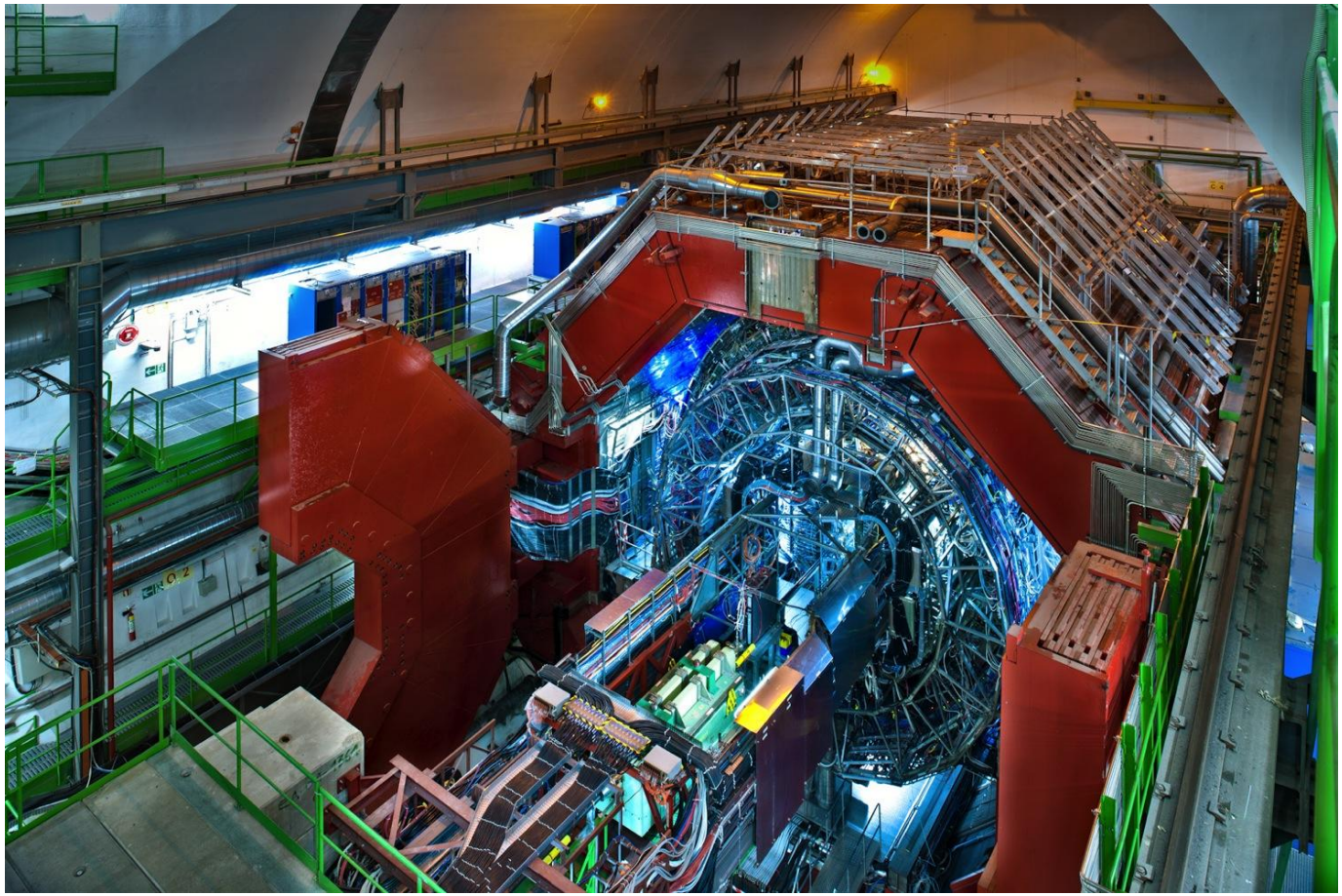
Symposium Italy-Japan 2012 on Nuclear Physics
Milano 20-23 November 2012

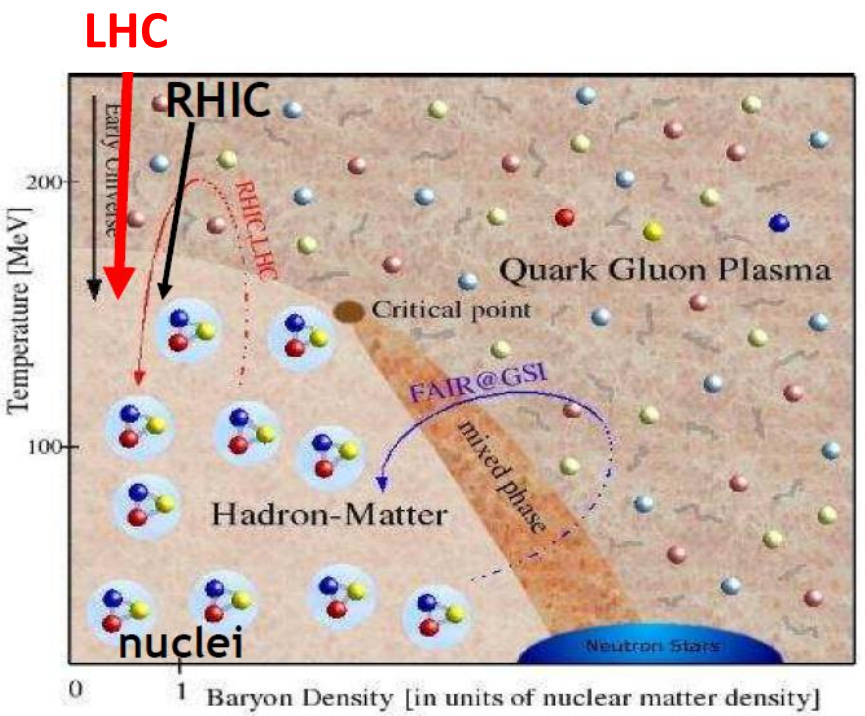
R. Nania
INFN Bologna

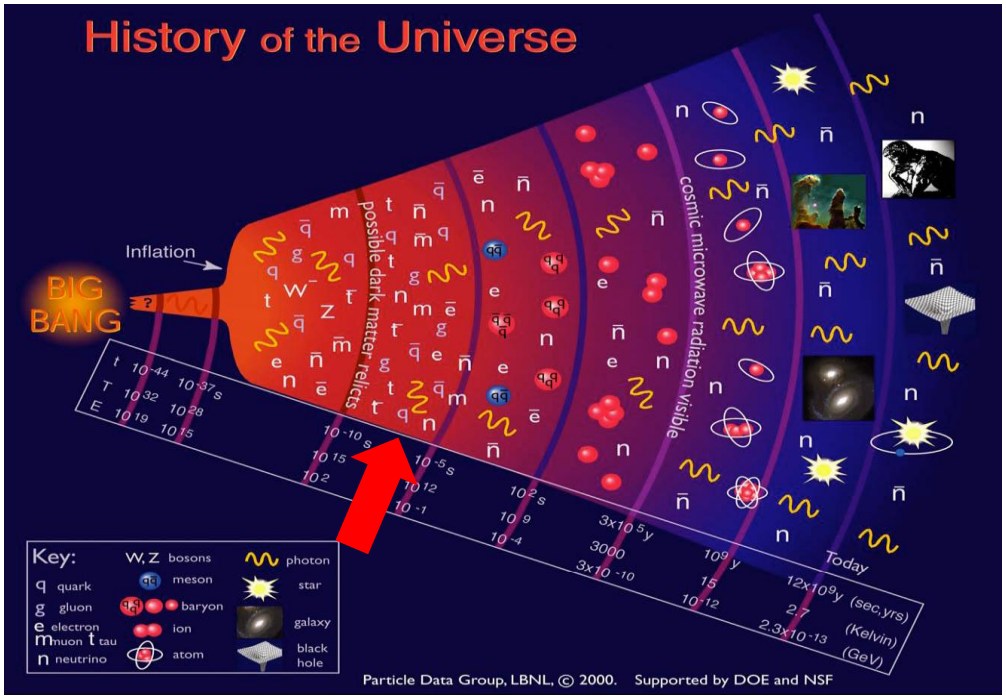
Latest results from ALICE at LHC



ALICE main motivations:

- Understand phase transition at high temperature and low baryon density
- Study the matter at 10 μs after Big-Bang



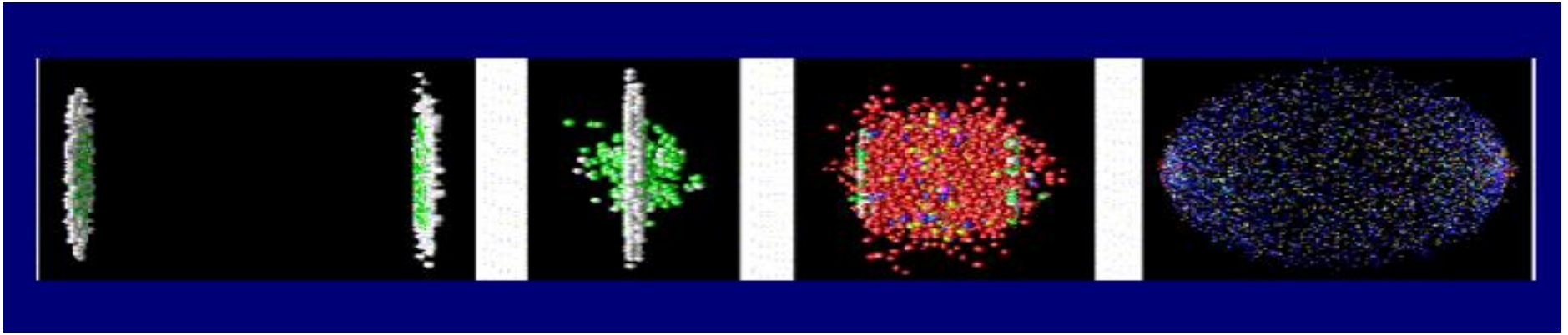


LHC at CERN collides Pb-Pb ions at $\sqrt{s_{NN}}$ = 2.76 or 5.5 TeV

The goal is to produce a matter with:

- Energy density >> 1 GeV/fm3
- Lasting for > 1 fm/c
- In a volume much larger than a hadron

Goal : Study the QCD predicted Quark Gluon Plasma (QGP)



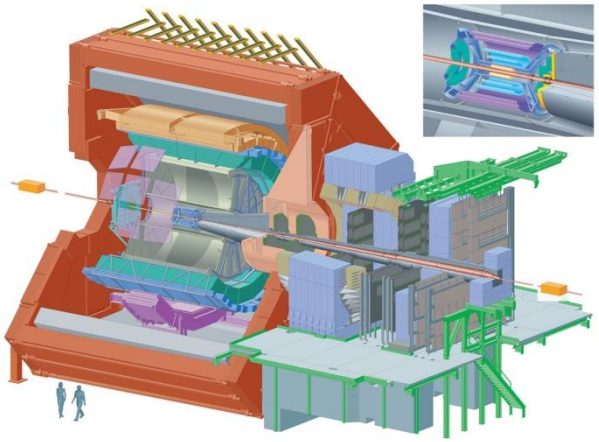
The ALICE Collaboration

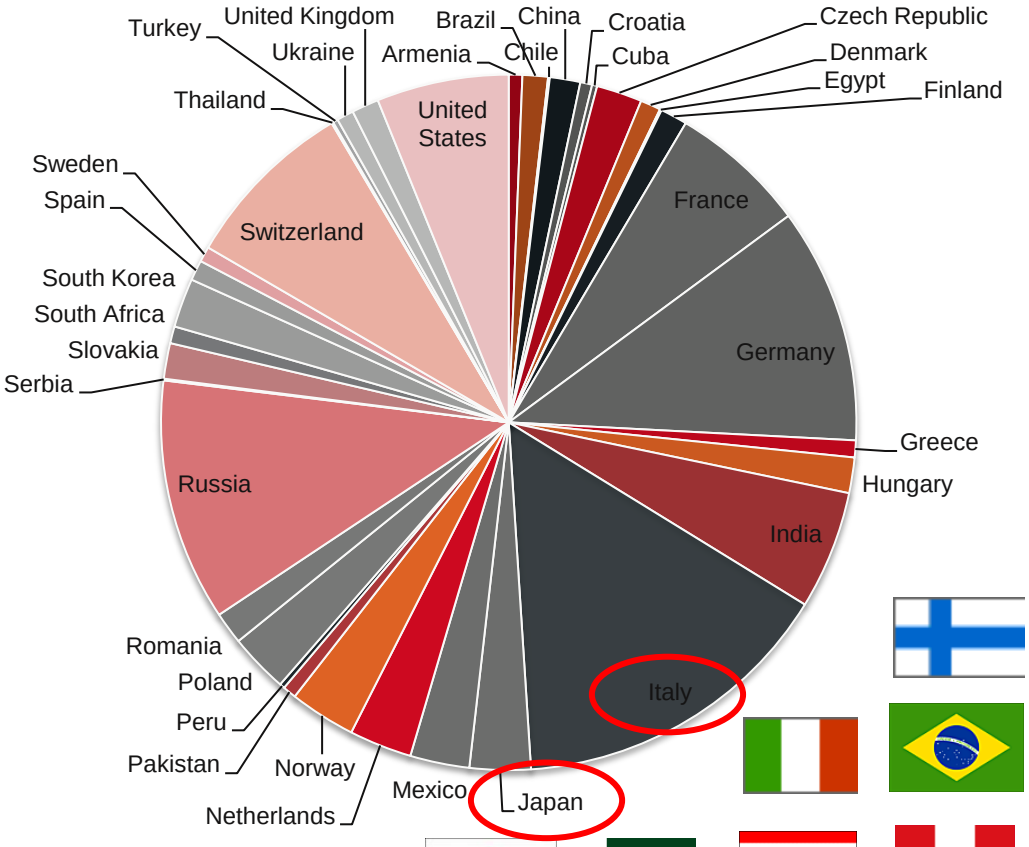
1990 Start design

.....

2009 Start data taking

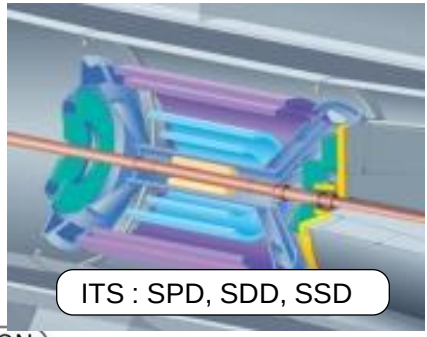
....





~ 1300	Members
35	Countries
132	Institutes
~ 160	MCHF capital cost (+ 'free' magnet)

A Large Ion Collider Experiment



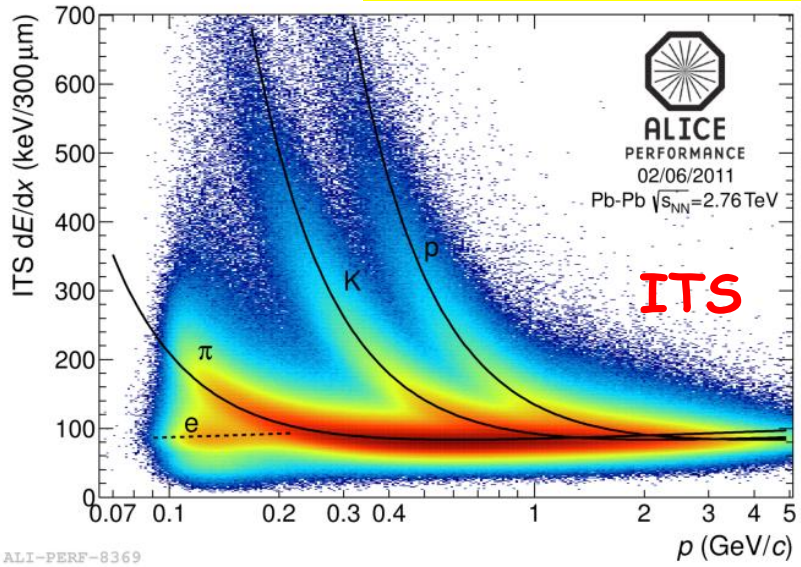
EMCAL
TRD
HMPID
ZDC ~116m from I.P.
PMD V0
ABSORBER
TRACKING CHAMBERS
MUON FILTER
TPC
TRIGGER CHAMBERS
ZDC ~116m from I.P.
DCAL
TOF
PHOS
ITS
DIPOLE MAGNET

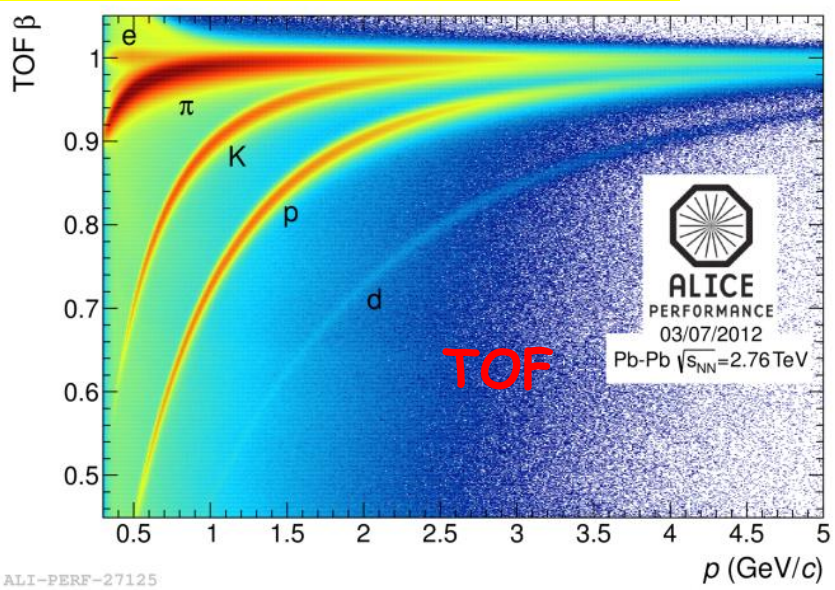
Italy (INFN and Universities)
Alessandria, Bari, Bologna, Cagliari,Catania, LNF, LNL, Roma, Padova, Torino, Trieste

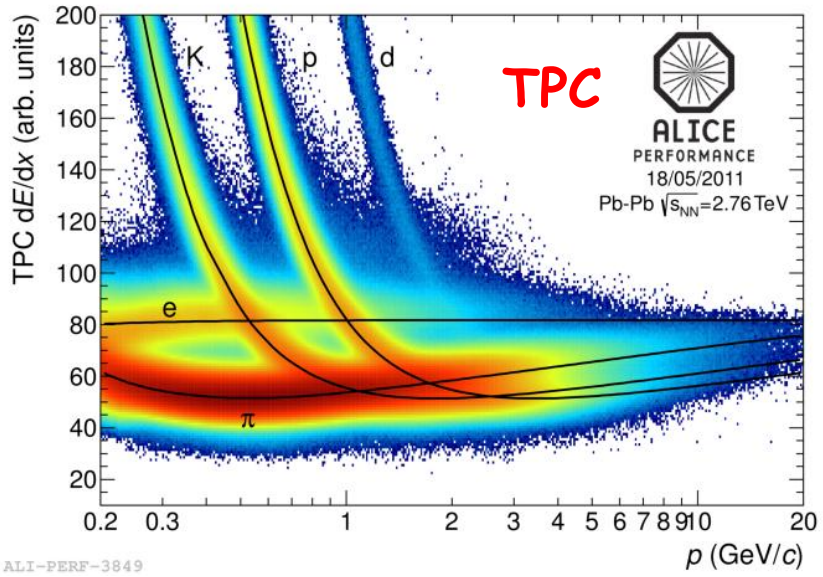
Japan
Hiroshima University
University of Tokyo
University of Tsukuba
RIKEN Institue

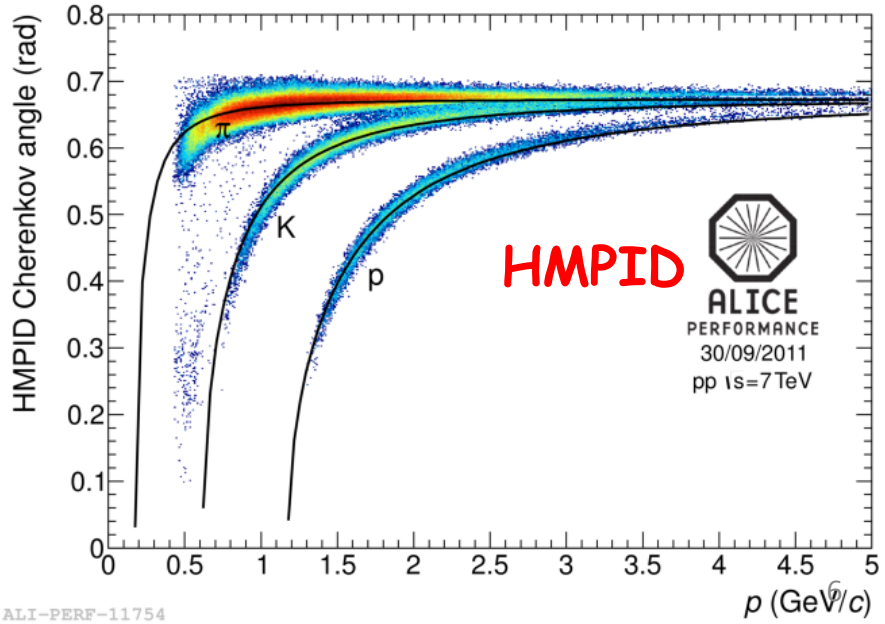
- Optimized for Heavy Ions Physics → high performances tracking and PID
- Complementary to the other LHC experiments

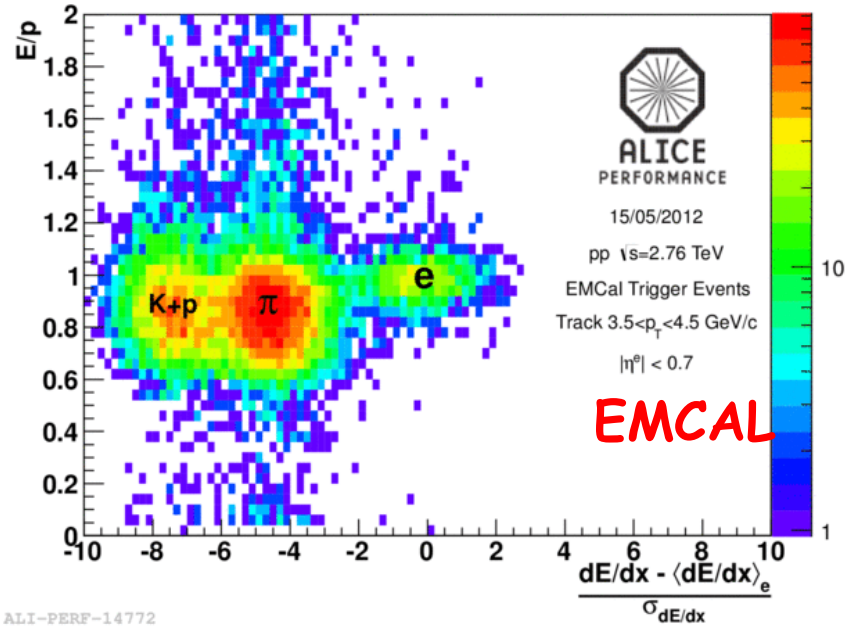
ALICE main detector performances

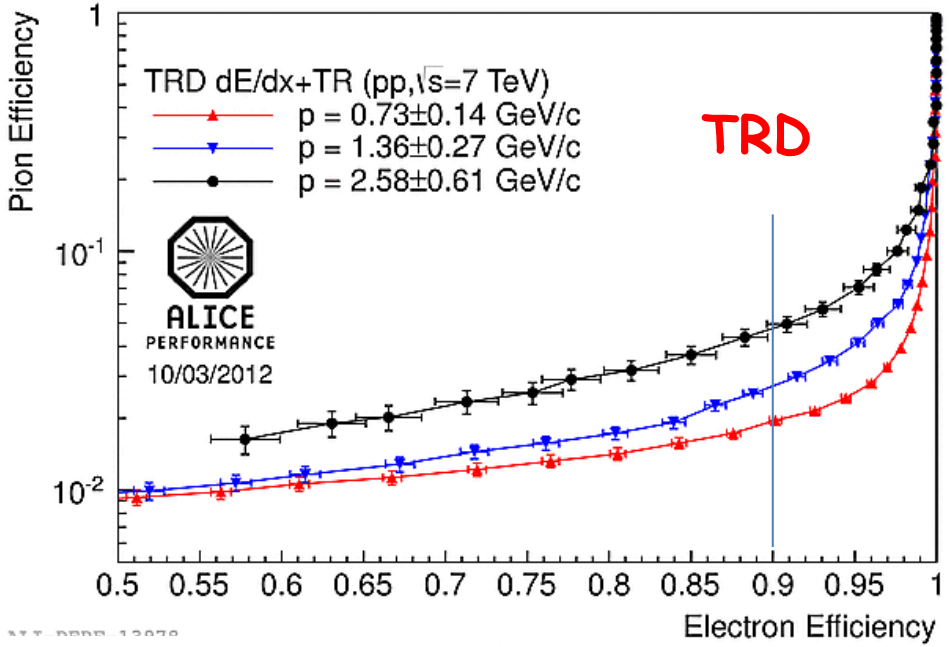


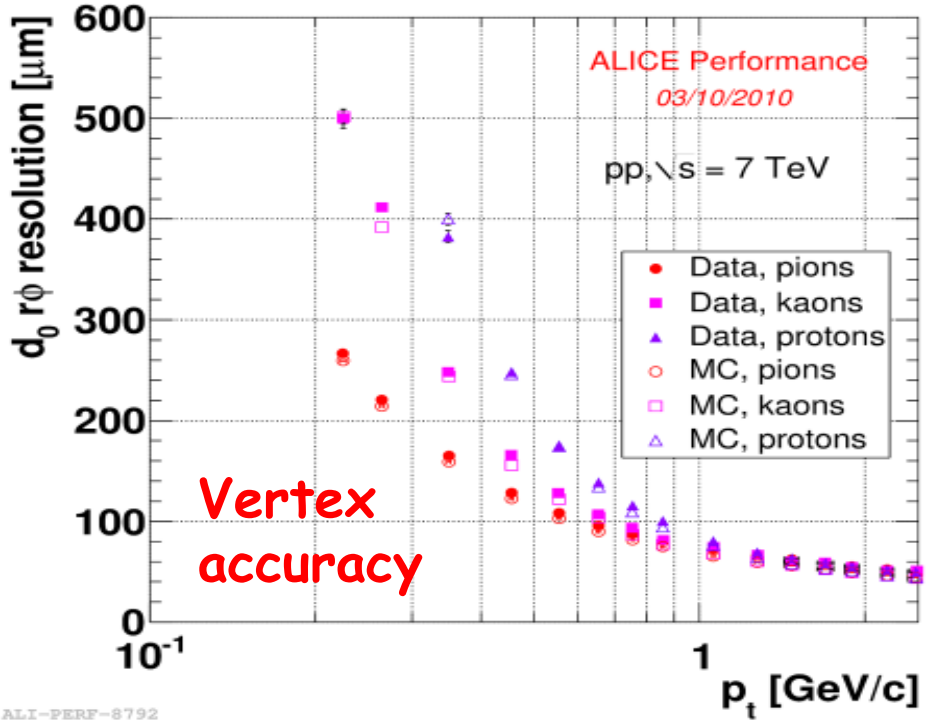







E/p
K+p
π
e
ALICE
PERFORMANCE
15/05/2012
pp √s=2.76 TeV
EMCal Trigger Events
Track 3.5<p_T<4.5 GeV/c
|η^e| < 0.7
EMCAL
dE/dx - ⟨dE/dx⟩_e / σ_dE/dx
ALI-PERF-14772


Pion Efficiency
TRD dE/dx+TR (pp,√s=7 TeV)
p = 0.73±0.14 GeV/c
p = 1.36±0.27 GeV/c
p = 2.58±0.61 GeV/c
TRD
ALICE
PERFORMANCE
10/03/2012
Electron Efficiency


d_0 rφ resolution [μm]
ALICE Performance
03/10/2010
pp, √s = 7 TeV
Data, pions
Data, kaons
Data, protons
MC, pions
MC, kaons
MC, protons
Vertex
accuracy
p_t [GeV/c]
ALI-PERF-8792

ALICE data with Heavy Ions

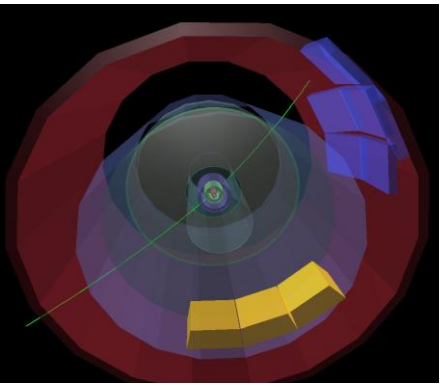
year	system	energy $\sqrt{s_{NN}}$ TeV	integrated luminosity
2010	Pb – Pb	2.76	~ 10 μb^{-1}
2011	Pb – Pb	2.76	~ 150 μb^{-1}
2013★	p – Pb	5.02	~ 30 nb^{-1}

Pb-Pb 2011

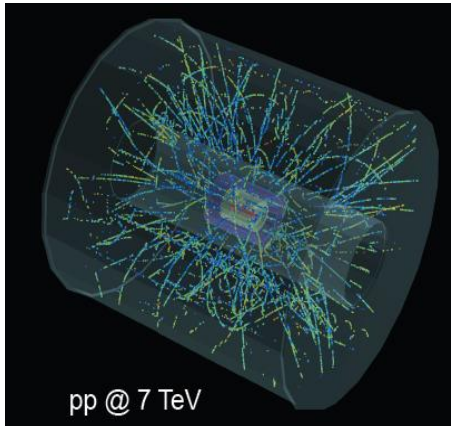
L_{peak} = 5 10^{26} $cm^{-2}s^{-1}$ (17x L_{peak}^{2010})

~1.4 x 10^8 Lead ions /bunch

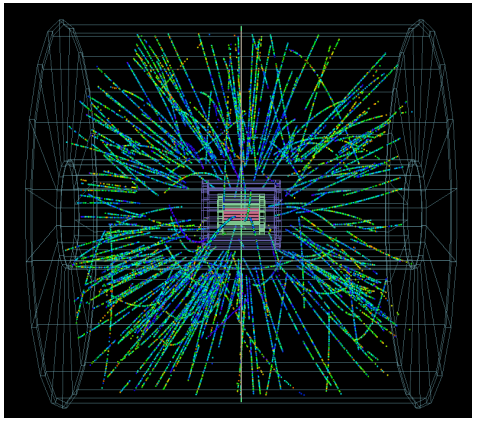
ALICE unique capabilities allow also important measurements in different types of collision : Pb-Pb , pp , p-Pb and gamma-pb



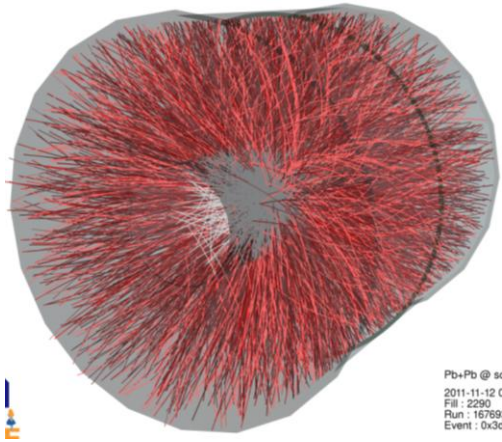
Gamma-Pb



p-p



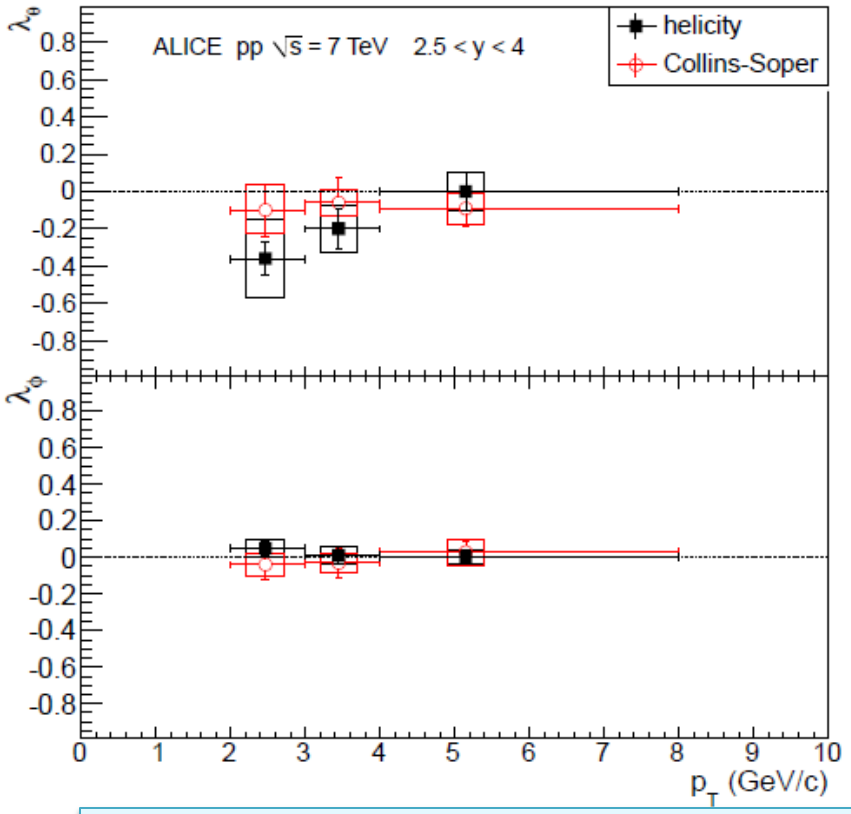
p-Pb



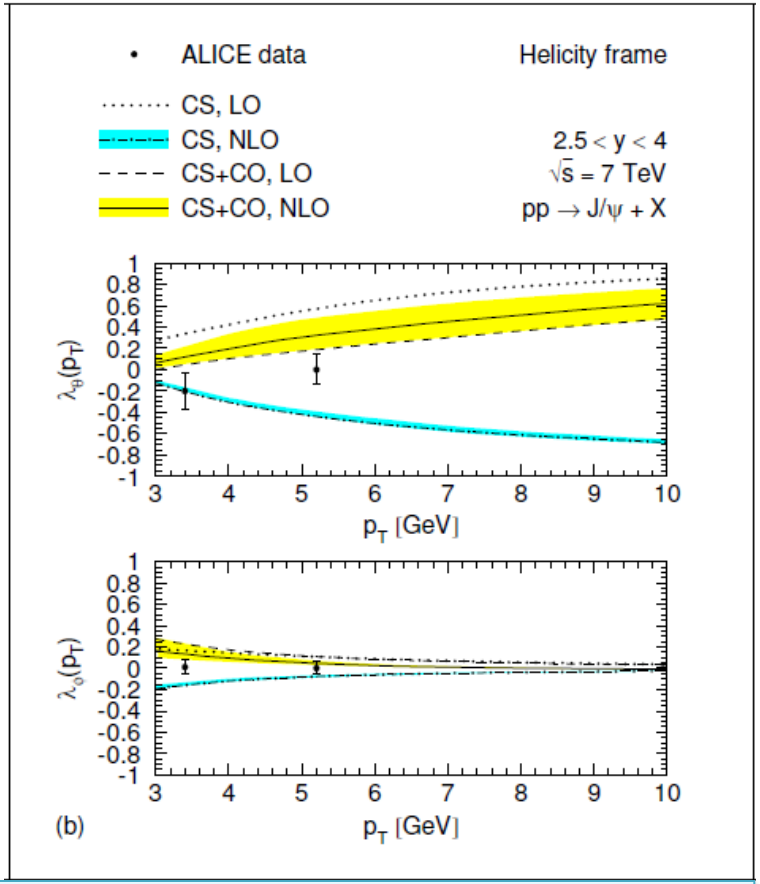
Pb-Pb

First measurement J/ψ polarization at LHC

ALICE, PRL 108 (2012) 082001

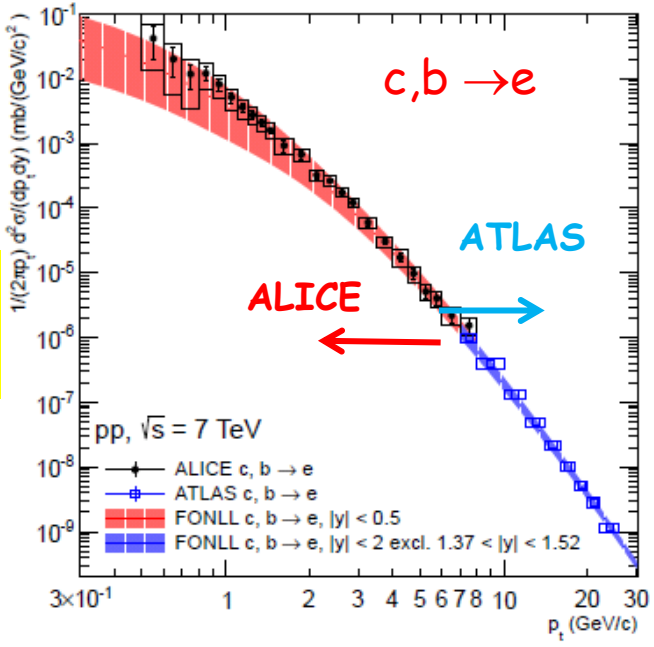


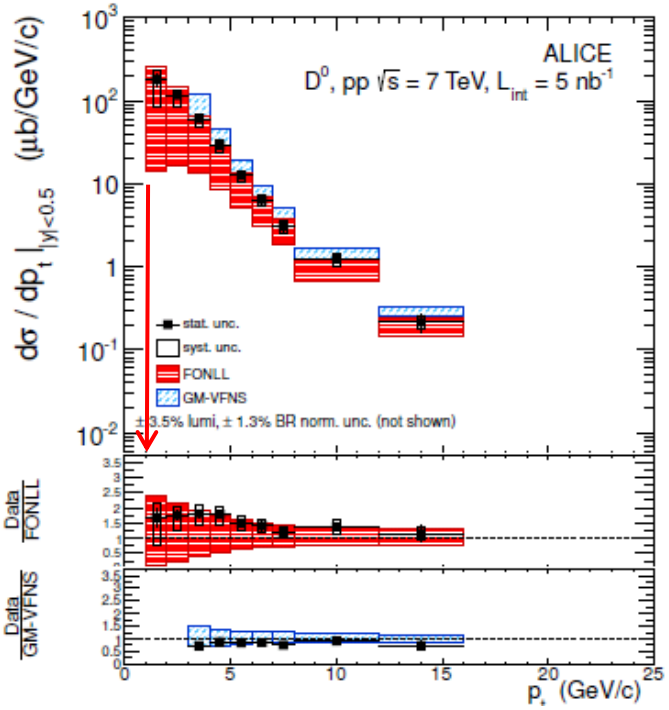
M.Butenschoen, A.Kniehl, arXiv:1201.3862



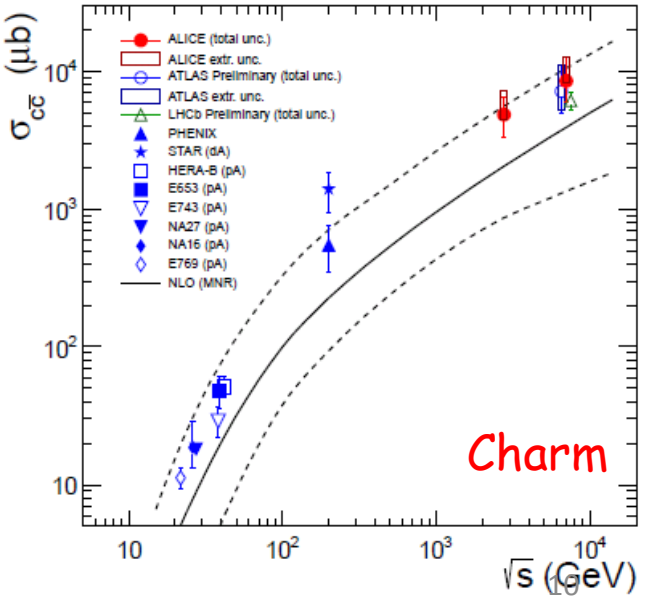
- Long standing puzzle with Tevatron results
- First result at the LHC: almost no polarization for the J/ψ
- Crucial input for tuning NRQCD parameters

Charm production in pp



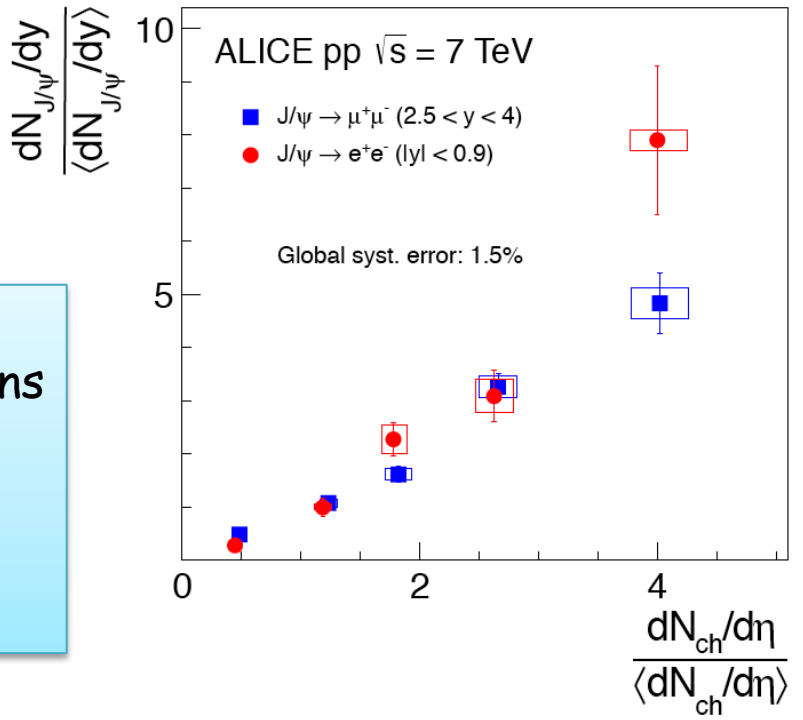


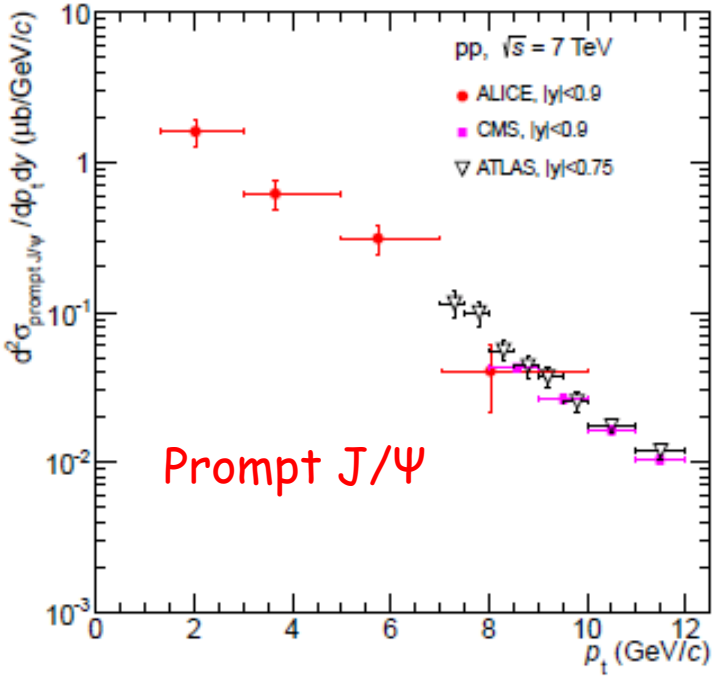
Measurements at low momentum, complementary to other LHC experiments.

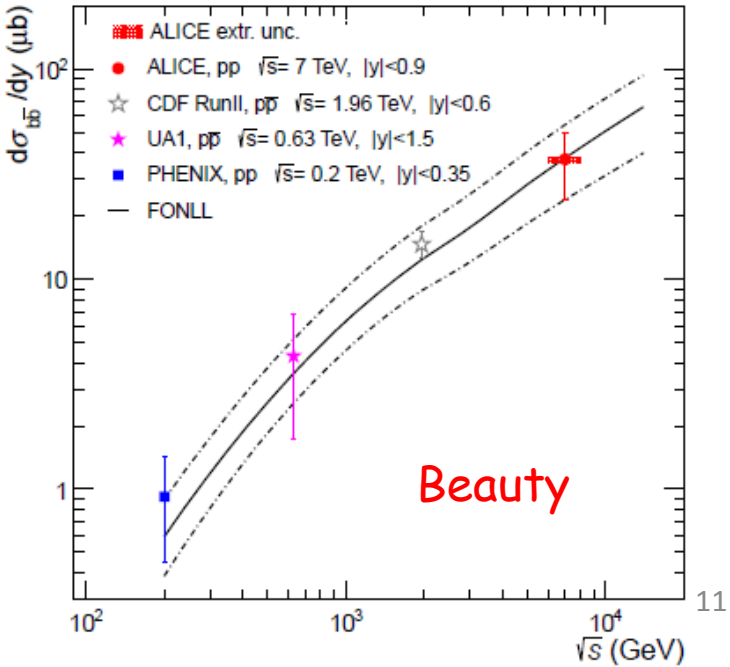


J/ψ production in pp

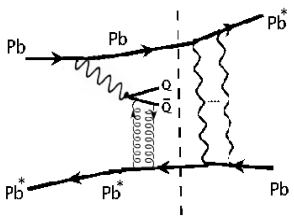
- Important measurement vs track multiplicity to compare with HI collisions at the same multiplicity
- Measurements at very low pt and determination of the total Beauty cross.section



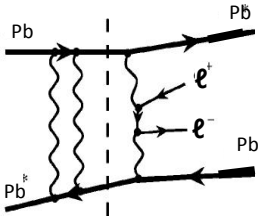




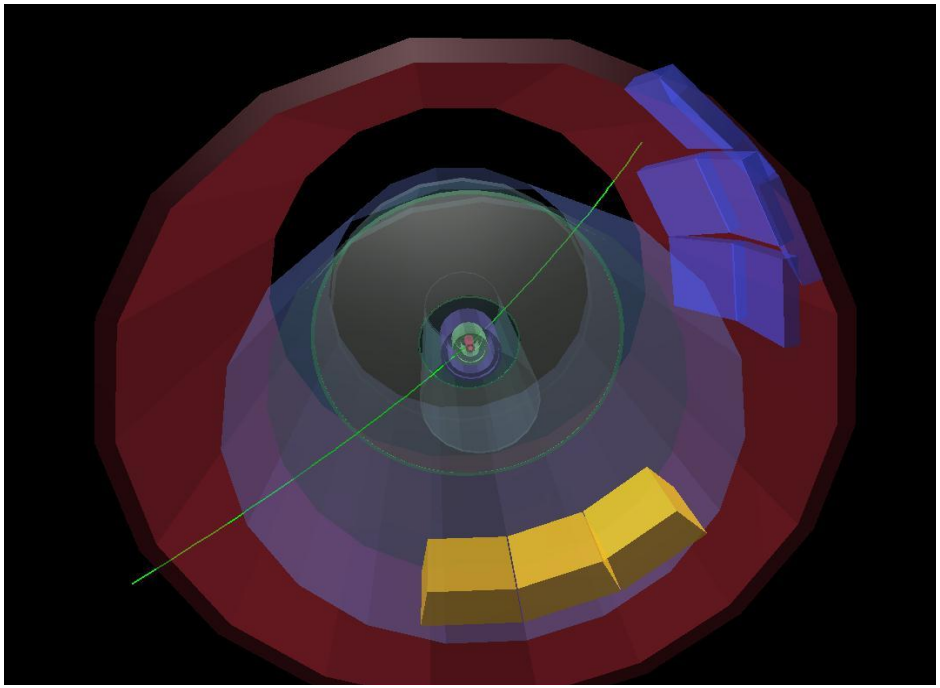
J/ψ production in untraperipheral collisions



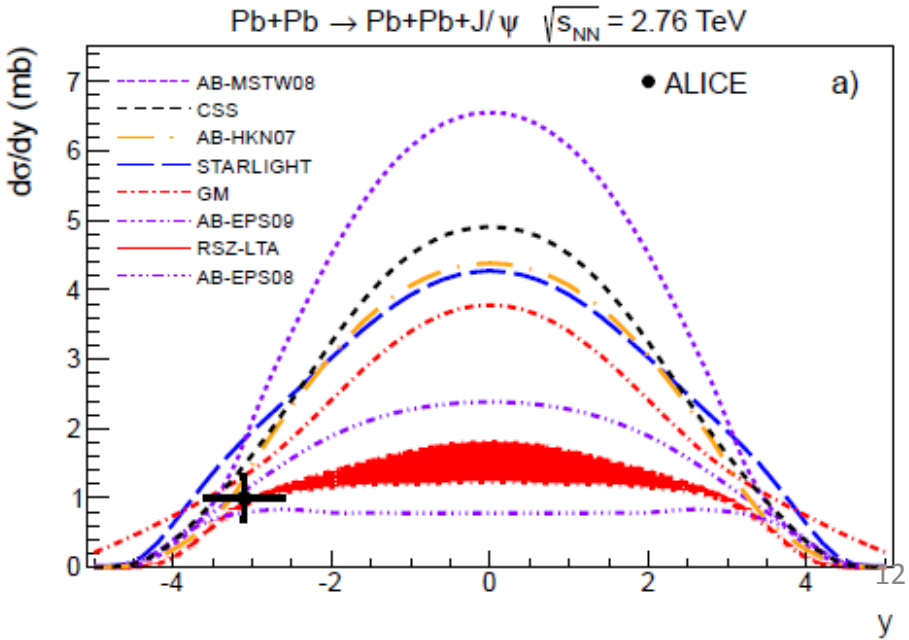
$\gamma A \rightarrow J/\psi$

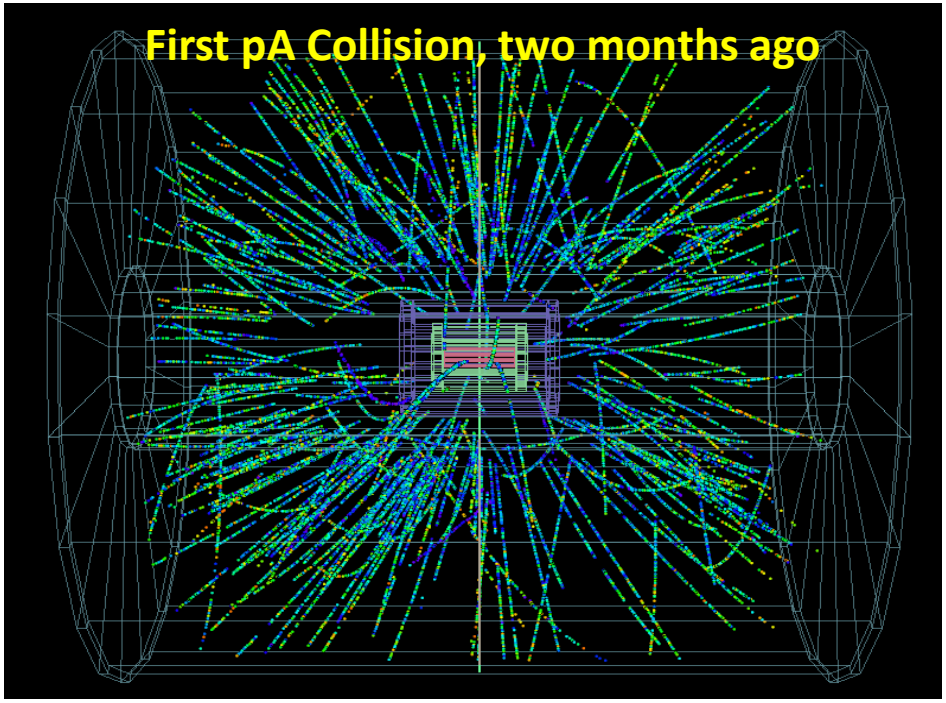


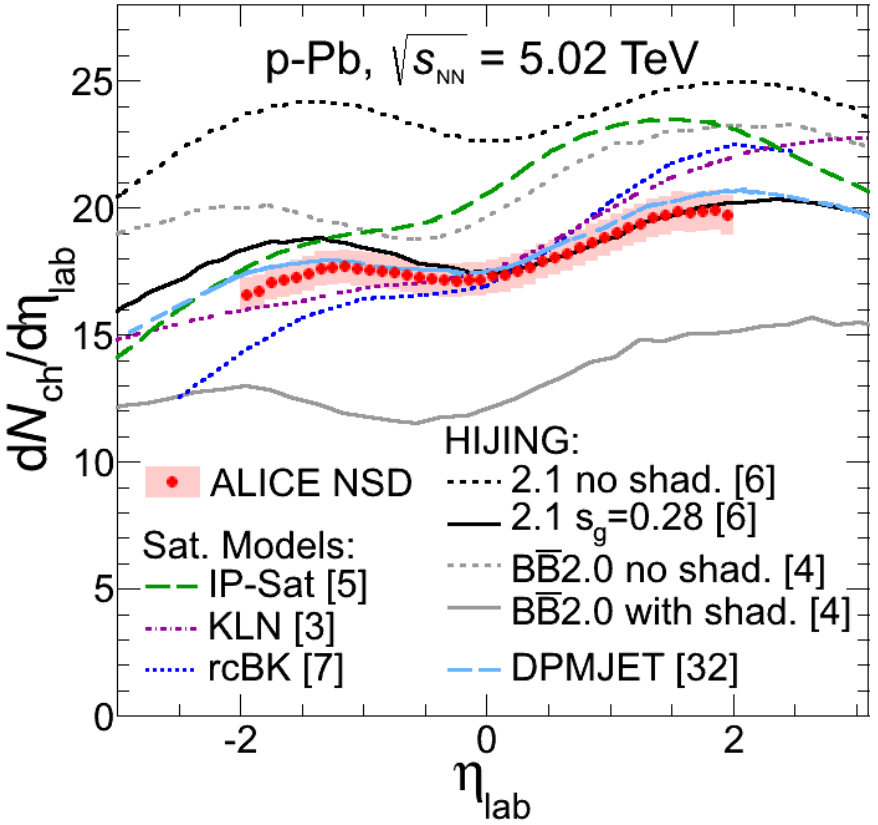
$\gamma\,\gamma \rightarrow J/\psi$



Cross section sensitive to Gluon PDF ad low-x

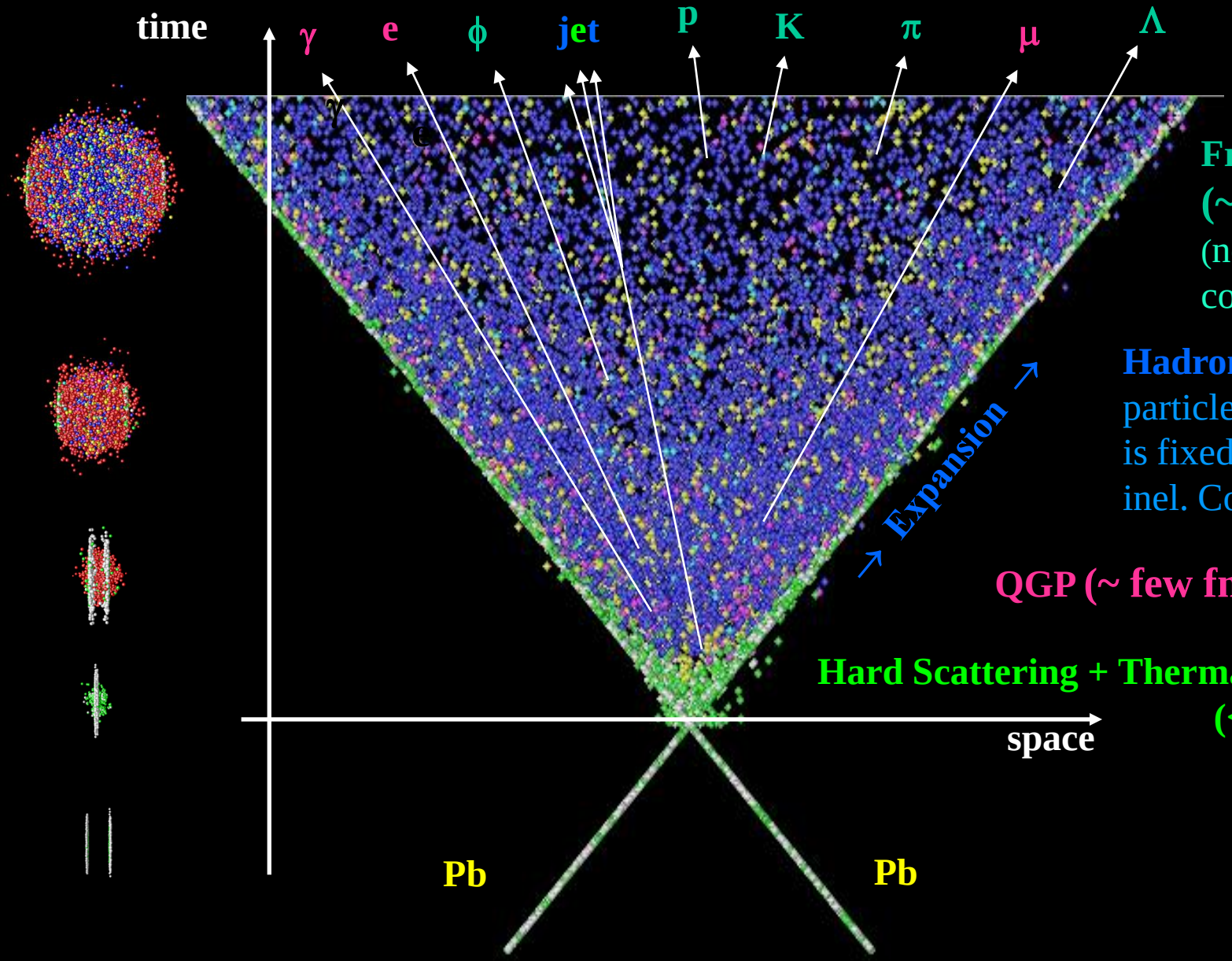


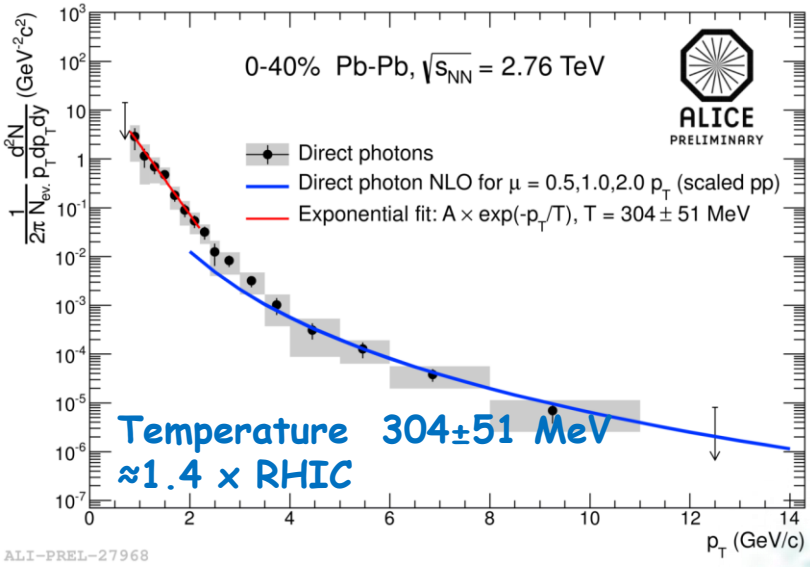


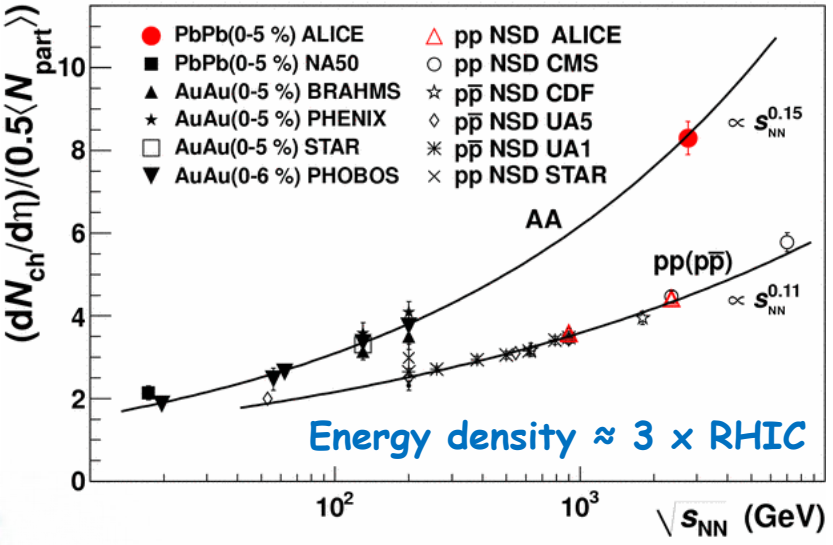


Saturation models predict larger asymmetries in η

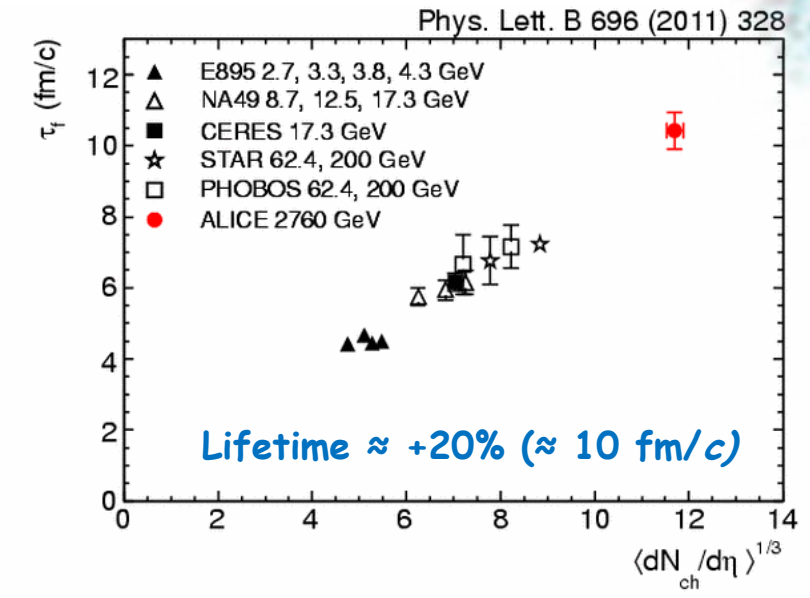
See T. Chujo talk
for further results

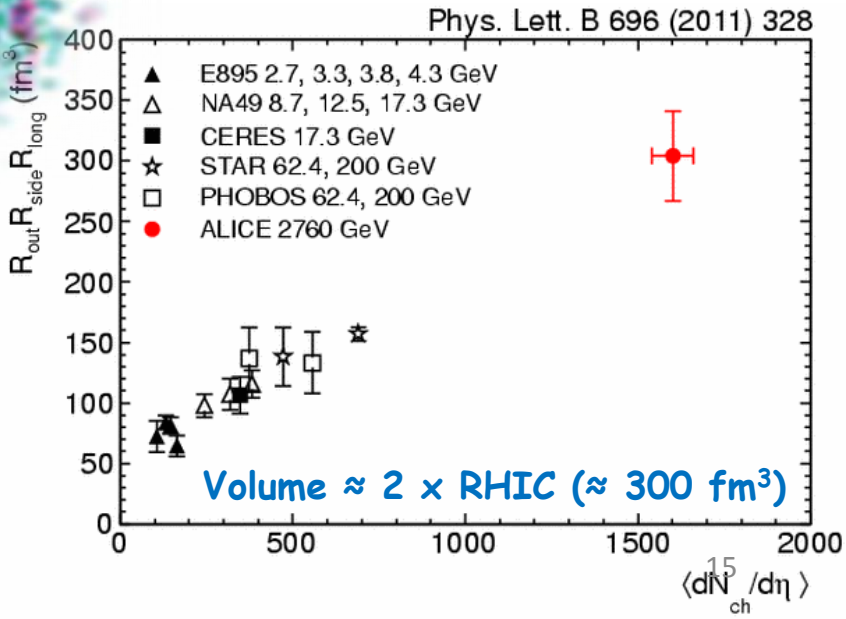

time
γ
e
ϕ
jet
p
K
π
μ
Λ
γ
e
Expansion
Freeze-out
(~ 10 fm/c)
(no more elastic collisions)
Hadronization
particle composition is fixed (no more inel. Collisions)
QGP (~ few fm/c)
Hard Scattering + Thermalization
(< 1 fm/c)
space
Pb
Pb





Global characterization of the medium

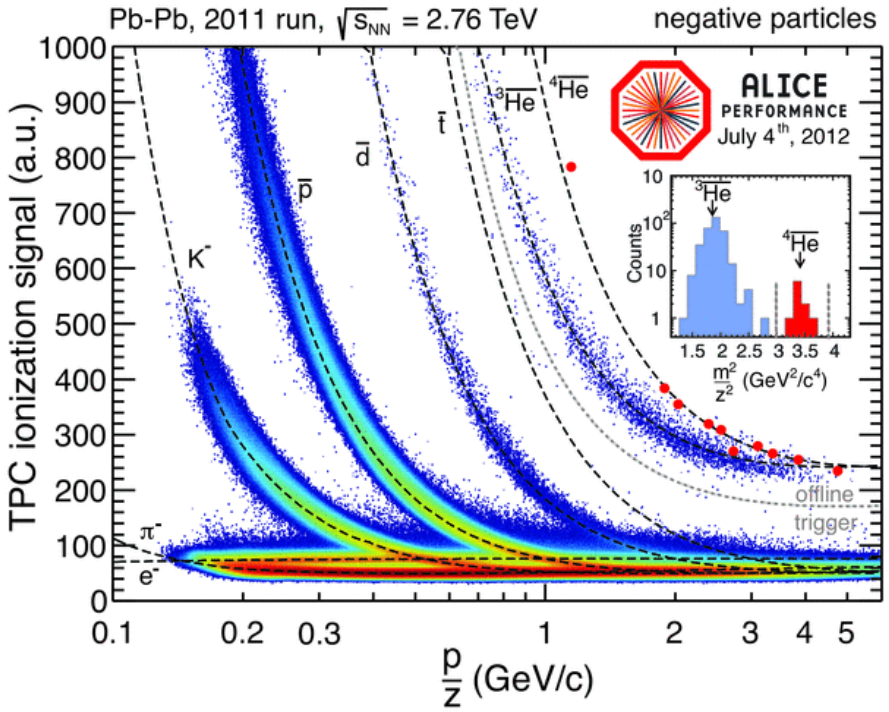


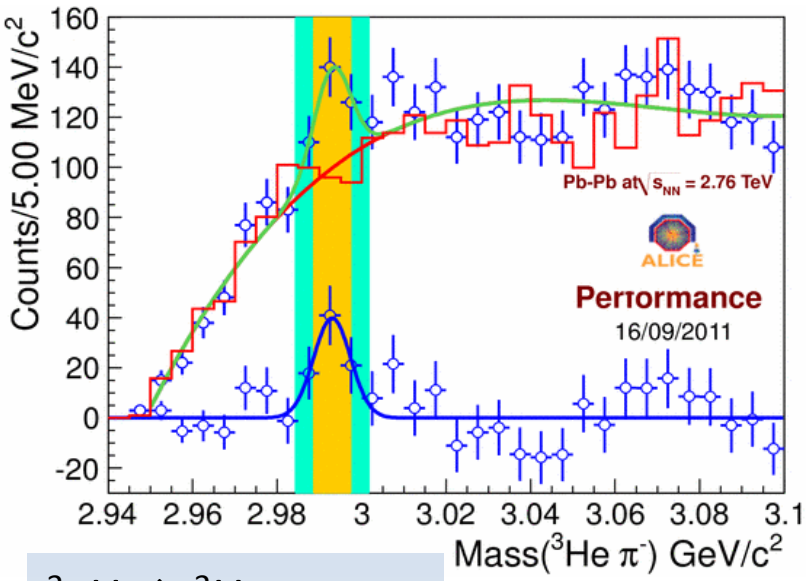


Nucleo-synthesis at LHC

Light Nuclei & anti-Nuclei

- **Anti-^{4}He** is the heaviest anti-nucleus ever observed
- **Hypertriton:** one proton replaced by L particle

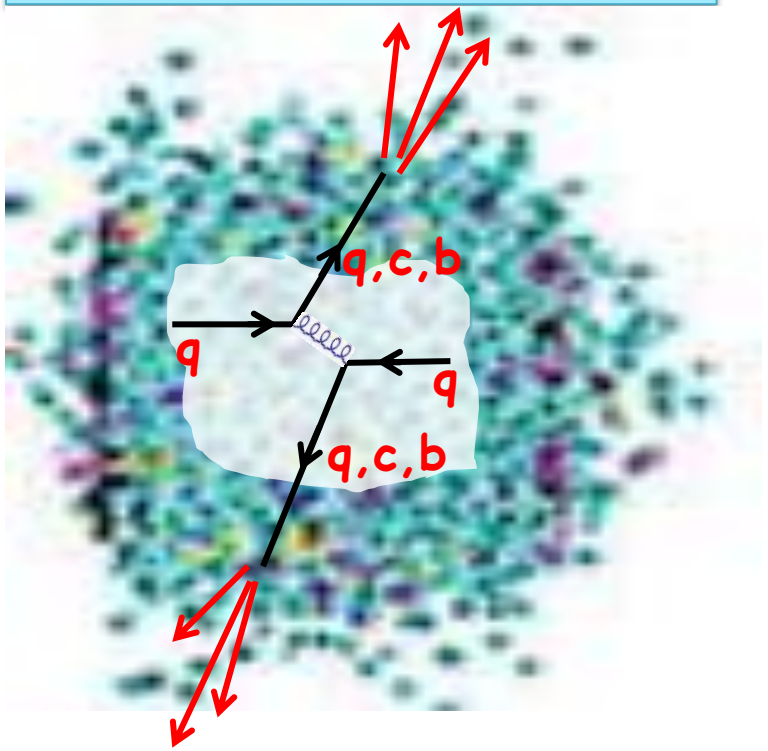




$^3_\Lambda H \rightarrow {}^3He + \pi^-$

How can we characterise the hot medium produced in the interactions ?

Hot medium tomography using hard probes produced in the collision

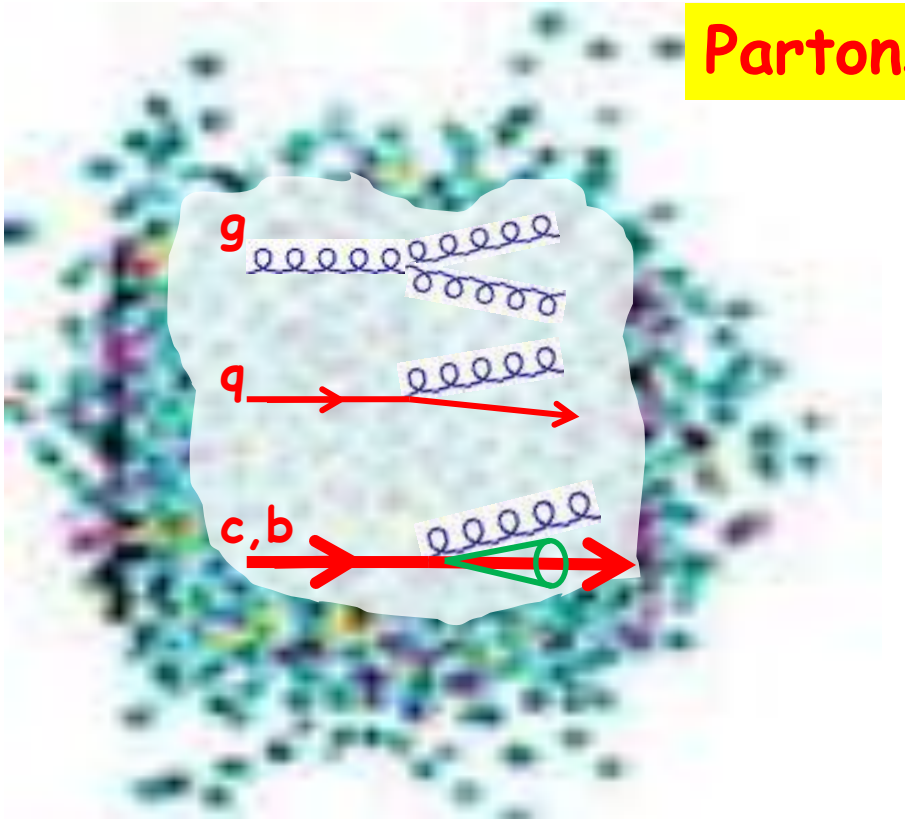


Via measurements of the bulk properties of the particles produced:
Spectra , hadrochemistry, elliptic flow , particle correlations …

T. Chujo talk

Heavy Flavour (this talk)
Jets , high pt particles (T.C.)

Partons energy loss in medium



Depends on:

Casimir factors related to flavour

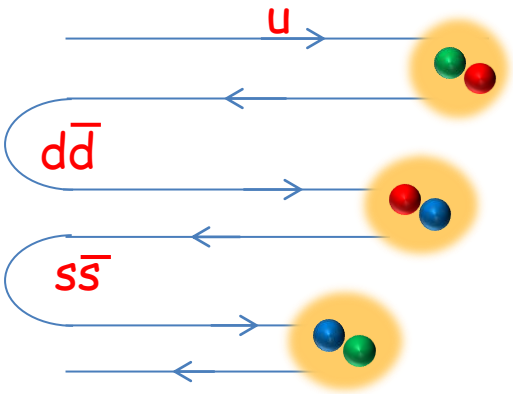
$C_R^{\,g} = 3 \qquad C_R^{\,q,c,b} = 4/3$

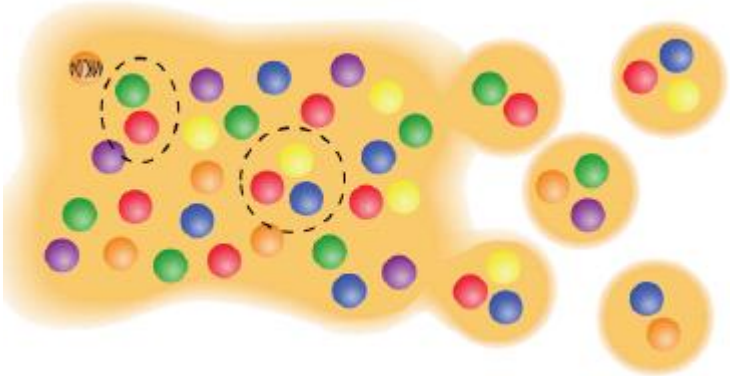
Mass (dead cone effect) → lower gluon radiation for c and b

Expectations:

$\Delta E_g > \Delta E_q > \Delta E_c > \Delta E_b$

Hadronization models in medium





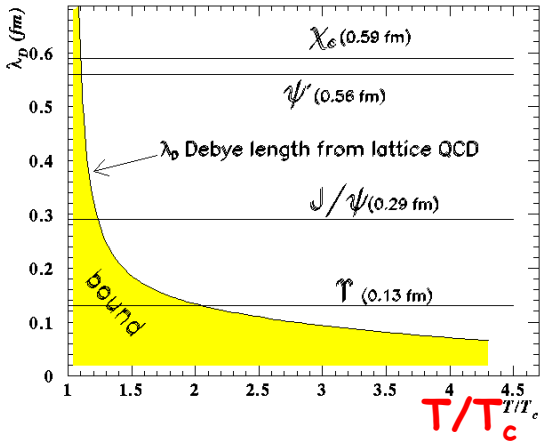
Lund fragmentation

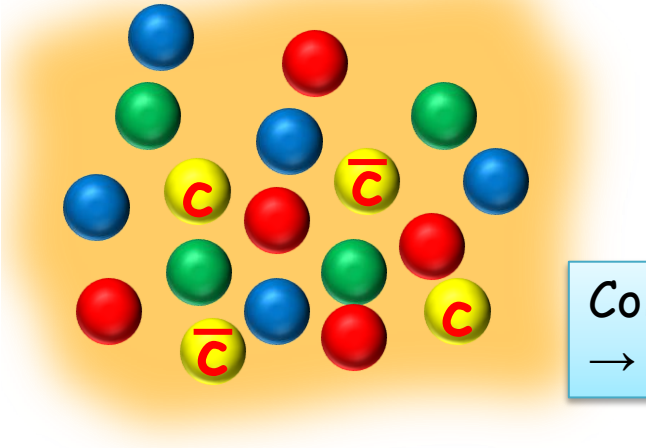
- Small baryon/meson ratio
- $p^{\text{final hadron}} < p^{\text{fragmenting parton}}$

Recombination

- higher baryon/meson ratio
- $p^{\text{final hadron}} > p^{\text{fragmenting parton}}$

λ Debye

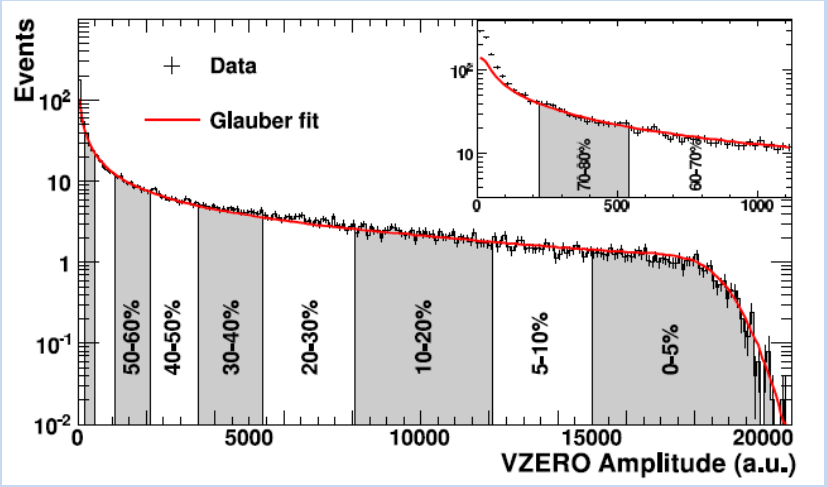




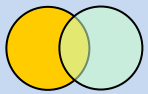
Color Screening
→ Charmonium

Variables definitions

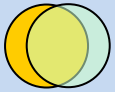
Centrality



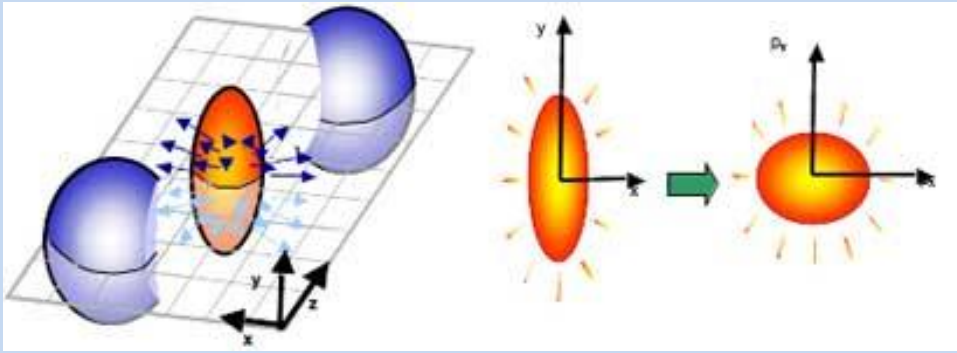
Peripheral (high %)



Central (low %)



Elliptic flow v2

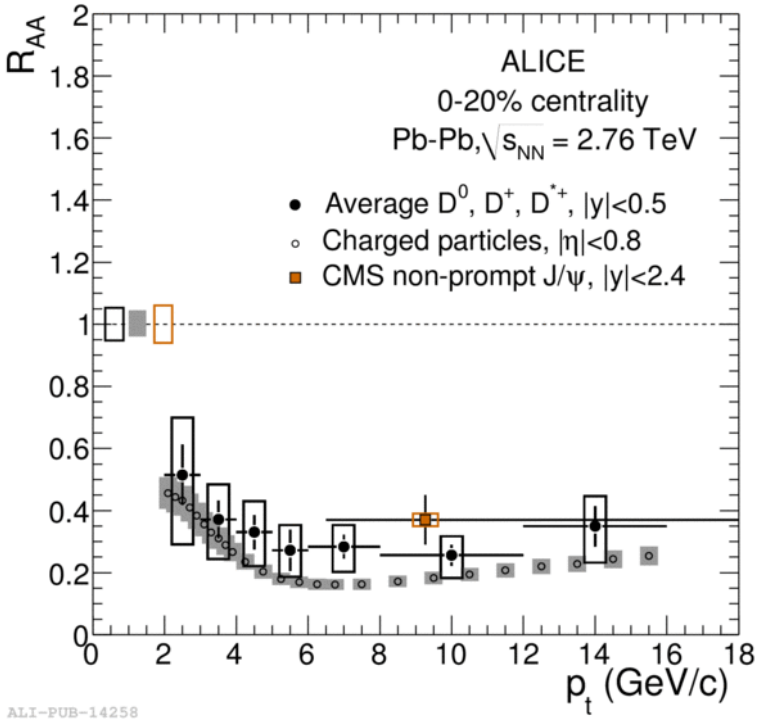


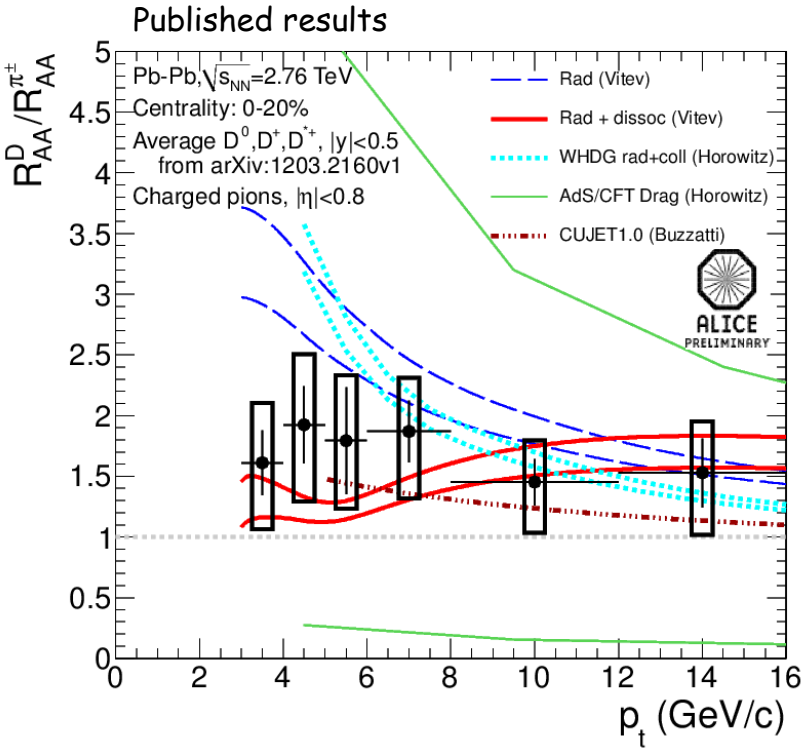
$$\frac{dN}{dp_T d\phi} = \frac{dN}{dp_T}\left[1 + 2v_2\cos(2\phi) + 2v_4\cos(4\phi) + \ldots\right]$$

Nuclear modification factor

$$R_{AA}(p_T) = \frac{\text{Yield}_{AA}(p_T)}{\langle N_{COLL}\rangle_{AA}\,\text{Yield}_{pp}(p_T)}$$

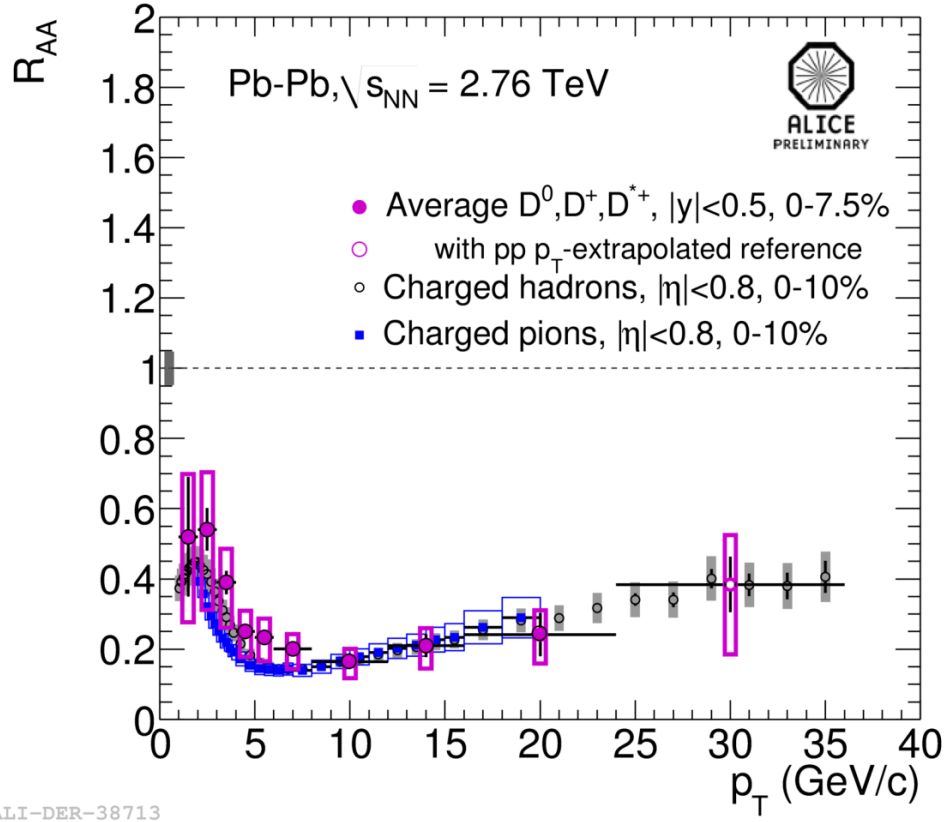
ALICE D production





Hints for an energy loss in medium with mass gerarchy $R^{\pi}_{AA} < R^{c}_{AA} < R^{b}_{AA}$

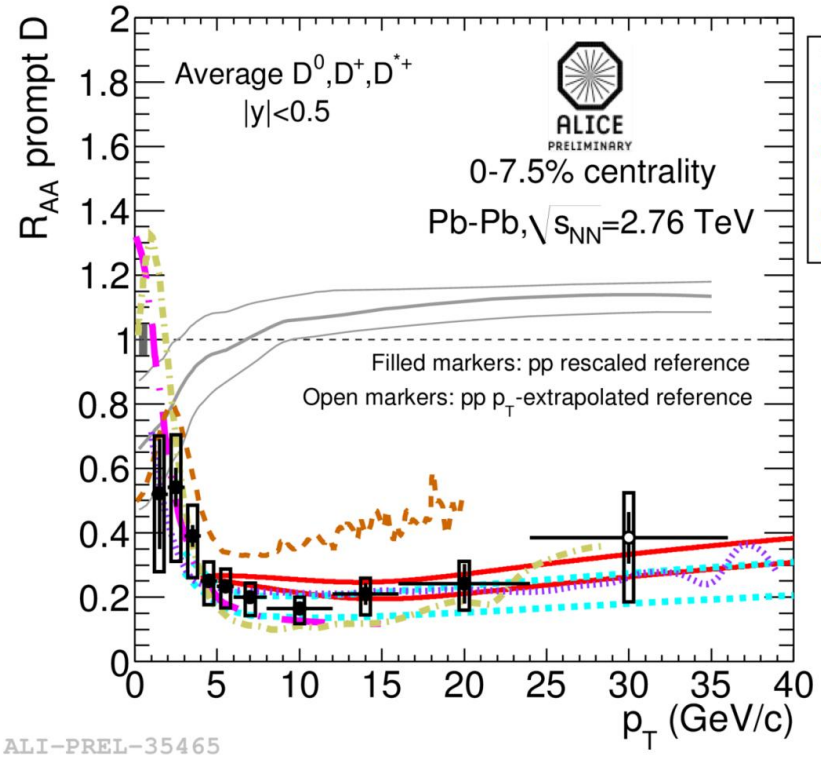
ALICE D production

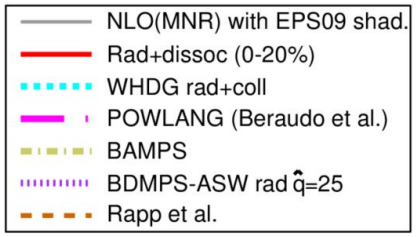


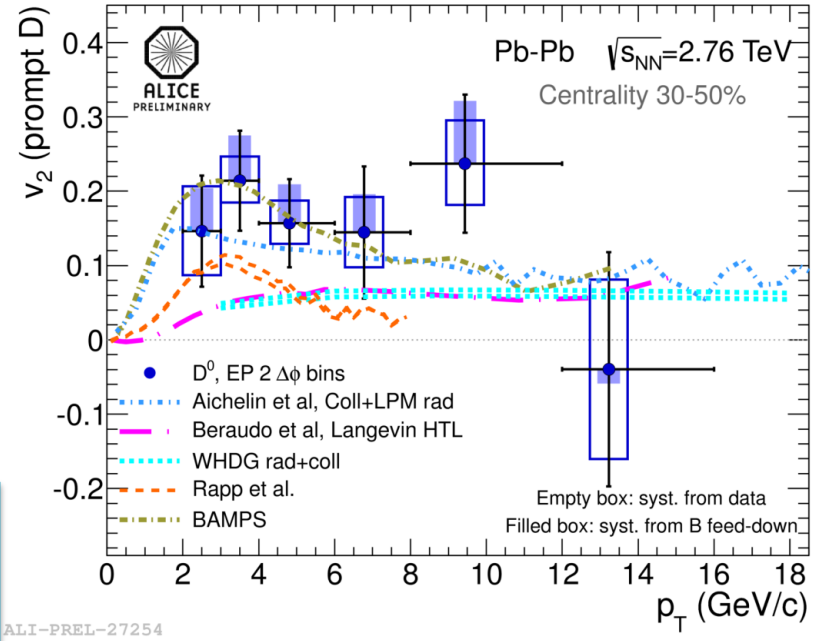
New data at higher pt compared with hadrons and pions:

- p_T < 8 GeV/c hint of slightly less suppression than for light hadrons
- p_T > 8 GeV/c both (all) very similar no indication of colour charge dependence

ALICE D production

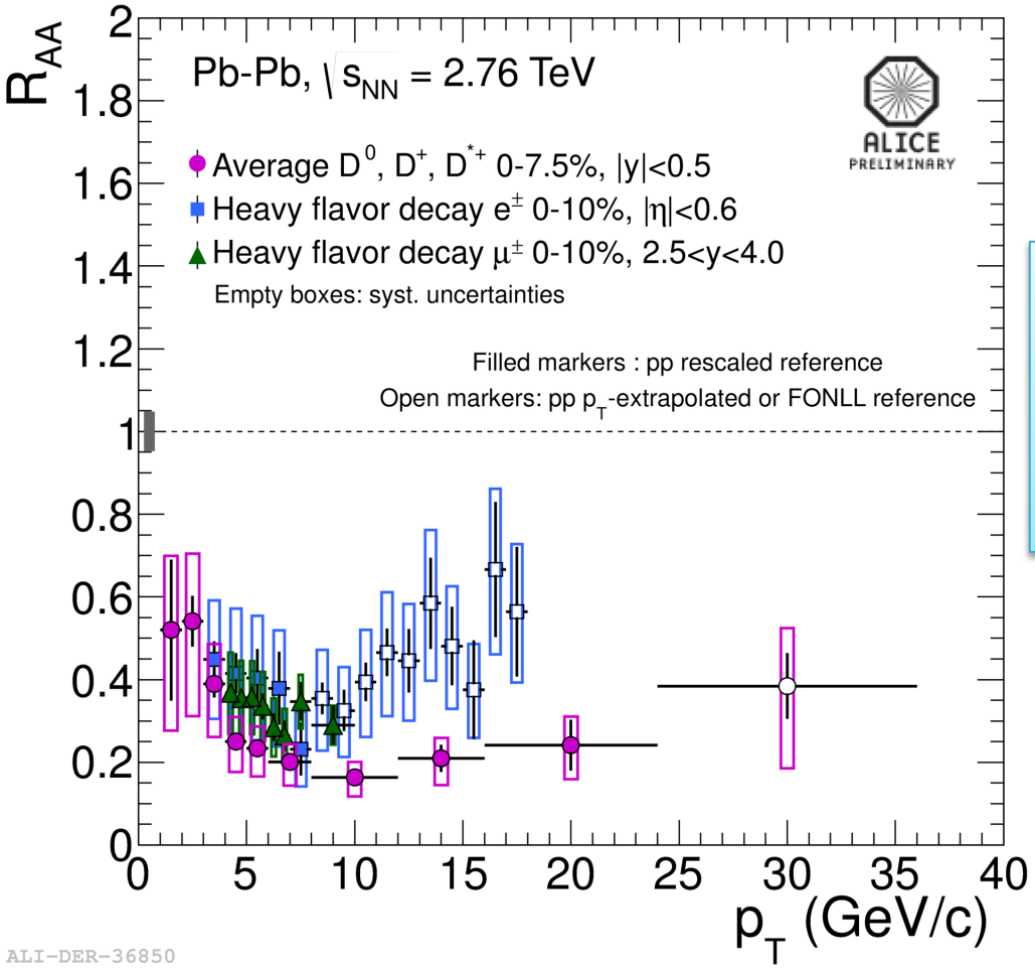






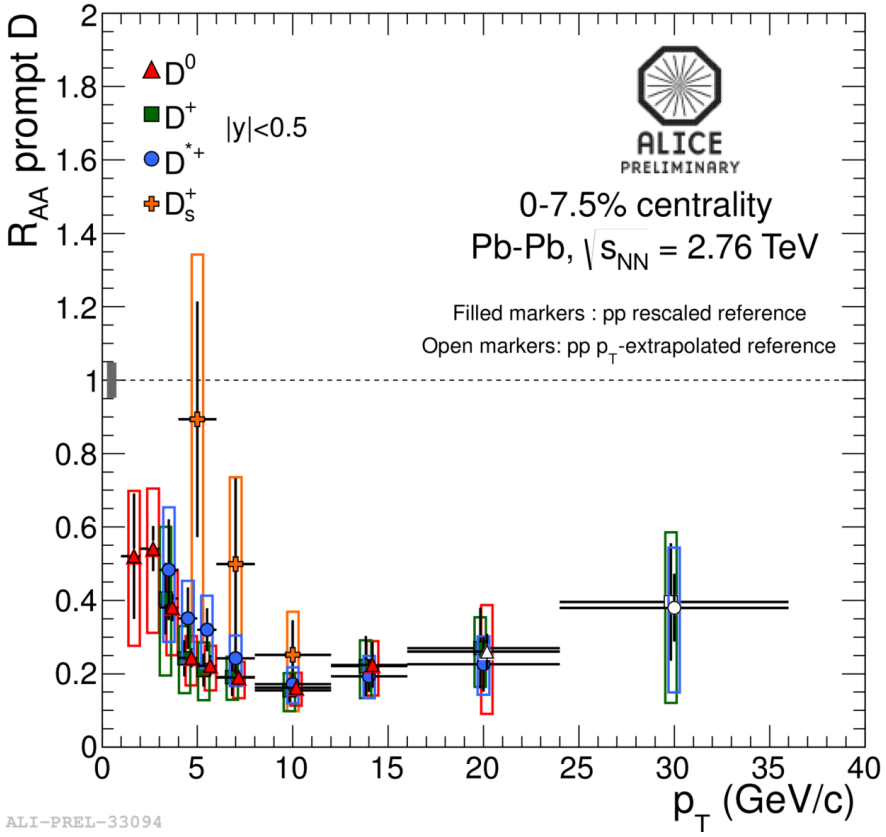
- Non zero v2 for D
- Model needs a simultaneous description of R_{AA} and v_2

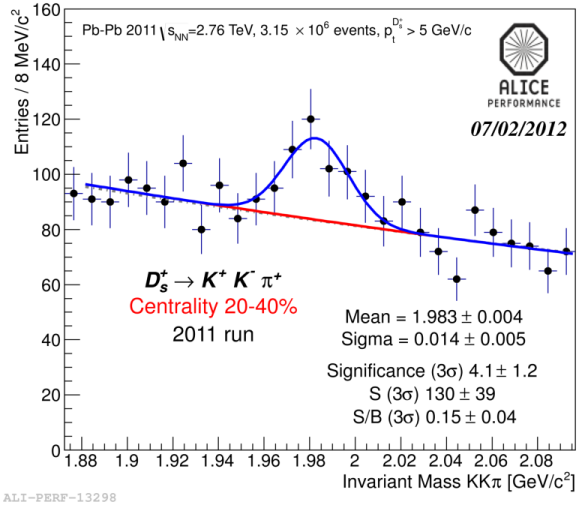
ALICE D production



- HF decay into e and μ have similar behavoir as D at low pt
- At high pt electrons go higher → B contribution ?

ALICE D_s production



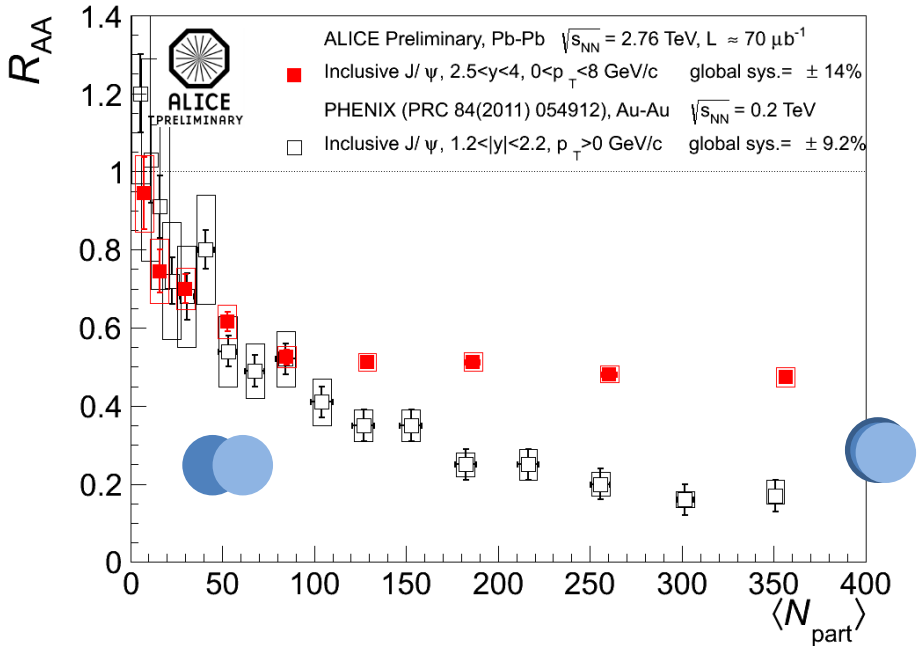


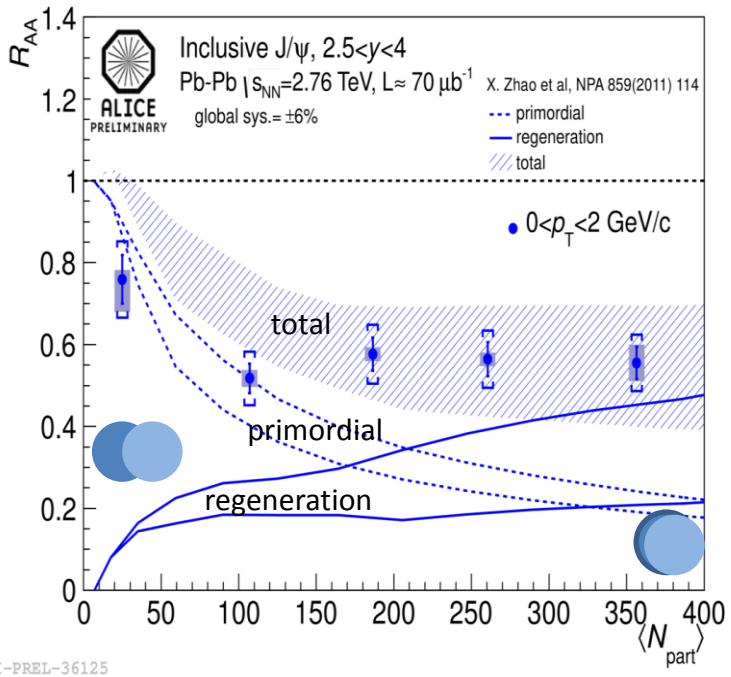
D_s signal shows hints for a lower suppression maybe also here some indications of recombination processes

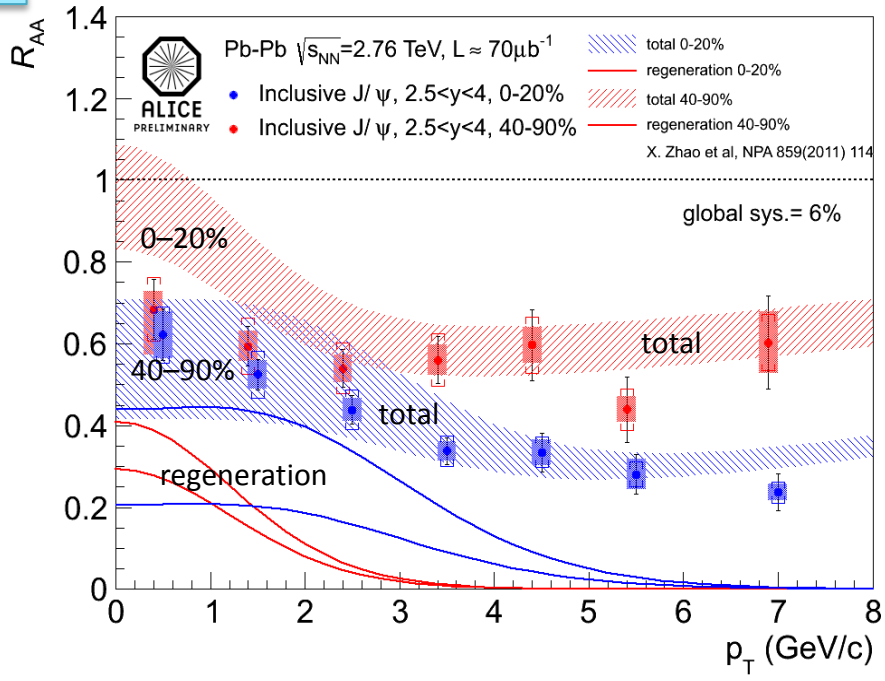
ALICE Charmonium Forward region

J/psi productions

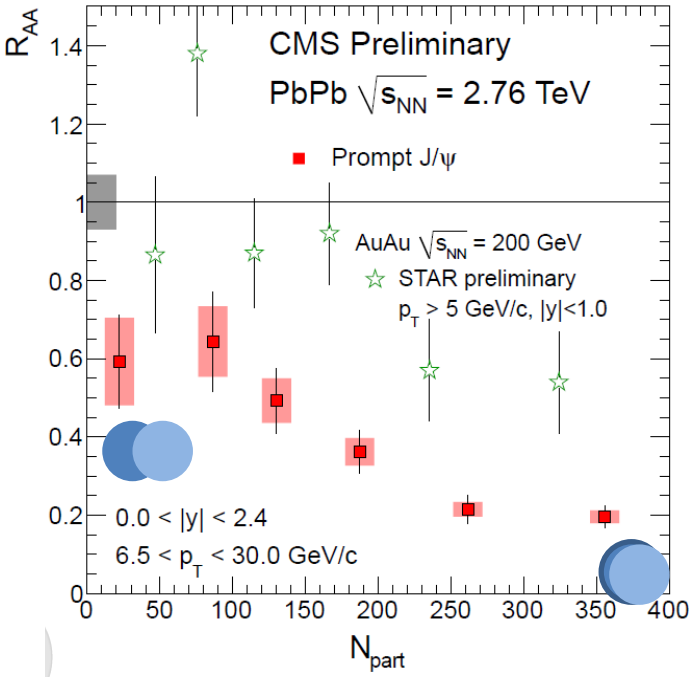
- ALICE R_{AA} higher than RHIC at low centrality
- Comparison with MC indicates contribution from rigeneration
- The effect is more visible at low pt and low centrality

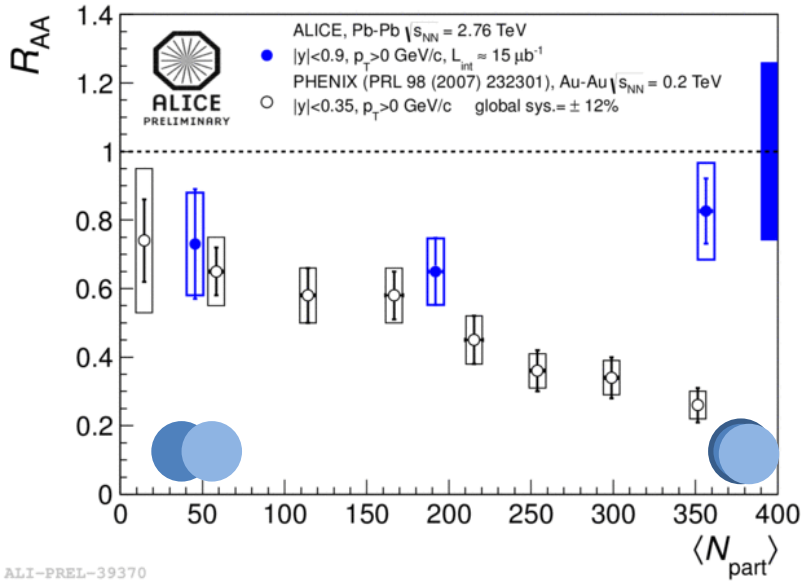






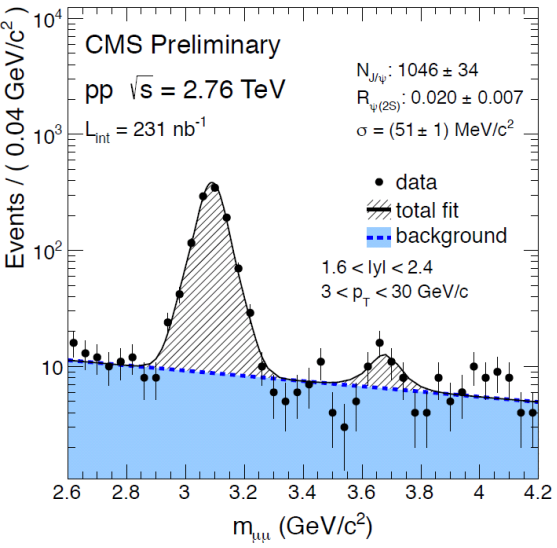
ALICE Charmonium in the central region

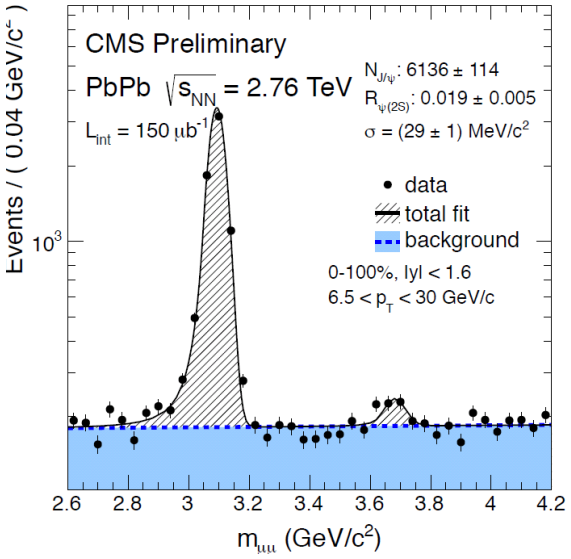


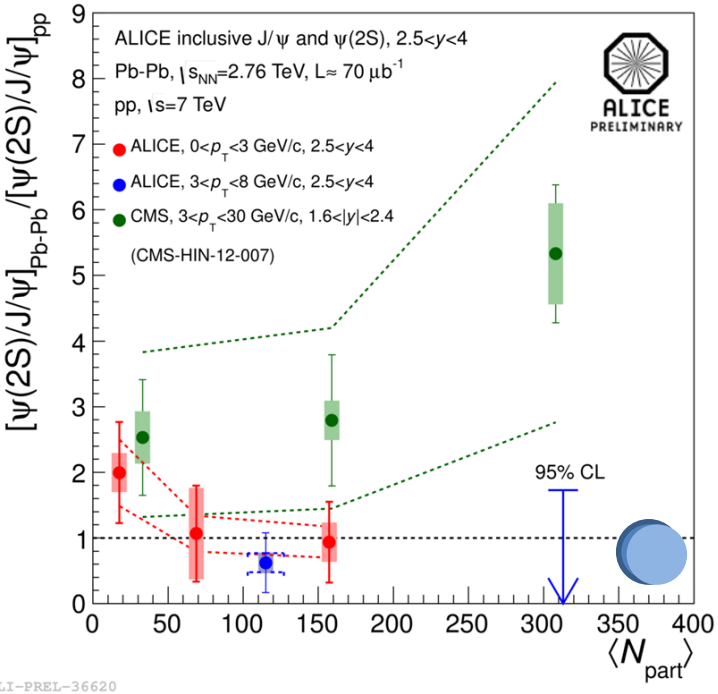


- Alice > PHENIX in central rapidity regions
- CMS < STAR for prompt J/Ψ ....

ALICE Charmonium In the central region

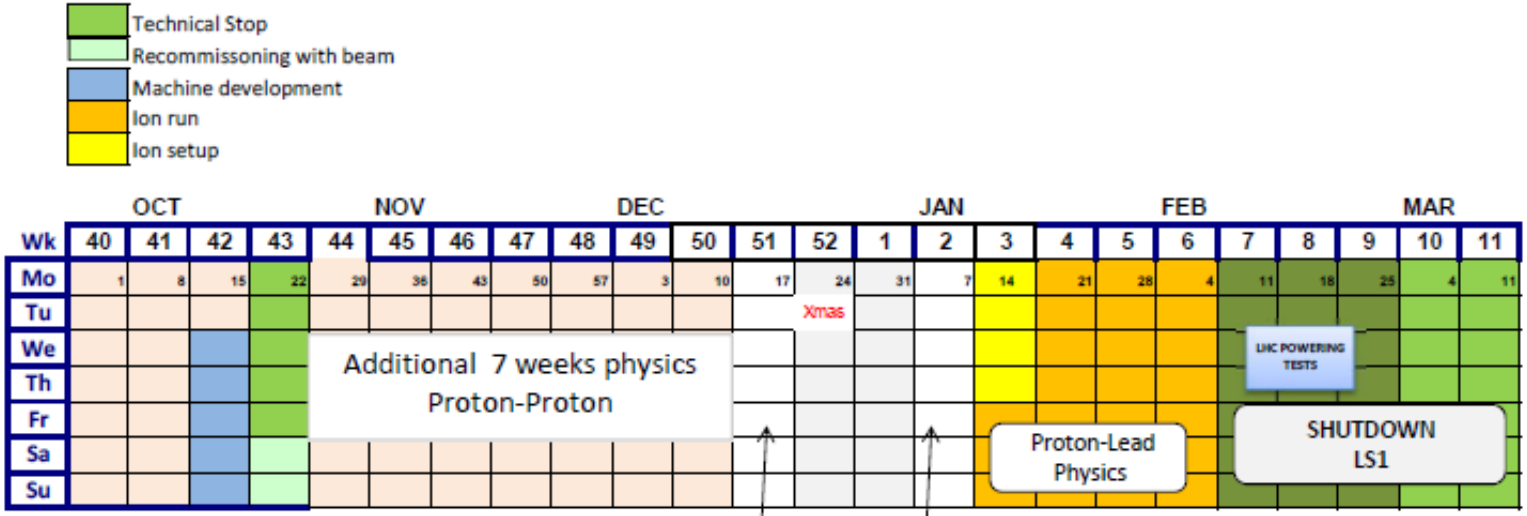






CMS Ψ′ production less suppressed than J/ Ψ
ALICE does not confirm , but different momenta cuts used

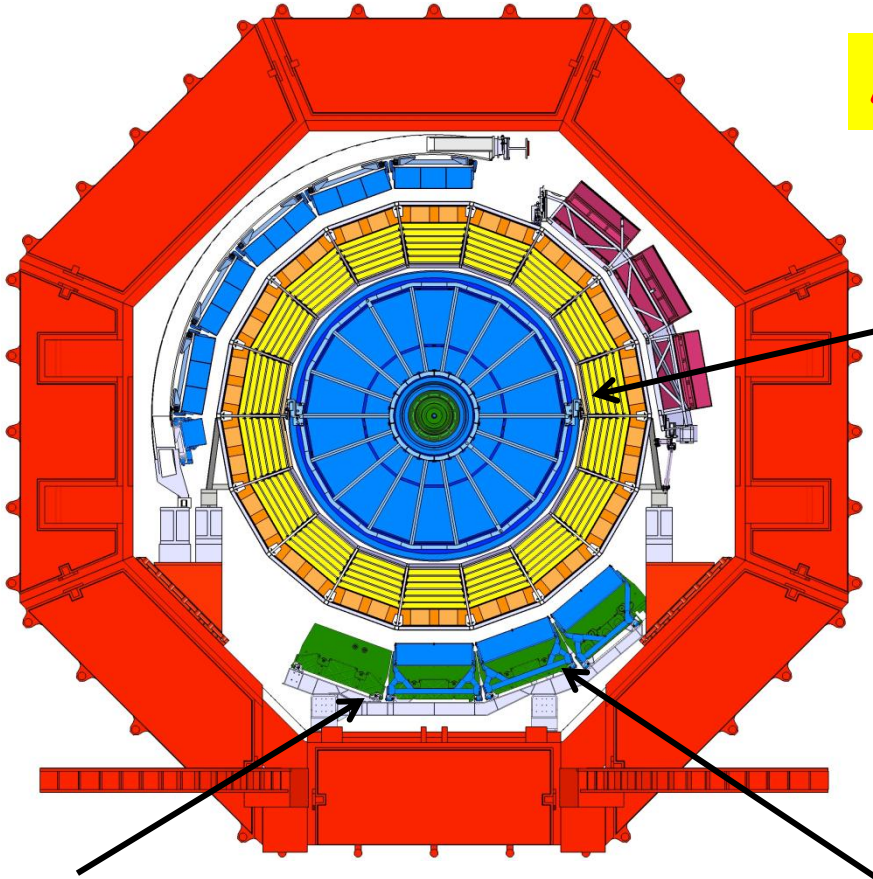
ALICE in the near future ....



→Until end 2014 ....

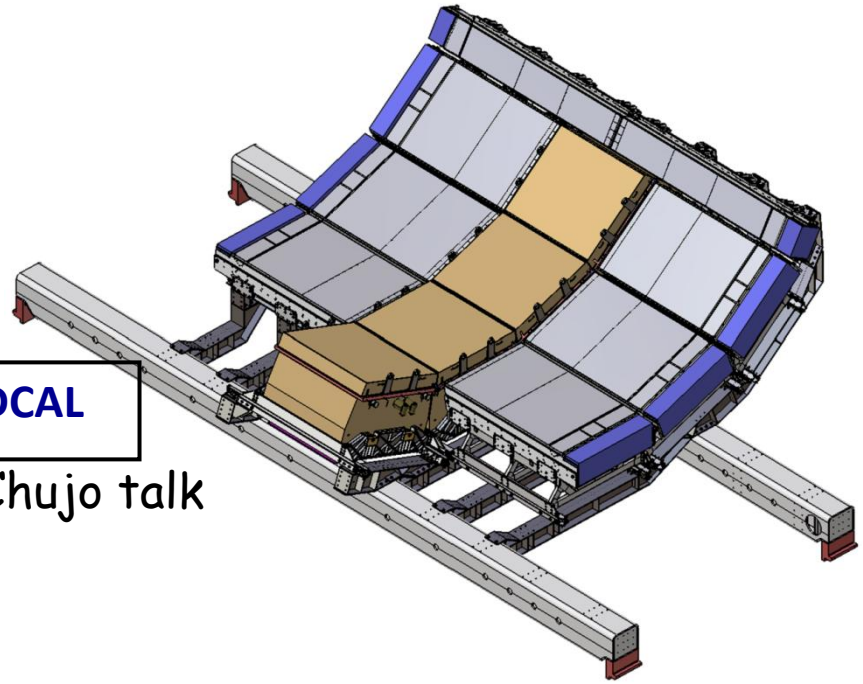
Proton-Lead run

ALICE completion during LS1



FULL TRD

4th PHOS SM



DCAL

T. Chujo talk

ALICE in the far future ....

Three main "unique" physics topics for the upgraded ALICE detector:

1. **Heavy-flavour transport parameters in the QGP**
   - Heavy-quark diffusion coefficient (QGP E.o.S, viscosity of the QGP fluid)
   - Heavy-quark thermalization and hadronization in the QGP
   - Mass dependence of parton energy loss in QGP medium

2. **Low-mass dielectrons: thermal photons and vector mesons from the QGP**
   - Photons from the QGP ($\gamma \rightarrow e^+e^-$) → map temperature during system evolution
   - Modification of ρ spectral function ($\rho \rightarrow e^+e^-$) → chiral symmetry restoration

3. **Charmonia (J/ψ and ψ') down to zero *pT***
   - Only the comparison of the two states can shed light on the suppression/regeneration mechanism
   - Study QGP-density dependence with measurements at central and forward rapidity

ALICE in the far future ....

Requirements:

- Low field and low material (precise measurements at low *pT)*
- High tracking precision (heavy flavour vertices)
- Particle identification (electrons and hadrons, ALICE's "specialities")
- High-rate capability (no trigger possible due to low S/B → store all events)

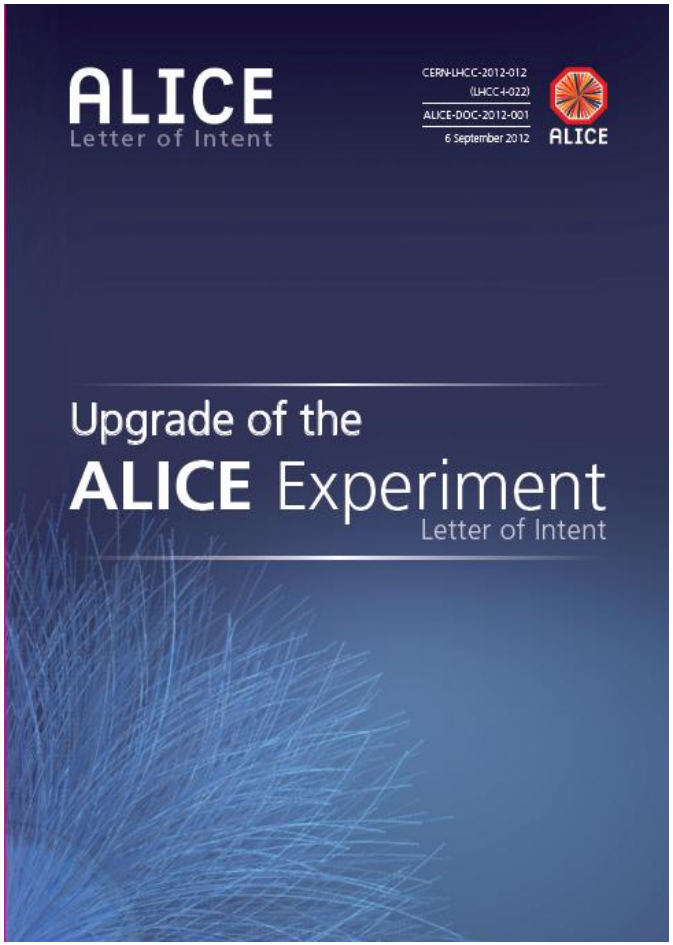
Targets:

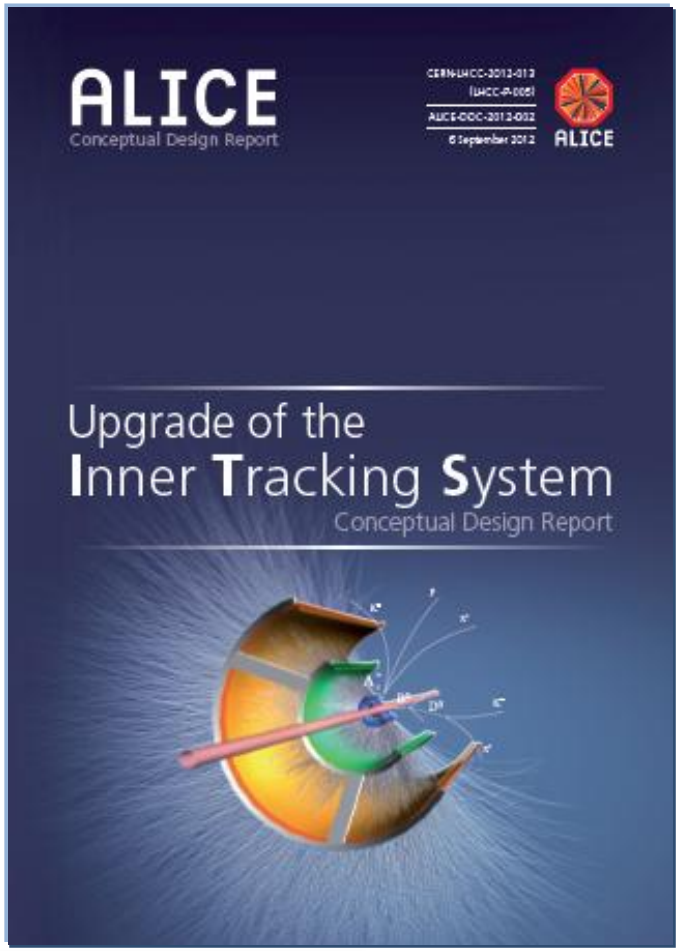
- LHC Pb-Pb luminosity after LS2 (~6×10^{27} $cm^{-2}s^{-1}$= 10 x current)
- Upgraded ALICE records Pb data at 50 kHz (currently <0.5 kHz)
- Integrate L_{int}=10 nb^{-1} after LS2 (~10^{11} minium-bias Pb-Pb events)

These imply:

- New ITS with largely improved resolution (x3), especially at low *pT*
- New readout GEM for TPC
- Upgraded read-out for EMCAL , HMPID , PHOS, TOF, TRD, MUON, ZDC
- Upgraded DAQ/HLT/Offline with High-rate capability

LoI and ITS CDR for the Upgrades
Documents : LHCC-I-022 and LHCC-P-005

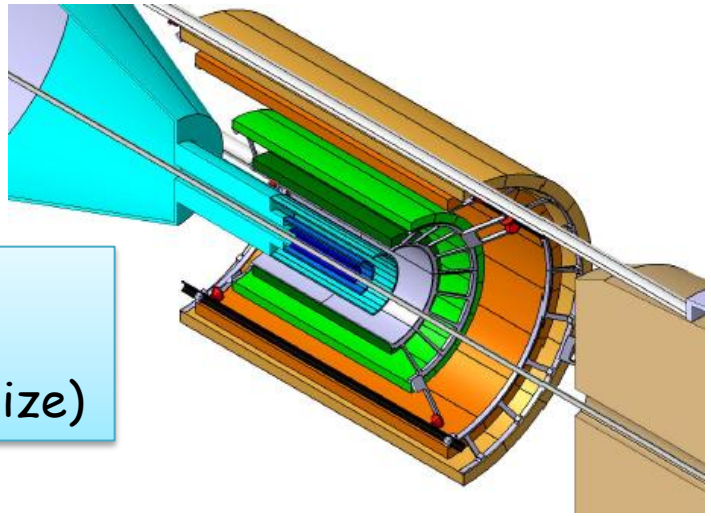




Ongoing studies for furthers upgrades:

- Muon Forward Tracker (MFT)
- Very High Momentum PID (VHMPID)
- Forward Calorimter at low angle (FOCAL)

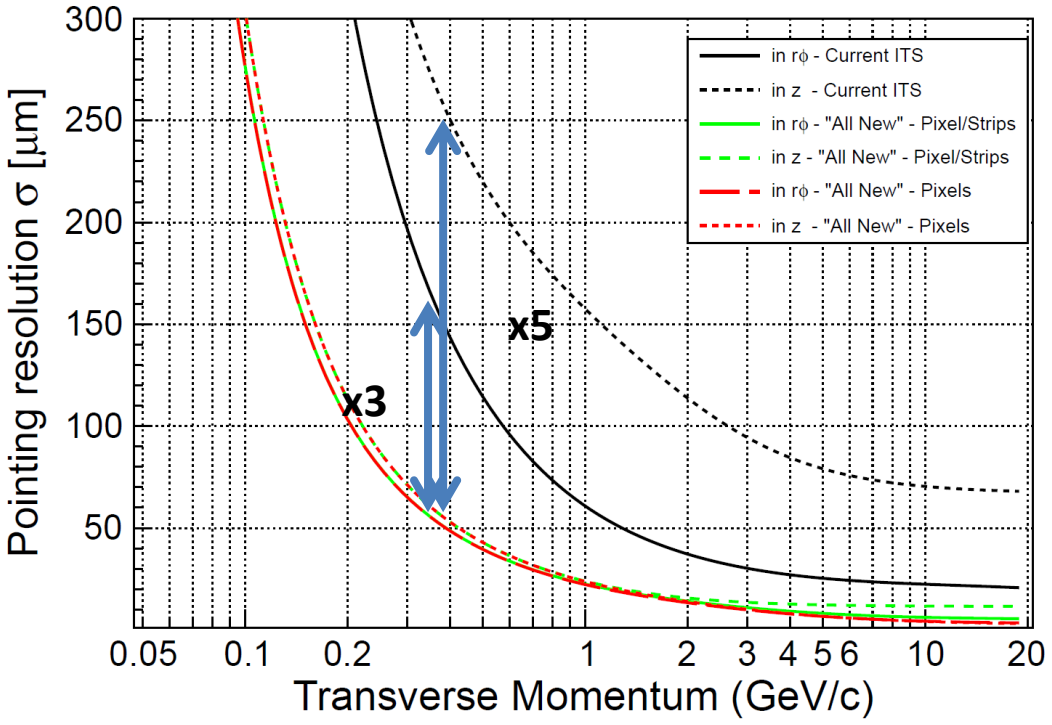
New ITS



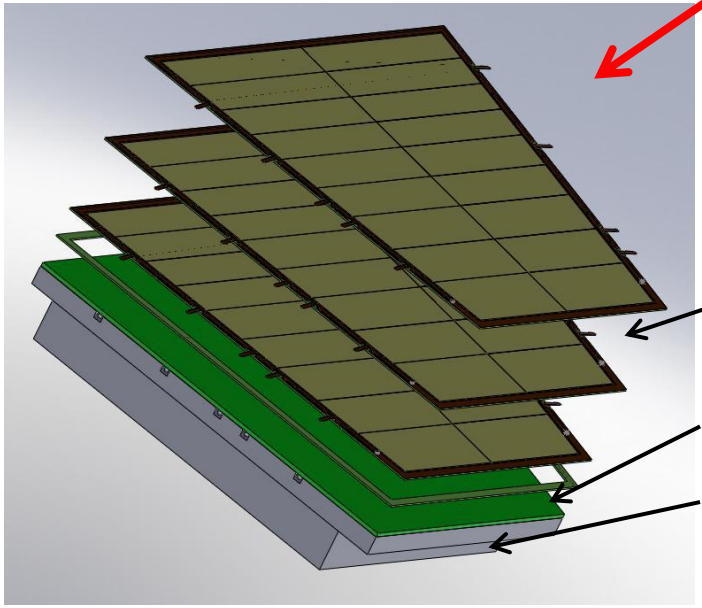
- Closer (3.9 cm →2.2 cm)
- Thinner (1% → 0.3% of *X0 / layer)*
- Smaller pixels (50x425 μm² → 20x20 μm² cell size)

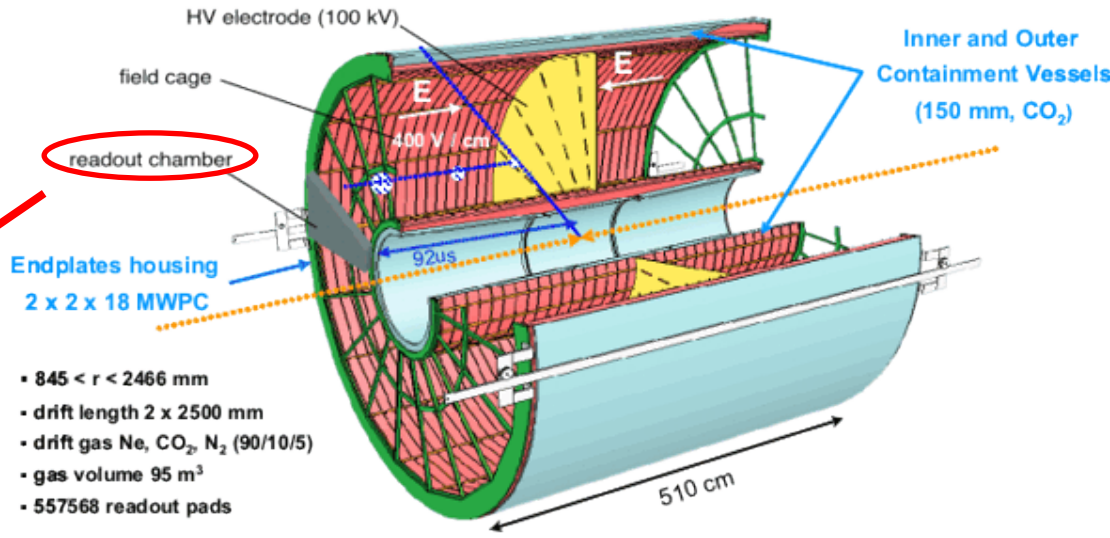
7 layers in total

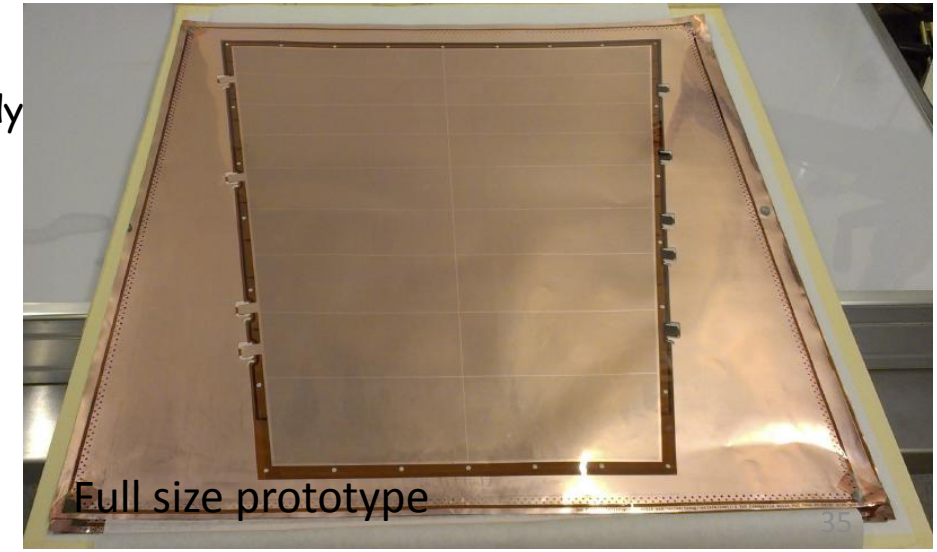
Option 1 : all pixel
Option 2 : 3 pixel/4 Strip



New TPC readout

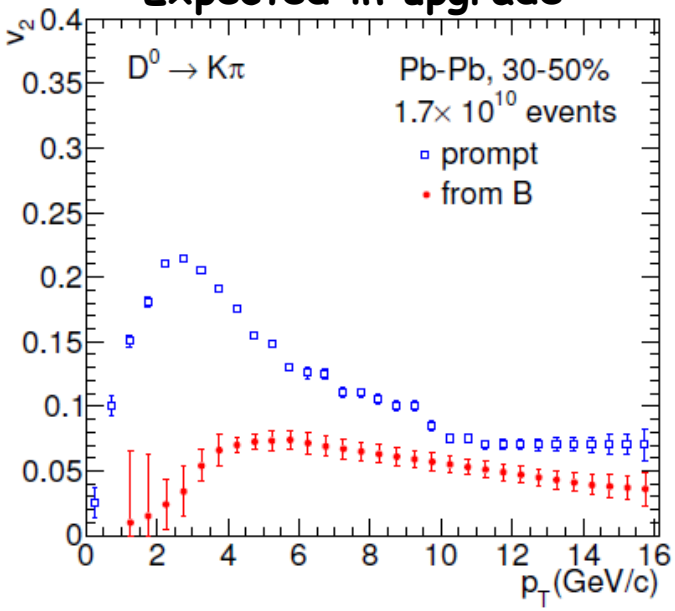




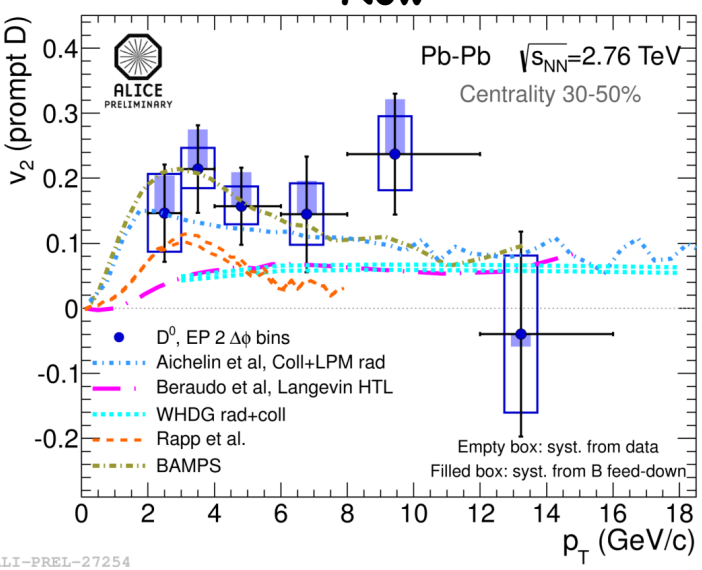


Physics gains : Charm mesons and baryons

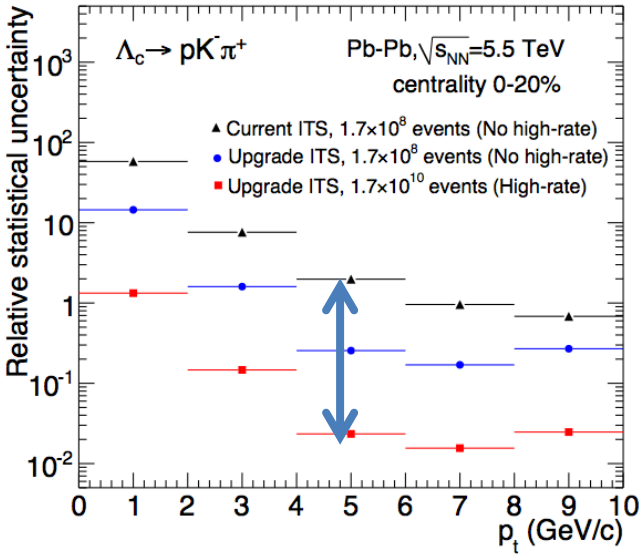
Expected in upgrade



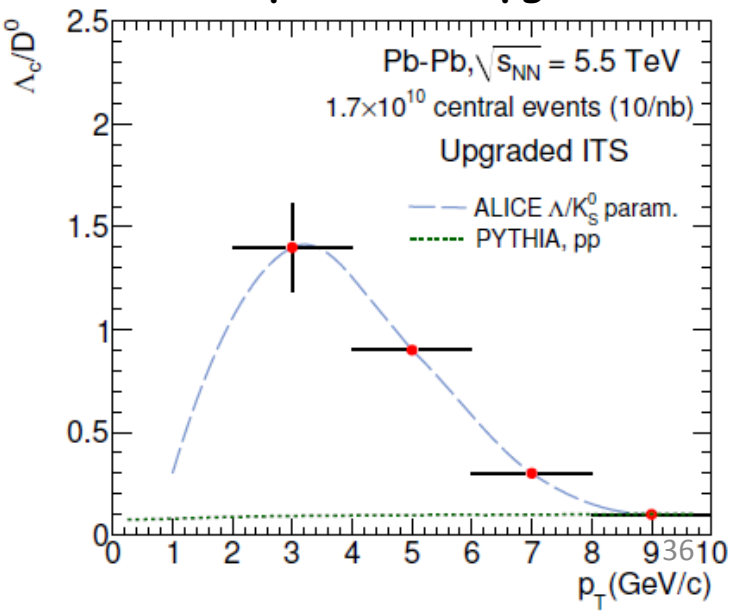
Now



Expected in upgrade

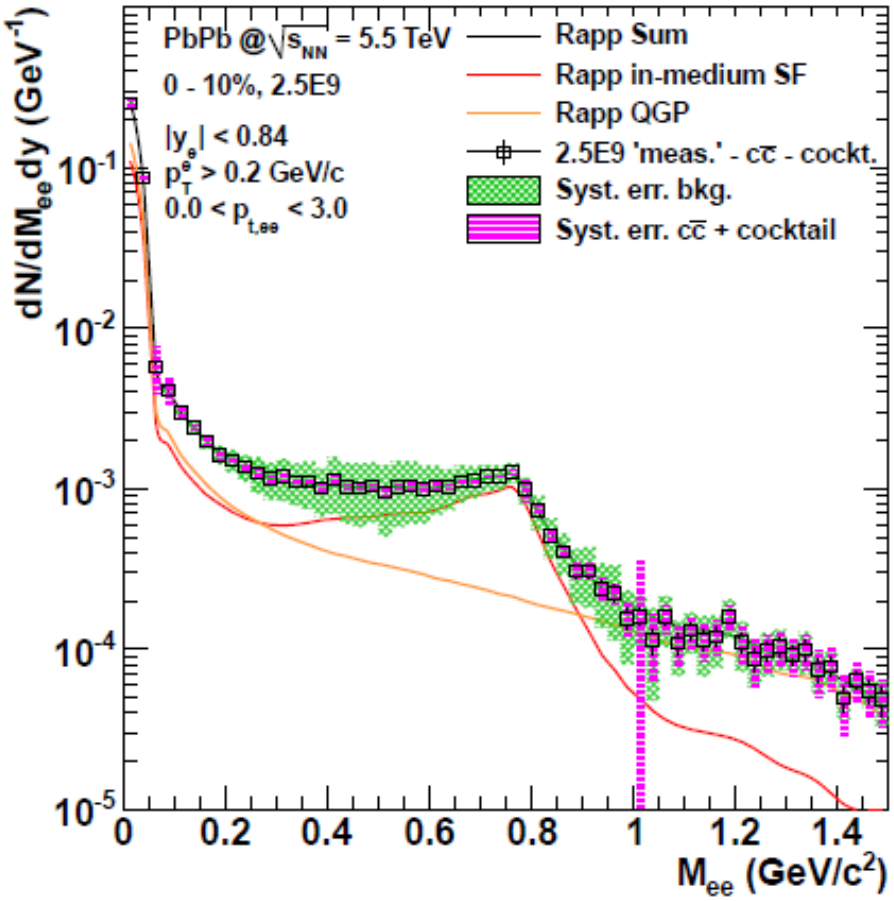


Expected in upgrade

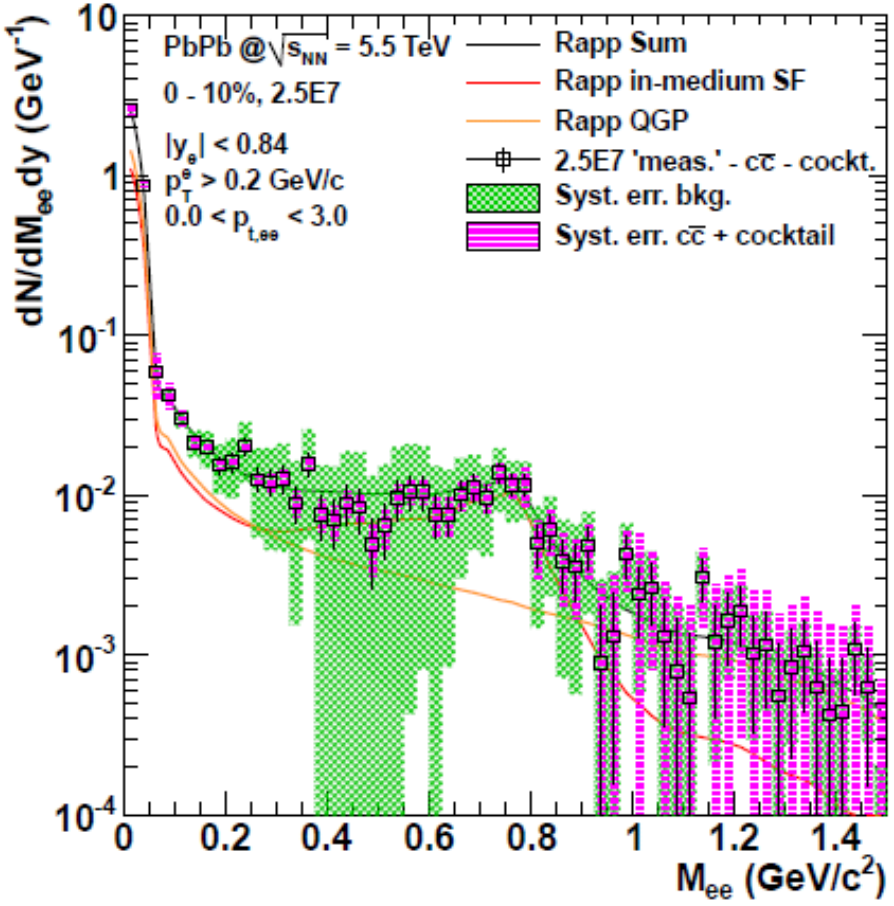


Physics gains : dileptons

Expected in upgrade

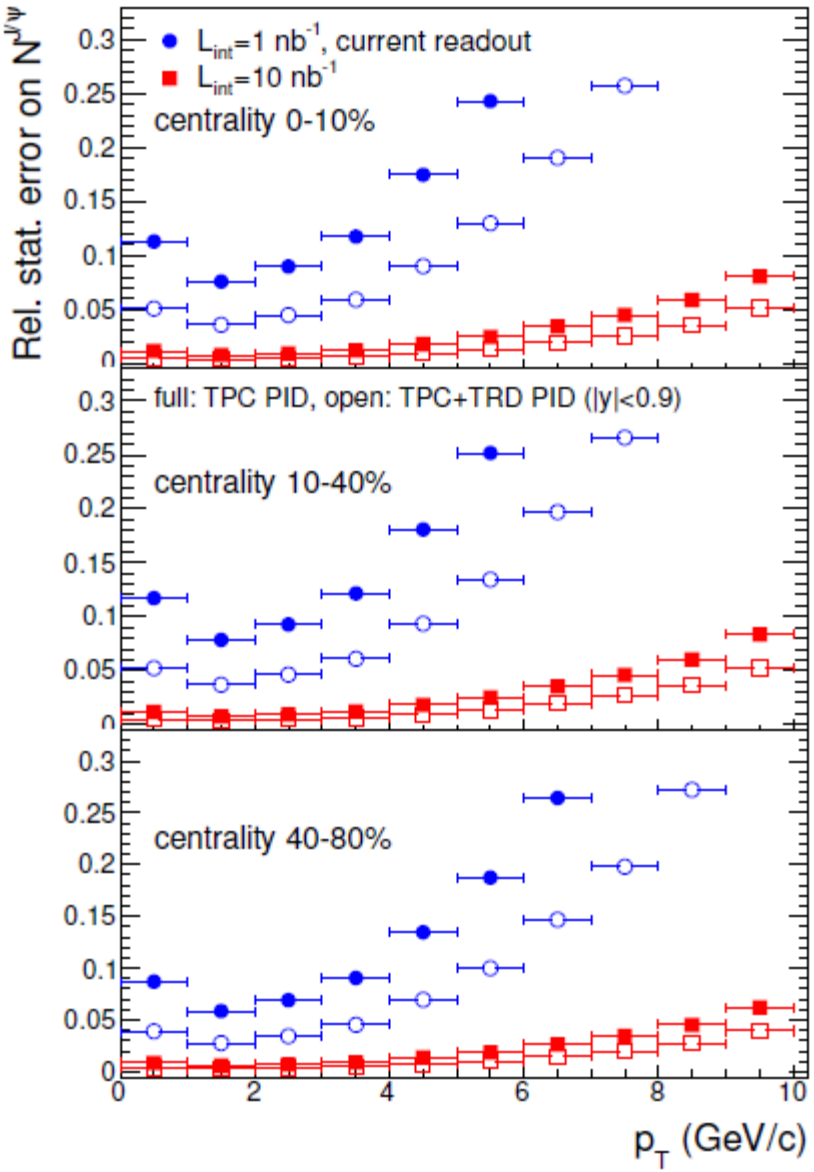


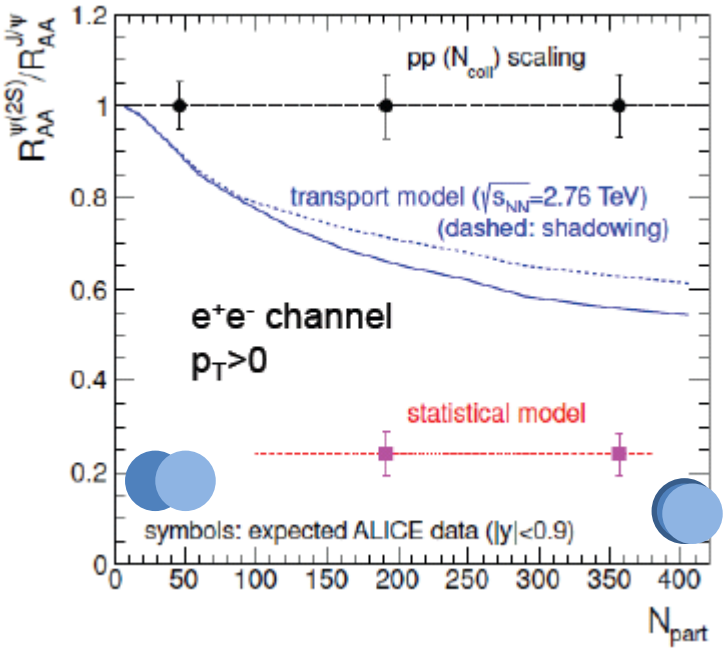
With current ALICE



Physics gains : Charmonia

Expected in upgrade





Much better discrimination power to distinguish various models

ALICE Upgrade Physics Reach

p_T coverage (p_T^{min}) and statistical error for current ALICE with approved programme and upgraded ALICE with extended programme.
Error in both cases at p_T^{min} of "approved".

Topic	Observable	Approved (1/nb delivered, 0.1/nb m.b.)	Upgrade (10/nb delivered, 10/nb m.b.)
Heavy flavour	D meson R_{AA}	p_T>1, 10%	p_T>0, 0.3%
	D from B R_{AA}	p_T>3, 30%	p_T>2, 1%
	D meson elliptic flow (for v_2=0.2)	p_T>1, 50%	p_T>0, 2.5%
	D from B elliptic flow (for v_2=0.1)	not accessible	p_T>2, 20%
	Charm baryon/meson ratio (Λ_c/D)	not accessible	p_T>2, 15%
	D_s R_{AA}	p_T>4, 15%	p_T>1, 1%
Charmonia	J/ψ R_{AA} (forward y)	p_T>0, 1%	p_T>0, 0.3%
	J/ψ R_{AA} (central y)	p_T>0, 5%	p_T>0, 0.5%
	J/ψ elliptic flow (forward y, for v_2 =0.1)	p_T>0, 15%	p_T>0, 5%
	ψ'	p_T>0, 30%	p_T>0, 10%
Dielectrons	Temperature IMR	not accessible	10% on T
	Elliptic flow IMR (for v_2=0.1)	not accessible	10%
	Low-mass vector spectral function	not accessible	p_T>0.3, 20%
Heavy nuclei	hyper(anti)nuclei, H-dibaryon	35% ($^4_\Lambda$H)	3.5% ($^4_\Lambda$H)

A possible running scenario for ALICE

2013-2014 TDRs and final approval from CERN
2014-2016 Construction

2018-LS2 Installation ALICE Upgrades

2019 – Pb–Pb 2.85 nb^{-1}
2020 – Pb–Pb 2.85 nb^{-1} (low magnetic field)
2021 – pp reference run (few months at HI cms energy)

2022 – LS3
2023 – LS3

2024 – Pb–Pb 2.85 nb^{-1}
2025 – $\frac{1}{2}$ Pb–Pb 1.42 nb^{-1} + $\frac{1}{2}$ p–Pb 50 nb^{-1}
2026 – Pb–Pb 2.85 nb^{-1}

Conclusions

- ALICE is collecting data in many different types of collisions: Pb-Pb , pp, p-Pb , gamma-Pb
- ALICE uniques detectors capability allow results complementary w.r.t. the other LHC detectors.
- Different types of measurements (Global variable, Bulk properties, Heavy Quarks, jet....) have characterized the properties of the hot medium produced at LHC in Pb-Pb collisions.
- Present measurements confirm the RHIC picture, adding new informations (expecially in the HF and jet part) , with some new and unexpected results (suppression and v2 of charm, suppression at high pt for example).
- The complete understanding of the QGP properties will require more precise measurements which the approved upgrade program will perform.