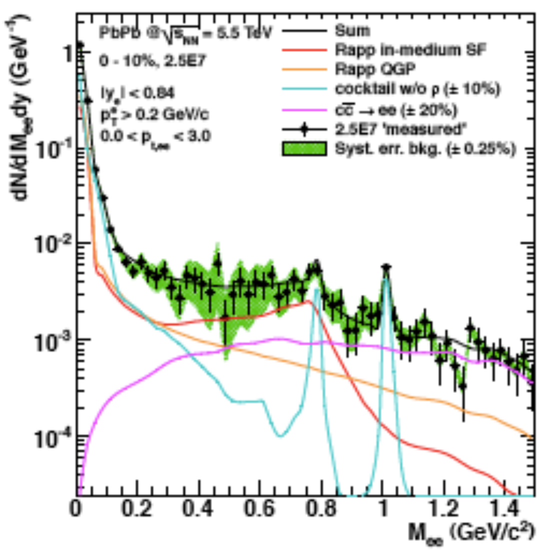
B = 0.5 T **B = 0.2 T**



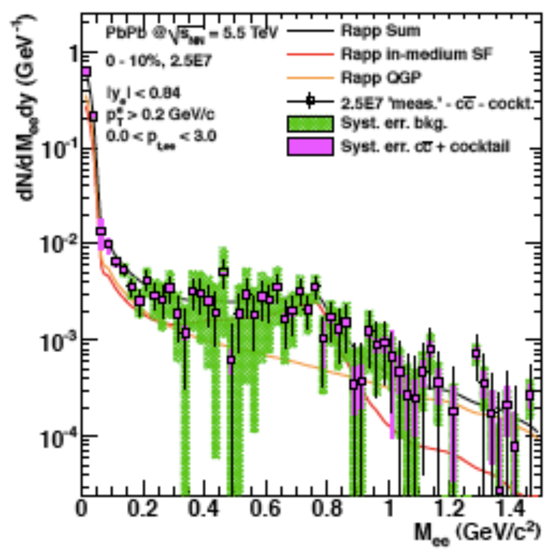
Study low mass dilepton excess

- Expected e^+e^- invariant mass spectra in Pb-Pb collisions at $\sqrt{s_{NN}}$ = 5.5 TeV:
  - Current ITS and TPC
  - B = 0.2 T
  - 2.5 × 10^7 events in centrality 0-10%, 5×10^7 events in centrality 40-60%
  - « Tight » cut on impact parameter

Dilepton inv mass



Excess spectra



Low-mass region M_{ee} < 1 GeV/c^2 dominated by systematic uncertainties from subtraction of combinatorial background. M_{ee} > 1 GeV/c^2 large systematic uncertainty from charm subtraction. Difficult analysis of thermal radiation spectrum

New ITS will help to suppress background by a factor ~ 2

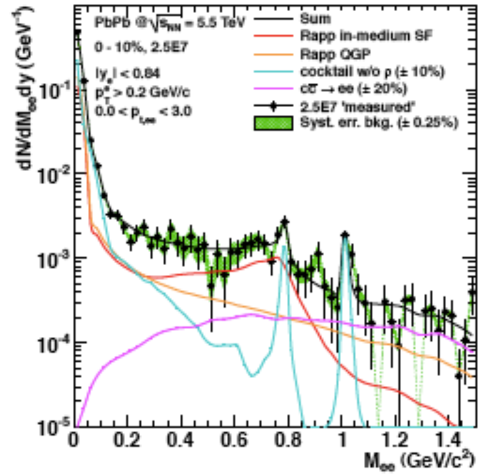
Study low mass dielectron excess

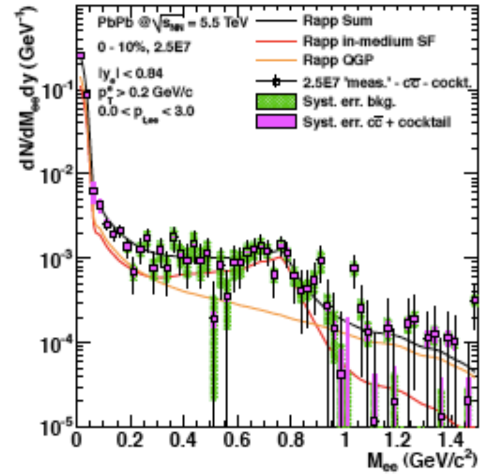
ALICE

Dilepton inv mass

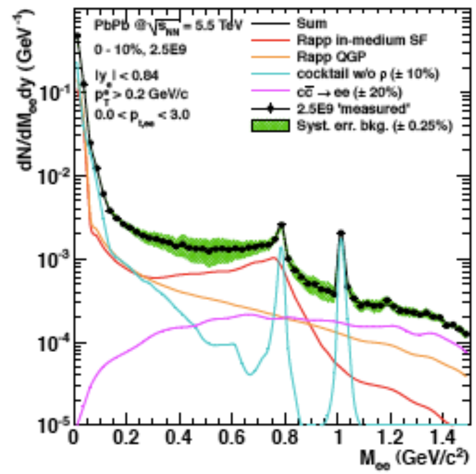
Excess spectra

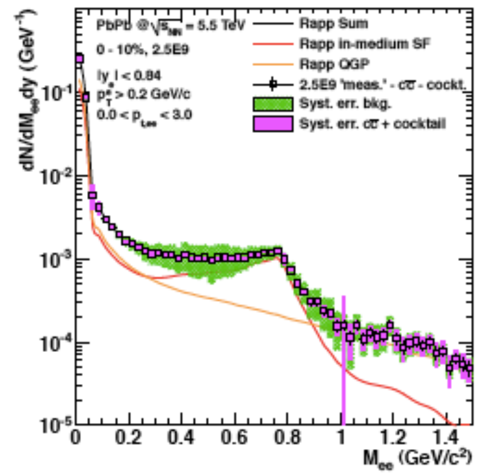
- Expected e⁺e⁻ invariant mass spectra in Pb-Pb collisions at $\sqrt{s_{NN}}$ = 5.5 TeV:
  - **New ITS and current TPC**
  - **Low interaction rate**
  - B = 0.2 T
  - 2.5 × 10^7 events in centrality 0-10%, 5×10^7 events in centrality 40-60%
  - « Tight » cut on impact parameter





- Expected e⁺e⁻ invariant mass spectra in Pb-Pb collisions at $\sqrt{s_{NN}}$ = 5.5 TeV:
  - **New ITS and new TPC**
  - **Low interaction rate**
  - B = 0.2 T
  - 2.5 × 10^9 events in centrality 0-10%, 5×10^9 events in centrality 40-60%
  - « Tight » cut on impact parameter



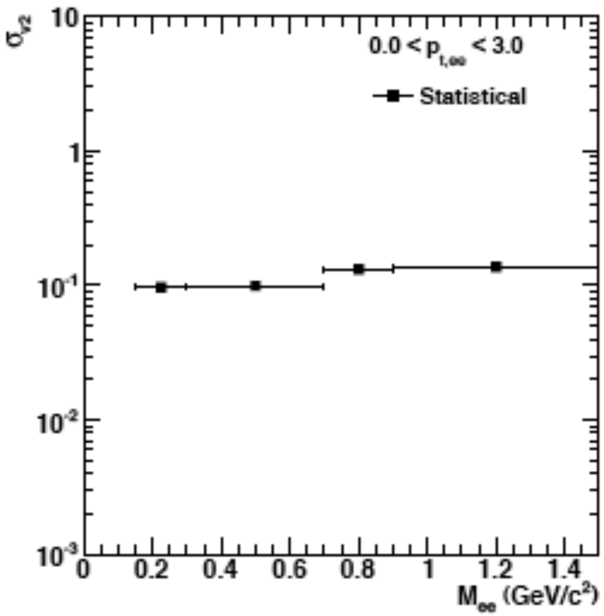


Statistical precision achieved with high-rate upgrade allows for a detailed and differential investigation of dilepton production

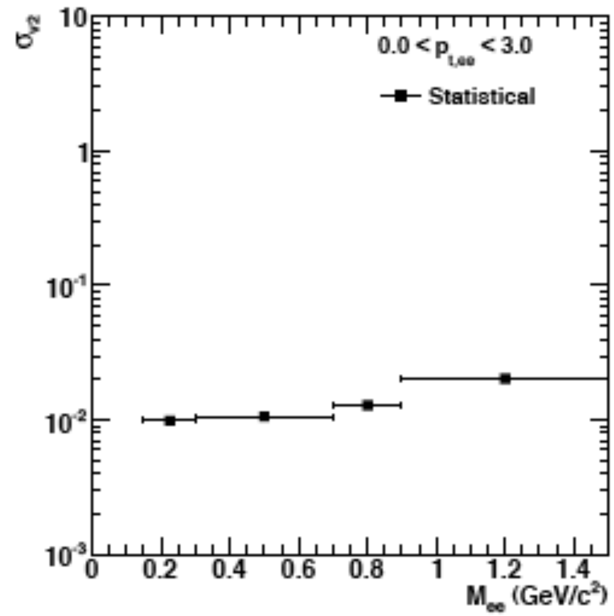
Dielectron v_2

- Investigation of dilepton collectivity
- Pb-Pb collisions, 40-60% centrality range
- Absolute statistical uncertainty of the elliptic flow coefficient v_2 of the e^+e^- excess spectrum as a function of M_{ee}

Current ITS, no high-rate upgrade



New ITS, high-rate upgrade



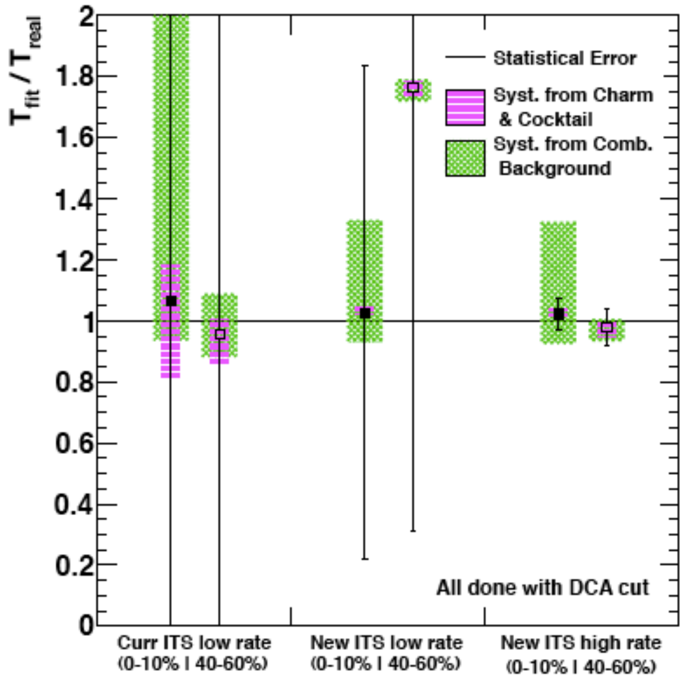
Significant improvement on v_2 measurement precision with new ITS and high-rate upgrade (one order of magnitude)

Temperature from dielectrons

- Information on the early temperature of the system can be derived from the invariant-mass dependence of the dilepton yield at masses $M_{ee} > 1$ GeV/c^2
- Exponential fit to the simulated spectra in $1 < M_{ee} < 1.5$ GeV/c^2 (T_{fit})

$$\frac{dN_{ee}}{dM_{ee}} \; \alpha \; e^{\left(-M_{ee}/T_{fit}\right)}$$

compared to a similar fit to thermal input spectrum (T_{real})



New ITS, high rate: Significant improvement in precision

Conclusions

- ALICE upgrade program approved by LHCC and ALICE upgrade Letter Of Intent available at https://cdsweb.cern.ch/record/1475243/files/LHCC-I-022.pdf

- **Ambitious Detector upgrade will take place during LS2**
  - New ITS
  - TPC chambers and R/O
  - Smaller beam pipe
  - HLT/DAQ/Offline
  - Upgrade of the readout of all the detectors to run at 50kHz interaction rate in Pb-Pb
  - MFT, Focal, VHMPID, Trigger detectors (T0 VZERO/ZDC) project under discussion. ALICE decision expected in march 2013

Summary of the physics reach with the upgrade for observables of interest →

Observable	Approved p_T^{Amin} (GeV/c)	Approved statistical uncertainty	Upgrade p_T^{Umin} (GeV/c)	Upgrade statistical uncertainty
Heavy Flavour				
D meson R_{AA}	1	10 % at p_T^{Amin}	0	0.3 % at p_T^{Amin}
D meson from B decays R_{AA}	3	30 % at p_T^{Amin}	2	1 % at p_T^{Amin}
D meson elliptic flow ($v_2 = 0.2$)	1	50 % at p_T^{Amin}	0	2.5 % at p_T^{Amin}
D from B elliptic flow ($v_2 = 0.1$)	not accessible		2	20 % at p_T^{Umin}
Charm baryon-to-meson ratio	not accessible		2	15 % at p_T^{Umin}
D_s meson R_{AA}	4	15 % at p_T^{Amin}	1	1 % at p_T^{Amin}
Charmonia				
J/ψ R_{AA} (forward rapidity)	0	1 % at 1 GeV/c	0	0.3 % at 1 GeV/c
J/ψ R_{AA} (mid-rapidity)	0	5 % at 1 GeV/c	0	0.5 % at 1 GeV/c
J/ψ elliptic flow ($v_2 = 0.1$)	0	15 % at 2 GeV/c	0	5 % at 2 GeV/c
ψ(2S) yield	0	30 %	0	10 %
Dielectrons				
Temperature (intermediate mass)	not accessible			10 %
Elliptic flow ($v_2 = 0.1$)	not accessible			10 %
Low-mass spectral function	not accessible		0.3	20 %
Heavy Nuclear States				
Hyper(anti)nuclei ${}^4_\Lambda$H yield		35 %		3.5 %
Hyper(anti)nuclei ${}^4_{\Lambda\Lambda}$H yield	not accessible			20 %