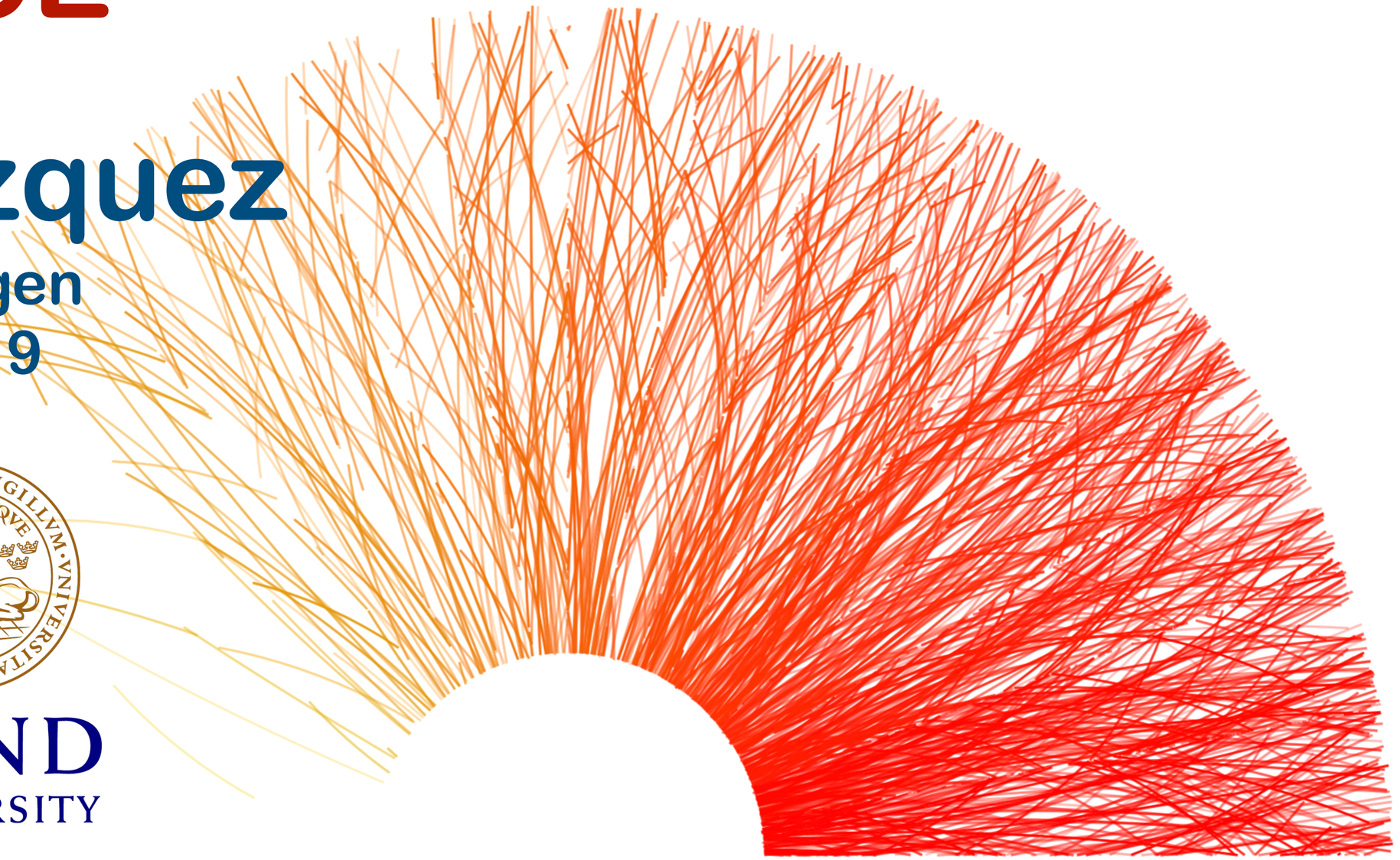
Characterisation of the QGP with ALICE

Omar Vázquez

Doktoranddagen
June 18, 2019

LUND UNIVERSITY



Outline

(1) Characterisation of the QGP with ALICE

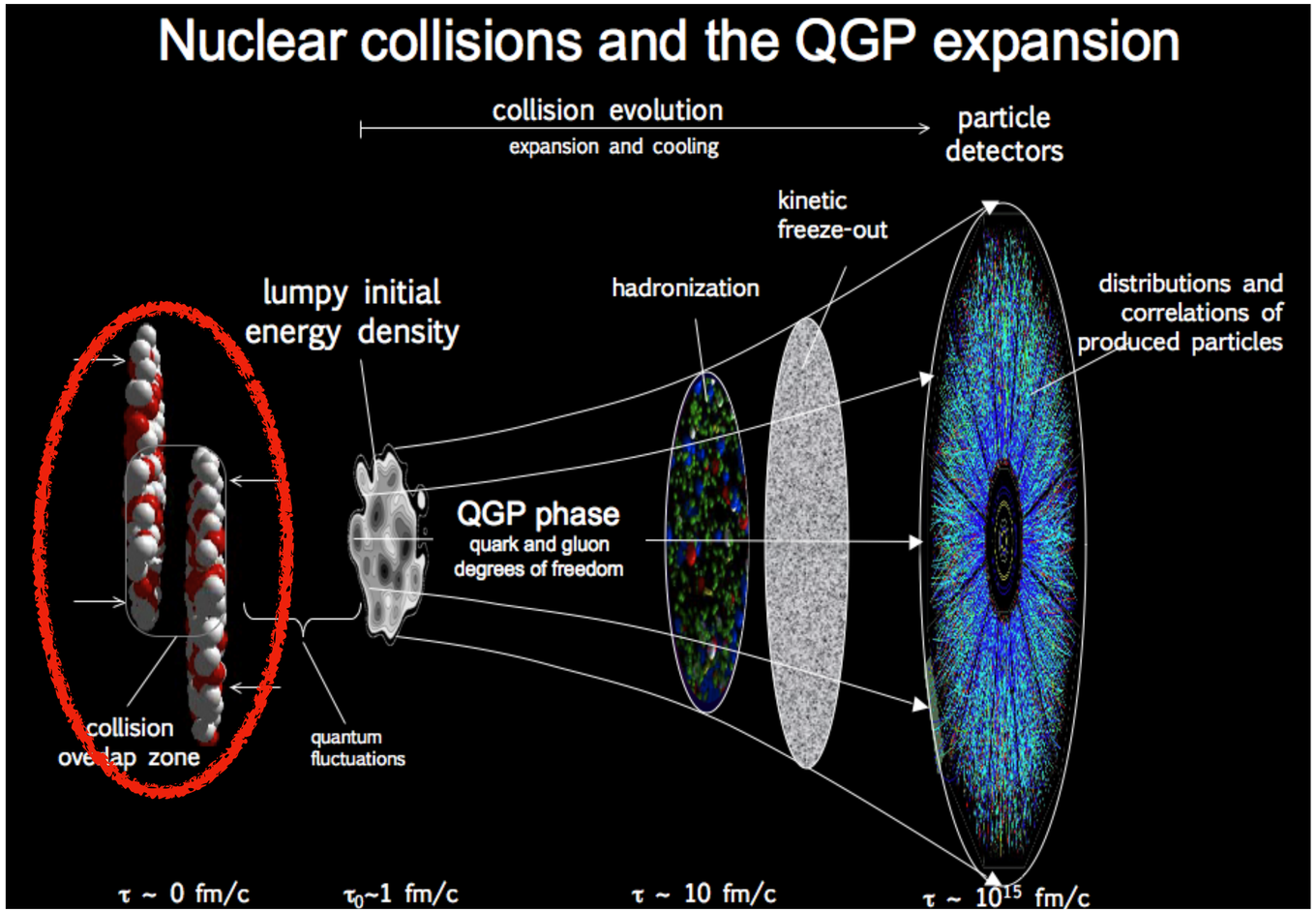
- Introduction
- ALICE at the LHC
- Results on soft physics
- Results on hard physics

(2) Summary of activities during my first year and near future plans

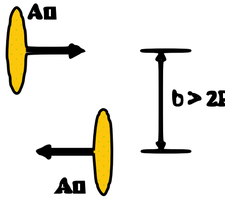
- Summary

Introduction

History of AA collision



1. **Initial collision**
   - **LQCD calculations predict a deconfinement transition from hadronic matter to QGP at an energy density of about** $1\ \mathrm{GeV/fm^3}$
     Let. Notes Phys. 583 209-249(2002)
   - **Currently calculation of LQCD set the transition temperature in the range between** $155 - 160\ \mathrm{MeV}$
     Phys. Rev. D 90 094503(2014)



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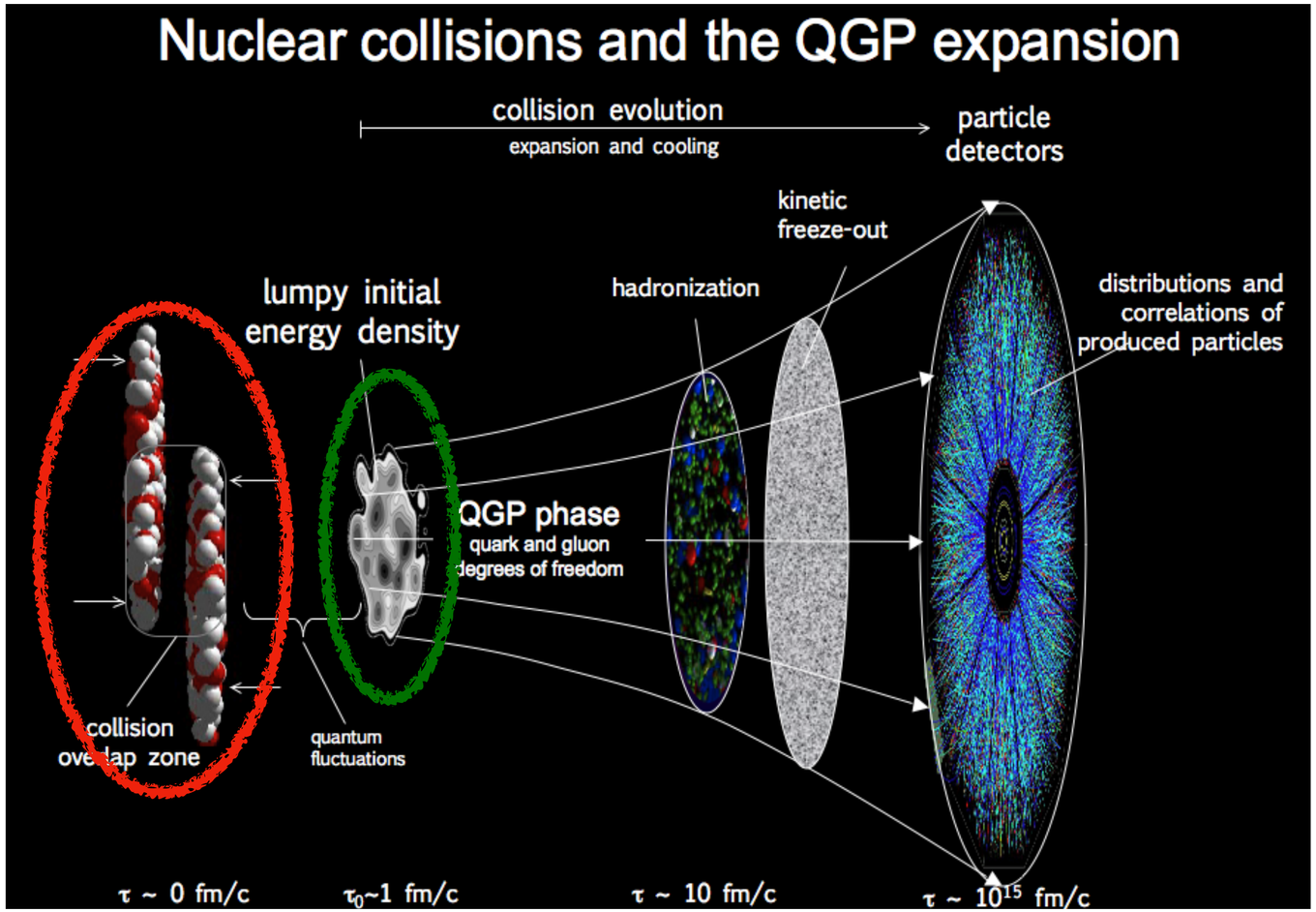

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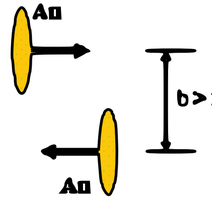

2. **Equilibrated QGP**
   - Measurements of direct photons at the LHC revealed a temperature of an equilibrated QGP of about $297\ \mathrm{MeV}$
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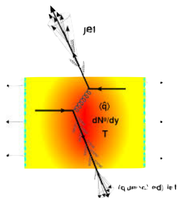
     Phys. Lett. B754 (2016)



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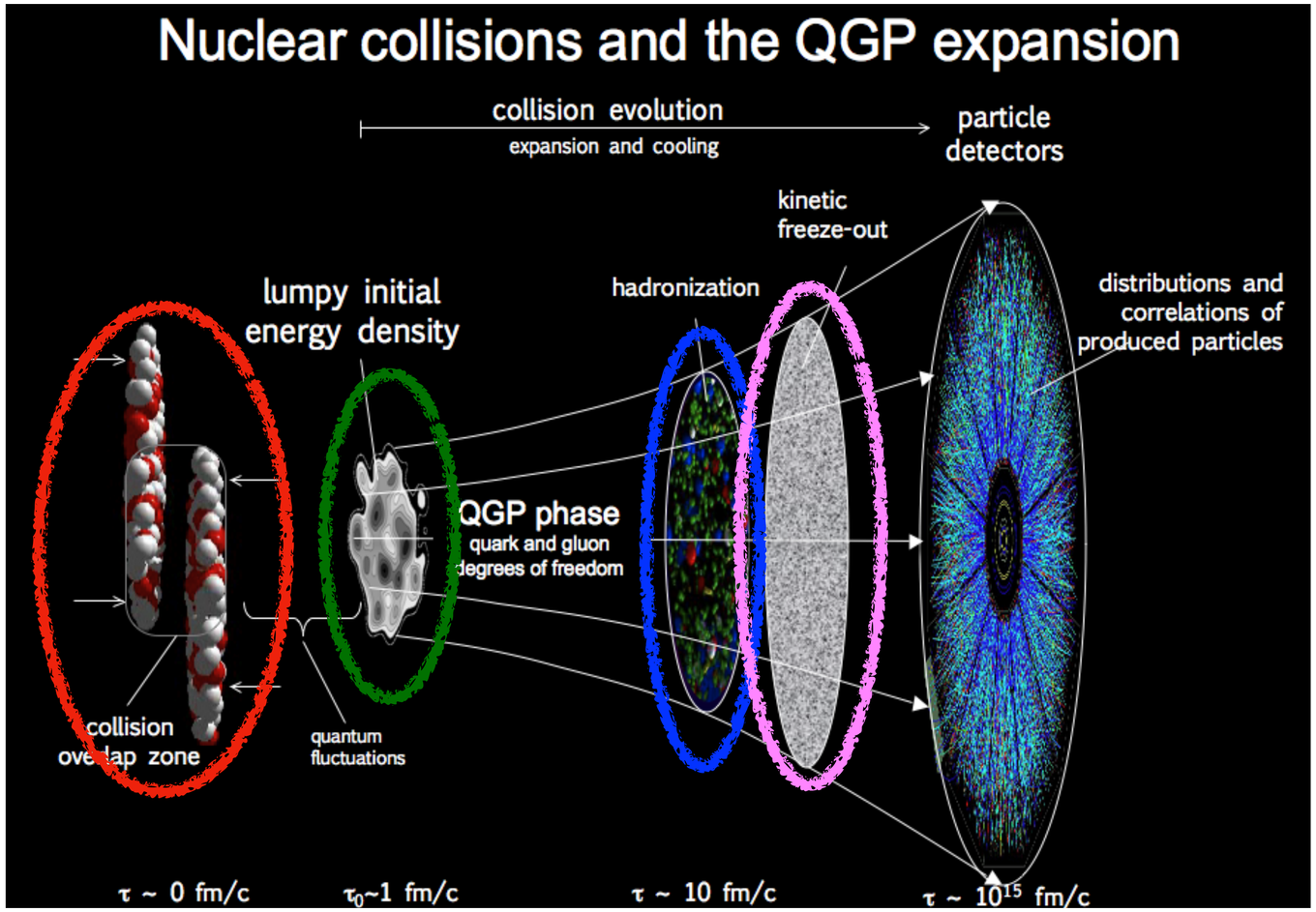

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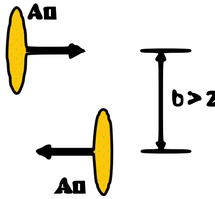

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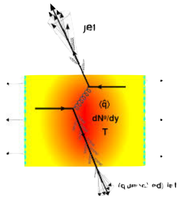
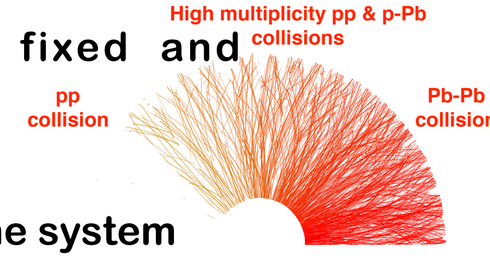


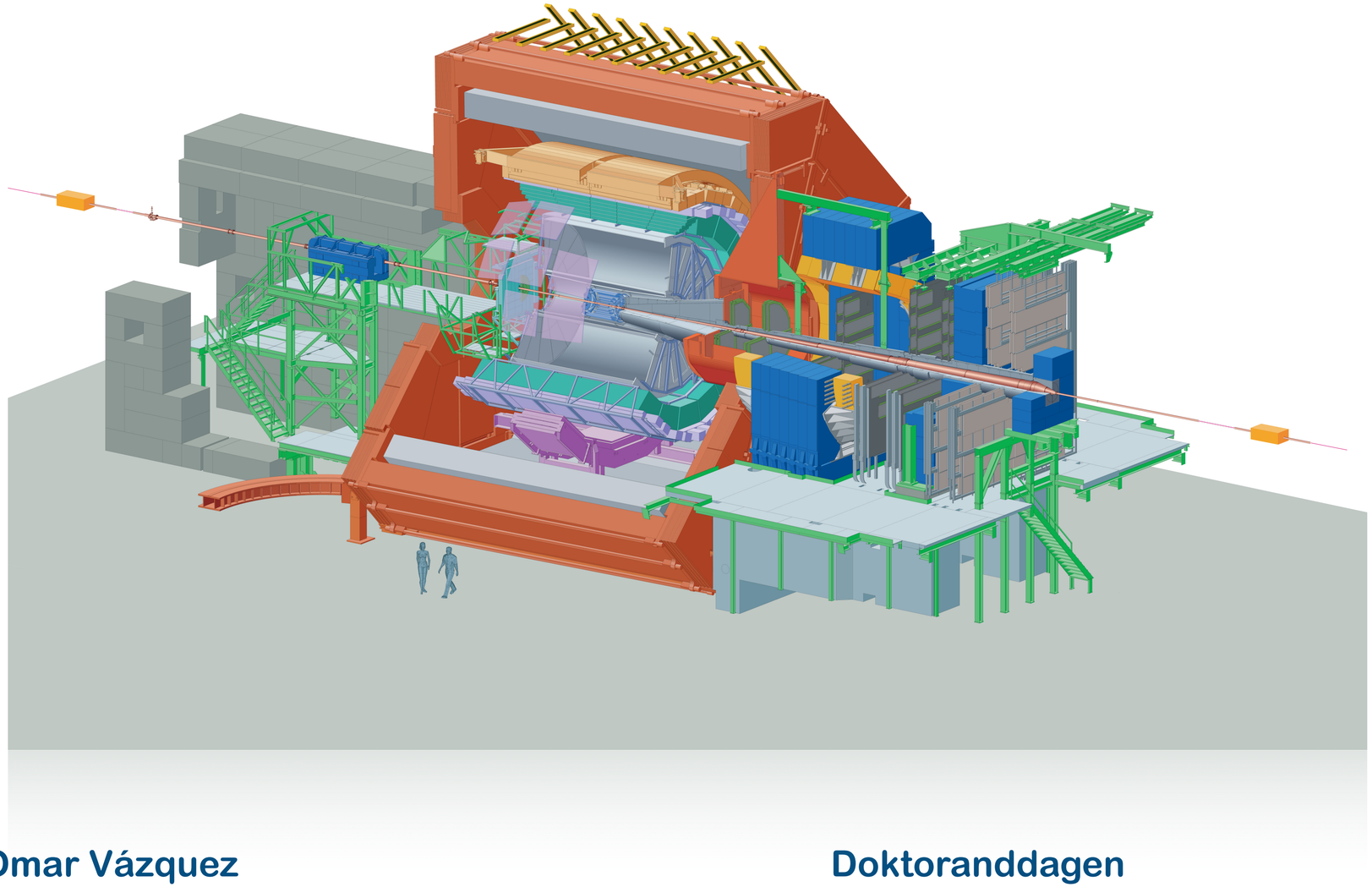
3. **Chemical freeze-out**
   - Particle composition is fixed and inelastic interactions cease
     Phys. Lett. B673 (2009)



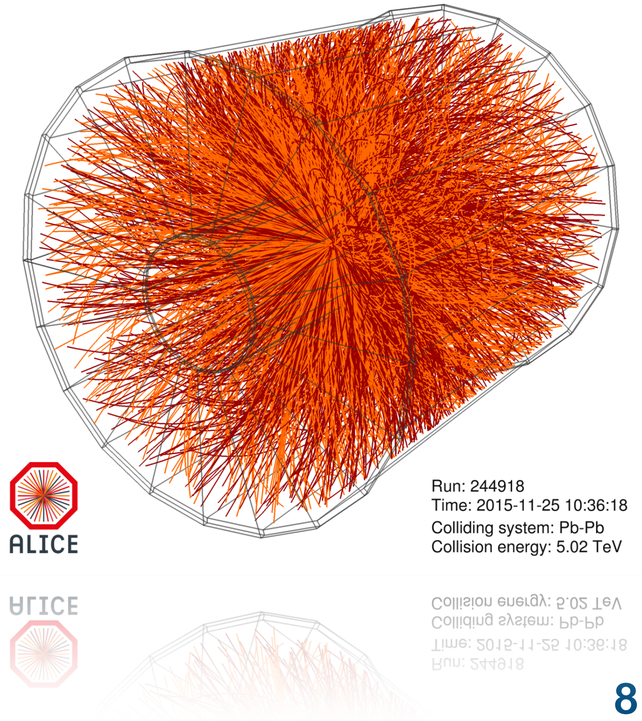
4. **Kinetic freeze-out**
   - Final states decouple from the system

ALICE at the LHC

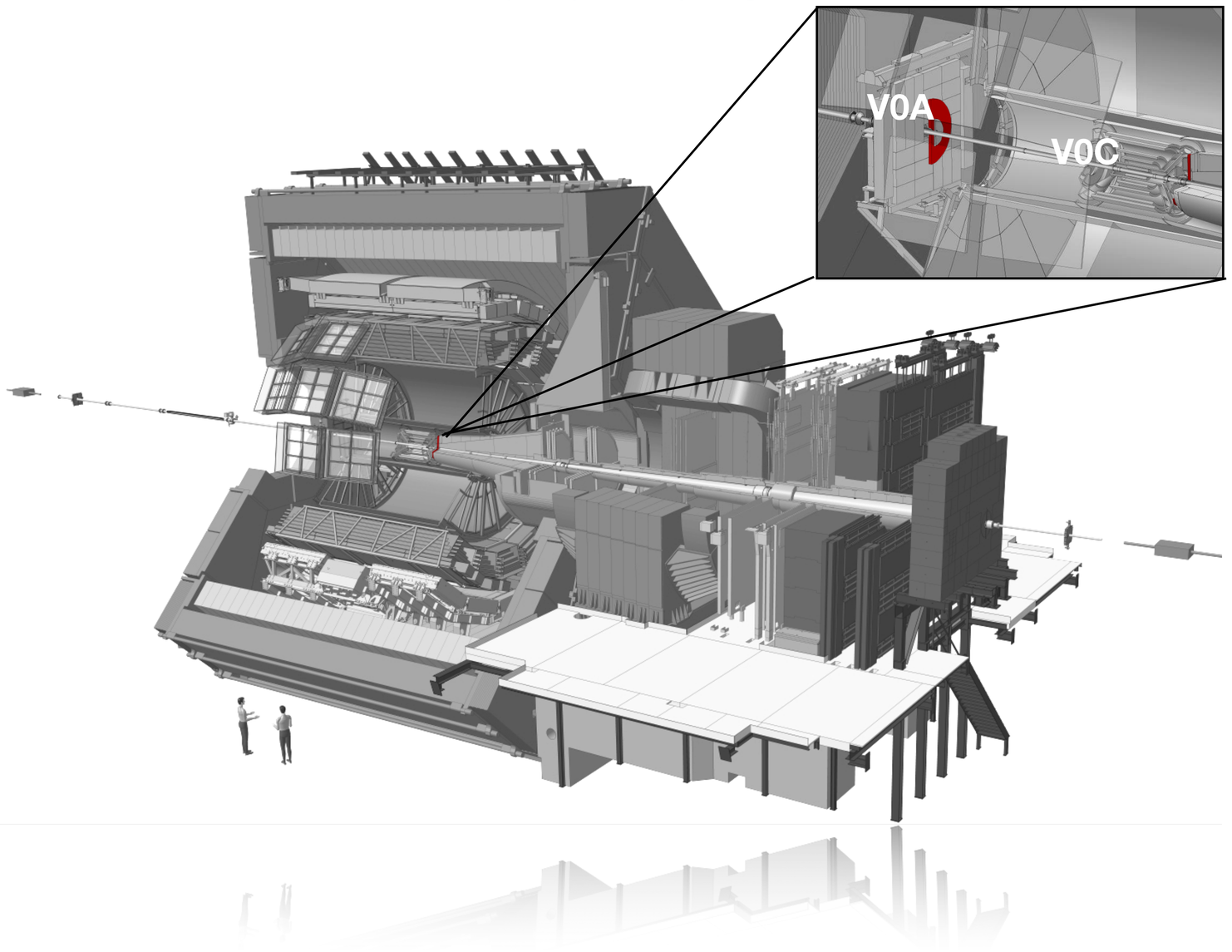
ALICE at the LHC



The dedicated experiment at the LHC for tracking and low-momentum particle identification in high-multiplicity environments

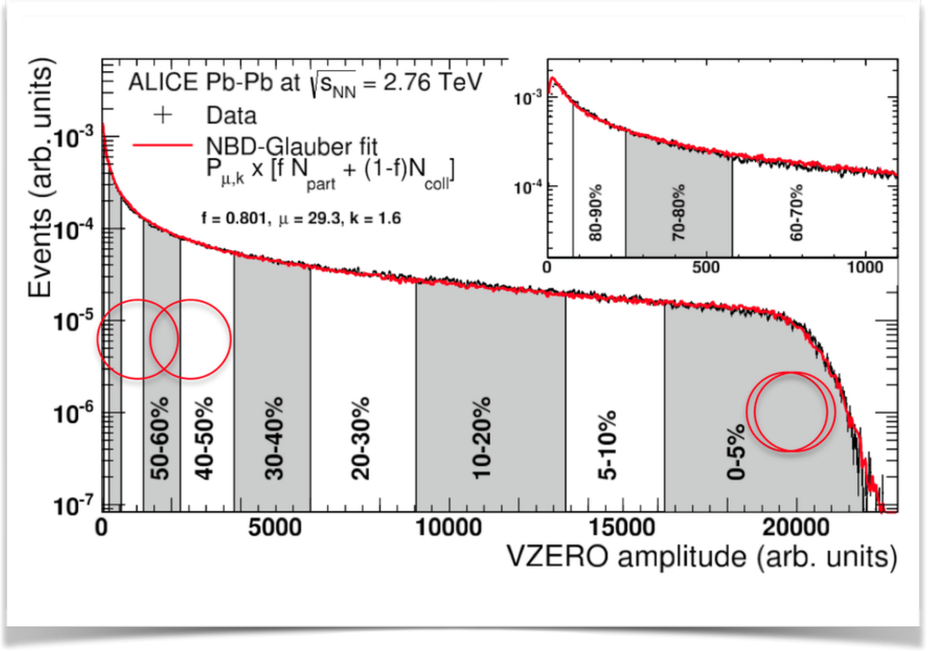


ALICE at the LHC



V0=V0A+V0C

- **Forward scintillator hodoscopes**
- **Triggering, background suppression and event classification**
- **The event classification is based on the amplitude of the total charge deposited in the V0 detector**
- **V0A** $(2.8 < \eta < 5.1)$ **and V0C** $(-3.7 < \eta < -1.7)$



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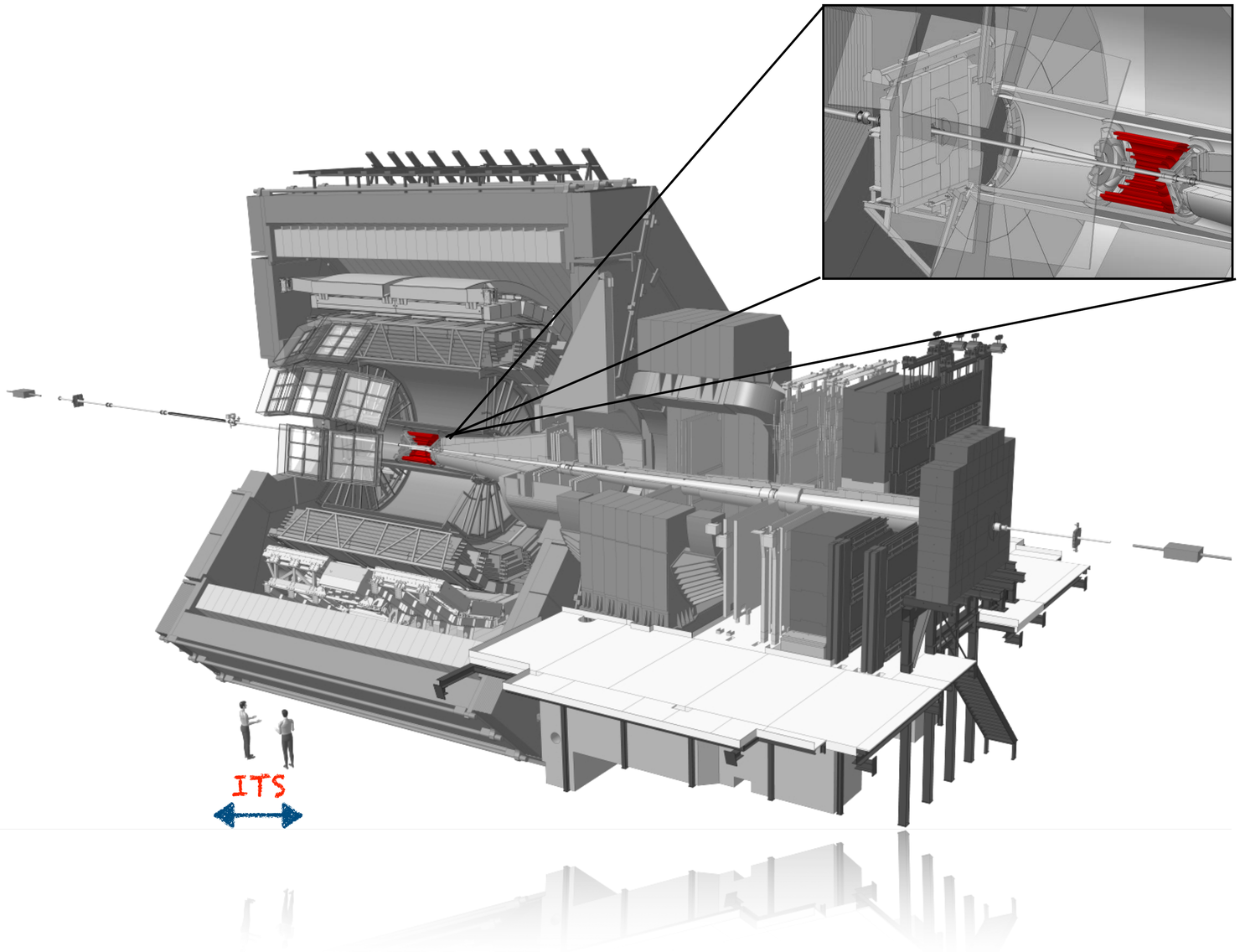
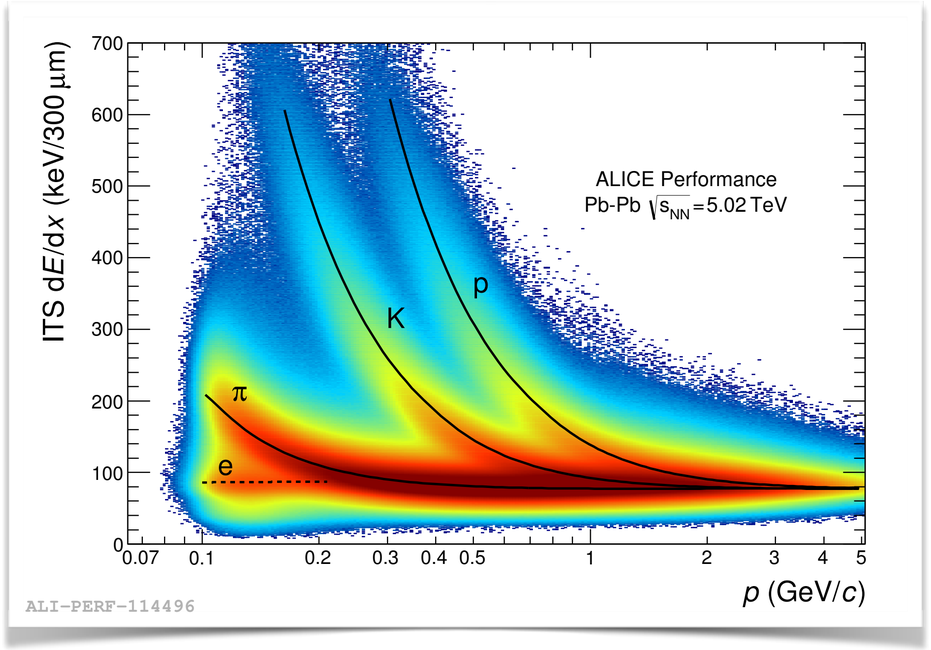


ITS = SPD+SDD+SSD

- **Six layers of silicon detector**
- **Vertex reconstruction, tracking, PID** ($\mathrm{d}E/\mathrm{d}x$)
- $|\eta| < 0.9$



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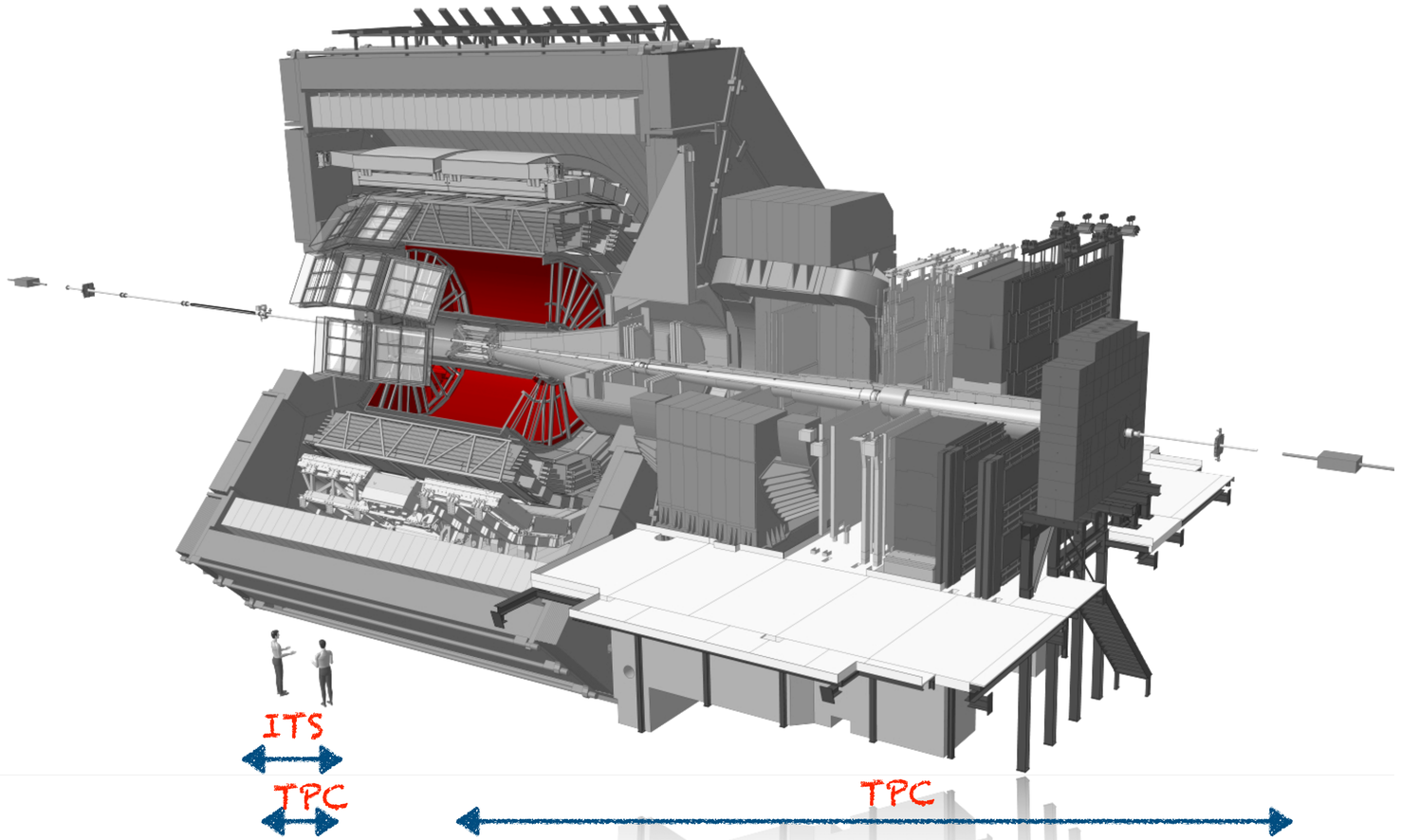
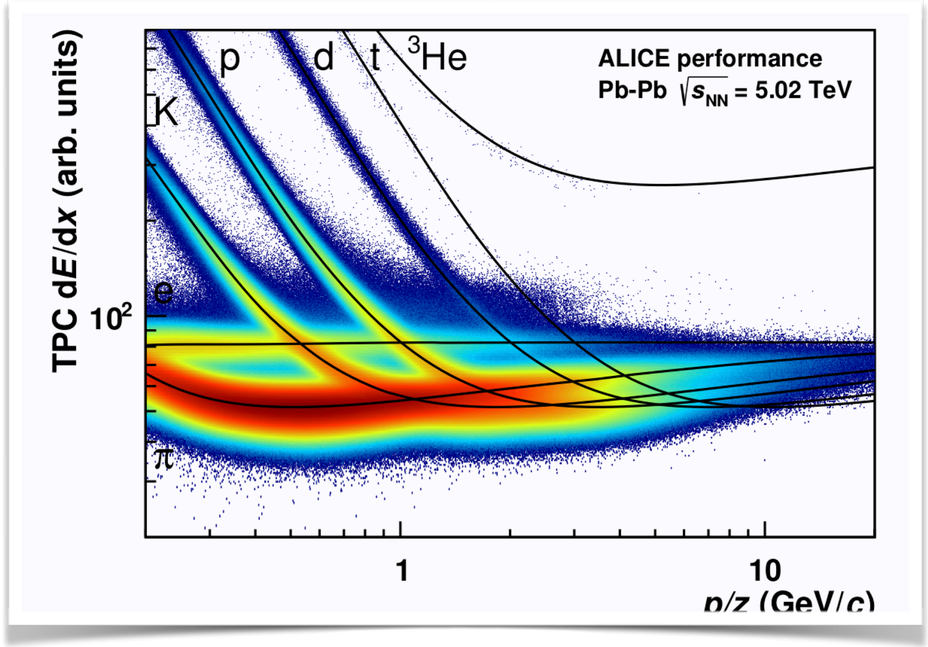
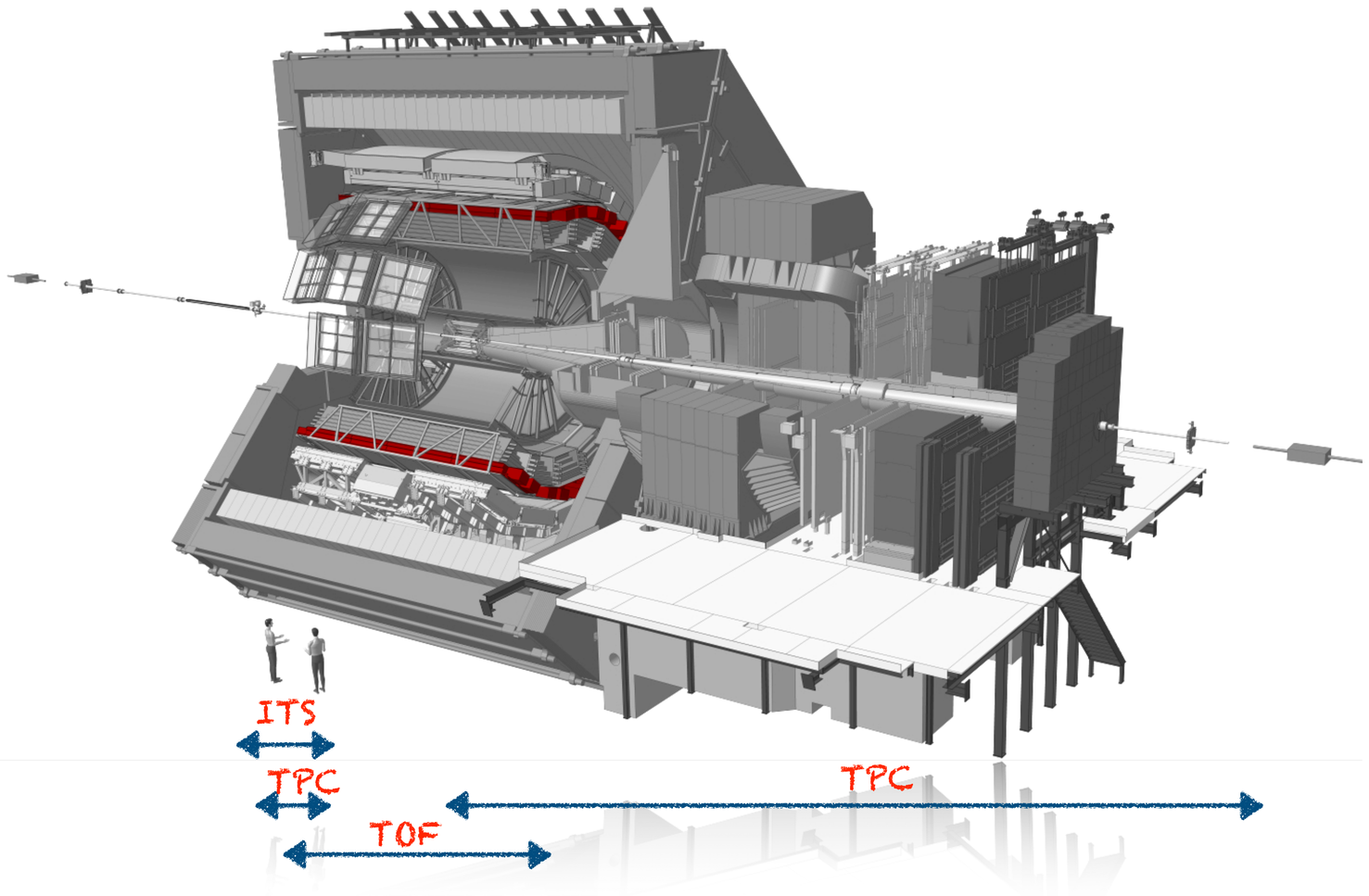


TPC

- Gas-filled cylindrical volume
- Vertex reconstruction, tracking, PID ($\mathrm{d}E/\mathrm{d}x$)
- $|\eta| < 0.9$

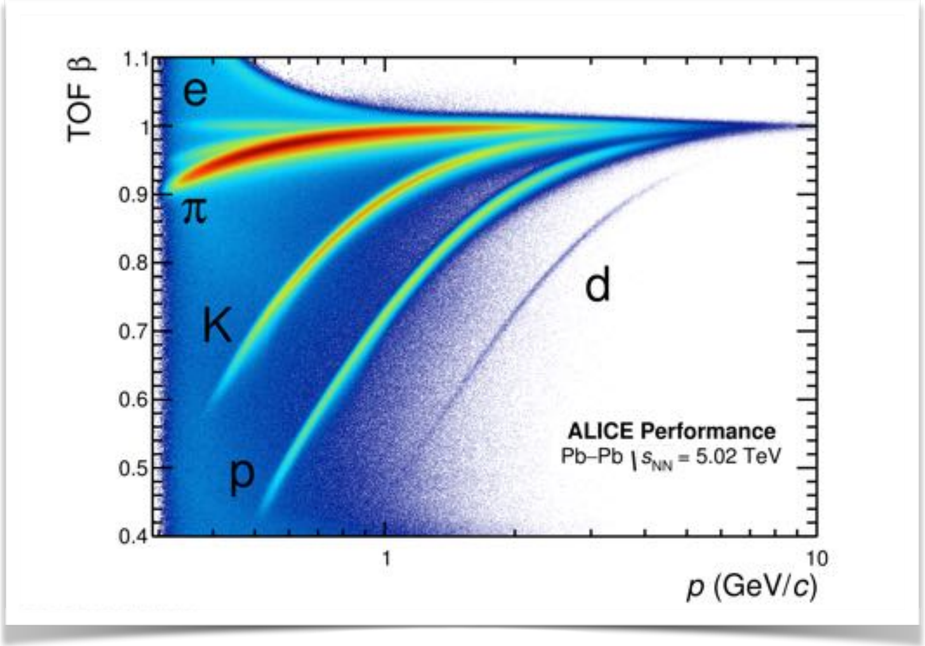


ALICE at the LHC



TOF

- **Resistive plate chamber**
- **PID (time-of-flight)**
- $|\eta| < 0.9$



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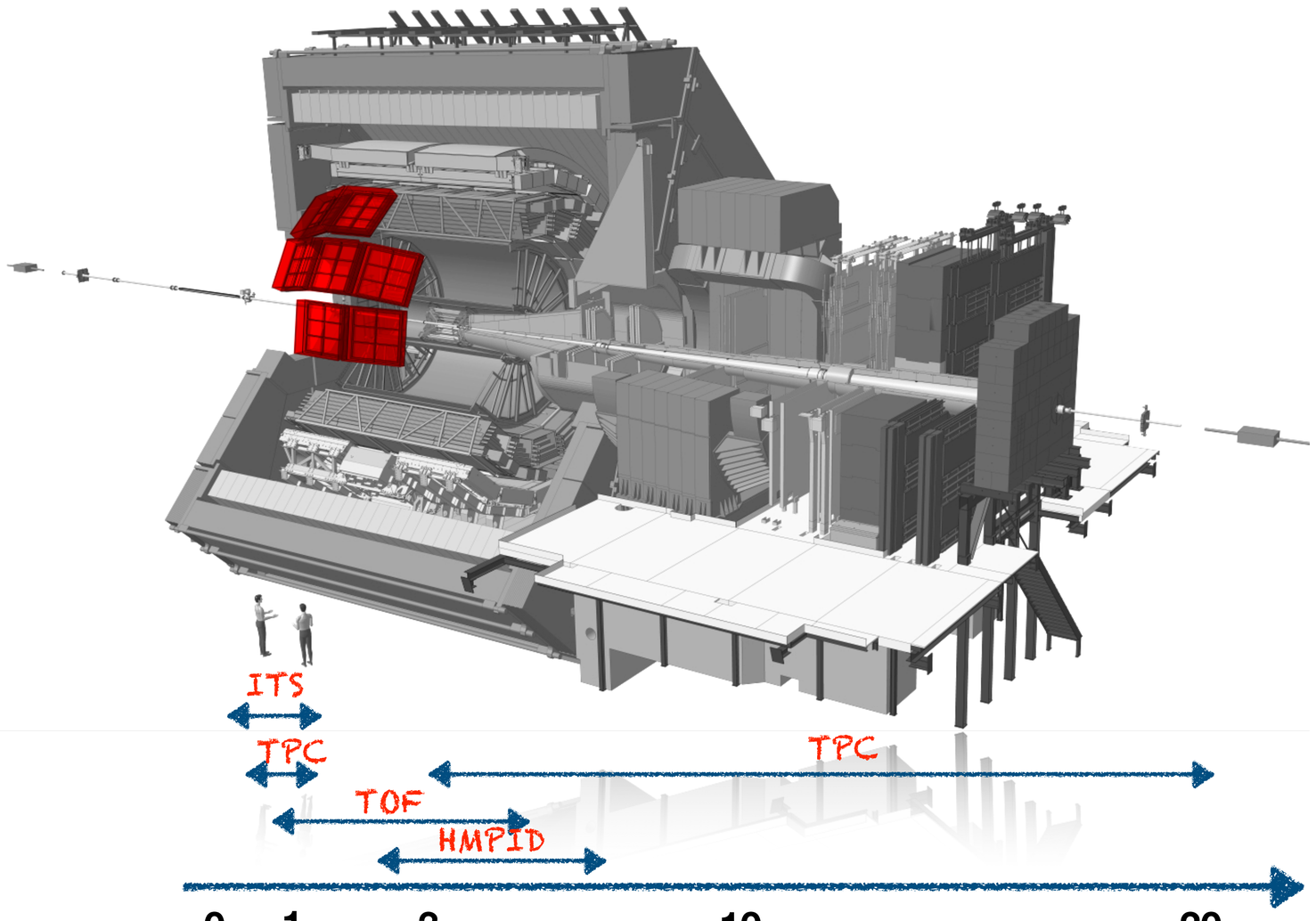
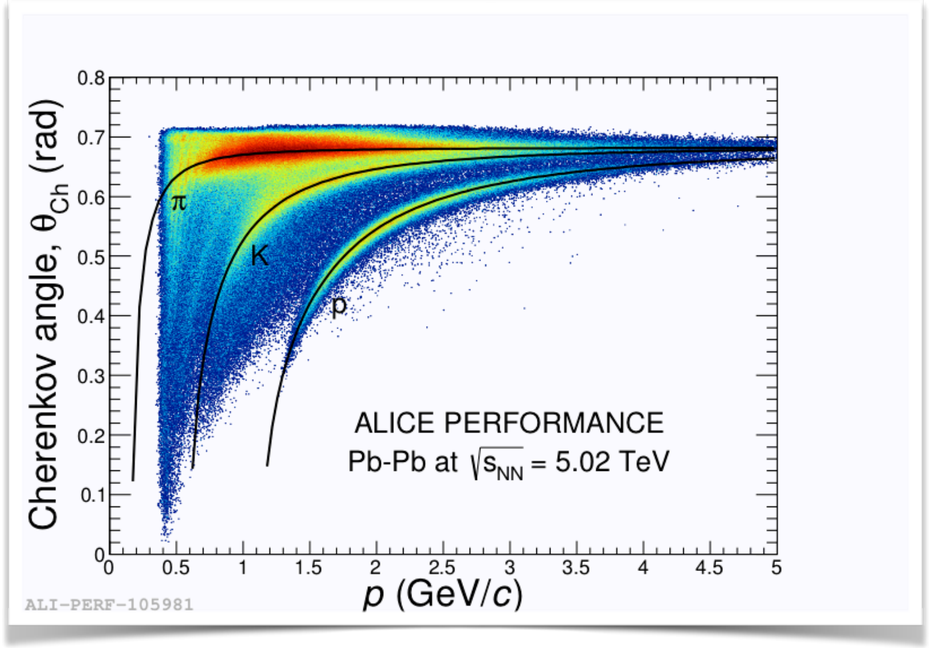


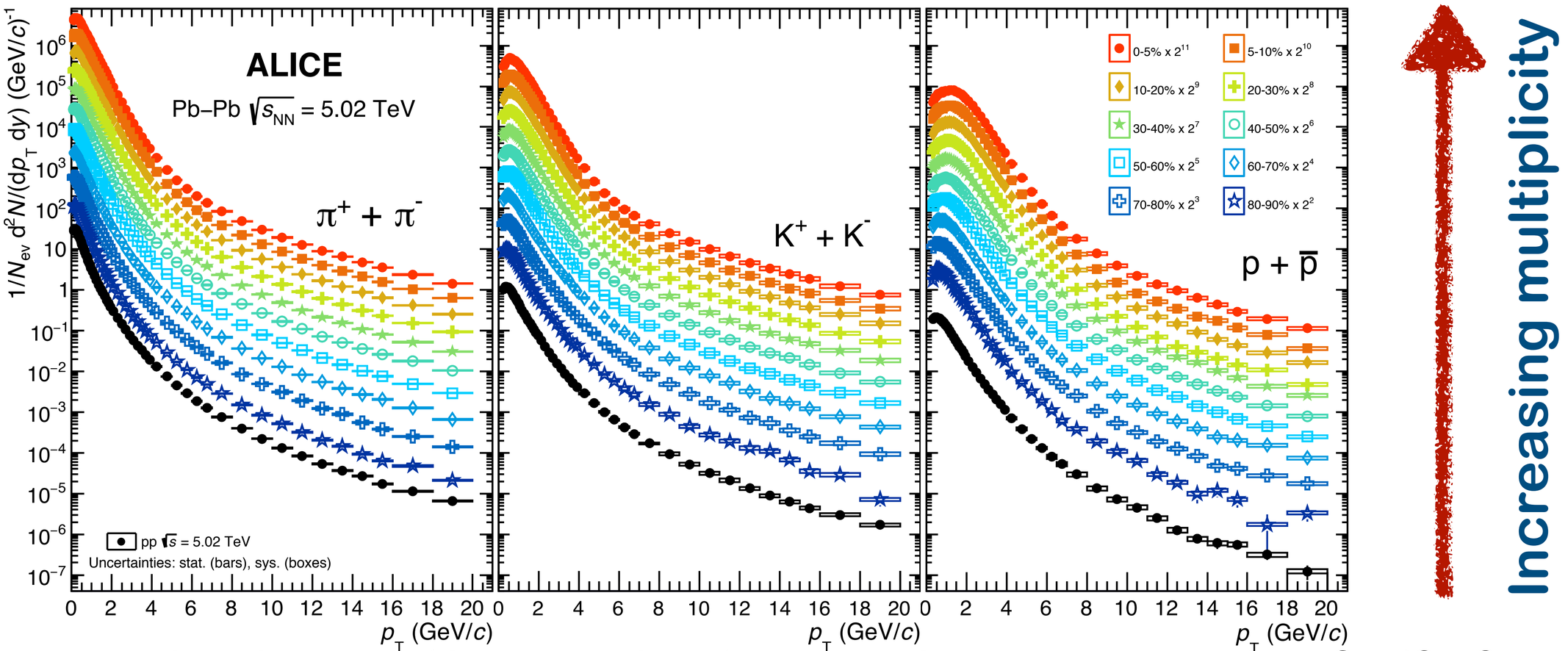
HMPID

- Seven identical proximity focusing RICH (Ring Imaging Cherenkov) counters
- PID (θ_{Ch})
- ~5% of TPC acceptance



Results on soft physics

Identified particle spectra



Increasing multiplicity

- The p_{T} spectra is the result of the combination of independent analyses employing the ITS, TPC, TOF, and HMPID sub detectors
- From peripheral to central collisions, a flattening of the spectra is observed around $1\ \mathrm{GeV}/c$. This effect follows a mass ordering
- Within the hydrodynamics picture, this effect is understood as a progressively stronger radial flow with increasing centrality that boosts low-p_{T} particles towards high-p_{T} values by a common velocity field

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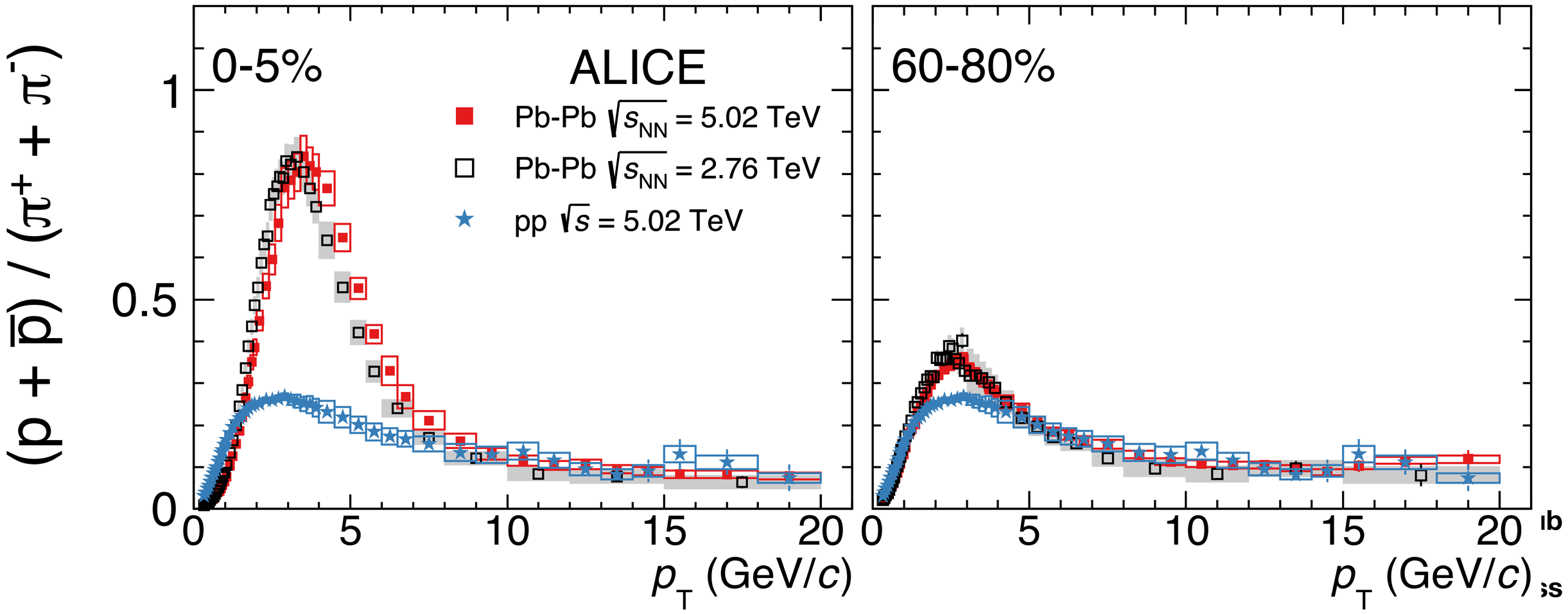

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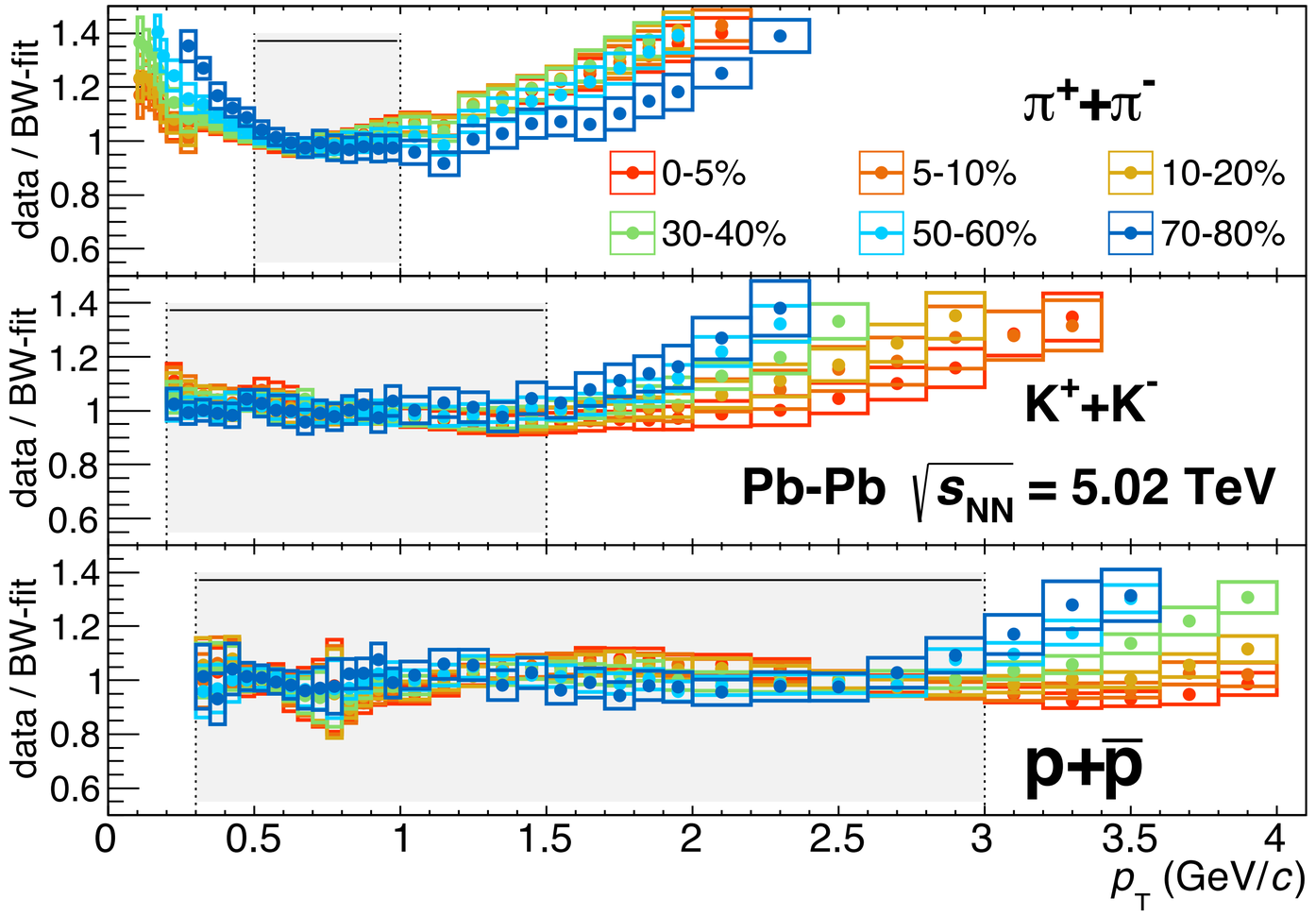
Blast-wave model

- This hydrodynamical-based model is used to characterise the evolution of the spectral shapes with centrality at the kinetic freeze-out by performing a simultaneous fit of the spectra with a blast-wave function
  Phys. Rev. C 48, 2462

- Three free parameters:
  - Freeze-out temperature: T_{kin}
  - Average transverse velocity: $\langle\beta_{\mathrm{T}}\rangle$
  - Exponent of the velocity profile: n

$$E\frac{d^3N}{dp^3} \propto \int_0^R m_T\, I_0\left(\frac{p_T \sinh\rho}{T_{kin_{\pi/\mathrm{K/p}}}}\right) K_1\left(\frac{m_T \cosh\rho}{T_{kin}}\right) r\,dr$$

$$m_T = \sqrt{{m_0}^2 + {p_T}^2} \quad \rho = \tanh^{-1}\beta_T \quad \beta_T = \beta_s\left(\frac{r}{R}\right)^n$$



Blast-wave model

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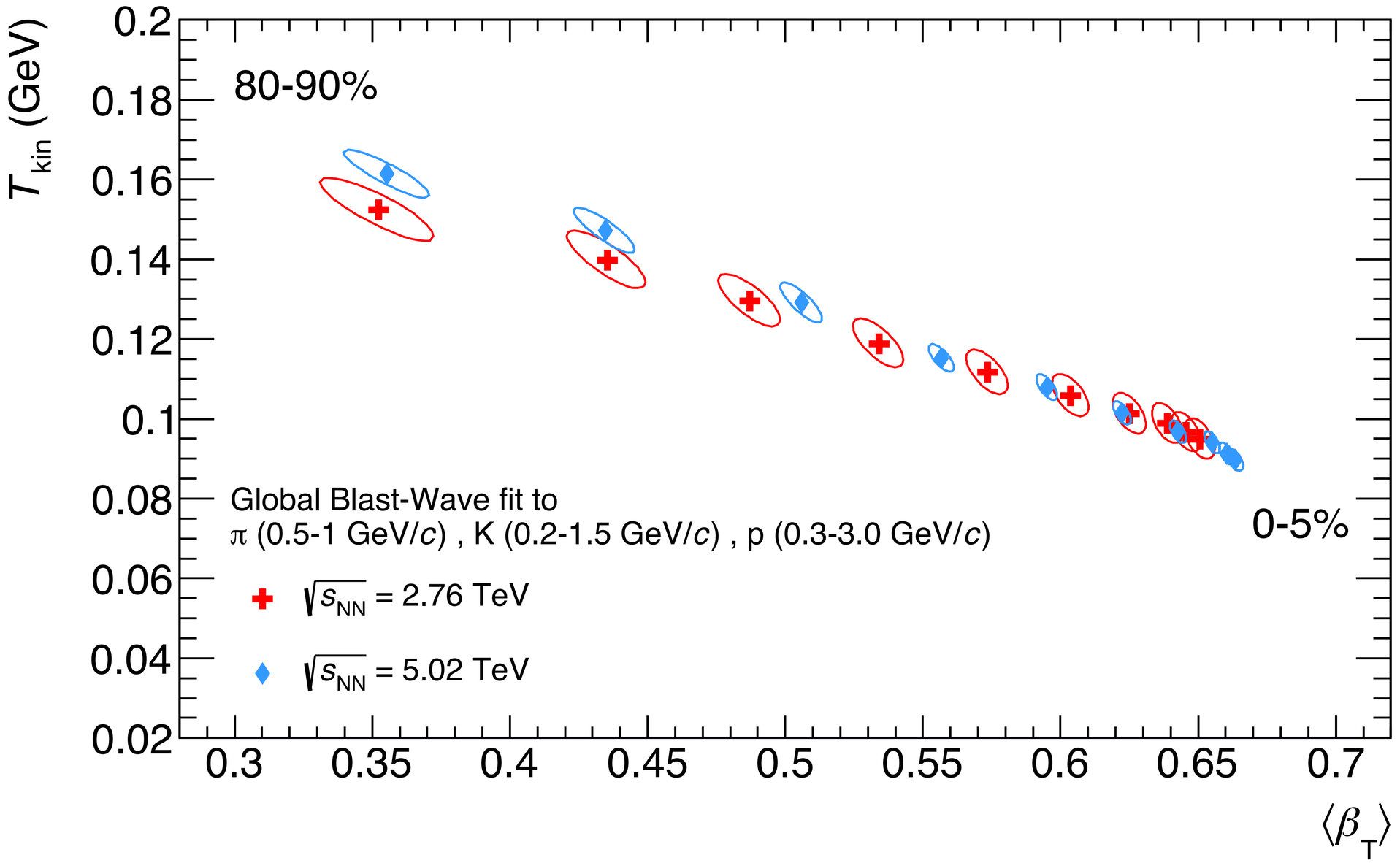
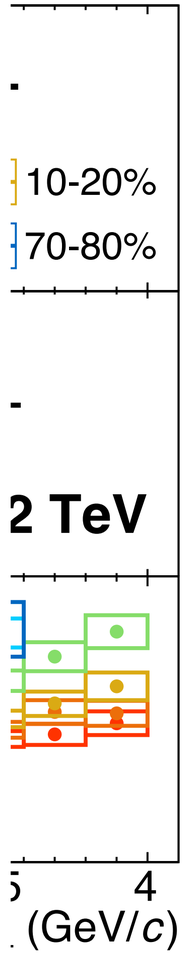
$$E\frac{d^3N}{dp^3}$$

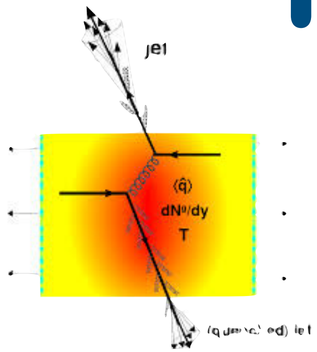
$$m_T = \sqrt{}$$



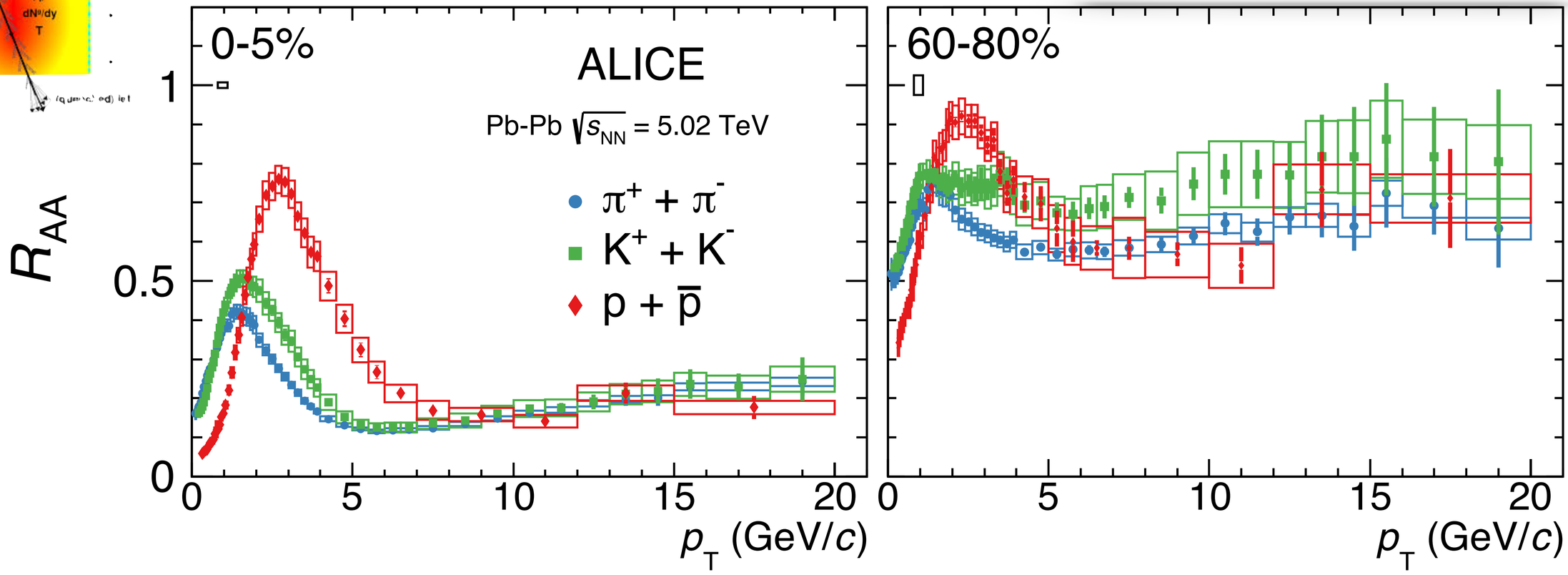


Results on hard physics

Nuclear modification factor



$$R_{\mathrm{AA}} = \frac{\mathrm{d}^2 N^{\mathrm{A-A}}/\mathrm{d}p_{\mathrm{T}}\mathrm{d}y}{\langle N_{\mathrm{coll}}\rangle \mathrm{d}^2 N^{\mathrm{pp}}/\mathrm{d}p_{\mathrm{T}}\mathrm{d}y}$$



- For $p_{\mathrm{T}} \lesssim 10$ GeV/c protons are less suppressed than pions or kaons, which is consistent with the mass ordering of radial flow effects
- Above $p_{\mathrm{T}} \approx 8$ GeV/c all particle species are equally suppressed

Summary of activities during my first year and near future plans

- Education

  - CERN school of computing ✓
  - Detector school (Copenhagen-Helsinki) ✓
  - Indian-summer school of Physics 2018:Phenomenology of Hot and Dense Matter For Future Accelerators ✓
    - Poster presentation: Energy density and path-length dependence of the fractional momentum loss in heavy-ion collisions at $\sqrt{s_{\mathrm{NN}}}$ from 62.4 to 5020 GeV.
      Phys. Rev. C 97, 014910
  - International school of subnuclear physics (Erice, Italy, 21/06/2019)
  - Particle physics phenomenology

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  - Production of $\pi/\mathrm{K}/\mathrm{p}$ as a function of event multiplicity in the rTPC in pp collisions at $\sqrt{s} = 13\ \mathrm{TeV}$
    - Recently discussed within the ALICE collaboration
  - Production of $\pi/\mathrm{K}/\mathrm{p}$ as a function of event multiplicity and transverse spherocity in pp collisions at $\sqrt{s} = 13\ \mathrm{TeV}$

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- Participation on conferences
  - LHCP2019 (Puebla, Mexico, 20/05/2019) ✓
    - Poster presentation: ALICE results on radial flow in small and large systems
  - EPS-HEP (Ghent, Belgium, 10/07/2019)
    - Parallel talk: Baryon production from small to large collision systems at ALICE
  - ALICE physics week (Prague, Czech Republic, 22/07/2019)

Publications

EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

CERN-EP-2018-XXX
25 May 2018

Production of charged pions, kaons and (anti-)protons in Pb−Pb and inelastic pp collisions at $\sqrt{s_{\rm NN}}$ = 5.02 TeV

ALICE Collaboration[E]

Abstract

Mid-rapidity production of $\pi^{\pm}$, $K^{\pm}$ and $(\overline{p})p$ measured by the ALICE experiment at the LHC, in Pb−Pb and inelastic pp collisions at $\sqrt{s_{\rm NN}} = 5.02$ TeV, is presented. The invariant yields are measured over a wide transverse momentum ($p_{\rm T}$) range from hundreds of MeV/c up to 20 GeV/c. The results in Pb−Pb collisions are presented as a function of the collision centrality, in the range 0−90%. The comparison of the $p_{\rm T}$-integrated particle ratios, i.e. proton-to-pion and kaon-to-pion ratios, with similar measurements in Pb–Pb collisions at $\sqrt{s_{\rm NN}} = 2.76$ TeV show no significant energy dependence. Blast-wave fits of the $p_{\rm T}$ spectra indicate that in the most central collisions radial flow is slightly larger at 5.02 TeV with respect to 2.76 TeV. Particle ratios (p/π, K/π) as a function of $p_{\rm T}$ show pronounced maxima at $p_{\rm T} \approx 3$ GeV/c in central Pb–Pb collisions. At high $p_{\rm T}$, particle ratios at 5.02 TeV are similar to those measured in pp collisions at the same energy and in Pb−Pb collisions at $\sqrt{s_{\rm NN}} = 2.76$ TeV. Using the pp reference spectra measured at the same collision energy of 5.02 TeV, the nuclear modification factors for the different particle species are derived. Within uncertainties, the nuclear modification factor is particle species independent for high $p_{\rm T}$ and compatible with measurements at $\sqrt{s_{\rm NN}} = 2.76$ TeV. The results are compared to state-of-the-art model calculations, which are found to describe the observed trends satisfactorily.

[E]See Appendix A for the list of collaboration members

Soon to be published

EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

CERN-EP-2018-XXX
Day Month 2018

π, K and p production as a function of multiplicity in pp collisions at $\sqrt{s}$ = 13 TeV

ALICE Collaboration[E]

Abstract

This paper presents the measurements of $\pi^{\pm}$, $K^{\pm}$, p and $\overline{\rm p}$ transverse momentum ($p_{\rm T}$) spectra as a function of charged-particle multiplicity density in proton-proton (pp) collisions at $\sqrt{s}$ = 13 TeV with the ALICE detector at the LHC. These measurements cover $p_{\rm T}$ ranges from 100 MeV/c to 20 GeV/c and are done in the rapidity interval $|y| < 0.5$. The $p_{\rm T}$-differential particle ratios exhibit an evolution with multiplicity similar to that observed in pp collisions at $\sqrt{s}$ = 7 TeV which is caught by some of the hydrodynamical and pQCD-inspired models shown in this paper. Furthermore, the $p_{\rm T}$-integrated hadron-to-pion ratios measured in pp collisions at two different center-of-mass energies are consistent, provided similar multiplicities are considered. This also extends to strange and multi-strange hadrons, suggesting that at the LHC energies particle hadrochemistry is dominantly driven by particle multiplicity and not by the collision energy. In contrast to this, the average transverse momenta of measured hadrons show hints of increase with the increasing collision energy, indicating that particle dynamics might be different at different center-of-mass energies.

[E]See Appendix A for the list of collaboration members

In preparation

Summary

- The ALICE experiment has proven to make precise measurements of tracking and PID down to $p_{\mathrm{T}} \approx 100\ \mathrm{MeV}/c$ allowing the exploration of the non-perturbative QCD regime

- By measuring the p_{T} spectra of identified particles in Pb—Pb collisions at the unprecedented energy of $\sqrt{s_{\mathrm{NN}}} = 5.02\ \mathrm{TeV}$, the creation of the QGP with the largest radial flow (about 2% larger than in Pb—Pb collisions at $\sqrt{s_{\mathrm{NN}}} = 2.76\ \mathrm{TeV}$) is confirmed

- Measurements of the R_{AA} revealed that pions, kaons and protons are equally suppressed. This suggest that jet quenching does not produce signatures that affect the particle composition

- The first year of my PhD has been a fruitful one (schools, conferences and analysis). In the near future my goal is to push for new ideas/measurements within ALICE and aim for publications

Thank you !

Avocados for guacamole and Agave for the tequila
Pictures taken from the garden last time I was at home

Thank you !

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