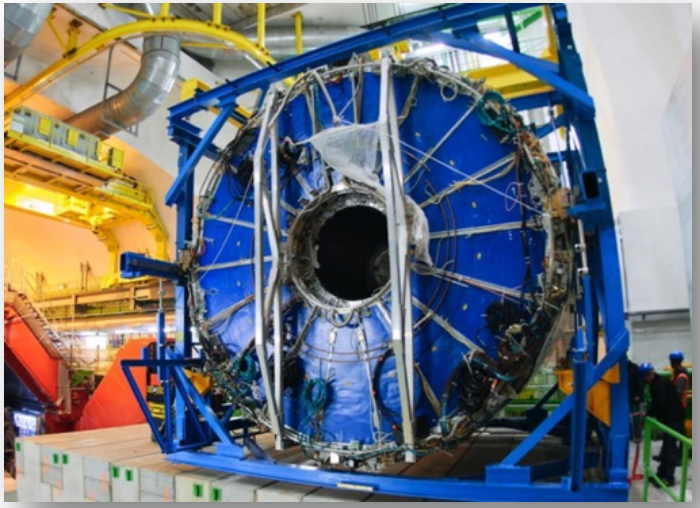
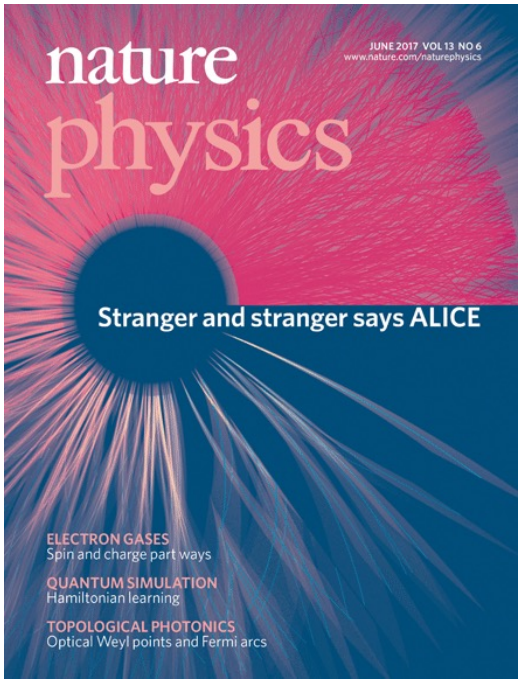
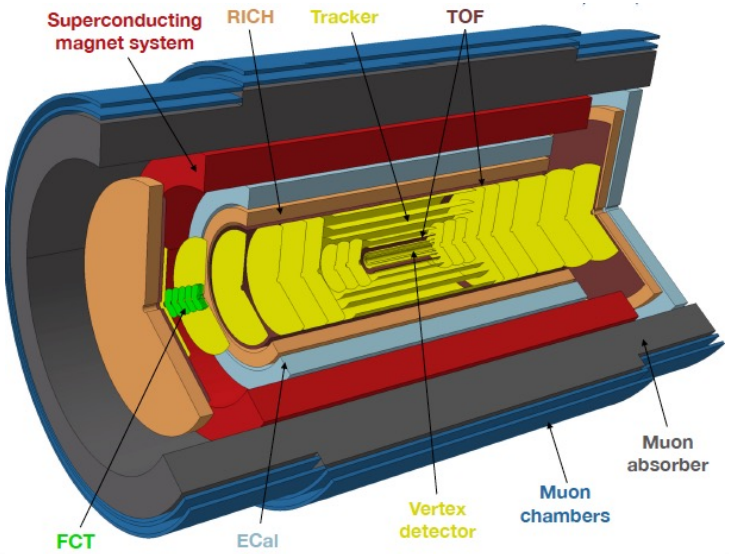
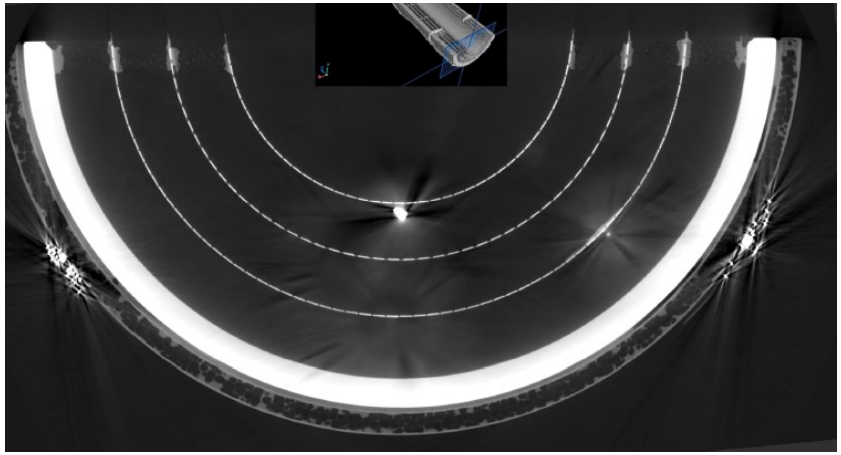
ALICE Activities in Lund





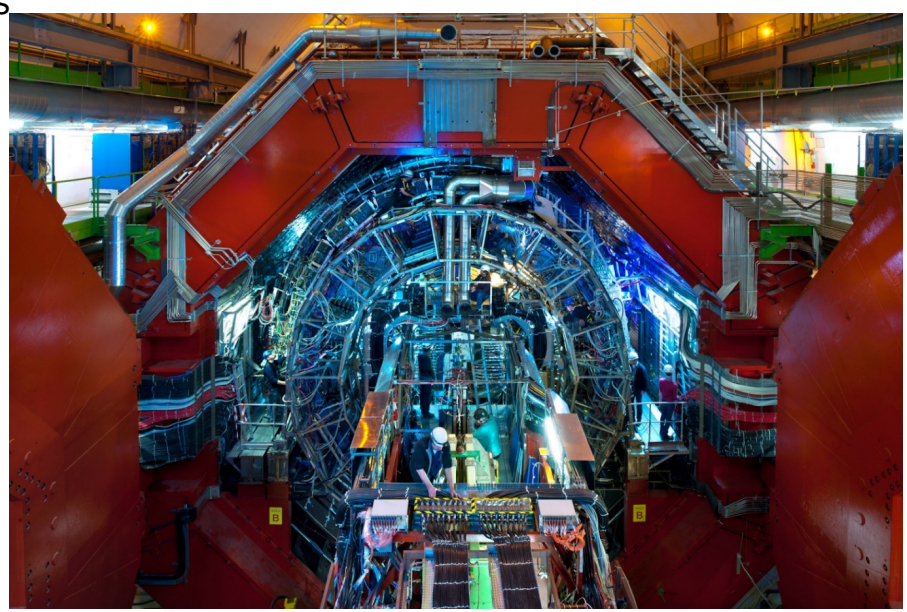




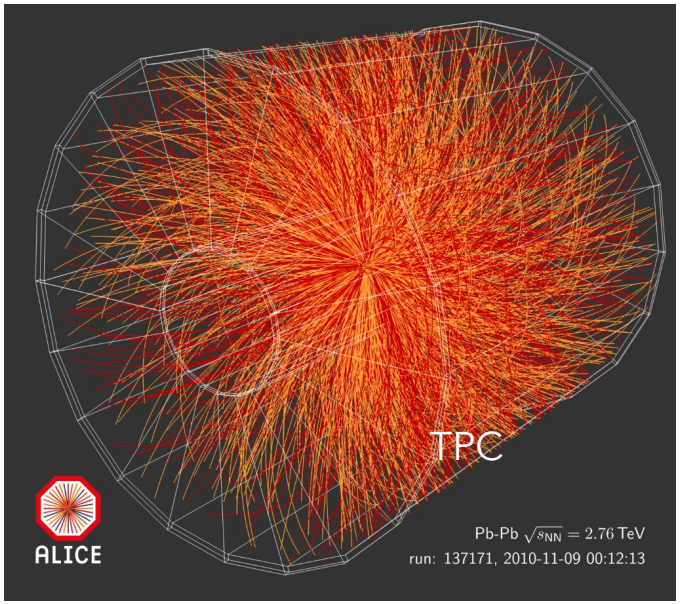
Intro: ALICE

ALICE studies the haystack

1000 authors
171 inst
40 countries



$10^{-42}m^3$ of Big Bang matter after $10^{-6}s$



PHYSICS

Lead Lead (PbPb) at LHC, Conditions much later (microseconds) during Big Bang

- Create Quark Gluon Plasma of nuclear size
- Bulk system of color charged particles.
- Thermodynamics of the strong force
- Phase transition to protons and neutrons (hadrons)

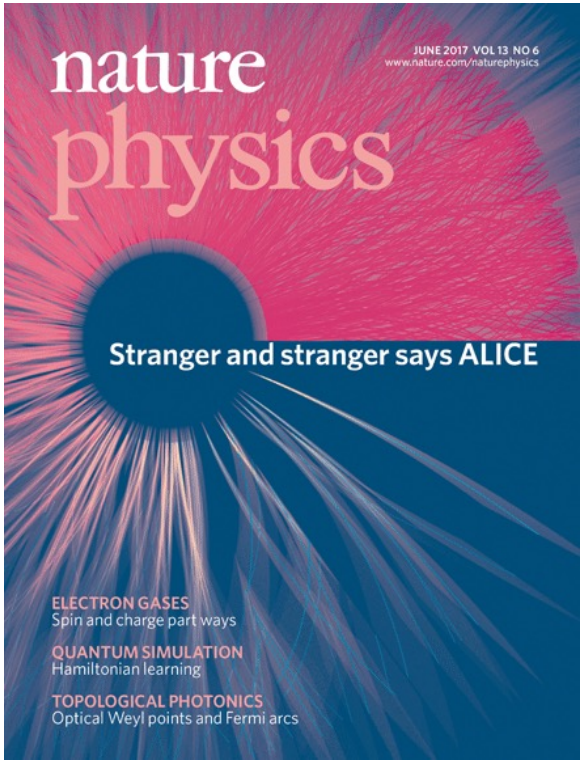
Experiment

- 1000 pp in $10^{-22}s$ – high multiplicity
- 10^4 Hz coll rate
- QGP debris - low momentum
- Difficult to trigger
- Particle identification (PID)
- Lund detector TPC 3D tracking +PID

Who: Lund ALICE Group

- 3 Seniors
  - Peter Christiansen, Alice Ohlson, David Silvermyr (HW)
    + Emeriti: Anders Oskarsson (HW)
- 1 Engineer (~25% FTE, 100% value)
  - Lennart Österman (HW)
- 2 Postdocs
  - Sumit Basu + new ITS3 Postdoc... (HW)
- 5 Ph.D. Students
  - Oliver Matonoha (defended June 9th), Joey Staa, Joachim Hansen, Kaare Iversen, Roman Nepeivoda
- Activities
  - Analysis: CLASH (KAW) – strangeness, fluctuations
  - Hardware: recent TPC Upgrade/Electronics (LS2), **future ITS3 (LS3),** ALICE 3 (LS4) : 3-4 people + 2 master students 2023
  - Individuals also work on detector R&D for: ILC (TPC), HIBEAM/NNBAR experiment at ESS, ESS**ν**SB, s/ePHENIX/EIC: more opportunities than we can really pursue...

ALICE Lund Group Activities - Analysis



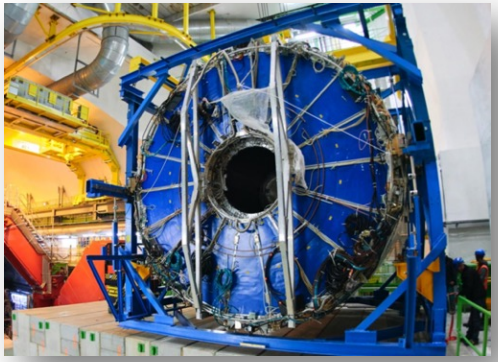
New small system physics:
- strangeness enhancement (LU),
- flow in small systems.

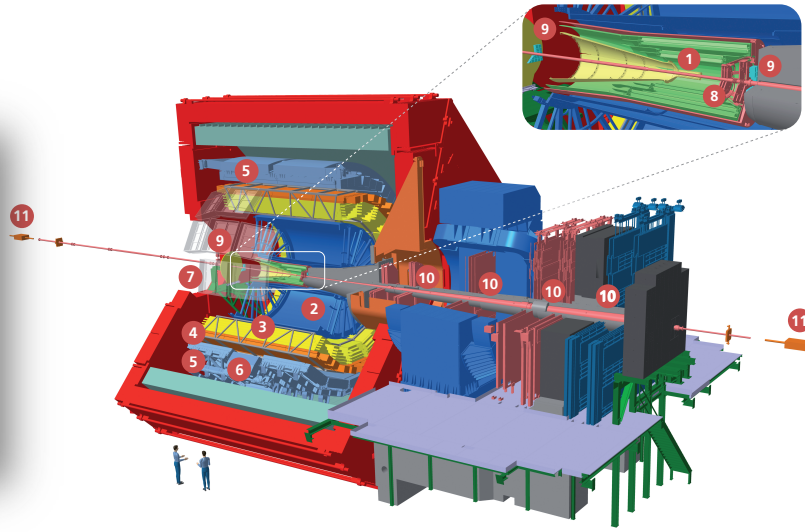
KAW grant (CLASH), with Peter C. and Leif Lönnblad as co-PIs to pursue this further

Spåtind 2023 overview of experimental results in heavy ion physics, Alice Ohlson:
https://indico.cern.ch/event/1168768/contributions/5177022/

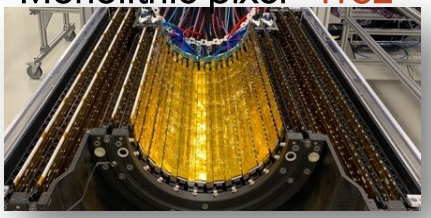
ALICE Detector Upgrades during LS2 (2019-2021)

GEM-based TPC readout

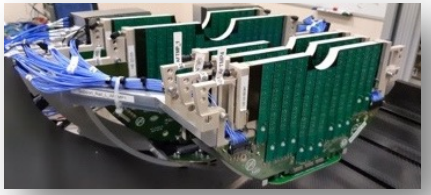




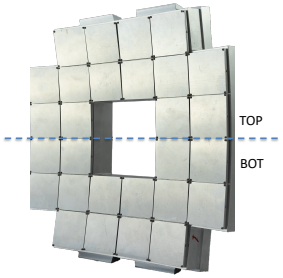
Monolithic-pixel - ITS2



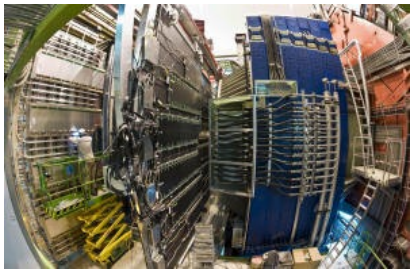
Pixel Muon Forward Tracker (MFT)



Fast Interaction Trigger FIT



Muon Spectrometer



New Central Trigger Processor (CTP)

Upgrade of R/O for EMCal, PHOS, TRD, HMPID, ZDC

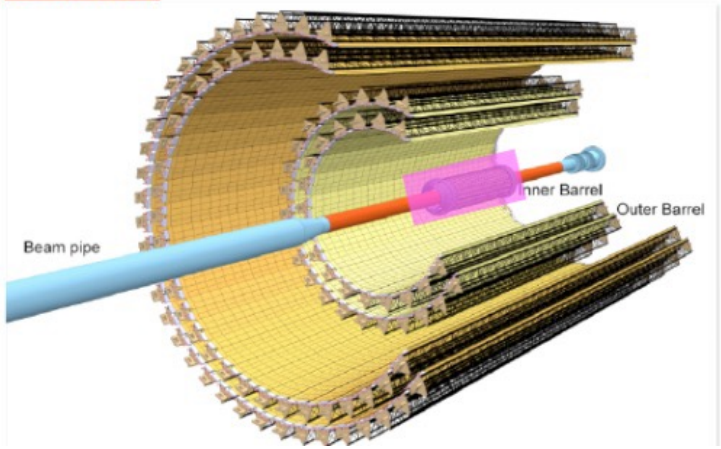
New Online/Offline (O2)

Present/Future: ALICE Pixel Detectors

*VR/RFI funding for LU activities 2022-2026 with ITS3

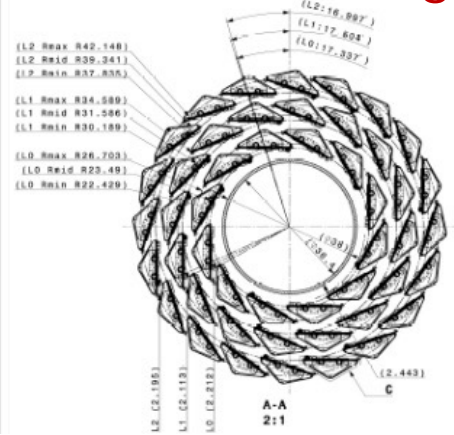
ALICE – Inner Tracker 2 – 2022

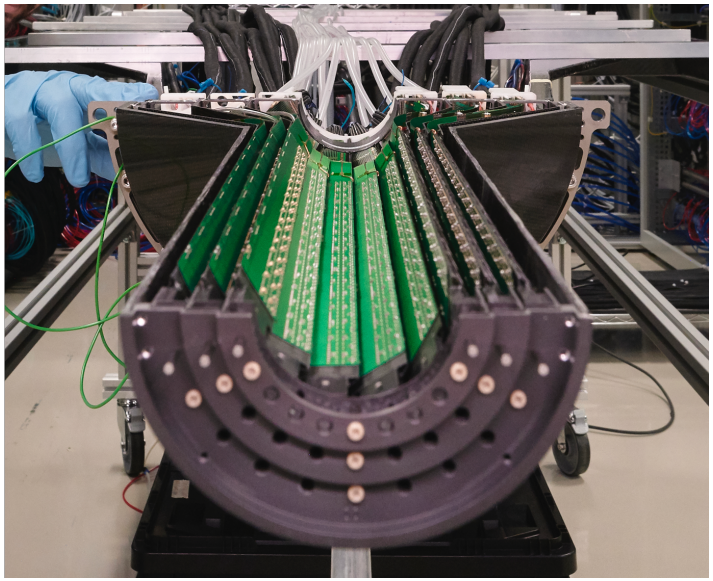
ITS2 layout



Inner barrel

3 layers
27 cm long

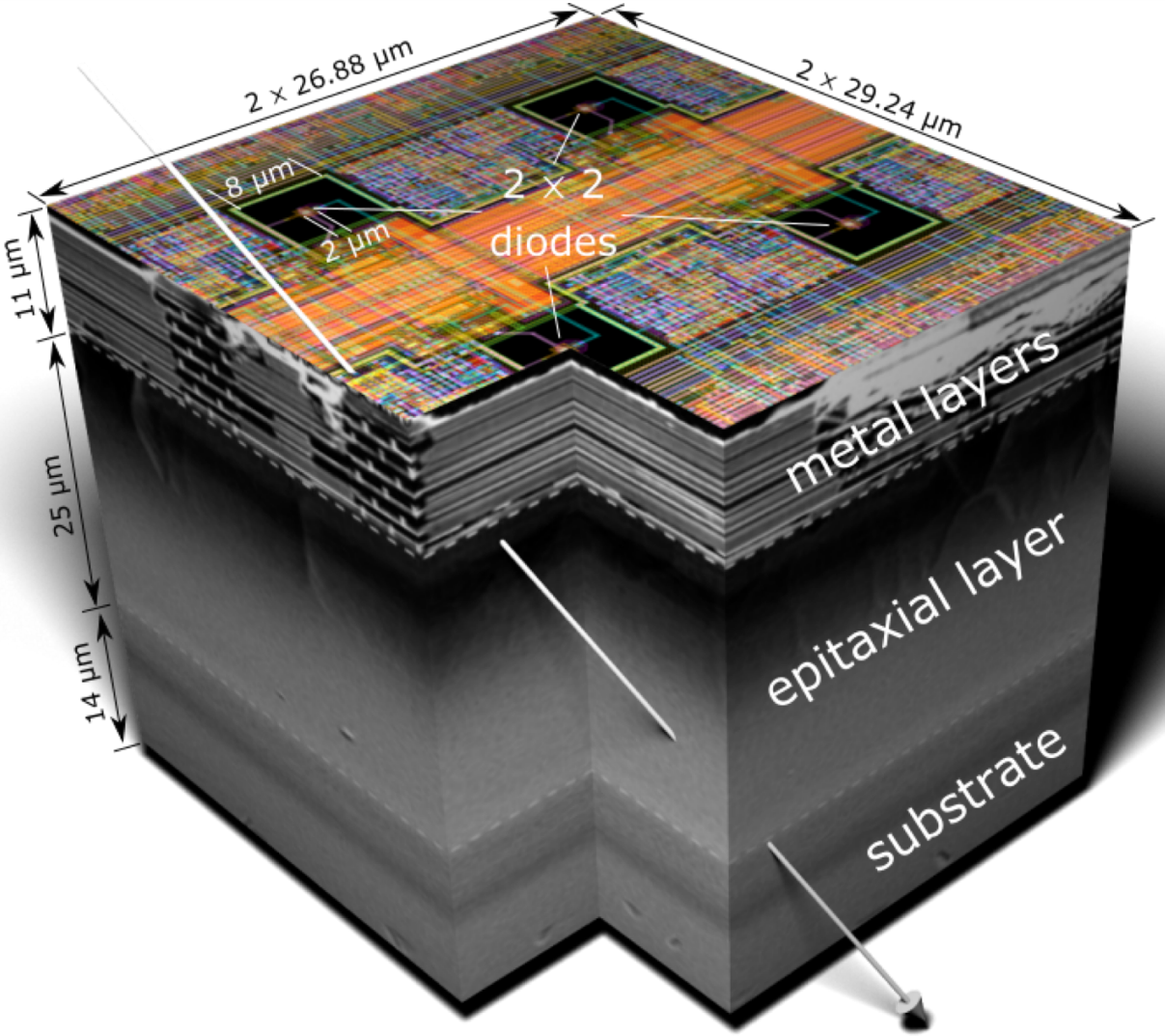




2022 Run3/4 ITS2
12.5 10^9 pixels, ~10 m^2 Si
IB: 30 x 30 μm^2 pixel size
0.35% X_0 (radiation length)

hybrid flex HDI
water cooling
CF support

Pixel Structure (2x2)

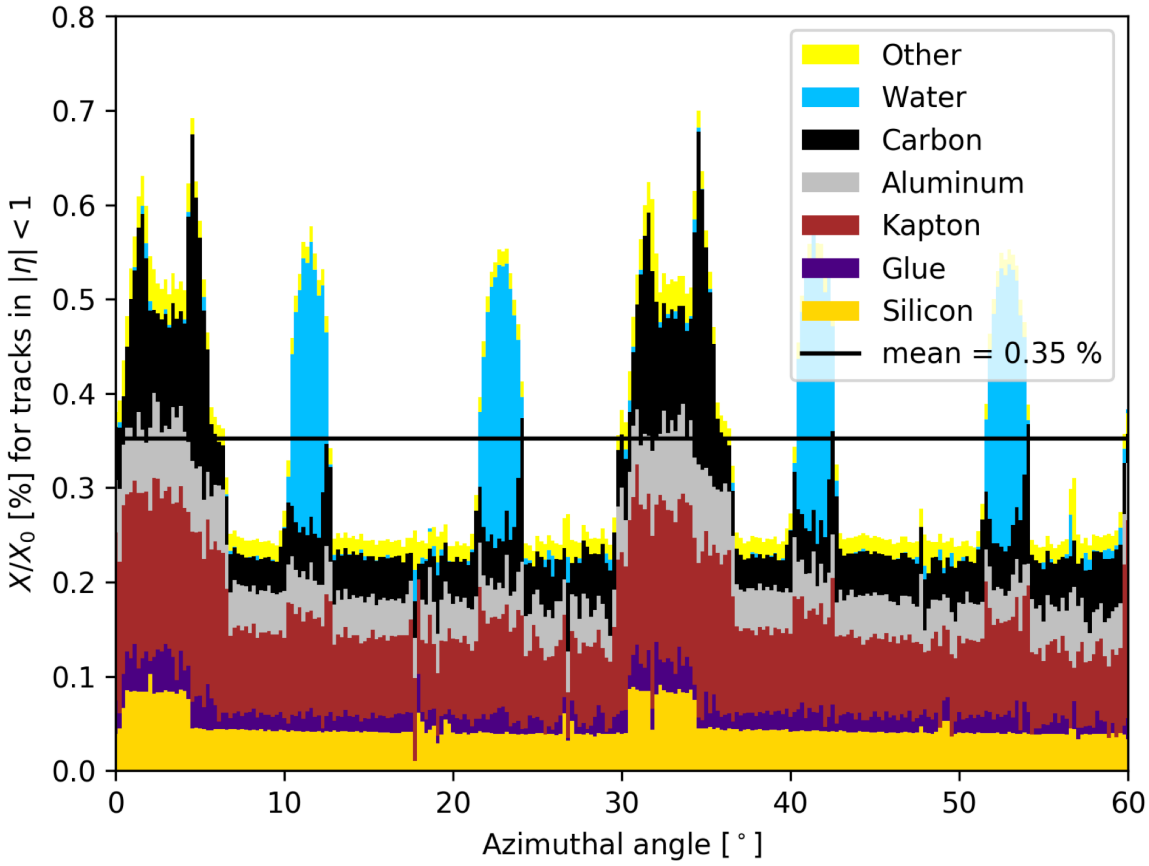


Transistors

Detector material

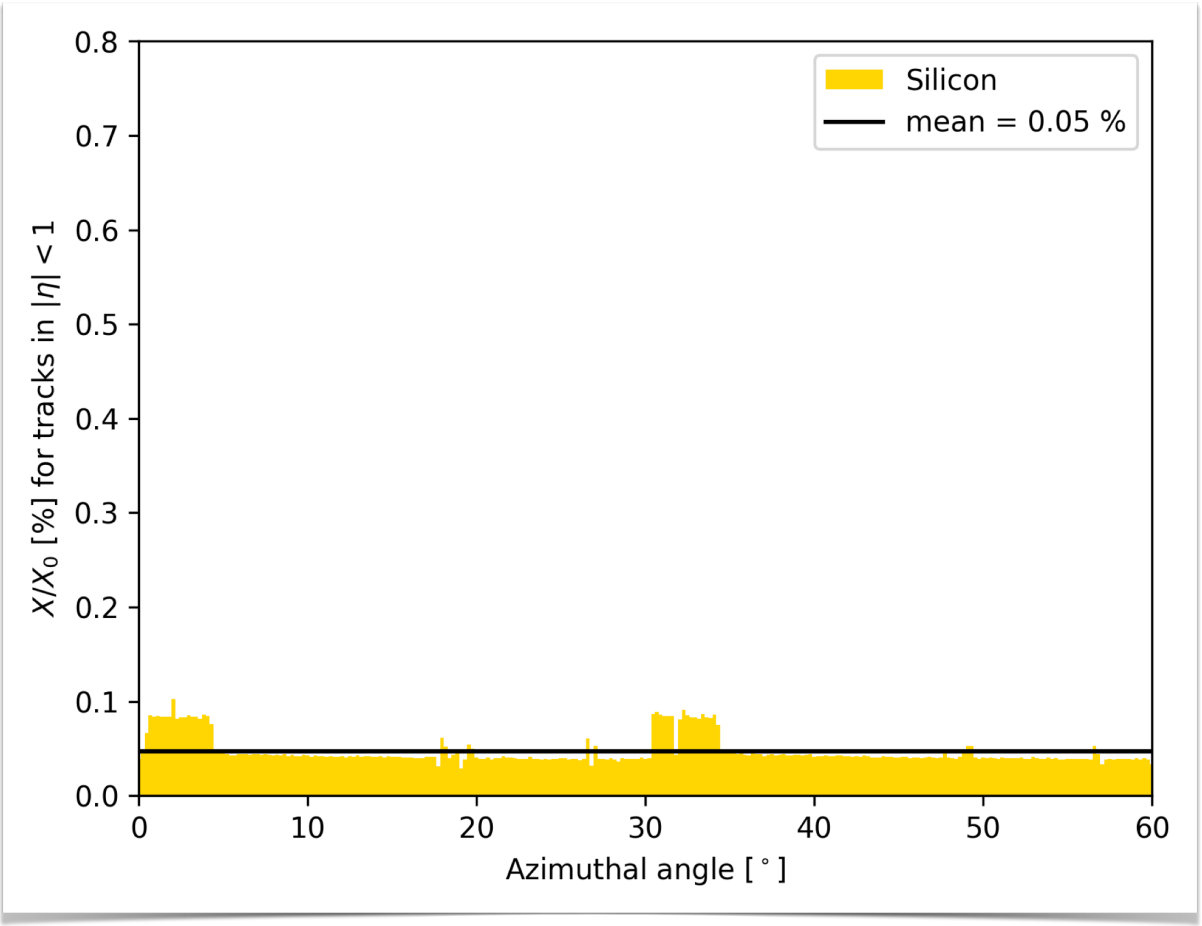
Material Budget ITS2

Prop. to track distortions



- ITS2
  - 0.35% X_0 per layer
  - Silicon contributes 15% only
  - Irregularities due to support/cooling
- What if ?
- Water cooling is removed
  - Air cooling
  - → 0.31% X_0 per layer
- Removal of the HDI hybrid flex board (power & data)
  - If integrated on silicon ASIC
  - → 0.14% X_0 per layer
- Removal of mechanical support
  - Stability due to bent silicon wafers
  - → 0.05% X_0 per layer

Material Budget ITS2 → ITS3



- ITS2
  - 0.35% X_0 per layer
  - Silicon contributes 15% only
  - Irregularities due to support/cooling
- What if ?
- Water cooling is removed
  - Air cooling
  - → 0.31% X_0 per layer
- Removal of the HDI hybrid flex board (power & data)
  - If integrated on silicon ASIC
  - → 0.14% X_0 per layer
- Removal of mechanical support
  - Stability due to bent silicon wafers
  - → 0.05% X_0 per layer

ITS3 Specifications & Layout

- Concept
  - replace inner 3 layers of ITS2 with ITS3

    280 mm long sensor ASICs

    out of 300 mm long stitched (overlapping metal layers) wafers

    20-40 µm thick (0.02-0.04% X_0)

    15 x 15 µm^2 pixel size

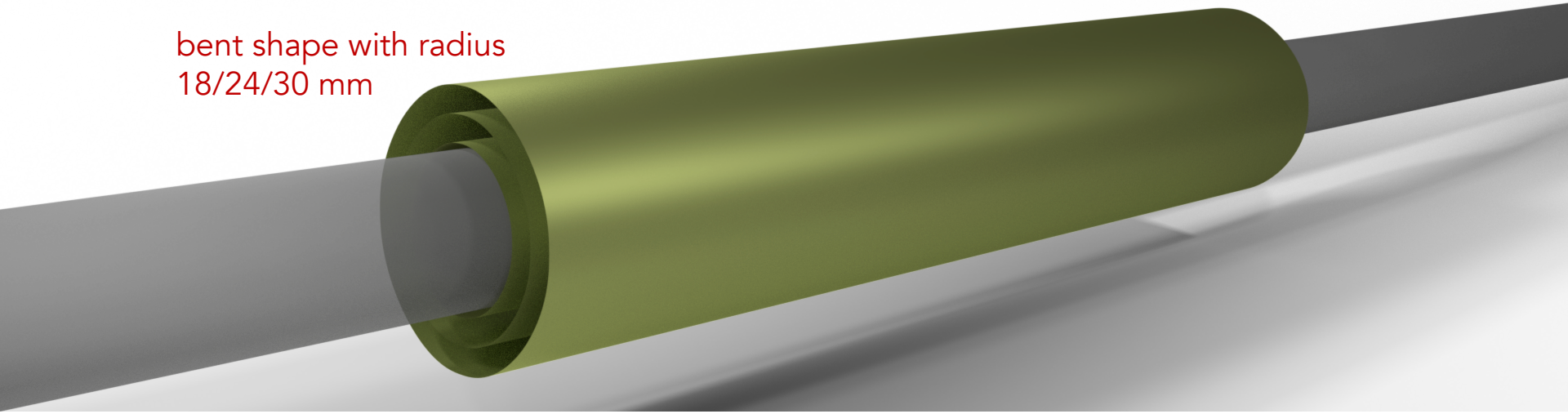
    bent shape with radius 18/24/30 mm

    carbon foam rib to hold ASICs in place

    air cooling

    homogenous material distribution

  - 6 sensor ASICs
    - 2 halves * 3 layers

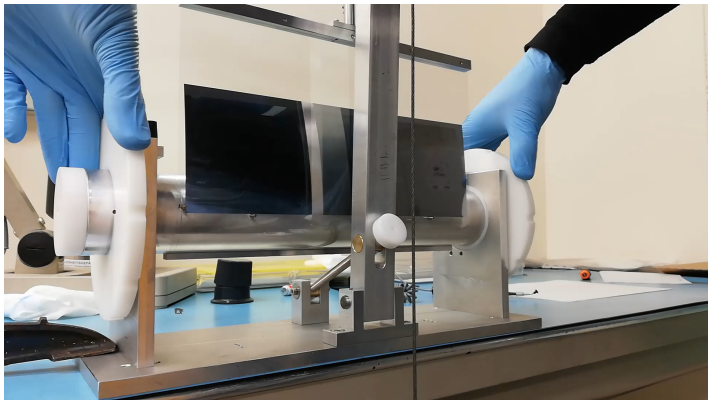


ITS3 Questions

- Idea
  - remove all but the silicon sensor ASIC and
  - bend it around beam pipe
    - for increased performance and mechanical stability
- Questions (many already adressed by collaborators)
  - Can thin silicon be bent without breaking?
  - Are bent silicon sensor ASICs functional?
  - Can long, thinned silicon sensors be integrated without a heavy CF structure?
  - Can the sensor be cooled with air-only efficiently?
  - Can a 280 mm long silicon sensor ASIC be produced?
  - Can the sensors be connected without additional HDI?

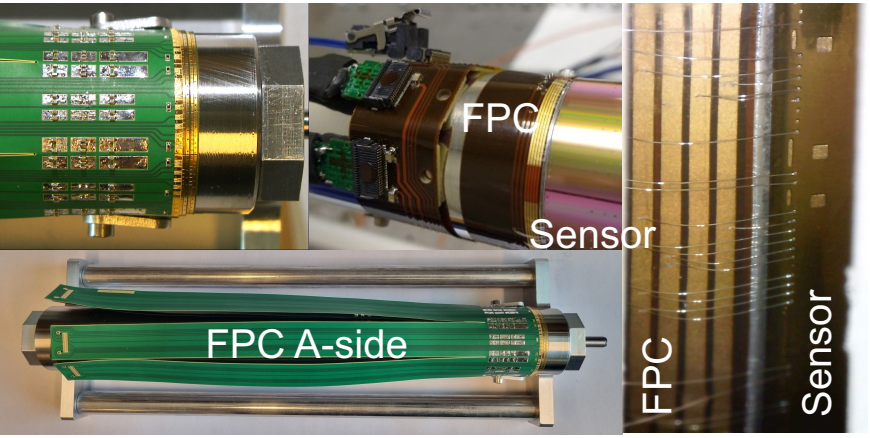
ITS3 Assembly

1) Sensor bending

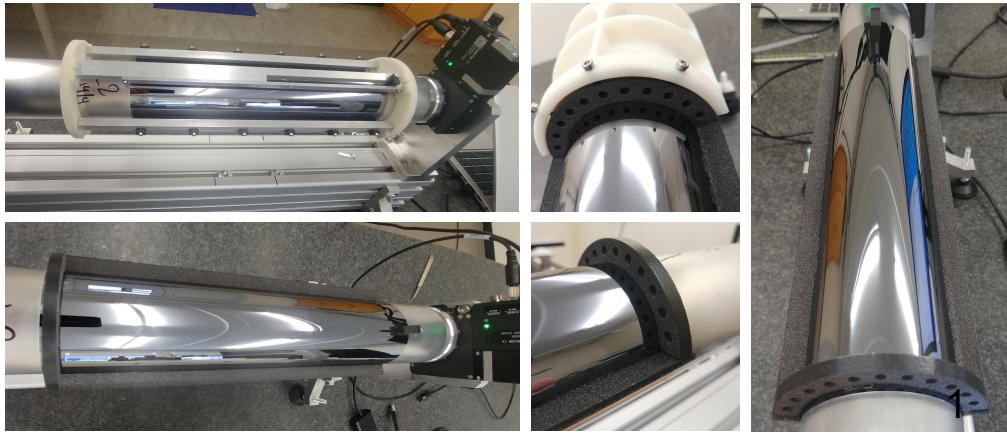


Half layer bending assembly sequence consolidated

2) Wire-bonding



3) Gluing of the mechanical supports



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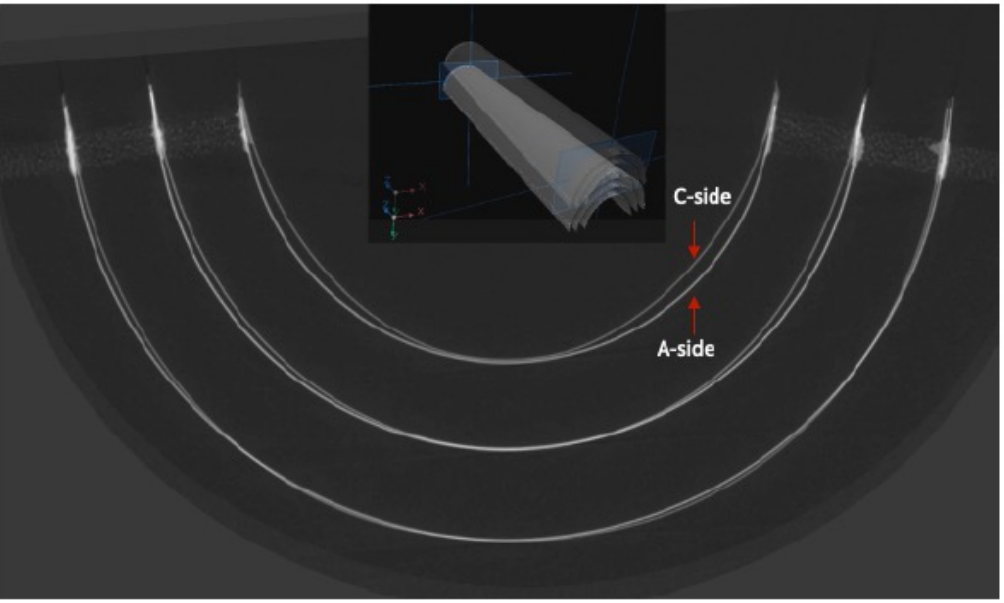
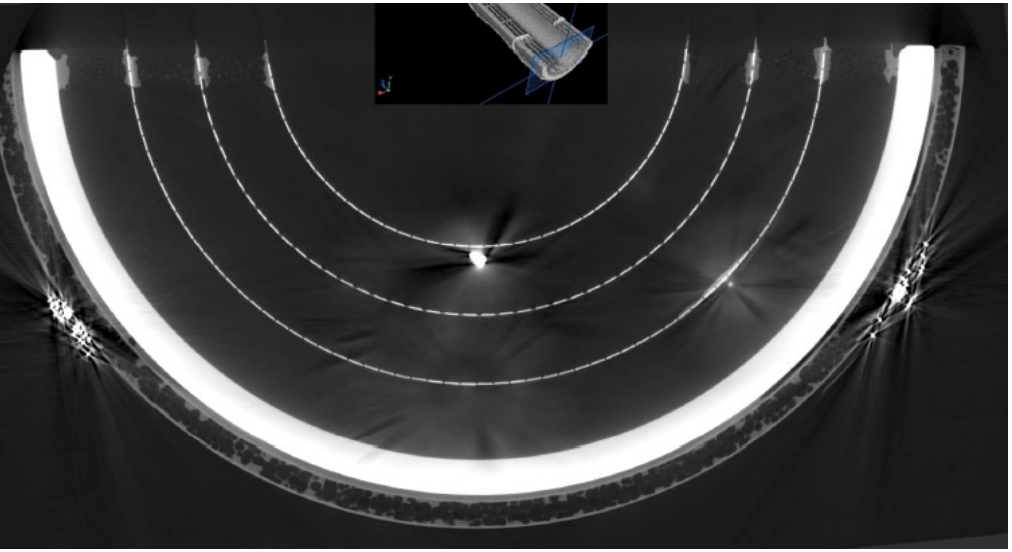
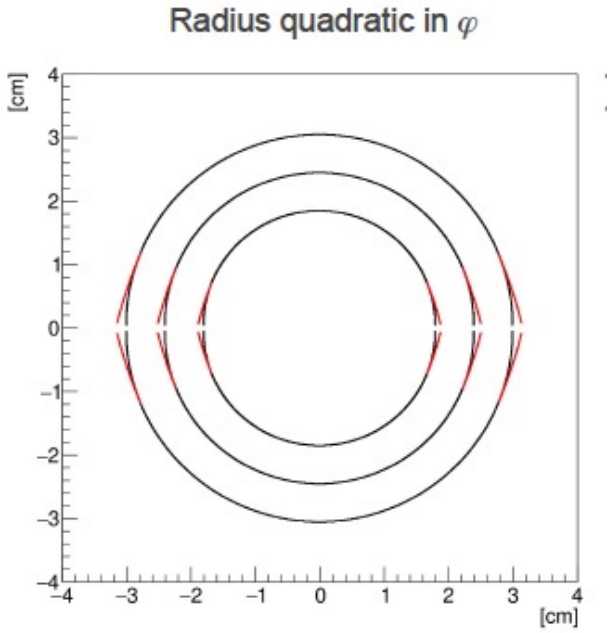
LU Master Student Project (Jesper K G)

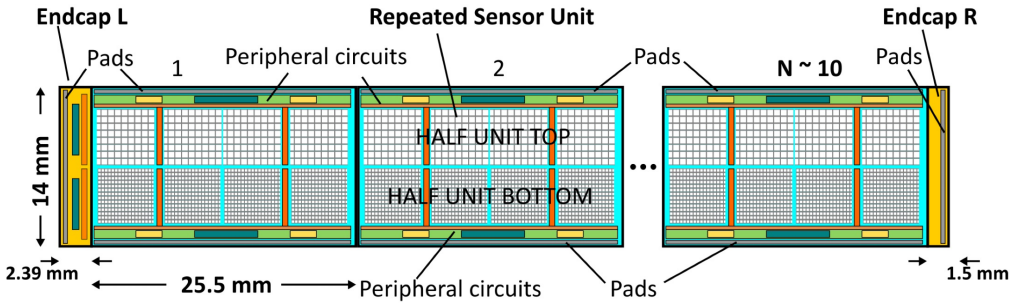


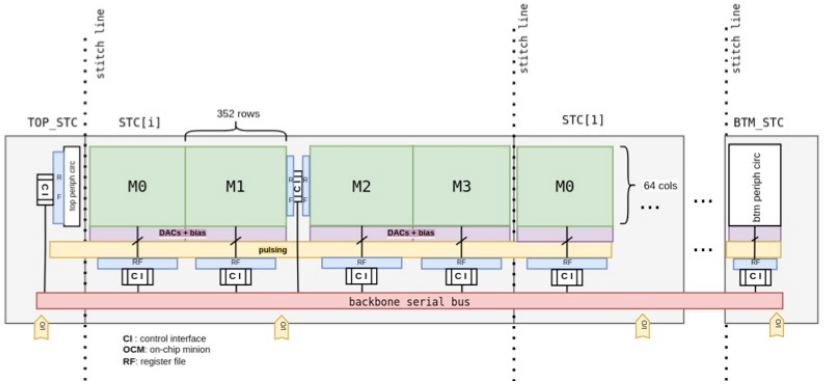


Implemented different distorsion models
Studies effects on vertexing & tracking efficiency, tracking resolution



Stitched sensor ASICs (MOSS)





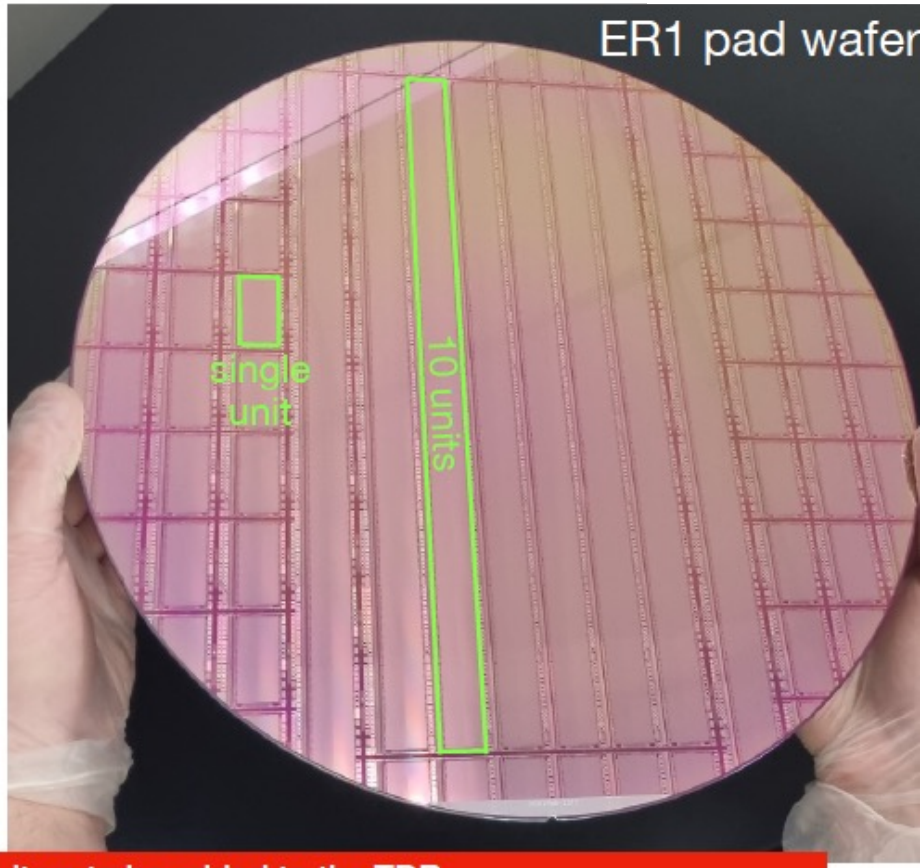
Primary Goals (Engineering Run 1)
Learn Stitching to make a charged particle detector
Interconnect power and signals on wafer scale design
Learn about yield
Study power, leakage, spread, noise, speed

MOSS / ER1 (May 2023)

Wafer-scale sensors

Engineering Run 1 (ER1) is back

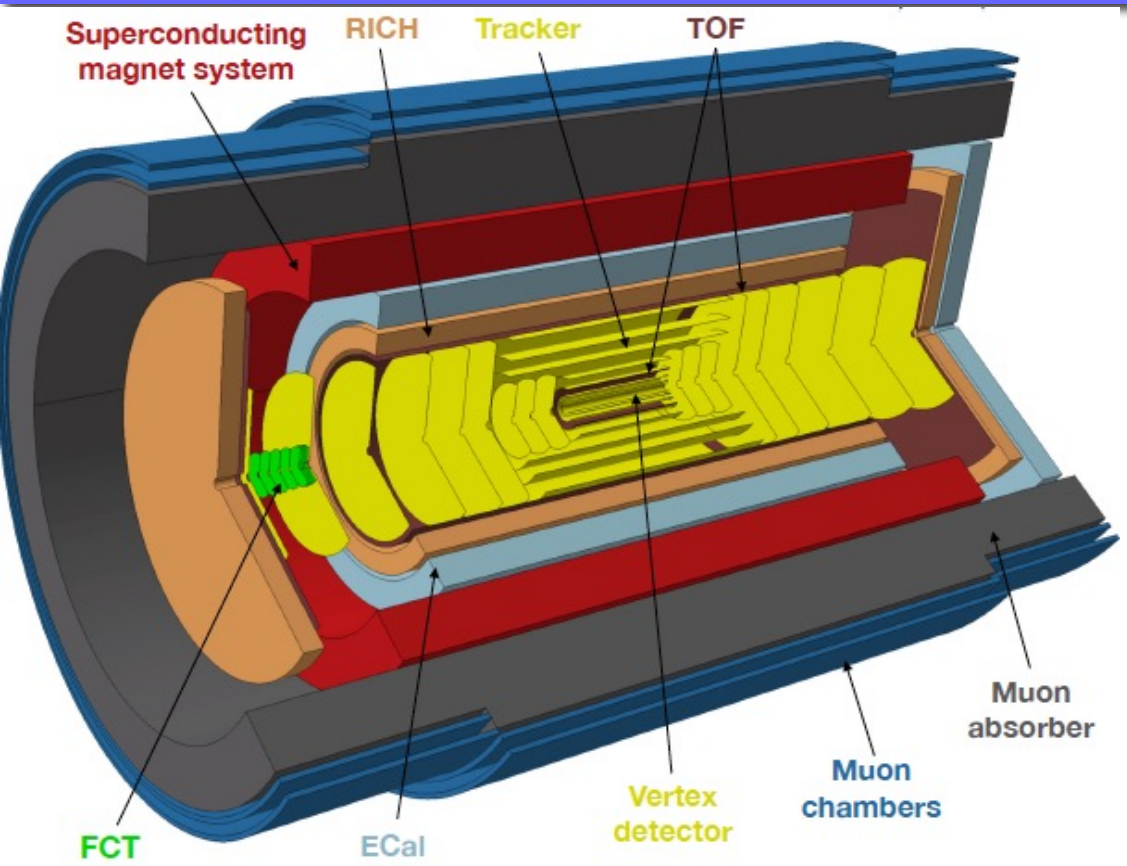
- First MAPS for HEP using stitching
  - one order of magnitude larger than previous chips
- "**MOSS**": 14 x 259 mm, 6.72 MPixel (22.5 x 22.5 and 18 x 18 μm²)
  - conservative design, different pitches
- "**MOST**": 2.5 x 259 mm, 0.9 MPixel (18 x 18 μm²)
  - more dense design
- Plenty of small chips (like MLR1)



This is the crucial and last remaining item to be added to the TDR

Lund is joining testing of large and small MOSS prototypes

ALICE 3: a next generation HI detector for Run 5 & 6



Fast and ultra-thin detector with precise tracking and timing

- Another factor 50x in luminosity
- Exploit higher LHC lumi with nuclei lighter than Pb
- Ultra-lightweight tracker based on CMOS pixels (MAPS), ~70 m^2 Si
- Si-based Time Of Flight determination: ~20ps time resolution
- Fast to sample large luminosity: 50-100x Run 3/4
- Large acceptance barrel + end caps $\Delta\eta = 8$

Ultimate performance for HF, thermal radiation and soft hadrons (p_T < 50 MeV/c)

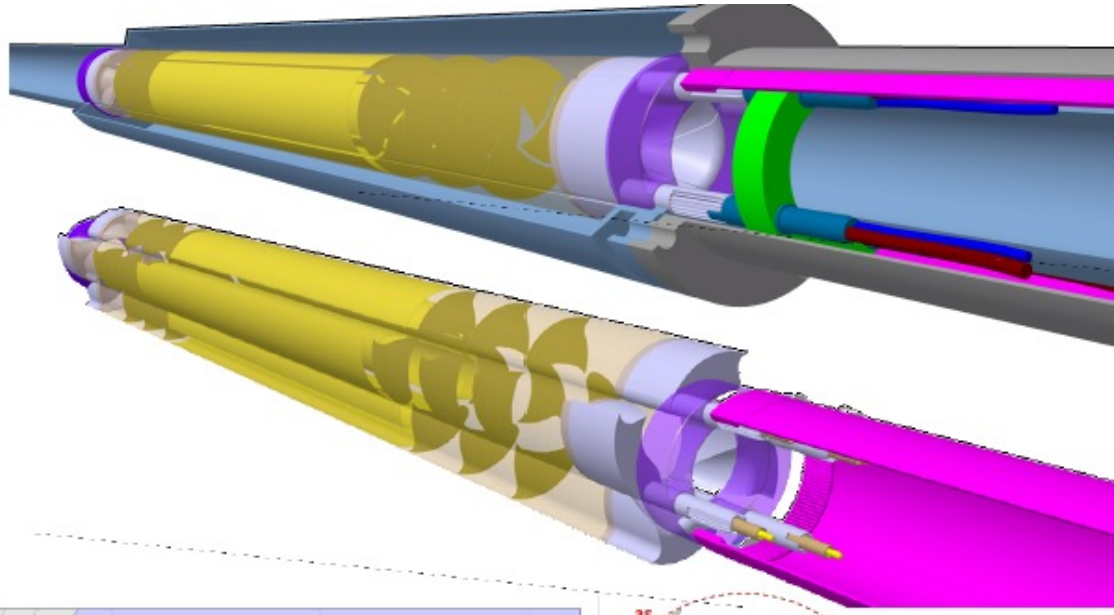
- Multiply heavy flavour, hadron production, multi-quark states
- Chiral symmetry restoration (e.m. probes)
- Beyond HI (phase space complementary to other experiments)
  - Violation of fundamental properties of quantum field theories (emission of soft photons)
  - New physics in soft sector, e.g. dark photons

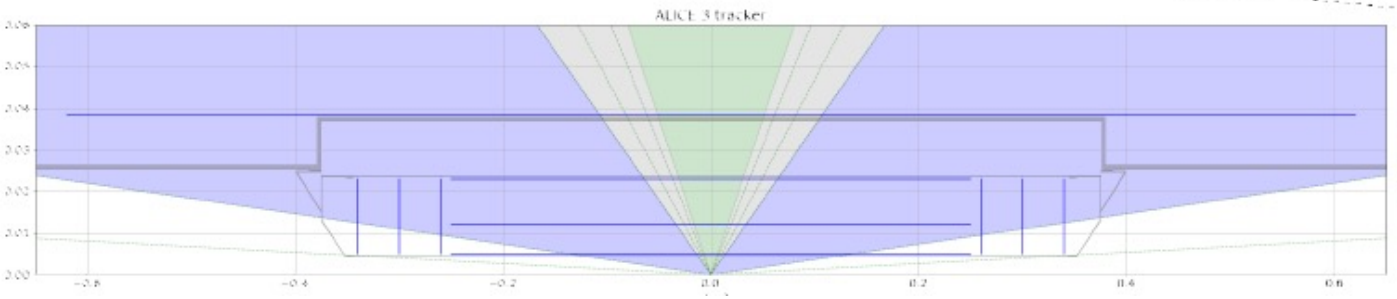
LoI : arXiv:2211.02491

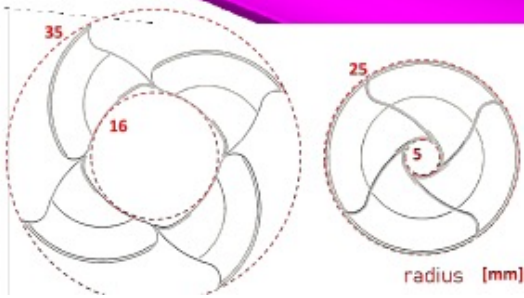
ALICE3 Inner Tracker / Vertex Detector

Main challenges: mechanical integration (inside beam pipe), spatial resolution (2.5 μm, i.e. 10 μm pitch), radiation hardness, power consumption…

- **Conceptual study of iris tracker**
  - Wafer-sized, bent MAPS (leveraging on ITS3 activities)
  - Rotary petals for secondary vacuum (thin walls to minimise material)
  - Matching to beam pipe parameters (impedance, aperture, …)
  - Feed-throughs for power, cooling, data
- **R&D programme** on mechanics, cooling, radiation tolerance





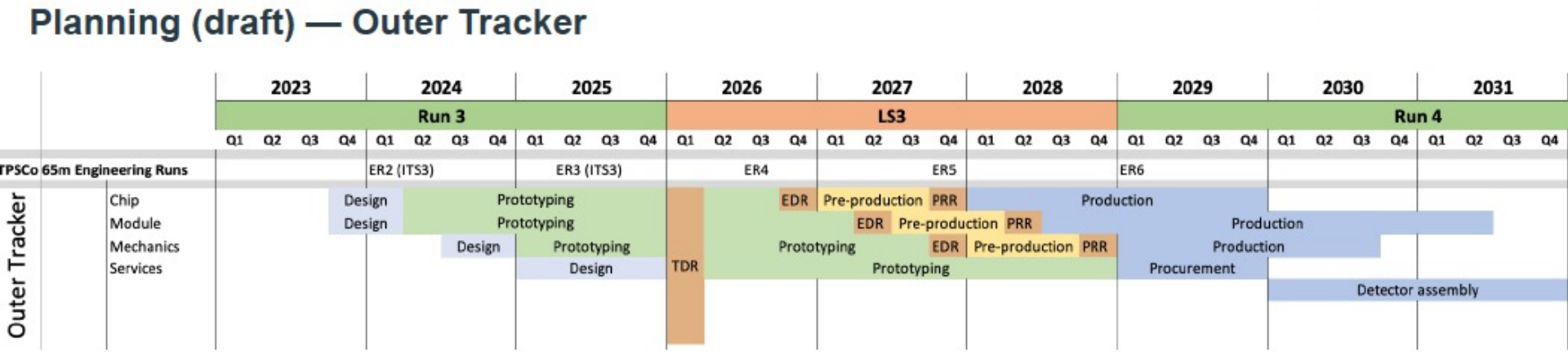


ALICE3 Outer Tracker

Outer Tracker: ~70 m^2 Si… (50 μm pixel pitch)

Main challenges: mass production, services integration, power consumption, fake-hit rate

Large involvement from former ALICE TPC group (as for ITS3 leadership)

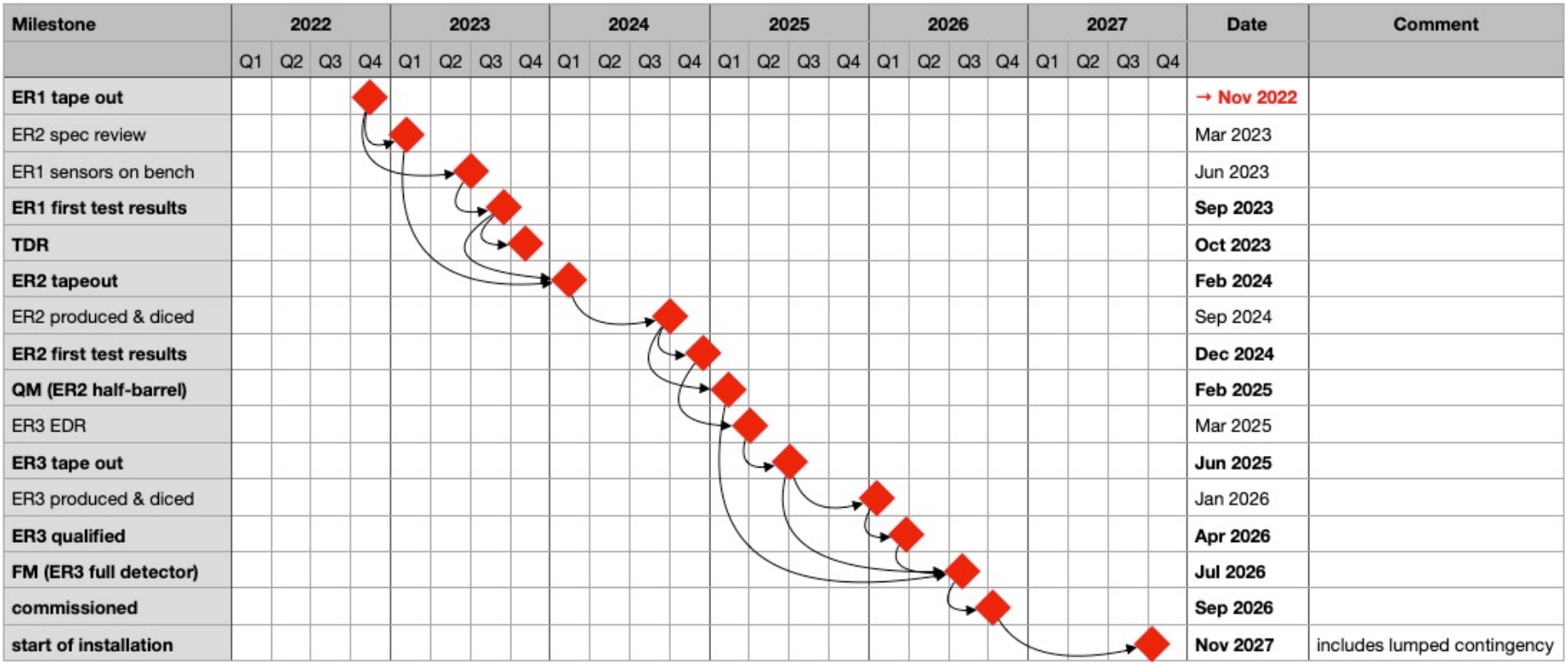


Summary

- Major ALICE upgrade during LS2 to take advantage of the luminosity increase. Lund heavily involved in TPC upgrade, in particular readout electronics.
- Lund group also lead ongoing analyses, in particular investigating strangeness production in smaller systems (e.g. pp in QGP domain).
- Present and future exciting hardware involvement in ITS3 (installation in ~2027) and ALICE3 (possible installation ~2033, Behovsinventering list 2023…).

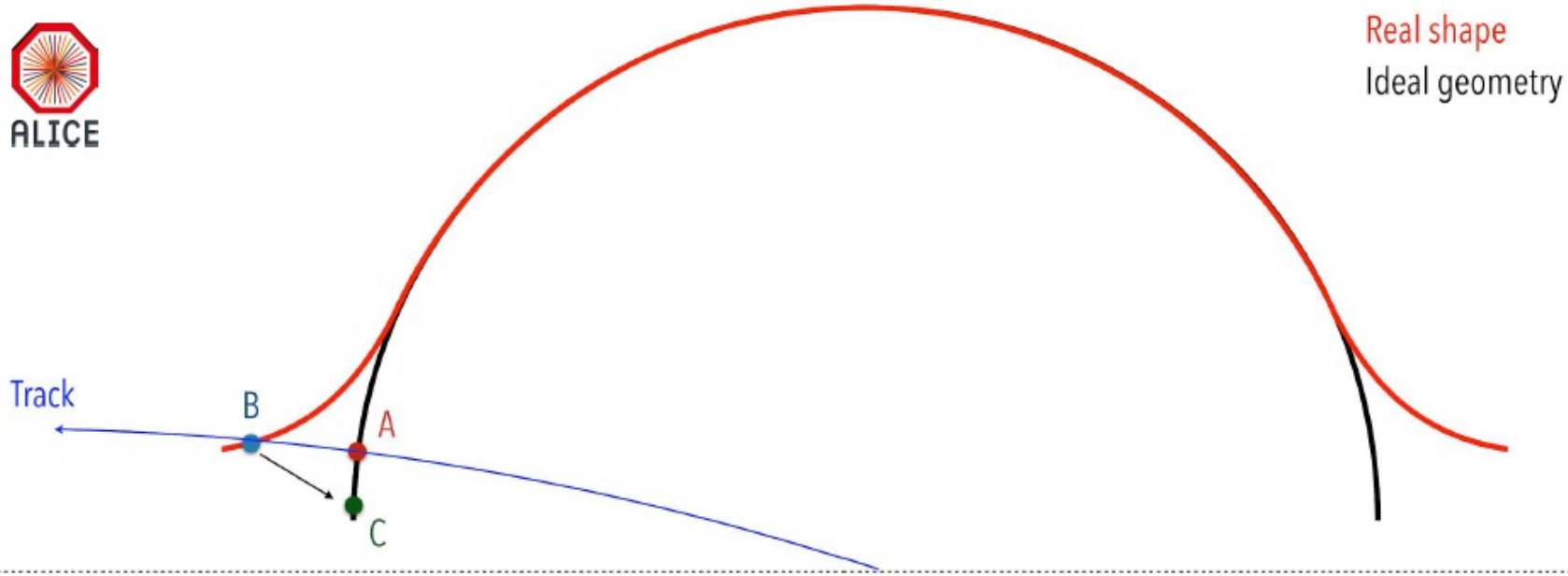
Extra

ITS3 Timeline



Milestone	2022				2023				2024				2025				2026				2027				Date	Comment
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4		
ER1 tape out																									→ Nov 2022	
ER2 spec review																									Mar 2023	
ER1 sensors on bench																									Jun 2023	
ER1 first test results																									**Sep 2023**	
TDR																									**Oct 2023**	
ER2 tapeout																									**Feb 2024**	
ER2 produced & diced																									Sep 2024	
ER2 first test results																									**Dec 2024**	
QM (ER2 half-barrel)																									**Feb 2025**	
ER3 EDR																									Mar 2025	
ER3 tape out																									**Jun 2025**	
ER3 produced & diced																									Jan 2026	
ER3 qualified																									**Apr 2026**	
FM (ER3 full detector)																									**Jul 2026**	
commissioned																									**Sep 2026**	
start of installation																									**Nov 2027**	includes lumped contingency

LU Master Student Project (Jesper K G)



A: hit that one would measure with an ideal geometry
B: real (measured) hit
C: measured hit projected in the ideal geometry
$\vec{\delta} = |A - C|$

2