ALICE UPGRADERS

LHCP Conference – Belgrade
25 May 2023
Robert Münzer (Goethe University Frankfurt)
For the ALICE collaboration
ALICE MAIN QUESTIONS

Main focus of the ALICE program is the study of QGP properties with HI collisions

- Extended to many other aspects of QCD during Runs 1 and 2
- QGP macroscopic and microscopic properties
- Temperature and viscosity
- Interaction of partons with the QGP at various momentum scales
- Hadronization of the QGP

Two main physics items driving the ALICE upgrade strategies:

- Transport and hadronization of heavy flavors (HF) in the medium: differential measurements of HF hadron production (suppression, enhancement, flow…) down to vanishing $p_T$
- Electromagnetic radiation from the medium: dilepton measurements below $J/\psi$ mass, down to zero $p_T$, to map the evolution of the collision

→ Light and high-granularity detector + continuous readout to access untriggerable probes with very low S/B

“Alice status and overview”
(I. Altsybeev : 22/05/23 09:30)
ALICE - UPGRADES FOR RUN 3

Upgrade of Time Projection Chamber (TPC) with GEM amplification

New Inner Tracking system (ITS)

New Fast Interaction Trigger (FIT)

New Muon Forward Tracker (MFT)

“Run 3 performance of new hardware with ALICE” (J. Liu 23/05/23 11:30)

Tracking and vertexing (M. Faggin 25/05/23 12:24)

Particle Identification (C. Sonnabend: 25/05/23 12:42)

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Continuous data taking of min. bias Pb-Pb data at 50 kHz

New data acquisition and reconstruction framework (Online – Offline , O²)
ALICE - UPGRADES FOR RUN 3

Run 3 Goals:
• pp: ~120 pb⁻¹
• p-Pb: ~0.3 pb⁻¹
• Pb-Pb: ~6.5 nb⁻¹

Run 3 Performance of new hardware with ALICE (J. Liu 23/05/23 11:30)
Tracking and vertexing (M. Faggin 25/05/23 12:24)
Particle Identification (C. Sonnabend: 25/05/23 12:42)
ALICE 2.1 : FUTURE UPGRADES

- FoCal
- ITS3

- 2010-2013
  - Run1
  - ALICE 1

- 2015-2018
  - LS1
  - Run2
  - ALICE 2

- 2022-2025
  - LS2
  - Run 3
  - LS3
  - ALICE 2.1

- 2029-2032
  - Run 4
  - LS4

- 2035-2038
  - Run 5
  - LS5
  - Run 6
  - ALICE 3
FoCaL – PHYSICS MOTIVATION

Forward physics at LHC provides an opportunity to study the low-x region ($< 10^{-5}$)

- Access to **non-linear QCD evolution**: investigate the onset of possible gluon saturation
- Quantify and constrain **modifications of gluon (n)PDFs**
- Direct photons provide a more direct access to the low-x region
  - No fragmentation
  - No final-state effects
- $\pi^0 / \pi^0 - \gamma$ correlations and $J/\psi$ in ultraperipheral collisions
### FoCaL – FORWARD CALORIMETER

**Requirements:**

- Energy resolution: ~<5% (EM) ~12% (hadron)
- Position resolution: ~ 5mm (EM shower)
  - Required for two shower separation

**FoCal-E:**

- Optimized for γ and π⁰ reconstruction
- Segmented in 18 layers of tungsten and silicon pads with low granularity (~ 1 cm)
- **Two layers of tungsten and silicon pixels with high granularity (~ 30 x 30 µm²)**
- Prototype tested in beam

**FoCal-H:**

- Cu-scintillator: direct γ isolation and jets
- Metal/scintillating calorimeter with high granularity of up to 2.5 x 2.5 cm²
- Prototype tested in beam

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FoCal Letter of Intent: CERN-LHCC-2020-009
https://inspirehep.net/literature/1805025

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3.4 < η < 5.8
FoCaL – FORWARD CALORIMETER

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Electron separation in FoCal-E

![FoCal-H prototype](image1)
![FoCal-E prototype](image2)

**ALICE FoCal-E Pixel**
- SPS H2, November 2022
- 300 GeV electron beam
- Layer 10

Number of pixel clusters / mm²
ITS3 - UPGRADE OF THE INNER TRACKER

Replacing the inner barrel of ITS2 with a next-generation vertex detector

- Pointing resolution $\approx r_0 \sqrt{x/X_0}$
- Silicon only contributes to 15% of budget for the ITS2 layers
- Pointing resolution can be improved
  - by **removing material** in the first layers
    - Move from water to air cooling
    - Integrate power and data on chip
    - Self-supporting structure
    - Reduce $X/X_0$ from 0.35% → 0.05%
  - by moving **closer to beamline**
    - Innermost layer from 22 mm to **18 mm radial distance** from beamline

http://cds.cern.ch/record/2703140
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http://cds.cern.ch/record/2703140
ITS3 - UPGRADE OF THE INNER TRACKER

Detector design

• Novel vertex detector:
  • Curved wafer-scale ultra-thin silicon sensors arranged in perfectly cylindrical layers
  • 280 mm long sensor MAPS (Monolithic Active Pixel Sensors) out of stitched wafers (2 halves x 3 layers)
  • Carbon foam rib to hold MAPS in place
  • Based on 65nm CMOS technology (Aglieri et al. https://arxiv.org/abs/2212.08621)

"Future Monolithic Pixel Detectors in ALICE and Beyond" (F. Carnesecchi : 25/05/23 12:06)
ITS3 – PHYSICS PERFORMANCE

- Physics measurements that benefit from ITS3 upgrade
  - Improved DCA resolution:
    - Charm baryons
    - Beauty-strange mesons and beauty baryons
    - Dileptons (heavy-flavor background rejection)
    - Search for exotic charmed nuclei
  - Reduced inner radius
  - Strangeness tracking (for charm-strange baryons, hypernuclei)
ALICE 3 : FUTURE

Nature of interactions with QGP of highly energetic quarks and gluons

- Connection between parton transport, collective phenomena and hadronization
  → Precision measurement of beauty quarks
- What are the mechanisms of hadron formation in QCD?
  → Systematic measurements of (multi-)charm, exotic hadrons
- Chiral symmetry restoration
  → Precision measurements of dileptons
- QCD chiral phase structure
  → Fluctuations of conserved charges
- Hadron interaction potential
  → Hadron-hadron correlations
- Searches BSM
  → Dark photons, axion-like particles in gamma-gamma, ..
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CERN-LHCC-2022-009
https://arxiv.org/abs/2211.02491v1
**ALICE 3 - REQUIREMENTS**

Vertex detector with excellent pointing resolution  
→ Better then 3-4 µm @ 1 GeV/c

Compact **all-silicon** tracker  
→ $p_T$ resolution better than 1% @ 1 GeV/c

**Particle Identification**  
→ Clean background suppression

**Large acceptance**  
$-4 < \eta < 4, p_T > 0.02$ GeV/c  
→ Statistics and correlations

Superconducting magnet system: max 2.0 T  
→ Effective provision of required magnetic field

Continuous readout and online processing  
→ Large data sample to access rare signals

**Luminosity Targets:**  
- Pb-Pb: 35 nb\(^{-1}\)  
- pp: 18 fb\(^{-1}\)

→ Novel detector concept based on innovative technologies relevant for future HEP experiments  
→ R&D started
ALICE 3 - VERTEX DETECTOR / IRIS

Conceptual study

- 3 layers of wafer-size, ultra-thin, curved, CMOS Active Pixel Sensors → Ultimate performance
- First layer at midrapidity: 5 mm from beam axis
- Limited to LHC aperture at injection energy (16mm)
- Unprecedented spatial resolution: $\sigma_{\text{pos}} \approx 2.5 \, \mu\text{m}$
- Extremely low material budget: 0.1% per layer
- Radiation requirements: $10^{16} \, 1\text{MeV} \, n_{\text{eq}} / \text{cm}^2$
  (ITS3 prototype already achieved $10^{15} \, 1\text{MeV} \, n_{\text{eq}} / \text{cm}^2$)

Challenges:

- Radiation hardness
- Cooling & services
ALICE 3 – OUTER TRACKER

- **8 + 2 x 9 tracking layers (barrel + disks)**
- 60 m² silicon pixel detector based on CMOS Active Pixel Sensor technology
- Compact: r_{out} ~80 cm, z_{out} ± 4 m
- Large coverage: ± 4 \( \eta \)
- **High-spatial resolution:** \( \sigma_{\text{pos}} \sim 5\mu m \) (req. < 10 \( \mu m \))
- Relative \( p_T \) resolution: ~1% over large acceptance
- Time resolution: ~100 ns
- Very low material budget: ~1% \( X_0 \) per layer
- Low power consumption: ~ 20 mW/cm²

Challenges:
- Integration
- Time performance
- Material budget
**ALICE 3 - PARTICLE IDENTIFICATION**

Time of Flight detectors:
- Separation power: $L/\sigma_{\text{TOF}}$
- Distance and time resolution crucial
- Larger radius results in lower $p_T$ bound
  - Time resolution: ~20ps
  - 2 TOF layers + endcaps
  - Silicon LGADs or CMOS with gain layer
  - Total silicon area: ~45m²

Complement PID reach of outer TOF to higher $p_T$ with Cherenkov detector
  - Aerogel radiator
    - $n=1.03$ (barrel)
    - $n=1.006$ (forward)
  - Total SiPM area ~60m²

Challenges:
- Radiation hardness of SiPM
ALICE 3 - MUON AND PHOTON IDENTIFICATION

Muon chambers at central rapidity
optimized for reconstruction of charmonia down to $p_T = 0$ GeV/c
- ~70 cm non-magnetic steel hadron absorber
- search spot for muons ~0.1 x 0.1 ($\eta \times \phi$)
- ~5 x 5 cm$^2$ cell size
- matching demonstrated with 2 layers of muon chambers
  - scintillator bars
  - wave-length shifting fibers
  - SiPM read-out
  - possibility to use RPCs as muon chambers

Large acceptance ECal (2$\pi$ coverage)
critical for measuring P-wave quarkonia and thermal radiation via real photons
- sampling calorimeter (à la EMCal/DCal):
  - e.g. O(100) layers (1 mm Pb + 1.5 mm plastic scintillator)
  - PbWO$_4$-based high energy resolution segment

Forward Conversion Tracker
Measurement of ultra-soft photons
- Thin tracking disks in 3 < $\eta$ < 5 in its own dipole field
- Very low $p_T$ photons (< 10 MeV/c)
ALICE 3 – EXPECTED PERFORMANCE

Measurement of D meson correlations

Goal: measure angular (de)correlations – direct probe of HF interaction with the QGP

- Strongest signal at low \( p_T \)
- Very challenging measurement: need good purity, efficiency and \( \eta \) coverage

\[ D - \bar{D} \] azimuthal correlation

→ Measurement in heavy-ion collisions only feasible with ALICE 3
ALICE 3 – EXPECTED PERFORMANCE

Measurement of multi-charm baryon

• Discrimination power on the role of the various hadronisation mechanisms
• In heavy-ion collisions at the LHC, large increase of multi-HF baryons (~1000) expected via coalescence with charm quarks from different hard scatterings ($N_c \sim 100$ in central Pb-Pb)

• $\Xi_{cc}^{++}$ reconstructed in the channel: $\Xi_{cc}^{++} \rightarrow \Xi_{cc}^{0} \pi^+ \rightarrow \Xi_{cc}^{0} \pi^+ \pi^+ \pi^+$
• $\Omega_{cc}^{-}$ reconstructed in the channel: $\Omega_{cc}^{-} \rightarrow \Omega_{cc}^{+} \pi^- \rightarrow \Omega_{cc}^{+} \pi^- \pi^+ \pi^+$
• $\Omega_{ccc}$ studies ongoing
ALICE 3 – EXPECTED PERFORMANCE

Precision measurement of dielectrons as function of mass and $p_T$

- Improved pointing resolution to reject heavy flavor
- Significant reduction of charm contribution and associated uncertainty → sensitive to $\rho$-meson spectral function modification due to chiral symmetry restoration
- Possibility for multi-differential dielectron measurements → time dependence of emission

CERN-LHCC-2022-009

ALICE came a long way in the investigation of QCD in extreme conditions

**More to come in Run 3 and Run 4** after successful upgrade (ALICE 2)

Further improvements planned for Run 4:
- **FoCal**: Forward calorimeter for measurement down to low x
- **ITS3**: Replacement of inner layers of ITS with novel silicon technology to reduce material budget and improve pointing resolution

Results obtained pose additional fundamental questions that require new heavy-ion detector at LHC

The physics questions and proposal for next generation heavy-ion experiment (ALICE 3) have been published in letter of intent in 2022

ALICE 3 pioneers several R&D directions that can have a broad impact on future HEP experiments (e.g. EIC, FCC-ee)

Next steps for ALICE 3:
- 2024: Scoping Document
- 2027: Technical Design Reports
THANK YOU FOR YOUR ATTENTION
BACKUP SLIDES
FOCAL – FORWARDS CALORIMETER

- PDFs determined from deep inelastic scattering, neutral current of DY processes -> region of pertubative QCD
- Linear equations for evolution towards higher Q2 («DGLAP») and towards lower x («BFKL»)
- At very lower x higher gluon densities (saturation) non-linear equations become relevant («BJK/JIMWLK»)
FoCAL PROTOTYPES

2010-2015
- ORNL / Japan prototype:
  - NIM A 988 (2021) 164796
- Indian prototypes:
  - NIM A 784 (2014) 24
  - JINST 15 (2020) 03, P03015

2014-2018
- Mini-FoCal (PADs only) in beam at P2

2014-2016
- MIMOSA pixel tower (EPICAL)
  - JINST 19 (2016) P01014

2018-2021
- ALPIDE pixel tower (EPICAL-2)
  - NIM A1045 (2020) 167539

2019-2022
- FoCal-E and H prototypes
  - final sensors and chips
  - close-to-final readout

Current state of the TB prototypes:

FoCal-E
- 18 LG Layers (Si Pads)
  - 9x8 array
  - 1cm2 resolution
- 2 HG Layers (Si Pixels)
  - L5 and L10
  - 6 O5 ITS HiCs
  - ~ 30 um2 res
- 20 Tungsten layers (~20 X₀)

FoCal-H
- 6.5 cm x 6.5 cm x 110 cm
- BCF12 scintillating fiber
- 49 (central), 25 (sides) SiPMs
- 2/3 CAEN DT5202 boards
FoCAL -E PIXEL @ SPS TEST BEAM IN 2022

- Successful commissioning of FoCal-E PIXEL (ALPIDE)
- Double and triple electron signature identified in preliminary analysis
- Distance between electrons here ~ 10 mm, demonstration of a good two gamma separation
ITS3 - LAYERS
• Beam Tests:
  • ALPIDE telescope used for the tests
  • Efficiency and resolution consistent with flat ALPIDEs
  • Spatial resolution uniform among different radii
ITS3 – UPGRADE OF INNER TRACKER

• Beam Tests:
  • ALPIDE telescope used for the tests
  • Efficiency and resolution consistent with flat ALPIDEs
  • Spatial resolution uniform among different radii

• R&D on the detector mechanics, sensor technology and readout system ongoing
  • Breadboard model 3 ready (Silicon based mock up with heaters)
  • Wind tunnel commissioned
ITS3 – UPGRADE OF INNER TRACKER

• Beam Tests:
  • ALPIDE telescope used for the tests
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  • Wind tunnel commissioned

• Wafer-scale sensors from Engineering Run
  • First MAPS for HEP using stitching
  • One order of magnitude larger than previous chips:
    • 14 x 256 mm
    • 6.72 MPixel
ITS3 - PERFORMANCE

- Study beauty-quark hadronisation mechanism
- $B_s^0$ production expected to be enhanced
- hadronisation of beauty quarks via recombination and enhanced strange-quark production in the QGP

- Improvement by a factor 2 in significance with ITS3
- provide access to $B_s^0$ measurement at very low $p_T$
**ITS3 - PERFORMANCE**

**$D_s^+$ reconstruction**

- **Non-prompt $D_s^+$ from $B$ decays:**
  - even if not direct measurement, sensitive to $B^0$
  - larger statistical precision than exclusive $B^0$ reconstruction

- **Comparison between non-prompt $D_s^+$ and non-strange $D$ mesons sensitive to beauty-quark hadronisation and strangeness enhancement**

- **Non-prompt $D_s^+$ azimuthal anisotropy**
  - Participation of beauty quarks in the collective motion and possible thermalisation in the QGP
  - Information about beauty-quark diffusion coefficient in the QGP

- **ITS3:**
  - sensitivity to discriminate azimuthal anisotropy for prompt and non-prompt $D_s^+$ (charm vs. beauty)
WHAT MAKES ALICE 3 UNIQUE

• ALICE 3 will have unique capabilities for the reconstruction of quarkonium states down to $p_T = 0$ and excellent performance for low energy photons (0.5 GeV and below)
  → high rates, wide acceptance (both in $\eta$ and $p_T$)

• $(\sigma_{\text{DCA}})$ of ALICE 3 is about 4 $\mu$m (comp. 30-50 $\mu$m (ALICE 2), 50-60 $\mu$m (CMS) similar kinematic range
  → $\Lambda_c$ and $\Lambda_b$ identification

• Azimuthal DD correlations measurements that provide unique direct access to heavy quark interactions with the QGP (low material budget)

• Unique $p_T$ reach not only for quarkonia, including P-wave states with photon detection in the calorimeter
  – Muons down to $p_T \sim 1.5$ GeV/$c$ at $\eta = 0$ (ATLAS / CMS: down to $p_T \approx 3–4$ GeV/$c$)

• The photon conversion tracker that is proposed as a part of ALICE 3 provides unique access to very soft photons, to test fundamental aspects of field theory in this regime
## SILICON LAYERS REQUIREMENTS

<table>
<thead>
<tr>
<th></th>
<th>Vertex Detector</th>
<th>Middle Layers</th>
<th>Outer Tracker</th>
</tr>
</thead>
<tbody>
<tr>
<td>Detection efficiency (%)</td>
<td></td>
<td>&gt;99</td>
<td></td>
</tr>
<tr>
<td>Spatial resolution (μm)</td>
<td>2.5</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Time resolution (ns)</td>
<td></td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Fake hit rate (pixel⁻¹ event⁻¹)</td>
<td>&lt;10⁻⁸</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Power consumption (mW cm⁻²)</td>
<td>70</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>Non-ionising energy loss (1 MeV nₑq / cm²)</td>
<td>1×10¹⁶</td>
<td>2×10¹⁴</td>
<td>6×10¹²</td>
</tr>
<tr>
<td>Total ionising dose (kGy)</td>
<td>3000</td>
<td>50</td>
<td>2</td>
</tr>
<tr>
<td>Pixel size (μm²)</td>
<td>O(10×10)</td>
<td>O(50×50)</td>
<td>O(50×50)</td>
</tr>
</tbody>
</table>
IRRADIAION TEST

A Large Ion Collider Experiment

IRRADIATION TEST

DPTs, 15 μm pixel pitch @ 20°C

Detection efficiency

Fake-hit rate

Non-irradiated

10^{13} 1 MeV n_{eq} cm^{-2} 2xOT

10^{14} 1 MeV n_{eq} cm^{-2} 1/2xML

10^{15} 1 MeV n_{eq} cm^{-2} 3xITS3

FHR measurement sensitivity limit

Performance at sub-zero temperatures?
SPATIAL RESOLUTION

APTS SF
Non-irradiated
type: modified with gap
split: 4
\( I_{\text{reset}} = 100 \, \text{pA} \)
\( I_{\text{bias}} = 5 \, \text{µA} \)
\( I_{\text{biasp}} = 0.5 \, \text{µA} \)
\( I_{\text{biasq}} = 150 \, \text{µA} \)
\( V_{\text{reset}} = 500 \, \text{mV} \)
\( V_{\text{well}} = V_{\text{sub}} = -1.2 \, \text{V} \)
\( T = 20 \, ^\circ \text{C} \)

ALICE ITS3 beam test preliminary
@SPS October 2022, 120 GeV/c hadrons
@PS August 2022, 12 GeV/c hadrons
Plotted on 27 Mar 2023

Association window radius: 75 µm. Plotting for thresholds above 3x noise RMS.
MAPS foils – chips within printed circuit boards
• «Novel» concept (revised and update from 2012)
• Will be studied further as an option
1. **Thinner LGAD sensors**
   - 25 and 35 µm thick prototypes
   - excellent time resolution < 25 ps
   - sensors of 10 µm in preparation

2. **CMOS sensors with gain layer**
   - sensors back from foundry
   - preparations of test beams

First very thin LGAD prototypes produced by FBK

25 µm and 35 µm -thick FBK single channel
Area = 1x1 mm²

SantaCruz single-channel LGAD read-out board V1.4 SCIPP 08/18 (G_\text{amp} \sim 6)

Tandem sensors produced by HPK

50 µm -thick HPK single channel
(W42 & W36 with different doping concentrations)
Area = 1.3x1.3 mm²

+ Second stage external amplifier (G_\text{amp} \sim 11-14)
PARTICLE IDENTIFICATION WITH TOF

Separation power \( L/\sigma_{\text{TOF}} \)
→ Distance and time resolution crucial
→ Larger radius results in lower \( \rho_T \) bound

2 barrel TOF layers (\(|\eta| < 1.75\))
• Outer TOF at \( r \approx 85\,\text{cm} \), surface: 30 \( \text{m}^2 \), pitch: 5 mm
• Inner TOF at \( r \approx 19\,\text{cm} \), surface: 1.5 \( \text{m}^2 \), pitch: 1 mm

1 forward TOF layers (1.75 < \(|\eta| < 4\))
• Inner radius = 15 cm, outer radius = 50 cm, \( z \approx 405\,\text{cm} \), surface 14 \( \text{m}^2 \), pitch: 1 mm to 1 mm

Silicon timing sensor:
CMOS sensor with gain (baseline)
• R&D in monolithic CMOS sensors with integrated gain layers
Conventional LGADs (fallback)
• R&D with very thin sensors

\( \sigma_{\text{TOF}} < 20\,\text{ps} \)

Total silicon area \( \sim 45\,\text{m}^2 \)
Complement PID reach of outer TOF to higher $p_T$ with Cherenkov detector

→ Ensure continuous coverage with the TOF

Aerogel radiator

- Refractive index $n = 1.03$ (barrel)
- Refractive index $n = 1.006$ (forward)

R&D on monolithic silicon photo sensors

Total SiPM area ~60m²
MORE ON PARTICLE IDENTIFICATION

Large acceptance Electromagentic calorimeter (2π coverage)
- Pb-Scintillator sampling calorimeter + at $\eta \approx 0$ crystal calorimeter
- Photons + high $p$ electrons identification
- Critical for measuring P-wave quarkonia and thermal radiation via real photons

Muon Identifier
- Absorber + 2 layers of muon detectors
- Muons down to $p_T \geq 1.5$ GeV/c
- Scintillator bars with SiPM read-out
- Possibility to use RPs as muon chambers

Forward conversion tracker
- Thin tracking disks in $3 < \eta < 5$ in its own dipole field
- Very low $p_T$ photons ($\leq 10$ MeV/c)

Search spot for muons $\sim 0.1 \times 0.1$ ($\eta \times \varphi$)
ALICE - R&D PROCESS

Silicon pixel sensors
- Thinning and bending of silicon sensors
  Expand n experience with ITS3
- Exploration of new CMOS processes
  First in-beam test with 65 nm process
- Modularization and industrialization

Silicon timing sensors
- Characterization of SPADs /SiPMs
  - First test in beam
- Monolithic timing sensors
  - Implement gain layers

Photon sensors
- Monolithic SiPMs
  Integrated read-out

Detector mechanics and cooling
- Mechanics for operation in beam pipe
  Establish compatible with LHC beam
- Minimization of material in the active volume
  Micro-channel cooling
MAGNET FIELD CONFIGURATION
PARTICLE IDENTIFICATION

Time of Flight detectors: Silicon timing sensors
Separation power  \( L/\sigma_{\text{TOF}} \)
→ Distance and time resolution crucial
→ Larger radius results in lower \( p_T \) bound
• 3 TOF layers ; Total silicon area : \(~45\text{m}^2\)

Complement PID reach of outer TOF to higher \( p_T \) with Cherenkov detector
• Aerogel radiator
• Total SiPM area \(~60\text{m}^2\)

Large Acceptance EmCal (2\( \pi \) coverage)
• Pb-scintillator sampling calorimeter
• Crystal calorimeter at \( \eta \sim 0 \)

Muon Identifier
• Absorber + 2 layers of muon detectors
• Muons down to \( p_T \geq 1.5 \text{ GeV/c} \)
ALICE 3 PHYSICS PERFORMANCE

Beauty Physics

\[ B^+ \text{ reconstruction} \]

\[ \Lambda_b \text{ elliptic flow, } v_2 \]

\[ \text{Significance(3\sigma)} \]

- ALICE 3 Study, no PID
- Pb-Pb \( \sqrt{s_{NN}} = 5.52 \text{ TeV}, 0\text{-}10\% \)
- \( L_{\text{int}} = 35 \text{ nb}^{-1} \)
- \( B^+ \rightarrow D^0 \pi^+, |y| < 1.44 \)

\[ p_T \text{ (GeV/c)} \]

\[ \text{Estimated } v_2 \]

- ALICE 3 Study \( L_{\text{int}} = 35 \text{ nb}^{-1} \)
- PbPb \( \sqrt{s_{NN}} = 5.5 \text{ TeV} 30\text{-}50\% \)
- \( \Lambda_b^0 \rightarrow \Lambda_c^+\pi(\Lambda_c^+ \rightarrow pK\pi^+), |y| < 1.44 \)

\[ p_T (\Lambda_b) \text{ (GeV/c)} \]

ALICE Coll. arXiv:2211.02491
PREDICTIONS FOR MULTI-CHARM BARYONS

http://arxiv.org/abs/2305.03687

- New paper: charm transport + hybrid hadronization with coalescence + fragmentation
- Broadly consistent with SHM expectation
- Large dynamics of yield enhancement: factor of 1000 for $\Omega^{++}_{ccc}$
- New: model allows for prediction of transverse momentum spectra!
ALICE 3 - PERFORMANCE

Heavy-flavor exotica: C-deuteron measurement

- First observation of a charmed nucleus feasible
- Extremely high significance if assuming the yield of the c-deuteron to match SHM expectations
ALICE 3 PHYSICS PERFORMANCE

Precise di-lepton measurement

- Spectral function of low mass dielectrons determined with 6-8% unc. in the region 0.4 ≤ m_{ee} ≤ 1.3 GeV/c^2
- Chiral mixing produces a 20-25% change versus vacuum spectral functions (0.8 ≤ m_{ee} ≤ 1.2 GeV/c^2)
- ALICE3 can observe chiral mixing effect and together with more differential measurements (dielectrons ν₂) constraint the modification of a₁ spectral function
BSM SEARCHES IN ULTRA-PERIPHERAL COLLISIONS

Ultra-peripheral heavy-ion collisions (UPC): clean environment + huge $Z^4 \approx 5 \cdot 10^7$ enhanced gamma+gamma rate w.r.t. pp

- Searches of BSM particle coupling predominantly to photons: modifications of the light-by-light scattering rates from virtual corrections from heavy particles (magnetic monopoles, vector-like fermions, dark sector particles)

- Precision measurements of EM couplings of SM particles: anomalous magnetic moment ($g$-2) of the tau

Challenge for ALICE 3: acceptance for tau and light-by-light scattering down to low $p_T$?
BSM SEARCHES IN UPCS

- Ultra-peripheral collisions (UPCs) are dominated by photon-photon and photon-nucleus interactions. Provide for a clean environment for axion-like particles (ALP) studies.

- Searches via $\gamma\gamma \rightarrow a \rightarrow \gamma\gamma$ process. Signal would be visible as a peak in the diphoton mass distribution.

- Performance on the estimated production cross-section given as mass and recast limit in the plane $(m_a, 1/\Lambda_a)$.
ITS PERFORMANCE

Impact parameter resolution

Transverse momentum [GeV/c]

Significance

ALICE Upgrade
$\Lambda_c \to pK^+\pi^+$
Pb–Pb 0-10%, $\sqrt{s_{NN}} = 5.5$ TeV

$L_{\text{int}} = 10$ nb$^{-1}$

$\rho_T$ (GeV/c)