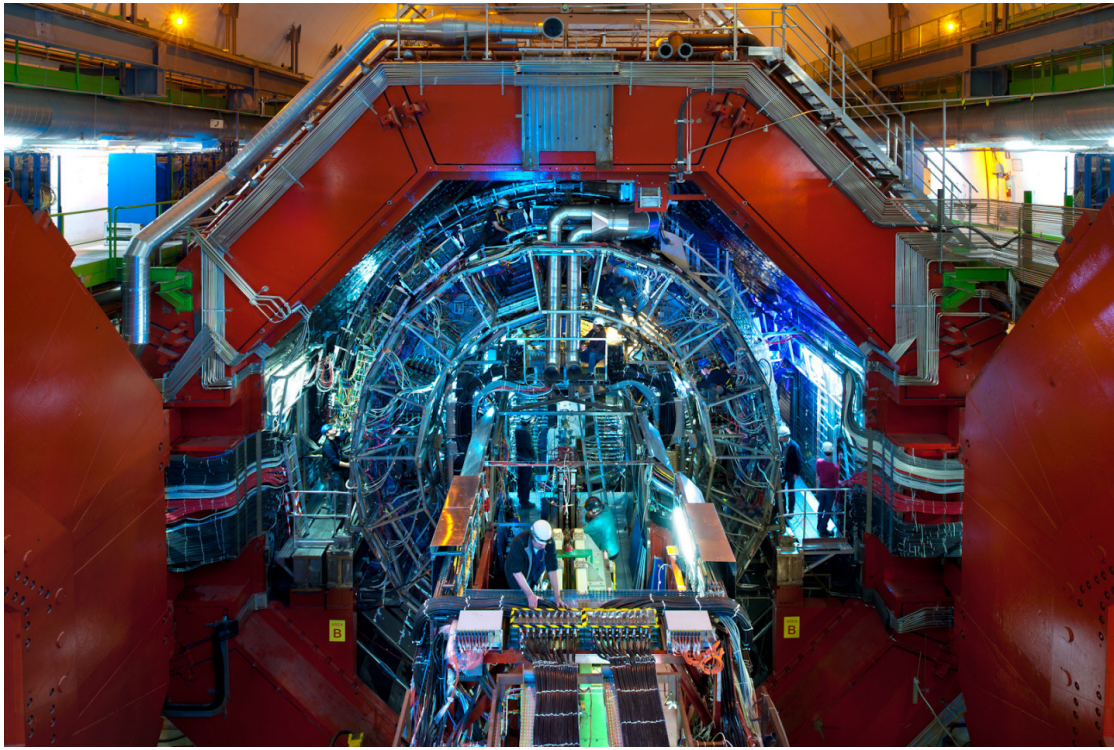
ALICE Report

Spencer Klein, LBNL, for the ALICE Collaboration

- ALICE and heavy-ion physics
- ALICE detector, with Run 3+ upgrades
  - Streaming DAQ
- Run 3 status report
- Looking ahead: FoCal
- Looking ahead: ALICE 3
- Conclusions



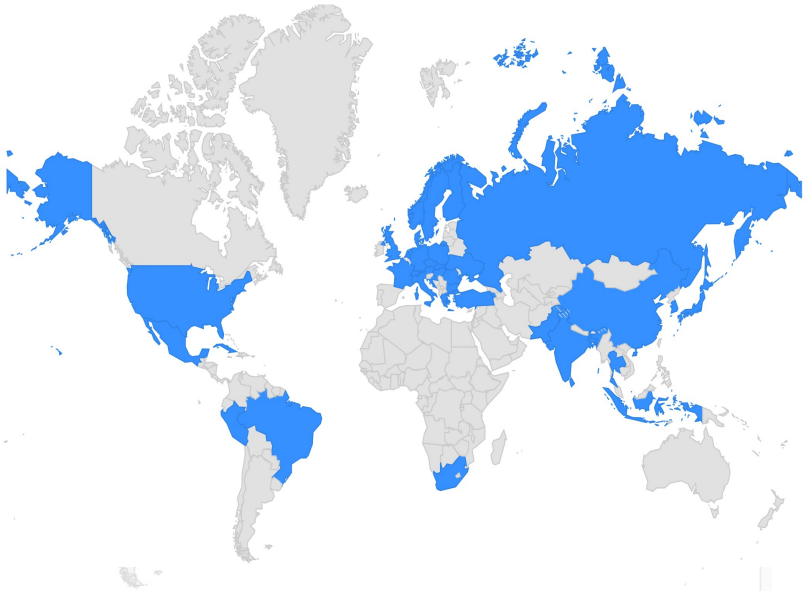
ALICE Collaboration and ALICE USA

ALICE collaboration and US leadership

Largest heavy-ion experiment in world

~~38~~ ~~156~~

~~39 countries, 162 institutes, 1924 members~~



US scope → 13 institutes & ~120 members

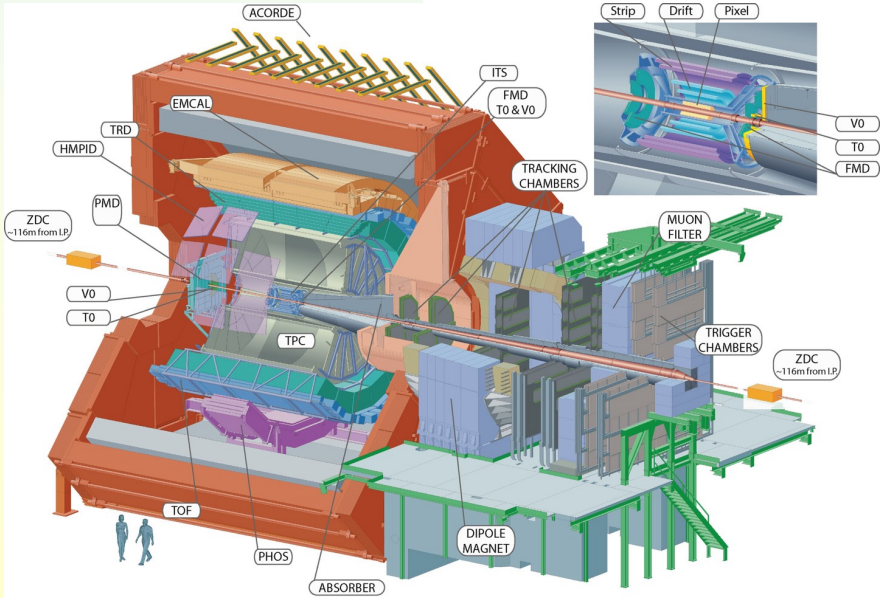
- ✓ Major contributions to EMCAL construction (Runs 1 & 2), **TPC and ITS upgrades** (Run 3)
- ✓ Two Tier-2 grid centers at LBNL and ORNL → **New analysis facility at LBNL**
- ✓ ~6% of total members and involved in **~25% of ALICE physics publications**

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

Collaborators from Russian institutions (except for Dubna) left CERN on Nov. 30th.

The ALICE Detector

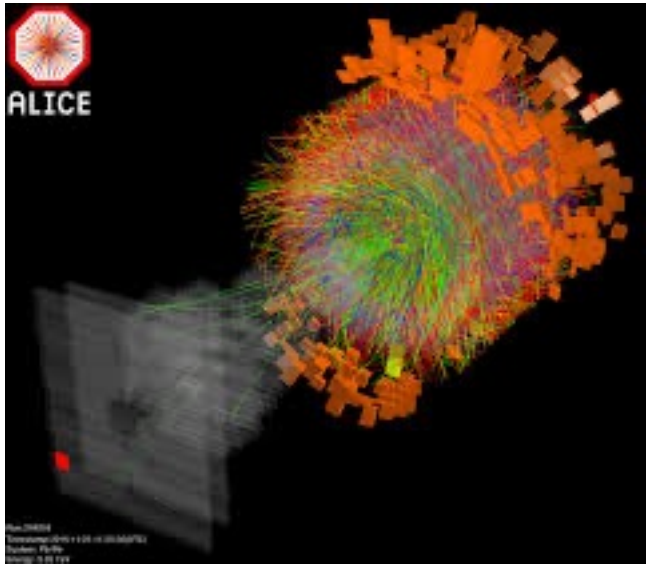
- Design optimized to study the quark gluon plasma
  - High multiplicities i. e. central lead-lead collisions
  - Coverage to low p_T
  - Particle identification
  - Other physics: ultra-peripheral collisions and low-x physics
- Central barrel covers $|\eta|<0.9$ for charged and (partial azimuth) neutral particles
- Forward muon spectrometer identifies muons



ALICE in Run 2

Some ALICE Physics

- The quark-gluon plasma
  - Hard probes (jets and heavy quarks)
    - Parton energy loss and medium modifications
  - Bulk probes
    - Particle abundance/thermal model
    - Hydrodynamic flow
  - Chiral symmetry breaking
    - Meson mass shifts
  - Temperature history
    - Direct photons and dileptons



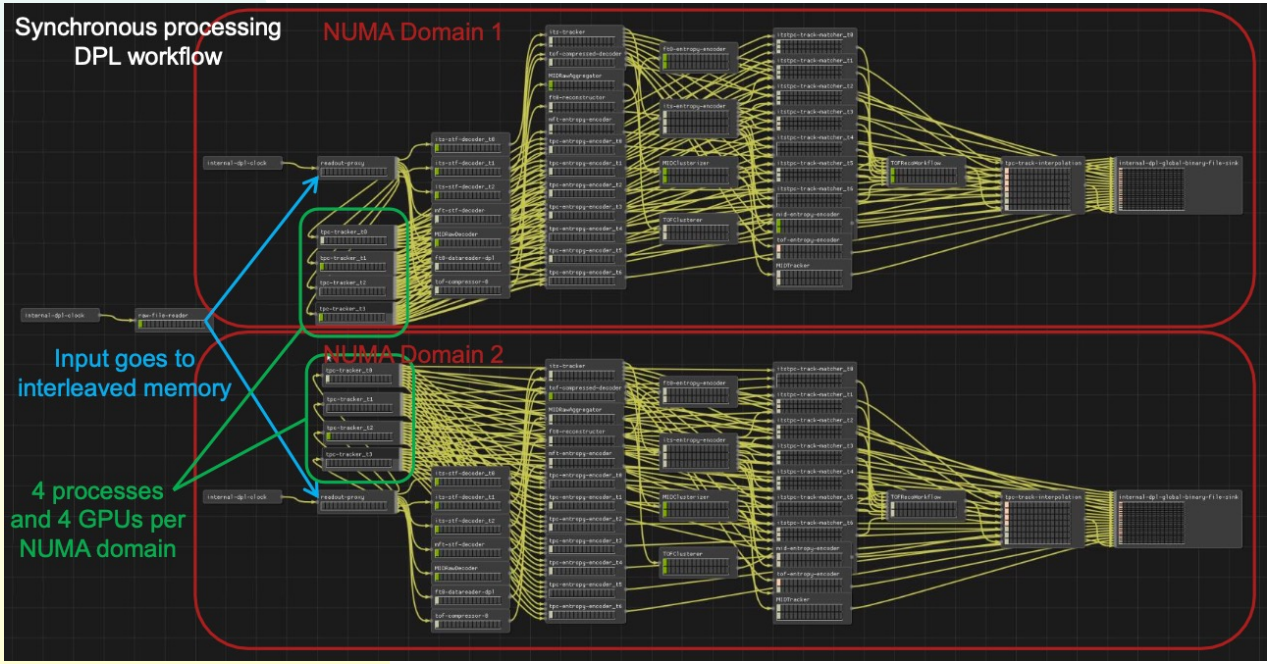
- The low-*x* structure of nuclei
  - Photoproduction in ultra-peripheral collisions
  - Hard probes in pA collisions
  - Forward particle production
- Antimatter interactions (in the detector)
  - Relevant for antimatter propagation in the galaxy

ALICE Run 3 Upgrades

- Many upgrades for higher rate running
  - Streaming DAQ system -> record every bit produced by the detector
    - For lead-lead running, all data is saved
    - For pp, cannot save every byte
      - Offline filter on few-week timescale
        - Requires fast calibration cycle turn-around
  - New TPC endcaps with GEM-based amplification
    - Decreased ion backflow to reduce space charge effects
- New ITS2 vertex detector
  - Monolithic Active Pixel Detectors
  - 29 μm by 26 μm pixels
  - Inner layers are 0.35% X_0/layer
- MFT forward tracker in front of muon spectrometer
  - Precision tracking to separate prompt μ from open heavy flavor

Run 3 - software

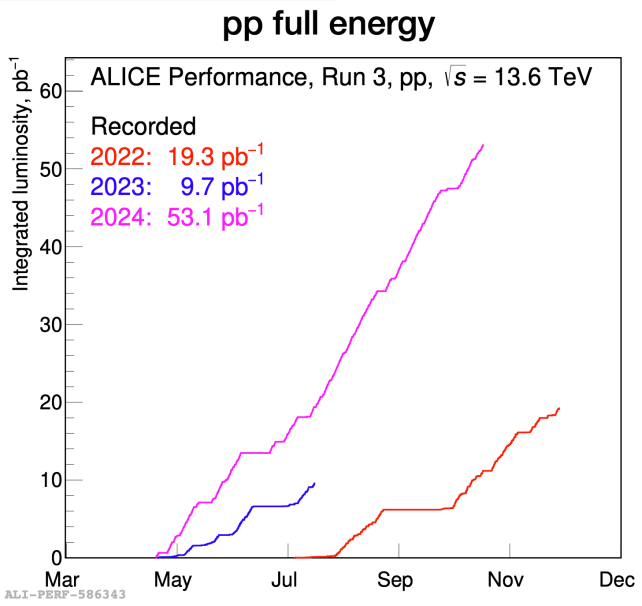
- New O^2 framework to handle increased data volume
  - Higher rate + higher pileup in TPC
- Fundamental rethinking of data storage, access and processing
  - Single framework for online and offline processing, analysis…
  - Faster processing at-scale
  - New data structures

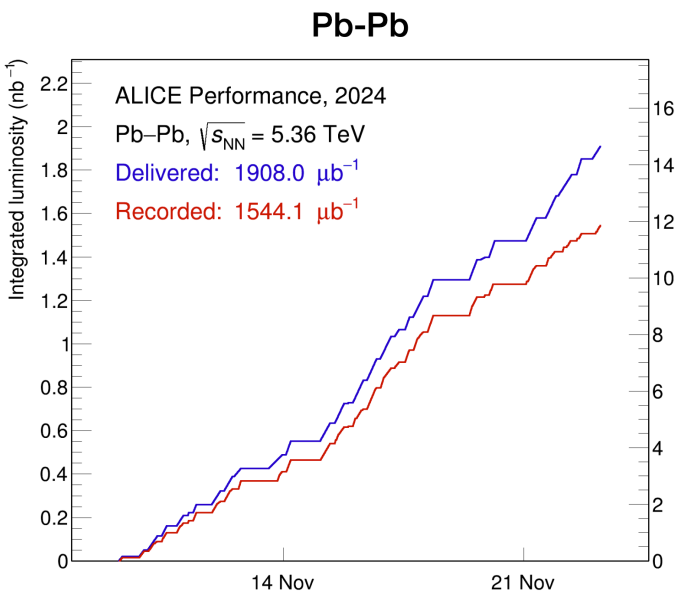


arXiv:2402.01205

2024 data collection

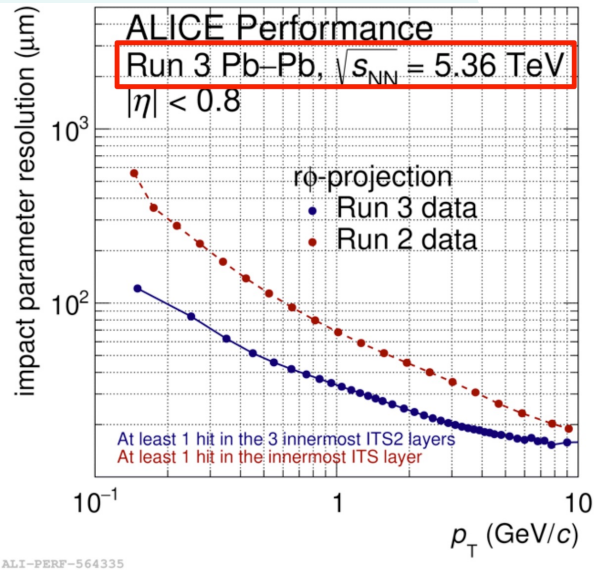
- 2024 Pb-Pb: 1.6 nb^{-1} recorded; pp: 53 pb^{-1}recorded
- Stable Pb-Pb running at 50 kHz interaction rate
  - Data rate ~ 700 GB/sec
  - 12 billion PbPb collisions recorded in 2024
- Stable pp running at 500 kHz
- 80% data collection efficiency
- Detector generally stable, with tolerable backgrounds
  - Some TPC rate-dependence observed and under investigation

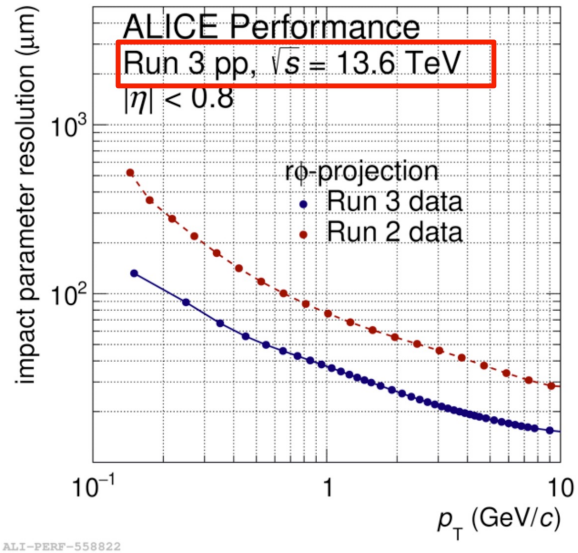


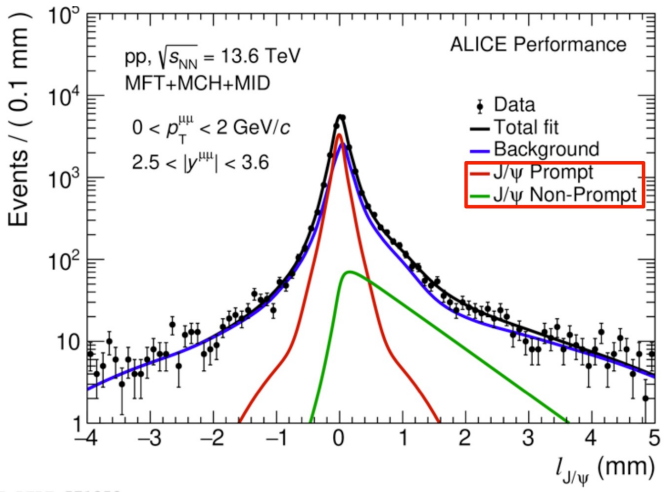


Run 3 vertexing performance

- Midrapidity transverse pointing 2 times better than Run 2
- Midrapidity longitudinal pointing 6 times better than Run 2
- Forward secondary vertexing using MFT

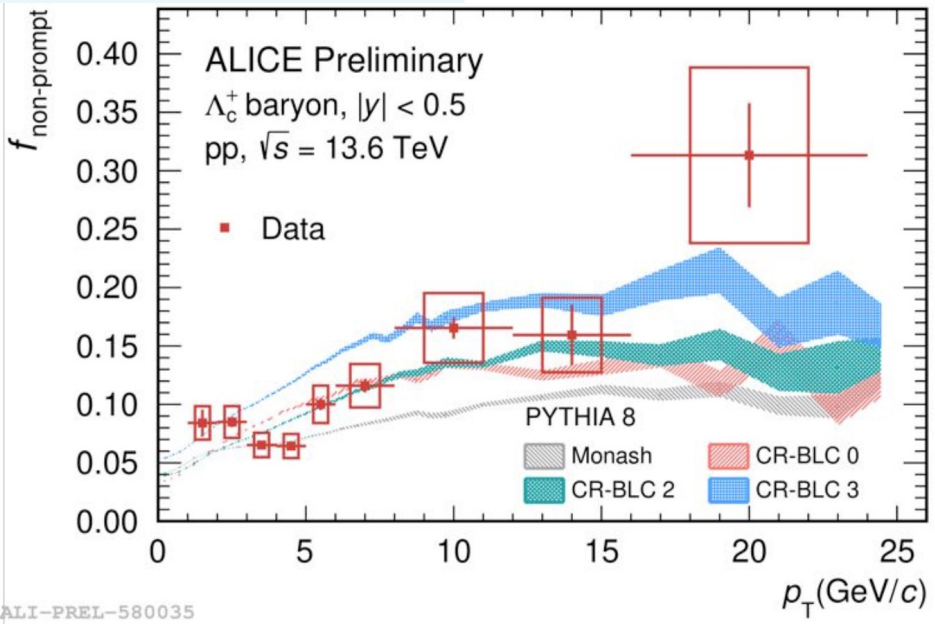




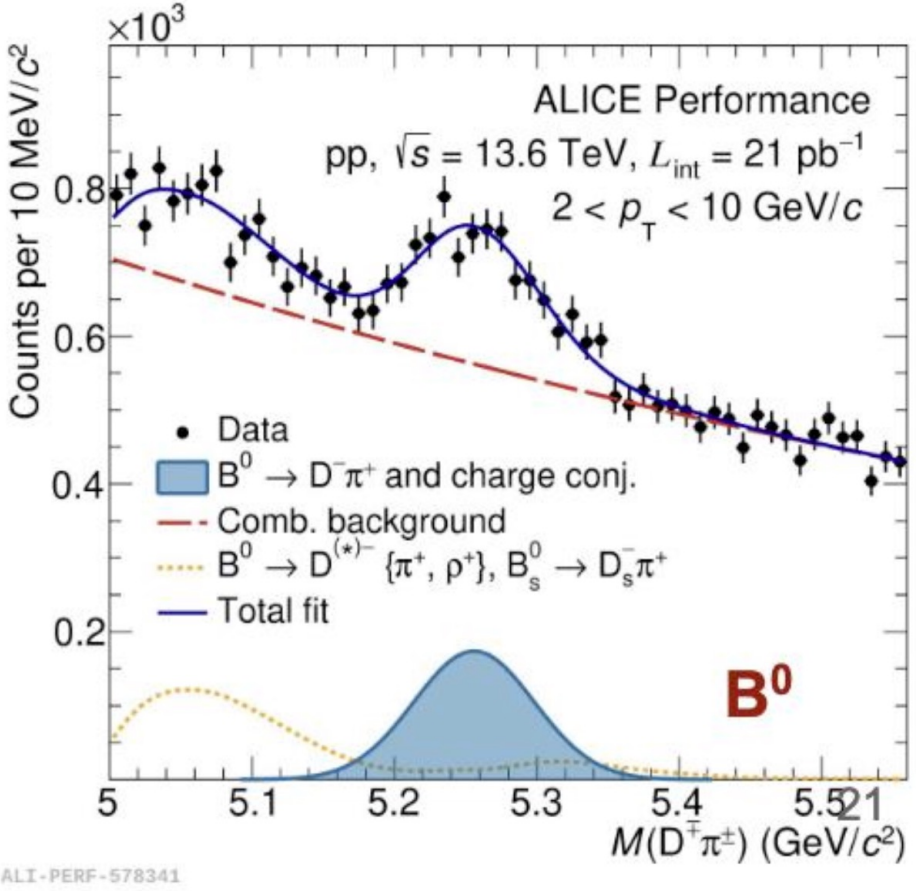


Charm and Beauty in Run 3

- Non-prompt fraction of Λ_c^+

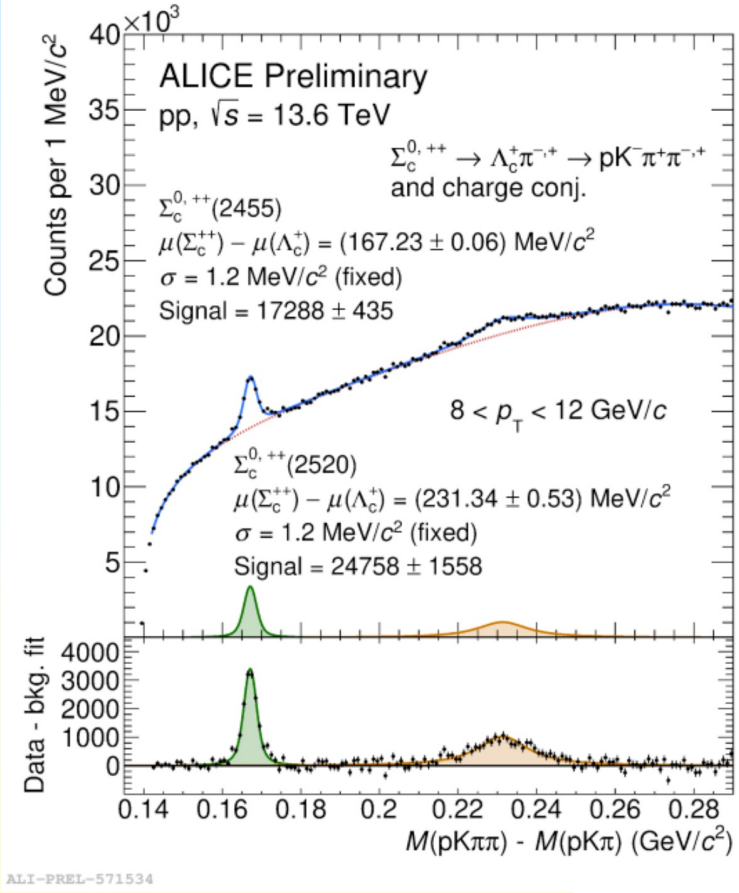


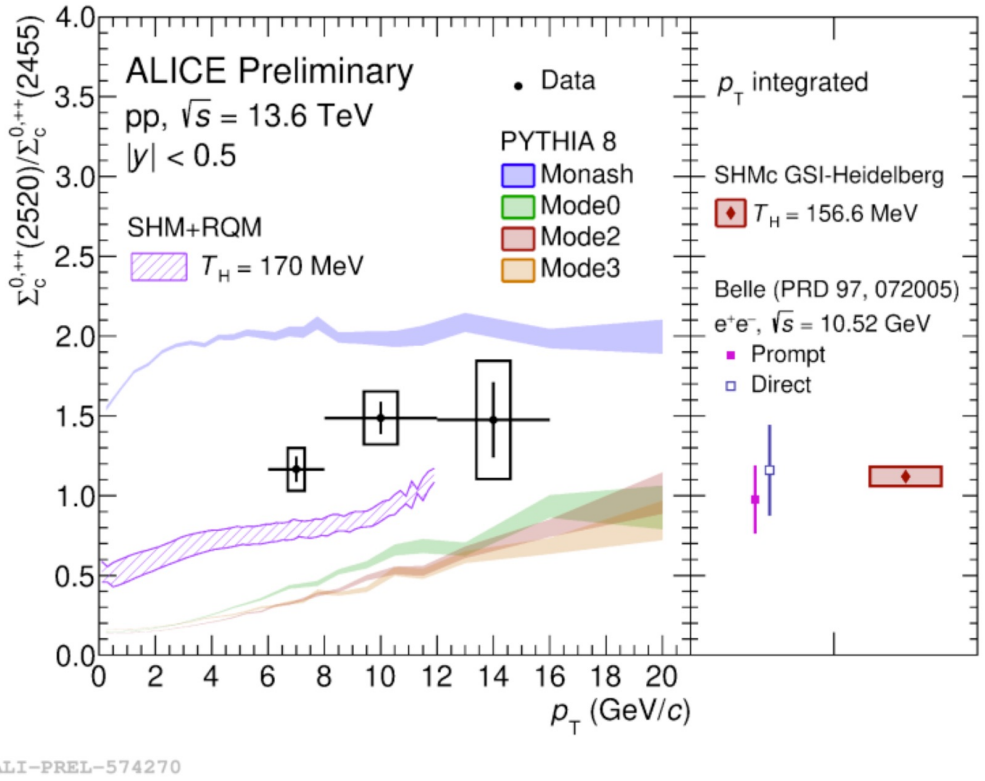
- B^0->$D^-\pi^+$



$\Sigma_c^{0,++}$ in Run 3 pp

$\Sigma_c^{0,++}$ (2455) and $\Sigma_c^{0,++}$ (2520) seen



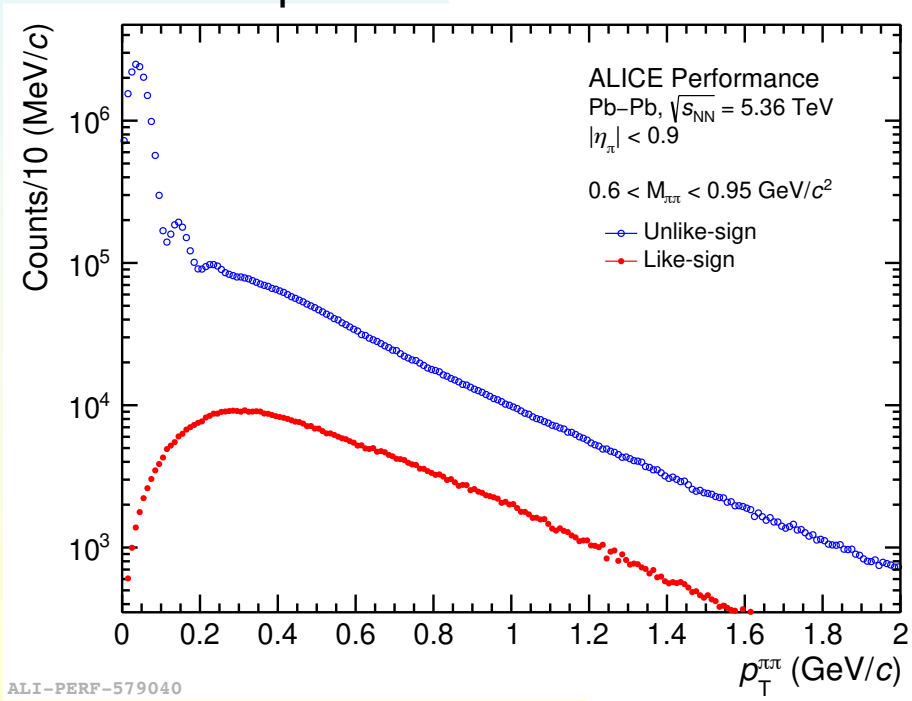


- $\Sigma_c^{0,++}$ (2520) / $\Sigma_c^{0,++}$ (2455) ratio similar to that in e^+e^- collisions
- $\Sigma_c^{0,++}$ (2520) / $\Sigma_c^{0,++}$ (2455) ratio a bit above thermal prediction
  - In range of PYTHIA tunes

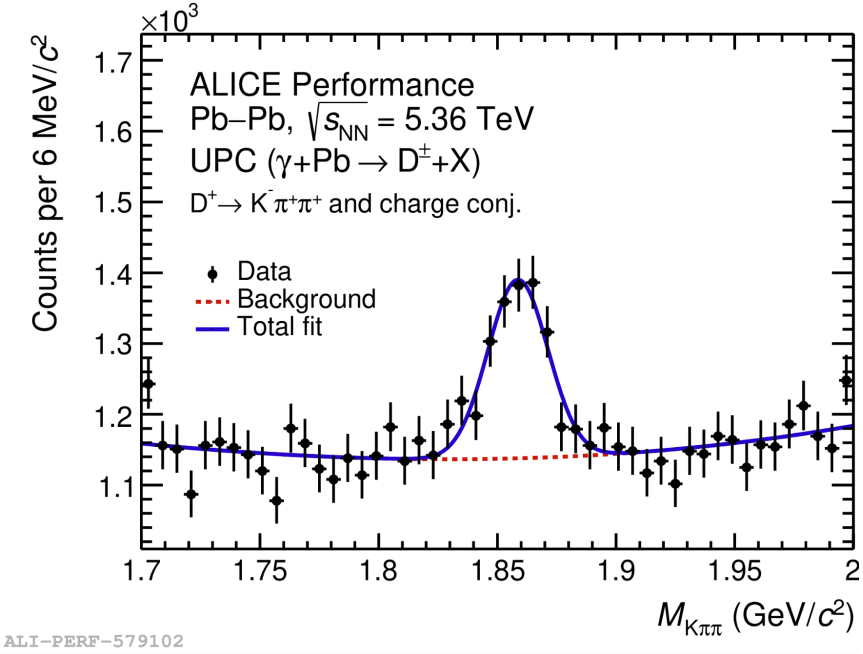
Ultra-peripheral collisions in Run 3

- Triggering has always been a UPC bottleneck
  - Eliminated by the new streaming DAQ!

p_T spectrum from ~ 15 million $\pi^+\pi^-$ events
>>100 times previous statistics

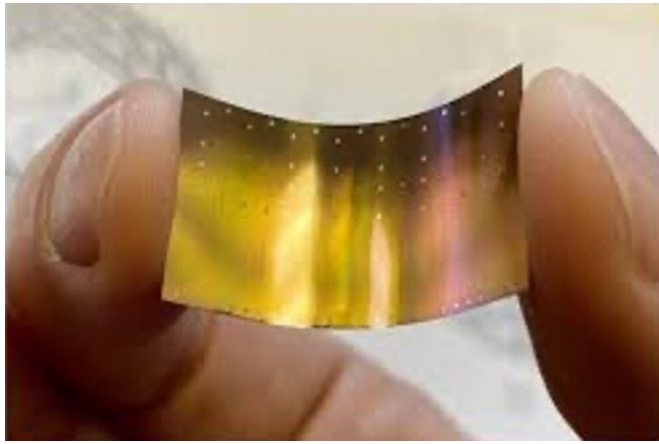


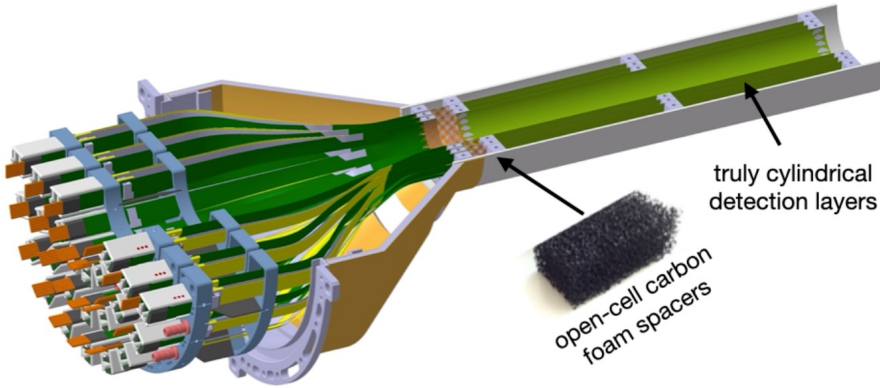
D^+ photoproduction
Not possible in Run 2



Run 4 Upgrades

- ITS3 vertex detector
  - Bent, wafer scale silicon
  - Carbon foam supports
  - Strong synergies with vertexer for the ePIC EIC detector
    - Shared development with U. S. ePIC
- Forward Calorimeter (FoCal)
  - $3.2 < \eta < 5.8$
  - EMCal + HCal
  - Low-*x* and studies of non-linear QCD evolution & saturation
  - Significant proposed U. S. involvement
    - Seeking funding from NSF

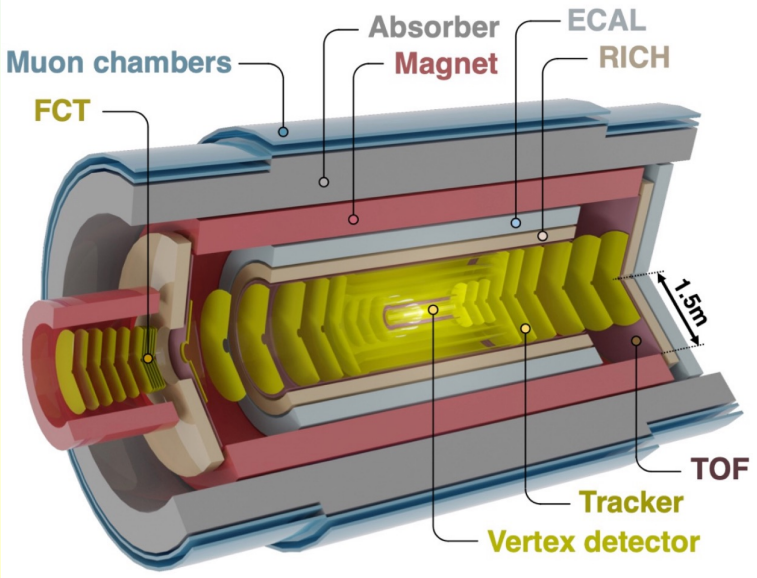


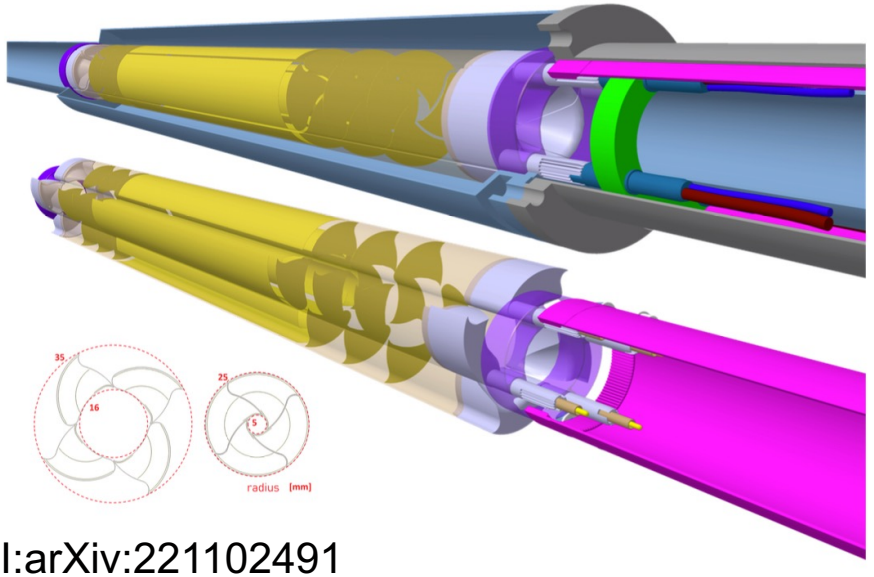


Looking further ahead, to Run 5

- ALICE 3 is a proposed large-acceptance ($|\eta|<4$) detector
  - All-silicon charged-particle tracker in a 2 T magnetic field
    - High precision 'clamshell' vertexer inside the beam pipe!
  - Particle identification: TOF + RICH
  - EM calorimetry for photons/electrons
  - Able to record all lead-lead collisions
- Proposed US leadership in outer disk tracker

New Collaborators Welcome!





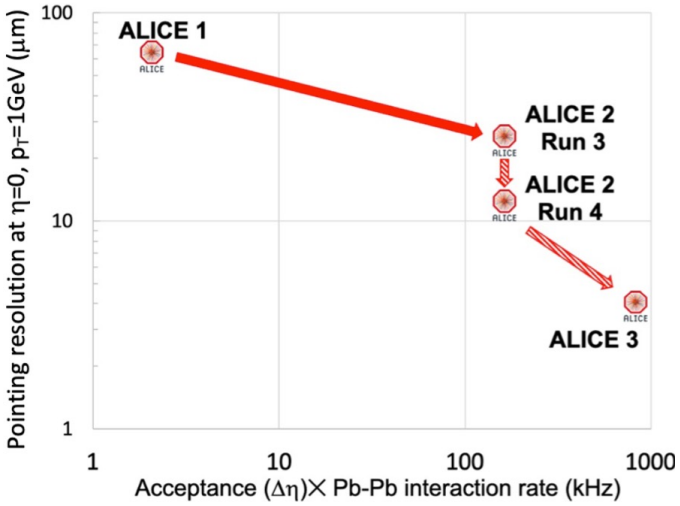
LoI:arXiv:221102491

ALICE 3 physics: A U.S.-centric list

- New probes of equilibrium &non-equilibrium behavior
  - Multi-charmed baryons, light nuclei/antinuclei
    - Including exotica – tetraquarks etc.
    - Test statistical model, measure flow, etc.
- Jet substructure
- Jet energy loss with photon-tagged jets
- Long-range correlations (in η - e. g. balance functions)
- Chiral symmetry restoration studies with baryons
- Photoproduction and low-*x* nuclear structure
  - Multiple vector mesons & quantum correlations
    - Bose-Einstein enhancements with unstable particles

Conclusions

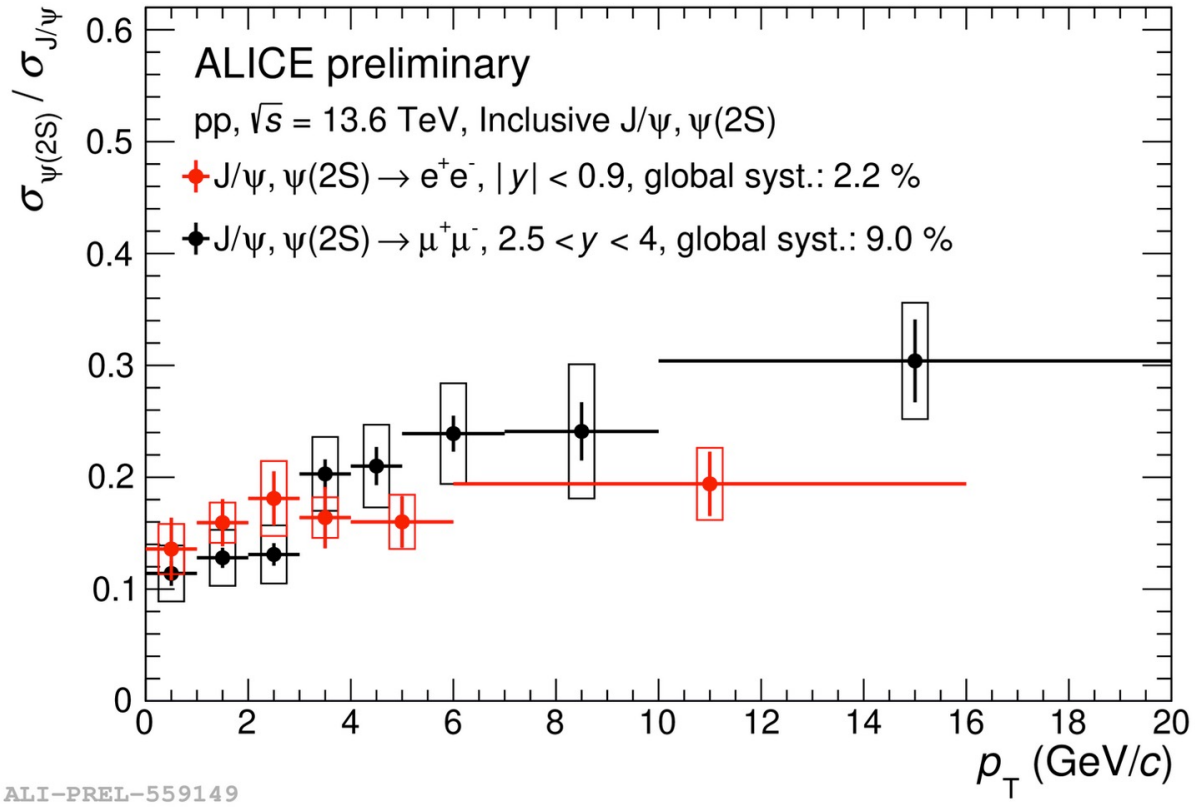
- The ALICE detector continues to produce strong physics results.
  - ALICE-USA has leadership in many of these topics.
- The Run 3 upgrades are yielding a large increase in statistics for many observables.
  - Early results look good.
- Looking ahead, we have a strong program of future upgrades.
  - ITS3 and FoCal for Run 4
  - ALICE 3 for Run 5
  - With these upgrades, ALICE has a long, bright future



Backup

Run 3 physics

- $\sigma(\psi')/\sigma(J/\psi)$ in pp collisions
  - Central region statistics improved by x300 from Run 2



Ratio of ψ(2S) to J/ψ in LHC Run 3 proton-proton collisions as a function of transverse momentum, showing ALICE's capability for measurements of the excited and ground charmonium states in the central (red points) and forward (black points) region. (Image: ALICE)