Brazilian Participation in ALICE

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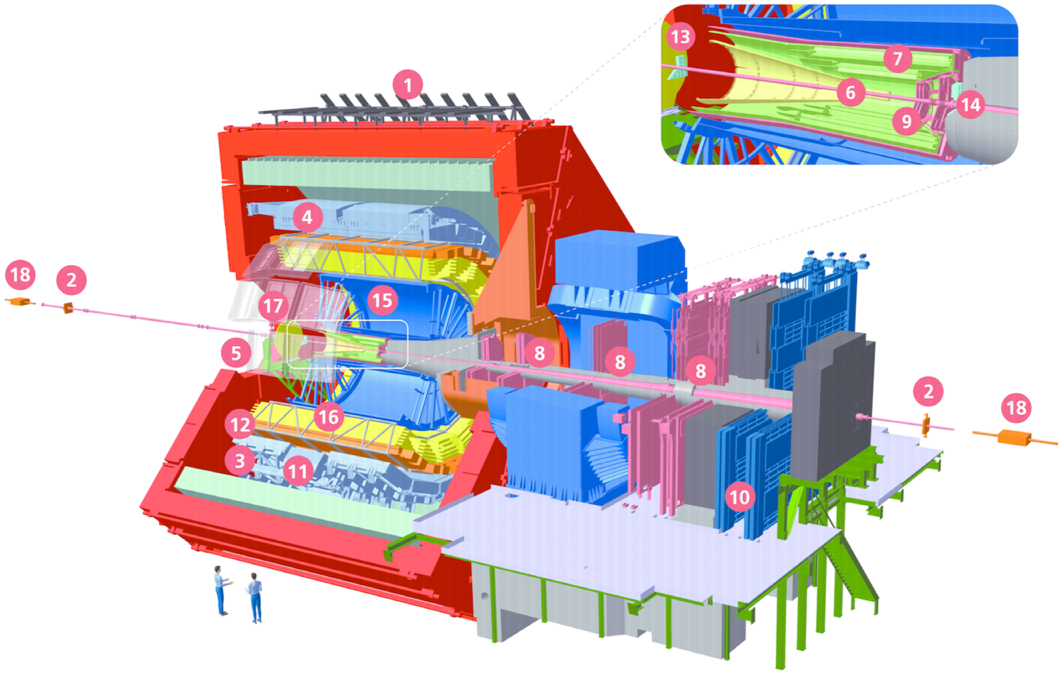
for the Brazil-ALICE Collaboration

What is ALICE?

- Optimized to study collisions of nuclei at the ultra-relativistic energies
  - 40 countries
  - 147 member institutes
  - 1861 members



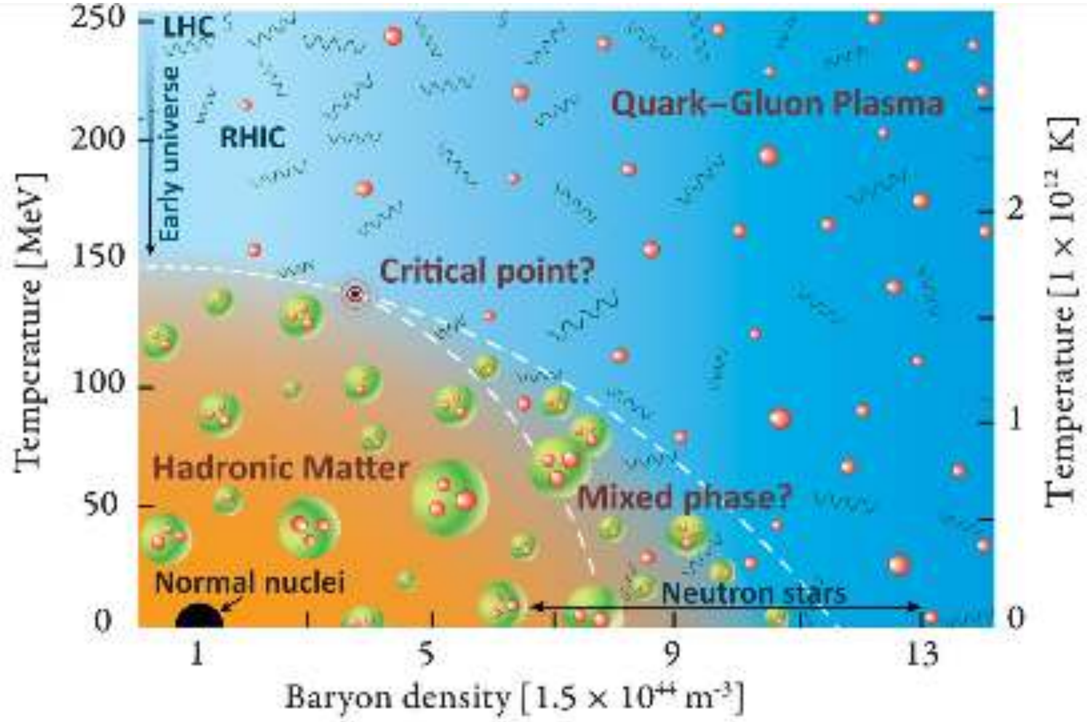
1. **ACORDE** | ALICE Cosmic Rays Detector
2. **AD** | ALICE Diffractive Detector
3. **DCal** | Di-jet Calorimeter
4. **EMCal** | Electromagnetic Calorimeter
5. **HMPID** | High Momentum Particle Identification Detector
6. **ITS-IB** | Inner Tracking System - Inner Barrel
7. **ITS-OB** | Inner Tracking System - Outer Barrel
8. **MCH** | Muon Tracking Chambers
9. **MFT** | Muon Forward Tracker
10. **MID** | Muon Identifier
11. **PHOS / CPV** | Photon Spectrometer
12. **TOF** | Time Of Flight
13. **T0+A** | Tzero + A
14. **T0+C** | Tzero + C
15. **TPC** | Time Projection Chamber
16. **TRD** | Transition Radiation Detector
17. **V0+** | Vzero + Detector
18. **ZDC** | Zero Degree Calorimeter

What are the ALICE goals?

- The study of matter under extreme conditions
  - Emergent QCD phenomena
  - Quark-gluon plasma characterization

"It is the simplest form of complex matter that we know of, ..., most directly connected to the fundamental laws that govern all matter in the universe."

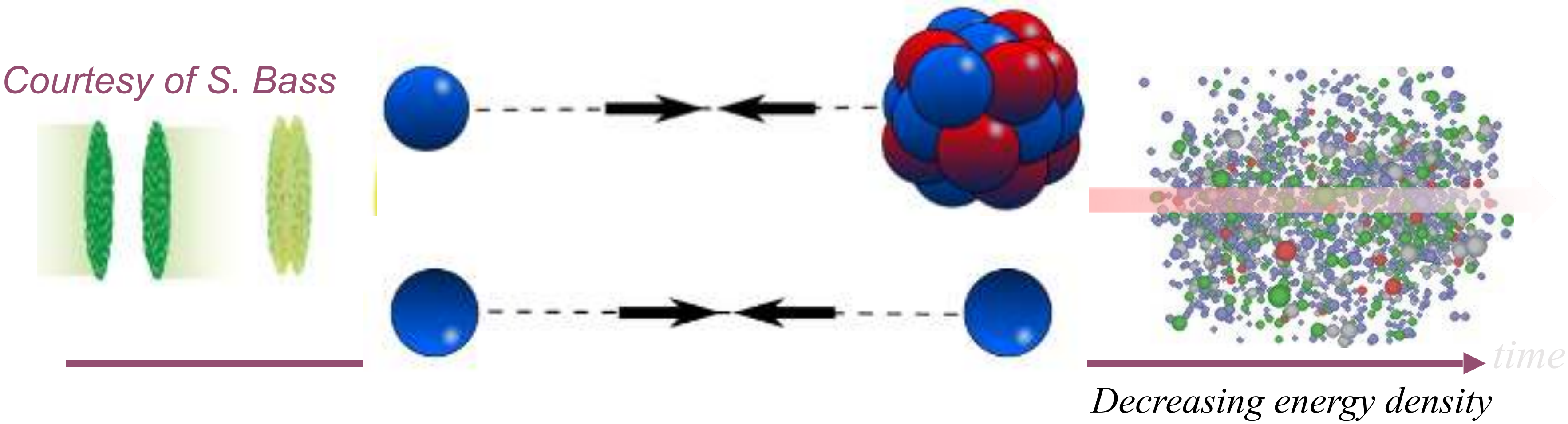
W. Busza, K. Rajagopal and W. van der Schee, Ann. Rev. Nucl. Part. Sci. 2018. 68:1–49



Brazil in ALICE

- Contribute to the ALICE program through a relevant participation in:
  - Physics data analysis
  - Development of state-of-the-art instrumentation
- The size of the Brazilian participation:
  - 9 faculty researchers + 1 postdoc (~1.75% of ALICE)
  - 12 PhD thesis defended + 10 PhD active students (~1.5% of ALICE)

How to achieve the ALICE goals?

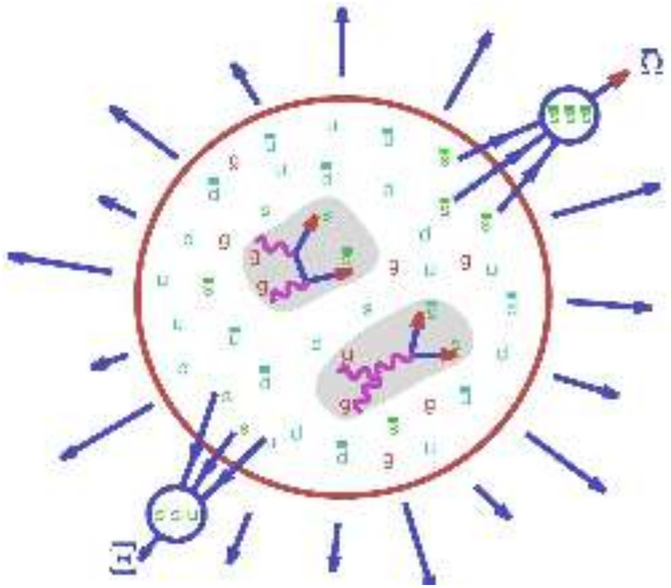


- Macroscopic characterization (long wavelength) of the QGP
  - Global (*bulk*) observables of the *freeze-out* state
- Microscopic characterization (short wavelength or quasi-particles) of the QGP
  - High-energy probes (*Hard Probes*)
- Comparison with more elementary collisions, such as p-p and p-Pb, is essential

Macroscopic View: Strangeness Enhancement

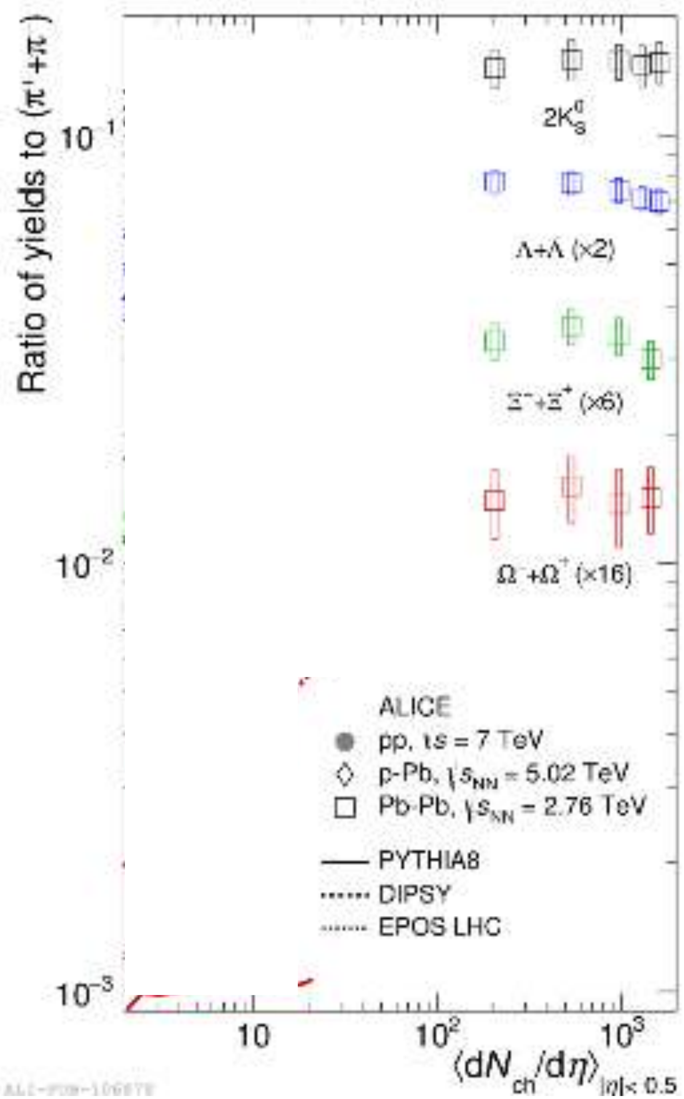
J. Rafelski e B. Müller, PRL48, 1982

- Direct production of strange hadrons via color string breaking is suppressed
  - Multistrange is even more suppressed
- Hadron reaction from single strange to multistrange is slow and kinetically disfavored
- **QGP scenario brings enhanced production of strange hadrons**

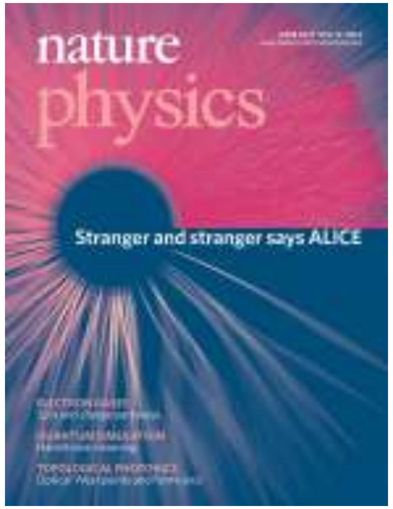


Strangeness Enhancement

- Strangeness Enhancement in pp data, where no QGP expected
- Strangeness increases with multiplicity following a universal trend
- Paradigm shift in heavy-ion physics
- Fundamental knowledge added to HEP

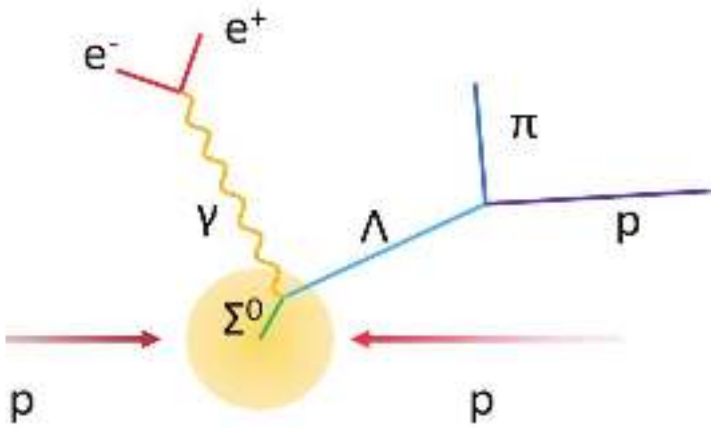


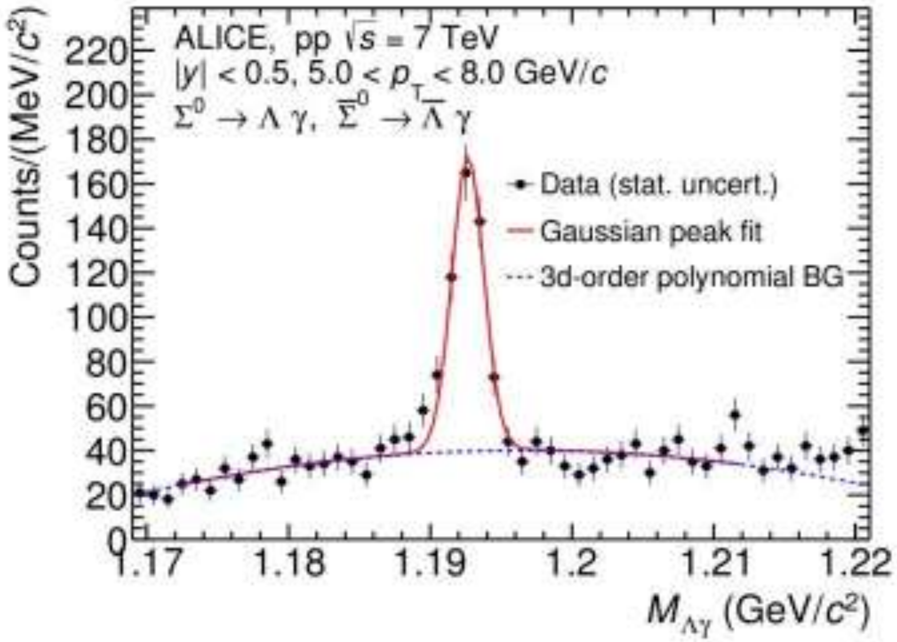
ALICE, Nature Phys. 13, (2017) 535



Next step: explore further the strangeness landscape

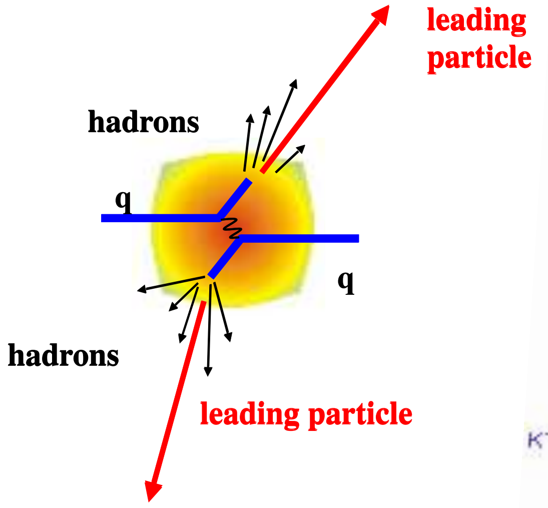
- Measurement of Σ^0 baryon in pp and Pb-Pb collisions
- Test of Isospin symmetry and insight into the mechanisms driving Σ^0 production
- Aplication of ML techniques for V0s/Cascades selection

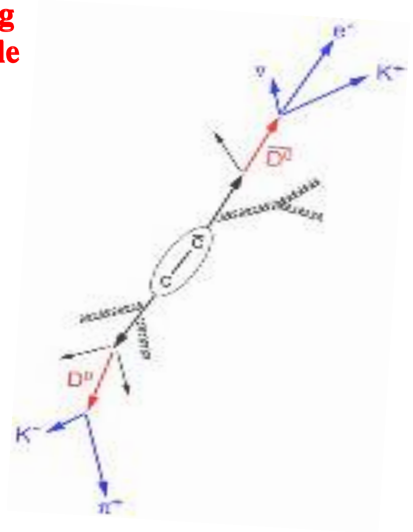


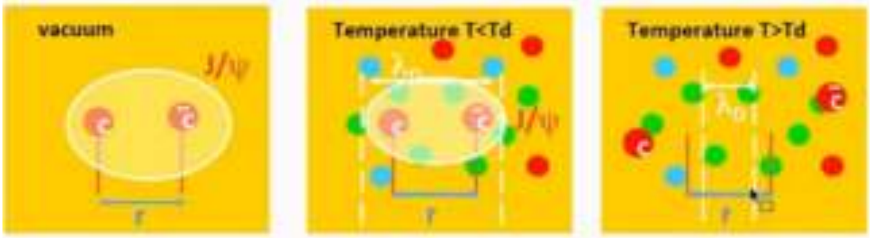


Microscopic View:
Heavy Flavor (Open states and Quarkonia)

- The production of heavy quarks is relatively well understood:
  - The production of heavy quarks is limited to initial hard scattering processes within a very short time interval and described by pQCD.
- Heavy quarks remain as such throughout their interaction with the medium and hadronization and their propagation occurs through well-known processes (similar to Brownian motion)
- Quarkonium states will be melted due to medium screening leading to quarkonia suppression
- Heavy quark mesons can be measured by their leptonic and hadronic decay

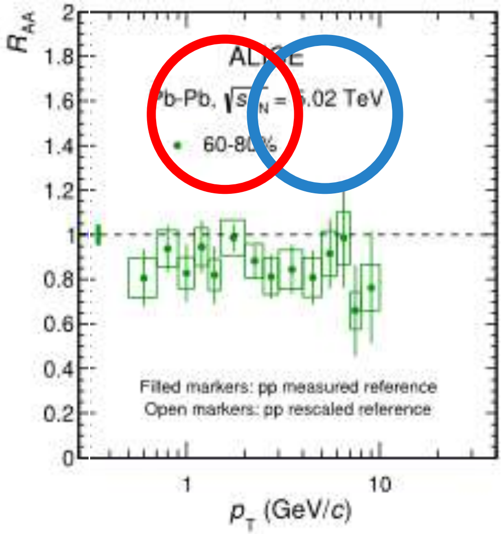






Nuclear Modification Factor

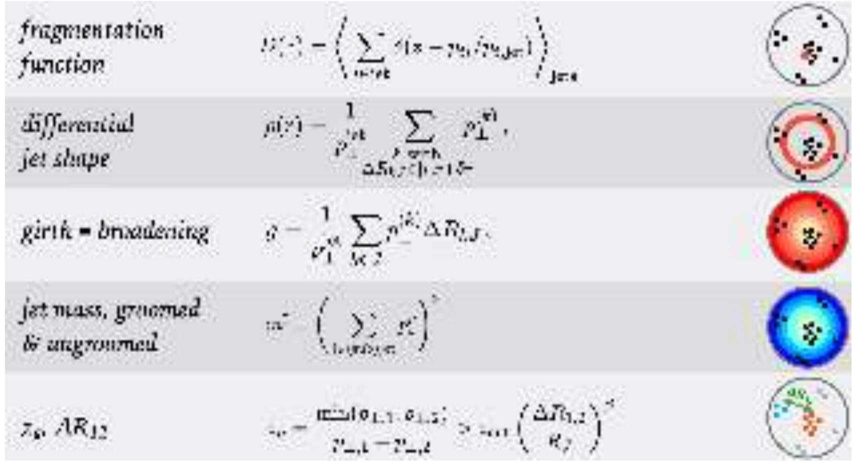
PLB 804 (2020) 135377

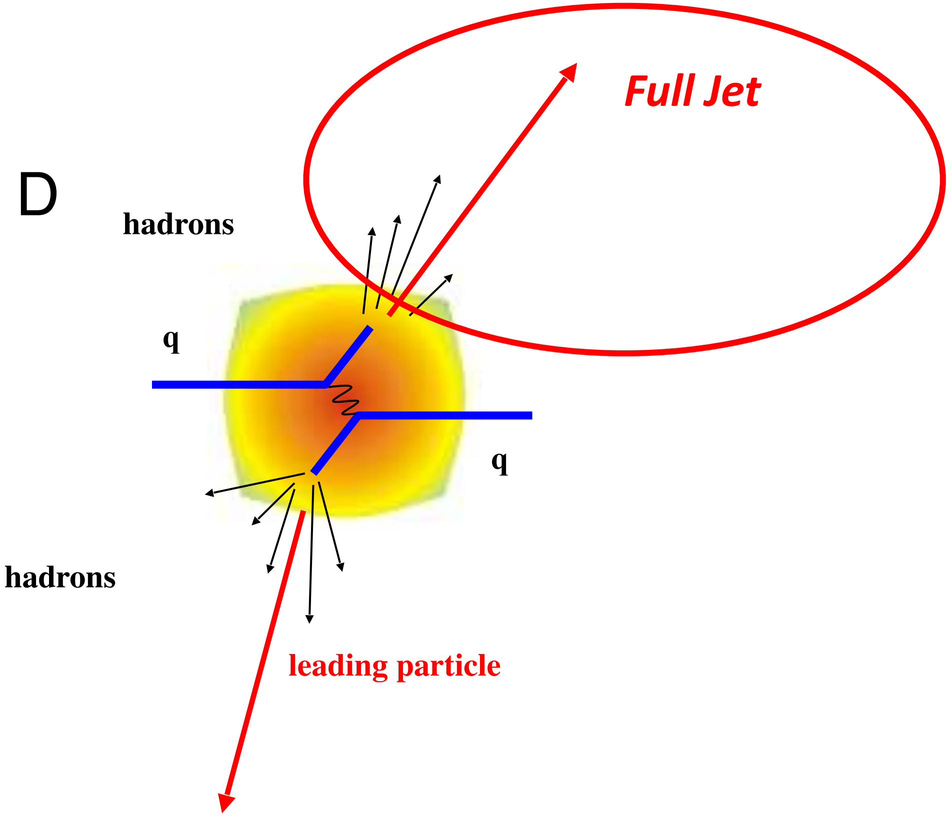


- Electrons originating from the decay of heavy quarks as a function of centrality
- **Clear suppression in more central Pb-Pb collisions!**
- Consistent with unity in p-Pb collisions

Next step: Heavy Flavor and Jets

- Go beyond the leading particle
  - Measure the full heavy flavor jet
- Heavy flavor jet tagged by electrons and mésons D
- J/ψ jet tagged
- Explore jet subestructure observables



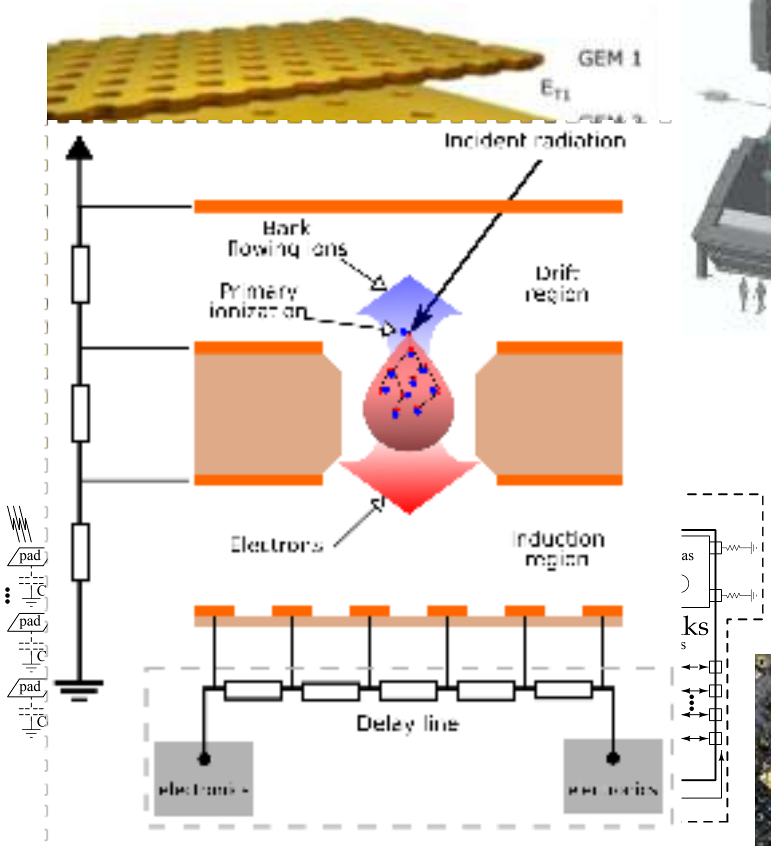


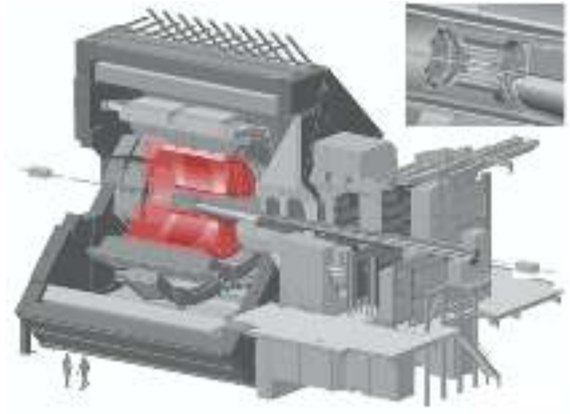
ALICE Upgrade for Run 3

- Several changes to reach 50kHz in Pb-Pb
  - A new ITS
  - **A faster and trigger-less readout for the TPC and MCH**
  - Full readout and DAQ chain rebuilt (O^2 project)
  - **Muon Forward Detector (MFT) added**
  - Some other detectors added/replaced

ALICE Upgrade for Run 3

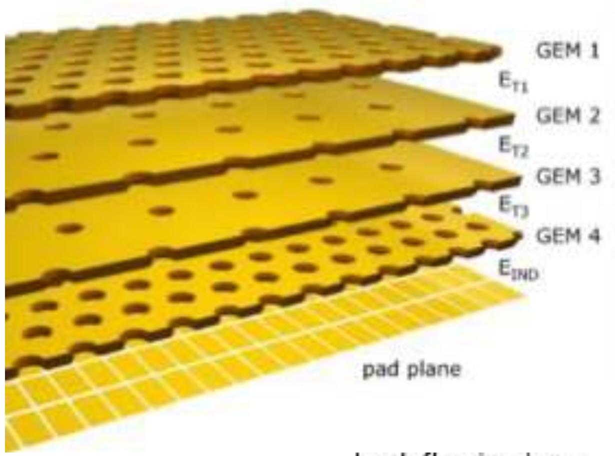
- Time Projection Chamber (TPC)
- Brazilian contribution:
  - **SAMPA chip**
    - A 32 input channels ASIC, made in CMOS 130nm technology
    - Combines analogic and digital functionalities in the same chip
    - Continuous readout

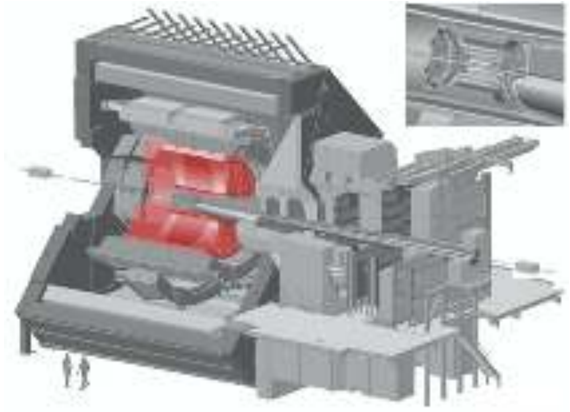


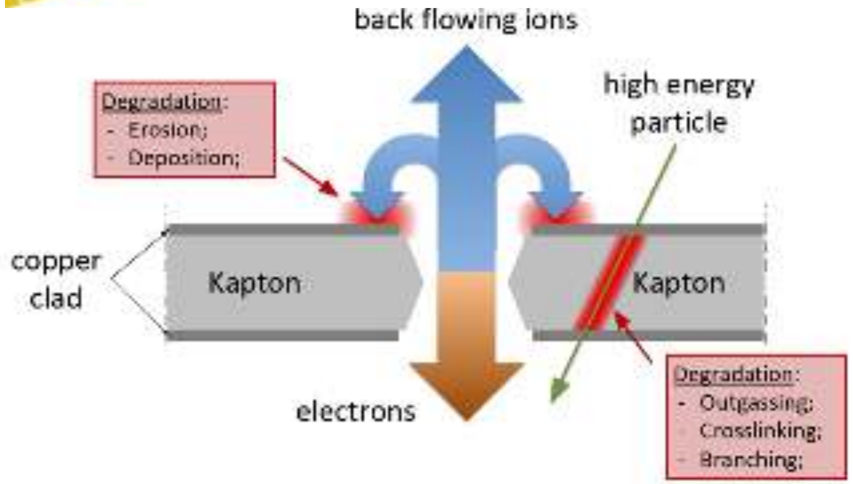


ALICE Upgrade for Run 3

- Time Projection Chamber (TPC)
- Brazilian contribution:
  - SAMPA chip
  - **ALICE TPC Aging Studies**
    - Better understanding of aging and degradation effects
    - Innovative contribution in using high chemical specificity analytical techniques

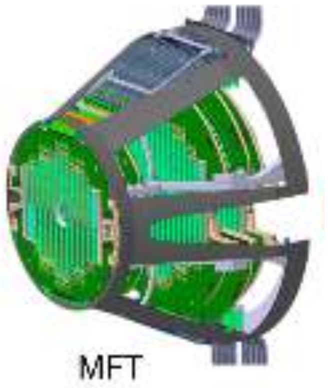


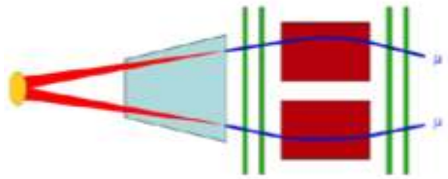




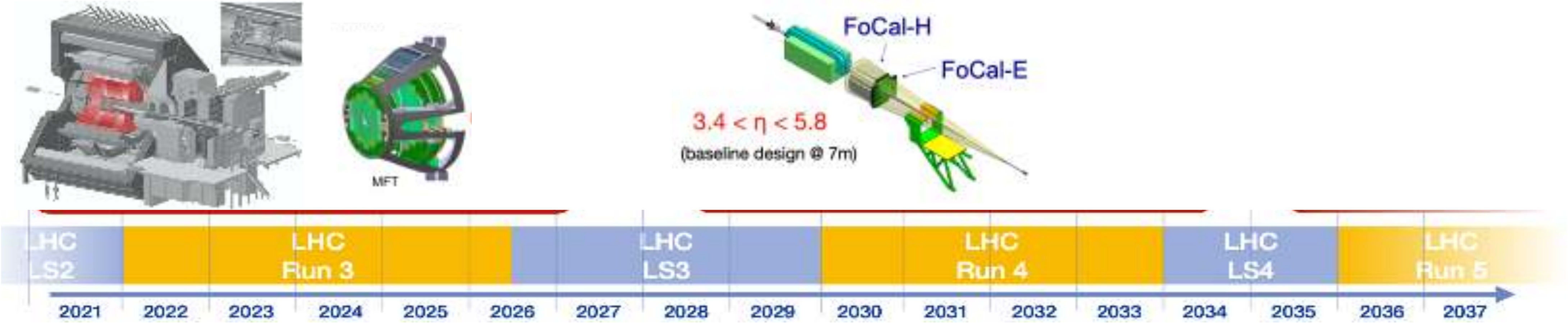
ALICE Upgrade for Run 3

- Muon Forward Tracker (MFT)
  - A new high-resolution Si tracker ($2.5 < \eta < 3.6$)
  - Adds precise vertexing capabilities to muon tracking at forward rapidity
- Brazilian contribution:
  - Mechanical Infrastructure
  - Software development (O2)





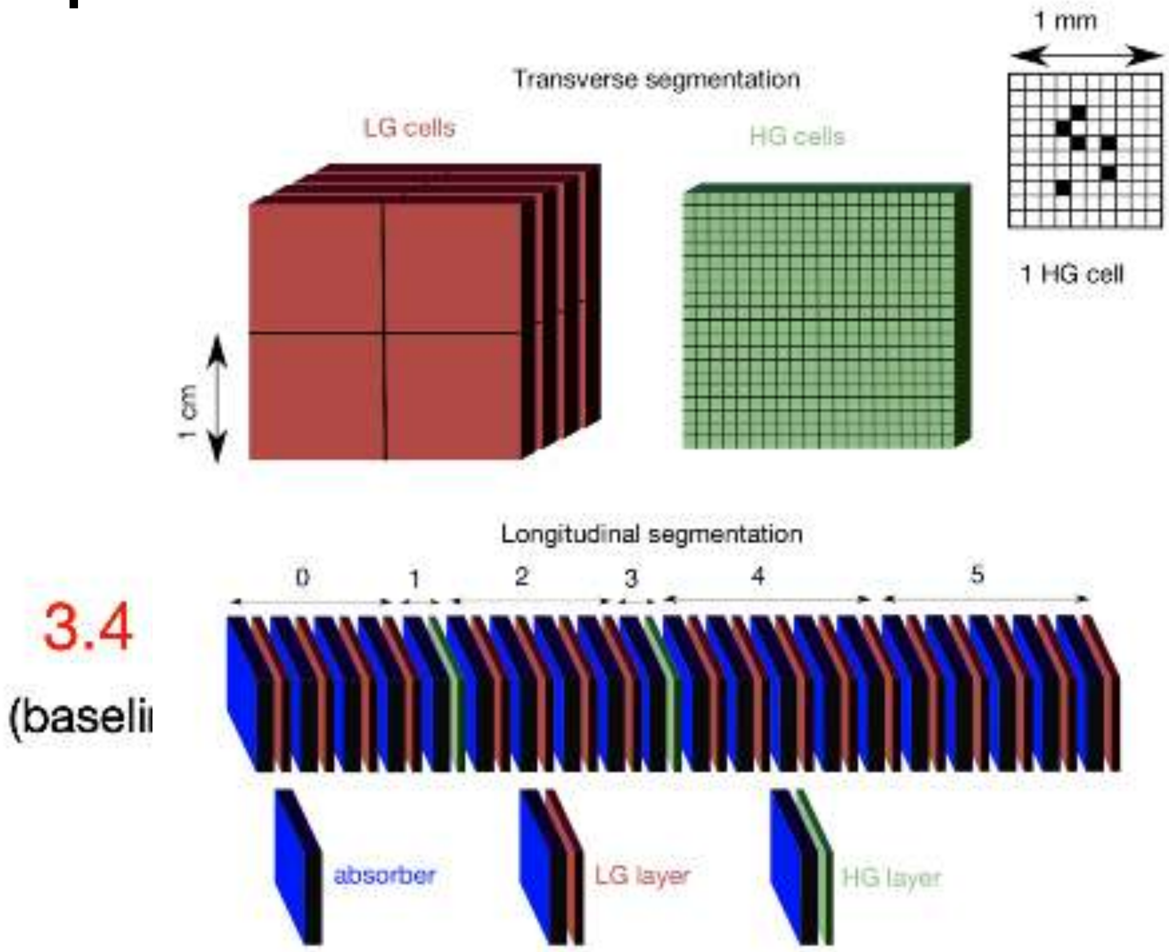
ALICE Upgrade for Run 4



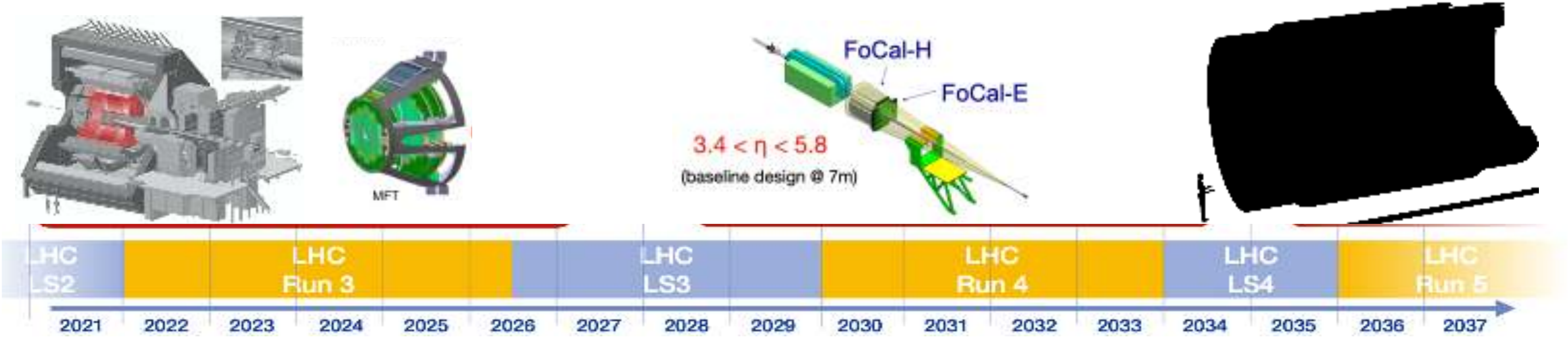
- Forward Calorimeter (FoCal)
  - Explore the small-x parton structure of nucleons and nuclei
  - Electromagnetic and hadronic calorimeters at the very forward region ($3.4 < \eta < 5.8$)

ALICE Upgrade for Run 4

- Electromagnetic calorimeter
  - Tungsten
  - Silicon Pixel (2 layers)
  - Silicon Pad (18 layers)
- Brazilian contribution:
  - Contribute to electronics of Pad Si layers
  - Software for the Detector Control System



Future: ALICE 3



- Next-generation heavy-ion programme at the LHC
- LHCC report: “ALICE 3 is a unique detector at the LHC in terms of having a low material budget, a few-micron pointing resolution, a large acceptance in eta, and hadron, electron and muon identification. The LHCC recognises that the different scoping options presented would enable a compelling and unique heavy ion physics program in Run 5”

Future: ALICE 3

- Innovative detector concept
  - Compact and lightweight all-silicon tracker
  - Retractable vertex detector (inner R = 0.5 cm)
  - Extensive particle identification
  - Large acceptance ($|\eta|$<4)
  - Superconducting magnet (2 T)
  - Continuous read-out and online processing
- Baseline layout since March: v2 w/o ECal

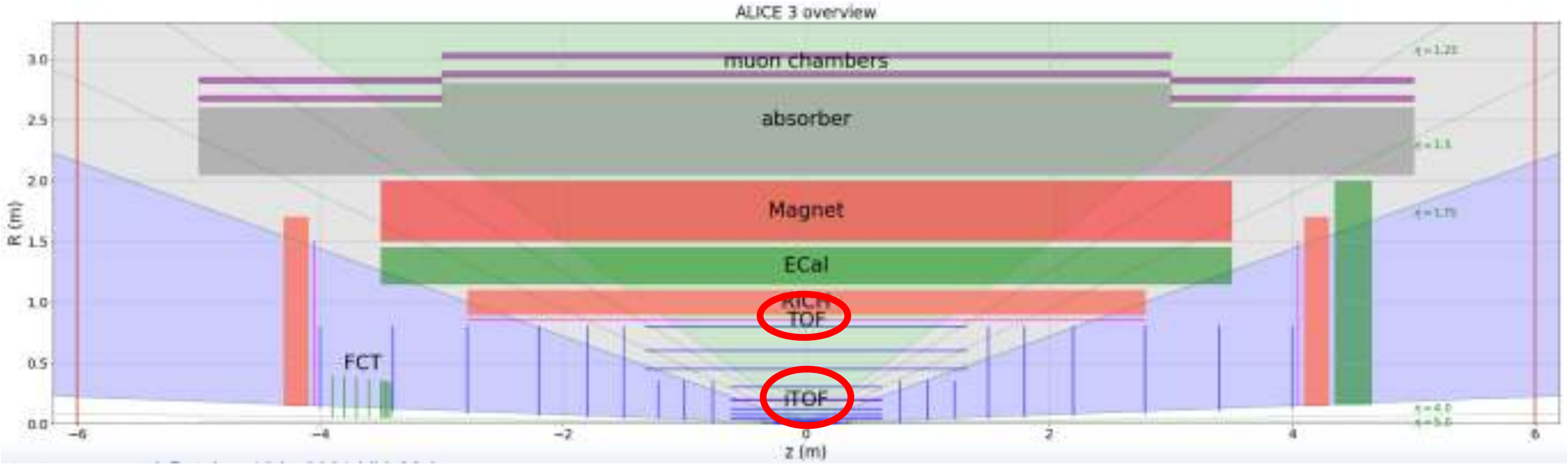
Superconducting magnet design

- **CNPEM** took the lead in SC magnet activities
- Started the design of the magnet in preparation for the Conceptual Design Report (June 2026)
- Furukawa Brazil is evaluating

  to resume SC cable production

Timing Layer

J. Klein, ALICE3 Workshop



- 2 barrel + 1 forward TOF layers
- TOF resolution $\sigma_{TOF} \approx 20$ ps
  based on silicon timing sensors
- Several Technologies are being considered
  - Ultra-Fast Silicon Detectors (UFSD)

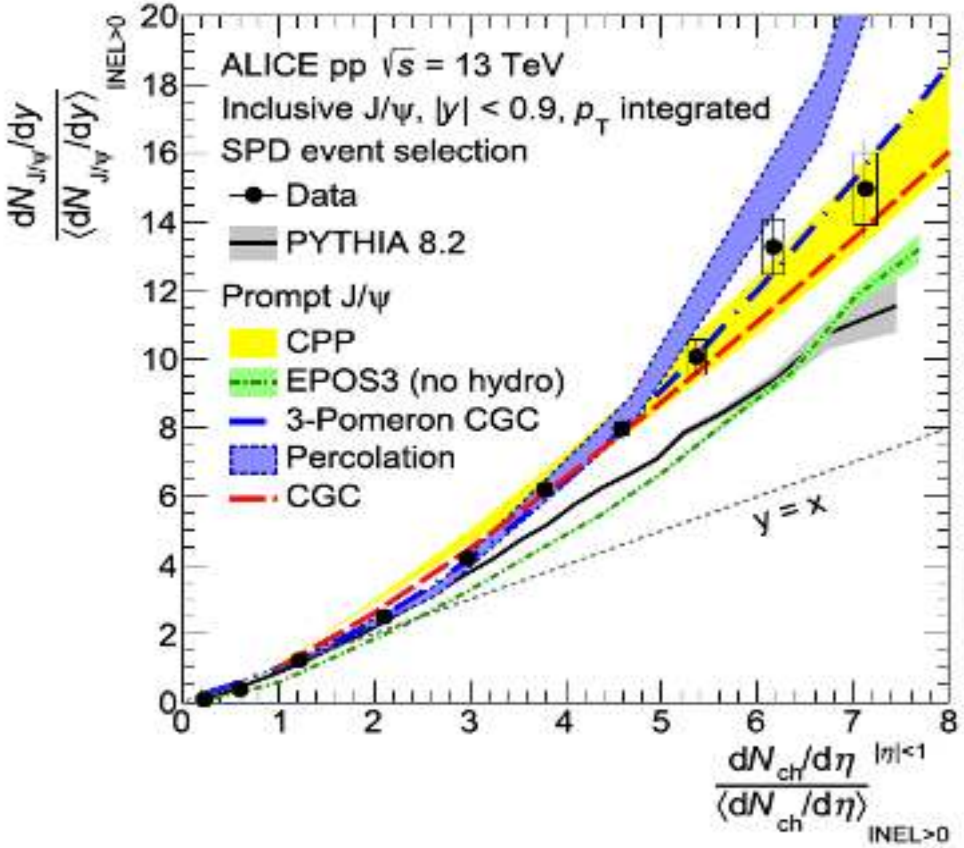
Final Considerations

- The experimental study of “QCD matter” through heavy ion collisions has yielded unexpected results that require further investigation
- ALICE is well-positioned to contribute significantly to this understanding
- Brazilian groups in ALICE, although representing a small fraction (~1.75%), have made important contributions in data analysis and instrumentation
- Run 3 and future prospects
  - The outlook is very promising moving forward!

Back-up

J/ψ vs. multiplicity in pp

- J/ψ self-normalized yield
- Increases faster than linear
- Enhancement is qualitatively described by several model calculations
  - Good discriminatory power



Unique ALICE 3 physics goals

- Understanding thermalisation in the QGP
  - degree of thermalisation of beauty: high-precision beauty measurements
  - approach to chemical equilibrium: multi-charm hádrons
  - direct access to charm diffusion: D-Dbar azimuthal correlations
- Access to temperature as function of time
  - high-precision di-electron mass spectra, pT dependence, elliptic flow
- Fundamental aspects of the QCD phase transition
  - net-baryon and net-charm fluctuations
  - mechanism of chiral symmetry restoration in the QGP: di-electron mass spectrum
- Laboratory for hadron physics
  - hadron-hadron interaction potentials
  - explore nature of exotic hadrons (e.g., tetraquarks, charm-nuclei)