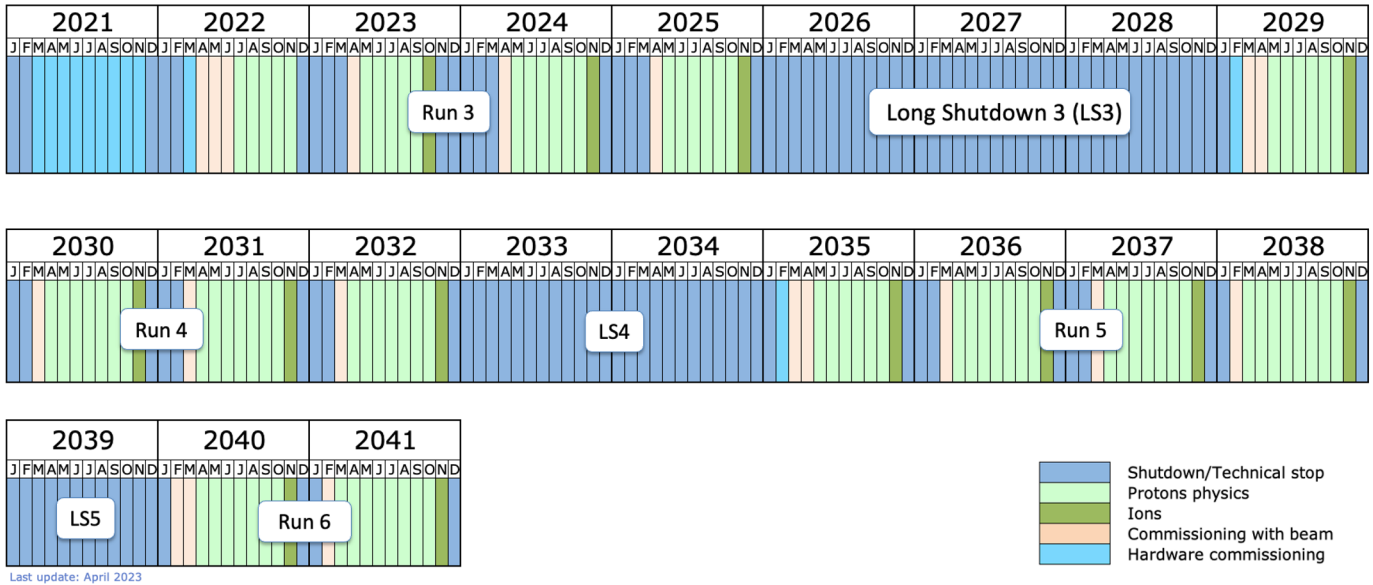
Future ALICE / ALICE 3

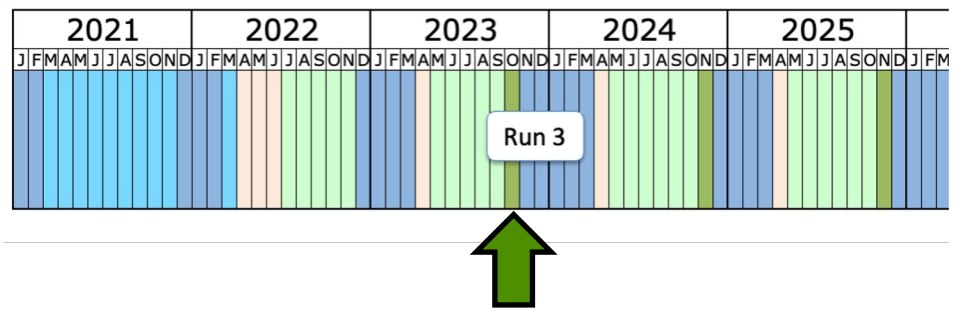
Silvia Masciocchi

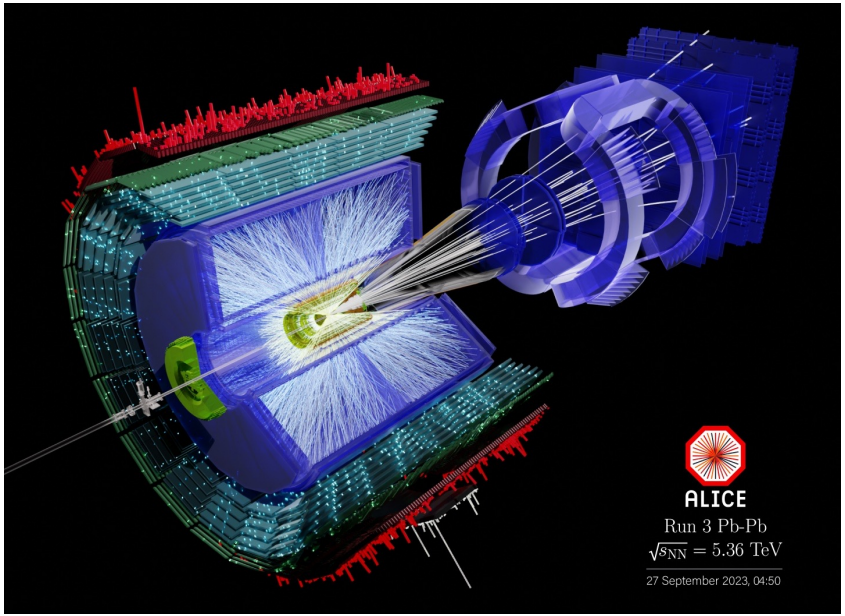


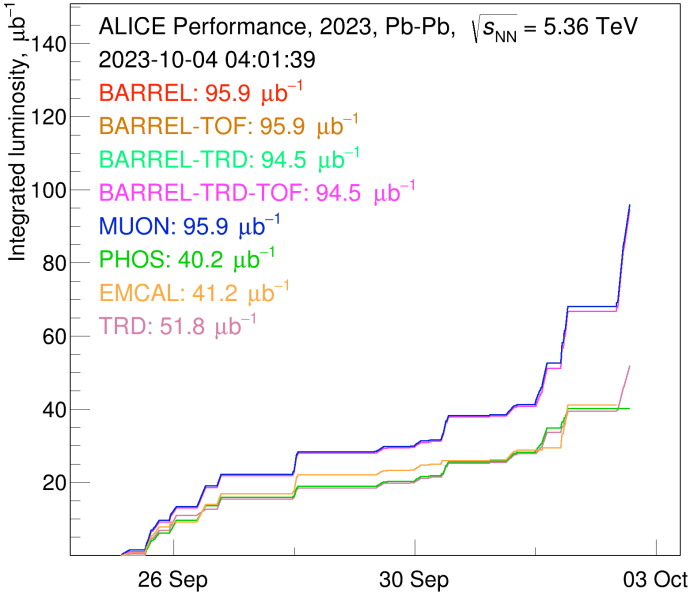
Fresh news !!!

Pb-Pb run started on September 26, 2023

https://alice-collaboration.web.cern.ch/ALICE_HI2023



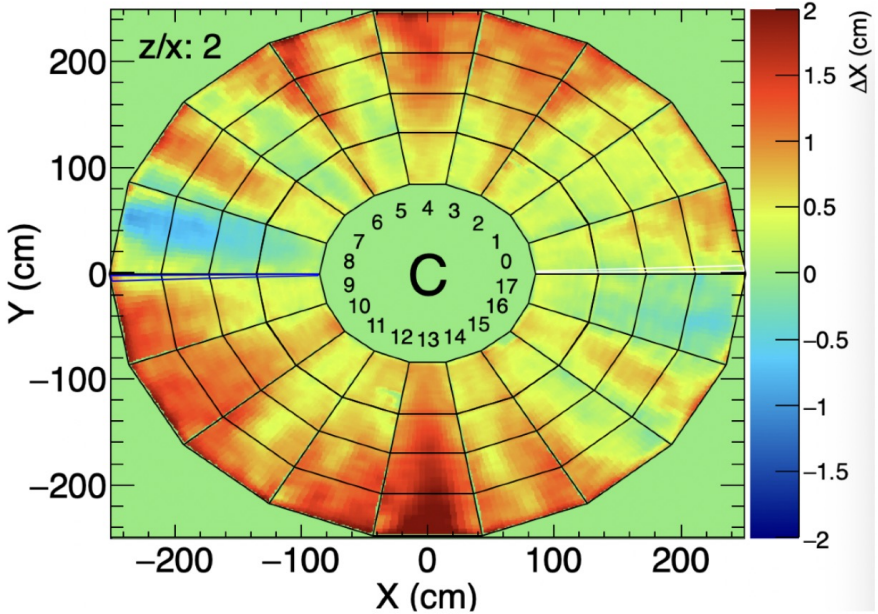




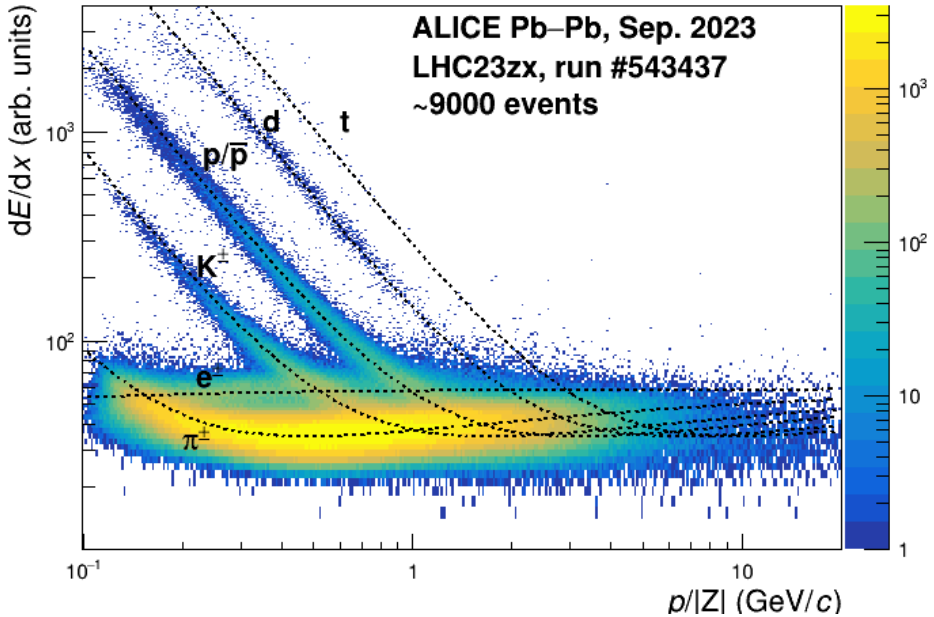
This morning: 740 M events recorded

TPC calibration and reconstruction in < 24 hours

First TPC distortion map (2 kHz)

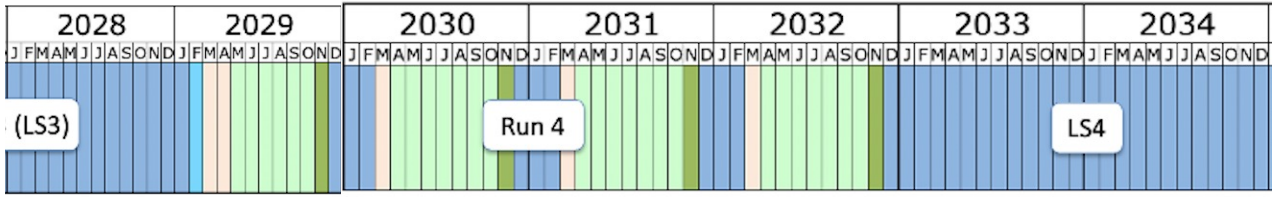


First TPC dE/dx plot



September	26	27	28	29	30	October 1	2	3	4
Pb-Pb nteraction rate:	2 k Hz	6 kHz		15 kHz					**30 kHz**

POF V: 2028 - 2034



ALICE: LHC Run 4 (2029– 2032)

- Complete goal of > 13 nb^{-1} hadronic Pb-Pb collisions
- Unprecedented large samples of proton-proton, p-Pb and Pb-Pb data

ALICE@GSI rich physics program:

- Charm and beauty physics (open and hidden)
- Hyper-nuclei and exotic hadrons
- System-size dependence (high-multiplicity pp → p-Pb → Pb-Pb: emergence of collective effects in (super-)small systems, link to ultra-cold atoms, Hd)

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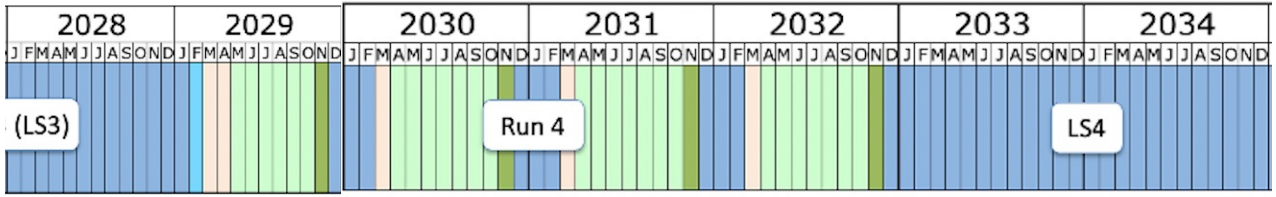

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ALICE@GSI rich physics program:

Plenty of hadron physics!
Fantastic data samples!

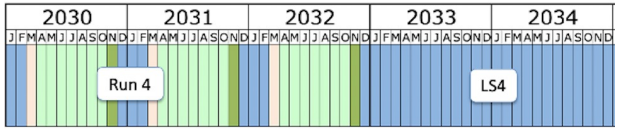
- Charm and beauty physics (open and hidden)
- Hyper-nuclei and exotic hadrons
- System-size dependence (high-multiplicity pp → p-Pb → Pb-Pb: emergence of collective effects in (super-)small systems, link to ultra-cold atoms, Hd)

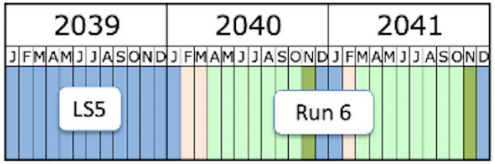
ALICE in (Run 3 and) Run 4

- “Constant” operating budget:
  common funds, detector operation and maintenance, shifts, representation at international conferences and workshops.
  Very modest contribution to the ITS3 realization

- Stable personnel plan:
  Critical items: TPC operation (1 retirement coming up)
  only 3 temporary positions for young scientists (+ third party funding)

ALICE 3





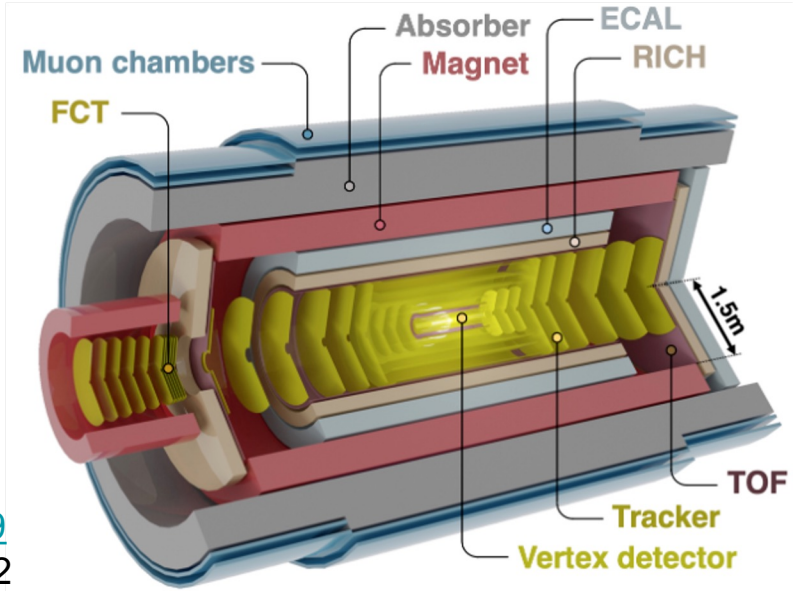
arXiv:2211.02491

Next generation heavy-ion experiment

- Tracking precision x 3
  <10 μm at p_T > 200 MeV/c
- Acceptance x 4.5
  |η| < 4 (with particle ID)
- Heavy-ion rate x 5
  Proton-proton rate x 25

Letter of Intent CERN-LHC-2022-009
Positive review by LHCC in March 2022

Scoping document by early 2024



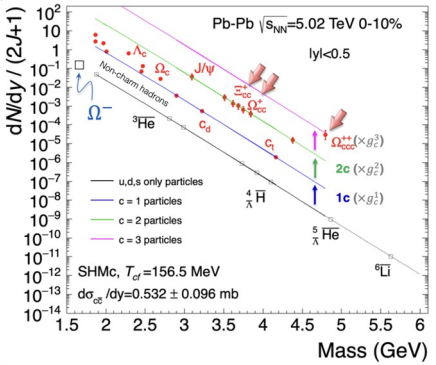
ALICE 3: Physics → from 2035 = POF V

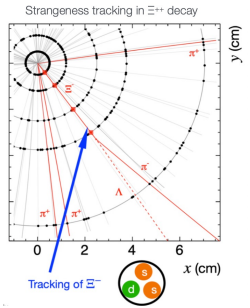
- **QGP thermal emission via dileptons**:
  very high precision, access to the time evolution of the system temperature

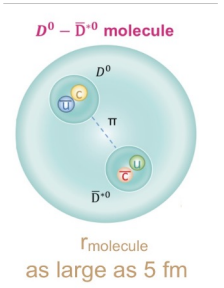
- **Heavy-flavor physics:** GSI
  multi-charmed hadrons: unique probe of hadronization
  interaction between charm hadrons, structure of exotic states
  D-Dbar (de-)correlations
  heavy-quark transport

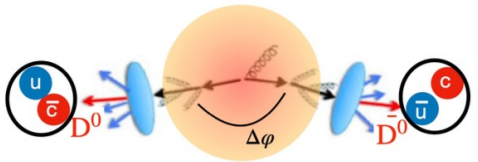
- First observation of charmed **nuclei**? GSI
  Hyper-nuclei (strangeness tracking)

- Net quantum number fluctuations (wide radidity range) GSI
- Soft photons (Low's theorem)
- Collisions of smaller nuclei GSI

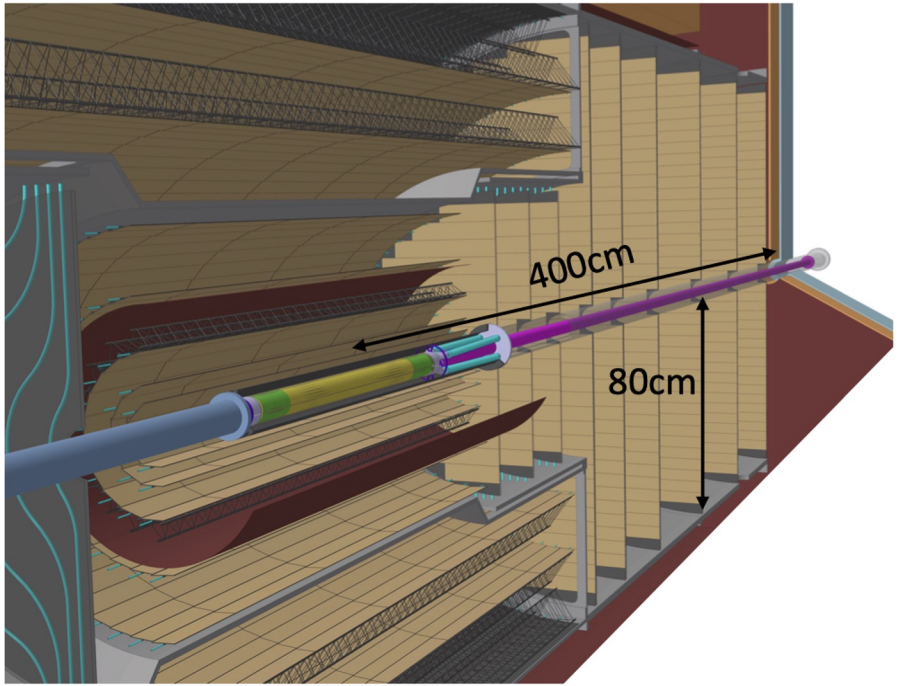








ALICE 3: Outer Tracker



Interest of the German university groups:

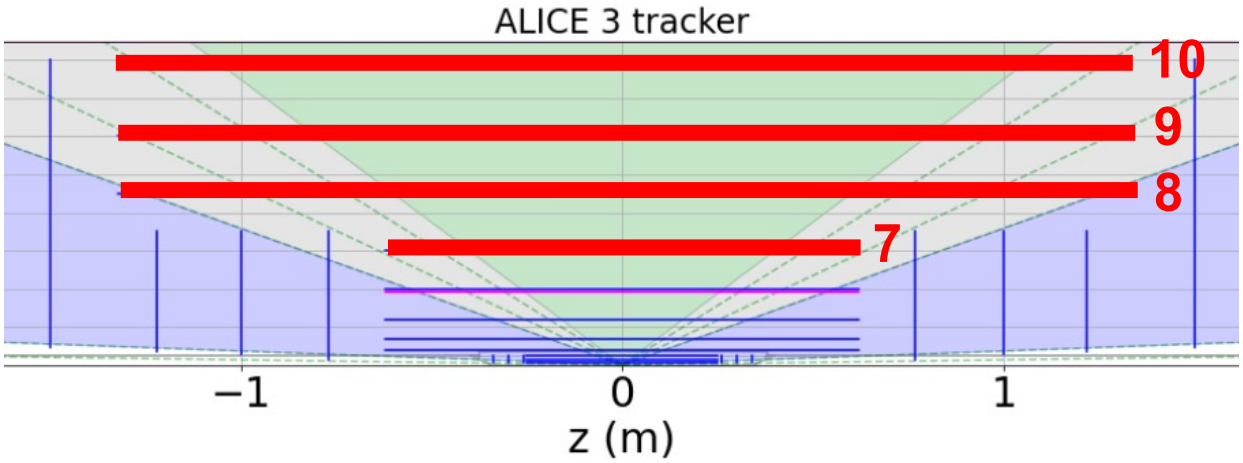
45 m^2 of pixel detectors:

- 8 rapidity units
- Compact (R~80 cm, z~ ±400 cm)
- Resolution ~10 μm → pixels 50x50 $μm^2$
- 1% of X_0 per layer
- Low power density ~ 20 mW/cm^2

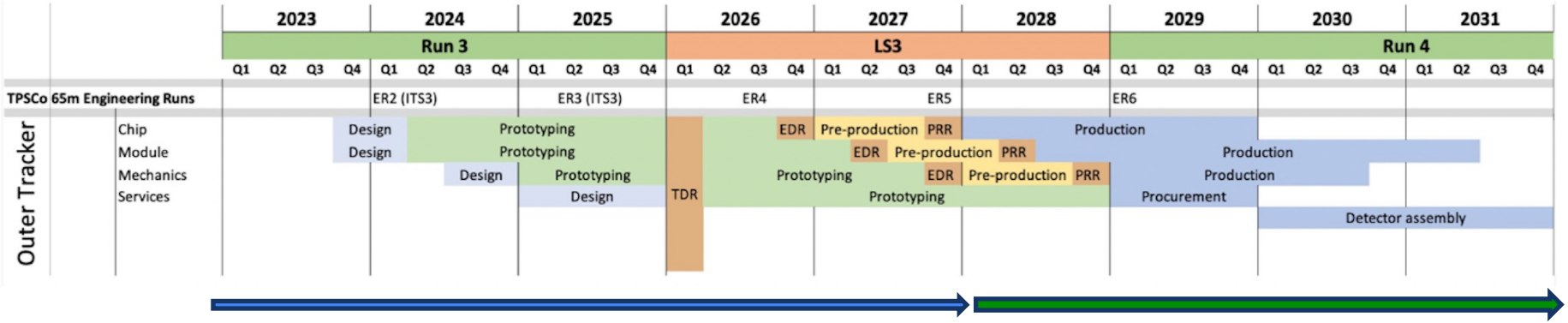
Industrialization of modules

GSI competences (DL, EE, workshops, ALICE) would be an ideal asset

Outer Tracker



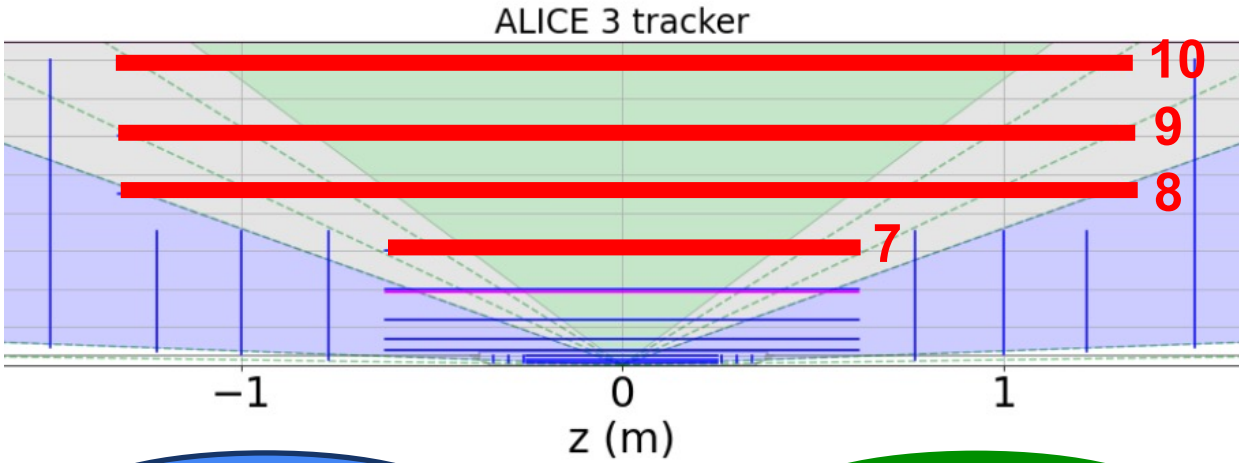
Schedule:



R&D and prototypes
Simulation, performance

Engineering Design Report
Production and integration

Outer Tracker



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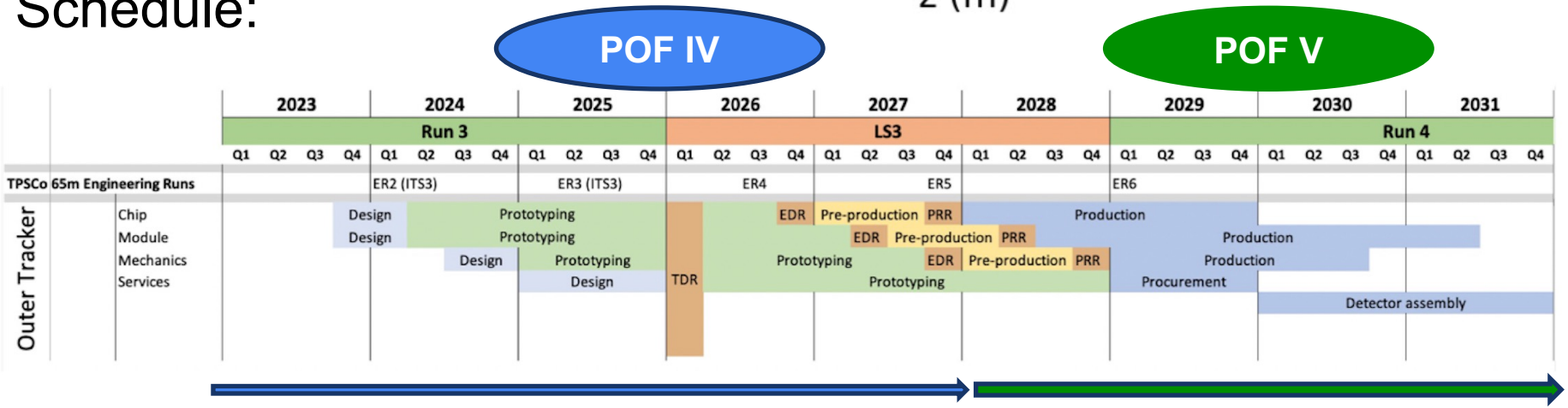

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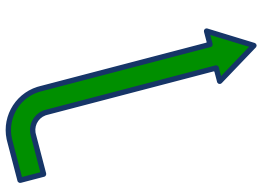
ALICE 3, Outer Tracker: GSI interests

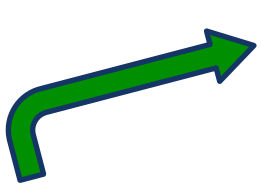


- **The Monolithic Active Pixel Sensors**
  Most probably in CMOS TPSCo 65 nm technology
  Detector Lab / GSI wide initiative (w/ Michael Deveaus, CJS)
    start an effort on ASIC design of MAPS
    with PhD students, in cooperation with IPHC Strasbourg (A. Maire, J. Baudot)
    aim at sensor for large area tracking systems, flexible to adapt to several experiments
    first discussions are happening

- **Module design** (together with Heidelberg and Bonn)
  “Lego” module concept
  Novel materials
  Industrialization

- **Interconnections** (together with Hd, Bonn, KIT / DESY within DTS)
  linked to industrialization, keeping the 45 m^2 in mind
  Also with Frankfurt (IKP, FIAS): readout

ALICE 3, Outer Tracker: GSI interests



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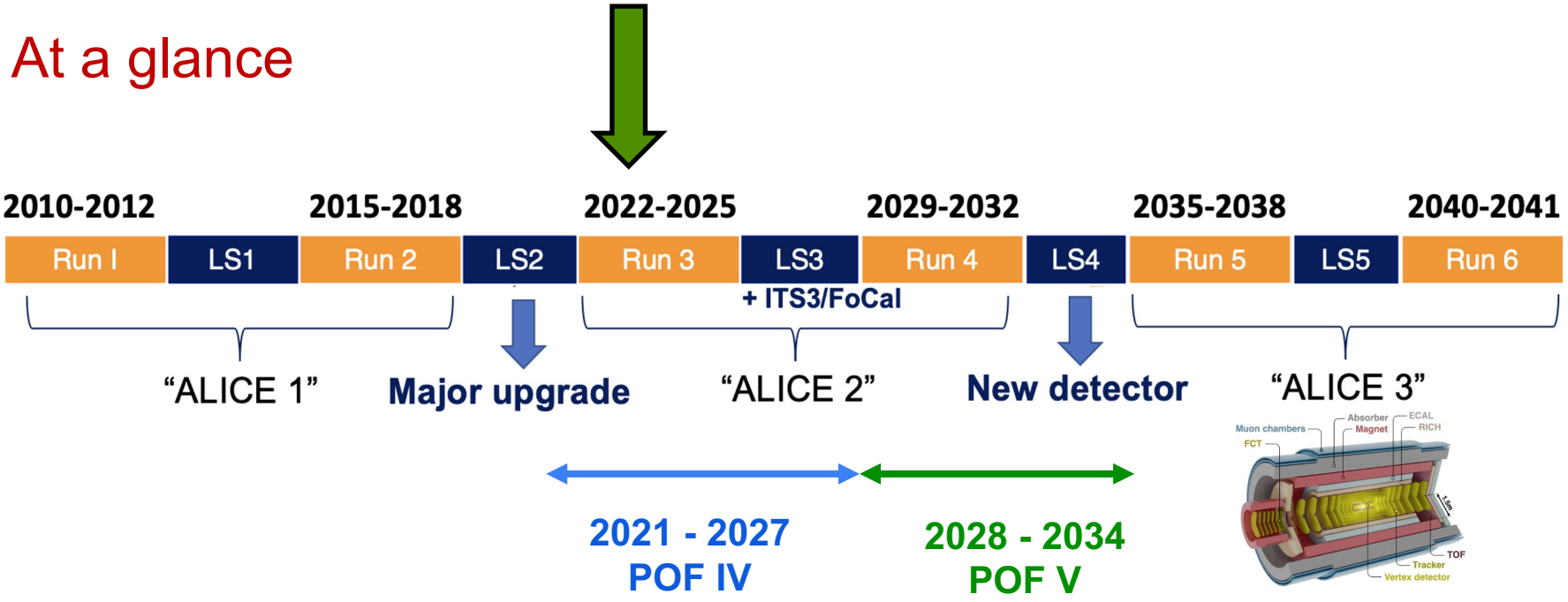
2024 – 2027: R&D and prototypes

- Moderate manpower increase
  (young scientists)
  + Heidelberg students (super attractive!)
- Moderate investment funds
  (largely depending on ASIC initiative)

NO EXACT ESTIMATES MADE YET

At a glance



- **Run 3**
- **R&D and ITS3 construction**
- R&D and prototypes for ALICE 3, OT

- **Run 4**
- Prototypes Outer Tracker, construction
- ALICE 3 physics performance studies

Spare: Run 5 and 6 integrated luminosities

System	$\mathscr{L}^{\text{month}}$	$\mathscr{L}^{\text{Run5+6}}$
pp	$0.5\,\text{fb}^{-1}$	$18\,\text{fb}^{-1}$
pp reference	$100\,\text{pb}^{-1}$	$200\,\text{pb}^{-1}$
A–A		
Xe–Xe	$26\,\text{nb}^{-1}$	$156\,\text{nb}^{-1}$
Pb–Pb	$5.6\,\text{nb}^{-1}$	$33.6\,\text{nb}^{-1}$

Spare: key physics observable and kinematic range of interest in ALICE 3

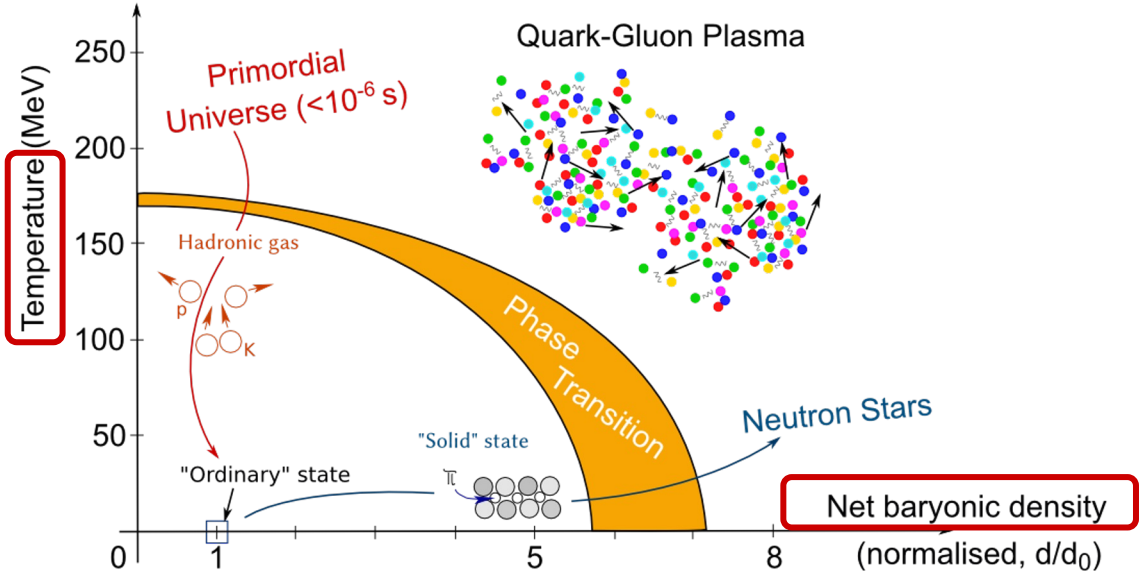
Observables	Kinematic range
Heavy-flavour hadrons	$p_{\mathrm{T}} \to 0$, $\lvert\eta\rvert < 4$
Dielectrons	$p_{\mathrm{T}} \approx 0.05$ to $3\,\mathrm{GeV}/c$, $M_{\mathrm{ee}} \approx 0.05$ to $4\,\mathrm{GeV}/c^2$
Photons	$p_{\mathrm{T}} \approx 0.1$ to $50\,\mathrm{GeV}/c$, $-2 < \eta < 4$
Quarkonia and exotica	$p_{\mathrm{T}} \to 0$, $\lvert\eta\rvert < 1.75$
Ultrasoft photons	$p_{\mathrm{T}} \approx 1$ to $50\,\mathrm{MeV}/c$, $3 < \eta < 5$
Nuclei	$p_{\mathrm{T}} \to 0$, $\lvert\eta\rvert < 4$

ALICE
Status and plans

Silvia Masciocchi (GSI)

GSI Research Retreat
July 18, 2023

Phase diagram of QCD matter: exploration via heavy-ion collisions



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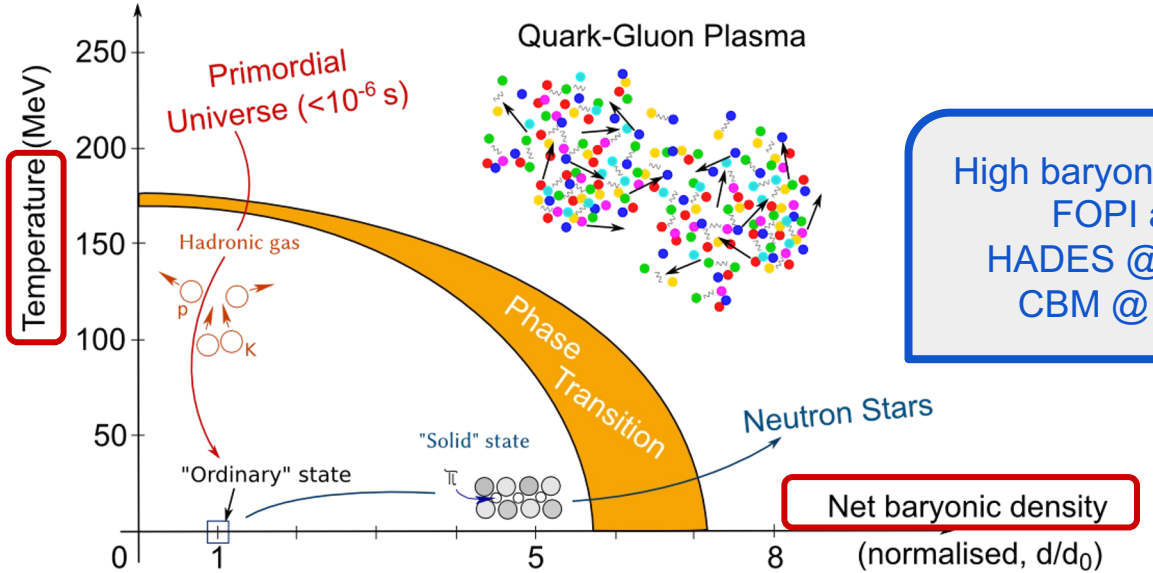
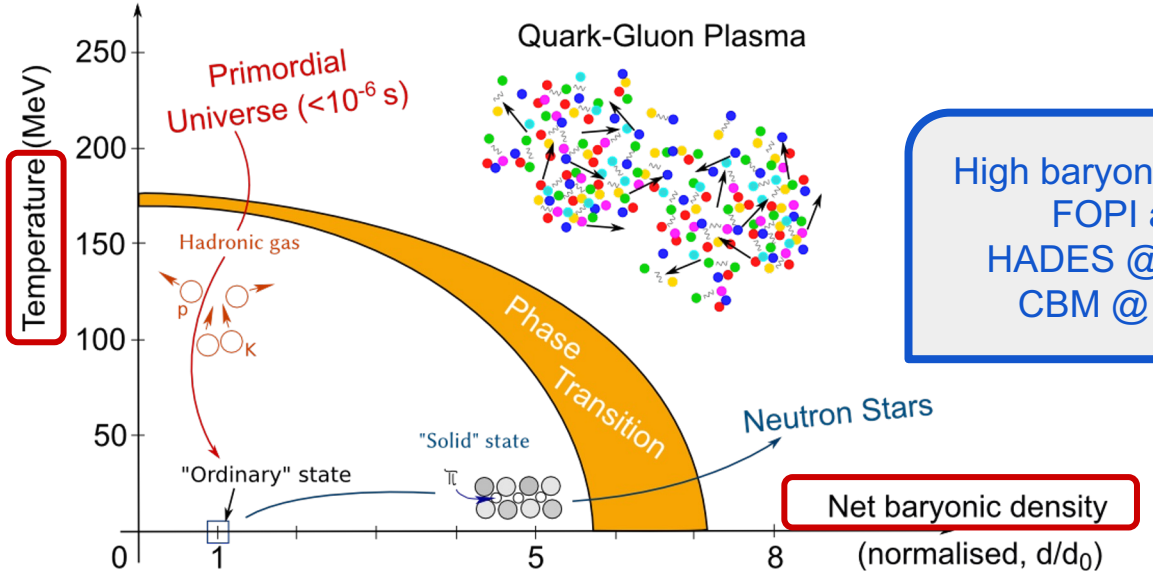


High baryonic density
FOPI and
HADES @ SIS18
CBM @ FAIR

Phase diagram of QCD matter: exploration via heavy-ion collisions

ALICE

@LHC
High temperature



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A Large Ion Collider Experiment @GSI since 1996

Peter Braun-Munzinger, S.M. (2011)

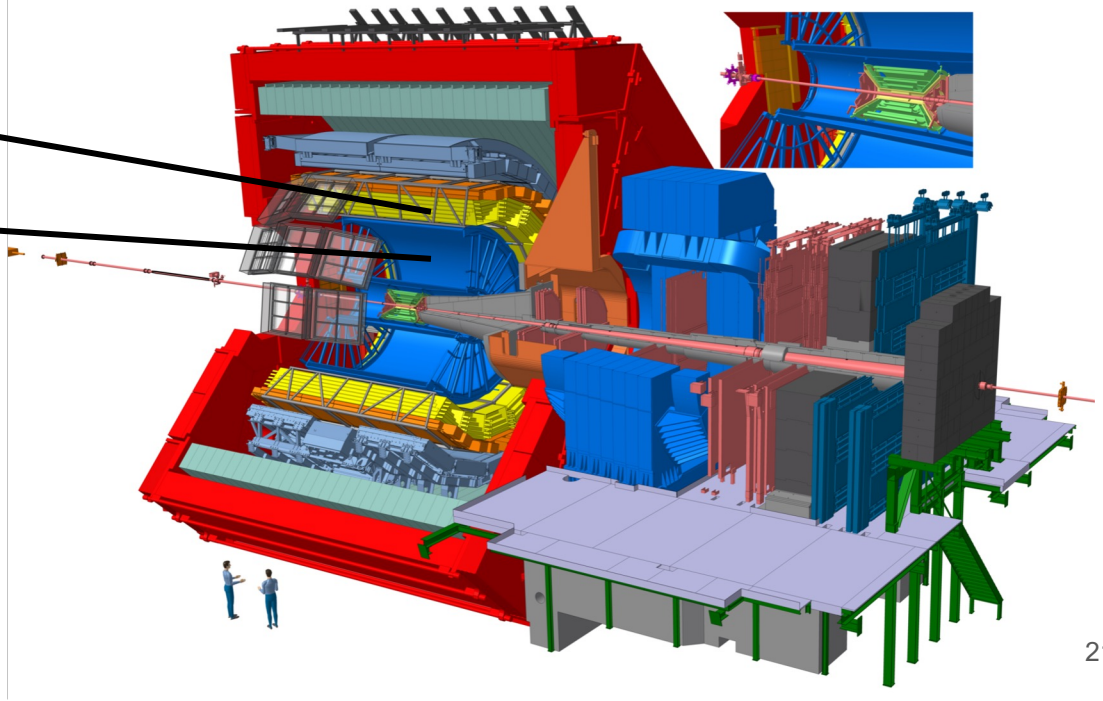
& Detector Laboratory
& Scientific IT Department

Transition Radiation Detector

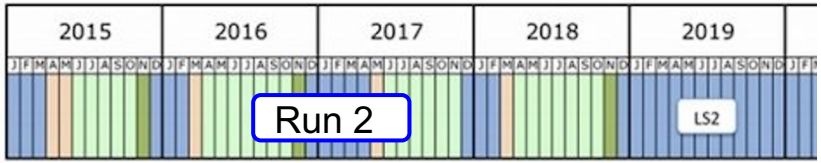
Time Projection Chamber

High Level Trigger

GRID Tier2 +
National Analysis Facility



LHC Runs 1 + 2: 2009 - 2018



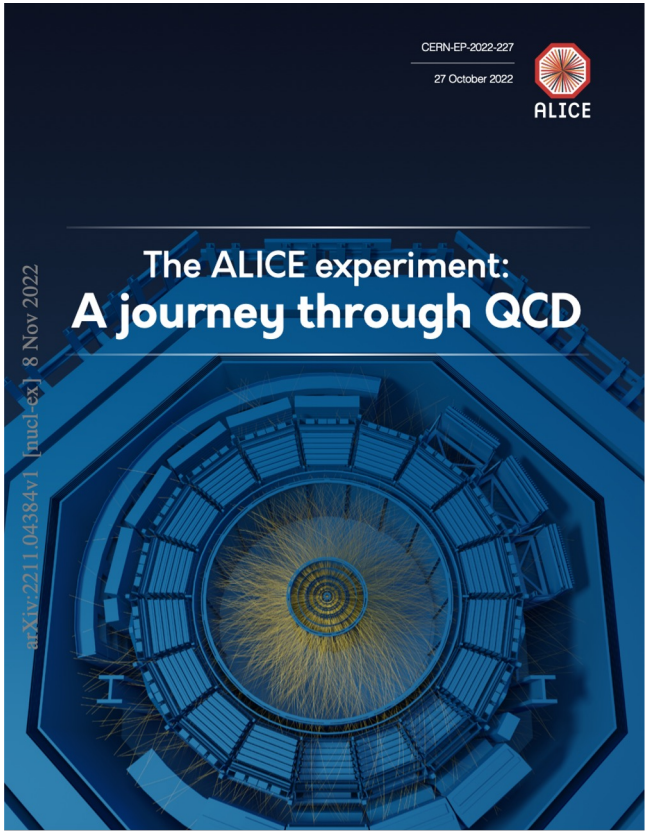
Pb-Pb: integrated luminosity = **1.0 nb^{-1}**
(up to few kHz interaction rate)

Proton-proton: 0.9 to 13.6 TeV
2×10^9
events

Proton-lead

443 papers

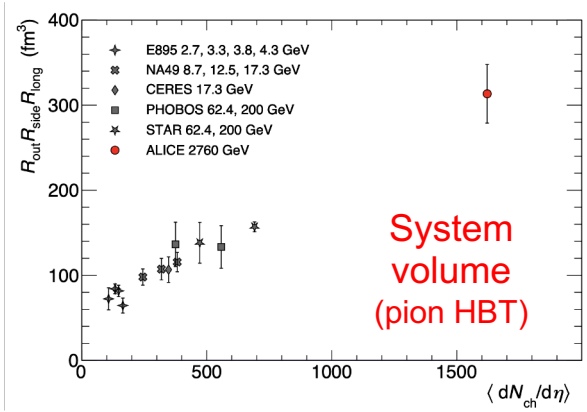
>30 PhD theses
in our group: DA & HD



ALICE review:
https://arxiv.org/abs/2211.04384

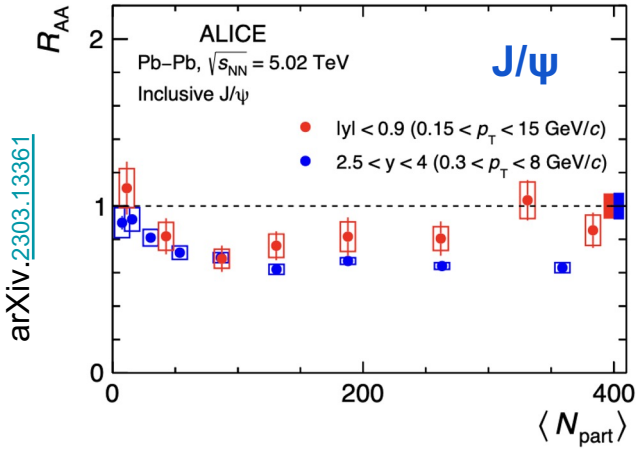
Hanbury-Braun and Twiss interferometry

Phys. Lett. B696 (2011) 328–337 — 391 citations



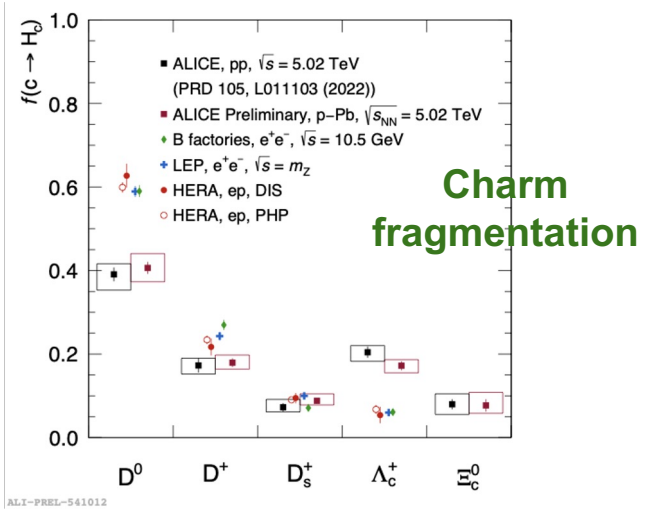
J/ψ production in Pb-Pb: Run 1+2 legacy paper

arXiv.2303.13361



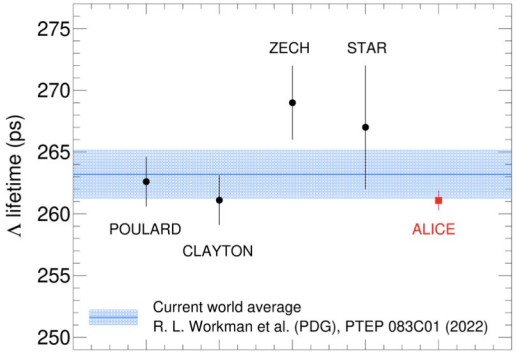
Charm fragmentation in hadronic collisions

KF particle, ML methods



arXiv.2205.13993

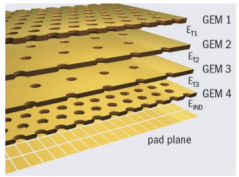
Λ hyperon: precise lifetime measurement



arXiv.2303.00606

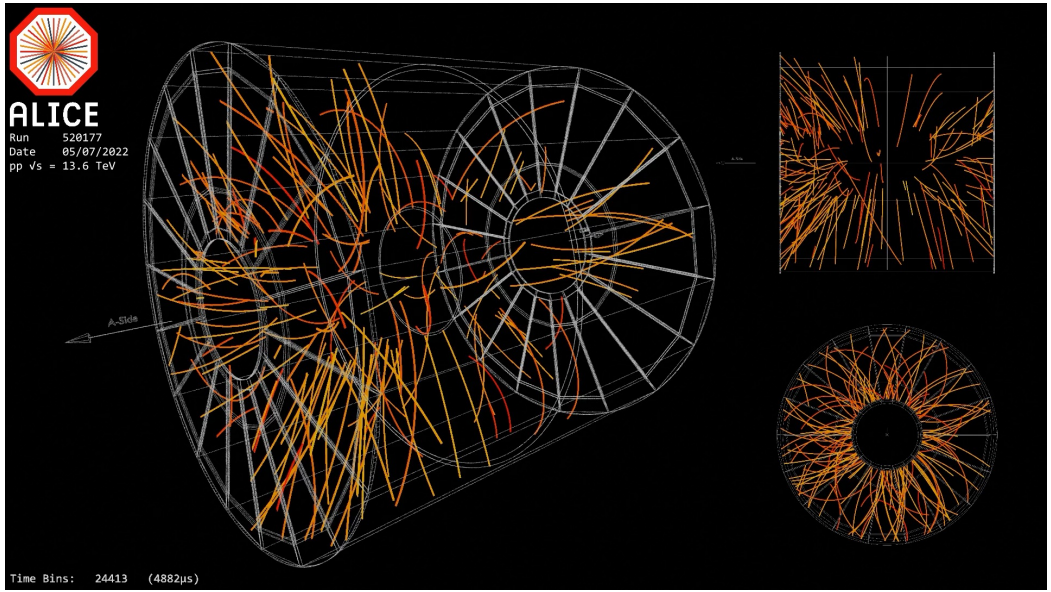
ALICE upgrades: installed in Long Shutdown 2 (2019-2021) → 50 kHz

Funded through Helmholtz large investment fund (LHC upgrades) Pb-Pb



GEM Time Project Chamber

From gated to continuous readout



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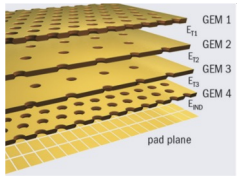

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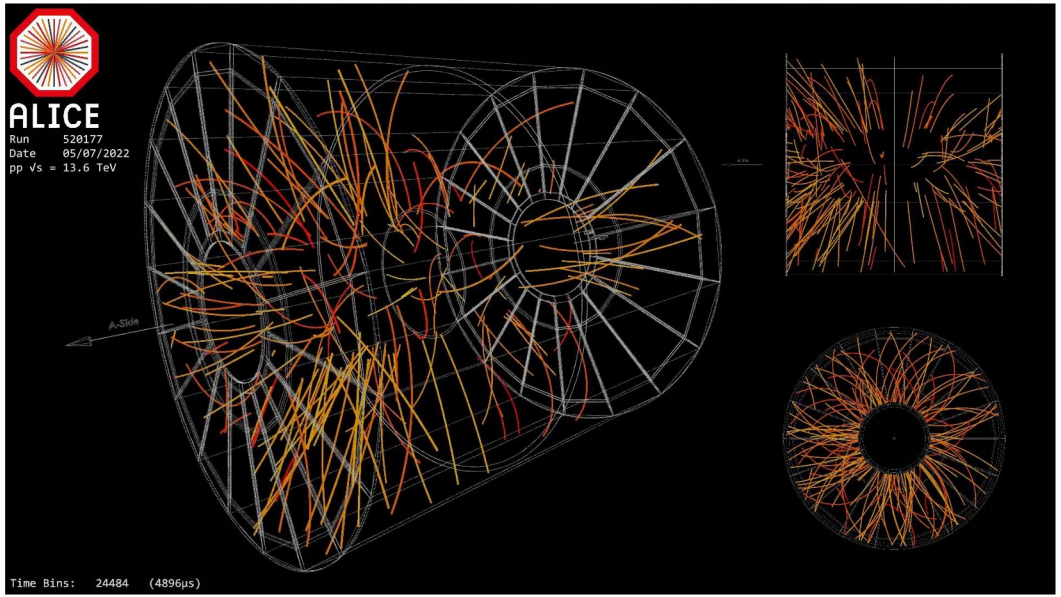

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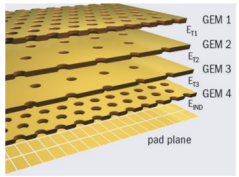

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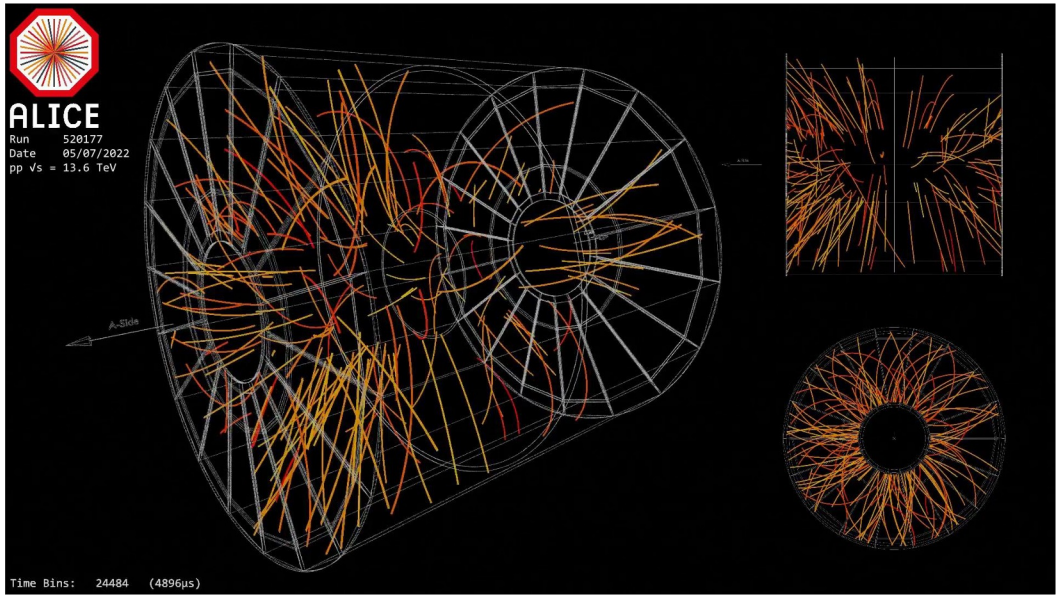
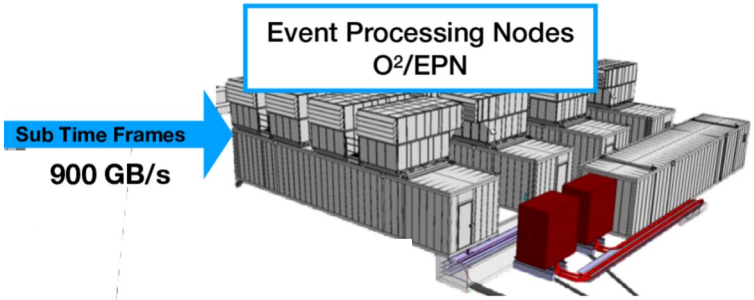


O^2 Online-Offline framework EPN farm



~ 250 servers
~ 2000 GPUs and CPUs
for calibration and reconstruction

Run 3 and 4

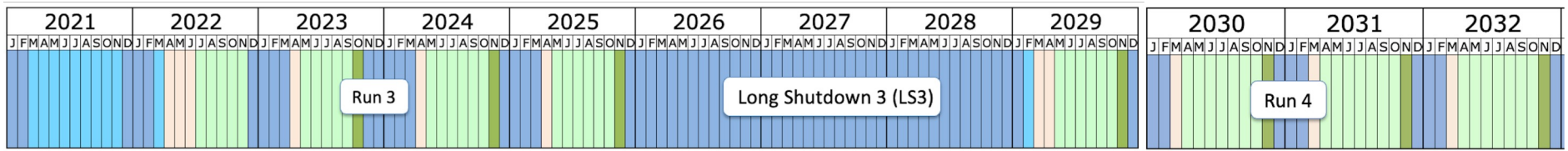
Heavy ions

Pb-Pb → 13 nb^{-1}
O-O
p-Pb

Proton-proton

- Originally mostly reference data
- Now special FILTER developed to store events of interests

2022: 500 x statistics of Runs 1+2!



Run 3 and 4

Huge statistics with improved detector performance !

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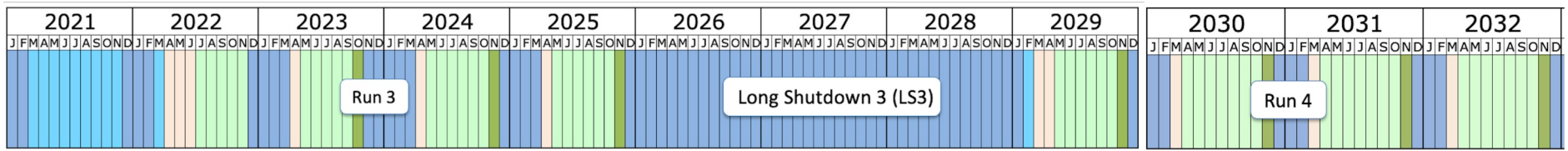
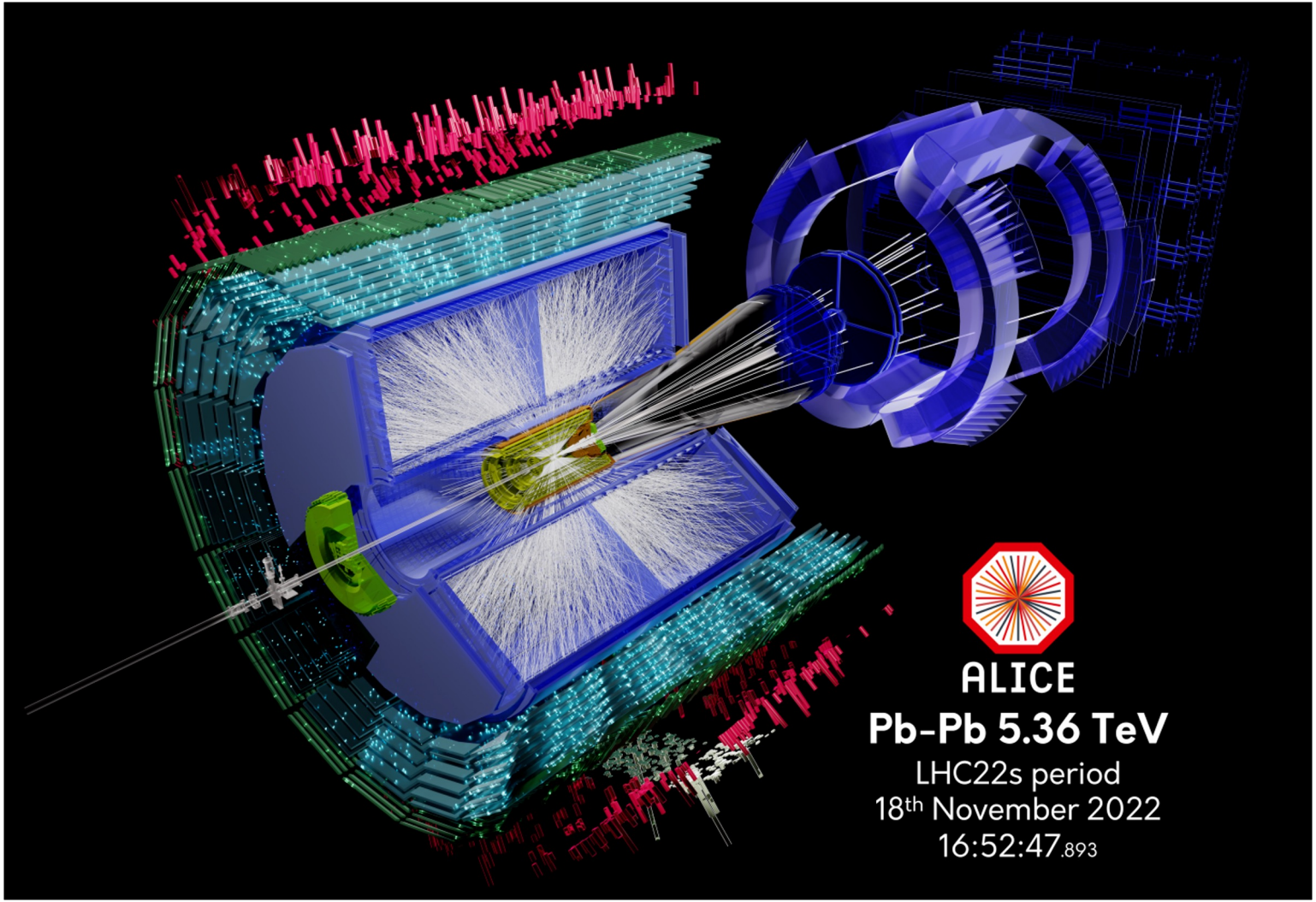
2022: 500 x statistics of runs1+2!




ALICE
Pb-Pb 5.36 TeV
LHC22s period
18th November 2022
16:52:47.893

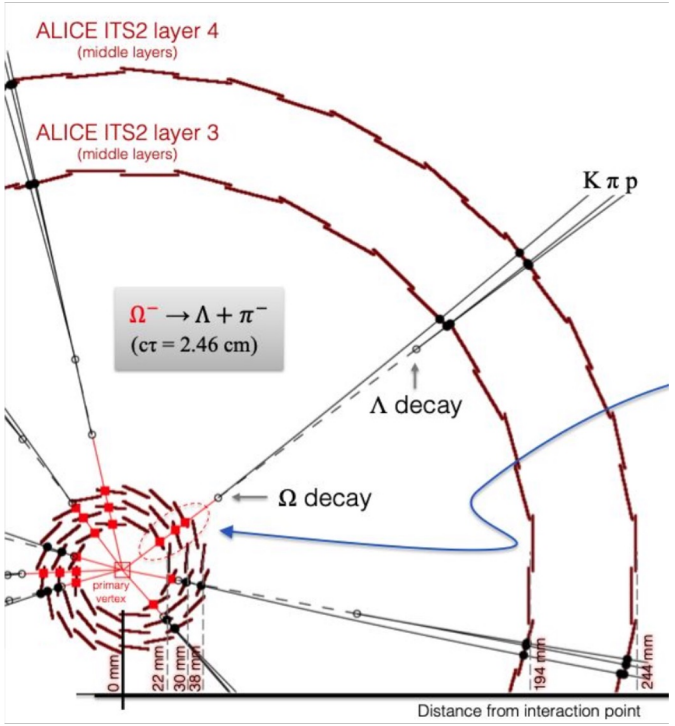
Run 3 and 4

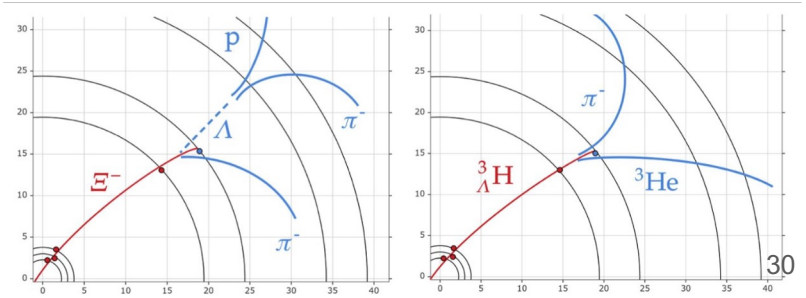
Open heavy flavors: **charm** and **beauty**
(baryons in Pb-Pb)

Heavy quarkonia states

Hyper-nuclei

→ Strangeness tracking with KF Particle code

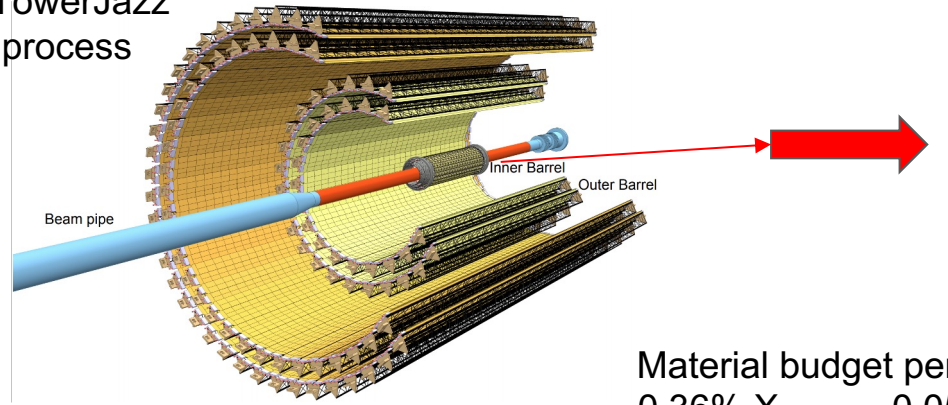


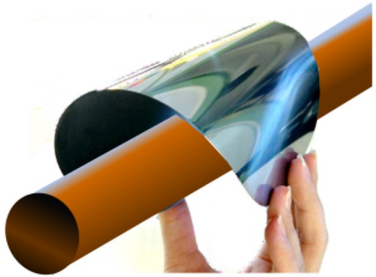


ALICE Inner Tracking System (ITS) → ITS2 → ITS3

LS2 LS3, 2028

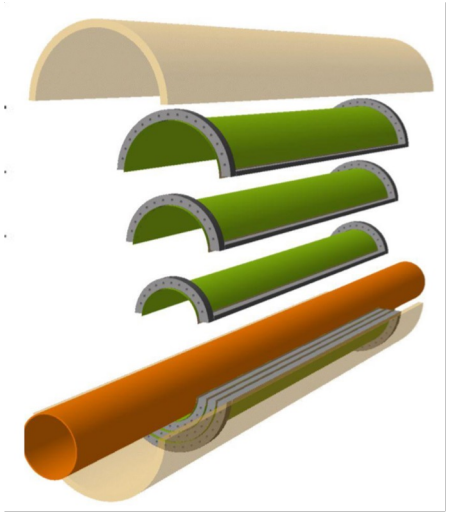
ALPIDE monolithic active pixel sensor
CMOS TowerJazz
180 nm process

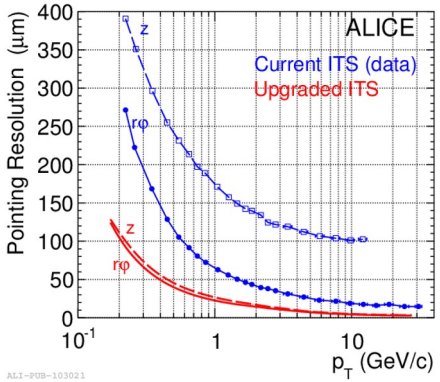




Material budget per layer
0.36% X_0 → 0.05% X_0

Radius of innermost layer
22 mm → 18 mm

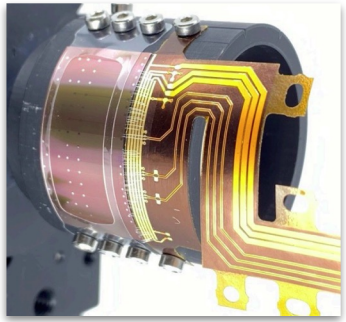


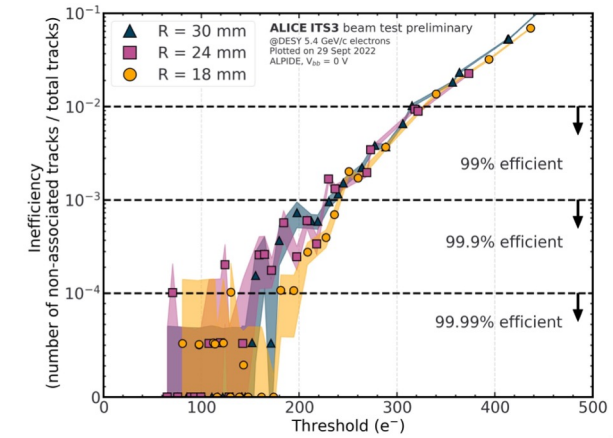


Monolithic Active Pixel Sensors: R&D ↔ pixels at DL, Michael Deveaux

Since 2019 (HD students)

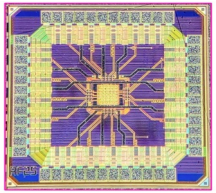
Bending (ALPIDEs)

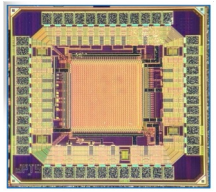


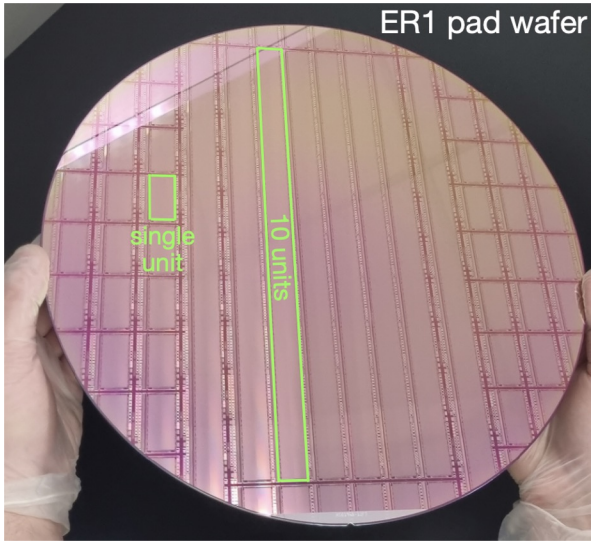


10.1016/j.nima.2021.166280

65 nm TPSCo technology with stitching

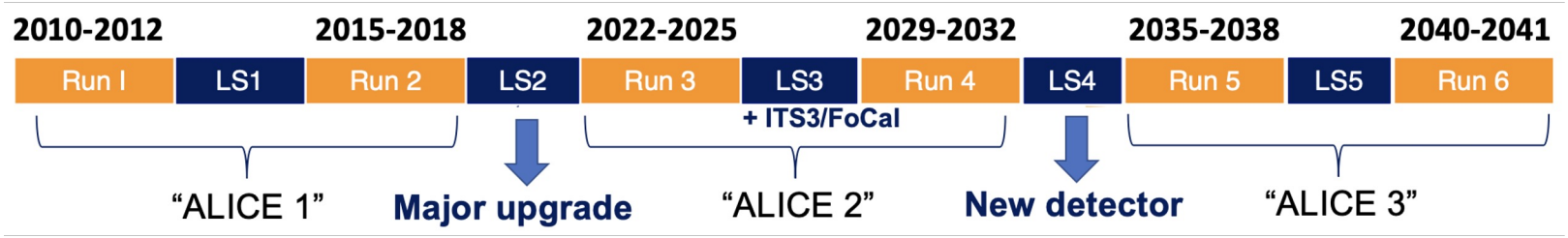






(Modest) contribution by GSI to ITS3 project

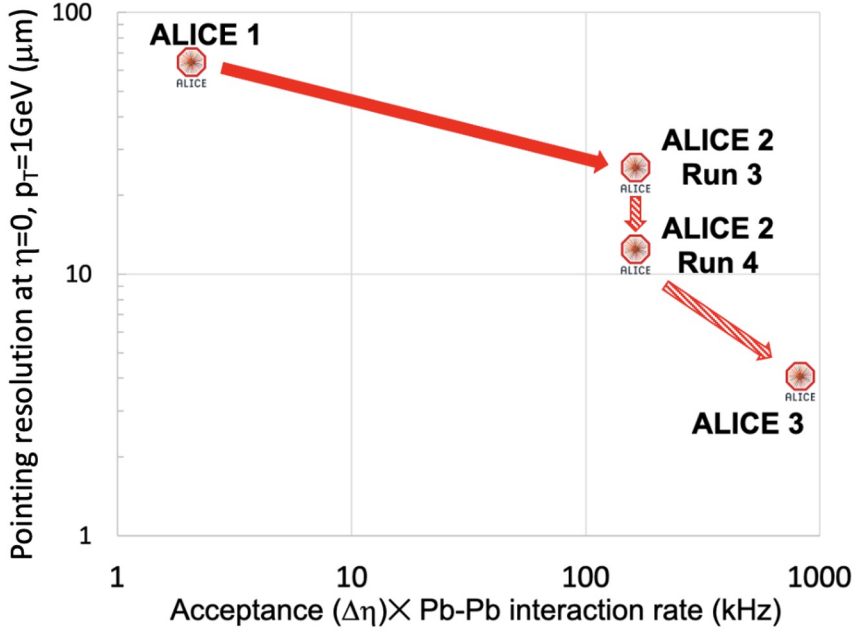
Beyond Run 4 (2032): ALICE 3



Enhance physics reach with better:

- Rate capabilities
- Acceptance
- Tracking precision

Gain access to unprecedented probes and precision

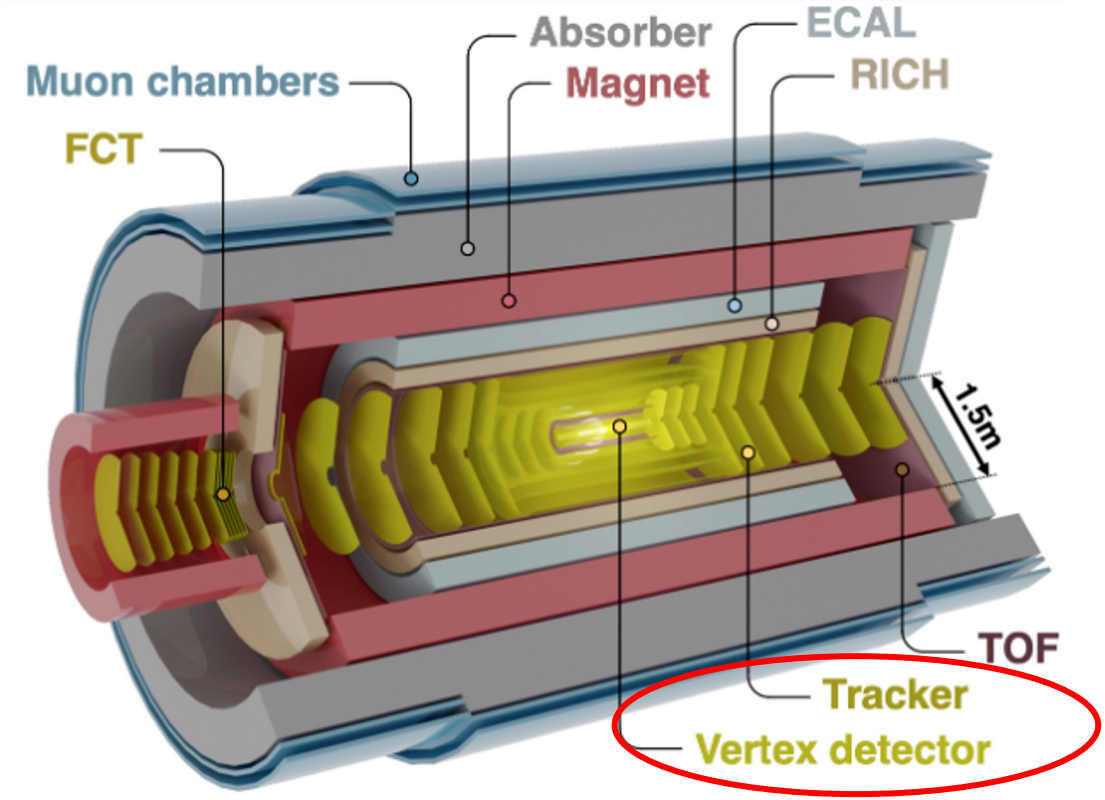


ALICE 3

Next generation heavy-ion experiment

- Tracking precision x 3
  <10 μm at p_T > 200 MeV/c
- Acceptance x 4.5
  |η| < 4 (with particle ID)
- Heavy-ion rate x 5
  Proton-proton rate x 25

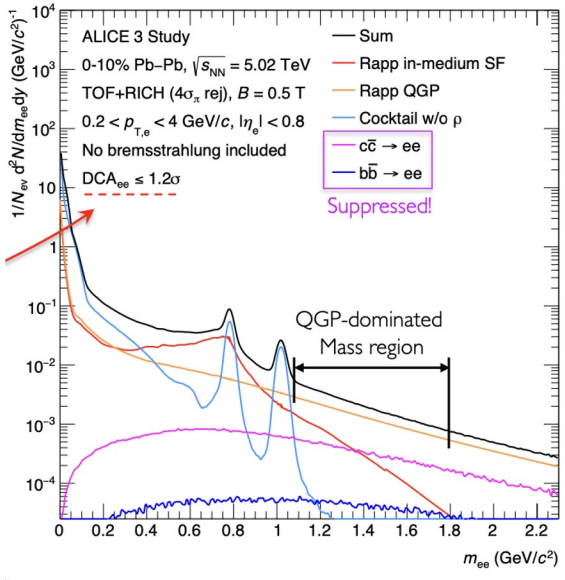
Letter of Intent CERN-LHC-2022-009
Positive review by LHCC in March 2022

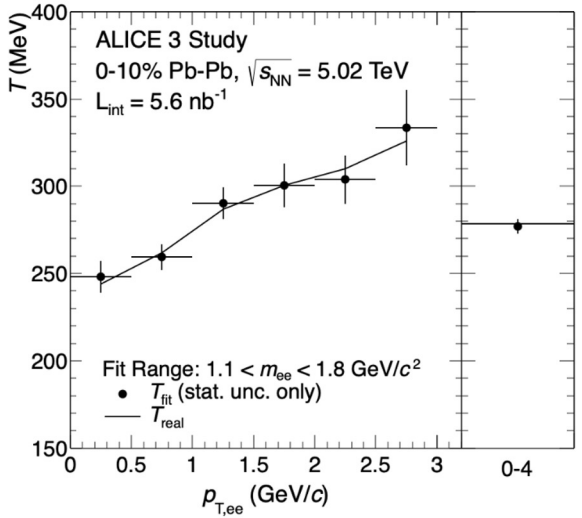


ALICE 3 physics: QGP thermal emission via dileptons

- High precision tracking (impact parameter)
- Electron identification (TOF, RICH, EMCal)

→ Heavy-flavor rejection at low p_T ⇒ EXTREME PERFORMANCE

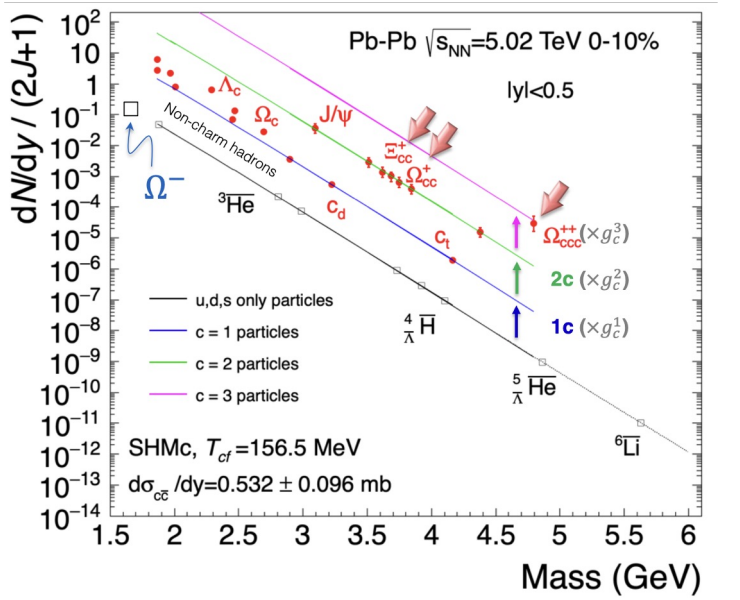




Access the time evolution of the temperature

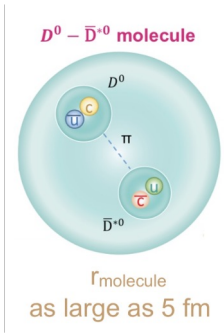
ALICE 3 physics: heavy flavors

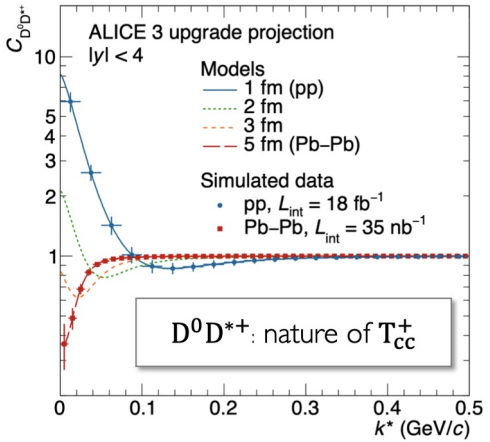
Multi-charm baryons:
Unique probe of hadronization
(recombination of multiple charm quarks)



A. Andronic et al., JHEP 07 (2021) 035

Interactions between charm hadrons
And study nature of charm exotic states

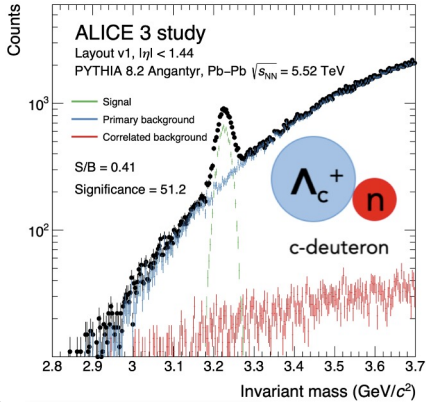




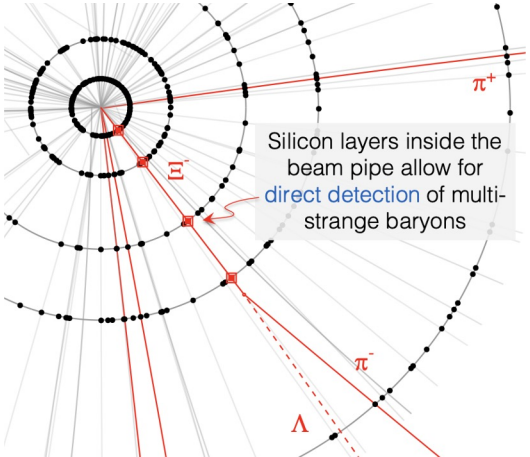
Plus D-D (de-)correlations
Heavy-flavor transport: e.g. Λ_c, Λ_b v_2

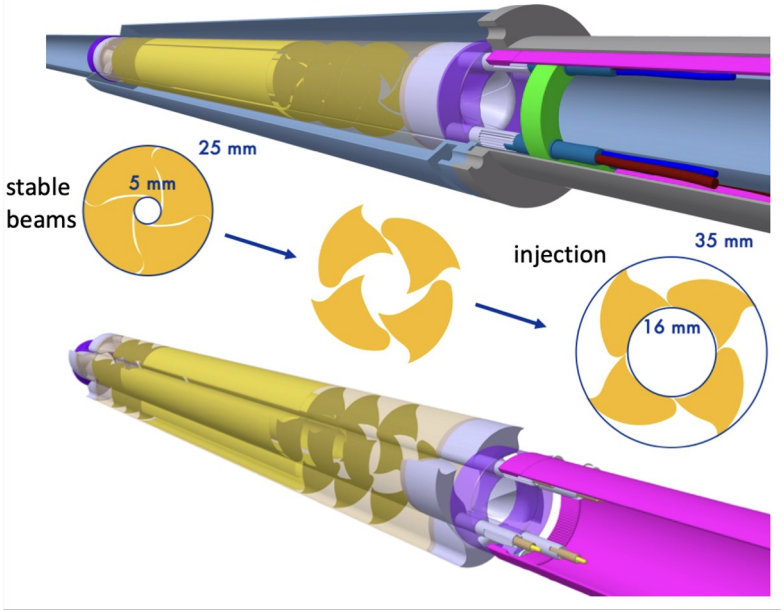
ALICE 3 physics: and more

- First observation of charmed nuclei?

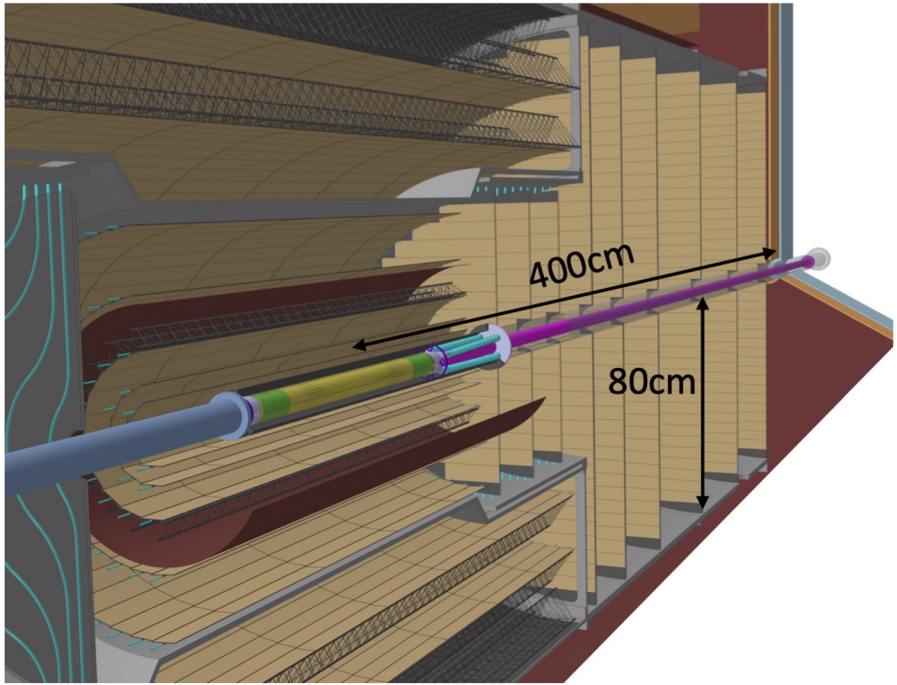


- Super strangeness tracking with the ALICE 3 vertex detector
  → strange particles, hyper-nuclei





ALICE 3: Outer Tracker



Interest of the German university groups:

60 m^2 of pixel detectors:

- 8 rapidity units
- Compact (R~80 cm, z~ ±400 cm)
- Resolution ~10 μm → pixels 50x50 $μm^2$
- 1% of X_0 per layer
- Low power density ~ 20 mW/cm^2

Industrialization of modules

GSI competences (DL, EE, workshops, ALICE) would be an ideal asset

A scoping document is being prepared (end 2023, beginning 2024)

Summary

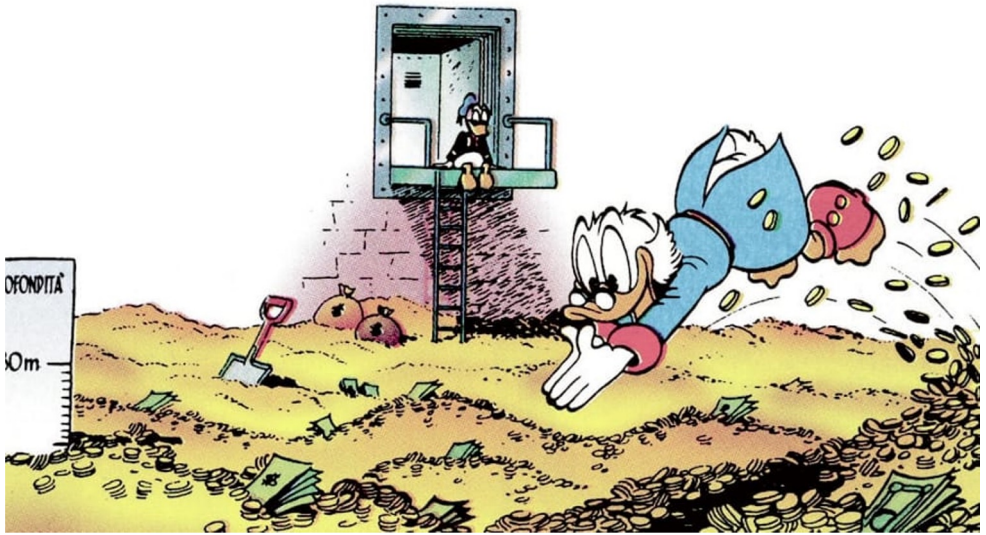
ALICE@GSI since 1996:
a very rich harvest

… and much more to explore ahead of us!

SPARES

Summary

ALICE@GSI since 1996:
a very rich harvest



GEM TPC: space charge distortion correction

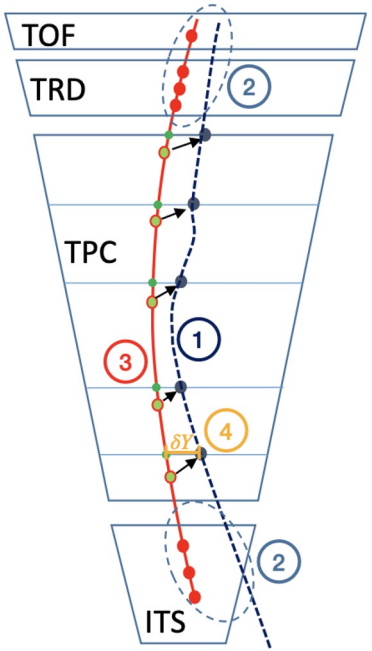
Track-to-cluster residuals

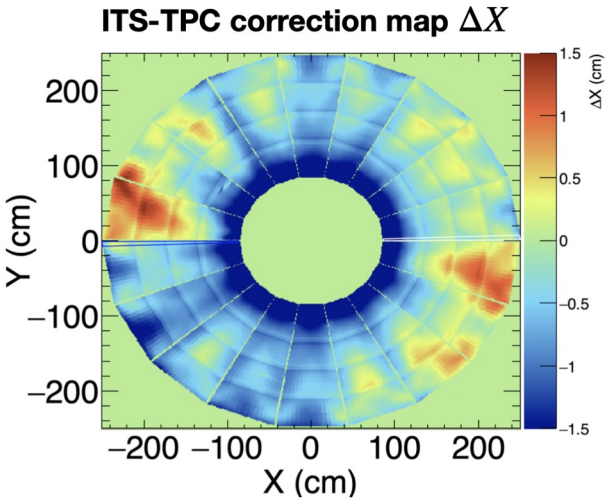
↓

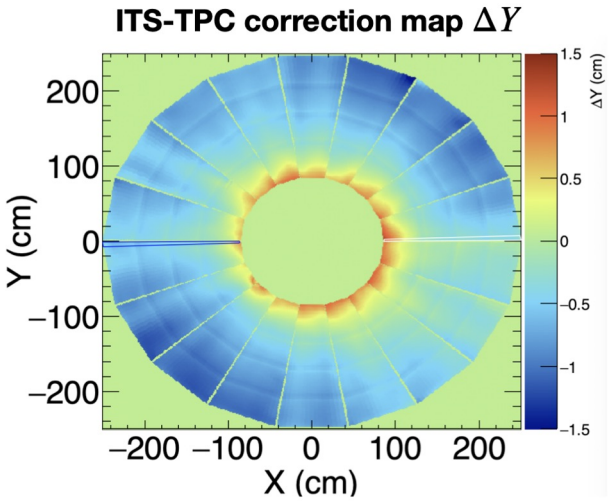
Correction maps Data/Simulation

↓

Spline object used in reconstruction







LHC schedule