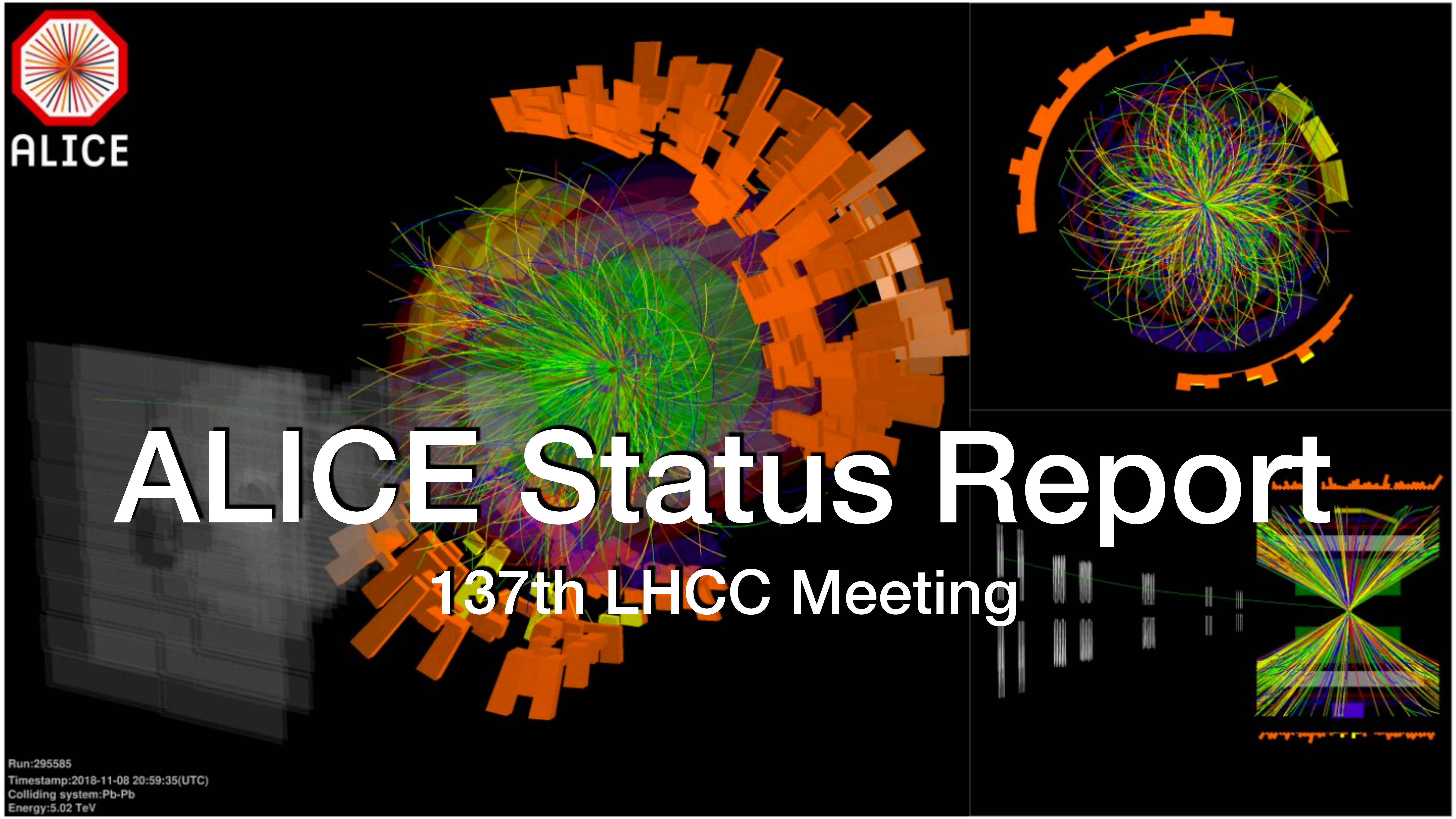


ALICE Status Report

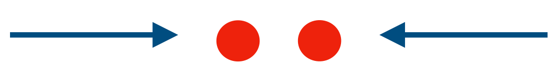
137th LHCC Meeting

Cristina Terrevoli
Univ. Of Houston
for the ALICE Collaboration

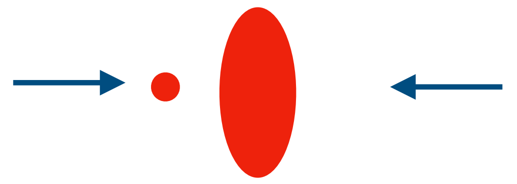
27 February 2019

ALICE publications: update since last LHCC

New Submissions:



- Measurement of D^0, D^+, D^* and D^+ production in pp collisions at $\sqrt{s}$ = 5.02 TeV
  - submitted to EPJC on 23/01/2019 arXiv:1901.07979
- Event-shape and multiplicity dependence of freeze-out radii in pp collisions at $\sqrt{s}$ = 7 TeV
  - submitted to JPG on 16/01/2019 arXiv:1901.05518
- Multiplicity dependence of (anti-)deuteron production in pp collisions at $\sqrt{s}$ = 7 TeV
  - submitted to PLB on 26/02/2019 arXiv:1902.09290

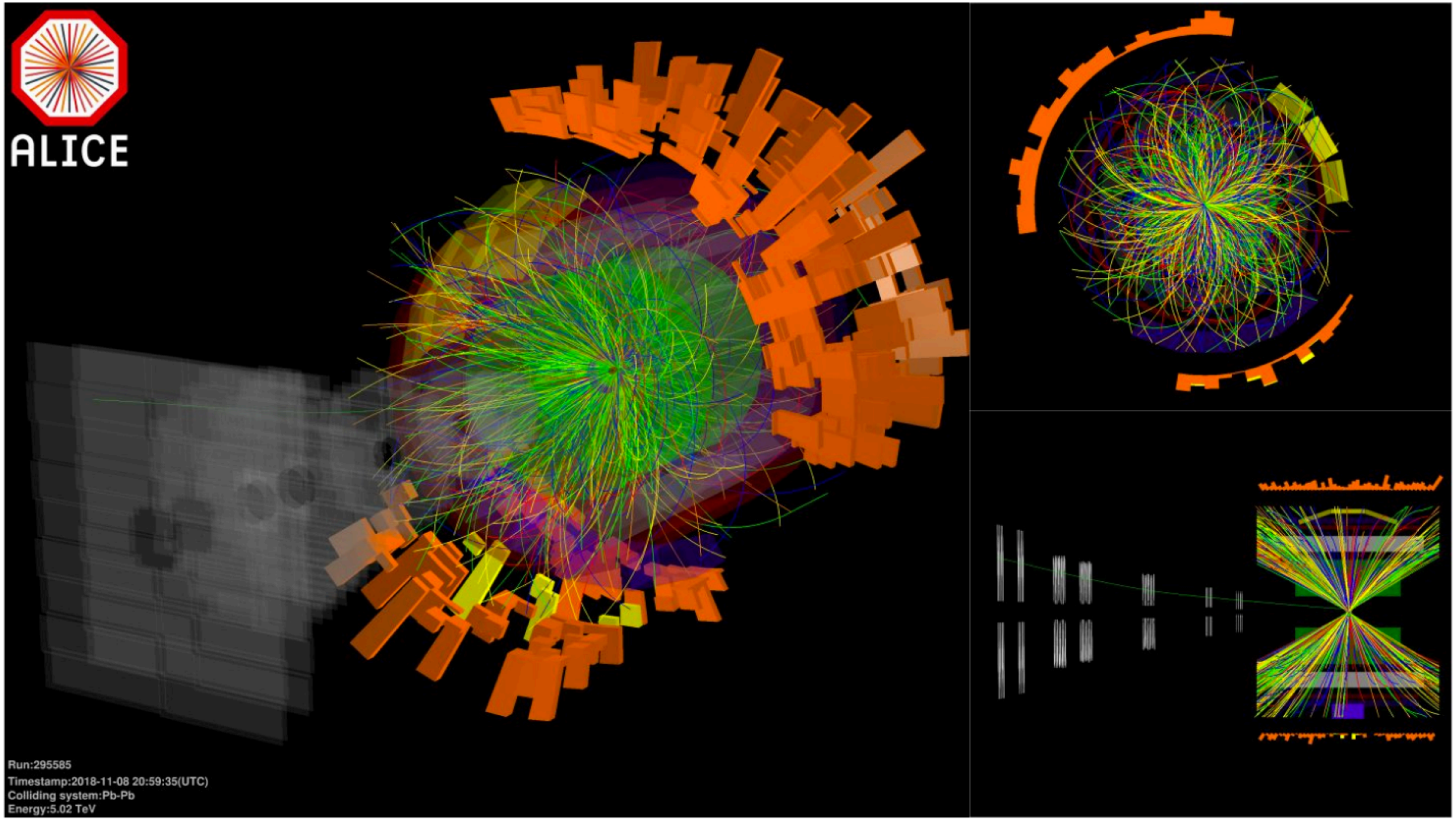


- Charged-particle pseudorapidiy density at mid-rapidity in p-Pb collisions at $\sqrt{s_{NN}}$ = 8.16 TeV
  - submitted to EPJC on 29/11/2019 arXiv:1812.01312

- Study of J/psi azimuthal anisotropy at forward rapidity in Pb-Pb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV
  - submitted to JHEP, on 29/11/2019 arXiv:1811.12727

- Calibration of the photon spectrometer PHOS of the ALICE experiment
  - submitted to JINST, on 19/02/2019, arXiv:1902.06145
- Real-time data processing in the ALICE High Level Trigger at the LHC
  - submitted to Computer Physics Communications, on 19/12/2018 arXiv:1812.08036

2018 Pb-Pb Campaign

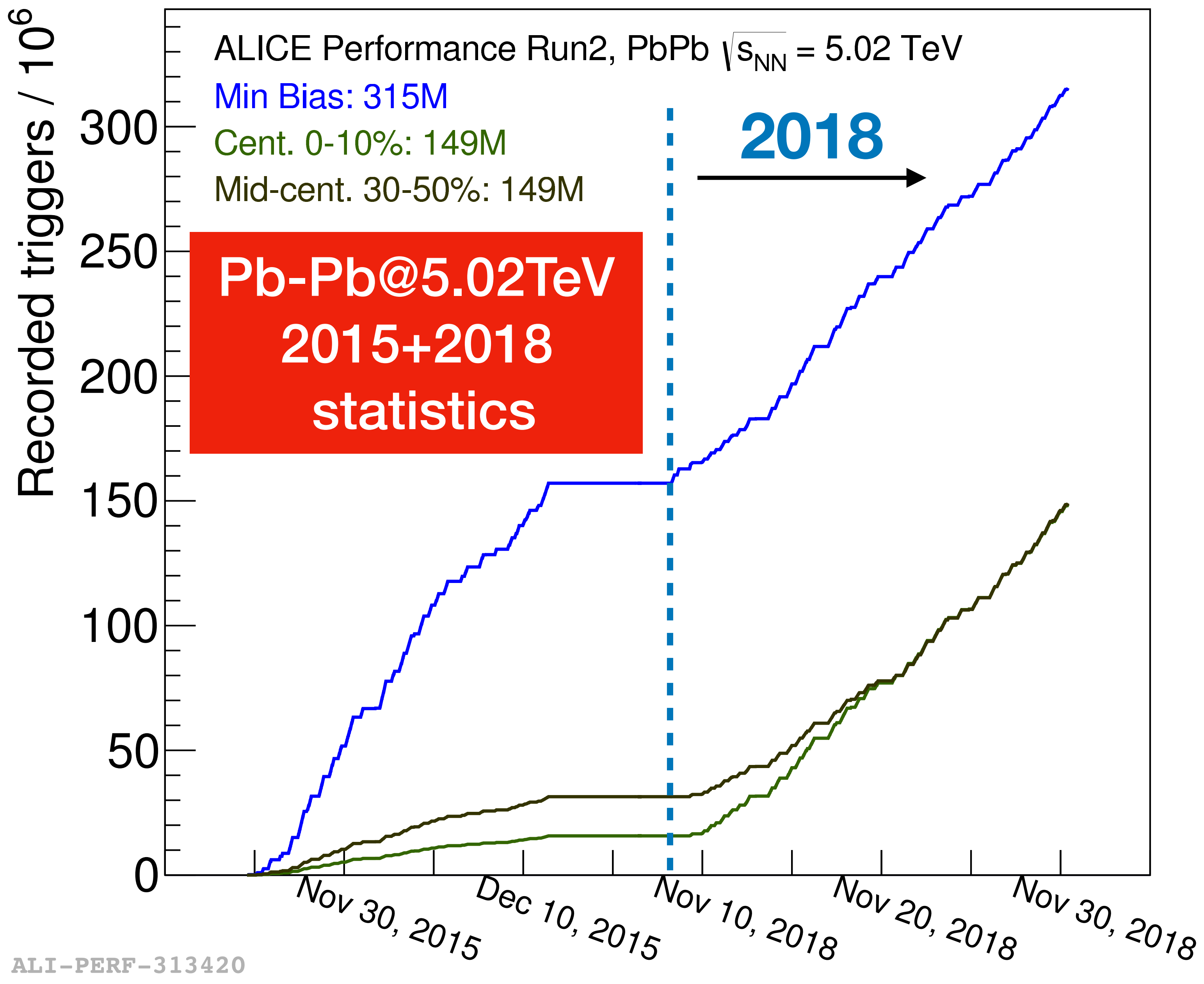


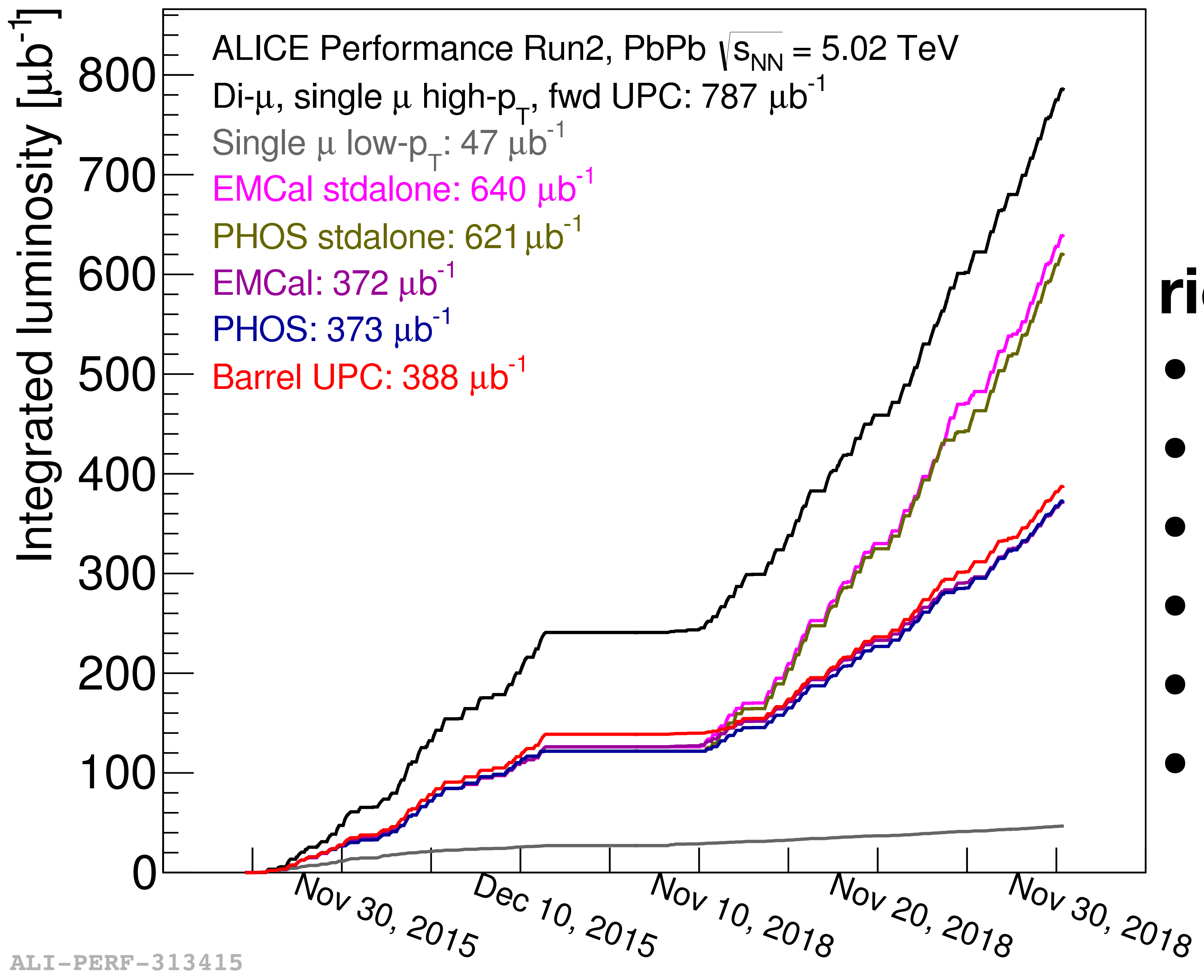
Run 2 statistics

2018 Pb-Pb data taking:

- **Minimum Bias** ~2015 Pb-Pb run
- **central 0-10% ~ 9** x 2015
- **mid-central 30-50% ~ 4** x 2015

- delivered luminosity ~ 2 x 2015



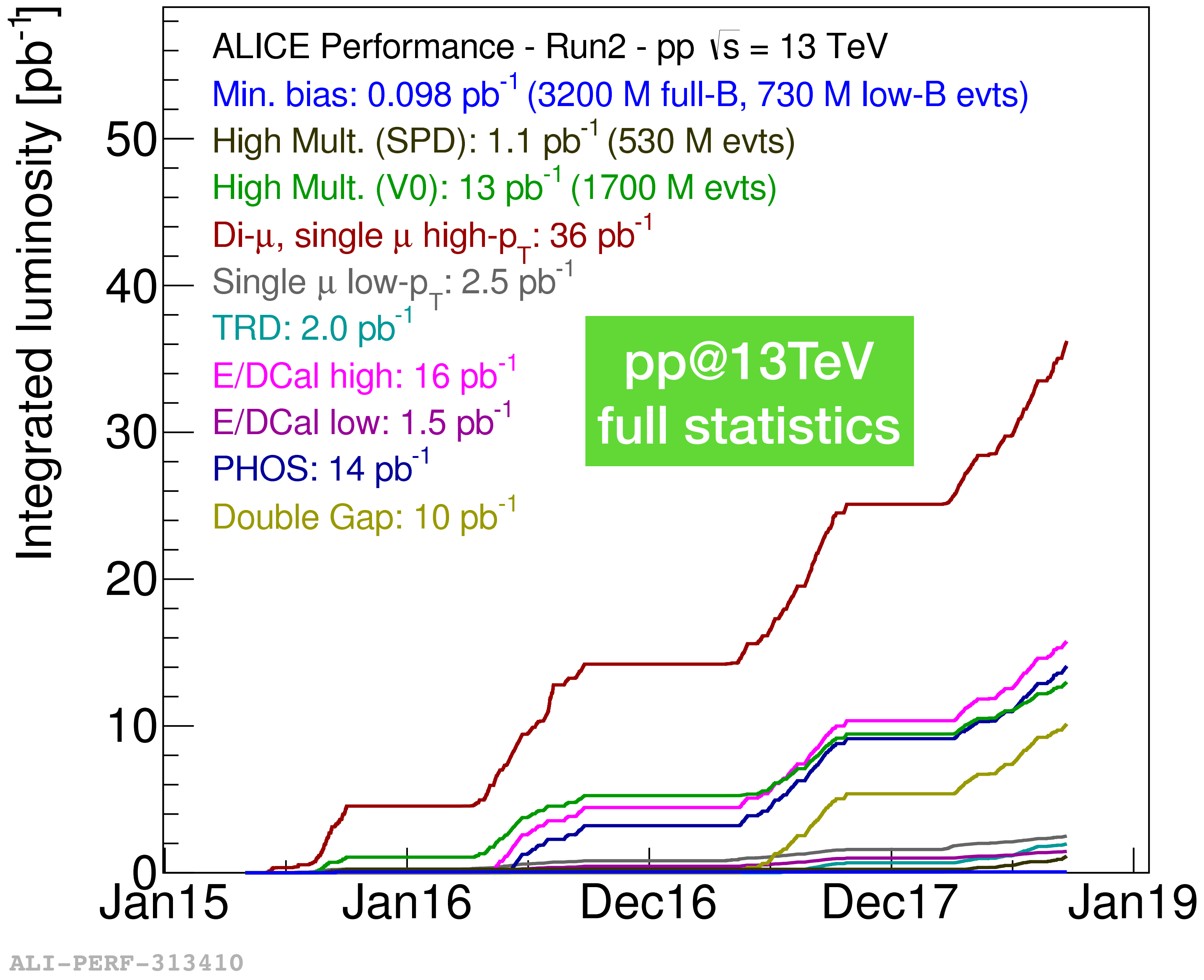


rich trigger menu:

- Minimum bias
- Central
- Mid-central
- Muon triggers
- EMCAL/PHOS
- UPC (fwd/barrel)

pp@13TeV total statistics:

- Minimum bias
- High multiplicity (V0 and SPD)
- Rare triggers: Muon, EMCAL/DCAL, PHOS, TRD, diffractive



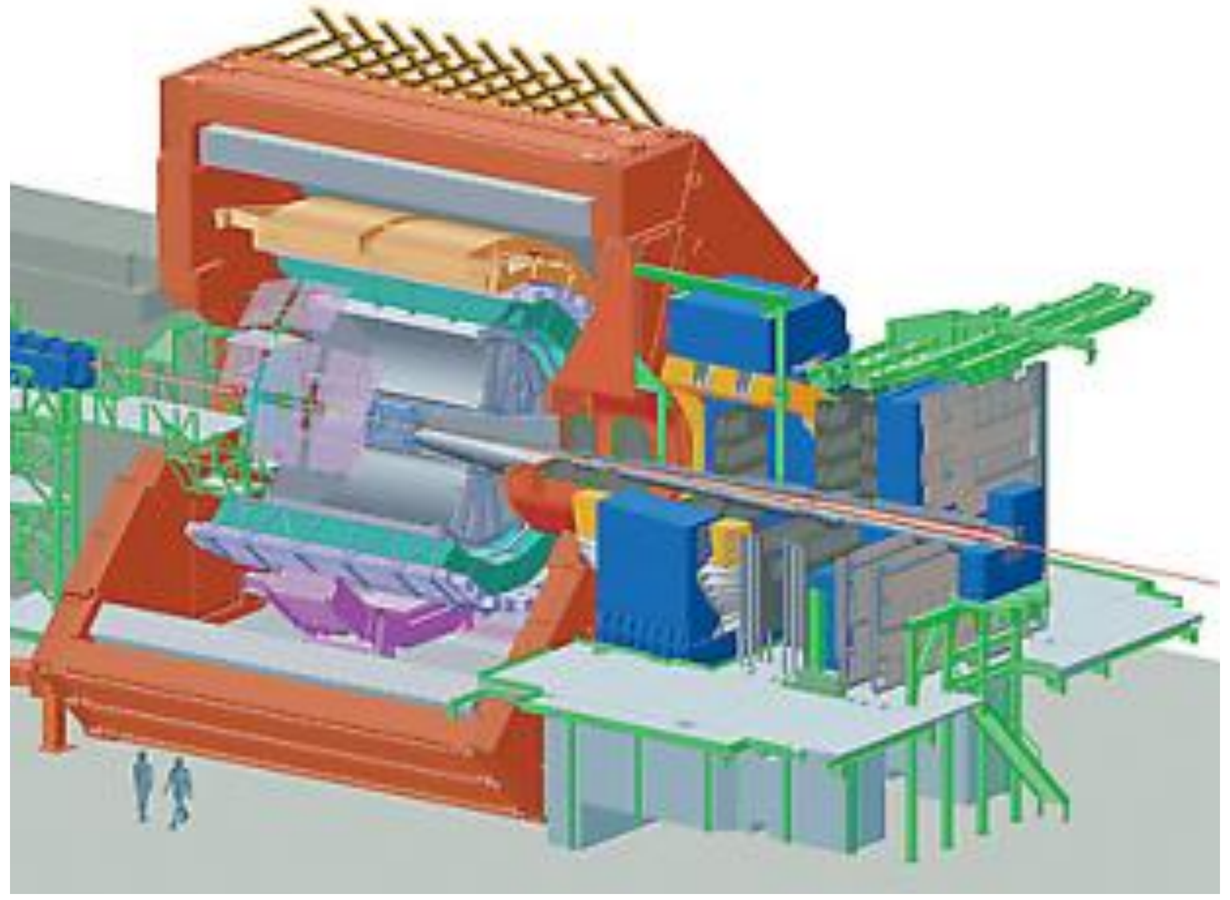
Data taking efficiency in 2018:

~ 92% for pp in 2018

~ 87% for Pb-Pb

Pb-Pb 2018: reconstruction status

- Pb-Pb data, two reconstruction streams
  - **Fast** reconstruction for muon spectrometer and calorimeters:
    - run synchronously with data taking
    - fast calibrations
  - **Fully-calibrated** reconstruction of barrel tracking detectors:
    - 2x calibration passes for central barrel with detailed QA
    - physics pass, will be ready in few days
      - **preliminary results for the summer conferences**



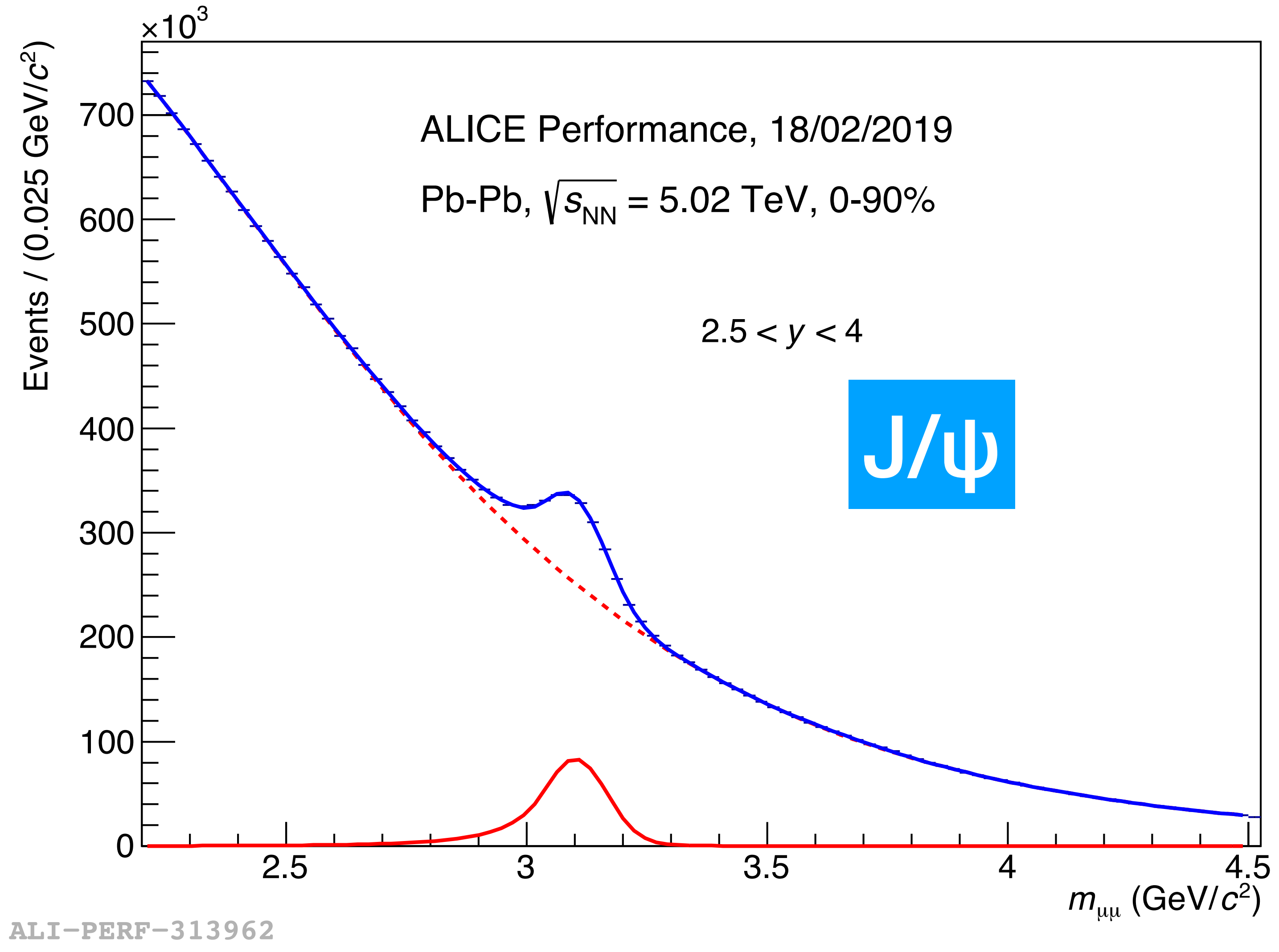
- Large amount of Monte-Carlo productions running for analysis support

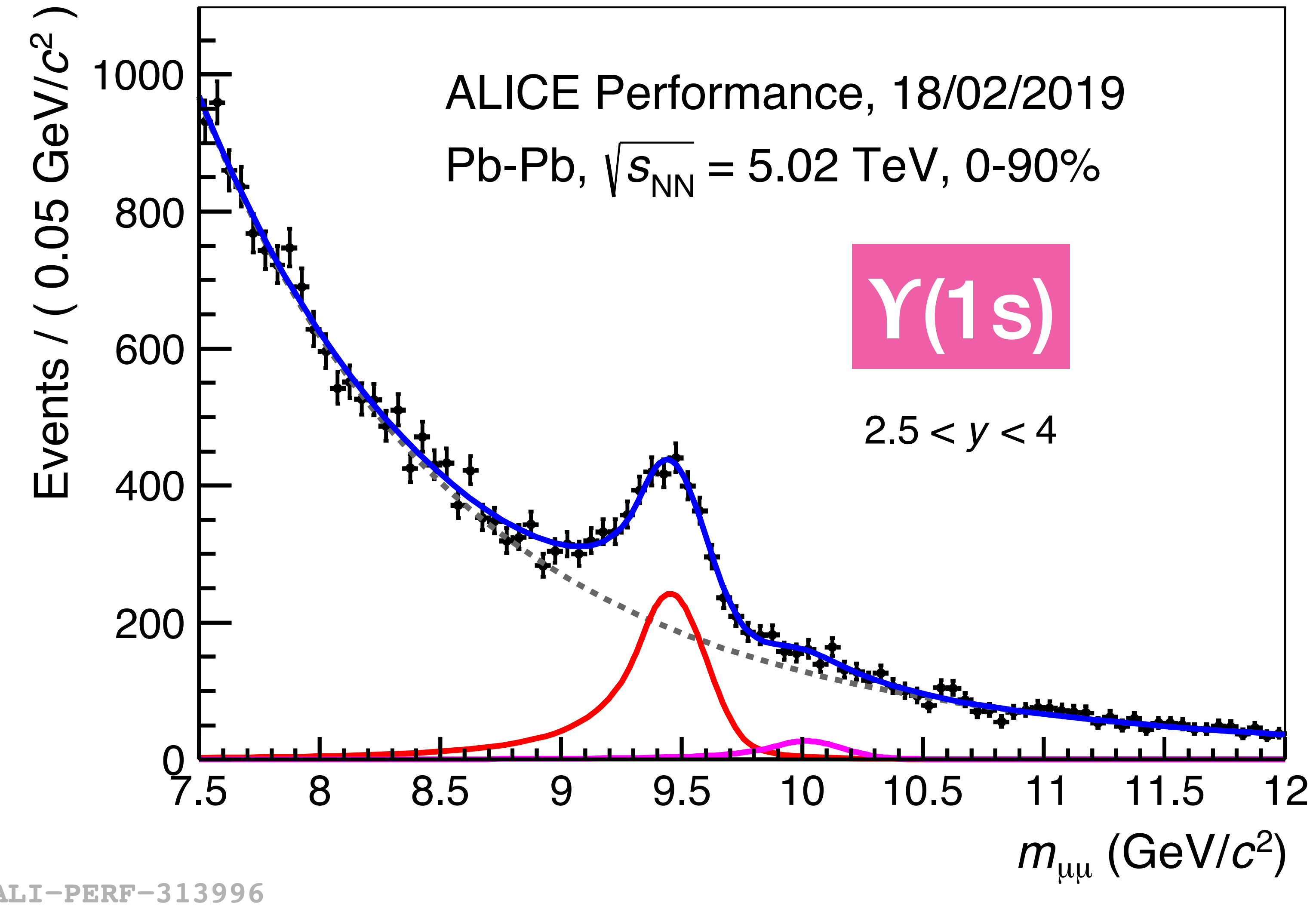
Excellent data quality

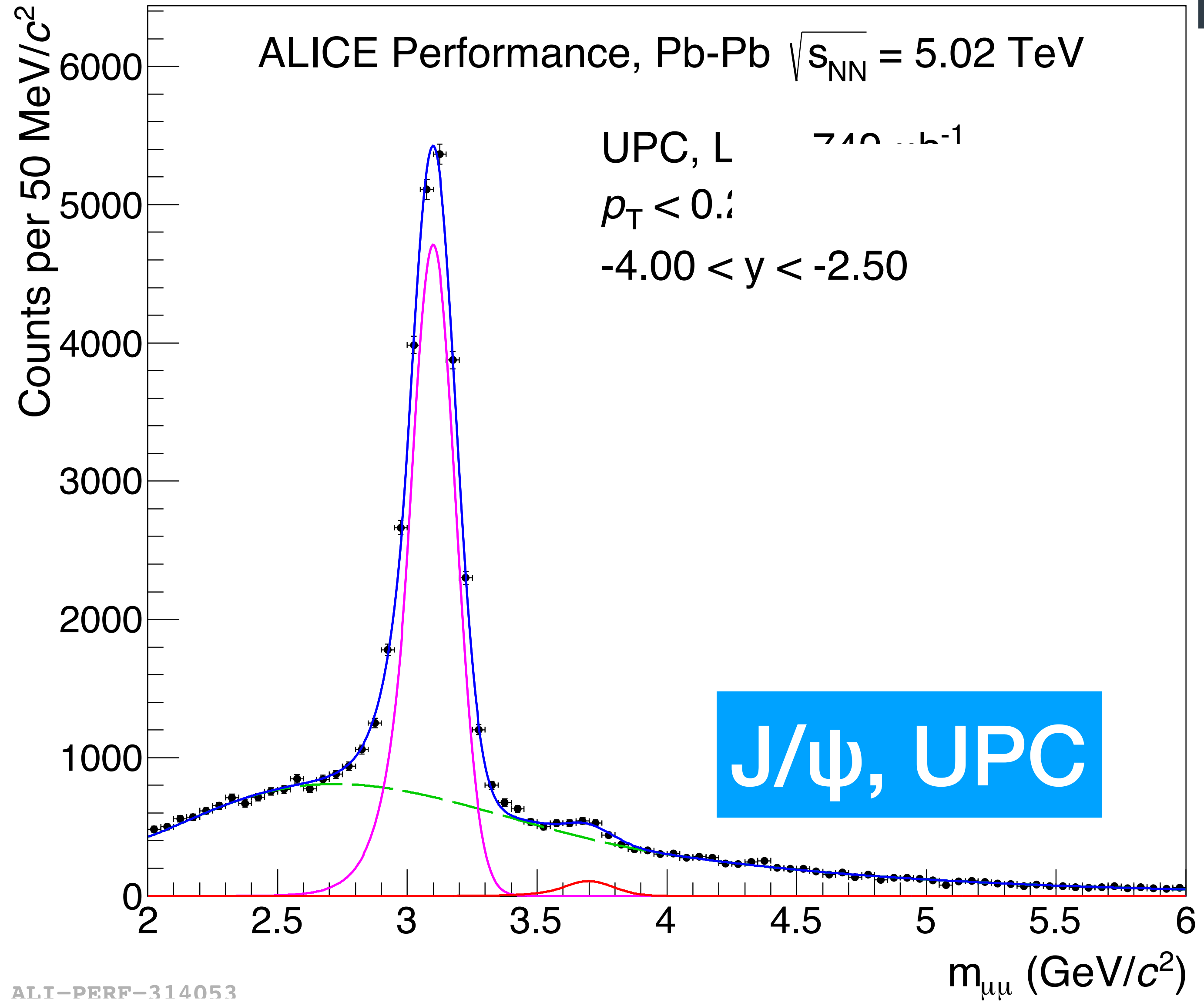
- large reduction of TPC space charge distortions w.r.t. 2015 Pb-Pb run, thanks to cover electrode settings, TPC gating grid voltage tuning

Pb-Pb 2018: data quality monitoring

Quarkonia, forward rapidity

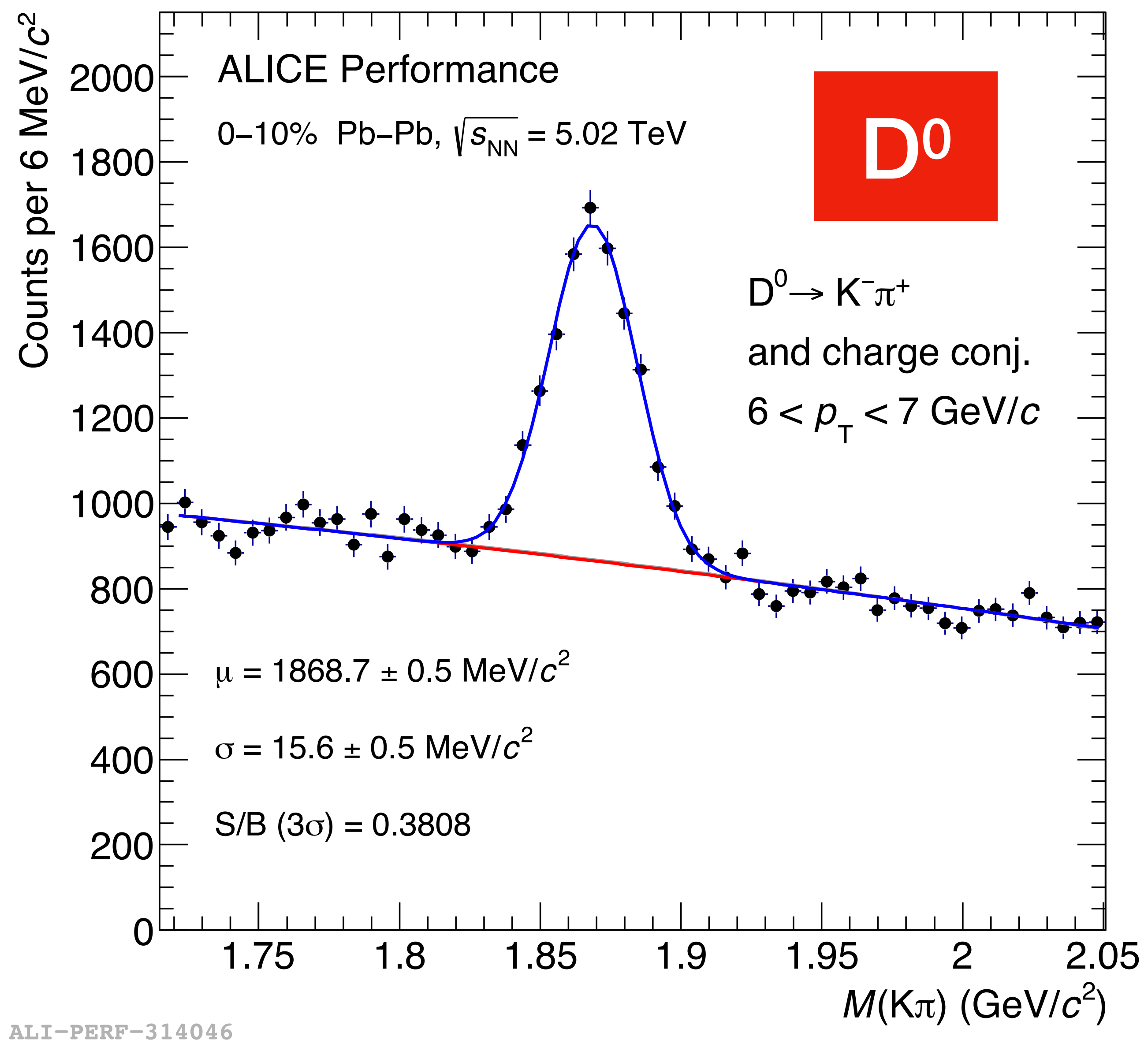


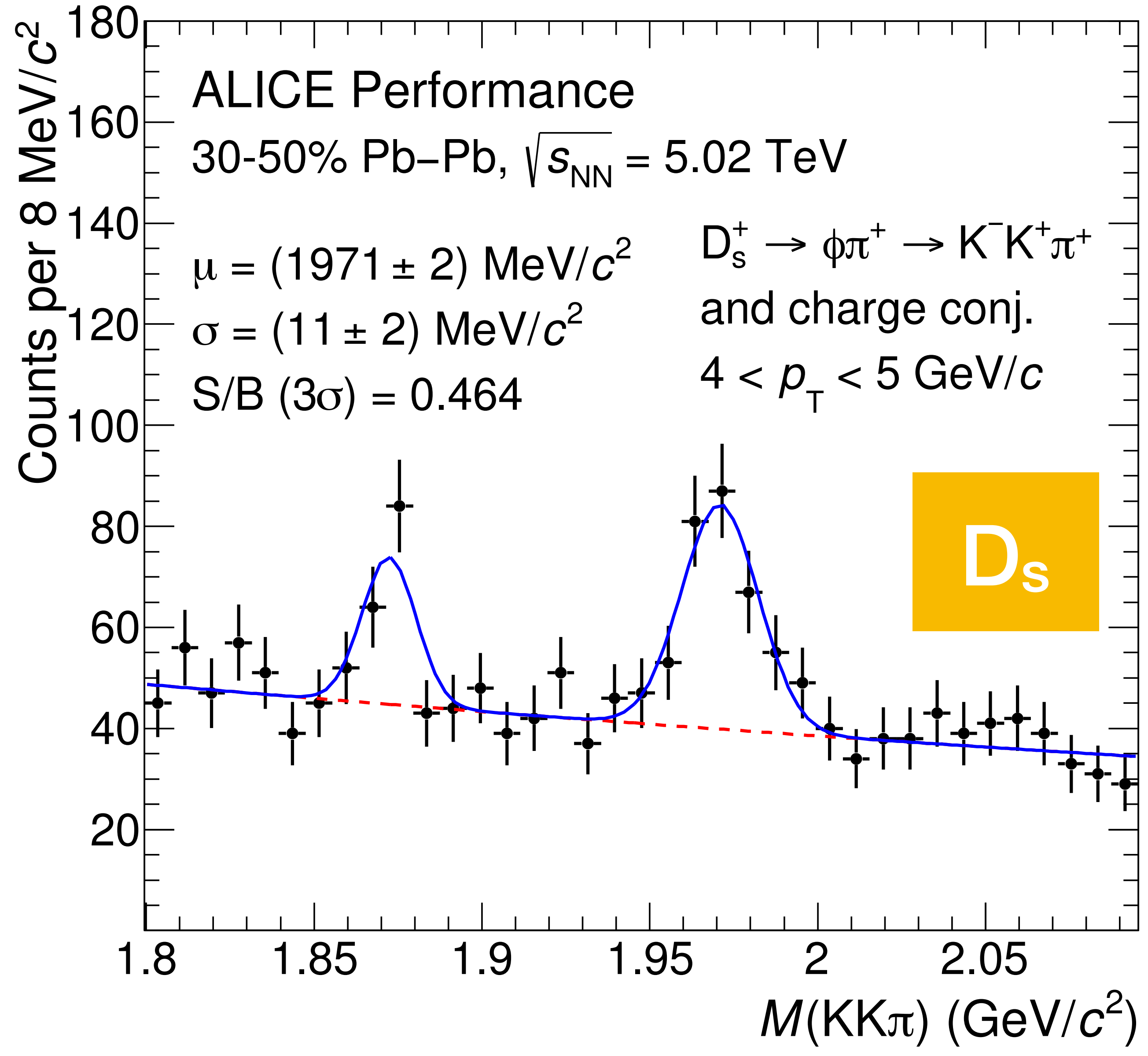


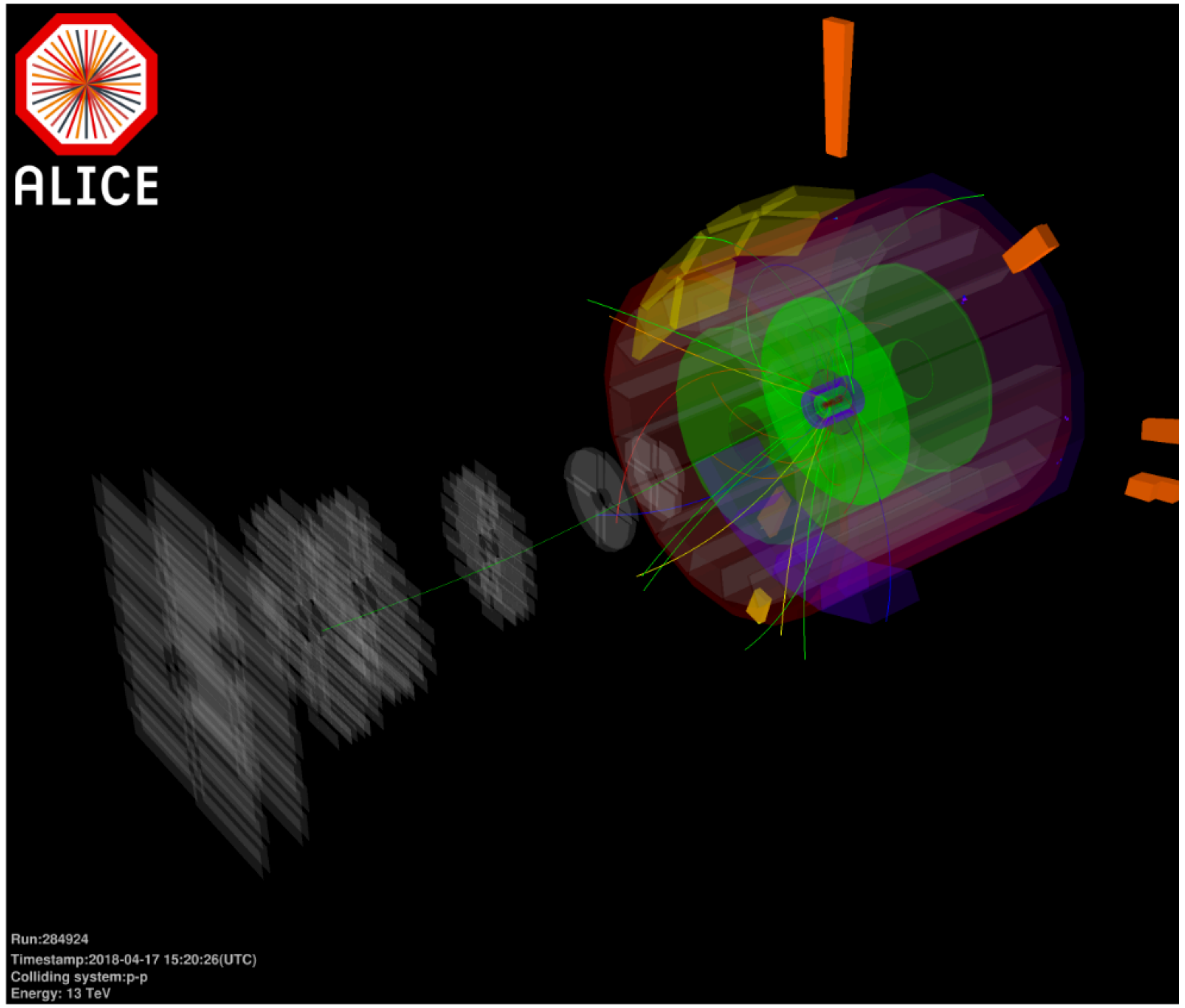


Charm mesons, mid-rapidity

partial statistics







Recent results from pp collisions

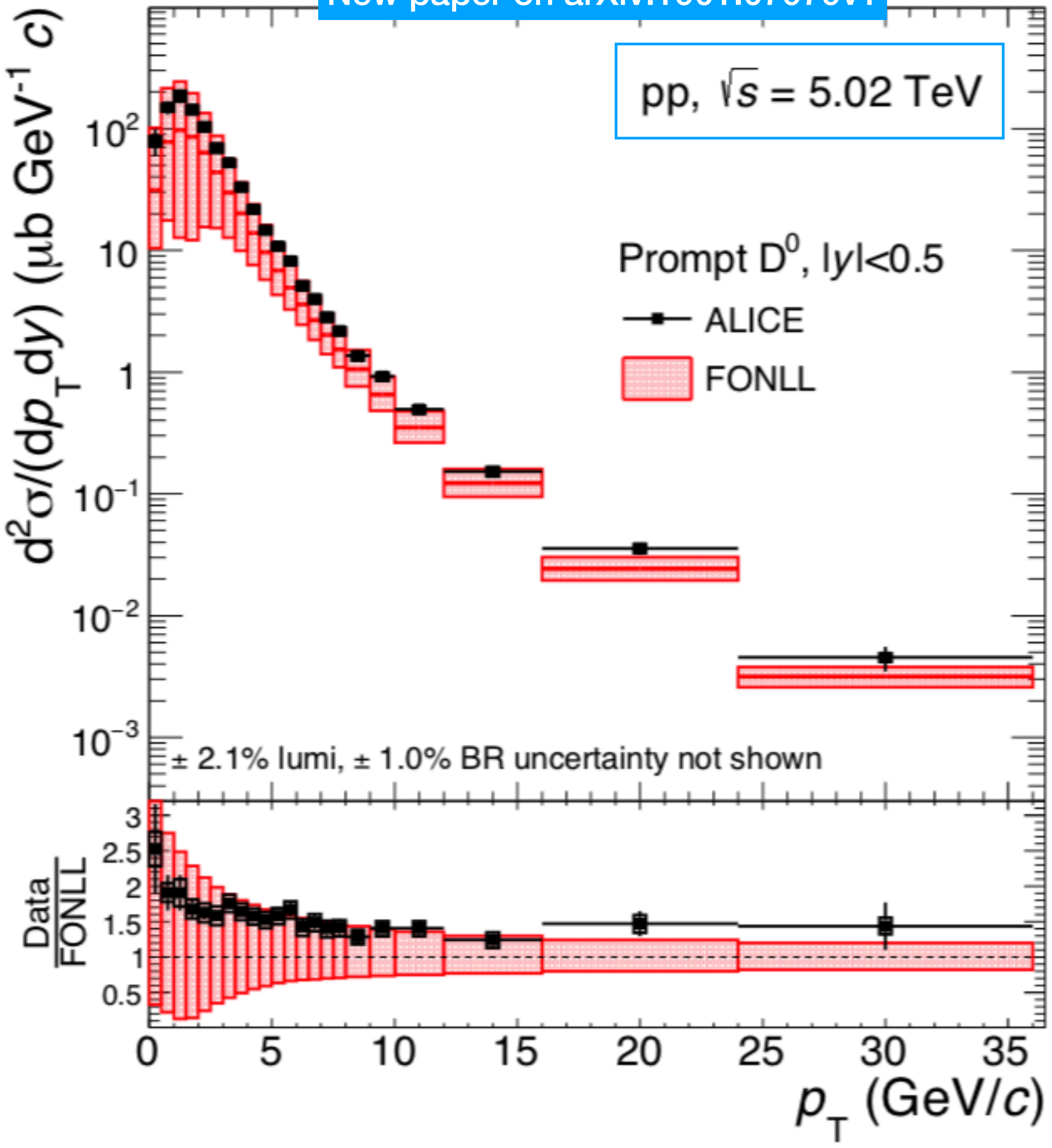
Heavy-flavour production in pp collisions

D-meson production cross section in pp collisions at $\sqrt{s}$= 5.02 TeV at mid-rapidity

- large data sample collected in 2017
- new reference for Pb-Pb and p-Pb
  - **better precision** with respect to previous reference, extrapolated with pQCD-based energy scaling of the $\sqrt{s}$= 7 TeV cross section to 5.02 TeV
  - possibility of **finer p_T intervals** with respect to those in the previous reference for a more detailed measurement of the p_T shape

crucial reference, measured with high precision, at the same energy as Pb-Pb and p-Pb measurements

New paper on arXiv:1901.07979v1



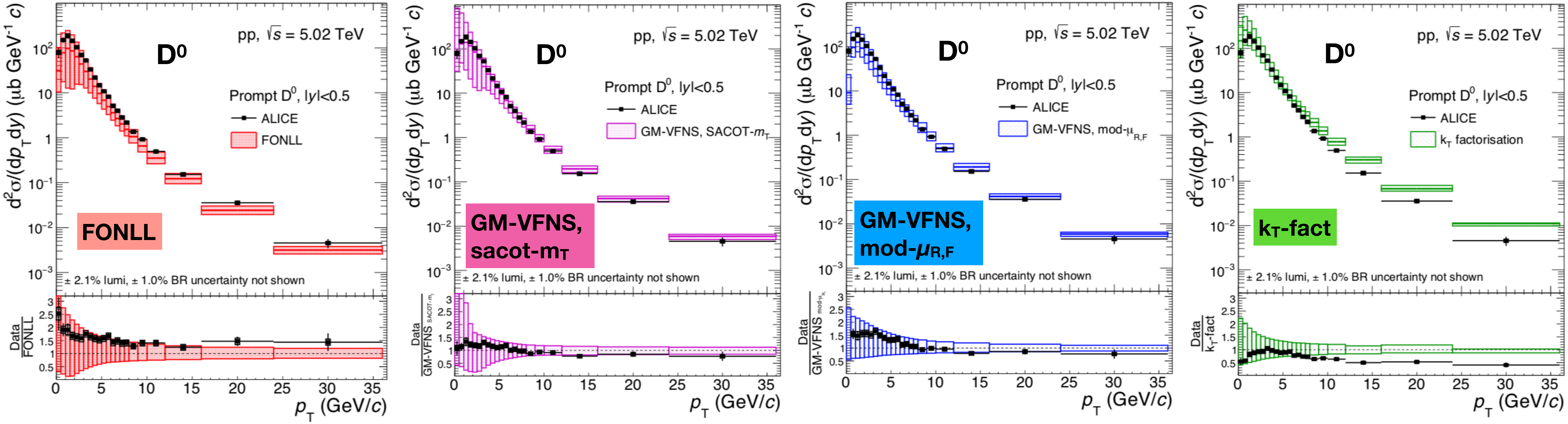
Heavy-flavour production in pp collisions

Not only reference for Pb-Pb and p-Pb: perturbative-QCD test

$$\frac{\mathrm{d}\sigma^{\mathrm{D}}}{\mathrm{d}p_{\mathrm{T}}^{\mathrm{D}}}(p_{\mathrm{T}};\mu_F,\mu_R) = PDF(x_1,\mu_F)PDF(x_2,\mu_F) \otimes \frac{\mathrm{d}\sigma^{\mathrm{c}}}{\mathrm{d}p_{\mathrm{T}}^{c}}(x_1,x_2,\mu_R,\mu_F) \otimes D_{c\to \mathrm{D}}(z = p_{\mathrm{D}}/p_{\mathrm{c}},\mu_F)$$

focusing on the same particle, ex: D^0

New paper on arXiv:1901.07979v1



- **Systematic comparison with several pQCD calculations** with different schemes: agreement within uncertainties
  - non-strange D-mesons are overestimated/underestimated in different p_{T} ranges by the theory
  - D_s production tends to be underestimated by all the pQCD calculations
- **Data: smaller uncertainties than theoretical ones:**
  - larger uncertainties at low p_{T}, dominated by factorisation and renormalisation scales of the perturbative calculations

Heavy-flavour production in pp collisions

ALICE

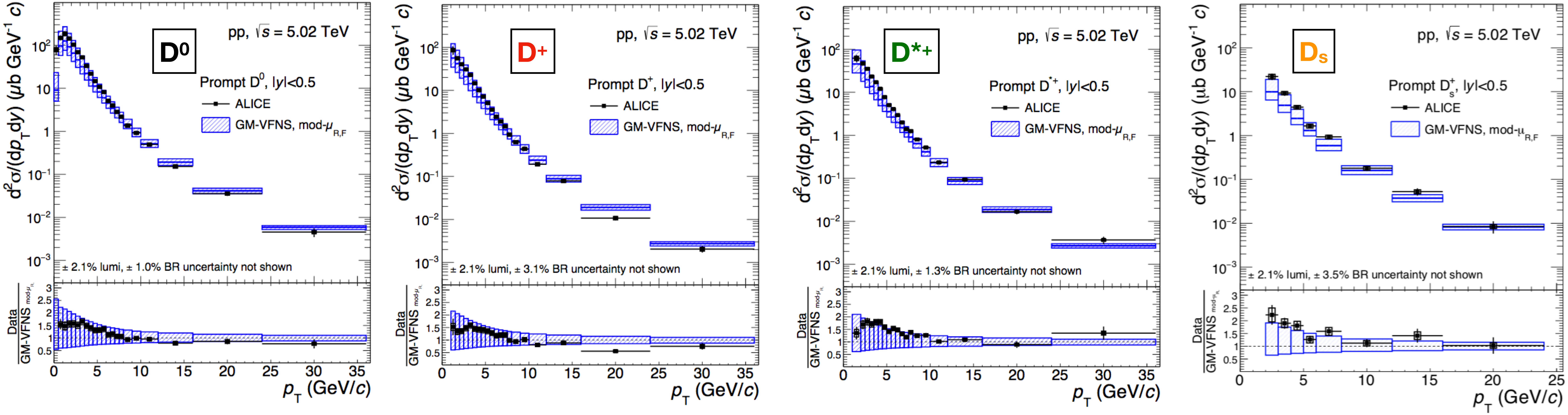
Not only reference for Pb-Pb and p-Pb: perturbative-QCD test

$$\frac{d\sigma^{D}}{dp_{T}^{D}}(p_{T};\mu_F,\mu_R) = PDF(x_1,\mu_F)PDF(x_2,\mu_F)\otimes\frac{d\sigma^{c}}{dp_{T}^{c}}(x_1,x_2,\mu_R,\mu_F)\otimes D_{c\to D}(z=p_D/p_c,\mu_F)$$

important measurement to constrain theoretical calculations

New paper on arXiv:1901.07979v1

focusing on the same theoretical calculation, ex: GM-VFNS, mod μ_F, μ_R



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Energy dependence

D-meson cross-section at different energies: ratios to reduce theoretical uncertainties

$$\frac{d\sigma^{D}}{dp_T^{D}}(p_T;\mu_F,\mu_R) = PDF(x_1,\mu_F)PDF(x_2,\mu_F)\otimes\frac{d\sigma^{c}}{dp_T^{c}}(x_1,x_2,\mu_R,\mu_F)\otimes D_{c\to D}(z=p_D/p_c,\mu_F)$$

New paper on arXiv:1901.07979v1

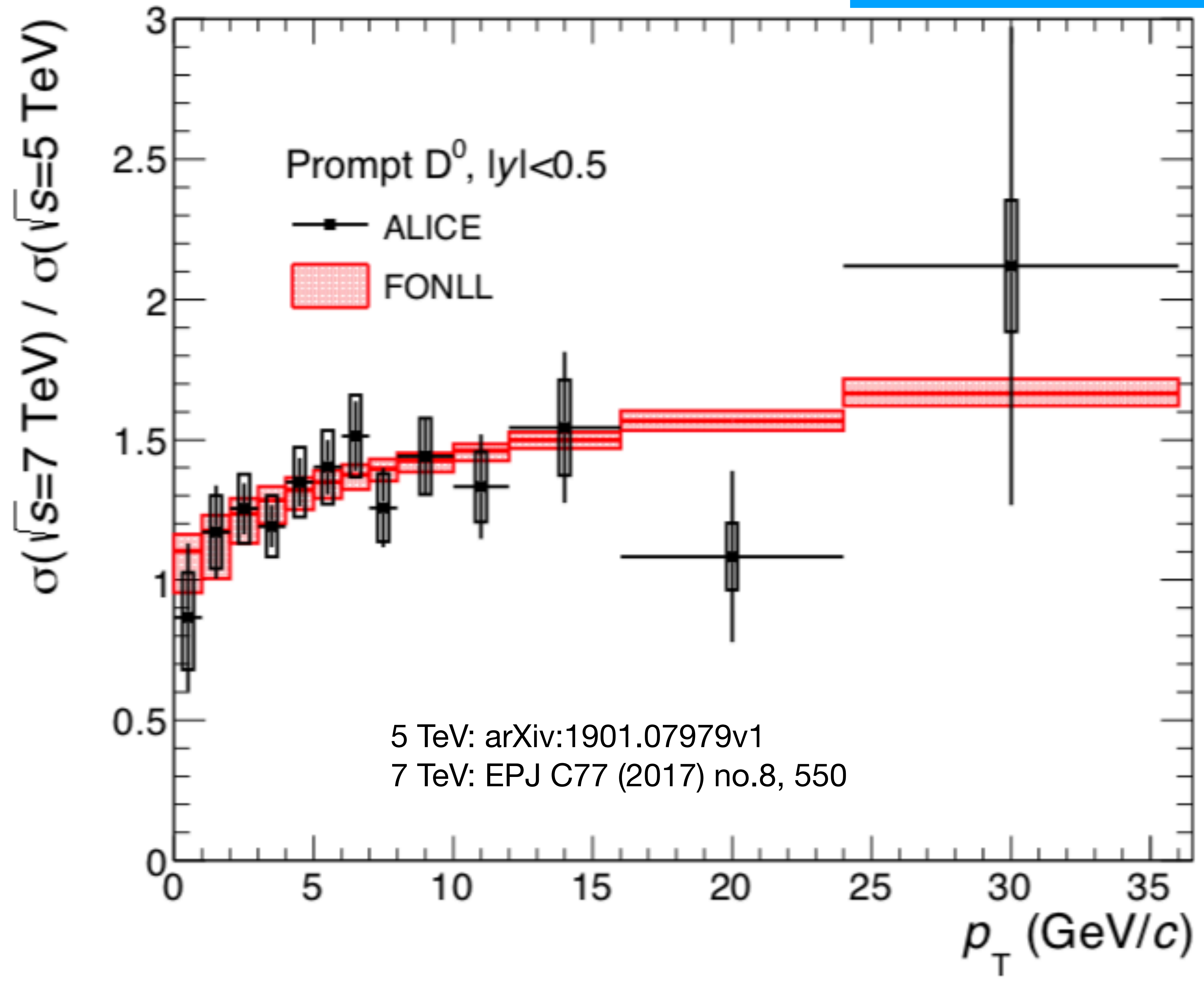
Systematic uncertainties of pQCD calculations reduced in the ratio, due to correlation from the parameters used in the calculations

- renormalisation and factorisation scales μ_F, μ_R, PDF partially cancel out
- m_Q, Frag. Func., B.R. fully correlated

- ALICE results **7/5 TeV ratio**: compatibility with FONLL predictions, that describe the energy evolution

Work in progress on more precise measurements with full pp@13TeV statistics for 13/5.02 TeV energy ratios

- Will also enable forward/central ratio with LHCb data (sensitive to small-x PDFs) Cacciari et al, Eur.Phys. J. C75 (2015) 610

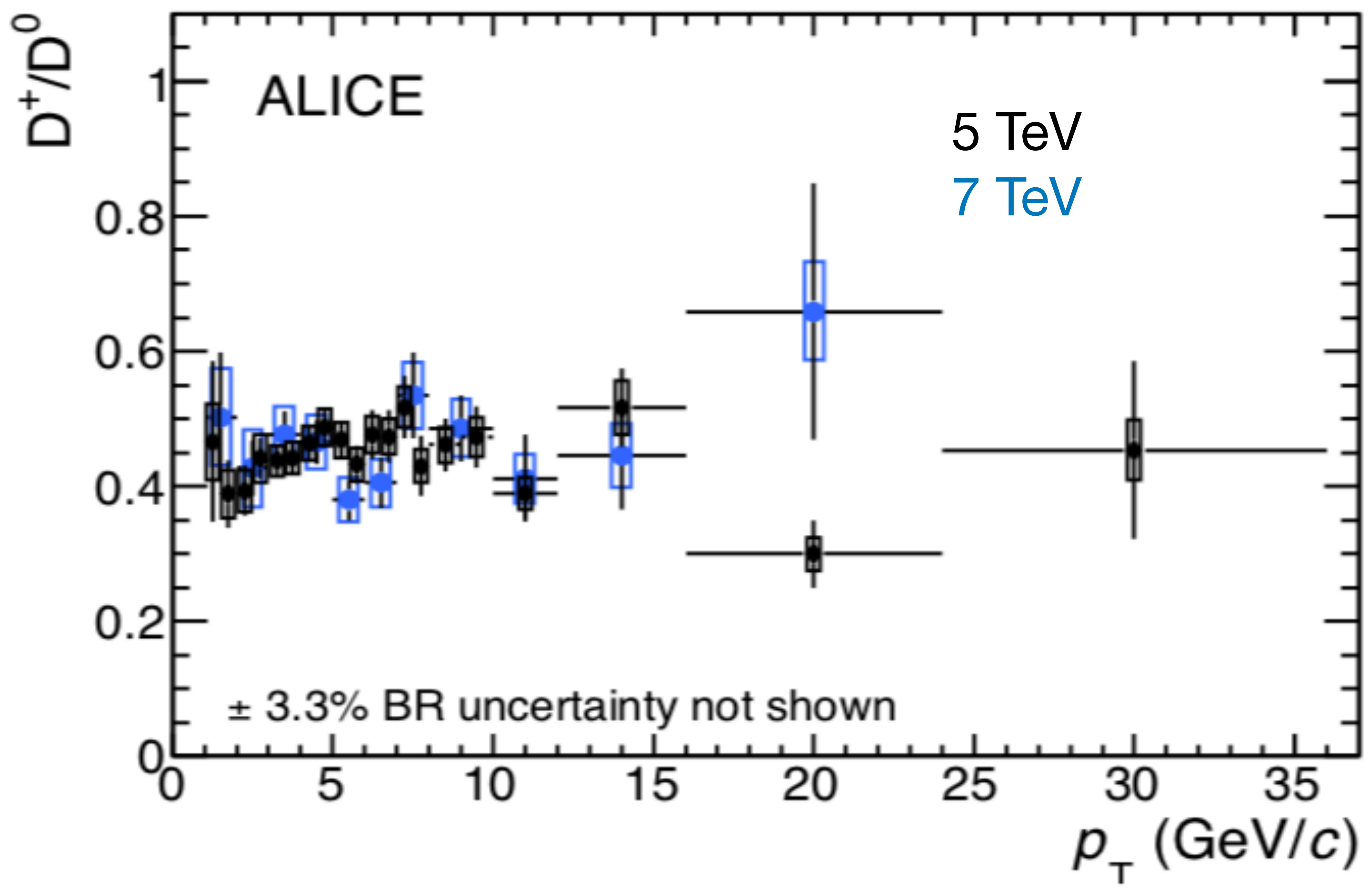


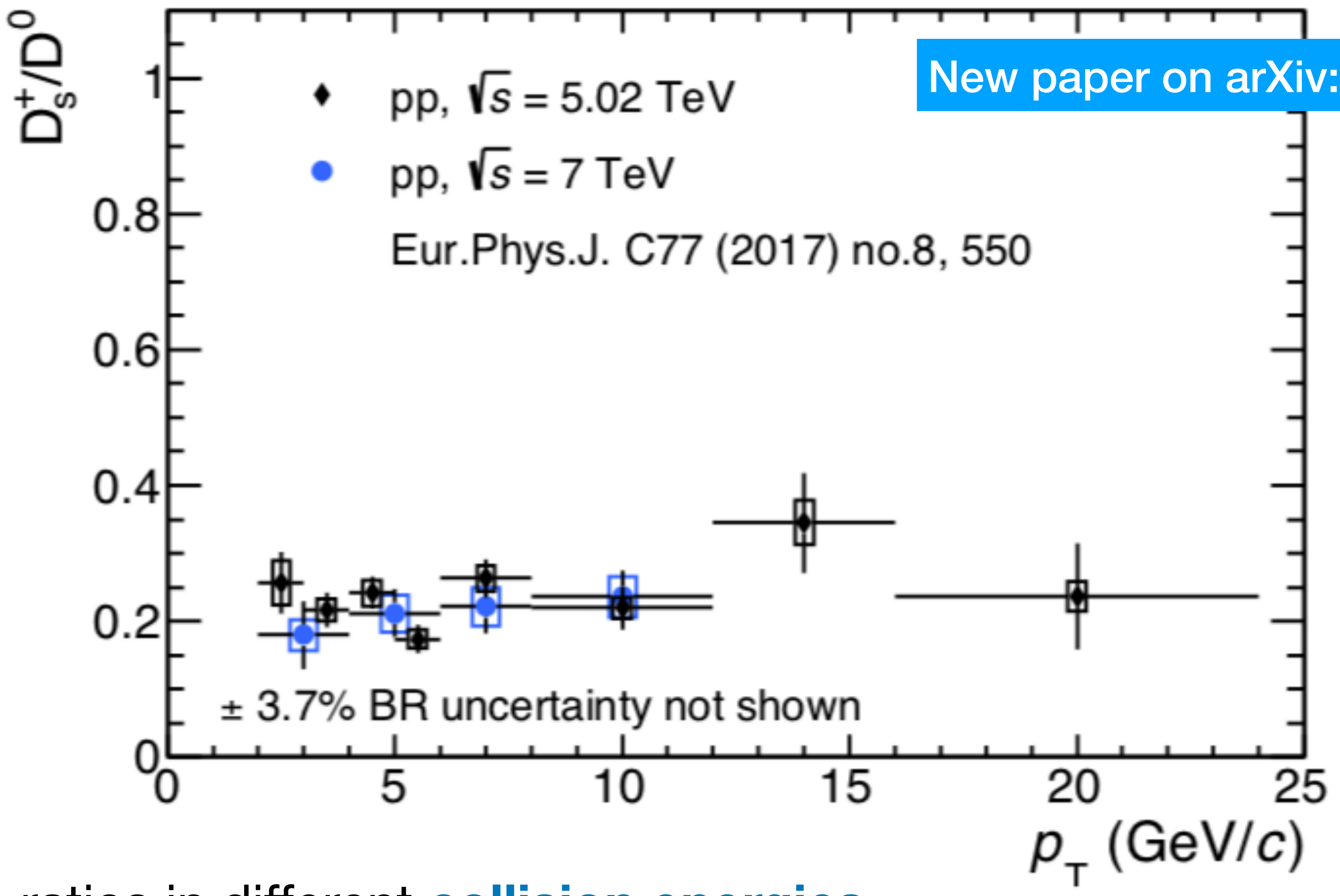
Heavy-flavour production: particle ratios

Particle species ratio at different energies: $\sqrt{s}$ = 5.02, 7 TeV

$$\frac{d\sigma^{D}}{dp_{T}^{D}}(p_{T};\mu_F,\mu_R) = PDF(x_1,\mu_F)PDF(x_2,\mu_F) \otimes \frac{d\sigma^{c}}{dp_{T}^{c}}(x_1,x_2,\mu_R,\mu_F) \otimes \boxed{D_{c\to D}(z=p_D/p_c,\mu_F)}$$

Sensitive to **ratio of Fragmentation Functions** for different hadronisation of charm quark





New paper on arXiv:1901.07979v1

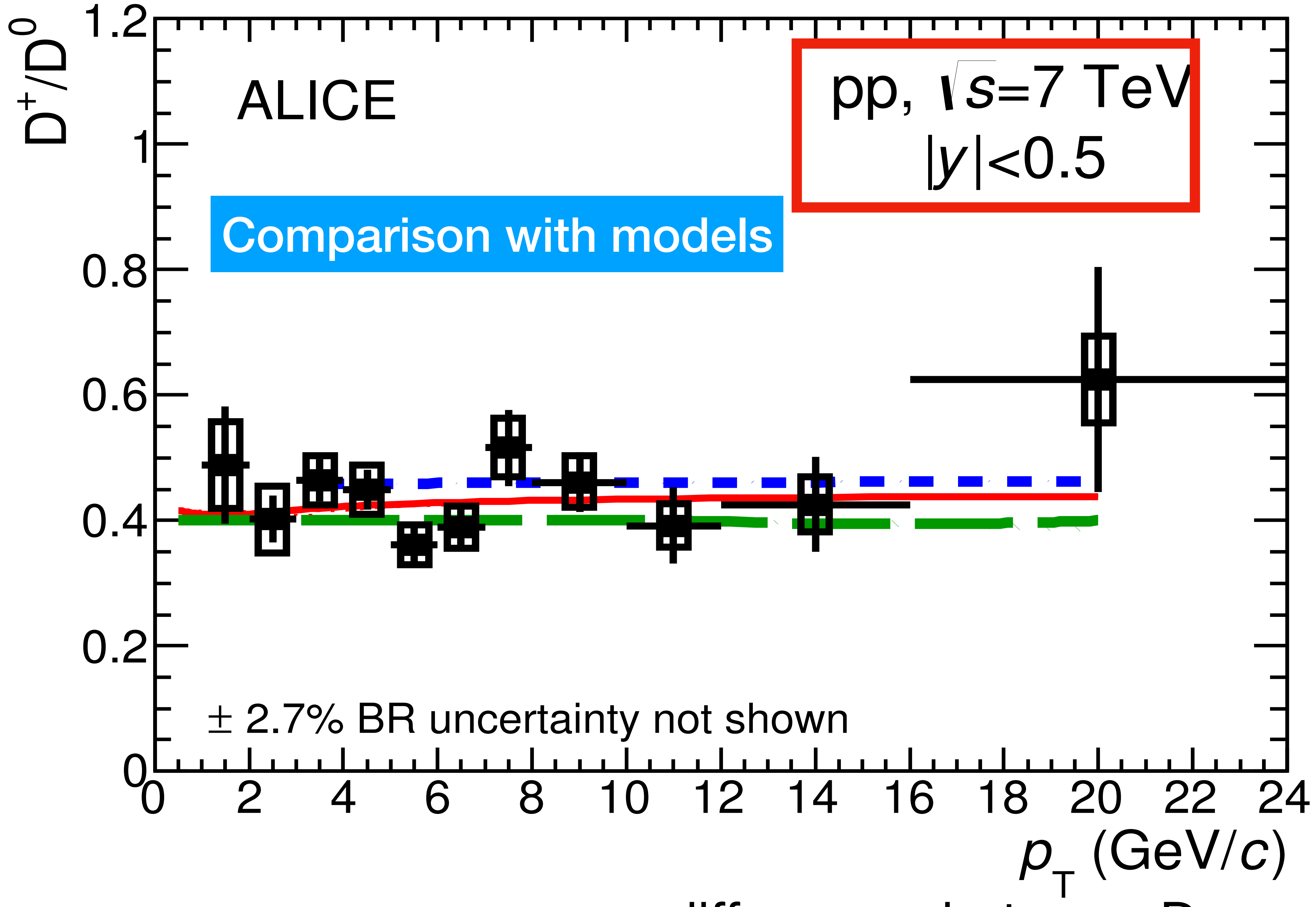
- no differences between D-meson ratios in different **collision energies**
- compatible with ratios measured in e+e- and ep collisions
  - no dependence on **collision systems**
- agreement with models
- **Universality of D-meson Fragmentation Functions**

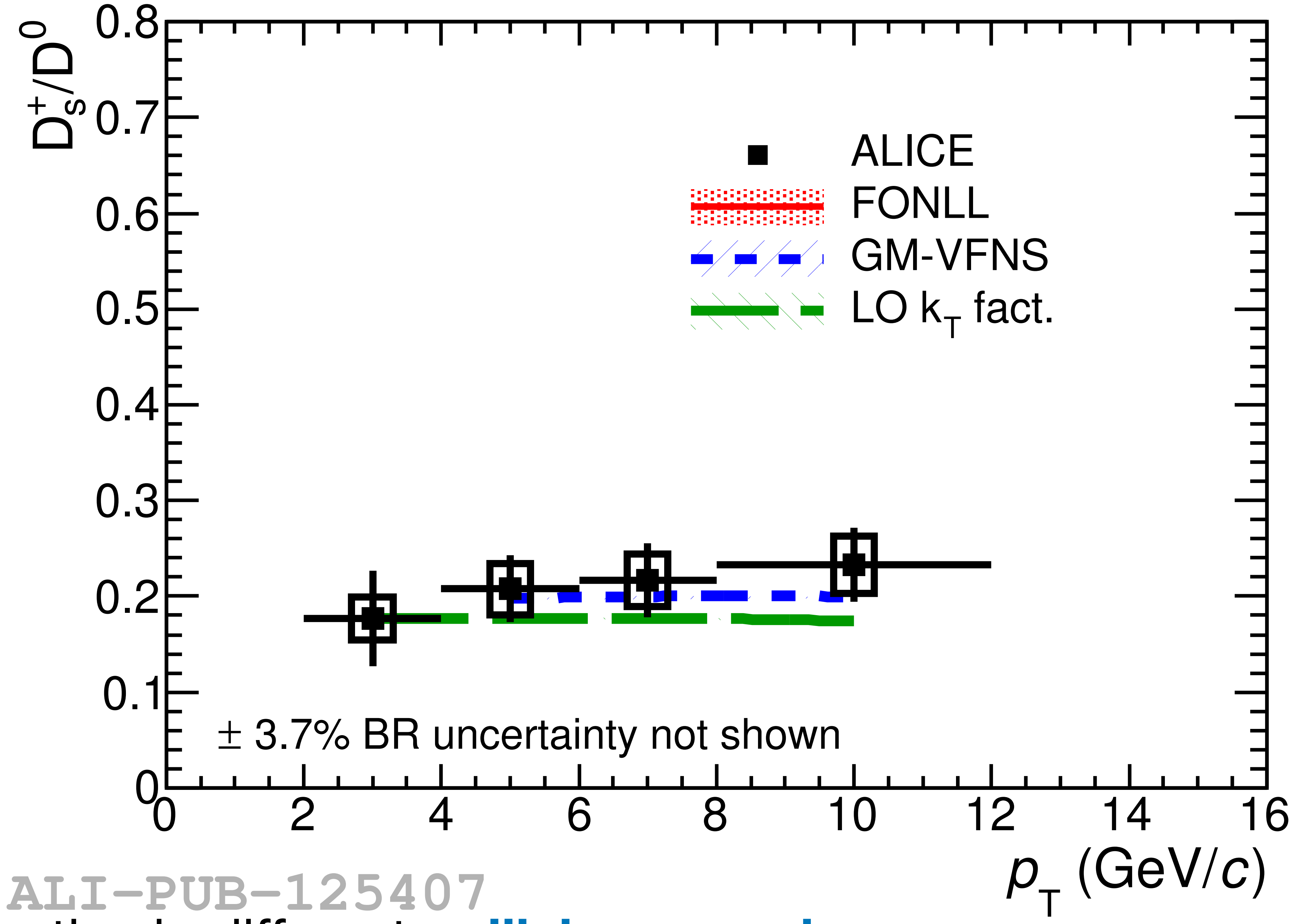
Heavy-flavour production: particle ratios

Particle species ratio at different energies: $\sqrt{s}$ = 5.02, 7 TeV

$$\frac{d\sigma^D}{dp_T^D}(p_T;\mu_F,\mu_R) = PDF(x_1,\mu_F)PDF(x_2,\mu_F)\otimes\frac{d\sigma^c}{dp_T^c}(x_1,x_2,\mu_R,\mu_F)\otimes \boxed{D_{c\to D}(z=p_D/p_c,\mu_F)}$$

Sensitive to **ratio of Fragmentation Functions** for different hadronisation of charm quark





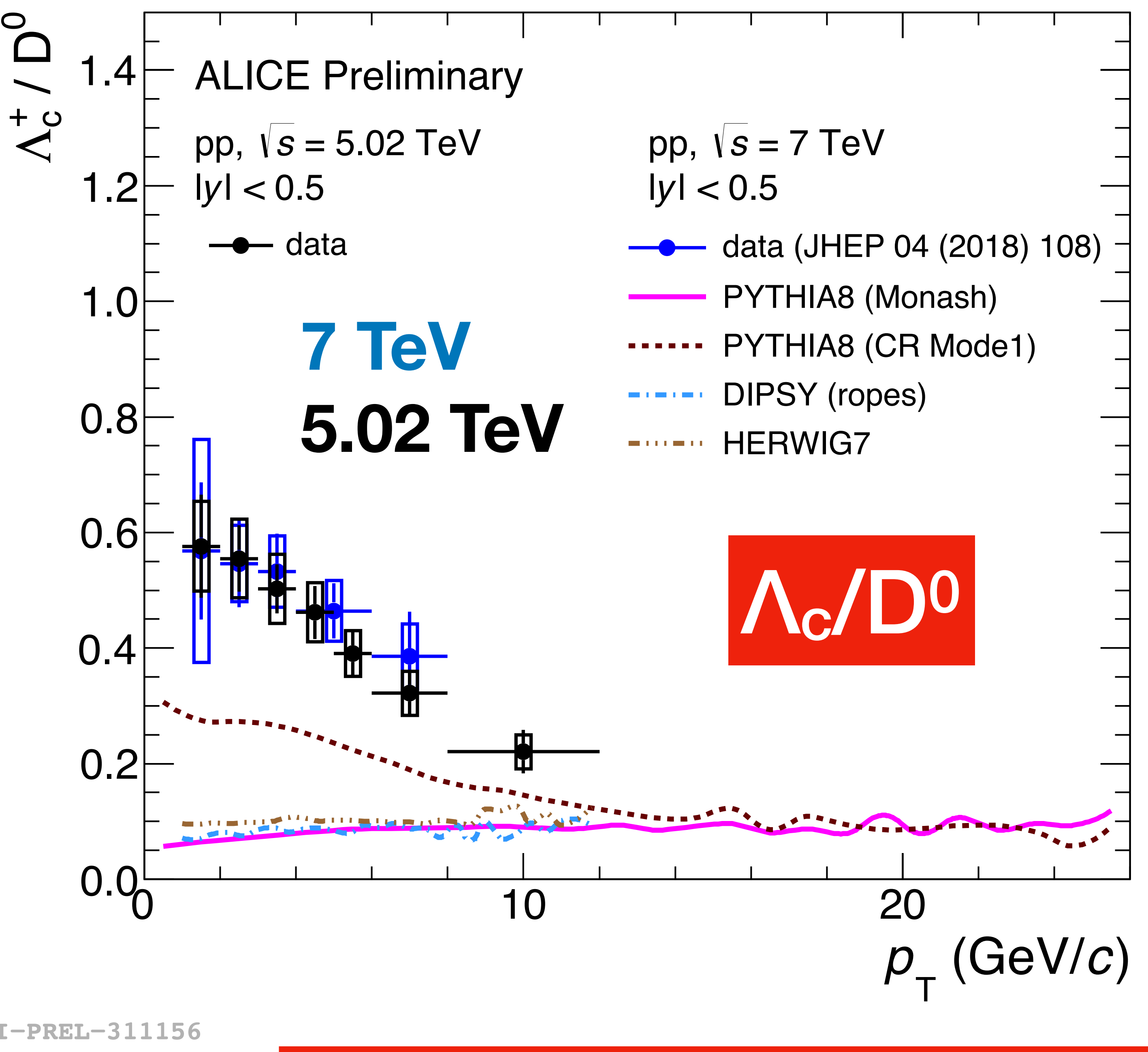
- no differences between D-meson ratios in different collision energies
- compatible with ratios measured in e^+e^- and ep collisions
  - no dependency on collision systems
- agreement with models
- **Universality of D-meson Fragmentation Functions**

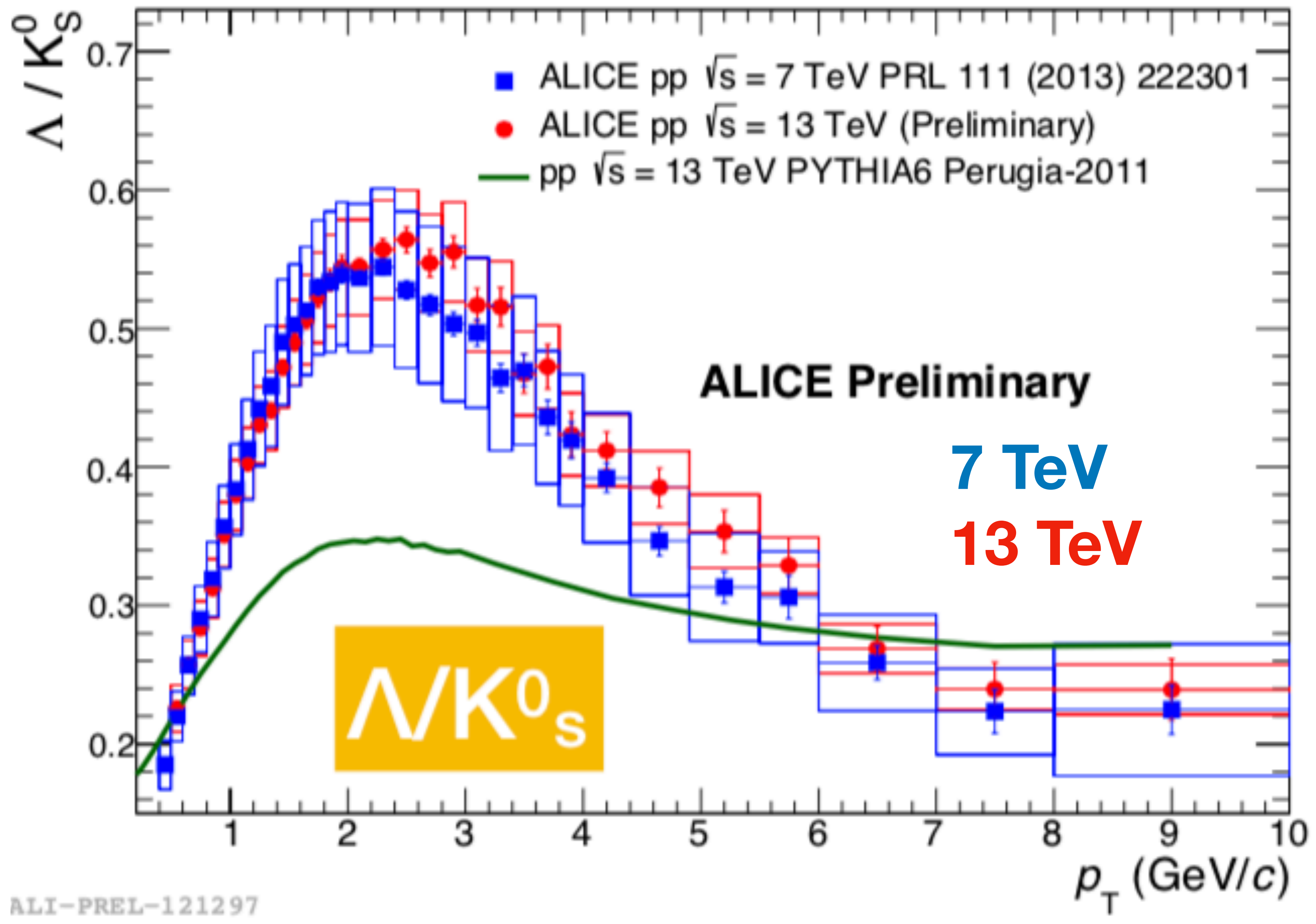
D-meson ratios independent of p_T and independent on the collision energy and collision system

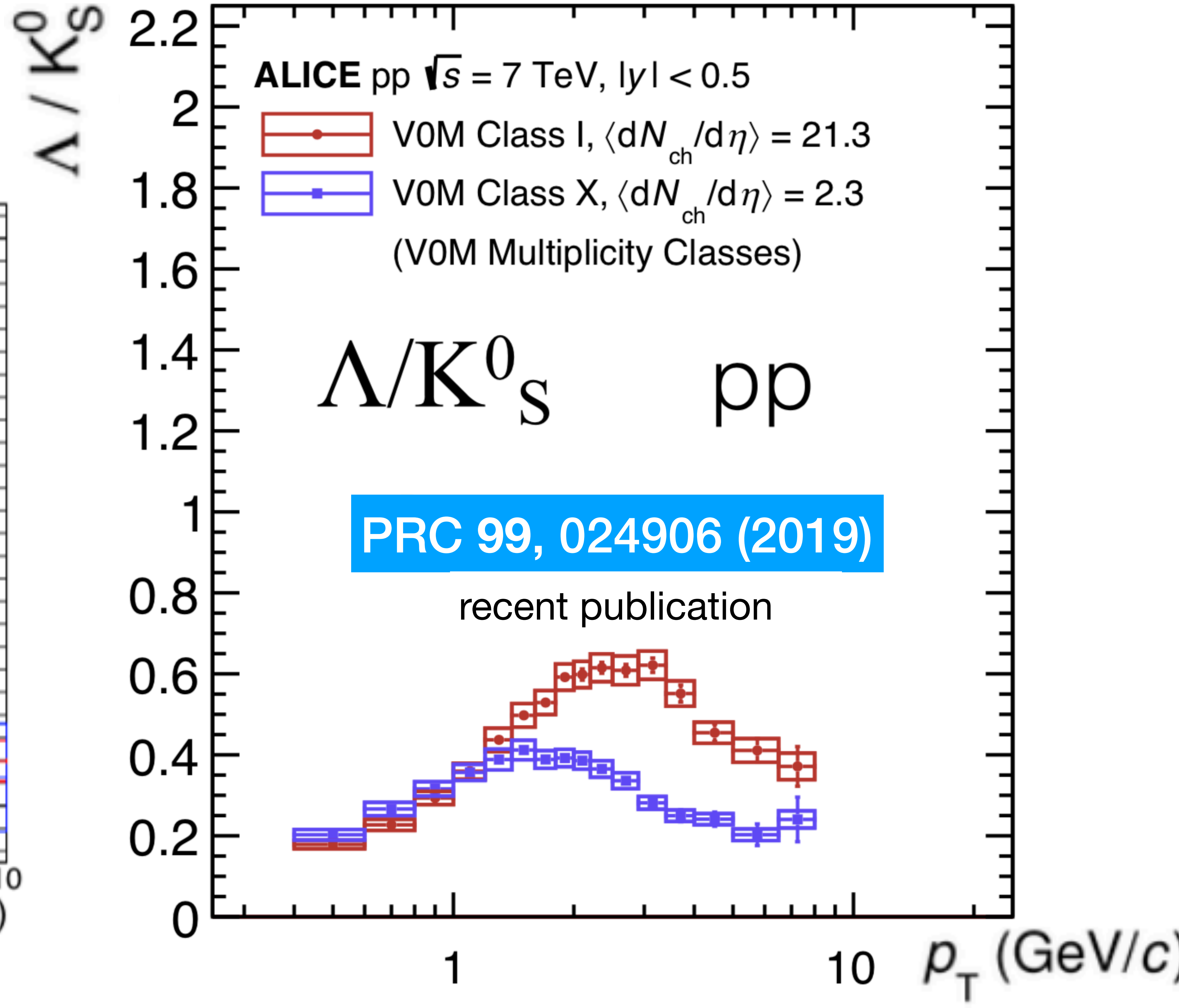
Baryon-to-meson ratio in heavy-flavour and light-flavour production

Baryon-to-meson ratios are not flat vs p_T

- enhancement at the intermediate p_T region, both in the heavy-flavor and light-flavour sectors
  - not reproduced by models, not seen in e^+e^- collisions







Similar baryon-to-meson ratio in pp collisions at different energies

Baryon-to-meson ratios: bump at intermediate p_T, specific to hadronic collisions

enhancement at intermediate p_T in high multiplicity pp events: peaks at same p_T range as 'radial flow' effects in Pb-Pb

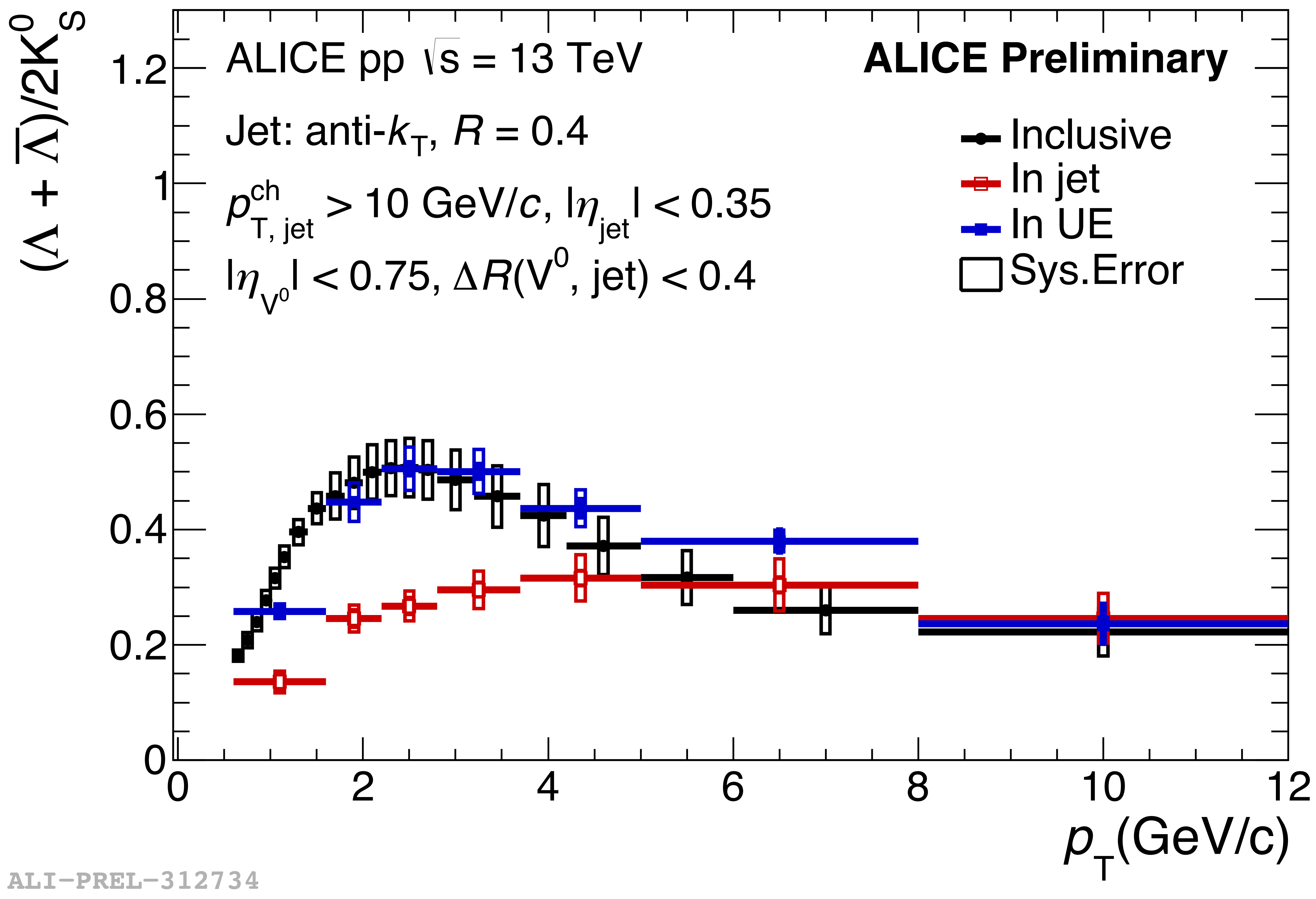
Strangeness production: particle ratios in jets

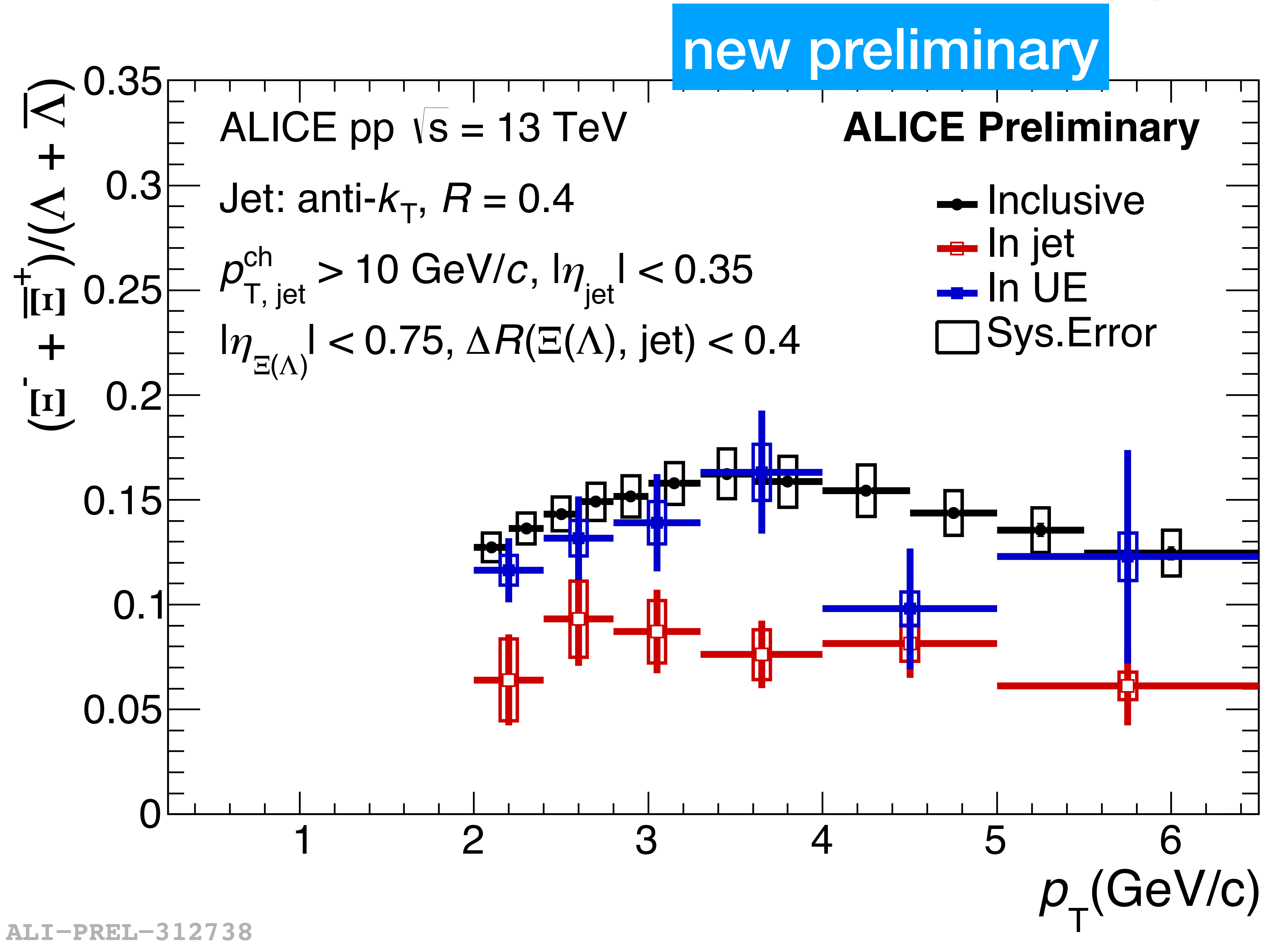
Baryon-to-meson enhancement: also due to a modification of jet fragmentation in medium?

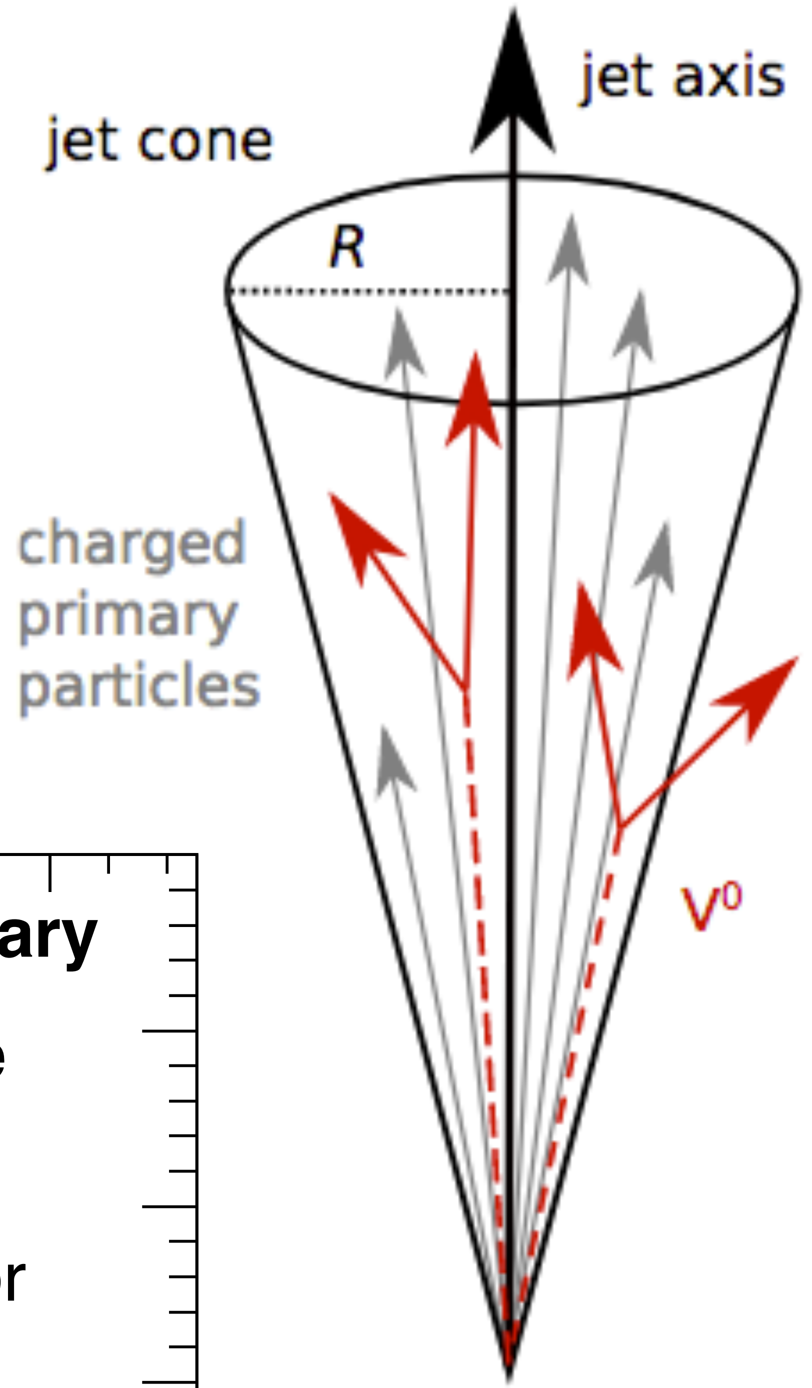
Separate hadrons produced in hard processes (**jets**) from hadrons produced in soft processes (**underlying event UE**).

Production ratio of Λ/K^0_S and Ξ/Λ in **pp collisions** $\sqrt{s}$ =13TeV:

- Ratio **in jets** is significantly **smaller than the inclusive ratio** at low and intermediate p_T
- **small bump** in **inclusive similar to that of UE dynamics**

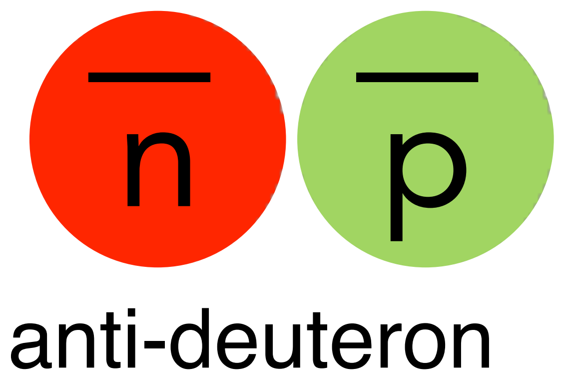


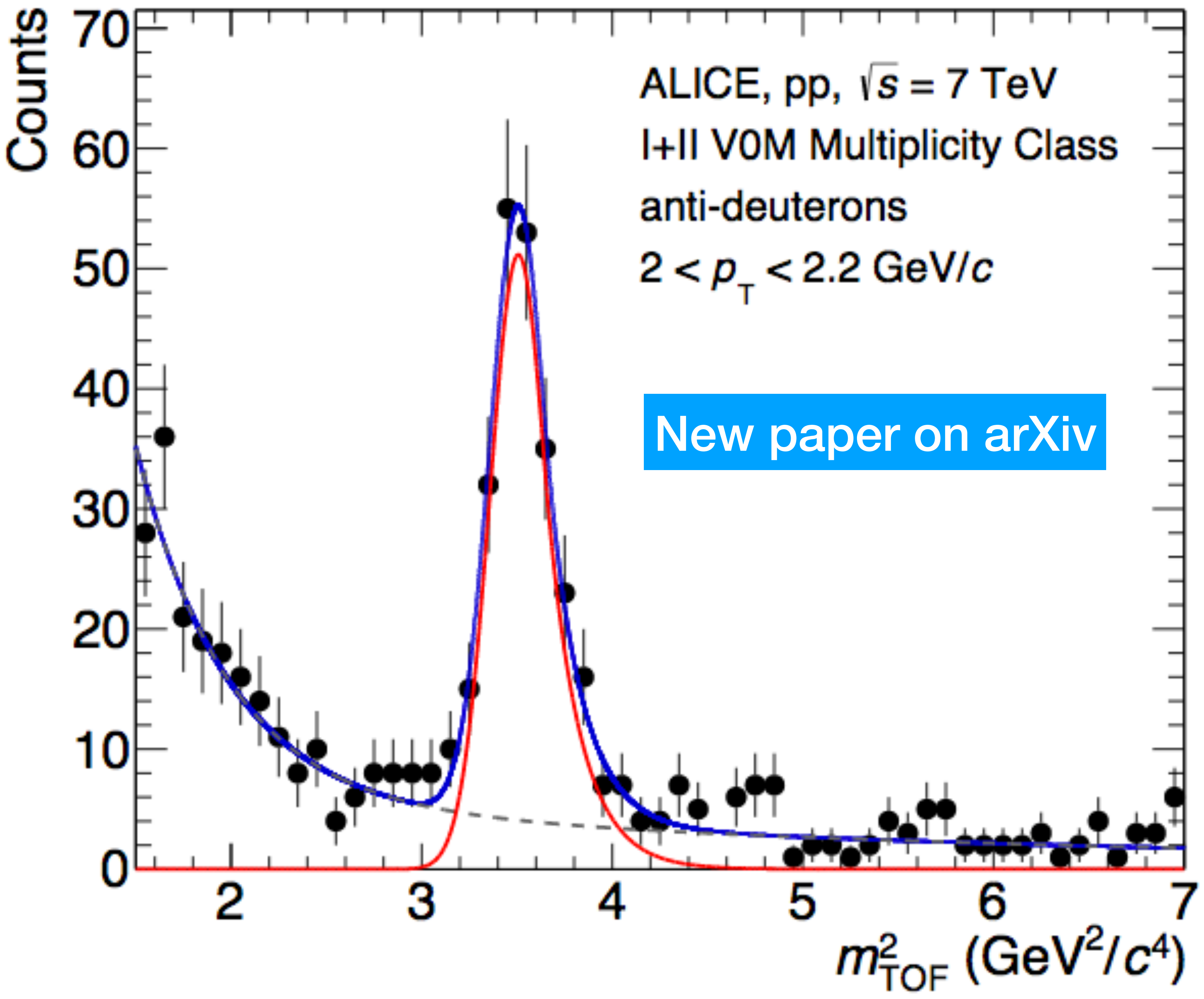




different production mechanisms inside UE w.r.t. jet

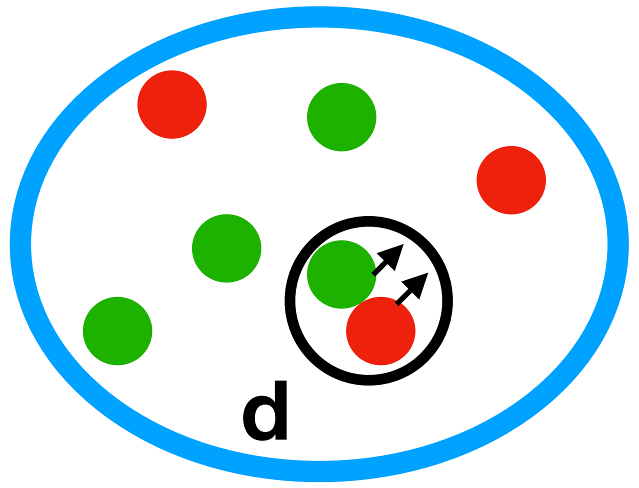
(anti-)deuteron production in pp collisions at √s = 7 TeV





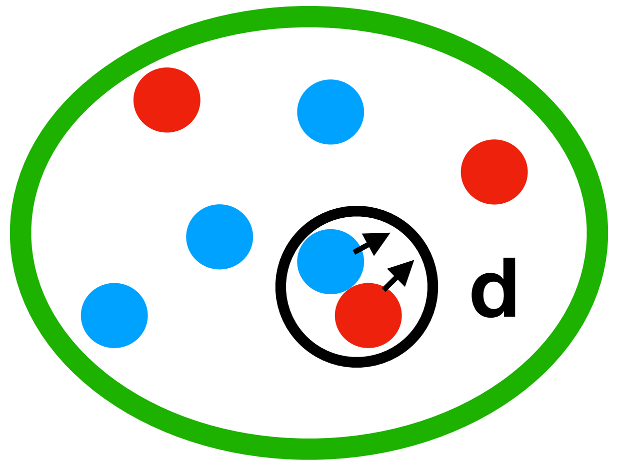
The production of composite anti-particles is **very rare:**
~ 0.005% of all negative particles are anti-deuterons.
Very clean PID needed! Very good performance in ALICE

Coalescence scenario:
(anti-)nuclei production by coalescence of (anti-)protons and (anti-)neutrons which are close by in momentum and configuration space.
deuteron ∝ proton x neutron => deuteron ∝ proton²



$$\frac{1}{2\pi p_T^d}\frac{d^2N^d}{dp_T^d dy} = B_2 \left(\frac{1}{2\pi p_T^p}\frac{d^2N^p}{dp_T^p dy}\right)^2$$

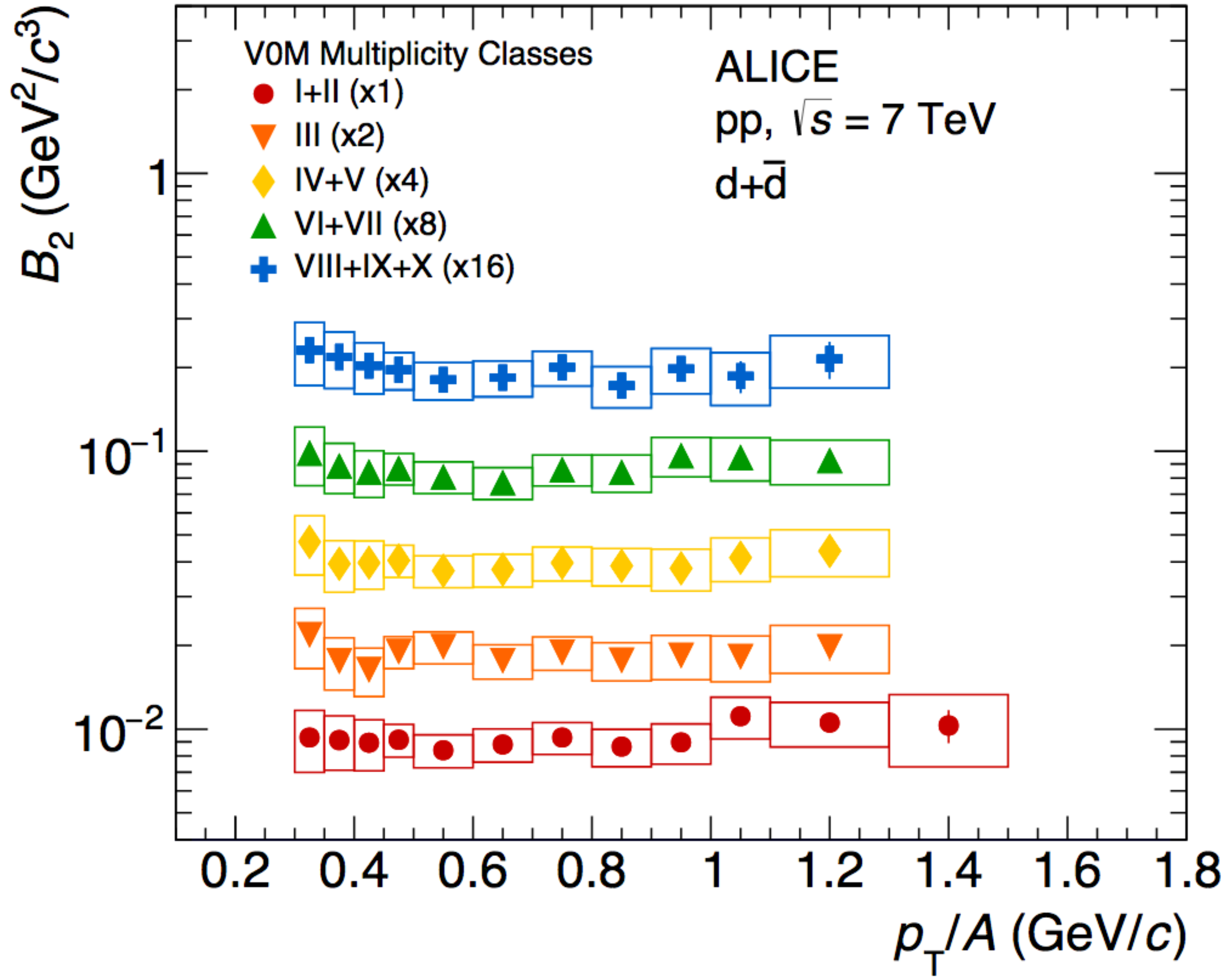
Multiplicity dependence of (anti-)deuteron production in pp collisions at $\sqrt{s}$ = 7 TeV



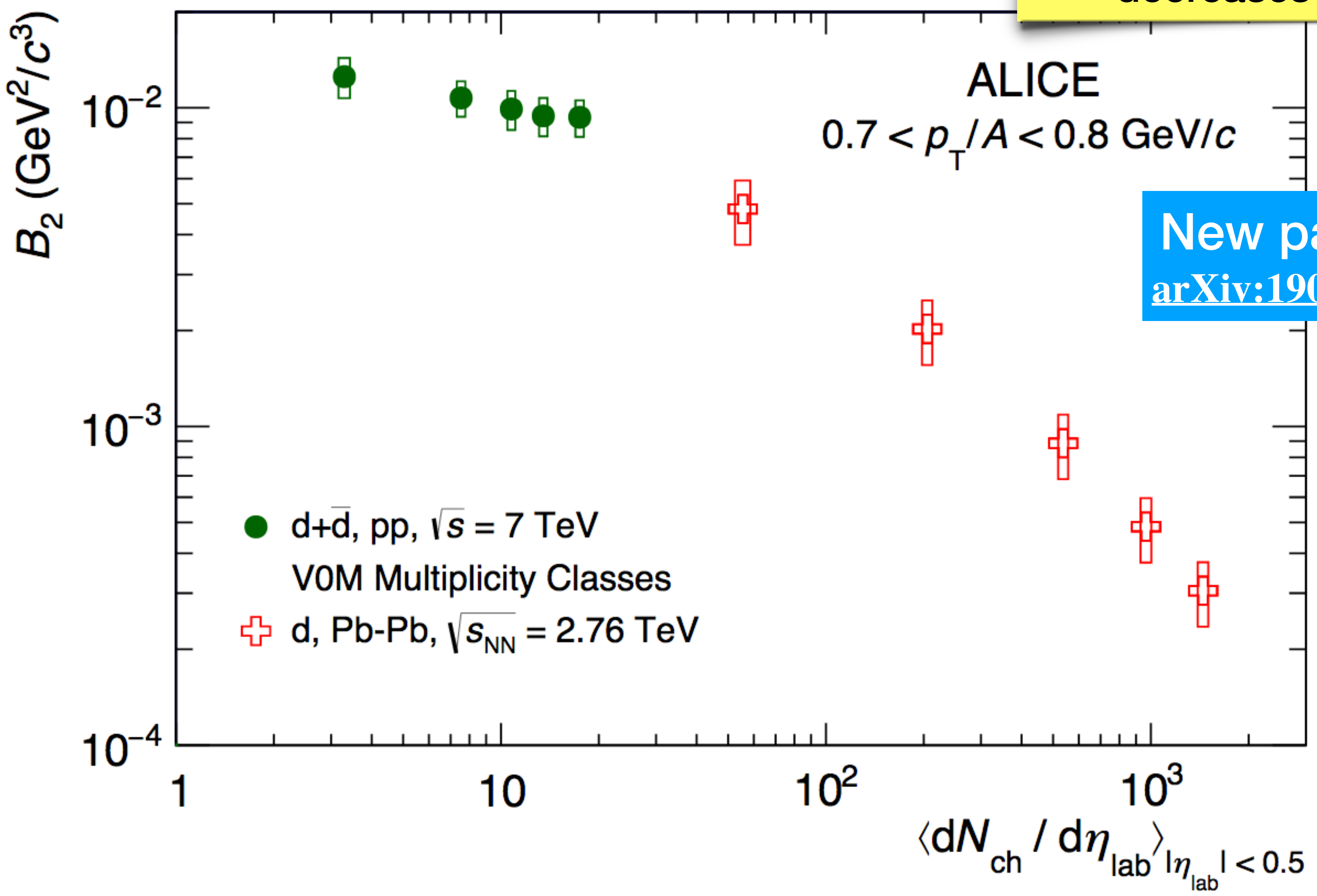
$$\frac{1}{2\pi p_{\mathrm{T}}^{\mathrm{d}}}\frac{\mathrm{d}^2N^{\mathrm{d}}}{\mathrm{d}p_{\mathrm{T}}^{\mathrm{d}}\mathrm{d}y} = B_2 \left(\frac{1}{2\pi p_{\mathrm{T}}^{\mathrm{p}}}\frac{\mathrm{d}^2N^{\mathrm{p}}}{\mathrm{d}p_{\mathrm{T}}^{\mathrm{p}}\mathrm{d}y}\right)^2$$

Coalescence parameter B_2 relates deuteron yield to proton yield

first measurement at LHC of (anti-)deuterons as a function of multiplicity in pp collisions: B_2 decreases with volume



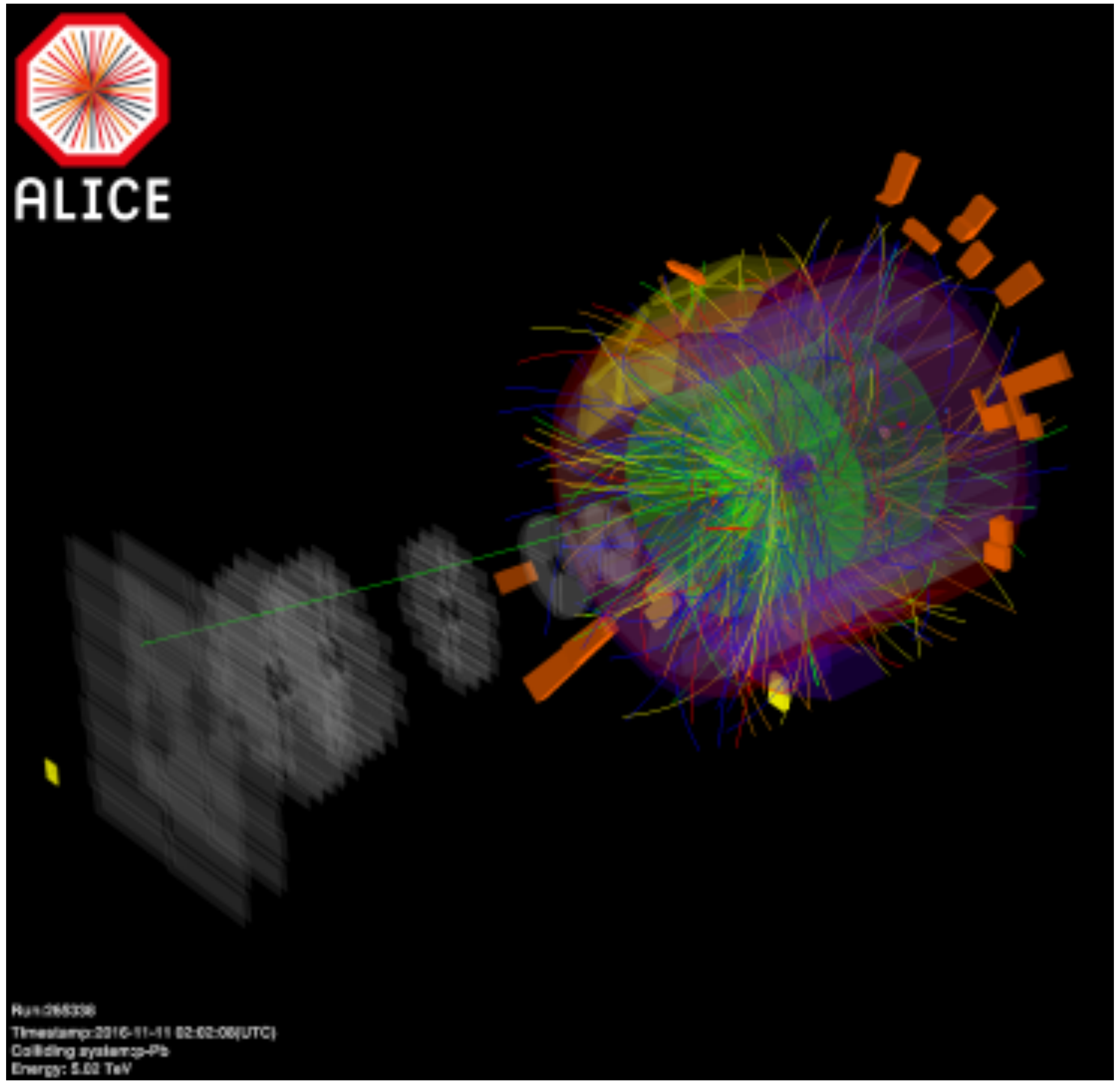
- B_2 no significant p_{T} dependence as expected in simple coalescence picture



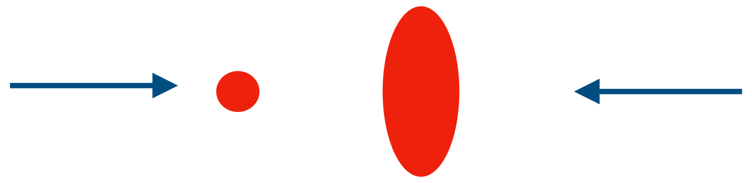
New paper on arXiv:1902.09290

B_2 as a function of multiplicity density in pp and in Pb-Pb

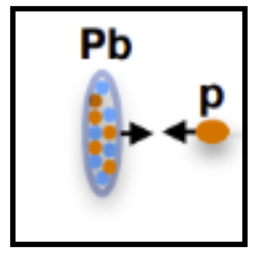
- 25% B_2 variation in pp from low to high mult. events
- more pronounced effect in Pb-Pb
  - ***increasing volume of emitting source affects B_2***



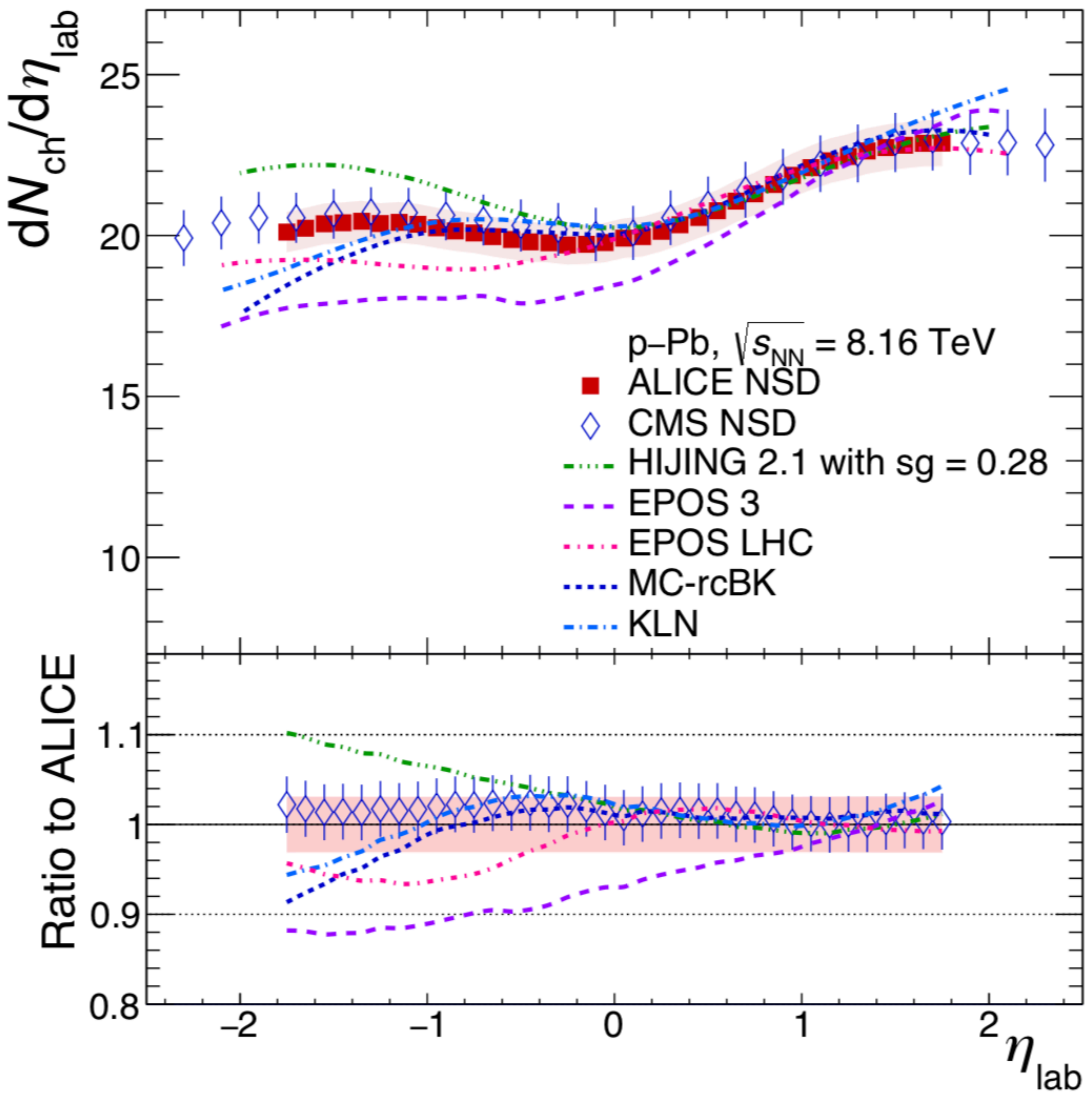
Recent results from p-Pb collisions



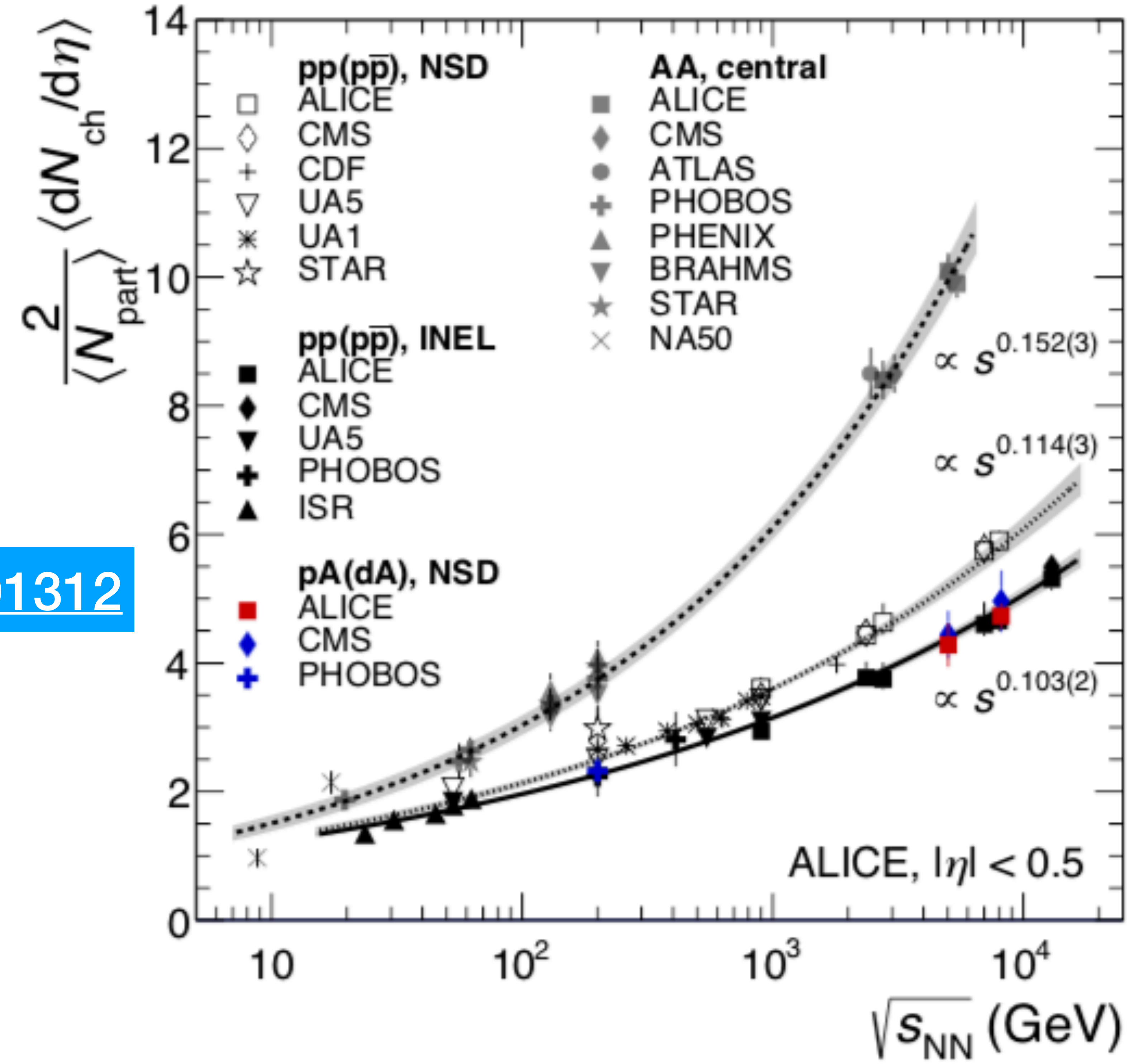
Charged-particle pseudorapidity density in p-Pb collisions at $\sqrt{s_{NN}}$ = 8.16 TeV



Pseudorapidity density measurements can provide constraints to the modelling of the initial state at small Bjorken-x



New paper on arXiv:1812.01312



$dN_{ch}/d\eta$ as a function of η_{lab}

Asymmetry between proton and lead hemispheres

- **models** based on different mechanisms for particle productions: discrepancies in the p-going side

$dN_{ch}/d\eta$ vs η measurements constrain models in the description of initial states at small x

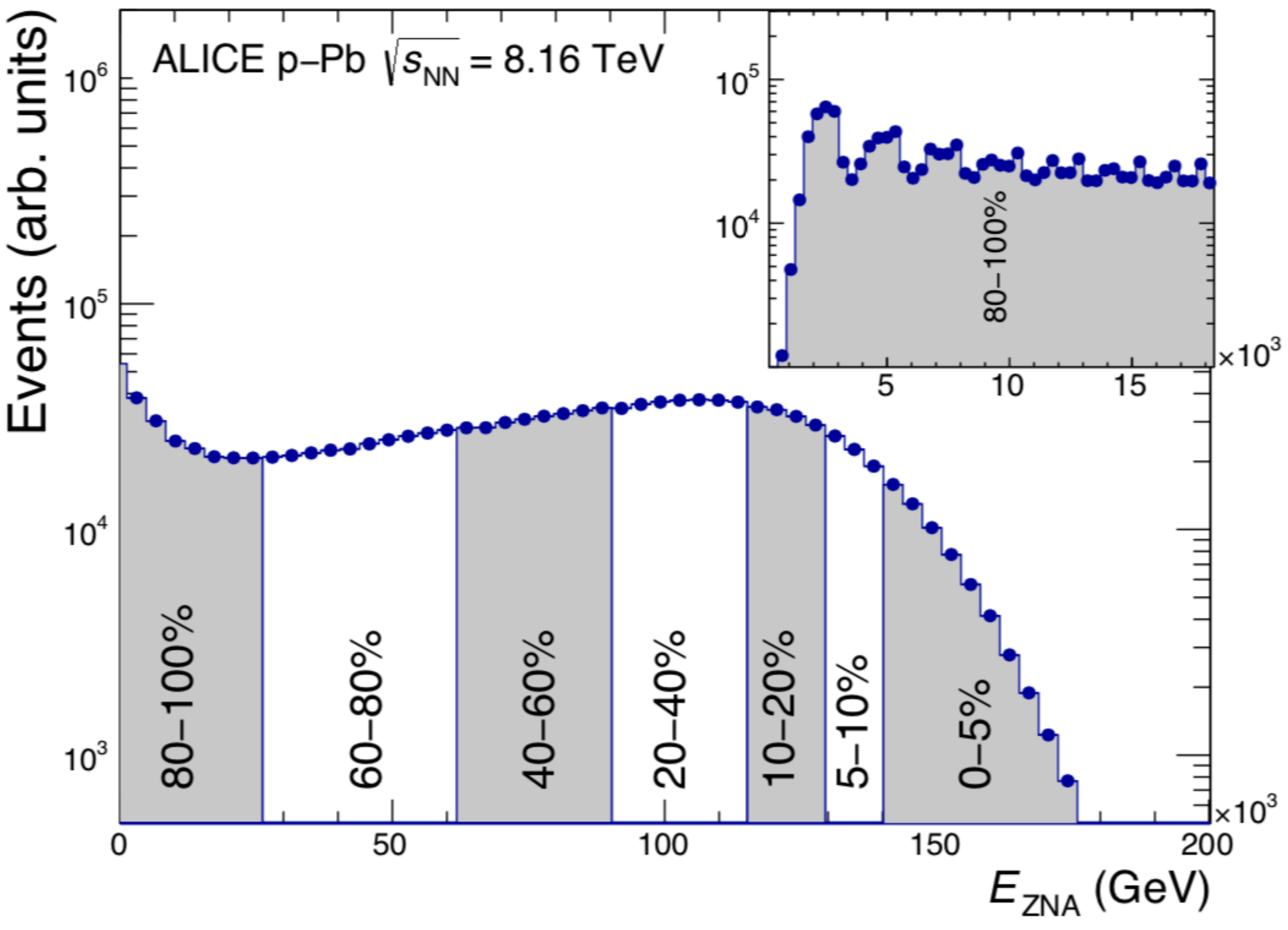
Charged particle multiplicity density in p-Pb collisions at $\sqrt{s_{NN}}$ = 8.16 TeV in $|\eta|$<0.5 is

- 9.5% higher than p-Pb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV
- p-A weaker dependence on $\sqrt{s}$ than AA, compatible with pp INEL

Charged-particle pseudorapidity density in p-Pb collisions in centrality ranges

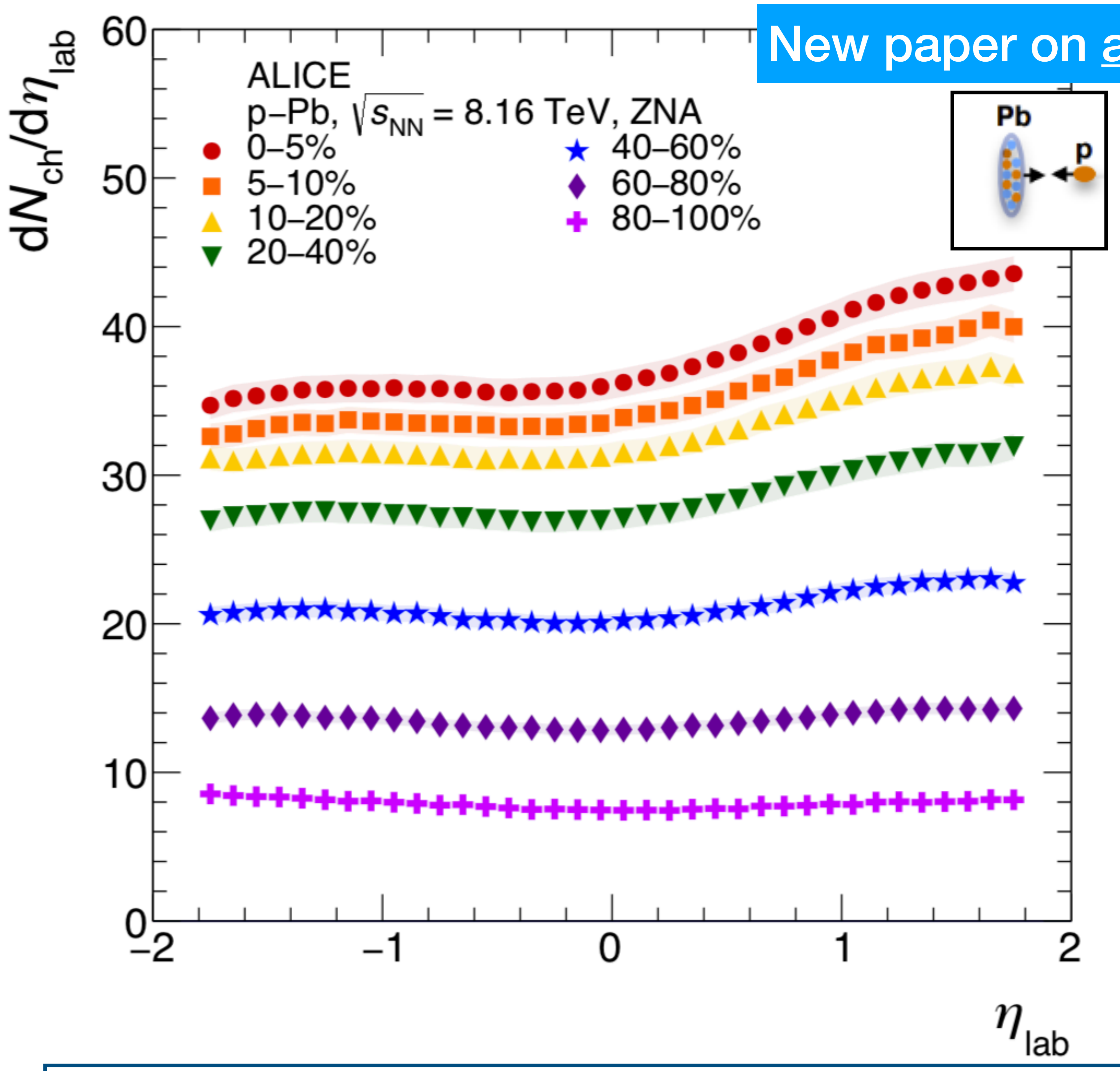
More differential analyses: measurements in different centrality classes

Centrality determined using energy deposited in ZDC detector, free from multiplicity fluctuation biases and observable well separated in pseudorapidity to limit effects of correlations in the collision range

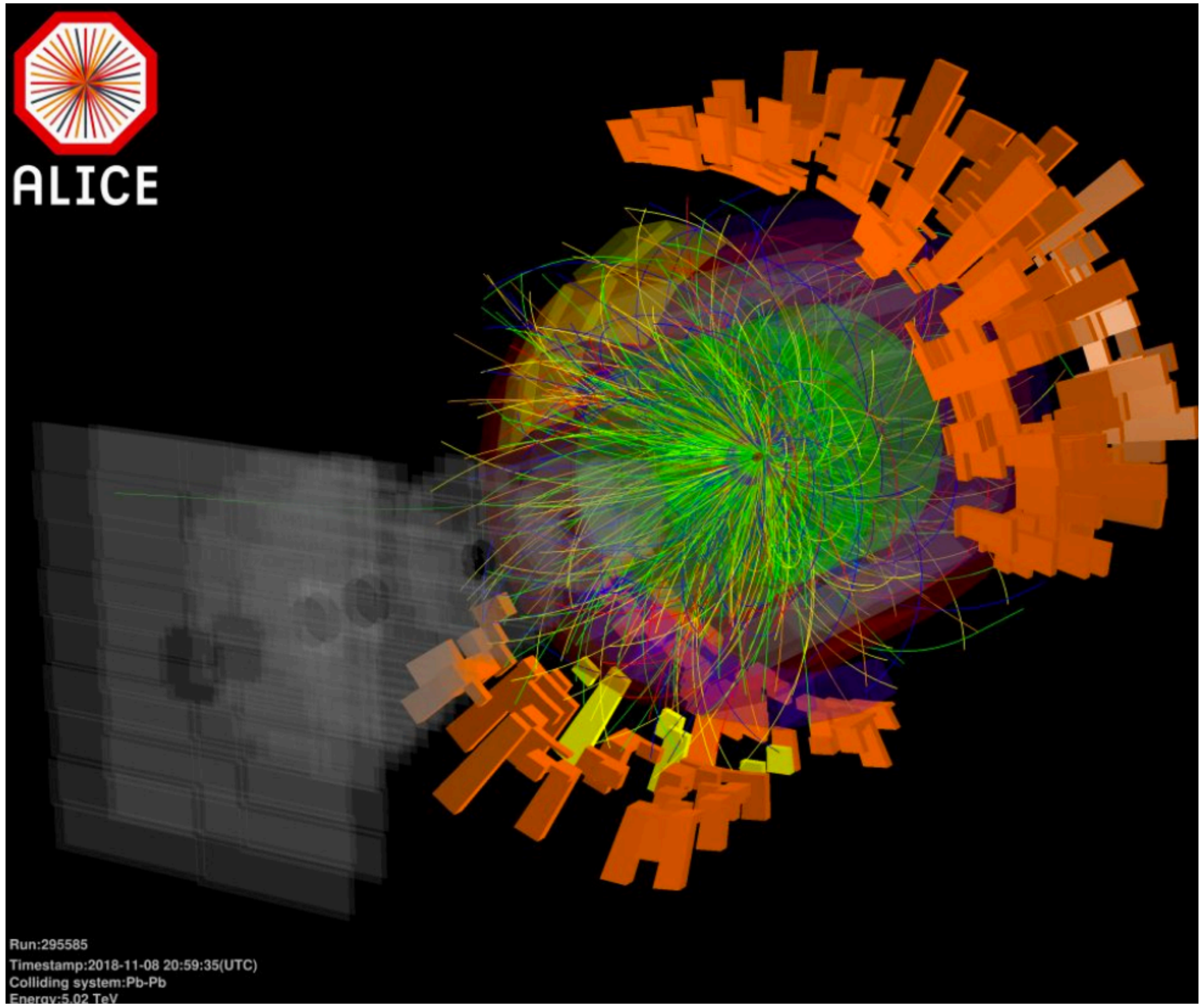


Neutron energy spectrum measured in the Pb-going side (ZNA)

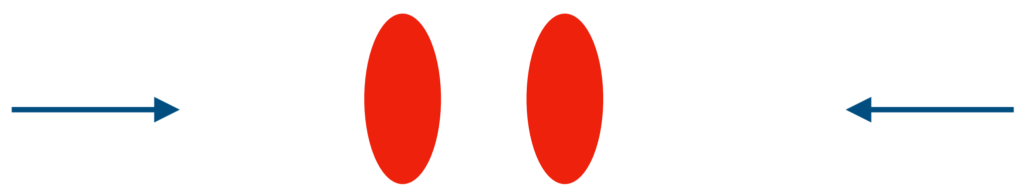
New paper on arXiv:1812.01312



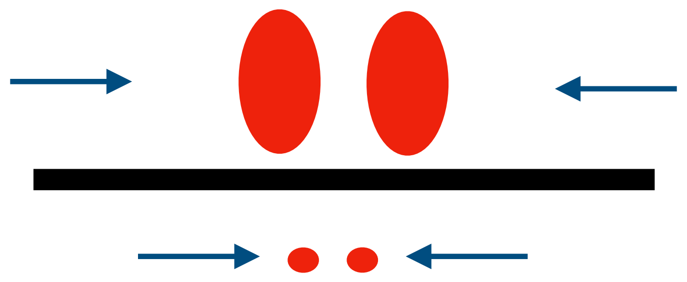
- Asymmetry is evident in most central events
- symmetric shape in peripheral 60-80% and 80-100%, similar to pp collision trend



Recent results from Pb-Pb collisions



b-quark energy loss in Pb-Pb collisions

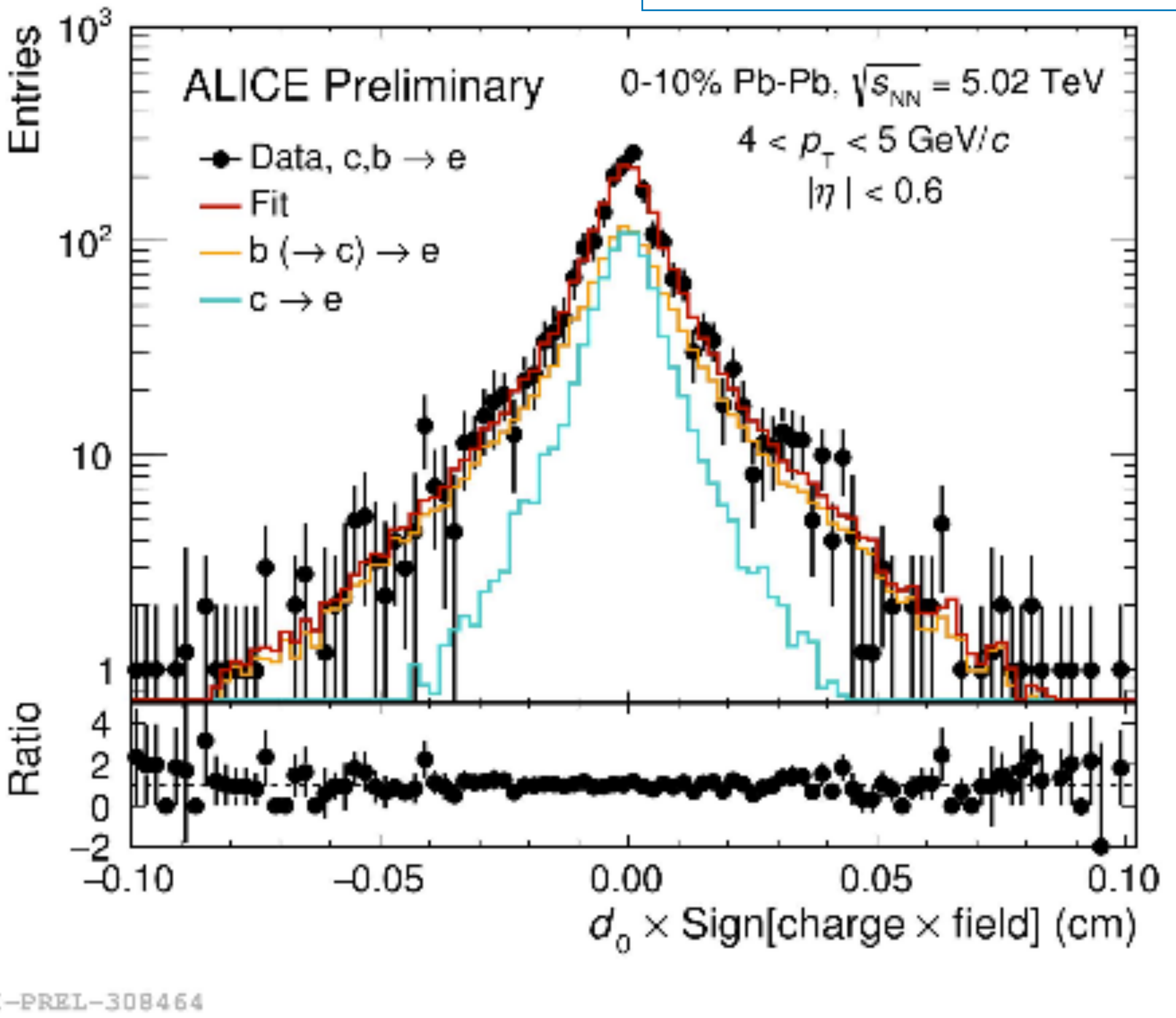


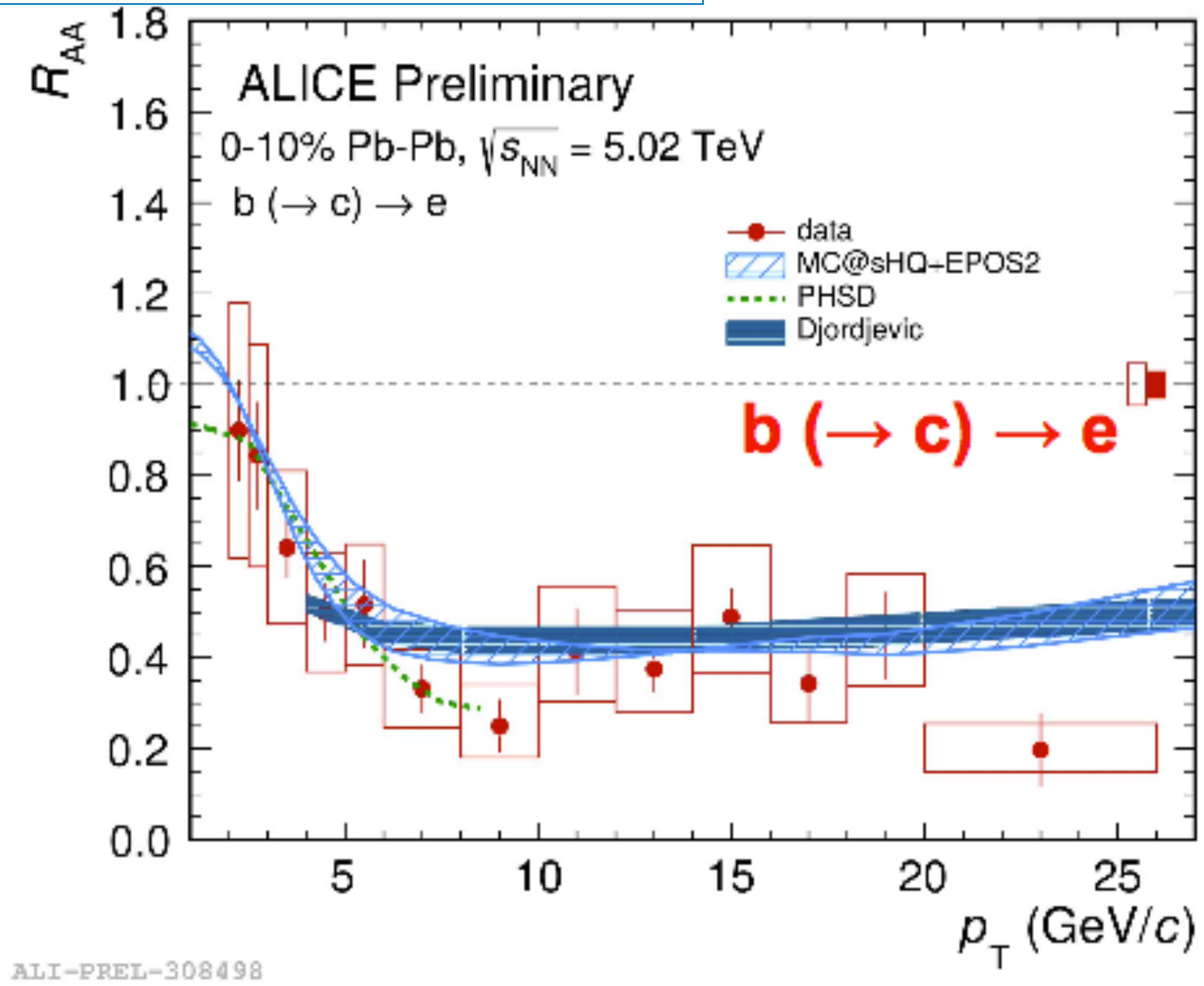
$$R_{AA}(p_T) = \frac{1}{< T_{AA} >} \times \frac{dN_{AA}/dp_T}{d\sigma_{pp}/dp_T} = \frac{QCD\ \text{Medium}}{QCD\ \text{Vacuum}}$$

strong suppression of beauty-hadron production in Pb-Pb collisions

New Preliminary

Electrons from beauty hadron decay in Pb-Pb@5.02 TeV at mid-rapidity



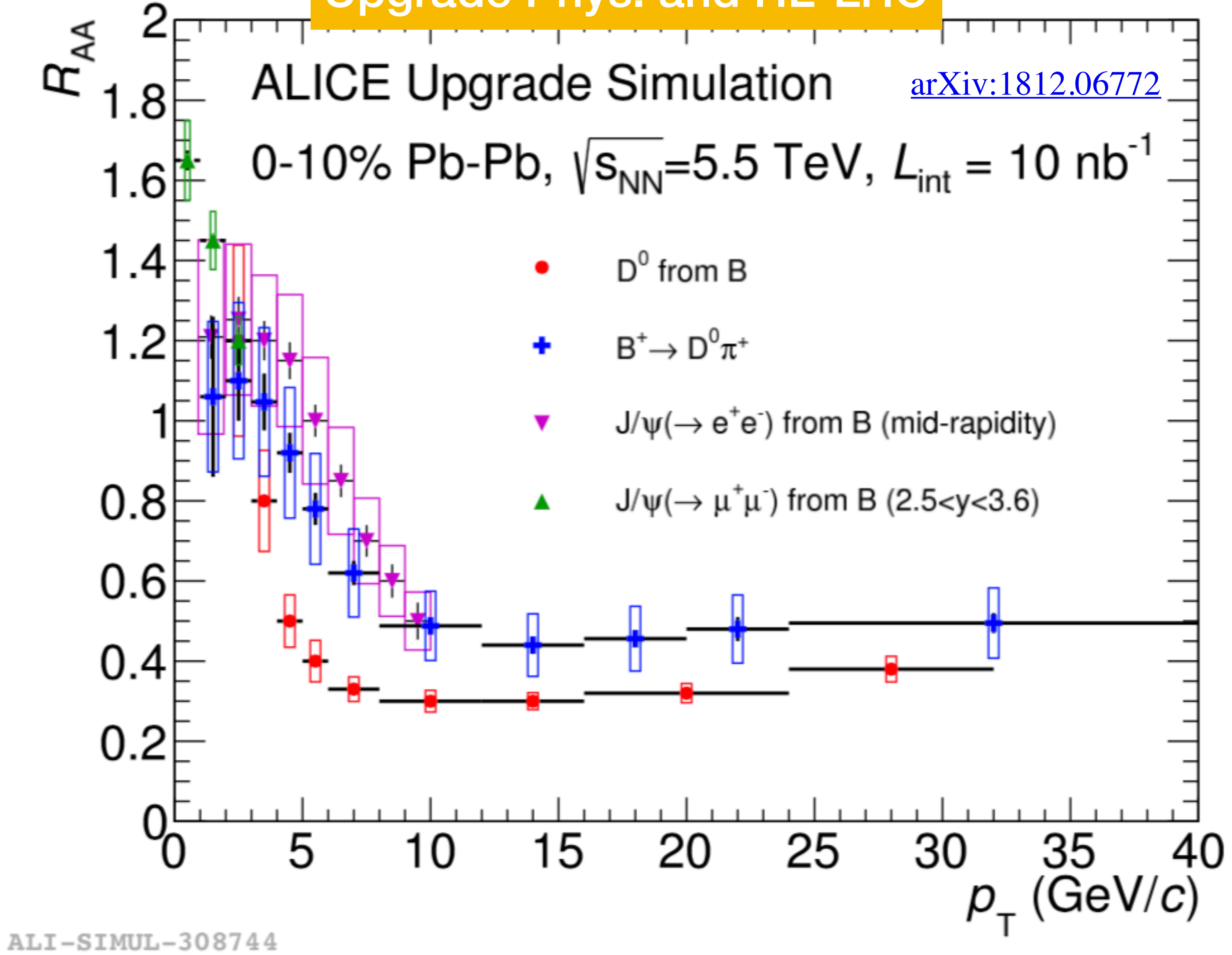


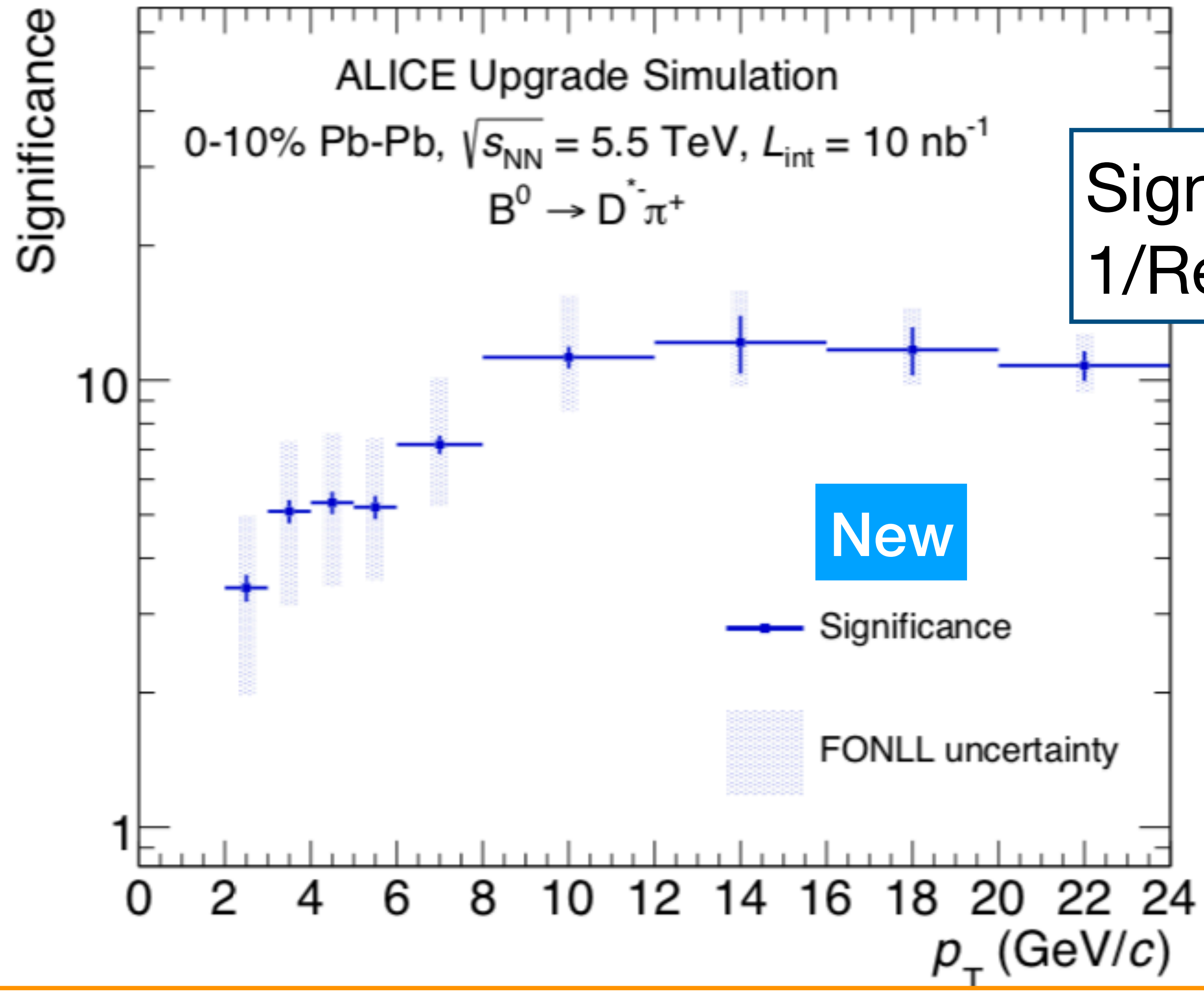
- Direct measurement of beauty-electron R_{AA} with electron DCA analysis to separate beauty from light and charm hadron decays
- yield measured up to 26 GeV/c

- Significant suppression in 0-10% described by models that include mass-dependent energy loss

Beauty measurements in Pb-Pb: prospects

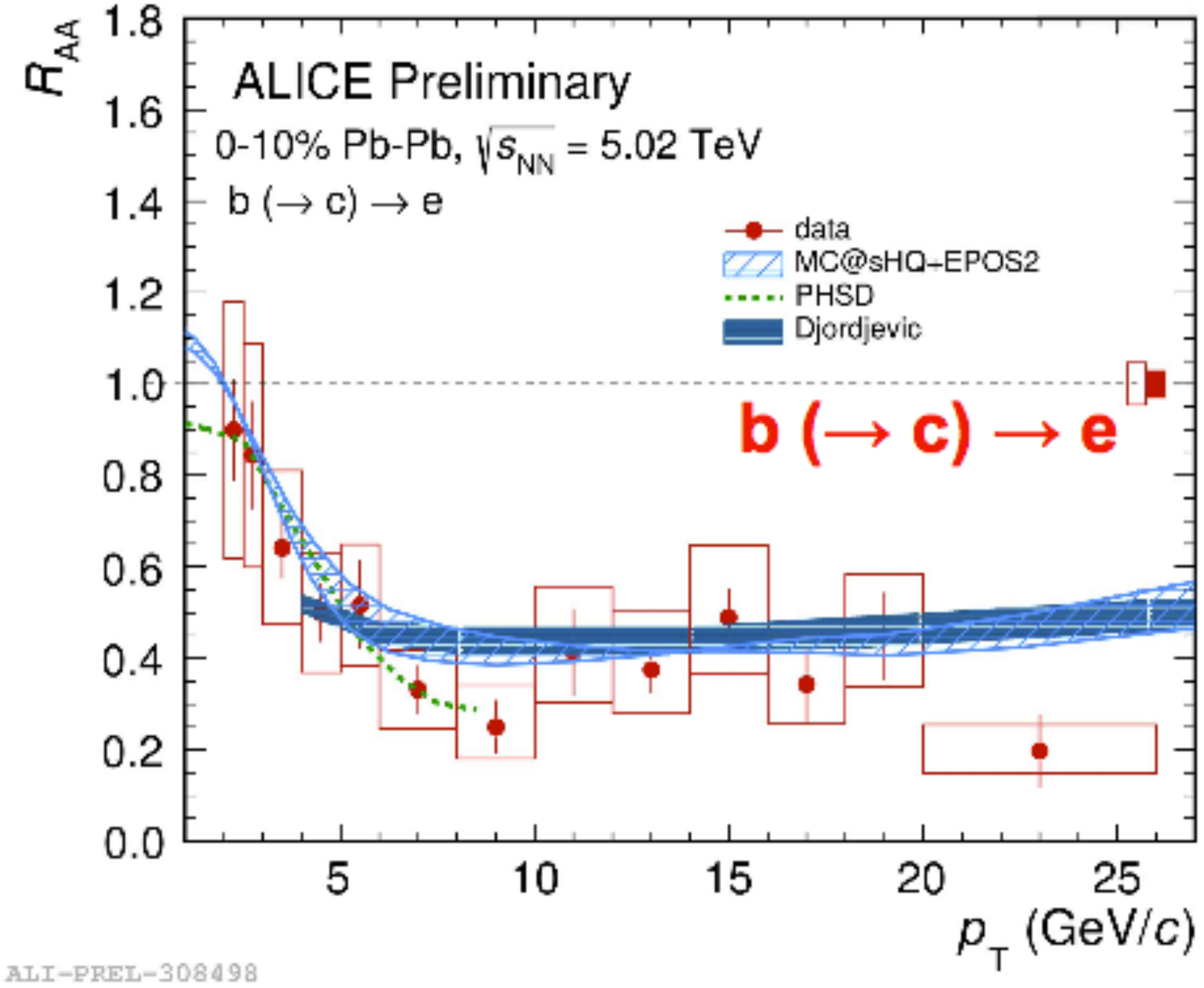
Yellow Report:
Upgrade Phys. and HL-LHC



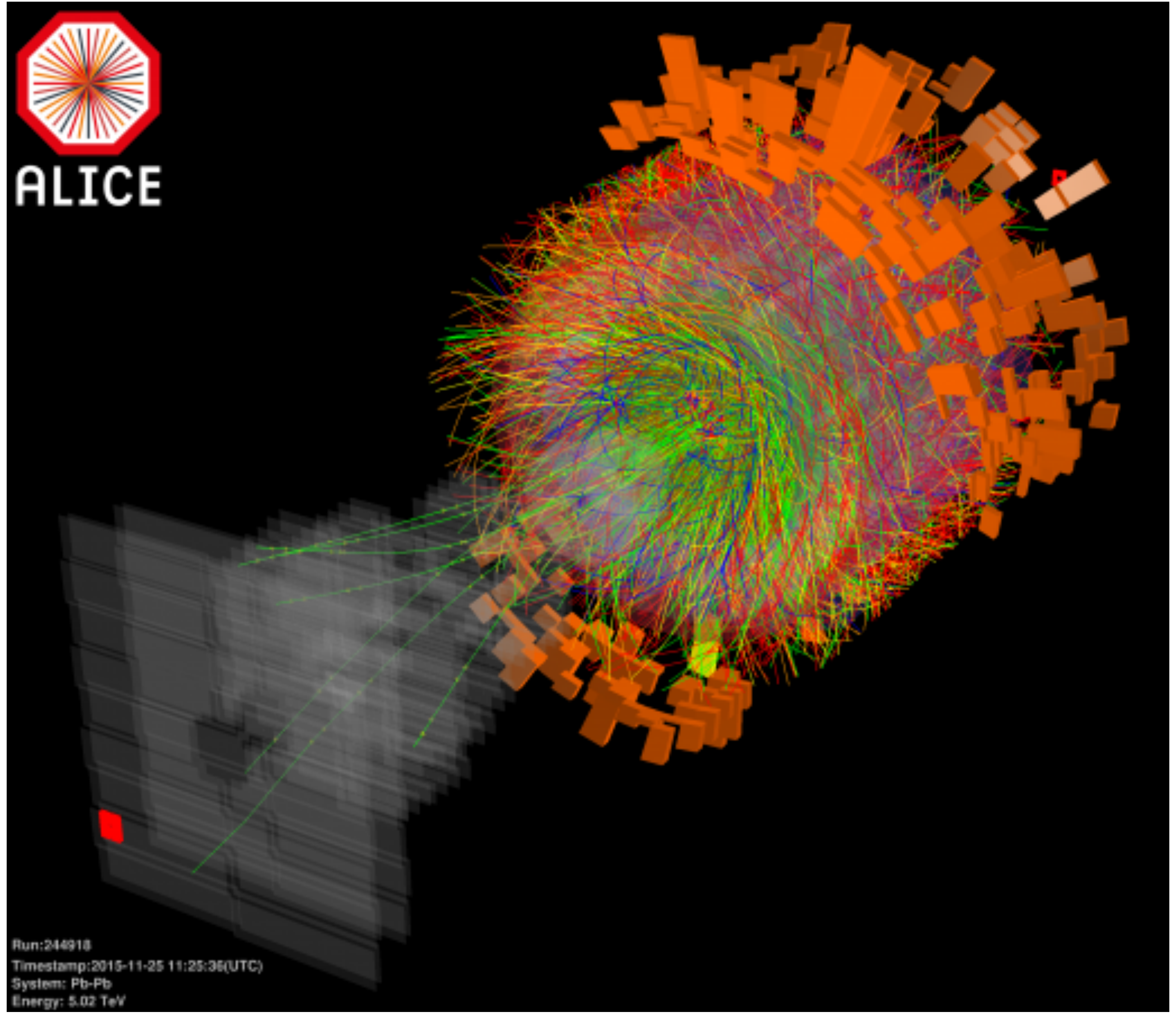


Significance=
1/Relative Uncertainty

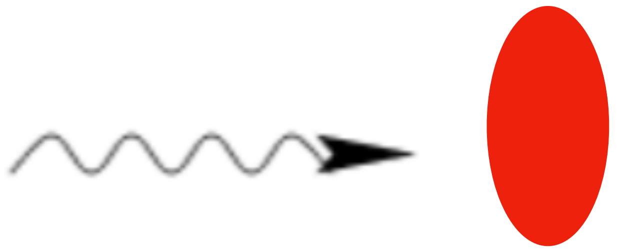
- **Plans with Pb-Pb 2018**:
  - improved precision for R_{AA}
  - first measurement of elliptic-flow v_2 of beauty-decay electrons
  - **Run3 data:** more precise measurement via full reconstruction of B mesons: $B^+\rightarrow D^0\pi^+$, $B^0\rightarrow D^{*+}\pi^-$ $B^+\rightarrow J/\psi\ K^+$ at mid-rapidity and non-prompt J/ψ at forward-rapidity

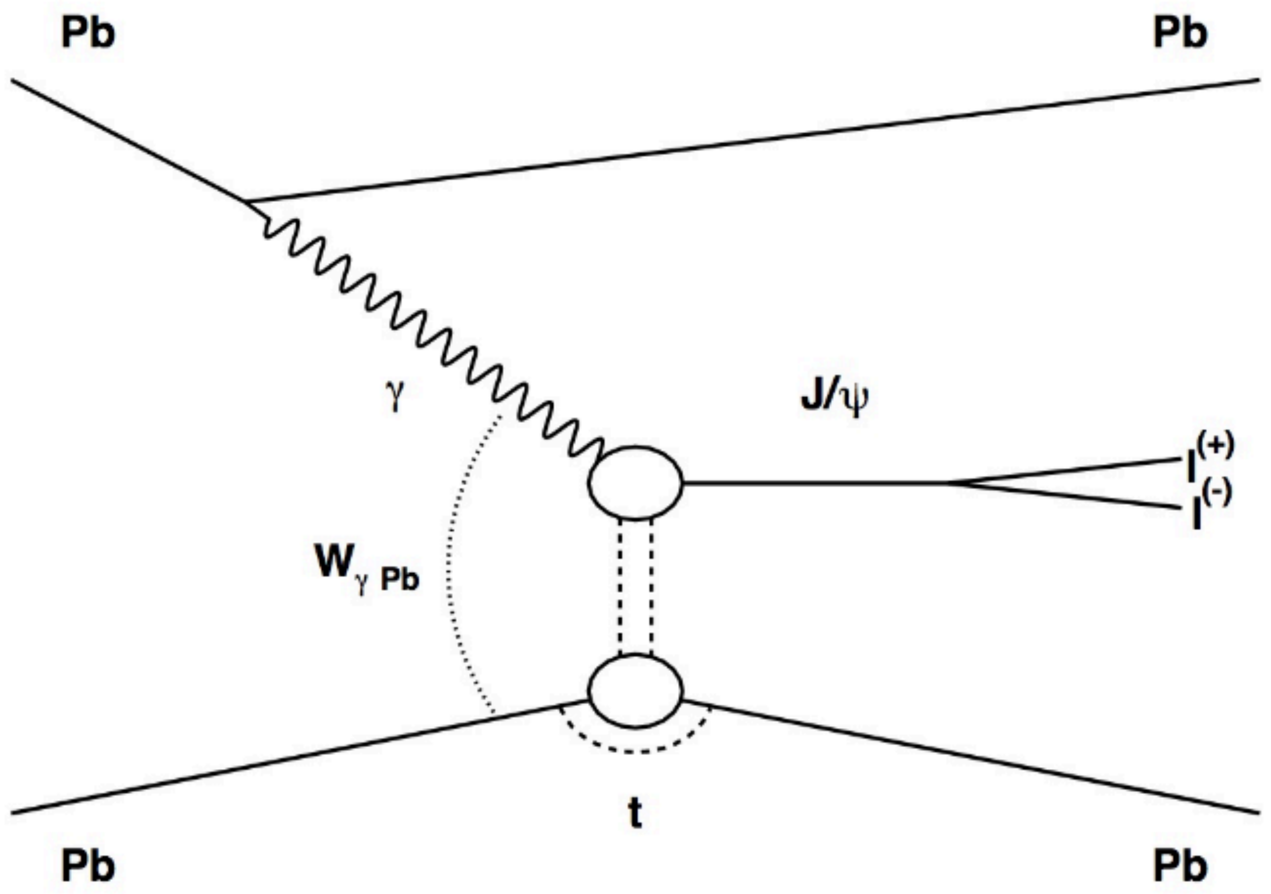


prospects for Run3: direct measurement of B via fully reconstructed decay topology



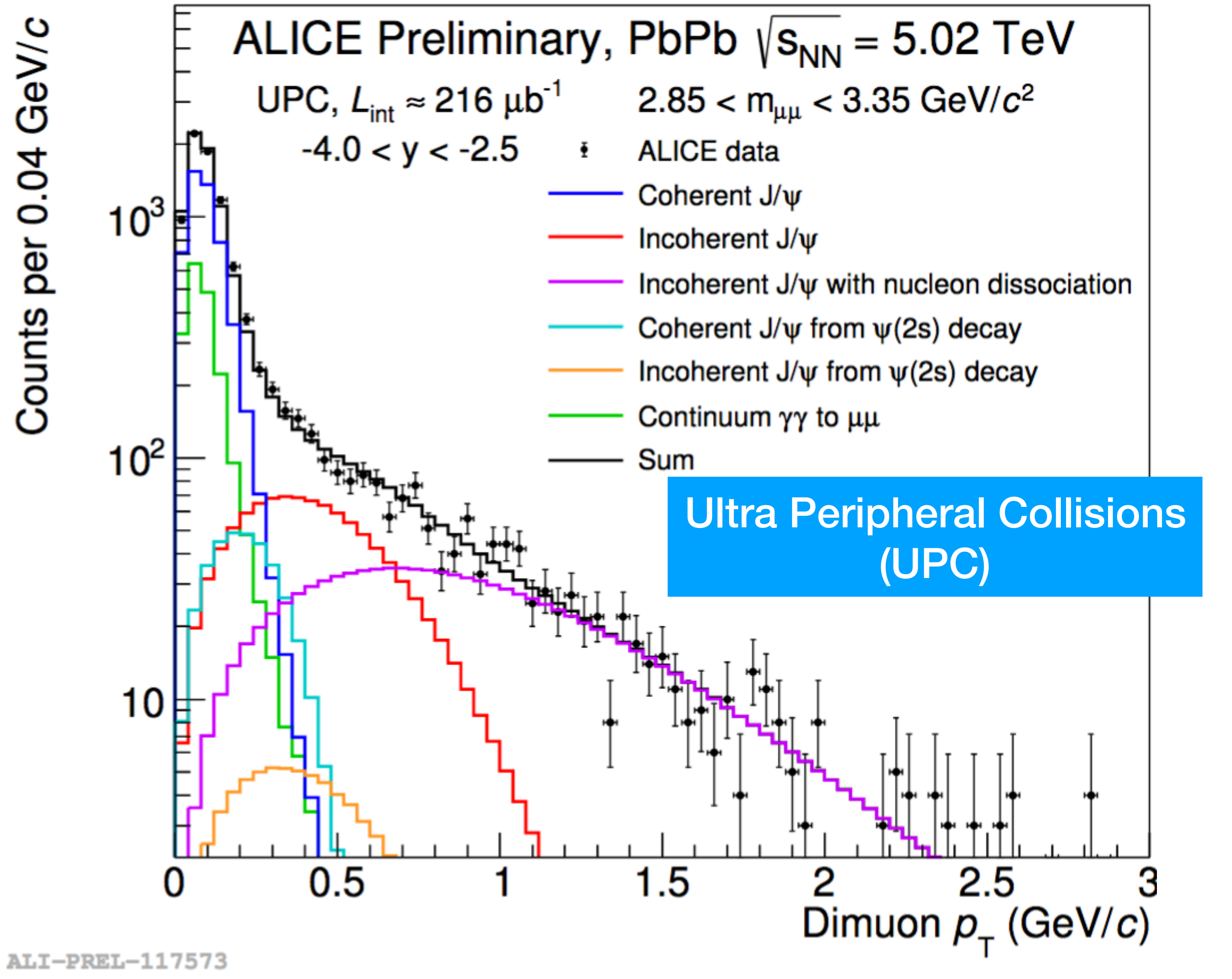
Pb-Pb collisions:
also a photon-Pb collision factory



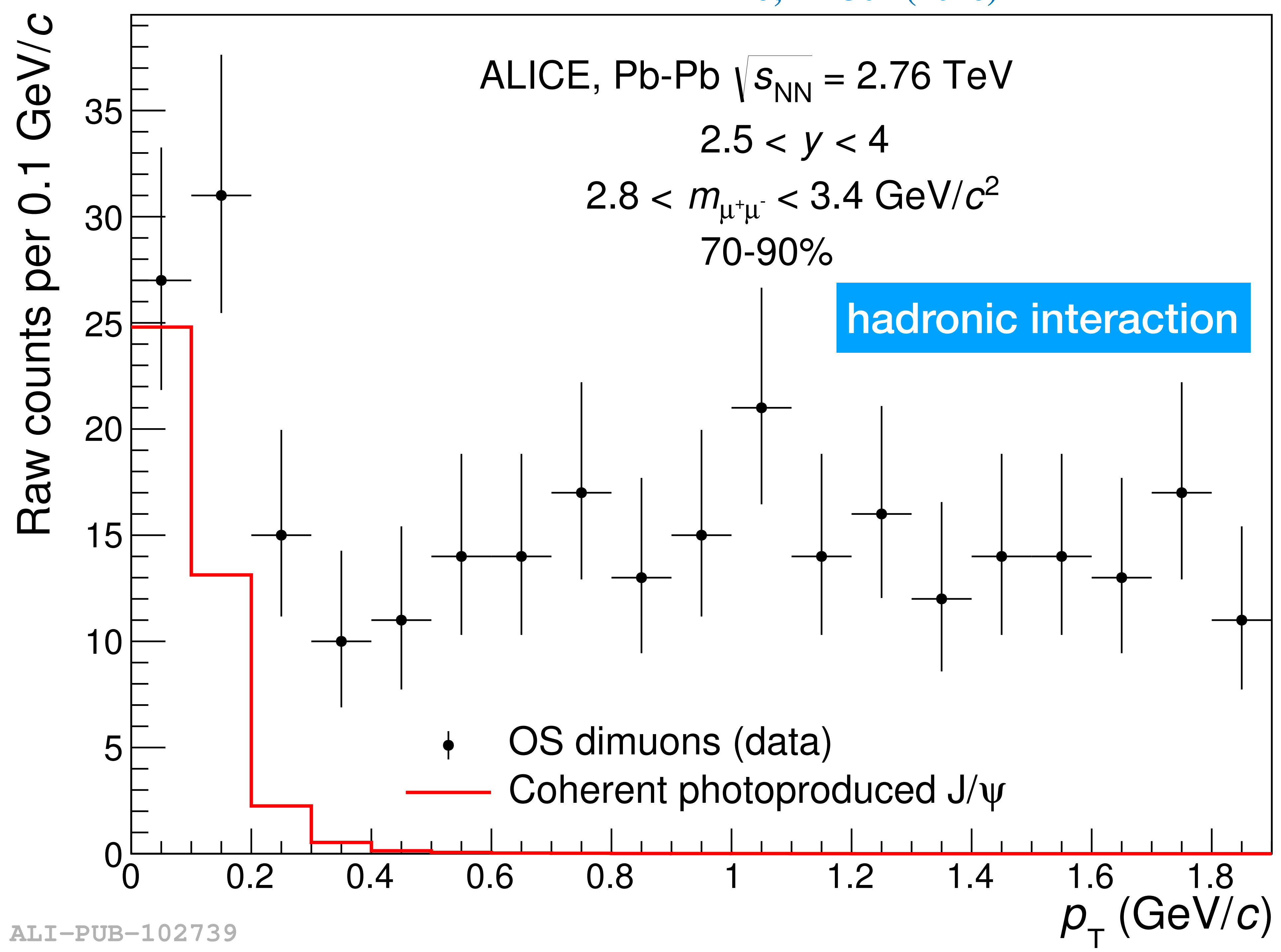


J/ψ Photoproduction in Pb-Pb collisions

J/ψ coherent photoproduction signature: small <p_T> ~ 50 MeV/c
→ Excess at low p_T w.r.t. recombination/regeneration scenario



PRL 116, 222301 (2016)



observed in UPC:
- hadronic interactions strongly suppressed
- electromagnetic interactions dominant

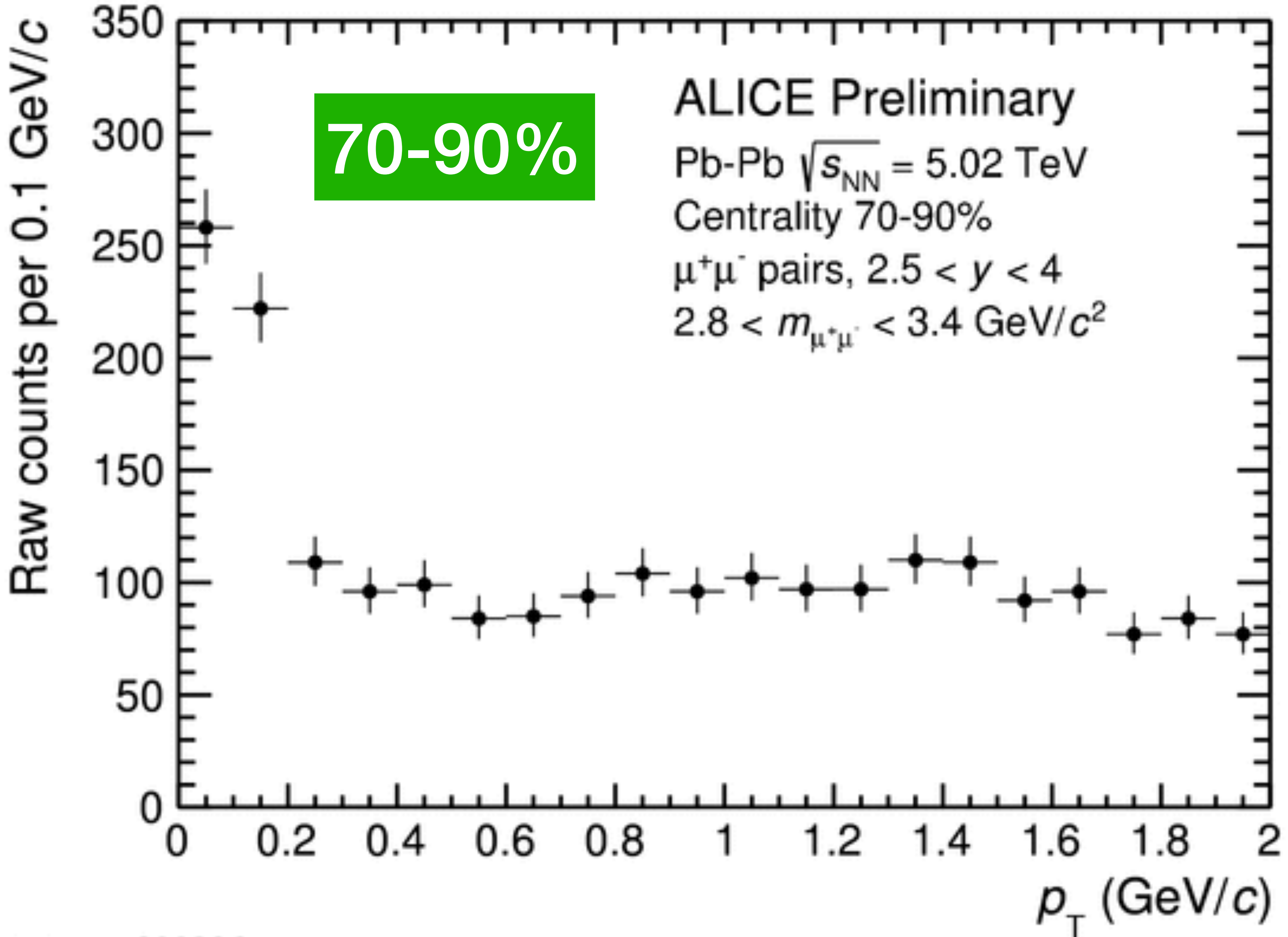
observed in peripheral Pb-Pb collisions at forward- and mid-rapidity at 2.76 TeV and 5.02 TeV, respectively
- interpreted as coherent vector meson (VM) photoproduction consistent with expectations from photoproduction models

VM photoproduction used to probe gluon distribution in the nucleus target at low Bjorken-x
- complementary information to the study of the J/ψ hadroproduction in p-Pb and Pb-Pb collisions

J/ψ Photoproduction in peripheral Pb-Pb collisions

ALICE

J/ψ hadroproduction: excess observed in peripheral Pb-Pb collisions at forward rapidity at $\sqrt{s_{NN}}$ = 5.02TeV



ALI-PREL-309896

New Preliminary

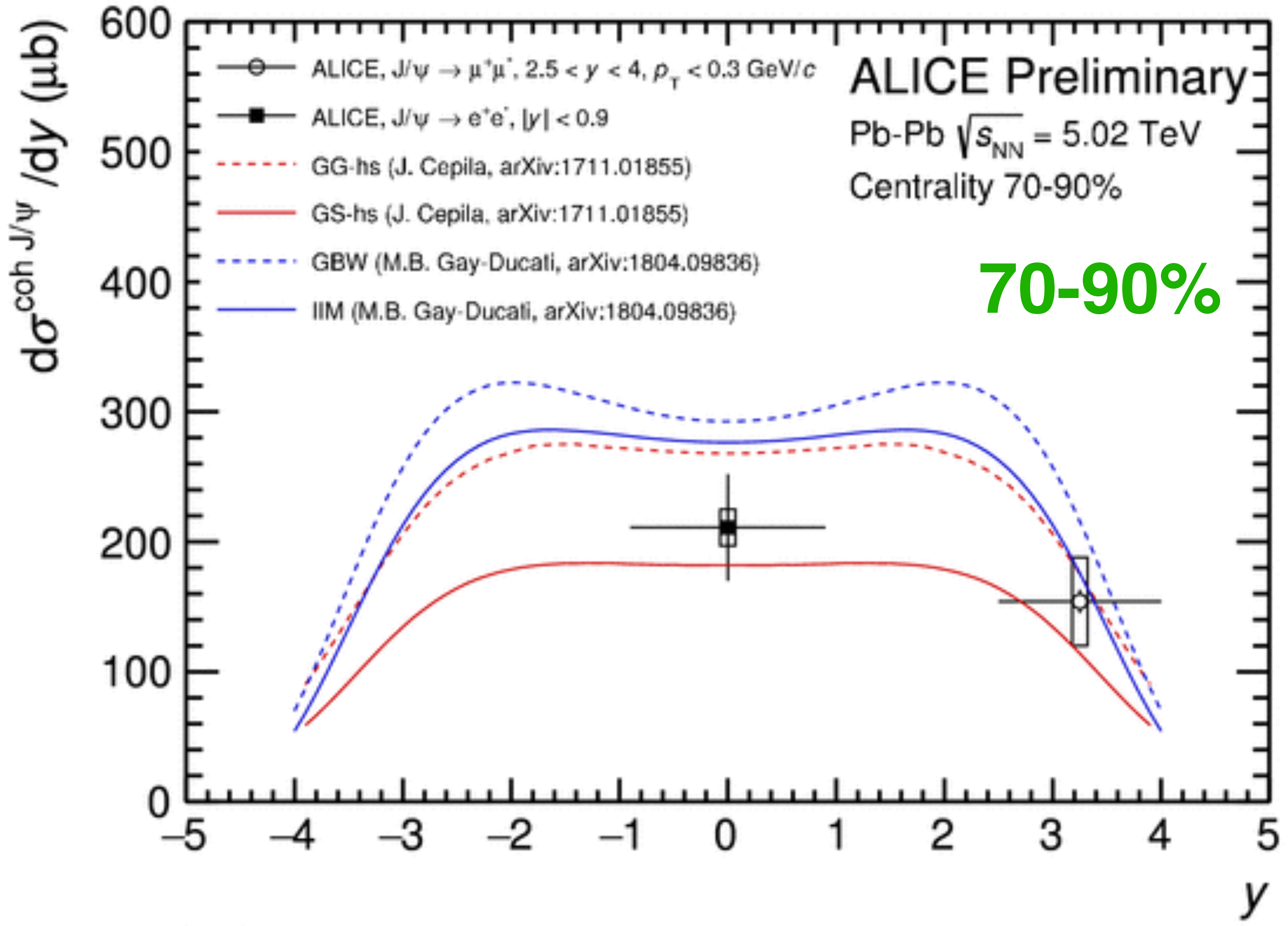
low-p_T excess seen in the centrality ranges **50-70%** and **70-90%**

excess has a significance > 10 σ

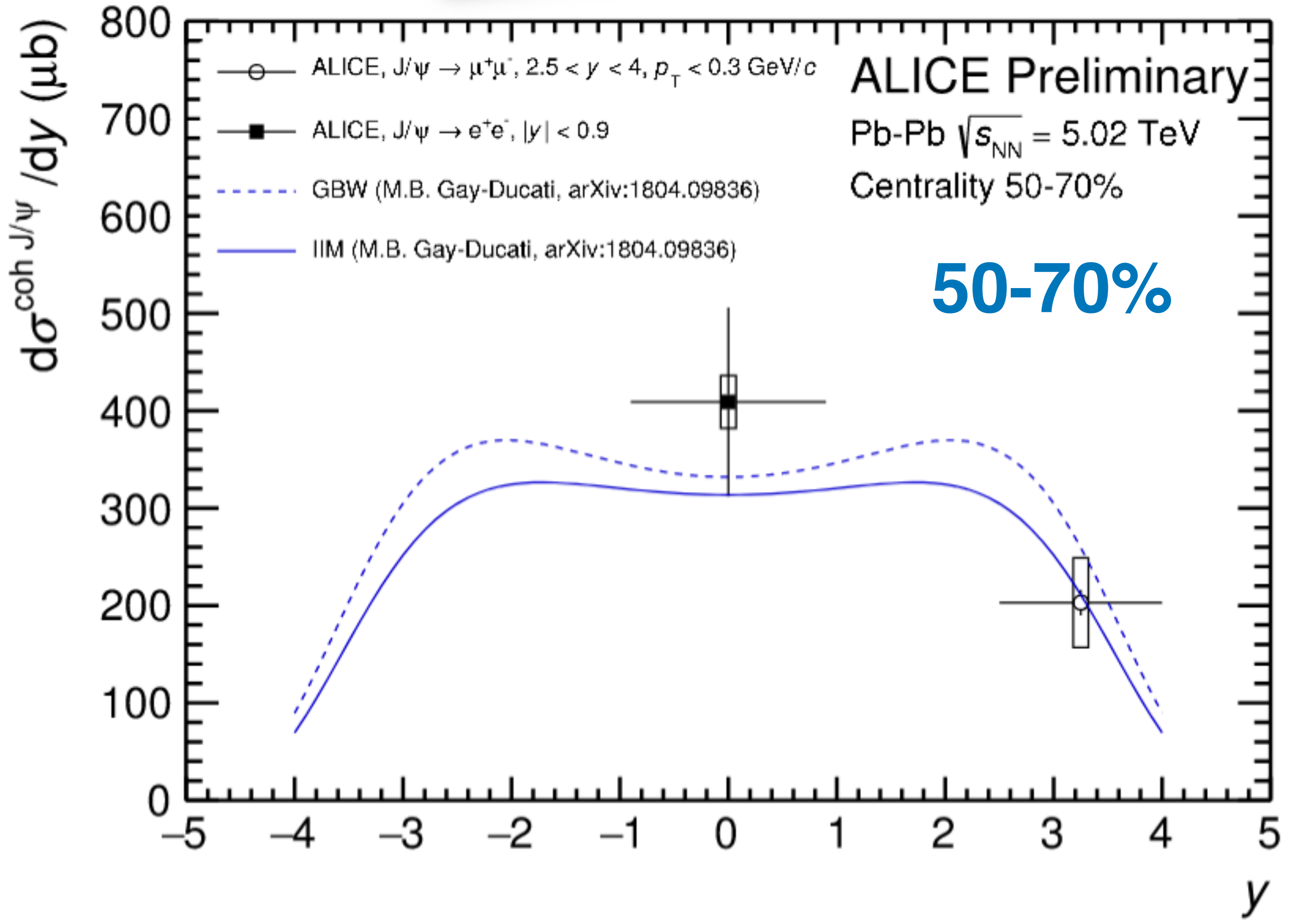
VM photoproduction measurements in peripheral Pb-Pb collisions can help to constraint photoproduction models in hadronic collisions

Cross-section of coherent J/psi photoproduction

- described by model calculations of photoproduction modified to account for nuclear overlap region



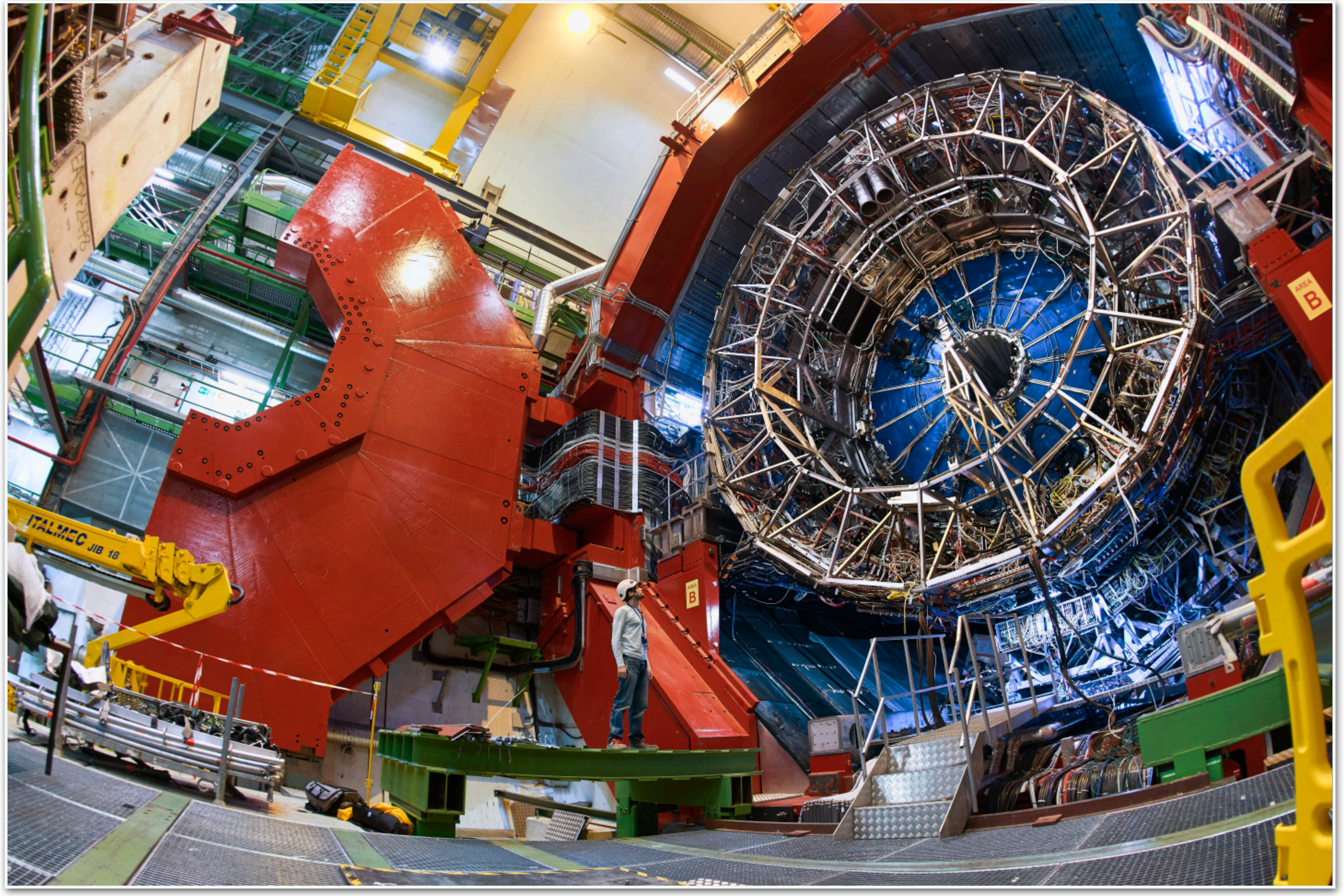
LI-PREL-309948



ALI-PREL-309953

Prospectives with new Pb-Pb 2018 data:

- centrality dependence at mid-rapidity
- other vector mesons



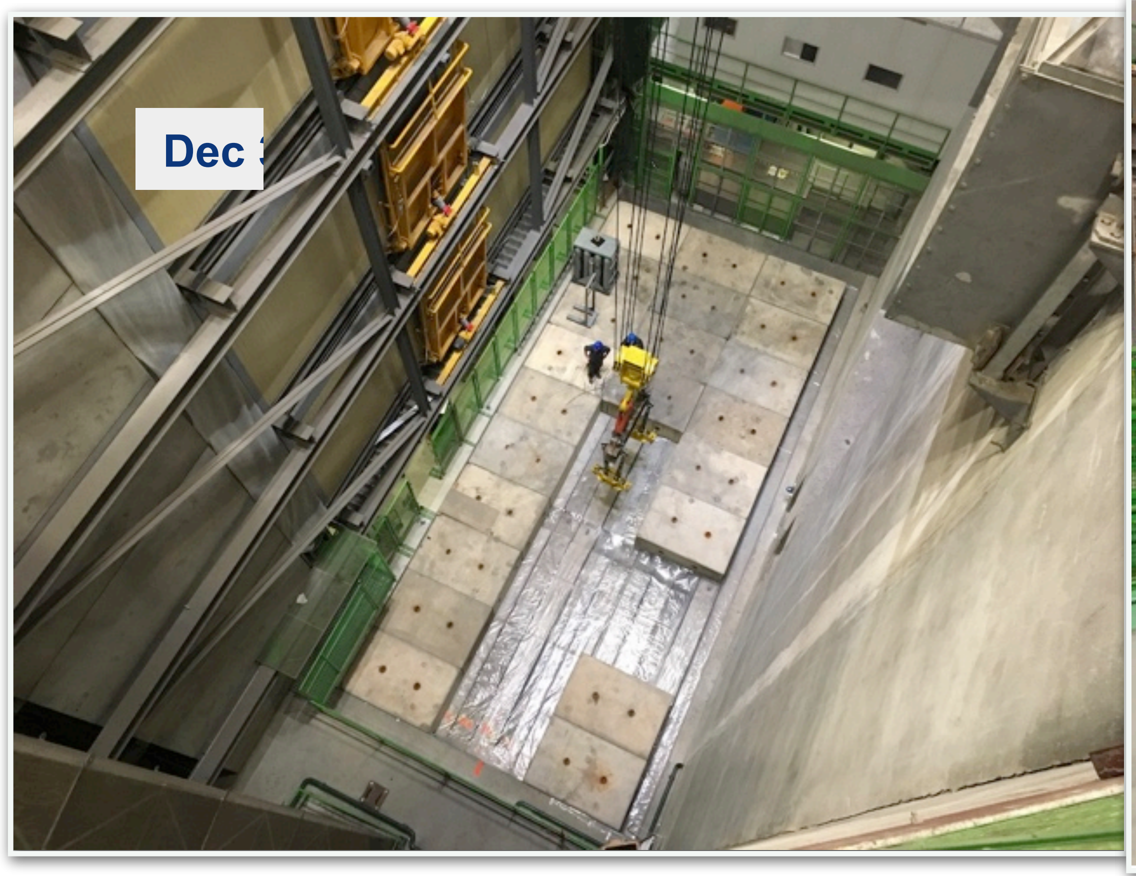
ALICE

LS2 Activities at Point2

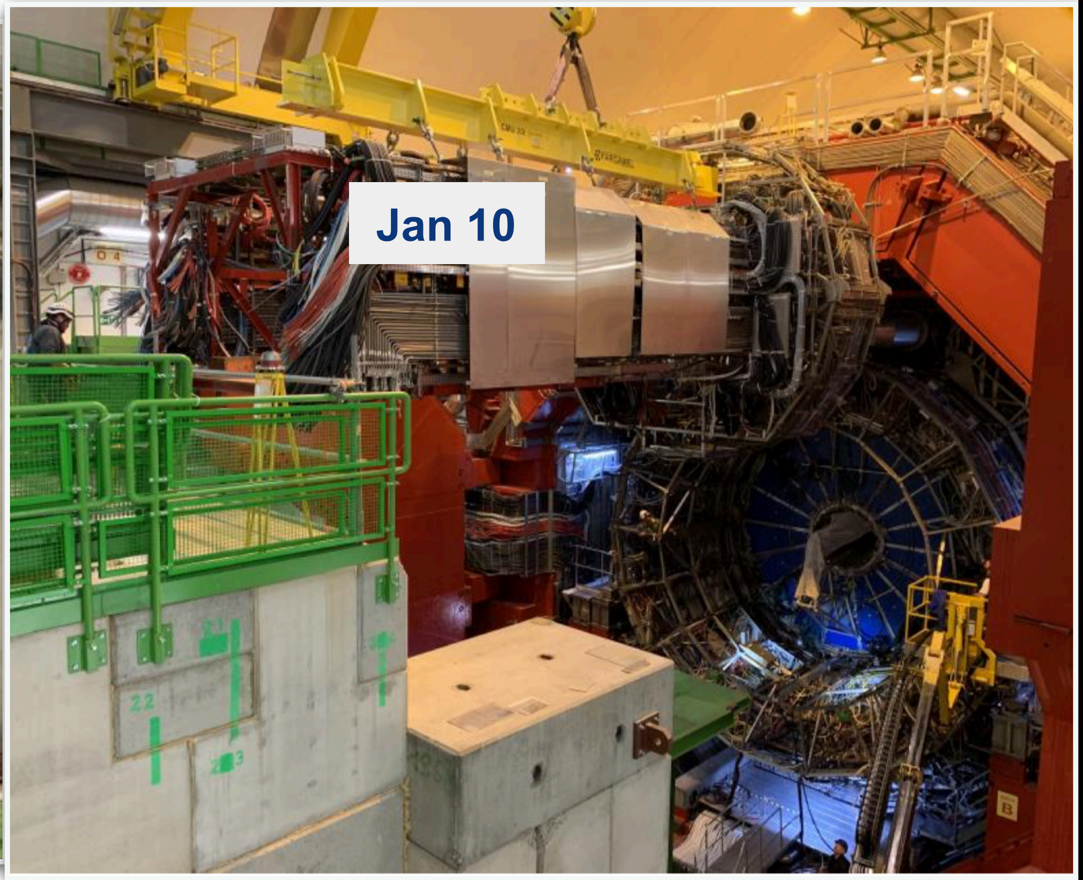
LS2 status

- **Many things ongoing at P2 – on track with the shutdown work.**
  - TPC moved to parking position on Feb 11th
  - SPD, forward detectors and central beampipe removed last week
  - ITS removed yesterday
  - **Next milestone: bring TPC to SXL2 on Tuesday March 5th**

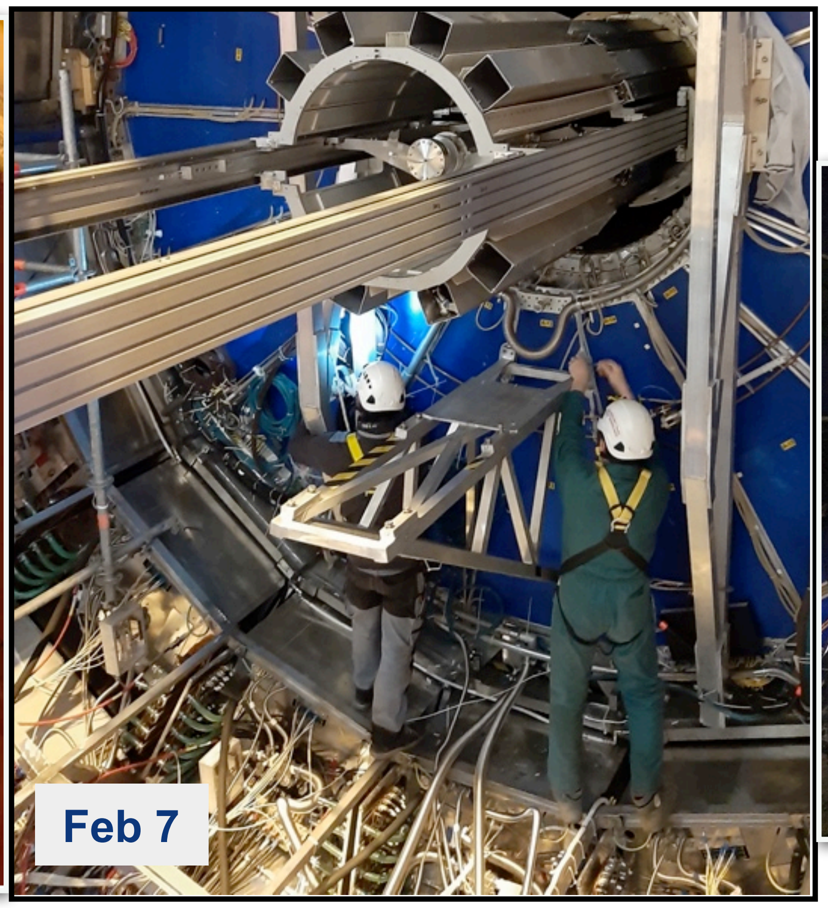
- Services: A-side removal done, C-side ongoing. Installation new cables & pipes will start in March.



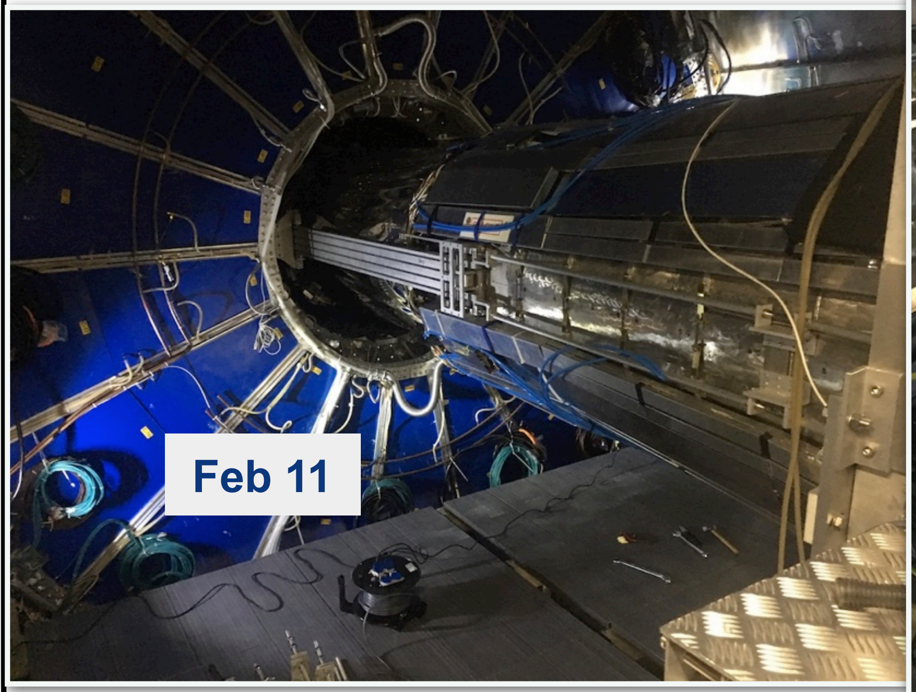
- Shield, compensator magnet removed
- L3 doors opened
- Transfer rails installed
- Services removal started



Miniframe unistalled



- Manual vacuum valve removed
- Beampipe and ITS transferred to rails



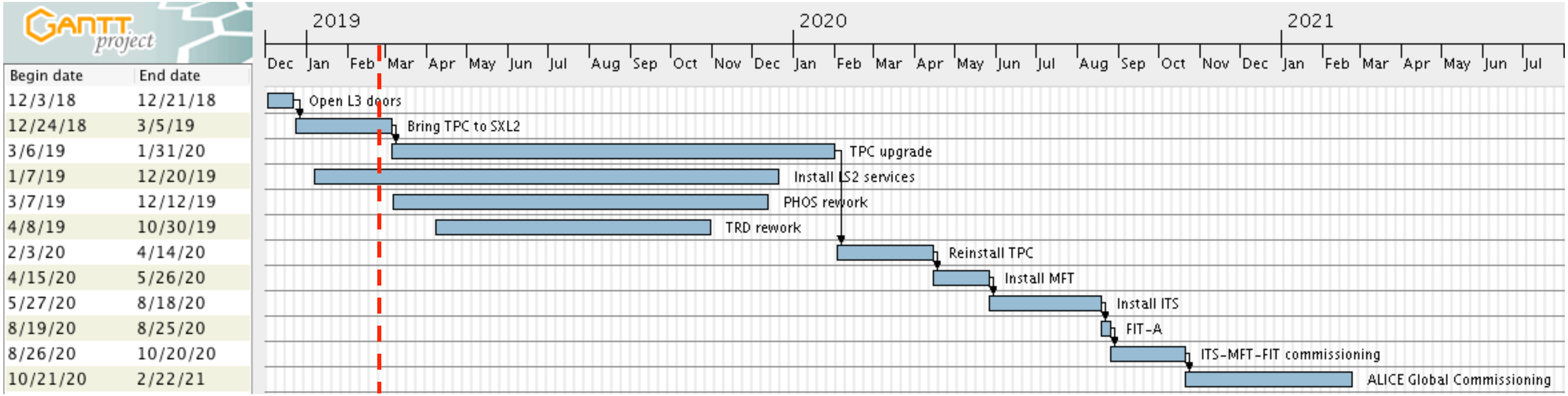
- TPC moved to parking position
- ITS fully disconnected
- Central beam pipe support removed

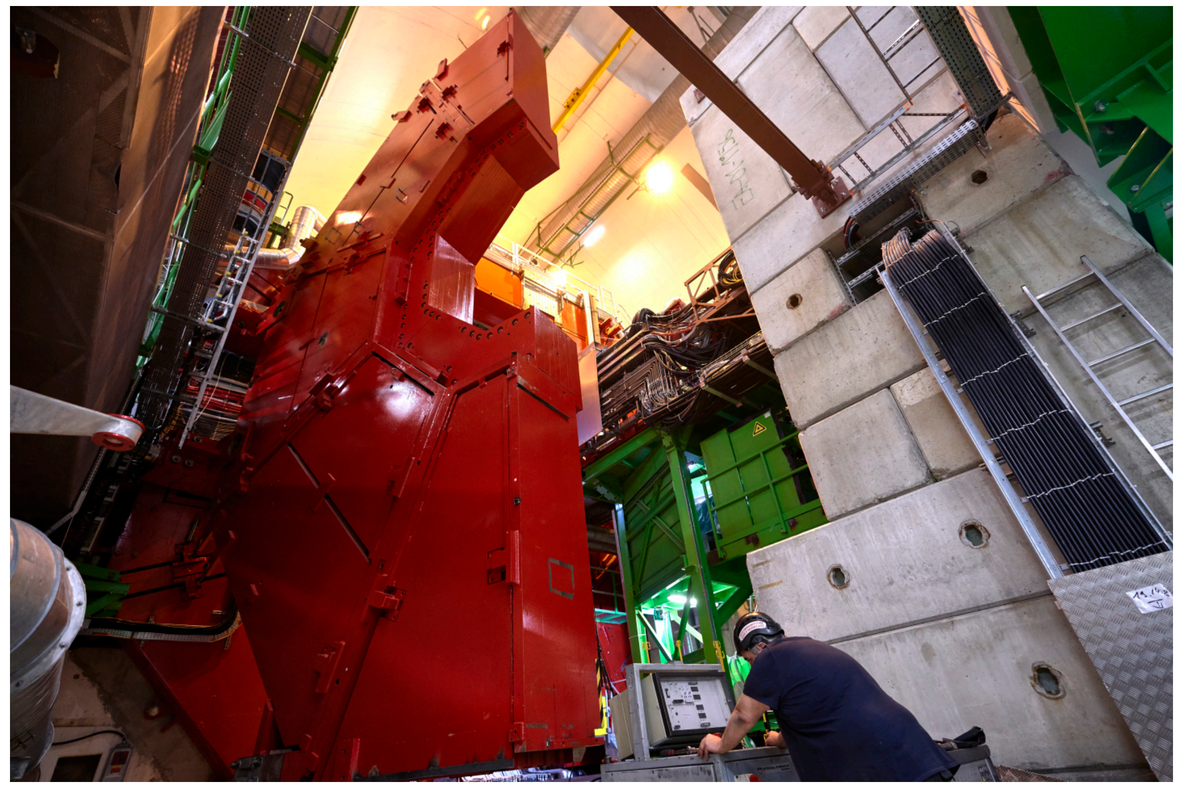
- ITS moved to parking position
- SPD and central beampipe removed

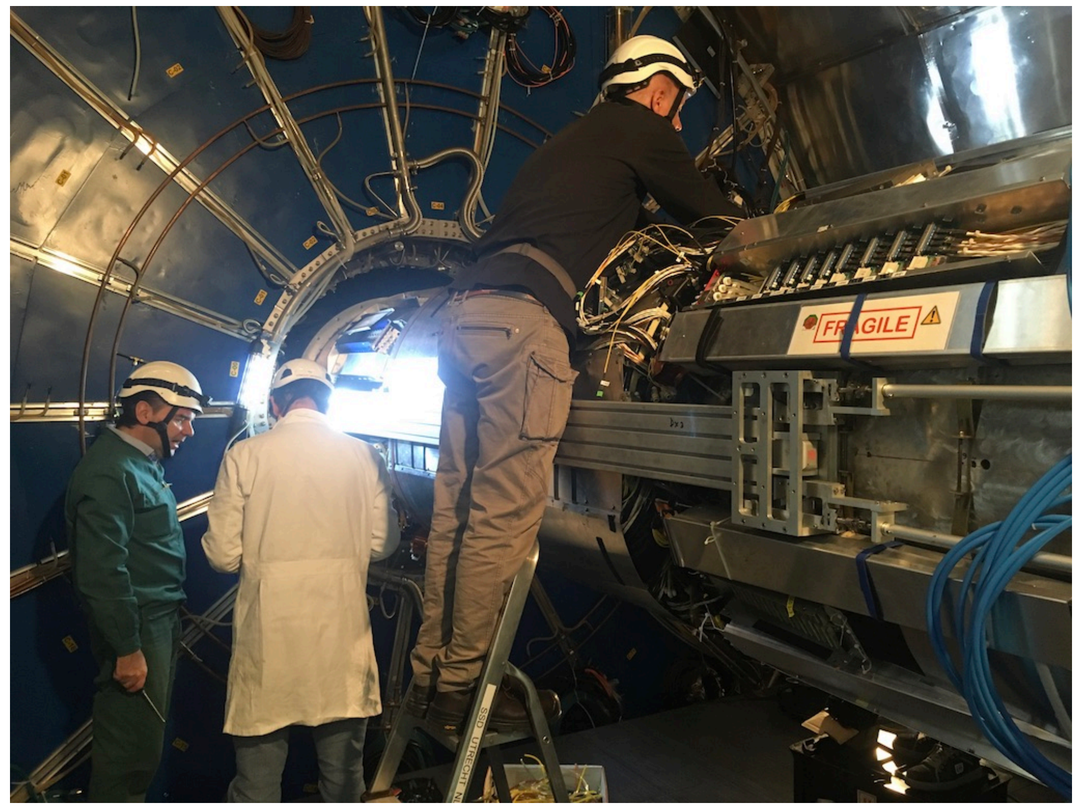
LS2 plans

ALICE

- 2019: TPC upgrade TRD-TOF-Calorimeter upgrade
- 2019-2020: Muon System upgrade
- 2020: Installation of TPC, ITS, MFT, FIT

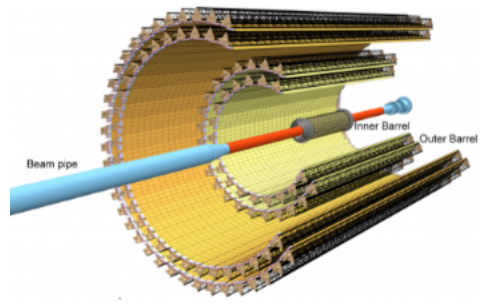






Upgrade status

ITS

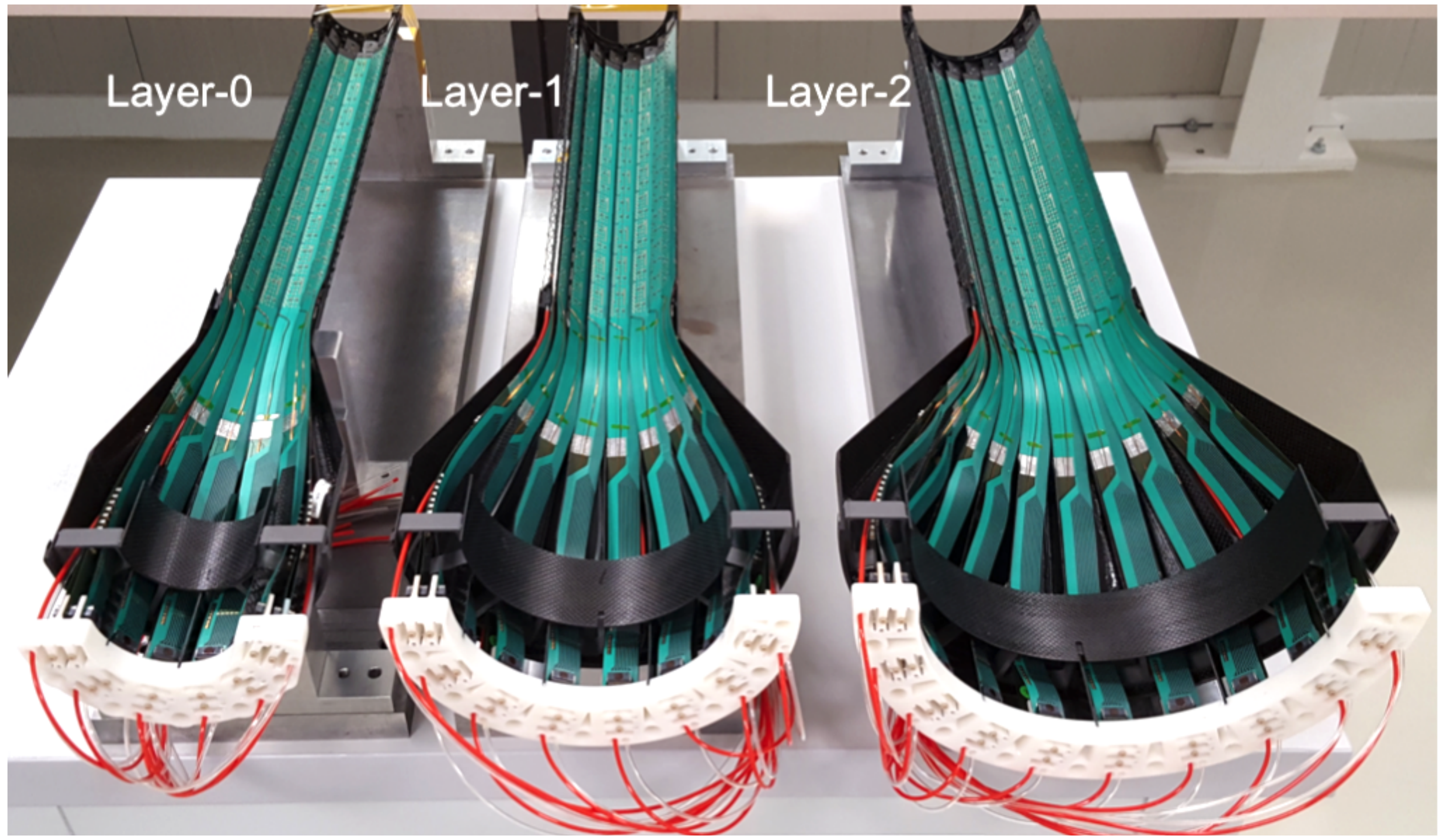


Inner Barrel HIC Production

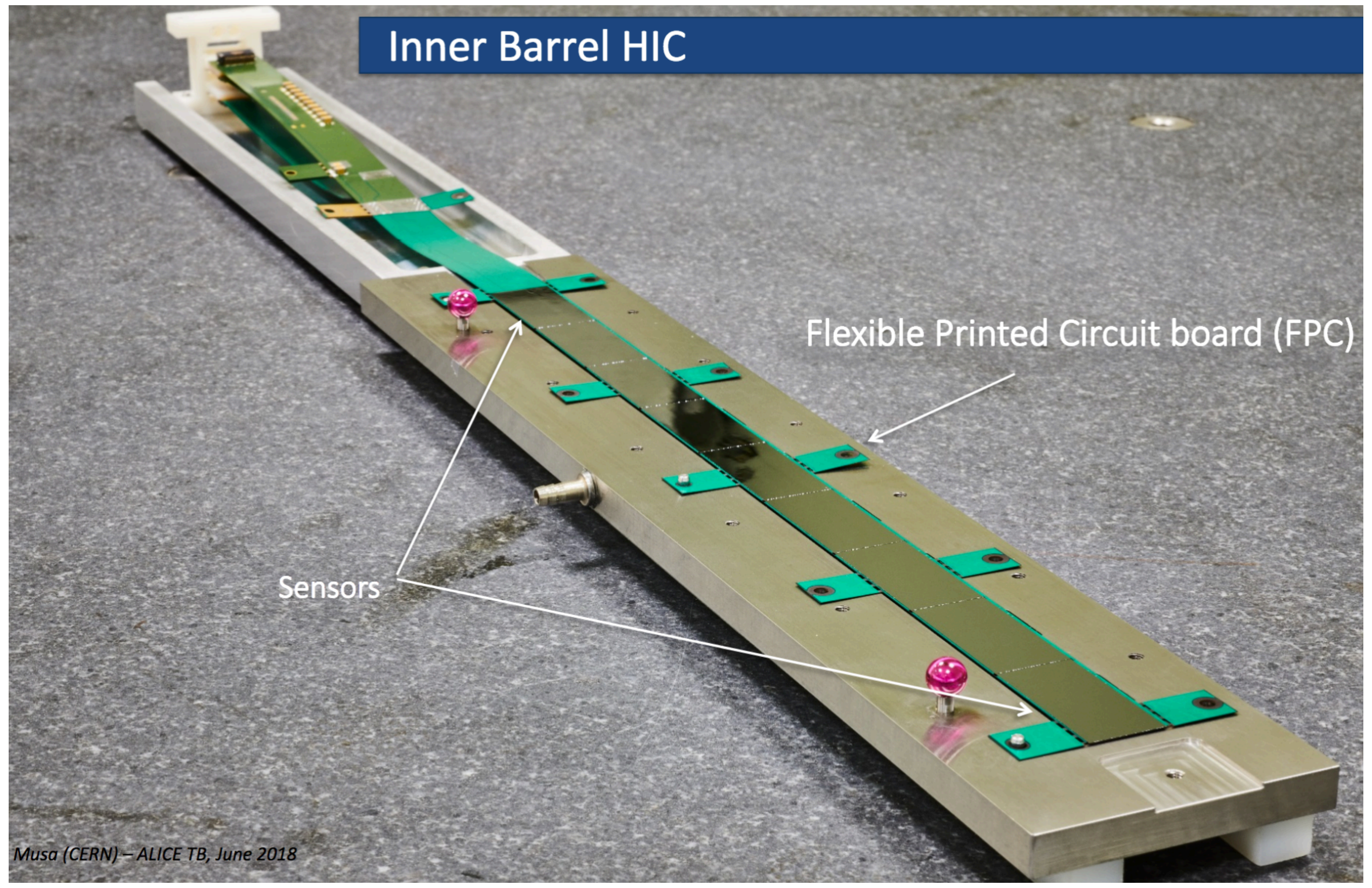
Inner Tracking System (ITS)

- 7 layers of Monolithic Active Pixel Sensor (MAPS)

IB-1 Production completed and layers assembled

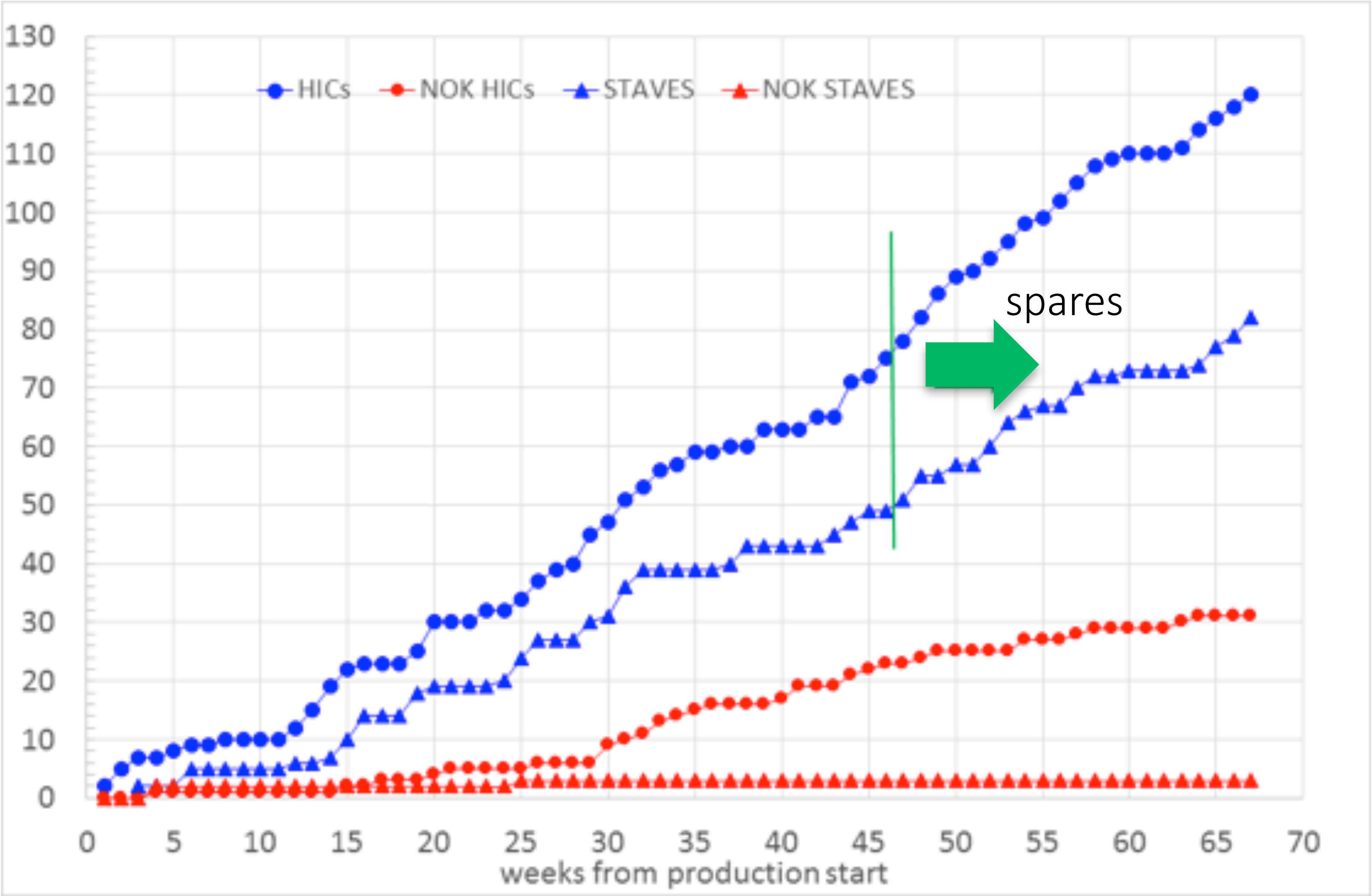


Hybrid Integrated Circuit (HIC)



Second IB barrel

Stave production

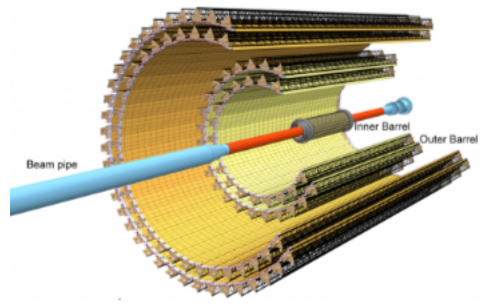


Construction of spare staves (IB-2)

✓Completed 36 spare staves: half IB-2 + 12 staves

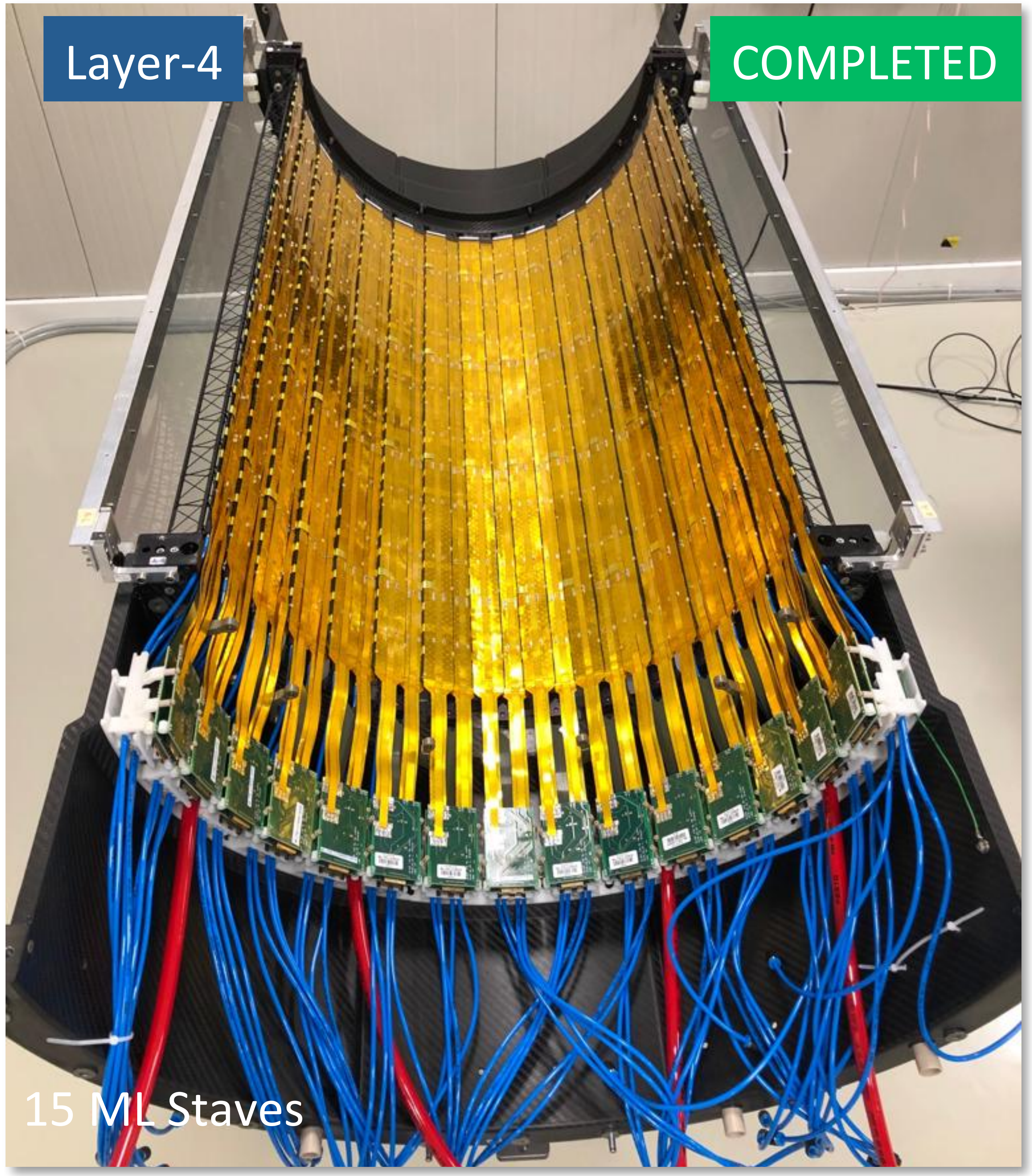
Only 12 staves missing to complete IB-2

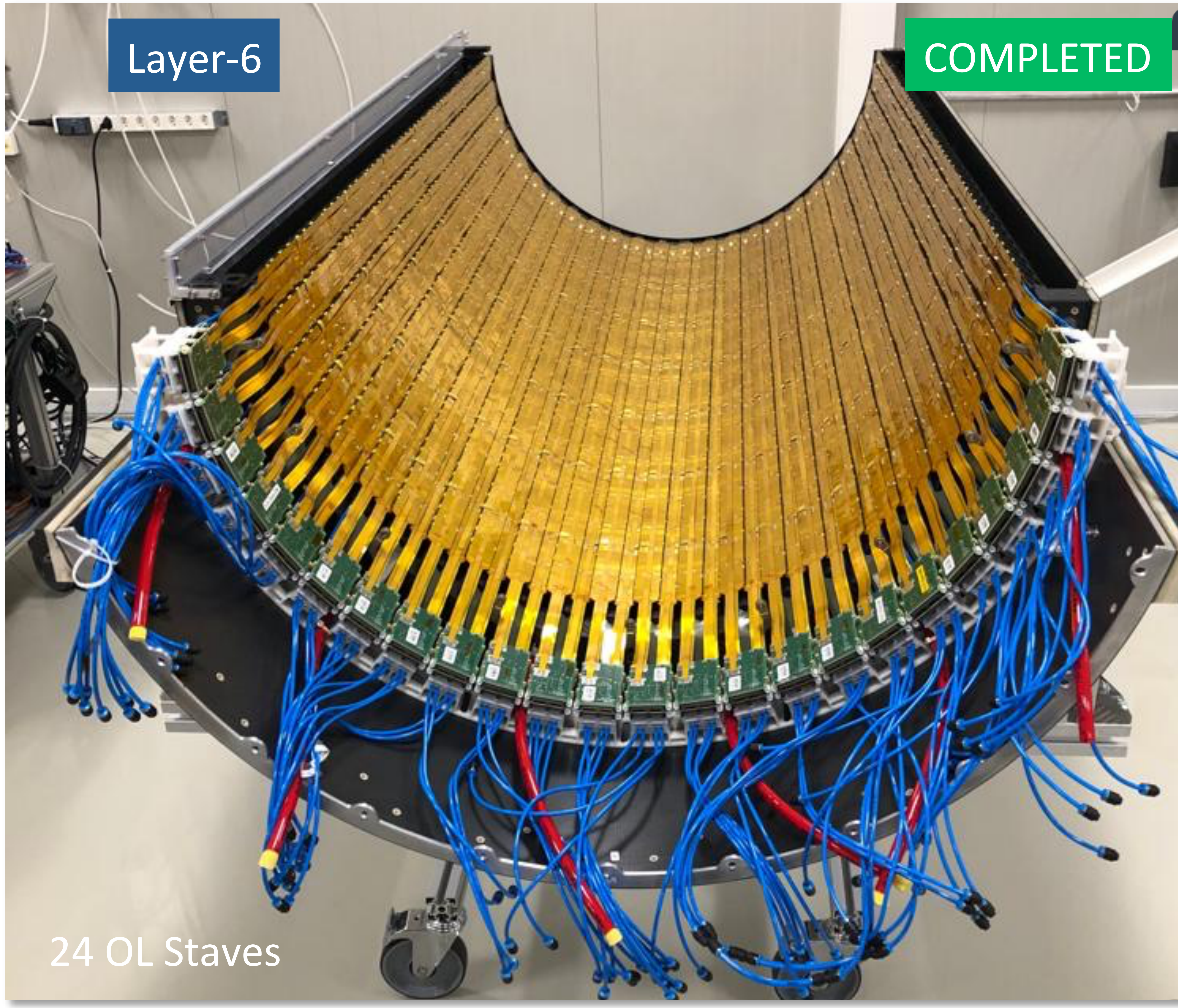
ITS

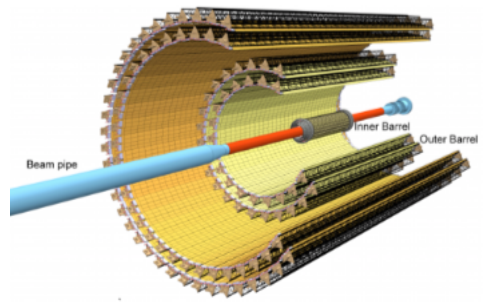


Outer Barrel - (half) Layer Assembly

ALICE

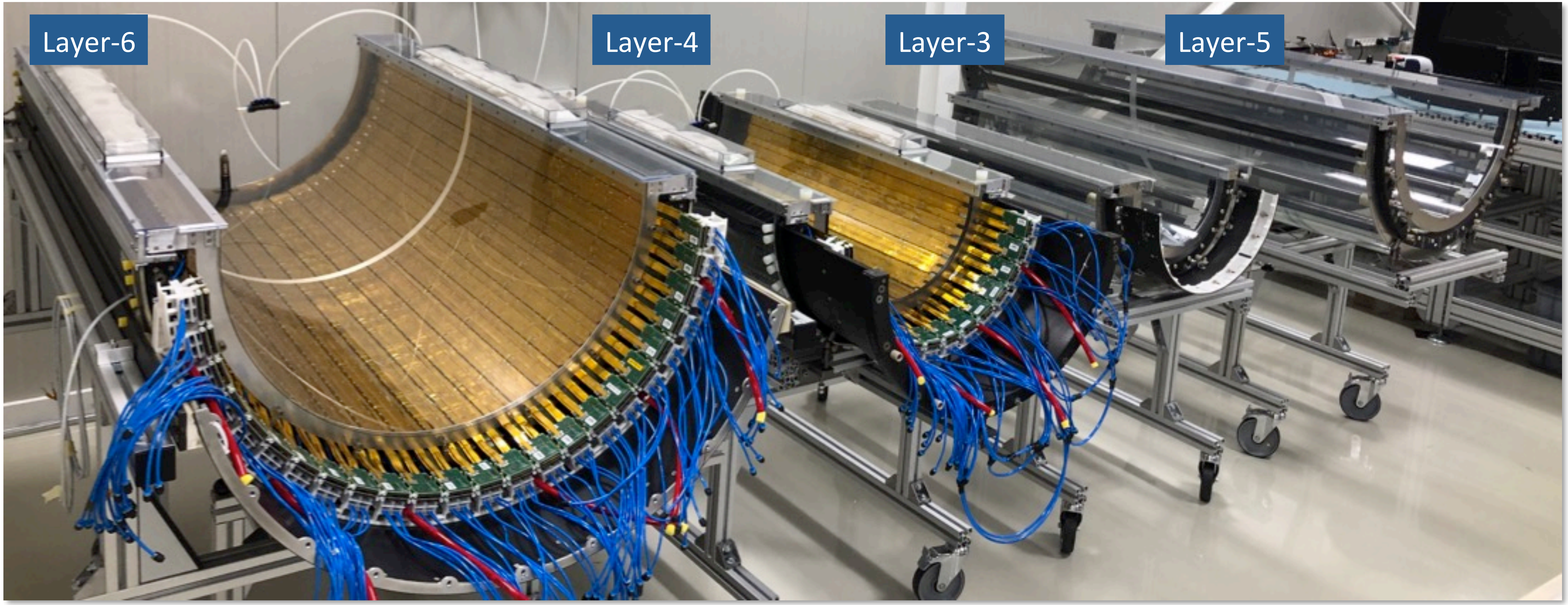






Outer Barrel - (half) Layer Assembly

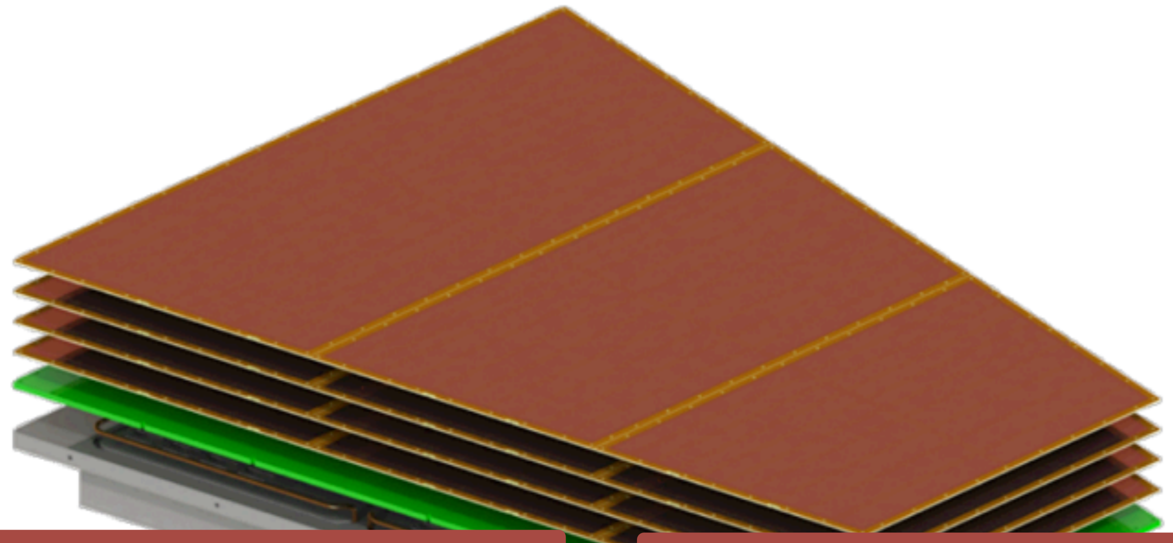
Mechanics and enclosures for layer 5 and layer 3 ready: installation is starting next week

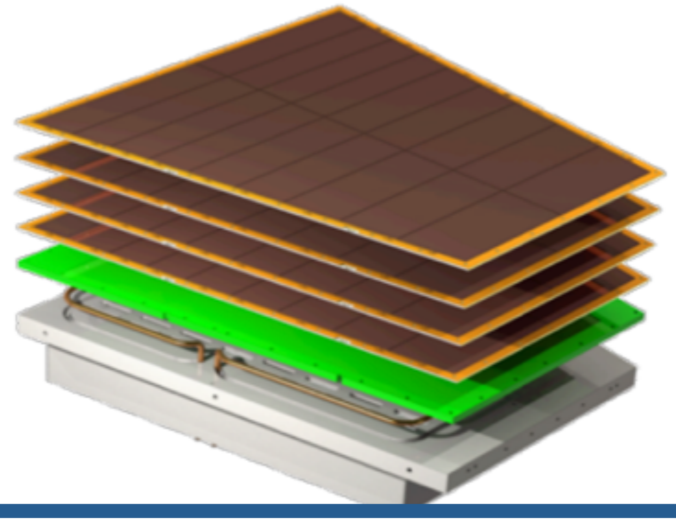


TPC Read Out Chamber (ROC) status overview

TPC Projection Chamber (TPC)
- New readout chambers using GEM technology
- New electronics for continuous readout (SAMPA)

Electron microscope photograph of a **GEM** foil





OROC assembly + testing
(HPD Bucharest)

20

20 assembled,
18 delivered

OROC assembly + testing
(GSI)

20

IROC assembly + testing
(U YALE)

40

40 assembled,
39 delivered

Assembly sites

CERN

Storage 3 / 77

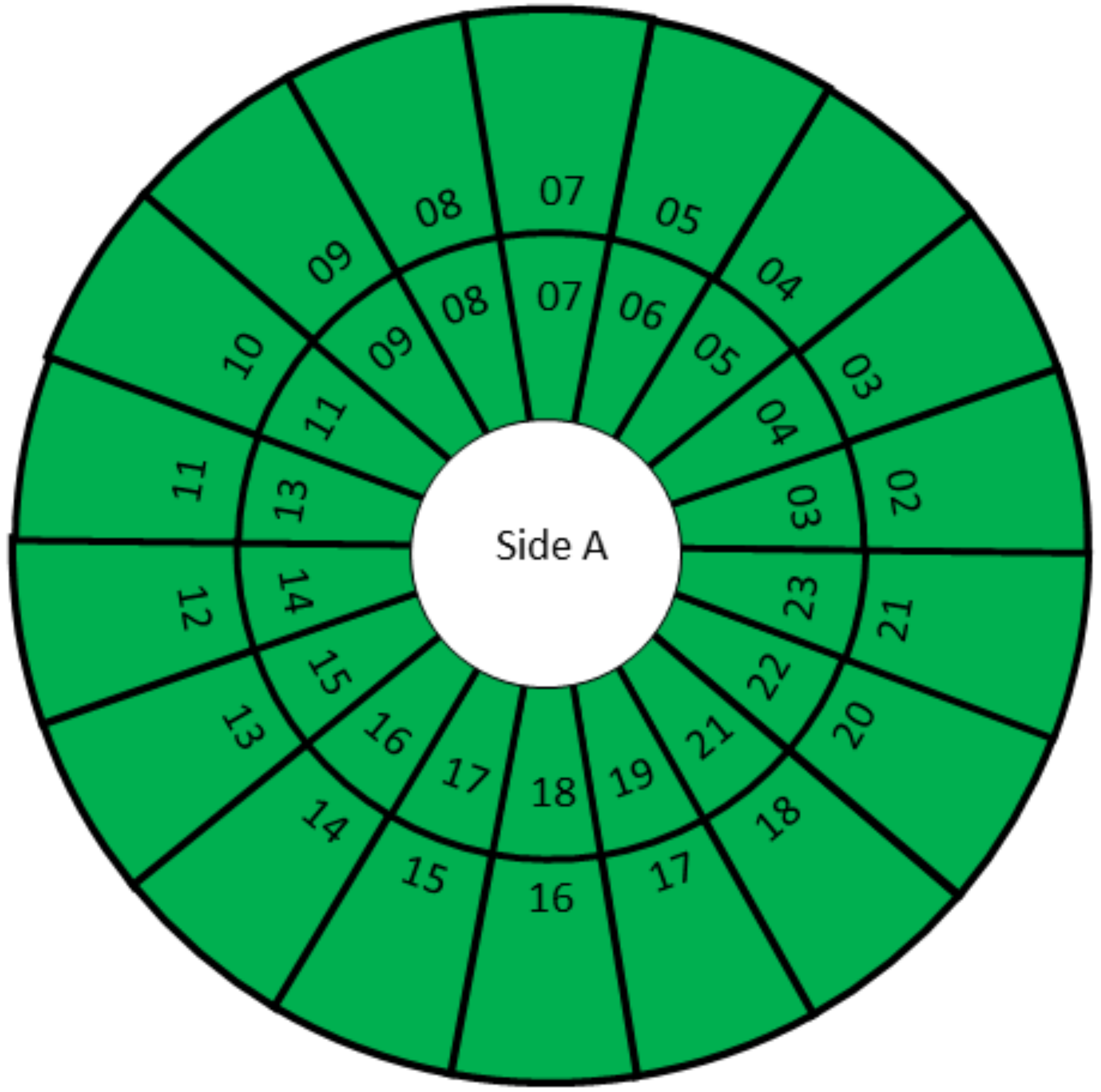
Test at LHC/GIF 4 / 76

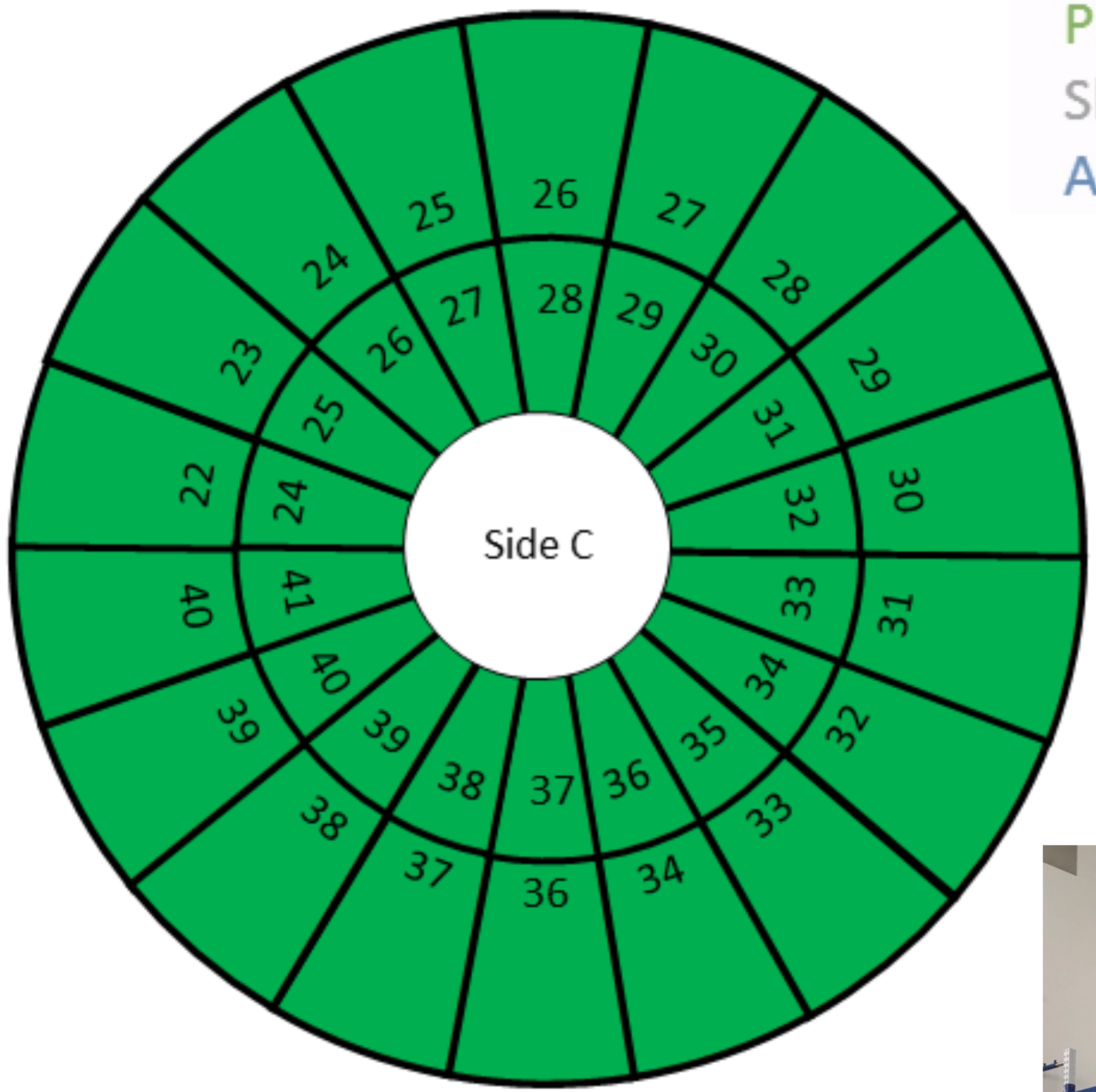
77/80 chambers at CERN
76 already tested!

TPC

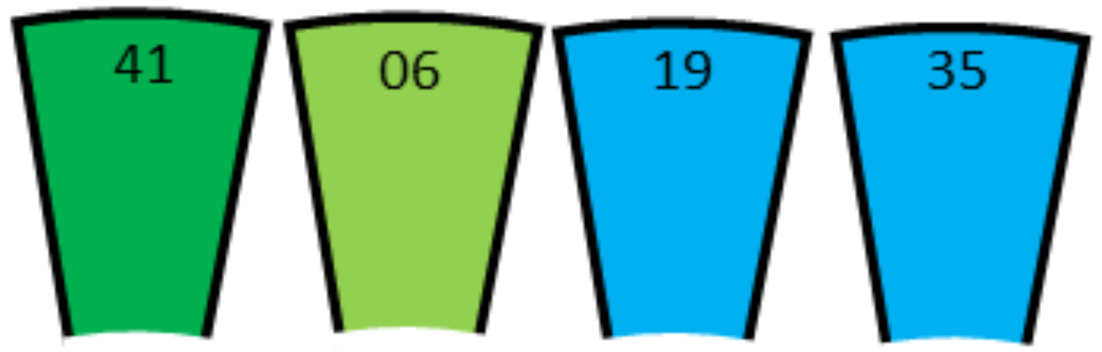
ROC certification status

72 chambers ready to fully setup the TPC. Testing of spares ongoing!

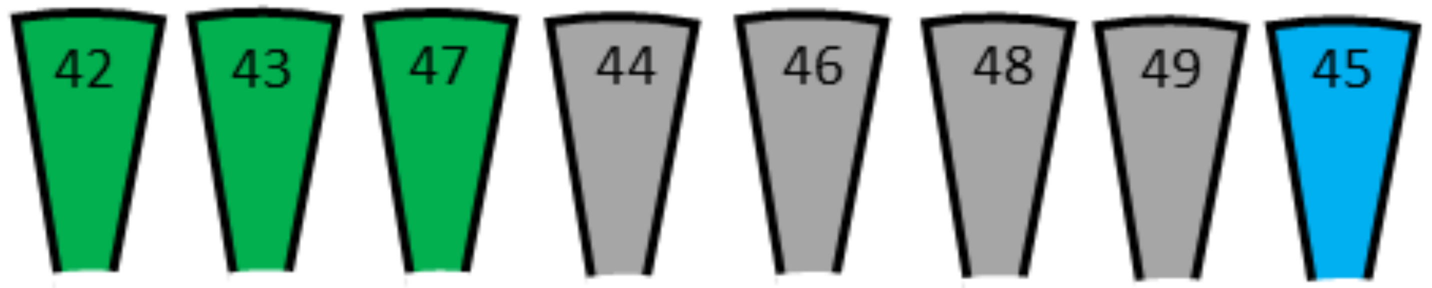




Stable, with beam/GIF/SI
Prepared for testing
Shipped to CERN
At assembly site



OROC spares



IROC spares

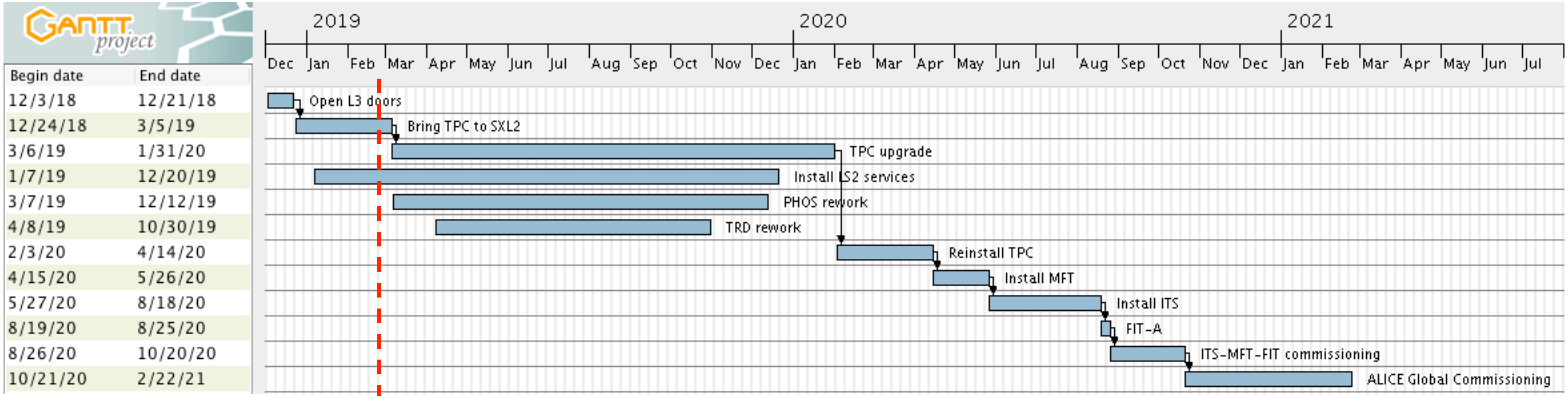
What's coming next…

1. TPC Upgrade, starting on March 7th . Well established day-to-day plan for 11 months.

3. Install new services - up to end of the year

5. Extract DCal (A-side), Phos and CPV - start on March 7th

7. TRD rework, from April to October



LHCC poster session

Contributions from ALICE:

1. Investigating diffractive processes with ALICE (Ernesto Calvo Villar)
2. Light flavor and resonance production in multiple collision systems (Bon-Hwi Lim)
3. Study of Υ production as a function of charged-particle multiplicity in pp collisions at $\sqrt{s}$= 13 TeV with ALICE (Tasnuva Chowdhury)
4. Measurement of ω mesons in pp collisions at $\sqrt{s}$ = 7 TeV with ALICE (Florian Jonas)
5. The ALICE Muon Forward Tracker commissioning: first beam tests. (Manuel Guittiere)
6. Construction and characterization of the upgraded Inner Tracking System for the ALICE experiment (Ivan Ravasenga)

Summary

Pb-Pb 2018 reconstruction status

- **large increase of statistics**
- **excellent quality** of the data
- **preliminary results will be ready for the summer conferences (SQM, EPS-HEP)**
  - intense campaign for the production of physics results with the new data

Overview of recent results

- pp:
  - heavy-flavour production as a test of pQCD calculations and precise reference for p-Pb and Pb-Pb data
  - strangeness production: more differential measurements to investigate the baryon/meson ratio enhancement in small systems
  - first measurement at LHC of (anti-)deuterons in pp collisions vs multiplicity
- p-Pb
  - measurements of pseudorapidity density can constraint the modelling of the initial state at small Bjorken-*x*
- Pb-Pb:
  - beauty energy loss in Pb-Pb collisions and prospects for future measurements
  - Coherent photoproduction of J/psi in peripheral Pb-Pb collisions

Upgrade productions and LS2 activities progressing well, on schedule

Thanks!

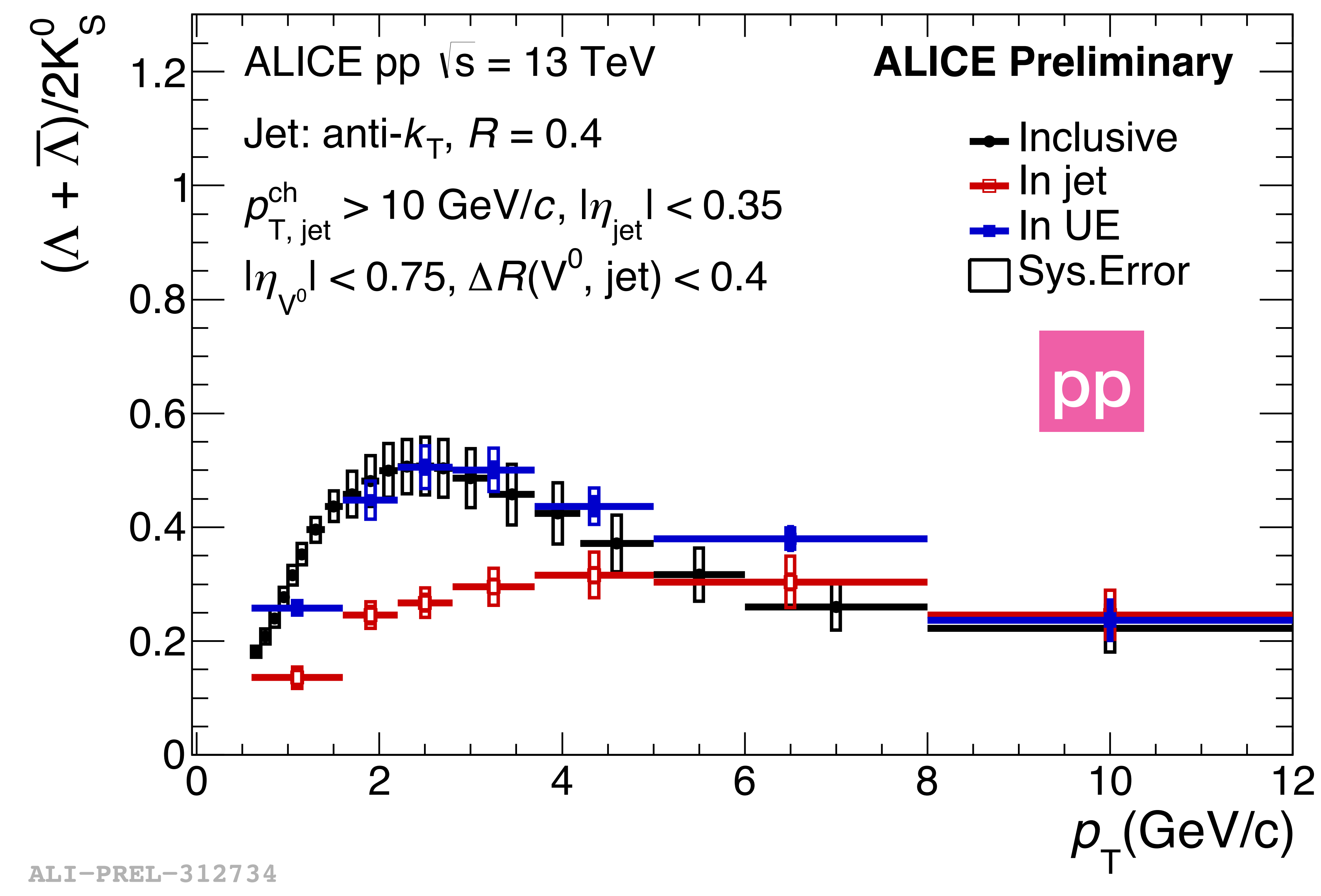
Backup

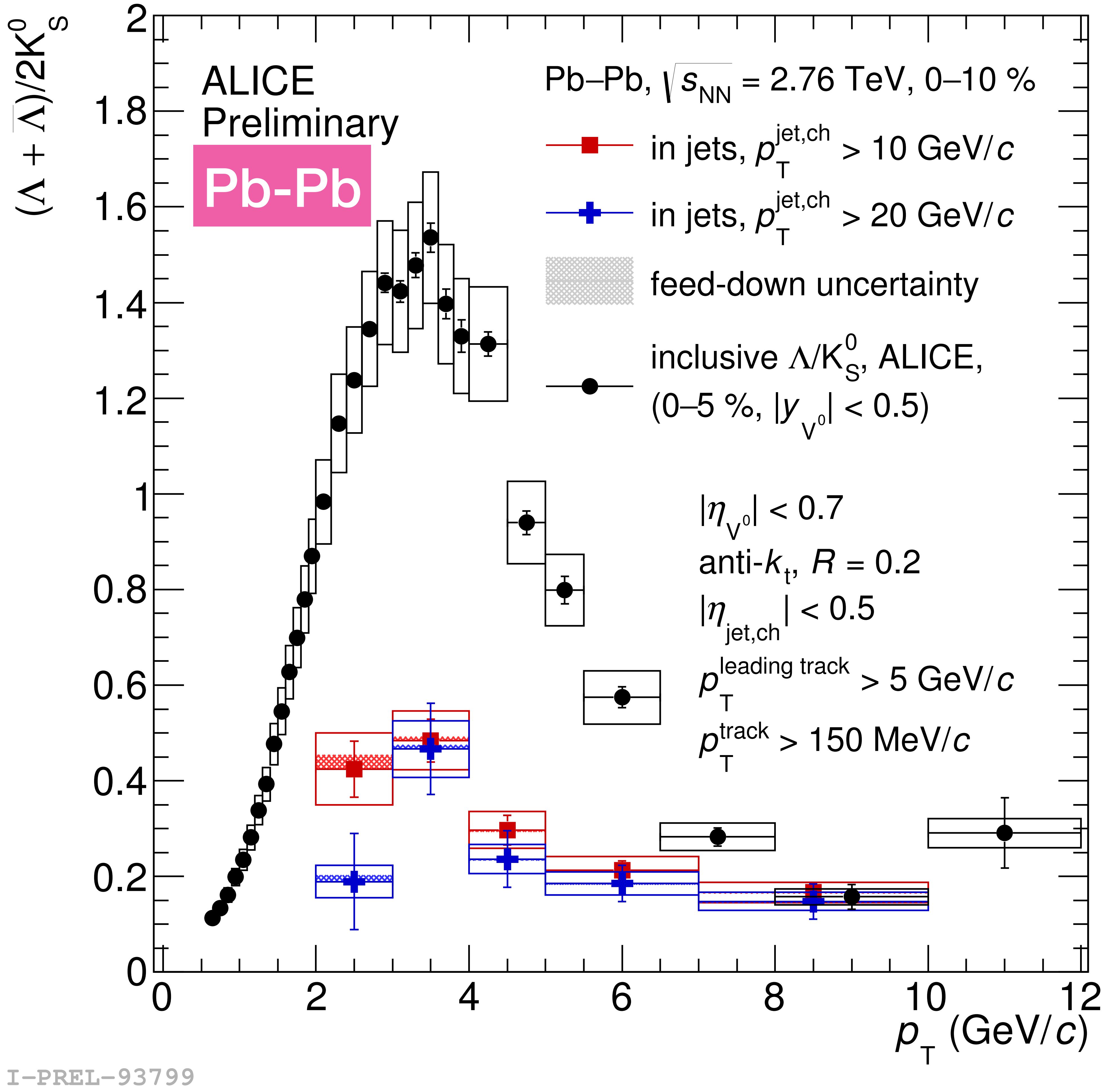
Strangeness production: particle ratios in jets

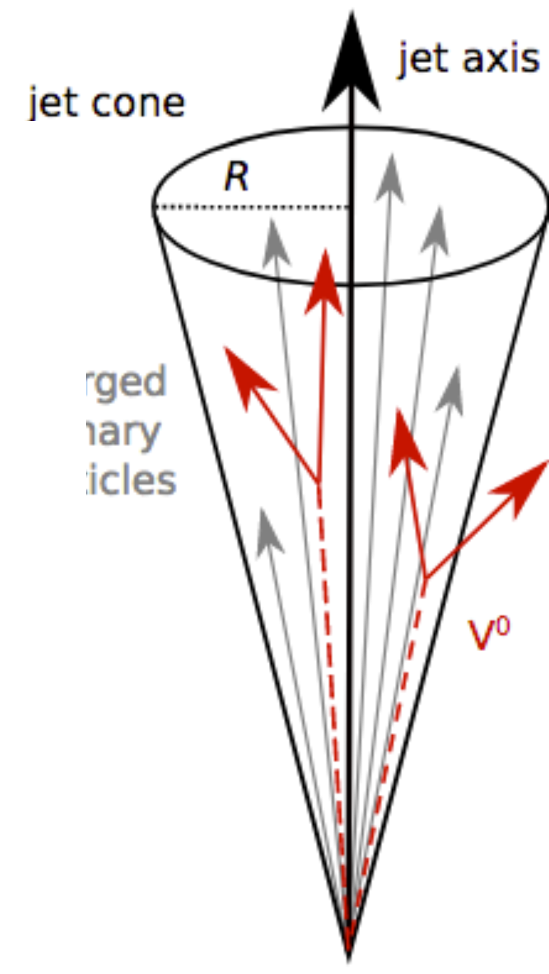
Separate hadrons produced in hard processes (**jets**) from hadrons produced in soft processes (**underlying event UE**).

in pp collisions: the ratio **in jets** is similar to Pb-Pb results for $p_T > 4 GeV/c$

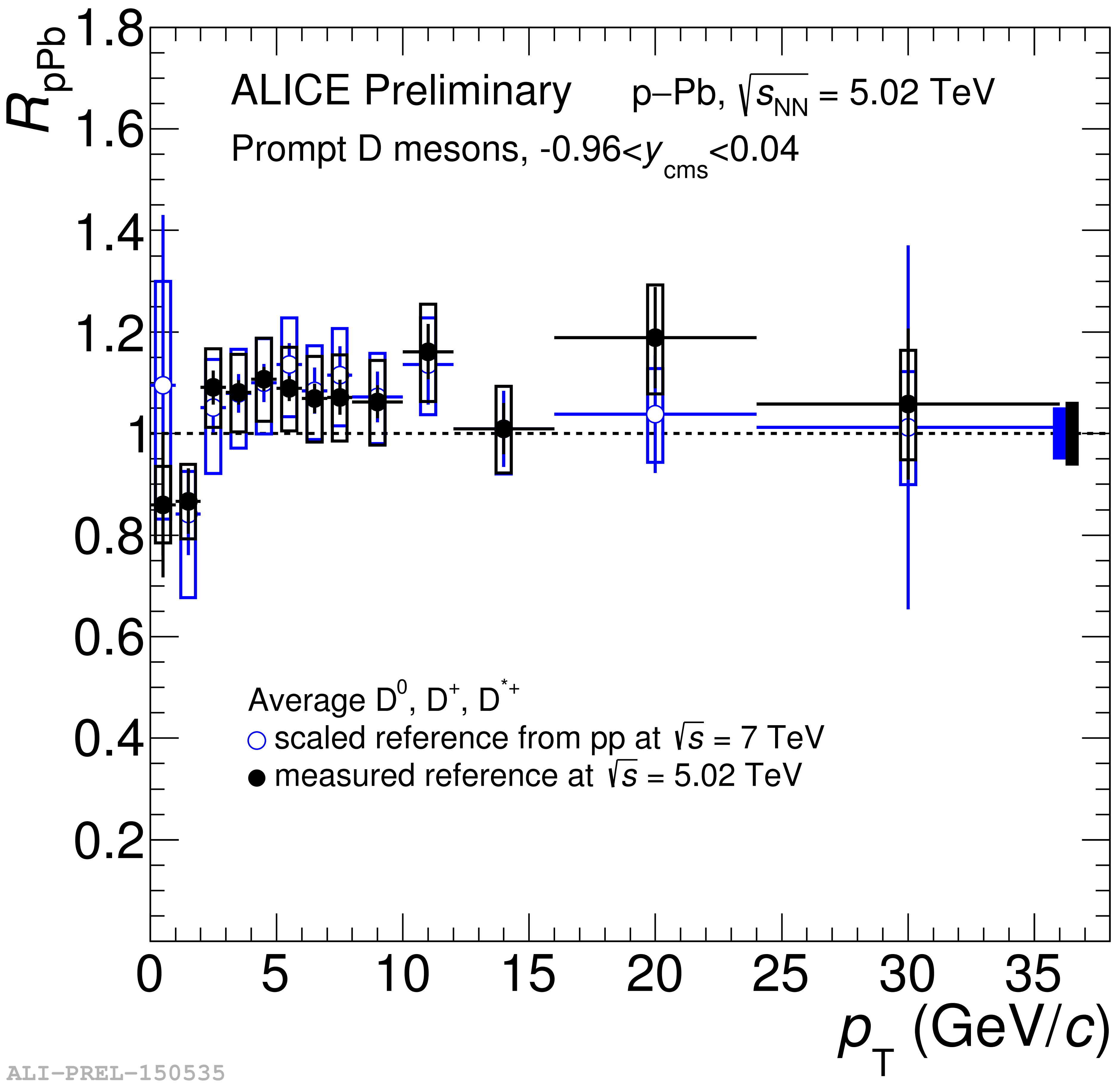
new preliminary

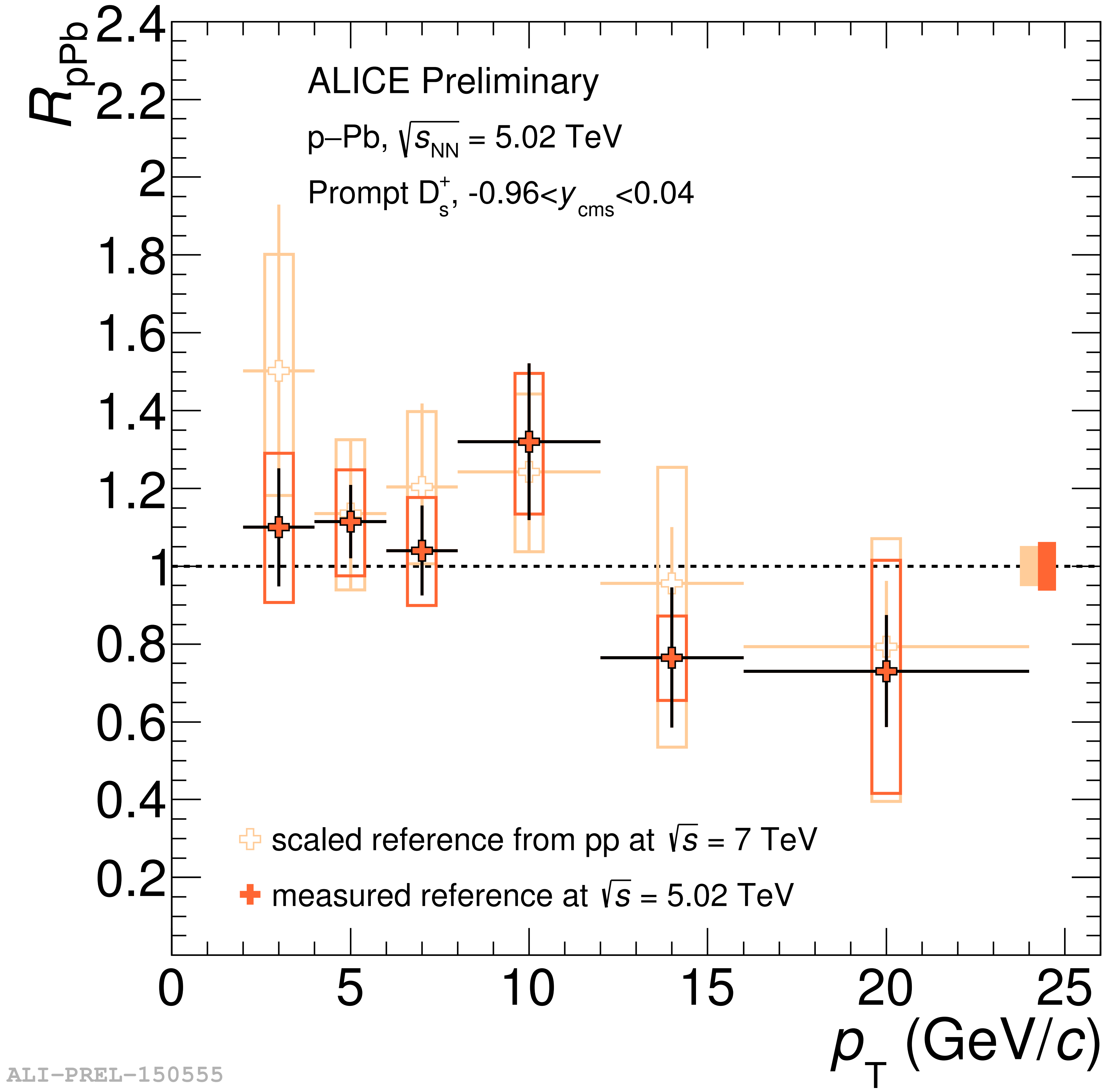






R_{pPb} with new Reference





- Reduced uncertainties
- non-strange and strange D-meson R_{pPb} compatible within uncertainties