Recent ALICE results on hard probes and future plans for ALICE

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LISHEP conference

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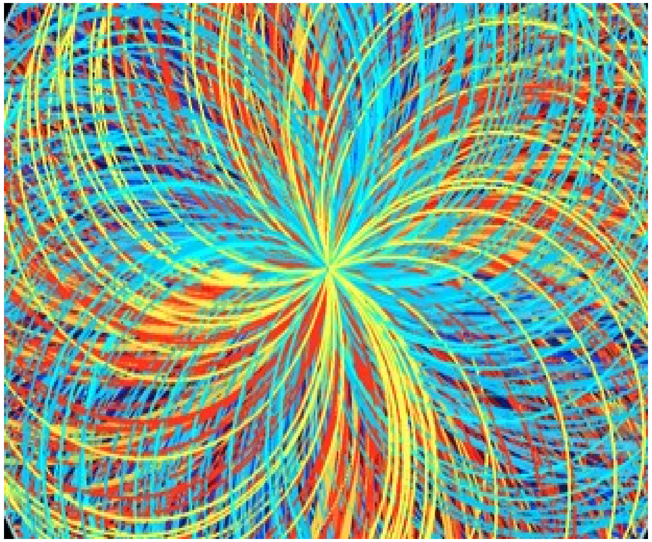
Plan of this talk

- **A Large Ion Collider Experiment**
  - The Collaboration
  - Detector
  - Data collected



Recent ALICE results on hard probes

Quarkonia
Open heavy-flavours
Ultra-peripheral collisions
Jets and photons → See talk by Yiota Foka

The future of ALICE

ALICE talks at LISHEP

Recent ALICE results on soft-physics

→ Yiota Foka → Thu

ALICE Diffraction Studies, Status and Plans

→ Gerardo Herrera → Mon

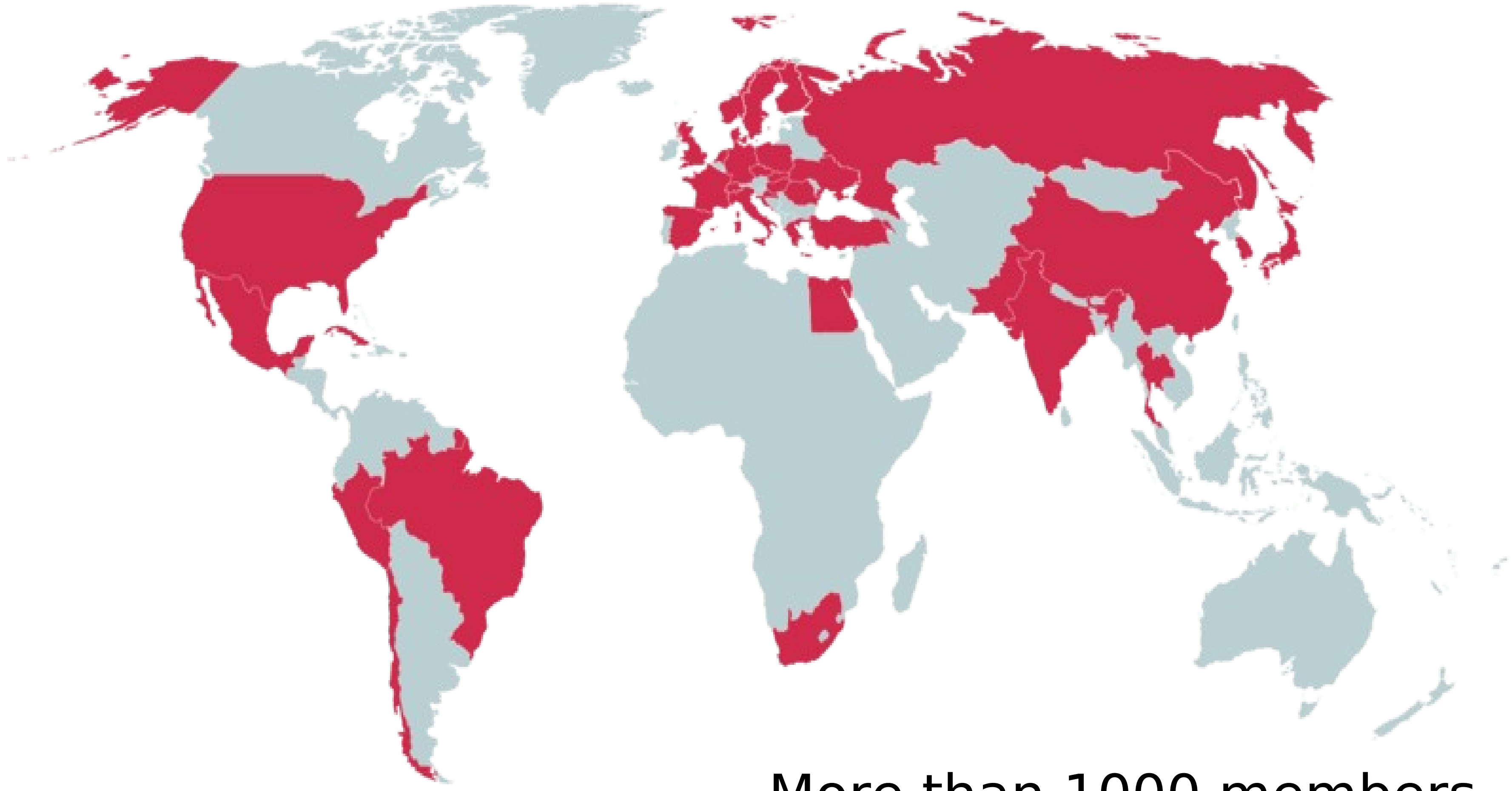
D meson production with ALICE

→ Ricardo Russo → Thu

Flow of phi-meson in Pb+Pb collisions at 2.76 TeV with the ALICE

→ Ajay Kumar DASH → Thu

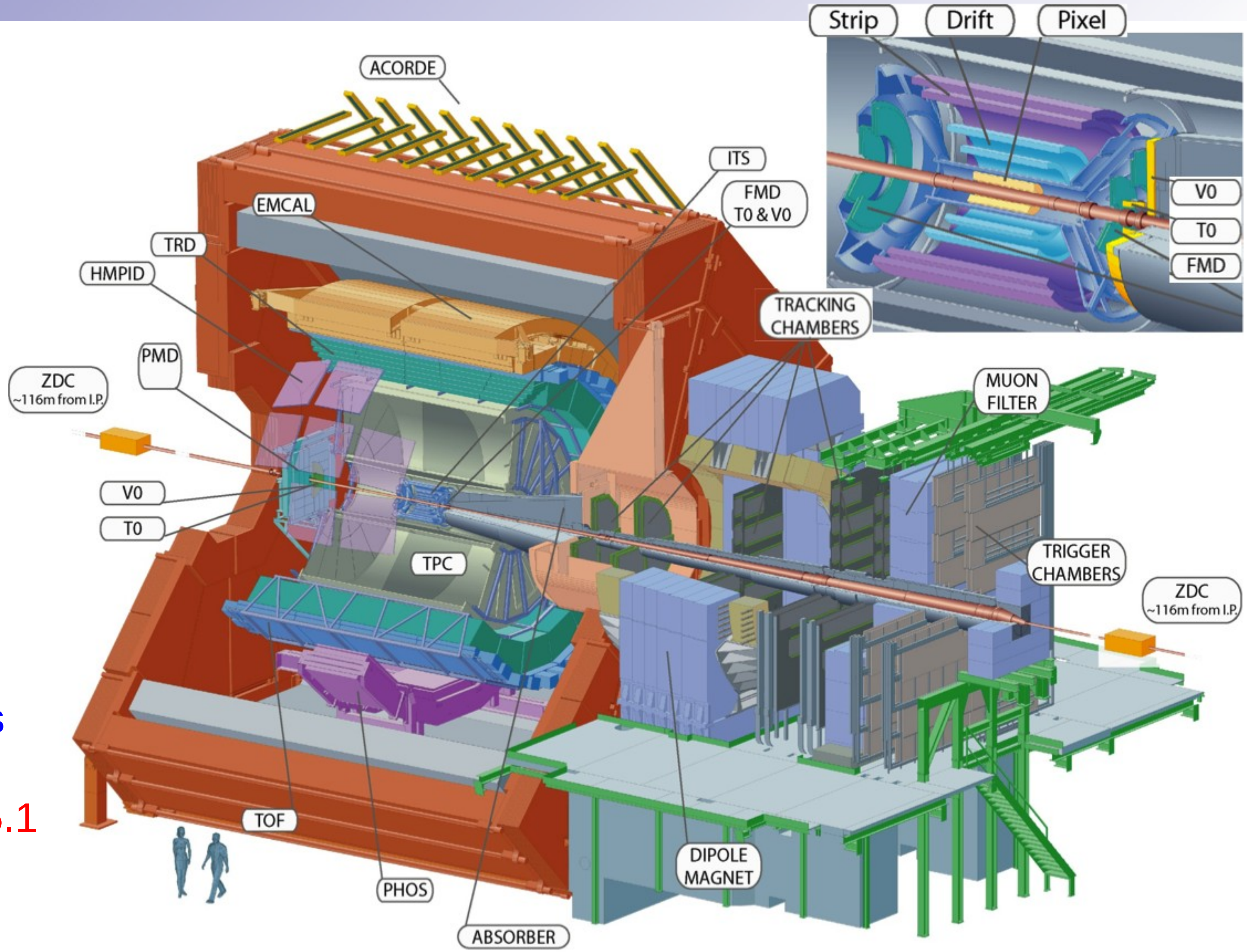
The ALICE Collaboration



More than 1000 members
More than 100 institutions
More than 30 countries

ALICE detector

Central Barrel
2 π tracking & PID
$|\eta| < 1$



ACORDE: cosmics
VZERO: centrality
η: -1.7– -3.7, 2.8–5.1
T0: timing
ZDC: centrality
FMD: N_{ch} $-3.4<\eta<5$
PMD: $N\gamma$, N_{ch}

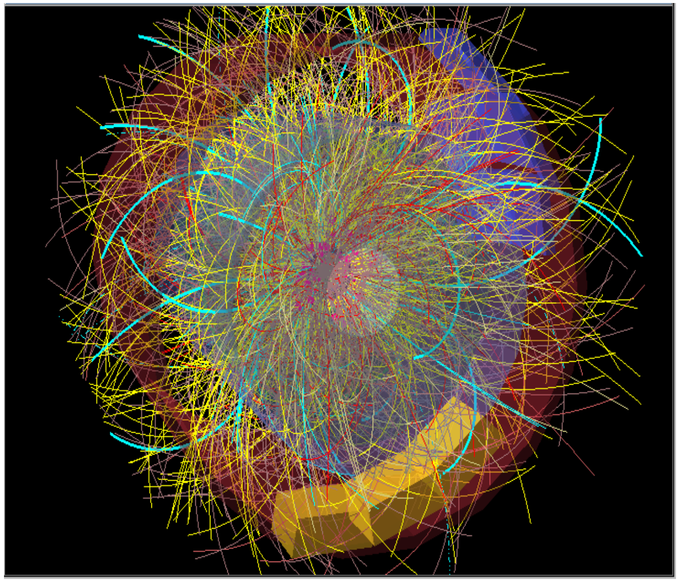
Muon Spectrometer
$-4.0 < \eta < -2.5$

Collected data

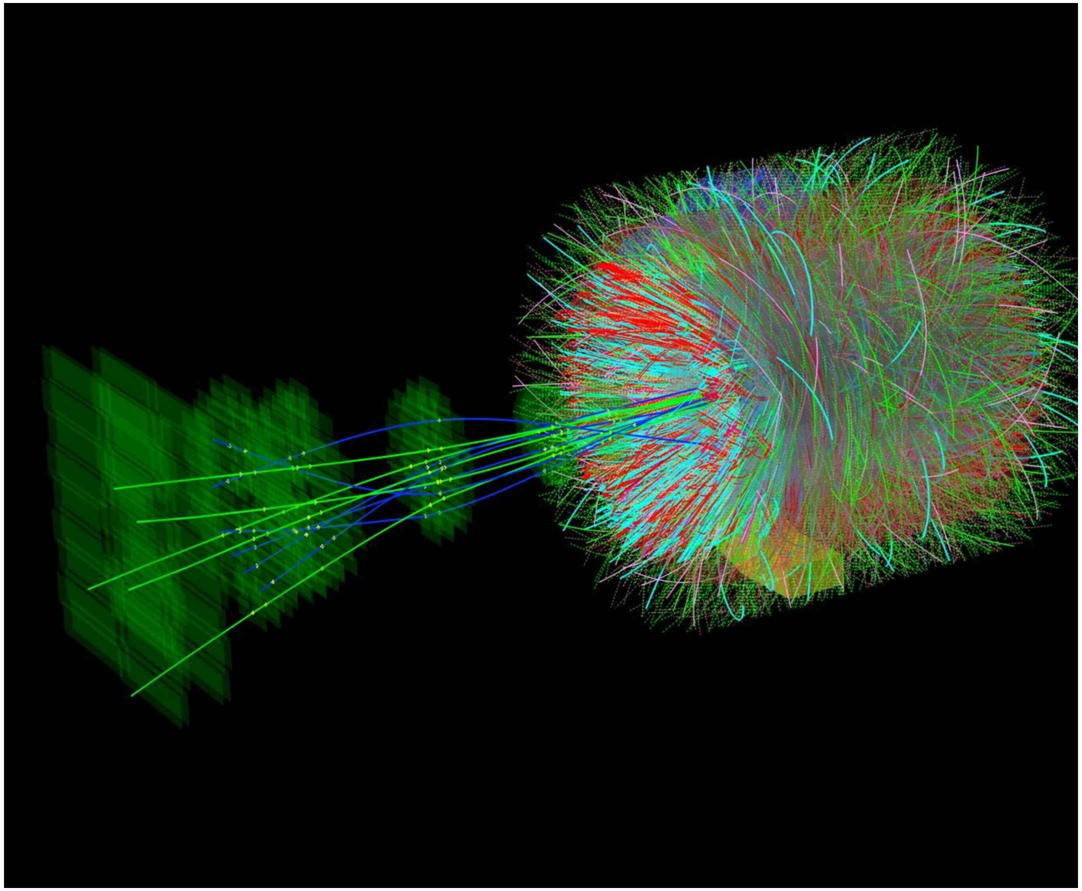
pp runs at 0.9, 2.36, 2.76, 7 and 8 TeV

Two PbPb runs at 2.76 TeV

pPb run at 5.02 TeV

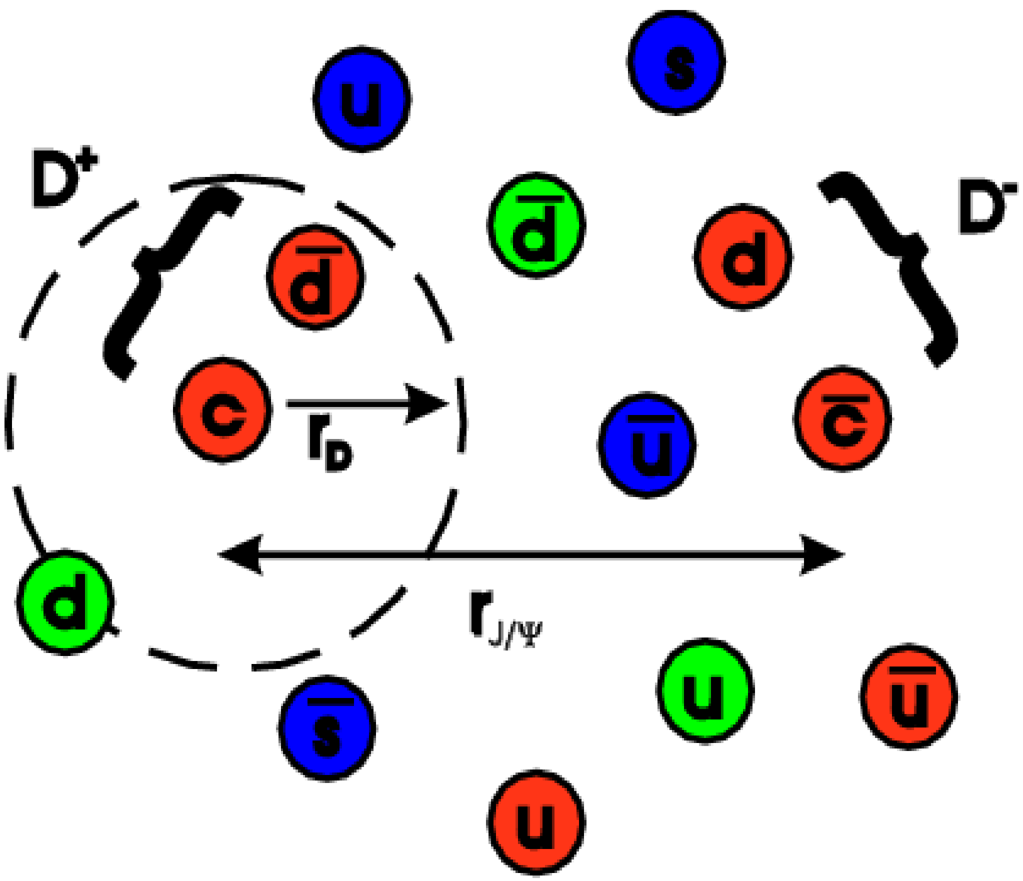


Quarkonia production



Why quarkonia in heavy-ion collisions

Signature for deconfined hadronic matter?



Colour screening in QGP:
Screening radius < size of J/ψ (~0.5 fm)

So cc bound state cannot survive in QGP. Seen at SPS energies. Measured also at RHIC.

At LHC energies, several mechanism processes take place

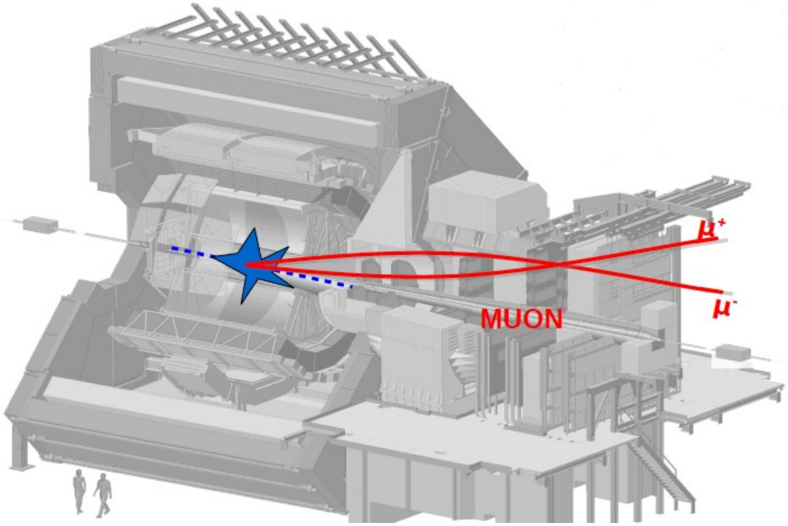
Nuclear modification factor:

$$R_{AA} = \frac{d^2 N^{AA} / dp_T d\eta}{\langle N_{coll} \rangle d^2 N^{pp} / dp_T d\eta}$$

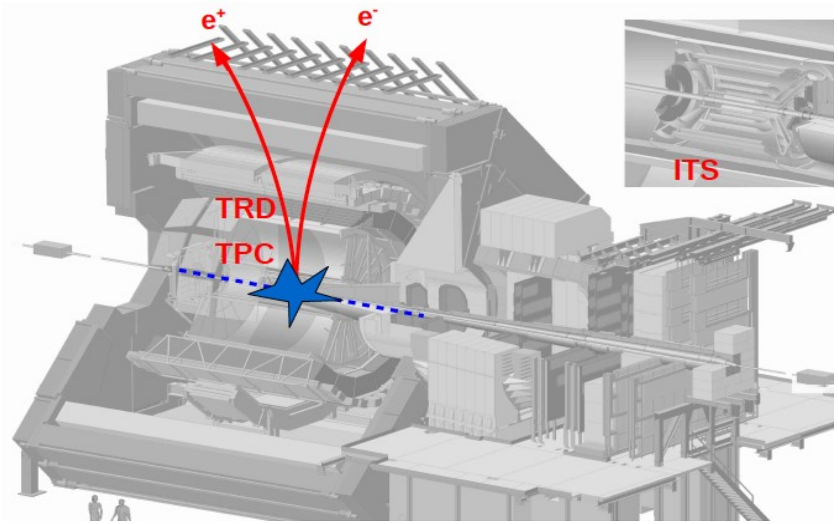
$$\langle N_{coll} \rangle = \langle T_{AA} \rangle \cdot \sigma_{pp}^{INEL}$$

Nuclear overlap function <T_{AA}> from Glauber related to the number of binary collisions Ncoll

Quarkonia production at ALICE



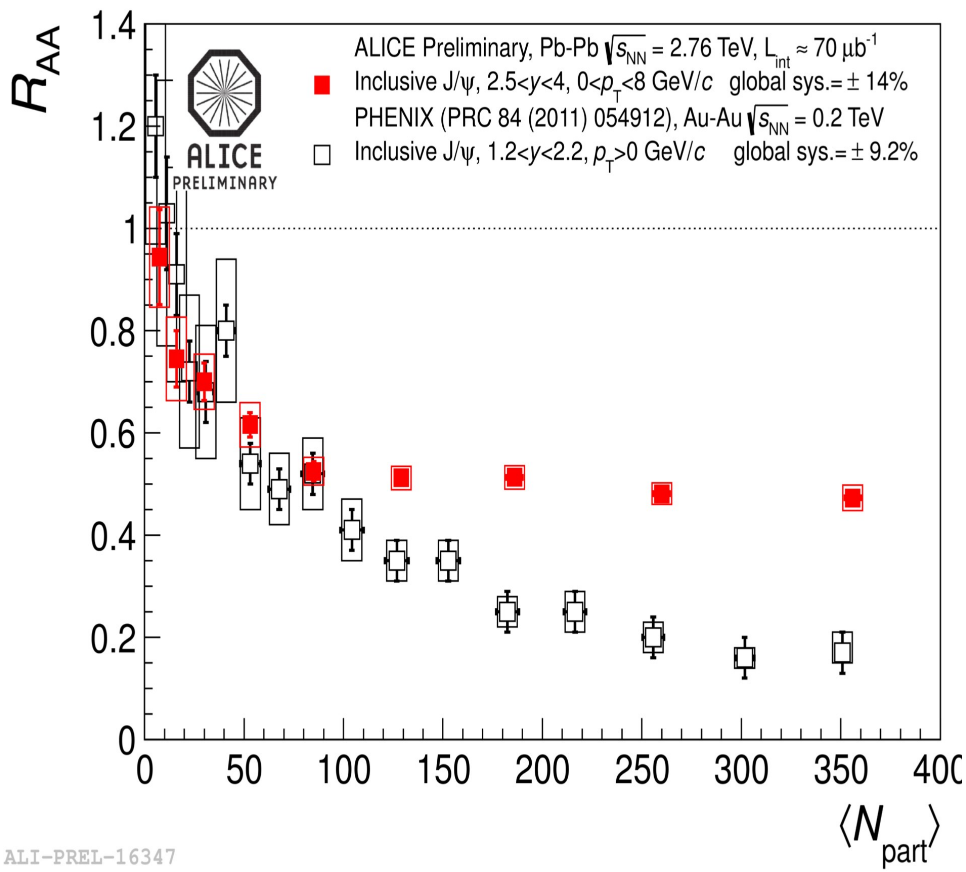
Forward dimuons

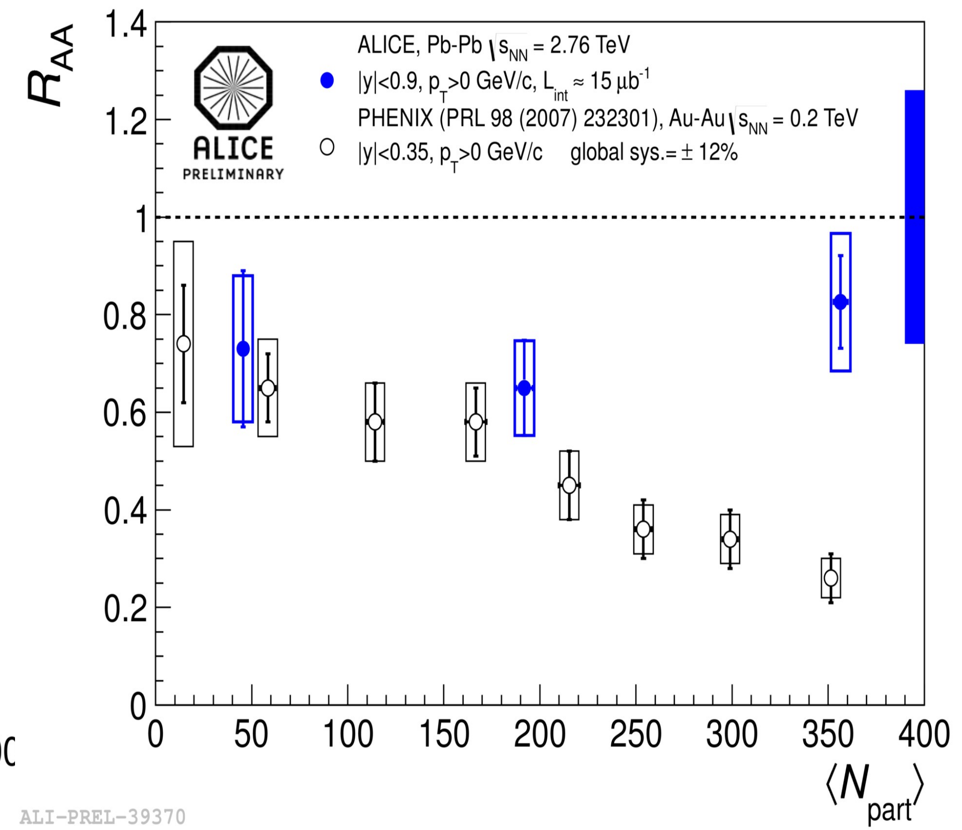


Mid-rapidity dielectrons

Measurements down to zero p_T

J/ψ nuclear modification factor



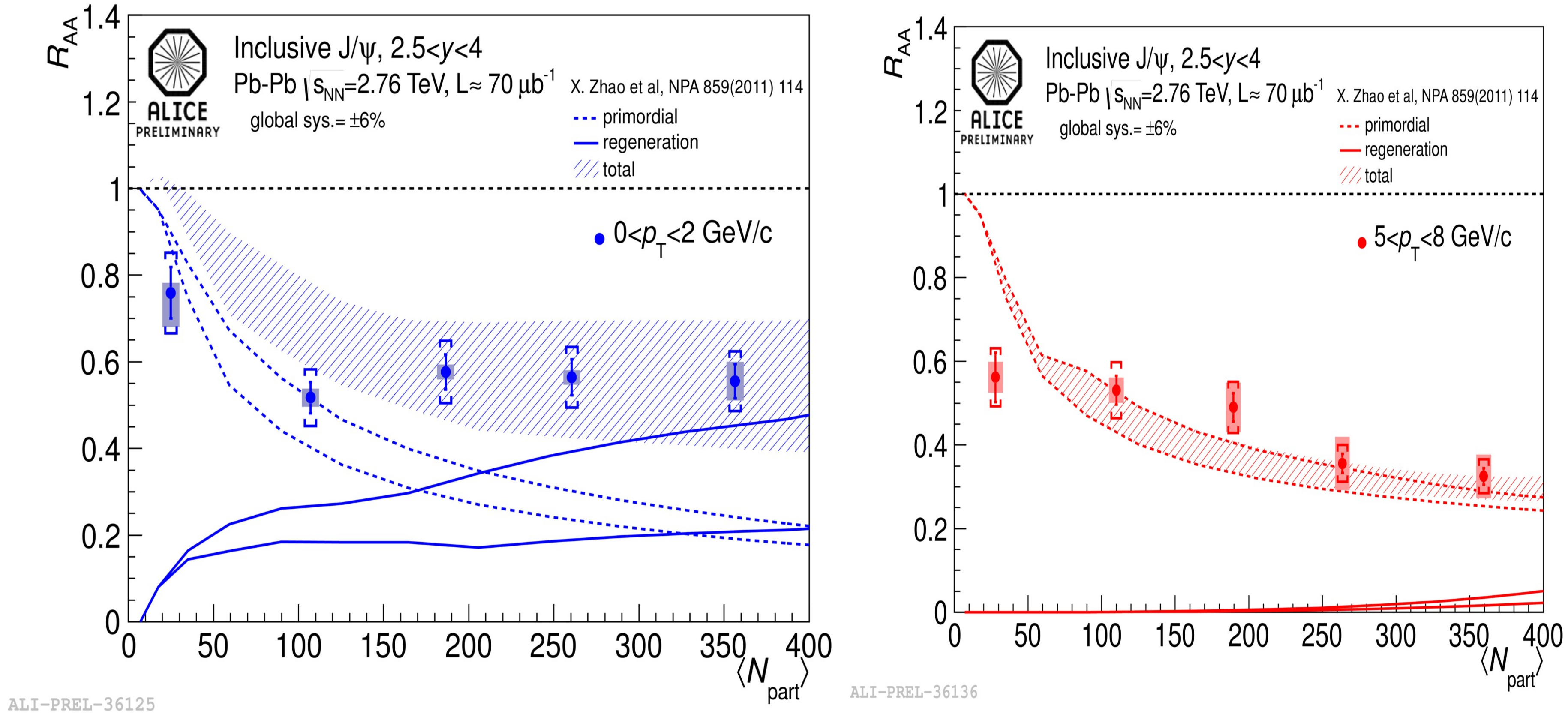


Centrality dependence for J/ψ R_{AA} at forward and central rapidities

Weak centrality dependence compared to lower energies

J/ψ R_{AA} suppresion pattern expected from regeneration, in qualitative terms

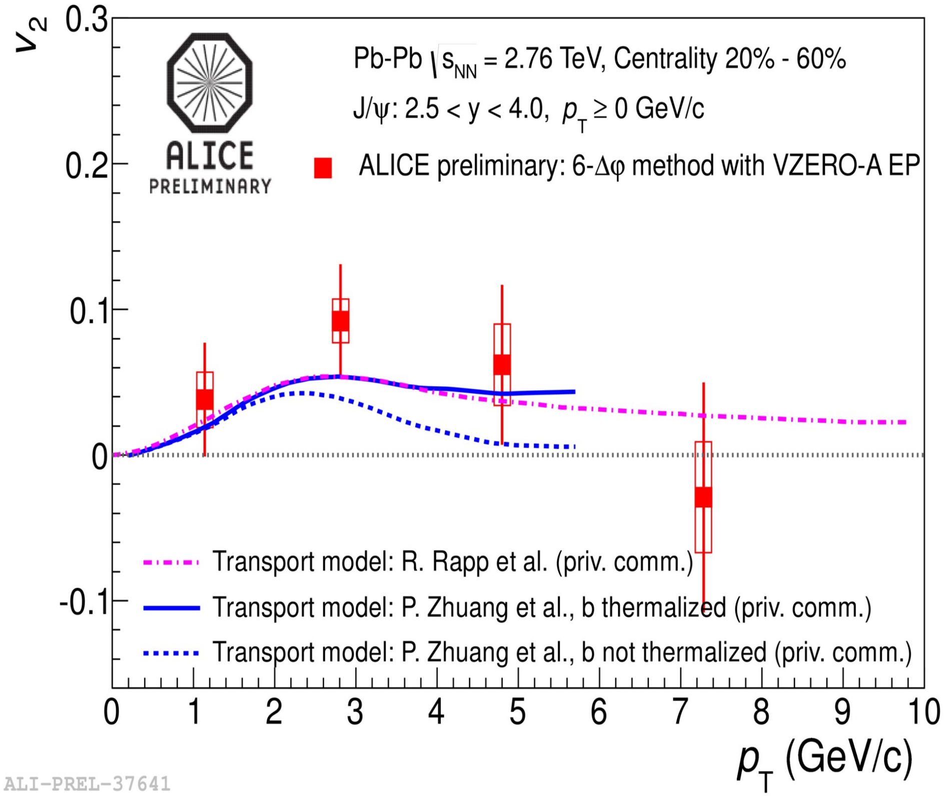
J/ψ R_{AA}: Data and models

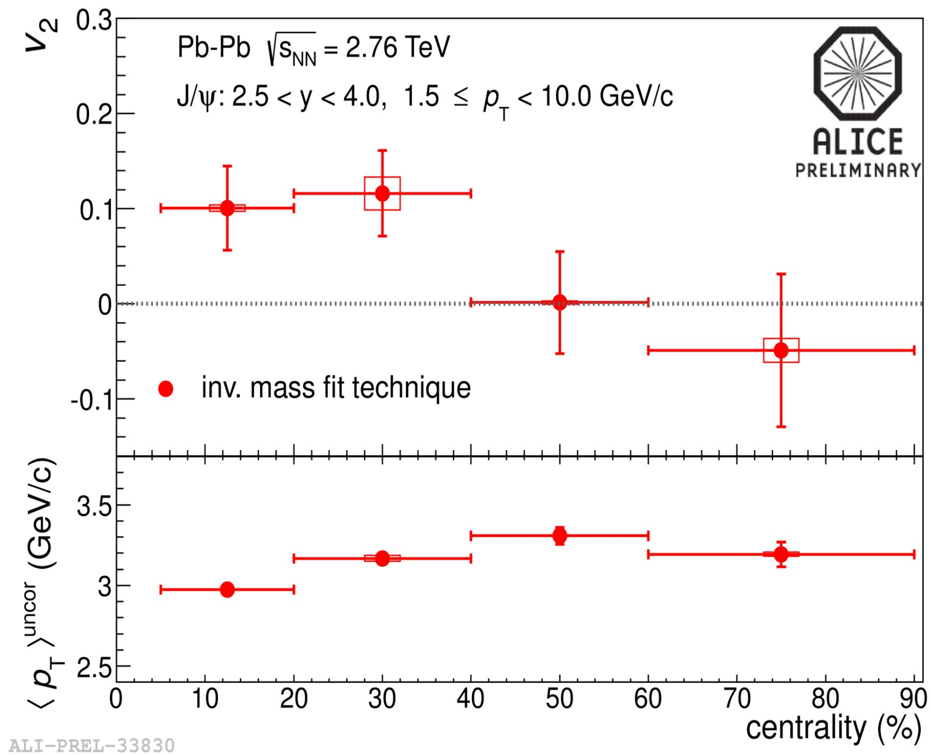


Suppression pattern is very sensitive to p_T

Recombination for high p_T J/ψ is negligible

J/ψ elliptic flow



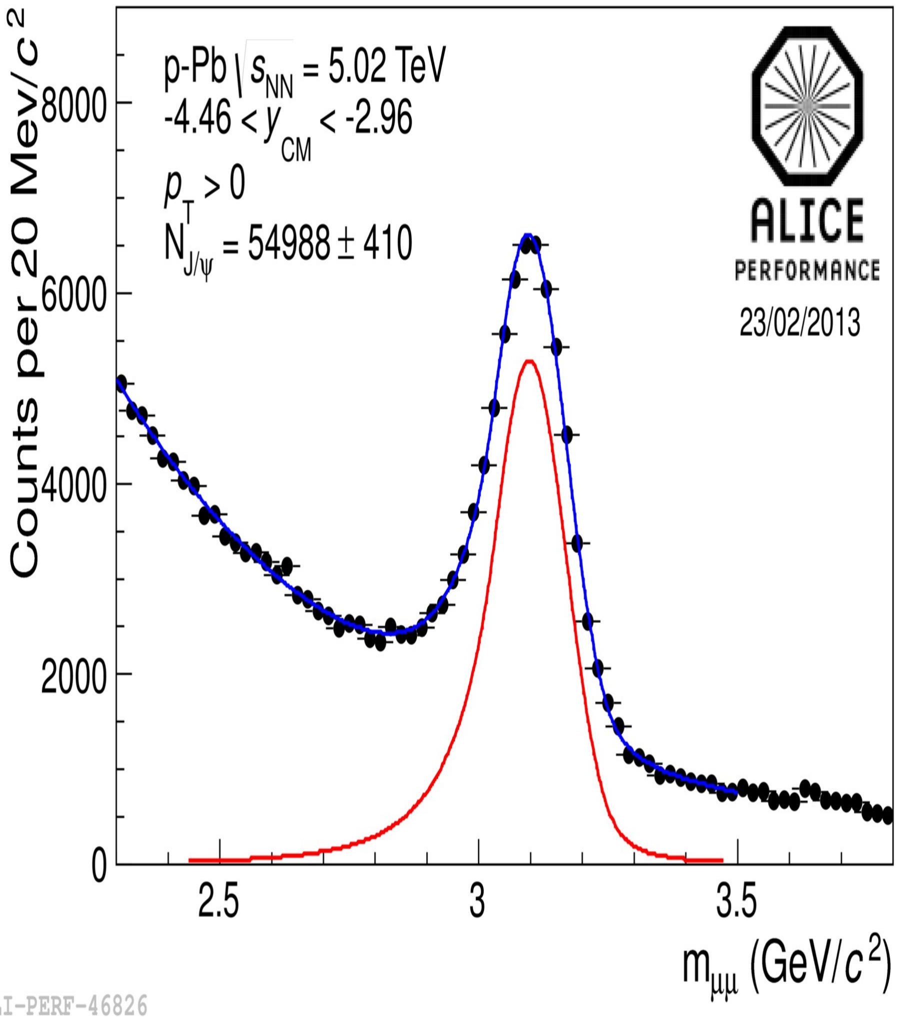


Hints for non-zero elliptic flow

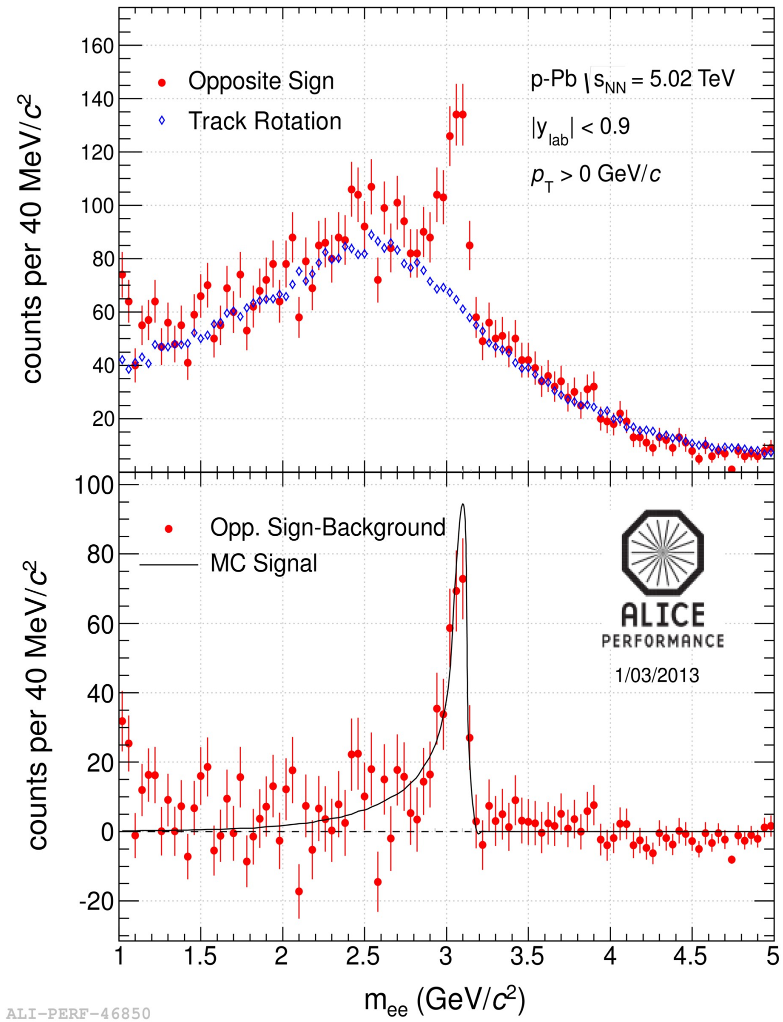
Taken together with J/ψ R_{AA} measurements, provide useful insights of production mechanisms

J/ψ in p+Pb collisions

Forward rapidity

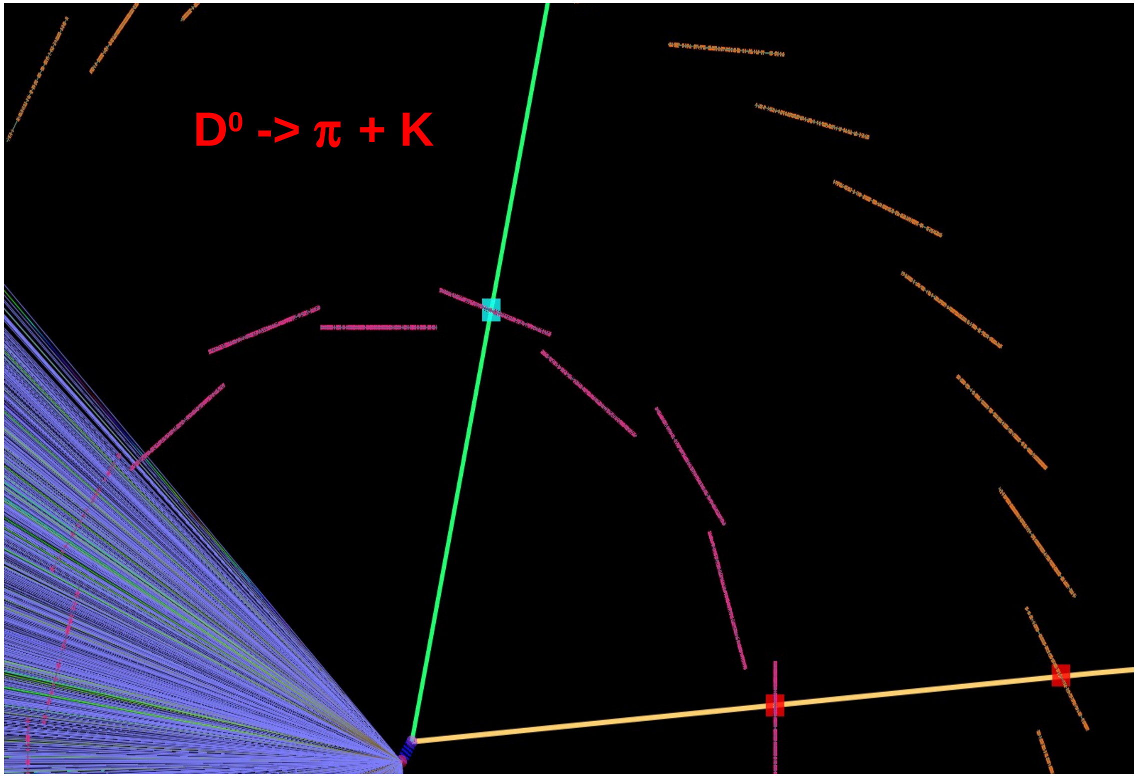


Mid-rapidity



J/ψ in p+A – important to address nuclear initial state effects

Heavy-flavour production



Open heavy-flavour at ALICE

Charmed mesons to hadronic decays

Mid-rapidity

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

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

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

$D^{*+} \rightarrow D^0\pi^+$

Heavy flavour decays

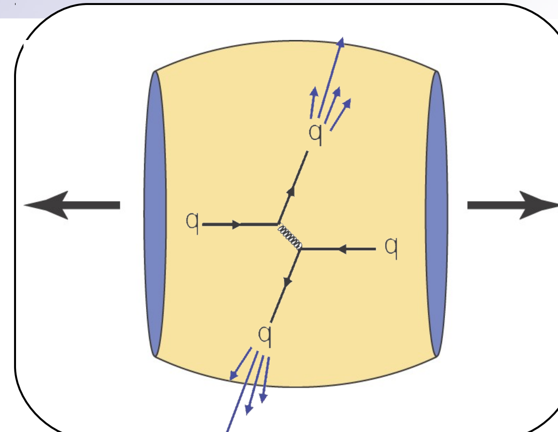
Mid-rapidity

$c, b \rightarrow e+X$

$c, b \rightarrow \mu+X$

Forward rapidity

Why to study heavy-flavour



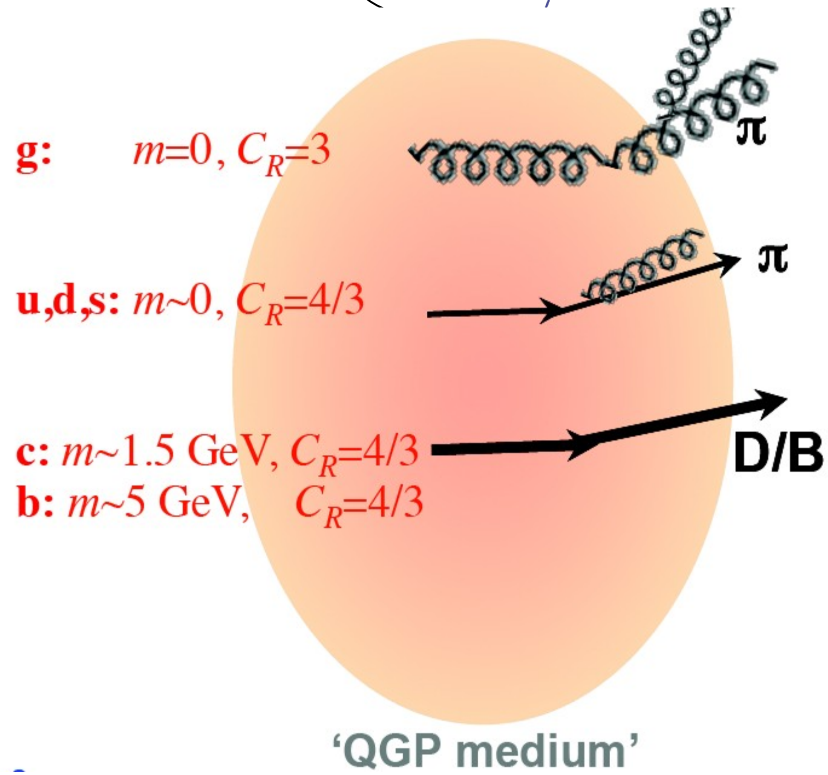
Parton Energy Loss

- Color charge C_R (larger for gluons)
- Mass m (larger for heavy quarks)

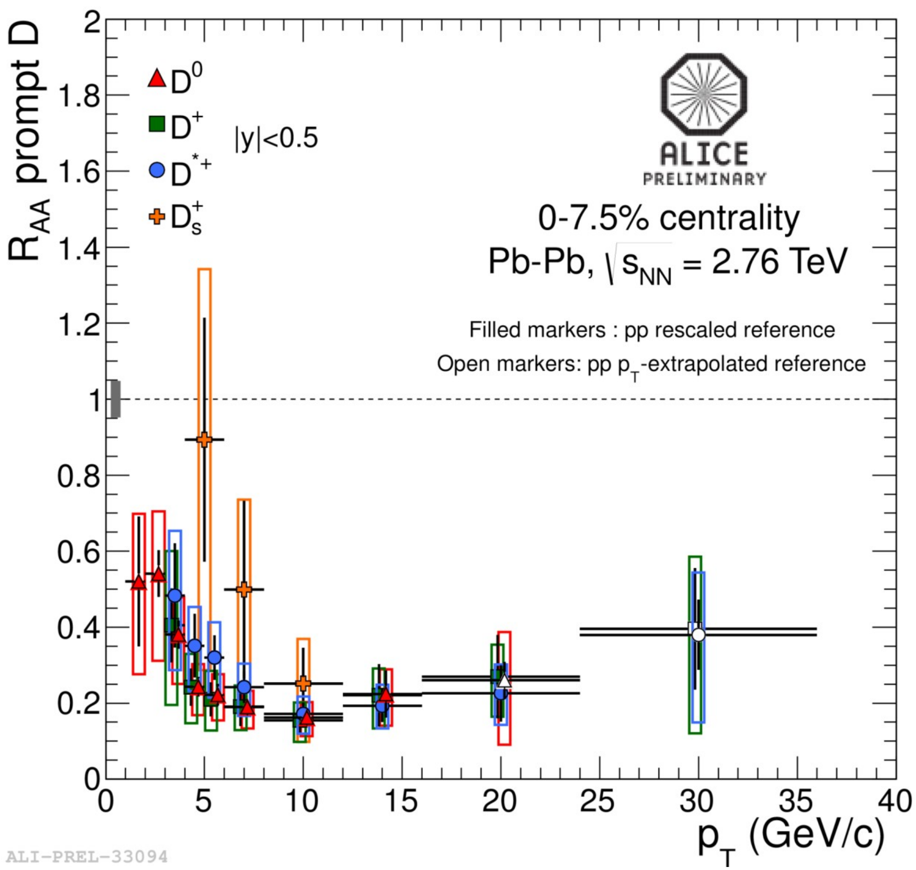
$$\Delta E(\varepsilon_{medium}; C_R, m, L)$$

$$\Delta E_g > \Delta E_{c \approx q} > \Delta E_b$$

$$\rightarrow \quad R^{\pi}_{AA} < R^{D}_{AA} < R^{B}_{AA}$$



Nuclear modification factor – **D mesons**



Strong suppression of prompt D mesons at mid-rapidity

R_{AA} results consistent within uncertainties

First heavy-ion results on D_s+

No conclusions yet on Ds enhancement at low – p_T

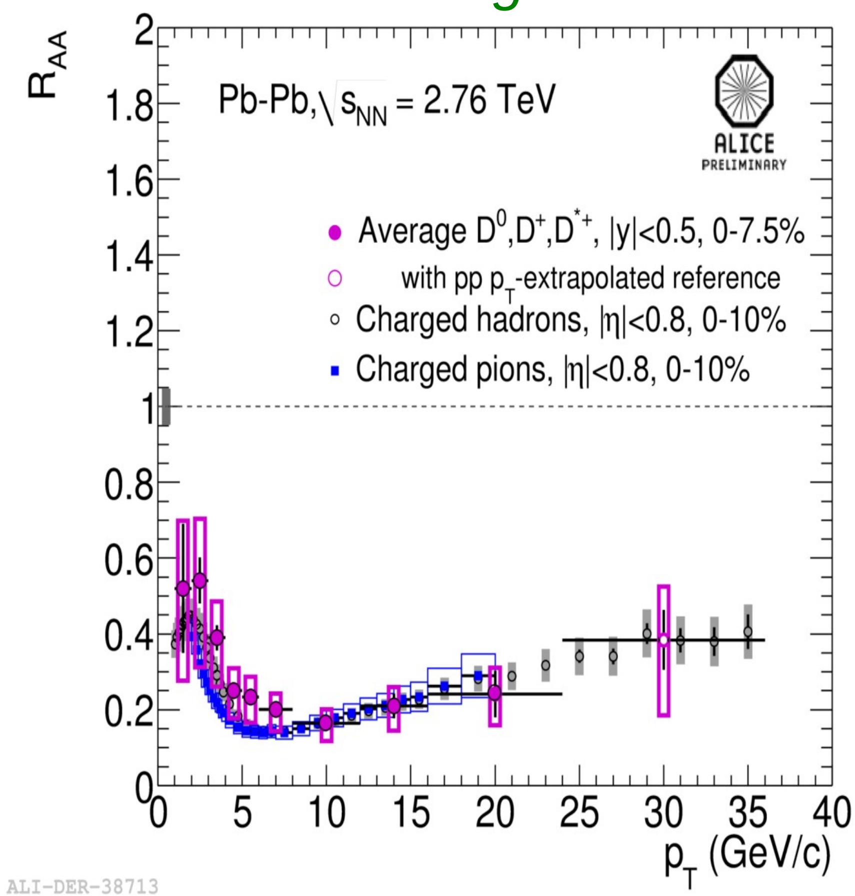
Current statistical and systematic uncertainties does not allow to distinguish it from c-quark coalescence with s-quarks

If charm quarks hadronise via recombination in the medium [1] the relative yield of D^+_s with respect to non-strange D meson expected to be enhanced in PbPb in the intermediate p_T range

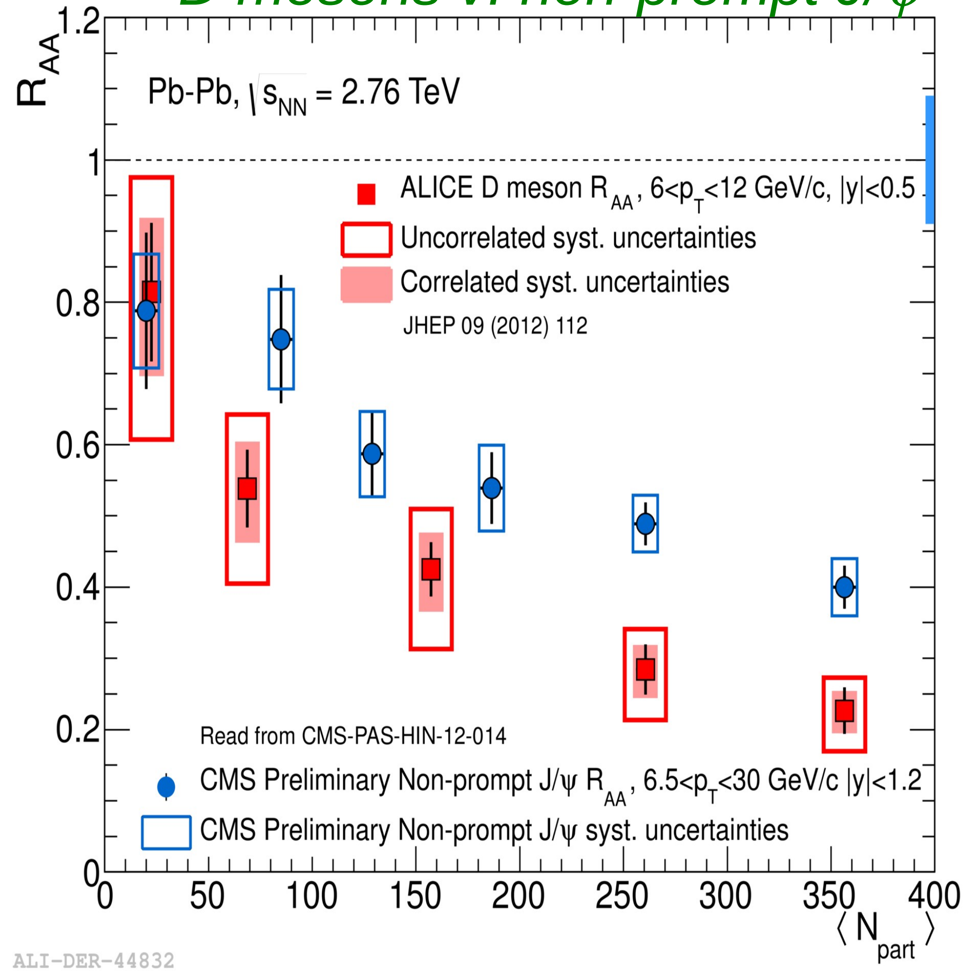
[1] I. Kuznetsova, J. Rafelski, Eur.Phys.J.C51:113-133,2007;
M. He, R. J. Fries and R. Rapp, arXiv:1204.4442 [nucl-th].

Nuclear modification factor – **D mesons**

D mesons v. charged hadrons



D mesons v. non-prompt J/ψ

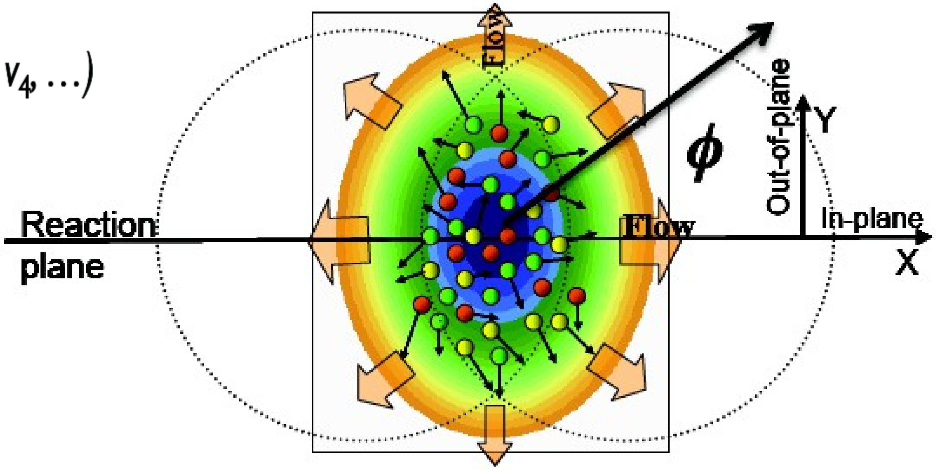


Interesting suppression patterns, but still too early to make any conclusions

Azimuthal anisotropy – D mesons

Does heavy flavour "flow" with medium?

$$\frac{dN}{Nd\phi} \Rightarrow 1 + 2v_2\cos\left(2(\phi - \Psi_{RP})\right) + \textit{higher harmonics } (v_3, v_4, \ldots)$$

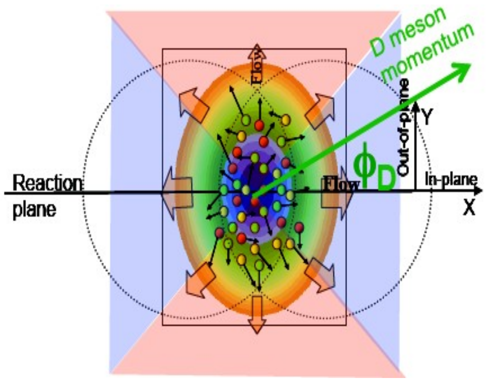


If heavy-quarks interact with the medium, heavy-flavoured hadrons should inherit the medium azimuthal anisotropies:

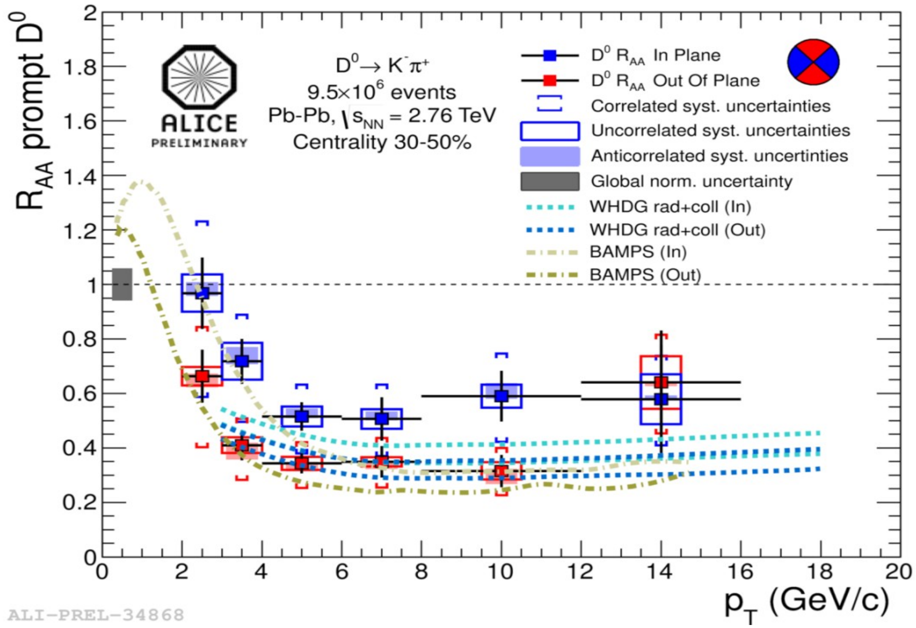
***v_2* at low- *p_T* :** degree of thermalisation

•***v_2* at high *p_T* :** path - length dependence of energy loss

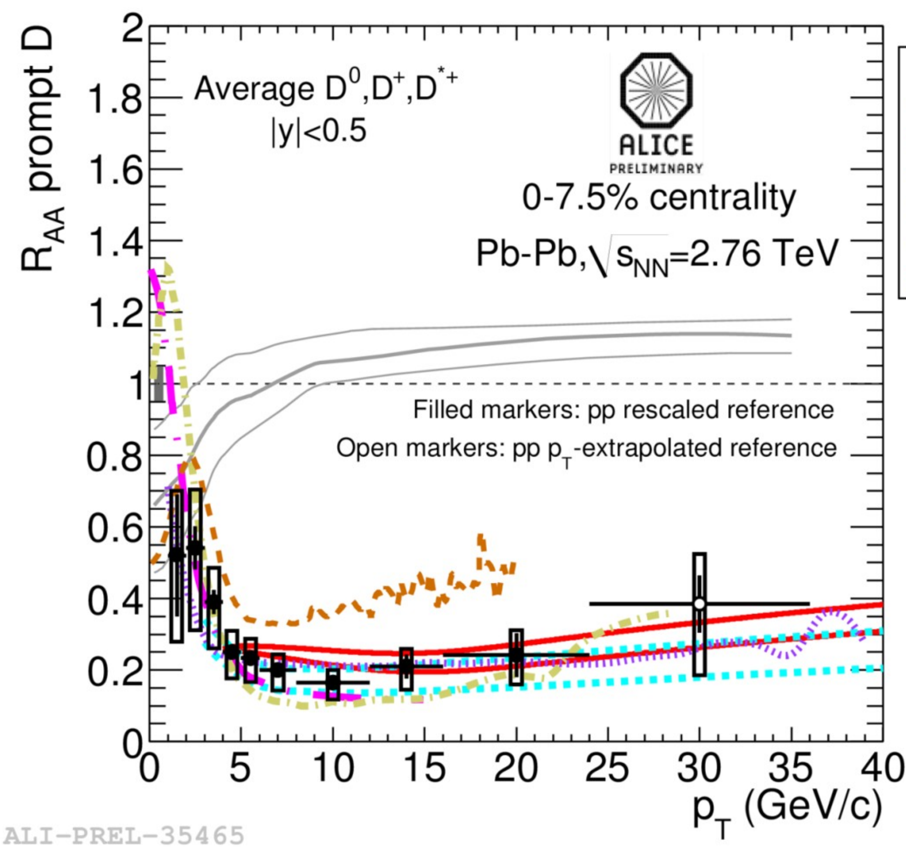
Suppression patterns in different azimuthal directions

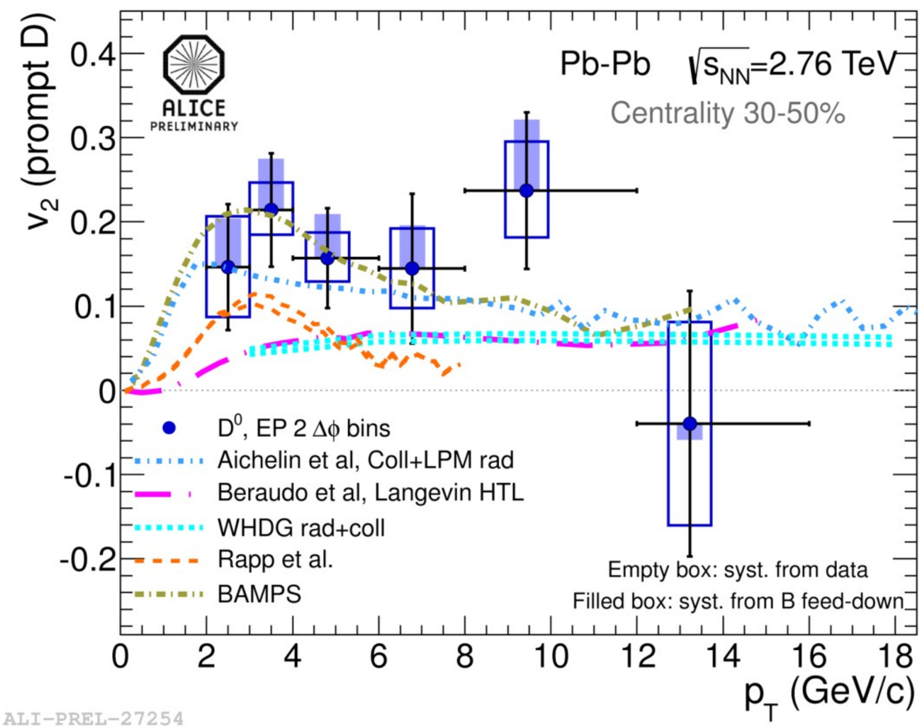


***R_{AA}* in- and out-of-plane:**
larger suppression out-of-plane (longer path length)



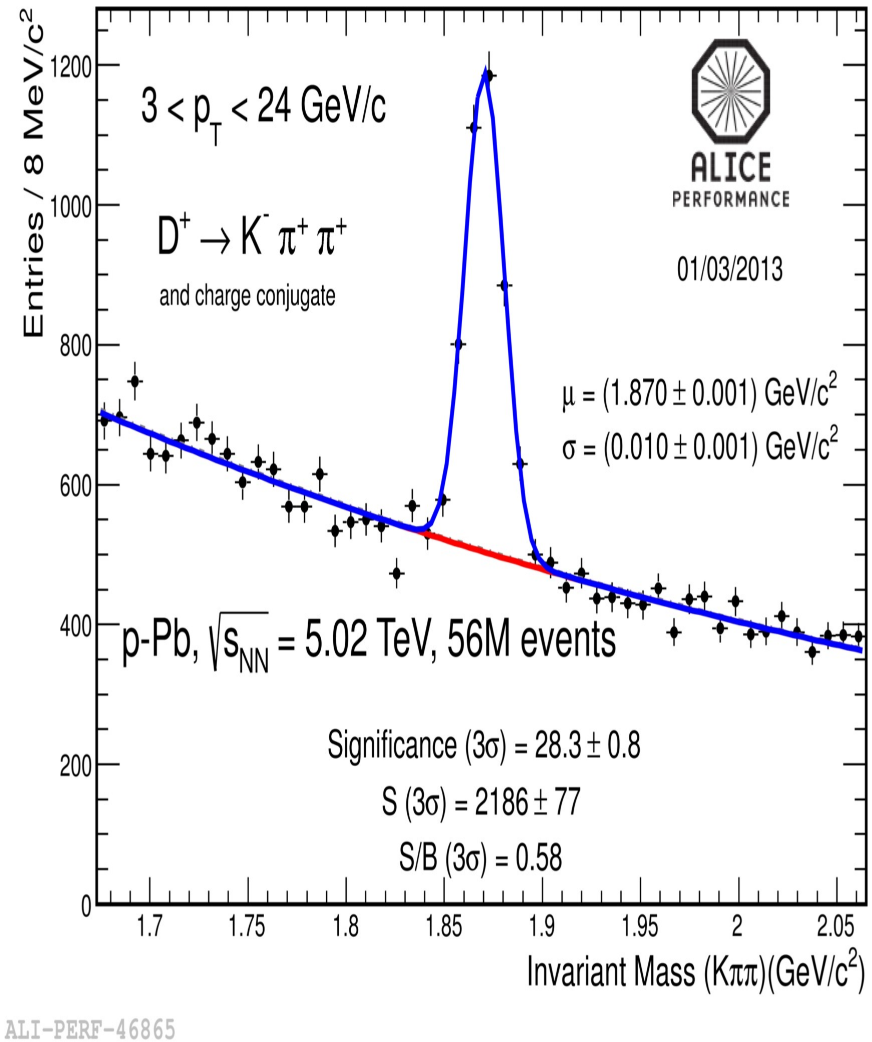
D meson R_{AA} and v_2

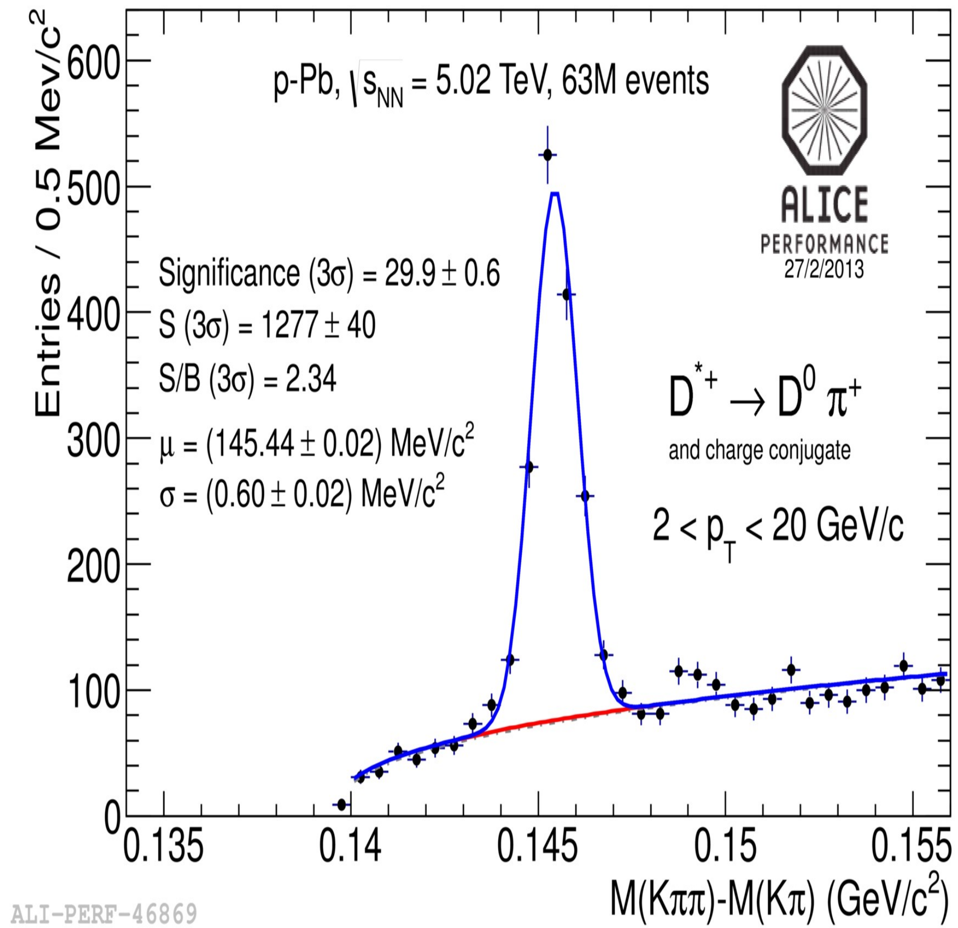




The challenge for models is to reproduce both the R_{AA} and the v_2 at the same time

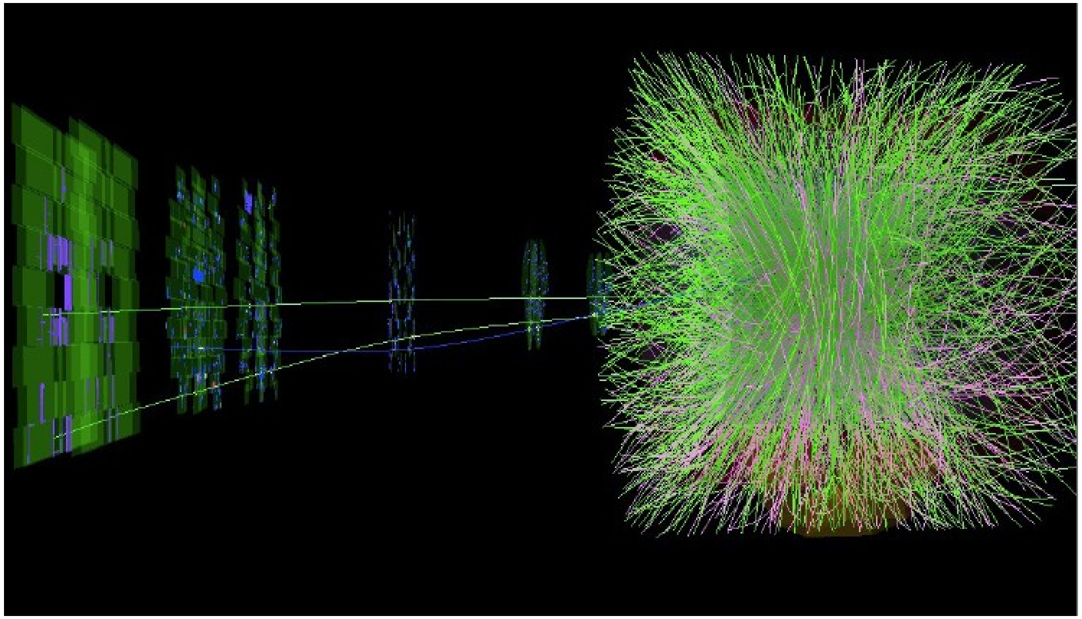
D mesons in p+Pb collisions

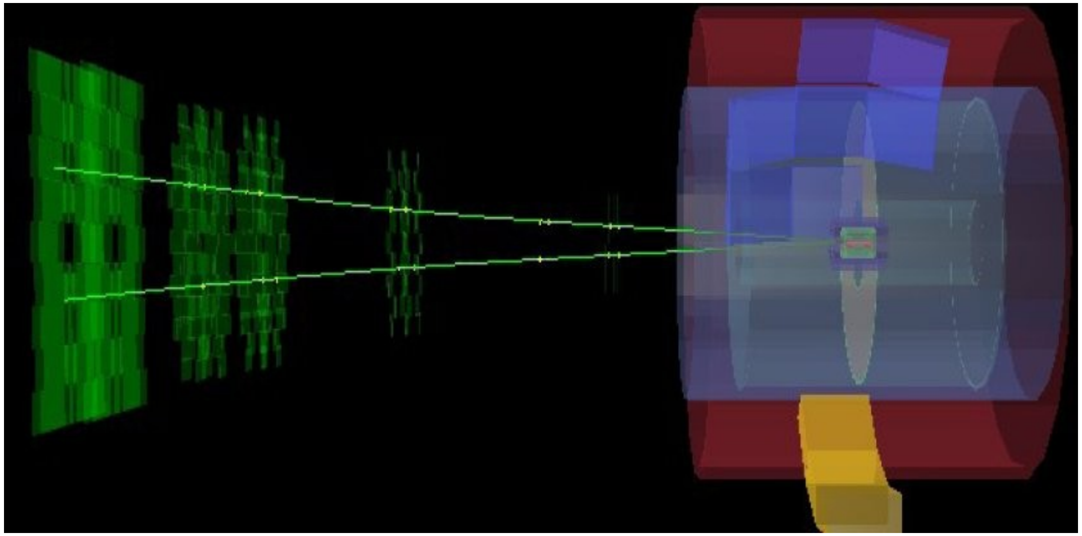




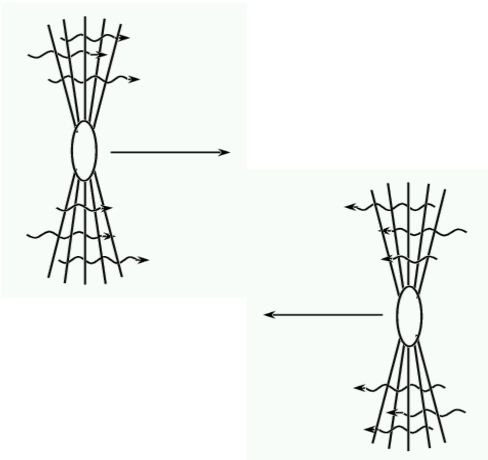
D^{*+}, D^0, D^+ D_s signals clearly visible in p+Pb – stay tuned

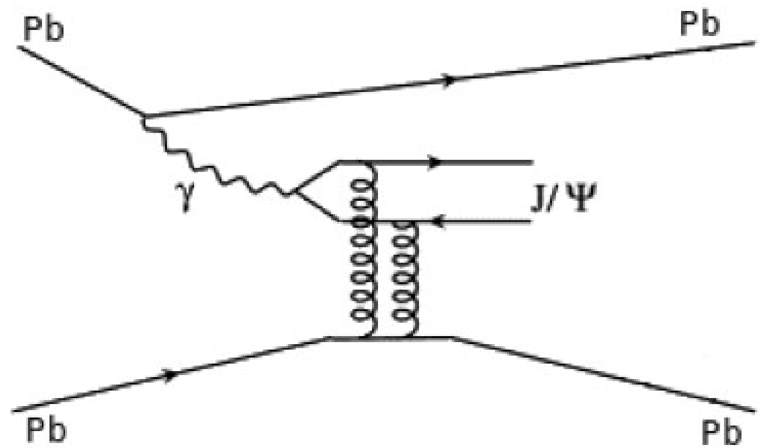
Ultra-peripheral collisions





Ultra-peripheral collisions

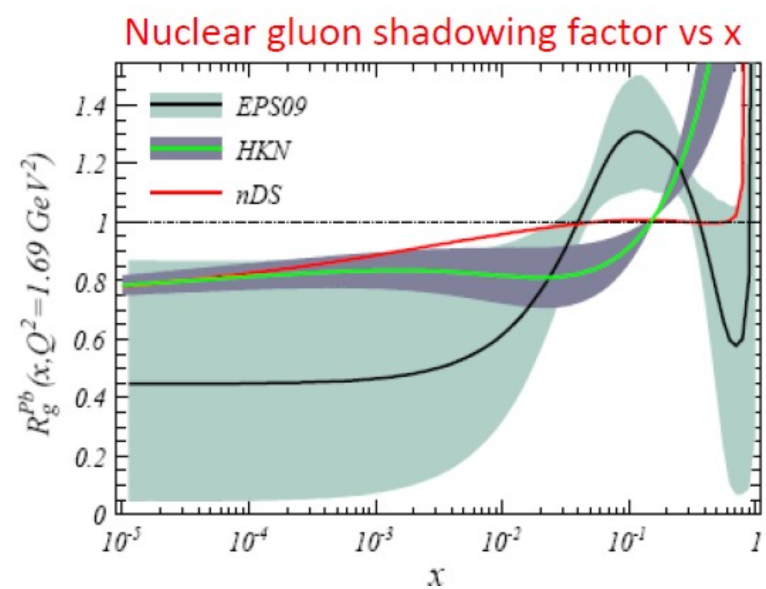




$$\frac{d\sigma}{dt}\Big|_{t=0} = \frac{\alpha_s^2 \Gamma_{ee}}{3\alpha M_V^5} 16\pi^3 \left[xg\left(x, \frac{M_V^2}{4}\right)\right]^2$$

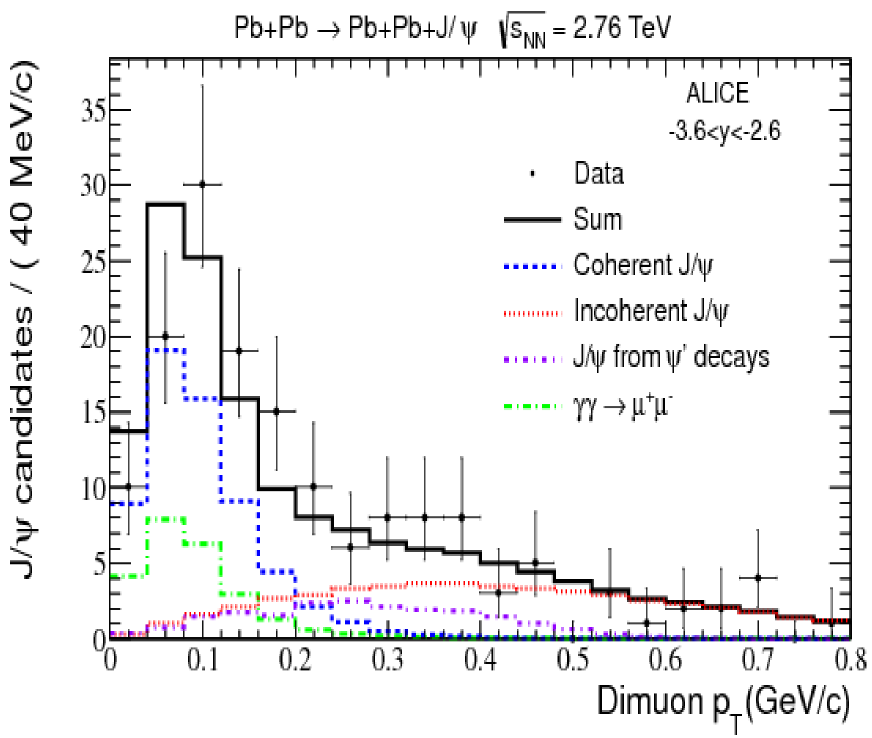
Ryskin 1993

$$\frac{\frac{d\sigma(\gamma A \to VA)}{dt}\Big|_{t=0}}{\frac{d\sigma(\gamma N \to VN)}{dt}\Big|_{t=0}} = \left[\frac{G_A(x, M_V^2/4)}{G_N(x, M_V^2/4)}\right]^2$$

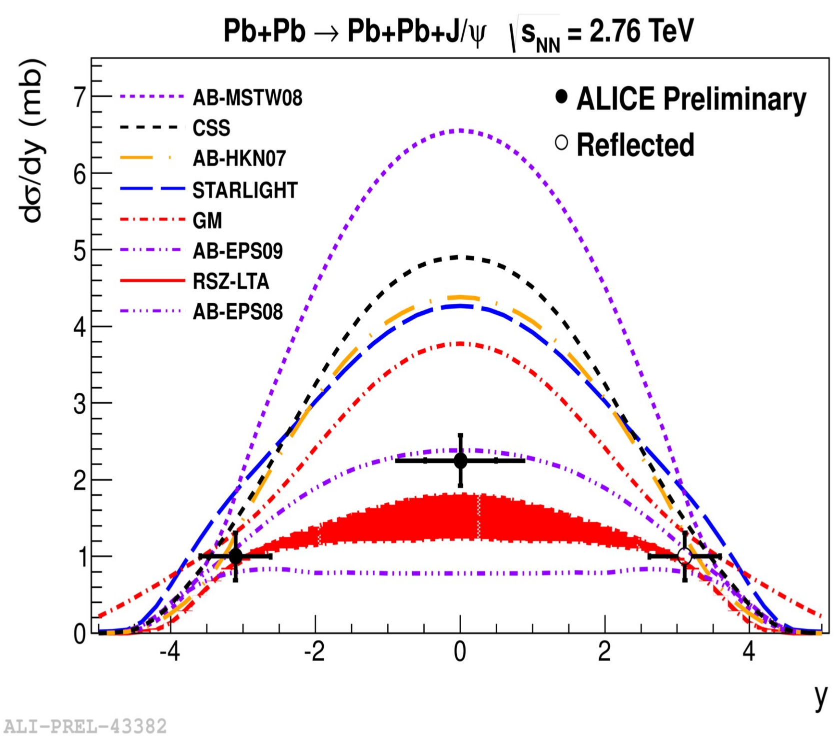


Ultra-peripheral Pb+Pb collisions

Clear coherent J/ψ candidates

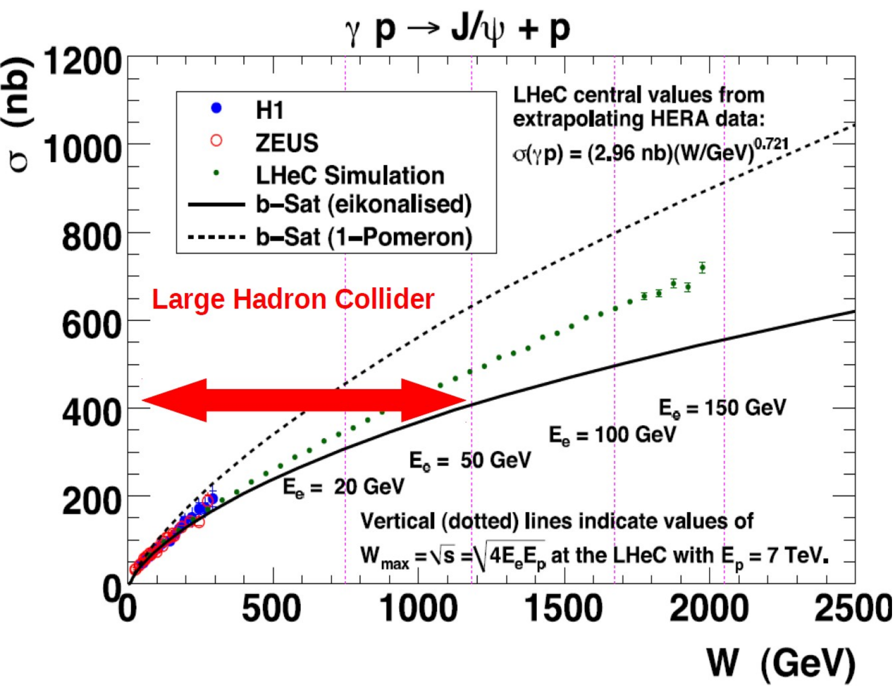


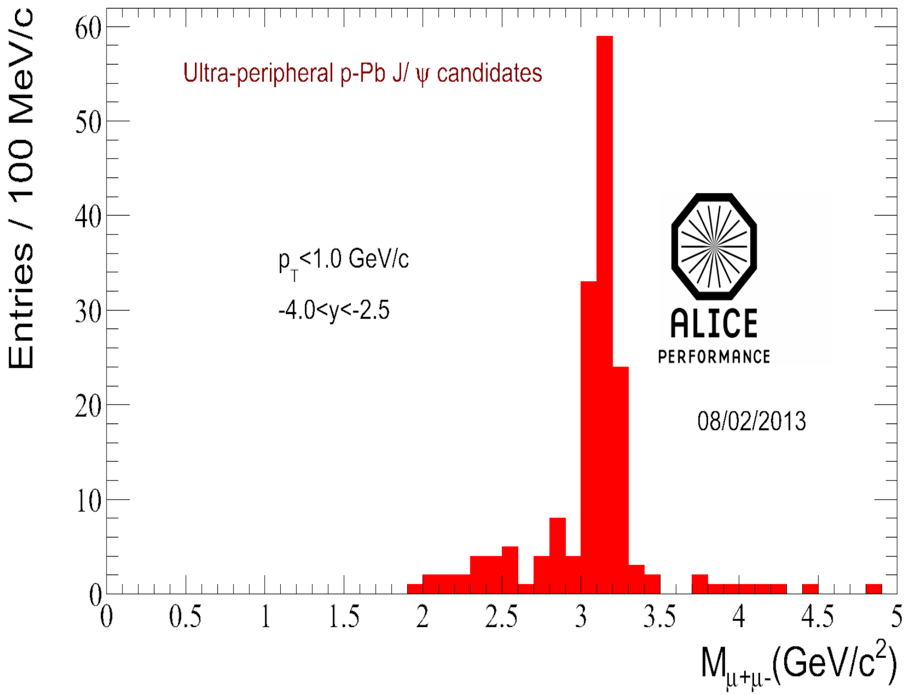
Rapidity dependence of coherent J/ψ cross section



Data favour models that include strong modifications to the nuclear gluon distribution (shadowing).

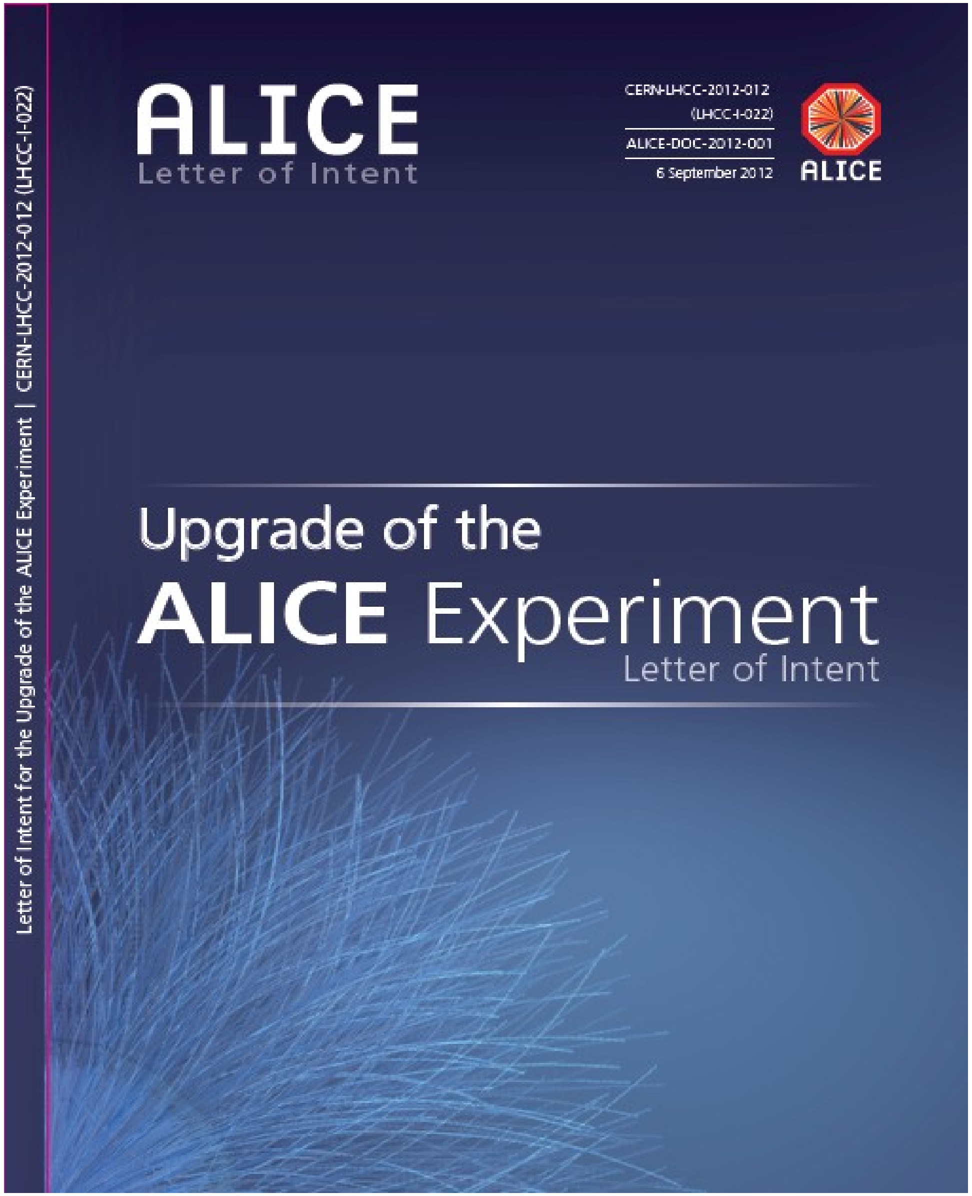
J/ψ photoproduction in γ+p using Pb+p





ALICE can explore Bjorken-x of 10^{-5} using J/ψ from γ+p interactions, reaching the Tev scale

The future of ALICE

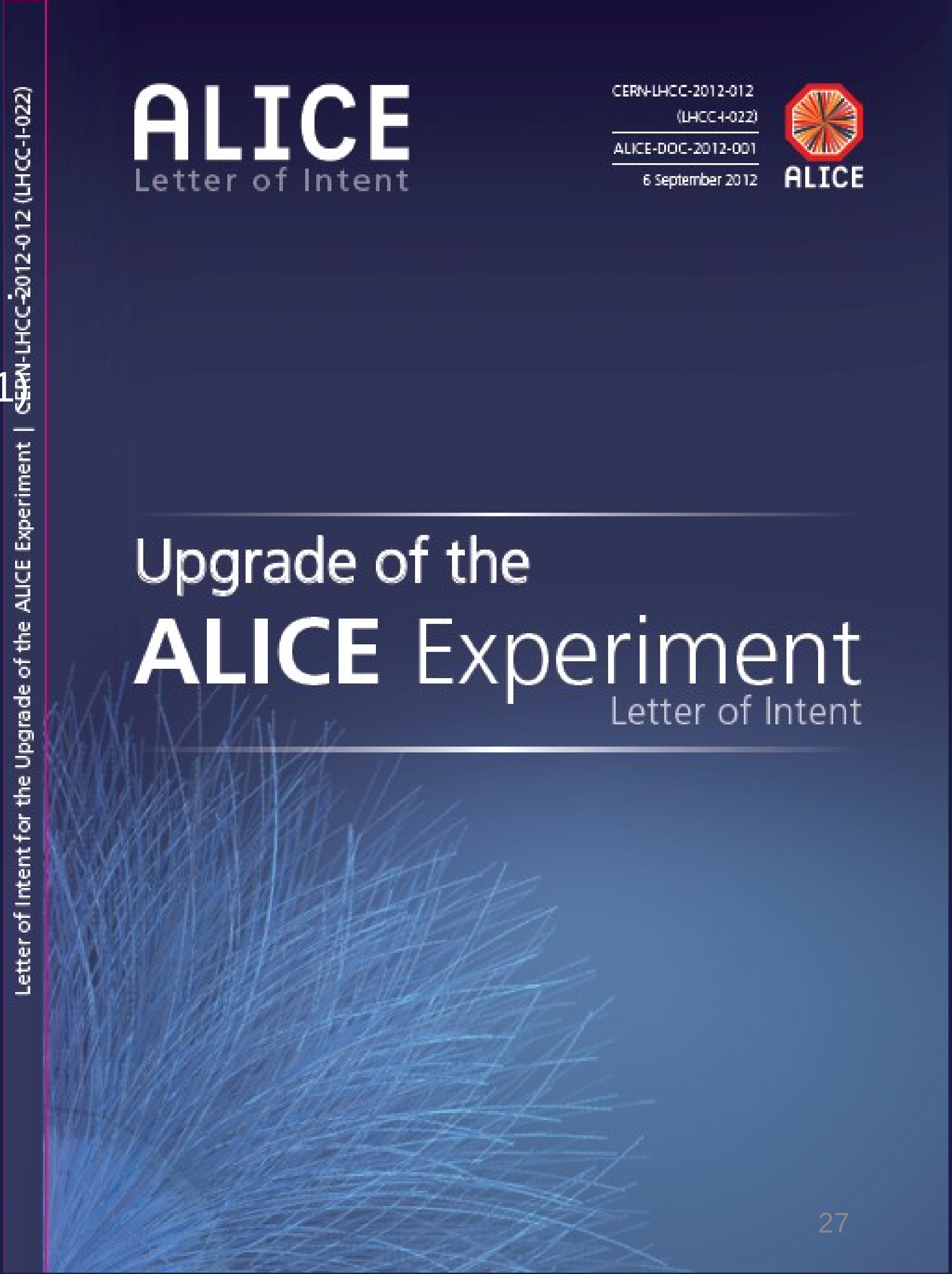


http://cdsweb.cern.ch/record/1475243

- 2013: **pPb and Pbp**
  initial state effects, shadowing...
- 2013-14: LHC Long Shutdown 1 (LS1)
- 2015-17: **FULL ENERGY !!**
  pp @ 7 TeV,
  PbPb @ $\sqrt{s_{NN}}$ = 5.5 TeV
- 2018: LHC Long Shutdown 2
- ≥ 2019: **HIGH LUMINOSITY**
  50 kHz PbPb collisions

ALICE UPGRADES

- New vertex detectors
- Faster readout, high level triggers...
- TPC with continuous readout ...



Physics motivation for Upgrade plans

Example of three unique features to ALICE

Charmonia - J/ψ and ψ(2S) - down to zero Pt

Distinguish between suppression and regeneration

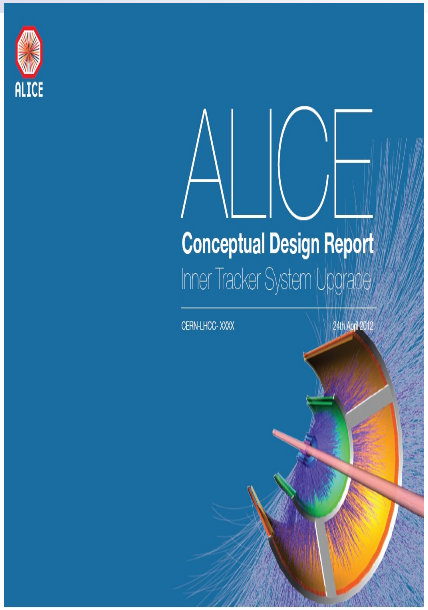
Low mass dielectrons: thermal photons and vector mesons from QGP

Photons from the QGP, mapping temperature during system evolution
Modification of ρ spectral function → chiral symmetry restoration

Heavy-flavour transport parameters in the QGP

Heavy-quark diffusion coefficient via precise HQ v2
Heavy-quark thermalisation and hadronisation in the QGP, via v2 and baryons
Mass dependence of parton energy loss in QGP medium

Upgrade plans



Essential requirements:

High precision tracking at low p_T

Upgrading read-out for detectors and central systems

New Inner tracker

Closer (3.9 cm → 2.2 cm)
Thinner (1% → 0.3% of X0 / layer)
Smaller pixels (50x425 μm^2 → 20x20 μm^2)

Upgrading read-out for TPC, TOF, TRD, MUON, ZDC, and DAQ, HLT and Offline, EMCal and PHOS

Record Pb data at 50 kHz (currently <0.5 kHz)
Integrated L =10 nb^{-1} after LS2

Additional upgrade projects under discussion

MFT, VHMPID and FOCAL

One more thing ...

ALICE talks at LISHEP

Recent ALICE results on soft-physics
→ Yiota Foka → Thu

ALICE Diffraction Studies, Status and Plans
→ Gerardo Herrera → Mon

D meson production with ALICE
→ Ricardo Russo → Thu

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Summary

Many interesting results coming out from ALICE

Several unique LHC measurements by ALICE, including identified hadrons, charm, low p_T J/ψ, UPC, amongst others

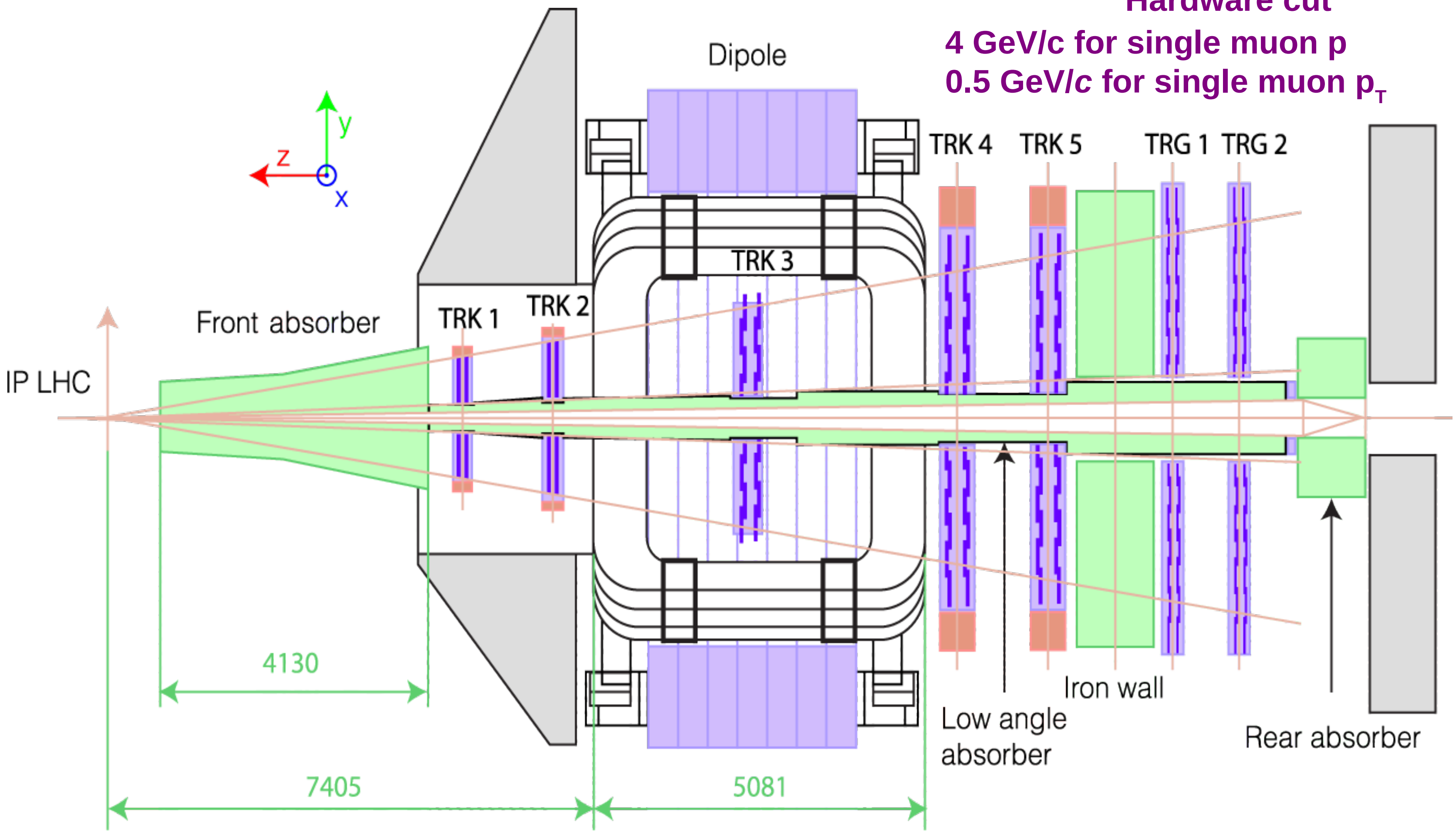
Also beautiful data collected in the 2013 pPb, crucial to understand expected/seen QGP features in PbPb, and providing ways to test saturation

Well defined strategy for ALICE upgrade projects, continuing exploring unique aspects at LHC energies

Additional slides

Muon spectrometer

Hardware cut
4 GeV/c for single muon p
0.5 GeV/c for single muon p_T



5 tracking stations (10 planes of MWPC) . 70 µm resolution in the bending plane

2 trigger stations (4 planes of RPCs)
~ 2ns response