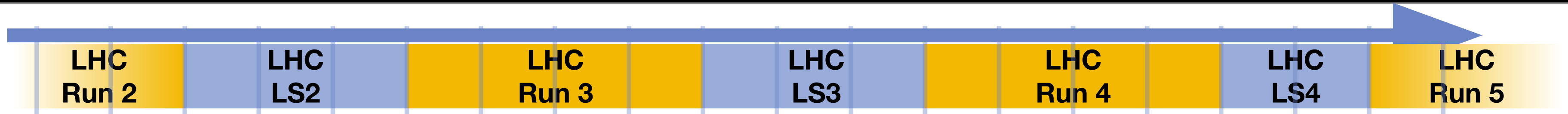
ALICE status report

Mattia Faggin
University and INFN, Trieste (Italy)

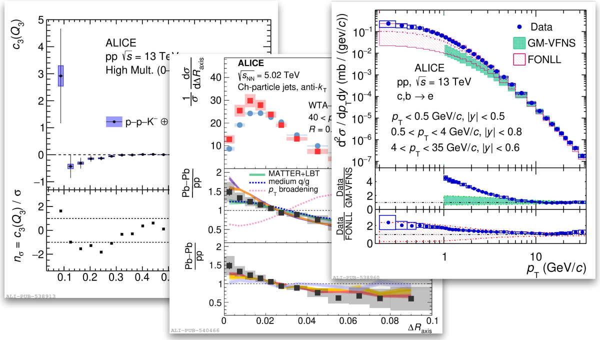
On behalf of the ALICE Collaboration
LHCC open session, 7th June 2023

Outline

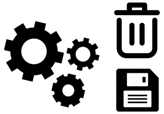
mfaggin@cern.ch



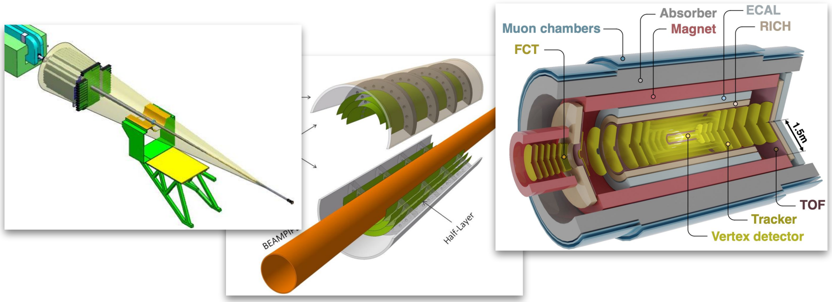
- **Part 1** - New physics results with Run 2 data
  - highlights from recent papers



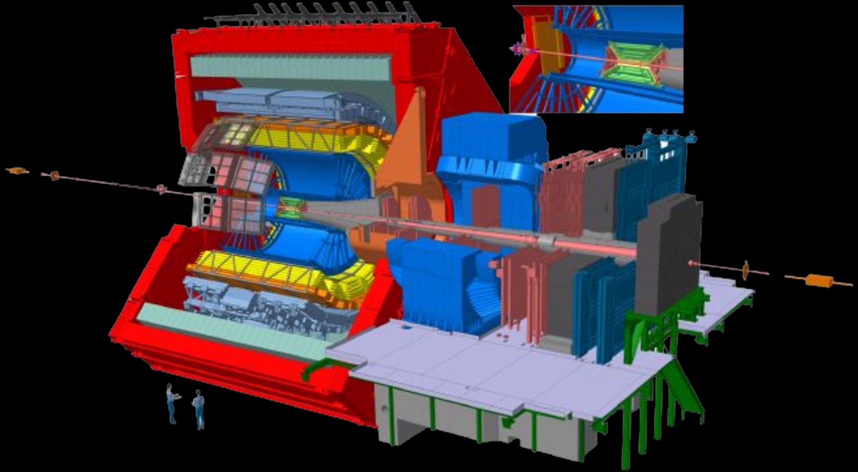
- **Part 2** - Run 3 operations and data processing
  - 2023 operations and planning
  - TPC firmware commissioning and preparation for HI data taking



- **Part 3** - Upgrade
  - Highlights on ITS3 and FoCal for Run 4
  - Highlights on ALICE 3 for Run 5, 6



Part 1
New physics results with Run 2 data



New submitted papers

ALICE

Bold: discussed in next slides

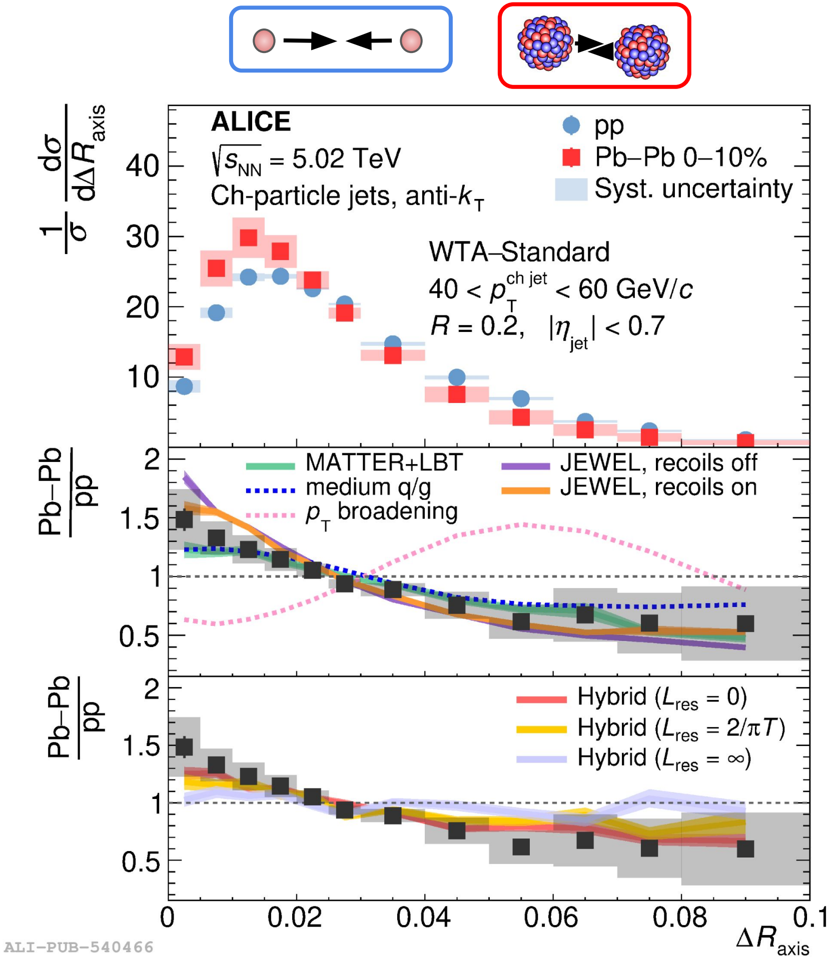
1. **[arXiv:2303.13347] *Measurement of the angle between jet axes in Pb–Pb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV***
2. [arXiv:2303.15317] *Data-driven precision determination of the material budget in ALICE*
3. **[arXiv:2303.13361] *Measurement of inclusive J/ψ production at midrapidity and forward rapidity in Pb–Pb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV***
4. **[arXiv:2303.13349] *Inclusive and multiplicity dependent production of electrons from heavy-flavour hadron decays in pp and p-Pb collisions***
5. [arXiv:2303.13414] *Higher-order correlations between different moments of two flow amplitudes in Pb–Pb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV*
6. **[arXiv:2303.13431] *Measurement of inclusive J/ψ pair production cross section in pp collisions at $\sqrt{s}$ = 13 TeV***
7. **[arXiv:2303.13448] *Study of the p–p–K^+ and p–p–K^- dynamics using the femtoscopy technique***
8. **[arXiv:2304.10928] *First polarisation measurement of coherently photoproduced J/ψ in ultra-peripheral Pb–Pb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV***
9. [arXiv:2304.12403] *Exclusive and dissociative J/ψ photoproduction, and exclusive dimuon production, in p–Pb collisions at $\sqrt{s_{NN}}$ = 8.16 TeV*
10. **[arXiv:2305.06169] *First measurement of the |t|-dependence of incoherent J/ψ photonuclear production***
11. [arXiv:2305.19060] *Energy dependence of coherent photonuclear production of J/ψ mesons in ultra-peripheral Pb–Pb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV*
12. [arXiv:2305.19093] *Accessing the strong interaction between Λ baryons and charged kaons with the femtoscopy technique at the LHC*
13. [ALICE-PUBLIC-2023-001] *Physics of the ALICE Forward Calorimeter upgrade*

442 ALICE papers submitted

Angle between jet axes in Pb-Pb at $\sqrt{s_{NN}}$ = 5.02 TeV

mfaggin@cern.ch

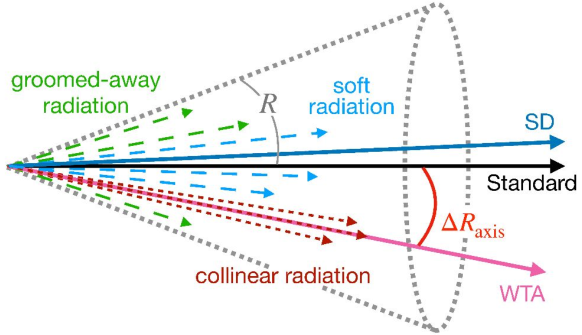
ALICE



arXiv:2303.13347

First $\Delta R_{axis}^{WTA\text{-}Standard}$ measurement in Pb–Pb collisions

New observables to study jet quenching



Standard: soft + hard

Soft Drop (SD): soft wide-angle radiation removed

Winner-Takes-All (WTA): hardest jet constituent

- Jet substructure measurements: sensitivity to different scales within the jet modification process

$$\Delta R_{axis} \equiv \sqrt{(y_{axis,1} - y_{axis,2})^2 + (\varphi_{axis,1} - \varphi_{axis,2})^2}$$

- $\Delta R_{axis}^{WTA\text{-}Standard}$ distribution narrowing in Pb–Pb compared to pp
  → larger suppression for wider jets (e.g. g-jets) with respect to narrow ones

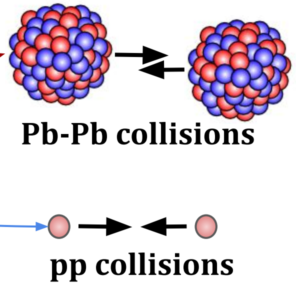
Inclusive J/ψ production in Pb–Pb at $\sqrt{s_{NN}}$ = 5.02 TeV

mfaggin@cern.ch

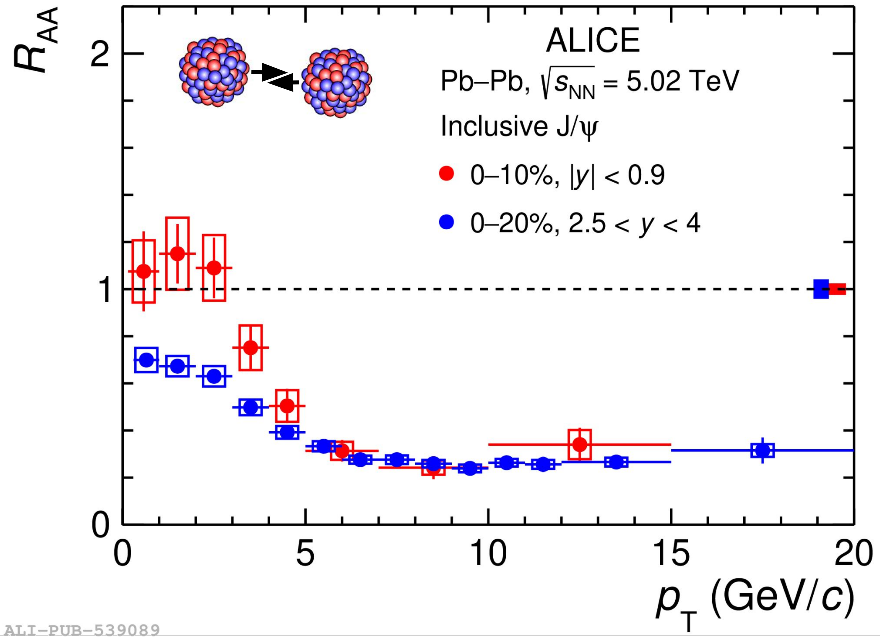
arXiv:2303.13361

Nuclear modification factor

$$R_{AA}(p_T, y) = \frac{1}{\langle T_{AA} \rangle} \frac{d^2N_{AA}/dp_T dy}{d^2\sigma_{pp}/dp_T dy}$$



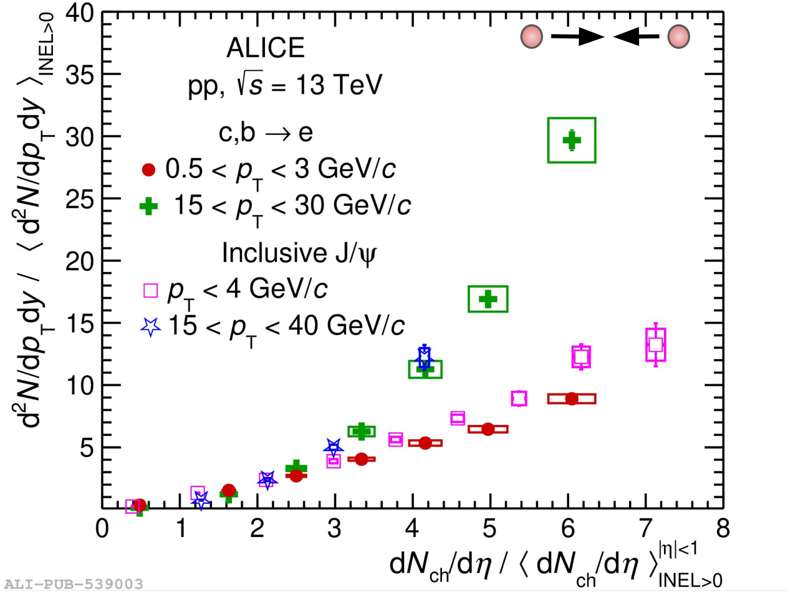
Investigate quarkonia production mechanisms in QGP



- R_{AA}(mid-y) > R_{AA}(forward-y) at low p_T
  - J/ψ formation via recombination
  - Larger c-quark density at mid-y induces larger production of J/ψ via regeneration
- R_{AA}(mid-y) ~ R_{AA}(forward-y) at high p_T
  - Weaker y-dependence of suppression/E-loss

arXiv:2303.13349

Electrons from heavy-flavour hadron decays vs. multiplicity



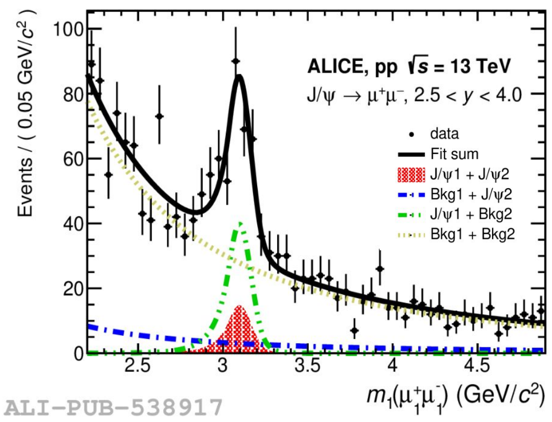
- Self-normalized yields of c,b→e compatible with those of other particles (e.g. J/ψ)
  - auto-correlation effects induced by particle production associated with jet activity

arXiv:2303.13431

Inclusive J/ψ pair production in pp collisions

Role of MPIs in particle production

1 of the 2 projections!



2 J/ψ ($c\bar{c}$) ==
2 hard scatterings

J/ψ pairs: 2D $\mu^+\mu^-$ inv. mass fit

$p_T > 0$
$2.5 < \eta < 4.0$

J/ψ pair cross section in pp at $\sqrt{s}$ = 13 TeV

$$\sigma(J/\psi\, J/\psi) = 10.3 \pm 2.3\,(\text{stat.}) \pm 1.3\,(\text{syst.})\ \text{nb}$$

~1000 lower than σ(J/ψ)

- Quarkonium-pair production golden tool to probe the MPI role on multi-heavy-quark hadronization
- Result compatible with LHCb result

arXiv:2303.13448

- Explore the two- and three-body interactions in p–p–K systems
- Search for kaonic bound states
- Studied via correlation functions

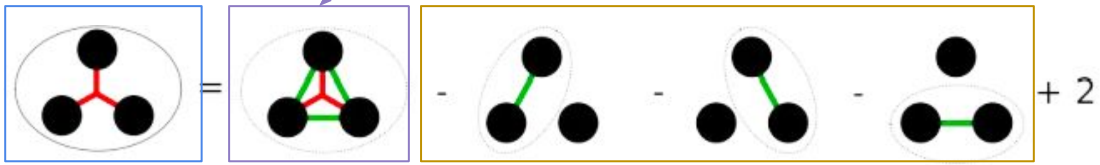
LHC as a laboratory to study hadron-hadron interactions

$$Q_3 = \sqrt{-q_{ij}^2 - q_{jk}^2 - q_{ki}^2}$$

Emitting source (anchored to p–p correlation in ALICE data, see PLB 811 (2020) 135849)

3-particle wave function

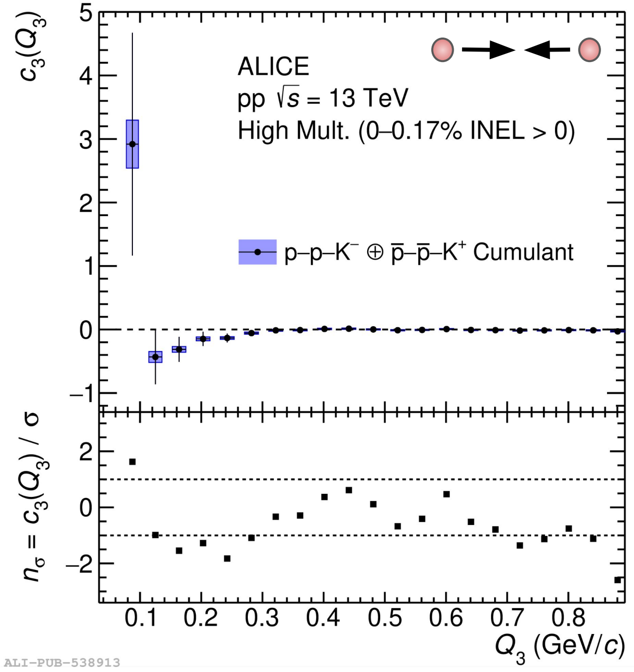
$$C(Q_3) = \mathcal{N} \times N_{\text{same}}(Q_3)/N_{\text{mixed}}(Q_3) = \int S(r_1, r_2, r_3)\, |\psi(Q_3, r_1, r_2, r_3)|^2\, d^3x_1 d^3x_2 d^3x_3$$



Genuine 3-body correlation

Measured 3-body correlation

2-body correlations



- Genuine 3-body correlation $c_3(Q_3)$ compatible with 0 within uncertainties
- p–p–K dominated contributions from 2-body interaction
  → Run 3 data to reduce the uncertainties at low Q_3
  → No evidence of p–p–K bound state

$|t|$-dependence of incoherent J/ψ photonuclear production

mfaggin@cern.ch

ALICE

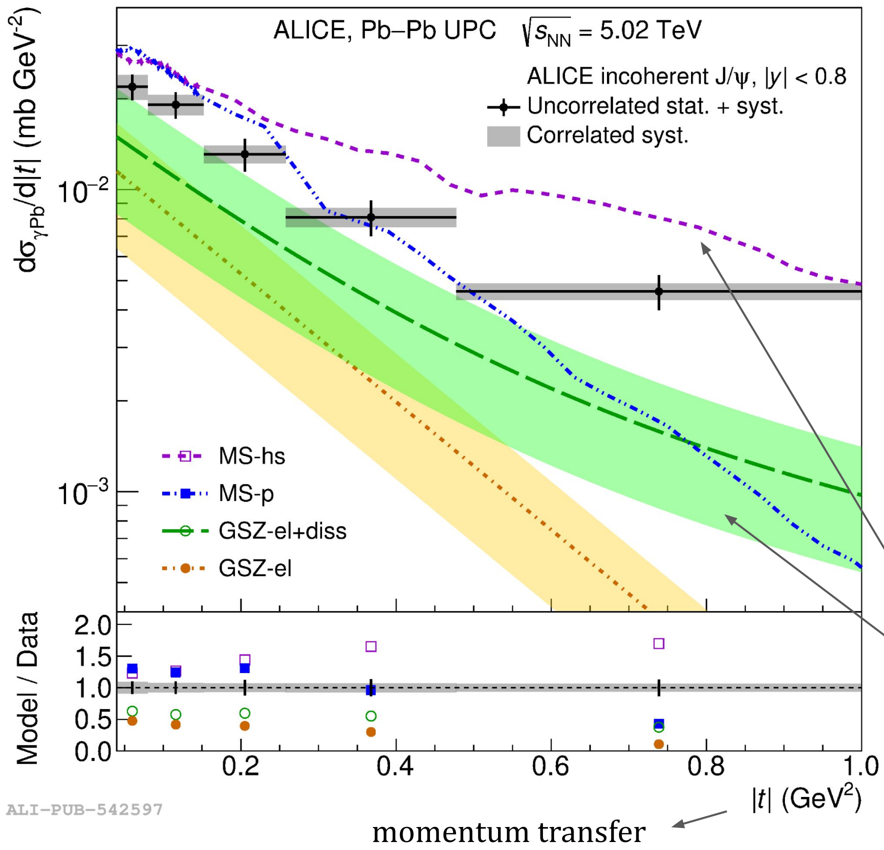
arXiv:2305.06169

$|y| < 0.8 \rightarrow x \sim (0.3\text{-}1.4) \times 10^{-4}$ $0.2 < p_T < 1$ GeV/c $|t| = p_T^2$

First measurement of this kind

Pb + Pb ⟶ J/ψ + Pb + Pb

Diffractive J/ψ photonuclear production sensitive to transverse **spatial distribution** of **gluon field** in **nuclei**



	γ interacts with	$\sigma_{\gamma Pb}$ sensitive to	$|t|$ regime
Coherent	nucleus	average target g-distribution	< 0.01 GeV^2
Incoherent	nucleon	variance target g-distribution	0.01 < $|t|$ < 0.1 GeV^2
	sub-nucleon	variance target g-distribution	> 0.1 GeV^2

- Sub-nucleonic quantum fluctuations needed to catch the measured $|t|$-dependence
  → first experimental step using quantum fluctuations of the gluon field to search for saturation/shadowing in heavy nuclei

First polarization measurement in UPC Pb–Pb at the LHC

Study of J/ψ polarization in UPC Pb–Pb collisions

arXiv:2304.10928

$$W(\cos\theta,\varphi) \propto \frac{1}{3+\lambda_\theta}\left[1+\lambda_\theta\cos^2\theta+\lambda_\varphi\sin^2\theta\cos 2\varphi+\lambda_{\theta\varphi}\sin 2\theta\cos\varphi\right]$$

Helicity frame:

- z: J/ψ direction
- y: ⊥ beam axis and J/ψ direction
- x: 3rd axis for right-handed triplet

Measured values

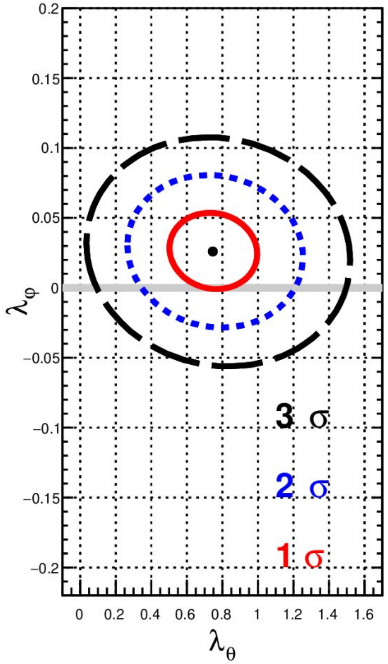
$\lambda_\theta = 0.75 \pm 0.25 \pm 0.24 \approx 1$

$\lambda_\varphi = 0.03 \pm 0.03 \pm 0.02 \approx 0$

$\lambda_{\theta\varphi} = 0.10 \pm 0.05 \pm 0.06 \approx 0$

$(\lambda_\theta, \lambda_\varphi, \lambda_{\theta\varphi}) = (1,0,0)$
Transverse polarization

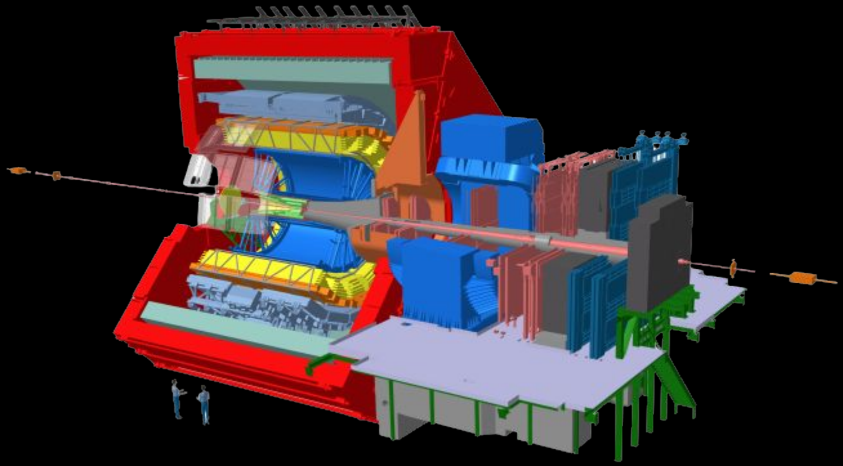
$(\lambda_\theta, \lambda_\varphi, \lambda_{\theta\varphi}) = (-1,0,0)$
Longitudinal polarization



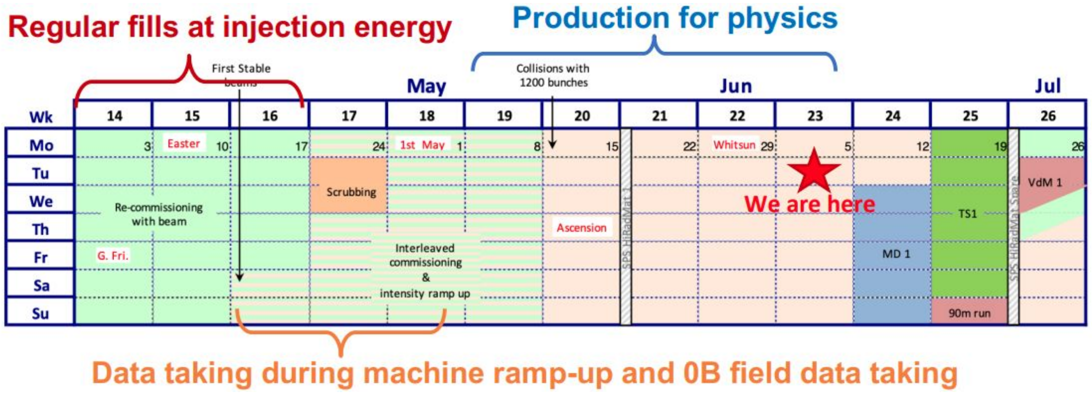
- Vector meson measurements showed transverse polarization
  → incoming γ polarization transferred to J/ψ (s-channel helicity conservation)
- Same conclusion for coherent photonuclear production of J/ψ in Pb–Pb at the LHC
- ALICE result compatible with J/ψ photoproduction at HERA

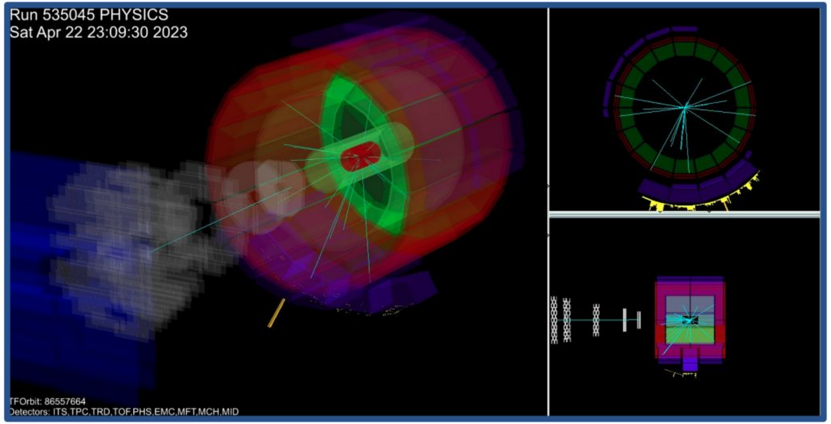
Eur. Phys. J. C 46 (2006) 585–603   Nucl. Phys. B 695 (2004) 3–37

Part 2
Run 3 operations and data processing

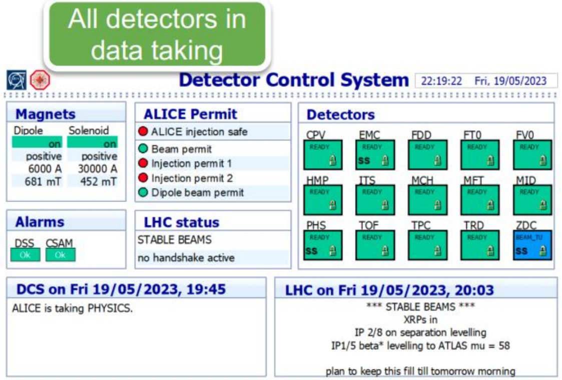


2023 operations and planning

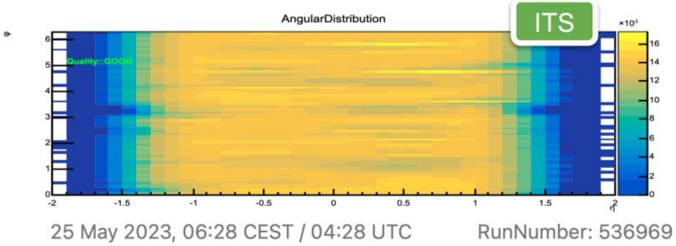


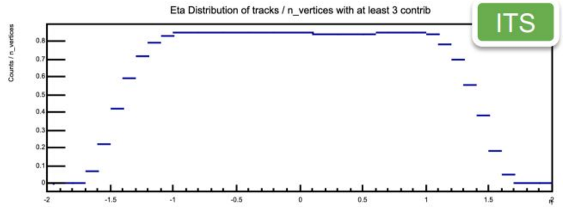


Async. reconstruction of ~0.3B collected events for muon-arm alignment ongoing



Good coverage and acceptance

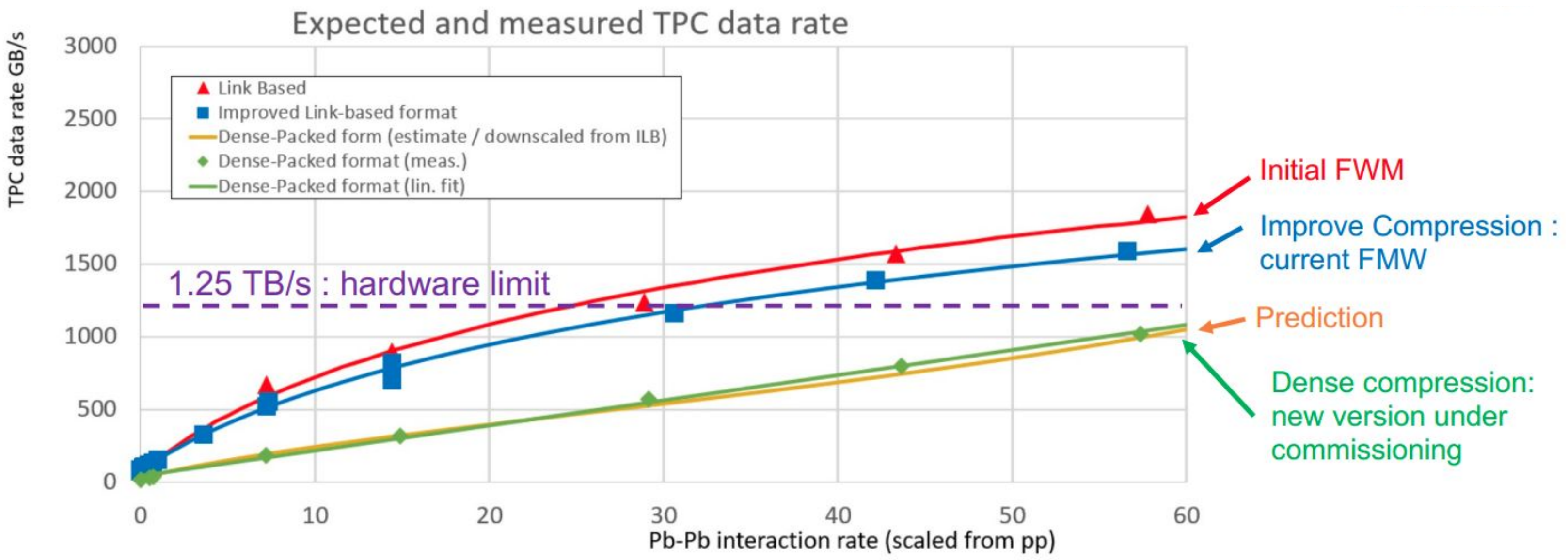




TPC data volume for HI

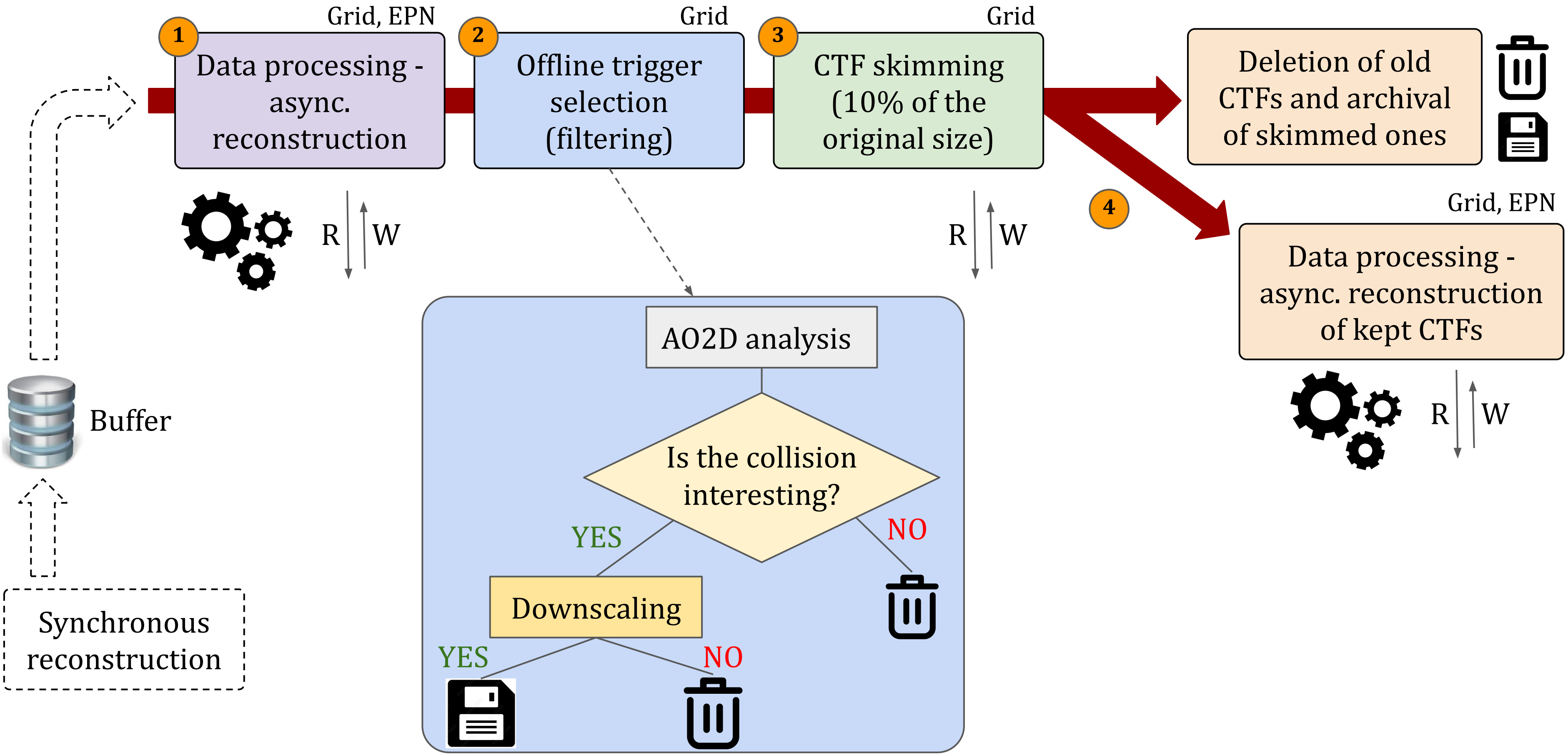
mfaggin@cern.ch

- New TPC firmware providing dense compression of data under commissioning
- Dense data format to reduce the data volume
- Tests performed with pp collisions up to 4 MHz ⟶ > 50 kHz Pb–Pb charged particle equivalent



With the new dense compression format the TPC data volume is under control for HI data taking during next autumn

Offline data processing steps

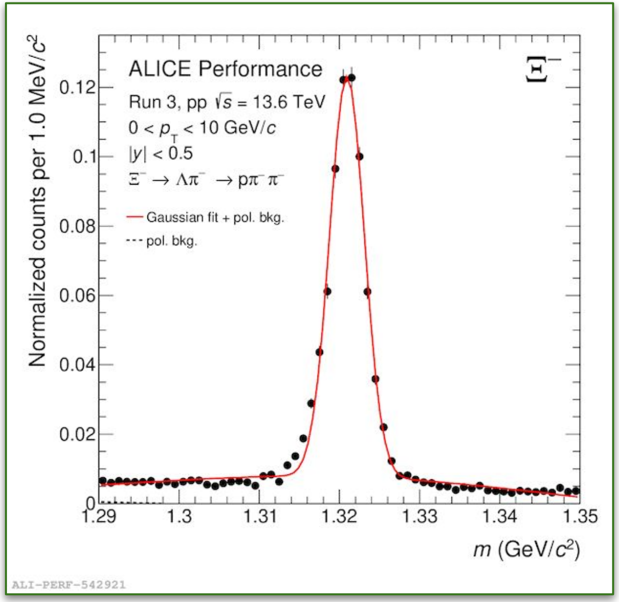


mfaggin@cern.ch

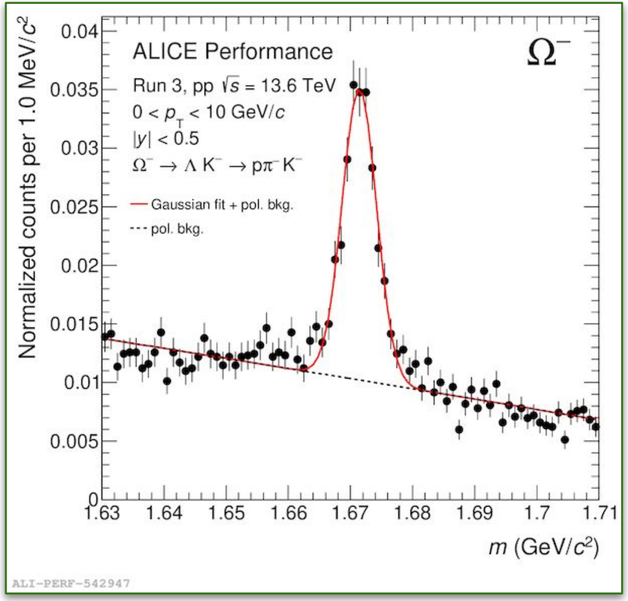
ALICE

- 52 PB of collected data to be skimmed
- 5 months between end of run in 2022 and beginning of run in 2023
  - study of QC, calibrations, reconstruction, skimming, free space before 2023 data taking
  - apass3 successfully finished in March 2023
  - apass4 with updated distortion calibrations ongoing

Multi-strange baryons



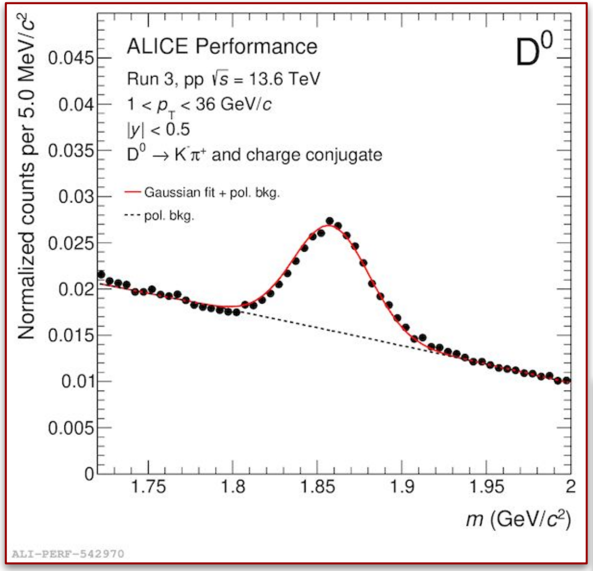
2022 pp data - Ξ^-



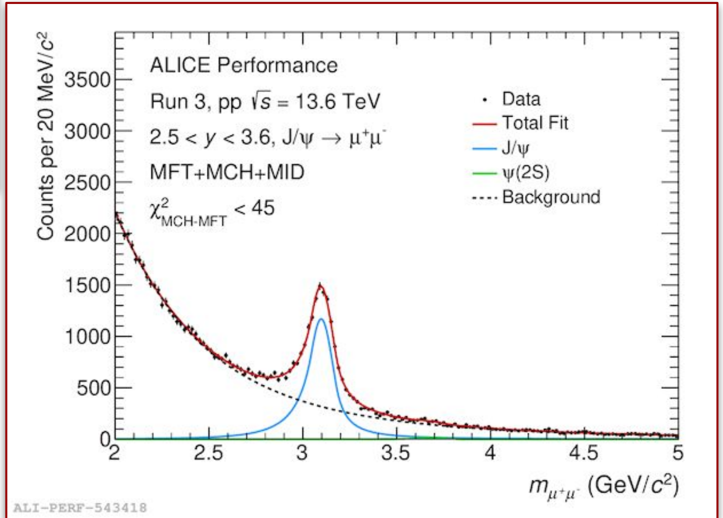
2022 pp data - Ω^-

Heavy-flavour hadrons and quarkonia

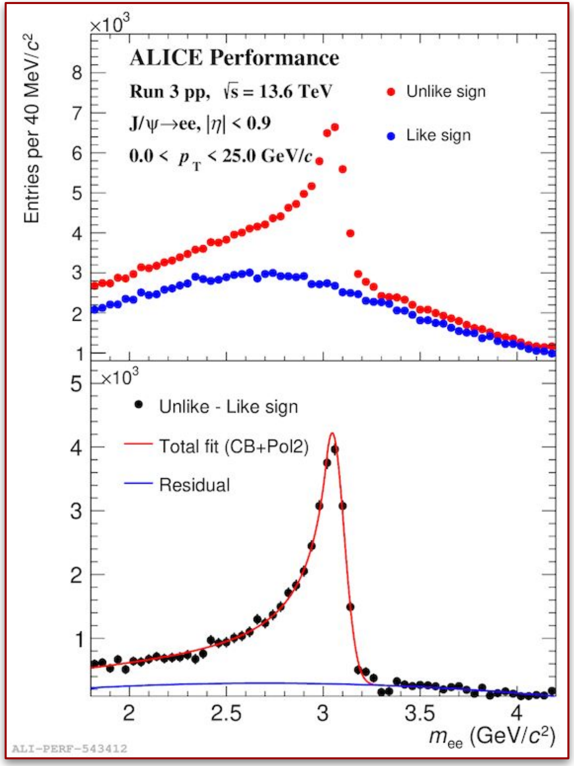
$D^0 \to \pi^+K^-$



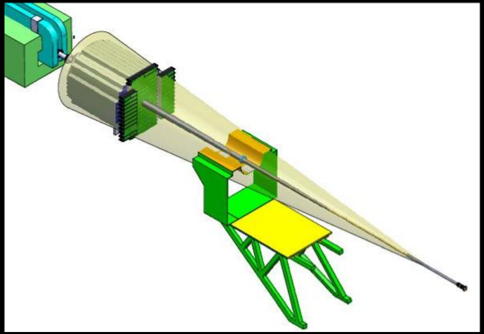
$J/\psi \to \mu^+\mu^-$

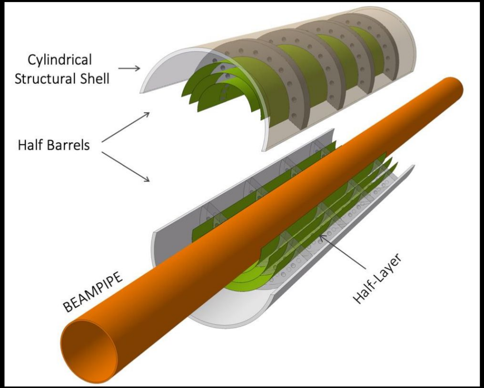


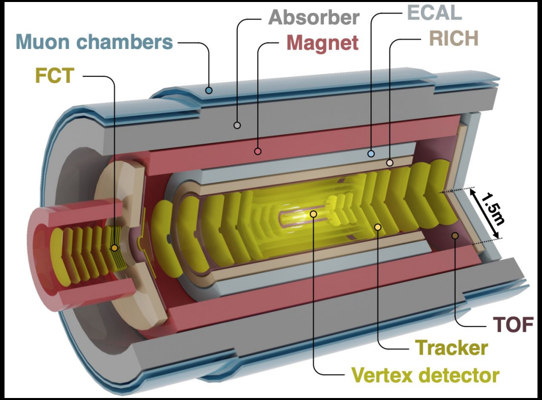
$J/\psi \to e^+e^-$



Part 3
Upgrade







ALICE upgrade projects

mfaggin@cern.ch

LHC Run 2 | LHC LS2 | LHC Run 3 | LHC LS3 | LHC Run 4 | LHC LS4 | LHC Run 5

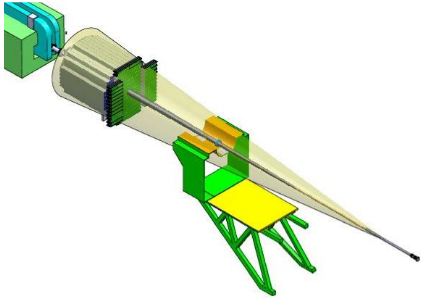
FoCal & ITS3

- Specific upgrade in LS3 (2026-2028)
- TDR preparation & submission this year

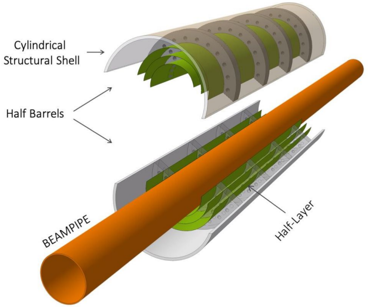
ALICE 3

- New detector in LS4 (2033-2034)
- LoI positively reviewed by LHCC in 2022
- Scoping Document in preparation

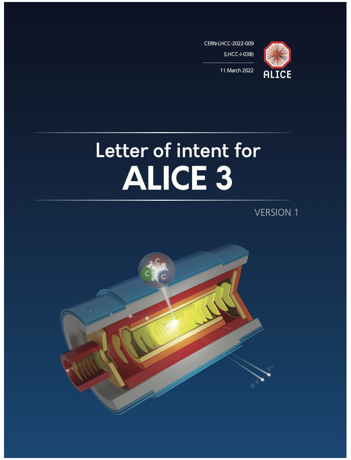
FoCal LoI: CERN-LHCC-2020-009



ITS3 LoI: CERN-LHCC-2019-018



CERN-LHCC-2022-009



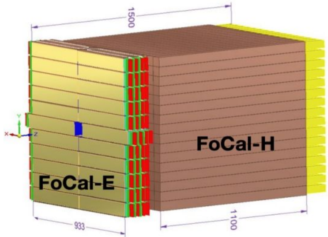
ALICE Upgrade Week, 8-12 May

mfaggin@cern.ch

All topics shown in next slides (and more!) were discussed during the last ALICE Upgrade Week

FoCal-E: segmented in 18 layers of tungsten and silicon pads with low granularity (LG, ~ 1 cm^2) and two layers of tungsten and silicon pixels with high granularity (HG, ~ 30x30 μm^2).

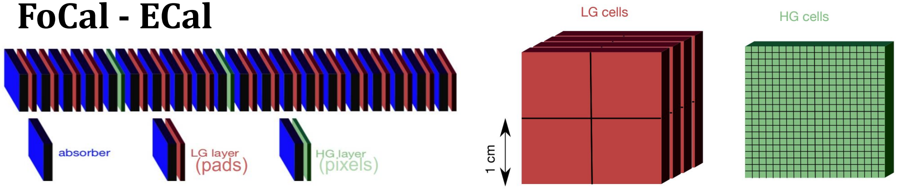
FoCal-H: metal/scintillating fiber calorimeter with high granularity of up to 2.5x2.5cm^2



***η* coverage**

$3.4 < \eta < 5.8$

FoCal - ECal

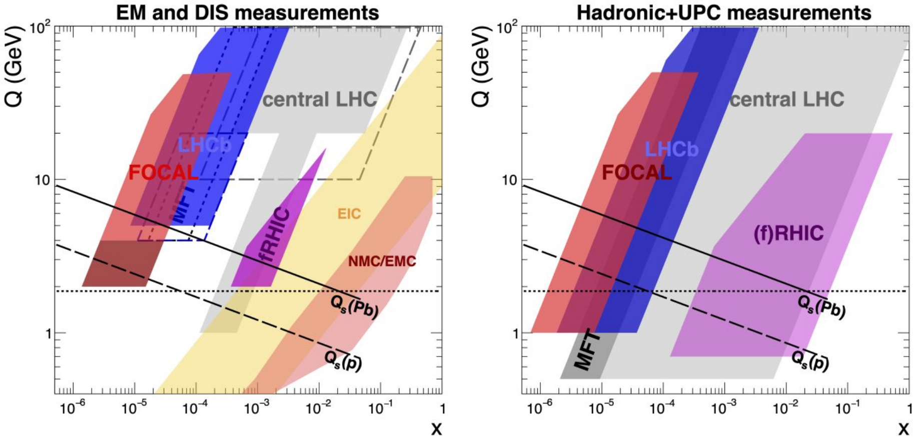


Update of the Physics program from LoI
ALICE-PUBLIC-2023-001

Goals

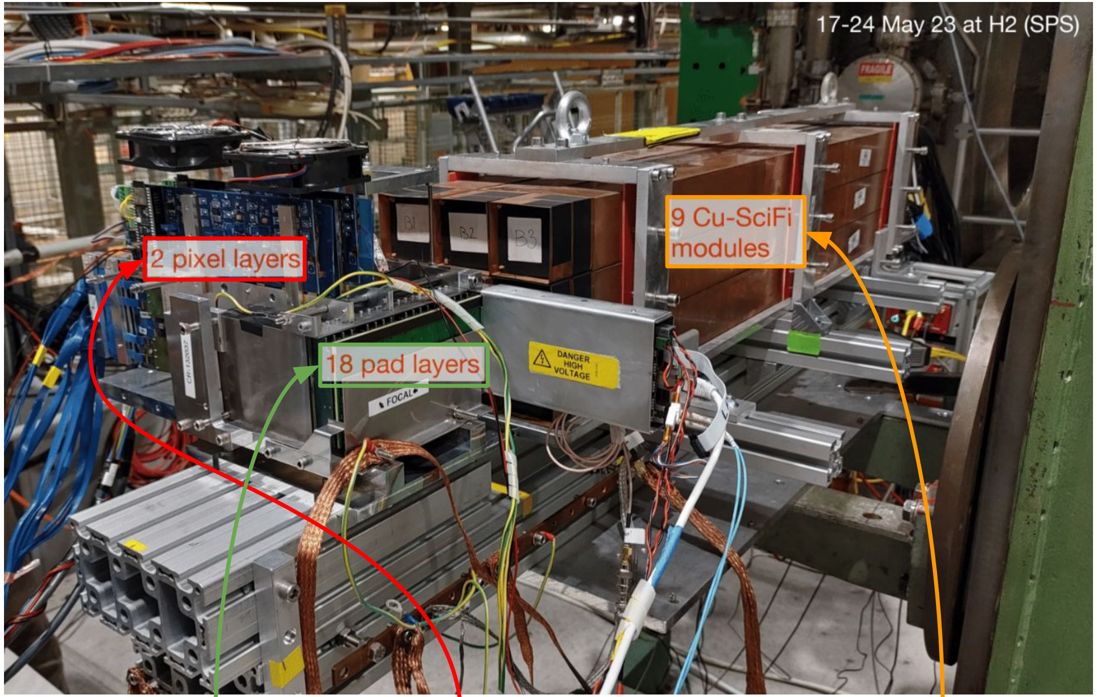
Explore gluon saturation at small Bjorken *x* by measuring forward direct-γ, π^0, jets + their correlations in p-Pb collisions and quarkonia in ultra-peripheral p-Pb and Pb-Pb collisions

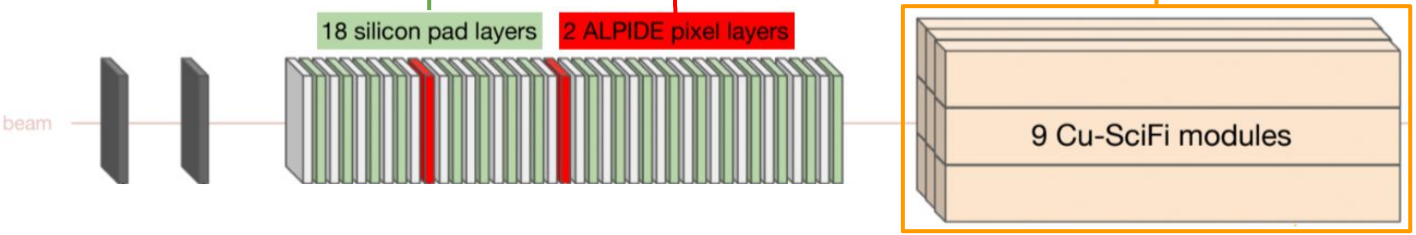
Direct photons, Drell-Yan



Setup for May 2023 test beam

mfaggin@cern.ch

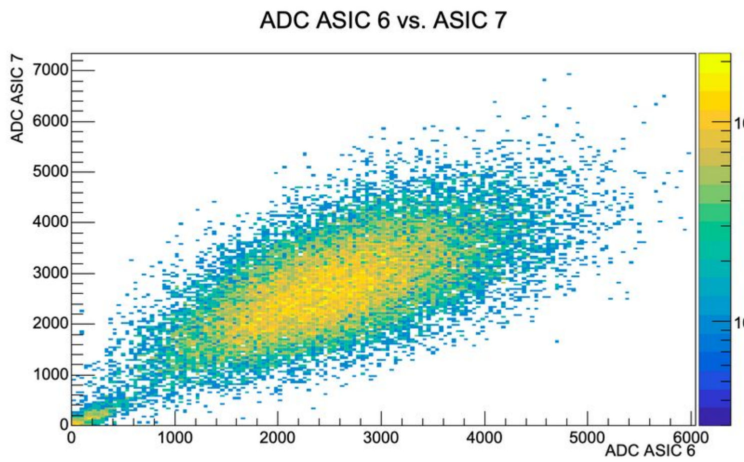




mfaggin@cern.ch

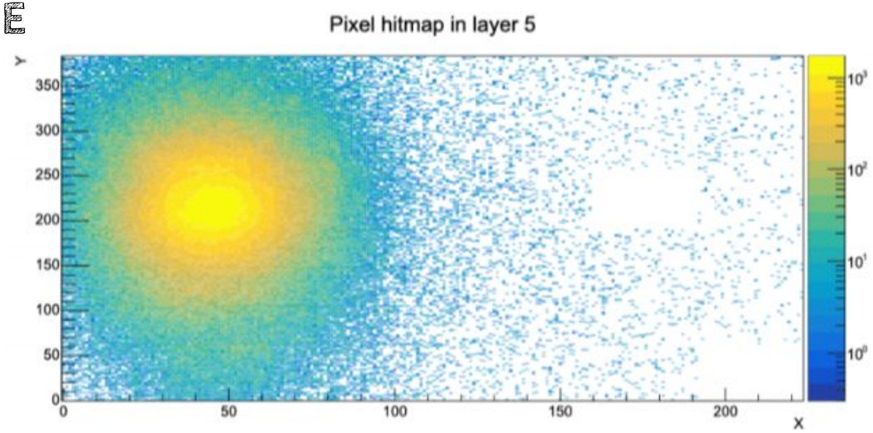
May 2023 test beam results

FoCal-E



ADC signal correlation between planes

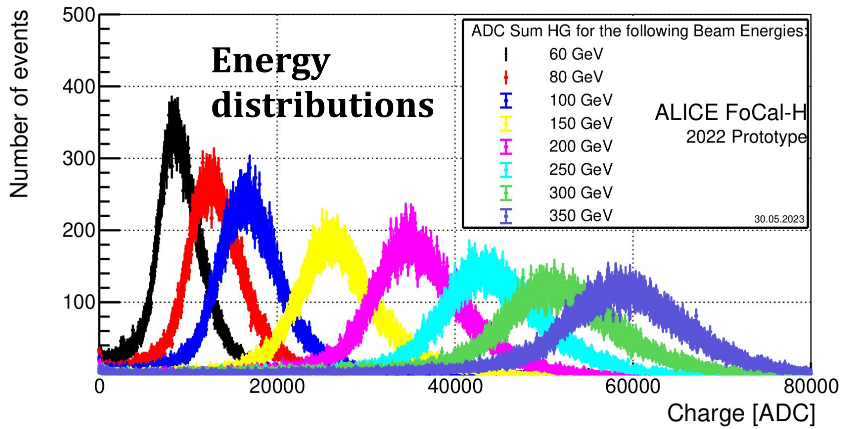
LG pads



HG pixels

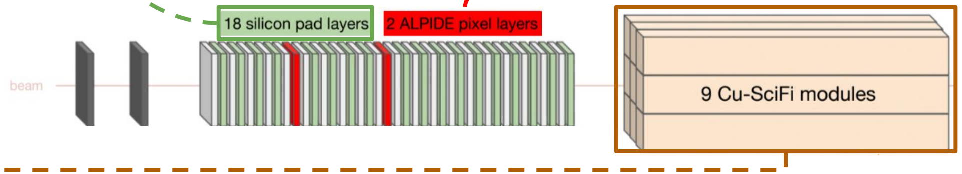
Pixel tests

- All ALPIDEs in acceptance functional
- Tests with continuous readout at 50 kHz and 100 kHz successfully done



Energy distributions

FoCal-H

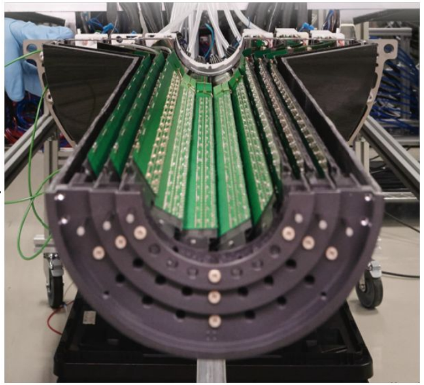


Inner Tracking System 3 (ITS3)

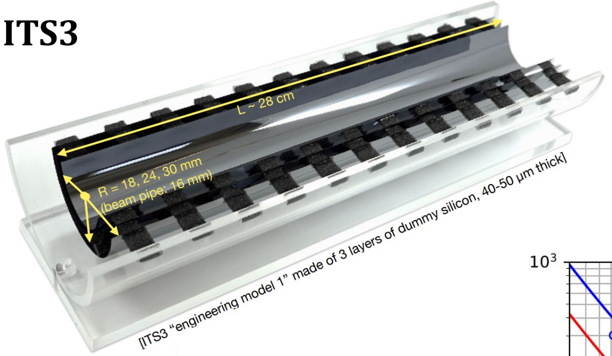
mfaggin@cern.ch

LHC Run 2 | LHC LS2 | LHC Run 3 | LHC LS3 | LHC Run 4 | LHC LS4 | LHC Run 5

ITS2 inner barrel (now)

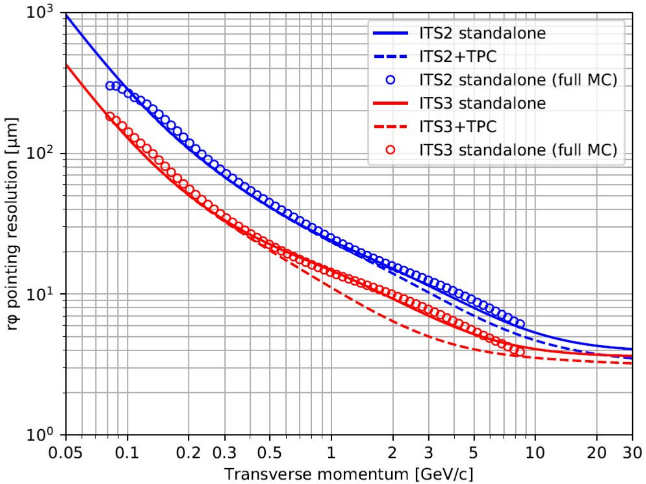


ITS3

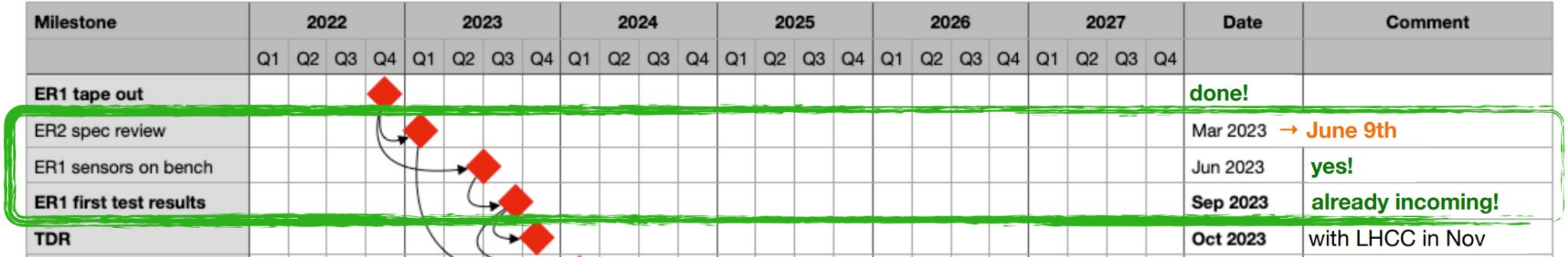


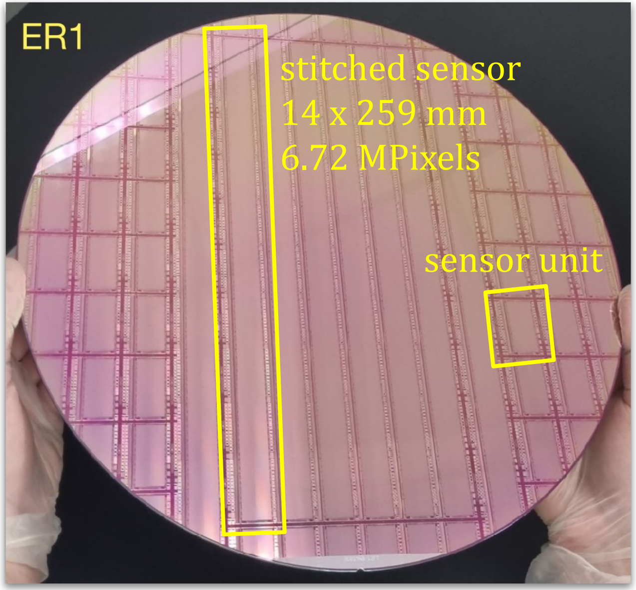
ITS2 → ITS3

~2x improvement



- Replacing the 3 innermost barrels by real half-cylinders (of **bent**, **thin** silicon)
- Rely on **wafer-scale sensors** (1 sensor per half-layer) in **65 nm** technology
- Minimised material budget and distance to interaction point
→ ~2x better pointing precision and substantially improved physics performance ("ideal detector")

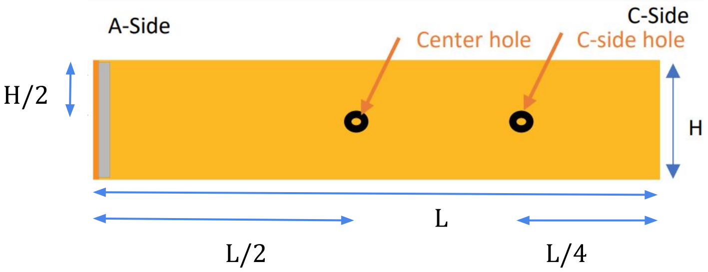




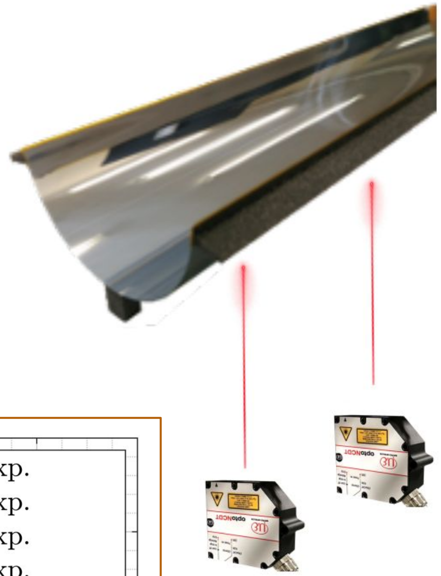
Main focus on performance of stitched sensor

- Engineering Run 1 (**ER1**): first stitched prototype chip
  - chips back on bench, **testing started**
  - first results from wafer probing: **alive**!
- Full-scale sensor prototype (ER2) specifications
  - takes into account off-detector readout concepts
  - review this Friday (June 9th)

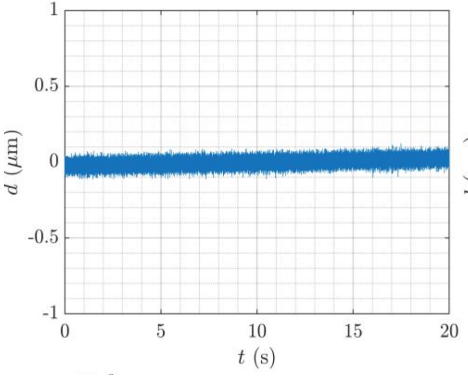
Vibration test measurements



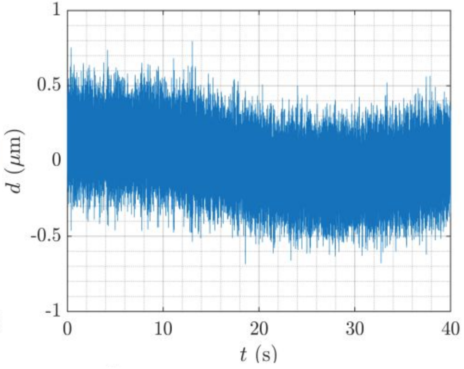
Air flow in vibration tests: 8 m/s



NO AIR FLOW

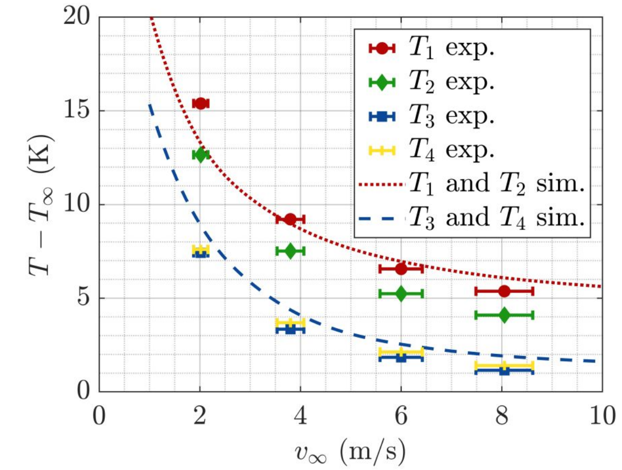


CENTER HOLE



< 1 μm radial displacement

Temperature tests

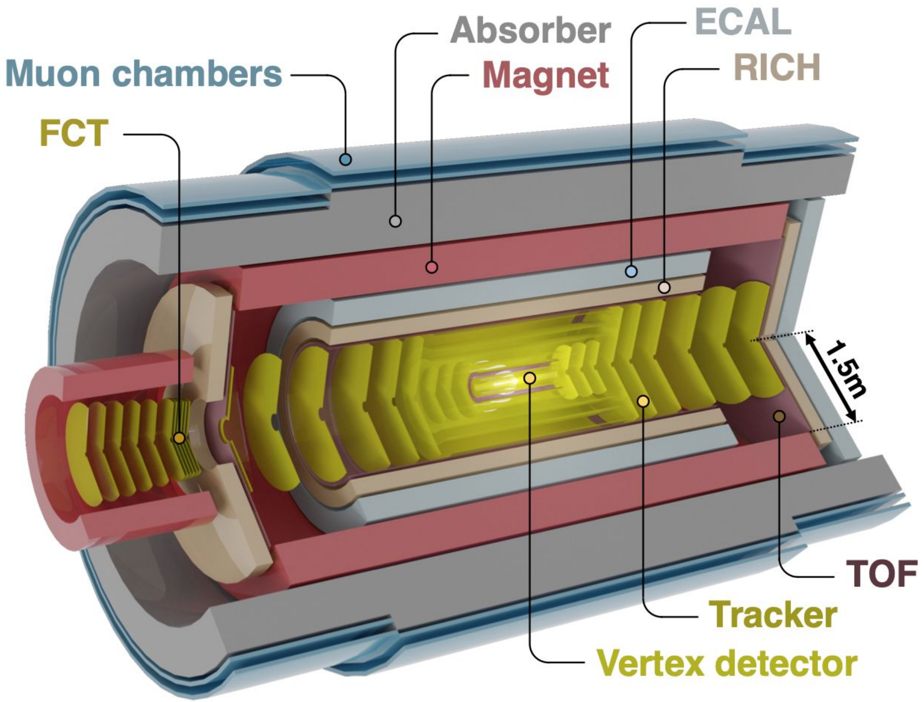


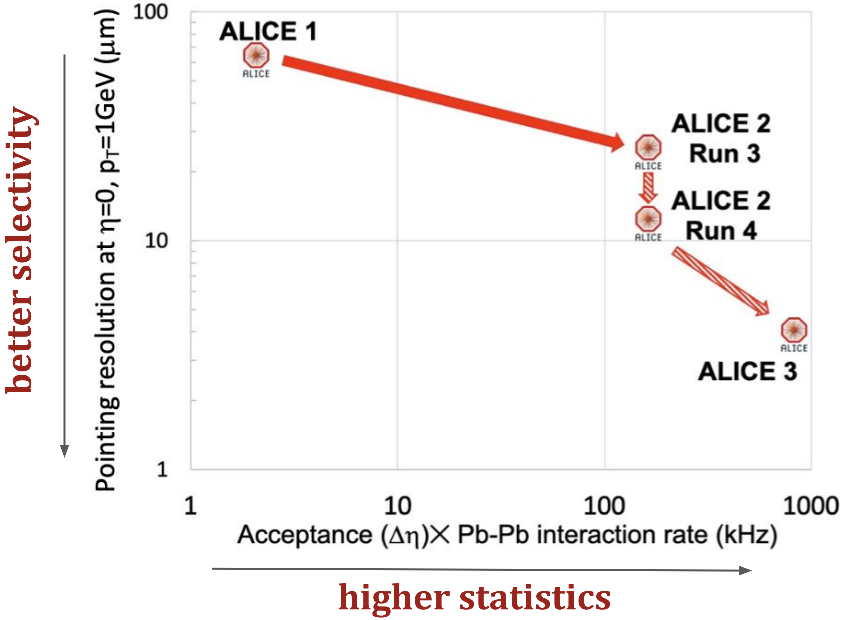
mfaggin@cern.ch

Novel and innovative detector concept

Completely new detector in 10 years from now

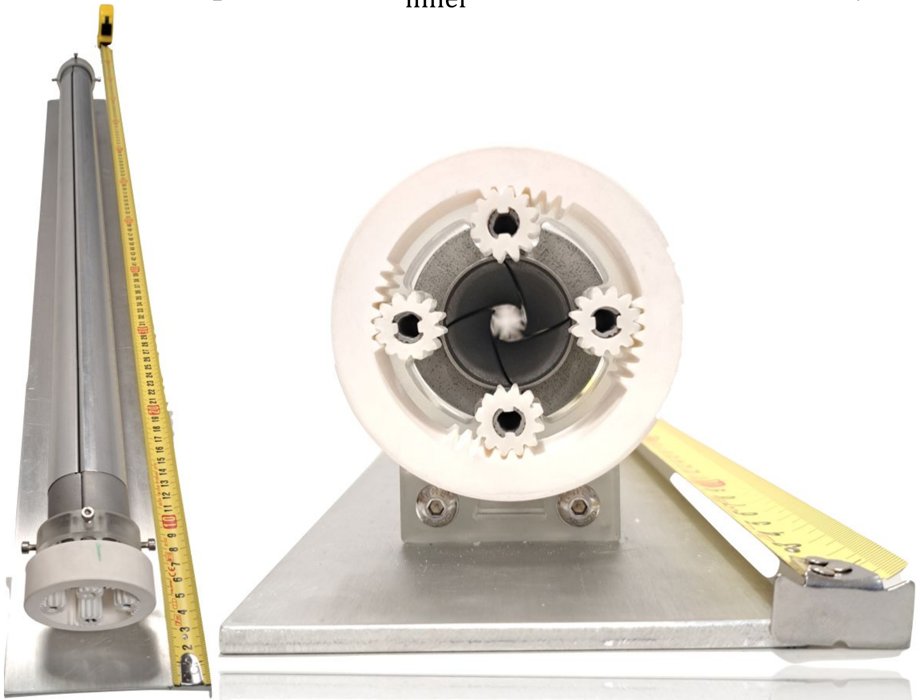
- Compact and lightweight all-silicon tracker
- Retractable vertex detector
- Extensive particle identification
- Large acceptance
- Superconducting magnet system
- Continuous read-out and online processing



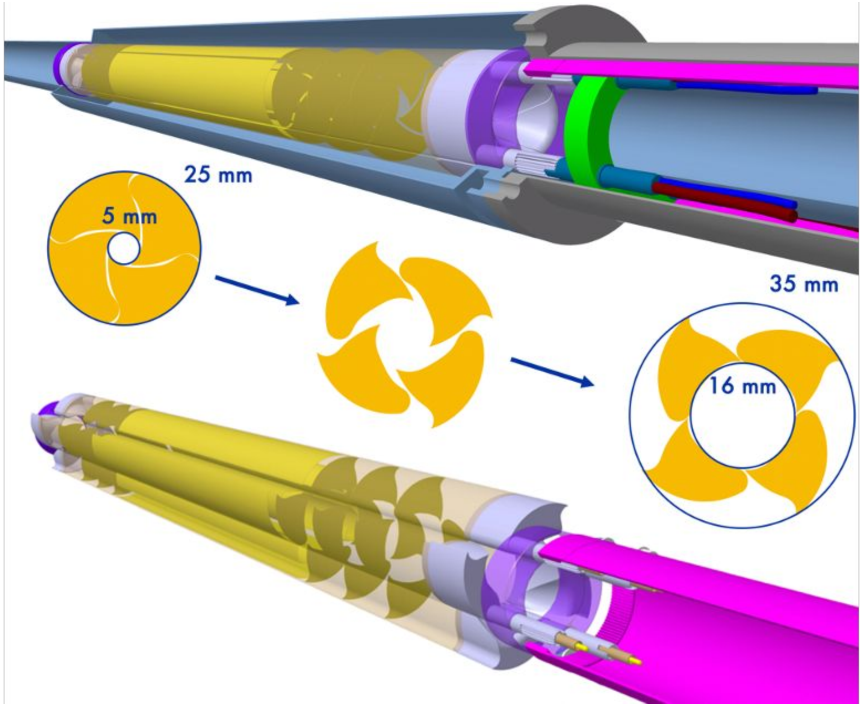


mfaggin@cern.ch

- R&D on retractable vertex detector concept inside beampipe (**iris**) ongoing
  - closed to R_{inner} = 5 mm during *stable beams* → improved pointing resolution w.r.t. ITS3
  - opened to R_{inner} = 16 mm for beam injection/adjustments



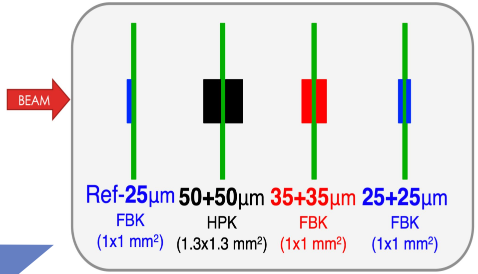
Bread Board Model 2 (BBM2): 800 mm long

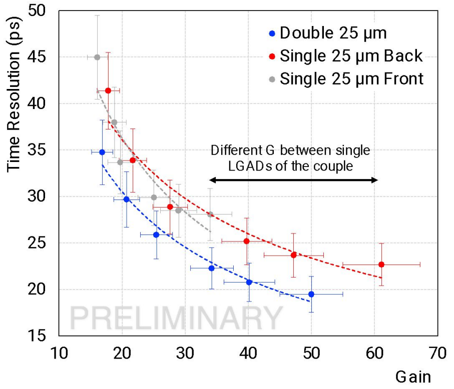


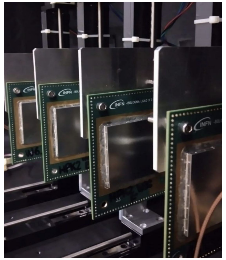
- Time resolution specification: ~20 ps
- R&D (design, simulations, prototype tests) for several silicon timing sensor options

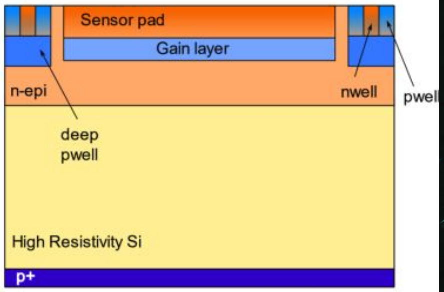
1. LGAD sensors: ~20 ps resolution measured in 2022 test beams with "double LGAD" sensors thinned to 25 μm (FBK - Italy)
2. Monolithic pixel sensors (CMOS) with gain layer:
   - prototypes now being qualified in lab.
   - new tests with beams in July and October

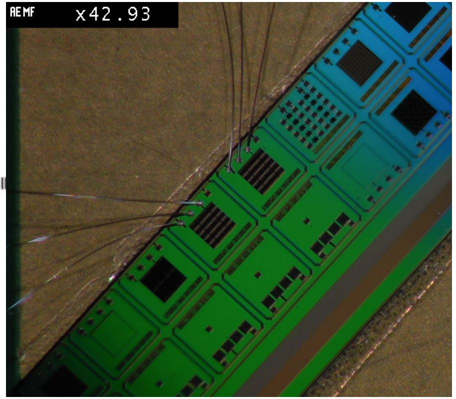
NEW





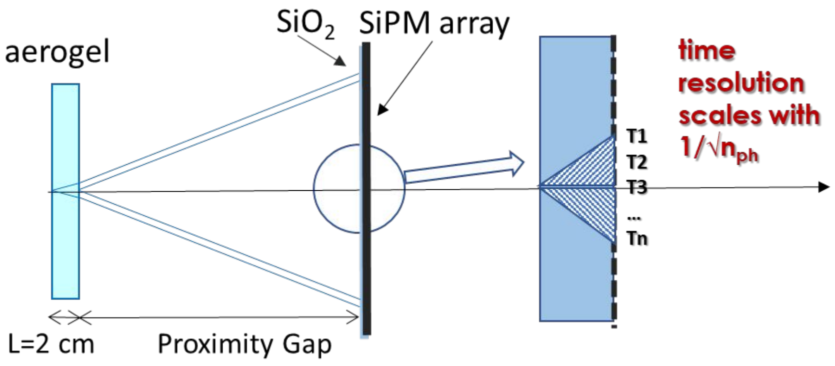






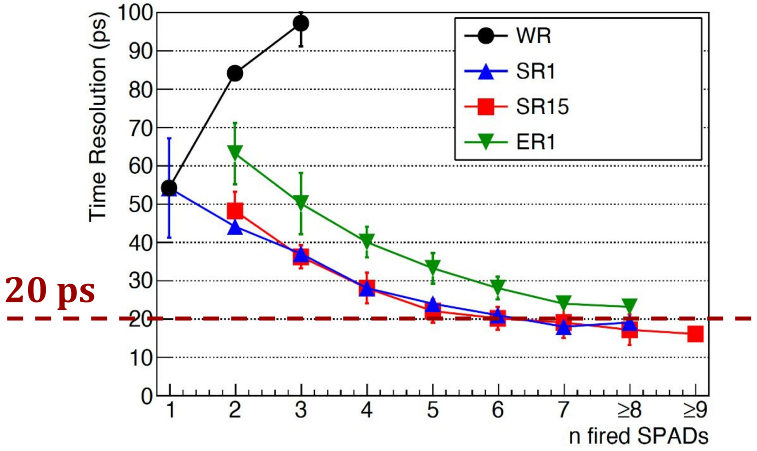
mfaggin@cern.ch

- New concept for Outer TOF measurement (R ~ 90 cm) being explored: use the RICH detector SiPM layer also for MIP timing by coupling a thin radiator window (e.g. SiO2)



- Detailed study of MIP detection in a single SiPM: Cherenkov radiation in protection layer (silicone or epoxy resin)
    - > 99% MIP detection efficiency
    - time resolution improvement due to signal increasing with amount of fired SPADs

NEW



Carnesecchi et al., arXiv.2210.13244

- **Part 1** - New physics results with Run 2 data
  - 12 new papers submitted for peer review since last LHCC meeting

- **Part 2** - Run 3 operations and data processing
  - ALICE will be able to acquire Pb–Pb data at the nominal IR ~ 50 kHz
  - 2022 pp data under filtering and skimming
  - 2023 pp data data collection ongoing

- **Part 3** - Upgrade
  - ITS3: successful tests on ER1 chip
  - FoCal: new test beam results confirm detector design
  - ALICE3:
    - ~2.5x improvement in pointing resolution with respect to ITS3 + much larger acceptance
    - R&D for vertex detector and Si sensors ongoing

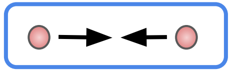
Thank you for the attention

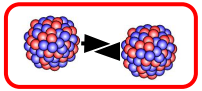
Backup

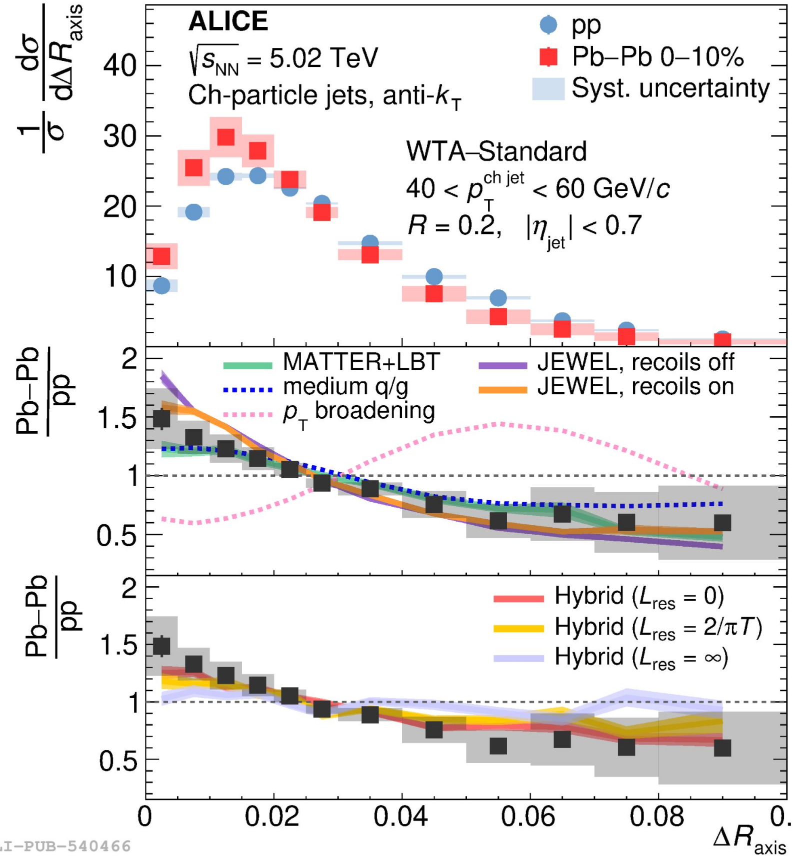
Angle between jet axes in Pb-Pb at $\sqrt{s_{NN}}$ = 5.02 TeV

mfaggin@cern.ch

arXiv:2303.13347

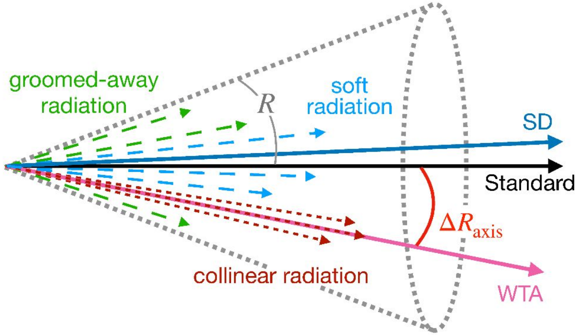






First $\Delta R_{axis}^{WTA\text{-}Standard}$ measurement in Pb–Pb collisions

New observables to study jet quenching



Standard: soft + hard

Soft Drop (SD): soft wide-angle radiation removed

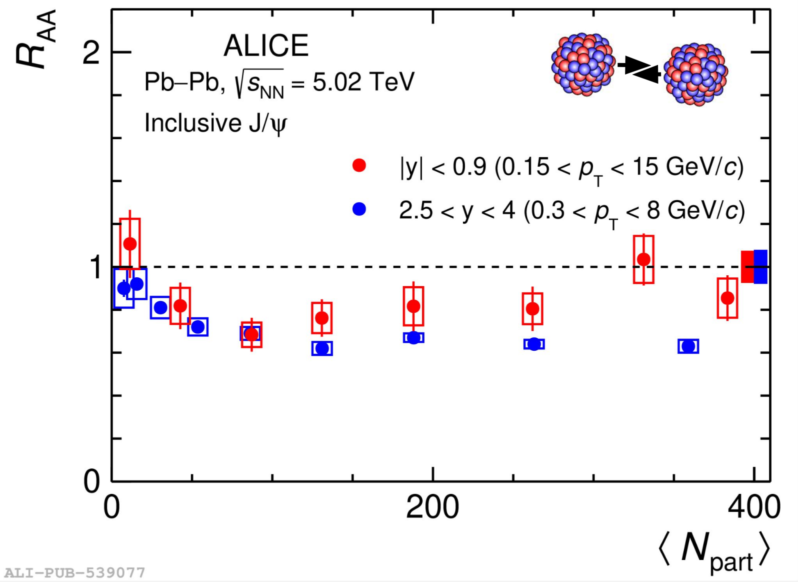
Winner-Takes-All (WTA): hardest jet constituent

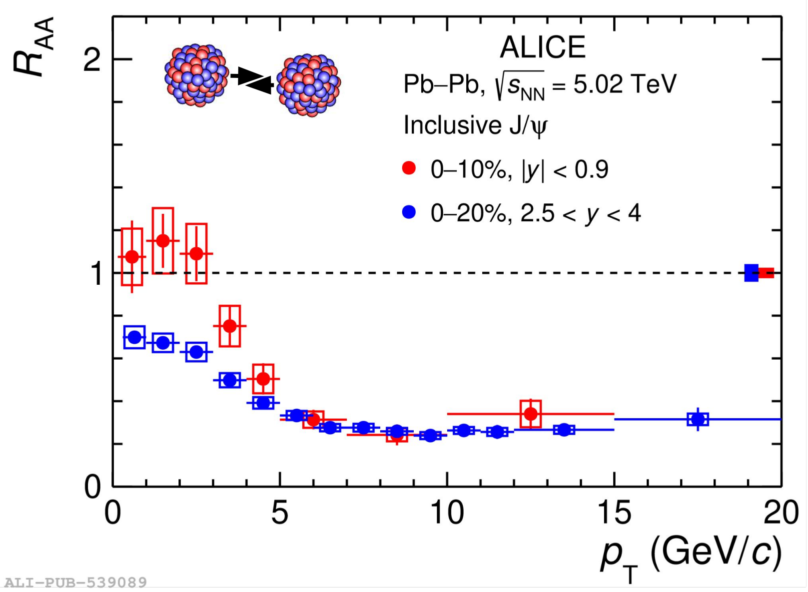
- Jet substructure measurements: sensitivity to different scales within the jet modification process

$$\Delta R_{axis} \equiv \sqrt{(y_{axis,1} - y_{axis,2})^2 + (\varphi_{axis,1} - \varphi_{axis,2})^2}$$

- $\Delta R_{axis}^{WTA\text{-}Standard}$ distribution narrowing in Pb–Pb compared to pp
  → more q-initiated jets, since g-initiated interact more with QGP and lose more energy (“medium q/g”)

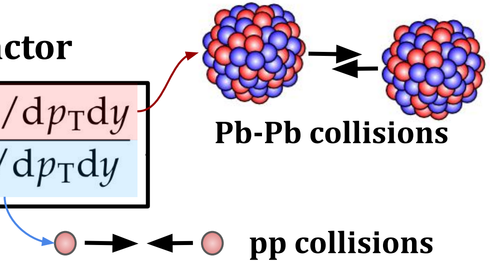
arXiv:2303.13361





Nuclear modification factor

$$R_{AA}(p_T, y) = \frac{1}{\langle T_{AA} \rangle} \frac{d^2N_{AA}/dp_T dy}{d^2\sigma_{pp}/dp_T dy}$$



- R_{AA}(mid-y) > R_{AA}(forward-y) at low p_T
  - J/ψ formation via recombination
  - Sensitivity to local c-quark density
- R_{AA}(mid-y) ~ R_{AA}(forward-y) at high p_T
  - Weaker y-dependence of suppression/E-loss

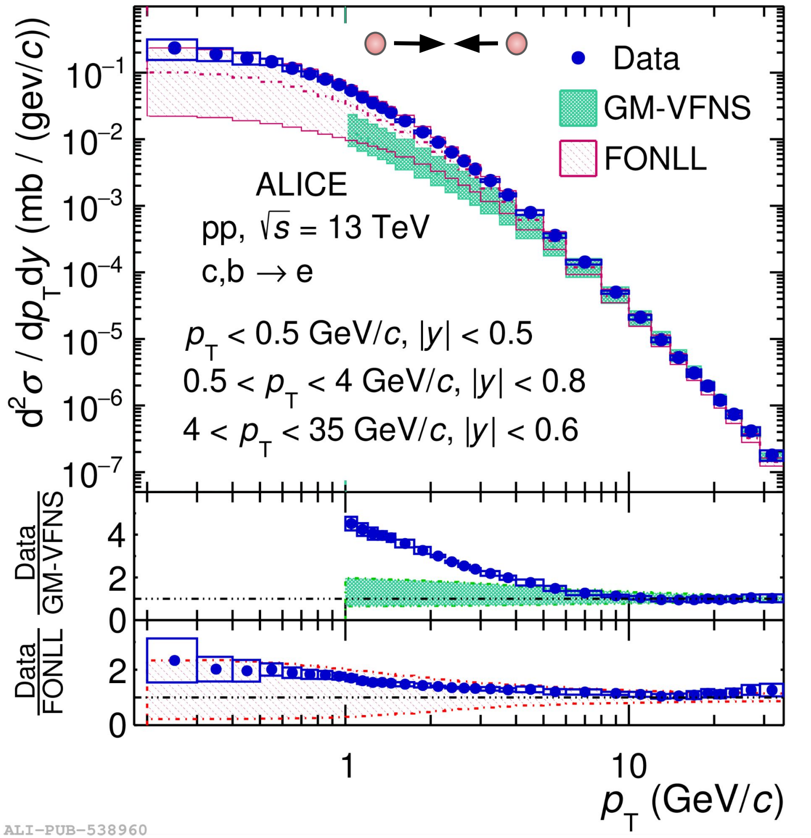
Inclusive and multiplicity-dependent HFe production

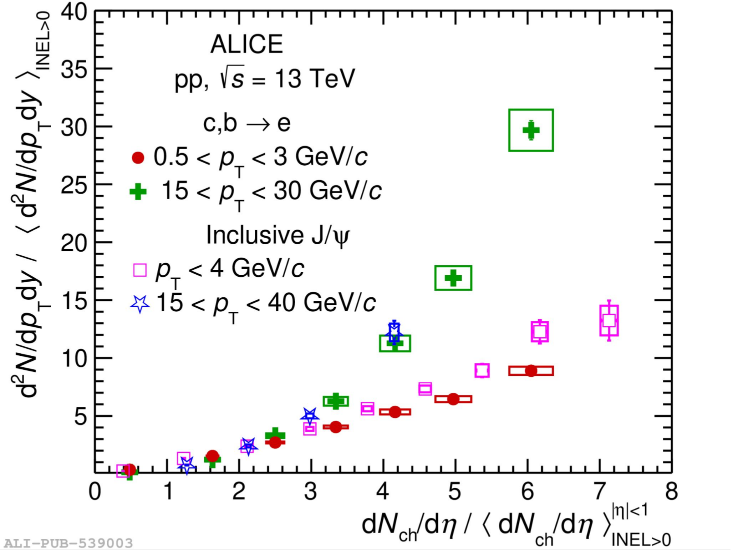
mfaggin@cern.ch

ALICE

Electron identification at mid-y with TPC, TOF and EMCal from p_T = 200 MeV/c (B=0.2 T) to p_T = 35 GeV/c

arXiv:2303.13349





- HFe cross section in 0.2 < p_T < 35 GeV/c on the upper edge of FONLL calculations
- Self-normalized yields of different species compatible
  - auto-correlation effects induced by particle production associated with jet activity

arXiv:2303.13431

- Double-parton scatterings (DPS): simplest multiple parton interaction (MPI)
  → studied with double-particle production
- Quarkonium-pair production golden tool to probe production mechanisms of heavy quarkonia
  → J/ψ pairs: 2D $\mu^+\mu^-$ inv. mass fit

$$F(m_1,m_2) = N \times S_1(m_1) \times S_2(m_2) + R_{B_1,S_2} \times B_1(m_1) \times S_2(m_2) + R_{S_1,B_2} \times S_1(m_1) \times B_2(m_2) + R_{B_1,B_2} \times B_1(m_1) \times B_2(m_2)$$

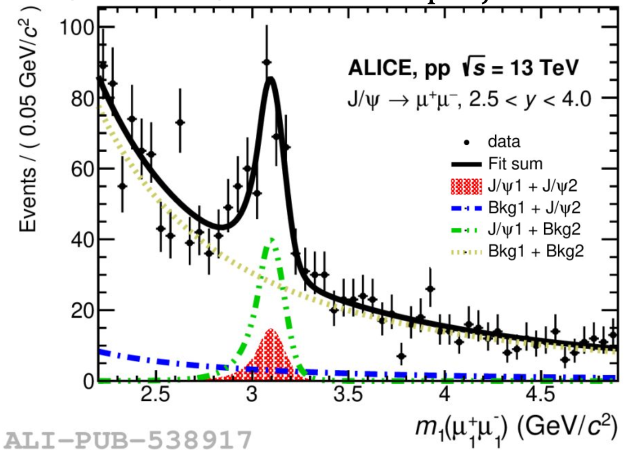
$$pp \to AB$$

$$\sigma^{DPS}_{A,B} = \frac{m}{2} \frac{\hat{\sigma}^A \hat{\sigma}^B}{\sigma_{eff}}$$

m: 1 if $A{=}{=}B$, 2 otherwise

σ_{eff}: pheno. parameter related to transverse overlap function between partons in proton (2-25 mb)

1 of the 2 projections!



J/ψ pair cross section in pp at $\sqrt{s}$ = 13 TeV

$$\sigma(J/\psi\, J/\psi) = 10.3 \pm 2.3\,(\mathrm{stat.}) \pm 1.3\,(\mathrm{syst.})\ \mathrm{nb}$$

$p_T > 0$
$2.5 < \eta < 4.0$

~1000 lower than σ(J/ψ)

- Compatible with LHCb in similar kinematic region (JHEP 06 (2017) 047)
- Prospects for Run 3:
  - separate prompt and non-prompt components
  - probe model calculations
    → relative contribution of SPS and DPS highly debated

arXiv:2303.13448

- Explore the two- and three-body interactions in p–p–K systems
- Search for kaonic bound states
- p–p–K genuine 3-body interaction with kaons studied via correlation functions

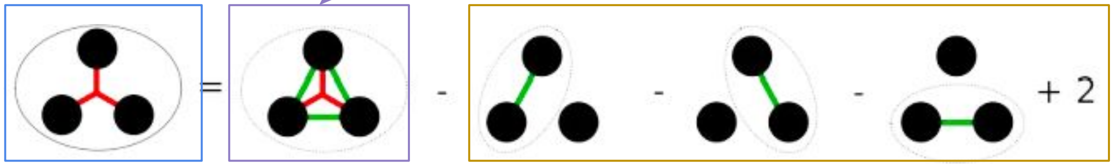
LHC as a laboratory to study hadron scatterings

$$Q_3 = \sqrt{-q_{ij}^2 - q_{jk}^2 - q_{ki}^2}$$

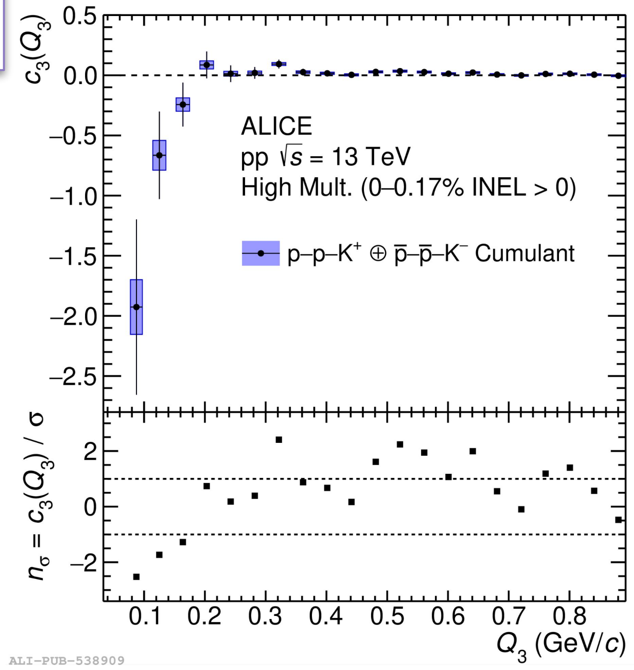
Emitting source (anchored to p–p correlation in ALICE data, see PLB 811 (2020) 135849)

3-particle wave function

$$C(Q_3) = \mathcal{N} \times N_{\text{same}}(Q_3)/N_{\text{mixed}}(Q_3) = \int S(r_1, r_2, r_3)\, |\psi(Q_3, r_1, r_2, r_3)|^2\, d^3x_1 d^3x_2 d^3x_3$$



Genuine 3-body correlation = Measured 3-body correlation − 2-body correlations

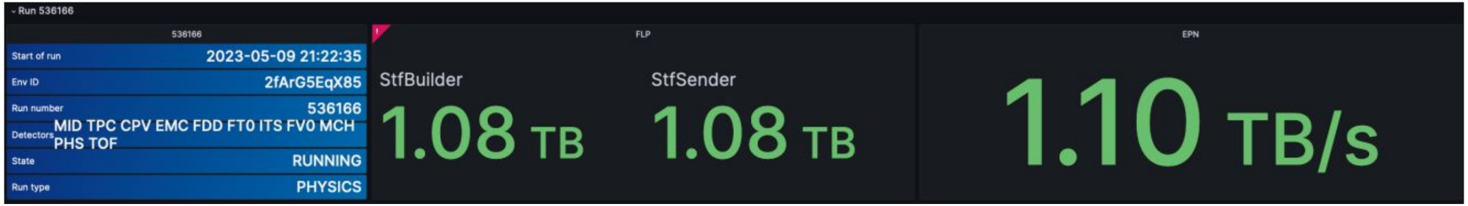


- Genuine 3-body correlation $c_3(Q_3)$ compatible with 0 within uncertainties
  - p–p–K$^-$ in the plot, p–p–K$^+$ in backup
- p–p–K dominated contributions from 2-body interaction
  → Run 3 data to reduce the uncertainties at low Q_3
  → No evidence of p–p–K bound state

High interaction rate for TPC data volume

mfaggin@cern.ch

- New TPC dense firmware under commissioning
- Dense data format to reduce the data volume
- Tests performed with pp collisions up to 4 MHz → > 50 kHz HI charged particle equivalent



vs. max. total FLP tolerance of 1.25 TB/s

Interaction-rate scans

IR	Mu	Duration	Data Rate
500 kHz	6%	~40 min	210 GB/s
1 MHz	12%	~30 min	360 GB/s
2 MHz	24%	~30 min	620 GB/s
3 MHz	36%	~60 min	865 GB/s
4 MHz	58%	~45 min	1.11 TB/s

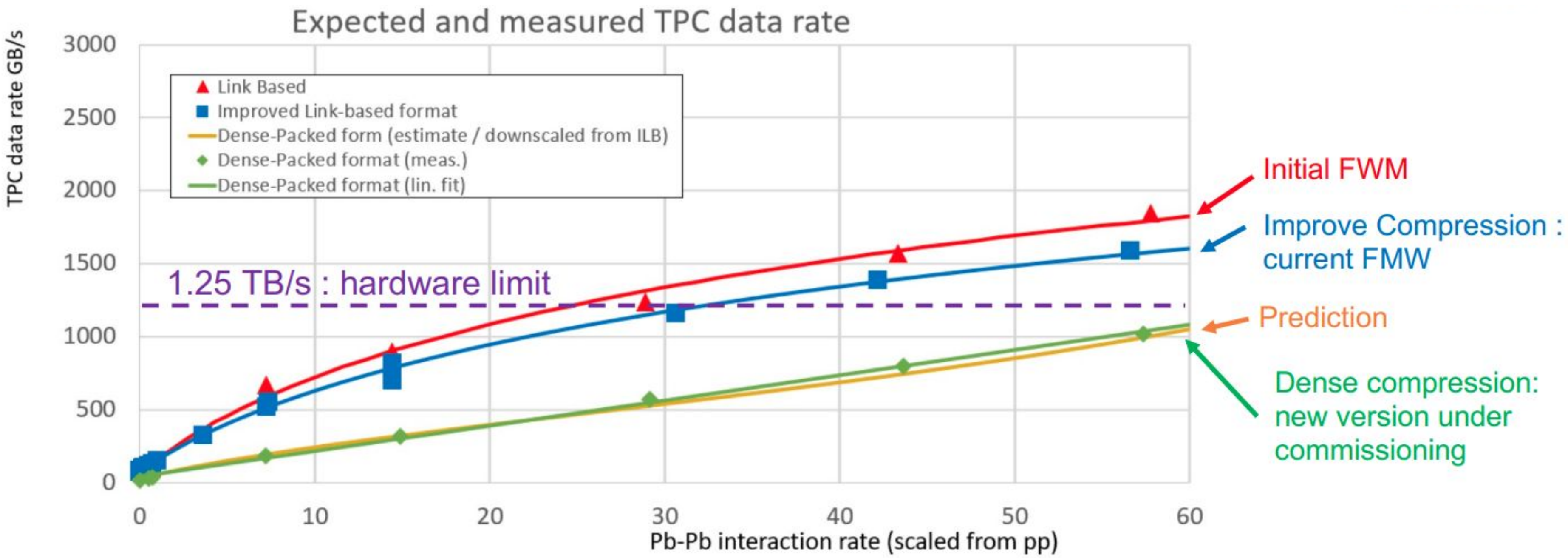
← Full processing with 130 EPNs (2 MHz)

← Max FLP rate < 10 GB/s vs. max. hardware tolerance 11 GB/s (4 MHz)

Max system tolerance
11 GB/s per FLPs
1.25 TB/s in total

TPC data volume for HI

mfaggin@cern.ch



With the new dense compression format the TPC data volume is under control for HI data taking during next autumn

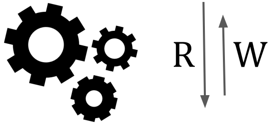
Data processing - async. reconstruction

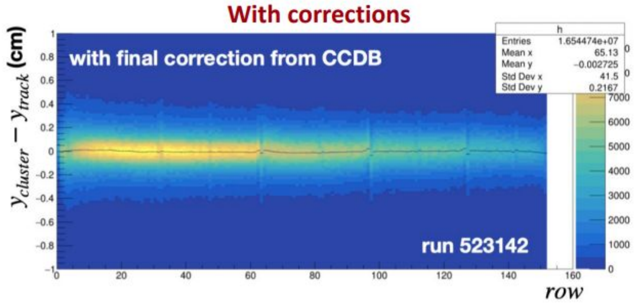
Offline trigger selection (filtering)

CTF skimming (10% of the original size)

Deletion of old CTFs and archival of new ones

Data processing - async. reconstruction of kept CTFs





2022 pp data

- 52 PB of collected data to be skimmed
- 5 months between end of run in 2022 and beginning of run in 2023
  - study of QC, calibrations, reconstruction, skimming, free space before 2023 data taking
  - apass3 successfully finished in March 2023
    - BUT! not optimal calibration for skimming due to uncalibrated TPC distortions
    - apass4 ongoing with distortions calibration, removing "ad-hoc" corrections to mitigate distortion effects

2023 pp data

- Disk buffer (currently, 103 PB useable) that will be filled will have to be freed before Pb-Pb data taking
- reconstruction, skimming and deletion during data taking
- share EPN resources with synchronous reconstruction

CTF skimming and reprocessing

mfaggin@cern.ch

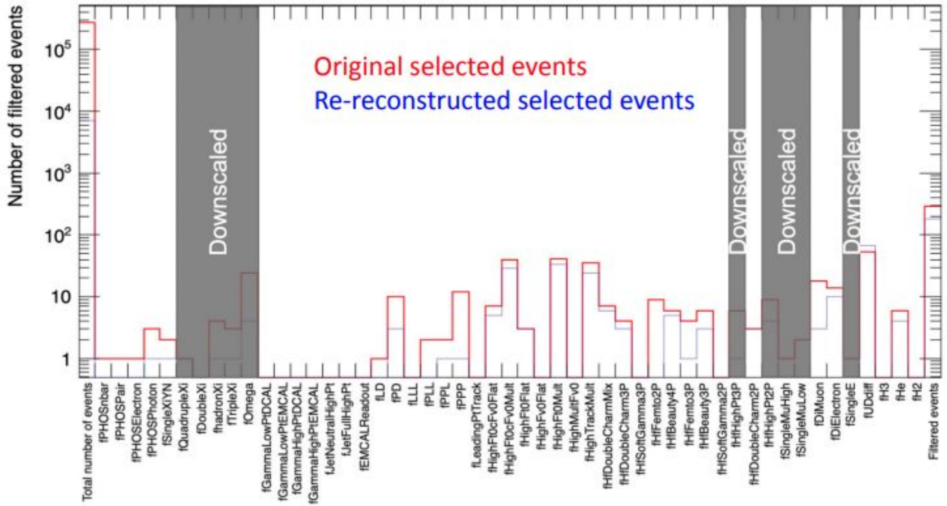
Data processing - async. reconstruction → Offline trigger selection (filtering) → **CTF skimming (10% of the original size)** → Deletion of old CTFs and archival of new ones

R W

Data processing - async. reconstruction of kept CTFs

R W

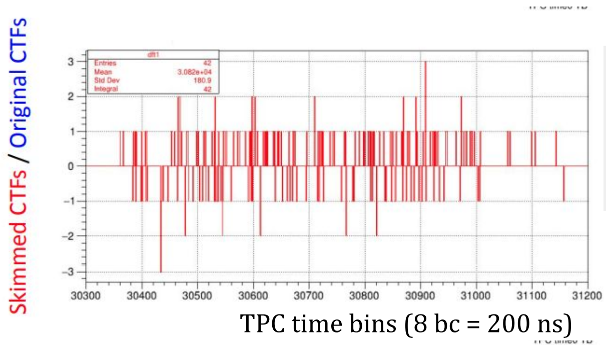
Initial expectation:find the same events that triggered the selection when re-reconstructing skimmed CTFs

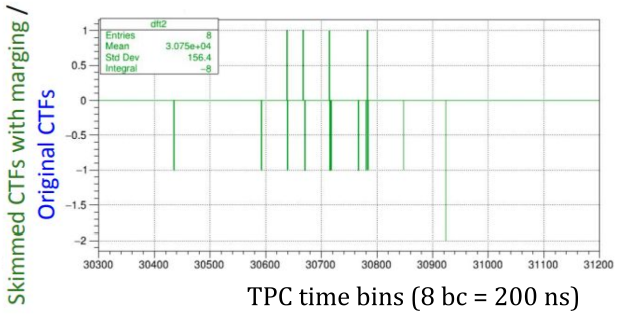


Not the case!

- Feature: TPC reconstruction “causally” connected to the full time frame
- Tracking combinatorics run continuously over the TF data: removing data, we change the combinatorics

mfaggin@cern.ch





Offline trigger selection (filtering)

CTF skimming (10% of the original size)

Deletion of old CTFs and archival of new ones

R W

Data processing - async. reconstruction of kept CTFs

R W

Plan: add a BC margin for the CTF filtering

TPC tracks compatible with the selected BCs:

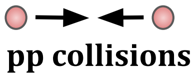
- Original CTFs
- Skimmed CTFs
- Skimmed CTFs with +-2000BC tolerance (+-0.5 drift time, that is ~ 100 μs)

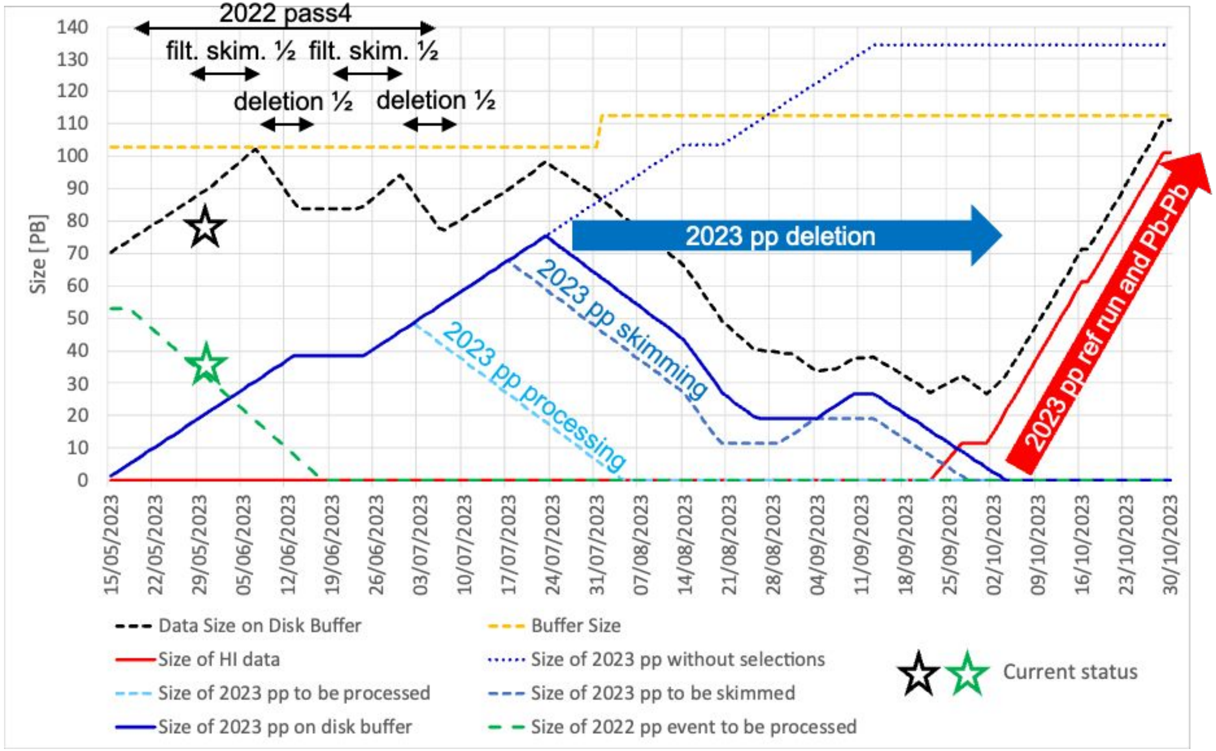
Not the case!

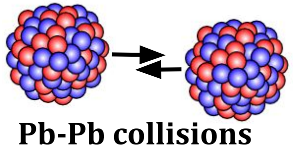
- Feature: TPC reconstruction "causally" connected to the full time frame
- Tracking combinatorics run continuously over the TF data: removing data, we change the combinatorics
- Adding additional tolerance in the selection window helps reducing the difference

Expected data accumulation on O2 disk buffer in 2023

mfaggin@cern.ch



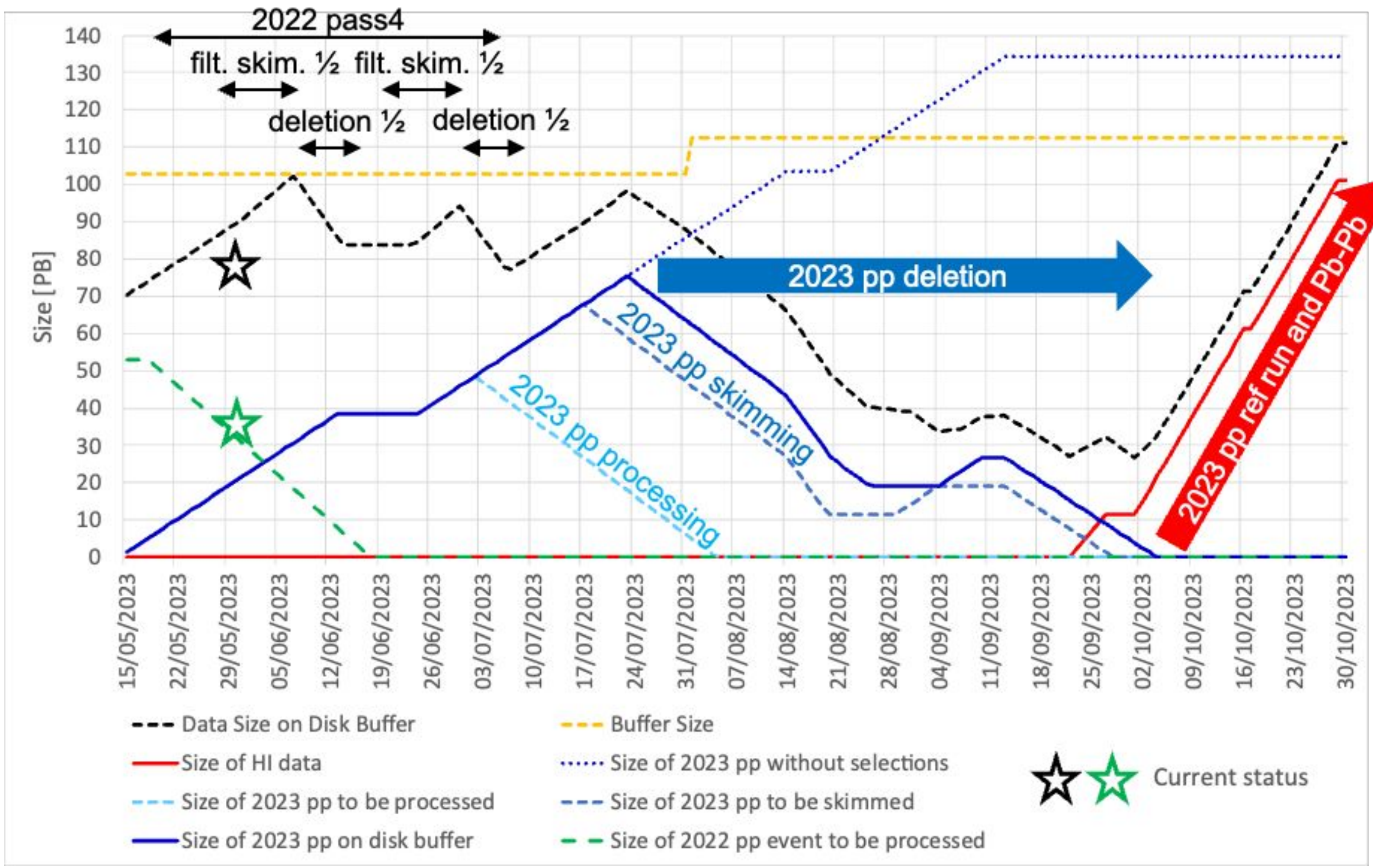




ALICE has a detailed program of 2022-2023 pp data processing and skimming before the Pb–Pb run in autumn 2023

Expected data accumulation on O2 disk buffer in 2023

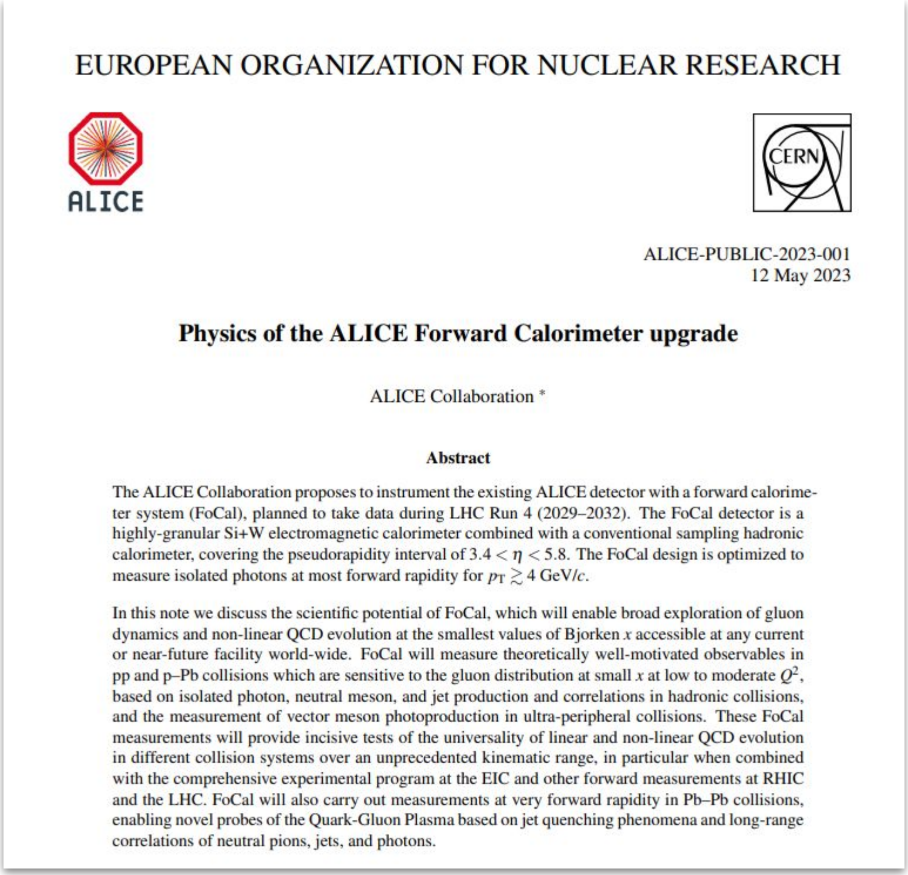
mfaggin@cern.ch



- Accumulation of new pp data @ 9 PB/week
- 4-5 weeks for processing 2022 apass4 on EPN and T0 + 1.5 weeks for filtering & skimming only on T0
- Only 10% of original CTF size kept after selections
- 2023 apass1 on 120 + 70 EPNs, T0 reserved for filtering and skimming
  - + 2 weeks for filtering & skimming
  - + 1 week for archival and deletion
- Max. read + write throughput: 100 GB/s

ALICE-PUBLIC-2023-001

Physics of the ALICE Forward Calorimeter upgrade



EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

ALICE-PUBLIC-2023-001
12 May 2023

Physics of the ALICE Forward Calorimeter upgrade

ALICE Collaboration *

Abstract

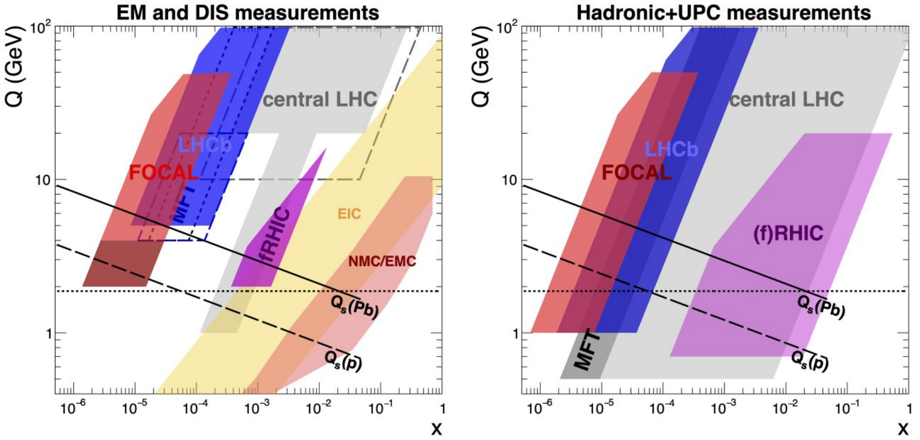
The ALICE Collaboration proposes to instrument the existing ALICE detector with a forward calorimeter system (FoCal), planned to take data during LHC Run 4 (2029–2032). The FoCal detector is a highly-granular Si+W electromagnetic calorimeter combined with a conventional sampling hadronic calorimeter, covering the pseudorapidity interval of $3.4 < \eta < 5.8$. The FoCal design is optimized to measure isolated photons at most forward rapidity for $p_T \gtrsim 4$ GeV/c.

In this note we discuss the scientific potential of FoCal, which will enable broad exploration of gluon dynamics and non-linear QCD evolution at the smallest values of Bjorken x accessible at any current or near-future facility world-wide. FoCal will measure theoretically well-motivated observables in pp and p–Pb collisions which are sensitive to the gluon distribution at small x at low to moderate Q^2, based on isolated photon, neutral meson, and jet production and correlations in hadronic collisions, and the measurement of vector meson photoproduction in ultra-peripheral collisions. These FoCal measurements will provide incisive tests of the universality of linear and non-linear QCD evolution in different collision systems over an unprecedented kinematic range, in particular when combined with the comprehensive experimental program at the EIC and other forward measurements at RHIC and the LHC. FoCal will also carry out measurements at very forward rapidity in Pb–Pb collisions, enabling novel probes of the Quark-Gluon Plasma based on jet quenching phenomena and long-range correlations of neutral pions, jets, and photons.

Goals

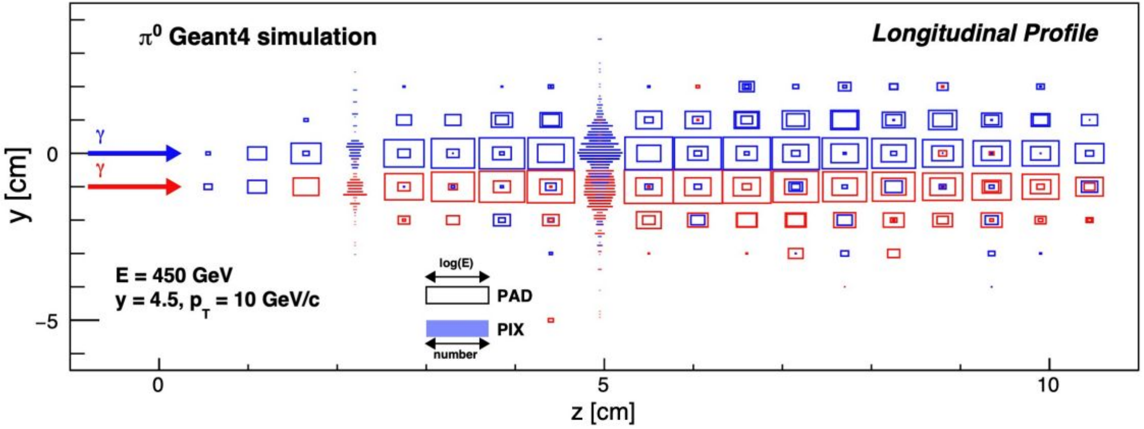
Explore gluon saturation at small Bjorken x by measuring forward direct-γ, π^0, jets + their correlations in p-Pb collisions and quarkonia in ultra-peripheral p-Pb and Pb-Pb collisions

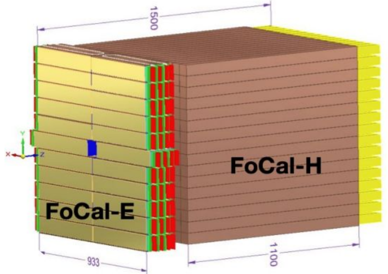
Direct photons, Drell-Yan

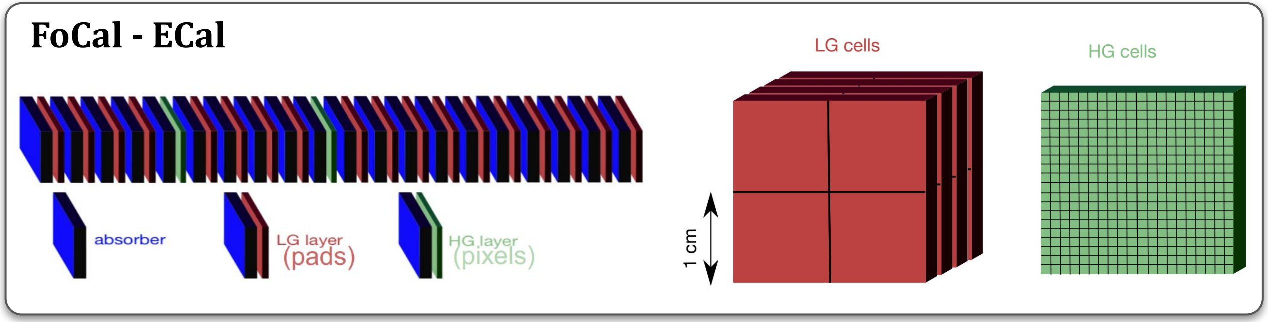


FoCal-E: segmented in 18 layers of tungsten and silicon pads with low granularity (LG, ~ 1 cm^2) and two layers of tungsten and silicon pixels with high granularity (HG, ~ 30x30 μm^2).

FoCal-H: metal/scintillating calorimeter with high granularity of up to 2.5x2.5cm^2







CERN-LHCC-2020-009

Forward Calorimeter (FoCal)

Full tower prototype

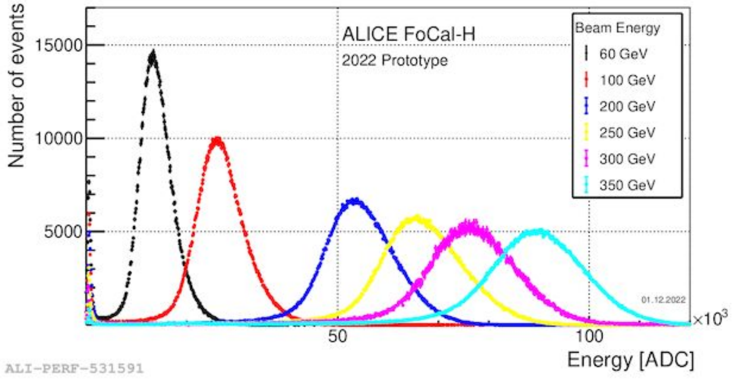
ECal

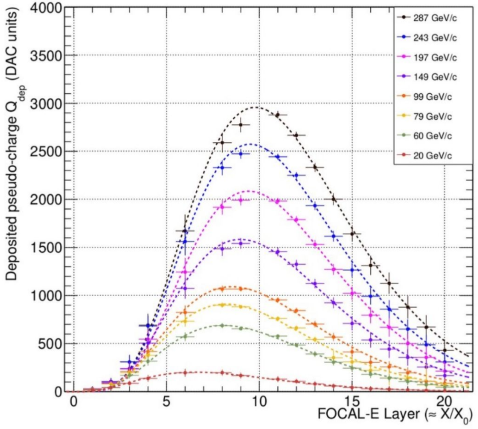
- Pads: test Time-over-Threshold for large dynamic range
- Pixels: test Outer Barrel HIC-based layers
- First time: pads + pixels with common CRU readout

HCal

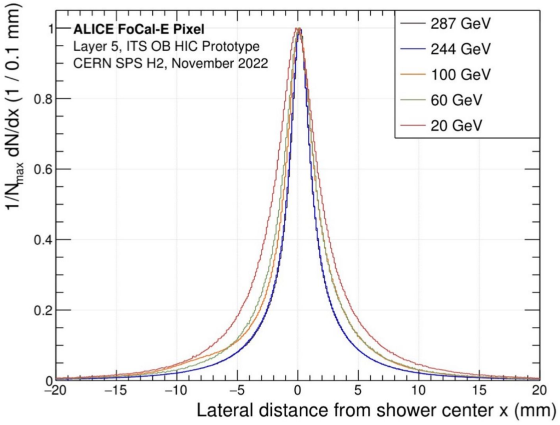
- 9 prototype modules
- Test commercial (CAEN) and custom (VMM) readout

HCal reconstructed charge distribution





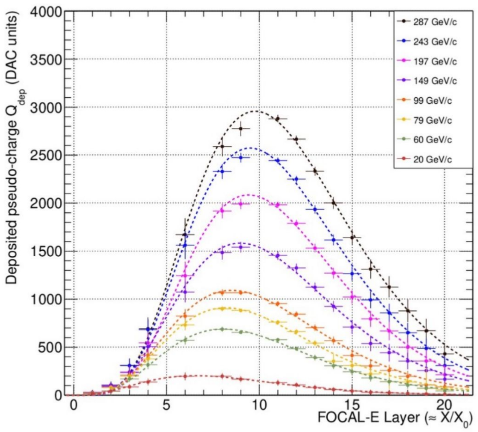
LG pad layers: longitudinal energy distribution



HG pixel layer 5: lateral shower distribution

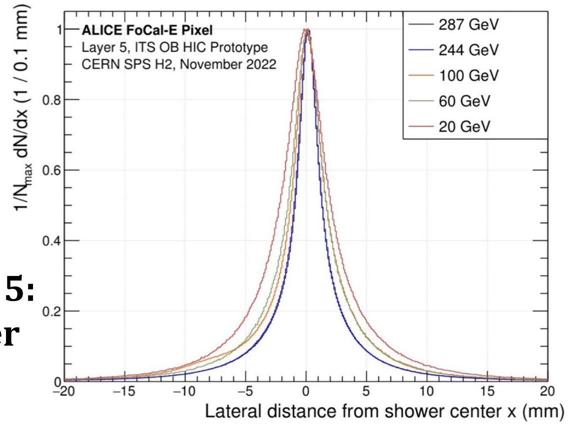
Results from November 2022 test beam at PS and SPS

Forward Calorimeter (FoCal)



LG pad layers: longitudinal energy distribution

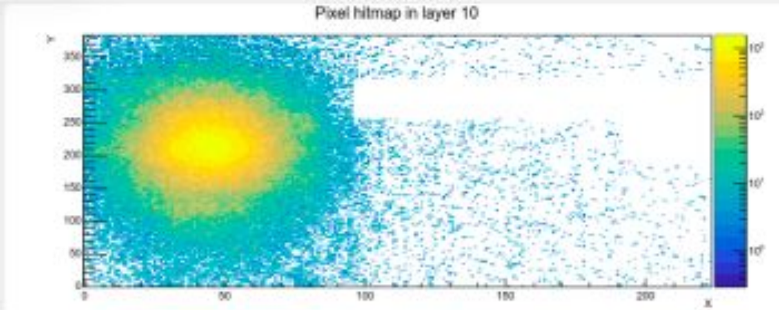
HG pixel layer 5: lateral shower distribution

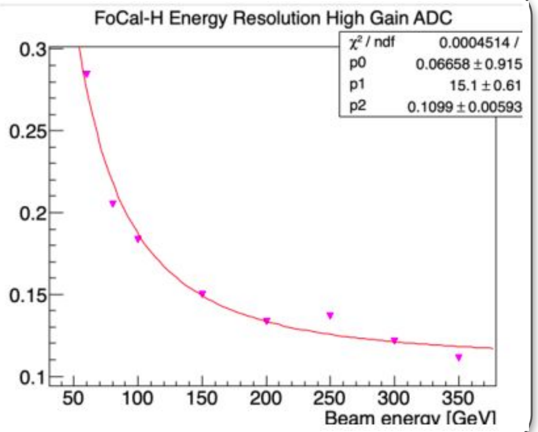


Results from November 2022 test beam at PS and SPS

Further positive results from May 2023 test beam

- FoCal-E pad timing
- Pixel studies
- FoCal-H energy resolution studies

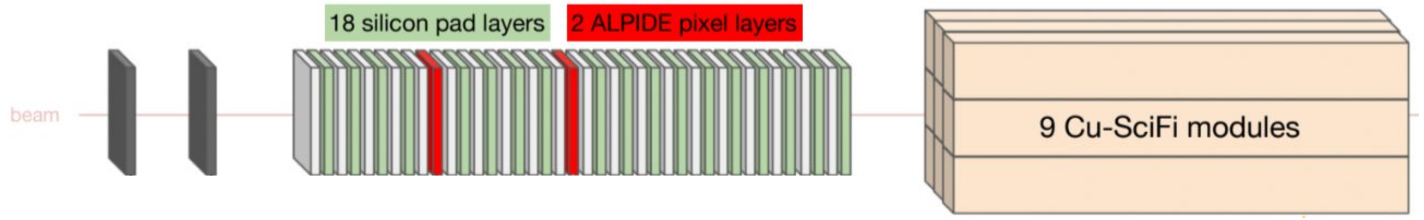




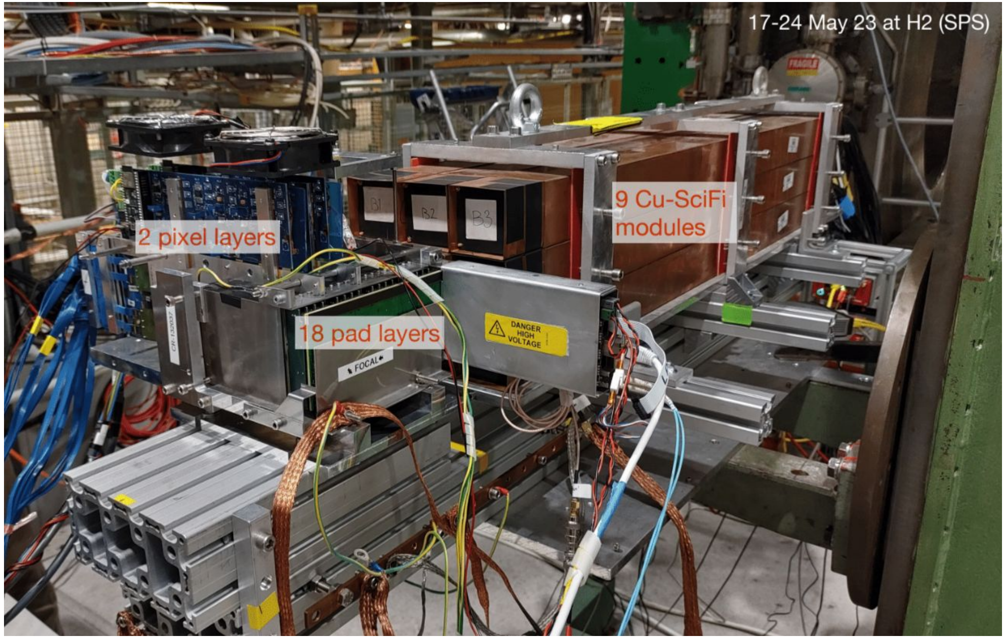
Detector design confirmed!

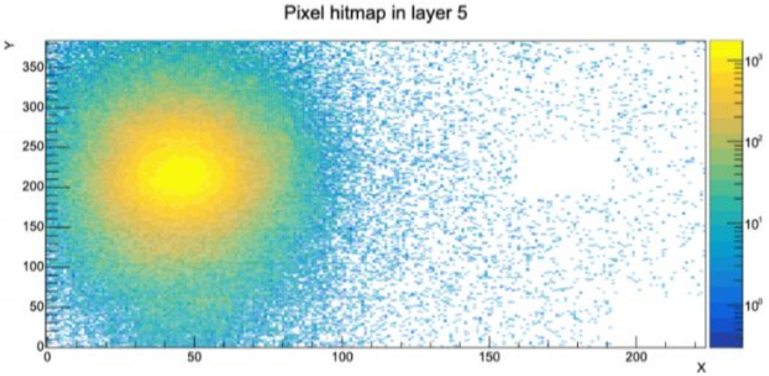
May 2023 test beam

mfaggin@cern.ch



Setup for May 2023 test beam





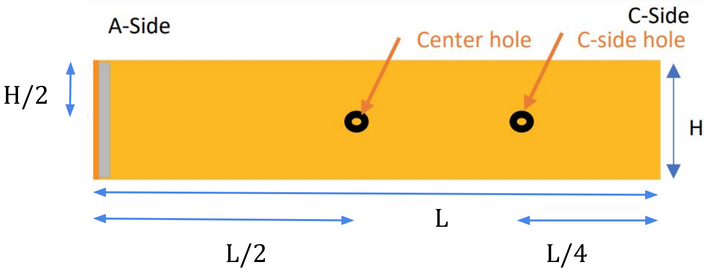
Pixel tests

- All ALPIDEs in acceptance functional
- Tests with continuous readout at 50 kHz and 100 kHz successfully done

Vibration test measurements

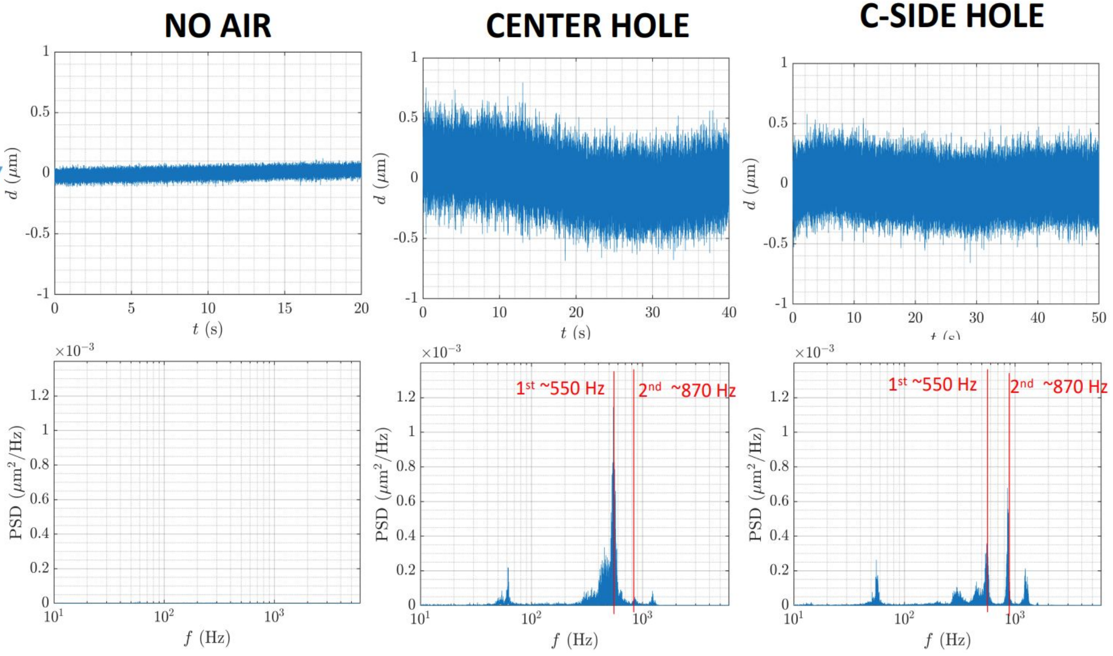
mfaggin@cern.ch

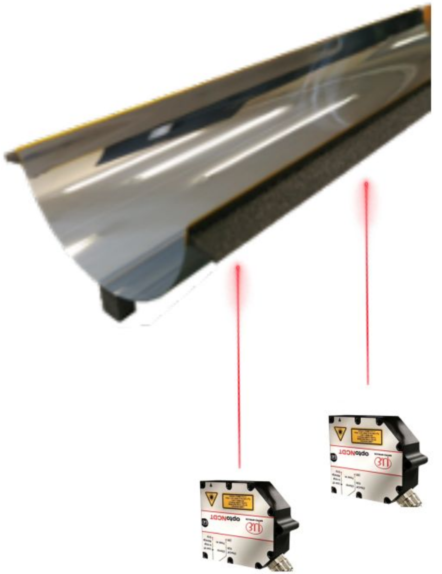
Air flow: 8 m/s



TIME HISTORY

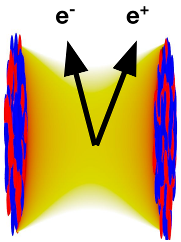
PSD

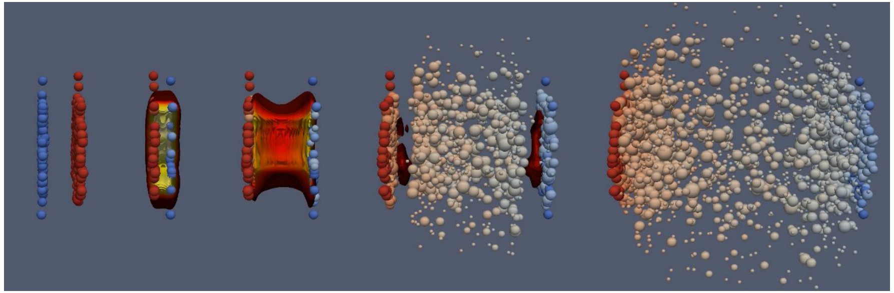




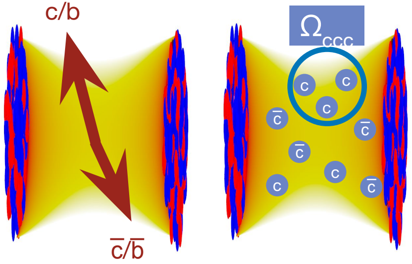
< 1 μm displacement at nominal air flows and power dissipations

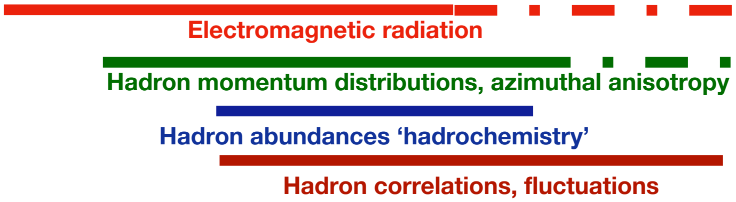
- **Precision measurements of dileptons**
  - ➡ evolution of the quark gluon plasma temperature
  - ➡ mechanisms of chiral symmetry restoration in the quark-gluon plasma





- **Systematic measurements of (multi-)heavy-flavoured hadrons**
  - ➡ transport properties in the quark-gluon plasma
  - ➡ mechanisms of hadronisation from the quark-gluon plasma





- **Hadron correlations**
  - ➡ interaction potentials
  - ➡ fluctuations
- …

➡ **Heavy-ion collisions at the LHC are ideal to address these questions, but require improved detector performance and larger data samples**

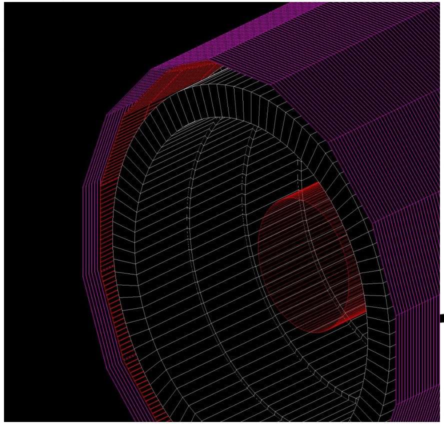
ALICE 3 R&D for Muon Identifier

mfaggin@cern.ch

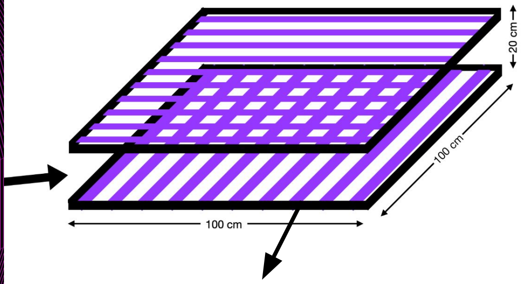
- Large area detector to identify muons after the hadron absorber (R ~ 2.5 m)
- Baseline with scintillator bars equipped with wavelength-shifting fibers and readout with SiPMs

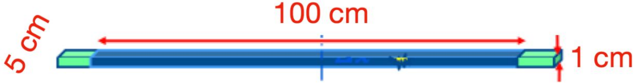
- Other options under study:
  - Scintillators without fibers
  - Resistive Plate Chambers (RPCs)
  - Multiwire Proportional Chambers (MWPCs)

- Test beam in June to characterise:
  - several prototypes of scintillator bars
  - prototypes of RPCs and MWPCs

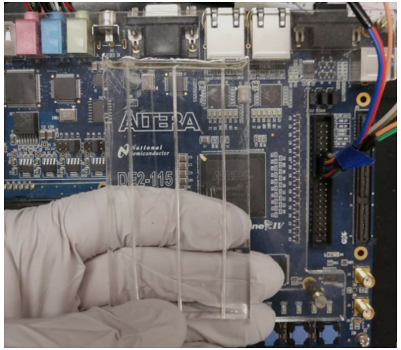


Muon chambers
Scintillator bars equipped with wave-length shifting fibres (width 5 cm, gap 20 cm)

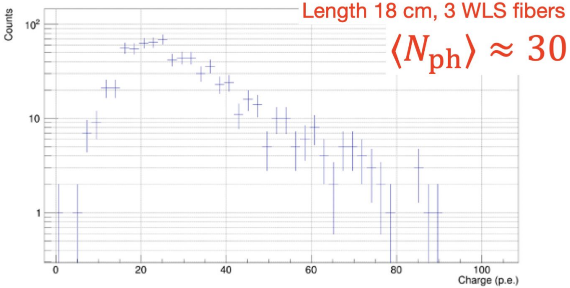




Made in Mexico: PPO 0.2%, POPOP 0.01%

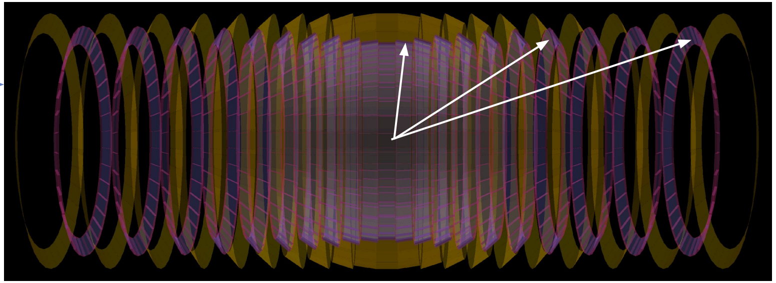


Lab test of bar with 3 fibers:



R&D for RICH detector

- Studies ongoing for several design options:
    - Proximity focusing with projective geometry
    - Mirror focusing with projective geometry
    - Dual radiator (aerogel+gas) for better electron-ID



Cherenkov radiator

- Test beam in October 2022 to qualify aerogel and electronics, and study dark count rate vs. cooling conditions

- Simulations for Pb-Pb with 2 cm aerogel radiator indicate that ALICE 3 specs performance can be reached