The ALICE PID performance in Run-1 and perspectives in view of Run-2

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Outline

Int. J. Mod. Phys. A 29 (2014) 1430044
J. Phys. G32, 1295 (2006)

ALICE

- The ALICE detector and the subsystems devoted to Particle IDentification (PID):
  - **Many different PID techniques** exploited by ALICE.
- The performance reached during Run-1

→ the different techniques are **complementary** allowing
  - to address different particle species or different momentum ranges,
  - to improve the PID performance when combining signals of many subsystems.
- The perspectives for Run-2
  - ALICE detector upgrades.
  - Development in the PID techniques.

Physics analyses with PID in ALICE

Soft physics (low p_T):

- Hadron production and spectra
- Hadron collective phenomena (v_n, radial flow, …)
- Weakly decaying particles, strangeness, resonances
- Femtoscopy
- Dielectron
- …

Evgeny KRYSHEN – Opening plenary

Alice OHLSON - Heavy ion 1: Parallel 3

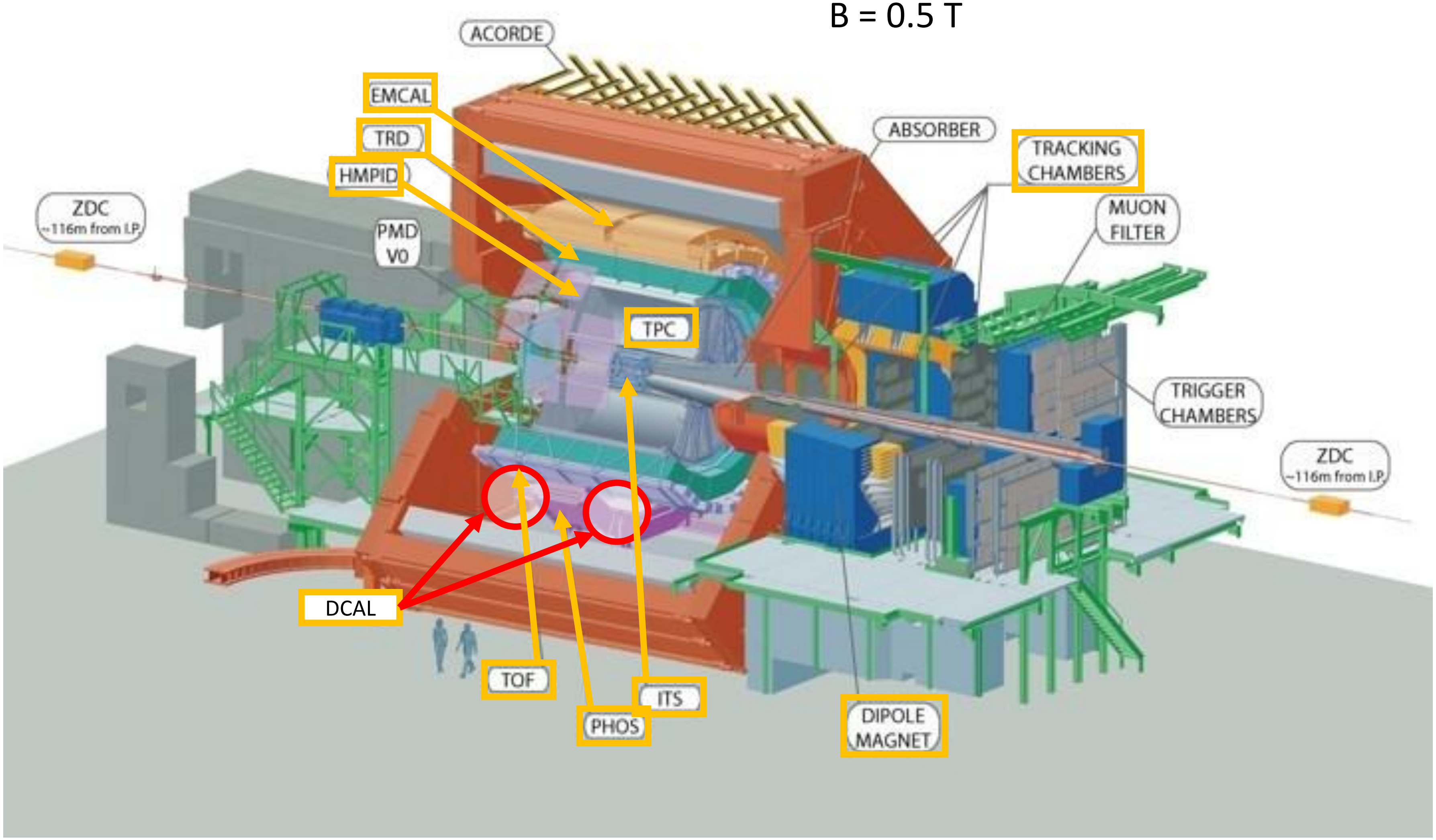
Hard physics (high p_T):

- Open charm
- Quarkonia
- Identification within jets and 2-particle correlations at high p_T
- Direct photons
- …

Yuri KHARLOV – SM – QCD 3 : Parallel 9

The ALICE detector
→ strongly PID oriented

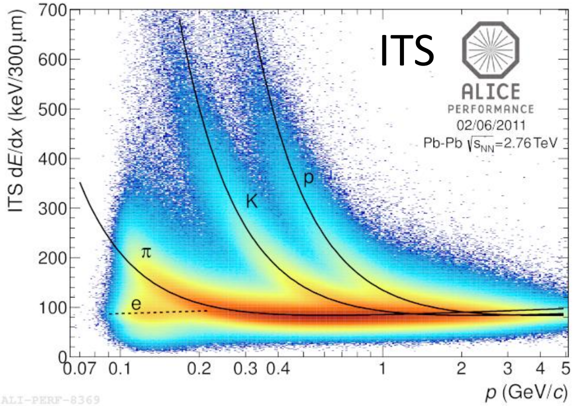
B = 0.5 T

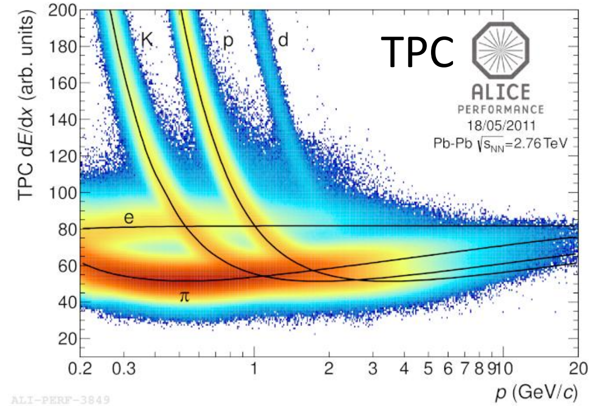


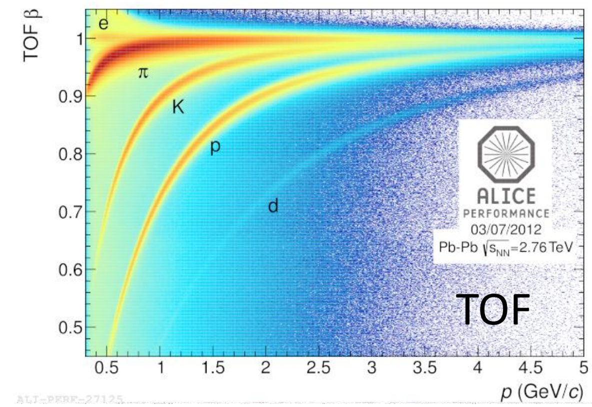
Detector performance in Run-1

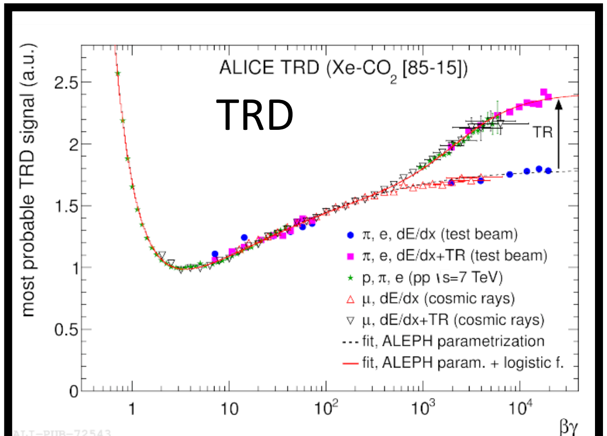
Hadron PID

Full azimuthal acceptance

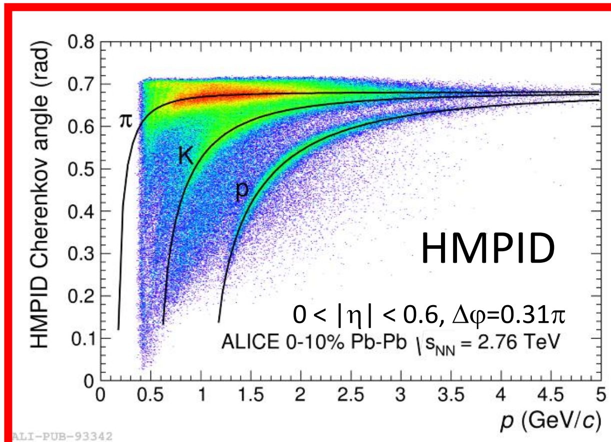








The PID capabilities of the detector were largely exploited during Run-1 in many analyses and collision systems (pp, pPb, PbPb).



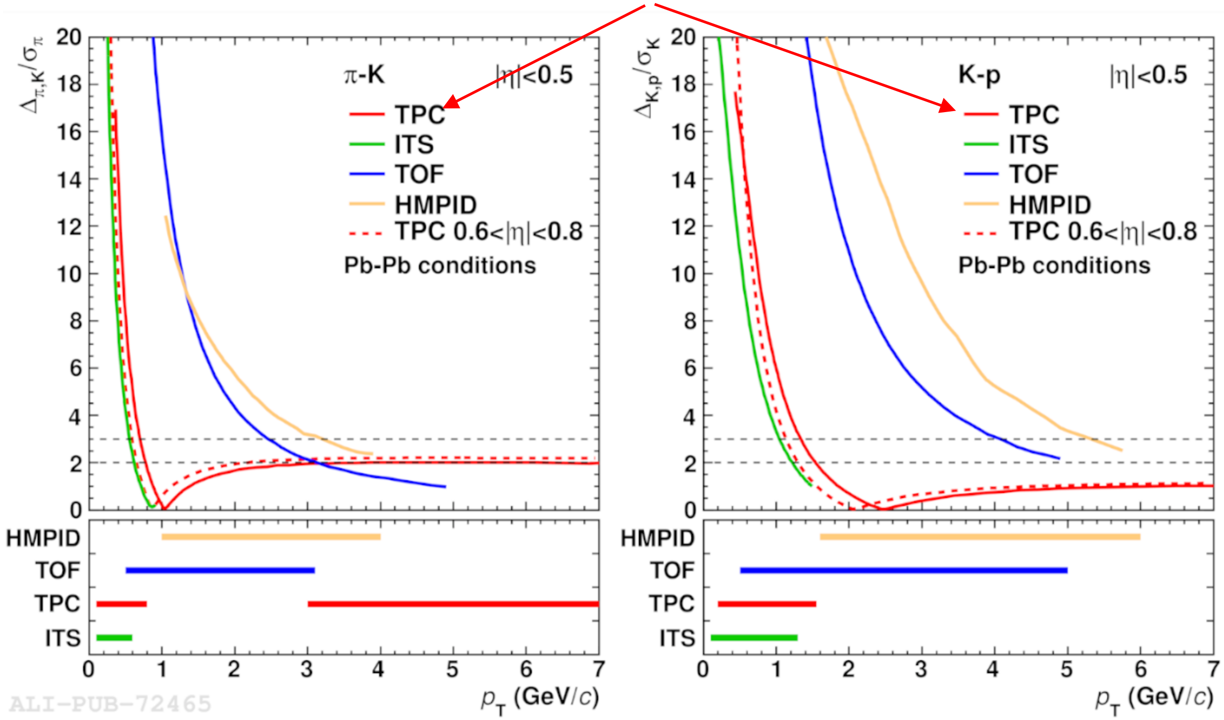
Limited acceptance

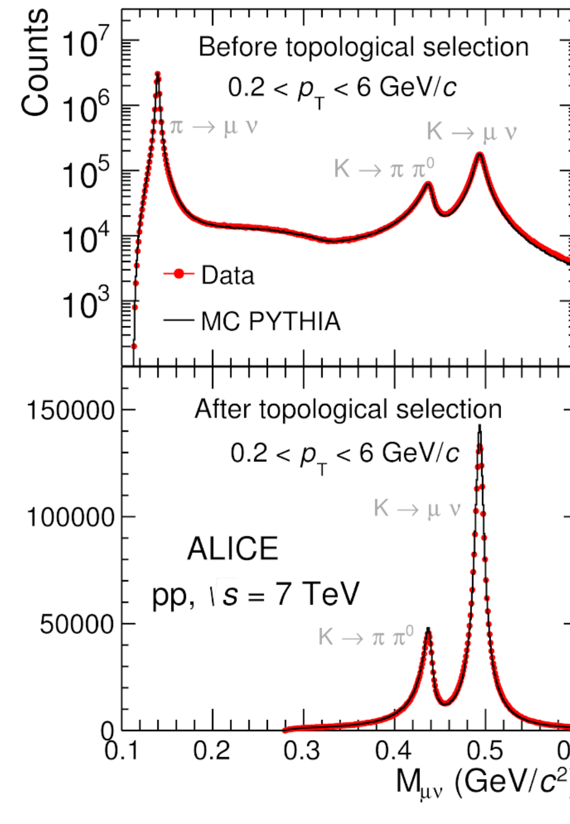
Azimuthal acceptance completed for Run-2

Jochen KLEIN – Performance 2: Parallel 8

Momentum range covered by ALICE PID techniques

TRD performance similar to TPC one



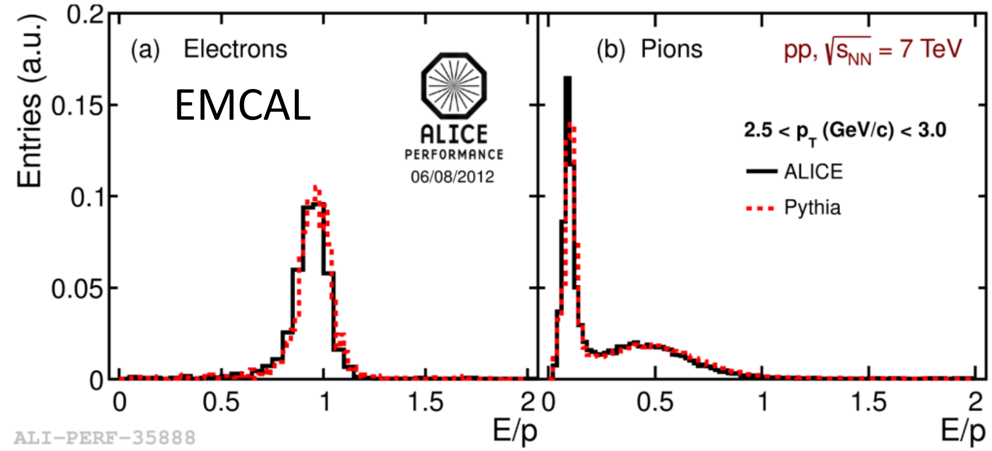


The separation power (number of standard deviations) vs momentum
→ **PID covered with continuity in a large momentum range (complementarity).**

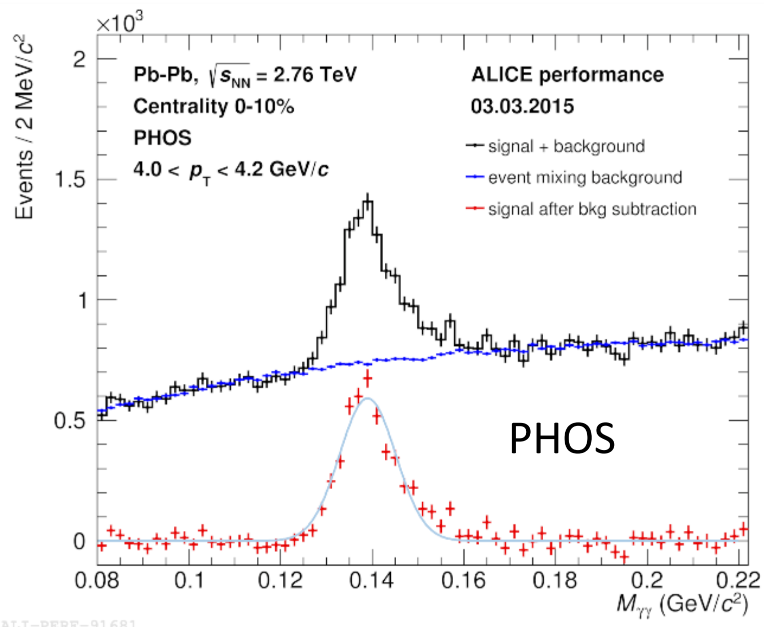
We are able to identify kaons also by looking at the topology of their decay (kink) in the TPC.

PID with calorimeters

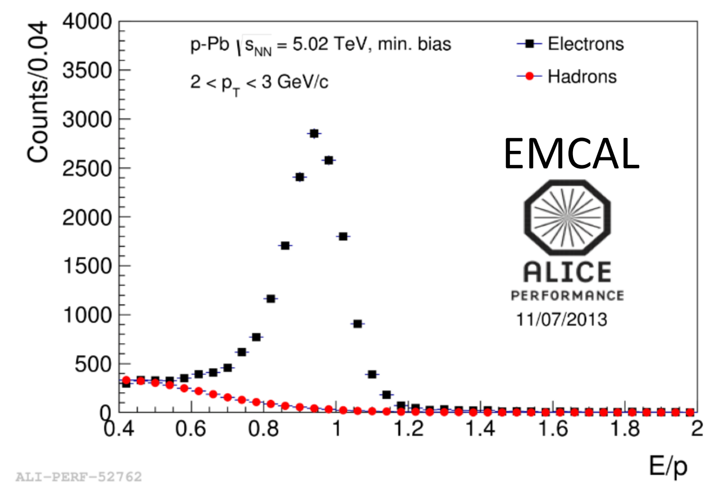
Photons and electrons energy well reconstructed in the calorimeters of ALICE (**PHOS, EMCAL, DCAL**)
→ neutral meson peaks like π^0 and η.



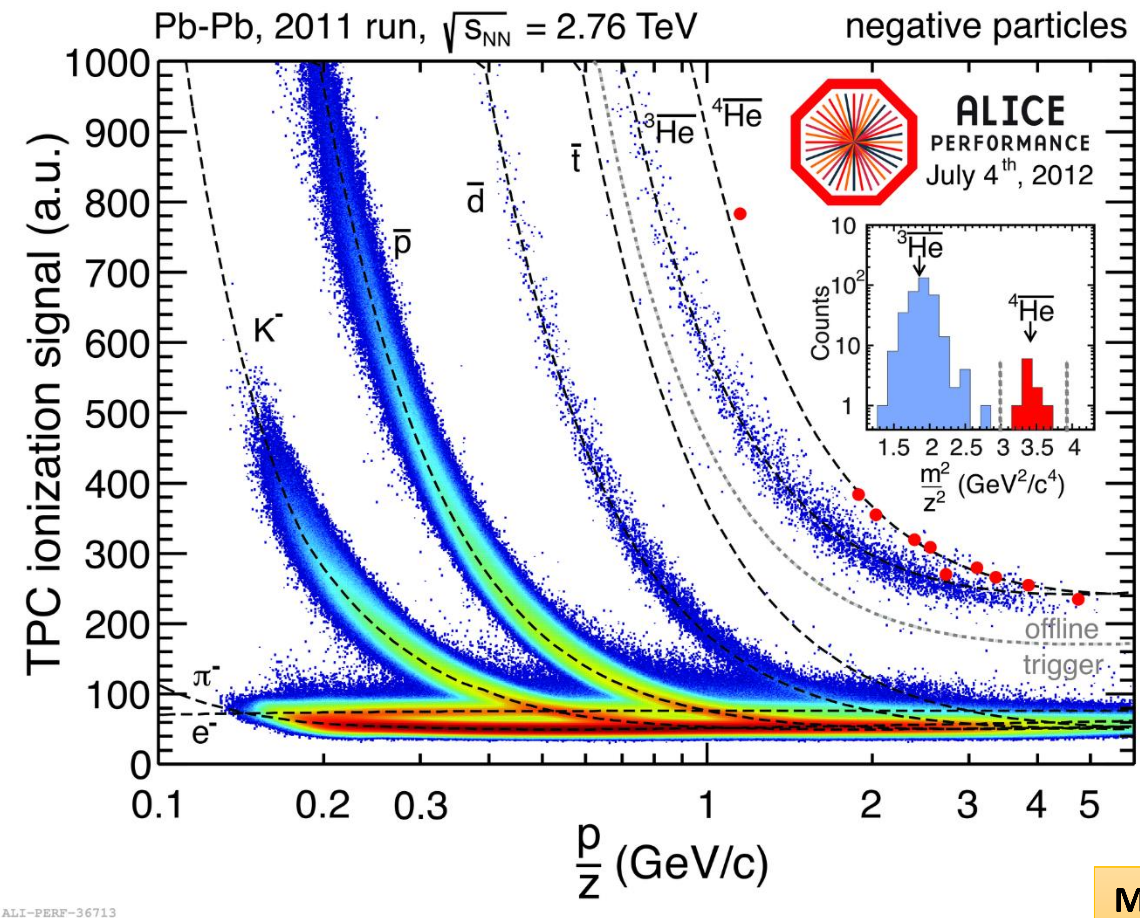
Energy/momentum ratio for electrons and hadrons in the EMCAL (DATA and MC).



π^0 peak as reconstructed via two γ (PHOS).



Not only hadrons → nuclei and antinuclei



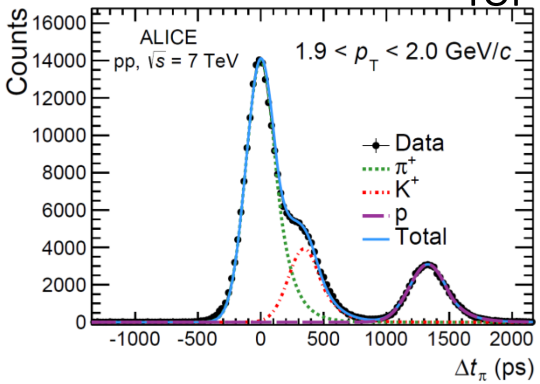
large production of light (anti)nuclei at the LHC very well measured by ALICE.

Maximiliano PUCCIO - Heavy ion 1: Parallel 3

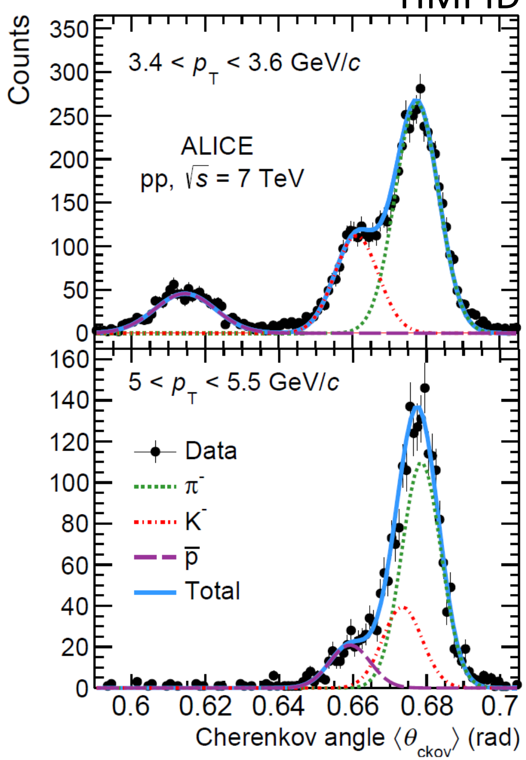
PID performances achieved in Run-1

Unfolding (particle spectra)

TOF



HMPID



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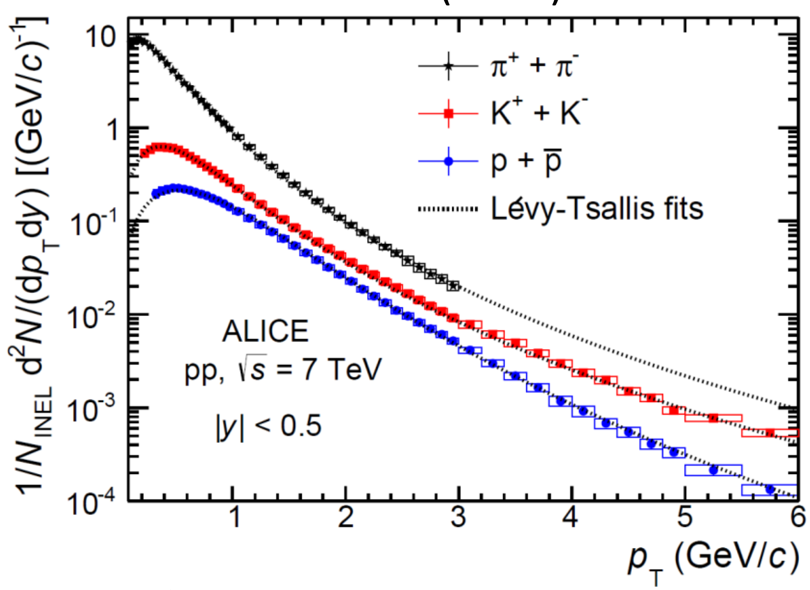
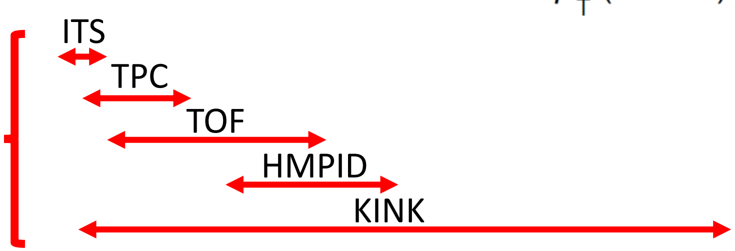


Kaon PID



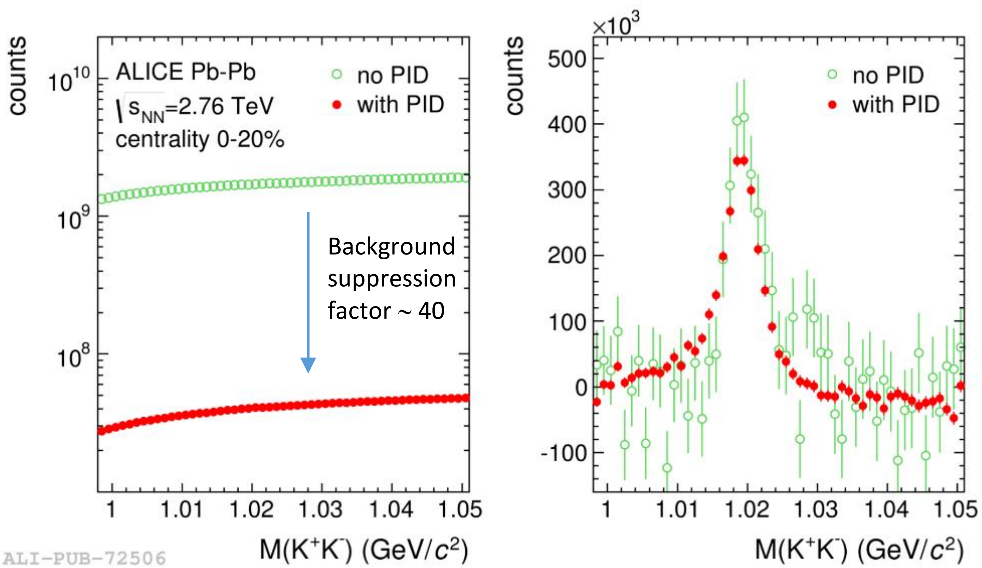
An unfolding statistical approach was typically used to measure the particle spectra with different detectors (then combined).

Track by track PID (n_σ cut)

A track by track PID requires to define some cuts on the quantities provided by the detectors. **The most common approach used in ALICE during Run-1 is to cut on the n_σ variable.**

$$n_\sigma = \frac{S - \hat{S}(H_i)}{\sigma}$$

- S: measured signal
- $\hat{S}(H_i)$: expected signal for a given mass hypothesis
- σ: detector resolution

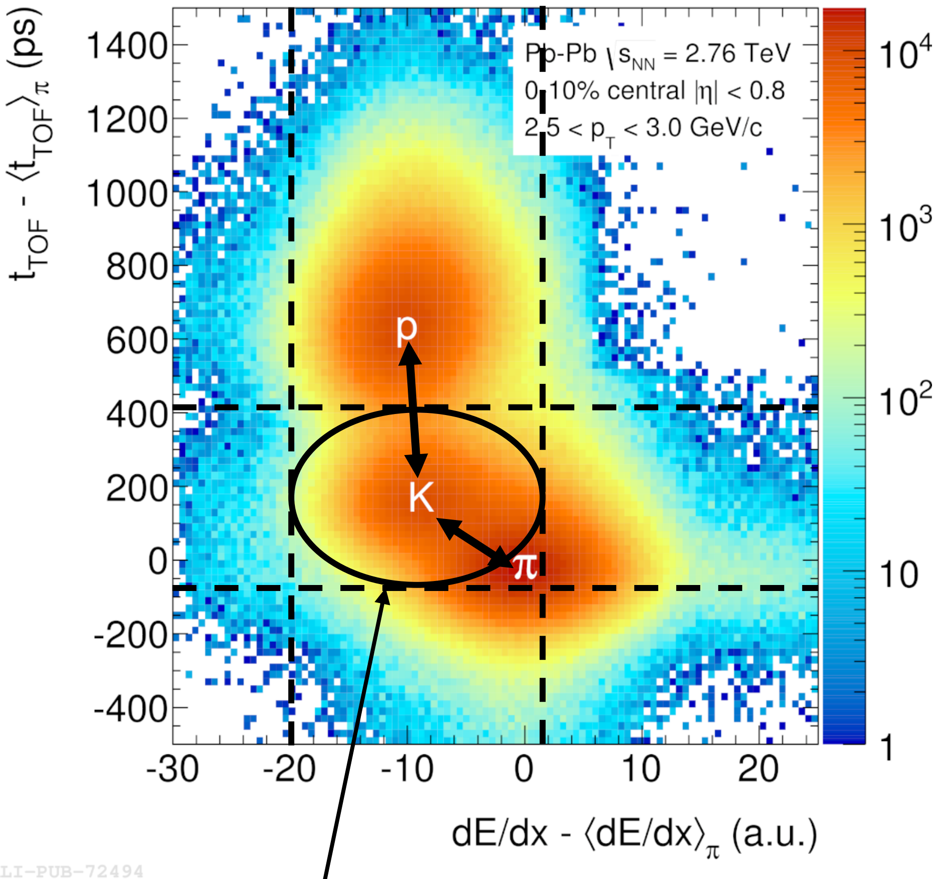


PID: 2σ cut (n_σ < 2) around the expected values (TPC dE/dx)

n_σ is expected to follow a Gaussian distribution centered at 0 (width=1).

A fixed cut on n_σ guarantees a constant PID efficiency independently of the momentum (99%, 95%, 68% for 3, 2 and 1σ cut respectively).

Combined PID



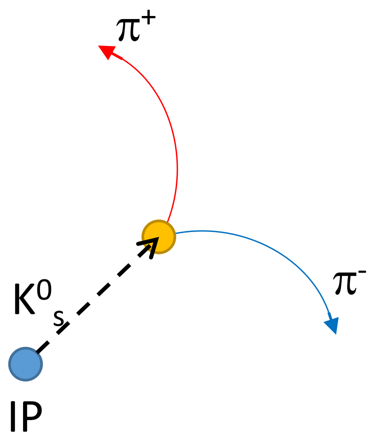
Elliptic cut corresponds to a cut on the variable:

$$n^2_{\sigma,comb} = n^2_{\sigma,TOF} + n^2_{\sigma,TPC}$$

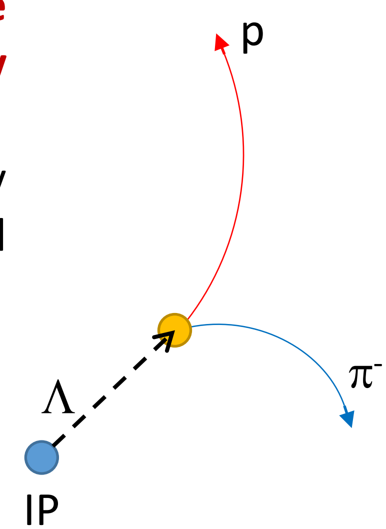
In the intermediate p_T region one single detector may be not sufficient to provide a good PID.
However **the combination of the information allows a good PID performance**.

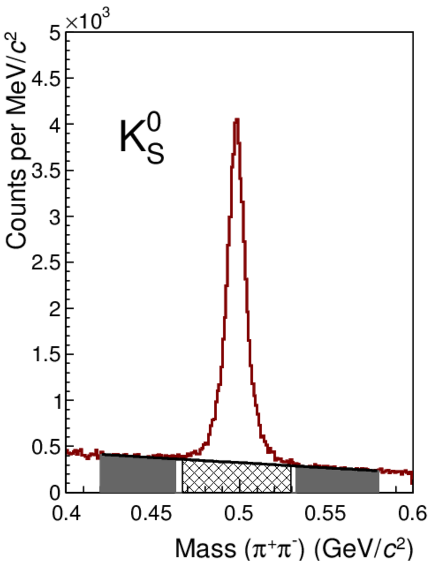
Such an approach was largely used using TPC and TOF in the p_T region up to 4 GeV/c.

PID from secondary decay vertices

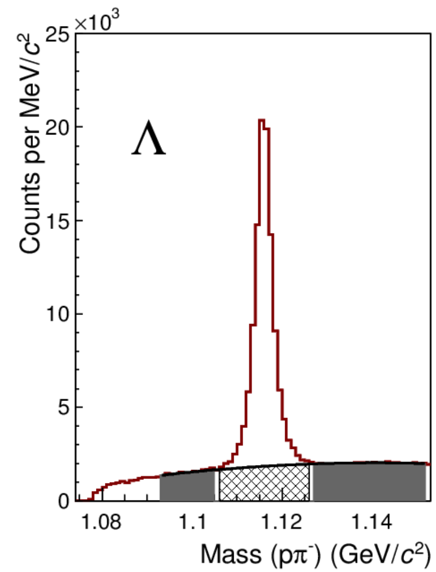


Neutral particles decaying weakly can be identified via their decay topology (secondary vertices).
The topology of the decay and the decay length are used to reject the combinatorial background from primary particles.





Their **daughters are also used to select almost pure samples of pions and protons** to refine the tuning of other PID ALICE systems.



Perspectives for Run-2

Detector upgrade in Run-2 (focusing on PID detectors)

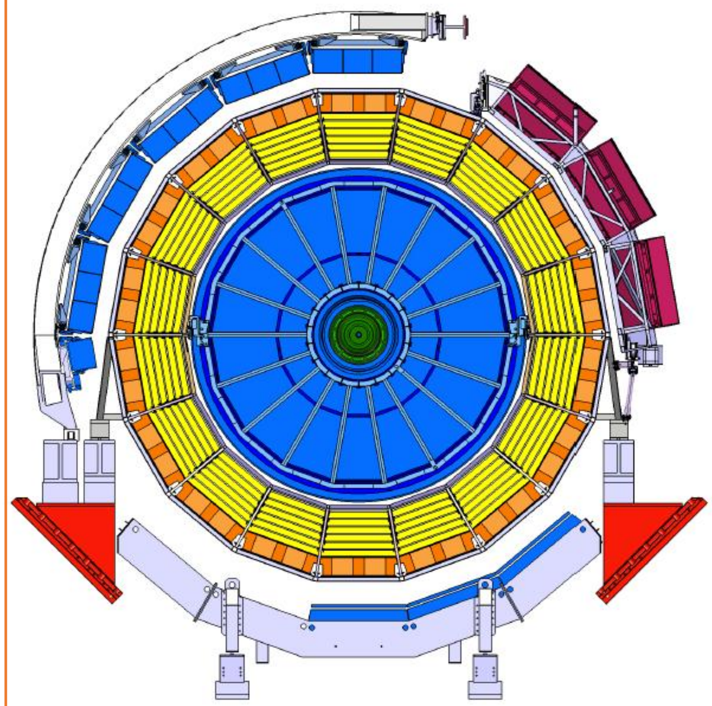
The main upgrade related with the PID detectors is the completion (13 → 18 modules) of the TRD installation in the central barrel.

Therefore, we will benefit of:

- Full acceptance TRD PID
- Improvement in the tracking (especially expected for the TOF matching) adding track clusters in the external region.

Other upgrades:

- DCAL installation
- One additional PHOS module
- Readout upgrade for TPC, TOF, TRD, EMCAL, PHOS



Jochen KLEIN – Performance 2: Parallel 8

Progress on multi-detector PID in view of Run-2

The **probability** that a certain detector signal, *S*, belongs to a particle species H_i: $P(H_i\,|S)$ can be expressed using **Bayes' theorem**:

$$P(H_i\,|\,\vec{S}) = \frac{P(\vec{S}\,|\,H_i)\,C(H_i)}{\sum_{\text{all species}} P(\vec{S}\,|\,H_k)\,C(H_k)}$$

$$P(\vec{S}\,/\,H_i) = \prod_{\alpha=ITS,TPC,...} P(S_\alpha\,/\,H_i)$$

$$P(S\,/\,H_i) = P(n_\sigma) = \frac{1}{2\pi\sigma}\exp(-n_\sigma^2/2)$$

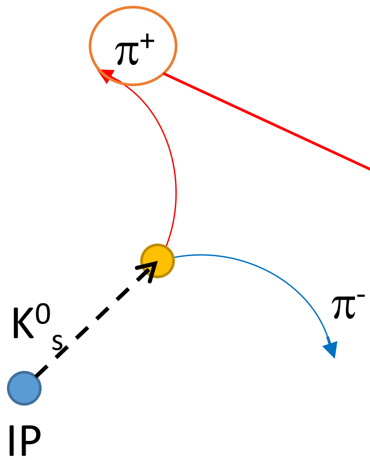
Particle species abundances

Normalization

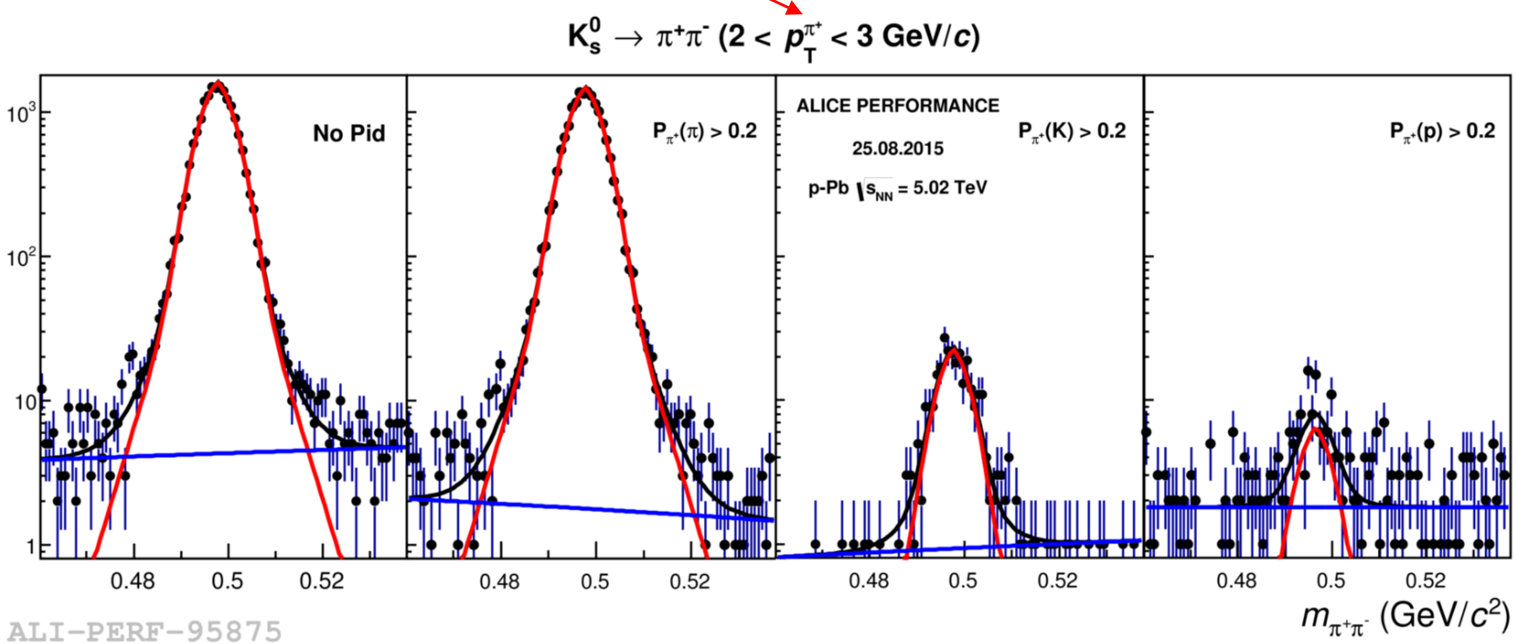
- The use of this variable easily allows to **manage multi-detector scenarios in a natural way**.
- PID efficiencies are extracted via MC → **the MC description has to be well under control** (see next slides)

A more detailed description of the method can be found in J. Phys. G32, 1295 (2006)

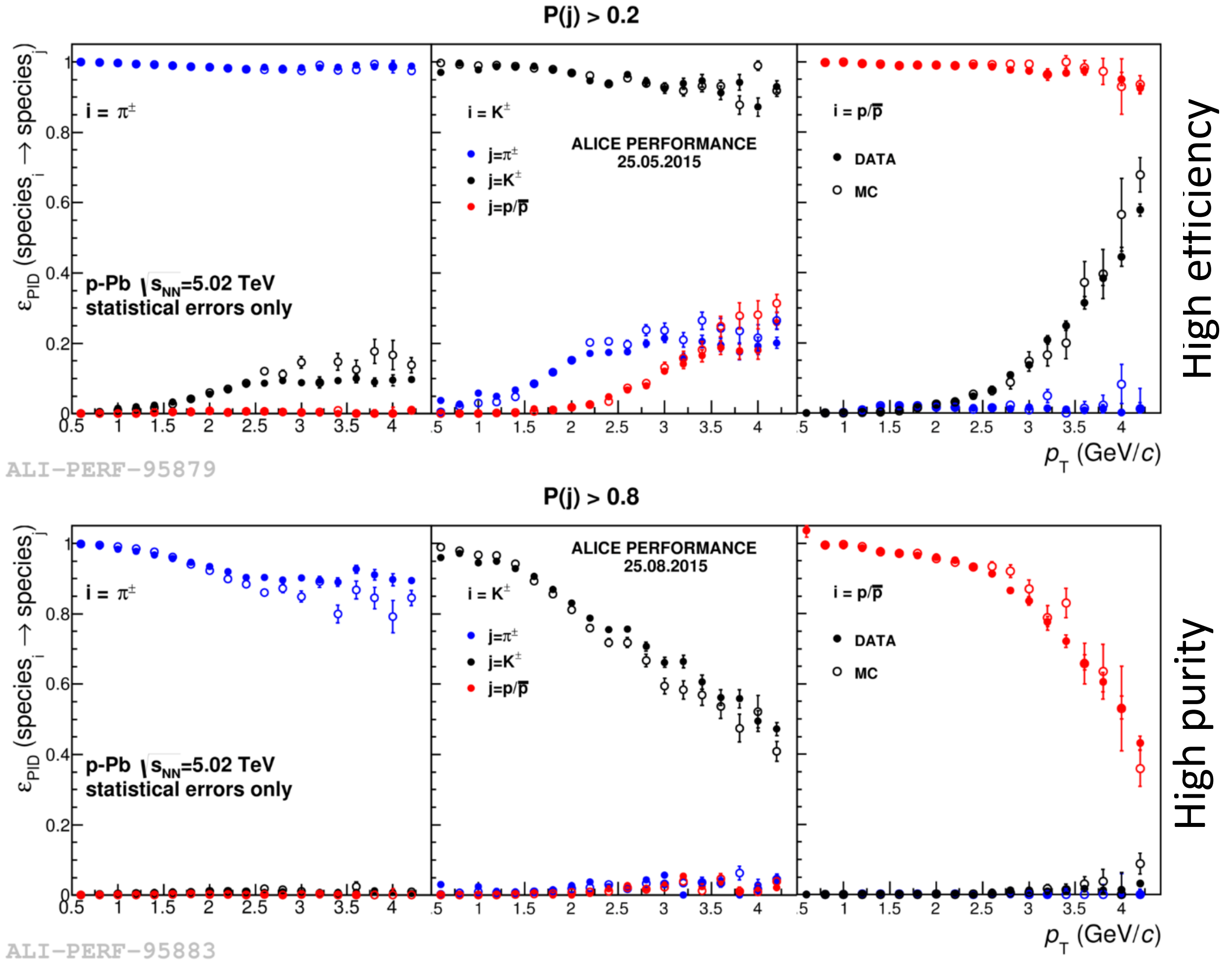
Validation of the Bayesian approach



K^0_s, Λ and ϕ peaks are used to select pure samples of π, K, p without applying any PID cut. Then different PID cuts are applied to check the consistency of the performances between data and MC.



Results for TPC and TOF combined PID



The combined PID using TPC and TOF PID signals were extensively tested using Run-1 data (p-Pb) with different requests on the Bayesian probability.

The consistency between data and MC is typically within 5% → **very good understanding of our detector responses**.

Such an approach will be extensively used in Run-2.

Conclusions

- **PID** is one of the most **characterizing feature of ALICE** → ~55% of the ALICE publications involve PID.

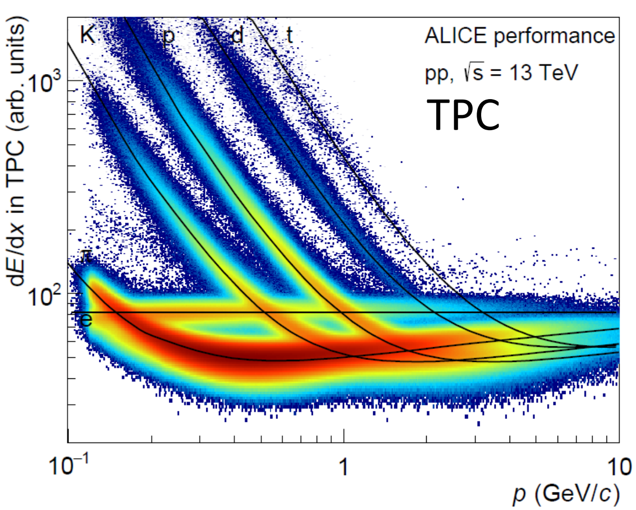
- **Different identification techniques** are used in ALICE to span a very wide range of momenta (and several particle species).

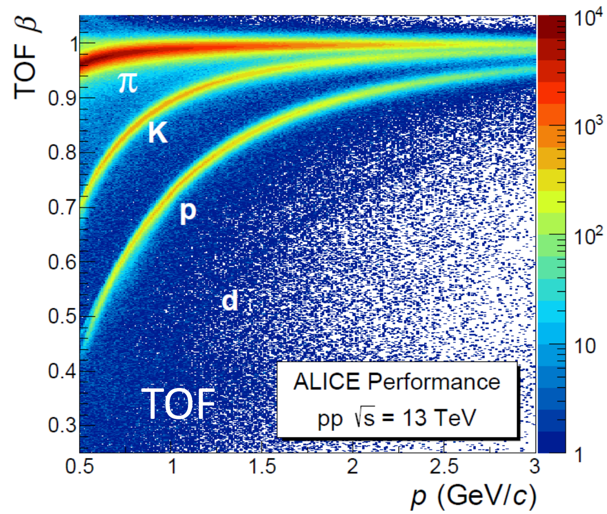
- Many PID approaches were successfully used during Run-1 → ALICE PID techniques and performance very well under control opening to more refined approaches **in Run-2 (multi-detector PID)**.

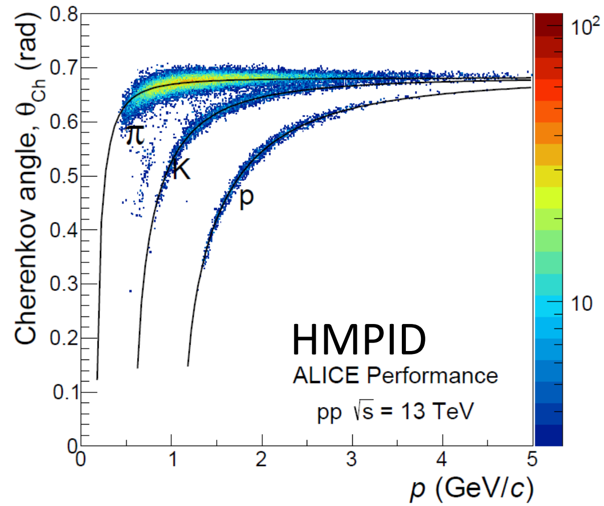
- The installation of the last TRD modules during the long shutdown completed the azimuthal coverage for Run-2.

ALICE has already started to identify particles with the new collisions at 13 TeV

Evgeny KRYSHEN – Opening plenary







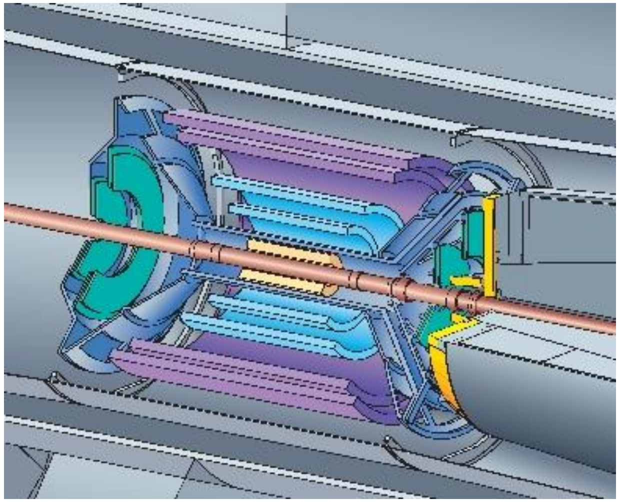
Thank you for your attention!

backup

ITS

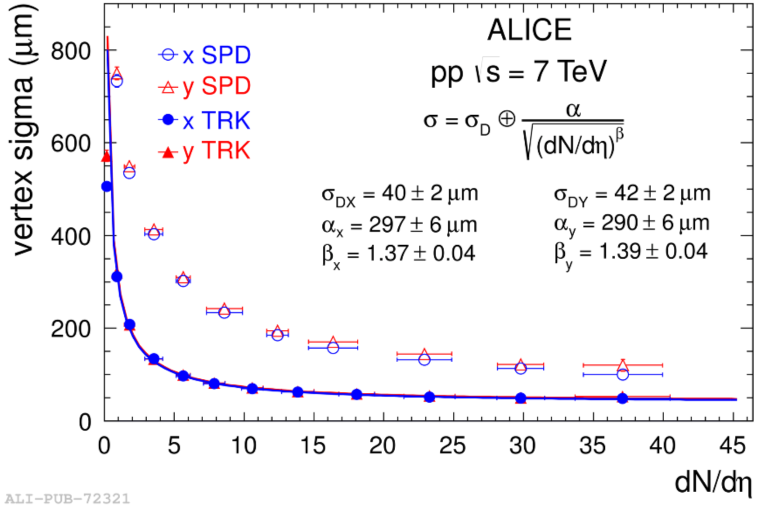
Six layers of silicon detectors

- Pixels (SPD) |η|<1.4
- Drift (SDD) → dE/dx
- Double-sided Strips (SSD) |η|<0.9 → dE/dx



R_{ITS} < 50 cm

Minimal momentum (B=0.5 T) ~ 100 MeV/*c*



TPC

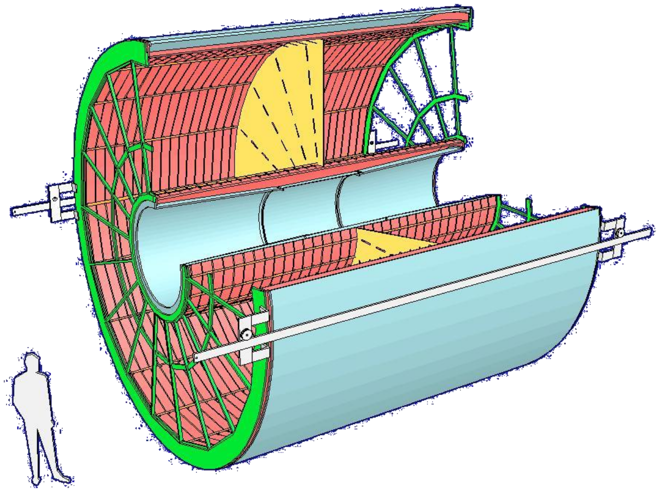
R_{TPC} = 80 – 280 cm

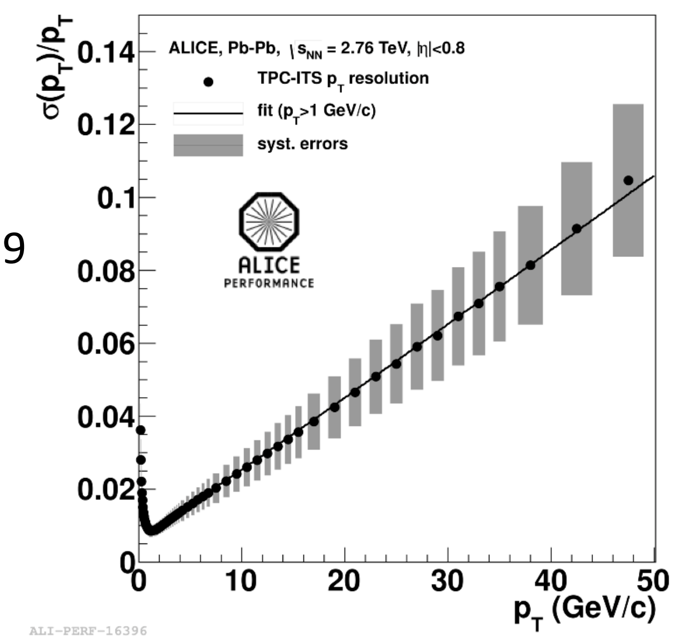
dE/dx resolution ~ 6% (pPb coll.)

18 sectors (Run-2) covering the whole azimuthal angle, $|\eta|<0.9$

Track finding efficiency for tracks with p_T > 1 GeV/*c* of > 90%

Rate capability for central collisions to be at least 200 Hz



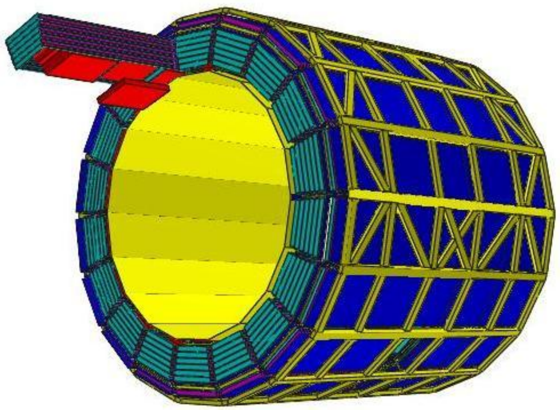


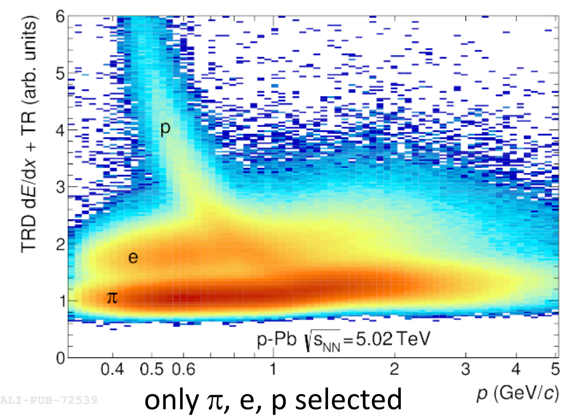
TRD

R_{TRD} = 290 – 370 cm
6 layers (radiator + drift chamber)

Pion rejection power > 100
dE/dx resolution ~ 10% (pPb coll.)

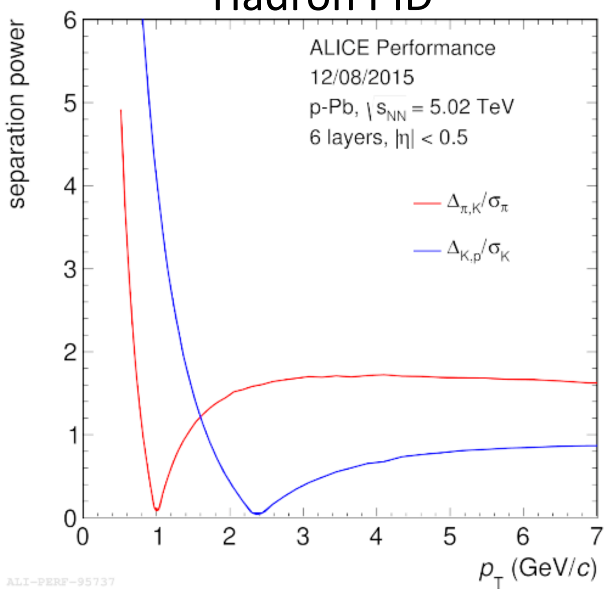
18 sectors (Run-2) covering the whole azimuthal angle, |η|<0.9





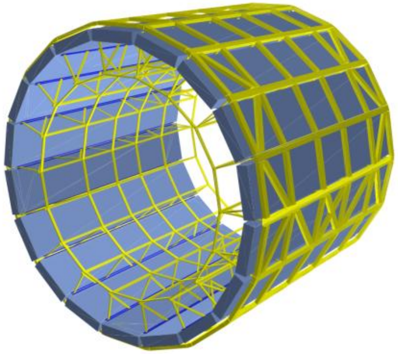
only π, e, p selected

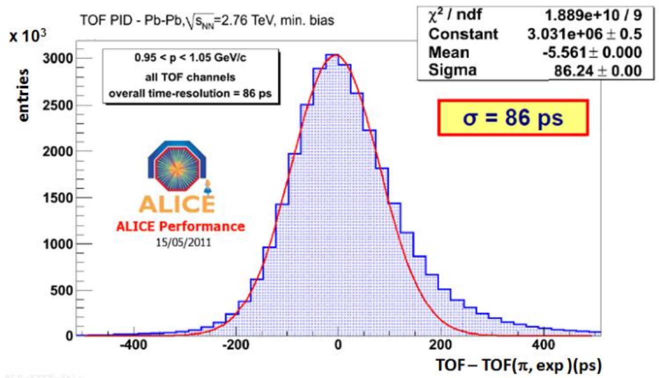
Hadron PID



TOF

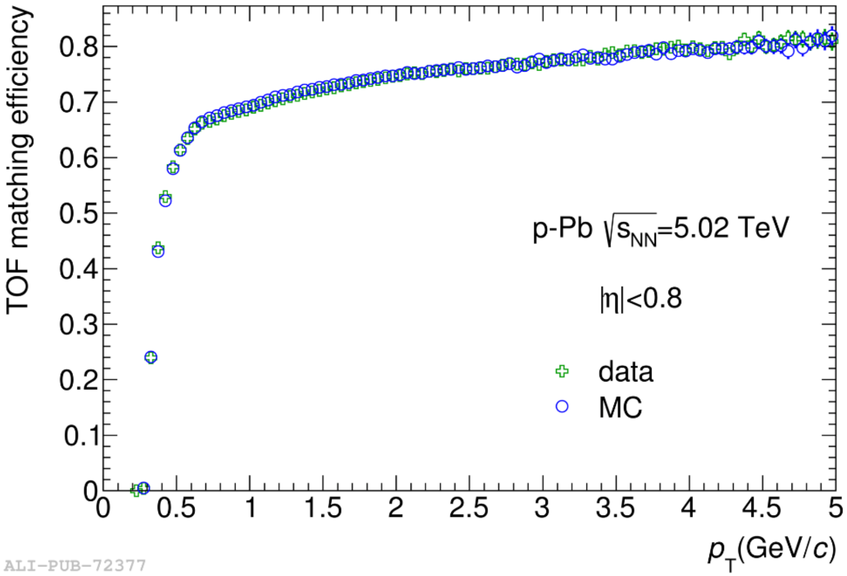
R_{TOF} = 370 cm
~157000 channels (2.5 x 3.5 cm^2)
Overall time resolution = 80 ps





Including start time resolution

18 sectors covering the whole azimuthal angle, |η|<0.9 except a small hole in front of the PHOS detector

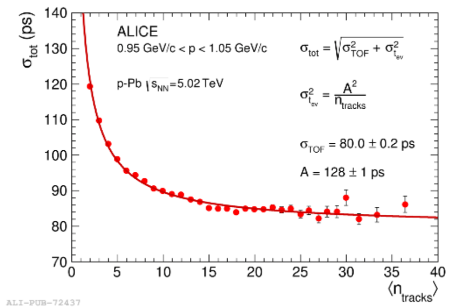


Start time provided by T0 scintillators or TOF tracks

T0 detector

OR

Combinatorial TOF tracks



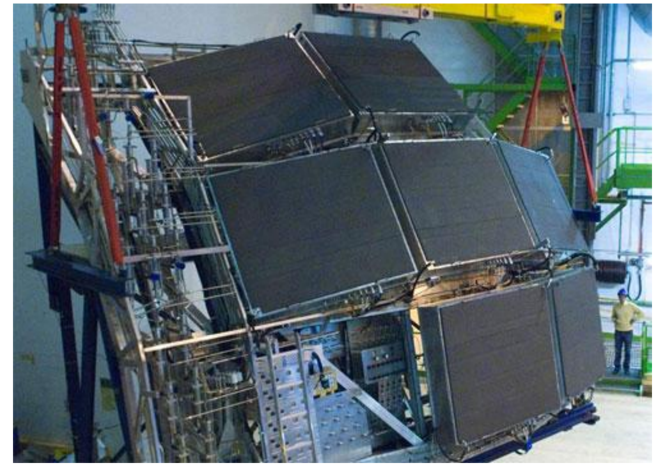
HMPID

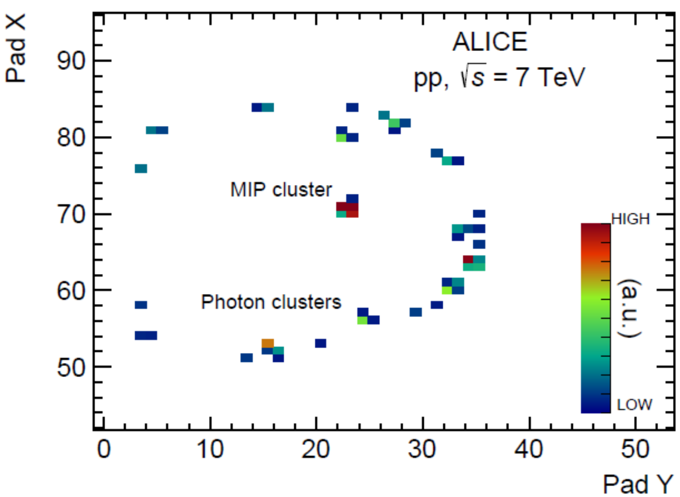
R_{HMPID} = 470 cm

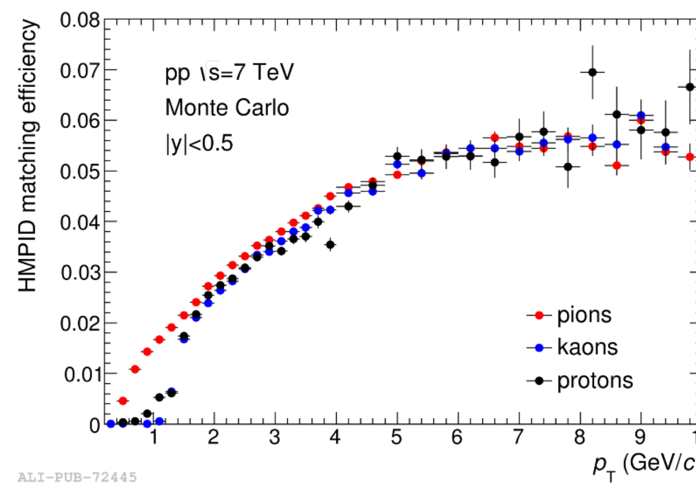
7 modules (ring-imagining Cherenkov)
C_6F_{14} radiator ←→ MWPC-based photon detectors

Coverage: $0 < |\eta| < 0.6$, $\Delta\varphi = 0.31\pi$

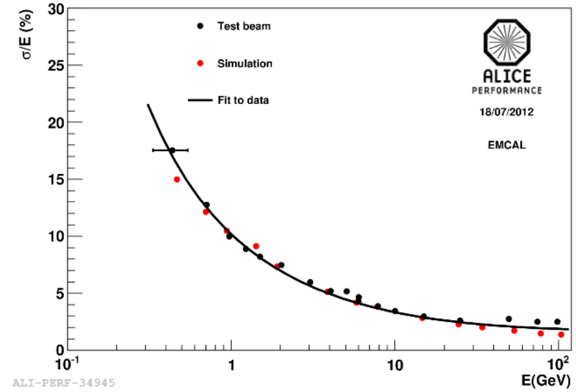
n~1.289 at 175 nm





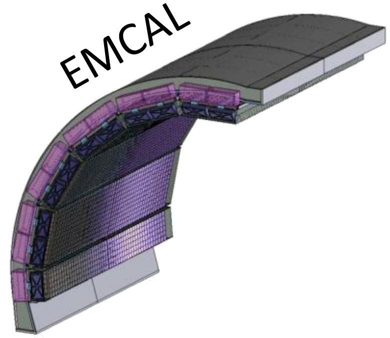


PHOS and EMCAL

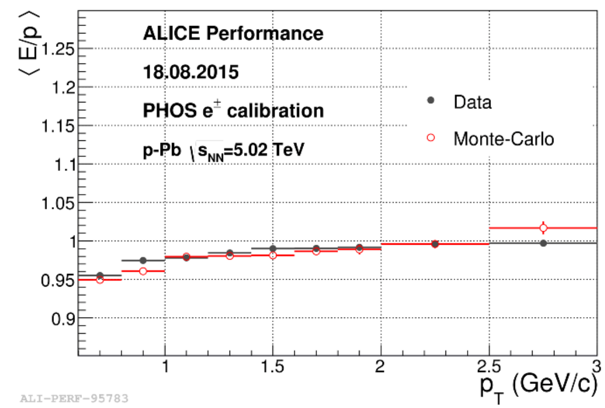


Coverage:
PHOS $0 < |\eta| < 0.12$, $\Delta\varphi=0.6\pi$
EMCAL $0 < |\eta| < 0.7$, $\Delta\varphi=0.6\pi$

EMCAL

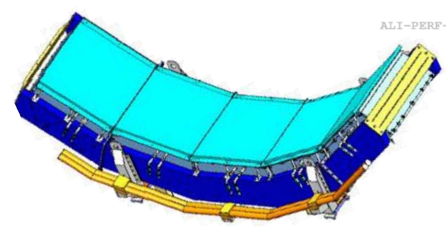


Granularity:
PHOS ($\Delta\eta\Delta\varphi$) 0.004x0.0004
EMCAL ($\Delta\eta\Delta\varphi$) 0.0143x0.0143



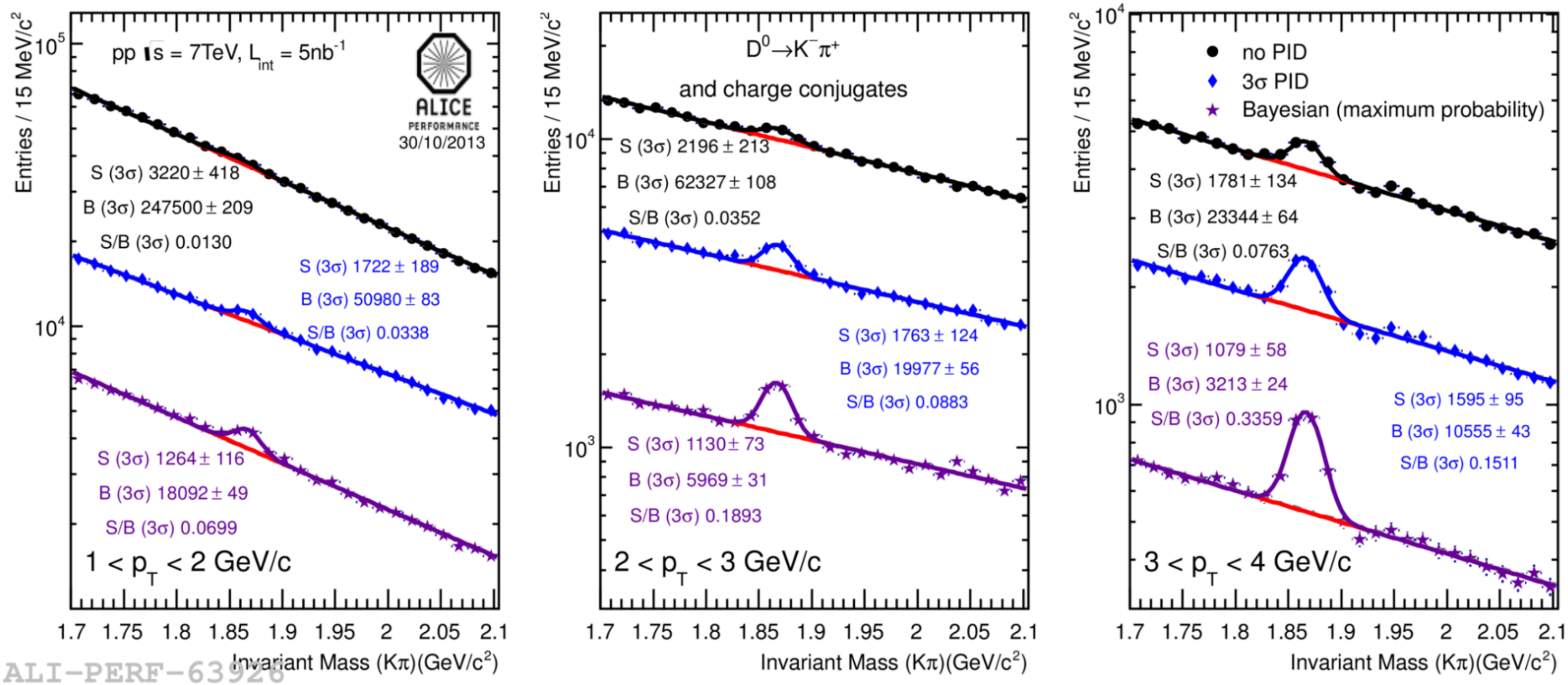
Energy resolution:
PHOS $3.3\%/\sqrt{E} \oplus 1.1\%$
EMCAL $7\%/\sqrt{E} \oplus 1.5\%$

PHOS – EMCAL → back to back topology



PHOS

Comparison of n_σ and Bayesian approaches



Comparison of different PID methods in reconstructing D0 mesons with TOF and TPC ALICE PID.