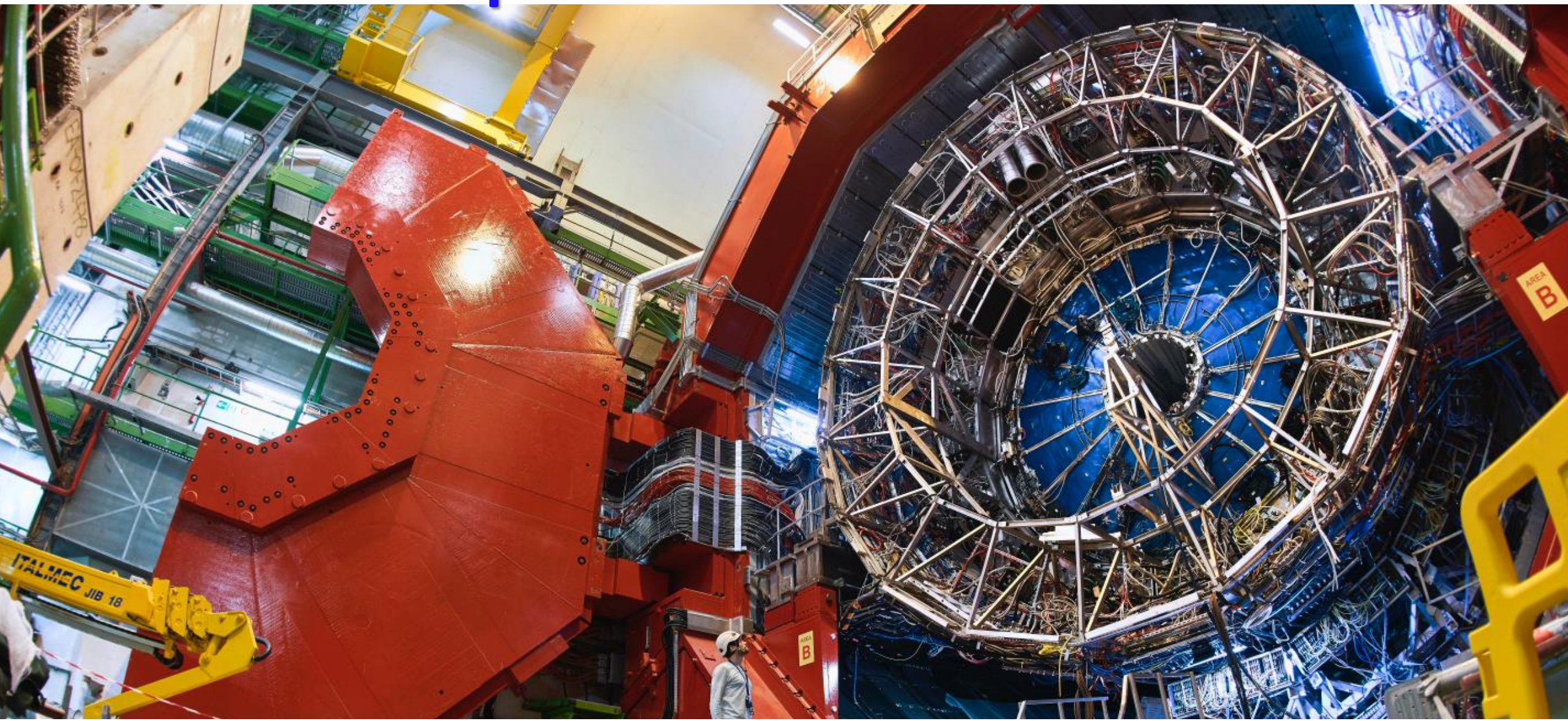
ALICE status report



Evgeny Kryshen (Petersburg Nuclear Physics Institute)
for the ALICE collaboration

145th LHCC Open Session
3 March 2021

Outline

- Physics
  - 8 new publications
- LS2 activities
  - Detectors
  - Data processing
  - Updated schedule
- Future upgrades
  - FoCal
  - ITS3

New papers and results since last LHCC

- arXiv:2101.04577 Coherent J/ψ and ψ′ photoproduction at midrapidity in ultra-peripheral Pb-Pb collisions at 5.02 TeV
- arXiv:2101.04623 First measurement of the |t|-dependence of coherent J/ψ photonuclear production
- arXiv:2101.02581 First measurement of coherent ρ^0 photoproduction in ultra-peripheral Xe-Xe collisions at 5.44 TeV

Ultra-peripheral collisions

- arXiv:2101.03110 Long and short-range correlations and their event-scale dependence in high-multiplicity pp collisions at 13 TeV
- arXiv:2101.02579 Event-by-event multi-harmonic correlations of different flow amplitudes in Pb-Pb collisions at 2.76 TeV
- arXiv:2102.12180 Measurements of mixed harmonic cumulants in Pb-Pb collisions at 5.02 TeV

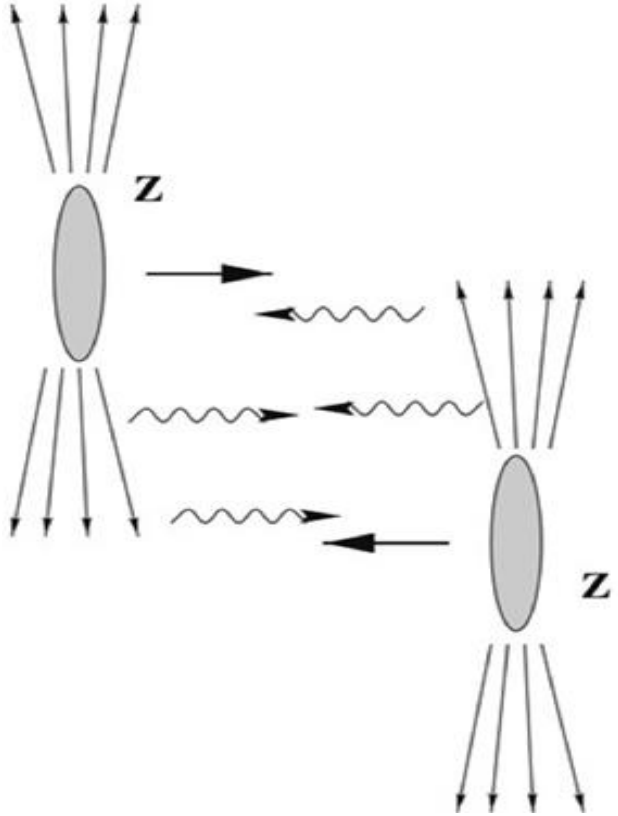
Flow

- arXiv:2101.03100 Production of pions, kaons, (anti-)protons and φ mesons in Xe-Xe collisions at 5.44 TeV
- arXiv:2102.13601 Measurement of beauty and charm production in pp collisions at 5.02 TeV via non-prompt and prompt D mesons

Particle production

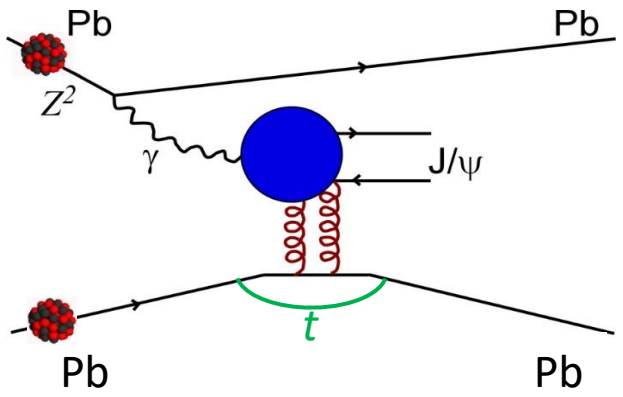
- ALICE-PUBLIC-2021-001 Public Note on the Pb-Pb lumi measurement
- Several preliminary results released in January for the IS2021 conference

Ultra-peripheral collisions

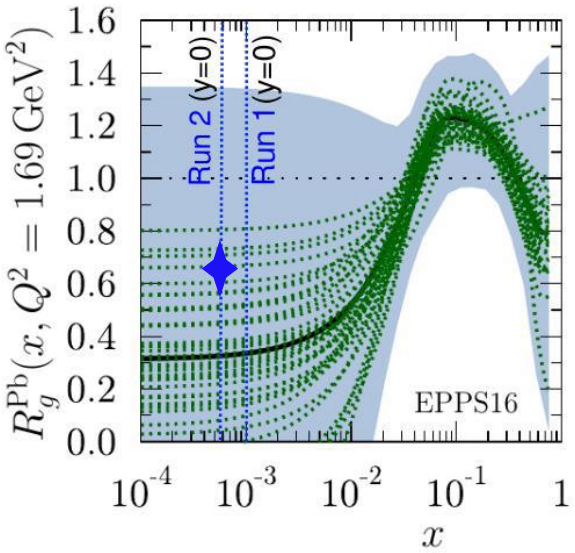


using photon-induced collisions to probe nuclear gluon density

Coherent J/ψ photoproduction in Pb-Pb UPC



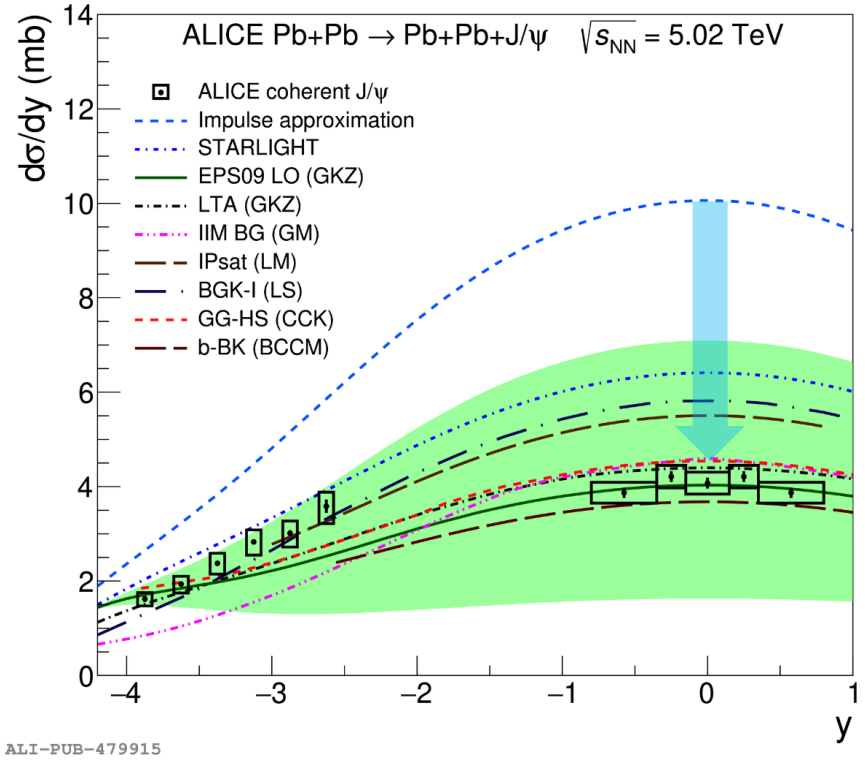
$$\left.\frac{d\sigma_{\gamma A\to J/\psi A}}{dt}\right|_{t=0} = \frac{M_{J/\psi}^3 \Gamma_{ee} \pi^3 \alpha_s^2(Q^2)}{48\alpha_{\rm em} Q^8}\left[x g_A(x,Q^2)\right]^2$$



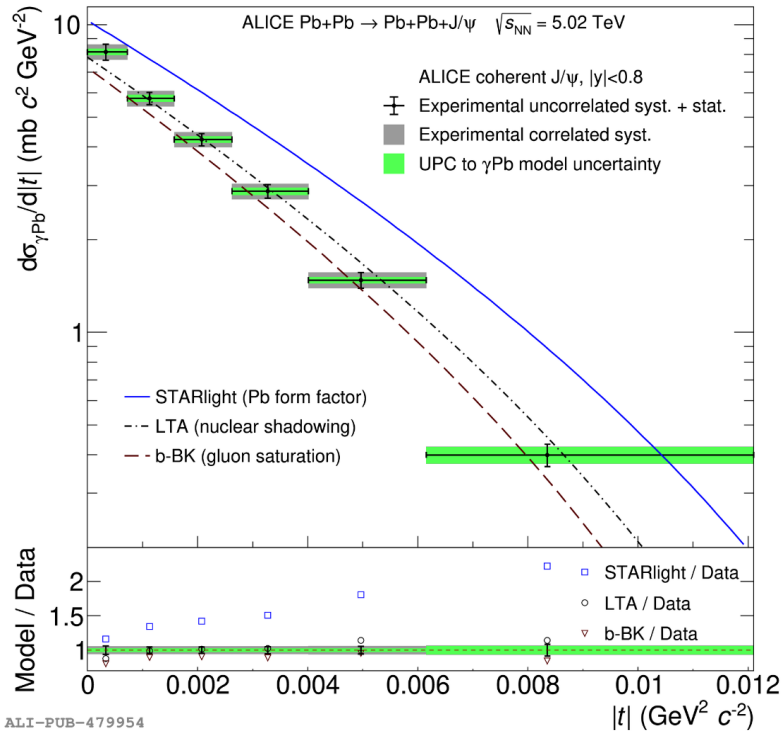
Eskola et. al., EPJC 77 (2017) 163

$$R_g^A(x,Q^2) = \frac{g_A(x,Q^2)}{A g_p(x,Q^2)}$$

arXiv:2101.04577



arXiv:2101.04623

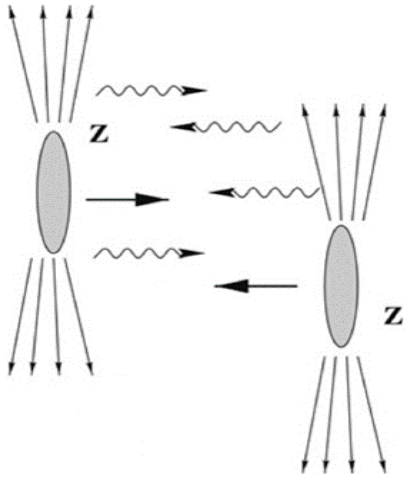


$|t| \approx p_T^2$

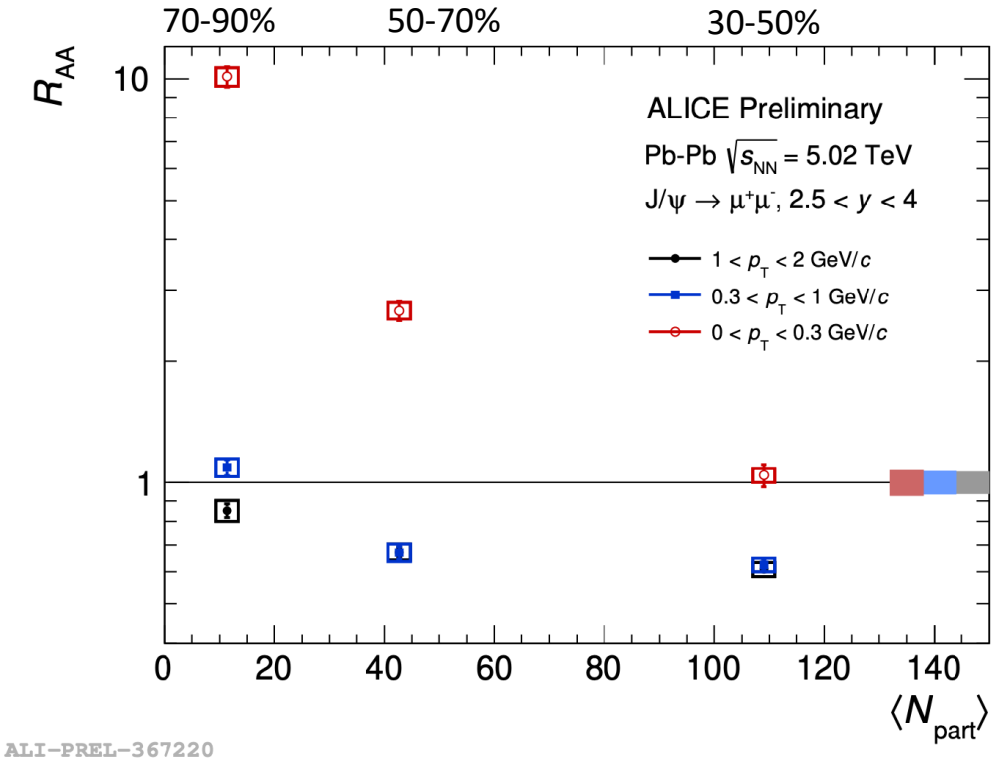
- Probing low-x gluon PDFs in the nucleus
- Comparison with the impulse approximation (no nuclear effects) allows for extraction of the gluon shadowing factor: $R_g \sim 0.65$ at $x \sim 10^{-3}$
- *t*-dependence is sensitive to transverse gluon distribution

For more details see LHC Seminar by Michal Broz on March 2

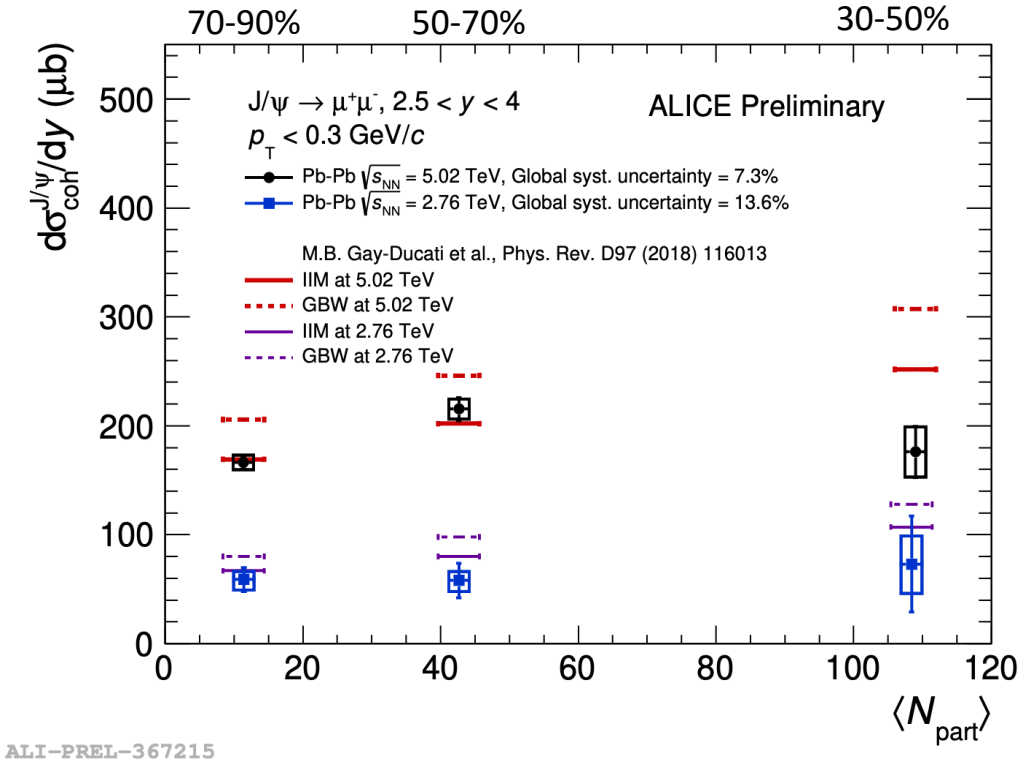
Excess of low-p_T J/ψ production in hadronic Pb-Pb



$b < 2R_A$



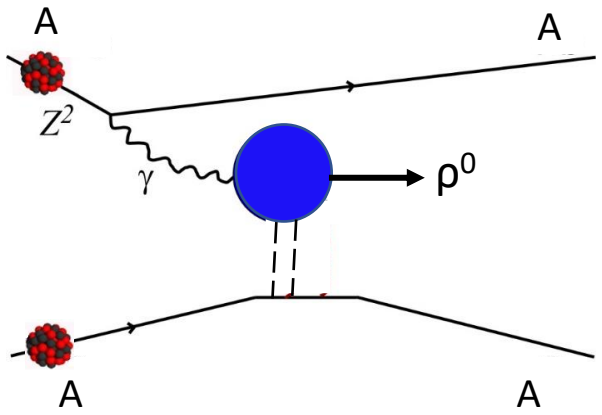
ALI-PREL-367220

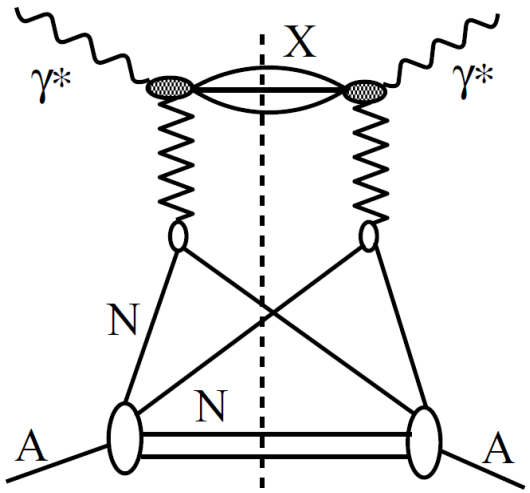


ALI-PREL-367215

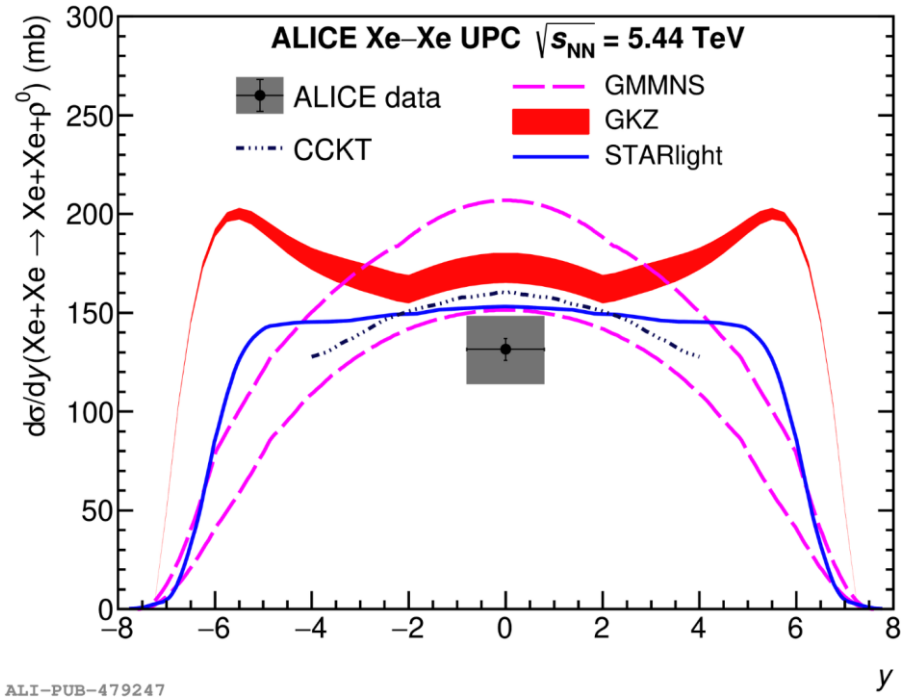
- An excess of J/ψ measured at p_T < 0.3 GeV/c in peripheral hadronic collisions up to 30-50% centrality
- Interpreted as coherent photoproduction accompanied by hadronic interactions.
  But why coherence is preserved? Which photon source? which gluon source?
- Models based on effective photon flux from spectators qualitatively describe the data in peripheral events but overpredict the data in more central events

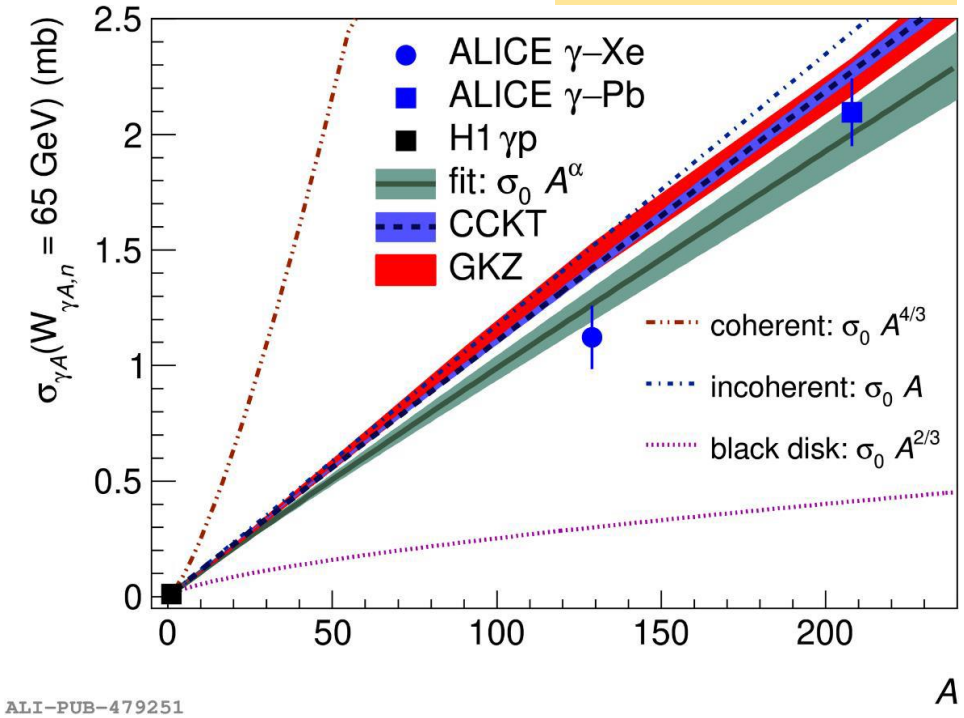
Coherent ρ^0 photoproduction in Xe-Xe UPC





arXiv:2101.02581

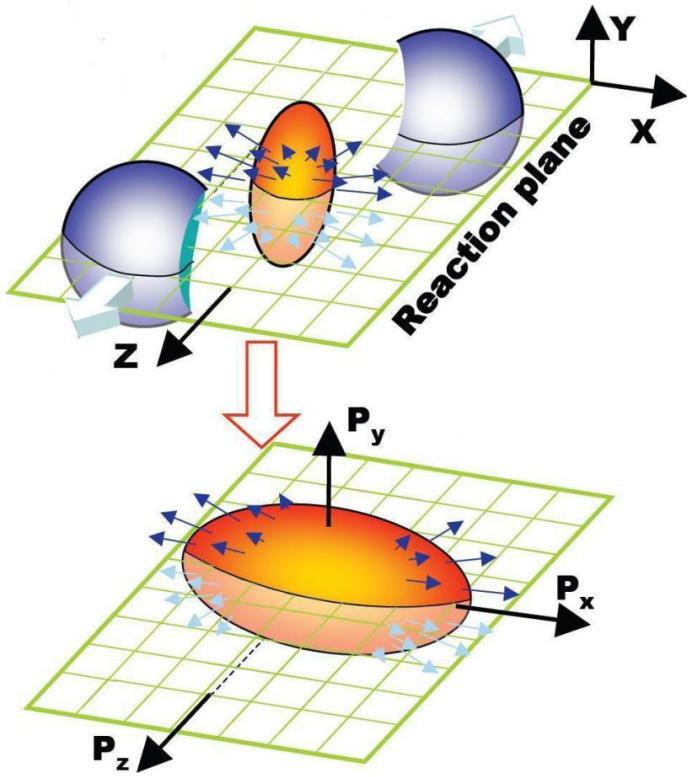




ρ^0 photoproduction allows for the study of shadowing mechanisms in the soft regime:

- approximately linear A dependence
- models based on inelastic Gribov-Glauber shadowing (GKZ, CCKT) reproduce the measured cross sections

Flow and correlation measurements



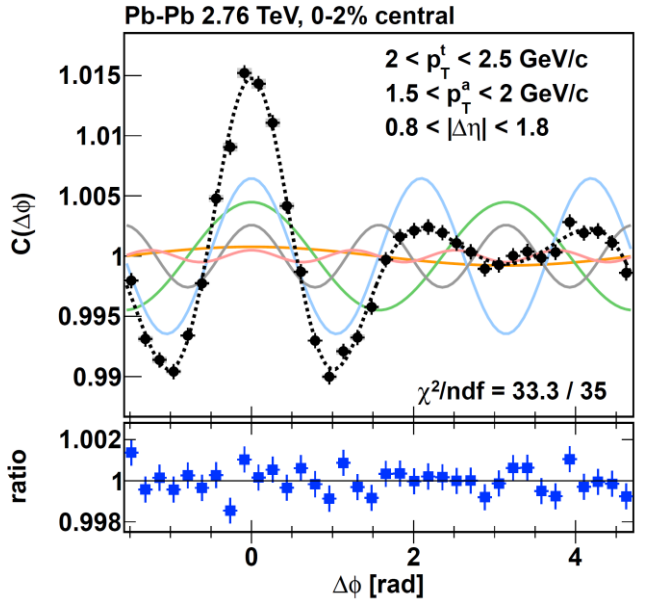
Fourier decomposition of azimuthal distributions:

$$\frac{dN}{d\phi} \propto 1 + \sum_{n=1}^{\infty} 2v_n(p_T)\cos\left(n(\phi - \Psi_n)\right)$$

Two-particle correlation measurements

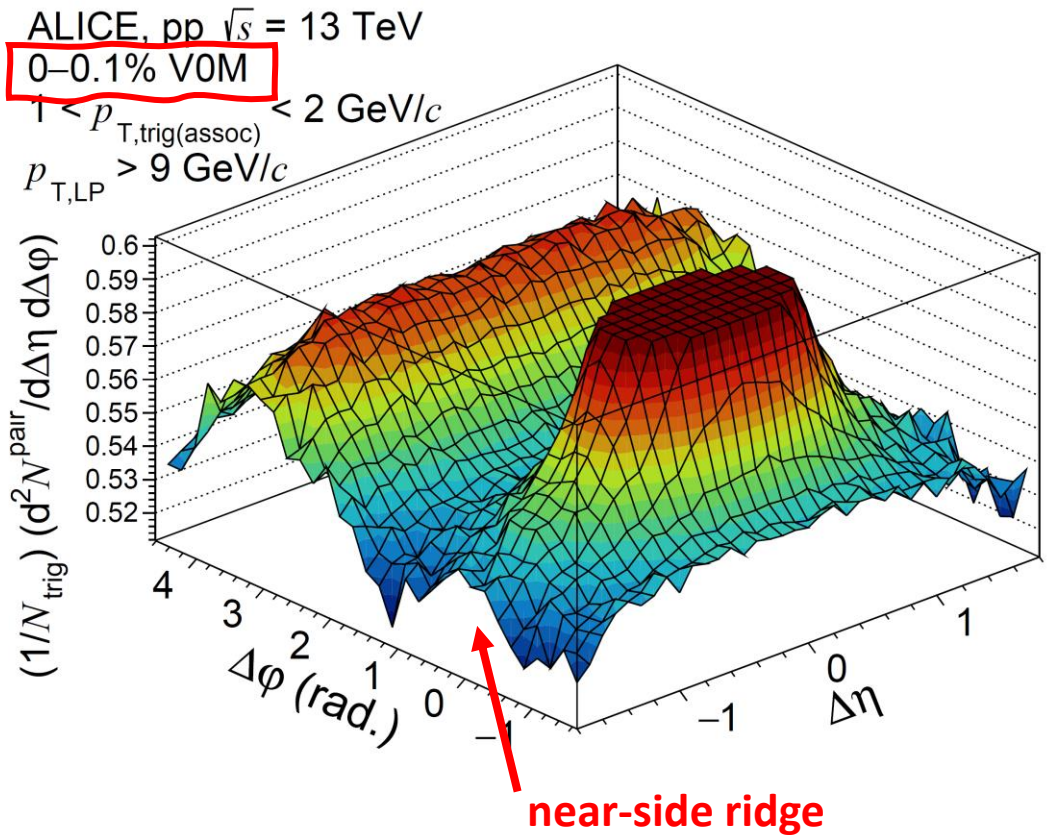
$$\frac{dN^{pairs}}{d\Delta\phi} \propto 1 + \sum_{n=1}^{\infty} 2V_{n\Delta}(p_T^t, p_T^a)\cos\left(n\Delta\phi\right)$$

$$v_n(p_T^t)v_n(p_T^a)$$

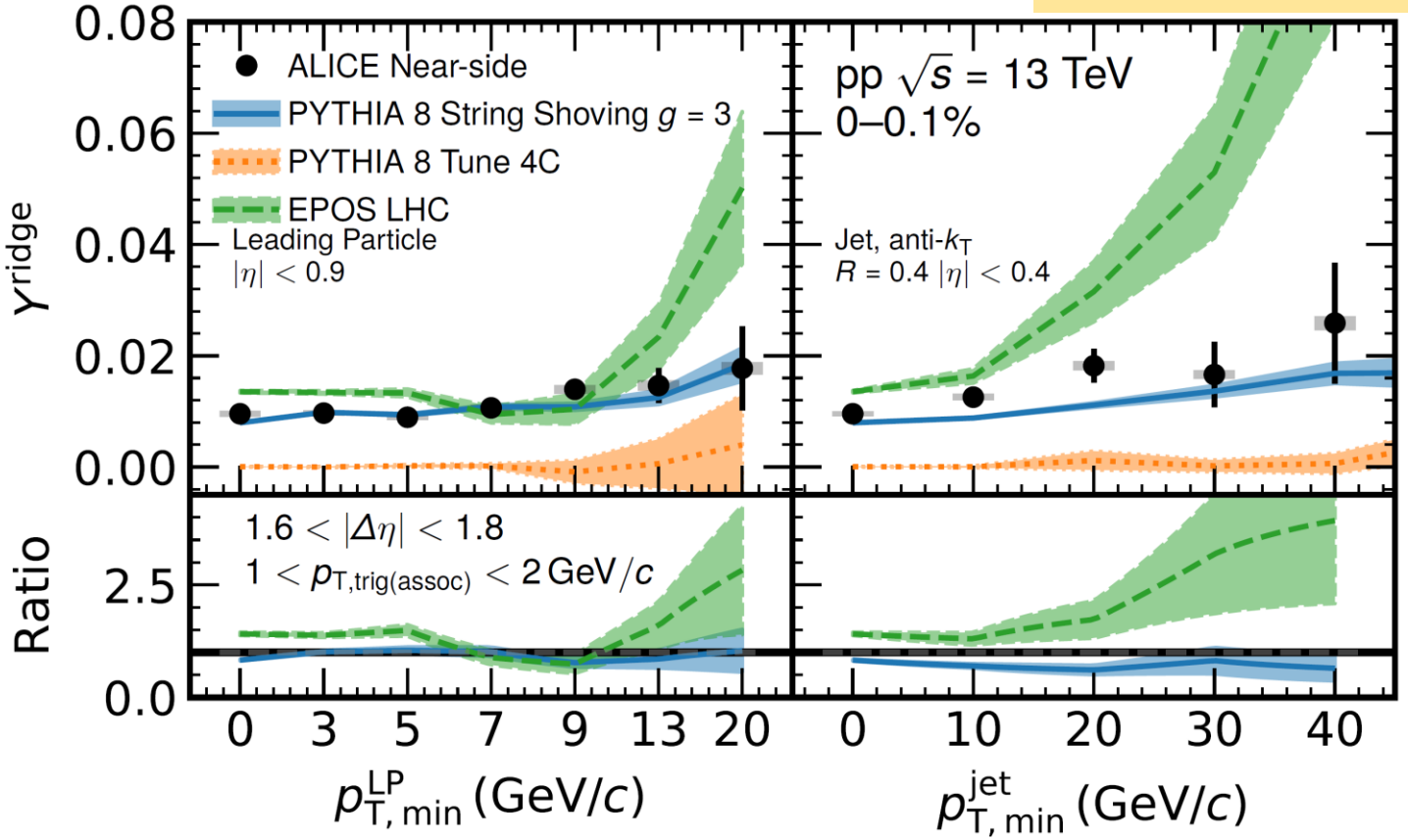


ALICE: PLB 708 (2012) 249

Ridge yield vs leading particle/jet p_T in pp



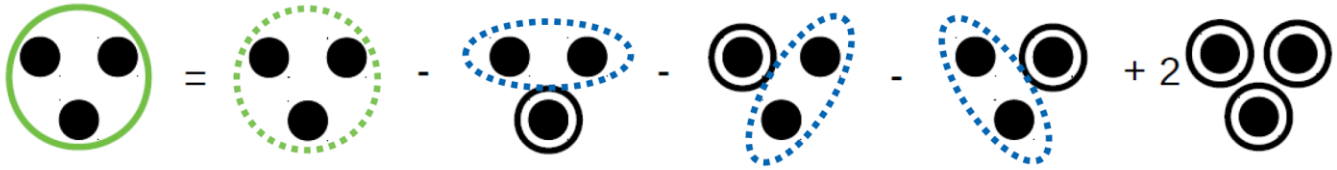
arXiv:2101.03110



- Study flow-like correlation in high multiplicity pp events
- Near-side ridge yield exhibits a slight increase with increasing leading particle/jet p_T
- Reproduced in PYTHIA 8 with string shoving mechanism, not by EPOS with hydrodynamic core

Correlations between flow amplitudes in Pb-Pb

$$\mathrm{SC}(k,l,m) = \langle v_k^2 v_l^2 v_m^2 \rangle - \langle v_k^2 v_l^2 \rangle \langle v_m^2 \rangle - \langle v_k^2 v_m^2 \rangle \langle v_l^2 \rangle - \langle v_l^2 v_m^2 \rangle \langle v_k^2 \rangle + 2 \langle v_k^2 \rangle \langle v_l^2 \rangle \langle v_m^2 \rangle$$

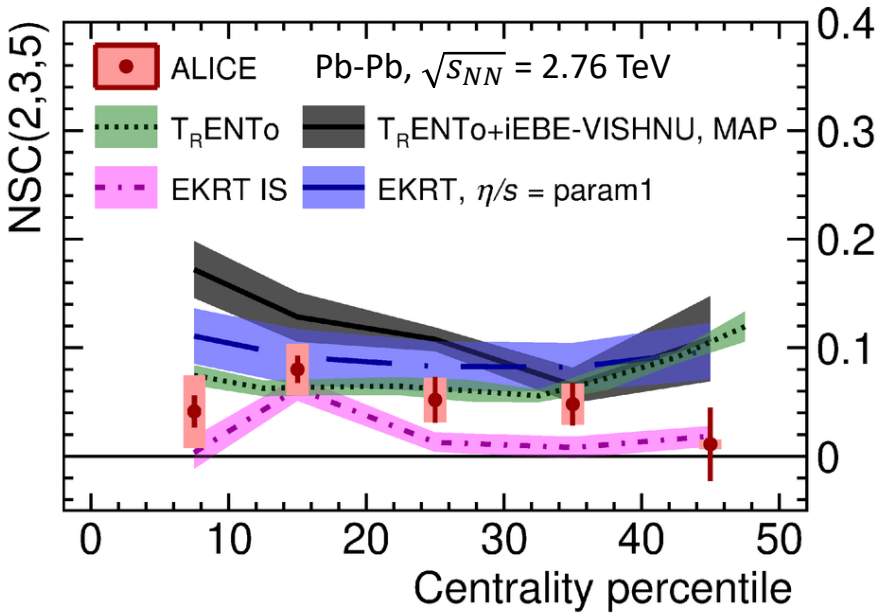


QGP Initial state

$$v_n \approx \kappa_n \varepsilon_n$$

Normalised symmetric cumulants: $\mathrm{NSC}(k,l,m) = \frac{\mathrm{SC}(k,l,m)}{\langle v_k^2 \rangle \langle v_l^2 \rangle \langle v_m^2 \rangle}$

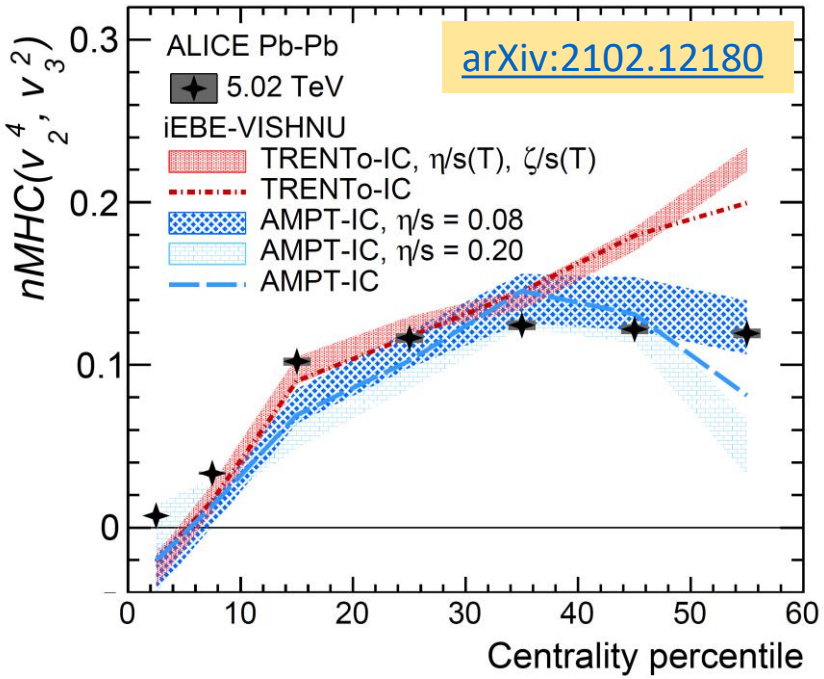
arXiv:2101.02579



Mixed harmonic cumulants:

$$MHC(v_2^4, v_3^2) = \langle v_2^4 v_3^2 \rangle - 4 \langle v_2^2 v_3^2 \rangle \langle v_2^2 \rangle - \langle v_2^4 \rangle \langle v_3^2 \rangle + 4 \langle v_2^2 \rangle^2 \langle v_3^2 \rangle$$

arXiv:2102.12180

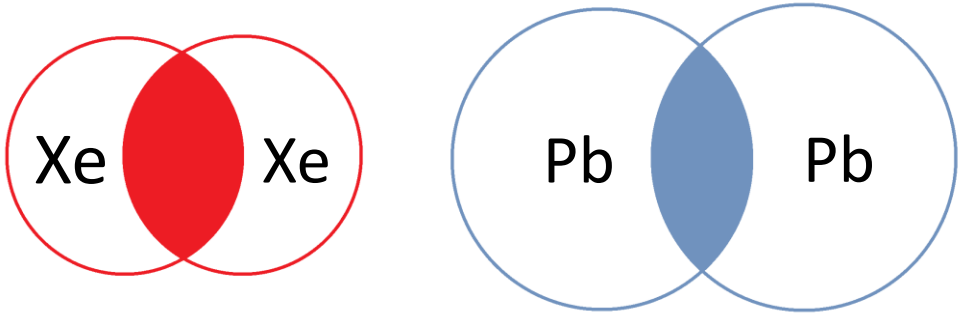


- Symmetric cumulants (SC) and mixed harmonic cumulants (MHC) insensitive to non-flow
- Normalised SC and MHC have different sensitivity to initial and final state effects

Identified particle spectra in Xe-Xe

Xe-Xe vs Pb-Pb: different eccentricity at the same multiplicity

arXiv:2101.03100



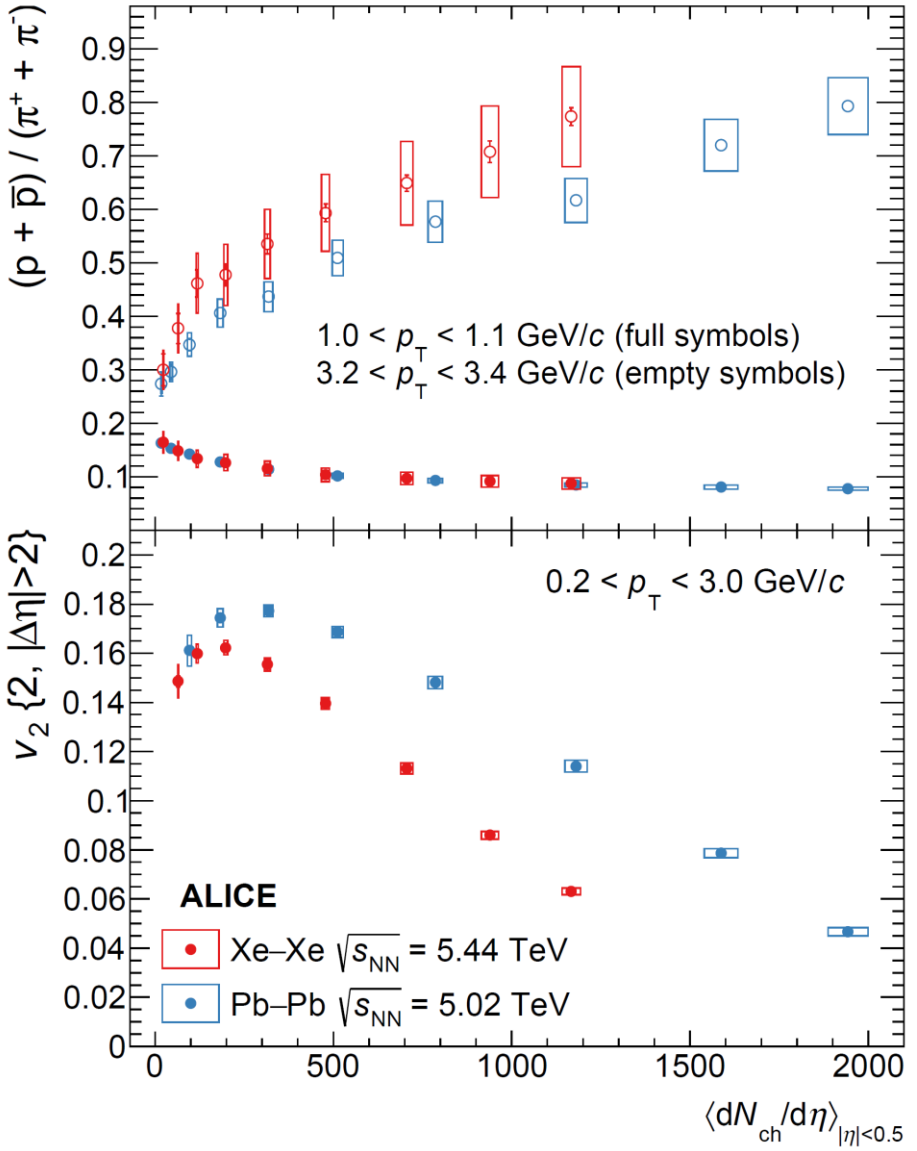
N_{ch}(Xe-Xe) ~ N_{ch}(Pb-Pb)

ε_2(Xe-Xe) < ε_2(Pb-Pb)

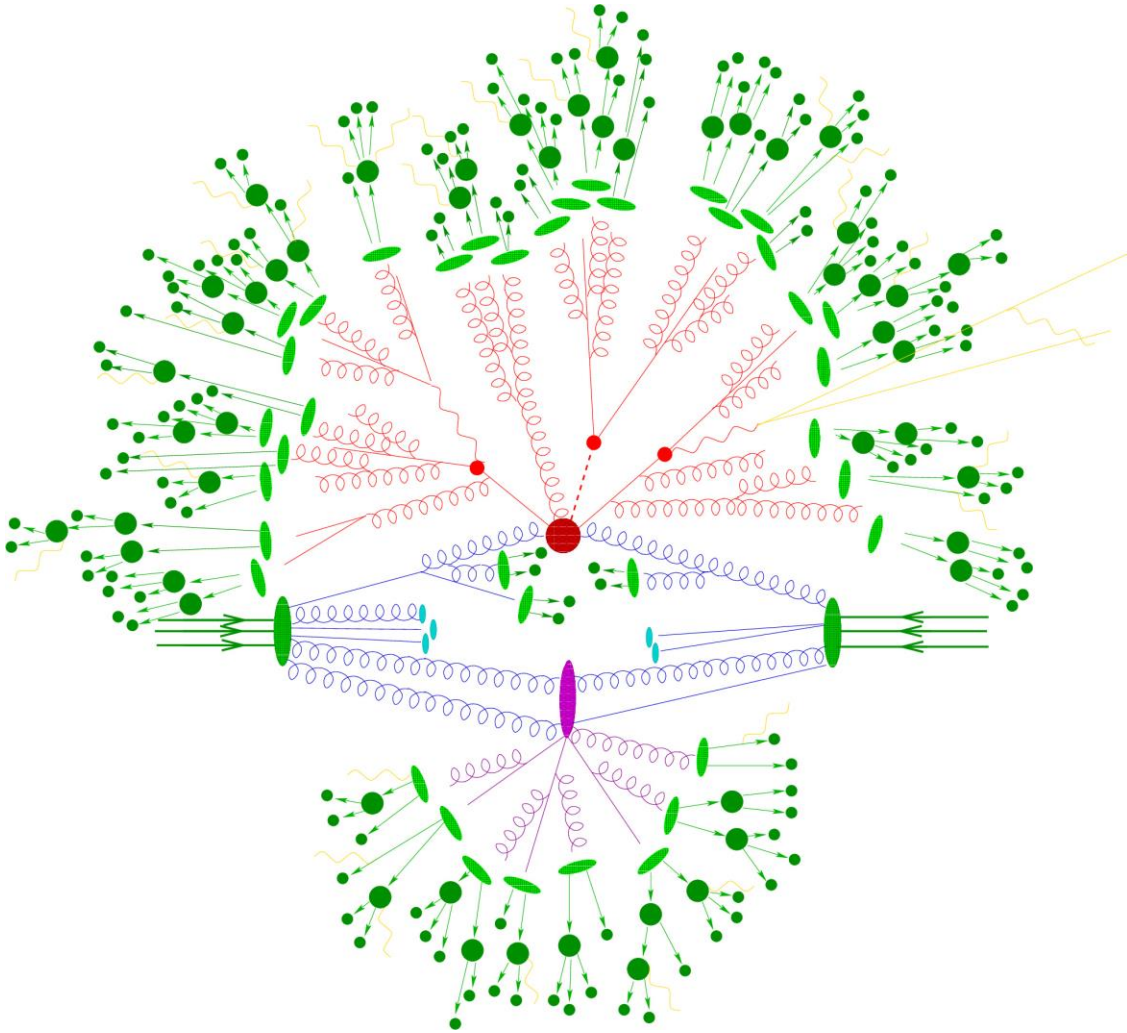
- Radial flow effects are similar:
  - increase of the p/π ratio at intermediate p_T
  - depletion at low p_T

  → Only driven by multiplicity
- Elliptic flow shows large differences at the same multiplicities

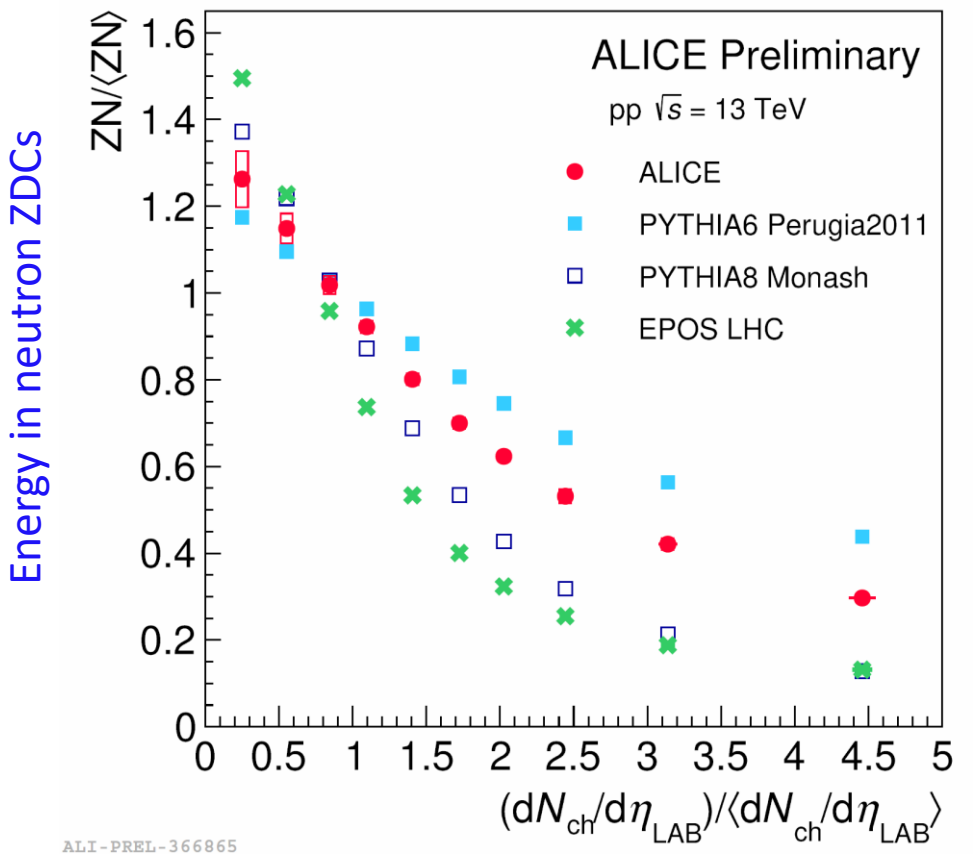
  → Also driven by eccentricity

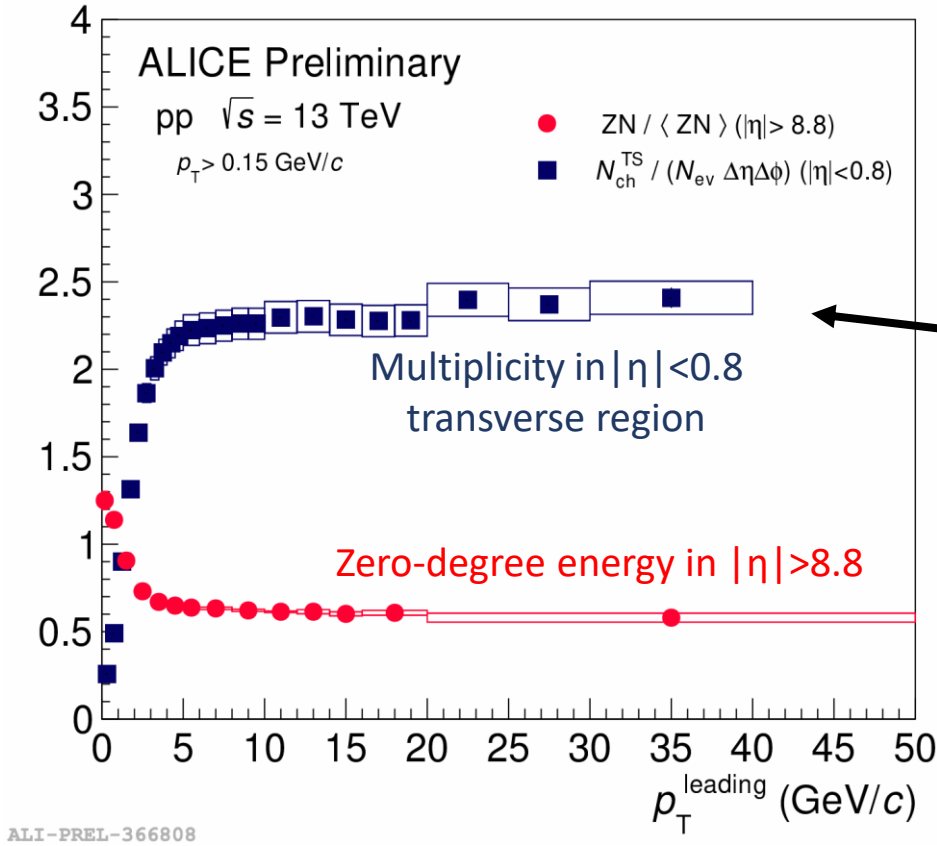


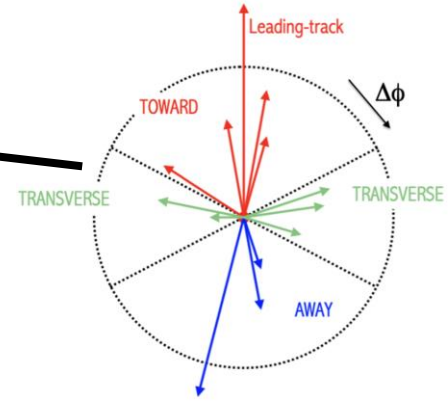
Particle production in pp collisions



Zero-degree energy to study pp and MPIs role





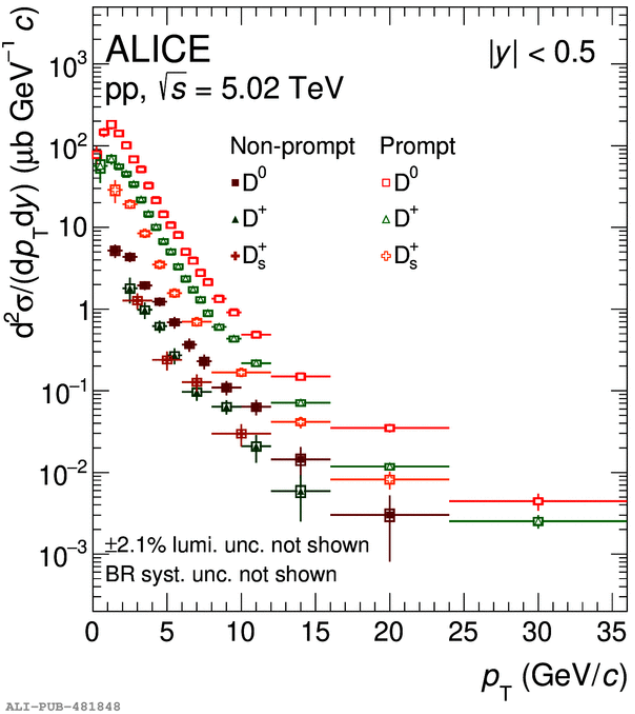


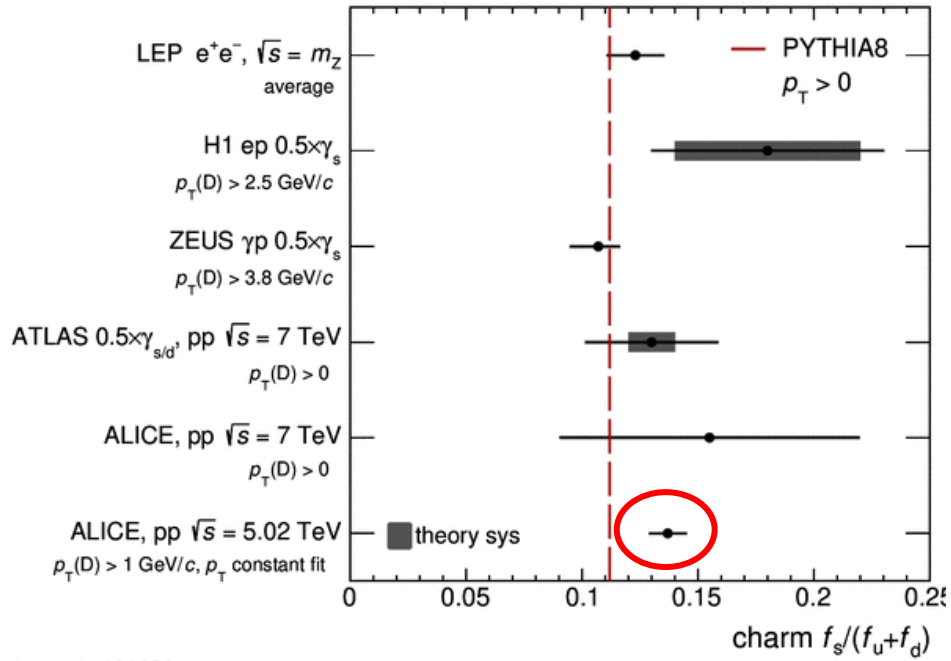
- Forward energy decreases with increasing particle multiplicity at midrapidity, described in generators with MPIs
- Small ZN → "central" pp, enhanced MPI, see Drescher, Strikman PRL 100 (2008) 152002

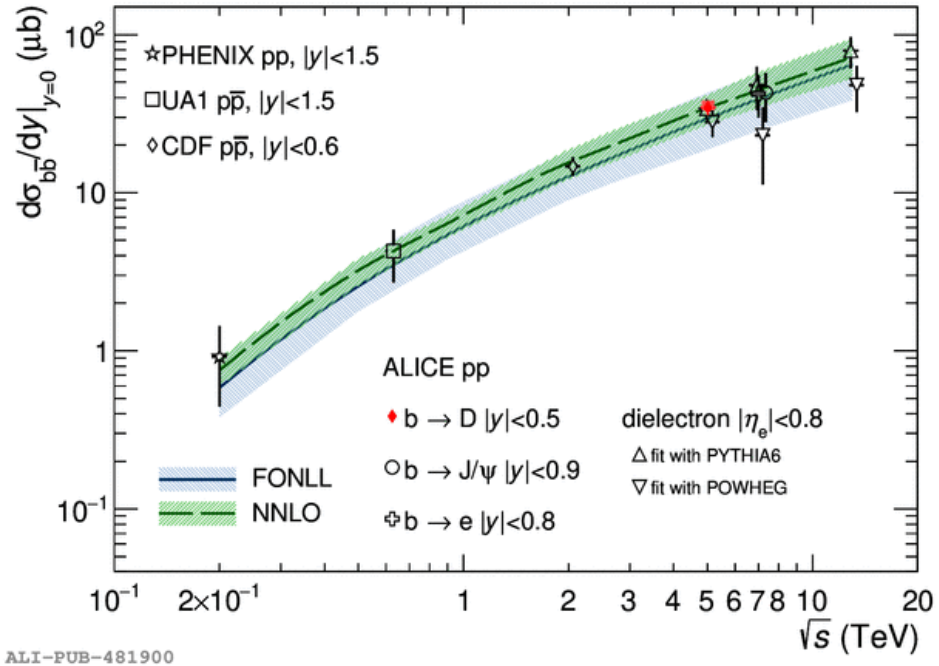
- The forward energy at |η|>8.8 shows a complementary behaviour to that observed for transverse charged particle multiplicity (|η|<0.8).
  → (anti-)correlation from initial stages
- Flattening for leading p_T>5 GeV/c also observed at zero-degree
  → ZN: additional constraint for MPI modeling

Beauty and charm production in pp

arXiv:2102.13601







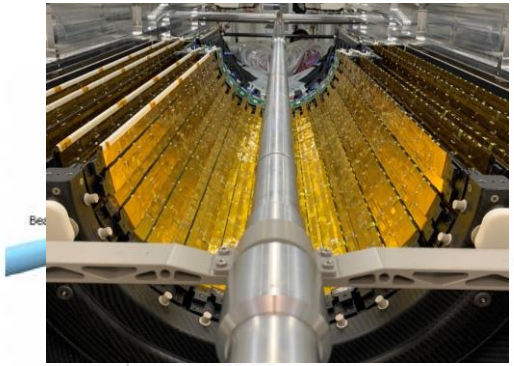
NNLO: Catani et al, arXiv:2010.11906

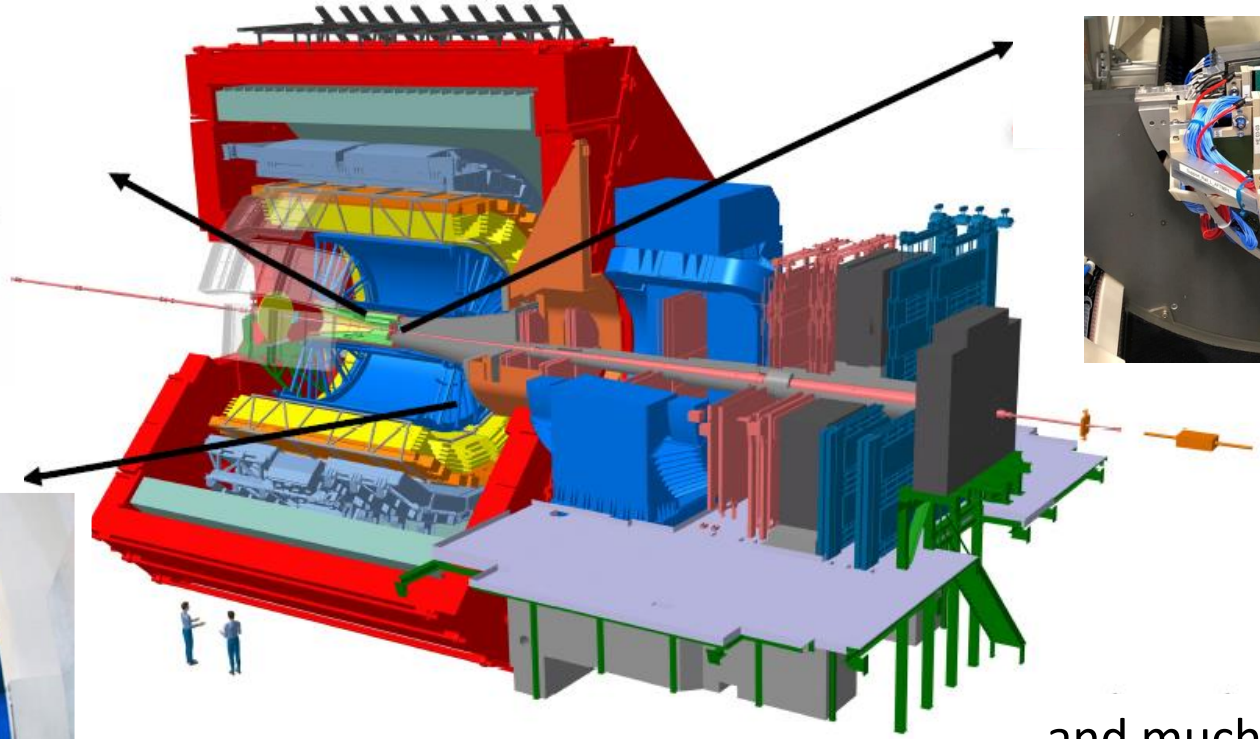
- ML techniques applied to separate prompt and non-prompt D mesons
- Most precise measurement of fragmentation fraction of heavy quarks to strange mesons
- Most precise measurement of $\sigma(b\bar{b})$ at y=0 described by new most accurate calculation (NNLO)

LS2 activities

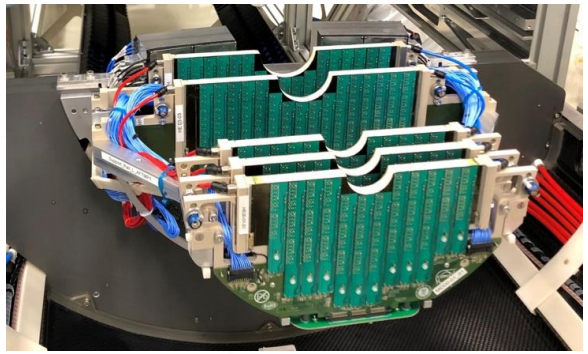
Upgrades for Run 3: reminder

All-pixel Inner Tracking System

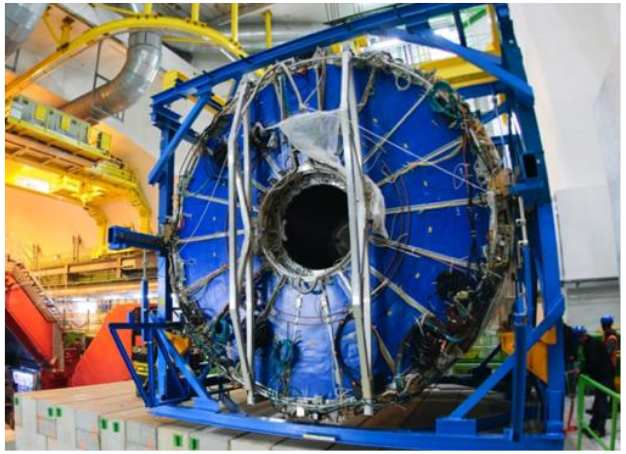




Pixel Muon Forward Tracker



GEM-based TPC readout



… and much more:

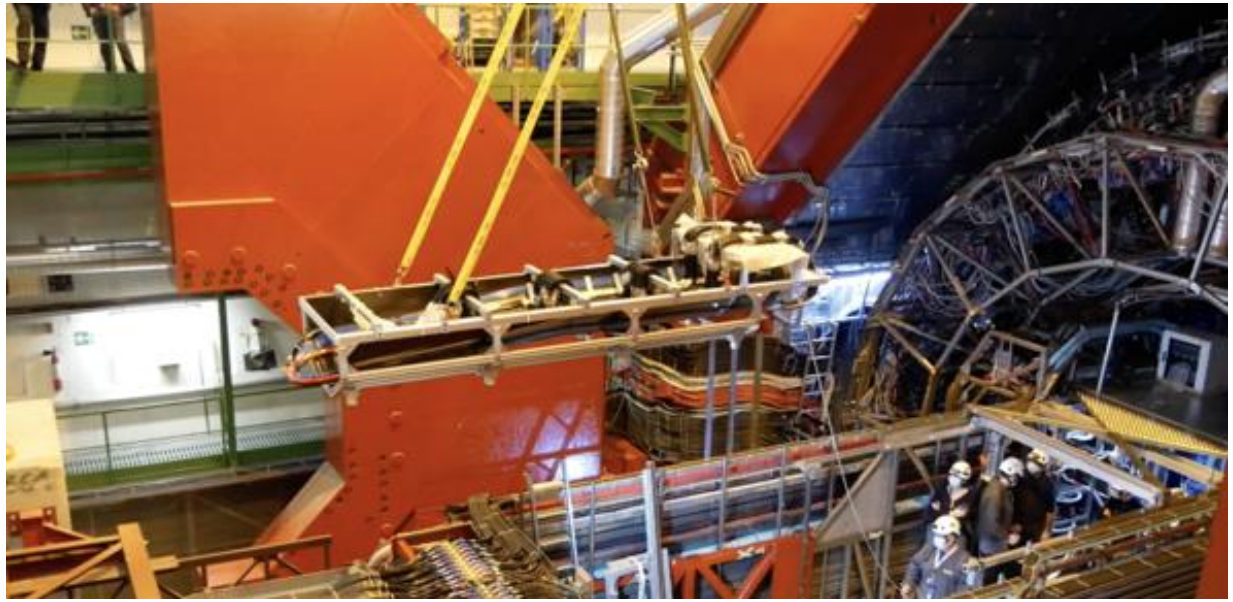
- Fast Interaction trigger
- New Online-Offline systems
- Readout upgrade of all detectors

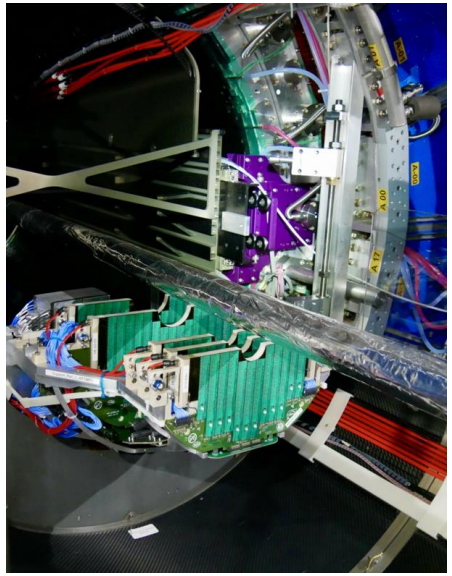
Main goal:

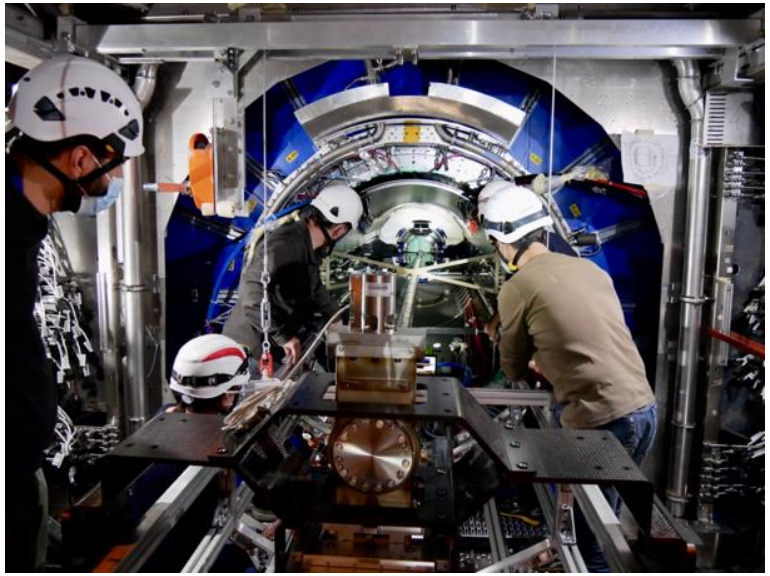
- Record minimum-bias Pb-Pb data at 50kHz (~ 1 kHz in Run 2)
- Collect 13/nb in Run 3&4 → x 100 minimum bias statistics wrt Run 1&2

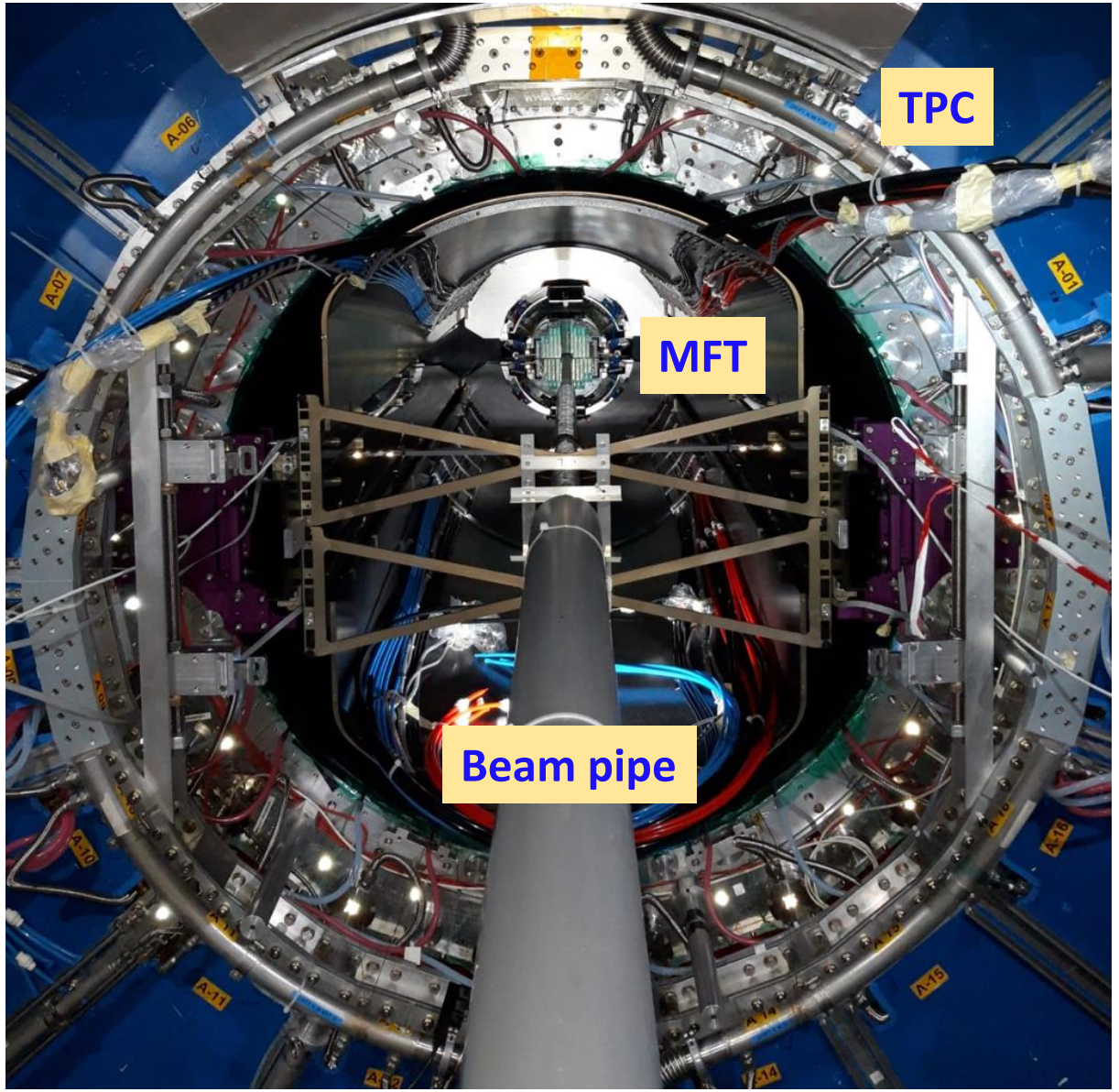
16 Nov: miniframe installation

December: MFT+FITC installation at P2



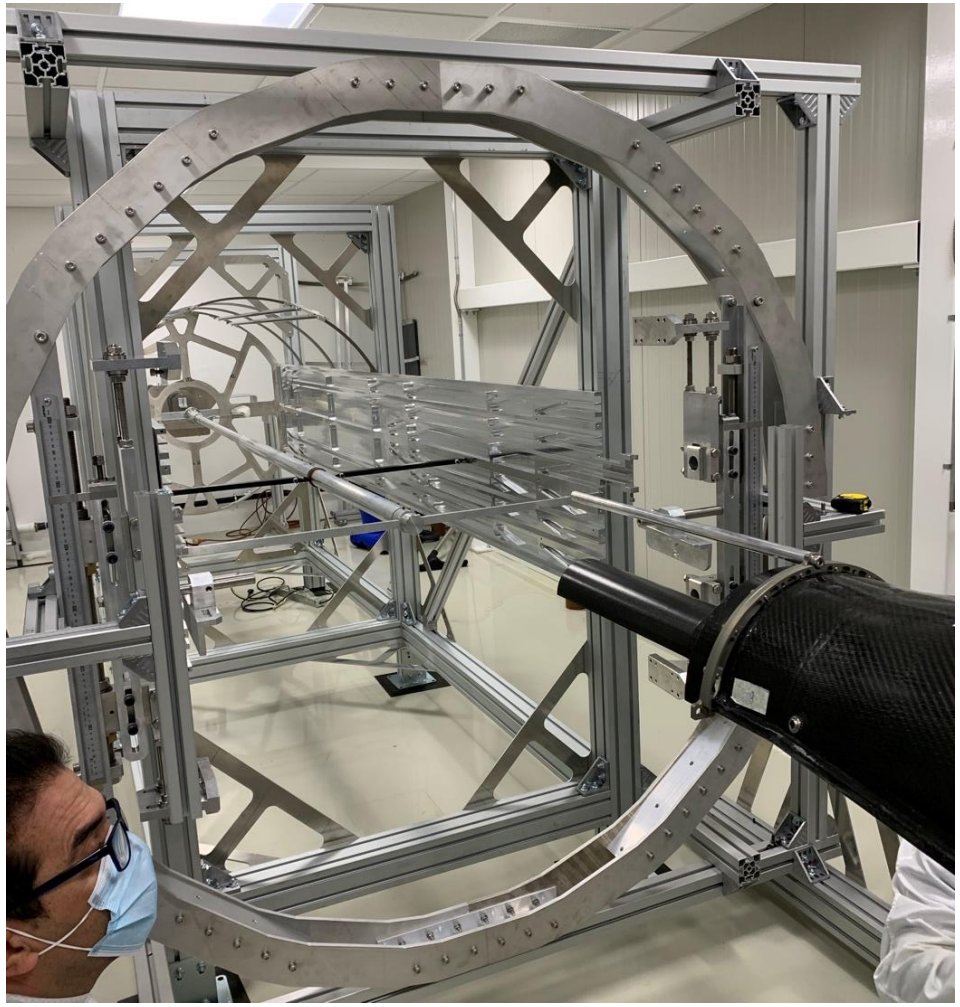


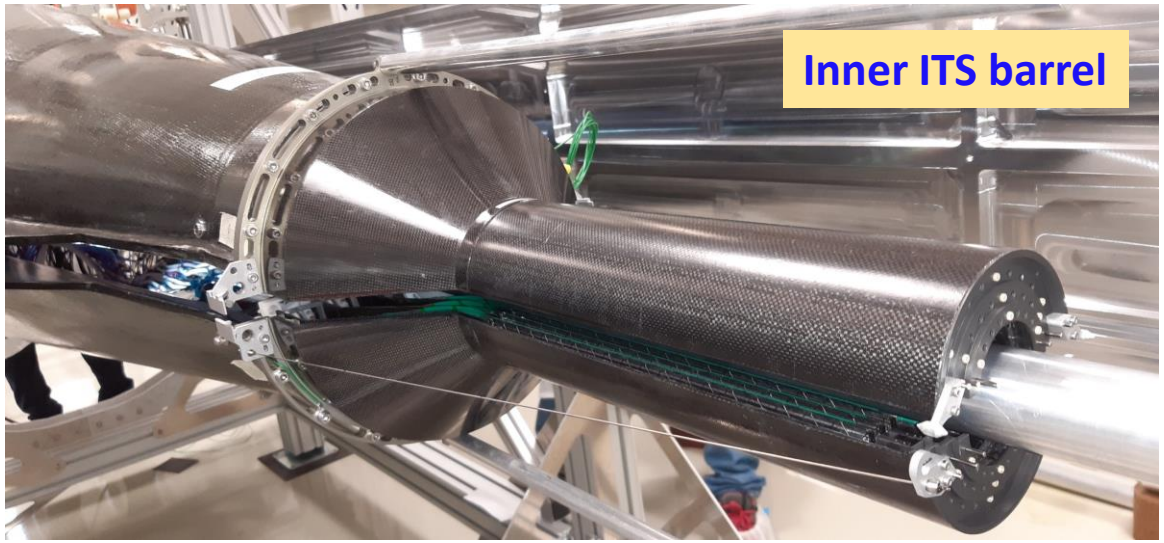




ITS installation tests

- On-surface commissioning completed in December
- Preparing for installation at P2
- Installation in the cavern is planned for mid March - April

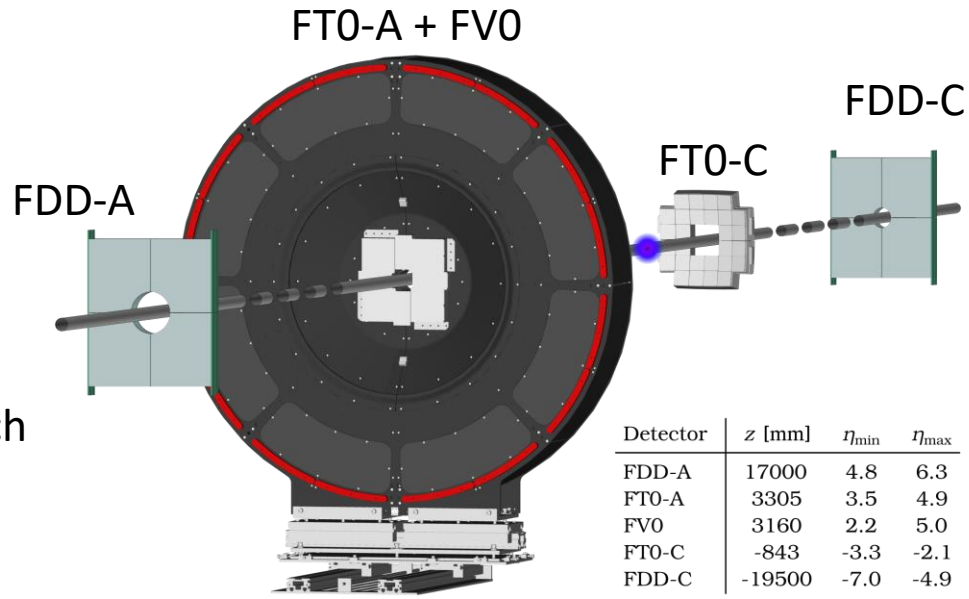




More activities

FIT:

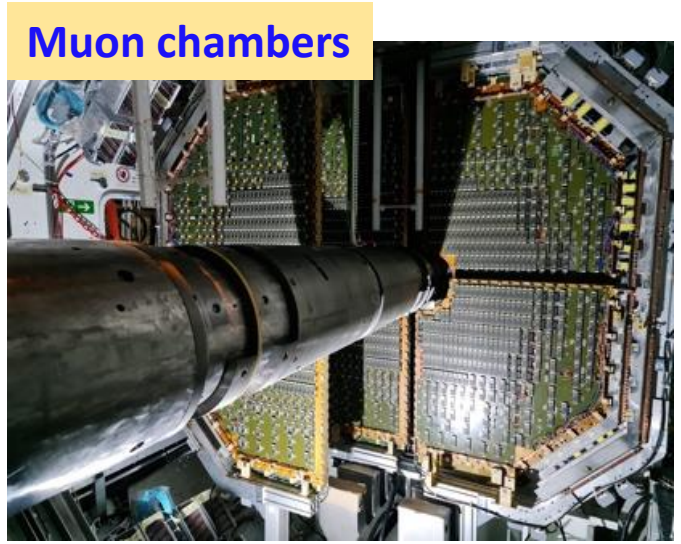
- FDD-C installed in the LHC tunnel
- FDD-A to be installed in the ALICE cavern
- FIT-A detector assembled. Installation in June



Detector	z [mm]	η_{min}	η_{max}
FDD-A	17000	4.8	6.3
FT0-A	3305	3.5	4.9
FV0	3160	2.2	5.0
FT0-C	-843	-3.3	-2.1
FDD-C	-19500	-7.0	-4.9

Muon chambers:

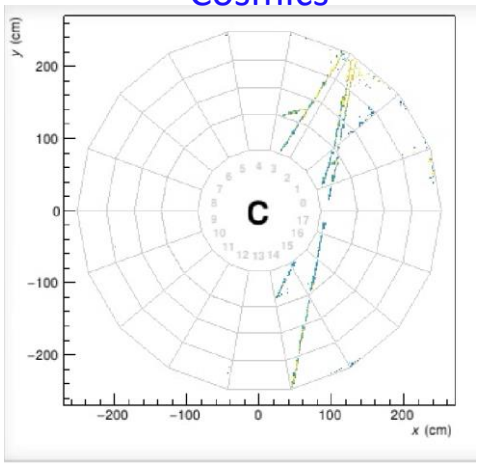
- Stations 3-4-5 ongoing, to be ready by end of March
- Station 2 ready to be installed
- Station 1:
  - 6/8 quadrants installed
  - 2/8 ready @ Orsay -> installed by end of April



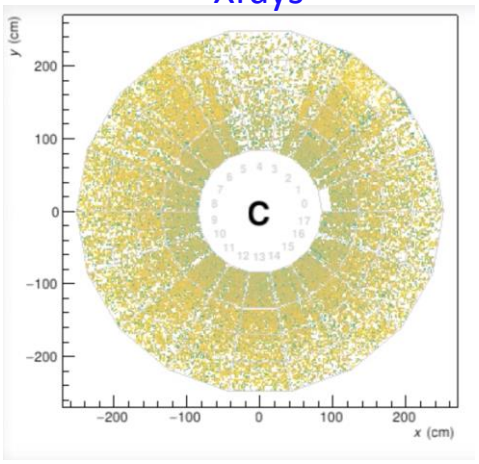
TPC:

- Fully connected to services
- First global runs with TOF
- Taking cosmics / Xray tests in continuous readout

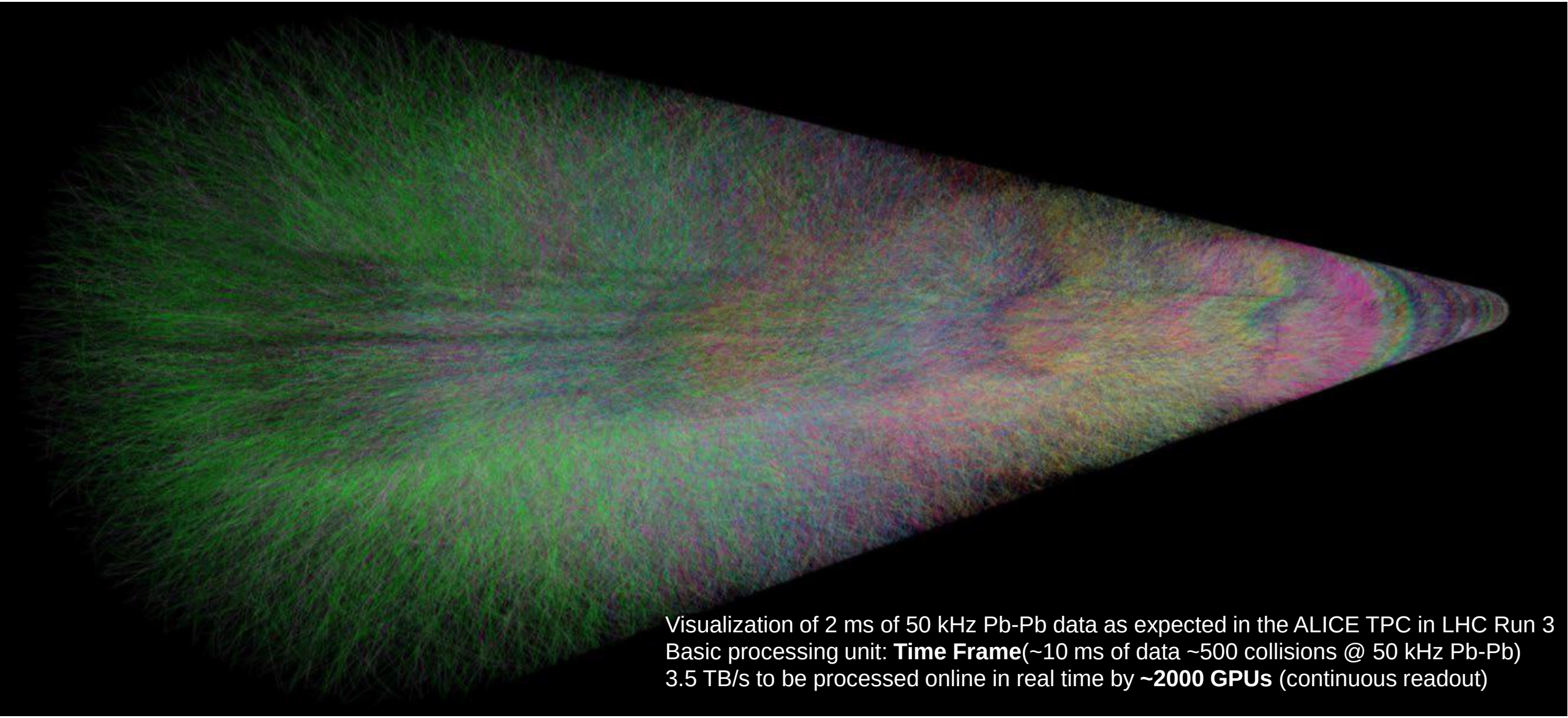
Cosmics



Xrays



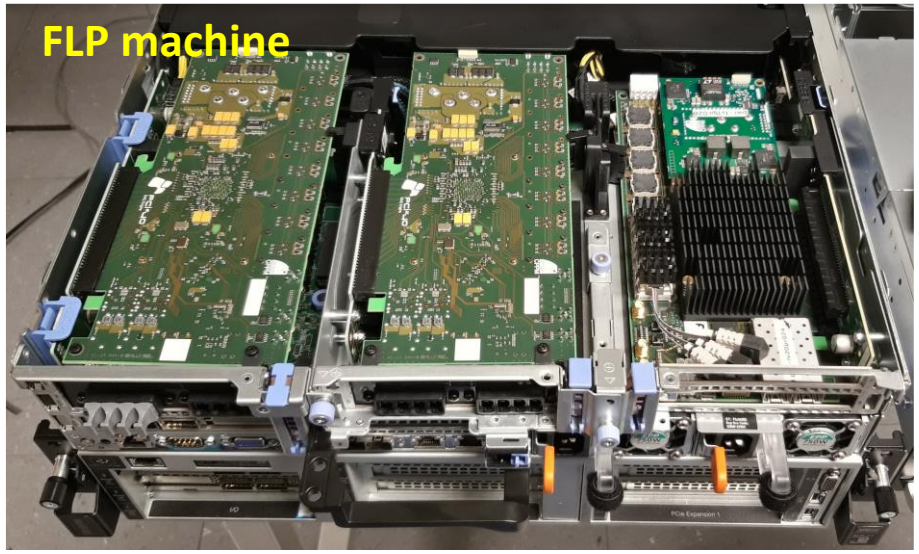
Data processing in Run3



Visualization of 2 ms of 50 kHz Pb-Pb data as expected in the ALICE TPC in LHC Run 3
Basic processing unit: **Time Frame**(~10 ms of data ~500 collisions @ 50 kHz Pb-Pb)
3.5 TB/s to be processed online in real time by **~2000 GPUs** (continuous readout)

O2: Online processing

- **First level processors (FLP):**
  - Readout of detectors (3TB/s) and raw data processing
  - 200 FLPs in CR1

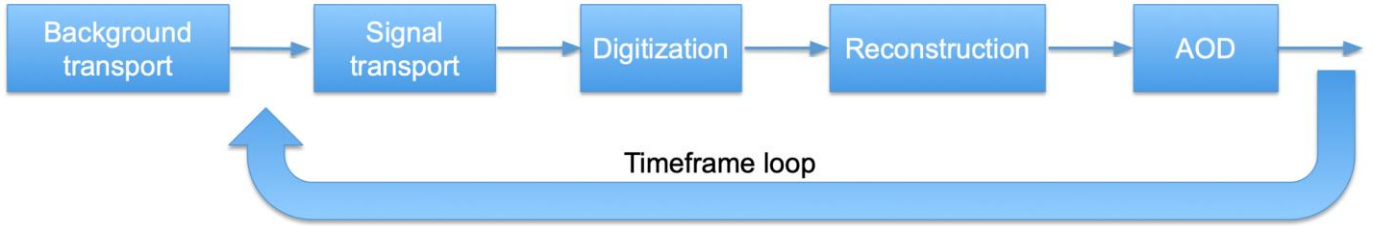


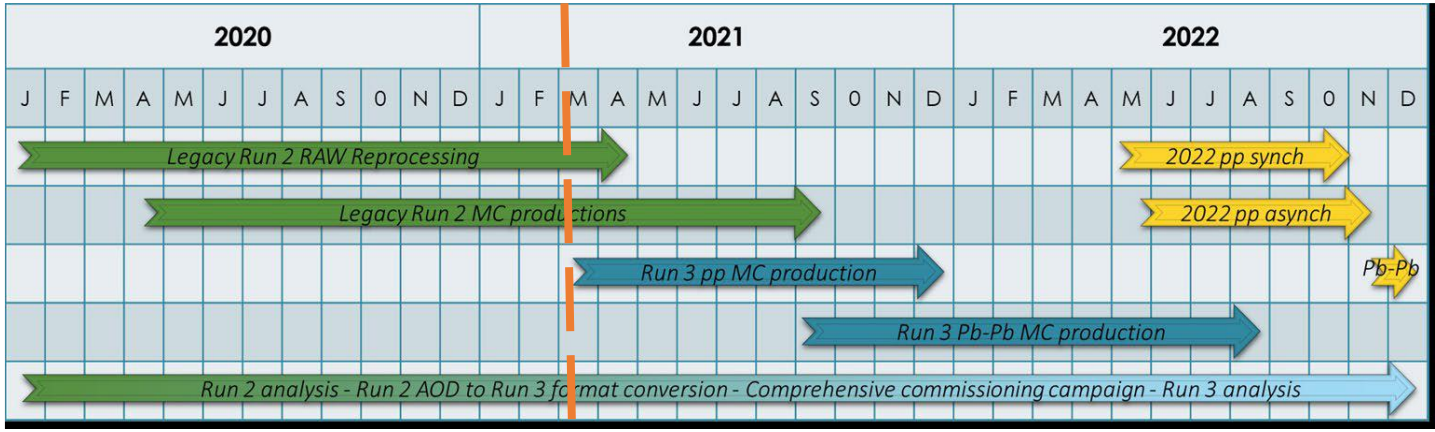
- **Event processing nodes (EPN):**
  - Synchronous event reconstruction
  - EPN servers delivered in Dec
  - Total: 250 EPNs with 2000 GPUs
  - Commissioning of data center is on-going
  - Significant progress in GPU processing

O2: simulations and analysis

Simulation

- Benchmarking with 100 event Time Frames on 8 core queues
- Run 3 Pb-Pb simulation is x2 faster than Run 2 without embedding
- Signal to Background embedding results in factor 4.7 increase of throughput
- Starting large-scale MC productions for Run 3





Analysis challenge

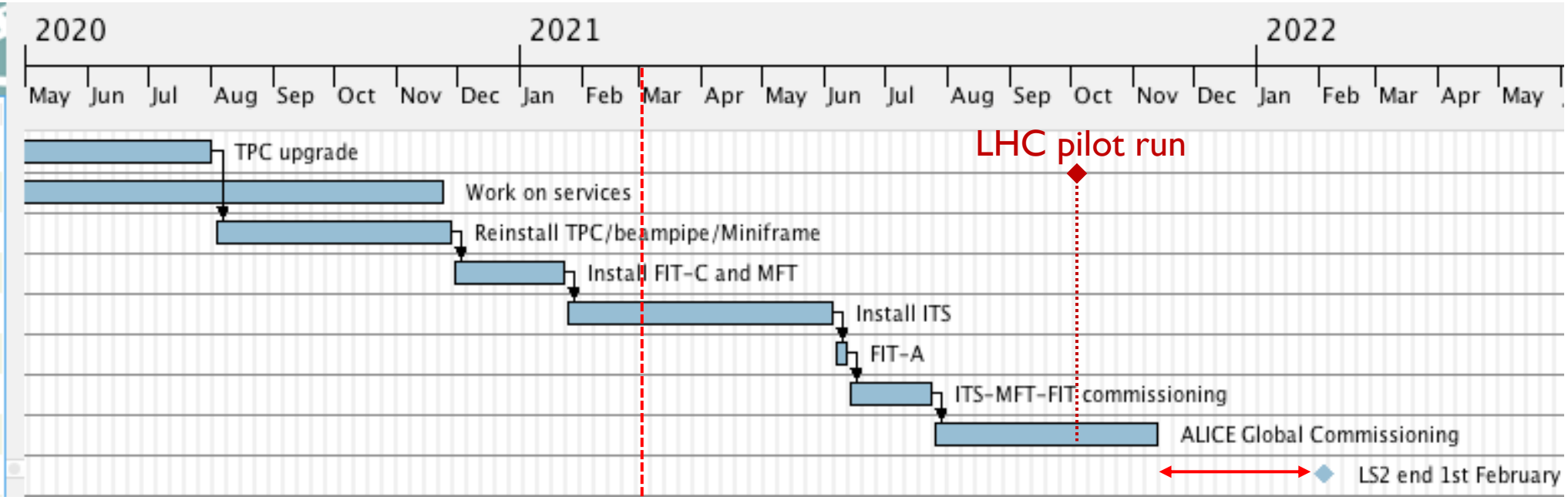
- Basic event selection, centrality estimation, track selection, PID response and secondary vertex finding
- 66 physics analysis tasks in O2 repository
- Running on Run 2 data samples converted into the new AOD format
- New organized distributed analysis AliHyperloop
- Benchmarking: factor 3-10 higher event throughput compared to Run 2 framework
  - optimisation ongoing

Updated schedule

- Schedule v43:
  - ITS installation starting 15 March (+2 weeks wrt v42)
  - 2.5 months contingency with respect to LS2 end date (-2 weeks wrt v42)
  - ALICE vacuum to be closed by June 2021
    → OK to inject low intensity beam by last week September 2021

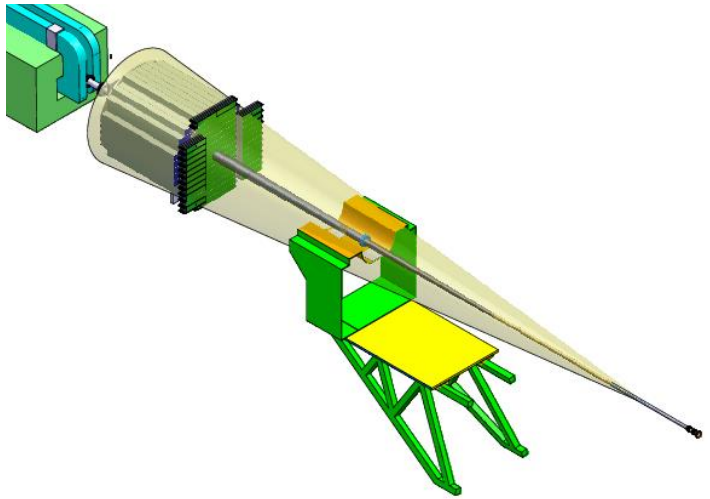
- Preparing shifts for global commissioning: 2 onsite (operations) + 2 remote (monitoring)

Begin date	End date	Dura...
6/3/19	31/7/20	368
7/1/19	23/11/20	491
4/8/20	27/11/20	84
30/11/20	22/1/21	40
25/1/21	4/6/21	95
7/6/21	11/6/21	5
14/6/21	23/7/21	30
26/7/21	12/11/21	80
1/2/22	1/2/22	0

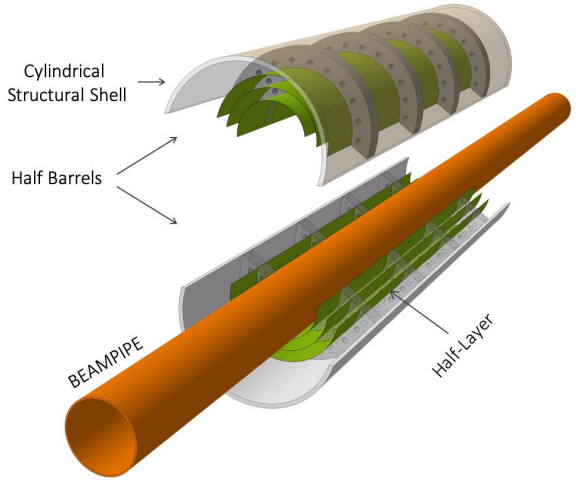


Future upgrades

FoCal

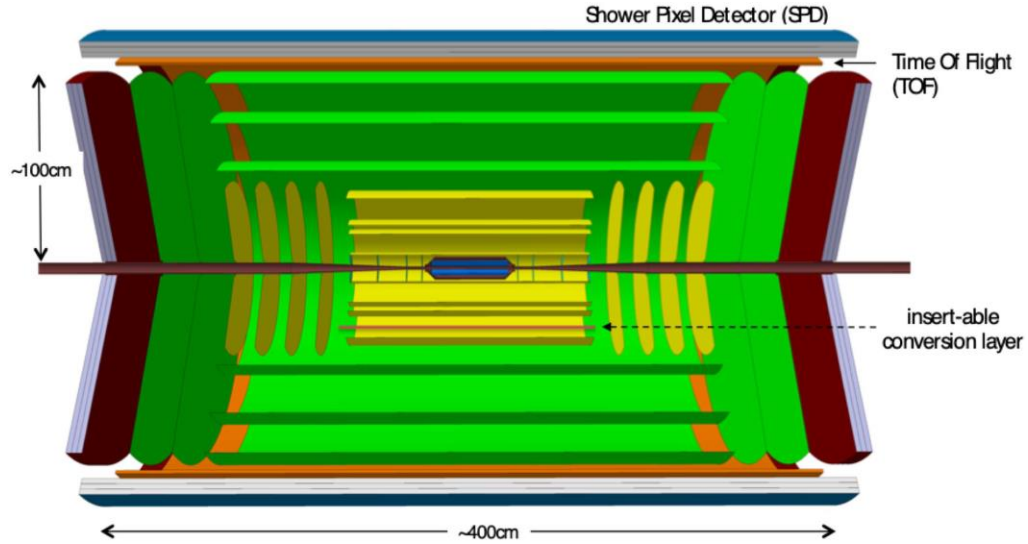


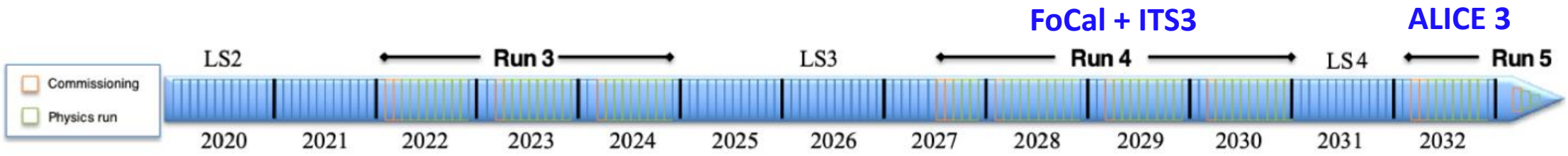
ITS3



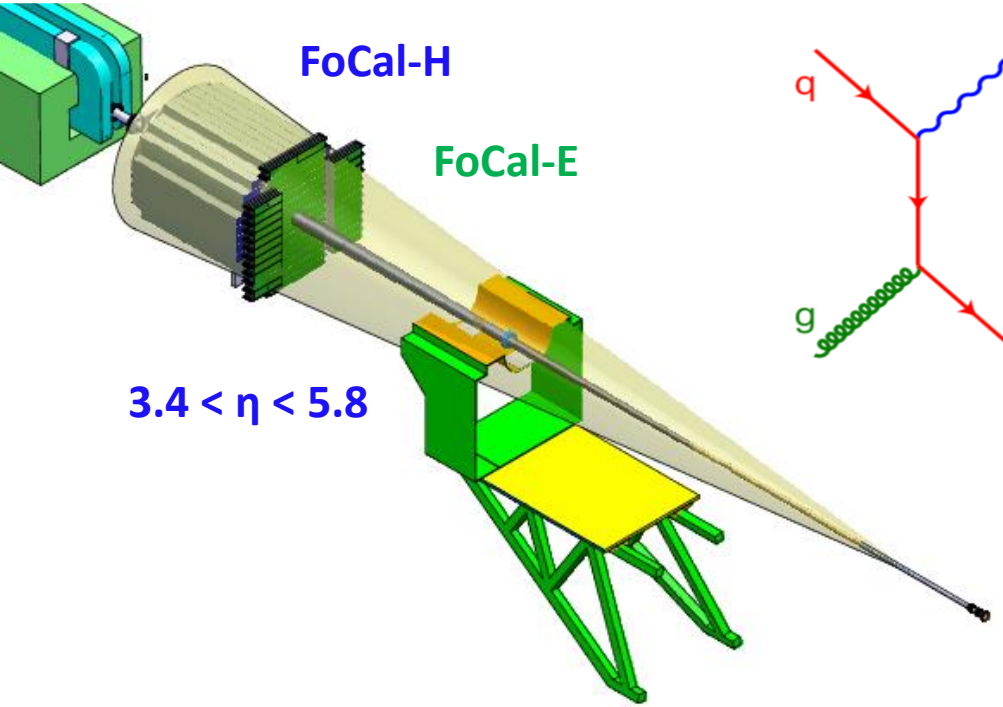
ALICE 3

New heavy-ion experiment for Run 5 and beyond
(not discussed today)

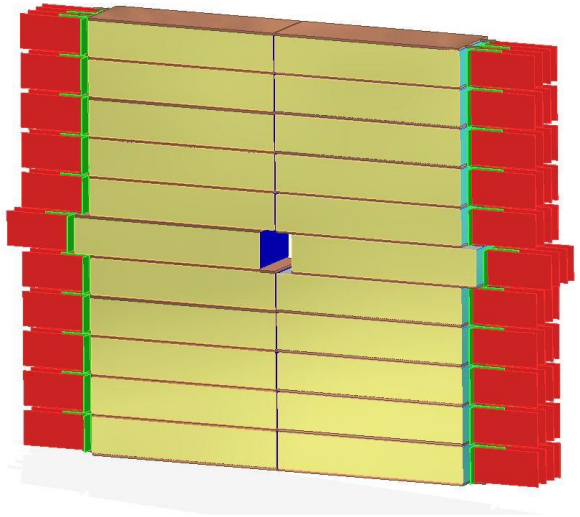


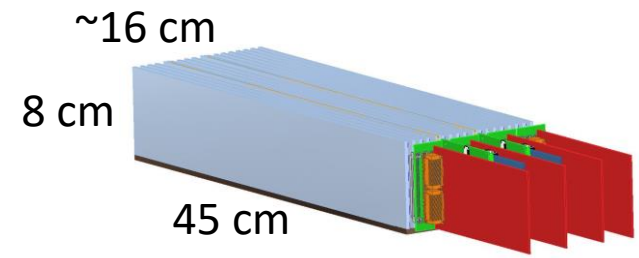


FoCal concept

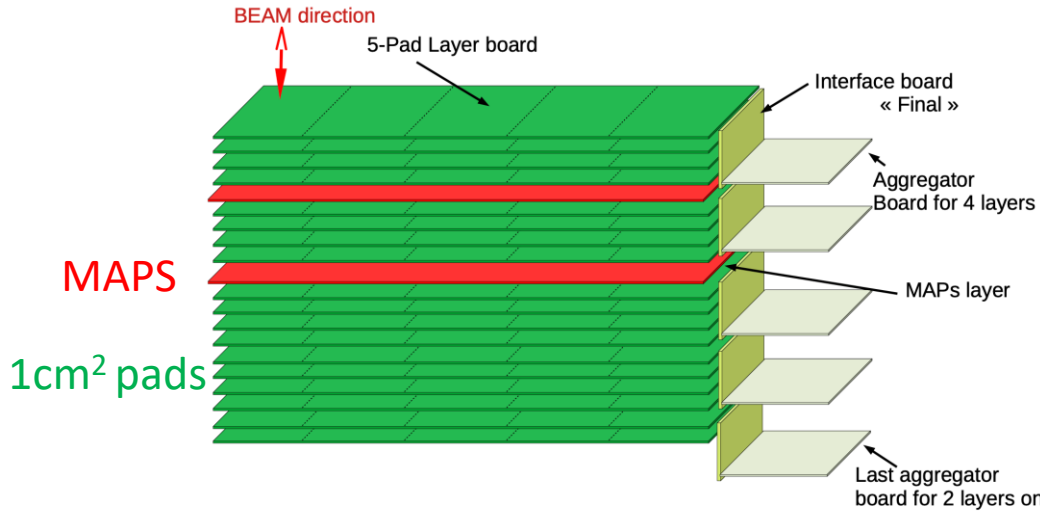


FoCal-E: 22 modules





- **Goal:** saturation/shadowing at low-x with direct photons in pp/p-Pb
- **Concept:**
  - FoCal-E: Si-W sandwich calorimeter with granularity ≈ 1 mm^2
  - FoCal-H: conventional sampling calorimeter for photon isolation
- **TDR in 2022** aiming at installation for Run 4 in 2026

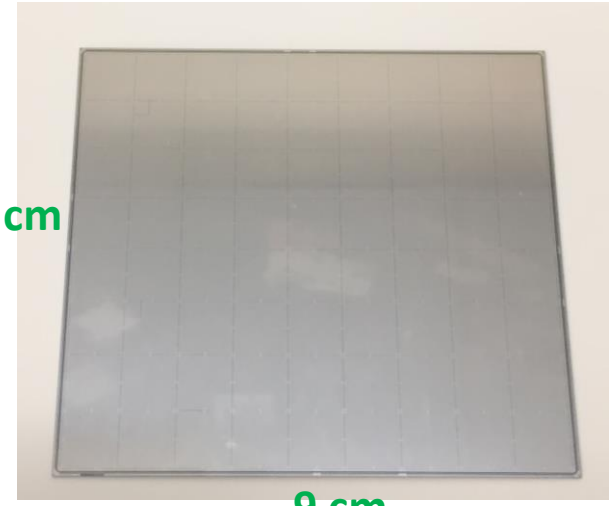


FoCal: preparation for test beams

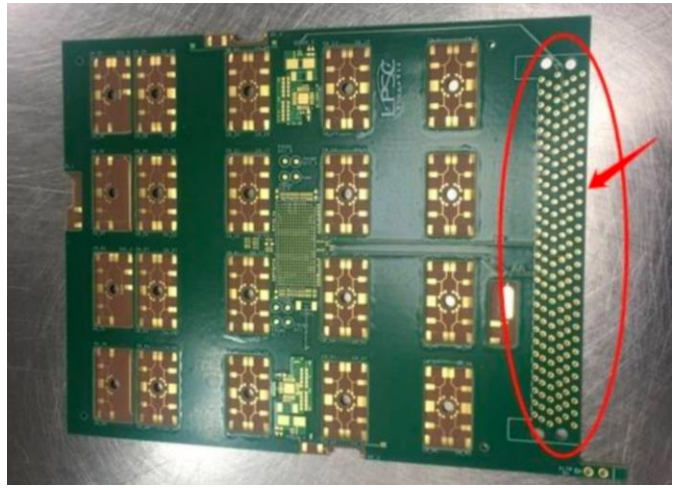
1cm²-granularity sensors:

- Test sensors with 8x9 geometry received in Dec
  - Lab tests ongoing
- One-sensor PCB received in Jan
- Readout boards under production

72 cells



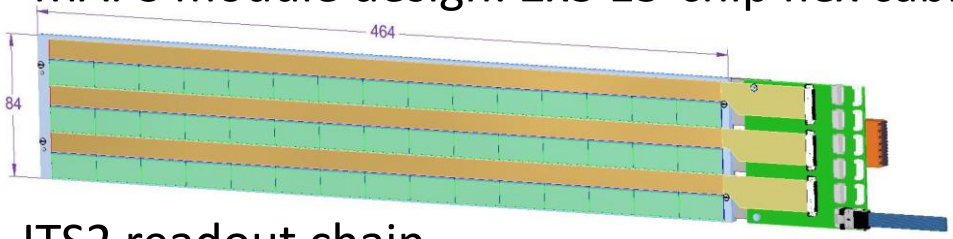
PCB for one sensor



High-granularity sensors (MAPS):

- 30-cm prototypes (9 ALPIDE chips) from pCT:

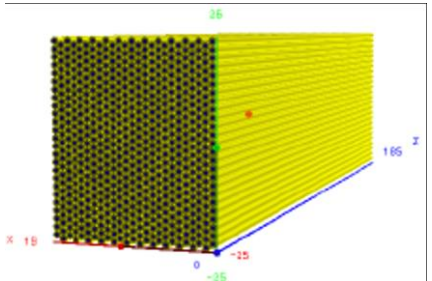
- MAPS module design: 2x3 15-chip flex cables



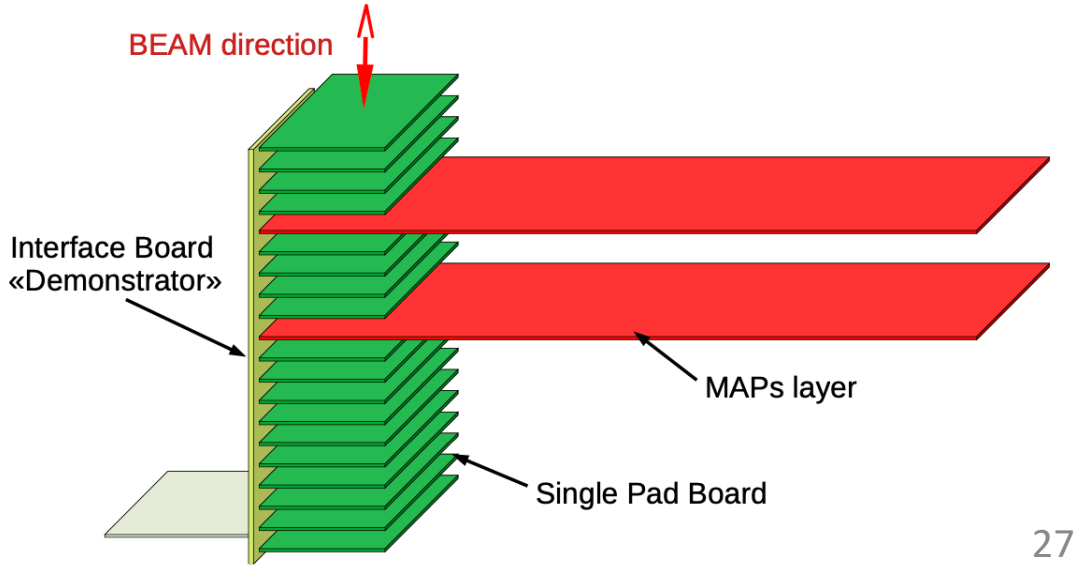
- ITS2 readout chain

FoCal-H prototype:

- Cu capillary tubes
- 10cm x 10cm area, 60-80 cm depth

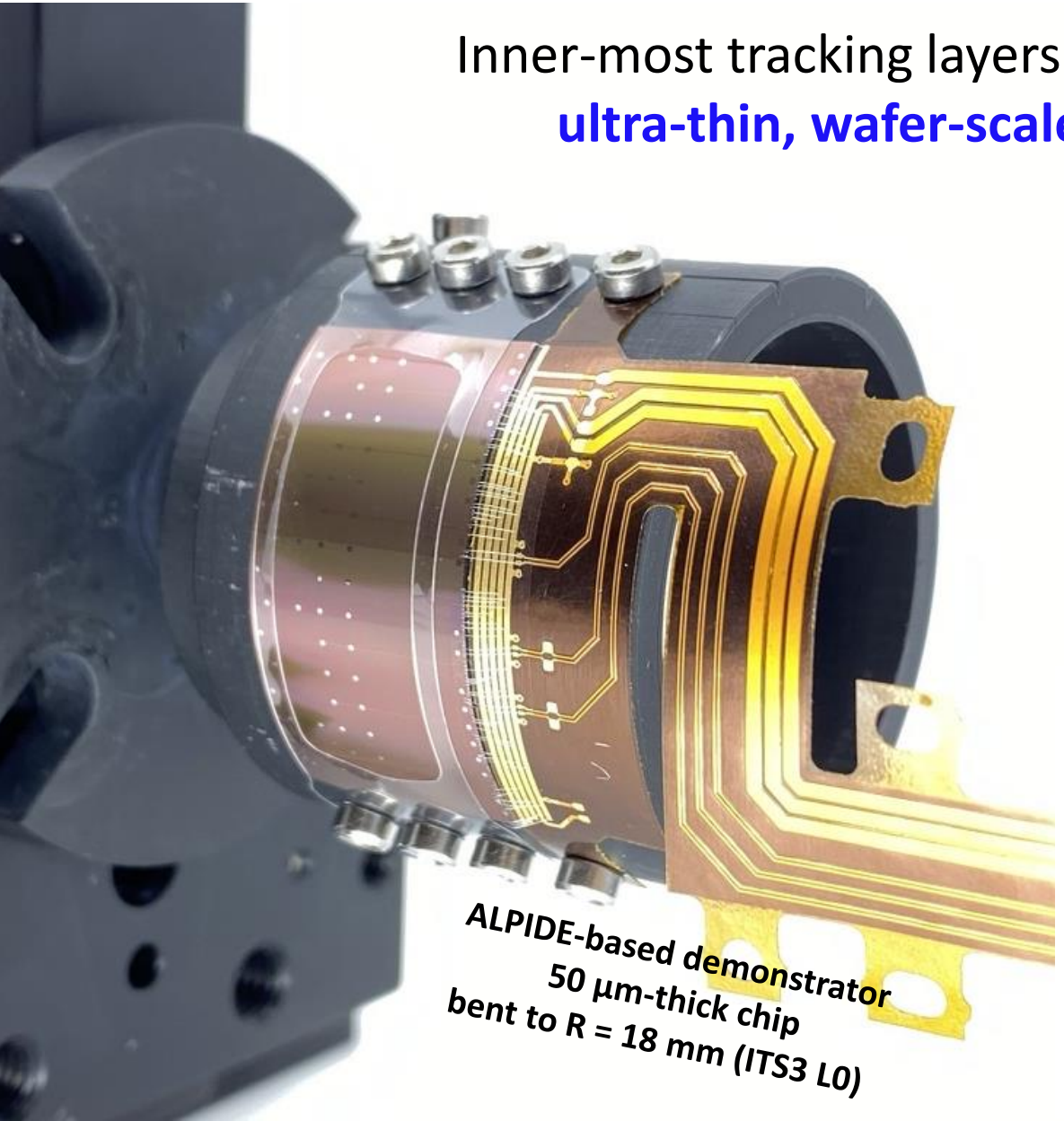


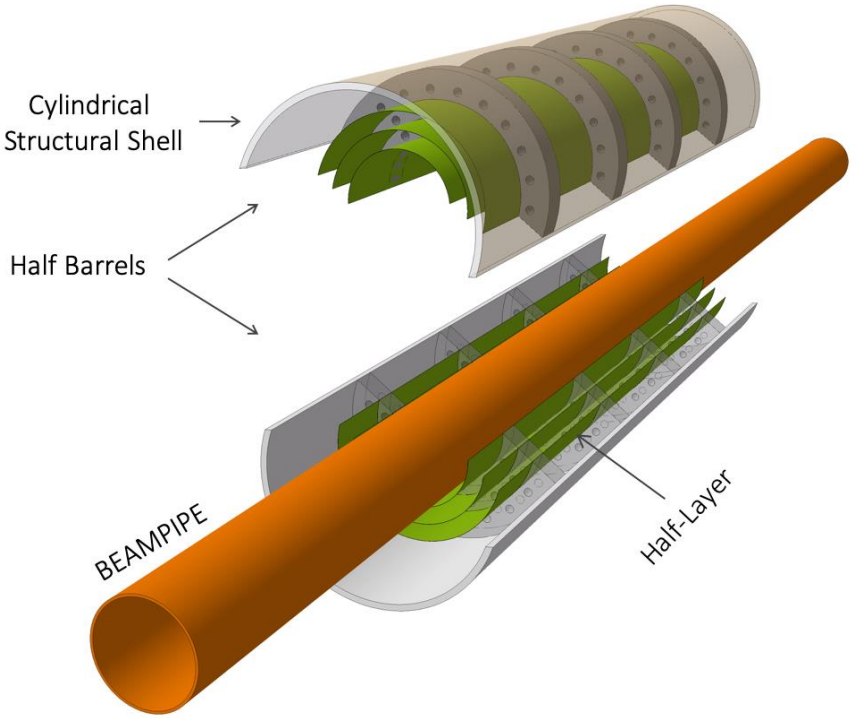
SPS testbeam in Sep 2021



ITS3: new ITS for Run 4

Inner-most tracking layers to be replaced by
ultra-thin, wafer-scale, bent MAPS

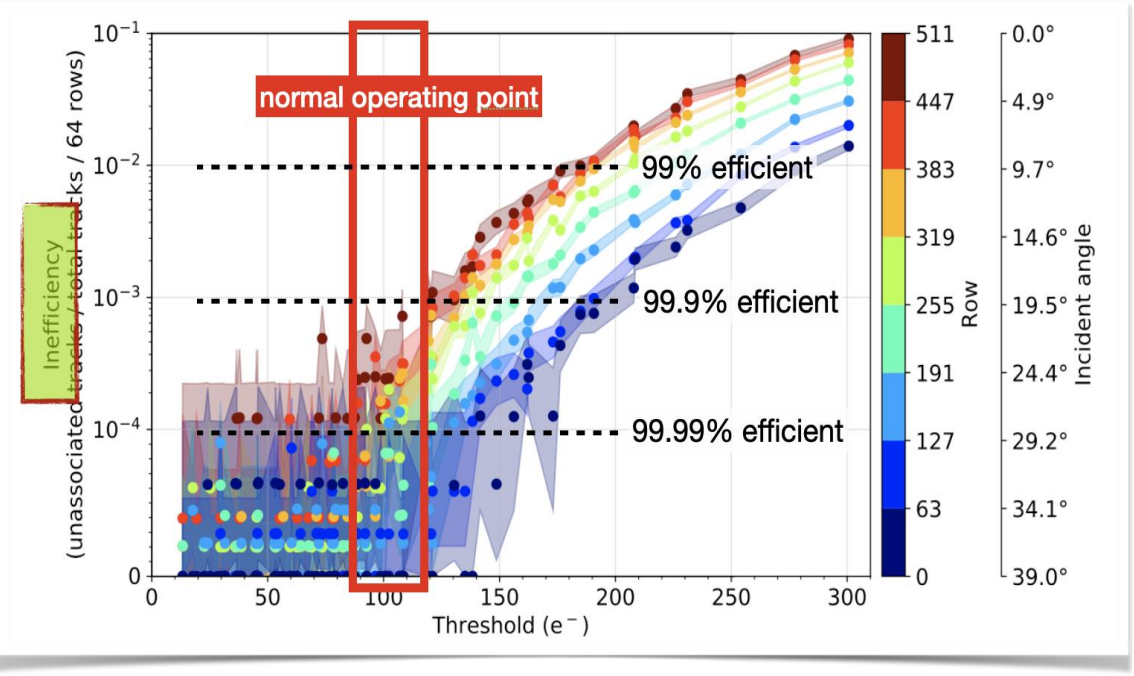


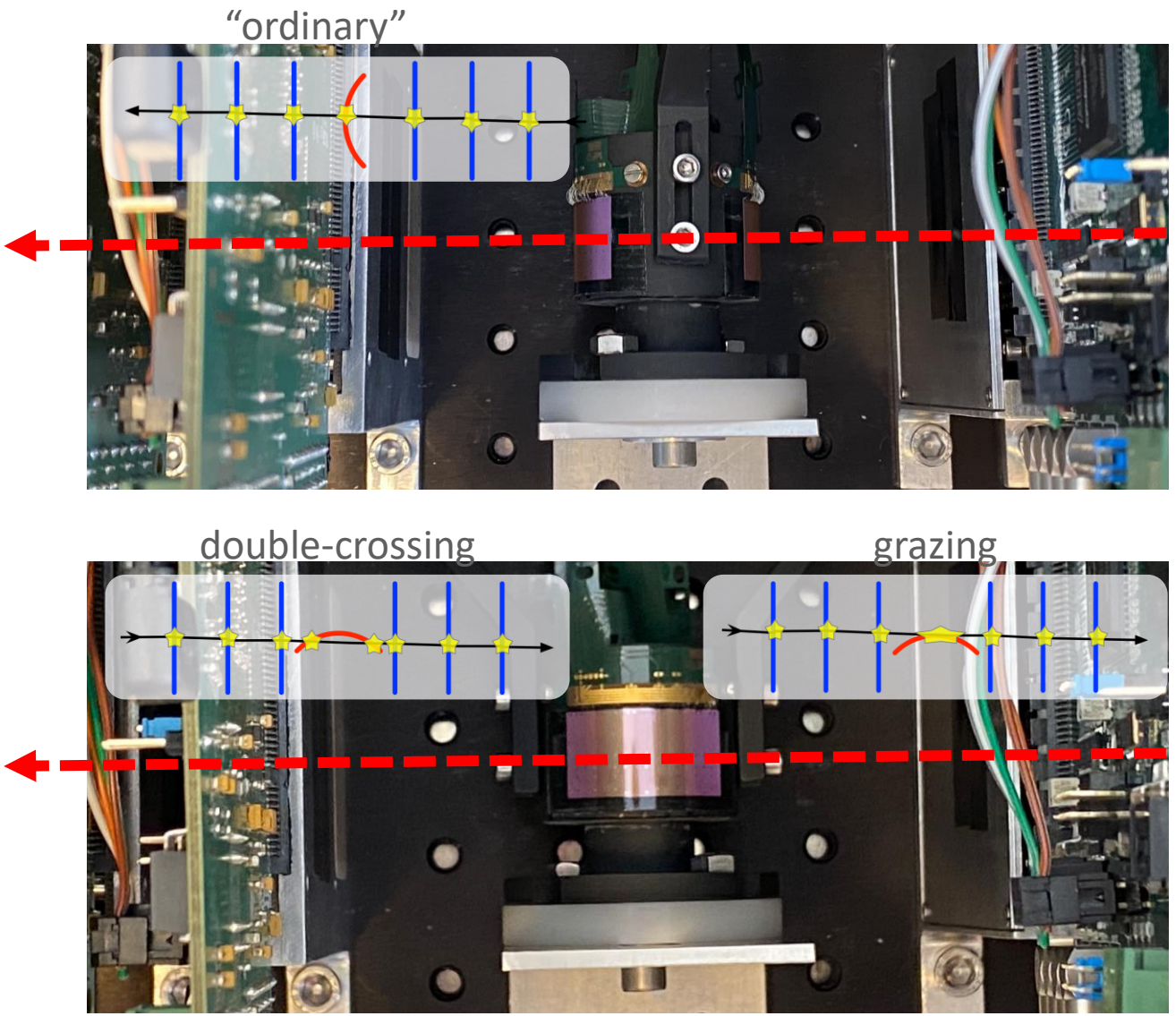


- **Large impact on key ALICE physics programme**
  - Charm and beauty hadronization, thermal low-mass dileptons, shown previously
  - Continues to attract new interests, more channels being opened (e.g. non-prompt D_s and Ξ_c^+)
- Very active R&D including many groups
  - working towards TDR

Characterisation of bent MAPS

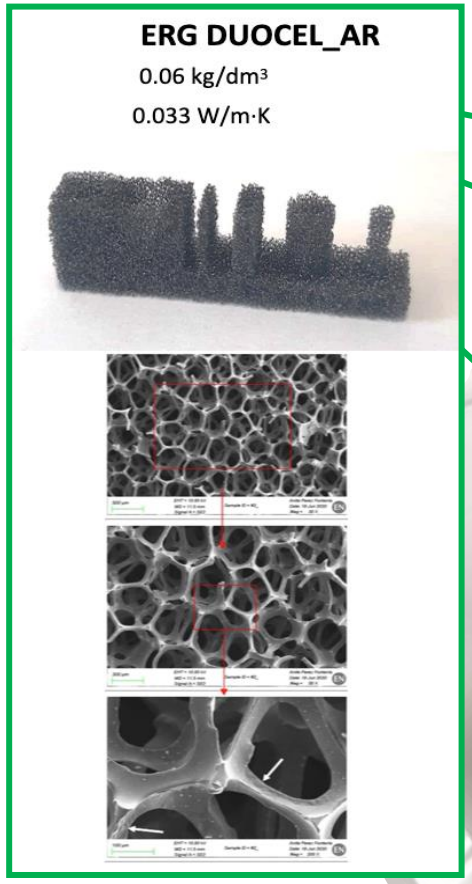
- While waiting for the first wafer-scale chips, significant effort is made with existing material
- Bent assemblies are now done routinely with different methods at various institutes
- 3 beam tests at DESY during 2020 (Jun, Aug, Dec) with different arrangements
- Confirming that bent MAPS are working





ITS3: Mechanics

- Carbon foam selection has been done
- Engineering module of Layer 2 was produced

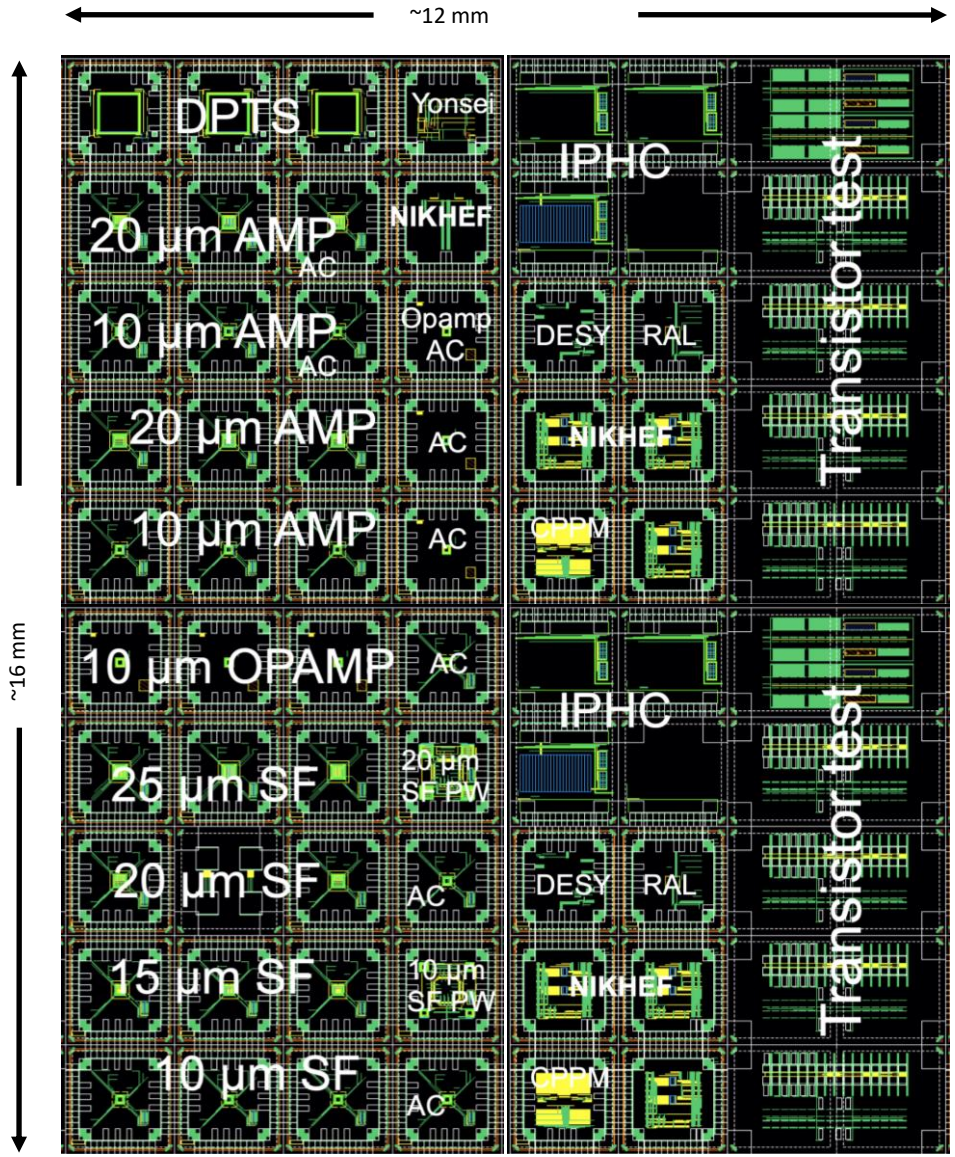


50 µm dummy Si wafer-scale chip

[ITS3 Layer 2 (R = 30 mm) engineering module]

ITS3: chip submission in 65 nm

- First submission in the TowerJazz 65nm technology
  - significant drive from ITS3
- Contains a comprehensive first set of structures to explore the technology:
  - transistor test structures
  - analog building blocks (band gaps, LVDS drivers, etc)
  - various diode matrices (small and large)
  - digital test matrices
- Estimated delivery: May 2021



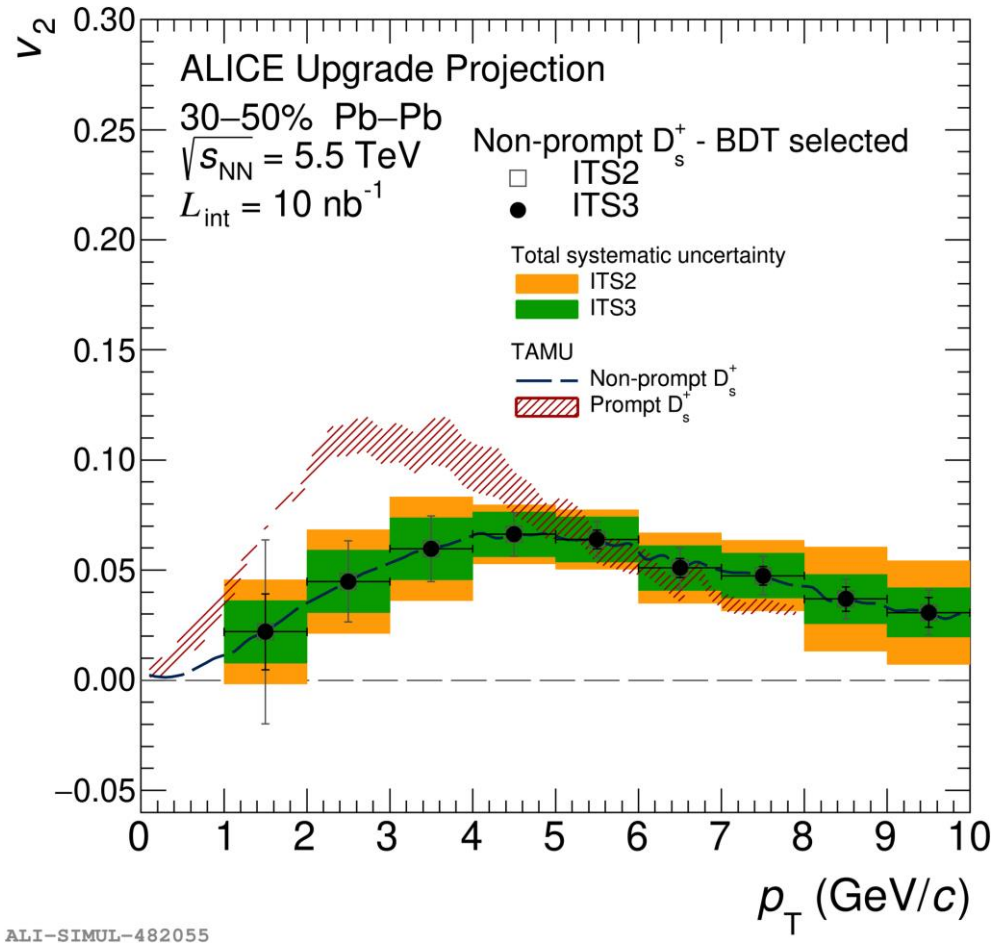
Summary

- **Physics:** output is continuing
  - 8 new papers with precise measurements of several observables
- **LS2 activities:** ongoing according to schedule
  - all important detector parts are already at CERN
  - installation is continuing (MFT at IP, ITS ready)
  - readout and computing on track
  - 2.5 months contingency according to current planning
- **Future upgrades:** good progress
  - ITS3: chip submission in 65 nm + first bent mechanics prototypes
  - FOCAL: preparing prototype for test beams
  - ALICE3: working towards an LoI

BACKUP

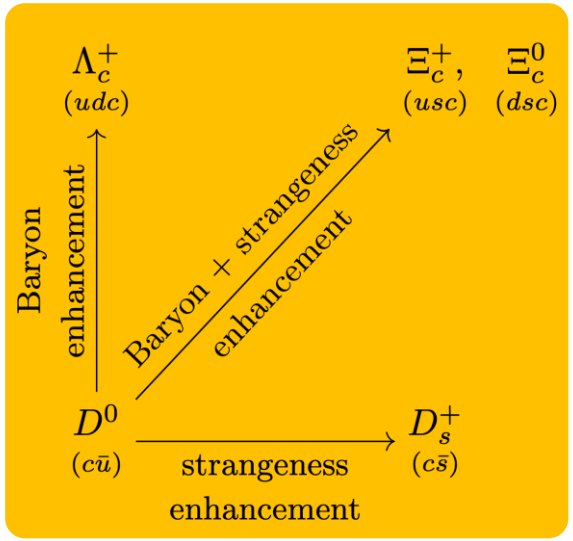
Recent additions to the ITS3 physics case

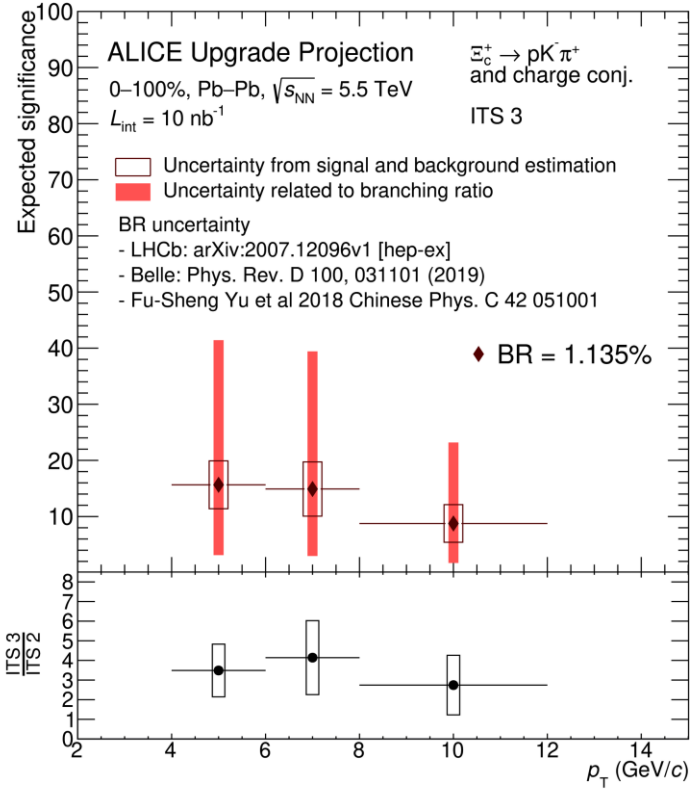
- Non-prompt D_s^+ with machine learning
  - ITS3 remains important for a decisive measurement at low p_T



ALI-SIMUL-482055

- Ξ_c^+ measurement to shed more light on charm hadronisation and "enhancements" in pp, p-Pb, Pb-Pb wrt e^+e^-
- ITS3 key in reconstruction ($c\tau \approx 135$ µm)





ALI-SIMUL-482042