HF chapter for Yellow Report

Elena Bruna for the “HF-chapter” group

INFN - To

March. 6th 2018

Contributors: E. Bruna, Z. Citron, A. Dainese, G. Innocenti, Y-J. Lee, J. Sun, M. Winn, S. Bass, A. Beraudo, V. Greco, I. Vitev

Key questions to address with HF in Run3/4

QGP properties

- Impact of **collisional / radiative** en. loss
- **Radial distribution** of energy lost
- Understanding **dead-cone effect**
- **Transport** properties
- **Recombination vs fragmentation**
- **Magnetic effects** on HF production

Key questions to address with HF in Run3/4

QGP properties

- Impact of **collisional / radiative** en. loss
- **Radial distribution** of energy lost
- Understanding **dead-cone effect**
- **Transport** properties
- **Recombination vs fragmentation**
- **Magnetic effects** on HF production

Charm, beauty R_{AA}

Jets and correlations

v_2, relation to bulk v_2 (ESE)

D_s, B_s, charm and beauty baryons

v_1

Key questions to address with HF in Run3/4

QGP properties

- Impact of **collisional / radiative** en. loss
- **Radial distribution** of energy lost
- Understanding **dead-cone effect**
- **Transport** properties
- **Recombination vs fragmentation**
- **Magnetic effects** on HF production

Charm, beauty R_{AA}

Jets and correlations

v_2, relation to bulk v_2 (ESE)

D_s, B_s, charm and beauty baryons

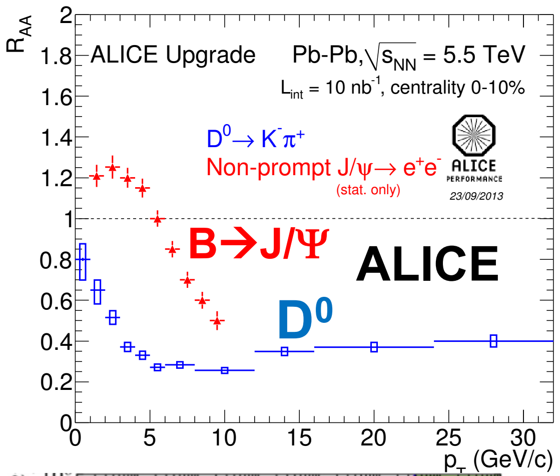
v_1

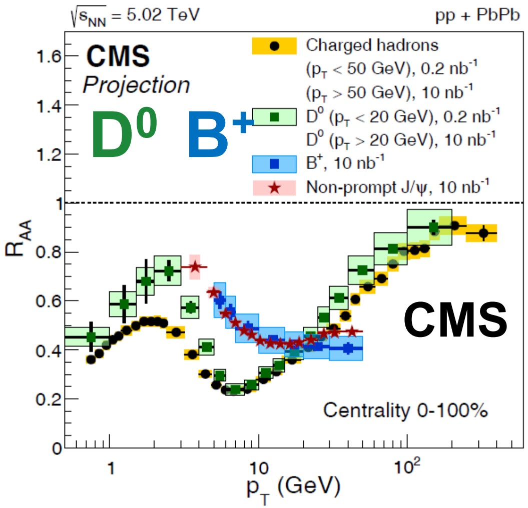
Small systems

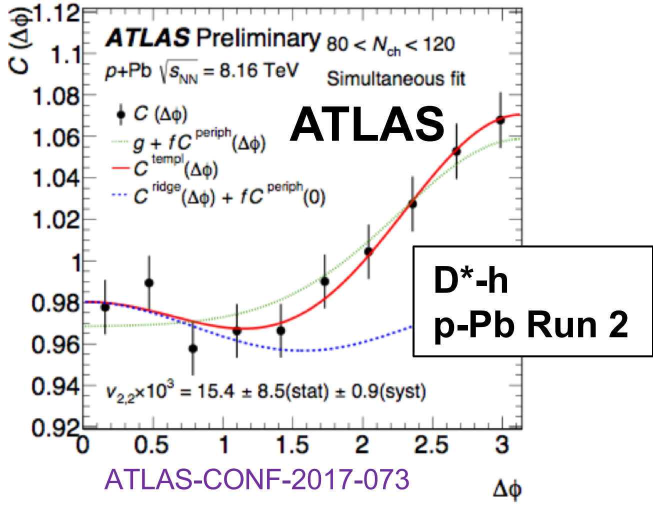
- HF production mechanisms
- **Onset of medium-like effects** for HF

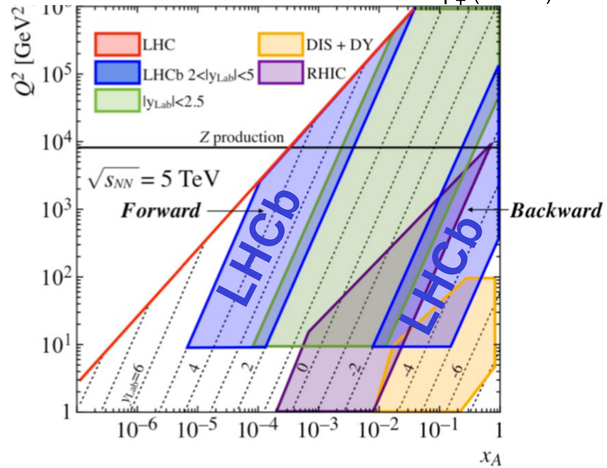
Multiplicity dependence of HF yields, v_2

Complementarity from the LHC experiments









Large phase space coverage
Different observables
Different systems

What precision do we need to put quantitative constraints on theory?

Preparation of the HF chapter

- Two meetings: Jan 25, Feb 20
  - Experimentalists + theorists
- Google doc to discuss the different scenarios
- Proposal to divide the chapter in different sections, with focus in each of them on:
  - State of the art
  - New projections: what can we learn more
  - Connection to theory to strengthen the physics message

Heavy-flavor chapter: outline (1/2)

1. Intro
2. Nuclear modification, elliptic flow
3. Directed flow

1.1 Impact of new detectors on heavy-flavour observables

1.2 Nuclear modification factor and collective flow

- Experiments: state of the art (open questions?) and estimates for low and high pt.
  - Observables: RAA, v2, v3 for D, B mesons (when possible for both), event-shape engineering v2 analyses
  - Complementarity: focus on complementarity (pt, y), provide plot of pt vs y for all experiments for a couple of observables.
- Connection to theory: constrain c and b diffusion coefficients. Additional insights from v2(D) vs v2(pi) on event-by-event

1.3 Directed flow

- Experiments: state of the art of v1 measurements, estimates for low and high pt
- Connection to theory: sensitive to early magnetic field

Outline (2/2)

4. c, b baryons
5. HF jets
6. (small systems)
7. HE-LHC
8. Conclusions

1.4 Charm and beauty baryons

- Experiments: state of the art, complementarity from different experiments. Observables: Lc, Lb.
- Connection to theory: potential to discriminate between different coalescence models.

1.5 Heavy-flavour jets

- Experiments: B, D-jets, Di-Bjets
- Connection to theory: constraints on mass dependence of in-medium splitting functions. Role of coherence (decoherence angle comparable to dead-cone angle).

→ **More differential observables: qualitatively new insights into dead cone & in-medium splitting**

1.6 Heavy flavours in small systems (in dedicate chapter)

- RpPb (D, B, baryons): mid and fwd rapidity to constrain CNM/small QGP effects in wide kinematic range
- v2 in high-multiplicity pPb (D, HF-decay electrons and muons) to constrain initial/final state effects
- pp high-multiplicity bridge between pp to PbPb to study HF production processes, onset of coalescence. Theory connection crucial

→ **Will enter the small-system chapter**

1.7 Plans for HE-LHC

Under discussion

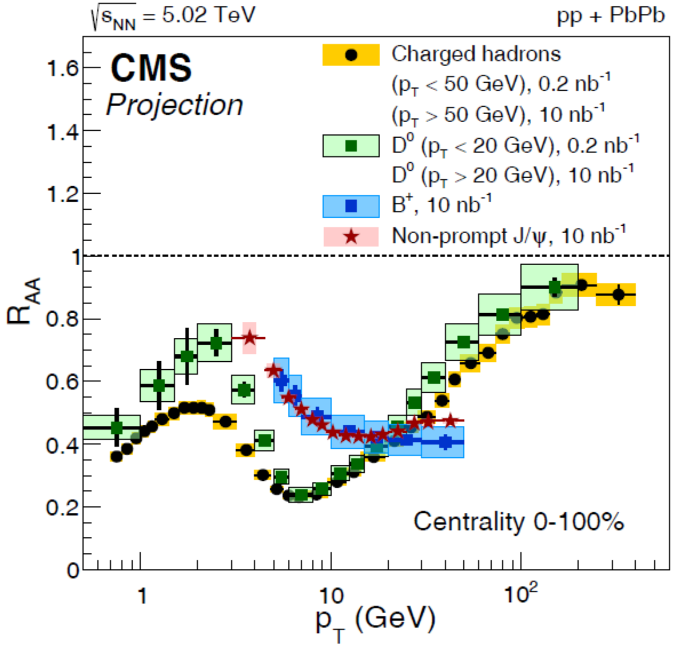
Ongoing studies in ALICE-HF for Run3/4

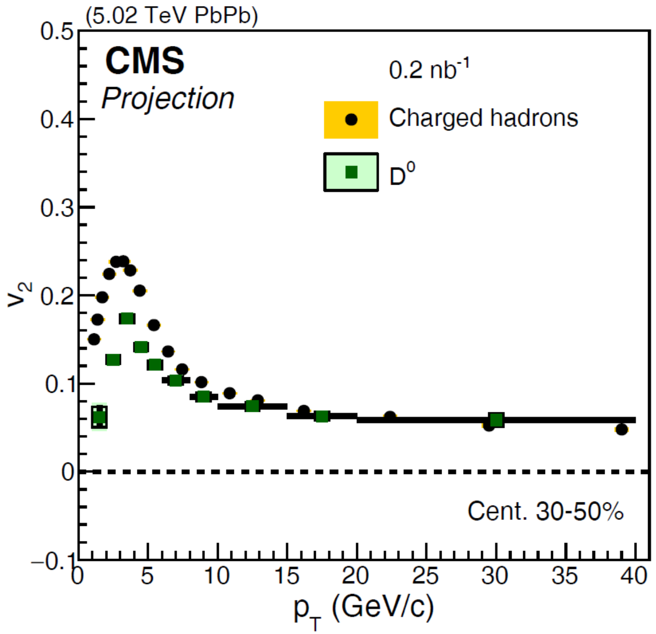
CERN-LHCC-2013-024
CERN-LHCC-2015-001
CERN-THESIS-2016-037
CERN-THESIS-2018-002

- Developments from what is available from ITS/MFT TDRs
  - Assessment of systematic uncertainties in case of projections with only statistical errors
  - Machine learning techniques for beauty baryons
  - D v_2 with event-shape engineering techniques

- New studies
  - $B^0 \rightarrow D^- e^+ \nu$
  - Heavy-flavor jets (D-jets)

CMS plans for HF studies

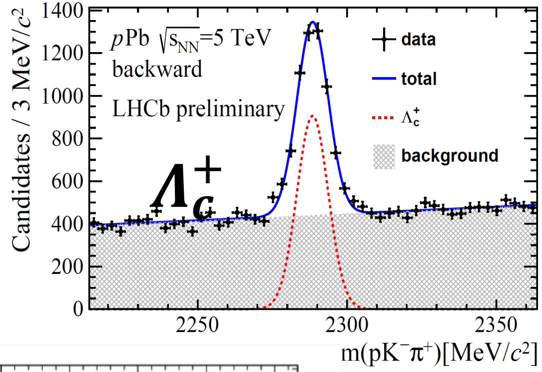




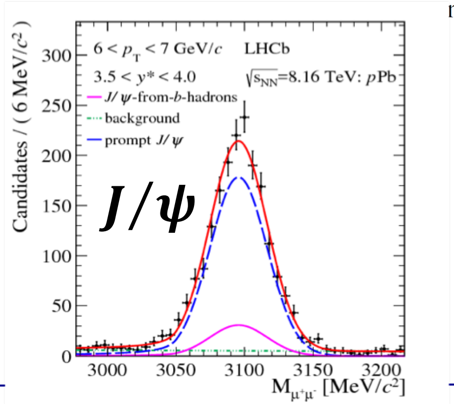
- Flavor dependence of parton energy loss and jet quenching could be studied with high statistics heavy flavor mesons
- Elliptic flow of charged hadrons and D^0 mesons
- **More differentially: charm and beauty jets, di-jets and substructures**

LHCb plans for HF studies

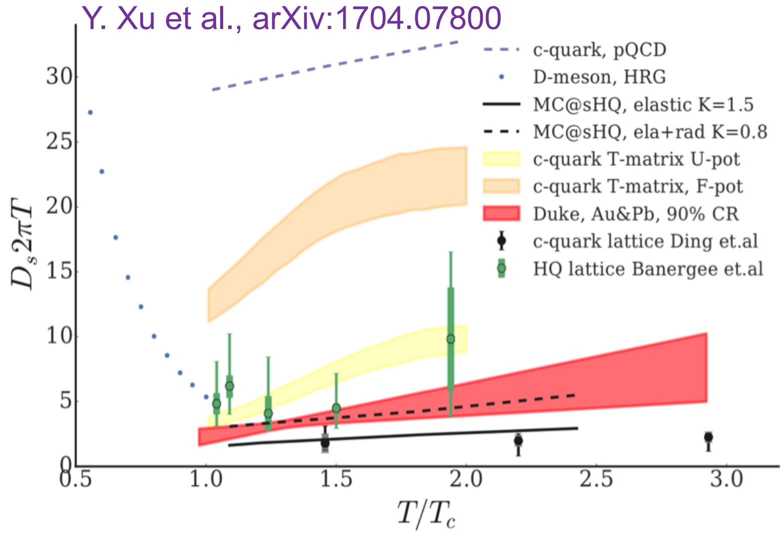
- PbPb
  - Ongoing full simulation of Λ_c^+ as show-case to study centralitv reach in Run3



- *p*Pb
  - assumed luminosity at $\sqrt{s_{NN}} = 8.16$ TeV: 160nb^{-1}
  - Possible measurements:
    - charm/beauty baryons
    - Heavy flavor correlations
  - In general, not limited by statistics
  - Need ideas on observables for the estimations
    - Limited manpower
    - Observables complement other experiments



Connection with theory



What precision do we need to put quantitative constraints on theory?

Some ideas to assess constraining power of D_s diffusion coefficient with precision from Run 3-4:

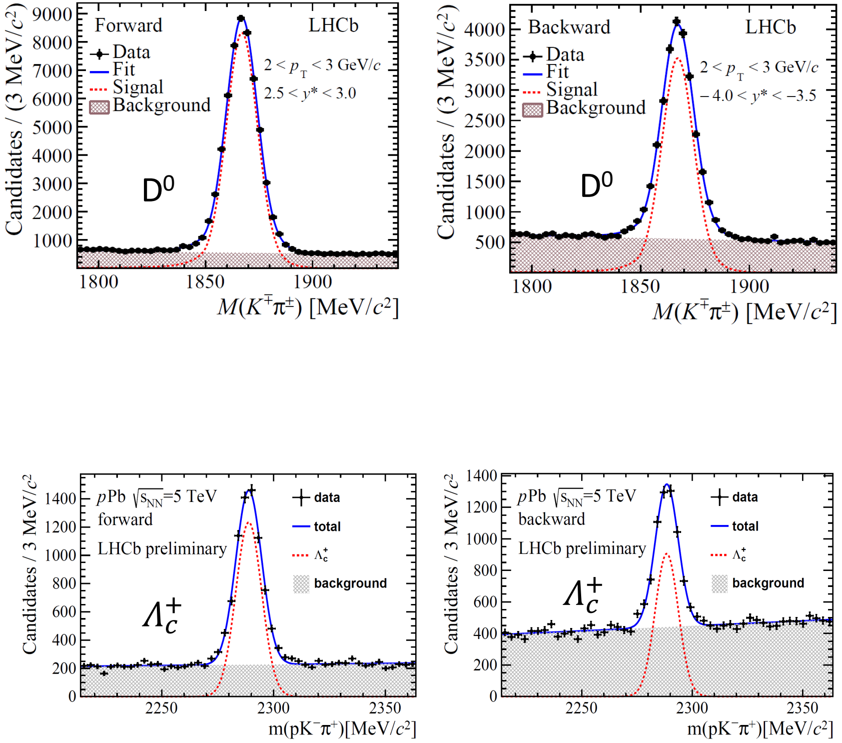
- Bayesian approach applied to our pseudo-data (R_{AA}, v_2, v_3 from all experiments)
- Fit pseudo-data scanning D_s values and providing a χ^2

See next talk

Backup

Raw yields estimation for open charm based on *p*Pb data

	D^0	Λ_c^+
Raw yield 5 TeV 1.6nb^{-1}	1M	15600
Estimated yield	~200M	3.1M

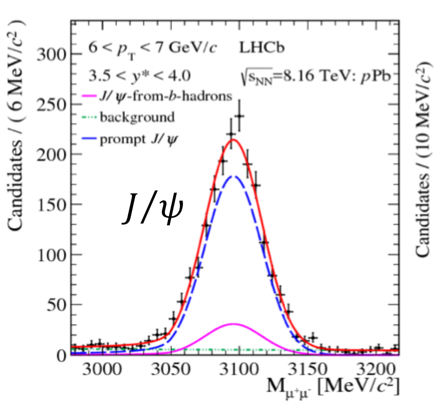


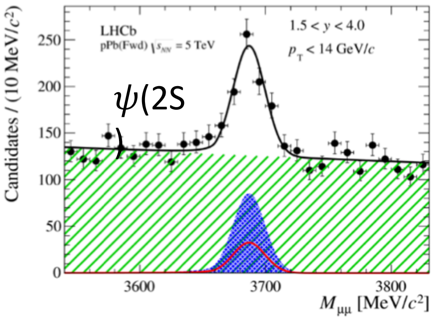
Forward and backward luminosities are added together

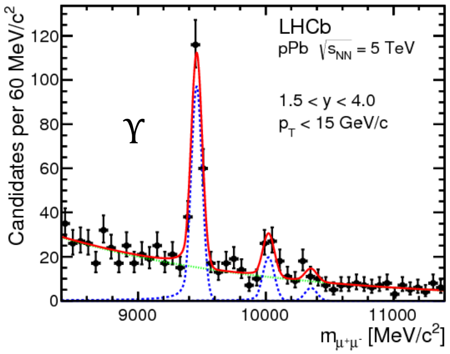
Assuming the charm cross section increases by a factor of 2 from 5 TeV to 8 TeV

Dimuon yields estimation based on *p*Pb data

	Raw yields from data	Estimated yields
J/ψ	1.1×10^{6} 8 TeV, 30nb^{-1}	5.8×10^{6}
$\psi(2S)$	495 5 TeV, 1.6nb^{-1}	1×10^{5}
$\Upsilon(1S)$	261 5 TeV, 1.6nb^{-1}	5.2×10^{4}
$\Upsilon(2S)$	58 5 TeV, 1.6nb^{-1}	1.2×10^{4}
$\Upsilon(3S)$	20 5 TeV, 1.6nb^{-1}	4×10^{3}



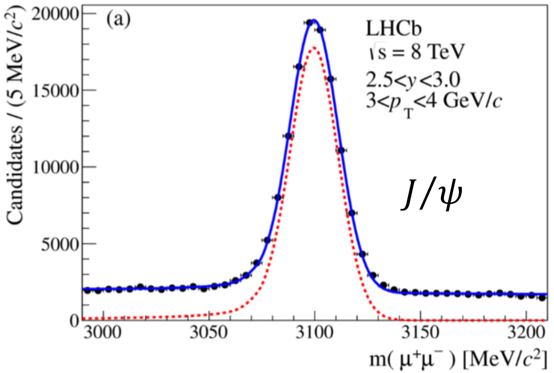


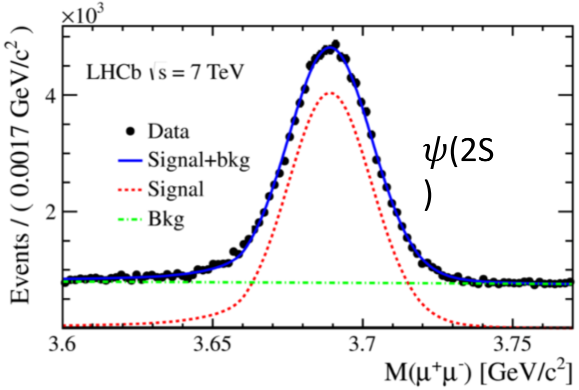


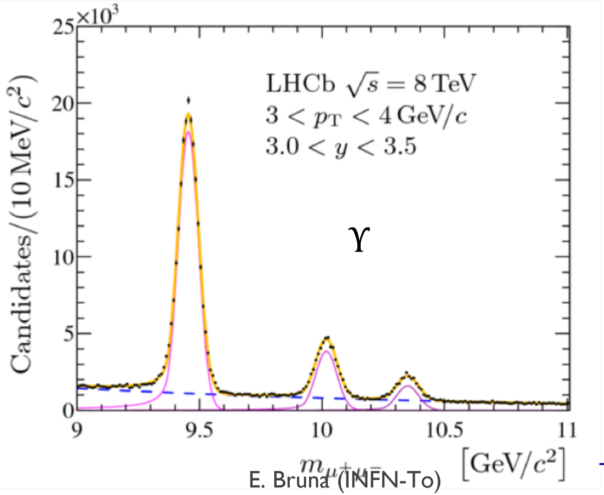
Forward and backward luminosities are added together

Assuming the heavy flavor cross section increases by a factor of 2 from 5 TeV to 8 TeV

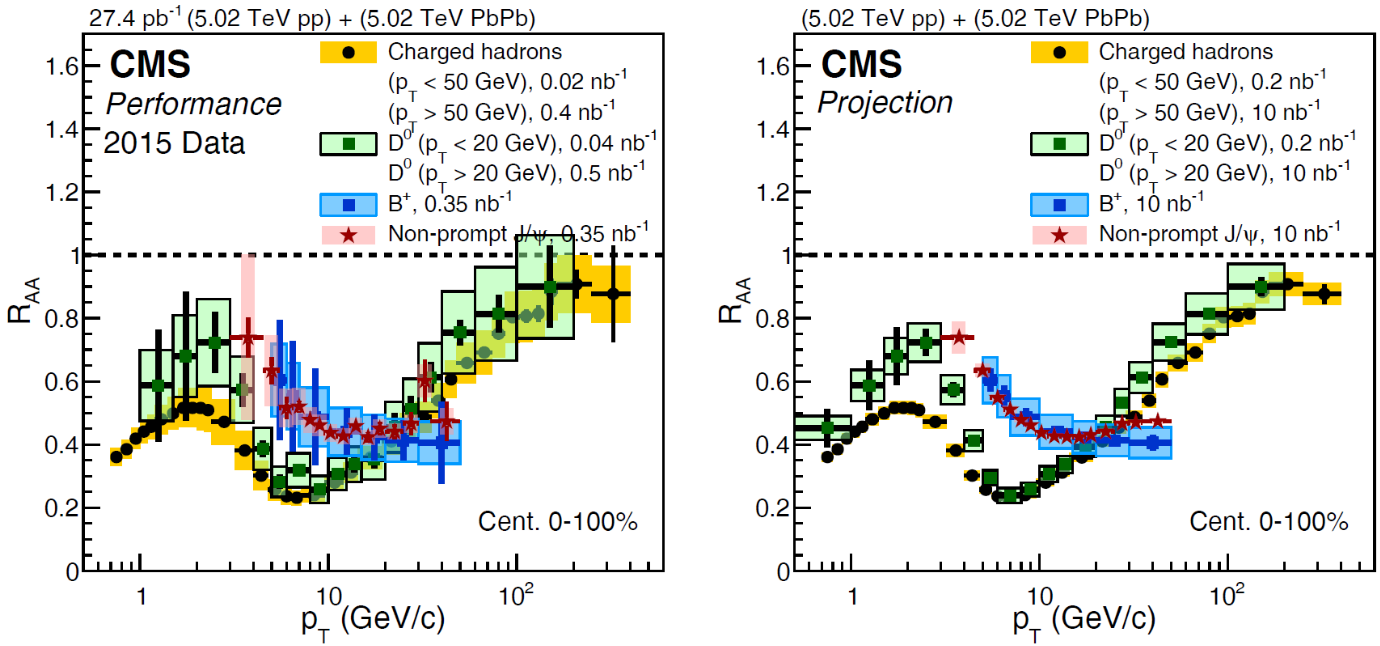
Dimuons states in *pp* data





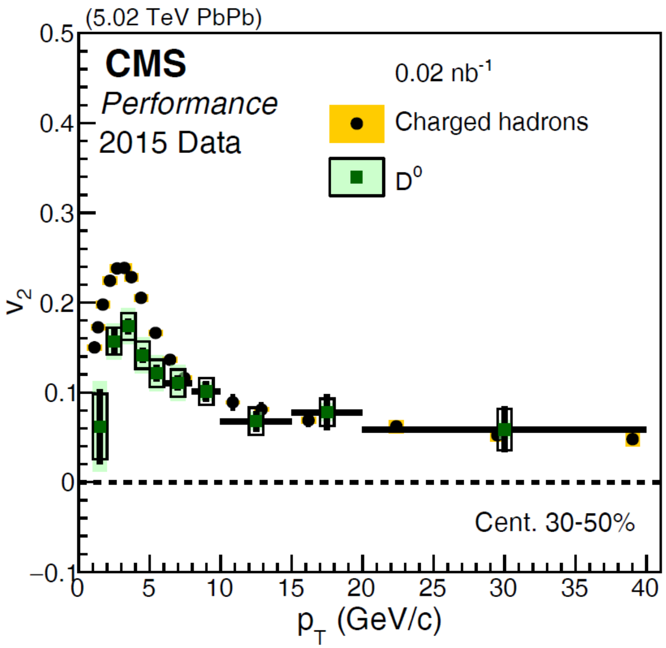


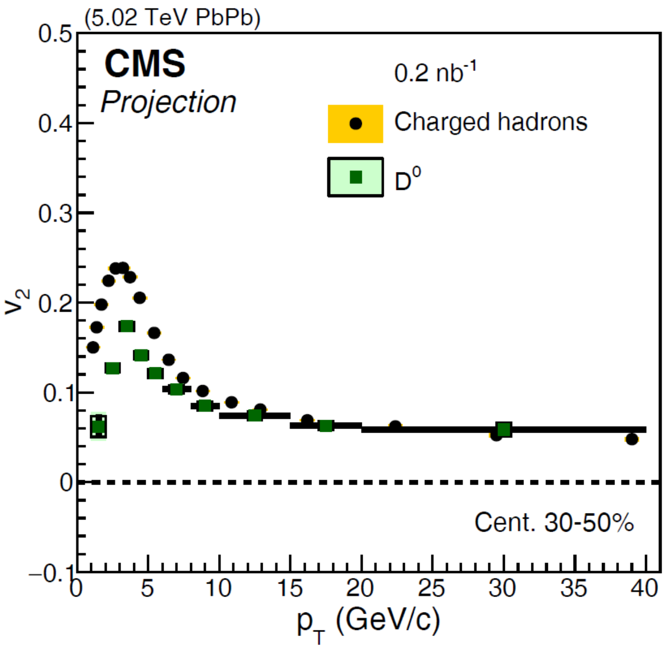
Heavy Flavor Mesons with CMS



- Flavor dependence of parton energy loss and jet quenching could be studied with high statistics heavy flavor mesons
- Central values: 2015 performance for D0: pT>2 from measurements, pT<2 from PHSD; Projection: adjust to be smooth. B+ RAA central value from Magdalena's calculation
- Reduced stat and syst by lumi, but has a minimum syst of 4% per track as tracking eff syst

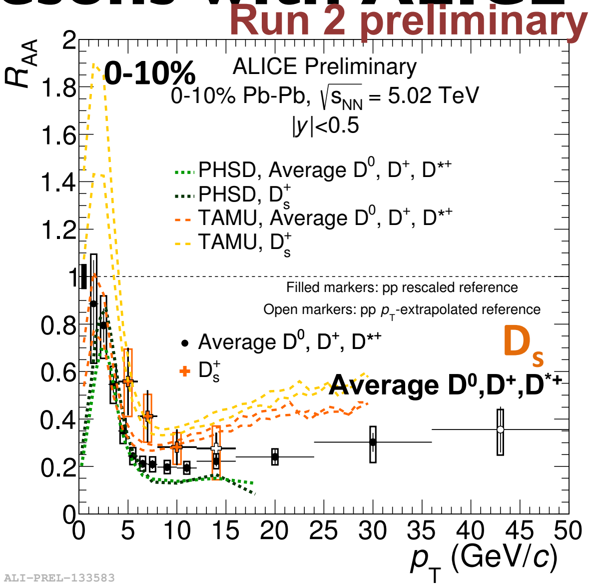
Identified hadron and D v_2



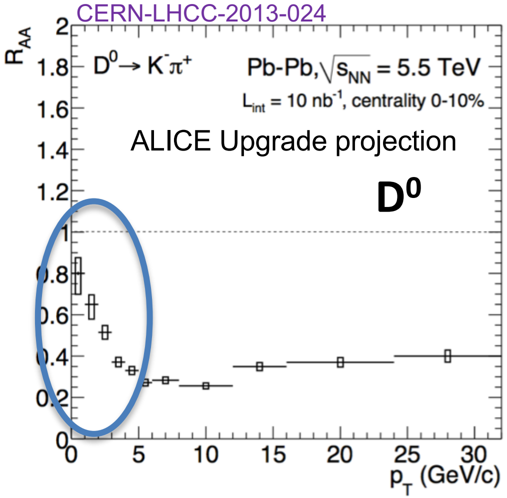


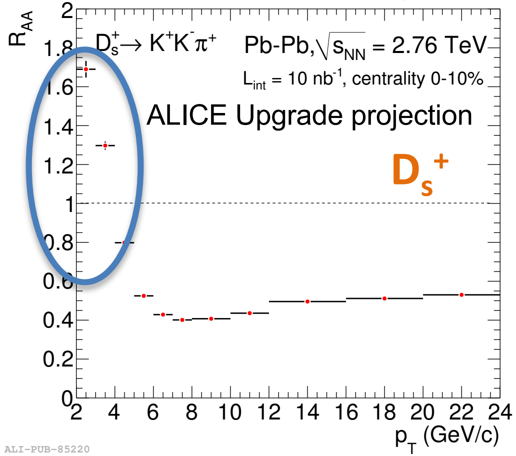
- Elliptic flow of charged hadrons and D^0 mesons
- Provide the strongest constrain on the c quark diffusion coefficients and path length dependence of the parton energy loss
- Extrapolation using data, reduced stat and syst. by lumi.

D mesons with ALICE



Projections (from ITS TDR)





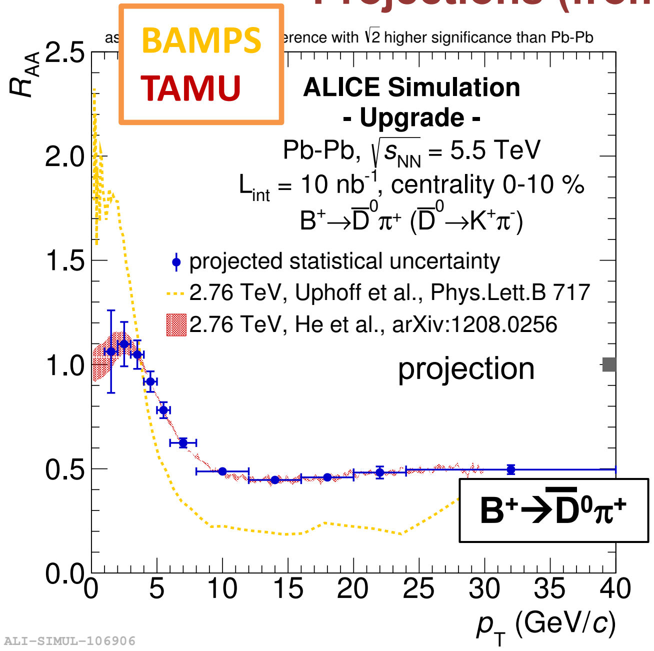
Precise measurements down to p_T=0

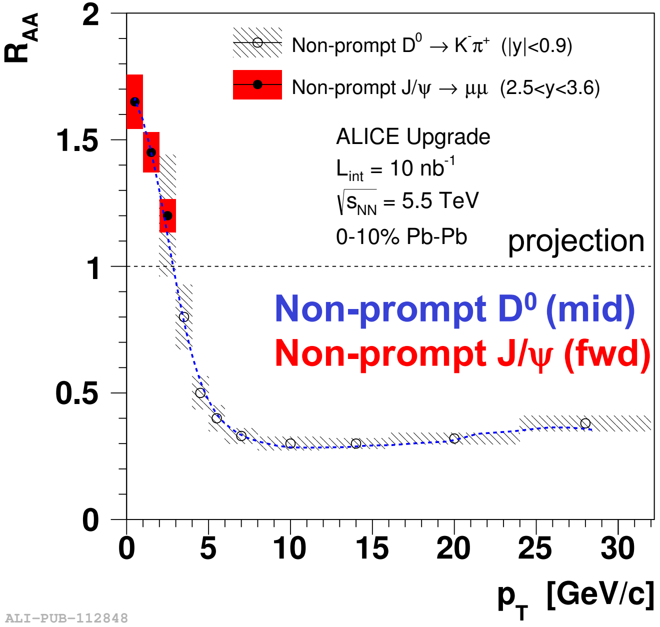
- **Discriminate models** to quantify microscopic interactions with the medium
- **Total charm cross section**
  - All charmed particles relevant (role of recombination for D_s, Λ_c,..?)
  - Reference for charmonium measurements

B mesons with ALICE

Projections (from ITS, MFT TDR, PhD theses)

CERN-LHCC-2013-024
CERN-LHCC-2015-001
CERN-THESIS-2016-037



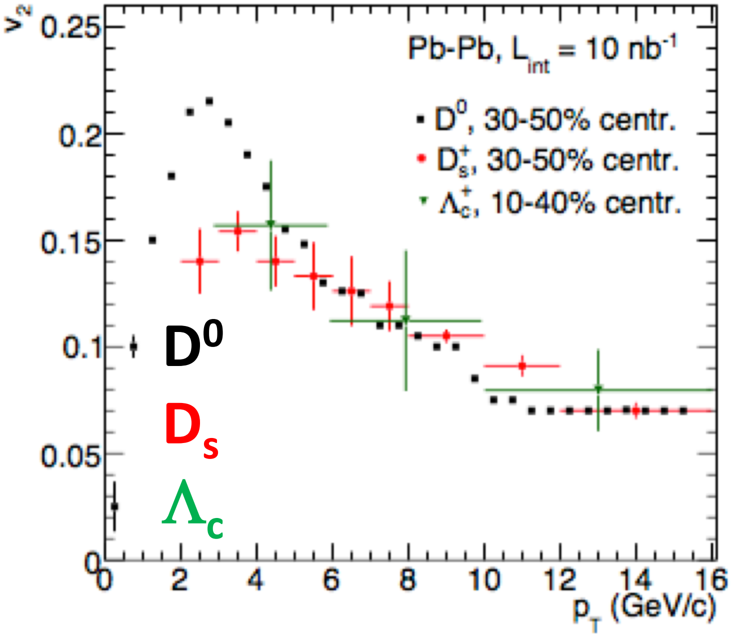


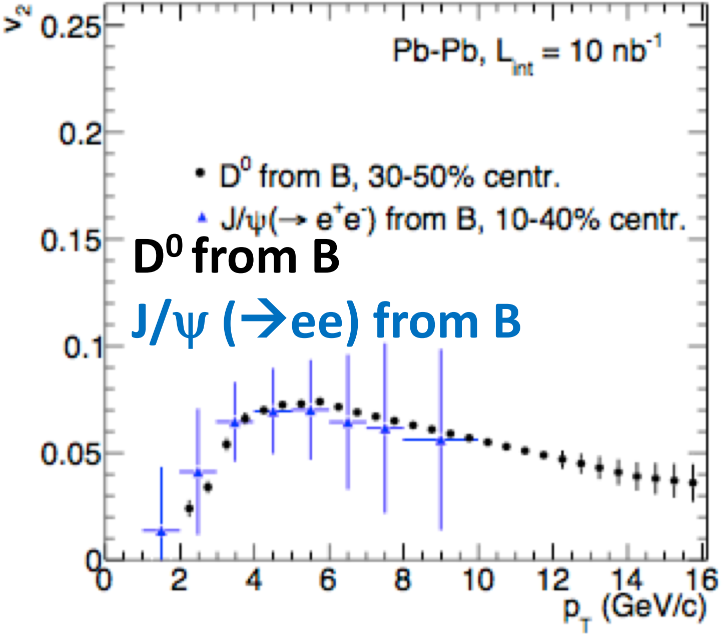
Beauty via Dπ, J/ψK, non prompt D and J/ψ, combining measurements at mid and forward rapidity

Precise R_{AA} and v_2 can **discriminate models at low p_T, where parton mass plays a role**, constrain the **b-quark diffusion coefficient** and probe b-quark **thermalisation**

Elliptic flow with ALICE

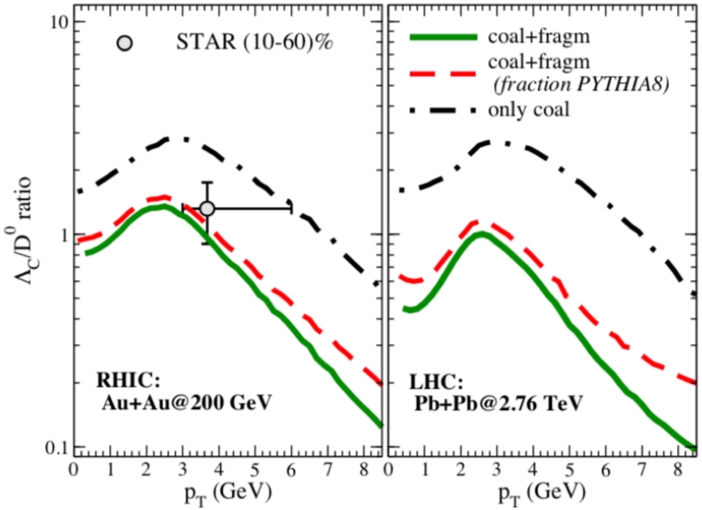
Projections (from ITS, MFT TDR)



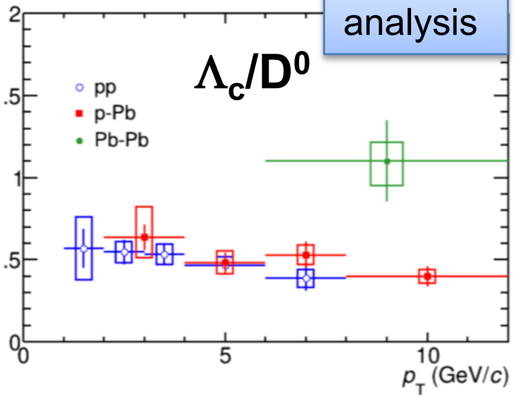


Provide the **strongest constrain on the c and b quark diffusion** coefficients and **path-length dependence** of the parton energy loss

Hadronization mechanisms of charm and beauty



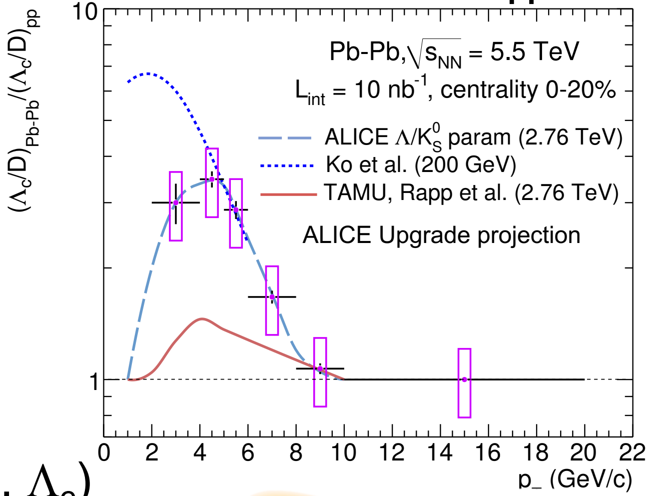
Current analysis



CERN-LHCC-2013-024

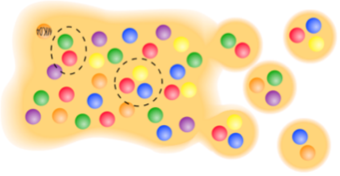
Projections (from ITS TDR)

$(\Lambda_c/D)_{AA}$ / $(\Lambda_c/D)_{pp}$



See Elisa's talk (Mon)

From RHIC to LHC: hints of charm recombination (D_s, J/ψ, Λ_c)



Λ_c/D : potential to discriminate among models at low momentum

Λ_b: access to thermalization and hadronization of beauty quarks

→ insight into hadronization and thermalization of charm and beauty