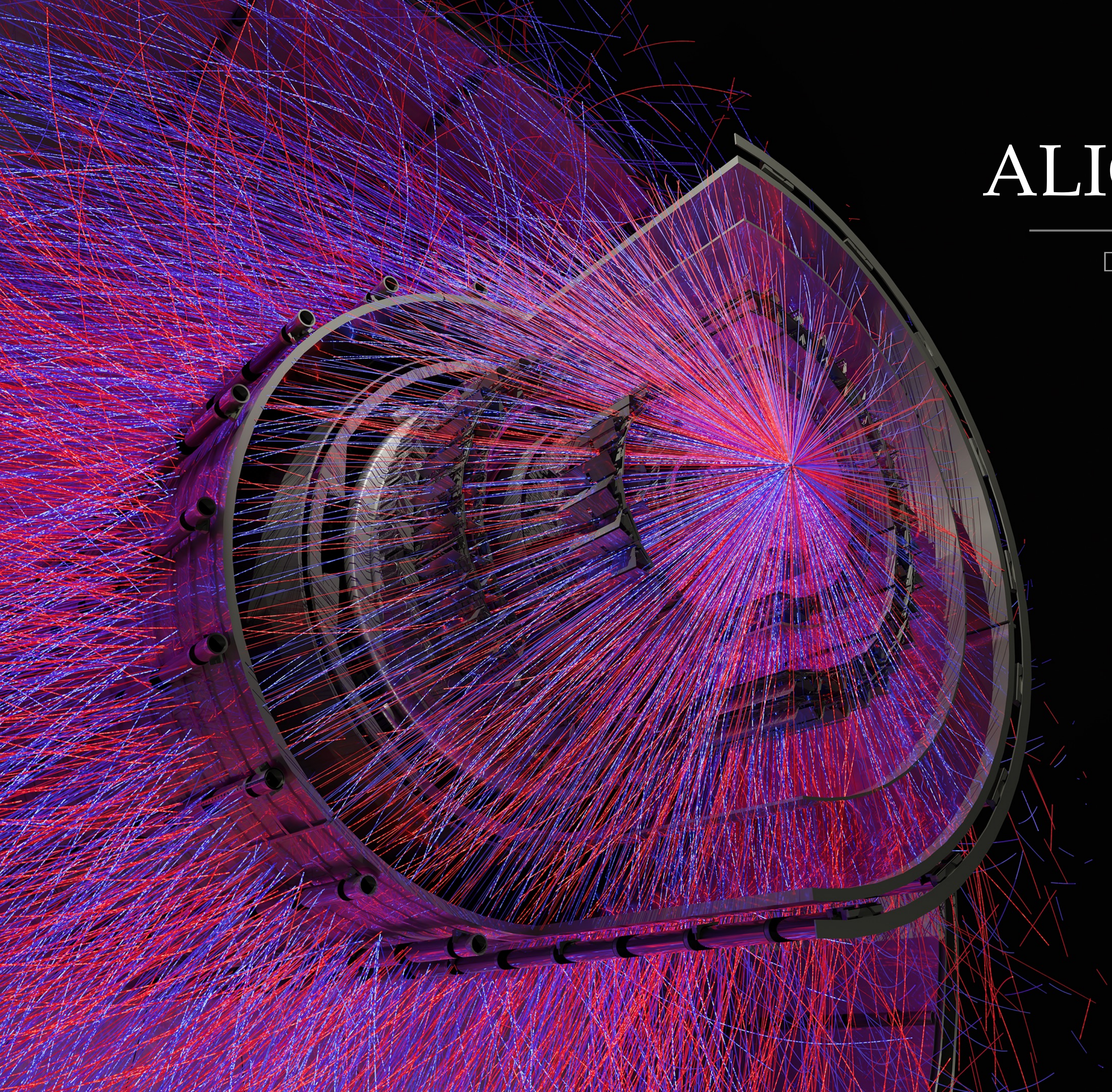


ALICE analysis and plans

David Dobrigkeit Chinellato for the ALICE / SMI group

ÖAW ÖSTERREICHISCHE AKADEMIE DER WISSENSCHAFTEN

SMI

ALICE

Introduction to ALICE/SMI

- Broadly, ALICE/SMI currently specialty lies in two sectors:
  - QCD-based phenomenology of both strangeness and heavy flavour versus system size (from pp to Pb-Pb)
  - Ultra-peripheral events: $\gamma p/\ \gamma Pb$ collisions allow for targeted studies with extremely short photon pulses

Broad field	Researcher	Key physics topics and responsibilities
Identified particles, hadronization	David Dobrigkeit Chinellato (JGL) • Romain Schotter (PD) • Jesper Gumprecht (PhD)	• LHC Run 2: high-precision mass measurement (Romain, David) • LHC Run 3: strange particles in Pb-Pb 5.36 TeV (Romain, David) • Upgrades: ALICE 3 tracker cooling + performance(Jesper, David)
	Elisa Meninno (senior PD / PI project) • Daniel Samitz (PD)	• LHC Run 3: Λ_c/D^0 measurements in pp/Pb-Pb (Elisa, Daniel) • LHC Run 3: dielectron measurement in Pb-Pb (Elisa, Daniel)
Ultra-peripheral collisions, excl. processes	Paul Bühler (GL) • Roman Lavicka (PD)	• LHC Run 2/3: Proton diffraction (Paul) • LHC Run 2/3: Tau g-2 measurement (Roman, Paul)

- In addition: administrative responsibilities (see ALICE collaboration site):
  - **Daniel Samitz**: Coordinator of the low-mass dielectrons Physics Analysis Group (PAG)
  - **David Dobrigkeit Chinellato**: ALICE Analysis Coordinator
  - **Roman Lavicka**: Coordinator of the ultra-peripheral collisions Physics Analysis Group (PAG)
  - **Roman Lavicka**: Austrian representative of Computer Resource Board
  - **Romain Schotter**: Junior Ambassador

Current activities: Run 2 analysis

High-precision multi-strange baryon mass measurement

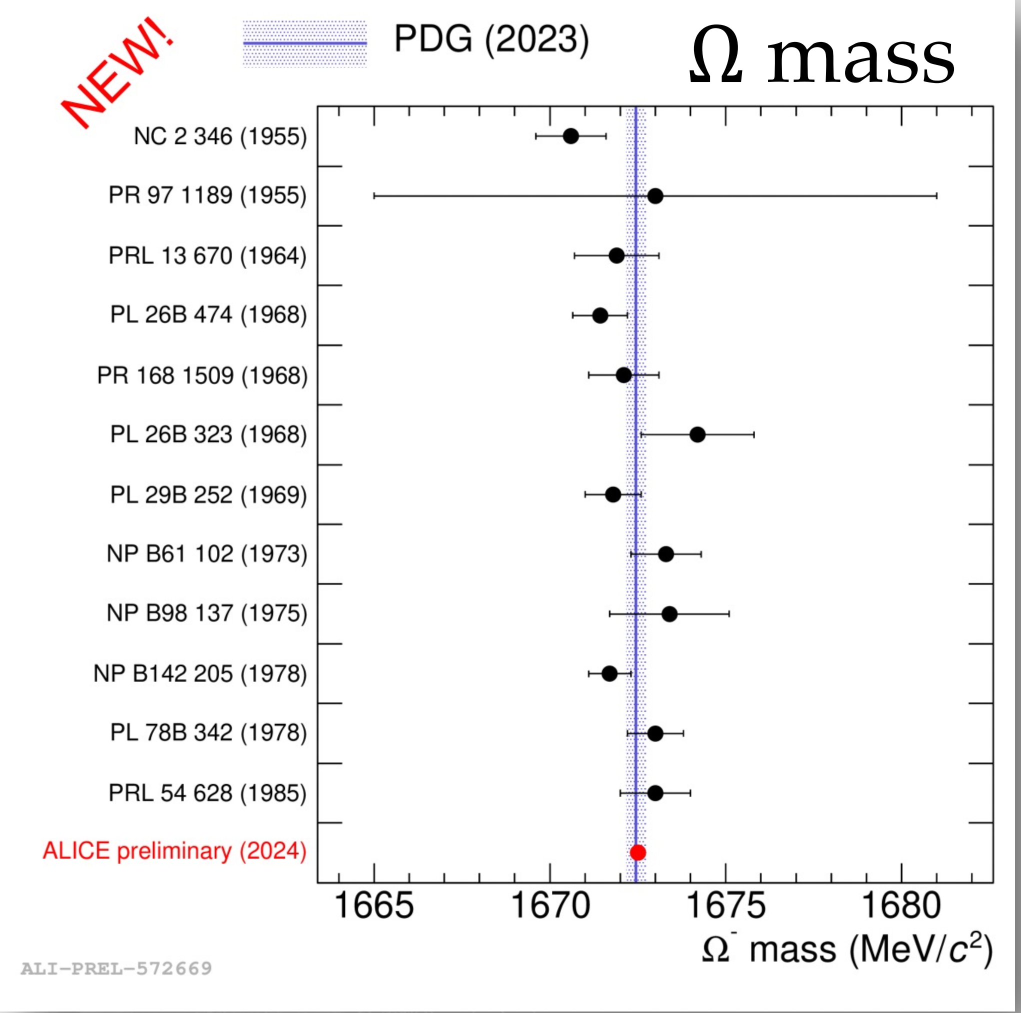
- Lattice QCD is the only tool to understand the hadron spectrum from first principles
- Mass measurements: **fundamental input to lattice QCD**
  - Physical scale comes from $M(\pi)$, $M(K)$ and $M(\Omega)$

- ALICE detectors and particle identification coupled with state-of-the-art analysis techniques lead to:
  - $M(\Xi) \rightarrow$ 15% smaller uncertainties
  - $M(\Omega) \rightarrow$ **10x** smaller uncertainties (!)

- Presented for the very first time at SQM2024 last week

- According to Zoltan Fodor (BMW Collaboration), a tenfold improvement in the uncertainties of the Ω mass in this analysis ***"would eliminate all uncertainties from the physical input."***

- Manuscript being prepared now
  - submission to Nature is likely

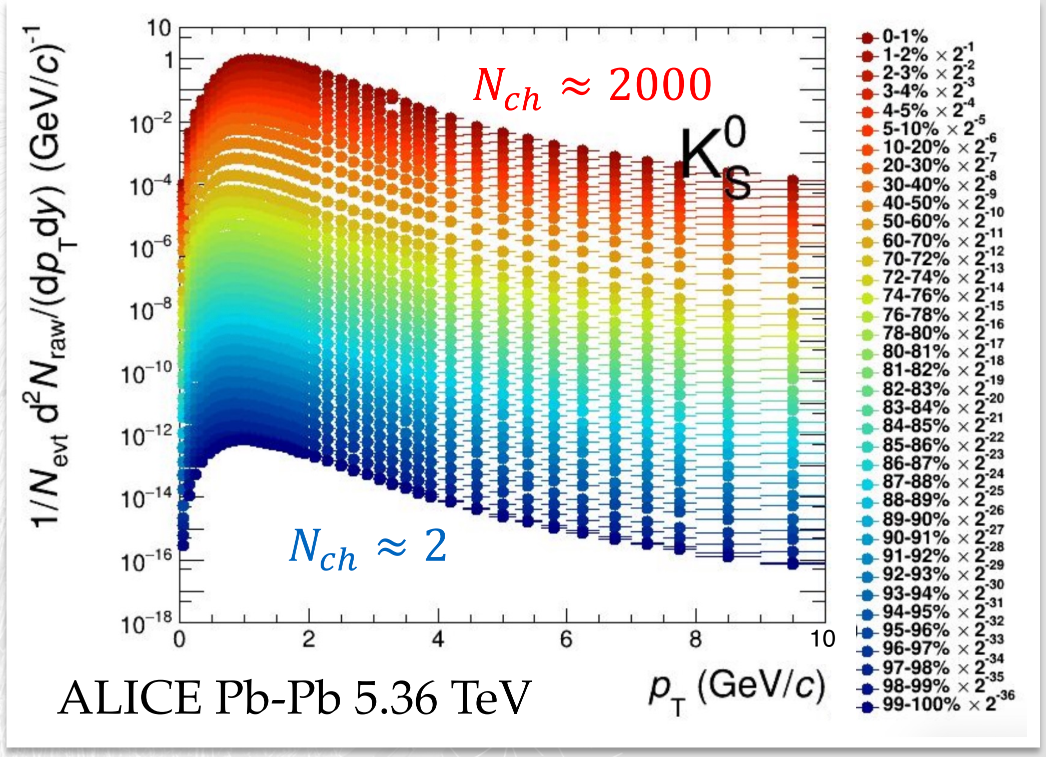


Current activities: Run 3 analysis

Strange hadron yields in Pb-Pb from 2 to 2000 particles

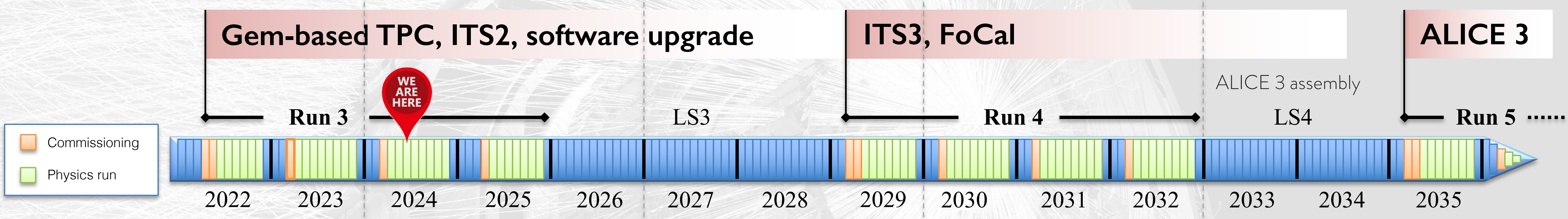
- Objective: leverage Run 3 data volume to study strangeness production from lowest to highest extremes
  - **Probe onset of strangeness enhancement with unprecedentedly high precision**
- "Tip of the spear": one of the first analyses of Pb-Pb data at 5.36 TeV in ALICE
  - Faces numerous challenges due to enormous change in ALICE data acquisition: continuous readout
  - Making significant progress, crucial work for the collaboration
- **Bonus**: use ultra-peripheral collisions as the extreme low multiplicity and leverage multiple specialties of ALICE/SMI!

(work in progress – internal only)



Medium- to long-range plans of ALICE/SMI

ALICE/LHC schedule



ALICE/SMI schedule

Pre-2023: Λ_c/D^0, dielectrons with ML, ultra-peripheral collisions

Run 3 Pb-Pb 5.36 strangeness analysis (ongoing)

ALICE 3 cooling + performance work (ongoing)

Run 3: Resonance hadronization study (FWF, **submitted**)

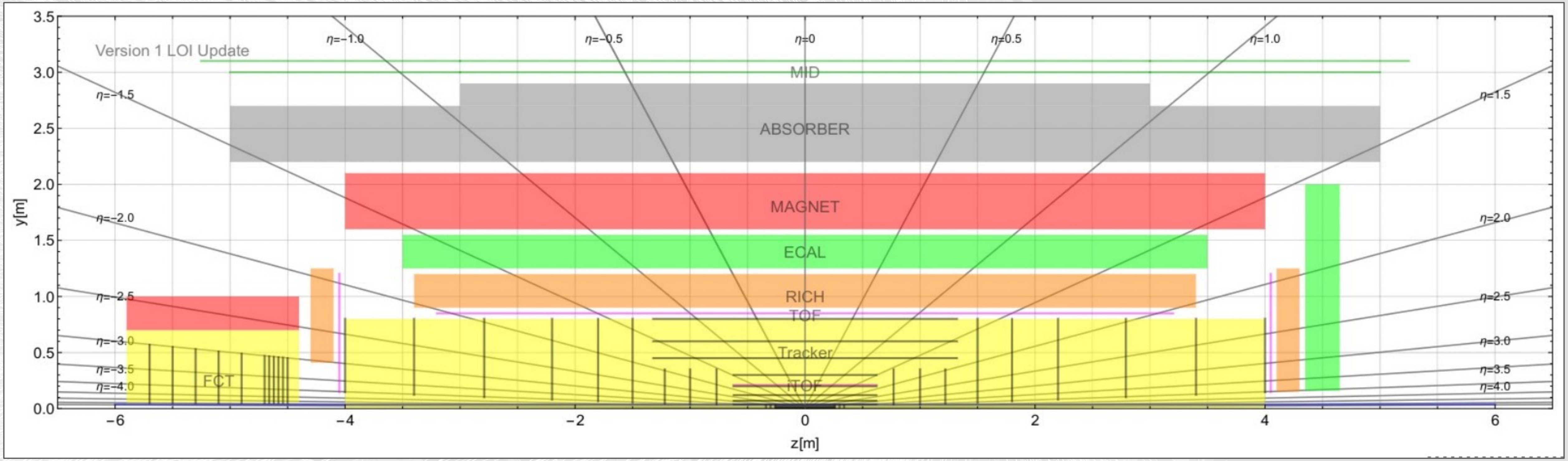
ALICE 3: tracker design study (FWF, **in preparation**, submission June/July)

“ColourNet”: MCDN on complex hadronic interactions (**in preparation**, submission November)

Scanning hadrons using Quantum Tomography (FWF, **in preparation**, submission July/August)

+ possible ERC grant proposal (Chinellato, being discussed)

The ALICE 3 detector: novel aspects



- State-of-the-art silicon tracker (~50m^2 surface area)
  - Retain ALICE capabilities for PID, low-p_T, high-multiplicity performance → enormous challenge
  - Necessary to meet physics requirements: (multi-)charm physics and dileptons in variable-mult hadronic environment
- Inner and Outer tracker design is still in flux; potential longer-term contribution envisaged in two fundamental ways:
  - **Tracker design**: industrial module fabrication with grouped pixels; synergy between IT and OT efforts to be investigated
  - **Tracking software**: connect performance to physics requirements and meet needs

ALICE 3 tracker: strategic map*

strategically summarized for brevity

Group	Focus of efforts	Comment
ALICE / Strasbourg / France	OT / charge collection	Partnership established for FWF project in preparation Includes e.g. personnel staying in Strasbourg
Grenoble / France	OT / readout	
TUM / Münich / Germany	OT / mechanical design	Partnership on cooling study (already ongoing)
CERN / Switzerland	Inner Tracker (overall)	

Requirements

25x more pixels

	Vertex Detector	Middle Layers	Outer Tracker	ITS3
Position resolution (μm)	2.5	10		5
Pixel size (μm²)	O(10 x 10)	O(50 x 50)		O(20 x 20)
Time resolution (ns RMS)	100	100		100* / O(1000)
In-pixel hit rate (Hz)	94	**42 (barrel)** / 12 (foward)	1 (barrel) / **16 (forward)**	54
Fake-hit rate (/ pixel / event)	$<10^{-7}$			
Power consumption (mW / cm²)	70	20		35
Particle hit density (MHz / cm²)	94	0.6 (barrel / forward)	0.06 (barrel) **0.6 (forward**	8.5
Non-Ionising Energy Loss (1 MeV n_{eq} / cm²)*	2×10^{15}	**6×10^{13} (barrel)** 6×10^{13} (forward)	3×10^{13} (barrel) **6×10^{13} (forward)**	3×10^{12}
Total Ionising Dose (Mrad)*	11	**3 (barrel)** / 3 (forward)	0.5 (barrel) / 3 **(forward)**	0.3

* updated values, from FLUKA simulations; safety factor to be decided

20x higher radiation load

- Pixel size being studied systematically
- OT: **pixel grouping** to be studied for reduction of power consumption, data routing complexity
- Complementarity between IT and OT important but different requirements
- Synergy with HEPHY being considered, to be discussed soon

ALICE 3 tracker: the software front

- Context: ALICE has expertise with low-p_T, high-multiplicity tracking only using TPC technology and at most $|\eta| < 1.5$
- ALICE 3 acceptance: $|\eta| < 4.0$: >2x larger!

- Requires major overhaul of ALICE software

- Tools exist (e.g. ACTS) but not at all optimised for:
  - High-multiplicity + low-p_T
  - Strangeness decays and tracking

- Enormous potential for ML application! →
- Needs to be firmly tethered to physics requirement
- PhD project included in FWF project for ALICE 3, in preparation

Ranking-based neural network for ambiguity resolution in ACTS

Corentin Allaire[1,*], *Françoise* Bouvet[1], *Hadrien* Grasland[1], and *David* Rousseau[1]

[1]Université Paris-Saclay, CNRS/IN2P3, IJCLab, 91405 Orsay, France

Abstract. The reconstruction of particle trajectories is a key challenge of particle physics experiments, as it directly impacts particle identification and physics performances while also representing one of the main CPU consumers of many high-energy physics experiments. As the luminosity of particle colliders increases, this reconstruction will become more challenging and resource-intensive. New algorithms are thus needed to address these challenges efficiently. One potential step of track reconstruction is ambiguity resolution. In this step, performed at the end of the tracking chain, we select which tracks candidates should be kept and which must be discarded. The speed of this algorithm is directly driven by the number of track candidates, which can be reduced at the cost of some physics performance. Since this problem is fundamentally an issue of comparison and classification, we propose to use a machine learning-based approach to the Ambiguity Resolution. Using a shared-hits-based clustering algorithm, we can efficiently determine which candidates belong to the same truth particle. Afterwards, we can apply a Neural Network (NN) to compare those tracks and decide which ones are duplicates and which ones should be kept. This approach is implemented within A Common Tracking Software (ACTS) framework and tested on the Open Data Detector (ODD), a realistic virtual detector similar to a future ATLAS one. This new approach was shown to be 15 times faster than the default ACTS algorithm while removing 32 times more duplicates down to less than one duplicated track per event.

CHEP 2023

Outlook

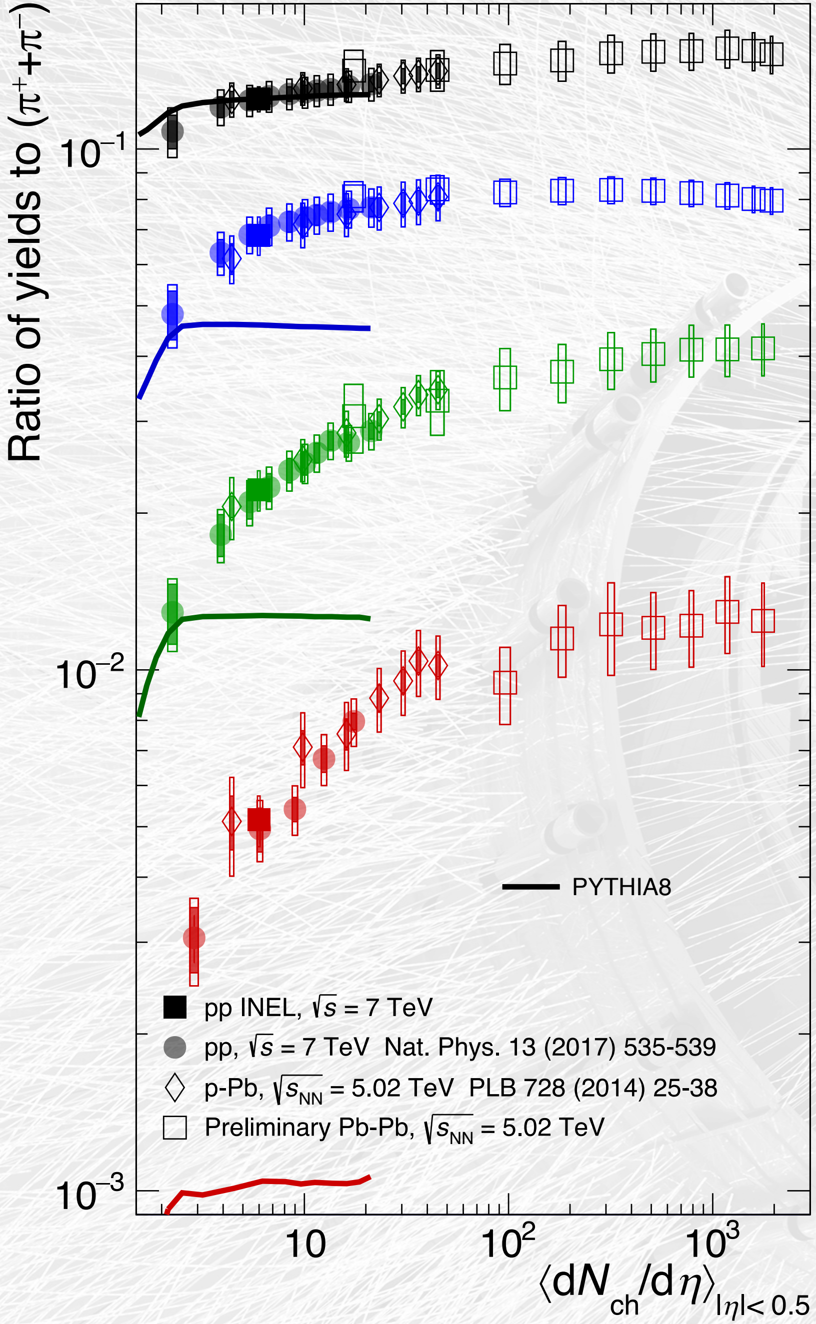
- ALICE SMI is engaged in, and will continue to be engaged in:
  - **Leadership in hadronization studies** with identified particles using Run 2 and Run 3 data
  - State-of-the-art **measurements of proton diffration and Tau g-2 using ultra-peripheral collisions**

- ALICE SMI targets:
  - A **stronger presence in the upgrade programme** of ALICE via participation in the ALICE 3 outer tracker efforts
  - 2025+: key contributions to the conceptual phase of deciding the tracker matrix: pixel grouping
  - 2025+: leveraging tracker specs towards unique state-of-the-art performance: low-pT, high-multiplicity weak decay (LF and HF) vertexing as well as strangeness tracking

- Longer term:
  - Contribution to ALICE 3 tracker performance tests and further developments once ALICE 3 is out of the conceptual design phase and as opportunities present themselves

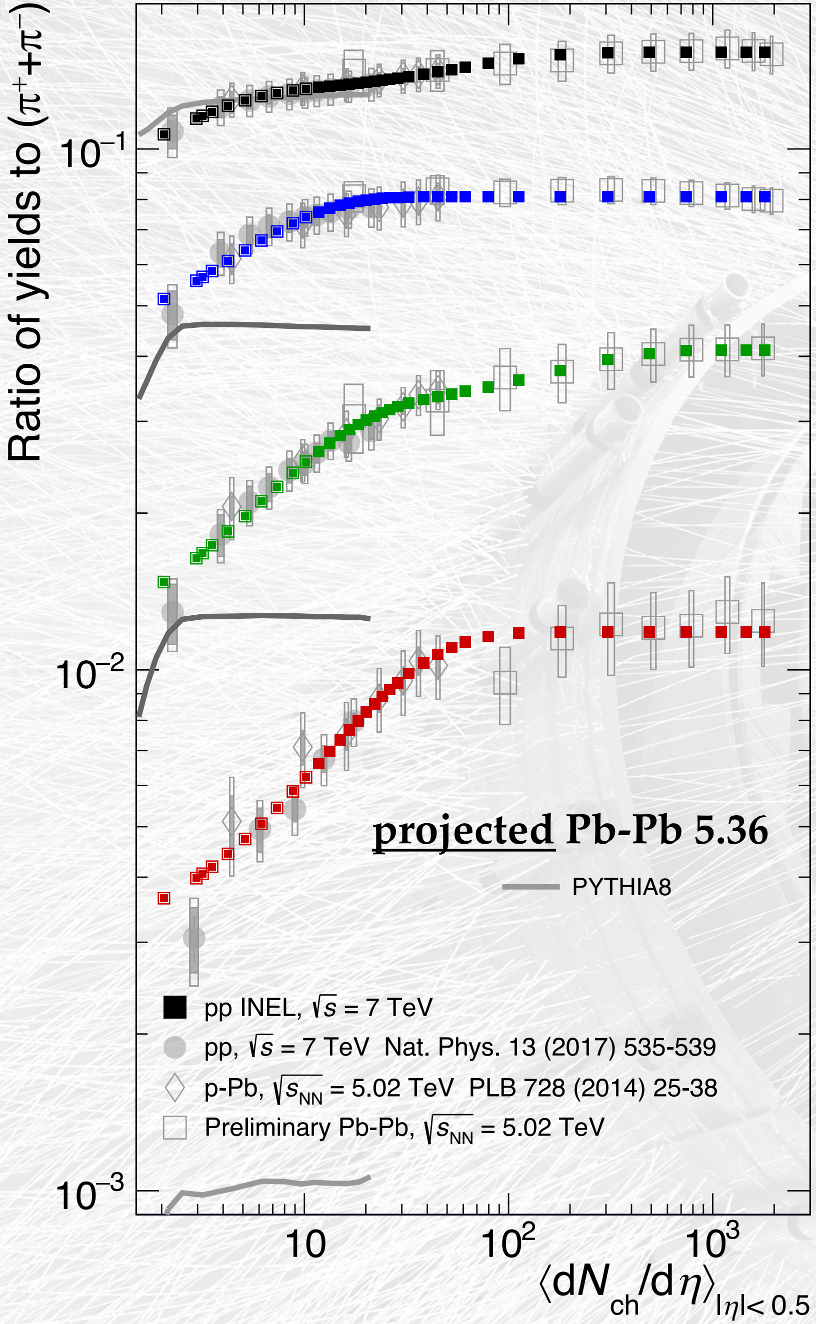
Thank you!

Backups



Strangeness enhancement: from 2 to 2000

- Physics motivation of strangeness analyses:
  - Baryon/meson ratio as a function of transverse momentum
  - Strange to non-strange particle ratios (shown with projected Pb-Pb!)
- **Onset behaviour within single system originally promised for Run 3 using pp**



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- **Onset behaviour within single system originally promised for Run 3 using pp**
- Pb-Pb 5.36 TeV provides us with the **unique opportunity to study onset behaviour with one single system** but "coming from above"!
- No extreme selection: **minuscule fraction of cross-section** not needed!
  - Selections remain at the percentage level
  - Projection: 1% wide from 80-100%, 2% wide from 70-80%, 5% wide from 60-70%
- Still, systematic uncertainties will be extremely challenging
  - Electromagnetic events dominate lowest multiplicities in Pb-Pb, to be studied
  - Expect news soon: **ALICE SMI is working on it**