Misura degli adroni composti da quark leggeri in funzione della molteplicità con l'esperimento ALICE

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Università di Bologna e INFN

Terzo Incontro Nazionale di Fisica Nucleare INFN2016

Frascati

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Outline of this presentation

- Collision systems at the LHC
- The ALICE experiment
- Particle multiplicity
- Signs of collectivity in small collision systems ?
  - Radial flow
  - Particle production in proton-proton collisions
  - Baryon/meson ratio
- Strangeness production
- Conclusions

Collision systems at the LHC

- **Lead–lead (Pb–Pb)**

  deconfined phase of matter (*quark gluon plasma/QGP*)

  hydrodynamic evolution

- **Proton–lead (p–Pb)**

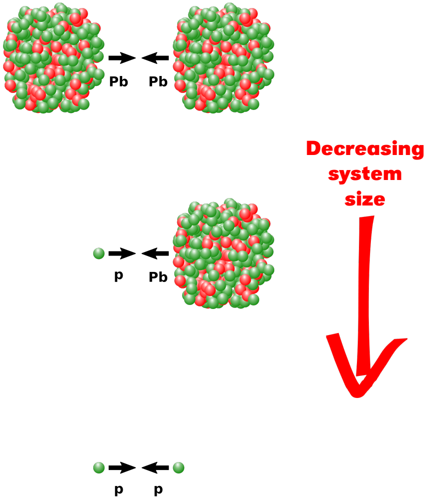
  intermediate system between the Pb–Pb and the proton-proton used to distinguish hot from cold nuclear matter effects

- **Proton–proton (pp)**

  used as a reference for the Pb–Pb and p–Pb cases

→ **deconfinement *not* expected**

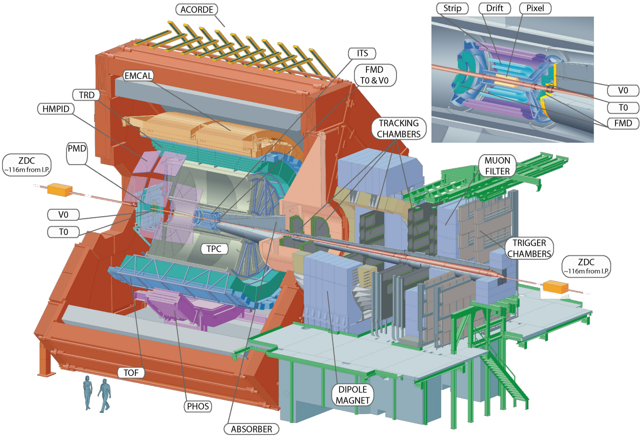
→ **collectivity *not* expected**



ALICE: A Large Ion Collider Experiment

Optimised for the study of heavy-ion collisions

- **Moderate magnetic field (B = 0.5 T) in the midrapidity region**
- **Low-momentum tracking down to $p_T \sim 100$ MeV/c**
- **High granularity to cope with the high occupancy**
- **Extensive particle identification (*PID*) capabilities**



Int. J. Mod. Phys. A29 (2014) 1430044

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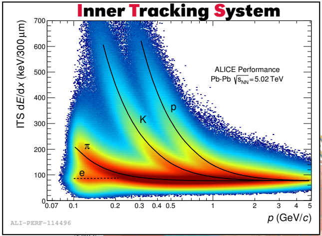

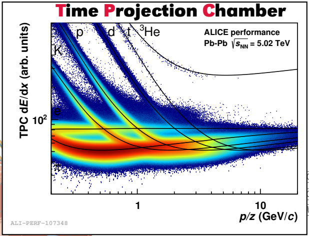

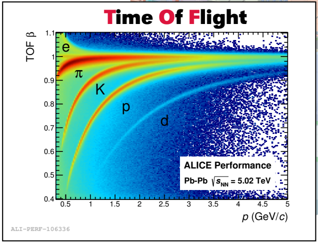

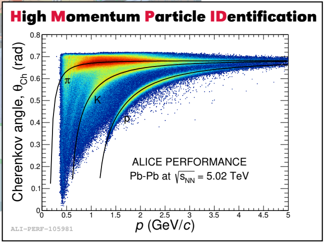

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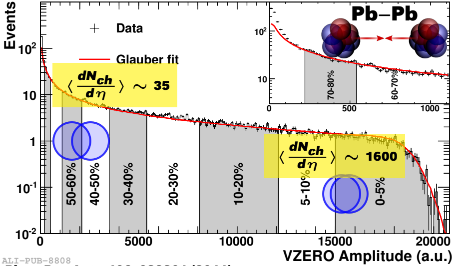
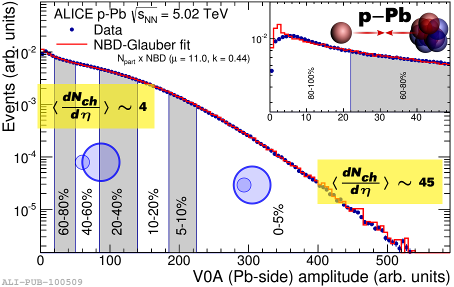
Particle multiplicity



Phys. Rev. Lett. 106, 032301 (2011)

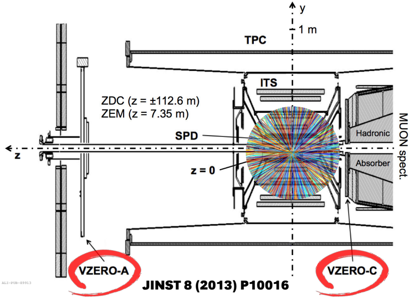


Phys. Rev. C 91 (2015) 064905

- **Multiplicity is defined as the number of charged particles per event**
- **In ALICE multiplicity classes are selected based on the amplitude of the signal in the V0 detector at *forward rapidity***

  $2.8 < \eta < 5.1$ V0A

  $-3.7 < \eta < -1.7$ V0C
- **Related to the collision centrality in Pb–Pb (collision impact parameter)**



JINST 8 (2013) P10016

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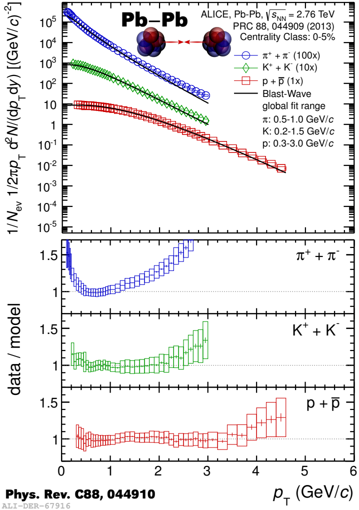
Collective evolution in Pb–Pb - *radial flow*



Phys. Rev. C88, 044910

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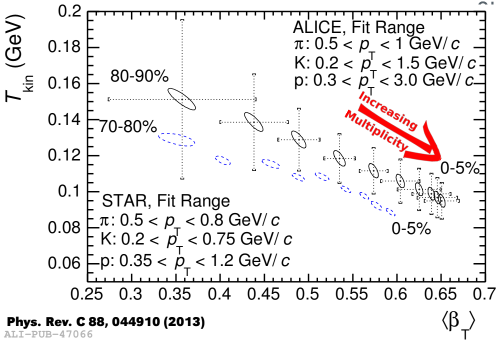


Phys. Rev. C 88, 044910 (2013)

ALI-PUB-47066

- **Mass dependence of the spectral shape**
  → radial flow
- **Blast Wave**
  → simplified hydrodynamic model
- **Well describes spectral evolution**
  → three parameters: m_T, β_T and T_{kin}

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

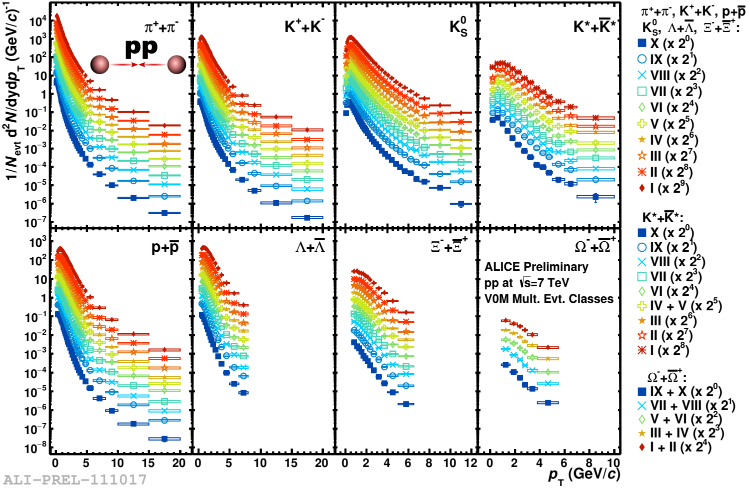
with $m_T = \sqrt{m^2 + p_T^2}$ **and** $\rho = \tanh^{-1}(\beta_T)$

Schnedermann, Sollfrank and Heinz Phys. Rev. C 48, 2462

β_T → **radial velocity**

T_{kin} → **kinetic freeze-out temperature (particle decoupling)**

Light-flavour particle spectra in pp



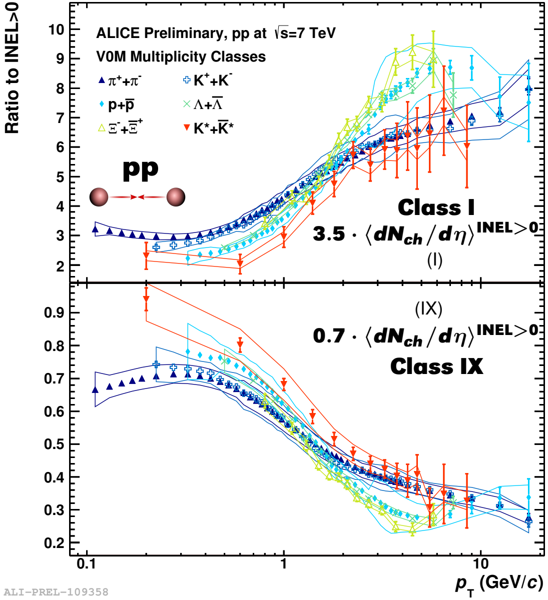
V0M Multiplicity Classes
π K p K^0_s K^* Λ Ξ Ω

$\langle dN_{ch}/d\eta \rangle^{INEL>0} \sim 6.0$

I $\rightarrow \langle dN_{ch}/d\eta \rangle \sim 3.5 \times \langle dN_{ch}/d\eta \rangle^{INEL>0}$
...
IX $\rightarrow \langle dN_{ch}/d\eta \rangle \sim 0.7 \times \langle dN_{ch}/d\eta \rangle^{INEL>0}$
X $\rightarrow \langle dN_{ch}/d\eta \rangle \sim 0.4 \times \langle dN_{ch}/d\eta \rangle^{INEL>0}$

$\Rightarrow$ **At higher multiplicities spectra are shifted towards higher p_T**

Spectra modification

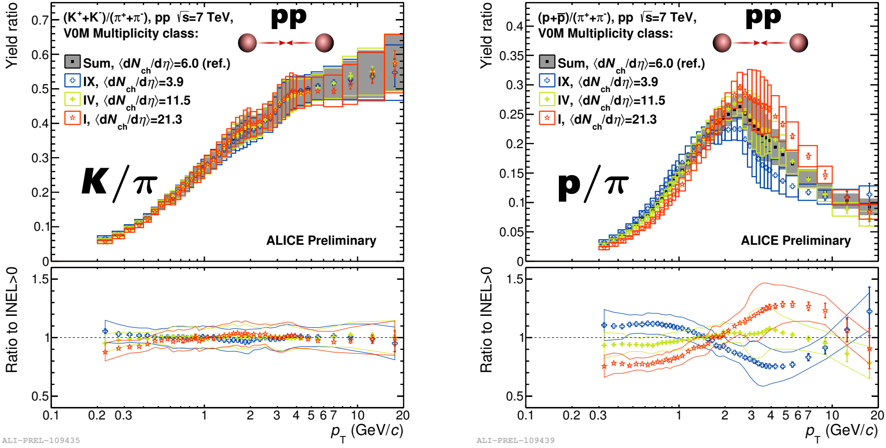


- Ratio to multiplicity-integrated (INEL > 0) spectra
- "Hardening" of the spectral shape at higher multiplicity

⇒ Similar to what is observed in Pb–Pb

⇒ Different behaviour for baryons and mesons

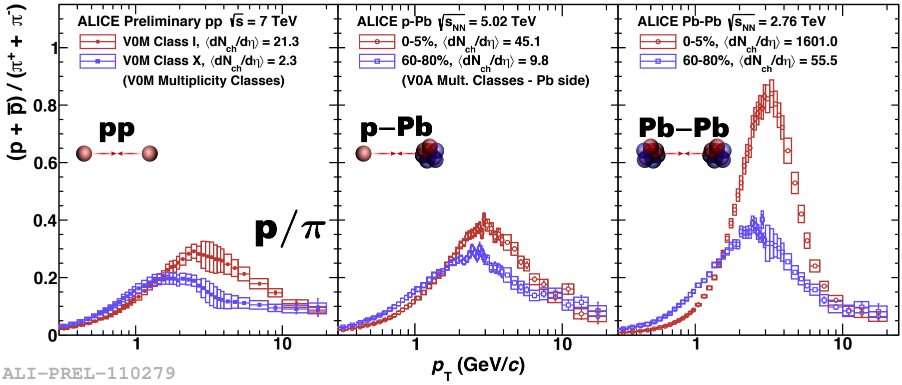
Baryon to meson ratio



⇒ **Depletion at low p_T and enhancement at intermediate p_T for p/π**

- **No significant multiplicity evolution for the ratio K/π as a function of p_T**

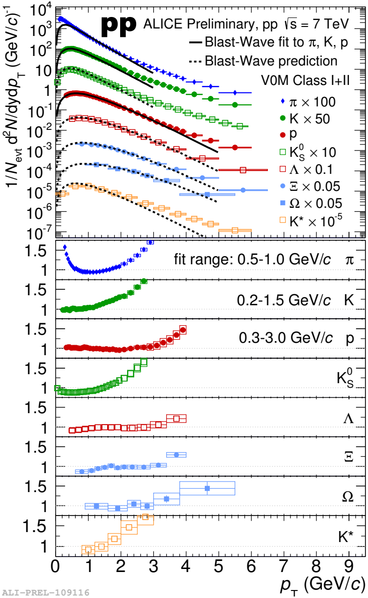
Baryon to meson ratio in pp, p–Pb and Pb–Pb

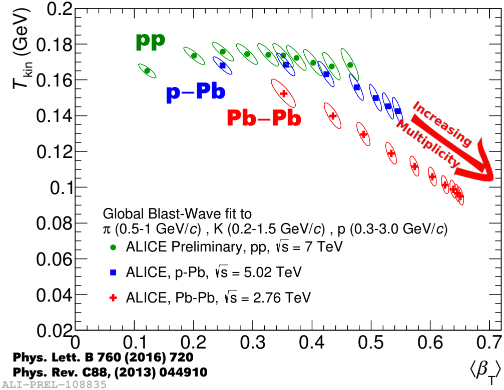


⇒ **Depletion at low p_T and enhancement at intermediate p_T for p/π**

⇒ **Observed in all three systems (collective evolution ?)**

Blast Wave fits in pp

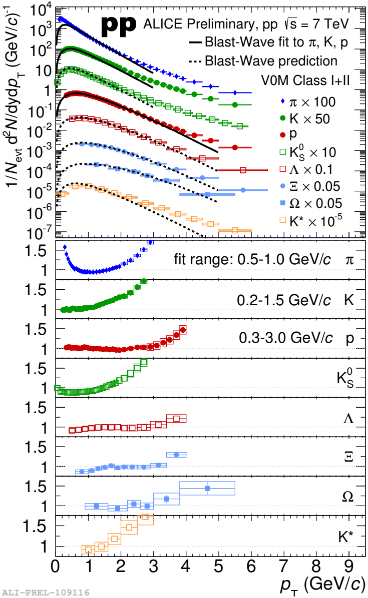


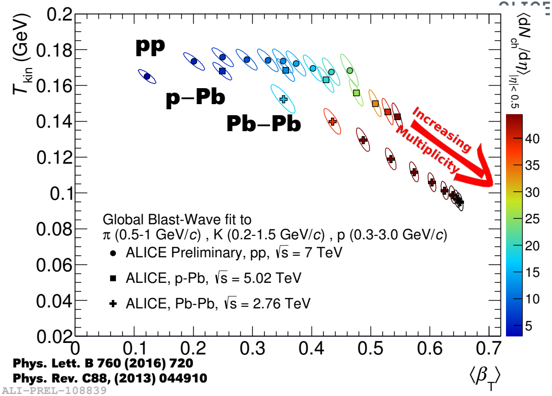


- **Highest multiplicity (class I+II)**
- **Simultaneous fit to the π, K and p spectra $\rightarrow$ parameter extraction**
- **Hyperons follow the Blast Wave predicted with the π, K, p fit parameters**

$\Rightarrow$ **pp and p–Pb parameters follow the same trend**

Blast Wave fits in pp





- **Highest multiplicity (class I+II)**
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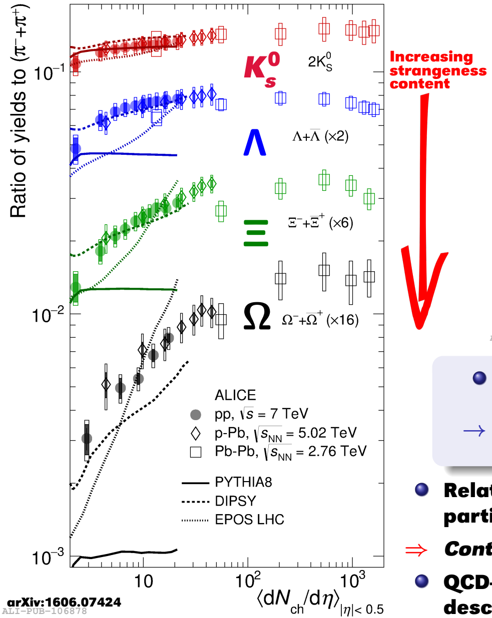
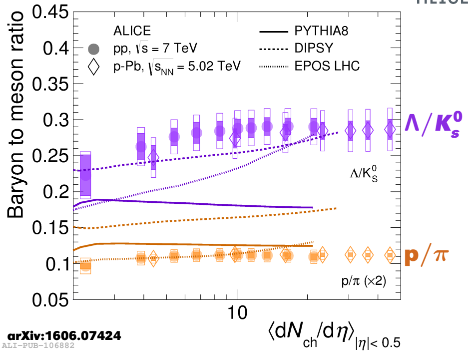
Production of strange particles





- **No significant multiplicity dependence for both Λ/K^0_s and p/π**

→ **Enhancement is not *mass* or *baryon number* dependent**

- **Relative increase in the production of strange particles**

⇒ ***Continuous evolution* for all three systems**

- **QCD-inspired models *do not* satisfactorily describe simultaneously all the observations**

Conclusions

- Similarities between the pp, p–Pb and Pb–Pb systems have been found at the LHC (collectivity, baryon/meson ratio and strangeness production)
  - Observation of an increase in the production of strange particles in pp collisions as a function of multiplicity (arXiv:1606.07424)

    Predictions from Monte Carlo models show poor agreement with data
  - Further investigations are necessary to understand the underlying particle production mechanisms in smaller systems

Conclusions

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  - **Observation of an increase in the production of strange particles in pp collisions as a function of multiplicity (arXiv:1606.07424)**

    Predictions from Monte Carlo models show poor agreement with data
- **Further investigations are necessary to understand the underlying particle production mechanisms in smaller systems**

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- Similarities between the pp, p–Pb and Pb–Pb systems have been found at the LHC (collectivity, baryon/meson ratio and strangeness production)
- Observation of an increase in the production of strange particles in pp collisions as a function of multiplicity (arXiv:1606.07424)

  Predictions from Monte Carlo models show poor agreement with data

► Further investigations are necessary to understand the underlying particle production mechanisms in smaller systems

Backup

Multiplicity classes

ALICE

Fractions of the INEL>0 cross-section:

$\pi, K, K^0_s, p, \Lambda, \Xi$

Class	$\frac{\sigma}{\sigma_{INEL>0}}$	$\langle \frac{dN_{Ch}}{d\eta} \rangle$
I	$0 - 0.95\%$	21.3 ± 0.6
II	$0.95 - 4.7\%$	16.5 ± 0.5
III	$4.7 - 9.5\%$	13.5 ± 0.4
IV	$9.5 - 14\%$	11.5 ± 0.3
V	$14 - 19\%$	10.1 ± 0.3
VI	$19 - 28\%$	8.45 ± 0.25
VII	$28 - 38\%$	6.72 ± 0.21
VIII	$38 - 48\%$	5.40 ± 0.17
IX	$48 - 68\%$	3.90 ± 0.14
X	$68 - 100\%$	2.26 ± 0.12

K^*

Class	$\frac{\sigma}{\sigma_{INEL>0}}$	$\langle \frac{dN_{Ch}}{d\eta} \rangle$
I	$0 - 0.95\%$	21.3 ± 0.6
II	$0.95 - 4.7\%$	16.5 ± 0.5
III	$4.7 - 9.5\%$	13.5 ± 0.4
IV + V	$9.5 - 19\%$	10.8 ± 0.3
VII	$28 - 38\%$	6.72 ± 0.21
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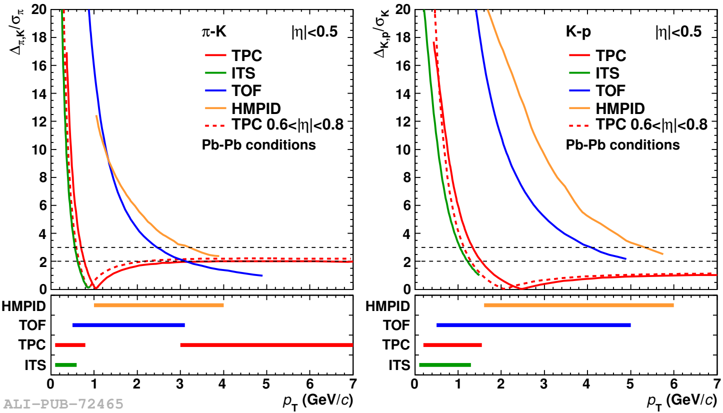
VIII	$38 - 48\%$	5.40 ± 0.17
IX	$48 - 68\%$	3.90 ± 0.14
X	$68 - 100\%$	2.26 ± 0.12

Ω

Class	$\frac{\sigma}{\sigma_{INEL>0}}$	$\langle \frac{dN_{Ch}}{d\eta} \rangle$
I + II	$0.0 - 4.7\%$	17.5 ± 0.5
III + IV	$4.7 - 14\%$	12.5 ± 0.4
V + VI	$14 - 28\%$	8.99 ± 0.27
VII + VIII	$28 - 48\%$	6.06 ± 0.19
IX + X	$48 - 100\%$	2.89 ± 0.14

ALICE PID detectors



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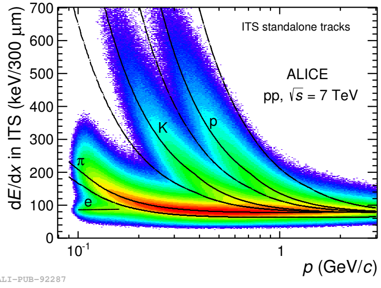
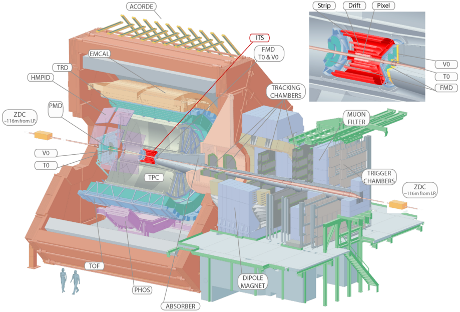
- **PID separation power for K/π and p/K for the ITS, TPC, TOF and HMPID detectors**
- **Combining the information from various detectors provides PID capabilities over a wide range of p_T**

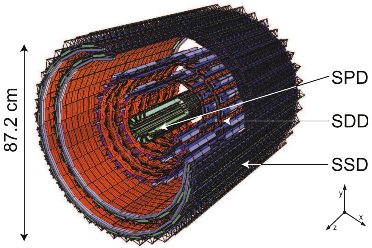
ALICE PID detectors

- **Inner Tracking System → ITS**





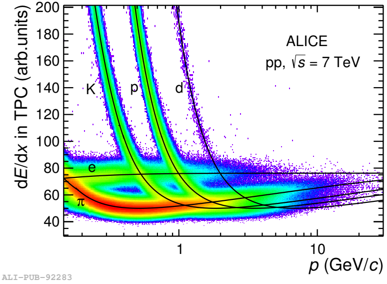
EPJC 75 (2015) 226



- **d*E*/dx measurement**

ALICE PID detectors

- Inner Tracking System $\longrightarrow$ **ITS**
- Time Projection Chamber $\longrightarrow$ **TPC**



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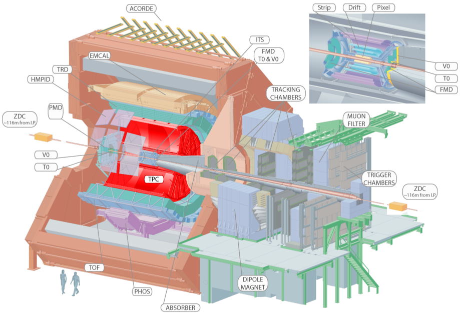
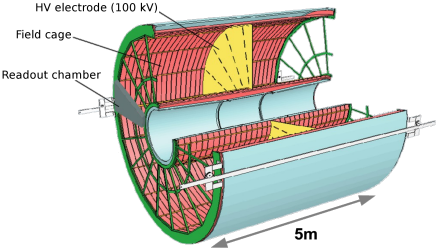
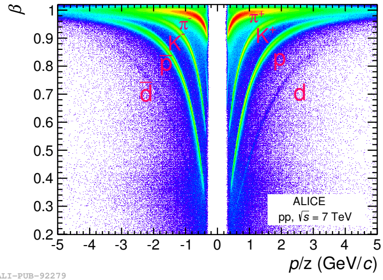
▶ **dE/dx measurement**





ALICE PID detectors

- **Inner Tracking System $\rightarrow$ ITS**
- **Time Projection Chamber $\rightarrow$ TPC**
- **Time Of Flight $\rightarrow$ TOF**



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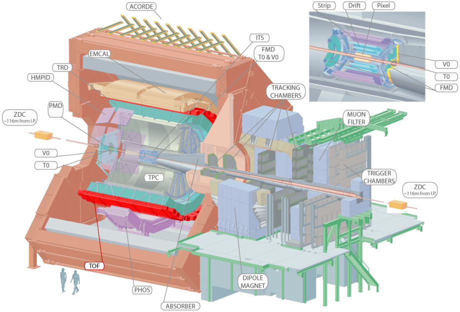
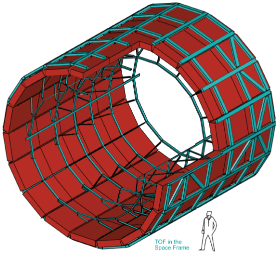
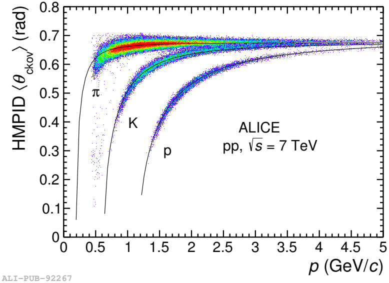
▶ **Time-of-flight measurement**





ALICE PID detectors

- Inner Tracking System → **ITS**
- Time Projection Chamber → **TPC**
- Time Of Flight → **TOF**
- High Momentum Particle IDentification → **HMPID**



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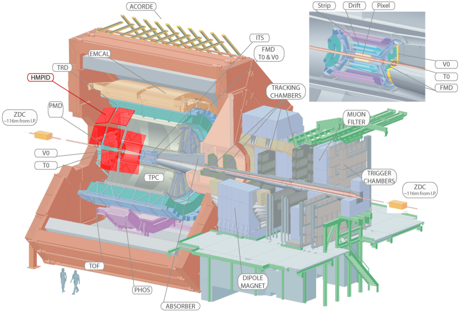
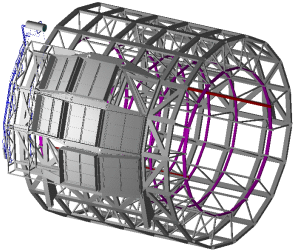
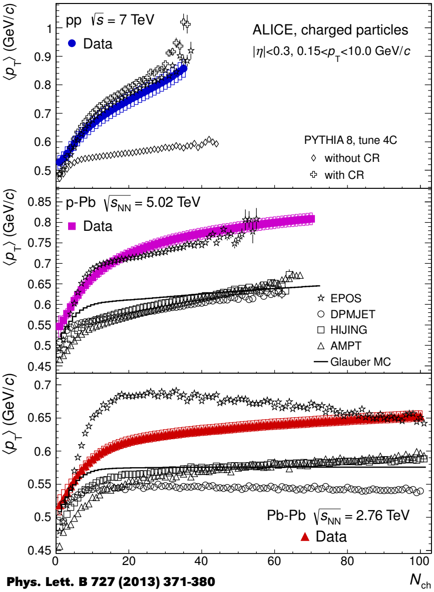
▶ **Cherenkov angle measurement**





$\langle p_T \rangle$ in pp, p–Pb and Pb–Pb collisions

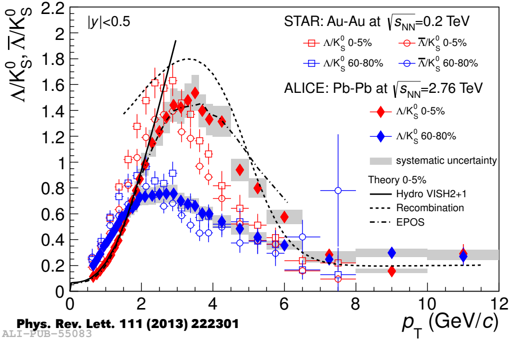
- **Very different regimes correspond to same values of $dN_{ch}/d\eta$**
- **In Pb–Pb $\langle p_T \rangle$ saturation at low multiplicity due to radial flow**
- **pp e p–Pb show similar behaviour at low multiplicity**



Phys. Lett. B 727 (2013) 371-380

Baryon/meson ratio

- **Baryon-meson enhancement in A–A**
- **Well described by hydro models**
- **Manifestation of the radial flow**



Phys. Rev. Lett. 111 (2013) 222301