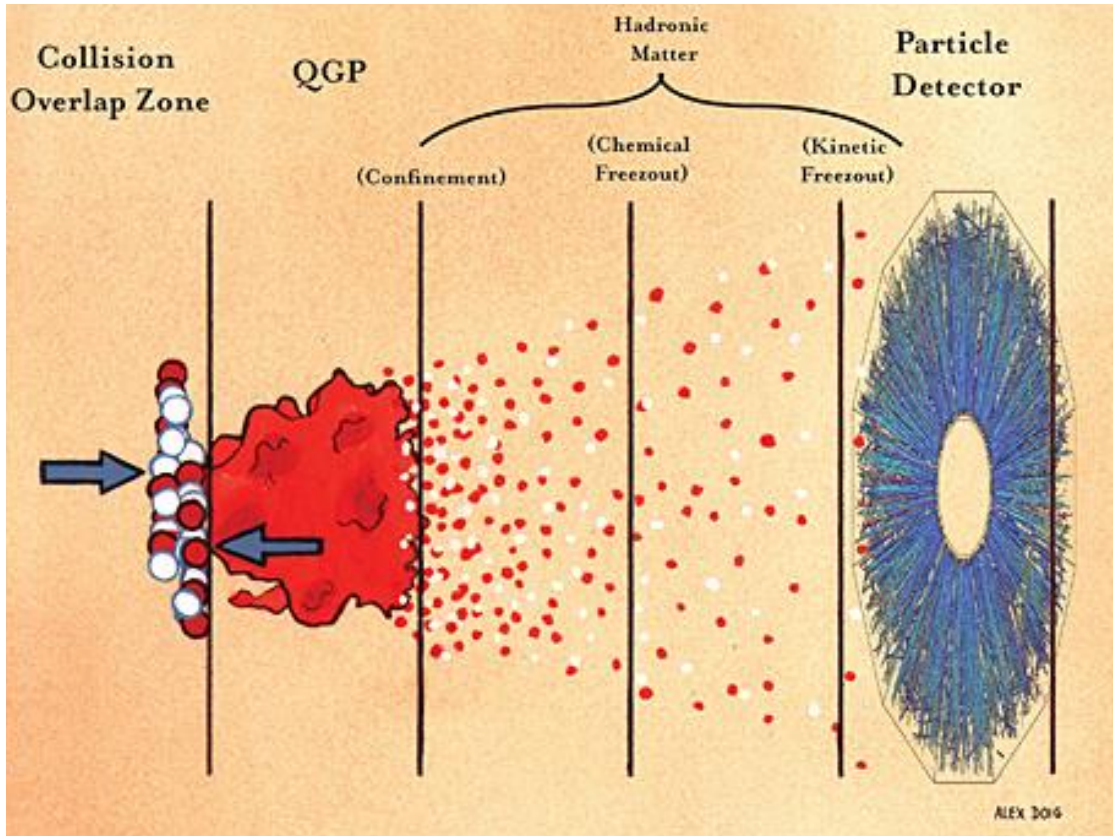


ALICE report

Anthony Timmins (ALICE-USA coordinator)

QCD in extreme conditions

Lattice QCD predicts **rapid change in hadronic thermodynamic properties** at critical temperature $T_c \approx 155$ MeV

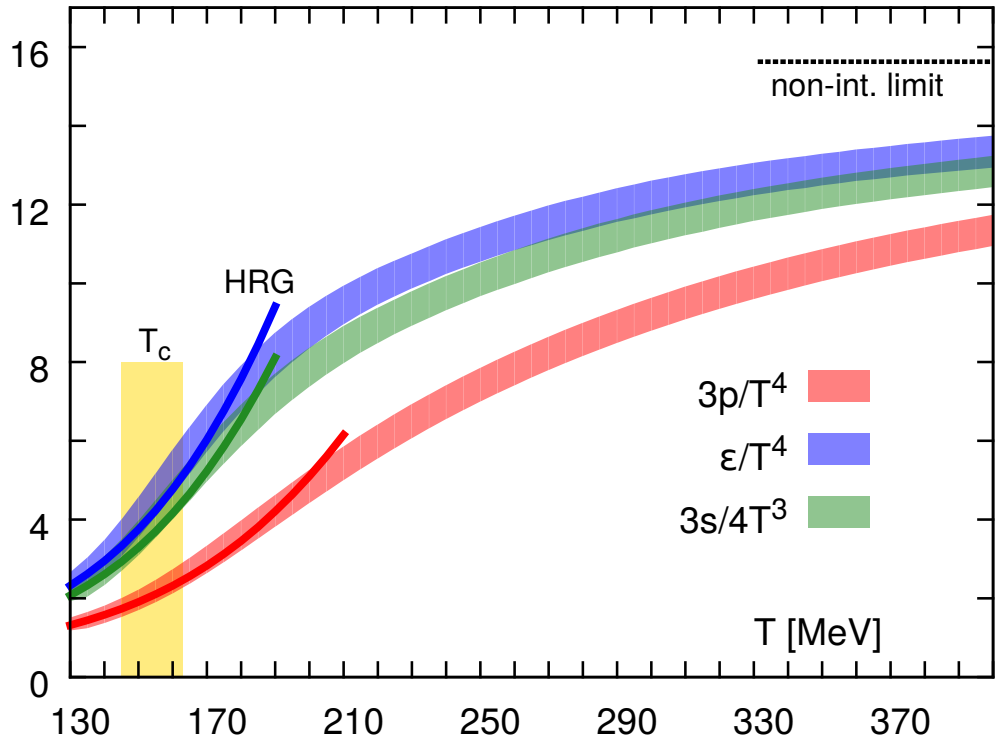
Formation of **quark-gluon plasma (QGP)**

✓Quarks & gluons no longer confined

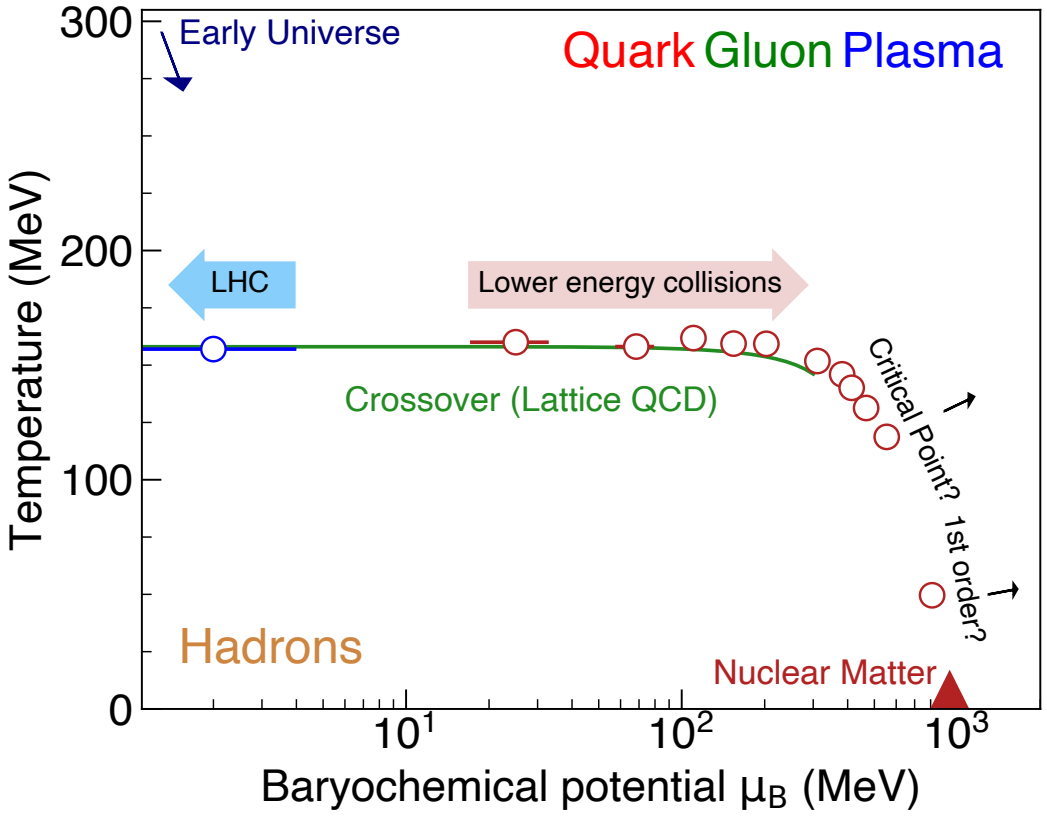
✓Chiral symmetry restored → loss of dynamical quark mass

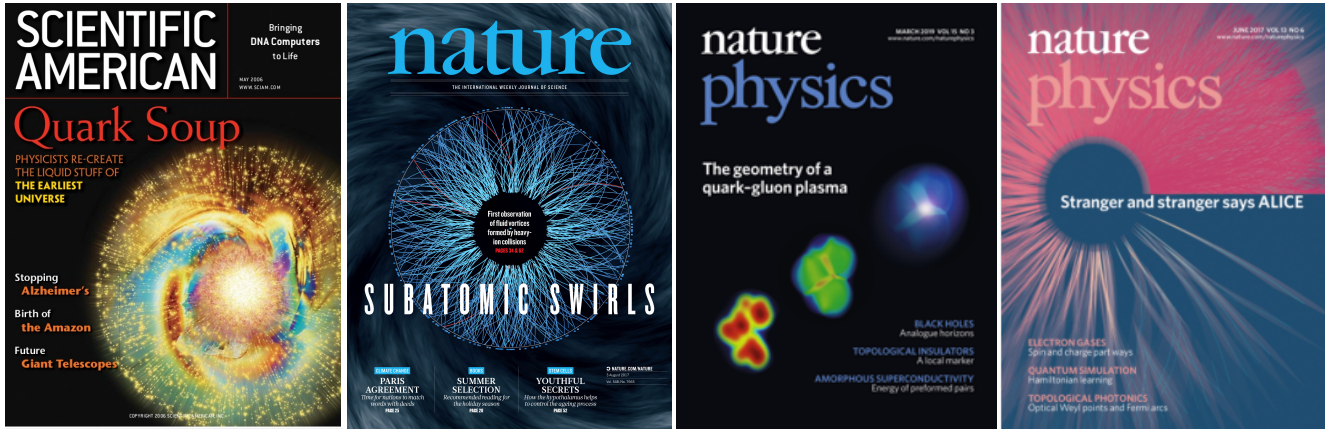
LHC heavy-ion collisions provide conditions that greatly **exceed QGP critical parameters…**

Hot QCD, PRD 90 (2014) 094503



Worldwide QGP studies





QGP at LHC has **highest temperatures** at $\mu_b \approx 0$ MeV

✓Similar to early universe ~10^{-6} seconds after big bang

Ongoing high energy nuclear collisions at RHIC → **new sPHENIX detector** and STAR

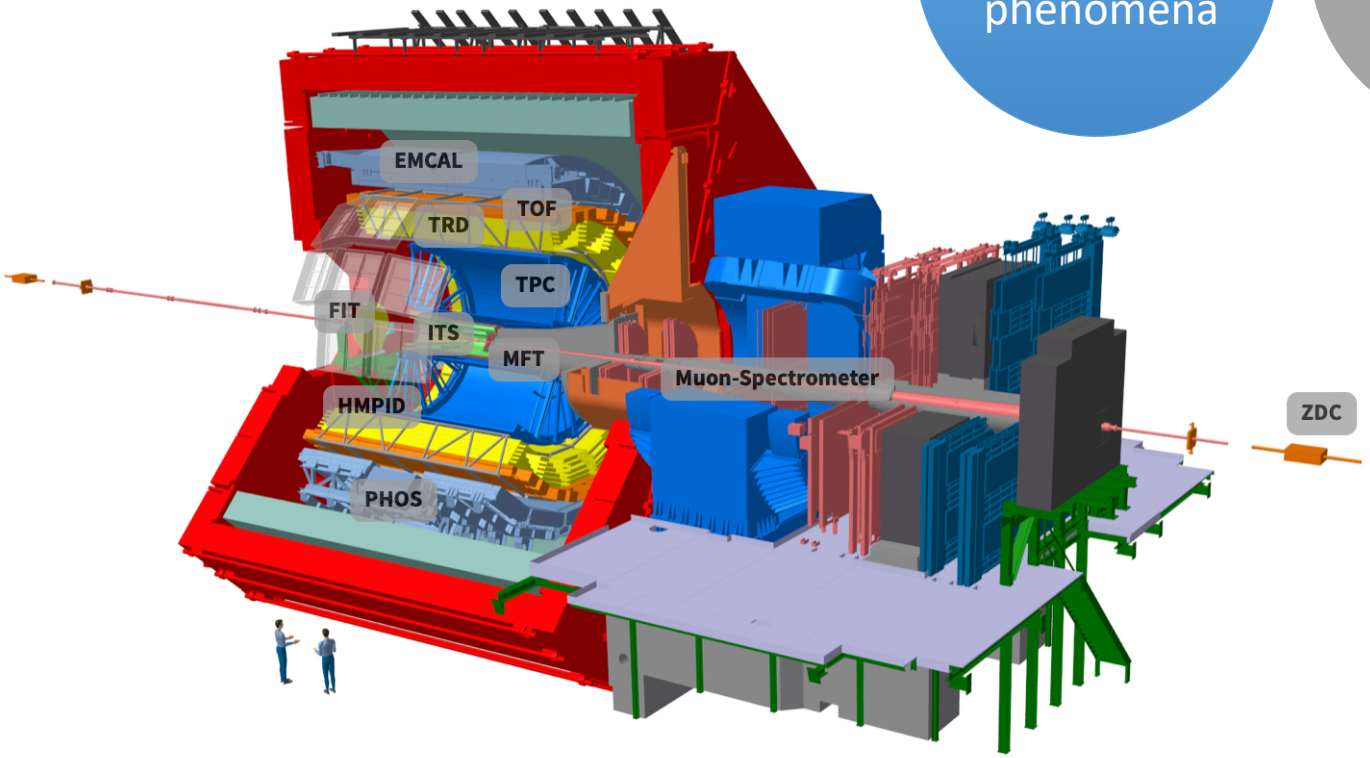
✓ Other programs at lower energies (e.g. SPS, FAIR)

ALICE physics program

Stellar and interstellar phenomena

Few body QCD

QGP properties



Rare hadron and nuclei interactions

Thresholds of QGP formation

Interior probes of protons and nuclei

Large acceptance and **world leading particle identification** probes all aspects of **QGP behavior**

✓Broad physics program utilizing heavy-ion and pp collisions

ALICE collaboration and US leadership

Largest heavy-ion experiment in world terms of membership

US scope → 13 institutes & ~120 members

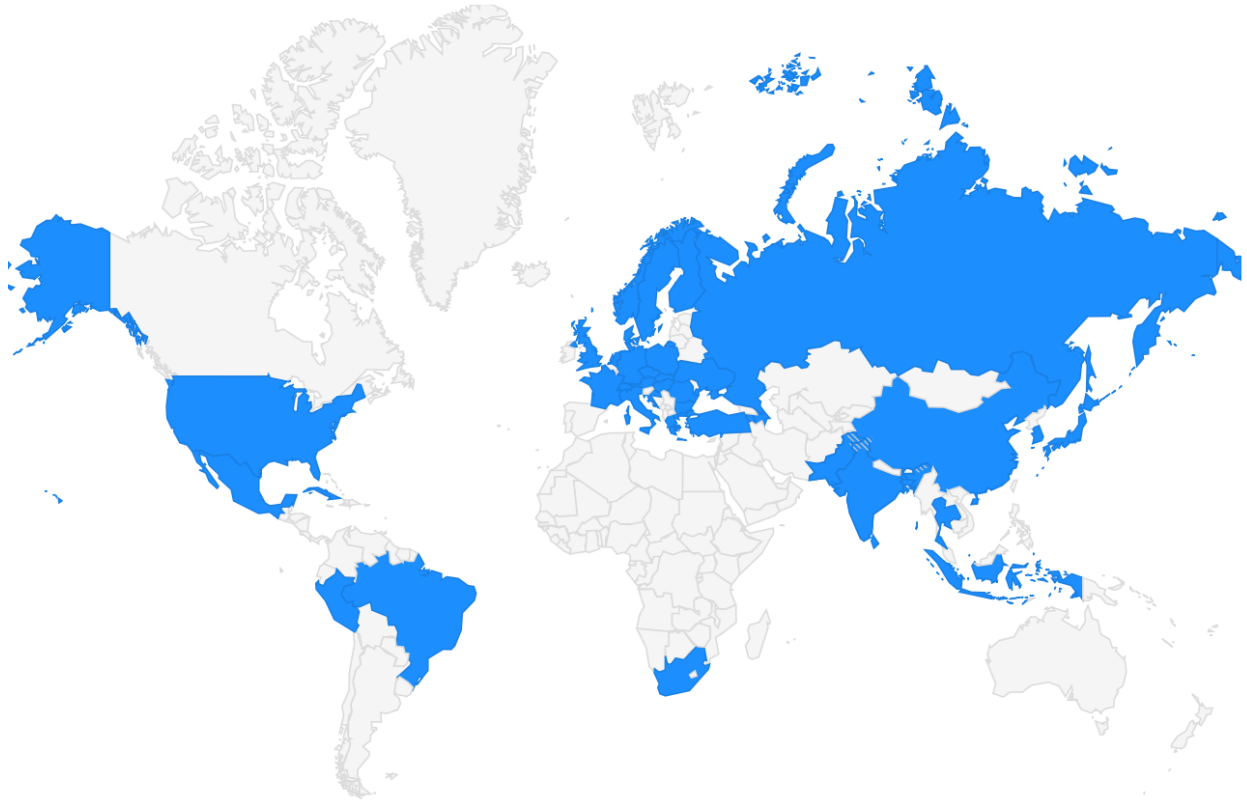
✓ Major contributions to EMCAL construction (Runs 1 & 2), **TPC and ITS upgrades** (Run 3)

✓ Two Tier-2 grid centers at LBNL and ORNL → **New analysis facility at LBNL**

✓ ~6% of total members and involved in **~25% of ALICE physics publications**

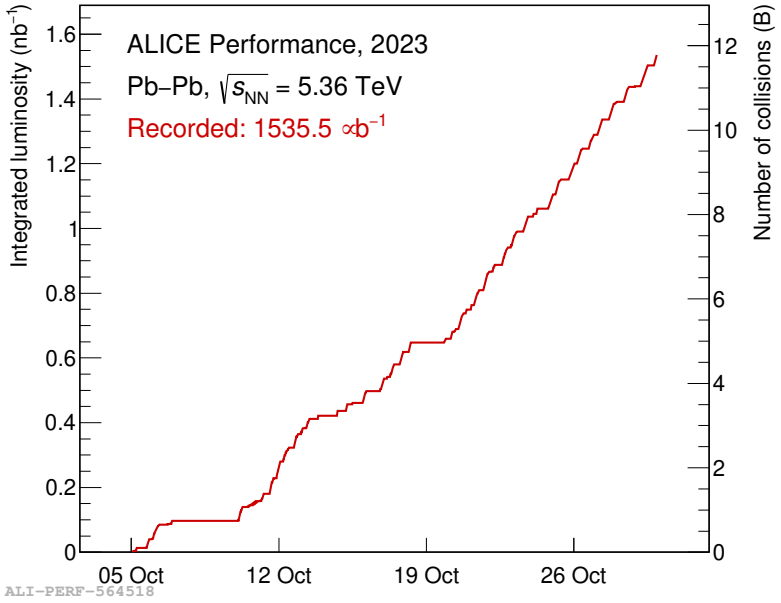
https://sites.google.com/lbl.gov/alice-usa

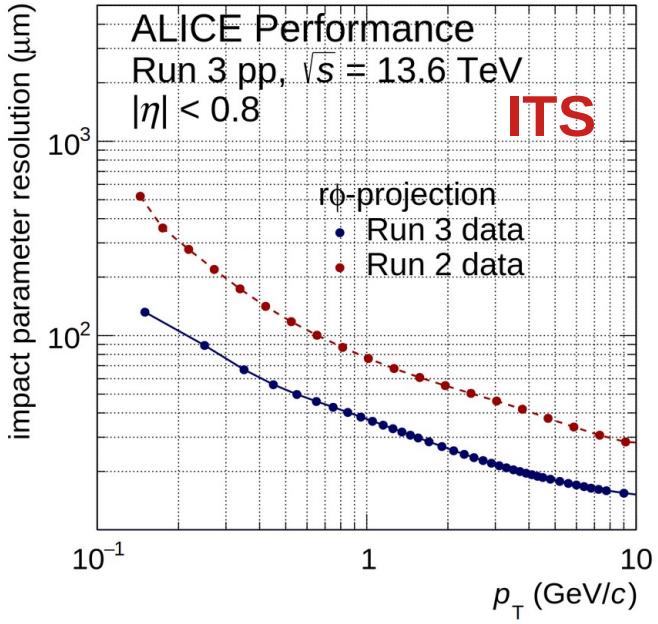
40 countries, 171 institutes, 2020 members

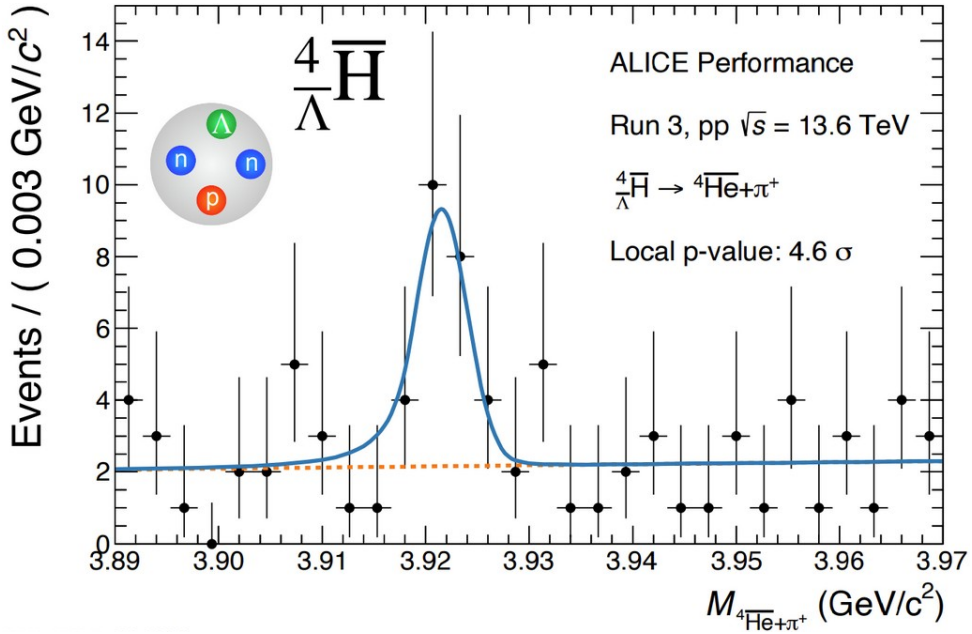


Status of data taking in Run 3

First signal!





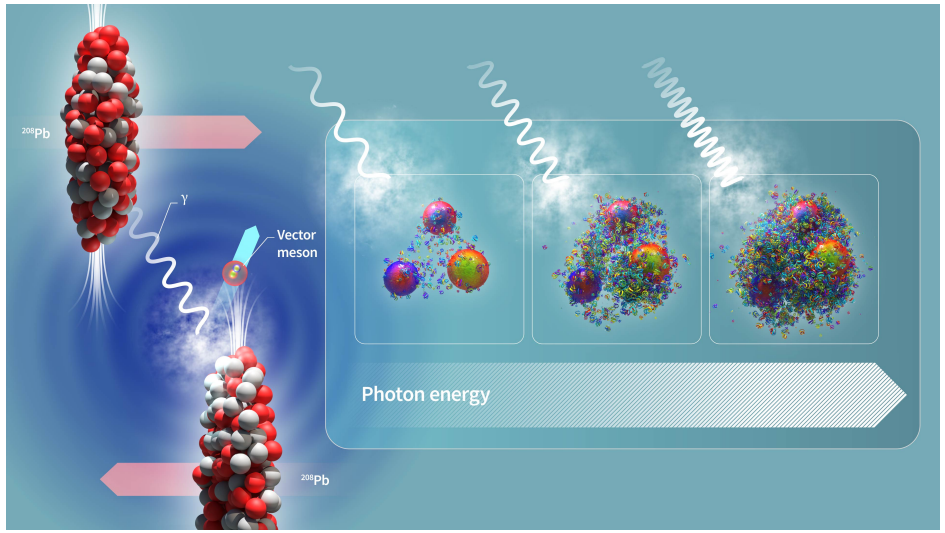


https://home.cern/news/news/experiments/alice-bags-about-twelve-billion-heavy-ion-collisions

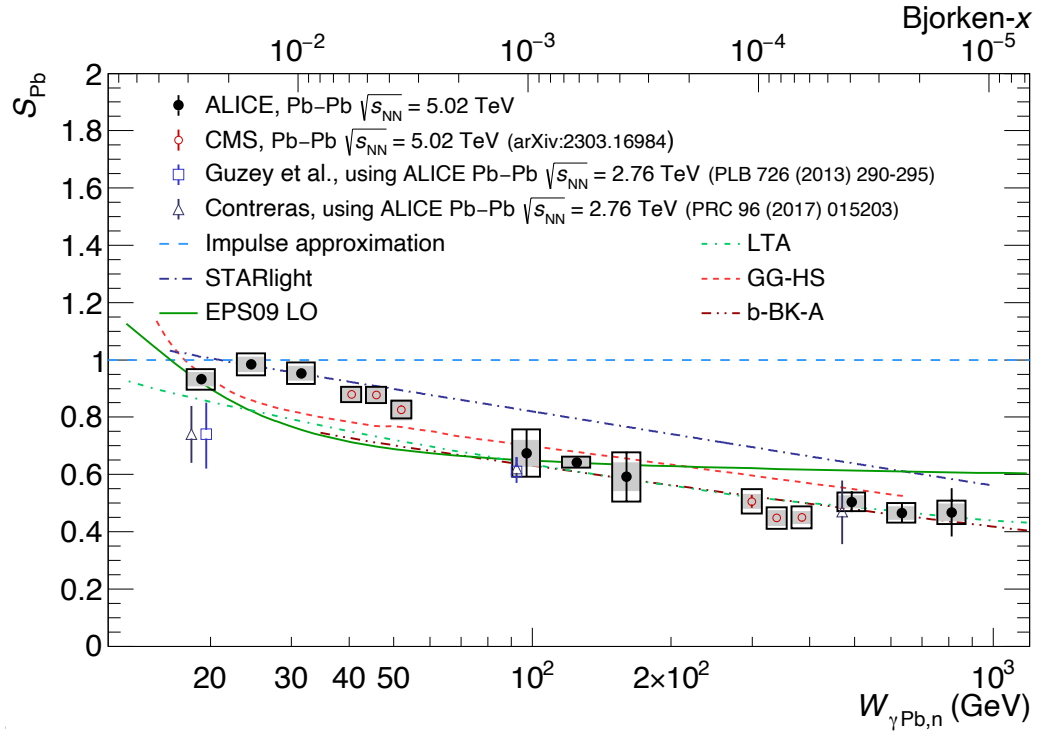
Hugely successful heavy-ion run this year → recorded 40x times data than Runs 1&2 courtesy of new continuous readout TPC

✓Taken ~30 pb of pp data → 500x times more than Runs 1&2 with **greatly improved track resolution**

Shinning light on the nucleus



https://home.cern/news/news/physics/alice-shines-light-nucleus-probe-its-structure

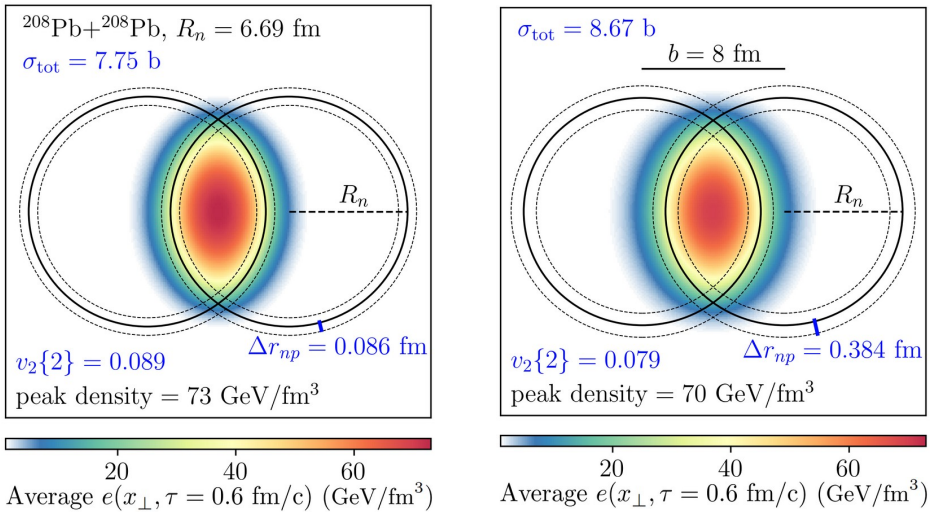


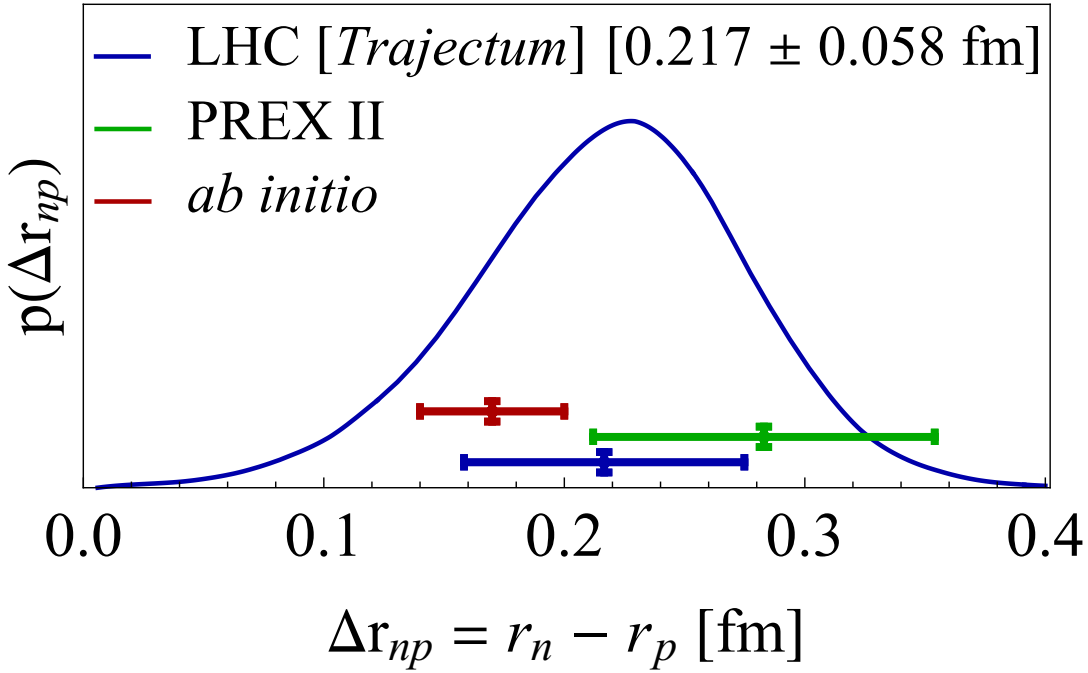
Coherent J/Ψ cross section in Ultra Peripheral Collisions (UPC) mirrors gluon distribution at low x

✓Clear suppression for nuclear cross sections at $x << 10^{-2}$

Long sought after evidence of **saturation of nuclear gluon PDF** (**GG-HS**) or other effects (**LTA**, **EPS09**)?

^{208}Pb neutron skin depth with ALICE data





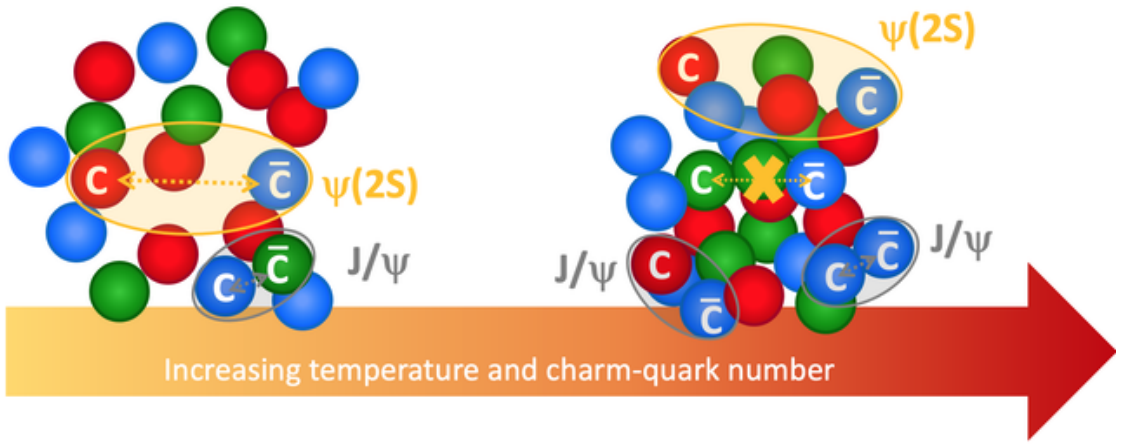
https://home.cern/news/news/physics/thick-skinned-using-heavy-ion-collisions-lhc-scientists-determine-thickness

Large neutron skin Δr_{np} leads to more diffuse and spherical QGP → reduces QGP flow

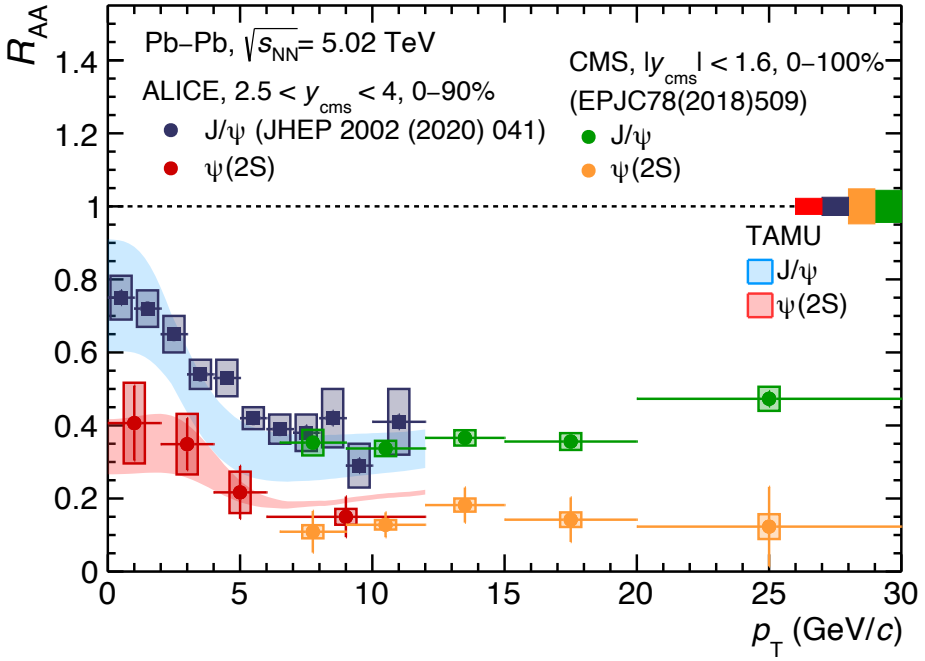
✓Bayesian analysis of v_2 and $\langle p_{\rm T} \rangle$ ALICE flow data offers **competitive constraints on Δr_{np}(Pb)**

✓**Relevant for neutron star equation of state…**

QGP suppression of hidden charm



https://home.cern/news/news/physics/alice-explores-hidden-charm-quark-gluon-plasma



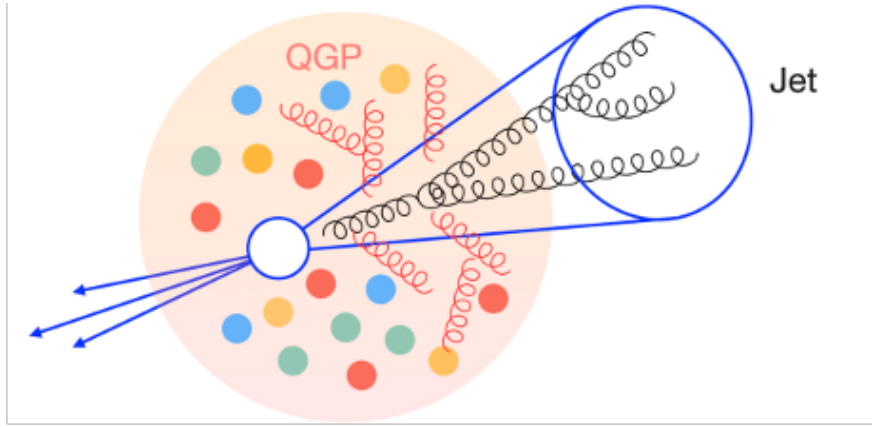
Quarkonia production probes QGP on sub fm scales → suppression in heavy-ions from QCD screening

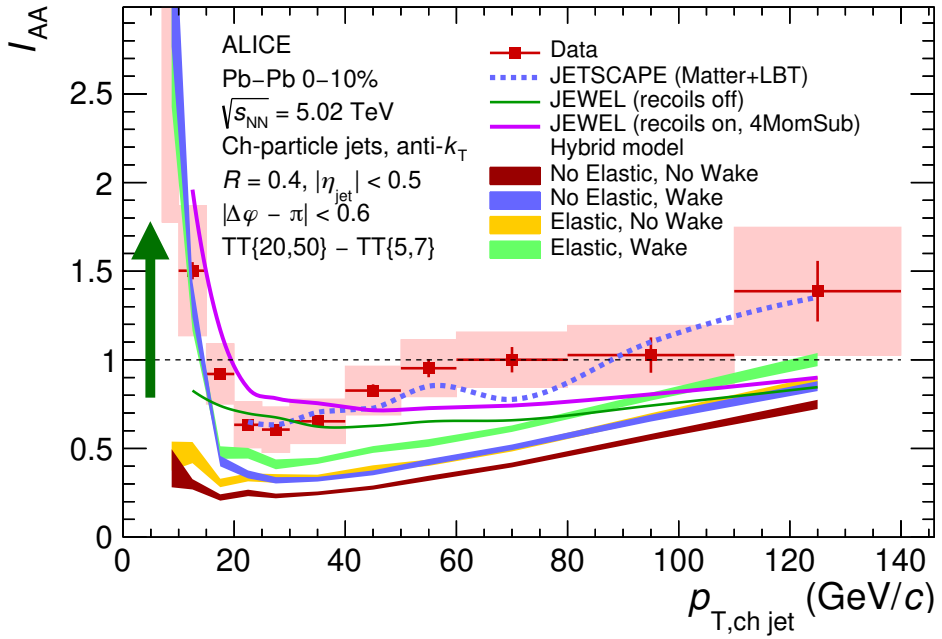
✓Ψ(2S) size ~0.4 fm roughly twice that of J/Ψ

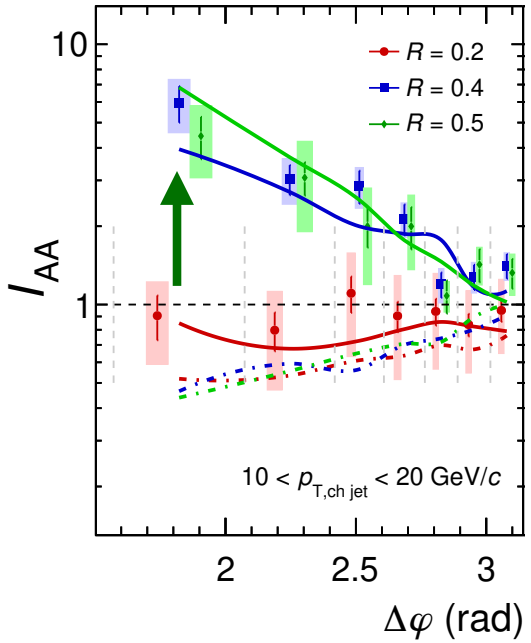
✓Clear indication of larger Ψ(2S) suppression → **QGP permeates smallest scales of parton interactions**

Jet interactions with QGP

LHC Seminar: https://indico.cern.ch/event/1312643/





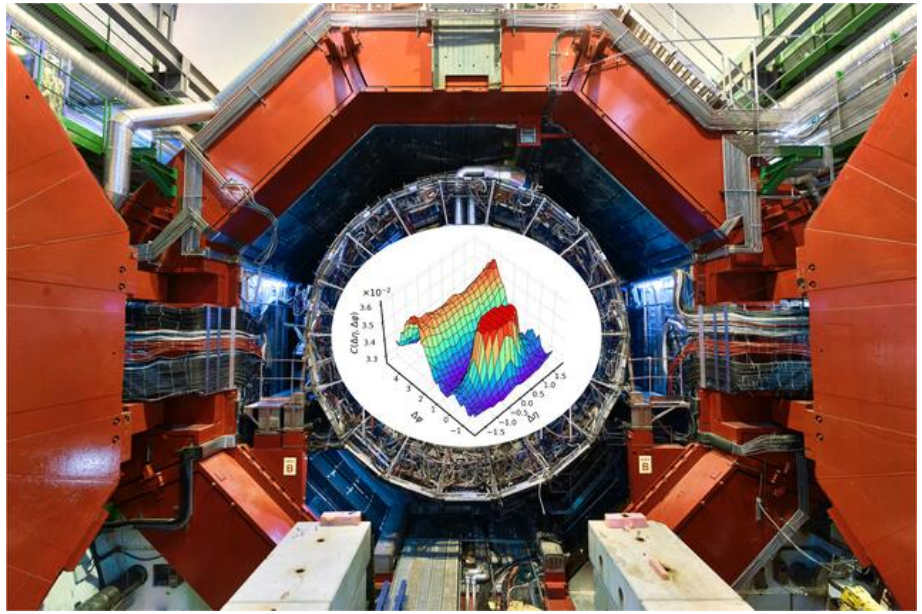


Jets are highest momentum probes of a QGP → finest resolution of **microscopic QGP structure**

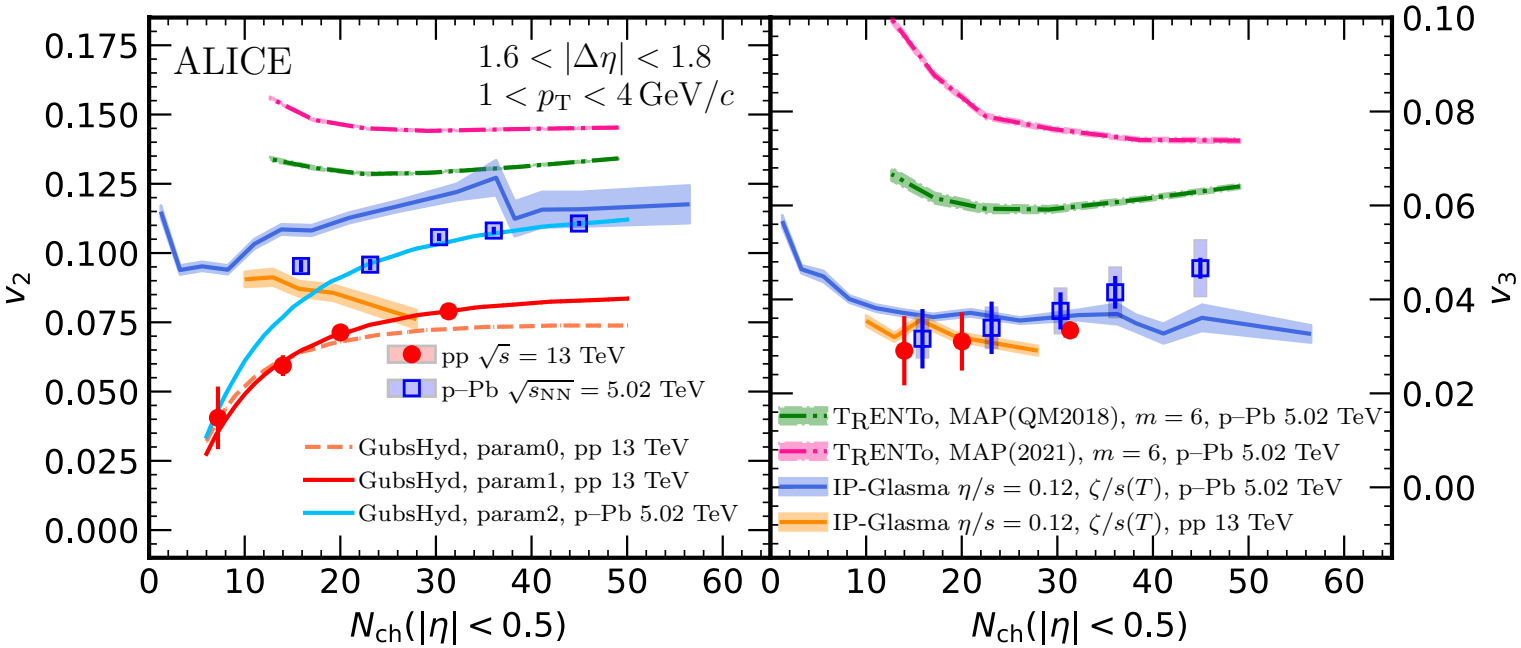
✓First observation of **enhancement of away-side jet yield** at low-p_T in Pb-Pb collisions

✓Described by QGP models of jet-medium interactions

Thresholds of QGP formation



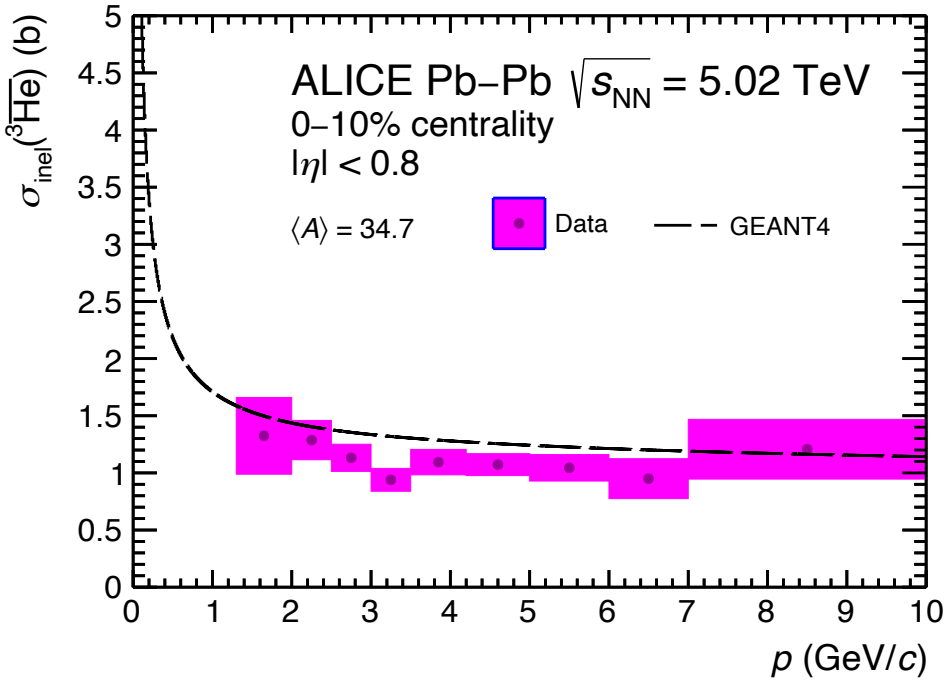
https://cerncourier.com/a/collectivity-in-small-systems-produced-at-the-lhc/

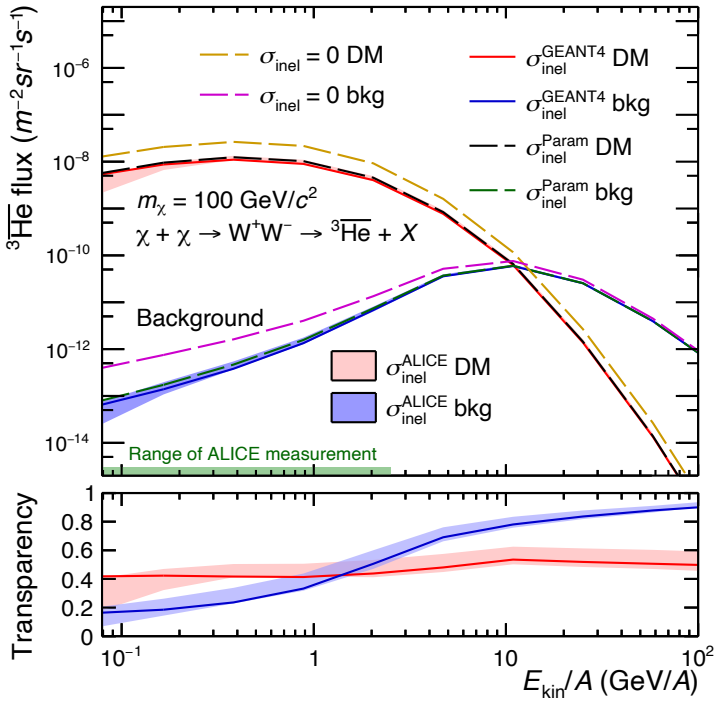


Discovery of **QGP-like effects in high multiplicity pp and p-Pb collisions** major finding at LHC

✓Recent ALICE results demonstrate QGP flow behavior **persists towards lower multiplicities**

Transparency of the milky way with ALICE





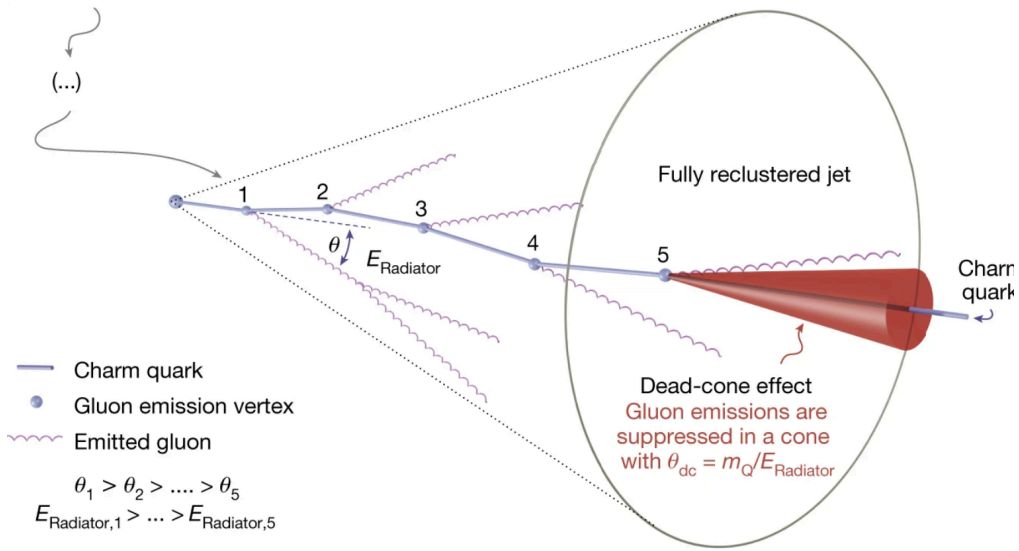
Nature Physics 19 (2023) 61–71

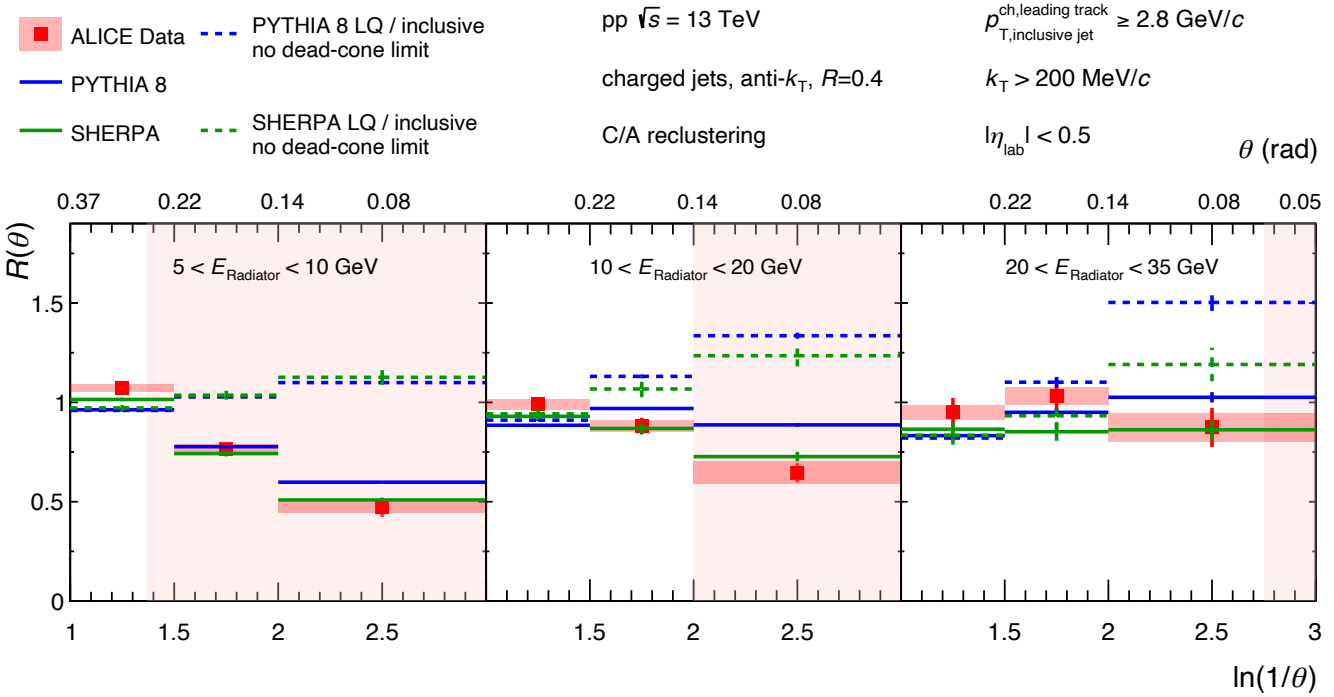
https://home.cern/news/news/physics/alice-estimates-how-transparent-milky-way-antimatter

Novel approach uses ALICE detector as target to **measure anti-He³ cross section**

✓Sensitive to **dark-matter (DM) interactions** → specific DM profile implies **transparency ~50%**

Discovery of QCD dead-cone effect





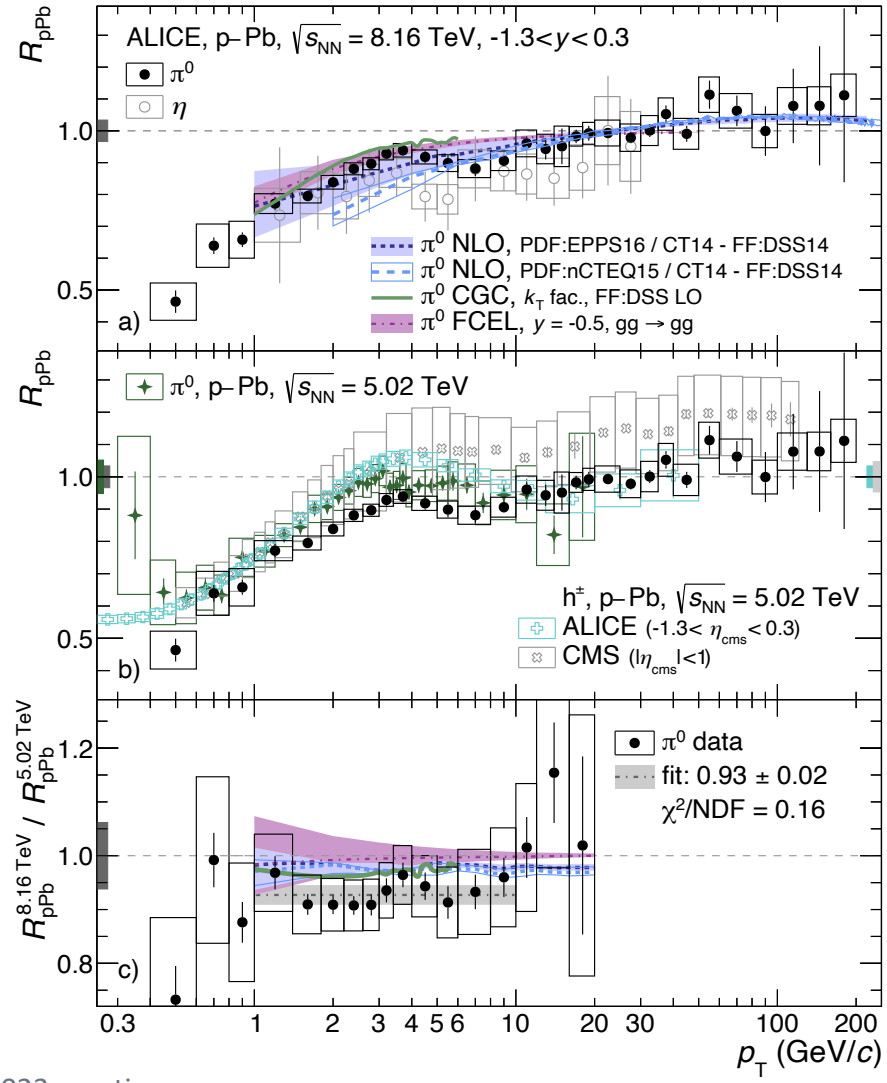
https://cerncourier.com/a/dead-cone-effect-exposed-by-alice/

Nature 605 (2022) 440–446

First direct observation of **gluon radiation suppression for charmed jets** in pp collisions

✓Fundamental feature of QCD and direct observation of non-zero (Higgs!) mass of charm quark

Pushing identified hadron production to limits



π⁰ measured up to $p_{\mathrm{T}} \sim 200$ GeV/c using in pp and p-Pb collisions using ALICE EMCAL

Suppression of meson production at low-p_{T} in p-Pb consistent with **gluon saturation or nuclear shadowing**

No sign of energy loss at high-p_{T}

✓Search for QGP-like jet-medium interactions in small systems continues…

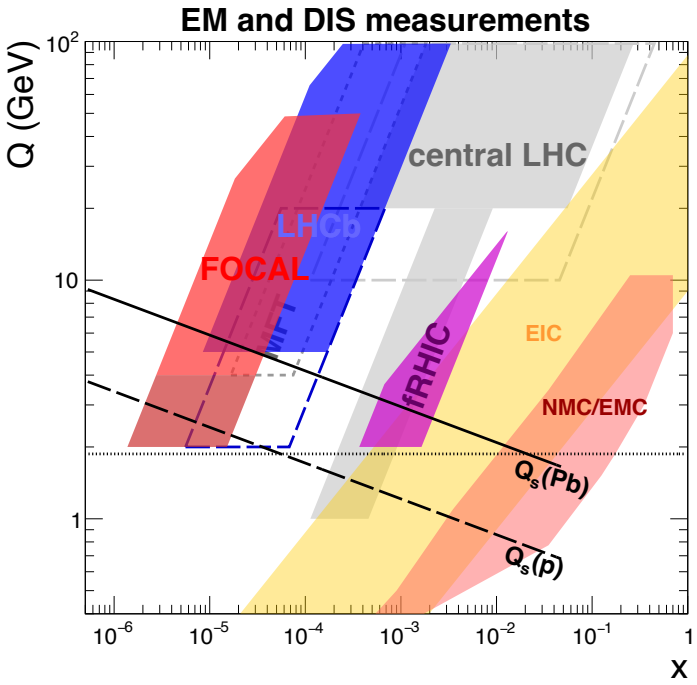
https://cerncourier.com/a/light-neutral-mesons-probed-to-high-pt/

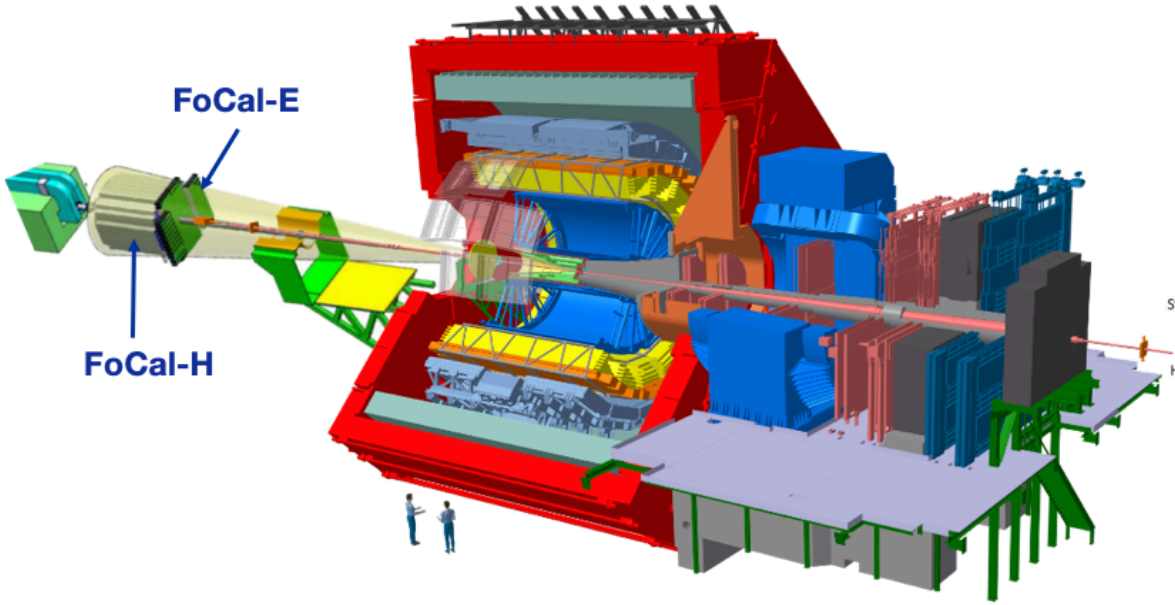
A. Schmier, Fri. at 8.40 am

ALICE in Run 4

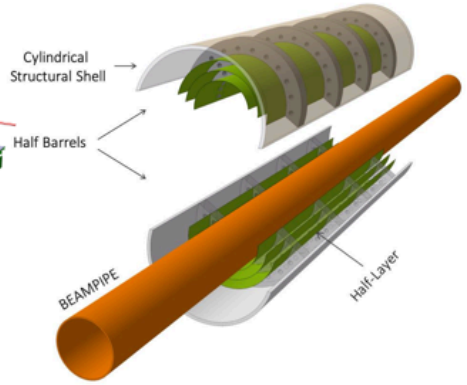
FoCal Letter of Intent (2020)
FoCal Physics (2023)
FoCal Physics Performance (2023)
TDR under review

Large US involvement





ITS3 Letter of Intent (2019)
TDR under review



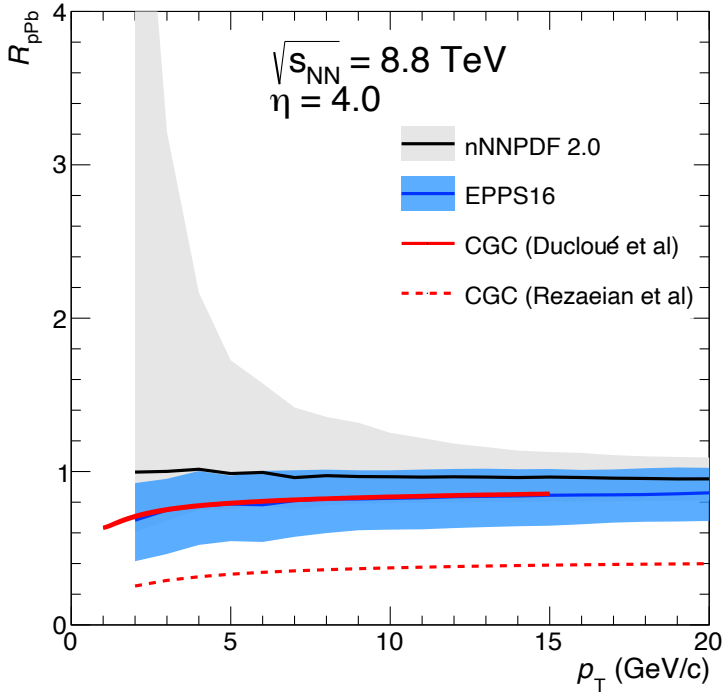
Forward Calorimeter (FoCal) and wafer-thin cylindrical **ITS3** to be installed

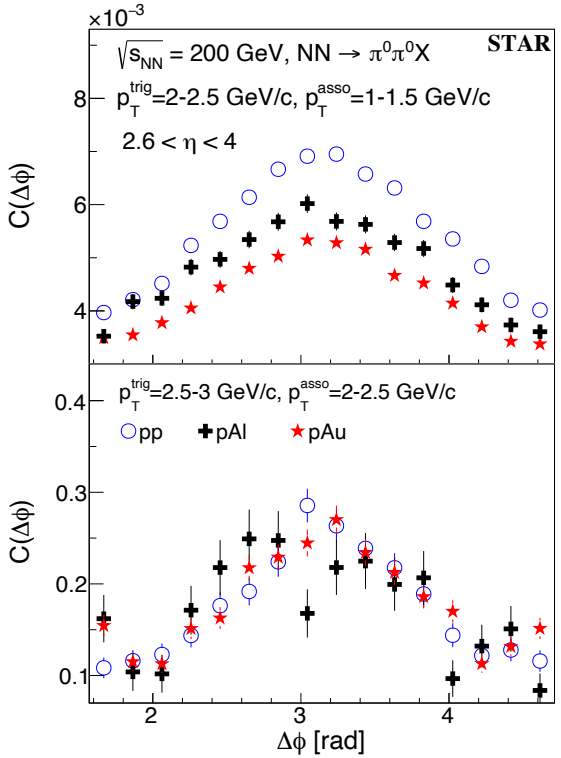
✓**ITS3** increases precision for heavy-flavor and electromagnetic probes in large & small systems

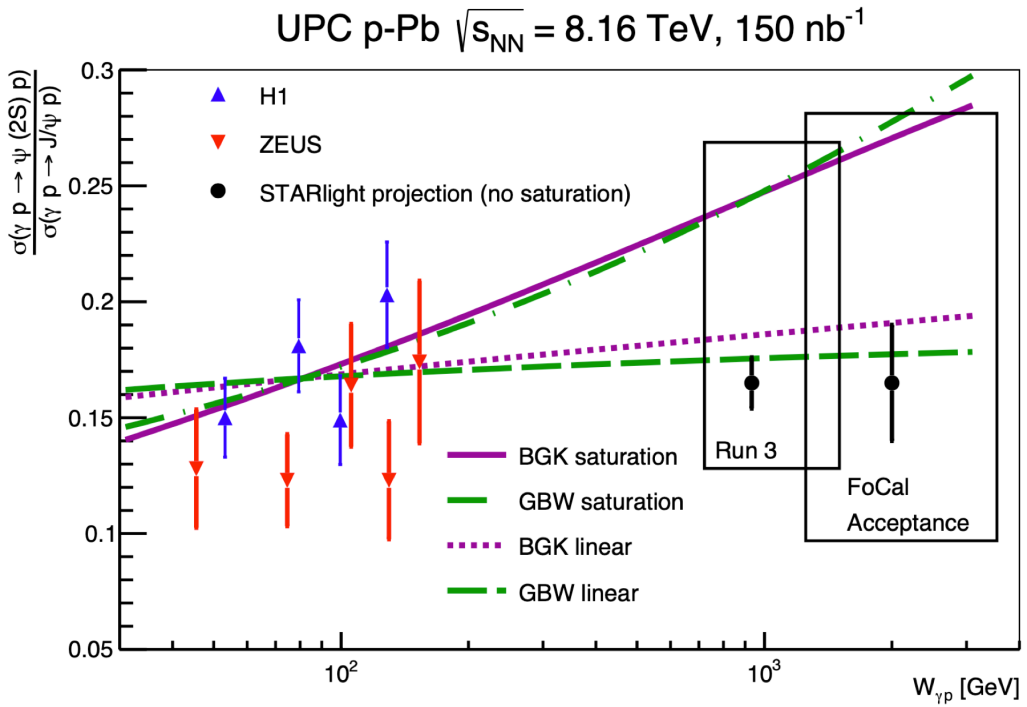
✓**FoCal** offers deepest explorations of **proton/nuclear structure** & complimentary to **future EIC studies**

A Gautam, Thurs. at 5.15 pm

Searches for gluon saturation with FoCal







Direct photon R_{pPb}

Compton scattering provides clean probe of gluon nPDFs

$\pi^0(\gamma)$-π^0 correlations

Bjorken-x reach 2 orders magnitude smaller than RHIC

UPC vector meson production

Quarkonia ratios highly sensitive to proton saturation

ALICE 3 - a next generation heavy-ion detector

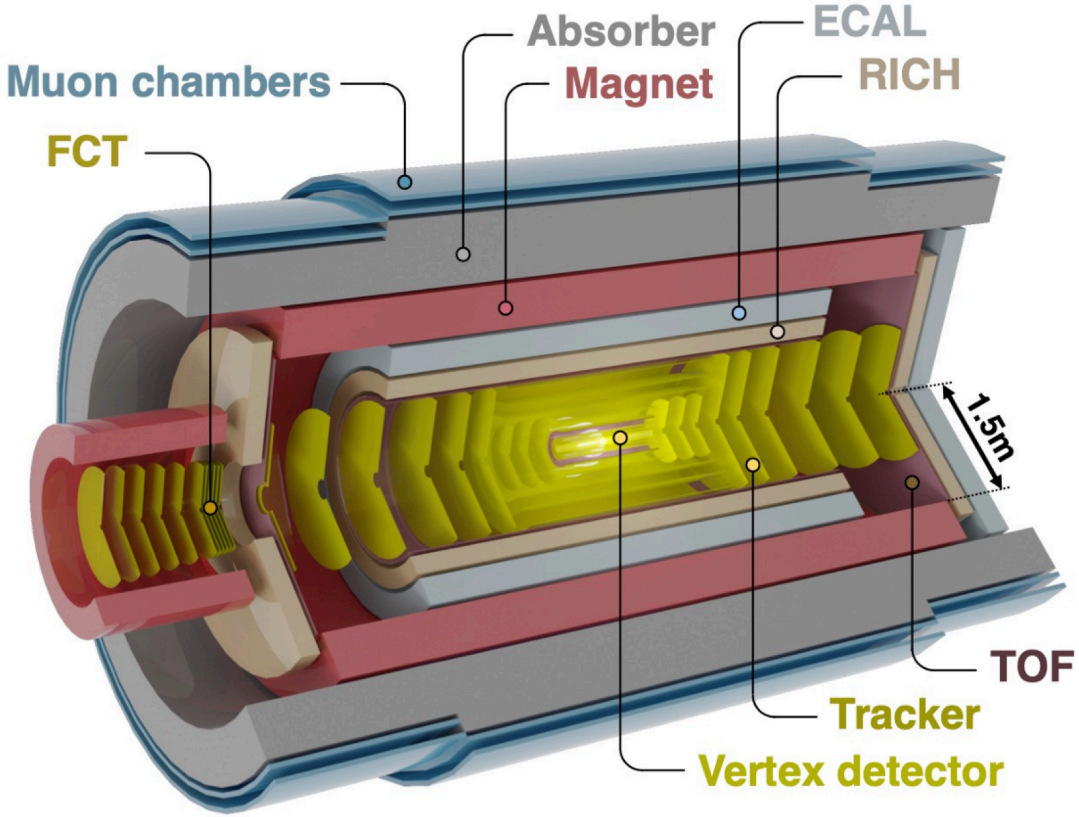
Compact all-silicon tracker with high-resolution vertex detector and **extremely low material budget** for **Run 5**

✓Superconducting magnet system up with B=2 T

Particle Identification over large acceptance: muons, electrons, hadrons, photons

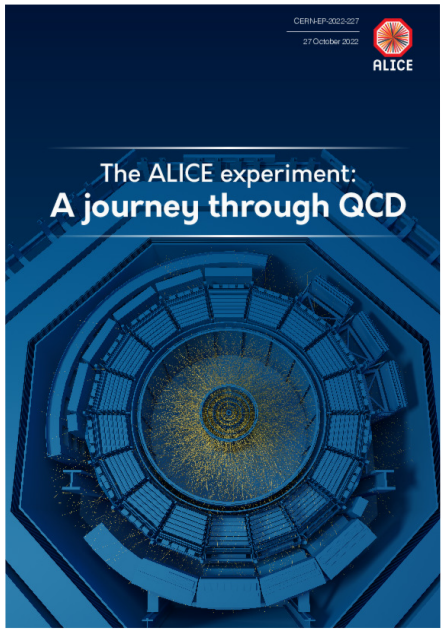
✓Fast read-out and online processing

Detector R&D for **next generation experiments synergies** between ALICE 3, EIC, FCC-ee



ALICE 3 physics program

arXiv:2211.04384



Key **QGP findings** from Runs 1 & 2 **with ALICE**

✓Evolves as almost perfect fluid that quenches jets

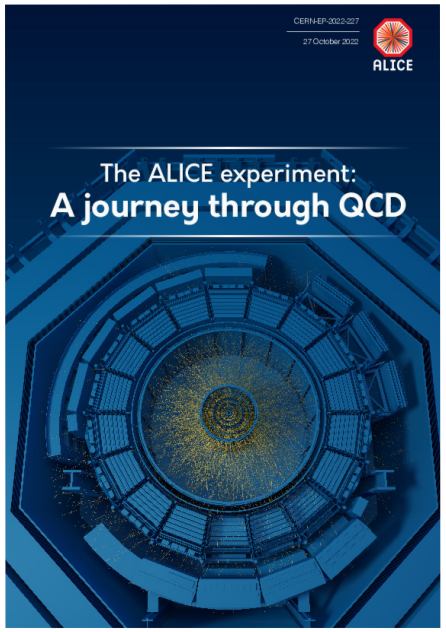
✓Produces light hadrons in apparent thermal equilibrium

✓Readily couples with heavy quarks

✓Indications formed in small systems

ALICE 3 physics program

arXiv:2211.04384



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- ✓Indications formed in small systems

What is **ALICE 3** designed to discover and explore?

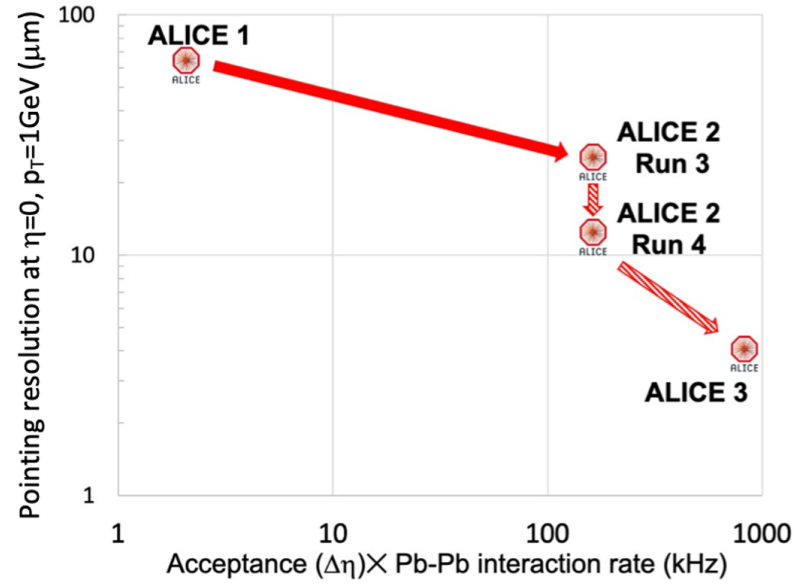
- ✓QGP temperature evolution and when equilibrium achieved
- ✓Limits and precision on heavy quark QGP diffusion
- ✓Nature of QCD phase transition at $\mu_b \sim 0$
- ✓Exotic hadron production mechanisms and hadronic interactions
- ✓Beyond Standard Model searches…

arXiv:2211.02491

Summary

ALICE continues to play **unique and successful role** at the LHC unraveling **emergent properties of nuclear matter**

ALICE upgrades open **new era of discovery potential and precision in QCD and QGP physics**



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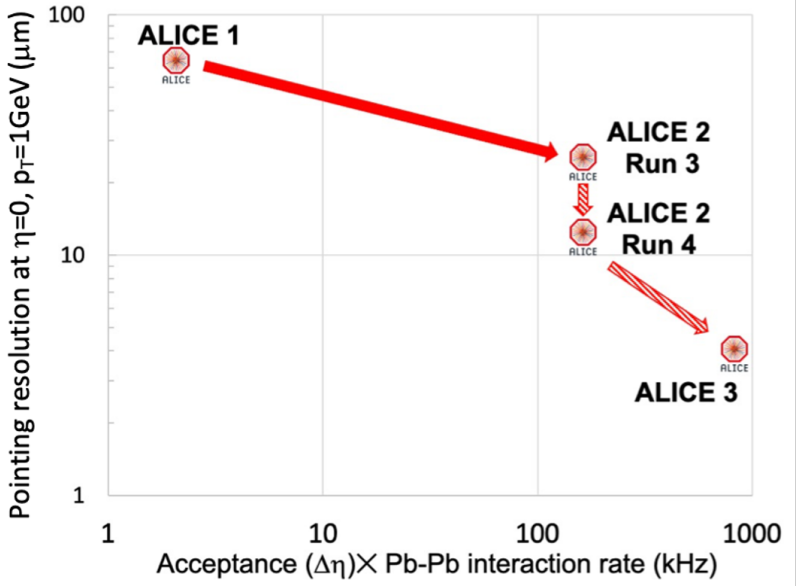

ALICE provides wonderful opportunity for [2023 US Long Range Plan for Nuclear Science] recommendation:

✓"Exploring the nature of **quark–gluon matter** at the RHIC and through **leadership across the heavy ion program at the Large Hadron Collider (LHC)**."

V Greene, Wed. at 10.25 am

Backup - ECFA Detector R&D roadmap