ALICE Status Report

Grazia Luparello for the ALICE Collaboration

(INFN Trieste)

132nd LHCC Meeting

30 November 2017

✓ *Operations in 2017*

2017 operations in pp @ 13 TeV

A Large Ion Collider Experiment

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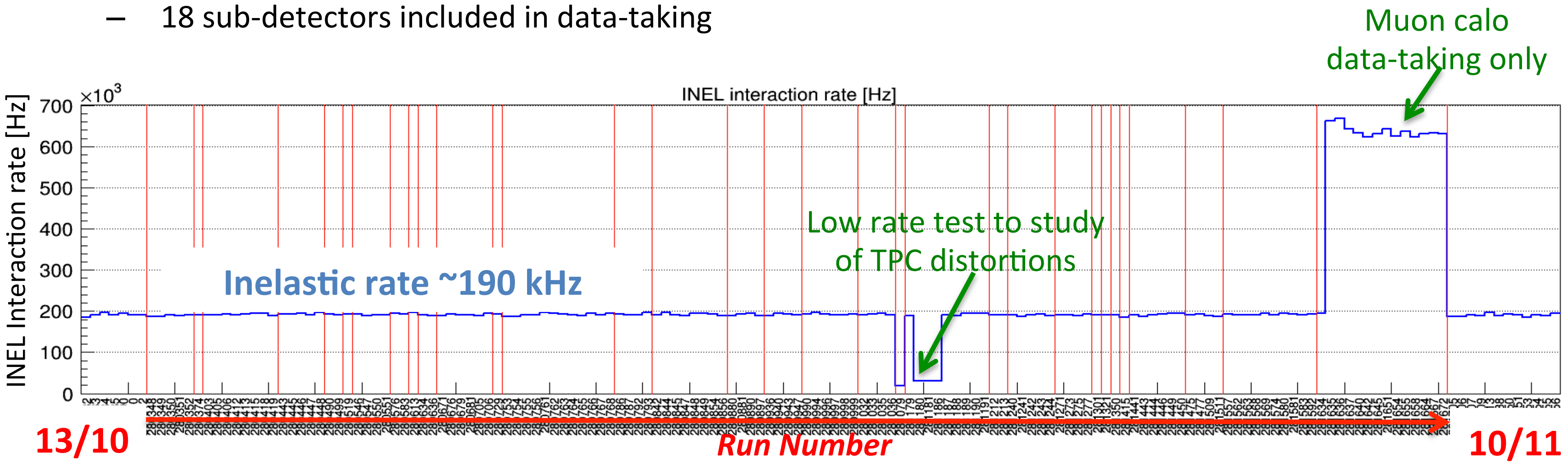
- **Stable operations at instantaneous luminosity 2.6 Hz/μbarn (μ~1%)**
- **Overall ALICE data-taking efficiency >91%**
  - 18 sub-detectors included in data-taking



- **Special runs**
  - Low-B data-taking in the central barrel during the LHC intensity ramp-up phase
  - Data-taking at very low-μ (~ 0.1%) including also Zero Degree Calorimeters during the van der Meer fills

2017 operations in pp @ 13 TeV: statistics

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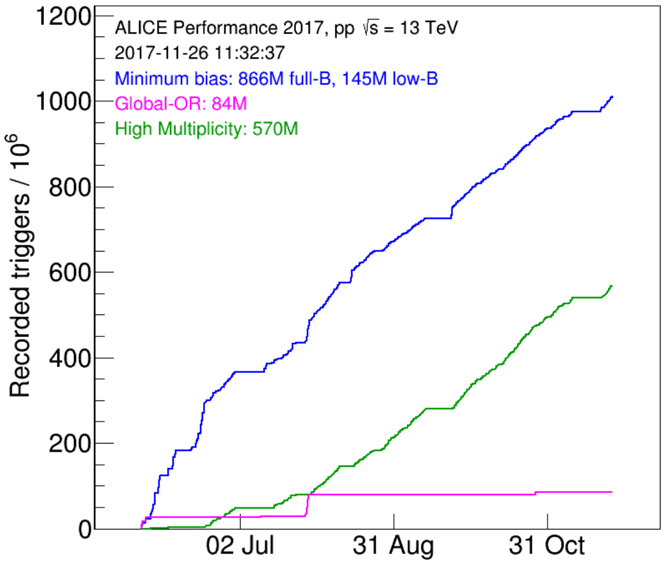
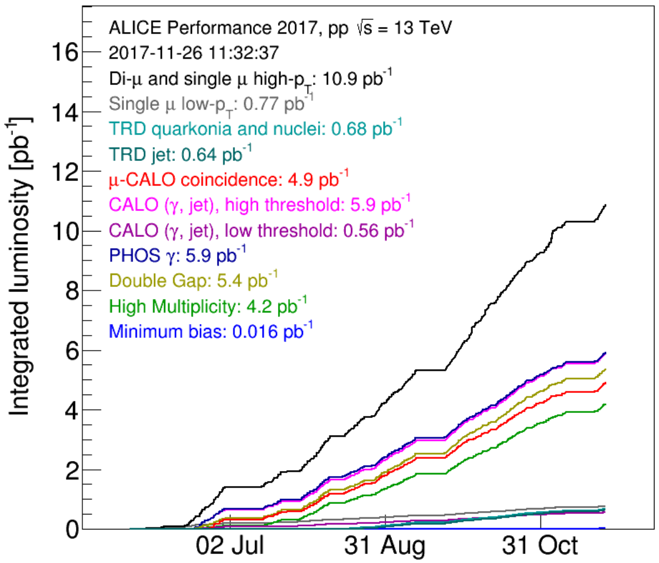
Running a rich trigger menu:

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





Xe-Xe pilot run @ 5.44 TeV

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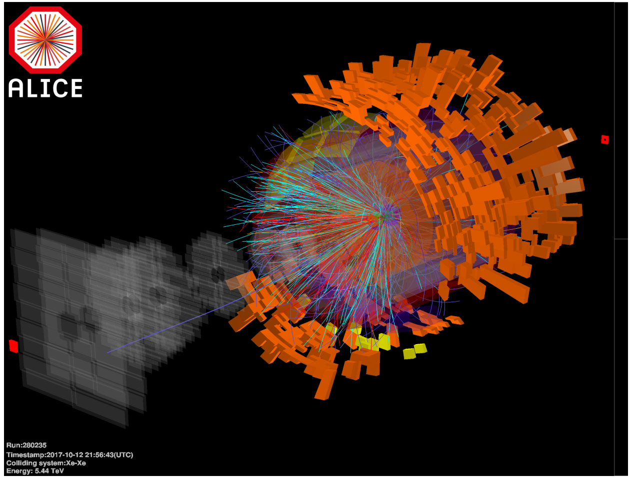
Data-taking conditions

- pp beam optics used -> **10m β* in IP2**
- **16 bunches** colliding in IP2
  ➔Hadronic interaction rate **~80Hz**
- Modified crossing angle to include the ZDC in the data-taking for centrality determination
- Reduced solenoid magnetic field (B = 0.2 T) to focus on the low p_T region



Trigger menu including:

minimum bias, ultraperipheral, muons

- **97.4% data-taking efficiency**
- **1.7M events collected**

Expected results on:

- p_T spectra of (non-)identified particles
- Azimuthal anisotropy

pp run @ 5 TeV

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- **Run 2 goal: 1B minimum bias events (130M already collected in 2015) + 1pb^{-1} of triggered data**
- 172h of Stable Beam + 1 fill for van der Meer scan (10h)

Data-taking conditions

- **10m β* in IP2**
- Instantaneous luminosity **~1Hz/μbarn (μ<0.5%)**, Interaction rate ~**50kHz**

Trigger menu

- Mainly Minimum Bias
- Calorimeters
- Diffractive triggers
- Muon triggers

Collected statistics:
- **986M minimum bias events in 180h of SB**
- **Muon triggers: 1.2 pb^{-1}**
- **Calorimeters: 0.9 pb^{-1}**

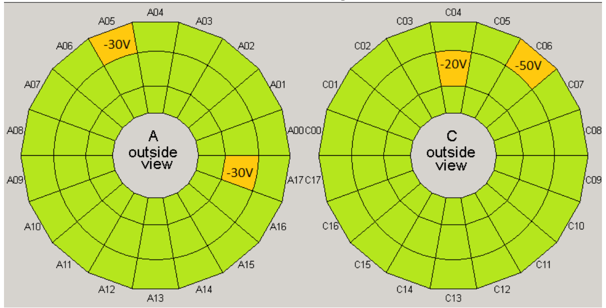
Thanks to LHC teams!

TPC operation

A Large Ion Collider Experiment

- **In 2017, TPC was operated with a $Ne\text{-}CO_2\text{-}N_2$ gas mixture**
  - Good stability under typical running conditions in pp at both 13 TeV and 5 TeV

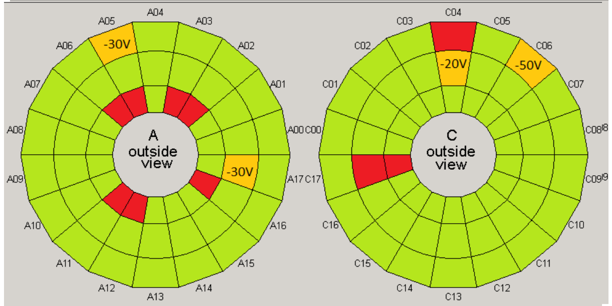
2.6 Hz/μbarn



TPC operation

- **In 2017, TPC was operated with a Ne-CO_2-N_2 gas mixture**
  - Good stability under typical running conditions in pp at both 13 TeV and 5 TeV
  - A **high rate test** performed in 2017 with a charged particle load equivalent to 2018 Pb-Pb operation revealed stability problems of the wire chambers

15 Hz/μbarn



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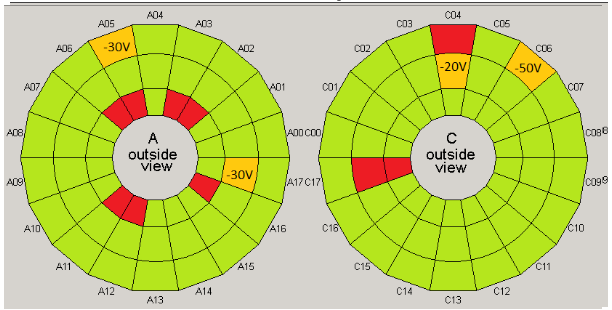

- **Decided to operate with a Ar-CO_2 gas mixture in 2018**
  - **Expect stable operations in Pb-Pb collisions at 10 kHz (as demonstrated in 2015)**
  - Correction procedure for space charge distortions in Ar well established on 2015/2016 data
  - Alternating cover electrode potentials will reduce space-charge distortions

✓ *Physics highlights*

Submitted papers since last LHCC

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Pb-Pb

Constraining the magnitude of the Chiral Magnetic Effects with Event Shape Engineering in Pb-Pb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV
arXiv:1709:04723 submitted to PLB

J/ψ elliptic flow in Pb-Pb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV
arXiv:1709:05260 accepted by PRL

Production of ^{4}He and $^{4}\overline{He}$ in Pb-Pb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV at the LHC
arXiv:1710:07531 submitted to NPA

Longitudinal asymmetry and its effect on pseudorapidity distributions in Pb-Pb collisions at $\sqrt{s}$ = 2.76 TeV
arXiv:1710:07975 submitted to PLB

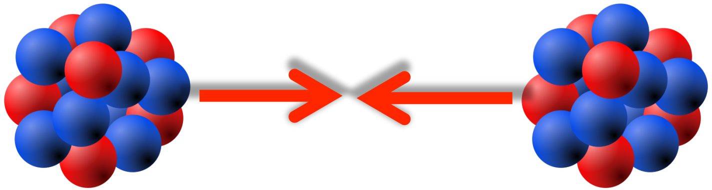
p-Pb

Search for collectivity with azimuthal J/ψ-hadron correlations in high multiplicity p-Pb collisions at $\sqrt{s_{NN}}$ = 5.02 and 8.16 TeV
arXiv:1709.06807 submitted to PLB

pp

Production of deuterons, tritons and ^{3}He nuclei and their anti-nuclei in pp collisions at $\sqrt{s}$ = 0.9, 2.76 and 7 TeV
arXiv:1709.08522 submitted to PRC

✓ *Physics highlights: Pb-Pb collisions*



Elliptic flow in Pb-Pb collisions

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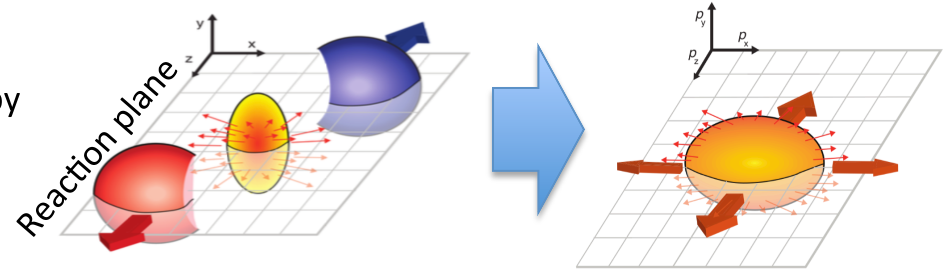
Initial spatial anisotropy of the nuclei overlap region



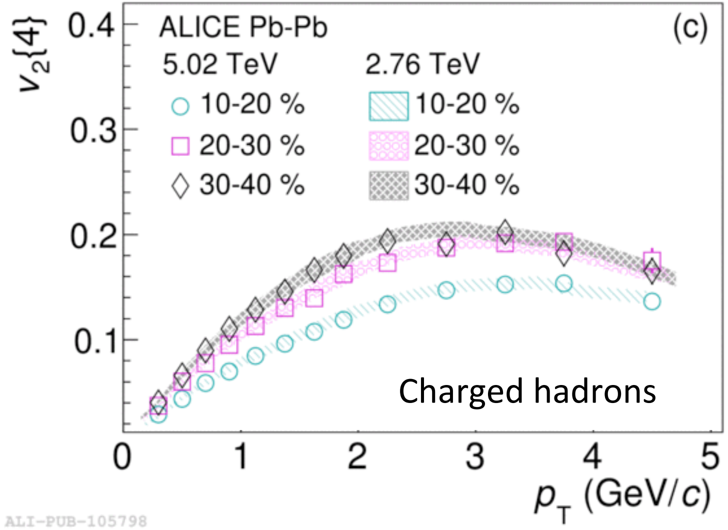
Momentum anisotropy of produced particles

Quantified via the Fourier expansion:

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

Elliptic flow (v_2)

Phys. Rev. Lett. 116, 132302



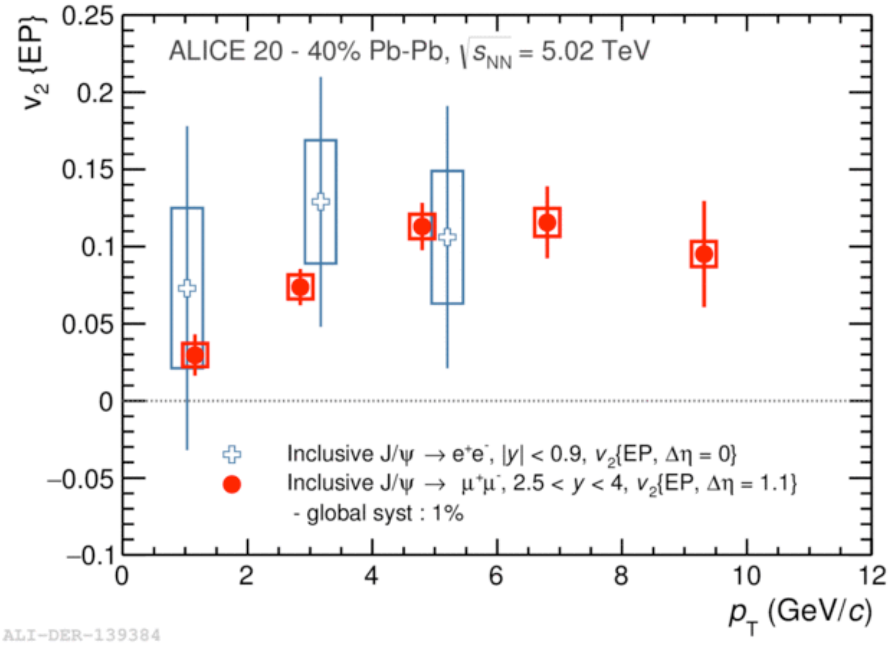
Important observable to understand the properties of the created medium:

- **Low p_T**: Sensitivity to the thermalization of the quarks in the medium
- **High p_T**: Path length dependence of energy loss in the QGP

J/ψ elliptic flow in Pb-Pb collisions

arXiv:1709:05260, accepted by PRL

- Evidence of J/ψ v_2> 0 in the interval $4<p_T<6$ GeV/c in semi-central collisions (significance 6.6σ)



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A Large Ion Collider Experiment

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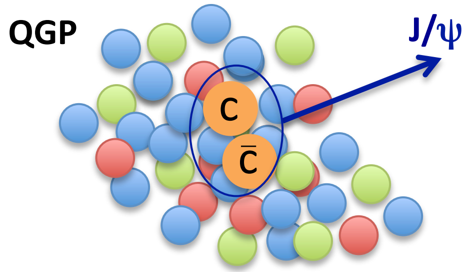
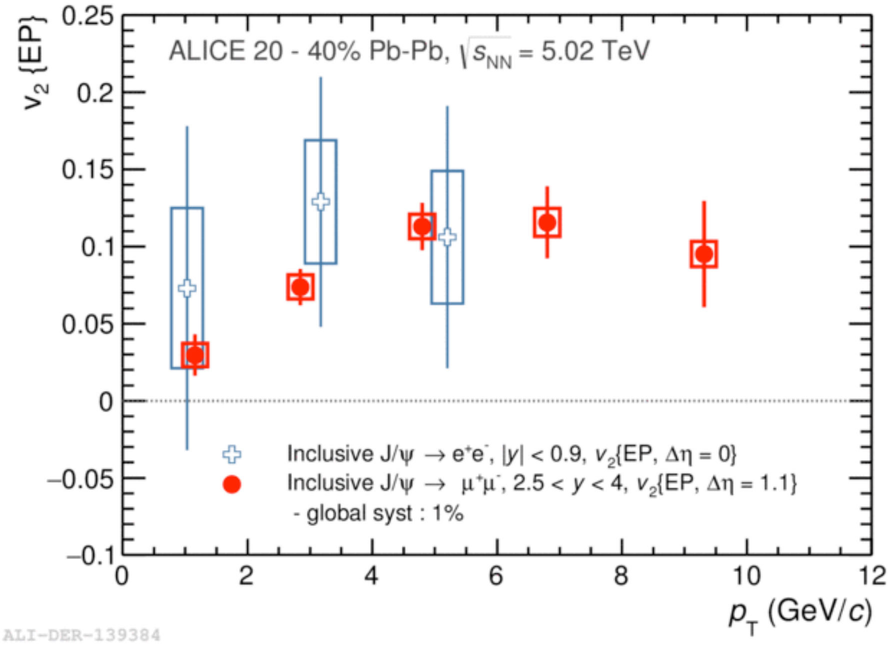
- **Evidence of J/ψ v_2> 0 in the interval 4<p_T<6 GeV/c in semi-central collisions (significance 6.6σ)**
- Low p_T J/ψ are formed by recombination of the charm quarks in the medium

➔charm quarks thermalize and flow with the medium





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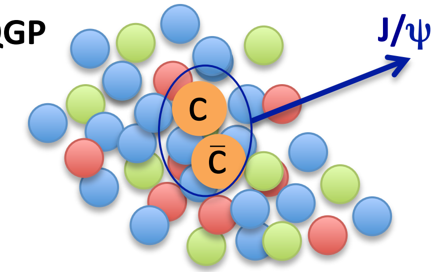
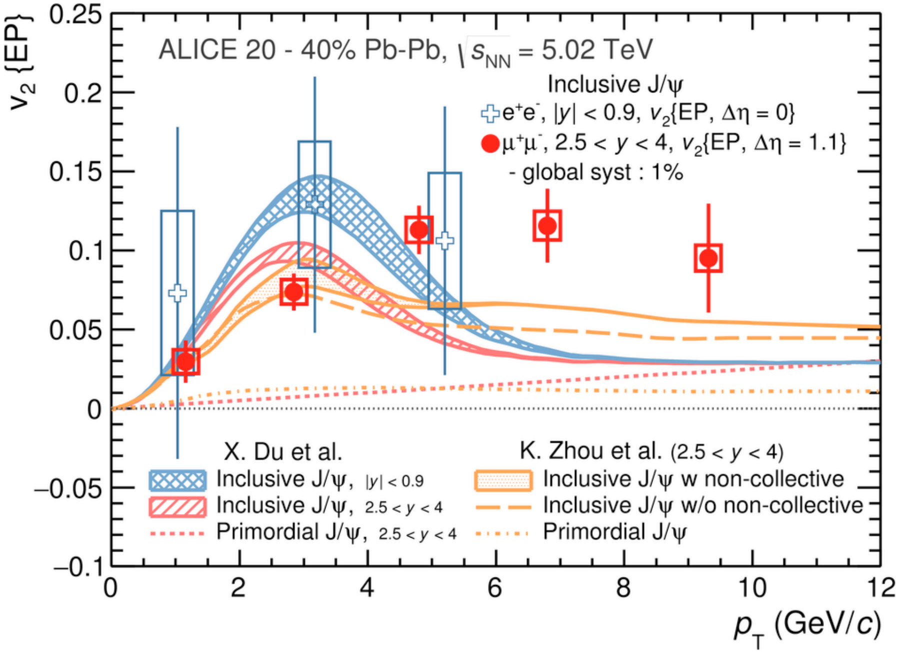


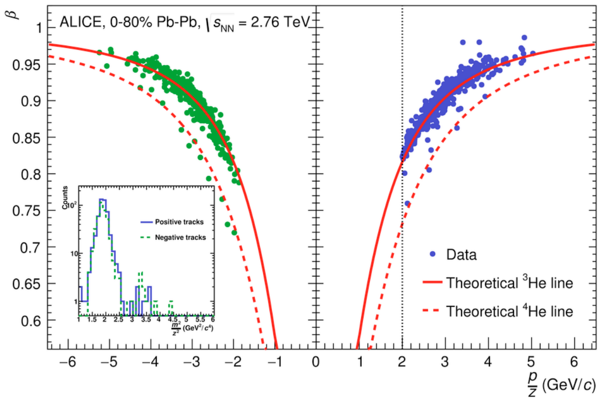


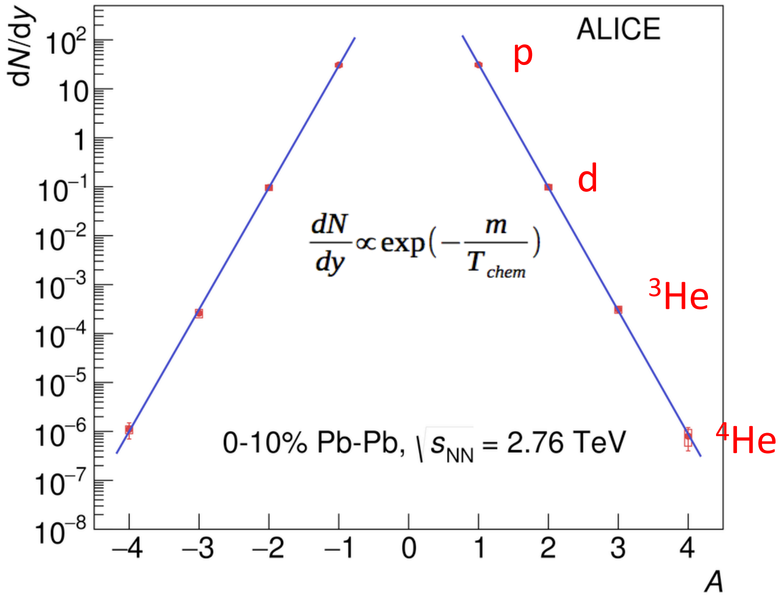
(Anti-)^{4}He production in Pb-Pb collisions

A Large Ion Collider Experiment

arXiv:1710:07531

Identification via dE/dx in the TPC and time-of-flight measurement in the TOF detector





- **Production yield compatible for particles and anti-particles**
- **Each added baryon gives a factor ~330 lower production yield**
- **Compatible with exponential fall predicted by the thermal model with T_{chem} ~156 MeV**

(Anti-)^{4}He production in Pb-Pb collisions

arXiv:1710:07531

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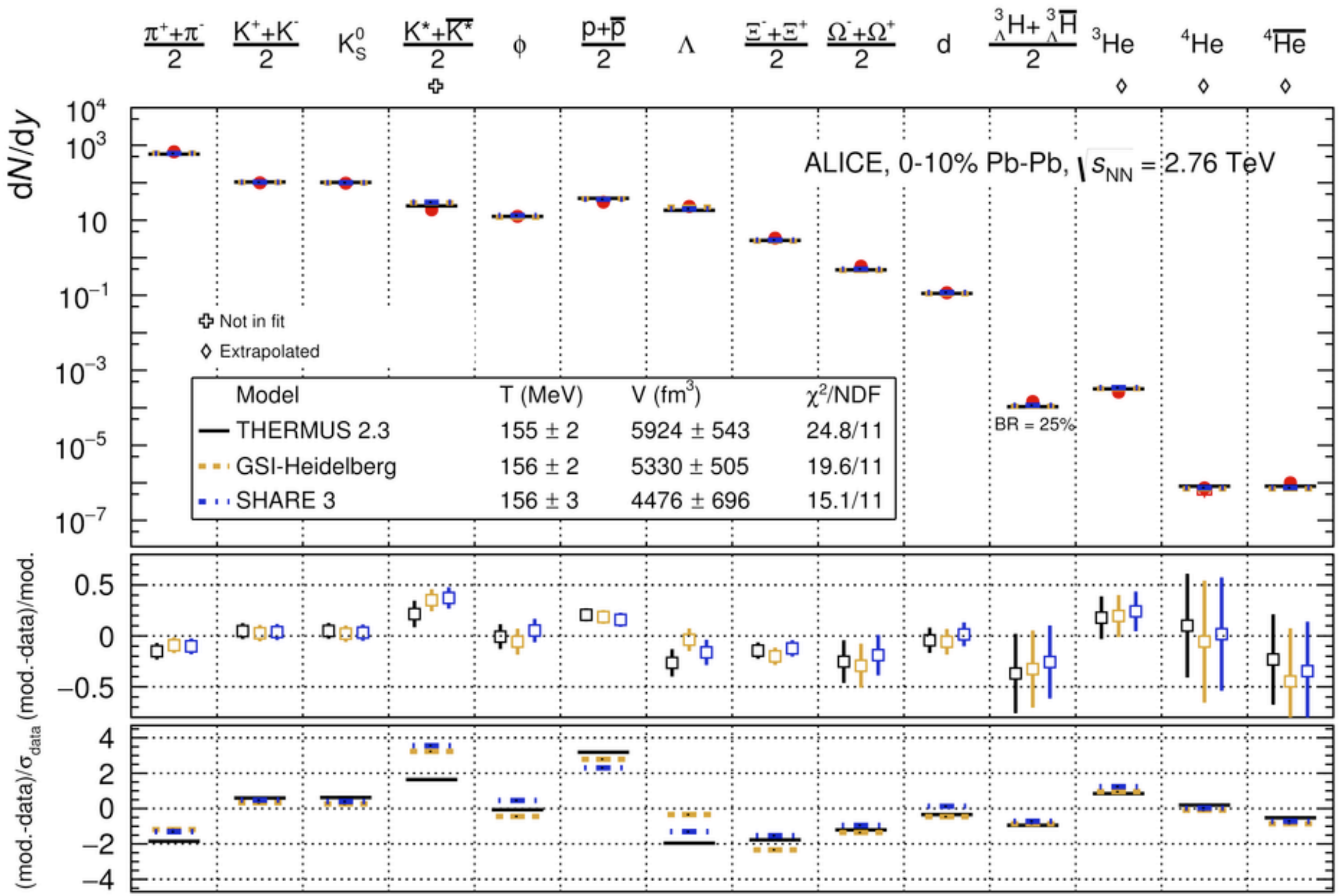

The p_T-integrated yields can be interpreted in terms of statistical (thermal) models

Particle yields of light flavor hadrons (including nuclei) described with a common chemical freeze-out temperature

T_{chem} = 156 ± 2 MeV

Baryon-AntiBaryon femtoscopy in Pb-Pb

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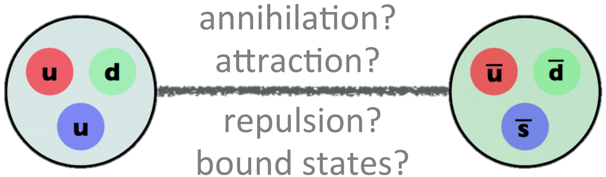
Using heavy-ion collisions to study interactions between baryons and anti-baryons



- Measure distributions of relative momenta of pair of particles to extract strong interaction parameters

$$C(k^*) = \int S(\mathbf{r})|\Psi(k^*, \mathbf{r})|^2 d^4\mathbf{r}$$

Source emission function — Pair wave function

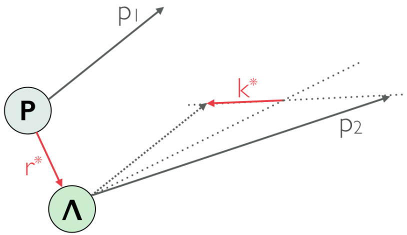
Experimentally:

$$C(p_1, p_2) = \frac{P(p_1, p_2)}{P(p_1) \cdot P(p_2)}$$

$$\Psi(\mathbf{k}^*, \mathbf{r}^*) = e^{-i\mathbf{k}^*\mathbf{r}^*} + f(k^*)\frac{e^{ik^*r^*}}{r^*}$$

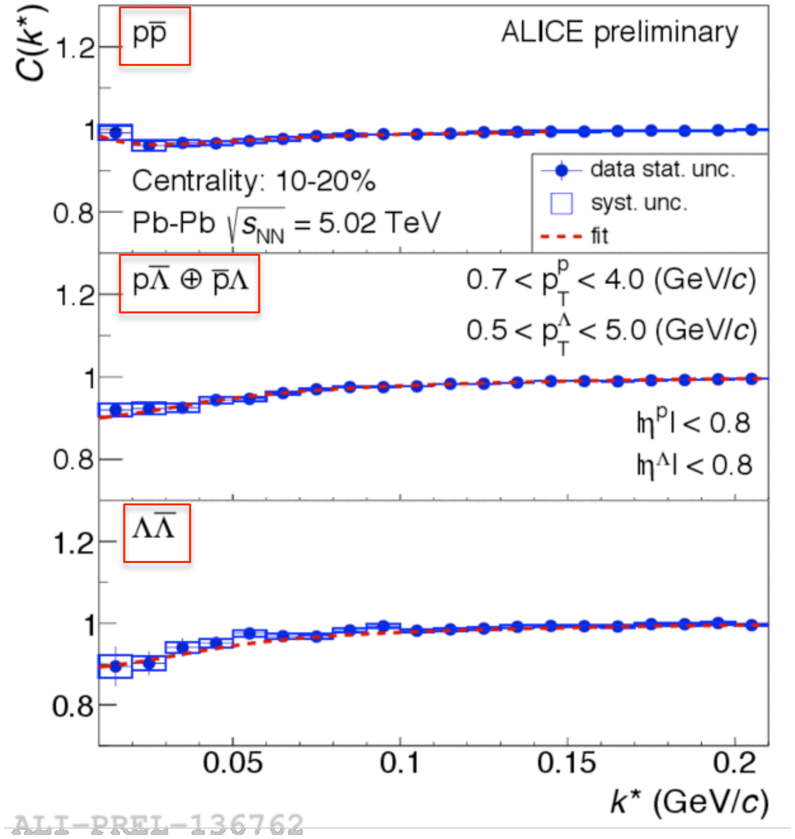
$$f^{-1}(k^*) = \frac{1}{f_0} + \frac{d_0 k^{*2}}{2} - ik^*$$

Scattering length (complex number) — Effective range



Baryon-AntiBaryon femtoscopy

A Large Ion Collider Experiment

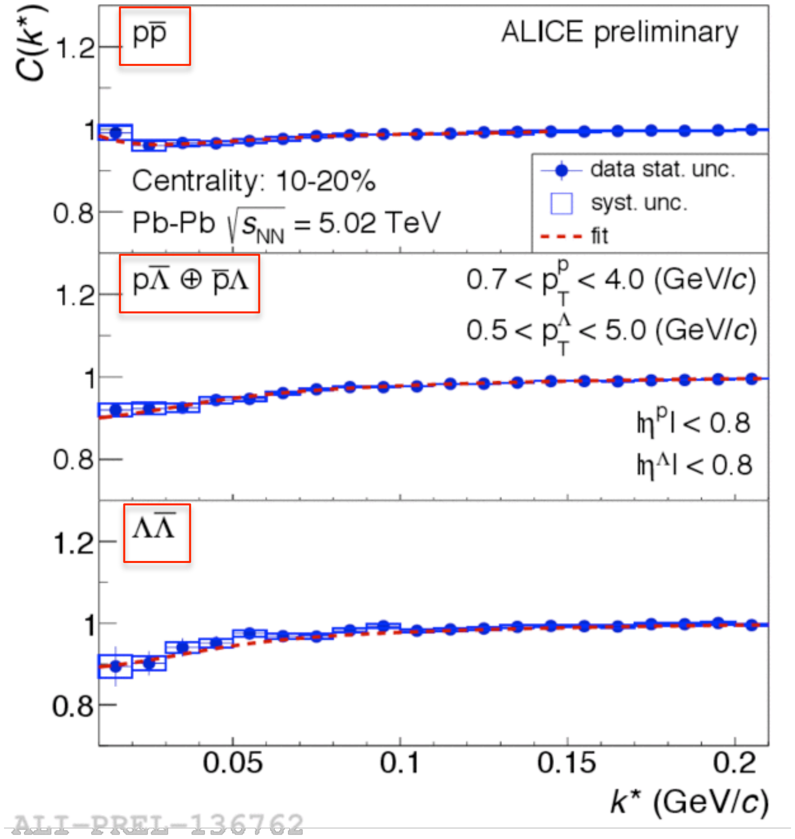


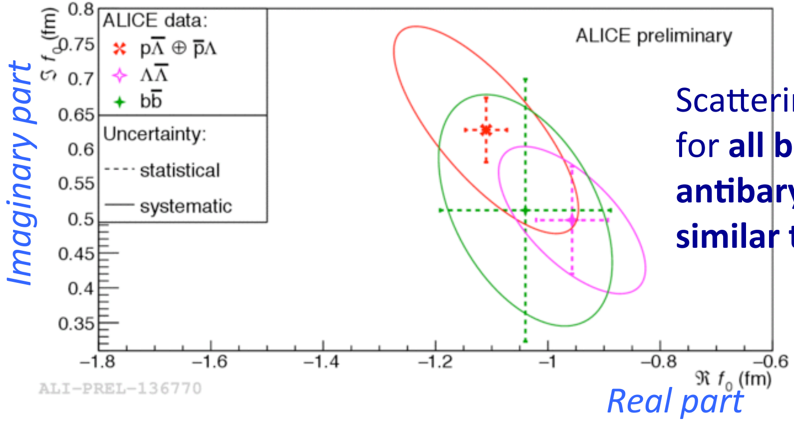
- **Simultaneous fit to all correlation functions:**
  - 2 energies
  - 3 pair combinations
  - 6 centrality intervals

  ➔(total 36 functions)

Baryon-AntiBaryon femtoscopy

A Large Ion Collider Experiment

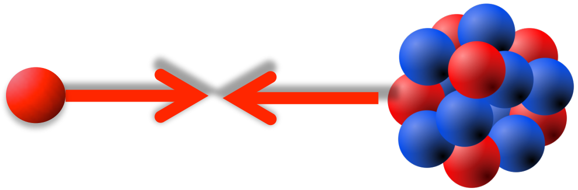




Scattering parameters for **all baryon-antibaryon pairs are similar to each other**

- **Negative real part of scattering length**
  ➔repulsive strong interaction or creation of a bound state
- Significant **positive imaginary part of scattering length**
  ➔presence of a non-elastic channel

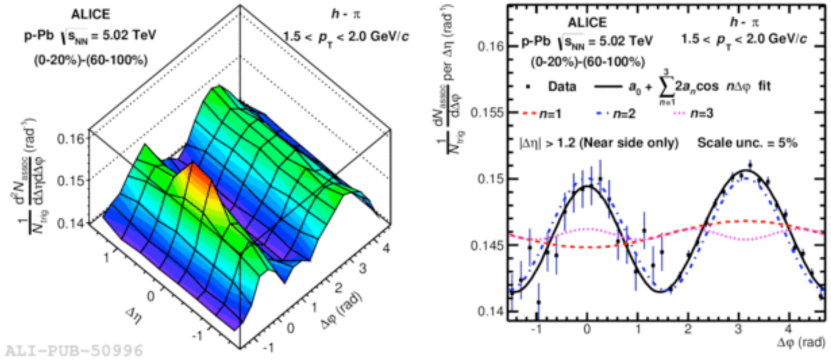
✓ *Physics highlights: p-Pb collisions*



Heavy-flavor decay electron v_2 in p-Pb

A Large Ion Collider Experiment

Double-ridge structure observed in (un)identified charged particles:
➔**Same signature as elliptic flow in Pb-Pb collisions**



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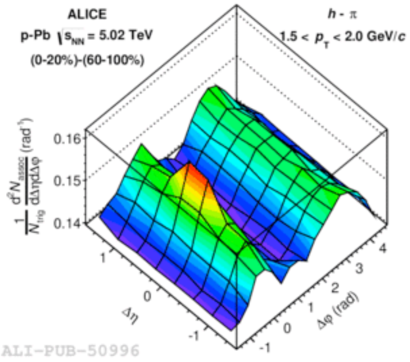
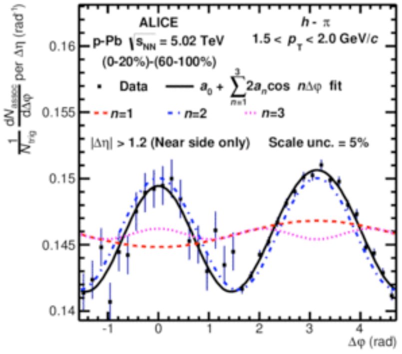
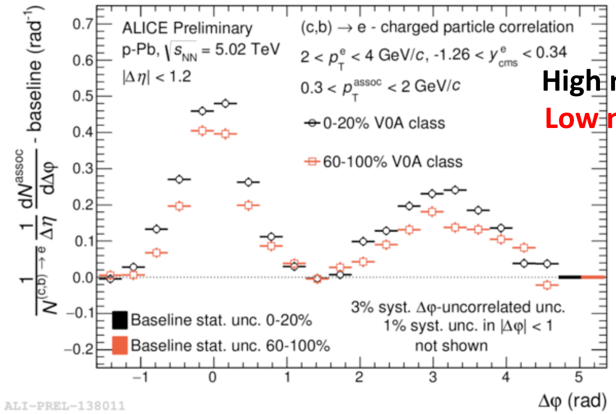




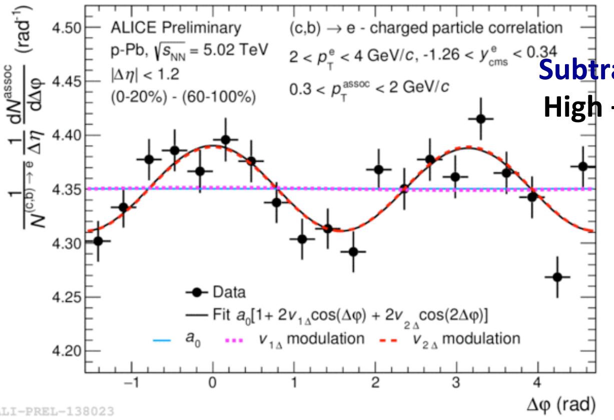
Does this holds also for charm?

Heavy-flavor electrons – hadron correlations



High multiplicity events

Low multiplicity events

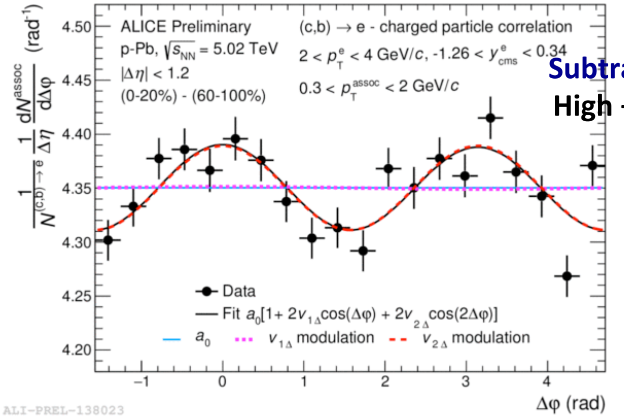


Subtraction

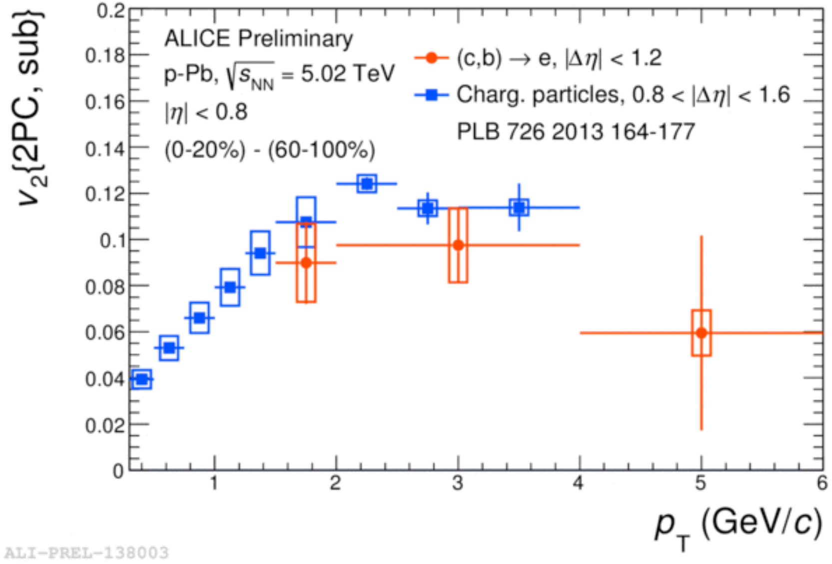
High – Low

Heavy-flavor decay electron v_2 in p-Pb

A Large Ion Collider Experiment



Subtraction
High – Low



- Positive v_2 of heavy-flavor decay electrons with 4.4σ significance
- Compatible with charged particle v_2

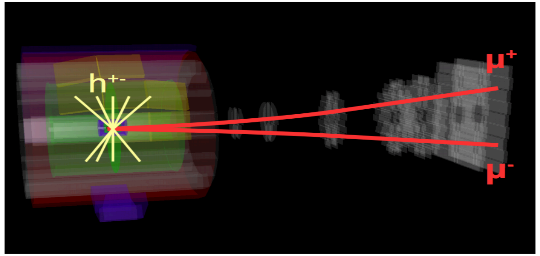
Suggests that charm participates in collective effects also in p-Pb; mechanism?

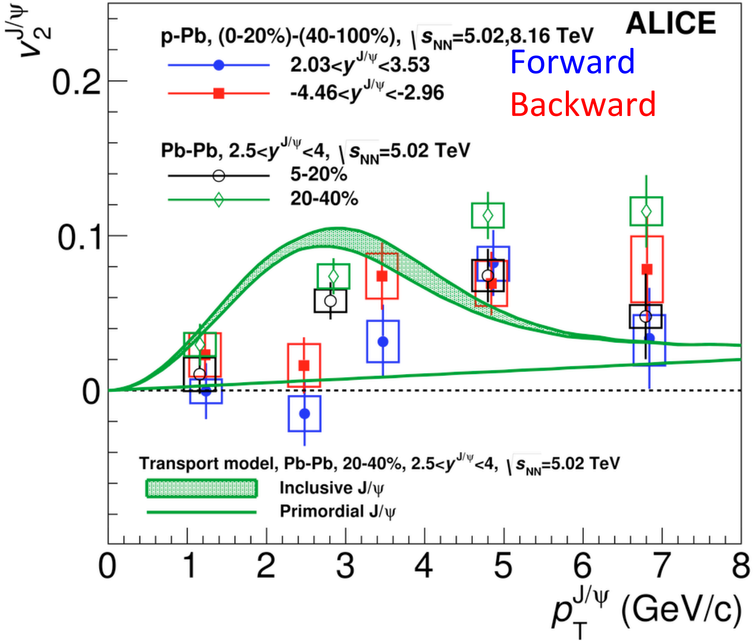
J/ψ v_2 in p-Pb collisions

A Large Ion Collider Experiment

arXiv:1709:06807

Azimuthal correlations between forward/backward J/ψ and mid rapidity charged particles





- **At p_T<3 GeV/c v_2 compatible with 0**

  No recombination expected in p-Pb due to the lower number of charm quarks produced

- **At p_T>3 GeV/c v_2>0**

  Total significance (forward + backward, 5.02 + 8.16 TeV) ~5σ

- Values compatible with J/ψ v_2 in central Pb-Pb collisions

Suggests that charm participates in collective effects also in p-Pb; mechanism?

Charm jet production in p-Pb collisions

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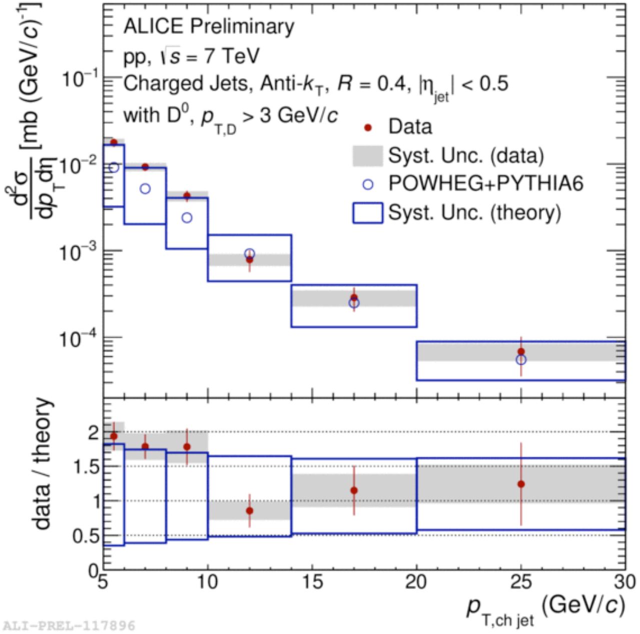
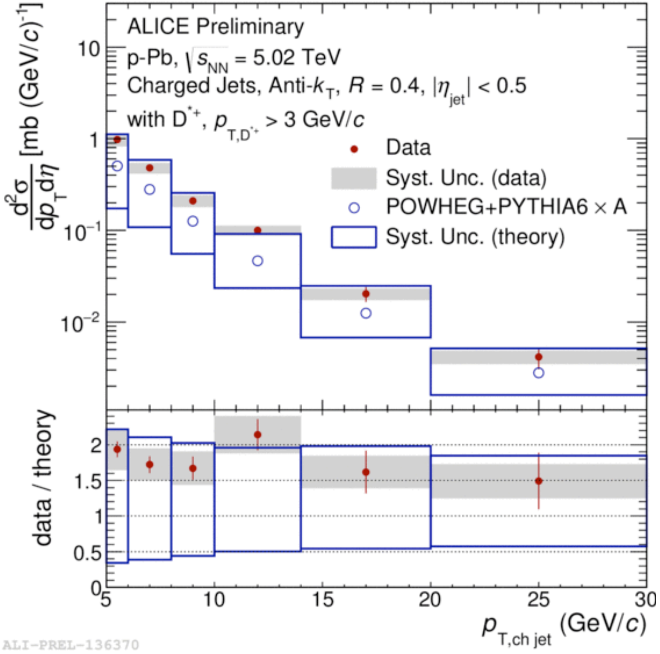
Measurement of D-jet spectrum from p_T=5 GeV/c to 30 GeV/c

- Described by POWHEG+PYTHIA6 (Perugia 2011 tune) simulations within uncertainties

Study charm jet properties and structure





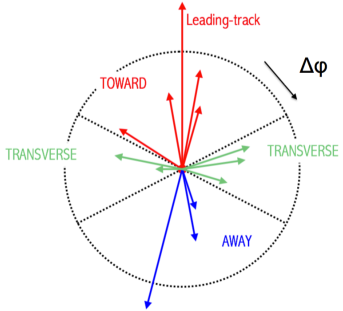
✓ *Physics highlights: pp collisions*

Underlying event in pp collisions

"Everything in a single particle collision except the hard process of interest"

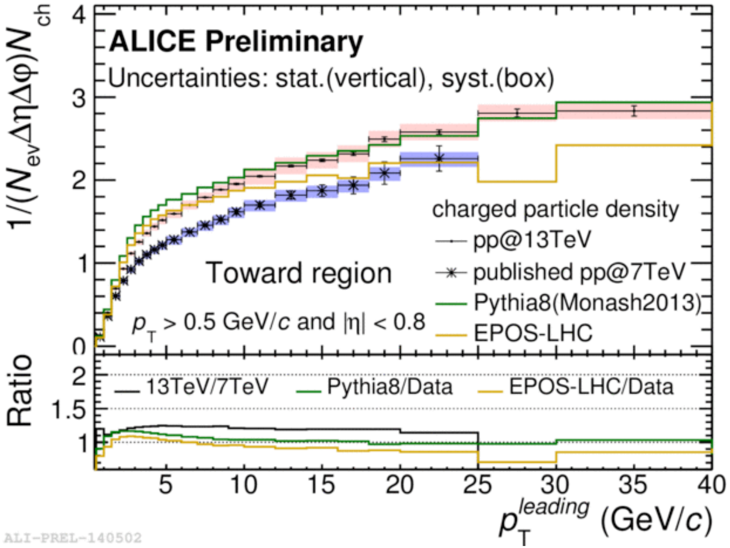
- MPI, initial and final state radiations, beam remnants etc.

Underlying events have impact on photons isolations, jet pedestals, vertex reconstruction & interest *per se*



Toward: |Δφ|<π/3
Transverse: π/3<|Δφ|<2π/3
Away: |Δφ|>2π/3

Average charged particle density



Toward and Away region

Collect fragmentation products from hard scatterings

Underlying event in pp collisions

A Large Ion Collider Experiment

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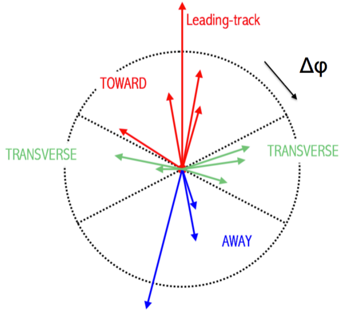


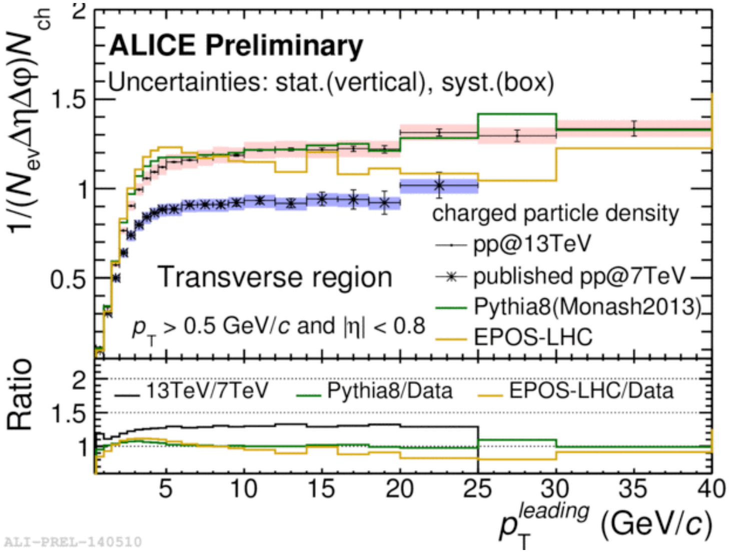
Toward: $|\Delta\varphi|<\pi/3$
Transverse: $\pi/3<|\Delta\varphi|<2\pi/3$
Away: $|\Delta\varphi|>2\pi/3$

Transverse region

$p_T^{leading} < 4$ GeV/c: increasing trend due to Multiple Parton Interactions

$p_T^{leading} > 4$ GeV/c: bulk particle production becomes independent from the hard scale

Average charged particle density



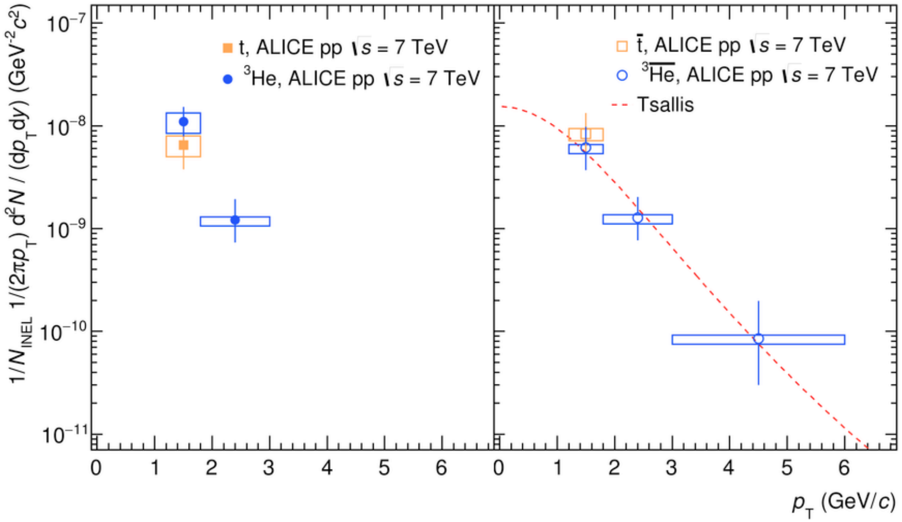
Triton and ^{3}He spectra in pp collisions

A Large Ion Collider Experiment

arXiv:1709:08522

ALICE

- **Address mechanisms of (anti)nuclei production**
- **Interesting also for cosmology:**
  Background for dark matter search



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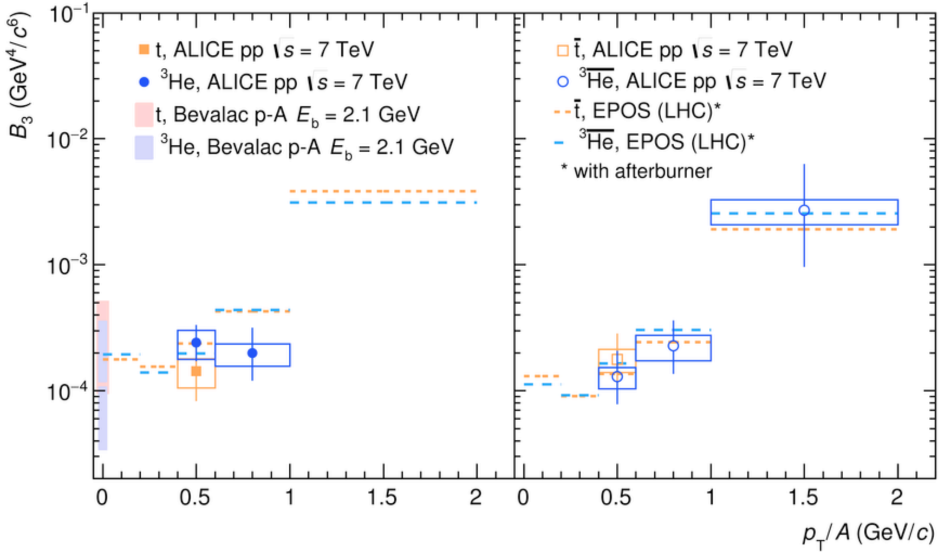

In the coalescence model:

$$E_A \frac{d^3N_A}{dp_A^3} = B_A \left(E_p \frac{d^3N_p}{dp_p^3} \right)^A$$

with A=3

Measured **nuclei** p_T-spectra

Measured **proton** p_T-spectra

- **B_3 increases with p_T**
- **B_3 well described by QCD-inspired generators when a coalescence-based afterburner is added**

✓ ALICE Upgrade

Inner Tracking System upgrade

A Large Ion Collider Experiment

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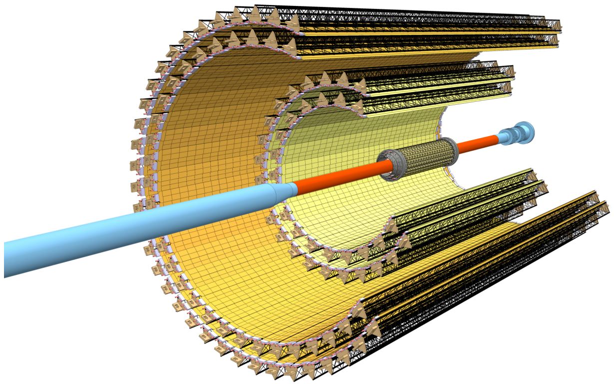
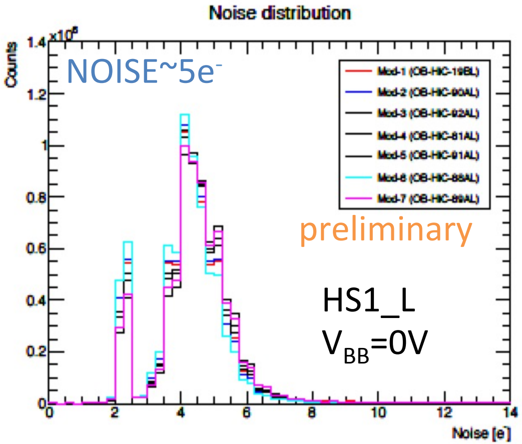
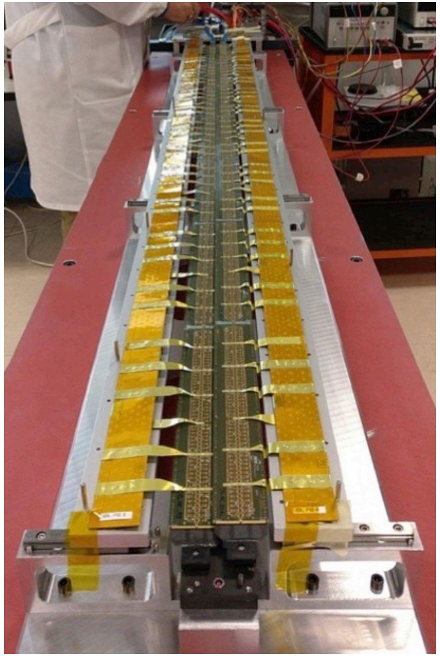
2 Outer Barrel staves produced and characterized

- Noise distribution measured in threshold scan on all 195 chips operated concurrently (**102M chips!**)
- Noise and threshold values are comparable to single chip ones







TPC upgrade: production status

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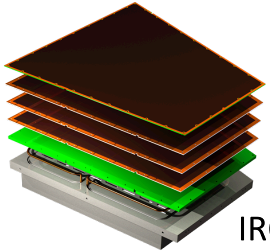
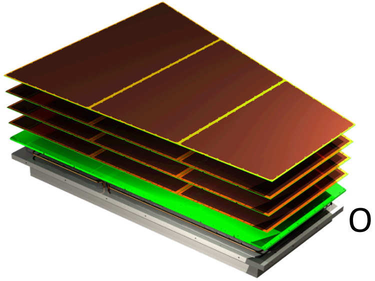
ROC components	Needed	Produced	Fraction (%)
Al-bodies	80	80	100
Padplanes	160	160	100
FEC connectors	15’000	15’000	100
HV cables	1’300	1’000	77
GEMs	720 (10% spares)	422	60
GEM frames	640	560	88

Assembly step	Goal	Assembled	Fraction (%)
Chamber bodies (IROC/OROC)	40/40	16/10	33
Padplane + FEC connectors (IROC/OROC)	40/120	23/45	43
GEM framing	640	226	35
Assembled Chambers (IROC/OROC)	40/40	8/4	15

- **Production of 40 IROCs and 40 OROCs is ongoing**
- Almost all components in hand
- GEM production continues until April 2018





TPC upgrade: ROC commissioning

A Large Ion Collider Experiment

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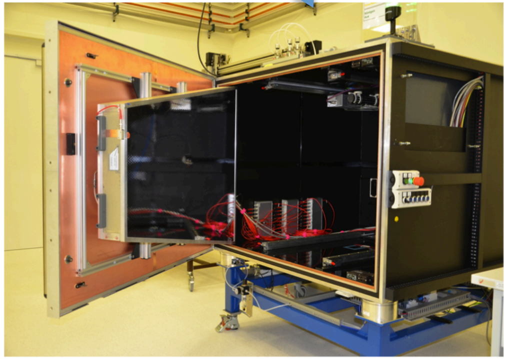
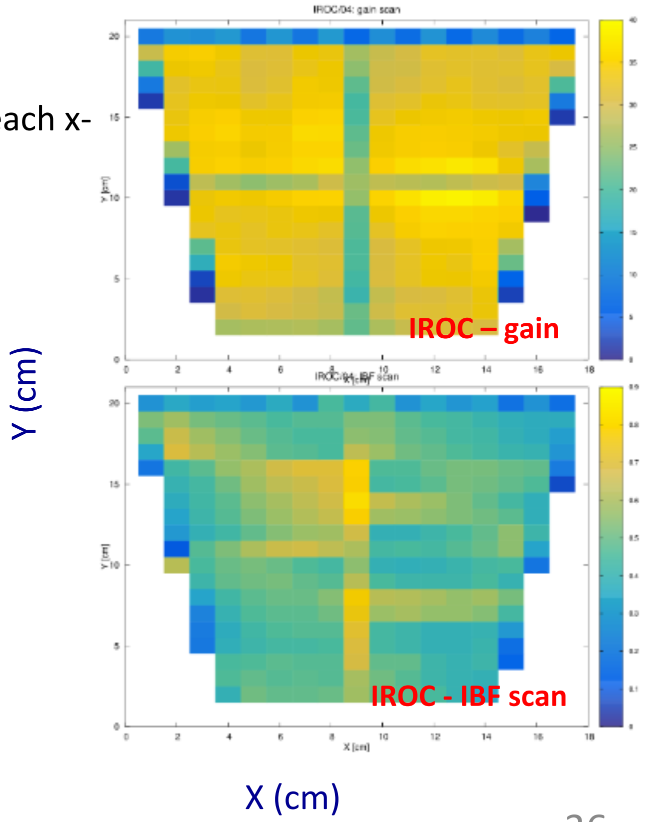
List of tests for ROC QA:

1. Gas tightness (< 0.5 ml/h)
2. Gain curve
3. Gain uniformity
4. IBF uniformity
5. Full X-ray irradiation (10 nA/cm^2) for 6h

- Collimated ^{55}Fe source or X-ray generator
- Measure anode and cathode currents for each x-y position





- High X-ray flux until reaching a current density of 10 nA/cm^2
- Record the anode and cathode currents
- After > 6 hours measure leakage current of GEMs at 250 V

SAMPA Front-end chip for TPC and Muon system

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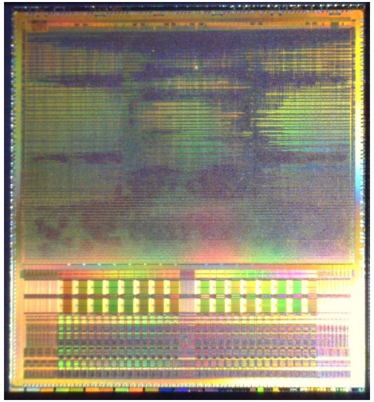
- **SAMPA V3 & V4 delivered end of October 2017**

- **Preliminary tests ongoing**
  - SEL sensitivity decreased
  - rate performance increased
  - building block performance improved

- **On schedule to PRR in Feb 2018**
- **5000 & 5000 ASICs available already now**



Installation of CR0 computing room

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- Layout finalized
- Preparation of the area started

Conclusions

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2017 data-taking campaign concluded successfully. Rich harvest including:

866M minimum bias pp events @ 13 TeV + 11pb^{-1} triggered data

1.7M Xe-Xe events @ 5.44 TeV

986M minimum bias pp events @ 5 TeV + ~1pb^{-1} of triggered data (muon and calo)

Analysis of Pb-Pb, p-Pb and pp from Run 1 and Run 2 is producing high quality physics results

Heavy ion collisions are also used as a laboratory to study baryon interactions

In p-Pb collisions, observation of non-zero v_2 for charm hints at collective effects; final state rescattering

Upgrade projects for Run 3 advancing well

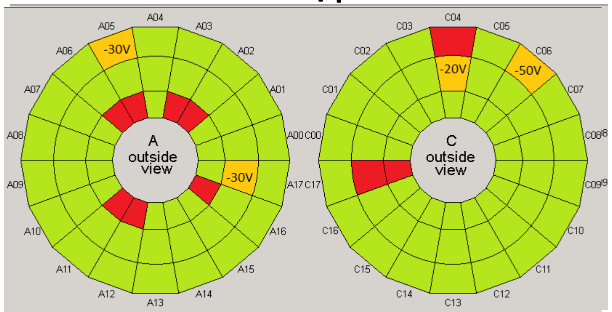
Now entered in the production phase

TPC operation

A Large Ion Collider Experiment

- **In 2017, TPC was operated with a gas mixture $Ne\text{-}CO_2\text{-}N_2$**
  - Good stability under typical running conditions in pp at both 13 TeV and 5 TeV
  - A **high rate test** performed in 2017 with a charged particle load equivalent to 2018 Pb-Pb operation revealed stability problems of the wire chambers

15 Hz/µb



- **Operation with a gas mixture $Ar\text{-}CO_2$ in 2018**
  - **promise stable operations in Pb-Pb collisions at 10 kHz (as demonstrated in 2015)**
  - Correction procedure for space charge distortions in Ar well established on 2015/2016 data
  - Alternating cover electrodes potentials can reduce space-charge distortions