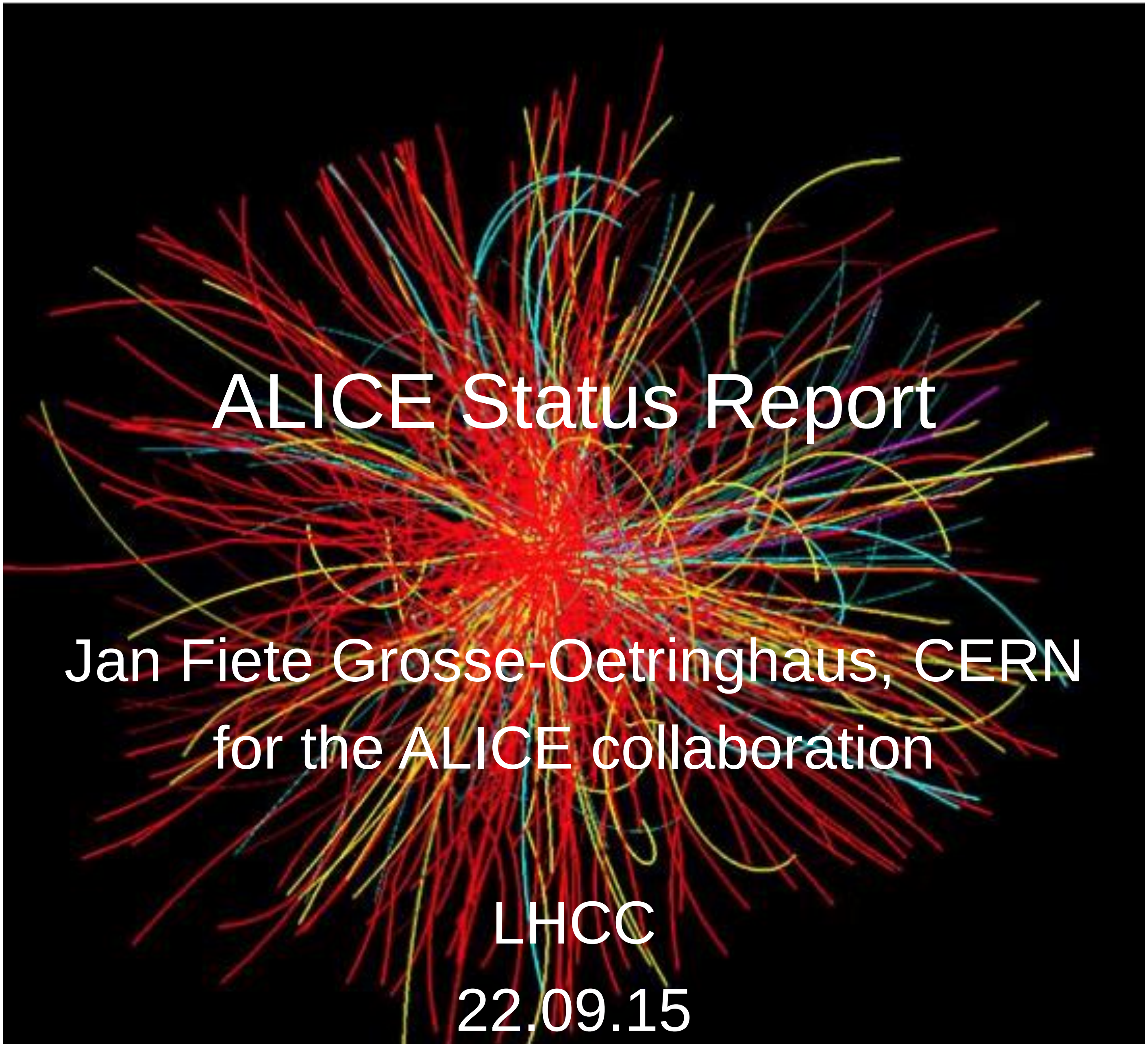


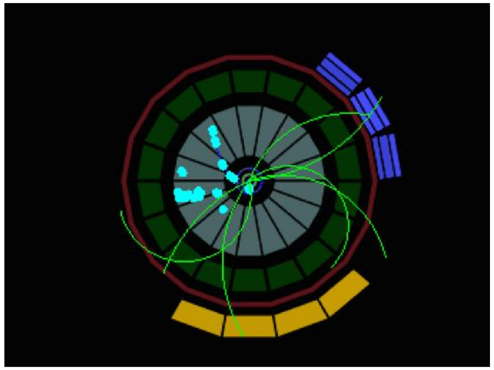
ALICE Status Report

Jan Fiete Grosse-Oetringhaus, CERN
for the ALICE collaboration

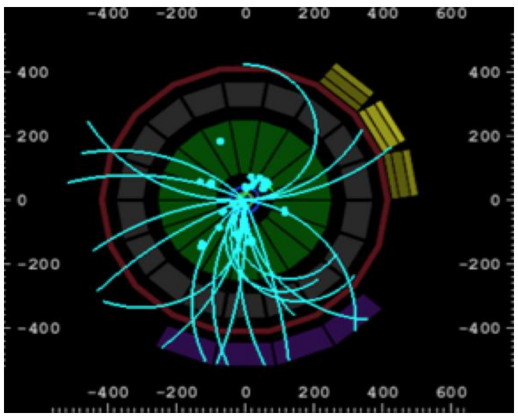
LHCC
22.09.15

Run 2 Started

Commissioning Phases



Quiet Beams at 900 GeV

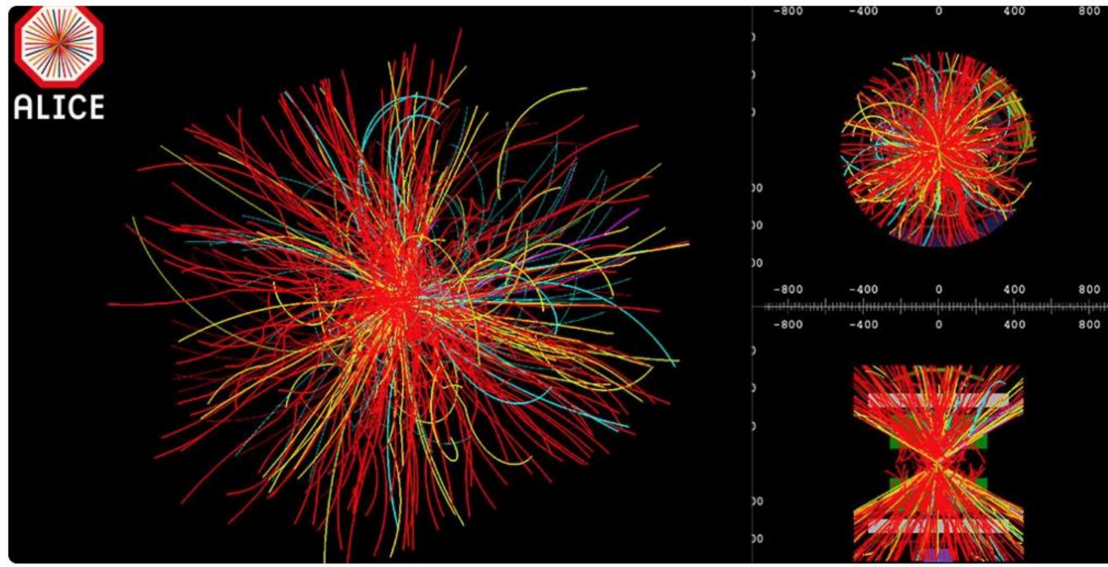


Quiet Beams at 13 TeV

13 TeV LHC Era

The Economist
@TheEconomist

Scientists at CERN announce a milestone turning knobs at the #LHC: this one goes to #13TeV econ.st/1dkYzqJ

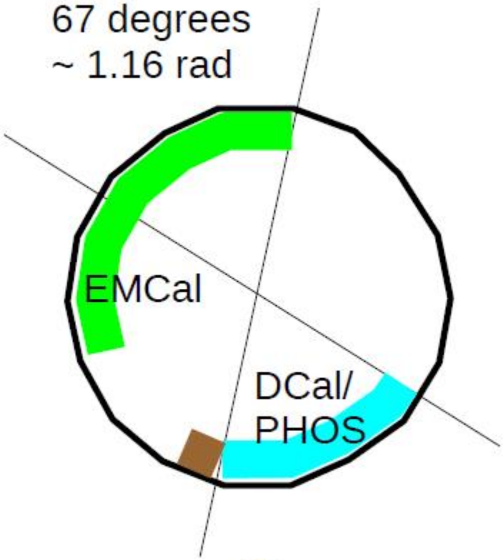


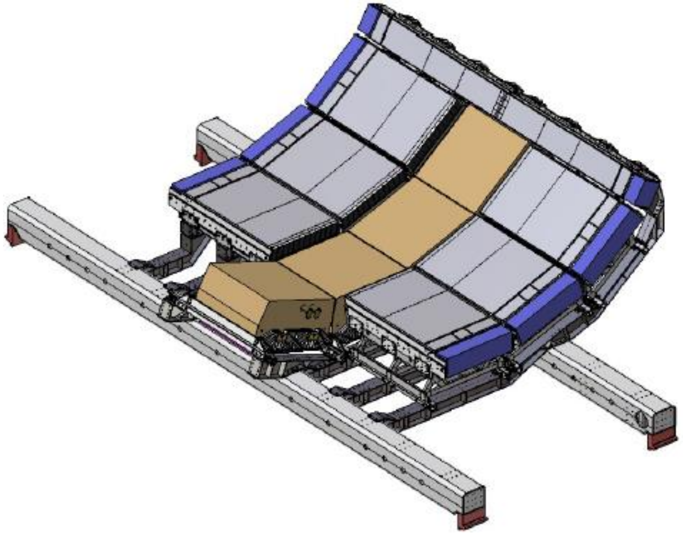
6/7/15, 10:44 AM

ALICE back in production !

Detector Status

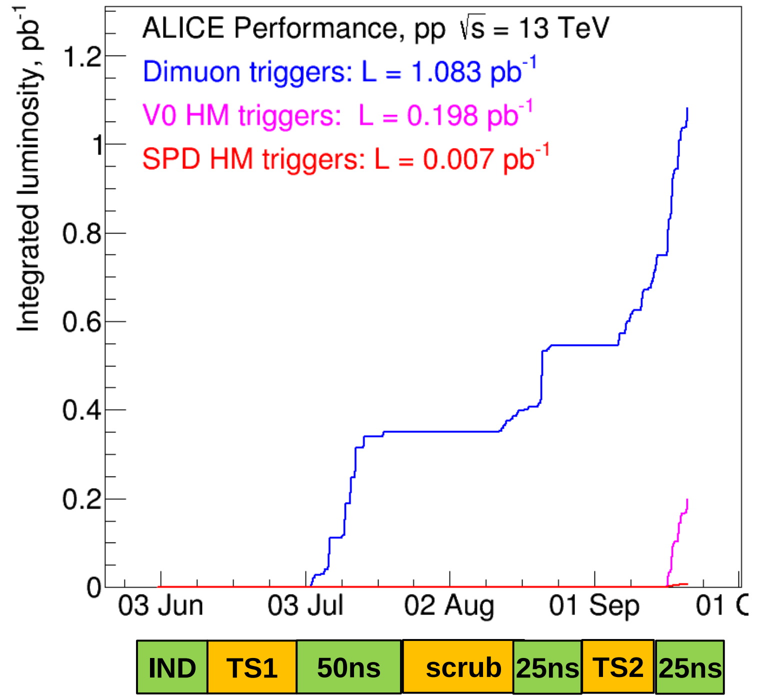
- Several detectors installed during LS1
  - New calorimeter DCal
  - 4th PHOS module + CPV installed
  - New forward trigger detector AD
  - TRD completed
- All systems integrated in DAQ
- New combined EMCAL, PHOS and DCal trigger
- Gas mixture in TPC changed to Ar-CO_2 to better cope with high particle flux

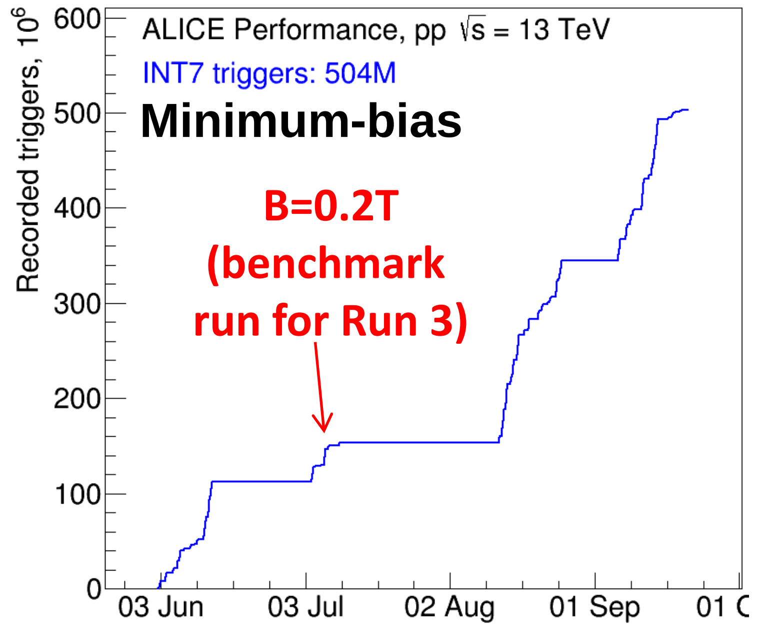




Data Taking

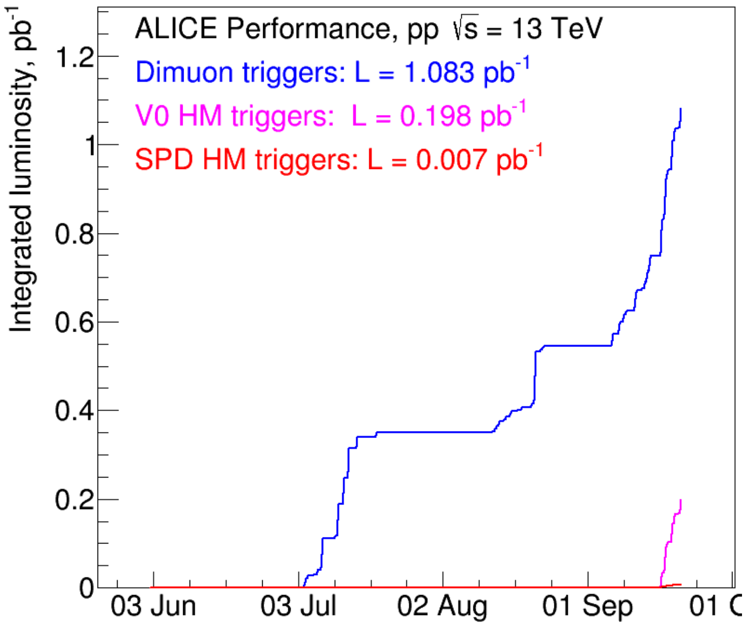
- Isolated bunches: Global OR triggers to enhance diffractive events (V0 | AD | ZDC | SPD)
- Muon data taking at high pileup
- Minimum bias data taking at low μ
- Continuing with 200-300 kHz rate including rare triggers
- Target statistics in 2015
  - 600 M minimum bias low μ
  - 4 pb^{-1} muon triggers
  - 2 pb^{-1} high multiplicity triggers





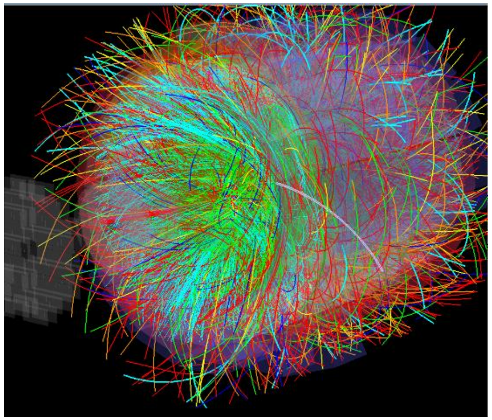
High-Multiplicity Trigger

- Aim: collect large high-multiplicity sample to investigate overlapping domain between pp and larger collisions system (p-Pb, Pb-Pb)
  - Collectivity and MPI
- Beam-background and pile-up rejection major challenge (even at low μ of ~2%)
- Forward and mid-rapidity trigger used
  - Explore selection bias
- In operation since last week
- Target for 2015: 2 pb^{-1}

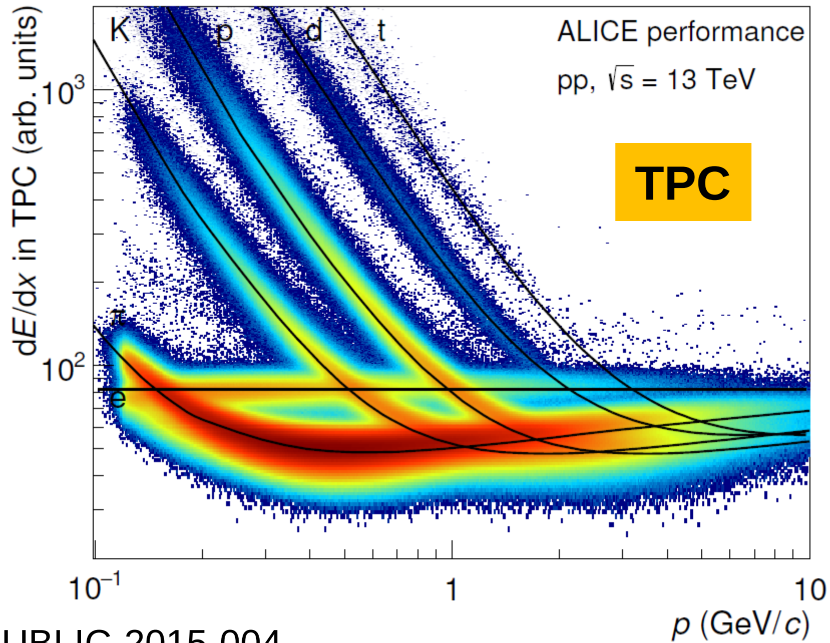


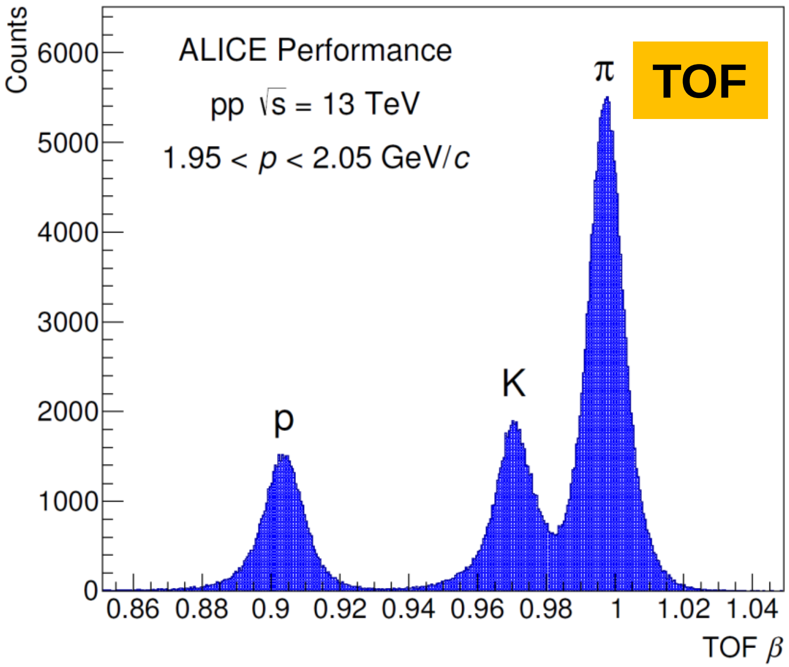
Detector Performance

- New detectors and triggers in operation
- Good stability and running efficiency
- Good momentum and dE/dx resolution with new gas in TPC



High-pile up event





ALICE-PUBLIC-2015-004

Publications

(since previous LHCC)

17 New Papers Submitted

Light Flavor

- Precision measurement of the mass difference between light nuclei and anti-nuclei, arXiv:1508.03986, **published in Nature Physics**
- Production of light nuclei and anti-nuclei in pp and Pb-Pb collisions at LHC energies, arXiv:1506.08951, submitted to PRC
- Phi-meson production at forward rapidity in p-Pb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV and in pp collisions at $\sqrt{s}$ = 2.76 TeV, arXiv:1506.09206 , submitted to PLB
- H^3_Λ and H^3_Λ (bar) production in Pb-Pb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV, arXiv:1506.08453, submitted to PLB
- Search for weakly decaying Λn and ΛΛ exotic bound states in Pb-Pb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV, arXiv:1506.07499, subm. to PLB
- Centrality dependence of the nuclear modification factor of charged pions, kaons, and protons in Pb-Pb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV, arXiv:1506.07287, submitted to PRC

Heavy Flavor

- Elliptic flow of muons from heavy-flavour hadron decays at forward rapidity in Pb-Pb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV", arXiv:1507.03134, submitted to PLB
- Centrality dependence of high-p_T D meson suppression in Pb-Pb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV, arXiv:1506.06604, subm. to JHEP

Jets

- Measurement of jet quenching with semi-inclusive hadron-jet distributions in Pb-Pb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV, arXiv:1506.03984, **accepted by JHEP**

Quarkonia

- Differential studies of inclusive J/ψ and ψ(2S) production at forward rapidity in Pb-Pb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV, arXiv:1506.08804, submitted to JHEP
- Centrality dependence of inclusive J/ψ production in p-Pb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV, arXiv:1506.08808, submitted to JHEP

Ultraperipheral & Cosmics

- Coherent ψ(2S) photo-production in ultra-peripheral Pb-Pb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV, arXiv:1508.05076, submitted to PLB
- Study of cosmic ray events with high muon multiplicity using the ALICE detector at the CERN Large Hadron Collider, arXiv:1507.07577, submitted to Journal of Astroparticle Physics

Correlations & Flow

- Centrality dependence of pion freeze-out radii in Pb-Pb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV, arXiv:1507.06842, submitted to PRC
- Event shape engineering for inclusive spectra and elliptic flow in Pb-Pb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV, arXiv:1507.06194, submitted to PRC, submitted to PRC
- One-dimensional pion, kaon, and proton femtoscopy in Pb-Pb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV, arXiv:1506.07884, submitted to PRC
- Forward-central two-particle correlations in p-Pb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV, arXiv:1506.08032, submitted to PLB

Publications

(since previous LHCC)

8 Papers Published

- Measurement of charged jet production cross sections and nuclear modification in p-Pb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV, arXiv:1503.00681, PLB749(2015)78
- Inclusive, prompt and non-prompt J/ψ production at mid-rapidity in Pb-Pb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV, arXiv:1504.07151, JHEP 07(2015) 051
- Elliptic flow of identified hadrons in Pb-Pb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV, arXiv:1405.4632, JHEP 06(2015) 190
- Charged jet cross sections and properties in proton-proton collisions at $\sqrt{s}$ = 7 TeV, arXiv:1411.4969, PRD 91(2015) 112012
- Rapidity and transverse-momentum dependence of the inclusive J/ψ nuclear modification factor in p-Pb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV, arXiv:1503.07179, JHEP 06(2015) 055
- Centrality dependence of particle production in p-Pb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV, arXiv:1412.6828, PRC 91(2015) 064905
- Measurement of dijet k_T in p-Pb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV, arXiv:1503.03050, PLB746(2015) 385
- Measurement of jet suppression in central Pb-Pb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV, arXiv:1502.01689, PLB746(2015) 1

2 Papers Accepted

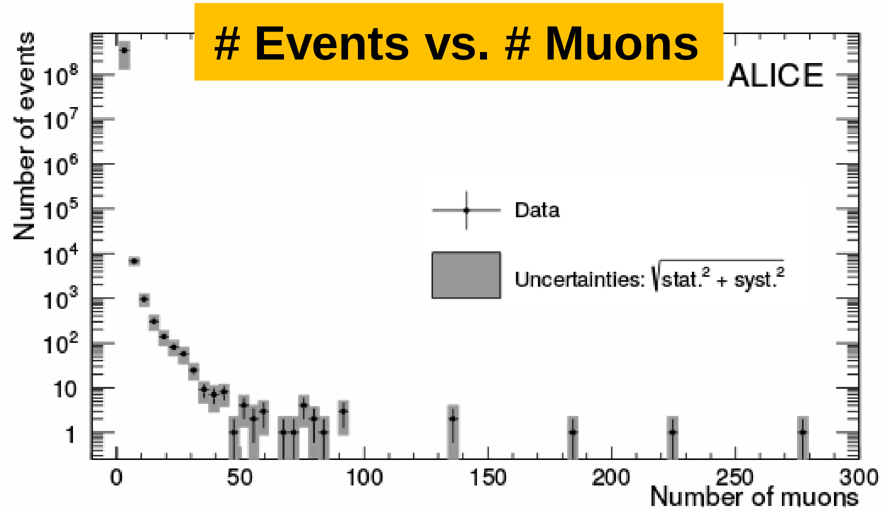
- Measurement of charm and beauty production at central rapidity versus charged-particle multiplicity in proton-proton collisions at $\sqrt{s}$ = 7 TeV, arXiv:1505.00664, accepted by JHEP
- Coherent ρ^0 photoproduction in ultra-peripheral Pb-Pb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV, arXiv:1503.09177, accepted by JHEP

Quark Matter conference (Kobe, Japan) next week

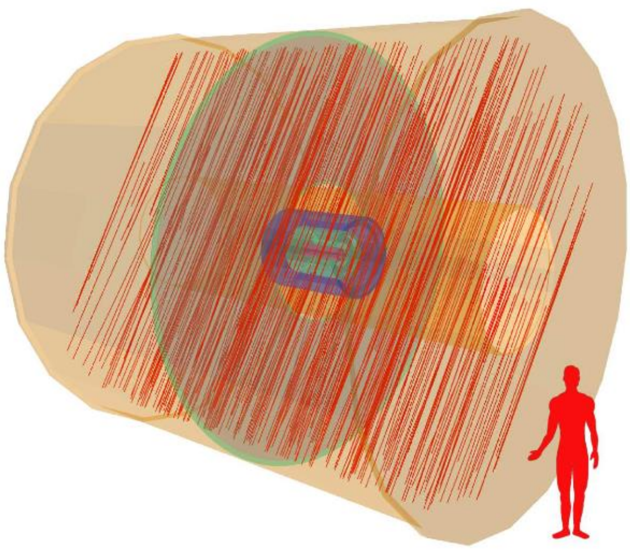
About 30 new results

Cosmic-Ray Muons

- 30.8 days active
- Multiplicity distribution
  - Compatible with mixed-ion primary cosmic-ray composition (CORSIKA 6990 QGSJET II-03)
- High-multiplicity tail
  - Highest multiplicity 276 muons
  - 5 events with >100 muons
  - Consistent with pure ion composition (proton gives 2-3 lower rates)



HMM events	CORSIKA 6990 QGSJET II-03 proton	CORSIKA 6990 QGSJET II-03 iron	CORSIKA 7350 QGSJET II-04 proton	CORSIKA 7350 QGSJET II-04 iron	Data
Period [days per event]	15.5	8.6	11.6	6.0	6.2
Rate [$\times 10^{-6}$ Hz]	0.8	1.3	1.0	1.9	1.9
Uncertainty (%) (syst + stat)	13	16	8	20	49

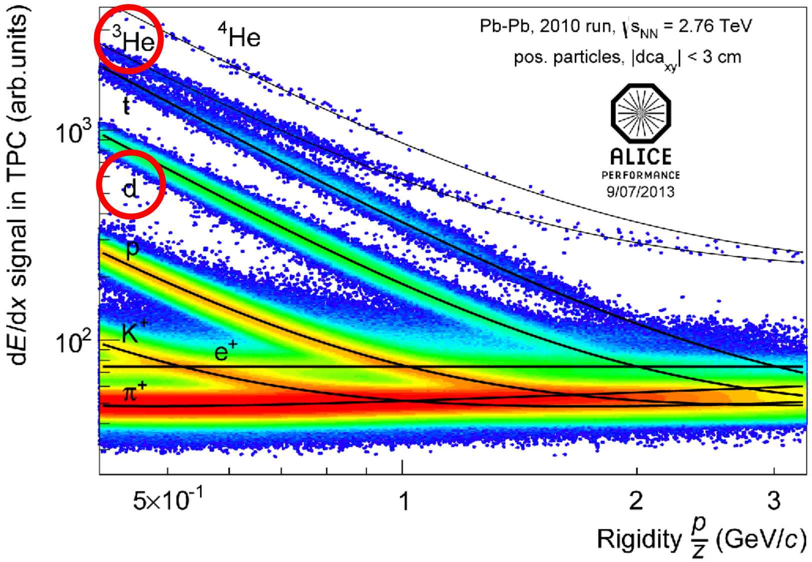


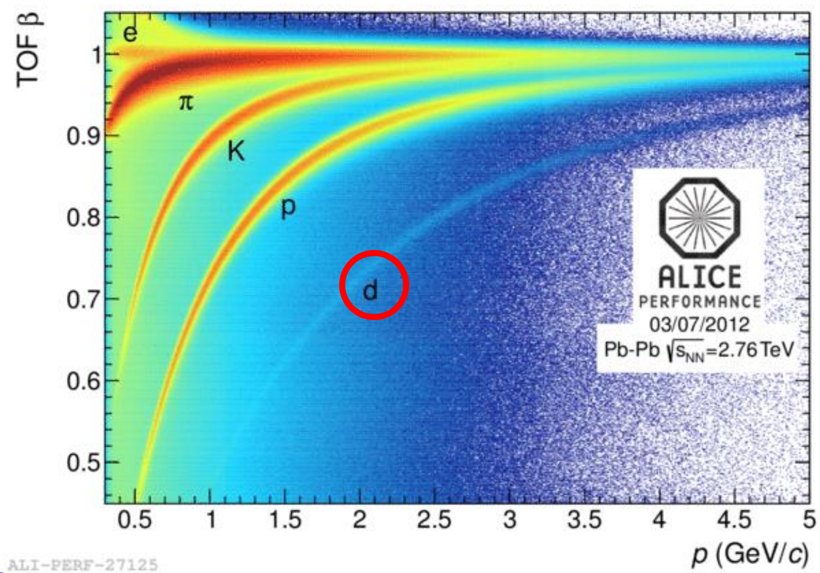
arXiv:1507.07577

Pb-Pb

Mass Difference of Nuclei

- Highest precision direct measurement of mass difference in nuclei sector d-$\bar{\mathrm{d}}$ and $^{3}\mathrm{He}$-$^{3}\overline{\mathrm{He}}$
- TPC+TOF PID
- Calculation of mass difference
  - Uncertainties cancel
  - Relative systematic uncertainties of 10^{-4} (d) and 10^{-3} (^{3}He)



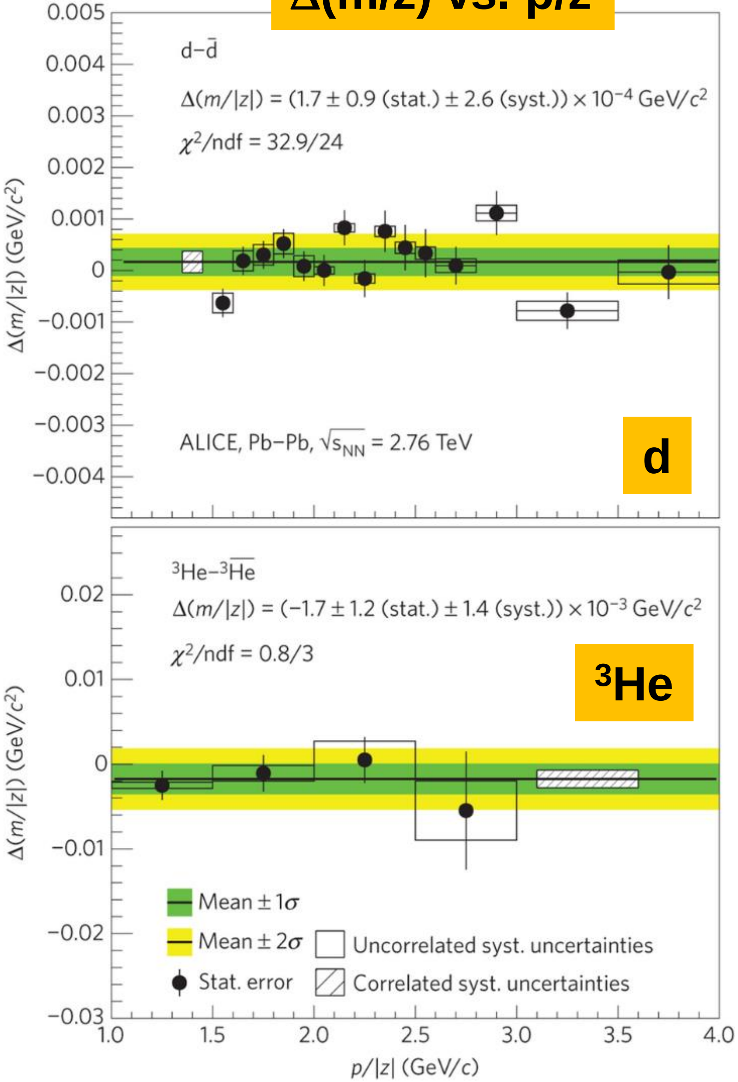


Nature Physics (2015), arXiv:1508.03986

Pb-Pb

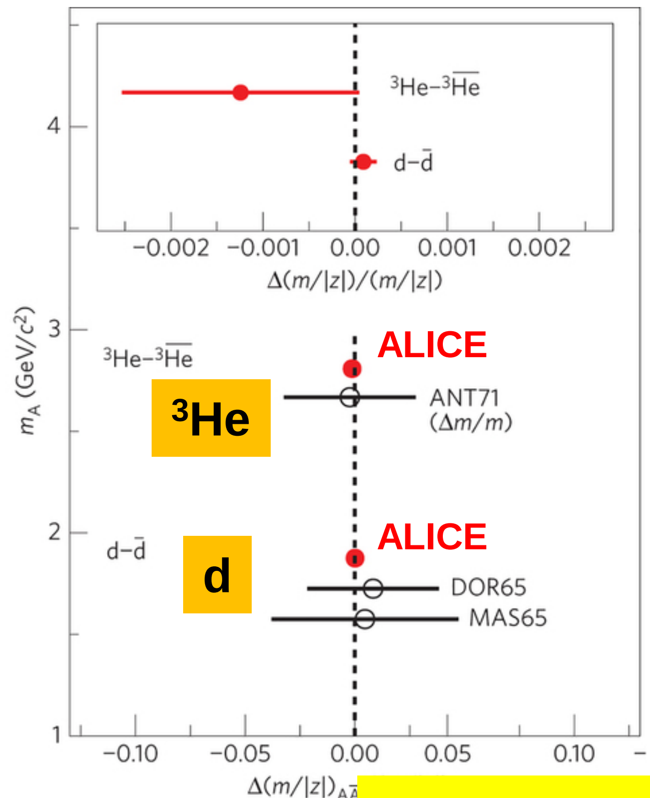
Mass Difference of Nuclei (2)

Δ(m/z) vs. p/z



d: $\Delta(m/z) = (1.7 \pm 0.9\ (stat) \pm 2.6\ (syst)) \cdot 10^{-4}\ GeV/c^2$
^{3}He: $\Delta(m/z) = (-1.7 \pm 1.2\ (stat) \pm 1.4\ (syst)) \cdot 10^{-3}\ GeV/c^2$

Nature Physics (2015), arXiv:1508.03986



Improvement by 1-2 orders of magnitude re previous limits

Pb-Pb

Mass Difference of Nuclei (3)

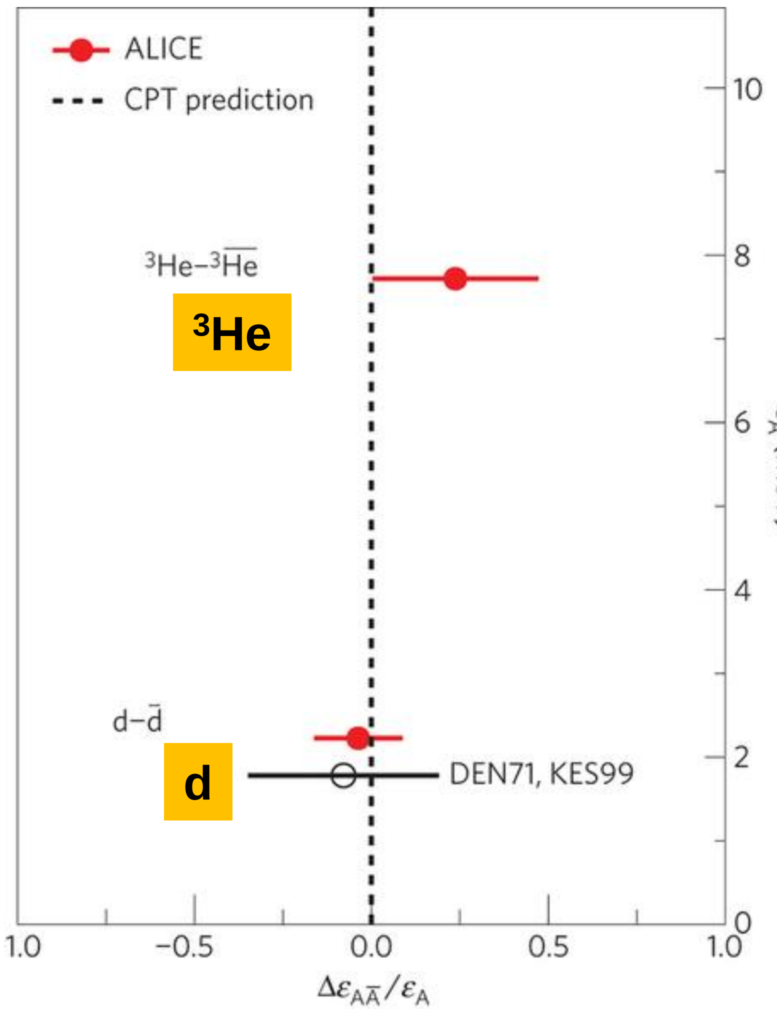
- Bound on CPT invariance of strong interaction binding nucleons into nuclei
- Calculate binding energy

$$\Delta\varepsilon_{A\bar{A}} = Z\Delta m_{p\bar{p}} + (A - Z)\Delta m_{n\bar{n}} - \Delta m_{A\bar{A}}$$

$$\frac{\Delta\varepsilon}{\varepsilon} = -0.04 \pm 0.05\,(\text{stat.}) \pm 0.12\,(\text{syst.}) \quad \textbf{d-}\bar{\textbf{d}}$$

$$\frac{\Delta\varepsilon}{\varepsilon} = 0.24 \pm 0.16\,(\text{stat.}) \pm 0.18\,(\text{syst.}) \quad {}^{3}\textbf{He-}\,{}^{3}\overline{\textbf{He}}$$

- Improves by factor 2 constraint for deuterons
- First determination for ^{3}He



Nature Physics (2015), arXiv:1508.03986

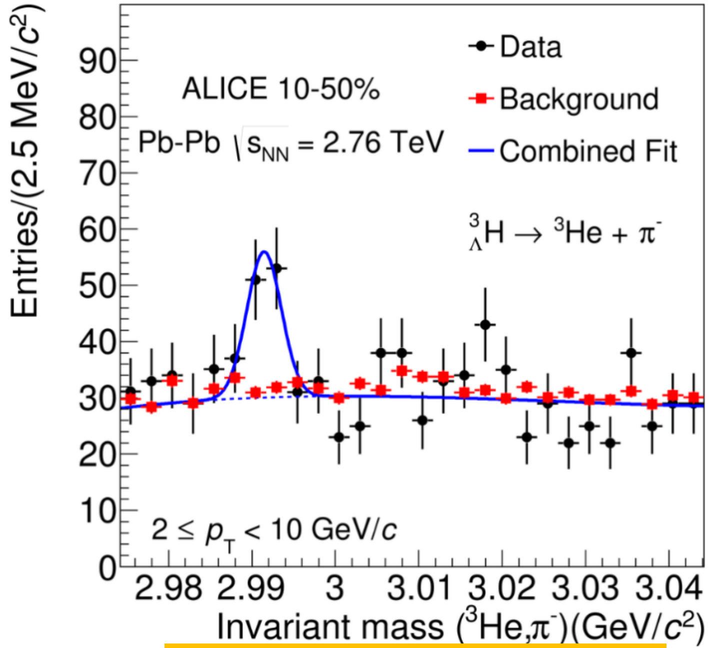
Pb-Pb

Hypertriton Nuclei

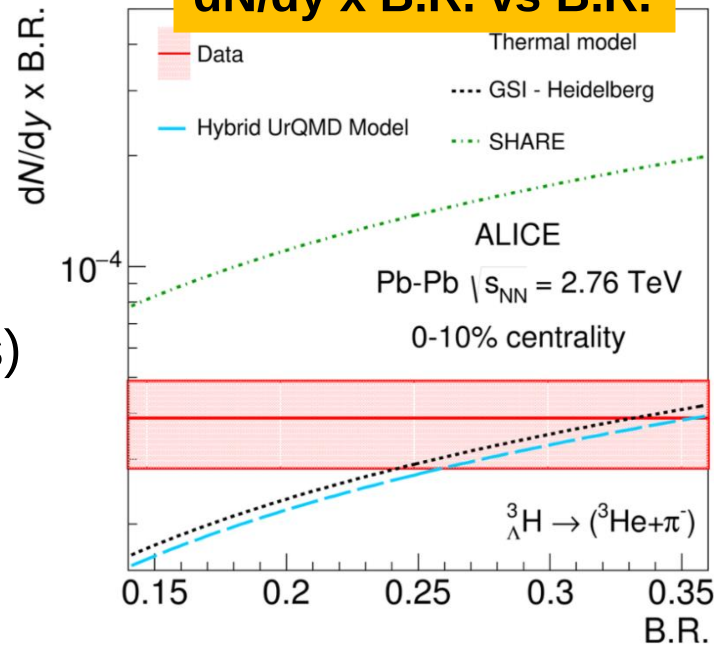
- Hypernuclei weakly bound
  → sensitive to final fireball stages

- First measurement at LHC
  - $^{3}_{\Lambda}H \rightarrow {}^{3}He + \pi^{-}$ (and c.c.)

- Coalescence or thermal models
  (long-standing item)
  - Rate consistent with thermal model prediction (same T as for light hadrons)
  - Equilibrium models favored for yield



dN/dy x B.R. vs B.R.



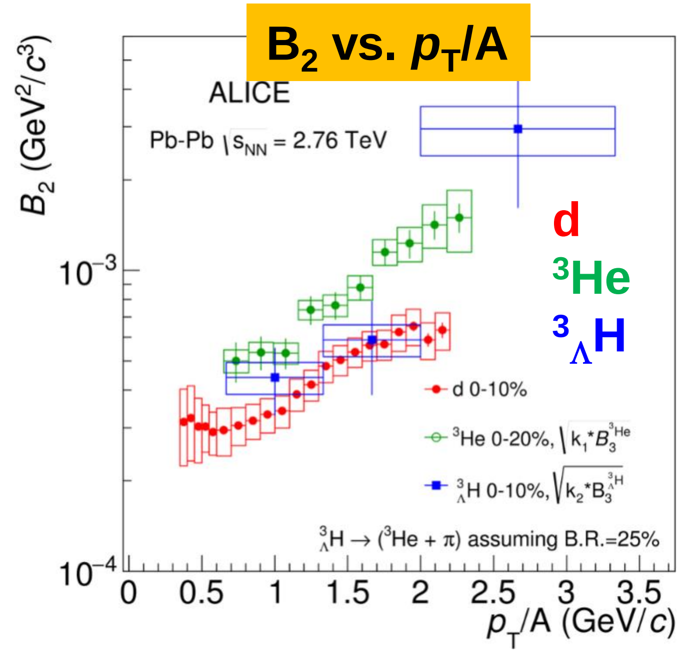
arXiv:1506.08453

Pb-Pb

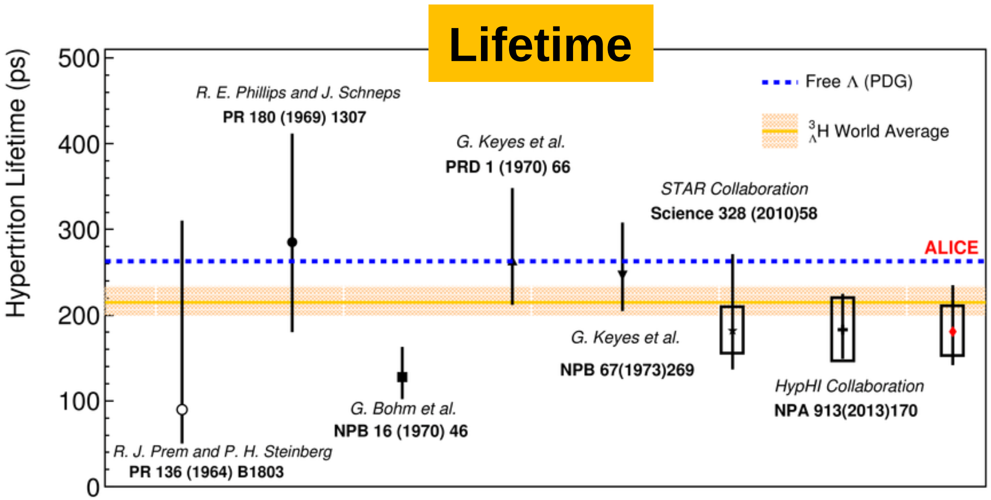
Hypertriton Nuclei (2)

- p_T distribution not compatible with simple coalescence picture

$$E_i \frac{d^3 N_i}{(dp_i)^3} = B_A \left(E_p \frac{d^3 N_p}{(dp_p)^3} \right)^A$$



- Lifetime determined from secondary-vertex distribution
  - $c\tau = (5.4^{+1.6}_{-1.2} \pm 1.0$ cm)
  - Uncertainties competitive for world average
  - Lifetime expected to be similar to free Λ (weakly-bound hypernucleus)

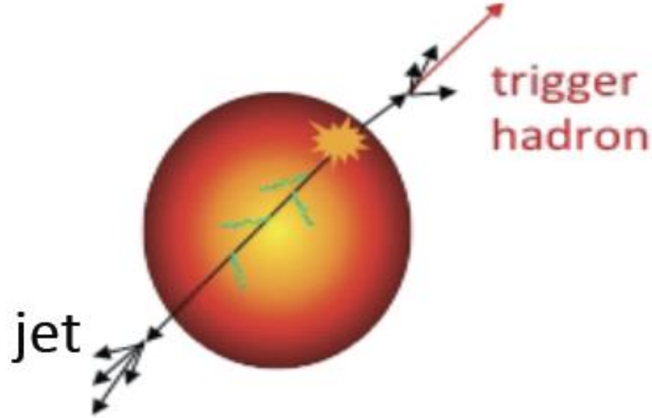


arXiv:1506.08453

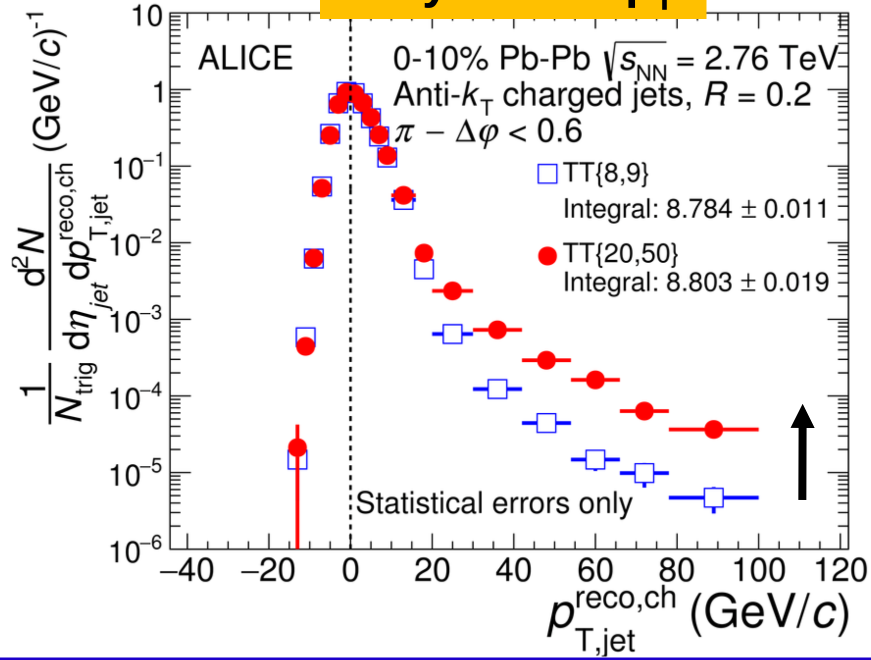
Pb-Pb

Hadron-Jet Correlations

- Charged jets with a recoil high p_T trigger particle
- Jet reconstruction with $p_{T,constituents} > 0.15$ GeV/c for $p_{T,jet} > 20$ GeV/c
- Novel subtraction technique
  - Compare trigger particle p_T ranges
  - Background jets invariant to trigger particle p_T
  - Extract additional jet yield → Δ_{recoil}



Jet yield vs. p_T



arXiv:1506.03984

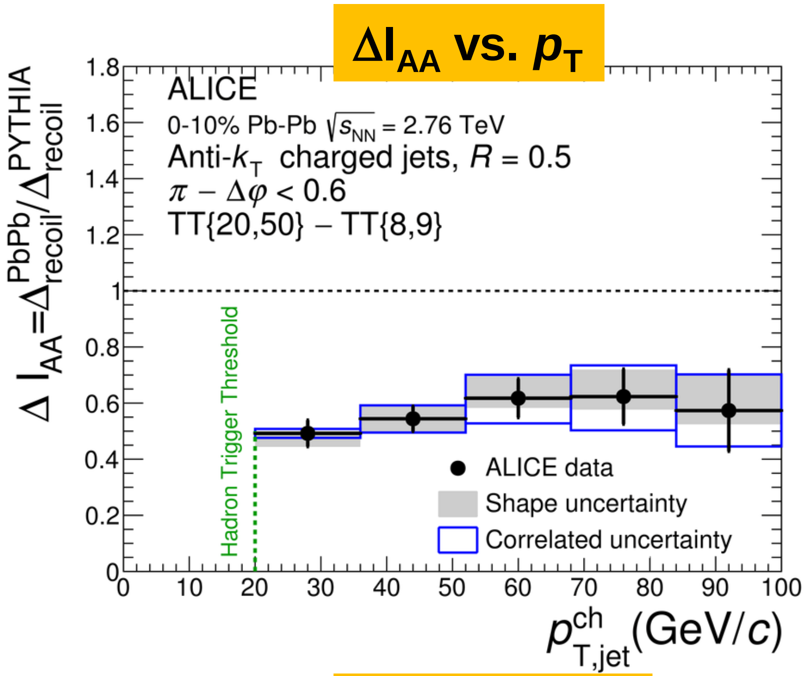
Hadron-Jet Correlations (2)

Pb-Pb

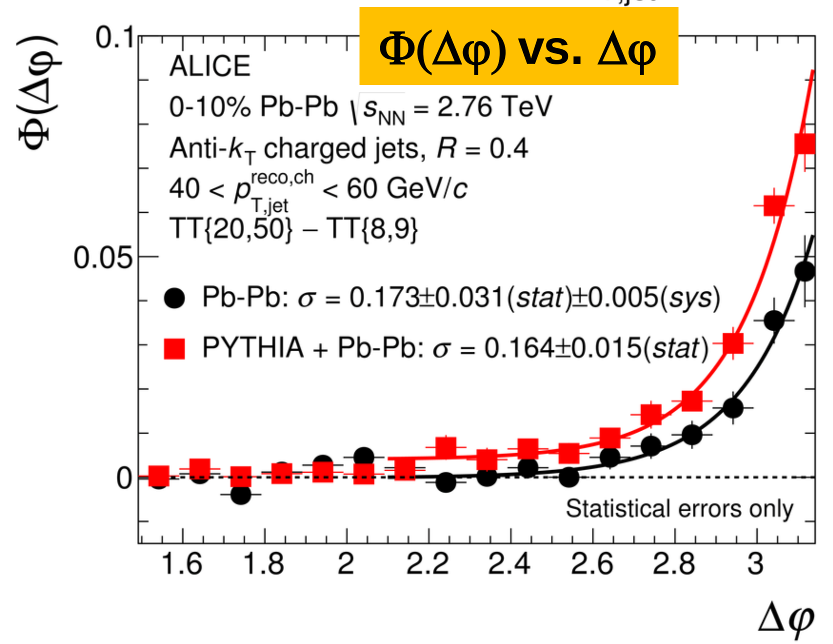
- Comparison of recoil-jet yield to vacuum expectation

$$\Delta I_{AA} = \frac{\Delta^{PbPb}_{recoil}}{\Delta^{PYTHIA}_{recoil}}$$

- Suppression by factor ~2



- Angular distribution of recoil jets
- No evidence for medium-induced broadening



arXiv:1506.03984

Pb-Pb

D R_{AA}

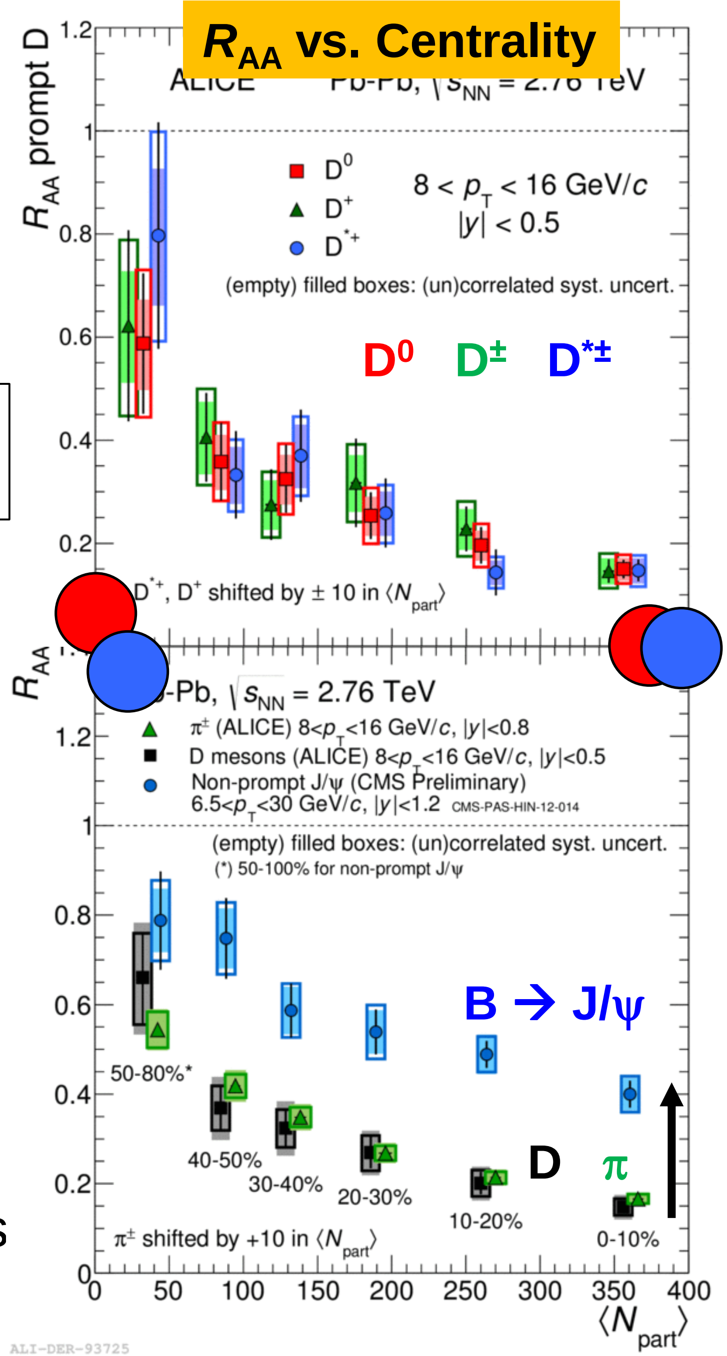
- Nuclear-modification factor

$$R_{AA} = \frac{dN_{AA} / dp_T}{\langle T_{AA} \rangle d\sigma_{pp} / dp_T}$$

= 1 no modification
< 1 suppression

- Centrality dependence of D^0, $D^{\pm}$, $D^{*\pm}$ R_{AA}
  - $5 < p_T < 16$ GeV/c
- Significant suppression at high p_T
  - Factor 5-6 in most central
- Sign of quark mass dependence
  - R_{AA} (B → J/ψ) > R_{AA} (D) ≈ R_{AA} (π)
  - Important input for energy-loss models

R_{AA} vs. Centrality

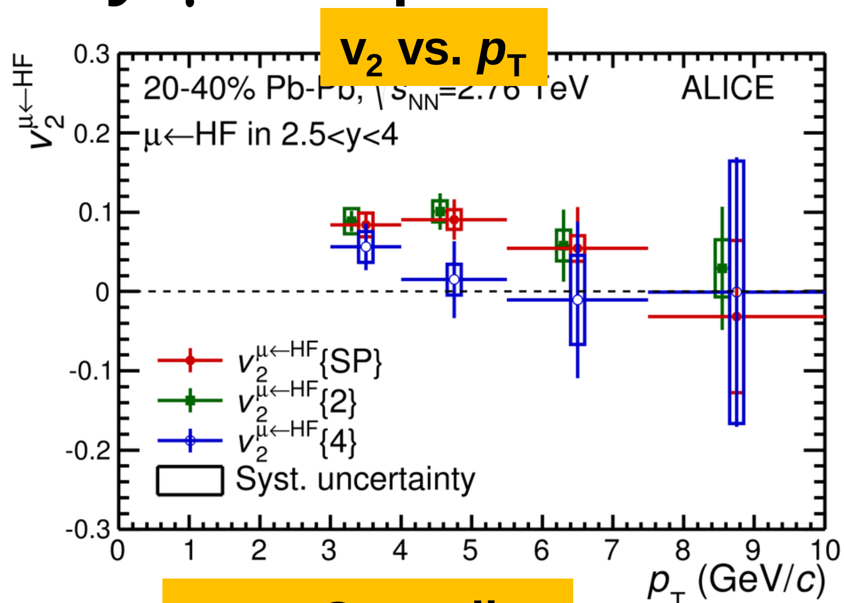


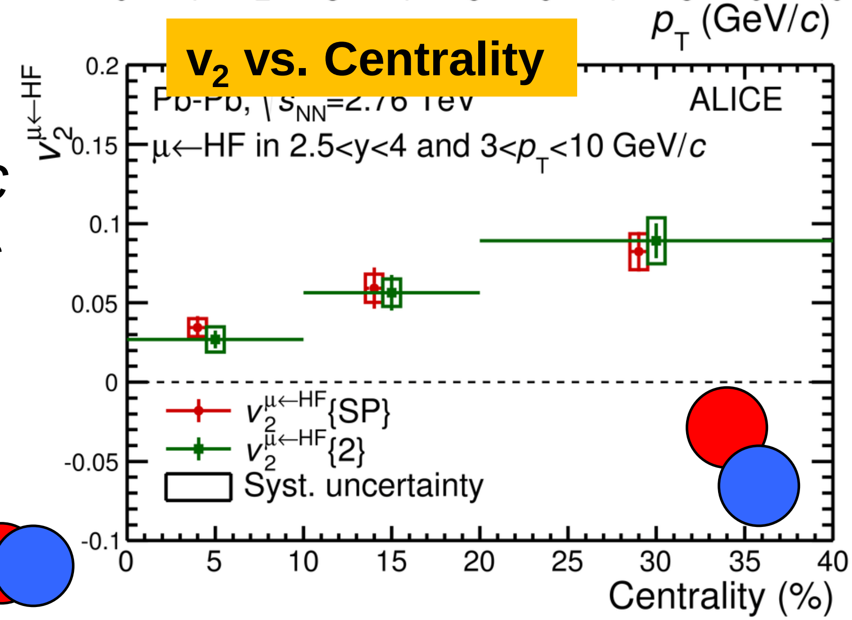
arXiv:1506.06604

Pb-Pb

Heavy-Flavor Decay μ Elliptic Flow

- Forward muons (2.5 < y < 4)
  - 0-40%, 3 < p_T < 10 GeV/*c*
  - 2 and 4 particle correlations
- Non HF decay μ subtraction
  - Measured v_2 in |η| < 2.5 (ATLAS)
  - v_2 of π and K in |y| < 0.8 (ALICE)
  - Extrapolation, detector simulation
- Significant v_2 for 3<p_T<5 GeV/*c*
  - Compatible with 0 above 5 GeV/*c*





arXiv:1507.03134

Pb-Pb

Heavy-Flavor Decay μ Elliptic Flow

- Forward muons (2.5 < y < 4)
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  - Measured v_2 in |η| < 2.5 (ATLAS)
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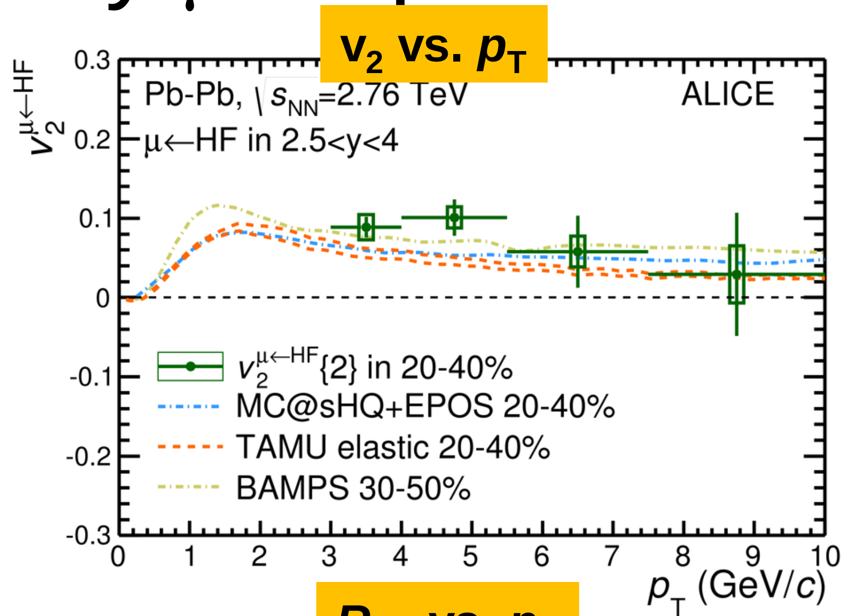
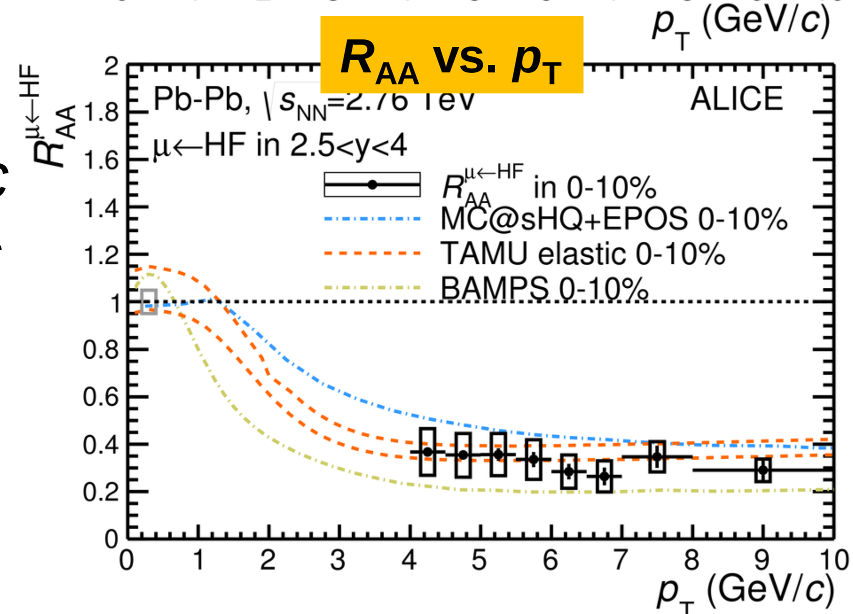
  - Extrapolation, detector simulation
- Significant v_2 for 3<p_T<5 GeV/*c*
  - Compatible with 0 above 5 GeV/*c*
- Simultaneous description of v_2 and R_{AA} imposes significant model constraints

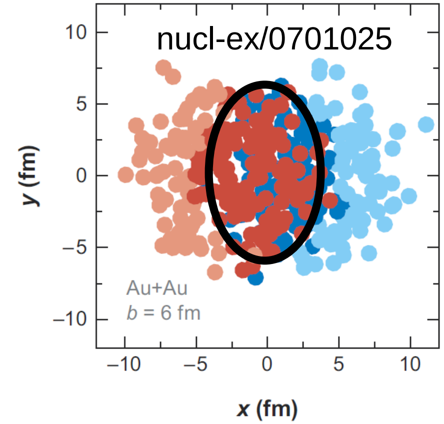




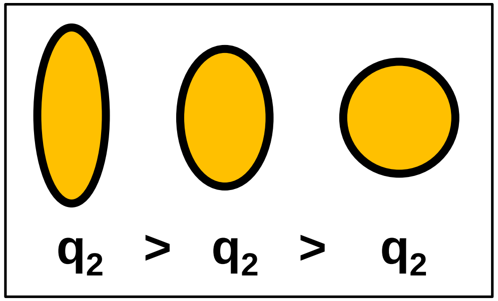
arXiv:1507.03134

Pb-Pb

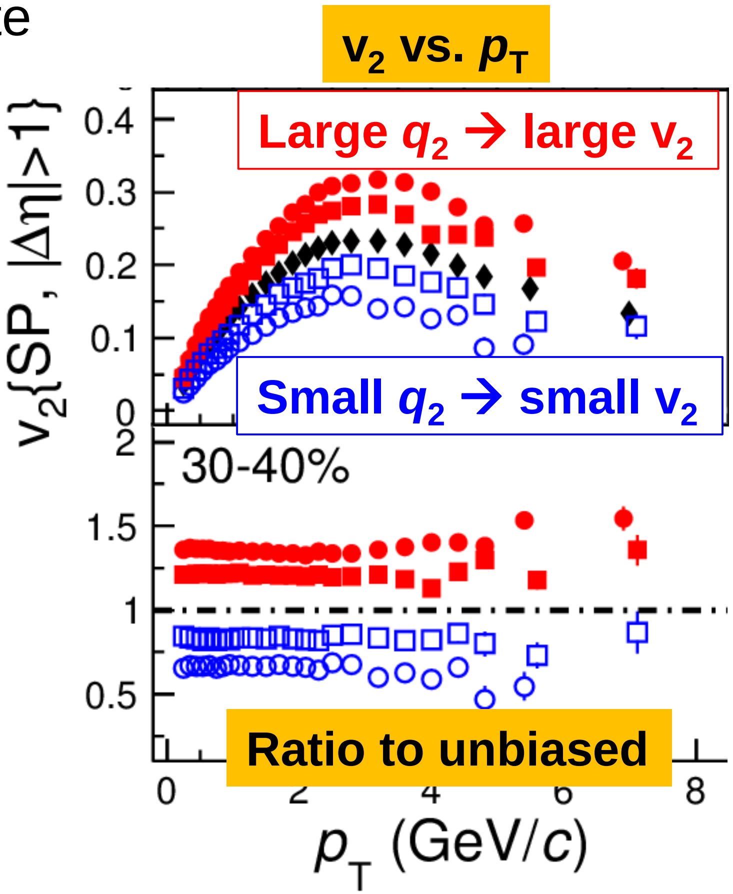
Event-Shape Engineering



- Novel method exploiting the large event-by-event variation of v_n (PLB719 (2013) 394)
  - Final-state v_2 correlated with initial-state eccentricities ε_2 (hydro with small η/s)
- Define event classes based on q_2 (measure of elliptic modulation)



$$q_2 = \frac{\sqrt{\left(\sum \cos 2\varphi_i\right)^2 + \left(\sum \sin 2\varphi_i\right)^2}}{\sqrt{M}}$$



  - Selection works along phase space
  - Bias on v_2 independent of p_T

Global event property is selected

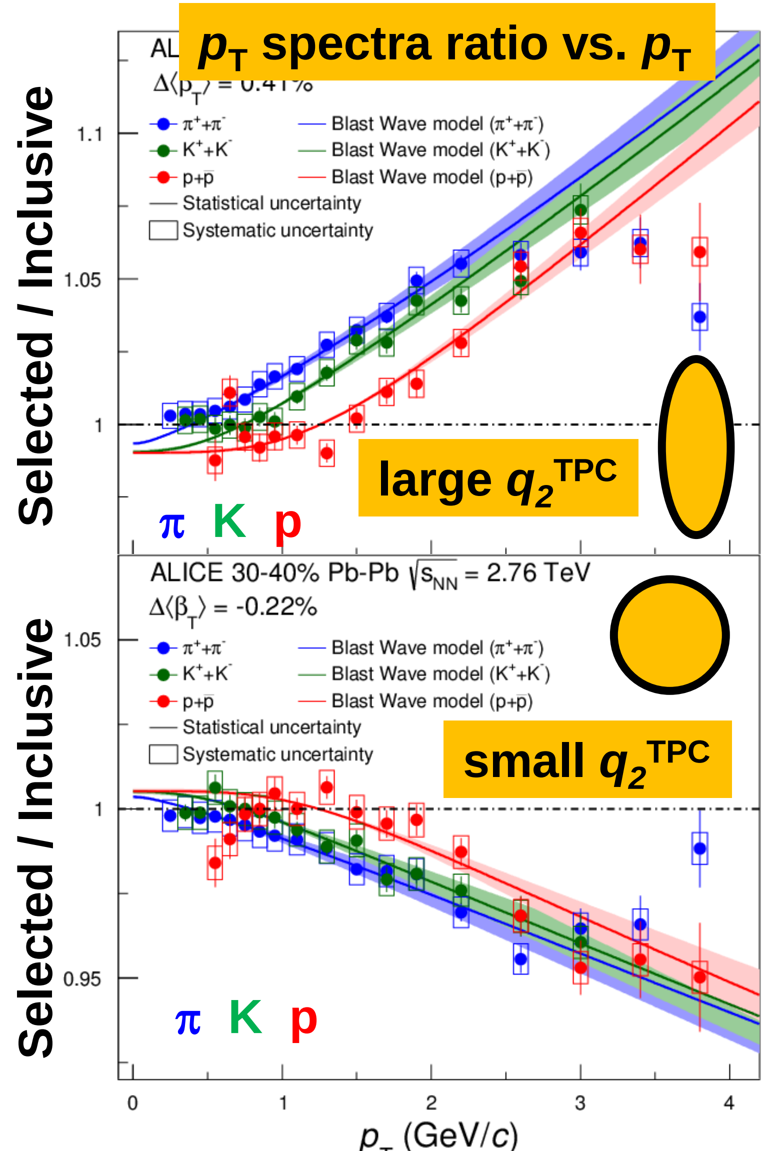
arXiv:1507.06194

Pb-Pb

Event-Shape Engineering (2)

- p_T spectra for π, K, p
  - Hardening for large q_2
  - Softening for small q_2
  - Magnitude depends on mass
- Quantify with Blast-Wave fit
  - Parameterization of hydrodynamic expansion
  - Fixed temperature T, allow change of expansion velocity β_T
  - β_T larger than inclusive for large q_2
  - β_T smaller than inclusive for small q_2
- q_2 (shape) and β_T (expansion) correlated

Significant input for initial state and hydrodynamic expansion models

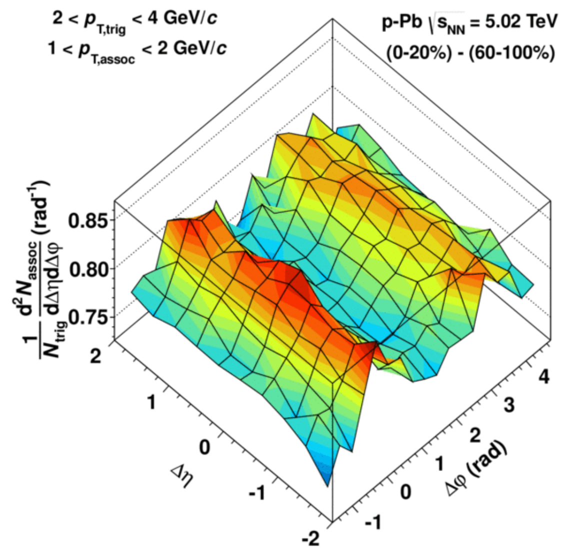


arXiv:1507.06194

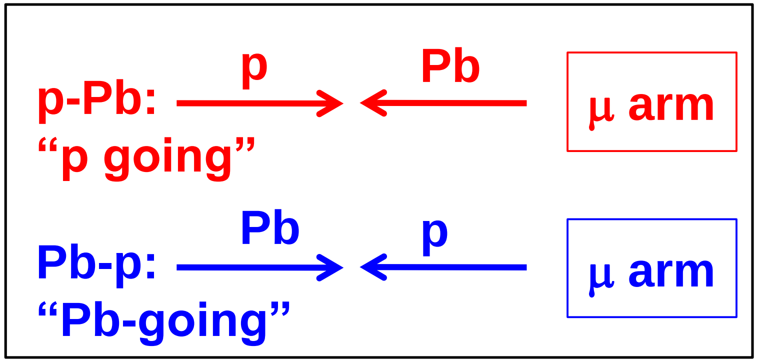
Blast-Wave: PRC 48, 2462 (1993)

p-Pb

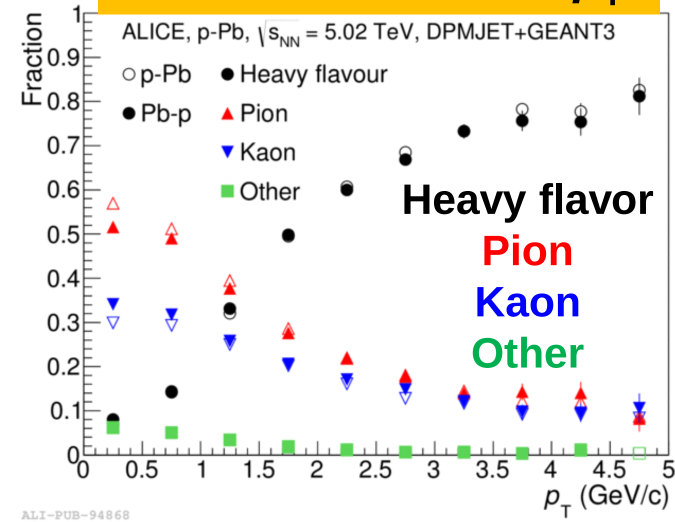
Ridges in p-Pb Collisions



- Collective nature of ridges in p-Pb collisions established at mid-rapidity (8 particle cumulants, mass ordering)
  - How long range is this effect?
  - Differences of p and Pb side?
- Correlations of hadrons at mid rapidity (tracklets) and forward inclusive muons
  - μ dominated by π and K at low p_T, and
  - by heavy flavor decays for p_T > 2 GeV/c



Particle fraction vs. p_T



arXiv:1506.08032

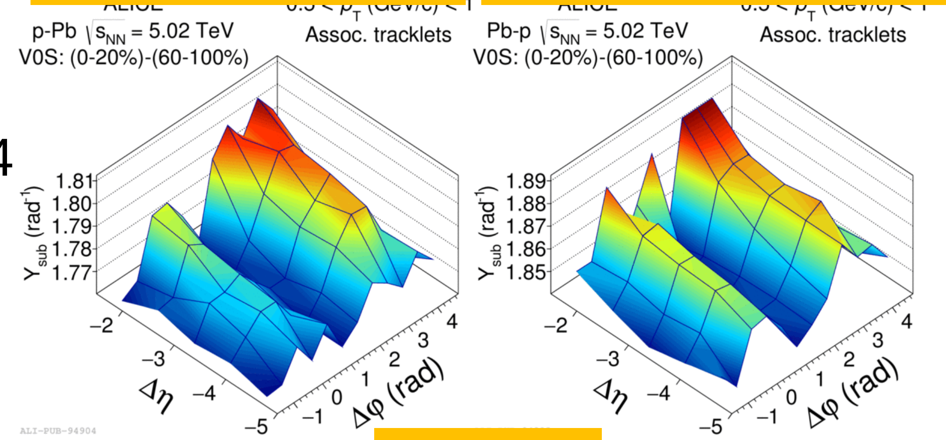
p-Pb

$\eta = \eta_{lab}$

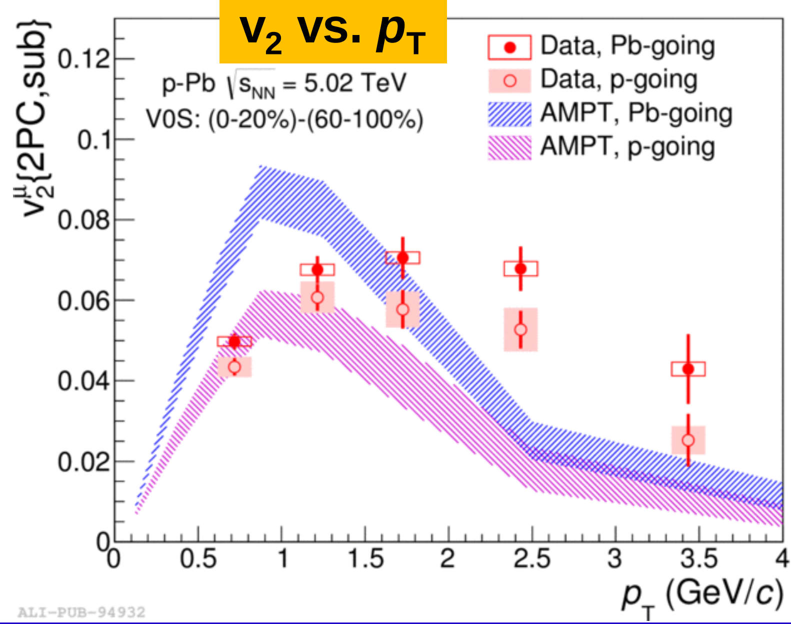
Forward-Central Correlations

- Jet contribution reduced by low-multiplicity subtraction
- Double ridge to $\Delta\eta \sim 5$ and $\eta \sim \pm 4$ (p and Pb-going)
- Quantified by $v_2^{\mu} = V_{2\Delta}^{\mu-h} / \sqrt{V_{2\Delta}^{h-h}}$
- p-going < Pb-going (16%)
- Comparison to AMPT model
  - Microscopic description of partonic and hadronic interactions
- Similar trend for inclusive μ
- For p_T > 2 GeV/c, HF > 60%
  - v_2^{HF}(AMPT) ~ 0
  - v_2^{HF} (data) > 0? or different particle composition?

p-going direction **Pb-going direction**



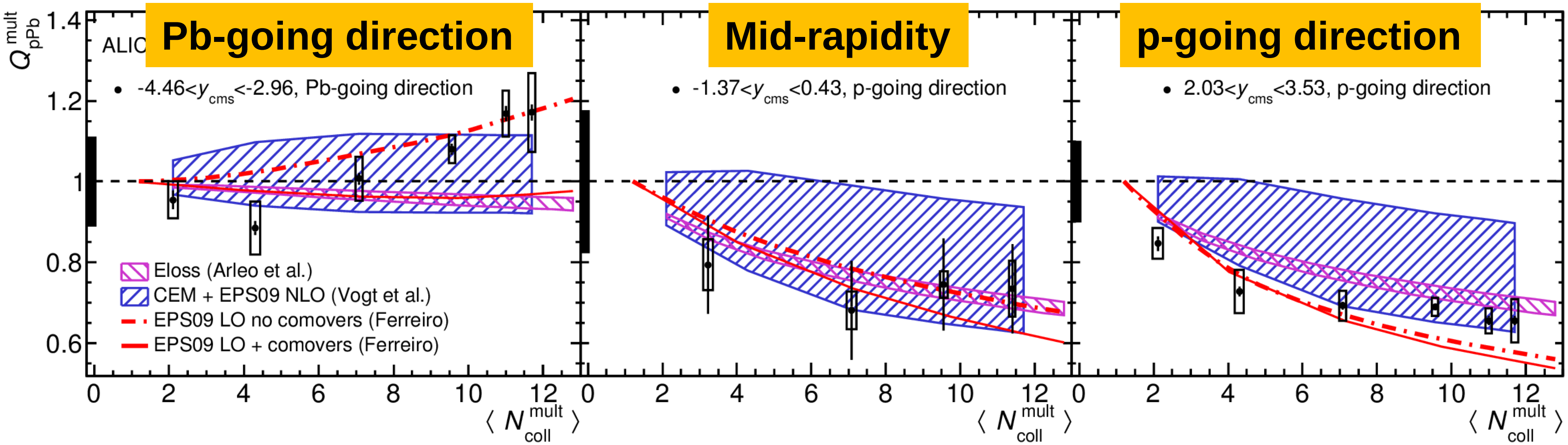
v_2 vs. p_T



arXiv:1506.08032

J/ψ Production in p-Pb

- J/ψ production as a function of event activity
- Compare to N_{coll} scaled pp (→ Q_{pPb})



- Slight enhancement in Pb-going direction
- Suppression at mid-rapidity and in p-going direction

Reproduced within uncertainties by cold nuclear-matter models

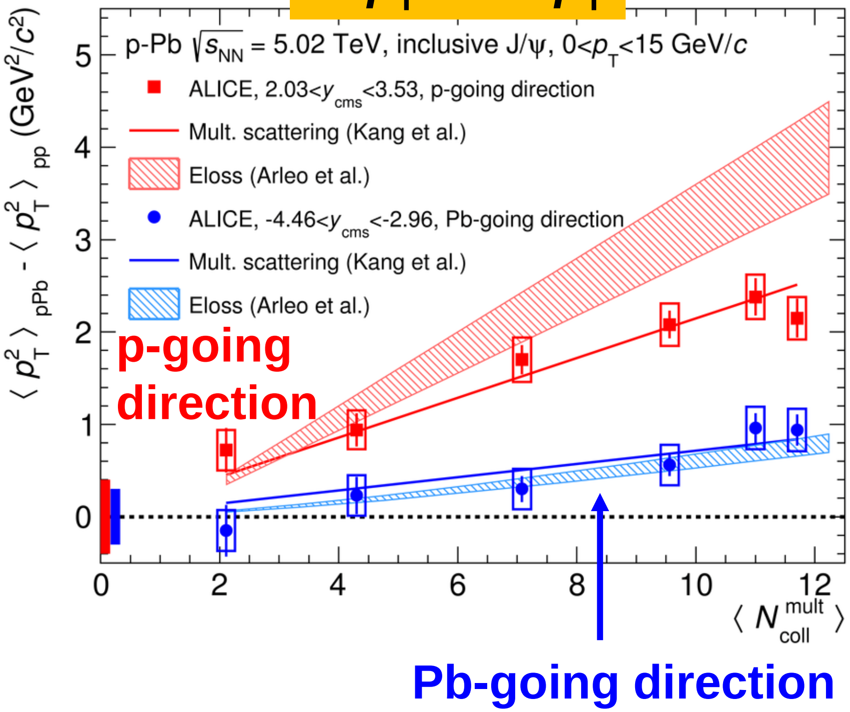
arXiv:1506.08808

J/ψ Production in p-Pb (2)

- $\Delta\left\langle p_{\mathrm{T}}^{2}\right\rangle = \left\langle p_{\mathrm{T}}^{2}\right\rangle_{pPb} - \left\langle p_{\mathrm{T}}^{2}\right\rangle_{pp}$

- Harder p_T distribution with increasing event activity
- Larger $\langle p_T^2 \rangle$ in p-going direction than in Pb-going direction

$\Delta\langle p_T^2\rangle$ vs. p_T



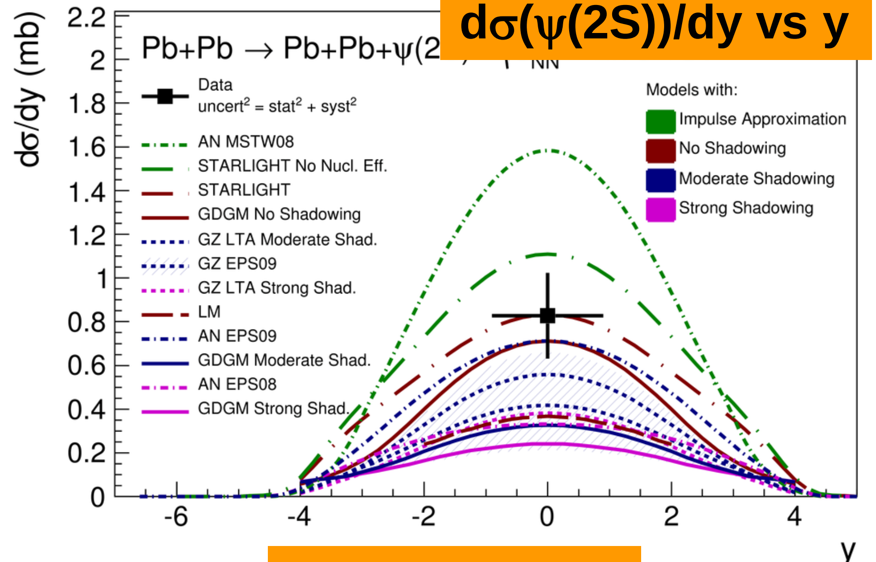
Model comparison suggests influence of initial and final-state rescattering

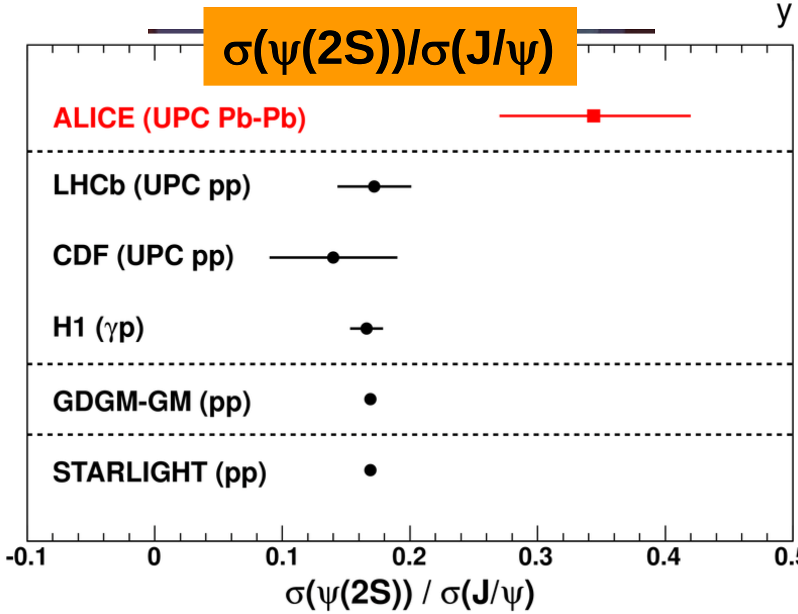
arXiv:1506.08808

Pb-Pb

Ultra-Peripheral Collisions

- Exclusive $\psi(2S)$ photo-production in nuclear target
  - $\psi(2S) \rightarrow l^+l^-$
  - $\psi(2S) \rightarrow l^+l^- + \pi^+\pi^-$
  - (separate in $\mu\mu$ and ee channel)
- Model constraints
  - Uncertainties on baseline
  - Strong shadowing disfavored
- Surprising difference of $\sigma(\psi(2S))/\sigma(J/\psi)$ in Pb-Pb and pp
  - Nuclear effects different for 1S than for 2S state?



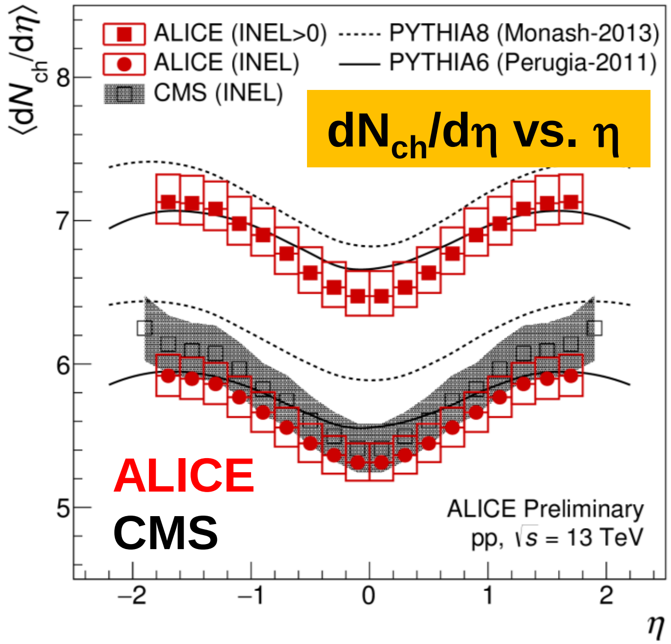


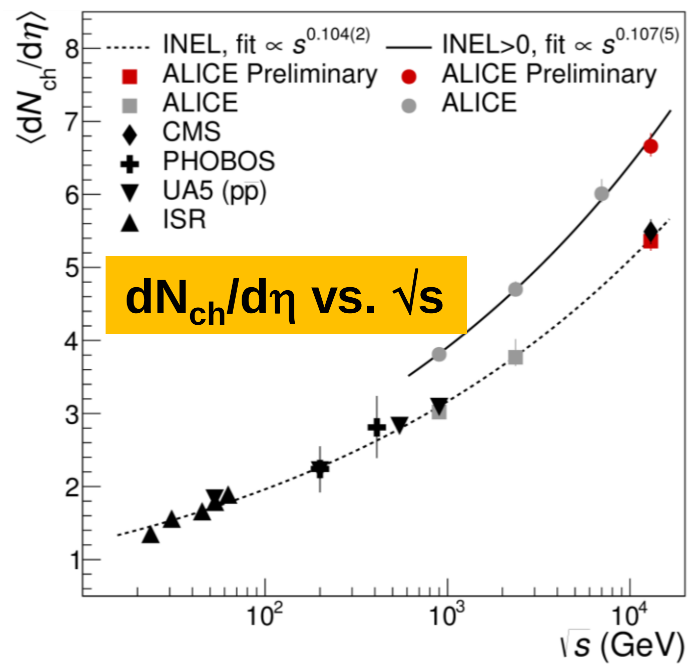
arXiv:1508.05076

pp

$dN_{ch}/d\eta$ @ 13 TeV

- Minimum-bias trigger using V0 and AD (new detector)
  - $-3.7 < \eta < -1.7$, $2.8 < \eta < 5.1$
  - $-7.0 < \eta < -4.8$, $4.9 < \eta < 6.3$
  - – Sensitive to about 96.6% of inelastic cross section
- Tracklets in two innermost detector layers (SPD, 3.9 cm, 7.6 cm)
- Two event classes
  - – Inelastic events
  - – At least one charged particle in $|\eta| < 1$
- ALICE and CMS consistent





ALICE-PUBLIC-2015-005

Summary

Large number of Run I analyses finalized across all ALICE topics

Precision Measurements

- Mass difference of nuclei and antinuclei → bound on CPT invariance
- Sign of quark mass dependence in heavy flavor energy loss?

Novel Techniques

- Hadron-jet correlations assess charged jets at 20 GeV/c in Pb-Pb
- Event shape engineering maps out initial state and hydrodynamical expansion

Plus many more, including first results at 13 TeV

ALICE up and running … eagerly waiting for heavy ions