ALICE status report

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LHCC meeting

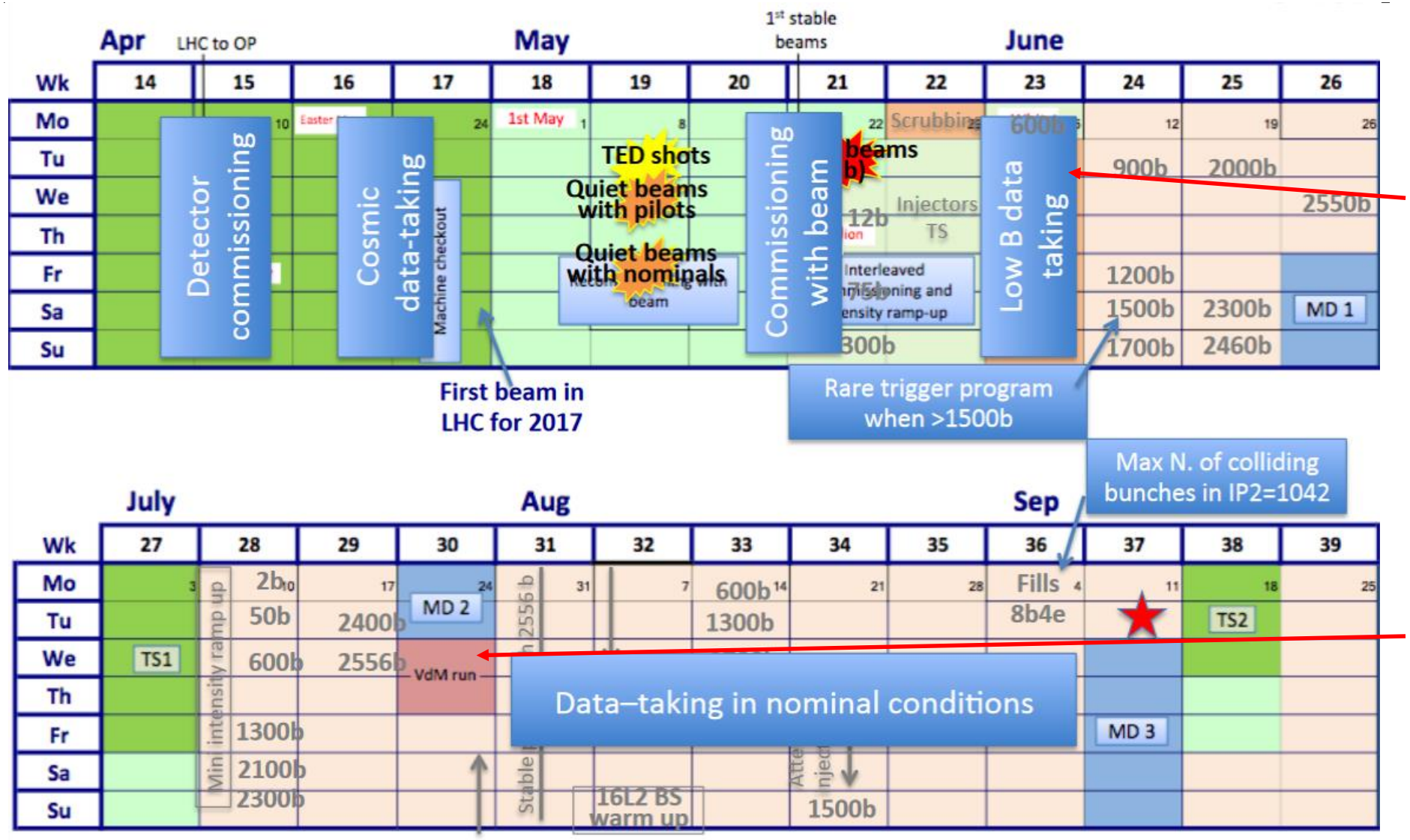
CERN, 13/09/2017

Outline

- Detector and data-taking status
- Physics results:
  - Papers and conferences
  - New results from pp collisions
  - Highlights from the latest p-Pb run
  - Highlights from Pb-Pb collisions
- Upgrade status
- Conclusions

Data-taking status

ALICE timeline in 2017



- Intense commissioning phase
- ~150 M minimum bias events collected with **reduced magnetic field** → study of **di-electron continuum and resonances** in the low-mass region
- Standard data-taking at a **luminosity of ~2.6 Hz/μb (μ ~ 1%)**
- **~80 M minimum bias events** collected with isolated bunches for **inelastic cross section and diffractive** measurements

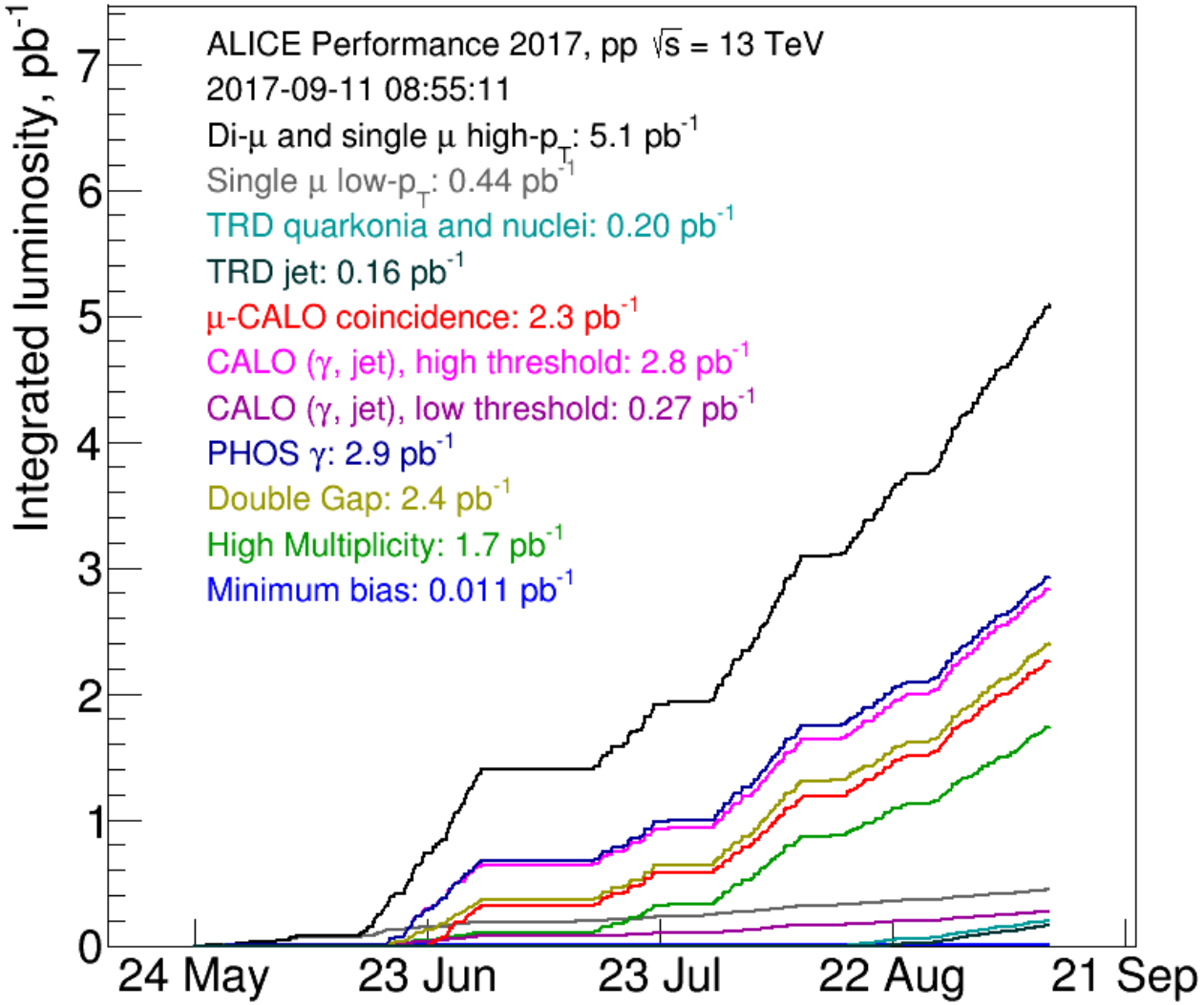
pp data-taking at √s = 13 TeV in 2017

Running a **rich trigger menu**:

- minimum bias
- high-multiplicity (V0-based)
- single and di-muon
- jet and γ from EM calorimeters
- electron, jet and (anti-)nuclei from the TRD
- double diffractive gap
- muon-calorimeter coincidences

Work in progress:

- *high-multiplicity (SPD-based)*
- *forward J/ψ from EM interactions*



Run II data-taking summary

	pp 5 TeV	pp 13 TeV	p-Pb 5.02 TeV	p-Pb 8.16 TeV	Pb-Pb 5.02 TeV
Luminosity for rare triggers (goal)	112 nb^{-1} (600 nb^{-1})	19 pb^{-1} (40 pb^{-1})	3.4 nb^{-1}	21 nb^{-1}	250 μb^{-1} (1 nb^{-1})
Number of minimum bias events (goal)	128 M (1000 M)	2 G (200 M low-B) (3.5 G)	764 M	70 M	157 M (250 M)
Number of high multiplicity / central events (goal)	- (-)	900 M (2.5 G)	- (-)	47 M	- (250 M)

pp reference run at 5 TeV is a major goal for 2017 data-taking

→ several p-Pb and Pb-Pb require these data

Physics results

10 Papers submitted since the last LHCC meeting

The ALICE Transition Radiation Detector: construction, operation, and performance
- **Submission Date:** 07/09/2017 **System:** detector performance **Energy:** 900 GeV 2.76 TeV 5.02 TeV 7 TeV 8 TeV
  Current Status: Submitted

1709.02743

Kaon femtoscopy in Pb-Pb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV
- **Submission Date:** 07/09/2017 **System:** Pb-Pb **Energy:** 2.76 TeV
  Current Status: Submitted

1709.01731

Systematic studies of correlations between different order flow harmonics in Pb-Pb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV
- **Submission Date:** 05/09/2017 **System:** Pb-Pb **Energy:** 2.76 TeV
  Current Status: Submitted

1709.01127

π^0 and η meson production in proton-proton collisions at $\sqrt{s}$ = 8 TeV
- **Submission Date:** 29/08/2017 **System:** p-p **Energy:** 8 TeV
  Current Status: Submitted

1708.08745

Charged-particle multiplicity distributions over a wide pseudorapidity range in proton-proton collisions at $\sqrt{s}$ = 0.9, 7 and 8 TeV
- **Submission Date:** 04/08/2017 **System:** p-p **Energy:** 900 GeV 7 TeV 8 TeV
  Current Status: Submitted

1708.01435

Measurement of deuteron spectra and elliptic flow in Pb-Pb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV at the LHC
- **Submission Date:** 23/07/2017 **System:** Pb-Pb **Energy:** 2.76 TeV
  Current Status: Submitted

1707.07304

Searches for transverse momentum dependent flow vector fluctuations in Pb-Pb and p-Pb collisions at the LHC
- **Submission Date:** 19/07/2017 **System:** Pb-Pb p-Pb **Energy:** 2.76 TeV 5.02 TeV
  Current Status: Accepted

1707.05690

D-meson azimuthal anisotropy in mid-central Pb-Pb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV
- **Submission Date:** 04/07/2017 **System:** Pb-Pb **Energy:** 5.02 TeV
  Current Status: Submitted

1707.01005

Measuring $K^0_S K^\pm$ interactions using Pb-Pb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV
- **Submission Date:** 13/05/2017 **System:** Pb-Pb **Energy:** 2.76 TeV
  Current Status: Accepted

1705.04929

Linear and non-linear flow modes in Pb-Pb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV
- **Submission Date:** 11/05/2017 **System:** Pb-Pb **Energy:** 2.76 TeV
  Current Status: Accepted

1705.04377

http://aliceinfo.cern.ch/ArtSubmission/submitted

ALICE at the main summer conferences

XII Workshop on Particle Correlations and Femtoscopy

12-16 June 2017

Nikhef

Amsterdam

The Netherlands

WPCF XXX 2017

15 talks

LHCP2017

The Fifth Annual Conference on Large Hadron Collider Physics

May 15-20, 2017, Shanghai , China

18 talks

EPS Conference on High Energy Physics

Venice, Italy 5-12 July 2017

EUROPEAN PHYSICAL SOCIETY HEP2017

22 talks

17th International Conference on

Strangeness in Quark Matter

Universiteit Utrecht

10-15 July 2017

Utrecht, the Netherlands

Utrecht 2017

22 talks

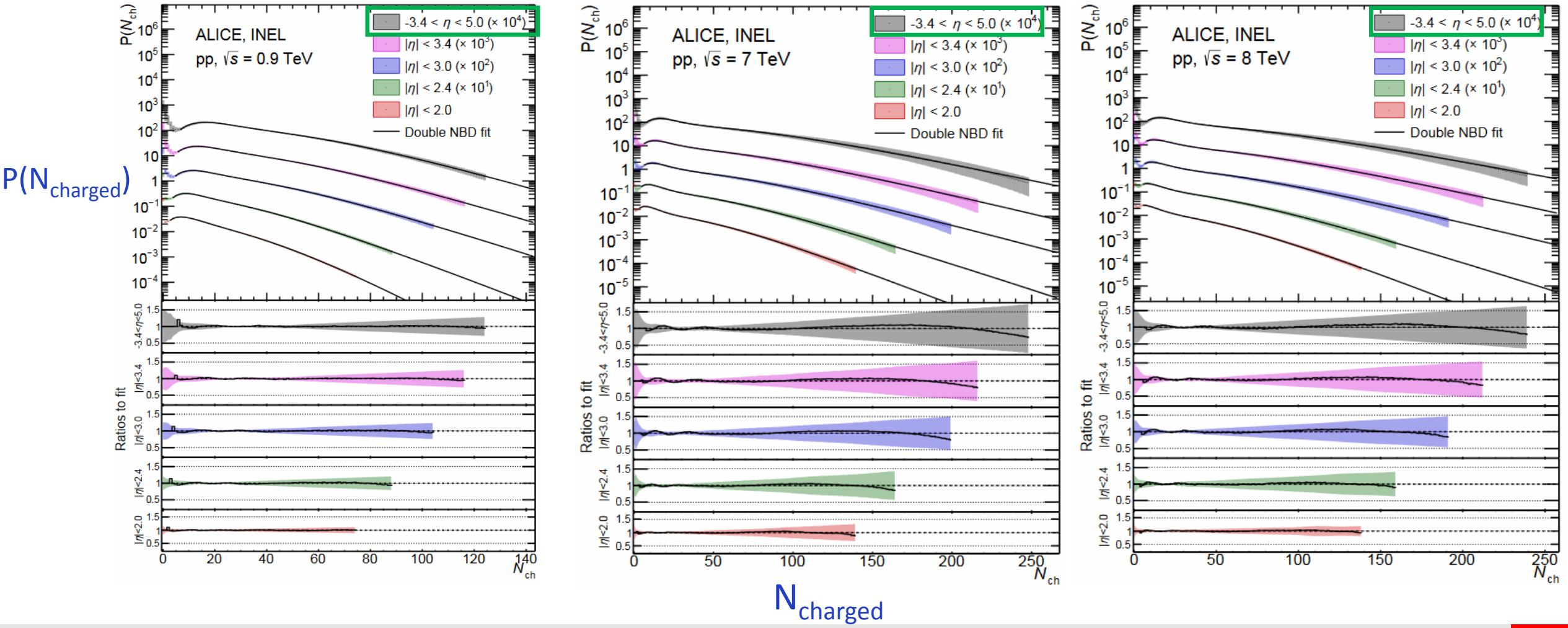
One of the three main heavy-ion conferences

New results from pp collisions

Multiplicity distributions over a wide pseudorapidity range

- Multiplicity distributions measured over **8.4 pseudorapidity units** at 3 different energies

arXiv:1708.01435



Multiplicity distributions over a wide pseudorapidity range

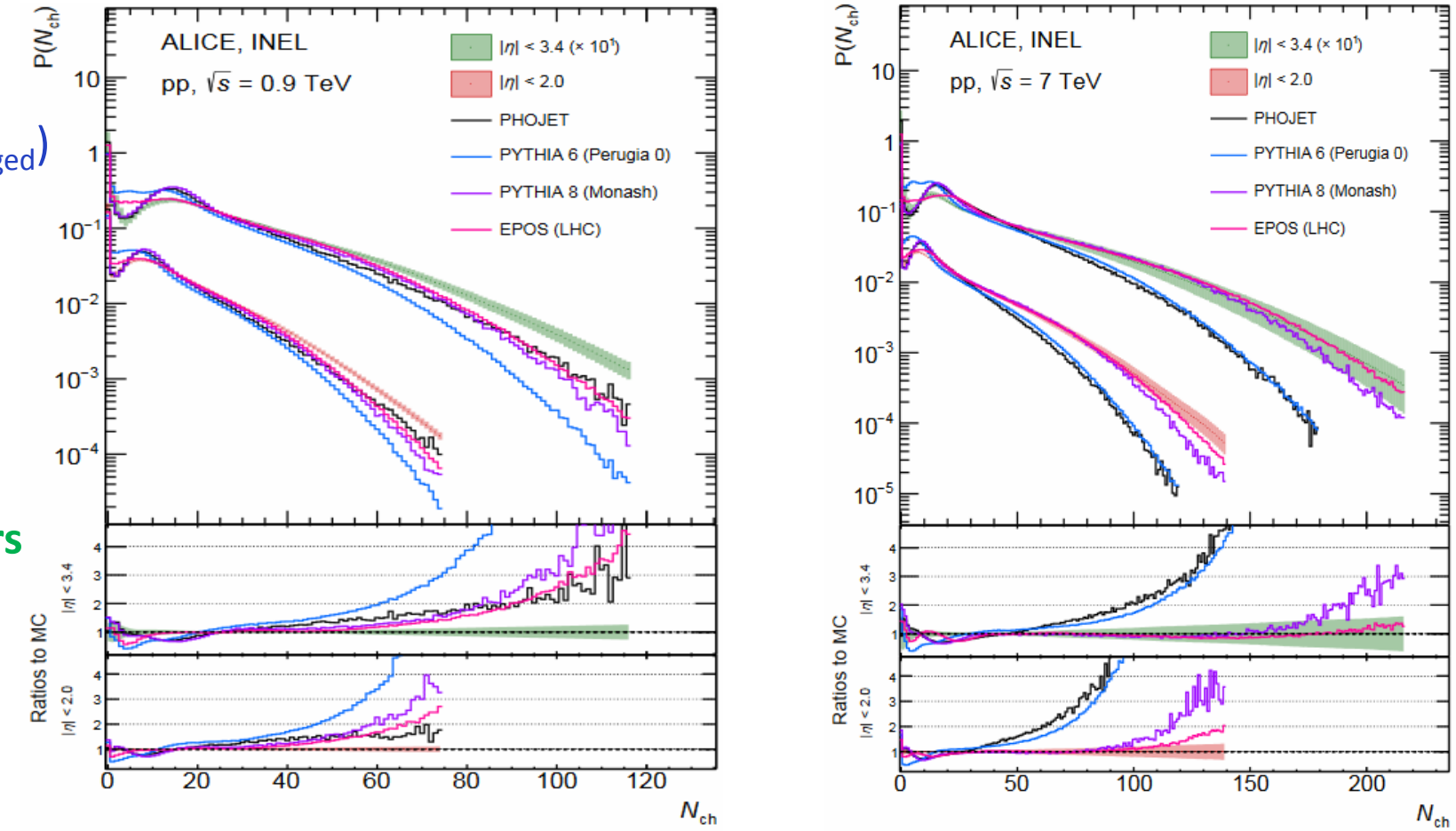
- Multiplicity distributions measured over **8.4 pseudorapidity units** at 3 different energies

arXiv:1708.01435

$P(N_{charged})$

One of the key observables to describe the **global properties of pp interactions**

Input for event generators

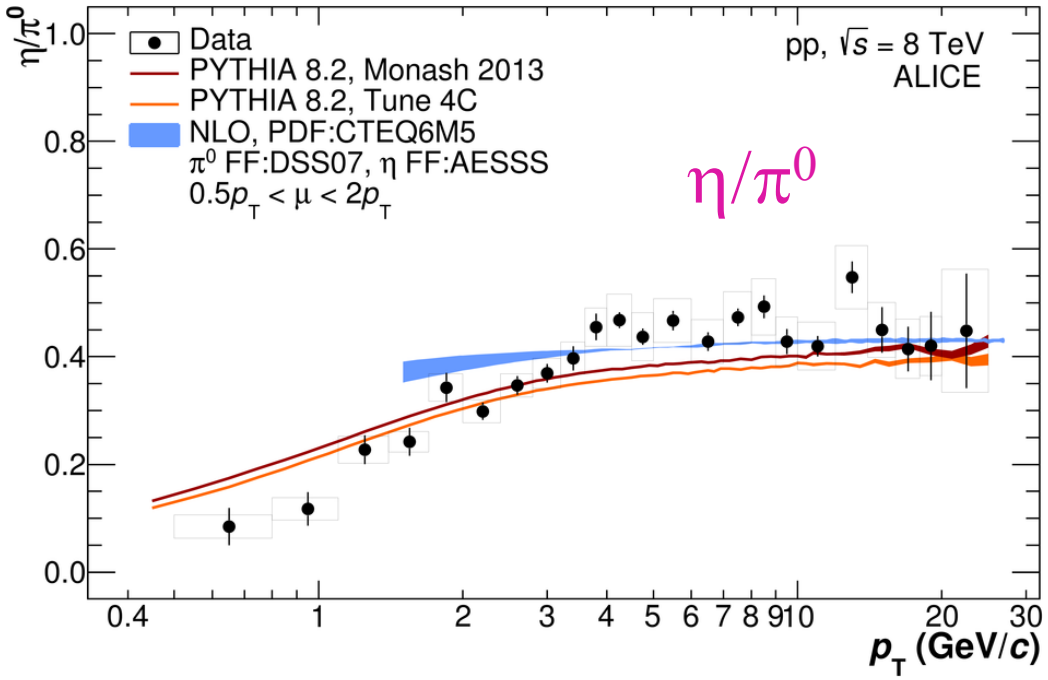


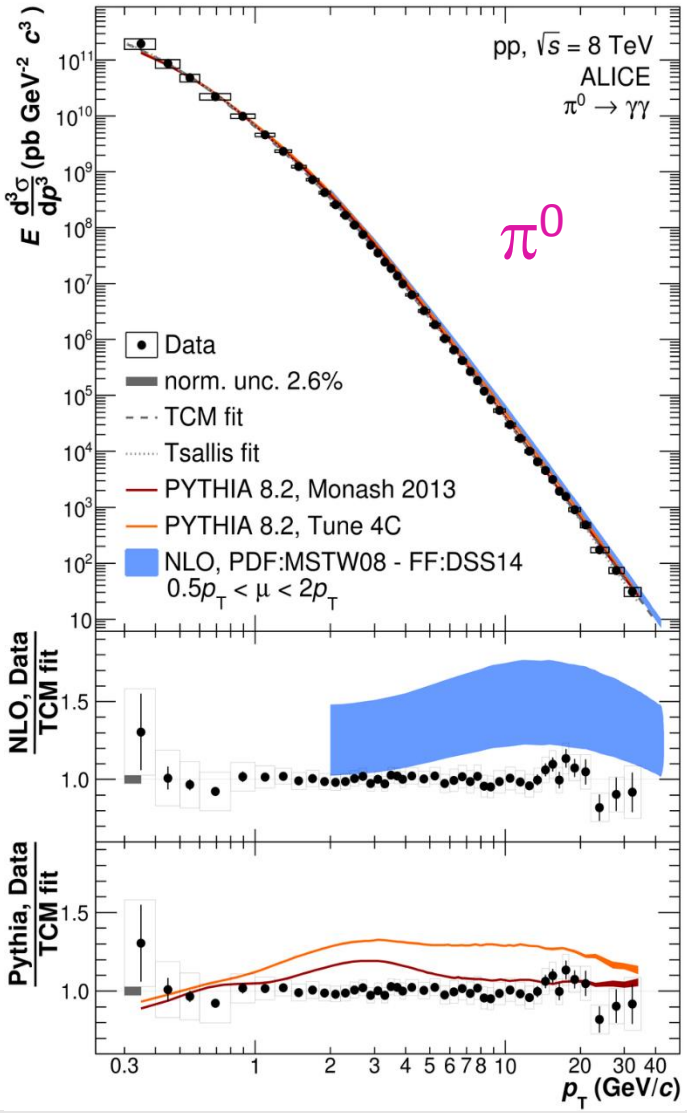
$N_{charged}$

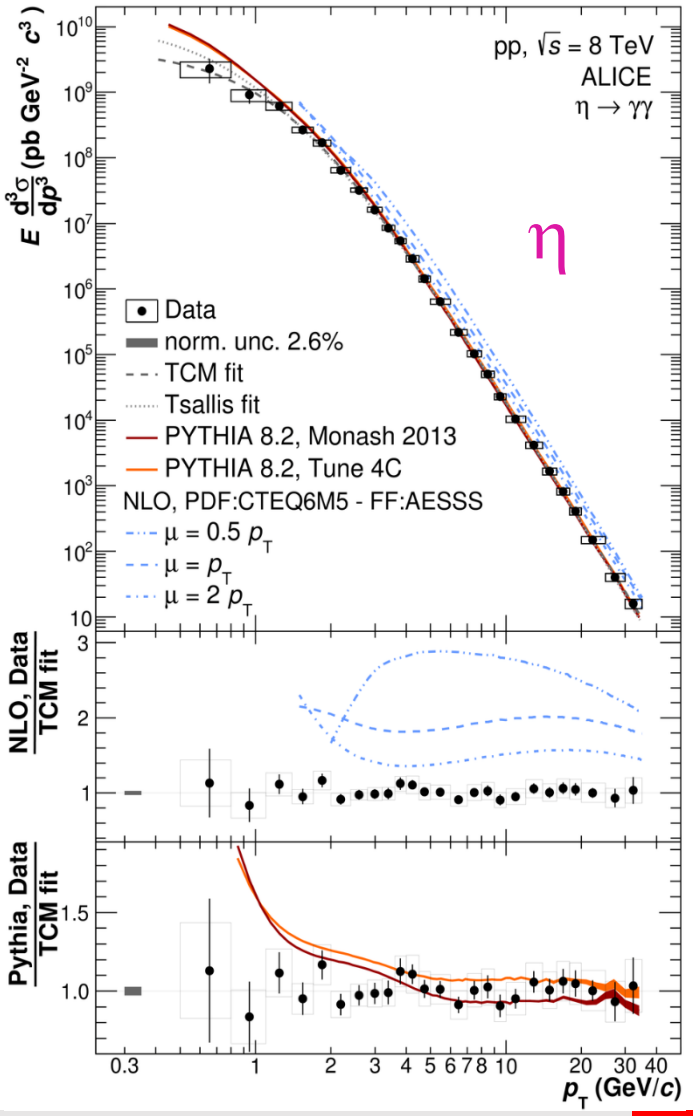
π^0 and η meson production in pp collisions at $\sqrt{s}$ = 8 TeV

arXiv:1708.08745

- **Four different reconstruction methods**
- Test of **gluon fragmentation functions**
  → η/π^0 ratio reproduced by pQCD + FF



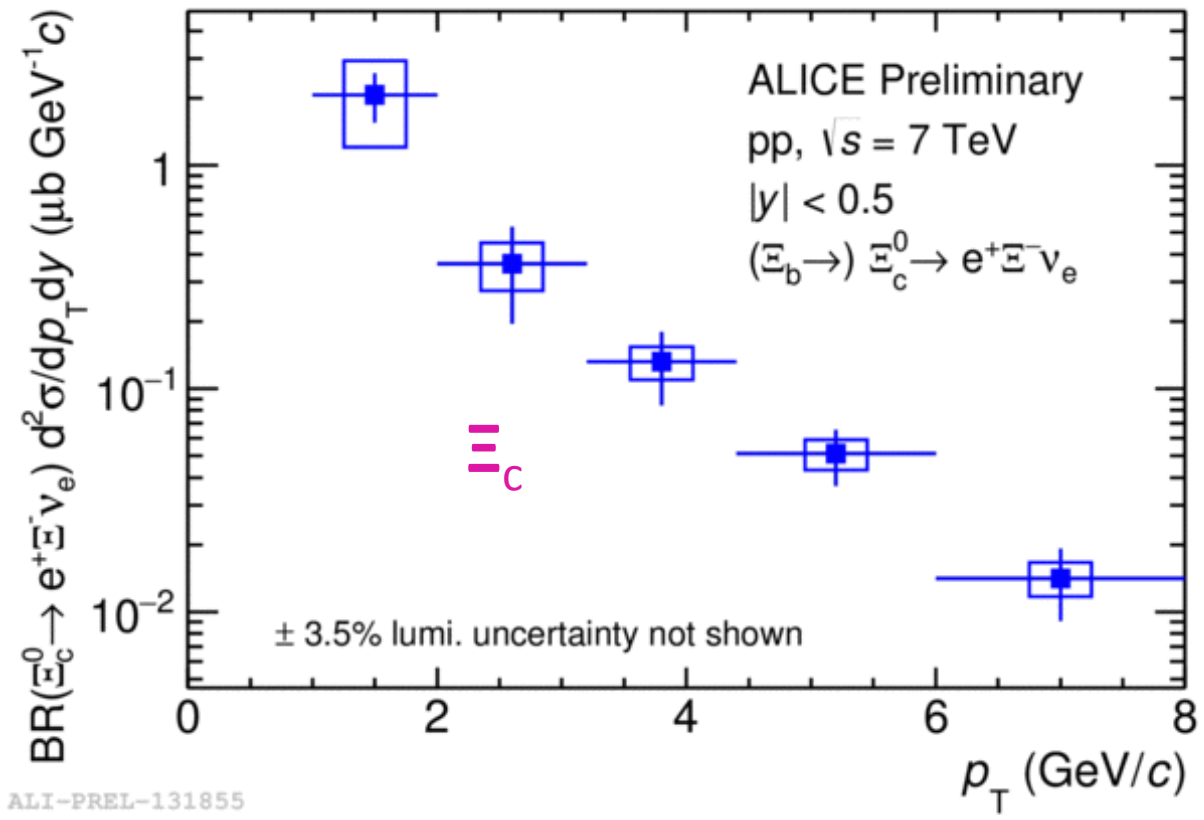


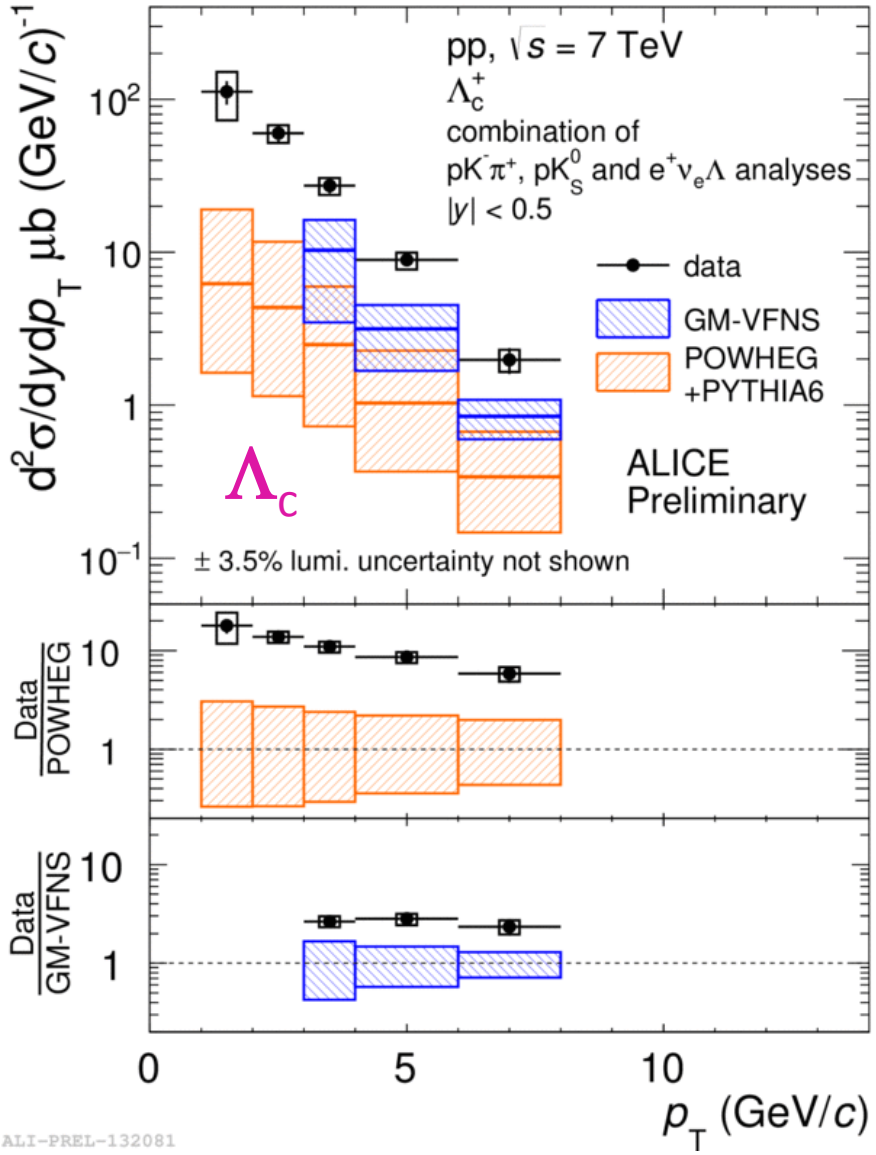


- Constrain event generators

Ξ_c and Λ_c production in pp (and p-Pb) collisions

- **First cross section measurement for $\Xi_c \rightarrow e^+ \Xi^- \nu_e$**
  in pp collisions at the LHC (note: unknown BR)





Ξ_c and Λ_c production in pp (and p-Pb) collisions

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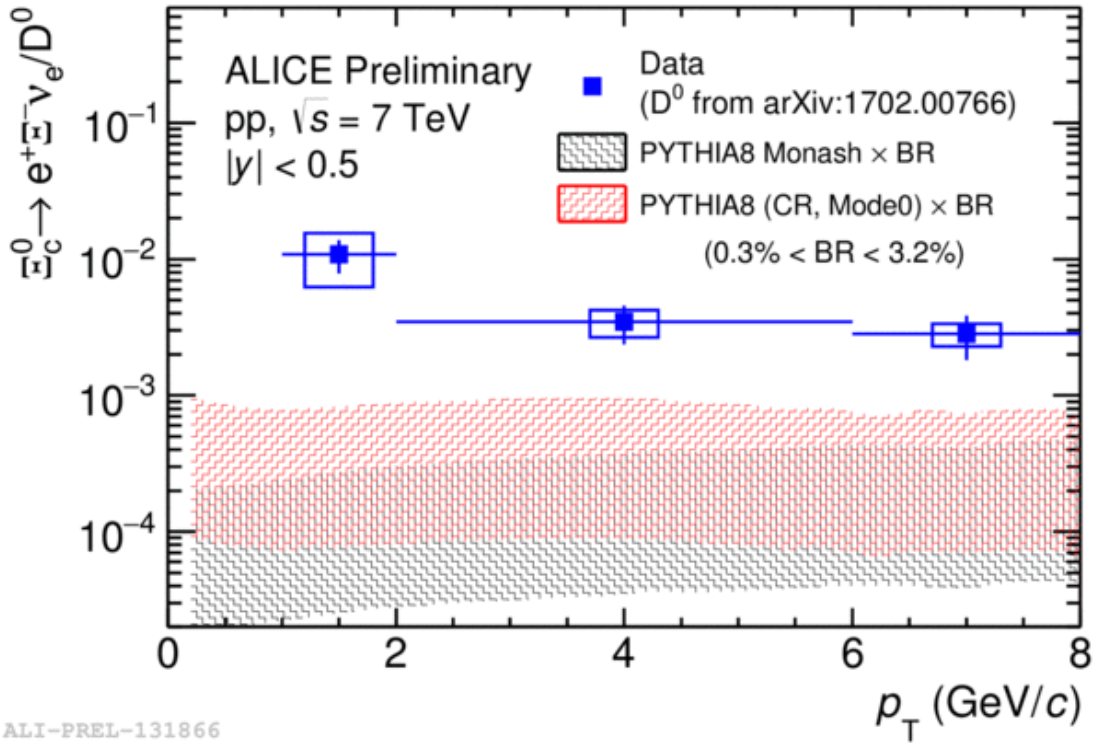
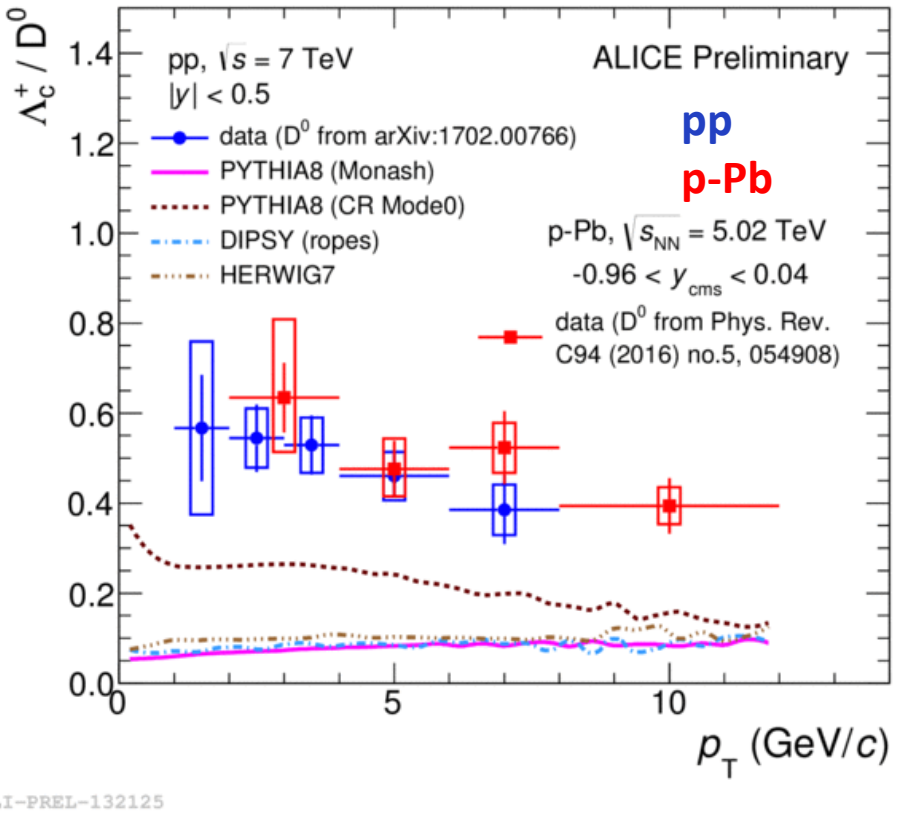
Ξ_c/D^0



- Ratio to D^0 is **sensitive to hadronisation models** (e.g. color reconnection vs ropes)

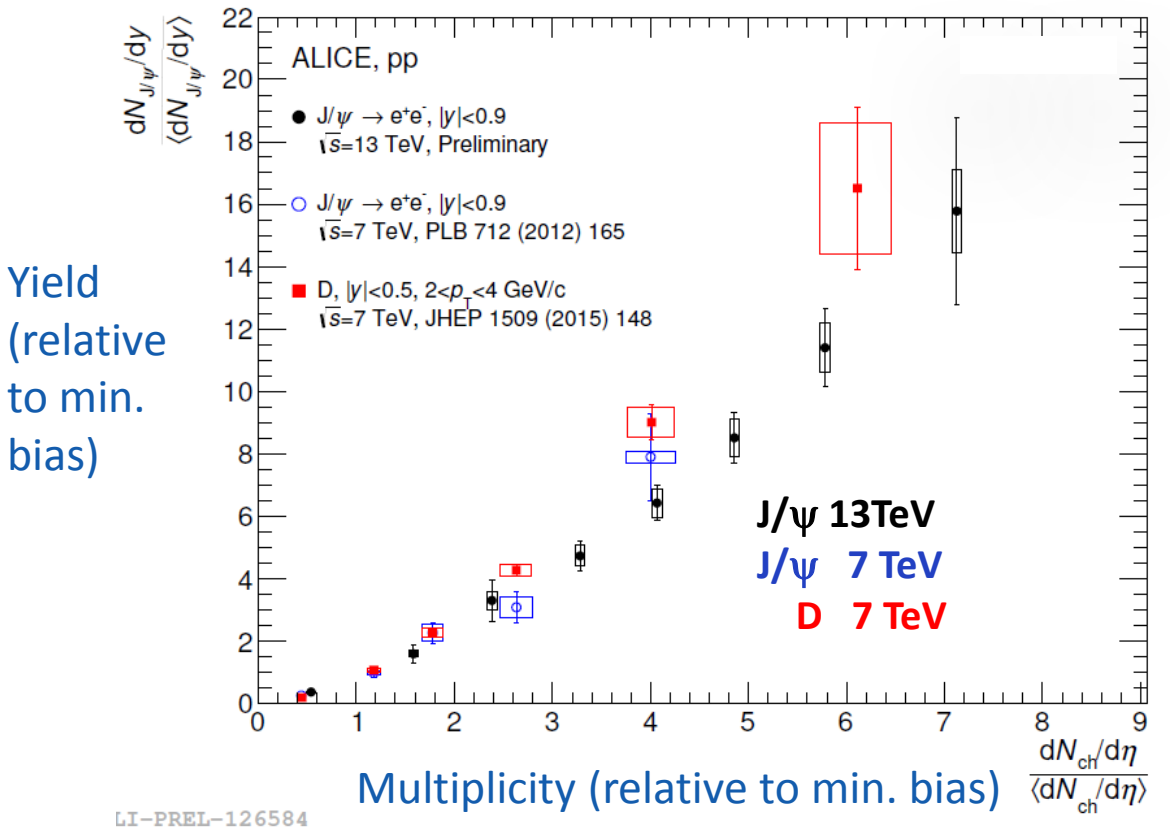
Λ_c/D^0



- Results compared to generators with different hadronisation mechanisms
- Ratio underestimated by models for both particles
- Λ_c / D^0 ratio in p-Pb compatible with pp

J/ψ and open HF production vs multiplicity in pp collisions

- Correlate **«soft» and «hard» components** of particle production
- Sensitive to **Multiple-Parton Interactions**
- Increase of the yields with multiplicity observed for D-mesons and J/ψ

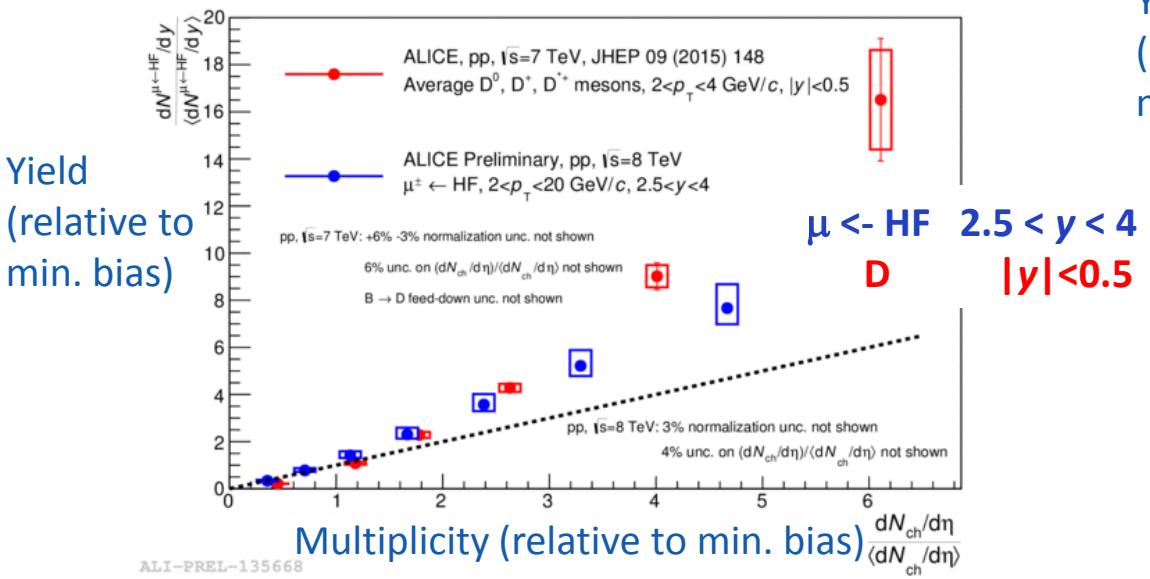


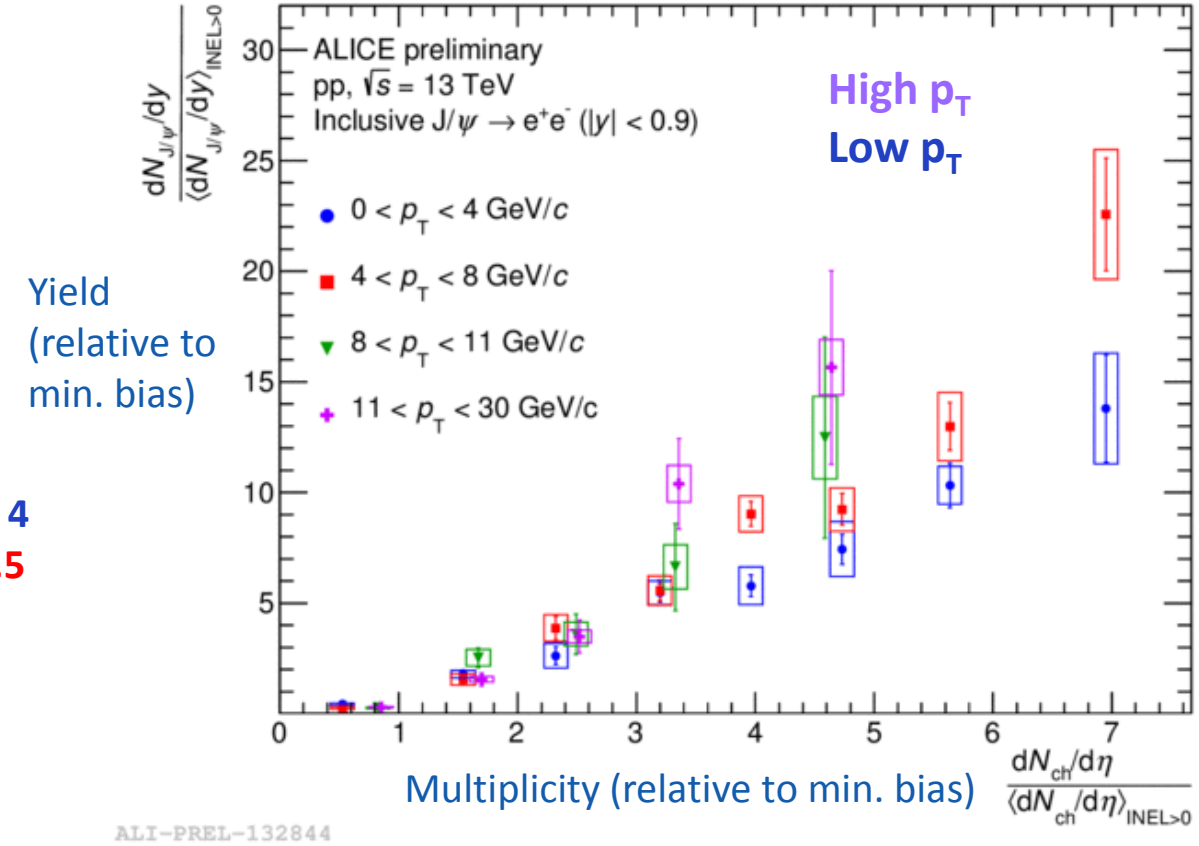
Yield (relative to min. bias)

Multiplicity (relative to min. bias)

J/ψ and open HF production vs multiplicity in pp collisions

- Correlate **«soft» and «hard» components** of particle production
- Sensitive to **Multiple-Parton Interactions**
- Increase of the yields with multiplicity observed for D-mesons and J/ψ
- **New results:**
  - **J/ψ vs mult. vs p_T at mid-rapidity (13 TeV)**
    → steeper slope with multiplicity at high p_T
  - **Muons from HF at forward rapidity (8 TeV)**
    → Slower increase wrt D mesons at mid-rapidity?





Highlights from the latest p-Pb run

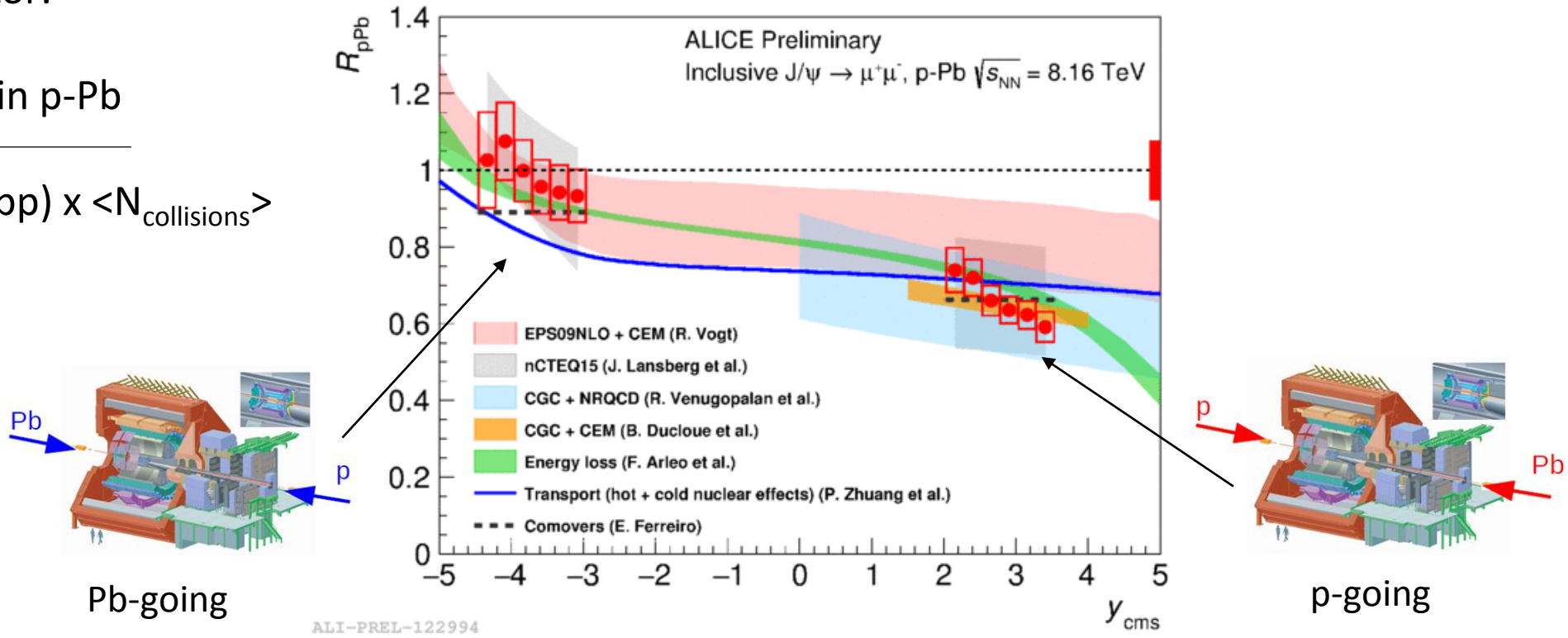
J/ψ production at forward rapidity in p-Pb collisions at $\sqrt{s_{NN}}$ = 8.16 TeV

- p-Pb collisions as a **benchmark experiment**
- ideal ground to test cold nuclear matter effects

Nuclear modification factor:

$$R_{pPb} = \frac{\text{Yield per event in p-Pb}}{(\text{Yield per event in pp}) \times \langle N_{collisions} \rangle}$$

ALICE-PUBLIC-2017-001



J/ψ production at forward rapidity in p-Pb collisions at $\sqrt{s_{NN}}$ = 8.16 TeV

- p-Pb collisions as a **benchmark experiment**
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New result:

Q_{pPb} : nuclear modification factor of J/ψ **as a function of the collision centrality**

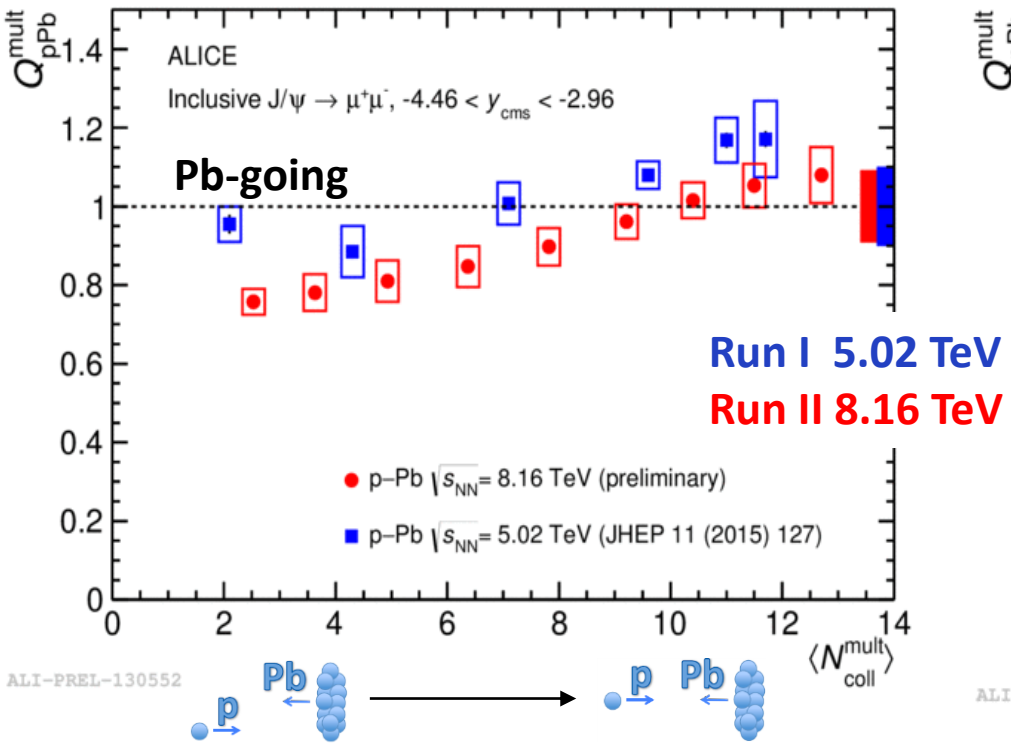
ALICE-PUBLIC-2017-007

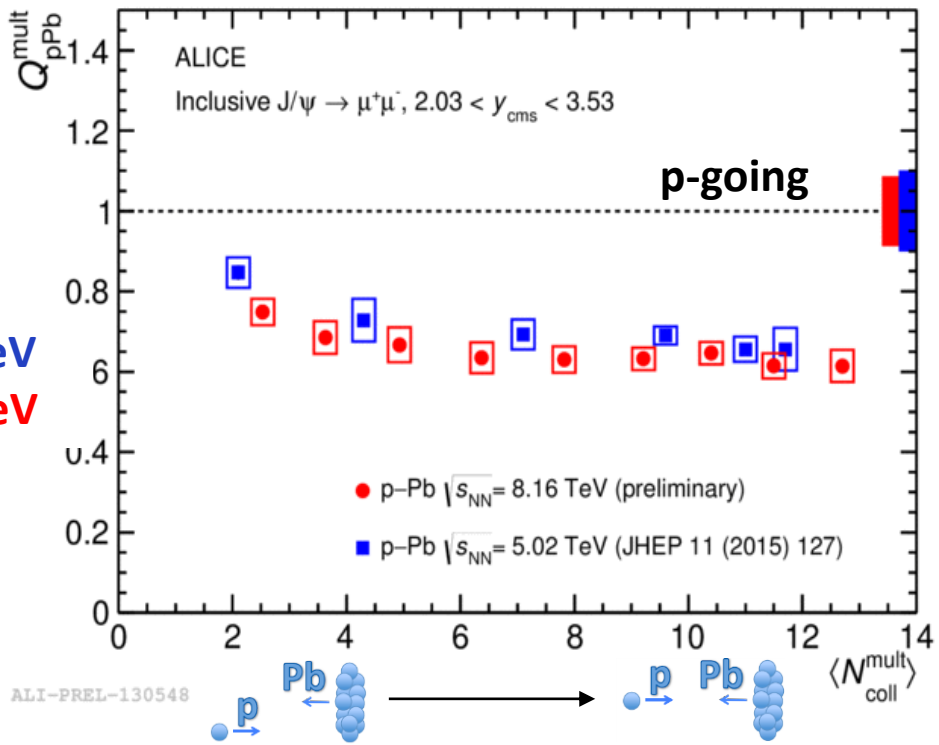
- Compatible with Run I results at 5.02 TeV

- **Finer binning**

- Opposite centrality dependence for Pb-going and p-going

→ Waiting for theoretical input at 8.16 TeV



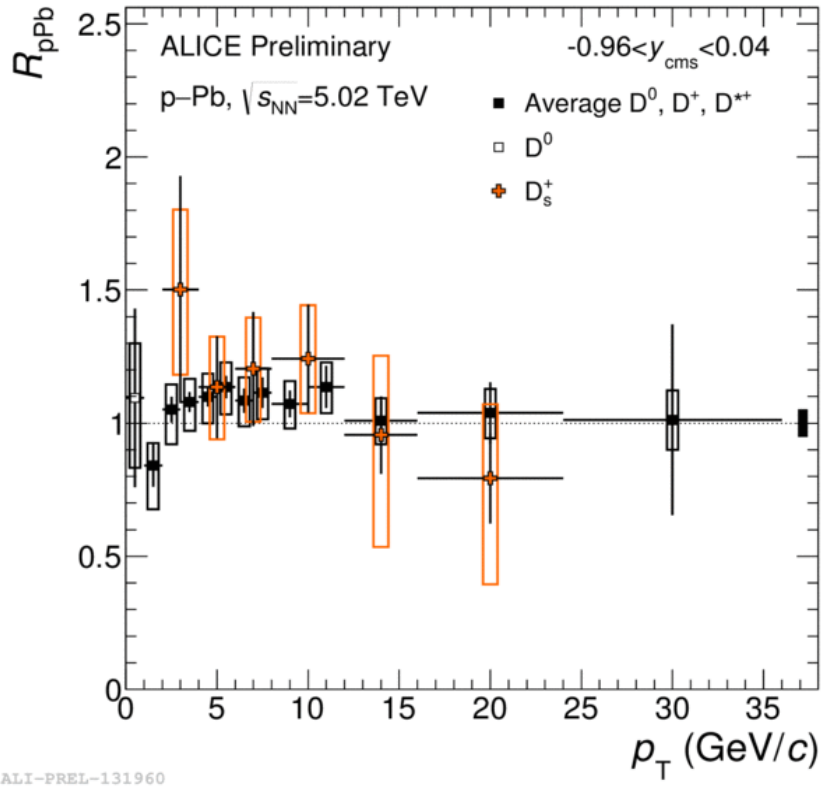


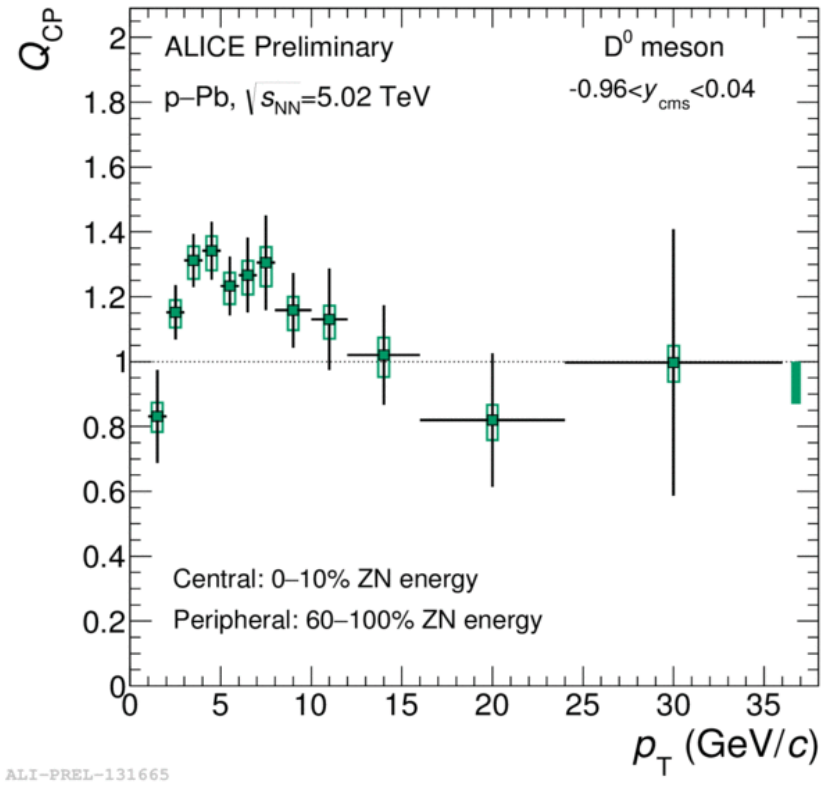
D-meson production at mid-rapidity in p-Pb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV

D-meson nuclear modification factor compatible with unity up to p_T ~ 35 GeV/c

Also compatible between strange and non-strange D mesons

Measurement precision mostly **limited by the pp reference** → looking forward to new pp data at 5 TeV!





ALICE-PUBLIC-2017-008

Ratio of central to peripheral Q_{pPb}:

Q_{CP} > 1 with 1.7σ significance in 3-7 GeV/c → room for **final state effects and, possibly, collectivity?**

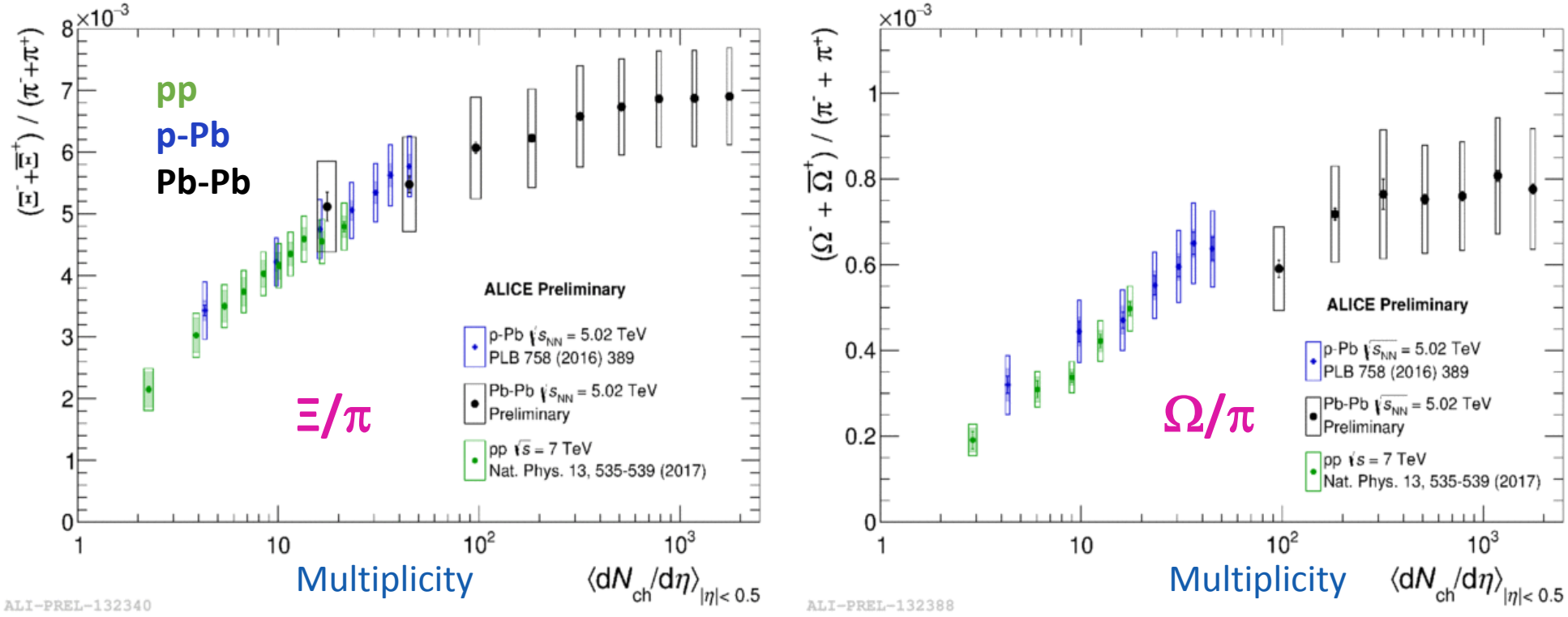
Highlights from Pb-Pb collisions

Strangeness production: from pp to Pb-Pb

New results on (multi-)strange baryon / pion ratios from Pb-Pb collisions at √s = 5.02 TeV

Run II statistics allows for **fine binning in event multiplicity**

→ for Ξ, peripheral Pb-Pb overlaps with high-mult. pp and p-Pb



Smooth behaviour across energies and colliding systems (also seen for K^0_S and Λ):

a **common underlying mechanism?**

Strangeness production: from pp to Pb-Pb

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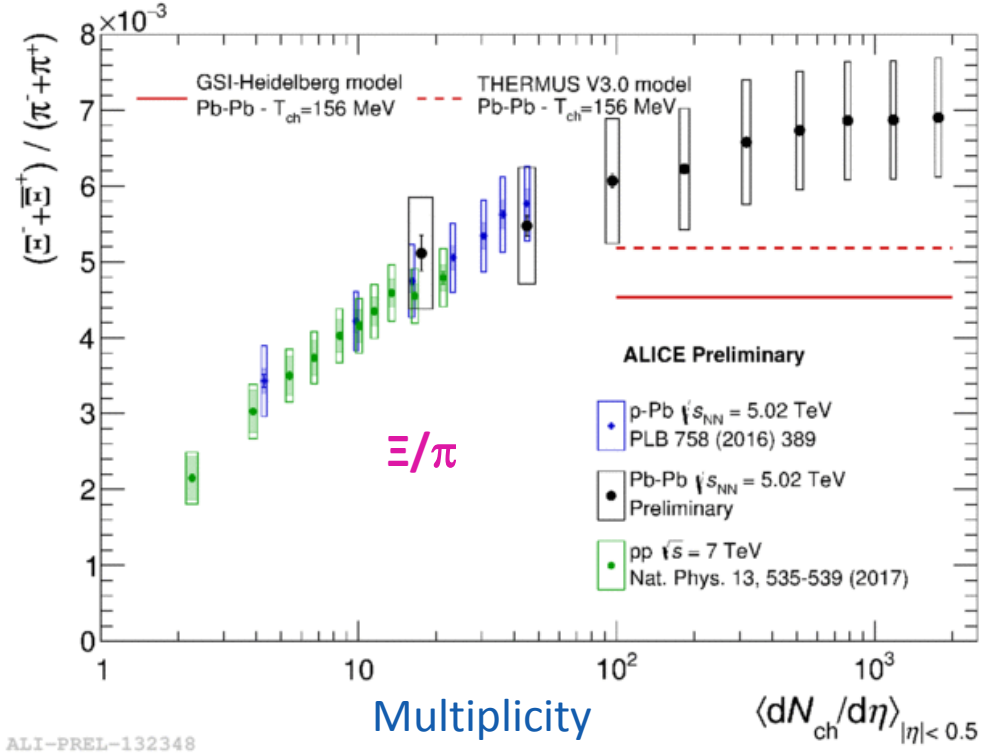
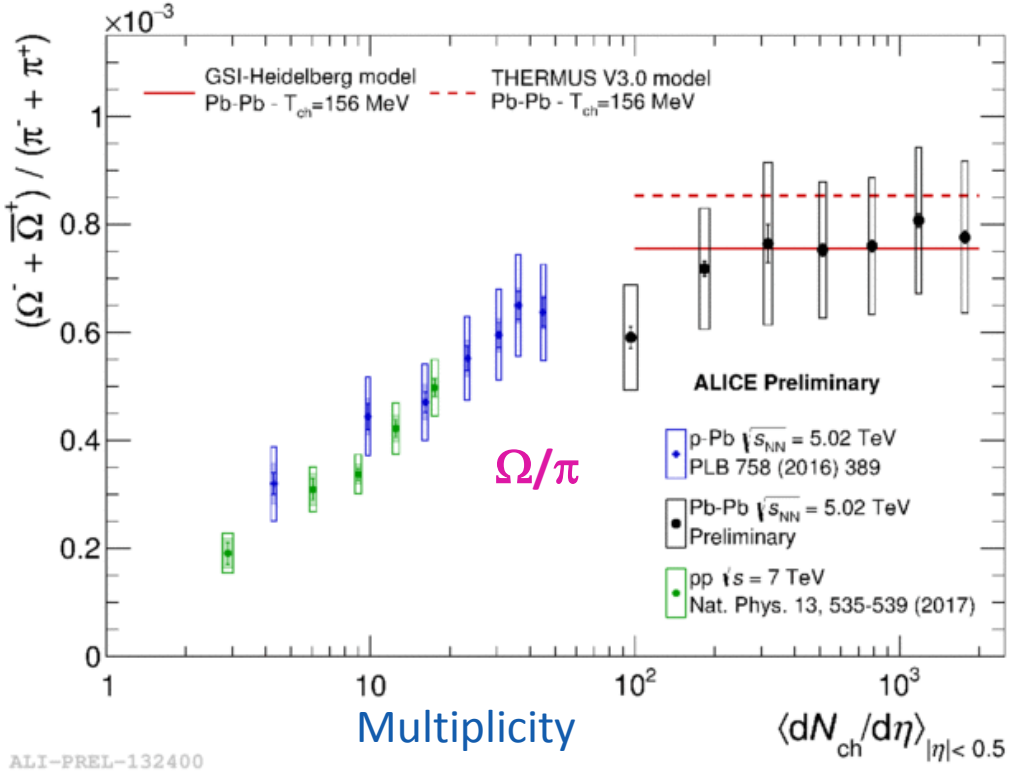


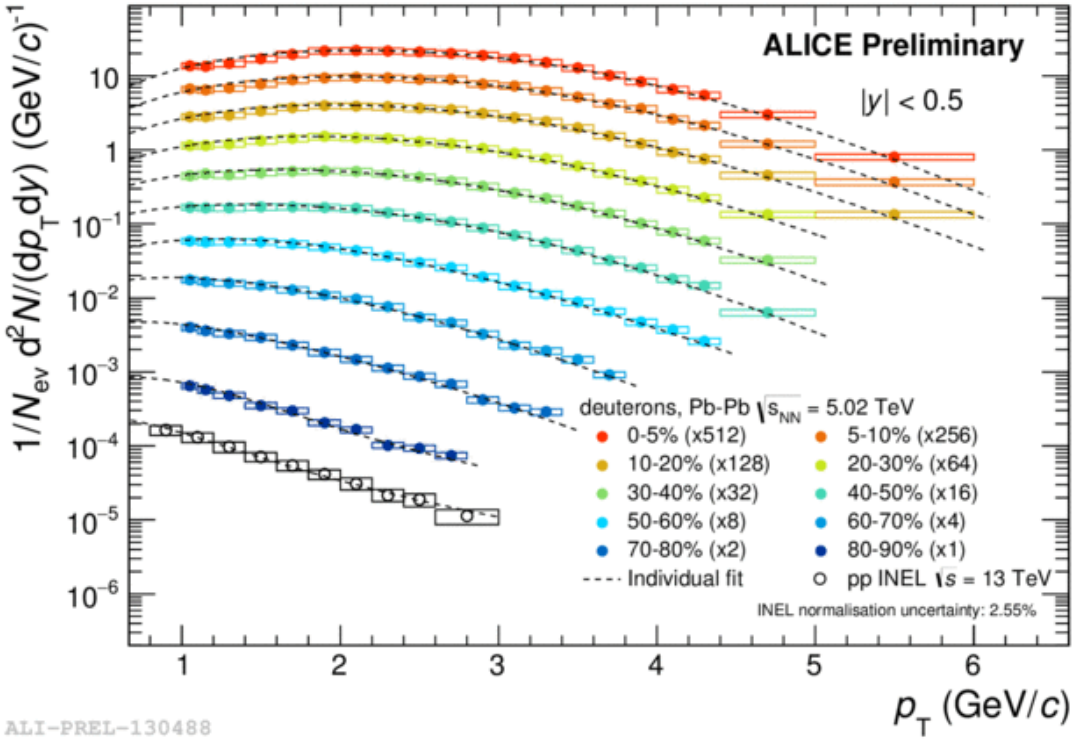


Thermal model: hadrons emitted by a source in thermal and chemical equilibrium, dN/dy ~$e^{-m/T}$

Predictions (T fitted to 2.76 TeV data) are within 2.1σ (<1σ) of data for Ξ (Ω)

Light (anti-)nuclei production in Pb-Pb (and pp) collisions

High-resolution measurement of deuteron spectra in 10 centrality classes (+pp) from Run II data



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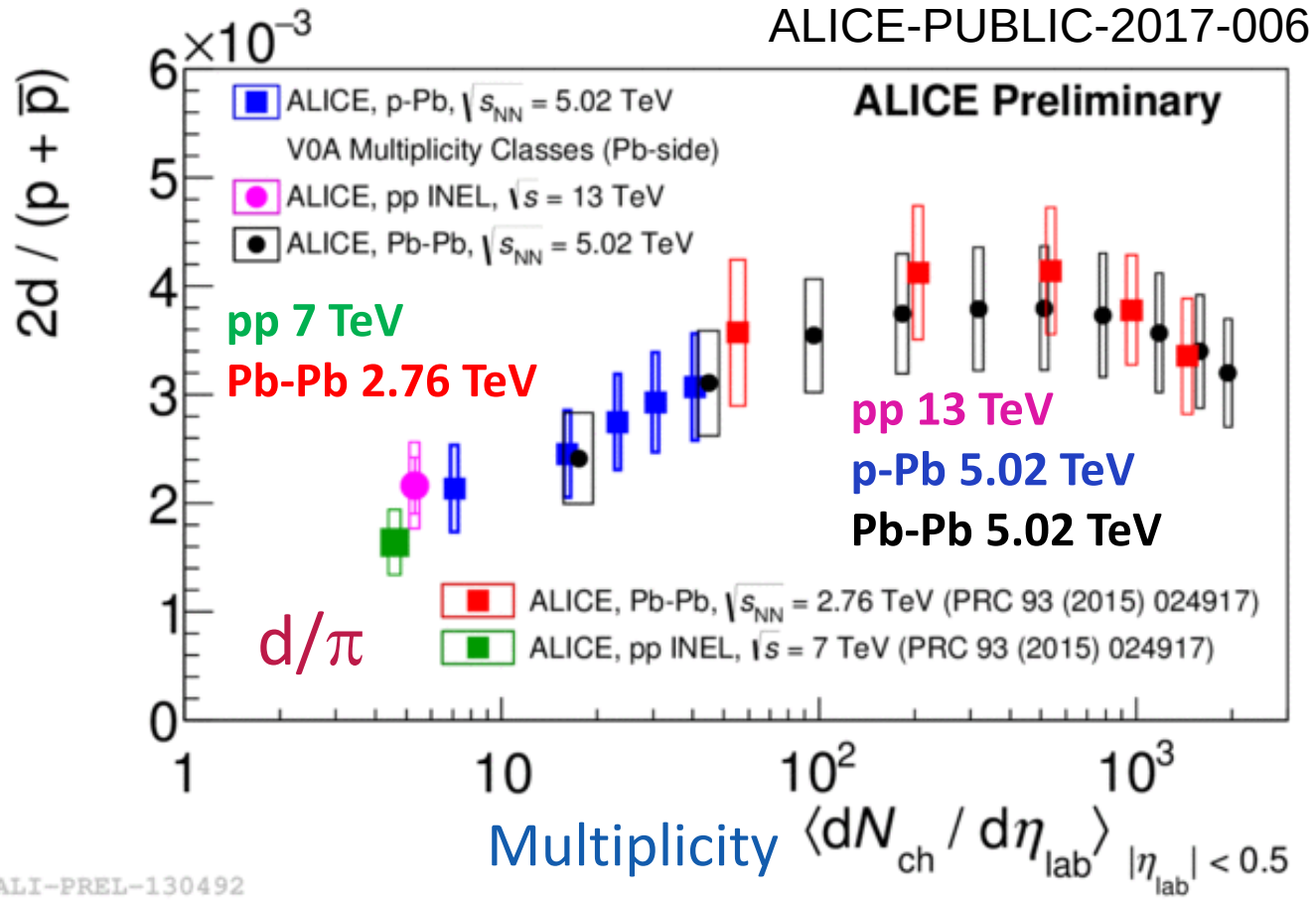
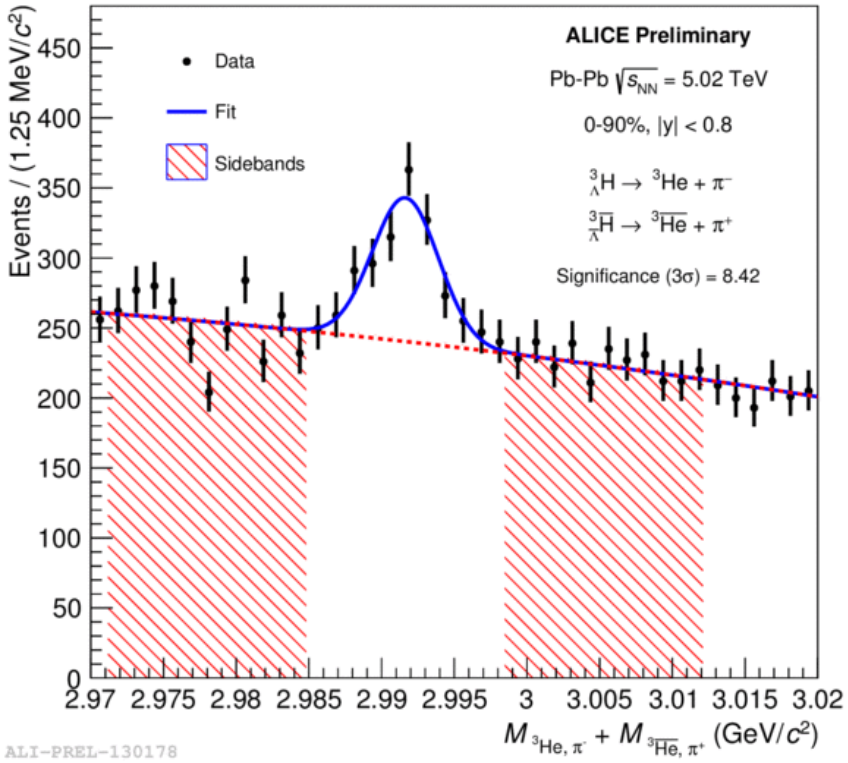
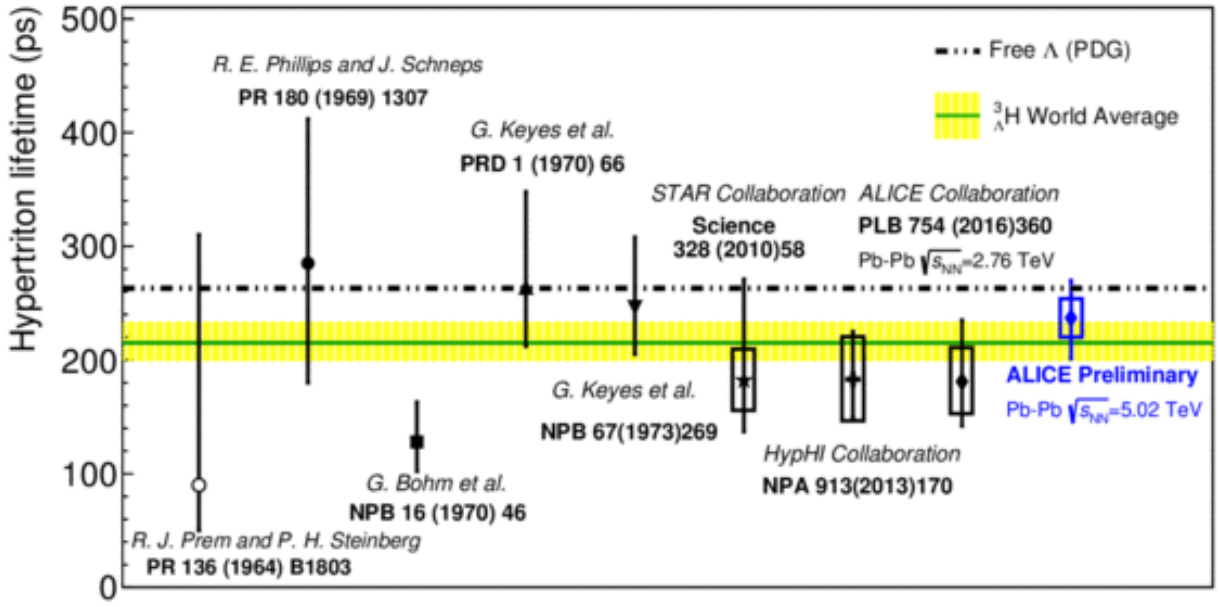


Sensitive probe of the hadronic scattering stage

Rising **trend of d/p ratio with multiplicity** until intermediate multiplicities, then saturation: interplay between coalescence and thermal production?

Measurement of the (anti-)hypertriton lifetime in Pb-Pb collisions





$^{3}_{\Lambda}H$ reconstructed in the ^{3}He-π decay channel (^{3}He identification via E-loss in TPC)

Result fully **compatible with the world-average and with the free Λ lifetime**

Significantly improved uncertainties wrt Run I

(and one of the most precise available measurements)

Charge-dependent directed flow in Pb-Pb collisions

- Search for **magnetic-induced charged currents** from moving nuclei

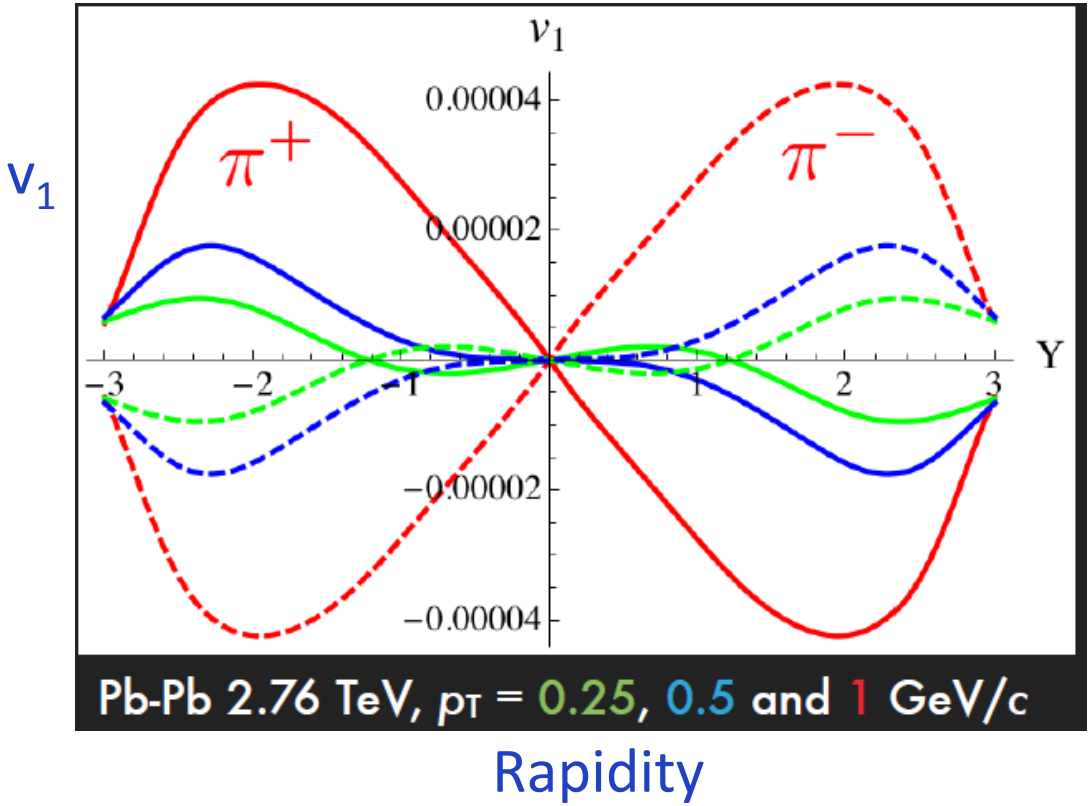
- Goal: **constrain the early-time magnetic field in the medium**
  → pre-requisite for studying its interactions with the quantum properties of the system
  (e.g. Chiral Magnetic Effect)

- Directed flow (v_1): quantifies **collective particle motion under pressure gradients** in the expanding system

$$\frac{dN}{d\varphi} \propto 1 + 2\boxed{v_1}\cos[\varphi - \Psi_1] + 2v_2\cos[2(\varphi - \Psi_2)] + 2v_3\cos[3(\varphi - \Psi_3)] + ..$$

- Magnetic field expected to induce a charge-dependent directed flow on particles in the medium

- Rapidity slope of ($v_1^+ - v_1^-$) expected to vary with p_T



v_1

Rapidity

U. Gursoy et al., Phys. Rev. C89(5) 054905 2014

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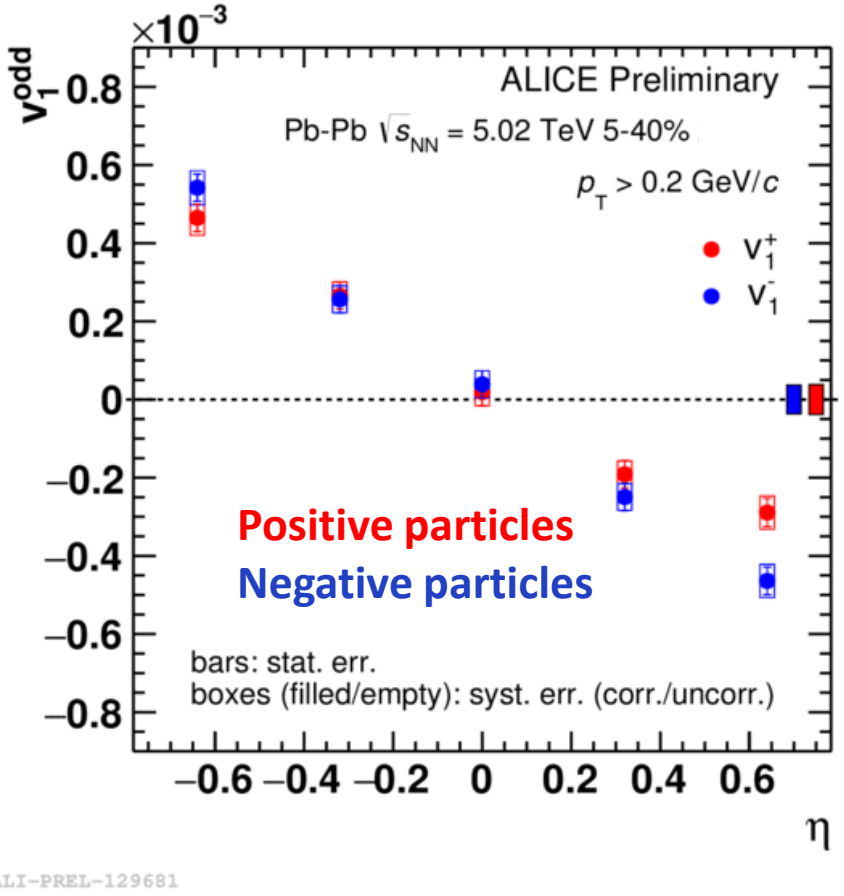
  (e.g. Chiral Magnetic Effect)

- Measurement performed so far for the pseudorapity-odd component of v_1



Charge-dependent directed flow in Pb-Pb collisions

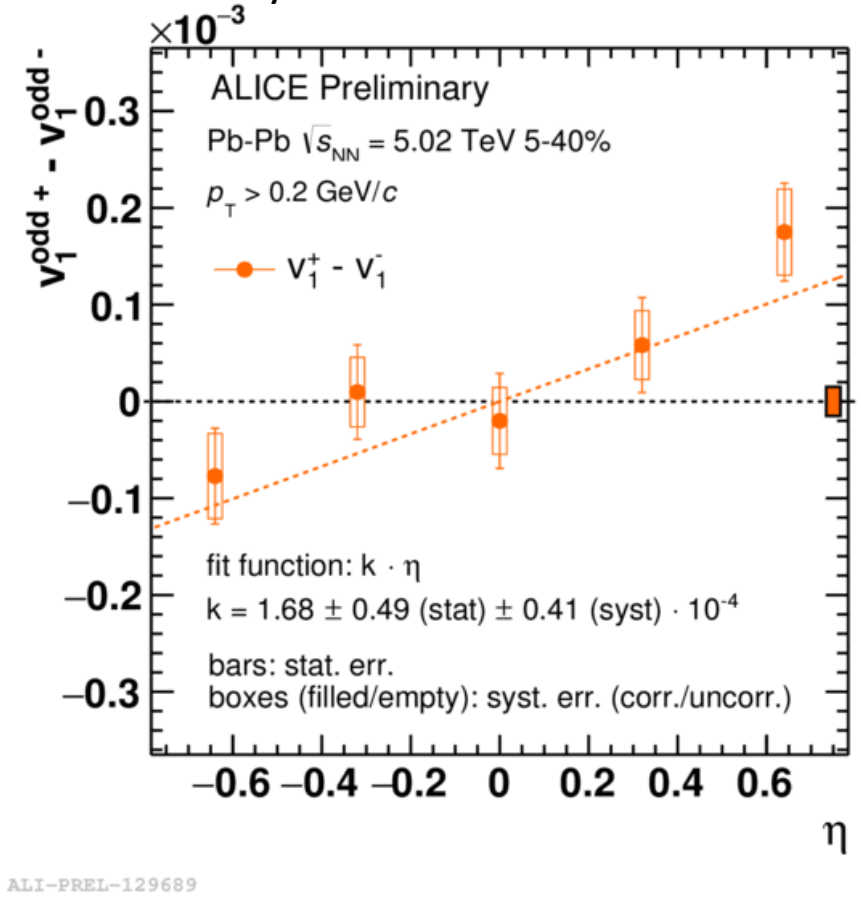
- Search for **magnetic-induced charged currents** from moving nuclei

- Goal: **constrain the early-time magnetic field in the medium**
  → pre-requisite for studying its interactions with the quantum properties of the system
  (e.g. Chiral Magnetic Effect)

- Measurement performed so far for the pseudorapity-odd component of v_1

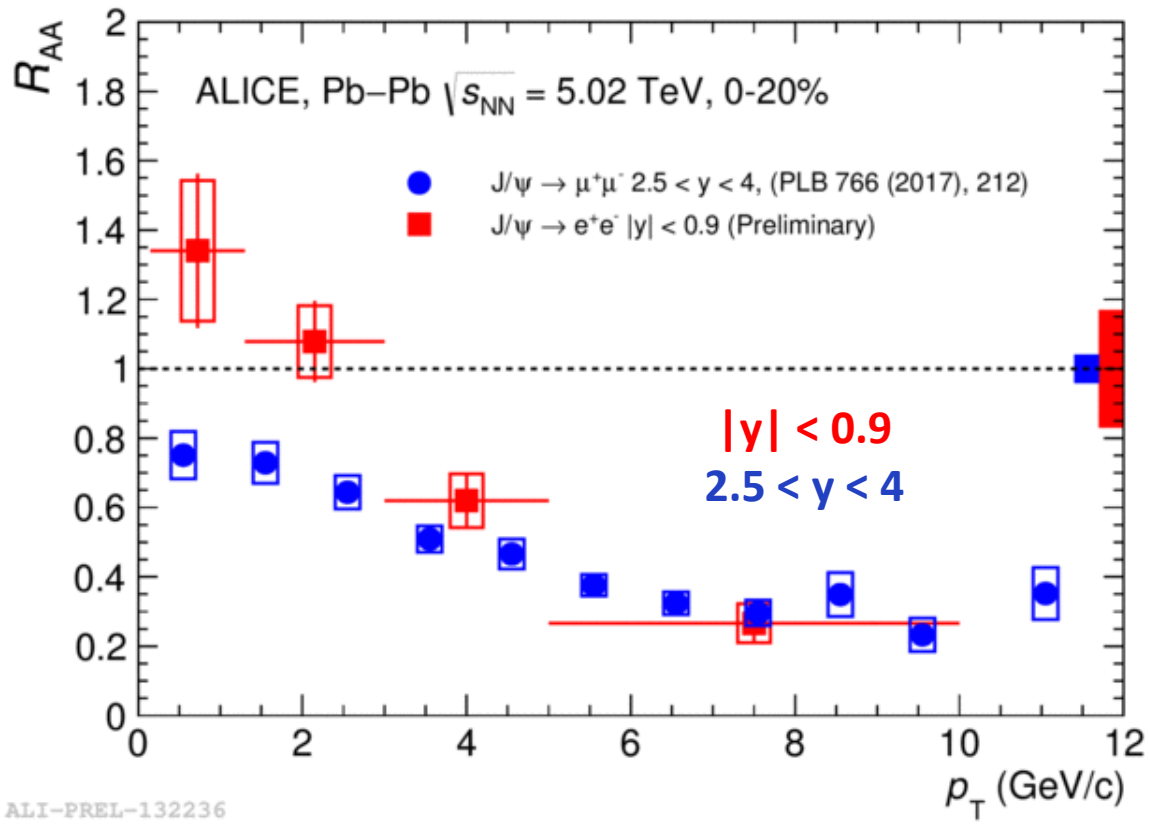
- **Non-zero slope measured** with a significance of 2σ

- Interpretation requires more data and further theoretical effort:
  - slope is 1-2 order of magnitude bigger than expectations, and of opposite sign
  - p_T-dependence
  - competing Faraday and Hall effects



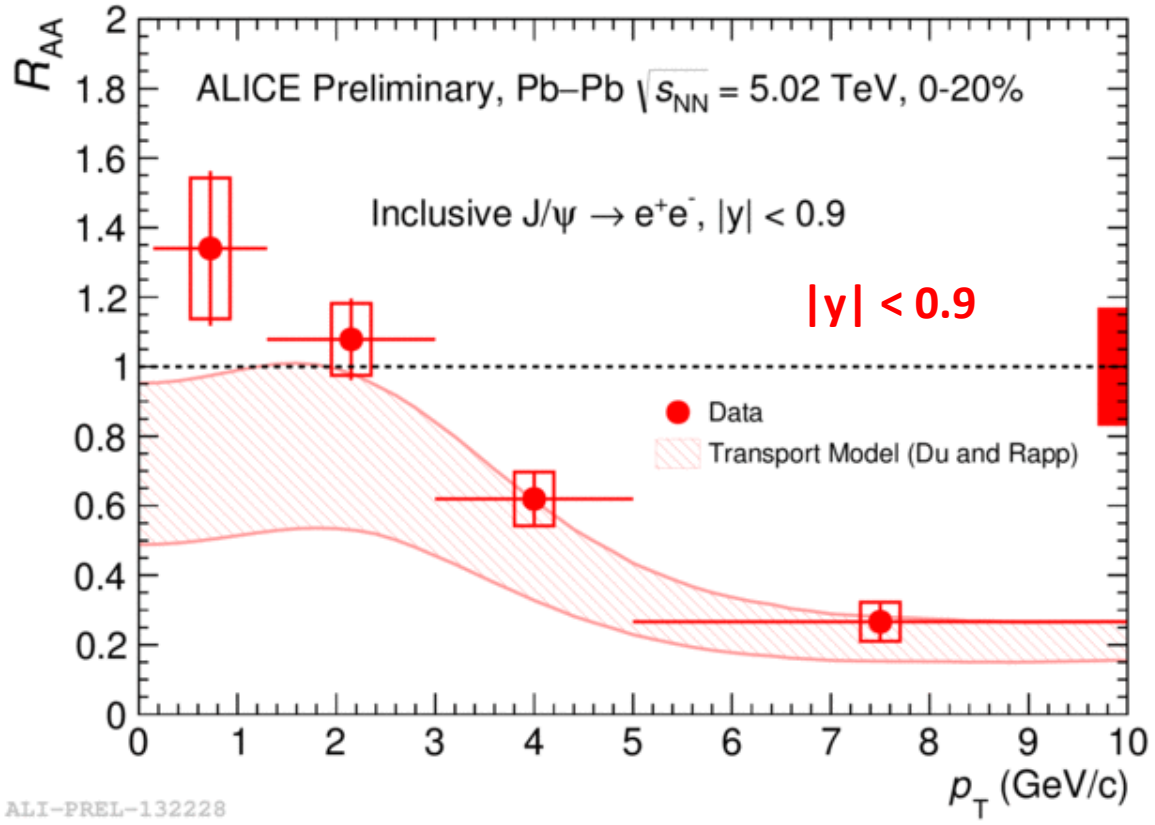
J/ψ nuclear modification factor at mid-rapidity

- **Measurement of the J/ψ nuclear modification factor vs p_T at mid-rapidity**
- Data indicate a **smaller suppression than at forward rapidity** in central collisions and low p_T
- Compatible with regeneration/recombination scenarios



J/ψ nuclear modification factor at mid-rapidity

- **Measurement of the J/ψ nuclear modification factor at mid-rapidity** with Run II data
- Data indicate a **smaller suppression than at forward rapidity** in central collisions and low p_T
- Compatible with regeneration/recombination scenarios
- Data sit on the upper side of the theory band from a transport model (with regeneration)



D-meson production

- **Measurement of the nuclear modification factor**
- Strong suppression of D mesons in central (0-10%) Pb-Pb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV
- Hint for a **smaller suppression of D_s^+** wrt non-strange D mesons
  → coalescence + strangeness enhancement?

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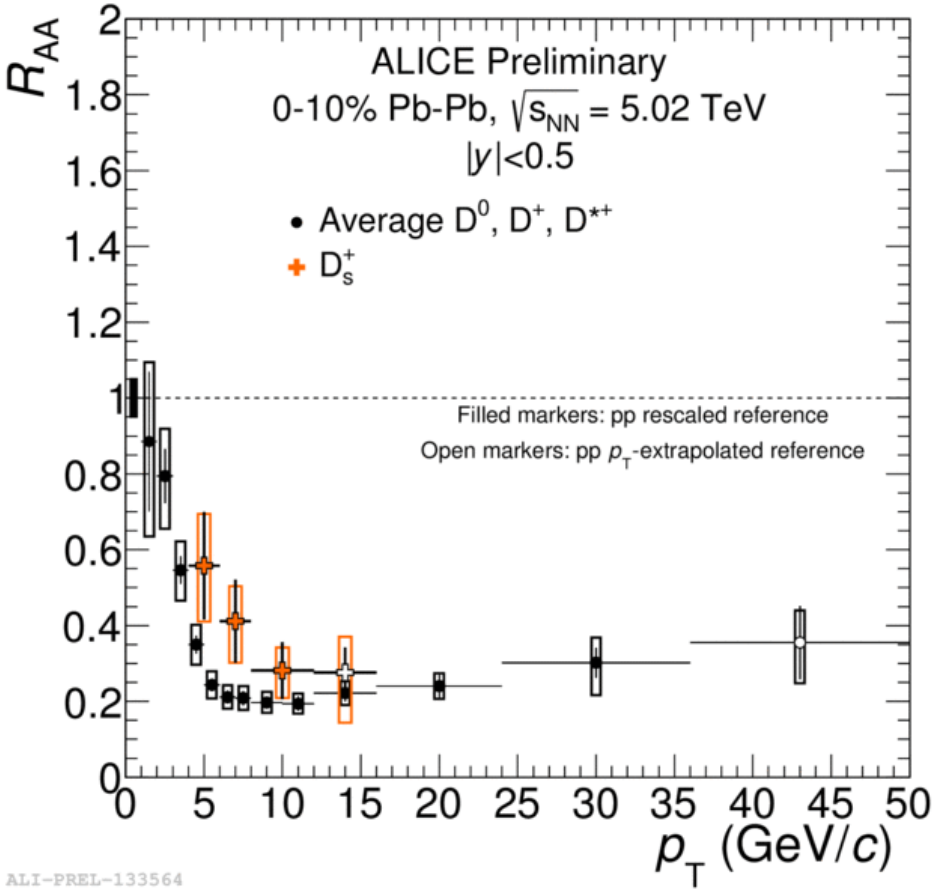


D-meson production

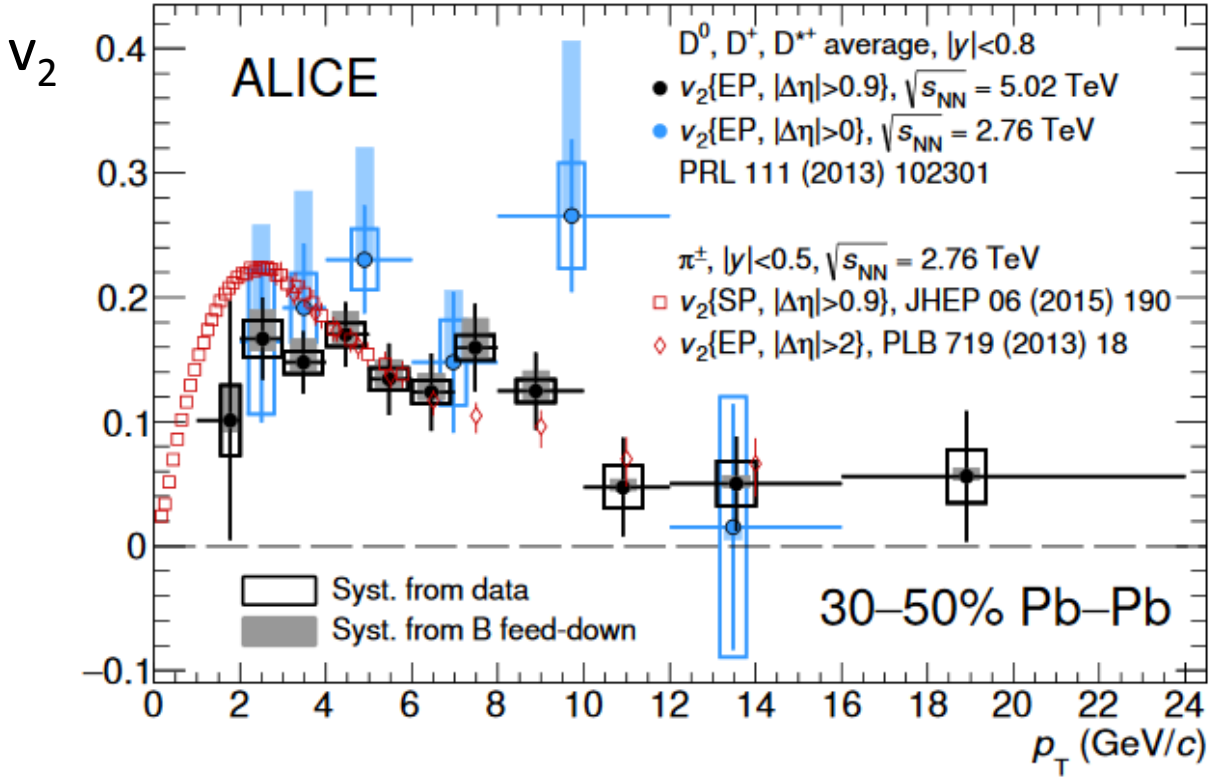
arXiv:1707.01005

- **Elliptic flow** is quantified by the v_2 coefficient

$$\frac{dN}{d\varphi} \propto 1 + 2v_1\cos[\varphi - \Psi_1] + 2\boxed{v_2}\cos[2(\varphi - \Psi_2)] + 2v_3\cos[3(\varphi - \Psi_3)] + ..$$

- Address collectivity in Pb-Pb collisions
  → study how the **initial system asymmetry affects final-state kinematical distribution**

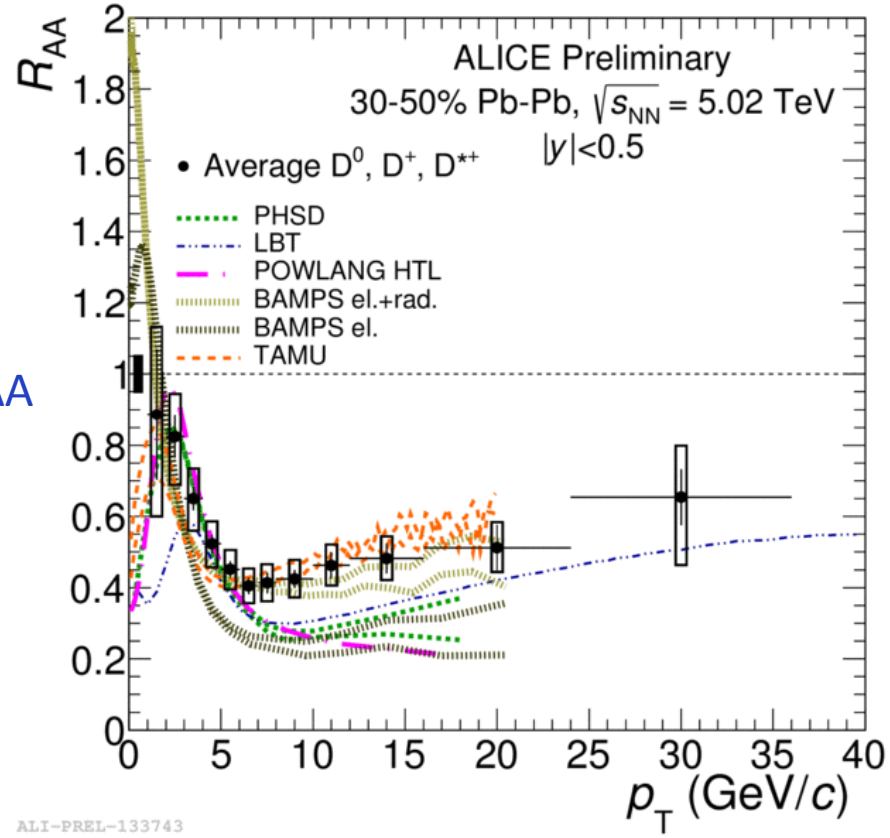
- **v_2 of D mesons measured** in semi-central collisions compatible with that of charged particles
  → points to a strong **participation of charm quarks in the collective motion**



D-meson production

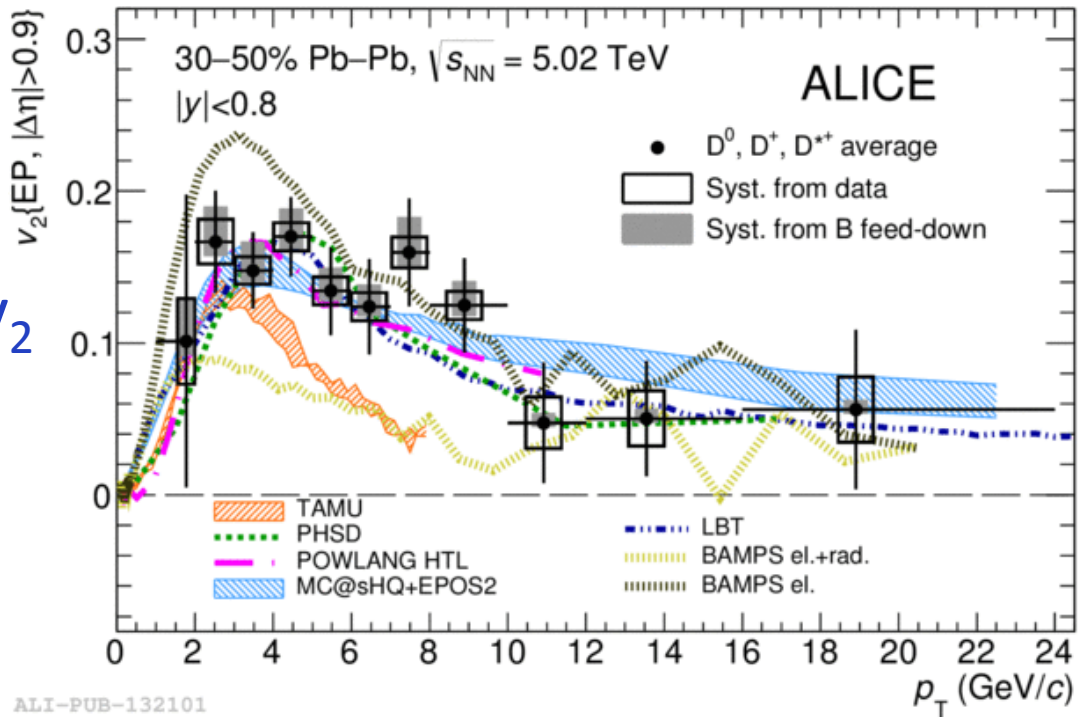
ALICE-PUBLIC-2017-003

R_{AA}



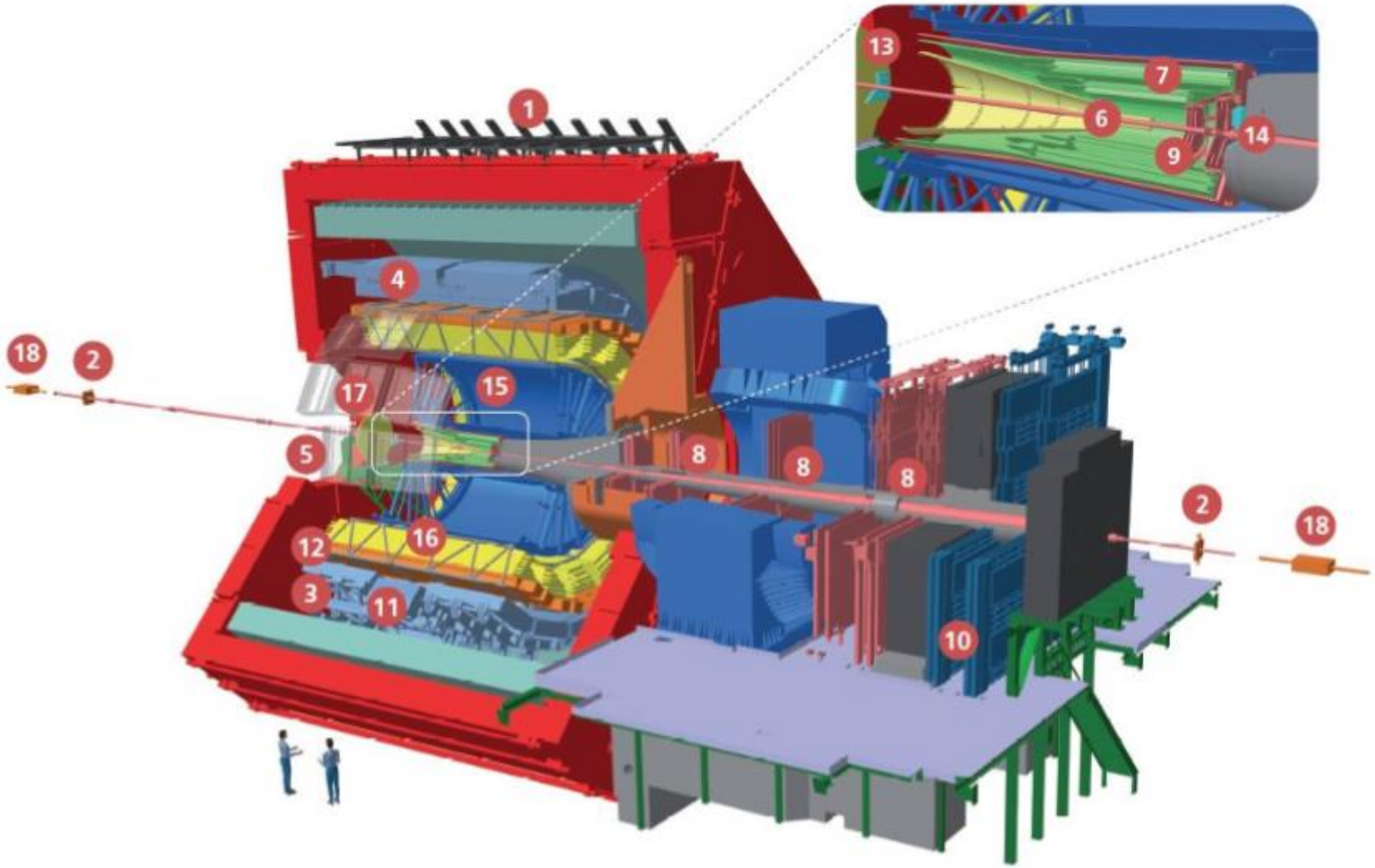
arXiv:1707.01005

v_2



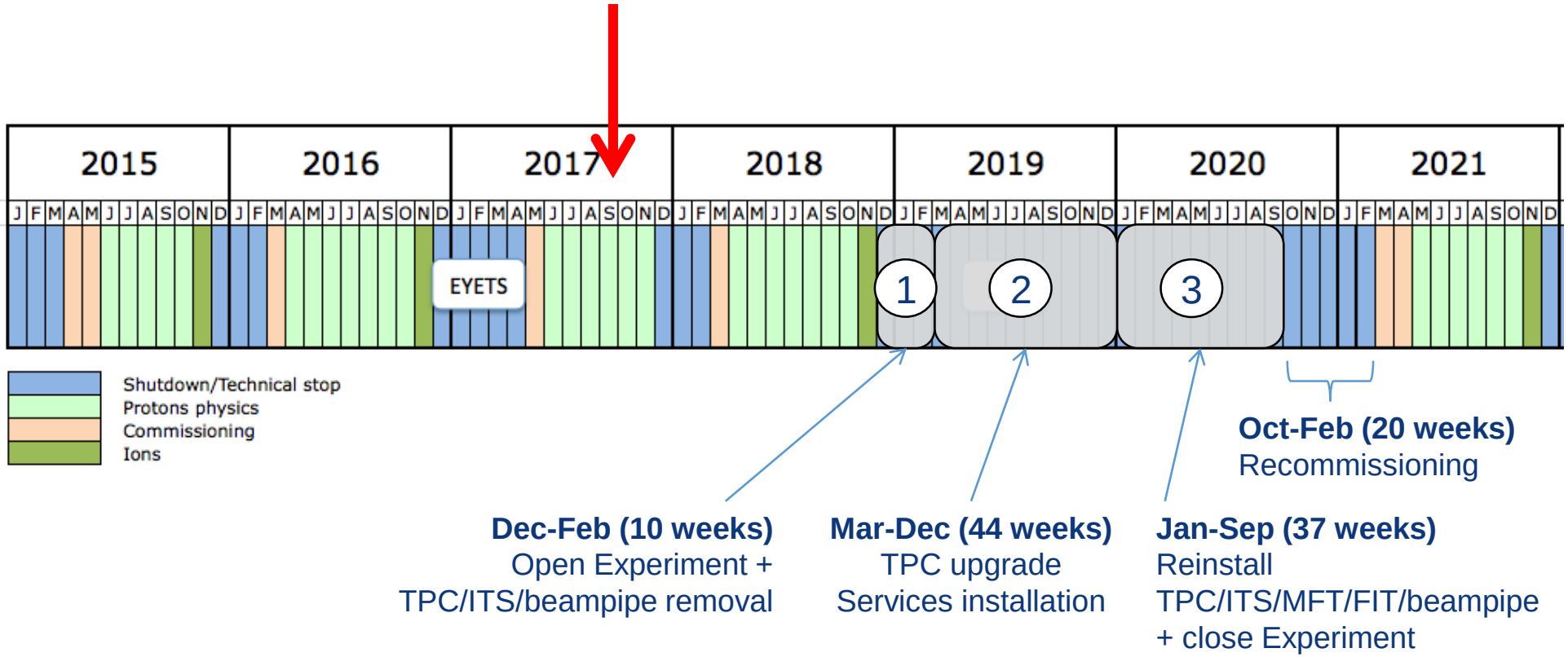
- The **measurements of v_2 and R_{AA} provide together important constraints** for the medium transport coefficients

Upgrade status



1. ACORDE | ALICE Cosmic Rays Detector
2. AD | ALICE Diffractive Detector
3. DCal | Di-jet Calorimeter
4. EMCal | Electromagnetic Calorimeter
5. HMPID | High Momentum Particle Identification Detector
6. ITS-IB | Inner Tracking System - Inner Barrel
7. ITS-OB | Inner Tracking System - Outer Barrel
8. MCH | Muon Tracking Chambers
9. MFT | Muon Forward Tracker
10. MID | Muon Identifier
11. PHOS / CPV | Photon Spectrometer
12. TOF | Time Of Flight
13. T0+A | Tzero + A
14. T0+C | Tzero + C
15. TPC | Time Projection Chamber
16. TRD | Transition Radiation Detector
17. V0+ | Vzero + Detector
18. ZDC | Zero Degree Calorimeter

Long Shutdown 2 schedule



Inner Tracking System upgrade

Pixel Sensor Chip (ALPIDE) – Production

Production Status	Nr. wafers	Nr. chips
delivered	560	24840

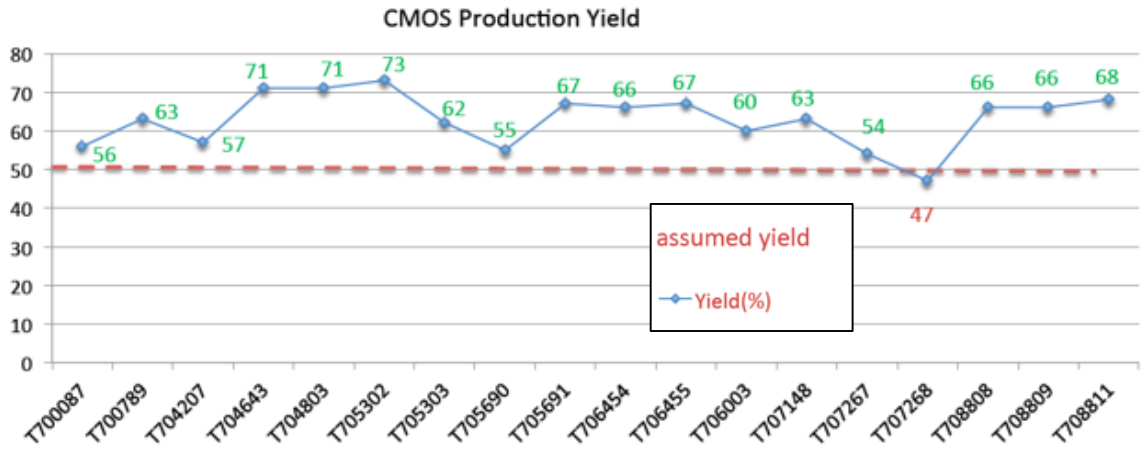
Full production order: 1200 wafers

2 wafers of each lot are shipped to CERN (monitor yield)

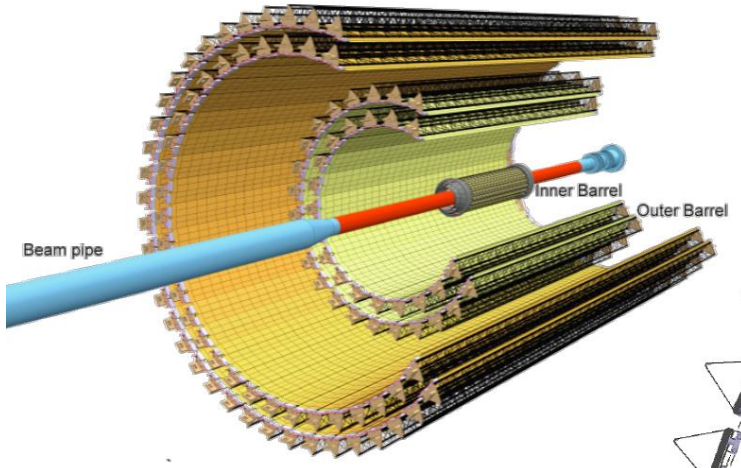
Remaining wafers are sent to Korea for thinning and dicing

Production proceeds smoothly
Throughput ⇨ 100 wafers/month

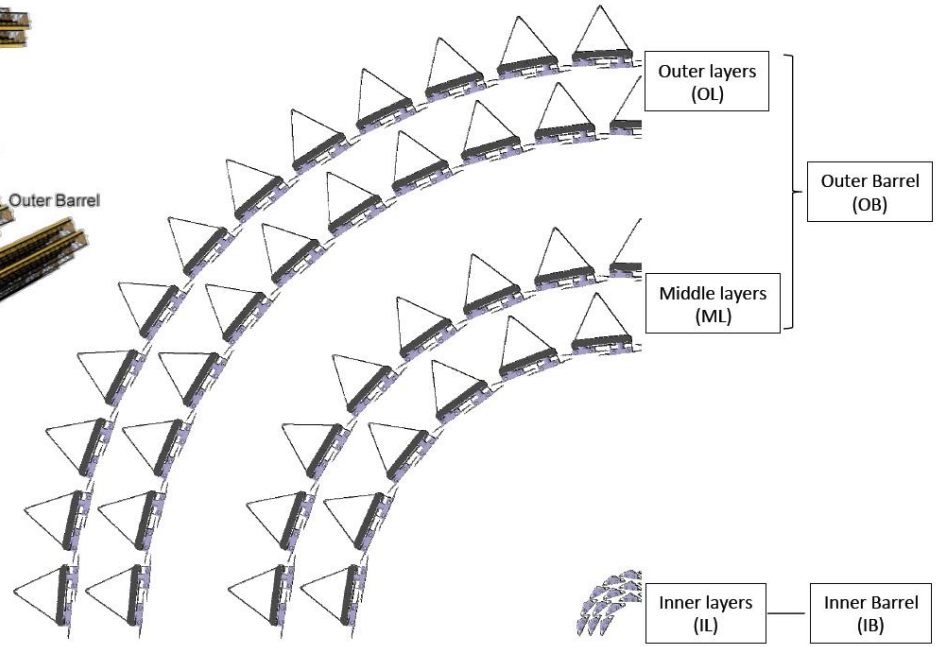
⇨ Production will continue till Feb 2018



Detector Layout



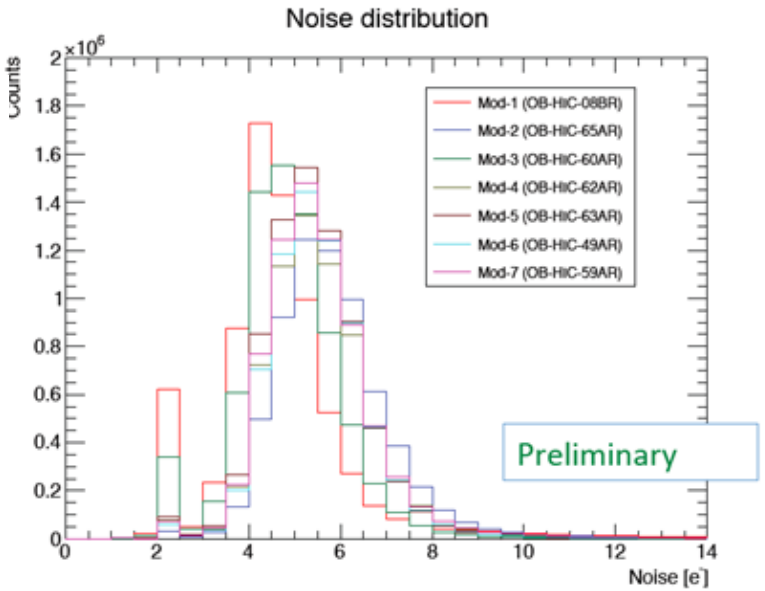
ITS structure
- 7 layers: 3 (IL), 2 (ML), 2(OL)
- 192 Staves: 48 (IL), 54 (ML), 90 (OL)



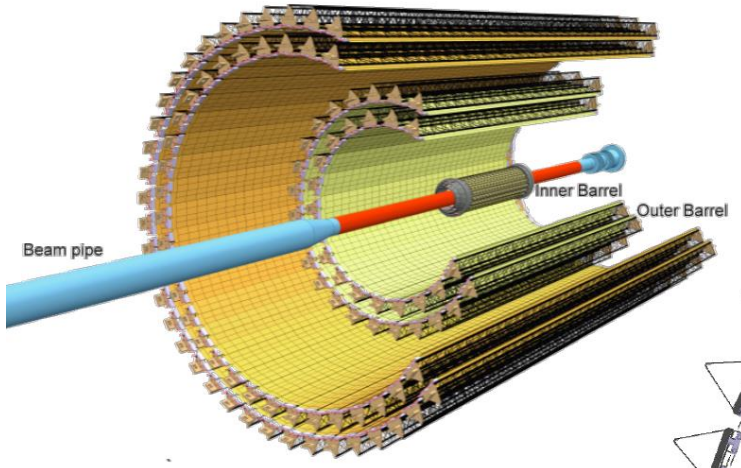
Layer #	6	5	4	3	2	1	0
N. of Stave	48	42	30	24	20	16	12

7

Inner Tracking System upgrade



Detector Layout



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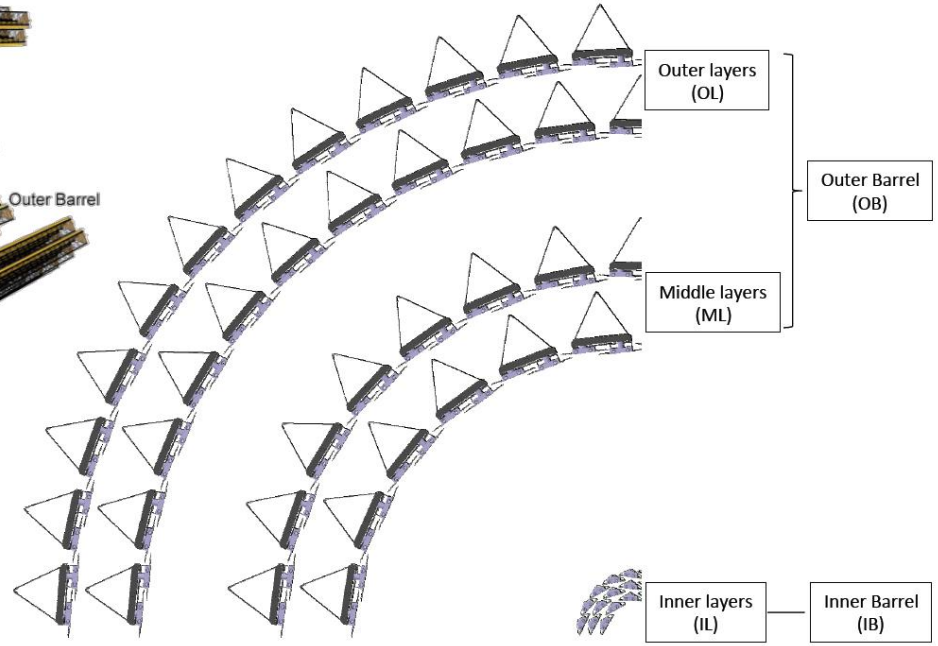


Layer #	6	5	4	3	2	1	0
N. of Stave	48	42	30	24	20	16	12

7

Stave Prototypes

- First half-stave of stave 1 tested in Torino; all 98 chips fully functional
- Plot shown here:
  - Noise distribution measured in threshold scan on all 98 chips operated concurrently → **51 M pixels!**
  - Threshold scan tests both readout and analogue performance
  - Noise value comparable to single chips

Time Projection Chamber upgrade

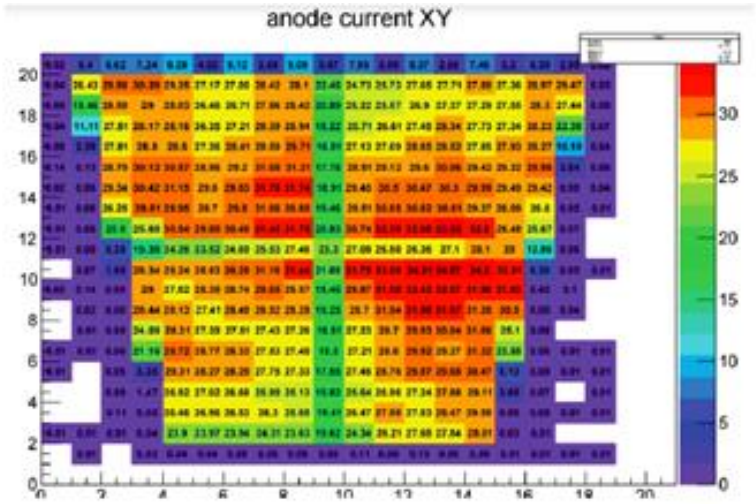
- Main detector upgrade: build **new GEM-based read-out chambers**
- 45% of all required GEM foils produced
- **Production completed by Apr 2018**
- First 5+5 full Inner + Outer Read-Out Chambers (IROC+OROC) being produced

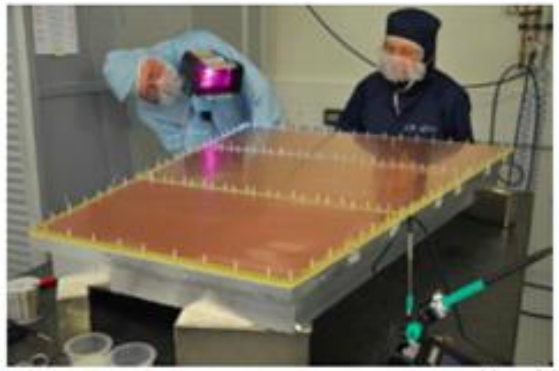
IROC:

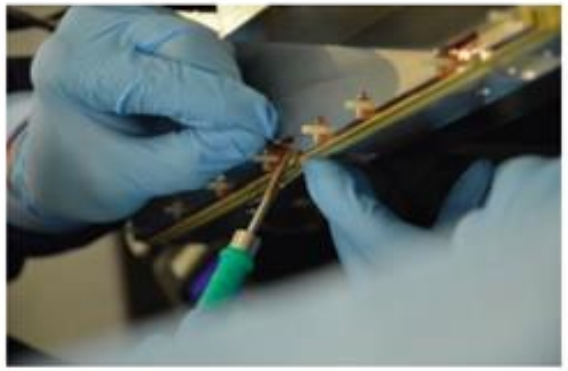
- 4 IROCs are ready and qualified
  - all acceptance criteria met
- 1 shipped to CERN for test at P2

OROC:

- All GEMs framed
- All chamber bodies assembled
- 1 OROC assembled at GSI
- 2 more OROC bodies at GSI for assembly in Sept.
- 2 more OROC bodies at Bucharest for assembly in Sept./Oct.





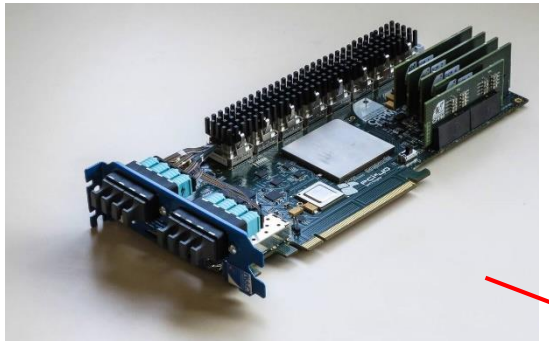


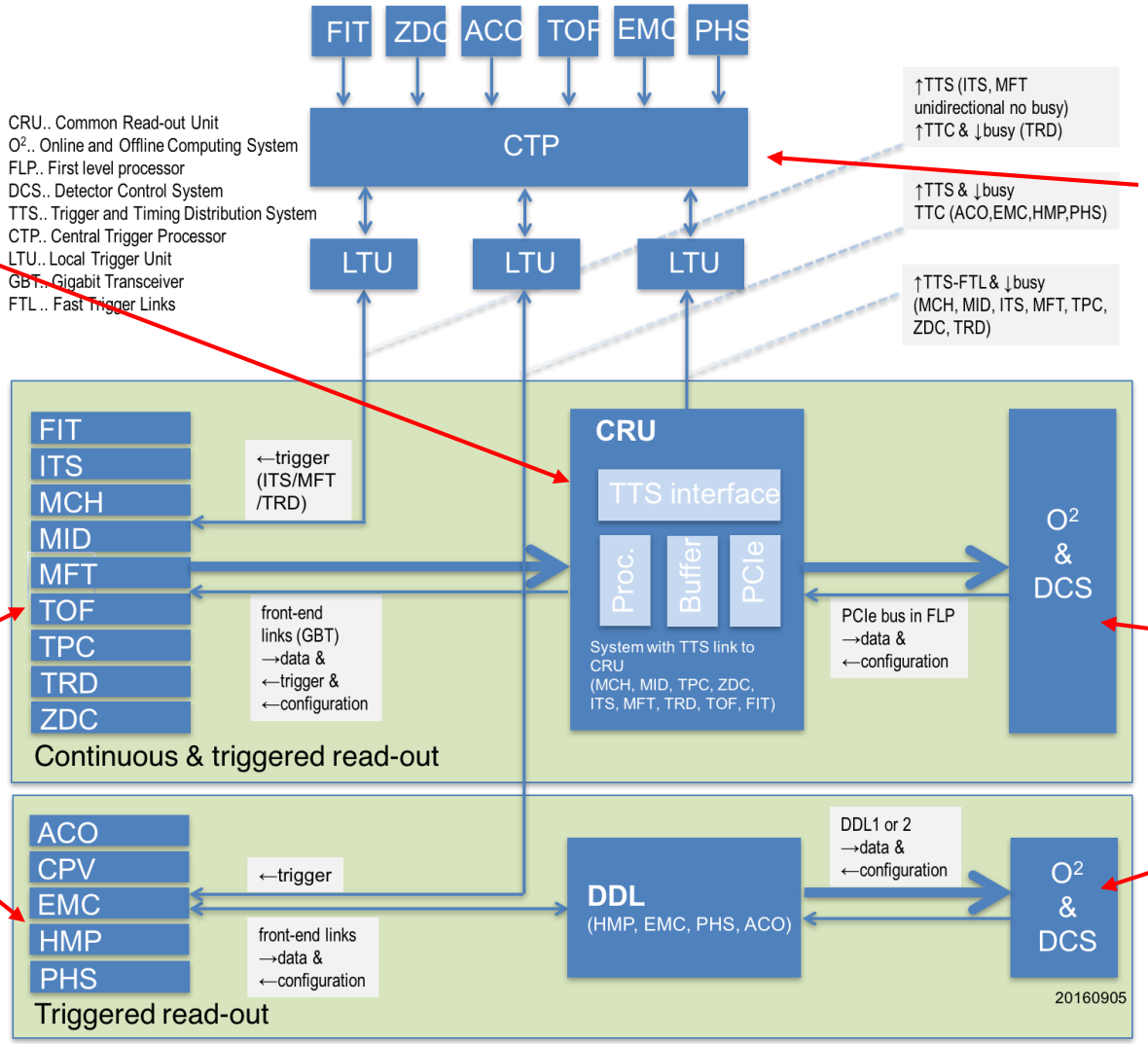
Electronics upgrade status

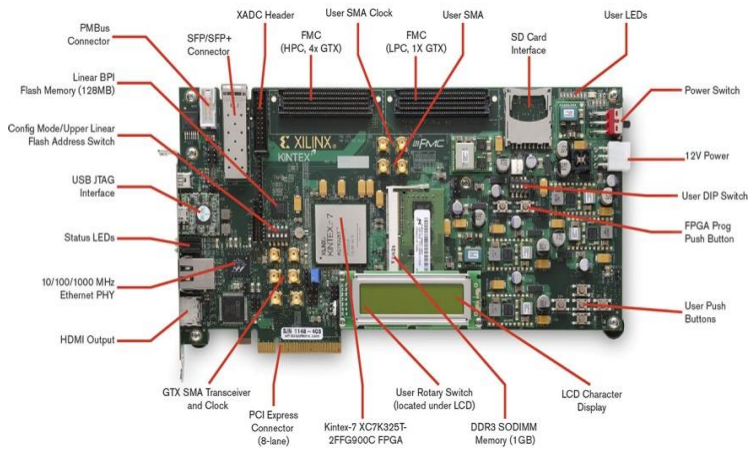
	Engineering Design Review	Production Readiness Review	Installation ready
CRU		Q4 2017	
CTP			
FIT read-out	26 Sept 2017	Dec 2018	
ITS ALPIDE			
ITS read-out		Jan 2018	
MCH system & FEC		Q2 2018	
MCH SOLAR		Oct 2017	
MFT		Q2 2018	
MID front-end			
MID read-out		Oct 2017	
SAMPA		Feb 2018	
TPC	4 & 5 Oct 2017	Jul 2018	
TOF			
ZDC	Dec 2017	Q4 2018	

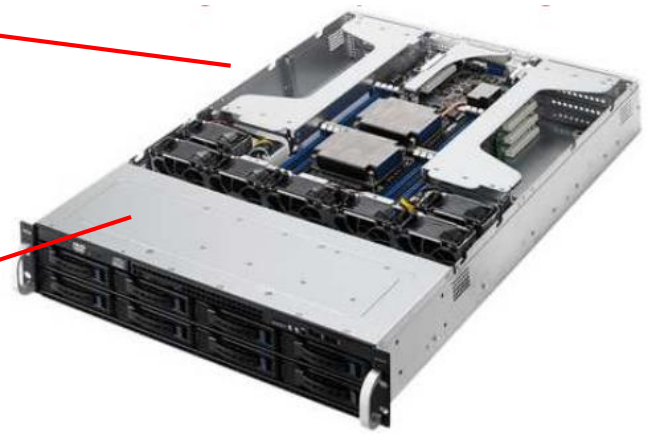
- **Moved from R&D into the pre-series and production phase**

Full electronics chain system test









Conclusions

- A **wealth of results from both Run II and Run I** data
  - study the properties of particle production in pp collisions
  - constrain cold nuclear matter effects in p-Pb collisions (+ onset of collectivity?)
  - study the hot and dense medium produced in Pb-Pb collisions in both the soft and hard sector

- Analysis of Run II data still in full swing
  →many **more results to come up soon**

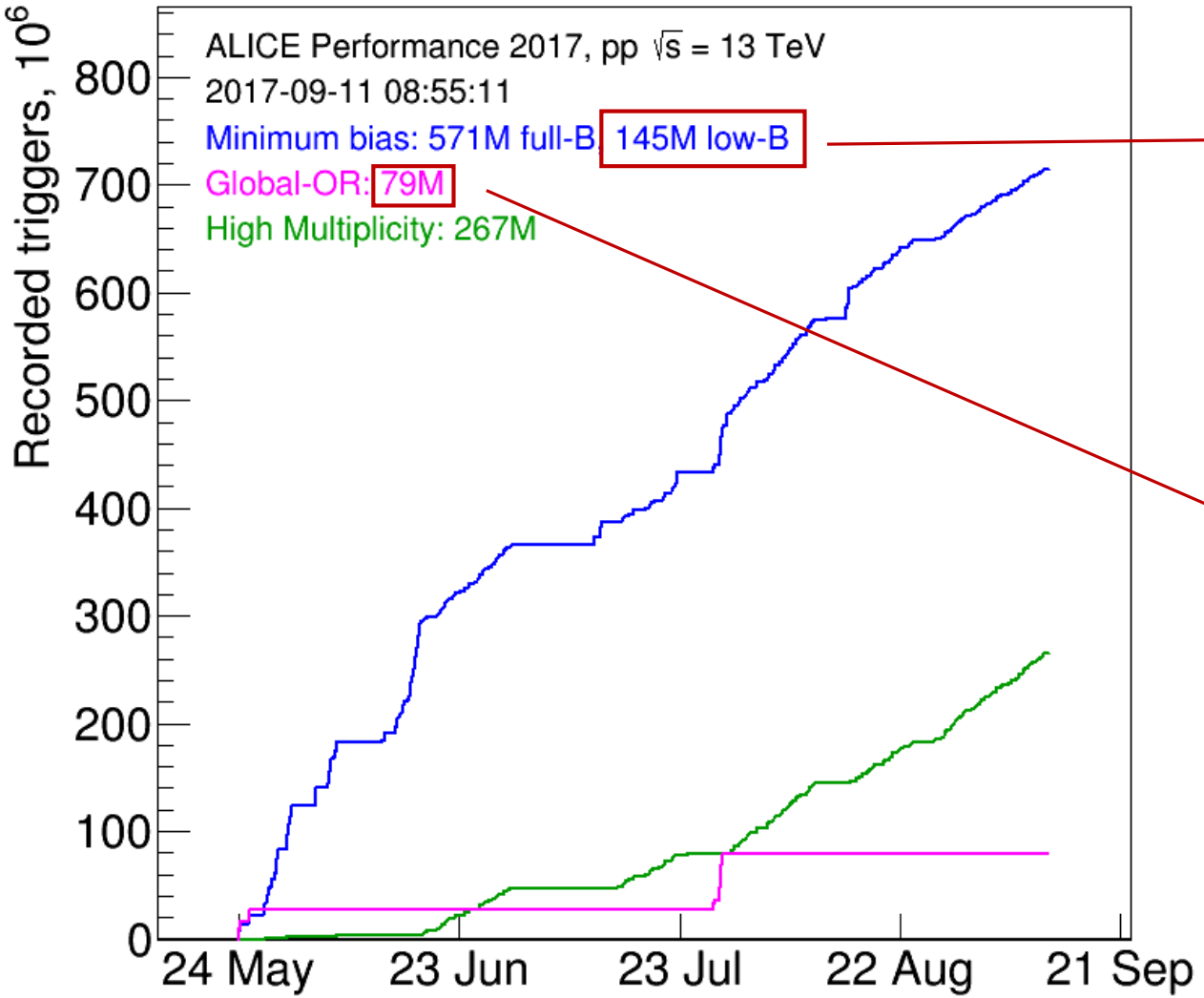
- **Promising 13 TeV pp data-set** being collected with a rich trigger menu

- Looking forward to the **pp run at 5 TeV**

- **Upgrade projects for Run III well on track**

Backup

Event statistics 2017 (pp 13 TeV)



~150 M events collected at reduced magnetic field in 2017 (+50 M in 2016)
→ study of di-electron continuum and resonances in the low-mass region

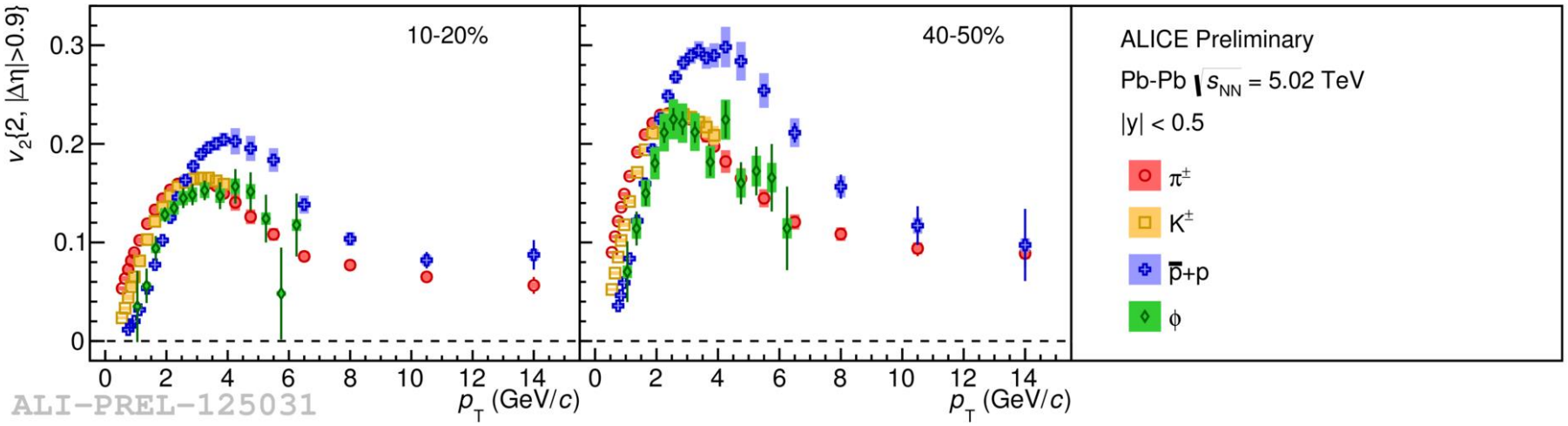
~80 M events collected with isolated bunches
→ inelastic cross section and diffractive measurements.
→ Exploit dedicated optics during vdM scans, allowing us to run our ZDCs in pp

Elliptic flow of identified particles in p-Pb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV

- **Elliptic flow** is quantified by the v_2 coefficient

$$\frac{dN}{d\varphi} \propto 1 + 2v_1\cos[\varphi - \Psi_1] + 2\boxed{v_2}\cos[2(\varphi - \Psi_2)] + 2v_3\cos[3(\varphi - \Psi_3)] + ..$$

- Typically used to address «collectivity» in Pb-Pb collisions
  → study how the **initial system asymmetry affects final-state kinematical distribution**
  → **mass-ordering**



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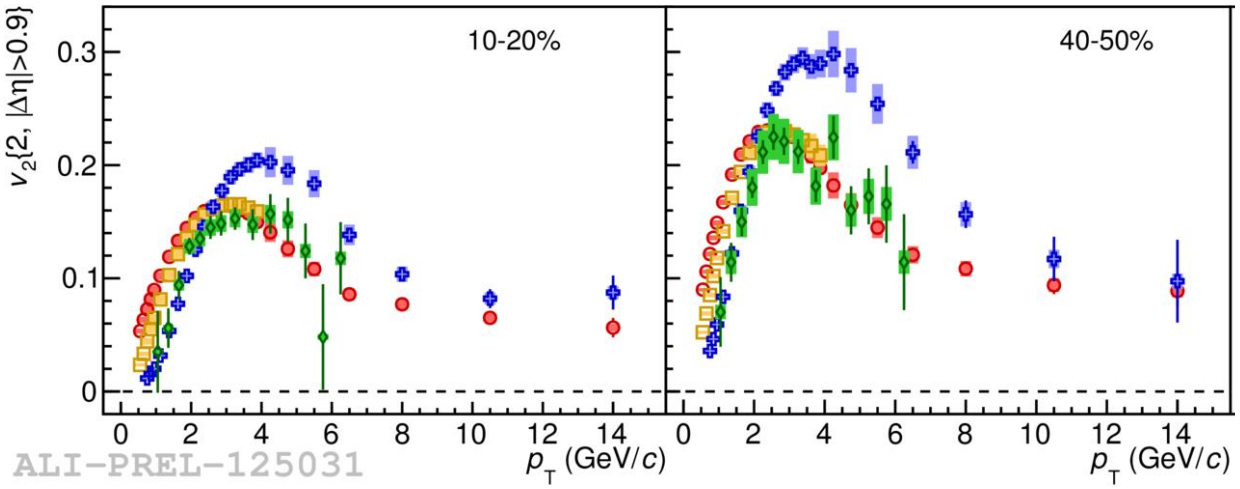
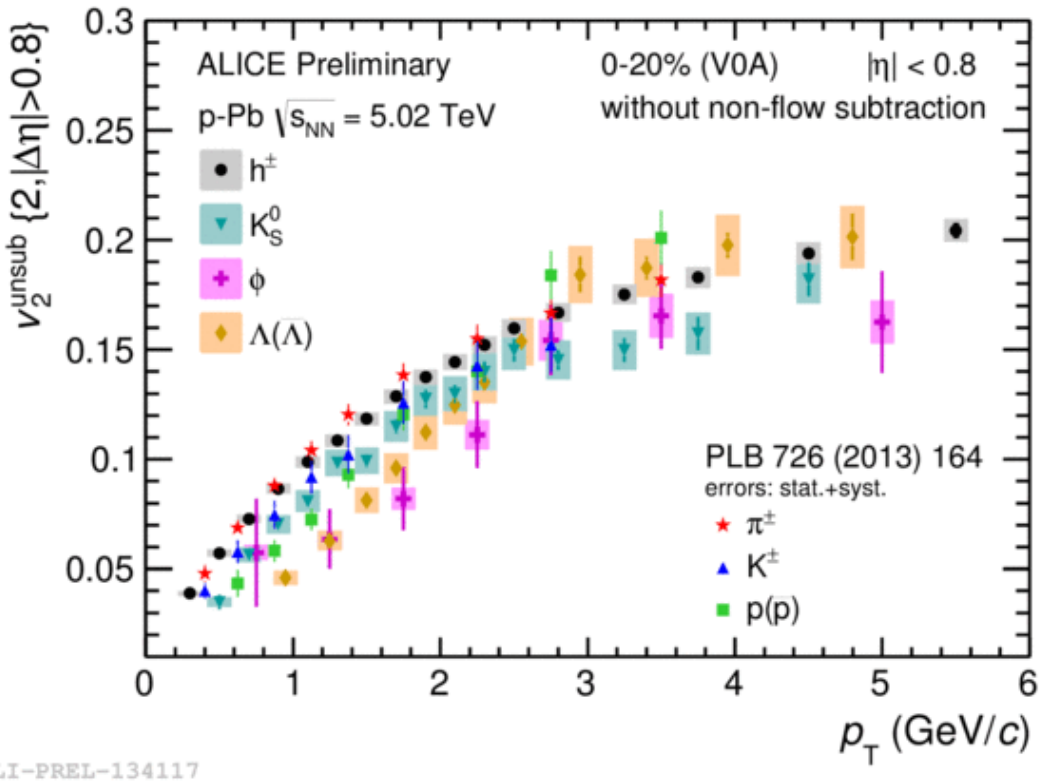


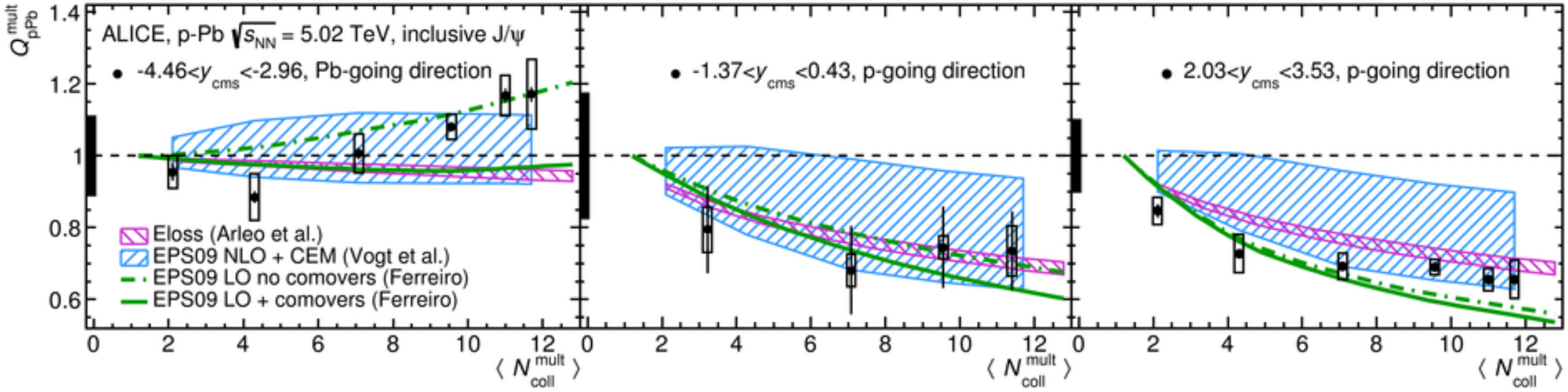
v_2 for identified particles measured in p-Pb collisions

Mass-ordering observed up to p_T ~2.5 GeV/c

More effort needed to understand the **role of non-flow contributions** to v_2



J/ψ Q_{pPb} at 5.02 TeV from Run I



D-meson and charged particles R_{pPb} and Q_{pPb}