ALICE upgrades

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CTU
CZECH TECHNICAL UNIVERSITY IN PRAGUE

4th miniworkshop difrakce a ultraperiferalnich srazek
15th September 2021

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EVROPSKÁ UNIE
Evropské strukturální a investiční fondy
Operační program Výzkum, vývoj a vzdělávání

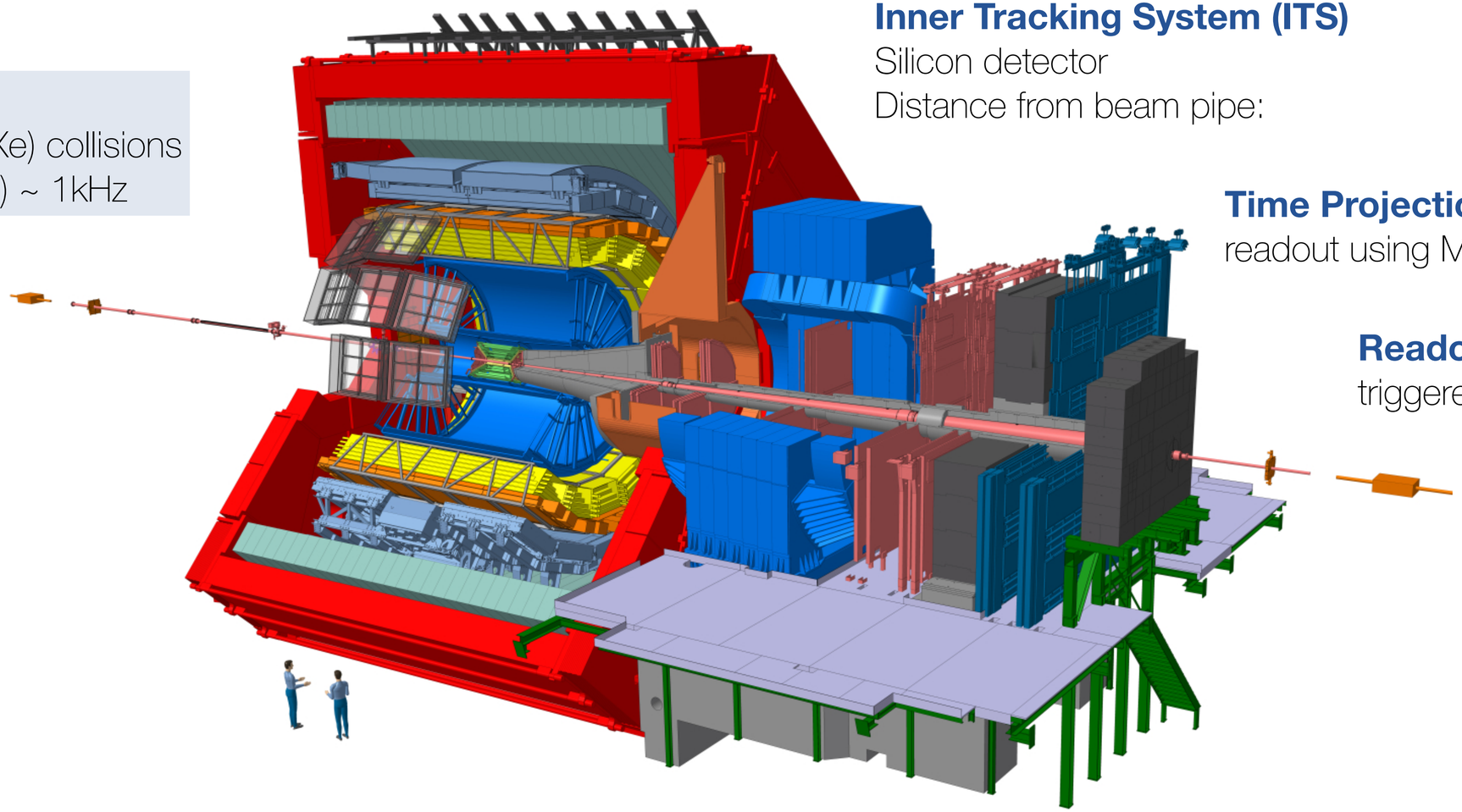
MINISTERSTVO ŠKOLSTVÍ, MLÁDEŽE A TĚLOVÝCHOVY

Current ALICE

2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020

Run 1 | **LS 1** | **Run 2** | **LS 2**

Runs 1 and 2:
pp, pPb, PbPb (XeXe) collisions
Readout rate (PbPb) ~ 1kHz



Inner Tracking System (ITS)
Silicon detector
Distance from beam pipe:

Time Projection Chamber (TPC)
readout using MWPC

Readout system
triggered data

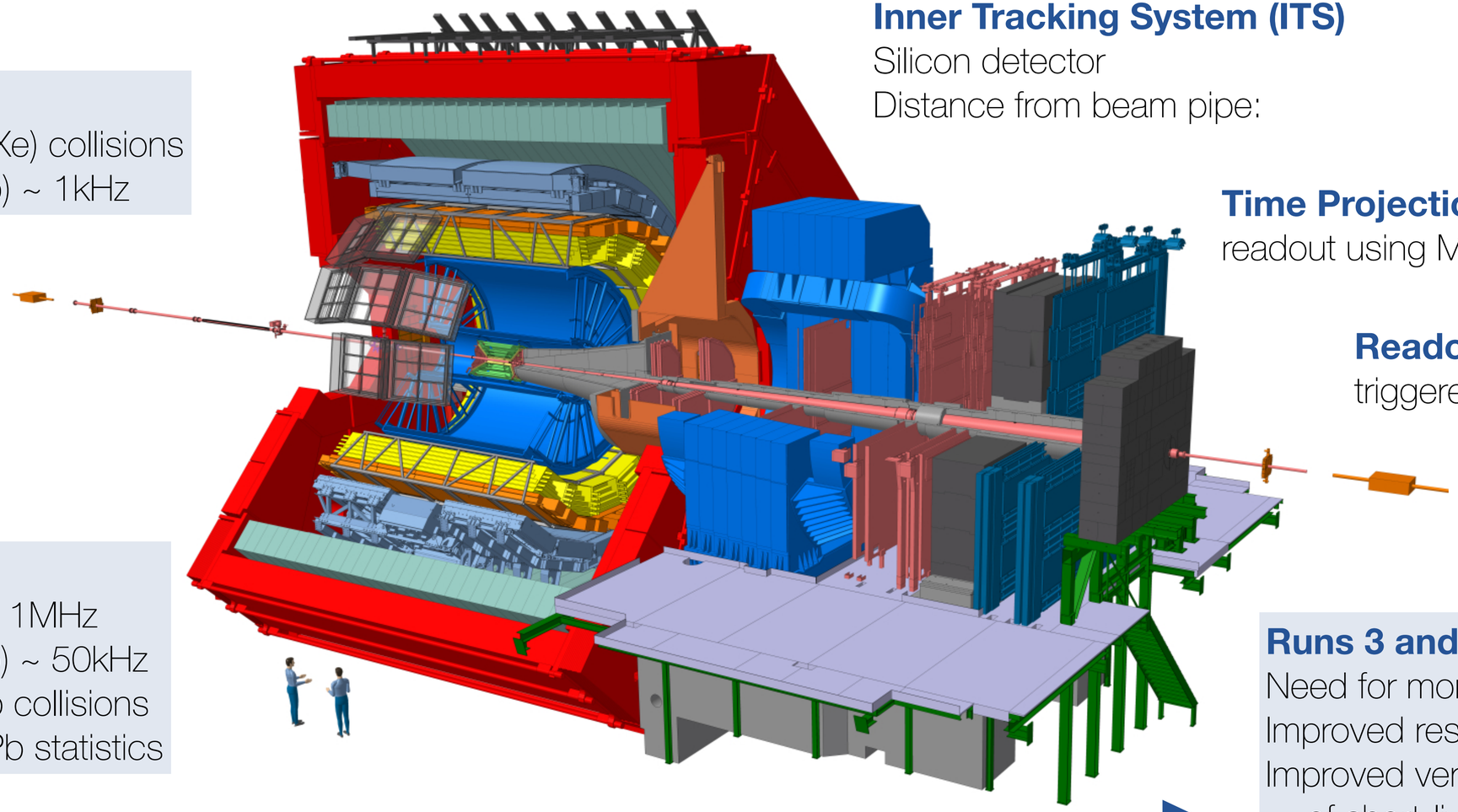
Current ALICE

2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020

Run 1 | **LS 1** | **Run 2** | **LS 2**

Runs 1 and 2:
pp, pPb, PbPb (XeXe) collisions
Readout rate (PbPb) ~ 1kHz

Runs 3 and 4:
Readout rate (pp) ~ 1MHz
Readout rate (PbPb) ~ 50kHz
pp, pPb, OO, PbPb collisions
x50 PbPb, x200 pPb statistics



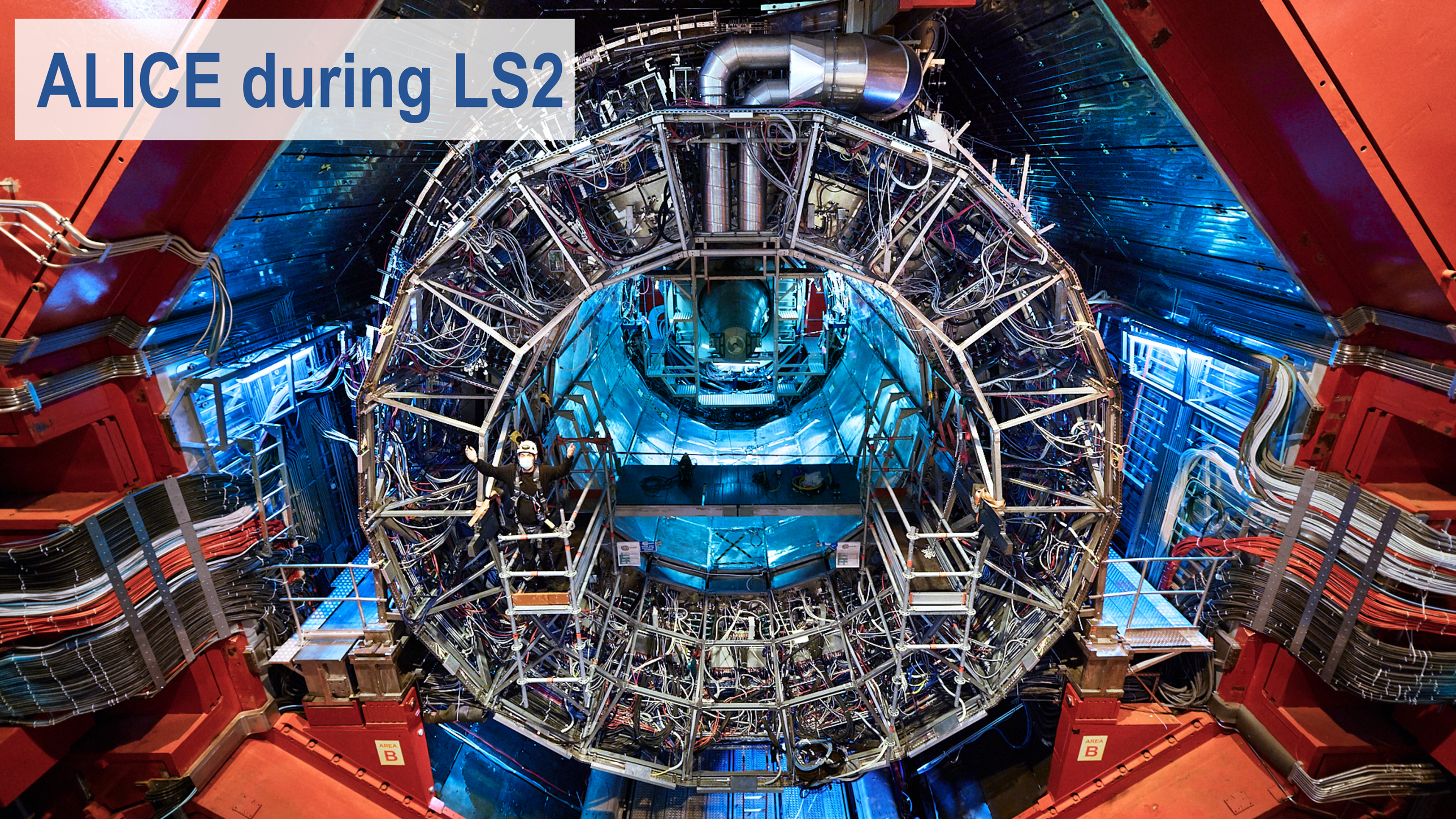
Inner Tracking System (ITS)
Silicon detector
Distance from beam pipe:

Time Projection Chamber (TPC)
readout using MWPC

Readout system
triggered data

Runs 3 and 4:
Need for more statistics
Improved resolution (at low p_T)
Improved vertex reconstruction of short-lived particles

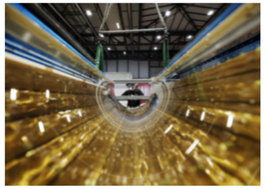
ALICE during LS2



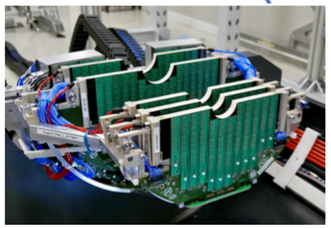
ALICE during Run 3

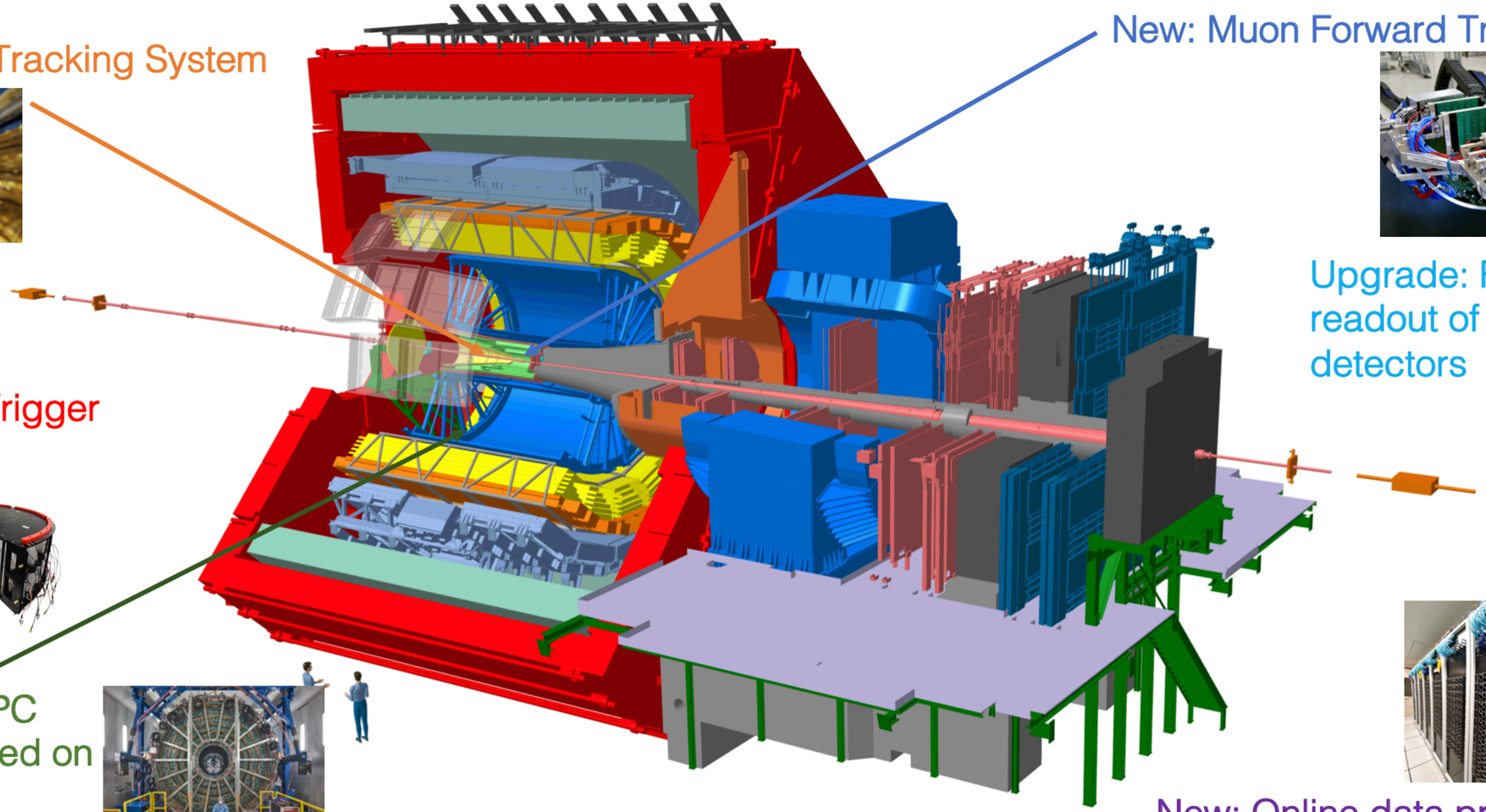
2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
Run 3				LS 3	Run 4				LS 4	Run 5	

New: Inner Tracking System



New: Muon Forward Tracker (MFT)





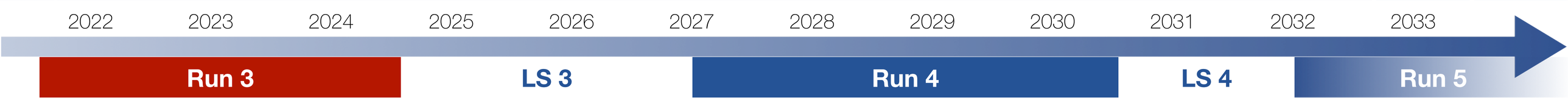
Upgrade: Frontend readout of various detectors

New: Fast Interaction Trigger (FIT)

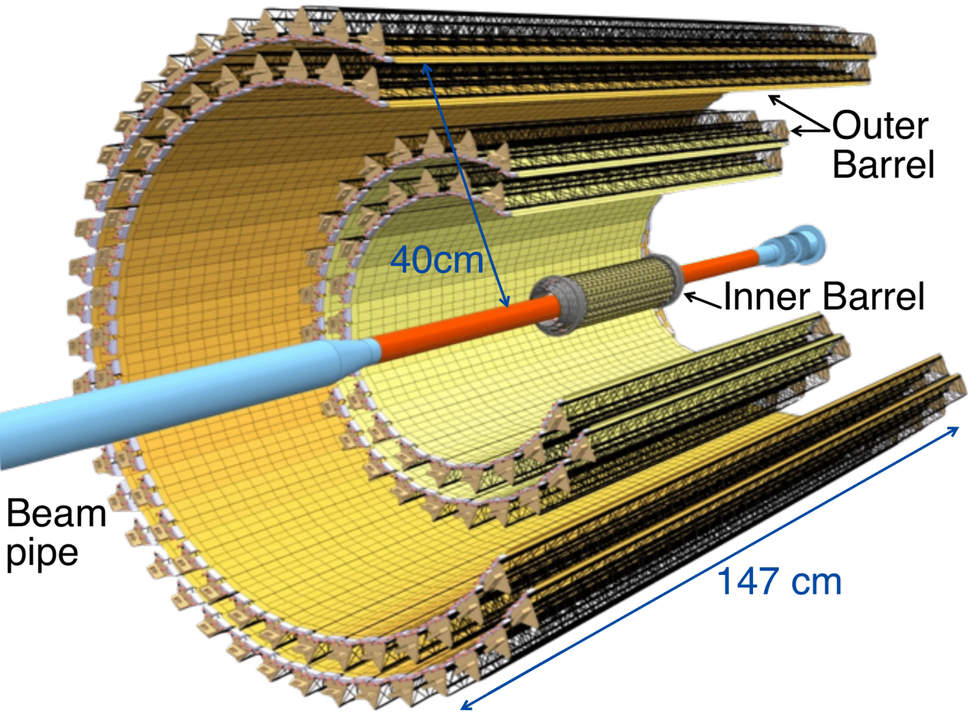
Upgrade: TPC readout based on GEM stacks

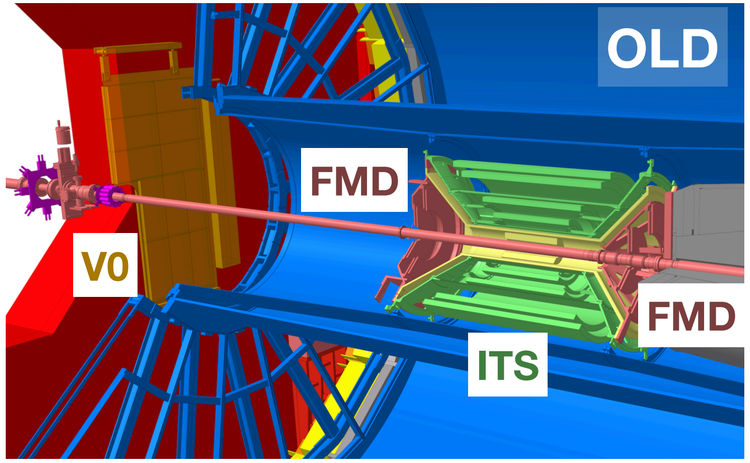
New: Online data processing (O^2)

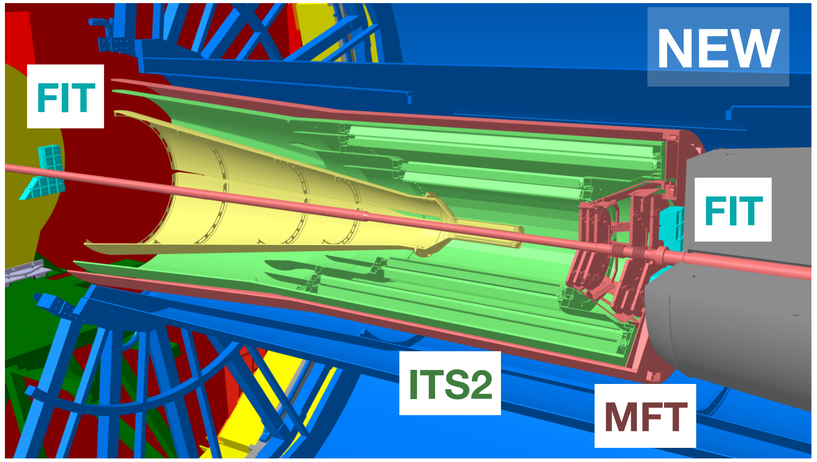
ALICE during Run 3



Inner Tracking System ITS2





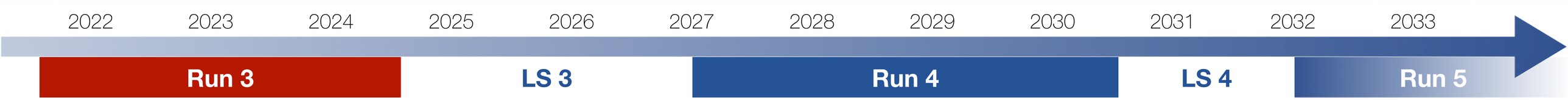


ALPIDE chip: based on MAPS (Monolithis Active Pixel Sensor
- Thickness: 50 μm
- Granularity: 2000 pixels/cm^2

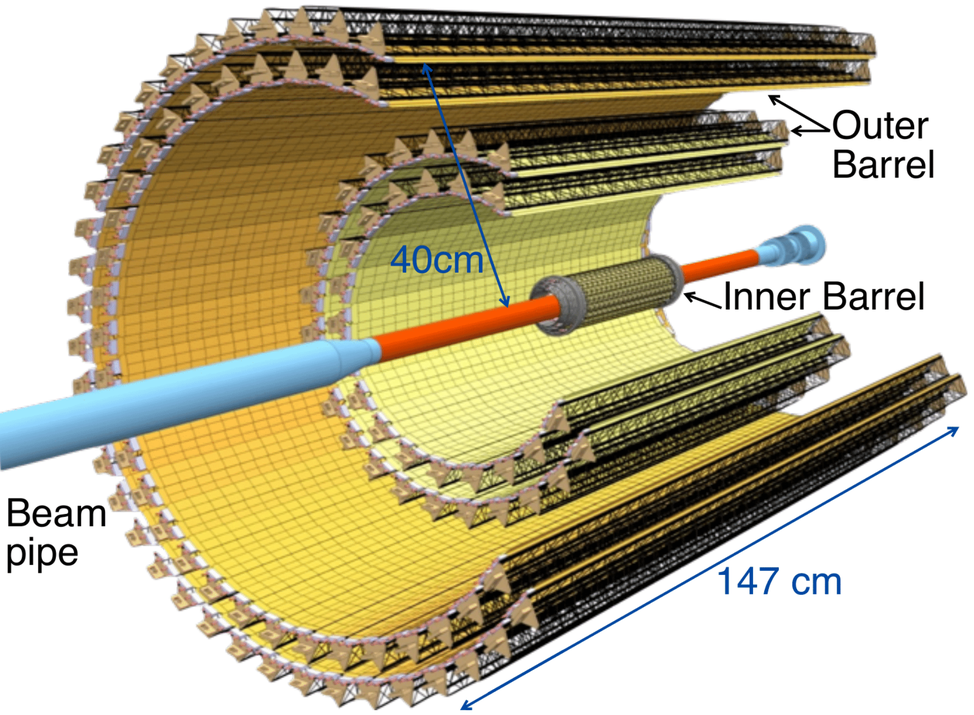
7 layers (3 layers Inner Barrel, 4 layers Outer Barrel)
~24k chips → 12.5G pixels
Smaller beam pipe → distance from the collision point: 22 mm
Readout rate: 100 kHz PbPb, 400 kHz pp

Participation of Řež ALICE group

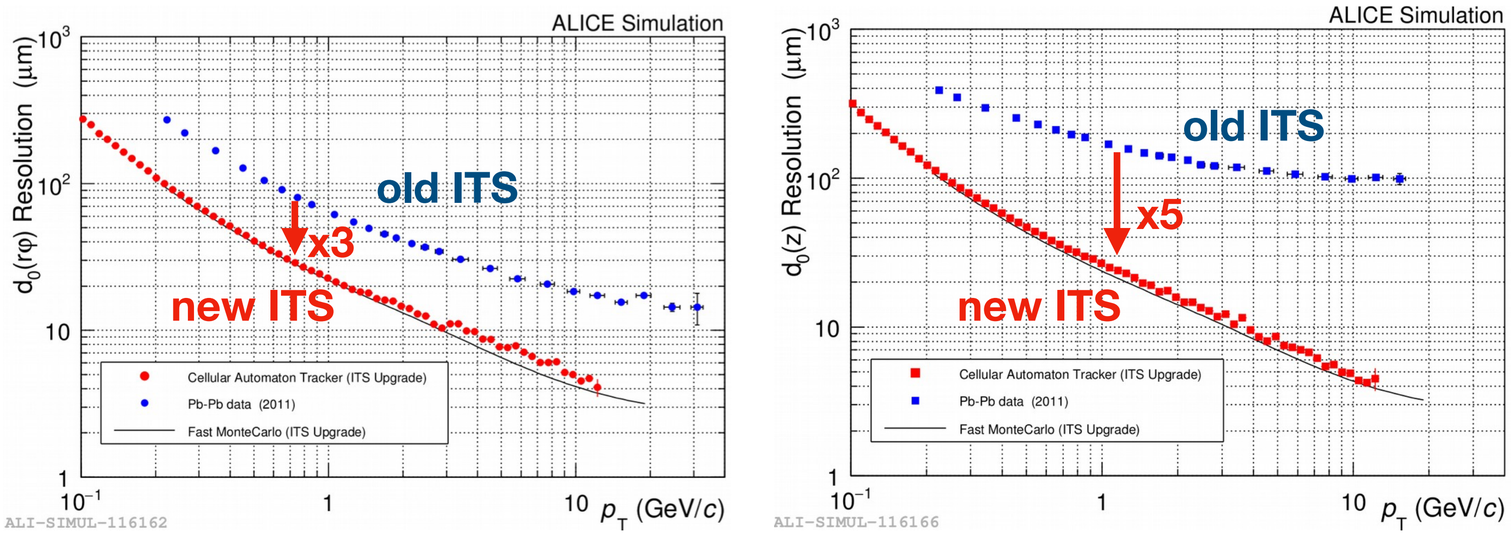
ALICE during Run 3



Inner Tracking System ITS2



Improved pointing resolution (rφ and z direction) = impact parameter d_0



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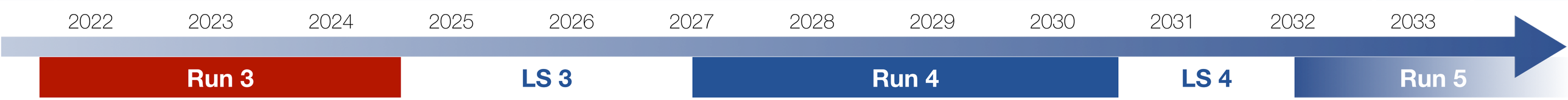
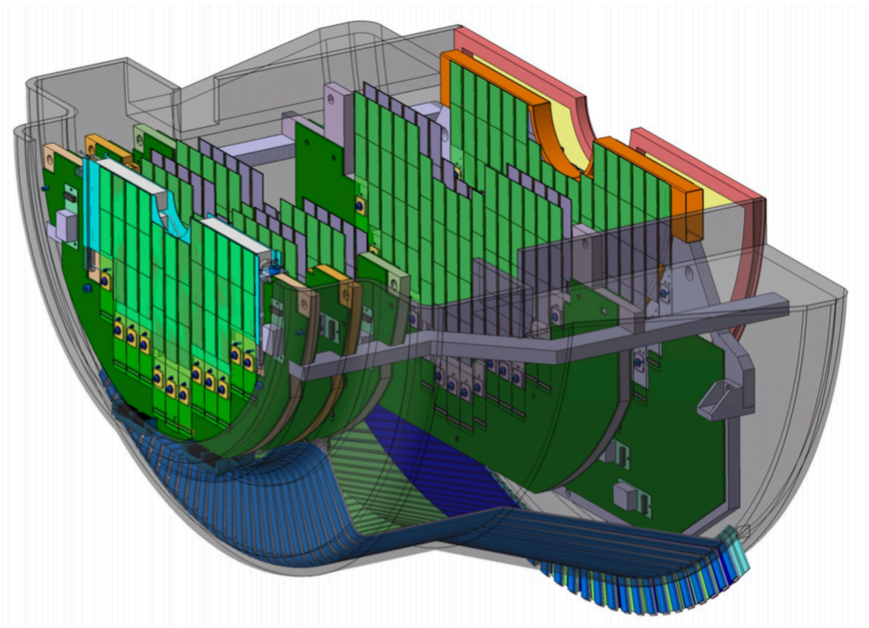
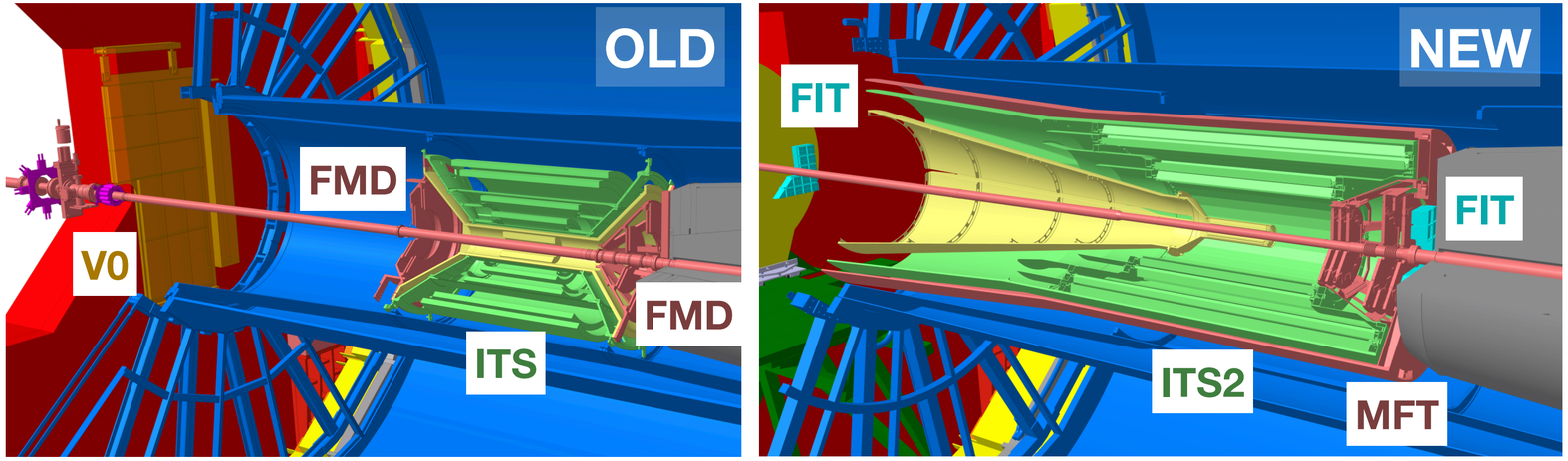


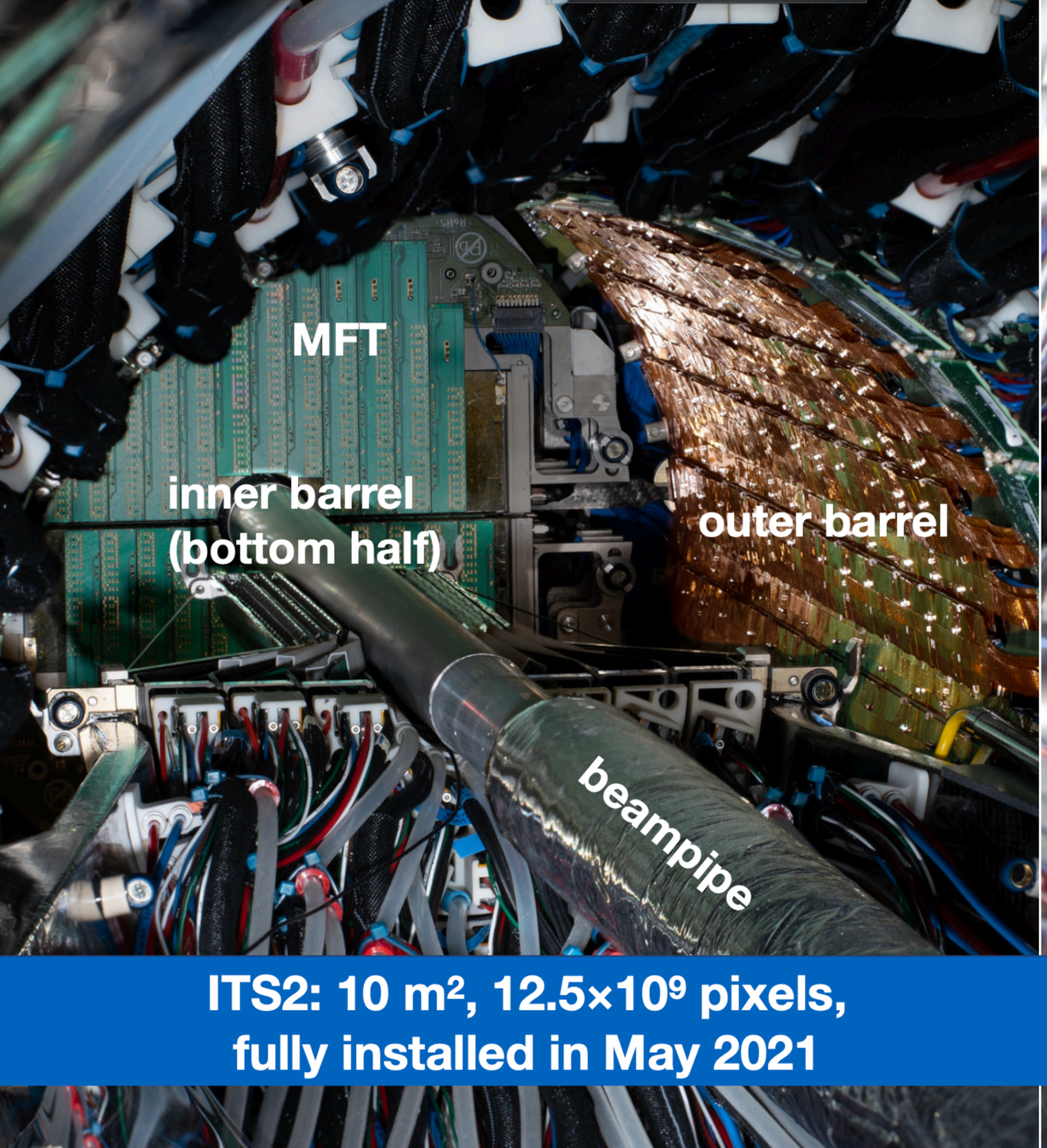
Muon Forward Tracker (MFT)

Participation of our ALICE group





ALPIDE chips (same as ITS2)
920 chips
$-3.6 < \eta < -2.45$
Track extrapolation of muon tracks to collision vertex
Selection of muons from secondary vertices



ITS2: 10 m², 12.5×10⁹ pixels, fully installed in May 2021

ALICE during Run 3

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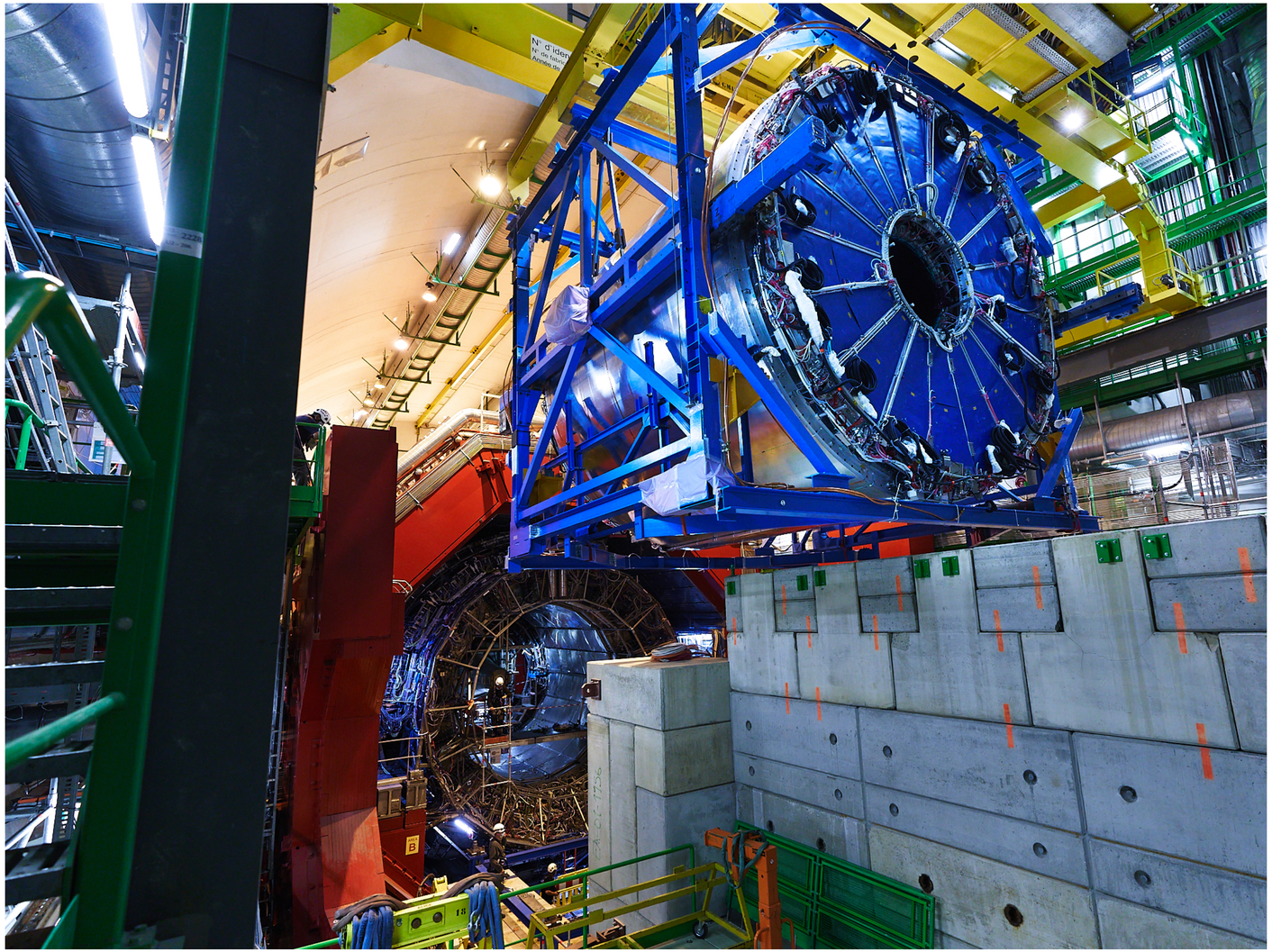
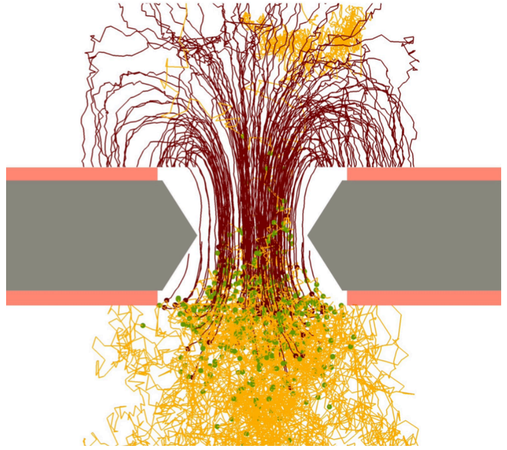
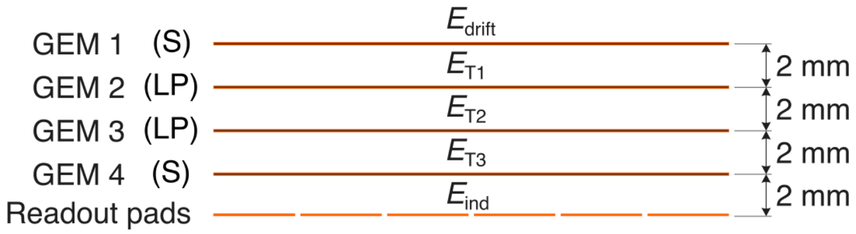
Run 3			LS 3		Run 4				LS 4	Run 5	





Time Projection Chamber (TPC)



Completely new readout: GEM stacks
- Avalanche creation in GEM hole
- Dominant part of ions absorbed on top side of GEM stack
- No more need for gating grid

Continuous readout (operated at 50 kHz PbPb)

ALICE during Run 3

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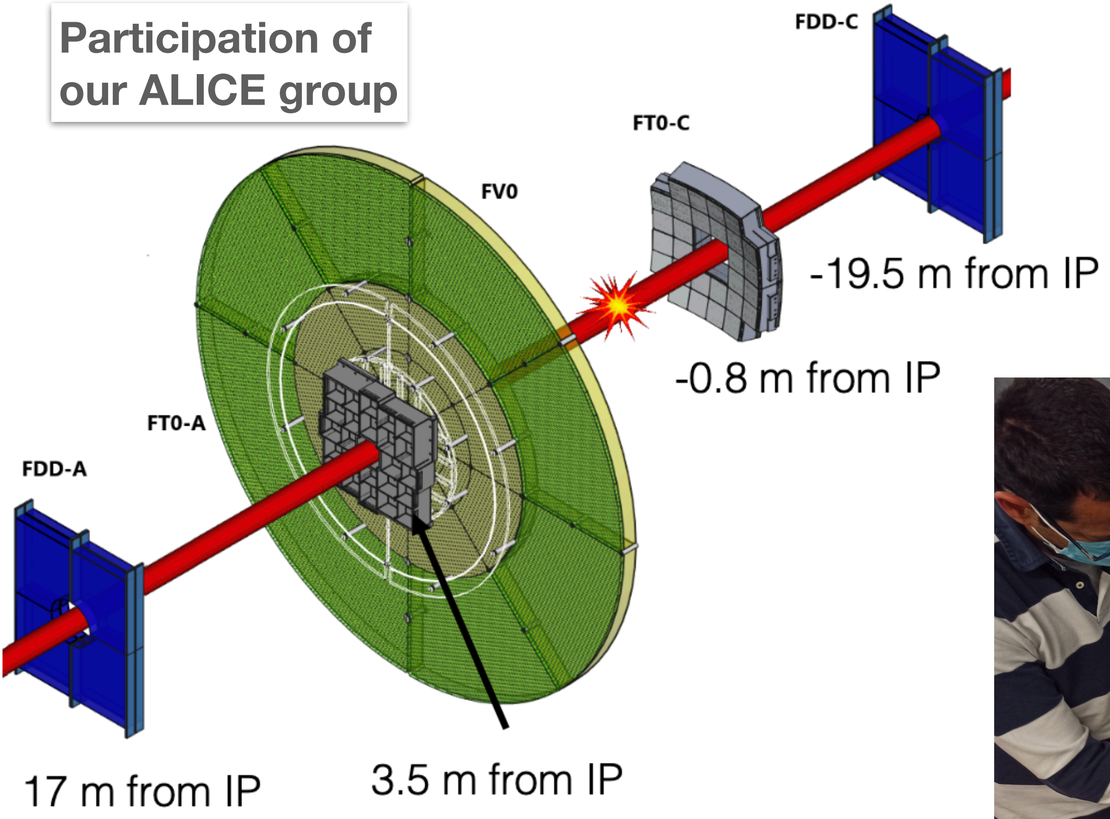
Run 3				LS 3	Run 4				LS 4	Run 5	

Fast Interaction Trigger (FIT)

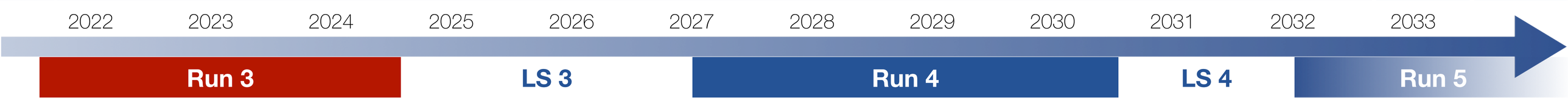
Participation of our ALICE group



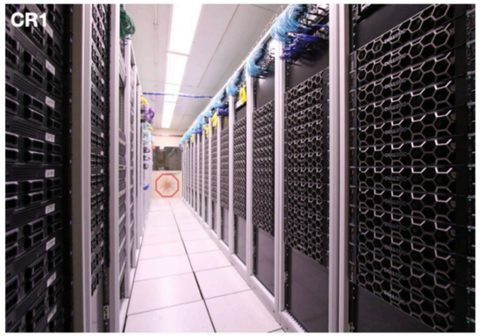
Fast minimum bias collision trigger with latency < 425 ns

Luminosity monitor
Centrality measurement
Event plane determination

ALICE during Run 3



200 First Level Processors (FLP) in CR1

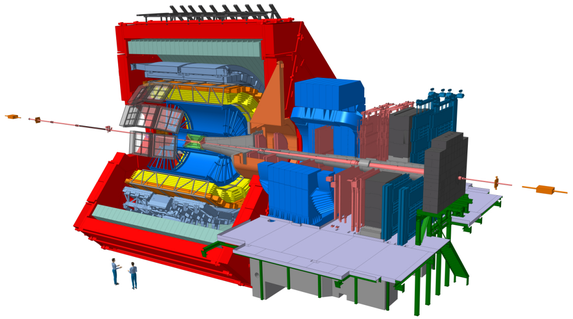


625 GB/s
Time frame building

250 Event Processing Nodes (EPN) with 2000 GPUs

3.5 TB/s
Raw detector data

100 GB/s
Permanent storage



CERN EOS Computing Center

Online & offline data processing (O^2)

Continuous readout (no trigger)
50 kHz PbPb → storing all raw data not feasible
→ significant compression needed

2 level reconstruction:
- First Level Processor (FLP)

Receiving and preparing data from the detector
- Event Processing Nodes (EPN)

Online reconstruction and calibration

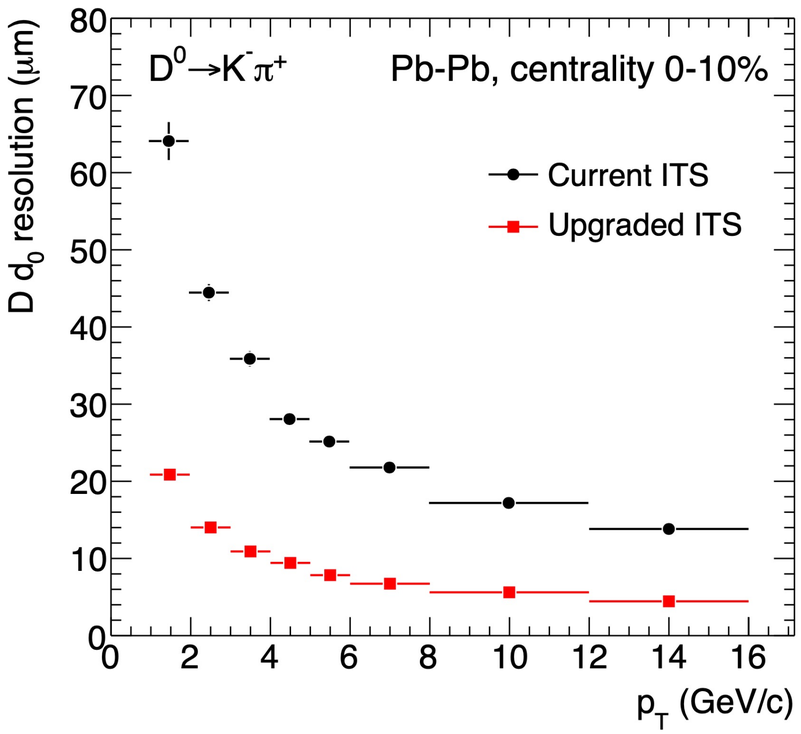
Compressed raw data to disk
i.e. only clusters and tracks for the TPC

Completely new software for data processing
and user analyses

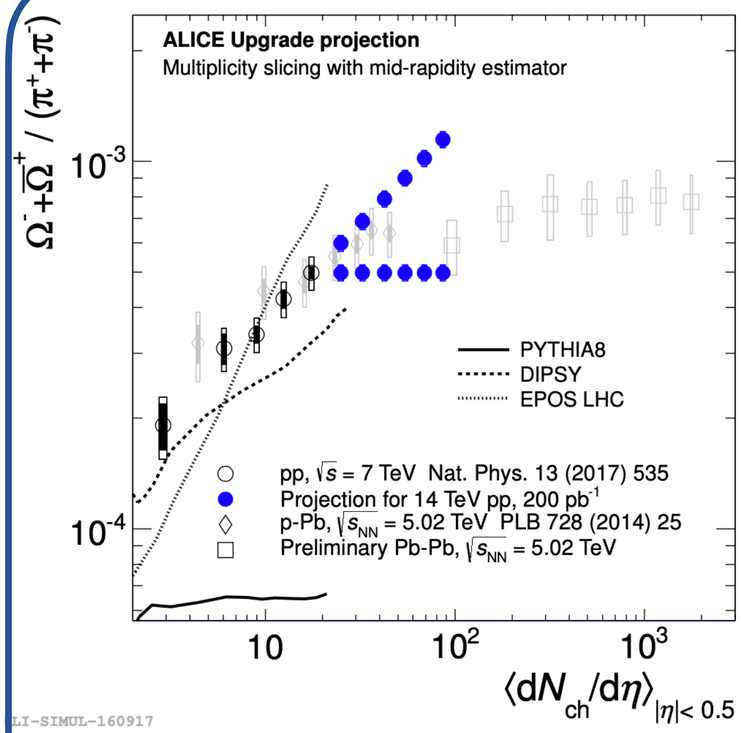
Physics improvements with ALICE 2.0

Several weeks of PbPb collisions at 5.52 TeV every year 2022-2024

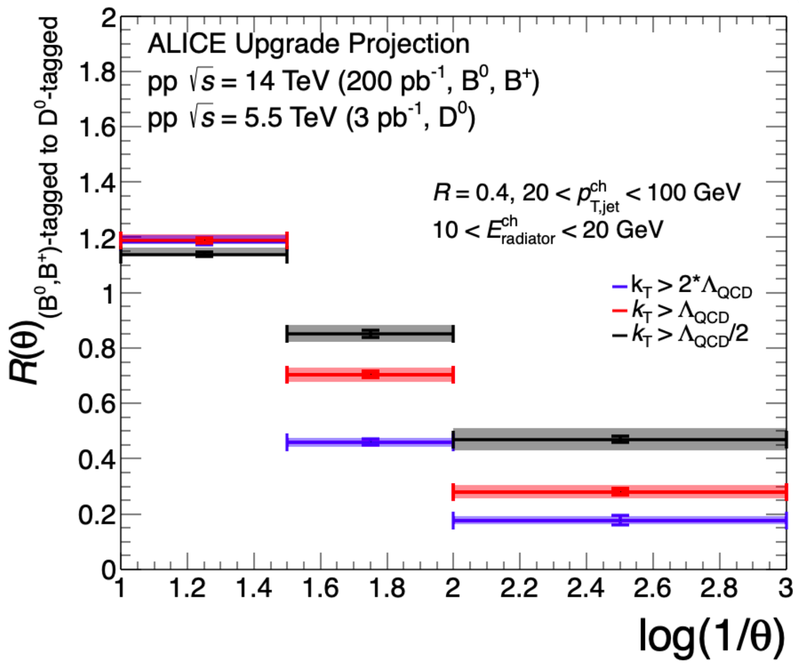
Dedicated physics program in pp collisions at 14 TeV in 2022-2024



Beauty via non-prompt D mesons
Improved resolution of impact parameter d_0



Reaching higher multiplicities
Overlap with PbPb (confirm whether trend of strangeness enhancement matches the one of PbPb)



Precision measurement of the dead-cone effect with B-tagged jets
(right now only D-tagged jets measured)

ALICE during Run 4

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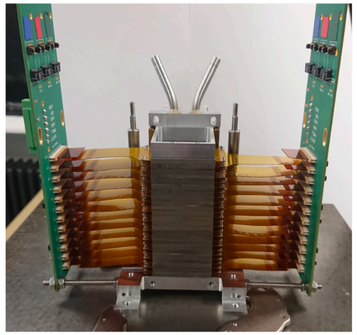
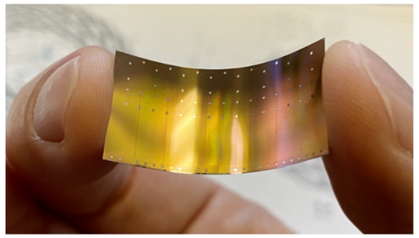
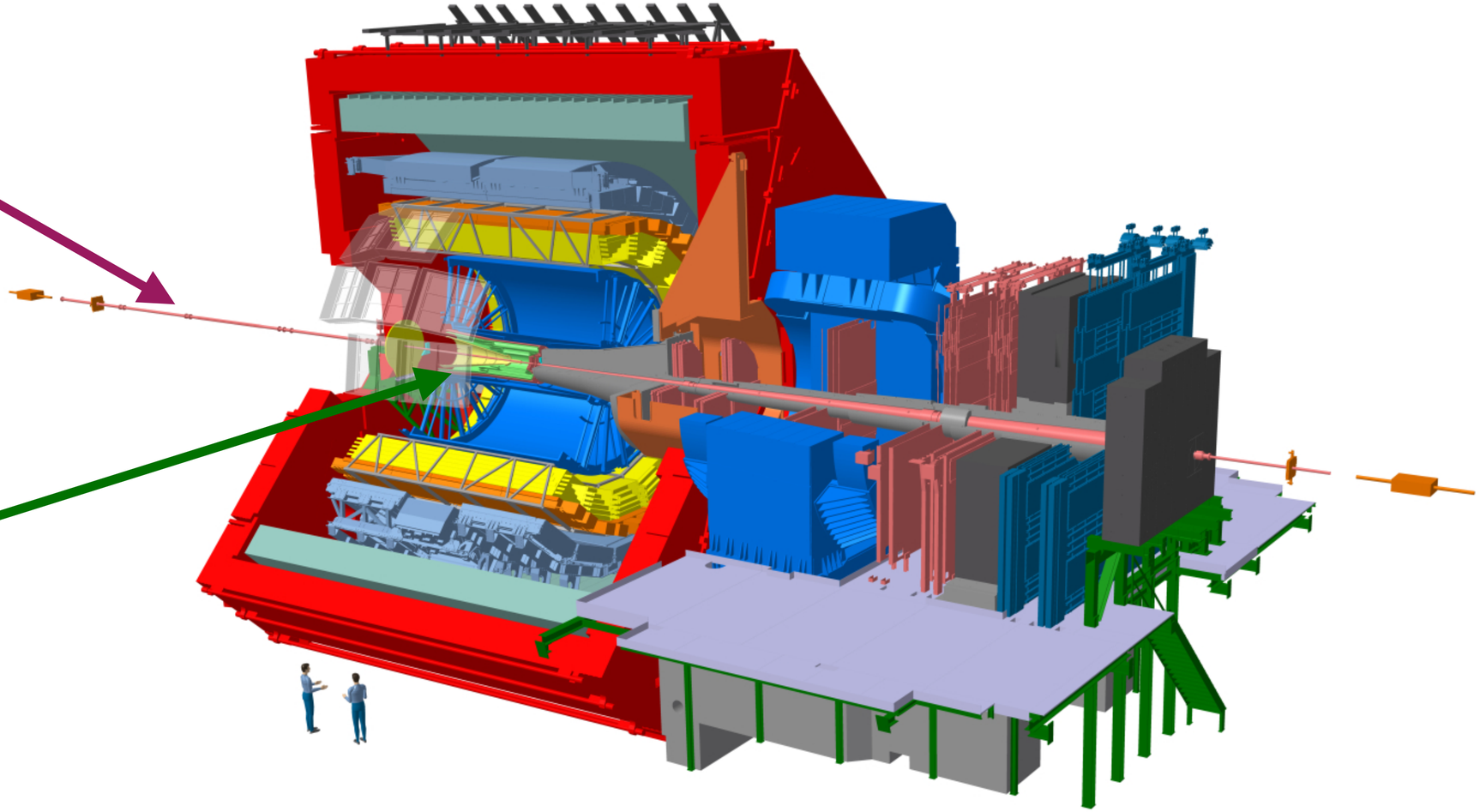
Run 3			LS 3		Run 4				LS 4	Run 5	

New: Forward Calorimeter (FoCal)

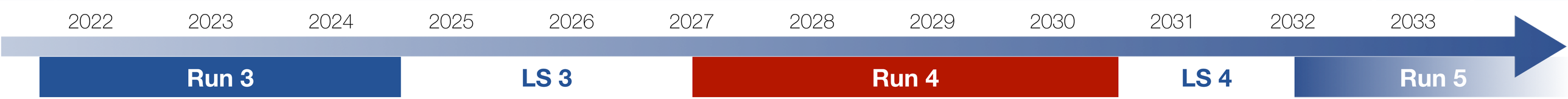


New: Inner Tracking System 3 (ITS3)





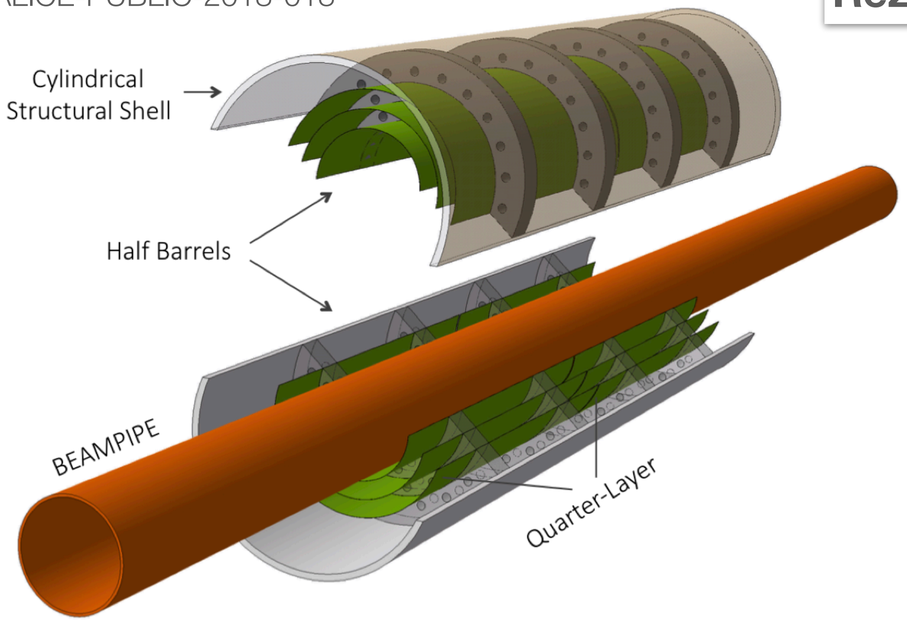
ALICE during Run 4



Inner Tracking System 3 (ITS3)

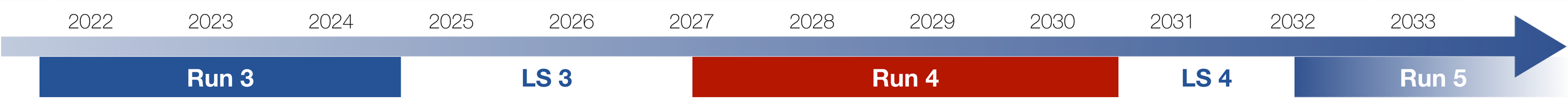
ALICE-PUBLIC-2018-013

Participation of Řež ALICE group



Ultra-thin bent MAPS
Lowest possible material budget 0.05% X_0/layer
Sensor thickness: 20-40 μm
$-2.0 < \eta < 2.0$
Distance to collision point: 16 mm

ALICE during Run 4



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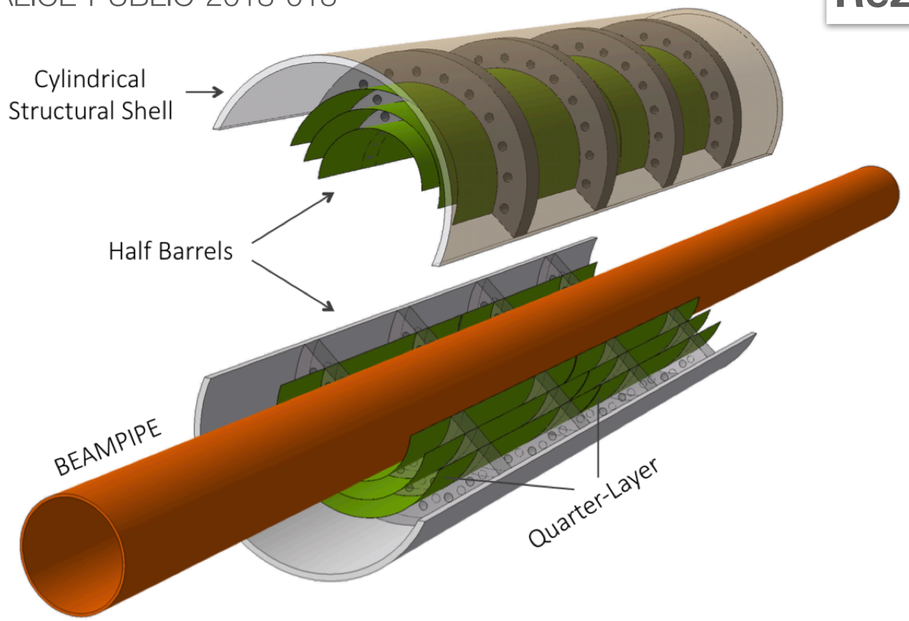

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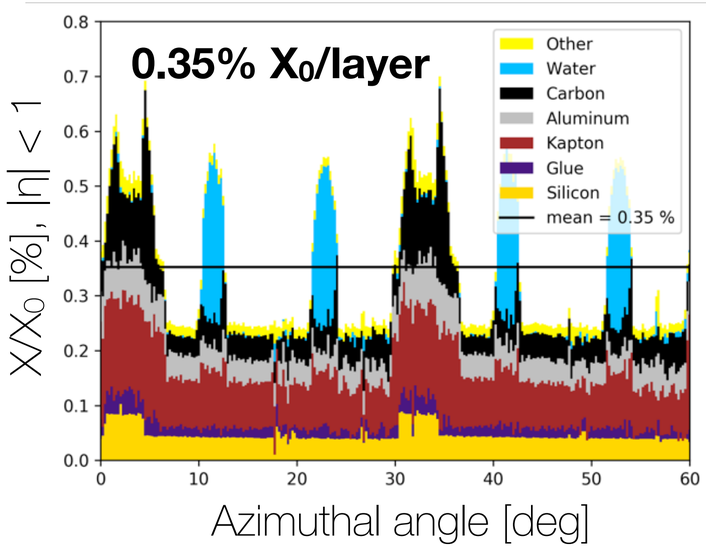

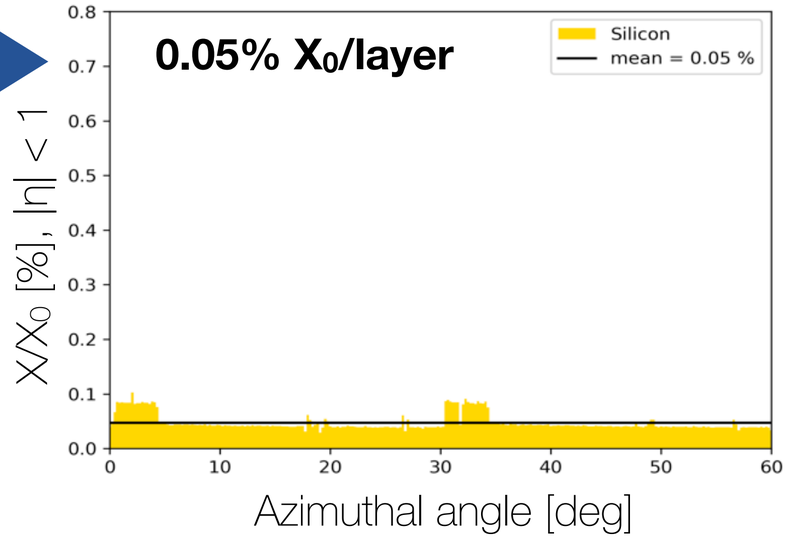

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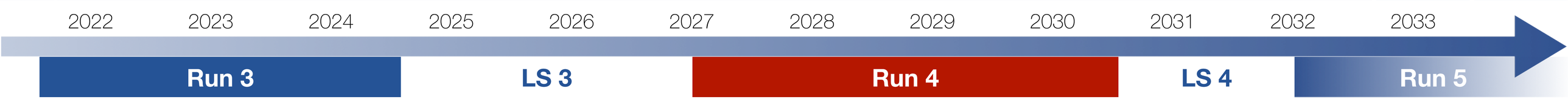
How is the material budget reduced:

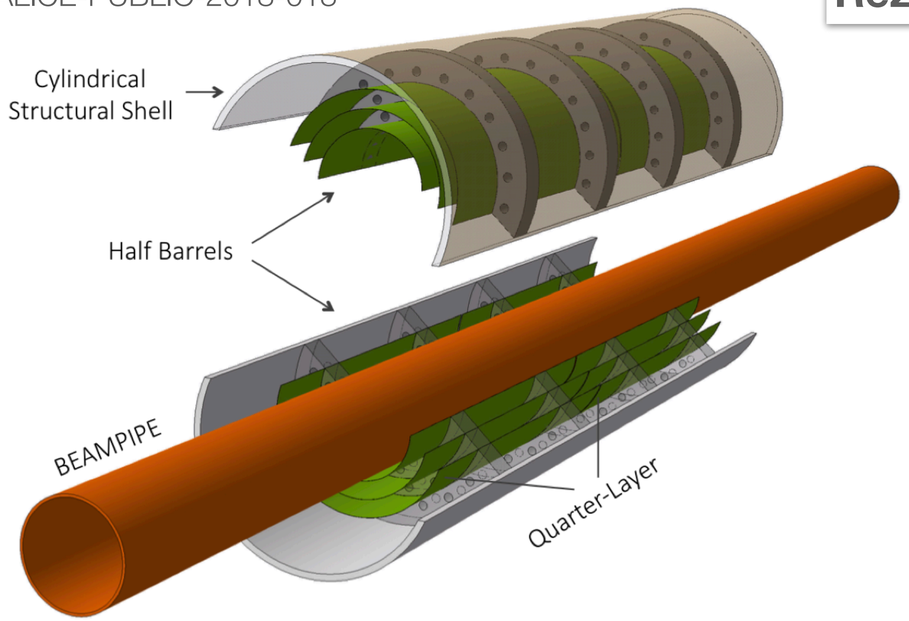
- Removal of water cooling
- Removal of circuit board
- Removal of mechanical support

ALICE during Run 4



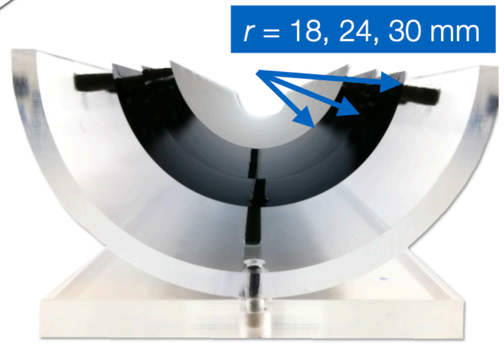
Inner Tracking System 3 (ITS3)

ALICE-PUBLIC-2018-013



Participation of Řež ALICE group

Mechanically held by carbon foam spacers



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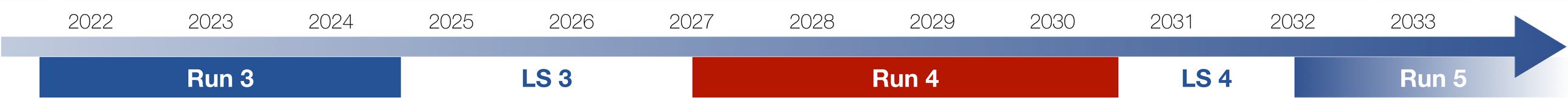
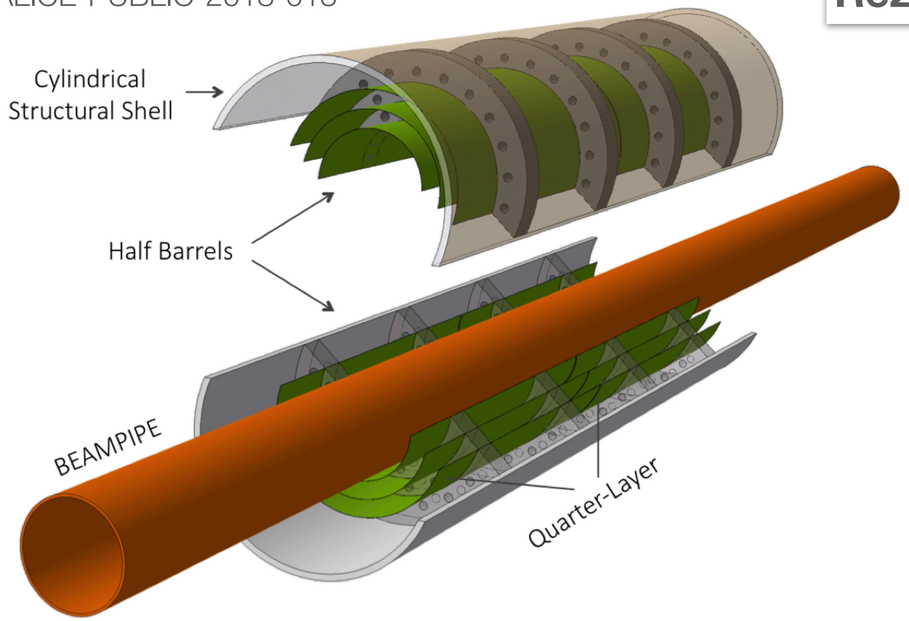
ALICE during Run 4



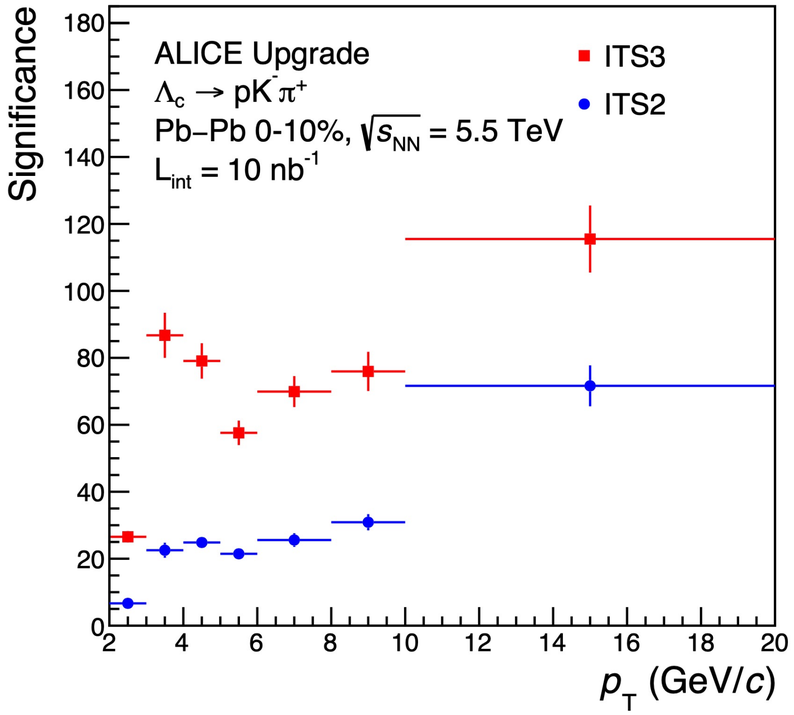
Inner Tracking System 3 (ITS3)

ALICE-PUBLIC-2018-013



Participation of Řež ALICE group

Significance = S/S+B



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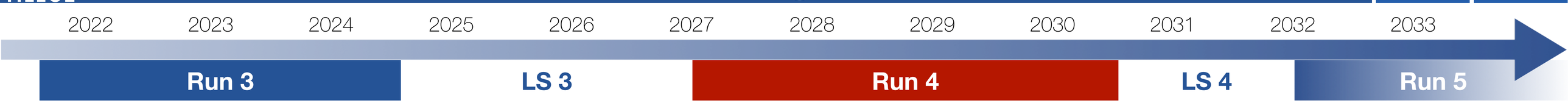
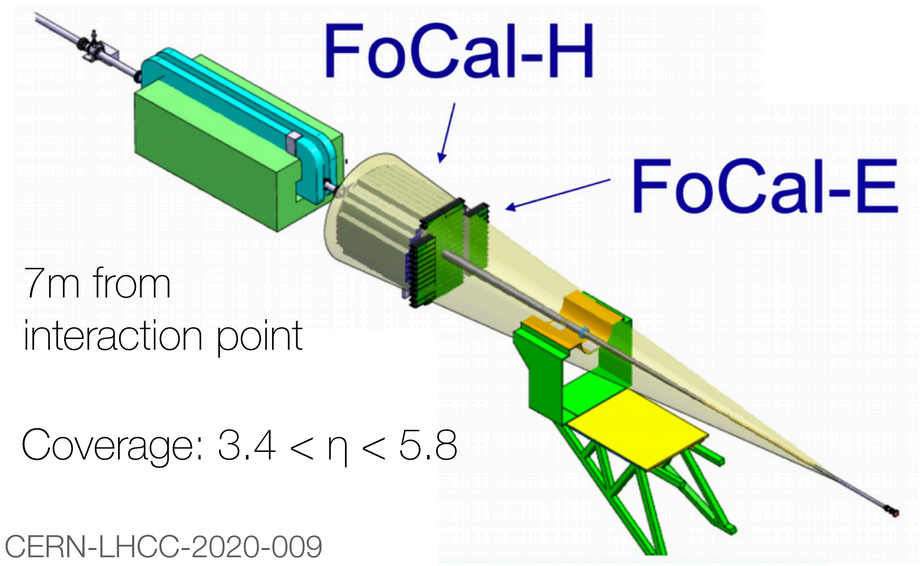
Important improvements at low p_T heavy flavor measurements

ALICE during Run 3



Forward Calorimeter (FoCal)



7m from interaction point

Coverage: $3.4 < \eta < 5.8$

CERN-LHCC-2020-009

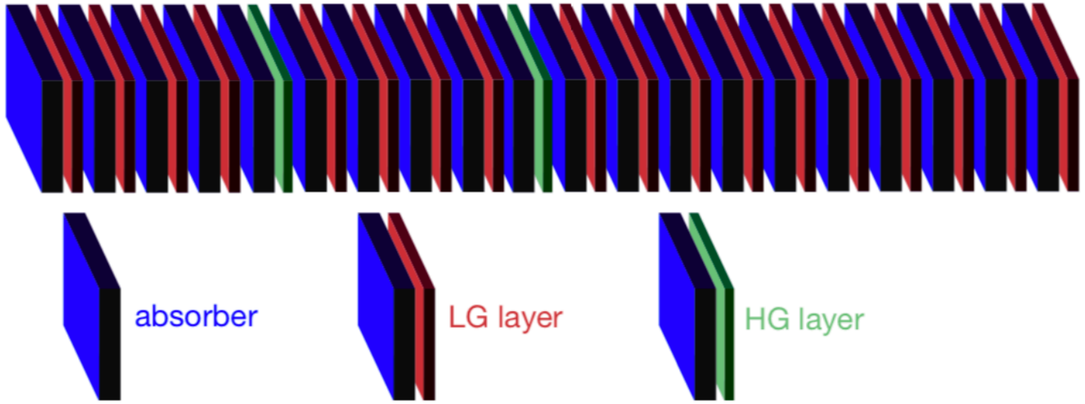
FoCal-E

Electromagnetic Si+W sampling calorimeter (length 20 X_0)

16 low granularity layers (LG) of Si pads (fast integration time 25 ns)

2 high granularity layers (HG) with MAPS based on ALPIDE (intergation time 5 μs)

High granularity sensors allow for separation of near-by showers (transverse separation 2 mm)



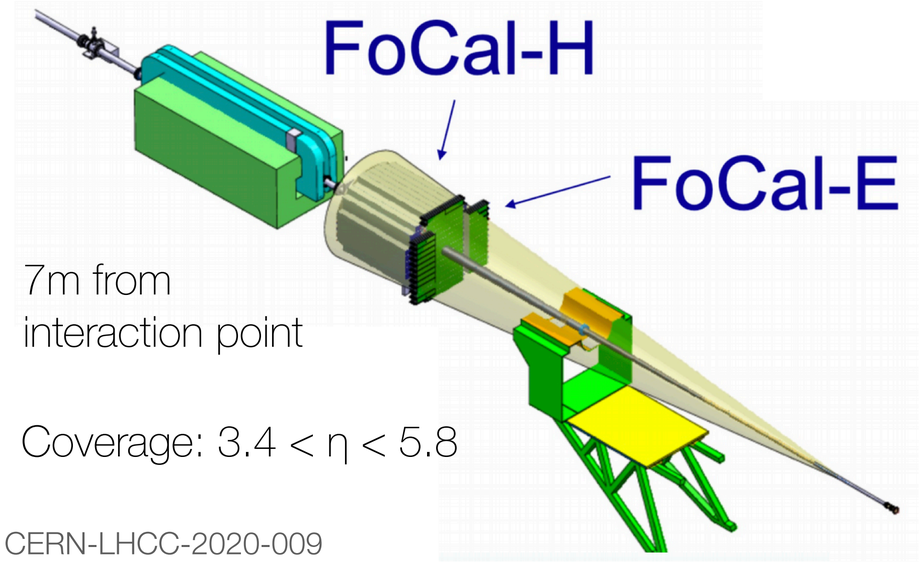
FoCal-H

Conventional hadronic sampling calorimeter (Cu + scintillating fibres)

ALICE during Run 3

2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
Run 3			LS 3		Run 4				LS 4	Run 5	

Forward Calorimeter (FoCal)



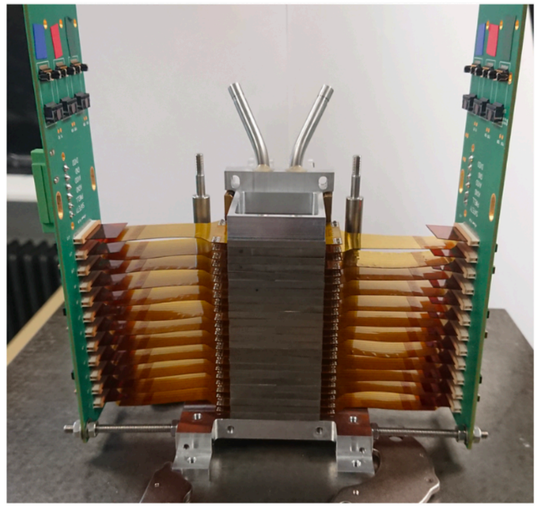
7m from interaction point

Coverage: $3.4 < \eta < 5.8$

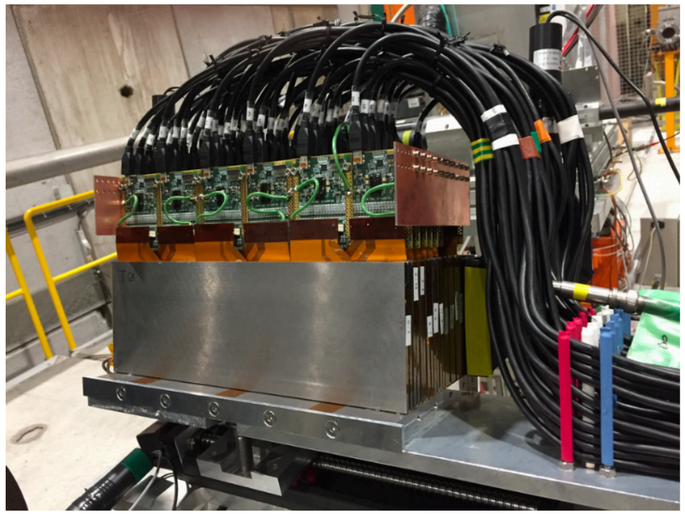
CERN-LHCC-2020-009

Two prototypes

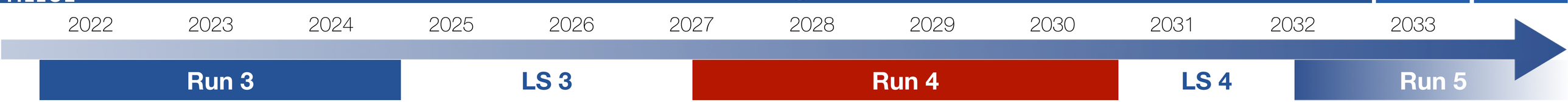
EPICAL (ALPIDE)
Si-W pixel prototype
detailed shower evolution



mini-FoCal
2018 test in ALICE cavern to verify background with pp 13 TeV collisions



ALICE during Run 3



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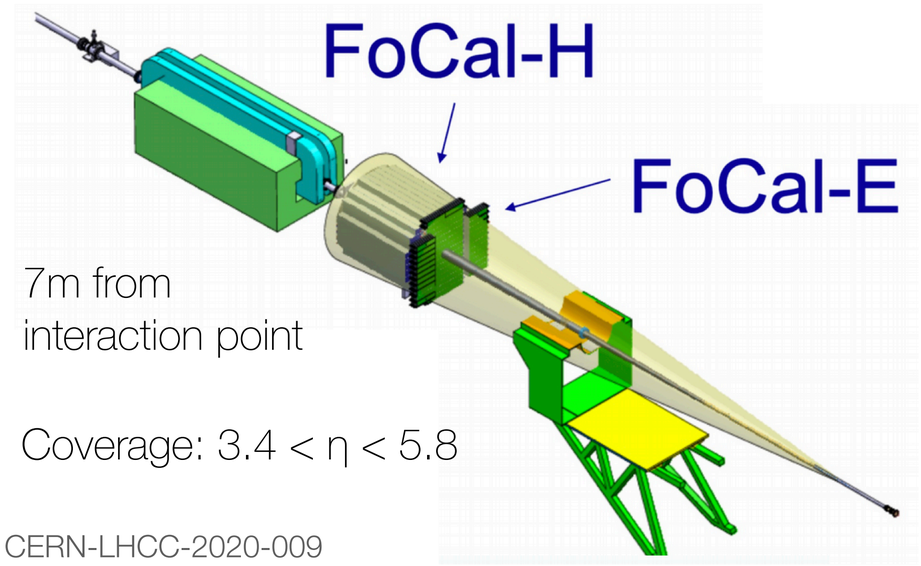


7m from interaction point

Coverage: $3.4 < \eta < 5.8$

CERN-LHCC-2020-009

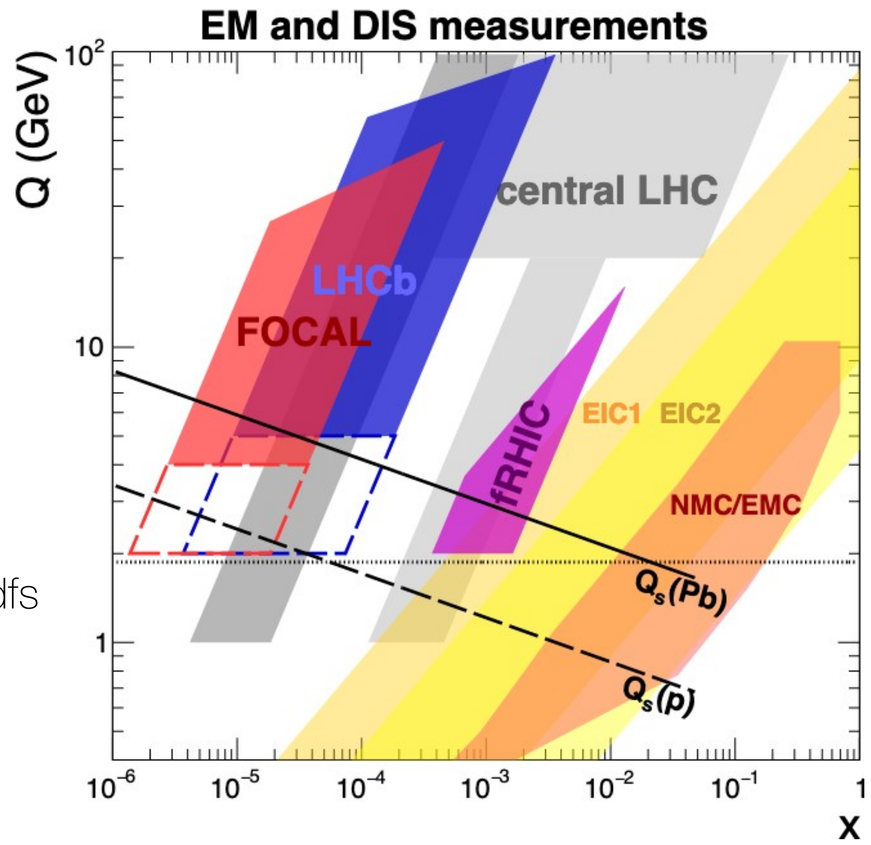
Measure the gluon density in p and Pb nuclei at small x and Q^2 to search for onset of gluon saturation

Observables sensitive to gluon PDF
- Direct photons (quark-gluon compton scattering)
- Heavy flavor (gluon fusion)

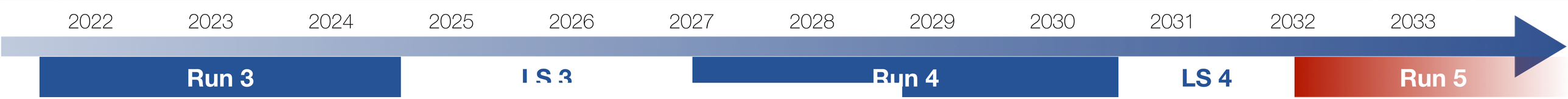
Significant constraints on nuclear pdfs

Long range flow-like correlations

Explore jet quenching at forward rapidity



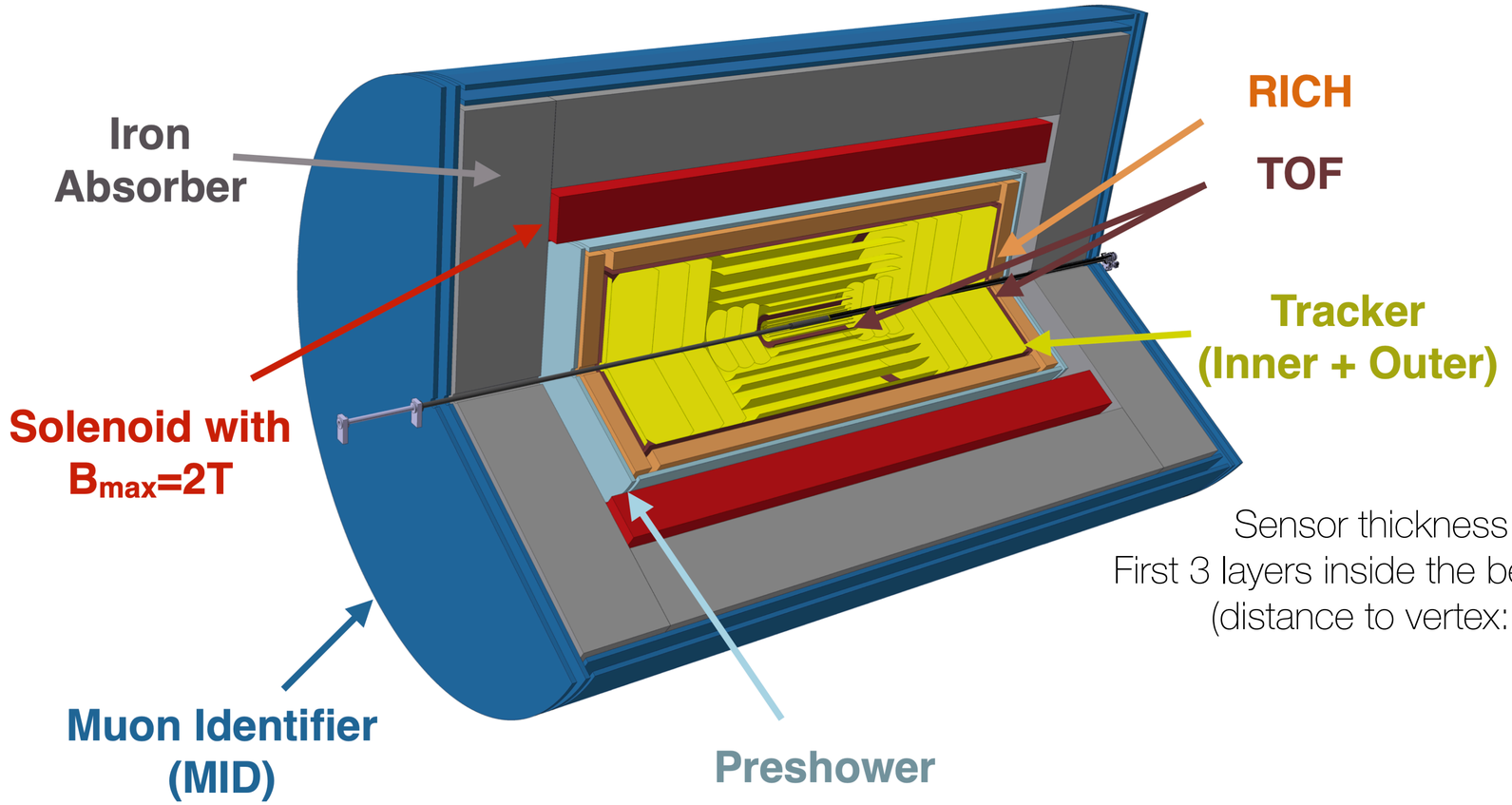
ALICE during Run 3



ALICE 3

Fast and ultra-thin detector with precise tracking and PID down to ~ tens of MeV

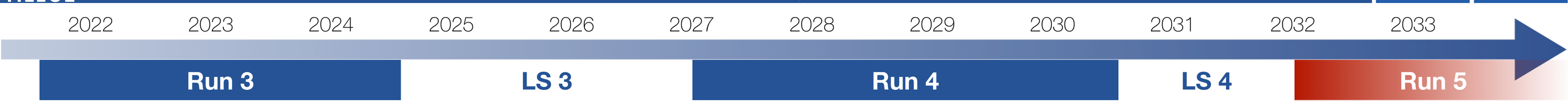
Coverage $|\eta| < 4$
B field 0.5 or 2 Tesla (later preferred)



Sensor thickness ~ 10 μm
First 3 layers inside the beam pipe (distance to vertex: ~ 5 mm)

Expression of interest, arXiv: 1902.01211
LoI, coming by the end of 2021

ALICE during Run 3



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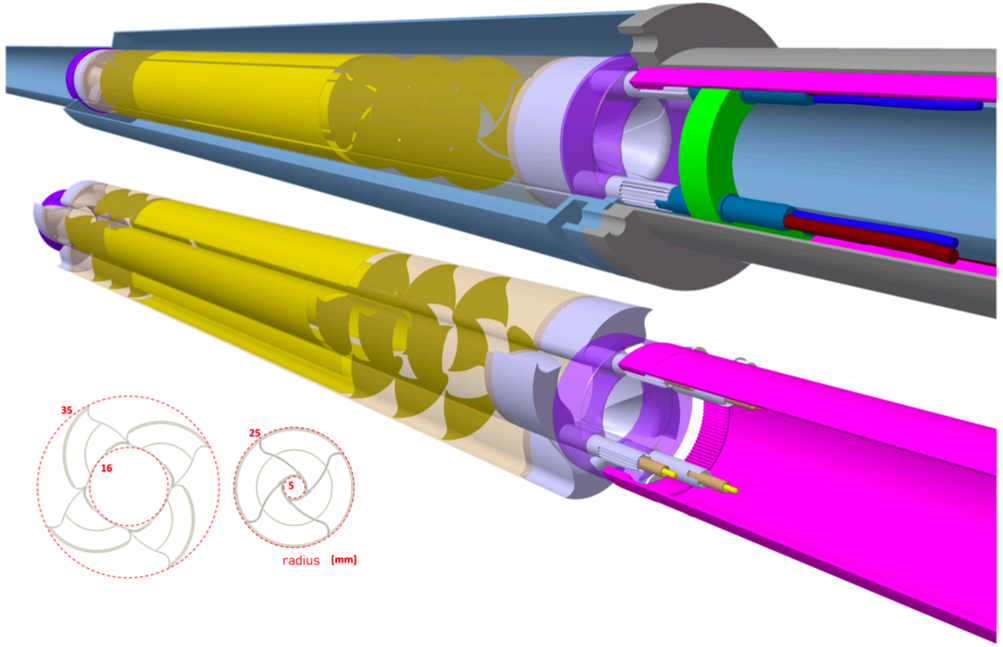
Physics programme:
pp collisions
PbPb collisions
lighter nuclei (Kr, …)

Multiple-heavy hadrons
Low-mass dielectron continuum
Nuclei and hypernuclei
nPDF measurements
HF flow in small and large systems

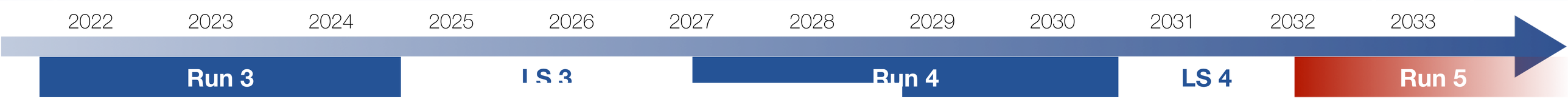
IRIS tracker



Inside of the beam pipe
Retractable
Placed in its own secondary vacuum

Expression of interest, arXiv: 1902.01211
LoI, coming by the end of 2021

ALICE during Run 3



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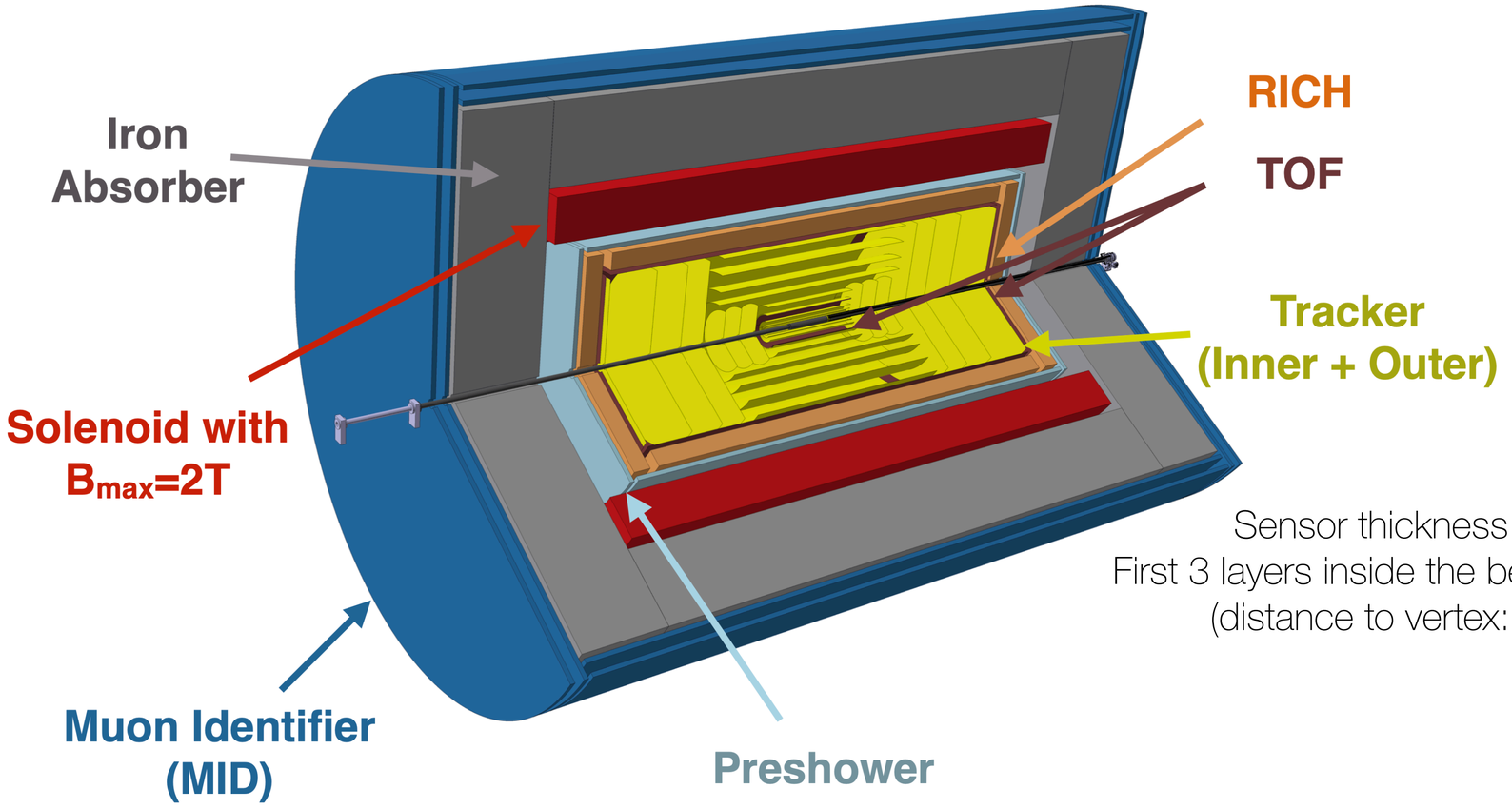

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Summary

Run 3

new **ITS3**
upgraded **TPC**
new **MFT**
new **FIT**
new Online&Offline system **O²**
and more ….

Run 4

new **ITS3**
new **FoCal**
and more ….

Run 5

new **everything**