A Large Ion Collider Experiment

ALICE UPGRADES

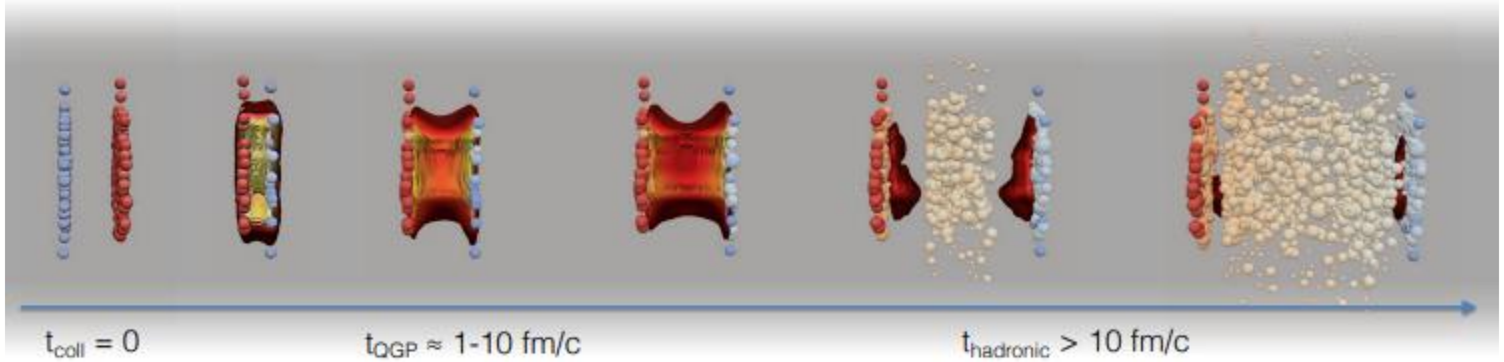
LHCP Conference – Belgrade

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

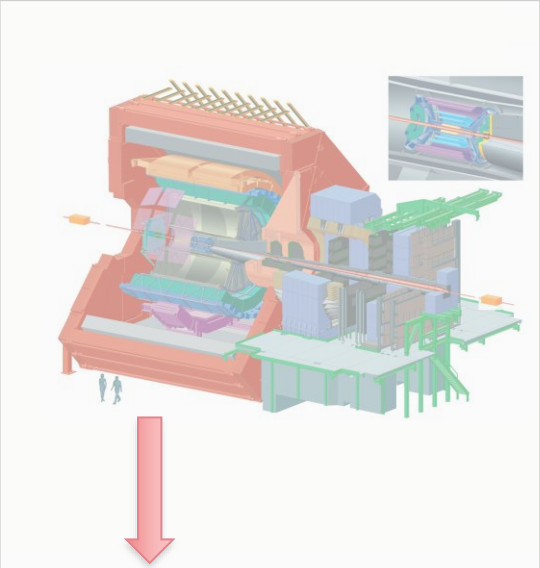
"Alice status and overview"
(I. Altsybeev : 22/05/23 09:30)

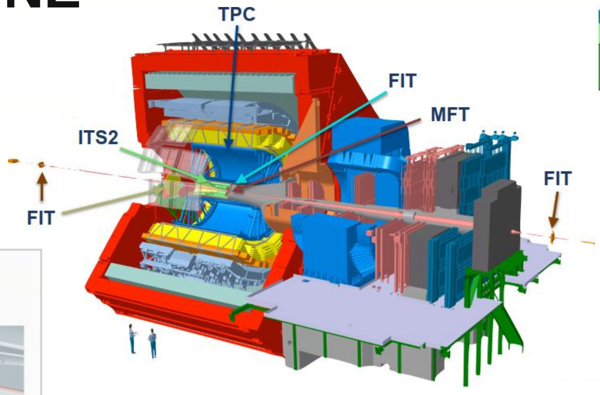
Two main physics items driving the ALICE upgrade strategies :

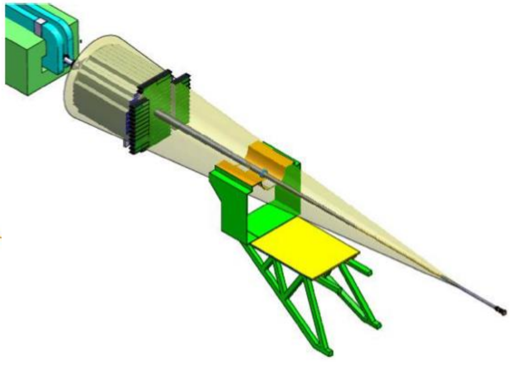
- **Transport and hadronization of heavy flavors (HF)** in the medium: differential measurements of HF hadron production (suppression, enhancement, flow…) **down to vanishing** p_T
- **Electromagnetic radiation from the medium**: dilepton measurements below J/ψ mass, down to zero p_T, to map the evolution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

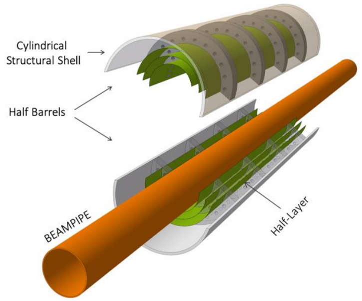
→ **Light and high-granularity detector + continuous readout to access untriggerable probes with very low S/B**

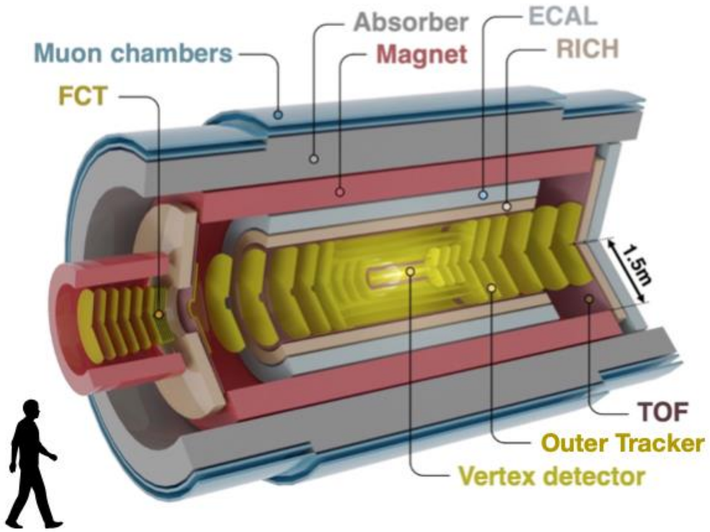
ALICE TIMELINE











2010-2013	2015-2018	2022-2025	2029-2032	2035-2038

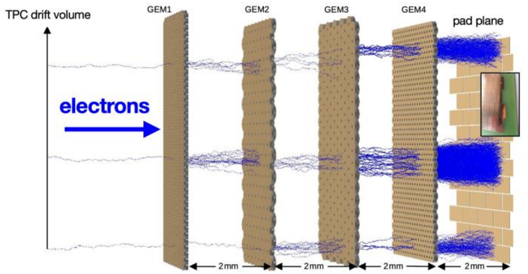
Run1 → LS1 → Run2 → LS2 → Run 3 → LS3 → Run 4 → LS4 → Run 5 → LS5 → Run 6

ALICE 1 | ALICE 2 | ALICE 2.1 | ALICE 3

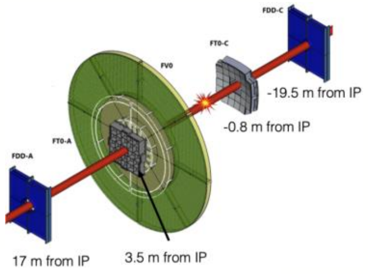
ALICE - UPGRADES FOR RUN 3

ALICE upgrades during the LHC Long Shutdown 2
arXiv:2302.01238

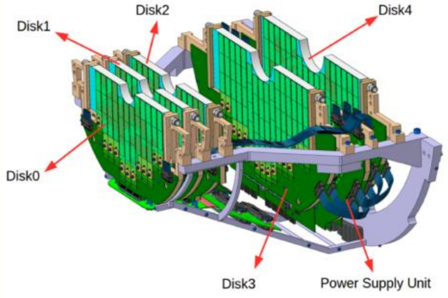
Upgrade of Time Projection Chamber (TPC) with GEM amplification



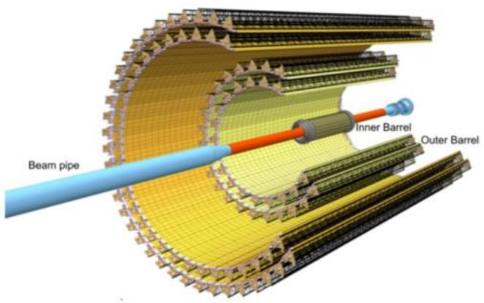
New Fast Interaction Trigger (FIT)

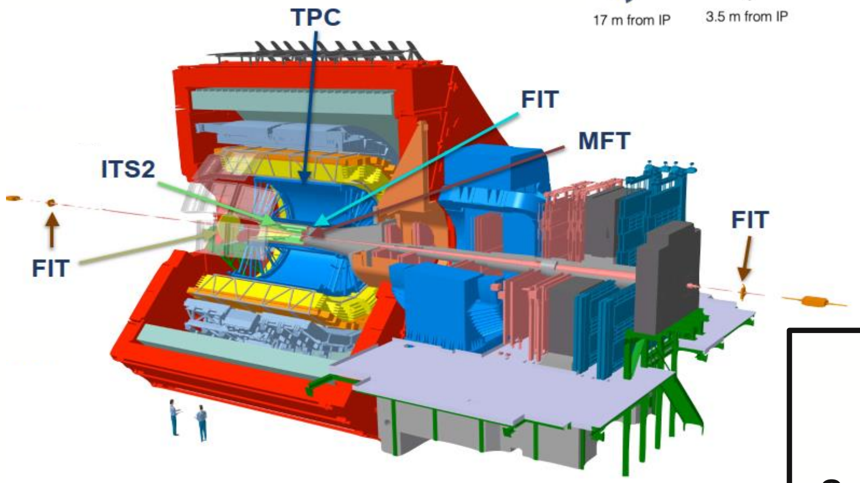


New Muon Forward Tracker (MFT)



New Inner Tracking system (ITS)





New data acquisition and reconstruction framework (Online – Offline , O^2)

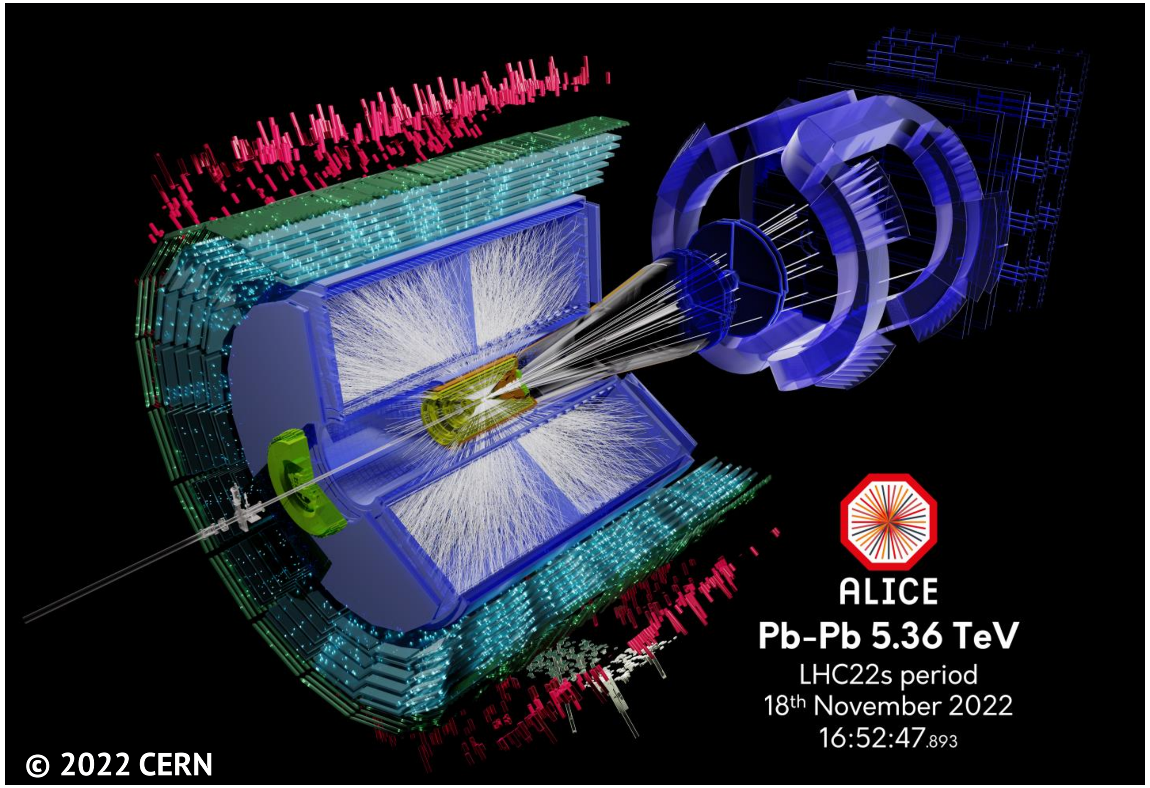
Continuous data taking of min. bias Pb-Pb data at 50 kHz

"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 - UPGRADES FOR RUN 3



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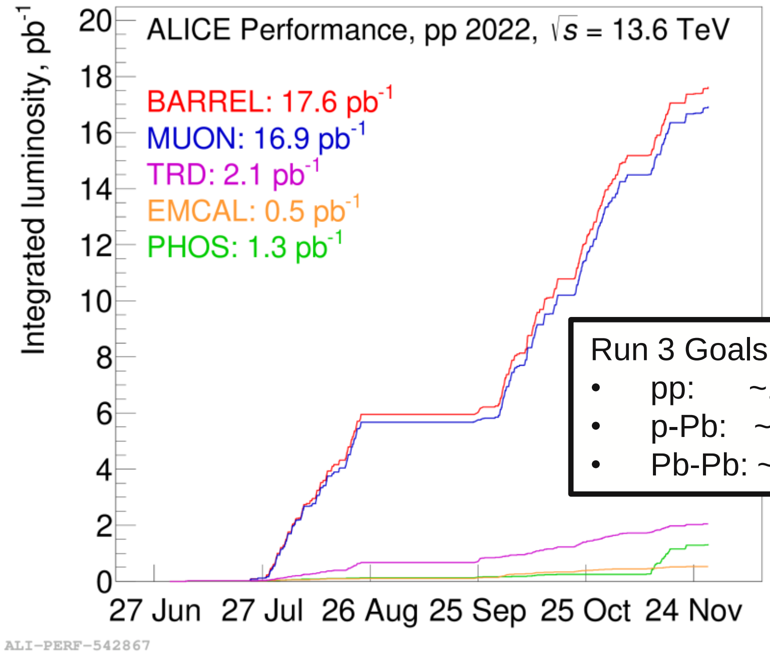

Run 3 Goals:
- pp: ~120 pb^{-1}
- p-Pb: ~0.3 pb^{-1}
- Pb-Pb: ~6.5 nb^{-1}

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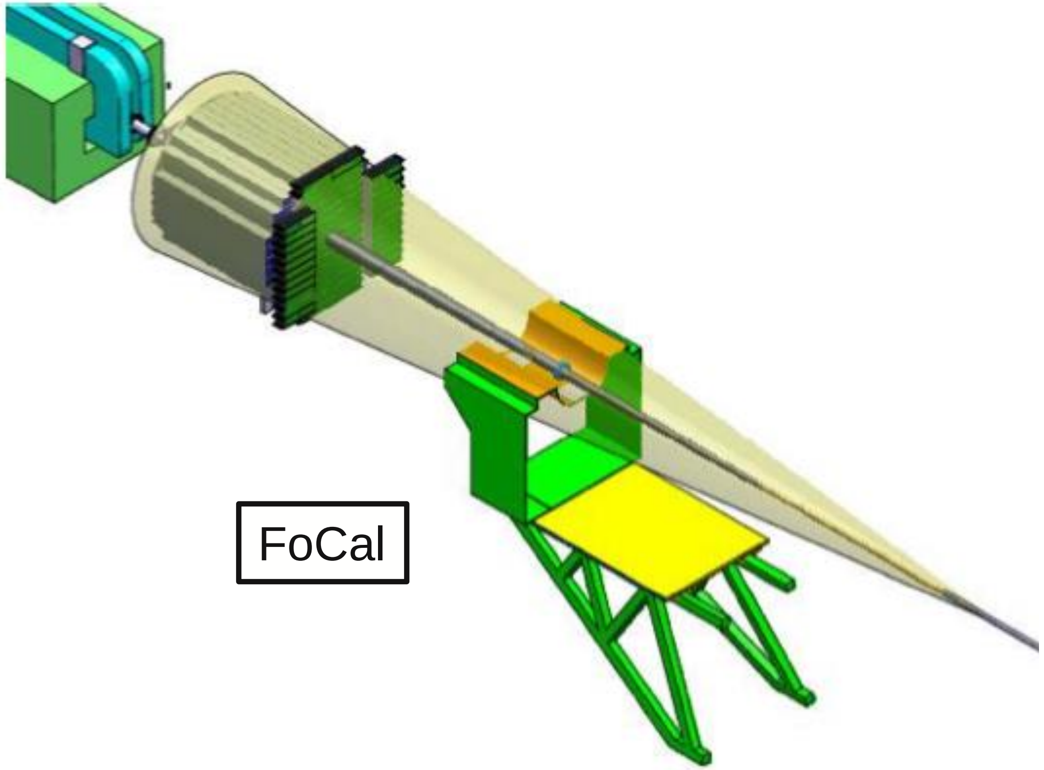
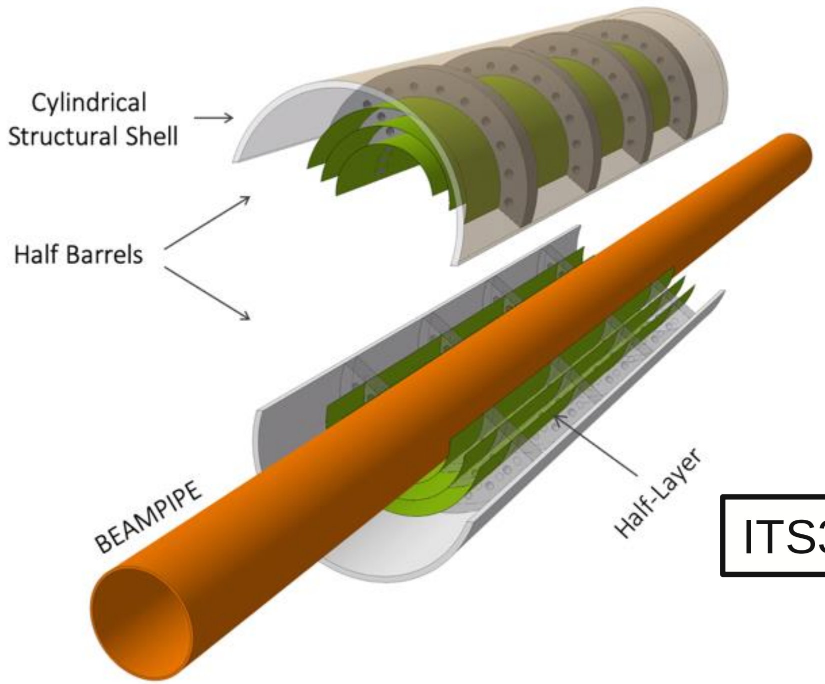
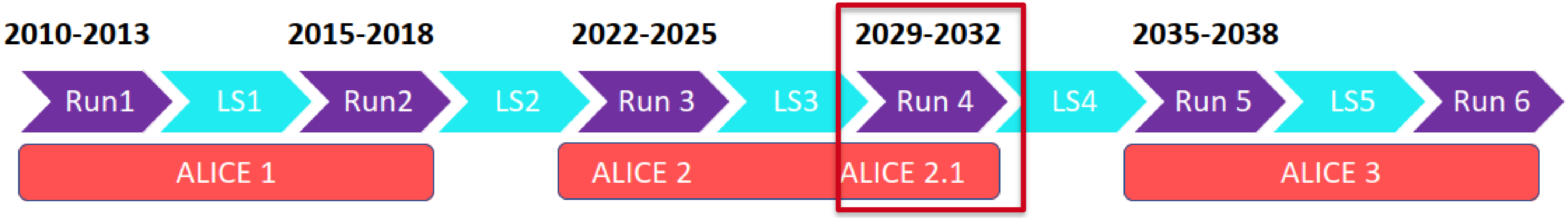
ALICE 2.1 : FUTURE UPGRADES



FoCal



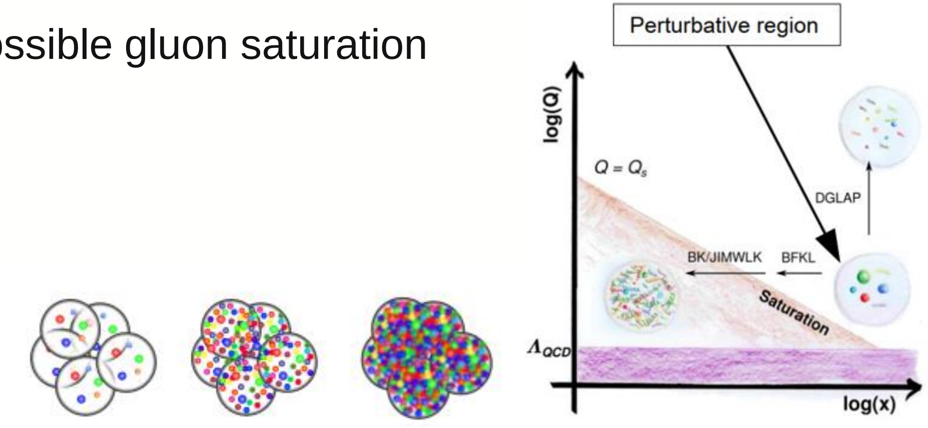
ITS3

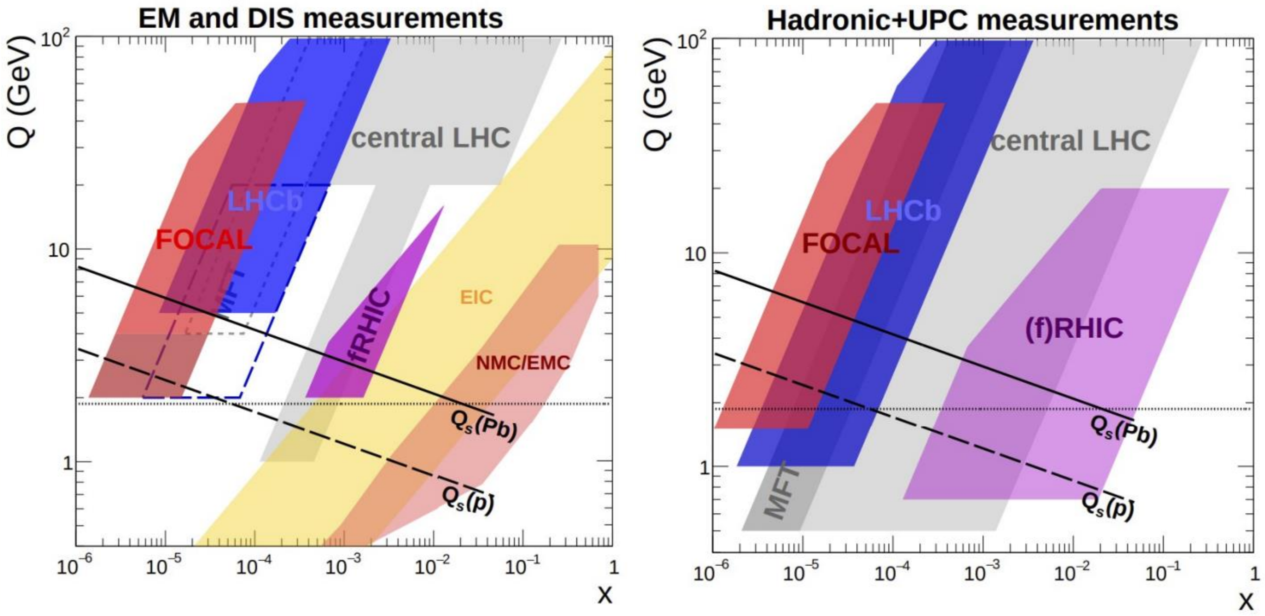


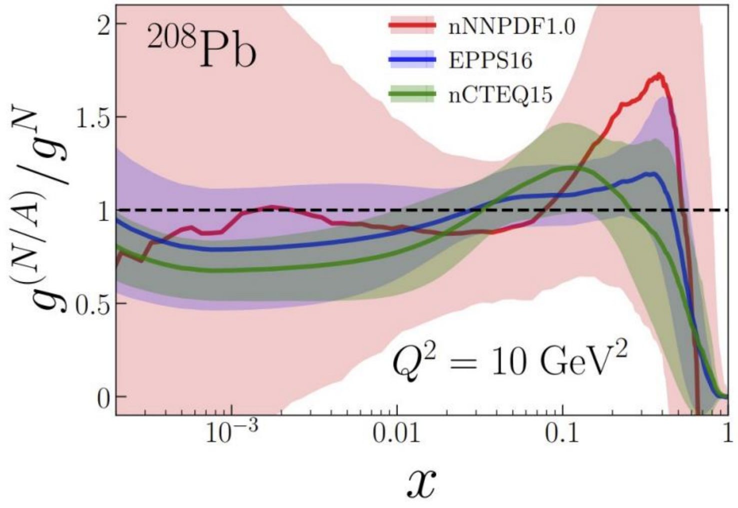
FoCaL – PHYSICS MOTIVATION

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
- π^0-π^0 / $\pi^0 - \gamma$ correlations and J/ψ in ultraperipheral collisions







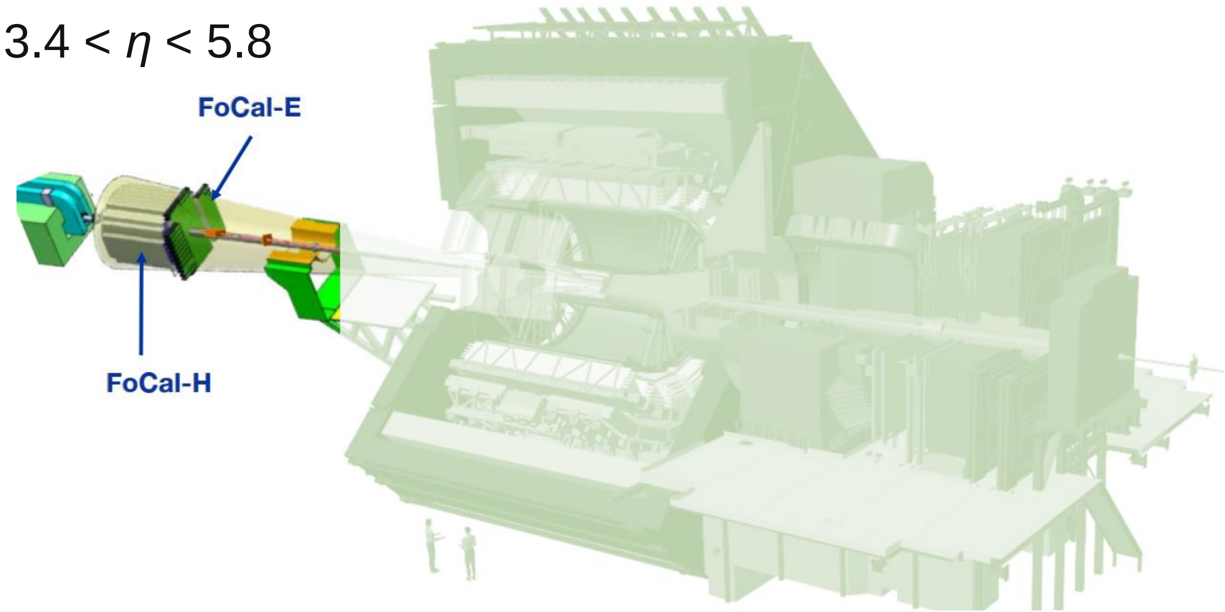
FoCaL – FORWARD CALORIMETER

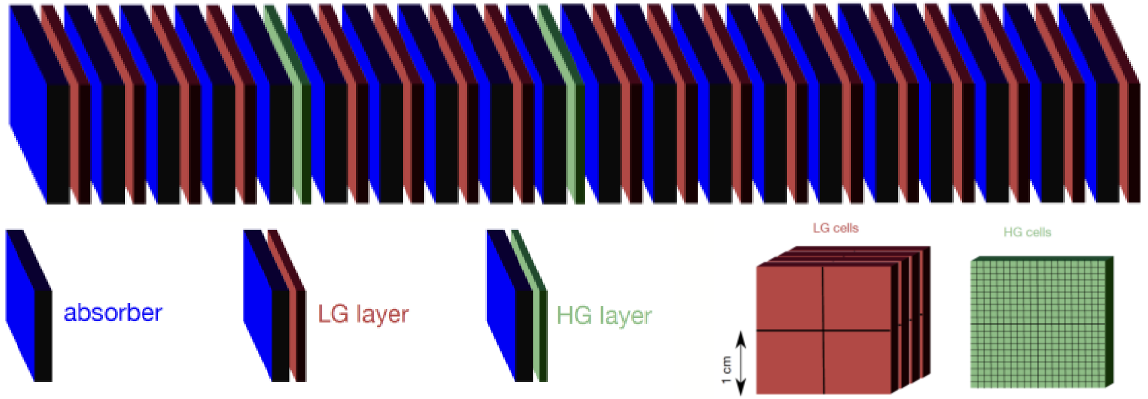
Requirements:
- Energy resolution: ~ <5% (EM) ~12% (hadron)
- Position resolution: ~ 5mm (EM shower)
  - Required for two shower separation

FoCal-E:
- Optimized for γ and π^0 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

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





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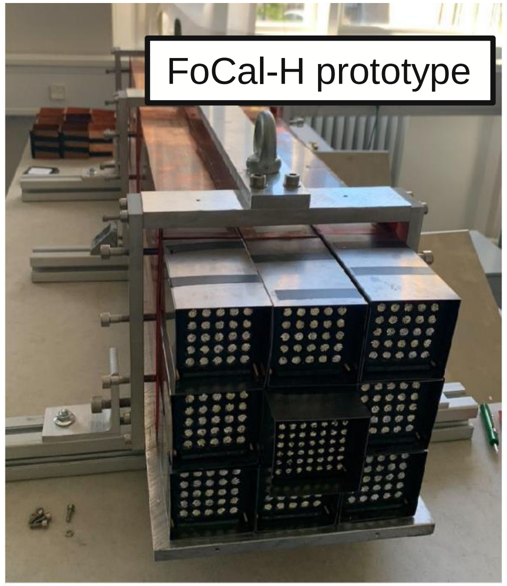
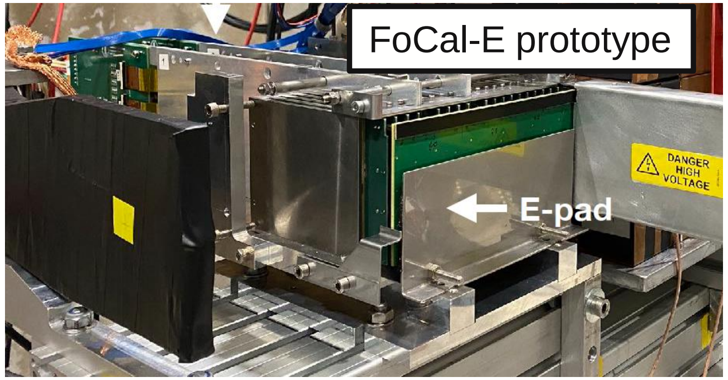
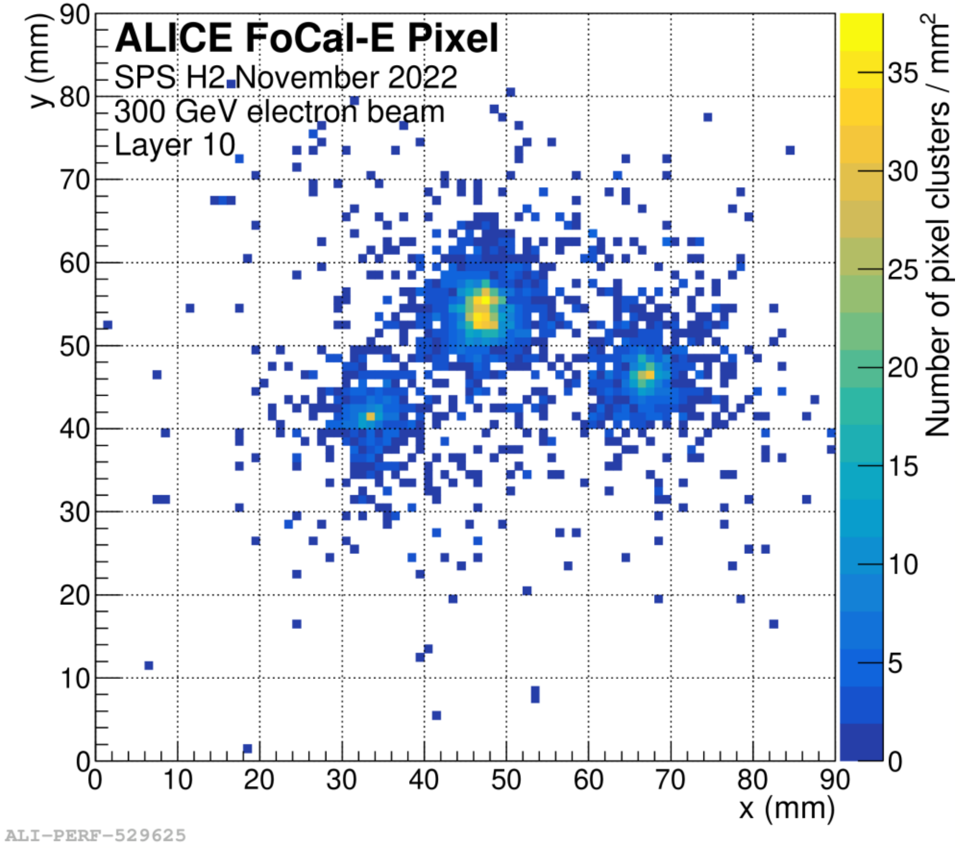




Electron separation in FoCal-E

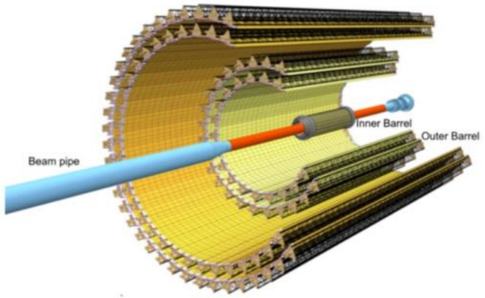


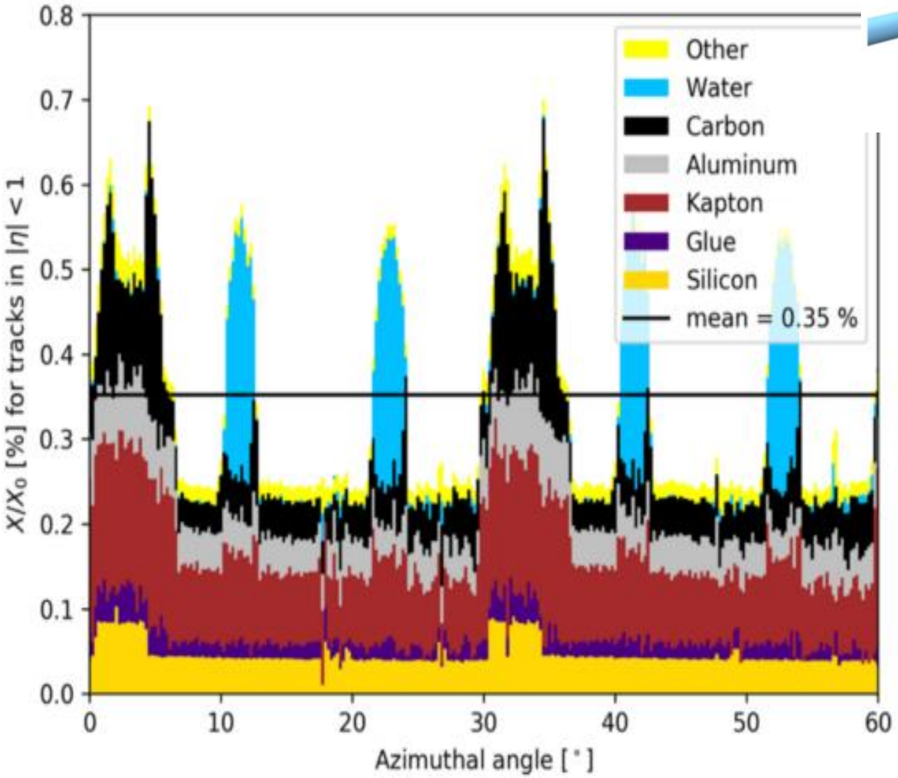
ALICE

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





ITS3 Letter of Intent: CERN-LHCC-2019-018
http://cds.cern.ch/record/2703140

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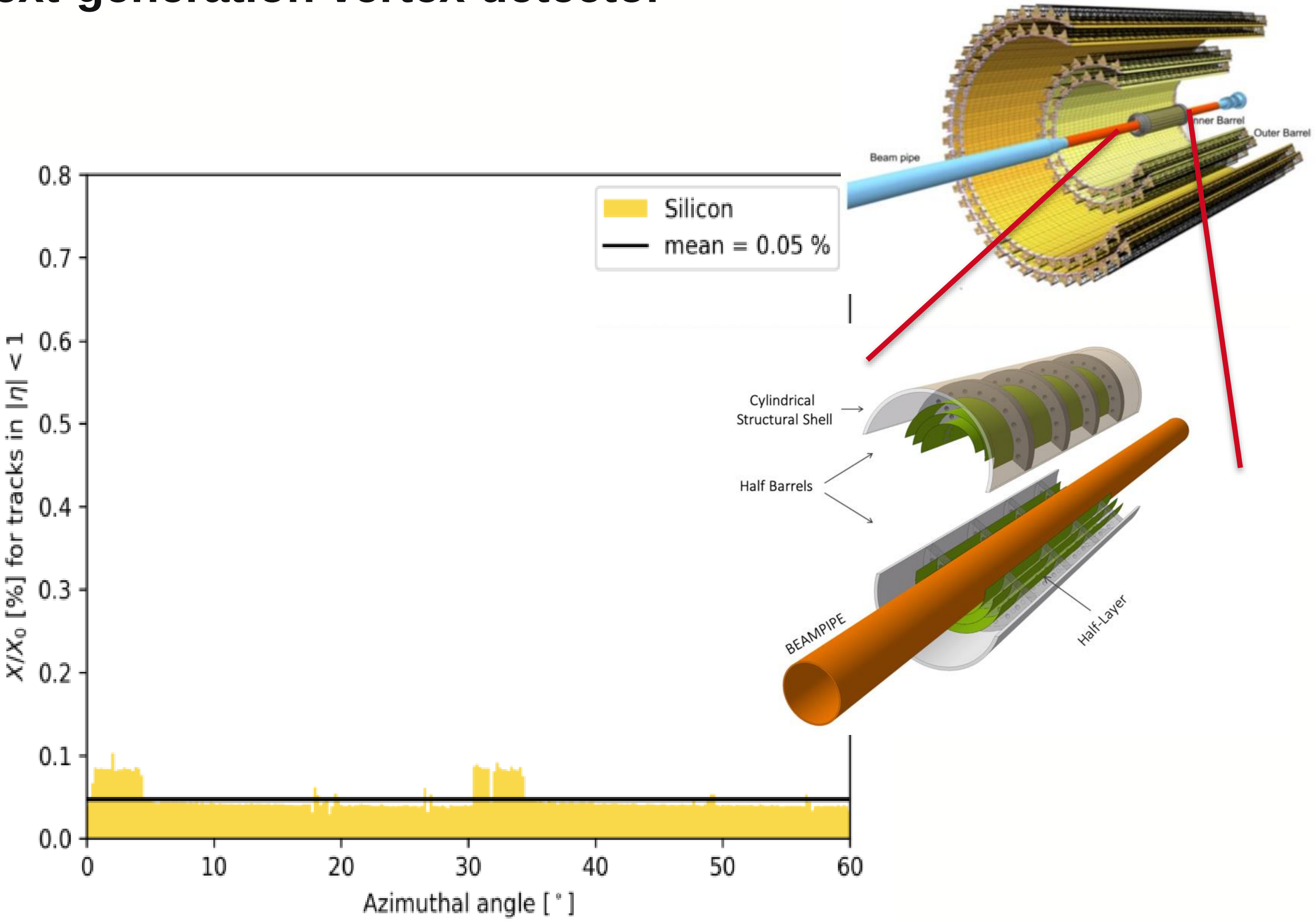

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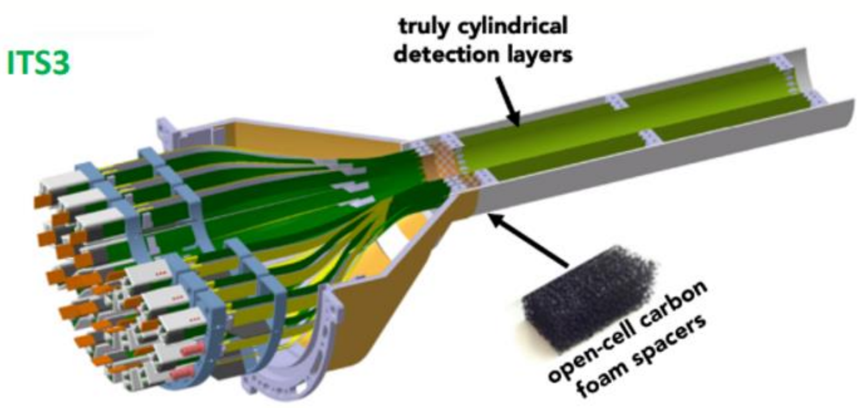
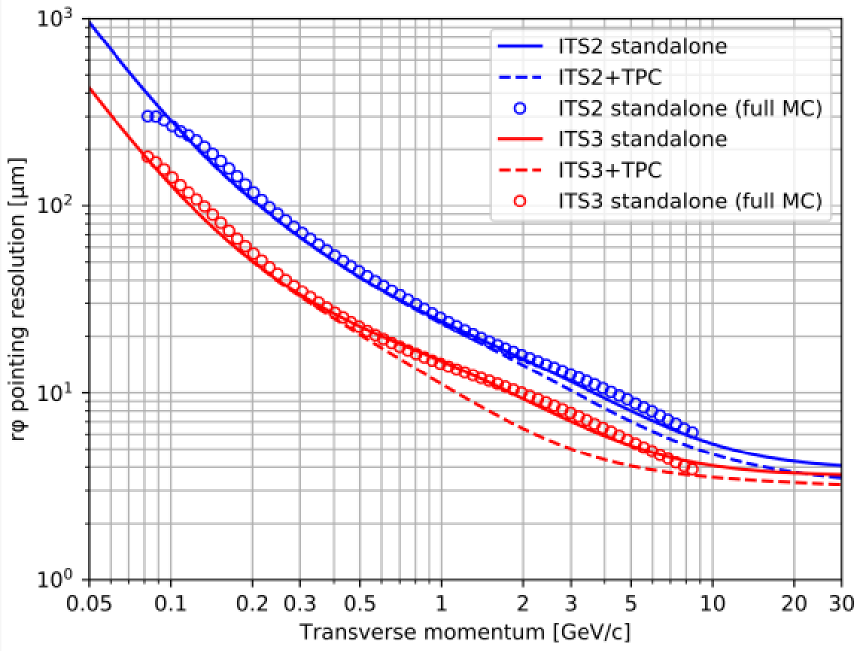
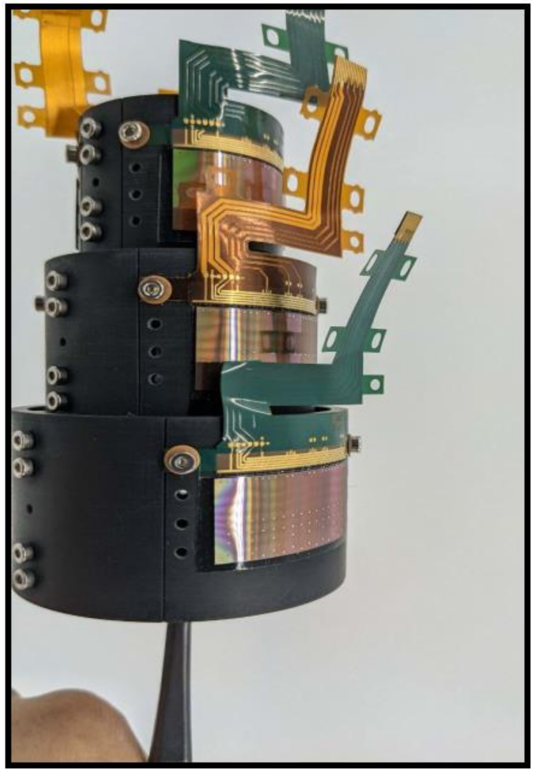
ITS3 - UPGRADE OF THE INNER TRACKER

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)



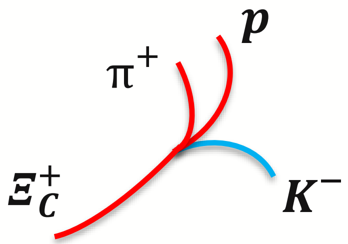




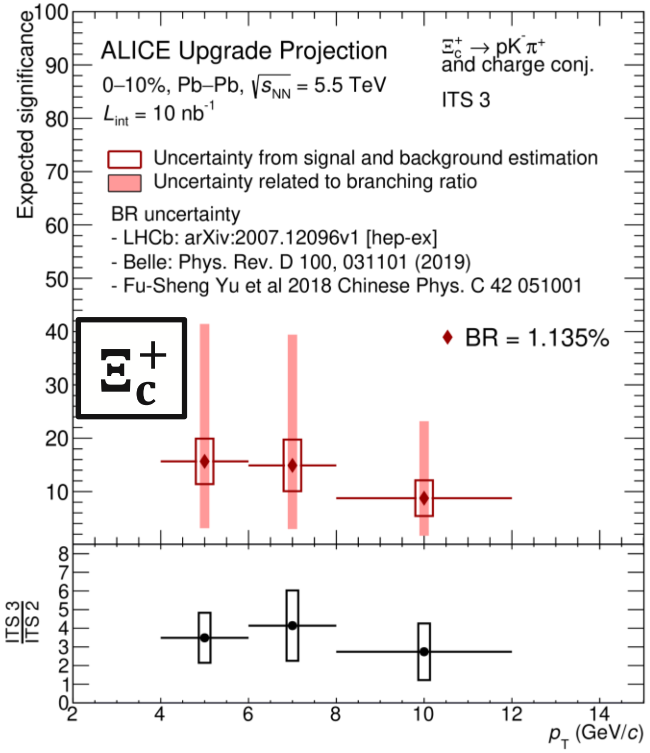
"Future Monolithic Pixel Detectors in ALICE and Beyond"
(F. Carnesecchi : 25/05/23 12:06)

CERN-LHCC-2019-018

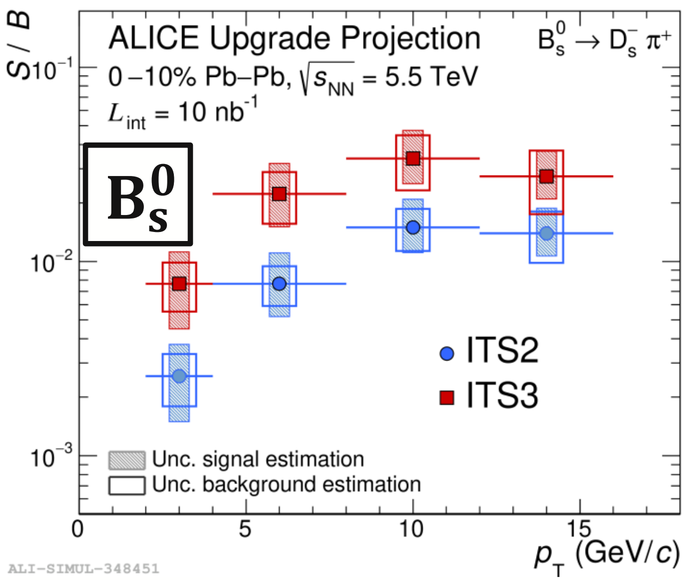
ITS3 – PHYSICS PERFORMANCE



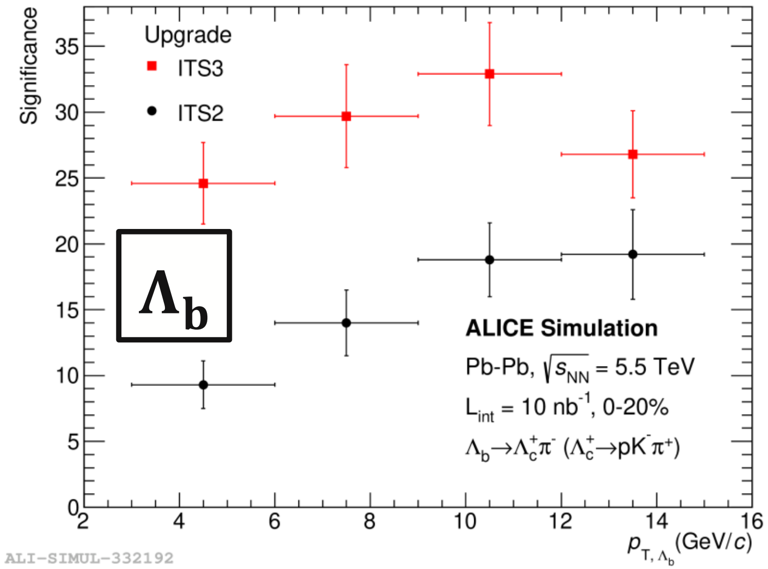
- Physics measurements that benefit from ITS3 upgrade
  - Improved DCA resolution:
    - Charm baryons
    - Beauty-strange mesons and beauty baryons
    - Dileptons (heavy-flavor background rejection)
    - Search for exotic charmed nuclei
  - Reduced inner radius
    - Strangeness tracking (for charm-strange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



ALI-SIMUL-482042

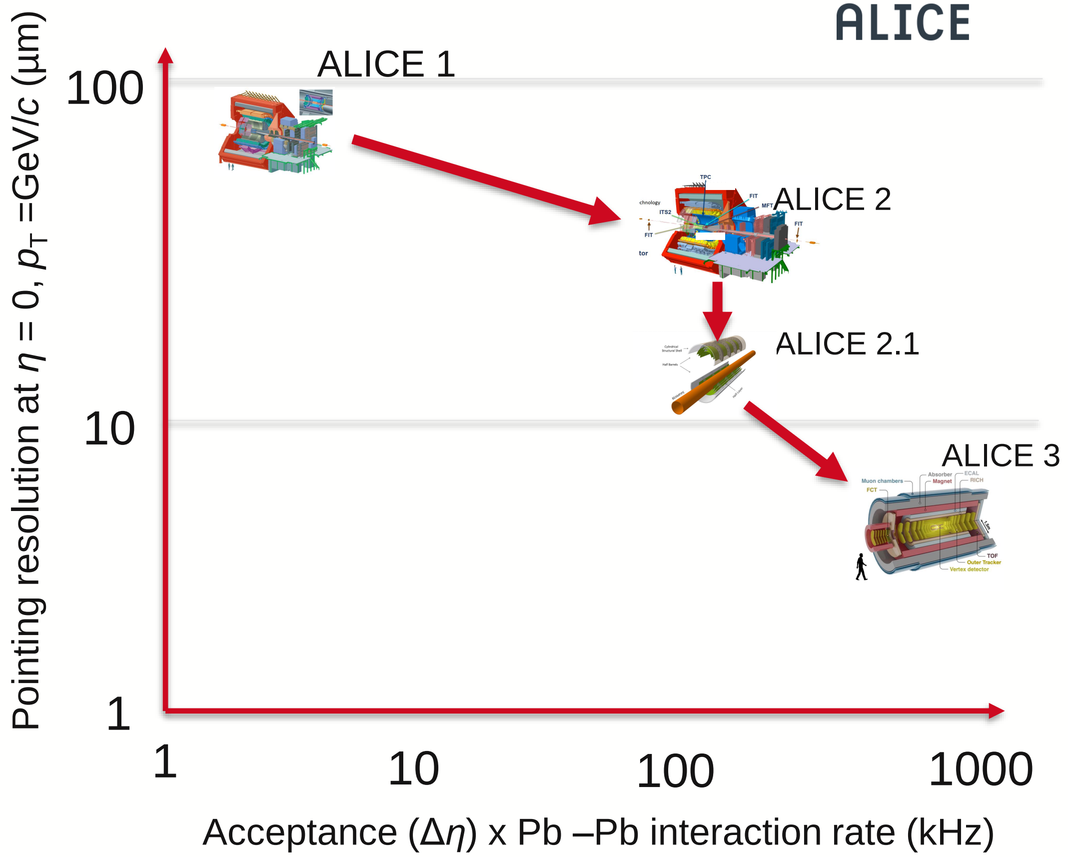


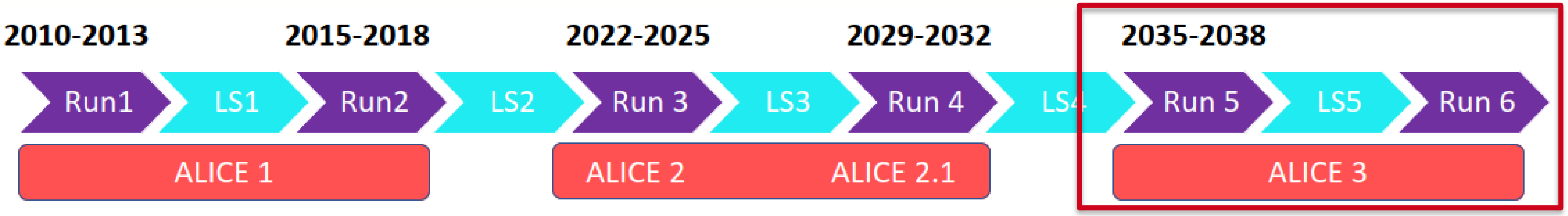
ALI-SIMUL-348451



ALI-SIMUL-332192

ALICE 3 : FUTURE

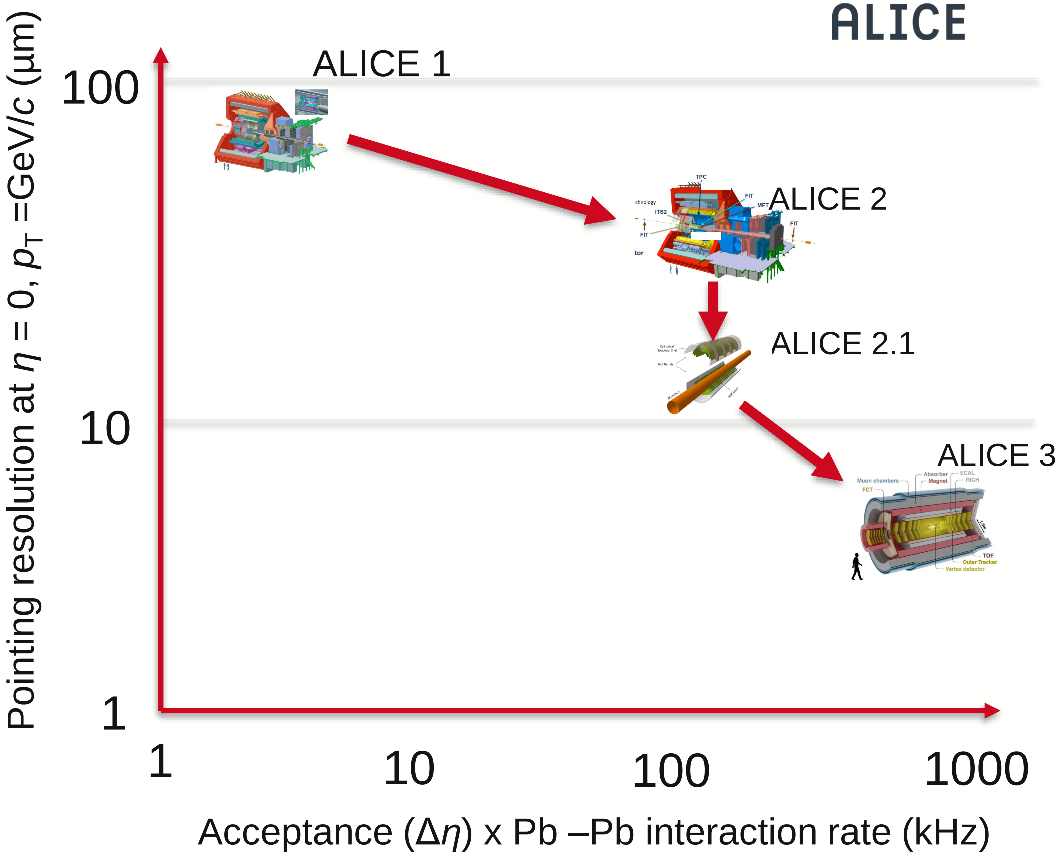


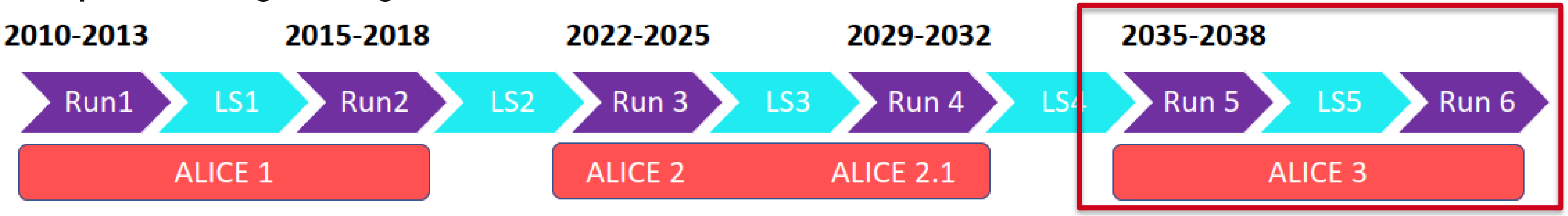


ALICE 3 : FUTURE

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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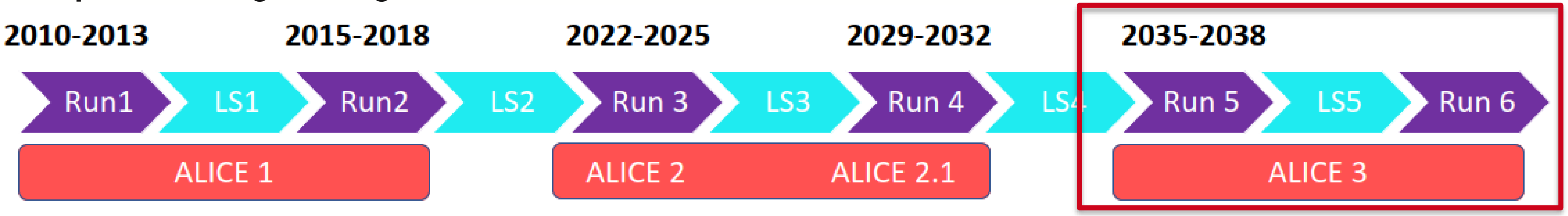
CERN-LHCC-2022-009
https://arxiv.org/abs/2211.02491v1



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*

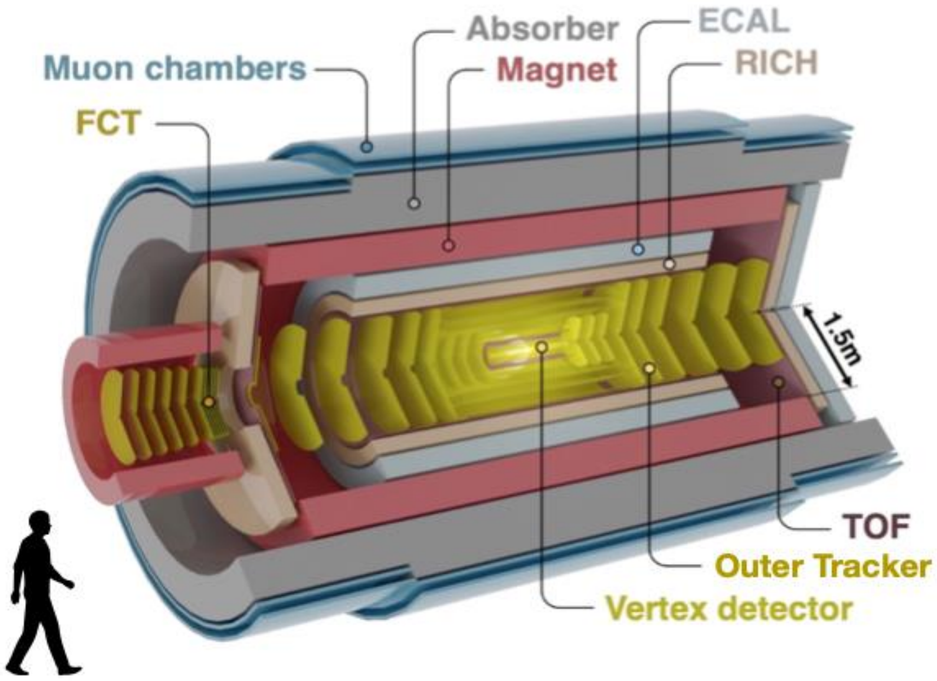
Particle Identification
→ Clean background suppression

Large acceptance -4 < η < 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}



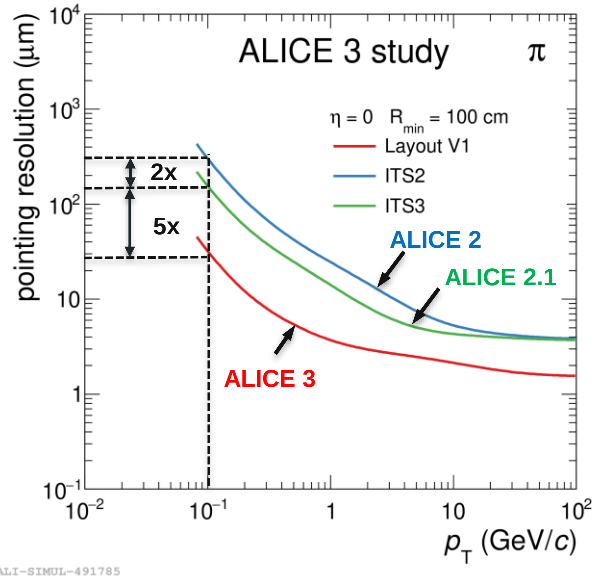
→ Novel detector concept based on innovative technologies relevant for future HEP experiments

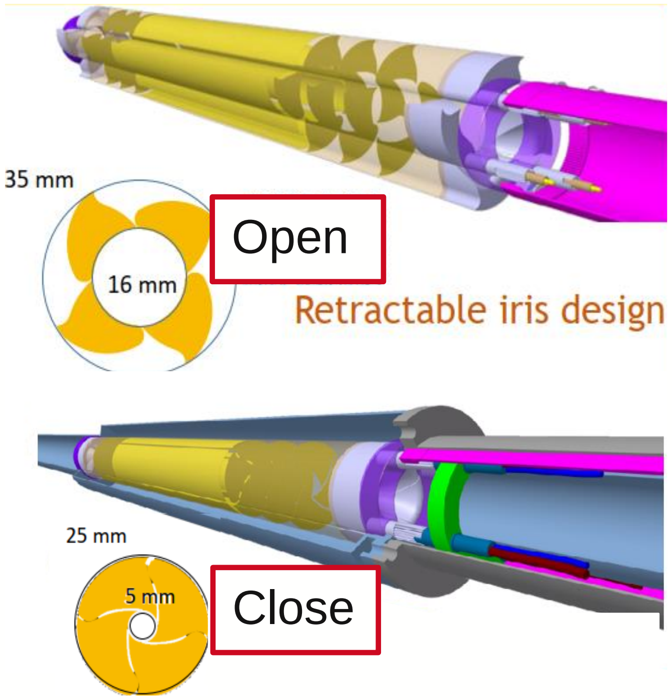
→ R&D started

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)**
- Unprecedent spatial resolution: σ_{pos} ~ 2.5 µm
- Extremely low material budget: **0.1% per layer**
- Radiation requirements: 10^{16} 1MeV n_{eq} /cm^2
  (ITS3 prototype already achieved 10^{15} 1MeV n_{eq} /cm^2)





Mockup

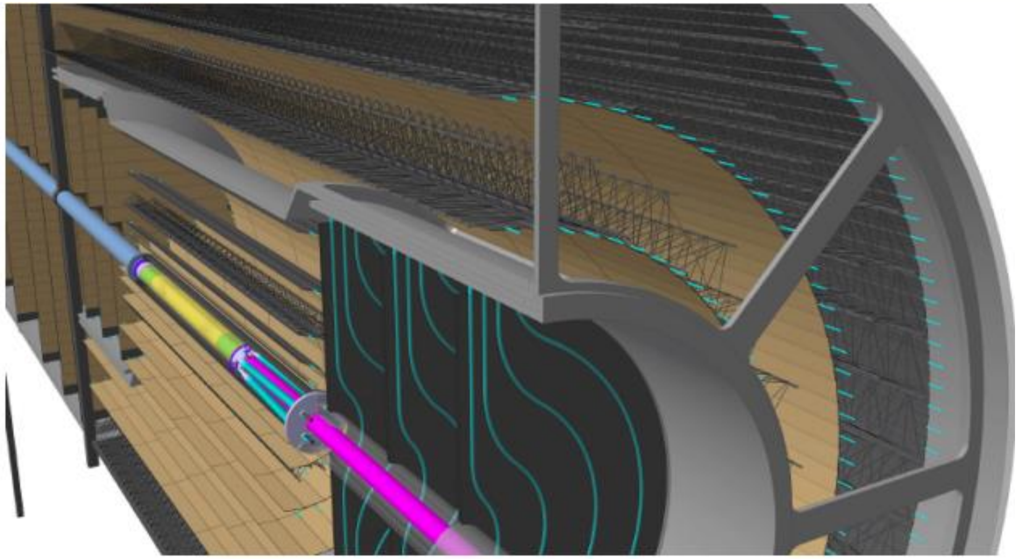
Challenges:
- Radiation hardness
- Cooling & services

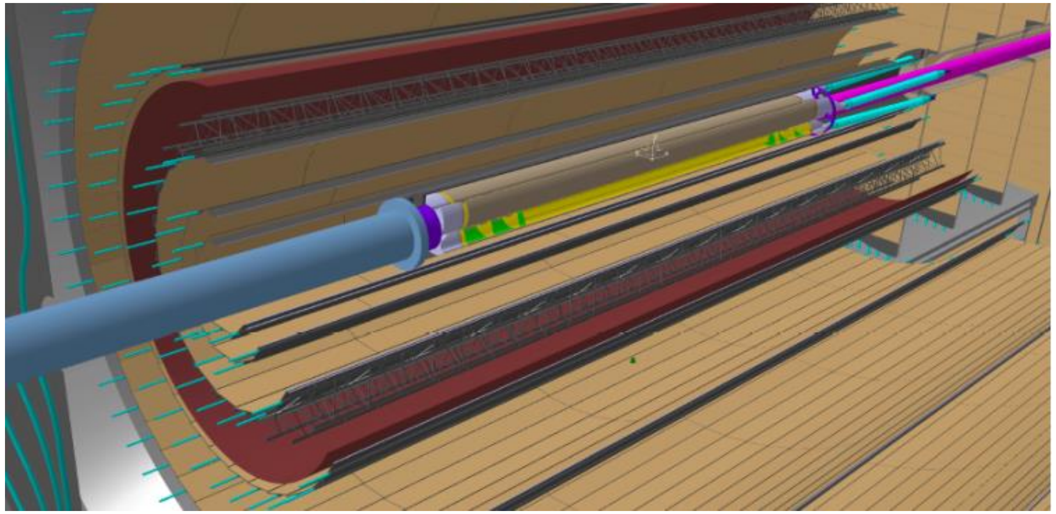
CERN-LHCC-2022-009

ALICE 3 – OUTER TRACKER

CERN-LHCC-2022-009

- <u>**8 + 2 x 9 tracking layers (barrel + disks)**</u>
- 60 m^2 silicon pixel detector based on **CMOS Active Pixel Sensor technology**
- Compact: $\mathbf{r_{out}}$ **~80 cm**, $z_{out} \pm 4$ m
- Large coverage: $\pm 4\ \eta$
- **High-spatial resolution: σ_{pos} ~ 5µm** (req. < 10 µm)
- 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/cm^2





Challenges:
- Integration
- Time performance
- Material budget

ALICE 3 - PARTICLE IDENTIFICATION

CERN-LHCC-2022-009

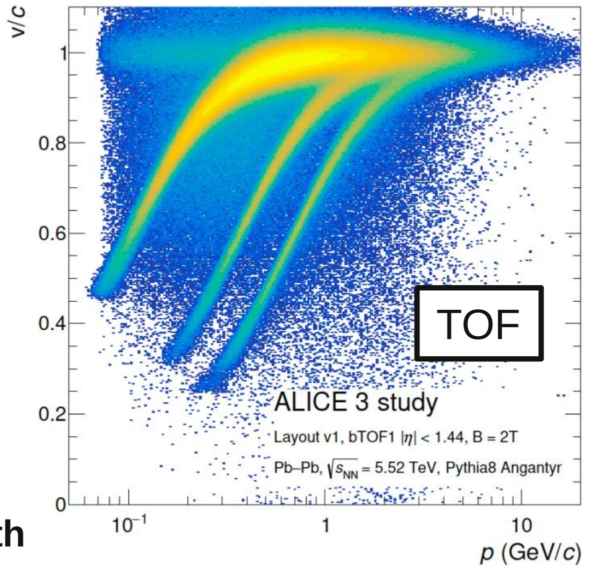
Time of Flight detectors:

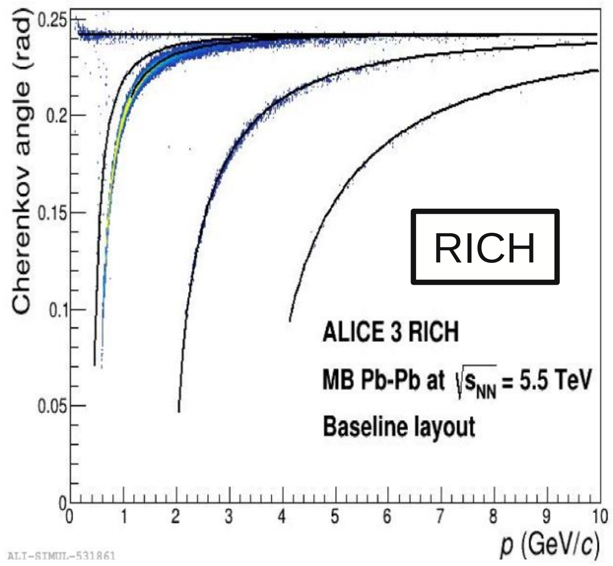
Separation power: L/σ_{TOF}

→ Distance and time resolution crucial

→ Larger radius results in lower p_T bound

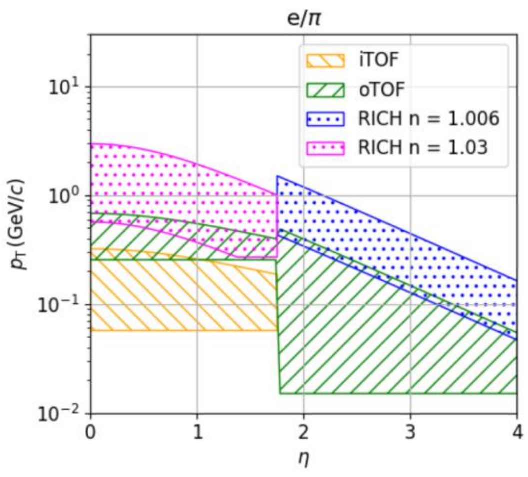
- Time resolution: ~20ps
- **2 TOF layers + endcaps**
- **Silicon LGADs or CMOS with gain layer**
- Total silicon area : ~45m^2

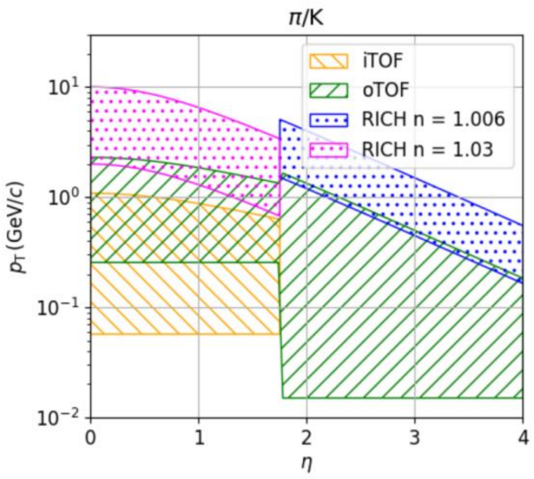




Complement PID reach of outer TOF to higher p_T with Cherenkov detector

- Aerogel radiator
  - n=1.03 (barrel)
  - n=1.006 (forward)
- Total SiPM area ~60m^2





Challenges:

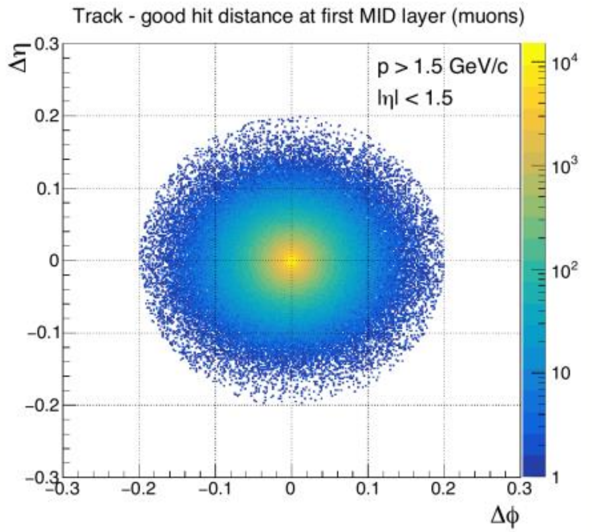
- Radiation hardness of SiPM

ALICE 3 - MUON AND PHOTON IDENTIFICATION

Muon chambers at central rapidity

optimized for reconstruction of charmonia down to $p_T = 0$ GeV/c

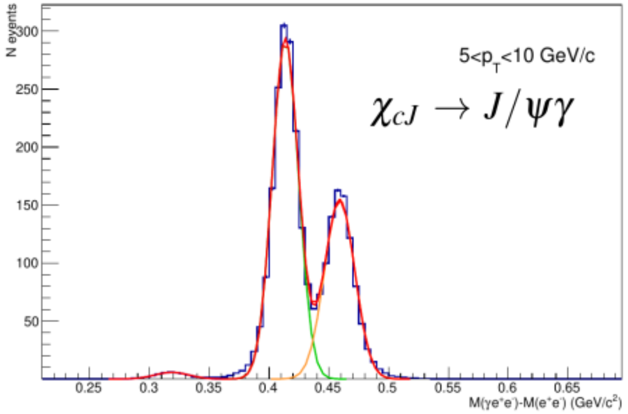
- ~70 cm non-magnetic steel hadron absorber
- search spot for muons ~0.1 x 0.1 (η x φ)
- ~5 x 5 cm^2 cell size
- matching demonstrated with 2 layers of muon chambers
    - scintillator bars
    - wave-length shifting fibers
    - SiPM read-out
    - possibility to use RPCs as muon chambers



Large acceptance ECal (2π 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)

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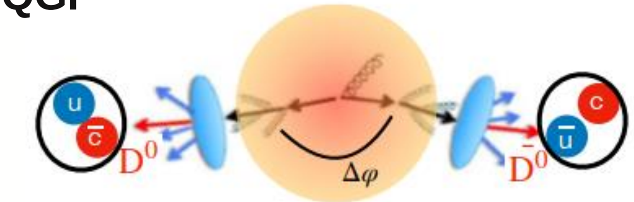
ALICE 3 – EXPECTED PERFORMANCE

Measurement of D meson correlations

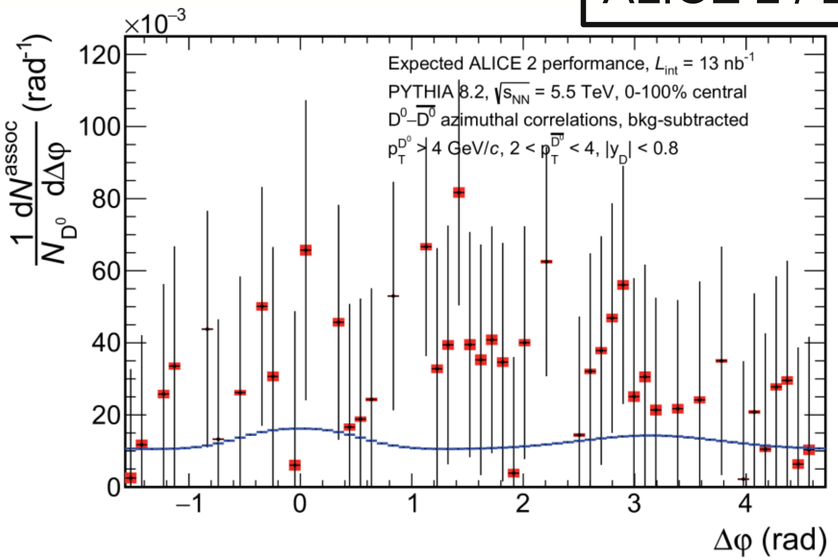
Goal: measure angular (de)correlations – direct probe of HF interaction with the QGP

- **Strongest signal at low p_T**
- Very challenging measurement: need good purity, efficiency and η coverage

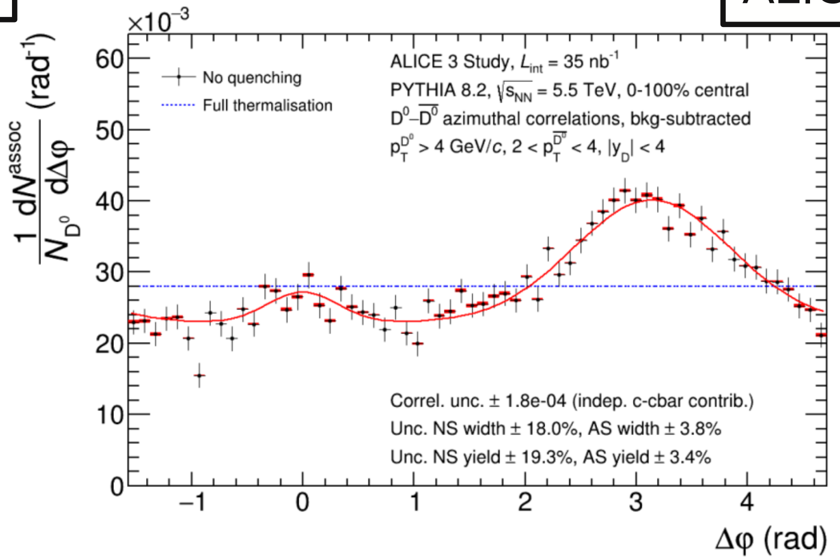


$D-\bar{D}$ azimuthal correlation

ALICE 2 / 2.1



ALICE 3



Pb-Pb / Pythia

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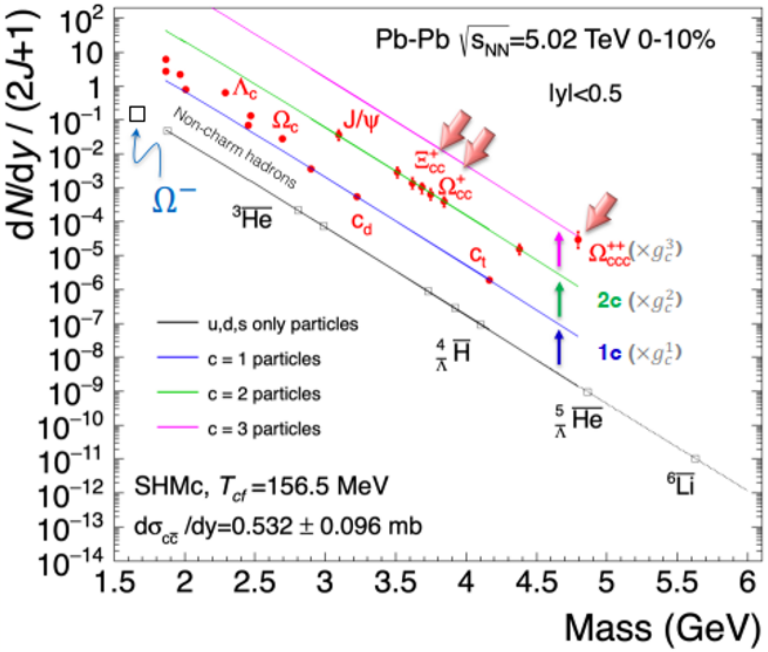
→ Measurement in heavy-ion collisions only feasible with ALICE 3

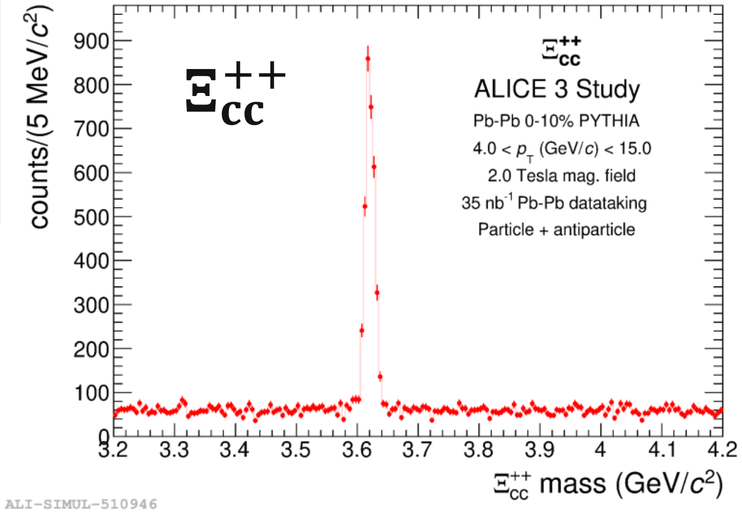
ALICE 3 – EXPECTED PERFORMANCE

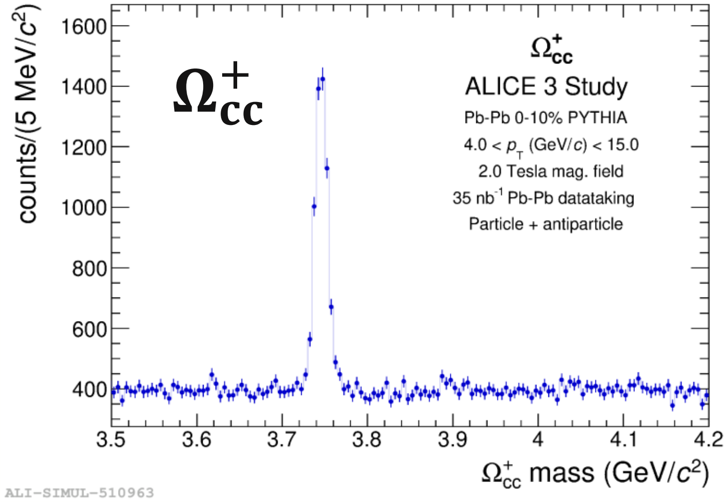
Measurement of multi-charm baryon



- Ξ_{cc}^{++} reconstructed in the channel $\Xi_{cc}^{++} \rightarrow \Xi_c^{+}\pi^{+} \rightarrow \Xi^{-}\pi^{+}\pi^{+}\ \pi^{+}$
- Ω_{cc}^{+} reconstructed in the channel $\Omega_{cc}^{+} \rightarrow \Omega_c^{0}\pi^{+} \rightarrow \Omega^{-}\pi^{+}\ \pi^{+}$
- Ω_{ccc} studies ongoing

- 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 ~100 in central Pb-Pb)





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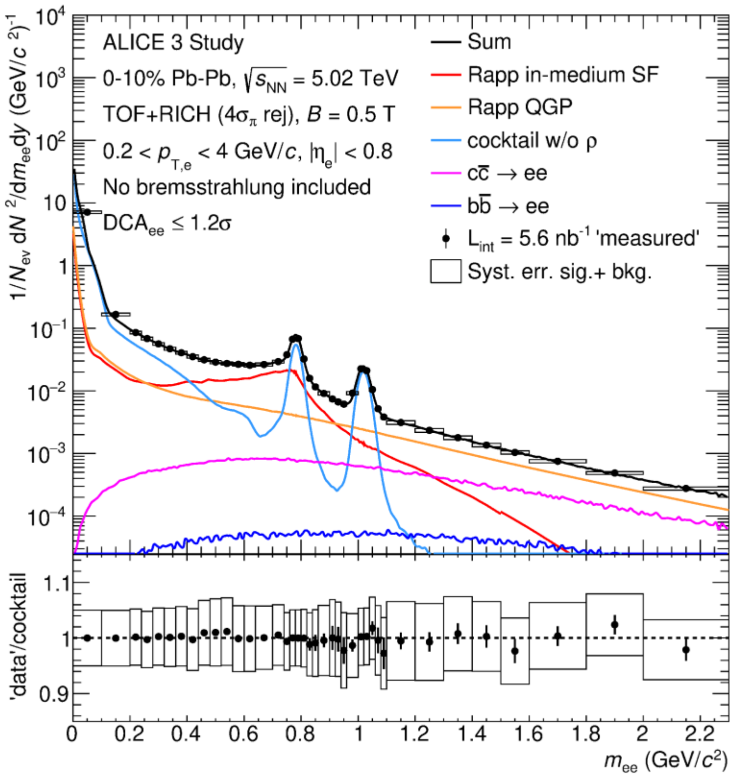
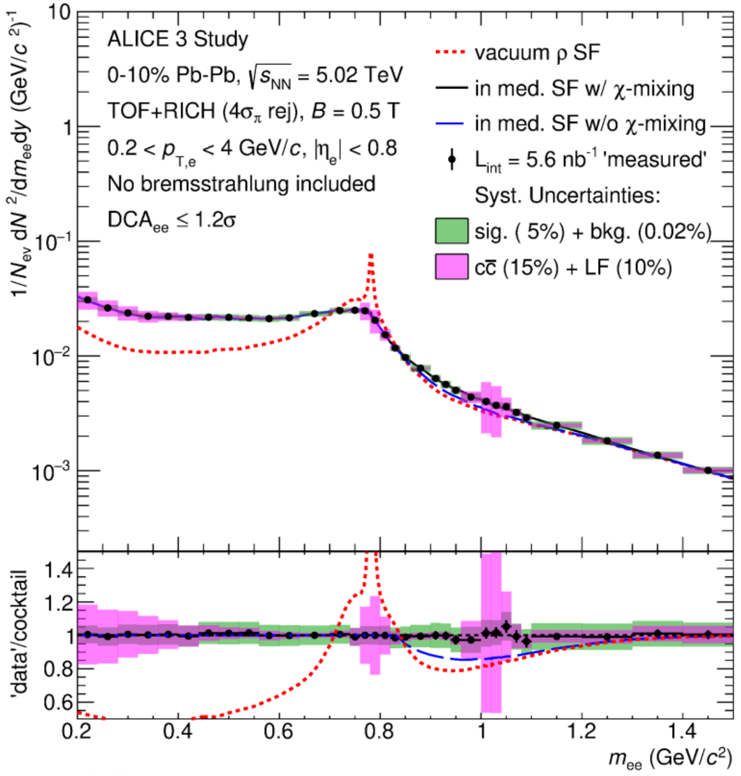
ALICE 3 – EXPECTED PERFORMANCE

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 ρ-meson spectral function modification due to chiral symmetry restoration
- Possibility for multi-differential dielectron measurements
  → time dependence of emission





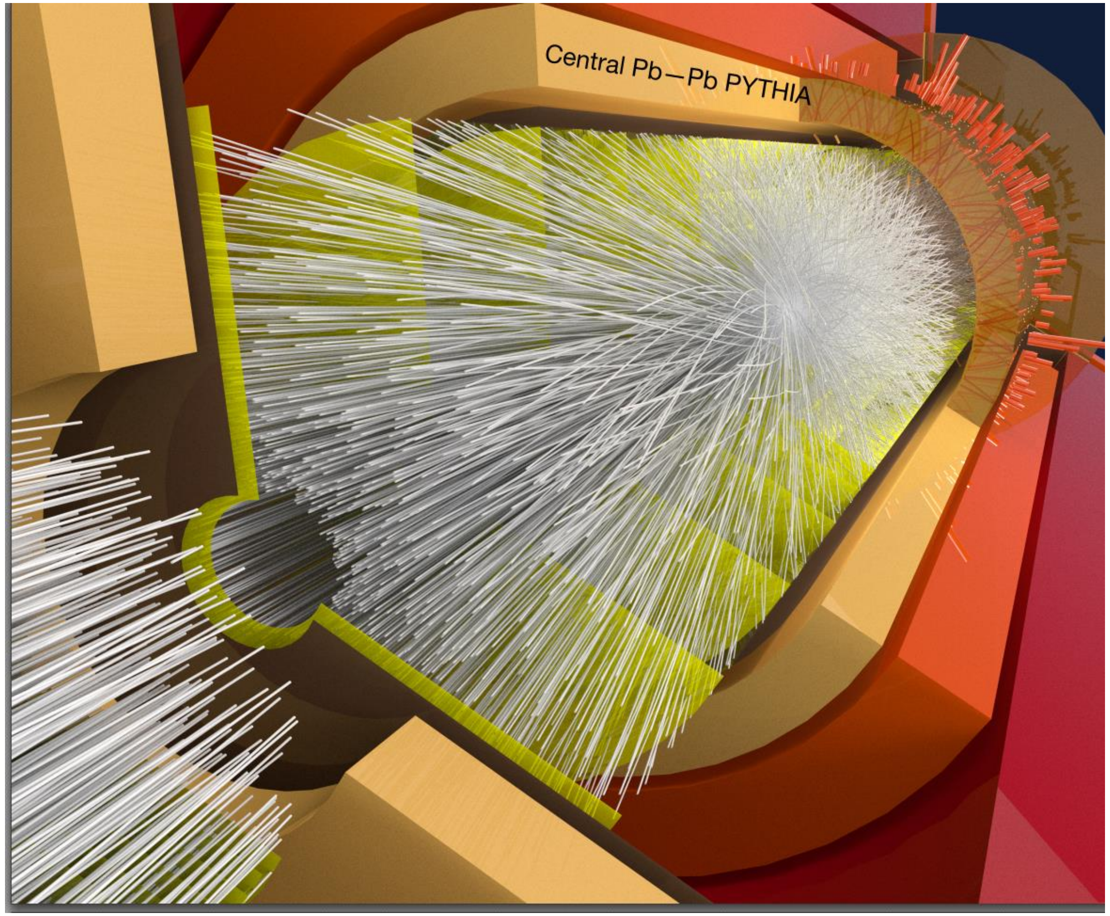
CERN-LHCC-2022-009

R. Rapp, Adv. High Energy Phys. 2013 (2013) 148253
P.M Hohler and R. Rapp, Phys. Lett. B 731 (2014) 103

SUMMARY

- 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

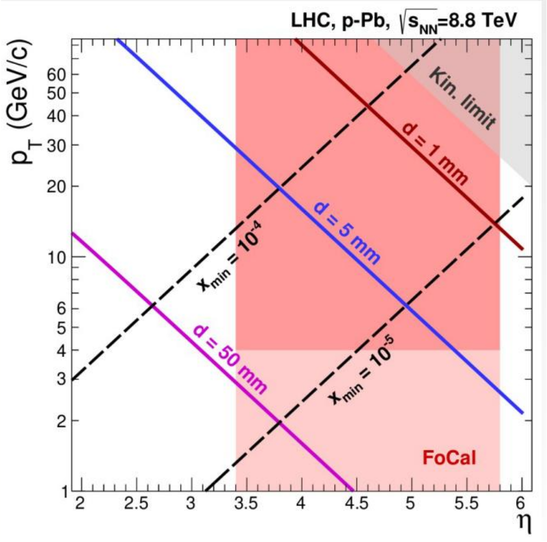
THANK YOU FOR YOUR ATTENTION

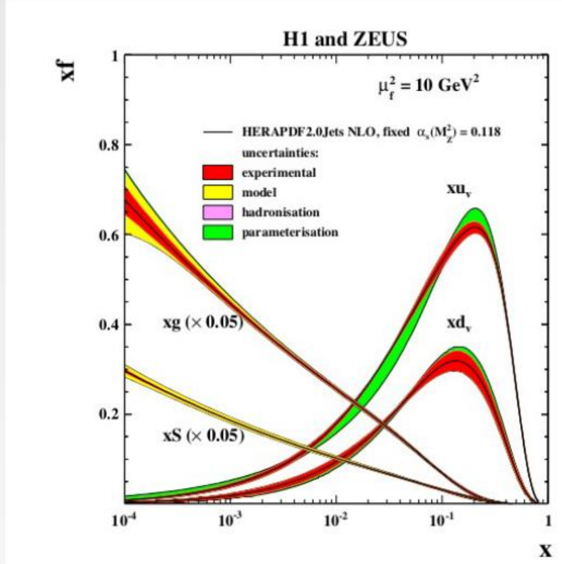


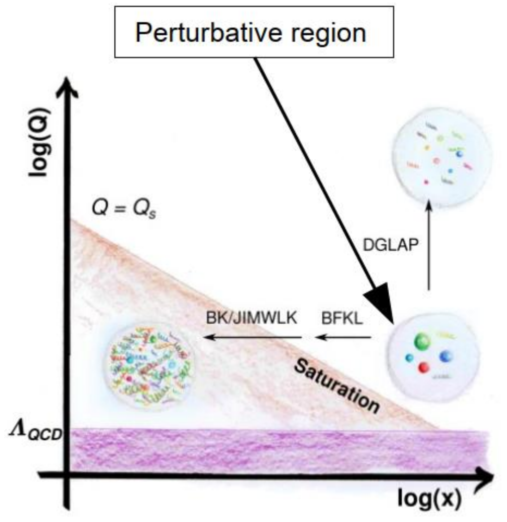
BACKUP SLIDES

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 vene lower x higher gluen desities (saturation) non-linear equations become relevent («BJK/JIMWLK»)

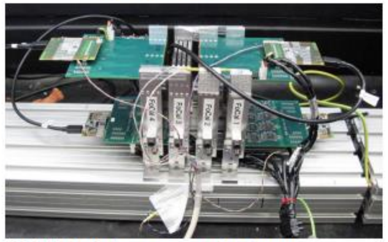






FoCAL PROTOTYPES

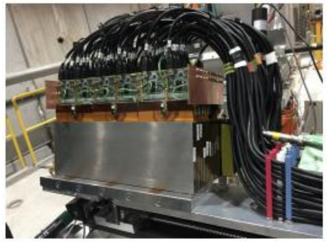
2010-2015



ORNL / Japan prototype:
- NIM A 988 (2021) 164796

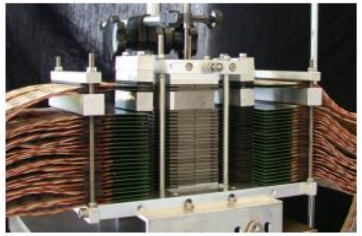
Indian prototypes:
- NIM A 764 (2014) 24
- JINST 15 (2020) 03, P03015

2014-2018



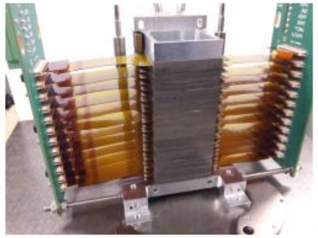
Mini-FoCal (PADs only) in beam at P2

2014-2016



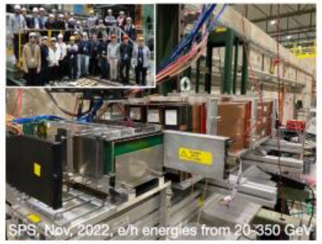
MIMOSA pixel tower (EPICAL)
JINST 13 (2018) P01014

2018-2021



ALPIDE pixel tower (EPICAL-2)
NIM A1045 (2023) 167539
arXiv:2209.02511

2019-2022



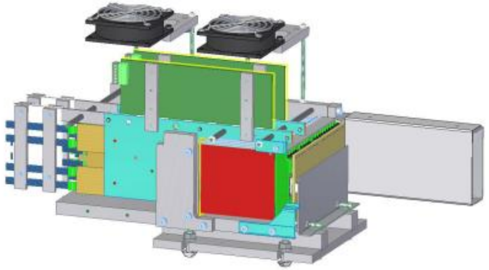
FoCal-E and H prototypes
- final sensors and chips
- close-to-final readout

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 OB ITS HICs
  - ~ 30 um2 res

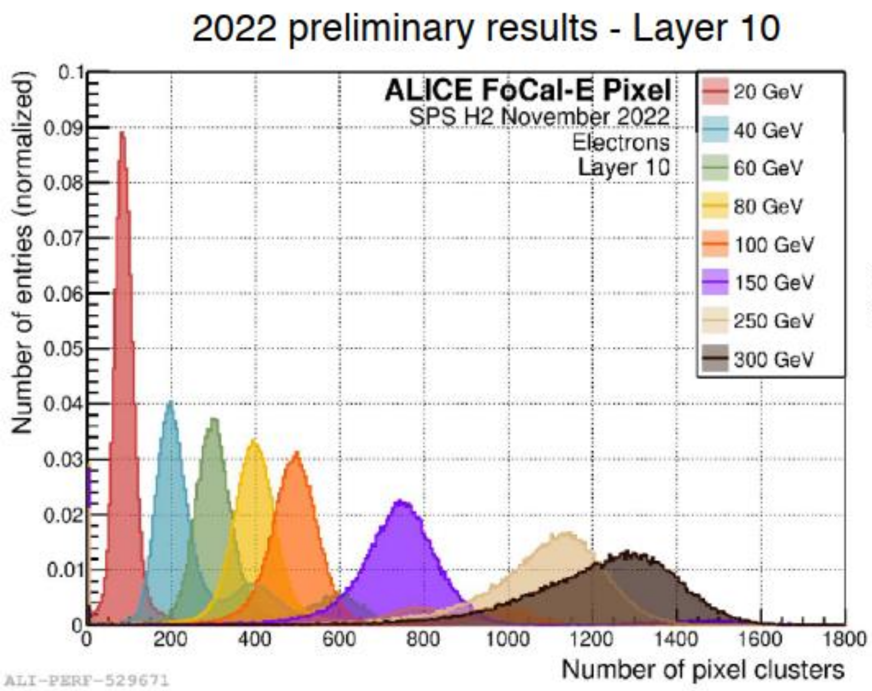
20 Tungsten layers (~20 X_0)



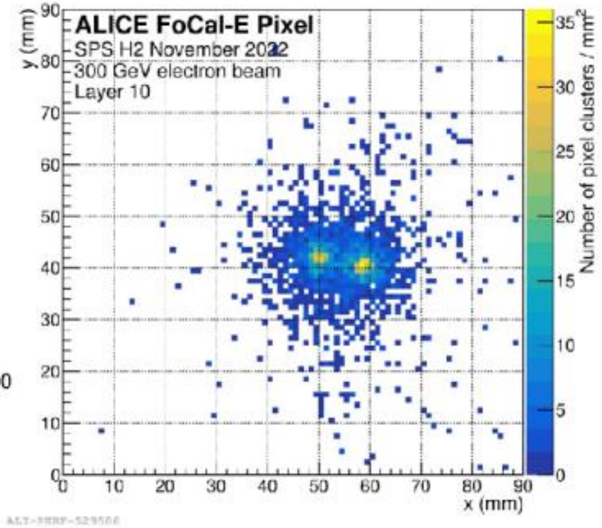
FoCal-H

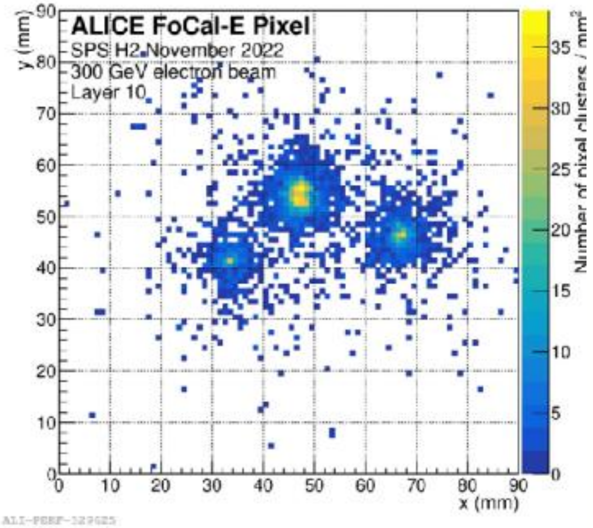
- 6.5 cm x 6.5 cm x 110 cm
- BCF12 scintillating fiber
- 49 (central), 25 (sides) SiPMs
- 2/3 CAEN DT5202 boards

FoCAL -E PIXEL @ SPS TEST BEAM IN 2022

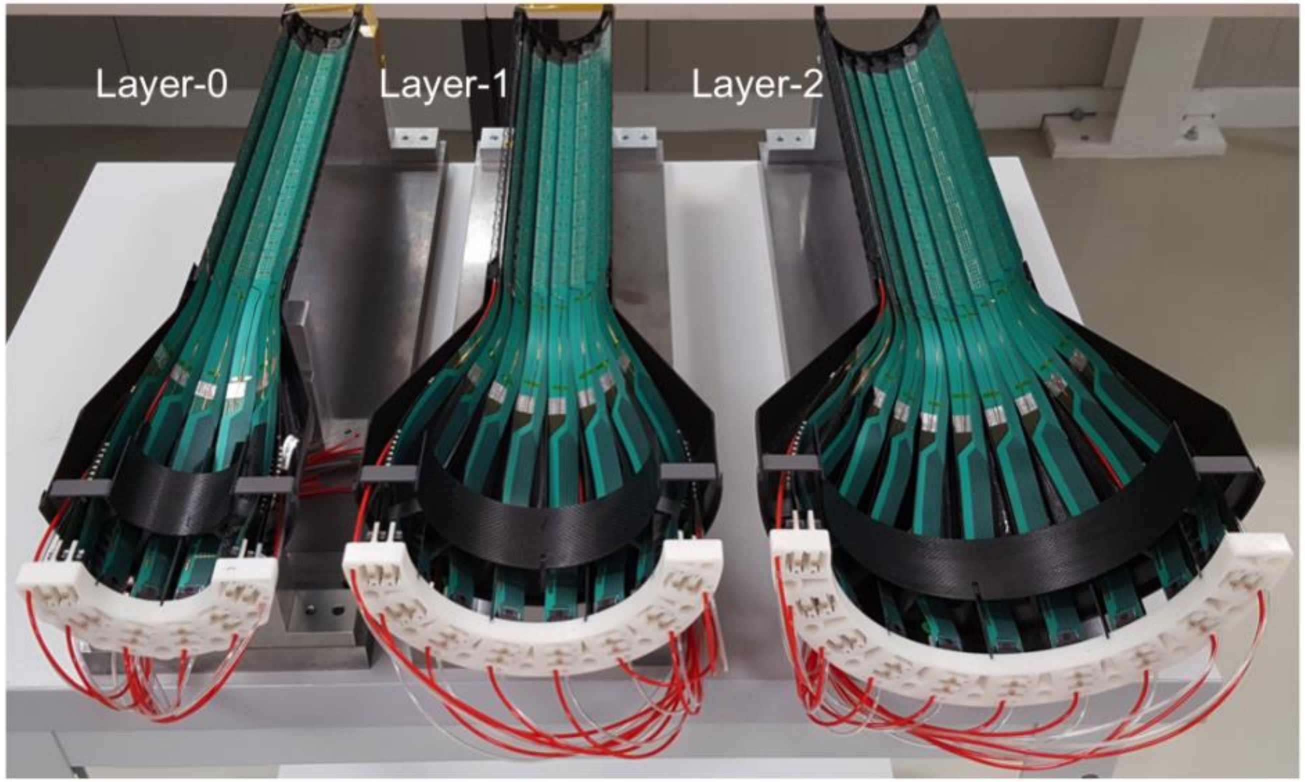


- Successful commissioning of FoCal-E PIXEL (ALPIDE)
- Double and triple electron signature identified in preliminary analysis
- Distance between electrons here ~ 10 mm, demonstration of a good two gamma separation



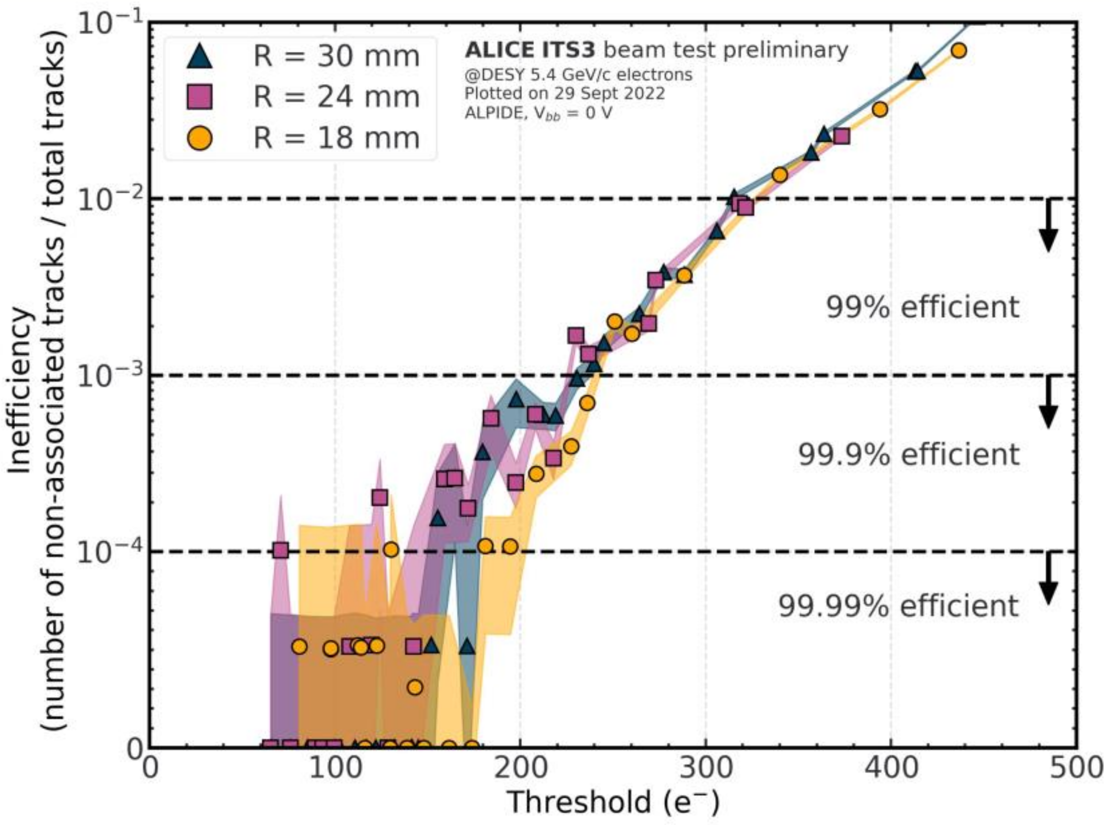


ITS3 - LAYERS



ITS3 – UPGRADE OF INNER TRACKER

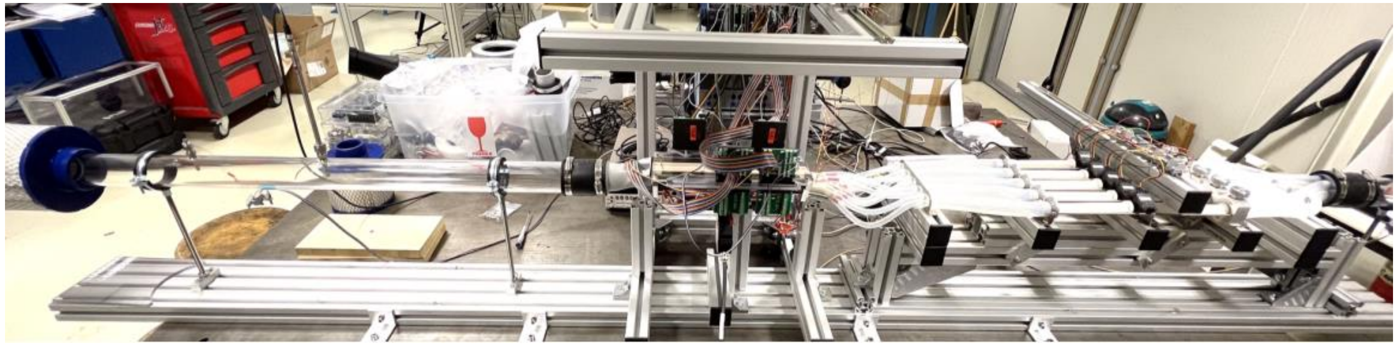
- Beam Tests:
  - ALPIDE telescope used for the tests
  - Efficiency and resolution consistent with flat ALPIDEs
  - Spatial resolution uniform among different radii

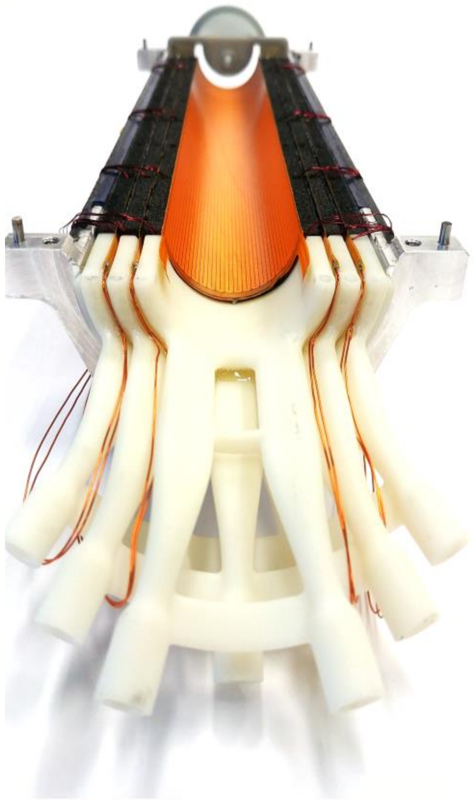


ITS3 – UPGRADE OF INNER TRACKER

- 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

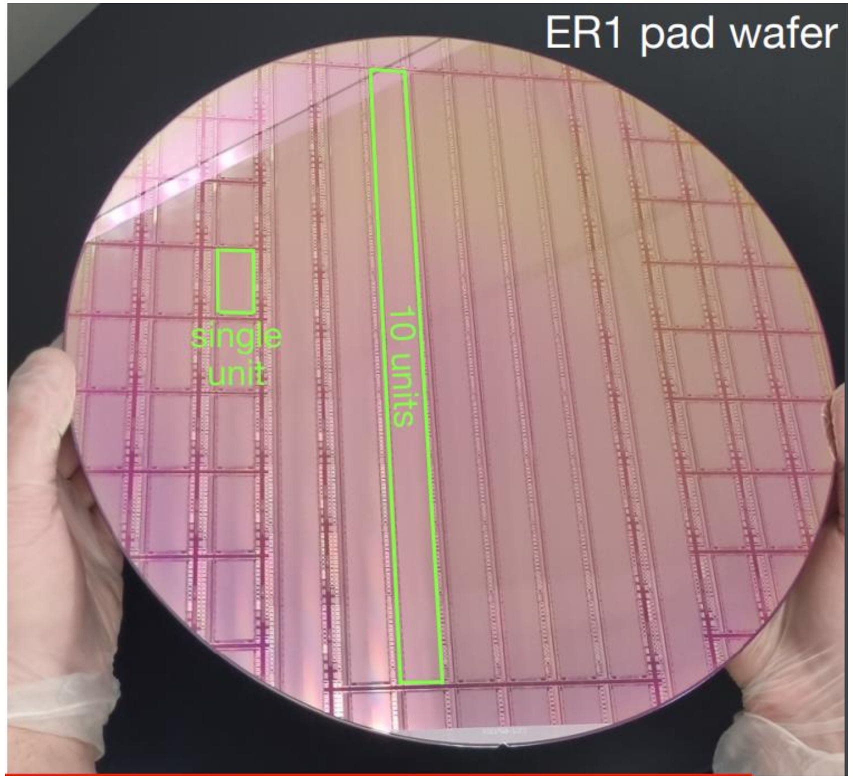




ITS3 Breadboard model 3

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

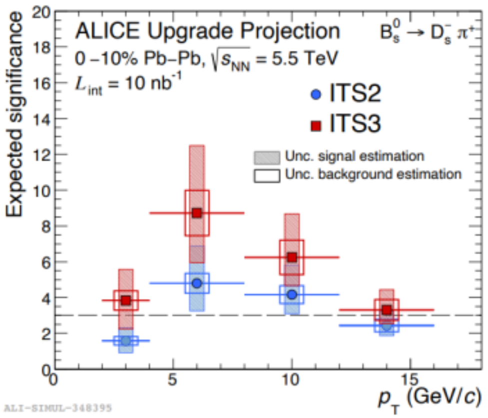


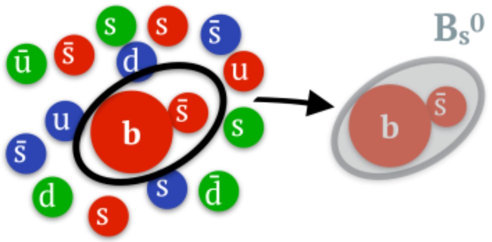
ITS3 - PERFORMANCE

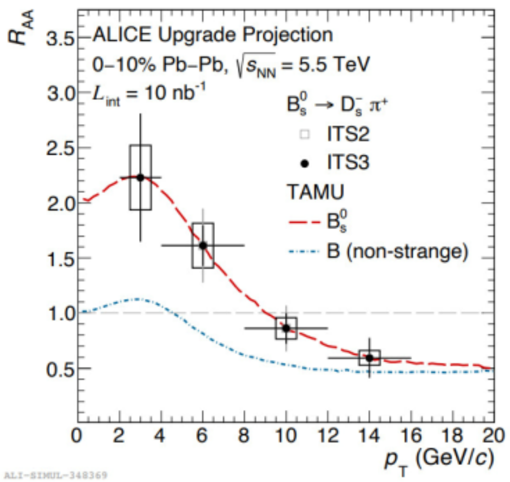
- Study beauty-quark hadronisation mechanism
- B_s^0 production expected to be enhanced
- hadronisation of beauty quarks via recombination and enhanced strange-quark production in the QGP

PLB 735, 445-450 (2014)

$B_s^0 \rightarrow D_s^- \pi^+ \rightarrow \phi \pi^- \pi^+ \rightarrow K^+K^-\pi^-\pi^+$







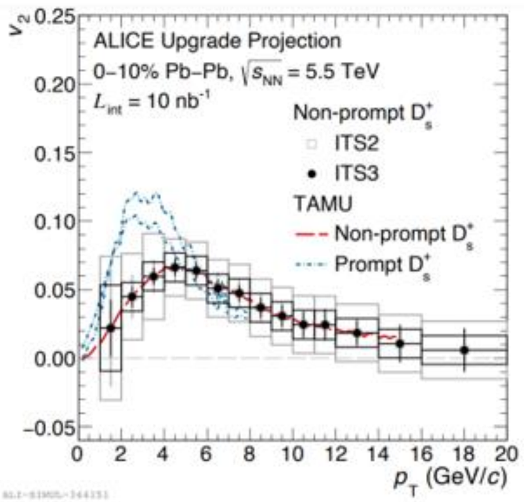
- Improvement by a factor 2 in significance with ITS3
- provide access to B_s^0 measurement at very low p_T

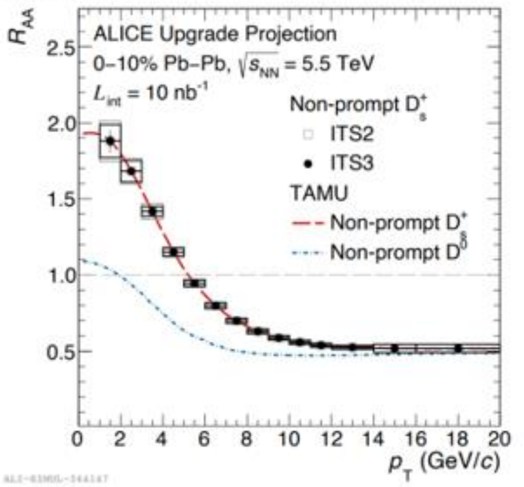
$$R_{AA} = \frac{1}{\langle N_{coll} \rangle} \cdot \frac{dN_{AA}/dp_T}{dN_{pp}/dp_T}$$

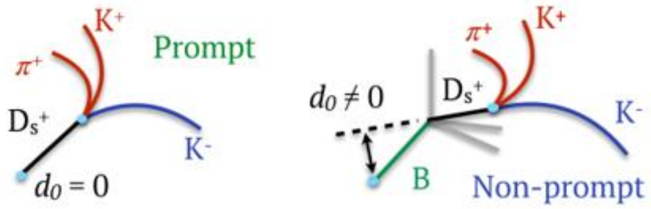
ITS3 - PERFORMANCE

D_s^+ reconstruction

$$D_s^+ \rightarrow \phi\pi^+ \rightarrow K^+K^-\pi^+$$







- Non-prompt D_s^+ from B decays:
  - even if not direct measurement, sensitive to B_s^0
  - larger statistical precision than exclusive B_s^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 η and p_T)

- **(σ_{DCA}) of ALICE 3 is about 4 μm (comp. 30-50 μm (ALICE 2) , 50-60 μm (CMS) similar kinematic range**
  → Λ_c and Λ_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 pT ≈ 3–4 GeV/c)

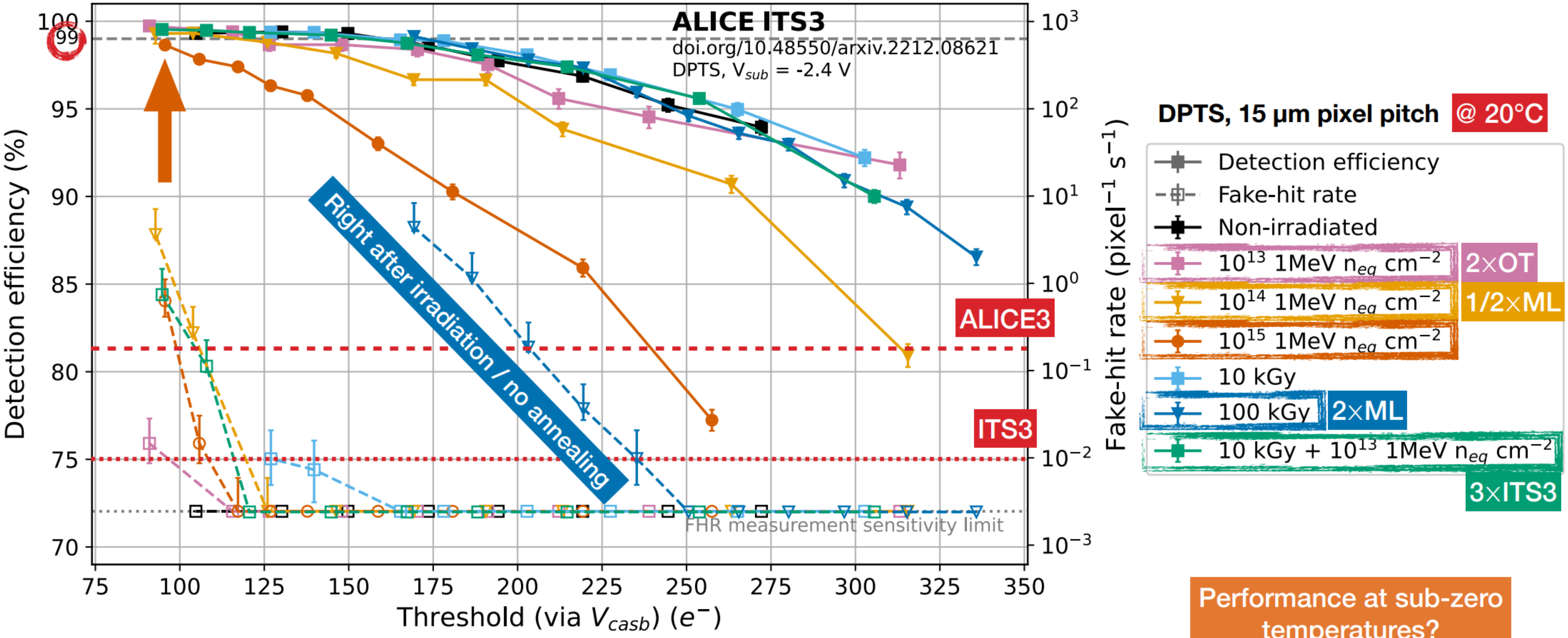
- The photon conversion tracker that is proposed as a part of ALICE 3 provides unique access to very soft photons, to test fundamental aspects of field theory in this regime

SILICON LAYERS REQUIREMENTS

ALICE

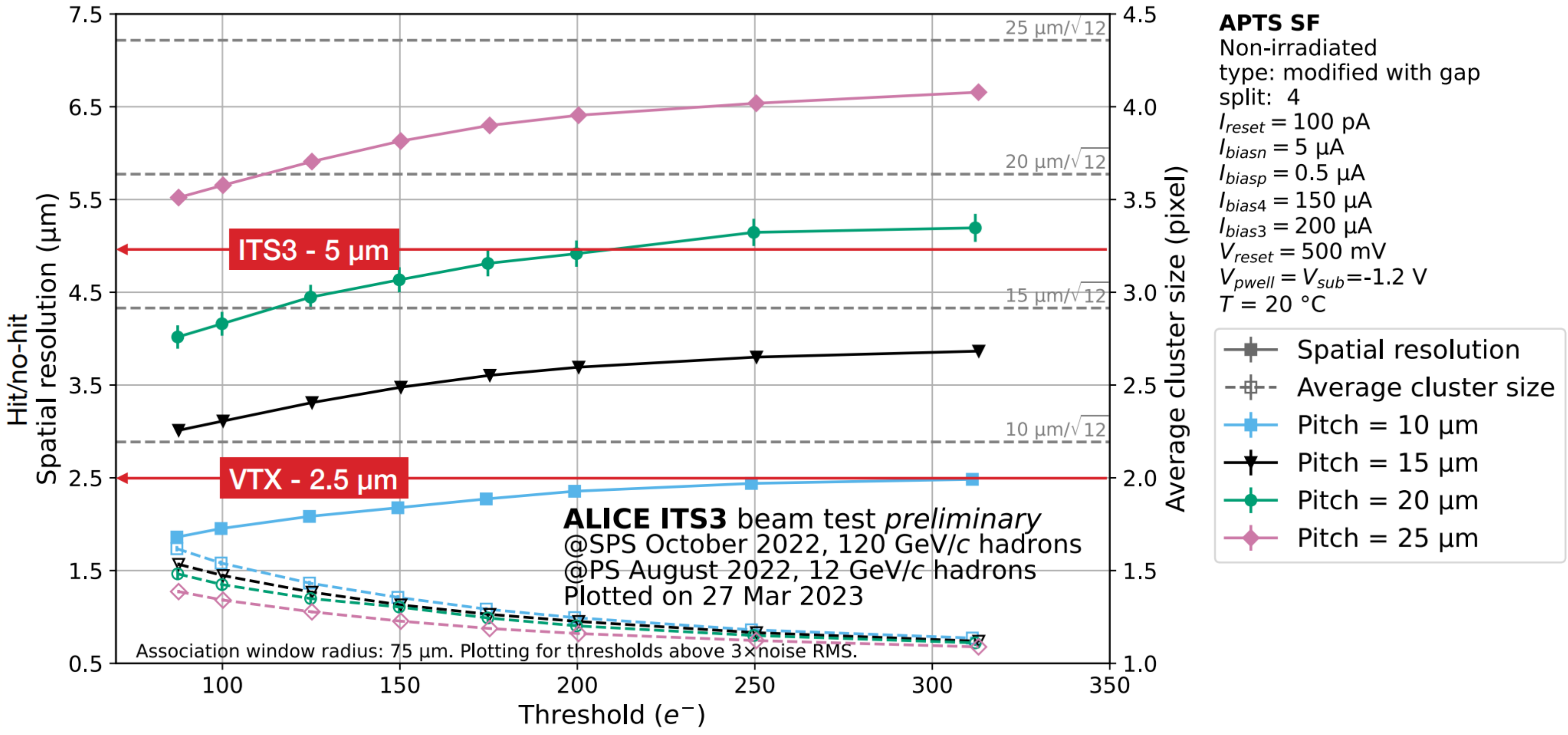
	Vertex Detector	Middle Layers	Outer Tracker
Detection efficiency (%)		>99	
Spatial resolution (µm)	2.5	10	
Time resolution (ns)		100	
Fake hit rate (pixel^{-1} event^{-1})		$<10^{-8}$	
Power consumption (mW cm^{-2})	70	20	
Non-ioninsing energy loss (1 MeV n_{eq} / cm^2)	1×10^{16}	2×10^{14}	6×10^{12}
Total ionising dose (kGy)	3000	50	2
Pixel size (µm^2)	O(10×10)	O(50×50)	O(50×50)

IRRADIATION TEST



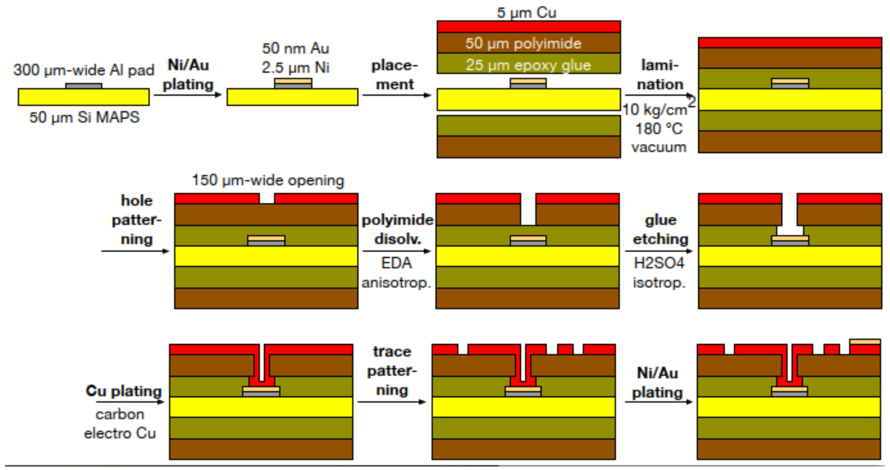
Performance at sub-zero temperatures?

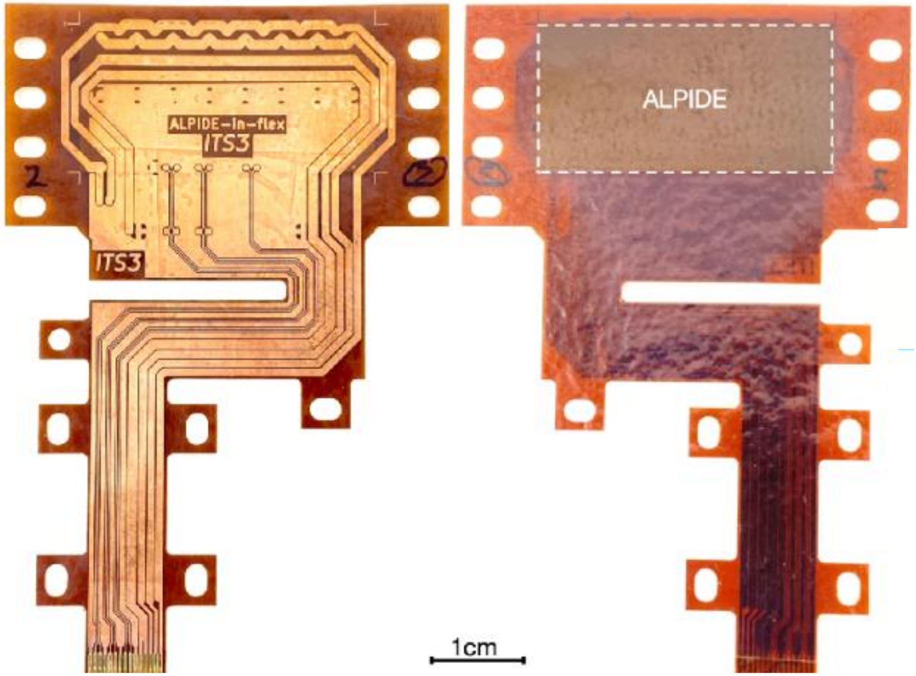
SPATIAL RESOLUTION

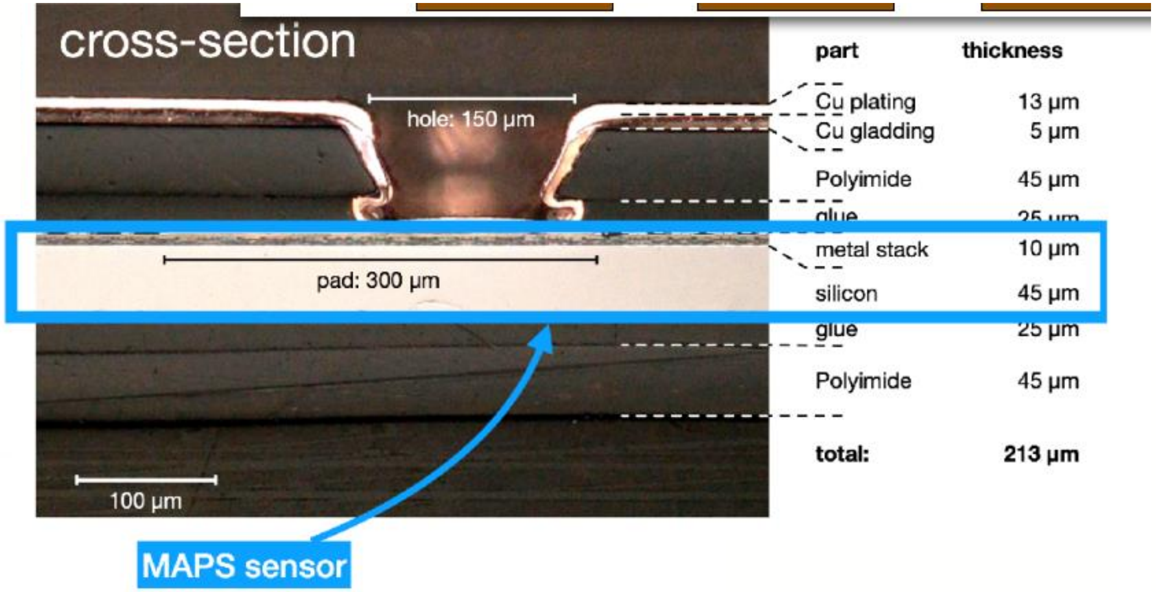


TRACKER EXAMPLE «MAPS»

MAPS foils – chips within printed circuit boards
- «Novel» concept (revised and update from 2012)
- Will be studied further as an option



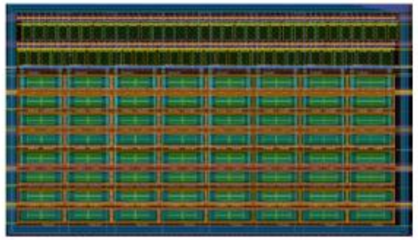


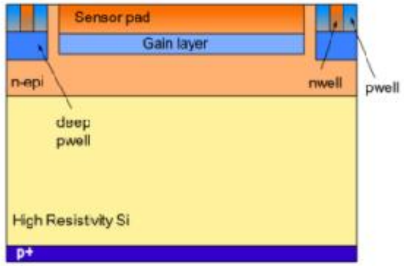


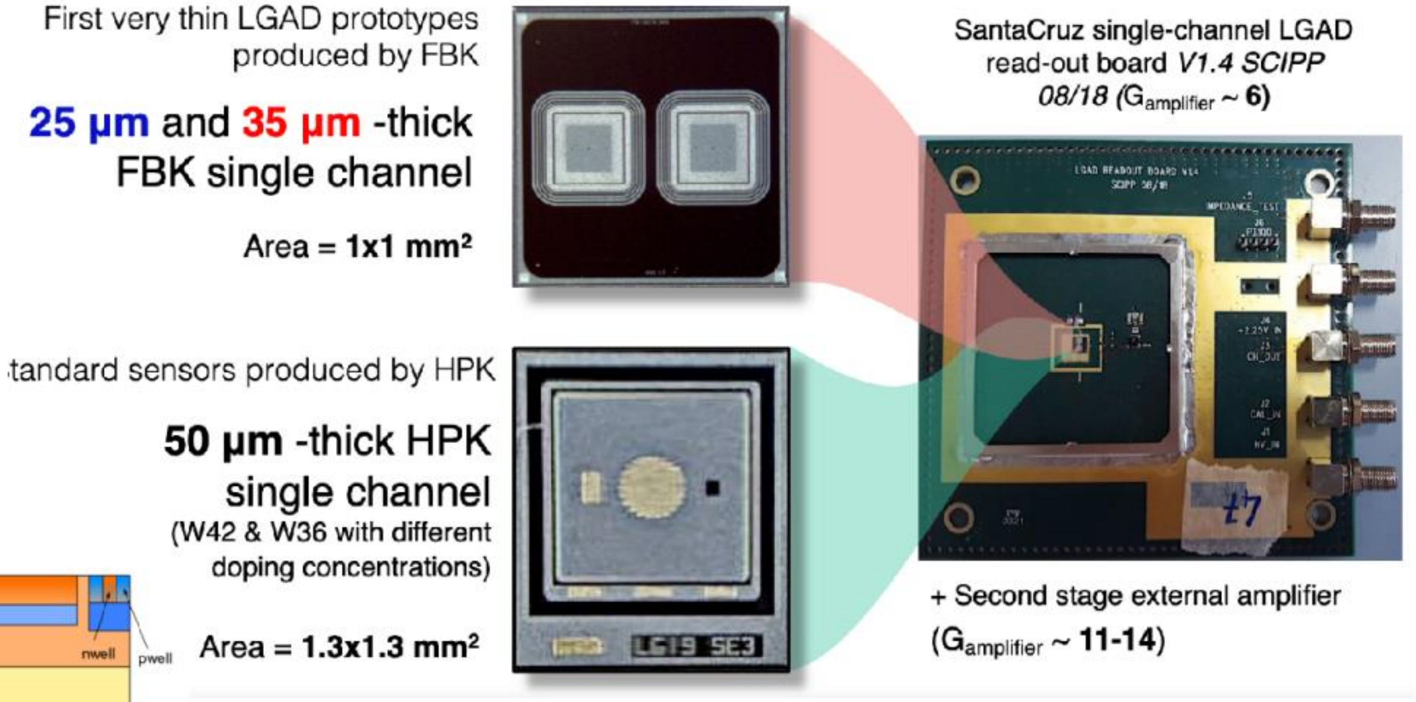
PIXEL SENSORS

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







PARTICLE IDENTIFICATION WITH TOF

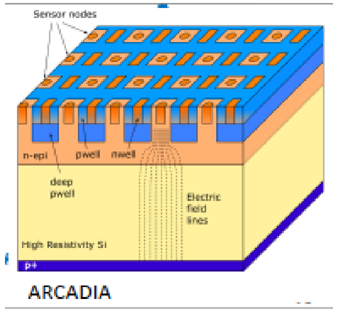
Separation power L/σ_{TOF}
→ Distance and time resolution crucial
→ Larger radius results in lower p_T bound

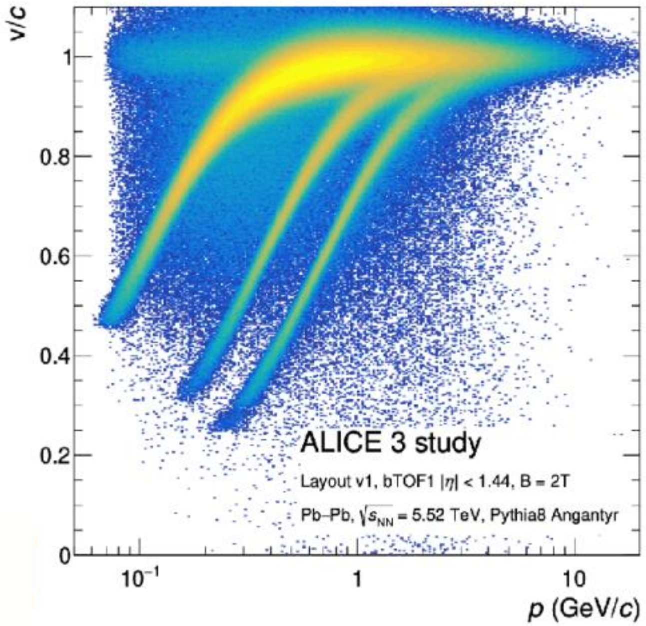
2 barrel TOF layers ($|\eta| < 1.75$)
- Outer TOF at r ≈ 85cm, surface: 30 m^2, pitch: 5 mm
- Inner TOF at r ≈ 19 cm, surface: 1.5 m^2, pitch: 1 mm

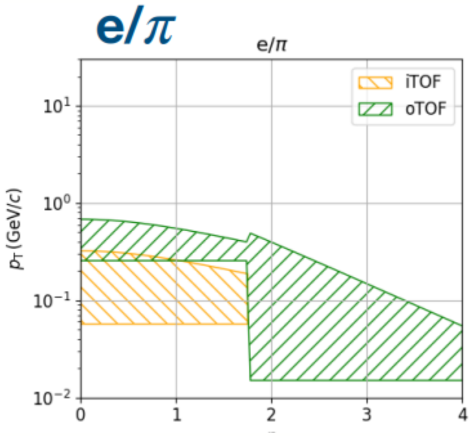
1 forward TOF layers($1.75 < |\eta| < 4$)
- Inner radius = 15 cm, outer radius = 50 cm, z ~405 cm, surface 14 m2, pitch: 1mm to 1 mm

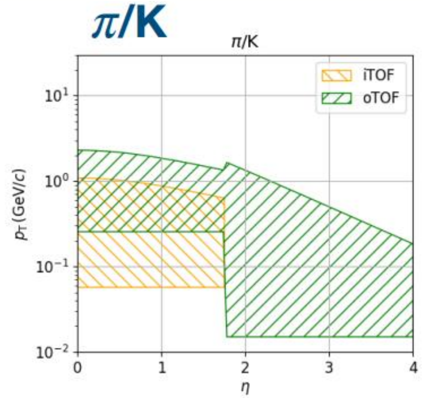
Silicon timing sensor:
CMOS sensor with gain (baseline)
- R&D in monolithis CMOS sensors with intgrated gain layers

Conventionl LGADs (fallback)
- R&D with very thin sensors









$\sigma_{TOF} < 20ps$

Total silicon area ~45m^2

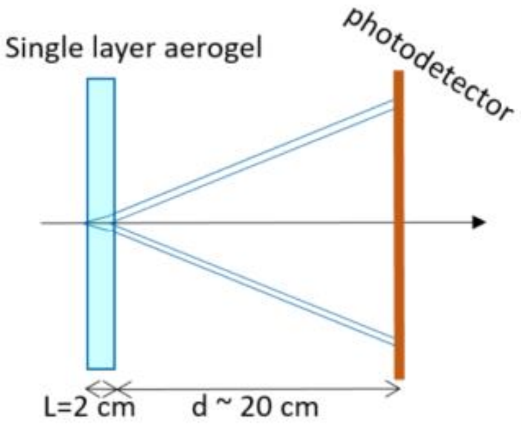
PARTICLE IDENTIFICATION WITH CERENKOV

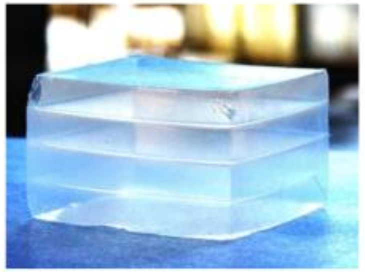
Complement PID reach of outer TOF to higher p_T with Cherenkov detector

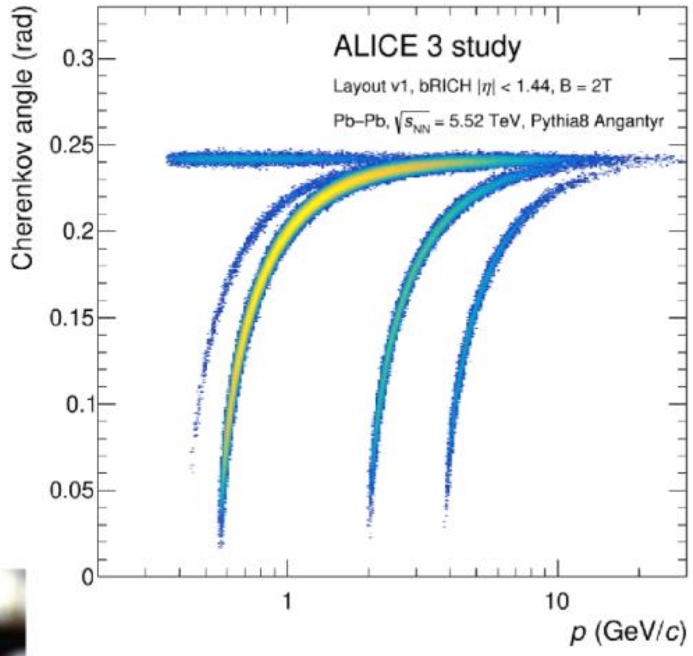
→ Ensure continuous coverage with the TOF

Aerogel radiator
- Refractive index n = 1.03 (barrel)
- Refractive index n = 1.006 (forward)

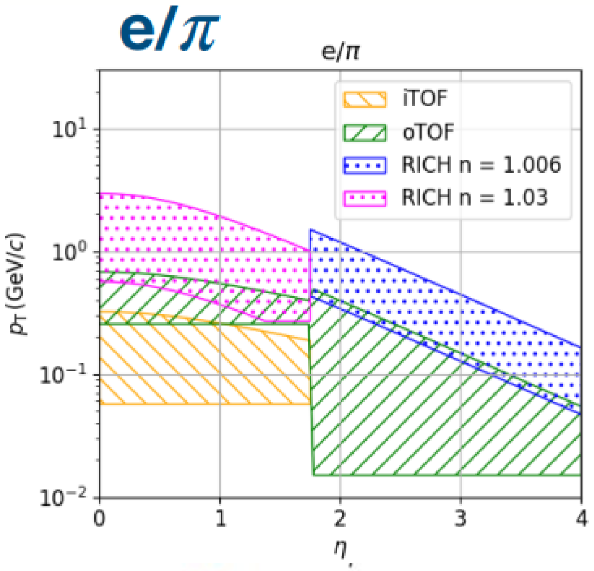
R&D on monolithic silicon photo sensors

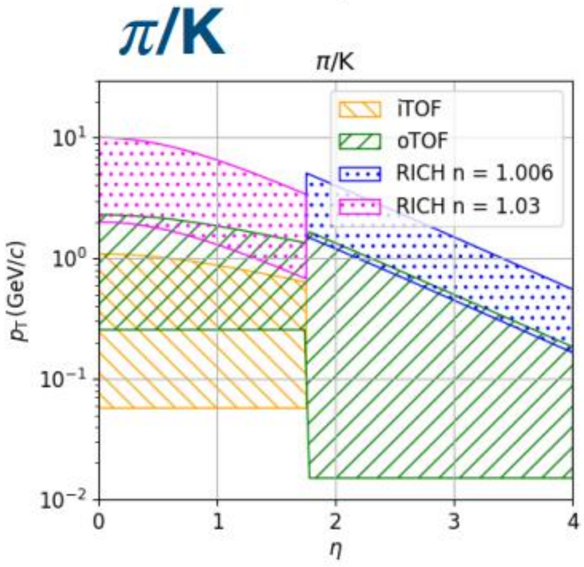



aerogel radiator



Total SiPM area ~60m²



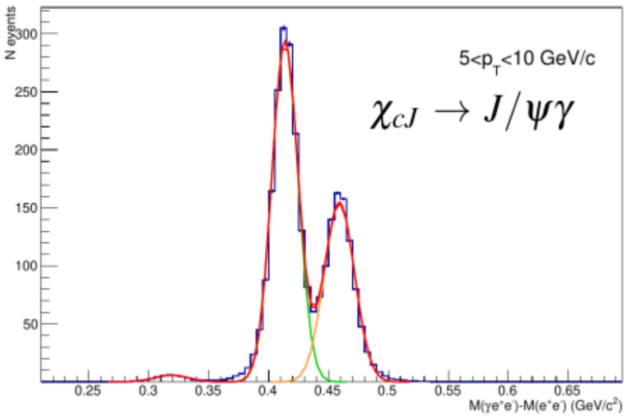


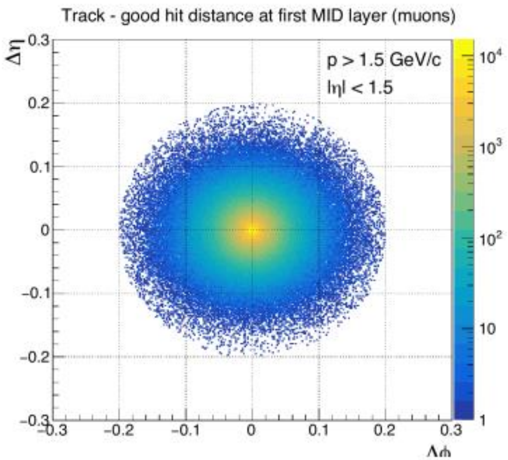
MORE ON PARTICLE IDENTIFICATION

Large acceptance Electromagentic calorimeter (2pi 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 ~0.1 x 0.1 (η x φ)

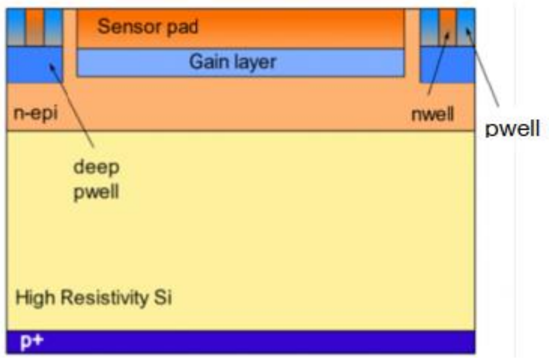
ALICE - R&D PROCESS

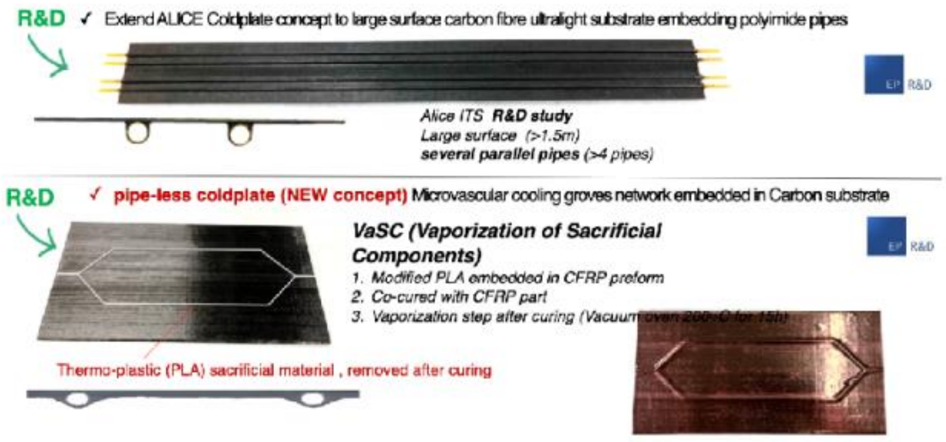
Silicon pixel sensors
- Thinning and bending of silicon sensors
  Expand n experience with ITS3
- Exploration of new CMOS processes
  First in-beam test with 65 nm process
- Modularization and industrialization

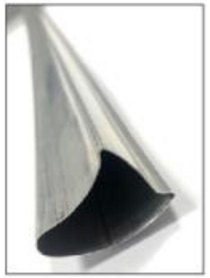
Silicon timing sensors
- Characterization of SPADs /SiPMs
  - First test in beam
- Monolithic timing sensors
  - Implement gain layers

Photon sensors
- Monolithic SiPMs
  Integrated read-out

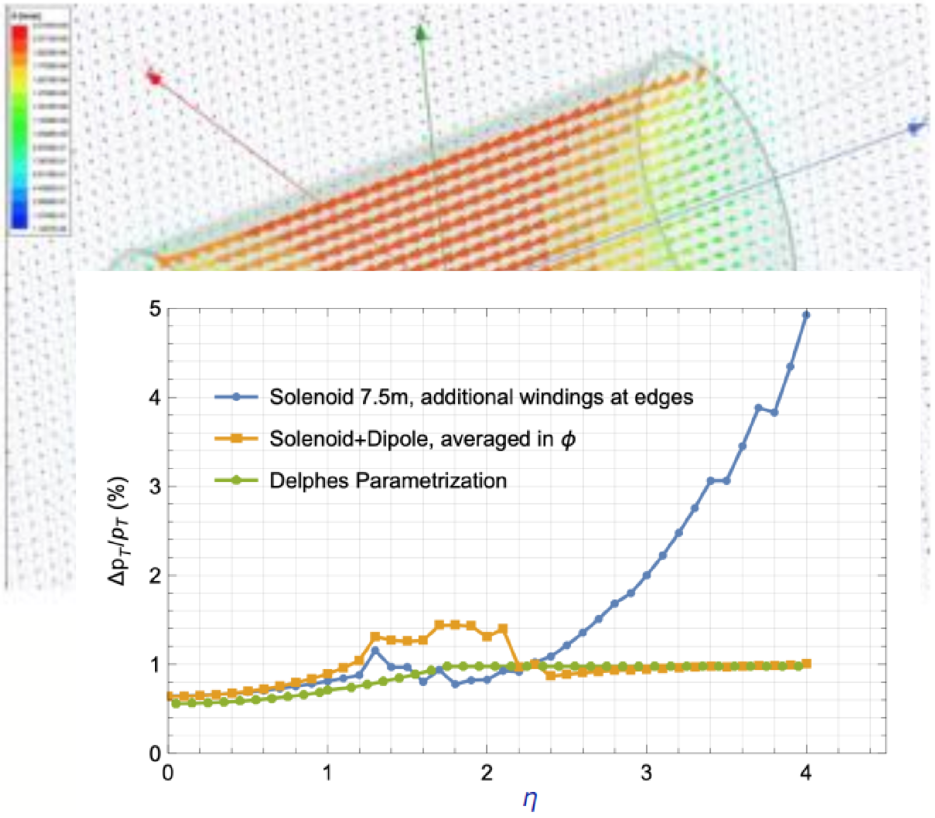
Detector mechanics and cooling
- Mechanics for operation in beam pipe
  Establish compatible with LHC beam
- Minimization of material in the active volume
  Micro-channel cooling

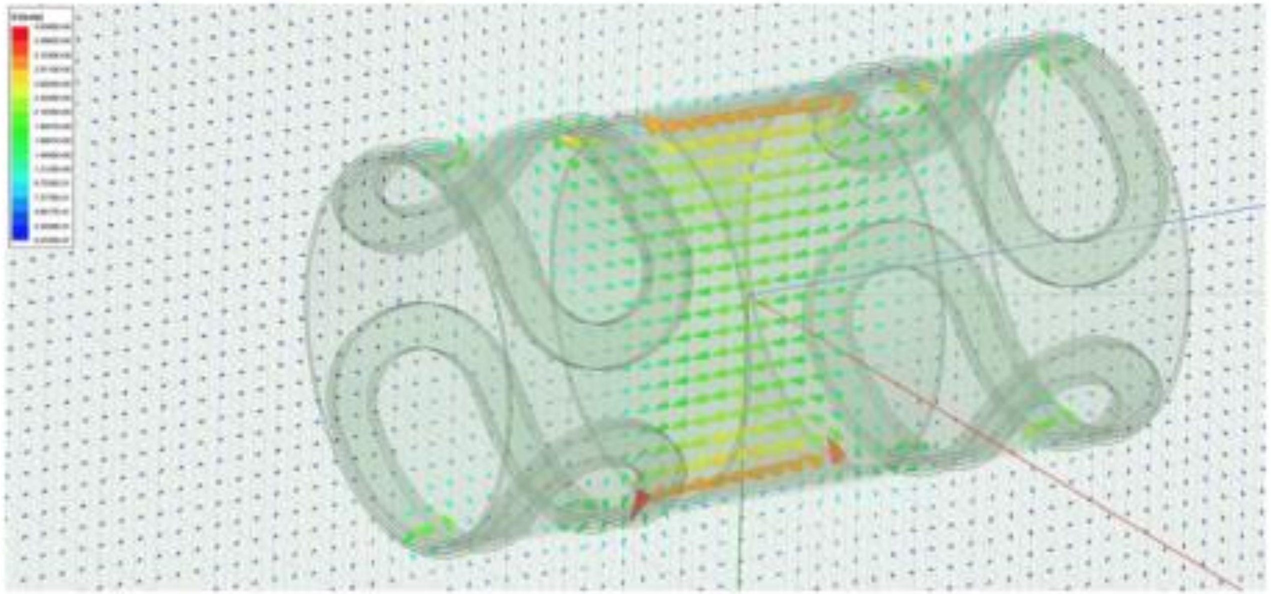






MAGNET FIELD CONFIGURATION





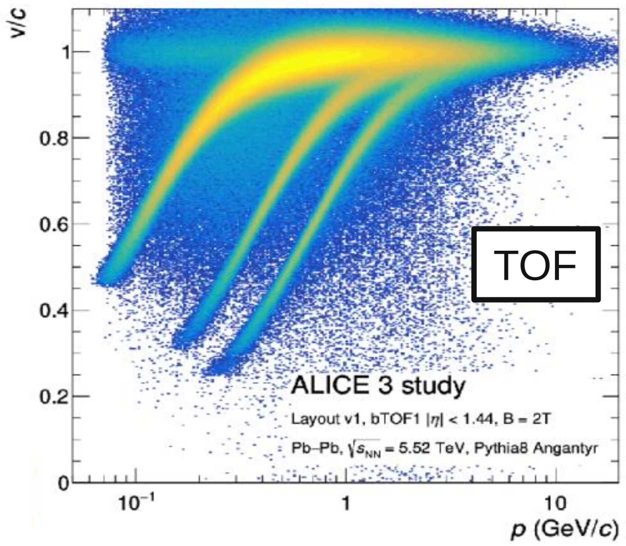
PARTICLE IDENTIFICATION

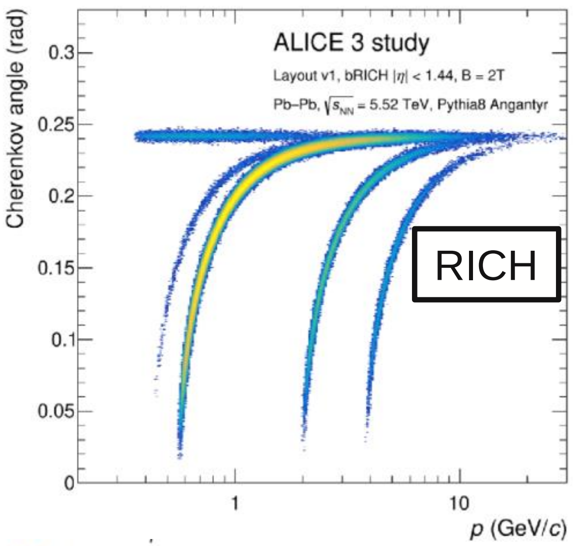
Time of Flight detectors: Silicon timing sensors
Separation power L/σ_{TOF}
→ Distance and time resolution crucial
→ Larger radius results in lower p_T bound
- 3 TOF layers ; Total silicon area : ~45m²

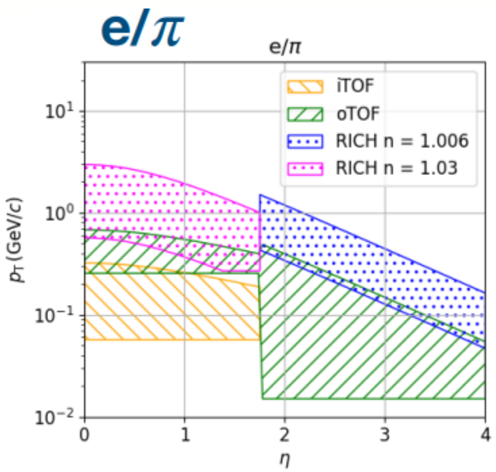
Complement PID reach of outer TOF to higher p_T with Cherenkov detector
- Aerogel radiator
- Total SiPM area ~60m²

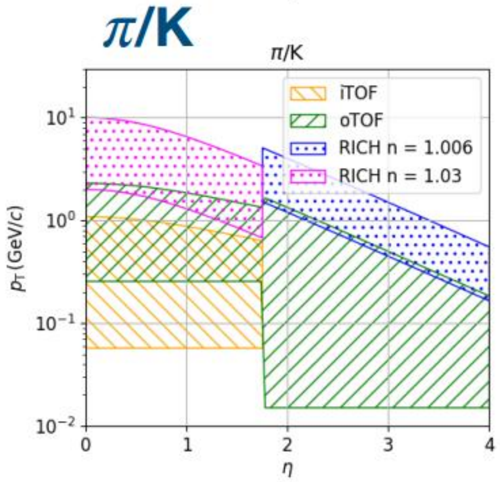
Large Acceptance EmCal (2π coverage)
- Pb-scintillator sampling calorimeter
- Crystal calorimeter at η~0

Muon Identifier
- Absorber + 2 layers of muon detectors
- Muons down to $p_T \geq 1.5$ GeV/c





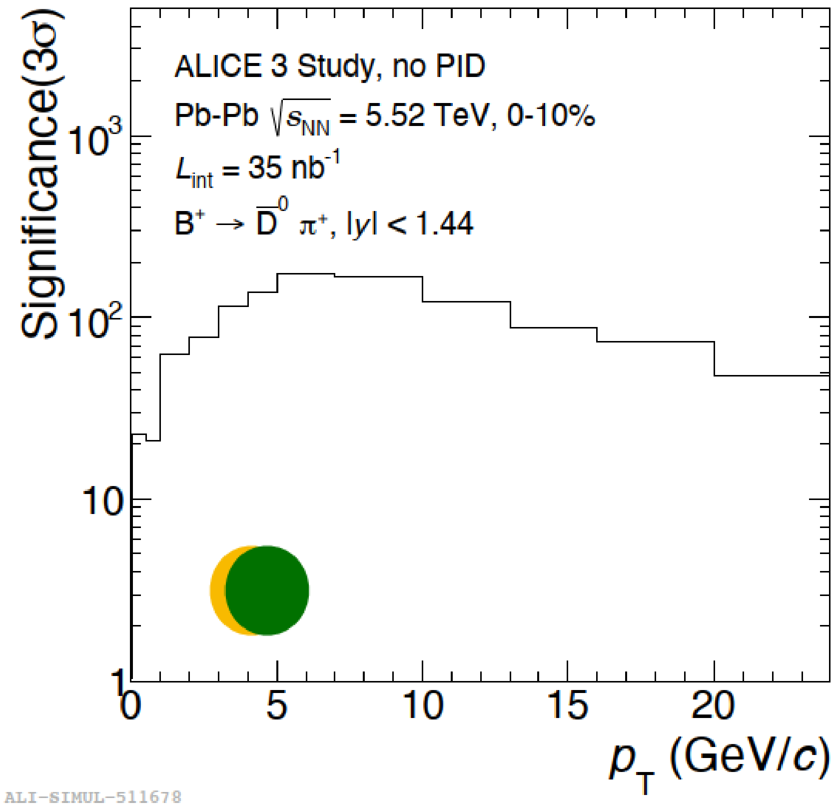




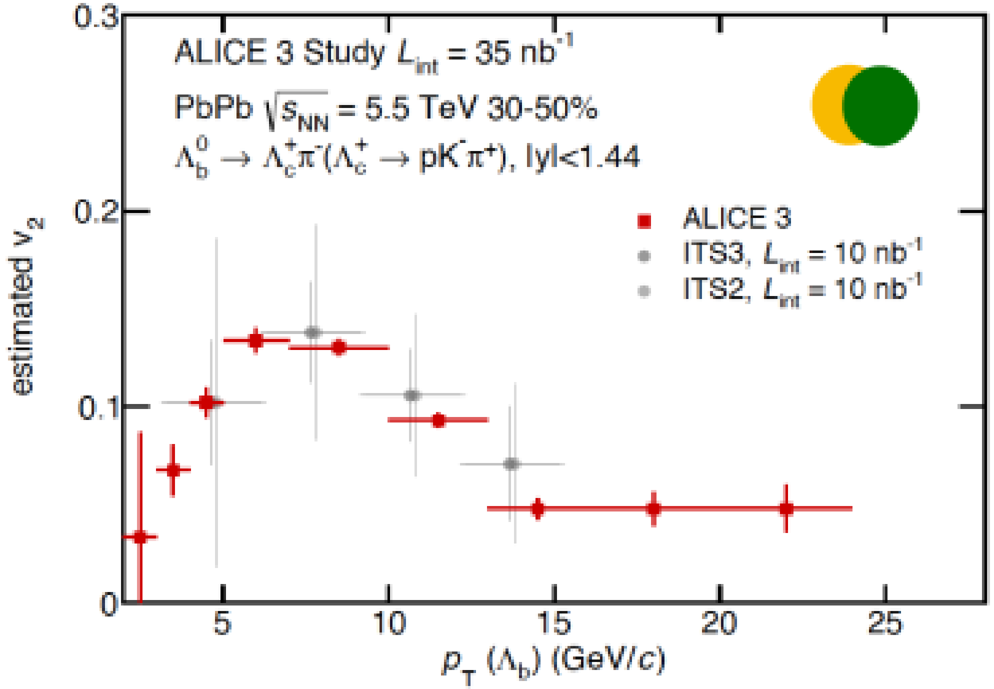
ALICE 3 PHYSICS PERFORMANCE

Beauty Physics

B⁺ reconstruction



Λ_b elliptic flow, v_2

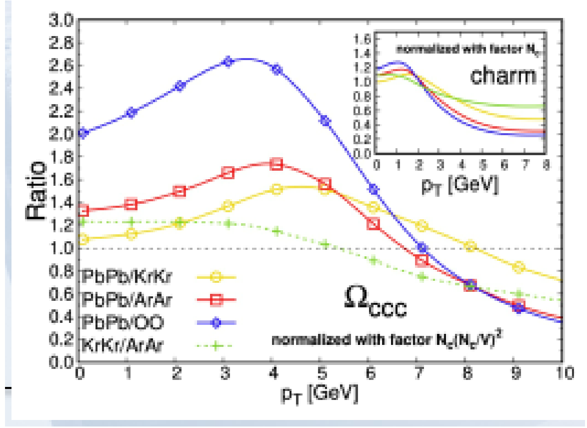


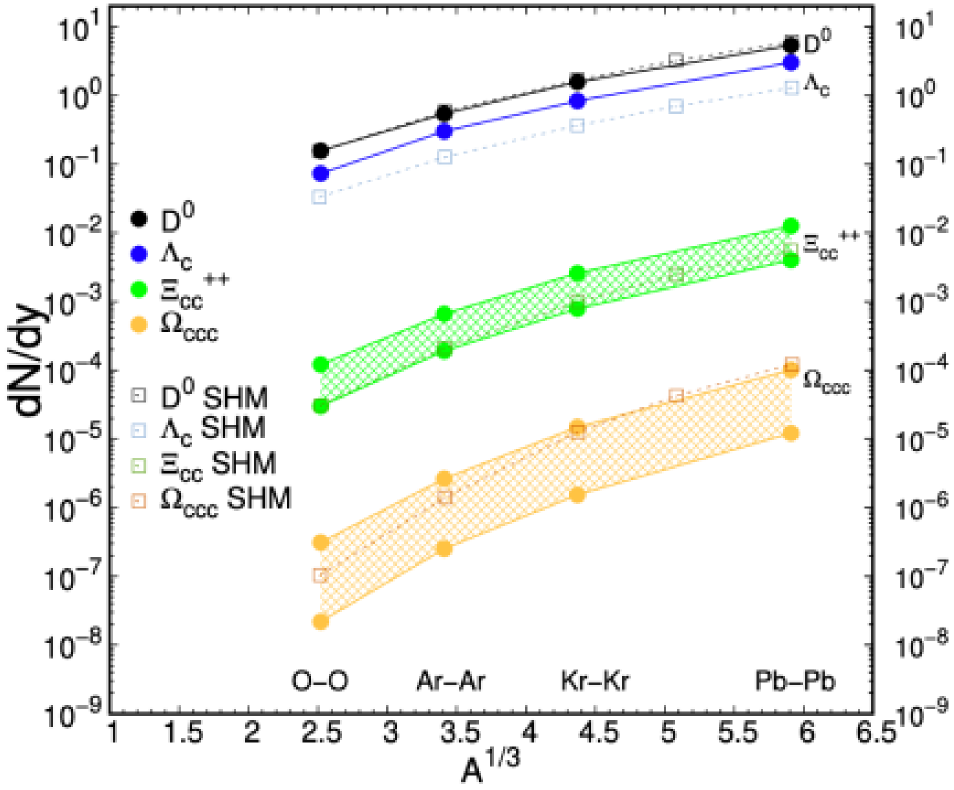
ALICE Coll. arXiv:2211.02491

PREDICTIONS FOR MULTI-CHARM BARYONS

http://arxiv.org/abs/2305.03687

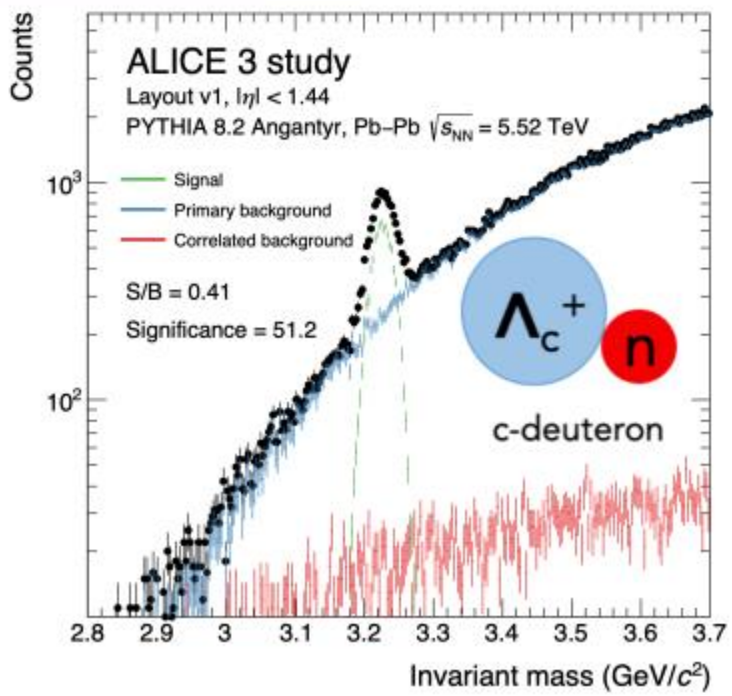
- New paper: charm transport + hybrid hadronization with coalescence + fragmentation
- Broadly consistent with SHM expectation
- Large dynamics of yield enhancement: factor of 1000 for Ω^{++}_{ccc}
- New: model allows for prediction of transverse momentum spectra!





ALICE 3 - PERFORAMANCE

Heavy-flavor exotica: C-deuteron measurement

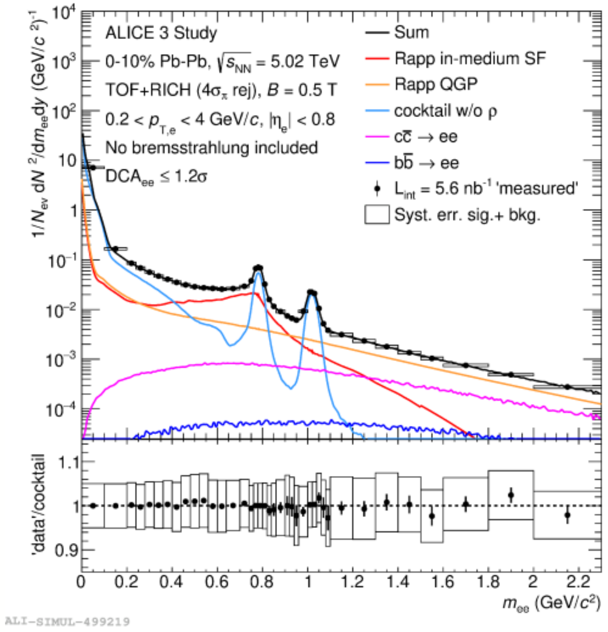


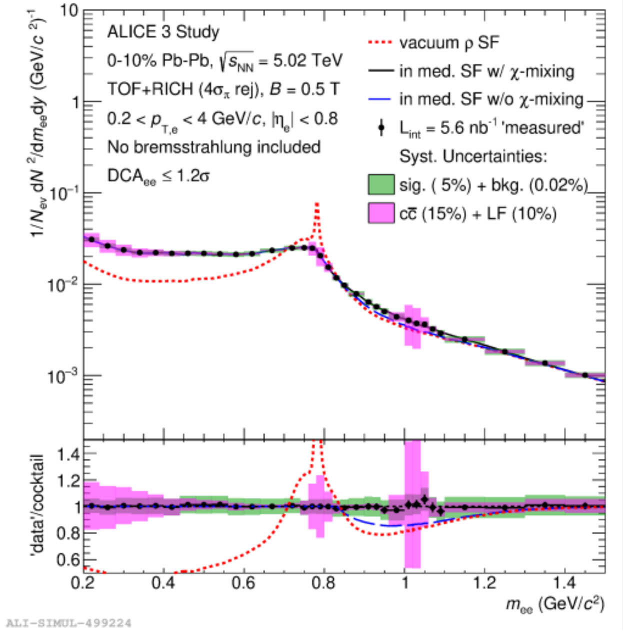
$$c_d \rightarrow d + K^- + \pi^+$$

- 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 measurment



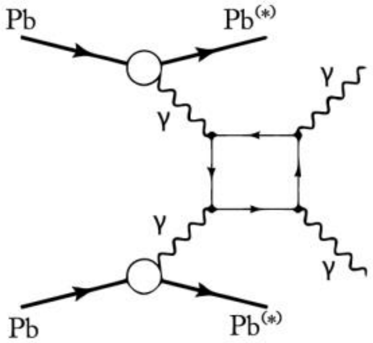


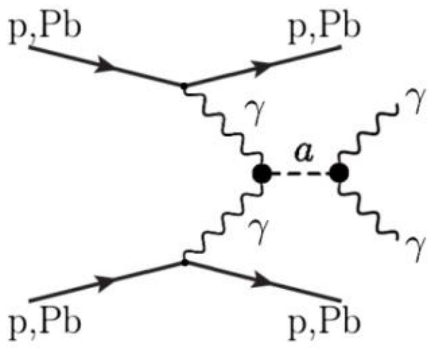
- Spectral function of low mass dielectrons determined with 6-8% unc. in the region 0.4≤ m_{ee} ≤1.3 GeV/c^2
- Chiral mixing produces a 20-25% change versus vacuum spectral functions (0.8≤ m_{ee} ≤1.2 GeV/c^2)
- ALICE3 can observe chiral mixing effect and together with more differential measurements (dielectrons v_2) constraint the modification of a_1 spectral function

BSM SEARCHES IN ULTRA-PERIPHERAL COLLISIONS

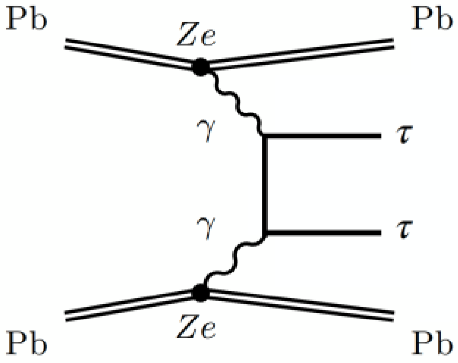
Ultra-peripheral heavy-ion collisions (UPC): clean environment + huge $Z^4 \approx 5 \cdot 10^7$ enhanced gamma+gamma rate w.r.t. pp

- **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)



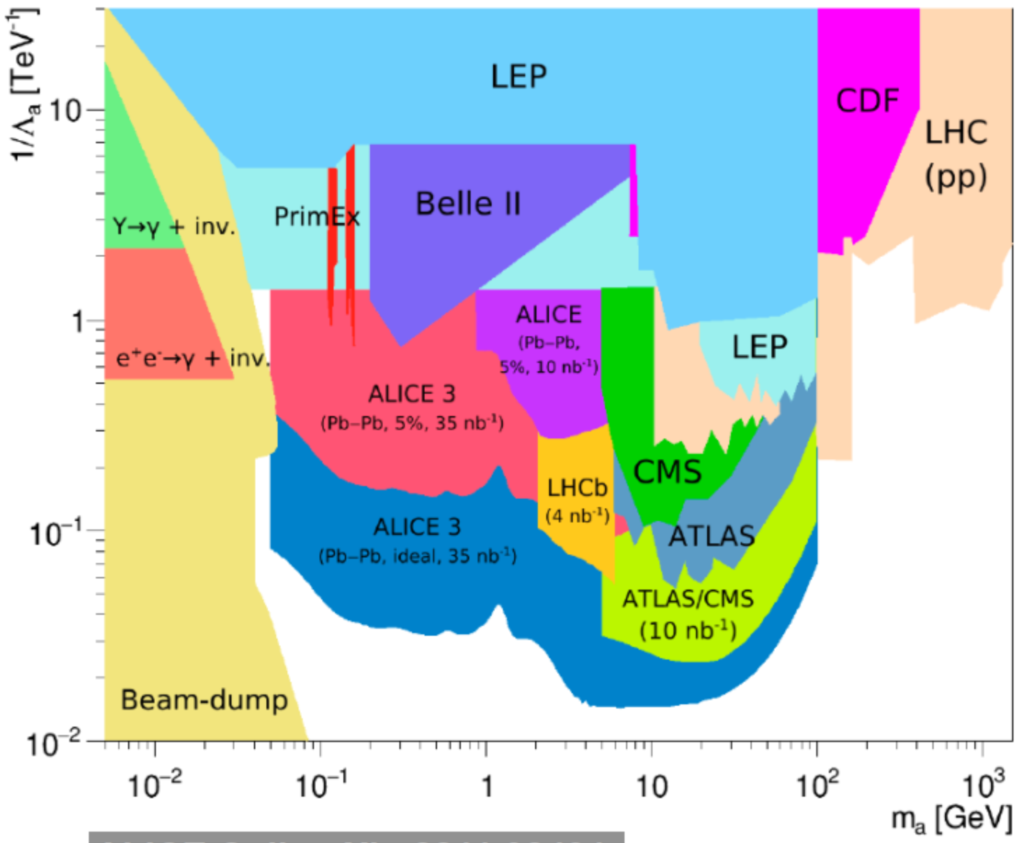


- **Precision measurements of EM couplings of SM particles:** anomalous magnetic moment (g-2) of the tau



➡ **Challenge for ALICE 3:** acceptance for tau and light-by-light scattering down to low p_T?

BSM SEARCHES IN UPCS



ALICE Coll. arXiv:2211.02491

- 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 γγ→a→γγ process. Signal would be visible as a peak in the diphoton mass distribu1on

- Performance on the estimated produc1on cross-section given as mass and recast limit in the plane $(m_a, 1/\Lambda_a)$

ITS PERFORMANCE